CHAPTER

13

Surface Water and Hydrology

CALVERT TO KAGARU ENVIRONMENTAL IMPACT STATEMENT

INLAND RAIL

ARTC

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

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13.1 Scope of chapter

The surface water chapter includes a description of the surface water quality impact assessment and the hydrology and flooding impact assessment undertaken for the Calvert to Kagaru Project (the Project).

For surface water quality (and resources), this chapter includes an assessment of the use of surface waters (known as environmental values (EVs)) and the water quality objectives (WQOs) that have been established to protect these values.

For hydrology and flooding, this chapter includes a detailed hydraulic assessment establishing the existing flooding and hydrology case followed by consideration of the proposed works and refinement of the Project drainage structures to minimise impacts to acceptable levels.

The existing environment is described, and an assessment is made of the potential impacts of the Project. Potential short- and long-term impacts on local and regional surface waterways have been assessed based on a review of the Project's construction and operation phases. The results of the impact assessment and recommended mitigation measures have been outlined, along with potential cumulative impacts.

Full details of the surface water quality assessment are provided in Appendix M: Surface Water Quality Technical Report. Full details of the hydrology and flooding assessment are provided in Appendix N: Hydrology and Flooding Technical Report.

Within this assessment, the water quality study area reflects the EIS investigation corridor for the Project including the proposed rail alignment, road reconfigurations, laydown areas and stockpile locations. Spatially, it is based on an approximate 1 km buffer on either side of the rail alignment, initially incorporating an area allowing for design changes and with further consideration of the hydrological catchment the Project passes through.

13.2 Terms of Reference

The Terms of Reference (ToR) describe the matters the proponent must address in the Environmental Impact Statement (EIS) for the Project. The matters relating to water quality and hydrology and flooding are contained in Table 13.1.

TABLE 13.1: TERMS OF REFERENCE COMPLIANCE TABLE—SURFACE WATER AND HYDROLOGY

Terms of Reference requirements—Water (general)		Where addressed
Existing environment		
11.36	Identify the water-related environmental values and describe the existing surface water and groundwater regime within the study area and the adjoining waterways in terms of water levels, discharges and freshwater flows.	Section 13.5 Appendix M: Surface Water Quality Technical Report: Section 5
11.37	With reference to the EPP (Water and Wetland Biodiversity) 2009, section 9 of the EP Act, and SPP State Interest Guideline - Water Quality, identify the environmental values of surface water within the project area and immediately downstream that may be affected by the project, including any human uses of the water and any cultural values.	Section 13.5 Appendix M: Surface Water Quality Technical Report, Section 5
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.	Sections 13.5.3, 13.5.4 and 13.5.5 Appendix M: Surface Water Quality Technical Report, Section 6
11.39	Describe any existing and/or constructed waterbodies adjacent to the preferred alignment.	Section 13.5.2.2 Appendix M: Surface Water Quality Technical Report, Section 5.5.4

Terms of Reference requirements—Water (general)		Where addressed
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 13.6 and 13.8 Appendix M: Surface Water Quality Technical Report, Section 7 and 9
11.42	Identify the quantity, quality and location of all potential discharges of water and wastewater by the project, whether as point sources (such as controlled discharges) or diffuse sources (such as irrigation to land of treated sewage effluent).	Section 13.6.1 Appendix M: Surface Water Quality Technical Report, Section 7
11.43	Assess the potential impacts of any discharges on the quality and quantity of receiving waters taking into consideration the assimilative capacity of the receiving environment and the practices and procedures that would be used to avoid or minimise impacts.	Sections 13.6.1 and 13.8 Appendix M: Surface Water Quality Technical Report, Section 7
11.45	Describe the potential impacts of in-stream works on hydrology and water quality.	Section 13.6 Appendix M: Surface Water Quality Technical Report, Section 7.1
11.46	Undertake a salinity risk assessment in accordance with Part B of the Salinity Management Handbook, Investigating Salinity. In particular, consider how the project will change the hydrology of the project area and provide results of the risk assessment.	Sections 13.5.2.5, 13.6.1, 13.7 and Figure 13.4 Chapter 9: Land Resources, Section 9.6.5 and Figures 9.8–9.13 Appendix M: Surface Water Quality Technical Report, Section 5.9 and Figure 5.14
Mitigation measures		
11.47	Describe how the water quality objectives identified above would be achieved, monitored and audited, and how environmental impacts would be avoided or minimised and corrective actions would be managed.	Section 13.7.1 Appendix M: Surface Water Quality Technical Report, Sections 8.1, 8.2 and 8.3
11.48	Describe appropriate management and mitigation strategies and provide contingency plans for:	Chapter 13: Surface Water and Hydrology, Section 13.7 Appendix M: Surface Water Quality Technical Report, Sections 2.6 and 8
	(a) Potential accidental discharges of contaminants and sediments during construction and operation	
	(b) Stormwater run-off from the project facilities and associated infrastructure during construction and operation, including the International Erosion Control Association, Best Practice Erosion and Sediment Control – November 2008 (Appendix 1), and the separation of clean stormwater run-off from disturbed and operational areas of the site	
	(c) Flooding of relevant river systems, the effects of tropical cyclones and other extreme events	Sections 13.7.2 and 13.8.2
	(d) Management of acid sulfate soils and acid producing rock and associated leachate from excavations and disturbed areas.	Sections 13.7.1.2 and 13.7.1.3 Appendix M: Surface Water Quality Technical Report, Sections 5.4.3, 8.2 and 8.3
11.50	Propose suitable measures to avoid or mitigate the impacts of in-stream works on water quality and the stabilisation and rehabilitation of any such works.	Section 13.7.1 Appendix M: Surface Water Quality Technical Report, Sections 8.1, 8.2 and 8.3
11.51	Where a salinity risk is identified, detail strategies to manage salinity ensuring the development must be managed so that it does not contribute to the degradation of soil, water and ecological resources or damage infrastructure via expression of salinity. See Part C of the Salinity management handbook second edition, Department of Environment and Resource Management 2011.	Section 13.7.1 Chapter 9: Land Resources, Section 9.7.2 Appendix M: Surface Water Quality Technical Report, Sections 8.1, 8.2 and 8.3

Terms of Reference requirements—Water (water resources)		Where addressed
Impact assessment		
11.52	Provide details of any proposed impoundment, extraction (i.e. volume and rate), discharge, use or loss of surface water or groundwater. Identify any approval or allocation that would be needed under the Water Act.	Section 13.7.1.3 Appendix M: Surface Water Quality Technical Report, Section 2.7
11.53	Detail any significant diversion or interception of overland flow. Include maps of suitable scale showing the location of diversions and other water-related infrastructure.	Section 13.5.2.2 and Figure 13.3 Appendix M: Surface Water Quality Technical Report, Section 2.5 and Figure 2.1
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) Alterations to riparian vegetation and bank and channel morphology (c) Direct and indirect impacts arising from the project. (d) Impacts to aquatic ecosystems, including groundwater-dependent ecosystems and environmental flows.	Sections 13.4.2, 13.6.1, 13.6.2, 13.8.1 and 13.8.2 Appendix N: Hydrology and Flooding Technical Report, Sections 6–9 Appendix M: Surface Water Quality Technical Report, Sections 7.1 and 7.2
11.58	Identify relevant Water Plans and Resources Operations Plans under the Water Act. Describe how the project will impact or alter these plans. The assessment should consider, in consultation with the Department of Natural Resources and Mines, any need for: (a) A resource operations licence (b) An operations manual (c) A distribution operations licence (d) A water licence (e) A water management protocol.	Sections 13.5.2.3 and 13.7.1.3 Chapter 3: Project Approvals, Section 3.4.35 and Table 3.4 Appendix M: Surface Water Quality Technical Report, Sections 5.10 and 7.2
11.59	Identify other water users that may be affected by the proposal and assess the project's potential impacts on other water users.	Sections 13.5.2.3 and 13.6.1 Appendix M: Surface Water Quality Technical Report, Sections 5.10 and 7.2
11.60	Identify and quantify likely activities involving the excavation or placement of fill that will be undertaken in any watercourse, lake or spring.	Section 13.6.1 Appendix M: Surface Water Quality Technical Report, Sections 2 and 7.1
Mitigation Measures		
11.62	Describe measures to minimise impacts on surface water and ground water resources.	Sections 13.7.1 Appendix M: Surface Water Quality Technical Report, Section 8 Appendix N: Hydrology and Flooding Technical Report, Section 9
11.63	Provide a policy outline of compensation, mitigation and management measures where impacts are identified.	

Terms of Reference requirements—Water (flood management)		Where addressed
Existing Environment		
11.64	A desktop assessment of the rail line and surrounding catchments must be undertaken and the potential for flooding qualitatively described. The desktop assessment must also identify any high-risk watercourse crossing or floodplain locations that warrant further detailed quantitative assessment.	Section 13.5 Appendix N: Hydrology and Flooding Technical Report, Sections 3 and 5
Impact Assessment		
11.65	For the locations assessed under paragraph 11.64, a flood study must be included in the EIS that includes: (a) Quantification of flood impacts on properties and existing infrastructure surrounding and external to the preferred alignment from redirection or concentration of flows (b) Identification of likely increased flood levels, increased flow velocities or increased time of flood inundation as a result of the project (c) Details of all calculations along with descriptions of base data and any potential for loss of flood plain storage.	Sections 13.4.2, 13.6.2 and 13.8.2 Appendix N: Hydrology and Flooding Technical Report, Section 9
11.66	The flood study should address any requirements of the Brisbane River Catchment Flood Study 2016, local or regional planning schemes and current accepted practice and statutory requirements in relation to flood plain management. The method of modelling used in the study should be described and justified.	Appendix N: Hydrology and Flooding Technical Report, Sections 5–9
11.67	Describe flood risk for a range of annual exceedance probabilities (including but not limited to the modelled Brisbane River Catchment Flood Study 2016 probable maximum flood) for the site, and assess how the project may change flooding characteristics particularly upstream afflux from the proposal and the impact of changed water regimes. Include a discussion of historical events.	Section 13.8.2 Appendix N: Hydrology and Flooding Technical Report, Sections 7–9
11.68	The study should consider all infrastructure associated with the project including levees, roads and linear infrastructure.	Sections 13.5.6 and 13.8.2 Appendix N: Hydrology and Flooding Technical Report, Sections 8 and 9
11.69	The EIS should describe the consultation that has taken place with landholders along the alignment regarding modelled potential impacts of the project on flooding. It should also include a discussion of how the results of consultation have been considered by the proponent in the EIS process.	Section 13.4.2.4 Chapter 5: Stakeholder Engagement and Appendix C: Consultation Report, Sections 5.5 and 5.6 Appendix N: Hydrology and Flooding Technical Report, Section 7.15
11.70	Reference must be made to relevant studies published by local governments.	Appendix N: Hydrology and Flooding Technical Report, Section 5.1
Mitigation Measures		
11.71	Identify all proposed measures to avoid or minimise risks to life, property, infrastructure, community (including damage to other properties) and the environment as a result of project impacts during flood events—particularly flood risks on individual properties and businesses, including in and around Calvert, Lanefield, Lower Mount Walker, Ebenezer, Mutdapilly, Purga and Washpool.	Sections 13.7.2 and 13.8.2 Appendix N: Hydrology and Flooding Technical Report, Section 9

13.3 Legislation, policy, standards and guidelines

13.3.1 Commonwealth and State legislation

The legislation, policies and guidelines relevant to the Project with respect to surface water, hydrology and flooding are in Table 13.2. This assessment has been undertaken in accordance with the Department of Environment and Heritage and Protection (DEHP) (now Department of Environment and Science (DES)) *information guideline for an environmental impact statement—TOR Guideline—Water*.

Relevant legislation and approvals are discussed further in Chapter 3: Project Approvals.

TABLE 13.2: REGULATORY CONTEXT

Legislation, policy or guideline	Relevance to the Project
Commonwealth	
Environment Protection and Biodiversity Conservation Act 1999 (Cth) (EPBC Act)	The EPBC Act is applicable to Projects that involve or have the potential to impact on nationally and internationally important flora, fauna, ecological communities and heritage places, defined under the EPBC Act as a Matter of National Environmental Significance (MNES). The Project is a controlled action (EPBC 2017/7944) as a result of the Project's potential impacts on listed threatened species and communities. The Project will be assessed under the bilateral agreement between the Queensland (QLD) and the Commonwealth governments. Project activities do not involve coal seam gas and large coal mining developments and are exempt from the trigger for MNES water resources.
State	
Environmental Protection Act 1994 (EP Act)	The objective of the EP Act is to achieve ecologically sustainable development by protecting QLD's environment while allowing for development that improves the total quality of life, both now and in the future, in a way that maintains the ecological processes on which life depends. Under the EP Act, environmental protection policies are developed to cover specific aspects of the environment. The EVs of QLD waterways, including those located within the water quality study area, are protected under the EP Act and the subordinate legislation. The Project triggers subordinate legislation under the EP Act, in regard to quality of QLD waters.
Planning Act 2016 (Planning Act)	The Planning Act sets out a planning system for development assessment, plan making and dispute resolution. Under the Planning Act, development is either accepted, assessable or prohibited. Assessment is carried out through the Development Assessment Rules (DA Rules). The Project will trigger the requirement to obtain approval for aspects of development that are assessable under Schedule 10 of the Planning Regulation (and integrated through other legislation as part of the DA Rules process) following completion of the EIS process.
Environmental Protection (Water and Wetland Biodiversity) Policy 2019 [EPP (Water and Wetland Biodiversity)]	The quality of QLD waters is protected under the EPP (Water and Wetland Biodiversity). The EPP (Water and Wetland Biodiversity) seeks to achieve the objective of the EP Act in relation to QLD waters. The EPP (Water and Wetland Biodiversity) lists the EVs and WQOs that need to be considered by planners and managers when making decision about waters and/or water quality. The Project will be required to assess the water quality within the area against the EPP (Water and Wetland Biodiversity) EVs and WQOs.

Legislation, policy or guideline	Relevance to the Project
Water Act 2000 (Qld) (Water Act)	The Project involves works within defined watercourses and as such the provisions of the Water Act may apply. Further, the Project involves the removal of vegetation, excavation or placing fill in a waterway, lake or spring. This will require a Riverine Protection Permit to authorise excavation and the Project will apply for licensing under the Riverine Protection Permit as necessary (if exemption is not granted as a Government-owned corporation). The Australian Rail Track Corporation Ltd is listed as an entity under Schedule 2 of the *Riverine protection permit exemption requirements* (WSS/2013/726). Project activities that involve diversion of watercourses will require approval under works that take or interfere with watercourse, lake or spring (for interference with overland flow).
Fisheries Act 1994 (Qld) (Fisheries Act)	The Fisheries Act provides for the management, use, development and protection of fish habitats and resources, together with the management of aquaculture activities. The Project transverses mapped waterways for waterway barrier works and therefore may trigger the requirement to obtain a Development Permit for Operational Works involving constructing or raising temporary and permanent waterway barrier works. The Project may require licensing for major risk of impact waterways in order to maintain connectivity and water quality.
South East Queensland (SEQ) Regional Plan 2017 (*ShapingSEQ*)	*ShapingSEQ* is the QLD Government's plan to guide the future for the SEQ region. *ShapingSEQ* is based on the understanding that the region relies on its environmental assets to support our communities and lifestyles. *ShapingSEQ* provides strategies to protect and sustainably manage the region's catchments to ensure the quality and quantity of water in our waterways, aquifers, wetlands, estuaries, Moreton Bay and oceans, meets the needs of the environment, industry and community. The Project has been identified as a key priority in the region-shaping infrastructure and is considered to be consistent with *ShapingSEQ*.
State Planning Policy 2017 (including State Planning Policy—State Interest Guideline (Water Quality) 2016	The State Planning Policy (SPP) is a key component of the QLD land use planning system which expresses the State's interest (as defined under the Planning Act) in land use planning and development. The SPP defined the QLD Government's state interests in land use planning and development, which notably includes State transport infrastructure. The SPP includes an SPP code (Water Quality Appendix 2) that provides performance outcomes to ensure development is planned, designed, constructed and operated to manage stormwater and wastewater in ways that support the protection of EVs identified in the EPP (Water and Wetland Biodiversity). While no components of the Project are assessable under the provisions of a local government planning scheme, State approval requirements will trigger a number of applications. As such, relevant provisions of the SPP will be required to be addressed as part of the supporting application materials to be submitted (around water quality performance outcomes with discharge from tunnel infrastructure) and will be considered in the assessment process.

13.3.2 Water quality guidelines

Various water quality guidelines were used to assess the quality of surface waters within the water quality study area against defined reference conditions, which enabled the quantification of WQOs. Applicable guidelines are briefly described below.

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

The *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (Australian and New Zealand governments (ANZG), 2018) provide a method for assessing water quality through comparison with guidelines derived from local reference values.

The guideline values were developed based on the following criteria:

- Level of environmental disturbance of surface waters (i.e. highly or slightly/moderately disturbed waters)
- Freshwater or saline surface water
- Waterbody elevation (i.e. upland or lowland aquatic environments)
- Biogeographic region (i.e. southeast or tropical Australia).

The ANZG 2018 Guideline values can be regarded as guideline trigger values that can be modified into regional, local or site-specific guidelines, with consideration to the variability of the subject environment, soil type, rainfall and contaminant exposure. Exceedances of the guideline trigger values indicate a potential environmental issue and trigger an environmental management response.

13.3.2.2 Queensland Water Quality Guidelines

The Queensland Water Quality Guidelines (QWQG) (Department of Environment and Heritage Protection, 2009) provide a framework for assessing water quality in QLD via the setting of WQOs. The QWQG are intended to address the need identified in the ANZG 2018 Guidelines by:

- Providing guideline values (numbers) that are tailored to QLD region and water types
- Providing a process/framework for deriving and applying more locally specific guidelines for waters in QLD.

13.3.2.3 Environmental Protection (Water and Wetland Biodiversity) Policy 2019

The EPP (Water and Wetland Biodiversity) provides a framework for:

- Identifying EVs for QLD waters, and identifying the WQOs to protect or enhance those EVs
- Including the identified EVs and WQOs under Schedule 1 of the EPP (Water and Wetland Biodiversity).

13.3.3 Water quality objectives and environmental values relevant to the Project

The Department of Environment and Science (DES) has published two reports relevant to the Project alignment listing relevant EVs and WQOs, including:

- Bremer River environmental values and water quality objective: Basin No 143 (part) including all tributaries of the Bremer River (Bremer River EV and WQOs) (Department of Environment and Resource Management (DERM), 2010a)
- Logan River environmental values and water quality objectives: Basin No 145 (part) including all tributaries of the Logan River (Logan River EVs and WQOs) (DERM, 2010b).

These documents, relevant to the catchment areas of the Bremer River and the Logan River, form part of Schedule 1 of the EPP (Water and Wetland Biodiversity) subordinate to the EP Act (DERM, 2010a; 2010b). The WQOs most relevant to the Project are those within the EPP (Water and Wetland Biodiversity) relating to moderately disturbed (as identified by the current condition within Schedule 1 of EPP (Water and Wetland Biodiversity)) surface water ecosystems. Default Australian and New Zealand Environment and Conservation Council (ANZECC) and Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ) (2000) guidelines for pesticides, heavy metals and other toxic contaminants are used where the regional EPP (Water and Wetland Biodiversity) guidelines are less applicable. Within the WQOs relevant to the Project, thresholds for the protection of aquatic ecosystems were selected for assessment of current environmental conditions.

The WQOs for the protection of aquatic ecosystems are associated with the most stringent trigger values. The achievement of these WQOs would then confer protection of other environmental values within Table 13.3. Given that no local or sub-regional WQOs for toxicants exist, the national WQOs for toxicants (metals and Polycyclic aromatic hydrocarbons (PAH)) at a 95 per cent protection level for species, apply to the water quality study area (ANZG, 2018). These WQOs are derived from the default toxicant guideline values for water quality in aquatic ecosystems within the ANZECC and ARMCANZ 2000 guidelines. Due to a limited number of independent samples at each monitoring site, single point data were assessed against the WQO, in lieu of generation of median values for assessment.

Under the Bremer River EV and WQOs and Logan River EVs and WQOs (DERM, 2010a; 2010b), EVs are identified for protection for particular waters. The aquatic ecosystem EV is the default applying to all waters. Further WQOs applying to different EVs other than the aquatic ecosystem (e.g. human use) are also identified.

The Project alignment traverses through five sub-catchments of the Bremer River and Logan River catchments, which have varying applicable EVs throughout. These EVs are outlined in Table 13.3 with reference to sites associated with the Project and subject to water quality sampling (refer Section 13.5.3). The WQO and ANZG 2018 guidelines for water quality relevant to the Project water quality sampling sites are outlined in Table 13.4 and Table 13.5.

TABLE 13.3: PROJECT ALIGNMENT SUB-CATCHMENT ENVIRONMENTAL VALUES

Environmental values	Aquatic ecosystems	Irrigation	Farm supply/use	Stock water	Aquaculture	Human consumer	Primary recreation	Secondary recreation	Visual recreation	Drinking water	Industrial use	Cultural and spiritual values
Bremer River catchment												
Mid Bremer (Site 2A)	✓	✓	✓	✓			✓	✓	✓	✓	✓	✓
Lower Warrill Creek (Site 3A)	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓
Western Creek (Site 1A Alt, 1A)	✓	✓	✓	✓				✓	✓			✓
Purga Creek (Site 13A, 6A, 12A)	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓
Logan River catchment												
Lower Teviot Brook (Site 11A, 10A, 9A, 8A)	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓

Source: DERM (2010a; 2010b)

13.3.4 Flood-related standards and guidelines

The design standards and guidelines applicable for the hydrologic and hydraulic investigation are:

- *AS7637:2014 Infrastructure Standard—Hydrology and Hydraulics* (Rail Industry Safety and Standards Board, 2014)
- *Guide to Road Design Part 5: Drainage—General and Hydrology Considerations*, (Austroads, 2013)
- *Australian Rainfall and Runoff: A Guide to Flood Estimation* (Ball, et al., 2016)
- *Evaluating Scour at Bridges, Hydraulic Engineering Circular Number 18* (HEC-18), Fourth Edition (US Department of Transport—Federal Highway Administration, 2001)
- *Hydraulic Design of Energy Dissipaters for Culverts and Channels, Hydraulic Engineering Circular Number 14* (HEC-14), Third Edition (US Department of Transport—Federal Highway Administration, 2006a)
- *Bridge Scour Manual* (Department of Transport and Main Roads, 2013b).

13.3.5 Independent international panel of experts for flood studies

The Australian and the Queensland governments established an independent international panel of experts for flood studies (the Panel) to provide advice to the Commonwealth and the Queensland Government on the flood models and designs developed by ARTC for Inland Rail in Queensland.

As an advisory body to government, the Panel is independent of the ARTC in respect of the development, public consultation and approvals for the Inland Rail EIS process. Relevant submissions received from public notification of the draft EIS will be provided to the Panel for consideration as part of its review.

Information on the Panel may be viewed at:

tmr.qld.gov.au/projects/inland-rail/independent-panel-of-experts-for-flood-studies-in-queensland.

TABLE 13.4: WATER QUALITY OBJECTIVES FOR MODERATELY DISTURBED SURFACE WATER ECOSYSTEMS INTERSECTED BY THE PROJECT

Sub-catchment	Management intent	Secchi depth (m)	Turbidity (NTU)	Chlorophyll *a* (µg/L)	Total N (µg/L)	Oxidised nitrogen (µg/L)	Ammonia N (µg/L)	Dissolved oxygen (% saturated)	pH	Organic N (µg/L)	TSS (mg/L)	Conductivity (µS/cm)
Bremer River catchment												
Mid Bremer (Site 2A)	Moderately disturbed	N/A	< 17	< 5	< 500	< 60	< 20	85 – 110	6.5 – 8.0	< 420	< 6	< 770
Lower Warrill Creek (Site 3A)	Moderately disturbed	N/A	<5	< 5	< 500	< 60	< 20	80 – 110	6.5 – 8.0	< 420	< 6	< 500
Western Creek (Site 1A Alt, 1A)	Moderately disturbed	N/A	< 17	< 5	< 500	< 60	< 20	85 – 110	6.5 – 8.0	< 420	< 6	< 770
Purga Creek (Site 13A, 6A, 12A)	Moderately disturbed	N/A	< 17	< 5	< 500	< 60	< 20	85 – 110	6.5 – 8.0	< 420	< 6	< 770
Logan River catchment												
Lower Teviot Brook (Site 11A, 10A, 9A, 8A)	Moderately disturbed	> 0.5	< 25	< 5	< 450	< 15	< 30	80 – 105	7.0 – 8.4	< 400	< 25	n/a

Table notes:
N = Nitrogen
P = Phosphorous
NTU = Nephelometric Turbidity Units
µg/L = micrograms per litre
mg/L = milligrams per litre
µs/cm = microsiemens per centimetre.

Source: DERM (2010a; 2010b)

TABLE 13.5: WATER QUALITY OBJECTIVES FOR 95% LEVEL OF SPECIES PROTECTION HEAVY METALS AND OTHER TOXIC CONTAMINANTS FOR THE PROJECT

Sub-catchment	Arsenic (III)(mg/L)	Cadmium (mg/L)	Chromium (mg/L)	Copper (mg/L)	Lead (mg/L)	Mercury (mg/L)	Nickel (mg/L)	Zinc (mg/L)	Naphthalene (mg/L)
Bremer River catchment									
Mid Bremer (Site 2A)	0.024	0.0002	0.0004	0.0014	0.0034	0.0006	0.011	0.008	0.016
Lower Warrill Creek (Site 3A)	0.024	0.0002	0.0004	0.0014	0.0034	0.0006	0.011	0.008	0.016
Western Creek (Site 1A, 1A (alt)	0.024	0.0002	0.0004	0.0014	0.0034	0.0006	0.011	0.008	0.016
Purga Creek (Site 13A, 6A, 12A)	0.024	0.0002	0.0004	0.0014	0.0034	0.0006	0.011	0.008	0.016
Logan River catchment									
Lower Teviot Brook (Site 11A, 10A, 9A, 8A)	0.024	0.0002	0.0004	0.0014	0.0034	0.0006	0.011	0.008	0.016

Table notes:
mg/L = milligrams per litre
Metals guidelines are based on dissolved status and are used throughout in reference against field-filtered water quality samples.

Source: ANZG (2018)

13.4 Methodology

13.4.1 Surface water quality

The description of the existing surface water condition is a desktop study from publicly available data complemented by contemporary field water quality samples (with seasonal variation) to enable an assessment of existing environmental conditions.

While periods of minimal hydrological flow within the watercourses across the Project were observed, they were considered to be indicative of the hydrological regime of the water quality study area. As such, the field data gathered during this assessment was considered to be indicative of existing environmental conditions and relevant for assessment under the ToR.

The assessment methodology has been designed to provide sufficient information to determine:

- Existing receiving surface water condition (with reference to Schedule 1 of EPP (Water and Wetland Biodiversity) required for investigation of potential Project impacts
- Residual and cumulative impacts
- Mitigation measures.

The desktop and field assessments (as a description of the existing environment) were used to determine the quality of receiving waters and were used in assessing the risk significance (in regard to qualification of potential contaminants) of specific potential impacts expected from the construction and operation phases of the Project.

In order to assess the surface water quality in the water quality study area, the following approach was adopted, which used two phases: desktop assessment and field assessment:

- Desktop and literature reviews of relevant databases were undertaken, and search area parameters, existing literature and previous study reports were reviewed.
- Surface water sampling sites were defined. Sites were initially identified during a gap analysis conducted as part of the desktop phase of the Project. Sites targeted watercourses that cross the proposed alignment, with additional sites located upstream and downstream of the alignment crossing (refer Figure 13.1 for locations).
- Three sampling events were undertaken to collect surface water samples from waterbodies that were selected to account for temporal and seasonal variability.
- In-situ water quality field data was collected, and samples were also collected for laboratory analysis. Samples were collected by a suitably qualified and experienced environmental scientist.
- Samples were collected from 15 of the proposed 16 aquatic ecology and water quality monitoring locations. It was not possible to collect water samples from all 16 locations due to the sites being dry and/or inaccessible at the time of the site visit.
- The following water quality parameters were measured in situ:
  - pH
  - Temperature
  - Electrical conductivity (actual and specific)
  - Salinity
  - Dissolved oxygen (dissolved and saturated)
  - Turbidity.
- Additionally, the following qualitative data was collected regarding visual water quality indicators:
  - Time
  - Water flow (none/low/mod/high/flood/dry)
  - Clarity (clear/slight/turbid/opaque/other)
  - Odour (normal/sewage/hydrocarbon/chemical)
  - Surface condition (none/dust/oily/leafy/algae)
  - Algae cover (none/some/lots)
  - Other visual observations/comments (colour, fish, presence of litter).
- Water quality samples were collected in accordance with industry-accepted standards and quality-assured procedures, including the Queensland *Monitoring and Sampling Manual* (DES, 2018b). Field quality control included rigorous sample collection, storage, decontamination procedures (where appropriate), and sample documentation. One duplicate sample was collected per sampling visit for quality assurance and quality control purposes.
- The collected samples were submitted to a National Association of Testing Authorities (NATA) accredited laboratory (Eurofins) for analysis of the water-quality parameters listed with 'limit of reporting' (LOR) values (i.e. the smallest concentration of analyte that can be reliably detected by laboratory analysis). Where parameters have also been measured in situ, these results have taken precedence:
  - pH
  - Suspended solids
  - Turbidity
  - Total phosphorus
  - Reactive filterable phosphorus
  - Speciated nitrogen (ammonia, nitrate, nitrite, organic nitrogen, total Kjeldahl nitrogen, total nitrogen)
  - Dissolved metals: (arsenic, cadmium, chromium, copper, lead, mercury, nickel, zinc)
  - Salinity
  - Electrical conductivity
  - Chlorophyll *a*
  - PAH.

These parameters were analysed to establish a preliminary contemporary assessment of the existing water quality within the water quality study area, against general WQOs to protect aquatic ecosystems, as indicated by the EPP (Water and Wetland Biodiversity). No further sampling for specific hydrocarbon or biocide was completed due to:

- Qualitative assessment of other hydrocarbon through olfactory/visual assessments during field sampling
- A specific mitigation requirement of aquatic-friendly pesticides nullifying the need for biocide assessment to determine assimilative capacity of the receiving environment.

Field and laboratory results were compared against respective Logan River catchment WQOs, Bremer River catchment WQOs and ANZG guidelines as outlined in Section 13.3.3.

13.4.1.1 Impact assessment methodology

The surface water quality assessment of the water quality study area used a significance-based impact assessment framework to identify and assess Project-related impacts in relation to environmental receptors.

For the purposes of the assessment, a significant impact depends on the sensitivity of the water quality receptor, the quality of the environment that is impacted, and the intensity, duration, magnitude and potential spatial extent of the potential impacts. Determination of the sensitivity, or vulnerability, of the surface water value/receptor and the magnitude of the potential impacts, facilitates the assessment of the significance of potential surface water impacts.

Refer Chapter 4: Assessment Methodology for further information on the impact assessment methodology.

Magnitude and sensitivity criteria are further detailed in Appendix M: Surface Water Quality Technical Report.

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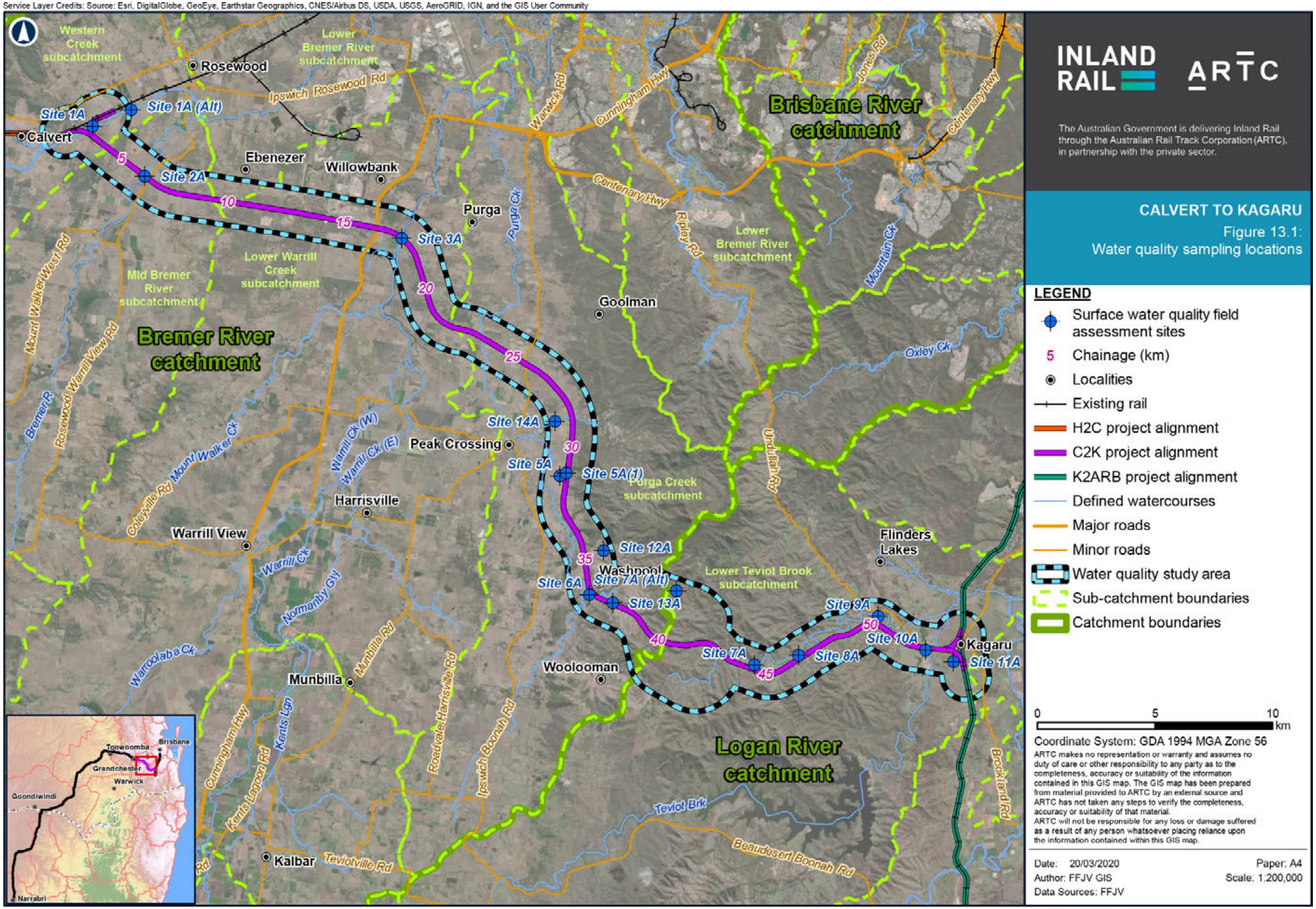

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13.4.2 Hydrology and flooding

The Project design has been guided and refined through the hydraulic design criteria and flood impact objectives as detailed in the following sections.

13.4.2.1 Hydraulic design criteria

Table 13.6 outlines the hydraulic design criteria that have guided the Project design. Detailed hydrologic and hydraulic modelling has been undertaken to meet these design criteria with a series of iterations undertaken to incorporate design refinement and stakeholder and community feedback. The resulting design outcomes, relative to these design criteria, are detailed in Appendix N: Hydrology and Flooding Technical Report.

TABLE 13.6: PROJECT HYDRAULIC DESIGN CRITERIA

Performance criteria	Requirement
Flood immunity	Rail line—1% Annual Exceedance Probability (AEP) flood immunity with 300 mm freeboard to formation level Tunnel portals—1 in 10,000 AEP event flood immunity
Hydraulic analysis and design	Hydrologic and hydraulic analysis and design to be undertaken based on *Australian Rainfall and Runoff* (ARR 2016) and State and local government guidelines ARR 2016 interim climate change guidelines are to be applied with an increase in rainfall intensity to be considered. No sea-level change considerations are required due to the location outside tidal zone ARR 2016 blockage assessment guidelines are to be applied
Scour protection of structures	All bridges and culverts should be designed to reduce the risk of scour with events up to 1% AEP event considered Mitigation to be achieved through providing appropriate scour protection or energy dissipation or by changing the drainage structure design
Structural design	1 in 2,000 AEP event to be modelled for bridge-design purposes
Extreme events	Damage resulting from overtopping to be minimised
Flood flow distribution	Locate structures to maintain efficient conveyance and spread of floodwaters
Sensitivity testing	Consider climate change and blockage in accordance with ARR 2016. Understand risks posed and Project design sensitivity to climate change and blockage of structures

13.4.2.2 Flood impact objectives

The impact of the Project on the existing flood regime was quantified and compared against flood impact objectives detailed in Table 13.7. These objectives address the requirements of the ToR and have been used to guide the Project design. Acceptable impacts will ultimately be determined on a case-by-case basis via interaction with stakeholders and landholders through the community engagement process using these objectives as guidance. This consultation will consider flood sensitive receptors and land use within the floodplains.

The flood impact assessment outcomes are outlined in Section 13.8.2 with additional detail in Appendix N: Hydrology and Flooding Technical Report.

TABLE 13.7: FLOOD IMPACT OBJECTIVES

Parameter	Objectives				
Change in peak water levels[1]	Existing habitable and/or commercial and industrial buildings/premises (e.g. dwellings, schools, hospitals, shops)	Residential or commercial/ industrial properties/lots where flooding does not impact dwellings/ buildings (e.g. yards, gardens)	Existing non-habitable structures (e.g. agricultural sheds, pump-houses)	Roadways	Agricultural and grazing land/forest areas and other non-agricultural land
	≤ 10 mm	≤ 50 mm	≤ 100 mm	≤ 100 mm	≤ 200 mm with localised areas up to 400 mm

Parameter	Objectives
Change in peak water levels[1] (continued)	Changes in peak water levels are to be assessed against the proposed limits. Changes in peak water levels can have varying impacts on different infrastructure/land and flood impact objectives were developed to consider the flood sensitive receptors in the vicinity of the Project. It should be noted that in many locations the presence of existing buildings or infrastructure limits the change in peak water levels
Change in duration of inundation[1]	Identify changes to time of inundation through determination of time of submergence (ToS) For roads, determine the average annual time of submergence (AAToS) (if applicable) and consider impacts on accessibility during flood events Justify acceptability of changes through assessment of risk with a focus on land use and flood sensitive receptors
Flood flow distribution[1]	Aim to minimise changes in natural flow patterns and minimise changes to flood-flow distribution across floodplain areas Identify any changes and justify acceptability of changes through assessment of risk with a focus on land use and flood sensitive receptors
Velocities[1]	Maintain existing velocities where practical Identify changes to velocities and impacts on external properties Determine appropriate scour mitigation measures taking into account existing soil conditions Justify acceptability of changes through assessment of risk with a focus on land use and flood sensitive receptors
Extreme event risk management	Consider risks posed to neighbouring properties for events larger than the 1% AEP event to minimise unexpected or unacceptable impacts
Sensitivity testing	Consider risks posed by climate change and blockage in accordance with ARR 2016 Undertake assessment of impacts associated with Project alignment for both scenarios

Table notes:
1. These flood impact objectives apply for events up to and including the 1% AEP event.

13.4.2.3 Methodology

The hydrology and flooding assessment of the Project uses a quantitative approach to impact assessment and has involved the following activities:

- Collation and review of available background information including existing hydrologic and hydraulic models, survey, rainfall and streamflow data, calibration information and anecdotal flood-related data. This review established which datasets were suitable to use for the EIS
- Determination of critical flooding mechanisms for waterways and drainage paths in the area surrounding the Project, i.e. regional flooding versus local catchment flooding
- Determination of high-risk watercourses that the alignment crosses qualitatively considering:
  - The catchment size, resulting flood flows and velocities
  - The land use in the vicinity of the rail alignment
  - The extent and depth of flood inundation
  - The duration of flood events and catchment response time
  - The proximity to and nature of flood sensitive receptors (eg houses, sheds, roads etc.)
- Development of tailored hydrologic and hydraulic models for key waterways
- Development of tailored hydrologic and hydraulic models for key waterways as base modelling for the Project assessment
- Validation of the hydrologic models and hydraulic models against recorded data for 1974, 2011 and 2013 historical flood events on Bremer River, Warrill Creek and Purga Creek and 1974, 1990 and 2013 on Teviot Brook
- Community and stakeholder engagement to validate model performance and gain acceptance of modelling and calibration outcomes
- Update of hydrologic and hydraulic models to include ARR 2016 design events
- Simulation of ARR 2016 design events without the Project (Existing Case) and comparison to previous studies to confirm drainage paths, waterways, and associated floodplain areas, and establish the existing flood regime in the vicinity of the Project. The range of flood event magnitudes assessed included the 20%, 10%, 5%, 2%, 1%, 1 in 2,000, 1 in 10,000 AEP and Probable Maximum Flood (PMF) events
- Inclusion of proposed rail alignment and drainage structures (Developed Case) in the hydraulic models and simulation of ARR 2016 design events

- Assessment of impacts of proposed alignment using the suite of design floods including consideration of change in flood levels, flow distributions, velocities and inundation periods
- Determination of appropriate mitigation measures to manage potential impacts including refinement of location and dimensions of major drainage structures under the Project alignment. Iterations were undertaken in the hydraulic models to achieve a design that meets the acceptance criteria
- Community and stakeholder engagement in accordance with the Australian Rail Track Corporation (ARTC) Flood Study Engagement Framework.

Comprehensive details of the hydrologic and hydraulic modelling undertaken are provided in Appendix N: Hydrology and Flooding Technical Report.

13.4.2.4 Stakeholder engagement

Community consultation has been undertaken at key milestones in alignment with ARTC's Flood Study Engagement Strategy. This has included:

- Data collection
- Feedback on hydrologic and hydraulic modelling calibration results
- Periodic updates to the community via e-newsletters and community sessions
- Updates on flood modelling progress at Community Consultative Committee (CCC) meetings
- Phone calls and emails to key individual landholders
- Feedback on design flood modelling results—community feedback on preliminary design solutions has been used to make a number of design modifications
- One-on-one consultation with landholders affected by changes in flooding behaviour.

Information collected during the consultation sessions was used to inform the development of the hydrologic and hydraulic models and provide validation of the performance of each model. This information was collated by ARTC from the consultation sessions.

In addition to the community information and engagement sessions, input was sought from key landholders during the flood model calibration process on a one-to-one basis in relation to historical flood events. A number of meetings were conducted with landholders within the floodplains upstream and downstream of the proposed Project alignment to gather further anecdotal flood data, which was used to improve the model validation process.

One-on-one meetings have been held with a number of landholders to discuss the impacts on the flooding regime associated with the Project alignment. The one-on-one landholder meetings were used to discuss:

- Existing 1% AEP event flood levels/depths
- Predicted 1% AEP event changes in peak water levels
- Potential impacts to houses and other infrastructure
- Potential mitigation options.

Stakeholder engagement meetings that were conducted to discuss potential flood impacts on State and local government-controlled assets included meetings with the Department of Transport and Main Roads (DTMR), Ipswich City Council (ICC) and Scenic Rim Regional Council (SRRC).

Details of the stakeholder and community sessions undertaken are documented in Chapter 5: Stakeholder Engagement and Appendix C: Consultation Report.

13.4.2.5 Terminology

The hydrologic and flooding investigation has adopted the latest approach to design flood terminology as detailed in ARR 2016. Accordingly, all design events are quoted in terms of AEP with the adopted terminology for the simulated design events in Table 13.8.

TABLE 13.8: EVENT TERMINOLOGY

Exceedances per year (EY)	AEP (%)	AEP (1 in x)	Average recurrence interval (ARI)
0.22	20	5	4.48
0.11	10	10	9.49
0.05	5	20	20
0.02	2	50	50
0.01	1	100	100
0.0005	0.05	2,000	2,000
0.0001	0.01	10,000	10,000

As an example, in general terms, a 1% AEP event means that there is a 1% chance of an event of that magnitude occurring in any given year.

13.5 Existing environment

13.5.1 Local government areas

The Project alignment traverses the local government area of ICC, between Calvert and Peak Crossing. From Peak Crossing to Kagaru, the SRRC is the majority regional council with a small portion of the proposed alignment (in proximity to Kagaru) crossing into Logan City Council (LCC) local government area.

13.5.2 Catchment overview

The Project alignment travels through the Bremer River and the Logan River catchments. The Bremer River catchment covers the area between Calvert and east of Woolooman where the Project alignment reaches the peak of the Scenic Rim mountain range. It then enters the Logan River catchment area as the Project alignment descends the Teviot Range towards Kagaru (refer Figure 13.2).

The Bremer River catchment is situated west of Brisbane within the local government boundaries of ICC and SRRC and expands to an area of approximately 2,030 square km (km^2) with the main Bremer River channel surrounded by smaller sub-catchments. The stream network length is approximately 4,425 km. The Project alignment predominantly traverses through the sub-catchments of Mid Bremer River, Lower Bremer River, Lower Warrill Creek, Western Creek and Purga Creek. Rainfall in the catchment is considered high along its steeper sections, which are situated to the south and east while the remainder of the catchment experiences average rainfall of under 1,000 mm/yr (SEQ Catchments, 2006). Dominant land uses within the Bremer catchment include grazing, native bushland, intensive agricultural and urban. The lower catchment is mostly urbanised, where the rest of the catchment is rural with the majority of the catchment cleared for cattle grazing. The upper catchment contains areas of natural bushland (DES, 2016a).

The Logan River catchment is situated to the south of Brisbane with its headwater in the McPherson and Main Ranges. The majority of the catchment features in the local government areas of the SRRC and LCC, but also includes small sections of other local government areas. The catchment area expands over 3,076 km^2 with approximately 5,500 km of stream network. The Project alignment intersects the sub-catchment of Lower Teviot Brook. Rainfall in the catchment is very high, especially in the eastern headwaters, which, combined with good recharge of groundwater associated with basalt geology, lead to permanent flow (SEQ Catchments, 2017). The dominant land uses within the Logan catchment include grazing, native bush, rural residential and intensive agriculture. The upper catchment has been cleared for agriculture, grazing and dairying while the mid- and lower-catchment flows through rural, residential and urban areas (DES, 2015).

13.5.2.1 Climate

A review of the Bureau of Meteorology (BoM) climate data was undertaken from the nearest monitoring station at Amberley Aeronautical Meteorological Office (AMO) (040004) approximately 38 km northwest of Kagaru. The water quality study area has a typical hot and dry climate and typically experiences warm-to-hot summers and mild-to-cool winters. Rainfall is seasonally distributed with a distinct wet season occurring during the summer months of December through February and an extended dry season during the months of April through September. Mean maximum monthly temperatures typically range from 30 °C in summer to 20 °C in winter (BoM, 2019).

Key characteristics relating to the climate of the catchment are as follows:

- The heaviest amount of rainfall is generally received in the summer months with an annual average rainfall of 67.36 mm (BoM, 2019)
- The average maximum temperature is 26.8 °C and the average minimum temperature is 13 °C (BoM, 2019)
- The water quality study area generally consists of higher evaporation in the summer months where the mean average evaporation rate is 7.4 mm compared to the winter months where the mean evaporation rate is 3.5 mm (BoM, 2019).

13.5.2.2 Defined watercourses

Under the Water Act, a watercourse is defined as a river, creek or other stream that includes a stream in the form of an anabranch or a tributary where water flows either permanently or intermittently regardless of flow frequency. A watercourse, however, does not include any section of a feature that has a tidal influence or is downstream of a defined limit (DNRM, 2014).

A number of defined watercourses (as shown in Figure 13.3) and unmapped waterways and waterbodies occur within the water quality study area. Defined watercourses crossed by the Project alignment include:

- Western Creek—at chainage locations Ch 1.20 km and Ch 3.10 km
- Bremer River—at chainage location Ch 6.30 km
- Warrill Creek—at chainage location Ch 17.60 km
- Purga Creek—at chainage locations Ch 23.40 km
- Sandy Creek—at chainage location Ch 28.70 km
- Unnamed tributary of Purga Creek—at chainage locations Ch 36.60 km, Ch 37.50 km and Ch 37.90 km
- Teviot Brook—at chainage location Ch 52.80 km.

Unmapped waterways intersected by the Project alignment are quantified using waterways barrier-works mapping and stream-order mapping (refer Appendix M: Surface Water Quality Technical Report). The unmapped waterways will be verified during the detailed design phase to determine their status under the Water Act.

A diversion of a waterway has been identified along a single stretch of a drainage pathway leading to an unnamed tributary of Purga Creek at locations where the rail embankment falls on top of existing flow paths. The affected waterway flow path is one of three discrete mapped overland drainage features, under the Water Act. The expected overland flow diversion is 260 m long and runs from Chainage 39.28 km to 39.54 km. Four other diversions of unmapped overland flow drainage diversions are identified and these run from Chainage 8.72 km to 8.98 km, Chainage 16.09 km to 16.20 km, Chainage 40.87 km to 41.11 km and Chainage 41.36 to 41.46 km (refer Figure 13.3).

ARTC and/or the construction contractor will obtain the relevant approvals for diversion and works that take or interfere with watercourse, lake or spring prior to construction.

For further details refer Appendix M: Surface Water Quality Technical Report.

There are a number of artificial or constructed waterbodies located within the water quality study area with some of these waterbodies intersected by the proposed alignment. These artificial or constructed waterbodies are predominantly rural farm dams used by stock. The artificial or constructed waterbodies that are intersected by the Project alignment are in Table 13.9.

TABLE 13.9: ARTIFICIAL WATERBODIES WHICH INTERSECT WITH THE PROJECT ALIGNMENT

Artificial waterbody (approximate chainage (km))	Associated waterway
Ch 2.90, 4.60, 6.10, 6.60, 8.60, 9.00, 9.70, 10.20, 10.30, 10.80	Unmapped waterway of Bremer River
Ch 11.70, 12.20, 13.40, 14.40, 16.10, 16.40, 17.50	Unmapped waterway of Warrill Creek
Ch 20.70, 21.00, 21.50, 21.80, 22.40, 24.90	Unmapped waterway of Purga Creek
Ch 26.60	Unmapped waterway of tributary of Purga Creek
Ch 28.20, 28.80, 29.20, 30.40,	Unmapped waterway of tributary of Purga Creek
Ch 31.80, 32.20, 33.80, 34.00, 35.10, 35.20, 36.40, 37.00, 37.80, 39.00	Unmapped waterway of Purga Creek
Ch 45.20, 45.60, 45.70	Unmapped waterway of Teviot Brook
Ch 49.60, 50.20, 50.90	Unmapped waterway of Teviot Brook
Ch 51.30, 53.90[a], 53.90[b], 54.00	Unmapped waterway of Teviot Brook

Table notes:
a and b denote discrete waterbodies located at the same relative chainage

13.5.2.3 Surface water resource and use

The Water Act provides a framework under which catchment-based Water Plans and Water Management Protocols (previously Resource Operations Plans) are developed in QLD. Water Plans establish a framework for sharing water between human consumptive needs and EVs. Water Management Protocols are developed in parallel with the Water Plans and provide a framework by which objectives from which the Water Plans are implemented, including water allocations and administrative directions.

Surface water resources within the water quality study area are primarily managed by the Water Plan (Moreton) 2007 and Water Plan (Logan Basin) 2007. Both plans include performance indicators and objectives such as:

- Environmental flow objectives: assessing periods of low flow and medium to high flow
- Water allocation security objectives.

The Moreton Water Management Protocol implements parts of the *Water Plan (Moreton) 2007*. The *Logan Basin Resource Operations Plan 2009* implements the *Water Plan (Logan Basin) 2007*. The Water Management Protocol defines the rules that govern the allocation and management of water in order to achieve the Water Plan outcomes.

Significant changes to the hydraulic regime of the watercourses are not expected to occur with design practices, which account for typical hydrological flow to which the water plans pertain. Ecological and general outcomes for the *Water Plan (Moreton) 2007* and *Water Plan (Logan Basin) 2007* (i.e. achieving ecological outcomes consistent with supporting natural outcomes by minimising changes to natural flow regimes) will not be impacted with minimal variance to typical hydrological flow. As such, the Project is expected to comply with the Moreton and Logan Basin water plans.

The DTMR provides boat launching ramps, floating walkways, pontoons and jetties throughout QLD. No public boating facilities are located within the water quality study area. There are known fishing spots in the Ipswich area, located east of the Project alignment and water quality study area in areas such as Kholo, Karalee and North Ipswich.

Within the water quality study area, the water allocation licence data indicates 296 megalitres (ML) per year is allocated within the Warrill Valley water management area (refer Table 13.10). The search for water allocations are limited to the water quality study area as identified impacts to water quality would be expected to primarily impact these users.

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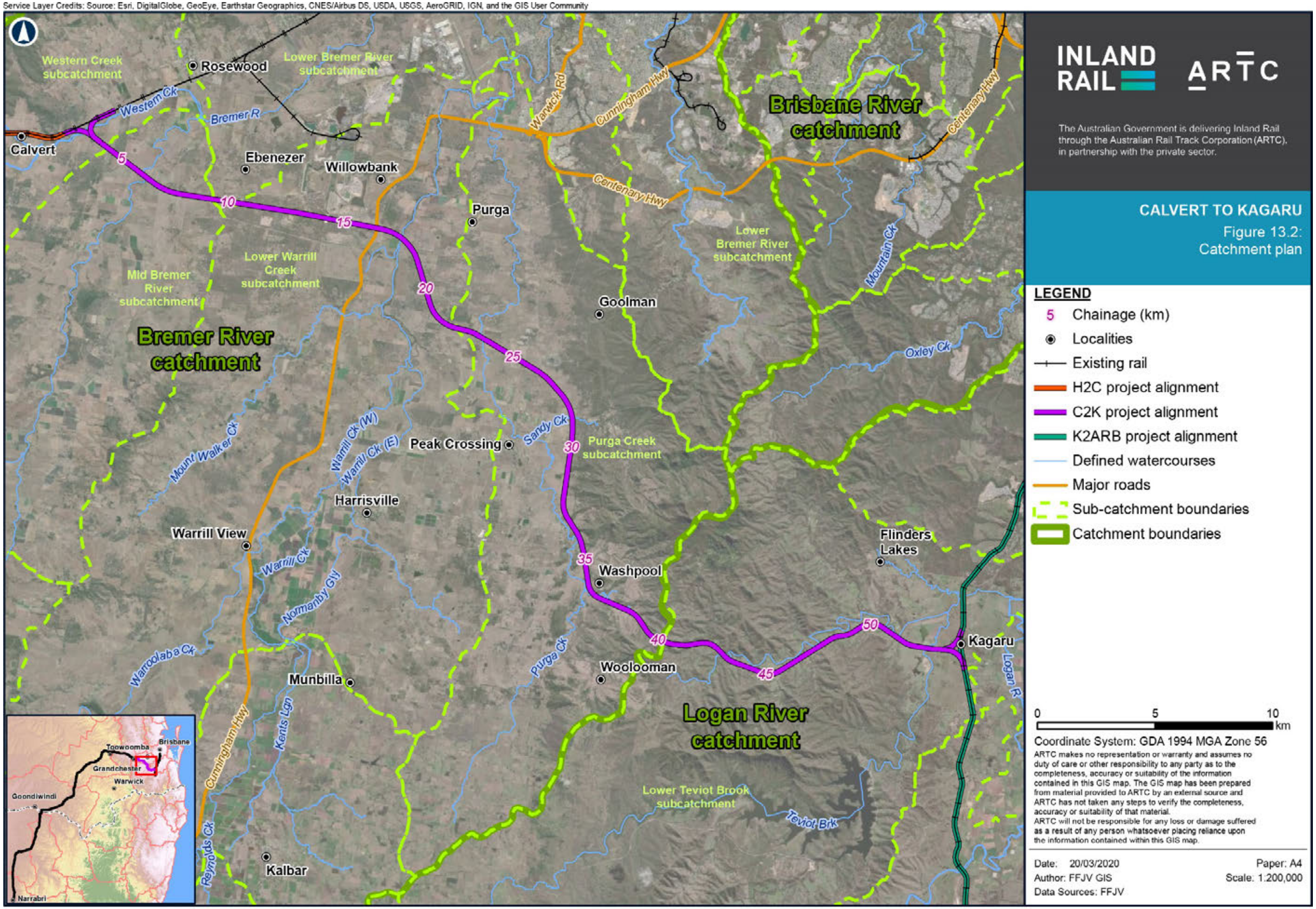

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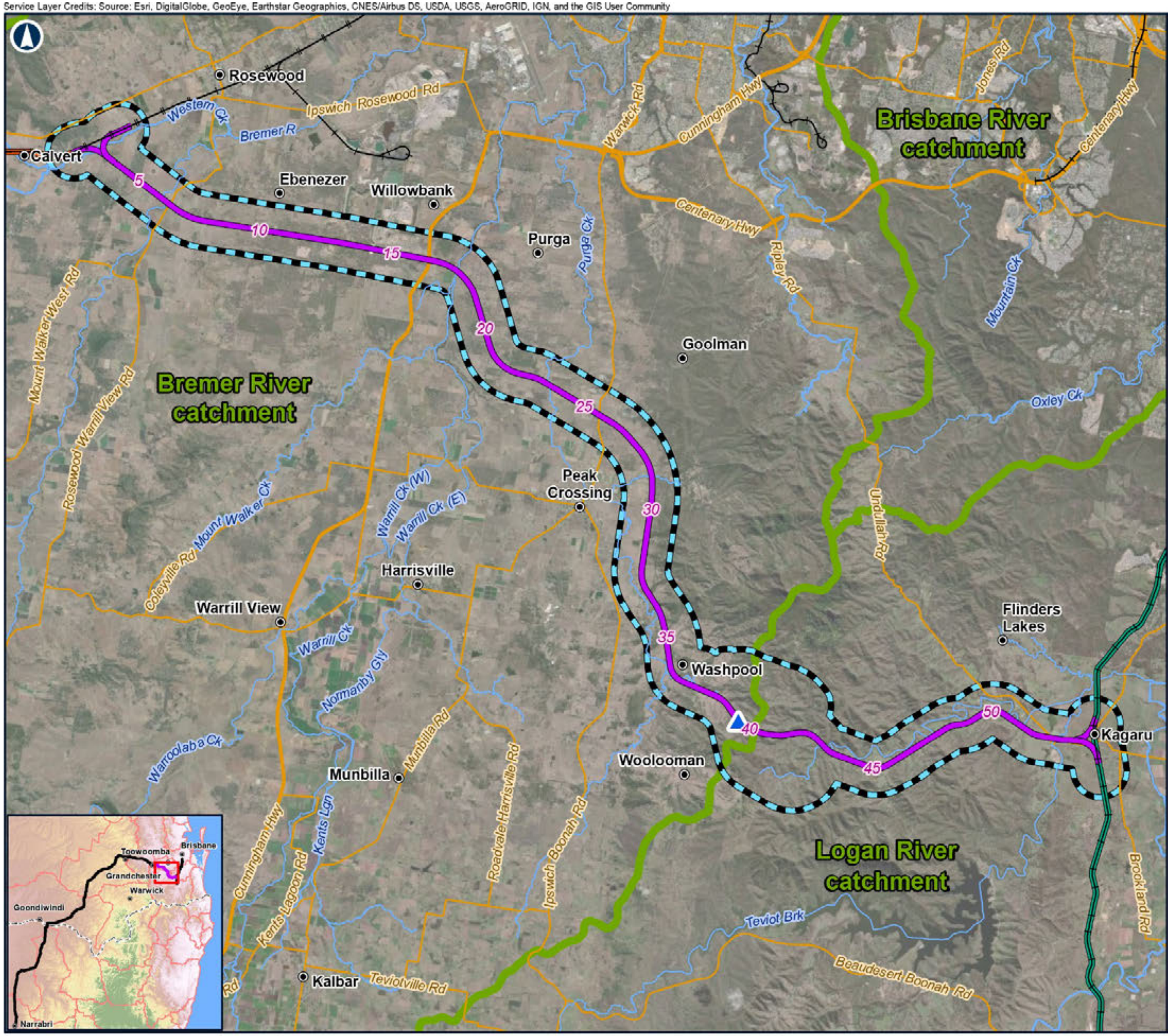

INLAND RAIL

ARTC

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

CALVERT TO KAGARU

Figure 13.3: Watercourses

LEGEND

- Diversion location (Ch 39.50km)
- 5 Chainage (km)
- Localities
- Existing rail
- H2C project alignment
- C2K project alignment
- K2ARB project alignment
- Defined watercourses
- Major roads
- Minor roads
- Water quality study area
- Catchment boundaries

0 5 10 km

Coordinate System: GDA 1994 MGA Zone 56

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Water resource catchments (and water supply buffer area) associated with the water quality study area (refer Appendix F of Appendix M: Surface Water Quality Technical Report) are limited to the Logan River Catchment. Human requirements for drinking water quality supply are considered to be covered by the protection of aquatic ecosystem environmental values (due to stringency of water quality objectives).

TABLE 13.10: SUMMARY OF 2018–2019 WATER ACCESS LICENCE DATA RELEVANT TO THE WATER QUALITY STUDY AREA (UNDER WATER REGULATION 2016)

Water source	No of water access licences	Water made available (ML/yr)
Warrill Creek (surface water source)	3	296
Warrill Creek East Branch (surface water source)	1	123

Source: DNRME, 2019

13.5.2.4 Sensitive environmental areas

Identified sensitive environmental areas for the Project include wetlands areas, identified fish habitat and groundwater dependent ecosystems (GDEs) within receiving waters areas. Sensitive environmental areas are those areas specifically protected by legislative framework. Sensitive environmental areas were included within the impact assessment as a 'high' sensitive category (refer Section 13.8.1).

For further detail refer Appendix J: Terrestrial and Aquatic Ecology Technical Report and Appendix M: Surface Water Quality Technical Report.

Wetlands

There are no wetlands of international importance (Ramsar wetlands) in, or within 10 km of, the water quality study area. Several ecologically significant wetlands (high ecological significance (HES)), which are considered matters of State environmental significance (MSES) under the Environmental Protection Regulation 2019 are present within the water quality study area with some in close proximity to the alignment. Of the 66 hectares of HES wetland that occur within the water quality study area, zero hectares are within the disturbance footprint and as such, no HES wetland are directly impacted by the Project.

Key HES wetland areas are located at the following chainage and watercourse:

- Two HES wetlands proximal to Western Creek (Ch 2.40 km)
- HES wetland at tributary of the Bremer River (Ch 5.20 km to 5.60 km)
- HES wetland at Upper Tributary Warrill Creek (Ch 17.00 km to Ch 17.60 km)
- HES wetland at Purga Creek (Ch 36.00 km)
- HES wetland at Teviot Brook (Ch 52.40 km to Ch 52.80 km).

Fish habitat

There are no declared fish habitat areas (FHA) mapped within the water quality study area. The nearest FHA is located over 35 km east of the eastern extent of the Project (Kagaru).

Groundwater dependent ecosystems

GDEs are ecosystems that require access to groundwater on a permanent or periodic basis to meet all or some of their water requirements so as to maintain their communities of plants and animals, ecological processes and ecosystem services (DES, 2014).

A review of refined scale potential GDE mapping (DES 2014) has been undertaken and the following GDEs aquifer categories have the potential to occur within the water quality study area:

- Unconsolidated sedimentary aquifers
- Consolidated sedimentary aquifers
- Metamorphic rock aquifers.

Surface water expression areas (aquatic GDEs) are considered to be the aspect of relevance to the surface water quality environment and are described alongside terrestrial GDEs below. As a conservative approach has been used to consider impact to GDEs, moderate and high confidence modelling of surface area have been identified within the existing environment.

Aquatic groundwater dependent ecosystems

Numerous watercourses traversing the water quality study area are designated as moderate potential GDEs from regional studies: including Western Creek, Bremer River, Warrill Creek, Purga Creek and Teviot Brook. The potential GDEs are described as wetlands 'supplied by alluvial aquifers with near-permanent flow' (refer Figure 4.8 in Appendix J: Terrestrial and Aquatic Ecology Technical Report).

Terrestrial groundwater dependent ecosystems

Within the water quality study area, to the west and east of the Teviot Range, several moderate potential terrestrial GDEs (from regional studies) are either intersected or close to the proposed Project alignment. These are described as wetland or riparian vegetation 'supplied by alluvial aquifers with near-permanent flow' (refer Figure 4.8 in Appendix J: Terrestrial and Aquatic Ecology Technical Report).

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

Springs

No springs were observed during field assessments associated with this EIS or identified from the GDE Atlas (BoM, 2019) within the water quality study area. Noting this, several first-order streams intersect the Project alignment and may be associated with natural springs.

As no ground truthing of these particular environments was undertaken, it has been assumed for the purposes of the EIS that the modelled extent of the aquatic and terrestrial GDEs are accepted as true presence, and therefore form a potentially sensitive receptor. GDEs and surface areas have been mapped as occurring within the water quality study area.

13.5.2.5 Salinity hazard

The water quality study area was broken down by the Australian Hydrologic Geospatial Fabric Catchment Geographical Information Systems layer, into smaller sub-catchments to enable a more precise analysis of the Project. The sub-catchments were analysed for salinity hazards in accordance with *Part B Investigating Salinity of the Salinity Management Handbook* (DERM, 2011). In particular, consideration was given to how Project construction activities may alter the hydrology of the water quality study area.

Once broken down into sub-catchments, the soils layer was intersected with the sub-catchments layer to identify which soils were dominant in each of the sub-catchments. Prior knowledge of soil type was applied to give a low, moderate, or high rating to each of the dominant soil types and provide an indication of inherent salt store.

The overall salinity hazard map was developed from the factors addressed above. Salinity hazard within the water quality study area was assessed using the CSIRO (2014) electrical conductivity mapping layer. The Project water quality study area generally contained low electrical soil conductivity between 0.05 dS/m and 0.1 dS/m, with two distinct patches of high electrical conductivity (0.5 dS/m to 1.0 dS/m) meandering through the water quality study area as the alignment crosses Western Creek, at Calvert, and the Bremer River, located west of Ebenezer.

Sections of the Project alignment directly intersect moderate-to-high salinity hazard rating areas (refer Figure 13.4)

Details of potential impact from the Project in relation to the overall salinity hazard and actions for mitigation are detailed further in Chapter 9: Land Resources.

13.5.3 Surface water quality and existing conditions

13.5.3.1 Summary of field and laboratory assessed surface water quality data

Water quality monitoring sites for the Project are shown in Figure 13.1. Water-quality results for field and laboratory assessments are in Sections 13.5.3.2 and 13.5.3.3 respectively.

Across all three sampling events, pH values for watercourses within both the Logan River and the Bremer River catchments were typically neutral and mostly within WQOs. Non-compliances of WQOs were noted, with one watercourse exceeding Bremer River WQOs and one watercourse exceeding Warrill Creek WQOs (refer Table 13.11).

Typically, turbidity values followed seasonal flow conditions across the sampling events (refer Table 13.11). Within the first sampling event, turbidity values were below WQOs for watercourses within both the Logan River and Bremer River catchments and followed a pattern of variable turbidity linked to low- to no-flow conditions during the sampling event. Mobilisation of sediment with higher-flow conditions was observed within the second sampling event, with high-level non-compliances of turbidity WQOs within both catchments. Within the second sampling event, sites 5A, 9A and 14A were the only sites (across both catchments) that did not exceed surface water turbidity WQOs. Within the third sampling event, stream flow conditions were representative of the environmental conditions experienced across the catchments, with minimal-to-no flow experienced throughout all the water quality monitoring sites and variable turbidity values (dependent on localised standing pool conditions during sampling event).

Electrical conductivity levels were typically below WQOs for the Logan River and Bremer River catchments. Noting that flow conditions varying between standing pools to high flow were present during the second assessment, the electrical conductivity levels observed were not considered atypical. A similar artefact of low-flow conditions was noted during the third sampling event, as those watercourses that were sampled were limited to standing pools and were likely exhibiting concentrations impacted by evaporation.

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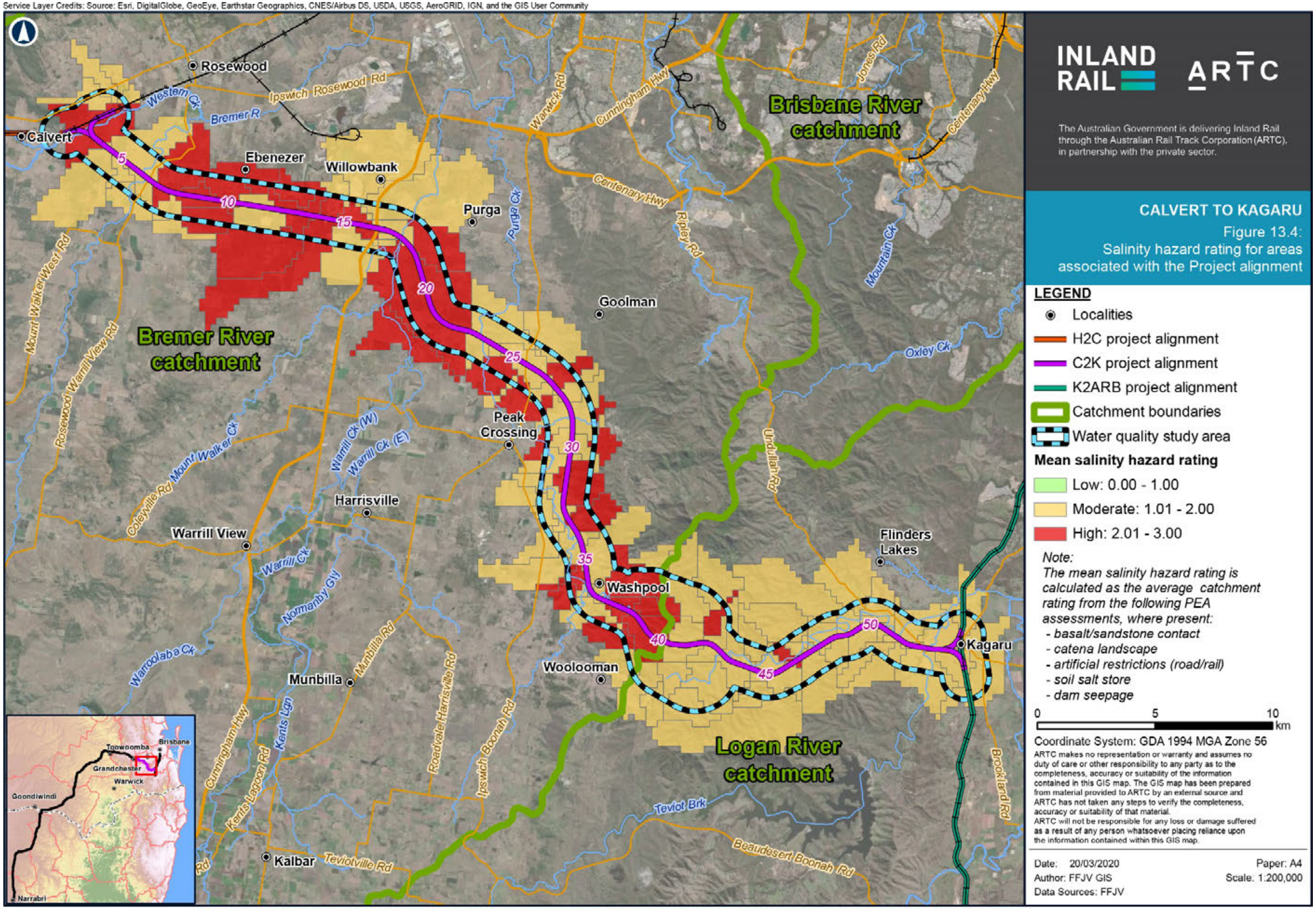

CALVERT TO KAGARU

Figure 13.4: Salinity hazard rating for areas associated with the Project alignment

Map by: ST/CN/MEF/RB Z:\GIS\GIS_3400_C2K\Tasks\340-EEC-201908021342_EIS_SurfaceWater_figures\340-EAP-201903060934_ARTCv2_A4_Fig13.4_Overall_Salinity_v3.mxd Date: 30/03/2020 12:53

In line with other physico-chemical parameters, dissolved oxygen concentrations within the watercourses demonstrated the disparity in flow conditions (refer Table 13.11). None of the sites sampled during the first round of monitoring were within WQOs. This pattern of non-compliance was present within the second round of sampling as, while improved, several sites across both the Logan River and Bremer River catchment still exhibited dissolved oxygen concentrations below WQOs. Within the third sampling event, dissolved oxygen concentrations were highly variable with some sites meeting WQO. It is worth noting that the sites with elevated dissolved oxygen concentrations also exhibited high chlorophyll *a* concentrations and indicate an enhancement of dissolved oxygen levels by algal photosynthesis within these sites.

Chlorophyll *a* concentrations did not follow any discernible pattern across the sampling periods with non-compliances noted during sampling events and across both the Logan River and Bremer River catchments (refer Table 13.12). Notably, most non-compliances were typically minor (relative to threshold concentrations for exceedance), with a notable exception of one site (11A) within the Logan River catchment exhibiting very high chlorophyll *a* concentrations during the first sampling event (that coincided with high levels of suspended solids and nutrient load), with a return to WQO levels in the second sampling event. Within the third sampling event, monitoring sites that were assessable typically did not meet WQOs for chlorophyll *a,* coinciding with non-compliances in other WQOs.

Patterns of degradation were noted within several of the watercourses across the sampling period, indicating the potential for existing anthropogenic influences (specifically, within sites 5A, 7A, 8A, 9A, 11A, 12A and 13A (refer Table 13.12)). Nutrient (primarily Total Phosphorus and Total Nitrogen) concentrations exceeded WQOs across sampling events; indicating limited improvement of water quality with an increase towards base-flow conditions. Of the non-compliances in nutrient concentrations, high levels of ammonia concentrations were noted in sites 5A, 5A (1) and 12A (both within the Bremer River catchment). As the 5A sites are located proximal to each other on the same watercourse, similar heightened concentrations are not considered atypical. Comparatively, site 12A exhibited ammonia concentrations elevated well above WQOs during the first event. Lower ammonia concentrations (yet exceeding WQOs) were noted during the second monitoring event, indicating improvement with a return to base-flow conditions. The site was dry at the time of the third sample event.

In general, WQOs for metals were typically met across all assessable water quality monitoring sites for the survey period (refer Table 13.13). Exceedances within two specific dissolved metals (copper and zinc) were noted in the second round of sampling for both the Logan River and Bremer River catchments, while no non-compliances were noted in the first round of sampling. Laboratory analysis of PAH concentrations at all sites were below detection limits, indicating no continued point source contamination of sampled sites, though it is recognised that these compounds are volatile and may not be very persistent in the environment.

13.5.3.2 Field assessment water quality results

The in-situ water quality results for the field assessed water quality assessments are provided in Table 13.11.

13.5.3.3 Laboratory assessed water quality results

The summary of the laboratory results for the laboratory assessments for the water quality study area are provided in Table 13.12 and Table 13.13.

TABLE 13.11: IN SITU WATER QUALITY RESULTS FOR THE PROJECT'S WATER QUALITY MONITORING SITES

Site	Date	pH	EC (µs/cm)	Temperature (°C)	Turbidity (NTU)	Salinity (ppt)	Dissolved oxygen (mg/L)	Dissolved oxygen (%)
Logan River catchment								
Logan River WQO	-	6.5 – 8.0	< 780	N/A	< 10	N/A	N/A	85–110
7A Dugandan Creek	27/09/2017	7.42	-	20.8	13.9	-	-	-
	27/02/2018	7.54	224	24.3	130	0.11	8.15	99
	13/03/2019	Dry at time of sampling						
7A alt Unnamed watercourse	27/09/2017	Dry at time of sampling						
	28/02/2018	7.26	160.5	23.6	95.5	0.08	6.75	79
	13/03/2019	Dry at time of sampling						
8A Dugandan Creek	27/09/2017	7.04	-	20.5	11.4	-	-	-
	28/02/2018	7.47	232.5	23.4	108	0.11	7.33	86.8
	13/03/2019	Dry at time of sampling						
9A Woollaman Creek	25/09/2017	7.83	-	25.0	10.2	-	-	-
	27/02/2018	7.59	176.3	24.5	88	0.08	7.09	85.1
	13/03/2019	Dry at time of sampling (*visual assessment due to no access at time of sampling)						
10A Teviot Brook	25/09/2017	6.93	-	18.5	10.2	-	-	-
	27/02/2018	6.85	78.3	26.1	90	0.03	0.9	16
	13/03/2019	7.52	2,775	27.2	7.8	1.37	5.55	71.5
11A Dam	25/09/2017	7.4	-	22.4	7.2	-	-	-
	27/02/2018	6.85	78.3	26.1	90	0.03	0.9	16
	13/03/2019	No access to site at sampling						
12A Unnamed watercourse	28/09/2017	7.51	-	19	11.5	-	-	-
	28/02/2018	7.54	202.6	24.7	101.1	0.1	7.5	92
	13/03/2019	Dry at time of sampling						

Site	Date	pH	EC (µs/cm)	Temperature (°C)	Turbidity (NTU)	Salinity (ppt)	Dissolved oxygen (mg/L)	Dissolved oxygen (%)
Bremer River catchment								
Western Creek/ Bremer River WQO	-	6.5–8.0	< 770	N/A	< 17	N/A	N/A	85 – 110
1A alt Western Creek	29/09/2017	7.49	-	18	5.9	-	-	-
	2/03/2018	7.82	338.4	25.5	76.2	0.16	3.63	44.1
	12/03/2019	Dry at time of sampling						
2A Bremer River	29/09/2017	Dry at time of sampling						
	28/02/2018	7.39	235	26.1	140	0.11	3.98	51
	12/03/2019	Dry at time of sampling						
5A Dam	26/09/2017	7.84	-	24.6	2.8	-	-	-
	28/02/2018	9.3	356.6	32.4	14.4	0.14	8.7	118.2
	13/03/2019	9.14	782	28.7	46.5	0.35	7.72	101.1
5A (1) Unnamed watercourse	29/09/2017	Dry at time of sampling						
	28/02/2018	6.75	156	26.1	77.5	0.07	0.55	7.7
	13/03/2019	Dry at time of sampling						
6A Unnamed tributary of Purga Creek	28/09/2017	7.66	-	19.2	5.3	-	-	-
	28/02/2018	7.52	321.9	27.2	105	0.15	6.2	77
	13/03/2019	7.49	3,206	23.5	39.6	1.72	1.45	17.1
13A Unnamed tributary of Purga Creek	26/09/2017	7.49	-	19.6	1.3	-	-	-
	28/02/2018	7.4	213.6	26.9	130	0.11	5.29	71
	13/03/2019	7.53	2,110	24.5	35.7	1.09	4.56	53.9
14A Unnamed tributary of Purga Creek	27/09/2017	Dry at time of sampling						
	28/02/2018	7.46	252.6	25.8	61.4	0.12	6.91	85
	13/03/2019	Dry at time of sampling						
Warrill Creek WQO	-	6.5–8.0	< 500	N/A	< 5	N/A	N/A	85 – 110
3A Warrill Creek	28/09/2017	8.01	-	21.2	0.4	-	-	-
	28/02/2018	Dry at time of sampling						
	13/03/2019	No access to site at sampling						

Table notes:
Coloured text where value is above WQO or outside WQO range where applicable N/A — not applicable ppt — parts per thousand

Source WQO: DERM (2010a; 2010b)

TABLE 13.12: KEY LABORATORY RESULTS FOR THE PROJECT WATER QUALITY MONITORING SITES

Site	Date	pH	Conductivity (at 25°C) (µs/cm)	Chlorophyll *a* (µg/L)[1]	Total P (mg/L)[2]	Filterable reactive nitrogen (mg/L)	Suspended solids (mg/L)	Turbidity (NTU)	Ammonia (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)	Organic nitrogen (mg/L)	Total Kjeldahl nitrogen (mg/L)	Total N (mg/L)
LOR	-	0.1	1	5	0.05 0.01	0.01	1	1	0.01	0.02	0.02	0.2	0.2	0.2
Logan River catchment														
Logan River WQO	-	6.5 – 8.0	< 780	< 5	< 0.05	0.02	< 6	< 10	< 0.02	-	-	< 0.42	-	< 0.5
7A Dugandan Creek	27/09/2017	8	1,500	<5	<0.05	<0.05	9.9	7.3	0.03	<0.02	<0.02	0.7	0.7	0.7
	27/02/2018	7.7	180	<5	0.09	<0.05	14	120	0.03	0.07	<0.02	0.9	0.9	0.97
	13/03/2019	Dry at time of sampling												
7A alt Un-named watercourse	27/09/2017	Dry at time of sampling												
	28/02/2018	7.4	140	<5	0.07	<0.05	10	90	<0.01	<0.02	0.03	0.5	0.5	0.5
	13/03/2019	Dry at time of sampling												
8A Dugandan Creek	27/09/2017	7.9	1,200	<10	<0.05	<0.05	12	6.6	0.06	<0.02	<0.02	0.5	0.6	0.6
	28/02/2018	7.4	180	<5	0.07	<0.05	7.7	99	0.02	0.06	<0.02	0.7	0.7	0.77
	13/03/2019	Dry at time of sampling												
9A Woollaman Creek	25/09/2017	8.2	940	<5	<0.05	<0.05	15	5.2	0.04	<0.02	<0.02	<0.02	0.7	0.7
	27/02/2018	7.4	160	<5	0.08	<0.05	45	140	0.03	0.04	<0.02	0.8	0.8	0.86
	13/03/2019	Dry at time of sampling (*visual assessment due to no access at time of sampling)												
10A Teviot Brook	25/09/2017	7.8	990	<5	<0.05	<0.05	6.8	5	0.02	0.09	<0.02	0.4	0.4	0.4
	27/02/2018	8	470	6	0.06	<0.05	14	9	0.02	<0.02	<0.02	0.5	0.5	0.5
	13/03/2019	8.2	2,700	<5	0.01	0.01	13	7.4	<0.01	<0.02	<0.02	0.29	0.3	0.29
11A Dam	25/09/2017	6.9	100	580	<0.05	<0.05	110	35	<0.01	<0.02	<0.02	2.3	2.3	2.3
	27/02/2018	6.8	49	<5	0.18	<0.05	33	32	0.05	<0.02	<0.02	0.6	0.6	0.6
	13/03/2019	Dry at time of sampling												
12A Un-named watercourse	28/09/2017	8.1	5,400	12	0.25	<0.05	11	2.4	0.89	<0.02	<0.02	1.6	2.5	2.5
	28/02/2018	7.3	180	<5	0.08	<0.05	6.4	97	0.07	0.19	<0.02	0.6	0.7	0.89
	13/03/2019	Dry at time of sampling												

Site	Date	pH	Conductivity (at 25°C) (μs/cm)	Chlorophyll *a* (μg/L)[1]	Total P (mg/L)[2]	Filterable reactive nitrogen (mg/L)	Suspended solids (mg/L)	Turbidity (NTU)	Ammonia (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)	Organic nitrogen (mg/L)	Total Kjeldahl nitrogen (mg/L)	Total N (mg/L)
LOR	-	0.1	1	5	0.05 0.01	0.01	1	1	0.01	0.02	0.02	0.2	0.2	0.2
Bremer River catchment														
Western Creek/ Bremer River WQO	-	6.5 – 8.0	< 770	< 5	< 0.05	<0.02	< 6	< 17	< 0.02	-	-	< 0.42	-	< 0.5
1A alt Western Creek	29/09/2017	8.1	910	33	0.17	0.11	14	5.9	0.04	0.03	<0.02	1.0	1	1
	2/03/2018	7.7	290	<5	0.48	0.92	22	58	0.02	0.2	0.05	1.0	1	1.3
	12/03/2019	Dry at time of sampling												
2A Bremer River	29/09/2017	Dry at time of sampling												
	28/02/2018	7.4	200	<5	0.54	0.36	49	95	0.07	0.05	<0.02	0.7	0.8	0.85
	12/03/2019	Dry at time of sampling												
5A Dam	26/09/2017	8.1	280	<5	0.19	0.12	8	8.4	0.08	<0.02	<0.02	1.4	1.5	1.5
	28/02/2018	8.5	270	11	0.07	<0.05	25	7.9	0.28	<0.02	<0.02	1.2	1.5	1.5
	13/03/2019	9.1	380	32	0.01	0.01	36	21	<0.01	<0.02	<0.02	1.6	1.6	1.6
5A (1) Un-named watercourse	29/09/2017	Dry at time of sampling												
	28/02/2018	6.8	130	<5	0.12	0.07	17	56	0.19	<0.02	<0.02	1.1	1.1	1.1
	13/03/2019	Dry at time of sampling												
6A Un-named tributary of Purga Creek	28/09/2017	8.1	2,800	<10	<0.05	<0.05	4.9	3.2	0.02	<0.02	<0.02	0.6	0.6	0.6
	28/02/2018	7.6	250	<5	0.08	<0.05	26	98	0.02	<0.02	<0.02	0.7	0.7	0.7
	13/03/2019	8.3	3,400	<5	0.02	0.01	42	34	0.67	0.06	<0.02	1.2	1.9	1.9
13A Un-named tributary of Purga Creek	26/09/2017	8.2	2,100	<5	<0.05	<0.05	3.8	0.3	0.03	<0.02	<0.02	0.3	0.3	1
	28/02/2018	7.6	200	<5	0.07	<0.05	95	120	<0.01	<0.02	<0.02	0.6	0.6	0.6
	13/03/2019	8.4	2,000	20	0.01	0.01	24	9.7	<0.01	<0.02	<0.02	0.59	0.6	0.59

Site	Date	pH	Conductivity (at 25°C) (µs/cm)	Chlorophyll *a* (µg/L)[1]	Total P (mg/L)[2]	Filterable reactive nitrogen (mg/L)	Suspended solids (mg/L)	Turbidity (NTU)	Ammonia (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)	Organic nitrogen (mg/L)	Total Kjeldahl nitrogen (mg/L)	Total N (mg/L)
LOR	-	0.1	1	5	0.05 0.01	0.01	1	1	0.01	0.02	0.02	0.2	0.2	0.2
14A Un-named tributary of Pura Creek	27/09/2017	Dry at time of sampling												
	28/02/2018	7.6	220	<5	0.09	<0.05	9.3	62	0.02	<0.02	<0.02	0.7	0.7	0.7
	13/03/2019	Dry at time of sampling												
Lower Warrill Creek WQO	-	6.5 – 8.0	< 500	< 5	< 0.05		< 6	< 5	< 0.02	-	-	< 0.06	-	< 0.5
3A Warrill Creek	28/9/2017	8.3	980	<10	0.07	0.05	3.5	1.1	<0.01	<0.02	<0.02	0.4	0.4	0.4
	28/02/2018	Dry at time of sampling												
	13/03/2019	No access to site at sampling												

Table notes:

Coloured text where value is above WQO or outside WQO range where applicable

1. Chlorophyll *a* concentrations during the 2017 assessment were recorded as <10 or <5 at concentrations below <10 µg/L
2. LOR changes for total P occurred between field assessments 2 (September 2018) and 3 (March 2019)

Source WQO: DERM (2010a; 2010b)

TABLE 13.13: DISSOLVED METAL AND INDICATIVE PAH LABORATORY RESULTS FOR PROJECT WATER QUALITY MONITORING SITES

Site	Date	Arsenic (mg/L)	Cadmium (mg/L)	Chromium (mg/L)	Copper (mg/L)	Lead (mg/L)	Mercury (mg/L)	Nickel (mg/L)	Zinc (mg/L)	Naphthalene (mg/L)
LOR	**-**	**0.001**	**0.0002**	**0.001**	**0.001**	**0.001**	**0.0001**	**0.001**	**0.005**	**0.001**
Logan River catchment										
Logan River WQO	-	0.024	0.0002	0.0004	0.0014	0.0034	0.0006	0.011	0.008	0.016
7A Dugandan Creek	27/09/2017	<0.001	<0.0002	<0.001	<0.001	<0.001	<0.0001	<0.001	<0.005	<0.001
	27/02/2018	<0.001	<0.0002	<0.001	0.001	0.001	<0.0001	0.001	<0.005	<0.001
	13/03/2019	Dry at time of sampling								
7A alt Unnamed watercourse	27/09/2017	Dry at time of sampling								
	28/02/2018	<0.001	<0.0002	<0.001	<0.001	<0.001	<0.0001	<0.001	<0.005	<0.001
	13/03/2019	Dry at time of sampling								
8A Dugandan Creek	27/09/2017	<0.001	<0.0002	<0.001	<0.001	<0.001	<0.0001	<0.001	<0.005	<0.001
	28/02/2018	<0.001	<0.0002	<0.001	<0.001	<0.001	<0.0001	<0.001	0.01	<0.001
	13/03/2019	Dry at time of sampling								
9A Woollaman Creek	25/09/2017	<0.001	<0.0002	<0.001	<0.001	<0.001	<0.0001	<0.001	<0.005	<0.001
	27/02/2018	<0.001	<0.0002	<0.001	0.002	<0.001	<0.0001	0.002	0.009	<0.001
	13/03/2019	Dry at time of sampling (*visual assessment due to no access at time of sampling)								
10A Teviot Brook	25/09/2017	<0.001	<0.0002	<0.001	<0.001	<0.001	<0.0001	<0.001	<0.005	<0.001
	27/02/2018	<0.001	<0.0002	<0.001	<0.001	<0.001	<0.0001	<0.001	<0.005	<0.001
	13/03/2019	<0.001	<0.0002	<0.001	<0.001	<0.001	<0.0001	<0.001	<0.005	<0.001
11A Dam	25/09/2017	<0.001	<0.0002	<0.001	<0.001	<0.001	<0.0001	<0.001	<0.005	<0.001
	27/02/2018	<0.001	<0.0002	<0.001	<0.001	<0.001	<0.0001	<0.001	<0.005	<0.001
	13/03/2019	Dry at time of sampling								
12A Unnamed watercourse	28/09/2017	0.002	<0.0002	<0.001	<0.001	<0.001	<0.0001	0.001	<0.005	<0.001
	28/02/2018	<0.001	<0.0002	<0.001	0.002	<0.001	<0.0001	0.001	<0.005	<0.001
	13/03/2019	Dry at time of sampling								

Site	Date	Arsenic (mg/L)	Cadmium (mg/L)	Chromium (mg/L)	Copper (mg/L)	Lead (mg/L)	Mercury (mg/L)	Nickel (mg/L)	Zinc (mg/L)	Naphthalene (mg/L)
LOR	**-**	**0.001**	**0.0002**	**0.001**	**0.001**	**0.001**	**0.0001**	**0.001**	**0.005**	**0.001**
Bremer River catchment										
Western Creek/ Bremer River WQO	-	0.024	0.0055	0.0004	0.0014	0.0034	0.0006	0.011	0.008	0.016
1A alt Western Creek	29/09/2017	0.002	<0.0002	<0.001	<0.001	<0.001	<0.0001	0.003	<0.005	<0.001
	02/03/2018	<0.001	<0.0002	<0.001	0.003	<0.001	<0.0001	0.004	0.008	<0.001
	12/03/2019	Dry at time of sampling								
2A Bremer River	29/09/2017	Dry at time of sampling								
	28/02/2018	<0.001	<0.0002	<0.001	0.004	<0.001	<0.0001	0.004	<0.005	<0.001
	12/03/2019	Dry at time of sampling								
5A Dam	26/09/2017	0.003	<0.0002	<0.001	<0.001	<0.001	<0.0001	<0.001	<0.005	<0.001
	28/02/2018	0.002	<0.0002	<0.001	<0.001	<0.001	<0.0001	<0.001	<0.005	<0.001
	13/03/2019	0.002	<0.0002	<0.001	<0.001	<0.001	<0.0001	<0.001	<0.005	<0.001
5A (1) Unnamed watercourse	29/09/2017	Dry at time of sampling								
	28/02/2018	<0.001	<0.0002	<0.001	0.003	<0.001	<0.0001	0.002	0.009	<0.001
	13/03/2019	Dry at time of sampling								
6A Unnamed tributary of Purga Creek	28/09/2017	<0.001	<0.0002	<0.001	<0.001	<0.001	<0.0001	<0.001	<0.005	<0.001
	28/02/2018	<0.001	<0.0002	<0.001	0.001	<0.001	<0.0001	0.001	0.006	<0.001
	13/03/2019	0.001	<0.0002	<0.001	<0.001	<0.001	<0.0001	0.003	<0.005	<0.001
13A Unnamed tributary of Purga Creek	26/09/2017	<0.001	<0.0002	<0.001	<0.001	<0.001	<0.0001	<0.001	<0.005	<0.001
	28/02/2018	<0.001	<0.0002	<0.001	0.001	<0.001	<0.0001	0.001	0.011	<0.001
	13/03/2019	0.006	<0.0002	<0.001	<0.001	<0.001	<0.0001	0.002	<0.005	<0.001
14A Unnamed tributary of Pura Creek	27/09/2017	Dry at time of sampling								
	28/02/2018	<0.001	<0.0002	<0.001	0.002	<0.001	<0.0001	0.002	<0.005	<0.001
	13/03/2019	Dry at time of sampling								
Lower Warrill Creek WQO	-	0.024	0.0055	0.0004	0.0014	0.0034	0.0006	0.011	0.008	0.016
3A Warrill Creek	28/09/2017	<0.001	<0.0002	<0.001	<0.001	<0.001	<0.0001	<0.001	<0.005	<0.001
	02/09/2018	Dry at time of sampling								
	13/03/2019	No access to site at sampling								

Table notes:
Coloured text where value is above WQO or outside WQO range where applicable

Source WQO: DERM (2010a; 2010b)

13.5.4 Summary of existing surface water quality condition

On comparison with historical water quality data for Warrill Creek, Purga Creek and Western Creek (refer Appendix M: Surface Water Quality Technical Report) water quality values observed during the three sampling rounds typically followed those of the gauging stations. Water quality was typically outside of WQOs with total suspended solids (TSS) exceeding WQOs historically and within the current assessment. Total nitrogen and total phosphorous as a typical anthropogenic contaminant also followed historical data with WQO non-compliance noted throughout the entire sampling event period.

While WQOs generally do not meet historical mean values, results from the three sampling rounds conducted for this study suggest that compliance with WQOs is affected by highly seasonal water flow conditions observed throughout the water quality study area. Within the gauging stations, a majority of the quantified water quality parameters (e.g. TSS, ammonia, total nitrogen and total phosphorus) did not meet WQOs. The gauging stations indicate discharge (ML/day) along Western Creek, Warrill Creek and Purga Creek were highly variable and indicate the low-flow conditions experienced across periods of the entire monitoring period are not atypical. Water quality (specifically physico-chemical parameters and laboratory-analysed data) was observed to improve with an increase in hydrological flow and the assimilative capacity would be expected to be greatest during high-flow conditions.

Moderate, low and very-low Aquascore riverine wetlands (refer Appendix M: Surface Water Quality Technical Report) were modelled along the Project alignment and correspond to the healthy water assessment of each catchment. The assessment indicates typical processes are 'good' with fair–average riparian condition throughout the catchment. While non-compliances of WQO were noted within particular parameters throughout the entire sampling event period, water quality can be generalised to be meeting a large variety of WQO and ANZG guidelines (including metals and PAH analysis). However, non-compliances of several nutrient contaminants are notable and continuing (through assessment of historic and current field assessment).

The water quality monitoring sites associated with moderate Aquascores for riverine wetlands were those on sections of the Western Creek, the Bremer River, Warrill Creek, Purga Creek and Teviot Brook. Those associated with low to very-low Aquascores were associated with a tributary of Western Creek and Purga Creek, Dugandan Creek and Woollaman Creek.

In summary, habitat conditions were not considered atypical (in terms of periods of low-surface hydrological flow); however, clear impacts of diminished flow conditions were noted throughout the sampling event. In regard to the field sampling event, water quality parameters improved with a higher-surface hydrological flow within the second field sampling event and, where water persisted, decreased in the third sampling event.

13.5.5 Surface water quality receptors

A receptor is a feature (including use by human and ecological components), area or structure that may be affected by direct or indirect changes to the environment. The water quality receptors were assessed against relevant legislation (refer Section 13.3) and the overarching values used to feed potential impacts which included:

- QLD's natural environment (including utilisation by native flora and fauna)
- Finite natural resources, with specific regard to wetlands
- Watercourses conducive to the maintenance of existing landforms, ecological health and biodiversity.

Due to the interconnected nature of the watercourses and waterbodies intersecting the Project alignment and residing within the water quality study area, the water quality receptors for the existing environment (as a whole of package) were assigned a moderate sensitivity due to several factors:

- Protected by State legislation
- Important for biodiversity
- Existing sensitivity (under threatening process) and/or high exposure to impacts.

To maintain a conservative approach to assessment, all waterways and waterbodies within the disturbance footprint water quality study area and downstream receiving environments were nominated as moderate-sensitivity water quality receptors for identification of potential impacts, associated mitigation measures and identification of residual impact after implementation of mitigation.

High-sensitivity water quality receptors were identified from the potential presence of the conservation significant species Australian Lungfish (*Neoceratodus forsteri*) and MSES wetlands within the water quality study area.

Therefore, sensitivity of all receiving waterways was considered as either moderate- or high-sensitivity water quality receptors. High-sensitivity water quality receptors include intersecting sections of the Project alignment associated with Western Creek, Bremer River, Warrill Creek and Teviot Brook.

For further information pertaining to the assessment of existing conditions and assessment of receptor sensitivity, refer Appendix M: Surface Water Quality Technical Report.

13.5.6 Existing floodplain infrastructure

Key existing infrastructure on floodplain areas in the proximity of the Project alignment includes:

- West Moreton Rail Line
- Waters Road
- Washpool Road
- Wild Pig Creek Road
- Undullah Road
- Levees and dams from farming practices.

The Project connects into the West Moreton Rail Line which is operated by Queensland Rail (QR). The QR rail line runs parallel to Western Creek and has multiple cross-drainage structures. During large flood events, the QR rail line is inundated by Western Creek. Running parallel to the QR rail line is Waters Road. This road is intermittently sealed, low level, and is inundated by Western Creek during frequent flood events.

Washpool Road is within the Purga Creek catchment. This road is also at a low level and inundated frequently. The Project proposes realignment of part of Washpool Road.

Wild Pig Creek Road and Undullah Road are within the Teviot Brook catchment. The Project proposes realignment of part of Wild Pig Creek Road. Undullah Road is directly upstream of Teviot Bridge and is inundated by frequent flood events.

As part of the *Brisbane River Strategic Floodplain Management Plan* (BRSFMP) (Queensland Reconstruction Authority, 2019) there is a recommendation to investigate a dry dam on Warrill Creek (S02 Project— Warrill Creek Flood Mitigation Dam). As part of this recommendation it was noted that these works could be incorporated with the Project. The Project design undertaken to date was aware of this potential dam; however, it has not been incorporated in the Project design. The Project design does not inhibit the investigation outlined in BRSFMP for the Warrill Creek dam or limit the investigation of potential synergies between the projects.

13.5.7 Existing flooding regime

Flooding in the vicinity of the Project alignment occurs through two mechanisms, or a combination of both, being:

- Rainfall over the waterway catchment areas upstream of the Project alignment
- Backwater from downstream major systems, e.g. in the vicinity of the Project alignment, Teviot Brook is affected by flooding on the Logan River system.

In addition to the major waterways, there are a number of small local drainage catchments that are intersected by the Project alignment.

Available data and previous studies were collected and reviewed to support the development and calibration of the hydrologic and hydraulic models for the Project. For the Bremer River and its tributaries, Western Creek, Warrill Creek and Purga Creek, the hydrologic model developed for the Brisbane River Catchment Flood Study (Aurecon, 2015) was adopted for the Project. For Teviot Brook a hydrologic model previously developed by LCC was adopted for the Project. Minor modifications were made to the hydrologic models to produce flow estimates at waterway crossings on the Project alignment.

Localised hydraulic models were developed for each major waterway crossing on the Project alignment based on a range of previous studies and latest available data. The extents of each of the hydraulic models are shown in Figure 13.5.

13.5.7.1 Calibration to historical flood events

Available background information was sourced to support validation of the hydrologic models and calibration of the hydraulic models including existing models, streamflow data and available anecdotal flood data. This data was sourced from a wide range of stakeholders.

Modelling of each waterway catchment was calibrated against three historical events with results matched to recorded data from a number of stream gauges, community feedback as well as anecdotal flood data. The Bremer River, and its tributaries, were calibrated against the 1974, 2011 and 2013 historical flood events and Teviot Brook was calibrated against the 1974, 1990 and 2013 historical flood events. The historical events were selected to represent a range of event magnitudes and durations. A good calibration against available information (including recorded stream gauge data, flood marker and community feedback) was achieved for all catchments and the hydrologic and hydraulic models were considered suitable for assessment of the Project alignment.

The magnitude of each of the historical events has been estimated at each of the major stream gauges in the waterway catchments. The estimated AEP of each event is outlined in Table 13.14 and Table 13.15.

TABLE 13.14: ANNUAL EXCEEDANCE PROBABILITY OF HISTORICAL EVENTS—BREMER RIVER CATCHMENT

	Estimated historical event AEP (%)		
Stream gauge	January 1974	January 2011	January 2013
Walloon	~0.5	~0.6	~8
Loamside	~0.1	~23	~33
Amberley	~1.4	~11.5	~5.7

TABLE 13.15: ANNUAL EXCEEDANCE PROBABILITY OF HISTORICAL EVENTS—TEVIOT BROOK CATCHMENT

	Estimated historical event AEP (%)		
Stream gauge	January 1974	April 1990	January 2013
Overflow	~4	~23	~6
Yarrahapinni	~1.4	~16.9	~6.6

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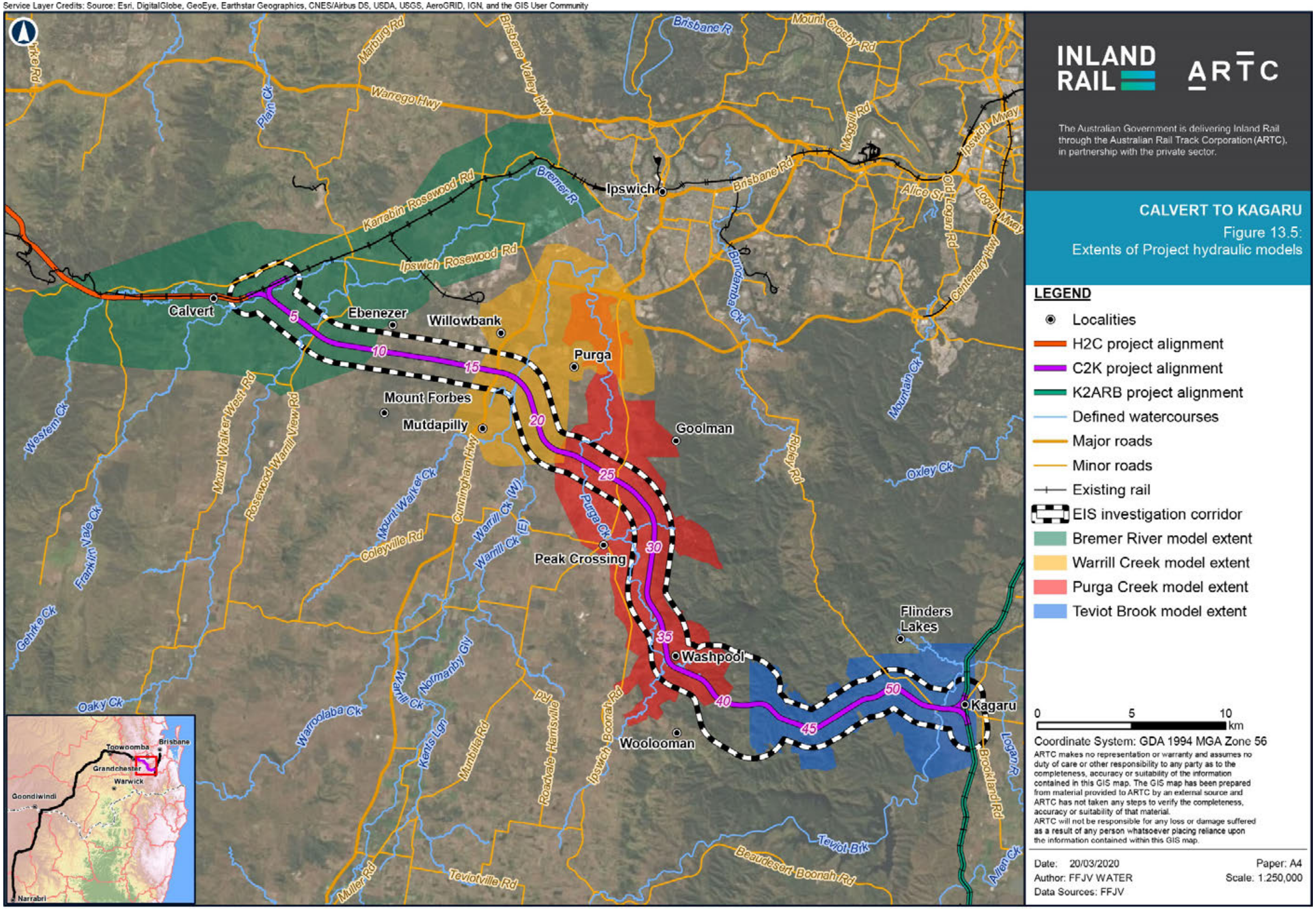

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Figure 13.5: Extents of Project hydraulic models

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13.5.7.2 Existing Case results

Modelling the Existing Case, i.e. current state of development, was undertaken to provide a base case against which the introduction of the Project alignment and associated drainage structures can be assessed. The Existing Case extent of inundation and peak water levels for the 1% AEP event for the modelled waterways are shown in Figure 13.6a to Figure 13.6f with 1% AEP event peak velocities shown in Figure 13.7a to Figure 13.7f. Details of the existing flood regime on each floodplain in the vicinity of the Project alignment are discussed in the following sections.

Bremer River/Western Creek

Under the 1% AEP event, the peak depth of water is approximately 7 m in the Bremer River channel and the inundated floodplain is over 500 m wide. There are no major roadways or key infrastructure in this location. Directly downstream of the Project alignment is the confluence of Western Creek and the Bremer River. The floodplain is significantly wider at this location and the peak flood depth in the river channel is approximately 7 m.

The peak depth in the Western Creek channel is between 5 m to 7 m deep in the channel and the inundated floodplain is over 1,000 m wide with an average depth of approximately 1 m as shown in Figure 13.6a. The existing West Moreton Rail Line and Waters Road both run parallel to Western Creek. The majority of the West Moreton Rail Line is above the 1% AEP flood level, but it is inundated in localised places. Waters Road is low level and is inundated by Western Creek during frequent flood events.

Table 13.16 is a summary of overtopping depths for key roads and the existing rail line in the vicinity of the Project alignment under a range of design events.

TABLE 13.16: BREMER RIVER—EXISTING CASE—OVERTOPPING DEPTHS OF KEY INFRASTRUCTURE

		Approximate overtopping depth (m)				
Infrastructure	**Location**	**1% AEP**	**2% AEP**	**5% AEP**	**10% AEP**	**20% AEP**
West Moreton Rail Line	Intersection with proposed alignment	0.30	0.20	Dry	Dry	Dry
Waters Road	Intersection of Waters Road/Kuss Road*	0.25	0.21	0.15	0.08	0.07

Table note:

* Waters Road runs parallel to Western Creek and is inundated by frequent to larger events over its entire length.

Peak Existing Case velocities on the floodplain areas are generally low, in the order of 0.5 to 1.0 m/s as shown in Figure 13.7a. Existing velocities in the creek and river channels near Project alignment for the 1% AEP event are shown in Table 13.17.

TABLE 13.17: BREMER RIVER—EXISTING CASE—1% AEP EVENT PEAK VELOCITIES

Waterway	1% AEP Existing Case peak velocities (m/s)
Western Creek	1.0 to 4.6
Bremer River	1.0 to 2.0

Warrill Creek

Under the 1% AEP event, flood waters in the main channel of Warrill Creek are over 8 m deep. The inundated floodplain is over 1,500 m wide with an average depth of over 1 m as shown in Figure 13.6b. There are no major roadways or key infrastructure within the 1% AEP flood extent. The Cunningham Highway runs parallel to Warrill Creek but is outside of the 1% AEP flood extent.

Figure 13.8 is a summary of overtopping depths for key existing infrastructure in the vicinity of the Project alignment under a range of design events.

TABLE 13.18: WARRILL CREEK—EXISTING CASE—OVERTOPPING DEPTHS OF KEY INFRASTRUCTURE

		Approximate overtopping depth (m)				
Infrastructure	Location	1% AEP	2% AEP	5% AEP	10% AEP	20% AEP
Cunningham Highway	Parallel to Warrill Creek	Dry	Dry	Dry	Dry	Dry

Existing Case velocities on the floodplain areas are generally low, in the order of 0.5 to 1.0 m/s as shown in Figure 13.7b. Existing velocities in the creek and river channels near Project alignment for the 1% AEP event are shown in Table 13.19.

TABLE 13.19: WARRILL CREEK—EXISTING CASE—1% AEP EVENT PEAK VELOCITIES

Waterway	1% AEP existing Case peak velocities (m/s)
Warrill Creek	1.0 to 2.5

Purga Creek

Under the 1% AEP event flood waters in the main channel of Purga Creek are between 1 m to 5 m deep. This variation in depth is due to the change in channel definition of Purga Creek. Where the Project alignment crosses the creek, the inundated floodplain is over 1,500 m wide during the 1% AEP event. Upstream of the main creek crossing, the Project alignment runs parallel to the creek and crosses a number of local tributaries as shown in Figure 13.6c and Figure 13.6d.

Washpool Road is a key road within the upper Purga Creek catchment. This road is low-level and is therefore inundated by frequent events. Table 13.20 is a summary of overtopping depths of Washpool Road under a range of design events.

TABLE 13.20: PURGA CREEK—EXISTING CASE—OVERTOPPING DEPTHS OF KEY INFRASTRUCTURE

		Approximate overtopping depth (m)				
Infrastructure	Location	1% AEP	2% AEP	5% AEP	10% AEP	20% AEP
Washpool Road	Purga Creek Crossing	1.45	1.40	1.35	1.25	1.15

Existing Case velocities on the floodplain areas are generally low, in the order of 0.25 to 1.0 m/s as shown in Figure 13.6c and Figure 13.6d. Existing velocities in the creek and river channels near Project alignment for the 1% AEP event are shown in Table 13.21.

TABLE 13.21: PURGA CREEK—EXISTING CASE—1% AEP EVENT PEAK VELOCITIES

Waterway	1% AEP Existing Case peak velocities (m/s)
Purga Creek—main creek crossing	3.0 to 3.2 m/s

Teviot Brook

The Project alignment crosses Teviot Brook approximately 5 km upstream of the confluence between Teviot Brook and the Logan River. Under the 1% AEP event, peak water levels in the lower reaches of Teviot Brook are a result of Logan River flood events rather than Teviot Brook flooding. Under this scenario, flood waters in the creek channel are over 10 m deep. There is considerable overbank flow with the inundated floodplain being approximately 800 m wide as shown in Figure 13.6e and Figure 13.6f.

Woollaman Creek, a tributary of Teviot Brook, runs parallel to the Project alignment. At the confluence of Woollaman Creek and Teviot Brook, peak water levels are influenced by the Logan River with peak flood depth of over 7 m occurring. The Project alignment crosses Woollaman Creek and its tributaries at multiple locations.

Table 13.22 is a summary of overtopping depths for key roads and the existing rail in the vicinity of the proposed alignment under a range of design events.

TABLE 13.22: TEVIOT BROOK—EXISTING CASE—OVERTOPPING DEPTHS OF KEY INFRASTRUCTURE

		Approximate overtopping depth (m)				
Infrastructure	Location	1% AEP	2% AEP	5% AEP	10% AEP	20% AEP
Undullah Road	Teviot Brook crossing	9.5	8.9	8.1	7.4	6.1
Brennan Road	South of Undullah Road intersection	3.3	2.6	1.7	1.0	Dry
Wild Pig Creek	South of Undullah Road intersection	7.4	6.8	6.7	5.2	4.1

Existing case velocities on the floodplain areas are generally low, in the order of 0.25 to 0.5 m/s as shown in Figure 13.7e and Figure 13.7f. Existing velocities in the creek and river channels near Project alignment for the 1% AEP event are shown in Table 13.23.

TABLE 13.23: TEVIOT BROOK—EXISTING CASE—1% AEP EVENT PEAK VELOCITIES

Waterway	1% AEP Existing Case peak velocities (m/s)
Teviot Brook	0.5 to 2.0
Wild Pig Creek	1.0 to 2.0

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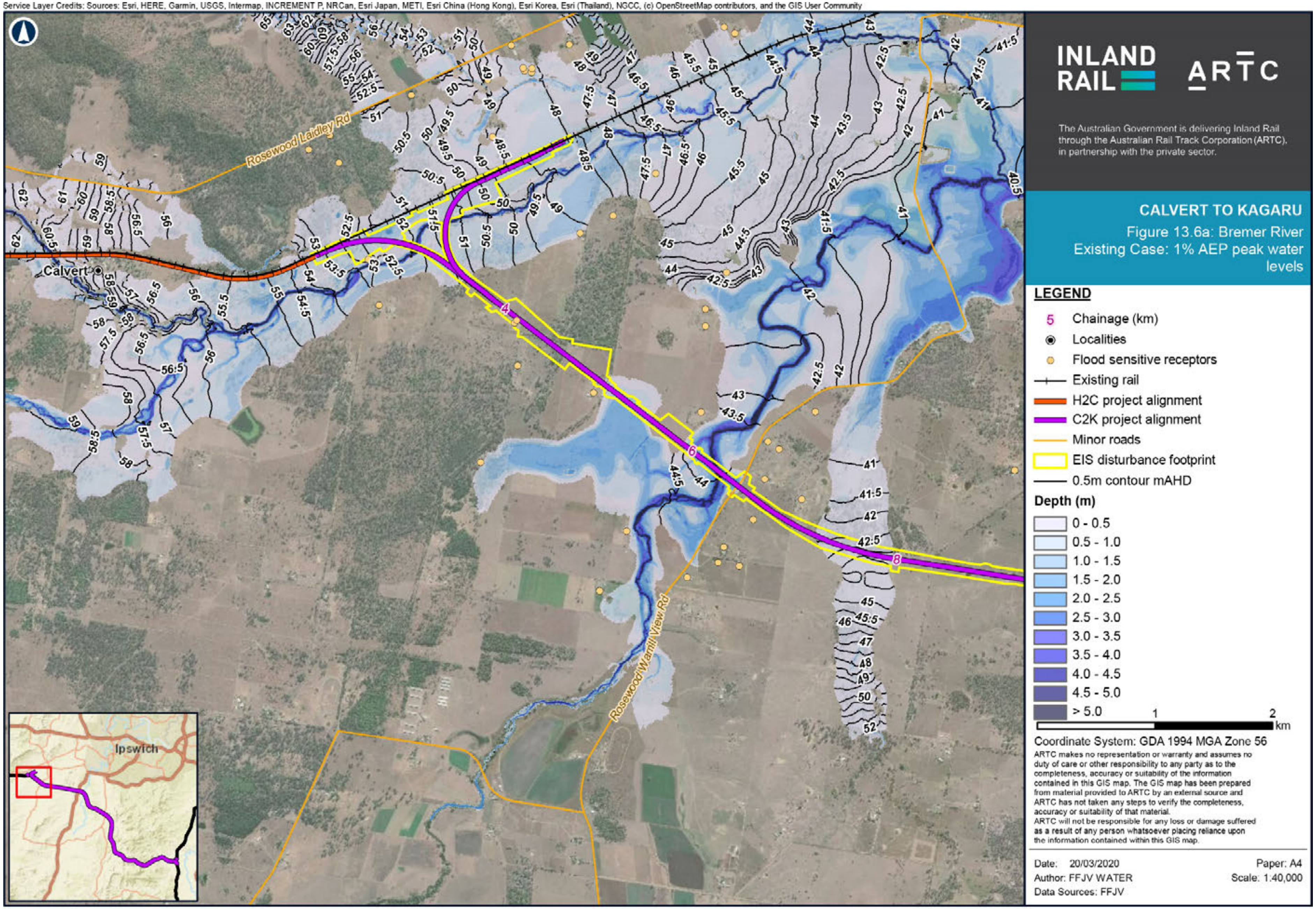

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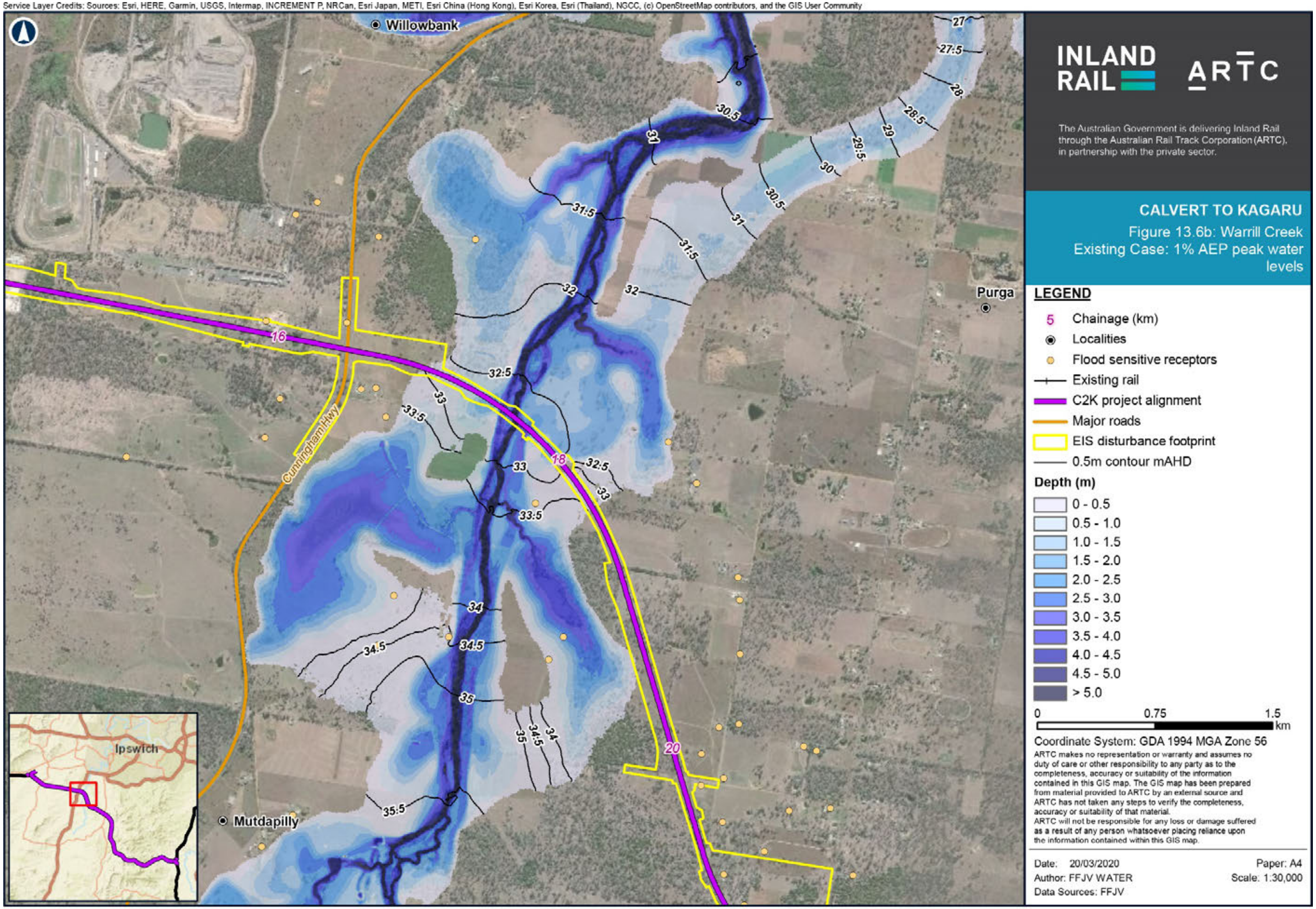

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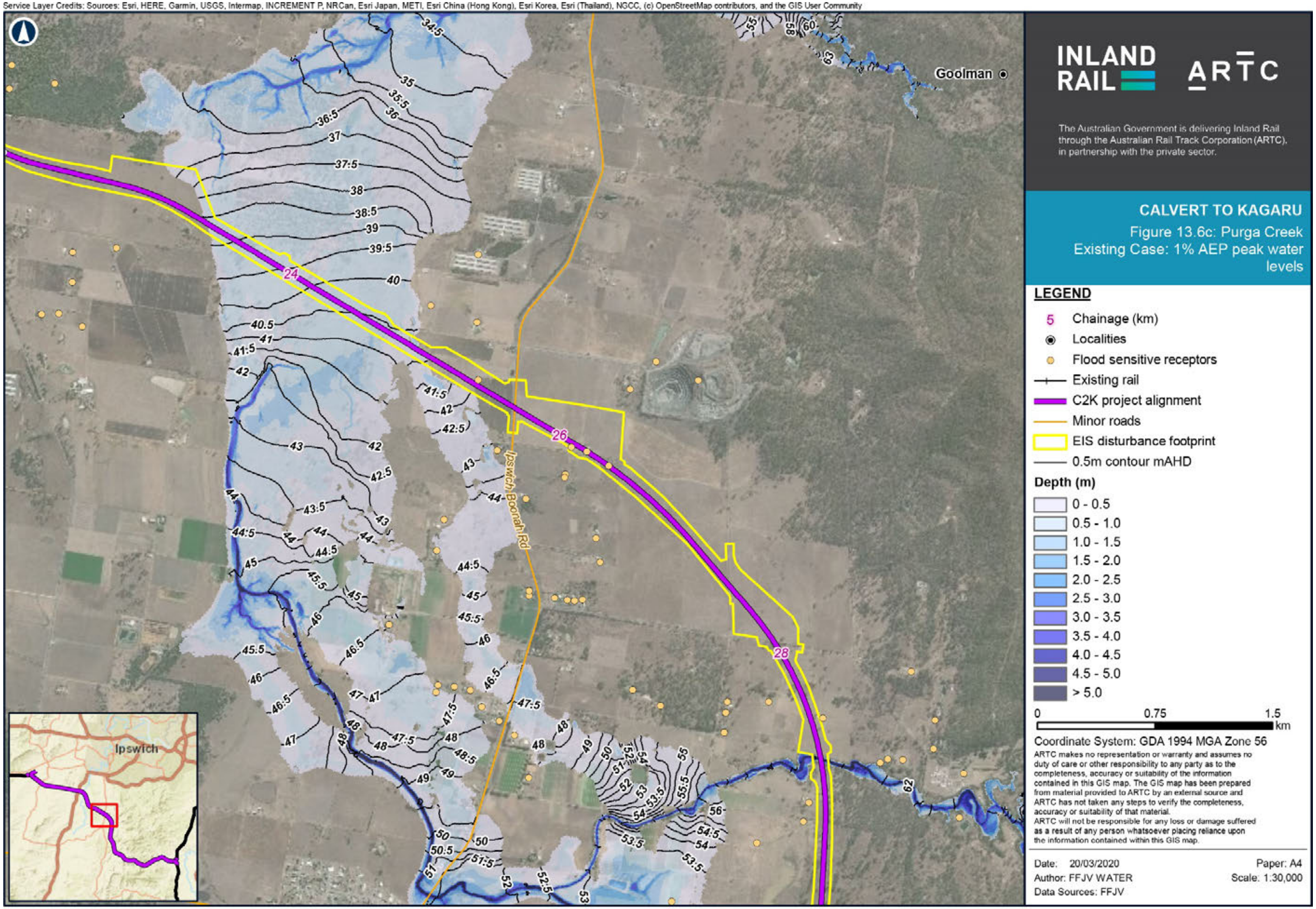

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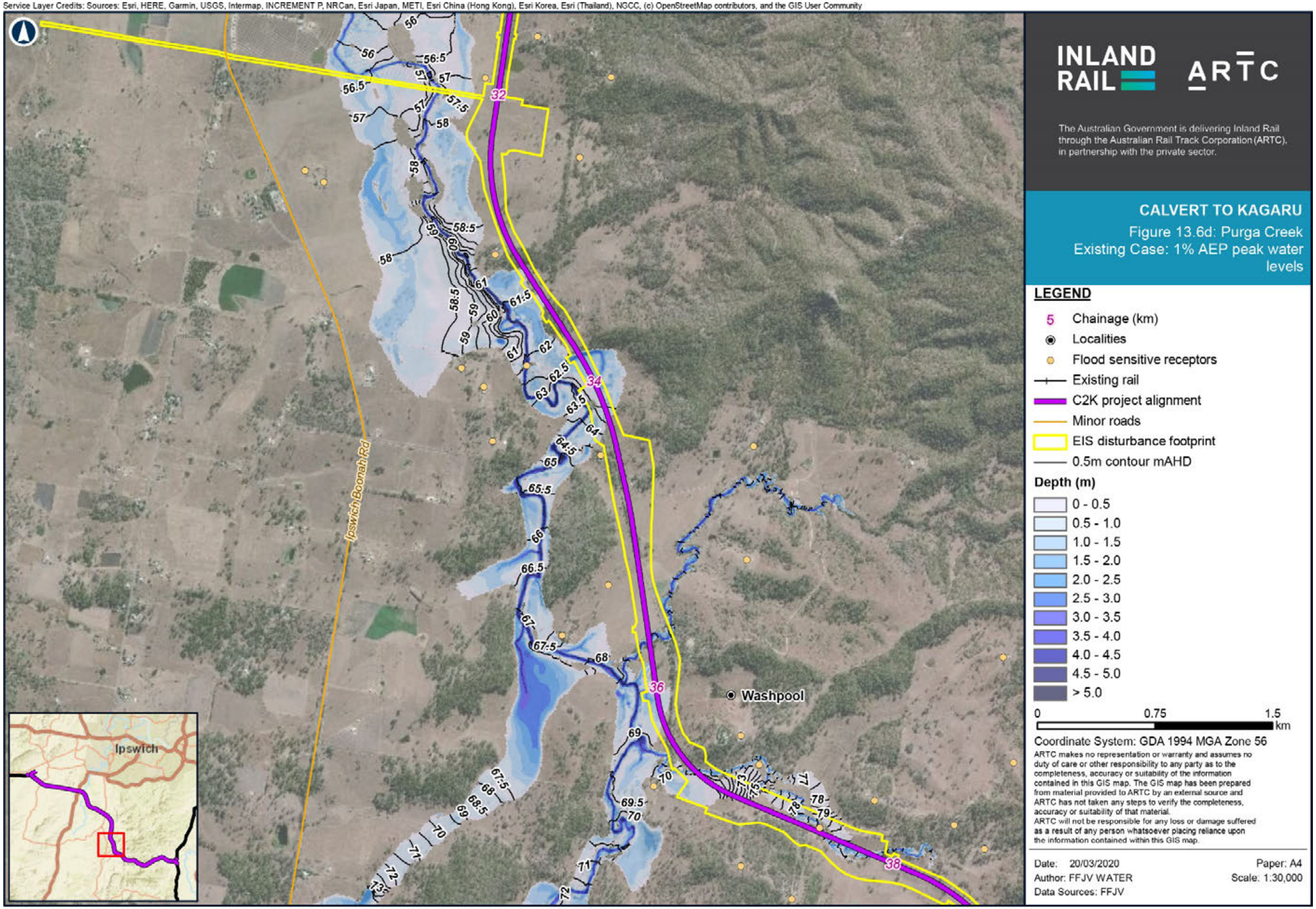

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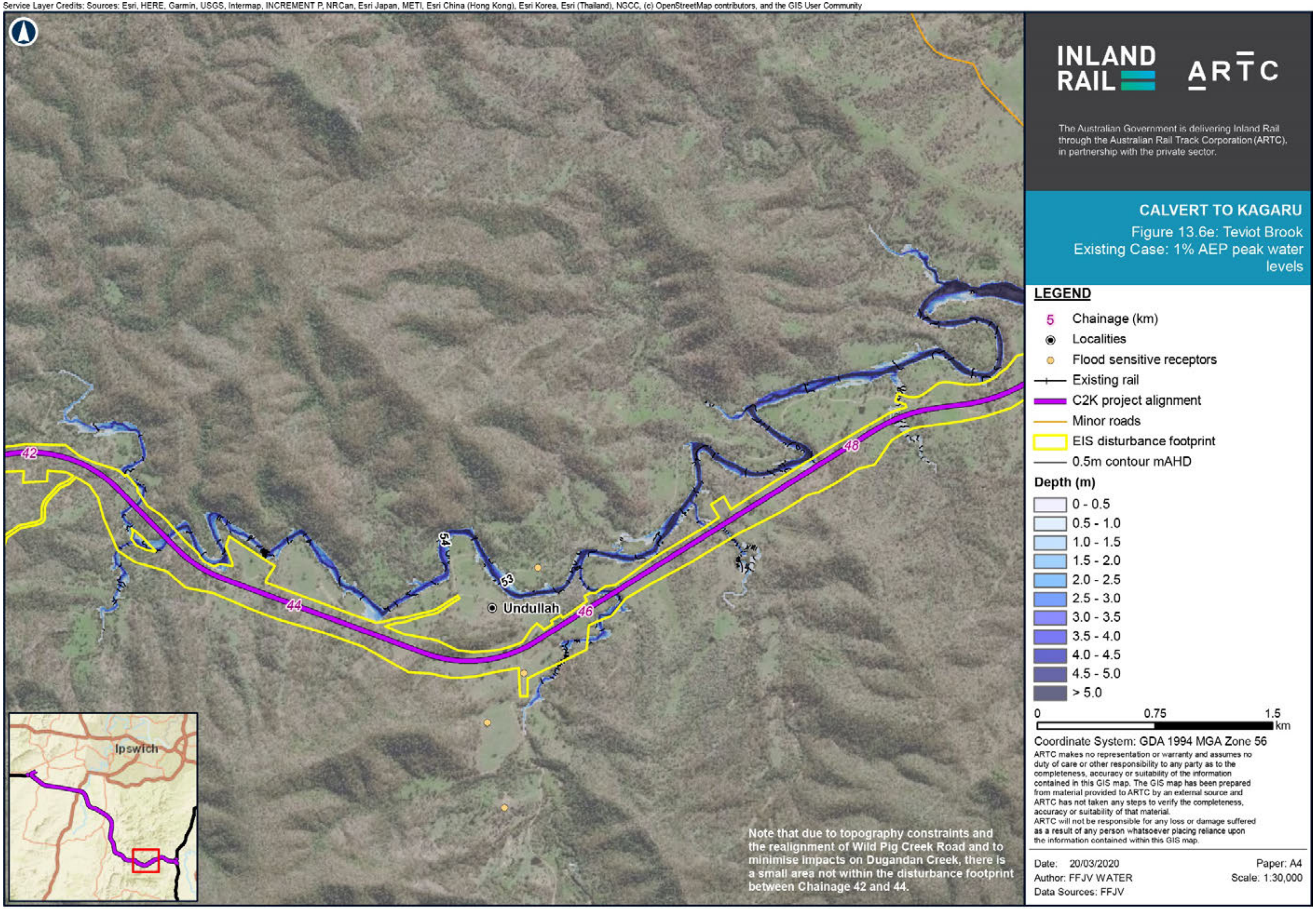

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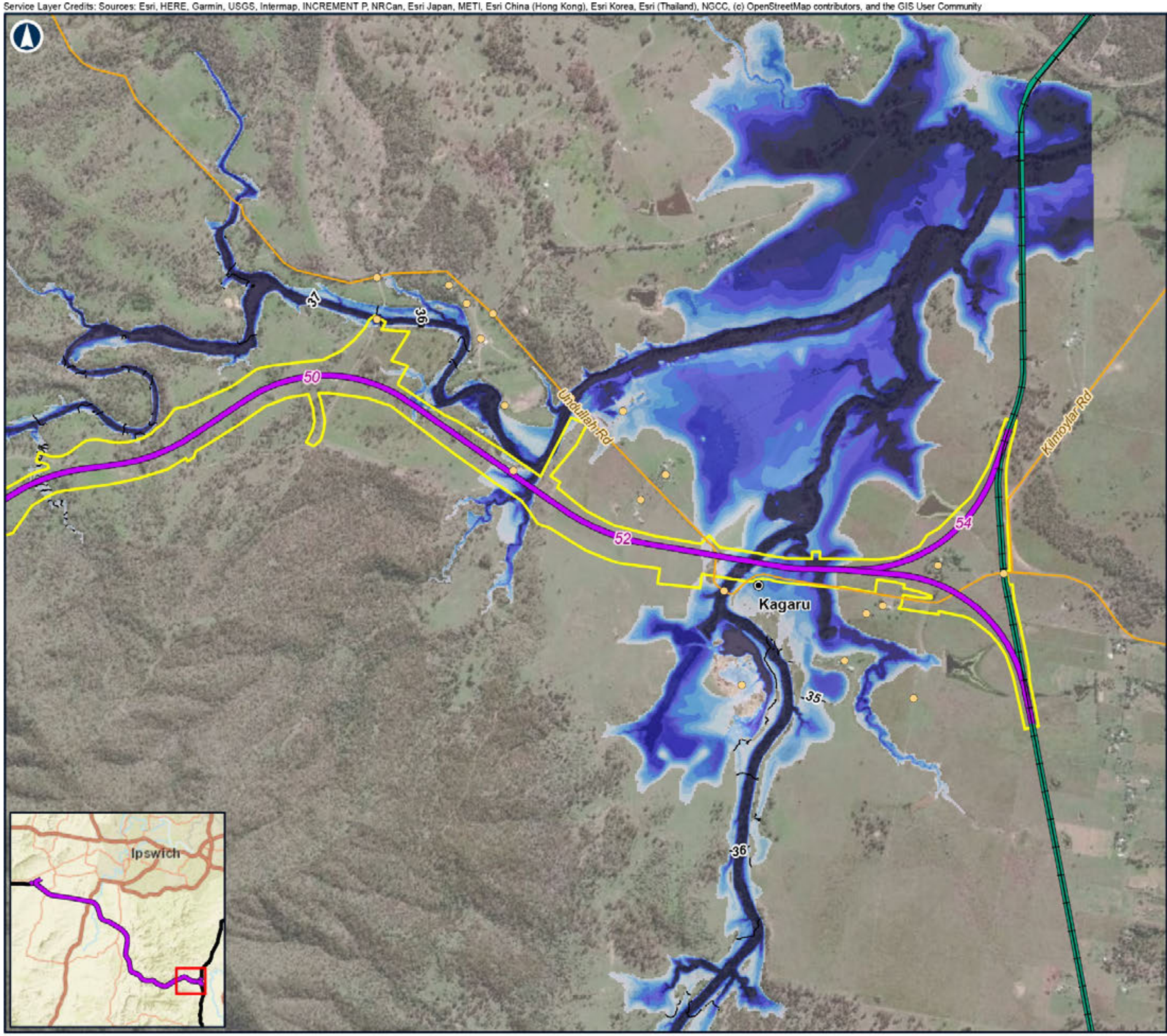

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Figure 13.6f: Teviot Brook Existing Case: 1% AEP peak water levels

LEGEND

- Chainage (km)
- Localities
- Flood sensitive receptors
- Existing rail
- C2K project alignment
- K2ARB project alignment
- Minor roads
- EIS disturbance footprint
- 0.5m contour mAHD

Depth (m)

- 0 - 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 2.5
- 2.5 - 3.0
- 3.0 - 3.5
- 3.5 - 4.0
- 4.0 - 4.5
- 4.5 - 5.0
- > 5.0

0 0.75 1.5 km

Coordinate System: GDA 1994 MGA Zone 56

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Data Sources: FFJV
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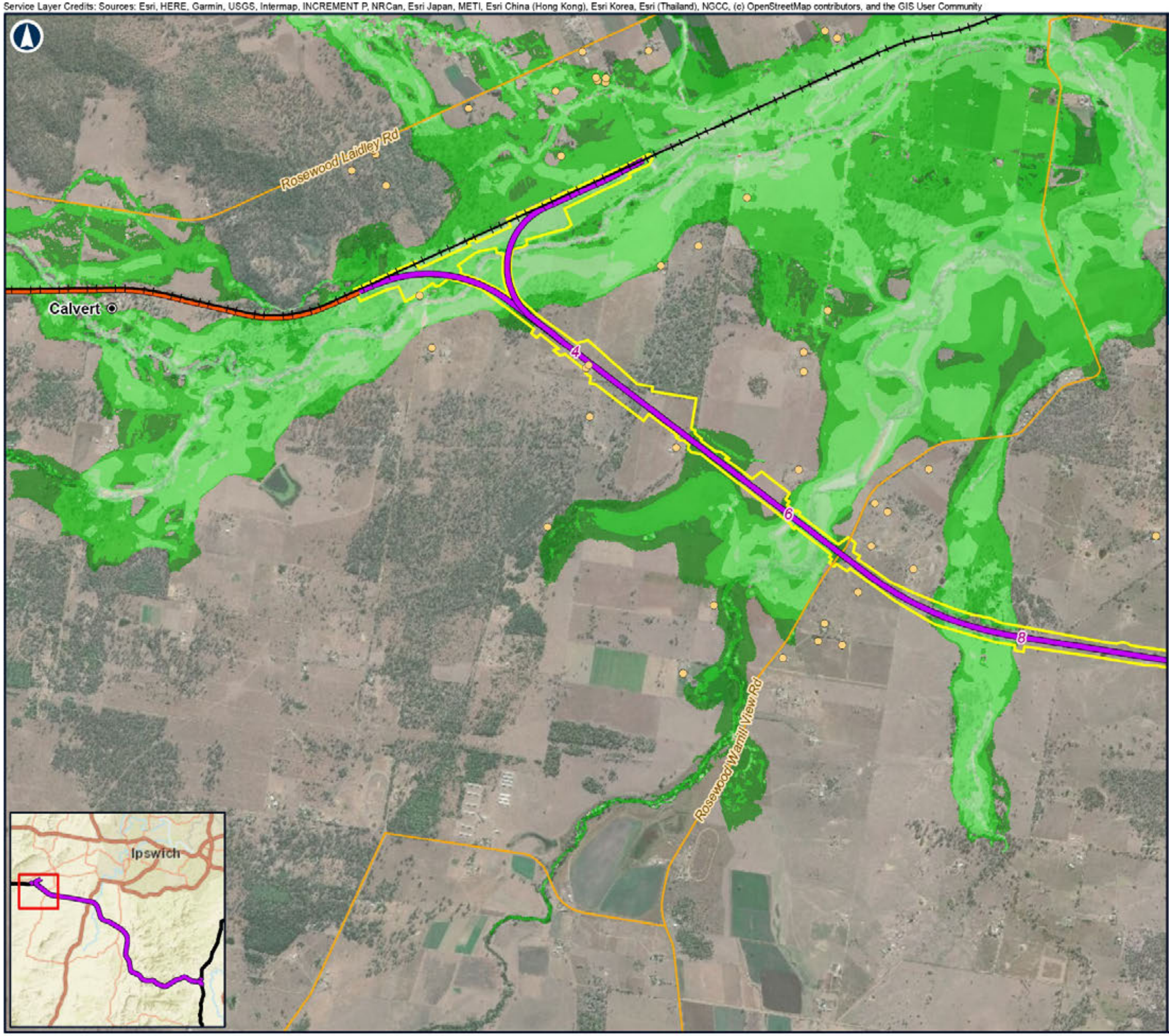

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Figure 13.7a: Bremer River Existing Case: 1% AEP peak velocities

LEGEND

- 5 Chainage (km)
- Localities
- Flood sensitive receptors
- Existing rail
- H2C project alignment
- C2K project alignment
- Minor roads
- EIS disturbance footprint

Peak velocity (m/s)

- 0.0
- 0.5
- 1.0
- 1.5
- 2.0
- 2.5
- 3.0
- 3.5
- 4.0
- 4.5
- 5.0

0 1 2 km

Coordinate System: GDA 1994 MGA Zone 56

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Author: FFJV WATER Scale: 1:40,000
Data Sources: FFJV

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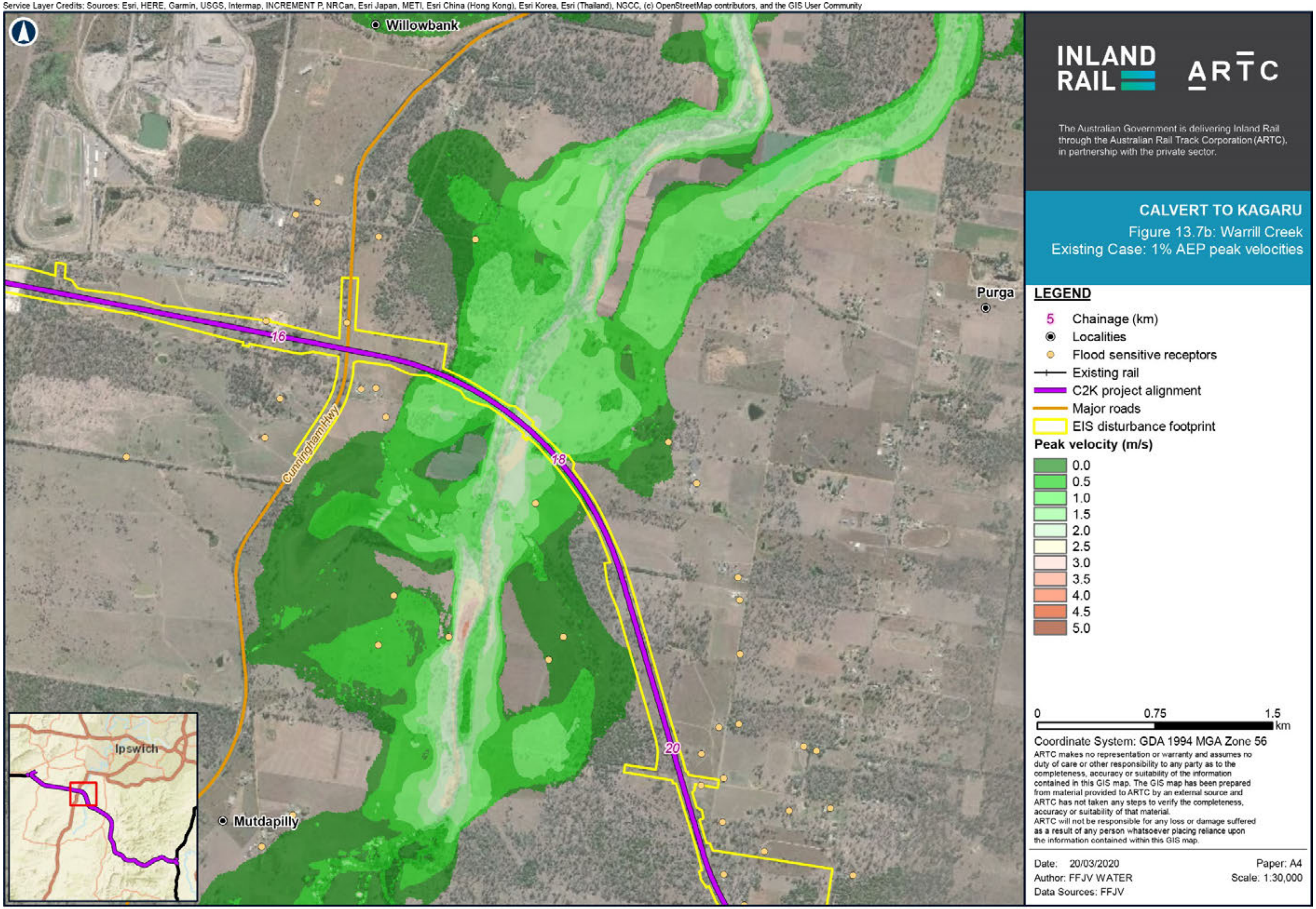

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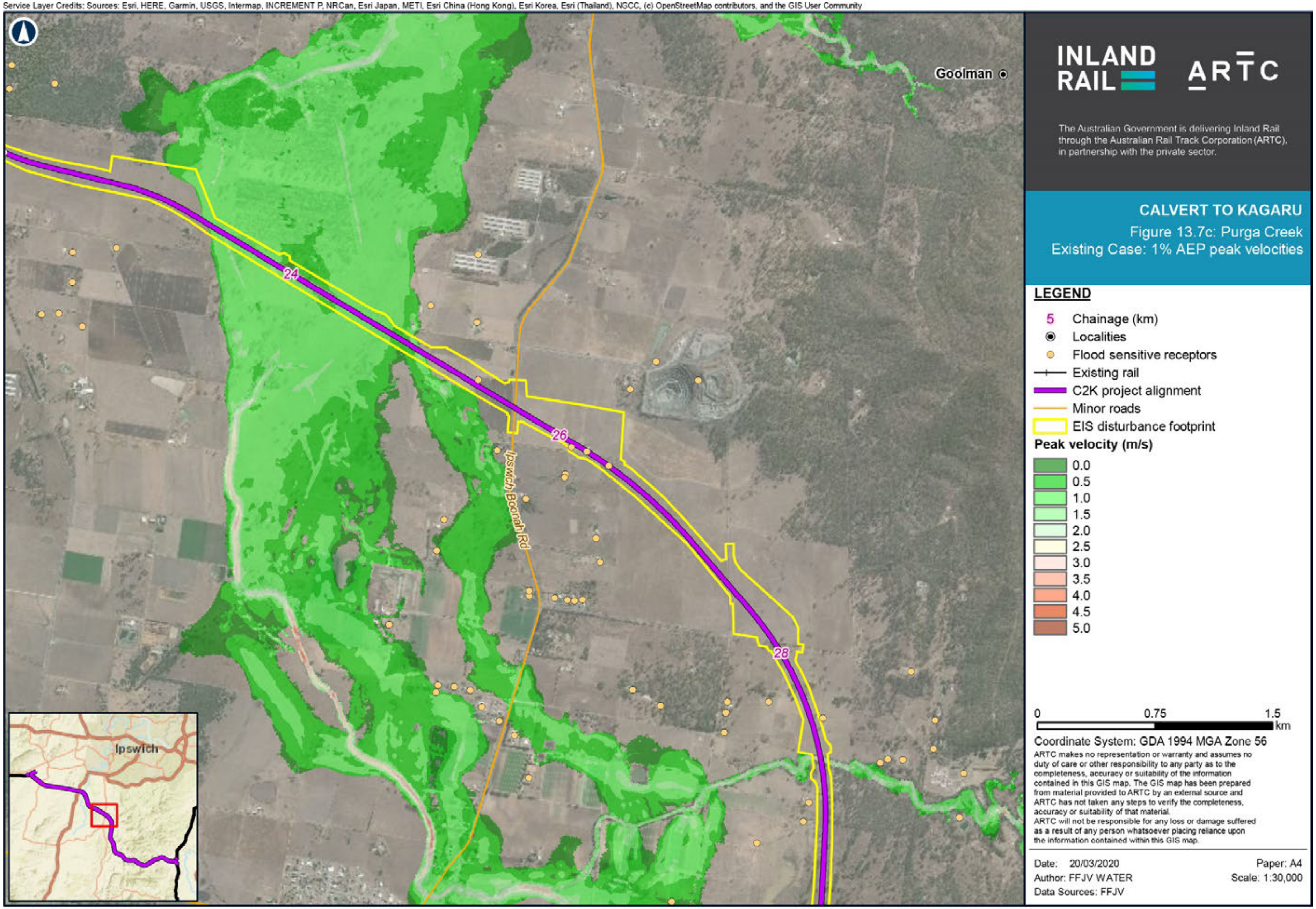

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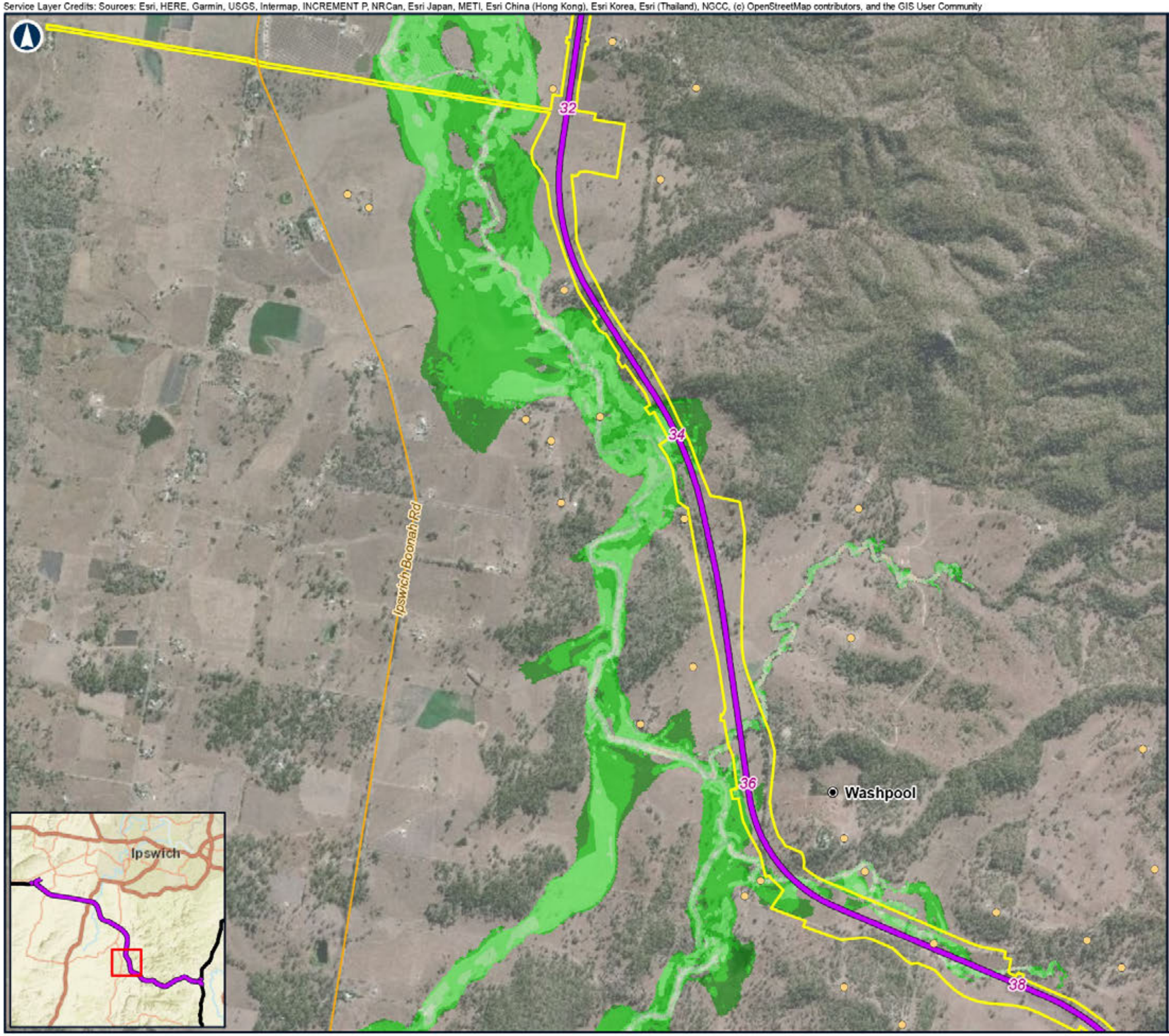

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Figure 13.7d: Purga Creek Existing Case: 1% AEP peak velocities

LEGEND

- 5 Chainage (km)
- Localities
- Flood sensitive receptors
- Existing rail
- C2K project alignment
- Minor roads
- EIS disturbance footprint

Peak velocity (m/s)

- 0.0
- 0.5
- 1.0
- 1.5
- 2.0
- 2.5
- 3.0
- 3.5
- 4.0
- 4.5
- 5.0

0 0.75 1.5 km

Coordinate System: GDA 1994 MGA Zone 56

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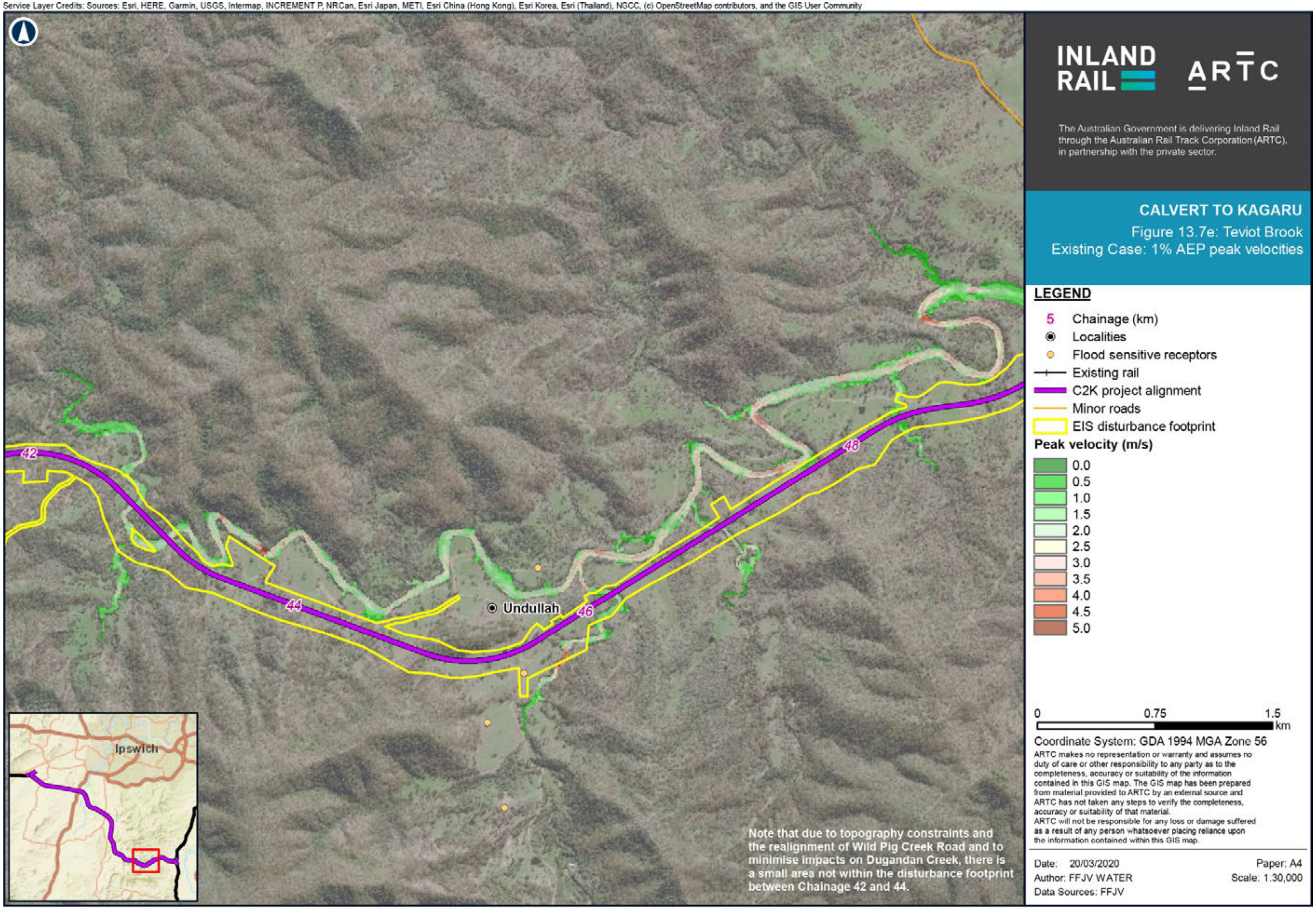

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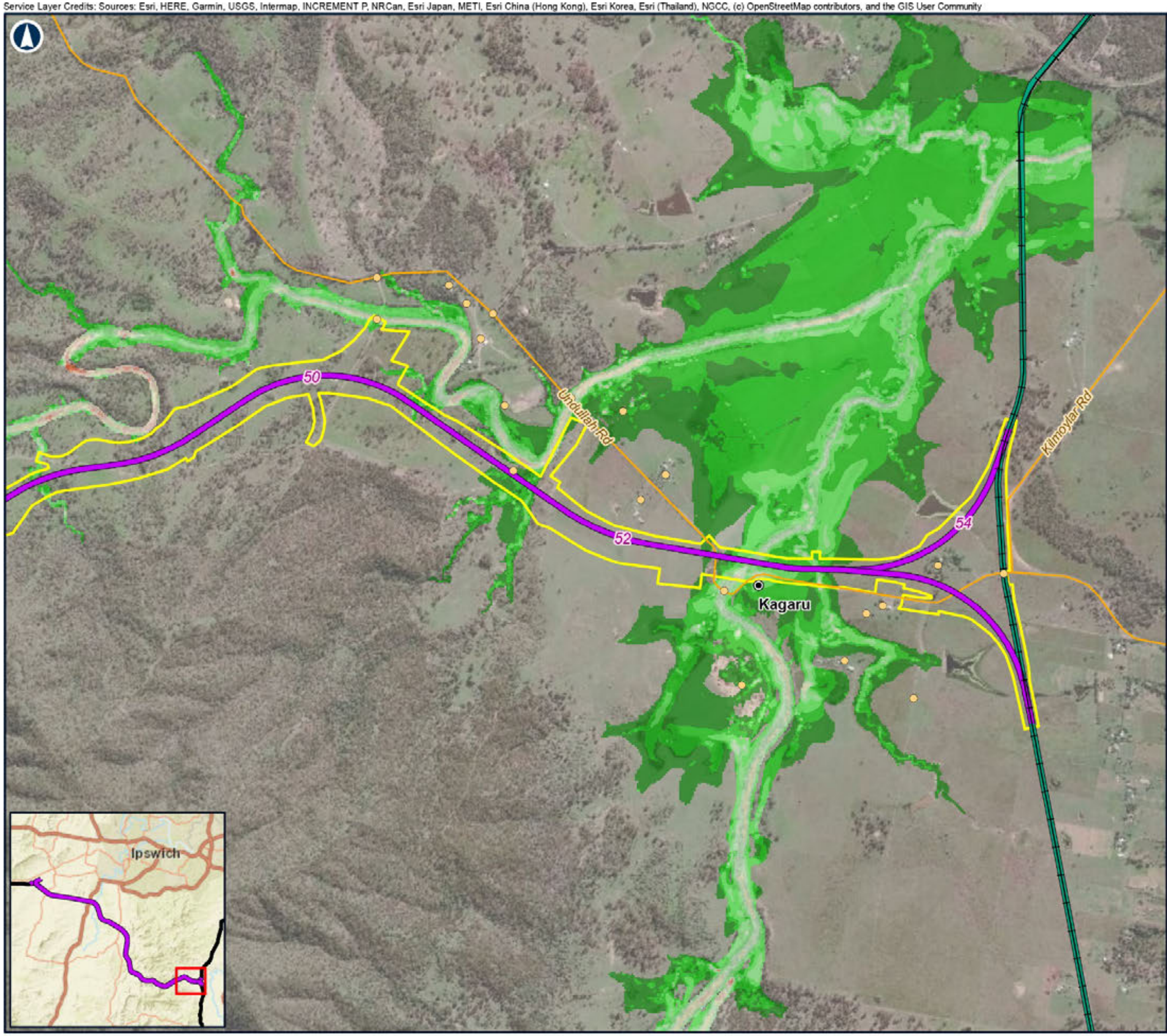

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CALVERT TO KAGARU

Figure 13.7f: Teviot Brook
Existing Case: 1% AEP peak velocities

LEGEND

- 5 Chainage (km)
- Localities
- Flood sensitive receptors
- Existing rail
- C2K project alignment
- K2ARB project alignment
- Minor roads
- EIS disturbance footprint

Peak velocity (m/s)

- 0.0
- 0.5
- 1.0
- 1.5
- 2.0
- 2.5
- 3.0
- 3.5
- 4.0
- 4.5
- 5.0

0 0.75 1.5 km

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13.6 Potential impacts

13.6.1 Surface water quality

Potential surface water quality impacts will be avoided or minimised through initial mitigation through design responses and proposed in situ mitigation measures as required. Potential impacts were assessed with consideration of the existing surface water quality condition, sensitivity of water quality receptors (including acknowledgment of downstream impacts and the assimilative capacity of the surrounding catchment).

The assessment of surface water quality included consideration of the assimilative capacity of the receiving environment through historical and existing compliance with WQOs and input from the existing surface water environment assessment from a variety of watercourses within both the Bremer River and Logan River catchments. Currently, the existing environment does not meet all the WQO for these catchments. The assimilative capacity was assessed using qualitative risk of degradation of water quality from potential Project impacts.

It is noted that electrical conductivity at high flow significantly decreases and it is considered likely that assimilative capacity of the watercourses within the water quality study area will be higher during higher flow conditions (refer Appendix E of Appendix M: Surface Water Quality Technical Report). In contrast, the lowest assimilative capacity and highest realisation of impact would occur during periods of extended low flow (such as those currently experienced). Noting this, potential impacts from the Project would likely occur with periods of continued rainfall, resulting in higher hydrological flow and greater assimilative capacity in regard to potential impacts.

Within this impact assessment, the total quantity of wastewater (across the entire alignment) was not calculated as the quantities are only considered for tunnel wastewater discharge during construction and operational works. Wastewater is considered to fall within two categories: produced onsite and produced offsite.

Onsite wastewater is identified as wastewater that is produced by the Project and relates to construction and operational phases. Offsite wastewater is identified as wastewater that is produced from overland flow passing through the disturbance footprint associated with the Project (including through longitudinal drainage to cross-drainage infrastructure) with export through drainage away from the site. Onsite wastewater is considered to be contained by the 22 sediment control basins used for construction.

Point-source discharge for the Project is anticipated only to occur along cut-and-fill lines. The principle discharges are considered to occur at cross-drainage infrastructure points as associated with potential upward seepage from aquifers. Given discharges will be reliant on the water quality and quantity of overland flows at these points, any impacts are likely to be minor.

Wastewater quality was incorporated as part of the significant impact assessment across several facets, including dewatering of artificial impoundments and tunnelling, and overland flow of construction water.

Potential contaminant impact from the Project was identified using Model for Urban Stormwater Improvement Conceptualisation (MUSIC) modelling. The contaminant discharge load was calculated against the drainage basins parallel to the Project alignment, as discharge was likely to consist of overland flow from precipitation. MUSIC modelling was compiled on the potential discharge water quality (refer Appendix M: Surface Water Quality Technical Report). Wastewater quality involving total suspended solids, total phosphorus and total nitrogen via MUSIC modelling of alignment drainage, indicated that impacts to rural areas associated with potential stormwater discharges are expected to be negligible with buffering from swales producing discharge of a better quality (reduced concentrations) than typical for rural areas. Modelled discharge along the alignment is predicted to contain suspended solids and nutrients in concentrations higher than forested conditions; however, these pollutant loads would be expected to be discharged from a comparable area of nearby rural catchment. It is expected that these pollutant loads will be contained within the areas of targeted restoration and be limited in impact to receiving waterways.

Through information gathered during the assessment process, sensitive receptors within the receiving environment (refer Section 13.5.5) that have the potential to be subject to significant impacts, have been identified within the water quality study area. These sensitive receptors are considered for the identification of potential impacts, associated mitigation measures and identification of residual impact after implementation of mitigation.

13.6.1.1 Construction phase impacts

A number of construction phase (including pre-construction phase) activities that are likely to impact the surface water quality are discussed below:

- Increased debris is considered to have the potential to impact all watercourses and waterbodies along the Project alignment due to conveyance through overland flow pathways to both static waterbodies and flowing watercourses and unmapped waterways. Increased debris and rubbish is considered to have the potential to result in a degradation of surface water quality receptors via both direct and indirect impacts. The potential impact to surface water quality values includes: a reduction in water flow (via mechanical blockages); loss of ecosystem values (via smothering and aquatic ecological value impact); and direct leachate impacts (via the accumulation of rubbish and debris blown off or washed away from a construction area into nearby waterways).
- Changes to receiving surface water quality and hydrology (principally from increased water turbidity and sedimentation load) are considered to result in indirect and direct impacts on surface water quality receptors. Without adequate mitigation measures in place, the potential indirect impacts from potential changes to overland flow pathways and diversions are considered to have a high risk of impacting surface water quality receptors associated with both:
    - Flowing watercourses and unmapped waterways
    - Static waterbodies occurring downstream of the Project works.
- Indirect surface water quality changes may occur downstream as a result of increased turbidity and sedimentation associated with an increase in mobilisation of sediment-bound metals and other substances. The mobilised substances have an increased potential to directly impact surface water quality values and indirectly impact aquatic ecosystem values. In addition, increased water turbidity and sedimentation may also result in significant changes to localised hydrological regimes, especially in pinch points (such as existing culverts), which may result in smothering of aquatic flora receptors, leading to a direct impact on surface water quality receptors. Alteration of surface water quality and hydrology from increased turbidity and sedimentation load may occur from a variety of Project activities such as:
    - Construction works resulting in elevated sediment concentrations in surface water runoff as a result of inadequate erosion sediment controls
    - Construction works involving disturbance to the riparian corridor may result in erosion and scouring of streambanks
    - Physical disturbance of stream beds and banks leading to a reduction in stability during construction of creek crossings
    - Erosion of cleared riparian areas and inadequate rehabilitation processes
    - Altered hydrological regimes from drainage flow change due to diversion at western tunnel portal
    - Dewatering works resulting in an increase of sediment loads from dewatering activities near excavations and water quality issues from dewatering activities associated with tunnel infrastructure works. Dewatering associated with decommissioning artificial waterbodies that intersect the Project alignment may additionally cause an increase in erosion and sedimentation of watercourses and drainage features if dewatering activities are not adequately managed.
    - Vegetation clearing, which could leave exposed soils prone to erosion
    - Bank-cutting to redirect the drainage feature at the western tunnel portal
    - Potential erosion risk associated with soils exposed during topsoil stripping, earthworks, excavation and trenching activities required for infrastructure and material borrow pits development
    - Changes to the physical attributes of waterways from removal of buffering vegetation.

- Altered hydrology and subsequent water chemistry changes are considered potential direct and indirect impacts from Project activities. Alteration to the hydrological regime of the Purga Creek catchment associated with tunnel dewatering is considered a potential direct impact on surface water quality receptors through potential changes in wetting and drying regimes. This is considered to indirectly impact surface water quality receptors downstream of the dewatering release through diversion changes to overland flow pathways and through potential changes to aquatic ecological values. Potential surface water quality changes from Project activities are considered a direct impact and have potential to impact all surface water quality receptors associated with the Project. Potential impact is expected to occur from all Project activities associated with potential changes to hydrology, especially those resulting in the liberation of contaminants (typically associated with problematic soils from any potential changes to hydrology). The direct impact on surface water quality receptors is considered to have a localised indirect impact on aquatic ecological receptors through degradation of water quality parameters. Project activities considered to cause a potential impact on hydrology and water chemistry are:
  - Clearing activities and construction of infrastructure, resulting in changes to habitat form (biotic and abiotic) through alteration of hydrological regime (flow and quality)
  - Accidental spills and leaks of chemicals or fuels from construction equipment or fuel storages, which could introduce chemicals into overland flows
  - Overland flow diversions (e.g. between Project Chainages Ch 39.28 to Ch 39.54 km)
  - Introduction of exotic weed species
  - Increase of sediment loads from dewatering activities near excavations and surface water quality issues from dewatering activities associated with tunnel infrastructure works, including the removal of wastewater from the tunnel during construction and operation. Dewatering associated with decommissioning artificial waterbodies that intersect the Project alignment may additionally cause an increase in erosion and sedimentation of watercourses and drainage features if dewatering activities are not adequately managed
  - Subsoil exposure within excavations and borrow pits which have the potential to result in the leachate of acid rock drainage from the soil into overland flow
  - The erosion of stockpiled materials, which could lead to increased nutrient concentrations in overland flow
  - Impact to proximal wetlands, with high-sensitivity receptor areas associated with Teviot Brook and Bremer River
  - Dewatering of tunnel infrastructure may result in changes to water quality within Purga Creek tributaries due to disparity in groundwater discharge from tunnel construction, resulting in potentially high impact to aquatic ecology and surface water quality.
- Increase in salinity at a localised and regional scope are considered potential indirect impacts from the Project activities. Salinity impacts on surface water quality receptors are considered to potentially occur from a variety of Project activities and have the capacity to result in regional impacts derived from point-source impacts associated with the Project works. Salinity issues are considered to have a direct impact on surface water quality receptors within the Project alignment and are further considered to have an indirect impact on ecosystem services (and water quality receptors) downstream of the point source salinity impact. Project activities considered to cause a potential increase in localised and regional salinity are due to:
  - Project alignment directly intersecting moderate to high-salinity hazard rating areas potentially resulting in discharge of saline runoff into proximal waterways, particularly within the high-salinity hazard rating areas that have been modelled as occurring along the Project alignment
  - Disturbance of saline soils during construction, which may increase salinity pressures in overland flows through identified high-risk salinity hazard areas.

- Erosion and sedimentation increases are considered a direct impact from Project activities. These are considered to have a direct impact on surface water quality receptors at a localised scope. At a regional scope after transport downstream from the point source, the impact is considered to be indirect. Transport of sediment and eroded material can be washed off into cleared areas or stockpiled areas during rainfall events. This may increase sediment loads and turbidity within waterways and potentially increase nutrient loads. Direct impact from degradation of surface water quality will be realised from changes to light conditions and loss of ecosystem services due to changes to aquatic flora and fauna structure. Project activities considered to potentially increase sedimentation and erosion primary involve:
  - In-stream earthworks leading to changes in surface water quality due to the number of new bridge structures and culverts that will be required for the Project
  - Stockpiling of sediment (e.g. from cut-and-fill processes), mulch or other materials near waterways has the potential for runoff during rain events and impacts to the water quality of nearby waterways
  - Inappropriate rehabilitation of riparian vegetation work areas.
- Introduction of contaminants from a variety of sources during construction is considered to be a direct impact from Project activities. The direct changes to surface water quality parameters are considered to have the potential for indirect changes to aquatic ecosystem services, leading to the potential for further impacts on surface water quality receptors. Project activities considered to increase the potential introduction of contaminants include:
  - Chemical, fuel and oil spills due to inappropriate storage controls and refuelling/maintenance procedures
  - Heavy metals entering waterways from rail grinding and welding
  - Compounds leaching from ballast materials
  - Spills associated with train derailments or breakdowns
  - Salts mobilised from surface soils or shallow groundwater changes
  - Dewatering activities leading to liberation of toxicants from potentially contaminated land
  - Disturbance of contaminated lands near waterways resulting in contaminated runoff entering waterways
  - Inadequately treated dewatering of tunnel infrastructure may result in hydrocarbons being introduced to the Purga Creek tributaries, resulting in a potentially high impact to surface water quality.

13.6.1.2 Operational phase impacts

Potential impacts and the operational phase activities likely to impact the surface water quality include:

- Increased debris due to:
  - Potential for rubbish and debris from operations to be blown off or washed away from the Project into proximal watercourses.
- Altered hydrology and water chemistry (increase in salinity) due to:
  - Changes to receiving water quality from tunnel dewatering discharge and point discharge from culvert locations along the alignment. Principally, the intrusion of groundwater into the tunnel, and, the associated dewatering regime may impact on the receiving watercourse, particularly in regard to salinity
  - Changes to hydrological regime with Purga Creek catchment associated with tunnel discharge due to improper hydrological flows from the treated discharge water.
- Introduction of contaminants from a variety of sources during operation due to:
  - Oil and grease spills—there is the potential for oil and grease from rolling stock to enter the waterways after heavy rainfall events without appropriate controls
  - Heavy metals from maintenance rail grinding and welding
  - Compounds leaching from ballast materials
  - Accidental spills from freight carriages during routine operations
  - Chemicals, including fuels and oils used for construction machinery (as an artefact of potential construction impact)
  - Structural failure—with the introduction of bridge or culverts within waterways, should these structures fail, there is the potential for impacts to water quality either from potential contaminants (debris) or from detained water flushing from collapsed structures. Furthermore, structural failure has the capacity to alter flow regimes and increase potential secondary salinity issues, with flow-on issues resulting in surface water quality degradation.

- Maintenance of the rail line or machinery near waterways (such as the crossing loops associated with Purga Creek at approximately Ch 36.13 km–Ch 36.87 km) has the potential to mobilise sediments from disturbed areas and increase the potential for litter or rubbish to enter waterways. Furthermore, oils and greases and other contaminants such as metals, have the potential to enter waterways from spills, and for impact from the use of environmental toxicants (such as biocides) to maintain operating infrastructure areas. Maintenance activities may result in the potential introduction of biocides, resulting in a loss of ecosystem service and subsequent direct and indirect impacts on water quality. These activities have the potential to impact nearby waterways, through discharge points without appropriate mitigation.
- Increase in erosion and sedimentation resulting from:
  - Earthworks and erosion of exposed soils (as an artefact of potential construction impact)
  - Construction of culverts and bridges within or nearby waterways. Potential for continued erosion and sedimentation without appropriate rehabilitation in these areas exists. This can increase sediment loads and turbidity within waterways. Increased sedimentation may then also impact the functioning of culverts should deposition become too high.

13.6.2 Hydrology and flooding

In terms of the flooding regime, there are a similar range of potential impacts associated with all phases (construction and operation) of the proposed Project. These impacts may affect existing dwellings, sheds, farm buildings and infrastructure, crops, roads etc. These flood sensitive receptors have been identified in the vicinity of the Project alignment and are shown in Figure 13.8. Potential impacts include:

- Changes in peak water levels and associated areas of inundation
- Concentration of flows, redirection of flows and/or changes to flood flow patterns
- Increased velocities leading to localised scour and erosion
- Changes to duration of inundation
- Increased depth of water affecting trafficability of roads and tracks.

The quantified flood impacts associated with the Project alignment and drainage structures are detailed in Section 13.8.2.

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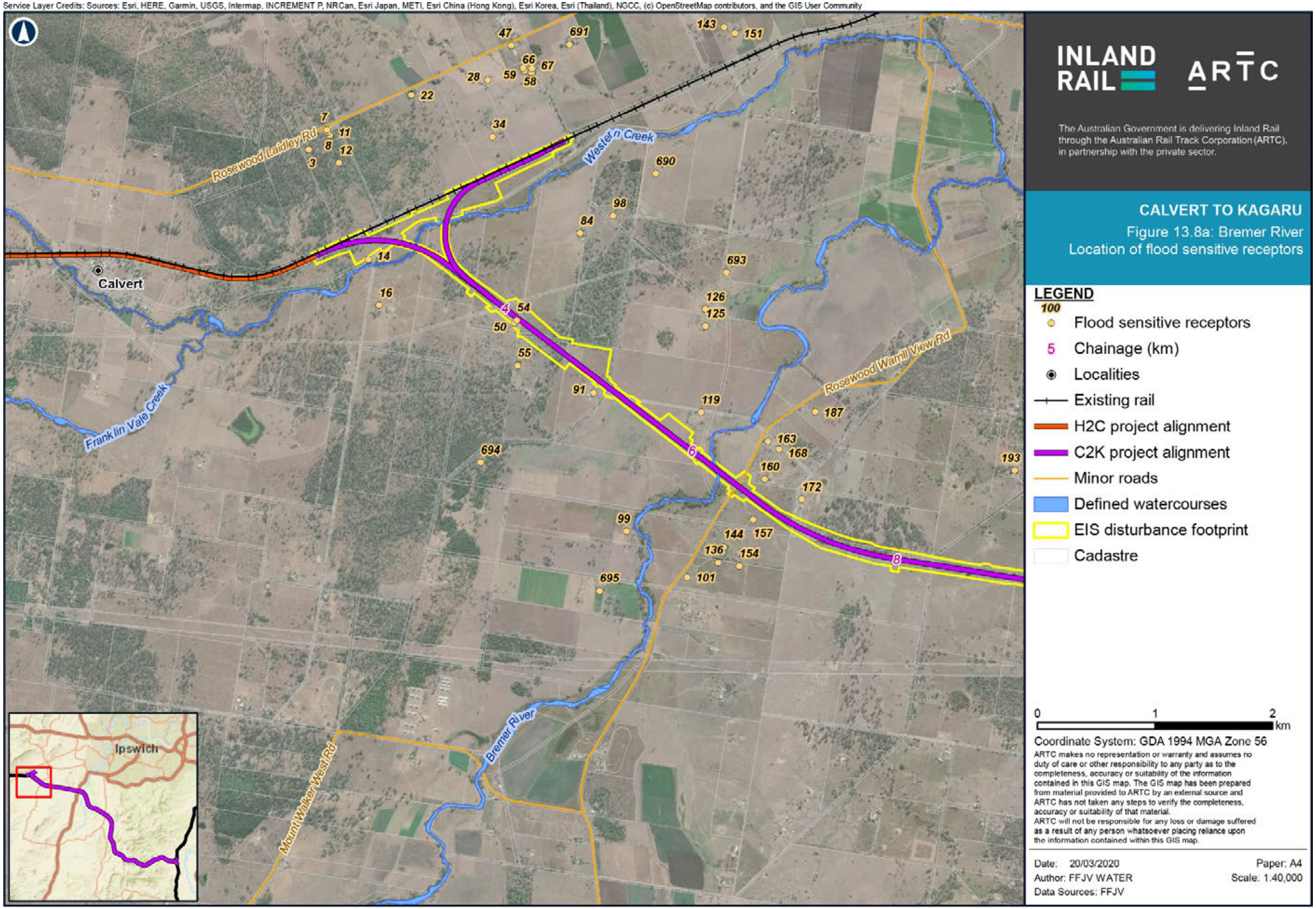

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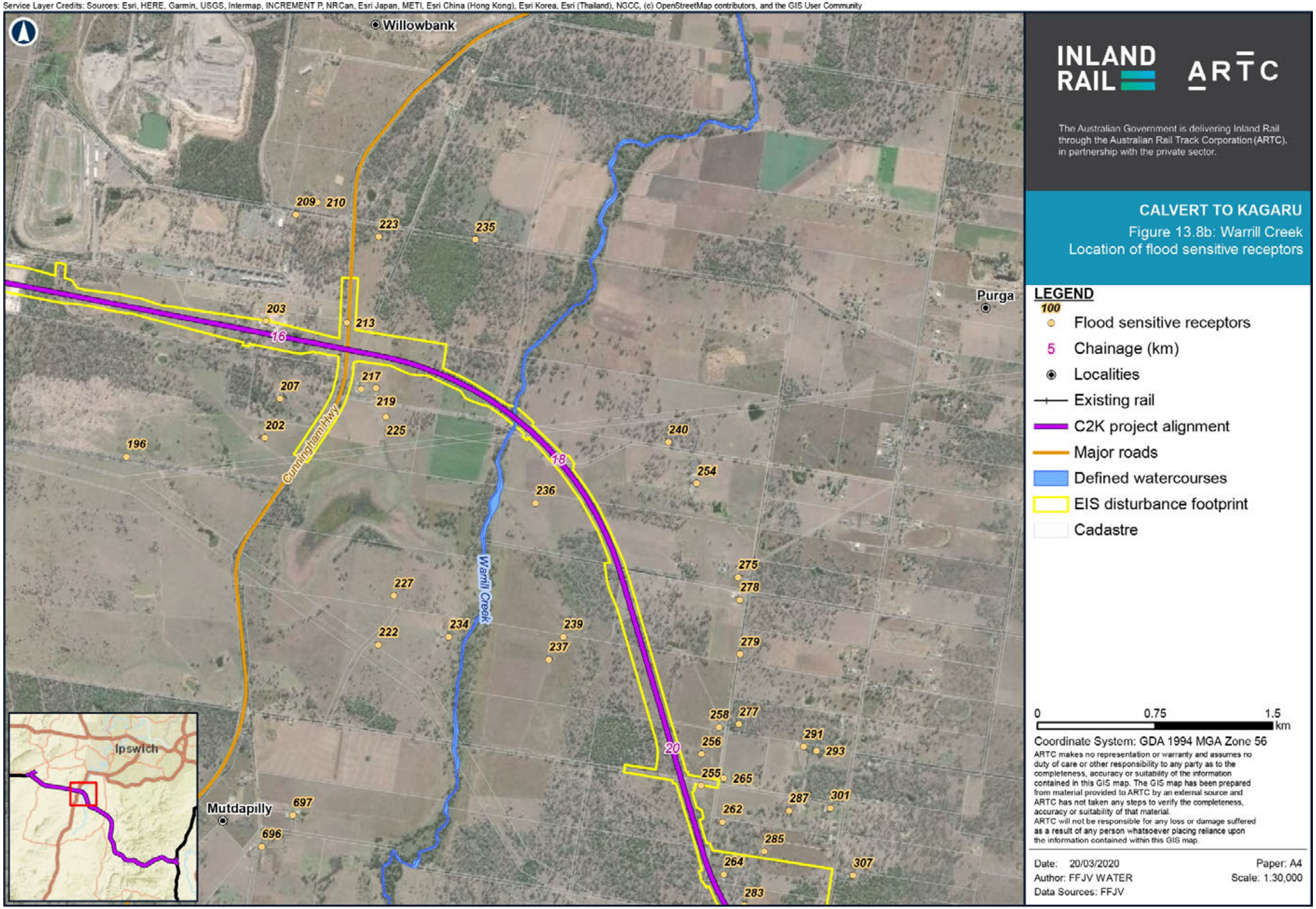

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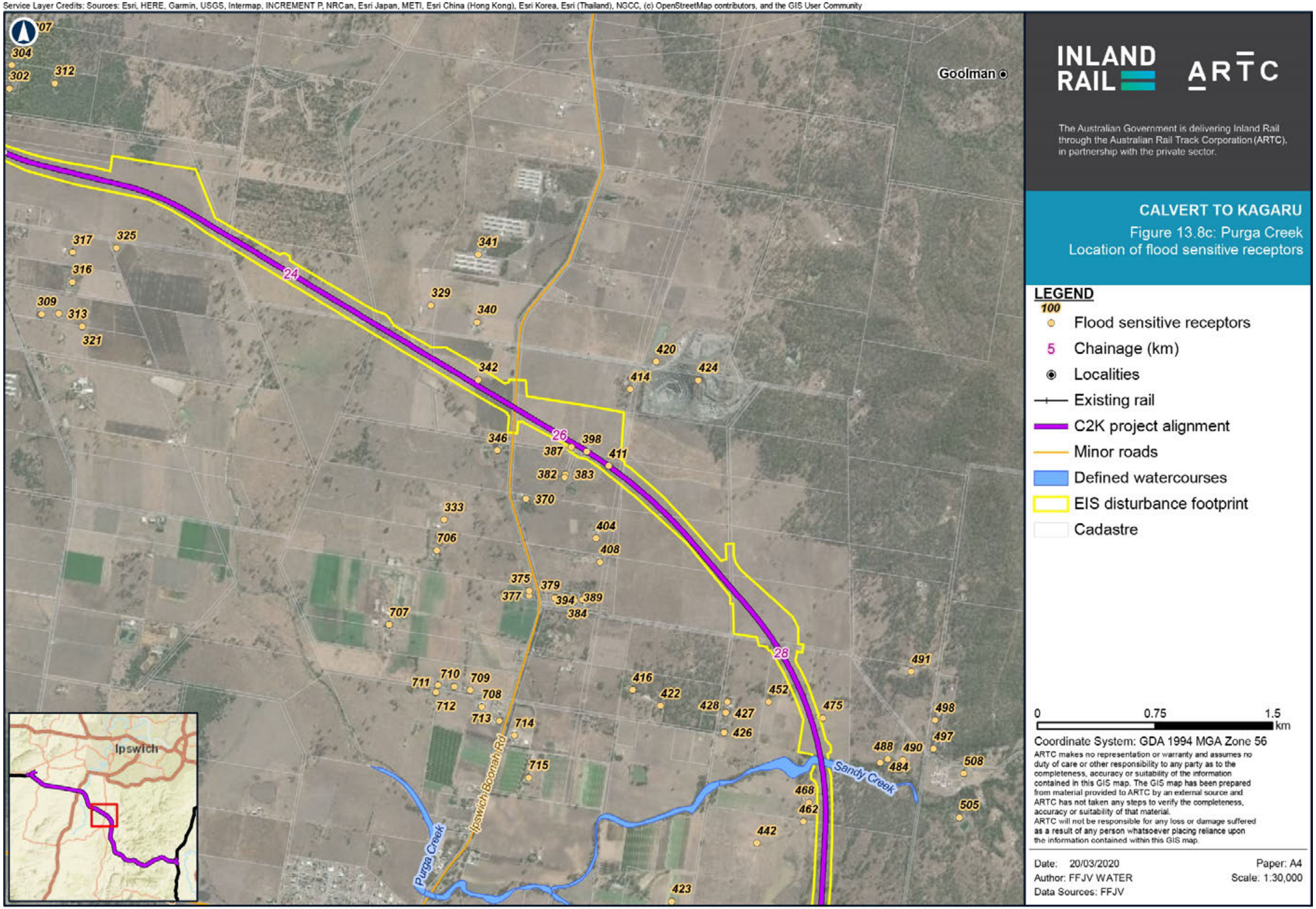

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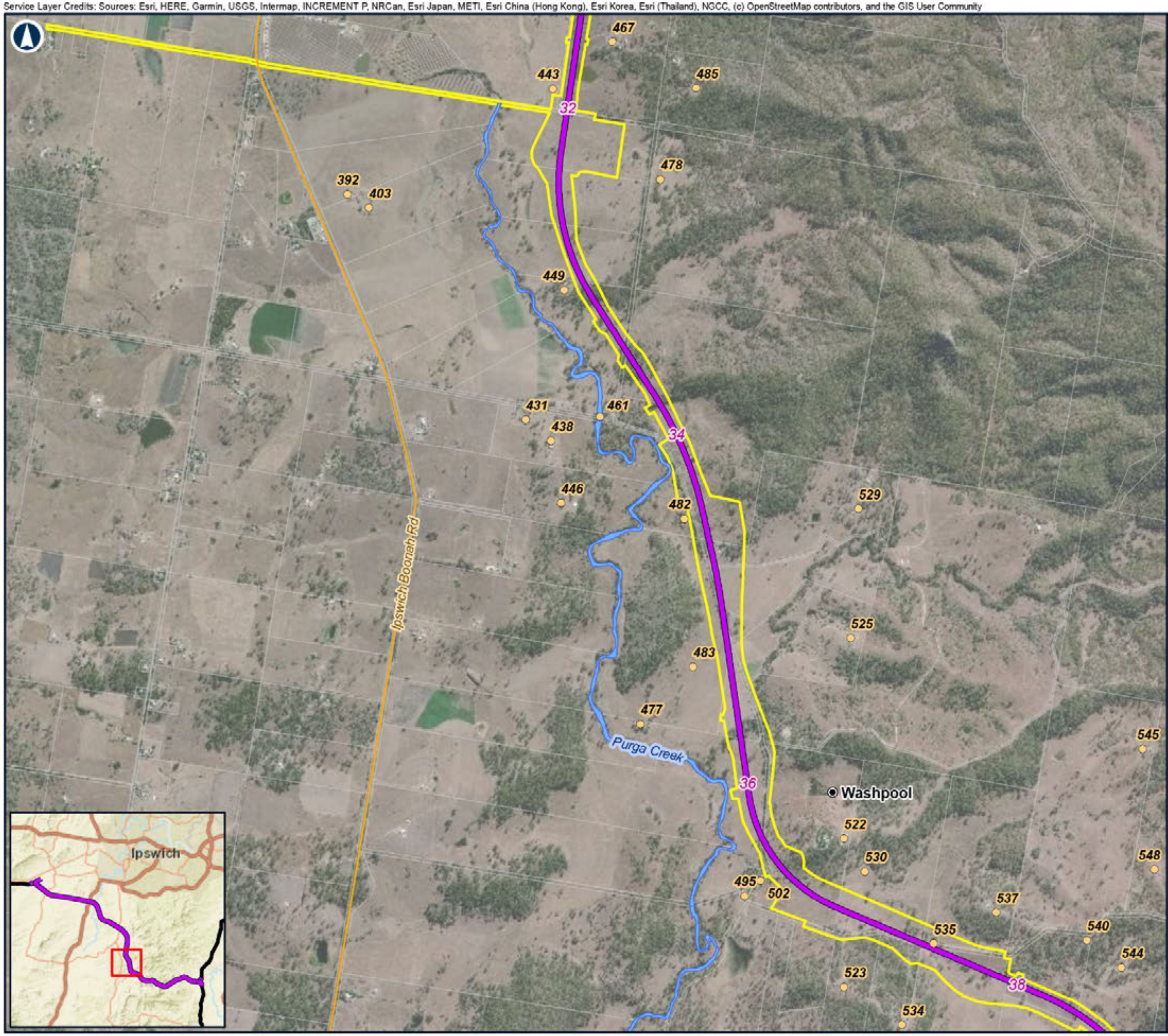

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CALVERT TO KAGARU

Figure 13.8d: Purga Creek
Location of flood sensitive receptors

LEGEND

- 100 Flood sensitive receptors
- 5 Chainage (km)
- Localities
- Existing rail
- C2K project alignment
- Minor roads
- Defined watercourses
- EIS disturbance footprint
- Cadastre

0 0.75 1.5 km

Coordinate System: GDA 1994 MGA Zone 56

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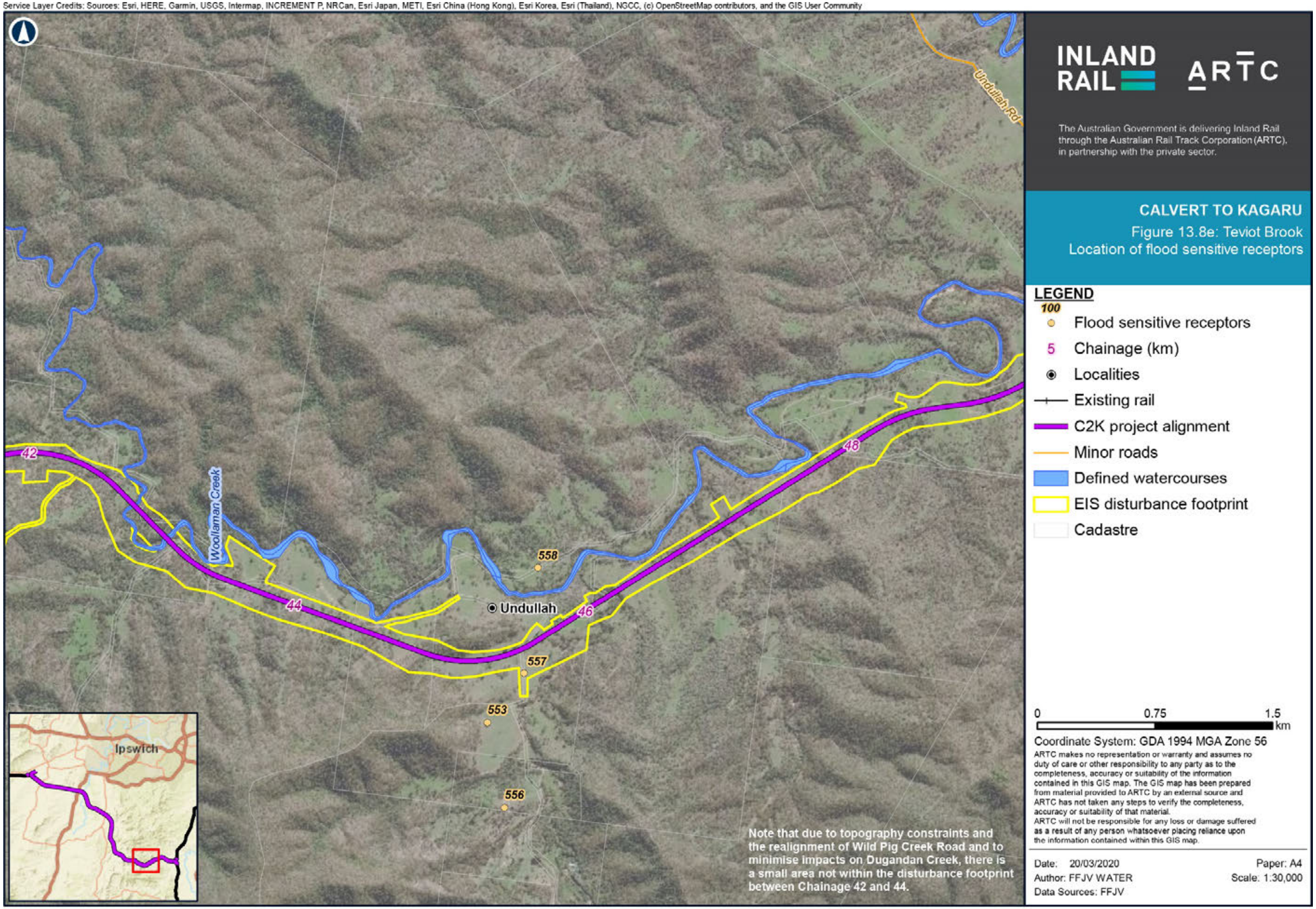

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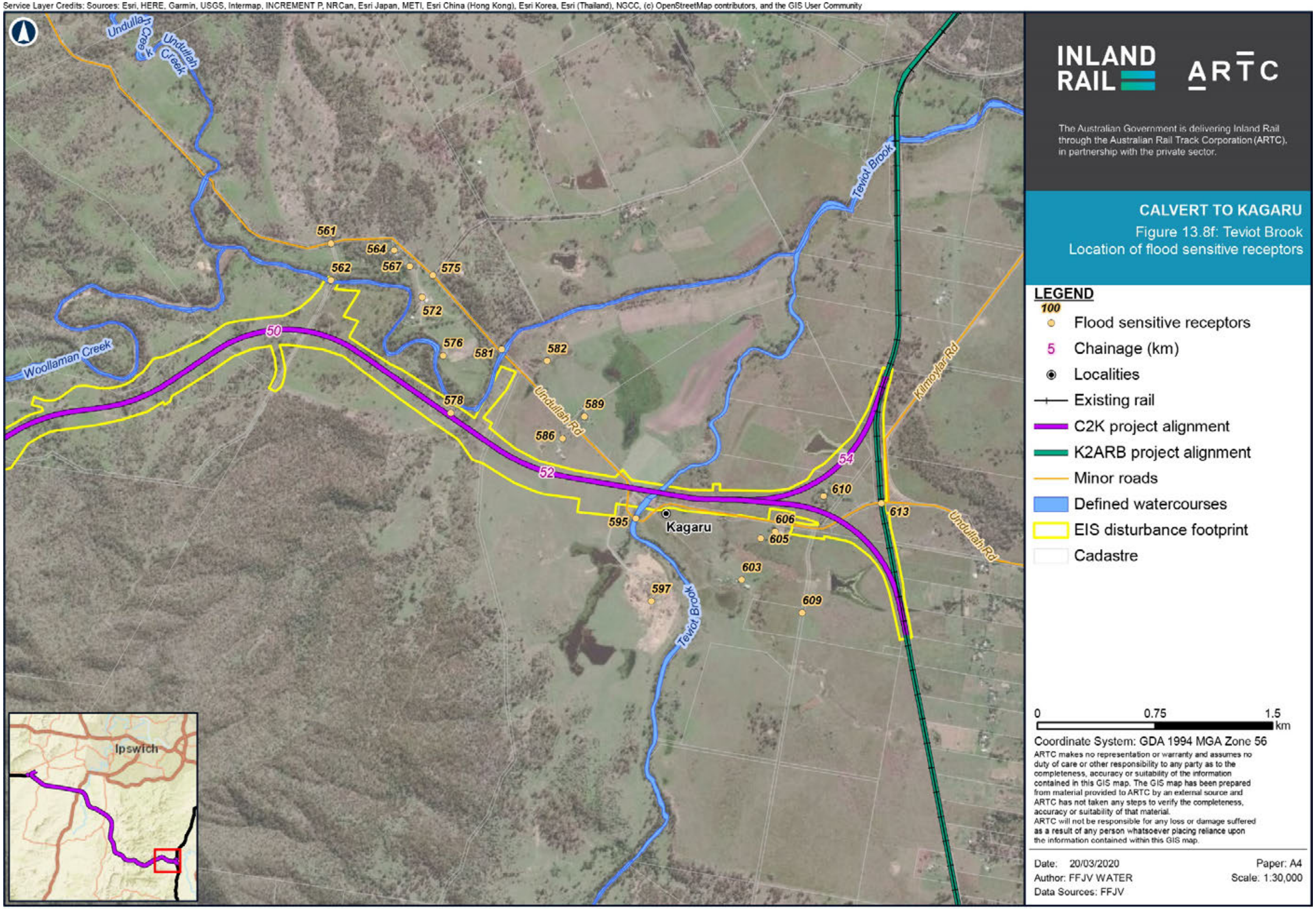

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13.7 Mitigation measures

13.7.1 Surface water quality

This section outlines both the mitigation measures included as part of the design and the mitigation measures that are proposed for application in future phases of the Project to manage predicted impacts to water quality. Mitigation measures have been developed to minimise impacts associated with construction and operation of the Project. Mitigation strategies have been developed based on the following hierarchical criteria:

- Primary: avoid potential impacts where possible during Project design considerations
- Secondary: minimise the severity and/or duration of the impact during Project design considerations
- Last: apply mitigation measures for unavoidable impacts.

13.7.1.1 Design considerations

The mitigation measures and controls in Table 13.24 have been incorporated into the Project's design and will be factored into the detailed design phases for the Project. These design considerations are proposed to avoid and minimise potential environmental impact associated with the Project and, therefore, contribute to a lowering of the initial impact risk rating for each potential impact before the application of in situ mitigation.

TABLE 13.24: INITIAL MITIGATION THROUGH DESIGN RESPONSES OF RELEVANCE TO SURFACE WATER

Aspect	Initial design measures
Interference with existing surface water and, water quality	▸ The Project uses the existing sections of the West Moreton System rail corridors as much as possible to avoid introducing a new linear infrastructure corridor across watercourses and floodplains, where possible ▸ Watercourse crossing structures (including culverts, viaducts and bridges) are designed to minimise the need for ongoing maintenance and inspection to maintain aquatic fauna (e.g. fish) passage and minimise the risk of blockages in reference to *Accepted development requirements for operational work that is constructing or raising waterway barrier works* (1 October 2018) (DAF, 2018) ▸ Bridges, viaducts and waterway crossings are designed to minimise impacts to bed, banks and environmental flows, in accordance with relevant regulatory requirements (as per requirements of DAF and the *Fisheries Act 1994*) ▸ The design has been developed to avoid the need to permanently divert watercourses, as defined and mapped under the Water Act (it is noted that no current defined watercourses are currently subject to diversion) ▸ The design has been developed to minimise impacts to watercourses, riparian vegetation and in-stream flora and habitats by adopting a crossing structure hierarchy where viaducts and bridges are preferred to culverts ▸ Bridge structures are provided in the design over the following watercourses, to minimise disturbance of aquatic habitats: Western Creek, Bremer River, Ebenezer Creek, Warrill Creek, Purga Creek, Sandy Creek, Dugandan Creek, Wild Pig Creek, Woollaman Creek and Teviot Brook ▸ Scour and erosion protection measures have been incorporated into the design in areas determined to be at risk, such as around culvert headwalls, drainage discharge pathways and bridge abutments ▸ Scour protection measures have been included around culvert entrances and exits, on disturbed stream banks and around waterfront land to avoid erosion ▸ Cross-drainage structures have been incorporated into the design where the Project intercepts existing drainage lines and watercourses. The type of cross-drainage structure in the design depends on various factors such as the natural topography, rail formation levels, design flow and soil type ▸ The design includes 22 sediment basins. All sediment basins are passive which allows surface runoff from a catchment to flow into the sediment basin without the need for pumping.

13.7.1.2 Proposed mitigation measures

In order to manage Project risks during construction, a number of mitigation measures have been proposed for implementation in future phases of Project delivery, as shown in Table 13.25. These proposed mitigation measures have been identified to address Project-specific issues and opportunities, legislative requirements, accepted government plans, policy and practice.

Table 13.25 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 13.29.

Within the water quality assessment of impacts and significance, pre-construction has been grouped with construction due to the similarity in potential impact. In addition to the proposed in situ mitigation measures indicated in Table 13.25, further management frameworks are proposed for discharge and runoff management, tunnel dewatering treatment, a surface water quality (receiving environment) monitoring and salinity management.

In addition to the mitigation measures identified above and as part of the detailed design stage when finalised positions of infrastructure elements (e.g. abutments/piers etc) are known and detailed soil studies are complete, geomorphological assessment of identified risk locations will be undertaken.

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

13.7.1.3 Management framework

The management framework described here is recommended to be developed during detailed design with implementation under pre-construction/ construction phase and continuation into operation as required.

Discharge and runoff management

Under the surface water monitoring framework to be developed, discharge and runoff will be monitored as part of the surface water monitoring required for the Construction Environmental Management Plan (CEMP). It will identify monitoring locations at discharge points, and selected locations in waterways where works are being undertaken.

Particular discharge and runoff management will be required for the release of collected water from within the tunnel infrastructure and will require specific management in regard to release into receiving waters. As discharge will likely involve a drainage feature proximal to the western tunnel portal, specific management of the hydrological regime of release will be required, in the form of periods of water/ dewatering releases into the drainage feature to minimise a change in hydrological regime and ecological processes.

In the event that WQOs cannot be achieved for receiving waters, alternate treatment/disposal options as adaptive management actions (i.e. disposal options in line with potential down-time of water treatment plant) are to be implemented in accordance with any relevant and applicable condition of approval or legislation and regulations in place. The water treatment plant is expected to have holding tanks of sufficient size to allow for holding of raw water during potential down time of the water treatment plant, to remove instances of raw water release into receiving environments.

TABLE 13.25: PROPOSED SURFACE WATER QUALITY MITIGATION MEASURES

Delivery phase	Aspect	Proposed mitigation measures
Detailed design	Water quality of waterways	Seek to further refine the disturbance footprint identified and assessed in the EIS to avoid and, where avoidance is not possible, further minimise impacts to all waterways including defined watercourses, currently unmapped waterways and drainage features (defined by the Water Act) and water quality of Western Creek, the Bremer River, Warrill Creek, Sandy Creek, Purga Creek, Woollaman Creek, Undullah Creek, Teviot Brook, their tributaries and downstream impoundments or users by: - Avoiding, then minimising, the extent and duration of temporary waterway diversions - Avoiding, then minimising, the extent of permanent waterway diversions or realignments. Where unavoidable, permanent waterway realignment/diversion design to include simulation of natural features e.g. meanders, pools, riffles, shaded and open sections, deep and shallow sections and different types of sub-strata, depending on the pre-disturbance environmental values - Planning and defining maintenance activity locations, construction compounds and storage areas, and management procedures - Undertaking pre-construction water quality monitoring and detailed design hydraulic modelling to inform temporary and permanent drainage design. Requirements for treatment train controls, scour protection etc., to be incorporated where necessary to achieve modelled compliance with established water quality objectives. Temporary and permanent measures must be appropriate to the site conditions, responding to the erosion risk assessment, environmental receptors, climatic zone and seasonal factors - Developing an Erosion and Sediment Control Plan (ESCP), in accordance with the International Erosion Control Association's *Best Practice Erosion and Sediment Control* (IECA, 2008) for implementation during pre-construction, construction and commissioning, which will establish and specify the monitoring and performance objectives for handover on completion of construction - Ensuring the disturbance footprint defined during detailed design allows sufficient space for provision of the required temporary and permanent erosion and sediment control measures/pollution control measures - Designing batters, cuts and other exposed surfaces to reduce erosion risk - Designing watercourse crossing structures (including culverts and bridges) to minimise the need for ongoing maintenance and inspection to maintain aquatic fauna (e.g. fish) passage and minimise the risk of debris deposition during large-flow events in accordance with relevant regulatory requirements.
	Monitoring	Develop the surface water monitoring framework to inform the development of the CEMP and the construction water quality monitoring program. It will identify monitoring locations including upstream, downstream and at the intersection of the Project disturbance footprint and watercourse. It will include the relevant water quality objectives, parameters, criteria and specific monitoring locations, frequency and duration identified in consultation with relevant regulators to reduce impacts to surface water quality. The water quality monitoring program will include (as a minimum): - Analysis of the representative background monitoring dataset - Identification of Project works and activities during construction and operation, including runoff, emergencies and spill events, that have the potential to impact on surface water quality of potentially affected waterways and riparian land (via discharge points) - A risk management framework for evaluation of the risks to surface water quality and ecosystems in the receiving environment, including definition of impacts that trigger contingency and ameliorative measures

Delivery phase	Aspect	Proposed mitigation measures

Detailed design (continued)	Monitoring (continued)	▸ The identification of locality-specific and construction-activity erosion and sediment control and stormwater management requirements relating to surface waters during construction, commissioning and operation
		▸ The presentation of WQO trigger values, standards and parameters against which changes to water quality will be assessed with regard to the ANZECC/ARMCANZ 2000/2018 Guidelines or other suitable guidelines. As a minimum this should include values for:
		  ▸ TSS—Equivalent to corresponding background (milligrams per litre (mg/L))
		  ▸ Turbidity—Equivalent to corresponding background (Nephelometric Turbidity Units (NTU))
		  ▸ pH 6.5–8
		▸ Oils and grease (no visible films). If oils and grease are visually evident, a sample will be forwarded to the laboratory for analysis. Establishment of construction surface water monitoring locations including waterways, waterbodies and wetlands (e.g. upstream of, downstream of, and at the intersection of the Project disturbance footprint and watercourse and tunnel dewatering into the Purga Creek sub-catchment) and discharge points, which are representative of the potential extent of impacts from the Project, including relevant analytes and frequency of monitoring
		▸ Identification of seasonal factors with the potential to influence water quality at the monitoring sites
		▸ A minimum monitoring period following the completion of construction completion criteria. Surface water quality during baseflow conditions, that meet representative pre-construction up and downstream background monitoring, and/or WQOs, will confirm adequate rehabilitation
		▸ The post-construction monitoring will assess the efficacy of constructed water control measures, as defined as part of drainage during detailed design of the Project (such as vegetated buffer-strip basins and vegetated swales)
		▸ Contingency and ameliorative measures in the event that adverse impacts to water quality are identified, with reference to the impact triggers defined as part of the water quality monitoring program
		▸ Surface water quality samples are to be collected and analysed in accordance with industry accepted standards and quality assured procedures, with laboratory analysis undertaken by NATA-accredited facilities.
		Commence the baseline water quality monitoring to obtain a suitable dataset, prior to construction, at waterway crossing locations to establish baseline water conditions and provide a sufficient seasonal variation.

	Drainage design, erosion sediment control	Water quality modelling will be undertaken to inform permanent drainage design for the rail and road realignments (i.e. requirements for treatment train controls, where necessary, to comply with established water quality objectives, scour protection) and to inform erosion and sediment control plans. Design defines temporary and permanent stormwater, erosion and sediment/pollution control measures in ESCPs and Reinstatement and Rehabilitation Plans, that comply with the International Erosion Control Association's (IECA) *Best Practice Erosion and Sediment Control* (IECA, 2008). The aforementioned plans will also establish and specify the monitoring and performance objectives for handover on completion of construction.

Delivery phase	Aspect	Proposed mitigation measures
Detailed design (continued)	Construction water	Developing a dewatering strategy where dewatering of artificial impoundments is required (e.g. dewatering of artificial impoundment at Ch 2.90 km and Ch 4.60 km) to comply with the *Biosecurity Act 2014* (Qld) to take reasonable measures to avoid the spread of pest species (with capacity to affect water quality) and in accordance with any required aquatic fauna species management plans. Requirements for construction water (volumes, quality, demand curves, approvals requirements and lead times) will be defined during detailed design and construction planning. This should include identification of opportunities to use dewatered artificial impoundments (where impacted along the alignment) for construction purposes. Construction water sources and demand will use a hierarchical approach to confirm the suitability of water sources, with a focus on using existing sustainable allocated water entitlements from private water holders. Licences, approvals and agreements to access water from sources identified in the finalised construction water strategy will be obtained. These may include water licences under the Water Act or access agreements with bulk water suppliers or private landholders. Specify performance criteria in the CEMP for construction water requirements to minimise the risk of adverse water quality, environmental or health impacts, and avoid the use of potable water where non-potable sources can be applied.
	Tunnel dewatering	Groundwater quality and hydraulic modelling will be undertaken to inform the design for the Teviot Range tunnel dewatering treatment facility. Develop a treatment and discharge plan, consistent with the water quality monitoring framework for implementation at the tunnel dewatering plant. The collected water will be required to meet the water quality objectives (to be established during baseline water quality monitoring) for release to Purga Creek, and schedule release periods so as to minimise changes in hydrological regime, physical and chemical characteristics and ecological processes. The treatment and discharge plan will also establish criteria and protocols in the event that releases during no-flow conditions are required.

Pre-construction	Erosion and sediment control (water quality related)	ESCPs will be developed as part of the CEMP, in accordance with IECA *Best Practice Erosion and Sediment Control* (2008). The ESCP will include the following procedures and protocols relevant to potential impacts on water quality values:
		▸ Soil/land conservation objectives for the Project
		▸ Management of problem soils, such as:
		  ▸ Acid sulfate soils, which may occur in proximity to artificial waterbodies or impoundments
		  ▸ Erosive or dispersive soils, such as sodosols that are expected to be encountered at Ch 10.00 km (associated with Ebenezer)
		  ▸ Cracking clays (vertosols) that are expected to be encountered in the disturbance footprint associated with the alignment in proximity of Purga and Willowbank
		  ▸ Saline soils, particularly in high-salinity hazard areas such as between Ch 7.50 km and Ch 22.50 km
		▸ Specification of the type and location of erosion and sediment controls. The erosion and sediment control measures will be developed by a Certified Professional in Erosion and Sediment Control (CPESC) and be in accordance with the IECA *Best Practice Erosion and Sediment Control* (2008)

Delivery phase	Aspect	Proposed mitigation measures

Pre-construction (continued)	Erosion and sediment control (water quality related) (continued)	▸ A Soil Management Plan that will include:
		  ▸ Locations for specific temporary/permanent erosion and sediment control measures, such as:
		  ▸ Sediment retention basins
		  ▸ Scour protection (included in the design)
		  ▸ Sediment fencing
		  ▸ Berms and other surface-flow redirection through disturbance areas
		▸ Nomination of location-specific erosion controls will include consideration of site conditions, proximity to environmental receptors, adjoining land uses, climatic and seasonal factors, and will be based on an erosion risk assessment
		▸ Minimise the area of disturbance during each stage to that required to enable the safe construction, operation and maintenance of the rail corridor
		▸ Scheduling of works in areas proximal to waterways (as risk water quality receptors) with consideration to periods of higher rainfall (summer months), where practical
		▸ Establish and specify the monitoring and performance objectives for handover on completion of construction
		▸ Stockpiling and management/segregation of topsoil, where it contains native plants, seed bank or weed material
		▸ Vehicle, machinery and imported fill hygiene protocols and documentation, in accordance with the requirements of the *Biosecurity Act 2014* (Qld)
		▸ Requirements for training, inspections, corrective actions, notification and classification of environmental incidents, record keeping, monitoring and performance objectives for handover on completion of construction.
		The ESCPs are to include a process for site- and activity-specific preparation when forecast large or high-intensity wet weather events are predicted. This may include but not be limited to removing plant and equipment out of riparian zones, stabilising/covering live work areas, additional application of soil binders/veneers and pre-event treatment and dewatering of sediment basins.

	Water quality	Review and adjust (as required) the surface water monitoring framework and develop the water-quality monitoring program as part of the Surface Water Sub-plan of the CEMP, with reference to the baseline (representative background) monitoring dataset. Dewatering/extraction of water from artificial impoundments will be undertaken after consultation with relevant stakeholders. To the extent possible and where required, stage Project works are to use dewatered artificial impoundments to reduce external water requirements. Dewatering strategies will be required to comply with the *Biosecurity Act 2014* (Qld) to take reasonable measures to avoid the spread of pest species (with capacity to affect water quality).

Delivery phase	Aspect	Proposed mitigation measures
Construction and commissioning	Erosion and sediment control	Clearing extents are limited to the disturbance footprint, and clearing is scheduled to minimise the exposure time of unprotected materials to prevent sedimentation of receiving waterways. Appropriate erosion and sediment control measures are to be implemented for each stage or element of the Project works, in accordance with the progressive revisions of the ESCPs that are undertaken by a CPESC in accordance with IECA *Best Practice Erosion and Sediment Control* (2008). Stages/elements are expected to include (but not be limited to): ▸ Vegetation clearing and grubbing ▸ Temporary access tracks and/or temporary waterway crossings ▸ Early installation of stormwater drainage and clean water catch drains to divert clean water flows through/around the construction site ▸ Bulk earthworks and interim topography changes ▸ Waterway diversions ▸ Bridge and culvert works ▸ Ballast placement ▸ Reinstatement activities ▸ Rehabilitation and landscape activities. Temporary waterway crossings are rehabilitated in accordance with the Reinstatement and Rehabilitation Plan. Where practical and or in accordance with specific flora and fauna management plans, vegetation clearing and ground disturbing works will be staged sequentially across the Project to minimise areas exposed to erosion and sediment risk of receiving waterways and drainage lines in accordance with the general environmental duty of the *Environmental Protection Act 1994* (Qld).
	Water quality	Implementation of the Surface Water Sub-plan. The surface water monitoring framework will include the relevant water quality objectives, parameters, criteria and specific monitoring locations, frequency and duration identified in consultation with relevant regulators to reduce impacts to surface water quality. To the extent possible, schedule works to utilise dewatered artificial impoundments along the alignment to reduce external water requirements. Dewatering strategies will be required to comply with the *Biosecurity Act 2014* (Qld) to take reasonable measure to avoid the spread of pest species (with capacity to affect water quality). In the event that water quality objectives cannot be achieved for waters to be released, alternate treatment/disposal options are to be implemented prior to release or re-use.

Delivery phase	Aspect	Proposed mitigation measures
Construction and commissioning (continued)	Water quality	Water will need to meet the established water quality objectives for receiving waterways before being released/discharged into local waterways. Water that does not comply with relevant water quality objectives will either be: ▸ Treated onsite to enable discharge ▸ Used for construction water purposes that is not quality dependent, if safe to do so and adequate environmental controls are in place ▸ Removed from site for disposal at an appropriately licensed facility. Bulk storage areas for dangerous goods and hazardous materials will be located away from areas of social and environmental receptors such that offsite impacts or risks from any foreseeable hazard scenario will not exceed the dangerous dose for the defined land use zone, i.e. either sensitive, commercial/community, or industrial, in accordance with the intent of the SPP. Appropriate register and records of chemicals, hydrocarbons and hazardous substances and materials onsite will be kept up to date as required by the CEMP. Where appropriate, this should include a relevant risk assessment prior to the substance coming to, and being used on site, plus a Safety Data Sheet Register. Licensed transporters operating in compliance with *Australian Code for the Transport of Dangerous Goods by Road & Rail* will be used for the transportation of dangerous goods. Chemicals stored and handled as part of construction activities will be managed in accordance with: ▸ The *Work Health Safety Act 2011* (Qld) and Regulation ▸ *AS 2187.4-1998 Explosives—storage, transport and use* ▸ *AS 1940-2017 Storage and Handling of Flammable and Combustible Liquids* ▸ *AS 3780-2008 The Storage and Handling of Corrosive Substances* ▸ Requirements of chemical safety data sheets ▸ Any relevant ERA conditions. Procedures will be established for safe and effective fuel, oil and chemical storage and handling. This includes storing these materials within roofed, bunded areas. The bunding will have floors and walls that are lined with an impermeable material to prevent leaching and spills. Construction tasks will be scheduled to avoid, where possible, bulk earthwork activities within the 1% AEP during periods of elevated flood risk. Where works cannot be scheduled outside of this time period, activity-specific flood readiness and response planning will be required. This planning will be developed in consultation with the relevant local government and QFES. Laydown areas and other construction facilities that are located within the 1% AEP will be temporary. Their planning and function in supporting construction will reflect the local flood risk. For example, hazardous goods will not be bulk stored in these locations. Mobile plant will not be stored in the 1% AEP when not scheduled to be in use for construction purposes. Plant maintenance and refuelling will be carried out with appropriate interception measures in place to avoid impacts to waterways, aquatic habitats and groundwater. Appropriate spill control materials, including booms and absorbent materials, will be onsite at refuelling facilities at all times. Appropriate waste bins will be located in laydown areas to facilitate segregation and appropriate containment of waste materials.

Delivery phase	Aspect	Proposed mitigation measures
Construction and commissioning (continued)	Construction water	The extraction of water will occur in accordance with licences, approvals and/or agreements. Volume monitoring during extraction will be required for each source point, with extraction logs maintained. Extraction reporting will occur, as required, in accordance with requirements of relevant licences, approvals and/or agreements obtained to cover this activity.
	Waterways	Maintenance activities and refuelling will be carried out at an appropriate distance from riparian vegetation and waterways, with appropriate measures in place to avoid impacts to surface water quality. Where this is not achievable due to type of activities (e.g. piling activities within a riparian zone), additional mitigation measures must be implemented to prevent impacts on water quality.
Operation	Water quality	Operational tunnel dewatering into the Purga Creek sub-catchment will be required to meet the established water quality objectives (or interim water quality guidelines) for receiving waterways before being released/discharged into local waterways. Water that does not comply with relevant water quality objectives will either be: ‣ Treated on-site to enable discharge ‣ Removed from site for disposal at an appropriately licensed facility. The effectiveness of permanent erosion controls (e.g. scour protection or vegetated swales) will be monitored as part of the maintenance inspection schedule for the Project: ‣ Controls that are found to be failing or not performing as intended will either be modified or replaced, as required ‣ Vegetation on the rail embankment slopes will be maintained to prevent slope face degradation. Maintenance of surface and subsurface drains will be required to ensure continued effectiveness and to minimise risk of impact to surrounding and downstream environments and structures.

Tunnel dewatering treatment

Water quality characteristics of groundwater tunnel drainage are expected to generally meet EPP (Water and Wetland Biodiversity) discharge criteria as regional WQOs for Purga Creek (refer Table 13.4 and Table 13.5). However, the salinity of groundwater drainage and total nitrogen may exceed salinity of receiving stream and required discharge criteria. This water will likely be processed through a water treatment plant and include hydrocarbon and first-flush separation before being released to Purga Creek. The discharged water will be expected to meet the WQOs for the protection of aquatic ecosystems of Purga Creek (under Schedule 1 of the EPP (Water and Wetland Biodiversity)).

A water treatment plant has been included in the proposed design for the Project. Particular discharge and runoff management will be required for the release of collected water from within the tunnel infrastructure and will require specific management in regard to release into receiving waters. Preliminary assessment of tunnel dewatering suggests that salinity and total nitrogen concentrations of tunnel inflows could exceed criteria for receiving surface waterbodies.

The water treatment facilities that may be required include:

- Screening treatment
- Detention tanks
- Aeration/flocculation tanks
- Chemical treatment
- Water-pumping facilities
- Sludge storage.

As discharge will likely involve a drainage feature (as an overland flow route to Purga Creek) proximal to the western portal, specific management of the hydrological regime of release will be required. This is expected in the form of periods of water/dewatering releases into the drainage feature to minimise a change in hydrological regime and ecological processes.

The collected water will be required to meet the WQOs for Purga Creek (refer Section 13.3.3) and will likely require processing through a water treatment plant include hydrocarbon separation.

Water from the plant may require further treatment prior to discharge to meet water quality objectives, as the water may become overtreated. In order to mitigate significant impact on the receiving waters, discharge will need to be monitored to ensure discharge does not result in the release of over-cleaned (i.e. water that is not representative of localised water quality parameters under WQO), treated water into the receiving waters.

Surface water quality (receiving environment) monitoring recommendations

A Water Quality Monitoring Program (WQMP) is proposed to monitor the effectiveness of mitigation measures for surface water quality. This will be required to be conducted prior to and throughout construction during the commencement of operational phases of the Project. During operations, it is expected the WQMP will be limited to monitoring discharge from the water treatment plant into Purga Creek.

The WQMP would be developed during the detailed CEMP and would include:

- Identification of works and activities during construction and operation of the Project, including runoff, emergencies and spill events, that have the potential to impact on surface water quality of potentially affected waterways and riparian land (via discharge points)
- A risk-management framework for evaluation of the risks to surface water quality and ecosystems in the receiving environment, including definition of impacts that trigger contingency and ameliorative measures
- The identification of environmental management measures relating to surface waters during construction and operation, including erosion and sediment control and stormwater management measures
- The presentation of WQO trigger values, standards and parameters against which any changes to water quality will be assessed, with regard to the relevant water quality guidelines and ANZG 2018 Guidelines. Where alternate guidelines are used to establish water quality goals, justification will be provided
- Representative background monitoring data for surface water quality to establish baseline water conditions prior to the commencement of construction
- Identification of construction and operational phase surface water monitoring locations (pending non-acceptance of current water quality monitoring locations) including waterways, waterbodies and wetlands, which are representative of the potential extent of impacts from the Project, including relevant analytes and frequency of monitoring
- Commitment to a monitoring period following the completion of construction or until the affected waterways and/or groundwater quality are certified by a suitably qualified and experienced independent expert as being rehabilitated to an acceptable condition, unless otherwise approved or directed by regulatory authorities. Surface water quality during baseflow conditions that meet background monitoring and/or WQOs will confirm adequate rehabilitation

- The monitoring must also confirm the establishment of operational water control measures, which will be identified as part of drainage during detailed design of the Project (such as vegetated buffer strips basins and vegetated swales)
- Contingency and ameliorative measures in the event that adverse impacts to water quality are identified, with reference to the impact triggers defined as part of the water quality monitoring program
- Surface water quality samples are to be collected in accordance with industry-accepted standards and quality assured procedures, including the *Queensland Monitoring and Sampling Manual* (DES, 2018b).

Noting that the current Project environment is under drought declaration, a contingency plan proposes to consider using water quality objectives under the EPP (Water and Wetland Biodiversity) as a contingent to site-specific water quality objectives derived from baseline monitoring. These would be expected to allow for the same process of assessment of impact to occur (as per the baseline collection of water quality data) if no flow conditions continue into the detailed design phase of the Project.

Salinity management

Salinity management (in regard to surface water quality) will be addressed by implementation of the Erosion and Sediment Control Plan and through characterisation of soil conditions across the water quality study area at a suitable scale in accordance with the CEMP prior to construction to inform design and environmental management measures. This includes identification of potential/actual acid sulfate soils, reactive soils, erosive soils, dispersive soils, saline soils, acidic soils, alkaline soils and contaminated land. The characterisation is considered to be used within the ESCP to identify problematic soils and assist the management of salinity during works and following the implementation of the Rehabilitation and Reinstatement Plan.

Surface water resources

Water will be required for dust control, site compaction and reinstatement during construction (refer Chapter 6: Project Description). A number of potential water sources have been investigated, including extraction of groundwater or surface water, private bores, recycled water and watercourses. These sources will be further explored during detailed design in consultation with regulatory agencies, local councils and landholders. Where water is not available, it will be transported to the site via tanker truck and stored in temporary storage tanks. Potable water for human consumption will be supplied in potable water tanks or as bottled water, as necessary.

Activities during the construction phase with the highest water demand are:

- Soil conditioning
- General dust suppression
- Dust suppression and maintenance of laydown areas and haul roads
- Construction offices and amenities.

Overall, an allowance of 190 litres per cubic metre (L/m^3) of earthworks has been made in building up the estimated water demand requirements. Overall Project water requirements are noted in Table 13.26.

Project water requirements for constructive workforce impact will be negligible due to no requirement for camp water. Onsite water will be expected to be provided for portable lavatories.

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 the detailed design phase of the Project (post-EIS) and will be dependent on:

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

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

- Public surface water storages, i.e. dams and weirs
- Recycled water, where appropriate
- Permanently (perennial) flowing watercourses
- Privately held water storages, i.e., dams or ring tanks, under private agreement
- Existing registered and licensed bores
- Mains water.

Drilling of new bores is the 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.

Extraction of water from a watercourse typically requires:

- A water entitlement, water allocation, water licence or water permit. It is noted that the Moreton and Logan Water Plans are fully allocated at this point in time and water would need to be supplied from an existing entitlement
- A development permit for use of water that is assessable development under the *Planning Act 2016*.

The DNRME maintains exemption requirements for construction authorities for the take of water without a water entitlement (WSS/2013/666). These exemption requirements may only be used by a constructing authority defined under Schedule 2 of the *Acquisition of Land Act 1967* (Qld) (AL Act) and includes state government departments and local governments (noting that the maximum permissible volume under these exemptions is 50ML). At present, these guidelines do not directly apply to ARTC and a water entitlement would be required for the extraction of water from a watercourse. The water entitlement requirements for the Project will be confirmed during detailed design and by the construction contractor.

The use of surface water and groundwater to supplement the construction demand for the Project may be considered if private owners of registered bores have capacity under their existing sustainable allocated entitlements that they wish to sell to ARTC or the construction contractor under private agreement.

Further options may need to be investigated depending on engagement with water-resource owners and the following aspects:

- If water is available to be provided from existing dams and weirs operated by Seqwater:
  - Water supply to meet the expected demand may be available from the Churchbank Weir (Warrill Creek) and Wyaralong Dam; however, consultation with Seqwater has indicated availability of water from Churchbank Weir would be subject to supply levels at the time construction water is required
  - At the time of writing it was considered that supply to downstream users of Churchbank Weir will likely cease around December 2020 and therefore, until significant rainfall occurs, it is unlikely there will be any water available at Churchbank Weir
- Further engagement with Seqwater will be required to confirm availability and supply arrangements during future stages of design and construction planning. If water is to be sourced from local town supplies, then an agreement will have to be made with the local councils on supply conditions. Local town supplies in the Warrill Valley are from a sole water source (Moogerah Dam) and without significant rainfall these supplies are likely to be under water supply restrictions
- If water is to be drawn from creeks and rivers intersecting the alignment, then approvals will be required under the Water Act
- Further approvals will also be required to draw water from groundwater bores
- Project water requirements in regard to constructive workforce impact will be negligible due to no requirement for camp water. Onsite water will be expected to be provided for portable lavatories.

TABLE 13.26: CONSTRUCTION WATER REQUIREMENTS

Construction activity/process/ phase	Uses/requirement	Approximate quantity (megalitres (ML))	Quality	Flow rate	Supply
Earthworks	Material conditioning, general dust suppression and general maintenance	480, 240, 190	Low	High	River, dam or bore
Concrete (by concrete supplier)	Bridge and culvert locations	To be determined	High	Low	Town mains due to quality requirements
Track works	Ballast dust suppression during ballasting and regulating activities	28	Low	Low	River, dam or bore

Table notes:
Construction activity timing includes:
- Earthworks: January 2022 to July 2024
- Concrete (Structures and Drainage): April 2022 to July 2025
- Trackworks: July 2025 to October 2025

The construction water requirements will be further refined following detailed design and once a construction contractor has been commissioned for the Project.

There is the potential to impact on users of surface water if the quality of water or the flow of water changes within offtake locations on Warrill Creek (as a proximal identifier of further impacts to downstream surface water users). The design of the alignment will ensure that the changes to flow are minimised and will not impact users.

The impact to water plans (supply and conveyance) within the disturbance footprint will be minimal due to limited overland flow interference and minimal diversion of defined watercourses. Hydrological modelling has not indicated significant changes to the current flow regimes and as such, minimal impact is expected to occur from the Project on supply and conveyance.

Impact to water plans will derive from diversion of watercourses and will principally be concerned with five trapezoidal diversion drains at locations where the rail embankment falls on top of existing flow paths. One unmapped waterway is considered to be potentially impacted and runs from Chainage 39.28 km to 39.54 km (refer Figure 13.3). ARTC and/or the construction contractor will obtain the relevant approvals for diversion and works that take or interfere with a watercourse, lake or spring prior to construction. For further details refer Appendix M: Surface Water Quality Technical Report.

Potential further impact to water plans may be expected due to the requirement for construction water, however, this is expected to be regulated by the necessary authorities and will be conducted in accordance with the strategy for sourcing construction water (refer Section 13.7.2.2).

Wyaralong Dam and Churchbank Weir (Warrill Creek) have been identified as potential construction water supply options. It is expected that the proposed offtake of water from these impoundments will comply with water plans and will not result in a loss of water quality from unregulated use of surface water resources due to Project activities.

Access to water also has implications other than those identified in the Water Act. These include impacts to Seqwater operations, recreational activities, neighbouring landholders and erosion of access tracks.

Impact to the surface water users will principally revolve around the impact on water quality from the identified potential impacts in Section 13.6, including increased debris, altered water quality and hydrology, altered water chemistry, salinity increase, an increase in erosion and sedimentation and introduction of contaminants. When considered at a highly conservative level, impacts to water quality as a result of Project activities during construction may have transient impacts to local water users, potentially restricting access to human drinking water, stock water and crop irrigation. As significant hydraulic changes are not expected from take or conveyance of construction water, impact to surface water users are considered to be restricted to those mentioned above. Noting that significant impacts on water quality are not considered within Project activities, a commitment to inform the resource operation licence holder (Seqwater) for the offtakes along Warrill Creek, will be undertaken.

Water quality protection of aquatic ecosystems will confer protection to current existing condition within the water quality study area, and water users downstream of the alignment. Therefore, identification of potential impact, mitigation measures (refer Section 13.7) and resulting impact assessment (refer Section 13.8.1) identifies any impact to surface water users.

13.7.2 Hydrology and flooding

13.7.2.1 Design considerations

The Project has been designed to achieve the hydraulic design criteria (refer Table 13.6) including 1% AEP flood immunity to rail formation level. At the same time, the design seeks to avoid impacts that do not meet the flood impact objectives (refer Table 13.7) for the flooding and drainage regime. Key strategies that have been adopted in developing the Project design are detailed in Table 13.27.

TABLE 13.27: INITIAL MITIGATION OF RELEVANCE TO HYDROLOGY AND FLOODING

Aspect	Initial design mitigations

Flooding and hydrology	▸ The Project has been designed to achieve the hydraulic design criteria (refer Section 13.4.2.1), and key design criteria including:
	  ▸ 50-year design life for formation and embankment performance
	  ▸ Track drainage ensures that the performance of the formation and track is not affected by water
	  ▸ Earthworks designed to ensure that the rail formation is not overtopped during a 1% AEP flood event
	  ▸ Embankment cross section can sustain flood levels up to the 1% AEP
	  ▸ Bridges are designed to withstand flood events up to and including a 1 in 2,000 AEP event
	  ▸ Where possible, the Project uses existing rail corridors to avoid introducing a new linear infrastructure corridor across floodplains. For the Project, this is limited to the section near Calvert, with the remainder of the alignment in greenfield areas.
	▸ The Project incorporates bridge and culvert structures to maintain existing flow paths and flood flow distributions.
	▸ Bridge and culvert structures have been located and sized to avoid increases in peak water levels, velocities and/or duration of inundation, and changes flow distribution in accordance with the flood impact objectives (refer Section 13.4.2.2).
	▸ Progressive refinement of bridge extents and culvert banks (number of barrels and dimensions) has been undertaken as the Project design has evolved. This refinement process has considered engineering requirements as well as progressive feedback from stakeholders to achieve acceptable outcomes that address the flood impact objectives.
	▸ Scour and erosion protection measures have been incorporated into the design in areas determined to be at risk, such as around culvert headwalls, drainage discharge pathways and bridge abutments.
	▸ A climate change assessment has been incorporated into the design of cross-drainage structures for the Project in accordance with the *Australian Rainfall and Runoff Guidelines* (2016) for the 1% AEP design event to determine the sensitivity of the design, and associated impacts, to the potential increase in rainfall intensity.
	▸ Identification of flood sensitive receptors and engagement with stakeholders to determine acceptable design outcomes.

Details of the Project design performance against the flood impact objectives is provided in Section 13.8.2. For further details regarding the hydrologic and hydraulic modelling approach and design outcomes, refer Appendix N: Hydrology and Flooding Technical Report, and for further details on engagement with stakeholders regarding hydrology refer Chapter 5: Stakeholder Engagement and Appendix C: Consultation Report.

13.7.2.2 Future mitigation measures

To manage and mitigate Project risks, mitigation measures have been proposed for implementation in future phases of Project delivery. These proposed mitigation measures have been identified to address Project-specific issues and opportunities including legislative requirements and accepted government plans, policy and practices.

Table 13.28 identifies the relevant Project phase, the aspect to be managed and the proposed mitigation measure.

TABLE 13.28: PROPOSED HYDROLOGY AND FLOODING MITIGATION MEASURES

Delivery phase	Aspect	Proposed mitigation measure
Detailed design	Flooding	▸ Consult with stakeholders including directly impacted landholders, local government authorities, State Government departments and local flood specialists to inform and refine the Project design. ▸ Continue to refine Project design in response to hydraulic modelling outcomes. This includes addressing flood impact objectives which include consideration of peak water levels, flow distribution, velocities and duration of inundation. The hydrologic and hydraulic modelling for Western Creek, Bremer River, Warrill Creek and Purga Creek will be reviewed and updated to consider the Ipswich City Council hydrologic and hydraulic modelling completed in early 2020. This will confirm bridge lengths, culvert sizing and numbers, localised scour and erosion-protection measures for both rail, road and other permanent Project infrastructure. When finalised positions of infrastructure elements (e.g. abutments/piers etc.) are confirmed and detailed soil studies are complete, geomorphological assessment of identified risk locations will be undertaken. ▸ Undertake a Project flood risk assessment to inform the siting and scale of temporary construction areas (including stockpiles, construction compounds, access, laydown areas etc) to ensure they are located in areas that do not experience periodic inundation. ▸ Construction planning reviews of the design to locate plant and equipment maintenance activities and chemical/hazardous goods storage facilities in accordance with the risk assessment and incorporate appropriate location-specific controls and procedures to minimise the risk and avoid impacts to waterways, aquatic habitats, and groundwater. ▸ Incorporate outcomes from consultation with stakeholders including directly impacted landholders, local government authorities, State Government departments and recognised subject matter experts to inform and refine the Project design.
Pre-construction	Flooding	▸ Impacts must be determined at all drainage structures and waterways affected by construction works. The change in flood levels and impacts on infrastructure and properties outside the rail corridor must be justified for a range of events up to and including the 1% AEP event.

Operation	Flooding	▸ Inspections will be carried out in accordance with ARTC's *Structures Inspection Engineering Code of Practice* (ETE-09-01) to identify defects and conditions that may affect waterway and drainage system capacity or indicate increased risk of flooding such as:
		  ▸ Scour
		  ▸ Blockages due to debris build up
		  ▸ Indication of floods overtopping a structure
		  ▸ Culvert or drain damage or collapse.

13.8 Impact assessment

13.8.1 Water quality significance impact assessment

A significance assessment has been undertaken following the impact assessment framework (refer Sections 7 and 8 of Appendix M: Surface Water Quality Technical Report). The significance impact assessment was generated using a conservative approach aligned with a conceptual model of projected impacts. This was coupled with all Project activities that may have a detrimental impact on the quality of surface water quality via proximal discharge points associated with the Project.

The high sensitivity value of MNES- and MSES-associated environments within the Project have been assessed separately with the remainder of the Project environments in relation to water quality. In order to account for habitat disturbance to MNES through changes to water quality, the high sensitivity is linked to sections of Western Creek, Bremer River, Warrill Creek and Teviot Brook that intersect with the Project alignment.

Impacts on water quality are based on a model of expected occurrences, regarding projected impacts (potential and specific) from Project activities. As such, critical failure of infrastructure is not considered a viable impact for impact significance assessment.

In summary, potential impacts were grouped into six general potential impacts:

- Increased debris
- Changes to receiving water quality and hydrology
- Increase in salinity
- Increases in erosion and sedimentation
- Increase in contaminants
- Exacerbation of listed impacts above, from inadequate rehabilitation processes.

It is expected these categories may interface and have the capacity to compound existing/new impacts as they arise (e.g. increased erosion resulting in compounding effect of contaminant leachate and water chemistry changes).

Within Table 13.29, the specific impacts (sectioned under the potential impact category) are assessed as a qualitative significance of impact with the design considerations (or initial mitigations) factored into the Project design. These are documented under the heading proposed additional mitigations (refer Table 13.24).

Additional mitigation and management measures (in situ mitigation), including those listed in relevant sub-plans, were then applied as appropriate to the phase of the Project to reduce the level of potential impact.

The residual significance of the potential impacts was then reassessed after mitigation and management measures were applied. The initial significance levels were compared to the residual significance levels in order to assess the effectiveness of the mitigation and management measures.

TABLE 13.29: IMPACT ASSESSMENT FOR POTENTIAL IMPACTS ASSOCIATED WITH WATER QUALITY

					Initial impact significance[1]		Residual impact significance of risk[2]	
Aspect	**Potential impact**	**Specific Impact**	**Phase**	**Sensitivity**	**Magnitude**	**Significance**	**Magnitude**	**Significance**
Erosion and sediment control	Increased debris	Contamination of waterway from debris from the Project to be blown into or washed into waterway	Pre-construction and construction	Moderate	Low	Low	Negligible	Low
			Operation					
			Pre-construction and construction	High[3]	Low	Moderate	Negligible	Low
			Operation					
		Restriction of flow within the waterways if too much debris is introduced to waterway or is stuck in culverts or creek crossings	Pre-construction and construction	Moderate	Moderate	Moderate	Negligible	Low
			Operation					
			Pre-construction and construction	High[3]	Moderate	High	Negligible	Low
			Operation					
Water quality Waterways	Changes to receiving water quality and hydrology	Routine tunnel dewatering operations resulting in a reduction of receiving water quality and changes to hydrological regimes specific to Purga Creek	Pre-construction and construction	Moderate	Major	High	Low	Low
			Operation					
		Diversion of overland flow (unmapped waterway) influencing local hydrological regime and subsequent water quality specific to Purga Creek	Pre-construction and construction	Moderate	High	Moderate	Low	Low
			Operation					
		Changes to receiving water quality from dewatering of artificial waterbodies	Pre-construction and construction	Moderate	Low	Moderate	Low	Low
Erosion and sediment control Water quality	Increase in salinity	Increased salinity in proximal watercourses from land disturbance	Pre-construction and construction	Moderate	High	High	Negligible	Low
				High[3]	High	Major	Negligible	Low

					Initial impact significance[1]		Residual impact significance of risk[2]	
Aspect	**Potential impact**	**Specific Impact**	**Phase**	**Sensitivity**	**Magnitude**	**Significance**	**Magnitude**	**Significance**
Erosion and sediment control General interference with existing surface water	Increases in erosion and sedimentation	Disturbance of the bed, banks and riparian zone of waterways	Pre-construction and construction	Moderate	High	High	Negligible	Low
			Operation		Moderate	Moderate	Negligible	Low
			Pre-construction and construction	High[3]	High	Major	Negligible	Low
			Operation		Moderate	High	Negligible	Low
		Increased turbidity and sedimentation and potential mobilisation of contaminants through erosion from disturbance activities near waterways	Pre-construction and construction	Moderate	High	High	Negligible	Low
			Operation		Moderate	Moderate	Negligible	Low
			Pre-construction and construction	High[3]	High	Major	Negligible	Low
			Operation		Moderate	High	Negligible	Low
		Increased turbidity and potential mobilisation of contaminants from stockpiled areas	Pre-construction and construction	Moderate	Moderate	Moderate	Negligible	Low
			Pre-construction and construction	High[3]	Moderate	High	Negligible	Low
		Increased turbidity and potential mobilisation of contaminants from dewatering activities near excavations	Pre-construction and construction	Moderate	Moderate	Moderate	Negligible	Low
			Pre-construction and construction	High[3]	Moderate	High	Negligible	Low
		Increased sedimentation can impact the function of culverts/creek crossing and impede flow of the waterway	Pre-construction and construction	Moderate	Moderate	Moderate	Negligible	Low
			Operation		Low	Low	Negligible	Low
			Pre-construction and construction	High[3]	Moderate	High	Negligible	Low
			Operation		Low	Moderate	Negligible	Low

					Initial impact significance[1]		Residual impact significance of risk[2]	
Aspect	**Potential impact**	**Specific Impact**	**Phase**	**Sensitivity**	**Magnitude**	**Significance**	**Magnitude**	**Significance**
Erosion and sediment control Water quality Waterways	Increase in contaminants	Contamination of waterway from inadequate storage of fuels, oils and contaminants	Pre-construction and construction Operation	Moderate	Low	Low	Negligible	Low
			Pre-construction and construction Operation	High[3]	Low	Moderate	Negligible	Low
		Runoff from areas of disturbed contaminated lands nearby waterways	Pre-construction and construction	Moderate	Low	Low	Negligible	Low
			Pre-construction and construction	High[3]	Low	Moderate	Negligible	Low
		Introduction of contaminants from stockpiled areas	Pre-construction and construction	Moderate	Low	Low	Negligible	Low
			Pre-construction and construction	High[3]	Low	Moderate	Negligible	Low
		Contaminants can enter waterways after rainfall events from rolling stock or after weed control activities	Operation	Moderate	Moderate	Moderate	Negligible	Low
			Operation	High[3]	Moderate	High	Negligible	Low
		Potential contamination of waterways from failed equipment or from failed infrastructure	Pre-construction and construction Operation	Moderate	Moderate	Moderate	Negligible	Low
			Pre-construction and construction Operation	High[3]	Moderate	High	Negligible	Low

Aspect	Potential impact	Specific Impact	Phase	Sensitivity	Initial impact significance[1]		Residual impact significance of risk[2]	
					Magnitude	Significance	Magnitude	Significance
Erosion and sediment control	Exacerbation of listed impacts above, from inadequate rehabilitation processes	Potential for sedimentation and increased turbidity within waterways if areas are either not rehabilitated or inadequate rehabilitation occurs	Pre-construction and construction	Moderate	Moderate	Moderate	Negligible	Low
			Operation					
			Pre-construction and construction	High[3]	Moderate	High	Negligible	Low
			Operation					
		Inadequate rehabilitation increasing erosion and sedimentation within waterways impacting the function of culverts/ creek crossing and impeding flow of the waterway	Pre-construction and construction	Moderate	Moderate	Moderate	Negligible	Low
			Operation					
			Pre-construction and construction	High[3]	Moderate	High	Negligible	Low
			Operation					

Table notes:
1. Includes implementation of design mitigation
2. Includes proposed mitigation measures
3. Western Creek, Bremer River, Warrill Creek and Teviot Brook

13.8.2 Hydrology and flooding

The Project alignment embankment, drainage structures and associated works were included in each of the hydraulic models to form the Developed Case. Progressive mitigation of impacts was undertaken through refinement of the design as detailed in Table 13.27 to arrive at the adopted design including bridges and culverts. A range of flood events, including extreme events, were modelled and resulting flood impacts associated with the adopted design were identified along the Project alignment and at flood sensitive receptors and neighbouring localities including Calvert, Lanefield, Lower Mount Walker, Ebenezer, Mutdapilly, Purga and Washpool.

The impact of the Project design has been mitigated with resulting impacts on the existing flood regime quantified and compared against the flood impact objectives listed in Table 13.7. The following sections present the outcomes of the flood impact assessment for each of the floodplains crossed by the Project alignment.

Detailed results are provided in Appendix N: Hydrology and Flooding Technical Report.

13.8.2.1 Bremer River/Western Creek

On the Bremer River floodplain, the Project design includes:

- Three rail bridges
- Five rail-reinforced concrete pipe (RCP) culvert banks.

Details of the floodplain structures required to convey Bremer River and Western Creek flood flows are shown in Table 13.30 with structure locations shown in Figure 13.9. Figure 13.9 also shows the location of local catchment drainage structures. Details of the local drainage culverts are provided in Appendix N: Hydrology and Flooding Technical Report.

TABLE 13.30: BREMER RIVER/WESTERN CREEK—FLOOD STRUCTURE LOCATIONS AND DETAILS

Chainage (km)	Structure name	Structure type	No of cells	Diameter (m)	Soffit level (m AHD)	Bridge length (m)
2.95	340-BR01	Bridge	-	-	54.20	966.0
1.30*	340-BR02	Bridge	-	-	53.40	782.0
5.34	C5.34	RCP	4	1.20	-	-
6.20	340-BR03	Bridge	-	-	48.20	684.0
7.38	C7.38	RCP	20	1.20	-	-
7.46	C7.46	RCP	40	1.20	-	-
7.76	C7.76	RCP	10	1.20	-	-
7.90	C7.90	RCP	15	1.20	-	-

Table notes:

* The main Project alignment introduces a deviation near this location to connect with the QR West Moreton Line. Chainage referenced is for the deviation that forks from the main Project alignment.

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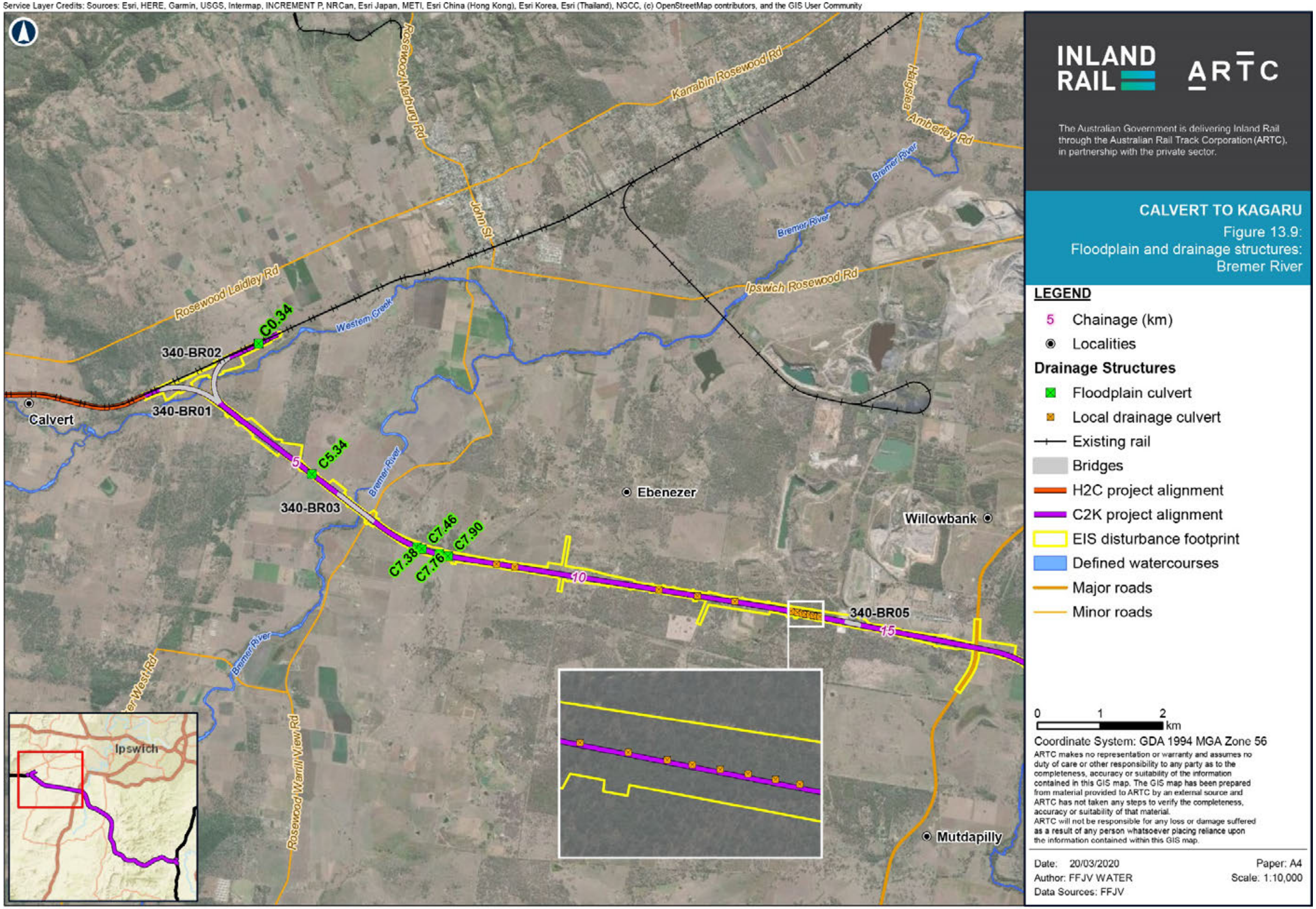

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Change in peak water levels

Figure 13.10 shows the change in peak water levels under the 1% AEP event and Table 13.31 details where the changes in peak water levels lie outside the flood impact objectives. Except for these locations, the changes in peak water levels under the 1% AEP event complies with the flood impact objectives (refer Section 13.4.2.2). This includes at the localities of Calvert, Lanefield, Lower Mount Walker and Ebenezer.

TABLE 13.31: BREMER RIVER/WESTERN CREEK—CHANGE IN PEAK WATER LEVELS OUTSIDE FLOOD IMPACT OBJECTIVES

Chainage (km)/ Location	Flood impact objectives	Change in peak water levels (mm)	Comment
Ch 3.45 km Agricultural land (Near the eastern abutment of the Western Creek Project rail bridge BR01)	≤200 mm (up to 400 mm)	+460	The changes in peak water levels are localised and located in an area removed from habitable dwellings, roadways and agricultural land.
Ch 7.00 km to Ch 7.90 km Agricultural land	≤200 mm (up to 400 mm)	+410	The change in peak water levels dissipates to less than 10 mm approximately 140 m upstream of the Project alignment. This affected area does not contain habitable dwellings, roadways or agricultural land based on the aerial imagery provided for the Project.

Analysis of the 20%, 10%, 5% and 2% AEP events was also undertaken and figures showing the change in peak water levels are in Appendix N: Hydrology and Flooding Technical Report. Each of the events have increasing levels of overbank flooding outside the defined creek channels with significant floodplain inundation starting under the 20% AEP event.

Under all events, minor changes in peak water levels occur near Waters Road and Kuss Road at the start of the Project alignment. This localised increase in peak water levels gradually spreads as the flood magnitude increases. Overall, the change in peak water levels on Waters Road and Kuss Road is less than 100 mm change under all of these events.

For events up to 2% AEP event there are no downstream impacts towards the Western Creek and Bremer River confluence.

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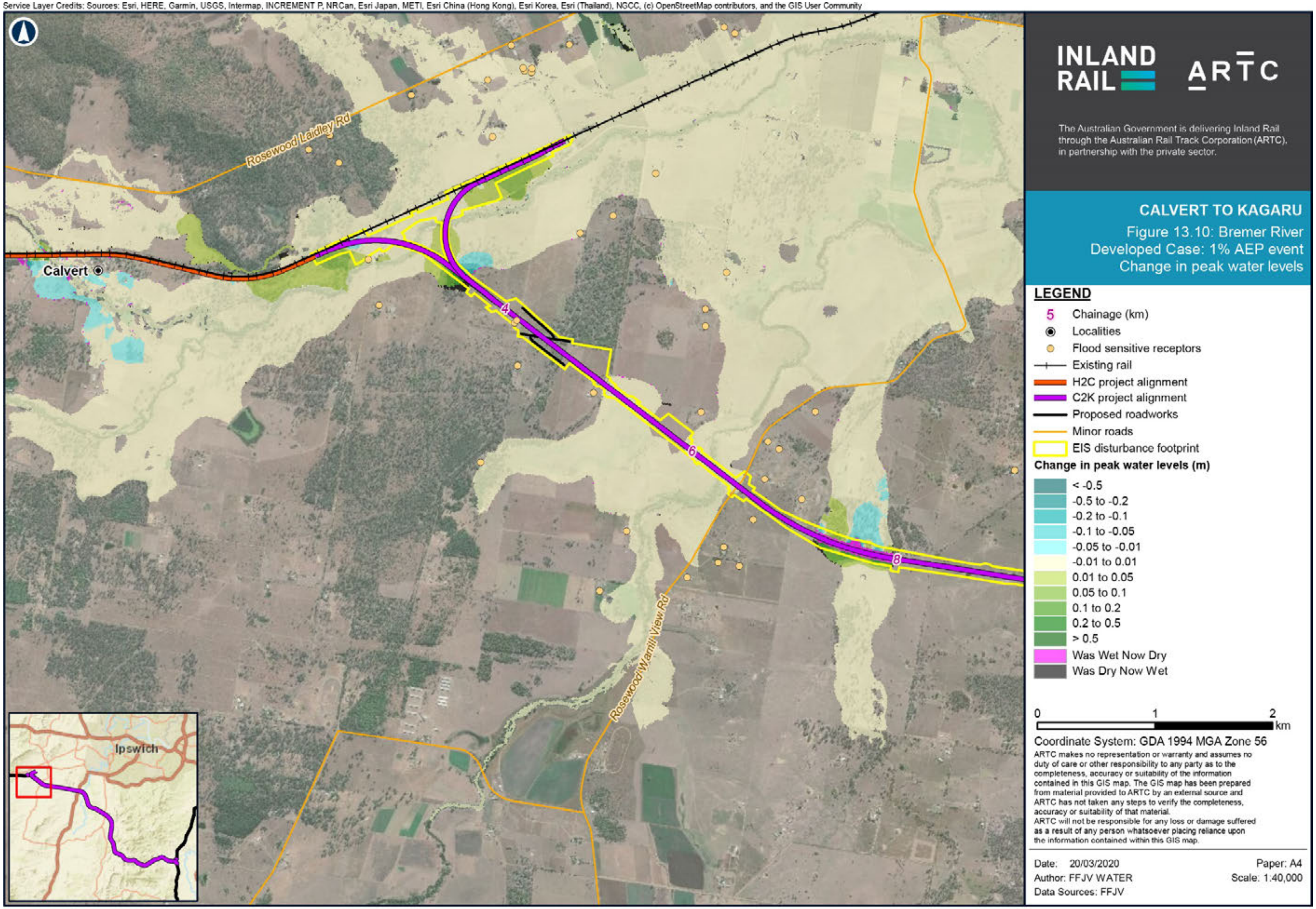

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Change to duration of inundation

The change in duration of inundation is quantified by assessing and comparing the ToS for the Existing Case and the Developed Case. The ToS for the 1% AEP event is in Table 13.32 for locations where changes in peak water levels lie outside the flood impact objectives. There are no adverse impacts at the localities of Calvert, Lanefield, Lower Mount Walker and Ebenezer.

TABLE 13.32: BREMER RIVER/WESTERN CREEK—1% AEP EVENT—CHANGE IN TIME OF SUBMERGENCE

Chainage (km)/ Location	Existing case ToS (hrs)	Developed case ToS (hrs)	Comment
Ch 3.45 km Agricultural land (Near the eastern abutment of the Western Creek Project rail bridge BR01)	47.4	60.0	At the eastern bridge embankment there is a localised increase of over 10 hours. This localised increase is contained to the creek overbank area and does not affect any existing infrastructure or flood sensitive receptors.
Ch 7.00 km and Ch 7.90 km	47.5	63.3	Upstream and downstream of the Project culverts at this location there is a localised increase of over 10 hours. This localised increase does not affect any existing infrastructure or flood sensitive receptors.

On the Bremer River floodplain, there are two roadways affected by a localised increase in peak water levels under the 1% AEP event. Waters Road and Kuss Road are low-lying roads that are increasingly inundated from the 20% AEP event upwards. Under the 1% AEP events they are inundated by over 0.5 m in locations. Under the 1% AEP event, the peak increase on Waters Road is 80 mm and up to 50 mm on Kuss Road.

The average annual time of submergence (AAToS) for the 1% AEP event has been determined for Waters Road and is detailed in Table 13.33. AAToS is a measurement of the estimated time per year of submergence of a roadway due to flooding. Kuss Road would experience an even lower change and therefore has not been calculated. This change in conditions does not result in a significant change to AAToS and therefore the amenity of both roadways is unchanged.

TABLE 13.33: AVERAGE ANNUAL TIME OF SUBMERGENCE COMPARISON AT WATERS ROAD

Location	AAToS existing case (hrs/yr)	AAToS developed case (hrs/yr)	Difference (hrs/yr)
Waters Road	31.4	31.6	+0.2

Flood flow distribution

Overall, the Project has minimal impacts on flood flows and floodplain conveyance/storage with floodplain structures designed to maintain the existing flood regime.

Velocities

Figure 13.11 shows the change in peak velocities under the 1% AEP event associated with the Project alignment. In general, the changes are minor, with most changes in velocities experienced immediately adjacent to the Project alignment. Velocity changes within the Western Creek and Bremer River main channels are negligible. There are no adverse impacts at the localities of Calvert, Lanefield, Lower Mount Walker and Ebenezer.

Peak water levels, flows and velocities from the hydrology and flooding investigation have been used to inform the scour protection design. The scour protection has been designed in accordance with *Austroads Guide to Road Design* (AGRD) *Part 5B: Drainage* (Austroads, 2013). Scour protection was specified where the outlet velocities for the 1% AEP event exceed the allowable soil velocities for the particular soil type for each location, which was identified from published soil mapping.

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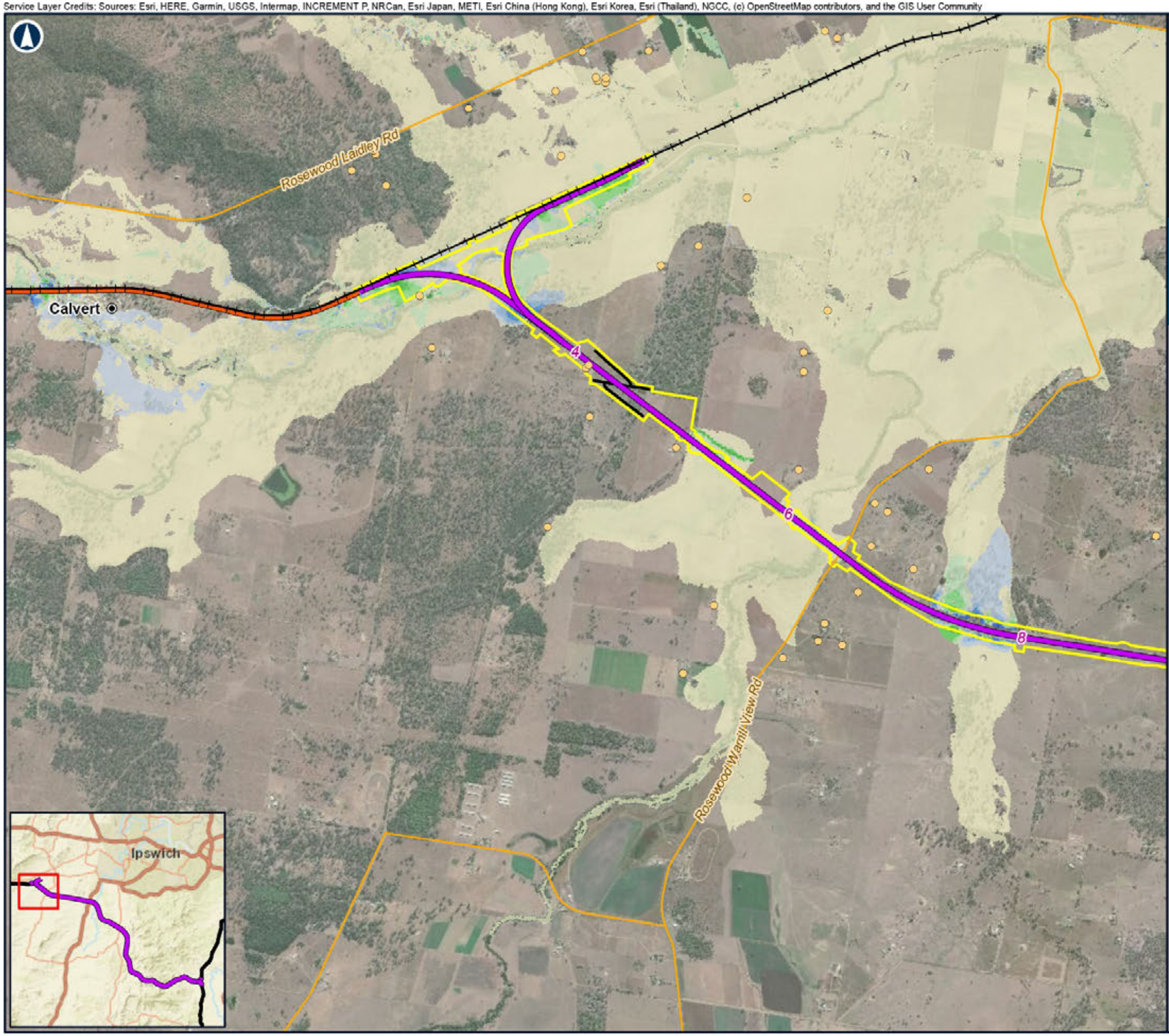

INLAND RAIL ARTC

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

CALVERT TO KAGARU

Figure 13.11: Bremer River Developed Case: 1% AEP event Change in velocities

LEGEND

- 5 Chainage (km)
- Localities
- Flood sensitive receptors
- Existing rail
- H2C project alignment
- C2K project alignment
- Proposed roadworks
- Minor roads
- EIS disturbance footprint

Change in peak velocity (m/s)

- < -0.50
- -0.50 to -0.20
- -0.20 to -0.10
- -0.10 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.50
- > 0.50

0 1 2 km

Coordinate System: GDA 1994 MGA Zone 56

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Author: FFJV WATER
Data Sources: FFJV
Paper: A4
Scale: 1:40,000

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Extreme events

Several design events larger than the 1% AEP event, including the 1 in 2,000 AEP, the 1 in 10,000 AEP and the PMF, have been modelled to assess the performance of the Project alignment and to review impacts on the existing flooding regime. Figure 13.12, Figure 13.13 and Figure 13.14 present the change in peak water levels for the 1 in 2,000 AEP, the 1 in 10,000 AEP and the PMF events respectively. Table 13.34 outlines the changes in peak water levels at flood sensitive receptors for these extreme events where the change exceeds 10 mm under one of the events. The existing depth of flooding is also detailed and as can be seen the larger impacts that occur under the PMF event occur generally when there are already high flood depths, as would be expected under such a rare event.

TABLE 13.34: BREMER RIVER—SUMMARY OF EXTREME EVENT IMPACTS AT FLOOD SENSITIVE RECEPTORS

Flood sensitive receptor number	1 in 2,000 AEP event		1 in 10,000 AEP event		PMF event	
	Change in peak water level (mm)	Existing case flood depth (m)	Change in peak water level (mm)	Existing case flood depth (m)	Change in peak water level (mm)	Existing case flood depth (m)
14 (Junction of Waters Road and Kuss Road)	+12	0.71	-2	0.90	+139	1.73
34 (House/sheds)	+1	0.15	+21	0.24	-100	1.30
58 (House)	0	0.22	+14	0.29	-74	1.48
59 (House)	-1	0.32	+14	0.39	-73	1.59
66 (House/sheds)	-1	0.40	+14	0.48	-71	1.71
67 (House)	-1	0.51	+14	0.59	-71	1.82
84 (House)	+5	0.94	0	1.11	+129	1.88
99 (House)	+27	0.24	+58	0.42	+410	1.47
119 (House/sheds)	+15	0.02	+24	0.14	-85	1.09
694 (House/sheds)	+41	0.47	+84	0.66	+536	1.64

The risk of overtopping of the Project alignment has been assessed for the modelled extreme events. During these extreme events the Project alignment is inundated at its junction with the QR West Moreton Line. At this location 150 m of the Project alignment is inundated by up to 1 m under the 1 in 2,000 AEP, the 1 in 10,000 AEP and the PMF events. The elevation of the Project alignment is driven by the need to pass over a number of roadways and therefore overtopping does not occur on the rest of alignment across the Bremer River floodplain.

Under these rare events, the bridge structures and culverts have been designed to allow adequate passage of flow during the flood events and 'damming' effects are therefore not expected to occur. In addition, failure of the embankment during a flood event is not predicted to result in a dam-failure type event as the water level on both sides of the embankment is predicted to be similar. In addition, there is no redirection of flood flows under these extreme events.

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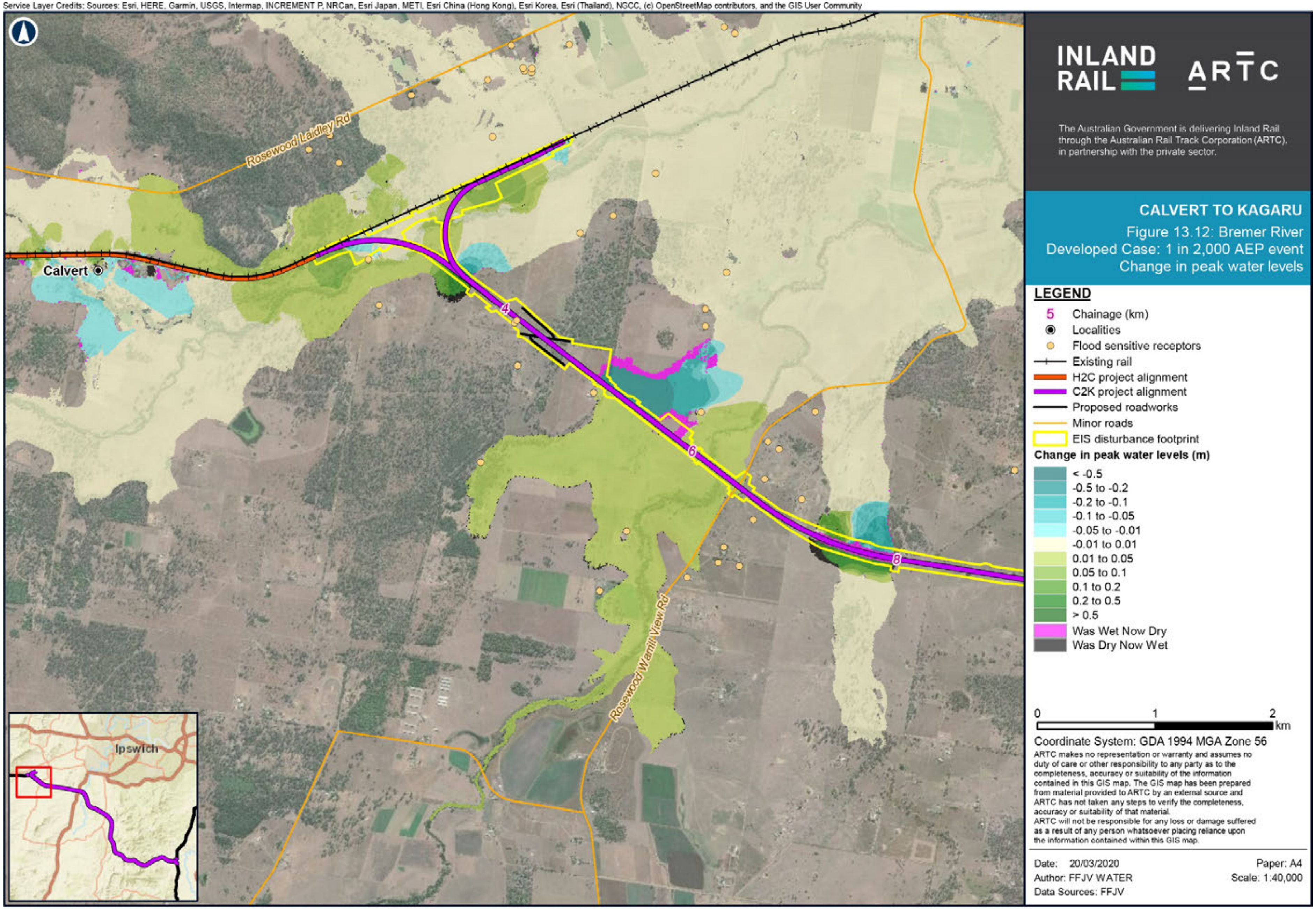

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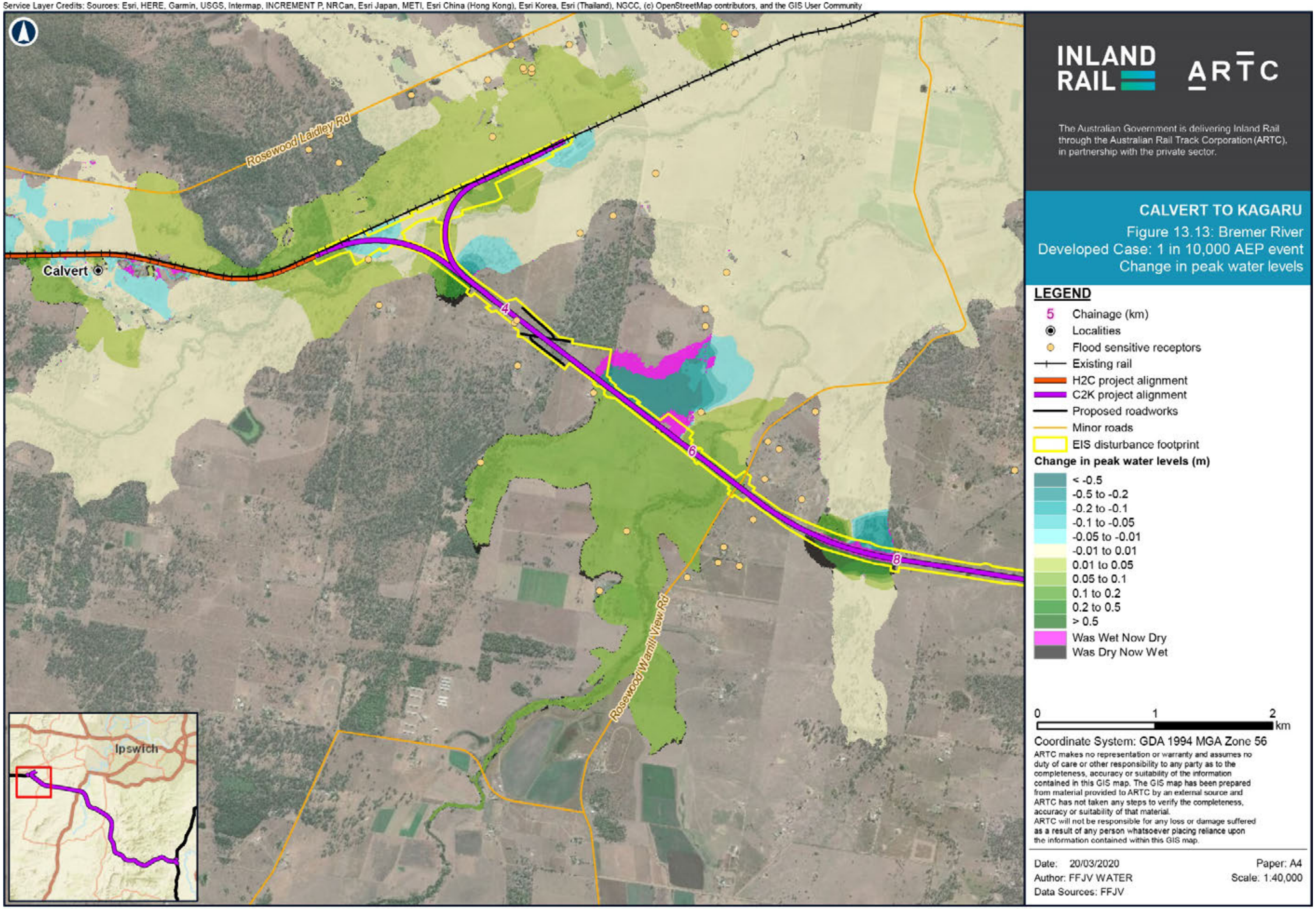

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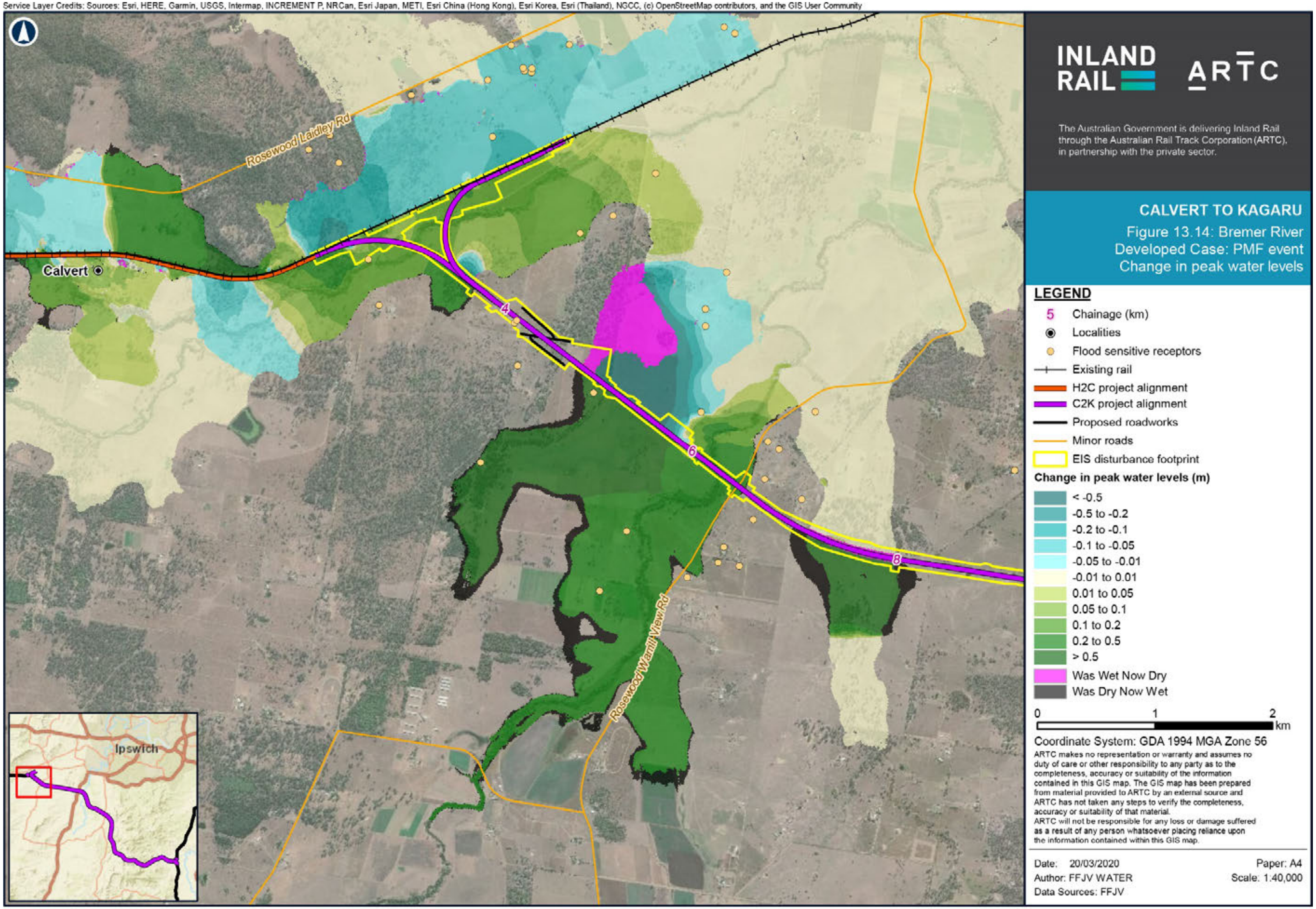

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Climate change

The climate change guidelines set out in ARR 2016 have been followed and used to assess the potential impact of increased rainfall on peak water levels in the vicinity of the Project alignment.

The Representative Concentration Pathways 8.5 (2090 horizon) climate change scenario has been adopted for the Project with an associated increase in rainfall intensity of 18.7 per cent across the catchment area. Climate change results in increased peak water levels of up to 300 mm in the vicinity of the Project alignment under the 1% AEP event.

Figure A7-D, within Appendix N: Hydrology and Flooding Technical Report, shows the change in peak water levels associated with the Project alignment for the 1% AEP event with climate change. The inclusion of climate change slightly increases the change in peak water levels around the Project alignment.

The only affected flood sensitive receptors are Waters Road and Kuss Road, with the change in peak water levels on Waters Road and Kuss Road still less than 100 mm. These roadways are already non-trafficable in the Existing Case and this increase in peak water levels does not affect the existing amenity.

The downstream extents of these impacts are similar to those under the 1% AEP event.

Blockage

Blockage of drainage structures has been assessed in accordance with ARR 2016 requirements. The blockage assessment resulted in no blockage factor being applied to bridges and a blockage factor of 25 per cent being applied to culverts. A minimum culvert size of 1,200 mm diameter was also adopted to reduce potential for blockage and for ease of maintenance.

ARR 2016 guidelines are focused on blockage of small bridges and culverts. The floodplain bridges proposed for the Project alignment are all multi-span large bridges and ARR 2016 notes that there are limited instances of multiple-span bridges being observed with blockages similar to those seen at single-span bridges or culverts.

Two blockage sensitivity scenarios were tested with both 0 per cent and 50 per cent blockage of all culverts. As no culverts are in the immediate vicinity of the flood sensitive receptors, there are no change to impacts on flood sensitive receptors under these blockage scenarios. The results are in Appendix A, Figure A7-E and Figure A7-F for the 0% and 50% blockage respectively within Appendix N: Hydrology and Flooding Technical Report.

13.8.2.2 Warrill Creek

On the Warrill Creek floodplain, the Project design includes:

- One rail bridge.

Details of the structure required to convey Warrill Creek flood flows are in Table 13.35 and the structure location is shown in Figure 13.15.

Figure 13.15 also shows the location of local catchment drainage structures. Details of the local drainage culverts are provided in Appendix N: Hydrology and Flooding Technical Report.

TABLE 13.35: WARRILL CREEK—FLOOD STRUCTURE LOCATIONS AND DETAILS

Chainage (km)	Structure name	Structure type	Soffit level (m AHD)	Bridge length (m)
17.65	340-BR07	Bridge	33.70	713

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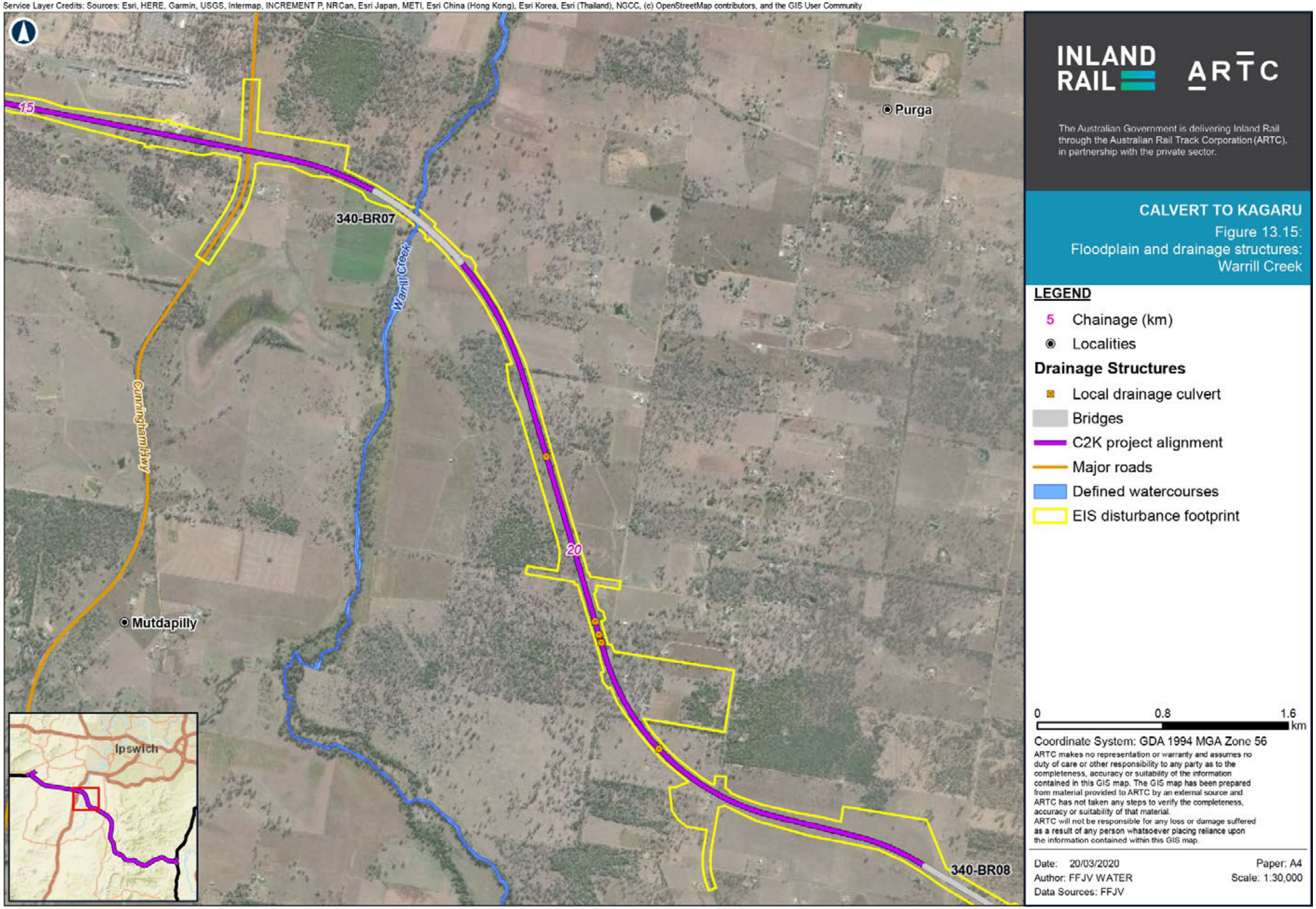

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Change in peak water levels

Figure 13.16 shows the change in peak water levels under the 1% AEP event and Table 13.36 presents details of where the changes in peak water levels lie outside the flood impact objectives. Except for these locations, the change in peak water levels under the 1% AEP event complies with the flood impact objectives (Section 13.4.2.2). This includes at the locality of Mutdapilly.

TABLE 13.36: WARRILL CREEK—CHANGE IN PEAK WATER LEVELS OUTSIDE FLOOD IMPACT OBJECTIVES

Chainage (km)/ location	Flood impact objectives	Change in peak water levels (mm)	Comment
Ch 17.65 km Warrill Creek Project rail bridge Agricultural land	≤ 200 mm* (localised increases of up to 400 mm)	+300	This change in peak water levels is on agricultural land and is localised. It reduces to less than 200 mm within 100 m of the Project alignment. This change in peak water levels is localised and in a rural area with no flood sensitive receptors nearby.

Table notes:

* Maximum, but may be less if identified from consultation

Analysis of the 20%, 10%, 5% and 2% AEP events was also undertaken and figures showing the change in peak water levels are in Appendix N: Hydrology and Flooding Technical Report. Each of the events have increasing levels of overbank flooding outside the defined creek channels, with significant floodplain inundation starting under the 10% AEP event. Changes in peak water levels do not start to occur until the 2% AEP event with no flood sensitive receptors affected.

Change in duration of inundation

The change in duration of inundation is quantified by assessing and comparing the ToS for the Existing and Developed cases. The ToS for the 1% AEP event is in Table 13.37 for locations where changes in peak water levels lie outside the flood impact objectives. There are no adverse impacts on the locality of Mutdapilly.

TABLE 13.37: WARRILL CREEK—1% AEP EVENT—CHANGE IN TIME OF SUBMERGENCE

Chainage (km)/ location	Existing Case ToS (hrs)	Developed Case ToS (hrs)	Comment
Ch 17.65 km Warrill Creek Project rail bridge	26	31.5	At the western and eastern embankments there is a localised increase in ToS of approximately 5 hours. This localised increase is contained to the creek overbank area and does not impact on any roads or flood sensitive receptors.

On the Warrill Creek floodplain, there are no roads impacted by the Project alignment and therefore there are no changes in ToS or AAToS for roads.

Flood flow distribution

Overall, the Project has minimal impacts on flood flows and floodplain conveyance/storage with floodplain structures designed to maintain the existing flood regime.

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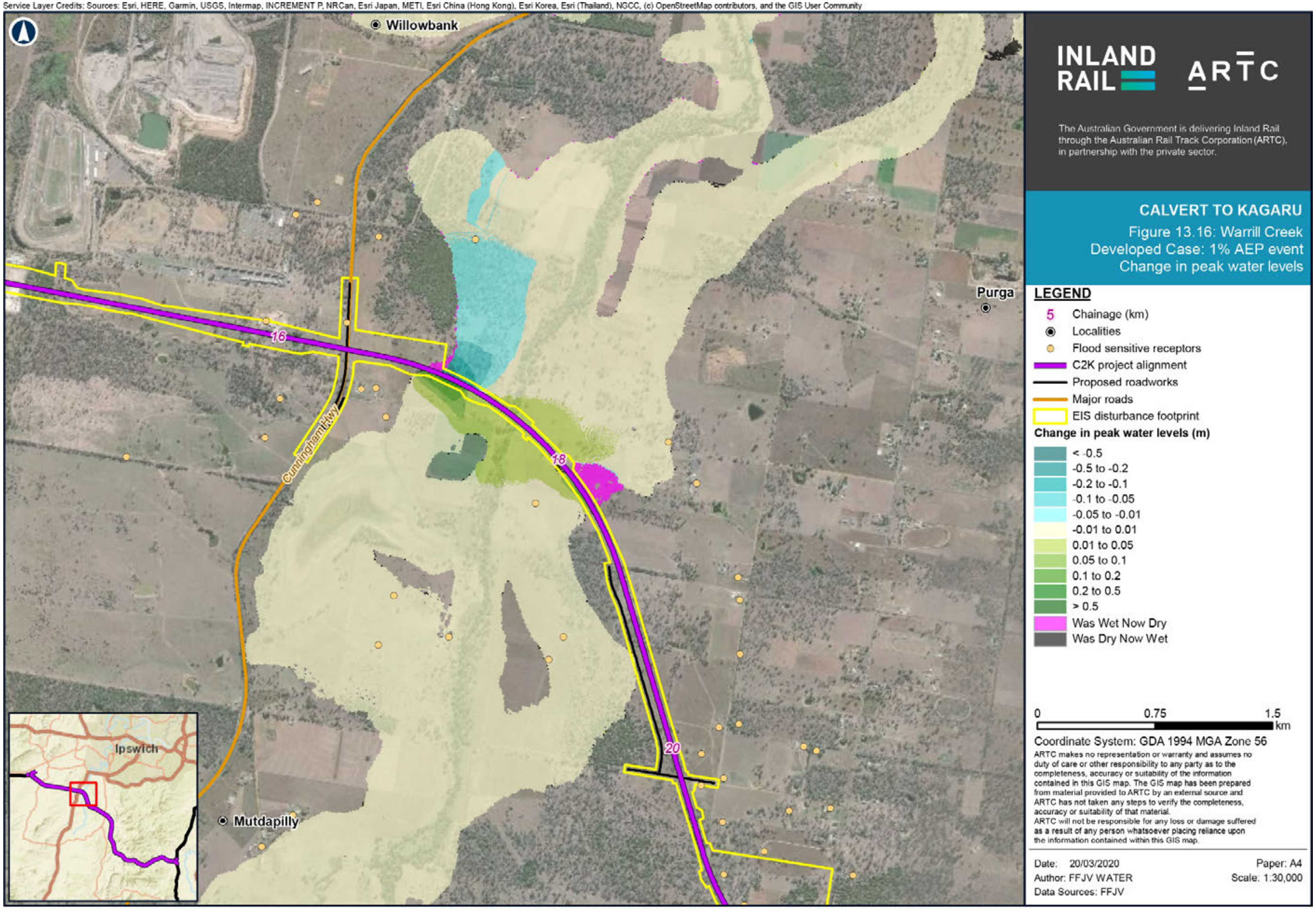

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Velocities

Figure 13.17 shows the changes in peak velocities under the 1% AEP event associated with the Project alignment. In general, the changes are minor, with most changes in velocities experienced immediately adjacent to the Project alignment. There are no adverse impacts on the locality of Mutdapilly.

Peak water levels, flows and velocities from the hydrology and flooding investigation have been used to inform the scour protection design. The scour protection has been designed in accordance with AGRD (Austroads, 2013). Scour protection was specified where the outlet velocities for the 1% AEP event exceed the allowable soil velocities for the particular soil type for each location, which was identified from published soil mapping.

Extreme events

Several design events larger than the 1% AEP event, including the 1 in 2,000 AEP, the 1 in 10,000 AEP and the PMF, have been modelled to assess the performance of the Project alignment and to review impacts on the flooding regime.

Figure 13.18, Figure 13.19 and Figure 13.20 present the change in peak water levels for the 1 in 2,000, 1 in 10,000 AEP and PMF events respectively. Table 13.38 outlines the changes in peak water levels at flood sensitive receptors for these extreme events where the change exceeds 10 mm under one of the events. The existing depth of flooding is also detailed and, as can be seen, the larger impacts that occur under the PMF event occur generally when there are already high flood depths as would be expected under such a rare event.

TABLE 13.38: WARRILL CREEK—SUMMARY OF EXTREME EVENT IMPACTS AT FLOOD SENSITIVE RECEPTORS

	1 in 2,000 AEP event		1in 10,000 AEP event		PMF event	
Flood sensitive receptor number	Change in peak water level (mm)	Existing case flood depth (m)	Change in peak water level (mm)	Existing case flood depth (m)	Change in peak water level (mm)	Existing case flood depth (m)
222 (Sheds)	+3	0.39	+8	0.46	+349	1.52
227 (Sheds)	+35	1.03	+52	1.19	+372	2.48
234 (House)	+10	0.51	+18	0.61	+280	1.54
237 (Sheds)	+39	0.86	+56	1.05	+313	2.52
239 (Access Road)	+39	3.09	+56	3.27	+322	4.71
696 (House/sheds)	+1	0.04	+1	0.18	+22	1.28

The risk of overtopping of the Project alignment has been assessed for the modelled extreme events. The elevation of the Project alignment is driven by the need to pass over a number of roadways and therefore overtopping does not occur on the alignment across the Warrill Creek floodplain.

Under these rare events, the bridge structures and culverts have been designed to allow adequate passage of flow during the flood events and damming effects are therefore not expected to occur. In addition, failure of the embankment during a flood event is not predicted to result in a dam-failure type event as the water level on both sides of the embankment is predicted to be similar. In addition, there is no redirection of flood flows under these extreme events.

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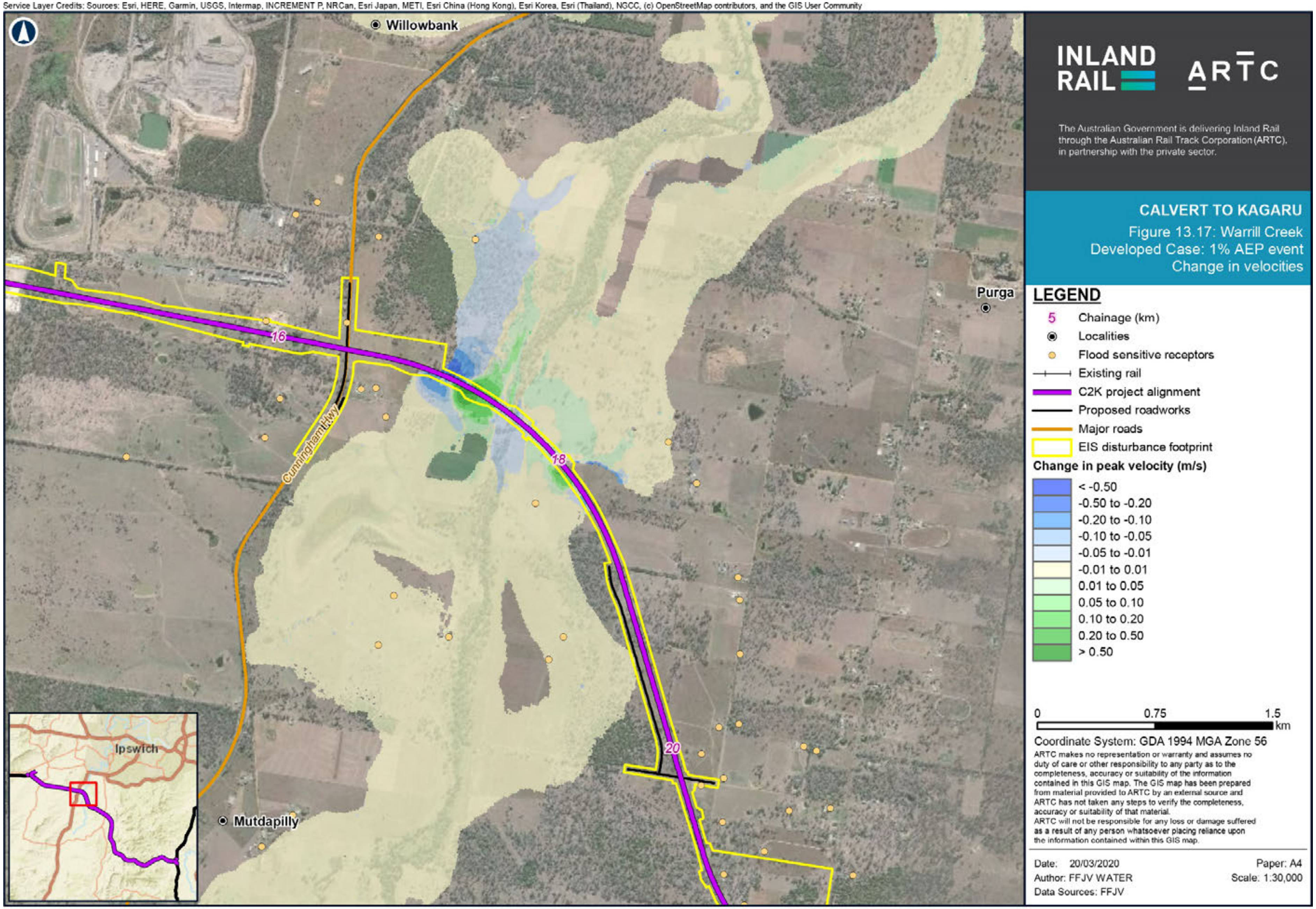

CALVERT TO KAGARU

Figure 13.17: Warrill Creek Developed Case: 1% AEP event Change in velocities

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Climate change

The climate change guidelines set out in ARR 2016 have been followed and used to assess the potential impact of increased rainfall on peak water levels in the vicinity of the Project.

The Representative Concentration Pathways 8.5 (2090 horizon) climate change scenario has been adopted for the Project with an associated increase in rainfall intensity of 18.7 per cent across catchment area. Climate change results in increased peak water levels of up to 370 mm in the vicinity of the Project alignment under the 1% AEP event.

Figure B7-D, within Appendix N: Hydrology and Flooding Technical Report, shows the change in peak water levels for the 1% AEP event with climate change. The inclusion of climate change introduces slight increases to the change in peak water levels around the Project alignment crossing of Warrill Creek. These changes impact on two upstream flood sensitive receptors, as detailed in Table 13.39. Under current conditions, the impact under the 1% AEP event is less than 10 mm at both flood sensitive receptors and this increases to just over 10 mm with the inclusion of climate change for the 2090 horizon. It should be noted that the depth of flooding would also increase with climate change and therefore it is considered that the relative change due to the Project alignment is minor.

TABLE 13.39: WARRILL CREEK—SUMMARY OF CLIMATE CHANGE IMPACTS AT FLOOD SENSITIVE RECEPTORS

	1% AEP event		1% AEP event with climate change	
Flood sensitive receptor number	Change in peak water level (mm)	Existing Case flood depth (m)	Change in peak water level (mm)	Existing Case flood depth (m)
227 (Sheds)	+5	0.36	+12	0.68
237 (Shed)	+6	0.13	+14	0.46

Blockage

Blockage of drainage structures has been assessed in accordance with ARR 2016 requirements. The blockage assessment resulted in no blockage factor being applied to bridges and a blockage factor of 25 per cent being applied to culverts. A minimum culvert size of 1,200 mm diameter was also adopted to reduce potential for blockage and for ease of maintenance.

ARR 2016 guidelines are focused on blockage of small bridges and culverts. The floodplain bridges proposed for the Project alignment are all multi-span large bridges and ARR 2016 notes that there are limited instances of multiple span bridges being observed with blockages similar to those seen at single-span bridges or culverts. Therefore, the blockage assessment resulted in no blockage factor being applied to the Warrill Creek bridge.

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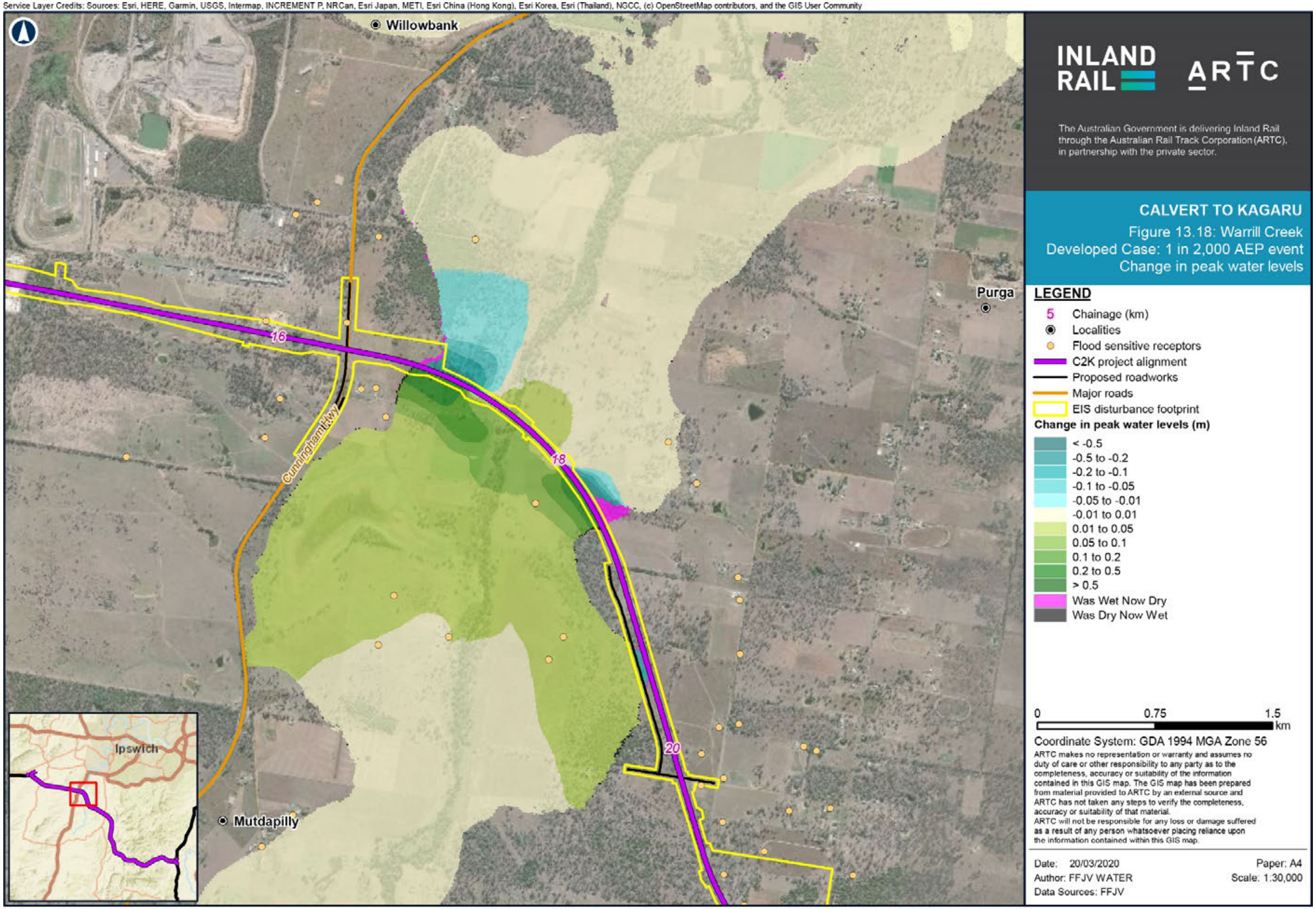

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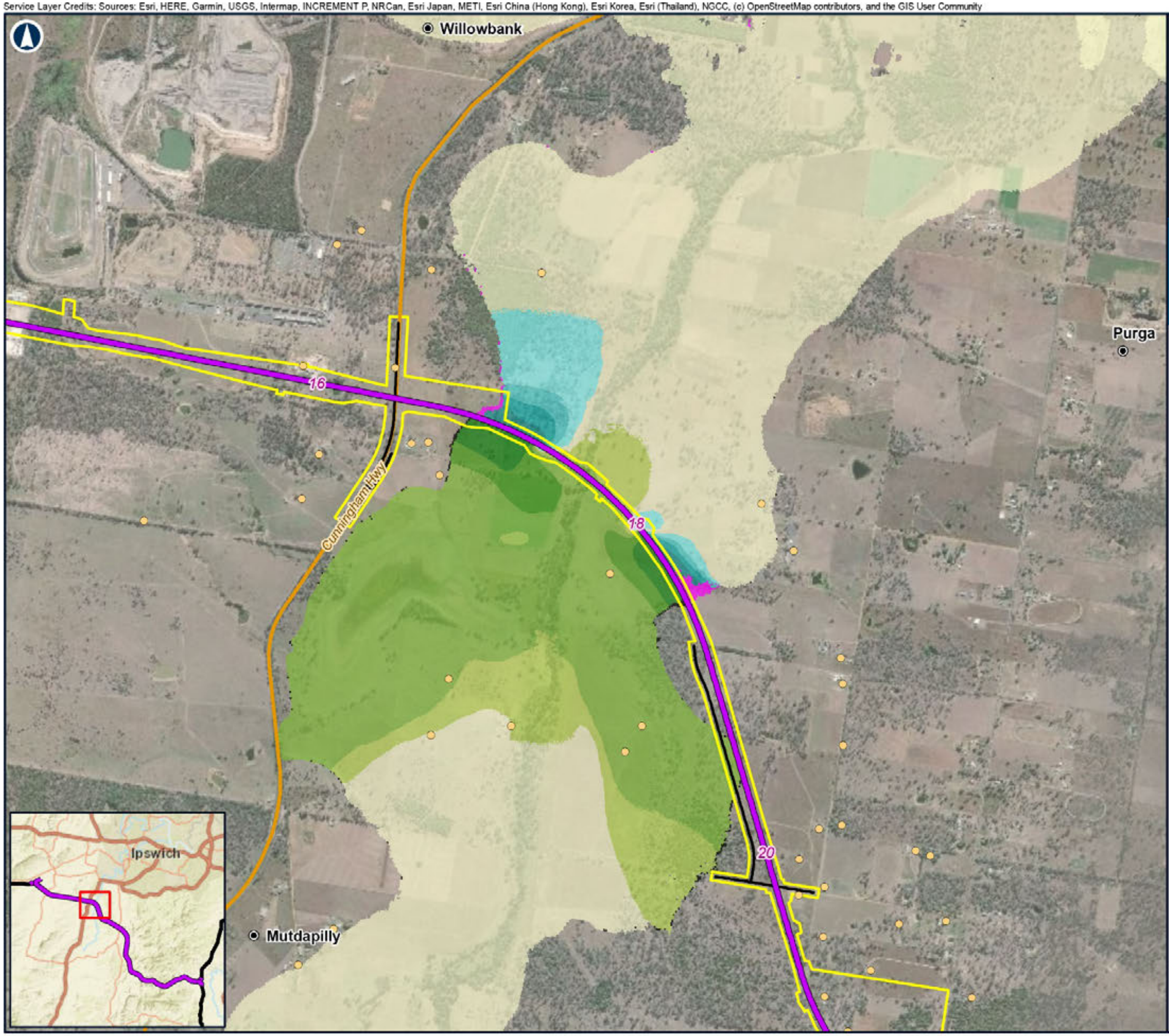

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CALVERT TO KAGARU

Figure 13.19: Warrill Creek Developed Case: 1 in 10,000 AEP event Change in peak water levels

LEGEND

- 5 Chainage (km)
- Localities
- Flood sensitive receptors
- C2K project alignment
- Proposed roadworks
- Major roads
- EIS disturbance footprint

Change in peak water levels (m)

- < -0.5
- -0.5 to -0.2
- -0.2 to -0.1
- -0.1 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.1
- 0.1 to 0.2
- 0.2 to 0.5
- > 0.5
- Was Wet Now Dry
- Was Dry Now Wet

0 0.75 1.5 km

Coordinate System: GDA 1994 MGA Zone 56

Date: 20/03/2020 Paper: A4
Author: FFJV WATER Scale: 1:30,000
Data Sources: FFJV

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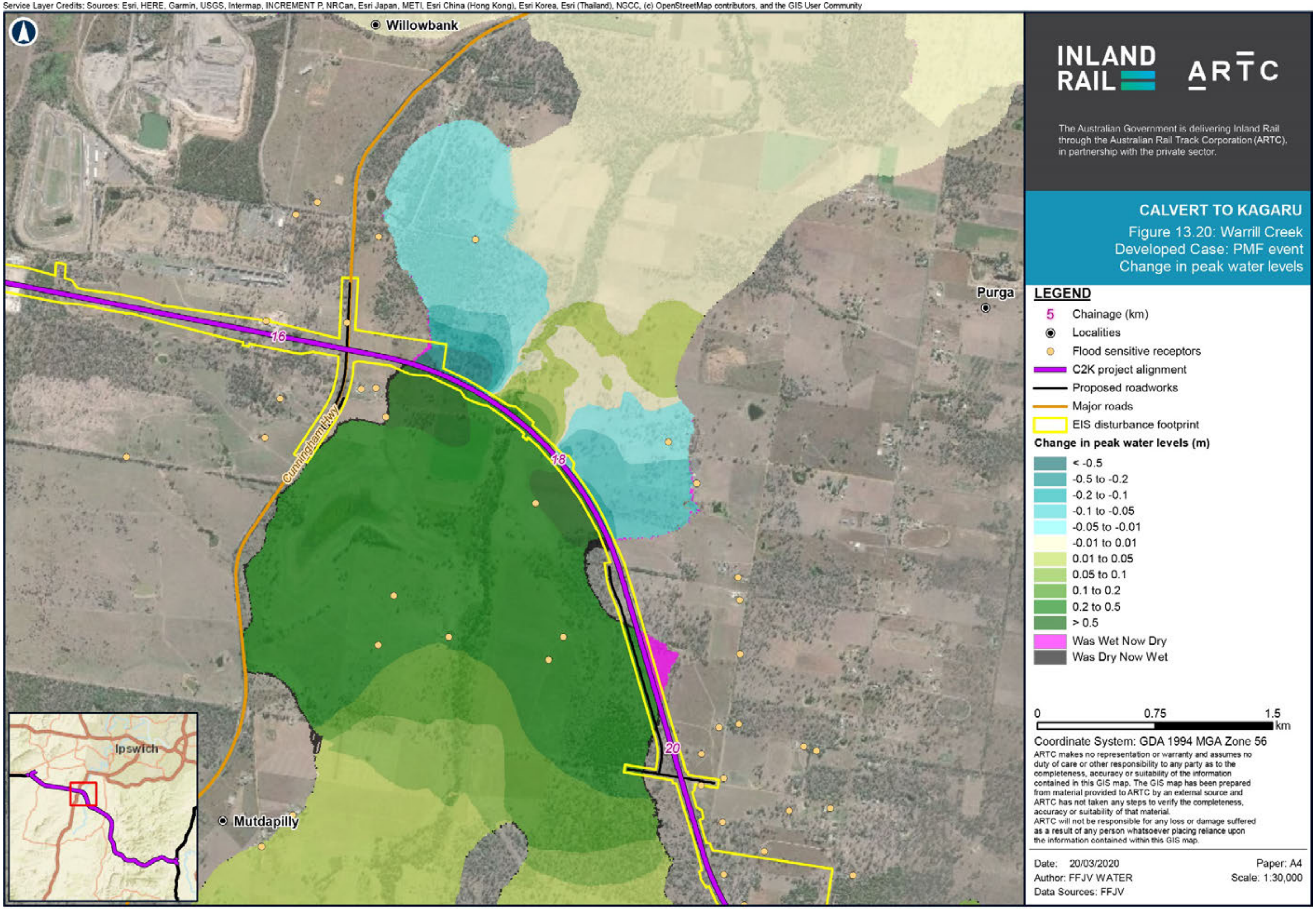

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13.8.2.3 Purga Creek

On the Purga Creek system, the Project design includes:

- Seven rail bridges
- One rail-reinforced concrete box culvert (RCBC) bank
- Two rail RCP culvert banks
- Five road RCP culvert banks.

Details of the rail and road structures required to convey Purga Creek flood flows are listed in Table 13.40 and Table 13.41, with rail structure locations shown in Figure 13.21. Figure 13.21 also shows the location of local catchment drainage structures. Details of the local drainage culverts are provided in Appendix N: Hydrology and Flooding Technical Report.

TABLE 13.40: PURGA CREEK—FLOOD RAIL STRUCTURE LOCATIONS AND DETAILS

Chainage (km)	Structure name	Structure type	No of cells	Diameter/ width (mm)	Height (m) or soffit level (m AHD)	Bridge length (m)
23.60	340-BR08	Bridge	-	-	46.60	621.0
24.71	340-BR09	Bridge	-	-	48.00	759.0
28.73	340-BR12	Bridge	-	-	66.80	115.0
33.81	C33.81	RCBC	9	2.40	2.10	-
34.21	C34.21	RCP	50	1.20	-	-
35.70	340-BR13	Bridge	-	-	73.80	115.0
36.08	C36.08	RCP	2	2.40	-	-
36.66	340-BR14	Bridge	-	-	77.60	138.0
37.53	340-BR16	Bridge	-	-	83.60	98.0
37.78	340-BR17	Bridge	-	-	85.70	299.0

TABLE 13.41: PURGA CREEK—ROAD STRUCTURE LOCATIONS AND DETAILS

Approximate chainage (km)	Road name	Structure type	No cells	Diameter (m)
35.70	Washpool Road	RCP	4	2.40
36.70	Washpool Road	RCP	20	1.80
37.10	Washpool Road	RCP	20	1.20
37.30	Washpool Road	RCP	4	2.40
37.50	Washpool Road	RCP	25	0.60

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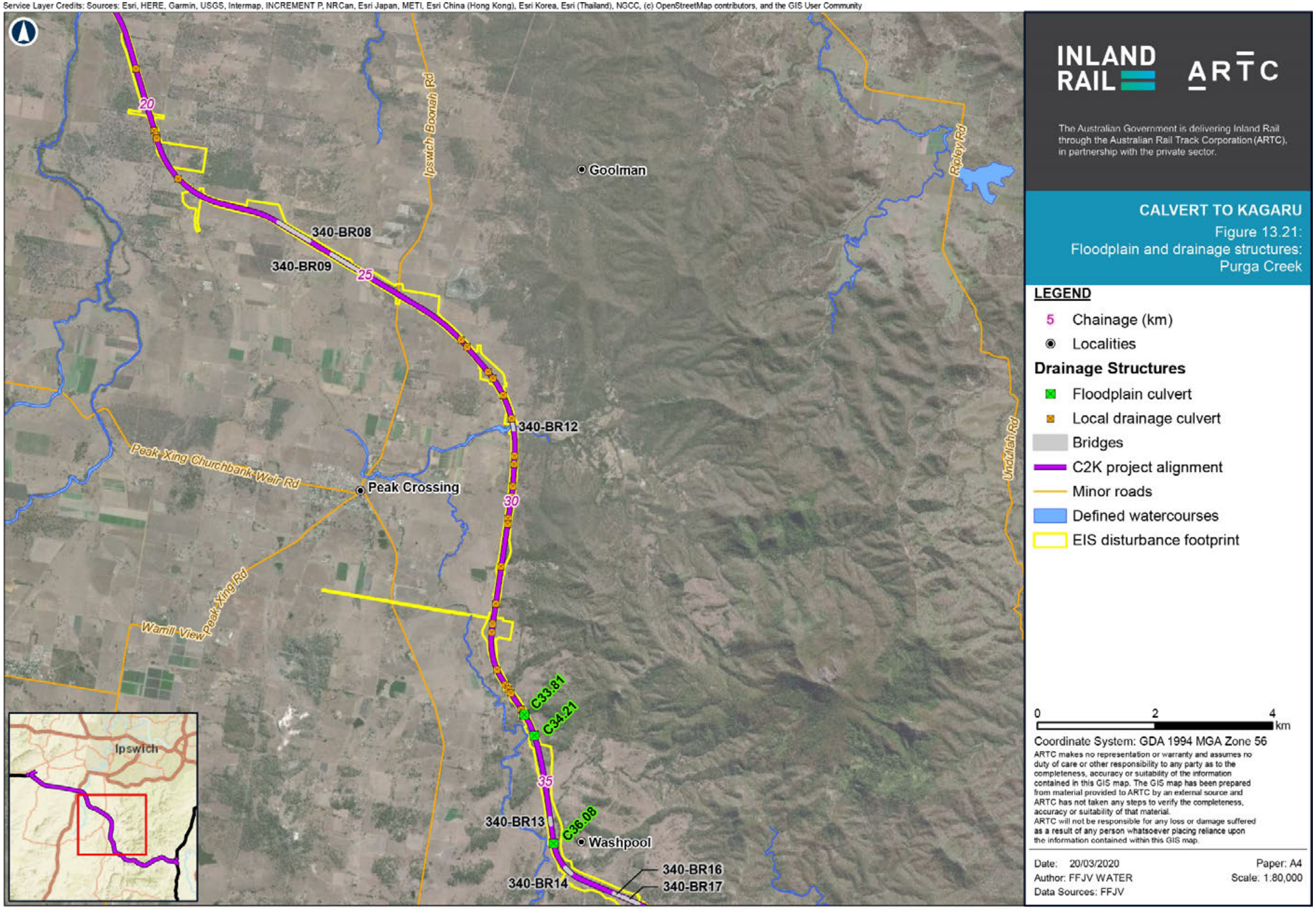

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Change in peak water levels

Figure 13.22a and Figure 13.22b show the change in peak water levels under the 1% AEP event and Table 13.42 shows details of where the changes in peak water levels lie outside the flood impact objectives. Except for these locations, the change in peak water levels under the 1% AEP event complies with the flood impact objectives (Section 13.4.2.2). This includes at the localities of Purga and Washpool.

TABLE 13.42: PURGA CREEK—CHANGE IN PEAK WATER LEVELS OUTSIDE FLOOD IMPACT OBJECTIVES

Chainage (km)/ location	Flood impact objectives	Change in peak water levels (m)	Comment
Ch 23.60 km to Ch 24.71 km Agricultural land Purga Creek Project rail bridge	≤200 mm* (localised increases of up to 400 mm)	+465	This change in peak water levels dissipates to less than 10 mm approximately 500 m upstream and 1.7 km downstream of the Project alignment. The channel flow depth is 1.5 m and overbank flow depth is 0.75 m at this location. This impact occurs on areas removed from habitable dwellings, roadways and agricultural land.
Ch 33.81 km to Ch 34.21 km Agricultural land	≤200 mm* (localised increases of up to 400 mm)	+400	This change in peak water levels localised to the north-east of the Project alignment. This impact occurs on areas removed from habitable dwellings, roadways and agricultural land based on the aerial imagery provided for the Project.
Ch 33.81 km to Ch 34.21 km Washpool Road	≤100 mm*	+200	This change in peak water levels results from Washpool Road being raised (by greater than 200 mm) and realigned for the Project level crossing. Realigning this roadway provides improved flood immunity for more frequent flood events at this location despite the increase to 1% AEP peak water levels. Overall flood immunity of Washpool Road is not governed by this location.
Around Ch 35.70 km Washpool Road	≤100 mm*	+400	This increase is due to raising the road height at this location. Culverts have been added for mitigation purposes. The increase in peak water levels is contained within the creek channel. This impact occurs on areas removed from habitable dwellings, roadways and agricultural land based on the aerial imagery provided for the Project.
Ch 46.94 km to Ch 37.78 km Rural land	≤200 mm* (localised increases of up to 400 mm)	+400	This increase is due to the realignment and upgrade of Washpool Road. All increases in peak water levels are contained within the Project boundary and no flood sensitive receptors are affected.

Table notes:

* Maximum, but may be less if identified from consultation

Analysis of the 20%, 10%, 5% and 2% AEP events was also undertaken and figures showing the change in peak water levels are in Appendix N: Hydrology and Flooding Technical Report. Each of the events have increasing levels of overbank flooding outside the defined creek channels with significant floodplain inundation starting under the 20% AEP event.

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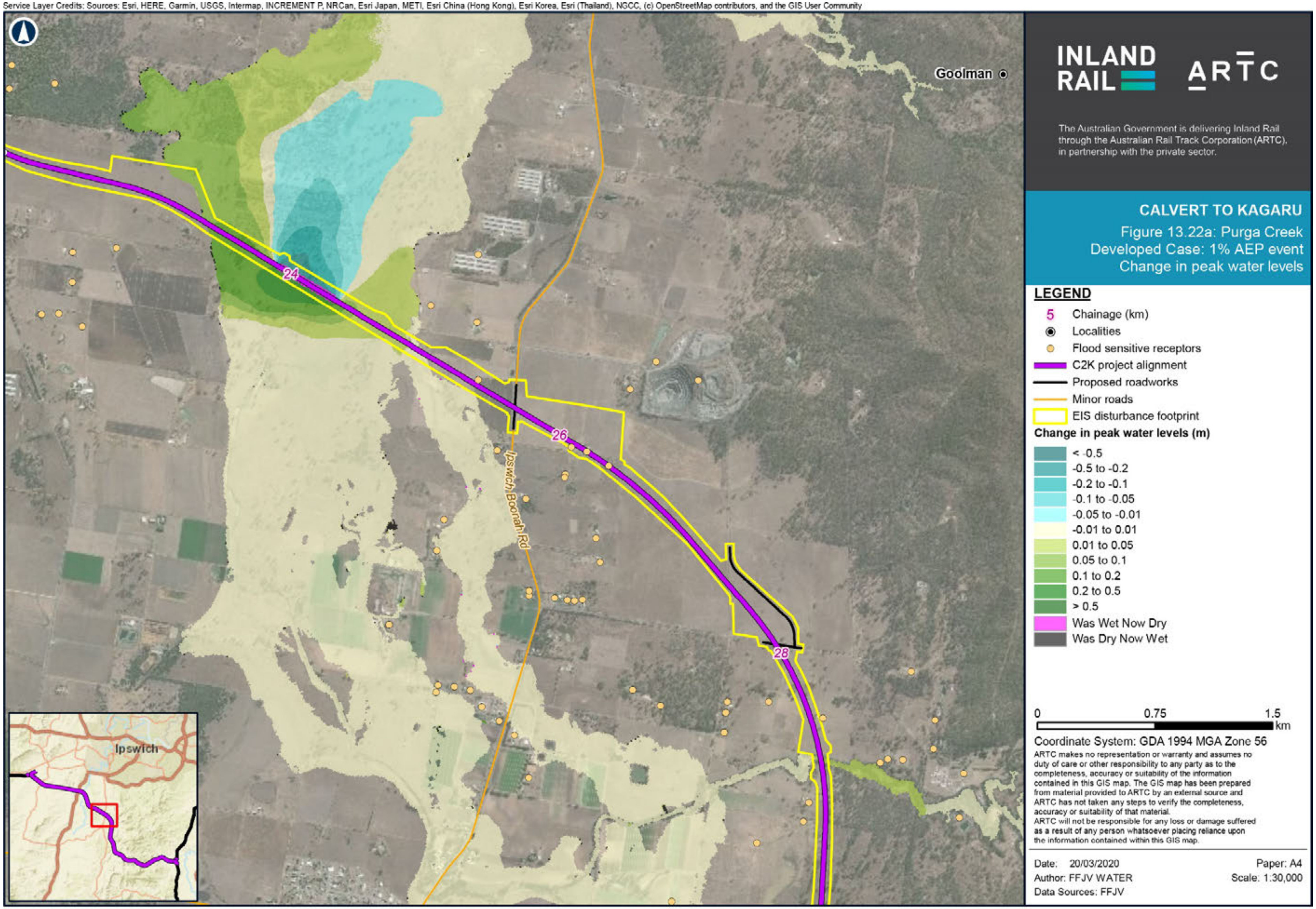

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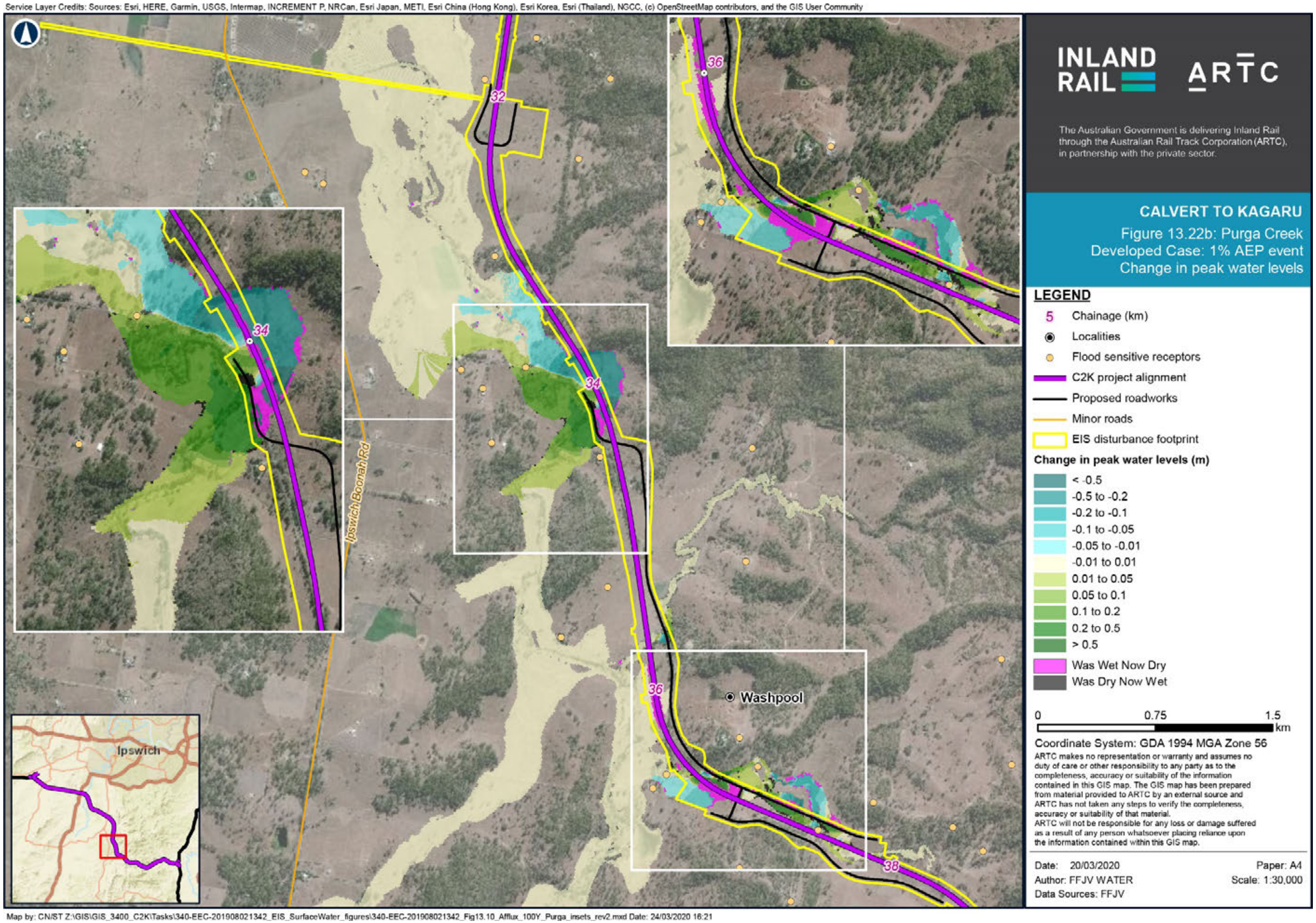

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CALVERT TO KAGARU
Figure 13.22b: Purga Creek
Developed Case: 1% AEP event
Change in peak water levels
LEGEND
5 Chainage (km)
Localities
Flood sensitive receptors
C2K project alignment
Proposed roadworks
Minor roads
EIS disturbance footprint
Change in peak water levels (m)
< -0.5
-0.5 to -0.2
-0.2 to -0.1
-0.1 to -0.05
-0.05 to -0.01
-0.01 to 0.01
0.01 to 0.05
0.05 to 0.1
0.1 to 0.2
0.2 to 0.5
> 0.5
Was Wet Now Dry
Was Dry Now Wet
0 0.75 1.5 km
Coordinate System: GDA 1994 MGA Zone 56
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Paper: A4
Author: FFJV WATER
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Data Sources: FFJV
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From the 20% AEP event upwards, changes in peak water levels occur where the Project alignment crosses the main Purga Creek channel, and its tributary Sandy Creek, and where the Project alignment runs parallel to the realigned Washpool Road. Changes in peak water levels gradually spread as the flood magnitude increases with impacts focused along the Project alignment. At the crossing of the main Purga Creek channel, the change in peak water levels are similar from 20% AEP event up to the 1% AEP event. Along Washpool Road, the change in peak water levels for these more frequent events are lower than that predicted for the 1% AEP event.

Change in duration of inundation

The change in duration of inundation is quantified by assessing and comparing the ToS for the Existing and Developed cases. The ToS for the 1% AEP event is in Table 13.43 and no flood sensitive receptors are affected. There are no adverse impacts on the localities of Purga or Washpool.

TABLE 13.43: PURGA CREEK—1% AEP EVENT—CHANGE IN TIME OF SUBMERGENCE

Chainage (km)/ Location	Existing Case ToS (hrs)	Developed Case ToS (hrs)	Comment
Ch 23.60 km to Ch 24.71 km Purga Creek Project rail bridge	68.0	70.5	There is an increase of the ToS of over two hours. This increase does not impact on any roads or flood sensitive receptors.
Between Ch 33.81 km and Ch 34.21 km Agricultural land	11.5	43.2	North-east of the Project alignment there is a localised increase in ToS of 31.7 hours. This localised increase does not impact on any roads or flood sensitive receptors.
Between Ch 33.81 km and Ch 34.21 km Washpool Road	11.5	42.6	On Washpool Road there is a localised increase of ToS of 31.1 hours. The increase is predominantly in the drainage channel running adjacent to Washpool Road and not on the actual road. The level of Washpool Road is raised in this area and the ToS of the roadway therefore reduced.
Around Ch 35.70 km Washpool Road	39.5	56.1	North-east of the Washpool Road realignment there is a localised increase in ToS of 16.6 hours. This increase is confined to the main channel and does not affect any flood sensitive receptors.
Ch 36.94 km to Ch 37.78 km Rural land	5.1	10.6	Around the Washpool Road realignment works there are instances of localised increases of up to 5.5 hours. These increases are parallel to the road alignment and do not impact on flood sensitive receptors.

Along Purga Creek there is one road affected by localised increases in peak water levels as detailed above. Table 13.44 outlines the AAToS for the Existing and Developed cases for Washpool Road. As the roadway is raised as part of the realignment there is a slight decrease in AAToS. AAToS is a measurement of the estimated time per year of submergence of a roadway due to flooding.

TABLE 13.44: AVERAGE ANNUAL TIME OF SUBMERGENCE COMPARISON FOR WASHPOOL ROAD

Location	AAToS Existing Case hrs/yr)	AAToS Developed Case (hrs/yr)	Difference (hrs/yr)
Washpool Road—Around Ch 33.81 km	47.8	47.4	-0.4

Flood flow distribution

Overall, the Project has minimal impacts on flood flows and floodplain conveyance/storage with floodplain structures designed to maintain the existing flood regime.

Velocities

Figure 13.23 shows the changes in peak velocities under the 1% AEP event associated with the Project alignment. In general, the changes are generally minor, with the greatest changes in velocities experienced between Ch 33.6 km and Ch 34.5 km. These changes do not exceed 0.7 m/s and therefore there is a limited risk of increased scour to the adjacent Washpool Road and in Purga Creek overbanks areas.

At the site of the Project rail bridge over Sandy Creek (Ch 28.73 km) and at an unnamed creek (Ch 37.53 km, adjacent to Washpool Road), the Existing Case peak velocities are around 3.0 m/s and slightly increase to a maximum of 3.3 m/s with the Project alignment in place. Appropriate scour protection measures are included in the design at these structures. There are no adverse impacts on the localities of Purga or Washpool.

Peak water levels, flows and velocities from the hydrology and flooding investigation have been used to inform the scour protection design. The scour protection has been designed in accordance with AGRD (Austroads, 2013). Scour protection was specified where the outlet velocities for the 1% AEP event exceed the allowable soil velocities for the particular soil type for each location, which was identified from published soil mapping.

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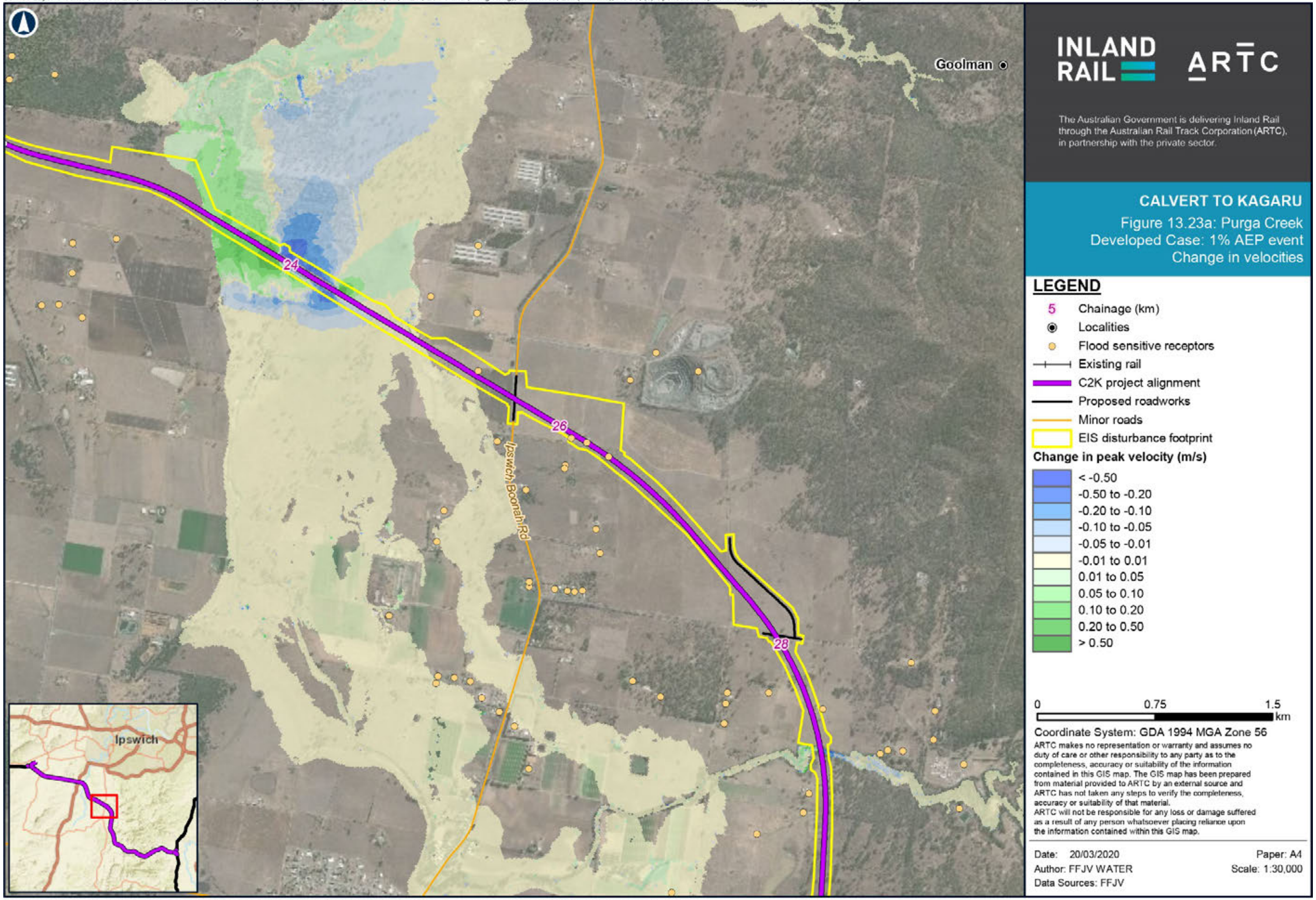

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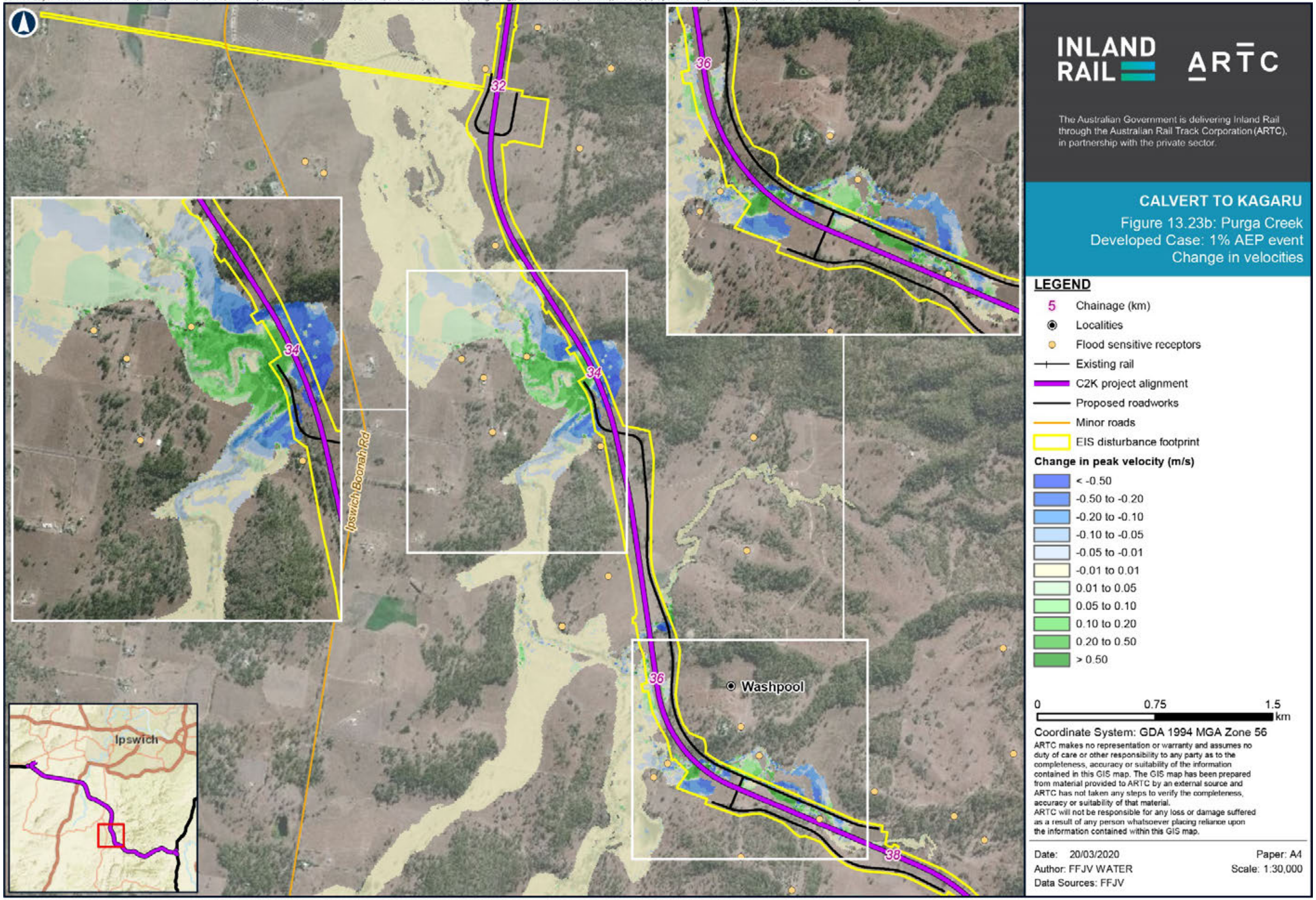

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Extreme events

Several design events larger than the 1% AEP event, including the 1 in 2,000 AEP, the 1 in 10,000 AEP and the PMF, have been modelled to assess the performance of the Project and to review impacts on the flooding regime. Figure 13.24, Figure 13.25, and Figure 13.26 present the change in peak water levels for the 1 in 2,000 AEP, the 1 in 10,000 AEP and the PMF events respectively. Table 13.45 outlines the changes in peak water levels at flood sensitive receptors for these extreme events where the change exceeds 10 mm under one of the events. The existing depth of flooding is also detailed and, as can be seen, the larger impacts that occur under the PMF event occur generally when there are already high flood depths as would be expected under such a rare event.

The flow that runs northwards along the eastern side of the Project alignment and introduces a new flowpath under the PMF event towards flood sensitive receptors 379, 194, 389 and 394 will require further refinement during detailed design.

TABLE 13.45: PURGA CREEK—SUMMARY OF EXTREME EVENT IMPACTS AT FLOOD SENSITIVE RECEPTORS

	1 in 2,000 AEP event		1 in 10,000 AEP event		PMF event	
Flood sensitive receptor number	Change in peak water level (mm)	Existing Case flood depth (m)	Change in peak water level (mm)	Existing Case flood depth (m)	Change in peak water level (mm)	Existing Case flood depth (m)
329 (House)	+18	0.06	+18	0.18	-37	1.19
333 (House)	+1	0.04	0	0.19	+14	1.20
346 (Sheds)	0	Dry	0	Dry	+38	0.64
375 (House)	0	Dry	0	Dry	+242	0.31
377 (Sheds)	0	Dry	0	Dry	+228	0.35
379 (House)	0	Dry	0	Dry	+243	0.37
384 (House)	0	Dry	0	Dry	+271	0.34
389 (House)	0	Dry	0	Dry	+457	0.40
394 (House)	0	Dry	0	Dry	+143	0.26
461 (Bridge*)	+23	4.51	+27	4.68	+16	6.13
475 (House)	0	Dry	0	Dry	+1102	0.33
484 (Sheds)	0	Dry	0	Dry	+27	Dry
502 (Bridge*)	+15	2.86	+15	3.16	+103	4.99
535 (Bridge*)	+402	1.88	+429	1.87	+535	2.57
706 (House/sheds)	+1	0.52	0	0.76	+11	2.04

Table notes:
* Flow depth in creek channel reported

The risk of overtopping has been assessed for the modelled extreme events. The 1 in 2,000 AEP and the 1 in 10,000 AEP events do not overtop the Project alignment. There is one section of the Project alignment overtopped under the PMF event at Ch 34.70 km where the formation level is overtopped by 0.4 m.

Under these rare events, the bridge structures and culverts have been designed to allow adequate passage of flow during the flood events and damming effects are therefore not expected to occur. In addition, failure of the embankment during a flood event is not predicted to result in a dam failure type event as the water level on both sides of the embankment is predicted to be similar. In addition, there is no redirection of flood flows under these extreme events.

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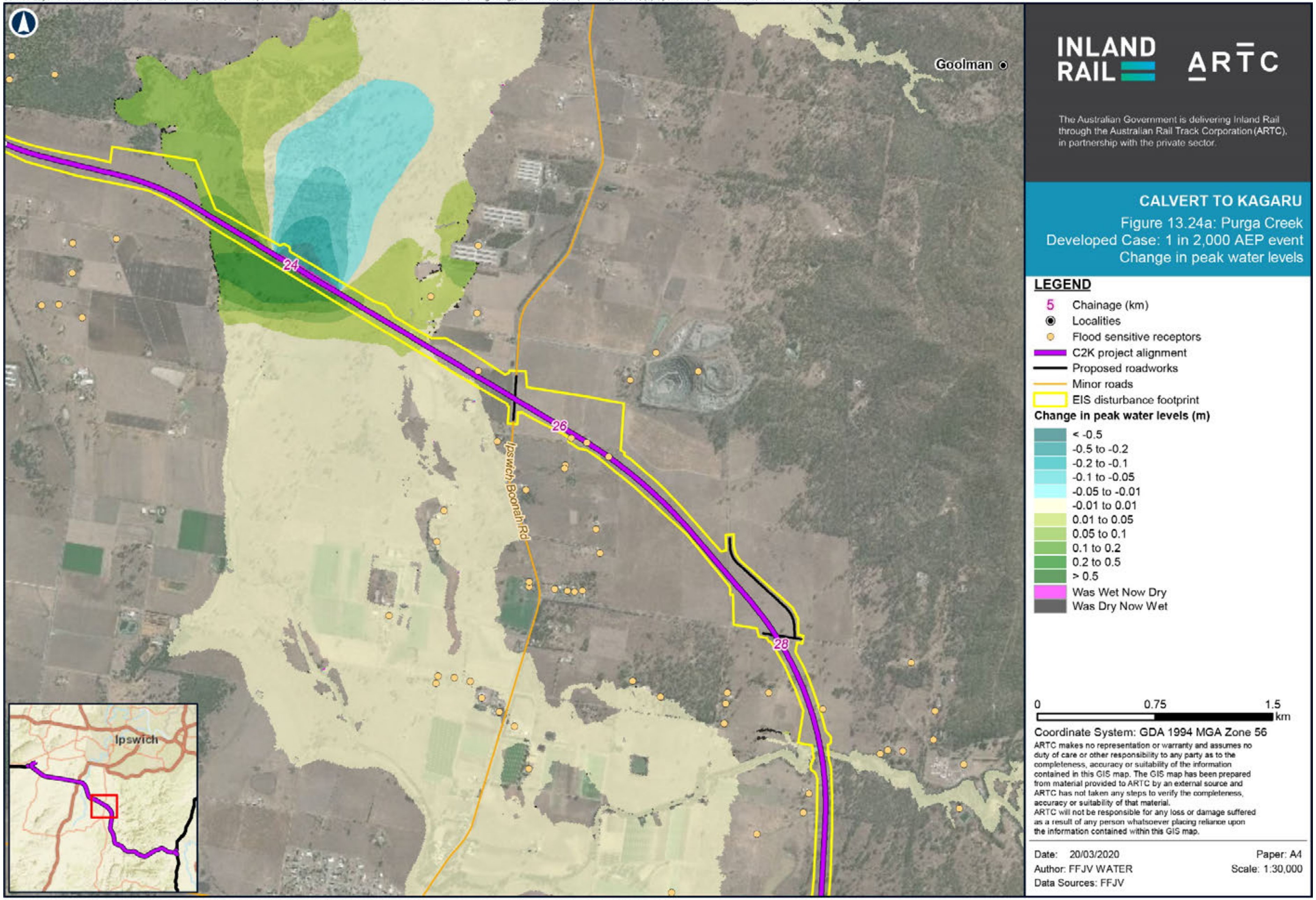

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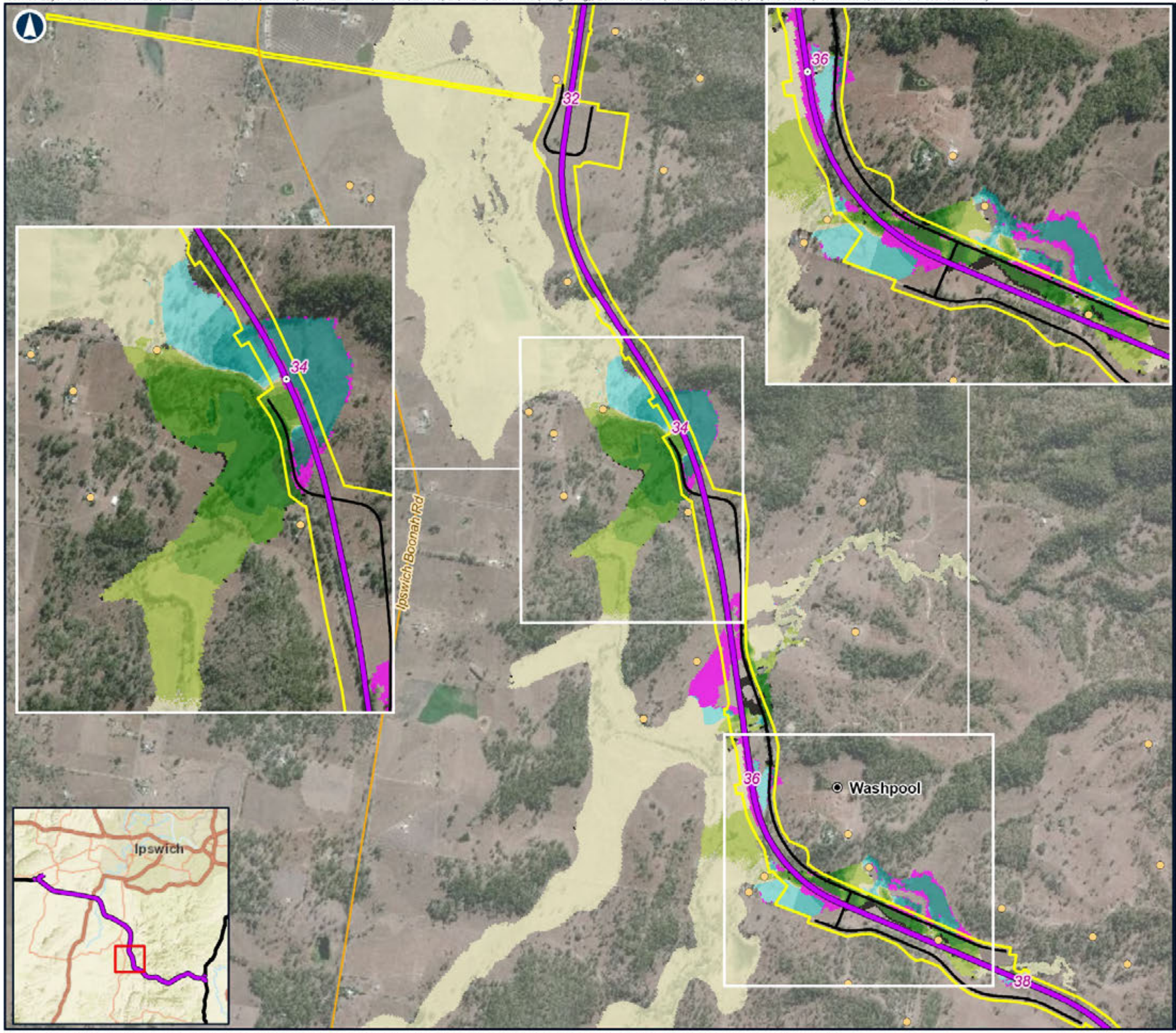

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CALVERT TO KAGARU

Figure 13.24b: Purga Creek
Developed Case: 1 in 2,000 AEP event
Change in peak water levels

LEGEND

- 5 Chainage (km)
- Localities
- Flood sensitive receptors
- C2K project alignment
- Proposed roadworks
- Minor roads
- EIS disturbance footprint

Change in peak water levels (m)

- < -0.5
- -0.5 to -0.2
- -0.2 to -0.1
- -0.1 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.1
- 0.1 to 0.2
- 0.2 to 0.5
- > 0.5
- Was Wet Now Dry
- Was Dry Now Wet

0 0.75 1.5 km

Coordinate System: GDA 1994 MGA Zone 56

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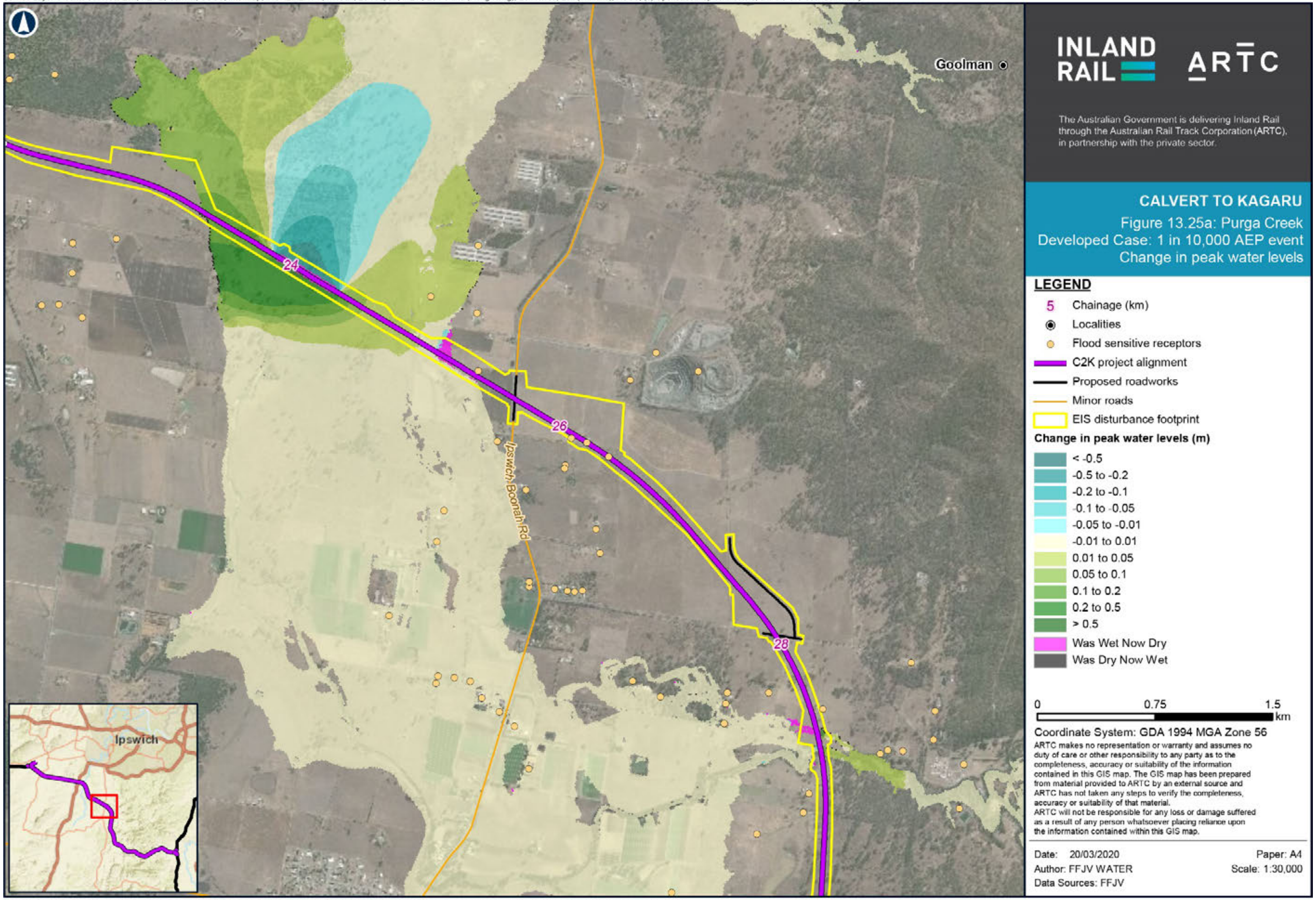

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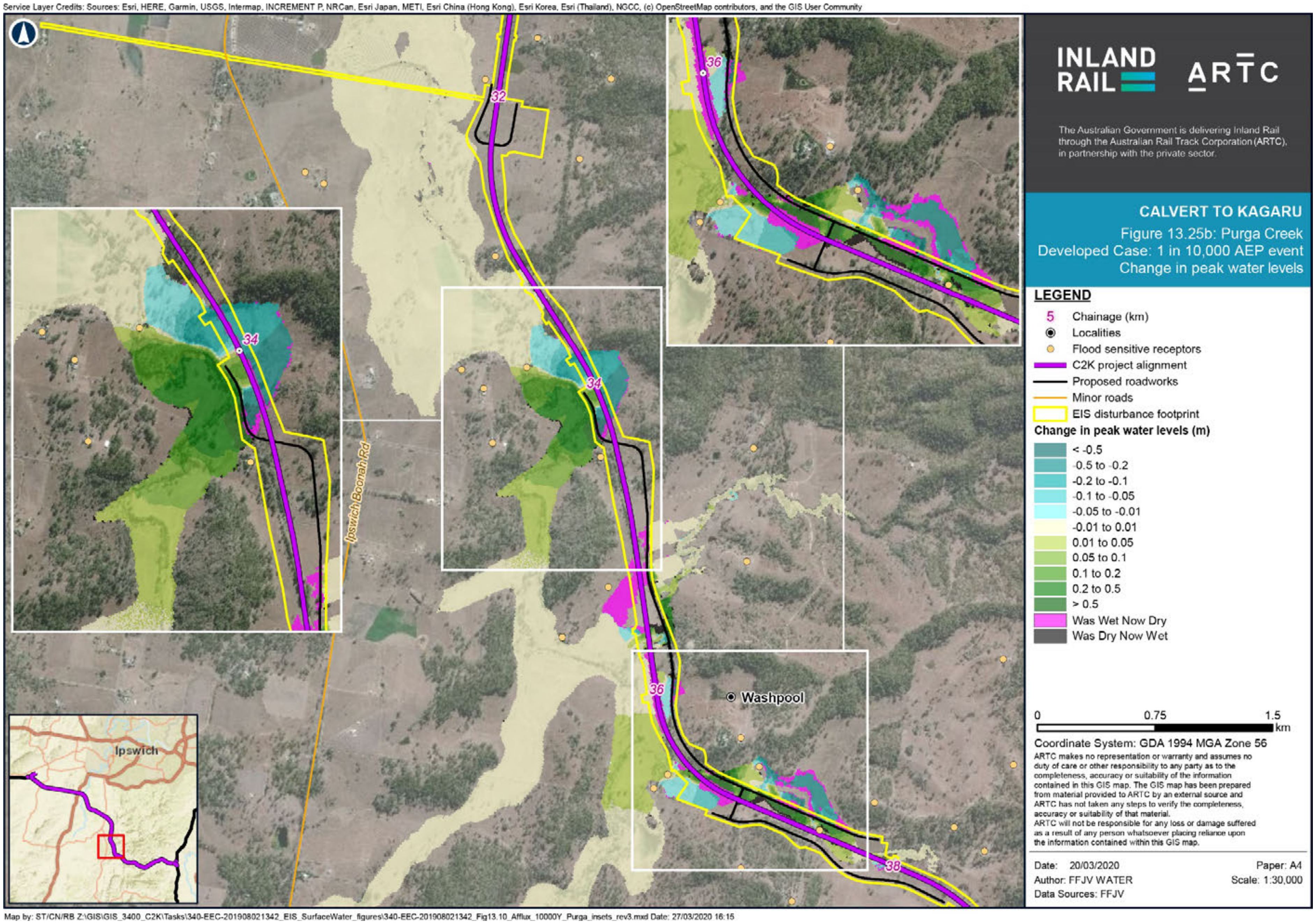

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32
34
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38
Washpool
Ipswich Boonah Rd
Ipswich
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Figure 13.25b: Purga Creek
Developed Case: 1 in 10,000 AEP event
Change in peak water levels
LEGEND
5 Chainage (km)
Localities
Flood sensitive receptors
C2K project alignment
Proposed roadworks
Minor roads
EIS disturbance footprint
Change in peak water levels (m)
< -0.5
-0.5 to -0.2
-0.2 to -0.1
-0.1 to -0.05
-0.05 to -0.01
-0.01 to 0.01
0.01 to 0.05
0.05 to 0.1
0.1 to 0.2
0.2 to 0.5
> 0.5
Was Wet Now Dry
Was Dry Now Wet
0 0.75 1.5 km
Coordinate System: GDA 1994 MGA Zone 56
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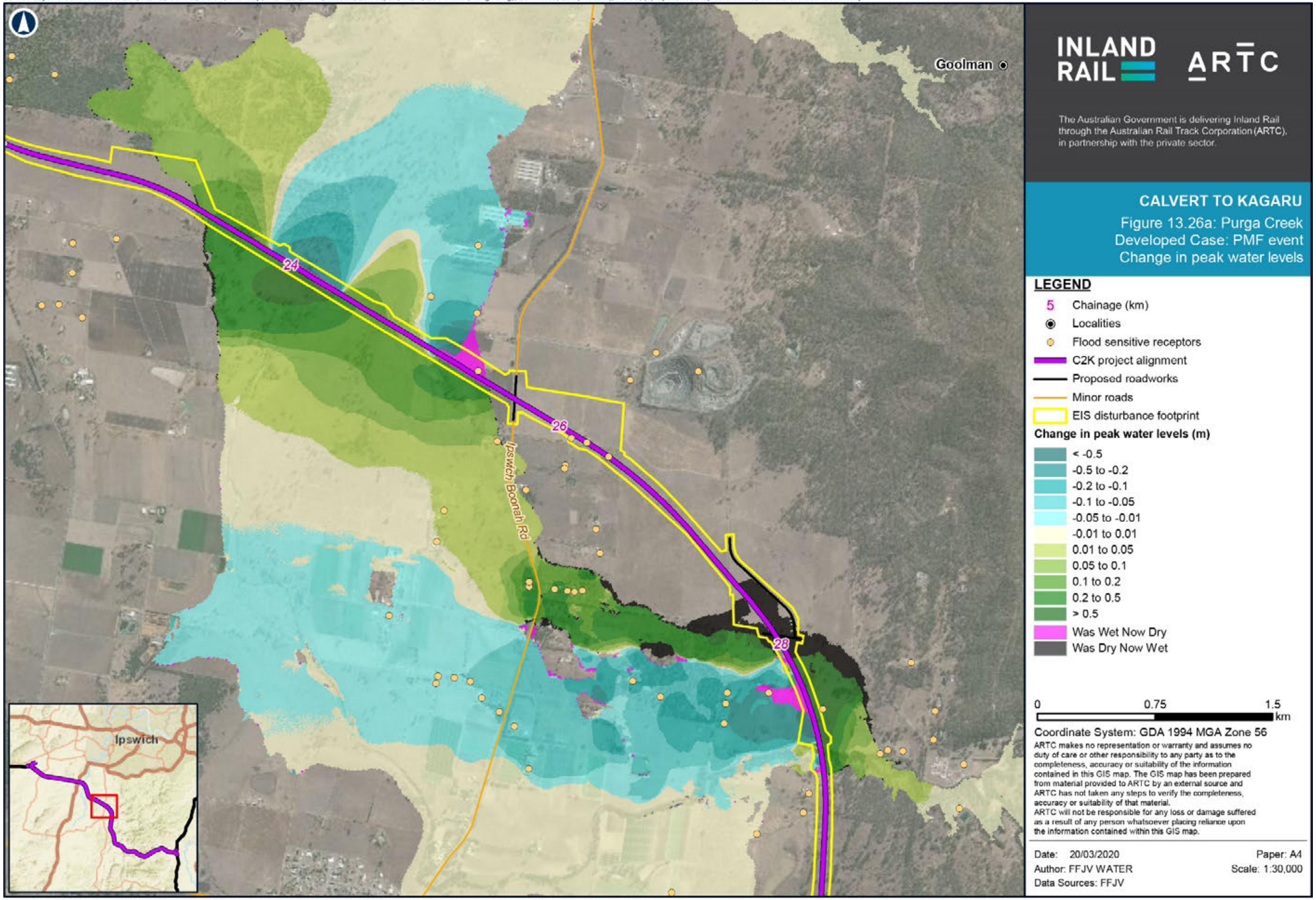

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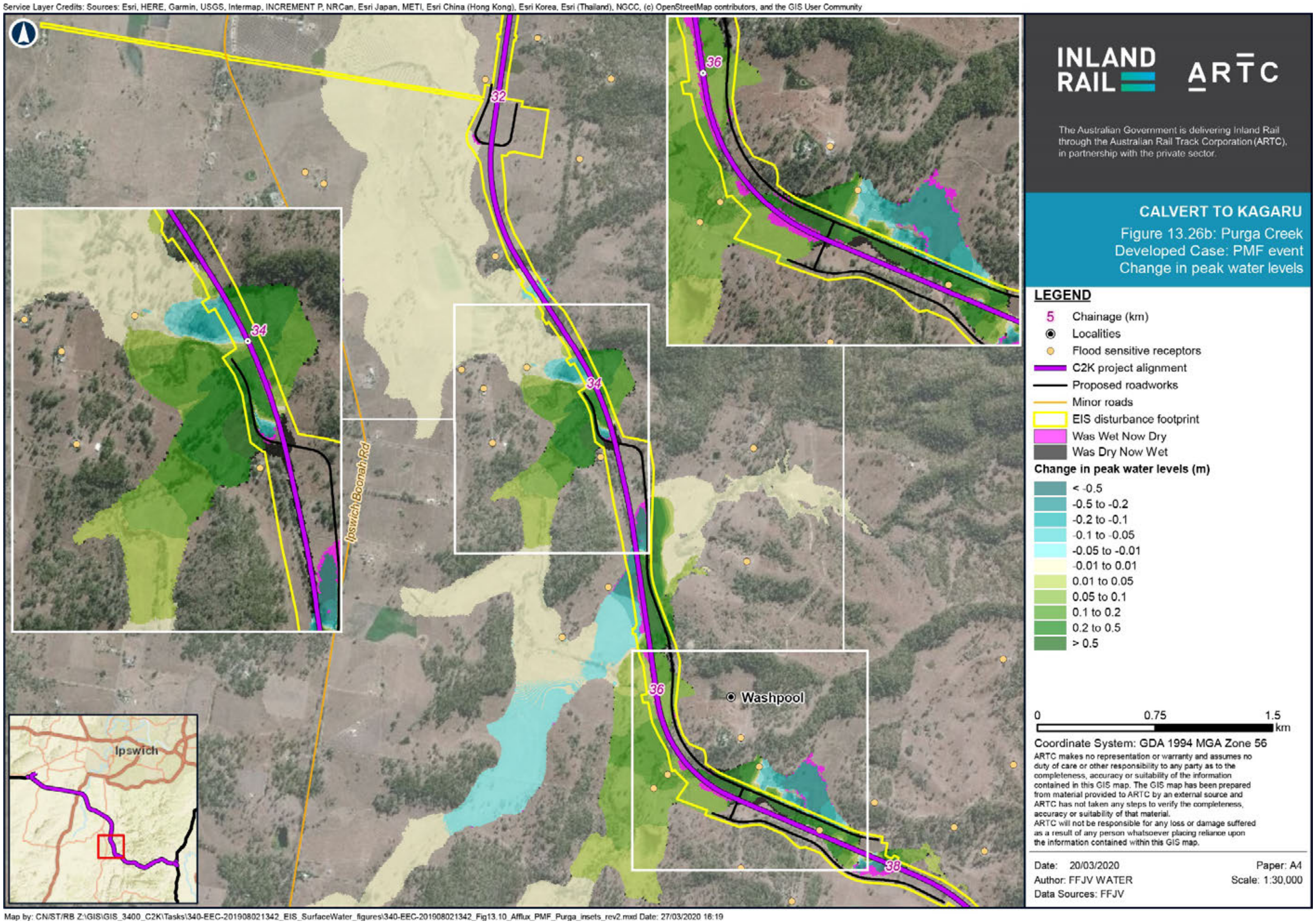
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Figure 13.26b: Purga Creek
Developed Case: PMF event
Change in peak water levels
LEGEND
5 Chainage (km)
Localities
Flood sensitive receptors
C2K project alignment
Proposed roadworks
Minor roads
EIS disturbance footprint
Was Wet Now Dry
Was Dry Now Wet
Change in peak water levels (m)
< -0.5
-0.5 to -0.2
-0.2 to -0.1
-0.1 to -0.05
-0.05 to -0.01
-0.01 to 0.01
0.01 to 0.05
0.05 to 0.1
0.1 to 0.2
0.2 to 0.5
> 0.5
0 0.75 1.5 km
Coordinate System: GDA 1994 MGA Zone 56
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Climate change

The climate change guidelines set out in ARR 2016 have been followed and used to assess the potential impact of increased rainfall on peak water levels in the vicinity of the Project.

The Representative Concentration Pathways 8.5 (2090 horizon) climate change scenario has been adopted for the Project with an associated increase in rainfall intensity of 18.7 per cent across catchment area. Climate change results in increased peak water levels between 200 mm and 500 mm in the vicinity of the Project alignment under the 1% AEP event.

Figure C7-D-1 and C7-D-2 within Appendix N: Hydrology and Flooding Technical Report show the change in peak water levels for the 1% AEP event with climate change. The overall extents of the changes in peak water levels under the 1% AEP event with climate change around Purga Creek is generally similar to those seen in the 1% AEP event.

Blockage

Blockage of drainage structures has been assessed in accordance with ARR 2016 requirements. The blockage assessment resulted in no blockage factor being applied to bridges and a blockage factor of 25 per cent being applied to culverts. A minimum culvert size of 1,200 mm diameter was also adopted to reduce potential for blockage and for ease of maintenance.

ARR 2016 guidelines are focused on blockage of small bridges and culverts. The floodplain bridges proposed for the Project alignment are all multi-span large bridges and 2016 notes that there are limited instances of multiple span bridges being observed with blockages similar to those seen at single span bridges or culverts.

Two blockage-sensitivity scenarios were tested with both 0 per cent and 50 per cent blockage of all culverts. The results for the 0 per cent and 50 per cent blockage are in Appendix C of Appendix N: Hydrology and Flooding Technical Report, Figure C7-E and C7-F respectively.

Washpool Road is predicted to experience up to a 50 mm reduction and greater than a 250 mm increase to peak water levels for the 0 per cent blockage and 50 per cent blockage scenarios respectively under the 1% AEP event. Under the 50 per cent blockage scenario, a new flow path is created around Ch 35.13 km due to the obstruction of flow caused by the upgrade of Washpool Road. No additional flood sensitive receptors were impacted by this change in flow distribution.

13.8.2.4 Teviot Brook

On the Teviot Brook system, the Project includes:

- Nine rail bridges
- One road RCP culvert bank
- One rail RCP culvert bank.

Details of the rail and road structures required to convey Teviot Brook flows are listed in Table 13.46 and Table 13.47 respectively. Rail structure locations are shown in Figure 13.27. Figure 13.27 also show the location of local catchment drainage structures. Details of the local drainage culverts are provided in Appendix N: Hydrology and Flooding Technical Report.

TABLE 13.46: TEVIOT BROOK—FLOOD STRUCTURE LOCATIONS AND DETAILS

Chainage (km)	Structure name	Structure type	No of cells	Diameter (m)	Soffit level (m AHD)	Bridge length (m)
41.87	340-BR18	Bridge	-	-	105.70	184.0
42.76	340-BR19	Bridge	-	-	97.30	138.0
43.06	340-BR20	Bridge	-	-	92.10	161.0
43.40	340-BR21	Bridge	-	-	87.90	230.0
46.20	340-BR22	Bridge	-	-	63.20	115.0
47.00	340-BR23	Bridge	-	-	59.20	161.0
48.33	C48.33	RCP	12	1.50	-	-
50.60	340-BR24	Bridge	-	-	46.20	207.0
51.35	340-BR25	Bridge	-	-	44.00	230.0
52.80	340-BR26	Bridge	-	-	41.60	722.0

TABLE 13.47: TEVIOT BROOK—ROAD STRUCTURE LOCATIONS AND DETAILS

Approximate Project chainage (km)	Road name	Structure type	No cells	Diameter (m)
43.00	Wild Pig Creek Road	RCP	9	2.40

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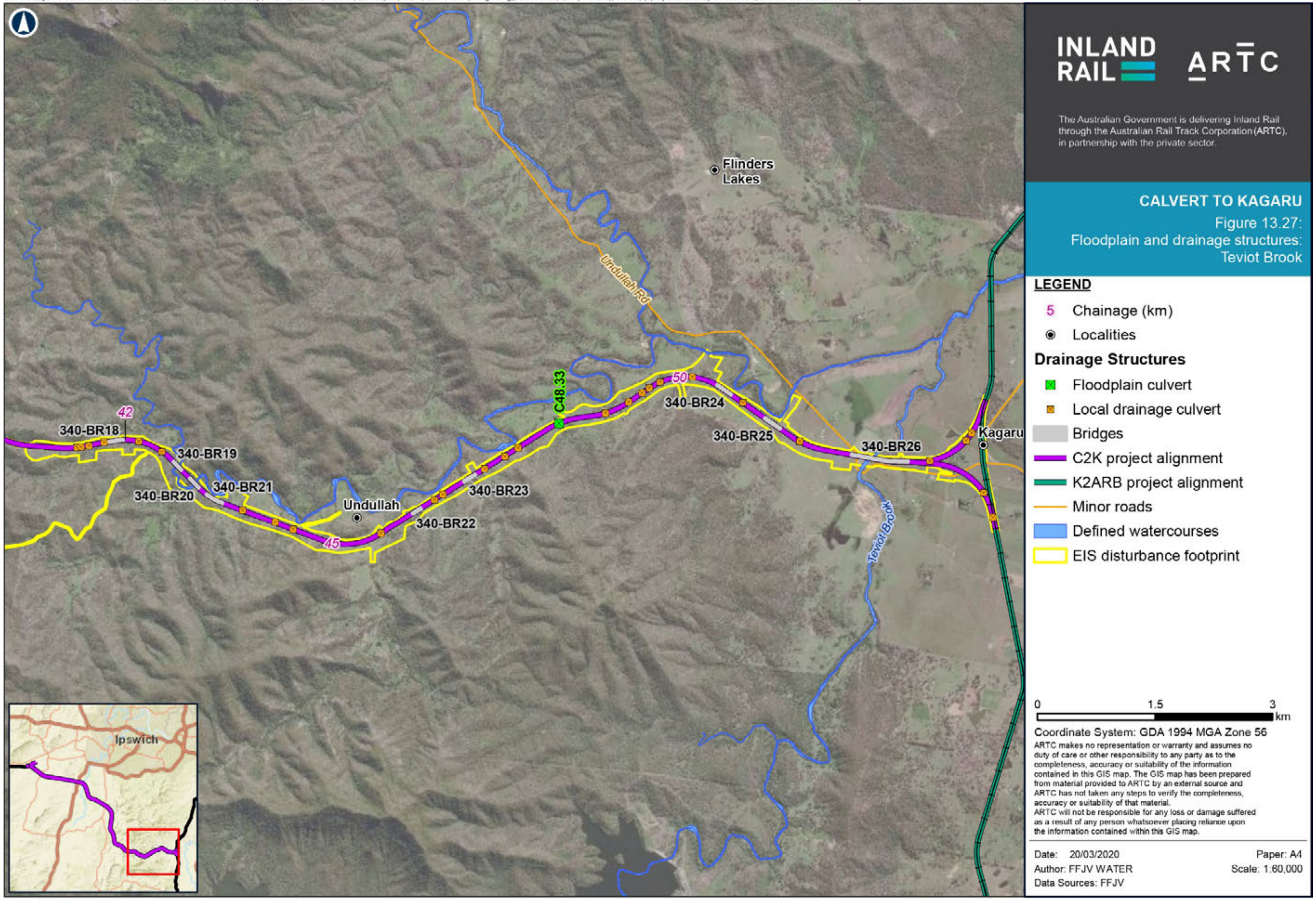

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Change in peak water levels

Figure 13.28a and Figure 13.28b show the change in peak water levels under the 1% AEP event and Table 13.48 details where the changes in peak water levels lie outside the flood impact objectives. Except for these locations, the change in peak water levels under the 1% AEP event complies with the flood impact objectives (Section 13.4.2.2).

TABLE 13.48: TEVIOT BROOK—CHANGE IN PEAK WATER LEVELS OUTSIDE FLOOD IMPACT OBJECTIVES

Chainage (km)/ Location	Flood impact objectives	Change in peak water levels (mm)	Comment
Approximate Ch 42.90 km Agricultural land (upstream of Wild Pig Road diversion road bridge)	≤200 mm* (localised increases of up to 400 mm)	+400	Flow in this location is highly channelised. This increase in peak water levels reduces to 200 mm approximately 350 m from the Project alignment. This area is highly vegetated with no nearby habitable dwellings or agricultural land.
Ch 48.33 km Agricultural land	≤200 mm* (localised increases of up to 400 mm)	+250	This impact decreases to 200 mm within the Project boundary. This area is highly vegetated with no habitable dwellings, roadways and agricultural land nearby based on the aerial imagery provided for the Project.

Table notes:
* Maximum, but may be less if identified from consultation

Analysis of the 20%, 10%, 5% and 2% AEP events was also undertaken, and figures showing the change in peak water levels are in Appendix N: Hydrology and Flooding Technical Report. At the Kagaru end of the Project alignment, each of the events have increasing levels of overbank flooding outside the defined creek channels, with significant floodplain inundation starting at the 20% AEP event. Flood flows to the west of this area, in Woollaman Creek, are channelised for all events from 20% to 2% AEP.

Under events from 20% to 2% AEP negligible changes in peak water levels occur within Woollaman Creek. At the road diversion of Wild Pig Creek Road localised increases in peak water levels occur across all events with no flood sensitive receptors impacted.

Change in duration of inundation

The change in duration of inundation is quantified by assessing and comparing the ToS for the Existing and Developed cases. The ToS for the 1% AEP event is in Table 13.49 and no flood sensitive receptors are affected.

TABLE 13.49: TEVIOT BROOK—1% AEP EVENT—CHANGE IN TIME OF SUBMERGENCE

Chainage (km)/ location	Existing Case ToS (hrs)	Developed Case ToS (hrs)	Comment
Upstream of Wild Pig Road	58.0	80.9	Upstream of the Wild Pig Road culverts there is a localised increase in ToS of 22.9 hours. This localised increase does not impact on any roads or flood sensitive receptors.
Ch 48.33 km	13.5	50.4	Upstream of the Project rail culverts there is a localised increase in ToS of over 36.9 hours. This localised increase does not impact on any roads or flood sensitive receptors.

On Teviot Brook and Woollaman Creek, there are no roads impacted by the Project alignment and therefore no changes in ToS or AAToS for roadways.

Flood flow distribution

Overall, the Project has minimal impacts on flood flows and floodplain conveyance/storage with floodplain structures designed to maintain the existing flood regime.

Velocities

Figure 13.28a–b and Figure 13.29 present the changes in peak velocities under the 1% AEP event associated with the Project alignment. In general, the changes are minor, with most changes in velocities experienced immediately adjacent to the Project alignment.

Peak water levels, flows and velocities from the hydrology and flooding investigation have been used to inform the drainage assessment for scour protection design. The scour protection has been designed in accordance with AGRD (Austroads, 2013). Scour protection was specified where the outlet velocities for the 1% AEP event exceed the allowable soil velocities for the particular soil type for each location, which was identified from published soil mapping.

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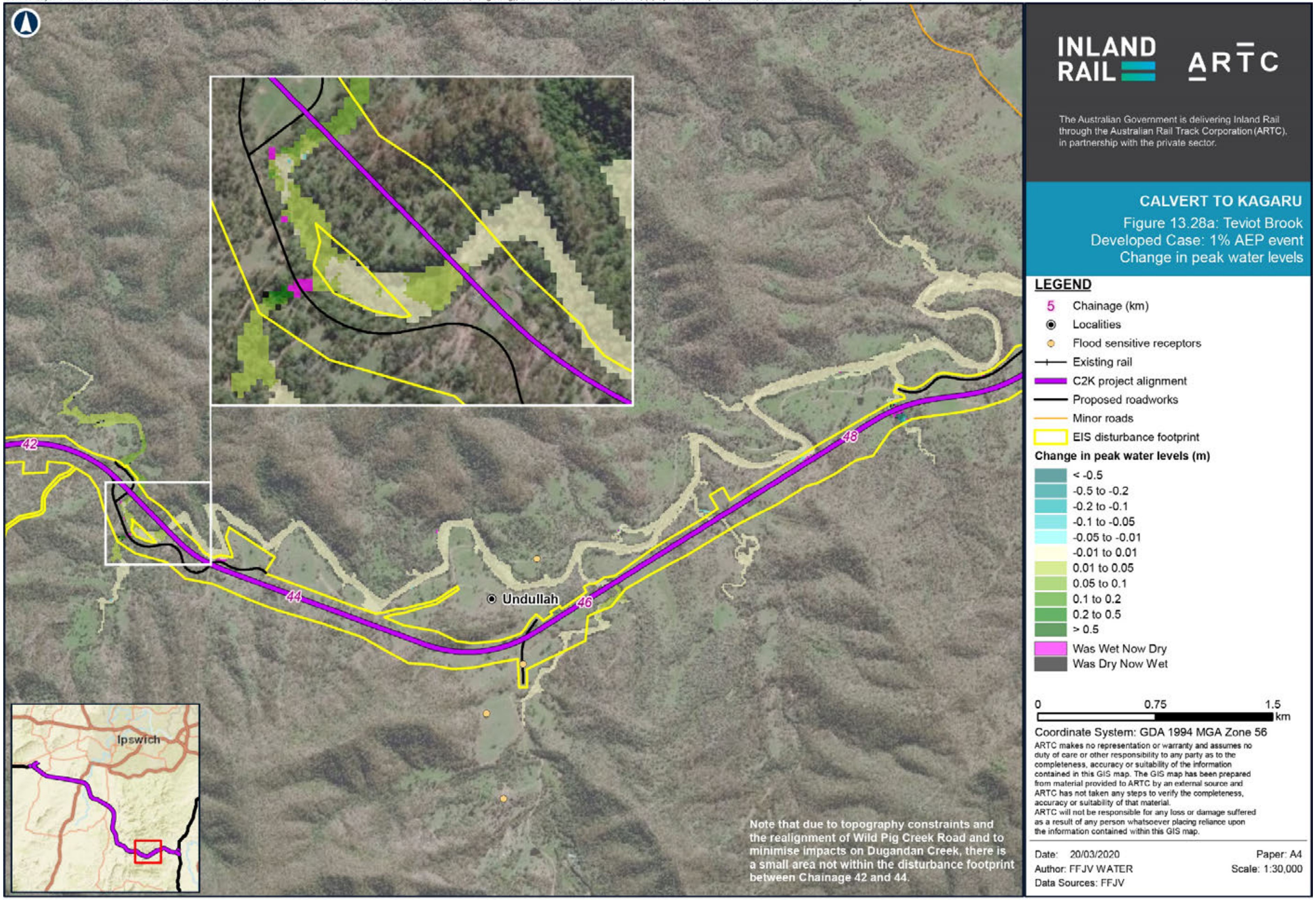

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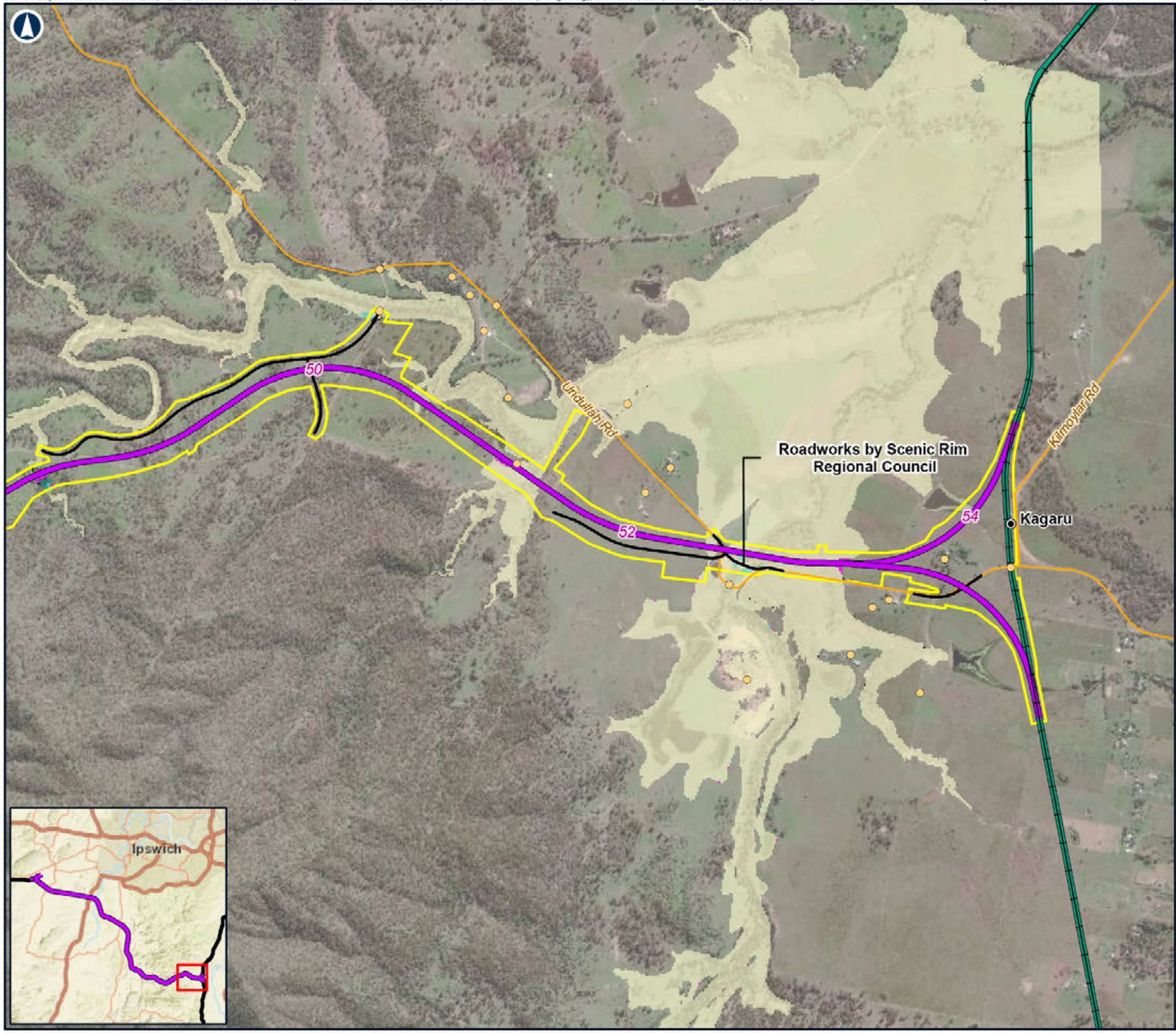

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CALVERT TO KAGARU

Figure 13.28b: Teviot Brook
Developed Case: 1% AEP event
Change in peak water levels

LEGEND

- 5 Chainage (km)
- Localities
- Flood sensitive receptors
- Existing rail
- C2K project alignment
- K2ARB project alignment
- Proposed roadworks
- Minor roads
- EIS disturbance footprint

Change in peak water levels (m)

- < -0.5
- -0.5 to -0.2
- -0.2 to -0.1
- -0.1 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.1
- 0.1 to 0.2
- 0.2 to 0.5
- > 0.5
- Was Wet Now Dry
- Was Dry Now Wet

0 0.75 1.5 km

Coordinate System: GDA 1994 MGA Zone 56

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Data Sources: FFJV

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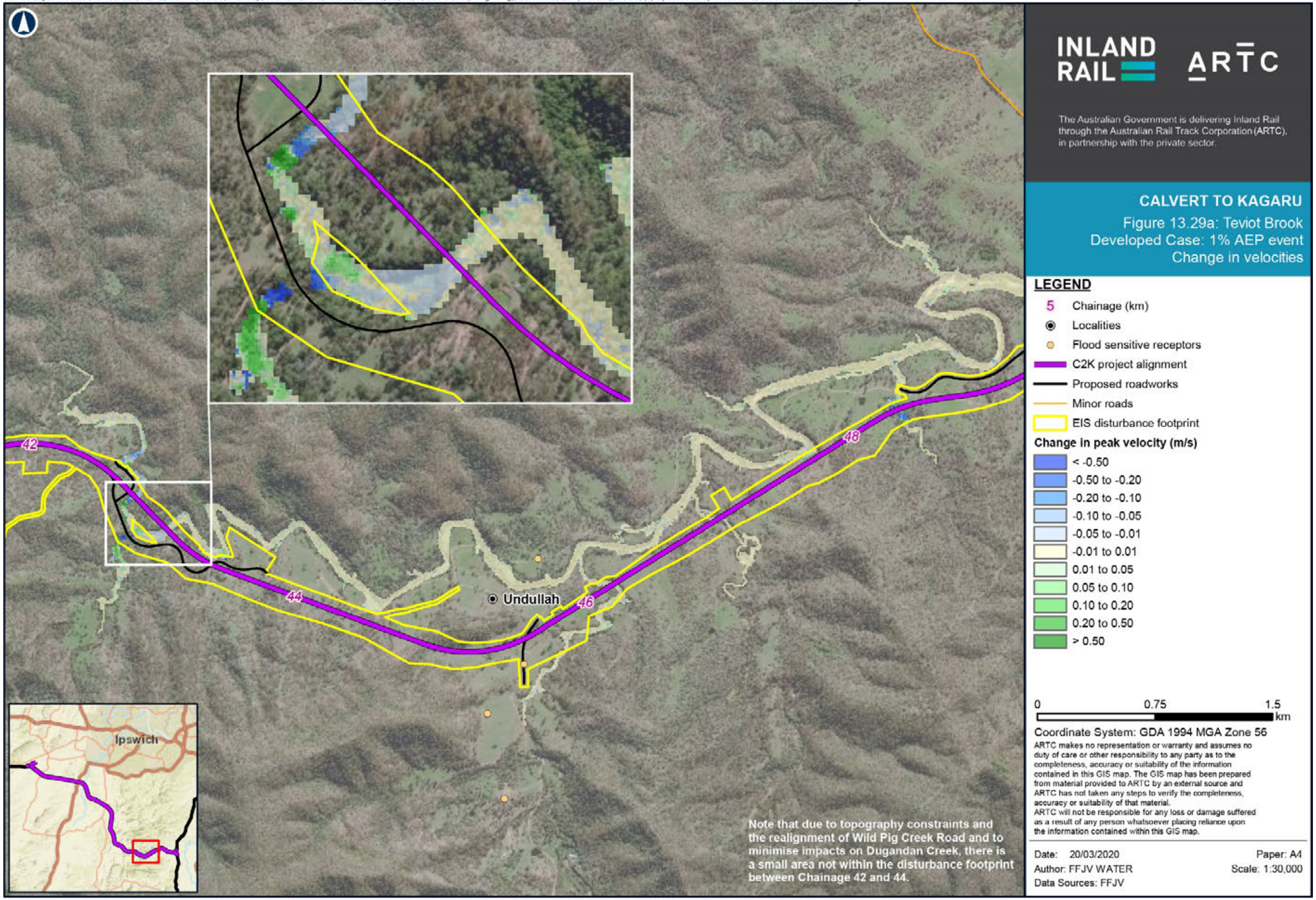

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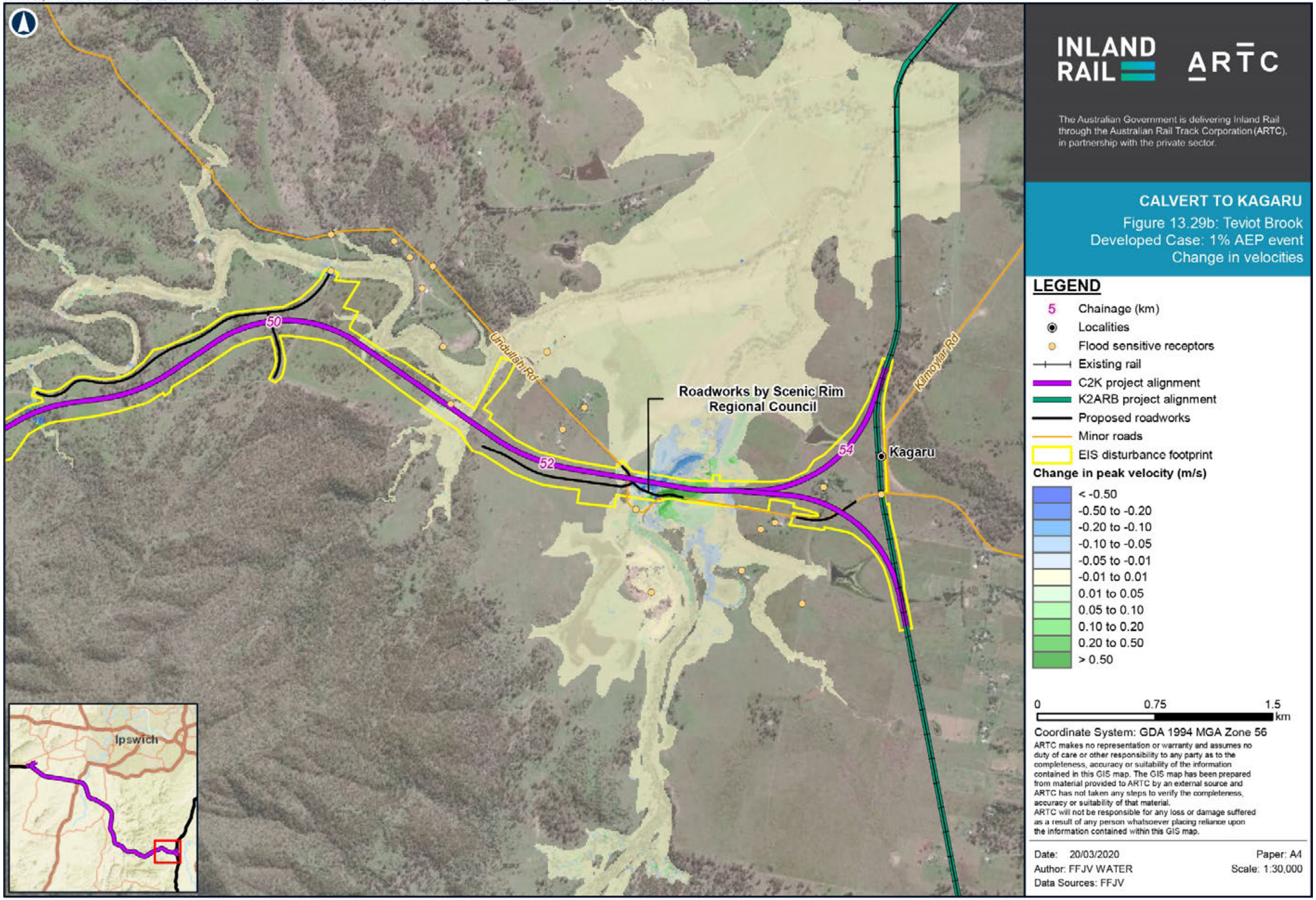

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Extreme events

Several design events larger than the 1% AEP event, including the 1 in 2,000 AEP, 1 in 10,000 AEP and PMF, have been modelled to assess the performance of the Project and to review impacts on the flooding regime. Figure 13.30, Figure 13.31 and Figure 13.32 present the change in peak water levels for the 1 in 2,000 AEP, the 1 in 10,000 AEP and the PMF events respectively. Table 13.50 outlines the changes in peak water levels at flood sensitive receptors for these extreme events where the change exceeds 10 mm under one of the events. The existing depth of flooding is also detailed and as can be seen the larger impacts that occur under the PMF event occur generally when there is already high flood depths as would be expected under such a rare event.

TABLE 13.50: TEVIOT BROOK—SUMMARY OF EXTREME EVENT IMPACTS AT FLOOD SENSITIVE RECEPTORS

Flood sensitive receptor number	1 in 2,000 AEP event		1 in 10,000 AEP event		PMF event	
	Change in peak water level (mm)	Existing Case flood depth (m)	Change in peak water level (mm)	Existing Case flood depth (m)	Change in peak water level (mm)	Existing Case flood depth (m)
595 (bridge*)	+4	13.55	+6	14.51	+13	19.41
597 (industrial/ commercial)	+5	13.14	+7	14.10	+16	19.0
603 (sheds)	+5	1.77	+7	2.74	+15	7.65
609 (unsealed road)	0	Dry	+7	0.13	+15	5.03

Table notes:
* Flow depth in creek channel reported

The risk of overtopping has been assessed for the modelled extreme events. The 1 in 2,000 AEP, the 1 in 10,000 AEP and the PMF events do not overtop the Project alignment.

Under these rare events, the bridge structures and culverts have been designed to allow adequate passage of flow during the flood events and damming effects are therefore not expected to occur. In addition, failure of the embankment during a flood event is not predicted to result in a dam-failure type event as the water level on both sides of the embankment is predicted to be similar. In addition, there is no redirection of flood flows under these extreme events.

Climate change

The climate change guidelines set out in ARR 2016 have been followed and used to assess the potential impact of increased rainfall on peak water levels in the vicinity of the Project alignment.

The Representative Concentration Pathways 8.5 (2090 horizon) climate change scenario has been adopted for the Project with an associated increase in rainfall intensity of 18.7 per cent across the catchment area. Climate change results in increased peak water levels of 420 mm in the vicinity of the Project alignment under the 1% AEP event.

The change in peak water levels for the 1% AEP event with climate change are shown in Appendix D of Appendix N: Hydrology and Flooding Technical Report (Figures D7-D-1 and D7-D-2). The inclusion of climate change has no impact on the change in peak water levels associated with the Project alignment.

Blockage

Blockage of drainage structures has been assessed in accordance with ARR 2016 requirements. The blockage assessment resulted in no blockage factor being applied to bridges and a blockage factor of 25 per cent being applied to culverts. A minimum culvert size of 1,200 mm diameter was also adopted to reduce potential for blockage and for ease of maintenance.

ARR 2016 guidelines are focused on blockage of small bridges and culverts. The floodplain bridges proposed for the Project alignment are all multi-span large bridges and ARR 2016 notes that there are limited instances of multiple span bridges being observed with blockages similar to those seen at single-span bridges or culverts.

Two blockage-sensitivity scenarios were tested with both 0 per cent and 50 per cent blockage of all culverts. The results are in Appendix D of Appendix N: Hydrology and Flooding Technical Report, Figure D7-E and Figure D7-F for the 0 per cent and 50 per cent blockage respectively within Appendix N: Hydrology and Flooding Technical Report. The proposed Wild Pig Road deviation is expected to experience more than a 500 mm increase in peak water levels under the 50 per cent blockage scenario. However, no flood sensitive receptors are impacted.

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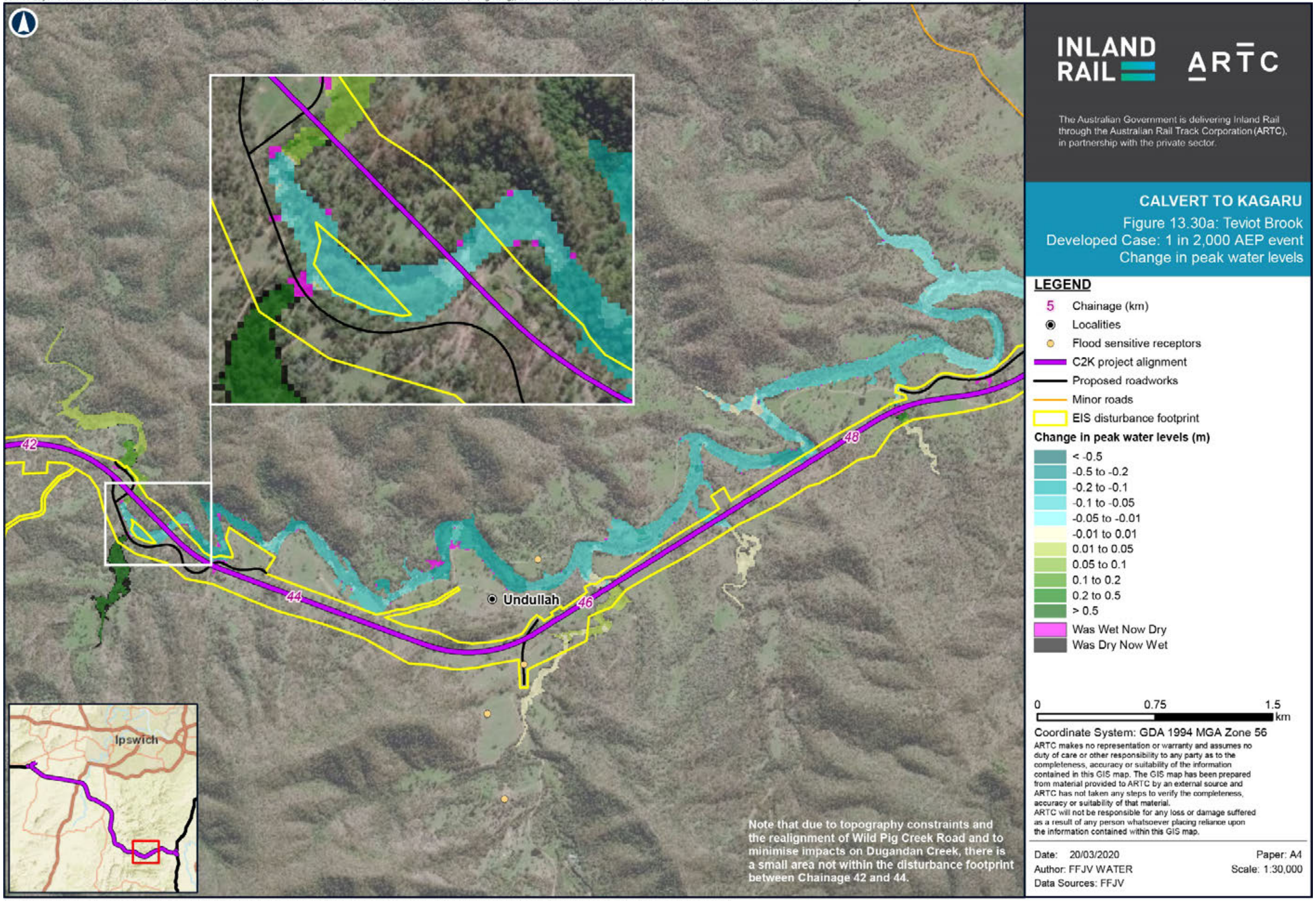

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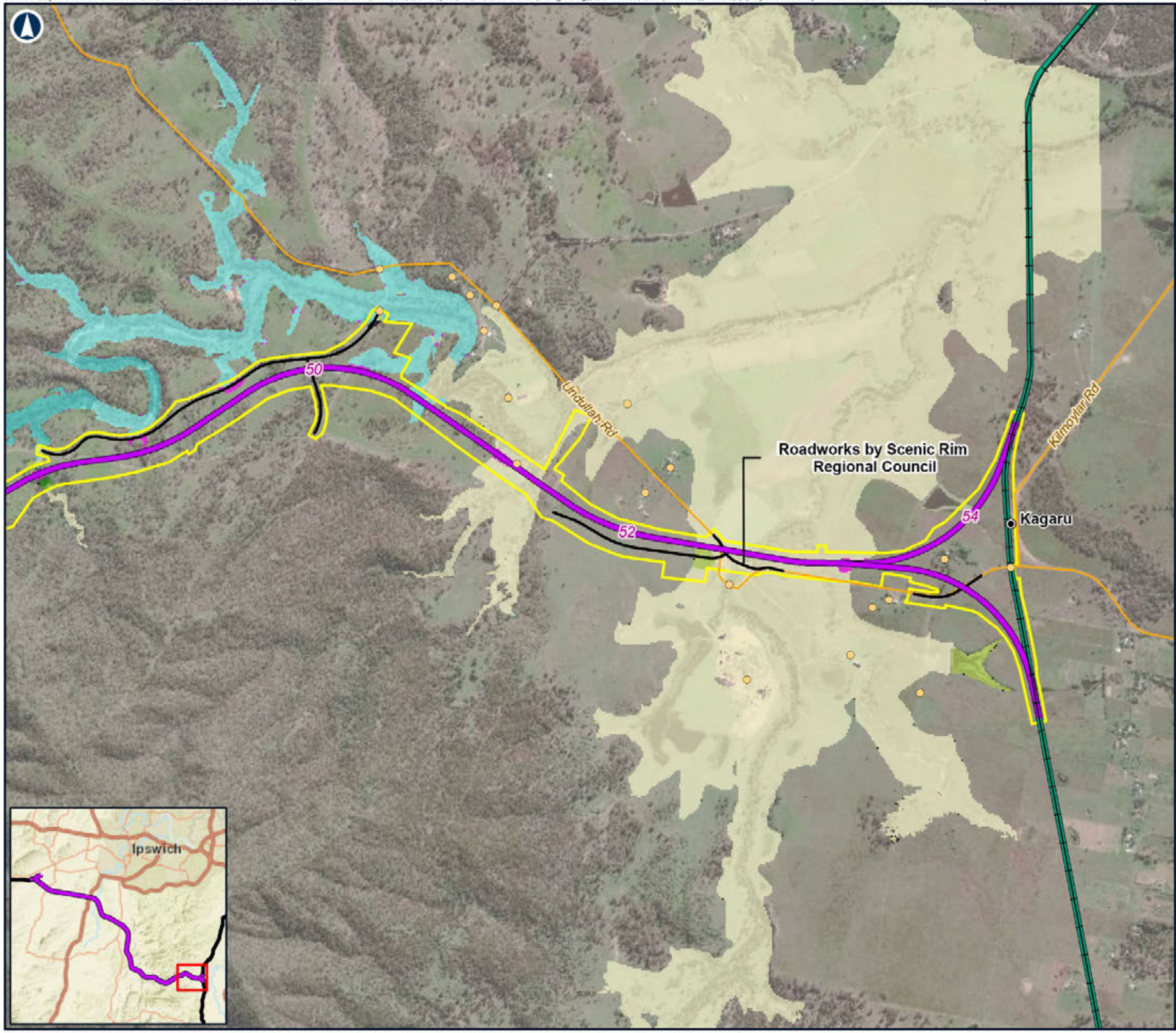

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CALVERT TO KAGARU

Figure 13.30b: Teviot Brook
Developed Case: 1 in 2,000 AEP event
Change in peak water levels

LEGEND

- 5 Chainage (km)
- Localities
- Flood sensitive receptors
- Existing rail
- C2K project alignment
- K2ARB project alignment
- Proposed roadworks
- Minor roads
- EIS disturbance footprint

Change in peak water levels (m)

- < -0.5
- -0.5 to -0.2
- -0.2 to -0.1
- -0.1 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.1
- 0.1 to 0.2
- 0.2 to 0.5
- > 0.5
- Was Wet Now Dry
- Was Dry Now Wet

0 0.75 1.5 km

Coordinate System: GDA 1994 MGA Zone 56

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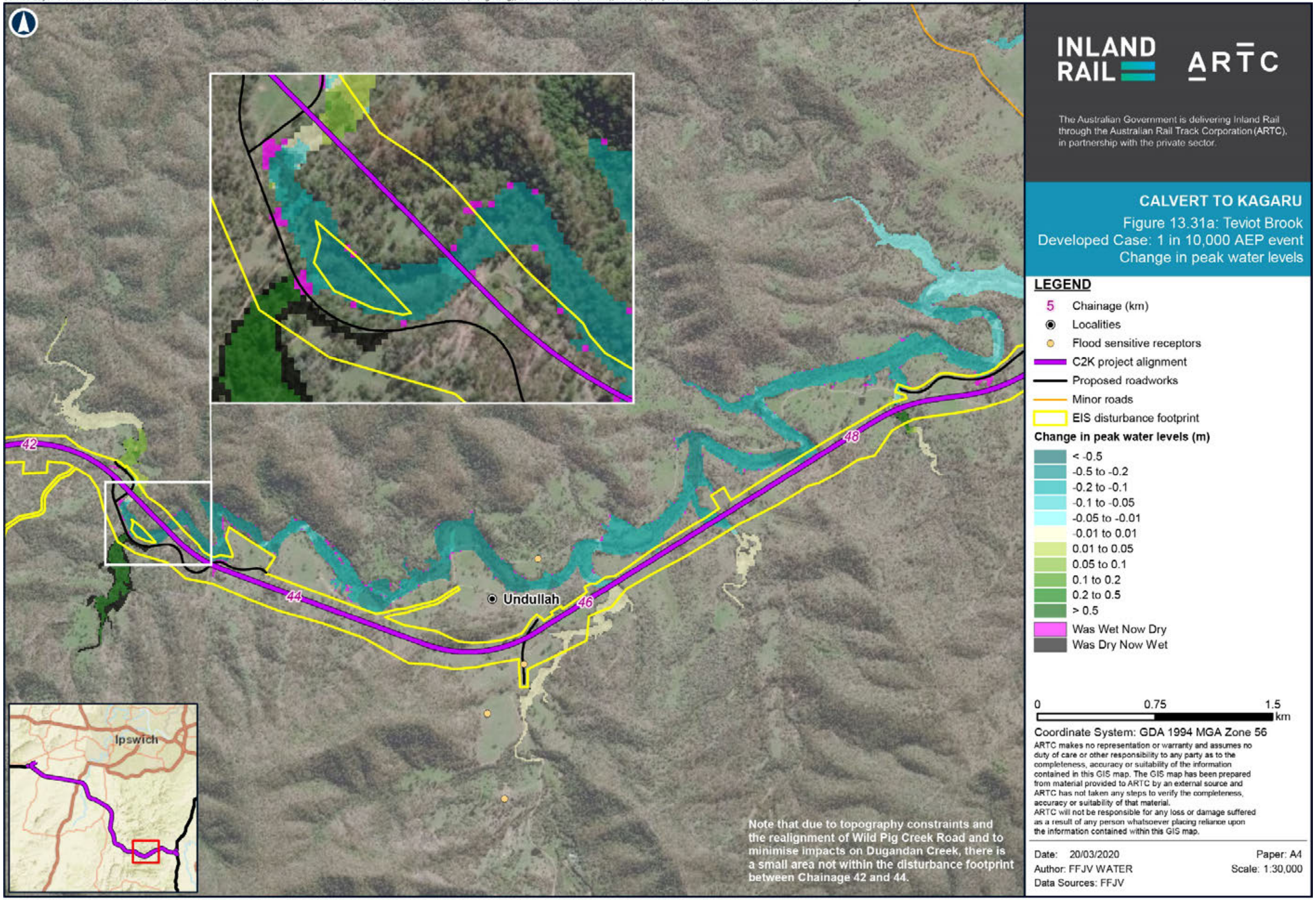

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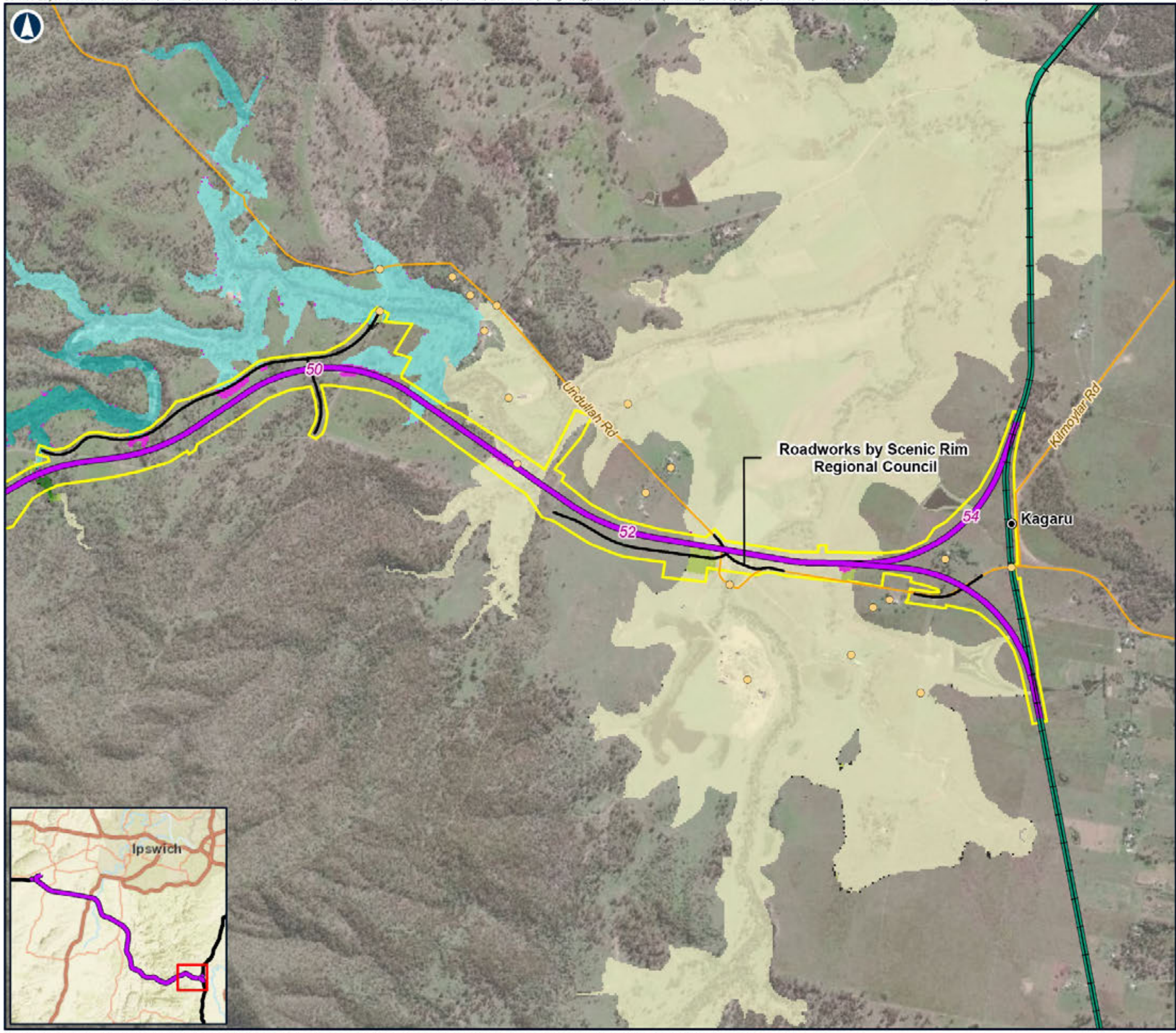

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CALVERT TO KAGARU

Figure 13.31b: Teviot Brook
Developed Case: 1 in 10,000 AEP event
Change in peak water levels

LEGEND

- 5 Chainage (km)
- Localities
- Flood sensitive receptors
- Existing rail
- C2K project alignment
- K2ARB project alignment
- Proposed roadworks
- Minor roads
- EIS disturbance footprint

Change in peak water levels (m)

- < -0.5
- -0.5 to -0.2
- -0.2 to -0.1
- -0.1 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.1
- 0.1 to 0.2
- 0.2 to 0.5
- > 0.5
- Was Wet Now Dry
- Was Dry Now Wet

0 0.75 1.5 km

Coordinate System: GDA 1994 MGA Zone 56

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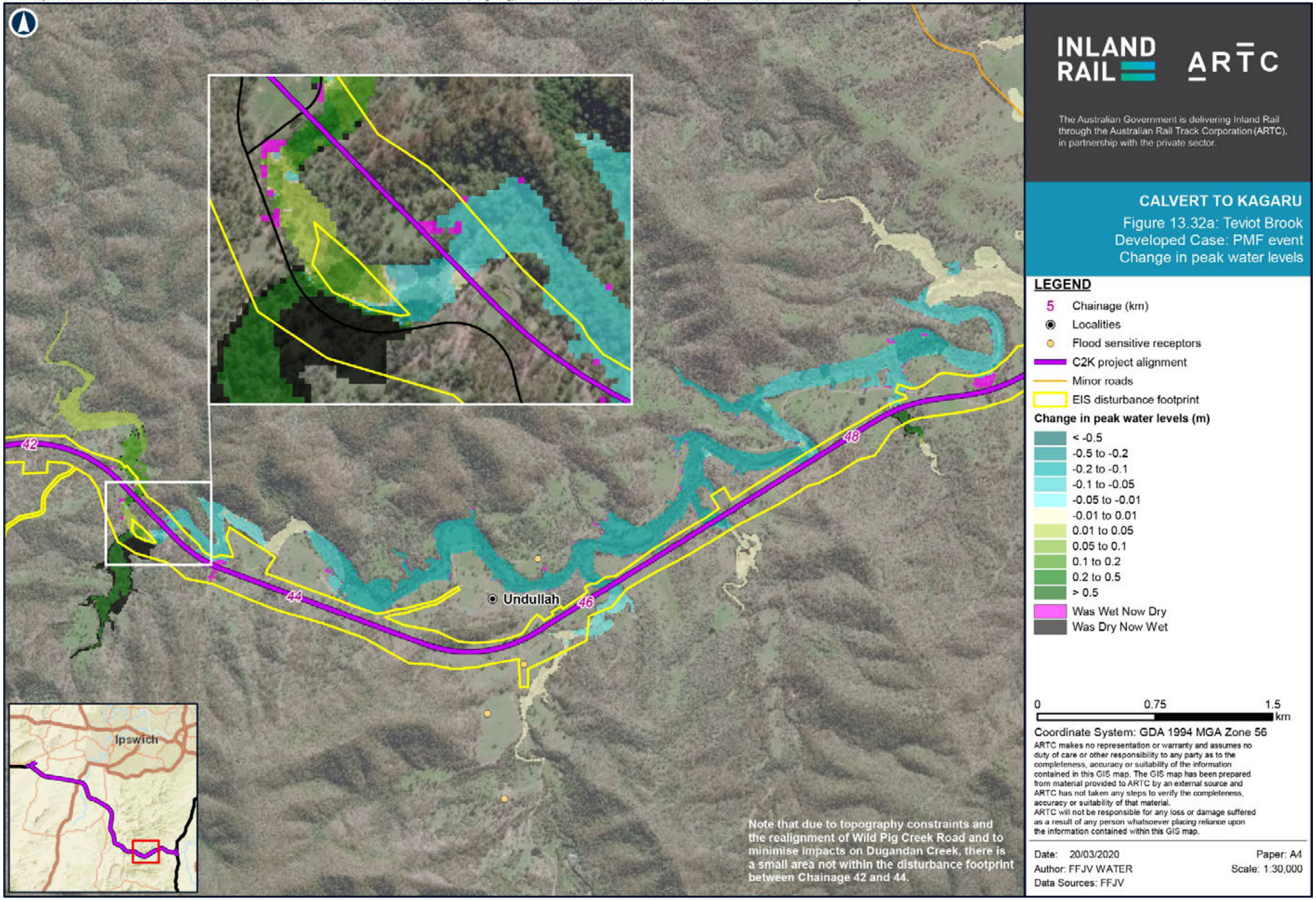

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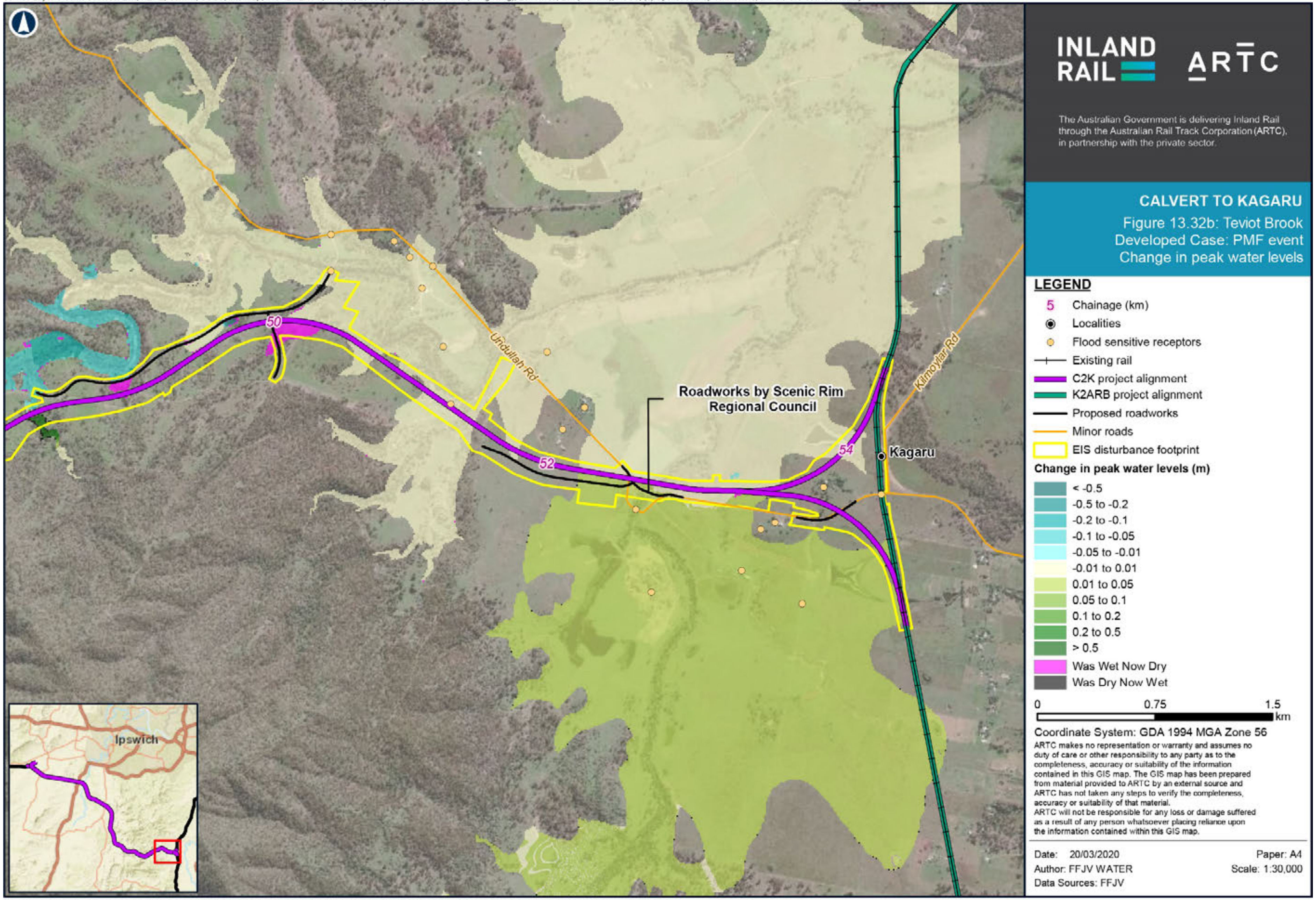

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13.9 Cumulative impacts

Cumulative impacts to the surface water quality and hydrology of the Project will be largely the product of:

- Riparian vegetation loss from vegetation clearing/removal
- Potential impacts to aquatic fauna species both through impacts to water quality and barrier works
- Displacement of flora and fauna species from invasion of weed and pest species
- Reduction in the connectivity of waterways
- Increase in erosion and sedimentation in the waterways
- Increase in litter (waste)
- Saline discharge into proximal waterways
- Increases in surface salinity around alluvial waterways.

The assessment of the significance of cumulative impacts relating to surface water quality is in Chapter 22: Cumulative Impacts, and provided that all of the assessable projects apply appropriate mitigation measures during construction, including CEMPs and salinity management plans, no material cumulative impacts are expected during the construction, operation or decommissioning phases of the Project.

In order to accurately assess the impacts of the Project, the hydrologic and hydraulic assessment of the Project included all existing infrastructure within the hydrology study area as a base case and then introduced the Project infrastructure. It is against this assessment of potential impacts of the developed case (which inherently included existing cumulative impacts) that appropriate mitigation measures were derived.

The significance of cumulative impacts for hydrology is anticipated to be of low significance. Further information on the potential cumulative impact of the Project relating to hydrologic and hydraulic aspects is in Chapter 22: Cumulative Impacts.

13.10 Conclusion

13.10.1 Water quality

The water quality study area is within the Bremer River and Logan River catchments, with several sub-catchments intersecting the Project alignment. Historic and field-assessed water quality was identified as not currently meeting all WQOs for the protection of aquatic ecosystems within each catchment.

All waterways within the water quality study area have been identified as sensitive receptors within the receiving environment that have the potential to be subject to significant impacts. These were nominated as moderate water quality receptors for identification of potential impacts, associated mitigation measures and residual impact after implementation of mitigation. Due to the moderate and high sensitivity of the water quality receptors within the water quality study area, significance of impact was assessed against these criteria.

The construction and operation of the Project has the potential to impact on water quality receptors through:

- Increased debris
- Change to water quality and hydrology
- Increase in salinity
- Increases in erosion and sedimentation
- Increase in contaminants
- Exacerbation of listed impacts above, from inadequate rehabilitation processes.

A significance assessment was undertaken and assessed the residual impact of identified potential impacts after assessment of design considerations and mitigation measures. The assessment identified:

- During the construction phase, the combination of design considerations and mitigation measures relevant to surface water quality would be sufficient to mitigate most potential impacts, such that the residual significance would be low
- For the operational phase, the combination of design considerations and mitigation measures relevant to surface water quality would be sufficient to mitigate most potential impacts, such that the residual significance would be low.

The significant impact assessment has identified that with design considerations and mitigation measures in place, the risk of significance of impact from construction (including pre-construction) and operation activities is low. It is not expected that significant residual impact on surface water quality will be a result of the Project.

13.10.2 Hydrology and flooding

The Project alignment crosses the floodplain of four major waterways, being the Bremer River, Warrill Creek, Purga Creek and Teviot Brook. Detailed hydrologic and hydraulic assessments have been undertaken due to the catchment size and substantial floodplain flows associated with each of these watercourses. Bremer River, Warrill Creek and Purga Creek all form part of the larger Brisbane River system. Teviot Brook is a tributary of the Logan River.

Hydrologic and hydraulic modelling was undertaken for each of these catchments with the models calibrated to multiple historical events using stream gauges records, community feedback and available anecdotal data. Based on this performance, the hydrologic and hydraulic models were considered suitable to assess the potential impacts associated with the Project alignment.

Design event hydrology was developed using the calibrated hydrologic models using ARR 2016 flood flow estimation techniques. The hydraulic models were run for a suite of design events from the 20% AEP event to the 1 in 10,000 AEP and PMF events.

Modelling of the current state of development (Existing Case) was undertaken and details of the existing flood regime were determined for the modelled design events. The proposed works associated with the Project were incorporated into the hydraulic models (Developed Case) and assessment of the potential impacts on the existing flood regime was undertaken. Changes in peak water levels, velocities, flow patterns and flood inundation extents and durations have been identified and mapped.

Consultation with stakeholders, including landholders, was undertaken at key stages, including validation of the performance of the modelling in replicating experienced historical flood events and presentation of the design outcomes and impacts on properties and infrastructure.

At Calvert, the Project alignment deviates from West Moreton Rail Line and then crosses the Bremer River, Warrill Creek, Purga Creek and Teviot Brook floodplains. The Project alignment passes near the localities Calvert, Lanefield, Lower Mount Walker, Ebenezer, Mutdapilly, Purga and Washpool. A number of these localities, including properties and infrastructure, and the QR rail line, are sensitive to flood conditions with flood sensitive receptors identified along the Project alignment.

Flood impact objectives shown in Table 13.7, have been established and used to guide the Project design including mitigation of impacts through refinement of the hydraulic design, including adjustment of the numbers, dimensions and location of major drainage structures. Table 13.51 summarises how the Project design performs against each of the flood impact objectives.

The hydrologic and flooding assessment undertaken demonstrated that the Project is predicted to result in impacts on the existing flooding regime that generally comply with the flood impact objectives. A comprehensive consultation exercise has been undertaken to provide the community with detailed information and certainty around the flood modelling and the Project design. In future stages, ARTC will continue to work with:

- Landholders concerned with hydrology and flooding throughout the detailed design, construction and operational phases of the Project
- Directly impacted landholders affected by the alignment throughout the detailed design, construction and operational phases of the Project
- Local governments, State departments and local flood specialists throughout the detailed design, construction and operation phases of the Project.

TABLE 13.51: FLOOD IMPACT OBJECTIVES AND OUTCOMES

Parameter	Objectives and outcomes				
Change in peak water levels	Existing habitable and/or commercial and industrial buildings/ premises (e.g. dwellings, schools, hospitals, shops)	Residential or commercial/industrial properties/lots where flooding does not impact dwellings/buildings (e.g. yards, gardens)	Existing non-habitable structures (e.g. agricultural sheds, pump-houses)	Roadways	Agricultural and grazing land/forest areas and other non-agricultural land
	⩽ 10 mm	⩽ 50 mm	⩽ 100 mm	⩽ 100 mm	⩽ 200 mm with localised areas up to 400 mm
	Objective: Changes in peak water levels are to be assessed against the above proposed limits. **Outcome:** Generally, the Project design meets the above limits with number of localised areas along the Project alignment where these limits are slightly exceeded. These areas are generally agricultural land or along Washpool Road where the road is being raised as part of the Project design. No flood sensitive receptors are impacted by the changes in peak water levels under the 1% AEP event.				
Change in duration of inundation	**Objective:** Identify changes to time of inundation through determination of ToS. For roads, determine AAToS (if applicable) and consider impacts on accessibility during flood events. **Outcome:** There are localised increases in duration of inundation (ToS) at the same locations where peak water levels are increased. These changes in inundation duration do not affect flood sensitive receptors except for three local roads being Waters Road, Kuss Road and Washpool Road. Waters Road has a +0.2 hrs/yr increase in AAToS which is a negligible change with Kuss Road experiencing an even lower impact. Washpool Road experiences a reduction in AAToS (-0.4 hrs/yr) near Ch 33.81 km due to the roadway being raised as part of the Project design.				
Flood flow distribution	**Objective:** Aim to minimise changes in natural flow patterns and minimise changes to flood flow distribution across floodplain areas. Identify any changes and justify acceptability of changes through assessment of risk with a focus on land use and flood sensitive receptors. **Outcome:** The Project has minimal impacts on flood flows and floodplain conveyance/storage with significant floodplain structures included to maintain the existing flood regime.				
Velocities	**Objective:** Maintain existing velocities where practical. Identify changes to velocities and impacts on external properties. Determine appropriate scour mitigation measures, taking into account existing soil conditions. **Outcome:** In general, changes in velocities are minor, with most changes in velocities experienced immediately adjacent to the Project alignment and no flood sensitive receptors impacted. Scour protection has been specified where the outlet velocities for the 1% AEP event exceed the allowable soil velocities for the particular soil type for each location, which was identified from published soil mapping.				
Extreme event risk management	**Objective:** Consider the risks posed to neighbouring properties for events larger than the 1% AEP event to minimise unexpected or unacceptable impacts. **Outcome:** A review of impacts under the 1 in 2,000 AEP, 1 in 10,000 AEP and PMF events has been undertaken with the existing flood depths and increase in peak water levels at flood sensitive receptors identified on each floodplain. Considering the flood depths that occur, particularly under the PMF event, indicates that the changes in peak water levels would be unlikely to exacerbate flood conditions during extreme events.				
Sensitivity testing	**Objective:** Consider risks posed by climate change and blockage in accordance with ARR 2016. Undertake assessment of impacts associated with Project alignment for both scenarios. **Outcomes:** Climate change—climate change has been assessed in accordance with ARR 2016 requirements with the representative concentration pathway 8.5 (2090 horizon) scenario adopted, giving an increase in rainfall intensity of 18.7 per cent across the catchment areas. The impacts resulting from changes in peak water levels under the 1% AEP event with climate change are generally similar to those seen under the 1% AEP event. Blockage—Blockage of drainage structures has been assessed in accordance with ARR 2016 requirements. The blockage assessment resulted in no blockage factor being applied to bridges and a blockage factor of 25 per cent being applied to culverts. Two blockage-sensitivity scenarios were tested with both 0 per cent and 50 per cent blockage of all culverts assessed. The resulting changes in peak water levels associated with the Project alignment are still localised and do not impact on any flood sensitive receptors.				