CHAPTER 13

Surface Water and Hydrology

NORTH STAR TO NSW/QUEENSLAND BORDER ENVIRONMENTAL IMPACT STATEMENT

INLAND RAIL

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

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13. Surface Water and Hydrology

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 for the North Star to NSW/Queensland border (NS2B) project (the proposal).

For water quality, this includes an assessment of environmental values and water quality objectives (WQOs) pertaining to the use of surface waters and the water-quality triggers that have been established to protect the environmental values. The most stringent applicable trigger values were those that confer the highest protective status, being the protection of aquatic ecosystems (with the exception of arsenic (V), where the more stringent *Australian Drinking Water Guidelines* (National Health and Medical Research Council (NHMRC), 2011) was applied).

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

The existing environment is described and an assessment is made of the potential impacts of the proposal. Potential short- and long-term impacts on local and regional surface waterways have been assessed based on review of the proposal's construction and operational 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 G: Surface Water Quality Technical Report. Full details of the hydrology and flooding assessment are provided in Appendix H: Hydrology and Flooding Technical Report.

The water quality study area for the surface water assessment is defined as the area including and surrounding the proposal disturbance footprint, with the potential to be directly or indirectly affected by the proposal in relation to impacts on water quality or the existing flooding regime.

Within this assessment, the water quality study area reflects the disturbance footprint for the proposal, including the proposed rail alignment, road reconfigurations, laydown areas and stockpile locations. Spatially, it is based on a 1-km buffer from the rail alignment, originally incorporating an area allowing for design changes and with further consideration of the hydrological catchment the proposal passes through.

The objectives and scope of the impact assessment are in line with meeting the requirements of the Secretary's Environmental Assessment Requirements (SEARs), which are detailed in Table 13.1. This assessment fulfils the requirements of the SEARs pertaining to:

- Water quality—SEARs 8. Flooding, Hydrology and Geomorphology—8.1 (d, e, f), SEARs 9. Water Hydrology 9.1, 9.2, 9.3 (a to f), 9.4, and SEARs 10. Water Quality 10.1 (a to i)
- Hydrology, flooding and geomorphology—SEARs 8. Flooding, Hydrology and Geomorphology—8.1 (a to j), 8.2 (a to k) and SEARs 9. Water Hydrology 9.3 (a).

13.2 Secretary's Environmental Assessment Requirements

This chapter has been prepared to address the SEARs as shown in Table 13.1.

TABLE 13.1 SECRETARY'S ENVIRONMENTAL ASSESSMENT REQUIREMENTS COMPLIANCE

	Item 8: Flooding, Hydrology and Geomorphology
Desired performance outcome	The project minimises adverse impacts on property, public safety and the environment resulting from alteration of the water flow characteristics of watercourses and overland flowpaths. Where feasible, the project includes remedial measures to mitigate any adverse water flow impacts, geomorphological impacts or flood safety risks caused by the existing rail infrastructure within the project area. Construction and operation of the project avoids or minimises the risk of, and adverse impacts from, infrastructure flooding, flooding hazards, geomorphological impacts or dam failure.

Current guidelines	NSW Government's Floodplain Development Manual (Department of Natural Resources 2005) PS 07-003 New guideline and changes to Section 117 direction and EP&A Regulation on flood prone land Practical Consideration of Climate Change – Flood risk management guidelines (DECC 2007) Australian Disaster Resilience Handbook 7 – Managing the Floodplain: A Guide to Best Practice in Flood Risk Management in Australia (2017) AS/NZS 3100:2009 Risk Management – Principles and Guidelines

SEARs requirement	EIS section
Item 8.1 The Proponent must:	
a) describe the location and size of all existing and proposed pipes, culverts and bridges, and the locations and annual exceedance probabilities of flows that overtop the existing formation and rail;	Sections 13.5.5, 13.5.6 and 13.8.2 Appendix H: Hydrology and Flooding Technical Report, Sections 8 and 9
b) describe the existing and proposed topography in all areas that could be potentially affected by floodwaters. This includes the spatial location, and the horizontal and vertical dimensions of all spoil mounds;	Sections 13.5.6, 13.8.2, 13.8.3 and Figure 13.2. Spoil mounds—Refer Chapter 6
c) describe and justify the proposed flood planning level for the project including the annual exceedance probabilities of the flood which will overtop the formation and rail. The flood planning level must consider adjacent infrastructure such as road crossings whose flood immunity is determined the project's flood planning level;	Section 13.8.2.10
d) assess the existing hydrology, geomorphology and flooding characteristics of all watercourses within and adjacent to the project area. This includes locating and assessing flowpaths emanating from existing culverts, pipes and bridges under the rail formation, or from overtopping of the existing formation in large storms;	Sections 13.5.4 and 13.5.6. Appendix H: Hydrology and Flooding Technical Report, Section 9. Appendix S: Aquatic Biodiversity Technical Report Section 4.3
e) develop and justify quantitative design limits on potential adverse flooding, hydrological and geomorphological impacts resulting from the project. These are to consider land use and include afflux, velocity, extent, duration, hazard, scour potential, etc;	Section 13.4.3.1, 13.4.3.2 and 13.8.2 Appendix H: Hydrology and Flooding Technical Report, Sections 4.1, 4.2 and 9
f) carry out geotechnical and geomorphological investigations to assess the propensity for scour, erosion and geomorphological changes to occur within any watercourses or overland flowpaths affected by the project;	Section 13.4.2, 13.5.4 and 13.8.2.10
g) consider the impacts of extreme floods up to the probable maximum flood including consideration to flood risks to people and property resulting from failure of the formation or washouts of ballast;	Section 13.6.3 Appendix H: Hydrology and Flooding Technical Report, Section 9
h) prepare preliminary engineering designs of the velocity dissipation or other mitigation works that are proposed to avoid adverse offsite scouring or geomorphological impacts on the adjoining land downstream of the project area, adjacent to locations where pipes, culverts or bridges are proposed or where the rail formation may be overtopped;	Section 13.8.2.4 and 13.8.2.10
i) at locations along the rail route, identify the width of land between the toe of the formation and the downstream boundary of the project area, that is available for the construction of these mitigation works; and	Section 13.8.2.4 and 13.8.2.10
j) where there is insufficient width of project land available for these works, clearly identify the extent of additional land beyond the project boundary that may be required, including the locations where easements over land or acquisition of land may be required.	All within proposal permanent footprint, therefore not required

SEARs requirement	EIS section
Item 8.2 The Proponent must assess and model the pre-construction, during construction and operational impacts of the project on flood behaviour for a full range of flood events up to and including the probable maximum flood (including consideration of the impacts of climate change and differing storm durations). This will include:	Section 13.8.2 and 13.8.3 Appendix H: Hydrology and Flooding Technical Report, Section 9.
a) utilising hydrologic and hydraulic models that are consistent with current best practice and utilise topographic and infrastructure data that is of sufficient spatial coverage and accuracy to ensure the resultant models can accurately assess existing and proposed water flow characteristics;	Appendix H: Hydrology and Flooding Technical Report, Sections 6 and 7
b) having these models independently peer-reviewed with the results published in the Environmental Impact Statement;	Section 13.8.4 Appendix H: Hydrology and Flooding Technical Report (Appendix E)
c) assessing any detrimental increases in the potential flood affectation, scouring or geomorphological changes to other properties, assets and infrastructure, over a full range of flood durations and flood frequencies;	Section 13.8.2 and 13.8.3 Appendix H: Hydrology and Flooding Technical Report, Section 9
d) where the existing rail infrastructure has an adverse flood impact on property or people, the flood assessment must consider the extent to which the project alleviates or exacerbates these existing impacts;	Section 13.8.2.1 Appendix H: Hydrology and Flooding Technical Report, Section 9
e) an assessment of the consistency (or inconsistency) with the applicable Council or the Office for Environment and Heritage floodplain management plans. The requirements of these plans must be discussed with the Office for Environment and Heritage and the Council;	Section 13.8.2.10
f) assessing whether each component of the project is compatible with the flood hazard of the land and the hydraulic functions of flow conveyance, floodway and flood storage;	Section 13.8.2.5 and 13.8.2.10
g) assessing upstream and downstream flow, level, velocity, hazard and scour potential;	Section 13.8.2 and 13.8.3 Appendix H: Hydrology and Flooding Technical Report, Section 9
h) assessing changes in upstream and downstream flowpaths (location, discharges and velocities);	Section 13.8.2 and 13.8.3 Appendix H Hydrology and Flooding, Section 9
i) quantifying and evaluating changes in flood safety risks on private and public land including roads and pathways;	Section 13.8.2.2, 13.8.2.9 and 13.8.2.10 Appendix H: Hydrology and Flooding Technical Report, Section 9
j) assessing any impacts that the project may have upon existing community emergency management arrangements for flooding. These matters must be discussed with the State Emergency Service and applicable Council; and	Section 13.8.2.9 and 13.8.2.10
k) evaluating and social and economic impacts that the project may have on the community as a consequence of changes to flooding, hydrology and geomorphology.	Chapter 23: Socio-economic Impact Assessment

Desired performance outcome	Item 9: Water – Hydrology Long term impacts on surface water and groundwater hydrology (including drawdown, flow rates and volumes) are minimised. The environmental values of nearby, connected and affected water sources, groundwater and dependent ecological systems including estuarine and marine water (if applicable) are maintained (where values are achieved) or improved and maintained (where values are not achieved). Sustainable use of water resources.
Current guidelines	Biodiversity Assessment Method (OEH 2017) Managing Urban Stormwater: Soils and Construction Volume 1 (Landcom 2004) and Volume 2 (A. Installation of Services; B. Waste Landfills; C. Unsealed Roads; D. Main Roads; E. Mines and Quarries) (DECC 2008) NSW Aquifer Interference Policy (DPI 2012a) NSW Sustainable Design Guidelines Version 4.0 (TfNSW 2017) Risk assessment Guidelines for Groundwater Dependent Ecosystems (Office of Water 2012)

SEARs requirement	EIS section
Item 9.1 The Proponent must describe (and map) the existing hydrological regime for any surface and groundwater resource (including reliance by users and for ecological purposes) likely to be impacted by the project, including stream orders, as per the Biodiversity Assessment Method.	In Section 13.5.2.2 key aspects of biodiversity are discussed, and reference made to Appendix S: Aquatic Biodiversity Technical Report, Section 4.3.1
Item 9.2 The Proponent must prepare a detailed water balance for ground and surface water including the proposed intake and discharge locations, volume, frequency and duration, sources, security and licensing requirements.	Section 13.6.2.1
Item 9.3 The Proponent must assess (and model if appropriate) the impact of the construction and operation of the project and any ancillary facilities (both built elements and discharges) on surface and groundwater hydrology in accordance with the current guidelines, including:	Sections 13.5.2.2 and 13.5.2.3 Chapter 7: Construction of the Proposal, Section 7.4
a) natural processes within rivers, wetlands, estuaries, marine waters and floodplains that affect the health of the fluvial, riparian, estuarine or marine system and landscape health (such as modified discharge volumes, durations and velocities), aquatic connectivity and access to habitat for spawning and refuge;	Section 13.6.2.1 Sections 13.8.1.2,13.8.2 and 13.8.3
b) impacts from any permanent and temporary interruption of groundwater flow, including the extent of drawdown, barriers to flows, implications for groundwater dependent surface flows, ecosystems and species, groundwater users and the potential for settlement;	Section 13.6 Appendix N: Groundwater Technical Report
c) changes to environmental water availability and flows, both regulated/licensed and unregulated/rules-based sources;	Section 13.6.2.1
d) direct and indirect increases in erosion, siltation, destruction or riparian vegetation or a reduction in the stability of river banks or watercourses;	Section 13.6.2.2 Sections 13.8.2.4,
e) minimising the effects of proposed stormwater and wastewater management during construction and operation on natural hydrological attributes (such as volumes, flow rates, management methods and re-use options) and on the conveyance capacity of existing stormwater systems where discharges are proposed through such systems; and	Section 13.6.2.2— Wastewater Section 13.8.1.2— Stormwater
f) water take (direct or passive) from all surface and groundwater sources with estimates of annual volumes during construction and operation.	Section 13.6.2.1
Item 9.4 The Proponent must identify any requirements for baseline monitoring of hydrological attributes.	Section 13.8 Appendix G: Surface Water Quality Technical Report

Desired performance outcome	Item 10: Water – Quality The project is designed, constructed and operated to protect the NSW Water Quality Objectives where they are currently being achieved, and contribute towards achievement of the Water Quality Objectives over time where they are currently not being achieved, including downstream of the project to the extent of the project impact including estuarine and marine waters (if applicable).
Current guidelines	NSW Water Quality and River Flow Objectives Using the ANZECC Guidelines and Water Quality Objectives in NSW (DEC 2006) Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC/ ARMCANZ 2000) Approved Methods for the Sampling and Analysis of Water Pollutants in NSW (DECC 2008) Managing Urban Stormwater: Soils and Construction Volume 1 (Landcom 2004) and Volume 2 (A. Installation of Services; B. Wte Landfills; C. Unsealed Roads; D. Main Roads; E. Mines and Quarries) (DECC 2008)

SEARs requirement	EIS section
Item 10.1 The Proponent must:	
a) state the ambient NSW Water Quality Objectives (WQOs) and environmental values for the receiving waters relevant to the project, including the indicators and associated trigger values or criteria for the identified environmental values;	Section 13.3.3
b) identify and estimate the quality and quantity of all pollutants that may be introduced into the water cycle by source and discharge point and describe the nature and degree of impact that any discharge(s) may have on the receiving environment, including consideration of all pollutants that pose a risk of non-trivial harm to human health and the environment;	Section 13.6.2.2 Section 13.6.2.3 Section 13.7.1
c) identify the rainfall event that the water quality protection measures will be designed to cope with;	Section 13.7.1
d) assess the significance of any identified impacts including consideration of the relevant ambient water quality outcomes;	Section 13.8.1.1 Section 13.8.1.2
e) demonstrate how construction and operation of the project will, to the extent that the project can influence, ensure that: - where the NSW WQOs for receiving waters are currently being met they will continue to be protected; and - where the NSW Water Quality Objectives are not currently being met, activities will work toward their achievement over time;	Section 13.8.1
f) justify, if required, why the WQOs cannot be maintained or achieved over time;	Section 13.8.1
g) demonstrate that all practical measures to avoid or minimise water pollution and protect human health and the environment from harm are investigated and implemented;	Section 13.6.1
h) identify sensitive receiving environments (which may include estuarine and marine waters downstream) and develop a strategy to avoid or minimise impacts on these environments; and	Section 13.5.2.2, 13.5.2.4 and 13.7 Chapter 11: Biodiversity Section 11.4.5, Section 11.5.1, Section 11.6
i) identify proposed monitoring locations, monitoring frequency and indicators of surface and groundwater quality.	Section 13.4.1

13.3 Legislation, policy, standards and guidelines

13.3.1 Commonwealth and state legislation

This section describes the legislative, policy and management framework relevant to surface water for the proposal, including:

- Legislative framework that applies to the assessment, within this chapter, of surface water applicable to the proposal, at the Commonwealth, state and local levels, and provides the statutory context for which the surface water quality assessment has been undertaken
- Statutory approvals that may be required as a result of potential impacts to surface water quality, based on consideration of the overall approvals pathway for the proposal
- ARTC's existing management plans and protocols and their relevance to the proposal.

The legislation, policies and guidelines relevant to the proposal with respect to surface water, hydrology and flooding are presented in Table 13.2.

TABLE 13.2 SUMMARY OF LEGISLATION, POLICIES, STRATEGIES OR GUIDELINES

Legislation, policy, strategy or guideline	Relevance to the proposal
Commonwealth	
Water Act 2007 (Cth) (the Water Act)	The Act provides the legislative framework for ensuring that the Murray–Darling Basin, as Australia's largest water resource, is managed in the national interest. This Act applies to the proposal because the proposal occurs within the Murray Darling Basin.
State (NSW)	

Water Management Act 2000 (NSW)	The Act establishes a statutory framework for the sustainable and integrated management of water in NSW. This Act applies to the proposal as the protection, enhancement and restoration of water resources is recognised as a key objective of the act and this needs to be considered in the design process.
	The key objectives are as follows:
	▶ To apply the principles of ecologically sustainable development
	▶ To protect, enhance and restore water sources, their associated ecosystems, ecological processes and biological diversity and their water quality
	▶ To recognise and foster the significant social and economic benefits to the state that result from the sustainable and efficient use of water, including:
	    ▶ Benefits to the environment
	    ▶ Benefits to urban communities, agriculture, fisheries, industry and recreation
	    ▶ Benefits to culture and heritage
	    ▶ Benefits to the Aboriginal people in relation to their spiritual, social, customary and economic use of land and water
	▶ To recognise the role of the community, as a partner with government, in resolving issues relating to the management of water sources
	▶ To provide for the orderly, efficient and equitable sharing of water from water sources
	▶ To integrate the management of water sources with the management of other aspects of the environment, including the land, its soil, its native vegetation and its native fauna
	▶ To encourage the sharing of responsibility for the sustainable and efficient use of water between the government and water users
	▶ To encourage best practice in the management and use of water.
	The main instruments applied to meet these objectives are the Water Management (General) Regulation 2018, Water Sharing Plans and the *NSW Aquifer Interference Policy*, which are discussed further in this section.

Legislation, policy, strategy or guideline	Relevance to the proposal
Water Act 1912 (NSW)	This act is gradually being phased out across NSW and replaced by the *Water Management Act 2000* (NSW). It is relevant where an activity leads to a take from a groundwater or surface water source not currently covered by a water sharing plan. As water sharing plans already apply to the proposal site, the *Water Act 1912* (NSW) does not apply.
Water NSW Act 2014 (NSW)	This act defines the functions and objectives of WaterNSW. The primary objectives relate to management of water supplies, supply of water with appropriate quality, ensuring that works in catchments are managed to protect water quality and health, etc. This act applies to the proposal because the act tasks WaterNSW with the protection and enhancement of water quality in declared catchment areas, including in relation to works within catchments such as those proposed for this proposal.
Water Management (General) Regulation 2018 (NSW)	This regulation details procedural, technical and licensing requirements under the *Water Management Act 2000* (NSW).
Water NSW Regulation 2013 (NSW)	Restricts access to lands immediately adjacent to water storage areas used for drinking-water supplies. Provides for regulatory powers to manage pollution activities that impact water quality. This regulation applies to the proposal as it could be considered a polluting activity.

Protection of the Environment Operations Act 1997 (NSW)	This act provides enforcement powers to the NSW Environment Protection Authority (EPA) to penalise polluting activities that may impact on water quality.
	Key features of this legislation include:
	- Protection of the environment policies
	- Environment protection licensing
	- Regulation of scheduled and non-scheduled activities:
	  - The NSW EPA is the regulatory authority for scheduled activities (activities declared under Schedule 1 of the *Protection of the Environment Operations Act 1997* (NSW))
	  - The NSW EPA is also the regulatory authority for non-scheduled activities, where activities are undertaken by a public authority.
	The proposal will be a scheduled activity (railway systems activities under Schedule 1) during construction and an environment protection licence would be required for this activity.

Draft Floodplain Management Plan for the Border Rivers Valley Floodplain (Department of Industry, 2018)	The Floodplain Management Plan for the Borders River Valley Floodplain is currently being finalised. The plan provides a framework for coordinating and assessing development works on a whole of valley basis. This management plan applies to the proposal because the plan defines management zones within the floodplain and the development constraints within each zone.

13.3.2 Water sharing plans

After the *Water Management Act 2000* (NSW) was introduced, water sharing plans have become the basis for equitable sharing of surface water and groundwater between water users.

Most of NSW is covered by water sharing plans. Where an activity leads to a take from a groundwater or surface water source covered by a water sharing plan, an approval and/or licence is required.

Typically, the *Water Management Act 2000* (NSW) requires:

- A water access licence to take water
- A water supply works approval to construct a work
- A water use approval to use the water.

There are three water sharing plans relevant to groundwater for the proposal site as follows:

- *Water Sharing Plan: NSW Border Rivers Unregulated and Alluvial Water Sources* (Department of Primary Industries (DPI), 2012b)

  This plan is applicable to 13 surface water and 4 alluvial groundwater sources, which are combined within the same plan due to the highly connected nature of these systems (DPI, 2012b). Surface water use within the proposal alignment is restricted to riparian offtake within the Croppa Creek and Whalan Creek watercourses.

- *Water Sharing Plan: NSW Border Rivers Regulated River Water Source* (Department of Water and Energy (DWE), 2009)

  This plan applies to all regulated river sections in the NSW Border Rivers Water Management Area (DWE, 2009), including the section of the Macintyre River at the NSW/QLD border in the northern section of the proposal.

- *Water Sharing Plan: NSW Great Artesian Basin Groundwater Sources* (DWE, 2009b)

  This plan applies to sandstone aquifers of the Great Artesian Basin and includes 5 identified water sources.

13.3.3 Water quality guidelines

13.3.3.1 Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC/ARMCANZ 2000/2018)

The *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (Australian and New Zealand Environment and Conservation Council (ANZECC) and Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ), 2000, 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 ANZECC/ARMCANZ 2000/2018 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.

The ANZECC (2000) Guidelines have recently been revised as the *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZECC & ARMCANZ, 2000). This assessment has been done in accordance with the SEARs, which makes specific reference to ANZECC (2000).

13.3.3.2 Australian Drinking Water Guidelines 2011

The *Australian Drinking Water Guidelines 2011* (National Health and Medical Research Council and Natural Resource Management Ministerial Council (NHMRC & NRMMC, 2011) are intended to provide a framework for good management of drinking water supplies to ensure safety at point of use. They have been developed for use by the Australian community and all agencies with responsibilities associated with the supply of drinking water, including catchment and water resource managers, drinking water suppliers, water regulators and health authorities.

13.3.3.3 New South Wales water quality objectives

For each catchment in NSW, the state government has endorsed the community's environmental values for water, known as water quality objectives (WQOs) (DPI, 2006). The NSW WQOs are based on the environmental values and human uses determined for their waterways by the community and set out long-term goals for consideration when assessing and managing the likely impact of activities on waterways. The WQOs provide goals that help in selecting the most appropriate management options. The guiding principles are that:

- Where the WQOs are being achieved in a waterway, they should be protected
- Where the WQOs are not being achieved in a waterway, all activities should work towards their achievement over time.

The WQOs have indicators to assess whether current conditions of the waterways support the identified values and uses. The WQOs are consistent with the national framework for assessment water quality as set out in the ANZECC/ARMCANZ 2018 (refer Section 13.3.3.1). The WQOs for NSW waterways refer to the 2000 version of the ANZECC/ARMCANZ technical guidelines to assess the water quality to protect these values; these Guidelines were updated in 2018 and it has been assumed that trigger values specified in the updated version now apply.

Twelve WQOs may be applied to waterways, depending on the categorisation of the waterway, and each is based on providing the right water quality for the environment and for the different uses people have for water. They are based on measurable WQOs for protecting aquatic ecosystems, recreation, visual amenity, drinking water and agricultural water. Noting this, objectives for water quality collected under the current proposal have been assessed using local catchment and NSW WQO objectives for the protection of aquatic systems for both uncontrolled streams and regulated watercourses. The WQO of protection of aquatic ecosystems is associated with the most stringent trigger values; therefore, the achievement of this WQO would also result in the achievement of the other relevant WQOs within the proposal.

13.3.3.4 Local water quality objectives

WQOs have been developed for each NSW Catchment Management Authority (CMA) and associated waterways and waterbodies, based on community values and uses for the area, as well as local conditions and waterway characteristics. Achieving each WQO is required to maintain existing good water quality, where present.

The proposal site falls within the Border Rivers–Gwydir CMA and the communities within this region have identified WQOs for rivers within this catchment (DPI, 2006). These values include the provision of water for uses such as drinking water, recreation, agriculture, domestic uses and conservation. The identified values are dependent on the local waterway categorisation, which are, in turn, dependent on the characteristics of the waterway.

Local water quality varies naturally due to a variety of factors, including the soils and slopes of the surrounding land, rainfall patterns, runoff patterns, different land uses and different land management practices. For this reason, the ANZECC/ARMCANZ 2018 Guidelines require that water quality criteria be determined according to the local conditions, using local reference data and risk-based decision frameworks and that this has been implemented through CMA WQOs.

The majority of the creeks and rivers that the proposal site crosses (excluding the Macintyre River) are classified as 'uncontrolled streams' within the Border Rivers catchment. This category covers waterways that are not in the other categories, such as town supply sub-catchments, streams in mainly forested areas and waterways affected by urban development.

The Macintyre River is the only river that the proposal will cross that is not considered an uncontrolled stream and is classified as a 'major regulated river' for catchment management purposes. This category applies to rivers that have large dams supplying irrigation water for substantial distances downstream. Flows are supplemented by releases from dams during the irrigation season, leading to fairly stable and unnaturally high water levels. River flow is substantially reduced during the non- or low-irrigation seasons.

Local WQOs for the watercourses proximal to the proposal were selected to confer the highest protective status. Regional water quality thresholds for the proposal were sourced from the NSW and Queensland Border Rivers catchment plans (due to the river requiring inter-state department management, and Macintyre River-specific management objectives produced by the Department of Environment and Science (Queensland Government) and are further summarised in Appendix G: Surface Water Quality Technical Report.

The WQOs for uncontrolled streams and for major regulated rivers within the proposal site are shown in Table 13.3, Table 13.4 and Table 13.5.

TABLE 13.3 WATER QUALITY OBJECTIVES FOR WATERWAYS WITHIN THE PROPOSAL SITE FROM (DPI, 2006)

WQO	Uncontrolled streams[1]	Major regulated rivers[1]
The protection of:	- Aquatic ecosystems - Visual amenity - Secondary contact recreation - Primary contact recreation - Livestock water supply - Irrigation water supply - Homestead water supply - Drinking water at point of supply—disinfection only - Drinking water at point of supply—clarification and disinfection - Drinking water at point of supply—groundwater - Aquatic foods (cooked)	- Aquatic ecosystems - Visual amenity - Secondary contact recreation - Primary contact recreation - Livestock water supply - Irrigation water supply - Homestead water supply - Drinking water at point of supply—disinfection only - Drinking water at point of supply—clarification and disinfection - Drinking water at point of supply—groundwater - Aquatic foods (cooked)

Table note:

1. The Macintyre River is the only major regulated river affected by the proposal. All other waterways in the vicinity of the proposal are classified as uncontrolled streams.

Key water-quality indicators and related numerical criteria (default trigger values) are based on the following:

- *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZECC/ARMCANZ 2000, 2018):
  - Slightly-to-moderately disturbed ecosystems (freshwater) criteria were used based on identified catchment values and conditions.
- The *Australian Drinking Water Guidelines 2011* (NHMRC & NRMMC, 2011) for arsenic (V), which is the most stringent guideline for this metal.

Local water quality varies naturally due to a variety of factors, including the soils and slopes of the surrounding land, rainfall patterns, runoff patterns, different land uses and different land management practices. For this reason, the ANZECC/ARMCANZ 2000 requires that water quality criteria be determined according to the local conditions, using local reference data and risk-based decision frameworks, and that this has been implemented through catchment WQOs.

The majority of the creeks and rivers that the proposal site crosses (excluding the Macintyre River) are classified as 'uncontrolled streams' within the Border Rivers catchment. This category covers waterways that are not in the other categories such as town supply sub-catchments, streams in mainly forested areas and waterways affected by urban development.

The Macintyre River is the only river that the proposal site will cross that is not considered an uncontrolled stream and is classified as a major regulated river for catchment management purposes. This category applies to rivers that have large dams supplying irrigation water for substantial distances downstream. Flows are supplemented by releases from dams during the irrigation season leading to fairly stable and unnaturally high water levels. River flow is substantially reduced during the non- or low-irrigation seasons.

TABLE 13.4 WATER QUALITY TRIGGER VALUES FOR THE PROTECTION OF AQUATIC ECOSYSTEMS APPLICABLE TO THE PROPOSAL (*ITALICISED* VALUES EXPRESSED AS 50TH PERCENTILE (MEDIAN) OF TEST DATA, RESPECTIVELY)

Sub-catchment	Management intent	Secchi depth (m)	Turbidity (NTU)	Total P (µg/L)	FRP (µg/L)[4]	Chlorophyll-*a* (µg/L)	Total N (µg/L)	Oxidised Nitrogen (µg/L)	Ammonium N (µg/L)	Dissolved Oxygen (% saturation)	pH	TSS[3] (mg/L)	Conductivity (µS/cm)
Mobbindry Creek (Sites 1–3, 13–15)	Moderately disturbed—aquatic ecosystems[1]	n/a	6–50	50	20	5	500	60	20	85–110%	6.5–8.5	25	125–2200
Back Creek (Sites 4–6)	Moderately disturbed—aquatic ecosystems[1]	n/a	6–50	50	20	5	500	60	20	85–110%	6.5–8.5	25	125–2200
Whalan Creek (Sites 7–9)	Moderately disturbed—aquatic ecosystems[1]	n/a	6–50	50	20	5	500	60	20	85–110%	6.5–8.5	25	125–2200
Mid-Macintyre[1] (Sites 10–12)	Moderately disturbed[2]	n/a	*30*	*70*	*20*	*3*	*575*	*10*	*20*	65–110% >5.0 mg/L	*7.4–8.0*	*25*	*245*
Forest Creek (Sites 16–21)	Moderately disturbed—aquatic ecosystems[1]	n/a	6–50	50	20	5	500	60	20	85–110%	6.5–8.5	25	125–2200

Table notes:

1. Source: NSW Water Quality Objectives (Border Rivers objective) and *ANZECC/ARMCANZ 2000 Guidelines*. Lowland river objectives applicable.
2. Source: Draft Water Quality Objectives for Queensland Murray–Darling Basin—Border Rivers Basin (Macintyre–Barwon Floodplain catchment waters—low flow). Sourced from *Healthy Waters Management Plan: Queensland Border Rivers and Moonie River Basins* (DES, 2019) and *Murray–Darling Basin Plan* (2012b) targets—all but dissolved oxygen percentage from the Healthy Waters Management Plan.
3. Total Suspended Solids (TSS) thresholds for watercourses other than Macintyre, as per Macintyre catchment waters
4. Filterable reactive phosphate (FRP) water quality trigger values are below Limit of Reporting (LOR) for laboratory analysis

TABLE 13.5 WATER QUALITY TRIGGER VALUES FOR 95 PER CENT LEVEL OF SPECIES PROTECTION FOR HEAVY METALS AND OTHER TOXIC CONTAMINANTS FOR THE PROPOSAL (BORDER RIVERS CATCHMENT)

Sub-catchment	Arsenic (V)[2] (µg/L)	Cadmium[1] (µg/L)	Chromium (VI)[1] (µg/L)	Copper[1] (µg/L)	Lead[1] (µg/L)	Mercury (µg/L)[3]	Nickel[1] (µg/L)	Zinc[1] (µg/L)	Naphthalene[1] (µg/L) (PAH)
Mobbindry Creek (Sites 1–3, 13–15)	10	0.2	1.0	1.4	3.4	0.06	11	8.0	16
Back Creek (Sites 4–6)	10	0.2	1.0	1.4	3.4	0.06	11	8.0	16
Whalan Creek (Sites 7–9)	10	0.2	1.0	1.4	3.4	0.06	11	8.0	16
Mid Macintyre[1] (Sites 10–12)	10	0.2	1.0	1.4	3.4	0.06	11	8.0	16
Forest Creek (Sites 16–21)	10	0.2	1.0	1.4	3.4	0.06	11	8.0	16

Table notes:

1. Trigger values applies to moderately disturbed watercourses Source: NSW Water Quality Objectives (Border Rivers Objective) (DPI, 2006) and *ANZECC/ARMCANZ 2000 Guidelines*. Lowland river objectives applicable.
2. For arsenic (V), the more stringent *Australian Drinking Water Guidelines* were applied (NHMRC & NRMMC, 2011); 10 µg/L in place of ANZECC's 13 µg/L.
3. Mercury 99% species protection value identified for mercury to account for potential bioaccumulation.

13.3.4 Flood-related standards and guidelines

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

- *AS7637:2014: Railway Infrastructure—Hydrology and Hydraulics* (Standards Australia, 2014)
- *Guide to Road Design Part 5: Drainage—General and Hydrology Considerations* (Austroads, 2013)
- *Australian Rainfall and Runoff: A Guide to Flood Estimation* (Geoscience Australia, 2016)
- *Evaluating Scour at Bridges, Hydraulic Engineering Circular Number 18 (HEC-18), Fourth Edition* (US Department of Transportation, 2001)
- *Hydraulic Design of Energy Dissipaters for Culverts and Channels, Hydraulic Engineering Circular Number 14 (HEC-14), Third Edition* (US Department of Transportation, 2006).

13.4 Assessment methodology

13.4.1 Water quality

The study area for the purposes of the water quality assessment includes the catchments through which the proposal is to be developed. The waterways are within the Border Rivers catchment. Specific focus is given to watercourses in proximity to the proposal, which includes the Macintyre River, Whalan Creek, Mobbindry Creek and Back Creek, Forest Creek, and an unnamed tributary of Mobbindry Creek, which all cross the proposal alignment.

13.4.1.1 Assessment methodology

To assess the surface water quality in the study area and determine potential environmental impacts, the following approach was adopted:

- Desktop and literature review of relevant databases, search area parameters, existing literature and previous study reports
- Field assessment between 20 August to 25 August 2018 to collect surface water samples from water bodies during one round of monitoring
- In-situ water quality field data was collected in addition to samples collected for laboratory analysis. All in-situ water quality field data and laboratory samples were collected by a suitably qualified and experienced environmental scientist.
- Samples were collected from 4 of the proposed 18 aquatic ecology and water quality monitoring locations. It was not possible to collect water samples from all 18 locations due to many being dry and/or inaccessible at the time of the site visit. The location of these sites was initially identified during a gap analysis conducted as part of the desktop phase of the proposal. Sites were located to target watercourses that cross the proposed alignment, with additional sites located upstream and downstream of the alignment crossing.
- A fully serviced and calibrated YSI Professional Plus water quality meter and a TPS WP-88 Turbidity Meter were employed to record the following in-situ water quality parameters:
  - 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)
  - Turbidity (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 *Approved Methods for the Sampling and Analysis of Water Pollutants in NSW* (Department of Environment and Conservation (DEC), 2008). 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/quality control purposes.
- The collected samples were submitted to a National Association of Testing Authorities accredited laboratory (Eurofins) for analysis of the following water quality parameters (where parameters have also been measured in-situ, these results have taken precedence):
  - pH (LOR—0.1 pH units)
  - Suspended solids (LOR—1 mgL^{-1})
  - Turbidity (LOR—1 NTU)
  - Total phosphorus (LOR—0.01 mgL^{-1})
  - Reactive phosphorus (LOR—0.01 mgL^{-1})
  - Speciated nitrogen (ammonia (LOR—0.01 mgL^{-1}), nitrate (LOR—0.02 mgL^{-1}), nitrite (LOR—0.02 mgL^{-1}), organic nitrogen (LOR—0.2 mgL^{-1}), total kjeldahl nitrogen (LOR—0.2 mgL^{-1}), total nitrogen (LOR—0.2 mgL^{1}))
  - Dissolved metals (field filtered): arsenic (V) (LOR—0.001 mgL^{-1}), cadmium (LOR—0.0002 mgL^{-1}), chromium (VI) (LOR—0.001 mgL^{-1}), copper (LOR—0.001 mgL^{-1}), lead (LOR—0.001 mgL^{-1}), mercury (LOR—0.0001 mgL^{-1}), nickel (LOR—0.001 mgL^{-1}), zinc (LOR—0.005 mgL^{-1})
  - Salinity (LOR—20 mgL^{-1})
  - Electrical conductivity (LOR—1 μscm^{-1})
  - Chlorophyll a (LOR—5 ugL^{-1})
  - Polycyclic aromatic hydrocarbons (universal LOR—0.001 mgL^{-1}).

Field and laboratory results were compared against Border Rivers WQOs and trigger values (DPI, 2006), and the *Australian Drinking Water Guidelines 2011* (NHMRC & NRMMC, 2011) as outlined in Section 13.3.3.3.

13.4.1.2 Limitations of assessment

This report has been prepared based on publicly available information and field water sampling results. The description of existing surface water values in this report is primarily a desktop study with most of the data sources being publicly available. These data sources are supplemented by visual observations gained during the water quality sampling field investigations. As such, inherent limitations exist within the current assessment and should be noted.

Limited water quality studies have been undertaken in regard to the proposal area. No water quality studies have been undertaken for environmental assessments in the area. Most data was associated with basic information obtained with watercourse-flow gauging. Further, the limited time available for field sampling has coincided with drought conditions within the proposal area of interest, resulting in limitations to obtaining proposed water quality sampling. During sampling events, no base-flow was evident within most of the watercourses during the first round of monitoring, and no follow-up monitoring was conducted due to prolonged dry conditions continuing from the first round of monitoring. Noting this, median water quality data calculated from observations of Macintyre River follow the field assessment of water quality values and indicate that the field assessment identified typical low-flow conditions, as typically experienced within the catchment.

Given the limited water-quality information available, further monitoring is recommended for the construction phases, as part of the proposal (refer Section 13.9.1).

13.4.1.3 Impact assessment methodology

The surface water quality assessment for the proposal uses a significance-based impact assessment framework to identify and assess proposal-related impacts in relation to environmental receptors.

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

A cumulative impact assessment was undertaken where potential surface water impacts of the proposal were assessed together with existing or planned surrounding activities. The cumulative impact assessment identified a low significance due to the physical distance of each project from the proposal and via adoption and implementation of recommended mitigation measures.

Magnitude and sensitivity criteria are further detailed in Appendix G: Surface Water Quality Technical Report and Appendix H: Hydrology and Flooding Technical Report and summarised further in Chapter 10: Assessment Methodology.

13.4.2 Geomorphology

A general assessment of existing fluvial geomorphological aspects of targeted waterways has been completed. Full details of the assessment are documented in Appendix S: Aquatic Biodiversity Technical Report. This report does not include assessment of all waterways within the study area due to land access constraints (primarily at the northern end of the alignment). The following locations were assessed:

- Whalan Creek—2 sites (major crossing)
- Macintyre River—2 sites (major crossing)
- Mobbindry Creek—3 sites
- Unnamed tributary of Mobbindry Creek—2 sites
- Back Creek—3 sites
- Forest Creek—3 sites.

The assessment of waterways was done in accordance with the Australian River Assessment System (AusRivAS) *Physical Assessment Protocol* (Parsons et al., 2002) and includes factors such as: channel shape and modifications; bank shape and slope; bedform features; bed compaction and stability; sediment matrix and angularity; factors affecting bank stability; type and extent of bars; and riparian zone structure and composition.

This assessment established the existing fluvial geomorphological conditions. To assesses the potential impact of the proposal on the existing flood regime, including the existing geomorphology, detailed hydraulic modelling of the floodplain and waterways was undertaken. Section 13.4.3.3 outlines the assessment methodology with the hydraulic modelling, identifying any changes in peak water levels, flood distribution and/or velocities that may alter the geomorphological conditions. Each of these impacts was quantified and mitigated through the design process. The impact assessment is detailed in Section 13.8.2.

13.4.3 Hydrology and flooding

The proposal design has been guided and refined through the hydraulic design criteria and flood-impact objectives as detailed below.

13.4.3.1 Hydraulic design criteria

Table 13.6 outlines the hydraulic design criteria that have guided the proposal 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 outcomes relative to these design criteria are detailed in Appendix H: Hydrology and Flooding Technical Report.

TABLE 13.6 PROPOSAL HYDRAULIC DESIGN CRITERIA

Performance criteria	Requirement
Flood immunity	Rail line—1% Annual Exceedance Probability (AEP) flood immunity to formation level.
Hydraulic analysis and design	Hydrologic and hydraulic analysis and design to be undertaken based on *Australian Rainfall and Runoff* (ARR 2016) (Geoscience Australia, 2016) and state/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 consideration required due to 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 ensure efficient conveyance and spread of floodwaters.
Sensitivity testing	Consider climate change and blockage in accordance with ARR 2016. Understand risks posed and proposal design sensitivity to climate change and blockage of structures. Consider additional sensitivity options as identified throughout the proposal development and as a result of stakeholder engagement.

13.4.3.2 Flood impact objectives

The impact of the proposal on the existing flood regime was quantified and compared against flood-impact objectives as detailed in Table 13.7. These objectives address the requirements of the SEARs and have been used to guide the proposal design. Acceptable impacts will ultimately be determined on a case-by-case basis, including interaction with stakeholders/landowners through the community engagement process using these objectives as guidance, leading to formal third-party agreements. This will take into account flood-sensitive receptors and land use within floodplain areas.

The flood impact assessment outcomes are outlined in Section 13.8.2 with additional detail in Appendix H: 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
	Changes in peak water levels are to be assessed against the above proposed limits. It is noted that 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 proposal. 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. For roads, determine the average annual time of submergence (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.				

Parameter	Objectives
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 and waterway geomorphology. Determine appropriate mitigation measures, taking into account existing soil and geomorphological conditions. Justify acceptability of changes through assessment of risk with a focus on land use and flood-sensitive receptors.
Hazard[1]	Identify changes to hazard categories and any impacts on external properties. 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 ensure no unexpected or unacceptable impacts.
Climate change and blockage	Consider risks posed by climate change and blockage in accordance with ARR 2016. Undertake assessment of impacts associated with proposal alignment for both scenarios. Consider additional sensitivity options as identified throughout the proposal development and as a result of stakeholder engagement.
Emergency management	Consider the impacts the proposal may have on existing community emergency management arrangements for flooding, as well as changes to flood safety risks on private and public land, including roads and pathways.
Compliance with floodplain management plans	Check to ensure consistency with applicable local governments or the Department of Planning, Industry and Environment (DPIE) floodplain management plans.

Table note:

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

13.4.3.3 Assessment methodology

The hydrology and flooding assessment of the proposal uses a quantitative approach to impact assessment. The assessment methodology was progressively refined as feedback from the community was considered and addressed. The refined methodology involved the following activities:

- Collation and review of available background information, including existing hydrologic and hydraulic models, survey, rainfall and streamflow data, flood photography, calibration information and anecdotal flood-related data. This information was provided from a range of sources, including LGAs, DPIE, landowners and community members. This review established which datasets were suitable to use to support the hydrologic and hydraulic modelling.
- Determination of critical flooding mechanisms for waterways and drainage paths in the study area, i.e. regional flooding versus local catchment flooding
- Adoption of the Department of Planning, Industry and Environment (DPIE) hydrologic and hydraulic modelling as the basis of modelling for the proposal assessment for Border Rivers floodplain:
    - The DPIE hydraulic model includes all constructed and approved structures on the floodplain and is the tool used by DPIE for assessment of proposed works on the floodplain
    - The provided hydraulic model is based on survey data which is a 10 m by 10 m gridded Digital Elevation Model (DEM) derived from Light Detection and Ranging (LiDAR) survey datasets, including the Macintyre 2013 and Gwydir 2013 datasets. Where LiDAR was not available, the dataset was supplemented with the Shuttle Radar Topographic Mission (SRTM) elevation data
    - The grid spacing used in the DPIE hydraulic model is 40 m
    - The provided DPIE model represents existing floodplain levees as a mixture of height limited and height unlimited layers giving a representation of approved levees on the floodplain.

- Update of the DPIE hydrologic model to include the 2011 historical event to support validation of the hydraulic sub-model performance
- Development of a hydraulic sub-model based on the DPIE hydraulic model focused on the study area. This model was also extended beyond Goondiwindi at the request of the community:
  - The sub-model allowed the level of floodplain detail to be increased, improved representation of the proposal alignment and reduced hydraulic model simulation times. The grid spacing used in the hydraulic sub-model was 30 m.
  - For each of the calibration/validation events, the model topography included the best representation possible of existing floodplain levees at the time of each historical flood event.
- Joint calibration of the hydrologic model and hydraulic sub-models including:
  - Validation of the hydrologic model and hydraulic sub-model against the available recorded and anecdotal data for the 1976, 1996 and 2011 historical flood events
  - Extensive community and stakeholder engagement to validate model performance, incorporate stakeholder and community feedback, leading to acceptance of modelling and calibration outcomes.
- Design event modelling including:
  - Update of DPIE hydrologic models to include ARR 2016 design event hydrology. 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
  - Preparation of Existing Case hydraulic sub-model to enable assessment of the proposal alignment and associated works. As part of the community and stakeholder engagement process, feedback identified that the levees represented in the DPIE hydraulic model as being of 'unlimited height', which, while appropriate for the DPIE assessment tool, did not represent the actual levee heights on the floodplain.

    For design of the proposal alignment and mitigation of impacts, it was important that the hydraulic sub-model reflected the topographic reality of the floodplain. As new LiDAR was planned along the rail corridor, it was possible to expand the capture to include a significant portion of the floodplain and to obtain current levee heights on the floodplain. Use of this updated 2019 LiDAR dataset is consistent with the SEARs (Item 8.2 (a)), which requires the use of data of sufficient spatial coverage and accuracy to ensure the resultant models can accurately assess existing and proposed water-flow characteristics; therefore, two Existing Case hydraulic sub-model have been prepared, being:
    - DPIE levees Existing Case—for this scenario the majority of the hydraulic sub-model area was covered by LiDAR collected for the proposal between September 2014 and January 2015. The hydraulic sub-model was set up using these datasets combined with the DPIE representation of floodplain levees.
    - 2019 LiDAR (and levees) Existing Case—used the new LiDAR flown and processed November 2019 to provide a snapshot of current floodplain topography, including current levee heights and floodplain features.
  - Taking account of stakeholder and community feedback, the downstream boundary of the hydraulic sub-model was also extended a significant distance downstream of Goondiwindi. This extension provided flood modelling results around the township and extended the calibration footprint of the modelling and hence increased certainty in the hydraulic sub-model predictions.
  - Simulation of ARR 2016 design events in the hydraulic sub-model for both Existing Cases and comparison to previous studies to confirm drainage paths, waterways, and associated floodplain areas, and established the existing flood regime in the vicinity of the proposal.
- Developed Case modelling including design assessment and refinement using the 1% AEP design event for both the DPIE levees hydraulic sub-model and the 2019 LiDAR hydraulic sub-model, including:
  - Inclusion of proposed rail alignment, drainage structures and associated works into the hydraulic sub-models and simulation of ARR 2016 design events
  - Assessment of impacts of proposal alignment against the flood-impact objectives 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 flood drainage structures under the proposed alignment. Iterations were undertaken using the hydraulic sub-model to achieve a design that met the flood-impact objectives and addressed the SEARs requirements.
  - The performance of the proposal alignment design against the flood-impact objectives has been documented in detail for the 2019 LiDAR hydraulic sub-model. This sub-model topography represents the current topography of the floodplain in which the proposal will be constructed.

- Developed Case modelling for the full range of design events (20% AEP to PMF) and assessment scenarios using the 2019 LiDAR hydraulic sub-model including consideration of:
  - Climate change
  - Blockage of drainage structures
  - Extreme events (1 in 2,000, 1 in 10,000 AEP and PMF events)
  - Flood hazard classifications
  - Emergency management planning and flood safety risk
  - Local government and/or DPIE Floodplain Management Plans including the *Draft Floodplain Management Plan for the Border Rivers Valley Floodplain* (Department of Industry, 2018) requirements
  - Construction accommodation camp and borrow pits during construction phase.
- Ongoing community and stakeholder engagement in accordance with the ARTC *Flood Study Engagement Framework* (2020) to confirm acceptance of the hydraulic sub-model and the proposal design against the flood-impact objectives.

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

13.4.3.4 Stakeholder engagement

Community consultation has been undertaken at key milestones in alignment with ARTC's *Flood Study Engagement Framework*. 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 meetings
- Phone calls and emails to key individual landowners
- Feedback on design flood modelling results—community feedback on preliminary design solutions have been used to make a number of design modifications
- One-on-one consultation with landowners affected by changes in flooding behaviour—this information has been considered as part of the EIS process.

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 landowners 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 landowners within the floodplains upstream and downstream of the proposed rail crossing to gather further anecdotal flood data, which was used to improve the model validation process.

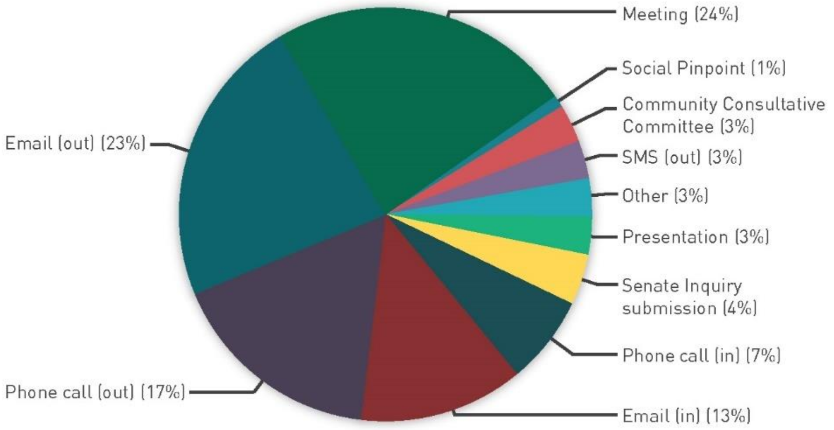
Key stakeholders have been consulted throughout the development, calibration and use of the flood modelling to assess flood impacts relative to their properties. Items discussed include:

- Flood-impact objectives for the project and how acceptable impacts on dwellings, sheds, roads and other floodplain infrastructure have been demonstrated
- Existing 1% AEP event flood levels and depths, flow patterns, velocities and durations of inundation
- Predicted 1% AEP event changes in flood levels/depths, flow patterns, velocities and durations of inundation
- Potential impacts on houses, sheds, roads and other floodplain infrastructure
- Potential mitigation options.

Consultation included the presentation of tables and maps to explain the rationale of the proposed flood-impact limits and their relative impact. The information was presented, and feedback collected, through the engagement methods shown in Table 13.8.

TABLE 13.8 CONSULTATION EVENTS WITH COMMUNITY

Event type	Number of events
Meeting	54
Email (out)	51
Phone call (out)	39
Email (in)	29
Phone call (in)	16
Senate Inquiry submission	8
Presentation	7
Community Consultative Committee	6
SMS (out)	6
Social PinPoint	2
Other	6
Total events	224



Key stakeholders included:

- Moree Plains Shire Council, Gwydir Shire Council, Goondiwindi Regional Council
- Transport for NSW (TfNSW), Murray–Darlin Basin Authority and the DPIE
- Directly affected landowners
- Asset owners
- Local flood specialists
- Community Consultative Committee members
- Toomelah Local Aboriginal Land Council (LALC)
- Broader community.

ARTC will continue to inform impacted landowners during detailed design.

Details of the stakeholder and community sessions undertaken are documented in Chapter 8: Consultation and Appendix D: Consultation Summary Report.

13.4.3.5 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 shown in bold in Table 13.9.

TABLE 13.9 EVENT NOMENCLATURE

Exceedances per year (EY)	AEP (%)	AEP (1 in x)	Average Recurrence Interval
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 per cent chance of an event of that magnitude occurring in any given year.

13.5 Existing environment

13.5.1 Local government areas

The proposal site falls within the Moree-Plains Local Government Area (LGA) and the Gwydir LGA. The Moree Plains LGA covers the area from the NSW and Queensland border to approximately 15 km south of Boggabilla, at which point the proposal alignment moves into the Gwydir LGA. ARTC have acknowledged and discussed the proposal with Goondiwindi Regional Council (GRC), but recognise it is not part of the approval area.

13.5.2 Catchment overview

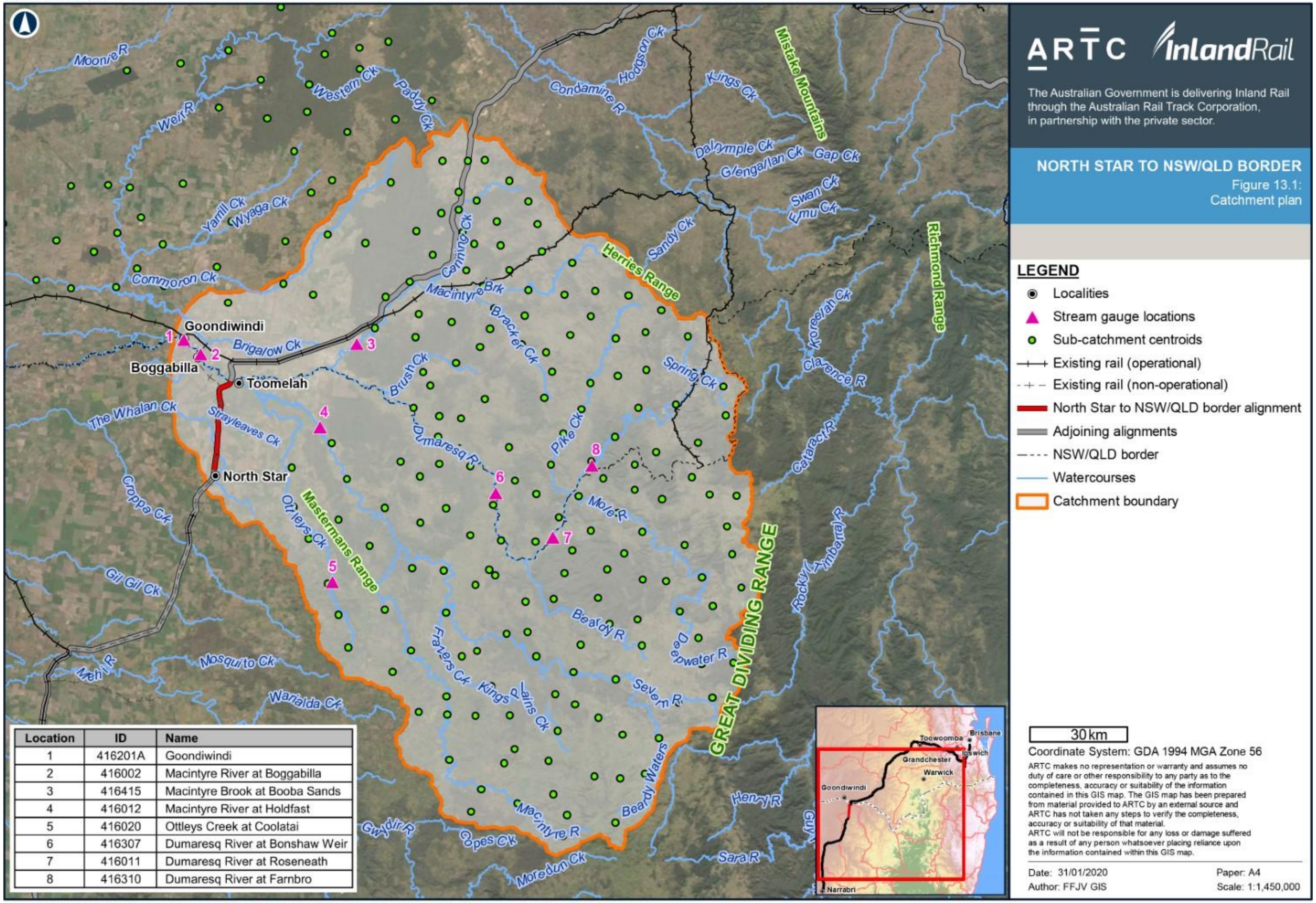
The proposal is located within the Border Rivers Catchment Management Area in NSW. This catchment is one of the northern-most catchments within the Murray–Darling Basin and is made up of a group of waterways that straddle the NSW/QLD border. The rivers of the catchment start at the Great Dividing Range and run westward, gradually merging to become the Barwon River, about 150 km downstream of the proposal, as shown in Figure 13.1.

The waterways within the catchment provide habitat for a range of native fish species including Murray cod (*Maccullochella peelii)*, silver perch *(Bidyanus bidyanus)* and purple-spotted gudgeon (*Mogurnda adspersa)* (refer Chapter 11: Biodiversity and Appendix S: Aquatic Biodiversity Technical Report). The nationally significant Morella Watercourse, Boobera Lagoon and Pungbougal Lagoon are located on the Macintyre River floodplain. These two significant lagoons are located approximately 30 km downstream of the proposal alignment, along the Morella Watercourse.

The Border Rivers catchment has the following key characteristics:

- The area of the catchment where the proposal is located is underlain by the Great Artesian Basin
- Land use is dominated by cattle and sheep grazing in the proposal site, with dryland crops grown on the slopes of the Great Dividing Range
- Irrigated crops (mostly cotton) on the western plains account for 2 per cent of the land area (Murray Darling Basin Authority, 2018)
- The Commonwealth Scientific and Industrial Research Organisation (CSIRO) reported in 2008 that 34 per cent of available surface water was extracted for use, which was considered high in comparison with other catchments in the Murray-Darling Basin (Parsons et al., 2008)
- The *Sustainable Rivers Audit 2* (Murray Darling Basin Authority, 2012) reported that the overall health of the rivers in the Border Rivers catchment was poor. The hydrology of the river system was rated as good; the fish community, macroinvertebrate community and physical form was rated as moderate; and the riverine vegetation was rated as poor.
- Surface water is used for stock watering, irrigation, drinking water, household use, recreation (primary and secondary) as well as for environmental and aesthetic purposes (Green, et al., 2012).

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



Location	ID	Name
1	416201A	Goondiwindi
2	416002	Macintyre River at Boggabilla
3	416415	Macintyre Brook at Booba Sands
4	416012	Macintyre River at Holdfast
5	416020	Ottleys Creek at Coolatai
6	416307	Dumaresq River at Bonshaw Weir
7	416011	Dumaresq River at Roseneath
8	416310	Dumaresq River at Farnbro

Map by: DTH Z:\GIS\GIS_270_NS2B\Tasks\270-IHY-201909261018_SurfaceWaterEIS\270-IHY-201909261018_ARTC_Fig13.01_CatchmentPlan_A4L.mxd Date: 29/01/2020 10:30

13.5.2.1 Climate

The proposal site is located in northern NSW. This area is classified as sub-tropical using the Koppen classification (Bureau of Meteorology (BoM), 2018a). Key characteristics relating to the climate of the catchment are as follows:

- The proposal site receives an average of 350 to 650 mm of rainfall each year with a low degree of variability. Rainfall primarily occurs in summer, with rain significantly increasing from October and with rain averaging around 100 mm per month in the summer months (Green et al., 2012). The area has an average of 50 days a year with rainfall greater than 1 mm (BoM, 2018a). Monthly rainfall data was sourced from the New Kildonan TM meteorological station located downstream of the Dumaresq–Macintyre River confluence (<5 km from the alignment) (BoM, 2018b). Rainfall for 2018 was typically lower than the long-term average (2001 to 2017), with the first half of 2018 demonstrating rainfall below 75 per cent of typical rainfall. The preceding 3-month period before the field assessment demonstrated rainfall at 10–21 per cent of average rainfall (May to July 2018). The area had been declared as drought affected in August 2018 (DPI, 2018a).
- The total average pan evaporation is approximately 1,800 to 2,000 mm per annum (BoM, 2018a)
- The mean monthly maximum temperature is between 18 degrees (July) and 34 degrees (January) Celsius (˚C), the mean monthly minimum temperature is between 6 ˚C (July) and 20 ˚C (January) (BoM, 2020).

13.5.2.2 Watercourses and waterbodies

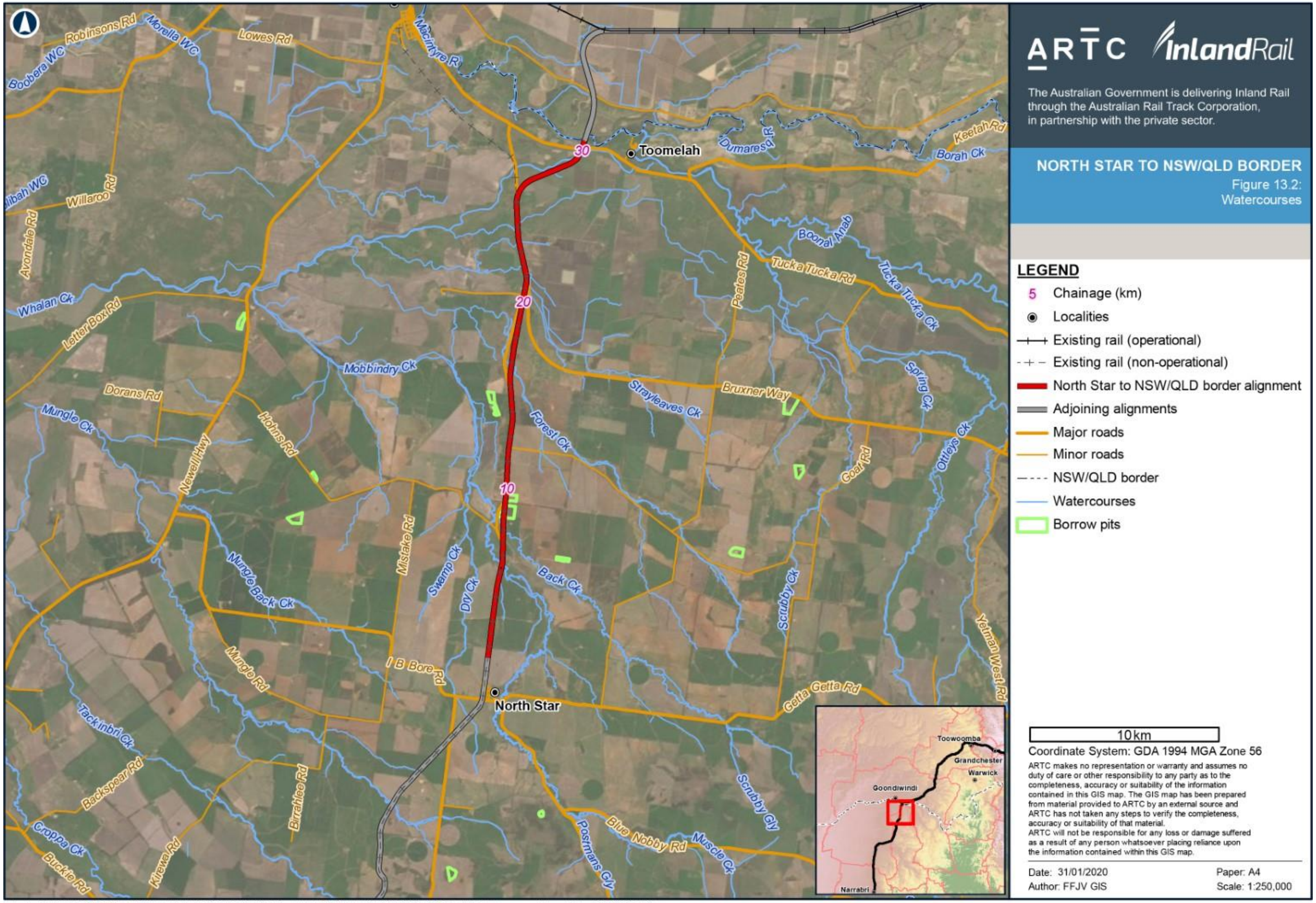
A number of watercourses and waterbodies occur in and around the proposal site as shown in Figure 13.2. This network of waterways is referred to as the Border Rivers and they traverse the Border Rivers Valley Floodplain. There have been many major floods in the last 40 years, including February 1976, which is considered the largest flood event that has been experienced in most areas of the floodplain. The Borders River Valley drains slowly due to the slow-moving nature of floodwaters across the flat terrain of the floodplain.

The proposal site crosses several anabranch streams of the Macintyre River, including Whalan Creek, that convey significant portions of the flood flow during moderate-to-major flood events. In addition, there are several smaller local creeks that cross the proposed alignment, including Forest Creek, Back Creek and Mobbindry Creek.

Key features of the waterways include:

- The Macintyre River, which is a perennial waterway within the proposal site with a well-vegetated riparian flood plain on either side of the river. It has high ecological value as a Class 1 Major Fish Habitat and is known to support threatened species such as the Murray cod (*Maccullochella peelii*), silver perch *(Bidyanus bidyanus)* and purple-spotted gudgeon (*Mogurnda adspersa)*. The Macintyre River is part of the Darling River Endangered Ecological Community
- Whalan Creek, which is an ephemeral waterway, larger than other creeks in the area and with a well-defined channel that is likely to flow seasonally. It is mapped as Class 2 Moderate Fish Habitat and is known to support fish populations
- Mobbindry Creek and Back Creek, which are ephemeral waterways with well-defined channels, with fringing rushes and sedges present. Both waterways are mapped as Class 4 Unlikely Fish Habitat
- An unnamed tributary of Mobbindry Creek, which is ephemeral, it is classified as Class 4 Unlikely fish habitat
- Forest Creek, which is an ephemeral, highly modified waterway with a poorly defined channel and limited or poor riparian vegetation. It is classified as Class 4 Unlikely Fish Habitat.

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



Map by: DTH Z:\GIS\GIS_270_NS2B\Tasks\270-IHY-201909261018_SurfaceWaterEIS\270-IHY-201909261018_ARTC_Fig13.02_Watercourses_A4L.mxd Date: 29/01/2020 10:29

There is one Endangered Ecological Community listed under the *Biodiversity Conservation Act 2016* (NSW): The Darling River Endangered Ecological Community. All of the waterways that the proposal site crosses are considered 'uncontrolled streams', with the exception of the Macintyre River, which is classified as a 'major regulated river' for catchment management purposes.

13.5.2.3 Licensed water users

Licensed water usage from unregulated and alluvial groundwater sources proximal to the proposal alignment throughout the 2018–2019 reporting period indicates that both surface water takes and groundwater use are important water sources in this catchment (described in Chapter 14: Groundwater). Surface water use within the proposal alignment is restricted to riparian offtake within the Croppa Creek and Whalan Creek watercourses. Licensed groundwater use within 5 km of the proposal area is separated into two broad regions—the northern section and the southern section of the proposal alignment (Border Rivers Alluvial Aquifer and Eastern Recharge Groundwater Sources, respectively) with licensed water usage from both sources approximately 485 and 17,487 ML/year respectively (WaterNSW, 2018).

13.5.2.4 Sensitive environmental areas

Identified sensitive environmental areas for the proposal include wetlands areas, identified fish habitat and groundwater dependent ecosystems (GDEs) within receiving waters. Sensitive environmental areas are those areas specifically protected by legislative framework. For further detail refer to Appendix S: Aquatic Biodiversity Technical Report. The following section provides a summary of sensitive environmental areas known within the water-quality study area.

Wetlands

There are no Wetlands of International Importance (Ramsar wetlands) within 10 km of the proposal site.

A wetland complex consisting of Morella Watercourse, Pungbougal Lagoon and Boobera Lagoon is part of a remnant channel of the Macintyre River south of Goondiwindi. This wetland complex is listed as a site of national importance in the Directory of Important Wetlands in Australia. It is not located within the proposal site—the wetland system is at a minimum of 8 km downstream of the proposal site, and hydraulically connected only during flood events.

The proposal site passes through, or in the vicinity of, the several aquatic GDEs (refer Table 13.10).

TABLE 13.10 SUMMARY OF AQUATIC GROUNDWATER DEPENDENT ECOSYSTEMS

Chainage	GDE category	Aquatic GDE description
Ch 5.70 km	Moderate	A narrow moderate potential aquatic GDE is identified in Mobbindry Creek. Proposed construction at this location is cut and fill. Classified ecosystem type is *river*.
Ch 28.00 km	High	A high potential aquatic GDE is identified at Malgarai Lagoon, located 1 km to the southeast of the alignment and 2.5km south of the Macintyre River. Classified ecosystem type is *wetland*. No construction activity in proximity to this feature.
Ch 30.50 km	Moderate	A moderate potential aquatic GDE is identified within the active Macintyre River channel and will be crossed by the alignment via a cut and fill as well as a bridge structure. Classified ecosystem type is *wetland*.
Ch 30.50 km	High	High potential aquatic GDEs are identified 2.5 km east of the alignment where it intersects the Macintyre River. No construction activities proposed in proximity to this GDE. Classified ecosystem type is *wetland*.

Source: BoM GDE Atlas (B0M, 2018c)

Fish habitat

Aquatic habitat is discussed in detail in Appendix S: Aquatic Biodiversity Technical Report with a summary presented here. 'Class' refers to a classification for fish passage, and 'type' refers to habitat sensitivity from the Fisheries NSW Policy (Fairfull & DPI, 2013) and *Guidelines for Fish Habitat Conservation and Management* (Fairfull & DPI, 2013):

- The Macintyre River is a perennial waterway within the proposal site with a well-vegetated riparian flood plain on either side of the river. It is known to support threatened species such as the Murray cod (*Maccullochella peelii*), silver perch (*Bidvanus bidvanus*) and purple-spotted gudgeon (*Mogurnda adspersa)*. The Macintyre River is part of the Darling River Endangered Ecological Community. It has high ecological value as a Class 1 Major Fish Habitat and Type 1 Highly Sensitive Fish Habitat.
- Whalan Creek is an anabranch of the Macintyre River, an ephemeral waterway, larger than other creeks in the area and with a well-defined channel that is likely to flow seasonally. It is known to support fish populations and is mapped as Class 2 Moderate Fish Habitat and Type 1 Highly Sensitive Fish Habitat.
- Mobbindry Creek and Back Creek are ephemeral waterways with well-defined channels that have fringing rushes and sedges present. They are ephemeral with some semi-permanent pools. Breeding or feeding habitat is available for some aquatic species. Both waterways are mapped as Class 4, Unlikely Fish Habitat, but since they are mapped by the DPI fish habitat maps as possible habitat for eel-tailed catfish, the waterways are considered Type 1 highly sensitive fish habitat.
- Forest Creek is an ephemeral, highly modified waterway with a poorly defined channel and limited or poor riparian vegetation; it is classified as Class 4 Unlikely Fish Habitat and Type 3 Minimal Sensitivity Fish Habitat
- An unnamed tributary of Mobbindry Creek, which is ephemeral, is classified as Class 4 Unlikely Fish Habitat and Type 3 Minimal Sensitive Habitat.

These habitats would be sensitive to the following key threatening processes: degradation of the riparian zone, clearing of vegetation and the use of chemicals that impact on water quality. These impacts have the potential to occur during the construction phase of the proposal, with some continuing risk during operation (refer Section 13.5). Impacts to the Darling River EEC are considered in detail in Appendix S: Aquatic Biodiversity Technical Report.

13.5.2.5 Salinity hazard

Salinity is a major land degradation issue and can impact on land salinisation, instream salt load and instream salt concentration (DPI, 2012a). The CMAs within NSW are required to develop Catchment Action Plans and in 2012/ 2013 a salinity tool was developed for integration into these plans. As part of the development of this tool, areas within each CMA were given a salinity hazard ranking based on a number of variables, such as salt stores, salinity outbreaks, water quality, salt loads, onsite and offsite impacts, presence of acid sulfate soils (ASS), presence of highly sodic soils, aquifer systems, ground water quality and ground water depth (DPI, 2013b).

The proposal site passes through an area with a very high salinity hazard ranking from North Star northwards for approximately 15 km (refer Figure 13.3) DPI determined that this is a result of:

- Flat-lying sediments and soils with a very high salt store
- Semi-confined shallow aquifers containing marginal to saline groundwater
- The area responding climatically and seasonally, with large saline sites developing across large sections of the landscape after wet periods
- The heavy textured soils containing a very high salt store
- Soil textures changing downslope, initiating salinity development.

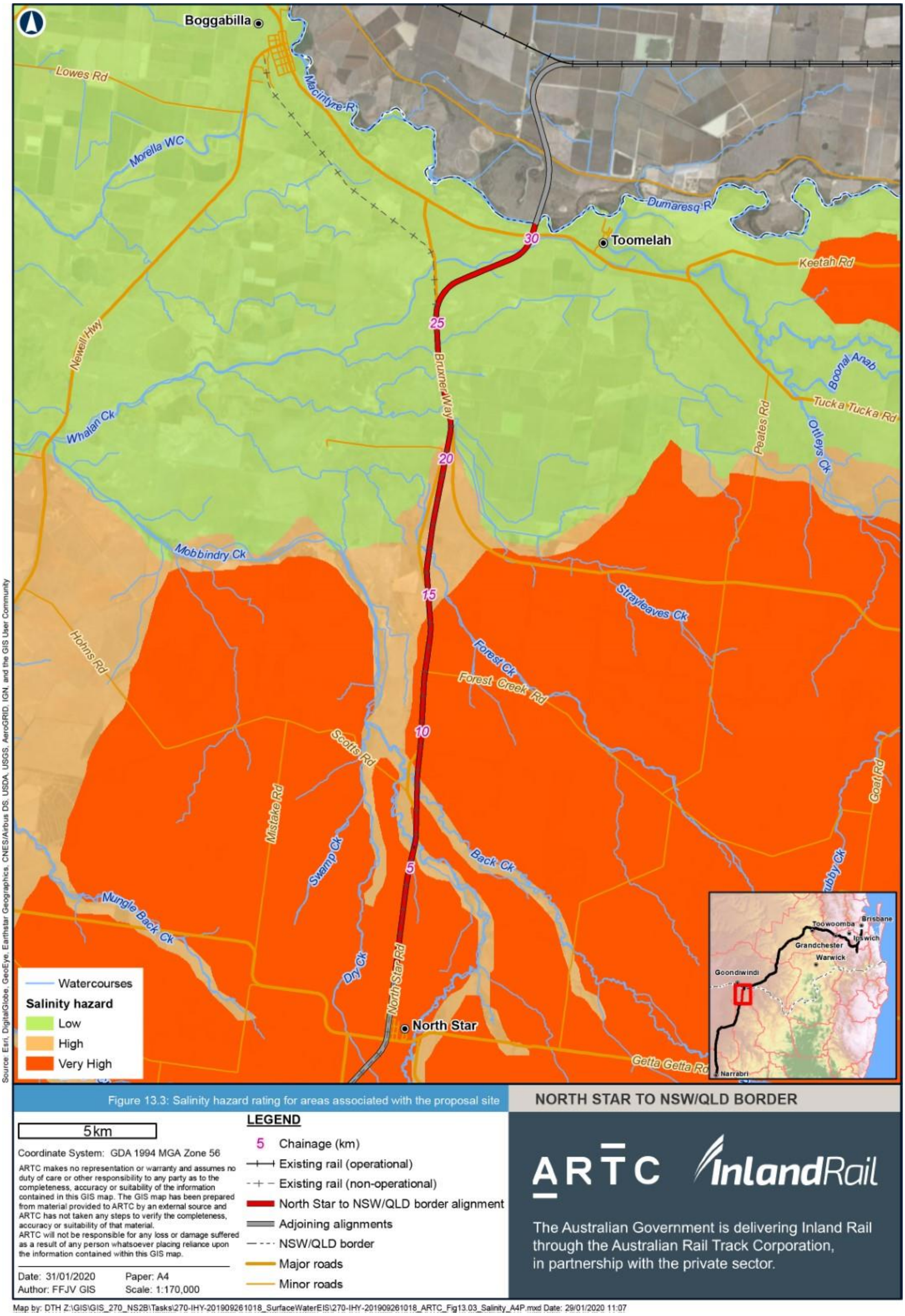


FIGURE 13.3 SALINITY HAZARD RATING FOR AREAS ASSOCIATED WITH THE PROPOSAL SITE

The risk of salinity development within the proposal alignment is largely restricted to interaction between agricultural land management practices and climatic/seasonal events (DPI, 2013b). Targeted salinity hazard and the corresponding resilience statement of the landscape by NSW DPI notes that salinity increases are realised within high salinity risk areas proximal to the proposal, due to soil health issues and intensive cropping, with marginal-saline semi-confined shallow aquifers. North of the 'very high' salinity hazard ranking area, the proposal site passes through areas with low salinity hazard ranking, noting that the area in the vicinity of named creeks and rivers has a high salinity hazard ranking (DPI, 2013b).

Effects on surface water systems (discharge points) would be expected, with development of salinity issues due to the interface between the semi-confined aquifers and watercourses. Noting this, the technical groundwater assessments indicate that the watercourses appear to be in a losing condition to groundwater systems and, therefore, the highest salinity risks would be expected to occur in periods of high rainfall, and associated increases in groundwater level (when groundwater increases to within 2 m of ground surface).

Between North Star and Chainage (Ch) 20.0, a very high-risk ranking exists along the proposal site and is associated with the flat-lying Jurassic-aged strata and residual soils of the Kumbarilla Beds and the Walloon Coal Measures (DPI, 2013b). These high-risk areas are particularly evident where stratigraphic changes or breaks in slope occur.

Spikes in salinity are known to occur in drainage systems, especially during wet climatic cycles, when the local system becomes saturated (DPI, 2013b). During such conditions, unconfined, shallow aquifers, such as the alluvium within Mobbindry and Back creeks, could experience spikes in salinity from surface water recharge as a result. Increases in recharge from irrigation also have the potential to increase salinity risks in these high-risk areas.

Saline soils can pose a risk to surface waters. A key threatening process to surface water could result from the direct exposure of disturbed saline soils to surface runoff, and the consequent entrainment of those salts to the receiving environment. This can lead to a decline in water quality from increased salt loads and localised electrical conductivity (EC) increases (DPI, 2013b).

Noting that sensitive receiving environments are proximal to the low salinity hazard areas at the northern section of the proposal alignment, salinity issues may arise during proposal works from highly localised risk areas (below resolution of available salinity hazard risk mapping).

Chapter 15: Land Resources and Contamination, provides further information on the potential impacts resulting from salinity hazards.

13.5.3 Surface water quality and existing conditions

13.5.3.1 General conditions and observations

A number of watercourses and waterbodies occur within the proposal site. The full geomorphic assessment (using the AusRivAS assessment methodology) is presented within the Existing Aquatic Environment section of Appendix S: Aquatic Biodiversity Technical Report.

The general conditions and observations at each of the field assessment sites (refer Figure 13.4 for locations) during the August 2018 site visit were limited to dry conditions. These are described in Table 13.11. The majority of sites assessed during the August 2018 field survey demonstrated low flow or dry conditions and are likely to be an effect of a lack of substantial preceding rainfall (< 45 mm) in the 111 days preceding the field survey period. Only the Macintyre River was flowing, and sampling from other sites was limited to isolated pools. Water quality data was derived from the field assessment and electrical conductivity data derived from interrogation of water-gauging stations on relevant watercourses, the Dumaresq River and Macintyre River upstream from the proposal (DPI, 2018b) are shown in Table 13.12 to Table 13.13. Sample collection dates and times can be found on the field data sheets shown in Appendix G: Surface Water Quality Technical Report (Appendix B).

TABLE 13.11 GENERAL WATER QUALITY SITE CONDITION DURING AUGUST 2018 SURVEY PERIOD

Site number	Surface water body	Description	Flow at assessment	Sample collection	Site condition
1	Mobbindry Creek	Low-gradient stream	Dry at assessment	No water chemistry	Channel form was varied but was expected to be dominated by run habitat with some pools present under base flow conditions. Riparian vegetation disturbed with overstorey, understorey and trailing bank vegetation present. Proximal floodplain is broad and undefined. Evidence of stock pressure.
2	Mobbindry Creek				
3	Mobbindry Creek				
4	Back Creek	Low-gradient stream	Dry at assessment	No water chemistry	Channel form appears that it would be expected to be dominated by run habitat under base flow conditions. Riparian vegetation disturbed with overstorey, understorey and trailing bank vegetation present. Proximal floodplain is broad and undefined. Evidence of stock pressure and artificial features.
5	Back Creek	Low-gradient stream	Low flow/Deep pool	Full assessment	
6	Back Creek	Low-gradient stream	Dry at assessment	No water chemistry	
7	Whalan Creek	Low-gradient stream	Dry at assessment	No water chemistry	Observed channel form would be expected to be split between pool and run habitat (under base flow conditions). Highly disturbed riparian vegetation. Proximal floodplain is broad and undefined. Evidence of stock pressure and artificial features.
8	Whalan Creek	Not assessed			
9	Whalan Creek	Low-gradient stream	Dry at assessment	No water chemistry	
10	Macintyre River	Not assessed			Observed channel would be expected to be dominated by run and pool habitat (under base flow conditions). Riparian vegetation disturbed but well represented. Proximal floodplain appears a matrix of remnant channels and scroll systems. Evidence of human infrastructure impact.
11	Macintyre River	Major low-gradient river	Low flow	Full assessment	
12	Macintyre River	Major low-gradient river	Low flow	Full assessment	
13	Unnamed tributary of Mobbindry Creek	Not assessed			Observed channel would be expected to be dominated by channelised run habitat (under base flow conditions). No riparian vegetation associated with watercourse. Proximal floodplain is broad and undefined. High degree of hydrological impact from artificial impacts, including in-stream dam and watercourse channelisation.
14	Unnamed creek	Modified creek	Dry at assessment	No water chemistry	
15	Unnamed creek	Low-gradient stream	Dry at assessment	No water chemistry	
16	Forest Creek	Undefined floodway	Isolated pool	Full assessment	Variable channel form due to high degree of human impact. Disturbed riparian associated with watercourse. Proximal floodplain is broad and undefined but impacted by infrastructure. High degree of hydrological impact from artificial impacts, including in-stream dam and watercourse diversion.
17	Forest Creek	Shallow floodway	Dry at assessment	No water chemistry	
18	Forest Creek	Undefined floodway			

TABLE 13.12 WATER QUALITY SITE DATA MEASURED *IN-SITU* FROM WATERCOURSES WITHIN PROPOSAL SITE (OMISSION OF NON-ASSESSED SITES) AND DATA DERIVED FROM THE NSW WATER QUALITY MONITORING PORTAL[1,2]

Site	Watercourse	Turbidity (NTU)	DO (mg/L)	DO (% saturation)	pH	Electrical conductivity (µs/cm)[1,2]	Water temperature (°C)	Salinity (g/L or PSU)	Alkalinity (mg/L)
5	Back Creek	119 (71)	3.9 (8.5)	34 (92)	7.2 (7.7)	261 (320) [1]	8.3	0.12	35 (71)
11	Macintyre River	13 (6.8)	9.4 (9.2)	90 (100)	7.9 (8.3)	429 (520) [1]	11.7	0.21	65 (200)
12	Macintyre River	13 (4.1)	8.8 (9.3)	84 (100)	7.7 (8.2)	410 (490) [1]	12	0.2	55 (200)
16	Forest Creek	75 (40)	9.3 (9.2)	97 (100)	8.2 (8.6)	516 (630) [1]	15.7	0.25	90 (278)
Water quality trigger values									
Sites 1–9, 13–21	Back Creek, Forest Creek	<50	-	85–110	6.5–8.5	125–2200	-	-	-
Sites 10–12	Macintyre River	<30	-	65–110	7.4–8.0	245	-	-	-

Table notes:
NTU = Nephelometric Turbidity Units
mg/L = milligrams per litre
µs/cm = microsiemens per centimetre
Highlighted orange colour where value is above WQO or outside WQO range where applicable. Where available, laboratory data is shown in brackets for comparison.
1. Guideline derived by NSW DPI from values recorded at DPI (NSW) Water Gauging Station Macintyre River at Holdfast. Long-term average electrical conductivity (µs/cm corrected for 25°C) June 2002 to November 2018 = 294; Max = 643.7 (total n = 5903).

TABLE 13.13 LABORATORY RESULTS FOR WATER QUALITY MONITORING SITES. HIGHLIGHTED DENOTES PARAMETERS THAT EXCEEDED RELEVANT WATER QUALITY OBJECTIVES THRESHOLD

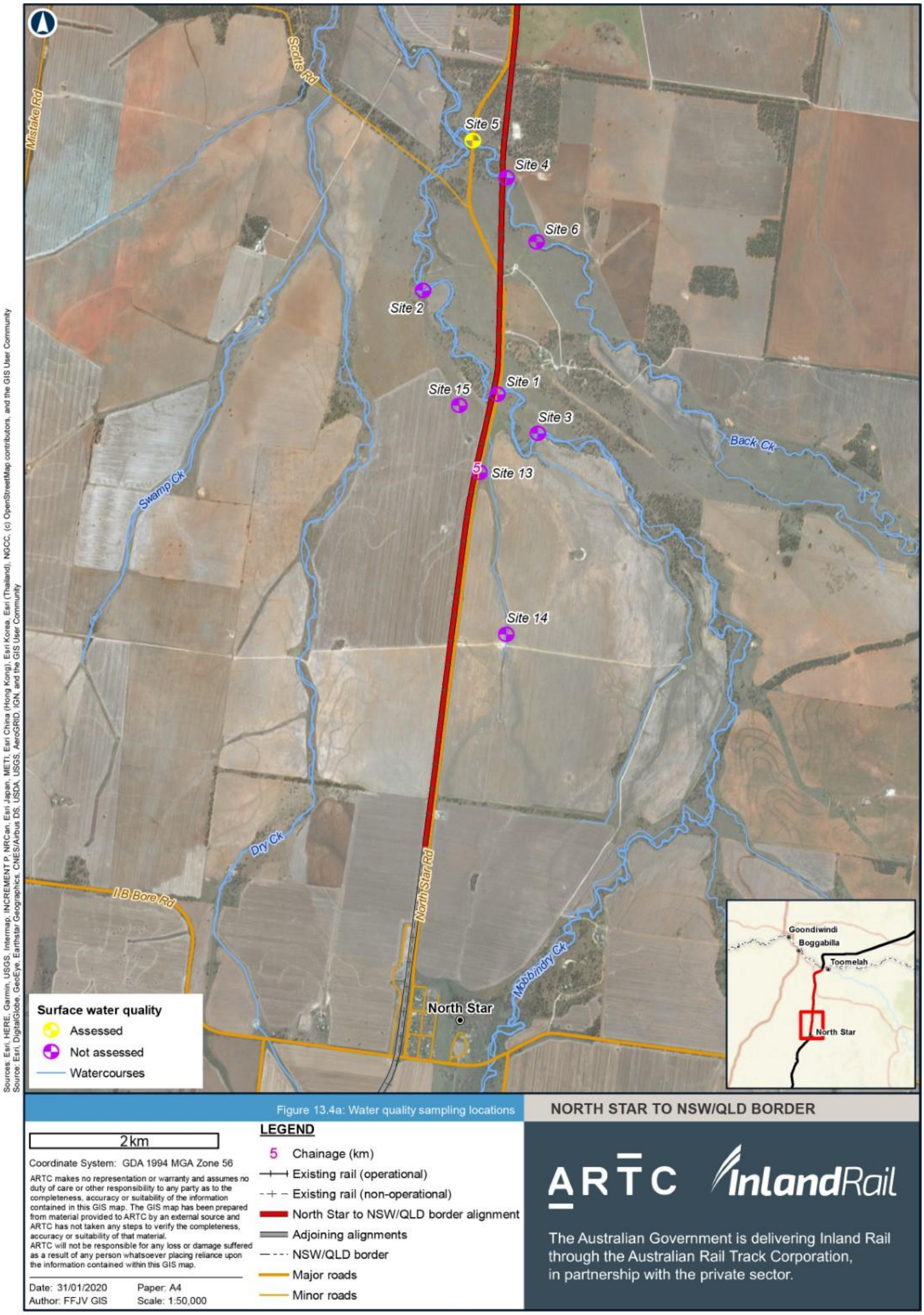
Site	Date	pH	Conductivity (µs/cm)	Total phosphorus (mg/L)	Filterable reactive phosphorus (mg/L)	Suspended solids (mg/L)	Turbidity (NTU)	Ammonia (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)	Oxidised nitrogen (mg/L)	Total Kjeldahl nitrogen (mg/L)	Total nitrogen (mg/L)
Sampling sites													
NS2B 5	Aug–2018	7.7	320	0.15	<0.05	65	71	0.11	0.11	<0.02	0.11	0.6	0.7
NS2B 11	Aug 2018	8.3	520	0.08	<0.05	14	6.8	0.03	<0.02	<0.02	<0.05	0.5	0.5
NS2B 12	Aug 2018	8.2	490	0.06	<0.05	9.1	4.4	0.03	0.03	<0.02	<0.05	0.4	0.4
NS2B 16	Aug 2018	8.6	630	0.1	<0.05	56	40	0.05	<0.02	<0.02	<0.05	1	1
Water quality trigger values													
Sites 1–9, 13–21	-	6.5-8.5	125-2200	0.50	0.02	25	<50	0.02	-	-	0.06	-	0.500
Sites 10–12	-	7.4-8.0	245	0.07	0.02	25	<30	0.02	-	-	0.01	-	0.575

Table note:
Highlighted denotes parameters that exceeded relevant WQO threshold

TABLE 13.14 HEAVY METAL (DISSOLVED) AND INDICATIVE POLYCYCLIC AROMATIC HYDROCARBON LABORATORY RESULTS FOR WATER QUALITY MONITORING SITES

Site	Date	Arsenic (V) (µg/L)	Cadmium[1] (µg/L)	Chromium (VI) (µg/L)	Copper (µg/L)	Lead (µg/L)	Mercury (µg/L)	Nickel (µg/L)	Zinc (µg/L)	Naphthalene (µg/L) (PAH)
Sampling sites										
NS2B 5	Aug 2018	<1	<0.2	<1	<1	<1	<0.1	4	<5	<1
NS2B 11	Aug 2018	1	<0.2	<1	<1	<1	<0.1	3	<5	<1
NS2B 12	Aug 2018	8	<0.2	2	2	<1	<0.1	12	5	<1
NS2B 16	Aug 2018	1	<0.2	<1	3	<1	<0.1	7	<5	<1
Water quality trigger values										
All sites	-	10	0.2	1.0	1.4	3.4	0.06	11	8.0	16

Table notes:
Highlighted denotes parameters that exceeded relevant WQO threshold
µg/L = microgram per litre
PAHpolycyclic aromatic hydrocarbon



Map by: DTH Z:\GIS\GIS_270_NS2B\Tasks\270-IHY-201909261018_SurfaceWaterEIS\270-IHY-201909261018_ARTC_Fig13.04_WQ_Sites_A4P.mxd Date: 29/01/2020 11:08

FIGURE 13.4A-C WATER QUALITY SAMPLING LOCATIONS

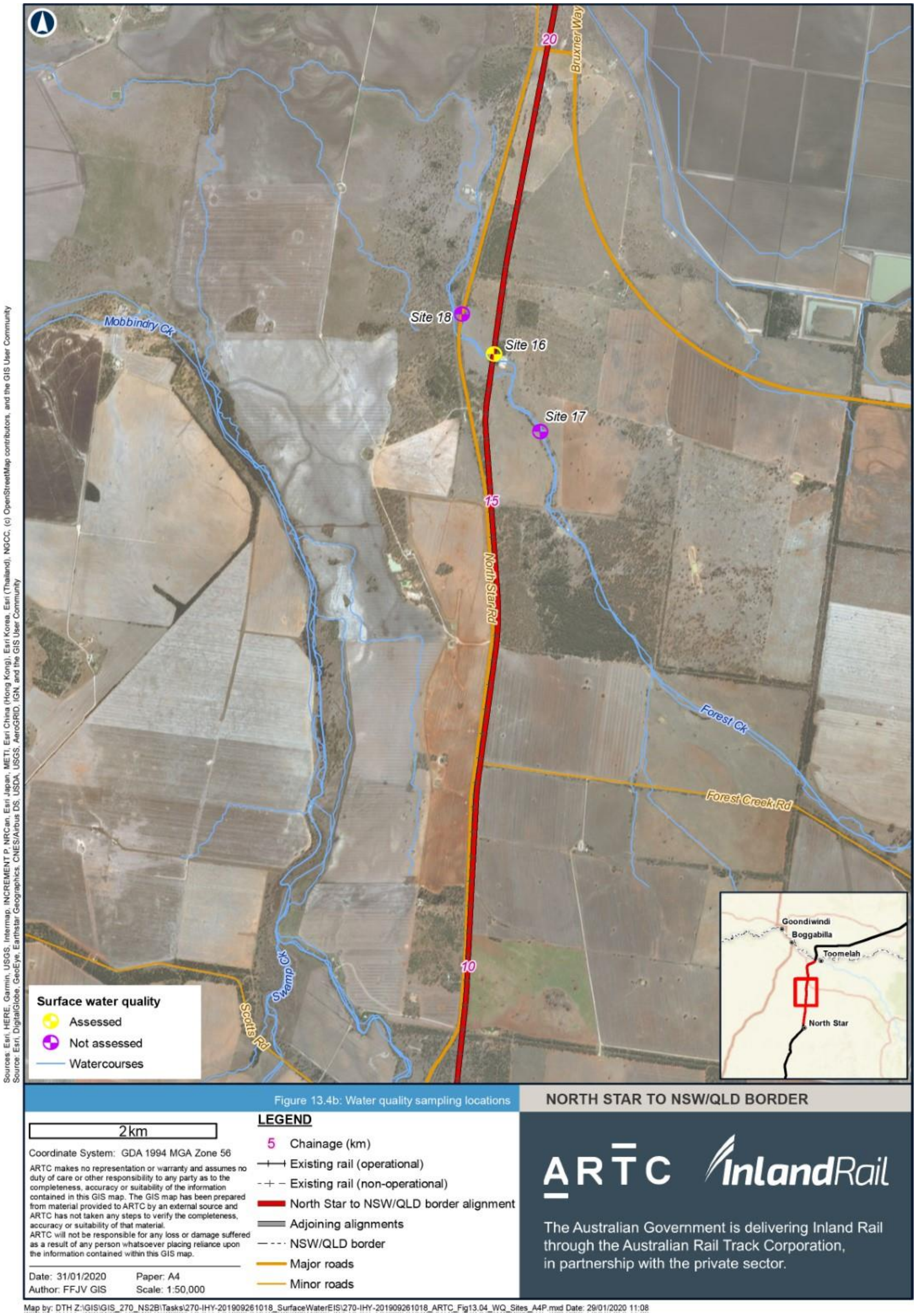
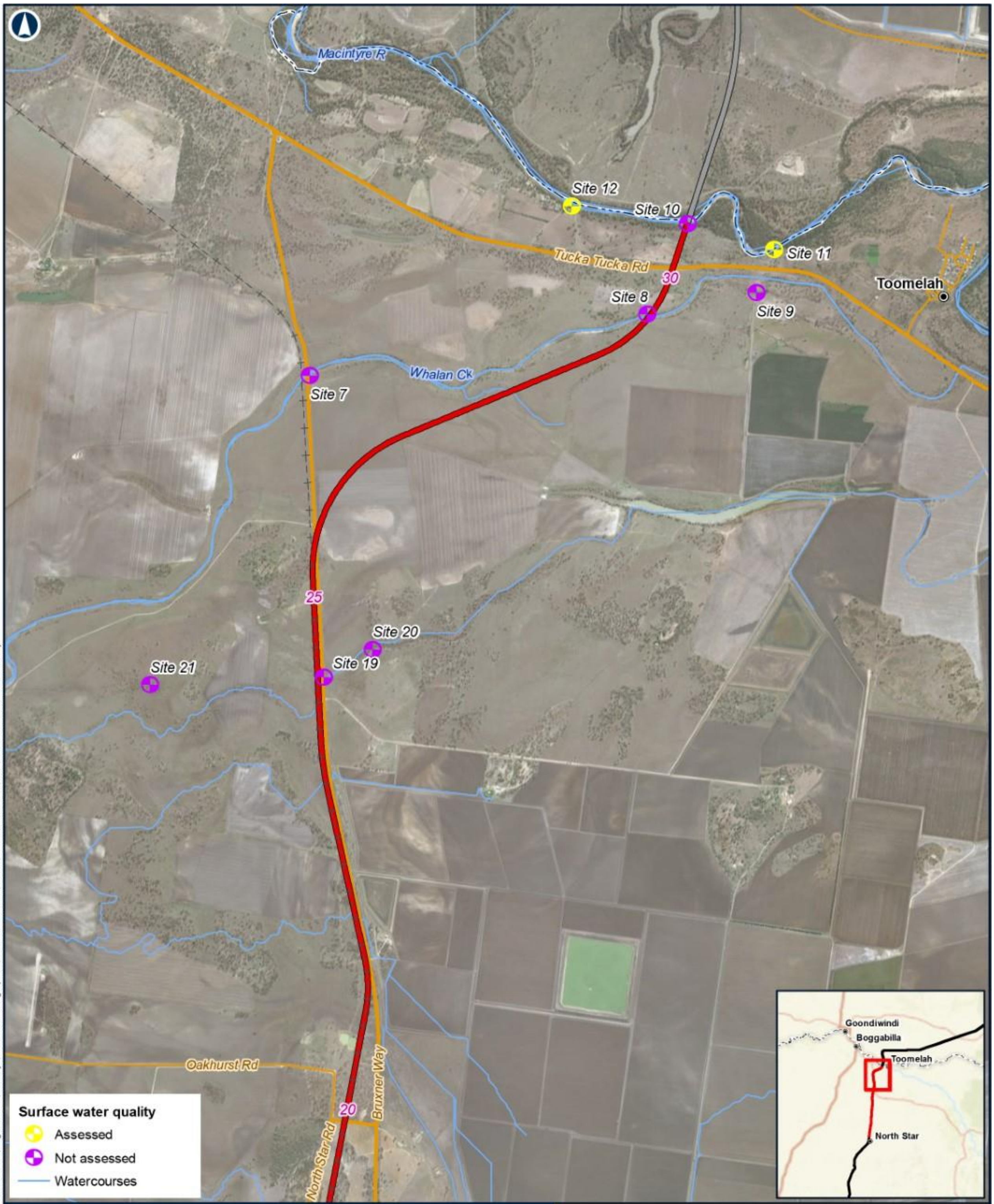


FIGURE 13.4B WATER QUALITY SAMPLING LOCATIONS



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

Figure 13.4c: Water quality sampling locations

NORTH STAR TO NSW/QLD BORDER

2 km

Coordinate System: GDA 1994 MGA Zone 56

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Date: 31/01/2020 Paper: A4
Author: FFJV GIS Scale: 1:50,000

LEGEND

- 5 Chainage (km)
- Existing rail (operational)
- Existing rail (non-operational)
- North Star to NSW/QLD border alignment
- Adjoining alignments
- NSW/QLD border
- Major roads
- Minor roads

ARTC InlandRail

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

Map by: DTH Z:\GIS\GIS_270_NS2B\Tasks\270-IHY-201909261018_SurfaceWaterEIS\270-IHY-201909261018_ARTC_Fig13.04_WQ_Sites_A4P.mxd Date: 29/01/2020 11:08

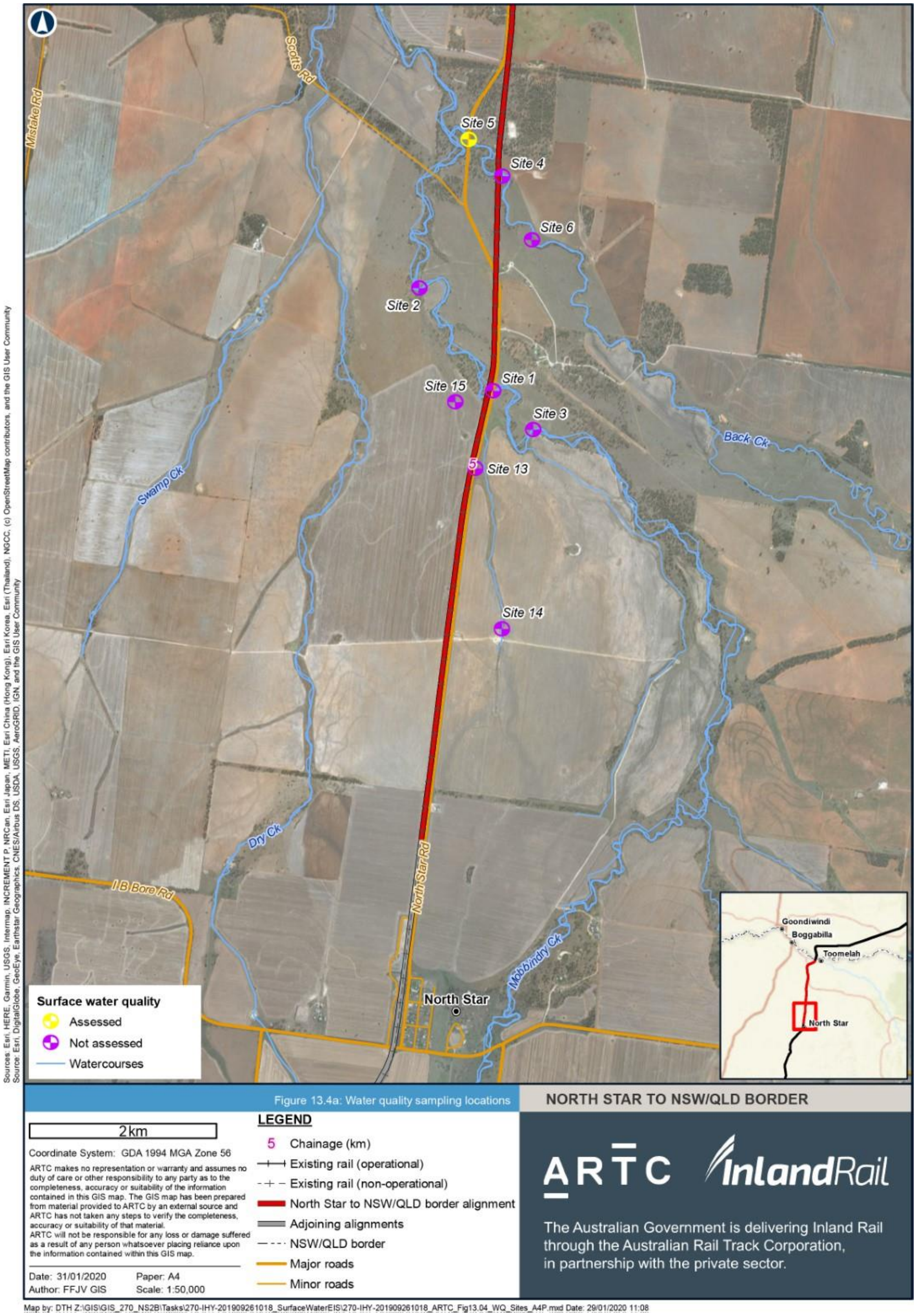


FIGURE 13.4FIGURE 13.4C WATER QUALITY SAMPLING LOCATIONS

13.5.3.2 Summary of data analysis and discussion

For Back Creek and Forest Creek, the physico-chemical data and laboratory assessment of water quality indicate that there is an observable anthropogenic impact at these sites. Both of these watercourses had elevated total phosphorus and nitrogen loads exceeding regional water-quality trigger values.

The two Macintyre River monitoring sites were closer to regional water-quality trigger values for nutrients; however, the site downstream of the proposal alignment exceeded water-quality trigger values for three heavy metals; chromium (VI), copper and nickel.

Long-term electrical conductivity data from the gauging stations located upstream of the proposal alignment, at the Dumaresq River and Macintyre River site indicated that the values observed within the single field survey were comparable to long-term datasets.

Laboratory analysis of polycyclic aromatic hydrocarbon (PAH) concentrations at all sites were below detection limits, indicating no continued contamination of sampled sites, though it is recognised that these compounds are volatile and may not be very persistent in the environment.

In summary, noting the constraint of limited field data, it is evident that during dry conditions, watercourses within proximity of the proposal are not fully meeting water-quality trigger values. It should be noted that conditions for the Forest and Back creeks (pools) during sampling do not constitute base-flow conditions used for an objective basis and, therefore, this data should be compared with caution for the assessment of water-quality trigger values.

13.5.3.3 Surface water quality variability

The timing of water quality monitoring was constrained by the timeframes of the assessment period. Only a limited assessment of temporal and spatial variability in surface water quality can be made as only one round of surface water quality monitoring has been conducted at four monitoring locations. In addition, it is noted that monitoring was conducted during spring, which is outside the peak rainfall period for the area; therefore, surface water monitoring results may not be representative of average conditions. Given that there was <2 mm rain for a period of approximately 40 days prior to the August 2018 sampling event, evaporation of the pooled water is likely to have occurred, potentially resulting in increased concentrations of some water quality parameters.

The habitats of the Border Rivers Catchment are known for their diversity of hydrological environments and the varied responses of different species to varying dryness or flood (Department of Environment and Science (DES), 2018). These ecosystems are well represented, with species adapted to ephemeral water availability. Many aquatic organisms in this environment are adapted to these drying phases and persist in pools/waterholes that act as refugia (DES, 2018). As water availability changes, so does water quality, since the compounds in the water column (such as salts) may become more concentrated as pools dry. Persistence in the waterholes would be determined by physiological thresholds of individual species. Floods and floodplain connectivity act to relieve these physiological stressors and are typically triggers for migration and breeding; therefore, increased concentrations or decreased water availability may reduce the viability of some species if floods recur at infrequent intervals.

13.5.4 Existing geomorphology

The geology and soils in the study area are summarised in Chapter 15: Land Resources and Contamination. There is a strong presence of alluvium deposits, which are associated with sediments deposited through the transportation of channelled stream water. The main form of alluvium deposit in the Moree Plains and Gwydir region is likely to consist of prairie soils, black earths and grey clays, which have developed on finer-grained sediment. Alluvium deposits in the region will potentially result in deposits of sand, silt or silty clay on low ridges along floodplains.

The dominant soil type along the study area for the proposed rail corridor was vertosol: clay rich soils (>35 per cent) with shrink-swell properties that exhibit strong cracking when dry and at depth have slickensides and/or lenticular structural aggregates. Due to high chemical fertility and water-holding capacity, vertosols have high agricultural potential; however, the soil requires a significant amount of rainfall prior to making it available to plants and shrink-swell phenomena could potentially create problems for foundations of structures (Isbell and National Committee on Soil and Terrain, 2016; Gray and Murphy, 2002).

A summary of the existing geomorphological environment is provided with the results of the AusRivAS geomorphological assessment in the Appendix G: Surface Water Quality Technical Report and the full description is provided in Appendix S: Aquatic Biodiversity Technical Report. Ephemeral creeks within the proposal area sit predominantly within broad floodplains and are often impacted by rural land-use activities such as clearing (refer Table 13.11). In-stream habitats are commonly runs, and pools are expected to be present after rain. Watercourses within the proposal area typically consist of gravel and/or sandy bed composite, and silt at some sites, and are not expected to be resistant to scour if exposed to high-velocity waters.

Watercourses and waterbodies occurring within the proposal site, include:

- Macintyre River—a perennial waterway with a well-vegetated riparian floodplain on either side of the river, it has highly sensitive fish habitats and is known to support threatened species such as the Murray cod (*Maccullochella peelii*), silver perch (*Bidyanus bidyanus*) and purple-spotted gudgeon (*Mogurnda adspersa*). The Macintyre River is part of the Darling River Endangered Ecological Community.
- Whalan Creek—an ephemeral waterway, larger than other creeks in the area and with a well-defined channel that is likely to flow seasonally
- Mobbindry Creek and Back Creek—ephemeral waterways with well-defined channels, with fringing rushes and sedges present
- Forest Creek—an ephemeral, highly modified waterway with a poorly defined channel and limited or poor riparian vegetation
- An unnamed tributary of Mobbindry Creek, which is ephemeral.

13.5.5 Existing floodplain infrastructure

Key existing infrastructure on or near the Macintyre River floodplain in the proximity of the proposal includes:

- Bruxner Way
- Tucka Tucka Road
- North Star Road
- Camurra–Boggabilla Railway (existing non-operational rail)
- Kildonan Road
- Eukabilla Road
- Queensland Rail (QR) Western Line
- Newall Highway
- Goondiwindi Town Levee
- Levees and dams associated with farming practices.

Bruxner Way is a low-level road with minor drainage structures, including bridges at larger waterway crossings. Tucka Tucka Road is a low-level road with minor drainage structures, including a bridge over Whalan Creek.

The non-operational Camurra–Boggabilla rail embankment is raised with limited drainage structures. The rail line runs in a northerly direction from North Star and then tracks west on the southern side of the Macintyre River towards Boggabilla. The existing rail embankment is in a state of significant disrepair and is elevated above the surrounding ground levels generally by approximately 0.5 to 0.8m, increasing up to 2m near Whalan Creek. It has limited transverse drainage structures, many of which are in a degraded state. The existing rail embankment restricts flows during flood events and is overtopped in larger events.

13.5.6 Existing flooding regime

Flooding in the study area occurs through two mechanisms, or a combination of both, being:

- Regional flood events caused by high flows in the Macintyre River, Dumaresq and/or Macintyre Brook systems
- Local catchment events due to rainfall over the local area.

13.5.6.1 Regional flood events

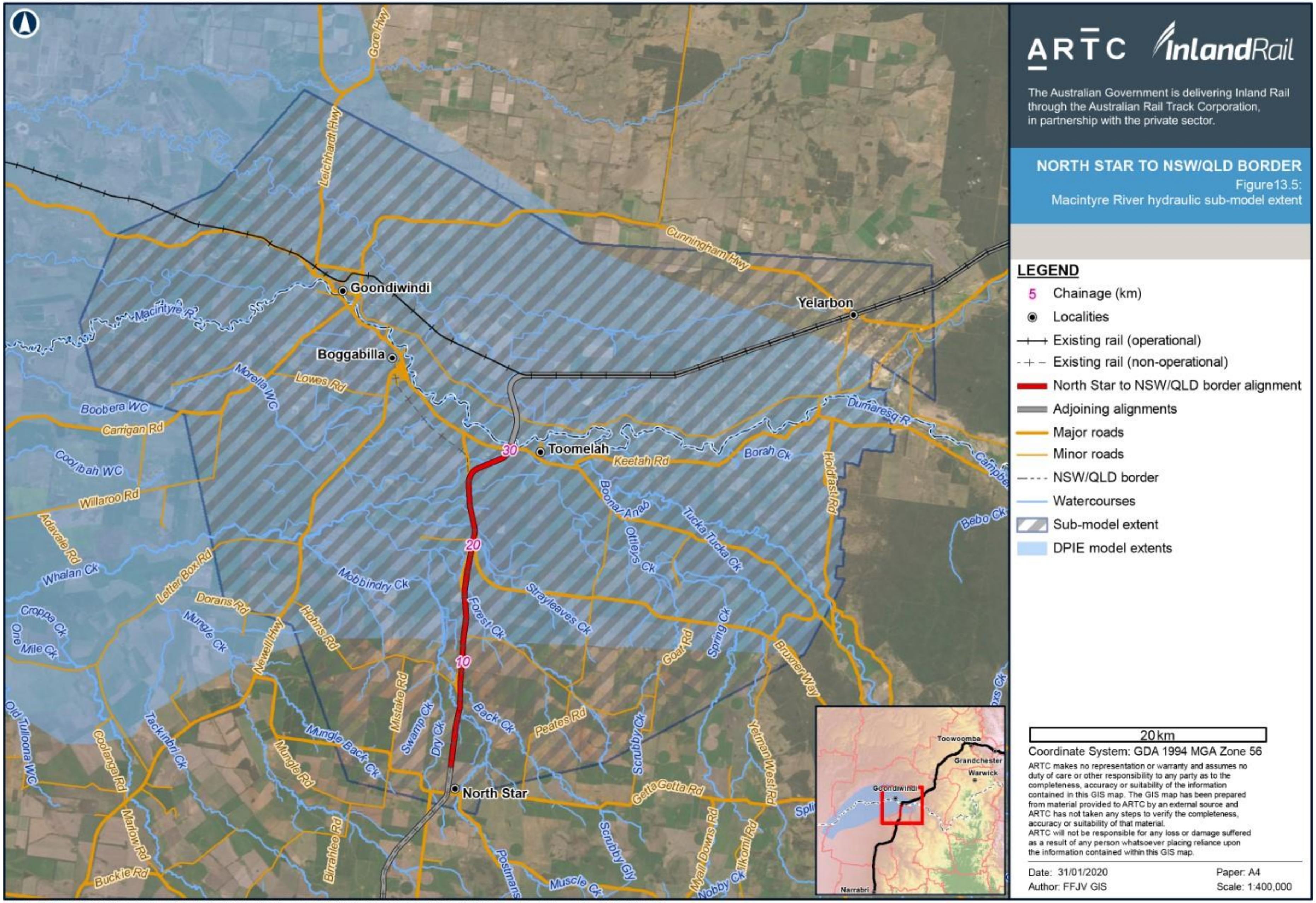
Available data and previous studies for the Macintyre River floodplain were collected and reviewed to support the development and calibration of the hydrologic and hydraulic models for the proposal. The DPIE Border Rivers Floodplain hydrologic and hydraulic models were identified as the most detailed and suitable models for the assessment of floodplain conditions and impacts of the proposal. The DPIE hydraulic model covers an area of approximately 1.1 million hectares extending from approximately 50 km upstream of Boggabilla to 40 km downstream of Mungindi.

A localised hydraulic sub-model of the DPIE hydraulic model has been developed; the extents of which are shown in Figure 13.5. The sub-model boundaries were selected to capture the extents of potential impacts associated with the proposal. Generally, increases in flood levels from linear infrastructure across a floodplain are anticipated to occur upstream of the infrastructure; therefore, the model downstream boundary was initially positioned immediately downstream of the Boggabilla stream gauge, which was used for calibration purposes.

Following community feedback of concerns regarding potential impacts of the proposal on flood levels in Goondiwindi, the hydraulic model was extended to downstream of Goondiwindi and recalibrated to both the Goondiwindi and Boggabilla stream gauges. As shown in Figure 13.5, the downstream model boundary was located approximately 18 km downstream of Goondiwindi to ensure model results were unaffected by the placement of the boundary.

Flows were extracted from the regional DPIE model and applied as inflow boundaries within the hydraulic sub-model (in accordance with the *Draft Floodplain Management Plan for the Border Rivers Valley Floodplain* procedures (Department of Industry, 2018). Runoff from rain falling directly onto the hydraulic sub-model area was not included in the model. The runoff generated from the sub-model areas would be small in comparison to the upstream catchment flows and, more importantly, will have been conveyed downstream before the peak river flows from the upstream catchment reach the area.

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



Map by: DTH Z:\GIS\GIS_270_NS2B\Tasks\270-IHY-201909261018_SurfaceWaterEIS\270-IHY-201909261018_ARTC_Fig13.05_SubModelExtent_A4L.mxd Date: 29/01/2020 11:10

When the hydraulic sub-model was established, it was validated against the DPIE regional hydraulic model to ensure results were consistent. The hydraulic sub-model water levels were found to be within 10 mm of the DPIE regional hydraulic model and, therefore, considered to suitably replicate the DPIE regional hydraulic model results.

13.5.6.2 Local catchment events

There are a number of local creeks that cross the existing non-operational rail alignment as shown in Figure 13.2. These drain towards Whalan Creek and include Strayleaves Creek, Forest Creek, Back Creek and Mobbindry Creek. Runoff from these local catchments has been included in the Macintyre River hydraulic sub-model. The critical duration flow for each catchment has been adopted as local catchment runoff and will have peaked and subsided before the main river flows reach the area. The peak flows are essential for design of transverse drainage.

As part of the proposal alignment design, longitudinal drainage and drainage of small catchment areas in the immediate vicinity of the alignment has also been assessed, with any required minor drainage structures identified.

13.5.6.3 Calibration to historical flood events

The Border Rivers floodplain has experienced many recent flood events, with the three highest floods on record considered for calibration of the hydrologic and hydraulic models. The DPIE hydrologic and hydraulic models were calibrated to the January 1996 and February 1976 events. The proposal hydraulic sub-model calibration also included the January 2011 event, to validate the previous modelling and to demonstrate the model performance for a recent flood event. The topography included in the models was varied to include representation of development on the floodplain, including levees, at the time of each flood event.

The hydrologic models and hydraulic sub-model were run for the three historical events and modelling results were compared to the Boggabilla and Goondiwindi stream-gauge records, recorded historical flood heights and flood photographs. This information was sourced from a range of stakeholders including DPIE, local landowners and local government authorities.

Full details of the calibration process and outcomes are presented in Section 7 of Appendix H: Hydrology and Flooding Technical Report. The following was concluded from the hydrologic and hydraulic calibration process:

- Boggabilla stream gauge:
  - The stream gauge is located approximately 11 km downstream of the proposal alignment and was operational for all three historical events. The location of the stream gauge changed slightly between the 1976 and 1996 flood events.
  - The hydraulic sub-model results for the three historical events flood events compare well to the recorded levels at the Boggabilla stream gauge (within -0.05m to +0.08m)
  - The hydraulic sub-model flows are within 4 per cent to 20 per cent of the stream gauge recorded flows, (noting that the flows are not recorded but, rather, are derived from a rating curve and, therefore, do not have the same level of confidence as the recorded level data).
- Goondiwindi stream gauge:
  - The stream gauge is located approximately 18 km downstream of the proposal alignment and was operational for all three historical events
  - The hydraulic sub-model was found to represent the peak levels reasonably well at the Goondiwindi stream gauge, being within 0.34 m of the recorded level for the 1976 event, 0.24 m for the 1996 event, and 0.23 m for the 2011 event.
  - The hydraulic sub-model flows were within 13 per cent to 33 per cent of the stream gauge recorded flows (noting that the flows are not recorded but, rather, are derived from a rating curve and, therefore, do not have the same level of confidence as the recorded level data).

The model results show that the hydraulic sub-model is representing the peak event flood levels, the volume of the flood events and the shape of the flood event hydrographs well across the three historical events.

- Comparison to historical flood heights and flood photographs:
  - There are 38 historical flood heights recorded across the hydraulic sub-model extent for the 1976 event. The 1976 hydraulic sub-model predicts flood levels that generally compare well with the recorded flood heights (generally within 0.3 m).
  - There are 8 historical flood heights recorded across the hydraulic sub-model extent for the 1996 event. The 1996 hydraulic sub-model predicts flood levels that generally compare well with the recorded flood heights (with four of the eight points within 0.15 m of the recorded heights). The extent of floodplain inundation in the hydraulic sub-model compares well to the aerial photography of the flood event with extents being slightly larger than the aerial photograph. As the time of capture of the aerial photograph is not known, it is possible that the photograph was not taken at the peak of the flood event but, rather, during the rising or receding phase of the flood. This would account for the difference in flood extent.
  - There are 52 historical flood heights recorded across the hydraulic sub-model extent for the 2011 event. The 2011 hydraulic sub-model predicts flood levels that compare very well with the recorded flood heights, with a mean difference of 0.24 m. The hydraulic sub-model inundation extent generally agrees with the aerial photography of the flood event; however, the predicted flood inundation extent appears larger in some areas than in the aerial photograph. This may be due to the shallow areas not being visible in the aerial photograph, or the photograph not being taken at the peak of the flood event.
  - In addition to the aerial photography of the 2011 flood event, a number of landowners were able to provide photographs that showed flood levels at homes on the floodplain. The hydraulic sub-model depth and flood extent results have been compared to these photographs and show a good match.

Overall, the hydraulic sub-model had a good match to levels at the Boggabilla and Goondiwindi stream gauges, the recorded flood heights across the floodplain and to the aerial and landowner flood photographs of flood inundation extents; therefore, the hydrologic models and hydraulic sub-model were considered suitably calibrated.

Appendix H: Hydrology and Flooding Technical Report includes a detailed discussion on the Boggabilla stream gauge and the rating curves that have been developed and used over time. This discussion highlights the complexity of assigning an AEP for historical events and it should be noted that this AEP would vary across the Macintyre River floodplain and within the contributing tributaries. Based on total Macintyre River flows upstream of Boggabilla (i.e. including breakout flows into Whalan Creek and Morella Watercourse), the estimated range of AEP of each historical event is presented in Table 13.15, as is the source of the flood waters for each event.

TABLE 13.15 ESTIMATED AEP OF HISTORICAL EVENTS FOR MACINTYRE RIVER FLOWS UPSTREAM OF BOGGABILLA

Historical event	Estimated AEP range	Source of flooding	Approximate duration
February 1976	Between 1 in 200 and 1 in 500	Concurrent Dumaresq River and Macintyre River flooding	≈ 6 days
January 1996	Between 1 in 30 and 1 in 50	Concurrent Dumaresq River and Macintyre River flooding	≈ 4 days
January 2011	Between 1 in 60 and 1 in 75	Ottleys Creek followed by Dumaresq River flooding	≈ 5 days

The AEP of historical events at the Goondiwindi stream gauge are not able to be defined due to limitations of the gauge rating and, therefore, the Flood Frequency Analysis. For further details, please refer to Appendix H: Hydrology and Flooding Technical Report.

13.5.6.4 Existing Case topography

Modelling of the Existing Case, i.e. current state of development on the floodplain, has been undertaken to provide a base case against which the introduction of the proposed rail alignment and associated drainage structures can be assessed.

As discussed in Section 13.4.3.3, two Existing Case hydraulic sub-model topography scenarios were developed, being:

- DPIE levees—the majority of the hydraulic sub-model area was covered by LiDAR collected for the proposal between September 2014 and January 2015. In this scenario, the hydraulic sub-model was set up using these datasets and the DPIE representation of floodplain levees.
- 2019 LiDAR (and levees)—as the flood modelling and associated consultation with the local landowners progressed, it was identified that changes to the floodplain topography had occurred since the completion of the 2014/15 LiDAR and that the DPIE levee representation may not reflect the current levees constructed on the floodplain. Therefore, new LiDAR was flown and processed in November 2019 to provide a snapshot of current topographic conditions, including current levee heights and floodplain features. The hydraulic sub-model was updated using 2019 LiDAR including representation of existing levees on the floodplain.

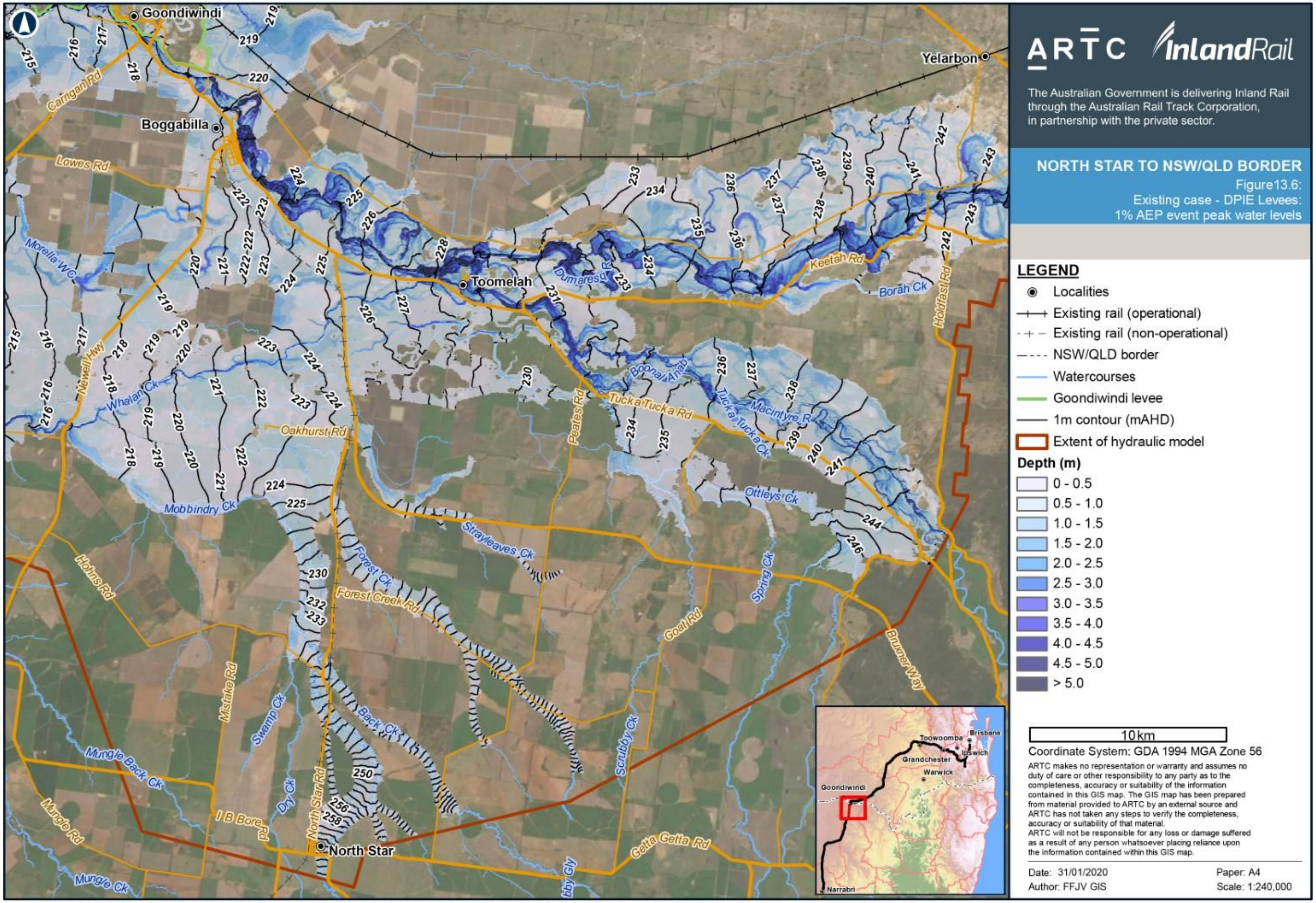
Through community engagement, it was identified that to model current floodplain conditions and adequately assess the proposal, the 2019 LiDAR and levees should be adopted as the Existing Case topography. The DPIE levee case has been used as a sensitivity test for the proposal.

13.5.6.5 Existing Case results

The Existing Case extent of inundation and peak water levels for the 1% AEP event for both scenarios, DPIE levees and 2019 LiDAR levees, have been assessed, with results presented in Figure 13.6 and Figure 13.7 respectively. Review of the results shows similar flood inundation extents across the wider floodplain with the key differences being that more overtopping of the existing levees is predicted to occur under the 2019 LiDAR scenario (refer Figure 13.7). This is due to the 2019 LiDAR picking up actual levee heights and the DPIE levees being representations of approved and constructed levees on the floodplain.

As discussed in Section 13.5.6.4, for this investigation, the 2019 LiDAR topography, including representation of the existing levees, has been adopted for identification and mitigation of impacts associated with the proposal alignment.

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



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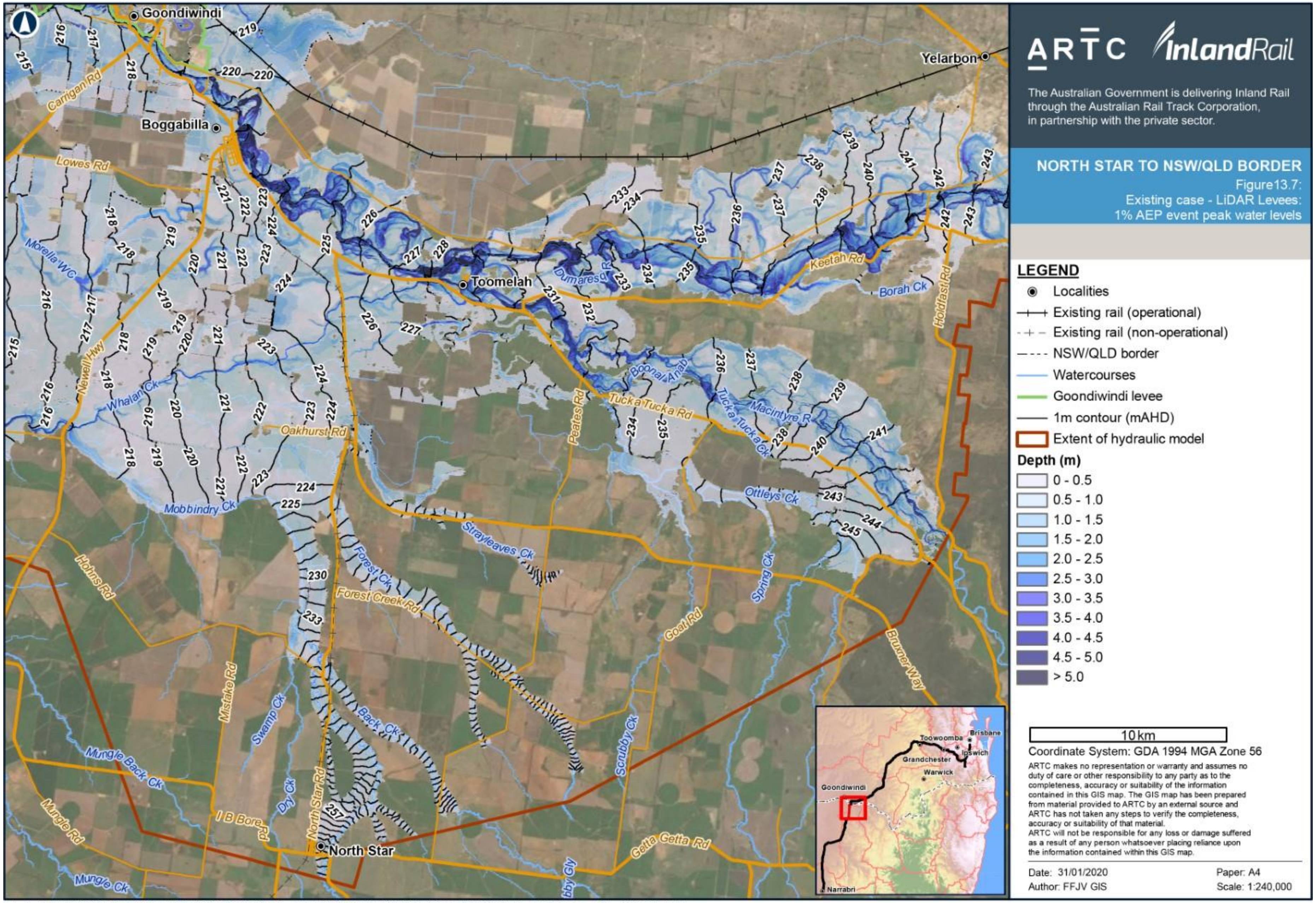
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



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From the modelling results it is noted that widespread inundation is predicted under the 1% AEP event on the Macintyre River floodplain, with depths of approximately 10–12 m in the Macintyre River, 6 m in Whalan Creek and up to 2 m on the floodplain area. Under the 1% AEP event, over 10 km of the existing non-operational rail line is inundated, and Bruxner Way is also inundated for approximately 8 km. There are also local access roads to properties and to the Toomelah township that are cut by flood waters. Flow remains mainly in creek and river channels for up to the 10% AEP event, with breakouts occurring downstream of the Toomelah township between a 10% and 5% AEP event.

Table 13.16 presents 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 13.16 EXISTING CASE—OVERTOPPING DEPTHS OF KEY INFRASTRUCTURE

		Maximum overtopping depth (m)				
Infrastructure	Location	1% AEP	2% AEP	5% AEP	10% AEP	0.2 EY
Kildonan Road	Intersection with proposed alignment	0.36	0.05	Dry	Dry	Dry
Tucka Tucka Road	Intersection with proposed alignment*	0.15	Dry	Dry	Dry	Dry
Bruxner Way	Whalan Creek channel	3.48	3.36	3.21	3.06	2.54
Bruxner Way	Whalan Creek breakout flows near intersection with Bruxner Way	0.83	0.69	0.48	0.15	Dry
Bruxner Way	Strayleaves Creek	1.57	1.56	1.49	1.39	1.29
Boggabilla Rail	Strayleaves Creek	1.40	1.38	1.32	1.24	1.14
North Star Road	Intersection with Bruxner Way	Dry	Dry	Dry	Dry	Dry
North Star Road	Forest Creek	0.92	0.8	0.77	0.70	0.61
Boggabilla Rail	Forest Creek	0.65	0.62	0.55	0.50	0.45
Boggabilla Rail	Back Creek	0.45	0.44	0.40	0.36	0.34
North Star Road	Mobbindry Creek	0.71	0.65	0.52	0.49	0.42
Boggabilla Rail	Mobbindry Creek	0.36	0.26	0.11	0.09	0.03

Table note:
* Tucka Tucka Road inundated to west and east of this location

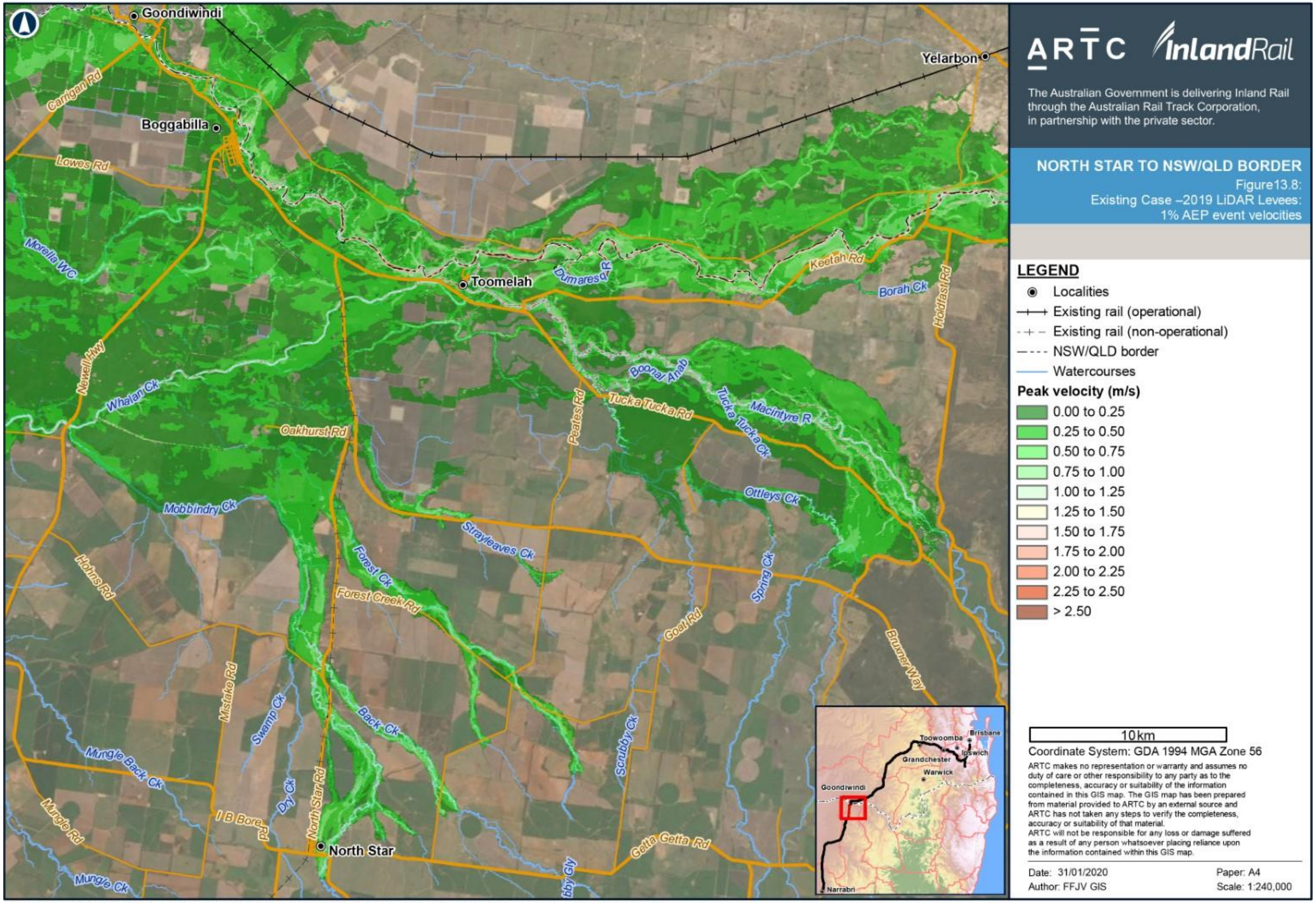
Existing Case velocities on the floodplain areas are generally low, in the order of 0.25 to 0.5 m/s, as shown in Figure 13.8.

Velocities are higher in the river and creek channels, with 1% AEP event velocities near the proposed alignment presented in Table 13.17.

TABLE 13.17 EXISTING CASE—1% AEP EVENT VELOCITIES IN WATERWAYS AT CROSSING OF PROPOSAL

Waterway	1% AEP Existing Case peak velocities (m/s)
Macintyre River	2.0 to 3.0
Whalan Creek	1.0 to 3.0
Strayleaves Creek	0.2 to 0.6
Forest Creek	0.5 to 1.0
Back Creek	1.0 to 2.2
Mobbindry Creek	2.0 to 2.2

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



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13.6 Potential impacts

13.6.1 Surface water quality receptors

A receptor is a feature, 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 ecological values used to feed potential impacts, which included:

- NSW natural environment (including use 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.

Some of the watercourses intersecting the proposal alignment that have been designated as having highly sensitive fish habitat are known to support threatened species such as the Murray cod (*Maccullochella peelii)*, silver perch *(Bidyanus bidyanus)* and purple-spotted gudgeon (*Mogurnda adspersa)*. Many of the ephemeral waterways have been assigned a minimal or unlikely sensitivity for fish habitat. For further information pertaining to the assessment of existing condition and assessment of receptor sensitivity refer Appendix G: Surface Water Quality Technical Report.

13.6.2 Surface water quality

The most stringent water quality trigger values apply to the protection of aquatic ecosystems. Designing and mitigating impacts to aquatic ecosystems will provide protection for other WQOs; therefore, the following outline on potential impacts focuses on the protection of the WQOs of aquatic ecosystems. Each of the potential impacts is discussed in greater detail in the following sections. Potential impacts to surface water quality WQOs are outlined for construction and operational works.

13.6.2.1 Proposal water requirements and usage

Water requirements for the construction period of the proposal are summarised in Table 13.18 and include an estimate of volumes anticipated.

TABLE 13.18 ESTIMATED WATER REQUIREMENTS DURING CONSTRUCTION ACTIVITIES

Construction activity/process	Uses/requirement	Approximate volume (Total ML)	Quality	Flow rate	Potential sources[a]
Earthworks	Material and soil conditioning, and general dust suppression	High 130 ML—material conditioning 62 ML—dust suppression 49 ML—haul road/laydown areas	Low	High	River, dam or bore
Construction camp	Drinking water, showers, toilets, washing and cooking facilities	Low—provided by ARTC from mains supply (1 ML/month of operation)	High	Low	Town supply and water harvesting
Concrete	Bridge and culvert locations	Medium	High	Low	Town mains due to quality requirements
Trackworks	Ballast dust suppression during ballasting and regulating activities	Low (0.36 ML)	Low	Low	River, dam or bore

Water requirements for earthworks and trackworks during the construction phase would be met with water sourced from the Boggabilla Weir, located on the Macintyre River, approximately nine kilometres upstream of Goondiwindi. The weir has a storage capacity of 5,850 ML and is used to re-regulate releases from Glenlyon Dam and to conserve unregulated inflows. There is an opportunity to apply for an approval or licence to take construction water from this water source to fulfil the construction water requirements. It is assumed the licence would be for approximately 100 ML per year (1.7 per cent of the weir's storage capacity) for a duration of approximately three years. The township of Boggabilla is currently supplied with water from the Boggabilla Weir. The township has a current entitlement of 120 ML per year (2 per cent of the storage capacity).

This proposal will have to be progressed with the Border Rivers Commission. Any impacts associated with this water extraction would be assessed as part of the water-use approval.

A water access licence from WaterNSW is generally required to extract water from rivers or aquifers to use for irrigation, industrial or commercial purposes. The *Water Management Act 2000* (NSW) governs the issue of water access licences and approvals for water sources (rivers, lakes, estuaries and groundwater) in NSW, where water sharing plans have commenced. There is a water sharing plan for the NSW Border Rivers Regulated River Water source currently in place (Department of Water and Energy, 2009).

Potential impacts to surface water associated with the use of water during the construction phase are assumed to be minimal due to the following:

- Potential for generation of construction water runoff is considered to be low, as most water will infiltrate into the ground or evaporate after being applied
- The quality and volume of runoff will be controlled through a soil and water management plan, and Erosion and Sediment Control Management Plan.

13.6.2.2 Construction phase impacts

The proposal-related activities associated with the construction, commissioning and reinstatement phases are listed in Table 13.19.

Potential impacts to water quality from the proposal during the construction phase include:

- Increased water turbidity and sedimentation as a result of:
  - Vegetation clearing, which could leave exposed soils prone to erosion
  - Topsoil stripping and earthworks, and excavation/trenching for infrastructure and material borrow pits, which could expose soils that could be eroded
  - Erosion of stockpiled materials, if these are not contained.
- Changes to water chemistry resulting from:
  - Accidental spills and leaks of chemicals or fuels from construction equipment or fuel storages, which could contaminate surface water during direct runoff, overland runoff and improper practices
  - Disturbance of saline soils during construction, which could increase salinity in runoff
  - Subsoil exposure within excavations and borrow pits, which could leach salts or other chemicals from the soil into overland runoff
  - The erosion of stockpiled materials, which could lead to increased nutrient concentrations in runoff.

The impact of sediment loads to be washed or deposited into downstream watercourses includes the potential to:

- Smother aquatic life and inhibit photosynthesis conditions for aquatic and riparian flora
- Impact breeding and spawning conditions of aquatic fauna
- Change water temperature conditions due to reduced light penetration
- Affect the ecosystems of downstream sensitive watercourses, wetlands and floodplains
- Increase turbidity levels in downstream watercourses at locations where water is extracted for any potable purpose.

Changes to the water chemistry of overland flow could create toxic conditions for downstream aquatic environments.

Wastewaters from wastewater provisions made for the construction accommodation facility would be treated by package treatment plants. Approvals related to the running of the accommodation will be provided by ARTC or the service provider selected to run the camps. The proposal seeks to manage wastewater in accordance with the principles of the waste hierarchy outlined in the *Waste Avoidance and Resource Recovery Act 2001* (NSW). The reuse of wastewater is beneficial to the environment, as it draws on a resource that would otherwise be discarded and wasted. It also reduces water usage, which is an ongoing concern within the LGAs of Gwydir and Moree Plains, which experience prolonged periods of drought. The effluent derived from the package sewage treatment system is proposed to be managed through irrigation. The fields to the north and south of the construction accommodation have been identified as a potential effluent disposal location, subject to further investigation in a future phase of the proposal.

The sewage treatment plant will only manage domestic sewer/wastewater produced by the proposed accommodation. Wastewater generated will be from the site kitchen, laundries, toilet and shower required to service the 350-person accommodation. All wastewater will be captured onsite and will be treated by a sewage treatment plant. The design and operation of the plant must ensure that the performance of the wastewater infrastructure meets the minimum requirements for human health and the environment relevant for the end use of the treated effluent, achieving water quality suitable for reuse in non-potable applications, e.g. irrigation.

The risk of in-stream earthworks leading to changes in water quality is considered to be low where there are existing water way crossings over Back Creek, Mobbindry Creek and Forest Creek, as existing infrastructure will be retained where possible.

A 1,750 m viaduct will be constructed over Whalan Creek and the Macintyre River. For these waterway crossings, it is expected that no substantial vegetation clearing or earthworks will be required at these locations. Where a new viaduct is proposed across a perennial stream (the Macintyre River), bridge piers will be constructed on the banks of the river, outside the established baseflow channel. Potential impacts to surface water during construction will be controlled through a Soil and Water Management Plan, and a sediment control management plan. All other constructed crossings are above ephemeral streams, and works will be undertaken when the stream beds are dry. Bridge construction methodology is described in more detail in Chapter 7: Construction of the Proposal.

Where vegetation clearance occurs, erosion risks would be controlled through replanting that will occur as part of the works. Salinity issues would be controlled with topsoil stripping, so that any exposed potentially saline soils can be covered prior to re-establishment of vegetation.

Changes to turbidity and chemistry could also result from localised change in overland flow regimes to proximal watercourses. Impacts could arise from diversions to surface water flow regimes that may be required, i.e. around borrow pits. If the diversions do not have sufficient conveyance capacity or stabilisation, they could lead to erosion, turbidity and sedimentation in waterways. Clearing activities may increase the amount of runoff and hence the volume and rate of water entering waterways, which could lead to erosion. Where borrow pits need to be dewatered, the water will not be discharged directly to waterways. Construction compounds would be located on land that is above the 20-year average recurrence interval flood level and located away from waterways. Construction compounds are discussed in more detail in Chapter 7: Construction of the Proposal.

TABLE 13.19 DESCRIPTION OF PROPOSAL-RELATED ACTIVITIES ASSOCIATED WITH CONSTRUCTION, COMMISSIONING AND REINSTATEMENT AND OPERATIONAL PHASE

Phase	Infrastructure activity	Description of activities	Duration of disturbance
Construction	Site preparation	Vegetation clearing	Permanent
		Topsoil stripping	Temporary/ Permanent
		Construction of temporary site compounds	Temporary
		Construction of rail access roads	Permanent
		Installation of offices, hardstands etc.	Temporary
		Stockpiling	Temporary
	Utility diversions	Excavation	Temporary
		Trenching	Temporary
		Modification, diversion and realignment of utilities and associated infrastructure	Temporary/ permanent
	Drainage	Culvert installation	Permanent
	Structures	Construction of bridges over main waterways	Permanent
		Road/rail bridge construction	Permanent

Phase	Infrastructure activity	Description of activities	Duration of disturbance
Construction	Civil works	Cutting construction	Permanent
		Embankment construction using cut to fill from rail alignment and borrow to fill from external borrow sources, where required	Permanent
		Construction of temporary haul roads	Temporary
		Drainage controls	Temporary/ Permanent
	Road works	Road realignment	Permanent
		Construction of permanent rail maintenance access roads	Permanent
	Rail logistics	Sleeper stockpiling	Temporary
		Rail stockpiling	Temporary
	Rail construction	Drilling	Temporary
		Ballast installation	Temporary
		Sleeper placement	Temporary
		Rail placement	Temporary
		Installation Train signals and communications infrastructure	Temporary
		Demobilising site compounds	Temporary
Commissioning and Reinstatement	Demobilisation/ Reinstatement	Establish permanent fencing	Permanent
		Restoration of disturbed areas, including revegetation where required	No disturbance
	Spoil mounds	Storage of excess or unsuitable cut and fill material used in the conversion of haul roads and construction access roads into permanent roads	Permanent
	Restoration	Minor maintenance works	Temporary
	Road works	Bridge and culvert inspections	No disturbance
		Sleeper replacement	Temporary
		Rail welding	Temporary
		Rail grinding	Temporary
		Ballast dropping	Permanent
		Track tamping	Permanent
		Major periodic maintenance	Permanent
Operation	Train operations	Train movement along rail	Permanent
	Operational maintenance	Ongoing vehicle movement within rail corridor	Permanent

Pollutants that may be introduced into the water cycle include:

- Sediments—resulting from earthworks and erosion of exposed soils could also lead to potential salinity issues
- Chemicals—including fuels and oils used for construction machinery, heavy metals from rail grinding and welding, compounds leaching from rail formation materials, and salts mobilised from surface soils or shallow groundwater.

The quantity of these pollutants that might discharge to the receiving environment during the construction phase is likely to be negligible, i.e. of such a small quantity that if any were released to the environment, remediation or clean-up could be immediately undertaken with equipment and materials kept on site. Many of the mitigation measures proposed for the management of the construction works have been specifically developed to limit the release of these pollutants to the environment (refer Appendix G: Surface Water Quality Technical Report).

All construction-phase works would be conducted in accordance with the Construction Environmental Management Plan (CEMP), which includes guiding the stripping, stockpiling and management of topsoil where it contains seedbank or weed material, and a Soil and Water Management Plan, and Erosion and Sediment Control Management Plan. Borrow pits, construction laydown areas and accommodation are construction-phase works that will be modelled by the contractor during the detailed design phase. No point-source discharges, other than construction accommodation treated wastewater irrigation to land, are proposed.

13.6.2.3 Operation phase impacts

The proposal-related activities associated with the operation phase are listed in Table 13.19. Potential impacts during operations include:

- Increases in water turbidity and sedimentation resulting from:
  - Repair or maintenance of roads or tracks requiring the removal of vegetation, which in turn could result in erosion and/or sedimentation of waterways
  - Increased runoff, which could result in erosion from the rail formation
  - The creation of concentrated flow paths, which have an increased potential to erode soils
- Potential changes to water chemistry during operation have been identified (Vo et al., 2015) and include:
  - Materials deposited onto the railway formation, such as potential spillages of fuel or chemicals from freight or trains
  - Wear of tracks or compounds formed from the dissolution of the rail formation materials
  - Repair or maintenance of roads or tracks, which could lead to the introduction of chemicals/materials to waterways.

Pollutants that may be introduced into the water cycle include:

- Sediments, resulting from erosion of exposed soils as a result of ad hoc maintenance works
- Chemicals, including fuels and oils used for machinery and railstock, heavy metals from rail or machine wear, compounds leaching from rail formation materials, and salts mobilised from surface soils or shallow groundwater if earthworks are required or flow paths diverted.

The quantity of these pollutants that might discharge to the receiving environment during the operations phase is likely to be negligible. Due to the distributed nature and likely stable landforms for the operation of these projects, it is unlikely that pollutants would be discharged beyond the rail corridor.

Materials may be deposited on the rail formation, which could build up over time and be washed off with stormwater runoff. The quantity of pollutants that might discharge to the receiving environment from surface runoff from the rail corridor was estimated using computer modelling software, Model for Urban Stormwater Improvement Conceptualisation (MUSIC). MUSIC is the industry-standard software for the estimation of pollutant generation in runoff, and treatment in stormwater treatment devices. This has been specifically addressed within Appendix G: Surface Water Quality Technical Report.

13.6.3 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 proposal. 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 proposed rail corridor and are shown in Figure 13.9.

Potential impacts include:

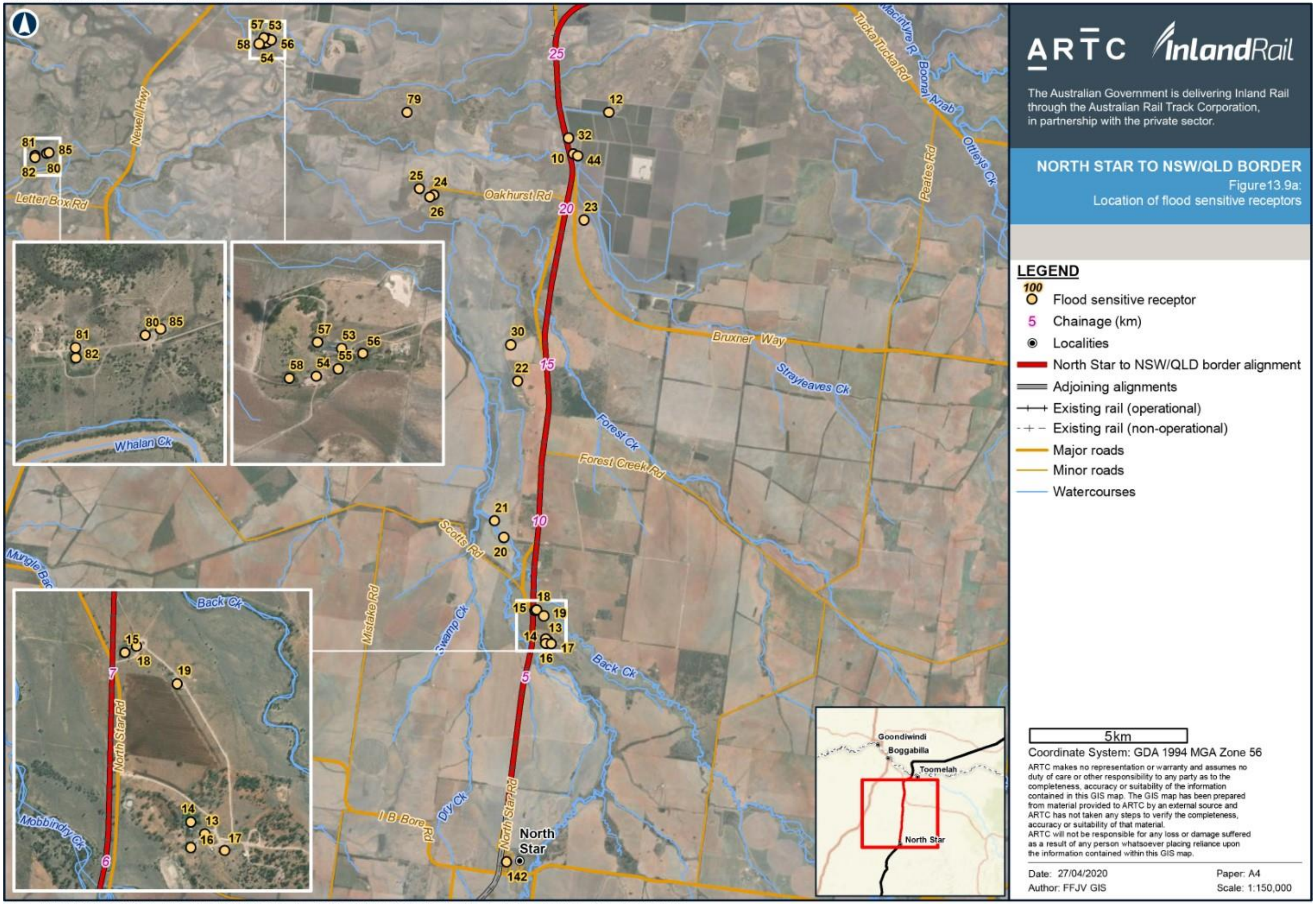
- Changes in peak water levels and associated areas of inundation
- Concentration of flows, redirection of flows and/or changes to flood-flow patterns
- Increased velocities leading to localised scour and erosion
- Changes affecting the existing fluvial geomorphologic conditions of waterways
- Changes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

Consideration of the *Draft Floodplain Management Plan for the Border Rivers Valley Floodplain* (Department of Industry, 2018) requires cumulative impacts to be evaluated. The DPIE Border Rivers Floodplain model has been used as a basis for this assessment. The DPIE model includes constructed and approved floodplain developments and, therefore, cumulative impacts in the floodplain have been addressed.

An assessment has also been undertaken of the removal of the existing non-operational Camurra–Boggabilla rail line, to determine impacts of the proposal with this older rail infrastructure removed.

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

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



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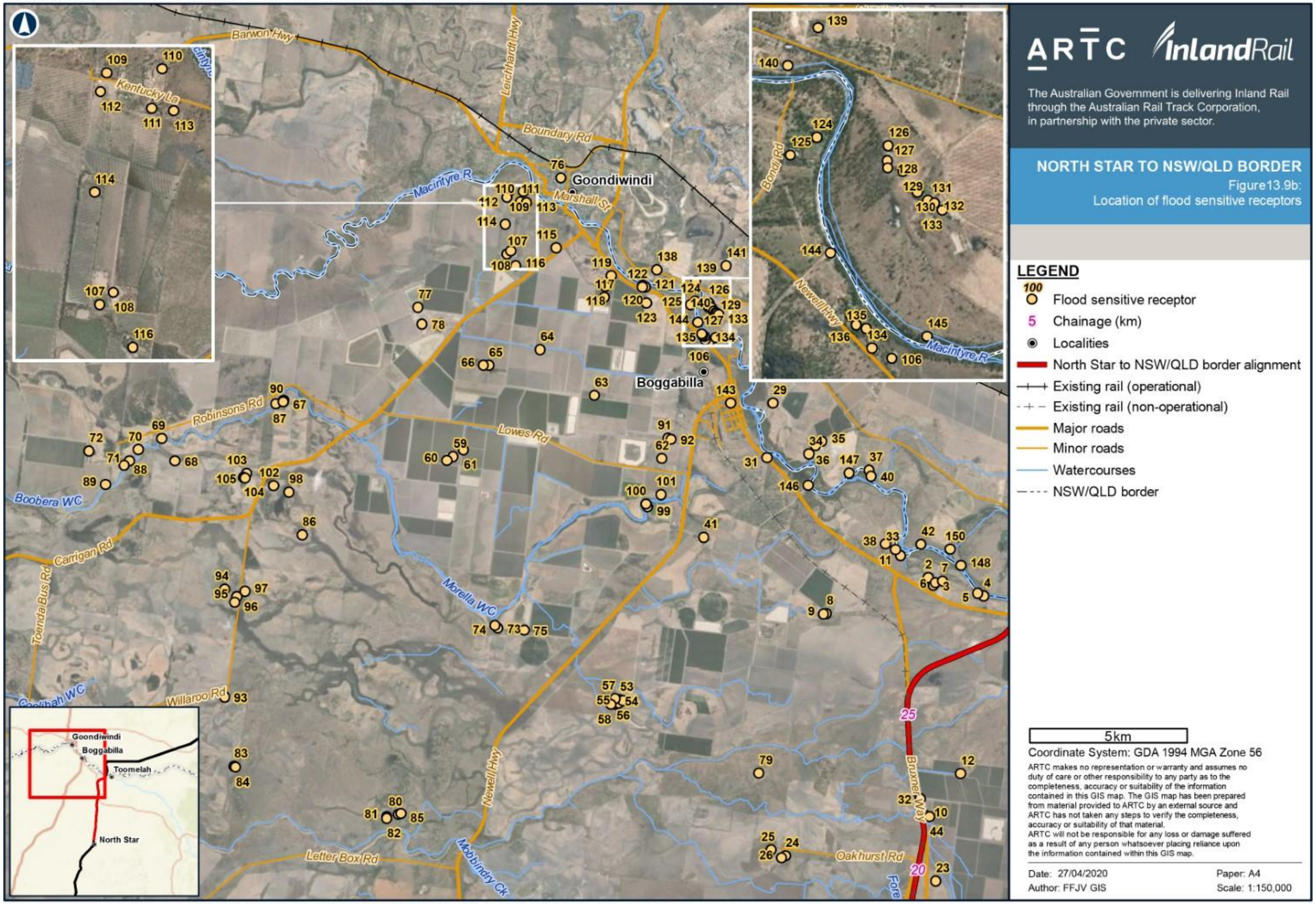
Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN,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



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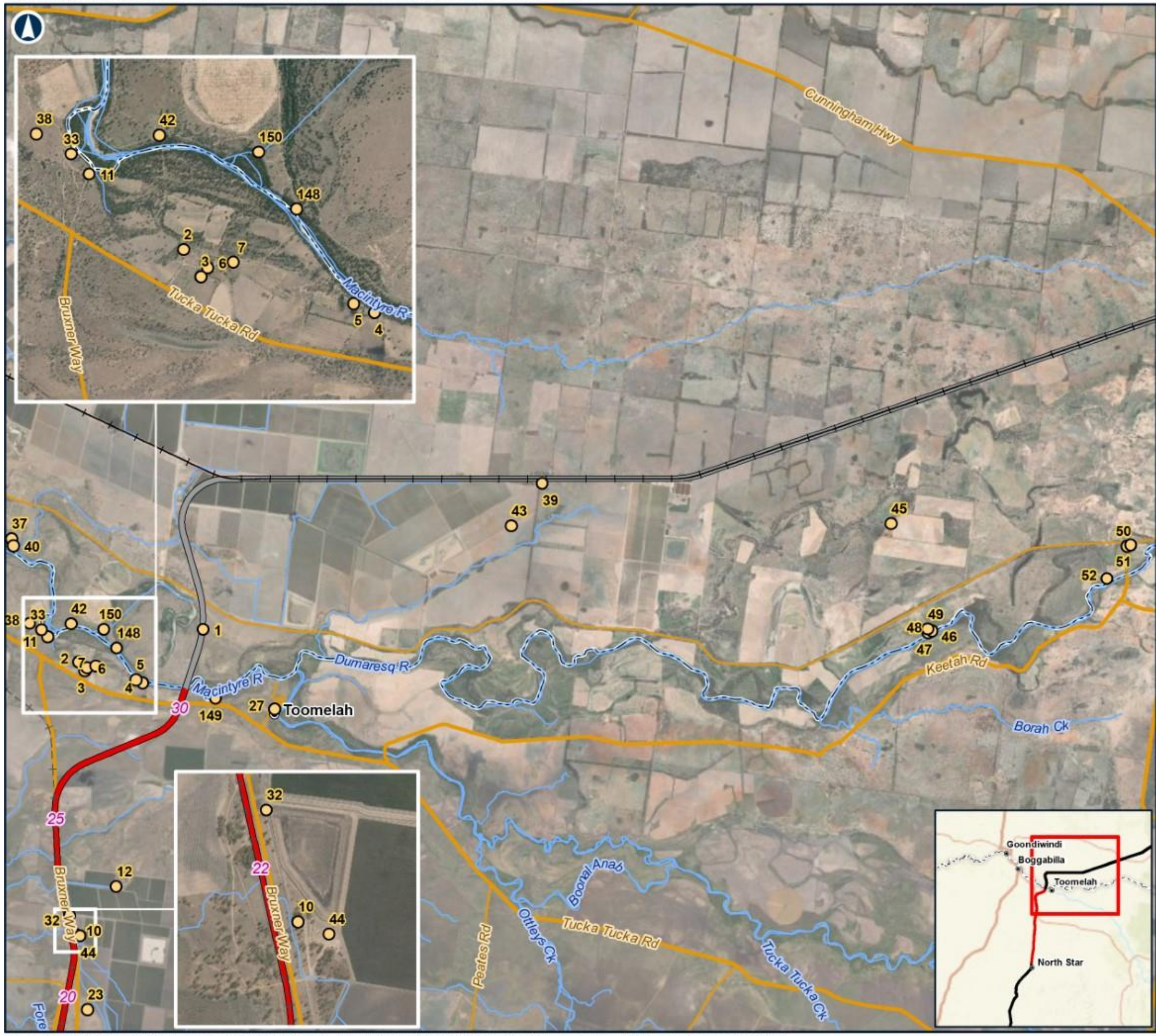
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



ARTC InlandRail

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

NORTH STAR TO NSW/QLD BORDER

Figure13.9c:
Location of flood sensitive receptors

LEGEND

- 100 Flood sensitive receptor
- 5 Chainage (km)
- Localities
- North Star to NSW/QLD border alignment
- Adjoining alignments
- Existing rail (operational)
- Existing rail (non-operational)
- Major roads
- Minor roads
- Watercourses
- NSW/QLD border

5km

Coordinate System: GDA 1994 MGA Zone 56

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13.7 Mitigation measures—current controls

13.7.1 Surface water quality

Following the ARTC impact assessment framework, suitable management measures to mitigate significant impacts are identified. The ARTC-approved impact mitigation measures, relevant to surface water quality, which will be implemented for the proposal, are provided in Table 13.20.

Mitigation for the construction phase includes environmental management measures to prevent or limit erosion and sedimentation through the design, planning and construction process, including:

- Preparation of erosion and sediment control plans, and soil management plans
- Siting of works to minimise the disturbance footprint
- Hydraulic modelling and analysis to confirm that measures are sized appropriately
- Earthworks guidelines and controls
- Implementation of erosion and sediment control measures
- Rehabilitation and reinstatement plans and works proposed for disturbed areas.

Construction-phase protection measures would be designed in accordance with the 'Blue Book' (*Managing Urban Stormwater: Soils and Construction, Volume 1*) (Landcom, 2004). The design and sizing of construction-phase water quality control measures varies depending on the soil types, and protection is typically provided for design events ranging between 0.5 to 4 events per year (i.e. between the three-month Average Recurrence Interval (ARI) event, or about 13 mm in one hour; to the two-year ARI event, or about 31 mm in 1 hour). This would be documented as a Soil and Water Management Plan and Erosion and Sediment Control Management Plan, as part of the CEMP.

Construction-phase activities with the potential to impact water chemistry, such as maintenance and refuelling, would be carried out with appropriate bunding or containment measures to avoid impacts to waterways, aquatic habitats, and groundwater, in accordance with regulatory requirements, legislation and regulations relevant to permissible works in/near watercourses and the release of contaminants to waters. Australian Standards relating to the storage and handling of hazardous substances would be adhered to where applicable. Mitigation for impacts arising from saline soils would be captured in soil management plans.

Mitigation for the operation phase includes measures to prevent or limit erosion and sedimentation by providing for hydraulic modelling and analysis, to guide the design of flow controls and site stabilisation measures so that they are sized appropriately for the expected conditions. Appendix H: Hydrology and Flooding Technical Report discusses the criteria that have been adopted for the design of rail drainage structures, many of which serve to minimise any alterations to existing flow characteristics. Most notably, flow velocities at drainage structure outlets have been limited, to minimise erosion and scour. Section 4.2 of Appendix H: Hydrology and Flooding Technical Report elaborates further on the velocity criteria, stating that soil properties are used to calculate allowable outlet velocities. Where no such values are available, conservative limits are adopted. Another key criterion has been the minimisation of changes to existing flood-flow distributions. Table 9.9 of Appendix H: Hydrology and Flooding Technical Report shows Design and Existing Case peak flows for the 1% AEP design event at various locations around the Border Rivers floodplain. Maximum changes are still under 2%.

TABLE 13.20 CURRENT CONTROLS FROM THE REFERENCE DESIGN FOR THE PROTECTION OF SURFACE WATER QUALITY

Delivery phase	Aspect	Proposed mitigation measures
Construction	Increased water turbidity and sedimentation	▸ A Soil and Water Management Plan, and Erosion and Sediment Control Management Plan will be developed as part of the CEMP, which complies with the project conditions of approval, relevant regulatory requirements and industry guidelines (e.g. *Managing Urban Stormwater—Soils and Construction—NSW*, Volume 1 (Landcom, 2004) and Volume 2 (DECC, 2008). This is expected to include: ▸ Water quality and soil/land conservation objectives for the project ▸ Temporary erosion and sediment control measures (including progressive erosion and sediment control plans that allow for staging of erosion and sediment controls as construction progresses) ▸ Rainfall monitoring requirements across the project area ▸ Workplace health and safety requirements relating to management of contamination and unexploded ordnance risk (UXO) ▸ Management of problem soils (e.g. ASS, erosive, dispersive, reactive, acidic, sodic, alkaline soils) ▸ Stockpiling and management/segregation of topsoil where it contains native plants, seedbank or weed material ▸ Vehicle, machinery and imported fill hygiene protocols and documentation ▸ Measures to prevent/minimise mud and dirt being tracked onto public roadways by trucks and any equipment leaving the site ▸ Requirements for training, inspections, corrective actions, notification and classification of environmental incidents, record keeping, monitoring and performance objectives for handover on completion of construction ▸ Any other requirements necessary to comply with conditions of approval, subsequent approvals or regulatory requirements. ▸ The construction of bridges, waterway crossings and waterway realignment/diversions is scheduled and/or staged to minimise impacts to bed, banks and environmental flows, in accordance with relevant regulatory requirements ▸ Design and construction of waterway realignments considers staging requirements/temporary works, in accordance with relevant regulatory requirements ▸ The siting of temporary construction facilities compounds, stockpiles, fuel storage, laydown areas, temporary access roads and staff parking will be in accordance with the project conditions of approval, and sited to minimise the extent of disturbance ▸ Temporary waterway crossings are rehabilitated in accordance with conditions of approval and the Reinstatement and Rehabilitation Plan ▸ Riparian vegetation and aquatic habitats are identified and avoided, where possible ▸ The project must be designed, constructed and operated so as to maintain the NSW WQOs where they are being achieved within the locality of this project, unless an Environment Protection Licence (EPL) in force in respect to the project contains different requirements in relation to the NSW Water Quality Objectives, in which case those requirements must be complied with. These outcomes will be identified within the CEMP.
Operations	Increased water turbidity and sedimentation	▸ The project boundary requirements defined for the project allow sufficient room for provision of the required temporary and permanent erosion and sediment/pollution control measures, where identified, as a mitigation measure for an identified environmental impact or risk.

Delivery phase	Aspect	Proposed mitigation measures
Construction	Changes to water chemistry	▸ The siting and scale of stockpiles, construction compounds, fuel storage and laydown areas and other construction areas shall be informed by a flood risk assessment, relevant conditions of approval and relevant regulatory requirements ▸ Opportunities to re-use/recycle construction water are identified and implemented where feasible during construction ▸ Requirements for construction water (volumes, quality, demand curves, approvals requirements and lead times) will be defined during design, e.g. water used for dust suppression will not result in adverse environmental or health impacts ▸ A surface water monitoring framework will be developed as part of the Soil and Water Management Sub-plan in the CEMP. It will identify monitoring locations at discharge points, and selected locations in watercourses where works are being undertaken. ▸ Water quality should be monitored during construction in accordance with the Surface Water Monitoring Framework ▸ Demolition of bridges and waterway crossing structures does not introduce pollutants or waste materials into waterways.
Operations	Changes to water chemistry	▸ Maintenance activities and refuelling must be carried out at an appropriate distance from riparian vegetation and waterways, with appropriate measures in place to avoid impacts to waterways, aquatic habitats and groundwater, in accordance with relevant regulatory requirements. Specifically, relevant legislation and regulations that specify requirements about permissible works in/near watercourses, and release of contaminants to waters should be referred to. Additionally, relevant Australian Standards should be considered and adhered to, where applicable and relevant. ▸ ARTC will implement its spill and contamination procedures during the operational phase of the project.

Operation-phase measures to mitigate impacts to water chemistry include the implementation of ARTC's spill and contamination procedures, as well as managing the proposal in accordance with ARTC's Environmental Management System/applicable licences/conditions of approval. Spill mitigation is specifically addressed in Chapter 15: Land Resources and Contamination.

Further, to assess that the construction of the proposed rail alignment does not impact water quality, surface water monitoring is proposed. This will include the relevant WQOs, parameters, and criteria from the EIS surface water quality chapter, for the specific monitoring locations and frequency described therein. Provision has been made in ARTC's proposed mitigation measures for corrective actions should the outcomes of rehabilitation and/or reinstatement/stabilisation not return to the representative baseline conditions for water quality.

13.7.2 Hydrology and flooding

13.7.2.1 Design considerations

The proposal 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 proposal design are detailed in Table 13.21.

TABLE 13.21 INITIAL MITIGATION OF RELEVANCE TO HYDROLOGY AND FLOODING

Aspect	Initial design mitigations

Flooding and hydrology	▶ The proposal has been designed to achieve the hydraulic design criteria (refer Section 13.4.3.1) and other 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 the 1 in 2,000 AEP event
	▶ The proposal uses the existing non-operational Boggabilla rail corridor as much as possible, to avoid introducing new linear infrastructure corridor across floodplain areas
	▶ The proposal design incorporates bridge and culvert structures to maintain existing flow paths and flood-flow distributions
	▶ The proposal design minimises changes to the existing flood-flow distribution and velocities so as to avoid impacting o the existing fluvial geomorphological conditions
	▶ Bridge and culvert structures have been located and sized to avoid increases in peak water levels, velocities and/or duration of inundation, and changes to flow distribution in accordance with the flood-impact objectives (refer Section 13.4.3.2)
	▶ Progressive refinement of bridge extents and culvert banks (number of barrels and dimensions) has been undertaken as the proposal 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 ARR 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 proposal design performance against the flood-impact objectives are provided in Section 13.8.2. For further details regarding the hydrologic and hydraulic modelling approach and design outcomes, refer to Appendix H: Hydrology and Flooding Technical Report and, for further details on engagement with stakeholders regarding hydrology, refer to Chapter 8: Consultation and Appendix D: Consultation Summary.

13.7.2.2 Future mitigation measures

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

Table 13.22 identifies the relevant proposal phase, the aspect to be managed and the proposed mitigation measure.

TABLE 13.22 FUTURE PHASE HYDROLOGY AND FLOODING MITIGATION MEASURES

Delivery phase	Aspect	Proposed mitigation measure
Detailed design	Hydrology and flooding	▸ Consult with stakeholders including directly impacted landowners, 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. This will confirm bridge lengths, culvert sizing and numbers, localised scour and erosion protection measures for both rail, road and other permanent Project infrastructure. ▸ 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.
Pre-construction	Hydrology and 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	Hydrology and flooding	▸ Inspections will be carried out in accordance with ARTC's *Structures Inspection Engineering Code of Practice* (ETE-09-01) (ARTC, 2019) 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-based assessment has been undertaken following the ARTC impact assessment framework. In summary, potential impacts were grouped into two categories:

- Increased water turbidity and sedimentation
- Changes to water chemistry.

Accordingly, suitable management measures to mitigate significant impacts have been identified. The current controls and impact mitigation measures relevant to surface water quality that will be implemented for the proposal, are provided in Table 13.20.

Impacts were assessed using the significance assessment method. Table 13.23 summarises the assessment undertaken for the potential impacts of the proposal on the surface water WQOs. For each identified potential impact, the assessment considered the following:

- The initial impact significance assessment rating assumes that the design considerations to reduce impacts would be implemented.
- The residual impact significance incorporates any additional mitigation measures that would be required to decrease the impacts of the assessed action. ARTC environmental management measures in the Inland Rail Program Environmental Management Plan (EMP) will be adhered to and applied to the assessed action.
- The sensitivity of the receiving environments was assessed to be 'high'. The Macintyre River and other waterways within the study area form part of an Endangered Ecological Community and are currently exposed to the threatening processes associated with rural land use, land clearing and disturbance, which are widespread and have compromised the integrity of this ecological community. The high sensitivity was selected to reflect the conservative assessment approach used throughout this report. Specific strategies for this sensitive environment receptor have not been implemented as construction surface water monitoring is expected to be used to identify any realised potential impact (from the moderate residual risk of impact). The key waterway considered in the significant residual impact is the Macintyre River (due to the perennial nature) and surface water monitoring will be used during construction.
- The magnitude of the initial impact was assessed to be moderate, as impacts would likely be contained within the region of the project. Application of appropriate project controls is expected to reduce the magnitude, resulting in a lower residual significance.

13.8.1.1 Construction-phase water quality management

The significance assessment identified that the current controls and impact mitigation measures relevant to surface water quality that would be implemented for the proposal, would be sufficient to mitigate a high degree of potential conceivable impacts during the construction phase, such that the residual significance would be moderate (refer Table 13.23).

Therefore, it is considered that all practical measures to avoid or minimise water pollution and protect human health and the environment from harm have been investigated and would be implemented through the mitigation measures outlined for the proposal.

With the proposed mitigation measures in place, the proposal construction impacts are considered transient and the activities of the proposal are not expected to worsen environmental conditions (where WQOs are not currently being met). The construction impacts are considered such that no activities are proposed that would compromise the ability of catchment management initiatives or activities to work toward the achievement of WQOs over time, considering that construction is transient and has the potential to improve the catchment through the operational phase. For example, where in-stream works need to be done (for the purposes of the project) to areas that are currently eroded or eroding, in-stream works will stabilise any erosion during the construction phase, followed by rehabilitation works to ensure long-term stability, thus contributing to an improvement in stream conditions over time during the operational phase. Specific strategies for this sensitive environment receptor have not been implemented as construction surface water monitoring is expected to be used to identify any realised potential impact (from the moderate residual risk of impact). The key waterway predicted to be impacted is the Macintyre River (due to its perennial nature), therefore surface water monitoring will be used during construction to monitoring activities.

13.8.1.2 Operation-phase water quality management

For the operation phase, the current controls and impact mitigation measures relevant to surface water quality were assessed to be sufficient for the purposes of mitigating impacts that could cause increased water turbidity and sedimentation. There is a risk of erosion that could result from changes to landform and overland flow paths. This risk would be managed by hydraulic modelling and analysis for any areas where flow paths would be altered, to ensure that mitigation measures were sized appropriately. Further, many stabilisation measures are recommended (refer Table 13.20); therefore, the operational environment within the rail corridor is expected to comprise a stable and well-vegetated landform.

Similarly, for changes to water quality related to changes to flow and drainage paths, mitigation measures have been assessed to be sufficient. The drainage design for the proposal for both longitudinal and cross-drainage has been designed to convey the 1% AEP event. The conveyance for these events has been based on flows estimated for the local and drainage catchments. Where regional floods could influence flows, these have also been considered; therefore, any changes to water quality resulting from changes to overland flow are expected to be minor and limited in extent.

Changes to flow within the rail corridor could be caused by the introduction of rail formation, which may reduce infiltration to subsoils; however, runoff from the rail formation would be designed to be spread as distributed flow along the length of the rail corridor and, therefore, no impacts to flow are expected beyond the rail corridor.

Impacts to water chemistry from the rail formation are expected due to the documented impacts of rail operation on water chemistry (Vo et al., 2015); therefore, additional operation-phase measures to mitigate impacts to water chemistry were considered necessary.

The requirements of the SEAR 10.1 (e) are:

> *Demonstrate how construction and operation of the project will, to the extent that the project can influence, ensure that:*
>
> - *Where the NSW WQOs for receiving waters are currently being met they will continue to be protected*
> - *Where the NSW WQOs are not currently being met, activities will work toward their achievement over time.*

To meet these requirements, runoff from the railway formation would need to be filtered. Filtration can be provided with designs typical for rail in rural areas, such as vegetated embankments and vegetated longitudinal drains/swales. Runoff from the rail formation is typically discharged as distributed flow from the rock ballast to the surrounding landform. When the flow interacts with vegetation on the embankments and surrounding soils, pollutants in runoff are treated, through the processes of physical settling and screening, chemical sorption and biological uptake. Vegetated embankments are considered part of the drainage design. Where the terrain requires it, vegetated longitudinal drains can also provide a similar filtration function; however, such longitudinal drainage has not currently been identified as a requirement for drainage for the proposal.

For the rail corridor, vegetated embankments (i.e. buffer strips) are complementary to, and already form part of, the drainage design; they allow for even, distributed flow along the length of the rail corridor. These buffer strips would be vegetated with grasses. Vegetated longitudinal drains would be used where long drainage is required, as these keep water on the surface, minimising the need to disturb soil through excavation. Other treatment devices, such as bioretention systems or constructed wetlands, were considered unsuitable for the rail corridor since they require concentrated flow and considerable excavation.

Further, the requirements of the SEAR 10.1 (b) are:

> *Identify and estimate the quality and quantity of all pollutants that may be introduced into the water cycle by source and discharge point and describe the nature and degree of impact that any discharge(s) may have on the receiving environment, including consideration of all pollutants that pose a risk of non-trivial harm to human health and the environment.*

To meet this requirement, the proposed rail formation and the proposed stormwater treatment systems were modelled using stormwater quality modelling software (MUSIC) to assess if the proposed treatments would be sufficient to ensure that the quality of runoff would not be impacted. This assessment determined that with such treatment measures in place, water quality leaving the rail corridor is expected to be similar to or better than the existing condition (summarised in Appendix G: Surface Water Quality Technical Report).

With these measures in place, it is considered that all practical measures to avoid or minimise water pollution and protect human health and the environment from harm have been investigated and would be implemented for the proposal. These mitigation measures would ensure that where the NSW WQOs for receiving waters are currently being met, they will continue to be protected, and where the WQOs are not currently being met, the activities of the proposal would not worsen the environmental conditions. Specific strategies for this sensitive environment receptor have not been implemented, as construction surface water monitoring is expected to be used to identify any realised potential impact (from the moderate residual risk of impact). The key waterway considered in the significant residual impact is the Macintyre River (due to the perennial nature) and surface water monitoring will be used during construction.

For the operation phase of the proposal, the stable and well-vegetated railway corridor is not likely to be a source of pollutants that would compromise catchment works designed to work towards the achievement of water-quality objectives.

TABLE 13.23 SIGNIFICANCE ASSESSMENT INCLUDING MITIGATION MEASURES RELEVANT TO SURFACE WATER QUALITY

Potential impact	Phase	Initial impact significance			Mitigation measures required in addition to design considerations	Residual significance	
		Sensitivity	Magnitude	Significance		Magnitude	Significance
Increased water turbidity and sedimentation	Construction	High	Moderate	High	Current controls are considered sufficient to mitigate potential impact magnitude (refer Table 13.20)	Low	Moderate
	Operations		Low	Moderate	Current controls are considered sufficient to mitigate potential impact magnitude (refer Table 13.20)	Negligible	Low
Changes to water chemistry	Construction	High	Moderate	High	Current controls are considered sufficient to mitigate potential impact magnitude (refer Table 13.20)	Low	Moderate
	Operations		Low	Moderate	Drainage design (as part of detailed design) to incorporate vegetated embankments to treat surface water runoff Otherwise, current controls are considered sufficient to mitigate potential impact magnitude (refer Table 13.20)	Negligible	Low

13.8.2 Hydrology and flooding—Operation phase

The proposal is responsible for the hydraulic design of all structures across the Macintyre River floodplain, which extends beyond the NSW/QLD border into Queensland. Hydraulic design of structures to the north of the Macintyre floodplain has been assessed and documented in the Inland Rail Border to Gowrie EIS that supports the Inland Rail program.

The proposed rail embankment, drainage structures and associated works were included in the hydraulic sub-model to form the Developed Case. Progressive mitigation of impacts was undertaken through refinement of the design as detailed in Table 13.21 to arrive at the adopted design, including bridges and culverts. A range of events, including extreme events, were modelled and the resulting impacts identified along the alignment and at flood-sensitive receptors.

The impact of the proposal on the existing flood regime has been quantified and compared against the flood-impact objectives listed in Table 13.7. The proposal design includes:

- Flood drainage structures:
  - 13 bridges
  - 26 reinforced concrete pipe (RCP) banks
  - 6 reinforced concrete box culvert (RCBC) banks.
- Local drainage structures:
  - 17 reinforced concrete pipe culvert banks
  - 1 reinforced concrete box culvert bank.
- Removal of non-operational rail line, up to southern side of Whalan Creek
- Roadworks, including drainage structures on Bruxner Way.

The location of the flood and local drainage structures are presented in Figure 13.10 with flood structure details provided in Table 13.24. Details of the local drainage structures are provided in Appendix H: Hydrology and Flooding Technical Report. The drainage structure upgrades to Bruxner Way are detailed in Table 13.25.

TABLE 13.24 FLOOD STRUCTURE LOCATIONS AND DETAILS

Chainage (km)	Waterway	Structure type	Number of culvert cells	Diameter/width of culvert or bridge length (m)	Culvert height (m) or lowest bridge soffit level (m AHD)	Culvert length (m)
5.58	Mobbindry Creek	RCP	2	1.05	-	17
5.76		Bridge (BR01)	-	109	243.30	-
6.08		RCP	7	2.10	-	18
6.12		RCP	7	2.10	-	16
6.23		Bridge (BR02)	-	170	242.91	-
6.53		RCP	6	2.10	-	17
6.58		RCP	5	2.10	-	17
8.11	Back Creek	Bridge (BR03)	-	67	238.60	-

Chainage (km)	Waterway	Structure type	Number of culvert cells	Diameter/width of culvert or bridge length (m)	Culvert height (m) or lowest bridge soffit level (m AHD)	Culvert length (m)
15.33	Forest Creek	RCBC	10	1.20	1.20	8
15.52		RCBC	10	1.20	1.20	10
15.67		RCP	10	1.20	-	13
15.83		RCP	20	1.20	-	14
15.90		RCP	20	1.20	-	14
15.98		RCP	20	1.20	-	16
16.08		RCP	20	1.20	-	15
16.29		Bridge (BR04)	-	40	229.00	-
16.49		RCBC	1	3.00	2.40	9
16.60		RCP	8	1.20	-	17
16.83		RCP	8	1.20	-	17
20.73	Strayleaves Creek	Bridge (BR05)	-	131	227.10	-
21.35		RCP	3	1.35	-	28
21.97		RCP	3	1.05	-	20
22.27		RCP	3	1.20	-	13
22.86	Whalan Creek	RCP	10	1.20	-	25
23.22		RCP	10	1.20	-	25
23.70		RCP	10	1.20	-	25
23.80		RCP	10	1.20	-	25
24.03		RCP	8	1.05	-	26
24.20		RCP	5	0.90	-	28
24.62		RCBC	35	1.20	0.90	27
24.71		RCBC	35	1.20	0.90	26
24.85		RCBC	35	1.20	0.90	30
25.34		Bridge (BR06)	-	131	227.77	-
25.80		Bridge (BR07)	-	104	229.90	-
26.09		Bridge (BR08)	-	156	230.40	-
27.06		RCP	10	1.20	-	15
27.56		Bridge (BR09)	-	116	227.70	-
28.03		Bridge (BR10)	-	117	227.70	-
30.35		Bridge (BR11)	-	1748	230.00	-
31.26		RCP	10	1.80	-	32
31.32	Macintyre River (the proposal area)	RCP	10	1.80	-	30
31.52		Bridge (BR12)	-	144	227.46	-
31.87		RCP	15	0.90	-	14
31.97		RCP	15	0.90	-	15
32.55		Bridge (BR13)	-	521	225.71	-

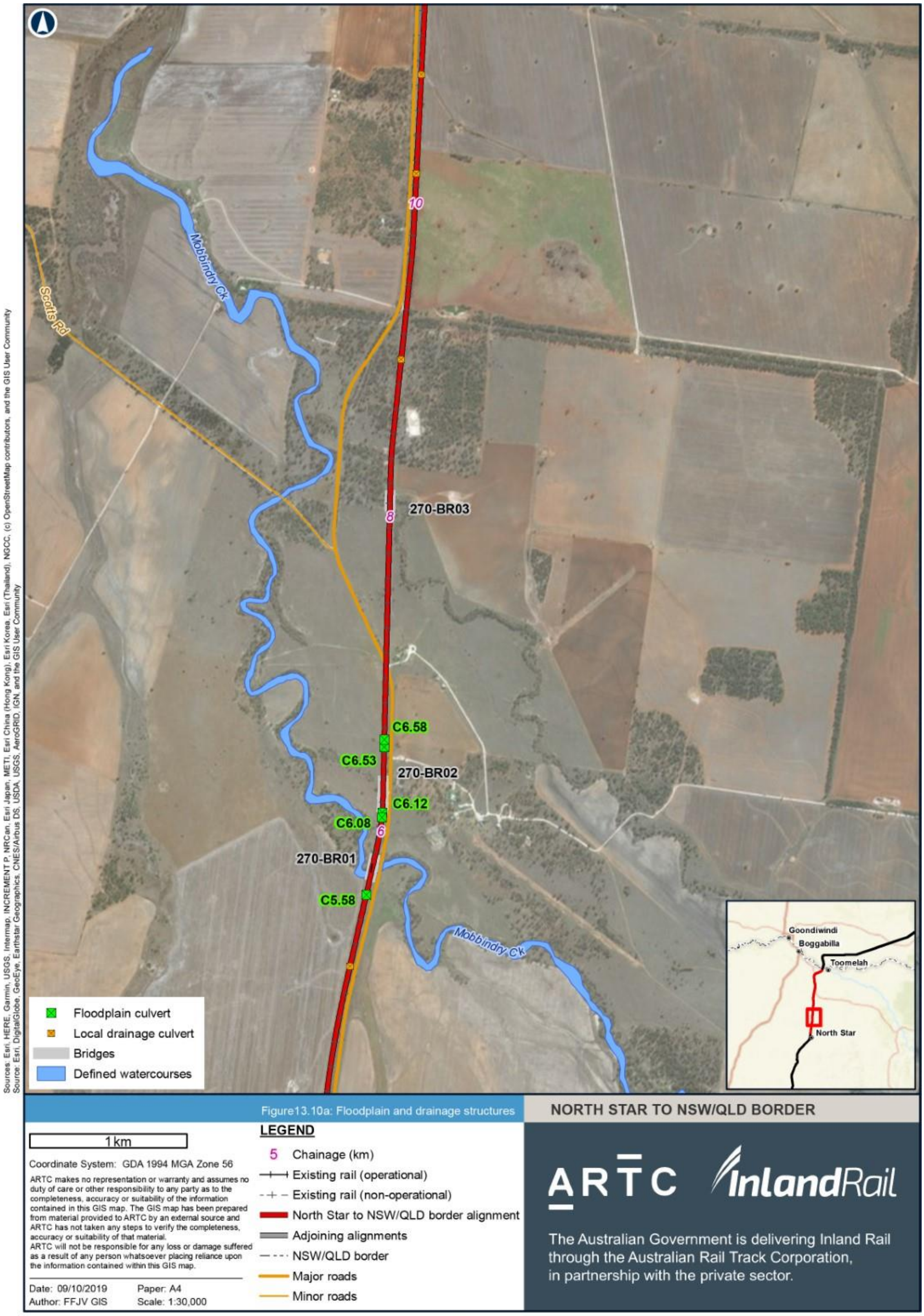

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FIGURE 13.10A-E FLOODPLAIN AND DRAINAGE STRUCTURES

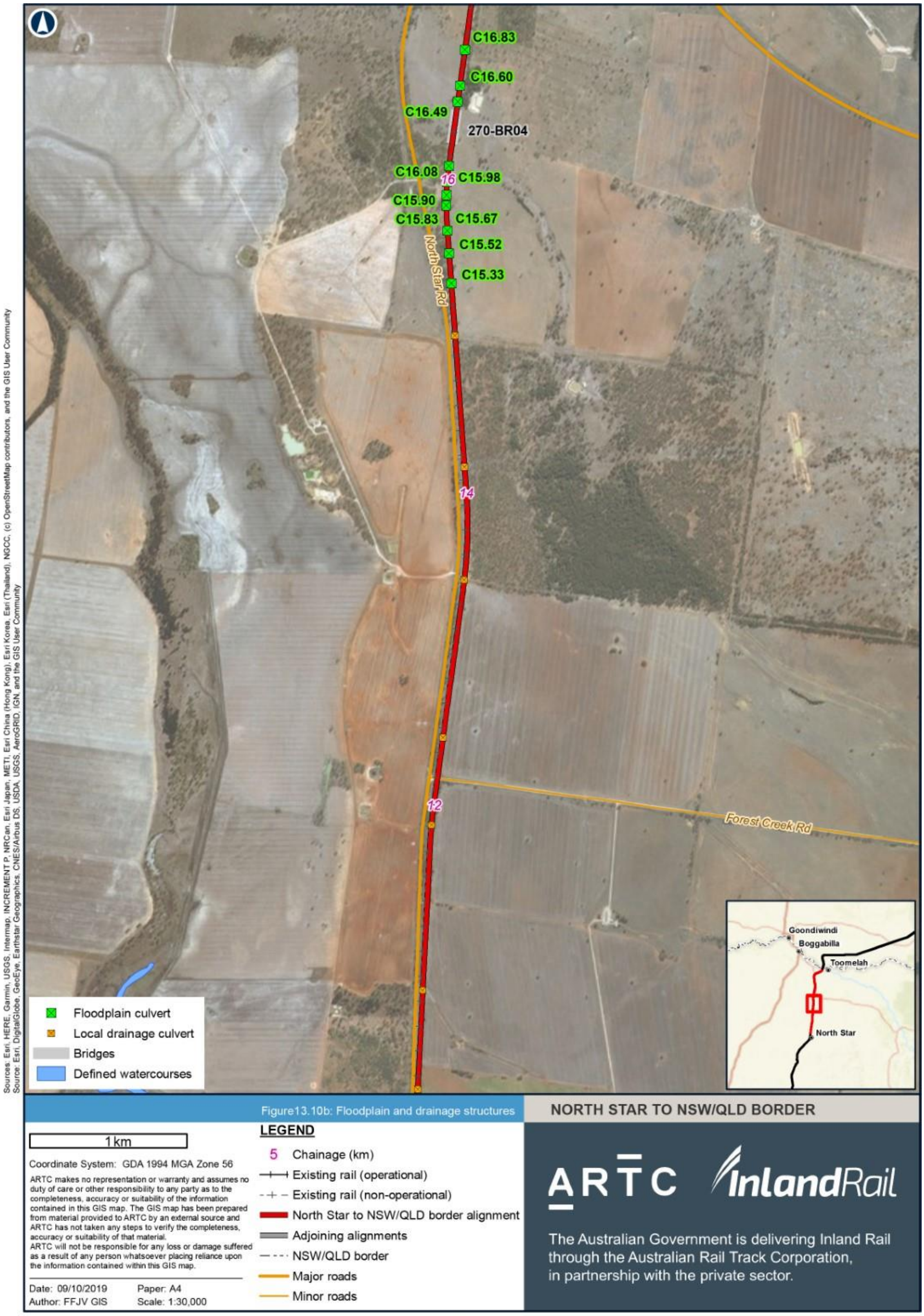

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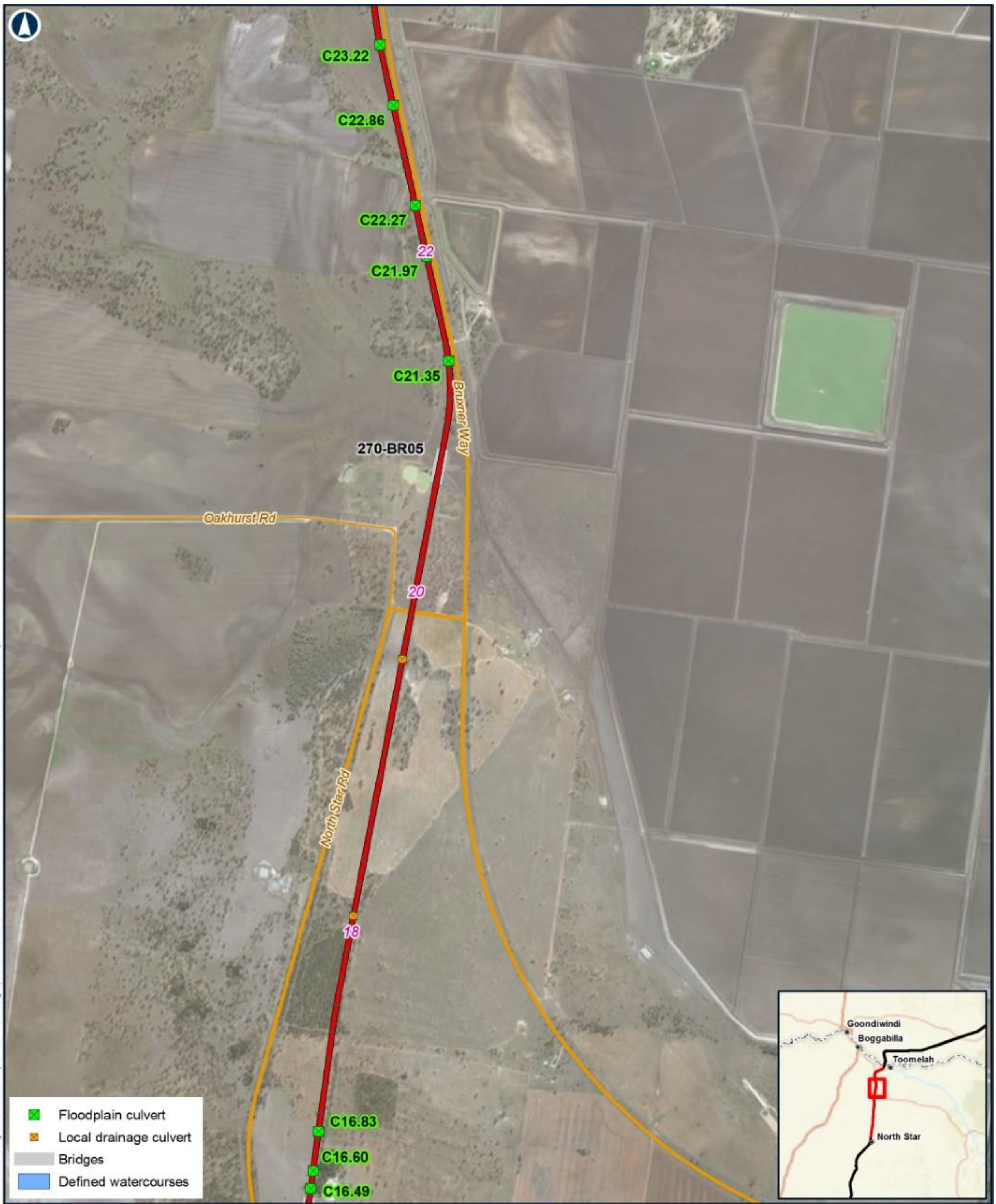
FIGURE 13.10B FLOODPLAIN AND DRAINAGE STRUCTURES



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

Figure13.10c: Floodplain and drainage structures

NORTH STAR TO NSW/QLD BORDER

1 km

Coordinate System: GDA 1994 MGA Zone 56

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LEGEND

- 5 Chainage (km)
- Existing rail (operational)
- Existing rail (non-operational)
- North Star to NSW/QLD border alignment
- Adjoining alignments
- NSW/QLD border
- Major roads
- Minor roads

ARTC InlandRail

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FIGURE 13.10C FLOODPLAIN AND DRAINAGE STRUCTURES

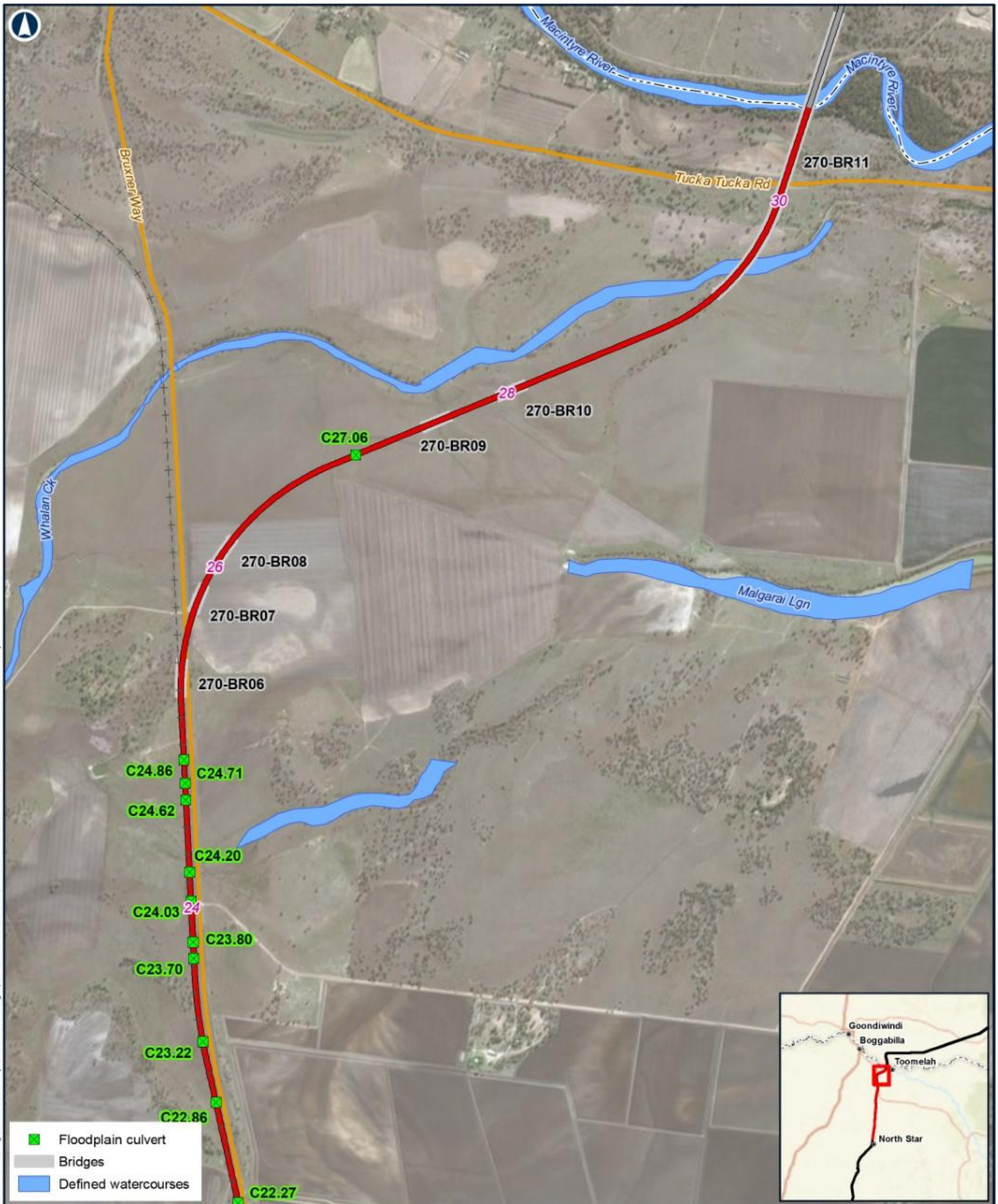

Figure13.10d: Floodplain and drainage structures

NORTH STAR TO NSW/QLD BORDER

1 km

Coordinate System: GDA 1994 MGA Zone 56

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LEGEND

- 5 Chainage (km)
- Existing rail (operational)
- Existing rail (non-operational)
- North Star to NSW/QLD border alignment
- Adjoining alignments
- NSW/QLD border
- Major roads
- Minor roads

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FIGURE 13.10D FLOODPLAIN AND DRAINAGE STRUCTURES

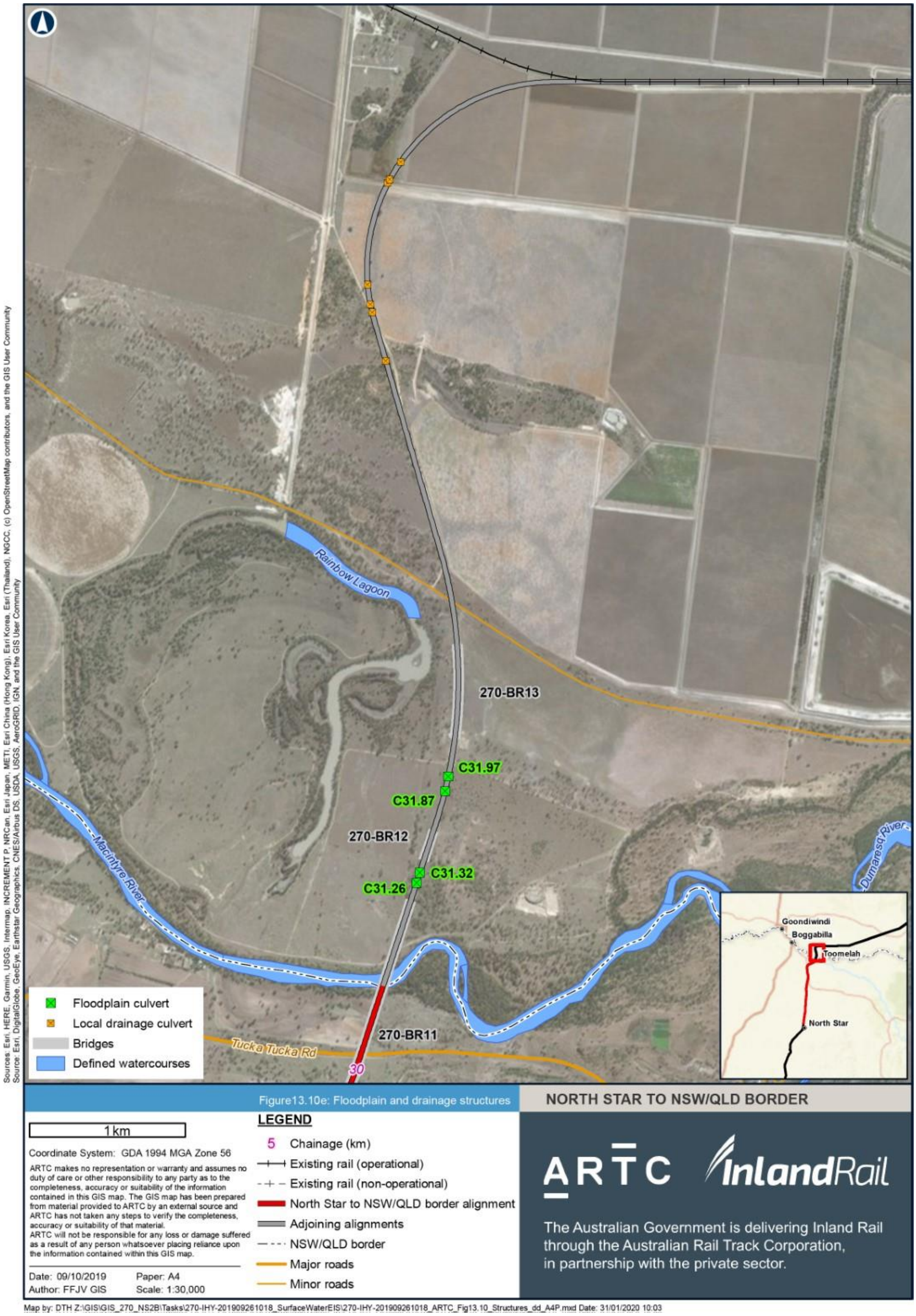


FIGURE 13.10E FLOODPLAIN AND DRAINAGE STRUCTURES

TABLE 13.25 BRUXNER WAY UPGRADE—CULVERT LOCATIONS AND DETAILS

Road chainage (km)	Culvert name	Road name	Structure type	Number of cells	Span (m)	Height (m)	Length (m)
0.27	C0.27_BW	Bruxner Way	RCBC	3	1.20	0.45	21
1.37	C1.37_BW	Bruxner Way	RCBC	3	1.20	0.30	17
1.71	C1.71_BW	Bruxner Way	RCBC	1	1.20	0.30	15

The hydraulic sub-model was run for the Developed Case for the suite of design events (20%, 10%, 5%, 2%, 1% AEP events and 1 in 2000, 1 in 10,000 and the PMF events) with key results and outcomes presented in the following sections. Detailed results are provided in the Appendix H: Hydrology and Flooding Technical Report.

13.8.2.1 Change in peak water levels

The change in peak water levels for the two modelled scenarios, DPIE levees and 2019 LiDAR levees, are presented in Figure 13.11 and Figure 13.12, respectively. Comparison of these figures shows that the impacts associated with the proposal alignment do not vary greatly between the two cases, even when the two different topographic datasets are used. For the remainder of the impact assessment against the flood-impact objectives, the 2019 LiDAR levee scenario has been adopted, as this reflects the current state of development on the floodplain.

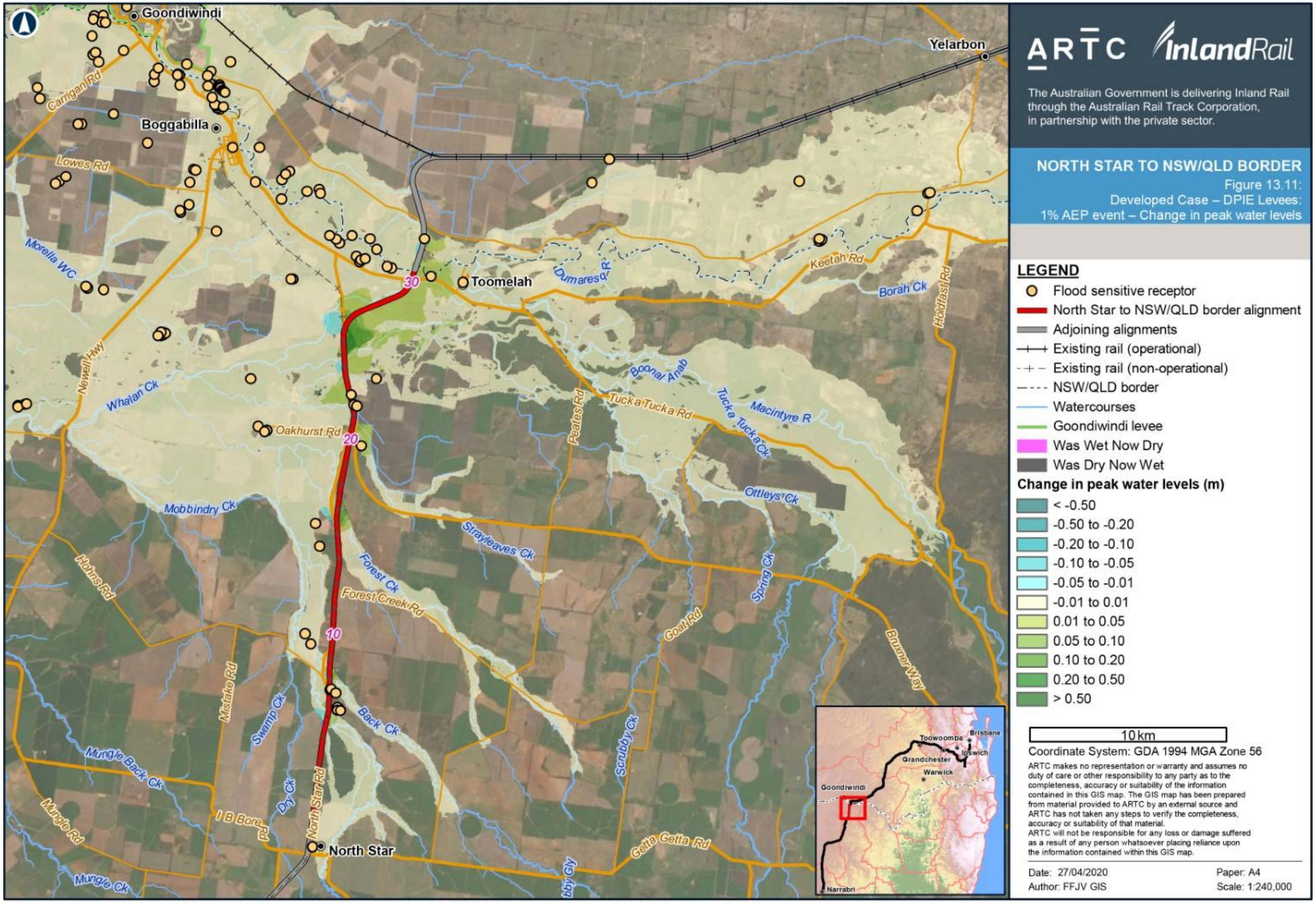
From the 2019 LiDAR 1% AEP event, the Developed Case has been predicted to result in changes to peak water levels that generally comply with the flood-impact objectives with results shown in flood-sensitive receptors on the floodplain identified in Figure 13.9.

The township of Toomelah is within 3 km of the proposed alignment, with the change in peak water levels predicted to be approximately 25 mm immediately upstream of the rail and reducing to less than 10 mm at the Toomelah township. To the south of Whalan Creek, the change in peak water levels is predicted to be up to 40 mm immediately upstream of the rail dissipating to less than 10 mm within 2.1 km.

Under the 1% AEP event, there are a number of localised occurrences where the change in peak water levels is predicted to be greater than 200 mm but less than 400 mm, which still complies with the flood-impact objectives. These are:

- Ch 5.60 km—with an increase of 230 mm dissipating to less than 200 mm within 30 m of the rail embankment, over an area of 0.002 km^2
- Ch 6.0 km—with an increase of 240 mm dissipating to less than 200 mm within 30 m of the rail embankment, over an area of 0.003 km^2
- Ch 8.4 km—with an increase of 240 mm dissipating to less than 200 mm within 30 m of the rail embankment, over an area of 0.005 km^2
- Ch 15.80 km (upstream of the Forest Creek crossing)—with an increase of 280 mm dissipating to 200 mm within 80 m of the rail embankment, over an area of 0.02 km^2
- Ch 20.80 km to 22.30 km—with an increase of 360 mm dissipating to less than 200 mm within 200m of the rail embankment, over an area of 0.24 km^2
- Ch 22.40 km—with an increase of 350 mm dissipating to less than 200 mm within 14 0m of the rail embankment, over an area of 0.04 km^2
- Ch 25.00 km—with an increase of 280 mm dissipating to less than 200 mm within 180 m of the rail embankment, over an area of 0.06 km^2.

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



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There are two locations where the change in peak water levels is above 400 mm, being:

- Ch 6.4 km—with an increase of 470 mm dissipating to less than 400 mm within 30 m, and to less than 200 mm within 100 m of the rail embankment, over an area of 0.02 km^2
- Ch 23.90 km—with an increase of 570 mm dissipating to less than 200 mm within 85 m of the rail embankment, over an area of area 0.025 km^2.

The related impacts on duration of inundation and impacts on existing infrastructure for these locations is discussed in the following sections.

For events smaller than the 1% AEP event, the changes in peak water levels reduce as the magnitude of the flood reduces and the flow is mostly contained to the creek and river channels. Appendix C of Appendix H: Hydrology and Flooding Technical Report presents the change in peak water levels at each flood-sensitive receptor for all design events.

In addition to considering the impact of the proposal on peak water levels, SEAR 8.2 (d) requires the following be considered:

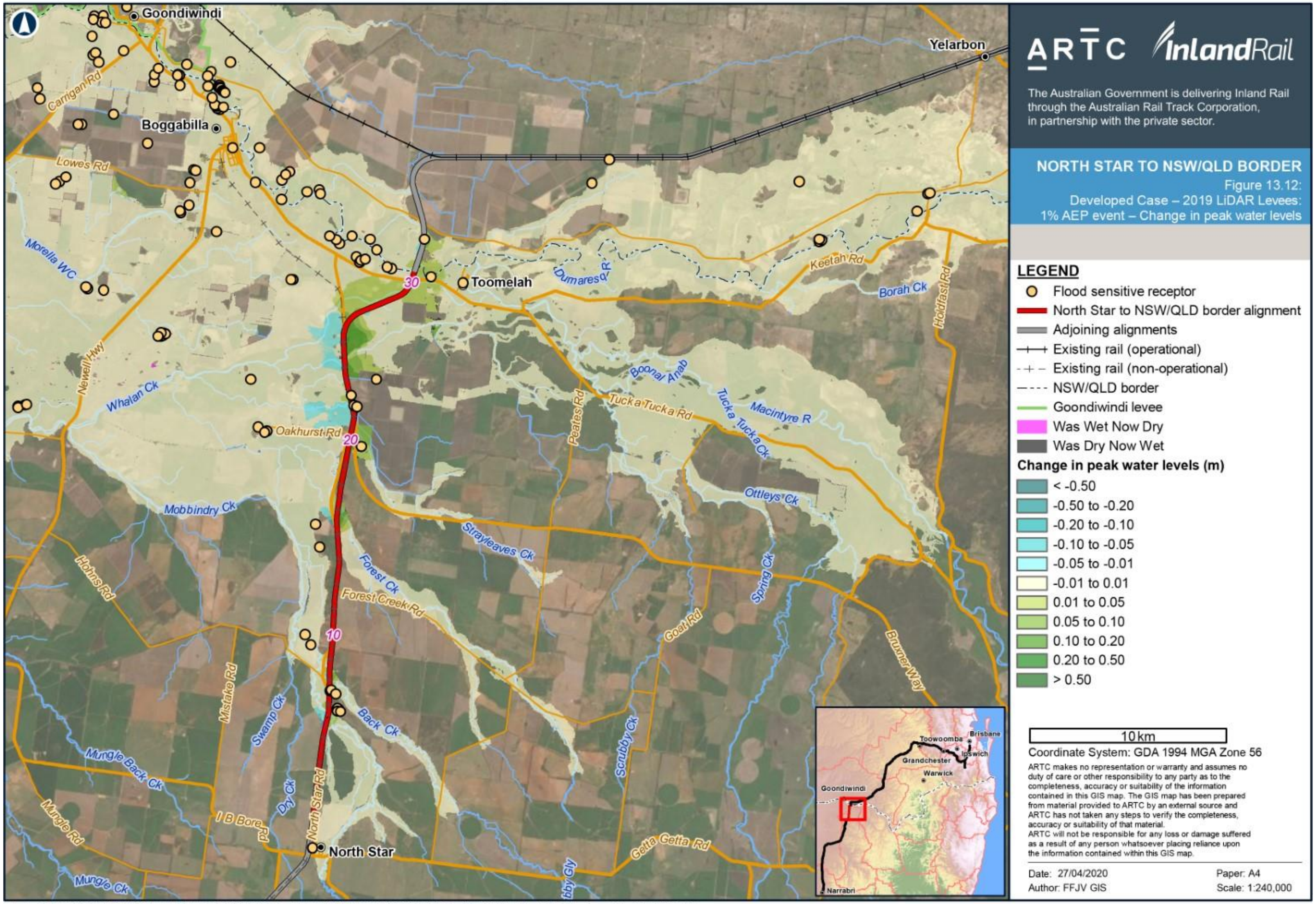
> *Where the existing rail infrastructure has an adverse flood impact on property or people, the flood assessment must consider the extent to which the project alleviates or exacerbates these existing impacts.*

The existing Camurra–Boggabilla rail line has been in place since 1932 and is currently truncated at North Star, with the remainder of the line to Boggabilla non-operational. The existing non-operational rail line and embankment is in a state of significant disrepair and is generally elevated above surrounding ground levels by 0.5 to 0.8 m, increasing up to 2 m near Whalan Creek. It has limited transverse drainage structures, many of which are in a degraded state. The existing rail embankment restricts flows during flood events and is overtopped in larger events.

With the Camurra–Boggabilla rail line having been in place for over 80 years, and considering its degraded state, it is difficult to determine if it has an adverse impact on existing flooding or not, especially given the other changes on the floodplain in this period; however, to address the SEAR requirement, a 1% AEP event hydraulic model run was undertaken with the existing non-operational rail removed from the Existing Case. The outcomes of this revised Existing Case have been compared against the 2019 LiDAR Developed Case results for the 1% AEP event. The change in peak water levels for the 1% AEP event for the Developed Case as compared to the revised Existing Case (with non-operational rail line removed) are presented in Figure A22 of Appendix H: Hydrology and Flooding Technical Report.

Comparison of Figure 13.12 with Figure A22 (in Appendix H) shows that, under the 1% AEP event, the removal of the non-operational rail from the Existing Case leads to increased peak water levels upstream of the non-operational rail alignment north of Whalan Creek towards Boggabilla and Goondiwindi. This increased extent of impact is directly related to the removal of the non-operational line from the Existing Case and the proposal alignment does not exacerbate or alleviate these impacts. The changes in peak water levels along the proposal alignment are the same in both scenarios.

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



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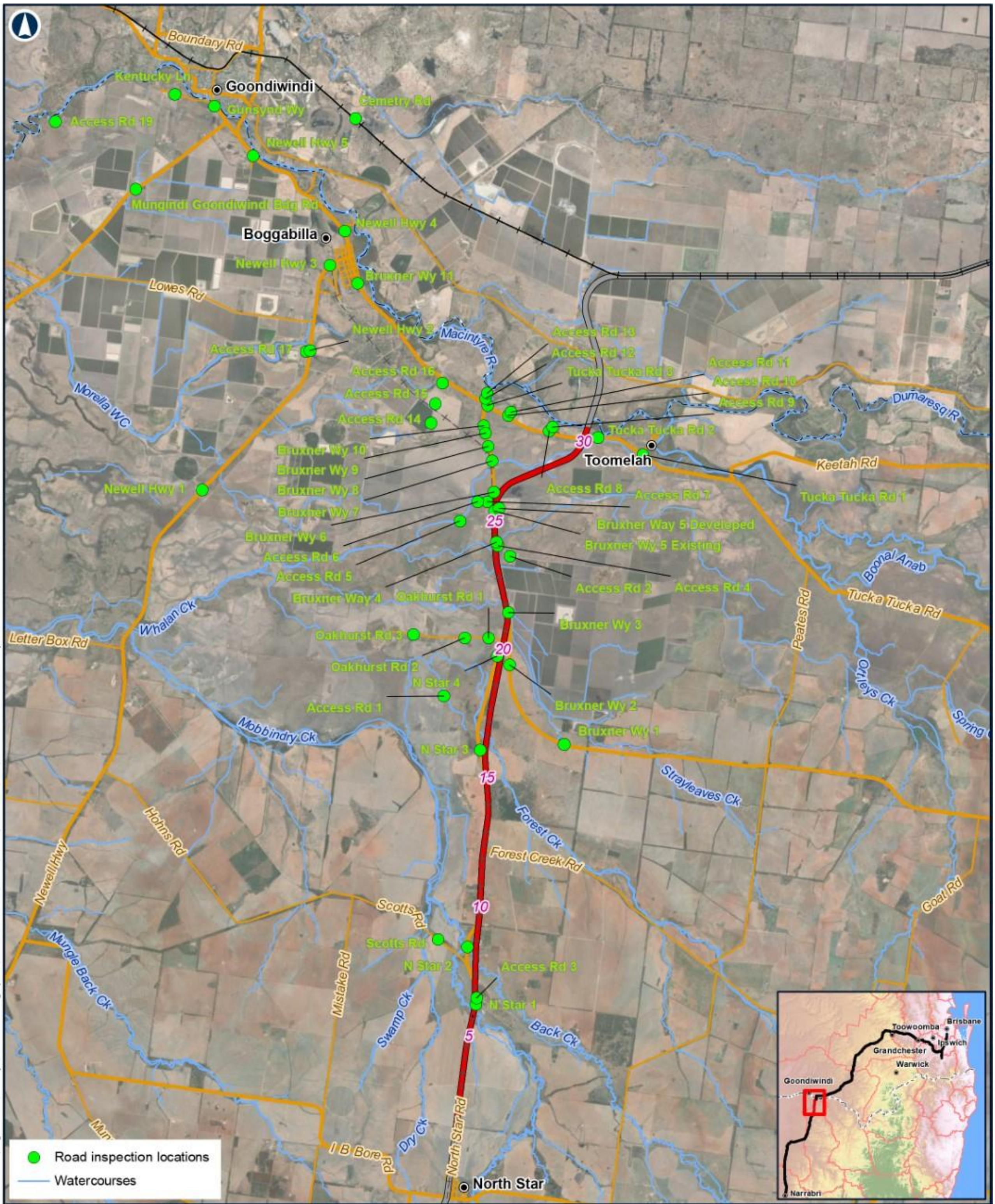
The change in peak water levels on roads across the floodplain has been assessed at a number of road inspection locations, which are shown in Figure 13.3.

The change in peak water levels on local roads on the floodplain all comply with the flood-impact objectives, with less than an increase of 100 mm, except at two locations—Bruxner Way (Bruxner Wy 3) and along North Star Road on Mobbindry Creek, to the north (Access Road 3) and south of North Star 1. Under the 1% AEP event, there is a localised increase in peak water levels from 90 mm to 405 mm (+315 mm) over a 50 to 100 m section of Bruxner Way. Bruxner Way is inundated to the north and south of this location by over 1 m of flood waters, with access not feasible by road. In this location, there is a culvert bank (3/1.35 m reinforced concrete pipe (RCP)) under the rail line. At North Star Road, there is an increase of up to approximately 300 mm. This location is predicted to be up to 550 mm deep in the existing 1% AEP event and not trafficable. Further refinement of the drainage structures in these locations should be assessed in the detailed design stage. Further discussion on the impacts on roads in terms of inundation periods is provided in Section 13.8.2.2.

TABLE 13.26 1% AEP EVENT—CHANGE IN PEAK WATER LEVELS FOR ROADS

Road name	Inspection location	Afflux (mm)
Local Access Roads	Access Rd 1	0
	Access Rd 2	+93
	Access Rd 3	+302
	Access Rd 4	+85
	Access Rd 5	-10
	Access Rd 6	-18
	Access Rd 7	-31
	Access Rd 8	0
	Access Rd 9	-1
	Access Rd 10	+2
	Access Rd 11	+1
	Access Rd 12	+2
	Access Rd 13	+1
	Access Rd 14	+3
	Access Rd 15	+1
	Access Rd 16	+1
	Access Rd 17	+2
	Access Rd 19	+1
	Cemetery Rd	0
	Gunsynd Wy	0
	Kentucky Ln	0
	Oakhurst Rd 1	-6
	Oakhurst Rd 2	-4
	Oakhurst Rd 3	+1
	Mungindi Goondiwindi Bdg Rd	0
	Scotts Rd	0
	Tucka Tucka Rd 1	+5
	Tucka Tucka Rd 2	+15
	Tucka Tucka Rd 3	+2

Road name	Inspection location	Afflux (mm)
Bruxner Way	Bruxner Wy 1	0
	Bruxner Wy 2	+20
	Bruxner Wy 3	+315
	Bruxner Wy 4	+45
	Bruxner Wy 5 Developed	+162
	Bruxner Wy 5 Existing	+102
	Bruxner Wy 6	+64
	Bruxner Wy 7	+12
	Bruxner Wy 8	+8
	Bruxner Wy 9	+6
	Bruxner Wy 10	+5
	Bruxner Wy 11	0
North Star	N Star 1	-25
	N Star 2	0
	N Star 3	-60
	N Star 4	+1
Newell Highway	Newell Hwy 1	-1
	Newell Hwy 2	+3
	Newell Hwy 3	0
	Newell Hwy 4	0
	Newell Hwy 5	0



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

Figure 13.13: Road inspection locations

NORTH STAR TO NSW/QLD BORDER

5km

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Date: 25/04/2020 Paper: A4
Author: FFJV GIS Scale: 1:200,000

LEGEND

- 5 Chainage (km)
- Existing rail (operational)
- Existing rail (non-operational)
- North Star to NSW/QLD border alignment
- Adjoining alignments
- NSW/QLD border
- Major roads
- Minor roads

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13.8.2.2 Change in duration of inundation

The change in duration of inundation is quantified by assessing and comparing the time of submergence for the Existing Case and Developed Case, which includes the proposal works. Figure A15–C in Appendix H shows the change in time of submergence across the floodplain under the 1% AEP event. Overall, the changes in inundation duration are limited, with the largest impacts experienced immediately upstream and downstream of the proposal alignment. Compared to the duration of the flood events on the Macintyre River floodplain, these changes are minor.

The time of submergence for the Existing Case and the change in duration of inundation due to the proposal, at the road inspection locations shown in Figure 13.13, are presented in Table 13.27 for the 1% AEP event.

Table 13.27 shows that increases in duration of inundation are minimal, with only one location subject to an increase greater than one hour. This is the same location discussed in Section 13.8.2.1—Bruxner Wy 3. With the proposal alignment in place, this location is inundated for approximately an additional 33 hours under the 1% AEP event. This localised impact affects only 50 to 100 m of the Bruxner Way, with the road to the north and south already inundated. Immediately to the north and south of this location, the period of inundation for Bruxner Way is approximately 85 hrs and 95 hrs respectively.

The change in duration of inundation for a range of events, up to the 1% AEP event, is detailed in Appendix H: Hydrology and Flooding Technical Report.

TABLE 13.27 TIME OF SUBMERGENCE AT ROAD INSPECTION LOCATIONS

Inspection location	Existing Case 1% AEP ToS (hrs)	1% AEP Time of Submergence (ToS) Difference (hrs)
Access Rd 1	80.61	+0.63
Access Rd 2	43.74	-0.20
Access Rd 3	82.82	-9.23
Access Rd 4	0	+10.96
Access Rd 5	63.74	0
Access Rd 6	57.74	+0.04
Access Rd 7	59.99	+0.09
Access Rd 8	47.38	+0.05
Access Rd 9	37.67	+0.02
Access Rd 10	43.59	+0.17
Access Rd 11	49.49	+0.05
Access Rd 12	33.10	+0.12
Access Rd 13	26.72	+0.08
Access Rd 14	31.34	+0.33
Access Rd 15	59.65	0
Access Rd 16	50.99	+0.05
Access Rd 17	24.73	+0.12
Access Rd 19	62.28	-0.01
Cemetery Rd	49.38	+0.03
Gunsynd Wy	64.86	-0.01
Kentucky Ln	62.99	-0.01
Oakhurst Rd 1	84.31	-0.01
Oakhurst Rd 2	0	0
Oakhurst Rd 3	56.41	-0.04
Mungindi Goondiwindi Bdg Rd	52.86	-0.01
Scotts Rd	7.86	-0.03
Tucka Tucka Rd 1	23.29	+0.29
Tucka Tucka Rd 2	67.30	+0.05

Inspection location	Existing Case 1% AEP ToS (hrs)	1% AEP Time of Submergence (ToS) Difference (hrs)
Tucka Tucka Rd 3	35.77	+0.14
Bruxner Wy 1	34.94	0
Bruxner Wy 2	2.98	+0.78
Bruxner Wy 3	40.00	+33.00
Bruxner Wy 4	52.05	+0.03
Bruxner Wy 5 developed	57.38	-3.95
Bruxner Wy 5 existing	59.59	+2.92
Bruxner Wy 6	56.02	-3.24
Bruxner Wy 7	40.55	+0.61
Bruxner Wy 8	64.17	0
Bruxner Wy 9	54.26	-0.01
Bruxner Wy 10	55.15	0
Bruxner Wy 11	13.68	+0.12
N Star 1	45.37	+2.74
N Star 2	41.20	+0.03
N Star 3	32.60	+3.05
N Star 4	54.09	-0.15
Newell Hwy 1	45.67	+0.06
Newell Hwy 2	37.99	+0.10
Newell Hwy 3	45.24	+0.09
Newell Hwy 4	50.50	+0.03
Newell Hwy 5	59.80	0

Average Annual Time of Submergence (AAToS) is a measurement of the estimated time per year of submergence of a roadway due to flooding. The AAToS has been determined for each road inspection location for the Existing and Developed Cases and the outcomes detailed in Table 13.28. The locations that are predicted to experience a change in AAToS of greater than 0.5 hours/year (hrs/yr) are on the southern tributaries of Strayleaves Creek (Bruxner Wy 2 and Bruxner Wy 3), Forest Creek (N Star 3) and Mobbindry Creek (N Star 1). N Star 1 and 3 are both downstream of the project alignment and experience a drop in the 1% AEP peak water levels, with an increase in the time of inundation. Bruxner Way 3 is discussed above in Section 13.8.2.1.

TABLE 13.28 AVERAGE ANNUAL TIME OF SUBMERGENCE AT ROAD INSPECTION LOCATIONS

Location	AAToS Existing Case (hrs/yr)	AAToS Developed Case (hrs/yr)	Difference (hrs/yr)
Access Rd 1	65.60	65.92	+0.32
Access Rd 2	1.43	1.37	-0.06
Access Rd 3	58.24	56.96	-1.28
Access Rd 4	0.31	0.42	+0.11
Access Rd 5	7.90	7.89	0
Access Rd 6	5.69	5.69	0
Access Rd 7	6.57	6.58	+0.01
Access Rd 8	2.36	2.37	+0.01
Access Rd 9	1.21	1.21	0
Access Rd 10	1.44	1.59	+0.16
Access Rd 11	2.87	2.89	+0.02
Access Rd 12	0.96	0.97	+0.01
Access Rd 13	0.68	0.69	+0.01

Location	AAToS Existing Case (hrs/yr)	AAToS Developed Case (hrs/yr)	Difference (hrs/yr)
Access Rd 14	0.63	0.64	0
Access Rd 15	4.74	4.73	-0.02
Access Rd 16	3.29	3.29	0
Access Rd 17	0.54	0.54	0
Access Rd 19	36.21	36.14	-0.06
Cemetery Rd	6.39	6.39	0
Gunsynd Wy	45.95	45.95	0
Kentucky Ln	37.36	37.35	-0.01
Oakhurst Rd 1	60.52	60.45	-0.08
Oakhurst Rd 2	0.19	0.23	+0.04
Oakhurst Rd 3	36.51	36.55	+0.05
Mungindi Goondiwindi Bdg Rd	20.12	20.10	-0.02
Scotts Rd	0.34	0.34	0
Tucka Tucka Rd 1	0.56	0.56	0
Tucka Tucka Rd 2	21.16	21.39	+0.23
Tucka Tucka Rd 3	1.05	1.05	0
Bruxner Wy 1	44.26	44.26	0
Bruxner Wy 2	0.26	1.38	+1.12
Bruxner Wy 3	1.61	1.64	+74.42
Bruxner Wy 4	1.72	1.72	0
Bruxner Wy 5 Developed	4.98	3.29	-1.69
Bruxner Wy 5 Existing	9.14	7.72	-1.43
Bruxner Wy 6	4.72	2.96	-1.76
Bruxner Wy 7	1.61	1.64	+0.03
Bruxner Wy 8	7.41	7.36	-0.05
Bruxner Wy 9	3.65	3.64	0
Bruxner Wy 10	4.62	4.62	0
Bruxner Wy 11	0.43	0.44	0
N Star 1	27.44	29.55	+2.11
N Star 2	27.42	27.43	+0.01
N Star 3	14.84	20.70	+5.86
N Star 4	19.05	19.08	+0.02
Newell Hwy 1	1.60	1.60	0
Newell Hwy 2	1.24	1.25	+0.01
Newell Hwy 3	1.45	1.46	0
Newell Hwy 4	3.54	3.55	+0.01
Newell Hwy 5	7.22	7.22	0

13.8.2.3 Flood flow distribution

The Macintyre River floodplain is complex, with many braided flow paths and channels. To assess potential changes to the flow distribution as a result of the proposal, flows have been extracted from the hydraulic sub-model at a number of locations across the floodplain, shown in Figure 13.14, for the Existing and Developed Cases.

The flow is calculated across the length of each line and measures the flow across the width of the floodplain (for the longer flow lines) or the main flowpath of key waterways (generally for smaller flow lines). Table 13.29 presents the comparison of flows for the 1% AEP event and shows that there are minimal changes between the Existing and Developed Cases. Under the 20%, 10%, 5% and 2% AEP events, this outcome is consistent with minimal changes to flow distribution.

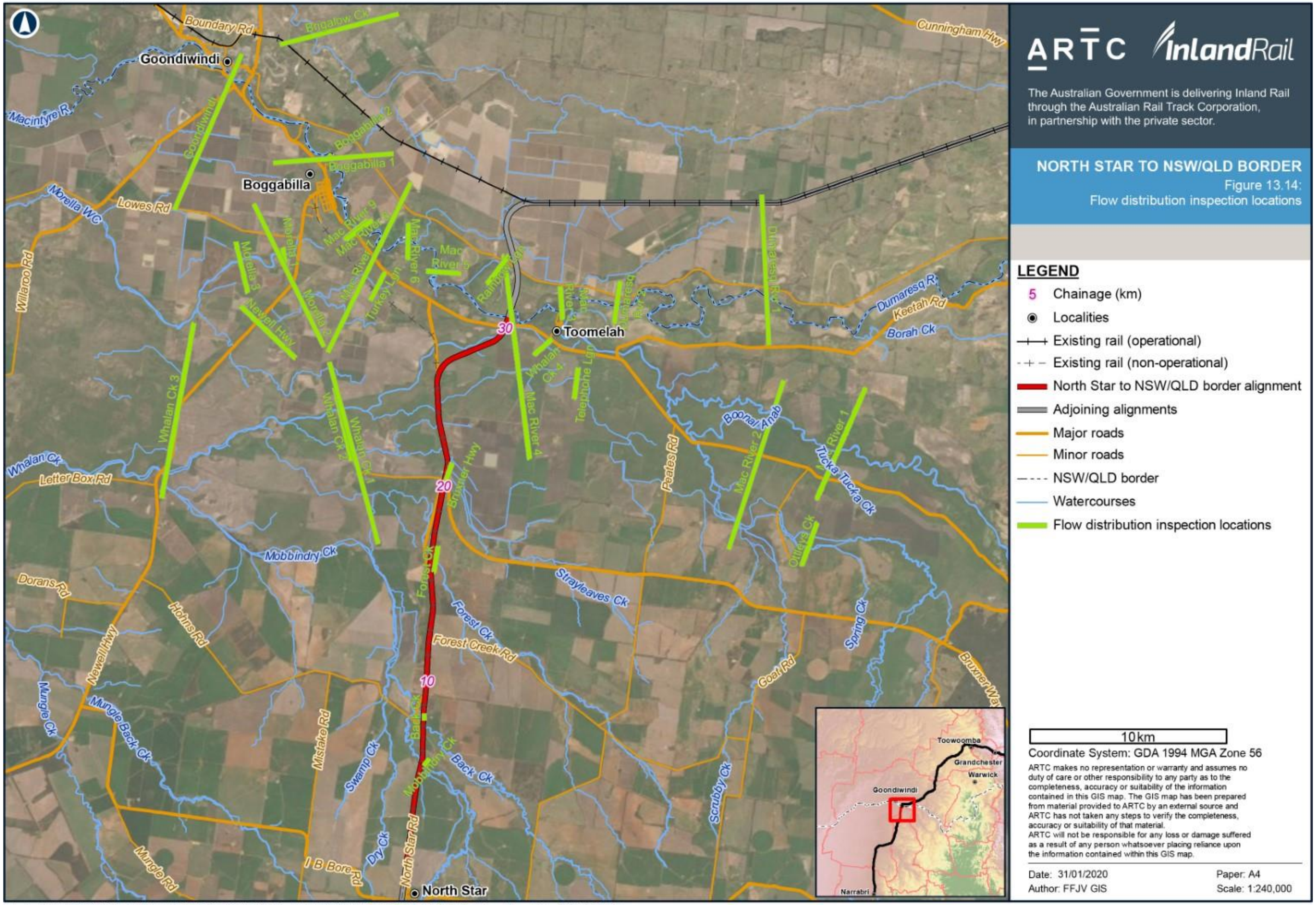
TABLE 13.29 1% AEP EVENT—FLOW COMPARISON

Flow comparison location	Existing Case Flow (m^3/s)	Developed Case Flow (m^3/s)	Change (%)
Boggabilla 1	3214	3214	0
Boggabilla 2	3201	3201	0
Brigalow Ck	1107	1107	0
Bruxner Way	127	122	-4.1
Dumaresq Rvr 1	3742	3742	0
Dumaresq Rvr 2	3203	3203	0
Forest Ck	191	194	+1.5
Goondiwindi	2037	2038	<0.1
Mac River 1	2119	2119	0
Mac River 2	2141	2141	0
Mac River 3	5362	5362	0
Mac River 4	5351	5351	0
Mac River 5	2911	2911	0
Mac River 6	3190	3190	0
Mac River 7	4253	4258	+0.1
Mac River 8	3245	3245	0
Mac River 9	3188	3188	0
Mobbindry Ck	285	291	+2.0
Morella 1	290	291	+0.3
Morella 2	1023	1028	+0.4
Morella 3	417	419	+0.5
Newell Hwy	529	531	+0.3
Ottleys Ck	53	53	0
Rainbow Lgn	740	742	+0.3
Telephone Lgn	120	120	0
Turkey Lgn	353	354	+0.2
Whalan Ck 1	1042	1036	-0.6
Whalan Ck 2	989	989	0
Whalan Ck 3	1353	1346	-0.5
Whalan Ck 4	331	330	-0.3

During the development of the proposal design, concerns regarding the impact of the alignment embankment on the southern side of Whalan Creek were raised through community and stakeholder engagement. The concerns related to the embankment potentially preventing the spread of flow from Whalan Creek in a south-westerly direction as flood events rise and, instead, additional flow being retained in Whalan Creek or redirected north-west toward Boggabilla and Goondiwindi.

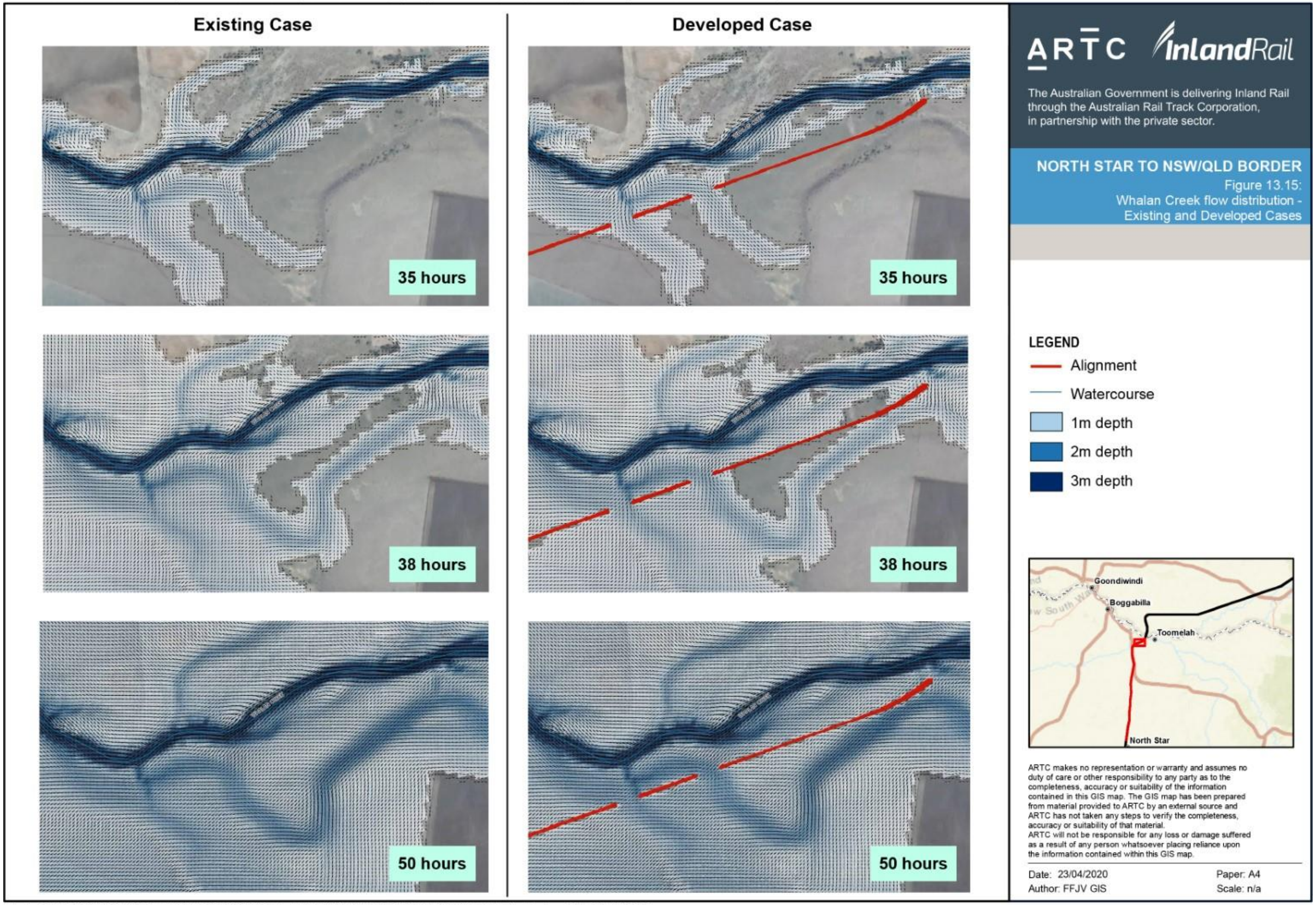
Figure 13.15 presents a series of snapshots from the 1% AEP event as flood levels rise and flow spreads out from Whalan Creek in the vicinity of Ch 27.00 km to Ch 29.00 km, approximately. Images for the Existing Case and Developed Case are presented with arrows showing the direction of flow and the length representing the speed of flow (i.e. velocity). Comparison of the Existing Case and Developed Case images over time shows that the proposal design includes bridge openings at appropriate locations to maintain flood-flow distribution and confirms that redirection of flood waters toward Boggabilla and Goondiwindi does not occur as a result of the proposal.

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



Map by: DTH Z:\GIS\GIS_270_NS2B\Tasks\270-IHY-201909261018_SurfaceWaterEIS\270-IHY-201909261018_ARTC_Fig13.14_Flow_A4L.mxd Date: 30/01/2020 11:53

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



Map by: DTH Z:\GIS\GIS_270_NS2B\Tasks\270-IHY-201909261018_SurfaceWaterEIS\270-IHY-201909261018_ARTC_Fig13.15_WhalanCk_A4L_v2.mxd Date: 23/04/2020 22:07

13.8.2.4 Velocities

Figure 13.16 presents the changes in peak velocities associated with the proposal design for the 1% AEP event. In general, the changes are minor (less than 0.1 m/s), with most changes in velocities experienced immediately adjacent to the proposal alignment.

The flood modelling has shown that the proposal design results in minimal changes to peak water levels, velocities and flood-flow distribution across the floodplain and in each of the waterways. This means that the proposal design minimises potential changes to the geomorphological conditions in the waterways and, as such, the risk of change to geomorphological conditions in each of the waterways is low.

Peak water levels, flows and velocities from the hydrology and flooding investigation have been used to inform the scour protection design. Scour protection at culverts has been designed in accordance with *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, with the soil type identified from published soil mapping.

Using a finer grid spacing (5 m) in the hydraulic model, an assessment of velocities at the proposal boundary has been undertaken and compared against permissible velocities set out in the *Border Rivers Valley Floodplain Management Plan* (Department of Industry, 2018). The velocities at the boundary were less than the maximum allowable soil velocity for the nominated soil conditions so, therefore, there is minimal risk of damage due to scour/erosion.

The type and extent of downstream protection works were assessed in the drainage design to inform the proposal's footprint. The longest length of scour protection required downstream of culvert banks is 14 m, with the available width from toe of embankment to the permanent proposal boundary at this location being approximately 20 m. Overall, the minimum width from toe of embankment to proposal boundary for the NS2B alignment is approximately 15 m, which means that all scour protection works will fit in this available width. The drainage design has demonstrated that there is adequate available width for scour protection within the feasibility design.

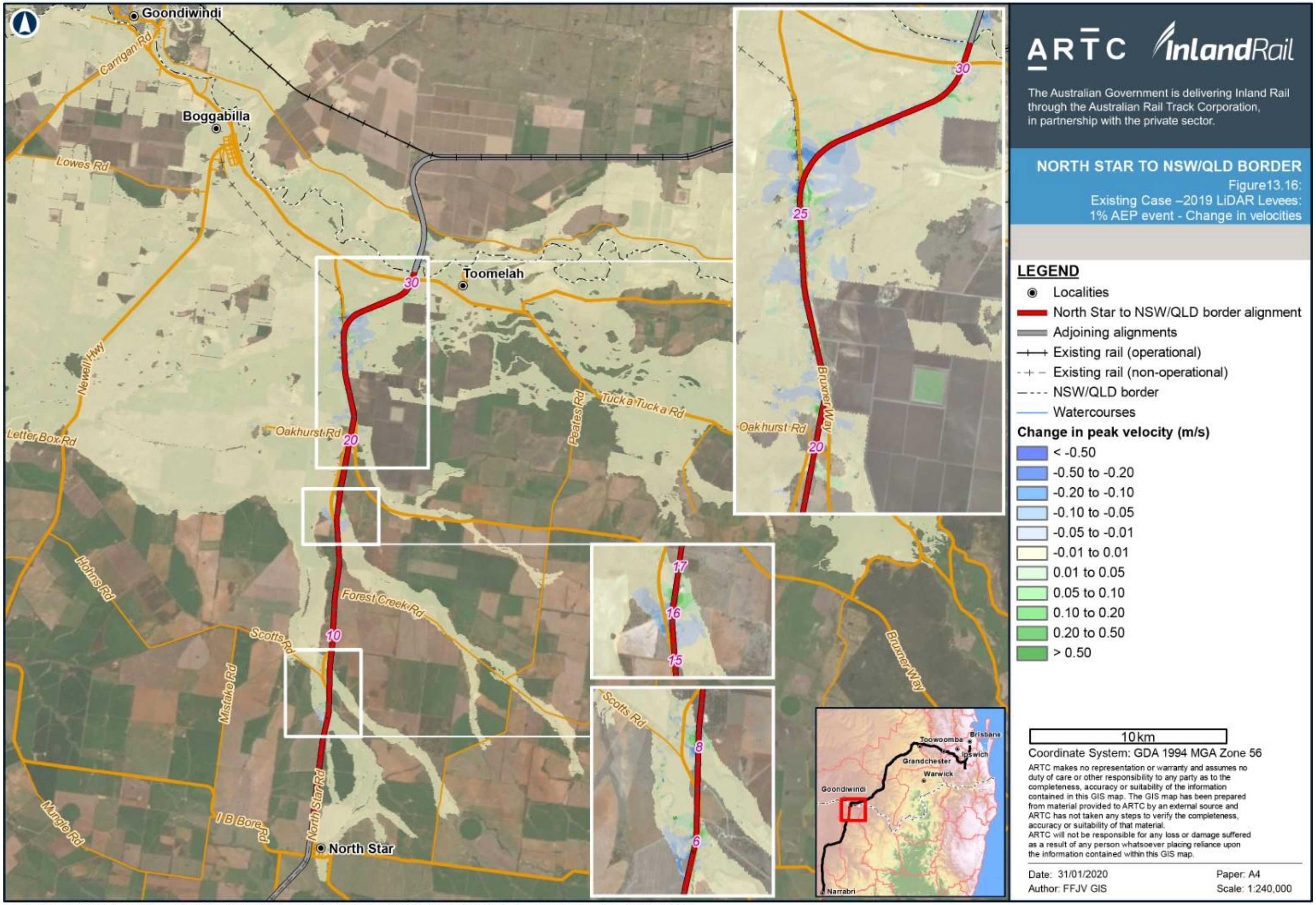
Along the proposal alignment, there is sufficient space between the embankment and the proposal boundary to cater for any additional required scour protection that may result from changes between feasibility and detailed design. Refined detailed drainage design will be undertaken to confirm scour protection requirements (as an engineering standard) during detailed design.

The velocities, with regards to concentrated flows, have been reviewed in line with the *Draft Floodplain Management Plan for the Border Rivers Valley Floodplain* (Department of Industry, 2018) to achieve suitable scour protection within the proposal's proposed boundaries. The velocity requirements associated with ground cover types, as identified in the *Draft Floodplain Management Plan for the Border Rivers Valley Floodplain* (Department of Industry, 2018), have been used to guide design of scour protection for each drainage path location along the alignment. Through the preliminary drainage design, and Floodplain Management Plan (FMP) requirements, the current permanent footprint includes the required scour protection width. Where the project falls outside of the Border Rivers FMP, the AGRD standard has been used to determine the acceptable velocity thresholds for projects of this nature. This approach, and the design outcomes, will be confirmed during detailed design when determining the localised soil type. Where design footprint requirements change to those identified within this EIS, a scour protection solution will be achieved either via an engineering design solution or in agreement with the impacted landowner.

Desktop analysis and the geotechnical investigations did not contain detailed information for a refined scour assessment at each bridge site. A conservative scour estimation based on the 1 in 2000 AEP event has been undertaken for pier substructure designs at each bridge site, based on available information, and will be refined during detailed design.

Further refinement, taking into account site-specific soil data for the structure locations, will be undertaken during detailed design. Site-specific geotechnical investigations will also be undertaken, which will provide the soil information. Using the updated data, the scour protection design will be reassessed during detailed design.

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



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13.8.2.5 Hazard classifications

The *Flood Hazard Guideline 7–3* ((Australian Institute for Disaster Resilience (AIDR), 2017a) from the *Australian Disaster Resilience Handbook Collection* (AIDR, 2017b) provide guidelines for the categorisation of flood hazard as shown in Figure 13.17. Using these guidelines, flood hazard mapping has been prepared for the Existing and Developed Cases, with the outcomes presented in Figure 13.18 and Figure 13.19 respectively.

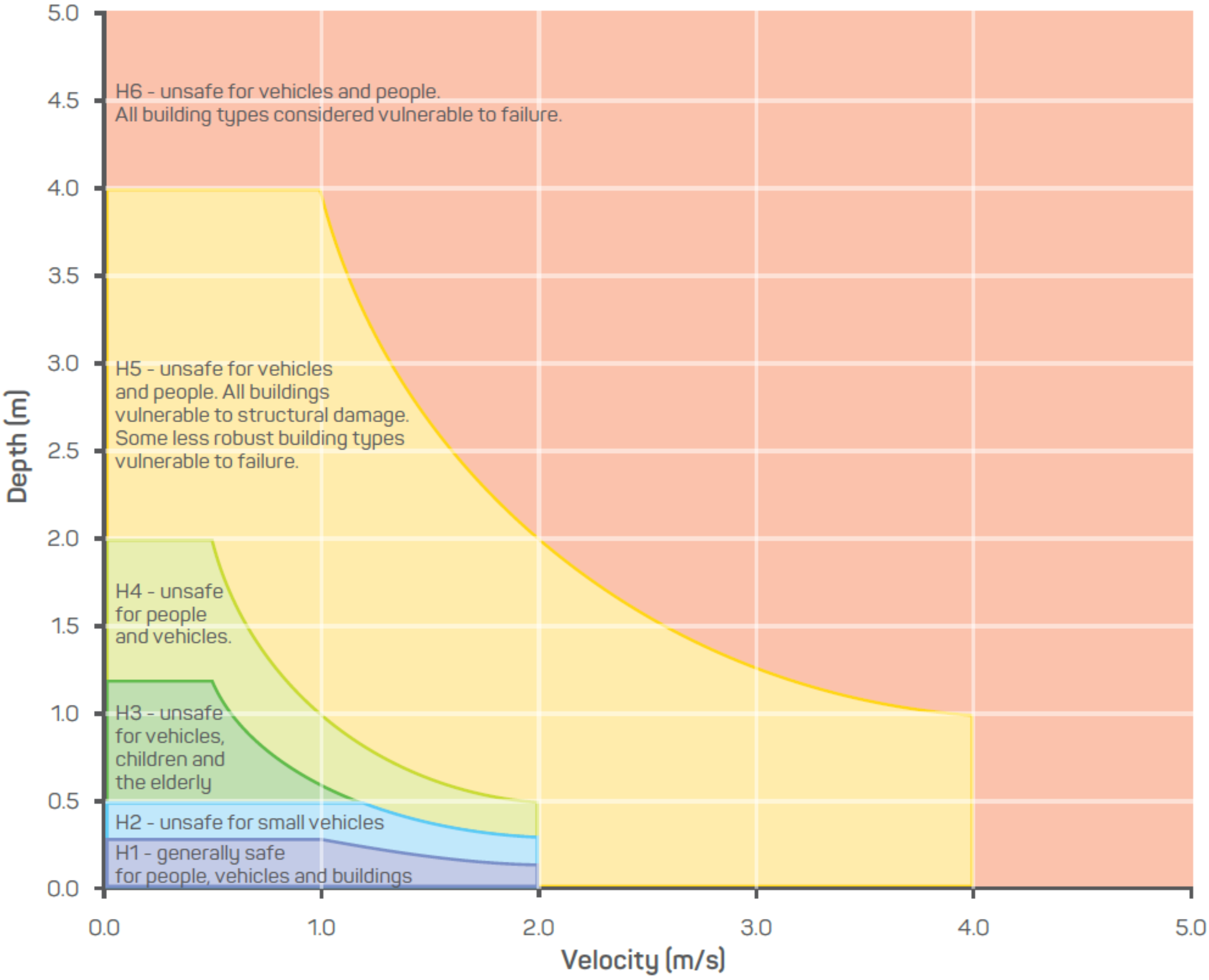


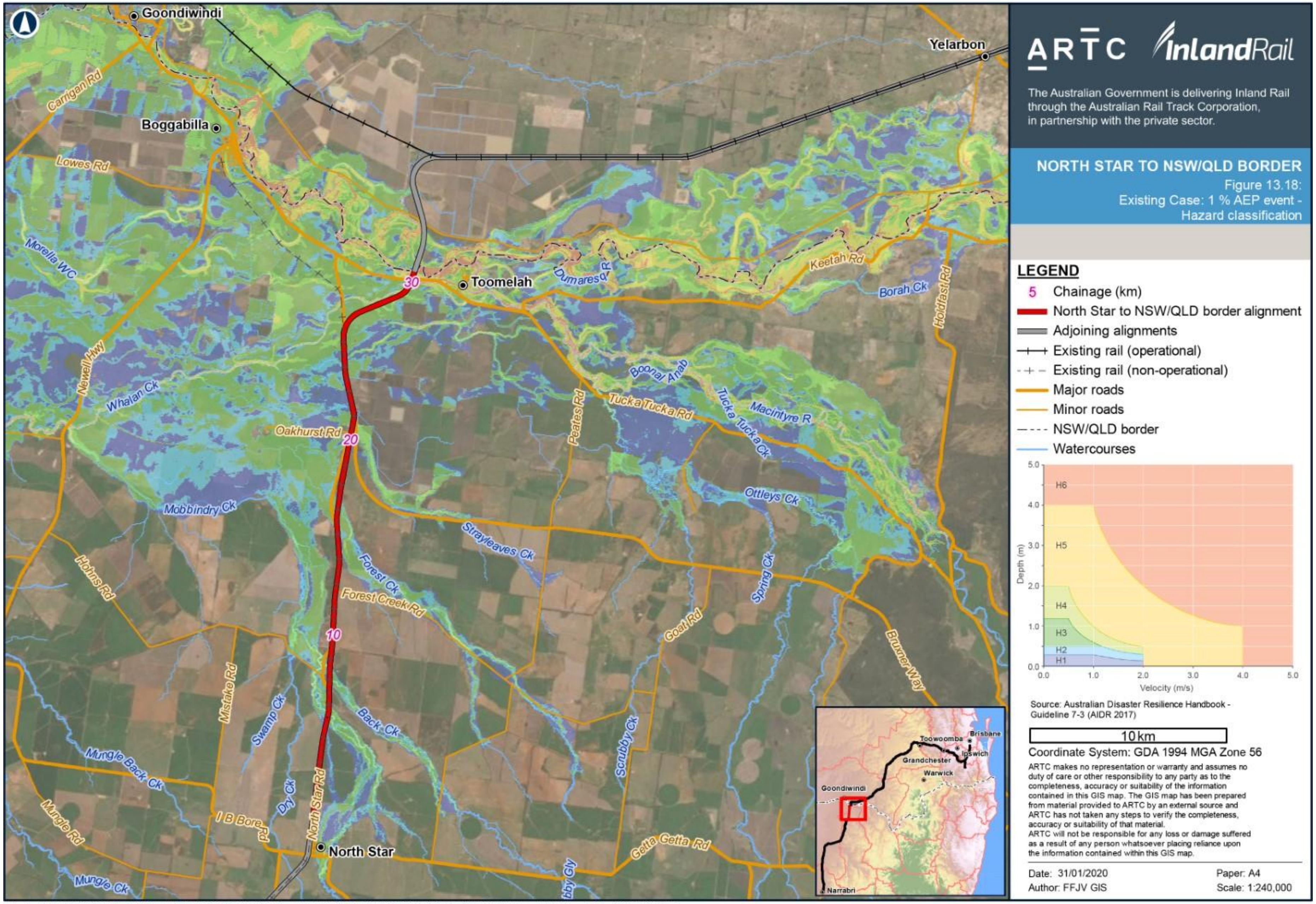
FIGURE 13.17 FLOOD HAZARD CLASSIFICATION, AUSTRALIAN DISASTER RESILIENCE HANDBOOK—GUIDELINE 7-3

Source: AIDR (2017)

As can be seen from Figure 13.18 and Figure 13.19, the lower hazard classifications (H1 to H3) generally apply across the majority of the floodplain area, with the higher classifications occurring in the creek and river channels. The highest classification (H6) applies along the deeper waterways; in particular, on the Macintyre River and Whalan Creek, due to higher flood depths and velocities than on the floodplain areas.

With the proposal in place, as shown in Figure 13.19, it can be seen that the proposal alignment does not change the hazard classifications. This is due to the fact that the changes to the peak water levels, flood-flow distribution and velocities are all minimised. Upstream of the proposal alignment where there are changes in peak water levels under the 1% AEP event, there are localised areas that move into the next higher hazard category (i.e. H2 to H3).

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



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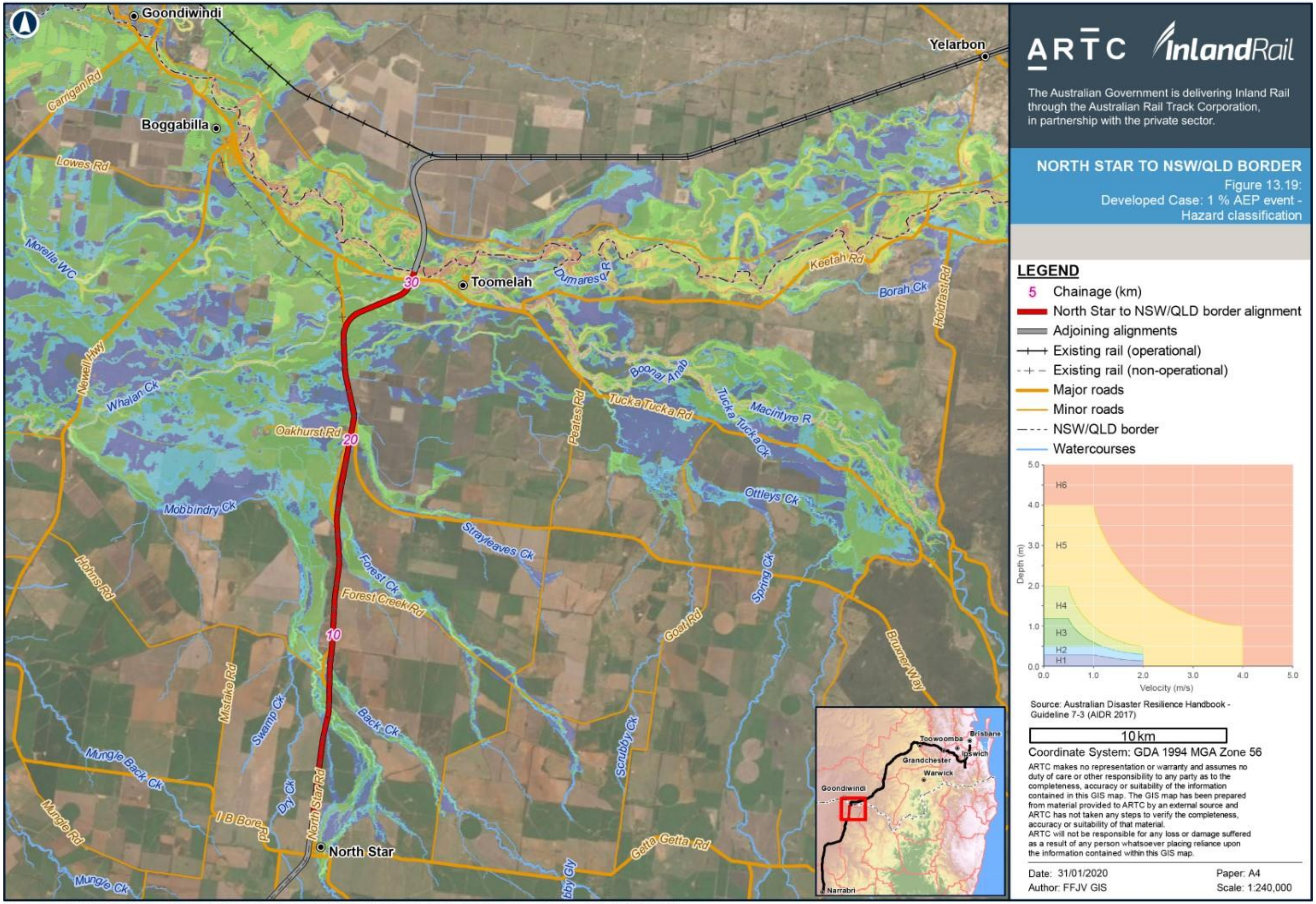
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



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13.8.2.6 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 proposal alignment and to review impacts on the flooding regime. Under extreme event scenarios, the focus of the assessment has been to identify any potential catastrophic issues. Figure 13.21, Figure 13.22 and Figure 13.23 present the change in peak water levels for the 1 in 2,000 AEP, 1 in 10,000 AEP and PMF events respectively.

Table 13.30 outlines the changes in peak water levels at flood-sensitive receptors for the assessed extreme events, where the change in peak water levels exceeds 50 mm under one of the modelled events. The locations of the flood-sensitive receptors are shown in Figure 13.9.

The Existing Case flood depth is also presented for each event in Table 13.30. As can be seen, the Existing Case flood depth at many locations is already high and the incremental increase in peak water levels associated with the proposal design is unlikely to have a detrimental impact.

There are limited locations where the change in peak water levels is elevated under the extreme events (i.e. flood-sensitive receptors (FSRs) 10, 12, 23 and 44) and a detailed review of modelling results was undertaken in these locations. This review determined the following:

- FSR 12 (house) is protected by local levee around the house. Existing Case peak water levels for the 1 in 2,000 AEP event and larger events overtop the local levee with depths of 1.4m and deeper
- FSRs 10 (house), 23 (Shed) and 44 (shed) are all located between existing floodplain levees located on the eastern side of Bruxner Way and the proposal alignment located in the western side of Bruxner Way. Modelling of the extreme events identifies that overtopping of the floodplain levees occurs under these large events and this leads to significant localised increases in peak water levels immediately upstream of the proposal embankment, approximately between Ch 20 km and Ch 24 km, which impacts these FSRs.

During detailed design, these outcomes will be discussed in detail with landowners and a range of alternative mitigation measures will be further investigated, including refined drainage structures, property specific solutions, scour and embankment protection, etc. Formal third-party agreements will be negotiated with landowners that take account of these impacts and any necessary mitigation measures.

TABLE 13.30 SUMMARY OF EXTREME EVENT IMPACTS AT FLOOD-SENSITIVE RECEPTORS

Flood-sensitive receptor number	Description	1 in 2,000 AEP event		1in 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)
1	Sheds	+210	1.13	+230	1.46	+330	2.60
2	House	+10	1.84	+40	2.10	+60	3.06
3	House	+20	1.08	+40	1.35	+70	2.33
6	Sheds	+10	1.01	+40	1.27	+60	2.24
7	Sheds	+10	1.34	+40	1.61	+60	2.59
10	House	+1,820	0.14	+1,900	0.71	+1,250	2.02
11	House	+10	0.89	+30	1.81	+60	0.65
12	House	+440	1.41	+640	1.67	+730	2.62
23	Sheds	+1,350	0.05	+1,440	0.66	+1,040	2.10
24	Sheds	0	0	+60	1.01	+40	2.14
27	Toomelah Community	+10	1.06	+50	1.40	+70	2.65
33	House	+10	0.90	+30	1.14	+50	2.04
37	Sheds	+10	0.07	+20	0.15	+50	1.05
38	House	+10	0.83	+30	1.07	+60	2.00
39	House	+80	0.84	+230	1.18	+210	2.32
40	House	+10	0.47	+20	0.69	+50	1.58

Flood-sensitive receptor number	Description	1 in 2,000 AEP event		1in 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)
42	Sheds	+10	1.41	+30	1.66	+60	2.61
43	Shed	+50	1.38	+150	1.79	+120	3.06
44	Shed	+1,530	0.30	+1,730	0.77	+1,270	2.08
149	Pump	+40	6.31	+70	6.65	+130	7.76
150	Pump	0	2.63	+20	2.88	+50	3.84

The risk of overtopping of the rail alignment has been assessed for the modelled extreme events, with Table 13.31 presenting the overtopping locations by chainage and the depth of water above formation level and over the rail level.

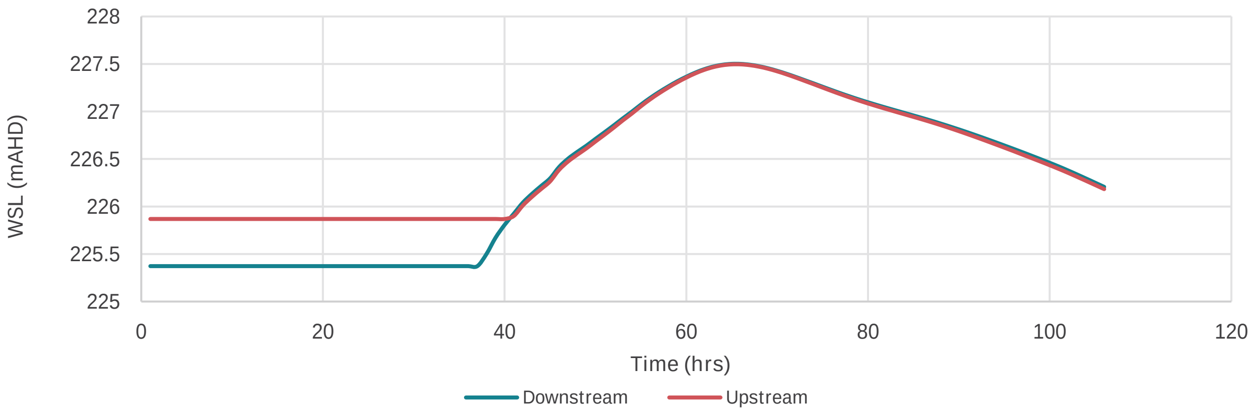
TABLE 13.31 EXTREME EVENTS—OVERTOPPING DEPTHS AND LOCATIONS

	Depth of water above formation level (m)			Depth of water above top of rail (m)		
Chainage (km)	1 in 2,000 AEP	1 in 10,000 AEP	PMF	1 in 2,000 AEP	1 in 10,000 AEP	PMF
7.20–8.10	-	-	1.0	-	-	0.3
15.00–17.00	-	-	0.9	-	-	0.2
18.70–20.80	1.4	2.0	2.7	0.7	1.3	2.0
20.80–25.50	0.5	1.2	2.0	-	0.5	1.3
28.00–28.50	-	0.1	1.2	-	-	0.5
28.50–31.00	-	0.3	1.4	-	-	0.7
31.00–34.00	-	-	1.2	-	-	0.5
34.00–39.50	-	0.2	2.0	-	-	1.3

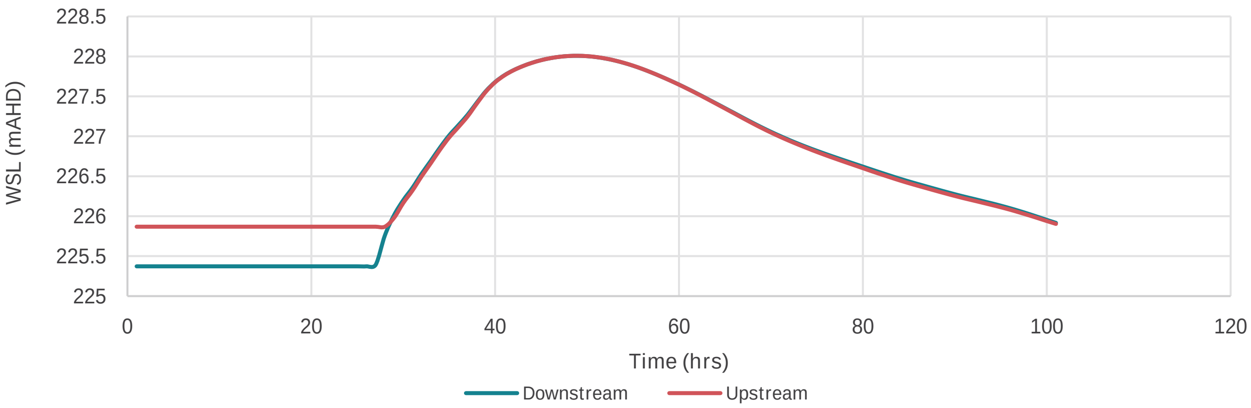
The portion of the alignment that experiences the largest increase in peak water levels upstream of the proposal alignment is approximately between Ch 20 km and Ch 24 km. In this area, there is a drop in water levels between the upstream and downstream sides of the alignment and overtopping occurring under the 10,000 AEP and larger events. During detailed design, mitigation measures to refine the design and to address the risks to the embankment and rail infrastructure as well as downstream properties will be investigated further. If required, this may include engineering solutions to increase the strength and resilience of the rail embankment in this specific location, thereby mitigating the flood risk impact to both the asset and the adjacent floodplains. It should be noted that the inclusion of the 2019 LiDAR has enabled accurate representation of existing levee heights and, therefore, the impact of the existing levees being overtopped has been identified.

Ch 28.00 km to Ch 28.50 km is a location of the overtopping under the 1 in 2,000 AEP event that functions differently to Ch 20 km to 24 km. Figure 13.20 presents the water levels on both sides of the rail during the 1 in 2,000 AEP, 1 in 10,000 AEP, and PMF events. The results show that at the time of overtopping (and throughout the event) the water levels are predicted to be similar on both sides of the rail embankment. Under these rare events, the bridge structures and culverts allow adequate passage of flow during the flood event; therefore, at the time of overtopping, a significant difference in water levels is not predicted and 'damming' effects are 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 throughout the event.

1 in 2,000 AEP Event Hydrograph



1 in 10,000 AEP Event Hydrograph



PMF Event Hydrograph

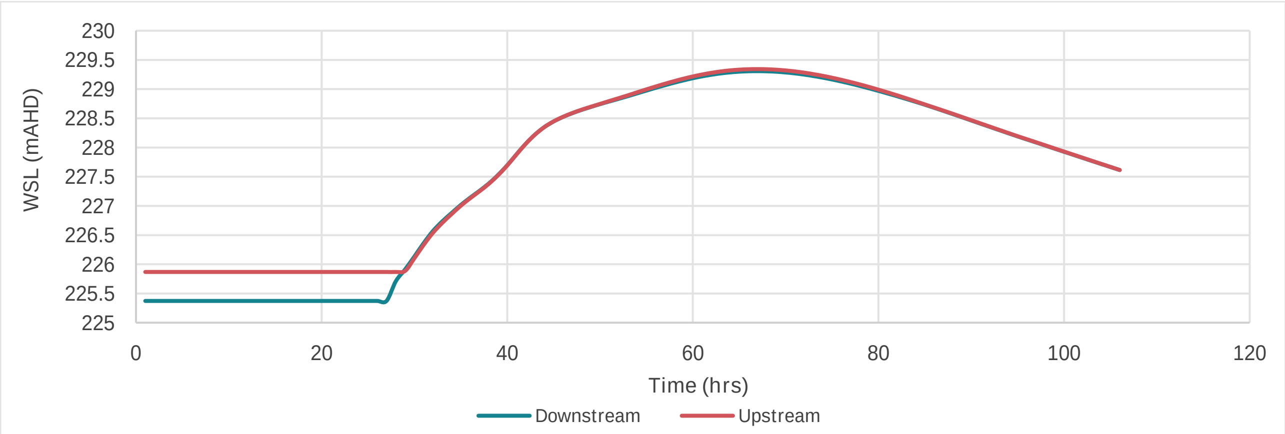
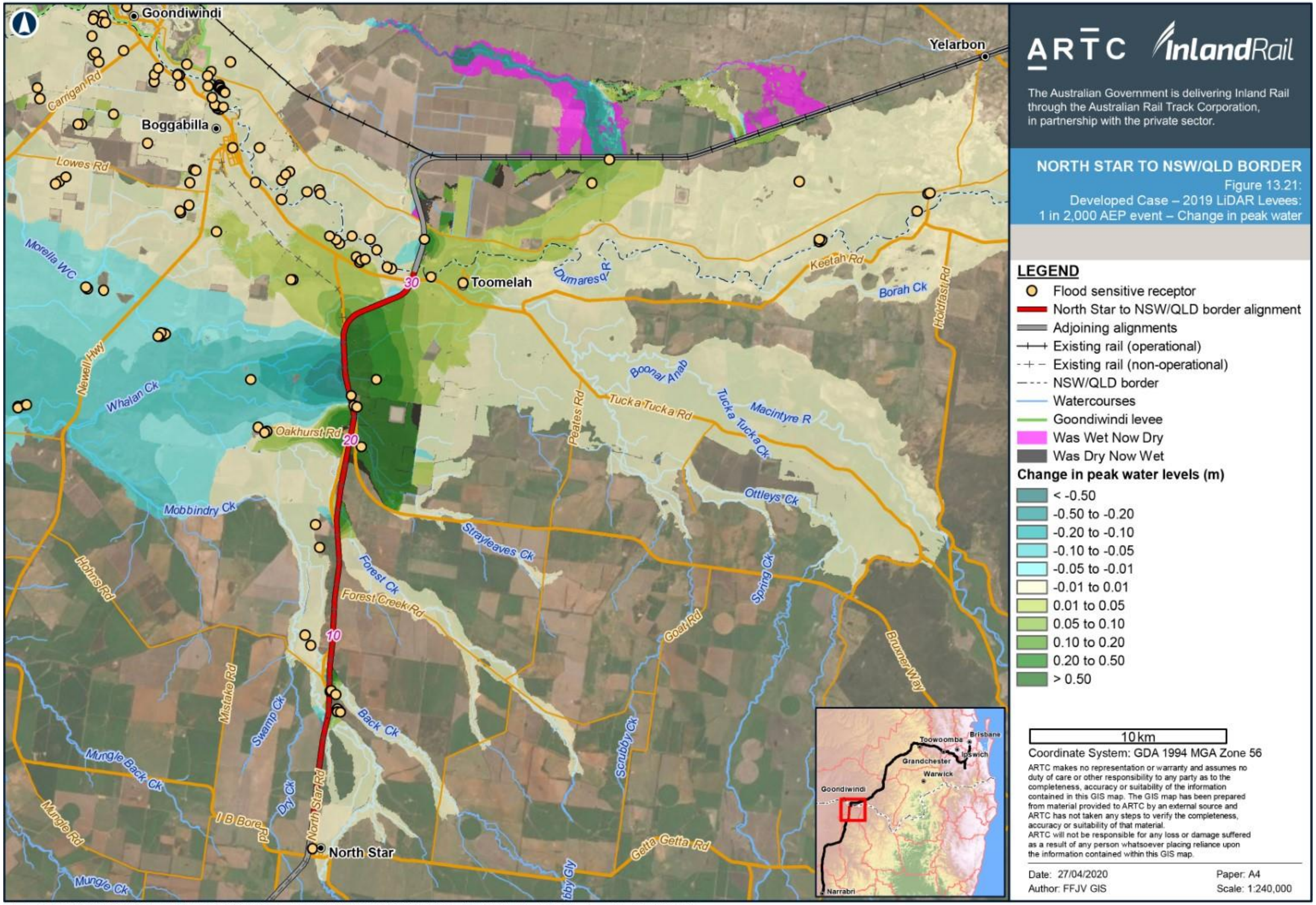


FIGURE 13.20 UPSTREAM AND DOWNSTREAM WATER LEVELS BETWEEN CH 28.00 KM TO CH 28.50 KM

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



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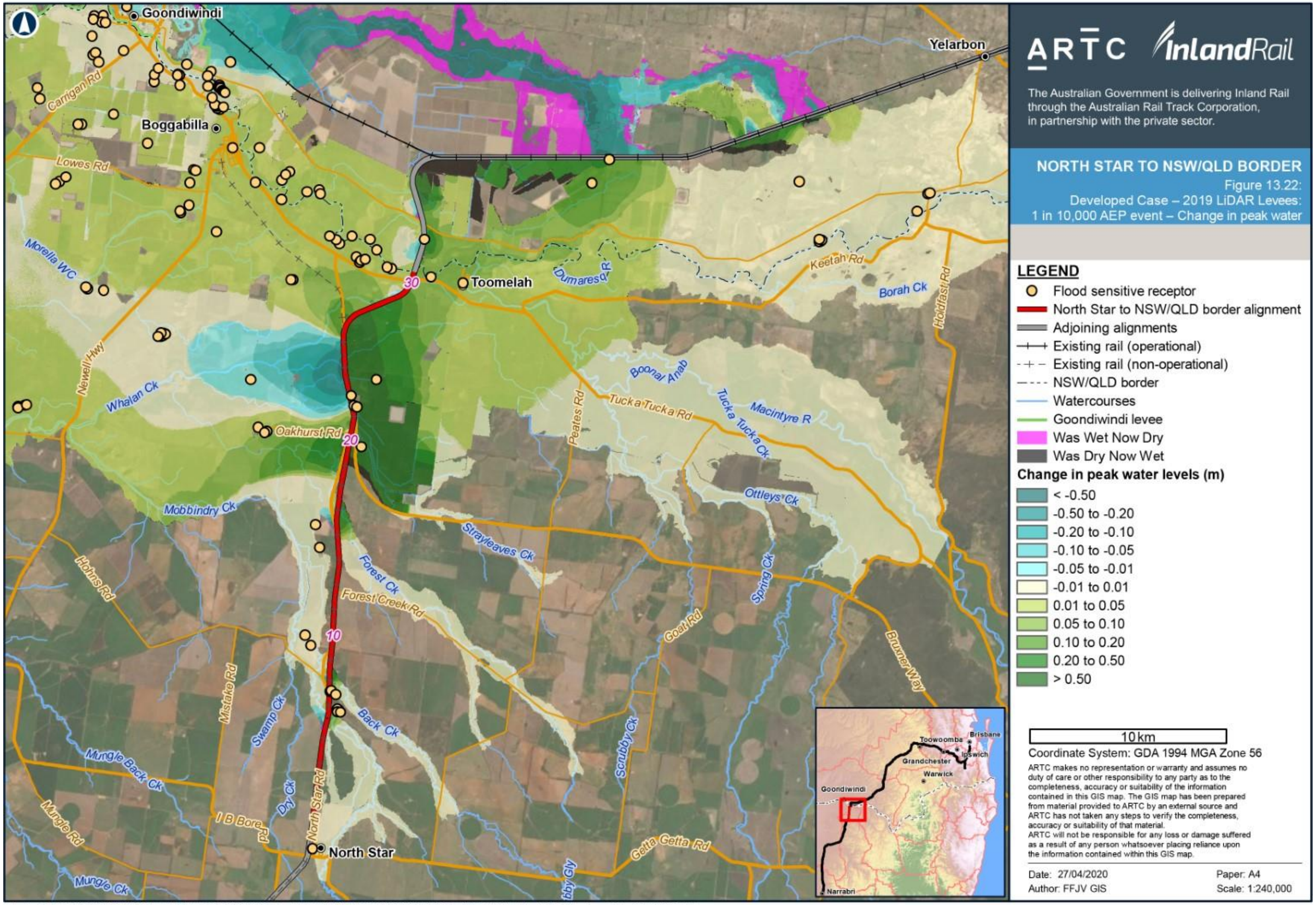
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



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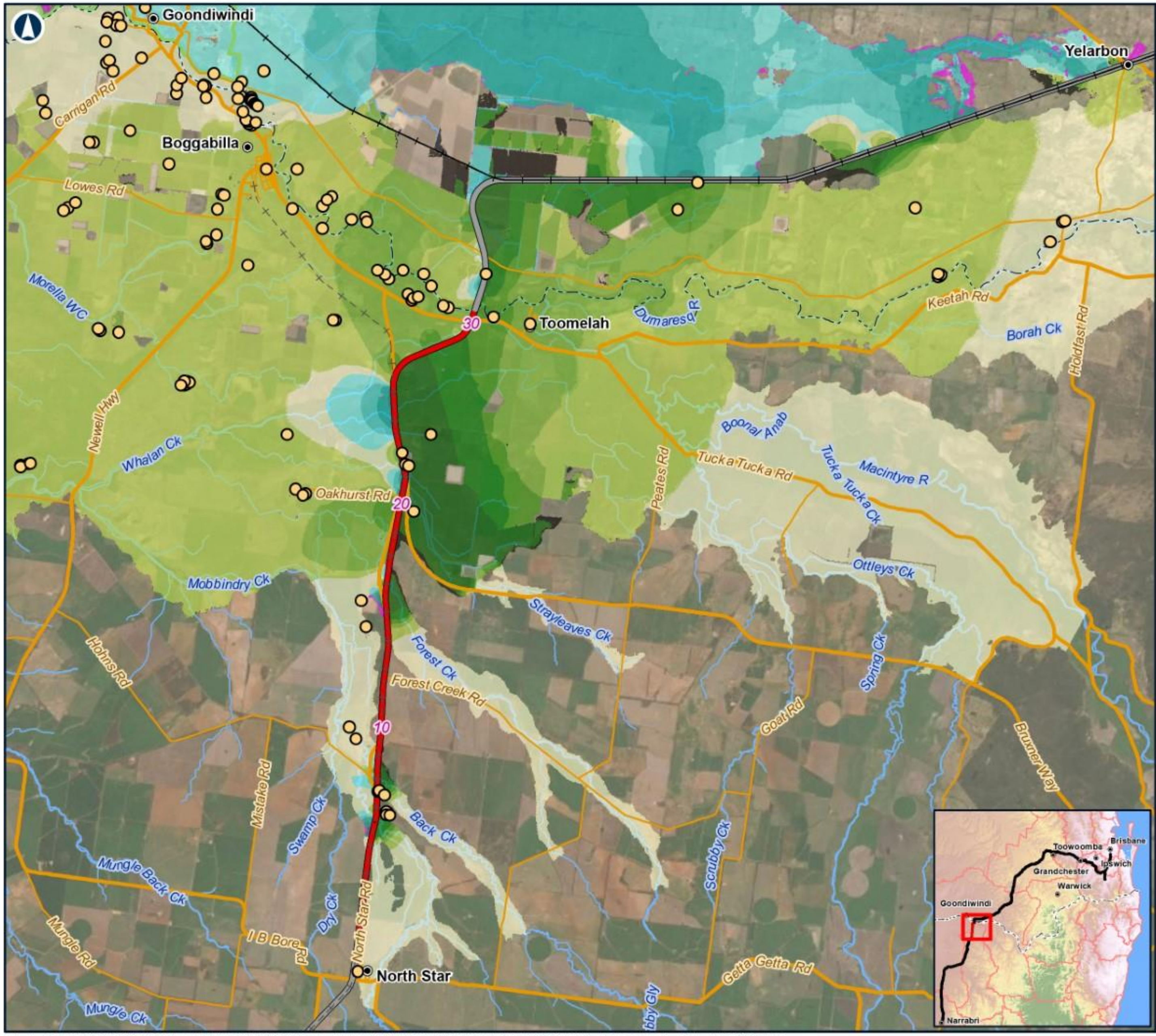
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



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NORTH STAR TO NSW/QLD BORDER

Figure 13.23: Developed Case – 2019 LiDAR Levees: PMF event – Change in peak water levels

LEGEND

- Flood sensitive receptor
- North Star to NSW/QLD border alignment
- Adjoining alignments
- Existing rail (operational)
- Existing rail (non-operational)
- NSW/QLD border
- Watercourses
- Goondiwindi levee
- Was Wet Now Dry
- Was Dry Now Wet

Change in peak water levels (m)

- < -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

10 km

Coordinate System: GDA 1994 MGA Zone 56

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13.8.2.7 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 proposal area.

The Representative Concentration Pathway (RCP) 8.5 climate change scenario has been adopted for the proposal, with an associated increase in rainfall intensity of 23 per cent across the catchment area. This results in peak water levels increasing by up to 0.4 m in the vicinity of the rail alignment, under the 1% AEP event, due to the increase in rainfall intensity. The rail alignment is not predicted to be overtopped as a result of the 23 per cent increase in rainfall intensity under the 1% AEP event, with peak flood levels below formation level.

With the 2090 horizon climate change allowance included in the 1% AEP, there is an increase in peak water levels in both the Existing and Developed Cases, which leads to higher changes in peak water levels at two of the identified flood-sensitive receptors, as shown in Table 13.32.

TABLE 13.32 1% AEP EVENT WITH RCP 8.5 CONDITIONS—CHANGE IN PEAK WATER LEVELS AT FLOOD-SENSITIVE RECEPTORS

Location	Description	1% AEP Event change in peak water levels (mm)*
4	Sheds	+120
26	House	+64

13.8.2.8 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 900 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 proposal 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. For the 1% AEP event, varying the level of blockage did not significantly change the impact on flood-sensitive receptors and the flood-impact objectives are still met.

During detailed design, the blockage factors will be reviewed in line with the final design and local catchment conditions. This may result in a varied and/or lower blockage factors being applied along the proposal alignment. It may also take into account risk assessments associated with blockage, and/or risk mitigation, where required.

13.8.2.9 Consideration of emergency management planning and flood safety risk

Potential impacts on emergency management planning would arise from increased duration of inundation and associated increased closure periods on roadways on the floodplain. This is typically measured using AAToS or Closure.

Modelling for the Developed Case, with the proposal design included, shows that across the range of design events considered that, with the exception of road inspection location Bruxner Wy 3, there is no increase in the inundation periods for local roads or any increase above 0.2 hrs/yr in AAToS or Closure (refer Table 13.28). The changes at Bruxner Wy 3 are localised, with flood depths of over 1 m immediately to the north and south of this location and durations of flooding exceeding 53 hours under the 1% AEP event. Bruxner Wy 3, in essence, is currently an isolated dry section of Bruxner Way that becomes inundated with construction of the proposal alignment and this will not affect the flood safety risk.

From review of the modelling results, it is evident that apart from at Bruxner Way 3, there are only minor changes in flood depths, inundation periods, velocities and flow distribution across the Macintyre River floodplain. There are no significant changes to flood safety risks on private and public land.

Therefore, from a flooding perspective, the construction of the rail alignment does not require a change to emergency management procedures.

13.8.2.10 Consistency with local governments or DPIE Floodplain Management Plans

A review has been undertaken of local government development requirements and DPIE Floodplain Management Plans. This has identified the following two plans that relate to the proposal alignment:

- *Moree Plains Development Control Plan 2013* (Moree Plains Shire Council, 2013b)
- *Draft Floodplain Management Plan for the Border Rivers Valley Floodplain* (Department of Industry, 2018).

Potential impacts associated with the portion of the proposal located to the north of the Macintyre River in Queensland will be addressed in a separate EIS under the *State Development and Public Works Organisation Act 1971* (Qld).

The following sections outline the requirements of the NSW agencies, their applicability to the proposal and how the requirements have been addressed. For the portion of the proposal within Gwydir Shire Council, an EIS is required to be undertaken for works of this nature and this document addresses this requirement.

Moree Plains Development Control Plan

This Development Control Plan requires that development is consistent with the NSW *Floodplain Development Manual* (Department of Natural Resources, 2005) and the *Moree and Environs Flood Risk Management Plan* (Moree Plains Shire Council, 2013a). It also requires that the development does not materially increase the risk to life and manages the risk to property. The Development Control Plan is primarily focused on residential, commercial and industrial development; however, the same principles would apply to the proposal. A set of decision criteria are included for all development applications, focused on parameters such as:

- Likelihood of increased risk to human life
- Likely effect of the development on the depth, velocity, and distribution of flood waters and flood behaviour
- The potential for cumulative adverse impacts
- The relationship to adjoining development.

The preceding sections in this chapter document the impact of the proposal on the existing flood regime and demonstrate that there is not a significant change to the flood risk for landowners, the broader community, infrastructure, and local or state governments due to the introduction of the proposal.

The *Moree and Environs Flood Risk Management Plan* (Moree Plains Shire Council, 2013) is focused on the locality of Moree and surrounding areas of Bendygleet, Yarraman and Gwydirfield and, therefore, does not cover the extent of the proposal alignment.

The NSW *Floodplain Development Manual* (Department of Natural Resources, 2005) is the background document that guides the development of floodplain management plans in NSW. This includes the derivation of flood planning levels for proposed works.

For the proposal, the flood planning levels relate to the level of flood immunity achieved by the proposal design. The target flood immunity for the proposal was the 1% AEP flood level, which varies across the floodplain area. The actual level of flood immunity is greater than the 1% AEP event and varies along the proposal alignment, with the proposal embankment height generally not controlled by peak water levels but rather by geometric constraints, e.g. the grade separation of the rail line and Bruxner Way.

Border Rivers Valley Floodplain Management Plan

The *Draft Floodplain Management Plan for the Border Rivers Valley Floodplain* (Department of Industry, 2018) includes management zones, rules and assessment criteria for granting or amending approvals for flood works within the plan area.

The proposal lies within quadrant one of four of the draft management zones associated with the *Draft Floodplain Management Plan for the Border Rivers Valley Floodplain* (Department of Industry, 2018). Due to the length of the proposal alignment, it passes through Management Zones A, B and C, which each have varying assessment rules.

Within proximity to the proposal are four identified areas categorised as Management Zone D. These are listed in Table 13.33.

TABLE 13.33 MANAGEMENT ZONE D AREAS IN THE VICINITY OF THE PROPOSAL

ID Number	Area of ecological significance	Ecological significance	Area (ha)	Distance from the proposal (approximate, m)
18	Malgarai Overflow	Functional capacity to act as an aquatic drought refuge. Waterbird habitat.	60	Adjacent (directly upstream)
17	Malgarai Lagoon	Significant lagoon/wetland listed on Schedule 5: Water Sharing Plan for the NSW Border Rivers Unregulated and Alluvial Water Sources 2012. Functional capacity to act as an aquatic drought refuge. Waterbird habitat.	67	1400
14	Gobbooyallana Lagoon (Turkey Lagoon)	Significant lagoon/wetland listed on Schedule 5: Water Sharing Plan for the NSW Border Rivers Unregulated and Alluvial Water Sources 2012Functional capacity to act as an aquatic drought refuge.	13	2500
60	Unnamed Lagoon 5	Functional capacity to act as an aquatic drought refuge.	13	1500

The eastern edge of the Malgarai Overflow is immediately upstream of the proposal. This area is predicted to become inundated between a 5% and 2% AEP regional flood event. In the 1% AEP event, change in flood levels in the eastern section of the zone are predicted to be up to 40 mm. Changes to flood levels in the Malgarai Overflow are not predicted in the smaller events (2% AEP and less). Change in velocity at Malgarai Overflow is predicted to be generally less than 0.01 m/s in the 1% AEP event. At the eastern edge of the overflow areas of up to -0.05 m/s, change in velocity are predicted in the 1% AEP event. Change to time of inundation is predicted less than 15 minutes across the four Management Zone D areas. Malgarai Lagoon, Turkey Lagoon and Unnamed Lagoon 5 are not predicted to experience changes to flood levels or velocities as a result of the proposal in the 1% AEP event. During detailed design, the proximity of the management zones and the interaction with the proposal will be considered further.

The assessment criteria applied during the EIS process, and documented in the EIS, are generally in accordance with the Floodplain Management Plan (FMP) requirements.

In addition to the management zones, the floodway network system has been considered. The northern portion of the proposal alignment traverses through the floodway zone within the floodway network. The floodway zone includes areas where significant discharge of floodwaters occurs and, in this case, it relates to the Macintyre River floodplain. The southern portion of the alignment is generally located along the edge of the inundation extent zone. The inundation extent zone includes areas that are important for the temporary storage of floodwater.

The assessment guidelines in the *Draft Floodplain Management Plan for the Borders River Valley Floodplain* (Department of Industry, 2018) are focused on control of development on the floodplain and, in particular, levee and drainage works. The proposal infrastructure across the floodplain includes substantial openings, in the form of bridges and culverts, to maintain existing flow distribution, which is particularly important in the floodway zone.

A number of design and assessment criteria are outlined in the *Draft Floodplain Management Plan for the Border Rivers Valley Floodplain* (Department of Industry, 2018) and the following respond to those criteria that relate to the proposal:

- Flood events to be considered:
  - Requirement: Undertake assessment of impacts using 1976 event flows and a range of design events
  - Assessment outcome: Consultation has been undertaken with DPIE regarding the hydrologic and hydraulic assessment undertaken to satisfy the SEARs requirements and concurrently address the FMP.

    The DPIE model, with all constructed and approved levees, was nominated by the FMP to be used to assess proposed works on the floodplain; however, following discussions with DPIE, it was agreed that it is essential for the proposal to consider the current topography on the floodplain when determining appropriate drainage structure locations. This is also consistent with the SEARs requirements. LiDAR was flown in November 2019 to provide details of current development across the floodplain. The 2019 floodplain topography may vary from that in the DPIE model as levees are at varying stages of development.

    Therefore, while both scenarios (DPIE levees and 2019 LiDAR) have been considered with the 1% AEP event, the 2019 LiDAR has been adopted as the key event under which impacts were assessed.

    The 1976 flows have been modelled to test the performance of the proposal design under varying scenarios (in the same way as the 1 in 2,000 AEP and other larger events have been considered). It should be noted that the 1976 flows used are consistent with the DPIE modelling (i.e. factored up by 20 per cent).

    The changes in peak water levels for the 1976 event flows are presented in Figure 13.24. Where the change in peak water levels is 10mm or greater at FSRs, under the 1976 flows event, then the impacts are presented in Table 13.34. The Existing Case flood depth is also presented in Table 13.34.

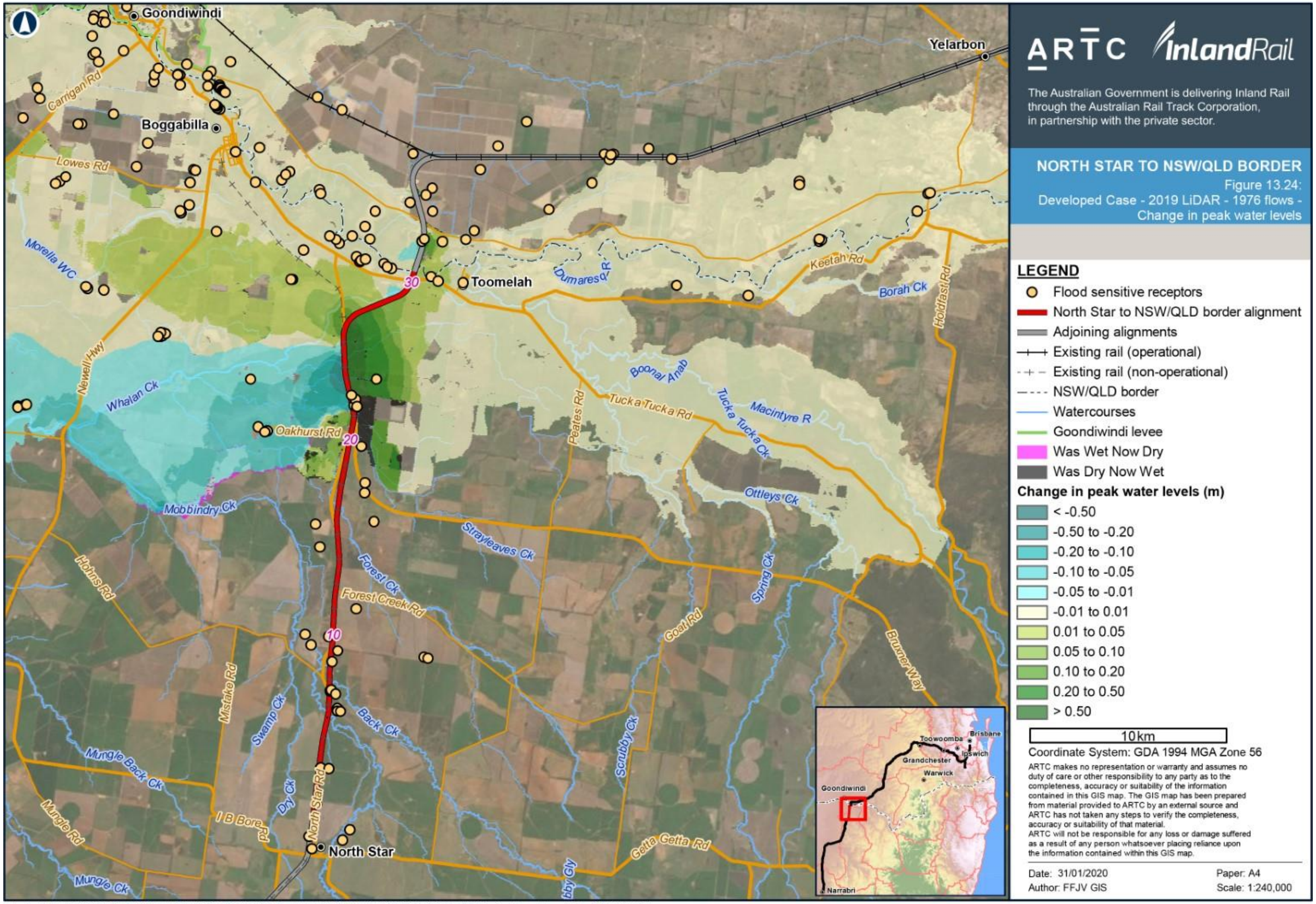
    During detailed design, these outcomes will be discussed in detail with landowners and a range of alternative mitigation measures will be further investigated, including refined drainage structures, property specific solutions, scour and embankment protection, etc. Formal third-party agreements will be negotiated with landowners that takes account of these impacts and the adopted mitigation measures.

TABLE 13.34 1976 FLOWS EVENT—CHANGE IN PEAK WATER LEVELS AT FLOOD-SENSITIVE RECEPTORS

Flood-sensitive receptor number	Description	Change in peak water level (mm)	Existing case flood depth (m)
1	Sheds	+140	0.63
8	House	+30	0.62
9	Sheds	+30	0.87
10	House	+870	0
12	House	+320	1.05
27	Toomelah Community	+10	0.60
41	Airport	+20	0.28
44	Shed	+620	0
59	House	+10	0.36
60	Shed	+10	0.73
67	House	+10	0.96
68	House	+10	0.22
69	House	+10	1.05
70	House	+10	0.99
71	House	+10	0.69
73	House	+10	1.76
74	Shed	+10	0.88
75	Shed	+10	1.84
87	House	+10	0.76
90	Shed	+10	1.38
103	House	+10	0.61
104	Shed	+10	0.57
149	Pump	+20	5.86

The proposal was assessed under a range of flood event magnitudes, including the 20%, 10%, 5%, 2%, 1%, 1 in 2,000, 1 in 10,000 AEP and PMF events. Section 13.8.2 details the assessment undertaken and resulting outcomes.

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



Map by: DTH Z:\GIS\GIS_270_NS2B\Tasks\270-IHY-201909261018_SurfaceWaterEIS\270-IHY-201909261018_ARTC_Fig13.24_DevCaseFlow_A4L.mxd Date: 30/01/2020 18:00

- Consideration of the cumulative impacts of development in the floodplain:
  - Requirement: The cumulative effects must be considered, including the loss of storage affecting the attenuation of flood peaks and any incremental changes to depth, velocity or flow distribution that may have occurred due to existing approved development.
  - Assessment outcome: The proposal assessment has used the DPIE Border Rivers floodplain model as a basis for the assessment. The DPIE model includes constructed and approved floodplain developments and, therefore, the cumulative impact of development on the floodplain has been addressed. Section 13.8.2 details the assessment undertaken and resulting outcomes. Section 13.8.2.1 outlines the change in peak water levels for the 1% AEP event where the Existing Case has the non-operational rail line excluded from North Star to Boggabilla.
- Change in peak water levels (allowable afflux):
  - Requirement: Assessment is required of changes to peak water levels in the vicinity of the alignment and surrounding floodplain area. The allowable peak water level increase will be assessed as part of a merit-based approach. Factors considered in assessing the acceptable increase will include the location of public and private infrastructure, such as dwellings, roads etc.
  - Assessment outcome: Detailed hydraulic modelling of the proposal alignment has been undertaken with refinement of the design to meet the flood-impact objectives set out in Table 13.7. Assessment of impacts at flood-sensitive receptors has been carried out. Section 13.8.2.1 details the assessment outcomes.
- Change in velocities (allowable velocity):
  - Requirements: No significant increase in velocities of flood flow in defined floodways. Velocities should be of an order that does not cause erosion and siltation under various land uses. Maximum permissible velocities are set out in Table 13.35.

TABLE 13.35 MAXIMUM PERMISSIBLE VELOCITIES

Ground condition	Maximum permissible velocities (m/s)*
Bare soil	0.4
Crop	0.6
Native tussocky grass	0.8

Source: Table 1.1 *Draft Floodplain Management Plan for the Borders River Valley Floodplain* (Department of Industry, 2018)
Table notes:
* Values based on soil classification—medium to heavy clay, highly pedal with moderate dispersibility (Soil Conservation Service of NSW)

  - Assessment outcome: Changes in peak velocities in the vicinity of the proposal alignment and surrounding floodplain area have been assessed and mapped. Section 13.8.2.4 details the assessment outcomes, with only minor changes in velocities predicted in defined floodways.
  - Where required, scour protection has been designed in accordance with AGRD Part 5B: Drainage. Scour protection was specified where the outlet velocities for the 1% AEP event exceed the allowable soil velocities, as defined in AGRD or the *Draft Floodplain Management Plan for the Borders River Valley Floodplain* (Department of Industry, 2018) for the particular soil type for each location. The existing soil type was identified from published soil mapping. Using the hydraulic modelling, the velocities at the project boundary were extracted and compared to the maximum permissible velocities in Table 13.35. In a number of locations, the existing velocities exceed the limits in Table 13.35; however, in these locations, the existing velocities have not been increased. In general, at the remaining drainage locations, the velocities at the boundary have met the requirements in Table 13.35. It should be noted that given grid spacing of the current hydraulic modelling, further refinement will need to be undertaken during detailed design. Further discussion is provided in Appendix H: Hydrology and Flooding Technical Report, Section 9.4.3.
  - Further refinement, taking into account site-specific soil data for the structure locations will also be undertaken during detailed design. Site-specific geotechnical investigations will be undertake, which will provide the soil information. Using the updated data, the scour protection design will be reassessed during detailed design.

- Allowable flow distribution:
  - Requirement: No overall flow redistribution is to occur in the area of the development. A less than +/- 2 per cent change in flow distribution is considered acceptable under the plan.
  - Assessment outcome: An assessment of the flow distribution at key locations on the floodplain was undertaken for the 1% AEP event and demonstrated that the proposal has very little impact on the flood-flow distribution. Section 13.8.2.3 details the assessment outcomes, which show that the changes in flow distribution are less than the specified +/- 2 per cent across the majority of the floodplain. There is one location, where Strayleaves Creek crosses Bruxner Way (refer Figure 13.14), where there is a minor decrease in flows at the road of 4 per cent. As the flow at this location is approximately 127 m^3/s (as compared to over 1,000 m^3/s at Whalan Creek downstream of this location) this change is considered acceptable.
- Geomorphology:
  - Requirement: Works must be located to ensure that there is no potential concentration of flows in rivers or streams that may affect river stability and there are non-scouring velocities.
  - Assessment outcome: The flood modelling has shown that the proposal design results in minimal changes to peak water levels, velocities and flood-flow distribution across the floodplain and in each of the waterways. This means that the proposal design minimises potential changes to the geomorphological conditions in the waterways and, as such, the risk of change to geomorphological conditions in each of the waterways is low.

13.8.3 Hydrology and flooding—Construction phase

13.8.3.1 Borrow pits

The proposed location of borrow pits for the construction phase are shown in Figure 13.25. These locations are all located outside of predicted 1% AEP flood inundation extents and, as such, will not affect regional flood events or be affected by these events.

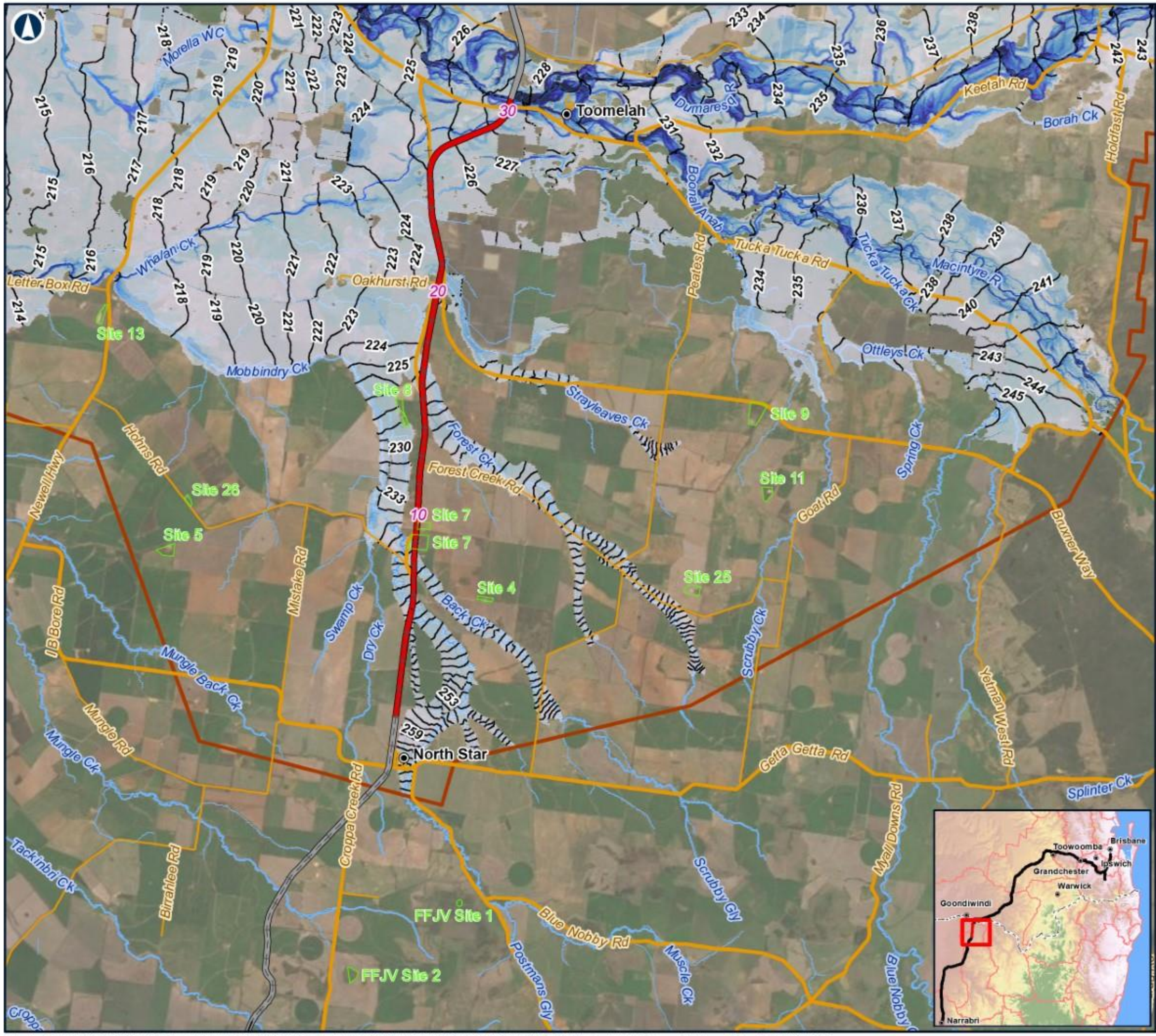
13.8.3.2 Construction accommodation

For the construction phase, one construction accommodation site, including laydown facilities, has been identified as required for the proposal alignment. The proposed location of the accommodation and laydown area is east of North Star, with access to the accommodation off North Star Road and Wilby Street.

A portion of the proposed accommodation potentially lies within existing 1% AEP event flood extents associated with Mobbindry Creek. The existing 1% AEP flood depths in this area are approximately 0.6 m and velocities range from 1.5 m/s in the creek channel to 0.5 m/s in overbank areas.

An assessment of the potential impacts of the temporary construction accommodation was undertaken, with areas filled to represent to the proposed temporary works. An area of approximately 8.2 hectares, representing the accommodation facility, was filled to provide 1% AEP event flood immunity. This is positioned directly to the east of the North Star township. To prevent increased water levels within North Star, a small bund, approximately 100 mm in height, was included on the eastern side of the township. A small local channel was included along the floodplain side of the accommodation to direct flows to replicate existing flow patterns.

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



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

NORTH STAR TO NSW/QLD BORDER

Figure13.25: Borrow Pit locations relative to 1% AEP flood inundation extent

LEGEND

- North Star to NSW/QLD border alignment
- Adjoining alignments
- Existing rail (operational)
- Existing rail (non-operational)
- NSW/QLD border
- Watercourses
- 1m contour (mAHD)
- Extent of hydraulic model
- Borrow pits

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

10km

Coordinate System: GDA 1994 MGA Zone 56

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Date: 31/01/2020 Paper: A4
Author: FFJV GIS Scale: 1:240,000

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The outcomes of the assessment are presented in Figure 13.26 and Figure 13.27 for the 1% and 20% AEP events respectively. The introduction of the accommodation diverts flood flows, restricting flow to the north-west, and the introduction of the local drainage channel mitigates a portion of this impact. Under the 1% AEP event, peak water levels increase by up to 300 mm in the floodplain area adjacent to the accommodation and reduces to less than 10 mm at Getta Getta Road. No houses are predicted to experience increased peak water levels. The North Star Sporting Club building is predicted to experience increases of up to 200 mm, due to its close proximity to the accommodation facility.

Under the 20% AEP event, peak water levels increase by up to 230 mm in the floodplain area adjacent to the accommodation and reduce to less than 10 mm at Getta Getta Road. No houses are predicted to experience increased peak water levels. The North Star Sporting Club building is predicted to experience increases up to 80 mm.

The final accommodation location and extents will be refined during detailed design and prior construction. Mitigation of the predicted impacts will include consideration of options such as:

- Refinement of location of the portion of accommodation currently within flood extents
- Construction of accommodation buildings on structure allowing water to flow under buildings
- Improvement of roads to withstand flood inundation and/or improve flood immunity
- Inclusion of bunding to protect structures such as the North Star Sporting Club.

These mitigation measures will be included in the Flood Risk Management section of the Accommodation Management Plan.

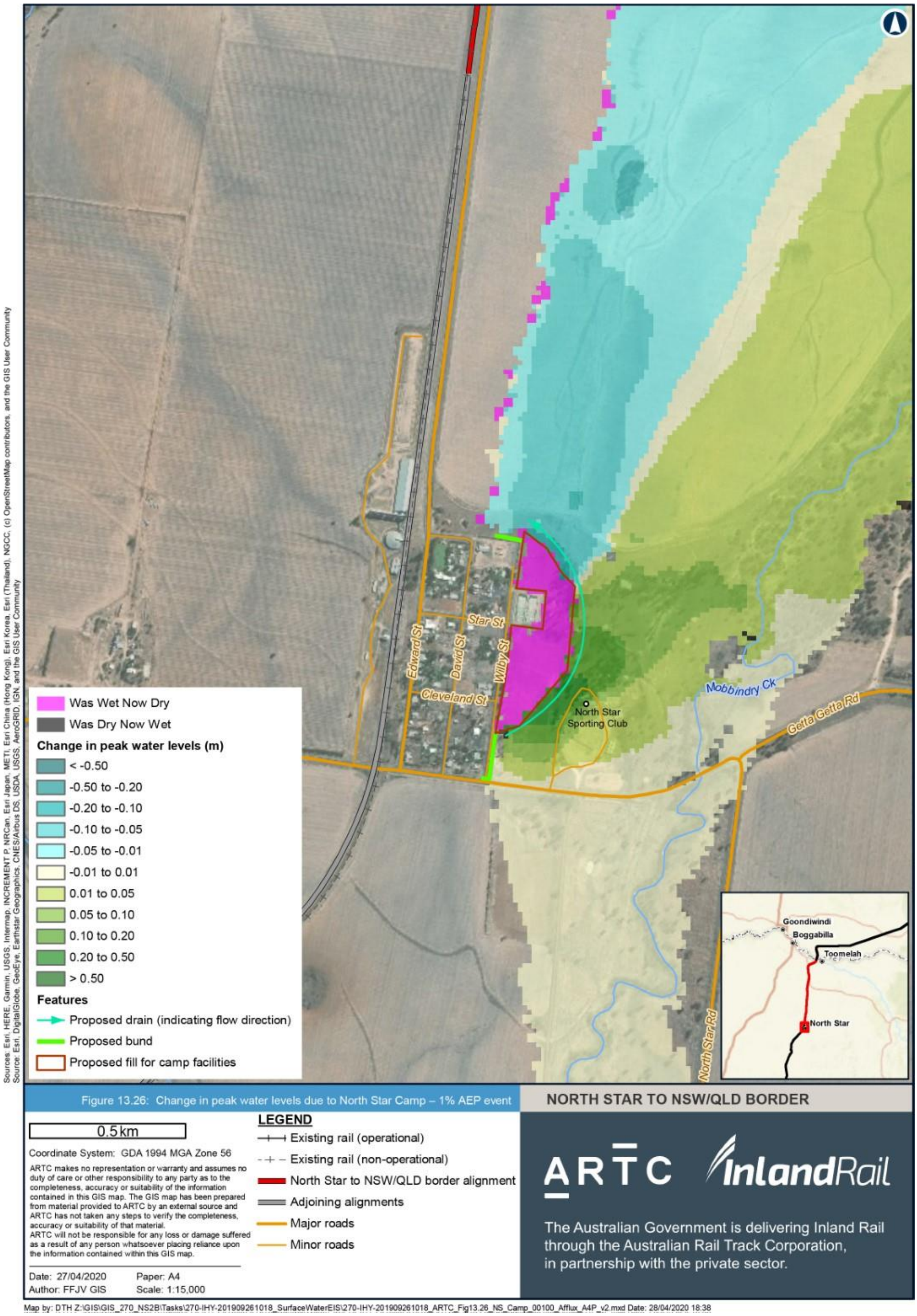

FIGURE 13.26 CHANGE IN PEAK WATER LEVELS DUE TO NORTH STAR CAMP—1% AEP EVENT

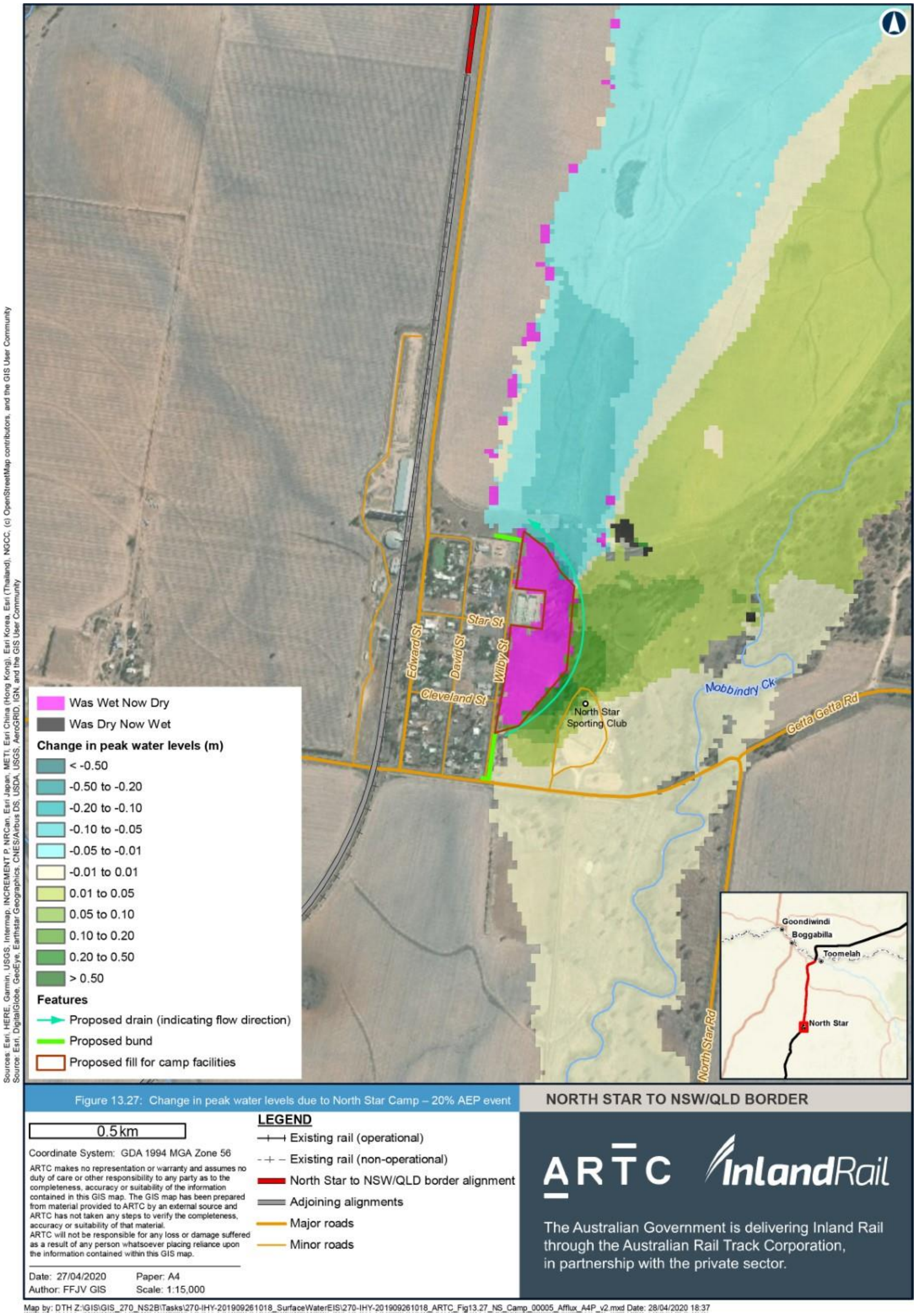

FIGURE 13.27 CHANGE IN PEAK WATER LEVELS DUE TO NORTH STAR CAMP—20% AEP EVENT

13.8.4 Hydrology and flooding—Independent peer review

An independent peer review of the hydrology and flood assessment documented in this chapter and Appendix H: Hydrology and Flooding Technical Report was undertaken by Neil Collins from BMT Global. This review was undertaken in accordance with the EIS Guidelines for Independent Reviewers. Findings from this review are provided in Appendix H: Hydrology and Flooding Technical Report.

13.9 Conclusions

This assessment fulfils the requirements of the Department of Planning, Industry and Environment SEARs pertaining to water quality and hydrology.

13.9.1 Water quality

The surface water quality assessment addressed a range of SEARs relating to surface water resources: SEARs 8. Flooding, Hydrology and Geomorphology—8.1 (d, e, f), SEARs 9. Water Hydrology 9.1, 9.2, 9.3 (a–f), 9.4, and SEARs 10. Water Quality 10.1 (a–i).

Potential impacts of the proposal to surface water quality were grouped into two categories:

- Increased water turbidity and sedimentation
- Changes to water chemistry.

A significance assessment was undertaken. The significance assessment was based on the following elements:

- The initial impact significance assessment rating assumes that the design considerations to reduce impacts would be implemented
- The residual impact significance incorporates any additional mitigation measures that would be required to decrease the impacts of the assessed action, i.e. ARTC environmental management measures in the Inland Rail Program EMP will be adhered to and applied to the assessed action.

Findings are summarised as follows:

- During the construction phase, the significance assessment revealed that the ARTC's current controls—the impact mitigation measures that form part of the design relevant to surface water quality—would be sufficient to mitigate the magnitude of potential conceivable impacts such that the residual significance would be moderate. With the proposed mitigation measures in place, the proposal construction impacts are considered transient and the activities of the proposal would not be considered to worsen environmental conditions (where WQOs are not currently being met). The construction impacts are considered so that no activities would compromise the ability of catchment management initiatives or activities to work toward the achievement of WQOs over time, considering that construction is transient and has the potential to improve the catchment water quality for the operational phase.
- For the operation phase, the current controls (mitigation measures) were assessed to be sufficient for the purposes of mitigating impacts that could cause increased water turbidity and sedimentation. The operational environment within the rail corridor is expected to comprise a stable and well-vegetated landform and, therefore, no erosion is expected.
- Operational impacts to water chemistry could result due to the potential impacts of rail operation on water chemistry; therefore, additional operation-phase measures to mitigate impacts to water chemistry were considered necessary. With these measures in place, it is considered that all practical measures to avoid or minimise water pollution and protect human health and the environment from harm have been investigated and would be implemented for the proposal. These mitigation measures would ensure that where the NSW WQOs for receiving waters are currently being met, they will continue to be protected, and where the water quality objectives are not currently being met, the activities of the proposal would not worsen the environmental conditions.

Therefore, with these measures in place, it is considered that all practical measures to avoid or minimise water pollution and protect human health and the environment from harm have been investigated and would be implemented for the proposal. These mitigation measures would ensure that where the NSW WQOs for receiving waters are currently being met, they will continue to be protected, and where the WQOs are not currently being met, the activities of the proposal would not worsen the environmental conditions.

Requirements for a monitoring program for surface water are outlined in Appendix G: Surface Water Quality Technical Report (Section 7.3 of that report). Monitoring is required to provide an ongoing assessment of the potential impacts of the proposal on the identified surface water WQOs.

13.9.2 Hydrology and flooding

The hydrology and flooding assessment addresses a range of SEARs—SEARs 8. Flooding, Hydrology and Geomorphology—8.1 (a–j), 8.2 (a–k) and SEARs 9. Water Hydrology 9.3 (a).

The proposal alignment crosses the Macintyre River floodplain, traversing both the Macintyre River channel, and several tributaries including Whalan Creek, Strayleaves Creek, Forest Creek, Back Creek and Mobbindry Creek. Detailed hydrologic and hydraulic assessments have been undertaken due to the catchment size and substantial floodplain flows associated with this extensive floodplain area.

DPIE models were used as a basis for the hydrologic and hydraulic assessment. DPIE used the 1976 and 1996 events to calibrate the provided hydrologic and hydraulic models. To confirm the reliability of the hydrologic and hydraulic models, the 2011 event was added as an additional calibration event. The hydrologic models were found to represent flows across the floodplain well, when compared to the recorded information for the 2011 event.

A hydraulic sub-model was developed, initially, covering the floodplain area down to Goondiwindi. Following stakeholder feedback, the hydraulic sub-model was extended to approximately 18 km downstream of Goondiwindi. The hydraulic sub-model reliably predicted the flood gauge heights at the Boggabilla and Goondiwindi stream gauges for all three historical events. Good correlation was achieved between the hydraulic model results and historical flood photos and recorded flood levels for the 1976, 1996 and 2011 flood events. Based on this performance, the hydrologic and hydraulic models were considered suitable to use to assess the potential impacts associated with the rail alignment.

Design event hydrology was developed using ARR 2016 flood-flow estimation methods. The hydraulic sub-model was run for a suite of design events ranging from the 20% AEP event to the PMF. The flows and levels predicted by the hydrologic and hydraulic models were compared to the results of a Flood Frequency Analysis of the Boggabilla and Goondiwindi stream gauges, as well as results from previous flood studies, and were found to be consistent. The design validation of the 1% AEP event indicated that the hydrologic and hydraulic models were adequately representing the 1% AEP event.

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 proposal were incorporated into the hydraulic model (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 landowners, 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. This consultation identified that the representation of the levees on the floodplain in the DPIE hydraulic model (includes approved and constructed levees) did not match the existing levees, particularly in terms of height. A LiDAR survey was undertaken in October 2019 to provide current details of the levees and this was incorporated into the hydraulic sub-model developed to assess the proposal alignment. Through discussions with DPIE it was agreed that the 2019 LiDAR and levees would be used to assess the proposal. The DPIE levee case has been used as a sensitivity test for the proposal.

Flood-impact objectives, as presented in Table 13.7, have been established and used to guide the proposal design, including mitigation of impacts through refinement of the hydraulic design through adjustment of the numbers, dimensions and location of flood drainage structures. Table 13.36 summarises how the proposal design performs against each of the flood-impact objectives.

TABLE 13.36 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 400mm
	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 small localised areas along the proposal alignment where these increases of up to 400 mm occur. These areas are very small in extent, with increases dissipating within 30 m to 200 m of the alignment. No flood-sensitive receptors are impacted by the changes in peak water levels under the 1% AEP event. There are two locations where the change in peak water levels exceed 400 mm. In both locations, the impact reduces to less than 200 mm within 100m or less of the rail embankment, with the impact limited to an area 0.025 km^2 or less. These impacts do not affect any flood-sensitive receptors.				
Change in duration of inundation	Objective: Identify changes to time of inundation through determination of ToS. For roads, determine AAToS and consider impacts on accessibility during flood events. Outcome: There are minor localised changes in the duration of inundation (ToS) upstream and downstream of the proposal alignment. These changes in inundation duration do not affect flood-sensitive receptors and, compared to the duration of the flood events on the Macintyre River floodplain, these changes are minor. The modelling results at a number of local roads have been inspected, with the depth of water, TOS and AAToS assessed. With the exception of one localised area on Bruxner Way, there is no adverse impact on existing roads. The localised area on Bruxner Way is isolated during flood events by flood waters to the north and south for long duration and with over 1 m of flood water. The localised increase in this location is therefore considered not to be an adverse impact.				
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 and waterway geomorphology. Determine appropriate scour mitigation measures, taking into account existing soil and geomorphological conditions. Outcome: In general, changes in velocities are minor, with most changes in velocities experienced immediately adjacent to the proposal alignment and no flood-sensitive receptors impacted. The proposal results in minimal changes to peak water levels, velocities and flood-flow distribution across the floodplain and in each of the waterways. This means that the proposal design minimises potential changes to the geomorphological conditions in the waterways and, as such, the risk of change to geomorphological conditions in each of the waterways is low. 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.				
Hazard	Objective: Identify changes to hazard categories and any impacts on external properties. Justify acceptability of changes through assessment of risk with a focus on land-use and flood-sensitive receptors. Outcome: There are no significant changes to hazard classifications across the floodplain as a result of the proposal alignment works.				

Parameter	Objectives and outcomes
Extreme event risk management	Objective: Consider the risks posed to neighbouring properties for events larger than the 1% AEP event, to ensure no 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. Overall, considering the high flood depths that occur, particularly under the PMF event, the changes in peak water levels would be unlikely to exacerbate flood conditions during extreme events. There are three locations, one house and two sheds, where water levels increase significantly under the extreme events. During detailed design, these outcomes will be discussed in detail with landowners and a range of alternative mitigation measures will be further investigated, including refined drainage structures, property solutions, scour and embankment protection, etc. Formal third-party agreements will be negotiated with landowners that takes account of these impacts and the adopted mitigation measures.
Emergency management	Objective: Consider the impacts the proposal may have on existing community emergency management arrangements for flooding as well changes to flood safety risks on private and public land, including roads and pathways. Outcome: There are no significant changes to flood depths, inundation extents or durations and, therefore, there are no changes to existing flood safety risks.
Sensitivity testing	Objective: Consider risks posed by climate change and blockage in accordance with ARR 2016. Undertake assessment of impacts associated with proposal alignment for both scenarios. Outcomes: Climate change—climate change has been assessed in accordance with ARR 2016 requirements, with the RCP 8.5 (2090 horizon) scenario adopted, giving an increase in rainfall intensity of 23 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.
Compliance with Floodplain Management Plan	Check to ensure consistency with applicable local government or DPIE floodplain management plans. Outcomes: Existing floodplain management plans have been reviewed including: ▸ *Moree Plains Development Control Plan* ▸ *Draft Floodplain Management Plan for the Border Rivers Valley Floodplain* (Department of Industry, 2018) For the portion of the proposal within Gwydir Shire Council, an EIS is required to be undertaken for works of this nature and this document addresses this requirement. The *Moree Plains Development Control Plan* does not cover the Macintyre River floodplain—the key document to be addressed is the Border Rivers Valley Floodplan Management Plan. The Border Rivers Valley Floodplan Management Plan has been reviewed and the proposal complies with all requirements. This includes consideration of impacts under a range of events, consideration of cumulative impacts, demonstrating acceptable changes in peak water levels, no significant increases in velocities (with velocities not to cause erosion and siltation), and no potential concentration of flows in rivers or creeks that may affect river stability or geomorphological conditions.

The hydrologic and flooding assessment undertaken has demonstrated that the proposal is predicted to result in impacts on the existing flooding regime that generally comply with the flood-impact objectives. Best-practice flood risk management, including sensitivity testing, has been applied in developing the proposal design, to minimise risk to life, property, infrastructure, the community and environment.

A comprehensive consultation exercise has been undertaken to provide the community with detailed information and certainty around the flood modelling and the proposal design. In future stages, ARTC will continue to work with:

- Landowners concerned with hydrology and flooding throughout the detailed design, construction and operational phases of the proposal
- Directly impacted landowners affected by the alignment throughout the detailed design, construction and operational phases of the proposal
- Local governments, state departments and local flood specialists throughout the detailed design, construction and operational phases of the proposal.