TECHNICAL REPORT

5

Surface water quality assessment

NARROMINE TO NARRABRI ENVIRONMENTAL IMPACT STATEMENT

INLAND RAIL

ARTC

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

ARTC Inland Rail

Narromine to Narrabri Project

Surface Water Quality Assessment

Technical Report 5

2-0001-250-EAP-00-RP-0004

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Table of contents

Table index

Figure index

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Executive summary

The proposal

The Australian Government has committed to delivering a significant piece of national transport infrastructure by constructing a high performance and direct interstate freight rail corridor between Melbourne and Brisbane, via central-west New South Wales (NSW) and Toowoomba in Queensland. Inland Rail is a major national program that will enhance Australia's existing national rail network and serve the interstate freight market.

The proposal consists of about 306 kilometres of new single-track standard gauge railway with crossing loops. The proposal also includes changes to some roads to facilitate construction and operation of the new section of railway, and ancillary infrastructure to support the proposal.

The proposal would link the Parkes to Narromine section of Inland Rail located in central western NSW, with the Narrabri to North Star section of Inland Rail located in north-west NSW.

Australian Rail Track Corporation Ltd (ARTC) ('the proponent') is seeking approval to construct and operate the Narromine to Narrabri section of Inland Rail ('the proposal').

The proposal is State significant infrastructure and is subject to approval by the NSW Minister for Planning and Public Spaces under the NSW *Environmental Planning and Assessment Act 1979* (EP&A Act). The proposal is also determined to be a controlled action under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act), and requires approval from the Australian Minister for the Environment.

This report

This Surface Water Quality Assessment has been prepared on behalf of ARTC for the proposal to support the environmental impact statement (EIS) for the proposal and responds to the Secretary's Environmental Assessment Requirements (SEARs) for water quality.

This report provides the results of the surface water quality impact assessment of the proposal. It includes consideration of the hydrological, geomorphic and water quality conditions within the proposal site. This report builds on findings from the flooding and hydrology assessment, aquatic ecology assessment, biodiversity assessment and groundwater assessments where applicable, which were also undertaken to inform the EIS. Recommended mitigation and management measures were identified in response to the impact assessment findings.

Water quality and sensitive receiving environments

The proposal site is located within the Macquarie River, Castlereagh River and Namoi River/ Narrabri Creek catchments. The proposal traverses numerous watercourses of which only 48 are named. Watercourses range from first order to ninth order streams of which most are intermittent, with the exception of the Macquarie River and Narrabri Creek which are permanently flowing (Strahler, 1952). There is a minimal amount of water quality data to describe the existing conditions along the corridor and publicly available information indicated water quality within the Castlereagh River, Namoi River and Macquarie-Bogan River catchments typically exceed guideline values for electrical conductivity, turbidity, salinity, pH, total nitrogen and phosphorus. The poor quality is likely to reflect the hydrology, existing soil conditions and agricultural land use practices within the study area.

Available data would need to be supplemented by pre-construction monitoring of perennial watercourses, particularly those that were identified as sensitive receiving environments, to create a reliable understanding of baseline water quality. A water quality monitoring program is recommended to effectively identify the existing water quality conditions.

The receiving environments in the study area that are considered to be sensitive are Narrabri Creek, Namoi River, a tributary of Namoi River, Bohena Creek, Bundock Creek, Goona Creek, Mollieroi Creek, Coghill Creek, Rocky Creek, Stockyard Creek, Etoo Creek, Baradine Creek, Bucklanbah Creek, tributary of Bucklanbah Creek, Salty Springs Creek, Quanda Creek, Caleriwi Creek, Tenandra Creek, Baronne Creek, Gulargambone Creek, Castlereagh River, Kickabil Creek, Ewenmar Creek, Backwater Cowal, Emogandry Creek and Macquarie River.

Impacts from the proposal during construction

The potential impacts of construction mainly relate to erosion and the generation of sediment, particularly during the construction of bridges and culverts in flowing watercourses. This could result in impacts on downstream water quality if management measures are not implemented, monitored, and maintained.

To mitigate these impacts, erosion and sediment control measures, including measures for the main watercourse crossings, would be implemented during construction in accordance with the CEMP. A surface water monitoring framework would be prepared to guide the monitoring of water quality.

Impacts from the proposal during operation

For the operational phase, the risks have been identified as being the potential for failure of the formation leading to downstream pollution as well as wear of rolling stock potentially leading to metals on the track, possible spills of oil or grease from rolling stock or dust off carriages. Maintenance works required during the life of the proposal could also impact the environment through fragments of metals getting onto the soil the soil surface, minor spills of chemicals or soil disturbance resulting from access and minor earthworks.

The key water quality objective is to ensure downstream watercourses and identified sensitive receiving environments are protected against the potential impacts from surface runoff generated by the proposal. There are a number of physical-chemical and toxicant parameters that need to be controlled during the construction and operation of the proposal to maintain or strive to achieve the required level of protection for nominated environmental values.

Recommended mitigation measures

A soil and water management plan would be prepared as part of the Construction Environmental Management Plan (CEMP) to manage erosion and sediment impacts associated with land disturbance and watercourse crossings so that impacts to soil and water quality are minimised throughout the construction phase.

Management measures implemented during the operational phase to protect water quality would include measures undertaken as part of ARTC”s standard operating procedures including:

- measures to minimise the potential for accidental spills
- managing the proposal in accordance with the water quality management requirements specified in the environment protection licence
- inspection and maintenance of scour protection measures at culvert discharge outlets and downstream of creek adjustments
- a monitoring program to assess and manage impacts on receiving watercourses while the site restabilises.

Overall, with the implementation of the proposed measures, the proposal is expected to have minimal impacts on existing background water quality and environmental values during both the construction and operation of the proposal. With due consideration of these proposed management measures to be implemented as part of the proposal construction and operation, there would be minimal adverse cumulative surface water impacts anticipated. The residual risk to sensitive receiving environments and environmental values identified is expected to be low provided the proposed management measures are implemented, maintained and monitored.

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Glossary and abbreviations

Acronym / term	Definition
ANZECC	Australian and New Zealand Environment and Conservation Council
ANZG	Australian and New Zealand Guidelines
ARMCANZ	Agriculture and Resource Management Council of Australia and New Zealand
ARTC	Australian Rail Track Corporation
ASRIS	Australian Soil Resource Information System
ASS	Acid sulfate soils
BC Act	*Biodiversity Conservation Act* 2016 (NSW)
BOD	Biochemical Oxygen Demand
BOM	Bureau of Meteorology
BTEXN	Benzene Toluene Ethylbenzene Xylenes and Naphthalene
CEMP	Construction Environmental Management Plan
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DECCW	(former) Department of Environment Climate Change and Water
DSEWPaC	Department of Sustainability, Environment, Water, Population and Communities
DPI	(former) Department of Primary Industries
DPIE	Department of Planning, Industry and Environment
DPIE (Water)	Department of Planning, Industry and Environment (Water) (formerly known as Department of Industries (Water))
DPIE (Regions, Industry, Agriculture and Resources – Agriculture)	Department of Planning, Industry and Environment (Regions, Industry, Agriculture & Resources - Agriculture) (formerly known as Department of Primary Industries (Agriculture)
DPIE (Regions, Industry, Agriculture and Resources – Fisheries)	DPIE (Regions, Industry, Agriculture & Resources – Fisheries) (formerly known as Department of Primary Industries – Fisheries)
EESG	Environment, Energy and Science Group of the Department of Planning, Industry and Environment (EESG) (formerly known as the Office of Environment and Heritage)
EIS	Environmental Impact Statement
EPA	Environment Protection Authority
EP&A Act	*Environmental Planning and Assessment Act 1979* (NSW)
EPBC Act	*Environment Protection and Biodiversity Conservation Act 1999* (Commonwealth)
EPL	Environment protection licence
FM Act	*Fisheries Management Act 1994* (NSW)
ESCP	Erosion and Sediment Control Plan

Acronym / term	Definition
GDE	Groundwater dependent ecosystem
LTV	long term trigger values
MBO	Monosulfidic Black Ooze
MDBA	Murray-Darling Basin Authority
mg/L	Milligrams per litre
ML	Mega litre
MNES	Matters of National Environmental Significance
MPN	most probable number
n	Number
NARCLiM	New South Wales and Regional Climate Model
NHMRC	National Health and Medical Research Council
NO_x	Oxidised nitrogen
NRMMC	Natural Resource Management Ministerial Council
NSW	New South Wales
NTU	nephelometric turbidity unit
NWQMS	National Water Quality Management Strategy
OEH	(former) Office of Environment and Heritage
PAHs	phenols and poly-aromatic hydrocarbons
POEO Act	*Protection of the Environment Operations Act 1997* (NSW)
The proposal	Defined as the construction and operation of the Narromine to Narrabri section of Inland Rail.
the proposal site	Defined as the area that would be directly affected by construction of the proposal (also known as the construction footprint). It includes the location of proposal infrastructure, the area that would be directly disturbed by the movement of construction plant and machinery, and the location of the compounds and laydown areas that would be used during construction.
QA/QC	Quality Assurance/Quality Control
Rail corridor	The corridor within which the rail tracks and associated infrastructure would be located.
SEARs	Secretary Environmental Assessment Requirements
STV	short-term trigger value
SREs	Sensitive Receiving Environments
TDS	Total dissolved solids
TN	Total Nitrogen
TP	Total Phosphorus
TRH	total recoverable hydrocarbons
TSS	total suspended solids
µg/L	Micrograms per litre
µS/cm	Microsiemens per centimetre

Acronym / term	Definition
WAL	Water access licence
WM Act	*Water Management Act 2000* (NSW)
WQO	water quality objective
WSP	Water Sharing Plan
YSI	A Xylem brand

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1. Introduction

1.1 Overview

1.1.1 Inland Rail and the proposal

The Australian Government has committed to delivering a significant piece of national transport infrastructure by constructing a high performance and direct interstate freight rail corridor between Melbourne and Brisbane, via central-west New South Wales (NSW) and Toowoomba in Queensland. Inland Rail is a major national program that will enhance Australia's existing national rail network and serve the interstate freight market.

The Inland Rail route, which is about 1,700 kilometres long, involves:

- using the existing interstate rail line through Victoria and southern NSW
- upgrading about 400 kilometres of existing track, mainly in western NSW
- providing about 600 kilometres of new track in NSW and south-east Queensland.

The Inland Rail program has been divided into 13 sections, seven of which are located in NSW. Each of these projects can be delivered and operated independently with tie-in points on the existing railway.

Australian Rail Track Corporation Ltd (ARTC) ('the proponent') is seeking approval to construct and operate the Narromine to Narrabri section of Inland Rail ('the proposal').

1.1.2 Approval and assessment requirements

The proposal is State significant infrastructure and is subject to approval by the NSW Minister for Planning and Public Spaces under the NSW *Environmental Planning and Assessment Act 1979* (EP&A Act). The proposal is also determined to be a controlled action under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act), and requires approval from the Australian Minister for the Environment.

This report has been prepared by the JacobsGHD Joint Venture as part of the environmental impact statement (EIS) for the proposal. The EIS has been prepared to support the application for approval of the proposal, and address the environmental assessment requirements of the Secretary of the NSW Department of Planning, Industry and Environment (the SEARs), dated 9 September 2020.

1.2 The proposal

The proposal consists of about 306 kilometres of new single-track standard gauge railway with crossing loops. The proposal also includes changes to some roads to facilitate construction and operation of the new section of railway, and ancillary infrastructure to support the proposal.

The proposal would be constructed to accommodate double-stacked freight trains up to 1,800 metres long and 6.5 metres high. It would include infrastructure to accommodate possible future augmentation and upgrades of the track, including a possible future requirement for 3,600 metre long trains.

The land requirements for the proposal would include a new rail corridor with a minimum width of 40 metres, with some variation to accommodate particular infrastructure and to cater for local topography. The corridor would be of sufficient width to accommodate the infrastructure currently proposed for construction, as well as possible future expansion of crossing loops for 3,600 metre long trains. Clearing of the proposal site would occur to allow for construction and to maintain the safe operation of the railway.

1.2.1 Location

The proposal would be located between the towns of Narromine and Narrabri in NSW. The proposal would link the Parkes to Narromine section of Inland Rail located in central western NSW, with the Narrabri to North Star section of Inland Rail located in north-west NSW.

The location of the proposal is shown in Figure 1.1.

1.2.2 Key features

The key design features of the proposal include:

Rail infrastructure

- a new 306 kilometre long rail corridor between Narromine and Narrabri
- a single-track standard gauge railway and track formation within the new rail corridor
- seven crossing loops, at Burroway, Balladoran, Curban, Black Hollow/Quanda, Baradine, The Pilliga and Bohena Creek
- bridges over rivers and other watercourses (including the Macquarie River, Castlereagh River and the Namoi River/Narrabri Creek system), floodplains and roads
- level crossings
- new rail connections and possible future connections with existing ARTC and Country Regional Network rail lines, including a new 1.2 kilometre long rail junction between the Parkes to Narromine section of Inland Rail and the existing Narromine to Cobar Line (the Narromine West connection)

Road infrastructure

- road realignments at various locations, including realignment of the Pilliga Forest Way for a distance of 6.7 kilometres
- limited road closures.

The key features of the proposal are shown in Figure 1.2.

Ancillary infrastructure to support the proposal would include signalling and communications, drainage, signage and fencing, and services and utilities.

Further information on the proposal is provided in the EIS.

Figure 1.1 **Location of the proposal**

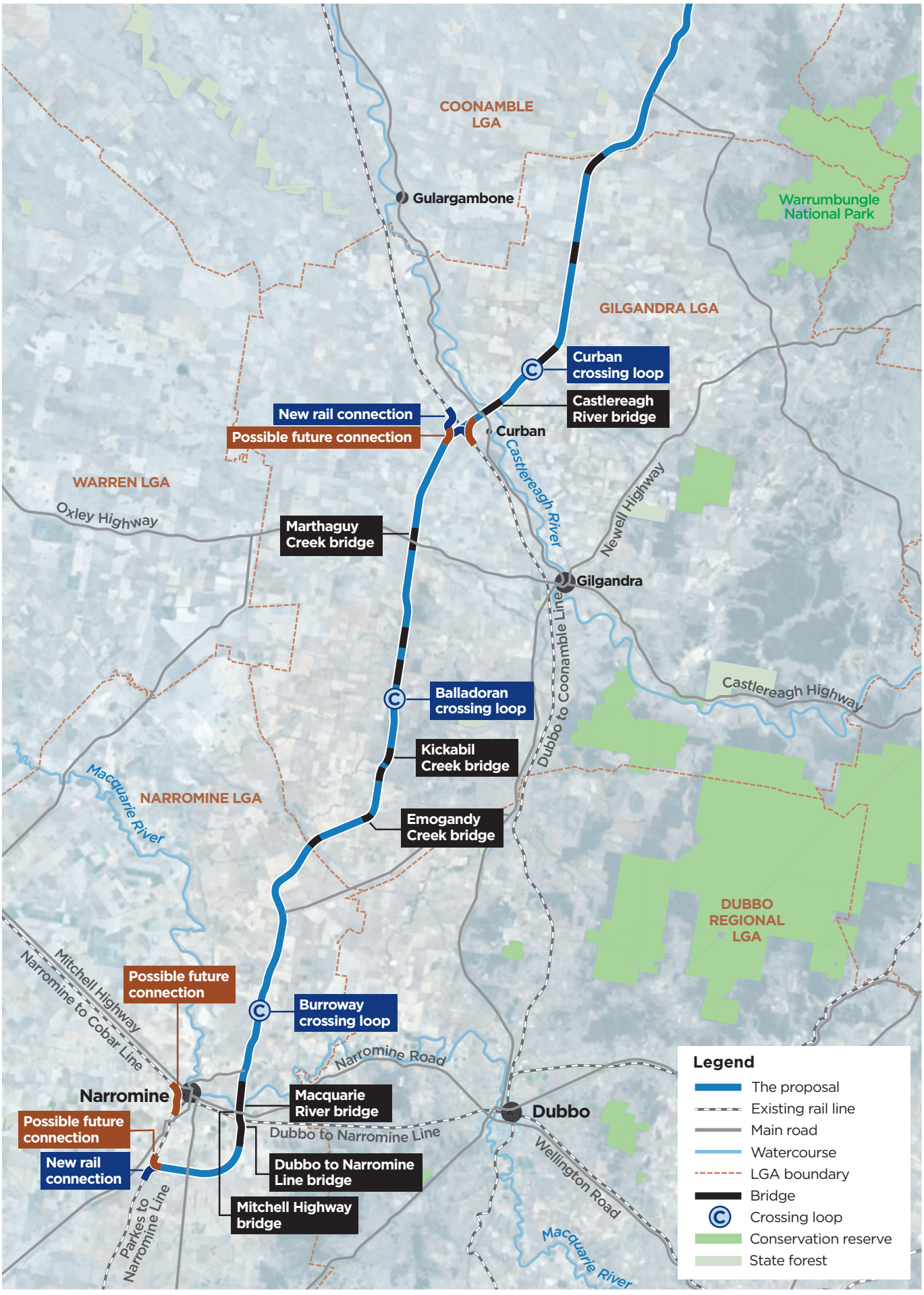

Figure 1.2a **Key features of the proposal**

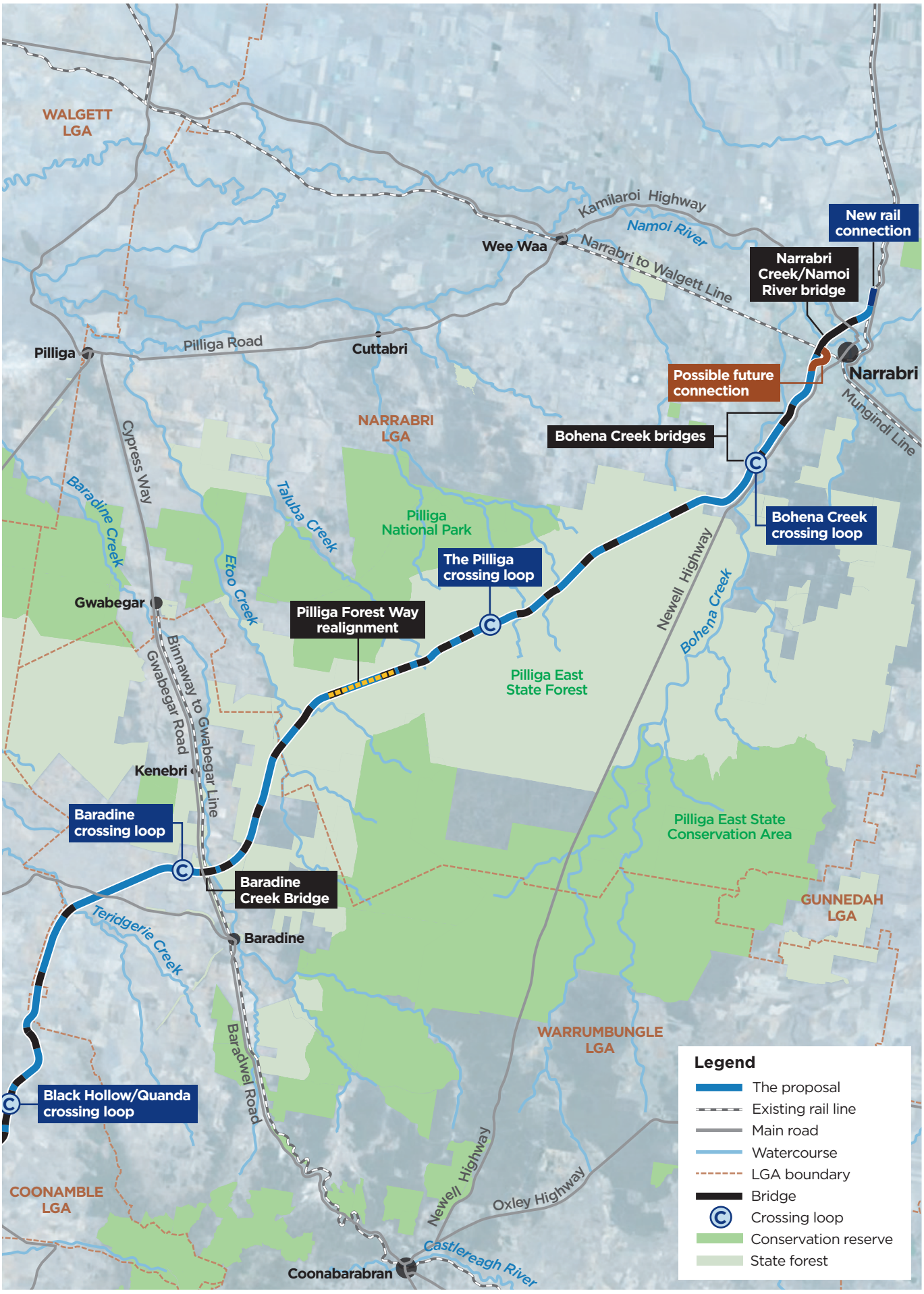

Figure 1.2b **Key features of the proposal**

1.2.3 Construction overview

An indicative construction strategy has been developed based on the current reference design to be used as a basis for the environmental assessment process. Detailed construction planning, including programming, work methodologies, staging and work sequencing would be undertaken once construction contractor(s) have been engaged and during detailed design.

Timing and work phases

Construction of the proposal would involve five main phases of work as outlined in Table 1.1. It is anticipated that the first phase would commence in late 2021, and construction would be completed in 2025.

Table 1.1 Main construction phases and indicative activities

Phase	Indicative construction activities
Pre-construction	• Establishment of areas to receive early material deliveries • Delivery of certain materials that need to be bought to site before the main construction work
Site establishment	• Establishment of key construction infrastructure, work areas and other construction facilities • Installing environmental controls, fencing and site services • Preliminary activities including clearing/trimming of vegetation
Main construction works	• Construction of the proposed rail and road infrastructure, including earthworks, track, bridge and road works
Testing and commissioning	• Testing and commissioning of the rail line and communications and signalling systems
Finishing and rehabilitation	• Demobilisation and decommissioning of construction compounds and other construction infrastructure • Restoration and rehabilitation of disturbed areas

Key construction infrastructure

The following key infrastructure is proposed to support construction of the proposal:

- borrow pits:
  - borrow pit A – Tantitha Road, Narromine
  - borrow pit B – Tomingley Road, Narromine
  - borrow pit C – Euromedah Road, Narromine
  - borrow pit D – Perimeter Road, Narrabri
- three main compounds, which would include a range of facilities to support construction ('multi-function compounds'), located at:
  - Narromine South
  - Curban
  - Narrabri West
- temporary workforce accommodation for the construction workforce:
  - within the Narromine South multi-function compound
  - Narromine North
  - Gilgandra
  - Baradine
  - within the Narrabri West multi-function compound.

The key construction infrastructure are shown in Figure 1.3.

Other construction infrastructure would include a number of smaller compounds of various sizes located along the proposal site, concrete batching plants, laydown areas, welding yards, a concrete pre-cast facility and groundwater bores for construction water supply.

1.2.4 Operation

The proposal would form part of the rail network managed and maintained by ARTC. Train services would be provided by a variety of operators. Inland Rail as a whole would be operational once all 13 sections are complete, which is estimated to be in 2025.

It is estimated that Inland Rail would be trafficked by an average of 10 trains per day (both directions) in 2025, increasing to about 14 trains per day (both directions) in 2040. This rail traffic would be in addition to the existing rail traffic using other lines that the proposal interacts with.

The trains would be a mix of grain, bulk freight, and other general transport trains. Total annual freight tonnages would be about 10 million tonnes in 2025, increasing to about 17.5 million tonnes in 2040.

Train speeds would vary according to axle loads, and range from 80 to 115 kilometres per hour.

1.3 Purpose and scope of this report

The purpose of this report is to assess the potential surface water impacts from constructing and operating the proposal. The report:

- addresses the relevant SEARs listed in Table 1.2
- describes the existing environment with respect to surface water quality
- assesses the impacts of constructing and operating the project on surface water quality
- recommends measures to mitigate and manage the impacts identified.

The methodology for the assessment is described in section 3.

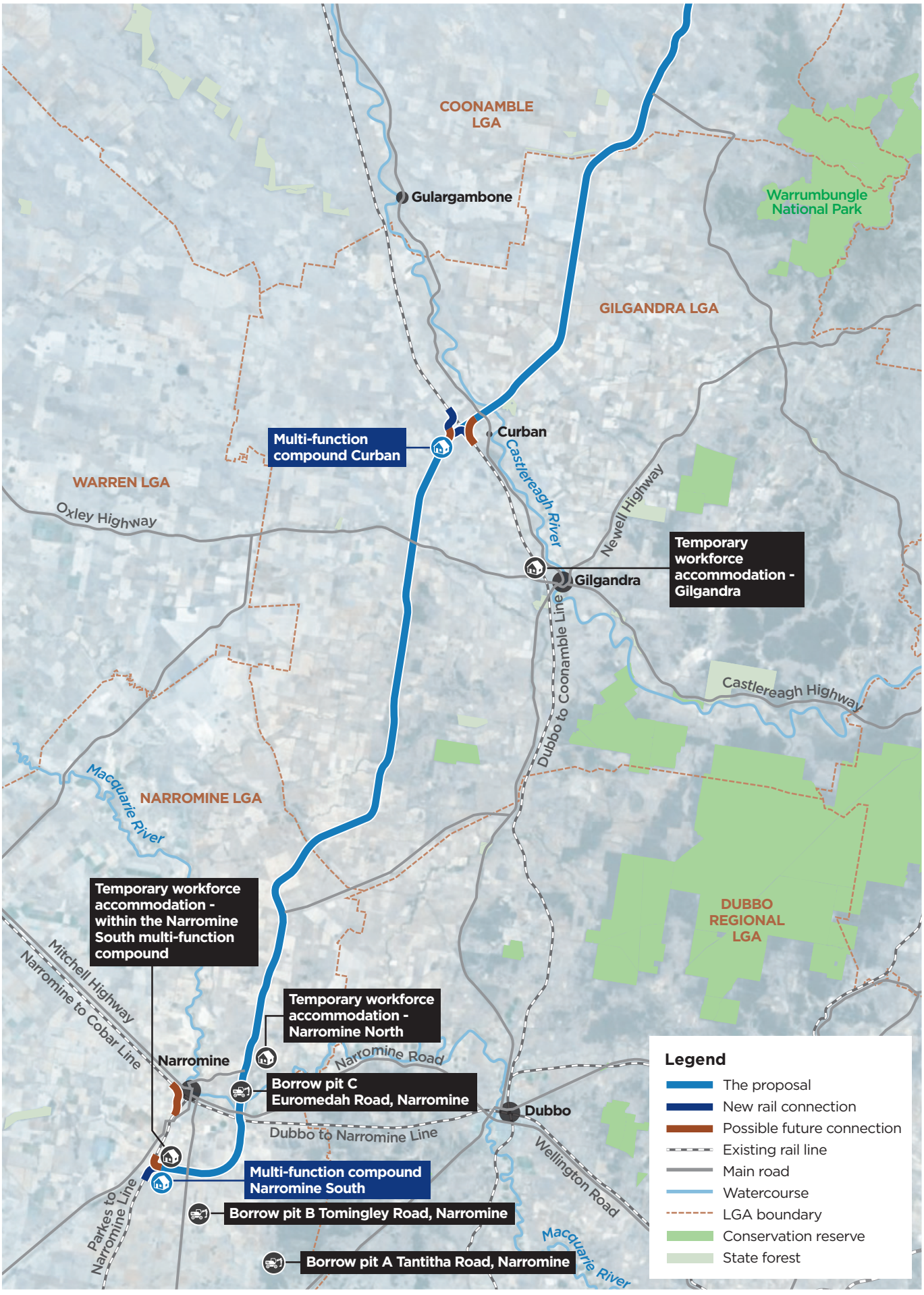

Figure 1.3a **Key construction infrastructure**

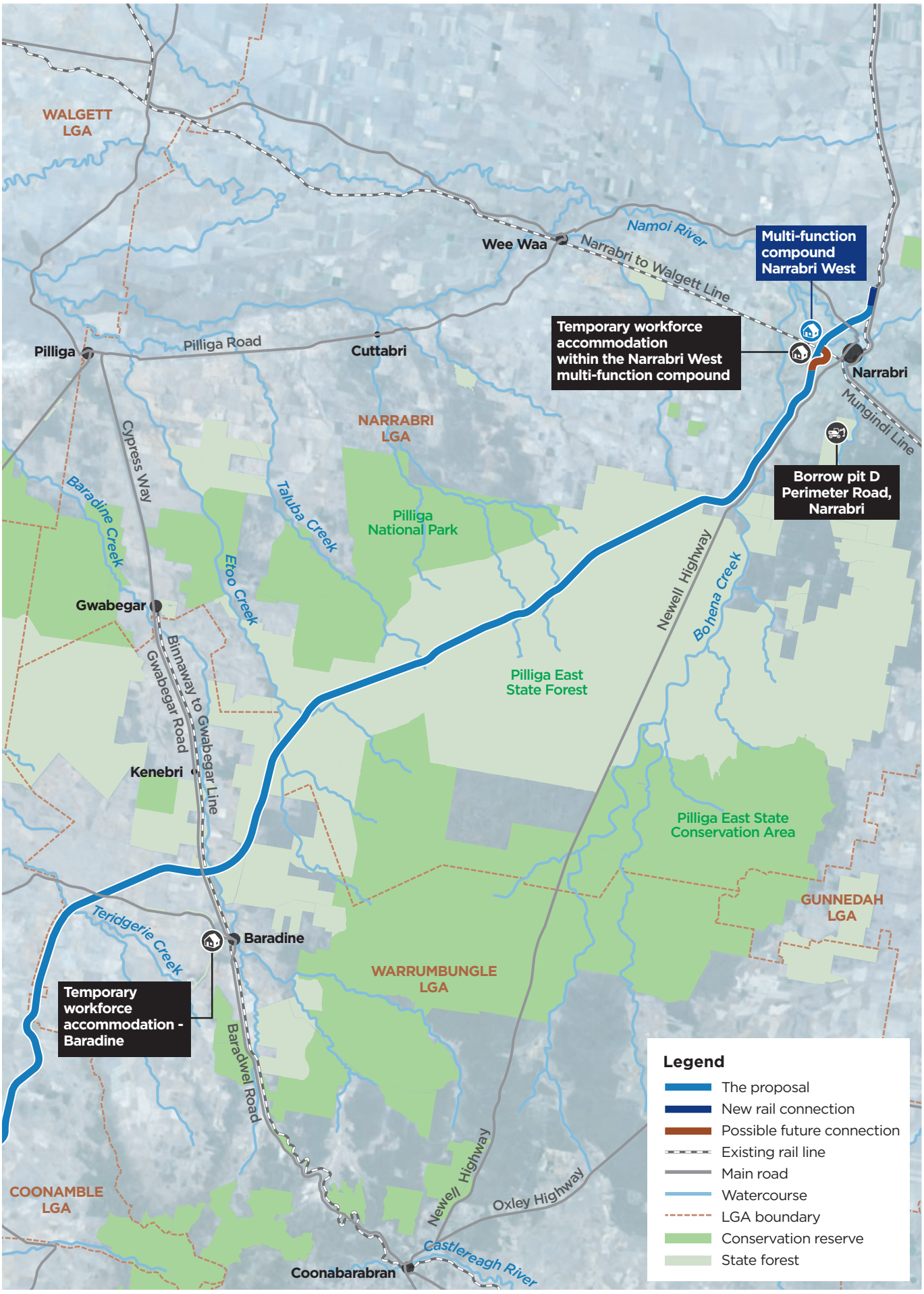

Figure 1.3b **Key construction infrastructure**

Table 1.2 SEARs relevant to this assessment

SEAR number	Requirements	Where addressed in this report
10.1	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 BAM.	Section 3.2 provides the methodology for describing the hydrological regime. Section 4.2 and section 4.6 describe the major river catchments the proposal traverses and associated watercourses. Section 4.7.1 identifies sensitive receiving waterways and associated stream order and hydrological attributes.
10.2	The Proponent must prepare a conceptual water balance for ground and surface water including indicative locations for proposed intake and discharge locations, volume, frequency and duration, potential sources, security and licensing requirements,	The water balance is provided in the *ARTC Inland Rail Narromine to Narrabri Groundwater Assessment (JacobsGHD, 2020c).*
10.3	The Proponent must assess (and model if appropriate) the impact of the construction and operation of the project (both built elements and discharges) on surface and groundwater hydrology in accordance with the current guidelines, including:	
	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 3.2.1 describes the methodology adopted to assess the impacts to surface water quality associated with construction and operation of the proposal. Sections 5.1, 5.2 and 5.3 list the potential (unmitigated) impacts from the construction of rail infrastructure, road infrastructure and key construction infrastructure. Section 6.1 and 6.2 lists the potential (unmitigated) impacts from the operation of rail infrastructure and road infrastructure With respect to aquatic connectivity and access to habitat for spawning and refuge refer to the *ARTC Inland Rail Narromine to Narrabri Aquatic Ecology Assessment* (JacobsGHD, 2020a).
	c. Changes to environmental water availability and flows, both regulated/licensed and unregulated/rules-based sources;	Potential changes to environmental availability and flows as a result of construction and operation of the proposal have been provided in section 5.4.3 and Table 6.3 respectively. Discussion on environmental water availability and flows is also provided in *ARTC Inland Rail Narromine to Narrabri Groundwater Assessment (JacobsGHD, 2020c).*

SEAR number	Requirements	Where addressed in this report
	d. Direct or indirect increases in erosion, siltation, destruction of riparian vegetation or a reductions in the stability of river banks or water courses;	Due to the design of the project and implementation of proposed mitigation and management controls, there would be no changes to the hydrological regime that would result in erosion or impact on the stability of the river banks during the construction and operation as discussed in sections 5.4.1, 5.4.3 and section 6.3 respectively).
	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;	Section 5.4.6 and section 6.3 provide discussion on the impact of stormwater and wastewater during construction and operation and how the effects of this on water quality and hydrology have been minimised.
	f. Water take (direct or passive) from all surface and groundwater sources with estimates of annual volumes during construction and operation	Section 5.4.3 provides discussion on water take from surface water sources during construction and for groundwater refer to *ARTC Inland Rail Narromine to Narrabri Groundwater Assessment (JacobsGHD, 2020c).*
10.4	The Proponent must identify any requirements for baseline monitoring of hydrological attributes.	Hydrological attributes of watercourse will be considered in the baseline water quality monitoring discussed in section 8.4. Additionally, a proposed hydrology monitoring program is provided in *ARTC Inland Rail Narromine to Narrabri Flooding and Hydrology Assessment (JacobsGHD, 2020d).*
11.1	a. State the ambient NSW Water Quality Objectives (NSW WQO) 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	The NSW Water Quality objectives and associated environmental values are provided in Table 2.1. The ANZG (2018) water quality criteria for protection of these environmental values relevant to the proposal area are provided in Table 3.1.

SEAR number	Requirements	Where addressed in this report
	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	Water quality pollutants that could be introduced into downstream watercourses are provided in sections 5.1, 5.2 and 5.3 (for construction) and sections 6.1 and 6.2 (for operation). The nature and degree of impact to water quality is provided in section 5.4.4 and section 6.3 for construction and operation respectively. Overall, pollutant runoff due to the proposal would be negligible and unlikely to cause long term harm to human health or the environment.
	c. Identify the rainfall event that the water quality protection measures will be designed to cope with	Water quality controls will be designed to meet the standards outlined in the Blue Book (Landcom 2004) as discussed in section 5.4.5 and section 8.3.
	d. Assess the significance of any identified impacts including consideration of the relevant ambient water quality outcomes	Section 5.4 and section 6.3 identify the likelihood of potential impacts and risk to water quality during the construction and operation of the proposal.
	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 WQOs are not currently being met, activities will work toward their achievement over time	The performance of the proposal during construction and the potential impacts on the NSW water quality objectives (WQOs) is provided in section 5.4.5. Discussion with respect to the performance of the proposal during operation and ability to meet the WQOs is provided in section 6.3.
	f. Justify, if required, why the WQOs cannot be maintained or acHhieved over time	A number of measures have been implanted to ensure that the proposal does not impact downstream water quality and aims to meet the nominated water quality objectives as discussed in section 5.4.5 and Table 6.3.
	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 8.1 provides a list of design measures to avoid or minimise water pollution. Where complete avoidance is not possible additional mitigation measures are proposed to further reduce impacts to surface water quality and are provided in section 8.2 and 8.3.
	h. Identify sensitive receiving environments (which may include marine waters downstream) and develop a strategy to avoid or minimise impacts on these environments	Section 3.2.3 describes the approach applied to determining sensitive receiving environments (SREs). Section 4.7 identifies the SREs within the proposal area.

SEAR number	Requirements	Where addressed in this report
	i. Identify proposed monitoring locations, monitoring frequency and indicators of surface and groundwater quality	A proposed water quality monitoring program is provided in section 8.4. Monitoring is proposed to occur, prior to construction, during construction and post construction, Proposed water quality indicators to be monitored are provided in section 8.4.5.

1.4 Structure of this report

The structure of the report is outlined below.

- Section 1 – provides an introduction to the report.
- Section 2 – provides an overview of legislation, policies and guidelines application to this assessment.
- Section 3 – describes the methodology and approach for the assessment.
- Section 4 – describes the physical characteristics and existing water quality of the proposal site.
- Section 5 – provides an assessment of the potential impacts to water quality from the construction of the proposal.
- Section 6 - provides an assessment of the potential impacts to water quality from the operation of the Proposal.
- Section 7 – provide an assessment of the potential cumulative impacts associated with the proposal.
- Section 8 – provides measures to avoid, mitigate and manage potential impacts to surface water and describes the proposed monitoring program.
- Section 9 – concludes the key findings and recommendations from the investigation.

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2. Legislative and policy context

This section provides assessment requirements and a review of the legislation and environmental planning instruments that are applicable to the surface water quality assessment of the proposal.

2.1 Legislative requirements

2.1.1 Commonwealth legislation

Environment Protection and Biodiversity Conservation Act 1999

The EPBC Act provides a regulatory framework to protect and manage Matters of National Environmental Significance (MNES). Under the EPBC Act, an action would require approval from the Minister for the Environment if the action has, will have, or is likely to have a significant impact on MNES. As there are there are no Ramsar listed wetlands in proximity to the proposal, the MNES relevant to the surface water quality assessment include listed threatened species and ecological communities

Where a project is likely to have a significant impact on a MNES, the project is referred to the Australian Minister for the Environment. The referral process involves a decision on whether or not the project is a 'controlled action'. When a project is declared a controlled action, approval from the Minister is required. The proposal has been declared a controlled action and approval under the EPBC Act is required.

2.1.2 NSW Legislation

Environmental Planning and Assessment Act 1979

As noted in section 1.1.2, the proposal is State significant infrastructure and is subject to approval by the NSW Minister for Planning and Public Spaces under the EP&A Act, and this report has been prepared as part of the EIS for the proposal to address the requirements of the EP&A Act and the SEARs for the proposal.

If State significant infrastructure approval is granted for the proposal, then approvals under various other NSW legislation will not be required. This includes, relevantly for this report:

- A permit under section 201, 205 or 219 of the *Fisheries Management Act 1994*; and
- A water use approval, a water management work approval or an activity approval of the *Water Management Act 2000*.

Protection of the Environment and Operations Act 1997

The *Protection of the Environment Operations Act 1997* (POEO Act) regulates air and water pollution, noise control and waste management.

Section 120 of the POEO Act makes the pollution of waters an offence. Environment protection licences under Chapter 3 of the Act are normally required for a broad range of activities listed in Schedule 1 of the POEO Act and aim to address water pollution issues created by those activities. For the purposes of this proposal, clause 33 (Railway infrastructure construction) and clause 33A (Railway infrastructure operations) are the most likely scheduled activities requiring an EPL. The ARTC currently hold an environmental protection licence (EPL) (No. 3142) for carrying out activities associated with railway systems. This licence obligates ARTC to comply with section 120 of the POEO Act and to maintain and implement erosion and sediment control measures during construction and maintenance in accordance with *Managing Urban Stormwater–Soils and Construction Volume 1* (Landcom, 2004) referred to as the Blue Book.

Water Management Act 2000 and Water Act 1912

The management of water within NSW is under two key pieces of legislation, the *Water Management Act 2000* (WM Act) and the *Water Act 1912* (Water Act). The Acts are administered by the NSW Department of Planning, Industry and Environment Water (DPIE (Water)) and Natural Resource Access Regulator (NRAR) as the regulators and DPIE (Water) as the policy maker. The objectives of the acts are to provide for sustainable and integrated management of the water sources of the state for present and future generations. The Water Act is being progressively phased out and replaced by the WM Act.

The WM Act establishes a system of licensing and approvals whereby access to water is generally regulated by way of water access licences (WALs).The WM Act implicitly recognises the need to allocate and provide water for the environmental health of rivers and groundwater systems, while also providing licence holders with more secure access to water and greater opportunities to trade water through the separation of water licences from land. The WM Act enables the State's water resources to be managed under water sharing plans, which establish the rules for sharing of water in a particular water source between water users and the environment, and rules for the trading of water in a particular water source.

The majority of water access licences are issued under the WM Act, however where there is no water sharing plan, some access rights are still issued in the form of licences or permits under the Water Act which are tied to the land.

The proposal is located within an area covered by the following water sharing plans (surface waters) and respective water sources:

- Water Sharing Plan for the Macquarie-Bogan Unregulated Rivers Water Sources 2012:
  - Wambangalong Whylandra Creek Water Source
  - Backwater Boggy Cowal Water Source
  - Coolbaggie Creek Water Source
  - Ewenmar Creek Water Source
  - Marthaguy Creek Water Source
- Water Sharing Plan for the Castlereagh Unregulated River Water Sources 2011:
  - Tooraweenah to Coonamble Tributaries Water Source
  - Teridgerie Creek Water Source
  - Gilgandra to Coonamble Water Source
- Water Sharing Plan for the Namoi Unregulated and Peel Unregulated Rivers Water Sources 2012:
  - Baradine Creek Water Source
  - Etoo and Talluba Creeks Water Source
  - Coghill Creek Water Source
  - Brigalow Creek Water Source
  - Bundock Creek Water Source
  - Bohena Creek Water Source
  - Spring and Bobbiwaa Creeks Water Source
  - Eulah Creek Water Source
  - Baradine Creek Water Source.

Fisheries Management Act 1994

The *Fisheries Management Act* 1994 (FM Act) provides for the protection of threatened fish and marine vegetation and it is administered by the Department of Regional NSW. The FM Act, in conjunction with the *Biodiversity Conservation Act* 2016 (BC Act), aims to conserve, develop and share fishery resources and conserve marine species, habitats and diversity.

The proposed alignment would cross a number of watercourses. Watercourse crossings have been designed were possible according to NSW Fisheries guidelines (*Why do Fish need to Cross the Road? Fish Passage Requirements for Watercourse Crossings* (Fairfull and Witheridge, 2003) and in consultation with NSW Fisheries staff to ensure minimum impact to aquatic habitats and species protected under the Act. Potential impacted species are assessed within the *ARTC Inland Rail Narromine to Narrabri Aquatic Ecology Assessment* (JacobsGHD, 2020a).

2.2 Water quality guidelines and policies

2.2.1 National Water Quality Management Strategy

The *National Water Quality Management Strategy* (NWQMS) (ANZECC/ARMCANZ, 2000) was formulated with the objective of achieving sustainable use of the nation's water resources by protecting and enhancing their quality whilst maintaining economic and social development.

The NWQMS contains guidelines for setting water quality objectives to sustain current or likely future environmental values for water resources. The *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZG, 2018) are part of the NWQMS and are relevant to the proposal as discussed below.

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

The Australian and New Zealand Environment and Conservation Council (ANZECC/ARMCANZ) published *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* to provide benchmarks for assessment of the existing water quality of watercourses. The guidelines have recently been updated to incorporate new science and knowledge developed over the past 20 years (ANZG, 2018). The ANZG (2018) *National Water Quality Guidelines for Fresh and Marine Water Quality* have been applied to understand the current health of the watercourses in the surface water study area and the ability to support nominated environmental values, particularly the protection of aquatic ecosystems. The ANZG (2018) guidelines provide recommended trigger value which have been considered when describing the existing water quality and key indicators of concern. However, many of the guideline values are still in a draft form, ie physical and chemical stressors for aquatic ecosystems for the relevant geographic region the Murray-Darling have not yet been completely updated.

2.2.3 NSW Water Quality and River Flow Objectives

The *NSW Water Quality and River Flow Objectives* (DECCW, 2006d) are the agreed environmental values and long-term goals for NSW surface waters. They set out:

- The community's values and uses (ie healthy aquatic ecosystems, water suitable for recreation or drinking water) for our watercourses (eg rivers, creeks, lakes and estuaries).
- A range of water quality indicators to assess whether the current condition of the watercourse supports these values and uses.

The Water Quality Objectives (WQO) provide environmental values for NSW waters and the ANZG (2018) guidelines provide the technical guidance to assess the water quality needed to protect these values. The proposal traverses three catchments - the Macquarie-Bogan, Castlereagh and Namoi catchments. The watercourses within these catchments have been categorised, and each category has numerous water quality objectives or environmental values for protection. Table 2.1 shows the categories relevant to watercourses within the study area and associated environmental values (DECCW, 2006a,b and c).

2.2.4 Managing Urban Stormwater – Soils and Construction

The Managing Urban Stormwater – Soils and Construction series of handbooks are an element of the NSW Government's urban stormwater program specifically applicable to the construction phase of developments. These provide guidance for managing uncontaminated soils in a manner that protects the health, ecology and amenity of urban streams, rivers estuaries and beaches through better management of stormwater quality.

The handbooks were produced to provide guidelines, principles and recommended minimum design standards for good management practice in erosion and sediment control during the construction of roads. Of particular relevance to the proposal are *Managing Urban Stormwater – Soils and Construction*: *Volume 1* (Landcom, 2004), *Volume 2C Unsealed Roads* (DECC, 2008a) and *Volume 2D Main Road Construction* (DECC, 2008b) (collectively referred to as the 'Blue Book').The construction mitigation measures proposed in this report are largely based on the guidelines provided in the Blue Book.

2.2.5 Guideline for Controlled Activities on Waterfront Land

Controlled activities carried out in, on or under waterfront land are regulated by the WM Act. This Act defines waterfront land to include the bed and bank of any river, lake or estuary and all land within 40 metres of the highest bank of the river lake or estuary. Under section 5.23 of the EP&A Act, an activity approval (including a controlled activity approval) under section 91 of the WM Act is not required for SSI. The former Department of Industry (Water) (now Department of Planning Industry and Environment (Water)) prepared guidelines for controlled activities which provide information on the design and construction of a controlled activity, and other ways to protect waterfront land. Despite the exemption, the design and construction of the proposal would take into account guidelines for controlled activities on waterfront land, namely the *Guideline for Watercourse Crossings on Waterfront Land* (DPI, 2012).

Key water quality indicators and related numerical criteria (default trigger value) have been nominated for each water quality objective (environmental value) using the ANZECC/ARMCANZ (2000) and ANZG (2018) guidelines.

Table 2.1 Watercourse category and environmental values (DECCW, 2006)

Category	Environmental values										
	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 pointe of supply – clarification and disinfection	Drinking water at point of supply - groundwater	Aquatic foods (cooked)
Major regulated rivers – rivers that have large dams supplying irrigation water (and some town and industrial water) for substantial distances downstream.	X	X	X	X	X	X	X	X	X	X	X
Mainly forested areas – streams that are valued for their conservation or recreational values.	X	X	X	X				X	X	X	X
Uncontrolled streams – streams with largely natural flow patterns, typically ephemeral often flowing into or through wetlands and billabongs.	X	X	X	X	X	X	X	X	X	X	X

2.2.6 Guidelines for Managing Risks in Recreational Water

The *Guidelines for Managing Risks in Recreational Water* (NHMRC, 2008) aim to protect the health of humans from threats posed by the recreational use of fresh waters.

The guidelines have been applied in this assessment to understand the current recreational water quality and potential threats to public health of watercourses that may be impacted by runoff during the construction and operation of the proposal.

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3. Methodology

3.1 Study area

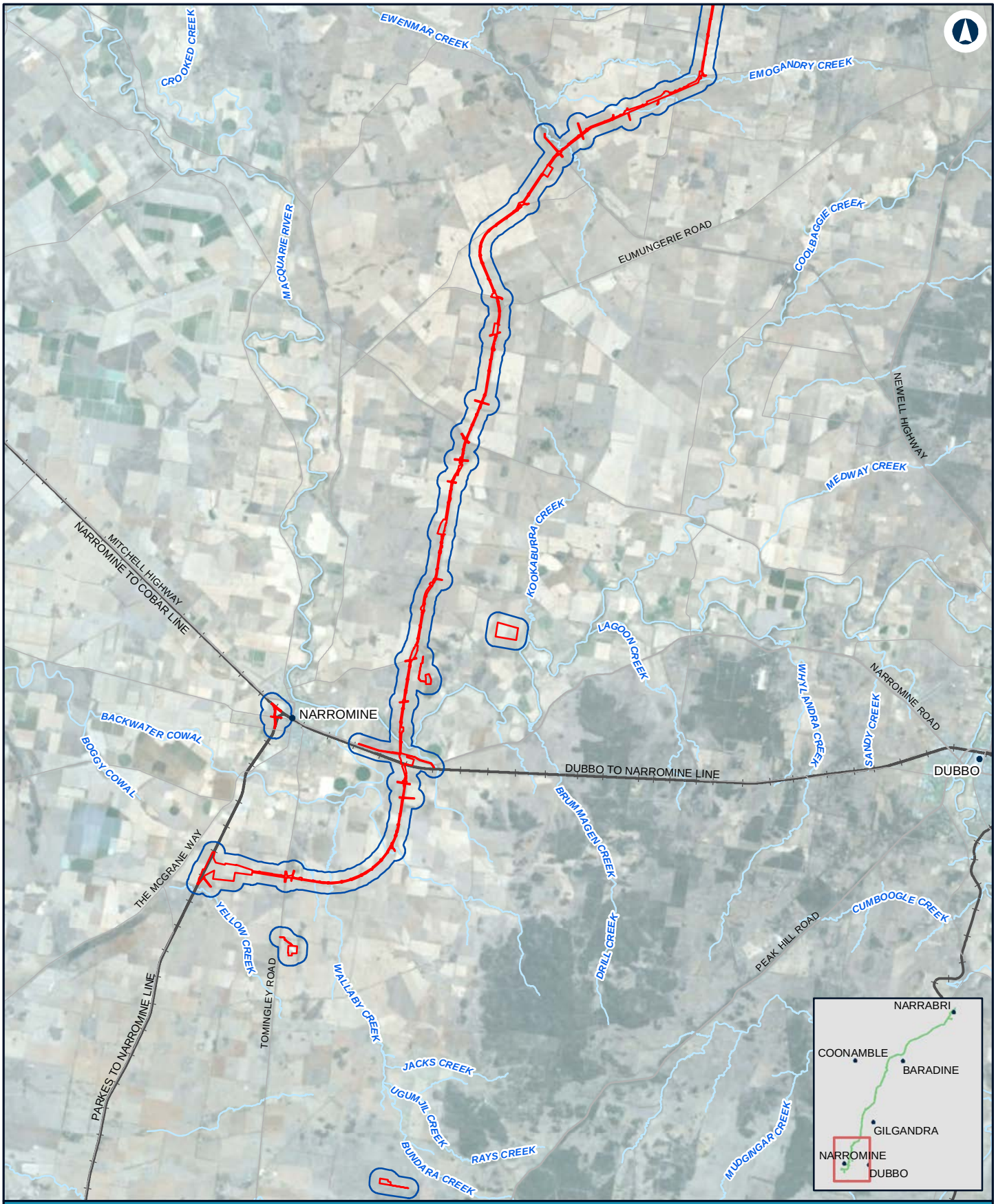
The study area for the surface water quality assessment is the area either directly or indirectly affected by the proposal. For the purposes of this surface water quality report, the study area is identified as the proposal site as shown in Figure 1.2 and comprises the construction and operational footprints and a 500-metre buffer around the alignment (refer Figure 3.1).

3.2 Surface water quality assessment

3.2.1 Methodology

The methodology for the assessment of surface water quality is outlined in the following sections and has included:

- Undertaking a desktop review and analysis to understand the existing environment and identify potential watercourse-specific risks. Water quality monitoring was undertaken in accordance with the *Approved Methods for Sampling and Analysis of Water Pollutants in NSW* (DECC, 2008).
- Site visits and water quality monitoring to support and enhance the findings of the desktop analysis and refine the understanding of potential issues.
- Assessment of impacts from construction and operation of the proposal on water quality with reference to the ANZG (2018) *Guidelines for Fresh and Marine Water Quality* with regard to the relevant water quality objectives and environmental values as identified in the *NSW Water Quality and River Flow Objectives (*DECCW, 2006d).
- The assessment of construction impacts is provided in three parts being rail infrastructure, road infrastructure and construction features within sections 5.1, 5.2 and 5.3 respectively.
- The assessment of operation impacts is provided in two parts, being rail infrastructure and road infrastructure, outlined in section 6.1 and 6.2 respectively.
- A qualitative assessment of cumulative surface water impacts by identifying major projects with a construction program that is likely to overlap with the proposal construction and/or is within the same surface water catchment.
- Identification of appropriate treatment measures to mitigate the impacts of construction and operation on surface water quality.



NARROMINE TO NARRABRI Study area Figure 3.1

0 3.5 7 Km

Coordinate System: GDA 1994 MGA Zone 55

Date: 16/03/2020 Paper: A4
Author: JacobsGHD Scale: 1:260,000
Data Sources: Basemap layers: NSWSS; Proposal: GHDJACOBS

LEGEND

- The proposal
- Study area
- Roads
- Railway
- Rivers/creeks

INLAND RAIL ARTC

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

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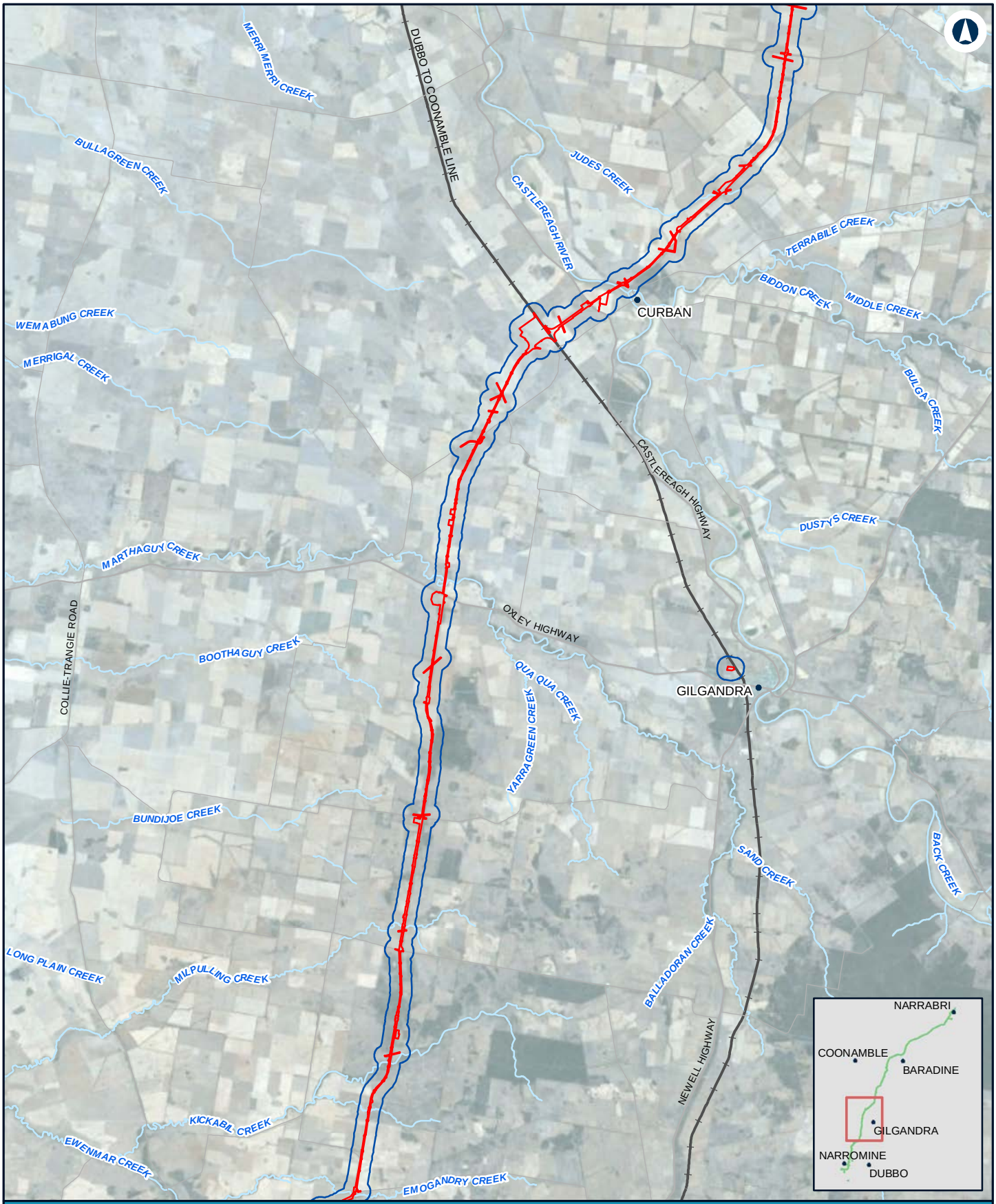

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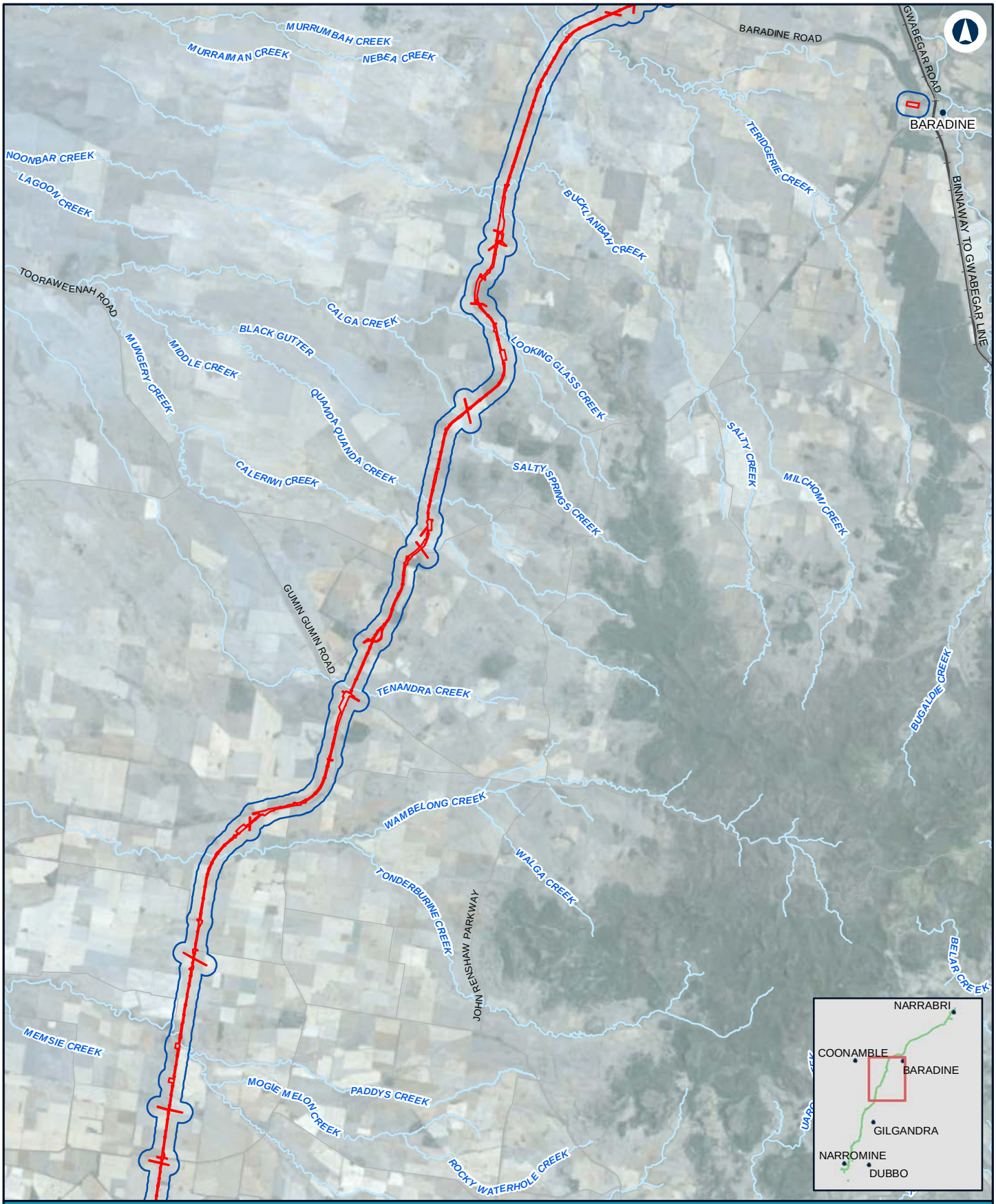

NARROMINE TO NARRABRI

Study area

Figure 3.1

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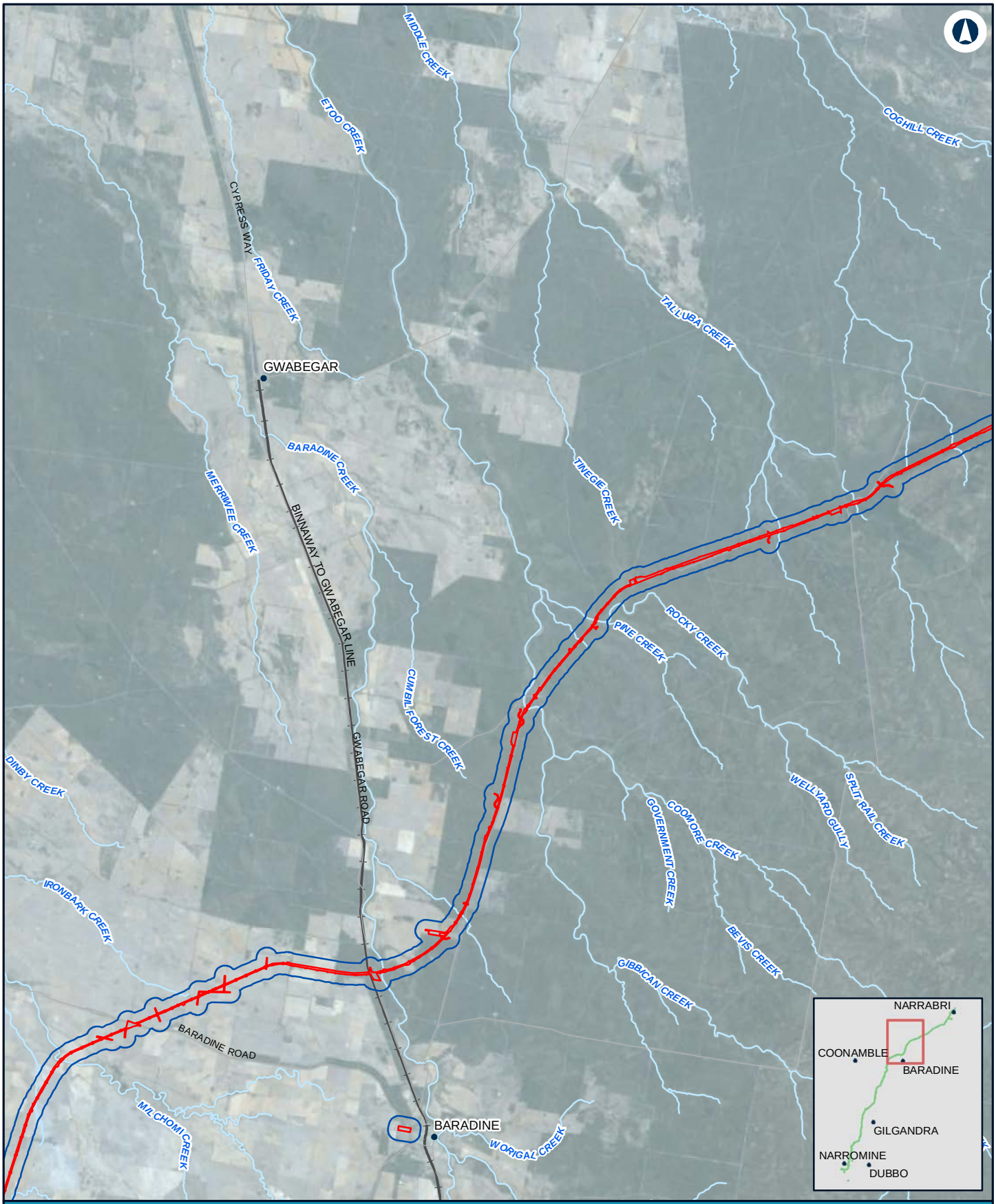

NARROMINE TO NARRABRI Study area Figure 3.1

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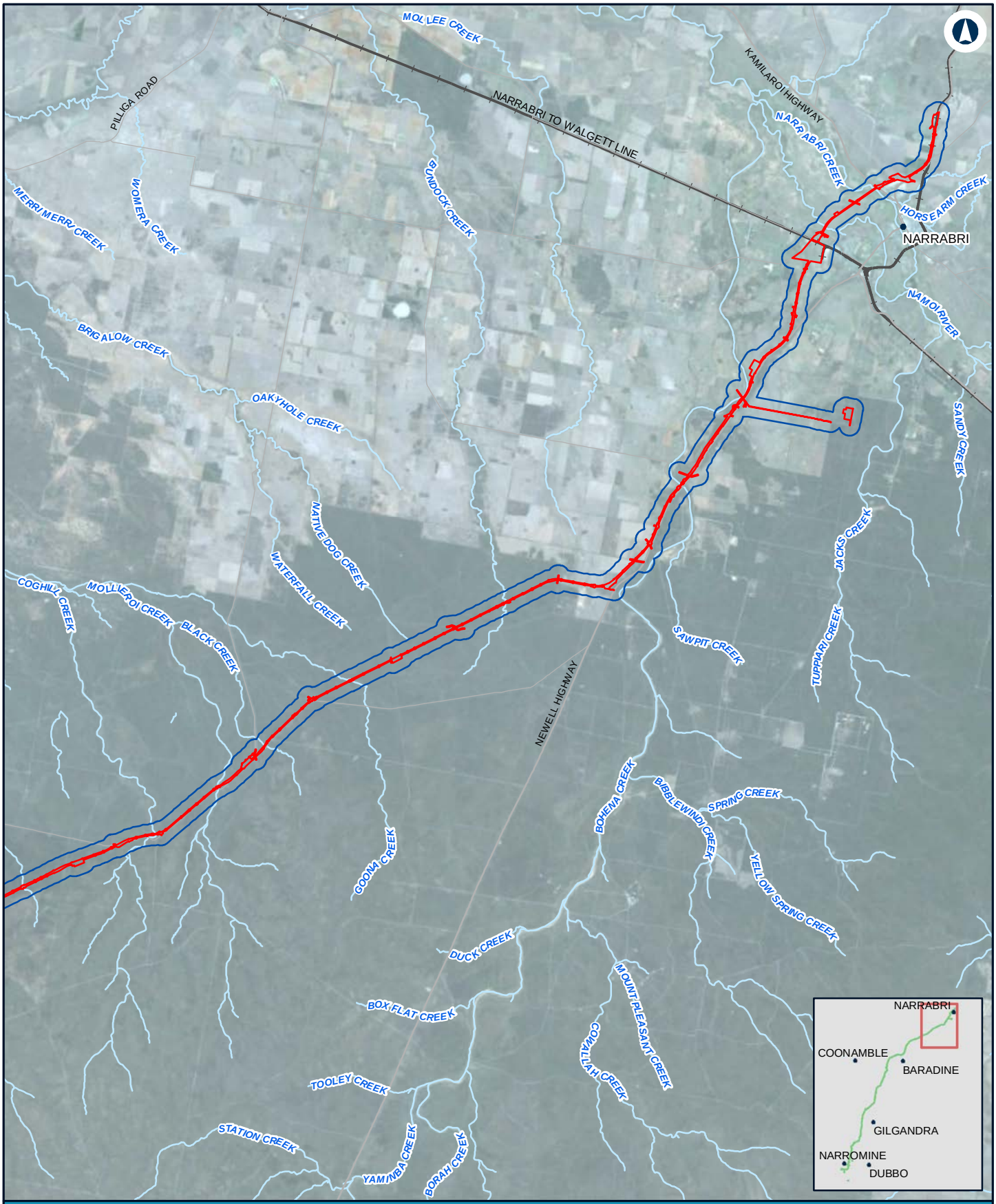

NARROMINE TO NARRABRI Study area Figure 3.1

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Coordinate System: GDA 1994 MGA Zone 55

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3.2.2 Surface water desktop review

A desktop review was completed of the study area of publicly available literature and water quality data to describe the physical and chemical water quality characteristics and environmental values. The information was used for the development of the site investigation plan for undertaking field assessments. The desktop review included the following:

- identifying the state of watercourses through existing available data
- categorising the watercourse as high, moderate or low priority based on stream order as per Strahler (1952) and criteria for sensitive receiving environments
- identifying localised inputs and influences
- identifying suitable sites and developing parameters for a monitoring program.

The information was used for the development of the site investigation plan for undertaking field assessments.

3.2.3 Site classification

Sensitive receiving environments

Sensitive receiving environments (SREs) are environments that have a high conservation or community value or support ecosystem/human uses of water that are particularly sensitive to pollution or degradation of water quality. SREs were identified within 500 metres of the proposal (upstream and downstream) based on the following conditions:

- key fish habitat field assessment was completed in accordance with the requirements of DPI (2013)
- watercourse classification (Fairfull and Witheridge, 2003)
- key fish habitat mapping (DPI, 2007)
- presence of threatened aquatic species listed under FM Act and EPBC Act. Likelihood of presence is on based on threatened species distribution mapping (DPI, 2016) and database searches including the Protected Matters Search Tool (DAWE, 2020), Bionet Atlas records (EESG, 2020) and ALA records (ALA, 2020)
- groundwater and surface water dependent vegetation and fauna communities listed under the BC Act and EPBC Act
- proximity to a drinking water catchment
- areas that contribute to aquaculture and commercial fishing.

SREs in the study area have been considered in the design of the proposal and the implementation of water quality controls to minimise potential impacts to these environments. This is further discussed in the *ARTC Inland Rail Narromine to Narrabri Aquatic Ecology Assessment* (JacobsGHD, 2020a).

Water Quality Objectives

The Water Quality Objectives (WQO) provide environmental values for NSW waters and the ANZG (2018) guidelines provide the technical guidance to assess the water quality needed to protect these values. Additionally, the SEARs specify the protection of human health as an objective to be considered.

Therefore, the water quality objectives/environmental values considered in this assessment are protection of:

- aquatic ecosystems
- visual amenity
- primary and secondary contact recreation
- livestock water supply
- irrigation water supply
- homestead water supply
- drinking water at the point of supply – disinfection only; clarification and disinfection
- groundwater
- aquatic foods (cooked).

ANZG (2018) has published *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* to provide benchmarks for assessment of the existing water quality of watercourses.

These objectives and indicators are provided in Table 3.1. The ANZG guidelines provide trigger values for upland (>150 metre altitude) and lowland rivers (<150 metre altitude). However supporting information in *NSW Water Quality and River Flow Objectives* (DECCW, 2006d) suggests that for the NSW Murray Darling Basin (which the study area falls within), 250 metres may be a scientifically more appropriate altitudinal trigger to distinguish between lowland and upland rivers. For 90 per cent of the study area the altitude varies between 250 metres and 300 metres and therefore the ANZG (2018) upland river trigger values would apply. For the remaining 10 per cent, which is at the southern and northern extent of the alignment, the altitude is less than 250 metres and therefore the lowland river trigger values apply.

Table 3.1 Water quality objectives for lowland and upland rivers

Water quality objective	Indicator	Lowland River	Upland River
Aquatic ecosystems – maintaining or improving the ecological condition of waterbodies and their riparian zones over the long term	Total phosphorus	50 µg/L	20 µg/L
	Total nitrogen	500 µg/L	250 µg/L
	Chlorophyll-*a*	5 µg/L	n/a
	Turbidity	6-50 NTU	2-25 NTU
	Salinity (Electrical conductivity)	125-2200 µS/cm	30-350 µS/cm
	Dissolved oxygen	85-110 % saturation	90-110 % saturation
	pH	6.5-8.5	6.5-8
	Toxicants	As per ANZG (2018) toxicant default guideline values for water quality in aquatic ecosystems.	
Visual amenity – aesthetic qualities of waters	Visual clarity and colour	Natural visual clarity should not be reduced by more than 20%. Natural hue of water should not be changed by more than 10 points on the Munsell Scale. The natural reflectance of the water should not be changed by more than 50%.	

Water quality objective	Indicator	Lowland River Upland River
	Surface films and debris	Oils and petrochemicals should not be noticeable as a visible film on the water, nor should they be detectable by odour. Waters should be free from floating debris and matter.
	Nuisance organisms	Macrophytes, phytoplankton scums, filamentous algal mats, blue-green algae, sewage fungus and leeches should not be present in unsightly amounts. n/a
Secondary contact recreation – maintaining or improving water quality for activities such as boating and wading, where there is a low probability of water being swallowed	Faecal coliforms, enterococci, algae and blue-green algae	As per the NHMRC (2008) Guidelines for managing risks in recreational water. Secondary contact recreation – maintaining or improving water quality for activities such as boating and wading, where there is a low probability of water being swallowed.
	Nuisance organisms	As per the visual amenity guidelines. Large numbers of midges and aquatic worms are undesirable.
	Chemical contaminants	Waters containing chemicals that are either toxic or irritating to the skin or mucous membranes are unsuitable for recreation. Toxic substances should not exceed values in Table 9.3 of NHMRC (2008) guidelines.
	Visual clarity and colour	As per the visual amenity guidelines.
	Surface films	As per the visual amenity guidelines.
Primary contact recreation – maintaining or improving water quality for activities such as swimming where there is a high probability of water being swallowed	Faecal coliforms, enterococci, algae and blue-green algae	As per the NHMRC 2008 Guidelines for managing risks in recreational water.
	Protozoans	Pathogenic free-living protozoans should be absent from bodies of fresh water.
	Chemical contaminants	Waters containing chemicals that are either toxic or irritating to the skin or mucus membranes are unsuitable for recreation. Toxic substances should not exceed values in Table 9.2 of NHMRC (2008) guidelines.
	Visual clarity and colour	As per the visual amenity guidelines.
	Temperature	15°-35°C for prolonged exposure.
Livestock water supply – protecting water quality to maximise the production of healthy livestock	Algae and blue-green algae	An increasing risk to livestock health is likely when cell counts of microcystins exceed 11 500 cells/mL and/or concentrations of microcystins exceed 2.3 µg/L expressed as microcystin-LR toxicity equivalents.
	Salinity (electrical conductivity)	Recommended concentrations of total dissolved solids in drinking water for livestock are given in Table 4.3.1 of ANZECC Guidelines (ANZECC/ARMCANZ, 2000).

Water quality objective	Indicator	Lowland River Upland River
	Thermotolerant coliforms (faecal coliforms)	Drinking water for livestock should contain less than 100 thermotolerant coliforms per 100 mL (median value).
	Chemical contaminants	Refer to Table 4.3.2 of ANZECC Guidelines (ANZECC/ARMCANZ, 2000) for heavy metals and metalloids in livestock drinking water. Refer to Australian Drinking Water Guidelines (NHMRC and NRMMC, 2018) for information regarding pesticides and other organic contaminants, using criteria for raw drinking water.
Irrigation water supply – protecting the quality of waters applied to crops and pasture	Algae and blue-green algae	Should not be visible. No more than low algal levels are desired to protect irrigation equipment.
	Salinity (electrical conductivity)	To assess the salinity and sodicity of water for irrigation use, a number of interactive factors must be considered including irrigation water quality, soil properties, plant salt tolerance, climate, landscape and water and soil management. For more information, refer to Chapter 4.2.4 of ANZECC Guidelines (ANZECC/ARMCANZ, 2000).
	Thermotolerant coliforms (faecal coliforms)	Trigger values for thermotolerant coliforms in irrigation water used for food and non-food crops are provided in Table 4.2.2 of ANZECC Guidelines (ANZECC/ARMCANZ, 2000).
	Heavy metals and metalloids	Long term trigger values (LTV) and short-term trigger values (STV) for heavy metals and metalloids in irrigation water are presented in Table 4.2.10 of the ANZECC Guidelines (ANZECC/ARMCANZ, 2000).
Homestead water supply – protecting water quality for domestic use in homesteads, including drinking, cooking and bathing	Blue-green algae	Recommend twice weekly inspections during danger period for storages with history of algal blooms. No guideline values are set for cyanobacteria in drinking water. In water storages, counts of < 1000 algal cells/mL are of no concern. >500 algal cells/mL - increase monitoring. >2000 algal cells/mL - immediate action indicated; seek expert advice. >6500 algal cells/mL - seek advice from health authority.
	Turbidity	5 NTU; <1 NTU desirable for effective disinfection; >1 NTU may shield some micro-organisms from disinfection.

Water quality objective	Indicator	Lowland River Upland River
	Total dissolved solids	<500 mg/L is regarded as good quality drinking water based on taste. 500-1000 mg/L is acceptable based on taste. >1000 mg/L may be associated with excessive scaling, corrosion and unsatisfactory taste.
	Faecal coliforms	0 faecal coliforms per 100 mL (0/100 mL). If micro-organisms are detected in water, advice should be sought from the relevant health authority. See also the Guidelines for Microbiological Quality in relation to Monitoring, Monitoring Frequency and Assessing Performance in the *Australian Drinking Water Guidelines* (NHMRC and NRMMC, 2018).
	pH	6.5-8.5
	Chemical contaminants	See Guidelines for Inorganic Chemicals in the *Australian Drinking Water Guidelines* (NHMRC & NRMMC, 2004).
Drinking water – disinfection only, clarification and disinfection, groundwater – refers to the quality of drinking water drawn from the raw surface and groundwater sources before any treatment	Blue-green algae	Recommend twice-weekly inspections during danger period for storages with history of algal blooms. >500 algal cells/mL - increase monitoring. < 2000 algal cells/mL - water may be used for potable supply. >2000 algal cells/mL - immediate action indicated; seek expert advice. >6500 algal cells/mL - seek advice from health authority. >15 000 algal cells/mL - may not be used for potable supply except with full water treatment, which incorporates filtration and activated carbon.
	Turbidity	Site specific determinant
	Salinity (electrical conductivity)	<1500 µS/cm > 800 µS/cm causes a deterioration in taste
	Faecal Coliforms	0 faecal coliforms per 100 mL (0/100 mL)
	Total coliforms	95% of samples should be 0 coliforms/ 100 mL throughout the year. Up to 10 coliform organisms may be accepted occasionally in 100 mL. Coliform organisms should not be detected in 100 mL in any two consecutive samples.
	Dissolved oxygen	>80% saturation
	pH	6.5-8.5
	Chemical contaminants	See ANZG (2018) guidelines, Section 6.2.2.

Water quality objective	Indicator	Lowland River Upland River
Aquatic foods (cooked) – refers to protecting water quality so that it is suitable for production of aquatic foods for human consumption and aquaculture activities	Algae and blue-green algae	No guideline is directly applicable, but toxins present in blue-green algae may accumulate in other aquatic organisms.
	Faecal coliforms	*Guideline in water for shellfish:* The median faecal coliform concentration should not exceed 14 MPN/100mL, with no more than 10% of the samples exceeding 43 MPN/100 mL. *Standard in edible tissue:* Fish destined for human consumption should not exceed a limit of 2.3 MPN *E Coli* /g of flesh with a standard plate count of 100,000 organisms/g.
	Toxicants (as applied to aquaculture activities)	Metals: • Copper: less than 5 µgm/L • Mercury: less than 1 µgm/L • Zinc: less than 5 µgm/L. Organochlorines: • Chlordane: less than 0.004 µgm/L (saltwater production) • PCB's: less than 2 µgm/L.
	Physico-chemical indicators (as applied to aquaculture activities)	Suspended solids: less than 40 micrograms per litre (freshwater). Temperature: less than 2 degrees Celsius change over one hour.

3.2.4 Field data collection and monitoring

The desktop assessment identified that the proposal traverses four major rivers: the Namoi River/Narrabri Creek, Castlereagh River, Macquarie River and Narrabri Creek. There are 48 named watercourse crossings along the proposal site. Many of these watercourses are ephemeral or intermittent and are typically dry for much of the time. Watercourses chosen for field assessment were prioritised based upon the predicted presence of threatened aquatic species, stream order and the presence of key fish habitat. Watercourses were categorised into three categories - high, moderate and low priority watercourses (see Table 3.2).

Table 3.2 Watercourse priority

Priority Categorisation	Consideration	Watercourses
High	• Threatened fish species predicted to occur based on DPI mapping (DPI, 2016) • Key fish habitat (DPI, 2007a)	• Narrabri Creek* • Namoi River* • Tributary of Namoi River • Bohena Creek • Bundock Creek • Goona Creek • Mollieroi Creek • Coghill Creek • Rocky Creek • Etoo Creek • Baradine Creek • Bucklanbah Creek • Salty Springs Creek • Quanda Creek • Caleriwi Creek • Baronne Creek • Gulargambone Creek • Castlereagh River • Macquarie River* • Backwater Cowal
Moderate	• Key fish habitat (DPI, 2007a)	• Coolangla Creek • Black Creek • Talluba Creek • Stockyard Creek • Teridgerie Creek • Tributary of Bucklanbah Creek • Calga Creek • Tenandra Creek • Marthaguy Creek • Millpulling Creek • Kickabil Creek • Native Dog Creek • Emogandry Creek • Goulburn Creek • Ewenmar Creek • Wallaby Creek
Low	• No threatened fish species based on DPI mapping (DPI, 2016) • Not key fish habitat (DPI, 2007a)	• Tinegie Creek • Cumbil Forest Creek • Small Creek • Black Gutter Creek • Mungery Creek • Judes Creek • Bundijoe Creek • Pint Pot Gully Creek • All other unnamed tributaries.

* - Permanently flowing watercourse (perennial).

A site visit was undertaken at specific locations for high and moderate priority watercourses (where accessible) between 13 and 16 November 2018 and 19 and 27 March 2019. Priority was based upon the likelihood for threatened aquatic species, stream order (greater than third order) and the presence of key fish habitat. Water quality monitoring was carried out in conjunction with aquatic habitat assessments. No rain had fallen in the week prior to each monitoring event. The purpose of this site visit was to undertake water quality monitoring and to visually assess the condition of watercourses traversed by the proposal. Thirty-two sites were chosen for field assessment, however due to access constraints, only 25 watercourses were visited of which only five had sufficient water for sampling.

Five high priority watercourses were unable to be visited (Bucklanbah Creek, Salty Springs Creek, Quanda Quanda Creek, Caleriwi Creek and Baronne Creek). Assessment sites are listed in Table 3.3 and shown in Figure 3.2. Water quality sampling was undertaken where sufficient water was present. In situ water quality parameters including temperature, conductivity, salinity pH and dissolved oxygen were measured using a calibrated smarTROLL multiparameter handheld Probe or a YSI Pro Plus multi-parameter water quality meter. Turbidity was also measured in situ using a TB-31 handheld turbidity meter.

Table 3.3 Watercourse monitoring sites

Site Number	Watercourse	Sample type (date sampled)
1	Narrabri Creek	In situ and grab samples (2018)
2	Namoi River	In situ and grab samples (2019)
3a	Bohena Creek	Visual inspection
3b	Bohena Creek	Visual inspection
4	Bundock Creek	Visual inspection
6	Goona Creek	Visual inspection
7	Black Creek	Visual inspection
8	Black Creek tributary	Visual inspection
10	Mollieroi Creek	Visual inspection
11	Coghill Creek	Visual inspection
14	Talluba Creek	In situ and single grab sample (2019)
15	Tinegie Creek	Visual inspection
16	Rocky Creek	Visual inspection
17	Stockyard Creek	Visual inspection
18	Etoo Creek	Visual inspection
19	Cumbil Forest Creek	Visual inspection
20	Coolangla Creek	Visual inspection
21	Baradine Creek	Visual inspection
22	Tenandra Creek	Visual inspection
23	Gulargambone Creek	Visual inspection
24	Castlereagh River	Visual inspection
27	Kickabil Creek	Visual inspection
28	Ewenmar Creek	Visual inspection

Site Number	Watercourse	Sample type (date sampled)
29	Macquarie River	In situ and single grab samples (2018 and 2019)
30	Backwater Cowal	In situ and single grab sample (2018)
31	Emogandry Creek	Visual inspection

Measurements were generally collected at the edge of the watercourse (so as to not disturb streambed) between 15 and 30 centimetres below the surface depending on the depth of water. Sampling depth was recorded in the field. For each parameter measured in situ, three replicate measurements were recorded about 10 metres apart. Each parameter was then recorded as the average (arithmetic mean) of the three measurements. Individual replicates are also reported to provide an understanding of the variation between individual readings.

Single grab samples were collected at five sites over the two sampling occasions at the same location and depth as in situ monitoring. Grab samples were collected in pre-sterilised laboratory supplied bottles, labelled, stored on ice and sent to a NATA accredited laboratory for analysis. The analytical suite for laboratory analysis included:

- total nitrogen (TN) and oxidised nitrogen (NO_x)
- total phosphorus (TP)
- Benzene Toluene Ethylbenzene Xylenes and Naphthalene (BTEXN) and Total Recoverable Hydrocarbons (TRH)
- total metals (arsenic, cadmium, chromium, copper, lead, nickel, zinc and mercury).

Georeferenced photographs were taken at all sites.

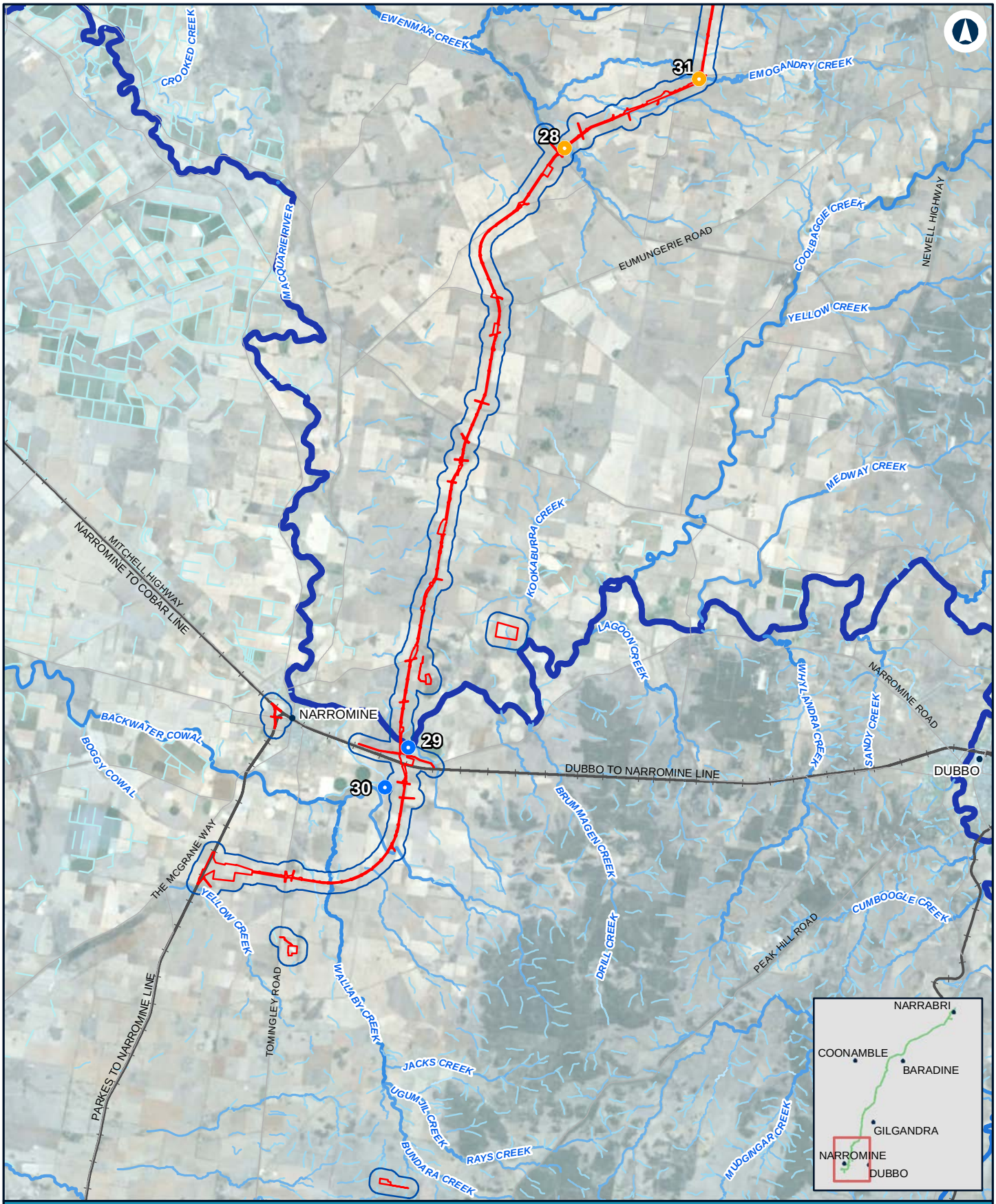
Due to the limited number of samples collected and ad hoc sampling regime, no field QA/QC sampling such as collection of duplicates, trip blanks and field blanks occurred. QA/QC was limited to calibration of field equipment prior to the two sampling events and laboratory QA/QC at the NATA accredited laboratory were samples were submitted for analysis.

3.3 Hydrologic assessment

An assessment of the hydrologic and hydraulic impacts of the proposal are provided in the *ARTC Inland Rail Narromine to Narrabri Flooding and Hydrology Assessment (*JacobsGHD, 2020d). This assessment is relevant to this surface water quality assessment as temporary or permanent changes in flow and velocities have the potential to impact on watercourse form and downstream water quality. Where relevant, information from flooding and hydrology assessment is utilised within this report.

3.4 Groundwater assessment

An assessment of the impacts of the proposal on the quantity and quality of groundwater is provided in the *ARTC Inland Rail Narromine to Narrabri Groundwater Assessment* (JacobsGHD, 2020c). This assessment is relevant if groundwater is encountered during excavation and required to be dewatered to surface water. Where relevant, information from the groundwater assessment is utilised within this report.



NARROMINE TO NARRABRI Waterways and monitoring locations in the study area Figure 3.2a

0 3.5 7 Km

Coordinate System: GDA 1994 MGA Zone 55

Date: 14/05/2020 Paper: A4
Author: JacobsGHD Scale: 1:260,000
Data Sources: Basemap layers: NSWSS; Strahler: DPIE; Proposal, monitoring sites: GHDJACOBS

LEGEND

- The proposal
- Study area
- Watercourse
- Monitoring site (sampling and visual inspection)
- Monitoring site (visual inspection only)

Strahler stream order

0 1 2 3 4 5 6 8 9

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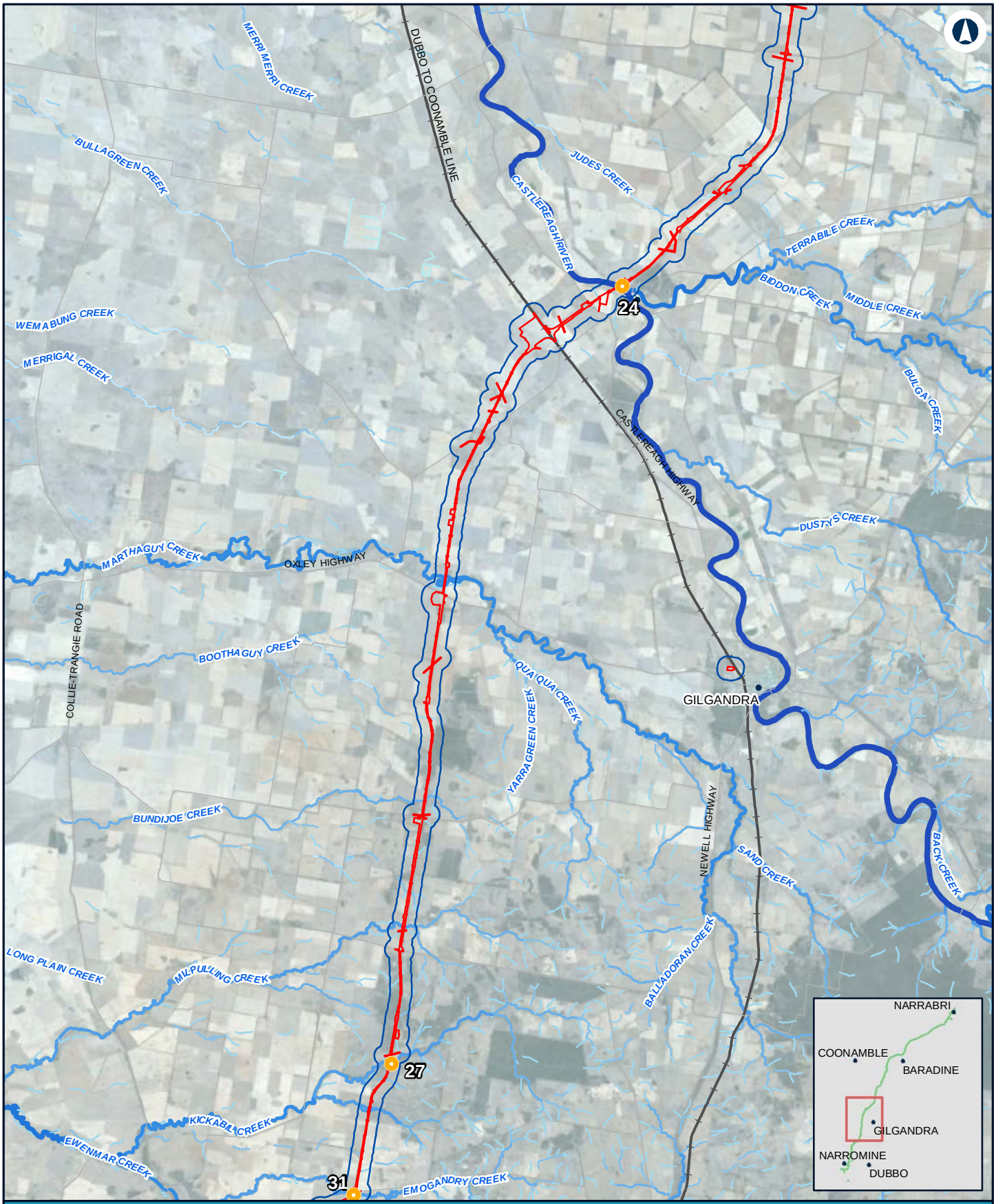

NARROMINE TO NARRABRI Waterways and monitoring locations in the study area Figure 3.2b

0 3.5 7 Km

Coordinate System: GDA 1994 MGA Zone 55

LEGEND

- The proposal
- Study area
- Watercourse
- Monitoring site (visual inspection only)

Strahler stream order

0 1 2 3 4 5 6 8

Date: 14/05/2020 Paper: A4
Author: JacobsGHD Scale: 1:260,000
Data Sources: Basemap layers: NSWSS; Strahler: DPIE; Proposal, monitoring sites: GHDJACOBS

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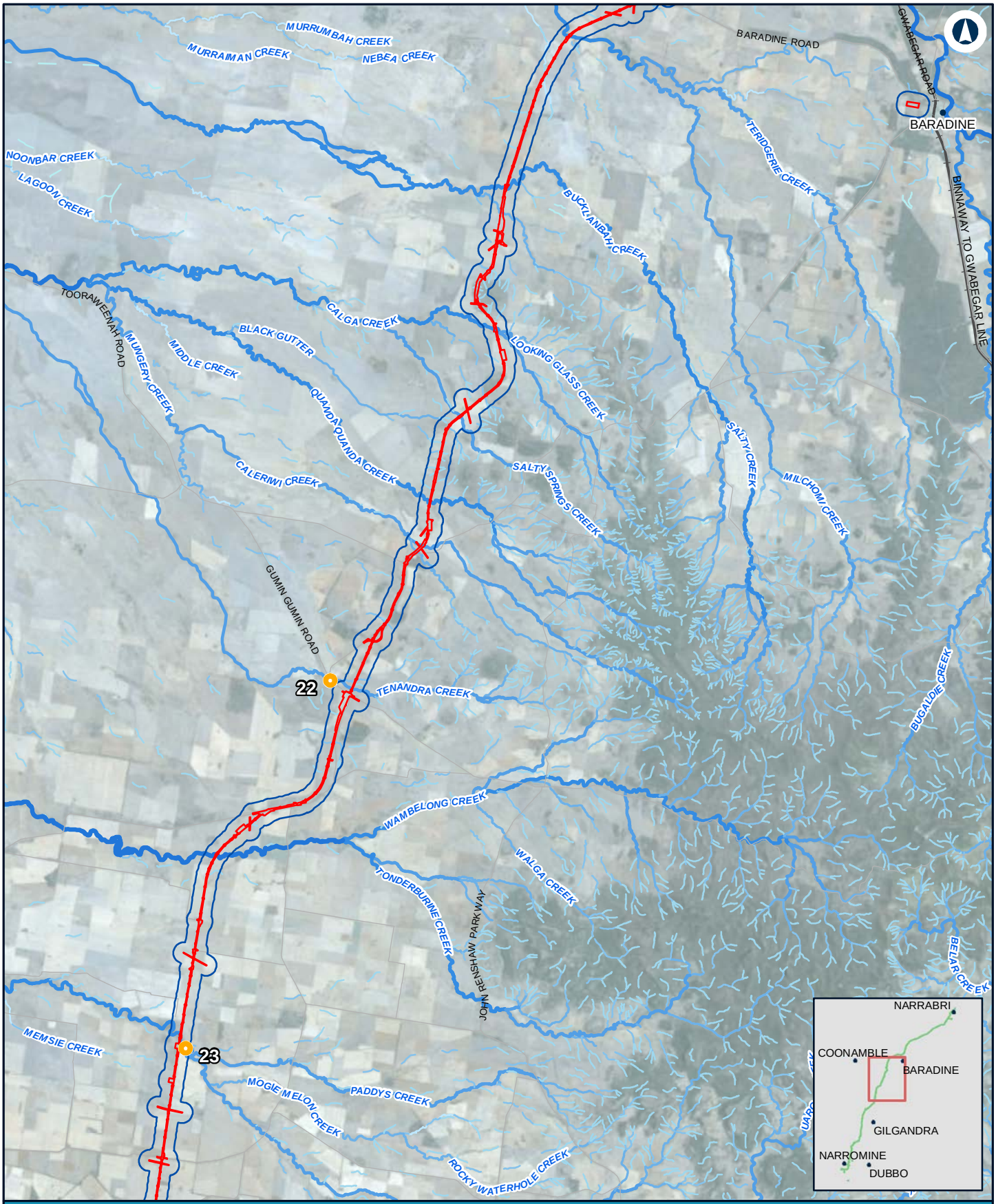

NARROMINE TO NARRABRI Waterways and monitoring locations in the study area Figure 3.2c

0 3.5 7 Km

Coordinate System: GDA 1994 MGA Zone 55

Date: 14/05/2020 Paper: A4
Author: JacobsGHD Scale: 1:260,000
Data Sources: Basemap layers: NSWSS; Strahler: DPIE; Proposal, monitoring sites: GHDJACOBS

LEGEND

- The proposal
- Study area
- Watercourse
- Monitoring site (visual inspection only)

Strahler stream order

0 1 2 3 4 5 6

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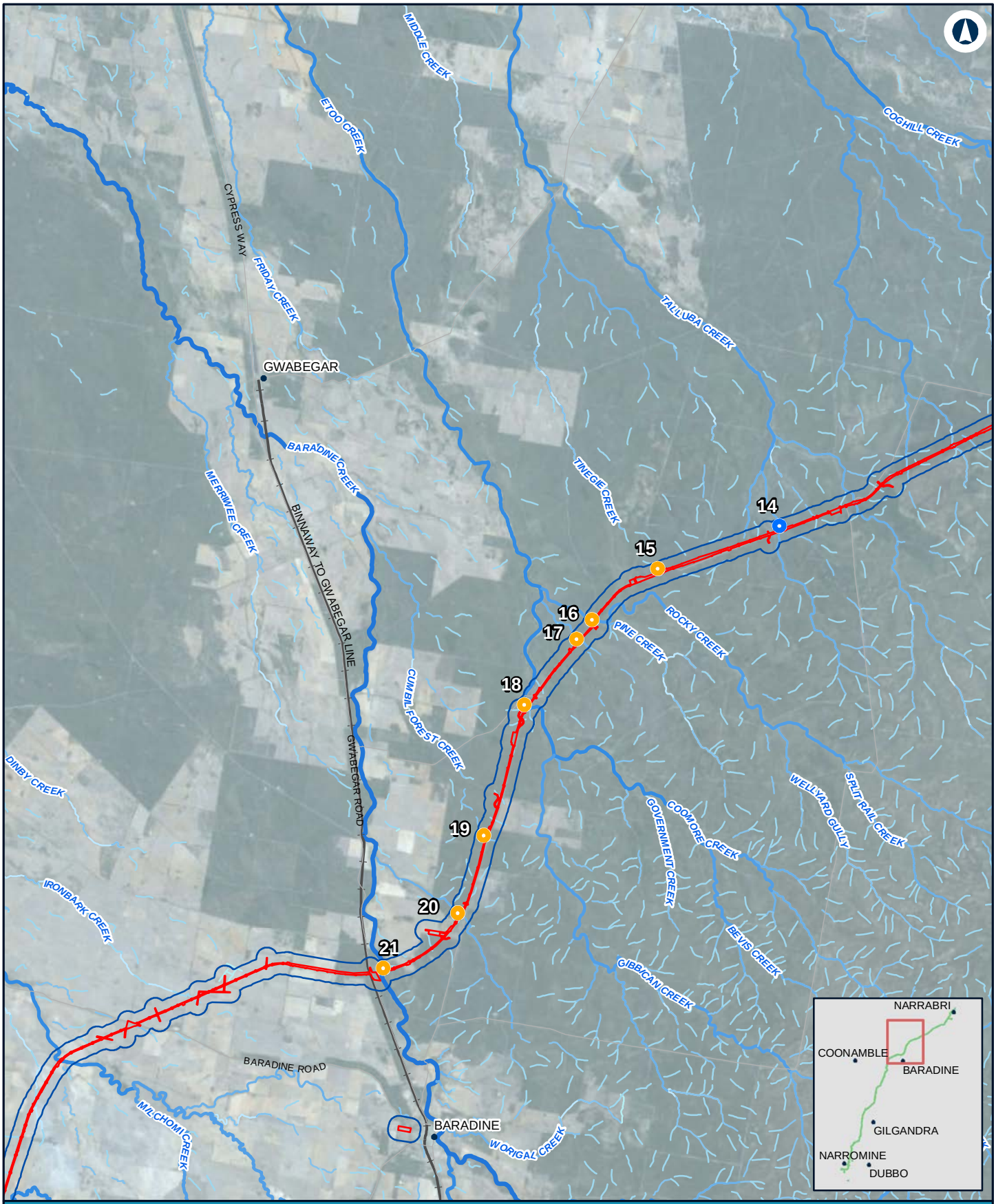

NARROMINE TO NARRABRI Waterways and monitoring locations in the study area Figure 3.2d

0 3.5 7 Km

Coordinate System: GDA 1994 MGA Zone 55

Date: 14/05/2020 Paper: A4
Author: JacobsGHD Scale: 1:260,000
Data Sources: Basemap layers: NSWSS; Strahler: DPIE; Proposal, monitoring sites: GHDJACOBS

LEGEND

- The proposal
- Study area
- Watercourse
- Monitoring site (sampling and visual inspection)
- Monitoring site (visual inspection only)

Strahler stream order

0 1 2 3 4 5 6

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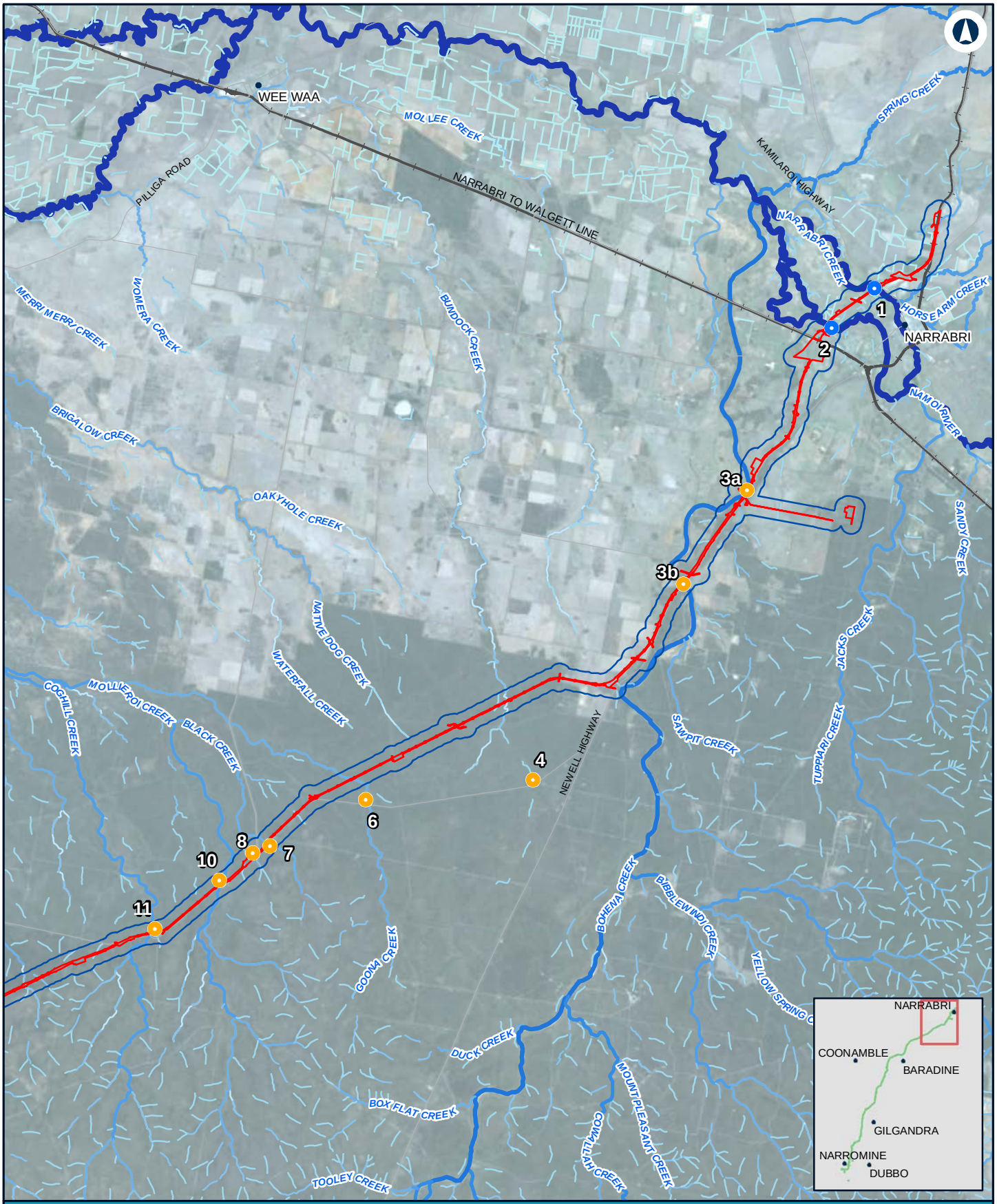

NARROMINE TO NARRABRI Waterways and monitoring locations in the study area Figure 3.2e

0 3.5 7 Km

Coordinate System: GDA 1994 MGA Zone 55

Date: 14/05/2020 Paper: A4
Author: JacobsGHD Scale: 1:260,000
Data Sources: Basemap layers: NSWSS; Strahler: DPIE; Proposal, monitoring sites: GHDJACOBS

LEGEND

- The proposal
- Study area
- Watercourse
- Monitoring site (sampling and visual inspection)
- Monitoring site (visual inspection only)

Strahler stream order: 0, 1, 2, 3, 4, 5, 6, 9

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4. Existing environment

4.1 Local government areas

The proposal area is located within the Narromine, Dubbo Regional, Gilgandra, Coonamble, Warrumbungle and Narrabri local government areas.

4.2 Catchments

The proposal traverses three major river catchments, with each of these being described in the following sub-sections and shown in Figure 4.1.

4.2.1 Namoi River catchment

The upland catchment of the Namoi River is boarded by the Great Dividing Range, approximately 1,500 metres above sea level and receives 640 millimetres of rainfall per annum. The catchment drains an area of 42,000 square kilometres and is heavily regulated, mostly via dams and instream regulatory structures. Major water storage dams within the catchment include Lake Keepit on the Namoi River, which also serves as flood mitigation for the area. Additionally, several weirs are constructed on the Namoi to regulate flows. Smaller dams include Spit Rock Dam on the Manilla River and Chaffey Dam on the Peel River, which was augmented to increase the permanent storage capacity from 62,000 mega litres (ML) to 100,000 ML (MDBA, 2018 and WaterNSW, 2015).

The Namoi River is the major river that traverses the catchment flowing over undulating topography. Downstream of Narrabri the landscape is low lying and generally flat, approximately 100 metres above sea level and receives approximately 400 millimetres rainfall per annum. High yield aquifers are present along the Namoi and Peel Rivers, which are important suppliers to farmland and domestic use. The lower part of the catchment west of Narrabri is less reliant on the river system due to direct access to the Great Artesian Basin. Generally, around 60 per cent of the water supply is extracted from surface waters. However, in dryer years groundwater may account for up to 75 per cent of the water supply (MDBA, 2018).

A diverse range of agricultural practices within the catchment rely heavily on groundwater and surface water supplies from the Namoi River System. Cattle and sheep grazing is the dominant land use, followed by grain crops including cotton farming. The system also supports the Billabong Wetlands downstream of Narrabri and the Pilliga State Forest (MDBA, 2018).

4.2.2 Castlereagh River catchment

The Castlereagh River catchment forms part of the Murray-Darling Basin and spans an area of 17,400 square kilometres. The catchment is located between the Namoi and Macquarie-Bogan catchments and contains predominantly agricultural grazing land as well as state forests including the Warrumbungle National Park and Goonoo State Conservation Area, south-east of Gilgandra (DPI, 2018a).

The streams within the catchment generally originate at high altitudes where rainfall is above 600 millimetres and discharge through topographically low landscapes. The Castlereagh River headwaters are located within the Warrumbungle Ranges and flows east to Coonabarabran and then in a southerly direction until it meets the confluence of the lower Macquarie River (DPI, 2018a).

The Castlereagh is an unregulated river and has no major public water storages but does have a number of small dams and weirs in the catchment. The major townships within the catchment include Coonabarabran, Coonamble and Gilgandra.

4.2.3 Macquarie-Bogan catchment

The Macquarie-Bogan catchment in central-west New South Wales spans an area of approximately 74,800 square kilometres. Variable elevations occur across the catchment ranging from 1,300 metres in the mountains south of Bathurst, to less than 100 metres on the western floodplains. The catchment encompasses the regional centres of Dubbo, Bathurst and Orange as well as the Macquarie and Bogan Rivers, which flow north-west to the Barwon River. Both rivers are regulated by Windermere and Burrendong dams and are major sources of both town and agricultural water and supports the Ramsar listed Macquarie Marshes located in the western reaches of the catchment between Dubbo and Brewarrina.

The Macquarie River discharges from the Great Dividing Range flowing through Bathurst and Dubbo before traversing the lower plains. The River consists of small dams constructed along its tributaries in order to supply town water. However, the Burrendong Dam near Wellington is the main source of water storage within the catchment (MDBA, 2018).

The Bogan River originates in the Harvey Ranges and flows North West through Nyngan before discharging to the Barwon River (MDBA, 2018). Agriculture is the primary land use within the catchment, which is largely dominated by livestock grazing (DPI, 2018b).

4.3 Terrain and land use

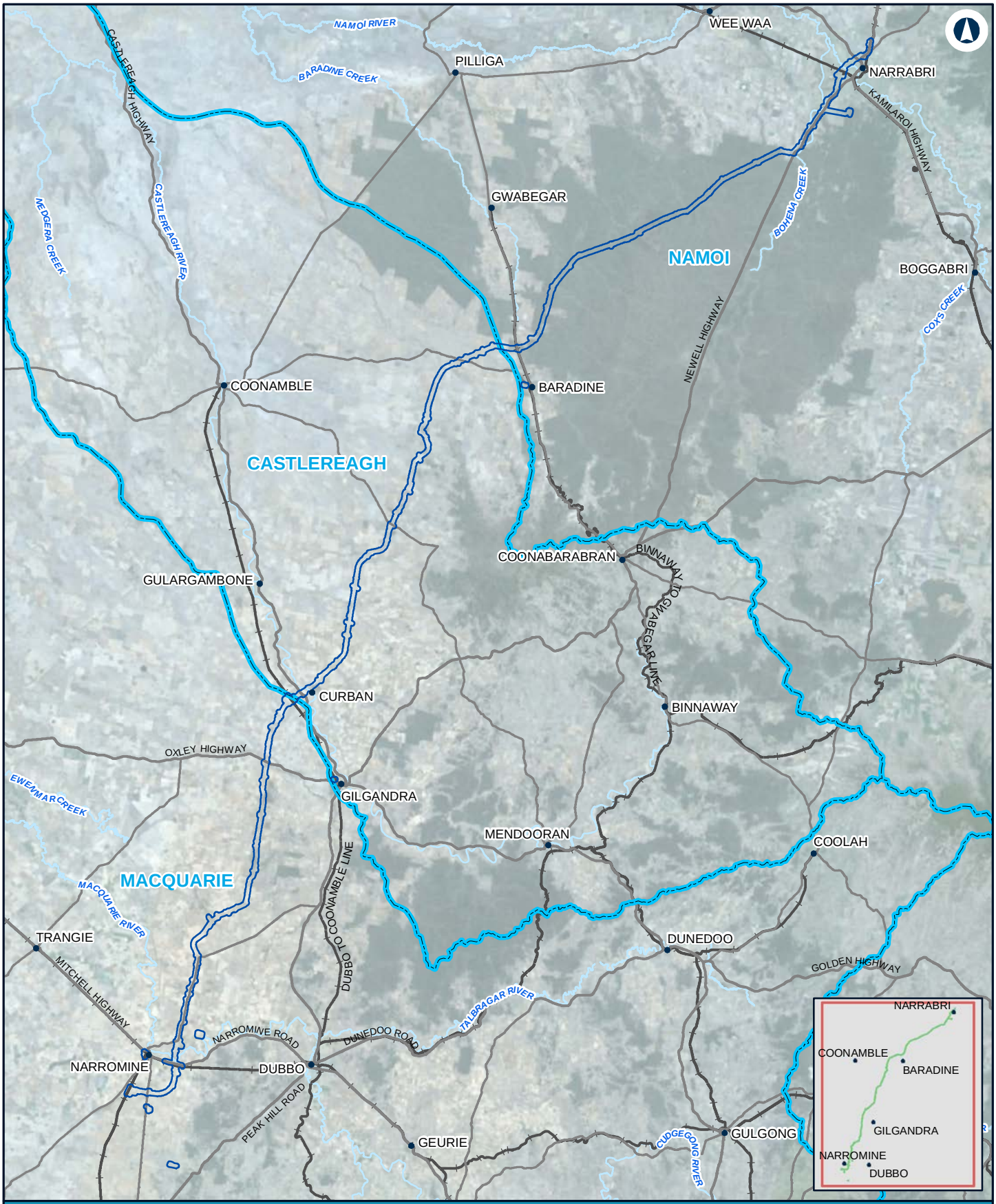
The catchments of the study area are typical of most basin catchments, rising near the Great Dividing Range at altitudes of 1,300 metres where streamflow originates (and rainfall is higher) before running through foothills and slopes where the rivers emerge onto expansive plains. The study area itself is characterised by moderately flat catchments and floodplains. Along the length of the proposal the terrain ranges between 200 metres and 300 metres in elevation. The majority of the construction activities for the proposal would largely occur within greenfield land.

The proposal is located near small urban areas and townships including Narromine and Narrabri at the southern and northern extent of the proposal and Gilgandra and Baradine within.

Major land uses in the Namoi River catchment include dryland and irrigated agricultural production and key industries of cotton, livestock production, grain and hay, poultry, horticulture and forestry (NOW, 2011). Extensive areas of land or conservation and forestry occur to the south of Narrabri within the Pilliga State Forest.

The Castlereagh catchment is predominately flat with the elevation of the study area ranging between 250 metres and 300 metres. Land use within the Castlereagh catchment is dominated by grazing and dryland cropping with very little irrigation occurring. Additionally, there is nearly 760 square kilometres of land conserved within national parks and conservation areas (DPI, 2016).

Land use within the Macquarie-Bogan catchment is predominately agriculture with more than 80 per cent of the catchment being used for grazing. The remaining 19 per cent of the catchment is used for dryland cropping, forestry, conservation, irrigation, residential and a very small proportion for mining.



NARROMINE TO NARRABRI Major water catchments Figure 4.1

0 10 20 Km

Coordinate System: GDA 1994 MGA Zone 55

Date: 16/03/2020 Paper: A4
Author: JacobsGHD Scale: 1:1,100,000
Data Sources: Basemap layers, catchments: NSWSS; Study area: GHDJACOBS

LEGEND

- Study area
- Catchment boundaries
- Road
- Railway
- Rivers/creeks

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4.4 Climate and current drought conditions

Climate in the Namoi region includes warm to hot summers with average maximum temperatures in January ranging between 32°C and 35°C and cool to mild winters with average maximum July temperatures of 16-17°C (CSIRO, 2006). The Namoi catchment receives approximately 500-700 millimetres of rainfall each year with peak precipitation occurring between November and February, however there is high variability in rainfall from one year to the next (CSIRO, 2006).

The Castlereagh and Macquarie-Bogan catchments have a dry semi-arid climate. Average annual rainfall in the catchment ranges from about 1200 millimetres in the south-east to 300 millimetres in the north-west. The average annual rainfall within the proposal area is approximately 500 millimetres per year. Generally, the highest rainfall is recorded over summer, and the driest conditions over autumn (DPI, 2015).

Climate change predictions for the Namoi include a warmer and drier climate. This change in climate would also see increased evaporation and an increase in the number of days the catchment experiences extreme heat and increased winds and fire risk. Despite the drier climate, there is also likely to be increased extreme wet weather events (CSIRO, 2006).

Climate change predictions for the Castlereagh and Macquarie-Bogan catchments is expected to occur and result in a decrease in spring rainfall but an increase in autumn rainfall. Summer rainfall is also expected to decrease. Temperature records show that the average temperatures in this region have been increasing since the 1970s and are expected to continue to increase, the greatest change in the maximum temperatures in spring and summer (DPI, 2015). Changes in predicted precipitation (rainfall) from current are provided in Table 4.1. These changes were calculated for the time periods 2020-2039 and 2060-2079 using the New South Wales and Regional Climate Model (NARCLiM).

Table 4.1 Predicted changes in rainfall (NARCLiM)

Parameter	Projected change (%) to 2020-2039	Projected change (%) to 2060-2079
Annual mean rainfall change	+ 0.5	+ 0.5
Summer rainfall	- 6.76	+ 10.66
Autumn rainfall	+ 22.3	+ 15.65
Winter rainfall	- 7.42	+ 14.1
Spring rainfall	- 0.66	- 6.07

As of 23 February 2020, New South Wales, and particularly inland areas located west of the Great Dividing Range, have been experiencing ‘drought’ to ‘intense drought’ conditions (DPI, 2020). Whilst it is acknowledged that there has been rainfall, the magnitude of rainfall has not alleviated these areas from drought conditions and is unlikely to have resulted in any change to the results of the field investigations.

4.5 Geology and soils

4.5.1 General

The study area is generally located within the Lachlan Fold Belt. Near surface materials include Tertiary to Quaternary alluvium and colluvial deposits over Jurassic sedimentary rock with Cainozoic mafic volcanic outcrops intermittently along the rail corridor.

Deep riverine deposits of black and red clayey silt, sand and gravels are predominantly associated with the near level terrain surrounding Moree, with alluvial deposits of gravel, sand, silts and clays with sandstone outcrops associated with the undulating terrain surrounding Narrabri.

4.5.2 Soil erosion and dispersive soils

Dispersive soils are those which by the nature of their mineralogy, and the chemistry of the water in the soil, are susceptible to separation of the individual clay particles and subsequent erosion of the very small particles. These smaller particles may then transmit through fine fissures or cracks in the soil under seepage flows. Dispersive soils are also susceptible to scouring due to surface run-off which is often exacerbated where flows are concentrated (ie low points such as gullies and culvert locations). In addition, if embankments containing dispersive soils become saturated, cyclic train loading may promote pumping of water within the formation into the overlying ballast, potentially fouling the ballast and affecting its structural integrity. Additionally, published mapping and site observations to date indicate that a significant proportion of the alignment (in the order of 70 per cent) is located within soils that may be dispersive in nature. The presence of these dispersive soils should be acknowledged, and appropriate management and design measures will need to be implemented to manage the soils during construction and operation of the proposal. Further information regarding the potential impacts from dispersive soils is provided in the EIS.

4.5.3 Acid sulfate soils

Acid sulfate soils (ASS) is the common term for naturally occurring sediments and soils containing iron sulphides. The exposure of these soils to oxygen as a result of excavation or drainage, can general sulfuric acid as the iron sulphides oxidise. The sulfuric acid can be readily released into the environment with potential adverse effects. The proposal site is not located within the risk areas for acid sulfate soils, as mapped by ASRIS (2013).

Other potential sources of acid to the environment are from acid sulfate rock and monosulfidic black ooze. Acid sulfate rock is often encountered due to the scale of earthworks or filling earthworks required for construction of proposals (Roads and Traffic Authority, 2005). Monosulfidic Black Ooze (MBO) are gels associated with soils that contain high concentrations of heavy metals. MBOs form when there is a combination of acid sulfate runoff, carbon (from plants) and a low flow environment. MBO has been identified in the Macquarie Marshes wetlands as wells as drains in inland areas (eg Griffith) and inland areas where salinisation occurs (Roads and Traffic Authority, 2005). Due to the location and construction methodology these sources present a low risk to the proposal.

4.6 Watercourses

4.6.1 Major river and basin systems

The proposal is located within the major water catchments of the Macquarie Bogan River Basin, Castlereagh River Basin and the Namoi River Basin.

4.6.2 Watercourses crossed by the proposal

Namoi River catchment

Named watercourses within the Namoi River catchment and traversed by the proposal, heading from south to north, include Baradine Creek, Coolangla Creek, Cumbil Forest Creek, Etoo Creek, Stockyard Creek, Rocky Creek, Tinegie Creek, Coghill Creek, Mollieroi Creek, Black Creek, Goona Creek, Bundock Creek, Bohena Creek, Namoi River and Narrabri Creek. There are also several unnamed tributaries traversed by the proposal.

Castlereagh River catchment

Named watercourses within the Castlereagh River catchment and traversed by the proposal heading from south to north include Castlereagh River, Judes Creek, Gulargambone Creek, Baronne Creek, Tenandra Creek, Mungery Creek, Caleriwi Creek, Quanda Creek, Black Gutter, Salty Springs Creek, Calga Creek, Noonbar Creek, Bucklanbah Creek, Small Creek, Teridgerie Creek and Ironbark Creek. There are also several unnamed tributaries traversed by the proposal.

Macquarie-Bogan River catchment

Named watercourses within the Macquarie-Bogan River catchment and traversed by the proposal, heading from south to north, include Wallaby Creek, Macquarie River, Ewenmar Creek, Goulburn Creek, Emogandry Creek, Native Dog Creek, Pint Pot Gully, Kickabil Creek, Milpulling Creek, Bundijoe Creek and Marthaguy Creek. There are also several unnamed tributaries traversed by the proposal.

The geomorphology of the watercourses traversed by the rail corridor was assessed via desktop to classify the river styles and the geomorphic condition and fragility of the watercourse. This information is provide in detail in the *ARTC Inland Rail Narromine to Narrabri Flooding and Hydrology Assessment* (JacobsGHD, 2020d) and briefly summarised in Table 4.2. The condition of named watercourses was divided into three broad categories:

- Good (natural and intact).
- Moderate (noticeably impacted by human disturbance).
- Poor (degraded).

The stream fragility refers to the sensitivity or susceptibility of a stream to changes or alterations in its geomorphic category when exposed to disturbances such as degradation (Outhet et al, 2004). Streams with higher fragility have a lower threshold to threatening processes and would show more geomorphic and physical change than streams that are less fragile or susceptible.

Table 4.2 Condition and fragility of watercourses traversed by the rail corridor

Chainage (km)	Watercourse	Condition	Fragility
Macquarie catchment			
6.9	Wallaby Creek	Poor	Moderate
16	Macquarie River	Good	Moderate
48.4	Ewenmar Creek	Good	High
52	Goulburn Creek	Poor	Moderate
55.9	Emogandry Creek	Moderate	High
60.2	Native Dog Creek	Poor	High
62	Pint Pot Creek	Poor	Moderate
62.8	Kickabil Creek	Moderate	High
69.7	Milpulling Creek	Poor	Moderate
76.2	Bundijoe Creek	Moderate	High
87.5	Marthaguy Creek	Moderate	High

Chainage (km)	Watercourse	Condition	Fragility
Castlereagh catchment			
105.2	Castlereagh River	Moderate	High
112.1	Judes Creek	Moderate	High
125.9	Gulargambone Creek	Moderate	High
135.5	Baronne Creek	Moderate	Moderate
147.1	Tenandra Creek	Moderate	High
153.5	Mungery Creek	Moderate	High
155.2	Caleriwi Creek	Poor	High
157.8	Quanda Creek	Poor	High
161.65	Black Gutter	Moderate	High
162.4	Salty Springs Creek	Poor	High
167.7	Calga Creek	Moderate	Moderate
175.4	Bucklanbah Creek	Moderate	Moderate
181.3	Small Creek	Moderate	High
183.65	Teridgerie Creek	Moderate	High
Namoi catchment			
200.95	Baradine Creek	Moderate	High
205.9	Coolangla Creek	Moderate	Moderate
209.95	Cumbil Forest Creek	Moderate	Moderate
216.8	Etoo Creek	Moderate	High
222.35	Rocky Creek	Moderate	Moderate
226.7	Tinegie Creek	Good	High
232.8	Talluba Creek	Moderate	Moderate
242.55	Rocky Creek	Moderate	Moderate
249.8	Coghill Creek	Moderate	Moderate
253.65	Mollieroi Creek	Moderate	Moderate
262.3	Goona Creek	Moderate	High
270.9	Bundock Creek	Moderate	High
282.6	Bohena Creek	Moderate	High
297.6	Namoi River	Poor	Moderate
300.75	Narrabri Creek	Poor	Moderate

4.7 Sensitive receiving environments

Sensitive Receiving Environments (SREs) were identified based on considerations outlined in section 3. Prior to undertaking any field assessment, it was determined that all watercourses that were predicted to support State and nationally listed aquatic species (DPI, 2016) were to be considered SREs. All but five of the watercourses predicted to support threatened species were visited in the field to groundtruth the findings of the desktop analysis, confirm the presence of aquatic habitat features and refine the understanding of potential issues. The watercourses that could not be visited, but were pre-determined to be SREs based on desktop analysis, were Bucklanbah Creek, Salty Springs Creek, Quanda Creek, Caleriwi Creek and Baronne Creek. Other watercourses that were not identified as supporting threatened species were visited in the field to determine whether they were SREs, based on the presence of aquatic habitat features.

The determination of SREs based on field assessment is documented in Table 4.3. These watercourses, as well as others that were identified as SREs are mapped on Figure 4.2. Further detail regarding the determination of SREs is outlined in the *ARTC Inland Rail Narromine to Narrabri Aquatic Ecology Assessment (*JacobsGHD 2020a).

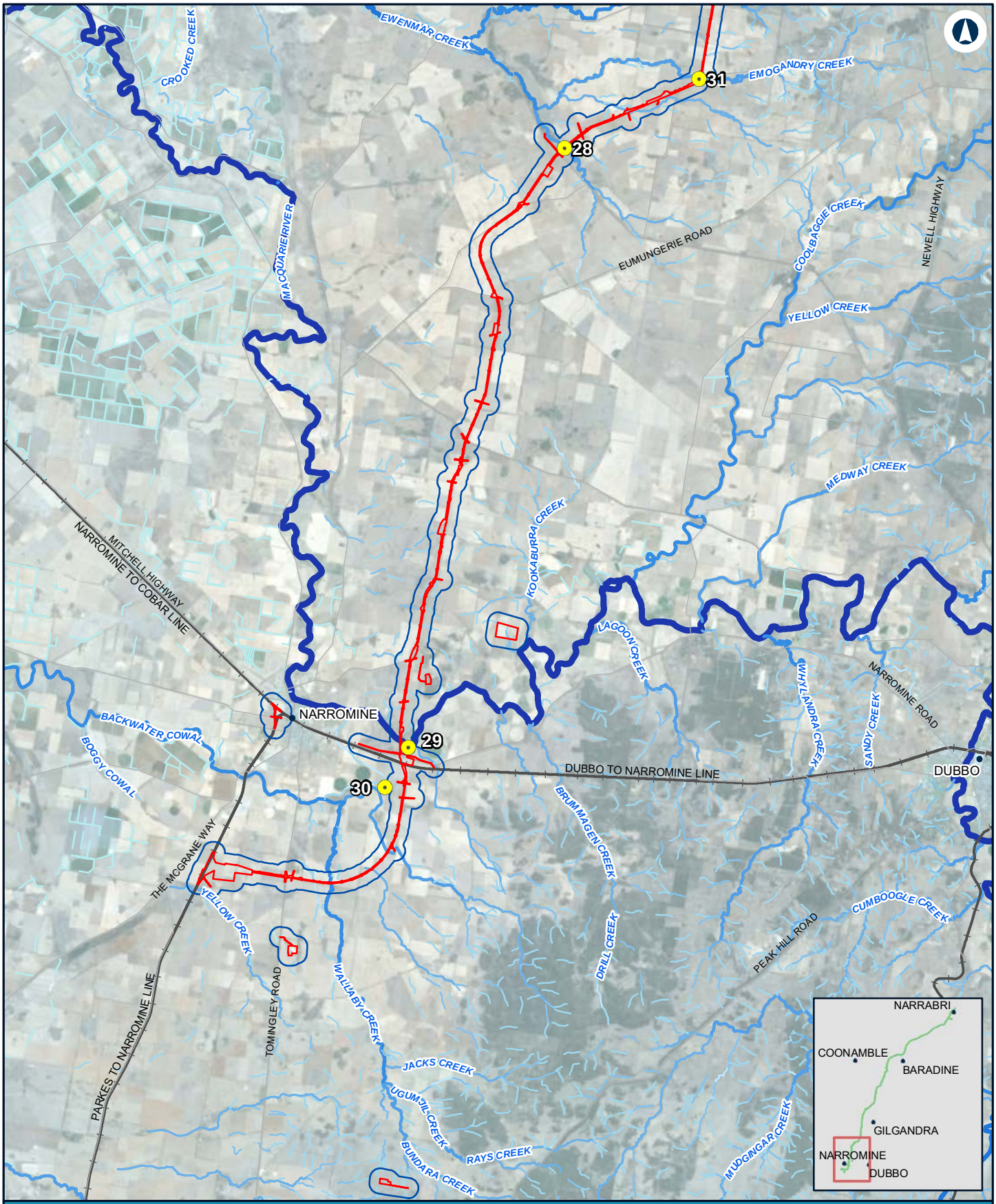
Table 4.3 Sensitive receiving environments

Surface water feature (site number)	Assessment against SRE considerations outlined in section 3.5.3.1	Sensitive receiving environment
Narrabri Creek	9th order major watercourse. Contains several threatened species (DPI, 2016). Classified as 'Type 1 – highly sensitive key fish habitat' (DPI, 2013). With respect of fish passage, classified as 'Class 1 – major key fish habitat' (Fairfull and Witheridge, 2003).	Yes
Namoi River	9th order watercourse. Threatened species likely to occur (DPI, 2016). Classified as 'Type 1 – highly sensitive key fish habitat' (DPI, 2013). With respect of fish passage, classified as 'Class 2 – moderately sensitive key fish habitat' (Fairfull and Witheridge, 2003).	Yes
Bohena Creek	6th order watercourse. Likely to contain threatened fish (DPI, 2016). Classified as 'Type 1 – highly sensitive key fish habitat' (DPI, 2013). With respect of fish passage, classified as 'Class 2 – moderately sensitive key fish habitat' (Fairfull and Witheridge, 2003).	Yes
Bundock Creek	Intermittent second order watercourse. Classified as 'Type 3 – minimally sensitive key fish habitat' (DPI, 2013). With respect of fish passage, classified as 'Class 3 – minimal key fish habitat' (Fairfull and Witheridge, 2003).	No

Surface water feature (site number)	Assessment against SRE considerations outlined in section 3.5.3.1	Sensitive receiving environment
Goona Creek	Intermittent third order watercourse. Threatened species likely to occur (DPI, 2016). Classified as 'Type 1 – highly sensitive key fish habitat' (DPI, 2013). With respect of fish passage, classified as 'Class 2 – moderately sensitive key fish habitat' (Fairfull and Witheridge, 2003).	Yes
Black Creek and tributary of Black Creek	Intermittent third and second order watercourse. Classified as 'Type 3 – minimally sensitive key fish habitat' (DPI, 2013). With respect of fish passage, classified as 'Class 3 – minimal key fish habitat' (Fairfull and Witheridge, 2003).	No
Mollieroi Creek	Intermittent fourth order watercourse. Threatened species likely to occur (DPI, 2016). Classified as 'Type 1 – highly sensitive key fish habitat' (DPI, 2013). With respect of fish passage, classified as 'Class 2 – moderately sensitive key fish habitat' (Fairfull and Witheridge, 2003).	Yes
Coghill Creek	Intermittent fourth order watercourse. Threatened species likely to occur (DPI, 2016). Classified as Type 1 'highly sensitive key fish habitat' (DPI, 2013). With respect of fish passage, classified as 'Class 2 – moderately sensitive key fish habitat' (Fairfull and Witheridge, 2003).	Yes
Talluba Creek	Intermittent third order watercourse. Classified as 'Type 3 – minimally sensitive key fish habitat' (DPI, 2013). With respect of fish passage, classified as 'Class 3 – minimal key fish habitat' (Fairfull and Witheridge, 2003).	No
Tinegie Creek	Intermittent first order watercourse. Classified as Type 3 'minimally sensitive key fish habitat' (DPI, 2013). With respect of fish passage, classified as Class 3 'minimal key fish habitat' (Fairfull and Witheridge, 2003).	No
Rocky Creek	Intermittent fourth order watercourse. Threatened species likely to occur. Classified as 'Type 1 – highly sensitive key fish habitat' (DPI, 2013). With respect of fish passage, classified as 'Class 2 – moderately sensitive key fish habitat' (Fairfull and Witheridge, 2003).	Yes

Surface water feature (site number)	Assessment against SRE considerations outlined in section 3.5.3.1	Sensitive receiving environment
Stockyard Creek	Third order watercourse. Classified as 'Type 1 – highly sensitive key fish habitat' (DPI, 2013). With respect of fish passage, classified as 'Class 2 – moderately sensitive key fish habitat' (Fairfull and Witheridge, 2003).	Yes
Etoo Creek	Intermittent fifth order watercourse. Likely to contain threatened fish (DPI, 2016). Classified as 'Type 1 – highly sensitive key fish habitat' (DPI, 2013). With respect of fish passage, classified as 'Class 2 – moderately sensitive key fish habitat' (Fairfull and Witheridge, 2003).	Yes
Cumbil Forest Creek	Intermittent first order watercourse. Classified as 'Type 3 – minimally sensitive key fish habitat' (DPI, 2013). With respect of fish passage, classified as 'Class 3 – minimal key fish habitat' (Fairfull and Witheridge, 2003).	No
Coolangla Creek	Intermittent third order watercourse. Classified as 'Type 3 – minimally sensitive key fish habitat' (DPI, 2013). With respect of fish passage, classified as 'Class 3 – minimal key fish habitat' (Fairfull and Witheridge, 2003).	No
Baradine Creek	Sixth order watercourse. Threatened fish likely to occur (DPI, 2016). Classified as 'Type 1 – highly sensitive key fish habitat' (DPI, 2013). With respect of fish passage, classified as Class 2 'moderately sensitive key fish habitat' (Fairfull and Witheridge, 2003).	Yes
Tenandra Creek	Ephemeral fourth order watercourse. Classified as Type 3 'minimally sensitive key fish habitat' (DPI, 2013). With respect of fish passage, classified as Class 3 'minimal key fish habitat' (Fairfull and Witheridge, 2003).	No
Gulargambone Creek	Fifth order stream. Threatened fish likely to occur (DPI, 2016). Classified as Type 1 'highly sensitive key fish habitat' (DPI, 2013). With respect of fish passage, classified as Class 2 'moderately sensitive key fish habitat' (Fairfull and Witheridge, 2003).	Yes
Castlereagh River	7th order watercourse. Likely to contain threatened species (DPI, 2016). Classified 'Type 1 – highly sensitive key fish habitat' (DPI, 2013). With respect of fish passage, classified as 'Class 1 – major key fish habitat' (Fairfull and Witheridge, 2003).	Yes

Surface water feature (site number)	Assessment against SRE considerations outlined in section 3.5.3.1	Sensitive receiving environment
Kickabil Creek	Intermittent fourth order watercourse. Classified as 'Type 1 – highly sensitive key fish habitat' (DPI, 2013). With respect of fish passage, classified as 'Class 2 – moderately sensitive key fish habitat' (Fairfull and Witheridge, 2003).	Yes
Ewenmar Creek	Intermittent fourth order watercourse. Classified as 'Type 2 – moderately sensitive key fish habitat' (DPI, 2013). With respect of fish passage, classified as 'Class 2 – moderately sensitive key fish habitat' (Fairfull and Witheridge, 2003).	Yes
Backwater Cowal	Wetland depression on the plain. Threatened fished predicted to occur (DPI, 2016). Classified as 'Type 1 – highly sensitive key fish habitat' (DPI, 2013). With respect of fish passage, classified as 'Class 2 – moderately sensitive key fish habitat' (Fairfull and Witheridge, 2003).	Yes
Emogandry Creek	Intermittent fourth order watercourse. Classified as 'Type 1 – highly sensitive key fish habitat' (DPI, 2013). With respect of fish passage, classified as 'Class 2 – moderately sensitive key fish habitat' (Fairfull and Witheridge, 2003).	Yes
Macquarie River	9th order watercourse. Threatened dish are likely to occur (DPI, 2016). Mapped as 'Type 1 – highly sensitive key fish habitat' (DPI, 2013). With respect of fish passage, classified as 'Class 1 – major key fish habitat' (Fairfull and Witheridge, 2003).	Yes
Macquarie Marshes Ramsar	Macquarie Marshes Ramsar listed wetlands occur approximately 100 km downstream of the study area along the Macquarie river. The site supports permanent populations of threatened fauna including Silver Perch and Murray Cod. (DAWE, 2018). Due to the significant distance from the study area it is unlikely the wetland would be affected by proposal activities.	Yes



NARROMINE TO NARRABRI Site Assessment – Sensitive Receiving Environments Figure 4.2a

0 3.5 7 Km

Coordinate System: GDA 1994 MGA Zone 55

Date: 14/05/2020 Paper: A4
Author: JacobsGHD Scale: 1:260,000
Data Sources: Basemap layers: NSWSS; Strahler: DPIE; Proposal, monitoring sites: GHDJACOBS

LEGEND

- The proposal
- Study area
- Watercourse
- Assessment site (sensitive receiving environment)

Strahler stream order

0 1 2 3 4 5 6 8 9

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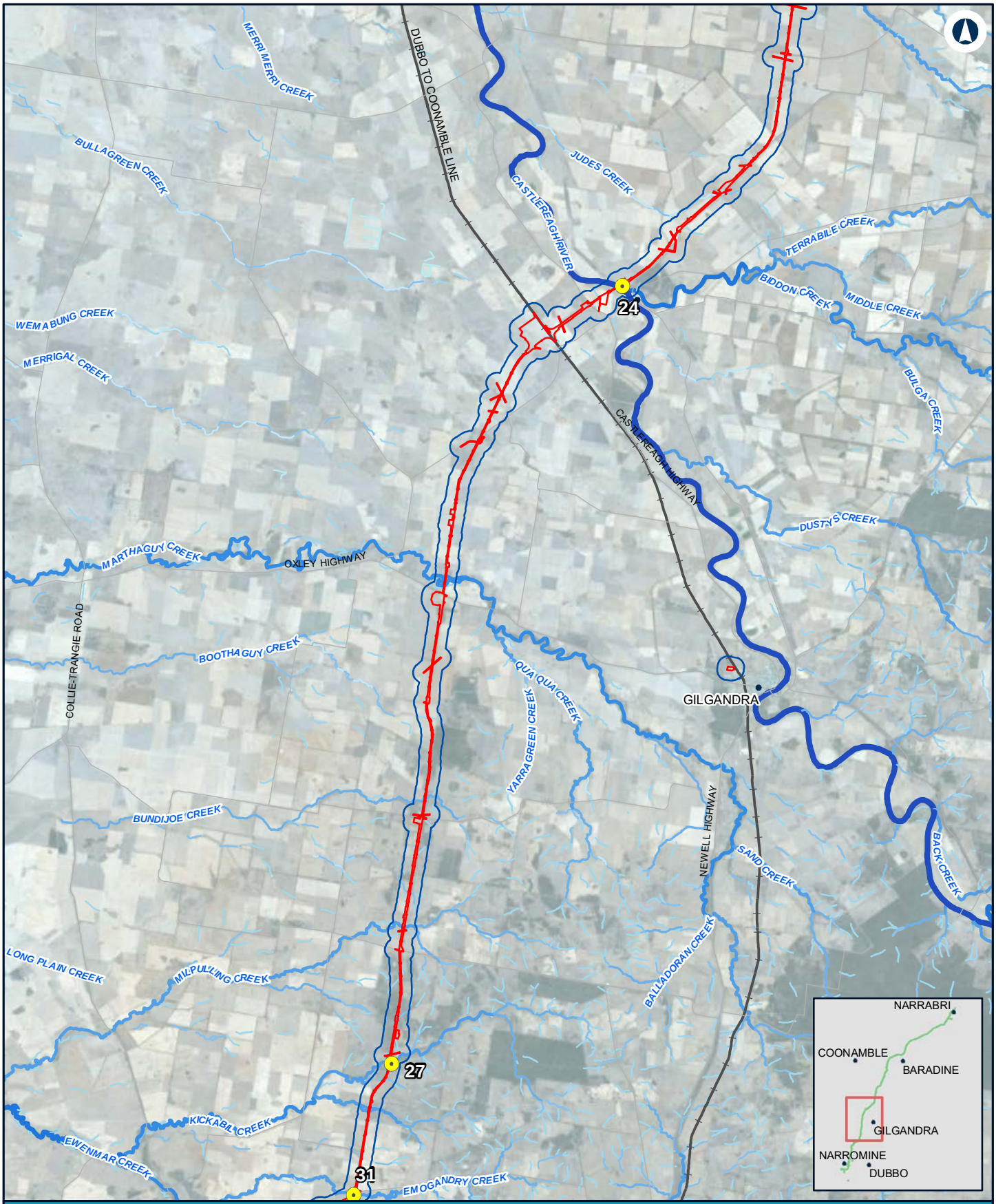

NARROMINE TO NARRABRI Site Assessment – Sensitive Receiving Environments Figure 4.2b

0 3.5 7 Km

Coordinate System: GDA 1994 MGA Zone 55

Date: 14/05/2020 Paper: A4
Author: JacobsGHD Scale: 1:260,000
Data Sources: Basemap layers: NSWSS; Strahler: DPIE; Proposal, monitoring sites: GHDJACOBS

LEGEND

- The proposal
- Study area
- Watercourse
- Assessment site (sensitive receiving environment)

Strahler stream order

0 1 2 3 4 5 6 8

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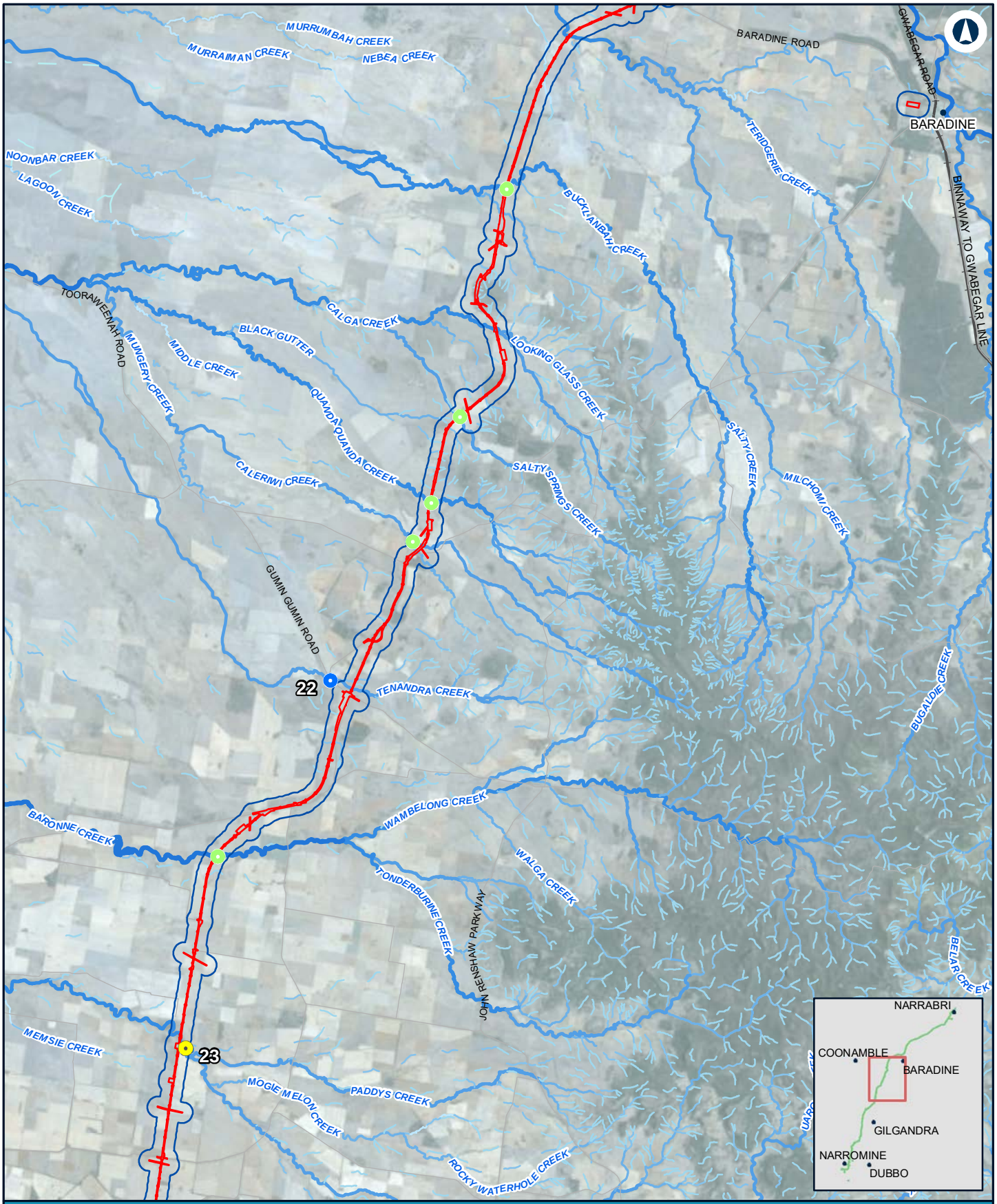

NARROMINE TO NARRABRI Site Assessment – Sensitive Receiving Environments Figure 4.2c

0 3.5 7 Km

Coordinate System: GDA 1994 MGA Zone 55

Date: 14/05/2020 Paper: A4
Author: JacobsGHD Scale: 1:260,000
Data Sources: Basemap layers: NSWSS; Strahler: DPIE; Proposal, monitoring sites: GHDJACOBS

LEGEND

- The proposal
- Study area
- Watercourse
- Assessment site (sensitive receiving environment)
- Assessment site (non-sensitive receiving environment)
- Not visited (sensitive receiving environment)

Strahler stream order

0 1 2 3 4 5 6

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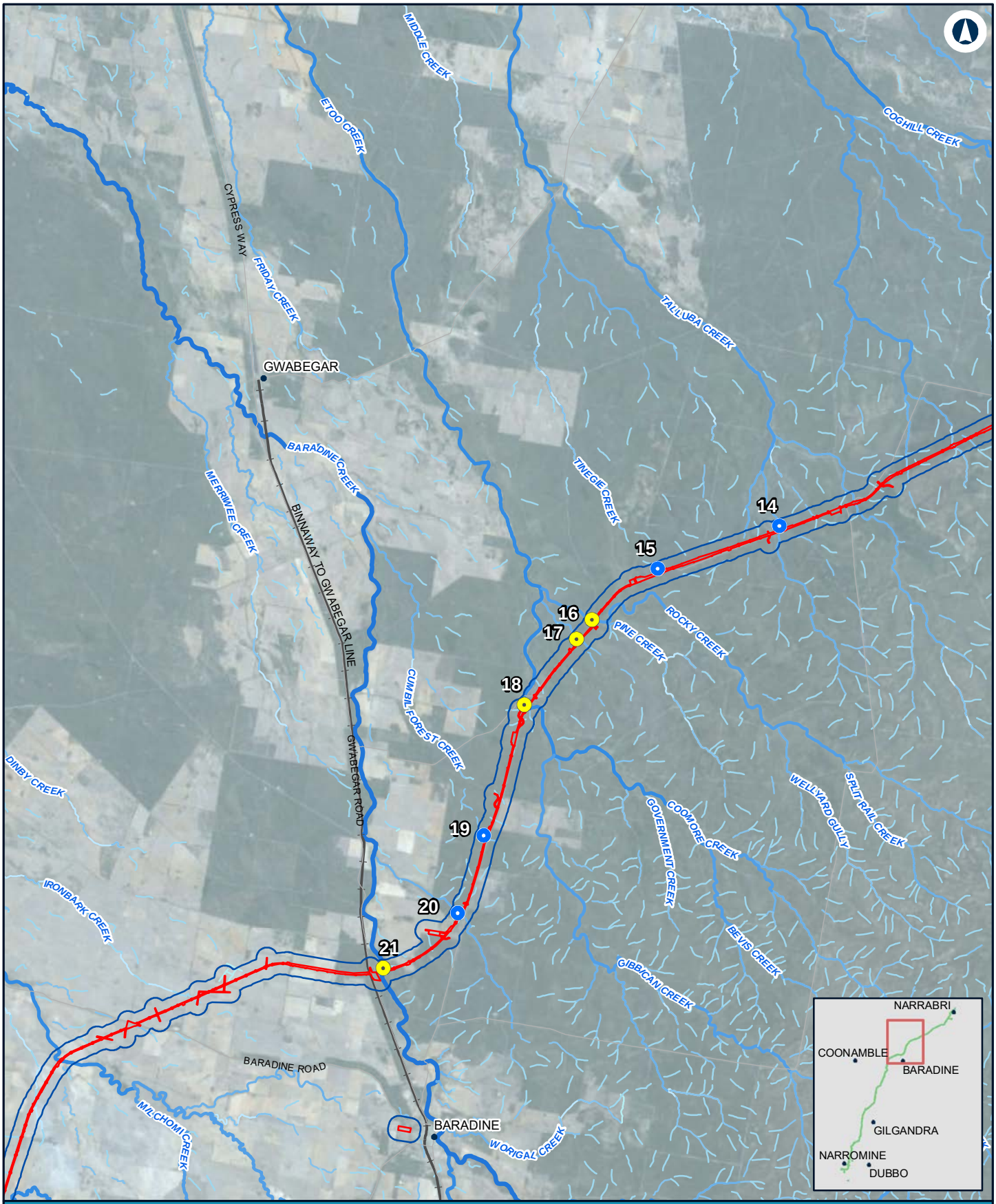

NARROMINE TO NARRABRI Site Assessment – Sensitive Receiving Environments Figure 4.2d

0 3.5 7 Km

Coordinate System: GDA 1994 MGA Zone 55

LEGEND

- The proposal
- Study area
- Watercourse
- Assessment site (sensitive receiving environment)
- Assessment site (non-sensitive receiving environment)

Strahler stream order

0 1 2 3 4 5 6

Date: 14/05/2020 Paper: A4
Author: JacobsGHD Scale: 1:260,000
Data Sources: Basemap layers: NSWSS; Strahler: DPIE; Proposal, monitoring sites: GHDJACOBS

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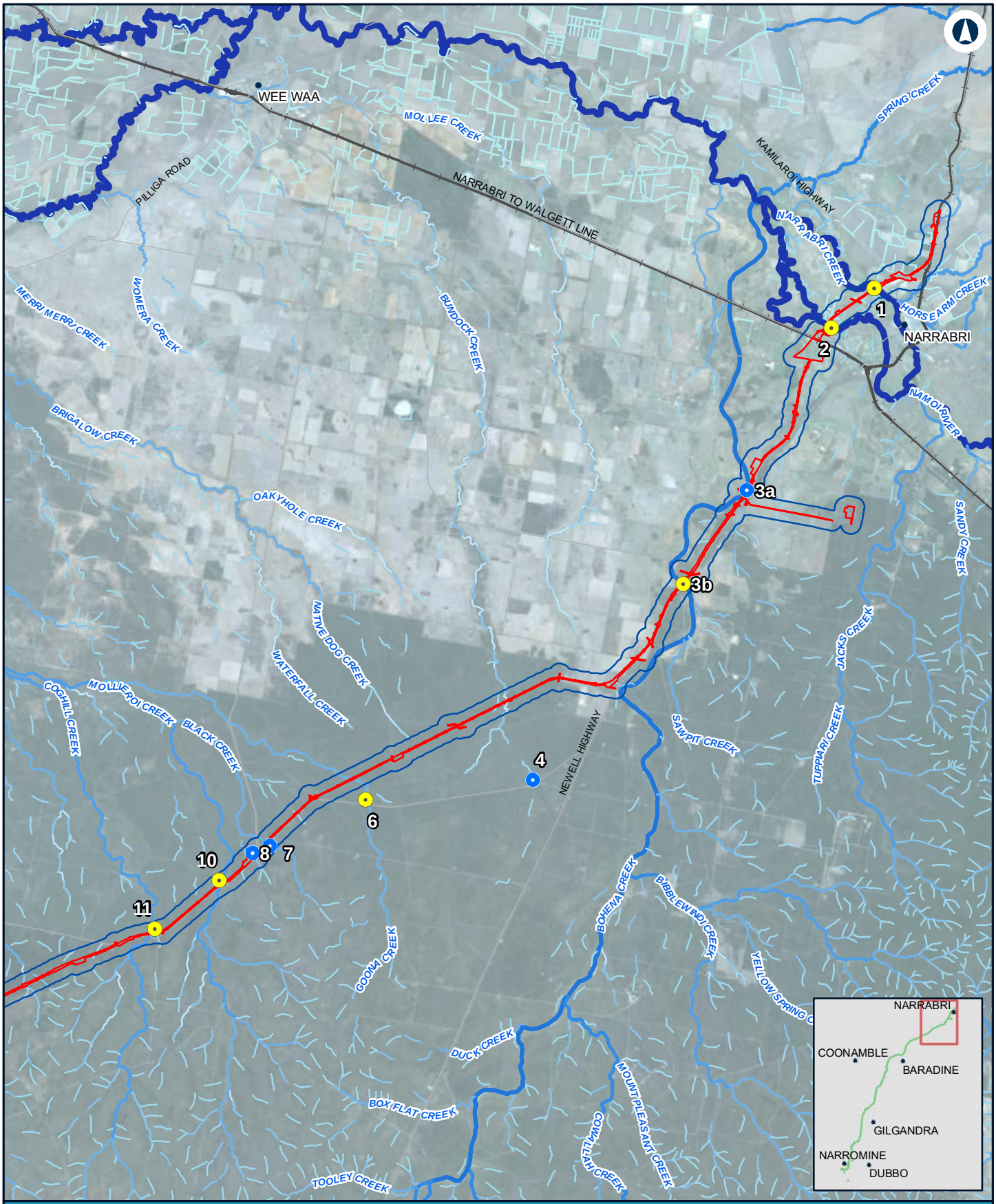

NARROMINE TO NARRABRI Site Assessment – Sensitive Receiving Environments Figure 4.2e

0 3.5 7 Km

Coordinate System: GDA 1994 MGA Zone 55

Date: 14/05/2020 Paper: A4
Author: JacobsGHD Scale: 1:260,000
Data Sources: Basemap layers: NSWSS; Strahler: DPIE; Proposal, monitoring sites: GHDJACOBS

LEGEND

- The proposal
- Study area
- Watercourse
- Assessment site (sensitive receiving environment)
- Assessment site (non-sensitive receiving environment)

Strahler stream order

0 1 2 3 4 5 6 9

INLAND RAIL ARTC

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4.7.1 Groundwater dependent ecosystems

Overview

Groundwater dependent ecosystems (GDEs) are ecological communities that are dependent, either entirely or in part, on the presence of groundwater for their health or survival. The NSW DPI *Water Risk Assessment Guidelines for Groundwater Dependent Ecosystems* (Serov et al., 2012) adopts the definition of a GDE as:

> "Ecosystems which have their species composition and natural ecological processes wholly or partially determined by groundwater".

GDEs might rely on groundwater for the maintenance of some or all of their ecological functions, and that dependence can be variable, ranging from partial and infrequent dependence, ie seasonal or episodic, to total continual dependence.

High priority GDEs

The groundwater Water Sharing Plans (WSPs) covering the proposal site identify areas of high priority GDE vegetation within the groundwater study area. The mapped high priority GDE vegetation areas are crossed by the proposal alignment at the following locations:

- Macquarie River
- Castlereagh River
- Gulargambone Creek
- Baradine Creek
- Etoo Creek
- Rocky Creek
- Goona Creek
- Bohena Creek
- Small unnamed tributary of Bohena Creek, located close (less than 200 metres) to Bohena Creek
- Namoi River
- Narrabri Creek.

In addition, review of the WSPs relevant to the proposal indicates there are 10 mapped high priority GDE springs within the study area. The closest is located about 10 kilometres from the alignment and all of the springs reside in the area covered by the WSP for the NSW Murray-Darling Basin Fractured Rock Groundwater Sources 2020, Lachlan Fold Belt Murray-Darling Basin Groundwater Source. High priority GDE springs within the study area are not discussed further as impacts due to the proposal are highly unlikely because of the large separation distance.

Bureau of Meteorology's GDE Atlas

The Bureau of Meteorology's GDE Atlas (BOM, 2018) was reviewed to investigate the potential for GDEs to exist within the broader region of the proposal. The atlas mapping outlined four main broad areas of mapped potential terrestrial GDEs and 14 potential aquatic GDEs which the proposal dissects. These are discussed in detail in the *ARTC Inland Rail Narromine to Narrabri Biodiversity Development Assessment Report* (JacobsGHD 2020b), and the *ARTC Inland Rail Narromine to Narrabri Aquatic Ecology Assessment* (JacobsGHD, 2020a) respectively.

4.8 Water quality

This following sub-section discusses the existing surface water quality within the three main catchments Namoi River catchment, Castlereagh River catchment and Macquarie River catchment where water quality data was available. Additional water quality monitoring was undertaken at watercourses traversed by the proposal (refer section 4.8.2), however at the time of monitoring many of the creeks were dry and no other water quality data is currently available at these locations. Whilst some rainfall did occur in March, much of this rain fell east of the Great Dividing Range. Given the antecedent drought conditions, any rainfall that may have occurred would have been likely to have a negligible impact on flow and water quality of watercourses and therefore no additional sampling was undertaken.

4.8.1 General

Namoi River catchment

Narrabri Creek at Narrabri is a regulated creek draining a catchment area of 25,120 square kilometres. Historically, the creek has had fluctuating levels of electrical conductivity, with higher conductivities being recorded during periods of low flow or following first flush rainfall events. Continuous monitoring every 15 minutes between 2002 and 2007 recorded median conductivity concentrations of approximately 500 µS/cm (Mawhinney, 2011).

The NSW Environment Protection Authority State of the Environment reporting in 2015 assessed the health of watercourses in the Namoi River catchment as poor. With respect to water quality the Namoi River generally had low conductivity (mean ~463 µs/cm) and elevated nutrients. Between 2009 and 2011, total nitrogen and phosphorus concentrations exceeded the recommended trigger values more than 75 per cent of the time (NOW, 2011).

Most current water quality reporting for the Namoi River at Mollee, and Narrabri Creek at Narrabri revealed nutrient concentrations exceeded the recommended limit 100 per cent of the time. Turbidity levels varied, with Narrabri Creek having slightly better turbidity with less than 25 per cent of the samples exceeding the guidelines compared to almost 50 per cent exceeding the guideline in the Namoi River. Macroinvertebrate condition across the Namoi Region is generally poor (DECCW, 2011). The 2015 *State of the Environment* report (NSW EPA, 2015) also states that water quality is poor due to elevated total nitrogen and phosphorus, however compliance for TN in the Namoi river had improved slightly since the previous reporting period of 2007-2011 inferring lower concentrations have been recorded over recent times.

Castlereagh River catchment

Water quality monitoring information from within the Castlereagh River catchment is limited, with sufficient water quality data only available for one site in the catchment, the Castlereagh River. The Castlereagh River has been monitored at one site consistently and results reported between 2007 and 2012 indicate that only turbidity and pH levels are considered good, with median levels within recommended guidelines. Total nitrogen, total phosphorus and salinity concentrations were all elevated and considered poor to very poor (DSEWPaC, 2011). Median salinity was 821 µs/cm (n=58) and notably higher than the recommended guideline of 30-350µS/cm, Median total nitrogen concentrations were 310 µg/L (n=31) and total phosphorus was 68.5 µg/L (n=56), both notably higher than the guidelines of 250 µg/L for TN and 20 µg/L for TP (DSEWPaC, 2011). Dissolved oxygen levels were lower than the recommended limit of 90 per cent saturation with median levels of 75 per cent saturation.

Macquarie-Bogan catchment

The water quality in the Macquarie-Bogan catchment is generally poor, with elevated total phosphorus and nitrogen resulting in frequent exceedance of guidelines. Salinity concentrations which were often elevated were also considered poor (DSEWPaC, 2011). The Macquarie River has been monitored at numerous locations within the catchment with total nitrogen and total phosphorus were consistently poor between the monitoring locations. Total nitrogen levels were elevated at all sites with concentrations generally two to four times the recommended limit of 250µg/L. Total phosphorus concentrations were also elevated exceeding the recommended guidelines by up to five times. Median electrical conductivity, dissolved oxygen and turbidity were classified as poor to fair between the sites due to low dissolved oxygen levels and elevated conductivity and turbidity. pH levels were consistently within the recommended guidelines along the Macquarie River.

The Bogan River generally exhibited poor water quality due to low dissolved oxygen concentrations (median 75.9 per cent) and elevated total nitrogen (median 845 µg/L) and total phosphorus (median 85 µg/L)/ Turbidity was also elevated and exceeded the limit of 25NTU. pH and conductivity complied with the ANZG (2018) guidelines for upland rivers.

Marthaguy Creek, which flows into the Macquarie River has been monitored between 2008 and 2012 and could be considered to have poor water quality. Dissolved oxygen and pH were the only indicators to comply with the relevant guidelines. Median conductivity of 421 µs/cm exceeded the upper limit of 350µS/cm and total nitrogen and total phosphorus were more than five and 10 times the recommended limit respectively, for protection of aquatic ecosystems. Additionally, unlike other sites in the catchment Marthaguy Creek recorded very high median turbidity (120NTU) which exceeded the guideline limit of 25NTU.

The poor water quality in the Macquarie-Bogan and Castlereagh catchments as described at the abovementioned sites is mostly due to the alteration to natural flow regime and changes in land use (DPI, 2018a).

4.8.2 Existing water quality

Proposal specific site inspections were carried out in November 2018 and March 2019 at watercourses identified as SREs and that were traversed by the proposal. Of the sites visited (refer section 3.2.4), only five had sufficient water for sampling. The results of this sampling are shown in Table 4.4 where bolded values denote results that exceeded the recommended guidelines.

Table 4.4 Water quality results from site visit

Indicator	Narrabri Creek^	Namoi River#	Talluba Creek#	Macquarie River+	Backwater Cowal^ (Dam)	ANZECC/ARMCANZ (2000) and ANZG (2018) WQ guidelines
Dissolved oxygen (% saturation)	**110.97**	**48.1**	**48.10**	105.6	105.6	90-110
Turbidity (NTU)	10.47			6.37	**461**	2-25
Electrical conductivity (µS/cm)	**398**	**1670**	109	148.07	**546**	30-350
pH	**8.31**	**8.41**	**6.42**	7.43	7.36	6.5-8

Indicator	Narrabri Creek^	Namoi River#	Talluba Creek#	Macquarie River+	Backwater Cowal^ (Dam)	ANZECC/ARMCANZ (2000) and ANZG (2018) WQ guidelines
Oxidised nitrogen (mg/L)	**0.23**	<0.05	**1.25**	<0.05	**2.5**	0.015
Total nitrogen (mg/L)	**0.9**	**5.8**	**1.7**	**0.3**	**5.6**	0.25
Total phosphorus (mg/L)	**0.14**	**0.24**	0.02	**0.055**	**0.75**	0.020
Arsenic (mg/L)	0.001	0.016	<0.0001	0.0015	0.006	0.024
Cadmium (mg/L)	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	0.0002
Chromium (mg/L)	**0.002**	<0.001	0.001	0.0008	0.001	0.001
Copper (mg/L)	**0.002**	**0.002**	**0.003**	**0.002**	**0.007**	0.0014
Lead (mg/L)	<0.001	<0.001	<0.001	<0.0001	**0.009**	0.0034
Mercury (mg/L)	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.00006
Nickel (mg/L)	0.008	0.006	0.003	0.0018	0.0012	0.011
Zinc (mg/L)	0.0007	<0.005	**0.011**	**0.0098**	0.007	0.008

^ sampled in 2018; # sampled in 2019; + sampled in 2018 and 2019

Narrabri Creek

Narrabri Creek was sampled in November 2018 and whilst at the time of sampling the creek appeared to be in better condition than most watercourses in the study area, particularly as it was flowing (although low) (refer Figure 4.3). Narrabri Creek at the time of sampling could be considered to have poor water quality and did not meet the recommended guidelines for protection of aquatic ecosystem for many of the parameters measured (refer Table 4.4). Dissolved oxygen, pH and electrical conductivity marginally exceeded the upper limits recommended by ANZG (2018) and nutrient concentrations were elevated exceeding the recommended guidelines for NO_x, TN and TP. The greatest exceedance for NOx, which was 15 times the limit. Concentrations of trace metals were low with the exception of chromium and copper which exceeded the recommend trigger value for 95 per cent species protection. Hydrocarbons and BTEXN were not detected.

Figure 4.3 Narrabri Creek (upstream and downstream)

Namoi River

The Namoi River was generally dry except for a stagnant pool of water when it was visited in March 2019 (refer Figure 4.4). This pool of water was sampled to infer the water quality of Namoi River for this assessment. The water quality of the pool was generally poor and reflective of the prevailing conditions (Table 4.4). Electrical conductivity concentrations were very high (four times the guideline) which is expected when there are no surface flows and pooled water is likely made up of groundwater which typically has much higher salinity than surface water. Dissolved oxygen levels were also low and likely attributable to the stagnant conditions and groundwater which naturally has low dissolved oxygen. Concentrations of both total nitrogen and total phosphorus were excessive and more than 24 and 12 times recommended guideline limits respectively. Trace metals were generally not detected or low with the exception of copper.

Figure 4.4 Namoi River

Talluba Creek

Talluba Creek is a tributary of Turragulla Creek which flows into the Namoi River. Talluba Creek was visited in March 2019 and at the time had no flow but a small pool of turbid water (refer Figure 4.5). The water quality of this pool was sampled which was generally poor. It exhibited low dissolved oxygen and elevated concentrations of nitrogen (oxidised and total) copper and zinc. The pH of the pool was marginally below the lower limit of 6.5. All other indicators complied with the relevant guideline limits for protection of aquatic ecosystems.

Figure 4.5 Talluba Creek

Macquarie River

The Macquarie River was sampled at the alignment during both the November 2018 and March 2019 site visits and exhibited low flow with sections of the river covered in macrophytes (Figure 4.6). The water quality of the Macquarie River was much better than other watercourses sampled in the proposal site, likely due to the better condition of the river and flowing water. Most indicators complied with the recommended limits for protection of aquatic ecosystems. Whilst both total nitrogen and phosphorus exceeded the recommended limits, they were recorded in noticeably lower concentrations than other sites. Copper and zinc were the only trace metals to be detected above the recommended guideline limits for 95 per cent species protection.

Figure 4.6 Macquarie River

Backwater Cowal (dam)

Backwater Cowal is a long watercourse that traverses the floodplain and significant wetland in the wet season. At the time of sampling in November 2018 water quality was sampled within a residual pool/dam that was highly turbid and murky (refer Figure 4.7). The dam had very high turbidity and electrical conductivity concentrations and very high nutrient concentrations. Total nitrogen and total phosphorus concentrations at the time were 22 and 37 times greater than the recommended guideline limits and oxidised nitrogen concentrations of 2.5mg/L were recorded which are 166 times the recommended limit. These excessive nutrient concentrations are likely attributable to the antecedent dry warm weather conditions and surrounding agricultural land use. With the exception of copper, trace metals were not detected or below the recommended guideline limits with the exception of lead.

Figure 4.7 Backwater Cowal (dam)

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5. Construction impact assessment

Disturbance of the land surface would be required for the construction of the proposal. Construction would involve a range of activities that can be categorised into three main components:

- rail infrastructure
- road infrastructure
- key construction infrastructure.

These construction activities present a potential risk to downstream water quality if management measures are not implemented, monitored or maintained throughout the construction phase.

5.1 Rail infrastructure

The key construction work associated with the rail infrastructure include:

- Main line track – construction of 306 kilometres of new single track gauge railway that would consist of track formation earthworks, railway ballast, concrete sleepers and track.
- Crossing loops – seven crossing loops of up to 2.2 kilometres in length would be constructed parallel to the new rail corridor. Each crossing loop would contain a maintenance siding with back up power supply.
- Bridges and culverts – where the proposal is required to cross existing roads, existing rail line and watercourses.
- Narromine West connection – a new junction that provides connectivity between the Parkes to Narromine Line and Parkes to Cobar Line.
- Connections with other rail lines - the proposal connects with existing rail lines that are part of the ARTC and Country Regional Network rail networks. These include connections with Parkes to Narromine Line, Dubbo to Coonamble Line, Narrabri to Walgett Line and Narrabri to North Star.
- Level crossings – required where the proposal interacts with existing roads, in order to cross the rail line.
- Turnouts – turnouts would be located at all connections with existing rail lines and at the end of each crossing loop.
- Embankments and cuttings – the new railway is being constructed in a predominately greenfield environment and therefore a number of cuttings and embankments would be required.
- Temporary ancillary infrastructure to support construction – including temporary construction sedimentation basins and haul roads during construction that are all located within the rail corridor.

The potential impacts to water quality associated with the construction of rail infrastructure are presented in Table 5.1 while further information regarding the likelihood of these impacts being realised is provided in section 6.1.

Table 5.1 Potential construction impacts on surface water quality

Construction activity / source of pollutants	Construction works	Potential surface water quality impacts	Receiving watercourses
Main line rail track Crossing loops and turnouts Level Crossings Connections with other rail lines Ancillary Infrastructure	• Earthworks and stockpiling • Transport of material • Vegetation clearing and mulching • Disturbance of contaminated land • Placing and compacting formation material and installing tracks • Tamping, grinding and ballast profiling • Relocation of utilities • Concreting • Establishment of water quality controls (sedimentation basins) • Vehicle movements to and from sites • Modifications to surface roads (within the rail corridor)	Potential impacts to water quality from construction works are caused from the mobilisation of sediments and pollutants into downstream receiving environments via wind or stormwater runoff. Potential causes of impacts may include: • Transportation of dust, litter and other pollutants associated with demolition construction can enter downstream waterways due to (via wind and stormwater runoff). • Erosion and transportation of exposed sediment associated with earthworks, including vehicle movements across exposed earth, stockpiling and cut and fill earthworks. • Soil and bank erosion and mobilisation of sediments from vegetation clearing. Tannin leachate from vegetation clearing and mulching can enter downstream watercourses. • Transportation of pollutants from accidental spillages or leaks of fuels and/or oils from the maintenance or refuelling of construction plant equipment. • Transportation of cement dust, concrete slurries or washout water. • Disturbance of contaminated land could result in exposure of hydrocarbons, metals and pesticides and transportation of contaminated sediments.	All watercourses within the study are have the potential to be impacted. At greatest risk are those identified as SREs including: • Macquarie River • Emogandry Creek • Backwater Cowal • Ewenmar Creek • Kickabil Creek • Castlereagh River • Gulargambone Creek • Marthaguy Creek • Baradine Creek • Etoo Creek • Stockyard Creek • Rocky Creek • Coghill Creek • Mollieroi Creek • Goona Creek • Bohena Creek • Namoi River • Narrabri Creek.

Construction activity / source of pollutants	Construction works	Potential surface water quality impacts	Receiving watercourses
		As a result of the above, the following impacts to water quality may occur: • Increased sediments resulting in increased nutrients in watercourses, which can lead to algal blooms. This reduces the environmental value of water by limiting its potential uses. • Sedimentation can result in increased turbidity of watercourses. Elevated turbidity could lead to fish kills due to clogging of fish gills. Increased turbidity can also reduce light penetration, which can limit the growth of aquatic vegetation. • Tannins can cause dark coloured water being discharged into downstream watercourses from construction. This can alter the instream pH and reduce visibility and light penetration. Tannins can also increase biochemical oxygen demand (BOD) which can decrease instream dissolved oxygen concentrations, which can impact on aquatic ecosystems and lead to fish kills. • Pollution from accidental spillages or leaks of fuels and/or oils from the maintenance or refuelling of construction plant equipment and accidental litter dispersion. • Decreased biodiversity, loss of habitat and fish kills from increased concentrations of toxicants. • Concrete dust, concrete slurries or washout water discharged to downstream watercourses can result in increased alkalinity and pH of downstream watercourses. This could increase the acidity of the water and mobilise heavy metals, which could result in fish kills.	

Construction activity / source of pollutants	Construction works	Potential surface water quality impacts	Receiving watercourses
Embankments and cuttings Embankments and cuttings are required in varying degrees along the majority of the proposal area.	• Excavation • Earthworks, cuttings and stockpiling • Transport of materials	Potential impacts to water quality from the construction of embankments and cuttings are caused from the mobilisation of sediments and pollutants into downstream receiving environments via wind or stormwater runoff. Potential causes of impacts may include: • Excavation activities associated with cut and fill which can result in sediment runoff and excess spoil storage, from dust generated from stockpiles or inappropriate storage, handling and disposal of spoil and from exposure of contaminants from previous landuses transported to downstream watercourses. • Increased movement of sediment from embankment slopes and velocity over the embankment. • Sedimentation can result when rain or runoff comes into contact with exposed areas and stockpiles. Sediment becomes suspended and transported downstream which can directly and indirectly impact watercourses. As a result of the above, the following impacts to water quality may occur: • Increased turbidity, lower dissolved oxygen and increased concentrations of nutrients, metal and other contaminants from increased sediment which can lead to algal blooms, aquatic weed growth, fish kills and reduced visual amenity. • Direct impacts of sedimentation include reducing light penetration (limiting the growth of macrophytes), clogging fish gills, algal blooms, altered stream geomorphology, smothering of benthic organisms and reduced visibility for fish. • Indirect impacts of sedimentation occur over the longer term and include accumulation of sediments instream and release of pollutants such as heavy metals and nutrients.	All watercourses within the study are have the potential to be impacted. At greatest risk are those identified as SREs including: • Macquarie River • Emogandry Creek • Backwater Cowal • Ewenmar Creek • Kickabil Creek • Castlereagh River • Gulargambone Creek • Baradine Creek • Etoo Creek • Stockyard Creek • Rocky Creek • Coghill Creek • Mollieroi Creek • Goona Creek • Bohena Creek • Namoi River • Narrabri Creek.

Construction activity / source of pollutants	Construction works	Potential surface water quality impacts	Receiving watercourses
Bridges and culverts Bridges and culverts that cross existing roads, rail lines and watercourses	• Instream works • Clearing of bed and banks • Instream bed levelling • Temporary diversion of water if present at time of construction • Vegetation clearing • Construction of watercourse crossings and installation of drainage structures and culverts • Concrete works • Construction of bridges (includes piling and use of a barge at the Macquarie River)	Potential impacts to water quality from the construction of watercourse crossings may include: • Leakage /spills of hydrocarbons or other chemicals from machinery with pollutants conveyed by stormwater runoff into watercourses or from vehicles transferring soil. • The construction of bridges can result in high volumes of sediments entering and polluting water from disturbance and erosion of creek and river bed and banks. Pollutants can also enter watercourses from construction machinery and concreting. • Concreting can result in concrete dust, slurries or washout water being discharged to downstream watercourses particularly where concrete works are at bridge crossings or close in proximity to watercourses. As a result of the above, the following impacts to water quality may occur: • Sedimentation can result in increased turbidity levels, reduced visual amenity and smothering of aquatic ecosystems. Instream structures can lead to scour and deposition of sediments due to changes in flow rates and paths. • Concreting and its by-products can result in increased alkalinity and pH which can be harmful to aquatic life. Water from concrete curing can be high in chromium and can accumulate in the gills of fish affecting the health of aquatic organisms.	Numerous watercourses would be crossed by bridges. All other watercourses would be crossed by culverts. Watercourses at greatest risk would be those that would have barge access and piling including: • Macquarie River • Castlereagh River • Narrabri Creek • Namoi River. • and any watercourses identified as SREs including: – Emogandry Creek – Backwater Cowal – Ewenmar Creek – Kickabil Creek – Gulargambone Creek – Baradine Creek – Etoo Creek – Stockyard Creek – Rocky Creek – Coghill Creek – Mollieroi Creek – Goona Creek – Bohena Creek.

Construction activity / source of pollutants	Construction works	Potential surface water quality impacts	Receiving watercourses
Dewatering	• Dewatering and infilling for farm dams • Discharges from sedimentation basins to downstream watercourses	Potential impacts to water quality from dewatering may result from: • Increased sediment, and nutrients and mobilisation of contaminants to downstream watercourses from dewatering. As a result of the above, the following impacts to water quality may occur: • Increased suspended sediments resulting in high turbidity and poor water clarity impacting on visual amenity. • Elevated nutrients and sediments can reduce dissolved oxygen resulting in proliferation of weeds and fish kills. • Dewatering activities during construction may mobilise sediments and contaminants and increase the turbidity of the receiving environments along the proposal, potentially having an impact on water quality.	All watercourses have the potential to be impacted.

5.2 Road infrastructure

The key construction work associated with the road infrastructure include:

- road realignments– changes to the existing road networks and new roads to be constructed would be required, including the realignment of the Pilliga Forest Way
- limited road closures.

The potential impacts to water quality associated with the construction of road infrastructure are presented in Figure 7.1 while further information regarding the likelihood of these impacts being realised is provided in section 6.2.

5.3 Key construction infrastructure

Key construction infrastructure is required throughout the construction period of the proposal. The potential impacts to surface water quality can occur from both the establishment of the infrastructure and the usage of the infrastructure. Key construction infrastructure for the proposal would include:

- Borrow pits – four borrow pits are required to provide general and structural fill for the proposal.
- Access tracks – constructed outside of the rail construction corridor and utilised throughout construction to facilitate movement of borrow material.
- Workforce accommodation – temporary workforce accommodation for up to 500 people would provide accommodation to the construction workforce. At the Narromine North and ‘Baradine temporary workforce accommodation facilities wastewater would be treated and potentially irrigated onsite, through the provision of wastewater treatment plants (WWTP). These WWTPs are expected to have membrane biological reactor technology, which produces high quality reclaimed water suitable for various beneficial reuses including recycling and irrigation. At the three remaining camps wastewater is proposed to be disposed of through connections to the towns’ existing wastewater network.
- Multi-function compounds – three multi-function compounds are proposed at Narromine South, Curban and Narrabri West to support a range of construction activities, including facilities such as office and amenities, laydown areas, material storage, topsoil storage, fuel and hazardous storage areas, maintenance areas, temporary workforce accommodation, welding yard, concrete precast yard and groundwater extraction bores.
- Compounds – numerous smaller compounds are required within the construction footprint to support construction.
- Concrete batch plants – fixed or mobile concrete batching plants would be established at the Curban multi-function compound, structure compounds at the Macquarie River, Castlereagh River and Narrabri Creek/Namoi River and general compound sites to supply concrete during construction.

The potential impacts to water quality associated with the key construction are presented in Table 5.3 and further detail regarding the likelihood of these impacts to be realised is provided in section 5.4.

Table 5.2 Potential construction impacts on surface water quality (road infrastructure)

Construction activity/source of pollutants	Construction works	Potential surface water quality impacts	Receiving watercourses
Road realignments and road closures Road realignments would be required at level crossings and may include raising of the road to the new level crossing height or diversion of the road on new alignment The realignment of Pilliga Forest Way for approximately 7 kilometre is also required.	• Earthworks including, cutting, excavation, ground levelling, stockpiling and vehicle movements across exposed earth • Vegetation removal and topsoil stripping • Relocation of utilities • Concrete works • Vehicle movements to and from site • Activities associated with construction for permanent works (eg landscaping, road marking etc)	Potential impacts to water quality from construction works associated with road realignments and road closures are caused from the mobilisation of sediments and pollutants into downstream receiving environments via wind or stormwater runoff. Potential causes of impacts may include: • Erosion and transportation of exposed sediment associated with earthworks, including vehicle movements across exposed earth, stockpiling and cut and fill earthworks. • Soil and bank erosion and mobilisation of sediments from vegetation clearing. Tannin leachate from vegetation clearing and mulching can enter downstream watercourses. • Transportation of pollutants from accidental spillages or leaks of fuels and/or oils from the maintenance or refuelling of construction plant equipment. • Transportation of concrete dust, concrete slurries or washout water. • Disturbance of contaminated land could result in exposure of hydrocarbons, metals and pesticides and transportation of contaminated sediments. As a result of the above, the following impacts to water quality may occur: • Increased sediments result in increased nutrients in watercourses, which can lead to algal blooms. This reduces the environmental value of water by limiting its potential uses. • Sedimentation can result in increased turbidity of watercourses. Elevated turbidity could lead to fish kills due to clogging of fish gills. Increased turbidity can also reduce light penetration, which can limit the growth of aquatic vegetation.	Watercourses in close proximity to the proposed works have the greatest risk of being impacted, specifically: • Bohena Creek and a first order tributary with the realignment of Pilliga Forest Way

Construction activity/source of pollutants	Construction works	Potential surface water quality impacts	Receiving watercourses
		• Tannins can cause dark coloured water being discharged into downstream watercourses from construction. This can alter the instream pH and reduce visibility and light penetration. Tannins can also increase BOD which can decrease instream dissolved oxygen concentrations, which can impact on aquatic ecosystems and lead to fish kills. • Oily films on surface water from spills reducing the visual amenity. • Pollution from accidental spillages or leaks of fuels and/or oils from the maintenance or refuelling of construction plant equipment and accidental litter dispersion. • Decreased biodiversity, loss of habitat and fish kills from increased concentrations of toxicants. • Concrete dust, concrete slurries or washout water discharged to downstream watercourses can result in increased alkalinity and pH of downstream watercourses. This could increase the acidity of the water and mobilise heavy metals, which could result in fish kills.	

Table 5.3 Potential construction impacts on surface water quality (key construction infrastructure)

Construction activity/ source of pollutants	Construction works	Potential surface water quality impacts	Receiving watercourses
Borrow Pits and associated access tracks	• Site clearance, including stripping of topsoil, vegetation removal. • Crushing, blasting and screening • Transport of blasted and crushed rock • Establishment of borrow pit access track • Truck and plant movements within and to and from site	Potential impacts to surface water quality from the establishment of borrow pits and their respective access tracks can be the result of: • Poor design of excavations from borrow pits, which may lead to ponding of water, scouring and bank erosion. • Blasting, crushing and screening produce a fine dust that can contain contaminants, which can be transported to downstream watercourses via wind and runoff. • Compaction of soil at access tracks, reducing infiltration of runoff and increased risk of this entering watercourses. • Potential for oil and diesel spills from plants and trucks. As a result of the above, the following impacts to water quality may occur. • Elevated turbidity, nutrients and other contaminants and low dissolved oxygen levels from exposed soil resulting in increased sedimentation. • Oily films on surface water from spills reducing the visual amenity. • Pollution from accidental spillages or leaks of fuels and/or oils from the maintenance or refuelling of construction plant equipment and accidental litter dispersion. • Decreased biodiversity, loss of habitat and fish kills from increased concentrations of toxicants. • Dust generated from crushing and blasting can contain contaminants and increase the toxicity of downstream watercourses reducing its suitability for protecting aquatic ecosystems. Dust may also result in increased turbidity.	• Borrow pit A – nearest watercourse is >2 km from borrow pit. • Access track for Borrow pit A is >1 km away from nearest watercourse. • Borrow pit B – nearest watercourse is >2 km from borrow pit. • Access track for Borrow pit B crosses Wallaby Creek. • Borrow pit C is ~1 km from Macquarie River. • Access track to Borrow pit C is >1 km from Macquarie River. • Borrow pit D – nearest watercourse >2 km. • Beginning of the access track to Borrow pit D is 60 metres away from Bohena Creek at its nearest point, however the Newell Highway and main construction corridor are located between the access track and the channel therefore runoff from the access track is unlikely to reach the watercourse.

Construction activity/ source of pollutants	Construction works	Potential surface water quality impacts	Receiving watercourses
Workforce accommodation Temporary workforce accommodation to accommodate workforce would be located at: • Narromine South multi-function compound • Narromine North • Gilgandra • Baradine • Narrabri West multi-function compound.	• Site clearance • Earthworks and movement of heavy vehicles • Implementation of water quality controls (sedimentation basins) • Implementation and operation of WWTPs • Irrigation of reclaimed water	Potential impacts to surface water quality from the establishment of temporary work force accommodation can include: • Potential for litter and debris to be blown off a construction area or transported off area by runoff and/or floods. • Transportation of soils and sediments associated with vegetation clearance and vehicle movements across exposed earth. • Potential for wastewater to be transported off site due to leaks or spills from the on site WWTPs at the Narromine North and Baradine facilities, or from recycling or irrigation, leading to runoff to surface water. • Tannin leachate entering downstream watercourses from vegetation clearing (and subsequent mulching). As a result of the above, the following impacts to water quality may occur: • Elevated turbidity, nutrients and other contaminants and low dissolved oxygen levels from exposed soil resulting in increased sedimentation. • Effluent is high in nutrients, harmful chemicals and disease causing bacteria and viruses from human waste, which can affect human health if people come in contact with contaminated water. Release of nutrients and chemicals can increase the toxicity of water and reduce dissolved oxygen thereby impacting on aquatic organisms. • Tannins can cause dark coloured water being discharged into downstream watercourses which can alter the instream pH and reduce visibility and light penetration. Tannins can also increase BOD which can decrease instream dissolved oxygen concentrations, which can impact on aquatic ecosystems and lead to fish kills.	All watercourses in close proximity to workforce accommodation areas.

Construction activity/ source of pollutants	Construction works	Potential surface water quality impacts	Receiving watercourses
Compounds Concrete batch plants	• Earthworks and vegetation clearing • Transport of spoil material from stockpiles sites • Concrete works • Concrete batching	Potential impacts to surface water quality from establishment of compounds for concrete batch plants can include: • Erosion and sedimentation due to clearing of the compound and access to the site. Resulting in transport of sediment downstream. • Runoff from construction compounds could be contaminated with by-products from activities occurring on sites such as welding, concreting, laydown. • Potential for oil and diesel spills from plants and trucks. • Potential for litter and debris to be blown off a construction area or transported off area by runoff and/or floods. • Run-off laden with cement powder dust, concrete slurries, or water from concrete washouts discharging to watercourses. As a result of the above, the following impacts to water quality may occur: • Increased alkalinity, chromium levels or changes in pH levels of watercourses as a result of chemicals used in treatment and curing of concrete, and cement dust being transported to watercourses via stormwater and wind. • Increased turbidity, suspended solids, nutrients and contaminants from the mobilisation of soils. • Concrete solids that are improperly disposed of can clog stormwater pipes and cause flooding. • Oily films on surface water from spills reducing the visual amenity.	All watercourses in close proximity to compounds, but those at greatest risk are Macquarie River, Castlereagh River, Namoi River/Narrabri Creek.

5.4 Construction impacts

The following subsections provide further information regarding the likelihood of the potential impacts identified in sections 5.1 to section 5.2 to be realised due to the proposal. Detailed mitigation measures that minimise potential construction impacts are provided in section 8.

5.4.1 Erosion and sedimentation

The construction of the proposal has the potential to impact on the soil environment, particularly given the prevailing drought conditions and erodible soils located within the study area. The activities, which pose the created risk and could result in erosion and sedimentation are:

- Vegetation removal – vegetation removal would expose soils to weathering processes, thereby increasing the risk of erosion and sedimentation.
- Works in watercourses has the potential to reduce the stability of beds and banks and contribute to erosion and sedimentation, particularly if riparian vegetation is removed.
- Cut and fill earthworks – cut and fill earthworks are located along the majority of the alignment and could affect the topography, geology and soils in the area. In areas of cut, the earthworks gave the potential to destabilise the landform. To reduce this risk the design of cuts has been considered to avoid and/or minimise potential destabilisation.
- Excavation at borrow pit sites – the excavation of borrow pit sites could lead to increased erosion and sedimentation if not managed appropriately.

  In areas of fill, soils and landform have the potential to be impacted due to erosion of soils during rainfall events by runoff. This can result in sedimentation of downstream drainage lines through mass movement of soils.

The key activities during construction that can directly or indirectly increase erosion and sedimentation include:

- Stockpiling – some excavation material would require stockpiling prior to being transferred and reused on the proposal. Stockpiles that are not adequately stabilised can result in material eroding away during windy or high rainfall events.
- Construction of railway line, access and haulage roads – during the construction of these features there is a risk of soil compaction from movement of heavy machinery, thereby disturbing the soil surface making it more susceptible to erosion.
- Construction of watercourse crossings – the construction of watercourse crossings comprises of culverts and bridges, both of which can require instream works. Additionally, installation of culverts would require some bed levelling and instream disturbance of soils. As the bridges and culverts would largely be constructed in watercourses that are ephemeral there would be no requirement for dykes or temporary access ways. These structures would be constructed when the watercourses are dry and the implementation of standard sediment and erosion controls would minimise the potential for water quality impacts associated with erosion and sedimentation. Only the Macquarie River Bridge and the Namoi River/Narrabri Creek Bridge would be constructed in flowing waters, and this would involve using bored piles that would be encased and would be constructed from barges so as to minimise sediment disturbance. Implementation of additional erosion and sediment controls such as silt curtains will also be considered. Therefore, the potential for disturbance of sediments within flowing watercourses would be low.

5.4.2 Land disturbance

The proposal has the potential to impact surface water quality throughout the construction phase by disturbing previously undisturbed land. Construction activities often involve disturbing soils and vegetation removal, which if inappropriately managed can result in soil erosion and deposition of sediment to downstream watercourses and sensitive receiving environments. Runoff from construction sites are the largest source of sediment to downstream watercourses.

Land disturbed by excavation and filling can increase erosion. Not only is the transport of sediment to downstream watercourses a source of pollution, but so too are the nutrients bound to these sediments.

Sedimentation is the deposition of these soil particles to downstream watercourses, which can impact the water quality causing high turbidity, reduced depth and increased algal productivity.

In addition to sediments and nutrients, a variety of other pollutants associated with land disturbed during construction can result in hazardous pollution if allowed to mobilise and be transported to downstream watercourses. Of particular concern are the hydrocarbons from construction vehicles.

The impact of land disturbance from construction of watercourse crossings on water quality would be minimal due to construction being undertaken during dry conditions (as the majority of the watercourses are ephemeral) and construction via barges for the Macquarie River and Namoi River/Narrabri Creek bridges which are flowing.

5.4.3 Water availability and flows

Due to the prevailing drought conditions, there is limited surface water available in the proposal area. No water extraction directly from any creek is proposed during construction of the proposal with water to be sourced via deep aquifers bores during construction. The total estimated volume of water to be used is 4,600 mega litres and is outlined within the *ARTC Inland Rail Narromine to Narrabri Groundwater Assessment* (JacobsGHD, 2020c). Water sourcing comprises of both non-potable (estimated to be 1400 mega litres per year) which would be sourced from groundwater bores and potable water (estimated to be 118 mega litres per year) which would be supplied by either town water supply or groundwater bores. Pumping of the deep aquifers has the potential to reduce creek and river baseflows without appropriate mitigation measures, and therefore could have a minor impact on environmental water availability and flows. The impacts associated with pumping of the groundwater bores for construction water are considered in the *ARTC Inland Rail Narromine to Narrabri Groundwater Assessment* (JacobsGHD, 2020c).

Water may be re-used (as a supplementary source to the primary water supply) during the construction stage for activities such as dust suppression, where there is appropriate supply and quality available within the sediment retention basins. However, it is noted that that the amount of surface water to be utilised for re-use from sediment retention basins is anticipated to be negligible over the life of the proposal.

Additionally, no construction machinery or structures would be place in watercourses that would cease or block flow. Therefore, the proposal is unlikely to reduce the quantity of water in nearby watercourses and drainage lines and would have no impact on environmental flows. Likewise, the construction of the proposal would not change the flow regime and therefore would not contribute to erosion or sedimentation of downstream watercourses.

5.4.4 Potential pollutants introduced to watercourse during construction

Without appropriate design of water quality controls, design and implementation of mitigation measures there are various pollutants that have the potential to be introduced into downstream watercourses during the construction phase of the proposal. They key pollutants of concern are summarised below:

- nutrients namely nitrogen and phosphorus that are bound to sediment which become mobilised during earthworks, dewatering, vehicle movements and stockpiling or from effluent leaks and spills or reuse for irrigation
- tannin leachate from vegetation clearing
- hydrocarbons, metals and pesticides that are bound to sediments, particularly disturbance of contaminated land or from effluent leaks and spills or reuse for irrigation
- fuels and oils from accidental spillages from the maintenance or refuelling of construction plant equipment or WWTPs
- bacteria and viruses from effluent leaks or spills from the WWTPs
- alkaline water and chromium generated from concreting and its by-products.

Measures implemented would largely comprise of erosion controls aimed at preventing soil erosion in the first instance and sediment controls aimed at capturing the soil particles once disturbed through soil erosion. Dewatering of farm dams would be undertaken in accordance with a dam dewatering protocol that would be prepared as part of the Construction Environmental Management Plan (CEMP).

With construction of sedimentation basins and implementation of the mitigation measures provided, water quality impacts due to construction runoff would be negligible.

By implementing management measures provided in the soil and water management plan, pollutant runoff due to leaks and spills, tannin leachate and the operation of batching plants would be negligible and would be unlikely to cause long-term harm to human health or the environment. Additionally, any mobile and fixed concrete batching plants would be established with appropriate erosion and sediment controls, consistent with current best practice.

If used for irrigation, the water from the WWTPs at the Narromine North and Baradine temporary workforce accommodation facilities would be treated to a relatively high quality and appropriate management practices would be adopted, such as balancing storages and proper irrigation scheduling to avoid excessive irrigation. The reclaimed water reuse scheme would be designed and operated in accordance with the *National Guidelines on Water Recycling* (Environment Protection and Heritage Council 2006) and the *Environmental guidelines: Use of effluent by Irrigation* (DECC 2004) so as to avoid impacts to water quality downstream.

5.4.5 Performance against NSW water quality objectives

There are a number of potential pollutants associated with construction activities that may affect performance of the proposal, including contamination, fuels and oils from machinery, tannins from cleared and mulched vegetation and sediment laden runoff as provided in Table 5.1 and Table 5.3. Each of these have the potential to impact on the water quality and subsequently the water quality objectives and environmental values of watercourses downstream of the proposal.

Construction of the proposal would require the implementation of standard erosion and control measures for all work areas that are designed to minimise pollutant loading downstream. Runoff from construction sites would be captured in sedimentation basins that would be constructed at regular intervals along the alignment and designed to meet the standards outlined in the Blue Book (Landcom, 2004) and the ANZG (2018) guidelines where possible. Sedimentation basins have been designed as Type D basins and sized to capture and treat the 80th percentile 5-day rainfall event for a hydrology group D soul with a runoff coefficient of 0.5. Any water captured in these basins would be reused on site for construction as opposed to being discharged where possible.

With the implementation of these management measures, pollutant loading to the receiving watercourses would be low and only likely under high flow conditions. If climatic conditions continue to be as observed over the past few years, the likelihood of high rainfall and subsequent runoff is very low.

Sedimentation basins would be provided at regular intervals, including at key infrastructure to capture any potential runoff during rainfall. Sedimentation basins would be designed to so that any discharge contains concentrations of total suspended sediments (TSS) of less than 50 mg/L. The ANZG (2018) guidelines state that ranges for turbidity and TSS are similar and by limiting TSS to <50 mg/L we would meet the recommended trigger values for nominated environmental values.

Discharge from sedimentation basins, where required, would also be undertaken in accordance with the relevant environmental protection licences. This means any discharge water would meet the water quality objectives provided in Table 3.1 and would be of better quality than that within the surrounding watercourses.

5.4.6 Stormwater and wastewater management

Stormwater could be generated at construction sites following wet weather and at temporary camps will be set up to provide accommodation and supporting services for workers. These temporary camps could also generate stormwater be altering the runoff regime due to introduction of impervious areas and increased concentrations and loads of sediments in runoff from roof areas and road pavements. To minimise the impact on downstream water quality and to control volumes and flow rates, stormwater will be managed by implementing standard erosion and sediment control measures sized and designed in accordance with *Managing Urban Stormwater – Soils and Construction*: Volume 1 (Landcom, 2004), Volume 2C Unsealed Roads (DECC, 2008a) and Volume 2D Main Road Construction (DECC, 2008b) (collectively referred to as the 'Blue Book').

Wastewater will be generated from the temporary accommodation camps and other onsite amenities (showers, toilets, laundry, cooking etc). The key risk to surface water would be related to discharge of untreated wastewater due to equipment failure. To manage the impact on downstream watercourses, wastewater will be transported via vacuum trucks to a wastewater treatment plant. Wastewater can also be generated from sedimentation basins, concrete batching plants and vehicle washdown areas. To minimise the risk to water quality, wastewater from construction activities would be contained onsite until water can be discharged to meet relevant water quality limits. In addition to considering the background water quality, consideration will also be given to the hydrological attributes of the receiving environment.

6. Operational impact assessment

The risks to water quality related to the operational phase of Inland Rail, that is the use of the constructed rail infrastructure and road infrastructure. Operations involve a range of activities that can be categorised into the two main components:

1. rail infrastructure
2. road infrastructure.

The operation of the proposal presents a potential risk to downstream water quality if operational management measures are not implemented, monitored or maintained.

6.1 Rail infrastructure

The operation of the rail infrastructure would involve operation of a single rail track with crossing loops, to accommodate double stacked freight trains up to 1,800 metres long and 6.5 metres high within a dedicated rail corridor.

The potential impacts to water quality associated with the operation of rail infrastructure are presented in Table 6.1.

Table 6.1 Potential operational impacts on surface water quality (rail infrastructure)

Operational activity / source of pollutants	Operational works	Potential surface water quality impacts	Receiving watercourses
Transport of material Runoff from the formation Maintenance activities	• Train operations – numerous trains travelling daily in both directions. • Weed control • Rail maintenance operations. • Vegetation clearing • Weed control • Operational road maintenance/upgrades • Drain clearing and maintenance of infrastructure such as rail grinding, points and signals	Potential impacts to surface water quality from the operation of the rail infrastructure can be caused by: • Transportation of pollution and sediments due to increased volume of runoff from less permeable surfaces. The runoff may contain sediments and gross pollutants from the rail formation, cuttings and from trackside drainage systems. • Pollution from accidental spillages or leaks of fuels and/or oils from the maintenance or refuelling of construction plan equipment and accidental litter dispersion. • Gross pollutant from runoff from the rail formation, cutting and from trackside drainage systems. This runoff could be high in heavy metals (from brake pads and track wear and points use). • Organics due to minor oil, grease and diesel spills from locomotives operating along the track. As a result of the above, the following impacts to water quality may occur: • Increased sediments can result in increased nutrients in watercourses, which can lead to algal blooms. This reduces the environmental value of water by limiting its potential uses. • Sediments entering downstream watercourses can increase turbidity and subsequently reduce the aesthetic quality of the watercourses and be harmful to fish and aquatic life. • Increased levels of heavy metals to downstream watercourses either directly or bound to sediment can be toxic to aquatic biota and fish. • Increased concentrations of herbicides and pesticides in downstream watercourses used in the maintenance practice to control weeds and trackside clearance can increase the toxicity of receiving watercourses and bioaccumulate in aquatic organisms. • Pollution from accidental spills/material released during transportation which could result in oily films on surface water reducing the visual amenity.	All watercourses within the study are have the potential to be impacted. At greatest risk are those identified as SREs including: • Macquarie River • Emogandry Creek • Backwater Cowal • Ewenmar Creek • Kickabil Creek • Castlereagh River • Gulargambone Creek • Baradine Creek • Etoo Creek • Stockyard Creek • Rocky Creek • Coghill Creek • Mollieroi Creek • Goona Creek • Bohena Creek • Namoi River • Narrabri Creek.

Operational activity / source of pollutants	Operational works	Potential surface water quality impacts	Receiving watercourses
Runoff from operational access road	• Use of road vehicles on internal access roads	Potential impacts to surface water quality from the operation of access roads can be caused by: • Pollutants entering downstream watercourses including sediments, nutrients, heavy metals, hydrocarbons, oils and grease and gross pollutants and litter from runoff. As a result of the above, the following impacts to water quality may occur: • Increased sediment loads and nutrients reduce light penetration through the water column or can smother aquatic flora and fauna. Decay of organic matter and some hydrocarbons can decrease dissolved oxygen levels resulting in fish kills, and can increase concentrations of heavy metals (including aluminium and iron) which are toxic to aquatic biota. Conversely, increased nutrients from sediments can result in excessive plant growth, resulting in algal blooms.	All watercourses within the rail corridor.

6.2 Road infrastructure

The potential impacts to water quality associated with the operation of road infrastructure are presented in Table 6.2.

Table 6.2 Potential operational impacts on surface water quality (road infrastructure)

Operational activity / source of pollutants	Operational works	Potential surface water quality impacts	Receiving watercourses
Changes in impervious areas due to road realignment resulting in increased runoff	• Use of road vehicles on new road sections	Potential impacts to surface water quality from the operational of realigned roads may be caused by: • Erosion and sedimentation from increased runoff transporting sediments downstream. • Pollutants entering downstream watercourses including sediments, nutrients, heavy metals, hydrocarbons, oils and grease and gross pollutants and litter from runoff. As a result of the above, the following impacts to water quality may occur: • Increased suspended solids, which can lead to increased turbidity, and silting of watercourses. This in turn can reduce light penetration through the water column and impact on aquatic flora and fauna. • Increased levels of heavy metals and hydrocarbons either directly or attached to sediments which are toxic to aquatic biota and fish. • Increased levels of litter, oils and grease which can reduce the visual amenity of the watercourses. • Excessive biochemical oxygen demand as a result of oxidation of hydrocarbons and reduction of metals leading to depletion of dissolved oxygen in the water. This may cause the death of aquatic organisms and result in the release of nutrients and heavy metals bound to the bed sediments due to anoxic conditions.	• All watercourses near realigned roads. • Bohena Creek and first order tributary from the realigned Pilliga Forest Way.

6.3 Operation impacts

During the operational phase of the proposal, the railway line would be complete, cleared areas would be landscaped and scour protection would be installed. There would be no exposed topsoil and therefore little or no risk of soil erosion and subsequent transport of sediment into nearby watercourses. Water quality risks during the operation would instead be associated with the operation of railway, maintenance activities and accidental spillages.

Table 6.3 identifies the main operation phase risks that are likely to impact the water quality adjacent to the proposal or in the receiving waters in an area likely to be directly impacted by the proposal.

Table 6.3 Water quality risks and potential mitigation measures during operation

Risk	Potential water quality impacts
Erosion and sedimentation	There is a period of time following the completion of construction where recently disturbed soils are susceptible to scour and erosion from stormwater runoff. This results in sedimentation, which can have both direct and indirect impacts on water quality. Direct impacts of sedimentation include reducing light penetration (limiting the growth of macrophytes), clogging fish gills, algal blooms, altered stream geomorphology, smothering of benthic organisms and reduced visibility for fish. Indirect impacts of sedimentation occur over the longer term and include accumulation of sediments instream and release of pollutants such as heavy metals and nutrients. Temporary soil stabilisation may be required immediately following construction to prevent potential erosion, topsoil loss or soil migration. This is particularly likely to be required following severe storms. A rehabilitation strategy would be prepared to guide the approach to rehabilitation of disturbed areas, and would include requirements for ongoing monitoring following the establishment of these areas, as described in the EIS.
Scouring	Faster flows velocities at railway crossings, at piles or edges of rail embankments could lead to potential scouring of river beds and downstream. Scour leads to an increase in silt load. This impacts to water quality include: • increased turbidity, lower dissolved oxygen and increased concentrations of nutrients, metal and other contaminants which can lead to algal blooms, aquatic weed growth, fish kills and reduced visual amenity • silting of watercourses and associated smothering of aquatic flora and fauna. By designing flow discharge points (culverts and longitudinal drainage) to include erosion controls such as rock protection, to slow velocities, risk of scouring would be minimal.

Risk	Potential water quality impacts
Stormwater runoff	Contaminated stormwater runoff from both railway and road infrastructure could result in: • Increased suspended solids, which can lead to increased turbidity, and silting of watercourses. This in turn can reduce light penetration through the water column and impact on aquatic flora and fauna. • Increased levels of heavy metals and hydrocarbons either directly or attached to sediments which are toxic to aquatic biota and fish. • Increased levels of litter, oils and grease which can reduce the visual amenity of the watercourses. • Excessive biochemical oxygen demand as a result of oxidation of hydrocarbons and reduction of metals leading to depletion of dissolved oxygen in the water. This may cause the death of aquatic organisms and result in the release of nutrients and heavy metals bound to the bed sediments due to anoxic conditions. Whilst realignments of some roads and the presence of the rail corridor may increase impervious areas in the proposal site the actual increase in impervious area would be very small relative to the total area of the catchments. The overall impact on surface water quality would be minimal. Runoff from the proposal is expected to be low and not change export of annual pollutant loads to downstream watercourses. Any surface water generated during maintenance activities would be managed by implementing standard erosion and sediment control measures in accordance with the Blue Book. As a result, it would be unlikely to decrease water quality during operation.
Pollution (leakages and spills)	Contamination of downstream watercourses from accidental spill of vehicle oils, lubricants and hydraulic fluids and other accidental spill including cargo spills. Spills and leakages can impact water quality by: • increasing toxicant concentrations into downstream watercourses, which may be toxic to aquatic biota and fish. • creating oily surface films, which can reduce the visual amenity of the watercourse. The potential for spills and leakages from maintenance vehicles and rolling stock would be minimised through implementation of ARTC's standard operating procedures.
Weed control	Maintenance practices to control weeds and trackside clearance involves the use of herbicides and pesticides, which can result in increased concentrations of the toxicants in downstream watercourses. This can impact water quality by increasing the toxicity of the receiving watercourse and bioaccumulation of these toxicants in aquatic organisms. Weed management within the proposal site would be undertaken in accordance with ARTC's standard operating procedures.

Risk	Potential water quality impacts
Water availability and flows	Water extraction from watercourses is not proposed for the operational stage of the proposal. Changes to groundwater levels during the operational phase of the proposal are assessed to be minor and therefore no impact to baseflows of watercourses in the proposal site. Potential changes to water availability and flows during the operation relate to the increase in impervious surface from the introduction of the rail alignment and supporting road network into an otherwise greenfield area and a change in surface flow paths within minor drainage lines. There will be very little change in the overall ratio of impervious to pervious catchment area, and the expected runoff from the proposal is low. Therefore, changes to downstream flow would be negligible and would not resulting in erosion and sedimentation.
Water quality – performance against NSW Water Quality Objectives	During the operation of the proposal there are not expected to be any activities that would generate wastewater. Stormwater runoff would be captured and released via overland flow. Runoff from the proposal is expected to be low and not change the export of annual pollutant loads to downstream watercourses, and therefore unlikely to decrease water quality. Additionally, implementation of appropriate scour protection and the design control measures would not prevent or hinder the achievement of future strategies aimed at meeting the water quality objectives. The limited water quality data available for watercourses with the potential to be impacted suggest that these watercourses are moderately disturbed as a result of existing land use practices. Additionally, any contribution of contaminants due to operation of the proposal is expected to be minimal. Therefore, the proposal is unlikely to have a material impact on the ambient water quality and is unlikely to impact on achieving the NSW Water Quality Objectives.

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7. Cumulative impacts

7.1 Overview

For an EIS, cumulative impacts can be defined as the successive, incremental, and combined effect of multiple impacts, which may in themselves be minor, but could become significant when considered together. The methodology and projects considered for the cumulative impact assessment are provided in detail in the EIS (Part D chapter D1). The study area for the cumulative biodiversity assessment is the local and regional catchments crossed by the project. Seven major projects were identified as having a cumulative impact and sufficient information to undertake a cumulative impact assessment. These include:

- APA - Western Slopes Pipeline
- Inland Rail – Narrabri to North Star
- Inland Rail – Parkes to Narromine
- Narrabri Gas Project
- Silverleaf Solar Farm, Narrabri
- Gilgandra Solar Farm
- Narromine Solar Farm.

7.2 Construction and operation

The water quality impacts associated with the construction and operation of the proposal are expected to be minor with the implementation of appropriate environmental management measures. Therefore, the proposal is expected to have a minor contribution to cumulative surface water quality impacts. The potential cumulative impacts for each catchment have been summarised in Table 7.1. Figure 7.1 shows the projects with the potential for cumulative impacts with the proposal.

7.3 Summary of cumulative impacts

With the implementation of mitigation measures during construction and operation, the proposal is expected to have only a minor contribution to cumulative surface water quality impacts.

The major projects also occurring within close proximity proposal site that were considered as part of the cumulative impact assessment are those that would have an immediate interface during the construction and/or operation of the proposal. Other projects occurring in the broader locality would likely have a negligible increase in surface flows or runoff. Combined with the distance to downstream watercourses and implementation of mitigation measures and controls, the cumulative impact is expected to be negligible.

Overall, the proposal, along with other ongoing and planned developments in the area, would have minor cumulative impact on surface water quality associated with the construction and minor cumulative impacts associated with operation. Where any minor impacts occur, they are likely to be either highly localised, temporary and/or readily assimilated into the existing watercourses.

Table 7.1 Summary of potential cumulative impacts

Common receivers	Potential impacts on common receivers during construction of the proposal	Construction mitigation measures	Potential impacts on common receivers during operation of the proposal	Operational mitigation measures	Construction and operation residual impacts
APA - Western Slopes Pipeline					
Macquarie River, Castlereagh River, and Namoi River.	Increased water quality pollutants, sediment loads and litter due to vegetation removal, excavation and equipment haulage	• Erosion and sediment controls • Staging of works and progressive rehabilitation	• Ongoing clearance of vegetation resulting in erosion and sedimentation	• Erosion and sediment controls	Provided the proposed controls are implemented, maintained and monitored, the cumulative impacts of the project on downstream receivers and SREs would be minimal.
Inland Rail - Narrabri to North Star					
Namoi River and Narrabri Creek	Increased water quality pollutants, sediment loads and litter into watercourses	• Erosion and sediment control measures in accordance with the Blue Book including sedimentation basins • Stockpile management • Water quality monitoring	• Increased water quality pollutants and litter into watercourses • Impacts on drainage infrastructure	• Design control measures • Flood mitigation measures • Water quality monitoring	Provided the proposed controls are implemented, maintained and monitored, the cumulative impacts of the project on downstream receivers and SREs would be minimal.
Inland Rail – Parkes to Narromine					
Backwater Cowal	Increased water quality pollutants, sediment loads and litter into watercourses	• Erosion and sediment control measures in accordance with the Blue Book including sedimentation basins • Stockpile management • Water quality monitoring	• Increased water quality pollutants and litter into watercourses due to accidental spills and leakages • Impacts on drainage infrastructure. • Hydrological impacts due to redirection of overland flows	• Design control measures • Flood mitigation measures • Water quality monitoring	Provided the proposed controls are implemented, maintained and monitored, the cumulative impacts of the project on downstream receivers and SREs would be minimal.

Common receivers	Potential impacts on common receivers during construction of the proposal	Construction mitigation measures	Potential impacts on common receivers during operation of the proposal	Operational mitigation measures	Construction and operation residual impacts
Narrabri Gas Project (Santos)					
Goona Creek, Bundock Creek, and Bohena Creek	Increased water quality pollutants, sediment loads and litter into watercourses from erosion and sedimentation, spills and drilling	• Erosion and sediment control measures in accordance with the Blue Book • Stormwater design • Water quality monitoring • Construction of water treatment plant	• Increased water quality pollutants and litter into watercourses due to accidental spills • Inappropriate stormwater management • Discharge of inappropriately treated water • Erosion and sedimentation	• Erosion and sediment control plans • Drainage upgrades • Managed releases • Water quality monitoring	Provided the proposed controls are implemented, maintained and monitored, the cumulative impacts of the project on downstream receivers and SREs would be minimal.
Silver Leaf Solar Farm (Narrabri)					
Namoi River and Narrabri Creek	Water quality pollutants, sediment loads and litter into nearby watercourses from soil disturbance and vegetation clearance	• Erosion and sediment control measures in accordance with the Blue Book • Progressive rehabilitation	• Spills and leaks from maintenance vehicles • Runoff from site	• Drainage upgrades • Emergency spill plans	Provided the proposed controls are implemented, maintained and monitored, the cumulative impacts of the project on downstream receivers and SREs would be minimal.

Common receivers	Potential impacts on common receivers during construction of the proposal	Construction mitigation measures	Potential impacts on common receivers during operation of the proposal	Operational mitigation measures	Construction and operation residual impacts
Gilgandra Solar Farm					
Emogandry Creek	Increased water quality pollutants, sediment loads and litter into watercourses	• Erosion and sediment control measures in accordance with the Blue Book • Staging of works and progressive rehabilitation • Stockpile management • Water quality monitoring	• Spills and leaks from maintenance vehicles	• Spill containment • Rehabilitation	Provided the proposed controls are implemented, maintained and monitored, the cumulative impacts of the project on downstream receivers and SREs would be minimal.
Narromine Solar Farm					
Macquarie River	Increased water quality pollutants, sediment loads and litter into watercourses	• Erosion and sediment control measures in accordance with the Blue Book • Site drainage and water quality controls	• Erosion and sedimentation • Runoff from site	• Drainage upgrades and water quality controls • Flood mitigation measures • Water quality monitoring	Provided the proposed controls are implemented, maintained and monitored, the cumulative impacts of the project on downstream receivers and SREs would be minimal.

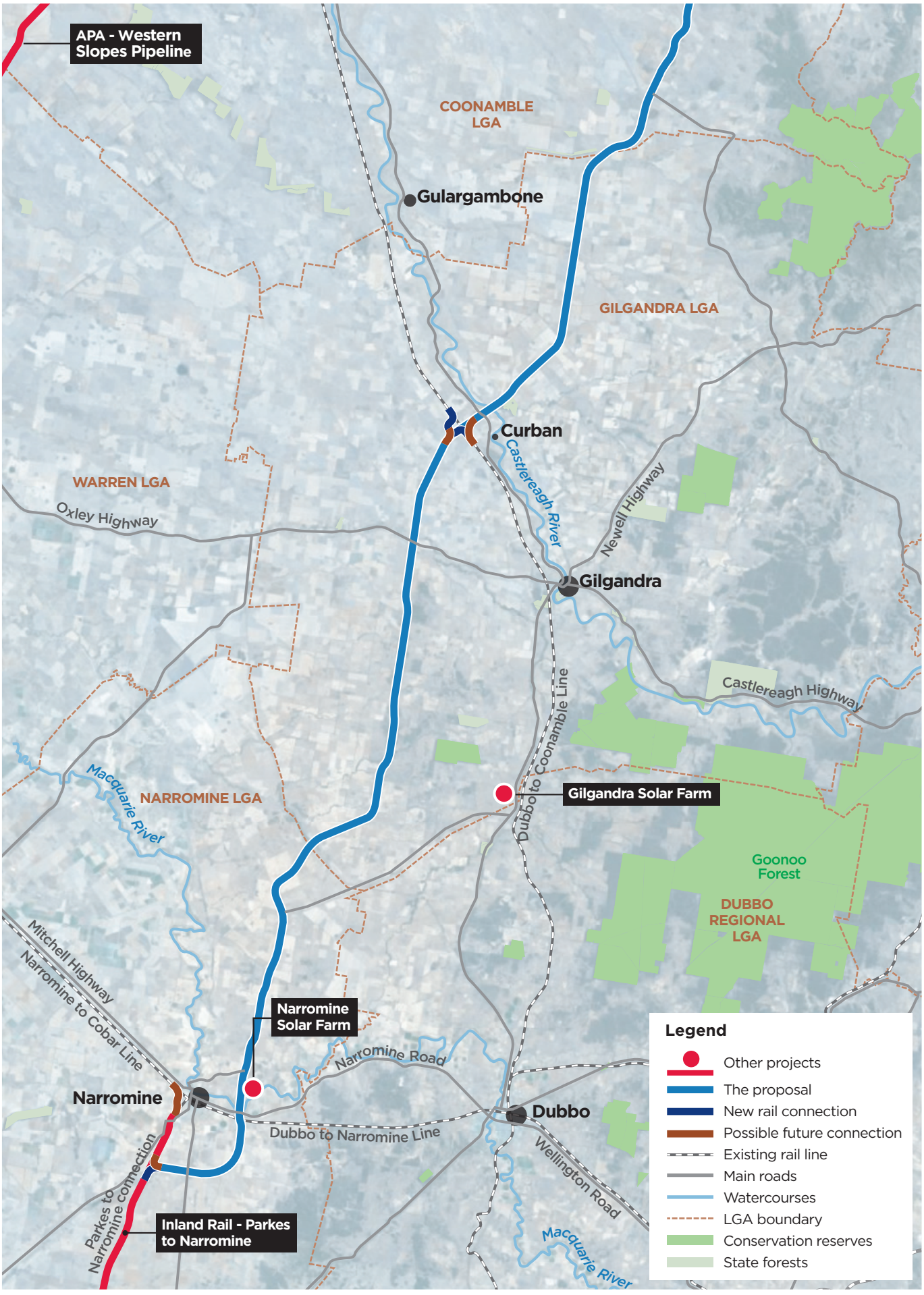

Figure 7.1 **Projects with the potential for cumulative impacts (map 1)**

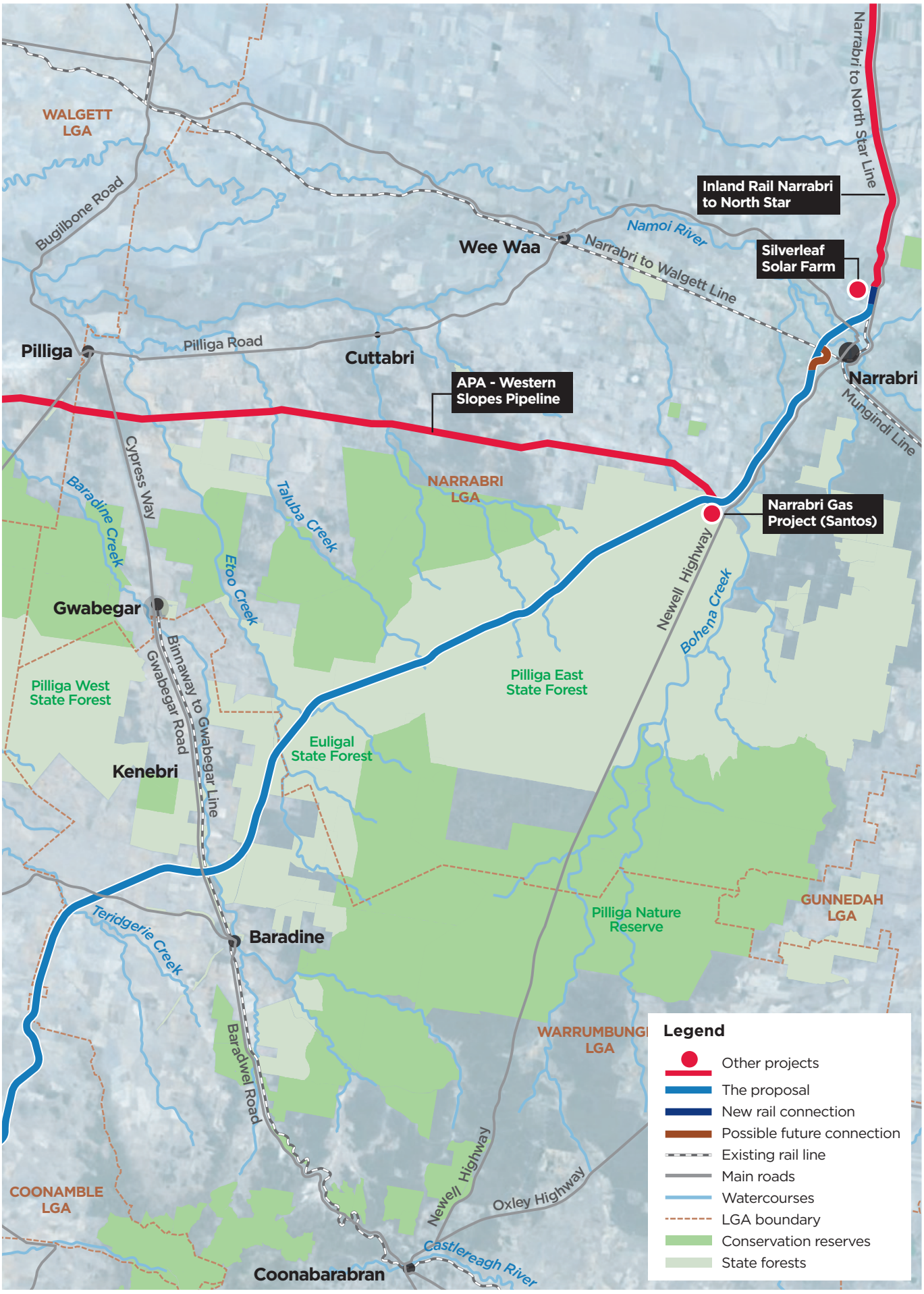

Figure 7.1 **Projects with the potential for cumulative impacts (map 2)**

8. Recommended mitigation measures

Measures to avoid, minimise or manage impacts to surface water are detailed in the following sections.

8.1 How potential impacts have been avoided/minimised

The proposal has been designed to avoid and minimise potential impacts to watercourses. The strategies that have been, and would continue to be implemented include the following:

- designing flow discharge points to include erosion controls such as rock protection to slow velocities and minimise risk of erosion from runoff that flows into and exits structures such as culverts
- designing bridges and culverts to have minimal impact on flow paths along the proposal site
- incorporating water quality controls such as sedimentation basins, water quality ponds and spill basins into the design as required
- designing batters and retaining structures using appropriate slope gradients to minimise erosion
- constructing bridge piers in flowing watercourses from barges to minimise sediment disturbance
- designing ballast drainage to discharge to suitable outlets and control points.
- works in the majority of watercourses would only be undertaken in dry weather conditions when watercourses are dry
- pre-cast culvert structures would be used, thereby minimising works in watercourses.

Where impacts could not be avoided, mitigation measures to minimise or manage impacts to watercourse are detailed in Table 8.1, Table 8.2 and Table 8.3. Additionally, Table 8.4 includes management measures which should be included in the soil and water management plan to manage impacts during construction.

As discussed in section 5 and section 6, impacts to water quality are largely related to changes in hydrology. Therefore, the mitigation measures detailed in *ARTC Inland Rail Narromine to Narrabri Flooding and Hydrology Assessment* (JacobsGHD, 2020d) are therefore also relevant to surface water quality.

8.2 Mitigation measures

Table 8.1 Measures for detailed design/pre-construction

Issue	Recommended mitigation measure – Detailed design/pre-construction
Water quality	The design features listed in 8.1 would continue to be refined and implemented to minimise the potential impacts of the proposal on water quality. The final approach regarding reuse options for wastewater from the Narromine North and Baradine temporary workforce accommodation facilities would be confirmed during detailed design. Any irrigation areas would be designed and operated in accordance with the risk framework and management principles contained in the *National Guidelines on Water Recycling* (EPHC, 2006) and the *Environmental guidelines: Use of effluent by* irrigation (DEC, 2004). This would include the following design requirements: • the irrigation area would be delineated based on the expected rate of irrigation and the drainage characteristics of the receiving soil • the quality of treated water would be determined to prevent accumulation of contaminants, with reference to the relevant guidelines • the irrigation area would be designed to include capacity to store treated water for the duration of typical wet weather events • the rate of irrigation would be optimised to avoid waterlogging or ponding of reclaimed water • soil and groundwater conditions would be monitored to identify and correct trends in soil salinity or other potential effects of irrigation.

Table 8.2 Measures for construction

Issue	Recommended mitigation measure – construction
Sedimentation and erosion management	A soil and water management plan would be prepared and implemented as part of the CEMP. The plan would include measures, processes and responsibilities to minimise the potential for soil and water impacts during construction, including the measures provided in Table 8.4. The plan would be prepared in accordance with relevant guidelines and standards, including *Managing Urban Stormwater – Soils and Construction: Volume 1* (Landcom, 2004), *Volume 2C Unsealed Roads* (DECC, 2008a) and *Volume 2D Main Road Construction (*DECC, 2008b) (collectively referred to as the 'Blue Book').
Discharge to surface water	Discharge to surface water would be undertaken in accordance with the environment protection license for the proposal, and would consider the hydrological attributes of the receiving waterbody.
Farm dam dewatering	A dam dewatering protocol would be developed as part of the soil and water management plan. It would consider: • options for reuse of water in the dam • licensing and approval requirements, where relevant • the quality and quantity of the water to be released, if relevant • strategies to minimise impacts to native, threatened or protected species • strategies to minimise spread of nuisance flora and fauna species.

Issue	Recommended mitigation measure – construction
Surface water monitoring	A surface water monitoring framework would be developed and implemented as part of the soil and water management plan in the CEMP. It would identify: • monitoring locations at discharge points and selected watercourses where works are being undertaken • monitoring parameters • frequency and duration of monitoring. The monitoring framework would include the relevant water quality objectives, parameters, and criteria from section 8.4 and would be developed in consultation with the Department of Planning, Industry and Environment, and the NSW EPA.
Works within watercourses	Works within or near watercourses would be undertaken with consideration given to the *Guidelines for Watercourse Crossings on Waterfront Land* (DPI, 2012*).*

Table 8.3 Measures for operation

Issue	Recommended mitigation measure – Detailed design/pre-construction
General water quality management	The proposal would be managed in accordance with the water quality management requirements specified in the environmental protection licence.

8.3 Management measures

Example management measures that would be included in the soil and water management plan are listed in Table 8.4.

Table 8.4 Management measures

Issue	Proposal specific mitigation measures
Land disturbance	During site establishment, vegetation removal will occur in a staged approach to minimise the amount of exposed area and sedimentation basins will be installed early, reducing the risk of sediment being transported to downstream watercourses. Sedimentation basins will be designed to capture and treat the 80th percentile five-day rainfall event and will be in designed in accordance with the relevant requirements of the Blue Book. Sedimentation basins will be designed so that the discharge is compliance with the ANZG (2018) water quality guidelines for protection of aquatic ecosystems. Bridge construction will be done so as to not obstruct any flow, with the exception to the Macquarie River and Namoi River/Narrabri Creek where a barge will be required (subject to water flow).
Instream structures	As far as practicable concrete usage will be minimal in locations within 100 metres of watercourses that have been identified as sensitive receiving environments. Where concrete works will be required over perennial watercourses, appropriate containment measures such as an encapsulation structure above the watercourse will be utilised to avoid ingress of concrete waste in the watercourses.

Issue	Proposal specific mitigation measures
	Culverts and bridges on ephemeral watercourses will be installed when the watercourse is dry and construction activities will cease prior to any rainfall. In the unlikely event that unexpected rainfall were to occur during construction, a contingency plan will be developed as part of the CEMP to ensure concrete waste is captured prior to mobilisation into the water. At perennial watercourses where two of the major bridge structures are proposed to be built (Macquarie River and Namoi River/Narrabri Creek), silt curtains will be placed around piling sites to ensure no sediment or polluted water can mobilise downstream. At barge sites that will be located on Macquarie River, Namoi River or Narrabri Creek, appropriate bunding will be included around the perimeter of the barge to prevent construction materials or spills from drilling equipment impacting the watercourse.
Working in watercourses	Where possible, access to watercourses by construction plant will be minimised. Construction works within and/or next to the watercourses and drainage lines will be minimised as much as feasibly possible to minimise disturbance of sediments in or near the waterway.
Erosion and Sedimentation	Erosion and Sediment Control Plans (ESCP) will be developed and implemented as part of the soil and water management plan Sediment traps or filters will be used to target the removal of sediments. They will be located at all discharge locations and appropriately maintained. Sediment and erosion control devices will be installed to minimise mobilisation and transport of sediment in accordance with the Blue Book. No stockpiles of materials or storage of fuels or chemicals will be located within high/medium flood risk areas or flow paths. Maintenance and checking of the erosion and sedimentation controls will be undertaken on a regular basis and any subsequent records retained. Sediment will be cleared from behind barriers/sand bags on a regular basis as required and all controls will be managed to ensure they work effectively at all times. The area of exposed surfaces will be minimised. Disturbed areas will be stabilised progressively to ensure that no areas remain unstable for any extended length of time. Soil and sediment that accumulates in erosion and sediment control structures will be reused where practicable during site reinstatement, unless it is contaminated or otherwise inappropriate for reuse. Work will cease where practicable during heavy rainfall events when there is a risk of sediment loss off site or ground disturbance due to waterlogged conditions. Sediment traps or filters will be used to target the removal of sediments, located at all discharge locations and appropriately maintained. Water collected in sediment basins will be re-used during construction or be directed as ‘overflow’ using flow distributors (and scour protection) to nearest existing drainage line Emergency spill procedures will be developed to avoid and manage accidental spillages of fuels, chemicals, and fluids during construction. Visual monitoring of local water quality (ie turbidity, hydrocarbon spills/slicks) will be undertaken on a regular basis to identify any potential spills.

Issue	Proposal specific mitigation measures
Spills and leakages	Emergency spill procedures will be developed to avoid and manage accidental spillages of fuels, chemicals, and fluids during construction. Spill kits will be maintained on-site at all times. Machinery will be checked daily to ensure that no oil, fuel or other liquids are leaking. Refuelling of plant and equipment will be undertaken within designated areas with appropriate controls. Vehicle wash down and/or cement truck washout will occur in a designated bunded area or off-site. The storage of hazardous materials, and refuelling/maintenance of construction plant and equipment, will be undertaken in clearly marked designated areas that are designed to contain spills and leaks. The storage of hazardous materials and dangerous goods will be undertaken in accordance with all relevant Australian Standards and regulatory requirements.
Watercourse geomorphology	Construction works within and/or next to the watercourses and drainage lines will be minimised as much as feasibly possible to minimise disturbance of sediments in or near the watercourse.
Water quality	Sedimentation basins constructed throughout the proposal to capture any sediment-laden runoff would be designed so that the discharge is compliance with the ANZG (2018) water quality guidelines for protection of aquatic ecosystems. During the operation of the proposal runoff from the railway would be captured via longitudinal (cess) drains and diversion drains. Water captured by these drainage structures would be designed to discharge via overland flow ensuring the stability of the downstream landform is not impacted. For drains that exceed the velocities of 1 m/sec, rock check dams or other flow dissipating devices would be used (subject to detailed design). This would reduce the impact risk of scour and the chance of sediment entering the watercourse during high rainfall events.
Surface water monitoring	A surface water monitoring framework would be developed and implemented as part of the soil and water management sub-plan in the CEMP. It would identify: • monitoring locations at discharge points and selected watercourses where works are being undertaken • monitoring parameters including pH, electrical conductivity, dissolved oxygen, temperature, total dissolved solids, total suspended solids, turbidity, major anions and cations, alkalinity, nutrients (oxidised nitrogen, total nitrogen, ammonia and total phosphorus) and contaminants of concern including total recoverable hydrocarbons, benzene, toluene, ethylbenzene, xylenes and naphthalene and total metals (arsenic, cadmium, chromium, copper, lead, nickel, zinc and mercury) • frequency and duration of monitoring. The monitoring framework would include the relevant water quality objectives, parameters, and specific monitoring locations that have been identified based on the hydrological attributes of the receiving watercourses, in consultation with the Department of Planning, Industry and Environment, and the NSW EPA. The proposed surface water monitoring program is provided in section 8.3.

8.4 Proposed monitoring program

A water monitoring program is proposed to be implemented to observe any changes in surface water quality that may be attributable to the proposal and to inform appropriate management responses. The program will be developed in consultation with the NSW EPA and Department of Planning, Industry and Environment and with reference to the ANZG (2018) water quality guidelines.

The monitoring program will include collection of baseline data for comparison to construction and operational monitoring data to understand, and respond to, any impacts from the proposal. An outline of each stage of the monitoring program (baseline, construction, post-construction) is provided in sections 8.4.2, 8.4.3 and 8.4.4.

The surface water quality indicators to be monitored are common to all stages of the monitoring program and are outlined in section 8.4.5.

Sampling locations and monitoring methodology do be undertaken during construction will be further developed during pre-construction and will be subject to availability of surface flow in watercourses. Selected monitoring locations will consider the hydrological attributes of the receiving watercourses.

8.4.1 Monitoring locations

Monitoring locations for surface water quality will be identified during detailed design. It will include collection of samples for analysis from sedimentation basin discharge points, visual monitoring of other points of release of construction waters and monitoring of downstream watercourses. Additional sites such as reference and/or control sites may also be selected as these are useful in determining impacts of a disturbance or pollution event.

8.4.2 Pre-construction (baseline) phase surface water monitoring

Due to the antecedent dry weather conditions, limited water quality data is available to categorise background water quality. It is recommended that baseline water quality monitoring be undertaken prior to construction. As a minimum this should include six months of monitoring during both dry and wet weather.

8.4.3 Construction phase surface water monitoring

The monitoring frequency during construction will be confirmed during detailed design however will include at least monthly construction monitoring at all monitoring sites, including event-based monitoring where practicable, following wet weather events.

Should the results of monitoring identify that the water quality management measures are not effective in adequately mitigating water quality impacts, additional mitigation measures will be identified and implemented as required.

8.4.4 Post-construction surface water monitoring

Surface water monitoring should continue for a minimum of 12 months following completion of construction, or until affected watercourses are certified by suitably qualified and experienced independent specialist as being rehabilitated to an acceptable condition (or as otherwise required by any project conditions of approval).

8.4.5 Surface water monitoring indicators

The surface water monitoring program will include both field parameters and laboratory analysis required to be sampled to protect the relevant water quality objectives outlined in Table 3.1 and may include following indicators:

- field parameters (electrical conductivity, pH, turbidity, dissolved oxygen and temperature)
- heavy metals (arsenic, cadmium, chromium, copper, lead, mercury, nickel, zinc, iron and manganese)
- nutrients (including ammonia, oxidised nitrogen, total nitrogen, total phosphorus, filterable reactive phosphorus)
- chlorophyll-*a*
- oil and grease
- benzene, toluene, ethylbenzene, xylene, naphthalene (BTEXN)
- phenols and poly-aromatic hydrocarbons (PAHs)
- total dissolved solids (TDS)
- total suspended solids (TSS).

Monitoring will also include visual inspection where there is potential release of construction water runoff. Due to the ephemeral nature of the majority of the watercourses monitoring surface water would consider the hydrological attributes of the receiving waterbody.

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9. Conclusions

The proposal traverses the catchments of the Namoi River, the Castlereagh River and the Macquarie-Bogan River. Whilst the catchments rise near the Great Dividing Range, the study area itself is characterised by moderately flat catchments and floodplains. Major land uses within these catchments include grazing, dryland cropping and conservation, with the majority of the construction activities for the proposal occurring within greenfield land.

The watercourses within the study area are generally in poor to moderate geomorphic condition and at the time of inspection exhibited very low to no flow due to the prevailing drought conditions. Water quality was assessed using background data and a single site specific monitoring event (where water was available) with the exception of the Macquarie River which was sampled on two occasions. Many watercourses where data was available exhibited poor water quality that did not meet the nominated environmental values. Key indicators which failed to meet recommended ANZG (2018) guidelines limits included total nitrogen and total phosphorus which were elevated and dissolved oxygen concentrations which were too low to support aquatic ecosystems. Electrical conductivity levels were also elevated, likely due to the very low flow conditions and the intrusion of more saline groundwater which constituted a greater proportion of the baseflow.

The construction and the operation of the proposal has the potential to impact watercourses within the study area. Construction related water quality impacts relate to erosion and sedimentation, particularly during construction of bridges and culverts in flowing watercourses which can results in increased pollutants, particularly nutrients that are bound to sediment. Water quality impacts associated with operation of the proposal can occur from failure of the formation, wear of rolling stock using track, spills from rolling stock or dust of carriages being transported downstream. Additionally, maintenance works required during the life of the proposal could result in dispersion of sediment, pollutants and pesticide from weed control and minor vegetation clearing.

The design of the proposal has considered the potential impacts to water quality which would largely occur during and following rainfall events and has included the following:

- designing flow discharge points to include erosion controls such as rock protection to slow velocities and minimise risk of erosion from runoff that flows into and exits structures such as culverts
- designed bridges and culverts to that there is minimal change or impact to surface flow paths
- designed batters and retaining structures using appropriate slope gradients to minimise erosion
- incorporated water quality control measures into the design such as sedimentation basins, water quality ponds and spill basins as required
- constructing bridge piers in flowing watercourses from barges to minimise sediment disturbance
- designing ballast drainage to discharge to suitable outlets and control points
- works in the majority of watercourses would only be undertaken in dry weather conditions when watercourses are dry
- pre-cast culvert structures would be used, thereby minimising works in watercourses.

To further minimise the impacts to surface water quality a range of measures would be refined and/or implemented during detailed design and the construction and operational phases of the proposal including:

- preparation and implementation of a soil and water management plan as part of the Construction Environmental Management Plan which would be prepared in accordance with the Blue Book and would include measures, processes and responsibilities to minimise the potential for water quality impacts during construction
- management of stockpiles
- emergency spill response procedures
- water quality monitoring via an approved procedure outlined within a soil and water management plan
- installation and management of water quality treatment measures such as sedimentation basins.

Overall, with the implementation of the proposed mitigation measures, the proposal is expected to have minimal impacts on existing background water quality and environmental values during both the construction and operation of the proposal. With due consideration of these proposed management measures to be implemented as part of the proposal construction and operation, there would be minimal adverse cumulative surface water impacts anticipated. The residual risk to SREs and environmental values identified is expected to be low provided the proposed management measures are implemented, maintained and monitored.

10. References

ALA (2020), *The Atlas of Living Australia*. Available at http://www.ala.org.au. Accessed April 2020.

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

ANZG (2018), *Australian and New Zealand Guidelines for Fresh and Marine Water Quality.* Australian and New Zealand Governments and Australian state and territory governments. Canberra ACT, Australia. Available at www.waterquality.gov.au/anz-guidelines.

ASRIS (2013), *Australian Acid Sulfate Soils Map*. Available at https://www.asris.csiro.au/ Accessed November 2018.

Department of Agriculture, Water and the Environment (2020), *Protected Matters Search Tool*. Available at http://www.environment.gov.au/webgis-framework/apps/pmst/pmst.jsf Accessed April 2020.

BOM (2018), *Groundwater Dependent Ecosystems Atlas*. Available at: http://www.bom.gov.au/water/groundwater/gde/ Accessed November 2018.

CSIRO (2006), *Climate Change in the Namoi Catchment,* Prepared for the NSW Government.

DEC (2004), *Use of Effluent by Irrigation*. Department of Environment and Conservation.

DECC (2008a), *Managing Urban Stormwater - Volume 2C Unsealed Roads.*

DECC (2008b), *Managing Urban Stormwater - Volume 2D Main Road Construction.*

DECC (2008c), *Approved Methods for Sampling and Analysis of Water Pollutants in NSW.*

DECCW (2006a), *Castlereagh River Water Quality and River Flow Objectives.* Department of Environment, Climate Change and Water.

DECCW (2006b), *Macquarie-Bogan River Water Quality and River Flow Objectives.* Department of Environment, Climate Change and Water.

DECCW (2006c), *Namoi River Water Quality and River Flow Objectives.* Department of Environment, Climate Change and Water.

DECCW (2006d), *NSW Water Quality and River Flow Objectives – Hunter River*. Department of Environment, Climate Change and Water.

DECCW (2011), *State of the Catchment 2010 – Namoi Region*. NSW Government. Available at: https://www.environment.nsw.gov.au/resources/soc/namoi/10352NAMriver.pdf Accessed February 2020.

DPI (2007), *Key Fish Habitat Maps*. Available at https://www.dpi.nsw.gov.au/fishing/habitat/publications/pubs/key-fish-habitat-maps. Accessed December 2018.

DPI (2012), *Guideline for Watercourse Crossings on Waterfront Land.*

DPI (2013), *Policy and guidelines for fish habitat conservation and management*, Department of Trade and Investment, Regional Infrastructure and Services.

DPI (2015), *Fish and Flows in the Northern Basin: responses of fish to changes in flow in the Northern Murray-Darling Basin* – Valley Scale Report*,* Final report prepared for the Murray-Darling Basin Authority. NSW Department of Primary Industries, Tamworth.

DPI (2016), *Freshwater threatened species distribution maps*. Available at https://www.dpi.nsw.gov.au/fishing/species-protection/threatened-species-distributions-in-nsw/freshwater-threatened-species-distribution-maps, Accessed March 2020.

DPI (2018a), *Basins and Catchments.* Available at https://www.industry.nsw.gov.au/water/basins-catchments/snapshots Accessed December 2018.

DPI (2018b), *Macquarie-Bogan,* NSW Government. Available at: https://www.industry.nsw.gov.au/water/basins-catchments/snapshots/macquarie-bogan, Accessed November 2018.

DPI (2020), *Combined Drought Indicator*. Available at: https://edis.dpi.nsw.gov.au/ Accessed February 2020.

DSEWPaC (2011), *National water quality assessment,* Report prepared by Sinclair Knight Merz for the Australian Government Department of Sustainability, Environment, Water, Population and Communities on behalf of the State of the Environment 2011 Committee. Canberra, 2011.

Environment Protection and Heritage Council, the Natural Resource Management Ministerial Council & the Australian Health Ministers' Conference (2006) *National Guidelines for Water Recycling: Managing Health and Environmental Risks.* November 2006.

Fairfull, S. and Witheridge, G. (2003), *Why do Fish Need to Cross the Road? Fish Passage Requirements for Watercourse Crossings.* NSW DPI Cronulla.

JacobsGHD 2020a, *ARTC Inland Rail Narromine to Narrabri Aquatic Ecology Assessment*.

JacobsGHD 2020b, *ARTC Inland Rail Narromine to Narrabri Biodiversity Development Assessment Report*.

JacobsGHD 2020c, *ARTC Inland Rail Narromine to Narrabri Groundwater Assessment*.

JacobsGHD 2020d, *ARTC Inland Rail Narromine to Narrabri Flooding and Hydrology Assessment*.

Landcom (2004), *Managing Urban Stormwater - Soils and Construction*, Volume 1, 4th Edition, Sydney.

Mawhinney, W. (2011), *Namoi Water Quality Project 2002 – 2007*. NSW Office of Water.

MDBA (2018), *Catchments*. Available online: https://www.mdba.gov.au/discover-basin/catchments Accessed December 2018.

NHMRC (2008), *Guidelines for Managing Risks in Recreational Water,* Australian Government.

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

NSW Environment, Energy and Science Group (2020), *BioNet* - the Atlas of NSW Wildlife Threatened Species Profile Database. Available at https://www.environment.nsw.gov.au/atlaspublicapp/ Accessed April 2020.

NSW Environment Protection Authority (2015) *NSW State of the Environment Report 2015*.

NSW Office of Water 2011, *Water resources and management overview – Namoi catchment,* NSW Government.

Outhet, D., Young, C., Lampert, G., Short, A. and Schneider, G. (2004), *River Style Geomorphic Fragility,* Unpublished internal draft paper for use throughout NSW by the Department of Infrastructure, Planning and Natural Resources and the Catchment Management Authorities.

Roads and Traffic Authority (2005), *Guidelines for the Management of Acid Sulfate Materials: Acid Sulfate Soils, Acid Sulfate Rock and Monosulfidic Black Ooze.* Roads and Traffic Authority, NSW.

Serov P., Kuginis. L., Williams, J.P. (2012), *Risk assessment guidelines for groundwater dependent ecosystems, Volume 1 – The conceptual framework,* NSW Department of Primary Industries, Office of Water, Sydney.

Strahler, A.N. (1952), *Hypsometric (area-altitude) analysis of erosional topography.* Bull. Geol. Soc. Am., 63, 1117-1142.

Water NSW (2015), *Chaffey Dam safety upgrade and augmentation*.

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