APPENDIX N

Groundwater Technical Report

NORTH STAR TO NSW/QUEENSLAND BORDER ENVIRONMENTAL IMPACT STATEMENT

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

Inland Rail North Star to NSW/QLD Border

Appendix N: Groundwater Technical Report

Australian Rail Track Corporation

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Abbreviations

Abbreviation	Explanation
AIAM	Adverse Impact Assessment Methodology
ANZECC	Australian and New Zealand Environment and Conservation Council
ANZECC/ARMCANZ 2000	Australian and New Zealand Guidelines for Fresh and Marine Water Quality
ARMCANZ	Agriculture and Resource Management Council of Australia and New Zealand
ARTC	Australian Rail Track Corporation Limited
BoM	Bureau of Meteorology
CEMP	Construction and Environmental Management Plan
CIA	Cumulative Impact Assessment
CMA	Catchment Management Authority
CRD	cumulative rainfall departure
DNRME	Department of Natural Resources, Mines and Energy
EAP	Environmental Assessment Procedure
EC	Electrical conductivity (µS/cm)
EP&A Act	Environmental Planning and Assessment Act 1979 (NSW)
FFJV	Future Freight Joint Venture’s
GAB	Great Artesian Basin
GDE	groundwater dependent ecosystems
Inland Rail	Melbourne to Brisbane Inland Rail
km	kilometres
L/s	litres per second
LGA	Local Government Area
m	metre
mAHD	metres above Australian Height Datum
mbgl	metres below ground level
MDBA	Murray Darling Basin Authority
ML/yr	Mega litre per year
NS2B	North Star to Border
NSW	New South Wales
NSW DPI	New South Wales Department of Primary Industry
NSW EPA	New South Wales Environment Protection Authority
OEMP	Operations Environmental Monitoring Program
SEARs	Secretary’s Environmental Assessment Requirements
TDS	Total dissolved solids (in relation to water quality)
the proponent	Australian Rail Track Corporation Ltd
TOC	Top of Collar
WAL	Water Access Licence
WQOs	Water Quality Objectives
WSP	Water Sharing Plan

1 Introduction

1.1 Proposal background

Future Freight Joint Venture (FFJV) was engaged by Australian Rail Track Corporation Ltd (ARTC) to undertake the groundwater environmental assessment in support of an Environment Impact Assessment (EIS) submission for the North Star to NSW/QLD Border proposal (the proposal). The proposal is a part of the Inland Rail Program that will form a national freight network approximately 1,700 kilometres (km) in length from Melbourne to Brisbane.

The currently proposed alignment for the proposal has been selected following a succession of geotechnical, engineering, and environmental desktop reviews and site assessments (2015 Alignment Development and Assessment Report). The proposal provides a connection between the Inland Rail sections Narrabri to North Star (N2NS) in the south and the NSW/QLD Border to Gowrie Inland Rail Project (B2G) in the north.

The proposal will comprise approximately 30 km of new track between the town of North Star and the NSW/QLD border. It will consist of approximately 25 km of new track within the existing Boggabilla rail corridor towards Whalan Creek, followed by a 5 km section within a greenfield rail corridor towards the NSW/QLD border. The centre point of the Macintyre River defines the NSW/QLD border (refer Figure 1.1).

The proposal includes construction of a 7 km section across the Macintyre River towards Kurumbul to tie into the Queensland Rail (QR) South Western Line. This 7 km section will be assessed in a separate EIS as part of B2G.

1.2 Scope and objectives

The objectives of the groundwater environmental assessment, in line with the objectives of the NSW Planning and Environment Secretary's Environmental Assessment Requirements (SEARs) (DP&E 2018), are provided in Table 1.1.

This groundwater environmental assessment includes a description of the groundwater resources, an assessment of environmental values, conceptualisation of the groundwater resources, and the assessment of potential impacts of the proposal by application of a significance assessment model.

Table 1.1 Groundwater related proposal objectives

Relevant SEARs objectives	SEARs item	Relevant section
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 proposal, including stream orders, as per the Biodiversity Assessment Method (BAM).	Item 9-1	Section 4.3 Section 5 Section 6 Section 9 Section 10
The Proponent must prepare a detailed water balance for ground and surface water including the proposed intake and discharge locations, volume, frequency and duration, sources, security and licensing requirements.	Item 9-2	Section 7.2
The Proponent must assess (and model if appropriate) the impact of the construction and operation of the proposal and any ancillary facilities (both built elements and discharges) on surface and groundwater hydrology in accordance with the current guidelines, including:		
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	Item 9-3a	Section 6.1 Section 6.7 Section 9

Relevant SEARs objectives	SEARs item	Relevant section
Impacts from any permanent and temporary interruption of groundwater flow, including the extent of drawdown, barriers to flows, implications for groundwater dependent surface flows, ecosystems and species, groundwater users and the potential for settlement	Item 9-3b	Section 9 Section 10
Changes to environmental water availability and flows, both regulated/licensed and unregulated/rules-based sources	Item 9-3c	Section 9.2.2 Section 9.2.3 Section 9.2.4
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	Item 9-3e	Surface Water Quality Technical Report (FFJV 2020)
Water take (direct or passive) from all surface and groundwater sources with estimates of annual volumes during construction and operation	Item 9-3f	Section 9.1.6 Surface Water Quality Technical Report (FFJV 2020)
The Proponent must identify any requirements for baseline monitoring of hydrological attributes	Item 9-4	Section 10.3
The Proponent must:		
State the ambient NSW Water Quality Objectives (NSW WQO) and environmental values for the receiving waters relevant to the proposal, including the indicators and associated trigger values or criteria for the identified environmental values	Item 10-1a	Section 6.9.1 Section 6.9.3
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	Item 10-1b	Section 9.2.6
Assess the significance of any identified impacts including consideration of the relevant ambient water quality outcomes	Item 10-1d	Section 11.2
Demonstrate how construction and operation of the proposal will, to the extent that the proposal can influence, ensure that: Where the NSW WQOs for receiving waters are currently being met, they will continue to be protected Where the NSW WQOs are not currently being met, activities will work toward their achievement over time	Item 10-1e	Section 9.2 and Section 10
Demonstrate that all practical measures to avoid or minimise water pollution and protect human health and the environment from harm are investigated and implemented	Item 10-1g	Sections 9.2 and 9.3
Identify sensitive receiving environments (which may include marine waters downstream) and develop a strategy to avoid or minimise impacts on these environments	Item 10-1h	Section 6.7 Section 10
Identify proposed monitoring locations, monitoring frequency and indicators of surface and groundwater quality	Item 10-1i	Surface Water Quality Technical Report (FFJV 2020)

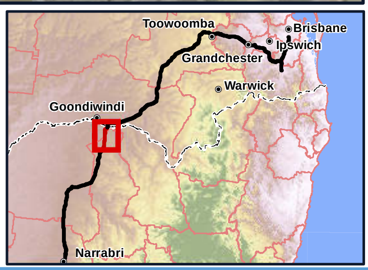
The description and assessment of groundwater resources are compiled in this technical groundwater report to supplement the EIS submission.

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

Map by: LCT/GN Z:\GIS\GIS_270_NS2B\Tasks\270-EAP-201910311020_Groundwater_Figures\270-EAP-201910311020_ARTC_Fig1.1_Proposal_Location_Rev1.mxd Date: 31/01/2020 16:25

Legend

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



A4 scale: 1:170,000

0 1 2 3 4 5 km

Future Freight
Integrating Community, Environment and Engineering

Date: 31/01/2020 Version: 1

Coordinate System: GDA 1994 MGA Zone 56

North Star to NSW/QLD border

Figure 1.1: Proposal location

2 Legislation and policy

This groundwater technical report has been prepared with consideration to key legislation, policies, standards and guidelines from the Commonwealth of Australia and the State of New South Wales. This section provides an overview of legislation relevant to the proposal.

2.1 Commonwealth legislation

2.1.1 Commonwealth Environment Protection and Biodiversity Conservation Act 1999

The *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) is the Australian Government's central piece of environmental legislation. It provides a legal framework to protect, manage and regulate nationally and internationally important environmental assets, defined in the EPBC Act as matters of national environmental significance (MNES). This Act includes the regulation of activities that may impact upon Commonwealth land.

The Department of the Environment and Energy (DoEE), who are responsible for administering the EPBC Act, has determined that the proposal does not have the potential for significant impacts on water resources. However, the EIS includes a specific section which focusses on MNES related to groundwater resources.

2.2 New South Wales legislation

2.2.1 Water Management Act 2000

The *Water Management Act 2000* (NSW) provides a framework for sustainable and integrated water management across NSW. The key objectives are as follows:

- To apply the principles of ecologically sustainable development
- To protect, enhance and restore water sources, their associated ecosystems, ecological processes and biological diversity and their water quality
- To recognise and foster the significant social and economic benefits to the State that result from the sustainable and efficient use of water, including:
  - Benefits to the environment
  - Benefits to urban communities, agriculture, fisheries, industry and recreation
  - Benefits to culture and heritage
  - Benefits to the Aboriginal people in relation to their spiritual, social, customary and economic use of land and water
- To recognise the role of the community, as a partner with government, in resolving issues relating to the management of water sources
- To provide for the orderly, efficient and equitable sharing of water from water sources
- To integrate the management of water sources with the management of other aspects of the environment, including the land, its soil, its native vegetation and its native fauna
- To encourage the sharing of responsibility for the sustainable and efficient use of water between the Government and water users
- To encourage best practice in the management and use of water.

The main instruments applied to meet these objectives are the Water Management (General) Regulation 2018, Water Sharing Plans (WSPs) and the NSW Aquifer Interference Policy which are discussed further below.

2.2.2 Water Act 1912

The *Water Act 1912* (NSW) is gradually being phased out across NSW and replaced by the *Water Management Act 2000*. The *Water Act 1912* is relevant where there an activity leads to a take from a groundwater or surface water source not currently covered by a Water Sharing Plan. As Water Sharing Plans already apply to the proposal site, the *Water Act 1912* does not apply.

2.2.3 Water Management (General) Regulation 2018

This regulation details procedural, technical and licencing requirements under the *Water Management Act 2000*, as well as the functions and powers of water supply authorities.

2.2.4 Protection of the Environment Operations Act 1997

The *Protection of the Environment Operations Act 1997* (NSW) is the central piece of environment protection legislation overseen by the NSW Environment Protection Authority (NSW EPA).

Key features of this legislation include:

- Protection of the environment policies (PEPs)
- Environment protection licensing
- Regulation of scheduled and non-scheduled activities:
  - The NSW EPA is the regulatory authority for scheduled activities (activities declared under Schedule 1 of the *Protection of the Environment Operations Act 1997*)
  - The NSW EPA is also the regulatory authority for non-scheduled activities, where activities are undertaken by a public authority.

The proposal will be a scheduled activity (railway systems activities under Schedule 1) during construction and an environment protection licence would be required for this activity.

2.3 Water sharing plans

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

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

Typically, the *Water Management Act 2000* requires a:

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

There are three WSPs relevant to groundwater for the proposal site as follows.

2.3.1 Water Sharing Plan: NSW Border Rivers Unregulated and Alluvial Water Sources (June 2012)

This WSP is applicable to 13 surface water and four alluvial groundwater sources which are combined within the same plan due to the highly connected nature of these systems (NSW DPI 2012a).

Alluvial water sources under this plan include the NSW Border Rivers – Downstream Keetah Bridge alluvial source associated with quaternary alluvium from the Macintyre - Dumaresq River system. This alluvial source underlies the proposal at the northern portion of the alignment from approximately Chainage (Ch) 25 km towards the NSW/QLD border. From approximately Ch 25 km down to North Star shallow groundwater is associated with the Croppa Creek and Whalan Creek surface water source and related alluvium.

Due to the shallow nature of these alluvial systems, this WSP is considered the most significant for the proposal activities.

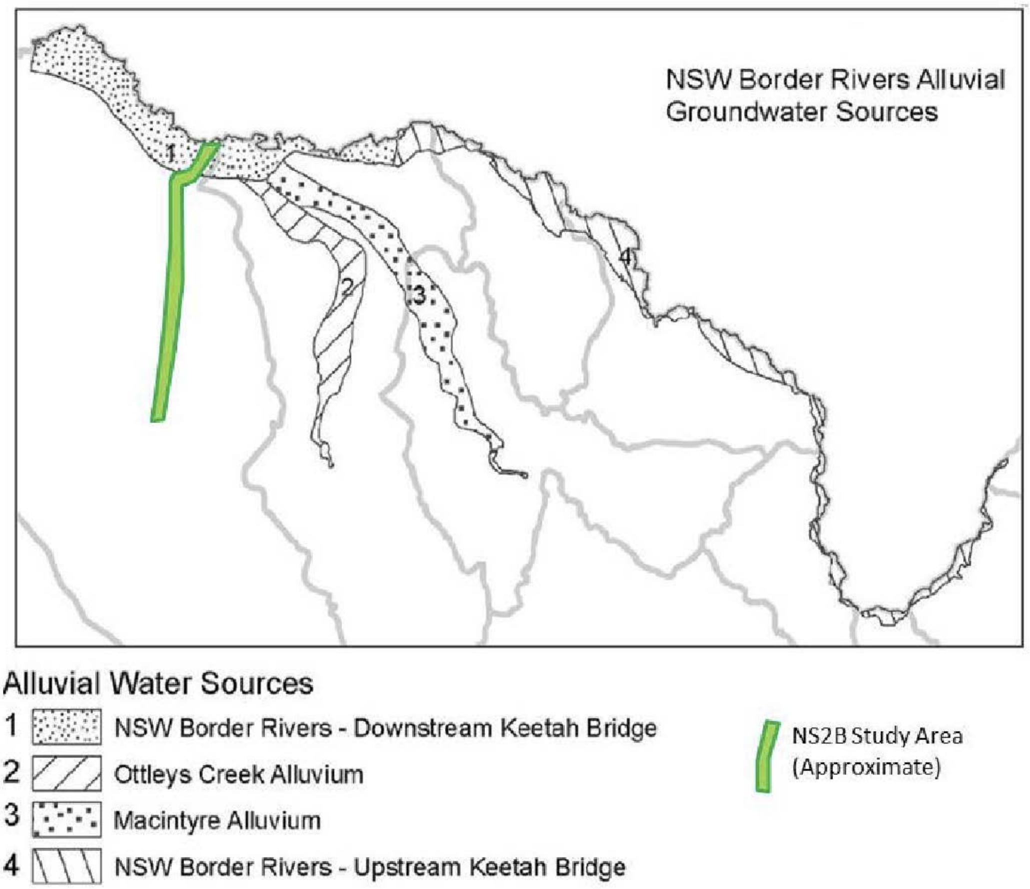


Figure 2.1 **Overview of New South Wales Border Rivers Alluvial Water Sources**

Source: Modified from NSW DPI 2012a

2.3.2 Water Sharing Plan: NSW Border Rivers Regulated River Water Source (June 2009)

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

2.3.3 Water Sharing Plan: NSW Great Artesian Basin Groundwater Sources (June 2008)

This plan applies to sandstone aquifers of the Great Artesian Basin (GAB) and includes five identified water sources. The proposal lies within the Eastern Recharge Ground Water Source which represents a region of groundwater recharge to the GAB via outcrop of the Pilliga Sandstone and overlying strata (NSW DWE 2009b). This WSP sets long-term annual average extraction limits (LTAAEL) for this groundwater source which have been developed for high volume irrigation in areas enveloping the proposal.

Many registered bores identified within 10 km of the proposal (refer Section 6.2) intersect/constructed within fractured rock aquifers related to this water source. The water-bearing zone is typically encountered between 40 and 200 metres below ground level (mbgl). Given the greater depth of this water source it is considered less significant to the proposal activities.

2.4 New South Wales policies

2.4.1 NSW Aquifer Interference Policy

The NSW Aquifer Interference Policy (NSW DPI 2012b) includes requirements for the evaluation of aquifer interference activities administered under the *Water Management Act 2000*. The main components to this policy are:

- All water taken must be properly accounted for
- The activity must address minimal impact considerations for impacts on the water table, water pressure and water quality
- Planning for measures in the event that the actual impacts are greater than predicted, including making sure that there is sufficient monitoring in place.

2.4.2 Sustainable Design Guidelines – Version 4

The Sustainable Design Guidelines (Transport for NSW 2017) aim to achieve sustainable development practices through the application of sustainability initiatives into the design and construction of transport infrastructure projects.

The primary aims of the guidelines include:

- Ensuring that the development, expansion and management of the transport network is sustainable and resilient to climate change
- Minimising the impacts of transport on the environment, encompassing transport operations, infrastructure delivery and maintenance and corporate activities.

2.4.3 NSW Groundwater Dependant Ecosystems Policy

The management of groundwater dependent ecosystems (GDEs) in NSW is outlined by the NSW Groundwater Dependent Ecosystems Policy (DLWC 2002) and includes the following key principles:

- The scientific, ecological, aesthetic and economic values of groundwater-dependent ecosystems, and how threats to them may be avoided, should be identified and action taken to ensure that the most vulnerable and the most valuable ecosystems are protected
- Groundwater extraction should be managed within the sustainable yield of aquifer systems, so that the ecological processes and the biodiversity of dependent ecosystems are maintained and/or restored. Management may include setting threshold levels critical for ecosystem health, and controls on extraction near GDEs.
- Priority should be given to ensuring that sufficient groundwater of suitable quality is available when needed:
  - For maintaining ecosystems which are known to be, are likely to be, groundwater dependent
  - GDEs which are under an immediate or high degree of threat from groundwater-related activities.

3 Methodology

3.1 Study area

The study area for the purposes of this groundwater technical report includes an area within a 1 km radius of the centre line of the proposal site. Where there is a paucity of available groundwater data, such as limited registered bore data and groundwater dependent ecosystems (GDEs), the search radius has been increased beyond the 1 km study area (i.e. 10 km). Potential borrow pits located up to 15 km from the proposal centre line have also been evaluated as part of this groundwater impact assessment.

3.2 Approach

To achieve the study scope and objectives outlined in the SEARs, the groundwater impact assessment comprises two components, a description of the existing hydrogeological environment and an assessment of the impacts of the proposal on that environment. To meet the requirements, the groundwater assessment comprised a staged approach to ensure the correct scientific development of the groundwater study:

- **Stage 1 – Desktop Review and Site Investigations:** Publicly available groundwater datasets and geological reports were reviewed to characterise baseline groundwater conditions, to identify relevant groundwater environmental values, to determine existing groundwater uses, and to develop a conceptual groundwater model.

  Groundwater investigations were completed during the period July to October 2018 concurrently with geotechnical investigations. This site-specific groundwater data was used to further refine and describe the baseline conditions and the conceptual model.

- **Stage 2 – Potential Groundwater Impacts and Significance Assessment:** Potential short and long-term impacts to groundwater (both local and regional) resources were assessed based on a review of the proposed rail alignment design (construction and operation) and the existing hydrogeological regimes identified in Stage 1.

  A qualitative significance assessment was undertaken in accordance with the Inland Rail Programme – Environmental Assessment Procedure (ARTC 2017). This approach considers the sensitivity (or vulnerability) of an environmental value and the magnitude of the impact to develop a significance rating. This process if discussed further in Section 3.3. Cumulative impacts were also considered during this stage (refer Section 11.3).

- **Stage 3 – Technical Report Preparation:** Preparation of this groundwater technical report which contains baseline groundwater data, a conceptual hydrogeological model, assessment of potential groundwater impacts, the results of the significance assessment, and recommended mitigation measures.

  The key outcomes of this technical report will be used to compile Chapter 13 of the EIS for the proposal.

3.3 Assessment methodology

A standardised approach to the groundwater impact assessment has been adopted.

Following the identification and assessment of baseline environmental values, the potential impacts of the proposal are described and assessed, and mitigation measures prescribed. Potential cumulative impacts are considered (refer Section 11.3).

The sensitivity of the environmental value and the magnitude of the impacts are the key elements considered to determine significance. These aspects were assessed using a significance matrix allowing for the determination of the appropriate significance classifications, as detailed in Table 3.1.

Table 3.1 Classifications adopted for the significance assessment

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

3.4 Data sources

Data used in this assessment is based on a review of publicly available information and an ongoing geotechnical assessment for the proposal. Regional (catchment) scale studies have also been reviewed to describe the existing groundwater resources and thus allow for the assessment of the proposal on the current groundwater status. It is noted that while there are ongoing investigations, these reports are not held within the public domain but have informed various aspects of the project to allow for an accurate understanding of the existing environment and, in turn, this accuracy is incorporated into the significance assessment for development of bespoke mitigation and management measures for identified potential impacts.

The description of the existing hydrogeological regime within the study area and the groundwater impact assessment is based on the following information sources (refer Table 3.2):

Table 3.2 Data sources for the Groundwater Technical Report

Data	Source
Hydrology/ climate	Historical Climate Database - Bureau of Meteorology (BoM) Appendix G: Surface Water Quality
Soil types	Inland Rail: Phase 2 - North Star to Border - Geotechnical Report – Factual (May 2019)
Geology	Inland Rail: Phase 2 - North Star to Border - Geotechnical Report – Factual (May 2019) Stratotectonic Map of New South Wales 1:1 000 000 (Scheibner 1997) Goondiwindi 1:250,000 Geological Sheet (Senior 1973) Toenda-1 Well Completion Report – Orion Petroleum Ltd QLD Registered Bores Online Database (Department of Natural Resources and Mines (DNRME) NSW Registered Bores Online Database (NSW Office of Water)
Groundwater levels and quality	NSW Registered Bores Online Database (NSW Office of Water) QLD Registered Bores Online Database (Department of Natural Resources and Mines (DNRME) Inland Rail: Phase 2 - North Star to Border - Geotechnical Report – Factual (May 2019) Inland Rail – Section 270 (North Star to Border) 100% Feasibility Design Scope of Works – Hydrogeology (September 2019)
GDEs	GDE Groundwater Dependent Ecosystem Atlas - BoM: (http://www.bom.gov.au/water/groundwater/gde/map.shtml)
Groundwater use and management	Gwydir Subregion - Bioregional Assessment Program – Australian Federal Government, Water Sharing Plans – (NSW Department of Primary Industries) Queensland Globe – Water Management Datasets (https://qldglobe.information.qld.gov.au/)

4 Physical environment

4.1 Location

The proposal is in north western NSW along a south to north alignment between the town of North Star and the Macintyre River at the NSW/QLD border (refer Figure 1.1). The alignment lies within the Border Rivers Catchment, which comprises an area of 49,500 km^2 across NSW and Queensland (DPI Water 2012a).

4.2 Land use

The primary land use surrounding the proposal site includes grazing, dryland cropping, irrigated production, and intensive industries such as feedlots and forestry.

Grazing and cropping comprise approximately 90 per cent of the land use within the wider Border Rivers Catchment (DPI Water 2012b).

Surface water and groundwater are utilised for irrigation in the area with cotton the dominant irrigation crop followed by other crops such as barley and sorghum.

4.3 Topography and drainage

The proposal site is characterised by flat lying alluvial plains drained by a network of intermittent watercourses. A review of topography from satellite imagery and elevation contours from the 1:100,000 Coppa Creek and Yetman topographic sheets indicates that surface elevation across the site ranges from 260 m Australian Height Datum (mAHD) in the south near North Star and slopes gently northwards to 220 m AHD at the Macintyre River near the NSW/QLD border.

The northern portion of the Study area consists of gently sloping farmland within and adjacent to the flood plains of the Dumaresq and Macintyre Rivers. The southern portion the alignment lies within or adjacent to the flood plains of minor flowing creeks flowing northwest to Whalan Creek. It is noted Strayleaves Creek is a surface water feature of interest for the proposal (located south of the proposal) and is considered an offshoot of Whalan Creek; therefore, for the purposes of this study, Whalan Creek is considered to include Strayleaves Creek.

A total of five watercourses are crossed by the proposed alignment and are summarised in Table 4.1 and included on Figure 4.2. Most watercourses intersected by the alignment are considered to have limited flow, generally only after rainfall events. Incised river beds are evident at Whalan Creek and at the larger Macintyre River channel at the NSW/QLD border. Stream orders presented in Table 4.1 were determined via the Strahler method which begins with new headwater flow paths assigned the number 1 with stream order increasing as streams of the same order intersect.

The Border Rivers catchment includes the catchments of the Dumaresq, Severn, Macintyre and Barwon Rivers which drain from the Great Dividing Range located east of the proposal site. River flow in the Macintyre River downstream of the Dumaresq River is regulated by both Glenlyon Dam and Pindari Dam (NSW DPI 2015a). Consequently, the operation of both the Glenlyon and Pindari dams have altered downstream flows, particularly by reducing low flow variability.

Table 4.1 Summary of watercourses intersected by the proposal site

Watercourse name	Chainage	Stream Order (Strahler)	Channel morphology from satellite imagery
Mobbindry Creek	Ch 5.7 km	3	Intermittent flow likely. Poorly defined, symmetrical floodplain.
Back Creek	Ch 8.1 km	3	Intermittent flow likely. Well defined channel, highly modified.
Forrest Creek	Ch 16.5 km	3	Intermittent flow likely. Weakly defined channel.
Whalan Creek	Ch 29.6 km	2	Well defined channel, larger than other creeks along the NS2B alignment. Likely to flow seasonally.
Macintyre River	Ch 30.6 km	6	Permanent waterway. Incised channel with well vegetated riparian flood plain. This river is regulated.

4.4 Climate

A seasonal rainfall pattern applies to the region with dry stable winters and warm to hot summers with moderate to heavy rainfall recorded during summer storm activity. The nearest weather stations to the proposal are the BoM Station 041521 at Goondiwindi Airport (1991 to 2015) and Station 041038 at Goondiwindi Post Office (1879 to 1991). These stations are approximately 17 km to the northwest of the proposal near the NSW/QLD border and have detailed climate records for the period 1879 to 2015. This climate data is considered representative of conditions at the proposal site and a summary is provided in Table 4.2.

Table 4.2 Climate summary for Goondiwindi Airport (Station 041521) and Goondiwindi Post Office (Station 041038) for the period 1887 to 2015

Month	Mean maximum temperature (ºC)		Mean minimum temperature (ºC)		Mean rainfall (mm)		Mean daily evaporation (mm)*	
	1879 to 1991[a]	1991 to 2015[b]	1879 to 1991[a]	1991 to 2015[b]	1879-1991[a]	1991 to 2015[b]	1879 to 1991[a]	1996 to 2015[b]
January	34.1	34.0	19.9	20.3	78.5	93.3	NA	10
February	33.1	32.6	19.5	19.7	69	72.8	NA	8.8
March	30.9	31.0	17.4	17.2	59.5	60.0	NA	7.4
April	26.9	27.7	13.2	13.0	38.7	20.7	NA	5.3
May	22.3	23.1	9.1	8.60	42.9	37.5	NA	3.5
June	18.8	19.8	6.1	6.00	40.3	33.2	NA	2.6
July	17.9	19.1	4.8	4.60	41.9	33.5	NA	2.7
August	20	21.5	6.	5.60	33.1	29.4	NA	4.0
September	23.9	25.5	9.2	9.40	39	31.7	NA	6.1
October	28	28.9	13.3	13.5	48.7	45.5	NA	7.9
November	31.4	31.3	16.6	17.1	59.8	64.1	NA	9.2
December	33.6	32.3	18.8	18.8	69.8	85.2	NA	9.5
Mean annual	**26.7**	**27.2**	**12.8**	**12.8**	**621.1**	**619**	**NA**	**6.4**

Table notes:

1. Goondiwindi Post Office (Station 041038)
2. Goondiwindi Airport (Station 041521)

Source: BoM Climate Statistics

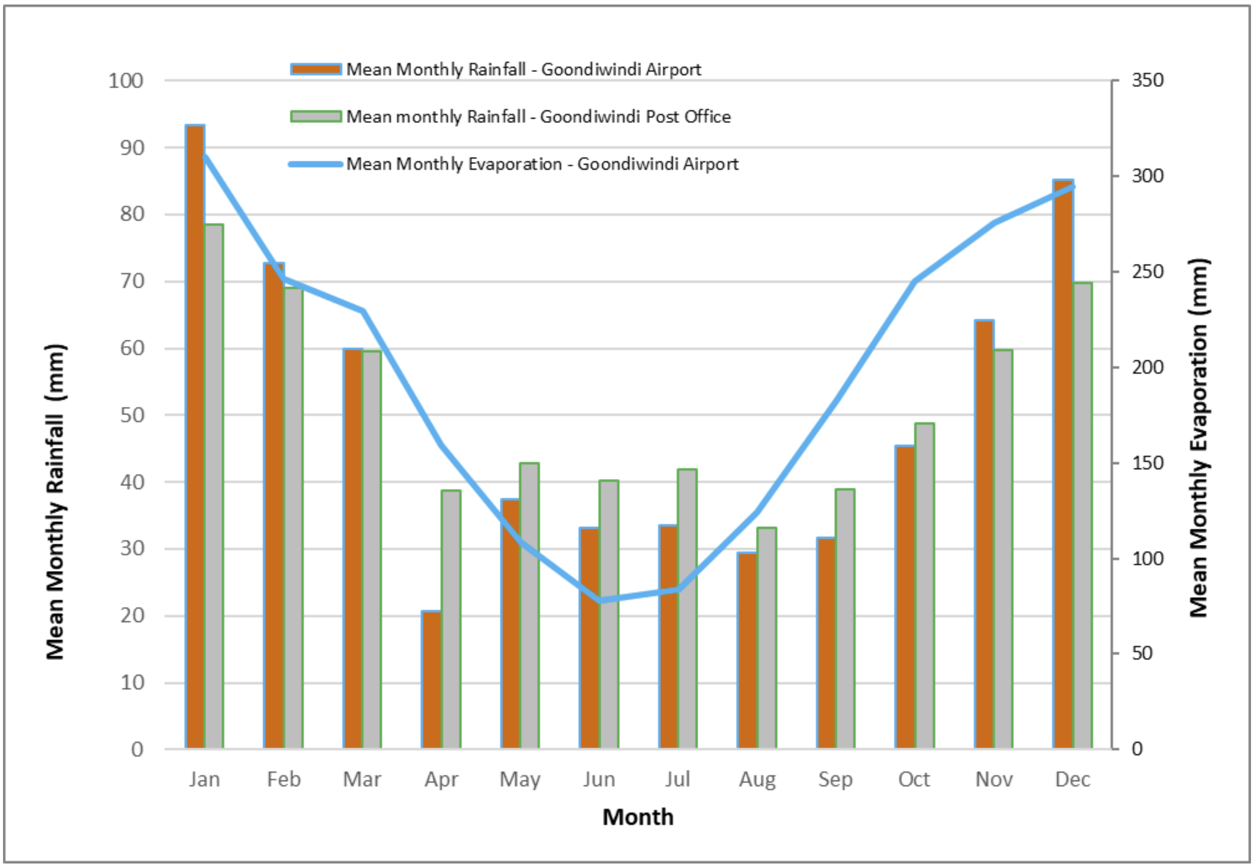


Figure 4.1 **Mean monthly rainfall and evaporation at Goondiwindi Airport (1995 to 2015) and Goondiwindi Post Office (1879 to 1991)**

Figure note:

There is no available evaporation data for Goondiwindi Post Office.

The summary data shows that the mean annual rainfall is approximately 619 mm per year with the average daily evaporation of 6.4 mm (approximately 2,336 mm/year) (refer Figure 4.1 and Table 4.2). This indicates that evaporation exceeds rainfall most of the year and that a negative climate budget prevails in the region. Model predictions on future aquifer recharge trends due to global warming indicate much of eastern Australia, including the Border Rivers Region, could experience a decrease in recharge (Commonwealth Scientific and Industrial Research Organisation (CSIRO) 2011). This decrease is projected for the period 2030 to 2050.

Cumulative rainfall deviation from long-term monthly rainfall records at Goondiwindi Airport are presented in Figure 4.3. Under steady-state conditions (i.e. no groundwater abstraction taking place), the trends in this plot may provide an indication of water level response in unconfined aquifers which receive direct rainfall recharge. A positive trend indicates periods of above average rainfall where increased groundwater recharge can occur in unconfined aquifers. A negative slope indicates periods of below average rainfall where decreased groundwater recharge may occur in unconfined aquifers.

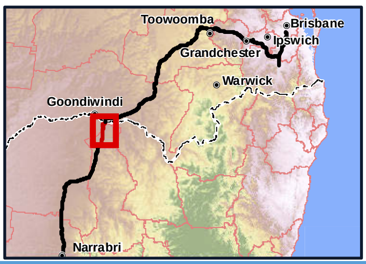
The period 1991 to 2015 at Goondiwindi Airport (Station 041521) presented in Figure 4.3 is considered representative of conditions along the proposal. The graph indicates:

- An increasing trend from 1995 to 2000 characterised by above average rainfall
- A decreasing trend from 2005 to 2010 characterised by below average rainfall followed by a period of increased rainfall from 2010 to 2012
- The region has experienced below average rainfall more recently (2013 to 2015).

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

Legend

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



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0 1 2 3 4 5km

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Coordinate System: GDA 1994 MGA Zone 56

North Star to NSW/QLD border

Figure 4.2: Proposal topography and main surface water features.

Figure 4.3 Cumulative deviation from long term mean rainfall for Goondiwindi Airport (1991 to 2015)

5 Geology

5.1 Regional geology

5.1.1 Basement and structural geology

Structurally the Proposal lies within the uplifted Tamworth Zone, a north trending fault bound basement block underlying the depositional Gunnedah and Surat basins (Scheibner, 1996). The New England Fold Belt lies to the east of this zone.

Based on regional mapping in the 1:250 000 Goondiwindi Sheet (Mond et al. 1972) and the NSW 1:1 500 000 Structural Framework Map Sheet (Scheibner, 1996), two major fault systems are evident in the region (refer Figure 5.1 and Figure 5.2):

- The Peel Fault is a major thrust system located approximately 8 km to the east of the study area. Near the NSW/QLD Border the Peel Fault is near the alignment but there is limited to no surface expression of this basement structure.
- The Goondiwindi Fault is a major basement thrust fault located approximately 20 km to the west of the study area and has been considered inactive since the Triassic period.

Minor faults have not been mapped in regional geological mapping and this is likely due to the extensive Quaternary cover of alluvium and colluvium across the region. A large dryland salinity scar near the Keetah Bridge at the NSW/QLD border has been associated with an offset from the Peel Fault. Here, the Peel Fault is postulated to provide a conduit for saline groundwater to infiltrate the soil profile and exacerbated erosion in this area. It is noted that this salinity scar is not close to the proposal, located over 28 km to the east of the proposal.

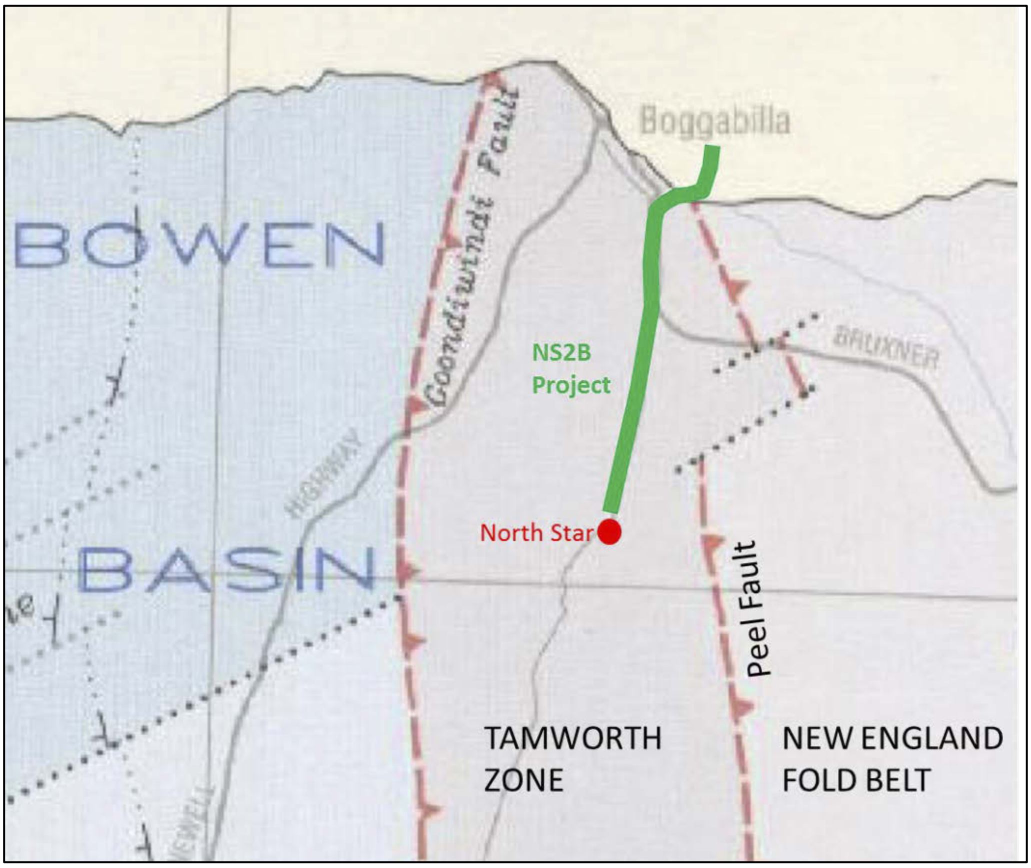


Figure 5.1 **Basement geology surrounding the proposal site**

Source: Modified from Scheibner 1996

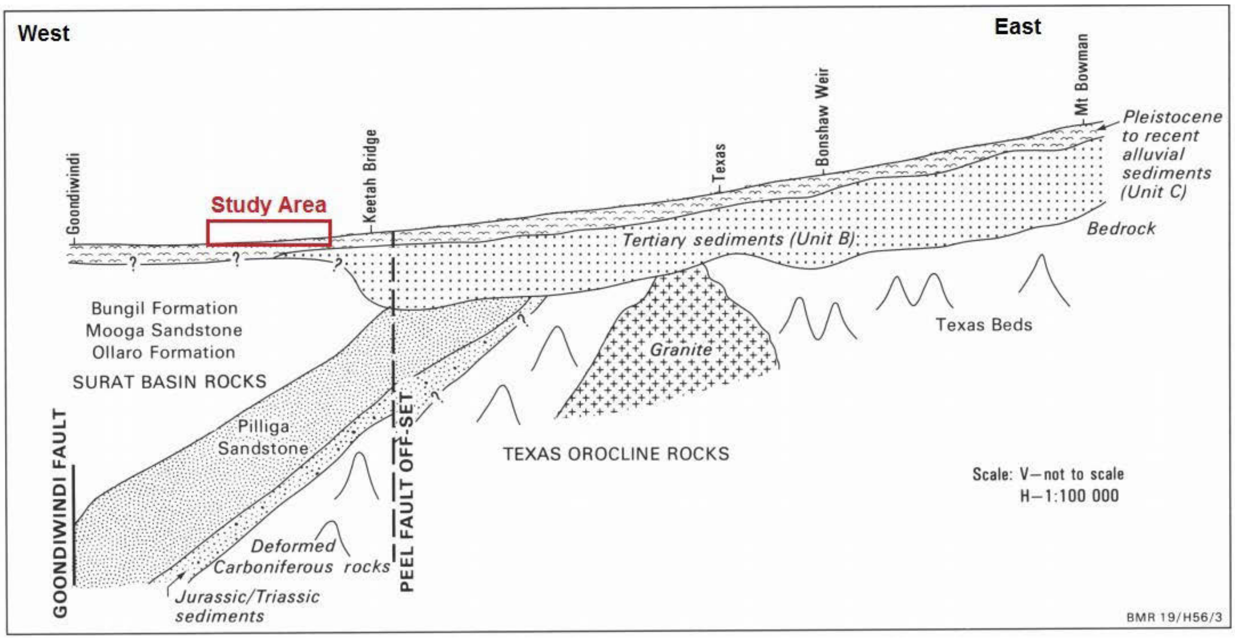


Figure 5.2 **Representative geological cross section**

Source: Modified from Knight et al. 1989

5.1.2 Sedimentary basins

The proposal lies in a region underlain by the Permo-Triassic aged Gunnedah Basin at depth; the Jurassic-Cretaceous aged Surat Basin overlies the Gunnedah Basin and underlies the proposal.

The Gunnedah Basin consists of marine and non-marine units lying unconformable on early Permian and older basement rocks (Ransley et al. 2015). This basin forms the central portion of the Sydney-Gunnedah-Bowen Basin system, a Permo-Triassic foreland basin system of eastern Australia. The Gunnedah Basin strata is likely to underlie the proposal but given the depth of these strata (>1,000 mbgl) is not considered significant for this groundwater technical report.

Overlying the western portion of the Gunnedah Basin is the Surat Basin which consists of clastic Jurassic and Cretaceous aged marine sediments. The Surat Basin began forming during a new phase of thermal subsidence after the Hunter-Bowen orogeny (Fielding et. al. 1993). The proposal is in the eastern extent of the Surat Basin on an uplifted block bound by the Goondiwindi and Peel fault systems.

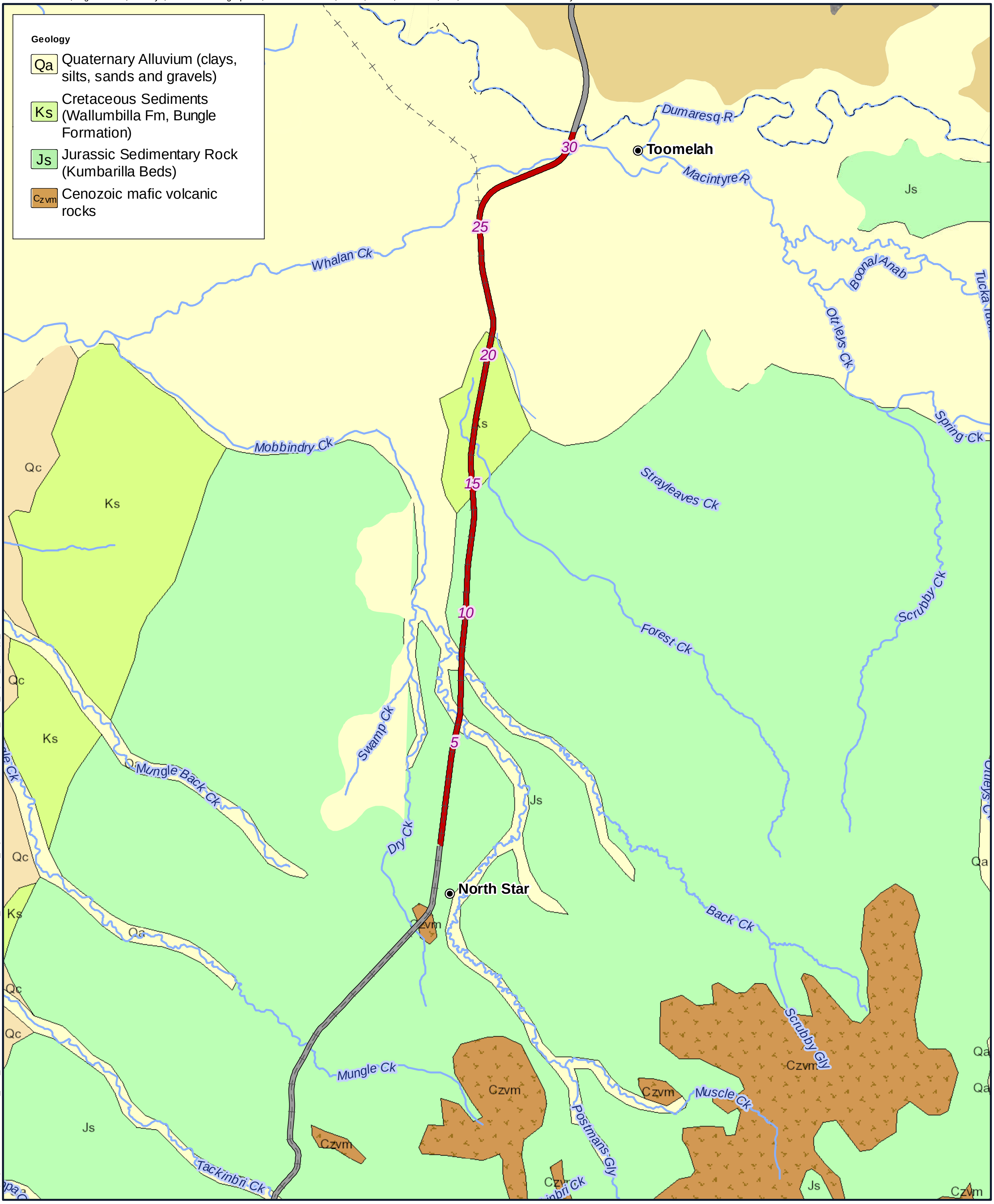
The Surat Basin forms an important sub-basin within the GAB (Ransley et al. 2015). Most registered bores installed in fractured rock aquifers tap into the Surat Basin strata near the proposal.

5.2 Surface geology and stratigraphy

From approximately Ch 20 km to Ch 30 km, the surface geology along the proposal alignment is characterised by Cenozoic alluvium (typically 20 to 60 m thick) which overlies Early Jurassic to Early Cretaceous strata of the Surat Basin (refer Figure 5.3). The alluvium is associated with the current Border River System and former paleochannels and alluvial fans.

South of approximately Ch 20 km, alluvium and colluvium is of limited extent and thickness, with thin sandy soils overlying the Surat Basin strata typical along this portion of the alignment. The lithostratigraphy of the region is summarised in Table 5.1.

GEOLOGICAL SURVEY OF NEW SOUTH WALES. 2009.New South Wales 1:1 500 000 Geology Map. First edition. Geological Survey of New South Wales, Department of Primary Industries, Maitland, NSW, Australia.
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

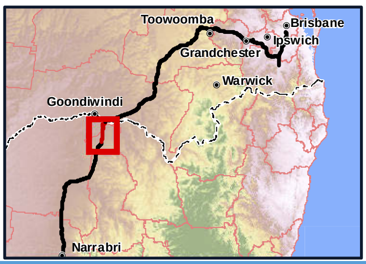


Map by: NCW Z:\GIS\GIS_270_NS2B\Tasks\270-EAP-201910311020_Groundwater_Figures\270-EAP-201910311020_FFJV_Fig5.3_geology_Rev1.mxd Date: 18/11/2019 18:13

Legend

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

Surface Geology
Geological Survey of NSW 2009. Surface geology of New South Wales1:1 500 000 map. Geological Survey of New South Wales, Maitland, Australia



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Coordinate System: GDA 1994 MGA Zone 56

North Star to NSW/QLD border
Figure 5.3: Surface Geology

Table 5.1 Summary of Lithostratigraphy for the Study Area (After Exon 1976 and Ransley et al. 2015)

Era	Period	Basin	Stratigraphic unit		Lithology	Thickness	Extent and comments
Cenozoic	Quaternary	-	Alluvium - Narrabri Fm		Clays, silts, sands and gravels. Variable uppermost clay unit present.	10 to 30 m	Semi-confined to unconfined aquifer associated with current rivers, paleochannels and old alluvial fans
	Quaternary to Tertiary	-	Alluvium - Gunnedah Fm		Unconsolidated interbedded silt, sands and gravels	35 to 80 m	Deeper, fluvio-lacustrine, semi-confined aquifer
	Tertiary	-	Mafic Volcanics		Basalts, tuff and agglomerate.	variable	Limited extent in the study area.
Mesozoic to Paleozoic	Cretaceous	SURAT BASIN	Wallumbilla Fm		Mudstone and siltstone	~ 100 m	Aquitard
			Kumbarilla Beds	Bungil Fm	Mudstone, siltstone, and carbonaceous sandstone.	< 200 m	Aquitard
				Mooga Fm	Clayey sandstone, siltstone and mudstones.	< 100 m	Aquifer
				Orallo Fm	Interbedded siltstone and mudstone	~ 150 to 250 m	Aquitard
	Jurassic			Pilliga Sandstone	Porous, fine to coarse massive sandstone and conglomerate	~100 to 300 m	Major aquifer for GAB & the Gwydir subregion
			Walloon Coal Measures		Claystone, shales, sandstones and major coal seams	~ 200 to 400 m	Leaky aquitard. the coal-bearing formations are poorly developed in the region compared to Queensland
			Hutton Sandstone		Porous quartz rich sandstone.	120 to 180 m	Aquifer
	Triassic - Permian	**GUNNEDAH BASIN**			Sandstone, siltstone, claystone, tuff and coal (refer Section 5.2)	Up to 1,200 m	Underlies Surat Basin/GAB. Limited bores within proposal site intersecting these strata.

5.2.1 Cenozoic alluvium

Alluvium (Qa) dominates the surface geology in the northern portion of the alignment (i.e. Ch 20 km to Ch 30 km refer Figure 5.3) and is associated with Cenozoic creek, river and lacustrine deposition from the Border Rivers System (i.e. Macintyre River and Whalan Creek). Less extensive alluvial deposits are also present in the flood plains and paleochannels of Forrest Creek, Mobbindry Creek and Back Creek in the south of the proposal site (refer Figure 5.3).

Based on registered bore descriptive entries, the alluvium typically ranges in thickness from 20 to 60 m with a maximum thickness of 100 m (NSW DPI 2015). The alluvium is vertically and laterally variable with interbedded clays, silts, sands and gravels. Registered bore lithological descriptions indicate the upper 5 to 10 m of the alluvium is fine grained with clays and sandy clays predominant.

Throughout the wider Gwydir sub-region, the alluvium forms an important aquifer for the region and is often subdivided into an upper unit called the Narrabri Formation and a lower Gunnedah Formation (discussed further in Section 6).

In the southern portion of the alignment (i.e. Ch 0 km to Ch 20 km), alluvial and colluvial sandy clays form a thinner unit typically 1.8 to 3 m thick (Senior, 1973). This overlies residual soils and extremely weathered Jurassic and Cretaceous sedimentary units.

Geotechnical boreholes completed during the 2018 site investigations have provided more site-specific details of the nature and extent of the alluvium in the groundwater study area and the findings are detailed in Table 5.2. Details of the site investigation works are provided in Section 7 and the location of these bores are presented in Figure 6.2.

Key observations for the site investigations include:

- Dominantly clay with minor silts to a maximum of 9 mbgl and underlain by residual soil and extremely weathered Kumbarilla Beds
- Confirmation that clays and clayey sands characterise the upper 5 to 6 m of the alluvium underlying the proposal
- A fining up sequence of gravels into overlying sands followed by clays was observed in most bore holes between Ch 20 km to Ch 35 km.

Table 5.2 Stratigraphic Summary of Alluvium observed in 2018 Site Investigations

Chainage	Unit	Thickness (m)	Description	Relevant Boreholes
Ch 0 km to Ch 20 km (Back, Forest, and Mobbindry Creeks)	Top Soil.	0 to 0.1 m	Clay, high plasticity, trace rootlets.	BH2201 BH2202 BH2203 BH2204
	Clay (with minor Silt).	5.0 to 9.0 m	ALLUVIUM: Grey - dark brown, low to high plasticity, stiff to hard, dry to moist.	
	Basal Contact.	NA	KUMBARILLA BEDS: Clay/Silts, lateralised, residual soil and extremely weathered siltstone and mudstone.	
Ch 20 km to Ch 26 km	Top Soil.	0.2 m	Clay, high plasticity, trace rootlets.	BH2206 BH2207 BH2208
	Clay (with minor Silt).	4.6 to 9.0 m	ALLUVIUM: Clay, high plasticity, dark brown, trace sand and gravel, dry – moist.	
	Sand and Gravel.	5.0 to 15.0 m Thickening towards north.	ALLUVIUM: Sandy Clay, Sand and Gravels, saturated, well graded, fining up trend.	
	Basal Contact.	NA	Residual Soil: Sandy Clay and Clay, moist, lateralised tertiary sequence or KUMBARILLA BEDS.	
Ch 26 km to Ch 30 km (Whalan Creek and Macintyre River crossings)	Top Soil.	0.3 m	Sandy Clay, trace rootlets.	BH2212 BH2213 BH2214 BH2215 BH2216 BH2217 BH2218
	Clay and Clayey Sand.	5.0 to 6.0 m	ALLUVIUM: grey – dark brown, mod-high plasticity, stiff to hard, moist.	
	Clayey Sand, Sand and Gravel.	5.0 to 10.0 m	ALLUVIUM: Variable clayey sand, Sand and sandy Gravel, moist to wet, medium dense to dense.	
	Basal Contact.	>20.0 m	Residual Soil: Lateralised tertiary sequence, predominantly clay and sand, possible equivalent to Gunnedah Formation.	

5.2.2 Tertiary Volcanics

Minor outcrops of volcanic rock, primarily consisting of basalt, tuff and associated agglomerates lie 1 to 2 km to the south of the proposal site. These are sourced from volcanic eruptions during the Paleogene and Neogene and locally intrude or overlie the Surat and Gunnedah basin strata. This unit was not reported to have been intersected in registered bores or during the 2018 site investigations.

5.2.3 Surat Basin

The Surat Basin Cretaceous and Jurassic sedimentary strata underlie the entire proposal site. In the southern half of the proposal, these strata lie close to surface as residual soils and extremely weathered shales and sandstones. In the northern half of the proposal, thicker layers of alluvium exist (up to 100 m thick). The Surat Basin strata dips gently to the west in the region (Senior, 1973).

5.2.3.1 Wallumbilla Formation

The Wallumbilla Formation consists predominantly of low permeability mudstones and siltstones which forms an aquitard overlying the Kumbarilla Beds (Ransley et. al. 2015). The thickness of this unit is up to 100 m.

5.2.3.2 Kumbarilla Beds

The Kumbarilla Beds represent a succession of fluvial, lacustrine and marginal marine facies deposited during the middle Jurassic to Middle Cretaceous periods. Most of the fractured rock groundwater bores surrounding the proposal site are tapping the Kumbarilla Beds. This unit includes:

- Bungil Formation (Mid-Cretaceous): This formation consists of siltstones, mudstones and carbonaceous sandstone associated with a lacustrine to marginal marine depositional environment (Ransley et al. 2015)
- Mooga Formation (Late Jurassic – Cretaceous): The Mooga Formation is considered a fluvial facies characterised by clayey sandstones interbedded with siltstones and mudstones with a typical thickness of less than 100m
- Orallo Formation (Late Jurassic): Flood Plain facies predominantly interbedded siltstone and mudstone
- Pilliga Sandstone (Mid-Late Jurassic): The Pilliga Sandstone is comprised of quartzose sandstone and conglomerate with minor interbedded of mudstone, siltstone and shales. The unit is representative of a high energy braided fluvial depositional environment and regionally forms an important aquifer in the GAB (Ransley et al. 2015).

During the 2018 site investigations, the Kumbarilla Beds were interpreted to have been intersected in three bore holes between Ch 0 km and Ch 20 km (BH2201 to BH2203 displayed in Figure 6.2a to c). The top of the Kumbarilla beds was encountered at between 5 to 10 mbgl and was characterised by extremely weathered siltstone and mudstones (FFJV 2019).

5.2.3.3 Walloon Coal Measures

The Walloon Coal Measures (WCM) are the most important coal resource of the Surat Basin. The primary units within the measures include claystones, shales, sandstones and coal seams (Exon 1976). Several registered bores near the proposal site tap the Walloon Coal Measures where free flowing aquifer conditions have been observed (refer Section 6.2). The screened intervals in these registered bores were typically over 300 mbgl.

5.2.4 Gunnadah Basin

The stratigraphy of the Gunnadah Basin contains up to 1200 m of marine and non-marine Permian and Triassic sediments with coal-bearing strata present in the form of the Black Jack Formation and the Maules Creek Formation (Exon 1976).

The Gunnedah Basin sedimentary rocks do not outcrop in the region and underlie the Jurassic and Cretaceous sedimentary rocks of the Surat basin. Petroleum exploration well Toenda-1 located 18 km to the west of the proposal site intersected the top of the Gunnedah Basin strata at 1,216 mbgl (Orion 2010).

The Gunnedah Basin strata will not be considered further in this technical review given the considerable depth of the strata and the shallow depth of disturbance associated with the proposed alignment. The basin strata also appear to be poorly developed in the area due to the presence of shallower, high quality groundwater resources.

6 Hydrogeology

This section provides a description of the existing hydrogeological regime(s) and is based on a review of available hydrogeological reports, site investigations between July to October 2018 (refer Section 7) and state government data sets described in Table 3.2.

There are two main aquifer systems present which are considered relevant to the proposal site:

- Cenozoic alluvium deposits associated with the Border Rivers Alluvium and other drainage systems crossed by the alignment (i.e. Macintyre River, Whalan Creek and Mobbindry Creek)
- Jurassic to Cretaceous sedimentary rocks of the Surat Basin which form part of the GAB (Kumbarilla Beds and the Walloon Coal Measures).

These aquifers have potential to be sensitive to possible groundwater-affecting activities associated with the proposal.

The following sections describe these aquifers in the context of the regional hydrogeological regime.

6.1 Existing hydrogeological understanding

6.1.1 Cenozoic Alluvium

6.1.1.1 Occurrence

Cenozoic aged alluvial aquifers are mapped in association with the current major watercourses (e.g. Macintyre River and Whalan Creek) and antecedent systems that form paleovalley fill and broad alluvial fan systems within and surrounding the proposal.

This aquifer is called the ‘NSW Border Rivers – Downstream Keetah Bridge’ Alluvial Water Source (NSW DPI 2012a). Other areas of mapped alluvium include narrower units within Mobbindry Creek and Whalan Creek. Subdivision of the alluvium into a shallow Narrabri Formation and deeper Gunnedah Formation is often applied to the alluvium in the Border Rivers region and is summarised in Table 6.1.

Table 6.1 Summary of Lithostratigraphy for the Study Area (After Exon 1976 and Ransley et al. 2015)

Alluvial Unit	Stratigraphic position	Lithology	Thickness	Aquifer properties
Narrabri Formation	Upper most unit, forms ground surface in river valleys.	Sands, gravels and silts	10 to 30 m	Unconfined aquifer, recharge from stream loss, rainfall and excess irrigation.
Undifferentiated Clay	Separates Narrabri and Gunnedah Formations.	Clay	2 to 15 m	Low permeability.
Gunnedah Formation	Overlies Surat Basin Strata.	Sands, gravels and clays. Fines up into clays.	Up to 70 m	Semi-confined, recharge from cross formational flow, leakage from underlying aquifers, rainfall /runoff.

Based on a review of registered bore lithological descriptions for the alluvium in the northern portion of the alignment, the water bearing zone is typically composed of sand or sandy gravels overlain by a fine-grained unit of clay, silt and clayey sands that may result in localised semi-confined conditions. This overlying fine grained unit extends from surface to 5 to 10 mbgl and was intersected in most site investigation boreholes between the Macintyre River and Whalan Creek (Ch 20 km to Ch 30 km). The depth to the top of the water bearing zone in alluvium is presented in Table 6.2 and is based on a review of registered bores and recent boreholes from the site investigations.

Table 6.2 **Summary of alluvium characteristics and depth to the water bearing zone along the proposal alignment**

Chainage	Description	Inferred depth to top of water bearing zone	Comments
Ch 0 km to Ch 5.7 km	Thin soils, alluvium and residual clays overlying Surat basin strata.	NA – no water bearing zone identified in alluvium or residual soils in (registered bores). Possible shallow perched groundwater in soils overlying clay.	Thin alluvium/colluvium inferred from registered bore: GW005170 (clays 0 to 9.1 mbgl) and GW901938 (clays 0 to 29 mbgl).
Ch 5.7 km	Alluvium at Mobbindry Creek.	4 to 10 mbgl but highly variable. No water observed in BH2201.	Alluvium related to alignment crossing. Inferred from registered bores GW967837, GW967836 and GW967835 and site investigation bore BH2201 in Mobbindry Creek alluvium.
Ch 8.1 km	Alluvium at Back Creek crossing.	4 to 10 mbgl but highly variable. No water bearing zone observed in BH2202.	Alluvium related to alignment crossing. Inferred from registered bores GW967837, GW967836 and GW967835 and site investigation bore BH2202 in Back Creek alluvium.
Ch 8.1 km to Ch 20.0 km	Thin soils, alluvium and residual clays overlying Surat basin strata.	NA - no water bearing zone identified in alluvium or residual soils in registered bores. Site investigation bore BH2203 in near Forest Creek crossing also dry.	GW018995 (0 to 3.0 m soil, 3 to 19.2 m clays, top of shale at 19.2 mbgl) GW004689 (0 to 1.0 soils, 1.0 to 33.22 mbgl clay).
Ch 20.0 km to Ch 29.6 km	Alluvium from Whalan – Macintyre fluvial systems. Sands and sandy Gravels.	Typically, 6.0 to 10 mbgl, alluvium gradually thickens from south to north along the NS2B alignment.	Based on registered bores GW036694, GW036693, GW027891, GW027893, GW027892 and site investigation bores BH2204, BH2206, BH2207, BH2208, BH2212, BH2214.
Ch 29.6 km to Ch 30 km	Macintyre River Alluvium. Sands and sandy Gravels.	Typically, 10 to 15 mbgl. Water bearing zone dominantly sandy gravels overlain by clays and sandy clays.	Based on registered bores GW022001, GW005224, 77498A, 77390, GW030585, GW030590, GW039280 and site investigation bores BH2213, BH2215, BH2216, BH2217, BH2218.

6.1.1.2 Regional groundwater recharge, discharge and flow

Groundwater flow in the Cenozoic Alluvium is likely to be controlled by topography and is limited to the areas where alluvial units are present. In order to assess groundwater levels spatially, the depths to water from each bore are converted to elevation (metres above the Australian Height Datum (mAHD)) to account for topographic relief and allow for comparison to other datasets. Figure 6.1 depicts the surface topography across the study area and ranges from approximately 260 m AHD near North Star to approximately 220 mAHD in the north, near the Macintyre River. Regional mapping of the water table indicates a general north to northwest flow of groundwater in the shallow alluvial aquifer across the study area. Groundwater elevations resultant from site investigation bores in October 2018 ranged from 213 to 218 m AHD which are generally consistent with the regional flow gradients and the distribution of alluvium (refer Figure 6.1).

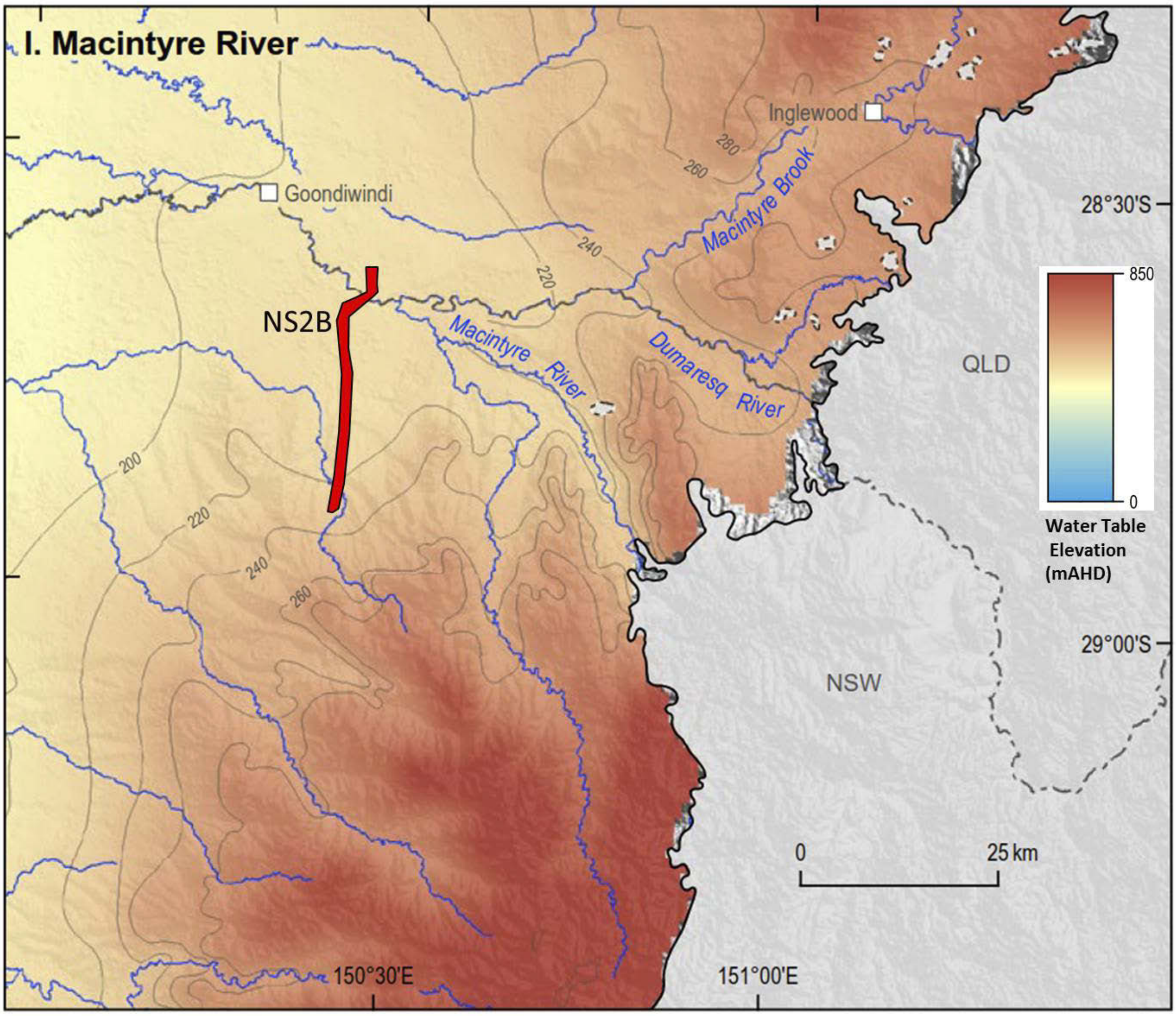


Figure 6.1 Regional water table elevation across the study area

Source: Modified from Ransley et al. 2015

Groundwater flow in the alluvium is considered to mimic topography and is limited by the distribution of alluvium in the region (i.e. between Ch 20 km to Ch 30 km and more localised in creeks further south). Local groundwater flow is expected to flow towards the perennial Macintyre River, particularly between Ch 20 km and Ch 30 km.

The alluvial aquifers are strongly linked to surface water features. This strong hydraulic connection is demonstrated during periods of high rainfall in several monitored bores near the proposal site (refer Figure 6.3). Flooding events such as events in January 1996 and July 1998 are clearly observed in monitored bores within the alluvium adjacent to Macintyre River where groundwater elevations rose up to 1m (refer bore hydrographs 41640005-B, GW36684 and GW036693 in Section 6.3.1).

Recharge to alluvial units is expected to occur via the following mechanisms:

- Recharge from stream losses from the regulated Dumaresq and Macintyre Rivers
- Recharge from stream losses during seasonal flow in minor creeks/tributaries (i.e. Mobbindry Creek)
- Direct infiltration from rainfall and irrigation where permeable alluvium units are exposed
- Upward leakage from underlying Surat Basin Strata (CSIRO 2007).

It is considered that alluvial units may provide a source of recharge to the underlying units where the underlying units are appropriately permeable and vertical gradient is downwards. Seepage from the alluvial aquifer into the underlying stratigraphic units could occur through the base of the alluvium.

Discharge is predominantly as throughflow in the alluvium. Limited effective storage in the coarser grained permeable alluvium is likely to result in groundwater level decline during the dry season (where not artificially recharged from the regulated Dumaresq and Macintyre rivers). Quaternary alluvium within the ephemeral creek systems (i.e. Mobbindry Creek and Forrest Creek) will not contain permanent groundwater as recharge to the alluvium seeps downwards into the under lying sedimentary units or downgradient due to low effective storage.

6.1.1.3 Hydraulic properties

No aquifer test data for the alluvium was obtained from publicly available registered bore datasets within the groundwater study area.

The NSW DPI estimates bore yields of up to 4.5 litres per second (L/s) for the NSW Border Rivers Downstream Keetah Bridge Alluvial Water Source.

Bore yields from available registered bore data indicate a wide range of yields, ranging from 0.2 to 3.8 L/s. this indicates high heterogeneity within the alluvium (fine up and down sequences) where yields are related to the extent and thickness of the coarser grained alluvium.

Slug tests were completed on five monitoring wells installed in the alluvium during the 2018 site investigations (refer Table 7.2). Hydraulic conductivity values (K) were typically 0.2 to 0.8 m/day which is broadly consistent with literature values for clayey sands and clayey gravels observed in the screened intervals (Heath, 1983). The values for BH2206 and BH2212 appear underestimated for the predominantly sand and gravel lithologies in the screened intervals. Slug tests are known to become less reliable when testing gravelly material due to higher transmissivities and the small portion of the aquifer tested by the slug test (Pucko and Verbovšek, 2015).

Based on a review of site investigation bore logs (FFJV 2019), the saturated thickness of the alluvium is interpreted to be 5 to 10 m in thickness. Using the site investigation data discussed above, transmissivity values are estimated to range from 1 to 8 m^2/day for the alluvium.

6.1.2 Jurassic to Cretaceous Sediments (Surat Basin)

6.1.2.1 Occurrence

Jurassic to Cretaceous strata of the Surat Basin underlies the entire proposal site. The alignment is in the Eastern Recharge Groundwater Source of the GAB (NSW DPI 2009b). A review of registered bores surrounding the alignment indicates most bores in the southern portion (Ch 0 km to Ch 22 km) are constructed within the Surat Basin strata.

The depth to the top of the unweathered Surat Basin strata is relatively shallow in the southern portion of the alignment, typically ranging from 10 to 40 mbgl.

Further north, towards Whalan Creek and the Macintyre River, the overlying alluvium thickens and results in the top of the Surat strata being intersected at depths ranging from 50 to 80 mbgl in registered bores (i.e. GW036693, GW027892, and GW27893).

The key hydrogeological units identified in registered bores installed in Surat Basin strata within the groundwater study area include:

- Kumbarilla Beds – observed between Ch 0 km to Ch 20 km below 5 to 9 mbgl as residual soils and extremely weathered clays in site investigation bore holes in 2018 (refer Table 5.2). Between Ch 20 km and Ch 30 km investigation bores did not encounter the Kumbarilla Beds due to greater thickness of alluvium in this area.
- Walloon Coal Measures (WCM) – not encountered in investigation boreholes in 2018 and only six registered bores are interpreted to be constructed within the WCM due to the greater depths to this unit within the study area. The top of this unit is typically encountered at greater than 200 mbgl (i.e. GW009991, GW901938 and RN18136).

The Wallumbilla Formation is recognised as regional aquitard; no registered bores are understood to be screened within this unit and therefore it has not been considered further in this technical report.

6.1.2.2 Groundwater recharge, discharge and flow

Registered bores, constructed in the Surat Basin strata, have water levels higher than the horizon where water was first intersected. This indicates groundwater resources include semi-confined to confined conditions (and thus less vulnerable to surface contaminants). Key characteristics of groundwater recharge and discharge in the Jurassic to Cretaceous strata include:

- On a regional scale, groundwater in the Surat Basin system underlies the alluvial aquifers and is mostly sourced from the Pilliga Sandstone. The groundwater is generally fresh and suitable for town water, stock and domestic use, but a high sodium adsorption ratio typically renders these GAB sandstone groundwater resources unsuitable for irrigation (refer Section 6.5.2 and Table 6.4).
- The Surat Basin strata near North Star are influenced by recharge from the GAB intake beds on the western slopes of the Great Dividing Range (NSW DWE 2009b). These intake beds can be associated with younger, higher quality water to support irrigation.
- Discharge is likely to occur via upward leakage into the overlying alluvium (CSIRO 2007). Vertical gradients and aquifer interactions are discussed further in Section 6.4.

A general northward hydraulic gradient is evident in the potentiometric surface for the Kumbarilla Beds based on registered bore water levels (refer Appendix A and Figure 6.2a to Figure 6.2c). Here, groundwater elevations range from 230 to 255 mAHD in the south near North Star to 210 to 220 mAHD near the Boggabilla Road – Bruxner highway junction to 200 to 210 mAHD near Kurumbul north of the Queensland border.

6.1.2.3 Hydraulic properties

There is limited data on aquifer properties from registered bores within the groundwater study area.

Yields from registered bores constructed in the Kumbarilla Beds were found to be low compared to the alluvium aquifers, ranging from 0.19 to 1.9 L/s. This may be related to the clay-rich aquitards intersected in the Kumbarilla Beds (refer Table 5.1). No pump test data was available for bores within a 5km radius of the proposal in the Kumbarilla beds however, literature values indicate typical horizontal hydraulic conductivity values range from 0.1 to 0.5 m/day (USQ 2011).

Generally, yields from bores tapping the Walloon Coal Measures are variable, ranging from 0.2 to 3.0 L/s (Department of Natural Resources and Mines 2016). Transmissivity values for the Walloon Coal Measures in bores near the NSW/QLD border range from 51 m^2/day (RN15624) to 110 m^2/day (RN15592). Based on DNRME bore cards to infer a saturated thickness, these transmissivities equate to approximate hydraulic conductivities of approximately 3 m/day (RN15624 - 19.2 m saturated zone) and 2 m/day (RN15592 – 63 m saturated zone).

The enhanced groundwater potential may be related to higher permeable coal seams (cleats and fracturing) within the Walloon Coal Measures.

6.2 Registered groundwater bores

A search of registered groundwater bores within a 10 km radius of the proposal site was completed in August 2018 and revisited in May 2019 to capture any bores registered after August 2018. The DNRME Groundwater Database (GWDB) was used to identify bores located in Queensland. For the NSW portion of the alignment, registered bores were identified using the WaterNSW online database and the BoM Australian Groundwater Atlas.

The search identified a total of 197 registered bores within a 10 km radius of the alignment centre line. The search radius extends into Queensland and returned bores were considered to inform the existing environment in this area; however, only registered bores in NSW are included in Appendix A as these are for consideration post-EIS (e.g. for potential consideration for construction water sources).

Out of the 197 registered bores identified, 86 were excluded from further evaluation in this technical report due to bore status (non-functional, abandoned, proposed bore not constructed yet), limited or no data on aquifer lithology, bore construction details and/ or water quality.

The remaining 111 registered bores are presented in Figure 6.2a-c and included in Appendix A (NSW registered bores only).

6.3 Groundwater levels

6.3.1 Cenozoic alluvium groundwater levels

A total of 59 out of 111 registered water bores within a 10 km radius of the alignment are identified to be constructed within the Cenozoic alluvium (refer to Figure 6.2 for the NSW registered bores). In many of these bores, the screened interval is shallower than 30 mbgl. Publicly available groundwater level data for these bores includes:

- Thirty-seven registered bores reported water levels; these range from 6.1 to 24.4 mbgl
- Eighteen registered bores with no water levels recorded, two of which were dry (GW036695 and GW039278)
- Monthly groundwater level data is available for the period 1987 to 2015 in bores GW036684, GW036694, GW036693 and GW036696.

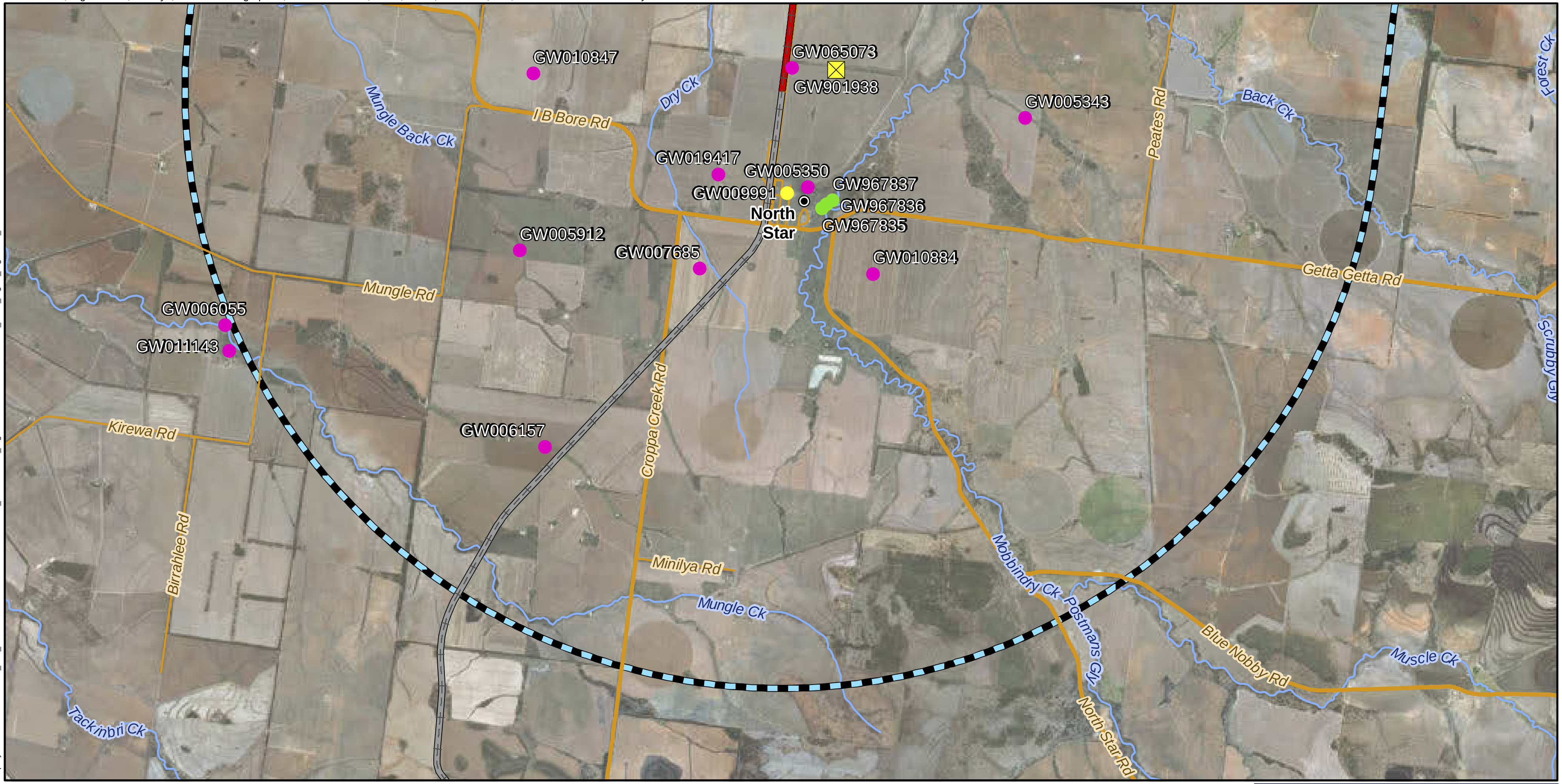
Bore GW036696 is located 5.6 km to the east of the study area but is considered representative of the Cenozoic alluvium. Hydrographs for groundwater levels in the Cenozoic alluvium and the CRD for Goondiwindi Airport are presented in Figure 6.3.

Long term natural fluctuations in groundwater levels in the alluvium can range up to 2 to 2.5 m as evident in the hydrograph for GW036694 over the monitored period (1987 to 2015) (refer Figure 6.3). Site specific groundwater level data from proposal monitoring wells for the period late July to early October 2018 showed similar variations in groundwater levels ranging from 0.17 m (BH2213) to 1.60 m (BH2212).

A review of monthly rainfall records shows groundwater levels typically increase by 0.5 to 1 m in response to major rainfall events (i.e. late 2010).

There is a general correlation of the CRD with groundwater levels in the alluvium indicating unconfined conditions with good hydraulic connection to surface water. An exception is GW036693 located at approximately Ch 25 km where a weak correlation with the CRD suggests potentially semi-confined conditions.

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



Map by: NCW/GN Z:\GIS\GIS_270_NS2B\Tasks\270-EAP-201910311020_Groundwater_Figures\270-EAP-201910311020_FFJV_Fig6.2_registered_Rev3.mxd Date: 11/02/2020 07:56

Legend

- 5 Chainage (km)
- Chainage point
- Localities
- Existing rail (non-operational)
- North Star to NSW/QLD border alignment
- Adjoining alignments
- Major roads
- Minor roads
- Watercourses
- Groundwater study area

Registered bores (monitored)

- Walloon Coal Measures

Registered bores

- Alluvium
- Kumbarilla Beds
- Walloon Coal Measures

A4 scale: 1:100,000

0 1 2 3 4 5 km

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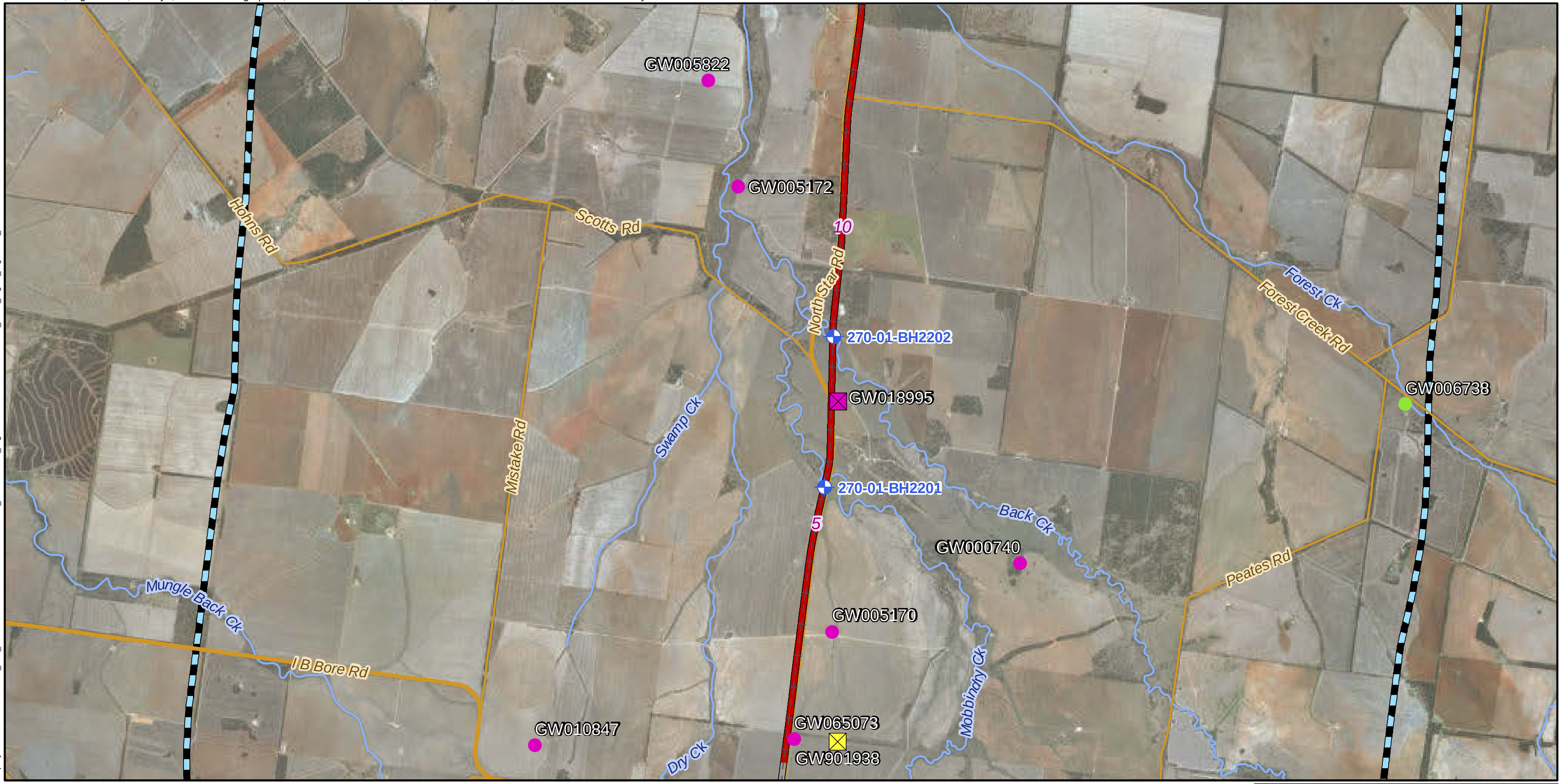
Coordinate system: MGA56

North Star to NSW/QLD border

Figure 6.2a: Registered bores

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



Map by: NCW/GN Z:\GIS\GIS_270_NS2B\Tasks\270-EAP-201910311020_Groundwater_Figures\270-EAP-201910311020_FFJV_Fig6.2_registered_Rev3.mxd Date: 11/02/2020 07:56

Legend

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

Major roads
Minor roads
Watercourses
Groundwater study area

2018 Site Investigation bores
Monitoring well

Registered bores (monitored)
Kumbarilla Beds
Walloon Coal Measures

Registered bores
Alluvium
Kumbarilla Beds
Walloon Coal Measures

A4 scale: 1:100,000

0 1 2 3 4 5 km

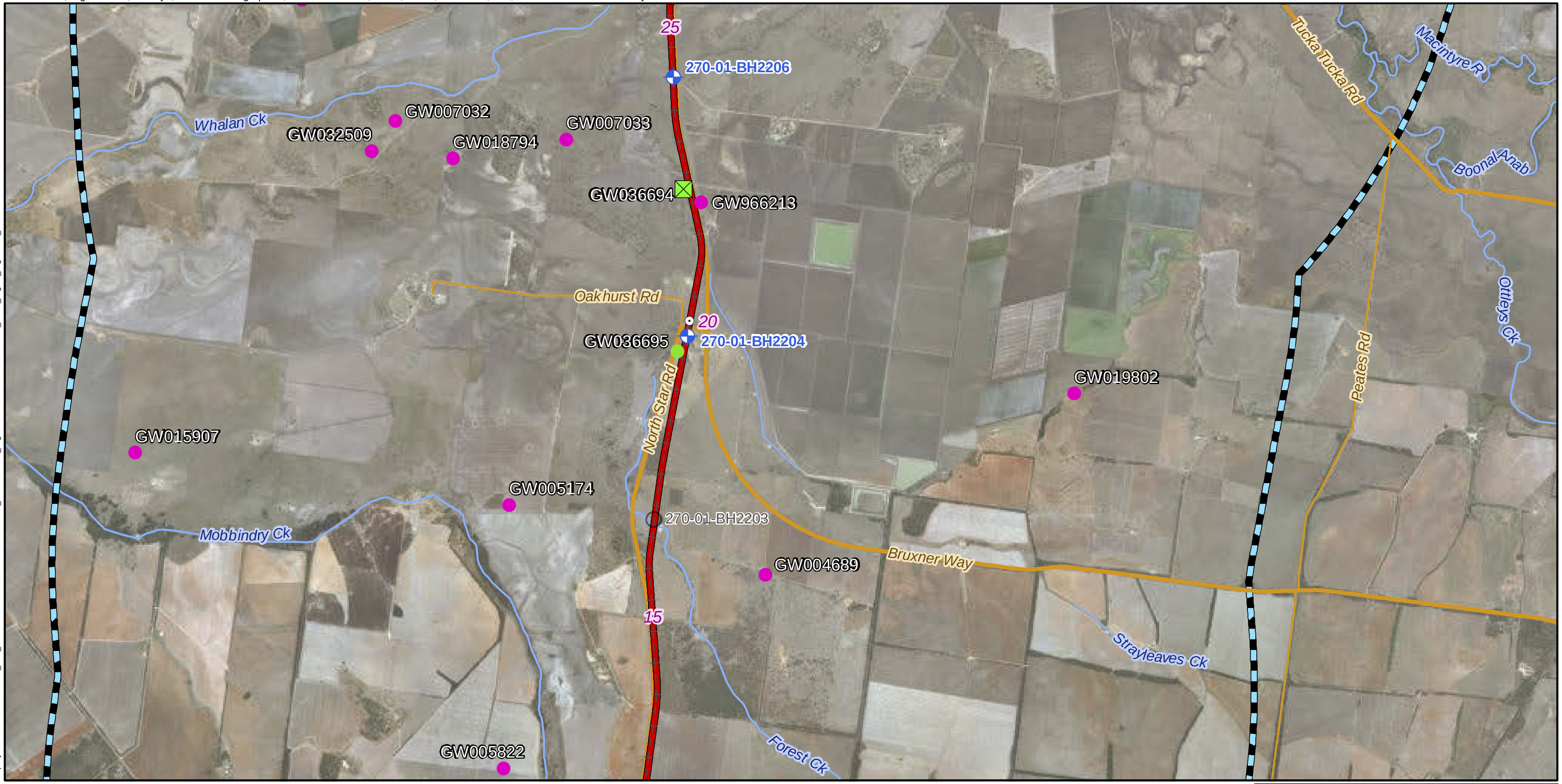
Future Freight
Integrating Community, Environment and Engineering

Date: 10/02/2020 Version: 3
Coordinate system: MGA56

North Star to NSW/QLD border
Figure 6.2b: Registered bores

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

Map by: NCW/GN Z:\GIS\GIS_270_NS2B\Tasks\270-EAP-201910311020_Groundwater_Figures\270-EAP-201910311020_FFJV_Fig6.2_registered_Rev3.mxd Date: 11/02/2020 07:56



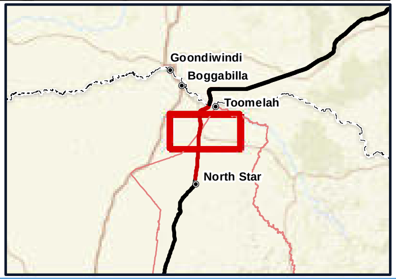
Legend

5 Chainage (km)
Chainage point
Existing rail (non-operational)
North Star to NSW/QLD border alignment
Major roads
Minor roads
Watercourses
Groundwater study area

2018 Site Investigation bores
Geotechnical borehole
Monitoring well

Registered bores (monitored)
Alluvium

Registered bores
Alluvium
Kumbarilla Beds



A4 scale: 1:100,000

0 1 2 3 4 5 km

Future Freight
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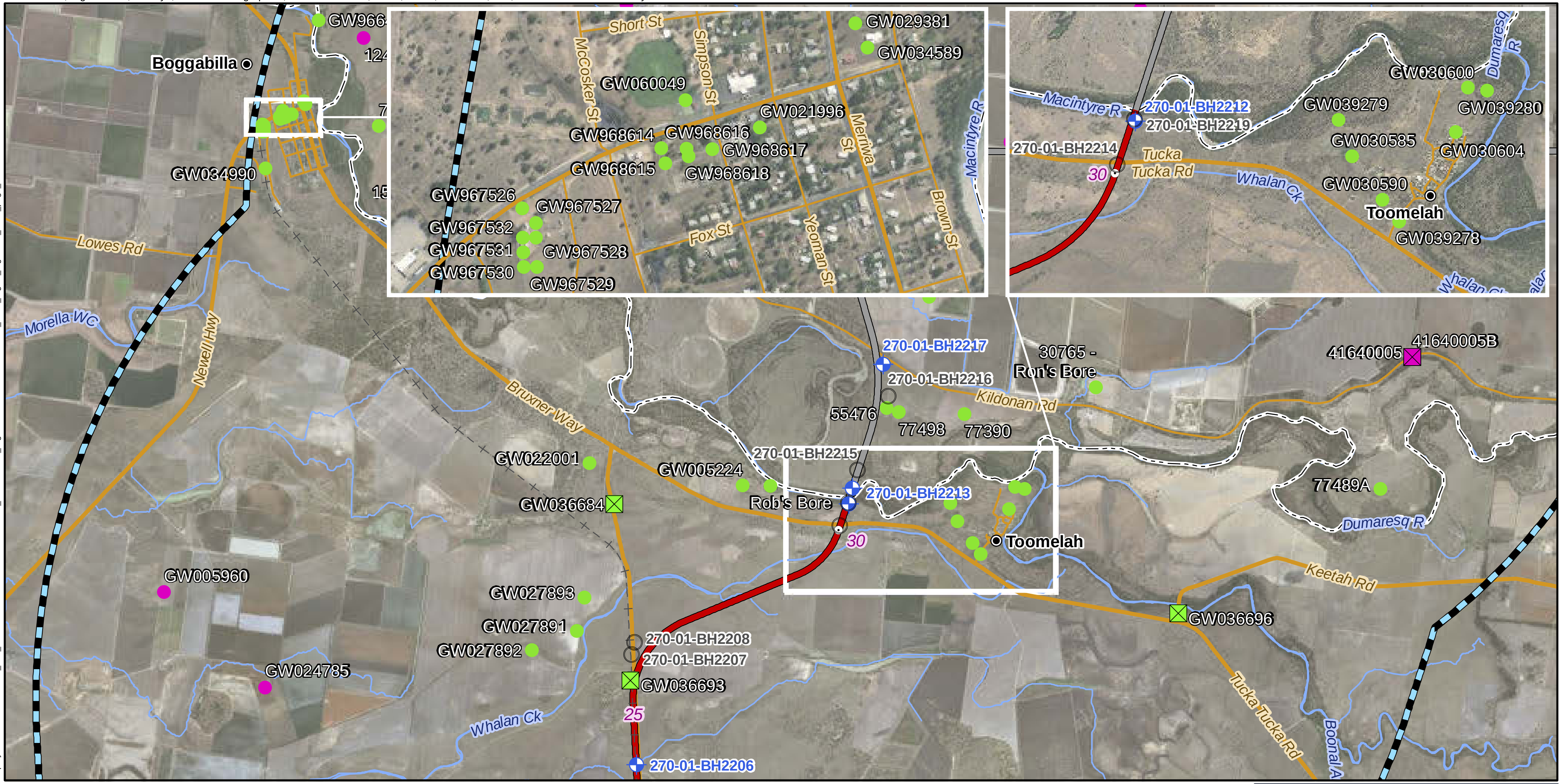
Date: 10/02/2020 Version: 3
Coordinate system: MGA56

North Star to NSW/QLD border
Figure 6.2c: Registered bores

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



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Legend

- 5 Chainage (km)
- Chainage point
- Localities
- Existing rail (non-operational)
- North Star to NSW/QLD border alignment
- Adjoining alignments
- Major roads
- Minor roads
- Watercourses
- Groundwater study area

2018 Site Investigation bores

- Geotechnical borehole
- Monitoring well

Registered bores (monitored)

- Alluvium
- Kumbarilla Beds

Registered bores

- Alluvium
- Kumbarilla Beds
- Walloon Coal Measures

A4 scale: 1:100,000

0 1 2 3 4 5 km

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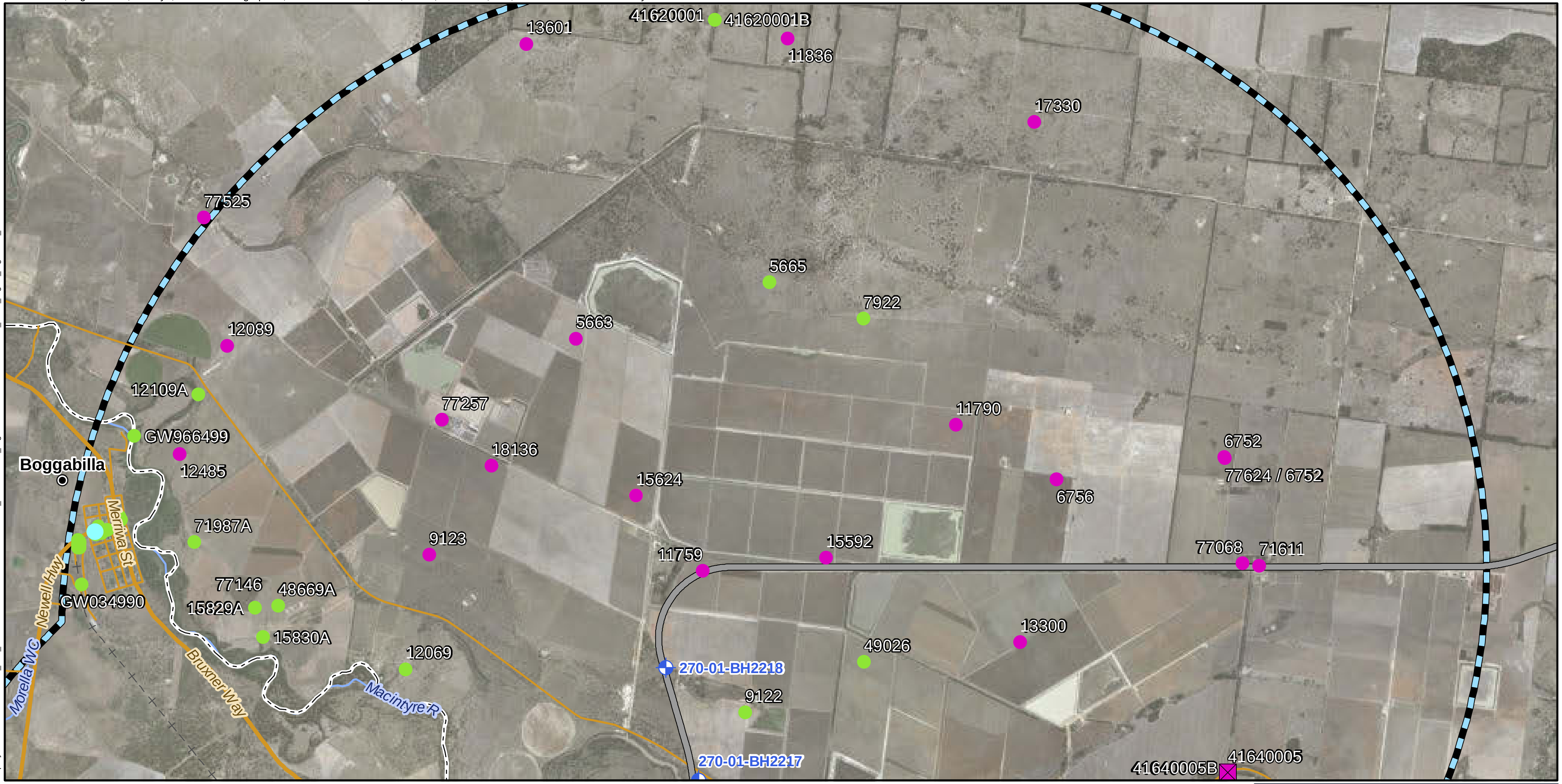
Date: 10/02/2020 Version: 3
Coordinate system: MGA56

North Star to NSW/QLD border
Figure 6.2d: Registered bores

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



Map by: NCW/GN Z:\GIS\GIS_270_NS2B\Tasks\270-EAP-201910311020_Groundwater_Figures\270-EAP-201910311020_FFJV_Fig6.2_registered_Rev3.mxd Date: 11/02/2020 07:56

Legend

- 5 Chainage (km)
- Chainage point
- Localities
- Existing rail (non-operational)
- Adjoining alignments
- Major roads
- Minor roads
- Watercourses
- Groundwater study area

2018 Site Investigation bores

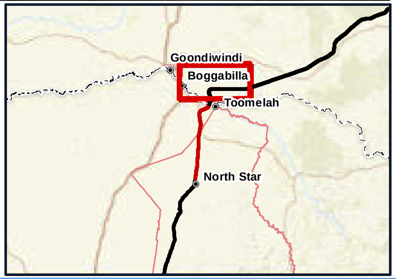
- Monitoring well

Registered bores (monitored)

- Alluvium
- Kumbarilla Beds

Registered bores

- Alluvium
- Kumbarilla Beds
- Walloon Coal Measures



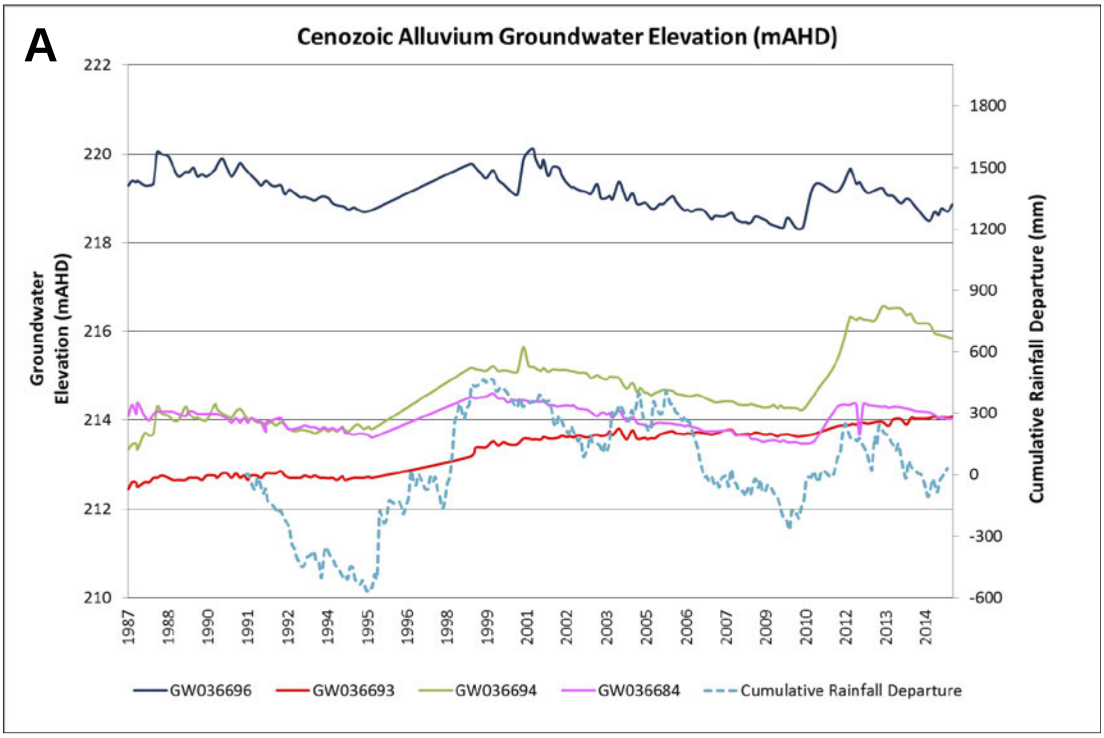
A4 scale: 1:100,000

0 1 2 3 4 5 km

Future Freight
Integrating Community, Environment and Engineering

Date: 10/02/2020 Version: 3
Coordinate system: MGA56

North Star to NSW/QLD border
Figure 6.2e:
Registered bores



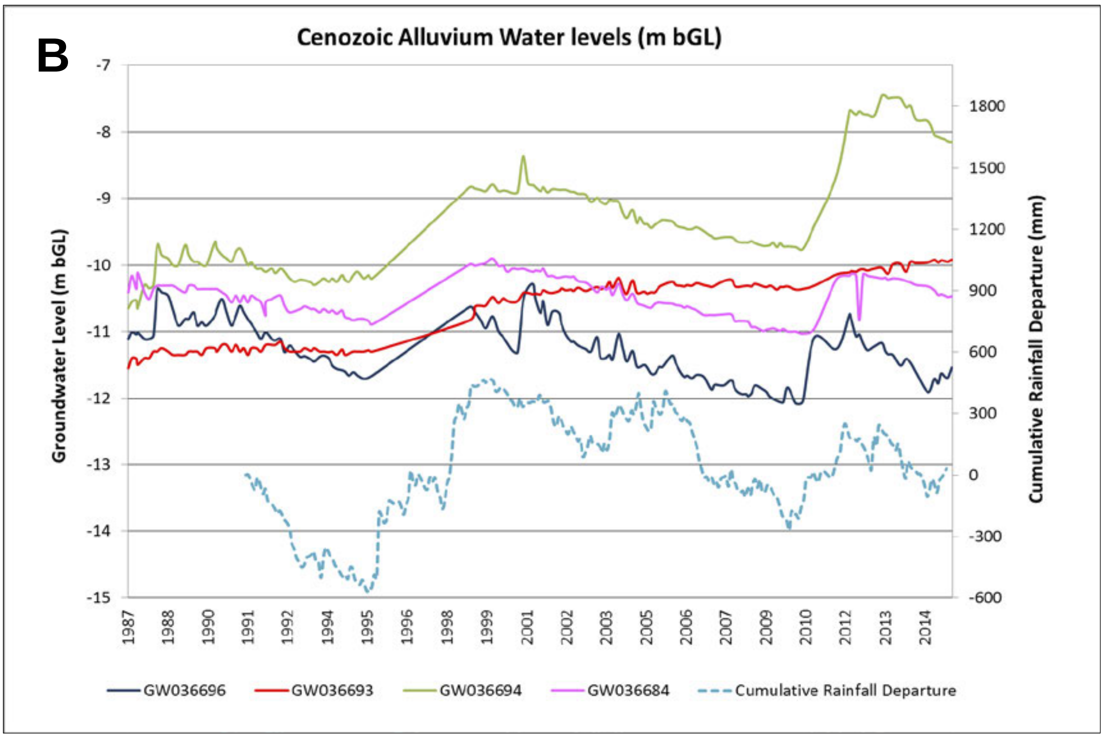


Figure 6.3 **Monthly groundwater levels within the Cenozoic Alluvium**

Figure notes:

a Ground water elevation in mAHD

b Water levels in mbgl.

Source: WaterNSW. Rainfall data for Goondiwindi Airport (BoM Station 041521) sourced from BoM

6.3.2 Jurassic – Cretaceous groundwater levels

6.3.2.1 Kumbarilla Beds

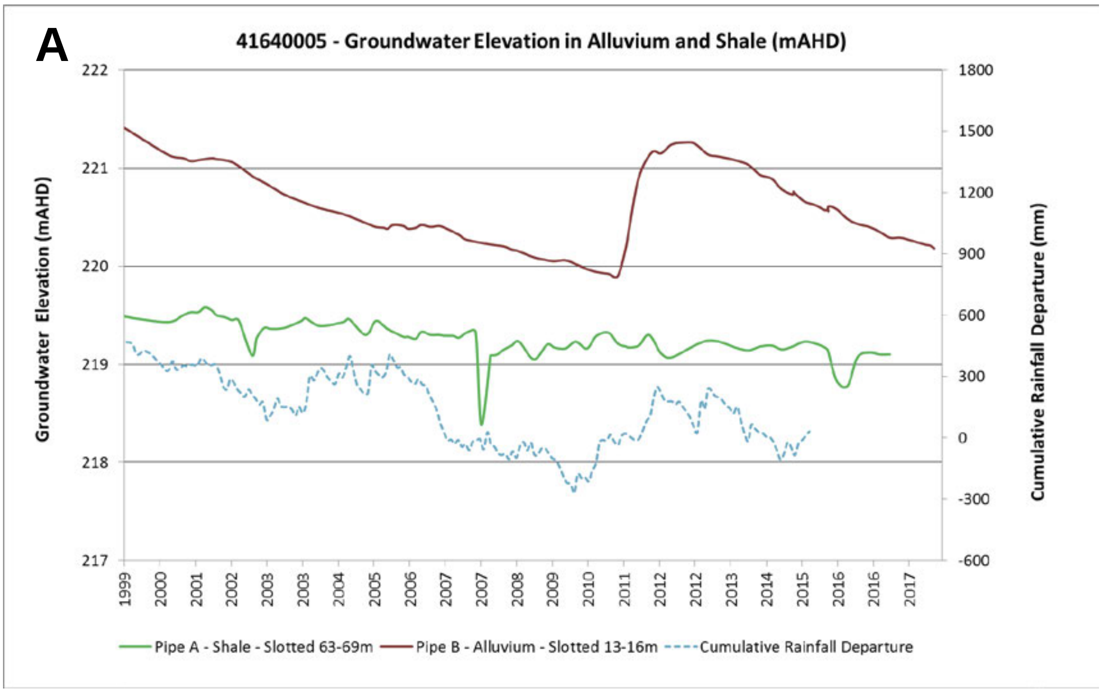
A total of 49 out of 111 registered bores within a 10 km radius of the alignment are logged to be screened within the Kumbarilla Beds (refer to Figure 6.2 for the NSW registered bores). Based on available public data the following can be inferred for groundwater levels:

- Fifteen bores had groundwater level data available and indicated the typical groundwater level ranges from 3.7 to 36 mbgl
- Groundwater levels are above the top of the initial water strike confirming the confined nature of this aquifer
- Sandstone is the dominant lithology within the screened intervals. The screen is installed at depths of less than 230 mbgl.

A representative groundwater level hydrograph for the Kumbarilla Beds is presented in Figure 6.4 (Pipe A) from the registered bore 41640005. This nested bore is located 8 km to the east of the alignment. A long term (decadal) decline in groundwater levels within the shale appears to correlate with the CRD. This weak response to the CRD trend indicates the Kumbarilla Beds are functioning as an aquitard compared to the nested bore constructed in the alluvium (refer Figure 6.4 - Pipe B). The registered function of the bore 41640005 is for monitoring and not for irrigation or water supply suggesting the trends in Figure 6.4 are representative of natural conditions.

6.3.2.2 Walloon Coal Measures

Three bores out of the 113 registered bores intersect the Walloon Coal Measures (15624, GW009991, and GW901938). These bores are constructed in sandstone with the screened interval typically at depths greater than 320 mbgl. Registered bore 15624 is reported to be artesian (free flowing at surface); registered bores GW009991 and GW901938 report average/measured groundwater levels of 7.0 and 25.7 mbgl, respectively.



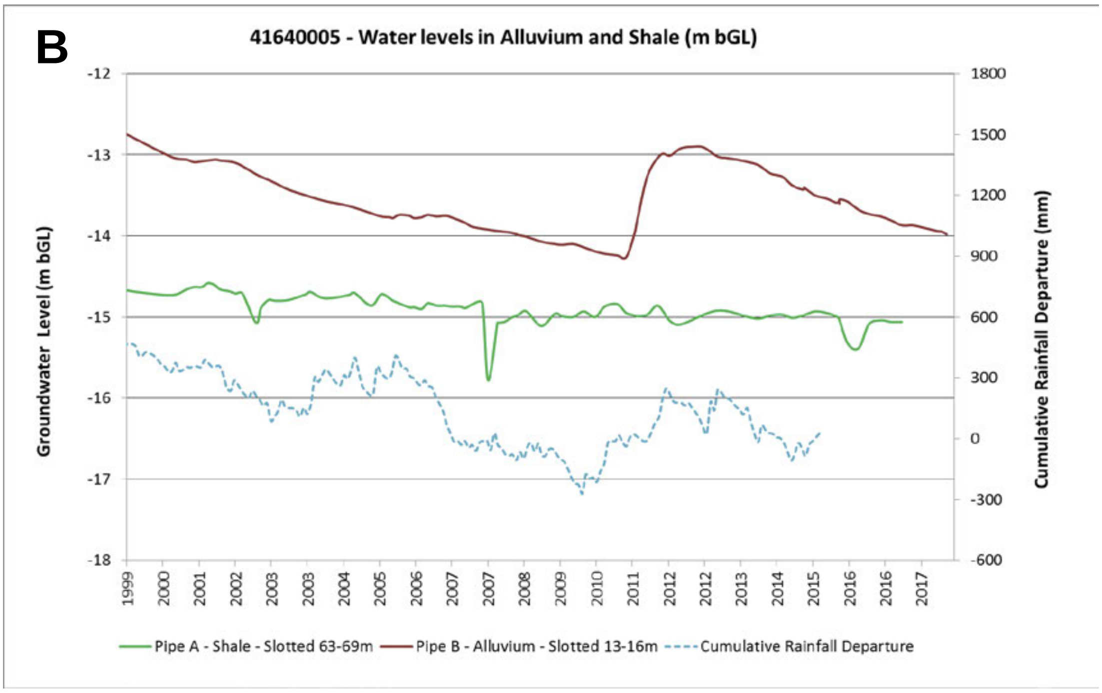


Figure 6.4 **Monthly groundwater level data within nested bore 41640005**

Figure notes:

a Ground water elevation in mAHD

b Water levels in mbgl.

Sources: Bore data sourced from DNRME. Rainfall data for Goondiwindi Airport (Station 041521) sourced from BoM.

6.4 Vertical gradients and aquifer interaction

Groundwater measurements from nested bores within the alluvium and underlying Kumbarilla Beds were assessed to interpret vertical groundwater gradients. Representative nested bore details and groundwater level data are presented in Table 6.3. Due to a lack of nested bore locations close to the alignment, bores from greater than the 5 km from the alignment were reviewed to characterise vertical gradients.

Table 6.3 Vertical groundwater evaluation form nested bore data from the Border Rivers region

Bore	Monitoring point	Depth (mbgl)	Unit	Water level (mAHD)	Distance from study area	Comment
41640005	Pipe B	13 to 16	Alluvium	220.29	9 km to east of Study Area at NSW/QLD Border	Downward gradient. Small water level separation between units. (levels gauged on 8/05/2017).
	Pipe A	63 to 69	Kumbarilla Beds	219.10		
GW036691	Pipe 1	13 to 19	Alluvium	221.41	13 km to east of Ch 20 km	Upward gradient. Kumbarilla water level markedly above alluvium water level (levels gauged on 13/10/2015).
	Pipe 2	179 to 203	Kumbarilla Beds	232.61		
GW036684	Pipe 1	18 to 26	Upper Alluvium	214	2 km north of Ch 25 km	Negligible vertical gradient. Upper and lower alluvium hydraulically connected (levels gauged on 13/10/2015).
	Pipe 2	29 to 35	Lower Alluvium	214		
GW036697	Pipe 1	4 to 8	Upper Alluvium	232.21	25 km east of Study area at NSW/QLD Border	Upward gradient. Kumbarilla water level markedly above alluvium water levels (levels gauged on 19/5/2015).
	Pipe 2	52 to 58	Lower Alluvium	234.3		
	Pipe 3	74 to 80	Kumbarilla Beds	236.15		

The nested well data indicates the following:

- There are notable differences in groundwater level between the Cenozoic alluvium (water table) and the Surat Basin strata (potentiometric levels)
- Near Ch 25 km (GW036684), there is little to no vertical gradient between the upper and lower alluvial aquifers (i.e. acts as a single unit)
- An upward vertical gradient between the Kumbarilla Beds and the overlying alluvium is evident to the east of the alignment in GW036697 and GW036691. This observed gradient is also likely to exist along the proposal alignment. The observed upward gradient is likely due to recharge via outcropping units such as the Pilliga Sandstone near the eastern boundary of the GAB, followed by subsequent ground water movement down dip towards the west.

Hydraulic interaction between alluvial aquifers and the underlying Surat Basin aquifers is likely to be limited due to:

- Low permeability of upper units in the Surat basin stratigraphy (i.e. Wallumbilla Formation)
- Saprolite development in the upper Surat Basin stratigraphy.

Exceptions may occur where paleochannels are deeply incised, such as in the Macintyre River area, where upward leakage from the Kumbarilla Beds could take place. Another potential mechanism for aquifer interaction is via faults that act as conduits for upward migration of groundwater to shallower systems. Evidence for fault induced aquifer interactions is documented along the Peel Fault to the east of the proposal where upward leakage of saline groundwater has occurred (Knight et al. 1989).

6.5 Groundwater quality

6.5.1 Regional salinity

Salinity presents a major land degradation issue which can impact on land salinisation, in-stream salt loads and concentrations. In NSW, Catchment Management Authorities (CMAs) produced salinity risk rankings within each catchment (CMAs are now part of the Local Land Services). This ranking has been developed considering several variables including salt stores, salinity outbreaks, surface water quality, aquifer type and groundwater quality (NSW DPI 2013).

Between North Star and Ch 20 km, a very high risk ranking exists along the proposal site and is associated with the flat lying Jurassic aged strata and residual soils of the Kumbarilla Beds and the Walloon Coal Measures (refer Figure 6.5) (NSW DPI 2013). These high-risk areas are particularly evident where stratigraphic changes or breaks in slope occur.

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

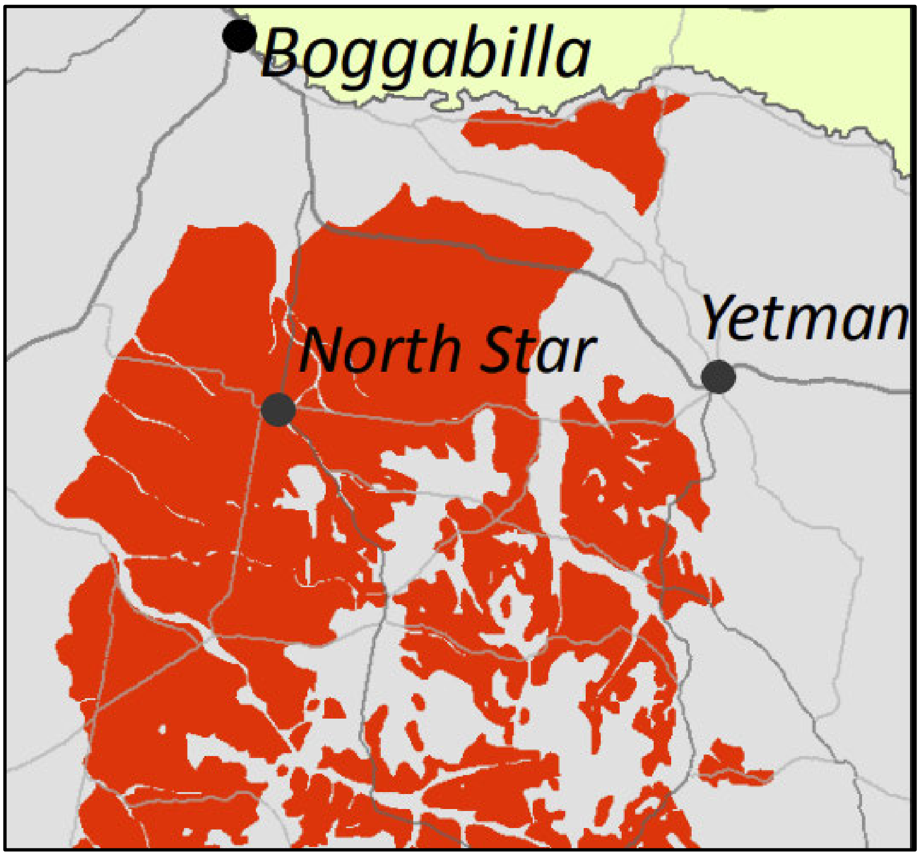


Figure 6.5 **High risk salinity hazard ranking (red) along the proposal site**

Source: NSW DPI 2013

6.5.2 Hydrochemistry

Regional groundwater chemistry is presented in Table 6.4. Due to a lack of hydrochemistry data from the NSW portion of the alignment, the data presented is from bores located in Queensland within a 10 km radius of the alignment. This data is considered representative of the Alluvium, Kumbarilla Beds and the Walloon Coal Measures. Additional site specific groundwater quality data was collected from seven proposal monitoring wells and three existing landholder bores in October 2018 (FFJV 2019) with this data presented in Table 6.5.

Table 6.4 Regional groundwater quality for relevant hydrostratigraphic units

	Guidelines		Cenozoic Alluvium				Kumbarilla Beds				Walloon Coal Measures			
Parameter	*ANZECC Stock (2000)*	*NHMRC Drinking Water - (2011)*	*Mean*	*Min*	*Max*	*# samples*	*Mean*	*Min*	*Max*	*# samples*	*Mean*	*Min*	*Max*	*# samples*
Field EC (uS/cm)			1217	316	4800	7	995	380	1600	4	1134	1129	1140	4
Field pH			NA	7.2	7.9	2	-	-	-	-	8.65	8.3	8.7	4
Lab EC (uS/cm)			492	380	449	11	1245	492	2000	25	1151	1117	1240	21
Lab pH			7.5	7.2	8.4	11	8.37	7.5	8.9	25	8.33	7.6	8.8	21
TDS (mg/L)	4000	600	332.9	490	250	11	747	333	1103	24	692	639.8	723.3	21
Bicarbonate (mg/L)			197	130	460	11	553	243	685	25	531	430	570	21
Total Alkalinity (mg/L)			159	110	385	12	496	200	819	28	457	390	480	21
SAR			7.6	3.2	10	12	36.5	3.1	59.1	28	46.9	31.1	54.4	16
Calcium (mg/L)	1000		6.5	2.9	25	12	4.5	0.9	37	28	2.4	1.7	5.8	21
Magnesium (mg/L)			5.4	2.2	26	12	2.7	0.1	24	28		0.1	2	11
Sodium (mg/L)		180	92	63	165	12	304	100	563	28	282	265	299	21
Potassium (mg/L)			2.18	1.2	4.4	11	2.2	1	3.2	23	1.5	1.1	1.9	16
Chloride (mg/L)		250	52.7	22.9	175	12	134.8	27	310	28	92.8	82	105	21
Sulphate (mg/L)	1000	500	11.26	3.9	27.5	11	11.76	0.4	40.5	20	26	18.7	35	21
Iron - Total (mg/L)		0.3	0.14	< 0.01	0.33	9	0.05	< 0.01	0.24	15	0.07	0.01	0.16	11
Aluminium - Total (mg/L)	5	0.2	0.19	< 0.05	1	7	<0.05	0	<0.05	10	<0.05	0	<0.05	5

Table notes:

EC = Electrical Conductivity

SAR = Sodium Adsorption Ratio

TDS = Total Dissolved Solids

Shaded values represent exceedances of groundwater assessment guideline values.

Source: DNRME and WaterNSW

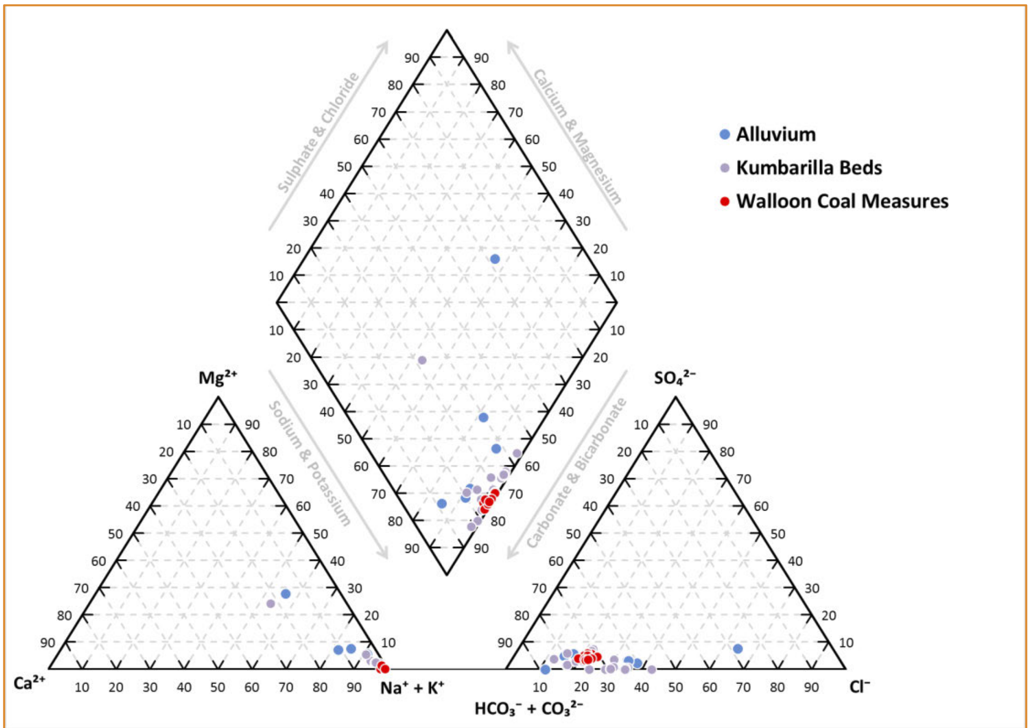


Figure 6.6 Piper plot for registered bores from the key aquifers within 10 km of the northern portion of the Study Area

Figure note:

Only ionically balanced sample results are displayed.

Source: DNRME

Table 6.5 Site investigation groundwater results obtained in October 2018

Parameter		Kumbarilla Beds	Kumbarilla Beds (inferred)	Wallumbulla Formation	Alluvium						
Bore / Well ID		BH2202	GW965240	BH2204	BH2206	BH2212	BH2213	BH2217	BH2218	Bore X	RN30765
Approx. NS2B Location		KP8.1	0.5km east of KP12.1	KP19.6	KP24.1	KP30.4	KP30.7	KP33.0	KP34.8	1.2km west of KP30.0	3.4km east of KP32.0
NS2B Bridge ID		270-BR02	NA	270-BR04	270-BR06	270-BR10	270-BR10	270-BR12	270-BR13	NA	NA
Field Readings	***pH***	6.66	3.24	5.56	7.51	7.07	7.38	7.42	7.35	6.86	7.78
	EC (µS/cm)	12900	43436	23100	2488	813	2096	879	1720	1494	1055
	DO (ppm)	3.77	50.6	4.96	3.29	2.93	1.92	3.45	3.98	9.3	3.49
	Redox (mV)	184.7	338.4	199.8	128.3	10.6	-73.2	92.5	42.3	-1.2	-167.8
Laboratory Results	***EC (µS/cm)***	13,600	44,900	23,800	2520	853	1200	926	1760	1450	1110
	TDS (mg/L)	8520	33,100	17,300	1460	507	751	564	1070	993	653
	Na (mg/L)	2380	7800	3390	471	142	250	170	350	123	246
	K (mg/L)	8	8	46	2	3	5	3	7	2	2
	Ca (mg/L)	312	1180	887	29	13	25	18	17	69	5
	Mg (mg/L)	260	1,310	653	26	10	14	9	24	49	3
	Cl (mg/L)	4680	17300	8900	553	154	94	122	246	362	128
	S04 (mg/L)	311	1,460	780	37	44	11	62	37	17	2
	Bicarbonate (mg/L)	959	<1	46	545	160	504	232	588	138	398
	Tot Alk (mg/L)	959	<1	46	545	160	504	232	588	138	398
	Nitrogen (mg/L)	0.31	0.04	0.09	1.22	0.02	0.47	1.4	1.37	184	0.01
	Hardness as CaC03	1850	8340	4900	179	74	120	82	141	374	25

Table notes:

EC = Electrical Conductivity

TDS = Total Dissolved Solids

Source: FFJV 2019

6.5.2.1 Cenozoic alluvium

Electrical conductivity (EC) data for registered bores in the alluvium in Table 6.5 indicates salinity is highly variable ranging up to 4,800 µs/cm suggesting fresh to brackish conditions. Laboratory total dissolved solids (TDS) values primarily from the Macintyre River alluvium in Queensland indicate the alluvium in the northern portion of the alignment is below the Australian drinking water guideline of 600 mg/L for TDS (NHMRC, 2011). Site specific groundwater sampling from the alluvium in October 2018 is broadly consistent with the regional bore data with salinity typically less than 2000 µS/cm. The highest salinity was recorded near the proposed bridge 270-BR06 with 2488 µS/cm in the alluvium (refer Table 6.5). Based on TDS values from registered bores and site investigation bores the alluvium slightly exceeds the drinking water guideline of 600 mg/L.

Regional monitoring from the NSW Border Rivers Unregulated and Alluvial Water Sources considers the Downstream Keetah Bridge Alluvium water source (i.e. Macintyre River and Whalan Creek alluvial units) to have high salinity unsuitable for irrigation with values typically ranging 14,000 to 50,000 µS/cm (DPI 2015).

Based on available registered bore data and the October 2018 sampling, the field measured pH ranges from 7.0 to 8.0 in the alluvium indicating neutral to slightly alkaline conditions.

Major ion chemistry for the alluvium displays the most variability and is likely a result of the different parent material in the alluvium sequences (refer Figure 6.6).

Based on the October 2018 sampling there were no hydrocarbons and pesticides detected in the alluvium along the proposal alignment FFJV 2019).

6.5.2.2 Jurassic – Cretaceous groundwater

Kumbarilla Beds

Water quality from registered bores tapping the Kumbarilla Beds have TDS values ranging from 333 to 1,100 mg/L while two locations sampled close to the alignment in October 2018 indicated TDS values can exceed 8,000 mg/L (refer Table 6.5). It is noted the site investigation bores are installed in the shallower weathered zone of the Kumbarilla Beds which may have contributed to higher salinity compared to the deeper registered bores in this aquifer. Water quality from registered and site investigation bores typically above the drinking water guideline of 600 mg/L for this aquifer.

Major ion chemistry is highly variable and likely to reflect the variety of formations tapped within the Kumbarilla Beds.

Walloon Coal Measures

Available salinity data indicates the Walloon Coal Measures are typically brackish to slightly brackish but still suitable for stock usage (TDS < 4,000 mg/L).

Major ion chemistry displays a tighter grouping compared to the other formations with higher proportions of sodium and potassium. No site investigation wells were installed in the Walloon Coal Measures.

6.6 Surface water – groundwater interactions

Regional assessments of surface water-groundwater interactions have identified the Macintyre River and other water courses in the region to generally be in a losing condition (Parson et al. 2008). This means that surface water typically infiltrates vertically to groundwater to recharge local groundwater within the alluvium. However, particularly in the Macintyre River, a reversal to gaining conditions could occur over short time periods in response to flood events which elevate the local water table.

The relationship between flow rates in the Macintyre River and groundwater elevation in the associated alluvial system are presented in Figure 6.7. High flow periods such as in late 2010 correlate with responses ranging from 1 m (GW036684 and GW036696) to 2 m (GW036694) increase in levels. The strongest connection to river flow is observed in GW036696 which is located in alluvium in close proximity to the active river channel.

The Glenlyon and Pindari Dams in the upper reaches of the Border Rivers Catchment result in regulated flows to the Severn and Macintyre Rivers (DPI 2012). Consequently, there is likely to be an artificial influence on recharge to alluvial aquifers during low flow periods (periods of dam discharge to the rivers).

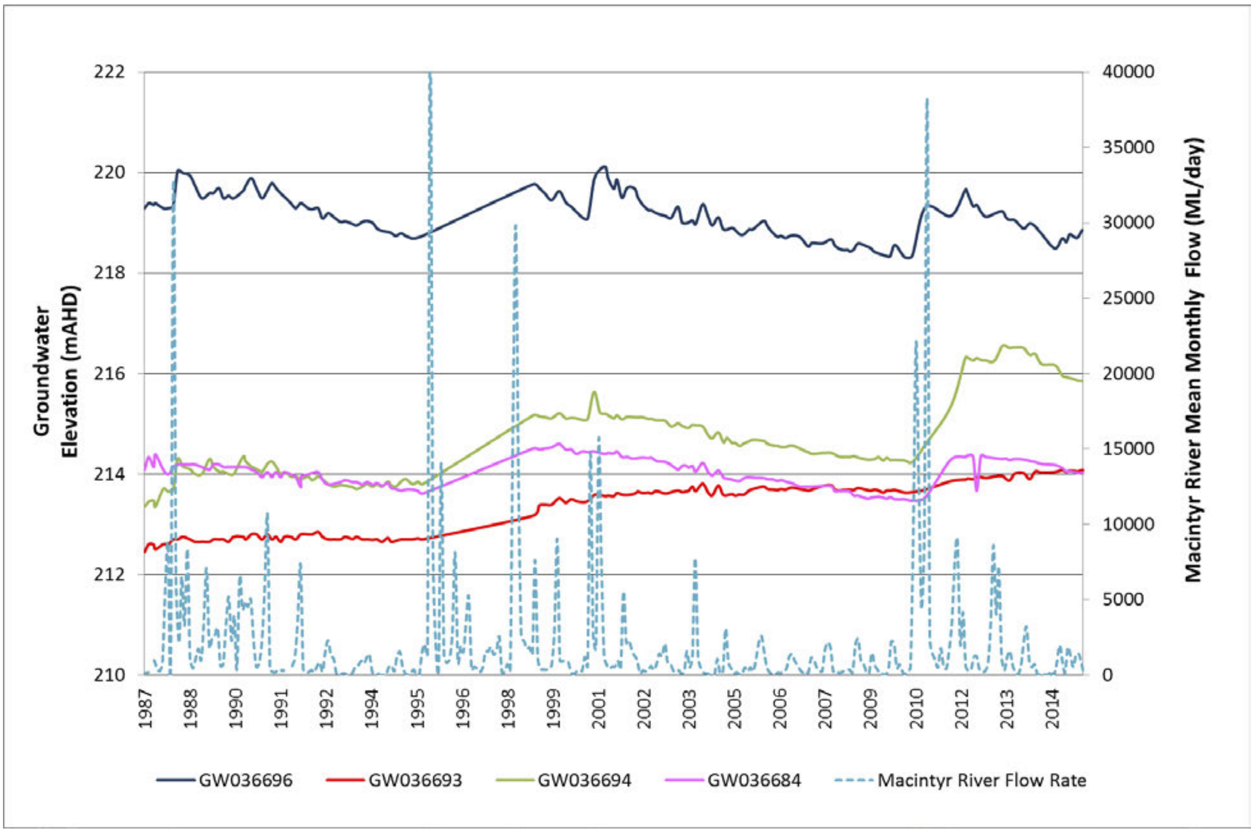


Figure 6.7 Hydrograph of groundwater elevations in alluvium and the Macintyre River mean monthly flow

Figure note:

Macintyre River flow rates sourced from BoM station 416002 at Boggabilla. Groundwater elevations sourced from WaterNSW.

6.7 Groundwater dependent ecosystems

An assessment of potential GDEs was completed by reviewing the following data sources:

- Relevant NSW Water Sharing Plans (which include scheduled listings of high priority GDEs)
- BoM Groundwater Dependent Ecosystems Atlas
- Findings within Biodiversity technical report prepared for the NS2B EIS (FFJV 2020).

The Water Sharing Plan for the NSW Border Rivers Unregulated and Alluvial Water Sources (2012) do not list any high priority groundwater dependent ecosystems within Schedule 8 of the plan.

No scheduled high priority GDEs were provided in the Water Sharing Plan for the NSW Border Rivers Regulated River Water Source (June 2009).

The BoM Groundwater Dependent Ecosystems Atlas was accessed to assess potential GDEs within or in close proximity to the proposal site. An approximate 2 km radius around the alignment centreline was reviewed for potential GDEs as a conservative approach. An overview of potential Aquatic GDEs is provided in Figure 6.8a-b and potential Terrestrial GDEs are provided in Figure 6.9a-b, respectively. Not all water features are shown in the figures due to the scale of the figure compared to the size of the feature. Potential impacts to identified GDEs are discussed in Section 9.2.4 with relevant mitigation measures discussed in Section 10.

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

Map by: NCW/GN Z:\GIS\GIS_270_NS2B\Tasks\270-EAP-201910311020_Groundwater_Figures\270-IGE-201901031120_Fig6-8_Aquatic_GDEs_Rev3.mxd Date: 10/03/2020 15:35

Legend

5 Chainage (km)
Localities
Existing rail (operational)
Existing rail (non-operational)
North Star to NSW/QLD border alignment

Adjoining alignments
Major roads
Minor roads
Watercourses

Aquatic GDEs
Moderate potential GDE

A4 scale: 1:100,000

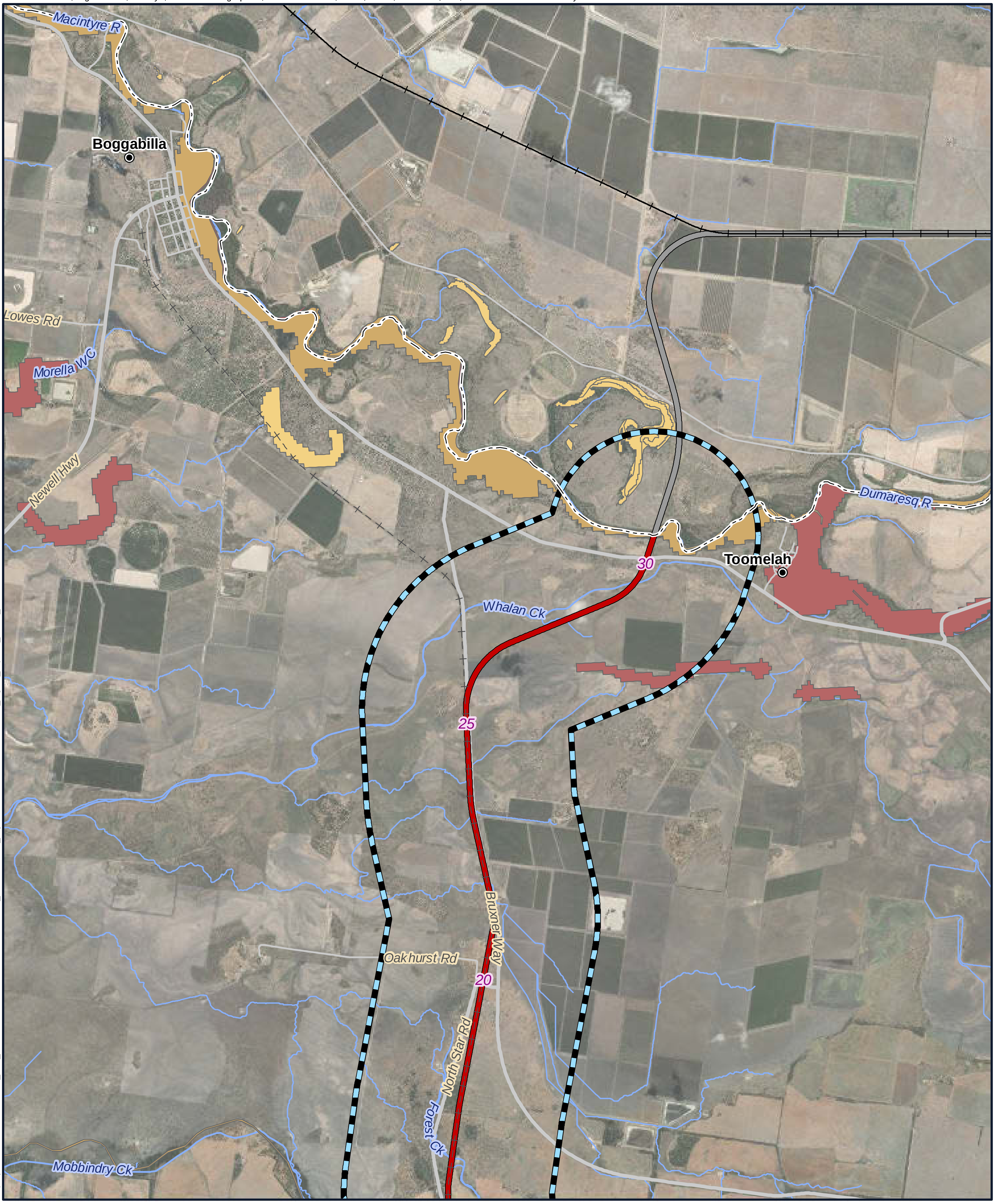
0 1 2 3 km

Future Freight
Integrating Community, Environment and Engineering

Date: 10/03/2020 Version: 3
Coordinate System: GDA 1994 MGA Zone 56

North Star to NSW/QLD border
Figure 6.8a: Aquatic GDEs

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



Map by: NCW/GN Z:\GIS\GIS_270_NS2B\Tasks\270-EAP-201910311020_Groundwater_Figures\270-IGE-201901031 1020_Fig6-8_Aquatic_GDEs_Rev3.mxd Date: 10/03/2020 15:35

Legend

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

Aquatic GDEs

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

A4 scale: 1:100,000

0 1 2 3 km

Future Freight
Integrating Community, Environment and Engineering

Date: 10/03/2020 Version: 3

Coordinate System: GDA 1994 MGA Zone 56

North Star to NSW/QLD border

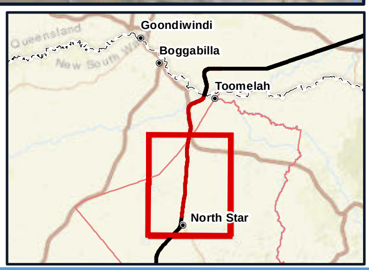
Figure 6.8b: Aquatic GDEs

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

Map by: NCW Z:\GIS\GIS_270_NS2B\Tasks\270-EAP-201910311020_Groundwater_Figures\270-IGE-201910311020_Fig6-9_Terrestrial_GDEs_rev4.mxd Date: 3/02/2020 12:22

Legend

- 5 Chainage (km)
- Localities
- Existing rail (operational)
- Existing rail (non-operational)
- North Star to NSW/QLD border alignment
- Adjoining alignments
- Major roads
- Minor roads
- Watercourses
- Groundwater study area
- High potential GDE
- Moderate potential GDE
- Low potential GDE



A4 scale: 1:100,000

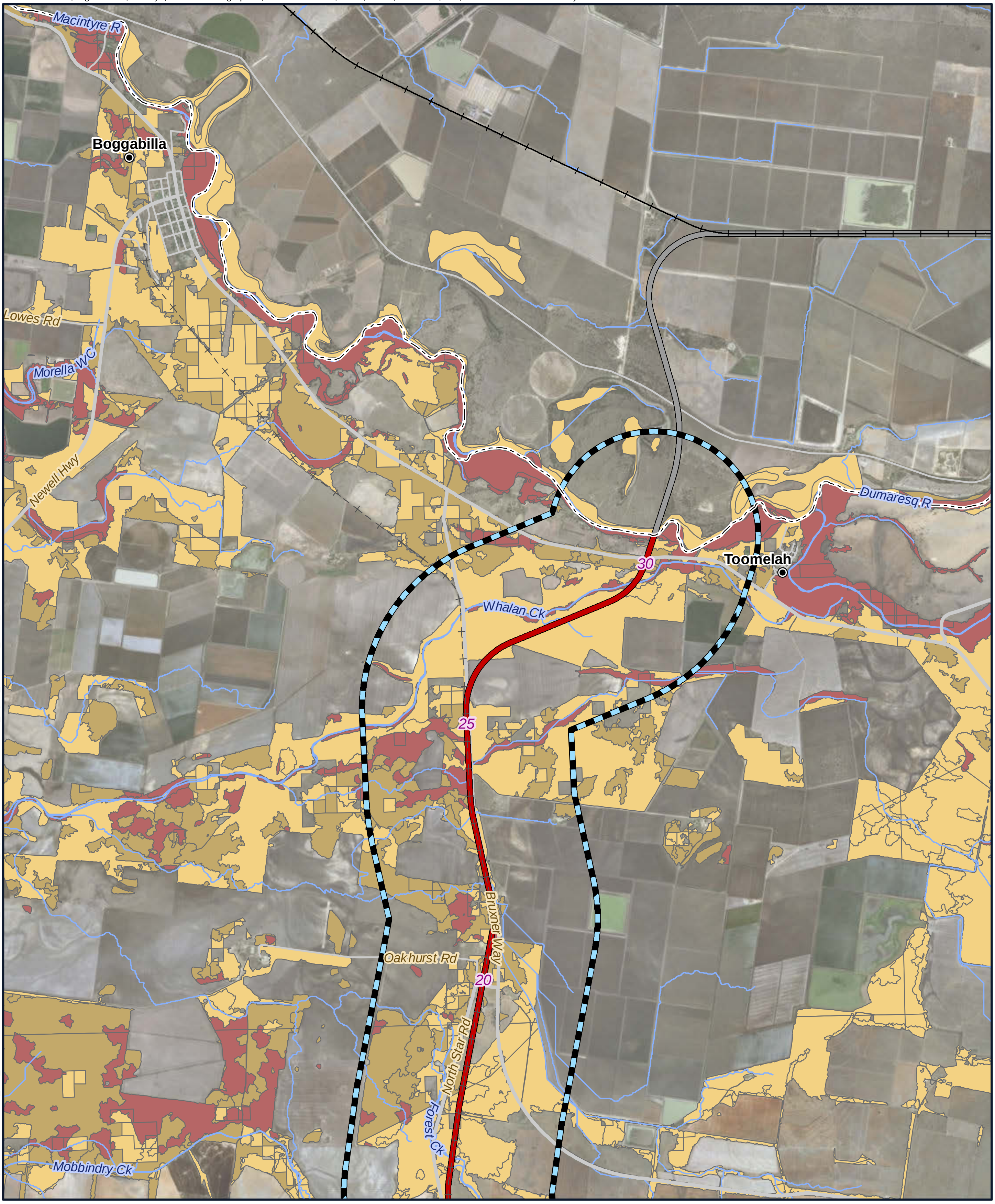
0 0.6 1.2 1.8 2.4 3 km

Future Freight
Integrating Community, Environment and Engineering

Date: 03/02/2020 Version: 4
Coordinate System: GDA 1994 MGA Zone 56

North Star to NSW/QLD border
Figure 6.9a: Terrestrial GDEs

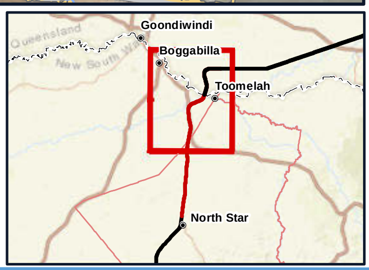
Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN,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



Map by: NCW Z:\GIS\GIS_270_NS2B\Tasks\270-EAP-201910311020_Groundwater_Figures\270-IGE-201910311020_Fig6-9_Terrestrial_GDEs_rev4.mxd Date: 3/02/2020 12:22

Legend

- 5 Chainage (km)
- Localities
- Existing rail (non-operational)
- North Star to NSW/QLD border alignment
- Adjoining alignments
- Major roads
- Minor roads
- Watercourses
- NSW/QLD border
- Groundwater study area
- High potential GDE
- Moderate potential GDE
- Low potential GDE



A4 scale: 1:100,000

0 0.6 1.2 1.8 2.4 3 km

Future Freight
Integrating Community, Environment and Engineering

Date: 03/02/2020 Version: 4

Coordinate System: GDA 1994 MGA Zone 56

North Star to NSW/QLD border

Figure 6.9b: Terrestrial GDEs

6.7.1 Aquatic groundwater dependent ecosystems

Identified aquatic GDEs are limited within the 2 km radius of the Study Area considered with no high potential aquatic GDEs intersected by the alignment. A summary of aquatic GDEs is provided in Table 6.6.

Table 6.6 Summary of aquatic groundwater dependent ecosystems

Chainage	GDE category	Aquatic GDE description
Ch 5.70 km	Moderate	A narrow corridor reported to have moderate potential as an aquatic GDE is identified in Mobbindry Creek. Proposed construction at this location is a bridge over Mobbindry Creek. Classified ecosystem type is river[1].
Ch 28.0 km	High	A high potential aquatic GDE is identified at Malgarai Lagoon located 1km to the southeast the alignment and 2.5km south of the Macintyre River. Classified ecosystem type is wetland. No construction activity in proximity to this feature.
Ch 30.5 km	Moderate	A moderate potential aquatic GDE is identified within the active Macintyre River channel and will be crossed by the alignment via a cut and fill as well as a bridge structure. Classified ecosystem type is wetland.

Table note:

1. The GDE database (developed by BoM) classifies this waterway as a river

Source: BoM GDE Atlas

Based on site inspections and the desktop review completed in the Chapter 10 (Biodiversity), the Macintyre River is considered the primary water way with habitat that could support six threatened aquatic species identified with a 'possible' likelihood of occurring within the proposal area. This includes the following species: Darling river snail (*Notopala sublineata*), Silver perch (Bidyanus bidyanus), Southern purple spotted gudgeon (*Mogurnda adspersa*), Murray cod *(Maccullochella peelii),* Eel-tailed catfish (*Tandanus tandanus),* Western olive perchlet (*Ambassis adassizii*).

6.7.2 Terrestrial groundwater dependent ecosystems

Moderate to high potential terrestrial GDEs are identified within a 2 km radius, these are included in Table 6.7.

Table 6.7 Summary of terrestrial groundwater dependent ecosystems

Chainage	GDE Category	Terrestrial GDE description
Ch 5.70 km	High	High potential terrestrial GDEs within the floodplains of Mobbindry Creek. This GDE is characterised by Red River Gums and open tall Forest associated with flood plains. The alignment intersects this feature with a short section of bridge proposed.
Ch 8.1 km	High	High potential terrestrial GDEs within the active channel of Back Creek. This GDE is characterised by Red River Gums and open tall Forest associated with the flood plains. The alignment intersects this feature with a short section of cut and fill proposed.
Ch 23.6 km to Ch 25.0 km	Moderate to High	Moderate to High potential, irregularly distributed terrestrial GDEs on the alluvial plains south of and along Whalan Creek. Characterised by River Coobah swamp wetland.
Ch 29.4 km to Ch 29.8 km	High	High potential terrestrial GDE within the active channel of Whalan Creek. Cut and fill proposed. Characterised by River Coobah swamp wetland.
Ch 30.4 km to Ch 30.7 km	High	High potential terrestrial GDEs on the Macintyre River with Red River Gums, open tall Forest, and marsh grassland associated with these flood plains.

Source: BoM GDE Atlas

6.7.3 Subterranean

No known or potential subterranean GDEs have been identified within the BoM GDE Atlas within 2 km of the alignment.

6.8 Groundwater use

A review of licence allocations for the main water source units covered by water sharing plans in the region was completed by searching the WaterNSW licence register (refer Table 6.8). Water licence allocations for the main alluvial (NSW Border Rivers Downstream Keetah Bridge) is limited to two licences which extract at total of 485 ML per year. This limited extraction allocation contrasts with the more productive alluvial unit to the east of the Keetah Bridge ('Upstream Keetah Bridge water source') (NSW DPI 2012a). The Eastern Recharge Groundwater Source (i.e. GAB) forms a significant water source for the region with 17,487 ML per year allocated under 79 access licences.

Table 6.8 Summary of 2018-2019 water access licence allocations relevant to the Study Area

Water source	Licence type	No of WALs	Water made available (ML/yr)
NSW Border Rivers Downstream Keetah Bridge (Alluvial Aquifer Source)	Aquifer	2	485
Croppa Creek and Whalan Creek (Surface Water and Alluvium Source)	Domestic and Stock	9	65.5
	Domestic and Stock (Domestic)	1	2
	Domestic and Stock (Stock)	2	10
	Unregulated River	22	15,674
GAB - Eastern Recharge Groundwater Source	Aquifer	79	17,487
	Domestic and Stock (Town Water)	1	32

Source: WaterNSW

A summary of water use based on registered bores is provided in Figure 6.10. A total of 55 bores within a 10 km radius of the proposal site provided sufficient data to assess the category of bore use and the corresponding aquifer. Based on the location, depth and lithology of these registered bores, the following can be deduced on water usage:

- In the northern portion of the alignment (Ch 20 km to Ch 30 km) bores are constructed predominantly within the Cenozoic alluvium with the type of bore/ groundwater use ranging widely. Bores located near the Macintyre River are predominantly used for water supply and domestic purposes (i.e. Toomelah township 2 km east of the alignment). Three bores within the alluvium to the east of Ch 25 km are classed as irrigation bores (GW027891, GW027892 and GW027893).
- Bore use in the southern portion of the alignment (i.e. Ch 0 km to Ch 20 km) is dominated by extraction from the Kumbarilla Beds and the Walloon Coal Measures for stock, and to a lesser extent, irrigation and domestic purposes. This reflects the limited extent of alluvium in the southern portion and the generally higher salinity associated with these deeper hydrostratigraphic units (refer Section 6.5.2.2).

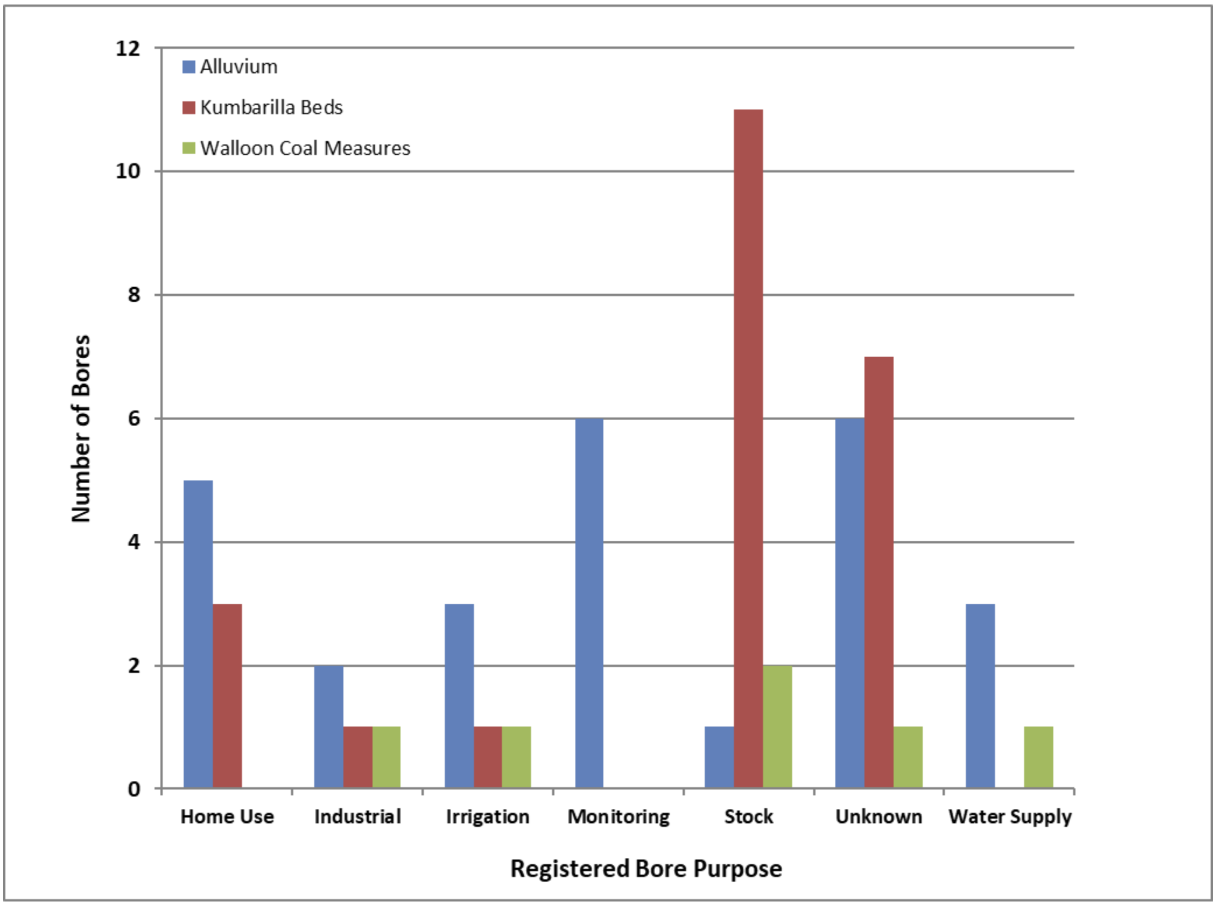


Figure 6.10 Registered bore use for bores within a 10 km radius of the proposal site

6.9 Groundwater environmental values

This section discusses the groundwater related environmental values relevant to the proposal site. The NSW Office of Water (formerly the Department of Environment and Conservation (DEC)) has defined environmental values and long-term goals for NSW's water quality in each catchment region. The Border Rivers (NSW) Water Quality and River Flow Objectives provide relevant groundwater values and trigger values for the proposal which are summarised in Table 6.9.

6.9.1 Environmental values of the proposal

6.9.1.1 Aquatic ecosystems

Regional Aquatic GDE data evaluated in Section 6.7.1 indicated there were no high potential aquatic GDEs intersected by or in close proximity to the proposal site (refer Figure 6.8a-b). The nearest high potential aquatic GDE is located at Malgarai Lagoon approximately 1 km to the east of the alignment. The Macintyre River is mapped as a moderate potential GDE located at the end of the proposal. Therefore, this environmental value is considered relevant to the proposal.

6.9.1.2 Visual amenity

This item is not applicable to groundwater as no springs have been identified in or adjacent to the alignment.

6.9.1.3 Farm water supply/use

Groundwater quality results presented in Section 6.5.2 indicate that groundwater abstracted from the shallow alluvial aquifer could be used for general farm purposes, although quality is noted to be highly variable. This environmental value is considered relevant to the proposal.

6.9.1.4 Stock water

In Section 6.8 registered bore use and the allocation of water access licencing was reviewed. This review confirmed that groundwater from the alluvium and particularly the Kumbarilla Beds is predominantly utilised for stock watering. Available salinity data presented in Section 6.5 indicated that the Cenozoic alluvium and Surat Basin aquifers are generally suitable for stock watering purposes (i.e. <4,000 mg/L for beef cattle as per the Table 4.3.1. ANZG 2018.

Groundwater results from site investigations in October 2018 further confirmed the suitability of groundwater from the Cenozoic alluvium for stock watering purposes (refer Table 6.4). This environmental value is considered relevant to the proposal.

6.9.1.5 Recreation

This environmental value is generally not considered to be relevant to in-situ groundwater and is a more common consideration for surface water. There is a possibility of seasonal bore water use to fill swimming pools. There are no registered groundwater springs within the study area which could be considered for recreational use.

This environmental value is not considered relevant to the proposal.

6.9.1.6 Drinking water

Groundwater from bores constructed within the Kumbarilla Beds and the Walloon Coal Measures are generally unsuitable for drinking water (i.e. greater than the Australian drinking water criteria of 600 mg/L for total dissolved solids [TDS]).

Results for TDS from the Cenozoic alluvium within the Queensland portion of the alignment indicate the alluvium is suitable for drinking water (based on salinity).

It is unclear if the registered bores designated for water supply near Toomelah Aboriginal Community are treated to mitigate any salinity issues.

As numerous registered bores within alluvial sediments reported uses and WAL include for domestic uses, this environmental value is considered relevant to the proposal a conservative measure.

6.9.1.7 Irrigation

Irrigation sourced from groundwater is an important value to the region, particularly in the North Star area with respect to the proposal. Irrigation in this area is primarily used for cotton production and, to a lesser extent, other irrigated crops such as cereals (NSW DWE 2009b). The threshold salinity tolerances for plants grown in loamy to clayey soils (considered to be the primary soil conditions) are 600 µS/cm to 7,200 µS/cm as stated in the ANZG. Based on salinity results presented in Section 6.5, the alluvium and Surat Basin strata generally report concentrations of salinity less than 2,000 µS/cm in the area, indicating groundwater is suitable for irrigation. An exception is considered to be bores constructed to intersect the upper weathered zone of the Surat Basin Kumbarilla Beds strata where site investigation bores have reported an association with salinity over 10,000 µS/cm (i.e. BH2202 and BH2204 in Table 6.5).

This environmental value is considered relevant to the proposal.

6.9.1.8 Cultural water

A review of the NSW Aboriginal Places and State Heritage Register as well and the Moree Plains and Gwydir Local Environmental Plans indicated there are no registered water sites of aboriginal cultural significance in close proximity to the proposal site.

This environmental value is not considered relevant to the proposal.

6.9.2 Summary of groundwater environmental values

Based on this review, the groundwater environmental values mapped using available local and regional information and site investigation results and considered to be relevant to the proposal include:

- Drinking water (Cenozoic alluvium only)
- Domestic use (Cenozoic alluvium and Surat Basin aquifers)
- Stock watering (Cenozoic alluvium and Surat Basin aquifers)
- Irrigation (Cenozoic alluvium and Surat Basin aquifers)
- Aquatic GDEs (Macintyre River).

6.9.3 Water quality objectives

Water quality objectives (WQOs) are long-term goals for water quality management that provide quantitative levels or written statements for specific indicators of water quality (i.e. salinity or pH) to protect environmental values defined in Section 6.9.1 and summarised in Section 6.9.2. The WQOs relevant to the proposal are presented in Table 6.9 and are in accordance with the Border Rivers WQO (NSW OEH, 2006) guidance documents.

Baseline groundwater quality data collected to date (refer Section 7.4) and the proposed ongoing baseline (background/pre-construction data) sampling will allow for appropriate site specific WQOs to be determined at various locations along the proposal. These will be based on an assessment of the ambient (background) groundwater quality data collected and with consideration to the NSW guideline values to define the WQOs to be maintained.

The available baseline groundwater quality data (October 2018) has been assessed against the Border Rivers WQOs to identify where the existing environment is within/below the relevant WQO trigger values and where the trigger values are currently exceeded along the proposal.

Table 6.9 Environmental water quality values relevant to groundwater for the Border Rivers Catchment

Water Quality Value	Description	Relevant groundwater unit	Relevant trigger values[1,2]	Comparison to existing environment
Aquatic ecosystems	Maintaining or improving the ecological condition of waterbodies and their riparian zones over the long-term. The objective applies to all-natural waterways as well as any artificial water courses which flow into natural waterways. Specific trigger values are defined for each waterbody type including upland rivers, lowland rivers and lake or reservoirs.	Macintyre River (direct); alluvial aquifers (indirect).	Total Nitrogen (N) – 0.5 mg/L (lowland rivers) Total Phosphorus – 0.05 mg/L (lowland rivers) pH - 6.5 to 8.5 (lowland rivers) Salinity (as EC) – 125 to 2,200 µS/cm (lowland rivers)	Site investigation bore's analytical results (refer Table 6.5) for alluvial aquifers along natural waterway (indirect WQO) compared to the WQOs: ▪ Total N – all results are above trigger value except bore RN30765 (0.3 mg/L), BH2206 and BH2217 (both 0.4 mg/L) ▪ Total P – all results above trigger value (0.07 mg/L to 0.47 mg/L) ▪ Salinity (as EC) – below the trigger values except location BH2206 (2,520 µS/cm) ▪ pH – within WQOs.

Water Quality Value	Description	Relevant groundwater unit	Relevant trigger values[1,2]	Comparison to existing environment
Livestock water supply	Protecting water quality to maximise the production of healthy livestock and applies to all surface and ground water.	Alluvium aquifers Surat Basin aquifers	Total Dissolved Solids (TDS) – no adverse impacts values (ANZG 2018 Guidelines): ▪ Beef cattle - 0 to 4,000 mg/L ▪ Sheep – 0 to 5,000 mg/L ▪ Horses - 0 to 4,000 mg/L.	Site investigation bores analytical results (refer Table 6.5) when compared to the WQOs: ▪ Alluvium aquifers – all below the trigger value of 4,000 mg/L ▪ Surat Basin aquifers – all above the trigger value of 5000 mg/L.
Irrigation water supply	Protecting the quality of waters applied to crops and pasture. Applies to all current and potential areas of irrigated crops, both small- and large-scale.	Alluvium aquifers Surat Basin aquifers	Trigger values as per ANZG 2018 guidelines: ▪ Chloride (Cl) - tolerant crops >700 mg/L. ▪ Sodium (Na) – tolerant crops >460 mg/L. ▪ Bicarbonate (HCO_3^-) – no trigger value.	Site investigation bores analytical results (refer Table 6.5) when compared to the WQOs: ▪ Chloride: – Alluvium aquifers suitable for sensitive to moderately tolerant crops (94 mg/L to 553 mg/L) – Surat Basin aquifers all above 700 mg/L (4,680 mg/L to 17,300 mg/L) ▪ Sodium: – Alluvium aquifers suitable for sensitive to tolerant crops (123 mg/L to 471 mg/L) – Surat Basin aquifers all above 460 mg/L (2,380 mg/L to 7,800 mg/L).
Homestead water supply	Protecting water quality for domestic use in homesteads, including drinking, cooking and bathing. Applies to all homesteads that draw water from surface and groundwater for domestic needs, including drinking water.	Alluvium aquifers. Surat Basin aquifers.	Total Dissolved Solids (TDS): ▪ <500 mg/L (good quality drinking water) ▪ 500 to 1,000 mg/L (acceptable) ▪ > 1 000 mg/L (unsatisfactory taste and corrosive) pH 6.5 to 8.5.	Site investigation bores analytical results (refer Table 6.5) when compared to the WQOs: ▪ Total dissolved solids: – Alluvium aquifers all good to acceptable quality (all samples above 500 mg/L but below 1,000 mg/L except BH2206 [1460 mg/L]) – Surat Basin aquifers all unsatisfactory taste and corrosive (all samples above 1,000 mg/L) ▪ pH: – Alluvium aquifers all within trigger value range – Surat Basin aquifers all above trigger value range except BH2202 (6.66).

Water Quality Value	Description	Relevant groundwater unit	Relevant trigger values[1,2]	Comparison to existing environment
Drinking water - Groundwater	Refers to the quality of drinking water drawn from the raw surface and groundwater sources before any treatment. Applies to all current and future licensed offtake points for town water supply and to specific sections of rivers that contribute to drinking water storages. The objective also applies to subcatchments or groundwaters used for town water supplies.	Alluvium aquifers Surat Basin aquifers.	Total Dissolved Solids (TDS) (ADWG 2017 values): ▪ 0 to 600 mg/L (good) ▪ 600 to 900 mg/L (fair) ▪ 900 to 1200 mg/L (poor) ▪ >1200 mg/L (unacceptable) pH 6.5 to 8.5.	Site investigation bores analytical results when compared to the WQOs are: ▪ Total dissolved solids: – Alluvium aquifers all range from good to poor, except BH2206 which is unacceptable (1,460 mg/L) – Surat Basin aquifers all unacceptable (8,520 to 33,100 mg/L) ▪ pH: – Alluvium aquifers all within trigger value range – Surat Basin aquifers all outside of trigger value range except BH2202 (6.66 pH units).

Table notes:

1 Trigger values sourced from the NSW Water Quality and River Flow Objectives online database (NSW Department of Environment and Conservation (DEC)).

2 Aquatic ecosystem trigger values are for lowland rivers given the DEC suggested altitude for upland rivers in the NSW Murray-Darling Basin of >250 m.

Source: NSW OEH 2006

Based on the data presented in Table 6.9, the following WQOs are not currently being met:

- Aquatic ecosystems (alluvial aquifers): total phosphorous, total nitrogen, and likely salinity (as EC) in some areas
- Livestock water supply (Surat Basin aquifers): TDS
- Irrigation water supply (alluvial and Surat Basin aquifers): chloride, sodium
- Homestead water supply:
  - Alluvial aquifers: likely TDS in some areas
  - Surat Basin aquifers: TDS, pH
- Drinking water – Groundwater (alluvial aquifers): likely TDS in some areas.

7 Field investigations

Geotechnical and hydrogeological site investigations were undertaken along the proposal from July to October 2018 (FFJV 2019). Results from these investigations have been considered in Sections 5 and 6 to compliment the desktop geological and hydrogeological reviews.

The hydrogeological field investigations included:

- Standpipe piezometer installation
- Permeability testing in standpipe piezometers
- Groundwater level monitoring
- Groundwater sampling
- Bore inventory and groundwater sampling of registered bores and private property bores.

Site investigations (geotechnical and hydrogeological) are summarised in Table 7.1.

7.1 Standpipe piezometer installation

Drilling and installation of standpipe piezometers were conducted according to the Minimum Construction Requirements for Water Bores in Australia – Edition 3 (Feb 2012). The design of the standpipe piezometer was provided by a qualified hydrogeologist, with installation conducted by the drilling contractor under the supervision of a qualified field engineer. A QLD and NSW licensed (Class 2) water bore driller was on site during the installation of the standpipe piezometer installation.

All standpipe piezometers were equipped with 50 mm diameter class 18 PVC screw jointed pipes with 0.4 mm slotted screens and blank casing. A borehole diameter of 96 mm was drilled for the installation of the standpipe piezometers. A filter pack (1 to 3 mm washed and graded sand/gravel) was placed in the annulus of the borehole around the screen section which was then sealed with a bentonite plug. The annular space above the bentonite plug was grouted to the surface where a protective monument or gatic cover was installed.

The completed standpipe piezometers were flushed after installation to remove drilling fluid (drill muds, polymers and additives) from the piezometer and stimulate fresh aquifer water representative of the aquifer to the piezometer. Drilling influences were flushed from the bore using air lifting or through introduced fresh water to the borehole. Additional volumes of groundwater were purged using either a manual bailor or a 12-volt Twister groundwater pump which was completed prior to sampling for water quality analysis. Multiple groundwater bore volumes were removed from each standpipe piezometer to stimulate flow of ambient groundwater toward the standpipe.

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

Bore completion is summarised in Table 7.2.

Table 7.1 Summary of site investigations completed in July to October 2018

Investigations		Purpose	Methodology and details	Applicability to this Groundwater Technical Report
Geotechnical Investigations	Geotechnical boreholes	Inform the geotechnical properties of the soil profile and characterise depth to basement near proposed bridge sections.	Fifteen locations drilled using hollow stem augers followed by rotary drilling (water). Selected locations were converted to groundwater monitoring wells.	Stratigraphic information from bore logs at bridge sections including aquifer lithology and overlying lithotypes (refer Section 5.2) Intersection of groundwater table ('water strike').
	Auger boreholes	Inform the geotechnical properties of the soil profile along the alignment.	Eighteen auger holes completed using the solid stem auger method to a target depth of 3 mbgl.	Characterise the soil profile overlying aquifers. Identify potential shallow groundwater in alluvium.
	Test pits	Provide assessment of the pre-existing rail formation.	Total of 42 test pits completed with an excavator to a maximum depth of 2.3 mbgl.	
	Seismic Refraction (SR) surveys	Complement the intrusive investigations Assess depths to bedrock at bridge sites.	Thirteen seismic refraction survey lines were completed.	Provide an indication of the thickness of alluvial aquifers near bridge sections.
Hydrogeological Investigations	Standpipe piezometer installation	Characterise the existing groundwater regime, particularly bridge sections.	Eight monitoring wells installed with 50 mm class 18 PVC with 0.4 mm slotted screen intervals. Well details are provided in Table 7.2.	
	Groundwater level monitoring		Groundwater levels measured in all proposal monitoring wells using a manual dip meter and continuous level loggers (In-Situ Rugged TROLL®) from July to October 2018. Level loggers set to record on an hourly basis.	Confirm depths to groundwater and fluctuations in groundwater levels. Discussed further in Section 6.3.
	Permeability testing		Six wells with slug tests completed. Hydraulic conductivity was estimated using AQTESOLV Pro 4.0 via the Hvorslev and KSG solution methods.	Provides addition data on aquifer properties discussed in Section 6.1.
	Groundwater sampling		Seven monitoring wells sampled manually using a bailer. Three landholder bores were also sampled. Field parameters were collected during sampling.	Analytical suites include major ions, pH, conductivity, total dissolved solids (TDS), metals, nutrients, hydrocarbons and pesticides. Results are discussed further in Section 6.5.

Source: ARTC 2018

Table 7.2 Site investigation proposal monitoring wells and bores

Location	Latitude (GDA94)	Longitude (GDA94)	Well depth (mbgl)	Screened interval (mbgl)	Screened Lithology[1]	SWL		Mean Hydraulic Conductivity, K (m/day)[2]	Aquifer
						(mbgl)	(mAHD)		
270-01-BH2201	-28.8711	150.4020	20.0	14 to 20	SILT	Dry	Dry	No analysed[3]	Kumbarilla Beds
270-01-BH2202	-28.8483	150.4042	20.45	8.5 to 17.5	CLAY	17.5	218.87	Not analysed	Kumbarilla Beds
270-01-BH2204	-28.7447	150.4167	20.45	8.5 to 20.5	Clayey SAND/CLAY	10.3	213.22	Not analysed[4]	Undifferentiated sedimentary rock
270-01-BH2206	-28.7056	150.4153	20	8.7 to 14.7	Sand/Gravel	11.26	213.54	0.01	Alluvium
270-01-BH2212	-28.6669	150.4526	23.2	11.2 to 23.2	Sandy CLAY/SAND	9.6	215.91	0.81	Alluvium
270-01-BH2213	-28.6645	150.4533	20	13.5 to 19.5	Sandy GRAVEL/SAND	11.91	215.09	0.19	Alluvium
270-01-BH2217	-28.6459	150.4590	20	9.2 to 15.2	Clayey GRAVEL/Sandy GRAVEL	12.3	215.3	0.42	Alluvium
270-01-BH2218	-28.6288	150.4538	20.45	8.8 to 14.8	Clayey Gravel/Gravelly SAND	11.99	213.71	0.16	Alluvium
GW965240	-28.8127	150.4130	12	Landholder bores					
RN30765	-28.6501	150.4939	60						
Robs' Bore	-28.6637	150.4391	20						

Table notes:

SWL = Standing Water Level

SWL measured on 3 to 4 October 2018

1 inferred from bore logs

2 mean value derived from falling and rising head tests

3 bore 270-01-BH2201 not analysed as bore was dry

4 bore 270-01-BH2204 not analysed as bore had not been fully recovered after development

7.2 Permeability testing

In-situ hydraulic testing using variable head test techniques was conducted at six newly installed standpipe bores. The variable head tests involve inducing a sudden change in the groundwater level within the bore casing by inserting (falling head test mode) and then removing (rising head test mode) a solid slug or by sudden displacement of the water column in the casing using a pneumatic slug (compressed gas) and then measuring the water level response using an automated pressure transducer water level logger to obtain continuous water level measurements during the test and monitor how long it takes for the static water level (SWL) to recover to its original level.

The SWL was recorded before the slug was inserted in each bore. The hydraulic head (water level) was monitored until it returned (decreased) to within 90 per cent of the SWL, or when sufficient data was deemed to be collected at slow-recovering bores. The automated measurements were confirmed by comparing manual measurements collected using a water level meter. The objective of a hydraulic test is to estimate horizontal hydraulic conductivity (K) of a water saturated rock or soil formation intersected by the screen segment of the bore.

Slug test data were analysed using AQTESOLV Pro 4.0 which is an industry standard program widely used in the field of hydrogeology for hydraulic parameter estimation. The hydraulic test data was analysed by using the Hvorslev (1951) and KGS (Hyder et al. 1994) solution methods. Hydraulic conductivity is reported in metres per day (m/s) and is a measurement of how easily water can move through pore spaces in a geological formation.

Hydraulic conductivity at each bore is summarised in Table 7.2.

7.3 Groundwater level monitoring

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

7.4 Groundwater quality monitoring

One round of groundwater quality sampling was conducted in accordance with AS/NZ 5667.1:1998 and AS/NZ 5667.11:1998 after completion of all standpipe bores for laboratory analyses. The sampling was conducted after completion of bore development; well purging was conducted using super twister pump, manual bailing, or both methods. Groundwater samples were collected in laboratory provided containers and shipped in a cooler box chilled with ice under Chain of Custody to ALS Laboratory in Brisbane (a NATA-accredited laboratory).

Samples were collected to provide quantitative data on groundwater chemistry, durability and/or salinity parameters. In total, seven groundwater samples were collected from standpipe bores on 7 October 2018 (270-01-BH2201 was dry during the sampling event and was not sampled). Field QA/QC samples were collected during sampling along with field physiochemical measurements at the time of sampling. Quality control samples were collected to check that the samples were of acceptable quality on which to make decisions regarding water quality at the site. Quality control samples provide information that clarifies potential data errors attributable to cross contamination, inconsistencies in sampling and analytical issues.

The following parameters were analysed for each groundwater sample:

- Major anions and cations (calcium, magnesium, sodium, potassium, chloride, fluoride, sulphate)
- Carbonate and bicarbonate alkalinity and hardness
- pH, electric conductivity and total dissolved solids

- Total and dissolved metals (arsenic, boron, beryllium, cadmium, chromium, cobalt, copper, manganese, iron, nickel, lead, selenium, vanadium, zinc and mercury)
- Nutrients (nitrate, nitrite, ammonia, total nitrogen, Total Kjeldahl Nitrogen (TKN) total phosphorus)
- Sodium adsorption ratio
- Hydrocarbons (phenols – standard level – 12 analytes, TPH/TRH (C6-C36 or 40)/BTEX plus VOC)
- Pesticides (OC pesticides – standard level – 21 analytes).

7.5 Summary of field investigations

A summary of key hydrogeological results is provided in Table 7.2, including the screened interval depths, the screened lithology, water levels and slug test results. Three landholder bores were included in the groundwater sampling round in October 2018; however, no water levels were measured, and no slug tests were completed in these bores. The proposal monitoring bores locations are presented on Figure 6.2a-c.

8 Conceptual groundwater model

A conceptual model of the hydrogeological regime(s) across the proposal site is presented on Figure 8.1 and summarised below. It is noted that a water balance for groundwater and surface water is a SEAR (Item 19.2, Table 1.1). The purpose of a water balance, and associated model(s), is to understand the impact of the take or release of water (surface or groundwater) as a result of a project. That is, to describe the flow of water in and out of a system (water budget). A water balance for the proposal is not considered warranted as there are no significant cuts, tunnels, or other structural components that are considered to result as water take (temporary construction dewatering is not applicable for water balance) from, or water discharge to, the water budget.

8.1 Key hydrostratigraphic units

Unconsolidated Cenozoic aged alluvium characterises the northern half of the alignment and has been deposited as continuous alluvial channels and paleo-fans from the Macintyre and Severn River systems. Cenozoic alluvium represents all alluvium encountered within/surrounding the proposal. In Figure 8.1, alluvium is represented by the yellow upper unit in the northern half of the proposal and as less extensive units further south. This Cenozoic alluvium is typically 20 to 60 m thick and overlies the Wallumbilla Formation and Kumbarilla beds (Surat Basin units). Registered bore and site investigation bore lithological descriptions indicate that the upper 5 to 10 m of the alluvium is dominated by fine grained alluvium (clays and sandy clays). The primary aquifers of the Cenozoic alluvium are the coarser grained sand and gravelly sand units of variable thickness. The Cenozoic alluvium also forms localised aquifer systems along ephemeral watercourses that include Mobbindry Creek, Back Creek, Forest Creek and Whalan Creek.

Groundwater levels in the Cenozoic alluvium typically range from 7 to 20 mbgl with regional groundwater flow to the north/northwest (lateral flow mimicking surface water flow). Topography plays a marked role with regards to local groundwater flow direction in the alluvial aquifers (i.e. a water table influenced by elevation).

Groundwater has been encountered at shallower depths (4 to 6 mbgl) in localised Cenozoic alluvium in ephemeral creek systems in the southern portion of the proposal site. Long-term (natural) fluctuations in groundwater levels in the alluvium are typically up to 1 m during major rainfall events. Yields for the alluvium typically range from 1to 4.5 L/s.

Based on available registered bore and site investigation data, the Kumbarilla Beds are typically intersected at 10 to 50 mbgl in the southern portion of the alignment and at greater depths in the northern portion of the alignment (100 to 200 mbgl). The upper portion of the unit characterised by highly weathered shales which yield high salinity groundwater (i.e. BH2202). Groundwater flow based on registered bore data is generally to the north. The Kumbarilla Bed aquifers are confined by over lying shale of Wallumbilla Formation and bore yields are typically <2 L/s.

The Walloon Coal Measures underlie the Kumbarilla Beds where the water-bearing zone is typically intersected over 300 mbgl in the proposal site. The measures are characterised by shales, sandstones and coal measures which host confined aquifers which in some instances in the proposal site are free flowing. Yields are typically higher in the Walloon Coal Measures ranging from 7 to 9 L/s based on limited data from registered bores near the alignment.

8.1.1 Recharge

The natural creeks along the proposal site form losing systems, recharging the underlying alluvium seasonally when flowing (during and immediately after the wet season). Recharge to alluvium that is hydraulically connected to the Macintyre River is subject to artificial recharge from the regulated river system which maintains permanent flow from upstream impoundments. Additional recharge to the alluvium will include direct infiltration from rainfall and irrigation (deep drainage).

The alluvium may provide a level of recharge to the underlying Kumbarilla Bed aquifer, where deep palaeochannels and faults provide hydraulic connection.

8.1.2 Discharge

Hydrographs from registered bores in the Cenozoic alluvium surrounding the proposal demonstrate a strong hydraulic connection to surface water (refer Section 6.3.1). The alluvial aquifers are recognised to discharge through vertical flow, as well as through evapotranspiration (EVT).

Registered bores tapping the alluvial aquifers near the proposal site demonstrate a wide variety of use including domestic and industrial use, irrigation and water supply.

Based on registered bore data and water licence allocations, water use from the Kumbarilla Beds and WCM is typically for stock watering and to a lesser extent irrigation.

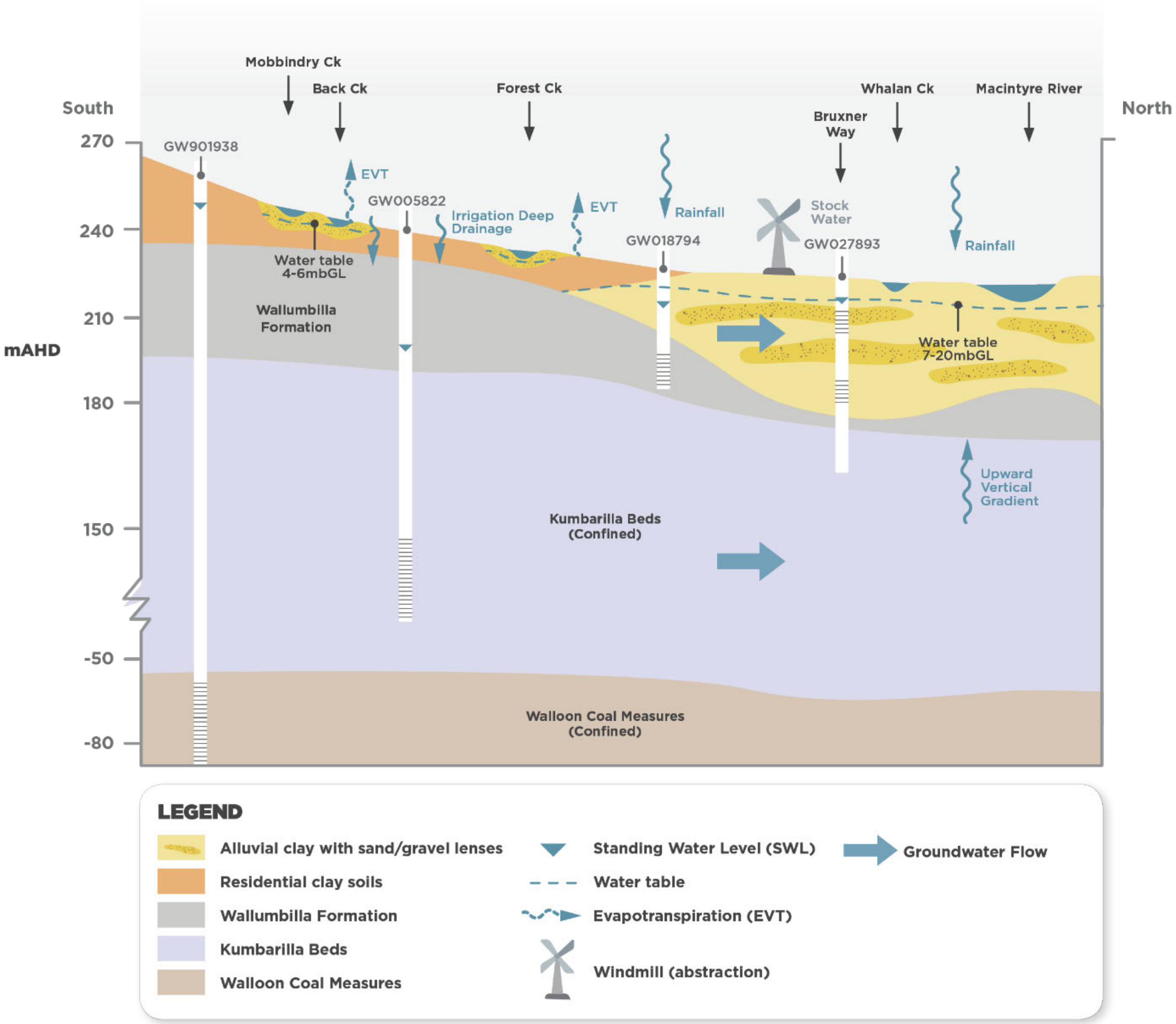


Figure 8.1 Conceptual hydrogeological model for the proposal

9 Potential impacts

9.1 Construction methodology

Construction of the ~30 km rail alignment will involve a combination of earthworks including cuts and embankments (to ensure required grade for trains), bridges and borrow pits to supply fill and aggregate for construction. The proposed construction methods for the alignment and the key assumptions for each method are provided in Table 9.1. The type and location of each proposed construction activity is presented in Figure 9.1.

Table 9.1 Summary of construction methods and assumptions

Method	Description	Assumptions
Embankments	Volumes of material emplaced and compacted to raise the profile of the railway alignment to meet design specifications.	No embankments are proposed over 10 m in height. No dewatering (possible alteration of shallow groundwater) is anticipated. Compaction may occur as part of the embankment construction works.
Cuts	Removal of soil and rock to maintain the grade of the alignment design. Stripping of topsoil of approximately 0.3 m below existing ground level is expected beneath most sections of earth works.	The maximum cutting depth is 2.3 m (FFJV 2019a).
Bridge and pilings	A total of 11 rail bridges are proposed to cross roads and waterways. Cast in Place (CIP) pilings to be emplaced on each bridge. A 1.8 km long viaduct is proposed over the Macintyre River and Whalan Creek. Some CIP pilings may be substituted with driven pilings in the detailed design phase.	Pilings currently proposed with a span width of 14 to 33 m and depth ranging from 8 to 43.5 mbgl. All piling designs are founded in soil and alluvium, no bedrock to be intersected (FFJV 2019).
Borrow pits	Shallow excavations at key designated locations near the proposal alignment to source soil, sand and gravel. The proposal is considering 11 potential borrow pit locations.	Depth of excavation typically less than 3.0 mbgl except for two pits located within Tertiary basalt (Discussed further in Section 9.1.7).

The location of proposed structures along the alignment are presented in Table 9.2**.**

Table 9.2 Summary of proposed structures and estimated groundwater level (after ARTC 2018)

Type	Structure ID	Start chainage (m)	End chainage (m)	Median surface elevation (mAHD)[1]	Median estimated WL (mAHD)[2]	Median estimated WL (m bgl)[2]
Cut[3]	270-C1	11340	11390	239	190	51
Bridge	270-BR01	5703	5815	242	184	58
Bridge	270-BR02	6136	6318	242	184	58
Bridge	270-BR03	8063	8133	236	194	42
Bridge	270-BR04	16264	16306	225	214	11
Bridge	270-BR05	20666	20802	225	214	11
Bridge	270-BR06	25240	25400	224	217	8
Bridge	270-BR07	25734	25848	224	217	8
Bridge	270-BR08	25988	26171	224	217	8
Bridge	270-BR09	27498	27624	224	216	8
Bridge	270-BR10	27968	28094	227	211	16
Bridge	270-BR11	29357	31107	226	214	12

Type	Structure ID	Start chainage (m)	End chainage (m)	Median surface elevation (mAHD)[1]	Median estimated WL (mAHD)[2]	Median estimated WL (m bgl)[2]
Embankment	270-E1	7280	9240	238	191	46
Embankment	270-E11	11340	11390	239	190	51
Embankment	270-E2	10390	11030	236	195	41
Embankment	270-E3	12330	12570	235	196	40
Embankment	270-E4	13710	14250	230	206	25
Embankment	270-E5	14980	16990	226	214	12
Embankment	270-E6	17930	18230	226	214	12
Embankment	270-E7	19640	32830	224	216	9

Table notes:

1 Surface elevation calculated based on cut/fill data provided by FFJV on 11 September 2019

2 Estimated WL calculated using a linear regression line produced using local groundwater data sourced from the NGIS (2018), the Queensland Globe Registered Bore Database and Site Investigation data from ARTC 2018.

3 Cut depth is proposed to be <2.3 mbgl.

9.1.1 Site clearing and grading

Site clearing and grading activities could potentially impact on shallow groundwater resources due to:

- Removal of vegetation reducing evapotranspiration, which can influence the groundwater discharge (i.e. result in higher groundwater levels)
- Compaction of ground resulting in reduced groundwater recharge
- Alteration of possible existing areas where ponding surface water occurs naturally, which could reduce groundwater recharge which could occur in these areas.

The limited area to be cleared and graded, compared to the large aquifer extents along the rail alignment is considered to have little or no impact on the groundwater resources (particularly as the rail corridor follows the existing non-operational Boggabilla rail corridor for the majority of the proposal site).

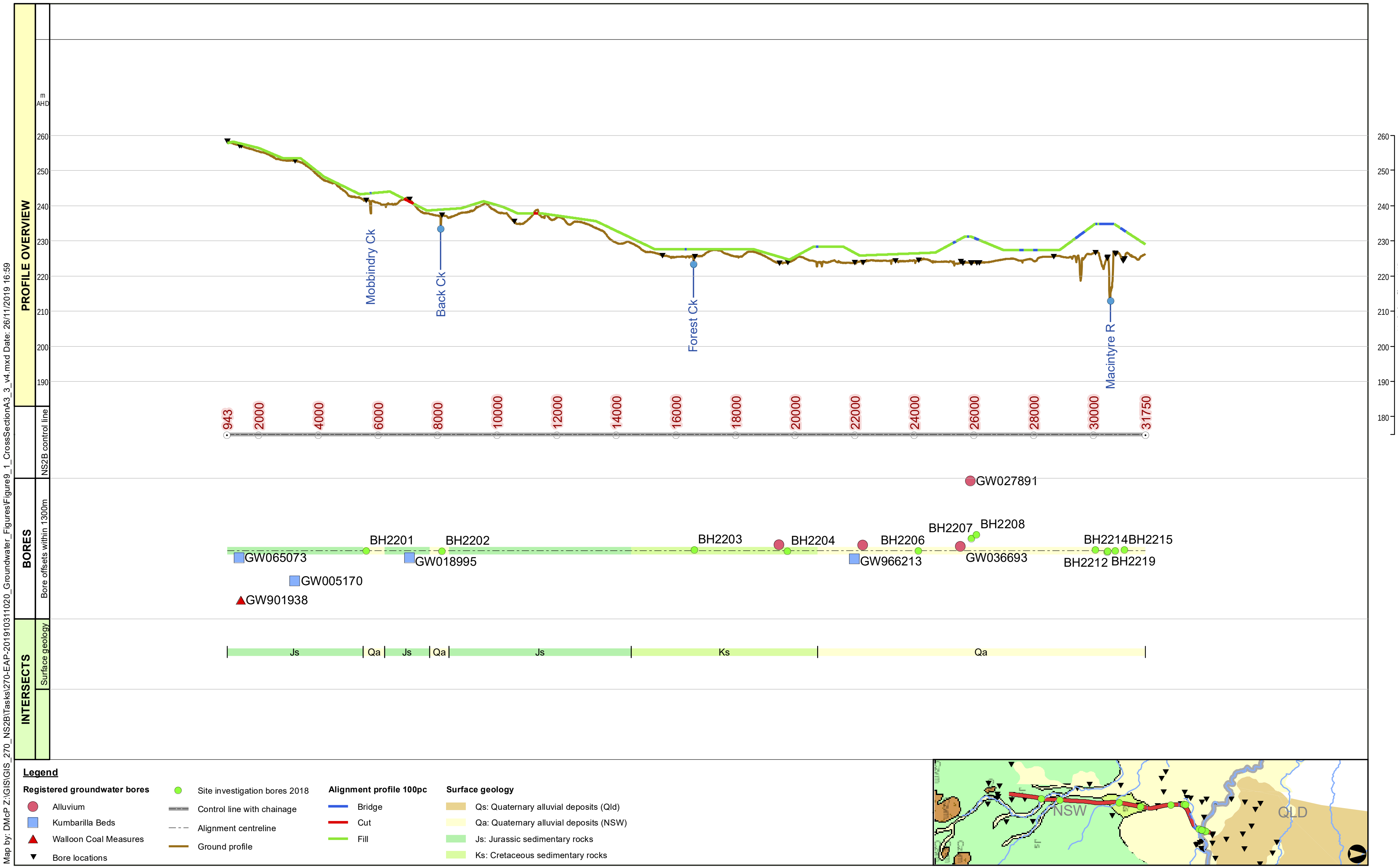
9.1.2 Piling activities

Piling associated with ground improvement works, to stabilise the bridge area, is proposed in the north of the alignment. The piling is to comprise the Cast in Place (CIP) piling technique with concrete emplaced via a tremmie line or other pumping method. This technique allows for the removal of augered soil/rock while pumping concrete or grout through the hollow stem to stabilise the ground. Future detailed design phases may include substitution of some CIP pilings with driven piles.

Piles with a diameter of 0.9 to 1.2 m are proposed for installation on 11 bridges between Ch 5 km to Ch 31 km. The pilings will have span length ranging from 14 to 33 m and will be installed to depths ranging from 8 to 43.5 mbgl.

The potential impacts of the piling works, on groundwater resources, can include:

- Alteration of aquifer parameters (lowering permeability)
- Alter groundwater flow patterns (mounding or drawdown hydraulically up- and down-gradient of the piles; upward leakage along the pile/soil interface)
- Reduction in groundwater resources through extraction of wet soil/rock during piling.



Horizontal lateral scale for bore offsets 1:60,000
Horizontal longitudinal scale as determined by chainage markers on C/L
Vertical plotting position: (Z-175) * 60

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North Star to NSW/QLD border

Figure 9.1: Proposal alignment profile

9.1.3 Consideration of these potential impacts includes:

- The potential impacts of the alteration of the aquifer parameters is considered limited due to the small area of alteration within the saturated sediments compared to the overall alluvium aquifer extent
- The spacing of the piles (non-continuous with regular spacing) does not result in a continuous hydraulic barrier of low permeable grout/cement, such that throughflow in the hydrostratigraphic units intersected by the piles will not be markedly influenced. It is therefore considered that the spacing between the piles is sufficient such that mounding (on the upgradient side) or dewatering (due to reducing in the throughflow on the downgradient side of the portal) is not expected to occur.
- The potential reduction in groundwater volumes due to the piling is limited as the CIP augering method, which allows for concrete slurry to be pumped through the hollow stem auger, restricts the amount of groundwater brought to surface
- Based on previous experience, only minor amounts of groundwater (within the wet sediment/soil/rock) will be brought to surface, some 5 to 10 Litres per 20 m deep auger hole. It is therefore recognised that, using the proposed piling methodology, will not require active dewatering and that the minor amounts of groundwater (as a slurry with soil/rock) will be managed at each pile/drill site.

9.1.4 Cut section

There is one cut section (270-C1) currently proposed along the alignment at approximately Ch 11.34 km to Ch 11.39 km. This cut is anticipated to reach a depth no greater than 2.3 mbgl within the alluvium and is not anticipated to encounter the water table.

9.1.5 Embankments

There are seven embankment sections (270-E1 to 270-E7) located between Ch 7.28 km and Ch 30 km. The expected subgrade for all embankments is Quaternary alluvium or colluvium.

9.1.6 Bridge and piling sections

The proposed design for the proposal includes 11 bridge sections between Ch 5.7 km to Ch 30 km with structural support from CIP pilings. The expected subgrade for all brigade and piling works is Quaternary alluvium or colluvium.

9.1.7 Construction Water

9.1.7.1 Construction activities

Estimated (preliminary) water requirements for the construction period of the proposal are presented in Table 9.3. Each construction activity will involve different levels of quantity, quality and flow rates to achieve the planned construction tasks (refer Table 9.3). The proposal is considering a surface water source near Boggabilla Weir which may be supplemented by groundwater abstracted from landholder bores with suitable existing water allocation licenses.

Groundwater quality indicates it is most suitable for use in earthworks and track works; however, groundwater is not the only, or preferred source of construction water for the proposal. Sources of construction water will be finalised during the detailed design phase of the proposal (post-EIS) and will be dependent on climatic conditions in the lead up to construction. The hierarchy of preference for accessing of construction water is generally anticipated to be as follows:

- Public surface water storages
- Permanently flowing watercourses
- Privately held water storages

- Existing registered and licensed bores
- Town water.

If groundwater is considered for sourcing of construction water, it will be sourced from existing registered and licensed bores. Therefore, the volumes extracted would be within the existing licensing limits and the extent of drawdown experienced would be localised and consistent with that which is currently permissible for each licensed bore.

It is noted that domestic needs will be prioritised above construction water supply and that existing sustainable allocated water entitlements will be sourced where possible.

Table 9.3 Estimated water requirements and potential water sources during construction activities (preliminary only)

Activity	Uses/requirement	Quality	Potential sources[a]	Approximate volume (ML)[a]	Timeframe (Duration)
Earthworks	Material conditioning and general dust suppression.	Low	River, dam or bore.	Conditioning (130 ML).	March 2021 to August 2022 (~1 year, 5 months).
				Dust suppression (62 ML).	January 2021 to January 2024 (~3 years).
				Haul road maintenance (49 ML).	April 2021 to January 2024 (~2 years, 9 months).
Construction camp	Drinking water, showers, toilets, washing and cooking facilities.	High	Town supply and water harvesting.	1.00 ML of water per month.	To be determined.
Concrete	Bridge and culvert locations	High	NA (no concrete batch plant provision for NS2B, local concrete suppliers may be engaged).	NA	To be determined.
Track works	Ballast dust suppression during ballasting and regulating activities	Low	River, dam or bore.	0.36 ML	Jul 2023 to Jun 2024 (~11 Months)

Table note:

a Potential water sources and estimated (indicative) volumes are preliminary only.

As shown on Figure 9.2, the greatest water demand will occur in the first year of construction where water use for conditioning, dust suppression and haul road maintenance all overlap.

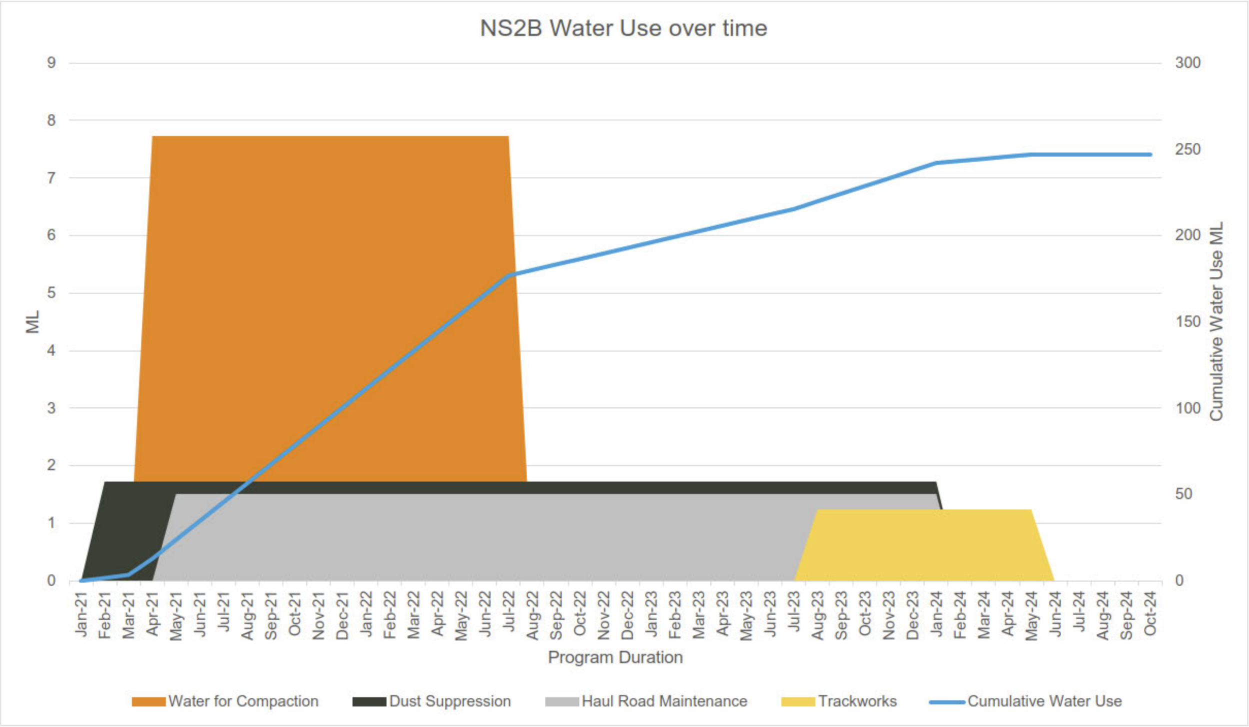


Figure 9.2 **Timeline of estimated water use for the proposal**

9.1.7.2 Construction camp water supply

One construction camp is currently proposed off North Star Road and Wilby Street in North Star. The camp will require an estimated 1 megalitre (1 ML) per month of operation. The township of North Star currently has access to water through the GAB with its allocation being 40 ML per year under the current water sharing plan (ceased July 2018); the construction camp is likely to utilise the North Star town water supply (refer Table 9.4 for bore information).

To reduce reliance on the North Star town water supply, rainwater harvesting system is to be implemented where practicable. A greywater recycling system may also be explored to reuse water for activities such as toilet flushing. All potable water supplies on the proposal will comply with the 2011 NHMRC Australian Drinking Water Guidelines (ADWG).

Table 9.4 **North Star water supply bore summary**

Bore ID	Yield (L/sec)	Latitude	Longitude	Comments
GW009991	8.84	-28.9279	150.3945	Water supply bore in North Star

Waste water produced from the construction camp will be treated by utilising an experienced and accredited supplier of commercial sewerage treatment systems. These systems can be designed for the capacity required in the construction camp and could remain in position for handover to the local township once the construction camp is decommissioned. The second alternative is to connect directly to the North Star system; however, this system is nearing capacity and upgrades would have to be undertaken by the proposal.

9.1.8 Borrow pits

Approximately 11 potential borrow pits are have been identified for the proposal to supply general fill, structural fill, ballast and/or capping. The proximity of the borrow pits range from within the proposal study area to up to 18 km from the alignment (refer Figure 9.3). A desktop assessment and geotechnical review were undertaken to evaluate the feasibility of each of the potential locations.

For the purposes of this groundwater impact assessment, the location of the 11 borrow pits has been reviewed in the context of the geological (i.e. alluvium versus Surat Basin strata) and the hydrogeological conditions (i.e. typical groundwater levels) discussed in Sections 5.2 and 6. A summary of this review is presented in Table 9.5.

Apart from borrow pit Site 1 and Site 2, which are located within Tertiary Basalts, the maximum depth of excavation anticipated for the potential pits is 3.0 m. Most borrow pits are interpreted to be developed in weathered sedimentary rocks of the Kumbarilla Beds and/or the Wallumbilla Formation. Based on registered bore and site investigation drilling data, the first water bearing zone intersected during drilling has been used to evaluate the potential to encounter shallow groundwater for each borrow pit (refer Table 9.5).

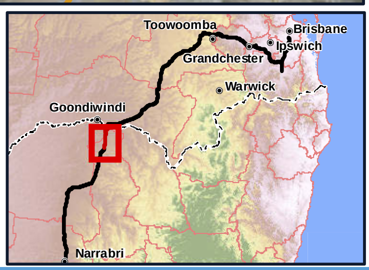
Based on this data, shallow groundwater is unlikely to be intersected at borrow pits located in the Kumbarilla Beds or the Wallumbilla Formation. Despite the deeper potential excavation depths at Site 1 and Site 2 (up to 24 m), shallow groundwater is also unlikely to be intersected.

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

Map by: NCW Z:\GIS\GIS_270_NS2B\Tasks\270-EAP-201910311020_Groundwater_Figures\270-EAP-201910311020_FFJV_A4P_Template.mxd Date: 13/11/2019 22:36

Legend

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



A4 scale: 1:200,000

0 1 2 3 4 5km

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Coordinate System: GDA 1994 MGA Zone 56

North Star to NSW/QLD border

Figure 9.3: Potential borrow pit locations

Table 9.5 **Summary of proposed borrow pit sites and potential for intersection of shallow groundwater**

ARTC site number	Approximate distance from rail alignment (m)	Estimated resource thickness (m)[a]	Formation [a]	Material description [a]	Estimated regional groundwater level (mbgl)[b]	Nearest bores reporting depth of water strike (mbgl)[b]	Potential for groundwater intersection
4	3,000	3.0	Kumbarilla Beds	Lateritised siltstone and sandstone.	>15	**BH2201** (Dry) & **BH2202** (17.5m) **GW000740:** 1.8km to S (water strike @ 57 .9m).	Unlikely
5	10,300	2.5	Kumbarilla Beds	Weakly lateritised sedimentary rock.	>50	**GW006151:** 1km to NW (water strike @ 121.9m) **GW006238:** 1.7km to E (water strike @ 55.8m).	Unlikely
8	730	3.0	Kumbarilla Beds	Lateritised siltstone and sandstone.	>20	**BH2203** (Dry) **GW005173:** 0.5km to E (water strike @ 39.6m).	Unlikely
9	14,300	3.0	Kumbarilla Beds	Lateritised siltstone and sandstone.	>40	**GW007410:** 1.2km to E (water strike @ 43.6m) **GW007518:** 2.5km to S (water strike @ 58.8m).	Unlikely
11	16,000	2.0	Kumbarilla Beds	Ferruginous caprock underlain by clayey sand.	>15	**GW007518:** 2.5km to S (water strike @ 58.8m) **GW965235:** 0.8km to S (slotted interval @ 19.3 to 20.3) **GW00613:** 1.5km to SW (water strike @ 160.9m).	Unlikely
13	14,000	2.0	Wallumbill a Beds	Highly weathered sedimentary rock.	>40	**GW031554:** 1.3km to SE (water strike @ 171.9m) **GW000502:** 2.8km to sth (water strike @ 45.7m).	Unlikely
25	12,500	3.0	Kumbarilla Beds	Lateritised siltstone and sandstone.	>50	**GW005591:** 0.7km to E (water strike @ 94.5m) **GW000638:** 1km to W (water strike @ 71.6m).	Unlikely
26	10,000	2.0	Kumbarilla Beds	Extremely weathered sandy clay.	>50	**GW006238:** 2.0km to SE (water strike @ 55.8m) **GW025529:** 3km to W (water strike @ 162.8).	Unlikely
7 and 7b	Within study area	3.0	Kumbarilla Beds	Sandy Clay and weathered siltstone and sandstone.	>15	**BH2202** (17.5m) **GW018995:** 2km to S (water strike at 76.2m) **GW049209:** 0.7km to N (water strike @ 138.4m).	Unlikely
1	8,000	12.5	Tertiary Basalt	Moderate to slightly weathered basalt.	>40	**GW018899:** 0.3km to S (water strike @ 59.13m) **GW006281:** 3km to S (water strike at 45.7m).	Unlikely
2	11,500	24.0	Tertiary Basalt	Moderate to slightly weathered basalt. Located on an elevated area 15 m above surrounding land surface.	>40	**GW011114** 0.8km to E (water strike @ 50.3m) **GW000856:** 0.8km to SE (water strike @ 112.7m)	Unlikely

Table notes:

a Based on desktop evaluation and site inspections by FFJV (FFJV 2019b, d)

b Estimated groundwater level based on nearest surrounding registered bores and/or NS2B site investigation bores. Water strike depths represents the first water bearing zone encountered during drilling as indicated on registered bore cards. Drilling data accessed from WaterNSW groundwater database on 22 May 2019 (https://realtimedata.waternsw.com.au/water.stm)

9.2 Construction – potential impacts

Construction activities for the proposal include a variety of activities which have the potential to impact on groundwater resources. These activities include earthworks (cut and fill sections), drainage construction, haul road and access track construction, track laying, bridge pilings and the excavation of borrow pits for construction materials.

9.2.1 Subsidence/consolidation

Only one cut is proposed (Ch 11.3 km) and the toe of the cut will be well above the inferred water table. The location of proposed structures along the alignment are presented in Table 9.2.

Pilings are not anticipated to require significant dewatering given the CIP construction method. Subsidence issues are unlikely to occur given that construction dewatering will be limited and not prolonged in nature.

Compaction could alter antecedent aquifer properties in the alluvium due to embankment construction. However, the risk is considered low given the water table is well below the existing ground surface at the proposed embankment sections (> 8 mbgl). The location of proposed structures along the alignment are presented in Table 9.2.

9.2.2 Groundwater levels

There are potential impacts to groundwater levels in the shallow alluvial aquifers from earthworks, cuttings and bridge piling works if temporary dewatering during construction occurs (i.e. potential decrease in levels). However, the likelihood any significant or active dewatering occurring is expected to be minimal (and likely passive dewatering) given:

- Groundwater infiltration into foundation bore holes, cuttings or other earthworks will be limited given the depth to the water table is typically 7 to 20 mbgl;
- No active dewatering (pumping) is anticipated at piling locations given only minor volumes of groundwater will be brought to surface, some 5 to 10 litres per auger hole using the CIP method. This volume of water would be managed at each drill site; and
- The construction works are limited in duration so consequently any (temporary) dewatering will also be restricted in duration.

Potential adverse impacts to groundwater elevations may occur where groundwater is sourced to supply water for construction activities. Over abstraction from an existing bore with a shared or purchased water entitlement may reduce water levels and in turn availability to other users. Other water sources are being considered to contribute to the supply of construction water (i.e. rainfall harvesting, farm dams and water recycling).

If a portion of the construction supply water is obtained from groundwater, short-term, localised impacts on shallow groundwater are expected with no significant impacts on groundwater resources, groundwater quality, or downstream users. Licencing to take water is likely to be required to meet requirements under the relevant Water Sharing Plans and will require consultation with the National Resource Access Regulator (NRAR).

Mitigation measures to minimise impacts on groundwater levels during the construction phase are provided in Section 10.

9.2.3 Groundwater flow

Potential impacts on groundwater flow in the shallow alluvial aquifers is expected to be minimal due to:

- The shallow depth of the proposed cuts along the alignment (<2.3 mbgl) is unlikely to create voids which intersect shallow groundwater or perturb the antecedent groundwater flow regime

- Foundation pilings associated with bridges are of a sufficient spacing and diameter to result in minimal impact on existing groundwater flow
- Reduction of permeability of natural soils beneath constructed embankments may alter flow direction of shallow groundwater in the alluvial aquifer.

The mitigation measures detailed in Section 10 are proposed where the depth of a cut or borrow pit has a perceived risk of intersecting shallow groundwater.

9.2.4 Groundwater dependent ecosystems

High potential aquatic GDEs were identified over 1 km from the proposed alignment at Malgarai Lagoon and in an upstream portion of the Macintyre River. High potential terrestrial GDEs were identified in several of the ephemeral waterbodies crossed by the proposal (refer Section 6.7.2). Proposal activities are not anticipated to affect shallow groundwater near these high priority GDEs due to a combination of:

- The distance of the GDE from the alignment
- The fact that construction works are not anticipated to intersect groundwater
- The alignment will largely comprise low height embankments which are not anticipated to significantly compact alluvial soils.

Given the limited impact on groundwater levels expected (refer Section 9.2.2), there is likely to be no adverse impacts on high potential terrestrial GDEs identified in Section 6.7 (refer Table 6.6 and Table 6.7).

9.2.5 Groundwater users

No impacts to the accessibility of groundwater for stock watering, irrigation and farm use are anticipated during construction of the Inland Rail proposal between North Star and the NSW/QLD border.

Potential impacts may arise due to cuts which intersect shallow aquifers resulting in a net loss in groundwater supply to impacted receptors. Sensitive receptors may include users in the vicinity of perennial water bodies or near shallow water supply bores such as the alluvium associated with Mobbindry Creek, Whalan Creek and Macintyre River system. The proposed depth of the cut at Ch 11.3 km (2.3 m, refer Section 9.1.4) is not expected to intersect the groundwater table and therefore this impact on users is expected to be minimal. Other impacts to users may include contaminants entering shallow aquifers and hydraulically connected surface water bodies and impacts on groundwater levels if bores are used to supply construction water (discussed further in Section 9.2.6).

Groundwater users may potentially be impacted if groundwater abstraction from landholder bores takes place to supplement water supplies for construction works. However, any abstraction for the proposal would be via the sharing or purchase of water from an existing water licence which already has annual abstraction limits assigned by regulatory authorities to negate adverse impacts.

9.2.6 Contamination

During the construction phase there will be potential sources of contamination to groundwater from:

- Accidental spills and leaks of hydrocarbons (oils, fuels, and lubricants) and other chemical associated with plant and equipment
- Water mixtures and emulsions related to washdown areas
- Waste water from the construction camps
- Upward leakage along piles/soil interfaces of saltier groundwater from the deeper confined aquifers into the fresher alluvial aquifer.

Direct infiltration of contaminants through the ground surface to the shallow aquifers will be limited due to the low permeability of clayey soils mapped in the upper 2 m of the soil profile across much of the alignment and that the depth to groundwater in this unit is typically > 7 mbgl.

Base on publicly available data on soil types near North Star, direct infiltration of treated waste water from the construction camp may be limited due to stiff clay/silty clay sodosol soils which could create ponding and surface water runoff issues. Pooling or runoff of such water may pose a risk to humans and stock in the surrounding area.

The ephemeral nature of most surface water bodies along the alignment is also likely to reduce the chance of contaminants in surface water infiltrating into shallow aquifers.

Potential contamination of the shallow alluvial aquifer could occur via inflow into foundation bore holes which intersect the water table. However, this is considered negligible as pilings will be grouted to surface for ground stability and therefore will not act as a conduit for surface contaminants to groundwater resources.

9.2.7 Vegetation and soil removal (salinity)

Clearing of deep-rooted vegetation may increase infiltration rates into shallow aquifers and lead to a rising groundwater table and possibly elevated soil salinity (Schofield and Scott 1991). Based on the low density of deep-rooted trees within the alignment, the effects of tree removal on soil salinity is not expected to increase salinity within the proposed rail corridor.

The seasonal nature of rainfall also reduces the proportion of time salinity issues can eventuate from a rising water table.

9.2.8 Acid rock drainage and acid sulphate soils

Potential acid sulphate soils (PASS) may present a risk though excavation of cuts in soils susceptible to acid forming conditions which can leach into the surrounding environment. PASS is often associated with low lying areas below 5 m AHD, such as alluvial plains where groundwater generally is close to the surface and materials in reducing conditions along coastal regions (DSITIA QLD 2014); however, the lowest elevation of the proposal is 220 mAHD.

There are no deep cuts along the proposal and the shallow cuts (less than 2.3 m deep) are anticipated to encounter the alluvial sediments. Borrow pits are expected to intersect the Kumbarilla Beds, a sedimentary sequence comprising sandstone, siltstone and mudstone; however, it is not anticipated to encounter groundwater at these locations. Assessment of PASS within the groundwater study area using the CSIRO (2014) Atlas of Australian Acid Sulphate Soils map indicated low probability of PASS to occur between North Star and the alignment west of Humptybung, and extremely low probability of PASS to occur for the remainder of the study area.

No indicators of PASS were observed during field investigations; however, in the event PASS is present during the construction phase of the proposal, mitigation measures will be undertaken as listed in Table 10.2.

9.3 Operation – potential impacts

There is a potential for increased groundwater levels due to surface loading of alluvial soils from embankments and other constructions along the alignment if groundwater is found to be shallow at these locations. Potential areas for compressible alluvial soils include localised portions of the low-lying Macintyre floodplain associated with abandoned river channels. However, it is expected these impacts, if any, will be localised due to the linear nature of the alignment and the depth to groundwater typically being over 7 mbgl.

Potential impacts on groundwater quality from the operation stage of the proposal can result from spills and leaks from normal operational activities and maintenance. These impacts are likely to be superficial in nature and not expected to impact on shallow aquifers.

10 Mitigation

This section identifies and discusses appropriate mitigation measures for the prevention or minimisation of the extent of groundwater impacts documented in Section 9. These measures are also summarised in Table 10.2.

A Construction Environmental Management Plan (CEMP) will be prepared during the detailed design process (post-EIS) to capture all mitigation measures that are required to be implemented prior to, or during construction of the proposal. The Environmental Management Plan (EMP) presented in the North Star to NSW/QLD border EIS will be used as a basis for the CEMP; the groundwater management and monitoring plan (GMMP) (refer Section 10.3) will inform the groundwater aspects of the EMP/CEMP as a groundwater sub-plan.

It is considered that at feasibility stage of the proposal, the mitigation measures (design and proposed) demonstrate all practical measures to avoid or minimise water pollution and protect human health and the environment from harm have been investigated and proposed to be implemented.

10.1 Design considerations

The mitigation measures and controls presented in Table 10.1 have been factored into the feasibility designs for the proposal. These design considerations are proposed to minimise the environmental impacts of the proposal and therefore contribute to a lowering of the initial impact risk rating for each potential impact.

Table 10.1 Initial mitigations of relevance to groundwater

Aspect	Initial mitigations
Water resources	The proposal is generally located within the existing non-operational Boggabilla rail corridor and has been aligned to be co-located with existing road infrastructure where possible, minimising the need to develop land and impact on water resources that have not previously been subject to disturbance for transport infrastructure purposes. The alignment (both lateral and vertical) has been designed to minimise earthworks, reducing the potential to impact water resources (for example dewatering of cuttings and embankment placement). Culverts and embankment constructions will be designed to minimise pre-loading and compaction of alluvial sediments. This will reduce the risk of altering shallow groundwater levels and recharge patterns. The current embankment designs allow for openings (i.e. culverts and bridge spans) near creeks and rivers to assist with flow. There is likely to be minimal impact to groundwater as a result of loading due to the comparatively small linear area involved and the depth to the alluvium aquifer, typically >7 mbgl. Permanent drainage structures (precast concrete pipe products) will be installed in areas where there are significant sections of embankment fill which incorporate significant cross drainage structures over floodplain areas.
Water quality	Maintenance activities, refuelling, and other tasks with potential to be spilled or released to the ground surface will only be carried out at select designated areas within the proposal footprint and at a minimum distance of 50m from surface water bodies and other sensitive receptors. In the event of a spill, the risk of impacting on shallow groundwater is reduced. Clearing extents are limited to that required to construct the works and associated environmental management controls.

10.2 Proposed mitigation measures

To manage and mitigate proposal impacts, several mitigation measures have been proposed for each study area for implementation in future phases of proposal delivery. These proposed mitigation measures have been identified to address proposal specific issues and opportunities including legislative requirements and accepted government plans, policies, and practices.

Table 10.2 identifies the relevant proposal phase, the aspect to be managed, and the proposed mitigation measure. The mitigations presented in Table 10.2 have then been factored into the assessment of residual significance, as documented in Table 11.1.

These proposed mitigation measures have been presented in the groundwater monitoring and management plan (GMMP), discussed in Section 10.3, which will be a subplan to the EMP and/or CEMP/OEMP in accordance with the project phase during which they would be implemented:

- Detailed design
- Pre-construction
- Construction
- Operation
- Decommissioning.

Table 10.2 Groundwater mitigation measures

Delivery phase	Potential impacts	Mitigation and management measures
Detail design	Water resources	■ Further assessment of design concepts at watercourse crossings to minimise embankment loading or compaction of alluvial sediments and mounding of groundwater levels (i.e. use of pilings) ■ Assessment of sizing for longitudinal drainage for permanent drainage features ■ Define requirements for construction water (volumes, quality, demand curves, approvals requirements and lead times), storage locations along the construction footprint e.g. water used for dust suppression will not result in adverse environmental or health impacts ■ Continue collection of baseline/pre-construction groundwater monitoring data (levels and quality) to ensure robust dataset for characterisation of the primary aquifers of relevance (refer Section 6.1) over a time sufficient to identify seasonal variation trends ■ Confirm groundwater allocations available per aquifer at cut areas which expect passive dewatering to ensure this approach is suitable ■ Seepage prevention measures will be investigated through the detailed design process for inclusion in the design, as appropriate.
	Water quality	■ Site inspections of proposed cut locations will be conducted to visually examine surface outcrops for sulphide minerals or remnant products indicative of sulphide mineralisation. This would inform the need for management of potential ARD from cuttings in sedimentary units prior to construction works. ■ Further assessment of potential borrow pit areas to confirm quality of material (e.g. not contaminated or ARD-potential areas) ■ Continue collection of baseline/pre-construction groundwater monitoring data (levels and quality) to ensure robust and comprehensive dataset for characterisation of the primary aquifers of relevance over time sufficient to identify seasonal variation trends ■ The baseline monitoring program will act as an early mitigation measure as the data collection will be incorporated into the GMMP for subsequent proposal stages to enable assessment for other aspects of impact assessment/mitigation.
Pre-construction	Water resources	■ Confirm (i.e. physical survey/'ground truth') the location of registered bores that may be lost due to construction or operation of the proposal and engage with licensed user to determine mitigation strategy (for example replacement of water supply, if required) ■ Undertake bore survey/census to identify any potential unregistered bores (landowners) which may be impacted by the proposal ■ Confirm source(s) for construction water requirements (surface water, groundwater, municipal supply, etc.) via consultation with relevant stakeholders (including landowners/occupants) prior to construction and appropriate approvals and agreements will be sought for the extraction of water. Where private water sources are utilised for construction then monitoring will be undertaken during extraction to ensure volumes and conditions stipulated by license requirements and/or private landholder agreements are met. ■ Environmental management requirements (e.g. WQOs) during construction are identified through appropriate baseline groundwater monitoring ■ Continue collection of groundwater pre-construction/baseline data (levels and quality) to ensure robust and comprehensive dataset to be incorporated into the construction GMMP, discussed further in Section 10.3 ■ Where practical, vegetation clearing and ground disturbing works will be staged sequentially across the proposal to minimise areas exposed to erosion and sediment impacts.

Delivery phase	Potential impacts	Mitigation and management measures
	Water quality	▪ Site inspections prior to the construction of cuts would provide an opportunity to visually examine surface outcrop for sulphide minerals or remnant products indicative of sulphide mineralisation. This would inform the management of potential ARD cuttings in the sedimentary units prior to construction works. ▪ Identification of contaminated, hazardous or potentially contaminated material on site (i.e. soil, ballast) will be subject to a risk assessment and managed in accordance with any relevant applicable legislation and regulations ▪ The reuse or retention of contaminated or potentially contaminated material on site (i.e. soil, ballast) will be managed by a suitably qualified person (SQP) where required.
Construction	Water resources	▪ Environmental management requirements and project commitments during construction to minimise potential impacts such as adverse effects on groundwater users and sensitive receptors (i.e. bores and potential groundwater dependent ecosystems (GDEs)) are implemented as per resource agreements ▪ Permanent drainage structures (precast concrete pipe products) will be installed in areas where there are significant sections of embankment fill which incorporate significant cross drainage structures over floodplain areas ▪ Implementation and adherence to the CEMP/EMP (and GMMP) with appropriate groundwater level and quality monitoring criterion based on the baseline groundwater monitoring, modelling, analysis, and regulatory requirements to minimise impacts to groundwater resources (e.g. regular groundwater monitoring) and enter into make-good arrangements with the owners of the groundwater bores as necessary ▪ Construction phase GMMP implemented and adhered to ▪ Opportunities to re-use/recycle construction water are identified and implemented where feasible during construction.
	Water quality	▪ Personnel involved in ground-disturbing works are familiar with the unexpected finds protocol/procedure and should be trained in the identification of potential contaminated soil/ material and the relevant controls that will be put in place in the event of its discovery. This includes: – How to recognise potential contaminated material (colour, texture, odour, presence of asbestos, metal, ash) from inert waste or materials – The correct use of spill kits – Stop work and corrective/containment actions – Classification and notification of incidents in accordance with the ARTC incident management procedure – Regulatory requirements ▪ Vehicle and plant maintenance activities will be undertaken in suitable areas with hardstand. This will minimise risk of contaminants from incidental spills or leaks from entering aquifers via infiltration or surface runoff. ▪ Refuelling will only occur at selected sites within the construction footprint, at a minimum of 50m from surface water bodies and other sensitive receptors. Refuelling locations will be equipped with on-site chemical and hydrocarbon absorbent socks/booms and spill kits. ▪ Spill kits will be available at all work fronts and laydown areas in the event of a spill or leak. All vehicles and machinery will have dedicated spill kits. ▪ Chemical and dangerous goods storage areas will be located in appropriately designed facilities, such as bunded areas, sealed or lined surfaces, hard stand areas, or storage within containers. Storage of chemicals, oils, fluids and other hazardous substances will be in accordance with the appropriate safety data sheets (SDS) and relevant Australian Standards. These measures would minimise the risk of contaminants from incidental spills or leaks from entering aquifers via infiltration or surface runoff.

Delivery phase	Potential impacts	Mitigation and management measures
		■ Laydown areas and storage areas will not be located in the vicinity of creeks or rivers or close to sensitive receptors such as existing groundwater bores or known GDEs ■ Drilling and excavation activities during construction will make use of drilling fluids and chemicals that are environmentally neutral and biodegradable. Mobile plant, drill rigs and equipment must be maintained in accordance with manufacturer requirements and inspected frequently to minimise breakdowns and decrease the risk of contamination. ■ Identification of contaminated, hazardous, or potentially contaminated material on site (i.e. soil, ballast) will be subject to a risk assessment and managed in accordance with relevant applicable legislation and regulations (e.g. potentially asbestos found in soil is to be managed and disposed of at a site authorised to accept asbestos waste as regulated by area) ■ Fill material will be clean, certified weed and contaminant free, and be required to comply with regulatory guidelines for the intended use ■ All excavated material which is suspected to contain sulphides should be stockpiled, lined and covered and managed to minimise rainfall infiltration and leaching. Where possible, treatment and onsite reuse are preferred to off-site disposal. A case-by-case assessment of the suitability of material for treatment and reuse will be required. ■ The reuse or retention of contaminated or potentially contaminated material on site (i.e. soil, ballast) will be subject to a risk assessment and/or occur as per the relevant components of the CEMP ■ Groundwater quality monitoring ongoing per CEMP/Construction phase GMMP.
Operation	Water resources	■ Groundwater levels for bores will be continuously monitored for variation from the baseline levels established prior to operation phase.
	Water quality	■ Operator will notify their employee(s) of the storage, handling, or transport of hazardous substances or dangerous goods ■ Operator will ensure appropriate controls are in place to prevent environmental incidents including leaks/ spills from refuelling activities and locomotive operations and to protect the environment in the event that incident occur ■ In the event of a spill, all necessary actions will be taken to contain the spill. The supervisor or person in charge of the work activity must be notified immediately. The matter will be recorded on the reportable environmental incident checklist and, in the case of a major spill or incident, the emergency management procedure (RLS-PR-044) will be followed. ■ Operation stage GMMP implemented and adhered to.

10.3 Groundwater management and monitoring program

The GMMP provides an ongoing assessment of the potential impacts identified in Section 9. The GMMP incorporates principles of performance assessment and adaptive management, a structured, iterative process of decision making. The GMMP will be assessed and updated after each phase of works (pre-construction/baseline, construction, and operation) such that the subsequent phase's GMMP is based on the outcomes of the previous phase.

The indicative pre-construction/baseline GMMP's primary objective is to develop a robust baseline dataset from which all subsequent monitoring will be assessed against for impact identification. This dataset will also inform the proposal-specific WQO trigger values. The pre-construction/baseline GMMP will be developed and implemented during the detail design stage to inform proposal-design aspects and ensure a suitable groundwater baseline dataset is established before starting any works.

The baseline/pre-construction dataset is to be the reference dataset for future groundwater monitoring and, as such, may be supplemented with existing groundwater data inclusive of, but not limited to, representative data from local councils, recent studies, etc. The baseline dataset will be compiled, and the construction GMMP developed, prior to the commencement of the construction phase of the proposal.

Subsequent groundwater monitoring during the construction phase, the construction GMMP, will be developed as a risk-based approach. Groundwater monitoring during construction will be aquifer, construction task, residual significance, and WQO-dependant. Monitoring will be localised to the area of the construction task identified to have a potential impact on groundwater quality and/or levels, as identified in Section 9 and their respective residual significance (refer Table 11.1). The localised task and risk-based monitoring will be performed at locations (distance and depth/aquifer) up- and down-gradient of the site where construction work is taking place. For example, where construction tasks are surficial in nature no monitoring of Surat Basin aquifers would be warranted; however, surficial construction tasks may require TDS and pH monitoring within the alluvial aquifers to ensure the baseline levels are not impacted as a result of local works (task-specific monitoring).

The operation phase GMMP will be based on the outcomes of the construction phase and will generally be warranted when a spill/incident occurs or a request for monitoring is made (e.g. from NSW EPA). These results will be assessed against the construction GMMP and baseline dataset, as appropriate.

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

An indicative network of monitoring bores in proximity to cuts are summarised in Table 10.3. The indicative network is subject to landholder negotiations and access and will be refined during the detail design phase. If bores specified in Table 10.3 cannot be accessed, or are unsuitable for monitoring for other reasons, an alternative existing bore may be nominated. In the absence of a suitable alternative existing bore, dedicated environmental monitoring wells may be installed. These environmental wells would be sited in locations to provide adequate coverage up and down hydraulic gradient in areas of potential groundwater impact.

The pre-construction (baseline) GMMP is discussed in the following subsections. The construction phase GMMP will be developed prior to commencement of construction tasks identified to potentially impact on groundwater resources that have an elevated residual significance or a WQO trigger.

Table 10.3 Indicative monitoring network for the proposal

Bore ID	Latitude (GDA94)	Longitude (GDA94)	Bridge ID or Chainage	Aquifer	Screen Interval (mbgl)	Monitoring type	Comments
GW018995	-28.8582	150.4047	Ch 7 km	Kumbarilla Beds	222.2 to 232.6	Water levels.	Monitoring of deeper units in Kumbarilla Beds. Located between 270-BR02 and 270-BR03.
BH2202	-28.8483	150.4042	270-BR2	Kumbarilla Beds	8.5 to 17.5	Water levels and quality.	Monitoring potential impacts relating to bridge construction.
BH2204	-28.7447	150.4167	270-BR04	Wallumbilla (inferred)	8.5 to 20.5		
BH2206	-28.7056	150.4153	270-BR06	Alluvium	8.7 to 14.7		
BH2212	-28.6669	150.4526	270-BR10	Alluvium	11.2 to 23.2		
BH2213	-28.6645	150.4533	270-BR10	Alluvium	13.5 to 19.5		
BH2217	-28.6459	150.4590	270-BR12	Alluvium	9.2 to 15.2		
GW036693	-28.6927	150.4145	Ch 25.5 km	Alluvium	14.0 to16.0	Water levels and quality.	Monitoring of background water levels (not proximal to bridges). Downgradient of 270-BR06. WaterNSW monitored bore 1987 to 2015.
GW036684	-28.6660	150.4124	2.8km north of Ch 25 km	Alluvium		Water levels and quality.	Down gradient monitoring of alluvium.
Bore X	-28.6637	150.4391	1.2 km west Ch 30 km	Alluvium	NA - total depth 20 m	Water levels and quality.	Down gradient monitoring of alluvium.

10.3.1 Groundwater level monitoring

Groundwater levels for bores within the indicative monitoring network are to be monitored using automated pressure transducers (groundwater level loggers) to record measurements at least every 12 hours. The pre-construction groundwater level dataset will form the basis from which potential impacts can be assessed during subsequent stages of the proposal.

Manual water level measurements are proposed to be collected bimonthly during establishment of the pre-construction/baseline groundwater dataset to allow for a quality control check against the pressure transducers. Pressure transducer data will be downloaded on a bimonthly basis, during this program, to coincide with manual water level measurements and groundwater quality monitoring (discussed in Section 10.3.2). The baseline/pre-construction groundwater monitoring program will be continuously ongoing to account for natural (seasonal) and anthropogenic fluctuations of groundwater levels prior to construction. This is pertinent for the alluvial sediments, as the water levels in these sediments are key to the design, construction, and operation of the proposal, are the most likely to vary over time due to rainfall, drought, local groundwater abstraction, etc., and will allow for identification of non-project related influences on groundwater levels.

For example, dewatering/pumping for construction works/water supply being undertaken for the Newell Highway Upgrade project may create an area of influence measurable in proximity to the proposal with potential to impact on groundwater resources and/or landholder bores. This information is important to capture to ensure discernibility between the impacts of the proposal and those from other influences.

The baseline monitoring program will be completed in enough time prior to commencement of construction works to allow for assessment of the data, including trends; the construction phase GMMP will also be developed at this time. Regular groundwater level measurements are to remain ongoing between proposal phases.

After completion of baseline monitoring program, and with consideration of the final detail design, the frequency and location of level measurements will be reviewed and amended for suitability to achieve the objectives of the groundwater monitoring program for the construction stage of the proposal. The shallow aquifer data will be considered together with regular surface water level monitoring data to inform the local hydraulic connectivity between surface water and shallow groundwater in the proposal footprint. This will inform the construction-stage GMMP's task-based, WQO-specific, residual significance score approach.

10.3.2 Groundwater quality monitoring

The pre-construction groundwater monitoring program is to include the indicative bores in Table 10.3 at a minimum to characterise the local groundwater quality prior to construction activities. The quality data collected during the baseline program will be used to assess potential impacts of the proposal on local groundwater resources and on proposal-specific WQOs through all stages of the proposal. Groundwater quality samples are to be collected for field and laboratory analyses on a bimonthly basis (to coincide with the groundwater level measurement pre-construction program).

The baseline groundwater quality program will be continuously ongoing to account for and allow characterisation of natural (seasonal) and/or anthropogenic variation prior to commencement of construction activities. This is especially applicable to the shallow aquifers hydraulically connected to surface water as, after the dry season (negligible recharge), the first-flush / high flow event that recharges these sediments can result in markedly different quality from data collected before, within, and after the wet season. In addition, the baseline quality dataset will indicate the potential for ARD prior to construction works and inform the suitability of local groundwater suitability for construction water purposes.

Field parameters to be collected during sampling include pH, electrical conductance (EC), temperature, redox potential (Eh), and dissolved oxygen (DO). The following analytical suite is suggested for laboratory analyses for the pre-construction groundwater quality dataset and is considered sufficient to identify potential ARD conditions and suitability of groundwater for construction water purposes (if warranted):

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

The pre-construction monitoring program will be completed in sufficient time prior to commencement of construction works to allow for assessment of the data, including trends; this data will be utilised to define proposal-specific WQOs for those identified to be currently exceeded (refer Section 6.9.3). The construction phase GMMP will also be developed at this time. Regular groundwater quality monitoring events are to remain ongoing between proposal phases.

After completion of baseline monitoring program, and with consideration of the final detail design, the frequency and location of groundwater quality sample events will be reviewed and amended for suitability to achieve the objectives of the groundwater monitoring program for the construction stage of the proposal. The shallow aquifer data will be complimented and considered together with regular surface water quality monitoring data to inform the local hydraulic connectivity between surface water and shallow groundwater in the proposal footprint. This will inform the construction-stage GMMP's task-based, WQO-specific, residual significance score approach.

Any WQOs derived for the proposal will be developed in reference to the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZG 2018) and the relevant parameters from the Border Rivers (NSW) Water Quality and River Flow Objectives discussed in Section 6.9.3.

Groundwater monitoring and sample collection will be conducted in accordance with recognised groundwater sampling guidelines such as Groundwater Sampling and Analysis – A Field Guide (Geoscience Australia, 2009) unless an updated version is available prior to commencement of the baseline monitoring program.

10.3.3 Data management and reporting

Appropriate data and reporting will be implemented for the pre-construction GMMP, to include:

- All groundwater data will be validated with suitable quality assurance and quality control (QA/QC) protocols applied
- Monitoring data will be reviewed on a quarterly basis initially to identify trends and compare to WQOs
- Reporting to be completed on an annual basis at a minimum through the pre-construction stage and present the assessment of water levels and water quality trends, including hydrographs and hydrochemical plots. The annual assessment will inform the location, frequency of monitoring, and analytical suites to be incorporated into the construction GMMP to ensure the objectives of the monitoring plans for the relevant stage of the proposal are achieved.

11 Impact assessment

A qualitative impact assessment based on a significance assessment methodology (refer Section 3.3) has been applied to assess potential impacts of the proposal to groundwater related EVs. A summary of the significance assessment is provided in Table 11.1.

For each of the potential impacts discussed in Section 9, the initial significance assessment was undertaken on the assumption that the design considerations (or initial mitigations) factored into the feasibility design phase (refer Table 10.1) have been implemented.

Additional mitigation measures, including those listed in relevant subplans (e.g. the GMMP, Section 10.3), were then applied as appropriate to the phase of the proposal to reduce the level of potential impact and are detailed in Table 10.2.

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

Cumulative impacts have been evaluated in Section 11.3.

11.1 Temporary impacts

Most potential impacts related to groundwater are considered temporary in nature and primarily associated with the construction phase of the proposal. The likelihood of a material impact on current groundwater conditions and users is low.

Final construction design, engineering controls and monitoring are generally considered to be adequate to mitigate potential impacts to groundwater. In the few locations where construction activities have the potential to intersect shallow groundwater, construction techniques have been identified for the proposal such that any impacts are mitigated and managed through the adopted engineering controls. The remainder may be managed through consultation with impacted landholders and implementation of suitable water source alternatives or compensation.

11.2 Long-term impacts

Beyond the construction stage of the proposal, the potential long-term impacts on groundwater are from:

- Ongoing operation of the proposal where potential impacts are likely to be surficial in nature and, through standard rail practices and procedures, not considered to impact on the shallow alluvial aquifer or the sedimentary aquifers
- Changes to groundwater levels and flow due to embankment loading and ongoing passive dewatering or drainage
- Long-term discharge and/or management of passive dewatering volumes to potential sensitive receptors, in terms of volume above baseline conditions or salinity issues
- Loss of registered bores within the construction/operation footprint
- Possible restricted access to pre-existing landholder bores.

The final construction designs, engineering controls, and monitoring are generally considered sufficient to mitigate potential impacts to groundwater environmental values. The remainder may be managed through consultation with impacted landholders and implementation of suitable water source alternatives or compensation.

Table 11.1 Significance assessment summary for groundwater

Potential impact	Phase	Initial significance[1]			Proposed additional mitigation measures[2]	Residual significance[3]	
		Sensitivity	Magnitude	Significance		Magnitude	Significance
Loss, damage, or restricted access to existing landholder bores	Construction	Moderate	Moderate	Moderate	**Early Works** Confirm (i.e. physical survey/'ground truth') the location of registered bores that may be lost due to construction or operation of the proposal (at least those within the construction footprint) and engage with licensed user to complete a bore assessment to determine mitigation strategy (for example replacement of water supply, if required). Undertake bore census/survey to identify unregistered bores with potential to be impact by the proposal. **Construction** Implementation and adherence to the CEMP/EMP (and GMMP) and adherence to make-good arrangements with the owners of the groundwater bores (registered and unregistered) as necessary.	Low	Low
	Operations		Moderate	Moderate			
Altered groundwater levels (increase or decrease) affecting groundwater users and GDEs (incl. impacts due to embankments and seepage to cuts)	Construction	Moderate	High	Moderate (as likely to be temporary)	**Design** Additional investigations and assessment of potential drainage/dewatering impacts associated with cut sections to further refine current understanding and inform detailed designs. Assessment of sizing for longitudinal drainage for permanent drainage features. Define requirements for construction water (volumes, quality, demand curves, approvals requirements and lead times), storage locations along the construction footprint e.g. water used for dust suppression will not result in adverse environmental or health impacts. **Early Works** Continue collection of groundwater baseline data (levels and quality) to ensure robust dataset to be incorporated into the GMMP, discussed further in Section 10.3. Impacts associated with dewatering (i.e. water table lowering) and environmental management requirements during construction are identified through appropriate baseline groundwater monitoring, modelling and analysis. **Construction/Operation** Implementation and adherence to the CEMP/OEMP (and GMMP) with appropriate groundwater level and quality monitoring criterion based on the baseline groundwater monitoring, modelling, analysis and regulatory requirements and make-good arrangements with the landowners (as necessary).	Moderate	Moderate (temporary)
	Operations		Low	Low		Low	Low
						Low	

Potential impact	Phase	Initial significance[1]			Proposed additional mitigation measures[2]	Residual significance[3]	
		Sensitivity	**Magnitude**	**Significance**		**Magnitude**	**Significance**
Subsidence/ consolidation due to groundwater extraction and/or loading	Construction	Moderate	Moderate	Moderate	**Design** Additional investigations and assessment of potential drainage/dewatering impacts associated with cut sections and areas with compressible alluvium to further refine current understanding and inform detailed designs. **Early Works** Continue collection of groundwater baseline data (levels and quality) to ensure robust dataset to be incorporated into the GMMP. Minimise the need to abstract groundwater for construction water by considering alternative sources. Approval requirements to be considered to assist with water supply planning for embankments and cuts. **Construction/Operation** Implementation and adherence to the CEMP/OEMP and GMMP with appropriate groundwater level and quality monitoring criterion based on the baseline groundwater monitoring, analysis and regulatory requirements and make-good arrangements with the landowners (as necessary).	Low	Low
	Operations		Low	Low		Low	Low
						Low	
Altered groundwater flow regime	Construction	Moderate	Moderate	Low	**Design** Detailed design considerations which minimise intersections of the water table that could perturb groundwater flow and designed with adequate spacing between structures that intersect groundwater (i.e. pilings). **Early Works** Continue collection of groundwater baseline data (levels and quality) to ensure robust dataset to be incorporated into the GMMP. **Construction/Operation** Implementation and adherence to the CEMP/OEMP and GMMP mitigation measures during all phases of the proposal.	Low	Low
	Operations		Low	Low		Low	Low

Potential impact	Phase	Initial significance[1]			Proposed additional mitigation measures[2]	Residual significance[3]	
		Sensitivity	Magnitude	Significance		Magnitude	Significance
Contamination or altered water quality impacting vulnerable groundwater resources (spills or induced flow, borehole intersections. Upwards leakage along pile/soil interface)	Construction	Moderate	High	High	**Design** Ensure vehicle/locomotive maintenance and refuel areas are located on hardstand and in areas away from surface water features, potential GDEs, and groundwater users. Engineering design considerations for vulnerable areas along the rail alignment i.e. shallow groundwater table. Further assessment of borrow pit locations for potential-ARD material and suitability for construction purposes. **Early Works** Identification of contaminated, hazardous or potentially contaminated material on site (i.e. soil, ballast) will be subject to a risk assessment and managed in accordance with any relevant applicable legislation and regulations. The reuse or retention of contaminated or potentially contaminated material on site (i.e. soil, ballast) will be managed by a suitably qualified person (SQP) where required. **Construction/Operation** Implementation and adherence to the CEMP/OEMP and GMMP mitigation measures during all phases of the proposal. This includes spill kits on all vehicles, training of personnel in response management to contamination, strict heavy vehicle and drill rig maintenance practices. Adherence to the GMMP (refer Section 10.3).	Moderate	Moderate
	Operations		Low	Low		Low	Low
Vegetation removal and surface alteration affecting recharge/discharge, increasing associated salinity risks	Construction	Moderate	Moderate	Moderate	**Construction/Operation** Where practical, vegetation clearing and ground disturbing works will be staged sequentially across the proposal to minimise exposed areas. Adherence to the CEMP/OEMP with appropriate groundwater quality monitoring criterion based on the baseline groundwater monitoring and analysis (i.e. groundwater levels and salinity).	Low	Low
	Operations		Low	Low		Low	Low

Table notes:

1 Includes implementation of initial mitigations specified in Table 10.1.
2 Additional mitigations and controls, as identified in Table 10.2.
3 Assessment of residual significance once the initial and additional mitigation measures have been applied.

11.3 Cumulative impact assessment

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

The CIA was completed according to the following principles:

- Only existing or planned 'state significant' or 'strategic' projects outside the proposal were considered
- Inland Rail Projects immediately adjacent to the proposal have been included in the CIA
- A whole of program CIA was not included in the assessment and the CIA does not include impacts from past land use
- The Area of Influence (AOI) for the proposal based on the groundwater impact assessment completed for this technical report. Based on this assessment the potential impacts are localised and not to extend beyond the 1 km radius of the study area (based on shallow excavations, limited saturated thickness intersected, and low to moderate permeability results in a limited zone of influence around potential cuttings).

11.3.1 Surrounding projects and timeline relationships

Projects and operations surrounding the study area are presented in (refer Figure 11.1). The cumulative impact assessment only deals with projects that:

- Have been approved but where construction has not commenced
- Have commenced construction
- Have only recently been completed
- Are currently being assessed as State significant infrastructure within Gwydir, Moree Plains and Inverell local government areas or Coordinated Projects in Goondiwindi local government area.

Due to the localised potential groundwater impacts associated with the alignment, only applicable projects and operations (with potential impacts on groundwater) in Table 11.2 have been considered further for this CIA.

Table 11.2 Applicable projects considered for the cumulative impact assessment

Project and Proponent	Location	Description	EIS status	Lifespan (years)	Relationship to the Study Area
Border to Gowrie (B2G) – Inland Rail (ARTC)[1]	Immediately north of proposal site.	Comprised of approximately 146 km of new dual gauge track and 78 km of upgraded track from the NSW/QLD border, near Yelarbon, to Gowrie Junction, north west of Toowoomba in Queensland.	Project Feasibility	2016 to 2024/2025	Potential overlap of construction commencement for B2G and finalisation of proposal.
Narrabri to North Star (N2NS)– Inland Rail (ARTC)[2]	Immediately south of the proposal site. Narrabri (NSW) to the village of North Star in NSW.	An upgrade to approximately 188 km of track within the existing rail corridor and construction of approximately 1.6 km of new rail corridor.	Project Assessment (late 2017 to late 2018)	2016 to 2024/2025	Potential overlap of finalisation of N2NS and commencement of the proposal.
Newell Highway Upgrade, Mungle Back Creek to Boggabilla[3]	8 to 15 km west of the proposal site. Newell Highway, North of Moree.	This will improve safety for motorists and reduce future maintenance requirements. The project includes major work on 18 kilometres of new road pavement, 3.5 m wide lanes in each direction, intersection improvements, widening of road shoulders and provision of two new overtaking lanes.	Environment Protection License acquired, construction contract awarded to Fulton Hogan Construction Pty Ltd, in August 2018.	Late 2018 to 2021 (construction)	Potential overlap of the construction kicks off for the proposal and the completion of this Project.

Table notes:

1 https://inlandrail.artc.com.au/B2G

2 https://inlandrail.artc.com.au/N2NS

3 http://www.rms.nsw.gov.au/documents/projects/western-nsw/newell-highway

The timeline relationships for the respective ARTC projects and the Newell Highway upgrade are provided in Table 11.3. Each of the projects will have a degree of overlap during their construction phases respectively, in particular in 2021. The entire construction phase will be concurrent with construction along the Border to Gowrie Project immediately to the north.

Table 11.3 Project relationship timeline for North Star to Border proposal

Project	Year								
	2018	2019	2020	2021	2022	2023	2024	2025	2026
North Star to Border (ARTC)									
Border to Gowrie (ARTC)									
Narribri to North Star (ARTC)									
Newell Highway Upgrade - Mungle Back Creek to Boggabilla									

Construction	Operation	Decommissioning

11.3.2 Assessment of potential cumulative impacts

Cumulative impacts to groundwater would most likely to occur where multiple projects intersect and/or abstract from the same aquifers as the proposal. The key potential cumulative impacts for consideration include are provided in Table 11.4.

Table 11.4 Summary of potential cumulative impacts

Project	Potential cumulative impact	
	Groundwater levels	**Groundwater quality/ contamination**
North Star to Border (ARTC) Border to Gowrie (ARTC) Narribri to North Star (ARTC)	Potential overlap of impacts from dewatering and cuttings which intersect shallow aquifers. Primarily at the southern and northern ends of the proposal which abut these other ARTC projects. Possible subsequent impacts on GDEs and groundwater users.	Potential cumulative impact on the shallow aquifer from spills/leaks from heavy machinery, drill rigs.
Newell Highway Upgrade - Mungle Back Creek to Boggabilla	Activities related to possible borrow pits for aggregate which intersect shallow groundwater. Potential cumulative impacts from abstraction for construction water supply from the same aquifers as nearby ARTC projects.	

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

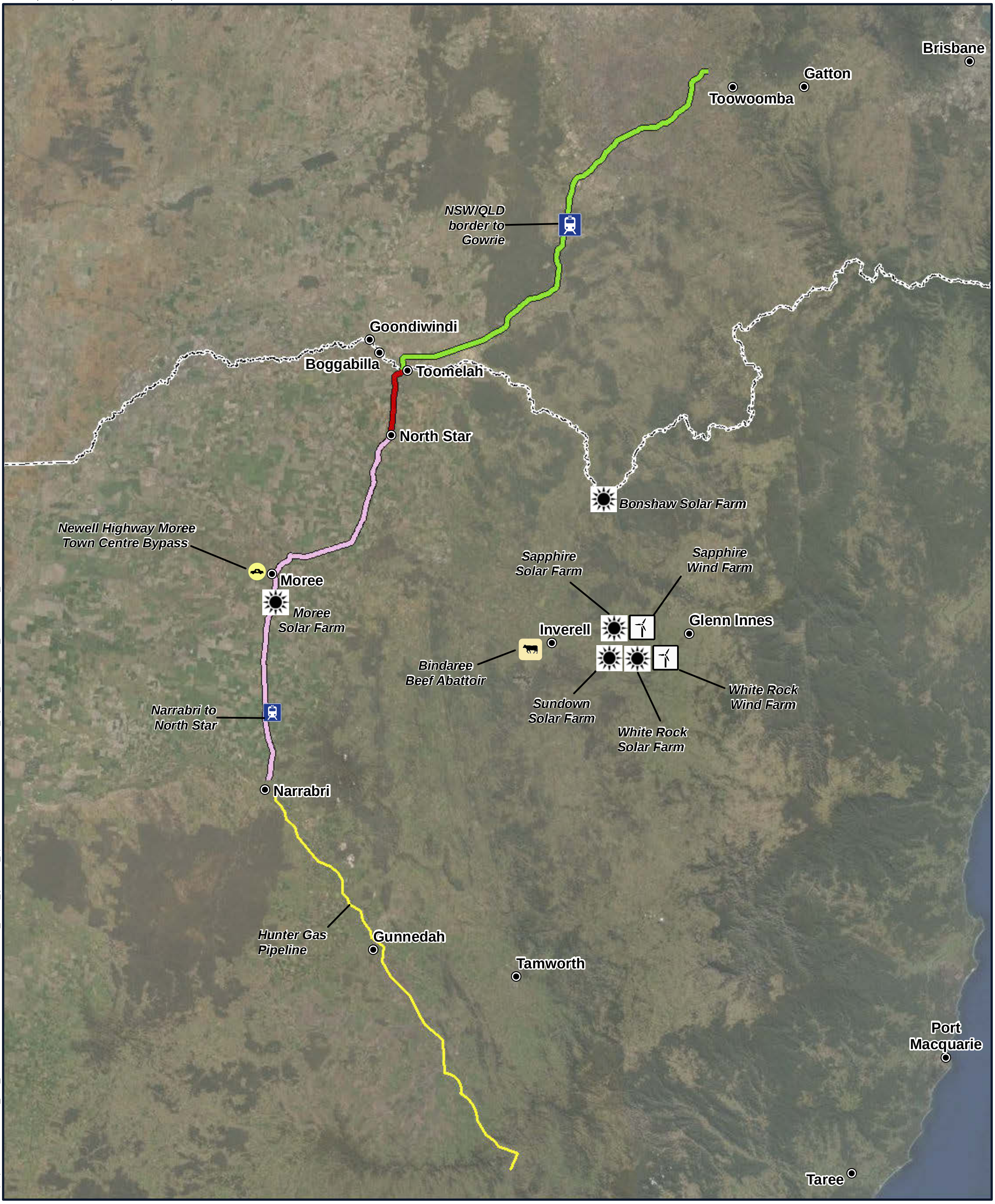
- The probability of the impact
- The duration of the impact
- The magnitude/ intensity of the impact
- The sensitivity of receiving environment.

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

- Low (relevance sum 1-6) – Negative impacts should be managed by standard environmental procedures. Special approval conditions are unlikely. Monitoring required as part of the general project monitoring.
- Medium (relevance sum 7-9) - Mitigation measures likely required and specific management practices to be applied. Specific approval conditions are likely.
- High (relevance sum 10-12) - Alternative actions should be considered and/or mitigation measures applied to demonstrate improvement. Specific approval conditions are likely and targeted monitoring is required.

Based on the above methodology the cumulative impacts for the proposal are summarised in Table 11.5.

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community
Esri, Garmin, GEBCO, NOAA NGDC, and other contributors



Map by: GN Z:\GIS\GIS_270_NS2B\Tasks\270-IGE-20190161416_NS2B_geotech_updates\270-IGE-20190161416_Fig11.1_Cumulative_assessment_v3.mxd Date: 14/11/2019 12:14

Legend

- Localities
- North Star to NSW/QLD border alignment
- NSW/QLD border

A4 scale: 1:2,300,000

0 20 40 60 80 100km

Future Freight
Integrating Community, Environment and Engineering

Date: 31/10/2019 Version: 2

Coordinate System: GDA 1994 MGA Zone 56

North Star to NSW/QLD border

Figure 11.1: Projects surrounding the proposal - cumulative assessment

Table 11.5 Summary of the cumulative impact assessment

Cumulative impact	Aspect	Relevance factor	Sum of relevance factors	Impact significance	Comments	Mitigation measures
Change in groundwater levels beyond the influence of drought effects	Probability of impact	1	5	Low	Due to localised impacts on shallow alluvium groundwater levels anticipated on the proposal site, the proposal is not likely to compound with activities on the Newell Highway Upgrade. Overlap of construction activities at the northern and southern ends of the proposal site with either ARTC projects exists.	Adherence to dewatering and water supply mitigation measures discussed in Section 10. Adherence to the NS2B GMMP to respond effectively to groundwater level drawdown triggers.
	Duration of the impact	1				
	Magnitude/ intensity of the impact	1				
	Sensitivity of receiving environment	2				
Groundwater quality and contamination	Probability of impact	1	5	Low	Primarily related to the shallow alluvial aquifer where potential intersections by excavations and contaminant spills can impact water quality. Unlikely to be relevant to the Newell Highway Upgrade due to distance. Overlap of construction activities at the northern and southern ends of the proposal site with either ARTC projects exists.	Implementation of the GMMP to identify and respond to triggers being breached. Adherence to the NS2B CEMP/OEMP to prevent and respond effectively to spills and leaks.

12 Summary

This groundwater technical report has been prepared to evaluate potential impacts of the proposal on groundwater resources to be included in the EIS submission. This assessment fulfils the requirements of the NSW Department of Planning and Environment SEAR's pertaining to water quality and hydrology.

The proposal will comprise approximately 30 km of new track between the town of North Star and the NSW/QLD border. The proposal is located within the NSW Border Rivers Catchment where the alignment is oriented approximately south to north and is proposed to cross four ephemeral creeks and the perennial Macintyre River at the northern end of the alignment (at the NSW/QLD border). Key groundwater management units, with respect to NSW groundwater management programs, include the NSW Border Rivers Unregulated and Alluvial Water Source and the NSW Great Artesian Basin Groundwater Source.

The proposal area is underlain by Cenozoic alluvium that unconformably overlies westward, gently dipping Cretaceous to Jurassic strata of the Surat Basin. The geology and hydrogeology for the proposal was evaluated using publicly available datasets and site-specific investigations (boreholes and monitoring wells) undertaken from July through October 2018. From approximately Ch 20 km to Ch 30 km, the proposal area is characterised by Quaternary alluvial sediments with typical thickness ranging from 20 to 60 m. The alluvium is associated with Cenozoic creek, river and lacustrine depositional events of the Border Rivers System; less extensive alluvial deposits are associated with Forrest Creek, Mobbindry Creek and Back Creek. Alluvial sediments south of Ch 20 km are generally thin and overlie weathered strata of the geologic Surat Basin sediments inclusive of the Wallumbilla Formation and/or Kumbarilla Beds, encountered at depths of 5 to 10 mbgl, between Ch 0 km to Ch 20 km.

There are two main aquifers of relevance to the proposal with respect to the groundwater impact assessment:

- Cenozoic alluvium deposits associated with the Border Rivers Alluvium and other drainage systems crossed by the alignment (i.e. Macintyre River, Whalan Creek and Mobbindry Creek). This shallow aquifer system is considered sensitive to potential groundwater-affecting activities associated with the proposal.
- Jurassic to Cretaceous sedimentary aquifers of the Surat Basin, which form part of the GAB (Kumbarilla Beds and the Walloon Coal Measures).

The primary water-bearing zone in the Cenozoic alluvium is characterised by sand and sandy gravels and is overlain by a less permeable fine-grained unit comprised of clay, silt, and clayey sands that may result in localised semi-confined conditions. Groundwater flow in the alluvium is inferred to mimic topography and is considered to be limited in lateral and vertical extent by the distribution of the alluvial sediments in the area. Local flow patterns of this aquifer are inferred to be towards the perennial Macintyre River, particularly between Ch 20 km to Ch 30 km.

Recharge to the alluvial aquifer is interpreted to result from stream losses from the Macintyre River and the ephemeral minor creeks/tributaries, and to a lesser extent, infiltration from rainfall and irrigation, and upward leakage from the underlying Surat Basin sediments. Groundwater levels for the alluvium are typically 7 to 20 mbgl; long-term seasonal variations are considered to typically be less than 2 m and are resultant from large rainfall and surface-water flow events. Water quality in the Cenozoic alluvium is generally good and considered suitable for stock, irrigation, and drinking water to an extent as salinity and total dissolved solids concentrations are reported to be below 2,000 µS/cm and 1,000 mg/L respectively. Registered groundwater bores utilising this aquifer are reported to primarily be located between Ch 20 km to Ch 30 km.

The Kumbarilla Beds, which underlie the alluvial sediments, form an important aquifer in the proposal area and represent the main fractured rock aquifer intersected by registered bores. Sandstone is the dominant lithology within the screened intervals and shales typically overlie these water-bearing zones; it is considered these shales may contribute to localised and potentially regional semi-confined to confined groundwater conditions. Groundwater in this aquifer is generally considered to flow northwards, per the hydraulic gradients evident in the reported potentiometric surfaces for the Kumbarilla Beds. Groundwater levels typically range from 4 to 36 mbgl with water levels typically reported to be higher than the initial water strike observed during drilling, which supports the confined nature of this aquifer. An upward vertical hydraulic gradient between the Kumbarilla Beds and the overlying alluvium is evident but aquifer interaction is likely to be limited due to the low permeability of the upper Surat Basin strata. Groundwater quality in the Kumbarilla Beds is generally suitable for stock watering and domestic purposes. However, weathered shales are recognised to overlie the sandstones which dominate this unit. Shallow bores constructed within these weathered upper shales report poor quality with salinity over 10,000 µS/cm and, thus, not suitable for stock watering or domestic uses.

The Walloon Coal Measures of the Surat Basin underlie the Kumbarilla Beds at a depth typically greater than 200 mbgl. As a result, there is a limited number of bores in the proposal area reported to intersect and/or utilise this aquifer. Recharge of the Kumbarilla Beds and the Walloon Coal Measures is influenced by recharge from the GAB intake beds, where the units crop out and/or subcrop on the western slopes of the Great Dividing Range.

The primary groundwater environmental values identified for the proposal include use for stock water, domestic use and irrigation from the alluvium, Kumbarilla Beds and Walloon Coal Measures. The alluvium is also considered suitable for drinking water based on nearby water quality in Queensland. The Macintyre River, which is hydraulically connected to the alluvium, has been identified as the primary water way with habitat which could support six threatened aquatic species, and as such, aquatic GDEs of the Macintyre River is considered a groundwater environmental values for the proposal.

Potential impacts of the proposal on the identified groundwater resources were evaluated in terms of possible impacts from the alignment on groundwater levels, groundwater flow, and water quality. The potential impacts are considered to be minimal given that the depths of the majority of structures along the alignment are not expected to intersect the alluvium groundwater. It is considered that an exception to this is piling works for bridge foundations in 11 locations (Ch 5.7 km and Ch 32 km) which may intersect the alluvial water table. However, the piling techniques adopted for the proposal (cast in place) are considered suitable to limit any interaction with the groundwater of this aquifer.

A significance assessment for all identified potential impacts of the proposal on these groundwater resources was undertaken; overall, impacts from the proposal on groundwater resources are considered to be low if the recommended mitigation measures are adopted. It is considered that potential moderate impacts from construction works, which will be temporary, may include possible altered groundwater levels (from abstraction to supply construction water or from temporary dewatering) and reduction in groundwater. However, mitigation measures have been developed to manage these potential impacts.

A GMMP is outlined in Section 10.3 to inform baseline groundwater conditions and provide an on-going assessment of the potential impacts of the construction and operation of the proposal on the identified groundwater environmental values. The program includes an indicative monitoring network for periodic water level and groundwater quality monitoring. Selected wells will be equipped with automated pressure transducers which record water levels. The proposed groundwater monitoring program is recommended to be reviewed on an annual basis to refine the well network and sampling frequencies.

The proposal is in line with the desired performance outcomes detailed in the SEARs and meets relevant guidelines.

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APPENDIX N

Groundwater Technical Report

Appendix A Register Bore Search: 10 km Radius— Construction Water Options

NORTH STAR TO NSW/QUEENSLAND BORDER ENVIRONMENTAL IMPACT STATEMENT

INLAND RAIL

ARTC

NSW Bore ID	Bore Depth (m)	Aquifer Type	Aquifer Lithology	Yield (L/s)	Water Level (mbTOC)	Screen Top (mbTOC)	Screen Bot (mbTOC)	Drilled Date	Bore Function	Latitude (GDA94)	Longitude (GDA94)
GW000656	315.4	FRACTURED	Sandstone	4.21	15.2			1/03/1921 0:00	Stock	-28.7957	150.4642
GW000708	195.9	FRACTURED	Shale/Sandstone	0.76	NA			1/04/1921 0:00	Stock	-28.8295	150.4942
GW000740	216.4	FRACTURED	Shale/Sst	0.63	36.5			1/10/1921 0:00	Stock	-28.8832	150.4353
GW000742	150.8	FRACTURED	Sandstone	0.15	NA			1/06/1921 0:00	Stock	-28.7898	150.4875
GW000924	163.1	FRACTURED	Shale	0.46	26.5			1/05/1922 0:00	Stock	-28.9626	150.4622
GW000997	184.4	FRACTURED	Shale	1.72	NA			1/12/1922 0:00	Stock	-28.9007	150.3231
GW001116	145.7	FRACTURED	Sandstone	0.61	1.5			1/01/1923 0:00	Domenstic	-28.9162	150.3220
GW001214	185.9	FRACTURED	Shale	0.63	21.9			1/07/1923 0:00	Unknown	-28.8629	150.3245
GW004689	207.3	FRACTURED	Sandstone	0.38	22.8	146.9	148.74	1/05/1938 0:00	Unknown	-28.7809	150.4292
GW005170	140.8	FRACTURED	Shale	NA	NA	47.85	56.38	1/08/1912 0:00	Unknown	-28.8929	150.4028
GW005172	123.7	FRACTURED	NA	NA	NA	101.2	120.09	1/03/1913 0:00	Unknown	-28.8254	150.3883
GW005174	194.1	FRACTURED	Sandstone	1.26	NA	179.8	NA	1/12/1913 0:00	Unknown	-28.7695	150.3856
GW005224	10.1	ALLUVIUM	Sandy Gravel	0.32	6.1	7	10	1/01/1958 0:00	Domenstic	-28.6637	150.4344
GW005343	121.9	WEATHERED ZONE	Sandstone	0.51	9.1	42.7	na	1/01/1912 0:00	Stock	-28.9173	150.4356
GW005350	63.4	FRACTURED	Sandstone	0.38	36	61	63.4	1/01/1910 0:00	Stock	-28.9270	150.3981
GW005822	161.5	FRACTURED	Sandstone	0.47	42.7	158.1	150.2	1/05/1934 0:00	Stock	-28.8093	150.3836
GW005912	81.4	FRACTURED	Sandstone	0.11	NA	45.1	46.02	1/07/1935 0:00	Stock	-28.9357	150.3483
GW005960	91.4	FRACTURED	Sandstone	0.06	NA	56.38	56.7	1/11/1935 0:00	Stock	-28.6779	150.3350
GW005961	160.3	FRACTURED	Sandstone	0.28	NA			1/10/1935 0:00	Domenstic	-28.9793	150.3620
GW005979	176.8	FRACTURED	Sandstone	0.76	NA			1/09/1946 0:00	Domenstic	-28.9562	150.3917
GW006157	134.7	FRACTURED	Sandstone	0.38	30.5	33.5	47.85	1/12/1936 0:00	Stock	-28.9654	150.3520
GW006193	139.9	FRACTURED	Sandstone	0.76	14.9			1/07/1937 0:00	Stock	-28.9193	150.3058
GW006200	197.5	FRACTURED	Sandstone	0.51	3			1/09/1937 0:00	Stock	-28.9307	150.3242
GW006238	170.7	FRACTURED	Sandstone	1.01	30.5			1/11/1937 0:00	Stock	-28.8432	150.3122
GW006510	86.6	FRACTURED	Sandstone	0.03	NA	30.48	31.39	1/06/1939 0:00	Domenstic	-28.9523	150.3172
GW006536	160	FRACTURED	Sandstone	0.38	NA			1/10/1939 0:00	Stock	-28.8429	150.3722
GW006574	337.1	FRACTURED	Sandstone	6.32	NA			1/01/1800 0:00:00	Stock	-28.6920	150.4897
GW007032	125.3	FRACTURED	red rock'	0.19	12.2	32.6	34.1	1/05/1939 0:00	Stock	-28.7112	150.3675
GW007033	213.4	FRACTURED	Sandstone	NA	NA	198.72	199.94	1/12/1941 0:00	Stock	-28.7145	150.3967
GW007080	250.5	FRACTURED	Shale	0.51	NA			1/12/1948 0:00	Domenstic	-28.9595	150.3800
GW007362	149	FRACTURED	Sandstone	3.16	NA			1/03/1947 0:00	Stock	-28.7509	150.3292
GW007681	220.1	FRACTURED	Sandstone/shale	0.63	NA			1/02/1949 0:00	Stock	-28.9398	150.3639
GW007685	243.8	FRACTURED	Multiple Sandstone zones	0.91	17.1	206	243	1/05/1971 0:00	Stock	-28.9390	150.3792
GW009844	219.2	FRACTURED	Sandstone	0.88	15.2			1/12/1951 0:00	Stock	-28.9498	150.3414
GW009991	329.2	FRACTURED	Sandstone	8.84	7	237.7	329.1	1/03/1952 0:00	Water Supply	-28.9279	150.3945
GW010847	126.2	FRACTURED	Shale	1.39	30.5	47.5	52.9	1/06/1954 0:00	Stock	-28.9090	150.3514
GW010884	181.1	FRACTURED	Sandstone	0.52	16.8	177.4	181	1/08/1954 0:00	Stock	-28.9404	150.4089
GW010982	137.5	FRACTURED	Sandstone	0.56	29.9			1/05/1954 0:00	Domenstic	-28.9448	150.4725
GW011009	182.9	FRACTURED	Sandstone	0.81	15.2			1/10/1954 0:00	Stock	-28.9357	150.3483
GW011112	265.2	FRACTURED	Sandstone	0.51	NA			1/03/1955 0:00	Stock	-28.9645	150.3997
GW015619	162.8	FRACTURED	Sandstone	0.73	10.7			1/08/1957 0:00	Stock	-28.8232	150.4825
GW015907	86.9	FRACTURED	Sandstone	1.26	2.7	80.21	86.86	1/10/1957 0:00	Stock	-28.7604	150.3217
GW015926	263.6	FRACTURED	Sandstone	1.19	21.3			1/08/1957 0:00	Stock	-28.7729	150.3686
GW016925	135.4	FRACTURED	Sandstone	NA	NA			1/01/1916 0:00	Stock	-28.8634	150.4781
GW018794	29	FRACTURED	Sandstone	0.46	12.2	22.55	23.46	1/11/1960 0:00	Stock	-28.7170	150.3772
GW018899	221.3	FRACTURED	Sandstone	0.4	113.4			1/04/1961 0:00	Stock	-28.9904	150.4208
GW018995	243.8	FRACTURED	Shale	0.35	18.2	222.2	232.56	1/10/1961 0:00	Domenstic	-28.8582	150.4047
GW019417	190.5	FRACTURED	Sandstone	1.26	11	175.3	189	1/02/1961 0:00	Domenstic	-28.9248	150.3828
GW019491	273.1	FRACTURED	Sandstone	1.77	6.1			1/12/1961 0:00	Stock	-28.9079	150.4592
GW019801	320	FRACTURED	Sandstone	7.38	NA			1/01/1911 0:00	Stock	-28.7668	150.5003
GW019802	103.6	FRACTURED	Sandstone	0.76	6.1	75.6	76.5	1/01/1800 0:00:00	Stock	-28.7545	150.4828
GW019900	300.5	FRACTURED	Sandstone/shale	3.95	3			1/09/1962 0:00	Stock	-28.7643	150.4825
GW020585	252.4	FRACTURED	Sandstone	0.61	15.5			1/09/1963 0:00	Domenstic	-28.9515	150.4003
GW022001	36	ALLUVIUM	Sand	0.51	16.4	28.9	35.96	1/07/1964 0:00	Stock	-28.6598	150.4083
GW027891	42.7	ALLUVIUM	Sand	3.79	11.9	16.8	19.8	1/10/1967 0:00	Irrigation	-28.6851	150.4056
GW027892	73.2	ALLUVIUM	Gravel	NA	11.9	14.6	15.5	1/01/1800 0:00:00	Irrigation	-28.6879	150.3978
GW027893	70.1	ALLUVIUM	Sandy Gravel	4.42	12.9	14.3	17.3	1/08/1967 0:00	Irrigation	-28.6801	150.4069
GW030585	45.7	ALLUVIUM	NA	0.44	10.7	12.2	15.5	1/08/1971 0:00	Domenstic	-28.6698	150.4711
GW030590	13.7	ALLUVIUM	Sandy Gravel	1.52	7.9	11.7	13.4	1/09/1971 0:00	Water Supply	-28.6732	150.4736
GW030600	13.4	ALLUVIUM	Sandy Gravel	0.19	8.9	10.7	11.5	1/10/1971 0:00	Domenstic	-28.6651	150.4828
GW030604	11	ALLUVIUM	Sandy Gravel	1.9	7.8	9.9	10.7	1/10/1971 0:00	Water Supply	-28.6682	150.4800
GW030832	40	ALLUVIUM	Sandy Gravel	NA	NA	12.8	14.5	1/09/1980 0:00	Water Supply	-28.6051	150.3624
GW030838	40	ALLUVIUM	clayey Gravel	NA	NA	18.8	22	1/10/1980 0:00	Water Supply	-28.6093	150.3635
GW032180	163.1	FRACTURED	Sandstone	2.53	10.2			1/03/1970 0:00	Domenstic	-28.7387	150.3728
GW032509	149.4	FRACTURED	Shale and Sandstone	2.27	7.6	76.4	164.6	1/03/1970 0:00	Stock	-28.7157	150.3633
GW034750	336.8	FRACTURED	Sandstone	4.55	1.8			1/09/1972 0:00	Stock	-28.8762	150.4783
GW035161	247.1	FRACTURED	Sandstone	0.51	37.1			1/07/1966 0:00	Stock	-28.9643	150.4447

NSW Bore ID	Bore Depth (m)	Aquifer Type	Aquifer Lithology	Yield (L/s)	Water Level (mbTOC)	Screen Top (mbTOC)	Screen Bot (mbTOC)	Drilled Date	Bore Function	Latitude (GDA94)	Longitude (GDA94)
GW036684	41	ALLUVIUM	Gravelly Sand	NA	NA	18	26	1/04/1987 0:00	Monitoring	-28.6661	150.4124
GW036684	41	ALLUVIUM	Gravelly Sand and clay	NA	NA	29	35	1/04/1987 0:00	Monitoring	-28.6661	150.4124
GW036693	22	ALLUVIUM	Sandy Gravel	NA	NA	14	16	1/03/1987 0:00	Monitoring	-28.6927	150.4145
GW036694	34	ALLUVIUM	Sandy Gravel	NA	NA	12	17	1/03/1987 0:00	Monitoring	-28.7225	150.4166
GW036695	18	ALLUVIUM	NA	NA	NA	NA	NA	1/03/1987 0:00	Monitoring	-28.7469	150.4150
GW036696	20	ALLUVIUM	Sandy Gravel	NA	NA	8	14	1/03/1987 0:00	Monitoring	-28.6844	150.5086
GW039278	39	ALLUVIUM	NA	NA	NA	NA	NA	1/08/1982 0:00	Domenstic	-28.6748	150.4750
GW039279	17	ALLUVIUM	NA	NA	NA	NA	NA	1/07/1982 0:00	Domenstic	-28.6670	150.4700
GW039280	30.8	ALLUVIUM	Yellow Sand	1	9.2	29	30	1/08/1982 0:00	Water Supply	-28.6648	150.4811
GW039380	380.7	FRACTURED	Sandstone	8.4	NA			1/05/1987 0:00	Water Supply	-28.6657	150.4800
GW044593	335.3	FRACTURED	Sandstone	2.27	NA			1/09/1975 0:00	Stock	-28.8226	150.4597
GW049209	318.6	FRACTURED	Sandstone	1.82	21.1			1/12/1978 0:00	Domenstic	-28.8323	150.4036
GW057765	175.3	FRACTURED	Sandstone	1.26	NA			1/07/1983 0:00	Domenstic	-28.9498	150.3706
GW065073	112.8	FRACTURED	NA	0.41	NA	76.5	76.8	10/11/1990 0:00	Industrial	-28.9090	150.3958
GW093556	382	FRACTURED	Sandstone	8	59.8			10/05/2008 0:00	Monitoring	-28.9846	150.3862
GW093557	426	FRACTURED	Sandstone	10	23.1			10/05/2008 0:00	Monitoring	-28.9140	150.3397
GW093558	357	FRACTURED	NA	8	NA			27/05/2008 0:00	Monitoring	-28.9378	150.4552
GW900011	495.3	FRACTURED	NA	0.57	NA			30/09/1993 0:00	Domenstic	-28.7383	150.3723
GW900931	366	FRACTURED	NA	NA	45.2			30/05/1996 0:00	Industrial	-28.9782	150.4417
GW901938	433	FRACTURED	Sandstone	NA	NA	358	430	30/08/1999 0:00	Irrigation	-28.9094	150.4033
GW902416	415	FRACTURED	NA	NA	NA			1/01/1800 0:00:00	Irrigation	-28.9587	150.3883
GW965237	10	NA	NA	NA	NA	8.7	9.7	20/04/1995 0:00	Monitoring	-28.8143	150.4243
GW965238	10	NA	NA	NA	NA	8.7	9.7	20/04/1995 0:00	Monitoring	-28.8093	150.4258
GW965239	10.3	NA	NA	NA	NA	9	10	21/04/1995 0:00	Monitoring	-28.8021	150.4099
GW965240	12	NA	NA	NA	NA	10.7	11.7	22/04/1995 0:00	Monitoring	-28.8127	150.4130
GW965340	7.7	NA	NA	NA	NA	6.45	7.45	6/04/1995 0:00	Monitoring	-28.9627	150.4609
GW965341	10	NA	NA	NA	NA	8.75	9.75	6/04/1995 0:00	Monitoring	-28.9489	150.4552
GW965342	10	NA	NA	NA	NA	8.75	9.75	6/04/1995 0:00	Monitoring	-28.9438	150.4547
GW965343	10	NA	NA	NA	NA	8.8	9.8	9/04/1995 0:00	Monitoring	-28.8813	150.4831
GW965344	10	NA	NA	NA	NA	8.75	9.75	9/04/1995 0:00	Monitoring	-28.8782	150.4917
GW965345	10	NA	NA	NA	NA	8.75	9.75	9/05/1995 0:00	Monitoring	-28.8686	150.4799
GW965370	346	FRACTURED	NA	NA	NA			2/02/2002 0:00	Water Supply	-28.9279	150.3939
GW967835	6	ALLUVIUM	Sandy Clay	NA	NA	4.5	5.5	29/04/2002 0:00	Monitoring	-28.9303	150.4004
GW967836	7	ALLUVIUM	Silty Clay	NA	NA	8.75	9.75	29/04/2002 0:00	Monitoring	-28.9297	150.4011
GW967837	5.8	ALLUVIUM	Sandy Clay	NA	NA	NA	NA	29/04/2002 0:00	Monitoring	-28.9291	150.4023
GW967983	400	FRACTURED	NA	6	17.6			21/04/2007 0:00	Domestic	-28.8268	150.3136