CHAPTER

14

Groundwater

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An Australian Government Initiative

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14 Groundwater

This chapter provides a summary of the groundwater assessment undertaken for the Narrabri to North Star (N2NS) Phase 2 Moree to Camurra North section of Inland Rail (the proposal). It describes the existing environment, assesses the impacts from construction and operation of the proposal, and provides recommended mitigation and management measures. The Groundwater Impact Assessment is in Technical Paper 5B of this Environmental Impact Statement (EIS).

The groundwater impact assessment addresses the Secretary's Environmental Assessment Requirements (SEARs) issued by the Department of Planning and Environment for the proposal in October 2020. The SEARs relevant to groundwater and where they are addressed are detailed in Table 14 1.

TABLE 14-1 SEARS FOR LAND USE AND PROPERTY

Key issue	Requirement	Where addressed
2. Water—hydrology Long-term impacts on surface water and groundwater hydrology (including drawdown, flow rates and volumes) are minimised. The environmental values of nearby, connected and affected water sources, groundwater and dependent ecological systems including estuarine and marine water (if applicable) are maintained (where values are achieved) or improved and maintained (where values are not achieved). Sustainable use of water resources.	1 Describe (and map) the existing hydrological regime for any surface and groundwater resource (including reliance by users and for ecological purposes) likely to be impacted by the project, including stream orders, as per the BAM.	Section 14.3
	2 Prepare a conceptual water balance for ground and surface water including the proposed intake and discharge locations, volume, frequency and duration, sources, security and licensing requirements.	Section 14.3.4
	3 Surface and groundwater hydrology impact of the construction and operation of the project and ancillary facilities (both built elements and discharges) on surface and groundwater hydrology in accordance with the current guidelines, including:	
	a natural processes within rivers, wetlands, estuaries, marine waters and floodplains that affect the health of the fluvial, riparian, estuarine or marine system and landscape health (such as modified discharge volumes, durations and velocities), aquatic connectivity and access to habitat for spawning and refuge	Chapter 12: Hydrology and flooding impact assessment and Chapter 13: Surface water quality impact assessment
	b impacts from permanent and temporary interruption of groundwater flow, including the extent of drawdown, barriers to flows, implications for groundwater dependent surface flows, ecosystems and species, groundwater users and the potential for settlement	Section 14.4
	c changes to environmental water availability and flows, both regulated/licensed and unregulated/rules-based sources	Chapter 12: Hydrology and flooding impact assessment and Chapter 13: Surface water quality impact assessment
	d direct or indirect increases in erosion, siltation, destruction of riparian vegetation or a reduction in the stability of river banks or watercourses	Chapter 12: Hydrology and flooding impact assessment and Chapter 13: Surface water quality impact assessment
	e minimising the effects of proposed stormwater and wastewater management during construction and operation on natural hydrological attributes (such as volumes, flow rates, management methods and re-use options) and on the conveyance capacity of existing stormwater systems where discharges are proposed through such systems; and	Chapter 12: Hydrology and flooding impact assessment and Chapter 13: Surface water quality impact assessment
	f water take (direct or passive) from surface and groundwater sources with estimates of annual volumes during construction and operation, including an assessment of the availability of water where water entitlement is required to be purchased.	Chapter 8: Construction of the proposal Section 14.4 (other potential groundwater take)

Key issue	Requirement	Where addressed
3. Water—quality The project is designed, constructed and operated to protect the NSW Water Quality Objectives where they are currently being achieved, and contribute towards achievement of the Water Quality Objectives over time where they are currently not being achieved, including downstream of the project to the extent of the project impact	**1** Water quality impacts, including:	
	a stating the ambient NSW Water Quality Objectives (NSW WQO) and environmental values for the receiving waters relevant to the project, including the indicators and associated trigger values or criteria for the identified environmental values	Chapter 13: Surface water quality impact assessment
	b identifying and estimating the quality and quantity of 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 pollutants that pose a risk of non-trivial harm to human health and the environment	Chapter 13: Surface water quality impact assessment
	c identifying the rainfall event that the water quality protection measures will be designed to cope with	Chapter 13: Surface water quality impact assessment
	d the significance of any identified impacts including consideration of the relevant ambient water quality outcomes	Chapter 13: Surface water quality impact assessment
	e demonstrating how construction and operation of the project will, to the extent that the project can influence, ensure that: **i** where the NSW WQOs for receiving waters are currently being met they will continue to be protected; and **ii** where the NSW WQOs are not currently being met, activities will work toward their achievement over time	Chapter 13: Surface water quality impact assessment
	f justifying, if required, why the WQOs cannot be maintained or achieved over time	Chapter 13: Surface water quality impact assessment
	g demonstrating that all practical measures to avoid or minimise water pollution and protect human health and the environment from harm are investigated and implemented	Section 14.6 & Chapter 13: Surface water quality impact assessment
	h identifying sensitive receiving environments (which may include estuarine and marine waters downstream) and develop a strategy to avoid or minimise impacts on these environments; and	Section 14.3.3 and 14.6 & Chapter 13: Surface water quality impact assessment
	i identifying proposed monitoring locations, monitoring frequency and indicators of surface and groundwater quality.	Section 14.6 & Chapter 13: Surface water quality impact assessment

14.1 Summary of impacts

The Lower Gwydir Alluvium has the potential to be impacted by certain construction activities and operation of the proposal.

Drawing on groundwater resources to supply construction water may result in short-term, localised impacts on existing users of groundwater; however, no significant long-term impacts on groundwater volumes, groundwater quality or existing groundwater uses are anticipated.

Changes to groundwater quality from contamination may occur due to:

- spillage and leaks of hazardous substances used during construction. These substances, including waste-water discharge, can interact with groundwater through surface infiltration
- potential impacts to groundwater availability and quality including:
  - changes to groundwater availability, as a result of piling impeding groundwater flow, or increased recharge associated with ponding of groundwater due to inadequate drainage
  - reduced recharge to aquifers may occur due to drainage diversions
  - changes to groundwater flow paths may mobilise salts, increasing the salinity of the water quality for downgradient receptors
  - changes to surface infiltration (ponding), evaporation or evapotranspiration, due to alteration of the existing vegetation coverage or surface topography, may either increase or reduce groundwater availability.

A groundwater mitigation and management plan (GWMMP) would be prepared as part of the construction environment management plan (CEMP). The GWMMP would comply with the proposal conditions and be implemented to monitor the effectiveness of mitigation and management measures applied during the construction phase of the proposal. Groundwater monitoring would be implemented for the proposal during construction and operation, using existing and additional bores, to monitor potential contamination and changes to quality or quantity. Specific mitigation measures are provided in 14.6.3 and Chapter 27: Approach to environmental management.

No residual groundwater impact is likely to result from the proposal.

14.2 Assessment approach

The key issues relating to groundwater are:

- long-term impacts on surface water and groundwater hydrology (including drawdown, flow rates and volumes) are minimised
- the environmental values of nearby, connected and affected water sources, groundwater and dependent ecological systems, including estuarine and marine water (if applicable), are maintained (where values are achieved) or improved and maintained (where values are not achieved)
- sustainable use of water resources
- the proposal is designed, constructed and operated to protect the NSW Water Quality Objectives (WQOs) where they are currently being achieved, and contribute towards achievement of the WQOs over time where they are currently not being achieved, including downstream of the proposal to the extent of the proposal impact, including estuarine and marine waters (if applicable).

14.2.1 Methodology

14.2.1.1 Study area

The study area for the purposes of this assessment is predominantly a 2-kilometre (km) buffer encapsulating this linear proposal site as shown in Figure 14-1. This site has been selected as it incorporates important environmental receptors such as registered groundwater bores, and aquatic and terrestrial groundwater dependent ecosystems (GDEs). This region is the basis of the groundwater impact assessment and development of the conceptual groundwater model.

14.2.1.2 Key tasks

To achieve the aims and objectives described above, the following key activities were undertaken:

- regulatory review—a desktop review summarising the relevant legislation, policies and guidelines relevant to the groundwater assessment
- data review—a desktop review of publicly available information on the known regional groundwater setting
- describe environmental setting—an assessment of the existing site baseline conditions and the physical mechanisms that might result in the inferred groundwater impacts potentially arising from the proposal
- assessment of impact—quantification, where applicable, of the potential groundwater impacts
- mitigation—where required, detail what mitigation measures are recommended to managed residual impacts.

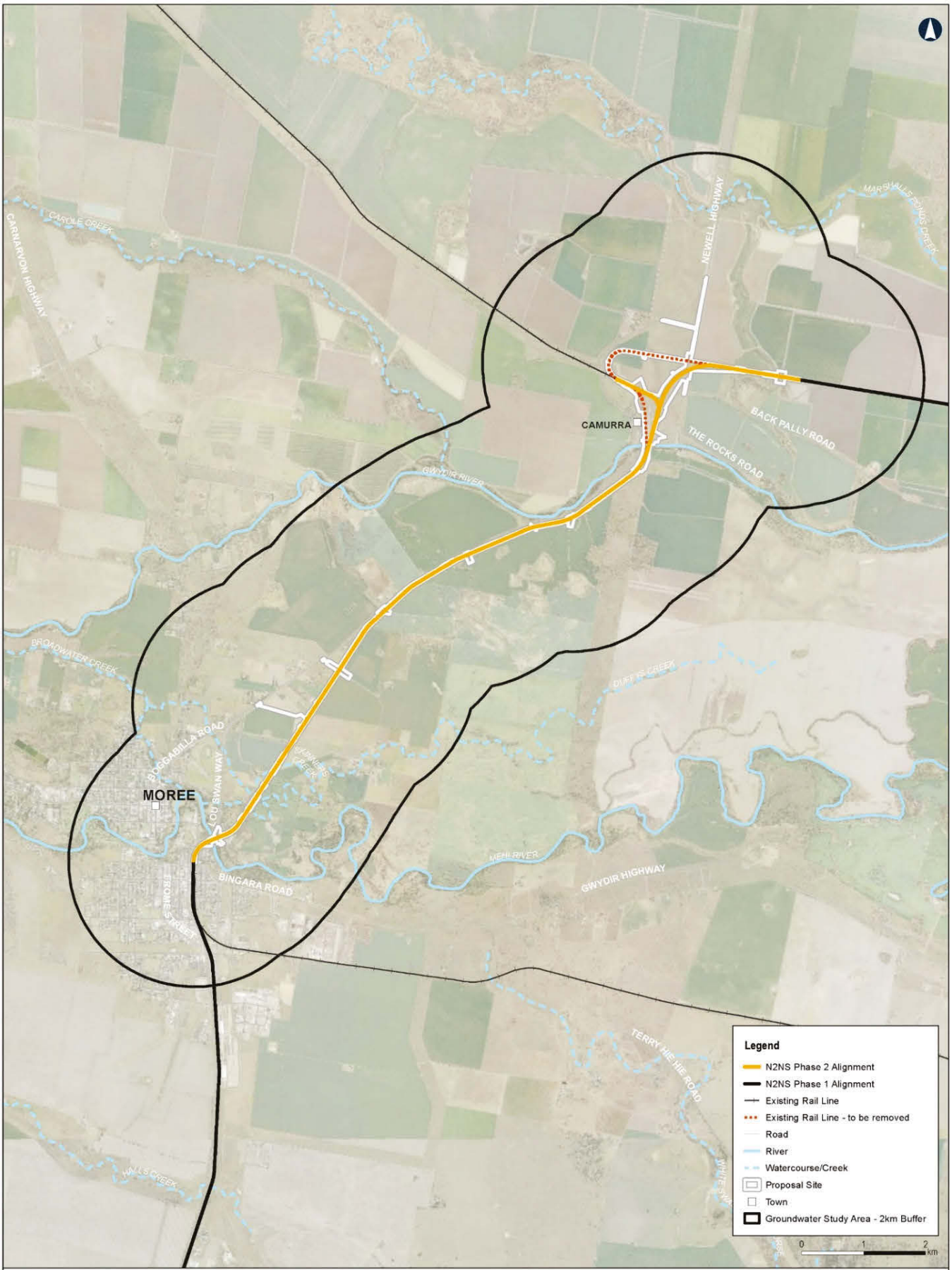

Figure 14-1 Groundwater study area

Data Sources: ARTC, IRDJV, LPI

Coordinate System: GDA 1994 MGA Zone 55
Scale: 1:55,000
Paper size: A3
Date: 9/22/2021

14.2.1.3 Desktop assessment

A desktop review of available data was undertaken to develop an understanding of the regulatory and hydrogeological environment within the study area. The following specific regulatory documents were considered in the assessment:

- the requirements of the *Water Act 1912* (NSW) and the *Water Management Act 2000* (NSW), which govern the use of water from sources (including rivers, lakes, estuaries and groundwater) in NSW
- relevant Water Sharing Plans (WSPs) made under the *Water Management Act 2000* (NSW), being the *Gwydir Alluvial Groundwater Source 2020* (DPIE, 2020)
- NSW *Aquifer Interference Policy* (NSW Department of Primary Industries (DPI), 2012)
- guidelines and policies relevant to the management of groundwater, including:
  - *Australian and New Zealand Guidelines for Fresh and Marine Water Quality 2018 revision* (ANZG, 2018)
  - *Australian and New Zealand Guidelines for Fresh and Marine Water Quality 2000* (ANZECC/ARMCANZ, 2000)
  - *NSW Groundwater Policy Framework (Department of Land and Water Conservation* (DLWC), 1998a), including the *NSW Groundwater Quality Protection Policy*
  - *NSW Groundwater Dependent Ecosystems Policy* (DLWC, 2002)
  - *NSW Groundwater Quantity Management Policy* (DLWC, 1998b).

The following databases were used to provide background information for topography, climate, geology and sensitive receptors:

- NSW Seamless Geology—Department of Regional NSW, used for identification of regional lithology and geological structures
- GDE information from the Bureau of Meteorology (BOM) GDE Atlas (2019a)
- registered groundwater bore data from the National Groundwater Information System (NGIS) (BOM, 2019b) and WaterNSW
- climate data, including rainfall and evapotranspiration, from the BOM
- publicly available reports and databases further detailing the existing groundwater, geological, topographical and hydrogeological environments.

14.2.1.4 Impact assessment

The impact assessment characterises the potential changes to the existing condition of the groundwater environment associated with the construction and operation of the proposal. Impacts to groundwater resources can be simplified into two categories: impacts to groundwater quality and impacts to groundwater availability (groundwater levels, or flows).

The impact assessment focuses on the following:

- impacts to *groundwater quality*—is there an adverse impact to the beneficial use of the resource?
- impacts to *groundwater availability*—is there an adverse impact to groundwater levels, groundwater flows and availability to existing groundwater users and sensitive receptors?

14.2.2 Legislative and policy context

Where relevant, the groundwater assessment was undertaken in accordance with:

- the requirements of the *Water Act 1912* (NSW) and the *Water Management Act 2000* (NSW), which govern the use of water from sources (including rivers, lakes, estuaries and groundwater) in NSW
- the Water Sharing Plans for the *Gwydir Alluvial Groundwater Sources* (DPIE, 2020), including the following water sources:
  - *Lower Gwydir Groundwater Source*
  - *Upper Gwydir Groundwater Source*
- *NSW Aquifer Interference Policy* (NSW DPI, 2012) (discussed further below)

- guidelines and policies relevant to the management of groundwater, including:
  - *Australian and New Zealand Guidelines for Fresh and Marine Water Quality 2018 revision* (ANZG, 2018)
  - *Australian and New Zealand Guidelines for Fresh and Marine Water Quality 2000* (ANZECC/ARMCANZ, 2000)
  - *NSW Groundwater Policy Framework, including the NSW Groundwater Quality Protection Policy* (DLWC, 1998a), *the NSW Groundwater Dependent Ecosystems Policy* (DLWC, 2002), *the NSW Groundwater Quantity Management Policy* (DLWC, 1998b)).

Further discussion on the legislation and policies relevant to the assessment of groundwater are provided in Section 4 of Technical Paper 5B.

14.2.2.1 NSW Aquifer Interference Policy

The *NSW Aquifer Interference Policy* details minimal impact considerations for groundwater sources. The thresholds have been developed for both the highly and less productive groundwater sources. Based on the assessment of the study area in section 14.2.1, the criteria for highly productive groundwater sources is considered to be applicable, which are summarised as follows:

1. Impacts to the water table are considered to be minimal where the water table change is less than or equal to 10 per cent of the cumulative variation in the water table, and 40 metres (m) from any high priority GDE or high-priority culturally significant site. If the impact is greater, it must be demonstrated to the Minster's satisfaction that the variation will not prevent the long-term viability of a GDE or significant site.
2. Impacts to the water table are considered minimal if the cumulative decline in any water supply work is less than 2 m. If the impact is greater, make-good provisions apply.
3. Impacts to water pressure are considered minimal if the cumulative decline in any water supply work is not more than 40 per cent of the 'post-water sharing plan' pressure head above the base of the water source to a maximum of 2 m decline. If the predicted impact is greater, then appropriate studies are required to demonstrate to the Minister's satisfaction that the decline will not prevent the long-term viability of the affected water supply works, unless make-good provisions apply.
4. Impacts to water quality are considered minimal if:
   a. the change in groundwater quality remains within the current beneficial use category of the groundwater source beyond 40 m from the activity
   b. no increase of more than 1 per cent per activity in long-term average salinity, in a highly connected surface water source at the nearest point to the activity (alluvial water sources only)
   c. redesign of a highly connected surface water source that is defined as a reliable water supply is not an appropriate mitigation measure to meet conditions 4(a) and 4(b) above
   d. no mining activity to be below the natural ground surface within 200 m, laterally, from the top of a high bank or 100 m, vertically, beneath (or the three-dimensional extent of the alluvial water source—whichever is the lesser distance) of a highly connected surface water source that is defined as a reliable water supply
   e. not more than 10 per cent, cumulatively, of the three-dimensional extent of the alluvial material in this water source to be excavated by mining activity beyond 200 m, laterally, from the top of a high bank and 100 m, vertically, beneath a highly connected surface water source that is defined as a reliable water supply.
5. If condition 4(a) cannot be achieved, then appropriate studies are required to demonstrate to the Minster's satisfaction that the change in groundwater quality will not prevent the long-term viability of the dependent ecosystem, significant site or affected water supply works.

   If condition 4(b) or 4(d) are not met, then appropriate studies are required to demonstrate to the Minister's satisfaction that the River Condition Index category of the highly connected surface water source will not be reduced at the nearest point to the activity.

   If condition 4(c) or (d) are not met, then appropriate studies are required to demonstrate to the Minister's satisfaction that:
   a. there will be negligible river bank or high wall instability risks
   b. during the activity's operation and post-closure, levee banks and landform design should prevent the Probable Maximum Flood (PMF) from entering the activity's site; and low-permeability barriers between the site and the highly connected surface water source will be appropriately designed, installed and maintained to ensure their long-term effectiveness at minimising interaction between saline groundwater and the highly connected surface water supply.

14.3 Existing environment

14.3.1 Hydrogeology and groundwater levels

14.3.1.1 Topography and catchments

The topography of the study area is defined by the Gwydir River system and its floodplain. The headwaters of the Gwydir River are located near Uralla at approximately 1,200 metres Australian Height Datum (mAHD) to the south-east of Moree. From its source, the Gwydir River flows north-west through NSW tablelands before feeding into Copeton Dam. The flow of the Gwydir River has been anthropogenically altered by the construction of the dam (and, as such, is considered regulated from that point) and various weirs that divert flow into distributary channels, including the Mehi River, Moormin Creek and Carol Creek.

Downstream of Copeton Dam, the Gwydir River continues north-west through an alluvial valley before entering the flat plains near Biniguy. At Pallamallawa, upstream of Moree, the Gwydir loses flow to many anabranches and channels that characterise the lower part of the catchment.

The channel capacity of the Gwydir River at Pallamallawa is greater than the combined capacity of the distributary channels. This constriction in channel capacity downstream from Pallamallawa can result in overbank flows occurring downstream and may arise from small increases in flow.

Downstream of Moree, the Gwydir River splits into two major streams, being the Lower Gwydir Watercourse and the Gingham Watercourses. Both these watercourses provide flow to the Ramsar-listed Gwydir Wetlands, an extensive terminal wetland of national environmental significance. These wetlands are not groundwater dependent (NSW Department of Industry (DoI), 2018).

14.3.1.2 Hydrostratigraphy and groundwater depth

Hydrostratigraphic units (HSUs) are defined as geological materials of similar hydrogeological properties. Hydrostratigraphic units are generally based on stratigraphic units, although units of similar storage and transfer properties are often classified together as a single HSU.

The Lower Gwydir Alluvium is the main HSU underlying the study area. This HSU is comprised of the alluvial/colluvial sediments deposited by the historic Gwydir River system. It forms an extensive alluvial fan comprising fine-grained clays and silts, and coarse-grained sands and gravels. The Lower Gwydir Alluvium is broadly divided between two water bearing zones: a shallow aquifer system up to 30 m deep, known as the Narrabri Formation; and a deep aquifer system, the Gunnedah Formation, which extends to a depth of approximately 90 m.

Bore yields from the deeper aquifer system are up to 1,000 megalitres (ML) per year but supplies are typically in the range of 500 ML/yr. The highest yielding bores are located in an area between Moree and Ashley.

The HSU of the Great Artesian Basin (GAB) underlies the Lower Gwydir Alluvium. The GAB itself is a vast groundwater system covering more than one fifth of Australia. Due the relative depth of the GAB and the non-intrusive nature of the proposal, only the lower Gwydir Alluvium will be described in detail.

Groundwater levels within the Lower Gwydir Alluvium are largely controlled by topography, with hydraulic head decreasing from the higher elevation recharge area in the east to a low elevation discharge area in the west. In 2008, a review of groundwater levels within the Lower Gwydir Alluvium was undertaken and it showed that groundwater extraction from irrigation bores in the areas north of Moree to Ashley has seen significant drawdown and recovery declines (NSW DOI, 2018). Groundwater trading into that area has been restricted to manage potential cumulative impacts from groundwater users.

WaterNSW currently maintains a groundwater monitoring network throughout the study area, including several telemetered groundwater bores that monitor groundwater levels in both the shallow and deep aquifers of the Lower Gwydir Alluvium. Groundwater levels have been obtained from monitoring bore GW030456, which is ‘nested’, meaning it monitors both the shallow (one monitoring pipe) and deep aquifers (two monitoring pipes) within the Lower Gwydir Alluvium. The location of this groundwater monitoring bore is displayed in Figure 14-2.

Groundwater levels within the deep aquifer display influences of groundwater extraction from pumping from that aquifer—the dominant water resource for irrigators. Groundwater levels within the shallow aquifer do not exhibit the visible response to pumping from irrigation bores; however, they do follow a similar overall trend as the deep aquifer.

A summary of observed groundwater levels is presented in Table 14-2, with a hydrograph of groundwater levels within the shallow and deep aquifers presented in Figure 14-3.

TABLE 14-2 OBSERVED GROUNDWATER LEVELS FROM GW030456

GW030456 monitoring pipe	Max		Min		Average		Aquifer
	mBGL	mAHD	mBGL	mAHD	mBGL	mAHD	
Pipe 1 (10–15.2 mBGL)	6.08	200.52	11.04	195.56	8.94	197.66	Shallow aquifer
Pipe 2 (36.2–36.9 mBGL)	6.14	200.46	15.18	191.42	10.86	195.74	Deep aquifer
Pipe 3 (43–46 mBGL)	6.63	200.99	16.47	191.15	10.99	195.61	Deep aquifer

1. mBGL: metres below ground level
2. mAHD: elevation in metres with respect to the AHD

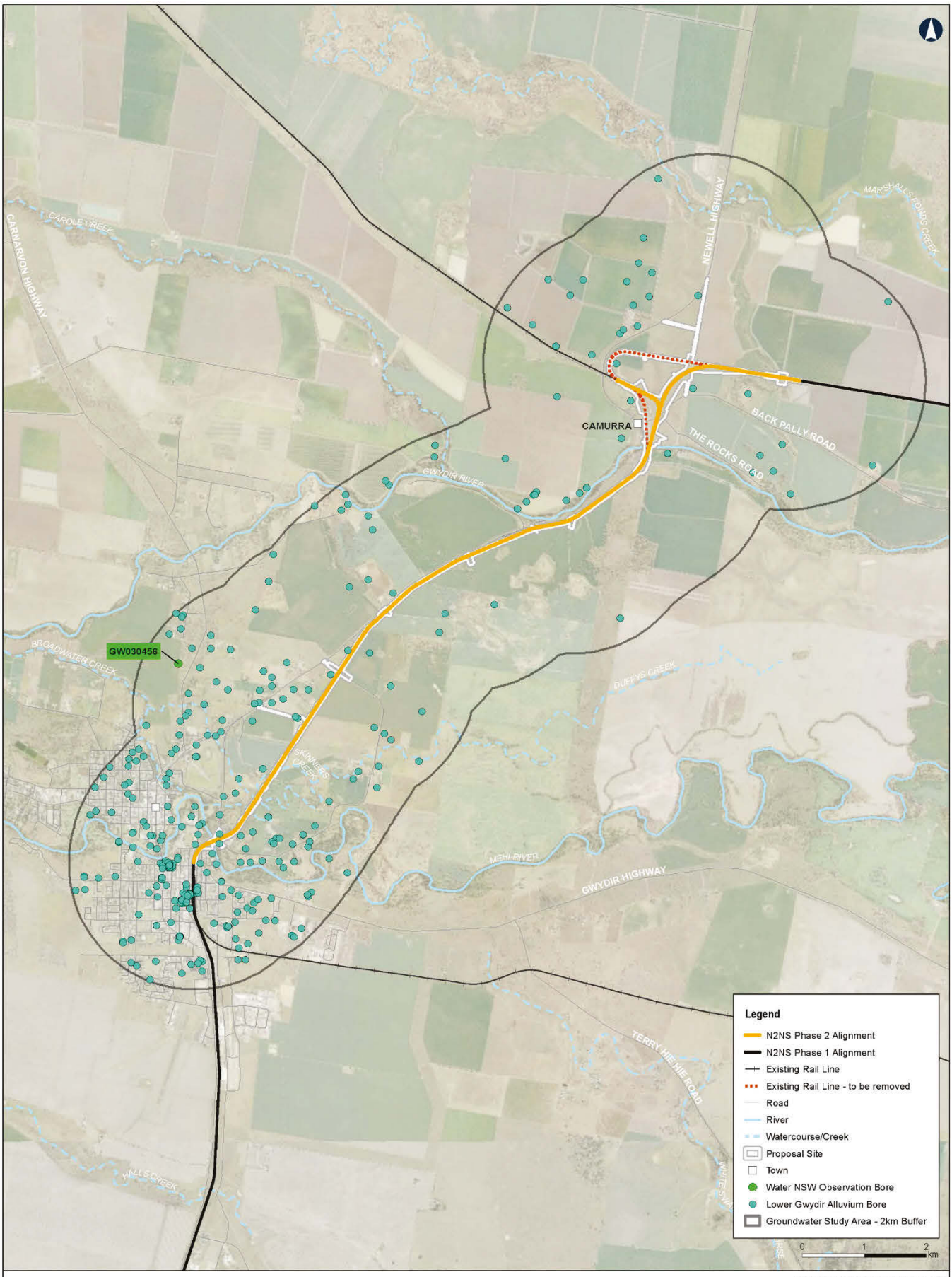

Figure 14-2 Registered groundwater bores within the study area

Data Sources: ARTC, IRDJV, LPI

Coordinate System: GDA 1994 MGA Zone 55
Scale: 1:55,000
Paper size: A3
Date: 9/22/2021

Map 1 of 1

N2NS_SF2_EIS_F14_02_RegisteredBores_r2v2.mxd

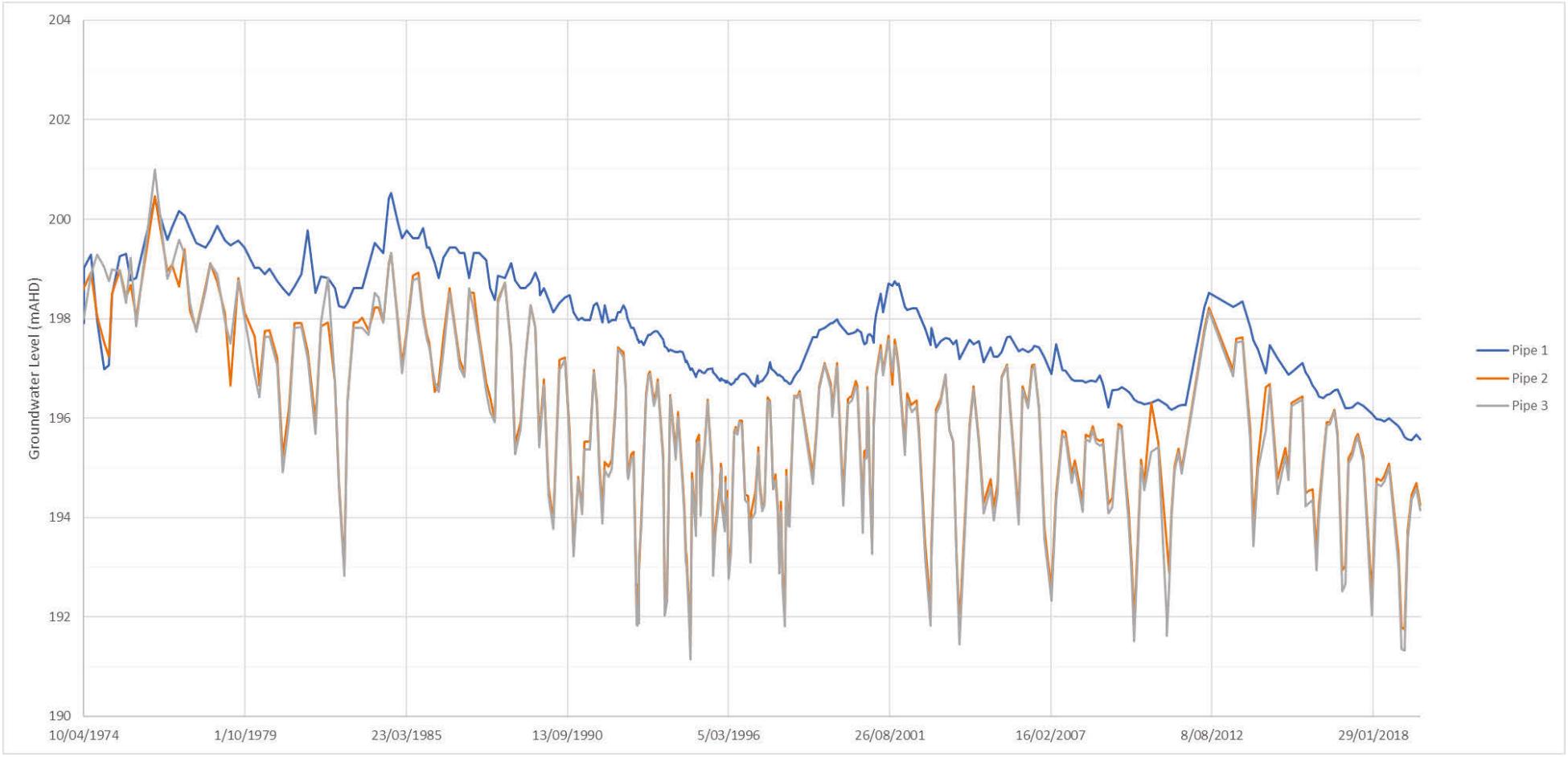

FIGURE 14-3 GROUNDWATER LEVELS FROM MONITORING BORE GW030456

14.3.2 Groundwater quality

Water quality within the Lower Gwydir Alluvium is of a high quality, supplying the town of Moree with potable water with only minor treatment. Numerous household and irrigation bores are also within the study area, reflecting the high quality of the resource. NSW Government groundwater monitoring bore salinity data for the Lower Gwydir Alluvium ranges from 200 µS/cm close to the rivers to over 3,000 µS/cm in the far west and at the periphery of the alluvium.

Groundwater quality has been characterised from previous water quality sampling undertaken, on behalf of the former NSW Office of Water, by Parsons Brinkerhoff (2011). This study characterised the deeper aquifer system within the Lower Gwydir Alluvium as being fresh with electrical conductivity values < 750 µS/cm and suitable for most beneficial uses, including drinking water supply, irrigation and stock water supply.

The upper aquifer system is reported as being fresh to brackish, with water quality surrounding the study area being reported as fresh and suitable for both drinking water supply and irrigation.

14.3.3 Sensitive receptors

14.3.3.1 Groundwater users

A search of the NGIS (BOM, 2019) and WaterNSW groundwater databases identified a total of 353 registered groundwater bores within the study area, of which, two are within the construction impact zone of the proposal. Of the 353 registered bores, 347 have been interpreted to take groundwater from the Lower Gwydir Alluvial.

The remaining six bores are drilled to considerable depth and are interpreted to source water from the GAB aquifers. Five of these bores have no listed purpose; however, it is noted that several artesian bores supply the Moree Artesian Aquatic Centre and private hot springs businesses in Moree.

Of the 353 bores located in the study area:

- 140 are functioning or in use
- 164 are in an unknown condition
- 49 bores are either non-functional, proposed or removed.

Details of the registered bores are provided in section 5.7.1 of Technical pPaper 5B: Groundwater impact assessment.

14.3.3.2 Groundwater dependent ecosystems

Two ecosystems have been identified within the study area that rely on the surface expression of groundwater. Both the main channels of the Mehi and Gwydir rivers are ranked as being low to moderate potential GDEs (BoM, 2019). The connectivity between groundwater and the Gwydir River is detailed in the *Gwydir Alluvium Water Resource Plan's* resource description (DPI, 2018).

Seven ecosystems have been identified within the study area that rely on the subsurface presence of groundwater, including:

- two high potential terrestrial (vegetation) GDEs were identified intersecting the proposal site—River Coolibah/Lignum Woodland wetland and River Red Gum open forest/Woodland wetland
- two low–moderate potential terrestrial (vegetation) GDEs were identified—Coolibah Open Woodland wetland, Weeping Myall Open Woodland
- three low potential terrestrial (vegetation) GDEs were identified—Poplar Box, partly derived Windmill Grass, Queensland Bluegrass +/- Mitchell grass grassland.

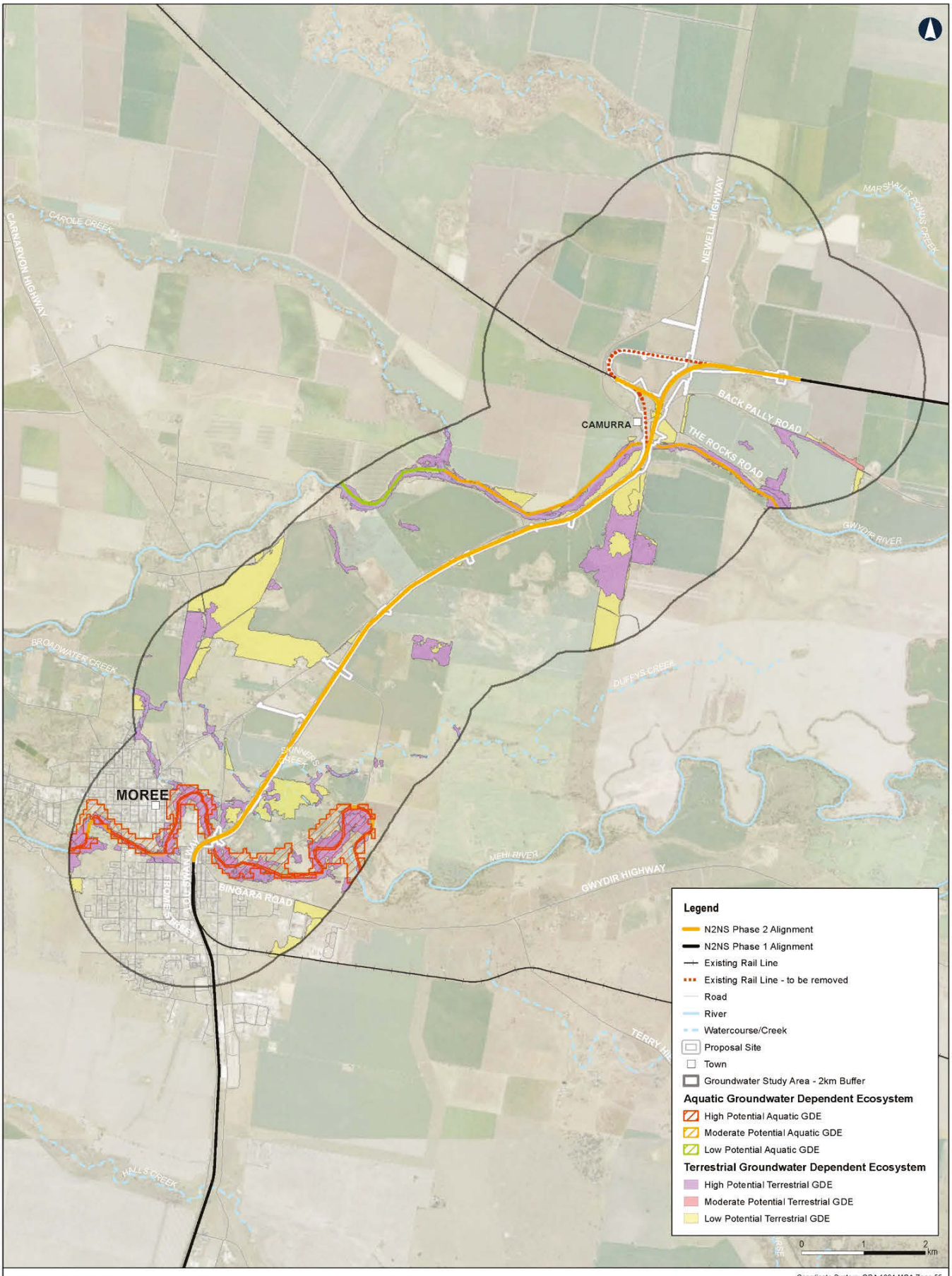

Figure 14-4 Groundwater dependent ecosystems within the study area

Data Sources: ARTC, IRDJV, LPI

Coordinate System: GDA 1994 MGA Zone 55
Scale: 1:55,000
Paper size: A3
Date: 9/22/2021

14.3.4 Existing groundwater balance

The NSW Government maintains a groundwater model of the Lower Gwydir Alluvium. This model was developed in 2002 (and updated in 2016) to support resource management and the development of the water sharing plan. Figure 14-5 shows the cumulative water budget from the 2016 groundwater model, reflecting the period since the commencement of the water sharing plan for the Lower Gwydir Alluvium (2006/07 to 2015/16). Inputs into the water budget come from rainfall, flood, irrigation, river leakage and boundary flows. Outputs are losses from evaporation, losses from plant transpiration, loss to streamflow, boundary flow and through direct extraction from groundwater bores. Inter-aquifer flow also occurs with the shallow aquifer recharging the underlying deep aquifer.

The groundwater budget shows a net reduction in storage of 5.45 gigalitres (GL) occurring during the 2006/07 to 2015/16 period. This reduction reflects the current stresses on the groundwater resource, with groundwater management aiming to limit extraction so that it does not impact on the long-term sustainability of the resource.

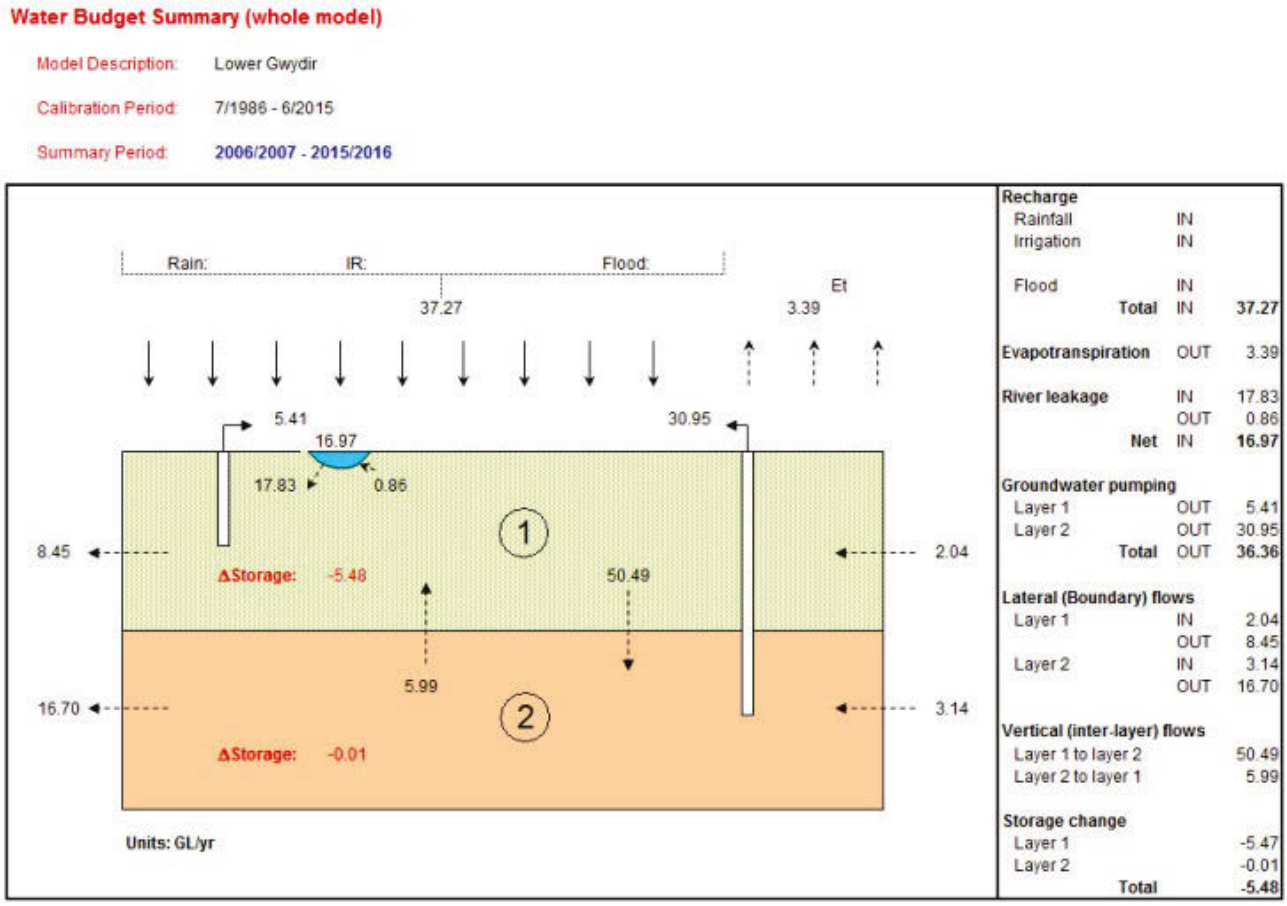

FIGURE 14-5 LOWER GWYDIR ALLUVIUM GROUNDWATER BUDGET 2006/2007 TO 2015/2016

14.3.5 Conceptual hydrogeological model

A conceptual hydrogeological model was developed for the groundwater impact assessment. Conceptual models are a useful tool that capture the existing environmental hydrological and hydrogeological aspects within the study area, and describe the interaction and functions between the two. The following section summarises the conceptual aspects of groundwater underlying the study area and its interactions with both natural and anthropogenic elements.

The study area is largely flat and is associated with the broad flood plains of the Gwydir River and its tributaries. The Gwydir and Mehi rivers straddle the study area in the north and south, respectively. Several smaller surface water features and irrigation channels are also present within the study area.

The Lower Gwydir Alluvium underlies the entire study area and is the principal hydrostratigraphic unit of the groundwater impact assessment. The Lower Gwydir Alluvium is a developed groundwater resource with a high density of groundwater bores that support agricultural irrigation and provide town water supply. The alluvium has been the subject of numerous hydrogeological studies; as such, the aquifer's properties are well defined.

The Lower Gwydir Alluvium is broadly divided into two water-bearing zones, being the shallow Narrabri Formation, extending up to 30 m below ground level, and the deeper Gunnedah Formation, which extends to depths of approximately 90 m below ground level. There is no laterally continuous horizon that identifies a distinct boundary between the two systems. While both the Narrabri and Gunnedah formations are productive units, reported yields from the deeper Gunnedah Formation are as great as 1,000 ML per year; however, yields are typically in the order of 500 ML per year. The highest yielding bores are located between Moree and Ashley.

The primary recharge mechanism for the Lower Gwydir Alluvium is direct rainfall, leakage from stream flow of the Gwydir River and its tributaries, and flood infiltration (the dominant mechanism). Recharge from other watercourses, surface water bodies and irrigation also contribute to the recharge of the Lower Gwydir Alluvium. Extraction by irrigators is the primary discharge mechanism of the Lower Gwydir Alluvium. Other discharge mechanisms include base flow in areas to East of Moree and through-flow towards the west.

To the east of Moree, the Lower Gwydir Alluvium connection with surface water features varies between a losing/gaining system. To the west of Moree, it becomes a disconnected system, meaning groundwater is no longer in hydraulic connection with surface water features. Within the study area, both the Gwydir and Mehi rivers are listed as being of low to medium potential GDE.

14.4 Construction water

As outlined in Chapter 8: Construction of the proposal, various construction activities require water, including:

- rail formation
- road pavement
- earthworks
- in-situ concrete structures
- rehabilitation works
- dust control
- potable water for construction compounds.

Preliminary estimates for water requirements for the placement and compaction of engineering fill range from 600 to 800 litres per square metre (m^3). The estimated total formation fill is that 150,000 m^3 required for the proposal would take approximately 120 ML of water to construct the earthworks.

A Construction Water Plan/Assessment (the Plan) for the Narrabri to North Star (Phase 1 and Phase 2) section of Inland Rail was undertaken by ARTC. The Plan identifies specific water supply options for the construction of the N2NS Inland Rail alignment in accordance with the framework set out in the larger ARTC Program-wide water plan. Due to the Plan containing commercial in confidence information, it is unsuitable for inclusion in a publicly available document.

The plan identifies four viable construction water supply options and associated recommendations:

Recycled wastewater

Narrabri and Moree sewage treatment plants are identified by the Plan as having the potential to provide a significant quantity of recycled water for construction use. Noting the proximity of the Moree Sewage Treatment Plant to the alignment, water sourced from this location would be favourable from a transport and storage perspective. ARTC would engage with these facilities/relevant local councils during detailed design to determine available volumes of construction water.

Tourist park produced water

The Plan notes there has been some interest from local tourist parks in providing ARTC with construction support and existing water supply. The Gwydir Thermal Polls Motel and Caravan Park in Moree is identified as the most viable water source within this category. Four additional tourist parks are identified as potential water sources; however, database searches for any existing environmental licenses for these sites, to understand their water use and discharge, were unsuccessful. Consultation with these tourist parks would be required during detailed design to identify any potential supply sources similar to the Gwydir Thermal Pools Motel and Caravan Park.

Coal seam gas produced water

The Plan identifies that the Narrabri Gas Project may provide water to meet the required construction water demand for the N2NS alignment; however, noting the location of the Narrabri Gas Project (i.e. 26 km south of Narrabri) the possibility of transporting water to the construction site may prove challenging. ARTC would assess the viability of this potential construction water source during detailed design.

Groundwater—Aquifer Water Access License water supply

Assessment of the existing aquifer Water Access Licenses (WALs) suggest that they may be a viable water supply option for the N2NS Phase 2 alignment. Across the entire alignment, 23 aquifer WALs are identified with excess capacity and within acceptable proximity of the alignment. A further 11 WALs are identified that may be considered; however, these WALs may not have excess capacity as they report usage that is comparable to their entitlement.

ARTC proposes to consult with the WAL holders during detailed design to assess their interest and capacity to supply water for the proposal on a commercial basis. No new WALs will be applied for.

As is recommended by the plan, ARTC will commence consultation with the key suppliers identified above. ARTC has determined that the most appropriate time for this consultation is during the detailed design period.

It should be noted that surface water is not identified as a viable water supply by the plan. This is due to few available sources being identified with unallocated supply and (at the time the assessment was undertaken) water restrictions being placed on potential surface water sources due to drought conditions. As such, any available water would be prioritised for town water and human consumption, rather than for construction projects.

ARTC notes an improvement in drought conditions in the region since the assessment was undertaken and will continue to monitor the viability of surface water, as part of an array of wider construction water supply options, during detailed design.

Based on the results of the Plan, it is unlikely that the availability of construction water will be a significant constraint.

14.5 Risk and impact assessment

14.5.1 Risk assessment

The risk assessment process has evaluated the proposal based on the EIS design, a draft construction methodology, and the existing conditions of the study area. The proposal phases to be assessed are as follows:

- construction phase
- operational phase.

To effectively and comprehensively recognise all potential risks to the proposal, it is necessary to identify impact pathways for the proposal. A risk is considered possible only when an impact pathway is present. An impact pathway is the cause and effect pathway or relationship that exists between a proposal activity and an aspect of the environment. A summary of proposal phases and examples of associated activities is in Table 14-3.

TABLE 14-3 PROPOSAL PHASES

Proposal phases	Main activities for each phase	Examples of aspects in each activity
Construction phase	Construction and manufacturing	Transport of materials to site, impacts on environment/social values, earthworks, environmental changes (weather), laydown areas, schedule delays.
Operations phase	Rail and infrastructure maintenance and operation	Weed control, grass cutting, track and ballast maintenance, drainage, long-term environmental/social impacts, emergency preparedness/response.

14.5.1.1 Impact pathways

Impacts have been classified in a temporal sense with the two temporal phases of the proposal consisting as:

- *the construction phases*, where impacts are likely to be short term and localised, e.g. spills and contamination, or groundwater extraction arising from trenching and excavation activities
- *ongoing phases*, where impacts can arise as a result of the construction activities or ongoing road operation, e.g. reduction of permeability due to embankment structures and groundwater deprivation downgradient of excavations.

Potential impact pathways identified with construction and operational phases of the proposal include:

- groundwater availability (take and volume): reduction in groundwater levels as a result of dewatering (construction and operational) resulting in reduced groundwater availability to existing groundwater users, GDEs, or baseflow to creeks or river systems. Dewatering may also cause settlement
- groundwater quality (contamination): change to groundwater quality from contamination can occur from the storage, spillage and leaks of hazardous substances, during construction activities or spillage during maintenance and transport activities post construction. These substances, including wastewater discharge, can interact with groundwater through surface infiltration. The presence of reactive natural soils may undergo changes associated with construction activities (i.e. lowering and rewetting of reactive soils)
- groundwater availability and quality (flow paths): changes to groundwater availability due to an increase in groundwater levels as a result of piling impeding groundwater flow, or increased recharge associated with ponding of groundwater due to inadequate drainage. Reduced recharge to aquifers associated with the drainage diversions. Changes to groundwater flow paths may mobilise salts, increasing the salinity of the water quality for downgradient receptors
- groundwater availability (recharge): changes to surface infiltration (ponding), evaporation or evapotranspiration due to alteration of the existing vegetation coverage or surface topography. This can either increase or reduce groundwater availability.

14.5.1.2 Potential impacts

The environmental risk assessment for the proposal is included in Section 6 of Technical Paper 5B: Groundwater impact assessment and discussed further in Appendix C: Environmental risk assessment of the EIS, including an assessment of the potential risks to groundwater.

The primary groundwater risks identified are listed in Table 14-4. All primary environmental risks were scored as Low and therefore did not require additional controls to be applied, with the exception of GW5, where the installation of groundwater monitoring bores within laydown storage/refuelling areas prior to construction and monitoring throughout the construction process, is recommended to further monitor the risk. This being on the assumption that hazardous materials and refuelling will be practised within construction sites and laydown areas.

TABLE 14-4 GROUNDWATER RISK SUMMARY

Risk ID	Description	Initial risk	Residual risk
GW1—Dewatering	Construction dewatering resulting in an unacceptable impact to sensitive receptors	Low	Low
GW2—Construction water supply	Raw water supply for construction is sourced from the Lower Gwydir Alluvium resulting in unacceptable impact on other groundwater users	Low	Low
GW3—Flow paths	Changes to groundwater flow paths or groundwater discharge impacting surface water and groundwater quality	Low	Low
GW4—Settlement	Changes to soil moisture content causing compression or settlement	Low	Low
GW5—Contamination (water quality)	Degradation of water quality through the movement of potentially existing contamination plumes within the groundwater environment	Low	Low
GW6—Contamination (groundwater)	Contamination of groundwater from construction activities during the construction phase and maintenance procedures during the operational phase	Low	Low
GW7—Recharge	Changes to groundwater recharge through altering surface infiltration	Low	Low

14.5.2 Impact assessment

The impact associated with the identified risks have been qualitatively assessed in Table 14-5.

TABLE 14-5 GROUNDWATER RISK SUMMARY

Risk ID	Qualitative risk assessment
GW1—Dewatering	Proposal is largely at grade and does not include deep excavations or cuttings that have the potential to intersect groundwater or require active dewatering. As no dewatering is required, the minimal impact considerations outlined in the Aquifer Interference Policy (AIP) are not exceeded; therefore, impacts are considered minimal.

Risk ID	Qualitative risk assessment
GW2—Construction water supply	Several potential water sources have been identified that may be used to source construction water for the proposal. These options include: ▸ more town water supply ▸ extraction of surface and or groundwater using existing licensed and/or new bores ▸ onsite water collection and storage, including existing and/or new dams ▸ reuse of low-quality water from sediment dams for dust suppression ▸ processed recycled water from commercial operations (e.g. Moree STP). The proposal is considering a number of potential water sources to supply construction requirements, and this will be finalised during the detailed design phase. Preferred water sources will depend on: ▸ climatic conditions in the lead up to construction and associated water availability ▸ access agreements with landowners for sourcing privately owned water ▸ access agreements with local governments for sourcing town water. The Lower Gwydir Alluvium is just one potential source for construction supply. If ARTC determine that groundwater is required to supply construction demand, then it would be sourced through on-market purchases from willing sellers with existing registered and licensed bores, within the regulated allocations of the related water allocation licences. Alternatively, ARTC may seek to obtain additional allocation through water trading within the Lower Gwydir Alluvium groundwater source. Trading within the Lower Gwydir Alluvium is permitted, subject to regulatory assessment, to ensure minimum impact considerations are not exceeded; therefore, any potential volume extracted for the proposal would be sourced from existing licensing limits and the extent of drawdown would be consistent with what is currently permissible under existing licensed conditions. As water trading within the Lower Gwydir Alluvium is subject to regulatory assessment, any proposed trade by ARTC will be assessed to ensure minimal impact considerations are met and that no adverse impact is realised on existing groundwater users (registered groundwater bores, environmental receptors); therefore, the potential for impacts during construction is considered negligible.
GW3—Flow paths	Proposal is at grade and does not include deep excavations or cuttings that have the potential to intersect groundwater or divert groundwater flow paths. Permanent piling associated with the bridge structures are individual steel-cased piles that do not form a continual barrier impeding groundwater. Embankment structures associated with rail ballast and tracks are predominantly pre-existing throughout the study area. Where new embankment structures are required for the greenfield section of the proposal, they do not contain significant mass (load) to cause a reduction in the underlying permeability that would impact on groundwater flow paths. As groundwater flow paths are not impacted through loading, the minimal impact considerations outlined in the Aquifer Interference Policy are not exceeded and, therefore, impacts are considered minimal.
GW4—Settlement	Embankment structures associated with the rail ballast and track are predominantly pre-existing throughout the study area. Where new embankment structures are required for the greenfield section of the proposal, they do not contain significant mass to cause a reduction in the underlying permeability that would impact on groundwater flow paths. Additionally, as the proposal does not require dewatering for construction, there is no pathway for settlement to occur from dewatering.
GW5—Contamination	During construction, the risk to groundwater quality from hazardous chemicals (e.g. fuel) that may leach through surface infiltration can be appropriately mitigated and managed to reduce the risk of contamination to low. During the operational phase, the consequence to contamination arising from rail incidents remains the same as current operation of the rail line. Impacts during construction and operation are not expected to exceed the minimal impact consideration for groundwater quality outlined in the Aquifer Interference Policy.
GW6—Recharge	Changes in land use and surface water hydrology are not likely to impact recharge patterns to the Lower Gwydir Alluvium. The proposal is required to maintain current flow paths and modelled impacts to flooding both up and down stream of the proposal has been assessed as minor and similar to baseline flood behaviour.

14.6 Mitigation and management

14.6.1 Approach to mitigation

Standard for most major projects, groundwater mitigation and management measures are to be implemented in accordance with relevant NSW legislative and policy requirements. Mitigation and management measures are implemented through the following:

- the development of ARTC's Site Environmental Management Plans for enabling works
- the development of a proposal-specific construction and environment management plan (CEMP) for main construction works
- ARTC's Environmental Management Systems for the operation of the proposal.

As the proposal's potential impacts to groundwater levels are considered negligible during construction and operation, no additional mitigation measures are proposed.

14.6.2 Consideration of the interaction between mitigation measures

Mitigation measures to minimise potential impacts to groundwater will also be implemented as part of those identified for hydrology and flooding (Chapter 12: Hydrology and flooding impact assessment), water quality (Chapter 13: Surface water quality impact assessment), and soils and contamination (Chapter 20: Soils and contamination).

14.6.3 Mitigation measures

As described in section 14.5.1, the only mitigation measures that are recommended are for groundwater monitoring, as construction activities have the potential to increase the occurrence of contaminants infiltrating to groundwater.

The measures outlined in Table 14-6 will be implemented to mitigate the potential groundwater impacts.

TABLE 14-6 MITIGATION MEASURES

Ref	Impact	Mitigation measures	Timing
GW1	Groundwater	A groundwater mitigation and management plan would be prepared as a sub plan as part of the CEMP. The plan would comply with the proposal conditions and be implemented to monitor the effectiveness of mitigation and management measures applied during the construction phase of the proposal. The groundwater mitigation and management plan would, at a minimum: - be based on baseline studies developed for the proposal - include procedures for the documentation and reporting of results - include requirements for training, inspections, corrective actions, notification and classification of environmental incidents, record keeping, monitoring and performance objectives for handover on completion of construction. A groundwater monitoring program would be developed and implemented as part of the plan to monitor potential groundwater impacts. The program would define the following: - monitoring parameters - monitoring locations - frequency and duration of monitoring.	Design and pre-construction
GW2	Groundwater	Further assessment of design concepts would be undertaken at watercourse crossings to minimise embankment loading or compaction of alluvial sediments and mounding of groundwater levels (i.e. use of pilings).	Design and pre-construction
GW3	Contaminants	Drilling and excavation activities during construction would use drilling fluids and chemicals that are environmentally neutral and biodegradable, where practical.	Construction
GW4	Groundwater quality	Laydown areas and storage areas would be located to minimise potential impacts on creeks, rivers, and/or sensitive receptors such as existing groundwater bores or known GDEs.	Operation

Ref	Impact	Mitigation measures	Timing
		Maintenance activities and refuelling would be carried out further than 50 metres from riparian vegetation and waterways, with appropriate measures in place to avoid impacts to groundwater in accordance with relevant regulatory requirements.	
GW5	Groundwater supply and discharge	In the event that groundwater is required for construction water supply, then all water take would be appropriately licensed. Consultation would be undertaken with relevant stakeholders (including landowners/occupants) prior to construction, and appropriate approvals and agreements would be sought for the extraction of water. Monitoring would be undertaken during extraction to ensure volumes stipulated by licence requirements and/or private landowner agreements are not exceeded. Meters would be installed and groundwater extraction recorded and reported in accordance with the relevant requirements of the Non-Urban Metering Policy (DPIE, 2020) and clause 21(6) of the Water Management (General) Regulation 2018. No groundwater discharge would be reintroduced to the groundwater system without appropriate testing and conformance to the relevant water quality control criteria.	Design and construction
GW6	Groundwater table	If excavations unexpectedly intersect the water table, potential impacts would be assessed by a hydrogeologist and adaptive mitigation measures implemented as required.	Construction
GW7	Groundwater bores	▸ The location of registered bores that may be lost due to construction or operation of the proposal would be confirmed (through physical survey or ground truth) and licensed users would be consulted to determine the appropriate mitigation strategy (e.g. replacement of water supply, if required). ▸ Decommissioning of bores would be undertaken in accordance with the *Minimum Construction Requirements for Water Bores in Australia—Edition 3* (National Water Commission, 2012).	Construction
GW8	Groundwater bores	Where groundwater monitoring identifies the potential for groundwater drawdown in existing bores to exceed the NSW Aquifer Interference Policy minimal impact considerations, make-good provisions would be triggered for those bores in consultation with the relevant landowners.	Construction and operation
GW8	Groundwater bore census	A bore census would be undertaken for existing licensed bores within 1 km of the proposal's bore fields, where landowners permit. The census would collect baseline groundwater level data and information on a given bore's typical usage and characteristics (including bore construction, pump depth, yield, water level during pumping and water level outside of pumping periods).	Pre-construction