TECHNICAL REPORT 4

Groundwater assessment

NARROMINE TO NARRABRI ENVIRONMENTAL IMPACT STATEMENT

INLAND RAIL

ARTC

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

ARTC Inland Rail

Narromine to Narrabri Project

Groundwater Assessment

Technical Report 4

2-0001-250-EAP-00-RP-0005

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Executive summary

The proposal

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

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

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

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

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

This report

This Groundwater Assessment has been prepared on behalf of ARTC for the proposal to support the environmental impact statement (EIS) for the proposal and responds to the Secretary’s Environmental Assessment Requirements (SEARs) for water resources.

The assessment presented in this report has included a review of relevant legislation, consideration of the existing conditions, an impact assessment to determine the significance of potential groundwater impacts as a direct result of the construction and operation of the proposal and a cumulative impact assessment. Recommended mitigation and management measures were identified in response to the impact assessment findings.

Proposed bore fields

The proposal also includes installation of groundwater bores and subsequent extraction of groundwater to supply non-potable construction water. The non-potable construction water requirements are subject to weather conditions and methodology selected by the construction contractor. However, it has been estimated that a total of about 4.2 giga litres would be required for non-potable construction water. As a yearly rate, about 1,400 mega litres of non-potable construction water is estimated to be required per year.

A total of 12 bore fields are proposed along the proposal site, which would be installed at a spacing of about 25 kilometres. The number of individual water bores within each proposed bore field ranges from four to ten, with an average of seven water bores per bore field. The majority of the proposed bore fields target groundwater from below the Great Artesian Basin (GAB), as the GAB and overlying alluvial groundwater sources are either close to being, or are, fully allocated. The proposal’s bore fields would extract groundwater from below the GAB, from either Lachlan Fold Belt units or Gunnedah-Oxley Basin units, or in areas of the proposal outside of the GAB, from Lachlan Fold Belt units.

For the purpose of the groundwater assessment, it has been conservatively assumed that all non-potable construction water would be sourced from groundwater. However, it is noted that other options for supply of non-potable construction water would continue to be explored at detailed design stage. Therefore, there is a chance groundwater take and associated impacts would be less than assessed in this report.

If non-potable construction water is sourced from groundwater, the volumes of groundwater extraction that would be required are considered negligible compared to the total water availability of the relevant groundwater sources. The estimated yearly non-potable construction water demand of 1,400 mega litres, if sourced from groundwater, would be sourced from the Gunnedah-Oxley Basin Murray Darling Basin Groundwater Source and Lachlan Fold Belt Murray Darling Basin Groundwater Source. It is estimated that about 980 mega litres per year and 420 mega litres per year would be required from the Gunnedah-Oxley Basin Murray Darling Basin Groundwater Source or Lachlan Fold Belt Murray Darling Basin Groundwater Source respectively for non-potable construction water. The estimated yearly non-potable construction water volumes are less than one per cent of that considered potentially available under a controlled allocation (80 per cent of Sustainable Diversion Limits) within the water sources.

Pumping of the bore fields is not proposed during the operational phase of the proposal.

Where there is benefit to the local community, the potential for retaining bores would be considered in consultation with relevant stakeholders (eg local councils).

In addition to non-potable construction water, a total of about 0.4 giga litres of water is required for potable purposes. Two of the five temporary workforce accommodation facilities, Narromine North and Baradine, may have their potable water sourced from groundwater bores (either existing or constructed for project), with water treatment provided as necessary. The estimated annual potable water demand for these sites is 14.7 mega litres per year and 29.4 mega litres per year for the Narromine North and Baradine temporary workforce accommodation facilities, respectively. These same two workforce accommodation facilities would have their wastewater treated and potentially irrigated onsite through the provision of wastewater treatment plants. The three remaining temporary workforce accommodation facilities would have their potable water demand and wastewater services provided by town services.

The Water Sharing Plan groundwater source for the majority of the upper groundwater in the area of the Narromine North and Baradine temporary workforce accommodation facilities is the Southern Recharge Groundwater Source associated with the GAB, with a small portion (south east corner) of the Narromine North facility potentially occupying an area of the Lachlan Fold Belt Murray Darling Basin Groundwater Source. A total of about 44 mega litres per year would be required from the Southern Recharge Groundwater Source associated with the GAB to supply potable water for the Narromine North and Baradine temporary workforce accommodation facilities. An exception to this would be if the Narromine North workforce accommodation bores were located in the small portion, which occupies the Lachlan Fold Belt Murray Darling Basin Groundwater Source. Options to service the temporary workforce accommodation facilities would be further investigated and developed at detailed design stage. A controlled allocation in the GAB Southern Recharge Groundwater Source is considered unlikely based on entitlement limits and existing allocation volumes. Therefore, the entitlement to cover groundwater extraction for the Narromine North and Baradine temporary workforce accommodation facilities would need to be purchased from the market.

The estimated groundwater extraction volumes outlined above are indicative at this stage and subject to refinement during detailed design as well as conditions encountered during construction.

Existing environment

Surface geology in the Narromine region of the proposal generally consists of alluvium, and less commonly, fine-grained metamorphosed rocks and siltstone/shale of the Lachlan Fold Belt. North of the Narromine region, the proposal is situated within the Coonamble Embayment region of the Surat Basin, a sub-basin of the GAB.

The GAB comprises Jurassic-Cretaceous sedimentary rocks. However, much of the GAB in the area of the proposal site includes a cover of Cenozoic alluvial, residual or colluvial material. The proposal crosses rivers, such as the Macquarie River and other rivers in the Narrabri region, which are associated with the alluvial deposits that are relatively thick, in the order of 30 metres to 70 metres, and subject to wide-scale groundwater extraction by industry.

The proposal bore fields would abstract groundwater from below the GAB. These proposed target units are seldom used as a water source in the area of the proposal, despite the overlying GAB rock and alluvial groundwater systems being heavily used for groundwater extraction themselves. One reason for the units below the GAB not being a popular water source is the significant depth to these units.

The depth of the GAB ranges from about 160 metres below ground level (mBGL) to 420 mBGL in the area of the proposal. The typical depth to the GAB floor in the proposal area is about 365 mBGL. A regionally significant aquitard is conceptualised to exist at the base of the GAB. It is considered that this aquitard would hydraulically separate the GAB groundwater systems from the underlying groundwater systems from which the proposal would extract groundwater.

While the proposal's bore field bores would be deep (at least 110 mBGL, but generally some +300 metres), all other proposal works and features would be relatively shallow. Bulk earthwork excavations required for the alignment and borrow pits have a maximum depth of about 12 mBGL and 20 mBGL respectively.

The depth to the water table is typically in the range of 10 mBGL to 20 mBGL but can be shallower (about five mBGL) in low-lying areas associated with rivers and creeks.

Impacts from the proposal during construction

A range of potential impacts that could impact a groundwater system during construction, include, but are not limited to, those outlined below.

- Pumping of the proposal bore field bores has the potential to cause groundwater level reduction (drawdown) in:
  - the groundwater systems that the proposal bore fields target
  - GAB rock groundwater systems that overlie the bore field target units
  - alluvial groundwater systems which overlie the GAB and bore field target unit groundwater systems
  - areas that host existing groundwater bores and groundwater dependent ecosystems
  - areas of shallow groundwater systems near creeks and rivers, which could subsequently cause reductions to creek and river baseflows.

  Except for drawdown in the groundwater systems the proposal bore fields target, the aquitard unit at the base of the GAB and drawdown at a minor number of existing bores, the likelihood of the above potential impacts occurring is considered low provided the recommended mitigation measures are employed.

  Pumping of bores to supply the Narromine North and Baradine temporary workforce accommodation facilities with potable water (after appropriate treatment) also has the potential to cause impacts; however, this would be managed and limited through adopting appropriate mitigation measures.

- Water quality of shallow groundwater systems adjacent to construction areas has the potential to be impacted by bore field construction water, where water quality of the proposal bore fields differs from the quality of the local groundwater. This could occur if groundwater applied for earthworks conditioning, dust suppression or wash down migrates to the water table without treatment. This could also have implications for surface water systems and vegetation in the construction footprint. Similarly, construction water of unsuitable quality that is not treated could compromise the structure of clay soils and exacerbate erosion. Concrete could also be compromised if the groundwater used for mixing is unsuitable.

  The likelihood and risk of these potential impacts is considered low provided recommended mitigation measures are employed.

- Bulk excavations have the potential to intersect the water table and lead to groundwater level drawdown. The drawdown could impact existing nearby groundwater bores, groundwater dependent ecosystems, and creek or river baseflow.

  The likelihood and risk of these potential impacts is considered low given the shallow depth of excavation proposed across the majority of the proposal site.

- Bulk excavations have the potential to intersect the water table and be subjected to groundwater inflows, which require discharge. Environments receiving the discharge (creeks, rivers or overland flow paths) could be impacted if the groundwater quality is poor.

  The likelihood and risk of these potential impacts is considered low given the shallow depth of excavation proposed across the majority of the proposal site.

- Existing groundwater bores within the construction footprint would require decommissioning. Records indicate 10 existing groundwater bores are located within the construction footprint.

- Groundwater contamination due to accidental spills or leaks of hazardous materials (such as fuels, lubricants and hydraulic oils). The potential for impacts associated with accidental spills or leaks would be minimised through the implementation of spill control procedures and measures that will be incorporated into the construction environmental management plan.

  Groundwater could also be contaminated by application of on-site wastewater, which has not been appropriately treated at the Narromine North and Baradine temporary workforce accommodation facilities. The likelihood and risk of this potential impact is considered low provided recommended mitigation measures are employed.

  Workers could be exposed to unsafe water quality if the groundwater used for potable purposes at the Narromine North and Baradine temporary workforce accommodation facilities is not given appropriate treatment. Exposure would be mitigated by applying appropriate treatment.

- The proposal bore field bores have the potential to provide groundwater flow pathways between groundwater systems, which are ordinarily poorly hydraulically connected, or not connected at all. This could occur due to ineffective hydraulic zonal isolation during bore construction.

  The likelihood and risk of this potential impact is considered low provided recommended mitigation measures are employed.

- There is a potential for surcharge loading associated with fill placement to cause short-term increases to groundwater levels in areas of fill placement, and/or permanent increases to groundwater levels if the increased stress permanently alters the hydraulic conductivity of the underlying water-bearing ground. This risk is applicable to relatively soft soils and is not expected to occur in areas where the water table is hosted within a fractured rock aquifer.

  The likelihood and risk of this potential impact is considered low.
- The construction footprint passes through mapped areas of potential groundwater dependent ecosystems. Therefore, some of this vegetation would require removal. Clearing of potential groundwater dependent ecosystems is covered in the *ARTC Inland Rail Narromine to Narrabri Biodiversity Development Assessment Report* (JacobsGHD, 2020a).

Impacts from the proposal during operation

A range of potential impacts to groundwater systems could occur during operation. Generally, the potential impacts during operation are the same or very similar to that applicable during the construction phase. The following additional or slightly different potential impacts could occur:

- Shallow groundwater systems could become contaminated if accidental spills or leaks of hazardous materials (such as fuels, lubricants and hydraulic oils) occurs during operation. This could occur due during maintenance or if cargo is lost from a train.

  The potential for impacts associated with accidental spills or leaks would be minimised through the implementation ARTC's standard operating procedures.
- Water quality of the shallow groundwater systems could be impacted by the introduction of poorer quality water, if construction water sourced from the proposal's bore fields is not of suitable quality and appropriate treatment is not provided. This is primarily a potential construction impact; however, could also occur during operation after application of the water ceases, due to leaching. With increasing operation time, the potential impact would likely reduce due to potential leachate concentration reducing over time.

  The likelihood and risk of this potential impact is considered low provided recommended mitigation measured are employed.
- The proposal bore field bores could provide groundwater flow pathways between groundwater systems, which are ordinarily poorly hydraulically connected, or not connected at all. This could occur due to ineffective hydraulic zonal isolation during bore construction or corrosion of bore casing during operation.

  The likelihood and risk of this potential impact is considered low provided recommended mitigation measured are employed.

Recommended mitigation measures

Risks to groundwater associated with the proposal are assessed as **low** provided the following recommended mitigation measures are employed.

Design phase

The following groundwater specific mitigation measures would be employed during the design phase:

- If the proposed bore fields are pursued by the construction contractor, bore field hydrogeological conditions would be confirmed through test bores undertaken within the post-approval stage. Specifically, the thickness and hydraulic conductivity of aquitard(s) layers at the base of the GAB would be verified by a hydrogeologist. Where the GAB is present, the proposal bores would be designed to abstract groundwater from below the GAB and below a reasonably thick aquitard unit, such that negligible drawdown to overlying GAB aquifers and the water table would result even after being pumped for up to about 500 days. Yields would also be assessed through the test bores. A hydrogeologist would assess if re-modelling of potential groundwater impacts are required following test bore observations deviating from the conceptual hydrogeological model and adopted model parameters presented in this report. This includes if the detailed design bore distribution is different from that assessed in this report due to increased bore quantities or under some circumstances, altered bore field locations.
- Bores at the two most southern proposal bore fields would be designed to extract groundwater from below depths of 160 and 110 metres below ground, to provide separation to existing bores.
- Proposal bore field groundwater quality would be assessed prior to usage for the suitability of its intended use. Where required, treatment systems would be designed to ensure water quality does not result in environmental impacts or design impacts. Design water quality criteria would depend on the environmental values of the receiving waterway and would be based on the Australian and New Zealand guidelines for fresh and marine water quality (Australian and New Zealand Governments and Australian state and territory governments, 2018).
- A field bore census would be undertaken on existing licensed bores within one kilometre of the proposal bore fields.
- Existing licensed bores within the construction and operation footprint would be decommissioned.
- If bore field locations are altered at detailed design stage, re-assessment of impacts would be undertaken in certain circumstances.
- The bore field bores would be designed using best practice methodologies to limit inter-groundwater system mixing. This would require zonal isolation and pressure cementing.
- As far as practicable, the borrow pits would be rehabilitated to have final ground levels above the water table.
- Groundwater level and quality monitoring would be undertaken in accordance with a groundwater monitoring program.
- If groundwater is pursued as a potable source, by the construction contractor, for the Narromine North and Baradine temporary workforce accommodation facilities, appropriate license entitlement would be obtained, appropriate water quality treatment provided and the bores would be sited to achieve impacts below the NSW Aquifer Interference Policy minimal impact considerations.

- Onsite wastewater systems for the Narromine North and Baradine temporary workforce accommodation facilities would be designed and operated in accordance with the *National Guidelines on Water Recycling* (EPHC, 2006) and the *Environmental guidelines: Use of effluent by irrigation* (DEC, 2004). The effluent would be treated to a high standard.

Construction phase

The following groundwater specific mitigation measures would be employed during the construction phase:

- Groundwater level and quality monitoring would be undertaken in accordance with a groundwater monitoring program.
- Controls would be incorporated into the construction environmental management plan to mitigate risks associated with accidental spills or leakages of hazardous materials (such as fuels, lubricants and hydraulic oils), including subsequent risk of groundwater contamination.

Operation phase

The following groundwater specific mitigation measures are recommended during the operation phase:

- Groundwater level monitoring at the bore field bores should continue during the operation phase until water levels recover to baseline levels, or if bore field pumping ceases during the construction phase, until water levels recover. Groundwater level monitoring beyond this is not anticipated to be required. However, the operational groundwater level monitoring requirements would be confirmed at the end of the construction period, or when the bore field is no longer used during construction.
- At this stage, groundwater level and quality monitoring is not considered necessary within the proposal site and borrow pits monitoring bores (and borrow pits themselves) during operation. However, this would be confirmed at the end of the construction phase.
- Incorporate operational controls to mitigate risks associated with accidental spills or leakages of hazardous materials (such as fuels, lubricants and hydraulic oils) occurring during operation.

Conclusion

Overall, subject to detailed design investigations and with implementation of the proposed mitigation measures, based on quantitative and qualitative assessment, the proposal is expected to have minimal impacts on the upper groundwater systems which are relevant to existing bores, the water table and groundwater dependent ecosystems. Temporary depressurisation of groundwater is likely to occur in the groundwater systems that the proposal's bore field bores would extract groundwater from. However, these groundwater systems are generally very deep and considered unlikely to significantly interact with the shallow groundwater systems applicable to existing bores, the water table and groundwater dependent ecosystems.

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Glossary and abbreviations

Acronym / term	Definition
AHD	Australian Height Datum
AIP	*NSW Aquifer Interference Policy*
AnAqSim	Analytical Aquifer Simulator
ANZG	Australian and New Zealand Guidelines for Fresh and Marine Water Quality
Aquitard	An aquitard comprises bed(s) of relatively low permeability material in a stratigraphic sequence and transmits water at slower rates than an aquifer. Aquitards can separate aquifers and partially disconnect the flow of water underground.
ARTC	Australian Rail Track Corporation
ASS	Acid sulfate soils
ASRIS	Australian Soil Resource Information System
BAM	Biodiversity Assessment Method
BOM	Bureau of Meteorology
CRD	Cumulative Rainfall Departure
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DECCW	(former) Department of Environment Climate Change and Water
DoI	(former) Department of Industry
DPI	(former) Department of Primary Industries
Drawdown	Groundwater level decline caused by an activity, such as groundwater extraction.
EIS	Environmental Impact Statement
EP&A Act	*Environmental Planning and Assessment Act 1979* (NSW)
EPBC Act	*Environment Protection and Biodiversity Conservation Act 1999* (Commonwealth)
GAB	Great Artesian Basin
GDE	Groundwater Dependent Ecosystem
GSC	Gilgandra Shire Council
Hydraulic zonal isolation	Bore construction that effectively isolates water bearing formations from one another.
LTAAEL	Long Term Average Annual Extraction Limit
mBGL	Metres below ground level
MDB	Murray Darling Basin
NEPC	National Environment Protection Council
NEPM	National Environment Protection Measure
NSW	New South Wales
NWQMS	*National Water Quality Management Strategy*
OEH	(former) Office of Environment and Heritage

Acronym / term	Definition
PB#	Proposal bore field reference
PSI	Preliminary Site Investigation
Rail corridor	The corridor within which the rail tracks and associated infrastructure would be located.
SDL	Sustainable Diversion Limit
SEAR	Secretary Environmental Assessment Requirements
Study area	The proposal site plus a 20 kilometre buffer either side.
SWL	Standing Water Level
The proposal	Defined as the construction and operation of the Narromine to Narrabri section of Inland Rail.
the proposal site	Defined as the area that would be directly affected by construction of the proposal (also known as the construction footprint). It includes the location of proposal infrastructure, the area that would be directly disturbed by the movement of construction plant and machinery, and the location of the compounds and laydown areas that would be used during construction.
WAL	Water Access Licence
WM Act	*Water Management Act 2000* (NSW)
WSP	Water Sharing Plan

1. Introduction

1.1 Overview

1.1.1 Inland Rail and the proposal

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

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

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

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

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

1.1.2 Approval and assessment requirements

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

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

1.2 The proposal

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

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

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

1.2.1 Location

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

The location of the proposal is shown in Figure 1.1.

1.2.2 Key features

The key design features of the proposal include:

Rail infrastructure

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

Road infrastructure

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

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

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

Further information on the proposal is provided in the EIS.

Figure 1.1 **Location of the proposal**

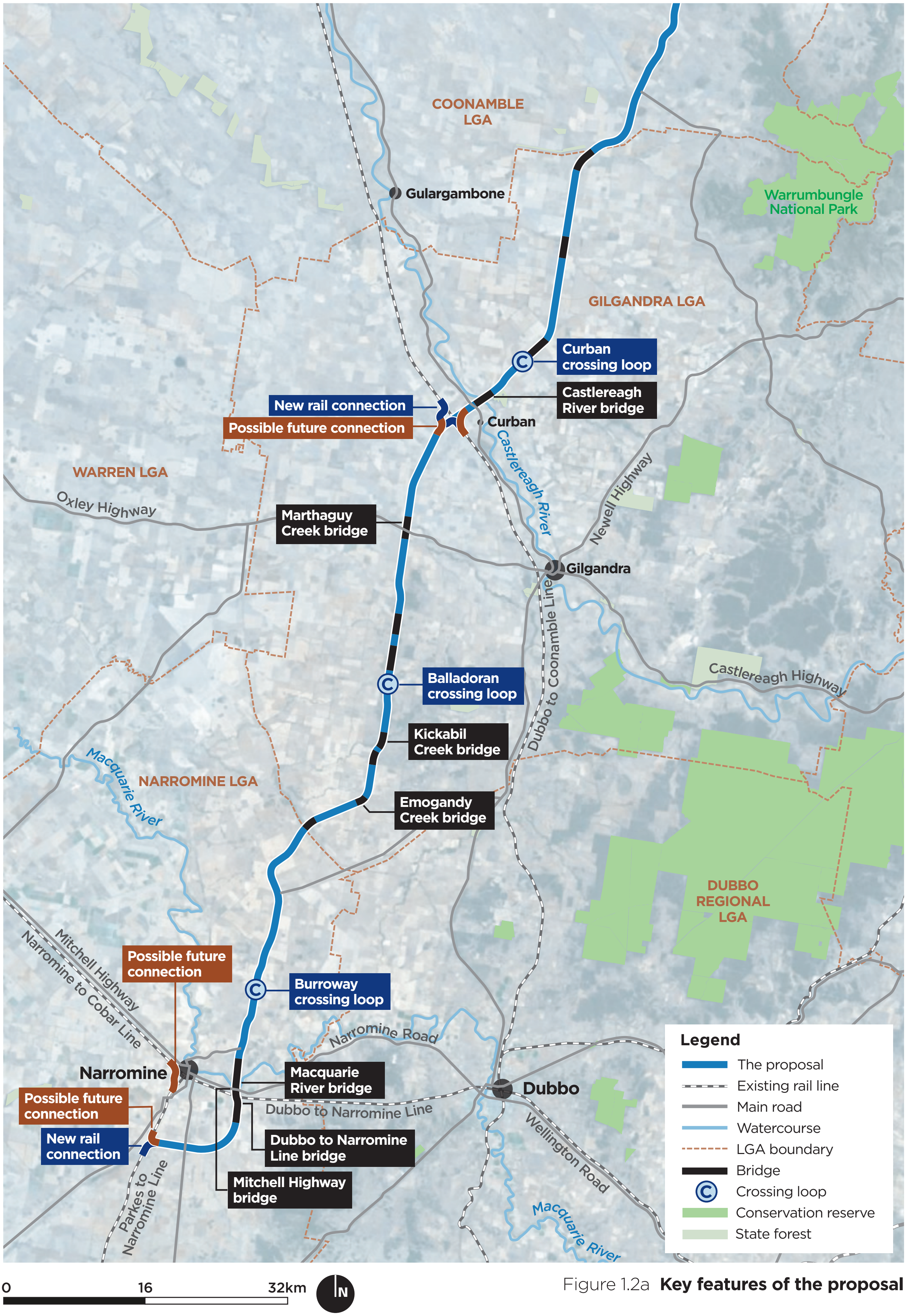


Figure 1.2a **Key features of the proposal**

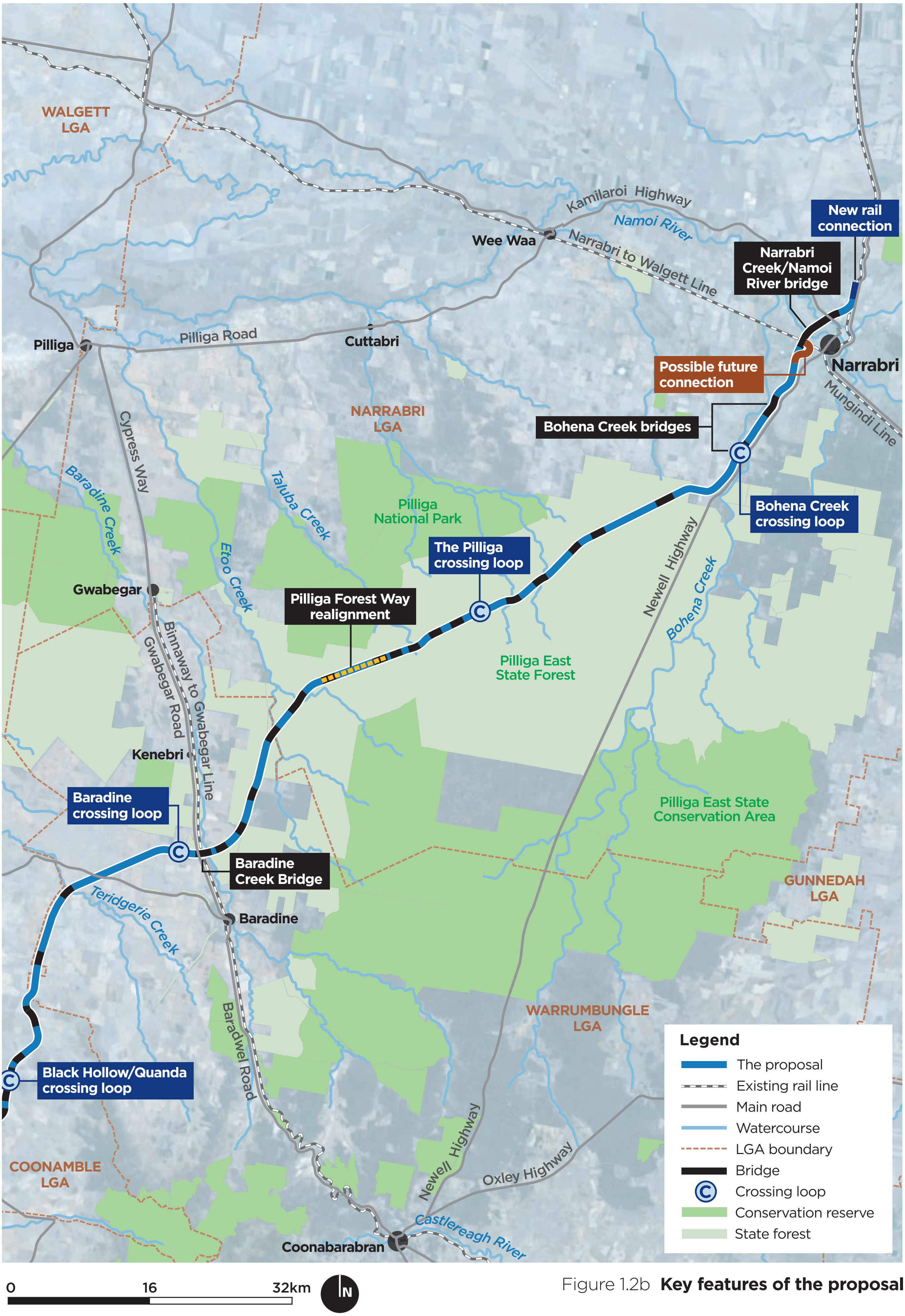


Figure 1.2b **Key features of the proposal**

1.2.3 Construction overview

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

Timing and work phases

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

Table 1.1 Main construction phases and indicative activities

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

Key construction infrastructure

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

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

The key construction infrastructure are shown in Figure 1.3.

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

1.2.4 Operation

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

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

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

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

1.3 Purpose and scope of this report

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

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

The methodology for the assessment is described in section 4.

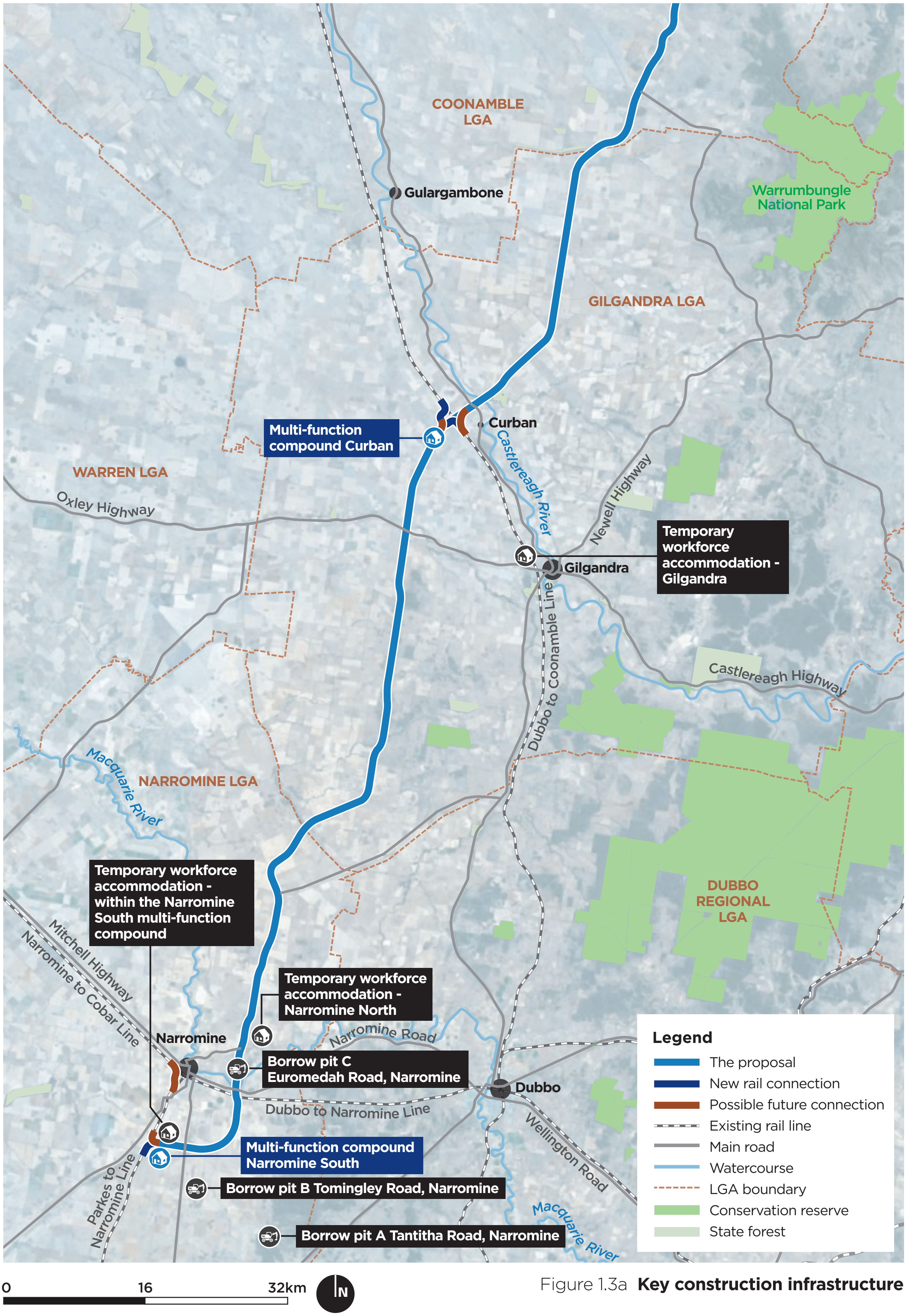


Figure 1.3a **Key construction infrastructure**

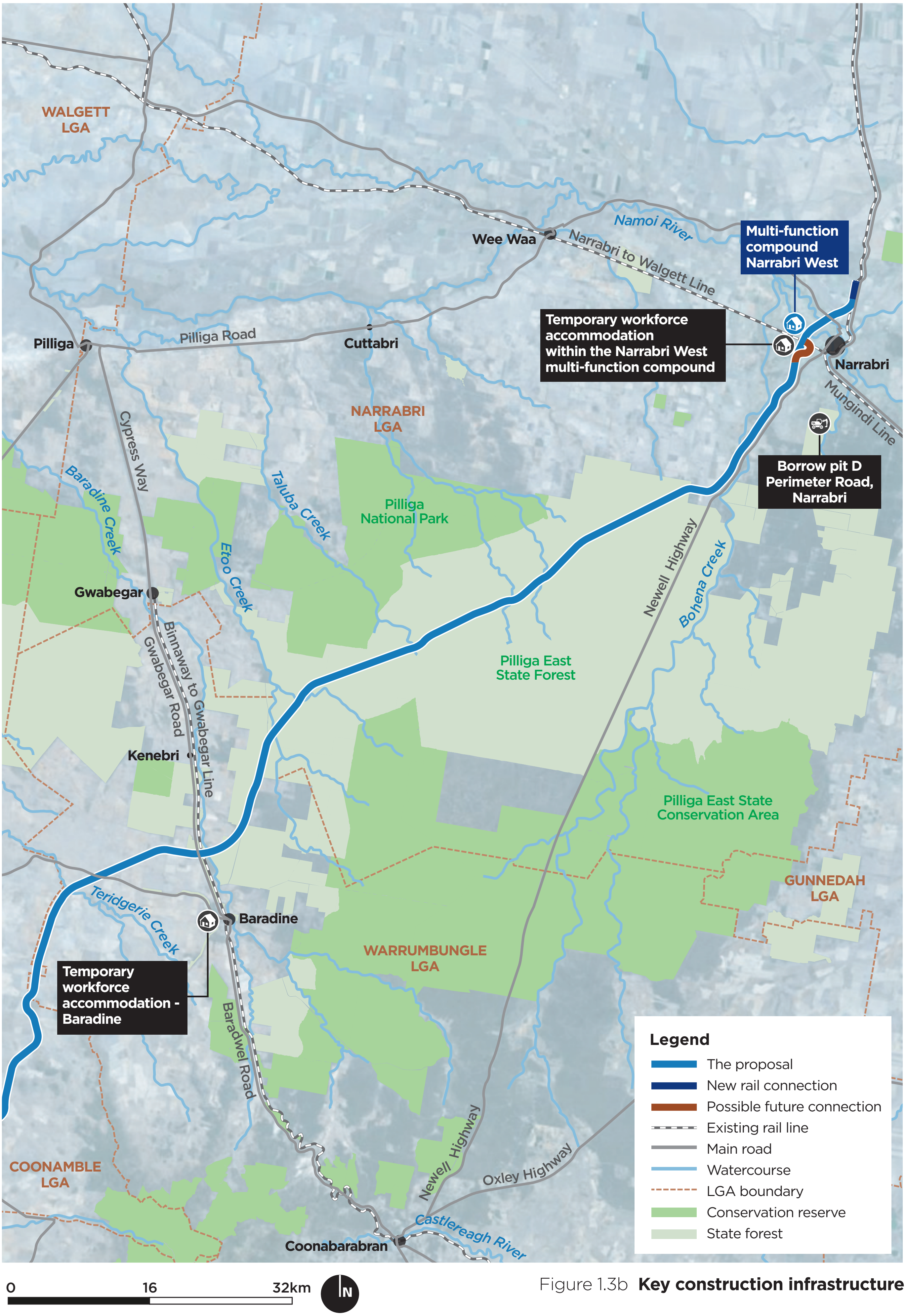


Figure 1.3b **Key construction infrastructure**

Table 1.2 SEARs relevant to this assessment

SEAR number	Requirements		Where addressed in this report
10.1	The Proponent must describe (and map) the existing hydrological regime for any surface and groundwater resource (including reliance by users and for ecological purposes) likely to be impacted by the project, including stream orders, as per the Biodiversity Assessment Method (BAM).		Sections 5.4 and 5.8 describe the existing hydrological regime for surface water and groundwater respectively. Refer to *ARTC Inland Rail Narromine to Narrabri Surface Water Quality Assessment* (JacobsGHD, 2020b) for more detailed coverage of the existing hydrological regime for surface water.
10.2	The Proponent must prepare a conceptual water balance for ground and surface water including indicative locations for proposed intake and discharge locations, volume, frequency and duration, potential sources, security and licensing requirements.		Refer to sections 8.1 to 8.3 for the conceptual water balance for groundwater and surface water. Sections 7.1.6 and 7.2.5 discuss groundwater take and licensing requirements during construction and operation. Refer to *ARTC Inland Rail Narromine to Narrabri Surface Water Quality Assessment* (JacobsGHD, 2020b) for discussions regarding potential discharge locations, security and licencing requirements for surface water.
10.3	The Proponent must assess (and model if appropriate) the impact of the construction and operation of the project and any ancillary facilities (both built elements and discharges) on surface and groundwater hydrology in accordance with the current guidelines, including:		
	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;	Refer to *ARTC Inland Rail Narromine to Narrabri Surface Water Quality Assessment* (JacobsGHD, 2020b) for assessment of construction and operation impacts to surface water systems.
	b.	impacts from any permanent and temporary interruption of groundwater flow, including the extent of drawdown, barriers to flows, implications for groundwater dependent surface flows, ecosystems and species, groundwater users and the potential for settlement;	Sections 6.1 to 6.4 cover modelled groundwater drawdown results. Sections 7.1 to 7.3 cover assessment of potential groundwater impacts. Cumulative impact assessment is covered in Sections 9.1 to 9.3.

SEAR number	Requirements	Where addressed in this report
	c. changes to environmental water availability and flows, both regulated/licensed and unregulated/rules-based sources;	Assessment of changes to environmental water availability is addressed in sections 6.1 to 6.4, 7.1 to 7.3 and 9.1 to 9.3. Refer to *ARTC Inland Rail Narromine to Narrabri Surface Water Quality Assessment* (JacobsGHD, 2020b) for changes to surface water sources.
	d. direct or indirect increases in erosion, siltation, destruction of riparian vegetation or a reduction in the stability of river banks or watercourses;	Refer to *ARTC Inland Rail Narromine to Narrabri Surface Water Quality Assessment* (JacobsGHD, 2020b).
	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	Refer to *ARTC Inland Rail Narromine to Narrabri Surface Water Quality Assessment* (JacobsGHD, 2020b).
	f. water take (direct or passive) from all surface and groundwater sources with estimates of annual volumes during construction and operation.	Sections 7.1.6 and 7.2.5 for water take from groundwater sources. No water take is proposed from surface water sources with the exception of sedimentation basins (refer section 8.2).
10.4	The Proponent must identify any requirements for baseline monitoring of hydrological attributes.	Baseline monitoring is discussed in section 10.1.
11.1	The Proponent must:	
	g. Demonstrate that all practical measures to avoid or minimise water pollution and protect human health and the environment from harm are investigated and implemented;	Sections 7.1 to 7.3 demonstrate that the risk of water pollution is low provided mitigation measures (section 11) are adopted.
	h. Identify sensitive receiving environments (which may include marine waters downstream) and develop a strategy to avoid or minimise impacts on these environments; and	Refer to *ARTC Inland Rail Narromine to Narrabri Surface Water Quality Assessment* (JacobsGHD, 2020b).

SEAR number	Requirements	Where addressed in this report
	i. Identify proposed monitoring locations, monitoring frequency and indicators of surface and groundwater quality.	Sections 10.1 to 10.3 cover groundwater monitoring. Refer to *ARTC Inland Rail Narromine to Narrabri Surface Water Quality Assessment* (JacobsGHD, 2020b) for surface water quality monitoring details.
12.3	The Proponent must assess the impacts of the project on soil salinity and how it may affect groundwater resources and hydrology.	Sections 7.1.7 and 7.2.6 assess the impacts of the proposal on soil and groundwater salinity.

1.4 Structure of this report

The structure of the report is outlined below:

- Section 1 – introduces the report
- Section 2 – provides an overview of proposed bore fields
- Section 3 – provides an overview of legislation, policies and guidelines applicable to this assessment
- Section 4 – describes the methodology and approach for the assessment
- Section 5 – described the physical characteristics and existing water quality of the groundwater at the proposal
- Section 6 – provides the analytical element groundwater model results
- Section 7 – provide an assessment of the impacts to groundwater from the construction and operation of the proposal
- Section 8 – provides estimated water use and a water balance
- Section 9 – provides an assessment of cumulative impacts
- Section 10 – describes the proposed monitoring program
- Section 11 – provides recommended mitigation and management measures
- Section 12 – concludes the key findings and recommendations from the investigation.

2. Proposal bore fields

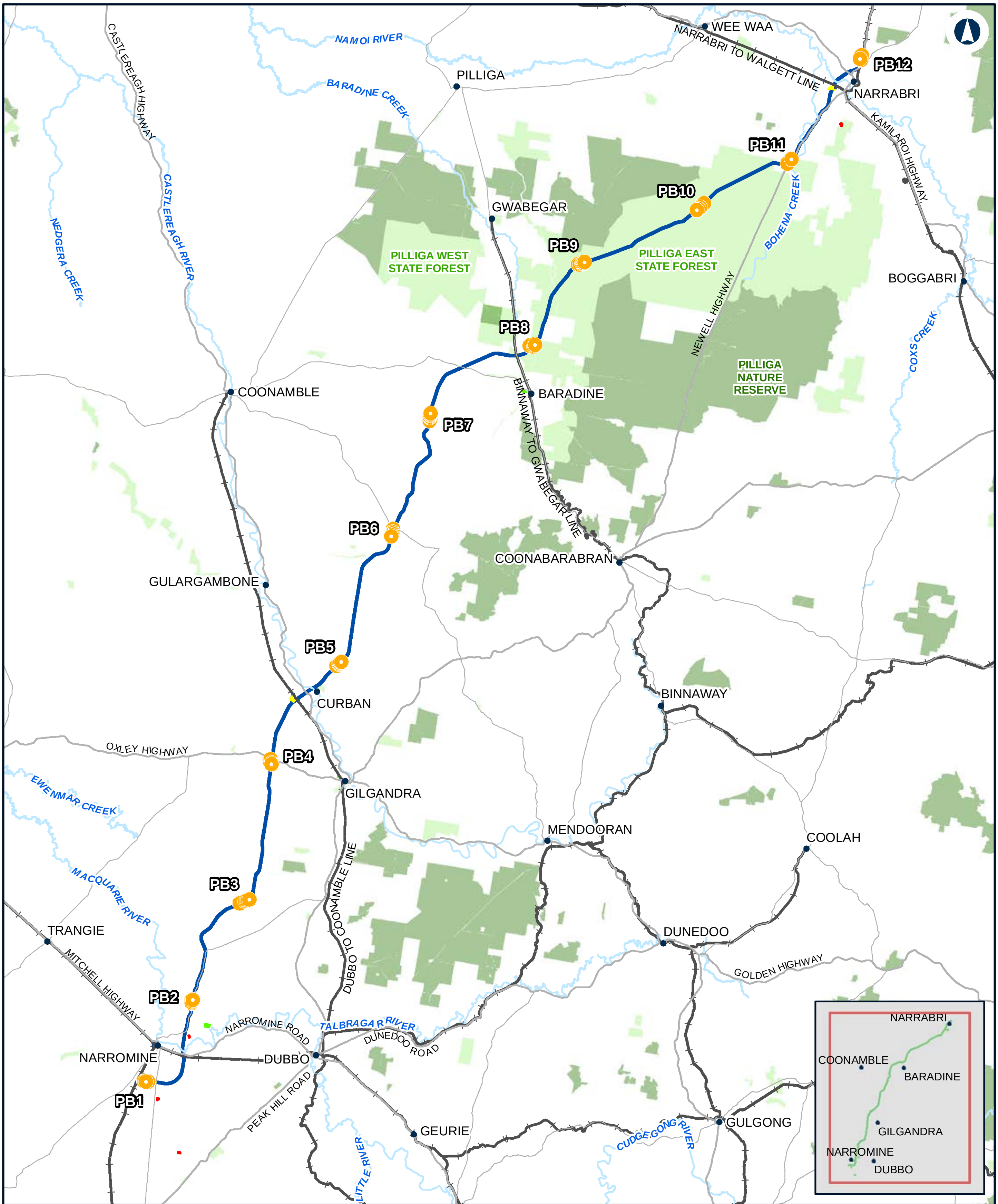
2.1 Non potable construction water bores

A total of 12 bore fields are proposed to supply non-potable construction water. The indicative bore field locations are shown in Figure 2.1 and, for the purpose of this report, have been assigned reference numbering that progresses from south (PB1 at Narromine) to north (PB12 at Narrabri). The bore fields are summarised as follows:

- 12 bore fields are proposed along the proposal site, which are typically spaced about 25 kilometres apart.
- The number of bores within each proposed bore field is shown in Table 2.1 and ranges from four to ten, with an average of seven bores per bore field. The total number of proposed bore field bores is 88.
- The majority of the proposed bore fields target groundwater from below the Great Artesian Basin (GAB), as the GAB and overlying alluvial groundwater sources are either close to being, or are, fully allocated.
- The proposal's bore fields would extract groundwater from below the GAB, from either Lachlan Fold Belt units or Gunnedah-Oxley Basin units, or at bore fields located outside of the GAB, from Lachlan Fold Belt units.
- The non-potable construction water demand to be sourced from the bores is estimated to be an average of about 3.8 mega litres per day over the entire length of the proposal. Annually, this demand is estimated to be about 1,400 mega litres per year.
- Pumping of the bore fields is not proposed during the operational phase of the proposal. Where there is benefit to the local community, the potential for retaining facilities installed for construction (eg bores and sedimentation basins) would be considered in consultation with relevant stakeholders (eg local councils). Any legislative approvals associated with retention and ongoing use of these facilities would be the responsibility of the party who takes ownership.

Table 2.1 Individual bore quantity at proposal bore fields

Proposal bore field	Individual bore quantity
PB1	5
PB2	4
PB3	10
PB4	7
PB5	7
PB6	8
PB7	8
PB8	7
PB9	8
PB10	10
PB11	7
PB12	7
Total	**88**



NARROMINE TO NARRABRI

Proposal borefields

Figure 2.1

0 10 20 Km

Coordinate System: GDA 1994 MGA Zone 55

Date: 30/03/2020 Paper: A4
Author: JacobsGHD Scale: 1:8,000,000
Data Sources: Basemap layers: NSWSS; Project elementsl: GHDJACOBS

LEGEND

- Alignment
- Borefields
- Borrow pits
- Multi function compounds
- Temporary workforce accomodation

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2.2 Potable construction water bores

In addition to non-potable construction water, an estimated total of approximately 0.4 giga litres of water is required for potable purposes.

Two of the five temporary workforce accommodation facilities, Narromine North and Baradine, may have their potable water sourced from groundwater bores (either existing or constructed for project), with water treatment provided as necessary. The estimated annual potable water demand for these sites is 14.7 mega litres per year and 29.4 mega litres per year for Narromine North and Baradine, respectively. These same two workforce accommodation facilities would have their sewage treated and potentially irrigated onsite. The remaining workforce accommodation facilities would have their potable water demand and wastewater services provided by town services.

The Water Sharing Plan (WSP) for the majority of the upper groundwater in the area of the Narromine North and Baradine temporary workforce accommodation facilities is the Southern Recharge Groundwater Source associated with the GAB, with a small portion (south east corner) of the Narromine North site potentially occupying an area of the Lachlan Fold Belt Murray Darling Basin (MDB) Groundwater Source.

A total of about 44 mega litres per year would be required from the Southern Recharge Groundwater Source associated with the GAB to provide potable water for the Narromine North and Baradine temporary workforce accommodation facilities. An exception to this would be if the Narromine North workforce accommodation bores were located in the small portion, which occupies the Lachlan Fold Belt MDB Groundwater Source.

Options to service the temporary workforce accommodation facilities would be further investigated and developed at detailed design stage, and therefore are subject to change. Bore locations and designs would be determined at detailed design stage. However, it is envisaged that the bores would be located close to or within the temporary workforce accommodation facilities.

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3. Legislative and policy context

The legislative and policy context relevant to groundwater are summarised in the following sections.

3.1 Water Act 1912 and Water Management Act 2000

Water resources in NSW are administered under the *Water Act 1912* and the *Water Management Act 2000* (WM Act) by the NSW Department of Planning, Industry and Environment (DPIE). The WM Act governs the issue of water access licences and approvals for those water sources (rivers, lakes, estuaries and groundwater) in NSW where WSPs have commenced. The WSPs for the study area have commenced and water management within the proposal area is therefore generally governed under the WM Act. The WSPs relevant to the proposal are described further in section 3.2.

Ordinarily, if a project extracts groundwater, whether directly due to pumping bores, or indirectly due to excavations beneath the water table intercepting groundwater seepage, the following approvals/licenses would typically be required:

- water use approval under section 89 of the WM Act
- water supply work approval (falls under umbrella of a water management work approval) under section 90 of the WM Act
- Water Access Licence (WAL) with sufficient entitlement volume in the relevant water source to account for the groundwater take.

Due to exemptions outlined in section 5.23 of the EP&A Act, groundwater extraction activities that are assessed and approved as part of State significant infrastructure projects are exempt from water use approvals and water management work approvals. Thus, if the proposal's groundwater extraction is assessed and approved as part of the State significant infrastructure proposal, only a WAL would be required. A WAL is required for dewatering and other taking of water from any water source which is covered by a water sharing plan under the WM Act. A WAL authorises the taking of a share of water from a specified water source in accordance with the volumetric entitlement in the WAL. That entitlement is measured by the number of units assigned to the WAL and the annual volumetric value of a unit for that water source as determined by the Minister administering the WM Act. Units can be transferred from one WAL to another. A WAL is held personally and may be transferred and otherwise dealt with in accordance with the WM Act. The WAL would need to be nominated to a water supply work.

ARTC and/or its contractor would determine how water for the construction of the proposal would be sourced and, if necessary, would obtain WALs with sufficient unit entitlements to satisfy the proposal's water take needs.

3.2 Water sharing plans

Numerous WSPs are established throughout NSW for groundwater. The purpose of a WSP is to provide water users with a clear picture of when and how water would be available for extraction, protect the fundamental environmental health of the water source and ensure the water source is sustainable in the long-term. WSPs are sometimes subdivided into subset areas, referred to as 'sources', based on groundwater system characteristics. Multiple WSPs and sources can occur vertically on top of one another due to different hydrogeological systems.

To determine WSPs/groundwater sources applicable to the proposal, the WSPs/groundwater sources were visualised using a NSW Government SEED Web Map Service, viewed within geographical information system software.

3.2.1 WSPs – construction footprint

Due to its length, the proposal covers numerous WSPs and groundwater sources. Except for the proposal bore fields (refer section 3.2.2), the upper most WSPs and groundwater sources are applicable to the proposal and are summarised in Table 3.1. For most of the proposal the upper most WSP is the NSW GAB Groundwater Sources 2020 and the groundwater source is the Southern Recharge Groundwater Source.

Table 3.1 Summary of upper groundwater WSPs/sources that proposal features occupy

Proposal feature	WSP	Groundwater source
Construction footprint (except for features below)	NSW MDB Fractured Rock Groundwater Sources 2020	Lachlan Fold Belt MDB Groundwater Source
	Macquarie-Castlereagh Groundwater Sources 2020	Lower Macquarie Zone 6 Groundwater Source
	NSW GAB Groundwater Sources 2020	Southern Recharge Groundwater Source
	Namoi Alluvial Groundwater Sources 2020	Lower Namoi Groundwater Source
Narromine North and Baradine temporary workforce accommodation facilities [1]	NSW GAB Groundwater Sources 2020[1]	Southern Recharge Groundwater Source [1]
Multi-function compound Narromine South	NSW MDB Fractured Rock Groundwater Sources 2020	Lachlan Fold Belt MDB Groundwater Source
Borrow pit A, Borrow pit B, Borrow pit C	NSW MDB Fractured Rock Groundwater Sources 2020	Lachlan Fold Belt MDB Groundwater Source
Borrow pit D	NSW GAB Groundwater Sources 2020	Southern Recharge Groundwater Source

Note: [1] A small portion (south east corner) of the Narromine temporary workforce accommodation facility may be in the Lachland Fold Belt MDB Groundwater Source.

3.2.2 WSPs – proposal bore fields

WSPs and groundwater sources at the proposed bore fields are shown in Table 3.2. Proposal bore (PB) field reference numbering within Table 3.2 progresses from south (PB1 at Narromine) to north (PB12 at Narrabri).

For the two southern most bore fields (PB1 and PB2), groundwater extraction is proposed to occur from the NSW MDB Fractured Rock Ground Sources 2020 WSP, Lachlan Fold Belt MDB Groundwater Source. This is the sole WSP/groundwater source for these two most southern bore fields. There are no WSPs/groundwater sources above or below this at these locations.

For the remaining bore fields (PB3 to PB12), it is proposed to extract groundwater from either one of the following WSPs/groundwater sources:

- NSW MDB Fractured Rock Ground Sources 2020 WSP, Lachlan Fold Belt MDB Groundwater Source
- NSW MDB Porous Rock Groundwater Sources 2020 WSP, Gunnedah-Oxley Basin MDB Groundwater Source.

In cases where both target WSPs/groundwater sources are present and superimposed vertically, it is proposed to extract groundwater from the upper of the two WSPs/groundwater sources. With reference to Table 3.2, it can be seen that about two thirds of extraction would be from the NSW MDB Porous Rock Groundwater Sources 2020 WSP, Gunnedah-Oxley Basin MDB Groundwater Source, with the remaining one third from the NSW MDB Fractured Rock Ground Sources 2020 WSP, Lachlan Fold Belt MDB Groundwater Source. To achieve this, with the exception of the two most southern proposed bore fields, the proposal bores need to penetrate and abstract groundwater from below the Namoi Alluvial Groundwater Sources 2020, Lower Namoi Groundwater Source and NSW GAB Groundwater Sources 2020, Southern Recharge Groundwater Source (applicable at PB12), or more commonly, penetrate beyond and extract groundwater from below the NSW GAB Groundwater Sources 2020, Southern Recharge Groundwater Source.

3.2.3 Recent groundwater trading and controlled allocation orders

The proposal bore fields would abstract water from the Gunnedah-Oxley Basin MDB Groundwater Source and Lachlan Fold Belt MDB Groundwater Source. Additionally, groundwater impact assessment (section 7) indicates one borrow pit located in the Lachlan Fold Belt MDB Groundwater Source may intersect the water table and therefore take water from this groundwater source. A summary of past groundwater trades and entitlement for these sources is provided in Table 3.3.

A water source has unassigned water when current water users' requirements (including licensed volumes and water to meet basic landholder rights) are less than the extraction limit in the WSP and, for water sources in the MDB, those requirements are also less than the sustainable diversion limit (SDL) in the *Basin Plan 2012* (Australian Government, 2018a) and associated amendments (Australian Government, 2018c).

The right to apply for a new access licence can be obtained through a competitive process, set out in a controlled allocation order. These orders are made under section 65 of the WM Act by the Minister for Water, Property and Housing. Alternatively, a person may apply directly for a special purpose WAL in very specific circumstances, or for a WAL with a zero share component (ie no water entitlement) and acquire a share entitlement through the trading of units.

The amount of water made available in any controlled allocation order is intended to keep total water requirements below 80 per cent of the appropriate extraction limit in any water source. For water sources in the MDB the appropriate extraction limit is the SDL and for all other water sources it is the long-term average annual extraction limit (LTAAEL).

Table 3.2 WSPs/groundwater sources at proposal bore fields

Proposal bore field (PB) reference	WSP/Groundwater Source and relative depth from ground level Shallowest	⟷		Deepest
PB1	NSW MDB Fractured Rock Groundwater Sources 2020- Lachlan Fold Belt MDB Groundwater Source			
PB2	NSW MDB Fractured Rock Groundwater Sources 2020- Lachlan Fold Belt MDB Groundwater Source			
PB3, PB4	NSW GAB Groundwater Sources 2020 – Southern Recharge Groundwater Source	NSW MDB Fractured Rock Groundwater Sources 2020- Lachlan Fold MDB Groundwater Source		
PB5, PB6, PB7, PB8, PB9, PB10, PB11	NSW GAB Groundwater Sources 2020 – Southern Recharge Groundwater Source	NSW MDB Porous Rock Groundwater Sources 2020– Gunnedah-Oxley Basin MDB Groundwater Source	NSW MDB Fractured Rock Groundwater Sources 2020- Lachlan Fold Belt MDB Groundwater Source	
PB12 (2 most south eastern bores)	Namoi Alluvial Groundwater Sources 2020 – Lower Namoi GW Source	NSW GAB Groundwater Sources 2020 – Southern Recharge Groundwater Source	NSW MDB Porous Rock Groundwater Sources 2020– Gunnedah-Oxley Basin MDB Groundwater Source	NSW MDB Fractured Rock Groundwater Sources 2020- Lachlan Fold Belt MDB Groundwater Source
PB12 (all bores except two south eastern most bores)	NSW GAB Groundwater Sources 2020 – Southern Recharge Groundwater Source	NSW MDB Porous Rock Groundwater Sources 2020– Gunnedah-Oxley Basin MDB Groundwater Source	NSW MDB Fractured Rock Groundwater Sources 2020- Lachlan Fold Belt MDB Groundwater Source	

Table 3.3 WSP trading and entitlement summary

Source	Water year	Volume traded (ML)	Dealings	Entitlement summary
Gunnedah-Oxley Basin MDB Groundwater Source	19/20	1,624	13	Entitlement limit = 127,500 ML Unassigned water = 81% Sustainable Diversion Limit = 127,500 ML
	18/19	2,268	13	
	17/18	1,196	6	
	16/17	1,512	6	
	15/16	1,062	3	
	14/15	1,060	5	
Lachlan Fold Belt MDB Groundwater Source	19/20	691	14	Entitlement limit = 253,788 ML Unassigned water = 72% Sustainable Diversion Limit = 259,000 ML
	18/19	426	13	
	17/18	356	5	
	16/17	176	3	
	15/16	395	5	
	14/15	136	2	

Source: NSW Water Register (WaterNSW, 2020a) and the Basin Plan Amendment Instrument (No.1) 2018 (Australian Government, 2018c).

Separate to above, bores used to supply the Narromine North and Baradine temporary workforce accommodation facilities with potable water (after treatment) will likely be located in the NSW GAB Groundwater Sources (2020) - Southern Recharge Groundwater Source. From review of WaterNSW (2020a), this source currently has 166 WALs, a total share component of about 27,528 shares or mega litres and a LTAAEL of 38,700 mega litres. A controlled allocation order in this water source is unlikely. Therefore, the entitlement to cover groundwater extraction for the Narromine North and Baradine temporary workforce accommodation facilities would need to be purchased from the market.

3.3 NSW Aquifer Interference Policy (2012)

The *NSW Aquifer Interference Policy* (AIP) (DPI, 2012) outlines minimal impact considerations for water table and groundwater pressure drawdown for high priority groundwater dependent ecosystems (GDEs) (as identified in the WSP), high priority culturally significant sites (as identified in the WSP) and existing groundwater supply bores. Water quality impact considerations are also outlined.

In the context of the AIP, the proposal is mostly located in a GAB porous rock groundwater recharge source and is considered to be underlain by highly productive groundwater sources. The proposal also hosts highly productive alluvial groundwater sources and near Narromine, a fractured rock groundwater source. For the purpose of adopting minimal impact consideration criteria from the AIP for groundwater impact assessment purposes, all groundwater systems applicable to the proposal were assumed to be ‘highly productive’. ‘Highly productive’ groundwater sources are defined by the AIP to have total dissolved solids concentrations of less than 1,500 milligrams per litre and yields greater than five litres per second at bores. In accordance with the AIP, the minimal impact considerations outlined in Table 3.4 apply.

Within Table 3.4, the term ‘make good provisions’ is used, which is from the AIP. Although not defined in the AIP, if make good provisions apply, a bore impacted due to drawdown requires replacement or some form of rectification. This could involve drilling of a replacement bore, possibly in a different location, or to a deeper depth to reinstate the pre-impacted groundwater level and bore yield.

Table 3.4 AIP minimal impact considerations for 'highly productive' groundwater sources

<table>
<tr><th>Water Source Type</th><th>Minimal impact considerations</th></tr>
<tr><td rowspan="2">GAB Recharge Groundwater Source (southern or eastern)</td><td>Water table
1. Less than or equal to 10% cumulative variation in the water table, allowing for typical climatic "post-water sharing plan" variations, 40 metres from any:
(a) High priority GDE; or
(b) High priority culturally significant site;
listed in the schedule of the relevant water sharing plan.
A maximum of a two metre decline cumulatively at any water supply work.
2. If more than 10% cumulative variation in the water table, allowing for typical climatic "post-water sharing plan" variations, 40 metres from any:
(a) High priority GDE; or
(b) High priority culturally significant site;
listed in the schedule of the relevant water sharing plan then appropriate studies will need to demonstrate to the Minister's satisfaction that the variation will not prevent the long-term viability of the dependent ecosystem or significant site.
If more than a two metre decline cumulatively at any water supply work then make good provisions should apply.</td></tr>
<tr><td>Water pressure
1.
(a) Less than 0.2 metres cumulative variation in groundwater pressure, allowing for typical climatic "post-water sharing plan" variations, 40 metres from any:
i. High priority GDE; or
ii. High priority culturally significant site;
listed in the schedule of the relevant water sharing plan.
(b) A cumulative pressure level decline of not more than 15 metres, allowing for typical climatic "post-water sharing plan" variations.
(c) The cumulative pressure level decline of no more than 10% of the 2008 pressure level above ground surface at the NSW State border, as agreed between NSW and QLD.
2. If the predicted pressure head decline is greater than requirement 1(a). above, then appropriate studies are required to demonstrate to the Minister's satisfaction that the decline will not prevent the long-term viability of the dependent ecosystem or culturally significant site. Pressure level decline should not:
(a) cause any flowing bore to cease to flow,
(b) be any more than one metres, allowing for typical "post-water sharing plan" variations, at any flowing water supply work unless make good provisions apply, or
(c) be any more than two metres, allowing for typical "post-water sharing plan" variations, at any non-flowing water supply work unless make good provisions apply.</td></tr>
</table>

Water Source Type	Minimal impact considerations
	Water quality 1. Any change in the groundwater quality should not lower the beneficial use category of the groundwater source beyond 40 metres from the activity. If condition 1 is not met then appropriate studies will need to demonstrate to the Minister’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.
Alluvial water sources (and fractured rock), for ‘highly productive groundwater sources’	**Water table** 1. Less than or equal to 10% cumulative variation in the water table, allowing for typical climatic “post-water sharing plan” variations, 40 metres from any: a. High priority GDE; or b. High priority culturally significant site; listed in the schedule of the relevant water sharing plan; or A maximum of a two metre decline cumulatively at any water supply work. 2. If more than 10% cumulative variation in the water table, allowing for typical climatic “post-water sharing plan” variations, 40 metres from any: a. High priority GDE; or b. High priority culturally significant site; listed in the schedule of the relevant water sharing plan then appropriate studies will need to demonstrate to the Minister’s satisfaction that the variation will not prevent the long-term viability of the dependent ecosystem or significant site. If more than a two metre decline cumulatively at any water supply work then make good provisions should apply.
	Water pressure 1. A cumulative pressure head decline of not more than 40% of the ‘post-water sharing plan’ pressure head above the base of the water source to a maximum two metre decline, at any water supply work. If the predicted pressure head decline is greater than requirement 1 above, 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.
	Water quality 1. Any change in the groundwater quality should not lower the beneficial use category of the groundwater source beyond 40 metres from the activity. 2. For alluvial groundwater systems, no increase of more than one per cent per activity in long-term average salinity in a highly connected surface water source at the nearest point to the activity. If condition 1 is not met then appropriate studies will need to demonstrate to the Minister’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 2 is not met then appropriate studies will need 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.

3.4 Groundwater Dependent Ecosystems Policy

The *NSW State Groundwater Dependent Ecosystems Policy* (Department of Land and Water Conservation, 2002) implements the WM Act by providing guidance on the protection and management of GDEs. It sets out management objectives and principles to:

- ensure that the most vulnerable and valuable ecosystems are protected
- manage groundwater extraction within defined limits thereby providing flow sufficient to sustain ecological processes and maintain biodiversity
- ensure that sufficient groundwater of suitable quality is available to ecosystems when needed
- ensure that the precautionary principle is applied to protect GDEs, particularly the dynamics of flow and availability and the species reliant on these attributes
- ensure that land use activities aim to minimise adverse impacts on GDEs.

3.5 National Water Quality Management Strategy

The *National Water Quality Management Strategy* (NWQMS) (Australian Government, 2018b) is the adopted national approach to protecting and improving water quality in Australia. It consists of several guideline documents, of which certain documents relate to protection of surface water resources and others relate to the protection of groundwater resources.

The primary document relevant to the assessment of groundwater risks for the proposal is the *Guidelines for Groundwater Quality Protection in Australia* (Australian Government, 2013). This document sets out a high-level risk-based approach to protecting or improving groundwater quality for a range of groundwater beneficial uses (called 'environmental values'), including aquatic ecosystems, primary industries (including irrigation and general water users, stock drinking water, aquaculture and human consumption of aquatic foods), recreational and aesthetic values (eg swimming, boating and aesthetic appeal of water bodies), drinking water, industrial water and cultural values.

For the purpose of this assessment, 'environmental values' pertaining to drinking water, which is considered to have the highest 'environmental value', were considered applicable.

The *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZG) (Australian and New Zealand Governments, 2018) provide a framework for conserving ambient water quality in rivers, lakes, estuaries and marine waters and list a range of environmental values assigned to that waterbody. The ANZG (2018) recommended guideline values have been considered in assessment of existing groundwater quality.

3.6 National Environment Protection (Assessment of Site Contamination) Measure 1999

The preliminary contamination assessment undertaken as part of the EIS adopted investigation procedures including those described within the National Environment Protection Council's (NEPC) *National Environment Protection (Assessment of Site Contamination) Measure 1999 (as amended in 2013)* (NEPM, 2013). Therefore, in addition to ANZG (Australian and New Zealand Governments, 2018) guideline values, groundwater investigation levels for fresh waters from NEPM (2013) have been considered in assessment of existing groundwater quality.

4. Assessment methodology

4.1 Study area

The groundwater impact assessment used a study area boundary of 20 kilometres from the proposal, as shown on Figure 4.1. The study area boundary was selected to:

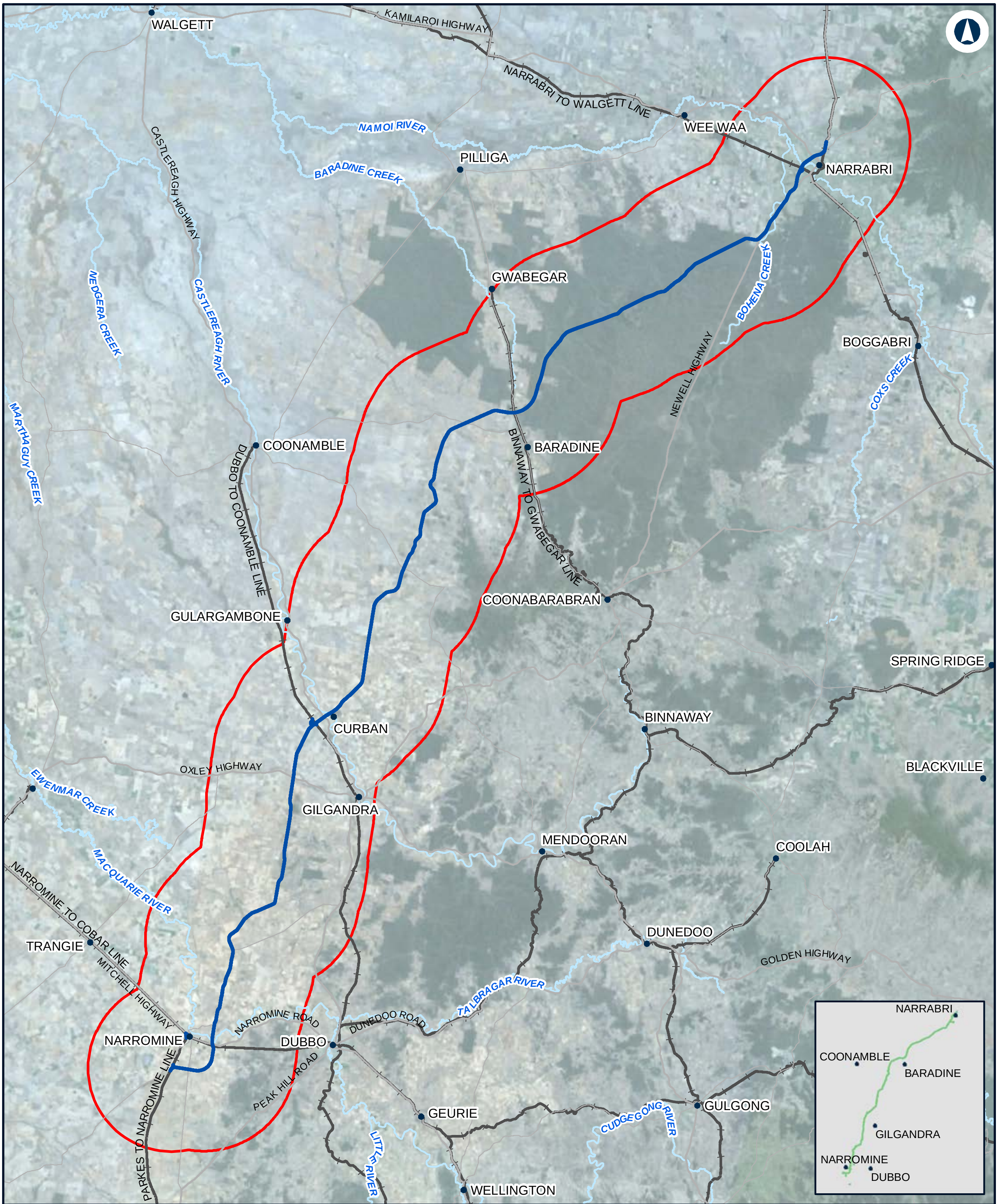
- encapsulate existing groundwater bores in the vicinity of the proposal, to increase the amount of bore data available for analysis
- be sufficiently large to accommodate all options that were under consideration during the preferred route selection process that has been undertaken for the proposal
- encapsulate potential groundwater level drawdowns associated with pumping the proposal bore field bores.

4.2 Methodology summary

Potential groundwater related impacts which may occur due to the proposal have been assessed by:

- characterising the existing environmental setting including climate, topography, geology, and groundwater occurrence, quality and use, including GDEs
- dedicated field investigations including drilling, groundwater monitoring bore installation, hydraulic conductivity testing and groundwater level/quality monitoring. Investigations were undertaken along the alignment and at proposed borrow pit locations
- creation of a hydrogeological conceptual model
- assessment of groundwater availability through reviewing groundwater allocation volumes and comparing these to the LTAAEL/SDL for applicable WSP groundwater sources
- assessment of the potential for the proposal to interact with the water table and underlying groundwater systems, including potential surface water drainage system baseflow impacts
- estimation of groundwater inflows into proposal excavations, including borrow pits
- estimation of groundwater impacts due to groundwater extraction to provide a water supply for the construction of the proposal, including potential surface water drainage system baseflow impacts
- assessment of potential groundwater related impacts against the minimal impact considerations of the AIP
- assessment of potential groundwater impacts in areas of potential GDEs
- providing recommendations for monitoring and management of identified potential impacts and risks, including mitigation measures as appropriate.

The specific methodologies used for these components of the methodology are summarised in the following sections.



NARROMINE TO NARRABRI Groundwater impact assessment study area boundary Figure 4.1

0 10 20 Km

Coordinate System: GDA 1994 MGA Zone 55

LEGEND

- Alignment
- Study area

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Date: 31/03/2020 Paper: A4
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4.3 Desktop assessment

Characterisation of existing groundwater conditions was completed using:

- Australian Government Geoscience Australia reports and data sets, including:
  - The Hydrogeological Atlas of the GAB (Ransley et. al, 2015)
  - A technical report on the hydrostratigraphy, hydrogeology and system conceptualisation of the GAB (Ransley et. al, 2012)
  - Formation base surfaces (Geoscience Australia, 2013) of the main hydrostratigraphic units in the GAB.
- Bureau of Meteorology (BOM) *GDE Atlas* (BOM, 2018a) to investigate the potential for GDEs to exist within the study area, as well as High Priority GDE mapping within the relevant WSPs (Section 3.2).
- *Australian Groundwater Explorer* (BOM, 2018b) and WaterNSW's (2020b) online bore database to investigate registered groundwater bores and associated groundwater level and salinity records in the region of the proposal.
- Data from six non-proposal groundwater monitoring bores (Table 4.1) to characterise long-term groundwater level variation. Bores were selected to provide a long period of monitoring data, representative coverage of the proposal area and a combination of alluvial and sandstone monitoring zones.
- BOM rainfall data from gauging stations in/around the study area:
  - Long-term historical rainfall and evaporation was characterised using mean monthly and annual rainfall from BOM Station 51005 (Narromine) and 53030 (Narrabri), and due to no data, as a proxy for Narromine and Narrabri respectively, mean monthly and annual evaporation from BOM Station 065035 (Wellington) and 055024 (Gunnedah).
  - Daily rainfall during groundwater level monitoring at proposal monitoring bores and at non-proposal bores selected to assess long-term groundwater level variation was sourced from BOM Station 51005 (Narromine) and 53030 (Narrabri). The data was sourced using the Queensland Government's online SILO (2020) database of Australian climate data. Data gaps in the record were interpolated by SILO (2020).
- WaterNSW *Water Register* (2020a) for data on existing groundwater users, including WAL holders and current allocation and LTAAEL volumes.
- Public domain reports and groundwater assessments from projects and developments near the alignment.
- Publicly available reports and data from adjacent Inland Rail projects.
- Publicly available maps, including geological maps, topography and drainage maps and soil maps.

Table 4.1 Non-proposal groundwater monitoring bores assessed for long-term groundwater level

Bore ID	Location	Screened depth (mBGL) and material	Groundwater level monitoring data period
GW030544.1.2	Narrabri	25.2 – 31.2, alluvial sand and clay	344 observations between 1971 and 2018
GW036285.1.1	Warrawee, about 15 km north west of Gilgandra	32 – 35, alluvial clay	81 observations between 1978 and 2017
GW036285.1.2	As above (same site but different pipe)	73 – 79, sandstone	1161 observations between 1978 and 2018
GW098010.1.1	About 4.7 km north east of Coonabarabran	11 – 23, sandstone	777 observations between 2011 and 2018
GW098011.1.1	Pilliga East State Forest, about 50 km north-north east of Coonabarabran	50 – 56, drillers log indicates 'unknown' but assumed to be sandstone based on drilling log	1086 observations between 2011 and 2018
GW273059.2.2	About 4.3 km north of Narromine town centre and about 200-300 from Macquarie River	25 – 27, drillers log indicates 'unknown'. Assumed to be alluvium	1124 observations between 2008 and 2018

4.4 Field assessment

4.4.1 Drilling program

Overview

Two separate drilling programs were completed for the proposal, both during 2019. An initial drilling program was undertaken to inform the assessment and design of the alignment. A supplementary drilling program was undertaken to inform the assessment and design of the borrow pit sites. Test drilling for the proposal bore fields accessing the Gunnedah-Oxley Basin MDB and Lachlan Fold Belt MDB Groundwater Sources has not been undertaken and would be undertaken during the post approval stage.

Alignment investigations

Thirty six groundwater monitoring bores were constructed as part of the 2019 drilling program.

Groundwater monitoring bore locations were selected to provide representative coverage over the length of the proposal. The bores were installed with a focus on areas where: a relatively deeper proposal excavation is proposed; groundwater interception potential is relatively high; low-lying areas (including near proposed bridges) and alluvial groundwater systems where relatively shallow water tables are anticipated. Monitoring bores were focused in these areas since they represent the areas where the proposal would most likely directly interact with groundwater.

Prior to siting the proposed groundwater monitoring bores, the ecology team was consulted regarding potential specific GDE areas that may require groundwater monitoring, and the potential of existing groundwater bores being impacted by proposal excavation dewatering was assessed. No specific GDE areas were flagged to require groundwater monitoring bores. No specific proposal groundwater monitoring bore siting was considered necessary to enable monitoring of proposal excavations due to potential dewatering impacts, as the likelihood of the proposal's excavations intersecting the water table was assessed to be low.

Proposal groundwater monitoring bores are shown in Figure 4.2 and summarised in Table 4.2. Of these bores, it is noted that BH-2-020 was decommissioned and cemented up after an initial monitoring period. The decommissioning was requested by Gilgandra Shire Council because the bore was in proximity of the road verge. This bore was not replaced because for the duration of monitoring, the bore was dry.

Borrow pit investigations

Four groundwater monitoring bores were constructed as part of the borrow pit drilling program. A single groundwater monitoring bore was constructed at each potential borrow pit site. The primary objective of the bores was to inform an assessment of whether the borrow pits would likely extend below the water table, and if so, assessment of associated potential groundwater impacts.

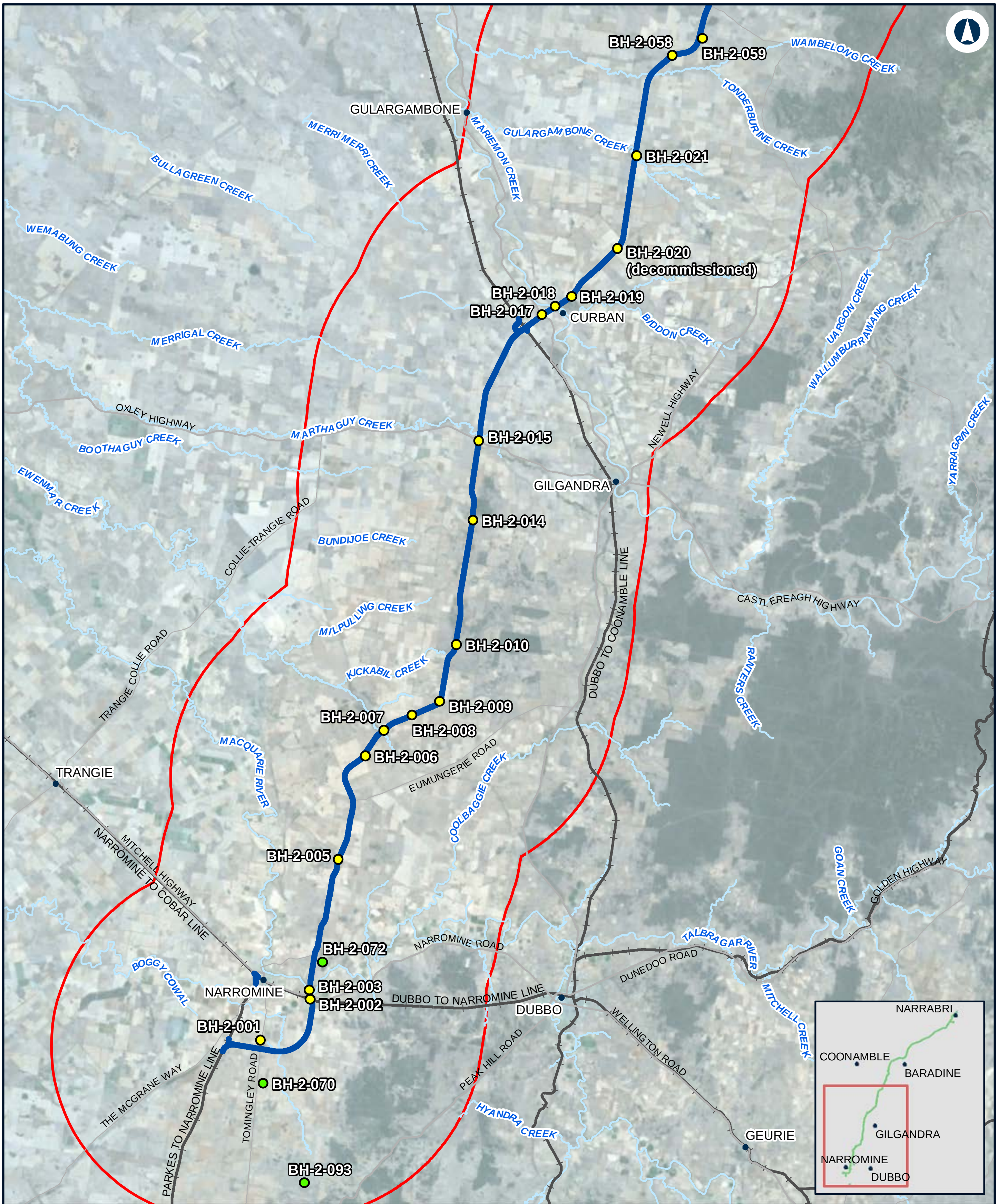
Proposal groundwater monitoring bores used to assess groundwater conditions at the borrow pits are shown in Figure 4.2 and summarised at the bottom of Table 4.2.

Groundwater monitoring bore construction

The proposal groundwater monitoring bores were designed by an experienced JacobsGHD hydrogeologist and constructed by the drilling contractor under supervision by a geotechnical engineer. Throughout the drilling program, the geotechnical engineer regularly consulted the hydrogeologist to obtain bore construction design details. The bores were designed and constructed in accordance with the *Minimum Construction Requirements for Water Bores in Australia* (National Water Commission, 2012).

The proposal's monitoring bores were developed as follows:

- Where possible, water was used for drilling with no polymers.
- Where polymers were required for alluvial/unstable holes, a non-bentonite based type was used which was biodegradable and designed to break down naturally/relatively quickly.
- The drilling contractor flushed the borehole significantly using the drill string and clean water until the return water started running clear. The flush water was collected in disposal drums or industrial grade containers and disposed of appropriately offsite.
- Following bore construction, the bores were purged until dry with a 12 volt pump. If the material surrounding the bore was too permeable to enable the bore to be purged dry with the 12 volt pump, then the bore was pumped until a minimum of three saturated bore volumes were removed. This was done to ensure water introduced by flushing/drilling did not influence groundwater level monitoring results.



NARROMINE TO NARRABRI Proposal groundwater monitoring bores

Figure 4.2a

0 8 16 Km

Coordinate System: GDA 1994 MGA Zone 55

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LEGEND

- Alignment
- Study area
- Groundwater monitoring bores
- Borrow pit groundwater monitoring bores

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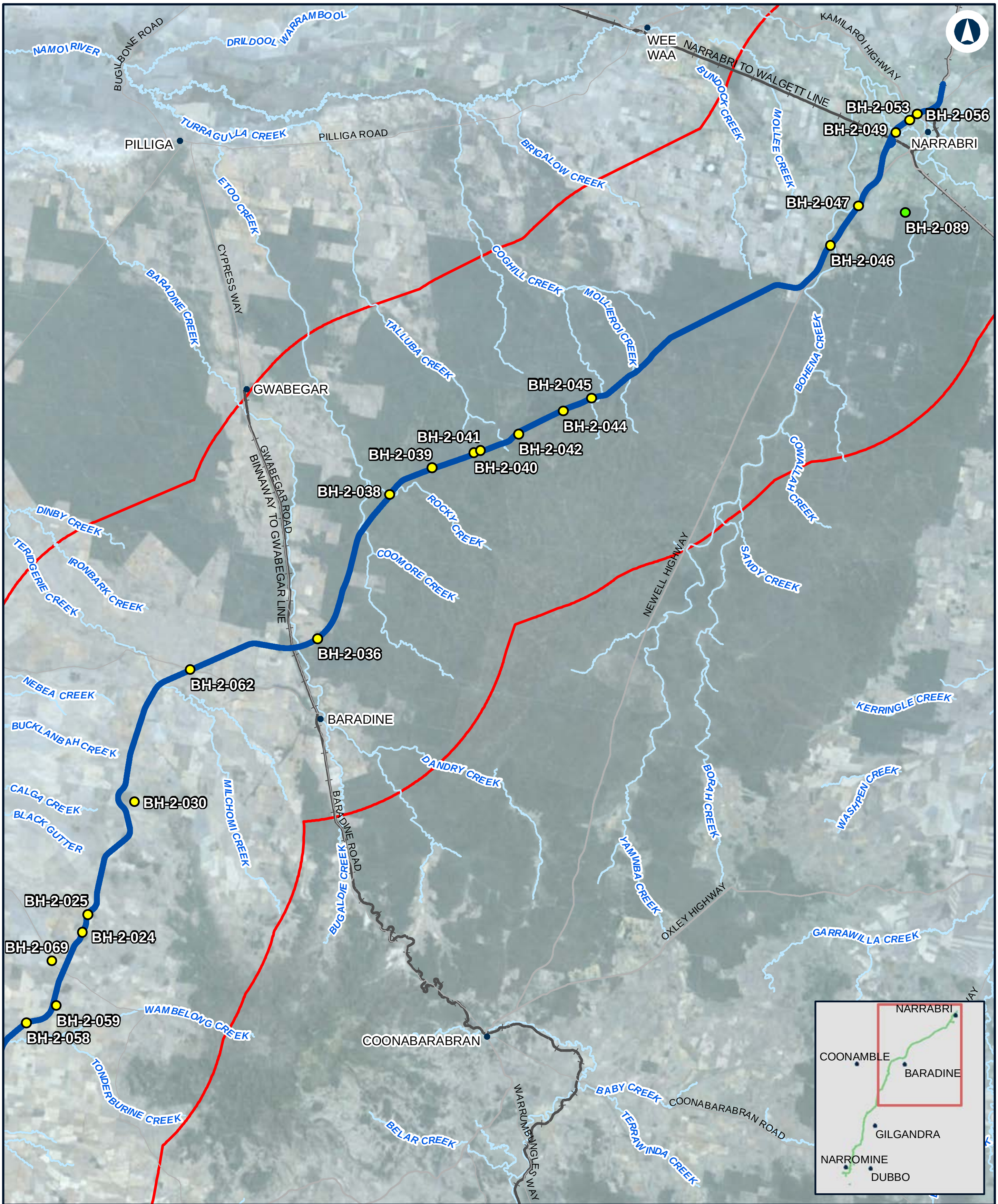

NARROMINE TO NARRABRI

Proposal groundwater monitoring bores

Figure 4.2b

0 8 16 Km

Coordinate System: GDA 1994 MGA Zone 55

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LEGEND

- Alignment
- Study area
- Groundwater monitoring bores
- Borrow pit groundwater monitoring bores

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Table 4.2 Proposal groundwater monitoring bore summary details and groundwater level monitoring period

Bore ID	Surface level (mAHD)	Easting	Northing	Screen depth (mBGL)	Screened material	Groundwater level monitoring data period
BH-2-001	246.01	616498	6426125	18.0-30.0	Clay and sandy clay (alluvial)	04/02/2019 – 23/06/2020
BH-2-002	241.33	622161	6430780	21.0-25.0	Gravelly sand and silty clay (alluvial)	04/02/2019 – 23/06/2020
BH-2-003	237.52	622107	6431856	12.0-18.0	Clayey sand, clayey silt, gravelly sand, silty sand (alluvial)	10/05/2019 – 23/06/2020
BH-2-005	280.54	625459	6446901	9.0- 15.0	Silty clay and clayey silt (extremely weathered/ residual)	06/02/2019 – 23/06/2020
BH-2-006	260.04	628555	6458765	7.25-16.25	Sandy clay, clayey sand (residual) and sandstone	06/02/2019 – 09/07/2019 [2]
BH-2-007	239.66	630679	6461717	18.0-29.7	Silty clay, sandy clay (alluvial and residual)	12/02/2019 – 09/07/2019 [2]
BH-2-008	252.37	633940	6463431	22.42-31.42	Sandy clay (residual) and sandstone	12/02/2019 – 09/07/2019 [2]
BH-2-009	264.40	637092	6465049	21.0-30.0	Sandy clay (residual), sandstone, silty clay, siltstone	15/02/2019 – 09/07/2019 [2]
BH-2-010	273.09	639003	6471595	21.51-30.51	Sandstone and siltstone	15/02/2019 – 09/07/2019 [2]
BH-2-014	292.89	640920	6485852	9.0-15	Sandstone and conglomerate	15/02/2019 – 13/07/2019 [2]
BH-2-015	259.63	641595	6495006	14.25-20.25	Sandstone and siltstone	18/02/2019 – 23/06/2020
BH-2-017	259.55	648884	6509482	9.0- 15.0	Clayey sand (alluvial)	05/03/2019 – 23/06/2020
BH-2-018	255.66	650396	6510432	6.5- 12.5	Silty clay, silty sand, clayey sand (alluvial)	25/02/2019 – 23/06/2020
BH-2-019	276.10	652248	6511589	14.44-20.44	Sandstone and siltstone	27/02/2019 – 23/06/2020

Bore ID	Surface level (mAHD)	Easting	Northing	Screen depth (mBGL)	Screened material	Groundwater level monitoring data period
BH-2-020[1]	285.78	657548	6517127	11.5-20.5	Sandstone	21/02/2019 – 10/07/2019 [1]
BH-2-021	266.81	659736	6527762	21.0-30.0	Siltstone and sandstone	21/02/2019 – 23/06/2020
BH-2-024	304.14	670324	6549707	9.5- 15.5	Sandstone	01/03/2019 – 26/06/2020
BH-2-025	297.07	670926	6551745	9.1- 15.1	Sandstone	01/03/2019 – 25/06/2020
BH-2-030	301.85	676310	6564677	11.21-21.21	Sandstone and siltstone	07/03/2019 – 25/06/2020
BH-2-036	299.14	697371	6583450	9.5- 15.5	Sandstone	06/03/2019 – 25/06/2020
BH-2-038	251.47	705629	6599978	21.0-30.5	Sandstone	13/03/2019 – 25/06/2020
BH-2-039	284.99	710508	6603083	9.0- 15.0	Sandstone and siltstone	08/04/2019 – 26/06/2020
BH-2-040	268.00	715361	6604841	9.0- 15.2	Sandstone	08/04/2019 – 26/06/2020
BH-2-041	272.99	716113	6605090	9.0- 15.0	Sandstone	08/04/2019 – 26/06/2020
BH-2-042	293.18	720470	6606972	9.36-15.36	Sandstone	20/03/2019 – 25/06/2020
BH-2-044	299.15	725603	6609586	8.87-14.87	Sandstone	26/03/2019 – 25/06/2020
BH-2-045	274.21	728876	6611070	9.0- 15.0	Sandstone	11/07/2019 – 26/06/2020
BH-2-046	234.29	756369	6628675	24.0-30.0	Sandstone	01/03/2019 – 25/06/2020
BH-2-047	223.93	759551	6633161	13.0-22.0	Sandy clay, clayey sand, silty sand (alluvial)	01/03/2019 – 25/06/2020

Bore ID	Surface level (mAHD)	Easting	Northing	Screen depth (mBGL)	Screened material	Groundwater level monitoring data period
BH-2-049	210.19	763849	6641585	17.0-23.0	Generally sand (alluvial)	18/03/2019 – 11/10/2019[4]
BH-2-053	210.23	765433	6643005	13.7-19.7	Clayey sandy gravel, clayey gravelly sand (alluvial)	18/03/2019 – 25/06/2020
BH-2-056	210.93	766295	6643728	9.0- 15.0	Sandy gravel (alluvial)	28/03/2019 – 26/06/2020
BH-2-058	281.63	663858	6539294	21.0-30.0	Sandstone, very minor conglomerate	23/03/2019 – 23/06/2020
BH-2-059	308.27	667323	6541247	14.0-20.0	Sandy clay (residual)	01/03/2019 – 26/06/2020
BH-2-062	258.26	682741	6579868	21.46-30.46	Sandstone and siltstone	07/03/2019 – 25/06/2020
BH-2-069	274.62	666808	6546406	21.0-30.0	Sandstone and siltstone	01/03/2019 – 25/06/2020
BH-2-093 (Borrow pit A)	339.65	621546	6409673	3.70 – 10.10	Sandy clayey silty gravel and clayey sand	03/07/2019 – 23/06/2020
BH-2-070 (Borrow pit B)	270.57	616792	6421119	5.50 – 12.00	Silty clay and clayey silt	03/07/2019 – 23/06/2020
BH-2-072 (Borrow pit C)	280.66	623628	6435043	8.40 – 15.20	Metamorphosed siltstone	04/06/2019 – 23/06/2020
BH-2-089 (Borrow pit D)	262.34	764957	6632408	8.70 – 15.50	Siltstone and sandstone	21/06/2019 – 23/01/2020[3] 10/02/2020 – 26/06/2020

Notes: [1] Monitoring period relatively short as bore was decommissioned at the request of Gilgandra Shire Council. Bore was not replaced as it was dry. [2] Relatively shorter groundwater level data logger period as logger was stolen. Groundwater levels still monitored manually. Logger not replaced as initial monitoring data and manual measurement data considered appropriate. [3] Logger failed to start and therefore no logger data for period. However, bore dry on 23.01.2020. [4] Access unavailable during mid to late June 2020 monitoring round.

4.4.2 Groundwater level and quality monitoring

Rail alignment monitoring bores

All 36 proposal groundwater monitoring bores were instrumented with non-vented data loggers to automatically measure and record groundwater levels at minimum six hourly intervals. Barometric data loggers were also deployed to enable barometric compensation of the data. The commencement of groundwater level monitoring was variable from bore to bore and generally dependent on the timing of bore construction. The earliest commencement of groundwater level monitoring occurred at BH-2-002 on 04/02/2019. The latest groundwater monitoring round that was used to inform the groundwater assessment occurred in mid to late June 2020. Groundwater monitoring bore summary details and the groundwater level monitoring period that was used to inform the groundwater impact assessment are summarised in Table 4.2.

Four separate groundwater quality sampling rounds were undertaken, and each round ran over one to two weeks. The groundwater sampling rounds were undertaken between:

- 18/03/2019 to 29/03/2019 (Round 1)
- 08/07/2019 to 19/07/2019 (Round 2)
- 08/10/2019 to 11/10/2019 (Round 3)
- 23/06/2020 to 26/06/2020 (Round 4).

The sampling rounds were undertaken over about a 15 month period to allow for capture of potential seasonable variability.

Samples were collected from all bores that were constructed at the time of the sampling round, and which had enough sample volume. Each sample was laboratory analysed for one or more of the following analytical suites in Table 4.3.

Table 4.3 Alignment groundwater monitoring bore groundwater quality analytical suites

Analytical suite	Analyte
1	• pH • EC • TDS • Hardness • Dissolved metals (arsenic, cadmium, chromium, copper, lead, mercury, nickel, zinc) • Major Ions (chloride, sulphate, sodium, potassium, magnesium, calcium; and carbonate bicarbonate, and hydroxide alkalinity). • Nutrients (ammonia, Kjeldahl Nitrogen Total, nitrate, nitrite, total nitrogen, total phosphate)
2	• Organochlorine pesticide (OCP) and organophosphorus pesticide (OPP)
3	• Total recoverable hydrocarbons (TRH), and benzene, toluene, ethylbenzene and xylene (BTEX)

Not all the proposal's bores were sampled each sampling round, as some bores were dry, not yet constructed or had insufficient water. A summary of the groundwater quality sampling conducted at each individual alignment groundwater monitoring bore is provided in Appendix B.

Proposal borrow pit monitoring bores

Groundwater level at the borrow pit groundwater monitoring bores was monitored at a maximum six hourly interval by data logger. Borrow pit groundwater monitoring bore summary details and the groundwater level monitoring period that was used to inform the groundwater impact assessment is summarised in Table 4.2.

Three separate groundwater quality sampling rounds were undertaken at the borrow pit bores:

- 10/12/2019 to 11/12/2019 (Borrow pit A, B, and C bores)
- 23/01/2020 (Borrow pit D bore only)
- 23/06/2020 to 26/06/2020 (all borrow pit bores).

The gap between sampling rounds was to allow for capture of potential seasonable variability.

For each sampling round, all bores which had enough sample volume and that weren't dry were sampled and laboratory analysed for suite 1 and suite 2 (see Table 4.3). In some cases total metals were analysed.

Sampling only occurred at the borrow pit A bore, as the other borrow pit bores were dry at the time of sampling.

4.4.3 Hydraulic testing

Hydraulic conductivity was estimated to inform the conceptualisation of the proposal's shallow groundwater systems. Rising head slug tests were completed at some of the proposal groundwater monitoring bores.

The testing involved removing water from the monitoring bores by a pump or bailer and measuring the subsequent water level recovery with a data logger. The data was analysed in aquifer testing software, AQTESOLV, using Hvorslev and Bower and Rice solutions.

A total of 14 alignment monitoring bores and one borrow pit groundwater monitoring bore were assessed (refer Table 4.4).

Table 4.4 Slug tested proposal groundwater monitoring bores

Bore ID	Bore purpose	Screen depth (mBGL)	Screened material
BH-2-002	Alignment monitoring bore	21.0-25.0	Gravelly sand and silty clay (alluvial)
BH-2-007	Alignment monitoring bore	18.0-29.7	Silty clay, sandy clay (alluvial and residual)
BH-2-015	Alignment monitoring bore	14.25-20.25	Sandstone and siltstone
BH-2-017	Alignment monitoring bore	9.0-15.0	Clayey sand (alluvial)
BH-2-018	Alignment monitoring bore	6.5-12.5	Silty clay, silty sand, clayey sand (alluvial)
BH-2-021	Alignment monitoring bore	21.0-30.0	Siltstone and sandstone
BH-2-030	Alignment monitoring bore	11.21-21.21	Sandstone and siltstone
BH-2-038	Alignment monitoring bore	21.0-30.5	Sandstone
BH-2-046	Alignment monitoring bore	24.0-30.0	Sandstone
BH-2-047	Alignment monitoring bore	13.0-22.0	Sandy clay, clayey sand, silty sand (alluvial)
BH-2-049	Alignment monitoring bore	17.0-23.0	Generally sand (alluvial)

Bore ID	Bore purpose	Screen depth (mBGL)	Screened material
BH-2-053	Alignment monitoring bore	13.7-19.7	Clayey sandy gravel, clayey gravelly sand (alluvial)
BH-2-056	Alignment monitoring bore	9.0-15.0	Sandy gravel (alluvial)
BH-2-069	Alignment monitoring bore	21.0-30.0	Sandstone and siltstone
BH-2-093	Borrow pit A assessment	3.70 – 10.10	Sandy clayey silty gravel and clayey sand

4.5 Shallow proposal features impact assessment

Groundwater impact assessment was undertaken for shallow proposal features and deep proposal features. The proposal bore fields have been classified as deep proposal features and all the remaining proposal features have been classified as 'shallow' and are hereafter referred to as such.

4.5.1 Overview

For shallow proposal features, water table penetration by proposal bulk earthworks or borrow pit excavations was considered the primary potential groundwater impact mechanism. Therefore, a water table penetration assessment was undertaken.

A range of other potential groundwater impact risks were qualitatively assessed as outlined in section 4.5.4.

4.5.2 Water table penetration assessment

The likelihood and risks of proposal bulk earthworks or borrow pit excavations intersecting the regional groundwater table were assessed by:

- Analysing and assessing the proposal's excavation depths.
- Developing the conceptual groundwater model's groundwater depth, which included:
  - Using LEAPFROG (geological modelling software) to plot Geoscience Australia's (2013) GAB regional water table surface in a long section along the proposal's alignment.
  - Including proposal groundwater monitoring bores on the long section, including the maximum monitored groundwater levels up until the October 2019 monitoring round. It is noted that the maximum monitored groundwater levels over the entire monitoring period (until the June 2020 monitoring round) did not alter significantly compared to that observed to October 2019 and were only up to a maximum of 0.30 metres higher. For the majority of bores the maximum groundwater level didn't change between the October 2019 and June 2020 monitoring rounds. Therefore, for the purpose of showing monitored groundwater levels on the conceptual long sections, using the maximum level from data up until the October 2019 monitoring round is appropriate.
- Comparing water table depths from proposal groundwater monitoring bores and the GAB regional water table to the proposal's excavation depths.
- Consideration of the extent and frequency of likely water table penetration.
- Assessing the potential risks to perched or local groundwater systems due to penetration by proposal excavations.

- Assessing implications of potential drawdown for GDEs, groundwater dependent surface water flows and groundwater users.
- Assessing changes to environmental water availability.

Where investigations indicated that proposal excavations are likely to intersect the regional water table, associated groundwater inflow rates and areal drawdown extent were assessed through analytical modelling. Impacts were assessed against the AIP minimal impact considerations. The water table penetration assessment concluded that only one area of water table penetration was likely to occur, at borrow pit A. The method used to estimate the potential groundwater inflow and areal drawdown is summarised in section 4.5.3.

4.5.3 Borrow pit A groundwater inflow rate estimation

The method used to estimate groundwater inflow rate and areal drawdown extent at borrow pit A was as follows:

- Radius of influence – the areal drawdown extent (also known as radius of influence) was estimated using the Cooper-Jacob (1946) equation:

  Radius of influence (m) = *(2.25Tt/S)0.5*, where

  T = transmissivity (m^2/d)

  t = time (d)

  S = storage

Transmissivity was assigned a value based on the estimated hydraulic conductivity estimate at the borrow pit A groundwater monitoring bore (5×10^{-5} metres per day) multiplied by the assessed maximum water table penetration depth (2.94 metres). A range of time values were applied up to a maximum of ten years to demonstrate sensitivity and generate a range of potential radiuses of influence. A storage value of 0.1 was based on the material type (sandy clayey silty gravel and clayey sand). This is not supported by literature values and was selected based on experience. However, to address this, sensitivity analysis was undertaken. Sensitivity analysis revealed that varying the parameters in this equation made very little difference to the estimated areal drawdown extent.

- Groundwater inflows – potential groundwater inflow into Borrow pit A was estimated using the Dupuit-Forchheimer well discharge equation for an unconfined aquifer without recharge:

  Groundwater inflow (m^3/d) = $\pi K ho^2 / \ln(ro/rpit)$, where

  K = hydraulic conductivity (m/d)

  ho = water table interception depth (m) of extraction area

  ro = radius of influence (m)

  rpit = radius (m) of excavation area based on excavation area (m^2) represented as an equivalent circular area.

This equation represents the area of the borrow pit excavation assumed to extend beneath the water table as a large theoretical groundwater well. The same range of transmissivity, time and storage values used to estimate the areal drawdown extent were used in the Dupuit-Forchheimer equation, along with the estimated drawdown itself, as the drawdown extent dictates the hydraulic gradient of groundwater flow to the excavation area and therefore has an influence on the estimated groundwater inflow rate.

A borrow pit area of about 10.864 hectares and equivalent radius of about 186 metres was applied in the equation. This represents the entire borrow pit A and stockpiling area and is therefore considered conservative.

4.5.4 Additional potential groundwater impacts

Potential impacts to groundwater levels due to ground consolidation, impacts associated with groundwater inflows into excavations, impacts to GDEs, groundwater bores, surface water-groundwater interaction and groundwater contamination were assessed using the water table penetration assessment results, and using the conceptual groundwater model and established hydrogeological principles.

4.5.5 Minimal impact considerations

Potential groundwater impacts were assessed against the AIP minimal impact considerations, which are provided in section 3.3 and reported alongside demonstrated proposal compliance in section 7.3.

4.6 Bore field impact assessment

To assess potential impacts to groundwater systems due to groundwater extraction by the proposal's bore fields, a qualitative and quantitative assessment was undertaken.

4.6.1 Qualitative assessment

A qualitative assessment of the likelihood of non-permanent fixed duration bore field pumping for a period of about 500 days impacting groundwater systems was undertaken by considering:

- duration of pumping
- separation between the proposal's target groundwater source and overlying and adjacent groundwater systems
- separation between the proposal bore field bores and overlying and adjacent existing groundwater bores
- value of the proposal's target groundwater source and overlying and adjacent groundwater systems
- hydrogeological conceptualisation
- GDE mapping reviewed for assessment of shallow proposal features
- potential for cumulative inter-bore field impacts, and cumulative impacts with other projects.

Indirect potential impacts associated with application of the bore field groundwater to the land surface (for example, for dust suppression or compaction control purposes) were also assessed.

4.6.2 Analytical element groundwater models

Overview and objectives

To quantitatively assess potential impacts to groundwater due to bore field groundwater extraction, analytical element groundwater models were established.

The objectives of the modelling were to:

- assess the magnitude of drawdown which could eventuate in groundwater systems situated above proposal target groundwater source, or where relevant, in the same groundwater source

- via the drawdown results, provide a basis for qualitative assessment of potential impacts to existing groundwater bores, potential GDEs and river/creek baseflow.

Consultation

The modelling method was presented to NSW DPIE via a briefing letter on 26 February 2020 and during a meeting held on 11 March 2020. The modelling method was accepted in principal, however, NSW DPIE verbally recommended increased complexity for the models of the two most southern bore fields. Specifically, NSW DPIE recommended incorporation of Macquarie River alluvium where appropriate. This recommendation was made because the Macquarie River alluvium groundwater sources are heavily extracted by industry.

The final modelling method included assessment of Macquarie River alluvium as per NSW DPIE's verbal recommendation. Macquarie River alluvium was included in the model for the most southern bore field. For the second most southern bore field, the relevance of including the alluvium was assessed using geological maps and bore data. The base case model excluded the alluvium. However, potential impacts to alluvium groundwater systems were assessed through a sensitivity scenario model run.

Confidence level classification

The models are considered Class 1 confidence level models in accordance with the *Australian Groundwater Modelling Guidelines* (Barnett et al, 2012), for which the following uses are considered appropriate:

- predicting long-term impacts of proposed developments in low value aquifers
- estimating impacts of low-risk developments
- providing first-pass estimates of extraction volumes and rates for mine dewatering
- developing coarse relationships between groundwater extraction locations and rates and associated impacts
- understanding groundwater flow processes under various hypothetical conditions.

A Class 1 model is considered appropriate as the risks of groundwater impacts were qualitatively assessed to be low (section 7.1.1).

Modelling software

The models were established using AnAqSim, an analytical element groundwater modelling program (Fitts, 2019). This program is capable of multi-layer and transient (time-varying) simulations. The software superposes analytic solutions to yield a composite solution consisting of equations for head and discharge as functions of location and time. In time varying simulations, the program uses finite difference time steps in the same manner as MODFLOW, a widely used numerical groundwater model. The AnAqSim software is appropriate for low to moderate complexity scenarios. The elected software is commensurate with the level of data availability and the problem complexity, being pumping well simulation.

Simulations

Five of the twelve proposal bore fields were simulated individually to assess potential changes to groundwater levels. The five modelled bore fields are considered representative of, and conceptually similar to, the other bore fields. These include:

- PB1 – simulated because there are existing bores at this location that are licensed to abstract groundwater from the same source as the proposal. PB1 was also simulated because Macquarie River alluvium is present at this location and the hydrogeological conceptualisation is different to the remaining bore fields. PB1 is located outside the GAB, whilst all the other bore fields except for PB2 are located within (albeit below) the GAB.
- PB2 – simulated for similar reasons to PB1.
- PB3 – simulated as the bore field is located southern fringe of the GAB, where the proposal target groundwater source is shallower and the GAB hydrostratigraphic units are thinner. The thinner units make this location theoretically more susceptible to drawdown.
- PB7 – simulated to represent hydrostratigraphic layering at this location, and it is considered representative of PB4, PB5, PB6, PB8, PB9, PB10 and P11.
- PB12 – simulated as there are existing bores licensed to abstract groundwater from the same source as the proposal. This bore field was also simulated because it is in the general vicinity of Narrabri alluvium, which is currently heavily extracted by industry. Additionally, the proposal target groundwater source is shallower at this location and the main GAB rock aquifer hydrostratigraphic layer thinner.

Domain and boundary conditions

The five bore fields were modelled individually in separate models. All the model domains were bounded by a 12-sided approximately circular boundary consisting of specified head line boundaries, which formed the entire external boundary of the domain. This is an in-built boundary condition within the software which exists to enable rapid creation of simple model domains.

The specified head line boundary (also known as constant head boundary) for PB1 and PB2 was assigned based on standing water levels within public domain bore completion reports. The regional GAB water table surface was used to assign the boundary condition value in the remaining models. The same specified head boundary condition value was used for all model layers for a bore field simulation.

The in-built circular boundary condition requires a hydraulic gradient be assigned. A very low hydraulic gradient was assigned in all the models to achieve an effectively horizontal water table. Modelling of the actual regional groundwater flow gradients and flow directions was not considered necessary to simulate the bore fields.

Pumping bores were simulated in all the models at the quantity proposed for the given bore field. Each bore was positioned in x,y space as per the proposal. Therefore, the bore spacing in the model is as per the proposal. Typically, the bores are spaced at about 240 metres. The bores were all pumped continuously at two litres per second.

No other boundary conditions were applied, including recharge. The exclusion of recharge would make modelled drawdown more, thereby building conservatism into the model results. The exclusion is justified on the basis that the bore fields would be pumped for a non-permanent fixed duration (about 500 days).

Layering

The layering for PB1 was developed based on:

- two upper layers that were developed based on public domain bore completion report records
- a nominal 100 metre thick layer that the bore fields bores extract groundwater from
- a nominal 50 metre thick separation layer which separates the second layer and pumped layer.

The layering for PB2 was developed based on:

- a single upper layer that was developed based on public domain bore completion report records
- a nominal 100 metre thick layer that the bore fields bores extract groundwater from
- a nominal 50 metre thick separation layer which separates the first layer and pumped layer.

The layering for all the other bore field simulations was established based on the Geoscience Australia (2013) GAB hydrostratigraphic layering:

- The Cenozoic (alluvium) was represented as the upper layer (ie layer one), except at PB12 because it is absent at this location.
- The Hooray Sandstone and equivalents layer was represented as the second layer, except at PB12, where it was the upper layer (ie layer one). This layer was conceptualised to represent the main GAB hydrostratigraphic unit which behaves as an aquifer in the region of the proposal.
- The Jurassic-Cretaceous sequence was represented as the third layer, except at PB12, where it was the second layer. This layer was conceptualised to represent a regional aquitard.
- A nominal 100 metre thick layer that the bore fields bores extract groundwater from was represented as the fourth and final layer, except at PB12, where it was the third and final layer.
- The Injune Creek hydrostratigraphic unit was not represented in the model because it is thin and typically not present at most bore field locations.
- For all but the bottom model layer, the model layer thicknesses were based on the Geoscience Australia GAB hydrostratigraphic levels.

For all models, the layers and boundary condition head were established based on relative levels, with the ground level in the models represented as zero. This was done for convenience and is appropriate given the primary model result of interest is drawdown, not groundwater levels to a conventional datum such as the Australian Height Datum (AHD).

The model layering is summarised in Table 4.5.

Parameters

Parameters used in the models and justifications are summarised in Table 4.6. The model parameters were typically adopted based on hydrogeological modelling assessments completed by CDM Smith (2016) for the Santos Gas project and Aquaterra (2009) for the Narrabri Coal project.

Time discretisation

The models all had five time periods, with each period comprising 100 days and broken down into four time steps. The time steps had a multiplier of 1.5. This time discretisation results in a 500 day simulation time, which was adopted because this is the duration a bore field would likely be pumped to supply construction water.

Flow equations

Flow for the top layer in all models was set to be unconfined. Remaining layers were represented as ‘convertible’ layers (ie confined flow equations apply if head above layer top, if head below layer top unconfined flow equations apply).

Sensitivity analysis

Sensitivity analysis was undertaken on GAB models (PB3, PB7 and PB12) by:

- reducing the vertical hydraulic conductivity of the aquitard layer by one order of magnitude
- reducing the Cenozoic layer horizontal and vertical hydraulic conductivity by one order of magnitude.

Results reporting approach

Simulation results for PB1 and PB2 were reported by showing the modelled groundwater level drawdown contours in figures. The drawdown for the upper model layers which is applicable to existing groundwater bores was shown in the figures. The figures also showed existing bores, potential and High Priority GDE mapping and a base satellite image.

For the other bore simulations, because drawdowns in the upper model layers were very small, the maximum drawdown (occurs at centre of bore field) was reported in tables. Also, for PB12, the distance from the bore field to the two metre drawdown contour in the pumped model layer was reported in a table because existing bores access this groundwater source in this region.

Assessment criteria

Model results were assessed against the AIP minimal impact considerations (refer to section 3.3).

Table 4.5 Model layer summary

Bore field simulation model	Layer	From/to	Justification
PB1	Layer 1 (alluvium)	0 to -66	Layer bottom based on average depth to rock noted in completion reports for existing nearby bores (GW000306, GW001568, GW000367, GW802725, GW802807 and GW002441). Quantifying potential groundwater level drawdown in this layer was a key model objective.
	Layer 2 (rock)	-66 to -113	Layer bottom assigned to be equal to the depth of deepest existing bore within 5 km of bore field. Quantifying potential groundwater level drawdown in this layer was a key model objective.
	Layer 3 (rock – separation layer)	-113 to -163	A nominal 50 metre separation layer was assigned between Layer 2 and Layer 4, the pumped layer. A nominal layer thickness is appropriate because the same hydraulic properties were applied for Layers 2, 3 and 4.
	Layer 4 (rock – pumped)	-163 to -263	A nominal 100 metre thick layer was assigned for the bore field bores to extract from. Unless high hydraulic conductivity and storage fortuitously occur, with a low hydraulic conductivity, the bore field bores would need to span an interval of about 100 metres to maximise transmissivity and minimise drawdown in the pumping bores.
	Specified head line boundary groundwater level in all layers	-35	The standing water level at existing bores in the region of the bore field typically ranges from about 30 to 40 mBGL.
PB2	Layer 1 (rock, and alluvium in a sensitivity simulation)	0 to -60	Layer bottom assigned to be equal to the depth of deepest existing bore near bore field, which has a depth of 57.9 mBGL. Quantifying potential groundwater level drawdown in this layer was a key model objective.
	Layer 2 (rock – separation layer)	-60 to -110	Same reasoning as Layer 3 in PB1.
	Layer 3 (rock – pumped)	-110 to -210	Same reasoning as Layer 4 in PB1.
	Specified head line boundary groundwater level in all layers	-20	The standing water level at existing bores in the region of the bore field is typically about 20 mBGL.
PB3	Layer 1 (Cenozoic)	0 to -54	Based on Geoscience Australia GAB hydrostratigraphic unit surfaces. Quantifying potential groundwater level drawdown in Layers 1 and 2 was a key model objective.
	Layer 2 (Hooray sandstone and equivalents)	-54 to -113	

Bore field simulation model	Layer	From/to	Justification
	Layer 3 (Jurassic-Cretaceous aquitard at base of GAB)	-113 to -159	
	Layer 4 (Sub-GAB rock – pumped)	-159 to -259	Sam reasoning as Layer 4 in PB1.
	Specified head line boundary groundwater level in all layers	-26	Geoscience Australia GAB water table surface depth at centre of bore field is about 26 mBGL.
PB7	Layer 1 (Cenozoic)	0 to -71	Based on Geoscience Australia GAB hydrostratigraphic unit surfaces. Quantifying potential groundwater level drawdown in Layers 1 and 2 was a key model objective.
	Layer 2 (Hooray sandstone and equivalents)	-71 to -331	
	Layer 3 (Jurassic-Cretaceous aquitard at base of GAB)	-331 to -379	
	Layer 4 (Sub-GAB rock – pumped)	-379 to -479	Same reasoning as Layer 4 in PB1.
	Specified head line boundary groundwater level in all layers	-21	Geoscience Australia GAB water table surface depth at centre of bore field is about 21 mBGL.
PB12	Layer 1 (Hooray sandstone and equivalents)	0 to -93	Based on Geoscience Australia GAB hydrostratigraphic unit surfaces. Quantifying potential groundwater level drawdown in Layer 1 was a key model objective.
	Layer 2 (Jurassic-Cretaceous aquitard at base of GAB)	-93 to -232	
	Layer 3 (Sub-GAB rock – pumped)	-232 to -332	Same reasoning as Layer 4 in PB1.
	Specified head line boundary groundwater level in all layers	-12	Geoscience Australia GAB water table surface depth at centre of bore field is about 12 mBGL.

Table 4.6 Groundwater model parameters

Bore field simulation model	Layer	Parameters	Model values	Justification
PB1	Layer 1 (alluvium)	Horizontal hydraulic conductivity (m/d)	0.05	The alluvium is generally clayey in the area of the bore field based on bore completion reports. Therefore, hydraulic conductivity is likely relatively low for alluvium. This is supported by the low bore density, which only increases closer to the Macquarie River and Narromine. The parameter values are intended to represent generally clayey alluvial material with some minor sand and gravel layers. A relatively low value for alluvium builds conservatism into the model results.
		Vertical hydraulic conductivity (m/d)	0.005	One order of magnitude reduction from horizontal hydraulic conductivity. Such an anisotropy ratio is commonly applied for sedimentary strata in modelling assessments.
		Specific yield	0.05	Adopted to represent generally clayey alluvium with some minor sand and clay. Accords with value applied to represent alluvium in CDM Smith (2016) groundwater model for Santos Narrabri gas project.
		Specific storage (m^{-1})	NA (unconfined layer)	NA (unconfined layer)
	Layers 2, 3, 4 (rock)	Horizontal hydraulic conductivity (m/d)	0.02	Value applied to generate a low transmissivity value that in conjunction with the specific storage value, still represents a bore that is feasible to pump. If the transmissivity was lower than this value, then bore pumping is not practical and the bore would likely be abandoned. The low value builds conservatism into the model results.
		Vertical hydraulic conductivity (m/d)	0.002	One order of magnitude reduction from horizontal hydraulic conductivity. Such an anisotropy ratio is commonly applied for sedimentary strata in modelling assessments.
		Specific yield	0.01	Low specific yield value applied to represent rock. Accords with value applied to represent rock in CDM Smith (2016) groundwater model for Santos Narrabri gas project.

Bore field simulation model	Layer	Parameters	Model values	Justification
		Specific storage (m^{-1})	5×10^{-6}	Uniform specific storage value applied for rock in all bore field models. Accords with value Aquaterra (2009) adopted to represent rock in a hydrogeological model for Narrabri Coal project. The value is considered suitable to represent all rock layers in all bore field models.
PB2	All layers (rock)	Same as PB1 layers 2, 3, 4	Same as PB1 layers 2, 3, 4	Same as PB1 layers 2, 3, 4
PB3, PB7, PB12	Cenozoic (rock or non-productive alluvium)	Horizontal hydraulic conductivity (m/d)	0.01	Value was applied to represent non-productive alluvium, not alluvium aquifers, and/or rock. A low value builds conservatism into the model results.
		Vertical hydraulic conductivity (m/d)	0.001	One order of magnitude reduction from horizontal hydraulic conductivity.
		Specific yield	0.01	Based on CDM Smith (2016) groundwater assessment for Santos Narrabri gas project. Value was applied to represent non-productive alluvium, not alluvium aquifers, and/or rock. A low value builds conservatism into the model results.
		Specific storage (m^{-1})	NA (unconfined layer)	NA (unconfined layer)
	Hooray sandstone and equivalents (rock)	Horizontal hydraulic conductivity (m/d)	0.1	Accords with values CDM Smith (2016) adopted to represent Pilliga Sandstone in a hydrogeological model for Santos Narrabri gas project.
		Vertical hydraulic conductivity (m/d)	0.01	
		Specific yield	0.01	
		Specific storage (m^{-1})	5×10^{-6}	Aquaterra (2009) – see PB1 justification
	Jurassic-Cretaceous aquitard at base of GAB (rock)	Horizontal hydraulic conductivity (m/d)	0.001	Accords with values CDM Smith (2016) adopted to represent Purlewaugh Formation (aquitard at GAB base) in a hydrogeological model for Santos Narrabri gas project.
		Vertical hydraulic conductivity (m/d)	1×10^{-5}	
		Specific yield	0.01	
		Specific storage (m^{-1})	5×10^{-6}	Aquaterra (2009) – see PB1 justification

Bore field simulation model	Layer	Parameters	Model values	Justification
	Pumped layer (either Gunnedah Oxley Basin or Lachlan Fold Belt rocks) (rock)	Horizontal hydraulic conductivity (m/d)	0.02	Same as PB1, Layers 2, 3 and 4
		Vertical hydraulic conductivity (m/d)	0.002	
		Specific yield	0.01	
		Specific storage (m^{-1})	5×10^{-6}	

Modelling limitations

The objective of the groundwater modelling is to quantify groundwater level drawdown that could occur due to pumping of the proposal bore fields, to inform a groundwater impact assessment. Assessing likely obtainable bore yields and detailed bore field design was outside of scope.

The modelling is not based on proposal specific bore investigation data and is instead based on a desktop review of available data and assumptions. Due to the absence of proposal specific bore investigation data, hydrogeological conditions at the bore fields may be different to those which were adopted for the purpose of the modelling. Consequently, recommendations have been made to address this data gap at detailed design stage. At detailed design stage, it is recommended that likely obtainable yields are assessed.

Once drilled and constructed, the bore field bores may yield substantially different to the assumed two litres per second rate that was adopted for modelling purposes. It is conceivable that some bores may yield so little that pumping them would be impractical. Conversely, higher than assumed yields are also a possibility.

4.7 Temporary workforce accommodation bores

Potential impacts associated with using bores to supply the Narromine and Baradine temporary workforce accommodation facilities with treated groundwater for potable water were assessed qualitatively. Potential impacts associated with application of onsite wastewater at these locations (if required) were also assessed qualitatively.

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5. Existing environment

5.1 Climate

5.1.1 Proposal rainfall and evaporation

Mean monthly and annual rainfall were sourced from BOM Station 51005 (Narromine) and 53030 (Narrabri). Mean monthly and annual evaporation were sourced from BOM Station 065035 (Wellington) and 055024 (Gunnedah), as proxies for Narromine and Narrabri respectively. The proxy evaporation data locations were used as they were the closest BOM station locations to the Narromine and Narrabri rainfall data locations which contained evaporation data. The climate data are summarised in Table 5.1. Average rainfall surplus (rainfall – evaporation) is also provided. The rainfall and evaporation statistics presented for the locations of Narromine and Narrabri are considered generally representative of conditions over the length of the proposal.

The rainfall and evaporation statistics indicate the proposal is generally characterised by low monthly and annual rainfall, and high evaporation. On average there is no rainfall surplus for any month. The lowest rainfall deficit occurs in June, where rainfall is still surpassed by evaporation by about four millimetres and eight millimetres for Narromine and Narrabri, respectively. Annual rainfall deficit is about -1265 millimetres and -1099 millimetres for Narromine and Narrabri, respectively, which in conjunction with the average monthly rainfall deficit values, indicates the proposal is typically subjected to dry conditions.

Cumulative Rainfall Departure (CRD) is an analysis technique that is used to normalise rainfall data to historical averages. CRD is used to assess visual correlation of rainfall trends with groundwater level trends. CRD is calculated from the cumulative sum of observed rainfall minus long-term average rainfall and sometimes displays correlation to groundwater levels, particularly where rainfall recharge is an important process. A climbing CRD line slope represents above average rainfall whilst a declining slope represents below average rainfall. The rainfall data for BOM Stations 51005 (Narromine) and 53030 (Narrabri) is sourced from the SILO LongPaddock database (SILO, 2020) which interpolates the raw data to derive datasets which are both spatially and temporally complete. A CRD graph is provided in Figure 5.1 which shows a climate of below average rainfalls since 2017. The CRD increases are representative of periods of increased rainfall, in 2010 and 2016 these rainfalls caused flooding in the Macquarie River.

Average rainfall and evaporation values suggest that groundwater recharge in the area of the proposal is likely to be low.

Table 5.1 Narromine and Narrabri rainfall, evaporation and rainfall surplus summary

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann.
Narromine	Mean Rainfall (mm) [1]	59.0	50.5	44.8	39.8	42.8	44.3	38.8	39.6	37.3	45.4	47.1	47.2	537
	Mean Evapor-ation (mm) [2]	272.8	221.2	195.3	126.0	77.5	48.0	52.7	74.4	102.0	158.1	207.0	266.6	1801.6
	Rainfall surplus (mm)	-213.8	-170.7	-150.5	-86.2	-34.7	-3.7	-13.9	-34.8	-64.7	-112.7	-159.9	-219.4	-1265.0
Narrabri	Mean Rainfall (mm) [3]	82.9	61.1	60.0	38.1	46.7	49.0	45.2	39.9	40.8	51.4	60.3	75.7	658.5
	Mean Evapor-ation (mm) [4]	238.7	190.4	182.9	129.0	83.7	57.0	58.9	86.8	120.0	167.4	201.0	241.8	1757.6
	Rainfall surplus (mm)	-155.8	-129.3	-122.9	-90.9	-37.0	-8.0	-13.7	-46.9	-79.2	-116.0	-140.7	-166.1	-1099.1

Notes: 1. Source: Narromine BOM Station (Station 51005).
2. Source: Wellington BOM Station (Station 065035), located about 50 km south east of Dubbo.
3. Source: Narrabri BOM Station (Station 53030).
4. Source: Gunnedah BOM Station (Station 055024), located about 85 km south-south east of Dubbo.

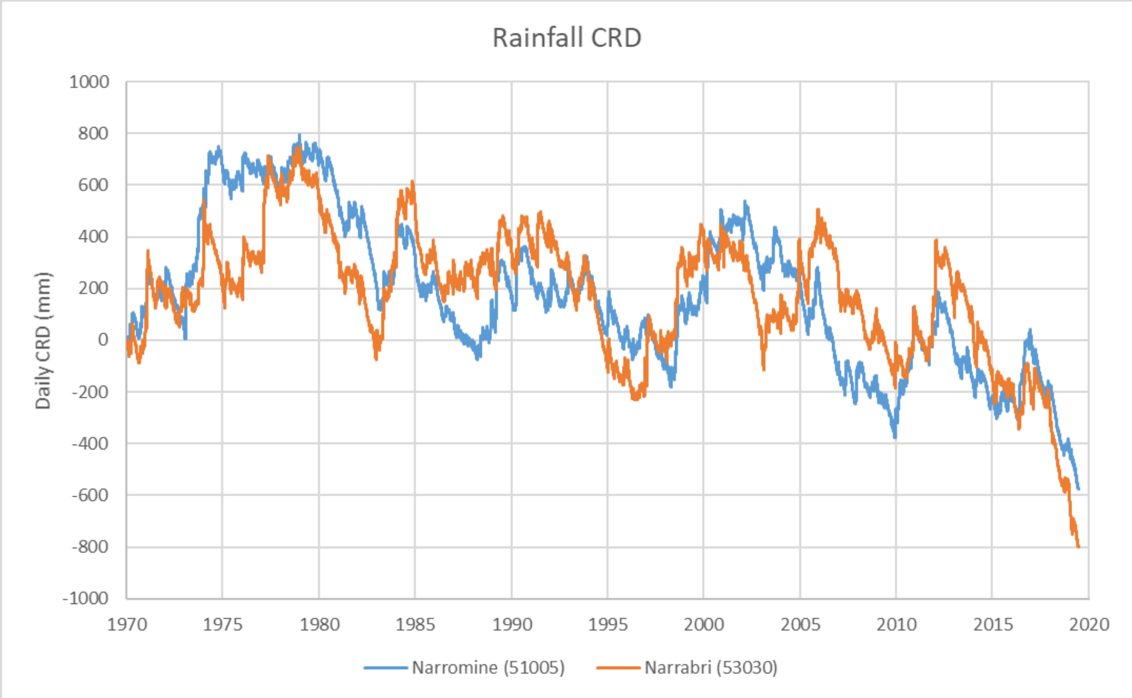


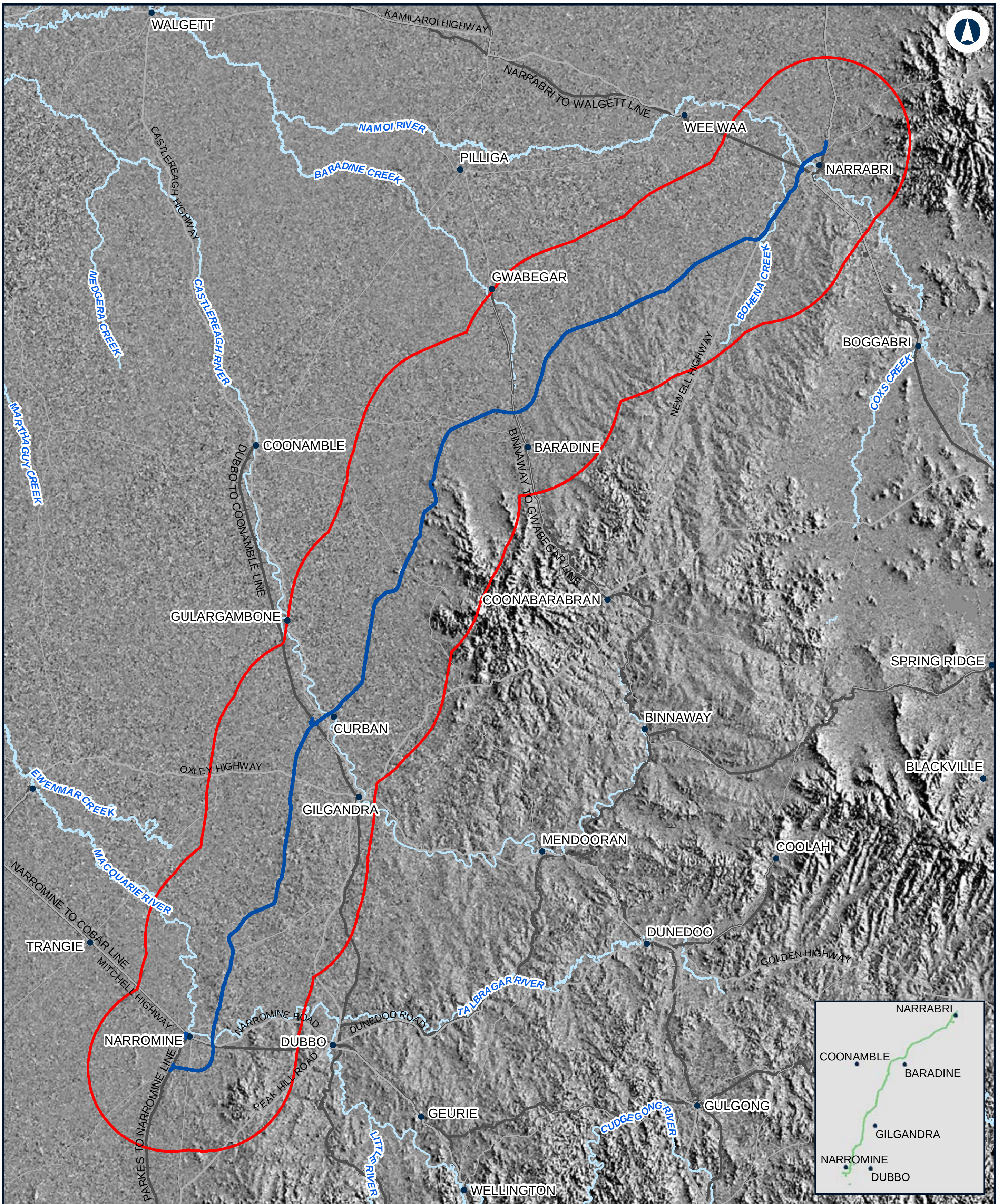
Figure 5.1 Cumulative rainfall departure for Narromine and Narrabri

5.2 Topography

The topography is dictated by its location relative to the rugged Great Dividing Range to the east and the lower-lying and typically flat GAB to the west. The alignment itself for the most part runs along the subdued foot slopes of the Great Dividing Range and as such the relief is varied. Some areas comprise flat to gently undulating terrain with hillslopes typically less than 10 degrees, whilst other areas comprise more pronounced moderate slopes, such as on the flanks of the Warrumbungles and through the Pilliga forest. The regional topography is demonstrated within the topographic relief map in Figure 5.2.

Reduced levels along the alignment range from about 210 mAHD to 310 mAHD.

The topography is punctuated by a large number of incised creeks and rivers which drain westward from the more elevated areas in the east. Regional drainage is to the north at the northern end of the alignment, away from the more elevated terrain of the Pilliga East State Forest. As such, the proposal crosses a large number of creeks and rivers where culvert structures and bridges are required in the design.



NARROMINE TO NARRABRI

Topographic relief map of north and western NSW

Figure 5.2

0 10 20 Km

Coordinate System: GDA 1994 MGA Zone 55

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Date: 31/03/2020 Paper: A4
Author: JacobsGHD Scale: 1:1,250,000
Data Sources: Basemap layers: NSWSS; Topography: NSW SRTM DEM hillshade; Project elements: GHDJACOBS

LEGEND

- Alignment
- Study area

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5.3 Land use

The proposal traverses five local government areas, these being Narromine, Gilgandra, Coonamble, Warrumbungle and Narrabri. Towns within or adjacent to the proposal include Narromine and Narrabri. Throughout the area of the proposal there are several rural residences and small communities.

The proposal area is dominated by agricultural industries, with significant cropping and livestock industries including cereal, other broad acre and hay production cropping, dryland grazing of beef cattle and sheep, and wool production. There are also several travelling stock reserves in the vicinity of the proposal.

Most of the land in the vicinity of the proposal has been cleared of the original vegetation for agricultural activities with scattered patches of remnant vegetation, mainly in the vicinity of watercourses, state forests and hilled areas unsuitable for agriculture.

Other key features/land use in the vicinity of the proposal include:

- grain storage and handling facilities at Curban
- commercial/industrial area west and north-west of Narrabri
- state forests including Merriwindi State Forest, Baradine State Forest, Cumbil State Forest, Euligal State Forest and Pilliga East State Forest
- the proposed Santos Narrabri Gas Project south of Narrabri.

5.4 Surface water

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

Excluding the major perennial river systems identified above, surface water within the proposal study area is predominately comprised of ephemeral waterways. This is a result of the size of the contributing watercourse catchment area, rainfall and evaporation patterns experienced in the region and limited base flow resulting from groundwater expression.

Additional detailed information is outlined within the *ARTC Inland Rail Narromine to Narrabri Surface Water Quality Assessment* (JacobsGHD, 2020b).

5.5 Regional geology

Surface geology in the Narromine region of the proposal generally consists of alluvium material, and less commonly, metamorphosed fine-grained rocks, and siltstone/shale of the Lachlan Fold Belt. Northwards of the Narromine region, the proposal is situated within the Coonamble Embayment region of the Surat Basin, a sub-basin of the GAB.

An overview geological map including the proposal is presented in Figure 5.3. Additionally, a pie chart showing simplified surface geology along the entire proposal alignment is provided in Figure 5.4. The geological map and pie chart are based on the following 1:250,000 geology maps:

- Narromine (Department of Mineral Resources, 1997)
- Nyngan (Geological Survey of NSW, 1996)
- Gilgandra (Geological Survey of NSW, 1968)
- Narrabri (Geological Survey of NSW, 1971).

The GAB primarily consists of Jurassic-Cretaceous sedimentary rock units; however, as shown in Figure 5.4, much of the GAB surface geology in the area of the proposal's alignment includes Cenozoic alluvial, residual or colluvial material. This cover material was derived from prolonged erosion of the adjacent 'highland' Surat Basin bedrock and Tertiary volcanic centres and has been deposited in the recent geological past, resulting in vast low-relief slopes and plains comprising significant thicknesses of alluvial and colluvial sediments. Recent deposition has been dictated by watercourses draining westward, from elevated ground to the east, with the primary river systems crossing the proposal including the Macquarie River at Narromine, the Castlereagh River at Curban, the Namoi River at Narrabri and their associated tributaries.

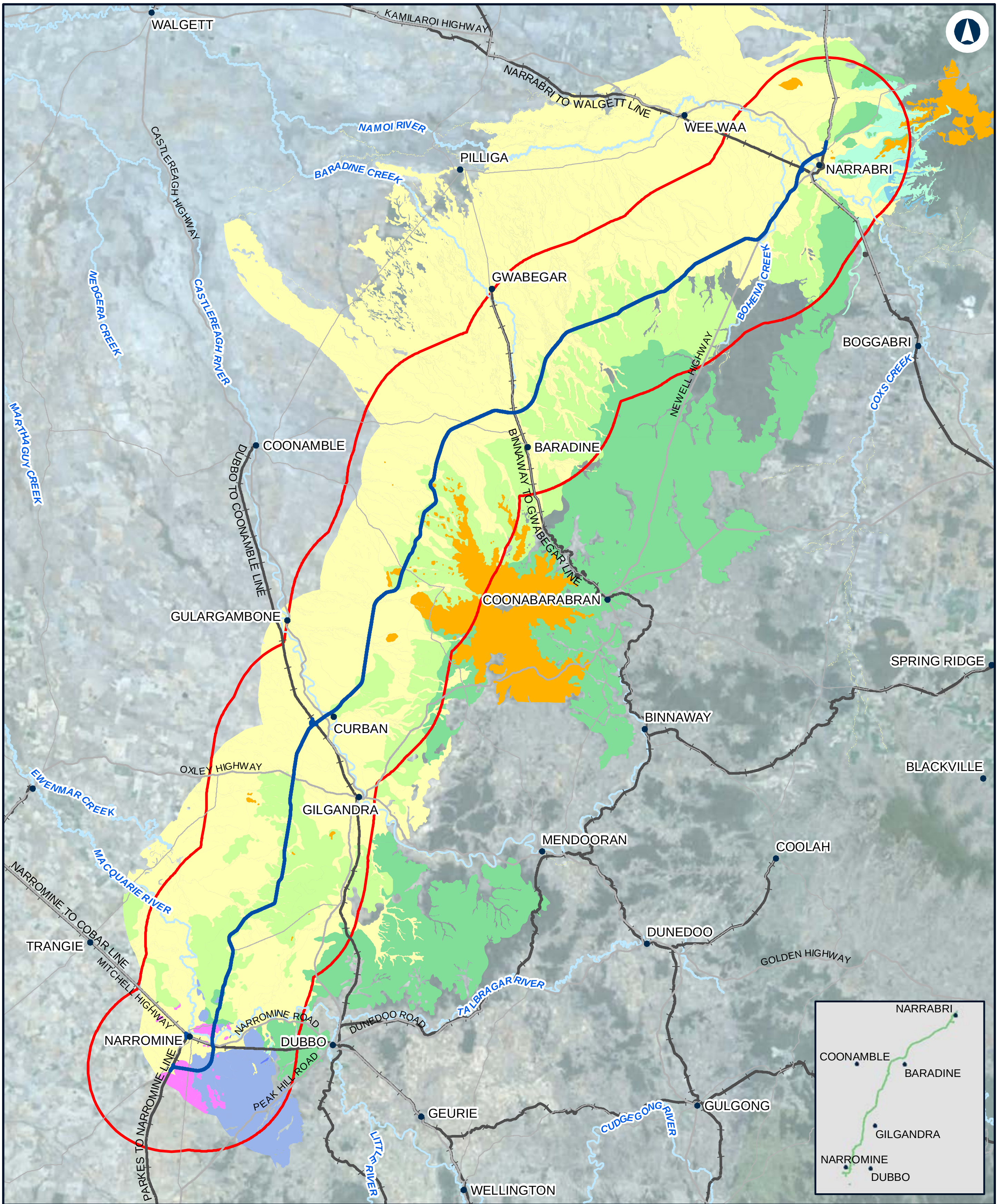
Due to the deep bores proposed, an appreciation of geology beneath the GAB is required.

The base of the GAB is deep and the following summary comments are provided based on Geoscience Australia's (2013) hydrostratigraphic surfaces:

- towards the southern extent of the GAB, at PB3, the base of the GAB is about 160 mBGL
- towards the northern extent of the proposal, at PB12, the base of the GAB is about 230 mBGL
- in between PB3 and PB12, the base of the GAB ranges from about 300 metres below groundwater level to 420 mBGL, with an average depth of about 365 mBGL.

The GAB overlies either Lachlan Fold Belt rock units or Gunnedah-Oxley Basin rock units.

A geological cross section for the Coonamble-Gilgandra region prepared by NSW DoI (2018) is provided in Figure 5.6, with the cross section location shown in Figure 5.5. In addition, a geological cross section and stratigraphy summary table for the Narrabri region taken from CDM Smith (2016) is provided in Figure 5.7 and Table 5.2, respectively. The Pulawaugh Formation in the lowest formation of the GAB. The cross sections indicate that the Pulawaugh Formation is underlain by either Garrawilla Volcanics or the Napperby Formation, or in the south of the proposal, probably the Lachlan Fold Belt.



NARROMINE TO NARRABRI Regional geological mapping

Figure 5.3

0 10 20 Km

Coordinate System: GDA 1994 MGA Zone 55

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Date: 31/03/2020 Paper: A4
Author: JacobsGHD Scale: 1:1,250,000
Data Sources: Basemap layers: NSWSS; Geology: DIRE; Project elements: GHDJACOBS

LEGEND

- Alignment
- Study area

Brigalow Belt South Bioregion Geology - DIRE 2003

- Quaternary alluvium and colluvial outwash
- Tertiary volcanics
- Cretaceous sedimentary rocks
- Jurassic sedimentary rocks
- Triassic sedimentary rocks
- Permian sedimentary rocks
- Devonian granites
- Silurian-Devonian granites
- Ordovician metasediments

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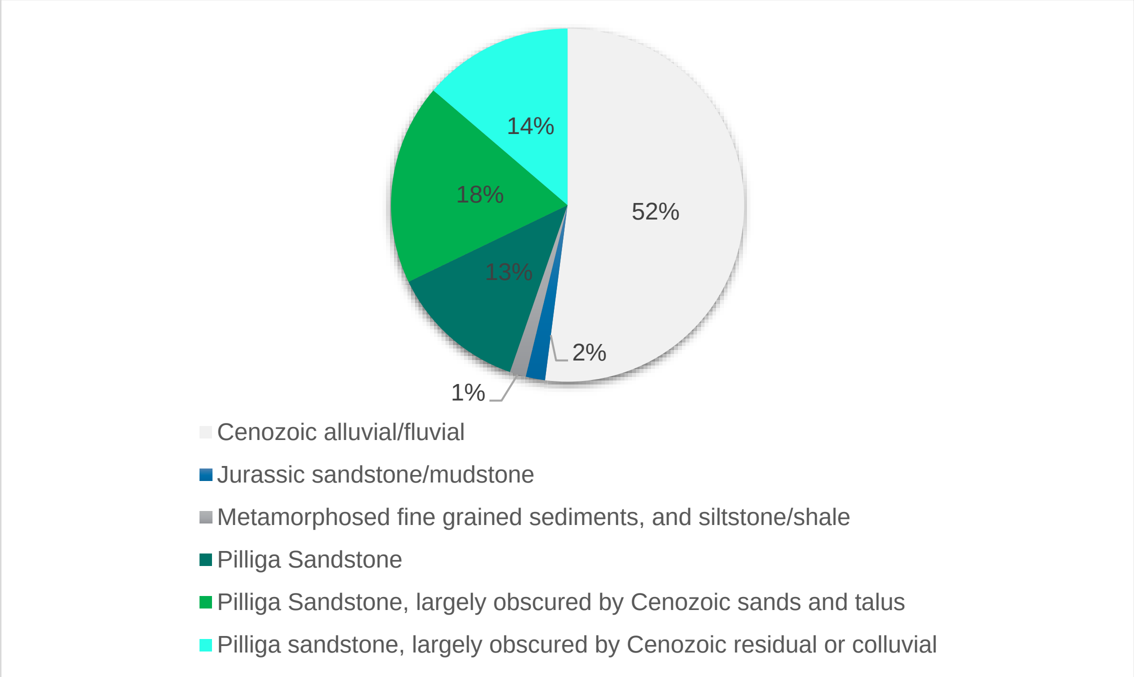
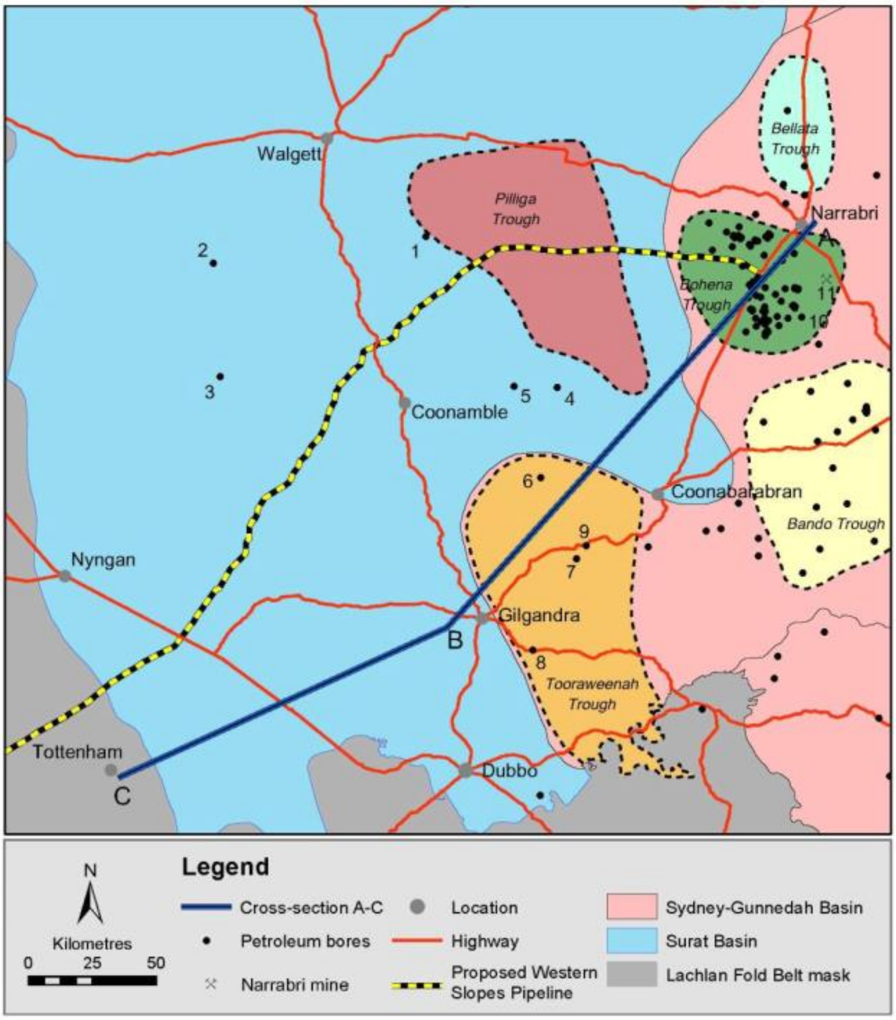
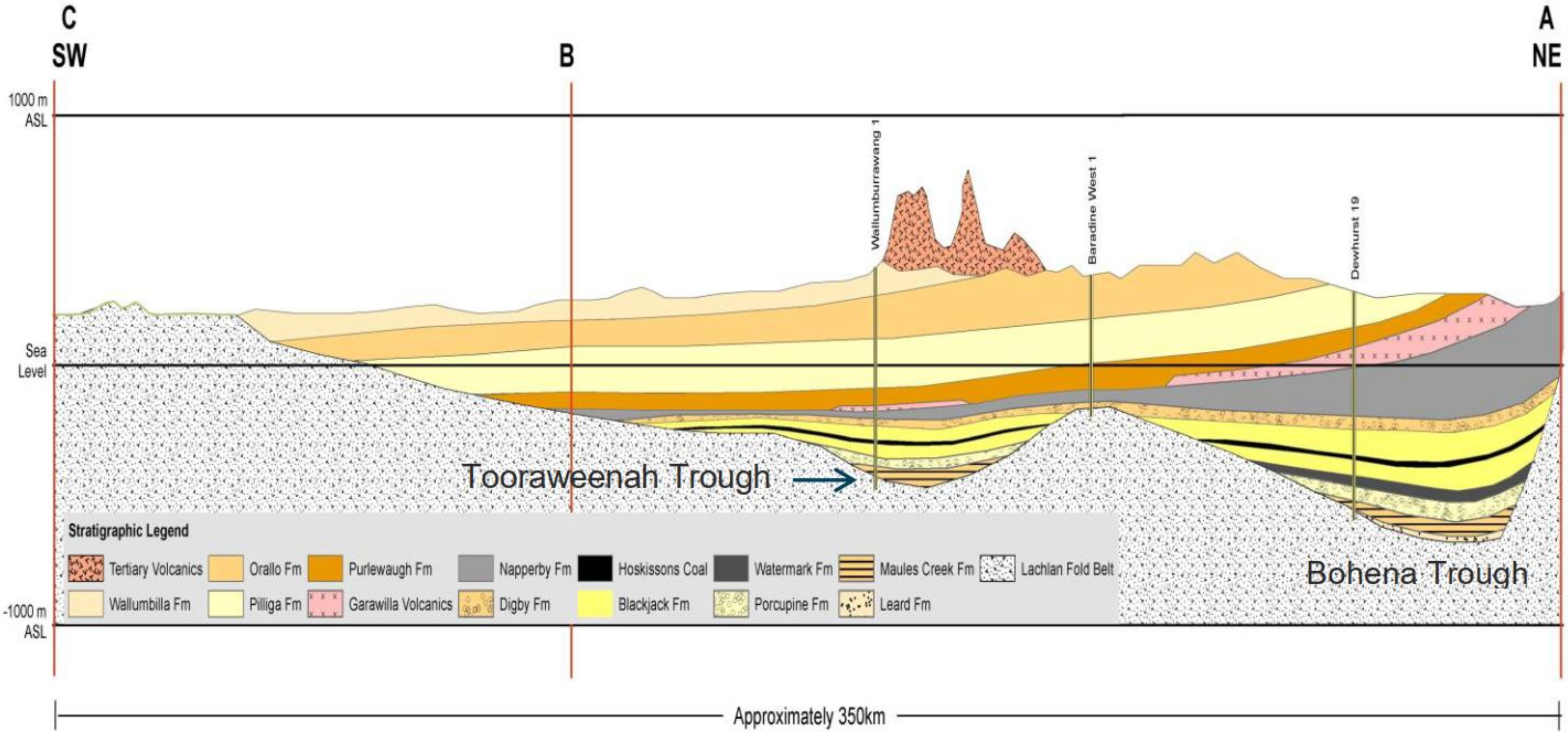


Figure 5.4 Pie chart of simplified surface geology over the proposal site



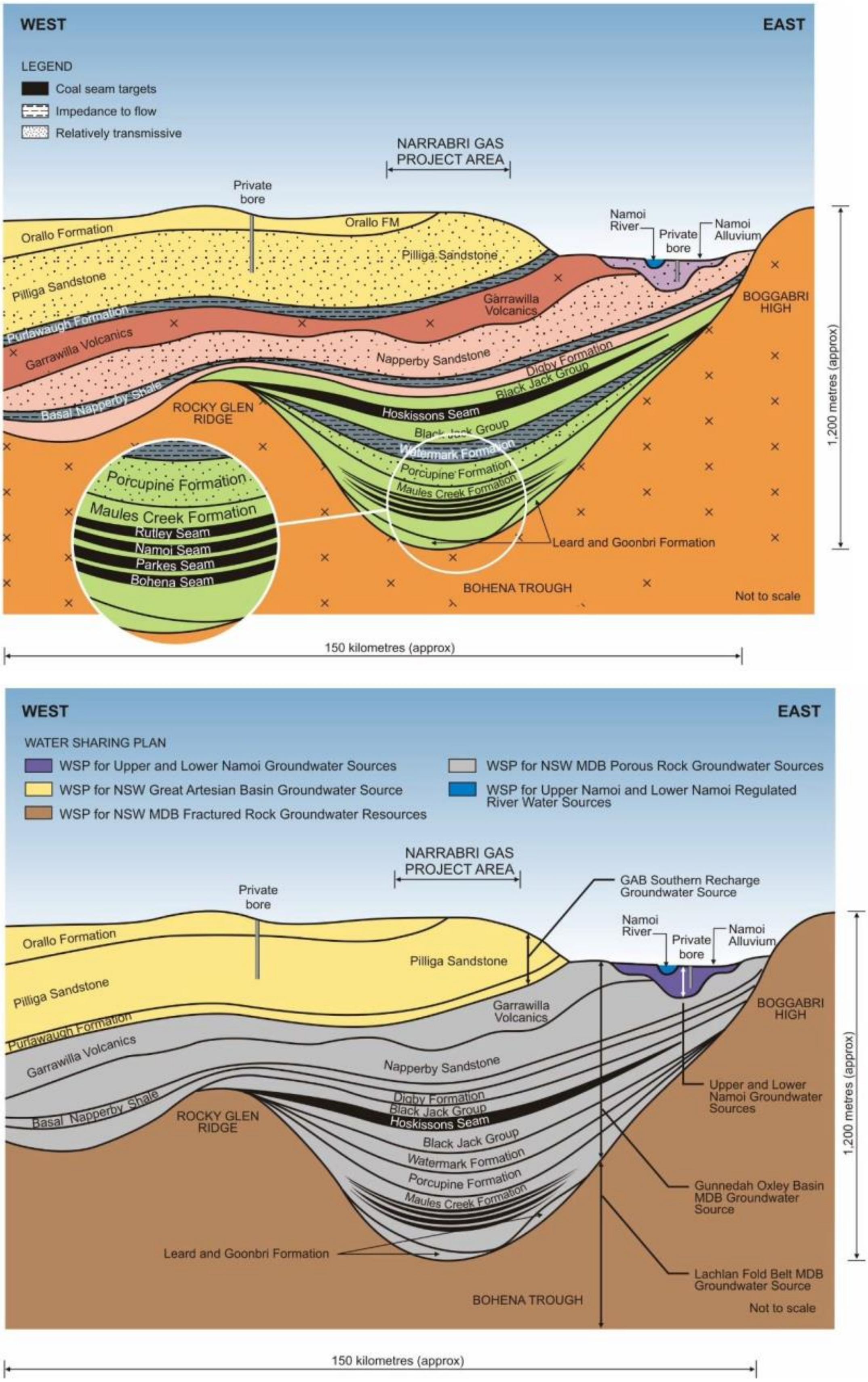
Source: NSW DoI, 2018

Figure 5.5 Coonamble – Gilgandra region cross section location



Source: NSW DoI, 2018

Figure 5.6 Geological cross section of Coonamble – Gilgandra region



Source: CDM Smith, 2016

Figure 5.7 Geological cross sections in Narrabri region

Table 5.2 Stratigraphy in Narrabri region of the proposal

Province	Period/ Epoch	Division	Group	Sub-group	Formation
Namoi Alluvium	Pleistocene				Narrabri fm
	Pliocene				Gunnedah fm
	Miocene				Cubbaroo fm
Vocanics					Warrumbungle Vol
	Eocene				Liverpool Range Vol
Surat Basin	Cretaceous	Middle	Blythesdale Gp (Keelindi Beds)		Bungil Fm Mooga Ss Orallo Fm
		Early			Pilliga Ss
	Jurassic	Late			
		Middle			Purlawaugh Fm
		Early	Garrawilla Volcanics		
Gunnedah Basin	Triassic	Late			
		Middle			Deriah Fm
					Napperby Fm
		Early			Digby Fm
	Permian	Late	Black Jack	Nea	Trinkey Fm
					Wallala Fm
				Coogal	Breeza Coal
					Clare Ss
					Hows Hill Coal
					Benelabri
					Hoskissons Coal
				Brothers	Brigalow Fm
					Arkarula Fm
					Melvilles Coal Mb
					Pamboola Fm
		Middle	Millie		Watermark Fm
					Porcupine Fm
		Early	Bellata		Upper Maules Creek Fm
					Rutley seam
					Interburden
					Namoi seam
					Interburden
					Parkes seam
					Interburden
					Bohena seam
					Lower Maules Creek Fm
					Goonbri Fm
					Leard Fm
Basement			Werrie Basalt and Boggabri Volcanics (Basement)		

Source: modified from CDM Smith, 2016

5.6 Soil

5.6.1 General

Information sourced from the NSW DPIE (2020) online eSPADE soil mapping database was utilised to characterise soil types along the alignment. The Office of Environment and Heritage soil mapping data indicates that soil types along the proposal can be described in four broad areas which share a similar suite of soil types:

- Narromine to the Oxley Highway – the main soil types are dominated by 'red brown earths, red earths and solodic soils'.
- Oxley Highway to Baradine – the main soil types are dominated by 'grey, red and brown clays (vertosols), black earths (vertosols), red brown earths, red earths and non-calcic brown soils'.
- Baradine to Narrabri – the main soil types are dominated by 'solodic soils and earthy sands'.
- Narrabri – the main soil types in the vicinity of Narrabri are dominated by 'solodic soils' south of Narrabri and 'grey, red and brown clays (vertosols) and black earths (vertosols)' close to Narrabri.

Further detailed soil information for the proposal is provided in the EIS.

5.6.2 Acid sulfate soils

Acid sulfate soil (ASS) is the common name for naturally occurring sediments and soils containing iron sulphides. The exposure of these soils to oxygen by drainage or excavation oxidises the iron sulphides and generates sulfuric acid. The sulfuric acid can be readily released into the environment, with potential adverse effects on natural and built environments. The majority of ASS are formed when available sulfate (which occurs widely in seawater, marine sediment, or saturated decaying organic material) reacts with dissolved iron and iron minerals forming iron sulphide minerals, the most common being pyrite. This generally limits their occurrence to deeper marine sediments and low-lying sections of coastal floodplains, rivers and creeks where surface elevations are less than about five mAHD.

Given the proposal location, distance from the coast, elevation (about 210 mAHD or higher) and with reference to the CSIRO's (2020) Australian Soil Resource Information System (ASRIS) which indicates that the alignment falls almost entirely within areas denoted as 'no known occurrence' or 'low probability' of ASS, ASS are generally not considered likely. However, it should be noted that although occurrence of ASS within the proposal is considered low and unlikely, ASRIS (CSIRO, 2020) did indicate a 'high probability' of ASS around the Macquarie, Castlereagh and Namoi rivers.

As outlined within RTA (2005), similar to ASS, acid sulfate rock can occur in lithologies that contain sulfide and sulfate minerals.

5.6.3 Salinity

The NSW DPIE (2020) eSPADE online soil database was reviewed to investigate soil salinity. Data was available for about 70 per cent of the proposal's length, from the proposal's southern extent up until the towns of Baradine/Kenebri, NSW. No data was available beyond Baradine/Kenebri, NSW. The following summary comments are offered:

- Overall salinity hazard is generally 'moderate' from the southern extent of the proposal up until a latitude roughly coinciding with the locality of Eumungerie, NSW. Moving northwards, salinity hazard is generally low until a latitude roughly coinciding with the locality of Armatree except for south of Curban, NSW, where it is mapped as moderate hazard. North of a latitude roughly corresponding to the locality of Armatree, overall salinity hazard is mapped to generally vary from moderate to high.
- Land salt is generally mapped as either 'low' or 'moderate' over the proposal length with available data (ie southern extent up until near Baradine/Kenebri, NSW).

Further information on soil salinity, as well as soil sodicity and dispersiveness in provided in the EIS.

5.7 Groundwater dependent ecosystems

5.7.1 Overview

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

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

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

5.7.2 High priority GDEs

High Priority GDEs (vegetation)

The proposal's relevant WSPs map areas of High Priority GDE vegetation within the groundwater study area. High Priority GDE vegetation as mapped by the WSPs is shown in Figure 5.8.

Mapped High Priority GDE vegetation areas are crossed by the proposal's alignment at the following locations:

- Macquarie River
- Castlereagh River
- Gulargambone Creek
- Baradine Creek
- Etoo Creek
- Rocky Creek
- Goona Creek
- Bohena Creek

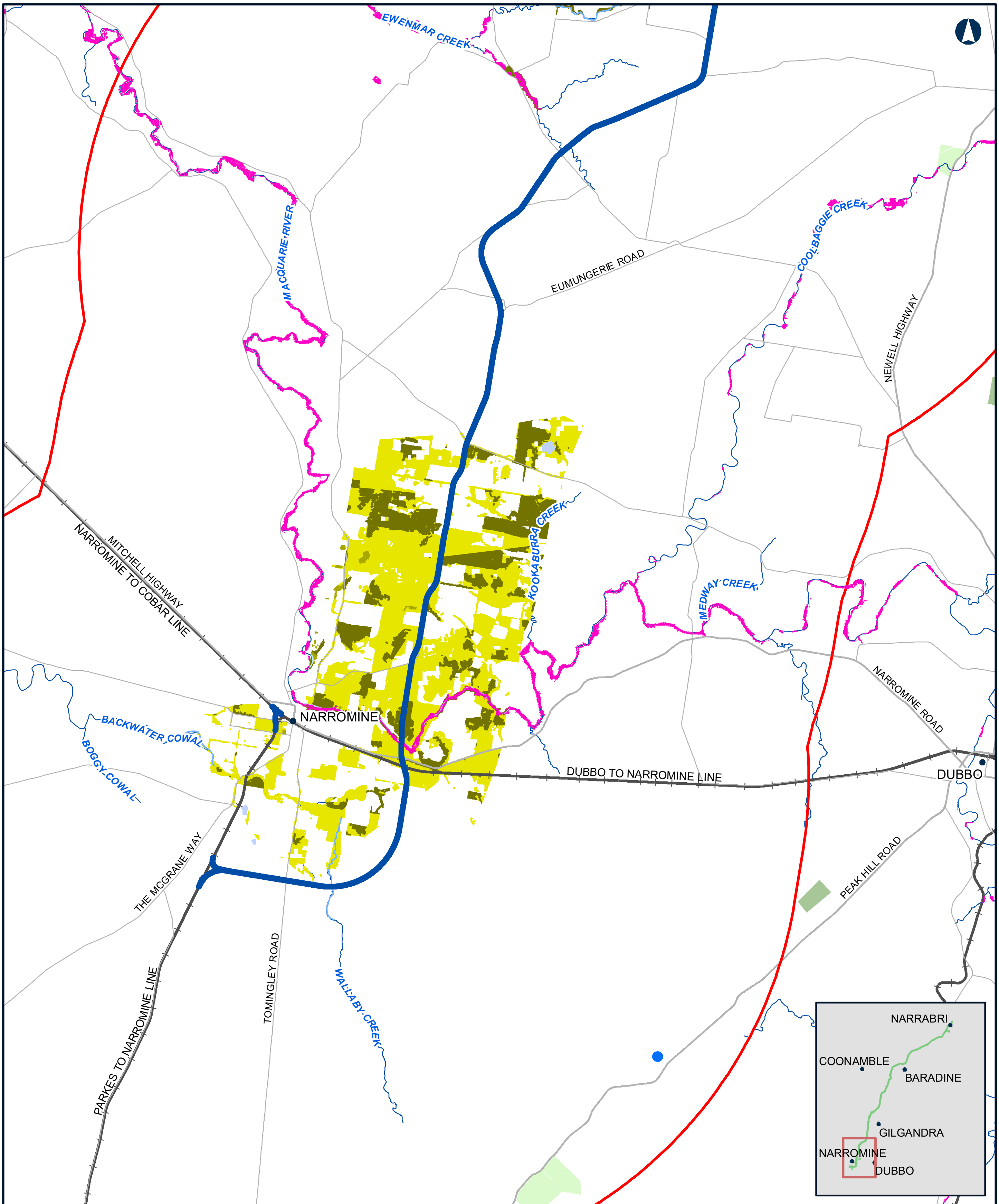
- Small unnamed tributary of Bohena Creek, located close (less than 200 metres) to Bohena Creek
- Namoi River
- Narrabri Creek.

High Priority GDEs (springs)

Review of the WSPs relevant to the proposal indicates there are 10 mapped High Priority GDE springs within the groundwater study area. The closest is located about 10 kilometres from the proposal site and all of the springs reside in the areas covered by the WSP for the NSW MDB Fractured Rock Groundwater Sources 2020, Lachlan Fold Belt MDB Groundwater Source. For completeness, High Priority spring GDEs within the groundwater study area are shown in Figure 5.8 but are not discussed further as impacts due to the proposal are highly unlikely because of the large separation distance.

5.7.3 Bureau of Meteorology's GDE Atlas

The Bureau of Meteorology's *GDE Atlas* (BOM, 2018a) was reviewed to investigate the potential for GDEs to exist within the broader region of the proposal. The GDE Atlas mapping is shown in Figure 5.8 and summarised below for potential terrestrial and aquatic GDEs respectively.



NARROMINE TO NARRABRI Potential GDE mapping (BOM, 2018a) and High Priority GDE mapping (NSW Gov WSPs) Figure 5.8a

0 3.5 7 Km

Coordinate System: GDA 1994 MGA Zone 55

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Date: 13/10/2020 Paper: A4
Author: JacobsGHD Scale: 1:260,000

Data Sources: Basemap layers: NSWSS; GDE: DIRE, DPI; Project elements: GHDJACOBS

LEGEND

- Alignment
- Study area
- High priority GDE vegetation (NSW Gov WSPs)
- High Priority GDE (spring) (WSP for the NSW MDB Fractured Rock Groundwater Sources 2020)
- High potential GDE - from regional studies (terrestrial)
- Moderate potential GDE - from regional studies (terrestrial)
- Low potential GDE - from regional studies (terrestrial)
- Moderate potential GDE - from national assessment (aquatic)
- Low potential GDE - from national assessment (aquatic)
- Unclassified potential GDE - from regional studies (aquatic)

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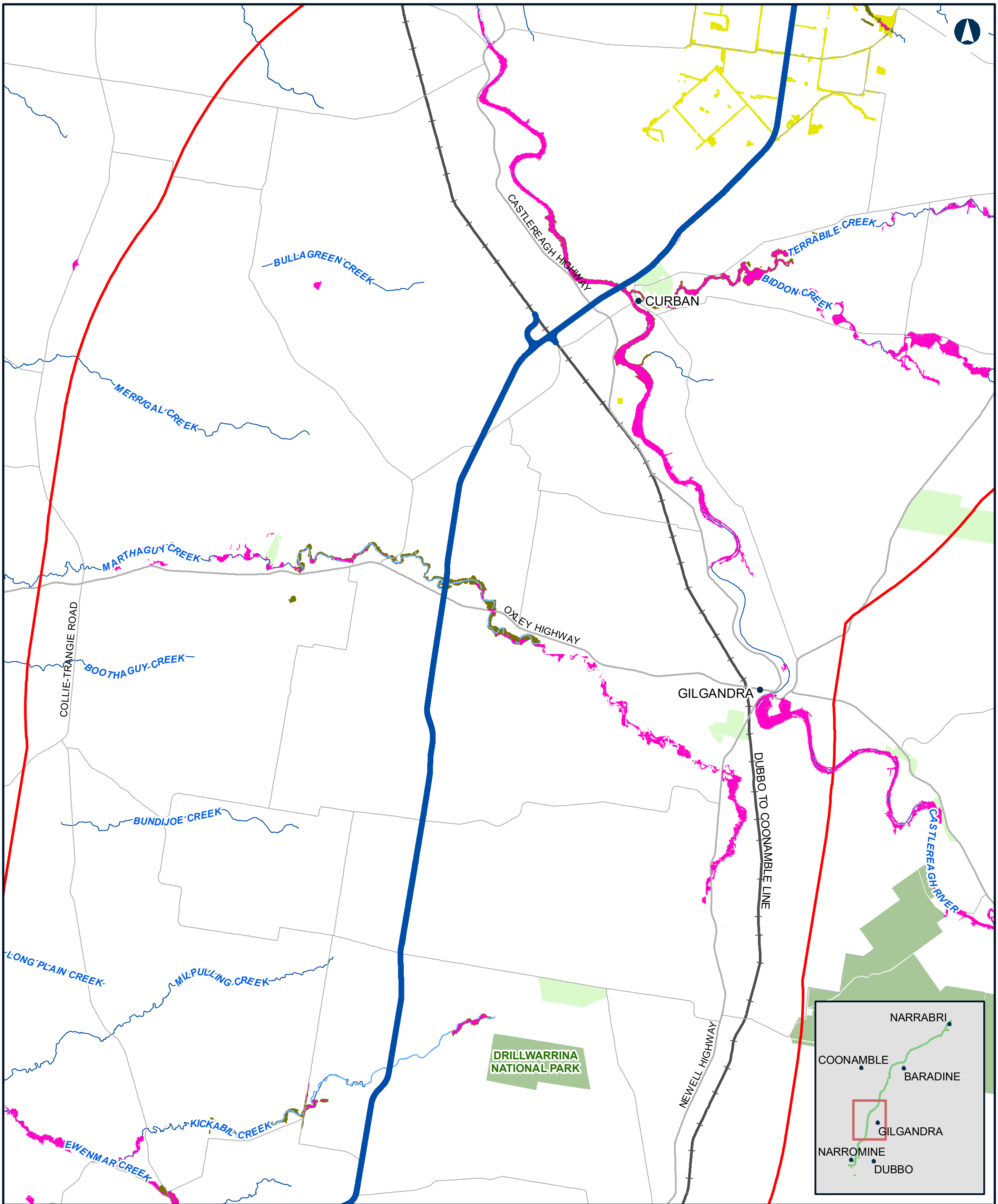

NARROMINE TO NARRABRI Potential GDE mapping (BOM, 2018a) and High Priority GDE mapping (NSW Gov WSPs) Figure 5.8b

0 3.5 7 Km

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LEGEND

- Alignment
- Study area
- High priority GDE vegetation (NSW Gov WSPs)
- High potential GDE - from regional studies (terrestrial)
- Low potential GDE - from regional studies (terrestrial)
- Moderate potential GDE - from national assessment (aquatic)
- Low potential GDE - from national assessment (aquatic)

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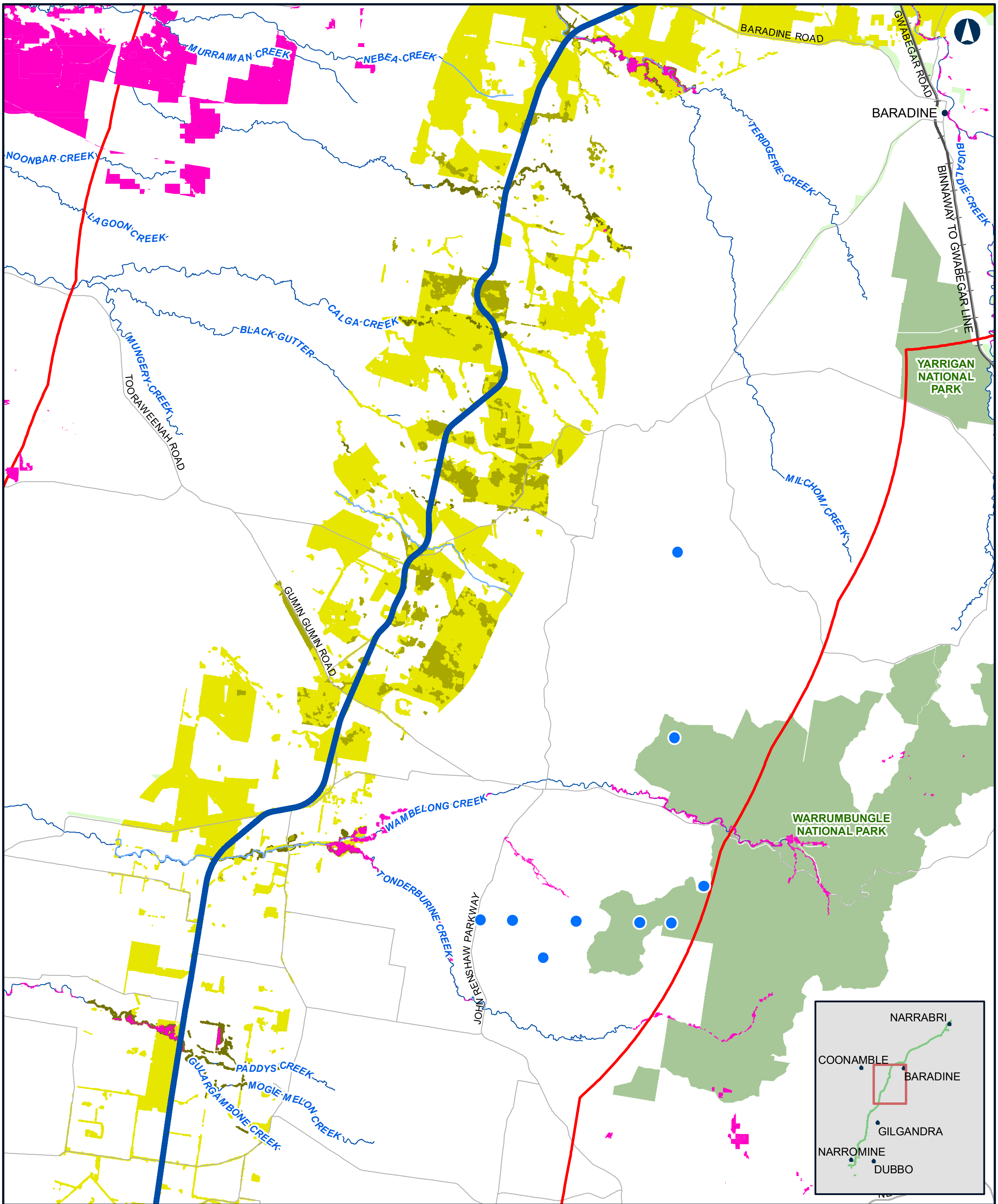

NARROMINE TO NARRABRI Potential GDE mapping (BOM, 2018a) and High Priority GDE mapping (NSW Gov WSPs) Figure 5.8c

0 3.5 7 Km

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LEGEND
- Alignment
- Study area
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- High Priority GDE (spring) (WSP for the NSW MDB Fractured Rock Groundwater Sources 2020)
- High potential GDE - from regional studies (terrestrial)
- Moderate potential GDE - from regional studies (terrestrial)
- Low potential GDE - from regional studies (terrestrial)
- Moderate potential GDE - from national assessment (aquatic)

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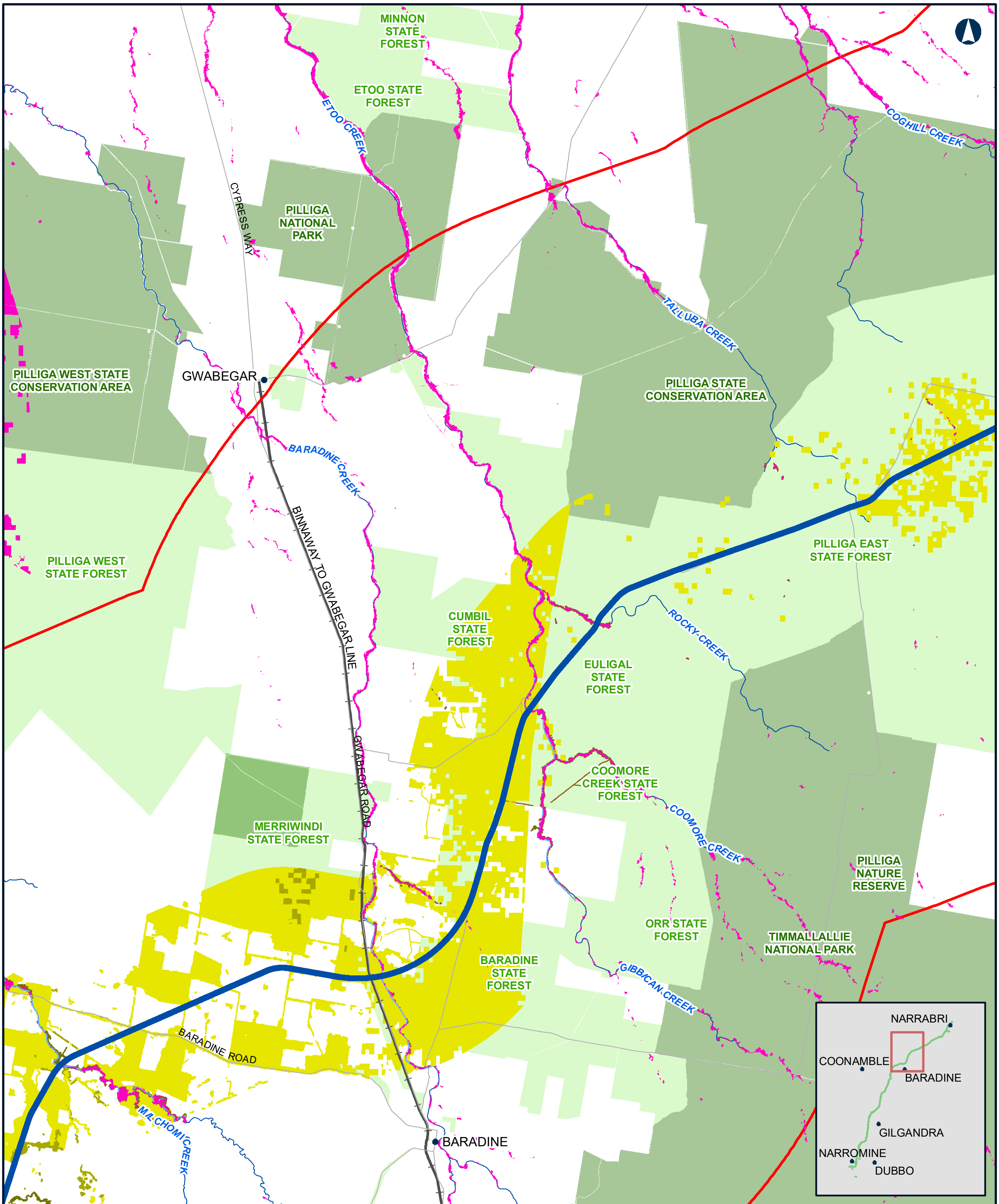

NARROMINE TO NARRABRI Potential GDE mapping (BOM, 2018a) and High Priority GDE mapping (NSW Gov WSPs) Figure 5.8d

0 3.5 7 Km

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LEGEND

- Alignment
- Study area
- High priority GDE vegetation (NSW Gov WSPs)
- High potential GDE - from regional studies (terrestrial)
- Moderate potential GDE - from regional studies (terrestrial)
- Low potential GDE - from regional studies (terrestrial)
- Moderate potential GDE - from national assessment (aquatic)

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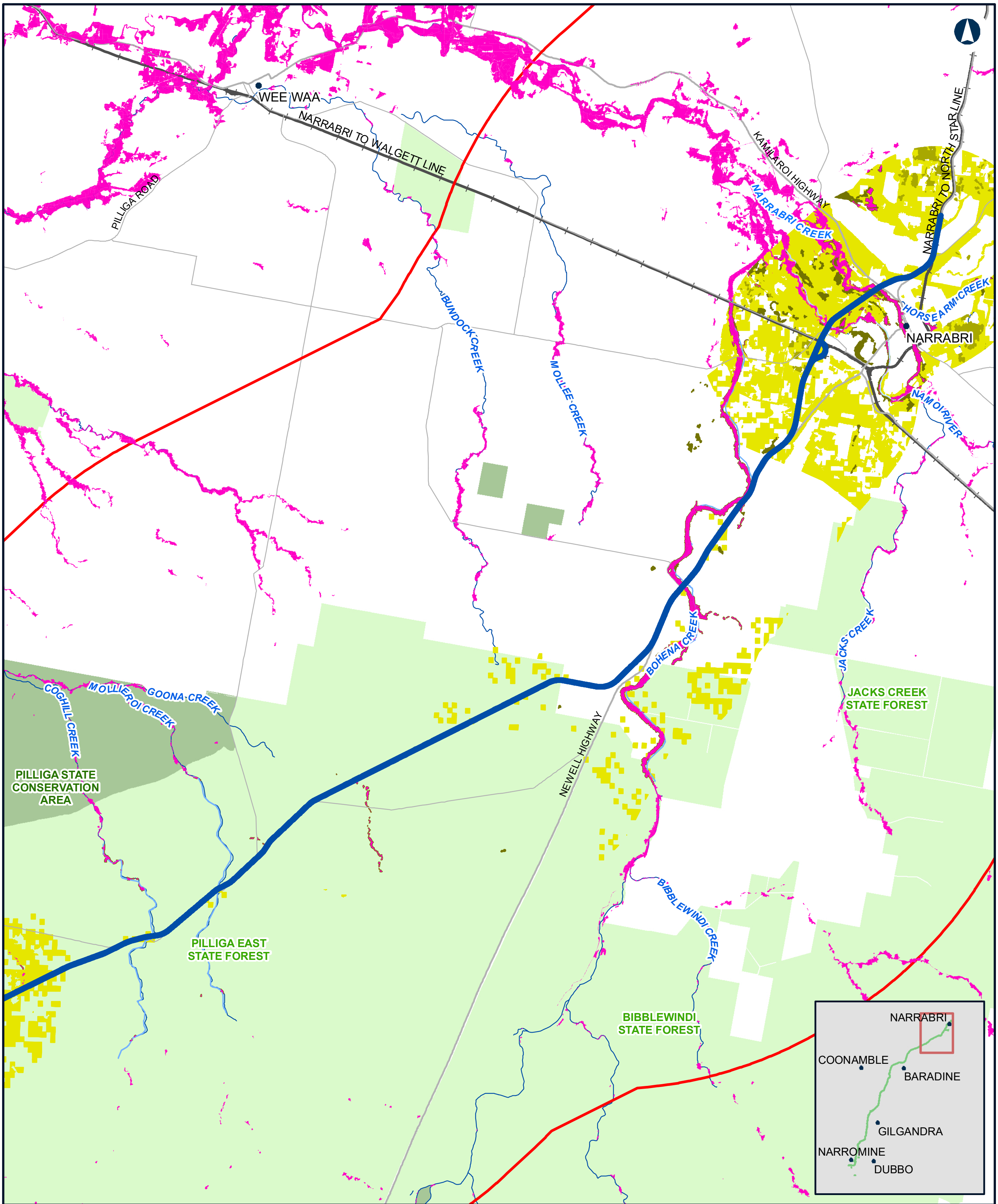

NARROMINE TO NARRABRI Potential GDE mapping (BOM, 2018a) and High Priority GDE mapping (NSW Gov WSPs) Figure 5.8e

0 3.5 7 Km

Coordinate System: GDA 1994 MGA Zone 55

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LEGEND

- Alignment
- Study area
- High priority GDE vegetation (NSW Gov WSPs)
- High potential GDE - from regional studies (terrestrial)
- Moderate potential GDE - from regional studies (terrestrial)
- Low potential GDE - from regional studies (terrestrial)
- Moderate potential GDE - from national assessment (aquatic)
- Low potential GDE - from national assessment (aquatic)
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Terrestrial GDE mapping

There are four main broad areas of mapped potential terrestrial GDEs which the proposal crosses:

- Narromine to Burroway area – low and high potential terrestrial GDEs including grasses and woodland species.
- Tonderburine to Kenebri area – low, medium and high potential terrestrial GDEs including woodland and forest species.
- Pilliga East State Forest – low potential terrestrial GDEs including woodland and forest species.
- Narrabri area – low and high potential terrestrial GDEs including grassland, woodland, forest and sedgeland species.

Aquatic GDE mapping

The proposal crosses 14 individual watercourses (Bohena Creek is crossed twice) which are mapped in the BOM's (2018a) GDE atlas as either low or moderate potential GDEs. These watercourses are documented in Table 5.3.

Table 5.3 BOM (2018a) Aquatic GDE potential mapping summary

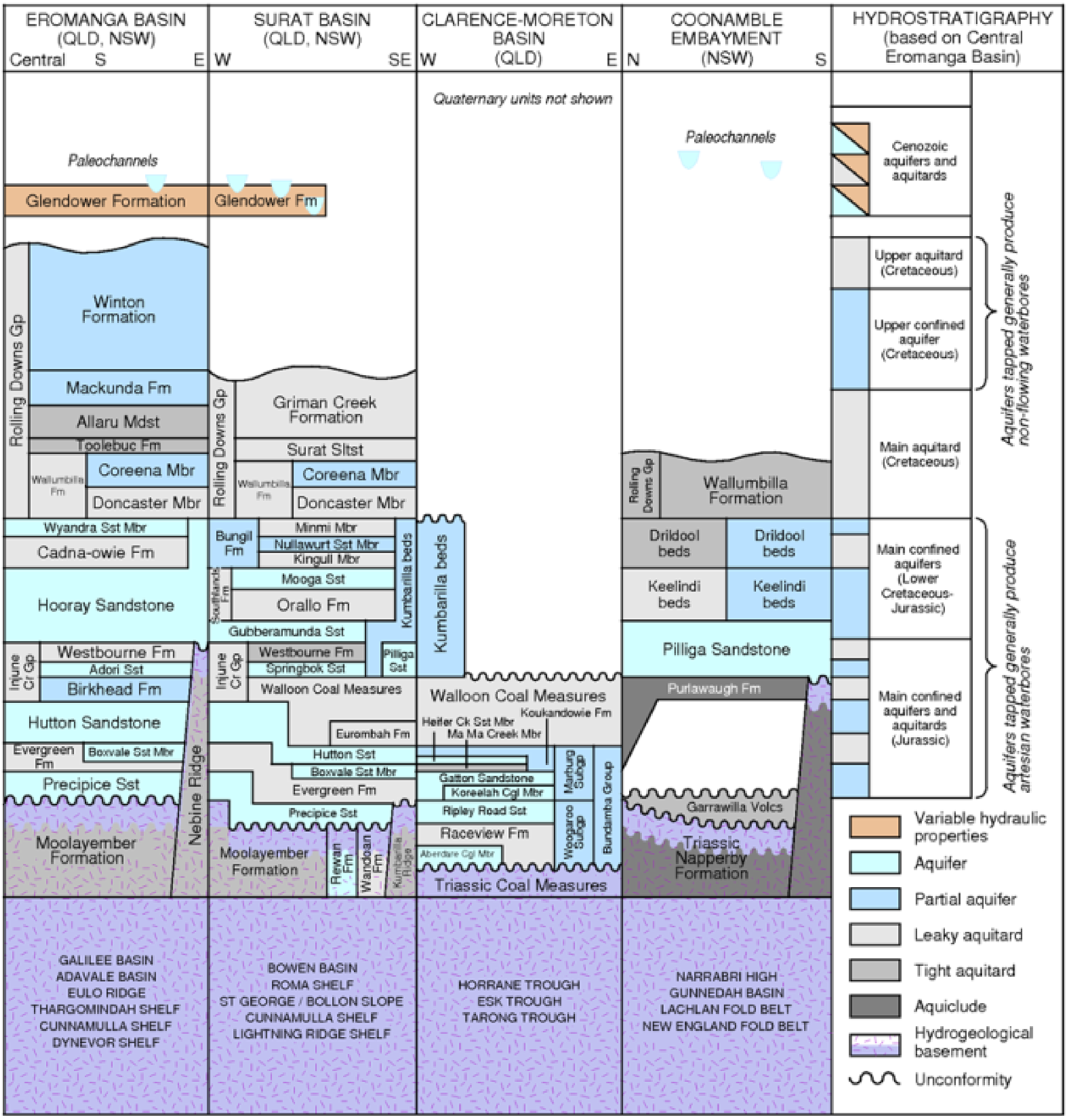
Creek or River	Aquatic GDE potential
Wallaby Creek	Moderate
Macquarie River	Low
Kickabil Creek	Moderate
Marthaguy Creek	Moderate
Castlereagh River, Curban	Low
Baronne Creek, south of Mount Tenandra	Moderate
Caleriwi Creek, north of Gulargambone Baradine Road	Moderate
Teridgerie Creek, south of Coonamble Road	Moderate
Baradine Creek, east of Gwabegar Road	Moderate
Etoo Creek, south of Aloes Road	Moderate
Coghill Creek	Moderate
Mollieroi Creek, near intersection of Jack Scott Road and Pilliga Forest Way Road	Moderate
Bohena Creek (crosses alignment twice)	Moderate
Namoi River	Low

5.8 Hydrogeology

5.8.1 Regional groundwater information

Hydrostratigraphic units

The majority of the proposal is in the Coonamble Embayment region in the east of the Surat Basin, which forms the south eastern portion of the GAB (Ransley et al, 2015). A stratigraphy relationship diagram which includes the Coonamble Embayment region is provided in Figure 5.9.



Source: Ransley et al, 2012

Figure 5.9 GAB stratigraphy

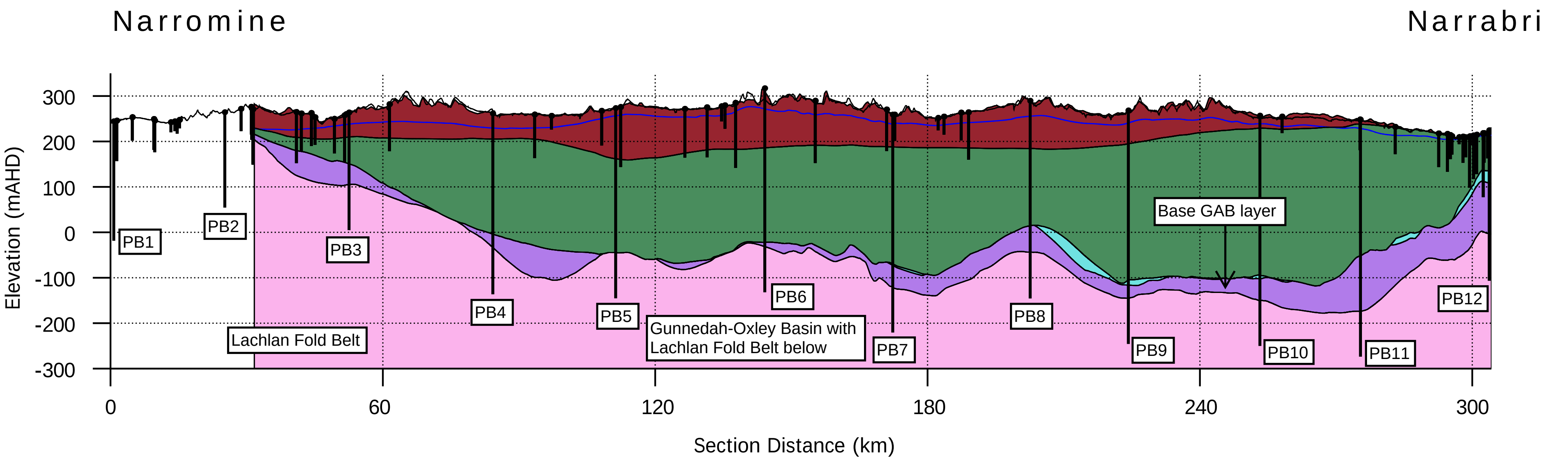
Geoscience Australia (2013) published surfaces of the principal GAB hydrostratigraphic units. To assist understanding of these units and to facilitate creation of a fence section (Figure 5.10), a three dimensional geological model of the GAB's main hydrostratigraphic units was prepared using the Geoscience Australia (2013) GAB hydrostratigraphic surfaces within Leapfrog, a geological modelling program.

The BOM's 'Australian Groundwater Explorer 3D Aquifer Visualisation: GAB', which is based on the same hydrostratigraphic surfaces, indicates whether the hydrostratigraphic units behave as aquifers or aquitards.

The Geoscience Australia (2013) GAB hydrostratigraphic units comprise:

- Cenozoic overburden – This unit consists of sedimentary basins, with accumulations of alluvial sediments in the valleys of major watercourses, deposits of colluvium and deposits of sedimentary rock. This unit thins and pinches out in the very northern portion of the alignment. Elsewhere, the Cenozoic material extends from the surface to depths ranging from about 10 to 100 metres.
- Hooray Sandstone and Equivalents – This unit generally behaves as an aquifer and encompasses the Pilliga Sandstone, which is the main rock aquifer of the GAB in the study area. Pilliga Sandstone is described as medium to very coarse grained, well sorted, angular to subangular quartzose sandstone and conglomerate, with minor interbeds of mudstone, siltstone and fine grained sandstone and coal and common carbonaceous fragments and iron staining (Meakin and Morgan, 1999). Rare lithic fragments are also present. This unit has a thickness of about 200-300 metres which decreases in the south (about 25 metres thick) and north (about 90 metres thick).
- Injune Creek Group – This unit generally behaves as an aquitard and is described to comprise calcareous lithic sandstone, siltstone, mudstone, coal, conglomerate (Exon, 1966). This unit exists in isolated portions in the north of the proposal, is relatively thin (up to about 25 metres thick) and is situated below the Hooray Sandstone and Equivalents.
- Jurassic-cretaceous material – The base of this unit forms the base of the GAB and top of either the Lachlan Fold Belt or Gunnedah-Oxley Basin rocks. The unit behaves as an aquitard or aquiclude (Ransley et al, 2012). The unit's thickness ranges from about 20 to 100 metres, with an average thickness of about 55 metres. Figure 5.10 shows the unit to thin or pinch out in isolated zones. However, other sources (Figure 5.6 and Figure 5.7) show the unit as regionally extensive. In Figure 5.6 the Pulawaugh Formation is synonymous with the Geoscience Australia (2013) Jurassic-Cretaceous unit. The unit underlies the Injune Creek Group and Hooray Sandstone and Equivalents.

It is noted that regional geological mapping (section 5.5) shows some differences for the upper unit when compared to the Geoscience Australia (2013) surfaces. Regional geological mapping shows Jurassic aged material outcropping in certain locations along the proposal's alignment, most notably in the Pilliga and Mount Tenandra regions. However, with the exception of the far northern area of the proposal, the Geoscience Australia (2013) surfaces show no outcropping of material older than Cenozoic. Based on the regional geological mapping (section 5.5), the Cenozoic cover is likely less extensive and thinner in places than indicated by Figure 5.10.



Legend

GAB Hydrostratigraphic Units (Geoscience Australia)

- Basement
- Injune Creek Group
- Cenozoic
- Jurassic-Cretaceous Sequence
- Hooray SS and equiv
- PB1 Centre bore at proposal borefield and borefield reference
- Existing licensed bore (with depth details) within 4km of proposal alignment
- GAB Water Table (mAHD) (Geoscience Australia))

Figure 5.10 Fence section along proposal alignment showing GAB hydrostratigraphic units, proposal borefield locations and existing bores within 4km of alignment

Scale: 1:1,300,000

Vertical exaggeration: 100x

0m 60000m

Groundwater bores

Bore density

Groundwater bore locations from the BOM's (2018b) Australian Groundwater Explorer were reviewed to investigate groundwater bore density in the region of the proposal. A total of 5,100 groundwater bores were identified within 20 kilometres of the proposal. Groundwater bore locations within 20 kilometres of the proposal are shown in Figure 5.11, which indicates that with the exception of the Pilliga East State Forest area, groundwater bore density is fairly consistent along and adjacent to the proposal with typical bore spacing of about 0.5-2.0 kilometres. In the Pilliga East State Forest area bore spacing is about 5-10 kilometres.

Licensed groundwater bores within one kilometre of the proposal site are listed in Table 5.4.

Table 5.4 Licensed groundwater bores within one kilometre of the proposal site

Bore ID	SWL (m)	Total depth (m)	Purpose	Status	Location		
					Easting	Northing	Suburb
GW001568	-	89	Stock / Domestic	Unknown	614948	6425614	Narromine
GW001373	-	51.8	Water supply	Unknown	618286	6424744	Narromine
GW801529	-	68	Water supply	Proposed	622273	6427139	Narromine
GW026753	-	69.8	Irrigation	Unknown	621667	6427506	Narromine
GW025922	-	31.1	Water supply	Unknown	621301	6427511	Narromine
GW040487	19.81	31.1	Water supply	Unknown	621042	6427729	Narromine
GW000553	-	57.3	Monitoring	Unknown	621147	6427790	Narromine
GW045544	-	25.9	Stock / Domestic	Functioning	621708	6428323	Narromine
GW000517	25.83	100.5	Monitoring	Abandoned	621832	6429113	Narromine
GW803131	-	37.5	Water supply	Functioning	621471	6429112	Narromine
GW803130	-	30.5	Water supply	Unknown	621506	6429233	Narromine
GW803140	-	49	Water supply	Removed	621445	6429240	Narromine
GW013682	-	29.7	Water supply	Abandoned	621444	6429263	Narromine
GW049334	15.19	18.3	Monitoring	Functioning	622853	6430398	Narromine
GW803129	-	22	Water supply	Functioning	621867	6430824	Narromine
GW803565	-	50	Water supply	Functioning	621220	6431252	Narromine
GW800438	-	21.5	Water supply	Functioning	621872	6431784	Narromine
GW096077	-	25	Monitoring	Functional	621062	6432214	Narromine
GW800577	-	18.5	Stock / Domestic	Functioning	621913	6432284	Narromine
GW012279	-	27.4	Irrigation	Proposed	621726	6432433	Narromine
GW800709	-	-	-	Functioning	621663	6432584	Narromine
GW057080	-	20	Water supply	Unknown	621453	6432705	Narromine
GW057143	-	22.5	Water supply	Unknown	621416	6432745	Narromine
GW804769	-	19	Water supply	Functioning	621380	6432845	Narromine
GW039464	-	40	Irrigation	Functioning	621341	6432890	Narromine

Bore ID	SWL (m)	Total depth (m)	Purpose	Status	Location		
					Easting	Northing	Suburb
GW012282	-	18.6	Water supply	Unknown	621809	6432833	Narromine
GW012275	-	19.8	Irrigation	Proposed	621731	6432864	Narromine
GW048672	-	53	Stock / Domestic	Unknown	621525	6433113	Narromine
GW054543	-	15.5	Water supply	Unknown	621239	6433301	Narromine
GW054573	-	16.7	Water supply	Unknown	621425	6433484	Narromine
GW054572	-	76[1]	Water supply	Unknown	621348	6433639	Narromine
GW801687	-	18	Water supply	Removed	623003	6433834	Narromine
GW015711	20.33	110.8	Monitoring	Unknown	622174	6437048	Narromine
GW801011	-	51.81	Water supply	Functioning	624663	6440884	Burroway
GW801010	-	35.05	Water supply	Functioning	624863	6440909	Burroway
GW000986	-	57.9	Water supply	Unknown	624972	6443081	Burroway
GW002591	-	64	Unknown	Unknown	624503	6445427	Burroway
GW001017	36.58	49.1	Monitoring	Unknown	625556	6445846	Burroway
GW028618	-	77.7	Stock / Domestic	Unknown	624682	6447242	Burroway
GW802138	-	61	Water supply	Functioning	625818	6448074	Burroway
GW016225	-	69.5	Water supply	Household	626186	6448024	Burroway
GW045259	-	122	Water supply	Household	626399	6448237	Burroway
GW003567	-	78.6	Stock / Domestic	Unknown	627581	6450502	Burroway
GW000197	-	112.7	Stock / Domestic	Unknown	626464	6457722	Burroway
GW003263	-	78.9	Unknown	Unknown	627638	6457184	Burroway
GW008036	32.82	83.8	Monitoring	Non-functioning	627571	6458109	Burroway
GW008327	-	72.5	Stock / Domestic	Unknown	628905	6459817	Burroway
GW005495	-	46.3	Unknown	Unknown	628810	6460650	Burroway
GW001789	-	60.90	Stock / Domestic	Unknown	629151	6460645	Burroway
GW00154	-	69.70	Stock / Domestic	Unknown	630888	6463056	Kickabil
GW000437	-	76.2	Water supply	Unknown	632599	6463342	Kickabil
GW803295	-	109	Water supply	Functioning	633748	6462350	Kickabil
GW002291	-	71	Water supply	Unknown	633741	6462342	Kickabil
GW008176	-	66.10	Water supply	Unknown	633577	6463853	Kickabil
GW001482	-	103.6	Stock / Domestic	Unknown	634861	6463682	Kickabil
GW801698	-	87	Water supply	Functioning	634926	6463368	Kickabil

Bore ID	SWL (m)	Total depth (m)	Purpose	Status	Location		
					Easting	Northing	Suburb
GW007492	-	76.2	Water supply	Unknown	636548	6466093	Kickabil
GW033536	-	91.4	Stock / Domestic	Functioning	638248	6471460	Balladoran
GW000154	-	103.6	Water supply	Unknown	638676	6472009	Balladoran
GW005231	-	106.6	Unknown	Unknown	638909	6477580	Balladoran
GW005783	-	112.4	Stock / Domestic	Non-functioning	641683	6491895	Gilgandra
GW008593	-	31	Water supply	Unknown	642523	6495518	Gilgandra
GW049338	-	21.3	Unknown	Unknown	641157	6495813	Gilgandra
GW010998	-	80.7	Stock / Domestic	Unknown	643025	6499514	Curban
GW036348	29.56	96	Monitoring	Proposed	643841	6503230	Curban
GW800733	-	28.65	Stock / Domestic	Functioning	644688	6503609	Curban
GW036338	26.51	90	Monitoring	Proposed	644773	6503894	Curban
GW008556	-	48.8	Water supply	Unknown	644865	6504817	Curban
GW045002	-	36.6	Water supply	Unknown	644241	6505472	Curban
GW033801	-	30.2	Stock / Domestic	Unknown	645103	6506785	Curban
GW009982	-	80.1	Water supply	Unknown	647116	6507403	Curban
GW018825	-	54.9	Stock / Domestic	Unknown	645625	6508287	Curban
GW008564	-	32	Stock / Domestic	Unknown	645721	6509425	Curban
GW010329	-	106.6	Stock / Domestic	Unknown	648709	6508151	Curban
GW001254	-	47.5	Unknown	Unknown	648398	6510373	Curban
GW028480	-	7.6	Exploration	Proposed	650872	6509967	Curban
GW028478	-	4.8	Exploration	Proposed	650979	6510089	Curban
GW028478	-	7.6	Exploration	Proposed	651269	6510085	Curban
GW032787	-	10.3	Water supply	Abandoned	650758	6511232	Curban
GW012565	-	60.9	Stock / Domestic	Functioning	652680	6510957	Curban
GW802319	-	109	Water supply	Functioning	652023	6512244	Curban
GW000559	-	92.9	Unknown	Unknown	651935	6512293	Curban
GW000593	-	61.8	Unknown	Abandoned	651675	6512604	Curban
GW005296	-	76.2	Water supply	Functioning	653982	6513341	Curban
GW002468	-	126.4	Unknown	Unknown	654110	6514879	Curban
GW803616	-	132	Water supply	Functioning	656676	6516600	Curban
GW030836	-	76.2	Water supply	Unknown	658251	6516480	Curban

Bore ID	SWL (m)	Total depth (m)	Purpose	Status	Location		
					Easting	Northing	Suburb
GW019182	-	66.4	Water supply	Unknown	657960	6521659	Armatree
GW000801	-	65.5	Unknown	Unknown	659640	6522711	Armatree
GW009677	-	107.2	Stock / Domestic	Unknown	659884	6530007	Tonderburine
GW009175	-	121.6	Water supply	Unknown	660724	6531349	Tonderburine
GW051875	-	87.5	Stock / Domestic	Unknown	659815	6532441	Tonderburine
GW009125	-	110.3	Stock / Domestic	Unknown	661120	6534762	Tonderburine
GW013840	-	48.7	Stock / Domestic	Unknown	660195	6536532	Gulargambone
GW007190	-	33.2	Stock / Domestic	Unknown	662114	657488	Gulargambone
GW045338	-	51.5	Stock / Domestic	Unknown	662417	6538253	Gulargambone
GW045339	-	64	Stock / Domestic	Unknown	663395	6538269	Gulargambone
GW005450	-	51.8	Stock / Domestic	Unknown	662427	6538961	Gulargambone
GW004838	-	105.8	Unknown	Unknown	664416	6539269	Tonderburine
GW005525	-	49	Unknown	Unknown	665278	6540210	Mount Tenandra
GW013442	-	33.8	Irrigation	Unknown	667386	6544674	Mount Tenandra
GW004365	-	276.1	Unknown	Functioning	667599	6546395	Mount Tenandra
GW019684	-	56.6	Stock / Domestic	Unknown	672483	6553678	Black Hollow
GW920649	-	137.1	Stock / Domestic	Functioning	672201	6554237	Black Hollow
GW020651	-	121.9	Stock / Domestic	Functioning	672721	6555307	Black Hollow
GW004096	-	341.30	Unknown	Unknown	674936	6562632	Quanda
GW013092	-	114.6	Water supply	Unknown	675520	6564316	Quanda
GW015435	-	115.2	Stock / Domestic	Unknown	674316	6566892	Teridgerie
GW010392	-	91.4	Water supply	Unknown	675581	6567949	Teridgerie
GW013273	-	57.9	Stock / Domestic	Unknown	675610	6569735	Teridgerie
GW020245	-	85.3	Stock / Domestic	Unknown	677298	6572295	Teridgerie
GW001858	-	68	Stock / Domestic	Unknown	678336	6575665	Baradine

Bore ID	SWL (m)	Total depth (m)	Purpose	Status	Location		
					Easting	Northing	Suburb
GW001824	-	135.6	Stock / Domestic	Unknown	678653	6575568	Baradine
GW005149	-	24.4	Stock / Domestic	Unknown	679184	6577130	Baradine
GW055088	-	27.4	Unknown	Unknown	679651	6578046	Baradine
GW001235	-	39.6	Stock / Domestic	Unknown	680544	6579047	Baradine
GW001144	-	61.2	Stock / Domestic	Unknown	684048	6580496	Baradine
GW000985	-	104.2	Unknown	Unknown	685393	6581459	Baradine
GW008394	-	64	Stock / Domestic	Unknown	687248	6581211	Baradine
GW044203	-	31.6	Stock / Domestic	Unknown	689547	6583480	Baradine
GW969811	-	41.7	Stock / Domestic	Functioning	691896	6583145	Baradine
GW001137	-	58.2	Water supply	Unknown	700591	6587222	Baradine
GW002443	-	58.2	Unknown	Unknown	700059	6585784	Baradine
GW970422	-	22	Exploration	Functional	751391	6623862	Bohena Creek
GW006577	-	67.6	Stock / Domestic	Unknown	753527	6624433	Bohena Creek
GW965761	-	25	Water supply	Unknown	755647	6625457	Bohena Creek
GW971263	-	54.9	Water supply	Functioning	755371	6625818	Bohena Creek
GW000017	-	124.7	Stock / Domestic	Unknown	754180	6626143	Bohena Creek
GW000514	-	138	Stock / Domestic	Unknown	754848	6627298	Bohena Creek
GW970568	-	1.74	Exploration	Functioning	756482	6628763	Bohena Creek
GW007862	-	85.6	Water supply	Unknown	757968	6629382	Bohena Creek
GW965153	-	60	Water supply	Unknown	758074	6630613	Jacks Creek
GW045133	-	48.8	Water supply	Unknown	762702	6636356	Narrabri
GW042691	-	51.8	Irrigation	Unknown	762870	636660	Narrabri
GW03554	-	48.7	Stock / Domestic	Unknown	762827	6637093	Narrabri
GW003716	-	74.3	Stock / Domestic	Unknown	762310	6638923	Narrabri
GW901674	-	64	Water supply	Unknown	761750	6639013	Narrabri
GW902083	-	99.06	Stock / Domestic	Unknown	761467	6639382	Narrabri
GW968713	-	86.9	Water supply	Functioning	762011	6639706	Narrabri
GW071866	-	67	Water supply	Unknown	763505	6639523	Narrabri
GW061059	-	91.4	Water supply	Functioning	763659	6639476	Narrabri

Bore ID	SWL (m)	Total depth (m)	Purpose	Status	Location		
					Easting	Northing	Suburb
GW967624	-	44	Water supply	Unknown	763673	6639488	Narrabri
GW063657	-	47.5	Water supply	Unknown	763504	6639696	Narrabri
GW026649	-	83.5	Irrigation	Abandoned	763471	6640528	Narrabri
GW968684	-	53	Water supply	Functioning	763438	6641244	Narrabri
GW968056	-	40.6	Water supply	Functioning	763468	6641624	Narrabri
GW030123	5.6	73.2	Monitoring	Unknown	763973	6641379	Narrabri
GW969289	-	30	Water supply	Functioning	764380	6641322	Narrabri
GW030544	1.69	31.5	Monitoring	Unknown	764780	6641575	Narrabri
GW071619	-	36.5	Water supply	Unknown	765112	6641775	Narrabri
GW966954	-	15.61	Water supply	Unknown	764561	6642860	Narrabri
GW967998	-	16	Water supply	Functioning	764183	6643331	Narrabri
GW028530	-	76.2	Irrigation	Functioning	764335	6643065	Narrabri
GW900398	-	25.6	Water supply	Unknown	765586	6642679	Narrabri
GW030122	6.43	57.6	Monitoring	Unknown	765404	6643070	Narrabri
GW900403	-	25.6	Water supply	Unknown	765668	6642945	Narrabri
GW050565	-	14	Water supply	Unknown	765800	6642845	Narrabri
GW065070	-	100	Water supply	Unknown	766547	6642750	Narrabri
GW025499	-	91.7	Monitoring	Functioning	766545	6642703	Narrabri
GW970882	-	95	Water supply	Functioning	766737	6642979	Narrabri
GW053917	-	44	Irrigation	Unknown	765922	6643458	Narrabri
GW011532	-	7	Irrigation	Unknown	766775	6643376	Narrabri
GW970625	-	18	Water supply	Functioning	766120	6643935	Narrabri
GW067672	-	28.5	Unknown	Unknown	765552	6644207	Narrabri
GW965287	-	16.76	Water supply	Unknown	765570	6644391	Narrabri
GW969285	-	23	Stock / Domestic	Functioning	765780	644350	Narrabri
GW017525	-	10.6	Irrigation	Unknown	765890	6644353	Narrabri
GW056947	-	15	Water supply	Unknown	765788	6644571	Narrabri
GW005122	-	8.5	Unknown	Unknown	765923	6644599	Narrabri
GW965081	-	25	Recreation	Unknown	766234	6644190	Narrabri
GW030121	5.41	112.8	Monitoring	Unknown	766600	6643873	Narrabri
GW901193	-	20	Commercial / Industrial	Unknown	766813	6643837	Narrabri
GW902386	-	24	Water supply	Unknown	767722	6643846	Narrabri
GW047774	-	85.3	Irrigation	Unknown	767493	6644283	Narrabri
GW902817	-	96	Irrigation	Unknown	767391	6644501	Narrabri
GW030120	11.3	91.4	Monitoring	Unknown	768231	6643864	Narrabri
GW059136	-	87	Irrigation	Unknown	768084	76644422	Narrabri

Bore ID	SWL (m)	Total depth (m)	Purpose	Status	Location		
					Easting	Northing	Suburb
GW965355	-	72.5	Irrigation	Unknown	768880	6644057	Narrabri
GW902203	-	102	Exploration	Unknown	768932	6644093	Narrabri
GW030242	13.44	83.8	Exploration	Unknown	768896	6643724	Narrabri
GW010573	-	15.5	Irrigation	Abandoned	769152	6645444	Narrabri
GW065028	-	141	Irrigation	Unknown	769179	6645443	Narrabri
GW012144	-	20.7	Irrigation	Abandoned	769261	6645503	Narrabri
GW012148	-	64.9	Irrigation	Abandoned	769291	6645656	Narrabri
GW012138	-	27.4	Irrigation	Unknown	768541	6645582	Narrabri
GW012113	-	94.4	Irrigation	Unknown	768521	6645891	Narrabri
GW012129	-	87.8[1]	Irrigation	Unknown	768605	6646012	Narrabri
GW053461	-	54.9	Irrigation	Functioning	768883	6646468	Narrabri
GW067438	-	23	Water supply	Unknown	768867	6646506	Narrabri
GW010612	-	50.5	Water supply	Unknown	769763	6647432	Narrabri
GW019353	-	36.2	Irrigation	Unknown	769773	6647832	Narrabri
GW971376	-	-	Monitoring	Unknown	769383	6648291	Narrabri

Source: BOM, 2018b

Note: 1. (-) Information not available from the BOM Australian Groundwater Explorer (BOM, 2018b)

Bore depth

Groundwater bore depth for the 5,100 bores within the study area was analysed as a proxy to determine the typical depth of targeted aquifer(s) in the study area. Bore depth statistics (Table 5.5) indicate that bores in the study area typically have shallow to moderate depths. The average depth was 66 metres and the 90th percentile was 122 metres.

Existing bores within four kilometres of the proposal's alignment which had a surface level value and bore depth value are shown on the fence section (Figure 5.10).

Table 5.5 Groundwater bore depth statistics

Groundwater bore depth statistics (m)							
Min	10th %ile	25th %ile	Mean	Median	75th %ile	90th %ile	Max
0	12	30	66	54	91	122	1,082

Bore water salinity

Available salinity and electrical conductivity (EC) data from the BOM's Australian Groundwater Explorer (2018b) was reviewed for the bores within 20 kilometres of the proposal. For the purpose of data analysis, the most recent salinity or EC value for each bore was assigned to the respective bore, and all salinity values were converted to EC values so that a single analyte could be analysed. EC statistics are summarised in Table 5.6 and the following summary points are made:

- 762 out of the 5,100 bores had salinity or EC data.
- Minimum, mean and maximum salinity values were 6 µS/cm, 1,567 µS/cm, 55,311 µS/cm respectively.

- In accordance with classifications from Mayer et.al (2005), beyond about the 30th percentile, EC values are at a minimum characteristic of brackish water, as is the median value. The average EC value is characteristic of saline water, as is the 90th percentile value. The maximum EC value of 55,311 µS/cm is characteristic of brine water.
- In accordance with classifications from Mayer et.al (2005), brackish water is feasible for irrigation of certain crops only and useful for most livestock, and saline water is useful for most livestock.

Table 5.6 Groundwater bore EC statistics

Groundwater bore EC (µS/cm)							
Min	10th %ile	25th %ile	Mean	Median	75th %ile	90th %ile	Max
6	329	576	1567	793	1,350	2,610	55,311

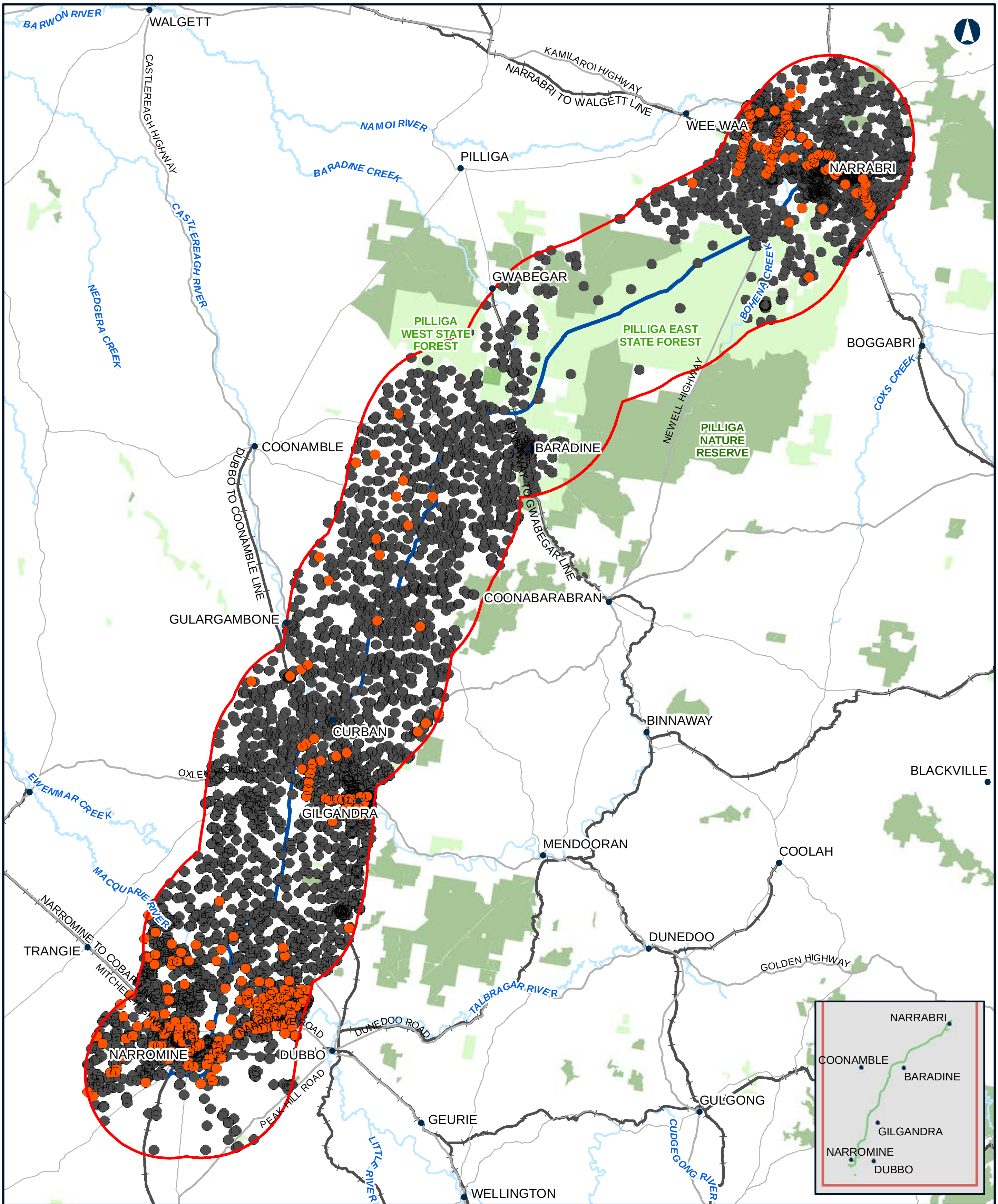
GAB regional water table level

The Australian Geoscience's (catalogue number 75830) regional interpretation of the water table elevation for the GAB is shown on the fence section (Figure 5.10). The regional water table occurs at a typical depth of about 20 metres to 30 mBGL; however, there are isolated areas where the regional water table is closer to the ground surface. In such areas the GAB's regional water table would be coplaner, higher or beneath, but closer to, perched water levels in overlying quaternary alluvium.

Regional GAB groundwater quality

Colour graded and contoured groundwater quality maps are provided in Ransley et al (2015) for a range of analytes for the Hooray Aquifer, which is considered to be broadly equivalent to the most commonly tapped rock aquifer by existing bores in the region of the proposal. Water quality parameter concentrations were visually interpreted from viewing the colour graded maps and are summarised below:

- Alkalinity as $CaCO_3$ – about 200-300 mg/L
- Total dissolved solids – about 600 mg/L (about 920 µS/cm), which is considered fresh
- Chloride – about 100 mg/L
- Sodium – about 200 mg/L
- pH – about 7.2
- Sulfate – about 10-20 mg/L
- Magnesium – about 10-50 mg/L
- Calcium – about 5-20 mg/L
- Potassium – about 5-10 mg/L
- Fluoride – about 0.7 mg/L.



NARROMINE TO NARRABRI Existing groundwater bores in study area Figure 5.11

0 10 20 Km

Coordinate System: GDA 1994 MGA Zone 55

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Date: 30/03/2020 Paper: A4
Author: JacobsGHD Scale: 1:1,240,000
Data Sources: Basemap layers: NSWSS; NGIS bores: BOM; Project elements: GHDJACOBS

LEGEND

- Alignment
- Study area
- Bores with one or less water level measurement
- Bores with more than one water level measurement

INLAND RAIL ARTC

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

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Recharge

The study area predominantly lies within a GAB groundwater recharge area, where recharge principally enters aquifer strata at exposed outcrops. Recharge may occur at lesser rates, via overlying strata, including alluvial groundwater systems, where there is potential for downward groundwater movement. Herczeg (2007) suggests that recharge rates are low (about 5 to 10 millimetres per year).

Discharge

Discharge of alluvial groundwater systems in the proposal area occurs through bore pumping, baseflow to rivers and vertical leakage to underlying aquifers (when hydraulic head is higher than that of underlying aquifers).

Discharge of deeper GAB groundwater systems in the proposal area occurs through bore pumping, vertical leakage to overlying aquifers (when hydraulic head is higher than that of overlying aquifers), including alluvial aquifers, and through springs (Herczeg, 2007).

Hooray Aquifer & Equivalents parameters

Previously estimated aquifer properties for the Hooray Sandstone and Equivalents hydrostratigraphic unit are summarised in Table 5.7.

Table 5.7 Estimated hydraulic properties of the Cadna-Owie-Hooray aquifers of the GAB from field tests

Reference	K_h (m/d)	K_v (m/d)	T (m²/d)	Storativity	Porosity
Habermehl (1980)	0.1 – 10	10^{-4} – 0.1	1 – 2000	10^{-5} – 10^{-4}	10 – 30
Audibert (1976)	0.02 – 82		0.1 – 2295	2.5 x 10^{-4} (mean)	0.21 (mean)
RUST PPK (1994)	1 – 13.1			2.7 x 10^{-4} (mean)	
Berry & Armstrong (1995)	1.6 – 18.5		5 – 380		
Armstrong & Berry (1997)	0.5 – 22		0.1 – 3200		

Notes: K_h = horizontal hydraulic conductivity, K_v = vertical hydraulic conductivity, T = transmissivity.

In groundwater modelling studies completed in the Narrabri region for the Narrabri Gas Project (CDM Smith, 2016) and Narrabri Coal Project (Aquaterra, 2009), the parameters summarised in Table 5.8 were adopted for modelling the upper formations applicable to the proposal.

Table 5.8 Summary of adopted model parameters for Santos Gas Project and Narrabri Coal Project groundwater models

Project	Source	Relevant unit(s)	K_h (m/d)	K_v (m/d)	S_s (/m)	S_y
Narrabri Coal Project	Aqua-terra (2009)	Alluvium	0.3 – 5	5.0 x 10^{-4} – 5.0 x 10^{-3}	5 x 10^{-6}	0.1
		Pilliga Sandstone	4 x 10^{-3} – 0.3	1.5 x 10^{-5} – 5.0 x 10^{-3}	5 x 10^{-6}	0.1
		Purlewaugh Formation	4 x 10^{-3} – 0.02	6.0 x 10^{-6} – 1.0 x 10^{-3}	5 x 10^{-6}	0.001
		Namoi alluvium	5	0.5	1 x 10^{-5}	0.1

Project	Source	Relevant unit(s)	K_h (m/d)	K_v (m/d)	S_s (/m)	S_y
Santos Gas Project	CDM Smith (2016)	Wallumbilla Formation to Orallo Formation	1×10^{-3}	1×10^{-5}	1×10^{-5}	0.01
		Pilliga Sandstone	0.1	0.01	1×10^{-5}	0.01
		Purlawaugh to Benelabri Formations	1×10^{-3}	1×10^{-5}	1×10^{-5}	0.01

Groundwater level variability and climate

The field groundwater monitoring program commenced in February 2019 and the monitoring period is considered too short to capture significant climatic variability. Therefore, to better understand long-term water level variability, selected bores from the WaterNSW real time data database were analysed. The selection of bores spatially covers the alignment from Narromine to Narrabri, temporally covers climatic variability through periods of high rainfall and drought and covers a range of lithologies from alluvial aquifers to sandstone hard rock aquifers. Table 5.9 details the bores selected for analysis and Figure 5.12 shows hydrographs for the bores.

Table 5.9 Bores analysed for long-term groundwater level variability

Bore Location	Bore ID	Lithology	Monitoring period	Water level range (mBGL)
Narrabri	GW030544.1.2	Alluvial Sand and Clay. Screened depth 25.2-31.2 m	Mar. 71 to Feb. 18	1.50 – 5.63
Warrawee (15 km NW of Gilgandra)	GW036285.1.1	Alluvial Clay. Screened depth 32-35 m	Sep. 78 to Mar. 17	22.02 – 24.52
Warrawee 15 km NW of Gilgandra	GW036285.1.2	Sandstone water supply. Screened depth 73-79 m	Mar. 78 to Nov 18	25.77 – 28.49
Coonabarabran	GW098010.1.1	Sandstone Screened depth 11-23 m	Jun 11 to Nov 18	14.86 – 15.84 *
Pilliga East State Forest	GW098011.1.1	Sandstone Screened depth 50-56 m	Jun 11 to Nov 18	40.11 – 40.39
Narromine	GW273059.2.2	Alluvial (Macquarie River) Screened depth 25-27 m	Nov 08 to Nov 18	10.90 – 14.93

Notes: * Erroneous data removed from calculation

The hydrographs (Figure 5.12) show water level variation of 0.2 metres at the Pilliga bore to about four metres at the Narrabri and Narromine bores. The abrupt water level increases in GW098010 at Coonabarabran in September 2011 and May 2018 are considered erroneous as they are single datapoints and are quality coded as “Ability to truly represent the monitored parameter is not known”. Bores located in the alluvium close to the major rivers show a greater water level range. The water level increase in 2016 at bore GW273059 screened in the alluvium near the Macquarie River correlates with a flood.

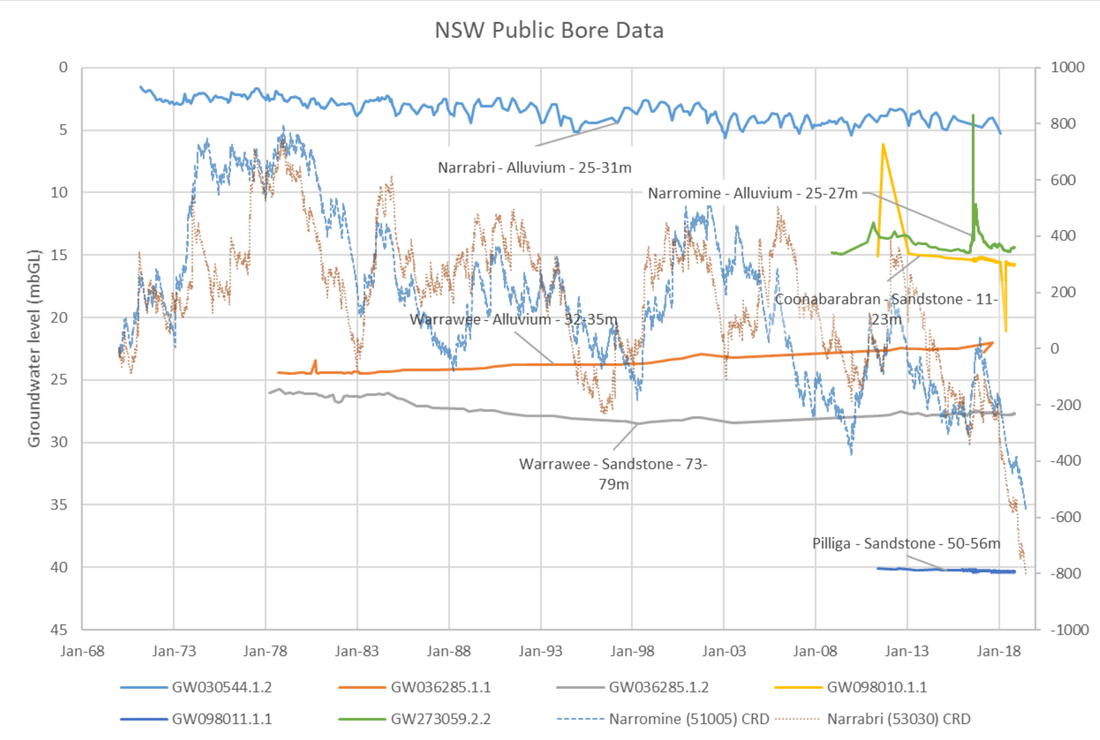


Figure 5.12 Hydrographs of bores analysed for long-term groundwater level variability

Bore field groundwater levels and quality

Currently there is no groundwater level and quality data for the groundwater sources that the proposal would extract from, at the depths the proposal would extract from. This is a data gap that would be closed at detailed design stage as outlined in the groundwater monitoring program (section 10).

5.8.2 Proposal groundwater data

Proposal groundwater monitoring bore groundwater level data

A summary of groundwater level data collected at proposal groundwater monitoring bores is provided in Table 5.10. Hydrographs for proposal bores which had groundwater are provided in Appendix A in datums of mAHD and mBGL. CRD is also shown on the plots and indicates below average rainfall occurred during the groundwater monitoring period.

Except for trends caused by bore purging or sampling, the hydrographs generally show minimal water level variation of less than about 0.25 metres, with a general slow decreasing trend throughout the monitoring period. Large deviations in water levels or outlier data points shown in the hydrographs are due to purging or sampling and are not representative of natural water level trends.

Table 5.10 Proposal groundwater monitoring bore groundwater level data summary

Project groundwater monitoring bore ID	Screen depth (mBGL)	Highest water level (mAHD)	Highest water level (mBGL)	Comment
BH-2-001	18.0-30.0	223.71	22.30	Generally dry; however, following significant rainfall the bore shows temporary water (saturated thickness in bore of about 5 to 7 m, which is 23 to 30 mBGL) that completely drains after about two months. This temporary water is not interpreted to be representative of parament groundwater levels.
BH-2-002	21.0-25.0	223.56	17.77	Stable, with slow minor decline
BH-2-003	12.0-18.0	224.30	13.22	Stable, with slow minor decline and some minor increases commencing January 2020.
BH-2-005	9.0-15.0	-	-	Dry
BH-2-006	7.25-16.25	-	-	Dry
BH-2-007	18.0-29.7	221.65	18.01	Stable
BH-2-008	22.42-31.42	-	-	Dry
BH-2-009	21.0-30.0	-	-	Dry
BH-2-010	21.51-30.51	-	-	Dry
BH-2-014	9.0-15	-	-	Dry
BH-2-015	14.25-20.25	246.51	13.12	Stable
BH-2-017	9.0-15.0	249.59	9.95	Stable, with slow minor decline and minor gradual increase commencing early 2020.
BH-2-018	6.5-12.5	248.61	7.05	Stable, with gradual minor increase from February 2020.
BH-2-019	14.44-20.44	-	-	Dry
BH-2-020	11.5-20.5	-	-	Dry. Bore has been decommissioned.
BH-2-021	21.0-30.0	242.71	24.10	Stable

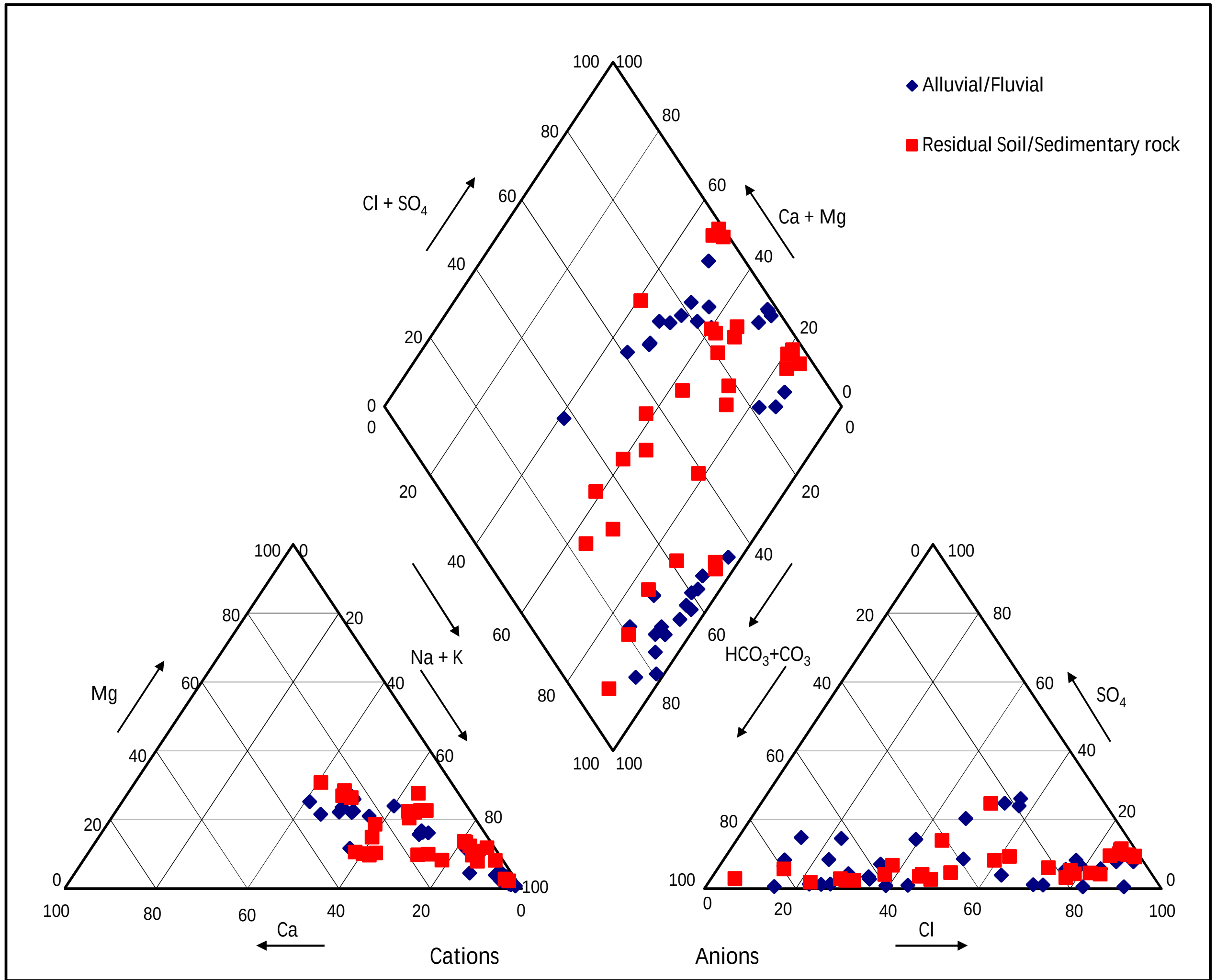
Project groundwater monitoring bore ID	Screen depth (mBGL)	Highest water level (mAHD)	Highest water level (mBGL)	Comment
BH-2-024	9.5-15.5	291.06	13.08	Generally dry, although temporarily has small amount of groundwater (about 2 m saturated thickness in bore) from April to early June 2020. This temporary water is not interpreted to be representative of parament groundwater levels.
BH-2-025	9.1-15.1	-	-	Dry
BH-2-030	11.21-21.21	296.25	5.60	Stable, with slow minor decline and minor increase from April 2020 to May 2020.
BH-2-036	9.5-15.5	-	-	Dry
BH-2-038	21.0-30.5	233.89	17.59	Stable, with slow minor decline and slight increase from February 2020 to March 2020.
BH-2-039	9.0-15.0	-	-	Dry
BH-2-040	9.0-15.2	-	-	Dry
BH-2-041	9.0-15.0	-	-	Dry
BH-2-042	9.36-15.36	-	-	Dry
BH-2-044	8.87-14.87	-	-	Dry
BH-2-045	9.0-15.0	-	-	Dry
BH-2-046	24.0-30.0	221.24	13.05	Stable, with slow minor decline and minor increase from February 2020 onwards.
BH-2-047	13.0-22.0	217.34	6.59	Stable
BH-2-049	17.0-23.0	205.56	4.63	Slow increase, then slow minor decline.
BH-2-053	13.7-19.7	203.31	6.92	Stable, with slow minor decline and then minor increase from February 2020.
BH-2-056	9.0-15.0	203.64	7.30	Stable, with slow minor decline and minor increase from January 2020 to March 2020.
BH-2-058	21.0-30.0	-	-	Dry
BH-2-059	14.0-20.0	295.49	12.78	Stable
BH-2-062	21.46-30.46	-	-	Dry
BH-2-069	21.0-30.0	262.72	11.90	Stable

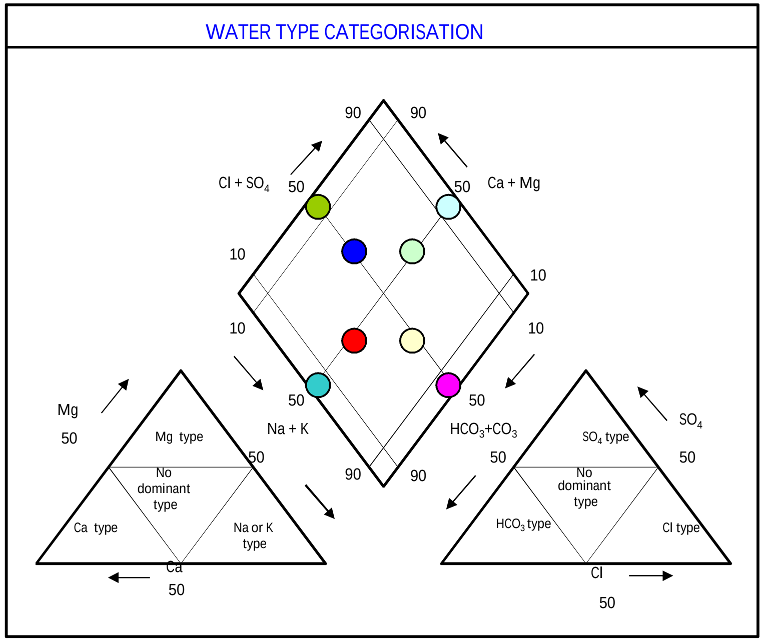
Project groundwater monitoring bore ID	Screen depth (mBGL)	Highest water level (mAHD)	Highest water level (mBGL)	Comment
BH-2-093 (Borrow pit A)	3.70 – 10.10	334.94	4.71	Stable
BH-2-070 (Borrow pit B)	5.50 – 12.00	-	-	Dry
BH-2-072 (Borrow pit C)	8.40 – 15.20	-	-	Dry
BH-2-089 (Borrow pit D)	8.70 – 15.50	-	-	Dry

Proposal groundwater monitoring bore quality data

A piper plot of major anion and cation laboratory testing results is provided in Figure 5.13 and an analytical suite summary and laboratory testing results are provided in summary tables in Appendix B and C respectively. The following summary comments are provided:

- Based on the piper plot, the cations are generally dominated by sodium and to a lesser degree potassium. The anions are generally dominated by either bicarbonate or chloride. The overall water type is generally either sodium bicarbonate or sodium chloride.
- Filtered heavy metals are generally low. However, copper, nickel and zinc are frequently above the ANZG (2018) freshwater 95 per cent toxicant default guideline values. Although mercury was below ANZG (2018) freshwater 95 per cent toxicant default guideline values, at three locations it was above the NEPM (2013) Table 1C groundwater investigation level for fresh water. The mercury results were very close to the laboratory limit of reporting.
- Nutrient levels are variable. At two locations ammonia was slightly above the ANZG (2018) freshwater 95 per cent toxicant default guideline value of 0.9 milligrams per litre. The maximum concentration was 2.6 milligrams per litre at BH-2-015.
- pH ranged from 6.6 to 8.4, with an average of 7.6.
- Low level hydrocarbons and some BTEXN chemicals were detected in BH-2-049 and BH-2-056 in some sampling rounds.
- Pesticides were below the laboratory limit of reporting.
- TDS ranged from 200 to 26,000 milligrams per litre, with an average value of 3,929 milligrams per litre. These TDS concentrations are representative of fresh to saline groundwater. The average concentration is representative of brackish water in accordance with Freeze and Cherry (1979).





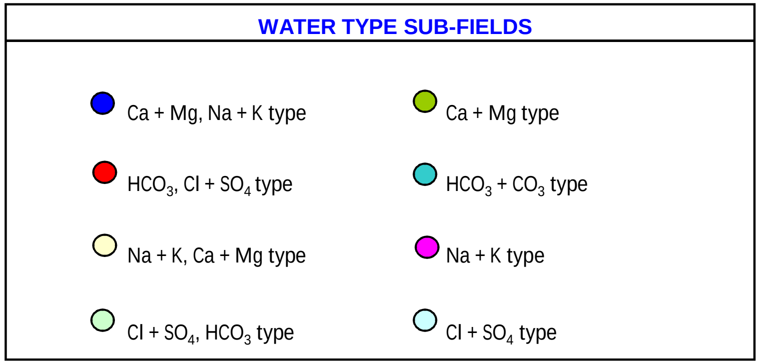


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Figure 5.13 Piper plot of major anions and cations

Groundwater contamination

Preliminary contamination assessment undertaken to inform the EIS identified a range of areas of environmental interest (AEI), including commercial/industrial areas, degraded road surfaces, transmission lines, buildings (potential chemical storage), forestry areas, disturbed ground, unknown land, stockpiles, an orchard, railway lines, cropping areas, a sewage treatment plant, potential effluent irrigation areas and ponds, a greenhouse, potential waste disposal areas, vehicle maintenance areas and Narrabri landfill/tip.

No potential PFAS sources (fire services or airports) are within two kilometres of the proposal.

Proposal groundwater bore groundwater chemistry results are provided in Appendix C and summarised in section 5.8.2.

5.8.3 Proposal groundwater monitoring bore hydraulic conductivity

Hydraulic conductivity estimates from testing are summarised in Table 5.11. Hydraulic conductivity is variable in the alluvium and low for rock. The highest hydraulic conductivity estimate was at BH-2-053 located at Narrabri, between Narrabri Creek and the Namoi River. This bore was screened in alluvial material.

Table 5.11 Hydraulic conductivity estimates for proposal groundwater monitoring bores

Bore ID	Screen depth (mBGL)	Screened material	Estimated hydraulic conductivity (m/d)	
			Hvorslev analysis	Bouwer and Rice analysis
BH-2-002	21.0-25.0	Gravelly sand and silty clay (alluvial)	1.07	0.80
BH-2-007	18.0-29.7	Silty clay, sandy clay (alluvial and residual)	2×10^{-4}	3×10^{-4}
BH-2-015	14.25-20.25	Sandstone and siltstone	2×10^{-3}	1×10^{-3}
BH-2-017	9.0-15.0	Clayey sand (alluvial)	0.02	0.01
BH-2-018	6.5-12.5	Silty clay, silty sand, clayey sand (alluvial)	4.32	2.64
BH-2-021	21.0-30.0	Siltstone and sandstone	6×10^{-4}	4×10^{-4}
BH-2-030	11.21-21.21	Sandstone and siltstone	0.05	0.04
BH-2-038	21.0-30.5	Sandstone	6×10^{-4}	7×10^{-4}
BH-2-046	24.0-30.0	Sandstone	0.02	0.02
BH-2-047	13.0-22.0	Sandy clay, clayey sand, silty sand (alluvial)	0.59	0.44
BH-2-049	17.0-23.0	Generally sand (alluvial)	0.31	0.22
BH-2-053	13.7-19.7	Clayey sandy gravel, clayey gravelly sand (alluvial)	7.41	5.55
BH-2-056	9.0-15.0	Sandy gravel (alluvial)	2.61	2.06
BH-2-069	21.0-30.0	Sandstone and siltstone	1×10^{-3}	2×10^{-3}
BH-2-093	3.70 – 10.10	Sandy clayey silty gravel and clayey sand	5×10^{-5}	2×10^{-5}

5.9 Conceptual hydrogeological model

5.9.1 Shallow groundwater systems

Shallow groundwater systems applicable to the proposal's shallow features are conceptualised as follows:

- groundwater depths typically of the order of 10 mBGL to 30 mBGL, but shallower than this near major rivers and in low lying areas
- unconfined to semi-confined
- fresh to saline water in accordance with Freeze and Cherry (1979)
- low recharge from rainfall, with vertical leakage from deeper groundwater systems occurring when hydraulic head is lower than that of underlying aquifers
- discharge occurs through bore pumping, baseflow to rivers and vertical leakage to underlying aquifers (when hydraulic head is higher than that of underlying aquifers)
- productive and heavily pumped alluvium in some areas, such as the Macquarie River and Namoi River regions
- groundwater flow direction is similar to broad topography trend, with rainfall recharge occurring in areas of high elevation and discharge occurring in the midslope areas (at springs), foothills and drainage lines
- variable groundwater system parameters.

5.9.2 Deep groundwater systems

Deep groundwater systems applicable to the proposal's bore fields are conceptualised as follows:

- Regional groundwater flow direction in the area of the proposal is generally to the west and north west (GABCC, 2014).
- Regional hydraulic gradient of the main GAB aquifer system(s) is low and generally about 0.1 – 0.15% (Smerdon and Ransley, 2012).
- The study area lies within a GAB groundwater recharge area, where recharge predominantly enters aquifer strata at exposed outcrops, or at lesser rates, via overlying strata where there is potential for downward groundwater movement. A recharge rate of less than 10 mm/year is expected.
- Discharge occurs through bore pumping, vertical leakage to overlying aquifers (when hydraulic head is higher than that of overlying aquifers), including alluvial aquifers, and through springs.
- The Hooray Sandstone and equivalents stratigraphic unit is conceptualised to behave as an aquifer. The Pilliga Sandstone is considered to fall within this unit and also behave as an aquifer.
- The Purlewaugh Formation at the base of the GAB is regionally significant and behaves as an aquitard.
- The units initially underneath the GAB likely have relatively low hydraulic conductivity. Regionally significant aquifers are not anticipated in the formations that are in close proximately to the base of the GAB.

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6. Analytical element groundwater model results

This section summarises the results from the analytical groundwater models used to quantify potential groundwater level drawdown due to bore field groundwater extraction. The methodology for the models is documented in section 4.6.2.

Five of the twelve proposal bore fields were simulated individually to assess potential changes to groundwater levels. The five modelled bore fields are considered representative of, and conceptually similar to the other bore fields.

6.1 PB1 results

Maximum drawdown in the upper model layer (ie layer one) was about three metres. The two metre and one metre drawdown contours extend up to about 500 metres and 750 metres respectively from the bore field. There is one existing bore (GW001568) situated in the drawdown area. The model predicted about 1.5 metres drawdown in layer one at the location of the bore.

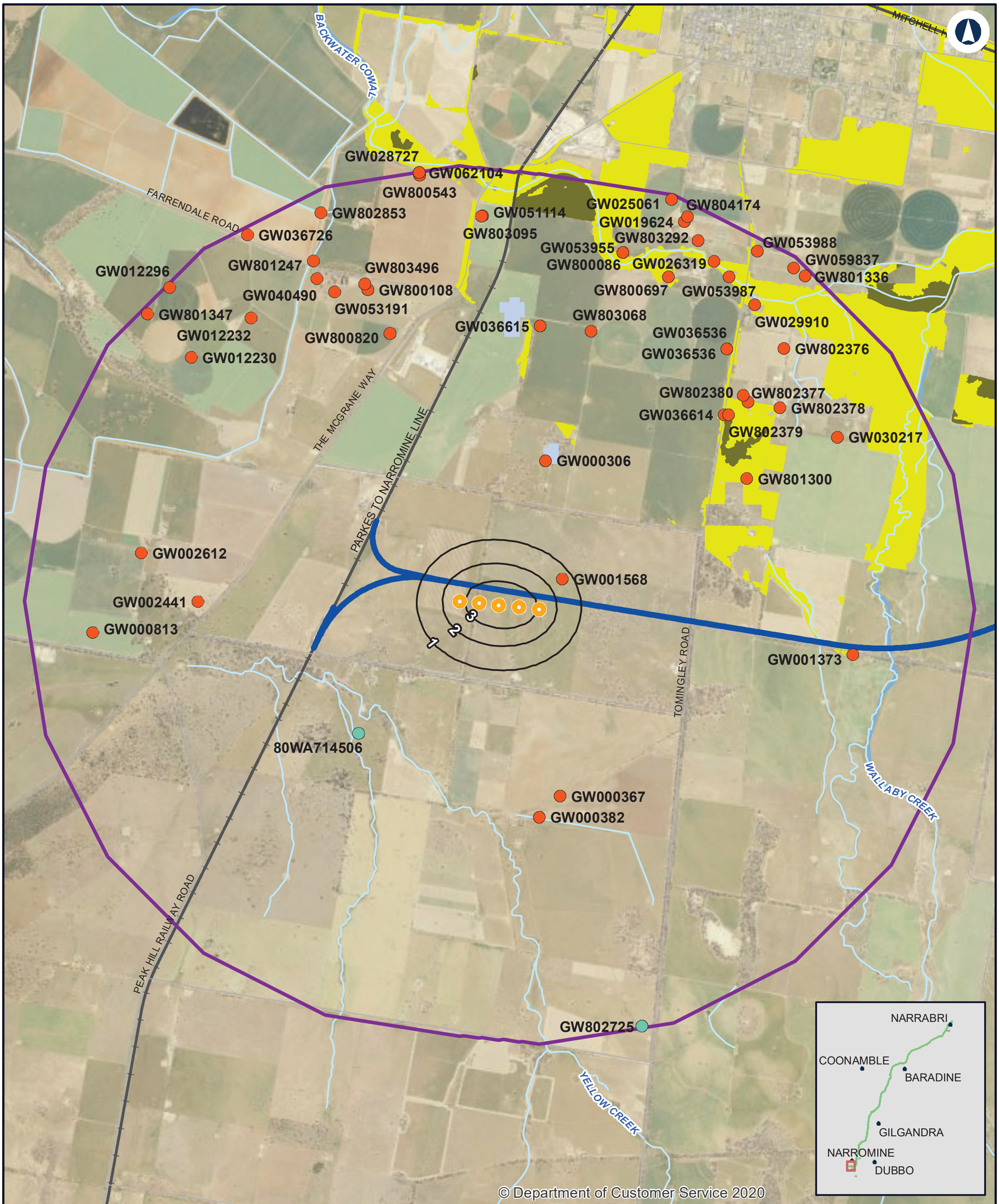
For the model's second layer (ie layer two), the maximum drawdown (at the bore field centre) was about 11 metres. The two metre and one metre drawdown contours extend up to about 950 metres and 1,200 metres from the bore field, respectively. There is one existing bore within the two metre drawdown contour – bore GW001568. The drawdown at this bore in Layer 2 of the model is about four metres.

Drawdown contours for layer one and layer two are shown in Figure 6.1 and Figure 6.2 respectively.

6.2 PB2 results

Maximum drawdown in the upper model layer (ie layer one) was about 37 metres. The two metre and one metre drawdown contours extend up to about one kilometres and 1.25 kilometres from the bore field, respectively. There is one existing bore (GW000986) within the two metre drawdown contour. The model predicted about 3.5 metres drawdown at the location of the bore.

Drawdown contours for layer one of the model are shown in Figure 6.3.



NARROMINE TO NARRABRI PB1 Layer One groundwater level drawdown Figure 6.1

0 0.8 1.6 Km

Coordinate System: GDA 1994 MGA Zone 55

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Date: 8/10/2020 Paper: A4
Author: JacobsGHD Scale: 1:60,000
Data Sources: Basemap layers: NSWSS; GDE, NGIS bores: BOM; Project elements: GHDJACOBS

LEGEND

- Alignment
- PB1 pumping bores
- NGIS bores
- Bores licensed to extract groundwater from Lachlan Fold Belt MDB Groundwater Source
- Drawdown contours
- PB1 5km buffer area
- High potential GDE - from regional studies (terrestrial)
- Low potential GDE - from regional studies (terrestrial)
- Moderate potential GDE - from national assessment (aquatic)
- Low potential GDE - from national assessment (aquatic)

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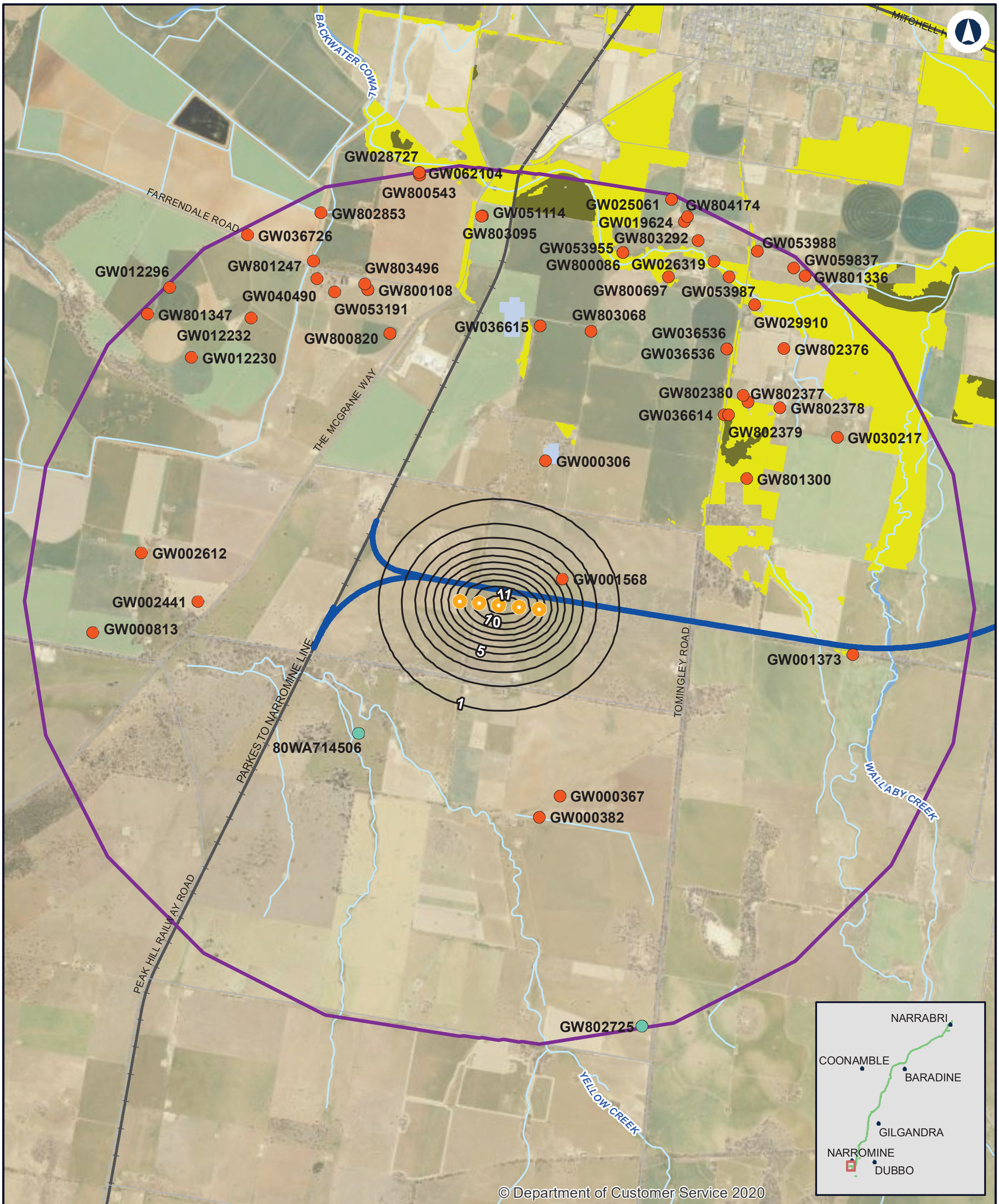

NARROMINE TO NARRABRI PB1 Layer Two groundwater level drawdown Figure 6.2

0 0.8 1.6 Km

Coordinate System: GDA 1994 MGA Zone 55

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Date: 8/10/2020 Paper: A4
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Data Sources: Basemap layers: NSWSS; GDE, NGIS bores: BOM; Project elements: GHDJACOBS

LEGEND

- Alignment
- PB1 pumping bores
- NGIS bores
- Bores licensed to extract groundwater from Lachlan Fold Belt MDB Groundwater Source
- Drawdown contours
- PB1 5km buffer area
- High potential GDE - from regional studies (terrestrial)
- Low potential GDE - from regional studies (terrestrial)
- Moderate potential GDE - from national assessment (aquatic)
- Low potential GDE - from national assessment (aquatic)

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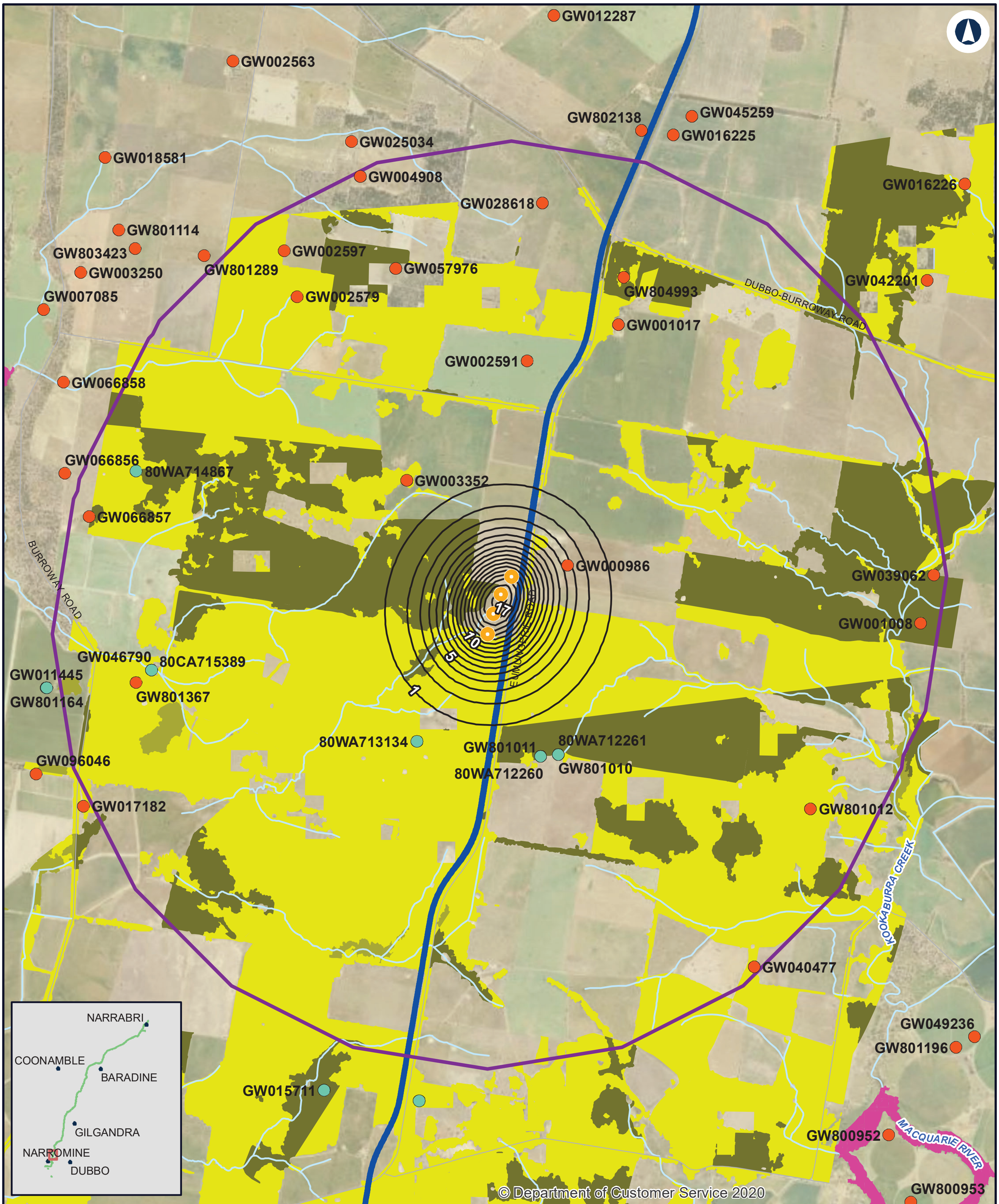

NARROMINE TO NARRABRI PB2 Layer One groundwater level drawdown Figure 6.3

0 0.8 1.6 Km

Coordinate System: GDA 1994 MGA Zone 55

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Date: 8/10/2020 Paper: A4
Author: JacobsGHD Scale: 1:8,000,000
Data Sources: Basemap layers: NSWSS; GDE, NGIS bores: BOM; Project elements: GHDJACOBS

LEGEND

- Alignment
- PB2 pumping bores
- NGIS bores
- Bores licensed to extract groundwater from Lachlan Fold Belt MDB Groundwater Source
- Drawdown contours
- PB2 5km buffer area
- High priority GDE vegetation (NSW Gov WSPs)
- High potential GDE - from regional studies (terrestrial)
- Moderate potential GDE - from regional studies (terrestrial)
- Low potential GDE - from regional studies (terrestrial)
- Low potential GDE - from national assessment (aquatic)

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6.3 PB3, PB7 and PB12 results

Modelled drawdown was less than one metre for the Cenozoic and Hooray and Equivalents GAB model layers in all the models.

For PB12, the distance from the bore field centre to the two metre drawdown contour in the pumped Gunnedah Oxley Basin model layer was about 4.1 kilometres.

These results are summarised in Table 6.1 and assessed in section 7, the groundwater impact assessment section.

Table 6.1 PB3, PB7 and PB12 groundwater level drawdown results summary

Bore field I.D.	Drawdown at bore field centre (m)		Distance (km) of 2 m drawdown contour from bore field centre
	Cenozoic layer	Hooray and equivalents layer	Pumped layer – Gunnedah Oxley Basin layer
PB3	0.39	0.63	NA [1]
PB7	0.15	0.37	NA [1]
PB12	NA – layer not present in model	0.02	4.1

Note: [1] Not measured as there are no existing bores in this groundwater source near the proposal bore field, or the groundwater source does not exist at proposal bore field.

6.4 Sensitivity analysis results

For the modelled sub-GAB bore fields (PB3, PB7 and PB12), the worst-case sensitivity run for drawdown impacts was the simulation which decreased the aquitard layer's vertical hydraulic conductivity by one order of magnitude. In this simulation, drawdown in the Cenozoic at the bore field centre was five metres and 1.9 metres for PB3 and PB7, respectively. For the Hooray and Equivalents layer, the drawdown was 7.1 metres, 3.8 metres and 1.2 metres for PB3, PB7 and PB12, respectively.

For the sensitivity simulation at PB2, which involved modelling the upper layer as alluvium instead of rock, the drawdown was less than the base case.

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7. Groundwater impact assessment

7.1 Construction impacts

The assessment in this section has been conducted against the following proposal features, as these features have the potential to affect groundwater:

- rail infrastructure including the construction of main line track and areas of related excavation
- road infrastructure
- borrow pits
- bore fields
- Narromine North and Baradine temporary workforce accommodation facilities.

All other proposal features are not anticipated to have any impact upon groundwater and are not discussed in this report.

7.1.1 Groundwater levels

Rail infrastructure and road infrastructure

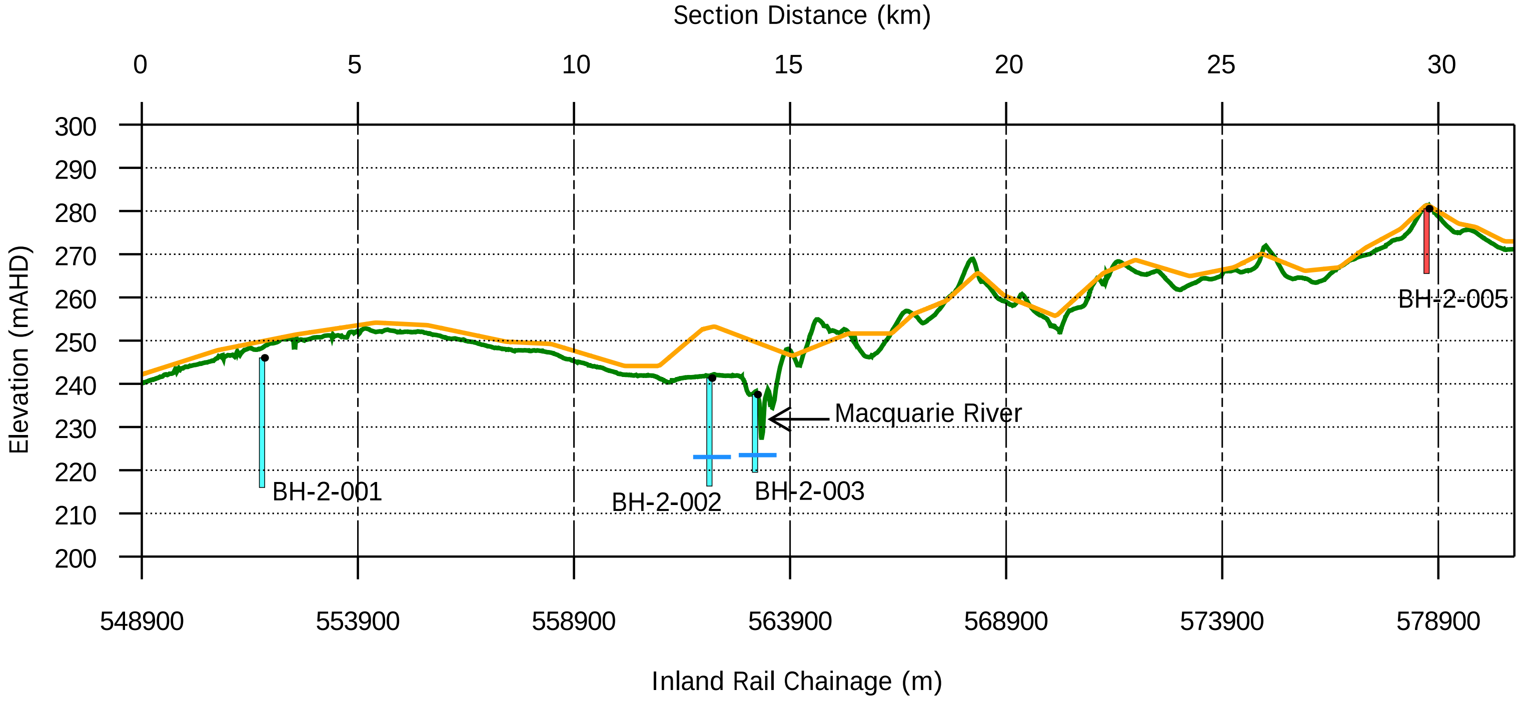
Cross sections shown in Figure 7.1 to Figure 7.6 indicate that the proposal cuts are not likely to intersect the water table. As such, alignment bulk earthworks are not anticipated to alter groundwater levels. Similarly, road infrastructure works are not anticipated to intersect the water table and therefore are not anticipated to alter groundwater levels.

There is a potential for surcharge loading associated with fill placement and the resulting increase in effective stress to cause short-term increases to groundwater levels in areas of fill placement, and/or permanent increases to groundwater levels if the increased stress permanently alters the hydraulic conductivity of the underlying water-bearing ground. This risk is applicable to relatively soft soils and is not expected to occur in areas where the water table lies within the rock. Groundwater level changes associated with these mechanisms would be localised and negligible and are not expected to impact any known GDEs.

Pilliga region works

Works in the Pilliga region, including rail infrastructure and road infrastructure, such as but not limited to, the realignment of the Pilliga Forest Way, are unlikely to intersect the water table.

Figure 7.1: Cross Section 1



Key

Groundwater Monitoring Bore Lithology

Alluvial

Residual or weathered sedimentary rock

Existing ground level

Railway design level

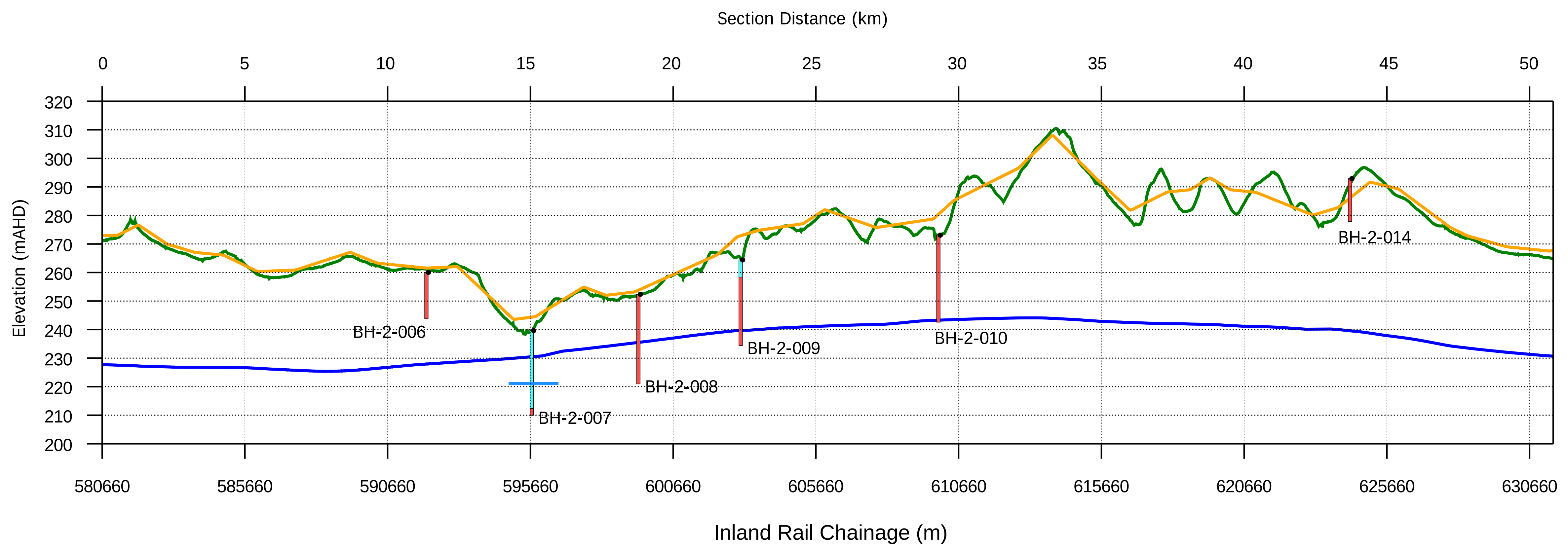
Maximum monitored groundwater level

Scale: 1:175,000 (A4)

Vertical exaggeration: 100x

0m 6000m

Figure 7.2: Cross Section 2



Key

Groundwater Monitoring Bore Lithology

Alluvial

Residual or weathered sedimentary rock

Existing ground level
Railway design level
GAB Water Table (mAHD) (Fed Gov)

Maximum monitored groundwater level

Scale: 1:175,000 (A3)

Vertical exaggeration: 100x

0m 10000m

Figure 7.3: Cross Section 3

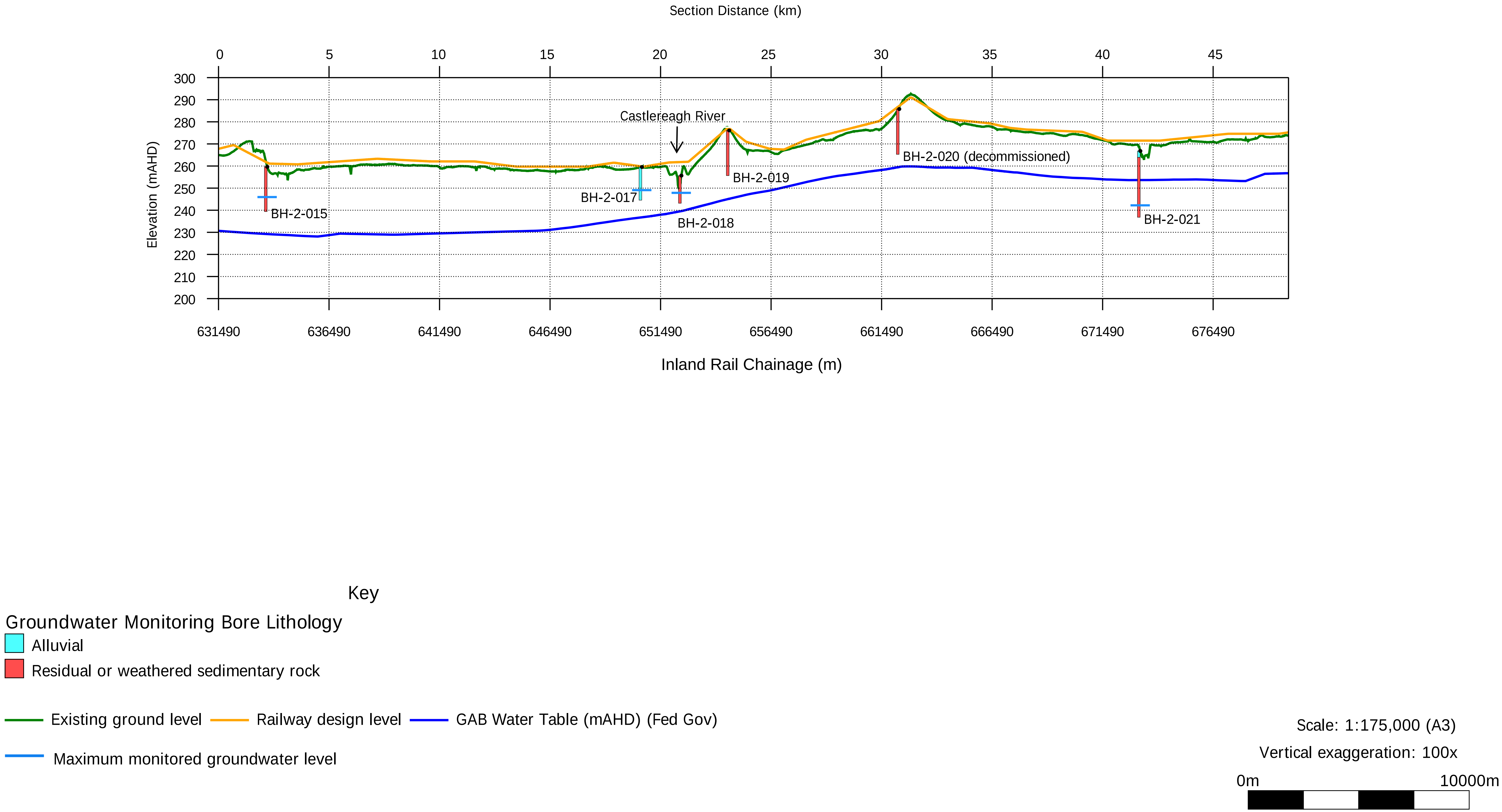
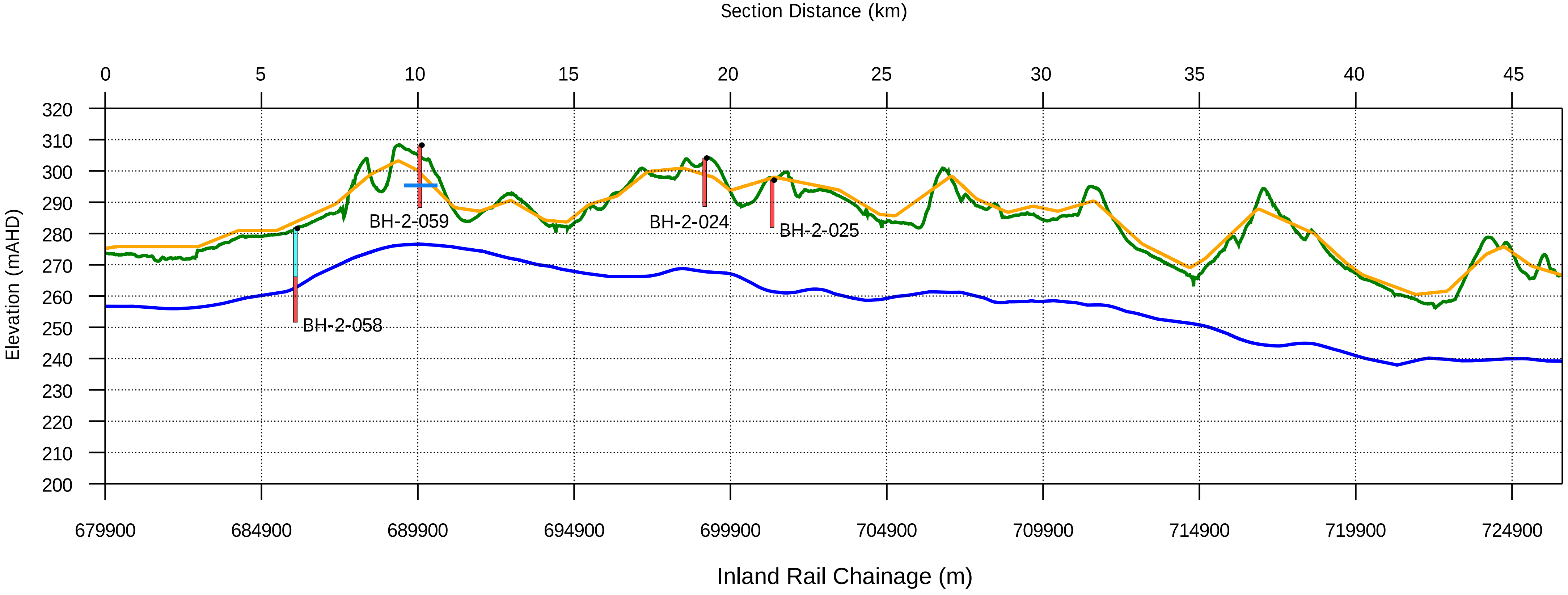


Figure 7.4: Cross Section 4



Key

Groundwater Monitoring Bore Lithology

- Alluvial
- Residual or weathered sedimentary rock

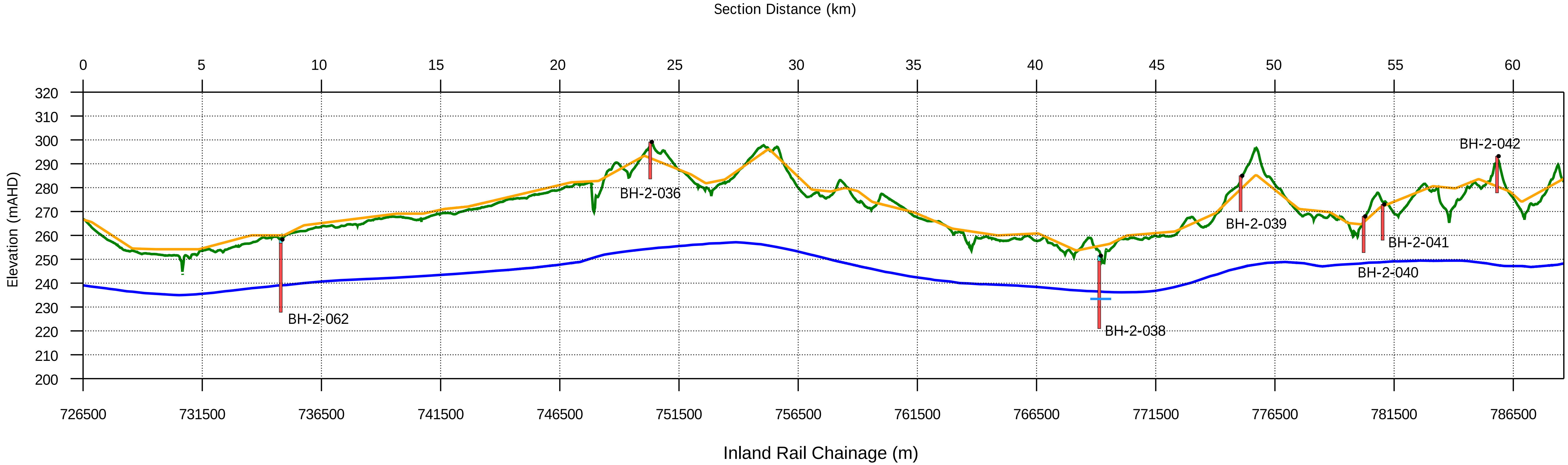
- Existing ground level
- Railway design level
- GAB Water Table (mAHD) (Fed Gov)
- Maximum monitored groundwater level

Scale: 1:175,000 (A3)

Vertical exaggeration: 100x

0m 10000m

Figure 7.5: Cross Section 5



Key

Groundwater Monitoring Bore Lithology

Alluvial

Residual or weathered sedimentary rock

Existing ground level

Railway design level

GAB Water Table (mAHD) (Fed Gov)

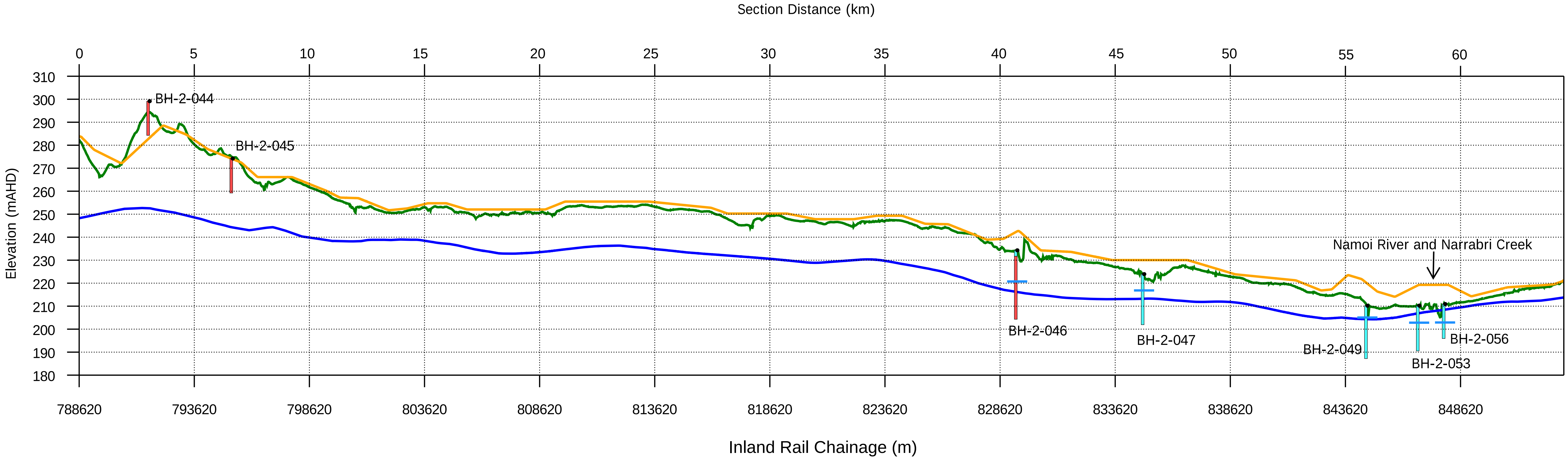
Maximum monitored groundwater level

Scale: 1:175,000 (A3)

Vertical exaggeration: 100x

0m 10000m

Figure 7.6: Cross Section 6



Key

Groundwater Monitoring Bore Lithology

Alluvial

Residual or weathered sedimentary rock

Existing ground level

Railway design level

GAB Water Table (mAHD) (Fed Gov)

Maximum monitored groundwater level

Scale: 1:175,000 (A3)

Vertical exaggeration: 100x

0m

10000m

Borrow pits

Water table interception is possible at borrow pit A and unlikely at the other three borrow pits based on monitored groundwater levels compared to indicative proposed borrow pit extraction depths and levels as outlined in Table 7.1.

Maximum groundwater level change at borrow pit A would occur at the pit and is assessed to be about three metres based on the pit's assessed water table penetration depth. Water level reduction would decrease with distance from the pit and as a worst-case scenario, is assessed to become indistinguishable within about 100 metres from the pit. Using data from the closest groundwater monitoring bore, 250-01-BH2093, the radius of influence extends to less than five metres from the borrow pit after ten years. This is because the hydraulic conductivity at this location is negligible (5×10^{-5} metres per day) and the transmissivity is very low. If a hydraulic conductivity value two orders of magnitude higher than the test value is assumed, the drawdown distance from the borrow pit is still less than 40 metres after a duration of ten years.

A potential localised three metre drawdown to groundwater levels is small and would not impact regional groundwater flow. Groundwater level changes, if any, would be localised to the borrow pit.

Table 7.1 Monitored groundwater levels compared to indicative proposed borrow pit extraction depths and levels

Borrow pit	Existing surface level in area of maximum extraction depth (mAHD)	Extraction level in area of maximum extraction depth (mAHD)	Representative groundwater monitoring bore details			Assessed borrow pit water table penetration depth (m)
			Bore I.D.	Total depth (mBGL/AHD)	Minimum groundwater depth (mBGL/AHD)	
Borrow pit A (main extraction area)	339	333.5	BH-2-093	9.55/330.1	4.71/334.94	1.44
Borrow pit A (stockpile area)	335	332				2.94
Borrow pit B	278	270	BH-2-070	12.12/258.45	Dry	NA - dry
Borrow pit C	288	268	BH-2-072	15.27/265.39	Dry	NA – dry
Borrow pit D	264	254	BH-2-089	15.56/246.78	Dry	NA - dry

Bore fields

A non-permanent fixed duration pumping (up to about 500 days) of the proposal bore field bores to supply construction water has the potential to temporarily reduce groundwater levels. Groundwater level reductions were modelled to be most pronounced in the groundwater sources where pumping is targeted, and where present, significantly less in overlying groundwater sources which are not directly pumped.

The proposal has the potential for groundwater pressure reductions in deep rock groundwater systems. For most of the proposal site, the groundwater source that the proposal is targeting is very deep and separated from overlying groundwater systems.

Modelled maximum drawdown to the GAB water table and underlying rock aquifer layer is less than one metre. Such a reduction meets the minimal impact considerations of the AIP (refer to section 3.3).

Qualitatively, the risk of the bore fields impacting groundwater levels in upper GAB groundwater systems is considered low because:

- The anticipated pumping duration is non-permanent (about 500 days).
- The proposed bores have a large separation distance between the groundwater source they would pump from and upper GAB aquifers that are currently pumped by existing bores. Aquitard(s) are conceptualised to separate the base of the GAB from the groundwater source the proposal would pump from.
- For the proposal site in the GAB region, there are no existing bores which are licensed to extract groundwater from the groundwater source that the proposal targets that are close to the proposal. The closest bore is located about six kilometres west of PB12. Therefore, it is unlikely existing bores would be subjected to noticeable groundwater level reductions in the GAB region of the proposal. There are some existing bores located near PB1 and PB2, located outside of the GAB region, which may experience groundwater level reductions. Groundwater level reduction at existing bores is assessed in section 7.1.4.

It is possible that enhanced groundwater flow along geological structures, such as faults, could hydraulically connect the groundwater systems that the proposal would pump from to upper groundwater systems. If this occurs, drawdown impacts could be worse than predicted. Within Ransley et. al (2015), there are very few mapped faults or other structural elements in the Coonamble Embayment region of the proposal. There is only one mapped fault near the proposal, a fault west of PB5. On the basis of limited structural elements, the risk of increased drawdown to upper groundwater systems to due to geological structures is considered low.

Modelled drawdown at existing licensed bores is discussed in section 7.1.4.

Narromine North and Baradine temporary workforce accommodation facilities

Pumping of groundwater bores for potable water at the Narromine North and Baradine temporary workforce accommodation facilities could lead to reduced groundwater levels in the vicinity of the pumped bores. The strategy for the provision of potable water from groundwater at these locations is still to be confirmed, including whether existing bores could be used, or whether new groundwater bores are proposed. Once this has been confirmed, further assessment would be undertaken during detailed design to confirm the potential for drawdown impacts associated with the extraction of groundwater for potable water at these facilities. A mitigation measure has been included to this effect. Provided the mitigation measure is employed, unacceptable impacts to groundwater are not anticipated.

7.1.2 Groundwater inflows and discharge

Rail infrastructure and road infrastructure

As outlined in section 7.1.1, the vertical alignment of the proposal is not likely to intersect the water table. As such, groundwater inflows due to bulk earthworks intercepting the water table are not expected. Similarly, road infrastructure works are not likely to intersect the water table and therefore groundwater inflows into excavations are not anticipated.

Borrow pits

Groundwater inflows as a result of borrow pit excavations intersecting the water table are not anticipated except for possible small groundwater inflows at Borrow pit A. If groundwater inflows occur at borrow pit A, they are anticipated to be low volumes as the estimated potential water table interception depth is only about three metres and the nearest groundwater monitoring bore was assessed to have very low hydraulic conductivity (about 5×10^{-5} metres per day).

The maximum groundwater inflow rate after a time of 30 days was 0.80 kilolitres per day (0.29 mega litres per year). After one year, this rate would likely decrease to 0.23 kilolitres per day (0.08 mega litres per year). The inflow rates are very low and would likely evaporate. Discharge of intercepted groundwater from the borrow pit to external areas is not anticipated to be required. However, may occur in combination with surface water.

If mixed discharge is required, the groundwater volume as a proportion of the total volume would likely be negligible. Any discharge from the borrow pit would be primarily surface water volumes.

The borrow pits are designed to free drain at completion of extraction. However, as far as practicable, the borrow pits would be rehabilitated to have finished ground levels above the water table to prevent ongoing interception of the water table.

Bore fields

Groundwater that is proposed to be extracted by the bore field bores is of unknown quality. Such data is not available from existing bores and would be acquired at detailed design stage. If this water is discharged to ground (for example, for earthworks conditioning, dust suppression or wash down), it is possible that shallow groundwater system water quality, surface water quality, vegetation and soils could be impacted. This could occur if construction water sourced from the proposal's bore fields is not of suitable quality and is not treated appropriately.

Mitigation measures for this risk are provided in section 11.

7.1.3 Groundwater dependent ecosystems

Rail infrastructure and road infrastructure

As outlined in section 7.1.1, the proposal's main track vertical alignment and road infrastructure are not likely to intersect the water table. Therefore, groundwater inflows and subsequent groundwater level drawdown due to bulk earthworks intercepting the water table are not expected. As a result, potential impacts to GDEs due to drawdown are not anticipated. Furthermore, potential minor water level changes associated with ground consolidation are not anticipated to impact potential GDEs.

The risk of GDEs being impacted by potentially reduced groundwater quality is assessed as low.

Borrow pits

Borrow pit A may intersect the water table by about three metres. The other borrow pits are not anticipated to intercept the water table. Potential GDEs in the region of borrow pit A are not mapped by BOM (2018a) or noted in the *ARTC Inland Rail Narromine to Narrabri Biodiversity Development Assessment Report* (JacobsGHD, 2020a) or *ARTC Inland Rail Narromine to Narrabri Aquatic Ecology Assessment Report* (JacobsGHD, 2020c). Also, there are no mapped High Priority GDEs near borrow pit A. Therefore, potential to impact GDEs from the excavation of borrow pit A is very low.

Bore fields

Bore field pumping is not anticipated to impact GDEs due to groundwater level drawdown. Base case modelled drawdown in upper model layers for the sub-GAB bore fields was less than one metre (maximum 0.39 metres). Such a change is small and in the bounds of natural variability due to climate and recharge processes.

Drawdown at PB1 and PB2 is not anticipated to impact GDEs as the existing standing water level in these locations is deep, about 35 metres (PB1) and 20 metres (PB2), with the existing vegetation unlikely to be interacting with a deep water table. There are no mapped High Priority GDEs near PB1 and PB2.

Narromine North and Baradine temporary workforce accommodation facilities

Pumping of groundwater bores for potable water at the Narromine North and Baradine temporary workforce accommodation facilities could lead to reduced groundwater levels in the vicinity of the pumped bores. This could have implications for GDEs. As noted in section 7.1.1 further assessment would be undertaken during detailed design to confirm the potential for drawdown impacts, including impacts to GDEs.

7.1.4 Groundwater bores

Rail infrastructure

Existing groundwater bores that are situated within the construction footprint would require decommissioning. Records indicate 10 existing groundwater bores are located within the construction footprint. The bore I.D.s are:

- GW008036
- GW018825
- GW000844
- GW066254
- GW012757
- GW026649
- GW030121 (pipe I.D. 1.2) – monitoring bore
- GW030121 (pipe I.D. 1.3) – monitoring bore
- GW030121 (pipe I.D. 1.3) – monitoring bore
- GW059136.

As outlined in section 7.1.1, the proposals main track vertical alignment and road infrastructure are not likely to intersect the water table. Therefore, groundwater level reductions at nearby existing bores are not anticipated.

Borrow pits

Groundwater level reductions at nearby existing bores due to excavations intercepting the water table are not anticipated.

The nearest existing bore to borrow pit A is 2.35 kilometres to the south. Drawdown is not expected to propagate to this bore.

Bore fields

The potential impacts below are based on the analytical element groundwater model results presented in section 6.

PB1

There is one existing bore within the one metre drawdown contour for both the model's alluvium layer (ie layer one) and upper rock layer (ie layer two). Bore GW001568 is about 430 metres from the PB1 bore field. The next closest existing bore is about 1.7 kilometres from the bore field.

Bore GW001568 is interpreted to primarily take water from alluvium (ie layer one in model), not the underlying rock (ie layer two in model). Modelled drawdown in the alluvium (ie layer one) was about 1.5 metres. Drawdown in the underlying rock model layer (ie layer two) was about four metres.

The modelled drawdown in the alluvium model layer (ie layer one) of about 1.5 metres is used for assessment of impacts at the bore. The modelled drawdown is less than two metres and therefore does not exceed the AIP minimal impact criteria (see section 3.3).

Although minimal drawdown was modelled, due to the bore's proximity (about 430 metres) to the bore field, mitigation of potential drawdown impacts is provided (section 11) as a contingency measure.

PB2

There is one existing bore within the two metre drawdown contour for the model's upper layer (ie layer one) that is applicable for nearby existing bores. Bore GW000986 is about 650 metres from the PB2 bore field. The next closest existing bore is about 1.5 kilometres from the bore field.

Modelled drawdown at bore GW000986 is about 3.5 metres. This exceeds the AIP minimal impact consideration drawdown criteria of two metres (see section 3.3) by about 1.5 metres. As such, mitigation of potential drawdown impacts at GW000986 is provided in section 11.

PB3 to PB12 (GAB)

Modelled drawdown was less than one metre for the GAB water table and Hooray Sandstone and equivalents layer. This amount of drawdown does not exceed the AIP minimal impact criteria (see section 3.3).

PB3 to PB12 (Lachlan Fold Belt MDB and Gunnedah-Oxley Basin MDB Groundwater Sources)

Outside of the Narrabri region of the proposal, there are no existing bores licensed to extract groundwater from either the Lachlan Fold Belt MDB and Gunnedah-Oxley Basin MDB Groundwater Sources. However, within the Narrabri region, there are existing bores licensed to abstract groundwater from the Gunnedah-Oxley Basin MDB Groundwater Source. The closest of these bores is located about six kilometres west of PB12.

The two metre drawdown contour for the Gunnedah-Oxley Basin MDB Groundwater Source model layer at PB12 extended about 4.1 kilometres from the bore field. Therefore, modelled drawdown impacts to existing bores do not exceed the AIP minimal impact criteria (see section 3.3).

Mitigation is not provided for these bores as potential drawdown impacts are not anticipated.

Narromine North and Baradine temporary workforce accommodation facilities

The pumping of groundwater for potable water at these facilities could reduce groundwater levels at existing bores. The bore water quality at existing bores could also be impacted by onsite application of effluent at these two facilities. This water quality issue is discussed in section 7.1.8. As noted in section 7.1.1 further assessment would be undertaken during detailed design to confirm the potential for drawdown impacts.

7.1.5 Surface water-groundwater interactions

Rail infrastructure and road infrastructure

As outlined in section 7.1.1, the proposal's vertical alignment is not likely to intersect the water table. As such, the proposal's vertical alignment is not anticipated to impact surface water-groundwater interaction through the altering of baseflows.

Potential water level changes due to surcharge loading associated with fill placement are anticipated to be localised and are not anticipated to impact baseflows.

Borrow pits

Minimal drawdown of the water table may occur at borrow pit A, however drawdown is not anticipated at borrow pit B, borrow pit C and borrow pit D. Furthermore, drawdown height and areal extent were both assessed to be small (section 7.1.1) at borrow pit A.

The anticipated drawdown would not cause baseflow reductions.

Bore fields

The modelled one metre drawdowns at PB1 and PB2 do not encroach on rivers or creeks.

Maximum modelled drawdown (occurs in centre of bore field) for the GAB water table is less than one metre for all base case simulations. Therefore, the bore fields are assessed as unlikely to alter surface water-groundwater interactions due to baseflow reduction.

Narromine North and Baradine temporary workforce accommodation facilities

The pumping of groundwater for potable water at these facilities could lead to reduced groundwater levels in the vicinity of the bores. This could have implications for baseflow to creeks/rivers in vicinity of the bores. As noted in section 7.1.1 further assessment would be undertaken during detailed design to confirm the potential for drawdown impacts.

7.1.6 Groundwater take and licensing

Rail infrastructure and road infrastructure

As outlined in section 7.1.1, the proposal's vertical alignment is not likely to intersect the water table. As such, acquiring license entitlement to cover groundwater inflows is unlikely to be required.

Borrow pits

Groundwater take is not anticipated at borrow pit B, borrow pit C and borrow pit D but may occur at a very low rate at borrow pit A.

It is anticipated that groundwater take at borrow pit A would be less than one mega litre per year. This groundwater take would require coverage by sufficient entitlement volume in the NSW MDB Fractured Rock Ground Sources 2020 WSP, Lachlan Fold Belt MDB Groundwater Source. It is recognised that the license volumes may need to be increased if higher than estimated groundwater inflow rates occur.

Bore fields

The upper target groundwater source for the proposal bores is as follows:

- NSW MDB Fractured Rock Ground Sources 2020 WSP, Lachlan Fold Belt MDB Groundwater Source – applicable for 26 proposal bore field bores.
- NSW MDB Porous Rock Groundwater Sources 2020 WSP, Gunnedah-Oxley Basin MDB Groundwater Source – applicable for 62 proposal bore field bores.

The non-potable construction water demand to be sourced from the bores is estimated to be an average of about 3.8 mega litres per day over the entire length of the proposal. Annually, this demand is estimated to be about 1,400 mega litres per year.

The relative percentage of Lachlan Fold Belt MDB Groundwater Source proposal bore field bores is about 30 per cent (ie 26 bores of the proposals overall 88 bores). The remaining 70 per cent (62 bores) comprise Gunnedah-Oxley Basin MDB Groundwater Source proposal bore field bores. Based on these percentages, the required allocation for the proposal's bore field bores from the Lachlan Fold Belt MDB Groundwater Source is estimated to be about 420 mega litres per year (30 per cent x 1400 mega litres per year). For the Gunnedah-Oxley Basin MDB Groundwater Source, the required allocation volume is estimated to be about 980 mega litres per year (1400 mega litres per year – 420 mega litres per year).

These allocations would likely be acquired through a controlled allocation with license volumes confirmed within the post approval stage.

Narromine North and Baradine temporary workforce accommodation facilities

A total of about 44 mega litres per year would be required from the NSW GAB Groundwater Sources 2020 WSP, Southern Recharge Groundwater Source for the extraction of groundwater for potable water at the Narromine North and Baradine temporary workforce accommodation facilities. A potential exception to this is if the Narromine North workforce accommodation bores were located in the small portion of the site (south east corner) which may occupy the Lachlan Fold Belt MDB Groundwater Source. The relevant groundwater source and volume of groundwater required would be further assessed at detailed design stage once the water supply strategy and details are confirmed.

A controlled allocation in the GAB Southern Recharge Groundwater Source is considered unlikely based on entitlement limits and existing allocation volumes. Therefore, the entitlement to cover groundwater extraction for the Narromine North and Baradine temporary workforce accommodation facilities would need to be purchased from the market.

7.1.7 Soil and groundwater salinity

Rail infrastructure and road infrastructure

Except for potential salinity impacts due to application of the bore field water, the proposal is not anticipated to impact existing salinity conditions as the proposal's vertical alignment is not likely to intersect the water table (section 7.1.1).

Mitigation measures for potential salinity impacts due to application of the bore field water are provided in section 11, noting that where bore field groundwater of an elevated salinity is present, appropriate water quality treatment would be provided prior to land application. With the recommended mitigation measures, salinity impacts are not anticipated.

Further assessment regarding soils and salinity is provided in the EIS.

Borrow pits

Borrow pit works are not anticipated to impact salinity conditions, as groundwater take is not anticipated at borrow pit B, borrow pit C and borrow pit D. The rate of groundwater take at borrow pit A is anticipated to be negligible. Furthermore, the salt concentration at the closest groundwater monitoring bore (BH-2-093) near borrow pit A is on the boundary between 'fresh' and 'brackish' in categories defined by Freeze and Cherry (1979). Groundwater monitoring results are summarised in Appendix C.

Bore fields

The bore field pumping is not anticipated to impact the salinity of shallow groundwater systems or soils. However, there is a risk that if the pumped groundwater quality is poor and not treated, impacts to soil, vegetation and shallow groundwater systems could occur if applied to the land surface. Groundwater that is proposed to be extracted by the bore field bores is of unknown quality. Such data is not available from existing bores and would be acquired at detailed design stage as outlined in the groundwater monitoring program (section 10). Mitigation measures for this potential impact are provided (section 11).

Narromine North and Baradine temporary workforce accommodation facilities

Onsite wastewater management and the potential application of effluent via irrigation at these locations could exacerbate groundwater and soil salinity. These risks would be limited in the first instance as reclaimed water would be of relatively high quality and appropriate management practices would be adopted, such as balancing storages and proper irrigation scheduling to avoid excessive irrigation are proposed.

Any irrigation areas would be designed and operated in accordance with the risk framework and management principles contained in the National Guidelines on Water Recycling (EPHC 2006) and the Environmental guidelines: Use of effluent by irrigation (DEC 2004). It is considered that this approach would avoid environmental harm and maintain the receiving soil and groundwater in a stable and productive state, given the following points.

- The irrigation area would be delineated based on the expected rate of irrigation and the drainage characteristics of the receiving soil.
- The quality of treated water would be determined to prevent accumulation of contaminants, with reference to the relevant guidelines.
- The irrigation area would be designed to include capacity to store treated water for the duration of typical wet weather events.
- The rate of irrigation would be optimised to avoid waterlogging or ponding of reclaimed water.
- Soil and groundwater conditions would be monitored to identify and correct trends in soil or groundwater salinity or other potential effects of irrigation.

The reclaimed water reuse scheme at these locations would be designed and operated in accordance with the risk framework and management principles contained in the *National Guidelines on Water Recycling* (Environment Protection and Heritage Council, 2006) and the *Environmental guidelines: Use of effluent by irrigation* (DEC 2004d). This approach would avoid harm to groundwater.

7.1.8 Groundwater contamination

Rail infrastructure and road infrastructure

The proposal's vertical alignment is not likely to intersect the water table (section 7.1.1). Therefore, the human health risks associated with construction workers being subjected to potential contamination is low. Similarly, risks to surrounding landowners and the environment is also low.

Shallow groundwater systems could become contaminated if accidental spills or leaks of hazardous materials (such as fuels, lubricants and hydraulic oils) occur during construction or operation.

Borrow pits

Groundwater interception is not anticipated at borrow pit B, borrow pit C and borrow pit D but may occur at a negligible rate at borrow pit A. The human health risk associated with exposure of construction workers to potentially contaminated groundwater at Borrow pit A is low. Risks to surrounding landowners and the environment is also low. Furthermore, contamination sources are limited within the localised area surrounding borrow pit A. The analytes tested at this location are not in concentrations that present a risk to human health. Groundwater monitoring results are summarised in Appendix C.

Shallow groundwater systems have the potential to become contaminated if accidental spills or leaks of hazardous materials (such as fuels, lubricants and hydraulic oils) occur during excavation.

The potential for impacts associated with accidental spills or leaks would be minimised through the implementation of spill control procedures and measures that will be incorporated into the construction environmental management plan.

Bore fields

Groundwater contamination risks associated with the bore fields are assessed as low. Inter-groundwater system water mixing could occur at the proposal bores due to inadequate zonal isolation during drilling. Mitigation measures for this potential impact are provided in section 11.

Groundwater quality extracted by the bore field bores would require testing prior to usage, to confirm suitable treatment requirements, which would mitigate risks to the environment, landowners and construction workers.

Narromine North and Baradine temporary workforce accommodation facilities

At the Narromine North and Baradine temporary workforce accommodation facilities, onsite wastewater management and application of effluent via irrigation could impact groundwater quality. This could have implications for existing bores and their users, proposed bores and their users and the environment, including adjacent GDEs, where relevant.

As noted in section 7.1.7 the reclaimed water reuse scheme at these locations would be designed and operated in accordance with the risk framework and management principles contained in the *National Guidelines on Water Recycling* (Environment Protection and Heritage Council 2006) and the *Environmental guidelines: Use of effluent by irrigation* (DEC 2004d). This approach would avoid harm to groundwater.

7.1.9 Potential for settlement

Groundwater drawdown has the potential to cause ground settlement due to increased effective soil stress as a result of water being removed from pore spaces, which in turn can cause consolidation of soils. This risk is generally applicable to relatively soft soils and is not expected to occur in areas where the water table is hosted in a fractured rock groundwater system. Settlement can cause damage to existing buildings and infrastructure.

As noted in the section 7.1.4, water table drawdown would be most pronounced around the bore fields, particularly PB1 and PB2. Water table drawdown at the bore fields, with the exception of PB2, is anticipated to be minor and within the range of typical groundwater level responses to long-term climate trends; therefore, it is not anticipated that settlement will occur at these bore fields. Anticipated drawdown at bore field PB2 is relatively greater than at the other bore fields, and likely beyond the range of typical groundwater level responses to long-term climate trends. Therefore, some settlement could occur at this location under certain conditions, such as large water table drawdown in areas of soft soils. The closest existing licensed groundwater bore to PB2 intersected rock at 2.44 metres below ground level and the standing water level is found below this depth. Alluvium soils are mapped to the east of PB2 and may be subject to drawdown up to six metres based on groundwater modelling results. However, existing infrastructure is not present in this area based on review of aerial photography. If settlement does occur at PB2, it is anticipated to be minor and unlikely to cause damage to existing buildings and infrastructure.

Therefore, during the construction phase of the proposal, potential settlement impacts are assessed as low risk.

7.2 Operational impacts

Pumping of the bore fields is not proposed during the operational phase of the proposal.

Where there is benefit to the local community, the potential for retaining bores would be considered in consultation with relevant stakeholders (eg local councils). Any legislative approvals associated with retention and ongoing use of these facilities would be the responsibility of the party who takes ownership. As such, the following information within this section only assesses the bore fields in relation to the proposal and not for ongoing use by other entities.

7.2.1 Groundwater levels

Rail infrastructure and road infrastructure

Potential impacts to groundwater levels due to rail and road infrastructure during the operational phase of the proposal are not expected to differ from that assessed for the construction phase of the proposal (section 7.1.1). The potential changes are assessed to be minor and are anticipated to be within the bounds of the AIP minimal impact considerations (see section 3.3).

Borrow pits

Potential impacts to groundwater levels due to borrow pits during the operational phase of the proposal are expected to be less than that assessed for the construction phase of the proposal (section 7.1.1). Only borrow pit A is assessed as likely to intersect the water table.

Rehabilitation of the borrow pits would be undertaken in accordance with the borrow pit rehabilitation strategy which has been prepared for the proposal (refer to the EIS). In accordance with this strategy, the borrow pits would be rehabilitated to have final ground levels above the water table. Therefore, with implementation of the borrow pit rehabilitation strategy, changes to groundwater levels would not occur, or would be negligible. The potential changes to groundwater levels during operation due to borrow pits are assessed to be minor and within the bounds of the AIP minimal impact considerations (see section 3.3).

Bore fields

As pumping of the bore fields during the operational phase of the proposal would not occur, potential groundwater level drawdowns during operation of the proposal would be negligible and within the bounds of the AIP minimal impact considerations (see section 3.3).

Narromine North and Baradine temporary workforce accommodation facilities

Pumping of the potential bores that would service the Narromine North and Baradine temporary workforce accommodation facilities would not occur during the operational phase of the proposal. Therefore, potential associated groundwater level reductions during operation of the proposal would be negligible and within the bounds of the AIP minimal impact considerations (see section 3.3).

7.2.2 Groundwater dependent ecosystems

As changes to groundwater levels during the operational phase of the proposal due to rail and road infrastructure, borrow pits, bore fields and the Narromine North and Baradine accommodation facilities are assessed to be minor (section 7.2.1), impacts to GDEs due to groundwater level drawdown during the operation phase are not anticipated. There is a potential for groundwater quality at GDEs in proximity to the Narromine North and Baradine temporary workforce accommodation facilities to be decreased due to the potential application of onsite wastewater at the Narromine North and Baradine temporary workforce accommodation facilities during the construction phase. This potential impact is primarily applicable to the construction phase but could also occur to a lesser degree during the operational phase if nutrient and salt loading alters groundwater recharge or surface water runoff quality. As noted in section 7.1.7, ensuring the wastewater treatment systems are designed and operated in accordance with the risk framework and management principles contained in the *National Guidelines on Water Recycling* (Environment Protection and Heritage Council 2006) and the *Environmental guidelines: Use of effluent by irrigation* (DEC 2004d) would avoid harm to groundwater, including any potential GDEs.

7.2.3 Groundwater bores

As changes to groundwater levels during the operational phase of the proposal due to rail and road infrastructure, borrow pits, bore fields and the Narromine North and Baradine temporary workforce accommodation facilities are assessed to be minor (section 7.2.1), impacts to existing groundwater bores as a consequence of groundwater level drawdown are not anticipated. Groundwater level drawdowns during the operation of the proposal are anticipated to be lower and within the bounds of the AIP minimal impact considerations (see section 3.3).

Potential groundwater quality reduction at existing bores due to application of onsite wastewater at the Narromine North and Baradine temporary workforce accommodation facilities is discussed in section 7.2.7

7.2.4 Surface water-groundwater interactions

As changes to groundwater levels during the operational phase of the proposal due to rail and road infrastructure, borrow pits, bore fields and the Narromine North and Baradine temporary workforce accommodation facilities are assessed to be minor (section 7.2.1), associated potential baseflow reductions during the operation of the proposal would be negligible.

7.2.5 Groundwater take and licensing

Rail infrastructure and road infrastructure

Groundwater take due to rail and road infrastructure is assessed as unlikely to occur, including during the operational phase of the proposal.

Borrow pits

Groundwater take could occur at borrow pit A during the operation of the proposal. However, a mitigation measure has been provided (section 11) that as far as practicable, would result in the borrow pit being rehabilitated to have final ground levels above the water table. With this mitigation measure, groundwater take during the operational phase at borrow pit A is as assessed as unlikely to occur. If this mitigation measure is not implemented, since borrow pit A is currently designed to free drain, the groundwater take would require licensing in perpetuity and is estimated to be less than one mega litre per year. This groundwater take would require coverage by sufficient entitlement volume in the NSW MDB Fractured Rock Ground Sources 2020 WSP, Lachlan Fold Belt MDB Groundwater Source. The license volume may need to be increased if higher than estimated groundwater inflow rates occur.

Bore fields

As pumping of the bore fields during the operational phase of the proposal would not occur, allocation for groundwater extraction would not be required.

Narromine North and Baradine temporary workforce accommodation facilities

Pumping of the potential bores servicing the Narromine North and Baradine temporary workforce accommodation facilities would not occur during the operational phase of the proposal. Therefore, allocation for groundwater extraction would not be required.

7.2.6 Soil and groundwater salinity

As changes to groundwater levels during the operational phase of the proposal due to rail and road infrastructure, borrow pits and the bore fields are assessed to be minor (section 7.2.1), soil and groundwater salinity impacts are not anticipated during the operational phase of the proposal for these elements.

Onsite application of effluent at the Narromine North and Baradine temporary workforce accommodation facilities during the operational phase of the proposal would not occur. However, soil and groundwater salinity could still be impacted during the operational phase of the proposal due to salt loading from onsite effluent application during the construction phase. This potential impact would be mitigated as described in section 7.1.7.

7.2.7 Groundwater contamination

Groundwater contamination risks during the operational phase of the proposal are expected to be lower than that assessed for the construction phase of the proposal (section 7.1.8).

During the operational phase of the proposal, potential contamination impacts are assessed as low risk. The potential for impacts associated with accidental spills or leaks would be minimised through the implementation ARTC's standard operating procedures.

Onsite application of effluent and pumping of proposal bores at the Narromine North and Baradine temporary workforce accommodation facilities during the operational phase of the proposal would not occur. However, groundwater quality could still be impacted during the operational phase of the proposal due to onsite effluent application during the construction phase. This could have implications for existing bores if water quality is reduced. This potential impact would be mitigated as described in section 7.1.7.

7.2.8 Potenital for settlement

Settlement risks during the operational phase of the proposal are expected to be similar to that assessed for the construction phase of the proposal (section 7.1.9).

During the operational phase of the proposal, potential settlement impacts are assessed as low risk.

7.3 NSW AIP minimal impact consideration assessment summary

7.3.1 Construction phase

Proposal except for Narromine North and Baradine workforce sites

Predicted groundwater level reductions during construction of the proposal are less than the AIP minimal impact considerations (see section 3.3) except for the following:

- Bore GW000986, located near PB2. At bore GW000986, about 3.5 metres of drawdown is predicted. As such, mitigation of potential drawdown impacts at GW000986 is provided in section 11 through agreeing to ‘make good provisions’.
- Modelled drawdown to groundwater pressure in the aquitard layer at the base of the GAB is greater than the minimal impact consideration criteria. Whilst the minimal impact consideration drawdown criteria is exceeded, this aquitard is very deep and therefore not relevant to existing bores and GDEs. Therefore, the viability of such assets is not anticipated to be impacted.

Groundwater level reductions are not anticipated to cause any existing flowing bores to cease flowing during the construction phase, nor is the beneficial use category of groundwater sources anticipated to be lowered beyond 40 metres of the proposal. Both the impact to flowing GAB bores and impacts to beneficial use are AIP minimal impact criteria considerations.

The separation distance from proposal bore fields to areas of mapped High Priority vegetation ranges from about 0.35 kilometres to 8.80 kilometres. Only three bore fields have a separation distance of less than one kilometre (PB8 – 0.75 kilometres, PB10 – 0.70 kilometres and PB11 – 0.35 kilometres). The separation distances are sufficiently large that impacts to areas of mapped High Priority vegetation due to water table drawdown are not anticipated. Furthermore, except for PB1 and PB2 (where no nearby High Priority GDEs are mapped), maximum modelled drawdowns to the water table are considered to be less than 10 per cent of the variation which occurs due to natural climatic variability, which is the AIP minimal impact consideration criteria for water table drawdown near GDEs.

Potential impacts to High Priority GDEs are assessed as likely to be less than the AIP minimal impact considerations (see section 3.3).

Narromine North and Baradine workforce sites

An assessment of the impacts of extracting groundwater to supply these workforce sites with potable water (after treatment) would be undertaken at detailed design stage once the water supply strategy and details are confirmed. The mitigation measures outlined in section 11 would be implemented to mitigate associated risks identified in the impact assessment (section 7). With these mitigation measures, unacceptable impacts to groundwater are not anticipated.

7.3.2 Operational phase

As pumping of the bore fields during the operational phase of the proposal would not occur, predicted groundwater level reductions during the operation of the proposal are less than the AIP minimal impact considerations.

Groundwater level reductions are not anticipated to cause any existing flowing bores to cease flowing during the operational phase, nor is the beneficial use category of groundwater sources anticipated to be lowered beyond 40 metres of the proposal.

7.4 Bore field bore siting flexibility

During detailed design, the location of the bore fields and individual bores may require alteration. The assessment results are such that there is some flexibility to re-position the bore fields without necessitating re-assessment by a hydrogeologist. However, under certain conditions, potential impacts due to altered bore field locations would require re-assessment by a hydrogeologist. These conditions are outlined in section 11.

8. Water use and water balance

Water is required for the construction phase of the proposal but is not required for the operational phase of the proposal.

8.1 Water demands

Water is a resource required over the entire length of the proposal site for a range of activities including earthworks, dust suppression, concrete, washdown and temporary workforce accommodation.

The water requirements are subject to weather conditions and methodology selected by the construction contractor. However, it has been estimated at a total of about 4.6 giga litres would be required as summarised in Table 8.1. This indicative water take would need to be confirmed during detailed design.

Table 8.1 Estimated total construction water requirements

Use	Volume (ML) for proposal site	Volume (ML) for typical 5 km section
Earthworks and formation preparation and materials conditioning	1850	30.2
Dust suppression (stockpiles and haul roads)	2270	37.1
Concrete	25	0.4
Washdown	20	0.3
Temporary workforce accommodation (potable water)	470	NA

As a yearly rate, the non-potable construction water demand is estimated to be about 1,400 mega litres per year.

8.2 Water balance

8.2.1 Inflow

Groundwater

It is presently estimated that most, if not all, of the non-potable construction water would be sourced from groundwater pumped from the proposal bore fields. Groundwater extraction from the bore fields would provide about 1,400 mega litres of construction water per year for the proposal site, or about 57.3 mega litres over the construction period for a five kilometre section of the proposal site.

Groundwater extraction from groundwater bores is also proposed to supply potable water for the Narromine North and Baradine temporary workforce accommodation facilities. To meet potable water demand for the construction workers, about 14.7 mega litres per year would need to be extracted for the Narromine North facility, and about 29.4 mega litres per year for the Baradine facility.

As discussed in section 7.1.2, groundwater inflows into excavations are not expected for the majority of the proposal site. The exception to this is borrow pit A, where small groundwater inflows are anticipated. It is likely that the maximum groundwater inflow rate would be between 0.08 and 0.28 mega litres per year. Due to the anticipated low inflow rates, discharge of groundwater is not likely to be required and any groundwater inflow would evaporate.

There may also be potential to encounter shallow groundwater during piling of bridges if bored piles are used. However, any groundwater inflow during piling would be minimal.

Run off and sedimentation basins

Sedimentation basins would be provided at regular intervals along the proposal site and would capture any runoff within the proposal site.

Water contained within the sedimentation basins would either be discharged to the nearest watercourse or could supplement the construction water volumes if required. However, it should be noted that the groundwater assessment described in this report has assumed all construction water would be supplied from groundwater pumped from the proposal bore fields.

Taking into consideration the potential for evaporation it is anticipated that up to 10.8 mega litres of water from the sedimentation basins would either supplement the construction water volumes or require discharge to a suitable watercourse over the construction period for a five kilometre section of the proposal site.

The impacts associated with potential discharge of the water from the sedimentation basins are considered in *ARTC Inland Rail Narromine to Narrabri Surface Water Quality Assessment* (JacobsGHD, 2020b).

Town services

It is anticipated that potable water for the Narromine South, Gilgandra and Narrabri West temporary workforce accommodation facilities would be provided through town services connections, with 14.7 mega litres per year being required for Narromine South and 29.4 mega litres per year being required for the Gilgandra and Narrabri West facilities.

8.2.2 Outflows

Construction water

Indicative construction water requirements for the proposal site as a whole and for a typical five kilometre section of the proposal site are listed in Table 8.1.

It is anticipated that during construction, most of the water used for activities would either be absorbed by the construction activity or product or evaporate. Potential surface water runoff from construction activities would be minor and managed by standard erosion and sediment controls.

Temporary workforce accommodation

Water would mainly be used at the temporary workforce accommodation to provide drinking water and water for site amenities and kitchens.

It is estimated that the facilities would produce a total of about 183 mega litres per year of wastewater, based on workers generating an average of 250 litres of wastewater per day each. Options to dispose of wastewater would include connections to the towns' existing wastewater network (where available), trucking or irrigation of treated wastewater. The preferred option/s would be confirmed by the construction contractor during detailed construction planning.

8.3 Opportunities to reduce water usage

Water for earthworks and dust suppression comprise the bulk of the water requirements for the proposal and the need varies along the proposal site based on the areas of cuts and fills. Generally there is limited opportunity to reduce these. However, opportunities that would be further explored during detailed design and construction include use of additives and use of different materials for haul roads. The estimated volumes for dust suppression are based on assumed weather conditions (ie less water would be required when it is raining) and typical rates used to minimise the generation of nuisance dust outside the construction footprint and provide for safe operation (ie driver visibility) of haul roads. Subject to consideration of potential off-site impacts and safety of haul road operations, a reduced dust suppression regime may be possible along parts of the proposal site.

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9. Cumulative impact assessment

This section provides a qualitative assessment of potential cumulative groundwater impacts which may occur due to the proposal interacting with other approved or proposed projects.

9.1 Overview

Cumulative impacts can be defined as the successive, incremental, and combined effect of multiple impacts, which may in themselves be minor, but could become significant when considered together. The methodology and projects considered for the cumulative impact assessment are provided in detail in the EIS (Part D chapter D1). Seven major projects were identified with sufficient information to undertake a cumulative impact assessment. These are shown in Figure 9.1 and include:

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

A separate and more detailed cumulative assessment has been undertaken between the proposal and the Narrabri Gas Project due to the greater level of information available and the community concerns regarding potential groundwater impacts associated with the Narrabri Gas Project.

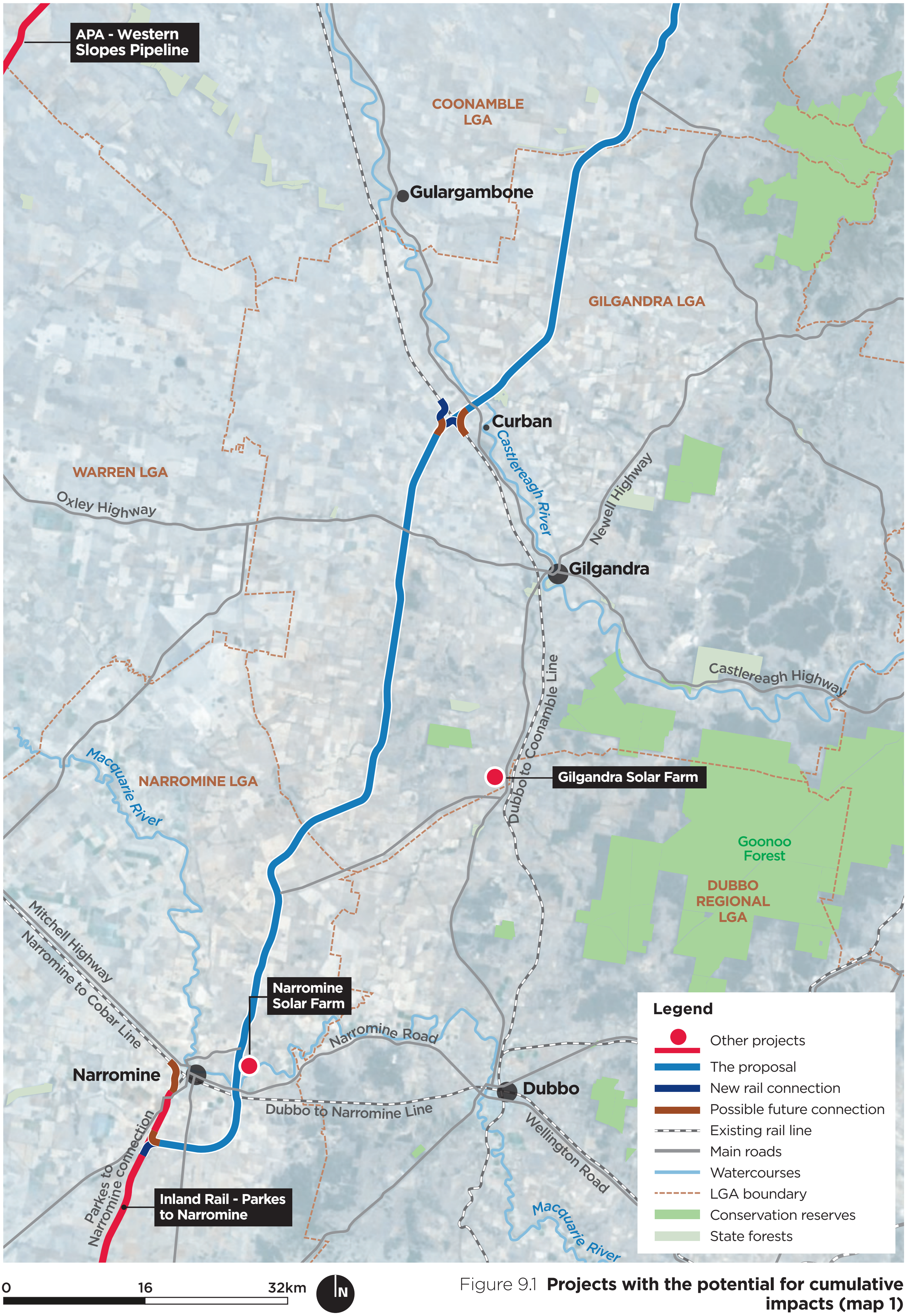

Figure 9.1 **Projects with the potential for cumulative impacts (map 1)**

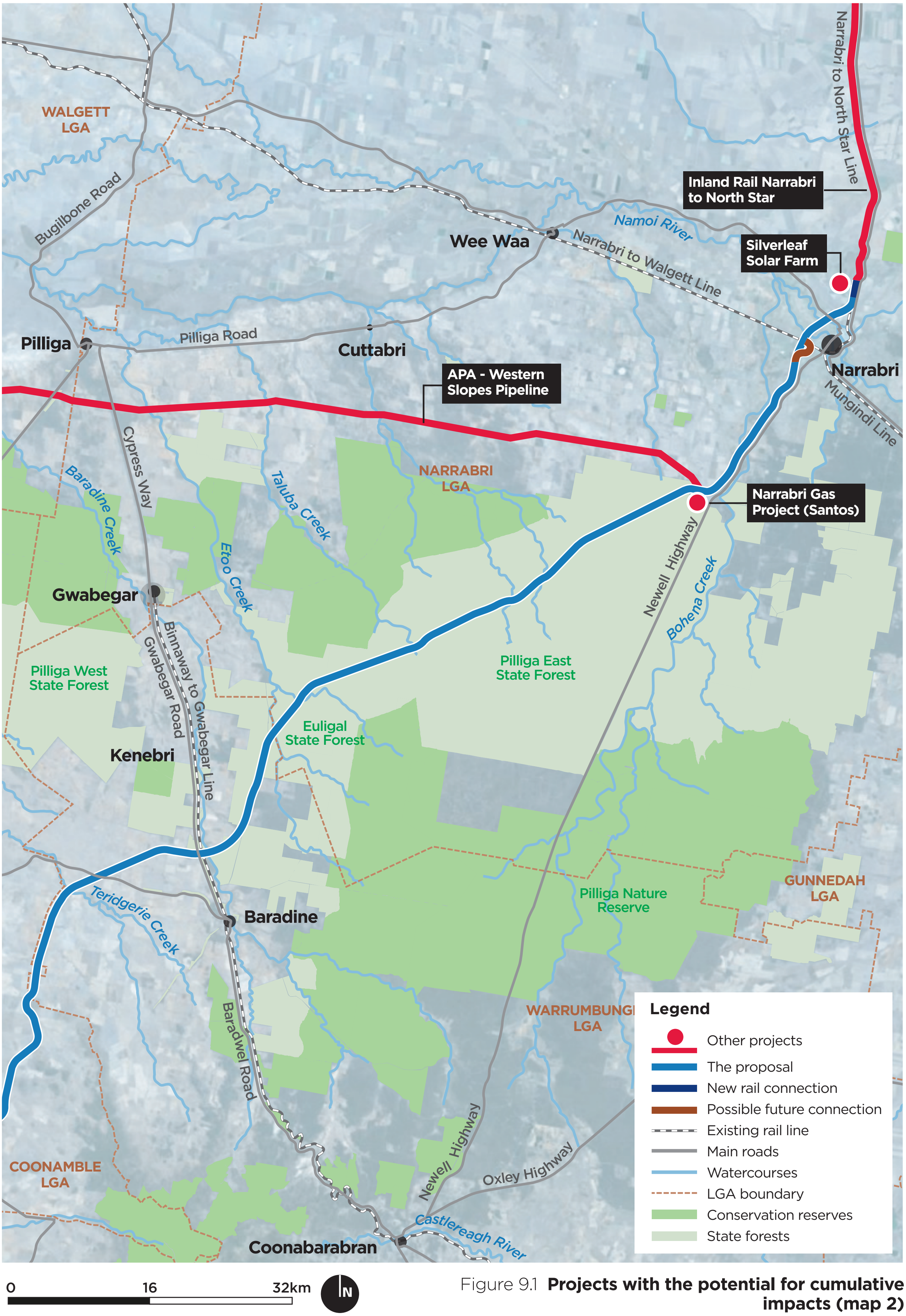

Figure 9.1 **Projects with the potential for cumulative impacts (map 2)**

9.2 Construction and operation

The cumulative groundwater impact assessment for both construction and operation is summarised in Table 9.1.

Table 9.1 Cumulative impact assessment

Project name	Cumulative impact assessment
APA - Western Slopes Pipeline	Cumulative impacts to groundwater are unlikely based on the spatial separation between the pipeline and the proposal. The Western Slopes Pipeline is located greater than 50 km from the proposal, except for the region where the pipeline project crosses the proposal to connect to the proposed Narrabri Gas Project. There is a small potential for cumulative impacts to groundwater quality in the area where the pipeline crosses the proposal, due to potentially hazardous material spills or leaks. This risk is considered to be low. Additionally, mitigation measures have been provided in section 11 which further lower the risk.
Inland Rail - Narrabri to North Star	Potential cumulative impacts could include: • Impacts to groundwater quality in the area where the proposal and Narrabri to North Star section of Inland Rail connect. This could occur if accidental spills or leaks of hazardous materials (such as fuels, lubricants and hydraulic oils) occur during construction. • Drawdown of groundwater levels due to groundwater extraction from bores to supply construction water. The groundwater quality risk is considered to be low. It is unlikely that a hazardous material spill or leak would occur close enough to result in a cumulative impact. Additionally, mitigation measures have been provided in section 11 which further lower the risk. The groundwater drawdown risk is considered to be low. The Narrabri to North Star section of Inland Rail EIS Hydrology and Flooding Assessment indicates groundwater would be generally abstracted under existing groundwater access licences. That report also indicates that ongoing operation of the Narrabri to North Star section of Inland Rail would not require sourcing of groundwater. The proposal bores will be deeper than existing bores minimising risk of water level reductions to existing bores. Mitigation measures have been provided in section 11 to lower the risk of groundwater level drawdown.
Inland Rail – Parkes to Narromine	Potential cumulative impacts could include: • Impacts to groundwater quality in the area where the proposal and Parkes to Narromine section of Inland Rail connect. This could occur if accidental spills or leaks of hazardous materials (such as fuels, lubricants and hydraulic oils) occur during construction. • Drawdown of groundwater levels due to groundwater extraction from bores to supply construction water. The risk of groundwater quality impacts is considered low. It is unlikely that a hazardous material spill or leak would occur close enough to result in a cumulative impact. Additionally, mitigation measures have been provided in section 11 which further lower the risk. The risk of groundwater drawdown impacts is considered low. The Parkes to Narromine section of Inland Rail EIS Hydrology and Flooding Assessment indicates groundwater would be generally extracted under existing groundwater access licences. That report also indicates that ongoing operation of the Parkes to Narromine section of Inland Rail would not require sourcing of groundwater. The proposal bores would be designed to be deeper than existing bores to minimise water level reductions to existing bores. Mitigation measures have been provided in section 11 to lower the risk of groundwater level drawdown.

Project name	Cumulative impact assessment
Narrabri Gas Project (Santos)	Compared to other assessed projects, the Narrabri Gas Project has the largest potential to cause cumulative impacts due to interacting with the proposal. There is a risk that the supply of construction water via the proposal bore fields in combination with Santos groundwater extraction could result in cumulative drawdown of groundwater level. This could have implications for existing bores, GDEs and river/creek baseflow. This risk is assessed below in section 9.3.
Silver Leaf Solar Farm (Narrabri)	Cumulative impacts to groundwater are unlikely based on the spatial separation between the proposed solar farm and the proposal. The solar farm is located site about 4 km north of Narrabri. It is unlikely that a solar farm would have significant long-term interactions with groundwater systems. Significant interaction with groundwater, if at all, would likely be limited to groundwater extraction during construction/operation. Such a project is not expected to require extraction of large volumes of groundwater, if at all.
Gilgandra Solar Farm	Cumulative impacts to groundwater are unlikely based on the spatial separation between the solar farm and the proposal. The solar farm is located over 15 km east of the proposal site.
Narromine Solar Farm	The project is in the early proposal phase and includes a new solar farm located about 10 km northeast of Narromine. The proposal is located on the western border of the solar farm. Cumulative impacts to groundwater are unlikely. It is unlikely that a solar farm would have significant long-term interactions with groundwater systems. Significant interaction with groundwater, if at all, would likely be limited to groundwater extraction during construction or operation. Such a project is not expected to require extraction of large volumes of groundwater, if at all.

9.3 Assessment of potential cumulative impacts – Narrabri Gas Project

9.3.1 Overview

As discussed briefly in Table 9.1, the Narrabri Gas Project has the largest potential to cause cumulative impacts due to interacting with the proposal when compared to the other reviewed projects. Therefore, this has been assessed separately in its own section.

There is a risk that pumping of the proposal bores to supply construction water in combination with Santos groundwater extraction could result in cumulative groundwater level drawdown. This could have implications for existing bores, GDEs and river/creek baseflow. This risk is primarily applicable in the area of proposal bore field PB11, due to it being within the proposed Santos Gas Project footprint. This is based on groundwater modelling results in the EIS technical groundwater report for the Santos Gas Project's (CDM Smith, 2016). Proposal bore fields PB10 and PB12 are also relatively close to the Santos Gas Project; however, base case drawdown predictions are relatively small at these locations.

The primary coal seam gas target of the Santos Gas Project are the early Permian coal seams (Rutley Seam, Namoi Seam, Parkes Seam and Bohena Seam). These seams are interpreted to be of the order of 1,000 metres deep at PB11. A secondary coal seam gas target of the Santos Gas Project is the late Permian coal seam (Hoskissons Seam), which is interpreted to be of the order of 700 metres deep at PB11.

CMD Smith (2016) indicates that the gas wells would be progressively drilled in the first 20 years of the Santos Gas Project. A 25 year construction and operation period is applicable for the Santos Gas Project. Progressive construction of the gas processing and water management facilities would take around 3 years (CDM Smith, 2016).

9.3.2 Groundwater modelling predictions

Base case Narrabri Gas Project groundwater level drawdown predictions are summarised as follows:

- Water table drawdown has been predicted to decline by less than 0.5 metres throughout the model.
- Modelled groundwater level drawdown in the Pilliga Sandstone is less than 0.5 metres throughout the model.
- Modelled groundwater level drawdown in the Late Permian targets (Hoskissons Coal Seam) at PB11 is five to ten metres. PB12 is north of the modelled one metre drawdown contour and is outside of the model boundary for that layer. PB10 is near the model boundary for the Late Permian targets model layer and drawdown of less than five metres is predicted at this location.
- Modelled groundwater level drawdown in the Early Permian targets (Rutley Seam, Namoi Seam, Parkes Seam and Bohena Seam) is a maximum of about 100 metres. At PB11, the predicted drawdown is interpreted to be in the range of 50 to 100 metres. There is some uncertainty with this because a non-uniform contour interval is used and not all contours are labelled. The model layer for the Early Permian targets does not extend to PB10. The boundary of this model layer is about eight kilometres north west of PB10. At PB12, the modelled drawdown in the Early Permian targets is less than one metre.

9.3.3 Qualitative impact assessment

The risk of cumulative impacts to groundwater systems as a result of the proposal interacting with the Narrabri Gas Project is considered **low** for the following reasons:

- CDM Smith (2016) base case modelled drawdown in the Late Permian targets is small and of the order of five to 10 metres at PB11. This target is interpreted to be about 700 metres deep and therefore would have some separation from the groundwater systems the proposal extracts from (ie anticipated to be from about 420 to 520 mBGL). CDM Smith (2016) conceptualisation includes aquitards (described as negligibly transmissive units) within this separation distance. These aquitards are anticipated to mitigate drawdown in overlying groundwater systems.
- Base case modelled drawdown in the Early Permian targets is large and interpreted to be in the range of 50 to 100 metres. However, these targets are very deep (about 1,000mBGL) and are far below where the proposal would abstract groundwater (ie anticipated to be from about 420 to 520 mBGL). The CDM Smith (2016) conceptualisation includes aquitards (described as negligibly transmissive units) within this separation distance. These aquitards are anticipated to mitigate drawdown in overlying groundwater systems.
- The proposal would only require bore pumping during construction for a non-permanent period of about 500 days. This is a short duration compared to the Santos project life of about 25 years (9,131 days). It is unlikely that the proposal extraction would coincide with peak Santos pumping. This is further evidenced by CDM Smith (2016) which indicates that the Santos wells would be progressively drilled over a 20 year period and that gas processing and water management facilities would take about three years to construct.
- The Santos modelled drawdown to upper groundwater systems of the water table and Pilliga Sandstone is small and no more than 0.5 metres.
- The nearest existing bores which are licensed to extract groundwater from the Gunnedah-Oxley Basin MDB Groundwater Source are located about 20 kilometres from PB11.

10. Groundwater monitoring program

A groundwater monitoring program would be developed following project approval and implemented as an environmental management measure (section 11). The groundwater monitoring program would be developed in consultation with NSW DPIE and relevant government agencies.

A preliminary groundwater monitoring program is outlined below.

10.1 Baseline data

10.1.1 Proposal site and borrow pit groundwater monitoring bores

Groundwater levels

The current groundwater level baseline data for the proposal site and borrow pits is considered appropriate. Nonetheless, it is recommended that groundwater levels at all existing proposal groundwater monitoring bores continue to be monitored automatically by data logger at six hourly intervals until construction commences.

Groundwater quality

The current groundwater quality baseline data for the proposal site and borrow pits is considered appropriate. No further baseline groundwater quality data collection is considered necessary.

10.1.2 Proposal bore fields

Following project approval and at the pre-construction stage, baseline groundwater quality and level data would be collected at the proposal bore fields as test bores are progressively drilled. A bore census would also be undertaken for existing groundwater bores that are within one kilometre of the proposal bore field bores.

Existing groundwater bores

Following project approval, a bore census would be undertaken for existing groundwater bores within one kilometre of the proposal bore field bores. The primary purpose of the bore census would be to collect baseline groundwater level data and information on a given bores typical usage and characteristics (eg bore construction, pump depth, yield, water level during pumping and water level outside of pumping periods).

Should existing bores experience water level reduction due to the proposal, the baseline data collected through the bore census would provide a basis to determine if the proposal has likely caused the water level reduction and therefore if ‘make good provisions’ should be activated.

At this stage the bore census would, where possible, be undertaken for the existing bores shown in Table 10.1. This would be confirmed within the post-approval stage.

It is noted that bore GW803616 is within the construction footprint. If it is determined that this bore would require decommissioning, the need to include it in the bore census would be re-evaluated.

Table 10.1 Existing groundwater bores that as a minimum would be included in bore census

Proposal bore field	Groundwater bore ID that would be included in bore census	Distance to closest proposal bore field bore
PB1	GW001568	430 m
PB2	GW000986	650 m
PB3	GW008176 GW001482 GW801698	900 m 300 m 620 m
PB4	GW049338	700 m
PB5	GW803616	400 m
PB6	GW013442	220 m
PB7	GW013273 GW010392	160 m 420 m
PB8	GW016877	820 m
PB9	NA	Closest existing bore is >10 km
PB10	NA	Closest existing bore is about 3.9 km
PB11	GW006577	80 m
PB12	GW067438 GW053461 GW012129 GW012113 GW012138 GW012148 GW012144 GW065028 GW010573 GW019353 GW971376 GW967981	170 m 170 m 570 m 710 m 940 m 780 m 910 m 950 m 950 m 880 m 680 m 530 m

Groundwater quality

Groundwater quality would be tested at a minimum of one test bore per proposal bore field for:

- pH
- EC
- TDS
- hardness
- dissolved and total heavy metals (arsenic, cadmium, chromium, copper, lead, mercury, nickel, zinc)
- major Ions (chloride, sulphate, sodium, potassium, magnesium, calcium; and carbonate bicarbonate, and hydroxide alkalinity)
- other analytes relevant to the design, which would be confirmed at detailed design.

A minimum of three groundwater quality sampling rounds would be undertaken at each bore field test bore.

The bore field baseline groundwater quality sampling results are required to inform a decision on whether water quality treatment design is required, and if required, to inform the treatment design.

Groundwater level

Groundwater level would be monitored at a minimum of one test bore per proposal bore field by data logger at a minimum six hourly interval to develop baseline data. Monitoring would commence following completion of bore construction.

10.2 Construction phase

10.2.1 Proposal site and borrow pit groundwater monitoring bores

Groundwater levels

Groundwater levels would continue to be monitored automatically by data logger at six hourly intervals during the construction period at all existing proposal site and borrow pit monitoring bores. The data would be downloaded and assessed at three month intervals.

It is noted that during construction, some proposal monitoring bores may require decommissioning. Monitoring should continue until decommissioning is required and a final sampling round should be undertaken shortly before decommissioning. At this stage, replacing the decommissioned bores is not considered necessary.

Groundwater quality

Groundwater quality monitoring is not considered necessary during the construction phase at proposal site and borrow pit monitoring bores. However, adaptive monitoring would be employed if unforeseen conditions are encountered or unforeseen events occur, such as contamination or interception of shallow regional water tables. In such circumstances, nearby existing bores would be monitored as required, or new monitoring bores installed.

10.2.2 Proposal bore fields

Groundwater levels

Groundwater level monitoring at bore field bores would be undertaken during the construction period. The purpose of the monitoring would be to provide data to assess bore performance and provide a basis to adjust pumping rates if required. The data would also provide a basis to inform assessment of whether make good provisions should apply at certain bores if complaints arise concerning water level reductions. The extent of the bore field groundwater level monitoring during the construction phase would be confirmed at detailed design stage and modified as required during the construction phase.

It is noted that to simplify bore field groundwater level monitoring during the construction phase, the pumping bores may need to be designed with conduits for dip meters or loggers, so entanglement is avoided when such items and lowered into the bores.

Groundwater quality

Groundwater quality should be sampled and analysed by laboratory at a minimum of one bore per bore field at monthly intervals during periods that the respective bore field is pumped. Analysis should be for the same analysis suite as outlined in section 10.2.2.

If the bore field water requires treatment, water quality testing would also be undertaken following treatment.

10.3 Operational phase

10.3.1 Proposal site and borrow pit groundwater monitoring bores

At this stage, groundwater level and quality monitoring is not considered necessary during operation. However, this would be confirmed at the end of the construction phase.

If borrow pit or alignment excavations intercept groundwater during the construction phase, operational groundwater monitoring requirements would be determined at the end of construction period, or when the borrow pit is no longer used during construction.

As discussed in the groundwater impact assessment (section 7), for both construction impacts (section 7.1) and operational impacts (section 7.2), groundwater systems are unlikely to be materially impacted by the borrow pits. The risk of the borrow pits materially impacting groundwater quality, levels/flow directions, baseflow, existing bores and GDEs is considered low. Also, as explained under the ‘borrow pit’ heading in section 7.2.5, groundwater take during the operational phase is assessed as unlikely to occur.

10.3.2 Proposal bore fields

Groundwater quality monitoring at proposal bore field bores is not considered necessary during operation as the bores would not be pumped; however, this would be confirmed at the end of the construction phase.

Groundwater level monitoring at the bore field bores should continue during the operation phase until water levels recover to baseline levels. Groundwater level monitoring beyond this is not anticipated to be required. However, the operational groundwater level monitoring requirements would be confirmed at the end of the construction period, or when the bore field is no longer used during construction.

11. Recommended mitigation measures

Measures to avoid, minimise or manage impacts to groundwater are detailed in Table 11.1.

Table 11.1 Groundwater mitigation measures

Issue	Proposal mitigation measures	Timing
Construction and potable water supply	Construction water supply options would continue to be explored during detailed design and could include reuse of excess water from the Narrabri Gas Project or other suitable facilities in the area or lease and/or purchase of existing water access licences from surrounding landholders. Potable water supply options would continue to be explored during detailed design.	Detailed design/ pre-construction
Impacts to existing bores	Where existing licensed bores are located within the proposal site, they would be decommissioned in accordance with the *Minimum Construction Requirements for Water Bores in Australia* (National Uniform Drillers Licensing Committee, 2012).	Detailed design/ pre-construction
	A bore census would be undertaken for existing licensed bores within one kilometre of the proposal's bore fields, where landholders 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).	Detailed design/ pre-construction
Bore field groundwater level drawdown impacts	Test bores would be installed during detailed design and further investigation would be undertaken by a qualified hydrogeologist to confirm the depth and location of the proposed bore field bores. The bore fields would need to consider the bore field design considerations detailed in section 11.1.	Detailed design/ pre-construction
Bore fields and Narromine North and Baradine temporary workforce accommodation bore groundwater licensing	The water volumes required to be extracted from groundwater for construction water and potable water would be confirmed and the appropriate approvals would be obtained prior to extraction. Monitoring would be undertaken during extraction to ensure volumes stipulated by licence requirements are not exceeded.	Detailed design/ pre-construction
Bore field water quality and drawdown	Groundwater level and quality monitoring would be undertaken in accordance with the groundwater monitoring program (section 10).	Detailed design/ pre-construction/construction

Issue	Proposal mitigation measures	Timing
Narromine North and Baradine temporary workforce accommodation bores drawdown and quality impacts due to onsite wastewater	Further assessment would be undertaken to determine the potential for the bores associated with the Narromine North and Baradine facilities to cause drawdown impacts. This would include ensuring any impacts to existing bores are below the NSW Aquifer Interference Policy minimal impact considerations.	
	Any onsite wastewater systems would be designed to treat wastewater to a high standard, have an appropriately sized irrigation area and have wet weather mitigation as necessary, such as reserve storage volume. The onsite wastewater systems would be designed and operated in accordance with the National Guidelines on Water Recycling (EPHC 2006) and the Environmental guidelines: Use of effluent by irrigation (DEC 2004).	Detailed design/ pre-construction
Narromine North and Baradine temporary workforce accommodation bores groundwater quality.	The groundwater quality from the bores associated with the Narromine North and Baradine facilities would be assessed for the suitability of its intended use. Where required, treatment systems would be designed and a monitoring program established to ensure water quality does not exceed the relevant drinking water criteria from the *National Water Quality Management Strategy Australian Drinking Water Guidelines 6 2011* (National Health and Medical Research Council, 2017).	Detailed design/ pre-construction
Bore field groundwater quality	Proposal bore field groundwater quality would be assessed for the suitability of its intended use. Where required, treatment systems would be designed to ensure water quality does not exceed the relevant water quality criteria from the *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZG, 2018).	Detailed design/ pre-construction
Impacts to existing 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 landholders.	Construction
Bore construction	The proposal bore fields and temporary workforce accommodation bores would be constructed by appropriately licenced drillers in accordance with the *Minimum Construction Requirements for Water Bores in Australia* (National Uniform Drillers Licensing Committee, 2012) and the relevant requirements for drilling within each Water Sharing Plan	Construction
Unforeseen water table penetration by bulk earthworks	If bulk excavations unexpectedly intersect the water table, potential impacts would be assessed by a hydrogeologist and adaptive mitigation measures employed as required.	Construction

Issue	Proposal mitigation measures	Timing
Unforeseen water table penetration by borrow pits	If excavations at borrow pit B, borrow pit C or borrow pit D intersect the water table, the potential impacts would be assessed by a hydrogeologist and additional management measures implemented as required.	Construction
Borrow pit A groundwater inflow rate	If the groundwater inflow rate at Borrow pit A is higher than estimated in this report, then the inflow rate and implications would be assessed by a hydrogeologist and adaptive mitigation measures employed as required.	Construction
Proposal bore fields	Where there is benefit to the local community, the potential for retaining bores post-construction would be considered in consultation with relevant stakeholders (eg local councils). Any approvals, operating costs and maintenance associated with retaining and using these bores would be the responsibility of the party who takes ownership.	Construction
Borrow pit rehabilitation	The borrow pits would be rehabilitated in accordance with the borrow pit rehabilitation strategy which includes the requirement to have final ground levels above the water table.	Construction

11.1 Bore field design considerations

11.1.1 Confirmation of hydrogeological conditions

Proposal bore field hydrogeological conditions would be confirmed through test bores at detailed design. Specifically, the thickness and hydraulic conductivity of aquitard(s) layers at the base of the GAB will be verified by a hydrogeologist (and most likely via drill stem packer testing). Where the GAB is present, the proposal bores will be designed to extract groundwater from below the GAB and below a reasonably thick aquitard unit that when pumped for about 500 days, would result in drawdown of less than one metre to overlying GAB aquifers and the water table. Yields will also be assessed through the test bores. A hydrogeologist will assess if re-modelling of potential groundwater impacts is required due to test bore observations deviating from the conceptual hydrogeological model and adopted model parameters presented in this report. This includes if the nominated bore distribution is different from that assessed in this report due to increased bore quantity.

11.1.2 Altered bore field locations

At detailed design stage, bore field locations may require alteration. Under certain conditions, potential impacts due to the altered bore field(s) would be re-assessed by a hydrogeologist. These conditions are outlined below.

- PB1 – potential bore field impacts would be re-assessed if:
  - the bores are moved to the north, north east or east by more than about 150 metres
  - the bores are moved to the south or west by more than about one kilometre
  - separation to adjacent bore fields is less than five kilometres
  - the bores are moved such that the separation to mapped High Priority GDE vegetation becomes less than 200 metres

- PB2 – potential bore field impacts would be re-assessed if:
  - the bores are moved to the north, north east or east by more than about 50 metres
  - the bores are moved to the south or west by more than about 700 metres
  - separation to adjacent bore fields is less than five kilometres
  - the bores are moved such that the separation to mapped High Priority GDE vegetation becomes less than 200 metres
- PB3, PB4, PB6, PB7, PB8, PB9, PB11 – potential bore field impacts would be re-assessed if:
  - separation to adjacent bore fields is less than five kilometres
  - the bores are moved such that the separation to mapped High Priority GDE vegetation becomes less than 200 metres
- PB5 – potential bore field impacts would be re-assessed if:
  - separation to adjacent bore fields is less than five kilometres
  - the bores are moved to the west, as a fault is mapped to the west
  - the bores are moved such that the separation to mapped High Priority GDE vegetation becomes less than 200 metres
- PB10 – potential bore field impacts would be re-assessed if:
  - separation to adjacent bore fields is less than five kilometres
  - the bores are moved more than about two kilometres closer towards the Santos Gas Project
  - the bores are moved such that the separation to mapped High Priority GDE vegetation becomes less than 200 metres
- PB12 – potential bore field impacts would be re-assessed if:
  - separation to adjacent bore fields is less than five kilometres
  - the bores are moved more than about two kilometres closer towards the Santos Gas Project
  - the bores are moved more than about 1.5 kilometres to the west
  - the bores are moved such that the separation to mapped High Priority GDE vegetation becomes less than 200 metres.

If the bore fields are moved within the above limits, re-assessment of potential impacts by a hydrogeologist is considered unlikely to be required. However, this would be confirmed by a hydrogeologist at detailed design stage.

11.1.3 Vertical separation to existing bores

To provide separation to existing bores, PB1 and PB2 bore field bores would be designed and constructed to extract groundwater from depths greater than 160 mBGL and 110 mBGL respectively. Remaining bore fields will automatically achieve vertical separation since they will be designed to extract from water sources from below the GAB.

12. Conclusions

In order to support the construction of the proposal, the need to install groundwater bores and subsequent extraction of groundwater to supply non-potable construction water has been identified. A total of 12 bore fields are proposed along the proposal site, which would be installed at a spacing of about 25 kilometres. The number of individual water bores within each proposed bore field ranges from four to ten, with an average of seven water bores per bore field.

The proposal features can be categorised into either shallow features or deep features. The 12 proposal bore fields are considered deep features and all the remaining proposal features are considered shallow. Shallow features include bulk earthwork excavations and have a maximum excavation depth of about 12 mBGL; additionally, borrow pits have a maximum excavation depth range from about two mBGL to about 20 mBGL. The proposal bore field bores are anticipated to have a minimum depth of about +110 mBGL and typical depths in the order of 300 to 500 mBGL. Depths would depend on groundwater flows encountered during drilling, as well as the depth required to surpass the GAB floor.

The risk of shallow proposal features and associated construction and operation impacting groundwater systems is assessed as being low. This is principally because the proposal's bulk earthworks are assessed as unlikely to intersect regional water tables and only borrow pit A is assessed as likely to intercept the water table by a small amount of about three metres and then only for the construction phase of the proposal.

The proposal bore fields are considered to have a relatively higher potential to cause groundwater impacts. Pumping of the bore field bores could lead to groundwater level drawdown, water table drawdown and creek and river baseflow reductions. However, subject to detailed design investigations and the prescribed mitigation measures in this report being employed, the risk to groundwater systems is assessed as low and such impacts are not anticipated. A key consideration in assessment of the risk is the non-permanent duration of pumping at the bore fields. The bore fields are only expected to be pumped for a non-permanent period of about 500 days during the construction phase and not pumped during the operational phase.

Base case analytical groundwater modelling predicts drawdown to the GAB water table and upper GAB aquifers of less than one metre, which meets the minimal impact criteria of the AIP. Modelled drawdown to groundwater pressure in the aquitard layer at the base of the GAB is greater than the minimal impact consideration drawdown pressure criteria. However, this aquitard is very deep and not relevant to existing bores and GDEs. Therefore, the viability of such assets is not anticipated to be impacted. Outside of the GAB, modelling predicted drawdowns greater than one metre and the maximum drawdown at an existing bore was 3.5 metres, which exceeds the minimal impact criteria of the AIP. To address this, the mitigation measure of 'make good provisions' would need to be established. Due to the short duration of pumping, if a bore is impacted by groundwater level drawdown and make good provisions are applicable, consideration should be given to 'making good' through providing tanker water. Potential impacts to High Priority GDEs are assessed as likely to be less than the AIP minimal impact considerations.

The bore fields have the potential to cause impacts to shallow groundwater systems, surface water systems and soils (including earthworks design) if the water quality is not suitable for the intended use and appropriate treatment is not provided. Water quality would be investigated prior to use and appropriate treatment systems designed if required.

Consolidation alluvial material due to fill placement has the potential to lead to minimal and localised groundwater level changes. Such changes are not anticipated to be detrimental to known ecosystems or groundwater systems. Similarly, drawdown induced subsidence is expected to be minimal and not lead to adverse impacts.

Cumulative impacts were assessed and the most significant potential cumulative impact is pumping of the proposal bore fields at the same time as Santos Gas Project bores are active. The simultaneous activity at both sites has the potential to increase groundwater level drawdown. This risk was assessed as being low and is primarily applicable at only one of the proposal's bore fields – PB11. It is noted that if excess water from the Santos Gas Project is used, the potential for cumulative impacts due to interacting with the proposal would be reduced or possibly eliminated.

In addition to the 12 proposal bore fields, groundwater bores may be pursued by the construction contractor as a potable water source (following treatment as required) for the Narromine North and Baradine temporary workforce accommodation facilities. Mitigation measures have been provided for these potential bores.

Overall, subject to detailed design investigations and with implementation of the proposed mitigation measures, the proposal is expected to have minimal impacts on the upper groundwater systems which are relevant to existing bores, the water table and GDEs. Temporary depressurisation of groundwater is likely to occur in the groundwater systems that the proposal's bore field bores would extract groundwater from. However, these groundwater systems are generally very deep and considered unlikely to significantly interact with the shallow groundwater systems applicable to existing bores, the water table and GDEs.

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Appendices

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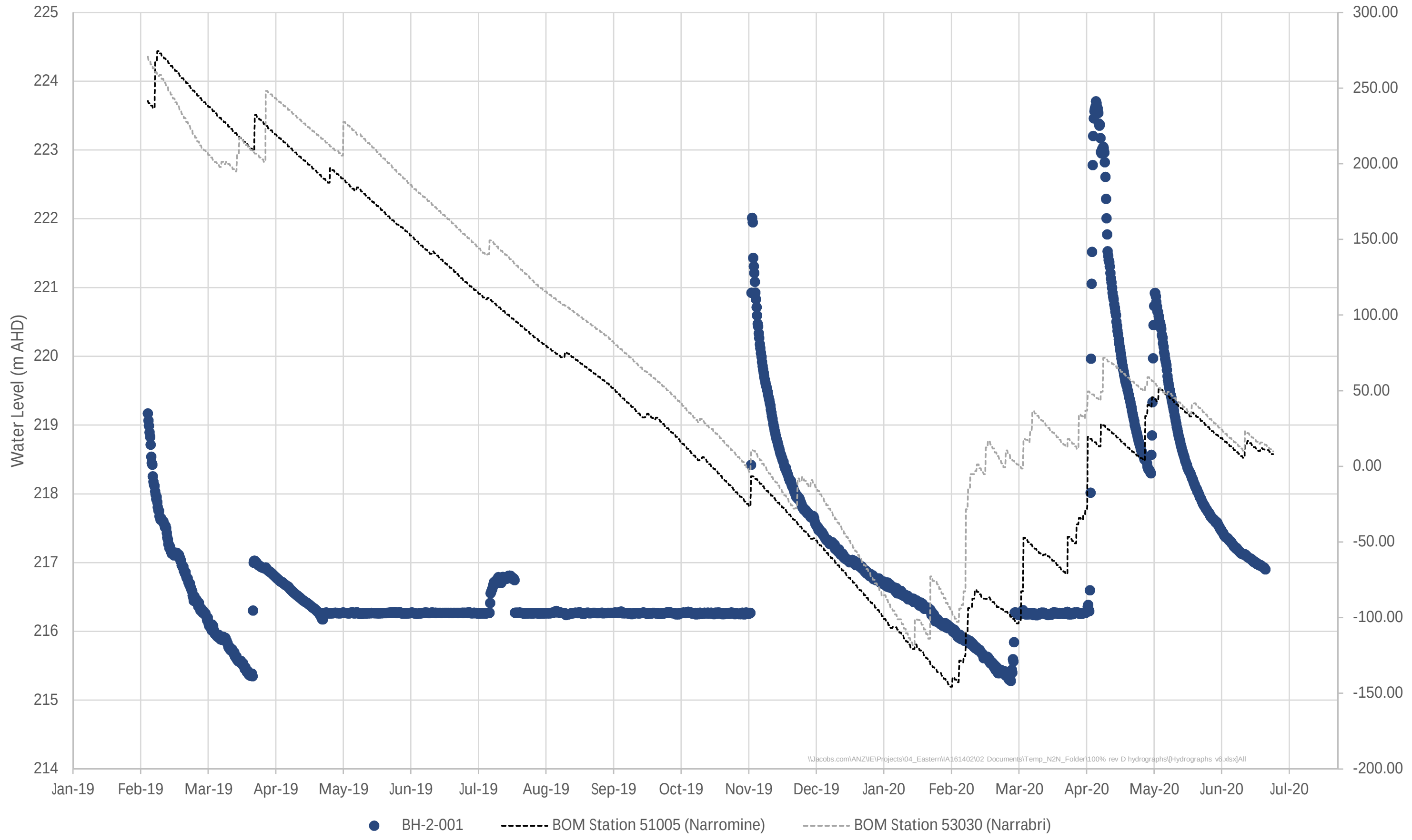
TECHNICAL REPORT

4

Groundwater assessment

Appendix A Proposal groundwater monitoring bore hydrographs

NARROMINE TO NARRABRI ENVIRONMENTAL IMPACT STATEMENT



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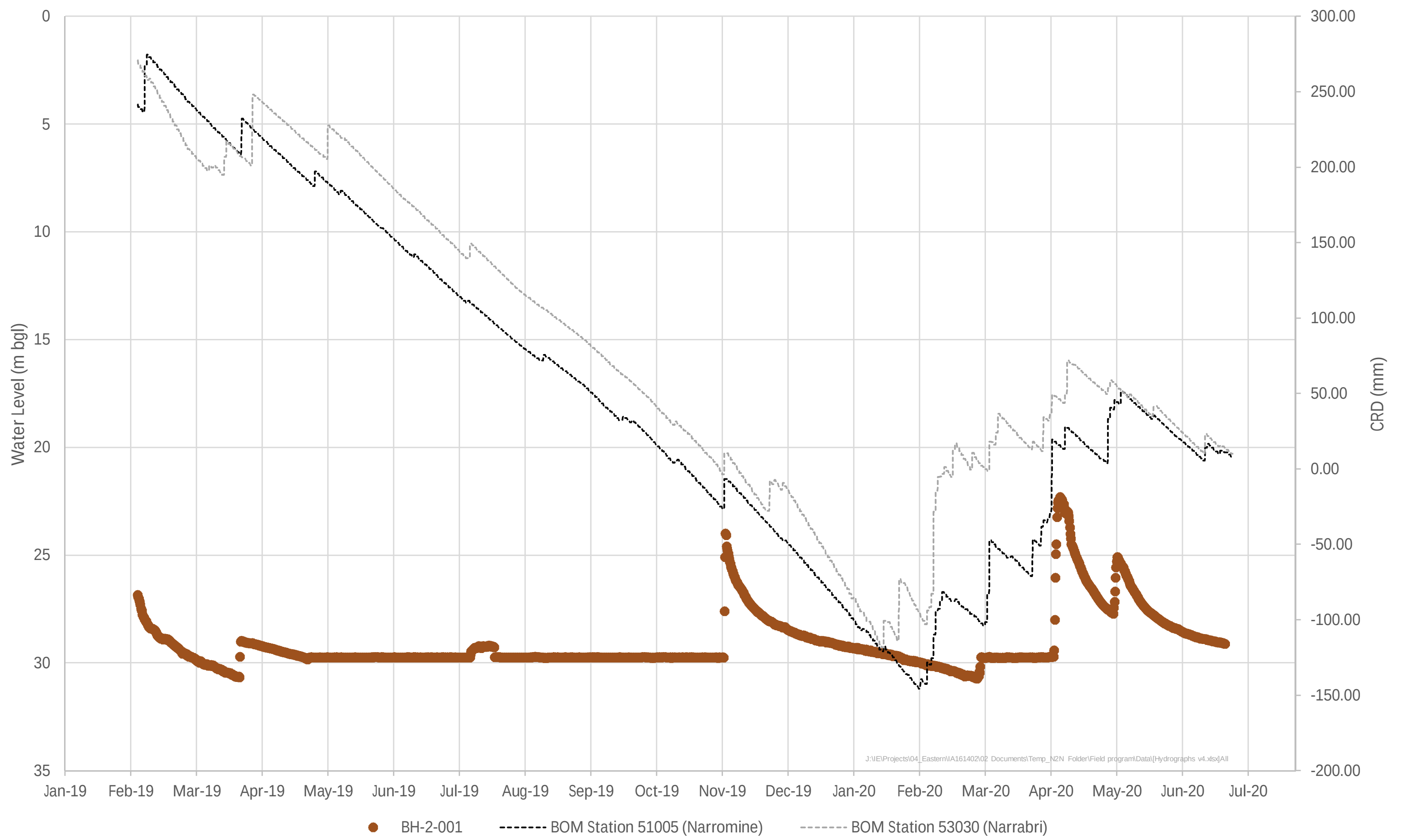

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CRD (mm)
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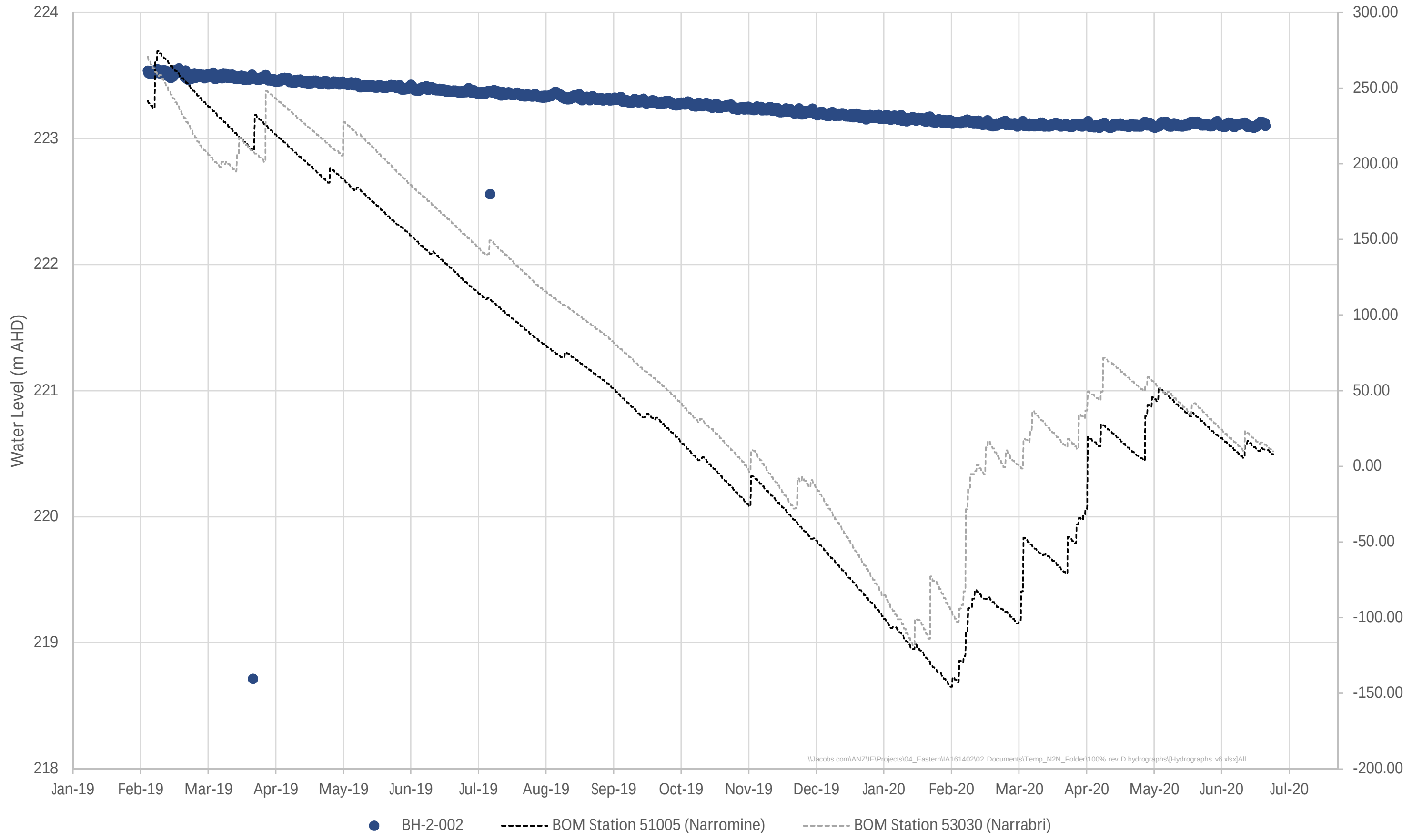

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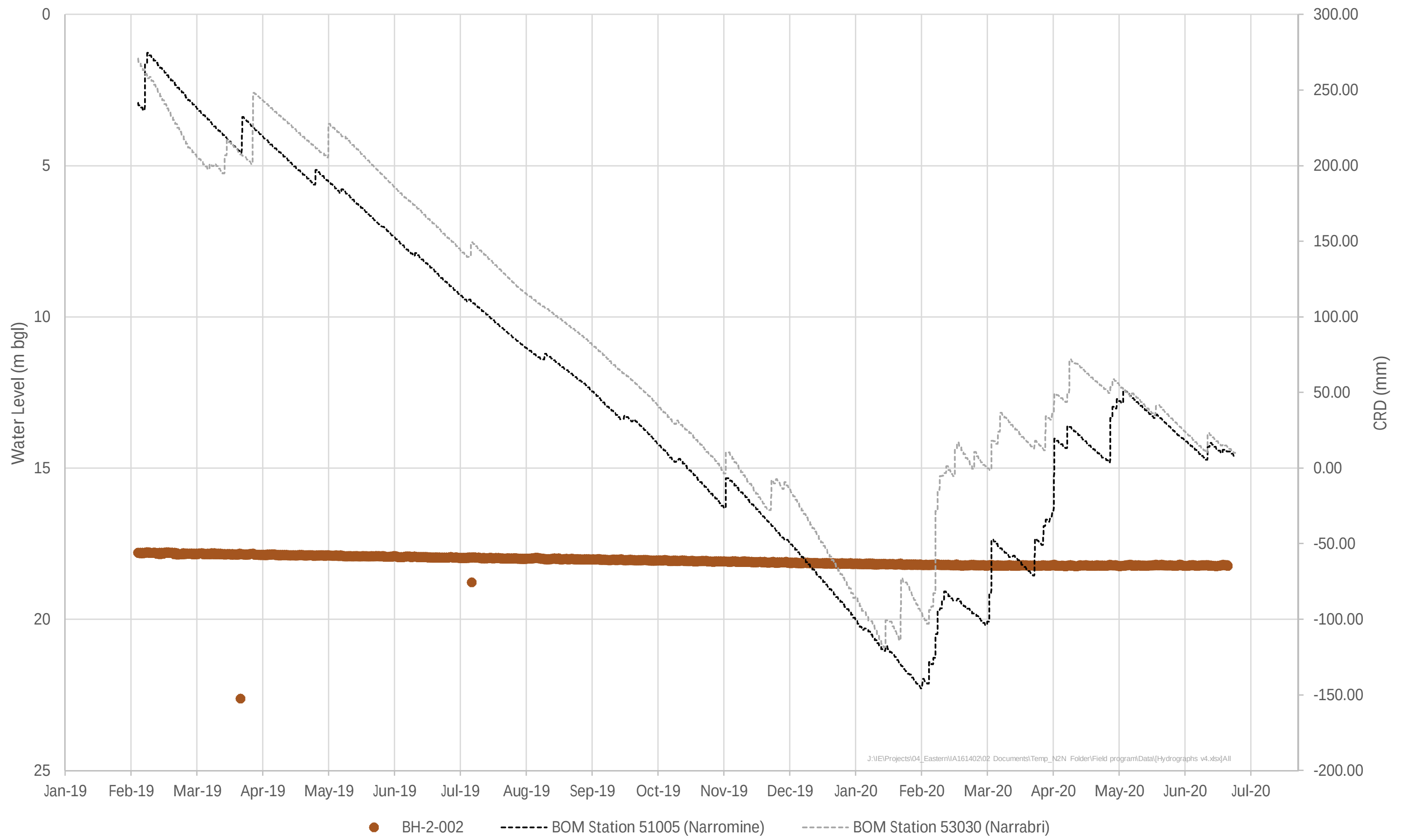

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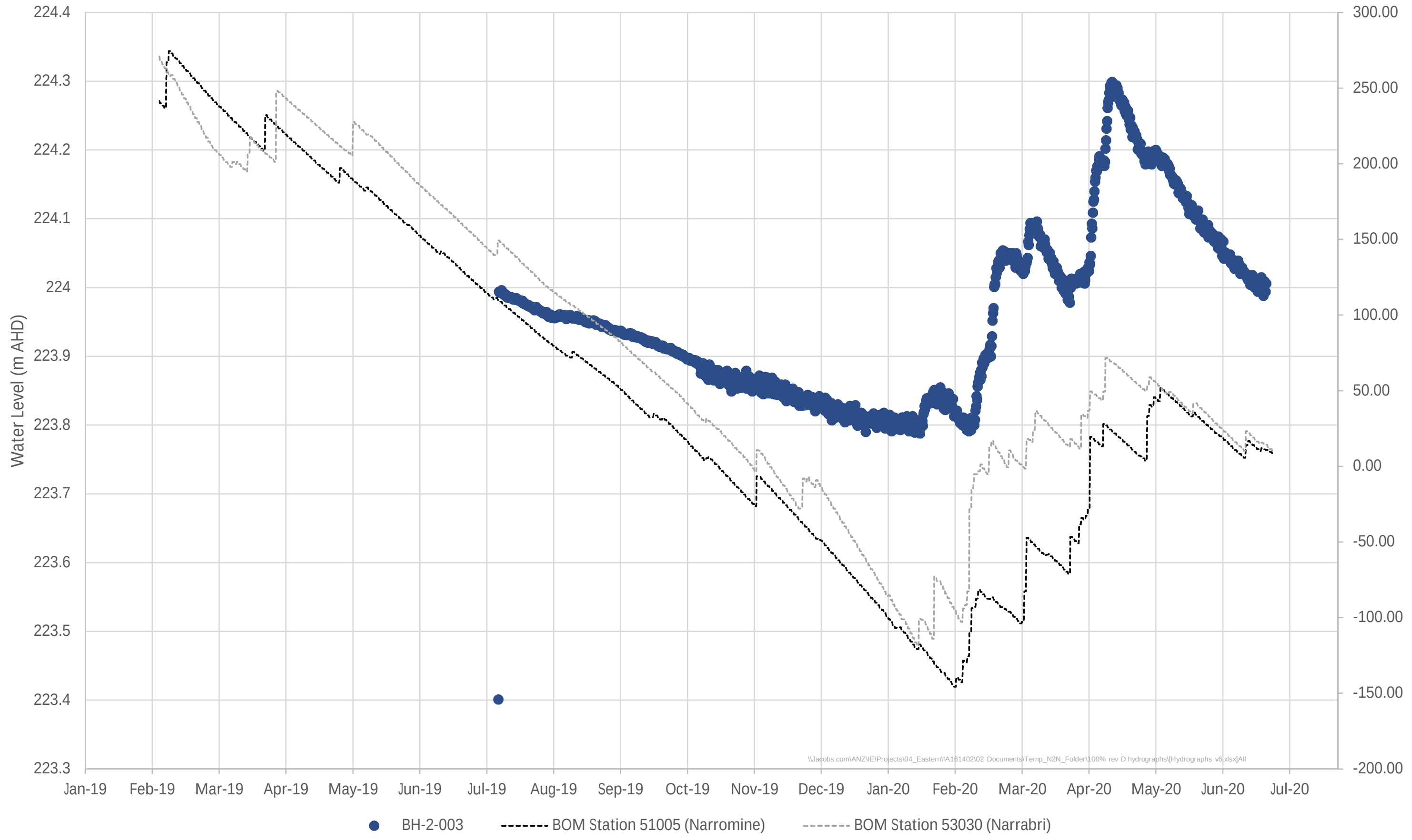
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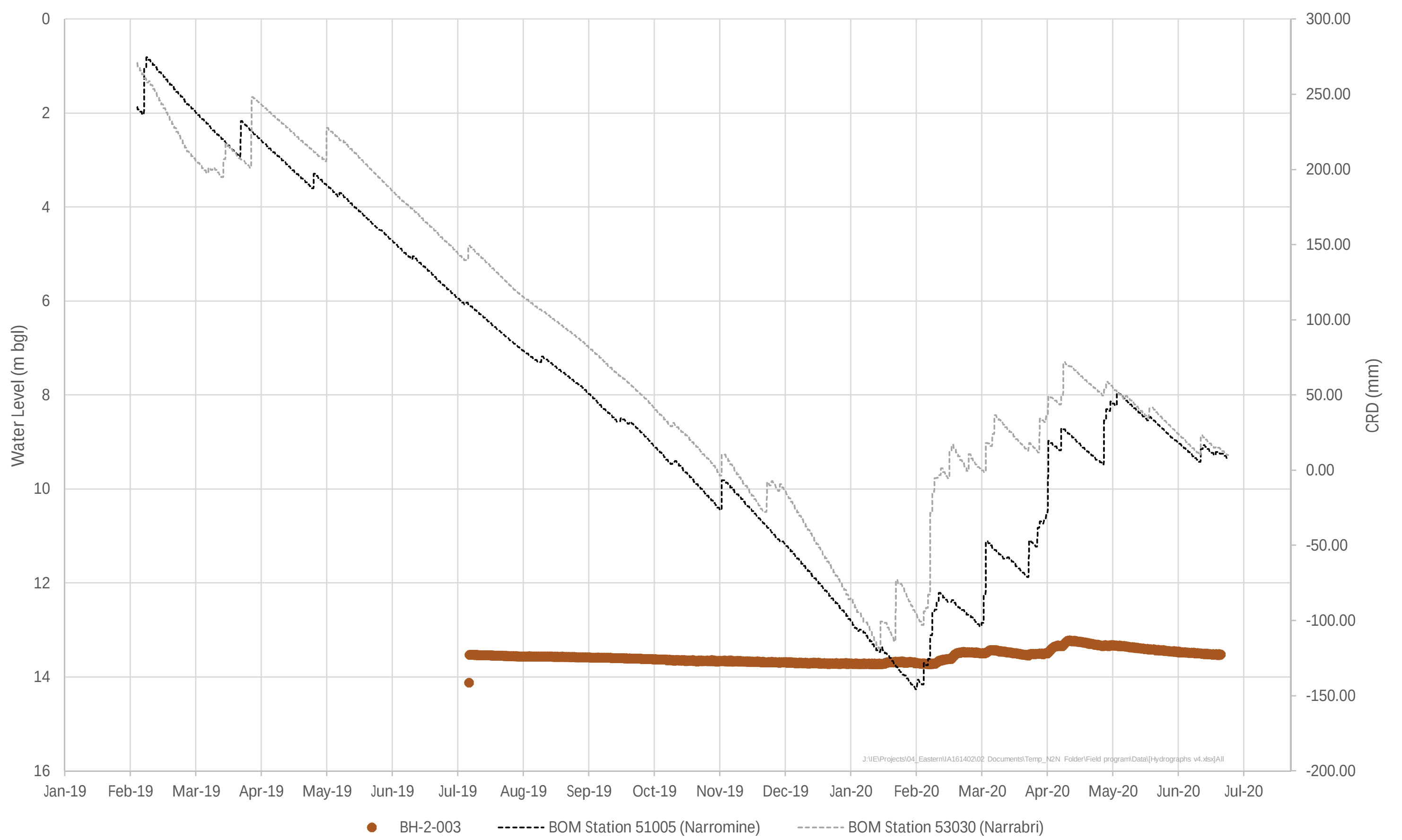
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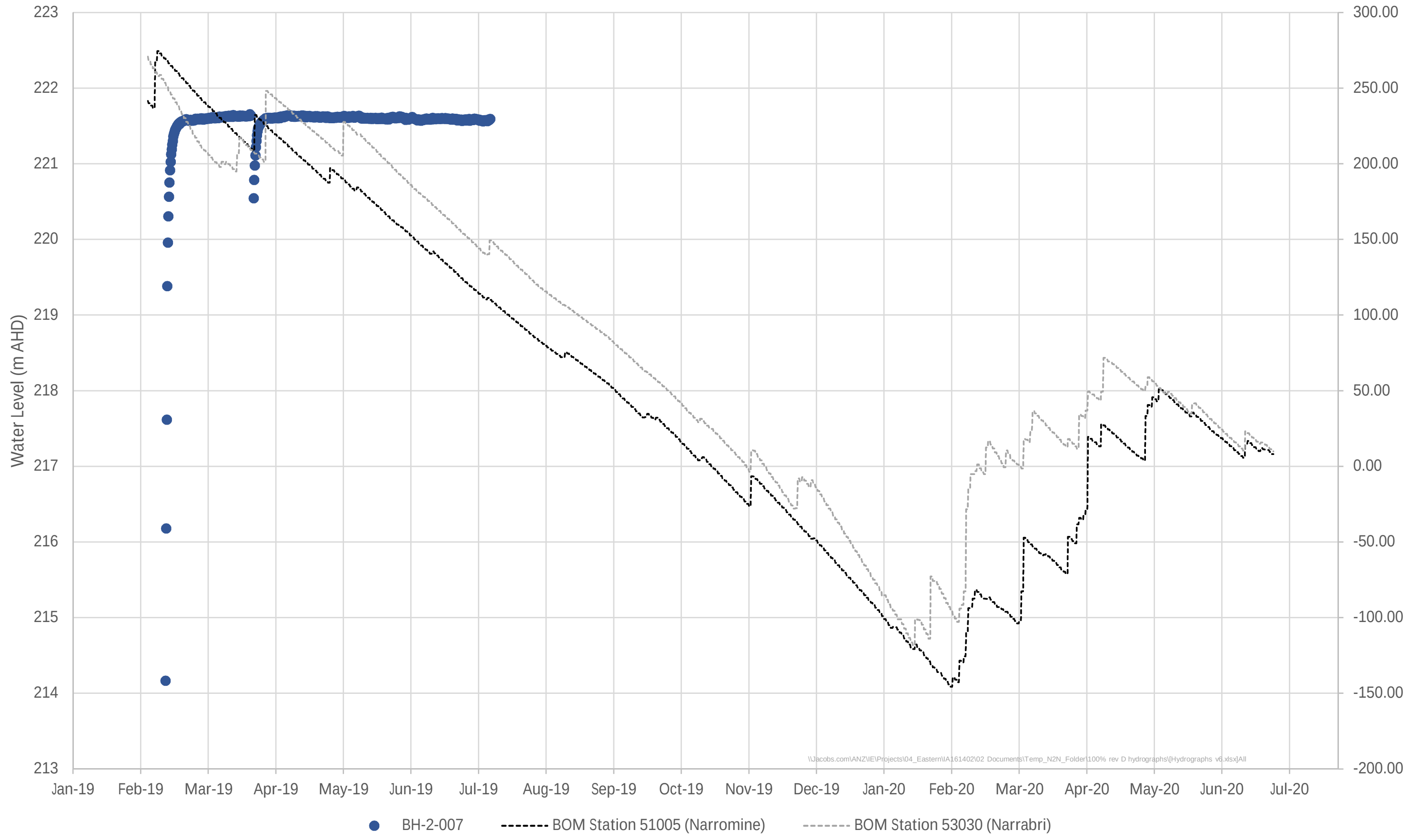
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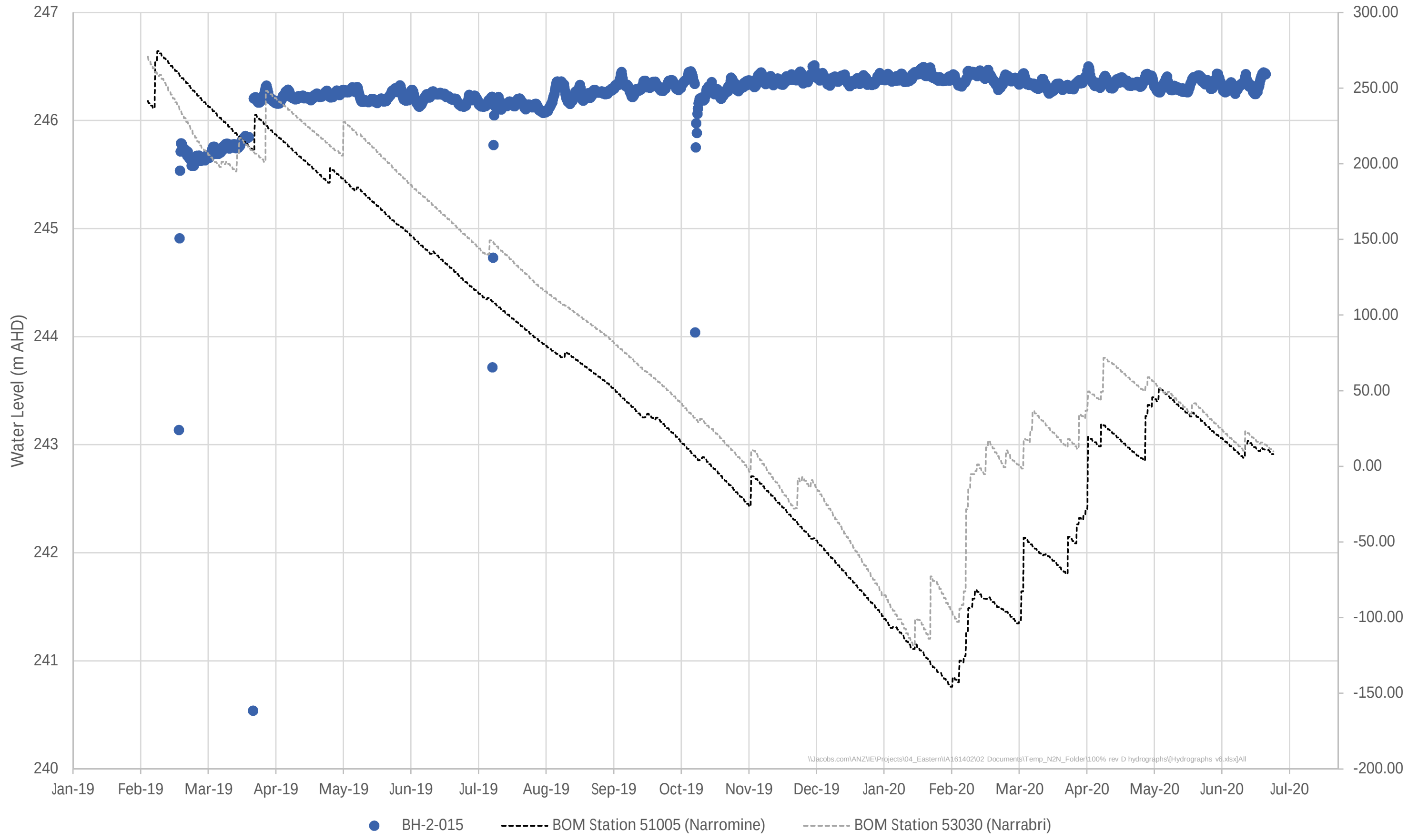
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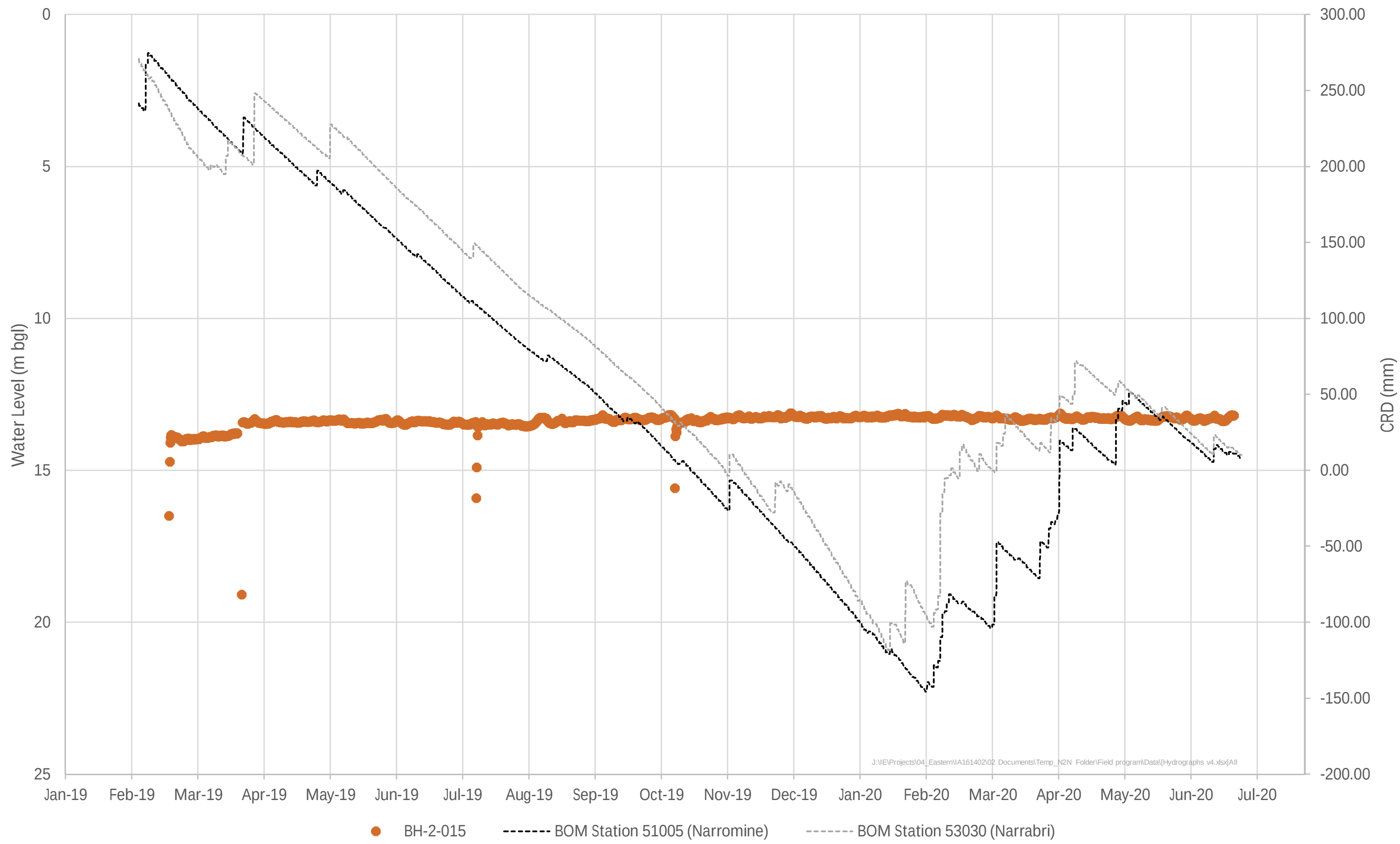
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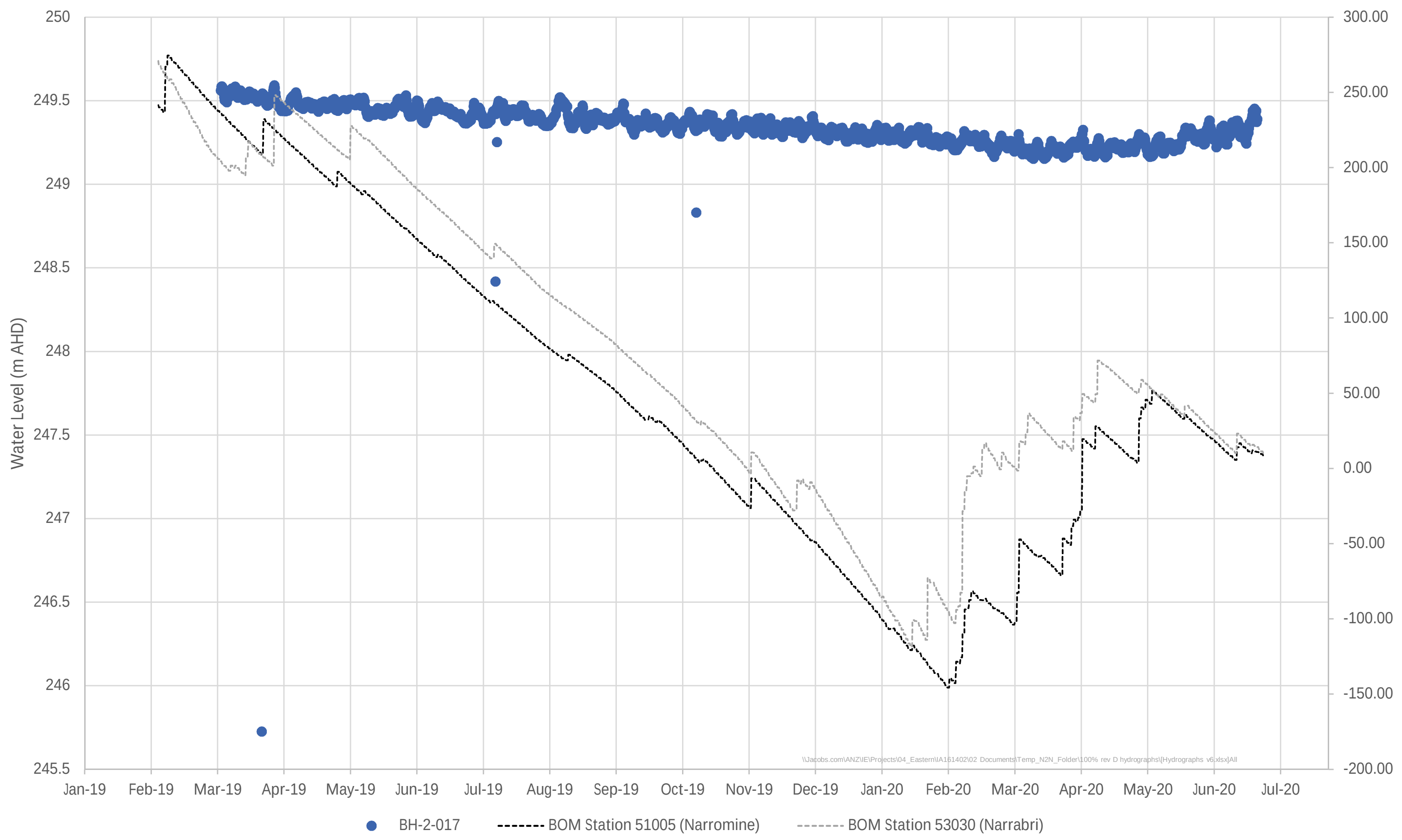

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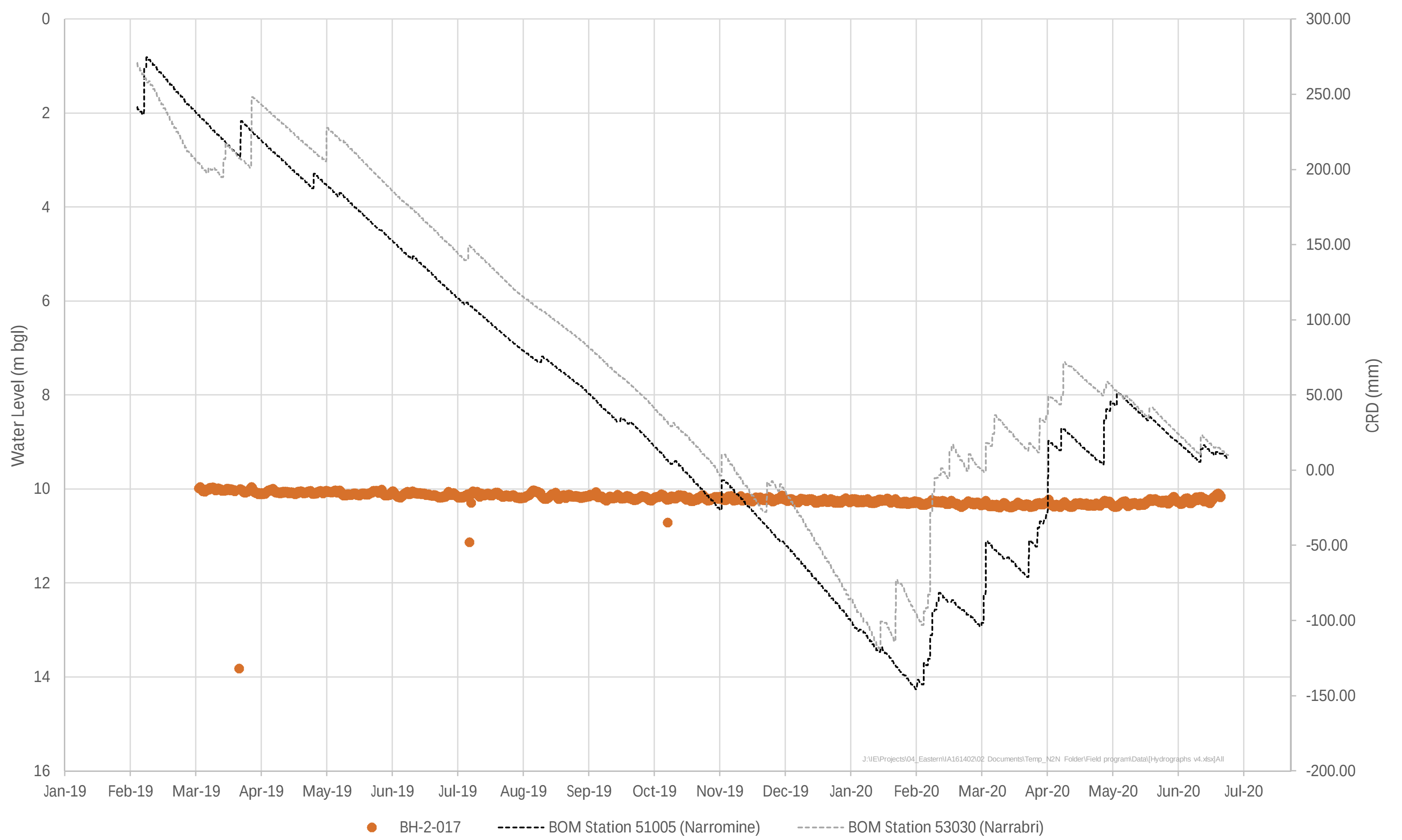

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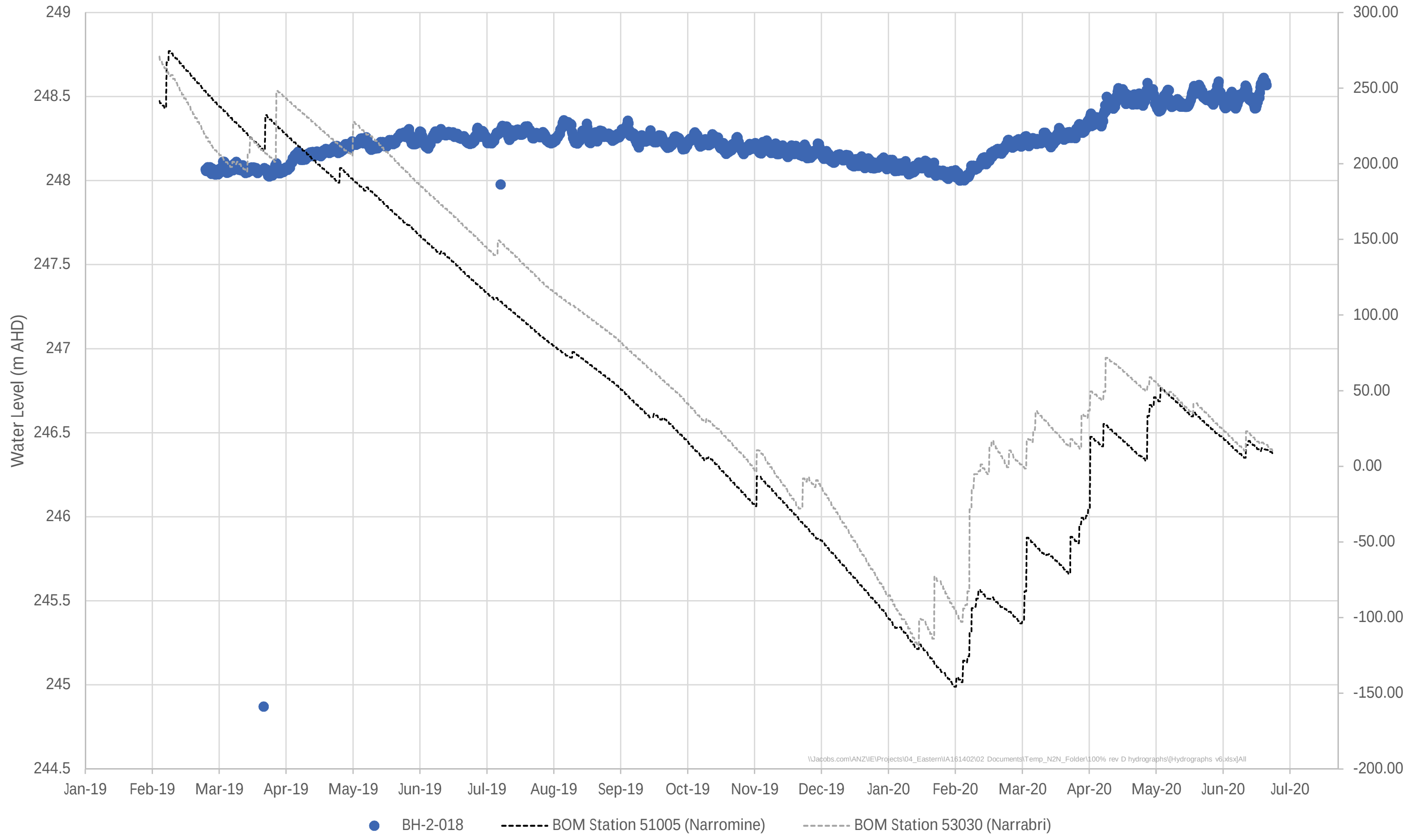
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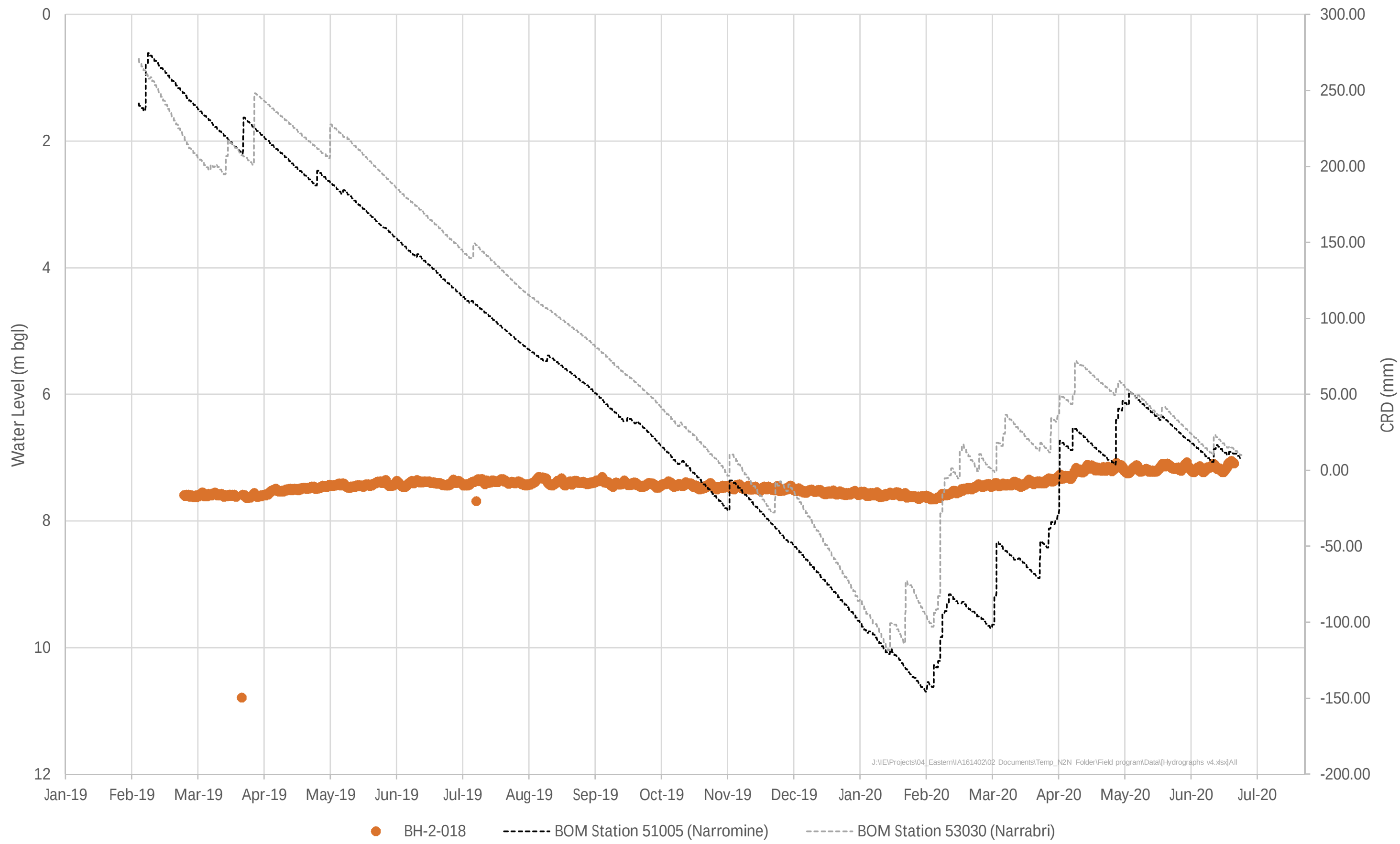
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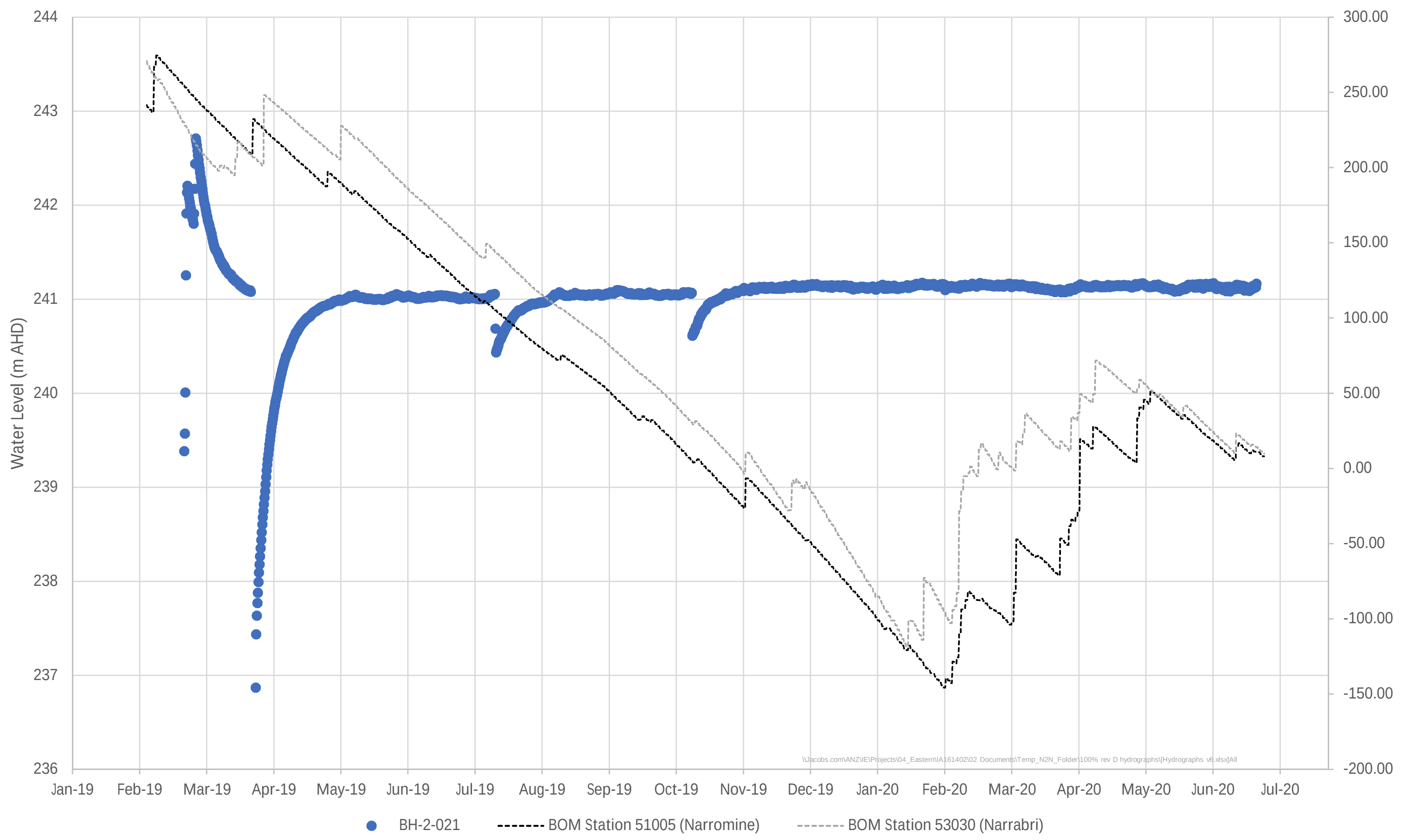

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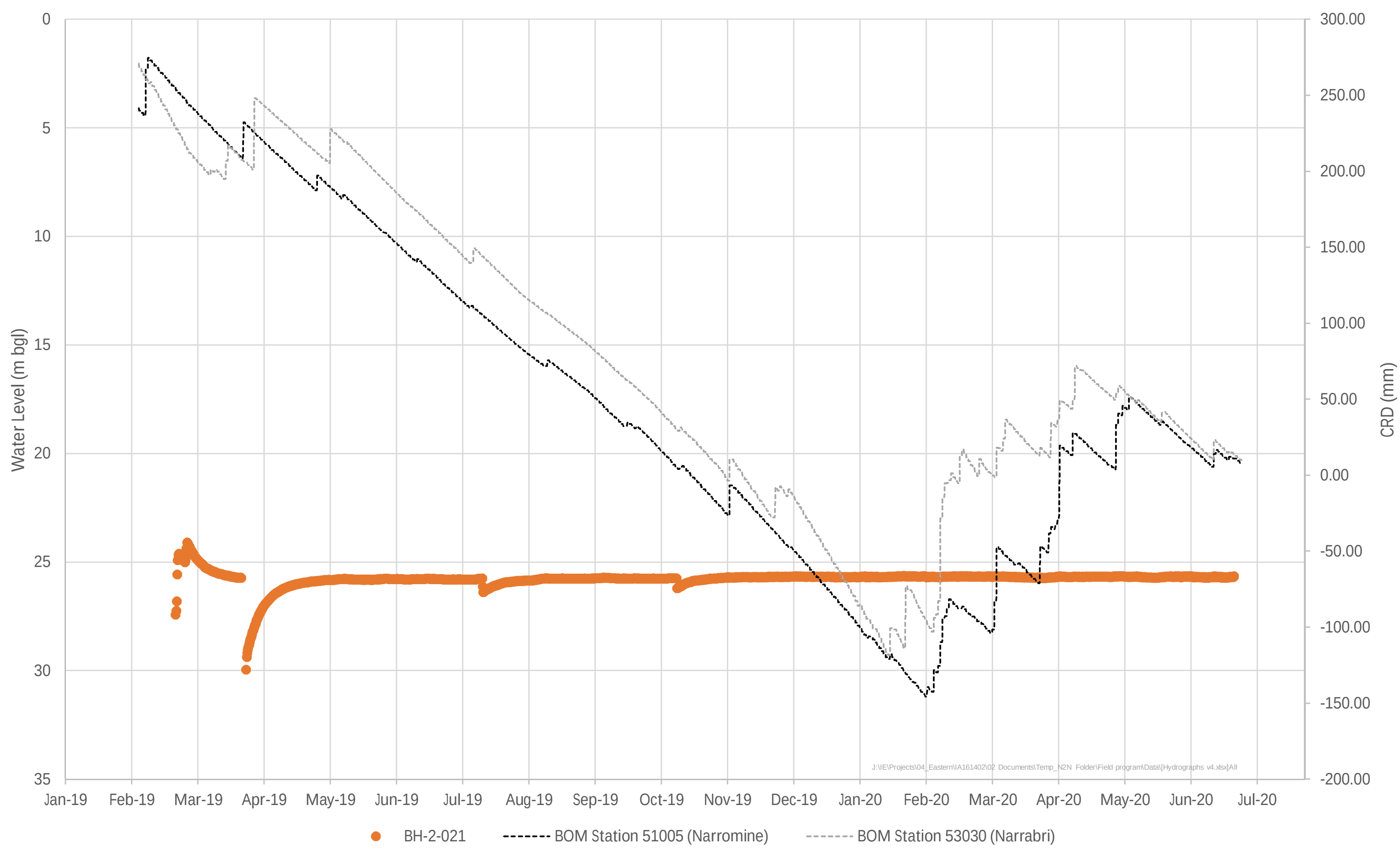

Water Level (m bgl)
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15
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30
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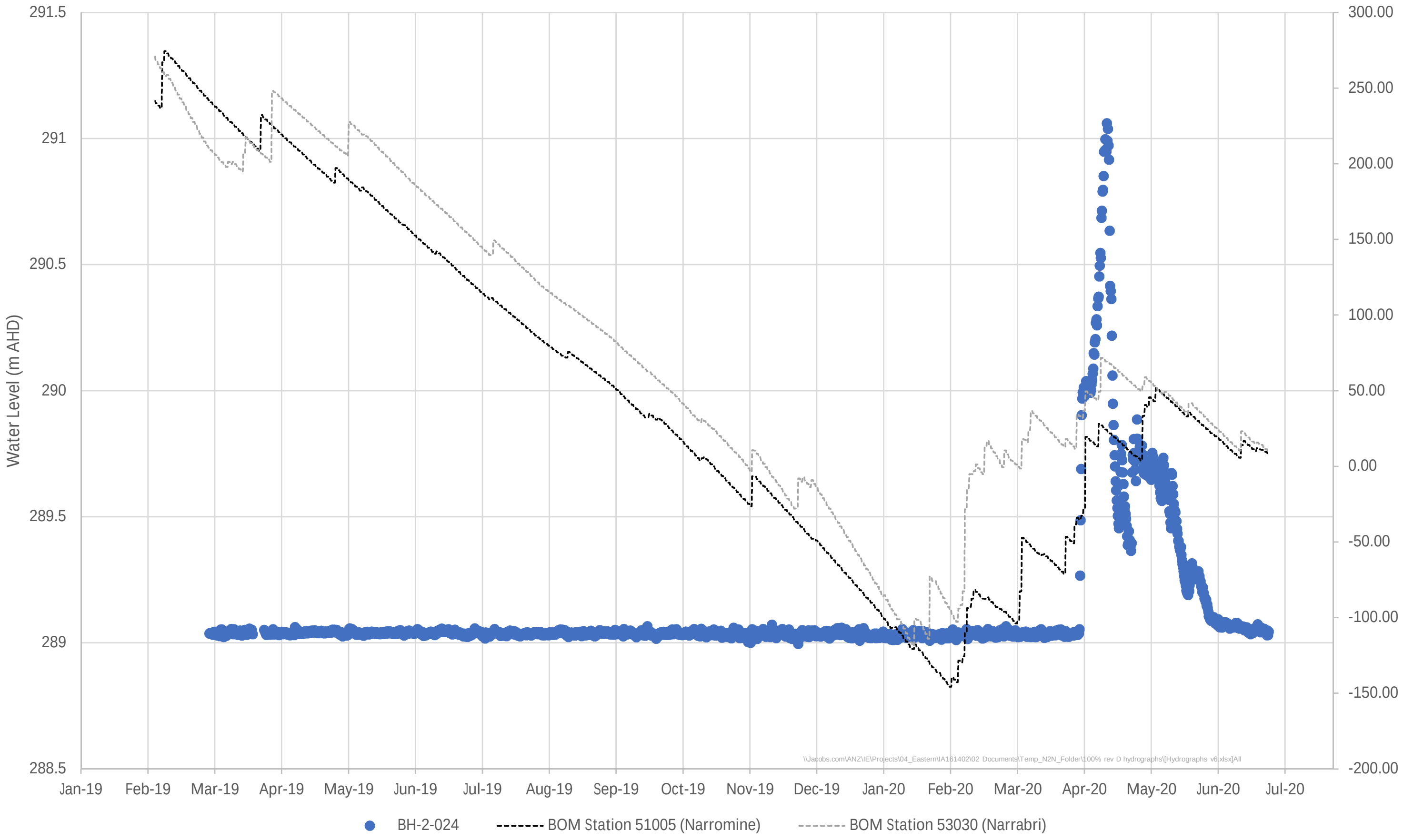
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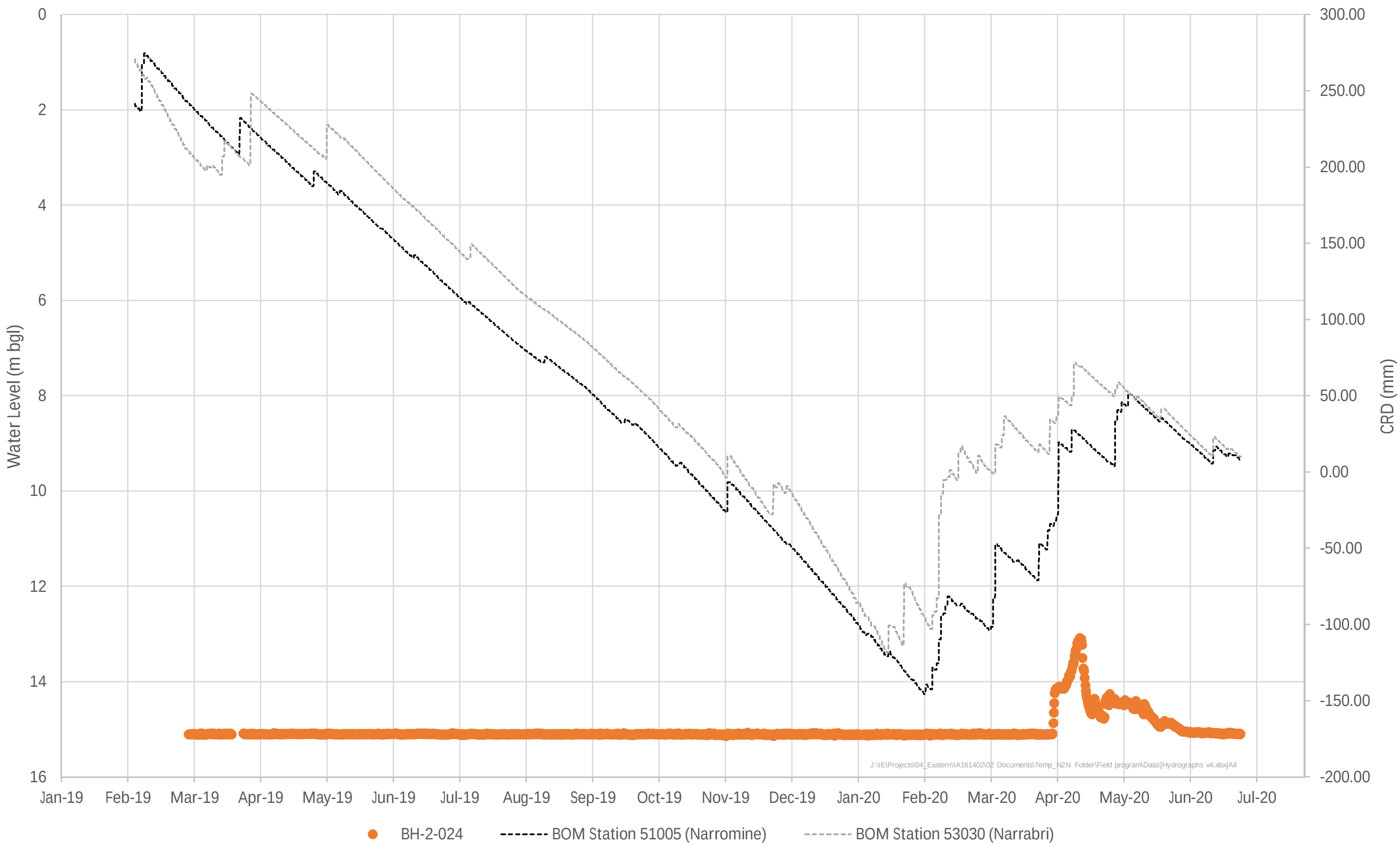
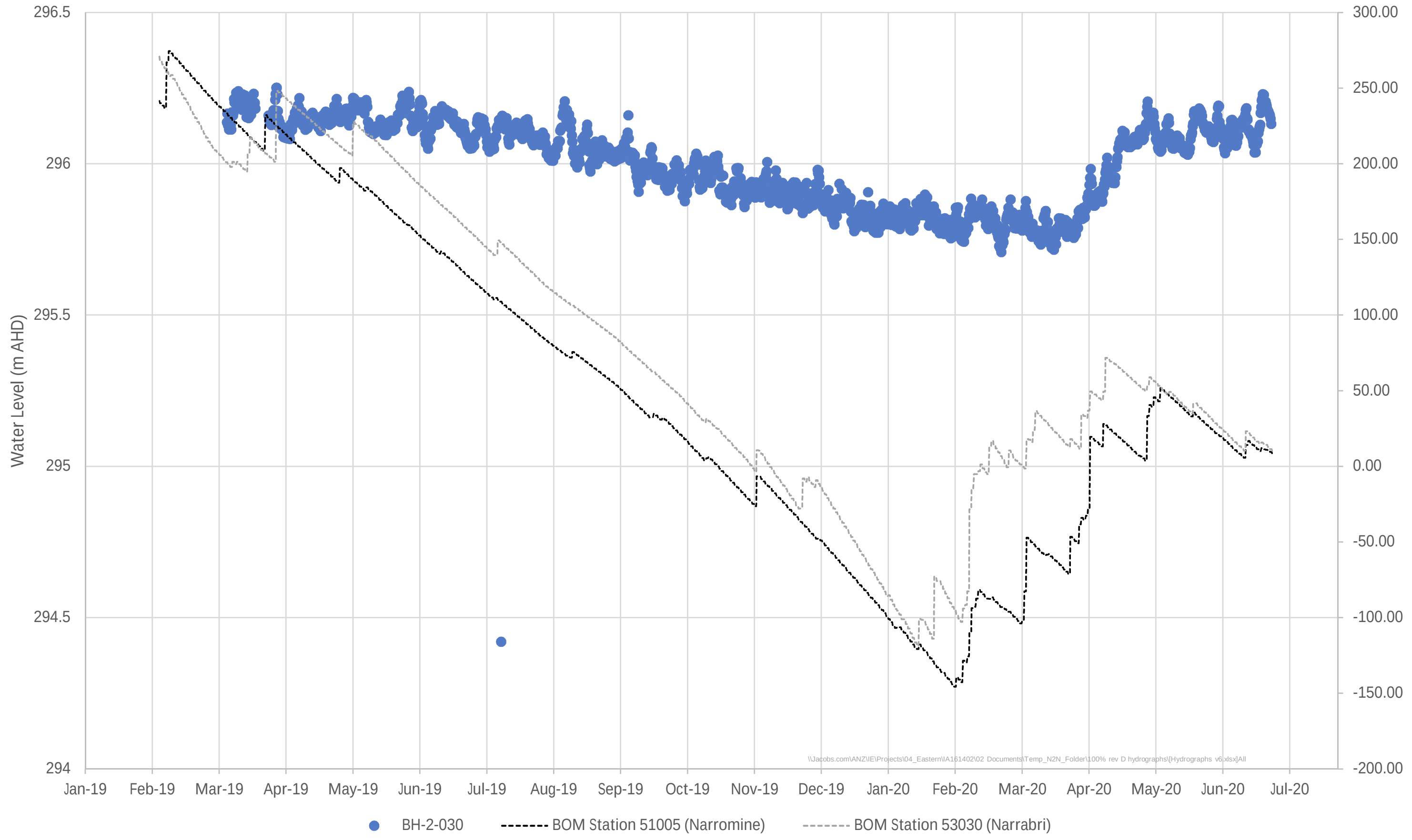
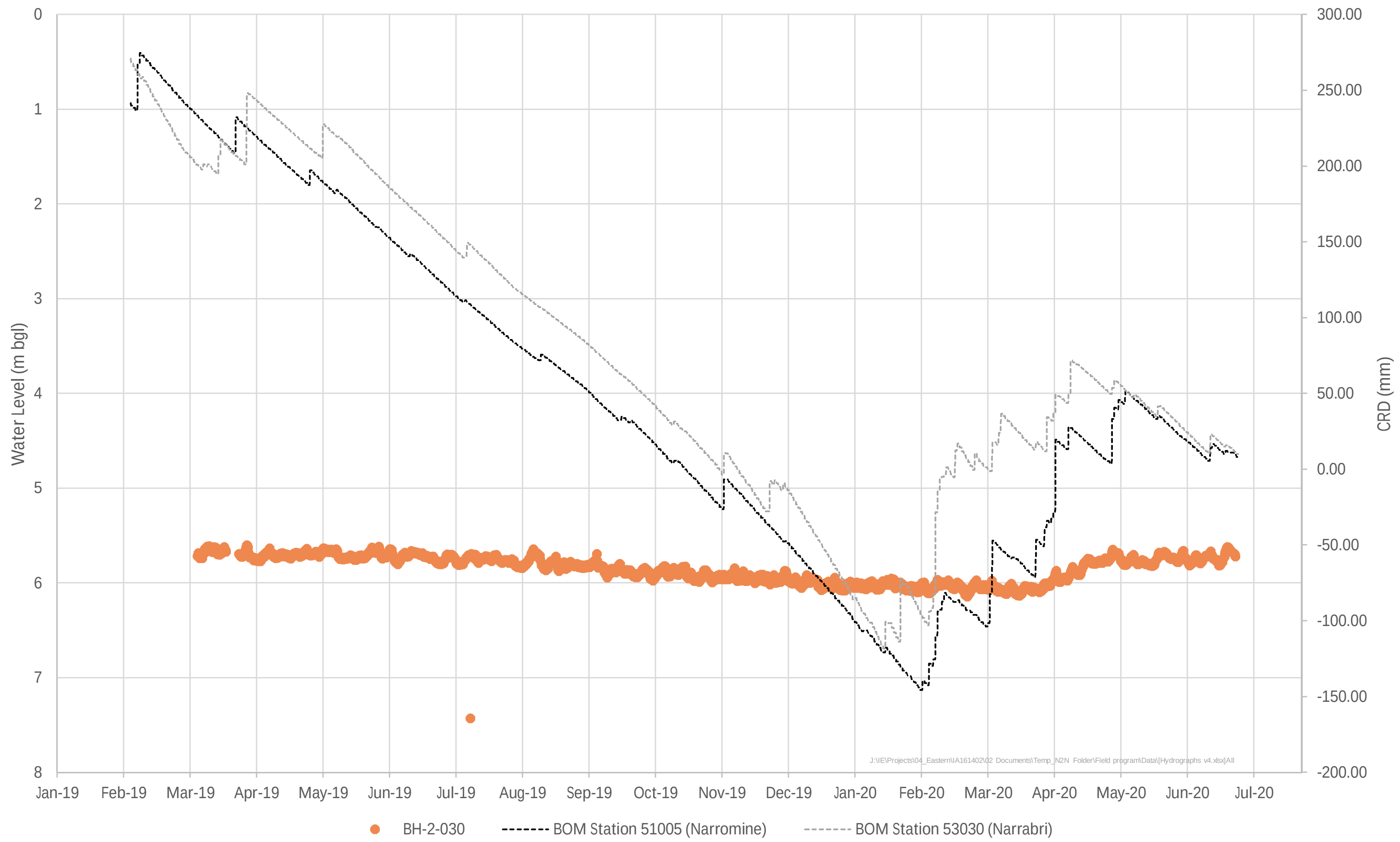
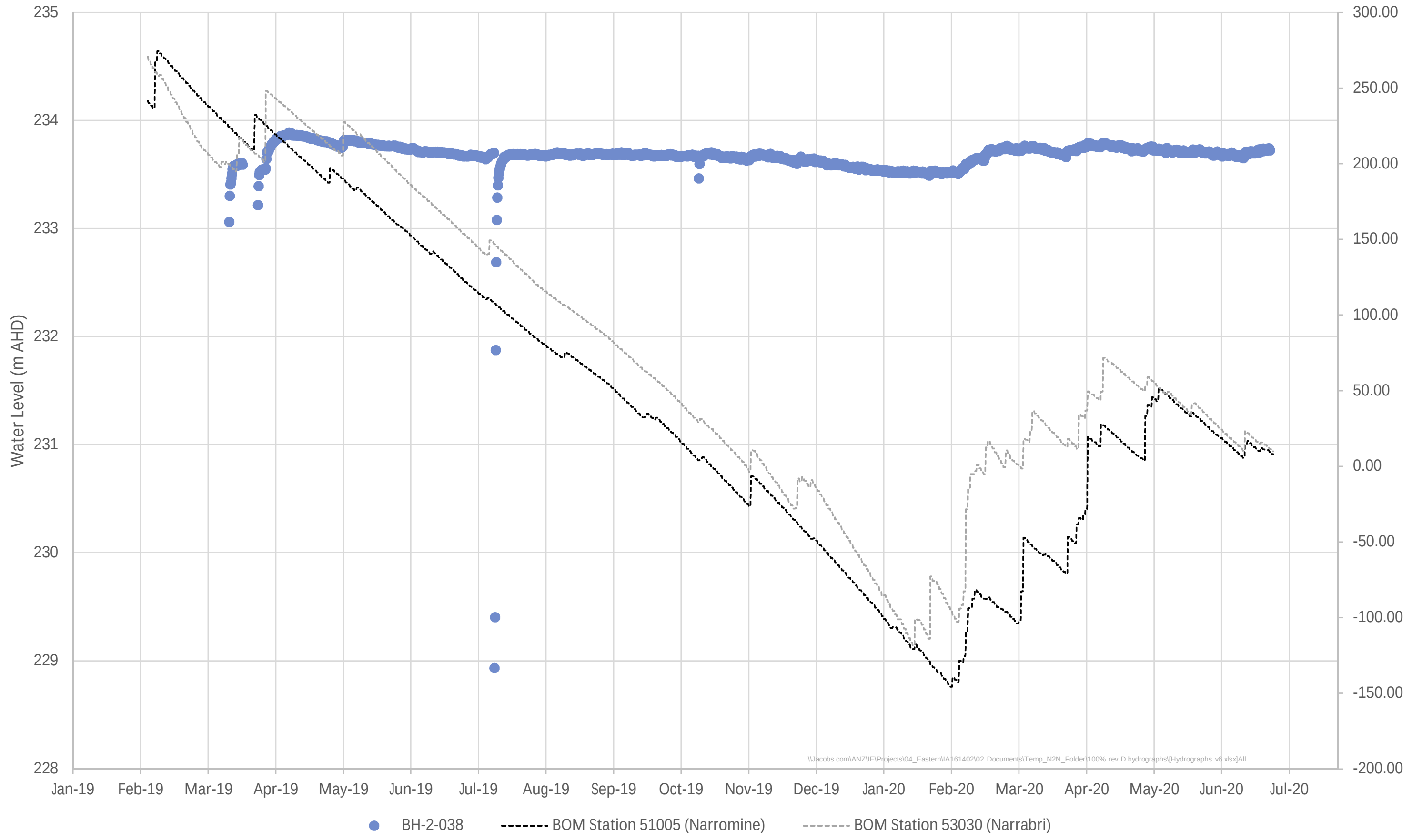
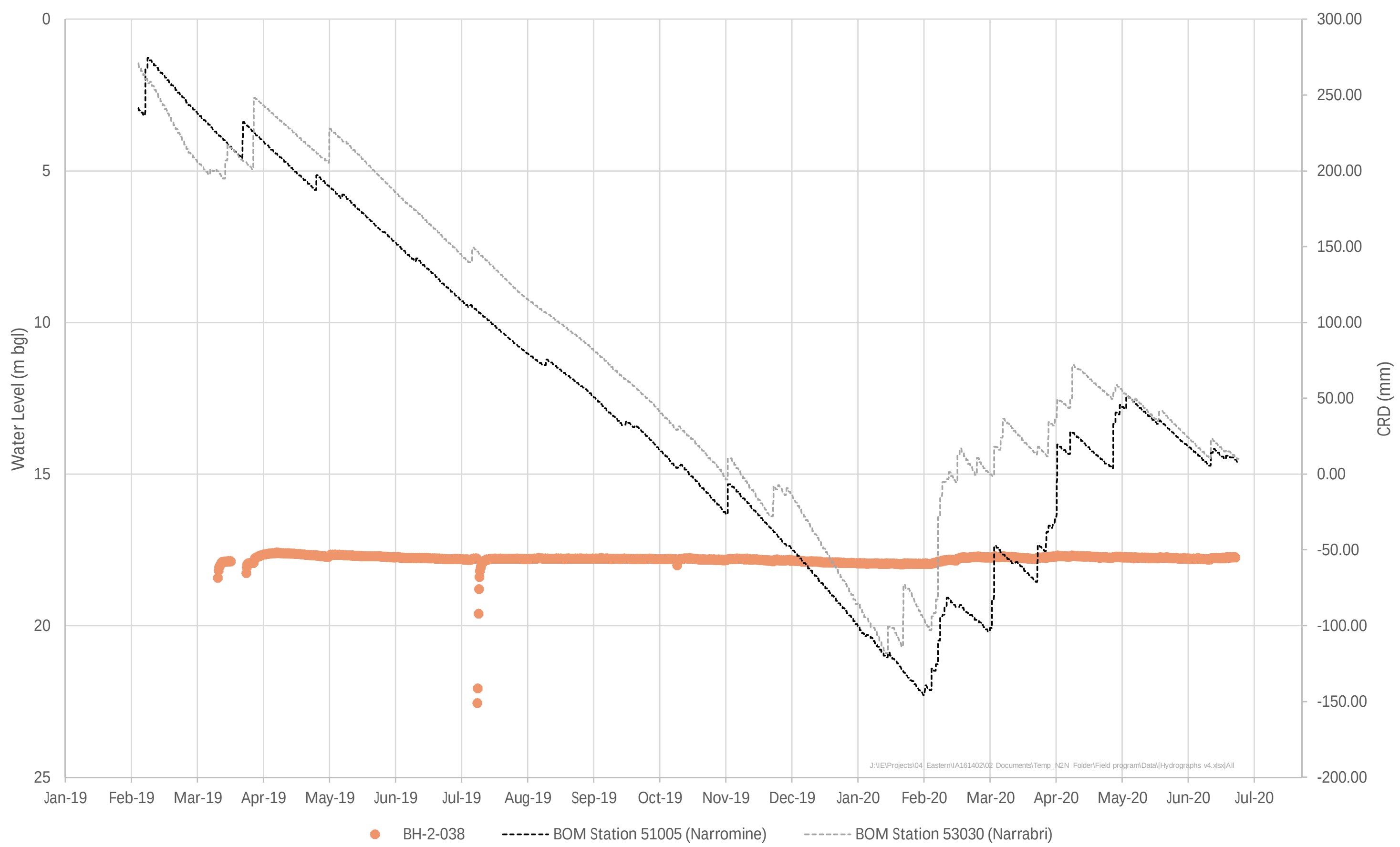
Jun-20
Jul-20
BH-2-024
BOM Station 51005 (Narromine)
BOM Station 53030 (Narrabri)


Water Level (m bgl)
0
2
4
6
8
10
12
14
16
300.00
250.00
200.00
150.00
100.00
50.00
0.00
-50.00
-100.00
-150.00
-200.00
CRD (mm)
Jan-19
Feb-19
Mar-19
Apr-19
May-19
Jun-19
Jul-19
Aug-19
Sep-19
Oct-19
Nov-19
Dec-19
Jan-20
Feb-20
Mar-20
Apr-20
May-20
Jun-20
Jul-20
BH-2-024
BOM Station 51005 (Narromine)
BOM Station 53030 (Narrabri)


Water Level (m AHD)
296.5
296
295.5
295
294.5
294
300.00
250.00
200.00
150.00
100.00
50.00
0.00
-50.00
-100.00
-150.00
-200.00
Jan-19 Feb-19 Mar-19 Apr-19 May-19 Jun-19 Jul-19 Aug-19 Sep-19 Oct-19 Nov-19 Dec-19 Jan-20 Feb-20 Mar-20 Apr-20 May-20 Jun-20 Jul-20
BH-2-030
BOM Station 51005 (Narromine)
BOM Station 53030 (Narrabri)


Water Level (m bgl)
0
1
2
3
4
5
6
7
8
CRD (mm)
300.00
250.00
200.00
150.00
100.00
50.00
0.00
-50.00
-100.00
-150.00
-200.00
Jan-19 Feb-19 Mar-19 Apr-19 May-19 Jun-19 Jul-19 Aug-19 Sep-19 Oct-19 Nov-19 Dec-19 Jan-20 Feb-20 Mar-20 Apr-20 May-20 Jun-20 Jul-20
BH-2-030
BOM Station 51005 (Narromine)
BOM Station 53030 (Narrabri)


Water Level (m AHD)
235
234
233
232
231
230
229
228
300.00
250.00
200.00
150.00
100.00
50.00
0.00
-50.00
-100.00
-150.00
-200.00
Jan-19
Feb-19
Mar-19
Apr-19
May-19
Jun-19
Jul-19
Aug-19
Sep-19
Oct-19
Nov-19
Dec-19
Jan-20
Feb-20
Mar-20
Apr-20
May-20
Jun-20
Jul-20
\\Jacobs.com\ANZ\IE\Projects\04_Eastern\IA161402\02 Documents\Temp_N2N_Folder\100% rev D hydrographs\[Hydrographs v6.xlsx]All
BH-2-038
BOM Station 51005 (Narromine)
BOM Station 53030 (Narrabri)


Water Level (m bgl)
0
5
10
15
20
25
CRD (mm)
300.00
250.00
200.00
150.00
100.00
50.00
0.00
-50.00
-100.00
-150.00
-200.00
Jan-19
Feb-19
Mar-19
Apr-19
May-19
Jun-19
Jul-19
Aug-19
Sep-19
Oct-19
Nov-19
Dec-19
Jan-20
Feb-20
Mar-20
Apr-20
May-20
Jun-20
Jul-20
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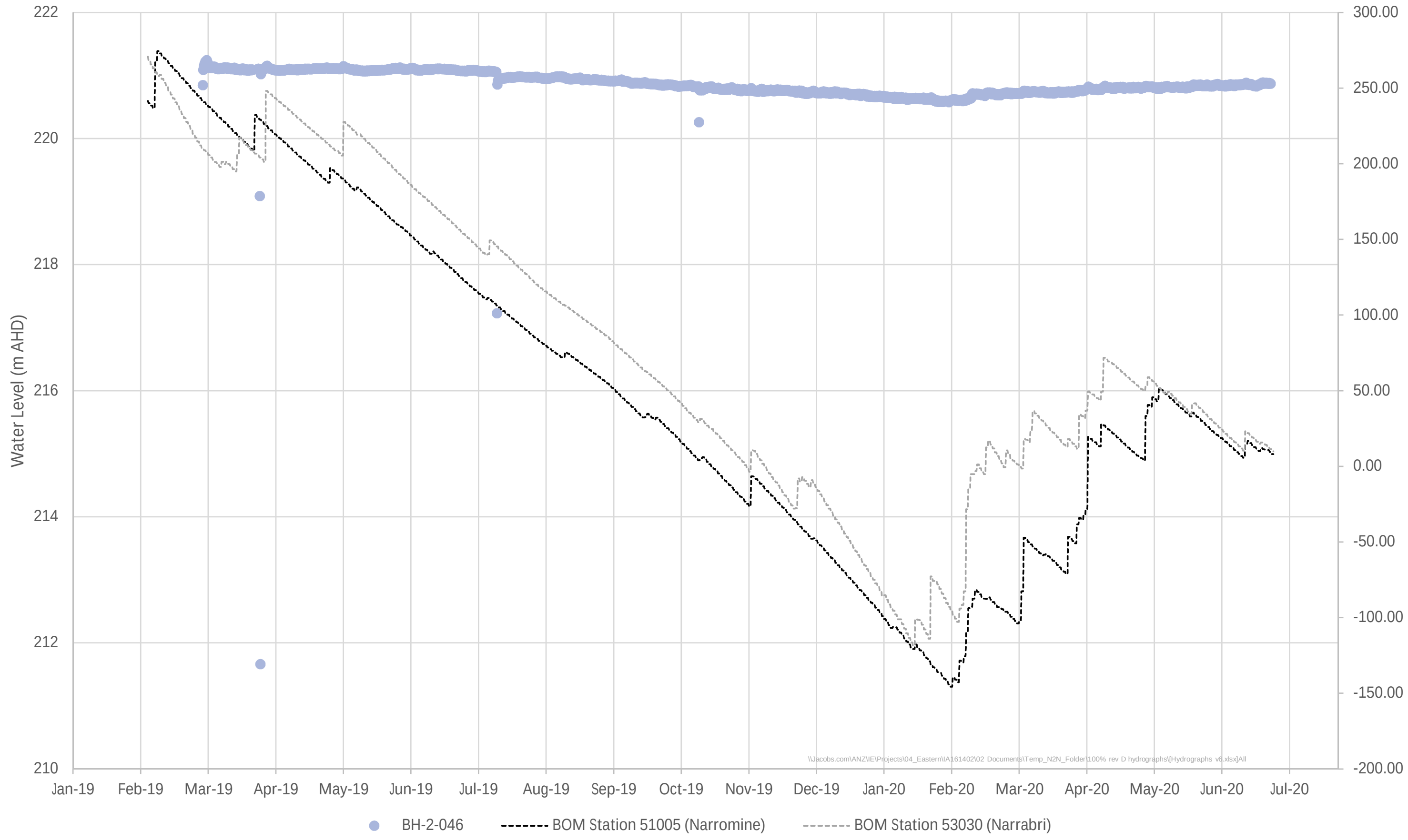
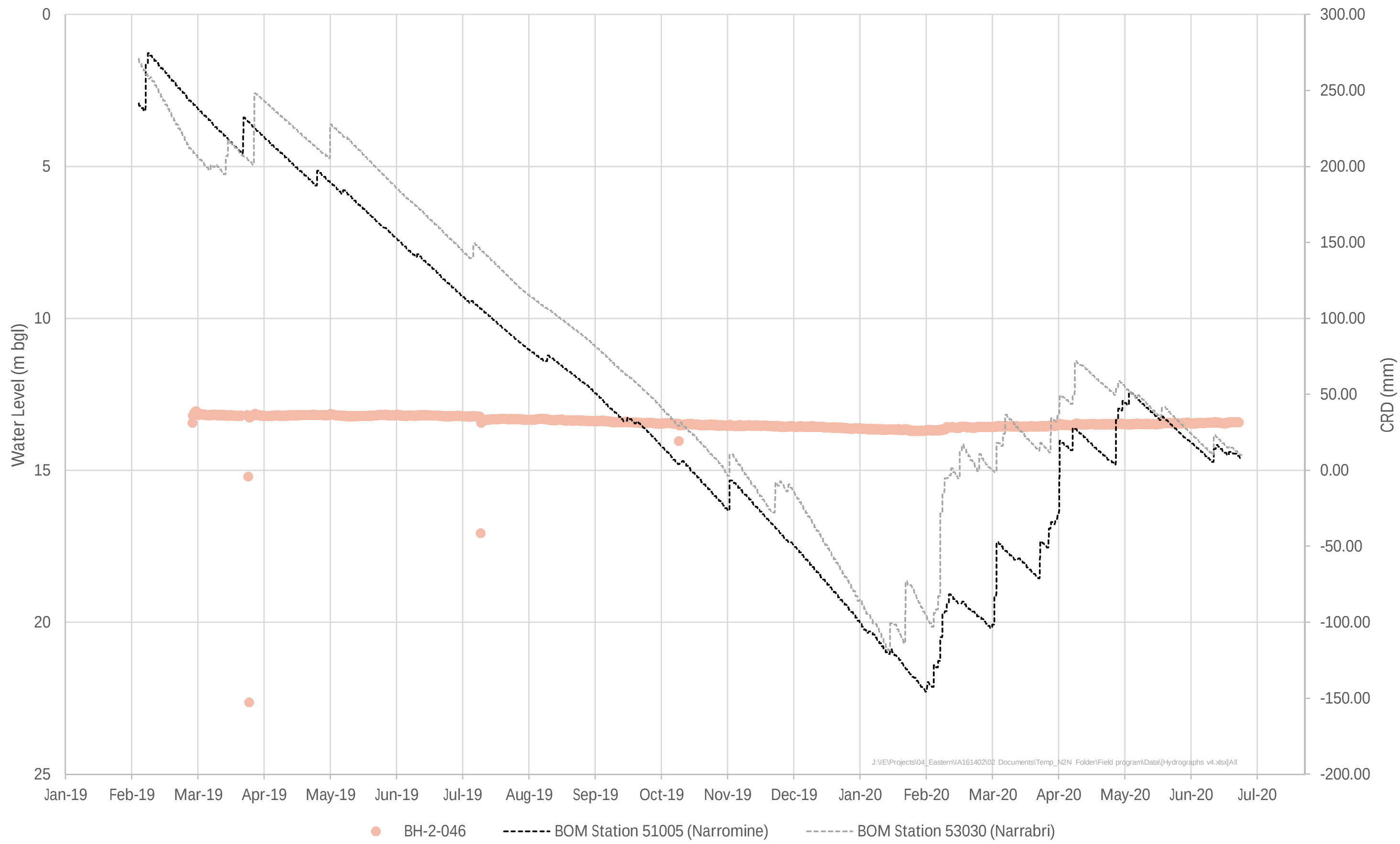
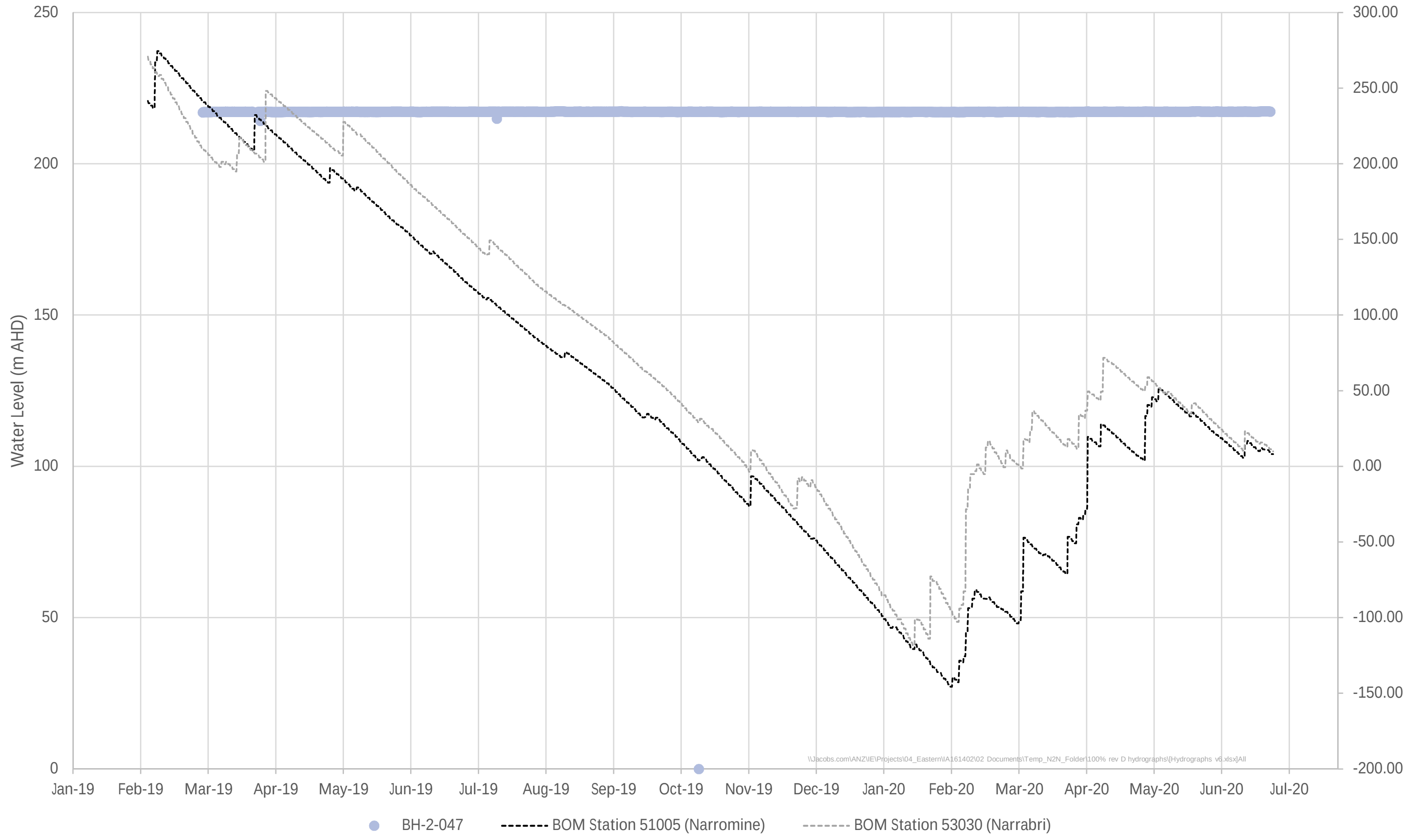
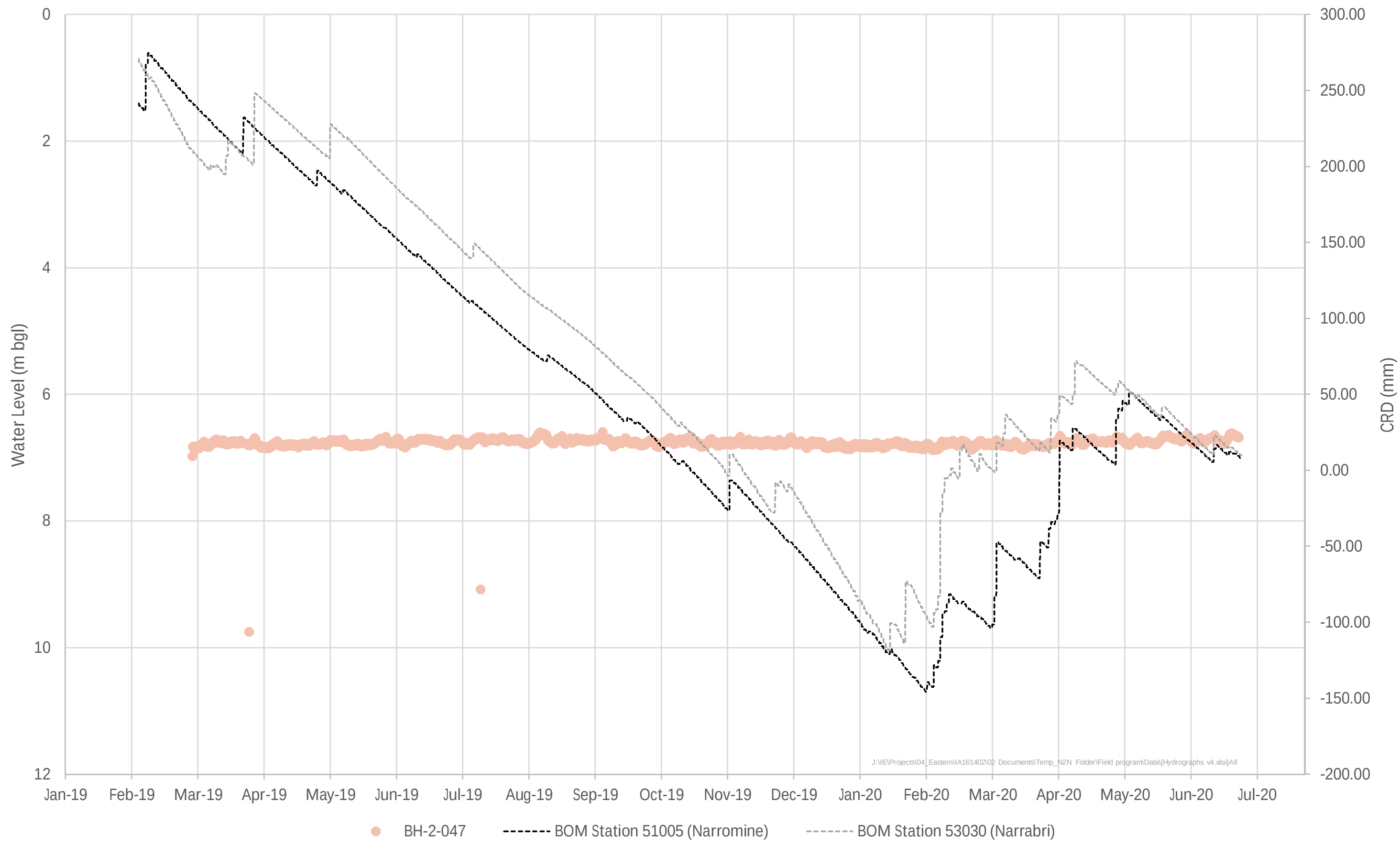
BH-2-038
BOM Station 51005 (Narromine)
BOM Station 53030 (Narrabri)


Water Level (m AHD)
222
220
218
216
214
212
210
300.00
250.00
200.00
150.00
100.00
50.00
0.00
-50.00
-100.00
-150.00
-200.00
Jan-19 Feb-19 Mar-19 Apr-19 May-19 Jun-19 Jul-19 Aug-19 Sep-19 Oct-19 Nov-19 Dec-19 Jan-20 Feb-20 Mar-20 Apr-20 May-20 Jun-20 Jul-20
BH-2-046
BOM Station 51005 (Narromine)
BOM Station 53030 (Narrabri)

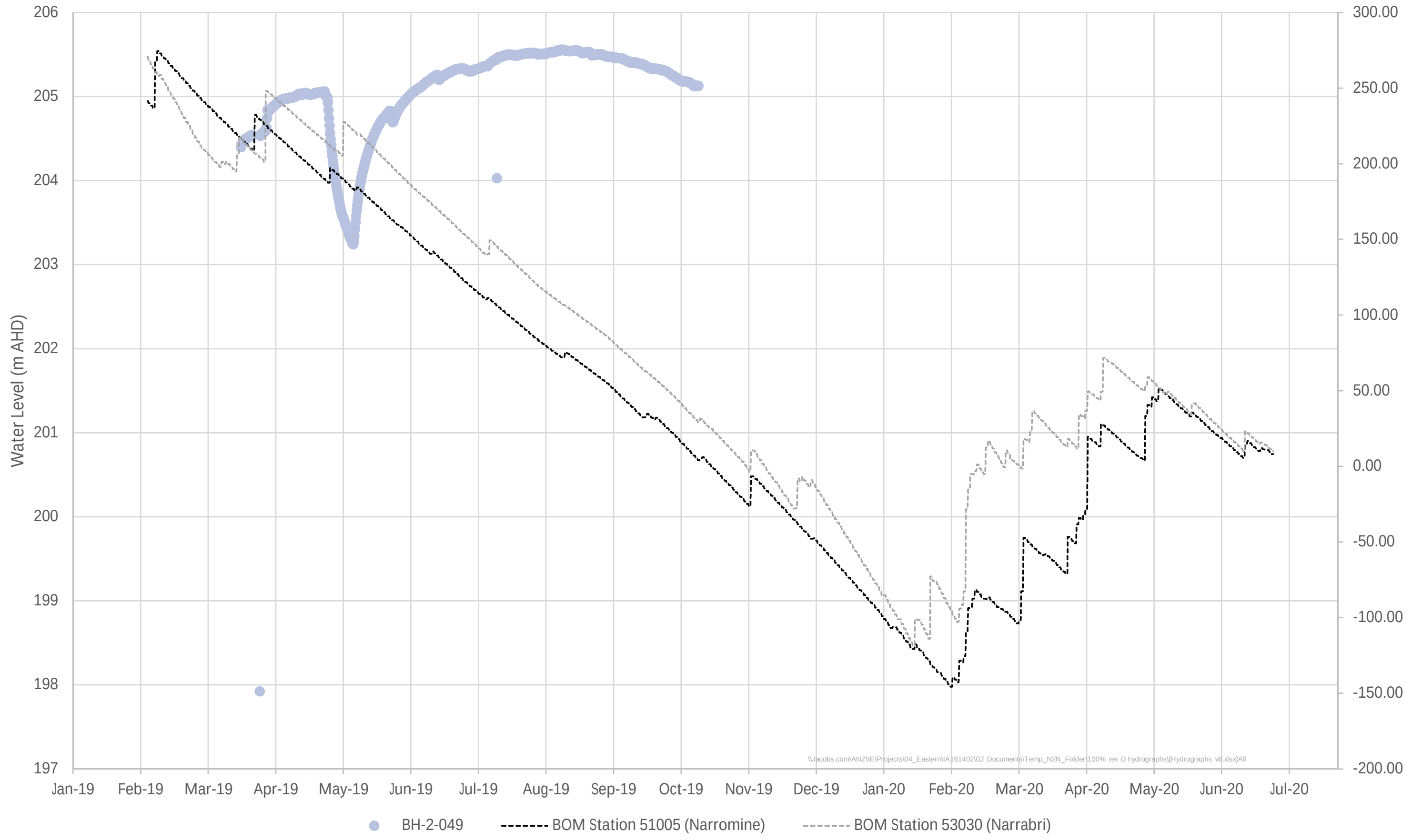

Water Level (m bgl)
0
5
10
15
20
25
CRD (mm)
300.00
250.00
200.00
150.00
100.00
50.00
0.00
-50.00
-100.00
-150.00
-200.00
Jan-19 Feb-19 Mar-19 Apr-19 May-19 Jun-19 Jul-19 Aug-19 Sep-19 Oct-19 Nov-19 Dec-19 Jan-20 Feb-20 Mar-20 Apr-20 May-20 Jun-20 Jul-20
BH-2-046
BOM Station 51005 (Narromine)
BOM Station 53030 (Narrabri)

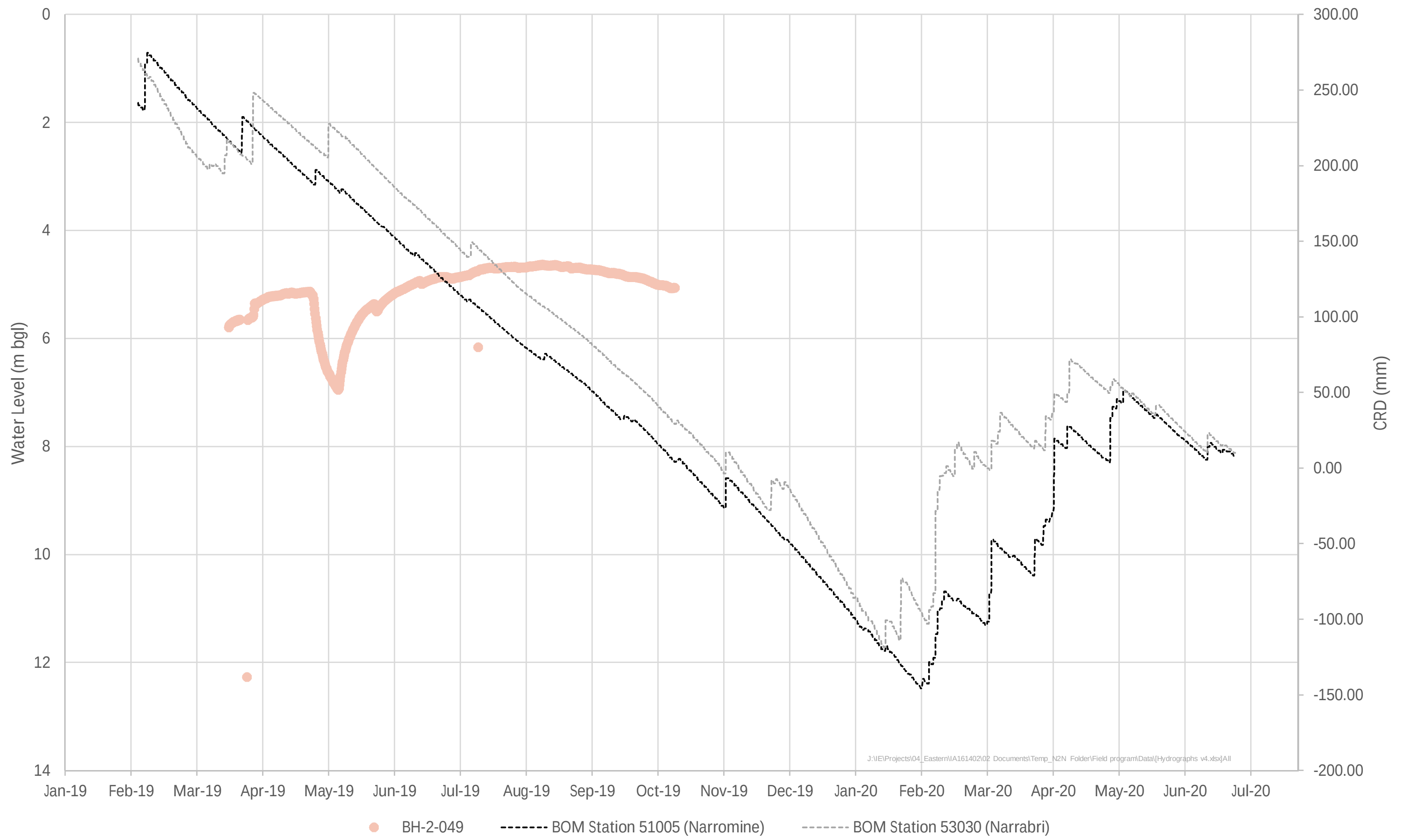


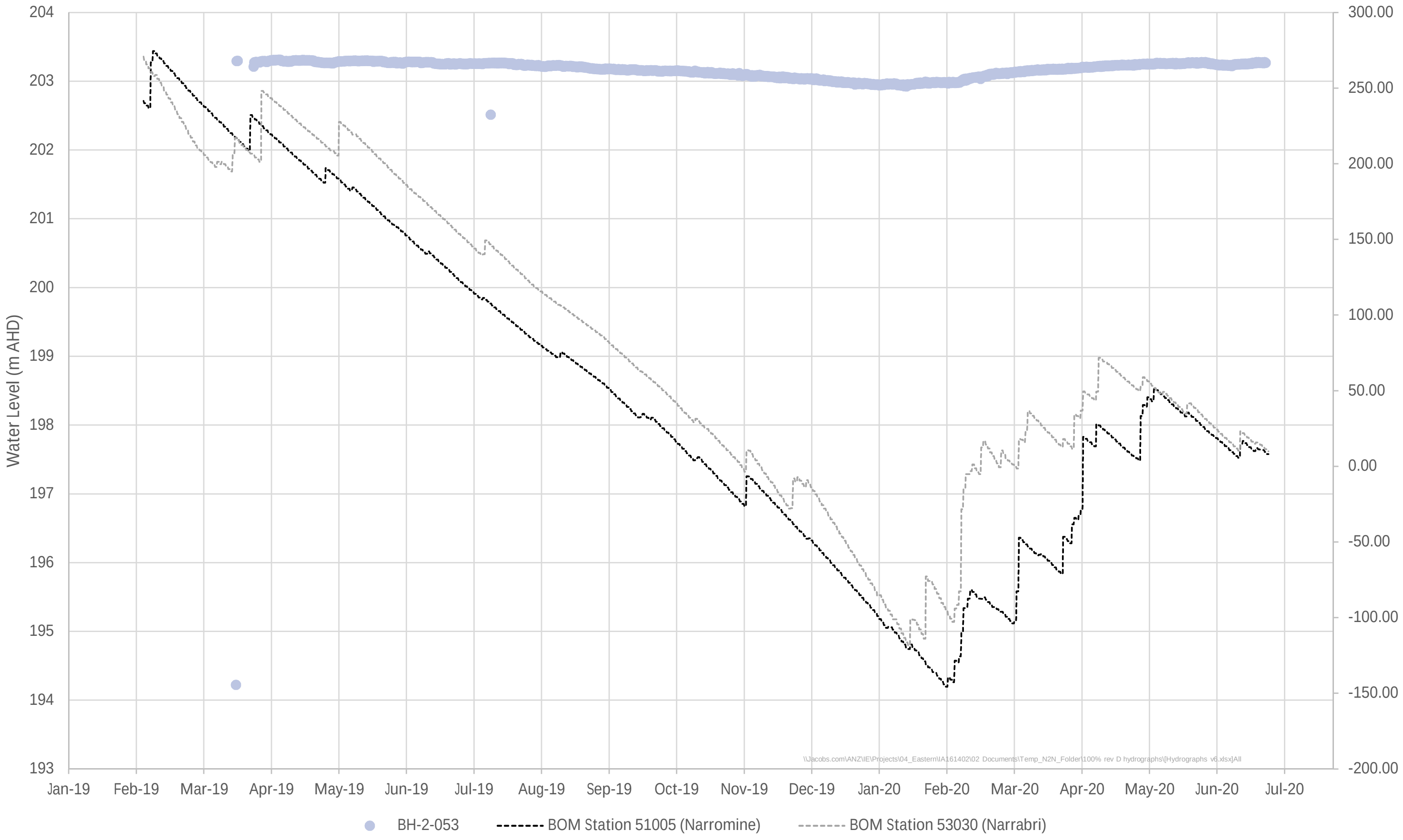
Water Level (m AHD)
250
200
150
100
50
0
300.00
250.00
200.00
150.00
100.00
50.00
0.00
-50.00
-100.00
-150.00
-200.00
Jan-19
Feb-19
Mar-19
Apr-19
May-19
Jun-19
Jul-19
Aug-19
Sep-19
Oct-19
Nov-19
Dec-19
Jan-20
Feb-20
Mar-20
Apr-20
May-20
Jun-20
Jul-20
BH-2-047
BOM Station 51005 (Narromine)
BOM Station 53030 (Narrabri)



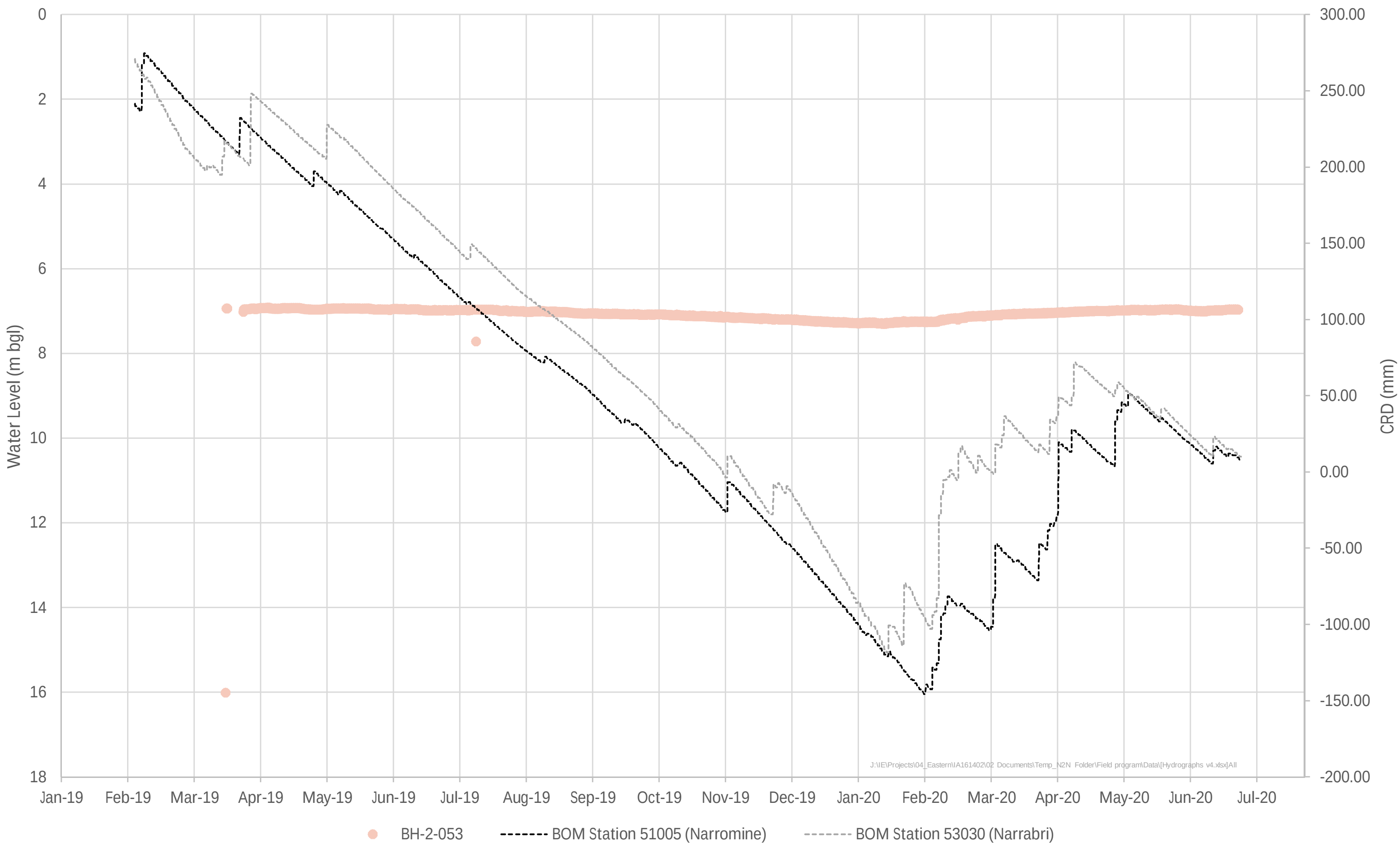
Water Level (m bgl)
0
2
4
6
8
10
12
CRD (mm)
300.00
250.00
200.00
150.00
100.00
50.00
0.00
-50.00
-100.00
-150.00
-200.00
Jan-19
Feb-19
Mar-19
Apr-19
May-19
Jun-19
Jul-19
Aug-19
Sep-19
Oct-19
Nov-19
Dec-19
Jan-20
Feb-20
Mar-20
Apr-20
May-20
Jun-20
Jul-20
BH-2-047
BOM Station 51005 (Narromine)
BOM Station 53030 (Narrabri)


Water Level (m AHD)
206
205
204
203
202
201
200
199
198
197
300.00
250.00
200.00
150.00
100.00
50.00
0.00
-50.00
-100.00
-150.00
-200.00
Jan-19
Feb-19
Mar-19
Apr-19
May-19
Jun-19
Jul-19
Aug-19
Sep-19
Oct-19
Nov-19
Dec-19
Jan-20
Feb-20
Mar-20
Apr-20
May-20
Jun-20
Jul-20
BH-2-049
BOM Station 51005 (Narromine)
BOM Station 53030 (Narrabri)

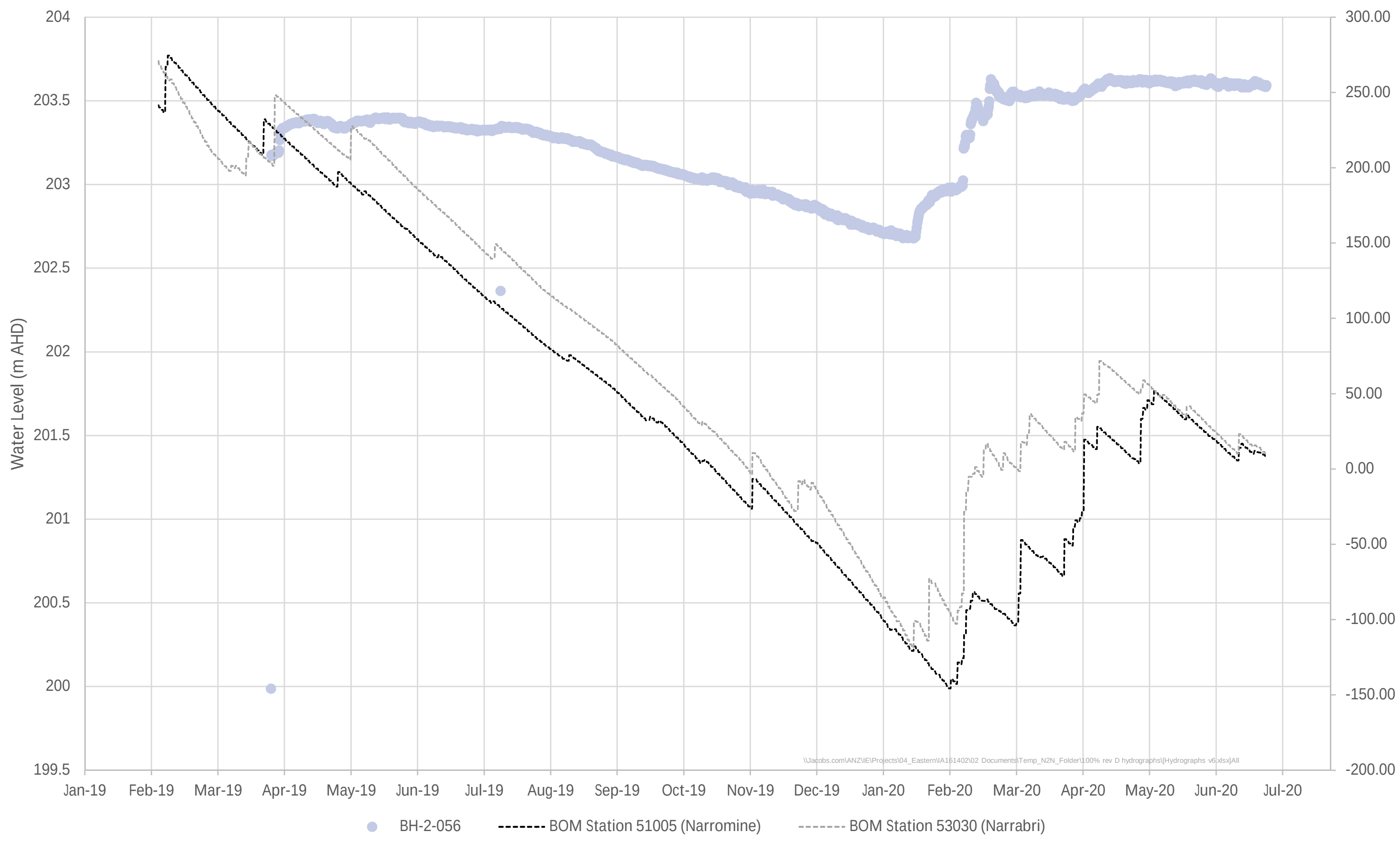

Water Level (m bgl)
0
2
4
6
8
10
12
14
CRD (mm)
300.00
250.00
200.00
150.00
100.00
50.00
0.00
-50.00
-100.00
-150.00
-200.00
Jan-19
Feb-19
Mar-19
Apr-19
May-19
Jun-19
Jul-19
Aug-19
Sep-19
Oct-19
Nov-19
Dec-19
Jan-20
Feb-20
Mar-20
Apr-20
May-20
Jun-20
Jul-20
BH-2-049
BOM Station 51005 (Narromine)
BOM Station 53030 (Narrabri)



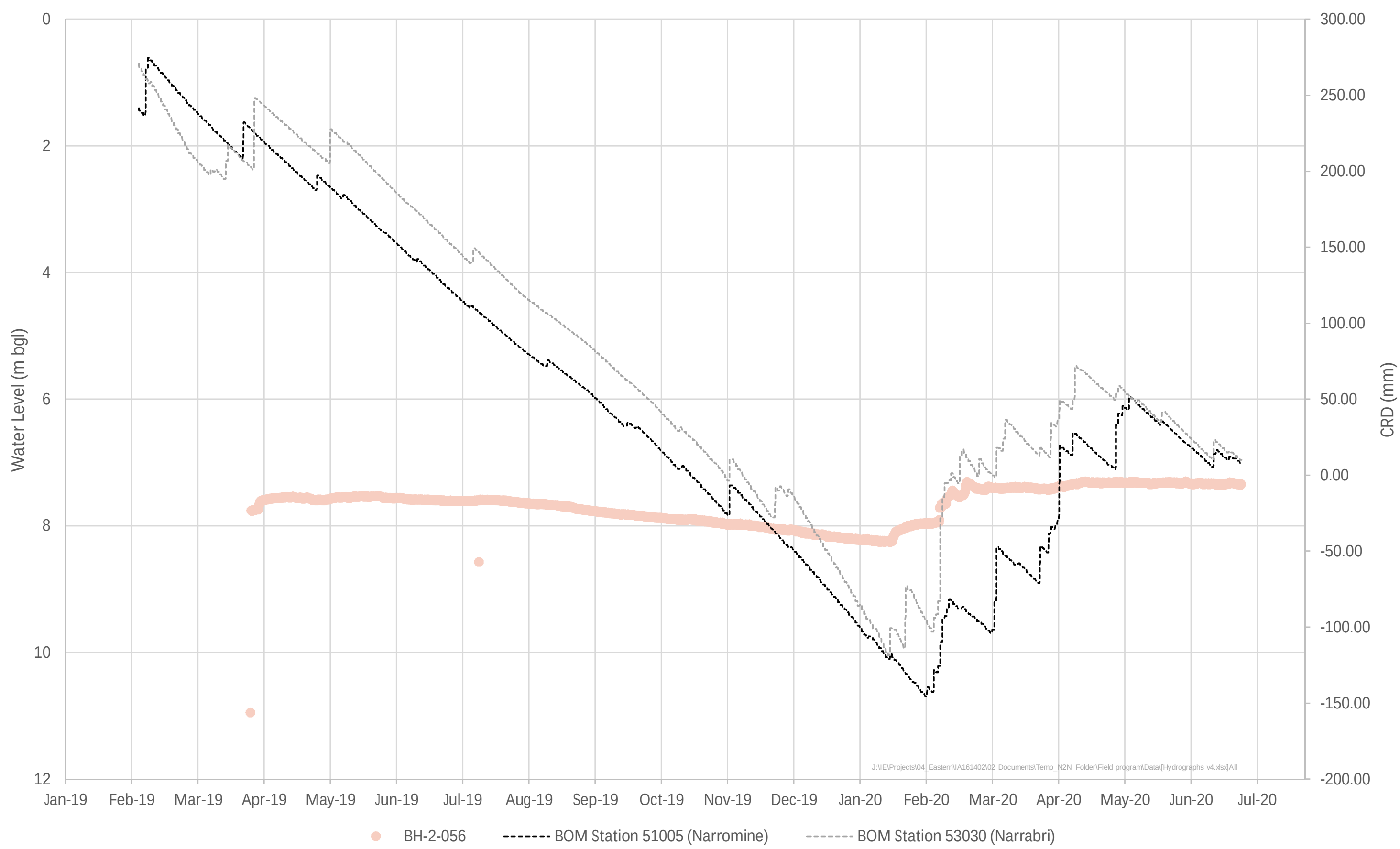
Water Level (m AHD)
204
203
202
201
200
199
198
197
196
195
194
193
300.00
250.00
200.00
150.00
100.00
50.00
0.00
-50.00
-100.00
-150.00
-200.00
Jan-19 Feb-19 Mar-19 Apr-19 May-19 Jun-19 Jul-19 Aug-19 Sep-19 Oct-19 Nov-19 Dec-19 Jan-20 Feb-20 Mar-20 Apr-20 May-20 Jun-20 Jul-20
BH-2-053
BOM Station 51005 (Narromine)
BOM Station 53030 (Narrabri)



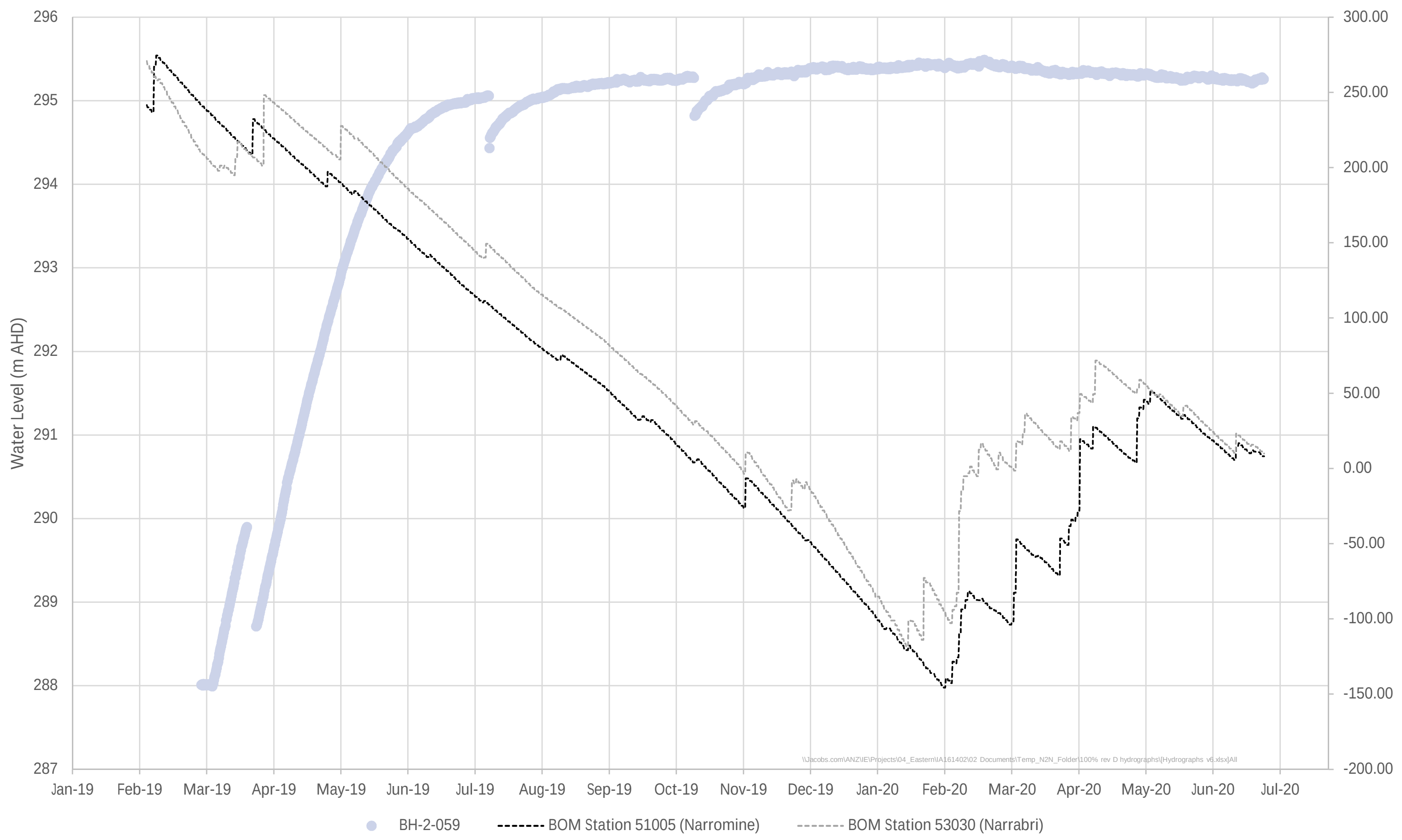
Water Level (m bgl)
0
2
4
6
8
10
12
14
16
18
CRD (mm)
300.00
250.00
200.00
150.00
100.00
50.00
0.00
-50.00
-100.00
-150.00
-200.00
Jan-19 Feb-19 Mar-19 Apr-19 May-19 Jun-19 Jul-19 Aug-19 Sep-19 Oct-19 Nov-19 Dec-19 Jan-20 Feb-20 Mar-20 Apr-20 May-20 Jun-20 Jul-20
BH-2-053
BOM Station 51005 (Narromine)
BOM Station 53030 (Narrabri)



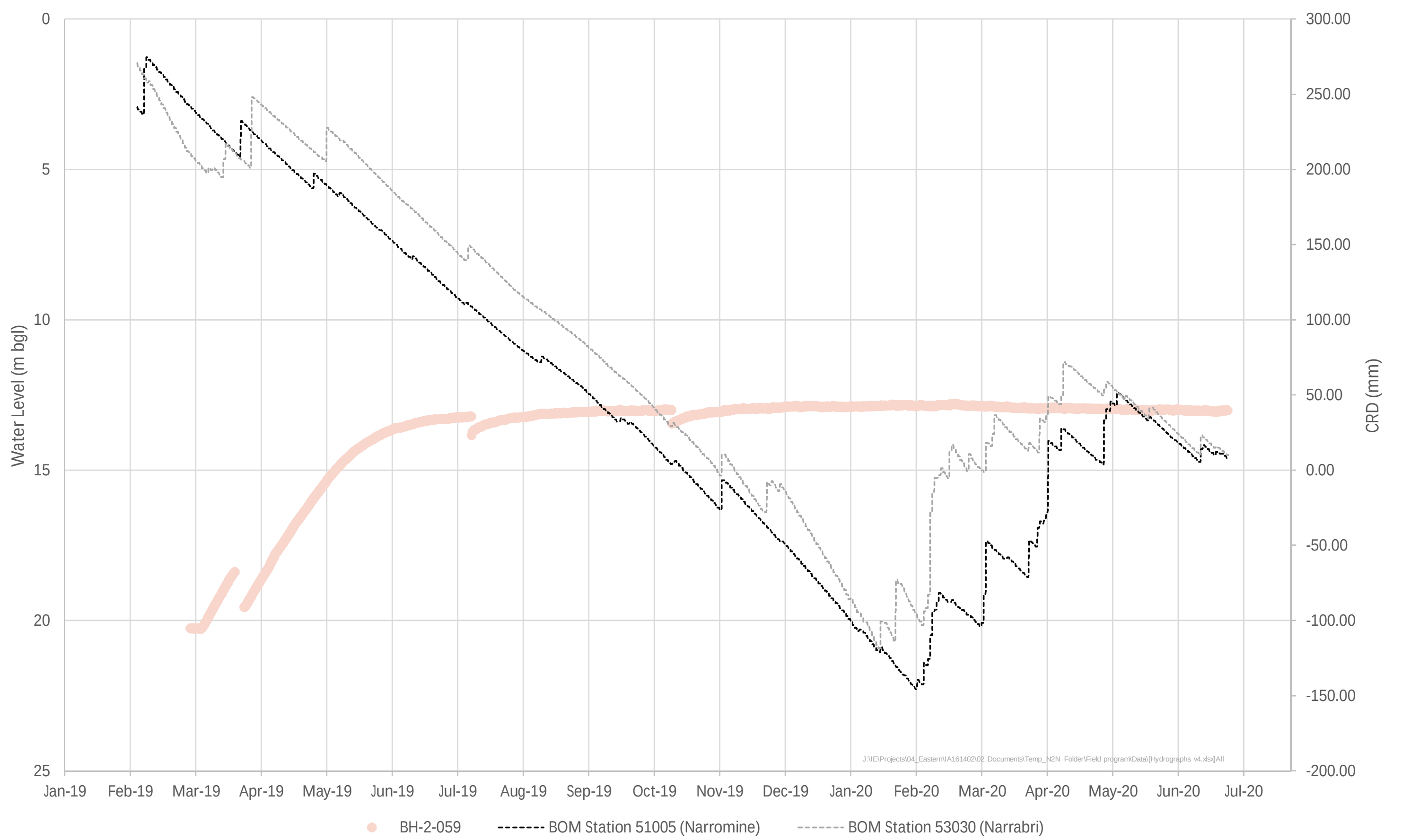
Water Level (m AHD)
204
203.5
203
202.5
202
201.5
201
200.5
200
199.5
300.00
250.00
200.00
150.00
100.00
50.00
0.00
-50.00
-100.00
-150.00
-200.00
Jan-19 Feb-19 Mar-19 Apr-19 May-19 Jun-19 Jul-19 Aug-19 Sep-19 Oct-19 Nov-19 Dec-19 Jan-20 Feb-20 Mar-20 Apr-20 May-20 Jun-20 Jul-20
BH-2-056
BOM Station 51005 (Narromine)
BOM Station 53030 (Narrabri)



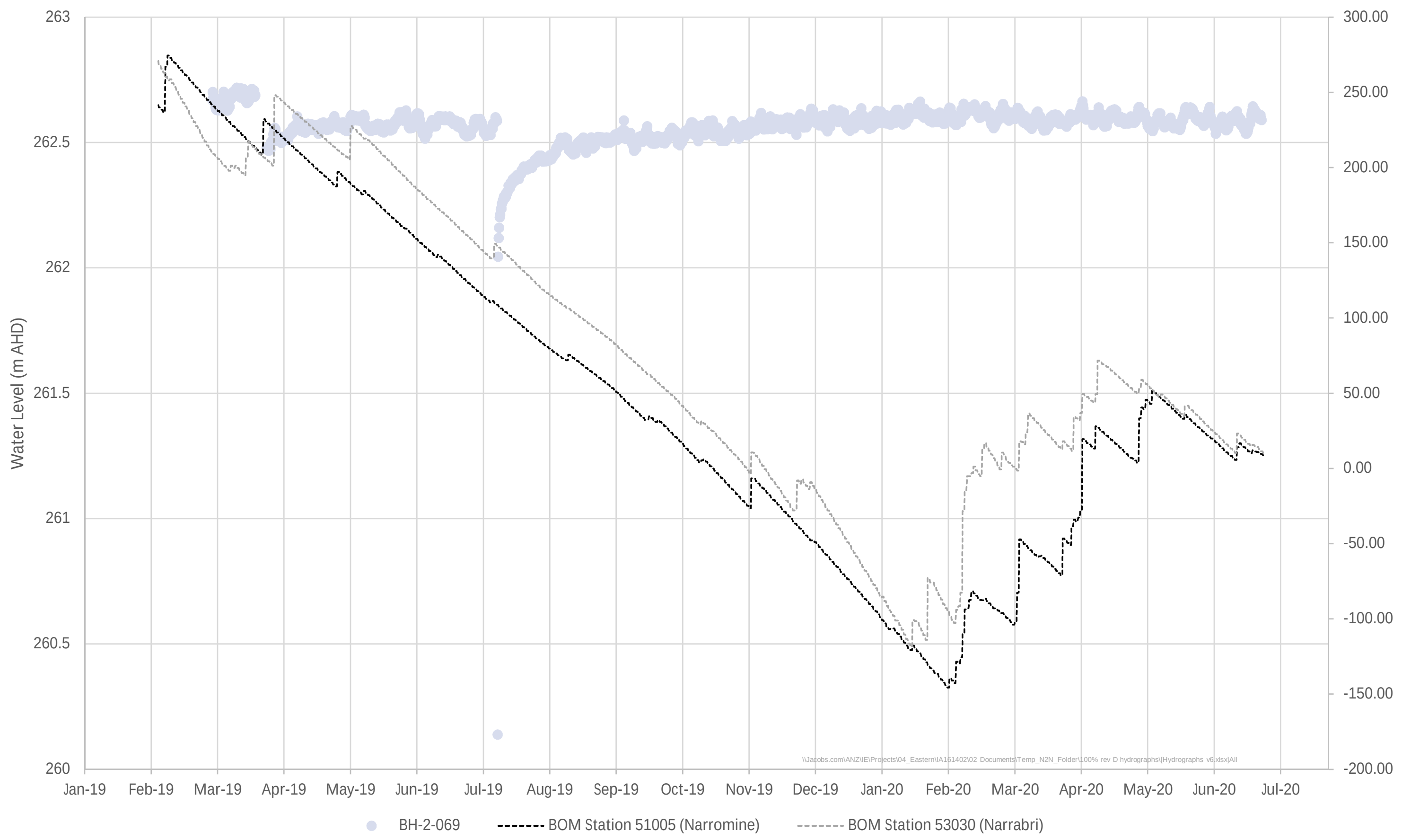
Water Level (m bgl)
0
2
4
6
8
10
12
CRD (mm)
300.00
250.00
200.00
150.00
100.00
50.00
0.00
-50.00
-100.00
-150.00
-200.00
Jan-19 Feb-19 Mar-19 Apr-19 May-19 Jun-19 Jul-19 Aug-19 Sep-19 Oct-19 Nov-19 Dec-19 Jan-20 Feb-20 Mar-20 Apr-20 May-20 Jun-20 Jul-20
BH-2-056
BOM Station 51005 (Narromine)
BOM Station 53030 (Narrabri)



Water Level (m AHD)
296
295
294
293
292
291
290
289
288
287
300.00
250.00
200.00
150.00
100.00
50.00
0.00
-50.00
-100.00
-150.00
-200.00
Jan-19
Feb-19
Mar-19
Apr-19
May-19
Jun-19
Jul-19
Aug-19
Sep-19
Oct-19
Nov-19
Dec-19
Jan-20
Feb-20
Mar-20
Apr-20
May-20
Jun-20
Jul-20
BH-2-059
BOM Station 51005 (Narromine)
BOM Station 53030 (Narrabri)



Water Level (m bgl)
0
5
10
15
20
25
CRD (mm)
300.00
250.00
200.00
150.00
100.00
50.00
0.00
-50.00
-100.00
-150.00
-200.00
Jan-19
Feb-19
Mar-19
Apr-19
May-19
Jun-19
Jul-19
Aug-19
Sep-19
Oct-19
Nov-19
Dec-19
Jan-20
Feb-20
Mar-20
Apr-20
May-20
Jun-20
Jul-20
BH-2-059
BOM Station 51005 (Narromine)
BOM Station 53030 (Narrabri)



Water Level (m AHD)
263
262.5
262
261.5
261
260.5
260
300.00
250.00
200.00
150.00
100.00
50.00
0.00
-50.00
-100.00
-150.00
-200.00
Jan-19
Feb-19
Mar-19
Apr-19
May-19
Jun-19
Jul-19
Aug-19
Sep-19
Oct-19
Nov-19
Dec-19
Jan-20
Feb-20
Mar-20
Apr-20
May-20
Jun-20
Jul-20
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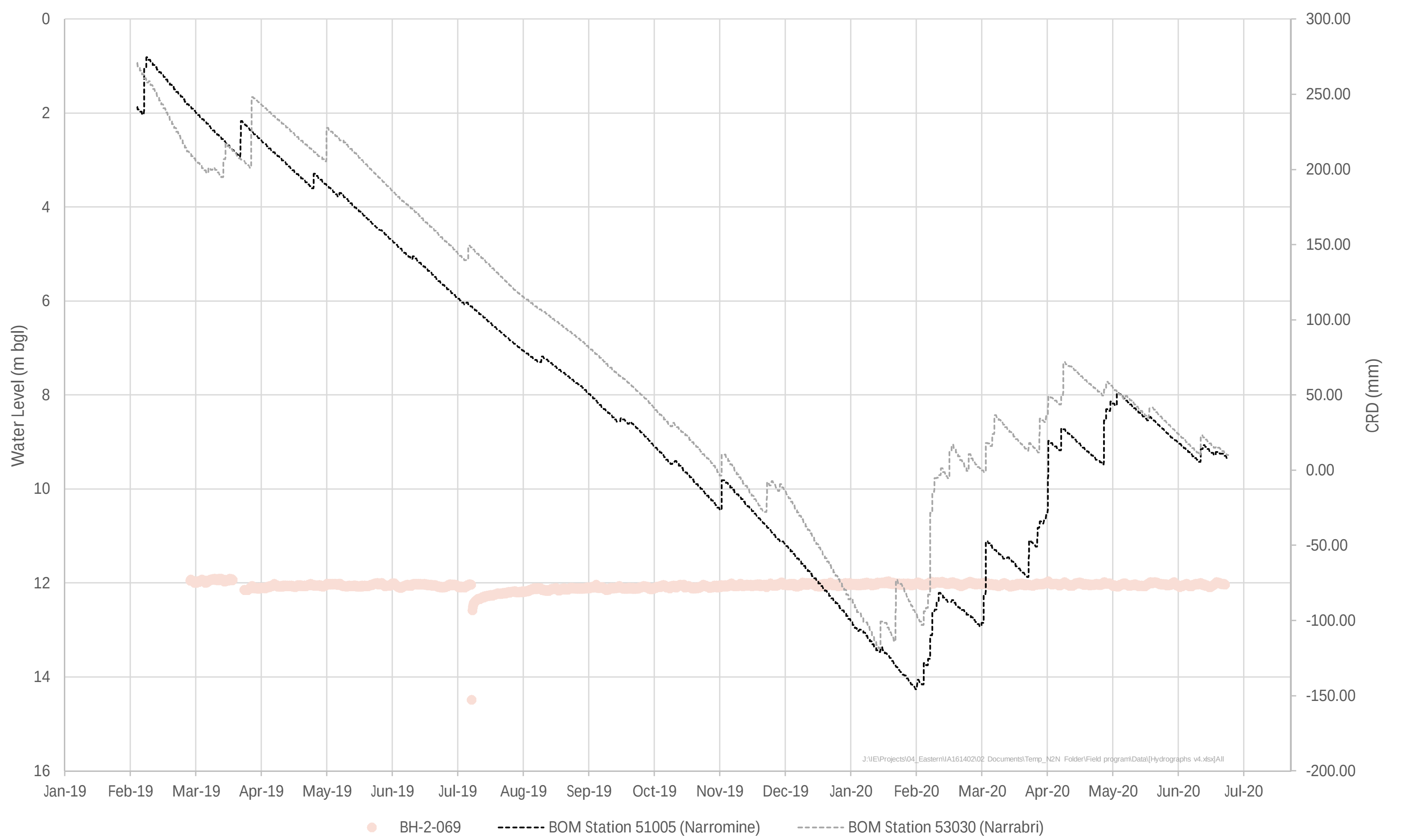
BH-2-069
BOM Station 51005 (Narromine)
BOM Station 53030 (Narrabri)



Water Level (m bgl)
0
2
4
6
8
10
12
14
16
CRD (mm)
300.00
250.00
200.00
150.00
100.00
50.00
0.00
-50.00
-100.00
-150.00
-200.00
Jan-19
Feb-19
Mar-19
Apr-19
May-19
Jun-19
Jul-19
Aug-19
Sep-19
Oct-19
Nov-19
Dec-19
Jan-20
Feb-20
Mar-20
Apr-20
May-20
Jun-20
Jul-20
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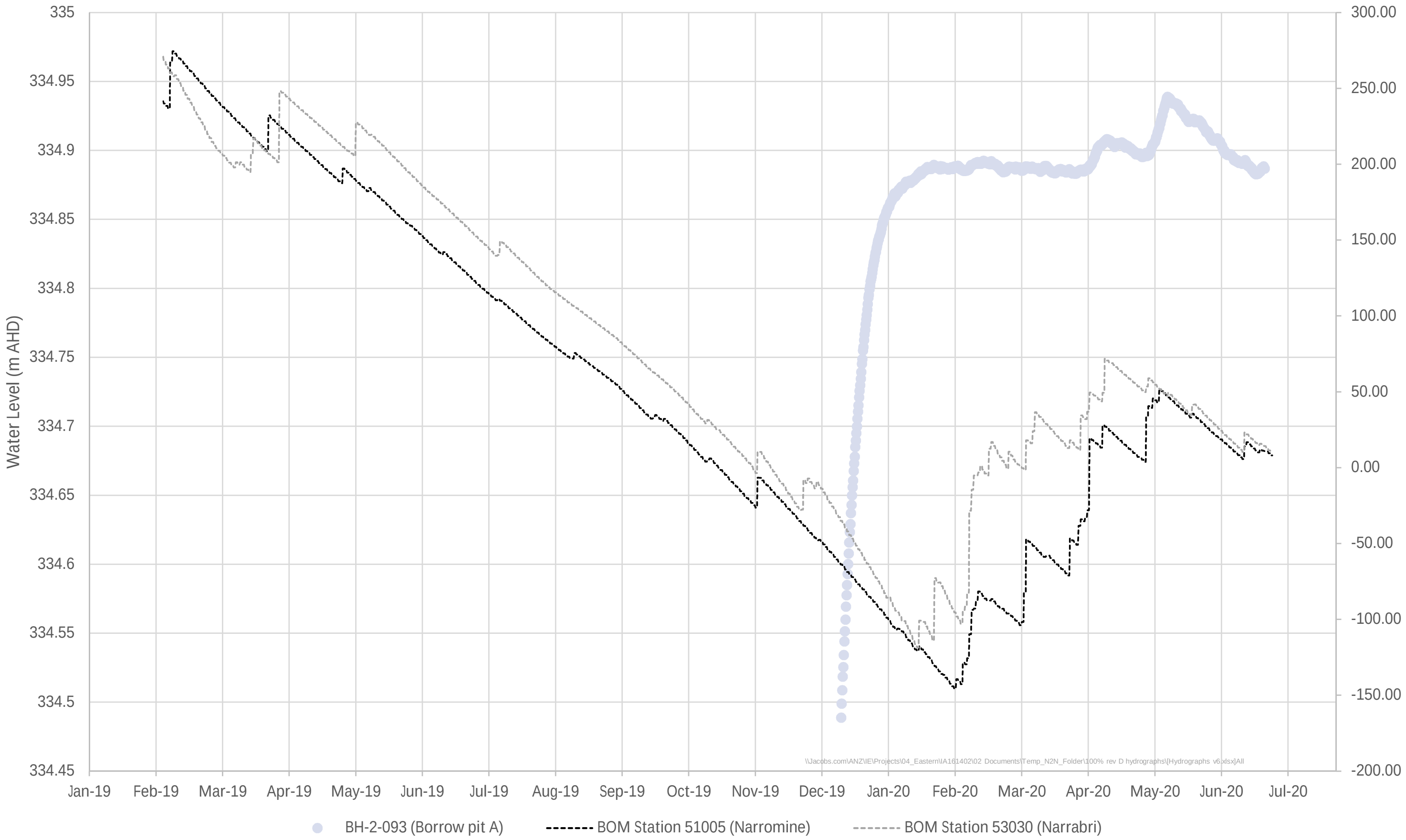
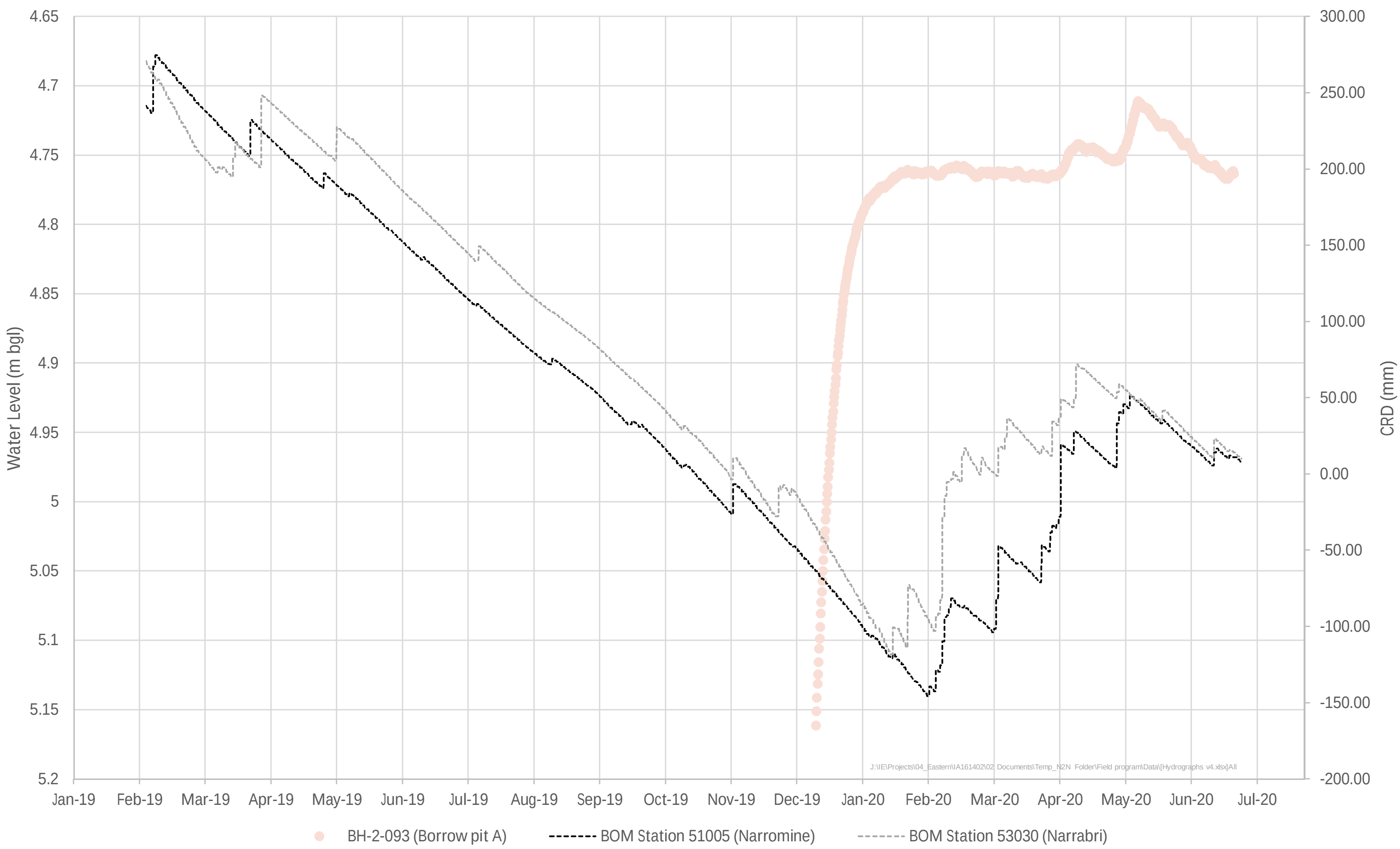
BH-2-069
BOM Station 51005 (Narromine)
BOM Station 53030 (Narrabri)



Water Level (m AHD)
335
334.95
334.9
334.85
334.8
334.75
334.7
334.65
334.6
334.55
334.5
334.45
300.00
250.00
200.00
150.00
100.00
50.00
0.00
-50.00
-100.00
-150.00
-200.00
Jan-19 Feb-19 Mar-19 Apr-19 May-19 Jun-19 Jul-19 Aug-19 Sep-19 Oct-19 Nov-19 Dec-19 Jan-20 Feb-20 Mar-20 Apr-20 May-20 Jun-20 Jul-20
BH-2-093 (Borrow pit A)
BOM Station 51005 (Narromine)
BOM Station 53030 (Narrabri)



Water Level (m bgl)
4.65
4.7
4.75
4.8
4.85
4.9
4.95
5
5.05
5.1
5.15
5.2
CRD (mm)
300.00
250.00
200.00
150.00
100.00
50.00
0.00
-50.00
-100.00
-150.00
-200.00
Jan-19 Feb-19 Mar-19 Apr-19 May-19 Jun-19 Jul-19 Aug-19 Sep-19 Oct-19 Nov-19 Dec-19 Jan-20 Feb-20 Mar-20 Apr-20 May-20 Jun-20 Jul-20
BH-2-093 (Borrow pit A)
BOM Station 51005 (Narromine)
BOM Station 53030 (Narrabri)

TECHNICAL REPORT

4

Groundwater assessment

Appendix B Alignment groundwater monitoring bore laboratory analysis suite summary

Alignment groundwater monitoring bore laboratory analysis suite summary

Sampling round	Bore ID	Groundwater quality testing suite			Reason for no sample				
		Suite 1	Suite 1 and 2	Suite 1, 2 and 3	Insufficient sample volume	Bore dry	Bores not constructed	Bore decomm-issioned	Site access unavailable
Round 1 – 18/03/19 to 29/03/19	BH-2-001					✓			
	BH-2-002		✓						
	BH-2-003						✓		
	BH-2-005				✓				
	BH-2-006					✓			
	BH-2-007		✓						
	BH-2-008				✓				
	BH-2-009				✓				
	BH-2-010				✓				
	BH-2-014					✓			
	BH-2-015		✓						
	BH-2-017		✓						
	BH-2-018		✓						
	BH-2-019		✓			✓			
	BH-2-020					✓			
	BH-2-021		✓						
	BH-2-024					✓			
	BH-2-025					✓			
	BH-2-030		✓						
	BH-2-036					✓			
	BH-2-038	✓							
	BH-2-039						✓		
	BH-2-040						✓		
	BH-2-041						✓		
	BH-2-042					✓			
	BH-2-044					✓			
	BH-2-045						✓		
	BH-2-046		✓						
	BH-2-047		✓						
	BH-2-049			✓					
	BH-2-053		✓						
	BH-2-056			✓					
	BH-2-058				✓				
	BH-2-059				✓				
	BH-2-062				✓				
	BH-2-069		✓						
Round 2 – 08/07/19 to 19/07/19	BH-2-001					✓			
	BH-2-002		✓						
	BH-2-003		✓						
	BH-2-005					✓			
	BH-2-006					✓			
	BH-2-007		✓						
	BH-2-008					✓			
	BH-2-009					✓			
	BH-2-010					✓			
	BH-2-014					✓			
	BH-2-015		✓						
	BH-2-017		✓						
	BH-2-018		✓						
	BH-2-019					✓			
	BH-2-020							✓	
	BH-2-021		✓						
	BH-2-024					✓			
	BH-2-025					✓			
	BH-2-030		✓						
	BH-2-036					✓			
	BH-2-038	✓							
	BH-2-039					✓			
	BH-2-040					✓			
	BH-2-041					✓			
	BH-2-042					✓			
	BH-2-044					✓			
	BH-2-045					✓			
	BH-2-046		✓						
	BH-2-047	✓							

Sampling round	Bore ID	Groundwater quality testing suite			Reason for no sample				
		Suite 1	Suite 1 and 2	Suite 1, 2 and 3	Insufficient sample volume	Bore dry	Bores not constructed	Bore decomm-issioned	Site access unavailable
	BH-2-049			✓					
	BH-2-053	✓							
	BH-2-056			✓					
	BH-2-058					✓			
	BH-2-059		✓						
	BH-2-062					✓			
	BH-2-069		✓						
Round 3 – 08/10/19 to 11/10/19	BH-2-001					✓			
	BH-2-002		✓						
	BH-2-003		✓						
	BH-2-005					✓			
	BH-2-006					✓			
	BH-2-007		✓						
	BH-2-008					✓			
	BH-2-009					✓			
	BH-2-010					✓			
	BH-2-014					✓			
	BH-2-015		✓						
	BH-2-017		✓						
	BH-2-018		✓						
	BH-2-019					✓			
	BH-2-020							✓	
	BH-2-021		✓						
	BH-2-024					✓			
	BH-2-025					✓			
	BH-2-030		✓						
	BH-2-036					✓			
	BH-2-038	✓							
	BH-2-039					✓			
	BH-2-040					✓			
	BH-2-041					✓			
	BH-2-042					✓			
	BH-2-044					✓			
	BH-2-045					✓			
	BH-2-046		✓						
	BH-2-047	✓							
	BH-2-049			✓					
	BH-2-053		✓						
	BH-2-056			✓					
	BH-2-058					✓			
	BH-2-059		✓						
	BH-2-062					✓			
	BH-2-069		✓						
Round 4 – 23/06/20 to 30/06/19	BH-2-001					✓			
	BH-2-002		✓						
	BH-2-003		✓						
	BH-2-005					✓			
	BH-2-006					✓			
	BH-2-007		✓						
	BH-2-008					✓			
	BH-2-009					✓			
	BH-2-010					✓			
	BH-2-014					✓			
	BH-2-015		✓						
	BH-2-017		✓						
	BH-2-018		✓						
	BH-2-019					✓			
	BH-2-020							✓	
	BH-2-021		✓						
	BH-2-024					✓			
	BH-2-025					✓			
	BH-2-030		✓						
	BH-2-036					✓			
	BH-2-038	✓							
	BH-2-039					✓			
	BH-2-040					✓			
	BH-2-041					✓			
	BH-2-042					✓			

Sampling round	Bore ID	Groundwater quality testing suite			Reason for no sample				
		Suite 1	Suite 1 and 2	Suite 1, 2 and 3	Insufficient sample volume	Bore dry	Bores not constructed	Bore decomm-issioned	Site access unavailable
	BH-2-044					✓			
	BH-2-045					✓			
	BH-2-046		✓						
	BH-2-047	✓							
	BH-2-049								✓
	BH-2-053	✓							
	BH-2-056			✓					
	BH-2-058					✓			
	BH-2-059		✓						
	BH-2-062					✓			
	BH-2-069		✓						

TECHNICAL REPORT

4

Groundwater assessment

Appendix C Groundwater quality results summary tables

NARROMINE TO NARRABRI ENVIRONMENTAL IMPACT STATEMENT

		Metals																
		Arsenic	Arsenic (filtered)	Cadmium	Cadmium (filtered)	Chromium (III+VI)	Chromium (III+VI) (filtered)	Copper	Copper (filtered)	Lead	Lead (filtered)	Magnesium	Mercury	Mercury (filtered)	Nickel	Nickel (filtered)	Zinc	Zinc (filtered)
		µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
EQL		1	1	0.2	0.2	1	1	1	1	1	1	500	0.1	0.1	1	1	5	5
NEPM 2013 Table 1C GILs, Fresh Waters				0.2	0.2			1.4	1.4	3.4	3.4		0.06	0.06	11	11	8	8
ANZG (2018) Freshwater 95% toxicant DGVs				0.2	0.2			1.4	1.4	3.4	3.4		0.6	0.6	11	11	8	8
Field ID	Date																	
BH-2-002	24/03/2019	-	4	-	<0.2	-	<1	-	<1	-	<1	32,000	-	<0.1	-	12	-	7
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	9/07/2019	-	<1	-	<0.2	-	<1	-	<1	-	<1	32,000	-	<0.1	-	11	-	8
	9/10/2019	-	<1	-	<0.2	-	<1	-	<1	-	<1	30,000	-	<0.1	-	8	-	<5
	23/06/2020	-	<1	-	<0.2	-	<1	-	<1	-	<1	34,000	-	<0.1	-	2	-	<5
BH-2-003	9/07/2019	-	<1	-	<0.2	-	<1	-	<1	-	<1	8,700	-	<0.1	-	12	-	<5
	9/10/2019	-	<1	-	<0.2	-	<1	-	<1	-	<1	7,000	-	<0.1	-	6	-	<5
	30/06/2020	-	<1	-	<0.2	-	<1	-	<1	-	<1	10,000	-	<0.1	-	<1	-	<5
BH-2-007	23/03/2019	-	<1	-	<0.2	-	<1	-	<1	-	<1	460,000	-	<0.1	-	22	-	7
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	9/07/2019	-	<1	-	<0.2	-	<1	-	<1	-	<1	470,000	-	<0.1	-	6	-	10
	9/10/2019	-	<1	-	<0.2	-	<1	-	<1	-	<1	470,000	-	<0.1	-	4	-	21
	24/06/2020	-	<1	-	<0.2	-	<1	-	<1	-	<1	360,000	-	<0.1	-	1	-	9
BH-2-015	23/03/2019	-	2	-	<0.2	-	2	-	<1	-	<1	280,000	-	<0.1	-	44	-	<5
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	10/07/2019	-	2	-	<0.2	-	<1	-	<1	-	<1	470,000	-	<0.1	-	25	-	90
	9/10/2019	-	<1	-	<0.2	-	<1	-	<1	-	<1	450,000	-	<0.1	-	20	-	13
	25/06/2020	-	<1	-	<0.2	-	<1	-	<1	-	<1	420,000	-	<0.1	-	12	-	11
BH-2-017	22/03/2019	-	2	-	<0.2	-	<1	-	4	-	<1	6,700	-	<0.1	-	10	-	13
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	10/07/2019	-	2	-	<0.2	-	<1	-	1	-	<1	61,000	-	<0.1	-	21	-	8
	9/10/2019	-	1	-	<0.2	-	<1	-	<1	-	<1	66,000	-	<0.1	-	11	-	<5
	25/06/2020	-	<1	-	<0.2	-	<1	-	3	-	<1	89,000	-	<0.1	-	10	-	12
BH-2-018	21/03/2019	-	36	-	<0.2	-	<1	-	<1	-	<1	110,000	-	<0.1	-	13	-	25
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	10/07/2019	-	2	-	<0.2	-	<1	-	<1	-	<1	41,000	-	<0.1	-	15	-	<5
	9/10/2019	-	1	-	<0.2	-	<1	-	<1	-	<1	68,000	-	<0.1	-	5	-	<5
	25/06/2020	-	3	-	<0.2	-	<1	-	<1	-	<1	80,000	-	<0.1	-	3	-	<5
BH-2-021	26/03/2019	-	2	-	<0.2	-	<1	-	2	-	<1	11,000	-	<0.1	-	3	-	<5
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	13/07/2019	-	<1	-	<0.2	-	<1	-	<1	-	<1	16,000	-	<0.1	-	4	-	<5
	9/10/2019	-	<1	-	<0.2	-	<1	-	<1	-	<1	17,000	-	<0.1	-	2	-	<5
	25/06/2020	-	1	-	<0.2	-	<1	-	<1	-	<1	34,000	-	<0.1	-	1	-	9
BH-2-030	20/03/2019	-	4	-	<0.2	-	<1	-	<1	-	<1	27,000	-	<0.1	-	8	-	8
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	10/07/2019	-	1	-	<0.2	-	<1	-	2	-	<1	120,000	-	0.2	-	4	-	10
	9/10/2019	-	1	-	<0.2	-	<1	-	<1	-	<1	120,000	-	0.1	-	1	-	<5
	29/06/2020	-	2	-	<0.2	-	<1	-	2	-	<1	130,000	-	0.2	-	3	-	<5
BH-2-038	26/03/2019	-	<1	-	<0.2	-	1	-	1	-	<1	14,000	-	<0.1	-	24	-	<5
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	11/07/2019	-	<1	-	<0.2	-	<1	-	<1	-	<1	21,000	-	<0.1	-	22	-	19
	9/10/2019	-	<1	-	<0.2	-	<1	-	<1	-	<1	16,000	-	<0.1	-	13	-	<5
	27/06/2020	-	<1	-	<0.2	-	<1	-	<1	-	<1	15,000	-	<0.1	-	32	-	19

		Metals																
		Arsenic	Arsenic (filtered)	Cadmium	Cadmium (filtered)	Chromium (III+VI)	Chromium (III+VI) (filtered)	Copper	Copper (filtered)	Lead	Lead (filtered)	Magnesium	Mercury	Mercury (filtered)	Nickel	Nickel (filtered)	Zinc	Zinc (filtered)
		µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
EQL		1	1	0.2	0.2	1	1	1	1	1	1	500	0.1	0.1	1	1	5	5
NEPM 2013 Table 1C GILs, Fresh Waters				0.2	0.2			1.4	1.4	3.4	3.4		0.06	0.06	11	11	8	8
ANZG (2018) Freshwater 95% toxicant DGVs				0.2	0.2			1.4	1.4	3.4	3.4		0.6	0.6	11	11	8	8
Field ID	Date																	
BH-2-046	26/03/2019	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	27/03/2019	-	2	-	<0.2	-	<1	-	2	-	<1	4,500	-	<0.1	-	2	-	12
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	12/07/2019	-	2	-	<0.2	-	<1	-	<1	-	<1	1,200	-	<0.1	-	<1	-	<5
	9/10/2019	-	1	-	<0.2	-	<1	-	<1	-	<1	1,000	-	<0.1	-	<1	-	<5
	26/06/2020	-	<1	-	<0.2	-	<1	-	<1	-	<1	<5,000	-	<0.1	-	<1	-	<5
BH-2-047	26/03/2019	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	27/03/2019	-	4	-	<0.2	-	2	-	4	-	2	3,300	-	<0.1	-	2	-	6
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	12/07/2019	-	4	-	<0.2	-	<1	-	<1	-	<1	2,000	-	<0.1	-	<1	-	<5
	9/10/2019	-	4	-	<0.2	-	<1	-	<1	-	<1	1,900	-	<0.1	-	<1	-	<5
	26/06/2020	-	2	-	<0.2	-	<1	-	<1	-	<1	<5,000	-	<0.1	-	<1	-	<5
BH-2-049	26/03/2019	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	27/03/2019	-	3	-	<0.2	-	<1	-	1	-	<1	3,700	-	<0.1	-	17	-	<5
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	12/07/2019	-	1	-	<0.2	-	<1	-	<1	-	<1	3,600	-	<0.1	-	<1	-	<5
	9/10/2019	-	1	-	<0.2	-	<1	-	<1	-	<1	3,200	-	<0.1	-	<1	-	<5
BH-2-053	26/03/2019	-	<1	-	<0.2	-	<1	-	1	-	<1	8,200	-	<0.1	-	10	-	<5
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	11/07/2019	-	<1	-	<0.2	-	<1	-	<1	-	<1	3,900	-	0.2	-	1	-	<5
	9/10/2019	-	<1	-	<0.2	-	<1	-	<1	-	<1	5,600	-	<0.1	-	<1	-	<5
	27/06/2020	-	<1	-	<0.2	-	<1	-	<1	-	<1	4,700	-	0.1	-	<1	-	<5
BH-2-056	26/03/2019	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	28/03/2019	-	<1	-	<0.2	-	<1	-	2	-	<1	5,800	-	<0.1	-	4	-	6
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	11/07/2019	-	<1	-	<0.2	-	<1	-	<1	-	<1	1,200	-	0.1	-	<1	-	<5
	9/10/2019	-	<1	-	<0.2	-	<1	-	<1	-	<1	1,200	-	<0.1	-	<1	-	<5
	26/06/2020	-	<1	-	<0.2	-	<1	-	<1	-	<1	700	-	<0.1	-	<1	-	<5
BH-2-059	10/07/2019	-	1	-	<0.2	-	<1	-	<1	-	<1	1,400,000	-	<0.1	-	110	-	24
	9/10/2019	-	1	-	<0.2	-	<1	-	<1	-	<1	1,400,000	-	<0.1	-	22	-	8
	29/06/2020	-	1	-	<0.2	-	<1	-	1	-	<1	1,200,000	-	<0.1	-	42	-	92
BH-2-069	21/03/2019	-	<1	-	<0.2	-	1	-	<1	-	<1	85,000	-	<0.1	-	2	-	17
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	10/07/2019	-	<1	-	<0.2	-	<1	-	<1	-	<1	28,000	-	<0.1	-	3	-	9
	9/10/2019	-	<1	-	<0.2	-	<1	-	<1	-	<1	27,000	-	<0.1	-	<1	-	<5
	29/06/2020	-	<1	-	<0.2	-	<1	-	<1	-	<1	33,000	-	<0.1	-	2	-	6
BH-93(BP-01)	24/06/2020	-	3	-	<0.2	-	<1	-	2	-	<1	15,000	-	<0.1	-	37	-	7
	11/12/2019	4	-	<0.2	-	22	-	5	-	4	-	26,000	<0.1	-	48	-	38	-

		Inorganics																			
		Soluble Bicarb as CaCO3*	Soluble Carbonate as CaCO3*	Alkalinity (Hydroxide) as CaCO3	Alkalinity (total) as CaCO3	Ammonia as N	Calcium	Chloride	Electrical conductivity (lab)	Kjeldahl Nitrogen Total	Nitrate & Nitrite (as N)	Nitrate (as N)	Nitrite (as N)	Nitrogen (Total)	Phosphate total (P)	Phosphorus	Potassium	Sodium	Sulphate	Total Dissolved Solids	Hardness as CaCO3
		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	uS/cm	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
EQL		20	10	20	20	0.01	0.5	1	1	0.2	0.05	0.02	0.02	0.2	0.01	0.01	0.5	0.5	5	10	5
NEPM 2013 Table 1C GILs, Fresh Waters																					
ANZG (2018) Freshwater 95% toxicant DGVs						0.9															
Field ID	Date																				
BH-2-002	24/03/2019	180	<10	<20	180	<0.01	57	210	-	<0.2	2.2	2.2	<0.02	0.9	0.05	-	1.6	160	120	-	270
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	9/07/2019	200	<10	<20	200	0.02	62	190	1,200	0.7	0.80	0.65	0.15	1.5	1.1	-	1.9	140	120	700	290
	9/10/2019	150	<10	<20	150	<0.01	56	190	1,100	1.3	0.88	0.88	<0.02	2.18	0.81	-	1.4	130	120	670	260
	23/06/2020	150	<10	<20	150	<0.01	65	170	900	<0.2	1.3	1.3	<0.02	1.3	-	0.09	<5	130	100	700	300
BH-2-003	9/07/2019	140	<10	<20	140	1.00	22	76	400	2.1	<0.05	<0.02	<0.02	2.1	1.6	-	2.5	33	17	200	91
	9/10/2019	69	<10	<20	69	0.09	15	60	290	5.6	<0.05	<0.02	<0.02	5.6	2.1	-	2.0	28	<5	210	67
	30/06/2020	100	<10	<20	100	0.37	22	46	310	1.2	<0.05	<0.02	<0.02	1.2	-	0.46	2.8	29	<5	200	97
BH-2-007	23/03/2019	420	<10	<20	420	0.03	610	6,600	-	<0.2	<0.05	<0.02	<0.02	<0.2	0.11	-	27	3,600	1,000	-	3,400
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	9/07/2019	550	<10	<20	550	0.03	590	8,300	23,000	1.9	<0.05	<0.02	<0.02	1.9	6.9	-	28	3,900	980	13,000	3,400
	9/10/2019	520	<10	<20	520	0.03	640	8,000	22,000	<0.2	<0.05	<0.02	<0.02	<0.2	0.20	-	28	3,800	980	15,000	3,500
	24/06/2020	530	<10	<20	530	0.02	550	5,600	10,000	0.3	<0.05	0.04	<0.02	0.3	-	0.64	19	3,000	690	14,000	2,900
BH-2-015	23/03/2019	570	<10	<20	570	2.6	190	6,000	-	3.4	<0.05	<0.02	<0.02	3.4	0.20	-	29	4,100	1,100	-	1,600
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	10/07/2019	740	<10	<20	740	1.4	320	5,600	27,000	2.2	<0.05	<0.02	<0.02	2.2	0.27	-	49	5,200	900	13,000	2,700
	9/10/2019	720	<10	<20	720	0.63	300	9,300	25,000	0.6	0.07	0.05	0.03	0.67	0.14	-	44	5,100	1,400	15,000	2,600
	25/06/2020	910	<10	<20	910	0.33	290	8,500	17,000	0.6	0.17	0.17	<0.02	0.77	-	0.43	35	5,300	1,300	15,000	2,400
BH-2-017	22/03/2019	490	<10	<20	500	<0.01	30	960	-	0.7	0.40	0.15	0.25	1.1	0.21	-	3.8	59	140	-	100
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	10/07/2019	600	<10	<20	600	<0.01	46	1,200	4,900	0.5	0.64	0.64	<0.02	1.14	0.11	-	<5	1,000	140	2,600	370
	9/10/2019	540	<10	<20	540	<0.01	55	1,600	5,300	<0.2	0.44	0.41	0.03	0.44	0.10	-	<5	1,100	150	3,000	410
	25/06/2020	520	<10	<20	520	0.27	81	1,600	4,700	0.9	0.72	0.67	0.06	1.62	-	1.3	<5	1,200	160	3,600	570
BH-2-018	21/03/2019	340	<10	<20	340	0.23	120	620	-	1.0	<0.05	<0.02	<0.02	1.0	0.04	-	68	480	<5	-	750
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	10/07/2019	230	<10	<20	230	0.51	58	230	1,400	1.8	<0.05	<0.02	<0.02	1.8	4.1	-	3.2	130	<5	720	310
	9/10/2019	250	<10	<20	250	0.20	100	1,100	2,300	0.8	0.05	<0.02	0.04	0.85	1.1	-	2.4	240	8.0	1,500	540
	25/06/2020	290	<10	<20	290	0.29	120	630	2,100	0.6	<0.05	<0.02	<0.02	0.6	-	<0.01	<5	290	12	1,700	640
BH-2-021	26/03/2019	-	-	-	-	-	29	-	-	0.8	<0.05	-	-	0.8	0.15	-	12	190	-	-	120
		190	<10	<20	190	0.14	-	150	-	0.6	<0.05	0.02	<0.02	0.6	0.04	-	-	-	100	-	-
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	13/07/2019	340	<10	<20	340	<0.01	41	140	1,300	<0.2	<0.05	<0.02	<0.02	<0.2	0.06	-	12	220	59	750	170
	9/10/2019	370	<10	<20	380	0.02	51	460	1,400	<0.2	<0.05	<0.02	<0.02	<0.2	0.06	-	13	230	52	820	200
	25/06/2020	480	<10	<20	480	0.09	95	240	1,300	<0.2	0.23	0.08	0.16	0.23	-	0.44	14	250	58	900	380
BH-2-030	20/03/2019	570	<10	<20	570	0.63	130	940	-	1.7	1.0	0.91	0.13	2.7	0.12	-	6.3	300	88	-	450
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	10/07/2019	530	<10	<20	530	0.04	94	1,200	4,200	2.1	3.9	3.9	<0.02	6	0.75	-	78	620	90	2,300	730
	9/10/2019	470	<10	<20	470	<0.01	110	1,300	4,400	1.1	6.9	6.9	<0.02	8	0.30	-	72	630	88	2,500	770
	29/06/2020	440	<10	<20	440	<0.01	150	1,300	4,600	1.1	9.5	9.5	0.02	10.6	-	0.36	71	740	72	3,100	890
BH-2-038	26/03/2019	-	-	-	-	-	28	-	-	0.4	<0.05	-	-	0.4	<0.01	-	34	63	-	-	130
		170	<10	<20	170	<0.01	-	66	-	<0.2	<0.05	<0.02	<0.02	<0.2	<0.01	-	-	-	<5	-	-
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	11/07/2019	270	<10	<20	270	-	11	49	630	-	-	-	-	-	-	-	50	62	<5	330	110
	9/10/2019	270	<10	<20	270	-	11	45	580	-	-	-	-	-	-	-	50	61	<5	330	95
	27/06/2020	190	<10	<20	190	0.16	15	43	460	0.7	<0.05	<0.02	<0.02	0.7	-	0.18	41	57	<5	300	99

		Inorganics																			
		Soluble Bicarb as CaCO3*	Soluble Carbonate as CaCO3*	Alkalinity (Hydroxide) as CaCO3	Alkalinity (total) as CaCO3	Ammonia as N	Calcium	Chloride	Electrical conductivity (lab)	Kjeldahl Nitrogen Total	Nitrate & Nitrite (as N)	Nitrate (as N)	Nitrite (as N)	Nitrogen (Total)	Phosphate total (P)	Phosphorus	Potassium	Sodium	Sulphate	Total Dissolved Solids	Hardness as CaCO3
		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	uS/cm	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
EQL		20	10	20	20	0.01	0.5	1	1	0.2	0.05	0.02	0.02	0.2	0.01	0.01	0.5	0.5	5	10	5
NEPM 2013 Table 1C GILs, Fresh Waters																					
ANZG (2018) Freshwater 95% toxicant DGVs						0.9															
Field ID	Date																				
BH-2-046	26/03/2019	120	<10	<20	120	<0.01	-	45	-	<0.2	<0.05	<0.02	<0.02	<0.2	0.03	-	-	-	5.5	-	-
	27/03/2019	-	-	-	-	-	5.3	-	-	<0.2	<0.05	-	-	<0.2	0.14	-	2.5	91	-	-	32
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	12/07/2019	130	<10	<20	130	<0.01	1.6	34	380	<0.2	<0.05	<0.02	<0.02	<0.2	0.27	-	1.7	77	<5	480	8.7
	9/10/2019	130	<10	<20	130	<0.01	1.2	47	360	0.3	<0.05	<0.02	<0.02	0.3	0.47	-	1.9	79	<5	550	7.3
	26/06/2020	110	<10	<20	110	<0.01	<5	37	290	<0.2	<0.05	<0.02	<0.02	<0.2	-	0.12	<5	79	<5	530	25
BH-2-047	26/03/2019	160	<10	<20	160	<0.01	-	23	-	<0.2	<0.05	<0.02	<0.02	<0.2	0.03	-	-	-	20	-	-
	27/03/2019	-	-	-	-	-	2.4	-	-	<0.2	<0.05	-	-	<0.2	0.25	-	4.5	110	-	-	20
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	12/07/2019	200	<10	<20	200	-	1.5	15	470	-	-	-	-	-	-	-	4.3	100	22	720	12
	9/10/2019	200	<10	<20	200	-	1.5	47	450	-	-	-	-	-	-	-	3.6	100	13	400	12
	26/06/2020	140	<10	<20	140	<0.01	<5	19	320	<0.2	<0.05	<0.02	<0.02	<0.2	-	0.29	<5	88	16	390	21
BH-2-049	26/03/2019	530	<10	<20	530	0.08	-	73	-	<0.2	<0.05	<0.02	<0.02	<0.2	0.02	-	-	-	<5	-	-
	27/03/2019	-	-	-	-	-	6.0	-	-	0.6	<0.05	-	-	0.6	0.38	-	6.8	290	-	-	30
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	12/07/2019	580	<10	<20	580	0.27	7.4	94	1,200	0.5	<0.05	<0.02	<0.02	0.5	0.62	-	9.6	260	19	720	33
	9/10/2019	570	11	<20	580	0.09	7.5	61	1,100	0.4	0.08	<0.02	0.07	0.48	0.62	-	8.9	270	<5	710	32
BH-2-053	26/03/2019	-	-	-	-	-	13	-	-	0.4	<0.05	-	-	0.4	0.18	-	9.6	360	-	-	67
		580	<10	<20	580	<0.01	-	170	-	<0.2	<0.05	<0.02	<0.02	<0.2	0.06	-	-	-	<5	-	-
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	11/07/2019	600	<10	<20	600	-	9.1	74	1,300	-	-	-	-	-	-	-	10	280	<5	730	39
	9/10/2019	670	<10	<20	680	0.15	11	160	1,600	0.6	<0.05	<0.02	0.04	0.6	1.6	-	8.0	370	<5	940	51
	27/06/2020	690	<10	<20	690	0.40	9.6	89	1,300	0.7	<0.05	<0.02	<0.02	0.7	-	0.42	12	320	<5	820	43
BH-2-056	26/03/2019	310	<10	<20	310	<0.01	-	64	-	2.4	<0.05	<0.02	<0.02	2.4	0.02	-	-	-	8.8	-	-
	28/03/2019	-	-	-	-	-	19	-	-	2.1	<0.05	-	-	2.1	0.01	-	13	200	-	-	71
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	11/07/2019	300	<10	<20	300	0.44	3.0	38	720	0.9	<0.05	<0.02	<0.02	0.9	0.24	-	3.5	160	19	450	12
	9/10/2019	300	<10	<20	300	<0.01	3.0	95	780	0.6	<0.05	<0.02	<0.02	0.6	0.20	-	2.9	190	47	530	12
	26/06/2020	310	<10	<20	310	0.18	1.5	41	690	0.5	<0.05	<0.02	<0.02	0.5	-	0.12	3.1	170	26	440	6.6
BH-2-059	10/07/2019	490	<10	<20	490	0.02	2,100	13,000	31,000	0.3	<0.05	<0.02	<0.02	0.3	0.04	-	110	4,900	1,800	18,000	11,000
	9/10/2019	470	<10	<20	470	<0.01	2,200	14,000	29,000	0.5	<0.05	<0.02	<0.02	0.5	0.03	-	110	4,600	2,000	22,000	11,000
	29/06/2020	530	<10	<20	530	0.14	1,700	10,000	27,000	1.1	0.11	0.11	<0.02	1.21	-	0.12	82	3,700	1,800	26,000	9,100
BH-2-069	21/03/2019	460	<10	<20	460	0.03	130	370	-	<0.2	<0.05	<0.02	<0.02	<0.2	0.04	-	5.1	210	75	-	670
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	10/07/2019	520	<10	<20	520	0.04	120	350	2,300	0.2	<0.05	<0.02	<0.02	0.2	0.26	-	6.6	320	65	1,300	410
	9/10/2019	500	<10	<20	500	0.25	130	860	2,200	0.3	<0.05	0.02	0.03	0.3	0.09	-	7.5	320	63	1,300	450
	29/06/2020	510	<10	<20	510	0.03	160	440	2,200	0.8	<0.05	0.02	<0.02	0.8	-	0.43	7.6	340	53	1,500	530
BH-93(BP-01)	24/06/2020	750	14	<20	760	0.27	<5	31	1,100	1.2	0.06	0.05	<0.02	1.26	-	0.69	72	270	24	860	65
	11/12/2019	800	<10	<20	800	0.22	6.0	53	1,600	1.1	0.07	0.07	<0.02	1.17	0.05	-	86	310	28	1,000	120

		Field Parameters							Physiochemical parameters
		DO (Field)	DO % (Field)	EC (field)	pH (Field)	Redox (Field)	TDS (Field)	Temp (Field)	pH (lab)
		mg/L	%	uS/cm	pH Units	mV	mg/L	oC	pH Units
EQL									0.1
NEPM 2013 Table 1C GILs, Fresh Waters									
ANZG (2018) Freshwater 95% toxicant DGVs									
Field ID	Date								
BH-2-002	24/03/2019	-	-	-	-	-	-	-	-
		1.4	16.3	1,216.7	6.12	-24.3	792.19	21.53	-
	9/07/2019	-	-	-	-	-	-	-	7.0
	9/10/2019	-	-	-	-	-	-	-	7.5
	23/06/2020	-	-	-	-	-	-	-	7.4
BH-2-003	9/07/2019	-	-	-	-	-	-	-	6.7
	9/10/2019	-	-	-	-	-	-	-	6.8
	30/06/2020	-	-	-	-	-	-	-	7.1
BH-2-007	23/03/2019	-	-	-	-	-	-	-	-
		1.66	20.9	21,904.2	6.44	-54.3	14,240.37	23.34	-
	9/07/2019	-	-	-	-	-	-	-	7.3
	9/10/2019	-	-	-	-	-	-	-	7.7
	24/06/2020	-	-	-	-	-	-	-	7.8
BH-2-015	23/03/2019	-	-	-	-	-	-	-	-
		2.57	32.3	20,824.1	6.45	-122.3	13,551.4	22.4	-
	10/07/2019	-	-	-	-	-	-	-	7.5
	9/10/2019	-	-	-	-	-	-	-	7.9
	25/06/2020	-	-	-	-	-	-	-	7.9
BH-2-017	22/03/2019	-	-	-	-	-	-	-	-
		4.25	54.4	4,424	7.6	65.8	2,912.64	25.73	-
	10/07/2019	-	-	-	-	-	-	-	8.1
	9/10/2019	-	-	-	-	-	-	-	8.2
	25/06/2020	-	-	-	-	-	-	-	8.3
BH-2-018	21/03/2019	-	-	-	-	-	-	-	-
		1.41	18	2,278.2	6.44	-147.1	1,458.47	25.87	-
	10/07/2019	-	-	-	-	-	-	-	6.9
	9/10/2019	-	-	-	-	-	-	-	7.6
	25/06/2020	-	-	-	-	-	-	-	7.4
BH-2-021	26/03/2019	-	-	-	-	-	-	-	-
		-	-	-	-	-	-	-	-
		1.15	13.3	990.9	7.65	-151.3	644.37	20.86	-
	13/07/2019	-	-	-	-	-	-	-	7.8
	9/10/2019	-	-	-	-	-	-	-	8.3
	25/06/2020	-	-	-	-	-	-	-	8.2
BH-2-030	20/03/2019	-	-	-	-	-	-	-	-
		2.08	25.5	3,832.3	6.73	-65	2,499.54	22.99	-
	10/07/2019	-	-	-	-	-	-	-	7.6
	9/10/2019	-	-	-	-	-	-	-	7.7
	29/06/2020	-	-	-	-	-	-	-	8.0
BH-2-038	26/03/2019	-	-	-	-	-	-	-	-
		-	-	-	-	-	-	-	-
		3.42	40.4	580.9	6.3	-154.1	377.37	22.07	-
	11/07/2019	-	-	-	-	-	-	-	6.9
	9/10/2019	-	-	-	-	-	-	-	7.8
	27/06/2020	-	-	-	-	-	-	-	7.0

		Field Parameters							Physiochemical parameters
		DO (Field)	DO % (Field)	EC (field)	pH (Field)	Redox (Field)	TDS (Field)	Temp (Field)	pH (lab)
		mg/L	%	uS/cm	pH Units	mV	mg/L	oC	pH Units
EQL									0.1
NEPM 2013 Table 1C GILs, Fresh Waters									
ANZG (2018) Freshwater 95% toxicant DGVs									
Field ID	Date								
BH-2-046	26/03/2019	-	-	-	-	-	-	-	-
	27/03/2019	-	-	-	-	-	-	-	-
		1.93	23	369.4	6.08	-60	240.36	23.12	-
	12/07/2019	-	-	-	-	-	-	-	6.6
	9/10/2019	-	-	-	-	-	-	-	7.1
	26/06/2020	-	-	-	-	-	-	-	7.3
BH-2-047	26/03/2019	-	-	-	-	-	-	-	-
	27/03/2019	-	-	-	-	-	-	-	-
		0.99	11.3	463.3	6.43	-145.8	301.68	21.06	-
	12/07/2019	-	-	-	-	-	-	-	6.9
	9/10/2019	-	-	-	-	-	-	-	7.5
	26/06/2020	-	-	-	-	-	-	-	7.7
BH-2-049	26/03/2019	-	-	-	-	-	-	-	-
	27/03/2019	-	-	-	-	-	-	-	-
		1.18	13.6	1,111.4	7.47	69.1	721.32	21.87	-
	12/07/2019	-	-	-	-	-	-	-	8.2
	9/10/2019	-	-	-	-	-	-	-	8.4
BH-2-053	26/03/2019	-	-	-	-	-	-	-	-
		-	-	-	-	-	-	-	-
		1.42	17.1	1,547.2	7.06	-150.7	1,004.8	23.1	-
	11/07/2019	-	-	-	-	-	-	-	7.5
	9/10/2019	-	-	-	-	-	-	-	8.3
	27/06/2020	-	-	-	-	-	-	-	8.1
BH-2-056	26/03/2019	-	-	-	-	-	-	-	-
	28/03/2019	-	-	-	-	-	-	-	-
		1.03	12.8	881.3	6.44	-154.1	572.86	25.37	-
	11/07/2019	-	-	-	-	-	-	-	7.7
	9/10/2019	-	-	-	-	-	-	-	8.1
	26/06/2020	-	-	-	-	-	-	-	8.2
BH-2-059	10/07/2019	-	-	-	-	-	-	-	7.2
	9/10/2019	-	-	-	-	-	-	-	7.6
	29/06/2020	-	-	-	-	-	-	-	7.5
BH-2-069	21/03/2019	-	-	-	-	-	-	-	-
		3.02	36.1	2,250.2	6.48	-95.2	1,463.94	22.35	-
	10/07/2019	-	-	-	-	-	-	-	7.3
	9/10/2019	-	-	-	-	-	-	-	7.5
	29/06/2020	-	-	-	-	-	-	-	7.5
BH-93(BP-01)	24/06/2020	-	-	-	-	-	-	-	8.4
	11/12/2019	-	-	-	-	-	-	-	8.1

		TRH - NEPM 2013 Fractions							TPH - NEPM 1999 Fractions					BTEXN							
		TRH >C6 - C10	TRH >C10 - C16	TRH >C16 - C34	TRH >C34 - C40	TRH >C10 - C40 (Sum of total)	TRH >C6 - C10 less BTEX (F1)	TRH >C10 - C16 less Naphthalene (F2)	TPH C6 - C9	TPH C10 - C14	TPH C15 - C28	TPH C29-C36	TPH C10 - C36 (Sum of total)	Benzene	Ethylbenzene	Naphthalene	Toluene	Xylene (m & p)	Xylene (o)	Xylene Total
		µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
EQL		20	50	100	100	100	20	50	20	50	100	100	100	1	1	10	1	2	1	3
NEPM 2013 Table 1C GILs, Fresh Waters														950		16			350	
ANZG (2018) Freshwater 95% toxicant DGVs														950		16			350	
Field ID	Date																			
BH-2-002	24/03/2019	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	9/07/2019	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	9/10/2019	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	23/06/2020	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BH-2-003	9/07/2019	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	9/10/2019	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	30/06/2020	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BH-2-007	23/03/2019	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	9/07/2019	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	9/10/2019	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	24/06/2020	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BH-2-015	23/03/2019	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	10/07/2019	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	9/10/2019	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	25/06/2020	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BH-2-017	22/03/2019	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	10/07/2019	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	9/10/2019	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	25/06/2020	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BH-2-018	21/03/2019	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	10/07/2019	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	9/10/2019	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	25/06/2020	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BH-2-021	26/03/2019	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
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	13/07/2019	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	9/10/2019	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	25/06/2020	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BH-2-030	20/03/2019	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	10/07/2019	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	9/10/2019	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	29/06/2020	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BH-2-038	26/03/2019	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
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	11/07/2019	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	9/10/2019	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	27/06/2020	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

		TRH - NEPM 2013 Fractions							TPH - NEPM 1999 Fractions					BTEXN						
		TRH >C6 - C10	TRH >C10 - C16	TRH >C16 - C34	TRH >C34 - C40	TRH >C10 - C40 (Sum of total)	TRH >C6 - C10 less BTEX (F1)	TRH >C10 - C16 less Naphthalene (F2)	TPH C6 - C9	TPH C10 - C14	TPH C15 - C28	TPH C29-C36	TPH C10 - C36 (Sum of total)	Benzene	Ethylbenzene	Naphthalene	Toluene	Xylene (m & p)	Xylene (o)	Xylene Total
		µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
EQL		20	50	100	100	100	20	50	20	50	100	100	100	1	1	10	1	2	1	3
NEPM 2013 Table 1C GILs, Fresh Waters														950		16			350	
ANZG (2018) Freshwater 95% toxicant DGVs														950		16			350	
Field ID	Date																			
BH-2-046	26/03/2019	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	27/03/2019	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	12/07/2019	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	9/10/2019	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	26/06/2020	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BH-2-047	26/03/2019	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	27/03/2019	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	12/07/2019	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	9/10/2019	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	26/06/2020	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BH-2-049	26/03/2019	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	27/03/2019	20	<50	<100	<100	<100	<20	<50	<20	<50	<100	<100	<100	<1	<1	<10	16	<2	<1	<3
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	12/07/2019	<20	<50	<100	<100	<100	<20	<50	<20	<50	<100	<100	<100	<5	<1	<10	<5	<2	<1	<3
	9/10/2019	<20	<50	<100	<100	<100	<20	<50	<20	<50	<100	<100	<100	<1	<1	<10	<1	<2	<1	<3
BH-2-053	26/03/2019	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	11/07/2019	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	9/10/2019	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	27/06/2020	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BH-2-056	26/03/2019	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	28/03/2019	110	60	<100	<100	<100	70	60	70	70	<100	<100	<100	<1	2	<10	17	14	6	20
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	11/07/2019	<20	<50	<100	<100	<100	<20	<50	<20	<50	<100	<100	<100	<8	<1	<10	<8	<2	<1	<3
	9/10/2019	<20	<50	<100	<100	<100	<20	<50	<20	<50	<100	<100	<100	<1	<1	<10	<1	<2	<1	<3
	26/06/2020	<20	<50	<100	<100	<100	<20	<50	<20	<50	<100	<100	<100	<1	<1	<10	<1	<2	<1	<3
BH-2-059	10/07/2019	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	9/10/2019	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	29/06/2020	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BH-2-069	21/03/2019	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	10/07/2019	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	9/10/2019	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	29/06/2020	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BH-93(BP-01)	24/06/2020	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	11/12/2019	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

		Organochlorine Pesticides (OCPs)																					
		4,4-DDE	a-BHC	Aldrin	Aldrin + Dieldrin	b-BHC	Chlordane	d-BHC	DDD	DDT	DDT+DDE+DDD	Dieldrin	Endosulfan I	Endosulfan II	Endosulfan sulphate	Endrin	Endrin aldehyde	Endrin ketone	g-BHC (Lindane)	Heptachlor	Heptachlor epoxide	Methoxychlor	Toxaphene
		µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	mg/L
EQL		0.1	0.1	0.1	0.1	0.1	1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.01
NEPM 2013 Table 1C GILs, Fresh Waters							0.03			0.006						0.01			0.2	0.01			0.0001
ANZG (2018) Freshwater 95% toxicant DGVs							0.08			0.01						0.02			0.2	0.09			0.0002
Field ID	Date																						
BH-2-002	24/03/2019	<0.1	<0.1	<0.1	<0.1	<0.1	<1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.01
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	9/07/2019	<0.1	<0.1	<0.1	<0.1	<0.1	<1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.01
	9/10/2019	<0.1	<0.1	<0.1	<0.1	<0.1	<1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.01
	23/06/2020	<0.1	<0.1	<0.1	<0.1	<0.1	<1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.01
BH-2-003	9/07/2019	<0.1	<0.1	<0.1	<0.1	<0.1	<1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.01
	9/10/2019	<0.1	<0.1	<0.1	<0.1	<0.1	<1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.01
	30/06/2020	<0.1	<0.1	<0.1	<0.1	<0.1	<1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.01
BH-2-007	23/03/2019	<0.1	<0.1	<0.1	<0.1	<0.1	<1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.01
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	9/07/2019	<0.1	<0.1	<0.1	<0.1	<0.1	<1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.01
	9/10/2019	<0.1	<0.1	<0.1	<0.1	<0.1	<1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.01
	24/06/2020	<0.1	<0.1	<0.1	<0.1	<0.1	<1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.01
BH-2-015	23/03/2019	<0.1	<0.1	<0.1	<0.1	<0.1	<1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.01
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	10/07/2019	<0.1	<0.1	<0.1	<0.1	<0.1	<1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.01
	9/10/2019	<0.1	<0.1	<0.1	<0.1	<0.1	<1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.01
	25/06/2020	<0.1	<0.1	<0.1	<0.1	<0.1	<1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.01
BH-2-017	22/03/2019	<0.1	<0.1	<0.1	<0.1	<0.1	<1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.01
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	10/07/2019	<0.1	<0.1	<0.1	<0.1	<0.1	<1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.01
	9/10/2019	<0.1	<0.1	<0.1	<0.1	<0.1	<1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.01
	25/06/2020	<0.1	<0.1	<0.1	<0.1	<0.1	<1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.01
BH-2-018	21/03/2019	<0.1	<0.1	<0.1	<0.1	<0.1	<1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.01
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	10/07/2019	<0.1	<0.1	<0.1	<0.1	<0.1	<1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.01
	9/10/2019	<0.1	<0.1	<0.1	<0.1	<0.1	<1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.01
	25/06/2020	<0.1	<0.1	<0.1	<0.1	<0.1	<1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.01
BH-2-021	26/03/2019	<0.1	<0.1	<0.1	<0.1	<0.1	<1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.01
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	13/07/2019	<0.1	<0.1	<0.1	<0.1	<0.1	<1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.01
	9/10/2019	<0.1	<0.1	<0.1	<0.1	<0.1	<1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.01
	25/06/2020	<0.1	<0.1	<0.1	<0.1	<0.1	<1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.01
BH-2-030	20/03/2019	<0.1	<0.1	<0.1	<0.1	<0.1	<1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.01
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	10/07/2019	<0.1	<0.1	<0.1	<0.1	<0.1	<1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.01
	9/10/2019	<0.1	<0.1	<0.1	<0.1	<0.1	<1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.01
	29/06/2020	<0.1	<0.1	<0.1	<0.1	<0.1	<1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.01
BH-2-038	26/03/2019	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	11/07/2019	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	9/10/2019	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	27/06/2020	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

			Organochlorine Pesticides (OCPs)																					
			4,4-DDE	a-BHC	Aldrin	Aldrin + Dieldrin	b-BHC	Chlordane	d-BHC	DDD	DDT	DDT+DDE+DDD	Dieldrin	Endosulfan I	Endosulfan II	Endosulfan sulphate	Endrin	Endrin aldehyde	Endrin ketone	g-BHC (Lindane)	Heptachlor	Heptachlor epoxide	Methoxychlor	Toxaphene
			µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	mg/L
EQL			0.1	0.1	0.1	0.1	0.1	1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.01
NEPM 2013 Table 1C GILs, Fresh Waters								0.03			0.006						0.01			0.2	0.01			0.0001
ANZG (2018) Freshwater 95% toxicant DGVs								0.08			0.01						0.02			0.2	0.09			0.0002
Field ID	Date																							
BH-2-046	26/03/2019		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	27/03/2019		<0.1	<0.1	<0.1	<0.1	<0.1	<1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.01
			-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	12/07/2019		<0.1	<0.1	<0.1	<0.1	<0.1	<1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.01
	9/10/2019		<0.1	<0.1	<0.1	<0.1	<0.1	<1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.01
	26/06/2020		<0.1	<0.1	<0.1	<0.1	<0.1	<1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.01
BH-2-047	26/03/2019		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	27/03/2019		<0.1	<0.1	<0.1	<0.1	<0.1	<1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.01
			-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	12/07/2019		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	9/10/2019		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	26/06/2020		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BH-2-049	26/03/2019		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	27/03/2019		<0.1	<0.1	<0.1	<0.1	<0.1	<1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.01
			-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	12/07/2019		<0.1	<0.1	<0.1	<0.1	<0.1	<1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.01
	9/10/2019		<0.1	<0.1	<0.1	<0.1	<0.1	<1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.01
BH-2-053	26/03/2019		<0.1	<0.1	<0.1	<0.1	<0.1	<1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.01
			-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
			-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	11/07/2019		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	9/10/2019		<0.1	<0.1	<0.1	<0.1	<0.1	<1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.01
	27/06/2020		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BH-2-056	26/03/2019		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	28/03/2019		<0.1	<0.1	<0.1	<0.1	<0.1	<1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.01
			-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	11/07/2019		<0.1	<0.1	<0.1	<0.1	<0.1	<1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.01
	9/10/2019		<0.1	<0.1	<0.1	<0.1	<0.1	<1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.01
	26/06/2020		<0.1	<0.1	<0.1	<0.1	<0.1	<1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.01
BH-2-059	10/07/2019		<0.1	<0.1	<0.1	<0.1	<0.1	<1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.01
	9/10/2019		<0.1	<0.1	<0.1	<0.1	<0.1	<1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.01
	29/06/2020		<0.1	<0.1	<0.1	<0.1	<0.1	<1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.01
BH-2-069	21/03/2019		<0.1	<0.1	<0.1	<0.1	<0.1	<1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.01
			-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	10/07/2019		<0.1	<0.1	<0.1	<0.1	<0.1	<1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.01
	9/10/2019		<0.1	<0.1	<0.1	<0.1	<0.1	<1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.01
	29/06/2020		<0.1	<0.1	<0.1	<0.1	<0.1	<1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.01
BH-93(BP-01)	24/06/2020		<0.1	<0.1	<0.1	<0.1	<0.1	<1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.01
	11/12/2019		<0.1	<0.1	<0.1	<0.1	<0.1	<1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.01

		Organophosphorous Pesticides (OPPs)																			
		Azinophos methyl	Bolstar (Sulprofos)	Chlorfenvinphos	Chlorpyrifos	Chlorpyrifos-methyl	Coumaphos	Demeton-O	Demeton-S	Diazinon	Dichlorvos	Dimethoate	Disulfoton	EPN	Ethion	Ethoprop	Fenitrothion	Fensulfothion	Fenthion	Malathion	Merphos
		µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	mg/L
EQL		2	2	2	20	2	20	2	20	2	2	2	2	2	2	2	2	2	2	2	0.002
NEPM 2013 Table 1C GILs, Fresh Waters					0.01					0.01		0.15					0.2			0.05	0.002
ANZG (2018) Freshwater 95% toxicant DGVs		0.02			0.01					0.01		0.15					0.2			0.05	
Field ID	Date																				
BH-2-002	24/03/2019	<2	<2	<2	<20	<2	<20	<2	<20	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<0.002
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	9/07/2019	<2	<2	<2	<20	<2	<20	<2	<20	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<0.002
	9/10/2019	<2	<2	<2	<20	<2	<20	<2	<20	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<0.002
	23/06/2020	<2	<2	<2	<20	<2	<20	<2	<20	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<0.002
BH-2-003	9/07/2019	<2	<2	<2	<20	<2	<20	<2	<20	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<0.002
	9/10/2019	<2	<2	<2	<20	<2	<20	<2	<20	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<0.002
	30/06/2020	<2	<2	<2	<20	<2	<20	<2	<20	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<0.002
BH-2-007	23/03/2019	<2	<2	<2	<20	<2	<20	<2	<20	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<0.002
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	9/07/2019	<2	<2	<2	<20	<2	<20	<2	<20	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<0.002
	9/10/2019	<2	<2	<2	<20	<2	<20	<2	<20	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<0.002
	24/06/2020	<2	<2	<2	<20	<2	<20	<2	<20	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<0.002
BH-2-015	23/03/2019	<2	<2	<2	<20	<2	<20	<2	<20	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<0.002
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	10/07/2019	<2	<2	<2	<20	<2	<20	<2	<20	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<0.002
	9/10/2019	<2	<2	<2	<20	<2	<20	<2	<20	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<0.002
	25/06/2020	<2	<2	<2	<20	<2	<20	<2	<20	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<0.002
BH-2-017	22/03/2019	<2	<2	<2	<20	<2	<20	<2	<20	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<0.002
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	10/07/2019	<2	<2	<2	<20	<2	<20	<2	<20	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<0.002
	9/10/2019	<2	<2	<2	<20	<2	<20	<2	<20	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<0.002
	25/06/2020	<2	<2	<2	<20	<2	<20	<2	<20	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<0.002
BH-2-018	21/03/2019	<2	<2	<2	<20	<2	<20	<2	<20	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<0.002
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	10/07/2019	<2	<2	<2	<20	<2	<20	<2	<20	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<0.002
	9/10/2019	<2	<2	<2	<20	<2	<20	<2	<20	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<0.002
	25/06/2020	<2	<2	<2	<20	<2	<20	<2	<20	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<0.002
BH-2-021	26/03/2019	<2	<2	<2	<20	<2	<20	<2	<20	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<0.002
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	13/07/2019	<2	<2	<2	<20	<2	<20	<2	<20	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<0.002
	9/10/2019	<2	<2	<2	<20	<2	<20	<2	<20	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<0.002
	25/06/2020	<2	<2	<2	<20	<2	<20	<2	<20	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<0.002
BH-2-030	20/03/2019	<2	<2	<2	<20	<2	<20	<2	<20	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<0.002
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	10/07/2019	<2	<2	<2	<20	<2	<20	<2	<20	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<0.002
	9/10/2019	<2	<2	<2	<20	<2	<20	<2	<20	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<0.002
	29/06/2020	<2	<2	<2	<20	<2	<20	<2	<20	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<0.002
BH-2-038	26/03/2019	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	11/07/2019	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	9/10/2019	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	27/06/2020	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Field ID	Date	Organophosphorous Pesticides (OPPs)																			
		Azinophos methyl	Bolstar (Sulprofos)	Chlorfenvinphos	Chlorpyrifos	Chlorpyrifos-methyl	Coumaphos	Demeton-O	Demeton-S	Diazinon	Dichlorvos	Dimethoate	Disulfoton	EPN	Ethion	Ethoprop	Fenitrothion	Fensulfothion	Fenthion	Malathion	Merphos
		µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	mg/L
EQL		2	2	2	20	2	20	2	20	2	2	2	2	2	2	2	2	2	2	2	0.002
NEPM 2013 Table 1C GILs, Fresh Waters					0.01					0.01		0.15					0.2			0.05	
ANZG (2018) Freshwater 95% toxicant DGVs		0.02			0.01					0.01		0.15					0.2			0.05	
BH-2-046	26/03/2019	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	27/03/2019	<2	<2	<2	<20	<2	<20	<2	<20	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<0.002
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	12/07/2019	<2	<2	<2	<20	<2	<20	<2	<20	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<0.002
	9/10/2019	<2	<2	<2	<20	<2	<20	<2	<20	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<0.002
	26/06/2020	<2	<2	<2	<20	<2	<20	<2	<20	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<0.002
BH-2-047	26/03/2019	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	27/03/2019	<2	<2	<2	<20	<2	<20	<2	<20	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<0.002
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	12/07/2019	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	9/10/2019	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	26/06/2020	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BH-2-049	26/03/2019	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	27/03/2019	<2	<2	<2	<20	<2	<20	<2	<20	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<0.002
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	12/07/2019	<2	<2	<2	<20	<2	<20	<2	<20	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<0.002
	9/10/2019	<2	<2	<2	<20	<2	<20	<2	<20	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<0.002
BH-2-053	26/03/2019	<2	<2	<2	<20	<2	<20	<2	<20	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<0.002
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		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	11/07/2019	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	9/10/2019	<2	<2	<2	<20	<2	<20	<2	<20	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<0.002
	27/06/2020	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BH-2-056	26/03/2019	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	28/03/2019	<2	<2	<2	<20	<2	<20	<2	<20	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<0.002
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	11/07/2019	<2	<2	<2	<20	<2	<20	<2	<20	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<0.002
	9/10/2019	<2	<2	<2	<20	<2	<20	<2	<20	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<0.002
	26/06/2020	<2	<2	<2	<20	<2	<20	<2	<20	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<0.002
BH-2-059	10/07/2019	<2	<2	<2	<20	<2	<20	<2	<20	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<0.002
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BH-2-069	21/03/2019	<2	<2	<2	<20	<2	<20	<2	<20	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<0.002
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	10/07/2019	<2	<2	<2	<20	<2	<20	<2	<20	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<0.002
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BH-93(BP-01)	24/06/2020	<2	<2	<2	<20	<2	<20	<2	<20	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<0.002
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																Halogenated Benzenes	EPA 621 Classification of Wastes	
		Methyl parathion	Mevinphos (Phosdrin)	Monocrotophos	Naled (Dibrom)	Omethoate	Parathion	Phorate	Pirimiphos-methyl	Pyrazophos	Ronnel	Terbufos	Tokuthion	Trichloronate	Tetrachlorvinphos	Hexachlorobenzene	Vic EPA IWRG 621 Organochlorine pesticides (Total)*	Vic EPA IWRG 621 Other organochlorine pesticides (Total)*
		µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	mg/L	µg/L	µg/L	µg/L	mg/L	mg/L
EQL		2	2	2	2	2	2	2	20	2	2	2	0.002	2	2	0.1	0.001	0.001
NEPM 2013 Table 1C GILs, Fresh Waters							0.004											
ANZG (2018) Freshwater 95% toxicant DGVs							0.004											
Field ID	Date																	
BH-2-002	24/03/2019	<2	<2	<2	<2	<2	<2	<2	<20	<2	<2	<2	<0.002	<2	<2	<0.1	<0.001	<0.001
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	9/07/2019	<2	<2	<2	<2	<2	<2	<2	<20	<2	<2	<2	<0.002	<2	<2	<0.1	<0.001	<0.001
	9/10/2019	<2	<2	<2	<2	<2	<2	<2	<20	<2	<2	<2	<0.002	<2	<2	<0.1	<0.001	<0.001
	23/06/2020	<2	<2	<2	<2	<2	<2	<2	<20	<2	<2	<2	<0.002	<2	<2	<0.1	<0.001	<0.001
BH-2-003	9/07/2019	<2	<2	<2	<2	<2	<2	<2	<20	<2	<2	<2	<0.002	<2	<2	<0.1	<0.001	<0.001
	9/10/2019	<2	<2	<2	<2	<2	<2	<2	<20	<2	<2	<2	<0.002	<2	<2	<0.1	<0.001	<0.001
	30/06/2020	<2	<2	<2	<2	<2	<2	<2	<20	<2	<2	<2	<0.002	<2	<2	<0.1	<0.001	<0.001
BH-2-007	23/03/2019	<2	<2	<2	<2	<2	<2	<2	<20	<2	<2	<2	<0.002	<2	<2	<0.1	<0.001	<0.001
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	9/07/2019	<2	<2	<2	<2	<2	<2	<2	<20	<2	<2	<2	<0.002	<2	<2	<0.1	<0.001	<0.001
	9/10/2019	<2	<2	<2	<2	<2	<2	<2	<20	<2	<2	<2	<0.002	<2	<2	<0.1	<0.001	<0.001
	24/06/2020	<2	<2	<2	<2	<2	<2	<2	<20	<2	<2	<2	<0.002	<2	<2	<0.1	<0.001	<0.001
BH-2-015	23/03/2019	<2	<2	<2	<2	<2	<2	<2	<20	<2	<2	<2	<0.002	<2	<2	<0.1	<0.001	<0.001
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	10/07/2019	<2	<2	<2	<2	<2	<2	<2	<20	<2	<2	<2	<0.002	<2	<2	<0.1	<0.001	<0.001
	9/10/2019	<2	<2	<2	<2	<2	<2	<2	<20	<2	<2	<2	<0.002	<2	<2	<0.1	<0.001	<0.001
	25/06/2020	<2	<2	<2	<2	<2	<2	<2	<20	<2	<2	<2	<0.002	<2	<2	<0.1	<0.001	<0.001
BH-2-017	22/03/2019	<2	<2	<2	<2	<2	<2	<2	<20	<2	<2	<2	<0.002	<2	<2	<0.1	<0.001	<0.001
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	10/07/2019	<2	<2	<2	<2	<2	<2	<2	<20	<2	<2	<2	<0.002	<2	<2	<0.1	<0.001	<0.001
	9/10/2019	<2	<2	<2	<2	<2	<2	<2	<20	<2	<2	<2	<0.002	<2	<2	<0.1	<0.001	<0.001
	25/06/2020	<2	<2	<2	<2	<2	<2	<2	<20	<2	<2	<2	<0.002	<2	<2	<0.1	<0.001	<0.001
BH-2-018	21/03/2019	<2	<2	<2	<2	<2	<2	<2	<20	<2	<2	<2	<0.002	<2	<2	<0.1	<0.001	<0.001
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	10/07/2019	<2	<2	<2	<2	<2	<2	<2	<20	<2	<2	<2	<0.002	<2	<2	<0.1	<0.001	<0.001
	9/10/2019	<2	<2	<2	<2	<2	<2	<2	<20	<2	<2	<2	<0.002	<2	<2	<0.1	<0.001	<0.001
	25/06/2020	<2	<2	<2	<2	<2	<2	<2	<20	<2	<2	<2	<0.002	<2	<2	<0.1	<0.001	<0.001
BH-2-021	26/03/2019	<2	<2	<2	<2	<2	<2	<2	<20	<2	<2	<2	<0.002	<2	<2	<0.1	<0.001	<0.001
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	13/07/2019	<2	<2	<2	<2	<2	<2	<2	<20	<2	<2	<2	<0.002	<2	<2	<0.1	<0.001	<0.001
	9/10/2019	<2	<2	<2	<2	<2	<2	<2	<20	<2	<2	<2	<0.002	<2	<2	<0.1	<0.001	<0.001
	25/06/2020	<2	<2	<2	<2	<2	<2	<2	<20	<2	<2	<2	<0.002	<2	<2	<0.1	<0.001	<0.001
BH-2-030	20/03/2019	<2	<2	<2	<2	<2	<2	<2	<20	<2	<2	<2	<0.002	<2	<2	<0.1	<0.001	<0.001
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	10/07/2019	<2	<2	<2	<2	<2	<2	<2	<20	<2	<2	<2	<0.002	<2	<2	<0.1	<0.001	<0.001
	9/10/2019	<2	<2	<2	<2	<2	<2	<2	<20	<2	<2	<2	<0.002	<2	<2	<0.1	<0.001	<0.001
	29/06/2020	<2	<2	<2	<2	<2	<2	<2	<20	<2	<2	<2	<0.002	<2	<2	<0.1	<0.001	<0.001
BH-2-038	26/03/2019	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	11/07/2019	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	9/10/2019	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	27/06/2020	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

																Halogenated Benzenes	EPA 621 Classification of Wastes	
		Methyl parathion	Mevinphos (Phosdrin)	Monocrotophos	Naled (Dibrom)	Omethoate	Parathion	Phorate	Pirimiphos-methyl	Pyrazophos	Ronnel	Terbufos	Tokuthion	Trichloronate	Tetrachlorvinphos	Hexachlorobenzene	Vic EPA IWRG 621 Organochlorine pesticides (Total)*	Vic EPA IWRG 621 Other organochlorine pesticides (Total)*
		µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	mg/L	µg/L	µg/L	µg/L	mg/L	mg/L
EQL		2	2	2	2	2	2	2	20	2	2	2	0.002	2	2	0.1	0.001	0.001
NEPM 2013 Table 1C GILs, Fresh Waters							0.004											
ANZG (2018) Freshwater 95% toxicant DGVs							0.004											
Field ID	Date																	
BH-2-046	26/03/2019	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
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		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	12/07/2019	<2	<2	<2	<2	<2	<2	<2	<20	<2	<2	<2	<0.002	<2	<2	<0.1	<0.001	<0.001
	9/10/2019	<2	<2	<2	<2	<2	<2	<2	<20	<2	<2	<2	<0.002	<2	<2	<0.1	<0.001	<0.001
	26/06/2020	<2	<2	<2	<2	<2	<2	<2	<20	<2	<2	<2	<0.002	<2	<2	<0.1	<0.001	<0.001
BH-2-047	26/03/2019	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	27/03/2019	<2	<2	<2	<2	<2	<2	<2	<20	<2	<2	<2	<0.002	<2	<2	<0.1	<0.001	<0.001
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	12/07/2019	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	9/10/2019	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	26/06/2020	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BH-2-049	26/03/2019	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	27/03/2019	<2	<2	<2	<2	<2	<2	<2	<20	<2	<2	<2	<0.002	<2	<2	<0.1	<0.001	<0.001
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	12/07/2019	<2	<2	<2	<2	<2	<2	<2	<20	<2	<2	<2	<0.002	<2	<2	<0.1	<0.001	<0.001
	9/10/2019	<2	<2	<2	<2	<2	<2	<2	<20	<2	<2	<2	<0.002	<2	<2	<0.1	<0.001	<0.001
BH-2-053	26/03/2019	<2	<2	<2	<2	<2	<2	<2	<20	<2	<2	<2	<0.002	<2	<2	<0.1	<0.001	<0.001
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		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	11/07/2019	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	9/10/2019	<2	<2	<2	<2	<2	<2	<2	<20	<2	<2	<2	<0.002	<2	<2	<0.1	<0.001	<0.001
	27/06/2020	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BH-2-056	26/03/2019	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	28/03/2019	<2	<2	<2	<2	<2	<2	<2	<20	<2	<2	<2	<0.002	<2	<2	<0.1	<0.001	<0.001
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	11/07/2019	<2	<2	<2	<2	<2	<2	<2	<20	<2	<2	<2	<0.002	<2	<2	<0.1	<0.001	<0.001
	9/10/2019	<2	<2	<2	<2	<2	<2	<2	<20	<2	<2	<2	<0.002	<2	<2	<0.1	<0.001	<0.001
	26/06/2020	<2	<2	<2	<2	<2	<2	<2	<20	<2	<2	<2	<0.002	<2	<2	<0.1	<0.001	<0.001
BH-2-059	10/07/2019	<2	<2	<2	<2	<2	<2	<2	<20	<2	<2	<2	<0.002	<2	<2	<0.1	<0.001	<0.001
	9/10/2019	<2	<2	<2	<2	<2	<2	<2	<20	<2	<2	<2	<0.002	<2	<2	<0.1	<0.001	<0.001
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BH-2-069	21/03/2019	<2	<2	<2	<2	<2	<2	<2	<20	<2	<2	<2	<0.002	<2	<2	<0.1	<0.001	<0.001
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	10/07/2019	<2	<2	<2	<2	<2	<2	<2	<20	<2	<2	<2	<0.002	<2	<2	<0.1	<0.001	<0.001
	9/10/2019	<2	<2	<2	<2	<2	<2	<2	<20	<2	<2	<2	<0.002	<2	<2	<0.1	<0.001	<0.001
	29/06/2020	<2	<2	<2	<2	<2	<2	<2	<20	<2	<2	<2	<0.002	<2	<2	<0.1	<0.001	<0.001
BH-93(BP-01)	24/06/2020	<2	<2	<2	<2	<2	<2	<2	<20	<2	<2	<2	<0.002	<2	<2	<0.1	<0.001	<0.001
	11/12/2019	<2	<2	<2	<2	<2	<2	<2	<20	<2	<2	<2	<0.002	<2	<2	<0.1	<0.001	<0.001

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