TECHNICAL PAPER 12

Groundwater

ALBURY TO ILLABO ENVIRONMENTAL IMPACT STATEMENT

ARTC INLAND RAIL

ALBURY TO ILLABO (A2I) PROJECT

TECHNICAL PAPER 12 – GROUNDWATER

JUNE 2022

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TABLE OF CONTENTS

CONTENTS (Continued)

CONTENTS (Continued)

CONTENTS (Continued)

LIST OF TABLES

LIST OF TABLES (CONTINUED)

LIST OF TABLES (CONTINUED)

LIST OF FIGURES

LIST OF APPENDICES

GLOSSARY AND ABBREVIATIONS

A2I	Albury to Illabo section of Inland Rail
Active level crossing	At grade road crossing of the rail corridor which uses flashing lights and boom barriers for motorists, and automated gates for pedestrians. These devices are activated prior to and during the passage of a train through a level crossing.
Alluvial	Sediments deposited by flowing water.
Alluvium	General term for unconsolidated deposits of inorganic materials (clay, silt, sand, gravel, boulders) deposited by flowing water.
Aquifer	Rock or sediment in a formation, group of formations or part of a formation that is saturated and sufficiently permeable to transmit economic quantities of water to wells and springs.
Beneficial use	A resource management tool to protect groundwater resources. It is a general categorisation of groundwater uses based on water quality and the presence or absence of contaminants. It is typically based on salinity concentrations.
Bore	Artificially constructed or improved groundwater cavity used for the purpose of accessing or recharging water from an aquifer. Interchangeable with borehole, piezometer.
Borehole	Includes a well, excavation, or other artificially constructed or improved groundwater cavity which can be used for the purpose of intercepting, collecting or storing water from an aquifer; observing or collecting data and information on water in an aquifer; or recharging an aquifer. Interchangeable with bore, well, piezometer.
Catchment	The land area draining through the main stream, as well as tributary streams, to a site. It always relates to an area above a specific location.
CDFM	Cumulative deviation from mean
CEMP	Construction Environment Management Plan
Clay	Deposit of particles with a diameter of less than 0.002mm, typically contains variable amounts of water within the mineral structure.
Conceptual model	A simplified and idealised representation of the physical hydrogeologic setting and the hydrogeological understanding of the essential flow processes of the system. This includes the identification and description of the geologic and hydrologic framework, media type, hydraulic properties, sources and sinks, and important aquifer flow and surface-groundwater interaction processes.
Confined aquifer	An aquifer bounded above and below by impervious (confining) layers. In a confined aquifer, the water is under sufficient pressure so that when wells are drilled into the aquifer, measured water levels rise above the top of the aquifer.
Construction compound	An area used as the base for construction activities, usually for the storage of plant, equipment and materials and/or construction site offices and worker facilities.

Construction environmental management plan	A site-specific plan developed for the construction phase of a project, to ensure that all contractors and sub-contractors comply with the environmental conditions of approval for the project and manage environmental risks properly.
Construction footprint	The area that would be used for the construction of the proposal.
CSSI	Critical State Significant Infrastructure
Culvert	A structure that allows water to flow under a road, railway, track, or similar obstruction.
Cumulative impacts	Impacts that, when considered together, have different and/or more substantial impacts.
Detailed design	The stage of design where proposal elements are designed in detail, suitable for construction.
Discharge rate	The rate of flow of water measured in terms of volume per unit time, for example, cubic metres per second. Discharge is different from the speed or velocity of flow, which is a measure of how fast the water is moving (e.g. metres per second).
Down line	Track within a dual-track section of corridor on which trains travel away Sydney Central station.
Drawdown	The change in groundwater level in a bore, or the change in water table elevation in an unconfined groundwater system, due to the extraction of groundwater.
Earthworks	All operations involved in loosening, excavating, placing, shaping and compacting soil or rock.
EIS	Environmental impact statement
Enhancement site	Discrete sites within the A2I proposal area that are proposed for infrastructure enhancement. Enhancement works at each of these discrete work sites may include raising, widening or replacing bridges, raising or replacing signal gantries, and lowering sections of track.
EP&A Act	NSW *Environmental Planning and Assessment Act 1979*
EPBC Act	Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*
EPL	Environment protection licence
Formation	General term used to describe a sequence of soil or rock layers.
Gantry	An overhead metal structure with a frame supporting equipment such as a signals, lighting or cameras.
GDE	Groundwater dependent ecosystem
GME	Groundwater monitoring events
Groundwater	Water found in the subsurface in the saturated zone below the water table or piezometric surface i.e. the water table marks the upper surface of groundwater systems.
Groundwater flow	The movement of water through openings and pore spaces in rocks below the water table i.e. in the saturated zone.
Groundwater quality	Groundwater quality relates to the condition of groundwater within a groundwater source and its suitability for different purposes.

Groundwater resource	Groundwater available for beneficial use, including human usage, aquatic ecosystems and the greater environment.
Groundwater study area	Encompasses the construction impact zone at each enhancement site location, with a with a 2 kilometre buffer.
HSU	Hydrostratigraphic units
Hydraulic conductivity	Measure of the ease with which water will pass through earth material; defined as the rate of flow through a cross-section of one square metre under a unit hydraulic gradient at right angles to the direction of flow (metres per day).
Hydrogeology	The study of the interrelationships of geological materials and processes with water, especially groundwater.
Impact	An event that disrupts ecosystem, community, or population structure and alters the physical environment, directly or indirectly.
Inland Rail program	The Inland Rail program comprises the design and construction of a new Inland Rail connection between Melbourne and Brisbane, via Wagga, Parkes, Moree, and Toowoomba. The route for Inland Rail is about 1,700km in length. Inland Rail will involve a combination of upgrades of existing rail track and the provision of new track.
LGA	Local government area
Loop line	Track which briefly leaves the main line and re-joins to allow for train passing or access to minor locations.
LTAAEL	Long-term average annual extraction limit
Main line	Primary track on which trains travel within a single track section of corridor.
MBDA	Murray-Darling Basin Authority
ML	Megalitres
Monitoring bore	A bore used to monitor groundwater levels or quality.
Operational footprint	Area occupied by permanent infrastructure and required for the operation of the proposal.
Overbridge	A bridge over a railway or road. For the proposal, overbridges refer to those structures which allow a road to pass over the railway.
Passive level crossing	At grade road crossing of the rail corridor which uses stop or give way signs for motorists, and 'look for trains' signs for pedestrians.
Pedestrian bridge	A bridge designed solely for pedestrians to cross a watercourse, rail corridor or road.
Permeability	The ease with which a fluid can pass through a porous medium and is defined as the volume of fluid discharged from a unit area of an aquifer under unit hydraulic gradient in unit time (cubic metres per day).
Precinct	Groupings of enhancement sites in line with the LGAs including Albury, Greater Hume – Lockhart, Wagga Wagga and Junee.
Rail corridor	The corridor within which the rail tracks and associated infrastructure are located
RMAR	Rail Maintenance Access Road

The proposal	Proposed enhancement works to structures and sections of track along 185 kilometres of the existing operational standard gauge railway between Albury and Illabo for the purpose of meeting Inland Rail specifications.
The proposal site	The areas that enhancement works are required to operate the Albury to Illabo section of Inland Rail. It includes the location of construction worksites, operational rail infrastructure, new bridge structures (road and shared user) and other ancillary work. It is otherwise referred to as the construction footprint.
Recharge	The process by which water is added from outside to the zone of saturation of an aquifer, either directly into a formation, or indirectly by way of another formation.
Runoff	All surface and subsurface flow from a catchment, but in practice refers to the flow in a river i.e. excludes groundwater not discharged into a river.
SEARs	Secretary's environmental assessment requirements
Shared user	Descriptor of infrastructure or path designed to accommodate pedestrians and cyclists safely to cross a watercourse, rail corridor or road.
SSI	State Significant Infrastructure
Standing water level	The height to which groundwater rises in a bore after it is drilled and completed, and after a period of pumping when levels return to natural atmospheric or confined pressure levels.
Study area	The wider area, including and surrounding the proposal site, with the potential to be directly or indirectly affected by the proposal. The extent of the study area varies according to the requirements of each assessment and the potential for impacts.
Track	The structure consisting of the rails, fasteners, sleepers and ballast, which conveys trains.
WAL	Water access licence
Water Act	*Water Act 1912* (NSW Legislation)
Water table	The surface in an unconfined aquifer or confining bed at which the pore water pressure is atmospheric; it can be measured by installing a well into the zone of saturation and then measuring the water level in the well.
WM Act	*Water Management Act 2000*
WRP	Water resource plan

EXECUTIVE SUMMARY

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 would enhance Australia's existing national rail network and serve the interstate freight market.

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

The proposal is Critical State Significant Infrastructure and is subject to approval by the NSW Minister for Planning under Division 5.2, Part 5 of the *Environmental Planning and Assessment Act 1979* (EP&A Act). This report has been prepared by WSP as part of the environmental impact statement (EIS) for the proposal and assesses the proposals impact to groundwater.

The groundwater assessment involved a desktop review and hydrogeological site investigations across four precincts (Albury, Greater Hume – Lockhart, Wagga Wagga and Junee) which contain 24 enhancement sites. Six monitoring bores were installed, and three groundwater monitoring events conducted to determine groundwater levels, quality and hydraulic conductivity at sites determined to be at increased risk of potential groundwater table penetration resulting from either construction or operation activities.

Two enhancement sites, Riverina Highway bridge at Albury and Kemp Street bridge at Junee, were determined to contain a high risk of intersecting the regional water table as part of construction activities. Groundwater would require dewatering for the installation of an underground storage tank at Riverina Highway bridge and for foundation improvements and retaining walls at Kemp Street bridge.

Quantitative estimate of construction dewatering volume, rates and radius of influence indicates that up to 0.7 megalitres (ML) of groundwater may be dewatered from within the Upper Murray groundwater source at Riverina Highway bridge over a period of 21 days. Inflow rates would be limited, at less than 0.2 litres per second (L/s), with a total dewatering depth of 1.8 metres (m). The resulting impact radius would be small, less than six metres radius from the dewatering activity. Dewatering is not expected to impact any neighbouring registered bores or groundwater dependent ecosystems (GDEs).

A conservative dewatering volume of up to 11.4ML was estimated for the construction phase as Kemp Street bridge and would be sourced from the Lachlan Fold Belt Murray-Darling Basin groundwater source over a period of 25 days. Estimated inflow rates were calculated at 0.4 to 1.0L/s, with a total dewatering depth of 1.8m and an associated 5.1m radius of influence.

Given the small impact radius, limited depth of dewatering and minimal time required for dewatering, the potential impact to the hydrogeological environment was generally considered low for both enhancement sites. However, one nearby registered water supply bore (GW064614) is located approximately 7.5m towards the south-southeast of the dewatering location at Kemp Street bridge. Due to the registered bore being listed for use as a water supply, even though it was outside the calculated impact radius, a conservative moderate risk rating was applied. Groundwater levels and any potential impact to quality resulting from dewatering are expected to recover shortly following completion of dewatering activities and therefore the construction impact is considered low.

One enhancement site, Pearson Street bridge at Wagga Wagga, does contain increased risk of track lowering and construction activities intersecting the groundwater table. The increased risk is dependent on future climatic conditions or potential changes in operational procedures of current nearby dewatering activities undertaken by Wagga Wagga City Council for urban salinity management. However, under current monitoring conditions, construction and operation activities are not anticipate to intersect the groundwater table. Long term historical groundwater monitoring undertaken by Wagga Wagga City Council indicates that groundwater levels have a strong correlation to climatic conditions and groundwater level responses can vary significantly depending on location with up to 3.4m fluctuation observed over 28 years at one nearby Wagga Wagga City Council monitoring bore. However, the potential impact to the hydrogeological environment is considered low during both construction and operation of the proposal due to any potential groundwater take (if occurring) would happen intermittently and during periods of wetter climatic conditions.

Groundwater at the remaining enhancement sites contains a low risk of being intersected. Therefore, the risk of impacts to the groundwater environment resulting from declining groundwater levels due to dewatering, changes to groundwater quality (salinity and contamination), settlement and changes to recharge are considered to be low.

An assessment of the proposals impact on aquifers and groundwater dependent ecosystems in regard to the minimal impact considerations of the NSW Aquifer Interference Policy was undertaken; the proposal complies with Level 1 minimal impact considerations.

Whilst the potential impacts resulting from the proposal during both construction and operation are considered low, appropriate mitigation measures would further reduce identified risks. Appropriate mitigation and management measures are proposed in this report.

1 INTRODUCTION

1.1 OVERVIEW

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 would enhance Australia's existing national rail network and serve the interstate freight market.

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

- 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 northern NSW and south-east Queensland.

Inland Rail has been divided into 13 projects, 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 Albury to Illabo section of Inland Rail ('the proposal').

The proposal is Critical State Significant Infrastructure (CSSI) and is subject to approval by the NSW Minister for Planning under Division 5.2, Part 5 of the *Environmental Planning and Assessment Act 1979* (EP&A Act). This report has been prepared 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 then NSW Department of Planning, Industry and Environment (the SEARs) (now the Department of Planning and Environment), dated 14 October 2020.

1.2 THE PROPOSAL

The proposal involves enhancement works to structures and sections of track along 185 kilometres of the existing operational standard gauge railway between Albury and Illabo. Enhancement works are required to provide the increased vertical and horizontal clearances required for double-stacked freight trains.

1.2.1 LOCATION

The proposal is generally within the existing active rail corridor between the town of Albury on the Victorian-NSW border and around three kilometres to the north-east of Illabo. The alignment passes through two major regional towns, Albury and Wagga Wagga, NSW, and several smaller regional towns. Works are proposed at 24 locations along the 'Main South Line' corridor, described as 'enhancement sites'.

The enhancement sites have been broken down into four precincts which align with the local government areas (LGA) of Albury, Greater Hume – Lockhart, Wagga Wagga and Junee, as identified in Table 1.1 and shown in Figure 1.1.

Table 1.1 Enhancement sites

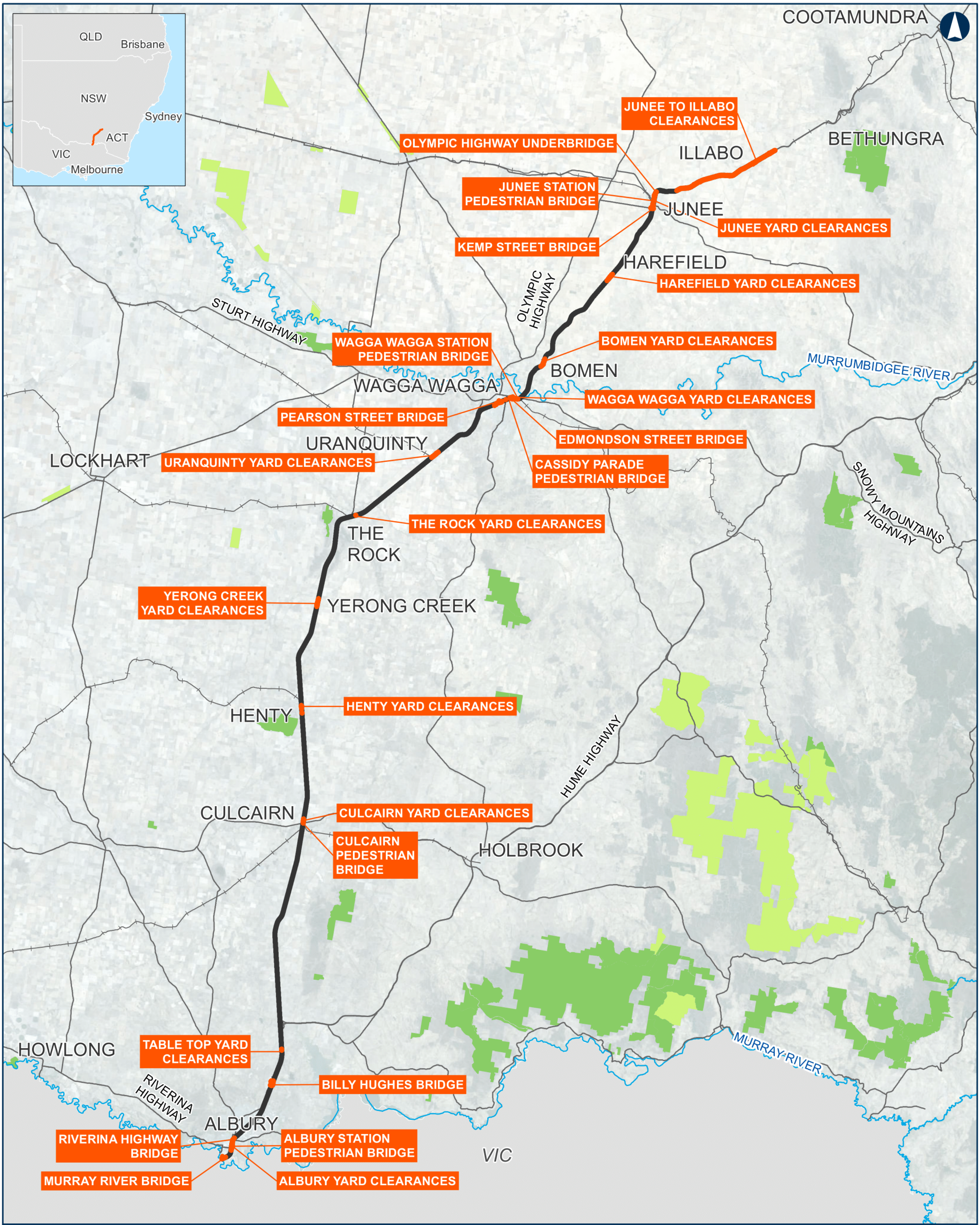
PRECINCT	ENHANCEMENT SITES
Albury	Murray River bridge
	Albury Station pedestrian bridge
	Albury Yard clearances
	Riverina Highway bridge
	Billy Hughes bridge
	Table Top Yard clearances
Greater Hume – Lockhart	Culcairn pedestrian bridge
	Culcairn Yard clearances
	Henty Yard clearances
	Yerong Creek Yard clearances
	The Rock Yard clearances
Wagga Wagga	Uranquinty Yard clearances
	Pearson Street bridge
	Cassidy Parade pedestrian bridge
	Edmondson Street bridge
	Wagga Wagga Station pedestrian bridge
	Wagga Wagga Yard clearances
	Bomen Yard clearances
Junee	Harefield Yard clearances
	Kemp Street bridge
	Junee Station pedestrian bridge
	Junee Yard clearances
	Olympic Highway underbridge
	Junee to Illabo clearances

1.2.2 KEY FEATURES

The key features of the proposal include:

- adjustments to approximately 44 kilometres of track across 14 enhancement sites to accommodate the vertical and horizontal clearances according to Inland Rail clearance specifications, comprising:
  - realignment of track within the rail corridor
  - lowering of track up to 1.6 metres at three enhancement sites
- changes to bridges and culverts at enhancement sites to accommodate vertical clearances and track realignment as follows:
  - replacement of two road bridges and adjustments to adjoining intersections
  - replacement of three pedestrian bridges
  - removal of two redundant pedestrian bridges
  - modifications to four rail bridges
- ancillary works, including adjustments to nine level crossings, modifications to drainage and road infrastructure, signalling infrastructure, fencing, signage, and services and utilities.

No additional works would be required outside the enhancement sites identified in Figure 1.1 as they meet the clearance requirement for the Inland Rail program.



Albury to Illabo Figure 1.1 Enhancement sites of the proposal

0 10 20 km

Coordinate System: GDA 1994 MGA Zone 55

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Date: 4/11/2021 Paper: A3
Author: WSP Scale: 1:500,000
Data Sources: ARTC, NSWSS

- Proposal site
- Track alignment
- Existing railway
- Main road
- River
- National Park
- State Forest

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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1.2.3 TIMING

Subject to approval, further design and procurement, construction of the proposal is planned to start in early 2024 and is expected to take about 16 months. The proposal would be fully operational in 2025 with enhancement sites progressively commissioned on completion of construction. Inland Rail as a whole would be operational once all 13 sections are complete, which is estimated to be in 2027.

1.2.4 CONSTRUCTION

An indicative construction methodology has been developed based on the current design to be used as a basis for the environmental assessment process. Overall, the construction strategy is based on an approach of dividing the proposal into four construction packages which align with the precincts: Albury, Greater Hume – Lockhart, Wagga Wagga and Junee.

Construction of the proposal would require:

- construction compounds, laydown areas and other areas needed to facilitate construction works
- temporary changes to the road network, including road closures to undertake works on road bridges and level crossings
- other ancillary works.

Construction within each precinct would generally involve the site establishment and enabling works, main construction works as relevant to the enhancement site and finishing works as outlined in Table 1.2.

Further information on the construction of the proposal is provided in Chapter 8 of the EIS.

Table 1.2 Indicative construction activities

CONSTRUCTION STAGES	INDICATIVE ACTIVITIES
Site establishment and enabling works	— Establishment of key construction infrastructure, work areas, access points and other construction facilities — Installation of environmental controls, fencing and site services — Preliminary activities including clearing/trimming of vegetation
Main construction works	— Track works — Rail bridge works — Road bridge replacement — Pedestrian bridge works — Associated infrastructure works on level crossings, culverts and signalling
Finishing works	— Testing and commissioning of the new and modified infrastructure — Demobilisation and removal of construction compounds and other construction infrastructure — Restoration of disturbed areas, as required, including revegetation and landscaping, where required

1.2.5 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.

The proposal would enable the use of double stacked trains along its entire length. Inland Rail would operate 24 hours per day and would initially accommodate double-stacked freight trains up to 6.5 metres high and up to 1,800 metres in length. The possible future use of the railway between Albury and Illabo by freight trains up to 3,600 metres long would be subject to separate assessment. Freight train speeds would range from 60 to 115 kilometres per hour, which is consistent with current train speeds.

The average number of freight trains movements between Albury and Illabo would increase from a current average of up to 12 per day in 2021 to 18 per day in 2025, further increasing to about 20 per day in 2040.

ARTC would continue to maintain the Main South Line. This would typically involve minor maintenance works, such as bridge and culvert inspections, rail grinding and track tamping, through to major maintenance, such as reconditioning of track and topping up of ballast as required. Maintenance works and schedule are not proposed to change as a result of the proposal and would continue in accordance with the existing Environmental Protection Licence which applies to the rail corridor (EPL 3142)..

Further information on the operation of the proposal is in Chapter 7 of the EIS.

1.3 PURPOSE AND SCOPE OF THIS TECHNICAL REPORT

This report has been prepared to identify and assess the potential impacts of the proposal in relation to groundwater. This report has the following objectives:

- provide context and information pertaining to relevant groundwater legislation
- describe the existing hydrogeological environment that may be impacted by the proposal
- identify and assess the potential proposals impacts to the existing hydrogeological environment
- provide suitable mitigation measures to reduce identified potential impacts.

This groundwater impact assessment addresses the relevant SEARs issued for the proposal on 14 October 2020. The SEARs relevant to water are presented in Table 1.3. Where the requirements relate to groundwater, the section or chapter within this report is referenced, however where the requirement relates to surface water, contamination or biodiversity, the relevant technical paper is referenced.

Table 1.3 Secretary's Environmental Assessment Requirements – Groundwater

KEY ISSUE	ASSESSMENT REQUIREMENT			REPORT REFERENCE
9 Water – Hydrology Long term impacts on surface water and groundwater hydrology (including drawdown, flow rates and volumes) are minimised. The environmental values of nearby connected and affected water sources, groundwater and dependent ecological systems including estuarine and marine water (if applicable) are maintained (where values are achieved) or improved and maintained (where values are not achieved). Sustainable use of water resources.	1	Describe (and map) the existing hydrological regime for any surface and groundwater resource (including reliance by users and for ecological purposes) likely to be impacted by the project, including stream orders as per the Biodiversity Assessment Method (BAM).		Technical Paper 8: Biodiversity development assessment report and Technical Paper 9: Aquatic biodiversity impact assessment
	2	Prepare a conceptual water balance for ground and surface water including the proposed intake and discharge locations, volume, frequency and duration, sources, security and licensing requirements.		Section 4.7, 5.2.3.2 and 5.3.3 Technical Paper 11: Hydrology, flooding and water quality
	3	Surface and groundwater hydrology impacts 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.	Technical Paper 11: Hydrology, flooding and water quality
		b	Impacts from any permanent and temporary interruption of groundwater flow, including the extent of drawdown, barriers to flows, implications for groundwater dependent surface flows, ecosystems and species, groundwater users and the potential for settlement.	Section 5.2 and 5.3
		c	Changes to environmental water availability and flows, both regulated/licensed and unregulated/rules-based sources.	Section 5.2.3.1 and 5.3.3 (groundwater scope) Technical Paper 11: Hydrology, flooding and water quality (surface water scope)
		d	Direct or indirect increases in erosion, siltation, destruction of riparian vegetation or a reduction in the stability of river banks or watercourses	Technical Paper 11: Hydrology, flooding and water quality (surface water scope)

KEY ISSUE	ASSESSMENT REQUIREMENT			REPORT REFERENCE
		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.	Technical Paper 11: Hydrology, flooding and water quality (surface water scope)
		f	Water take (direct or passive) from all surface and groundwater sources with estimates of annual volumes during construction and operation and an assessment of current market depth where water entitlement is required to be purchased.	Section 4.7, 5.2.2.3 Technical Paper 11: Hydrology, flooding and water quality (surface water scope)
	4	Identify and requirements for baseline monitoring of hydrological attributes.		Section 7.3
10 Water – Quality The project is designed, constructed and operated to protect the NSW Water Quality Objectives where they are currently being achieved, and contribute towards achievement of the Water Quality Objectives over time where they are currently not being achieved, including downstream of the project to the extent of the project impact including estuarine and marine waters (if applicable).	1	Water quality impacts, including:		
		a	Stating the ambient NSW Water Quality Objectives (NSW WQO) and environmental values for the receiving waters relevant to the project, including the indicators and associated trigger values or criteria for the identified environmental values.	Section 3.5 (groundwater scope) Technical Paper 11: Hydrology, flooding and water quality
		b	Identifying and estimating the quality and quantity of pollutants that may be introduced into the water cycle by source and discharge point and describe the nature and degree of impact that any discharge(s) may have on the receiving environment, including consideration of pollutants that pose a risk of non-trivial harm to human health and the environment.	Technical Paper 11: Hydrology, flooding and water quality Technical Paper 13: Contamination
		c	Identifying the rainfall event that the water quality protection measures will be designed to cope with.	Technical Paper 11: Hydrology, flooding and water quality
		d	The significance of any identified impacts including consideration of the relevant ambient water quality outcomes.	Section 5.2 and 5.3 (groundwater scope) Technical Paper 11: Hydrology, flooding and water quality

KEY ISSUE	ASSESSMENT REQUIREMENT	REPORT REFERENCE
	e Demonstrating how construction and operation of the project will, to the extent that the project can influence, ensure that: — where the NSW WQOs for receiving waters are currently being met they will continue to be protected — where the NSW WQOs are not currently being met, activities will work toward their achievement over time.	Technical Paper 11: Hydrology, flooding and water quality
	f Justifying, if required, why the WQOs cannot be maintained or achieved over time.	Technical Paper 11: Hydrology, flooding and water quality
	g Demonstrating that all practical measures to avoid or minimize water pollution and protect human health and the environment from harm are investigation and implemented.	Technical Paper 11: Hydrology, flooding and water quality Chapter 7 (groundwater scope) Technical Paper 13: Contamination
	h Identifying sensitive receiving environments (which may include estuarine and marine waters downstream) and develop a strategy to avoid or minimise impacts on these environments.	Technical Paper 11: Hydrology, flooding and water quality Section 4.6, 4.6.2 and Chapter 7 (groundwater scope)
	i Identifying proposed monitoring locations, monitoring frequency and indicators of surface and groundwater quality.	Section 7.3

1.4 STRUCTURE OF THIS REPORT

This report has been separated into the following chapters:

- **Chapter 1 – Introduction** – provides a broad introduction to the proposal and identifies the key features for assessment.
- **Chapter 2 – Legislation and policy context** – includes background information for assessed legislation, policy and guidelines.
- **Chapter 3 – Methodology** – provides information on the processes for assessment, including background information for the desktop and site investigations.
- **Chapter 4 – Existing environment** – describes the existing environment within the Study area. The Study area characterisation includes the findings of the desktop assessment and field investigations.
- **Chapter 5 – Impact assessment** – documents the identified risks and associated groundwater impacts that may be caused by the construction and operation of the Proposal.
- **Chapter 6 – Cumulative impacts** – outlines the potential cumulative impacts with respect to other known developments within the vicinity of the Proposal.
- **Chapter 7 – Mitigation and management measures** – provides the recommended mitigation and management measures to address the findings of the identified risk and impact assessment.
- **Chapter 8 – Conclusion**
- **Chapter 9 – References**.

Appendices to this report include:

- Appendix A – Registered bore search results
- Appendix B – Hydrographs
- Appendix C – Groundwater quality tables.

2 LEGISLATION AND POLICY CONTEXT

The following sections outline key Commonwealth and State legislations, policy and guidelines relevant to water resource management for the groundwater study area.

2.1 COMMONWEALTH LEGISLATION

2.1.1 ENVIRONMENTAL PROTECTION AND BIODIVERSITY ACT 1999

The objective of the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) is to protect and manage prescribed Matters of National Environmental Significance (MNES). Under the EPBC Act, proposed 'actions' that are likely to have a significant impact on MNES, on Commonwealth land, or that are being carried out by an Australian Government agency, must be referred to the Australian Minister for the Environment for assessment.

There are no controlled actions relevant to this assessment.

Preliminary environmental investigations identified threatened species under the EPBC Act which have the potential to be impacted by the proposal. As a result of the potential for impacts on protected matters, the proposal was referred to the (then) Australian Minister for the Environment in June 2020 (EPBC Referral No 2020/8670). On 29 June 2020, the Australian Government Department of Agriculture, Water and the Environment (DAWE) notified that the proposal is not a controlled action.

2.1.2 WATER ACT 2007

The *Water Act 2007* allows the Commonwealth in conjunction with the Basin States (South Australia (SA), Victoria (VIC), NSW, Queensland (QLD) and Australian Capital Territory (ACT)) to manage Australia's largest water resource, the Murray-Darling Basin (MDB), in the national interest. Notably it gives functions to the Bureau of Meteorology (BOM) in reporting of water information and transferred the powers and functions of the Murray-Darling Basin Commission to the Murray-Darling Basin Authority (MDBA) through the Murray-Darling Basin Agreement. The purpose of the Agreement is to:

> *'promote and co-ordinate effective planning and management for the equitable, efficient and sustainable use of the water and other natural resources of the Murray-Darling Basin, including by implementing arrangements agreed between the Contracting Governments to give effect to the Basin Plan, the Water Act and state water entitlements'.*

The MDB Plan 2012, hereafter referred to as the Basin Plan, uses water resource plans (WRPs) as a tool to effectively meet the objectives of the agreement. An outline of the Basin Plan, and the WRP's which apply to water resources relevant to the proposal are discussed in the following sections.

2.1.2.1 MURRAY-DARLING BASIN PLAN 2012

The Basin Plan aims to provide a coordinated approach to water use and management across the MDB's four states and the ACT. It provides a framework to balance environmental, social and economic considerations for water use and water quality to an environmentally sustainable level. The Basin Plan addresses surface water and groundwater use and water quality. Elements of the Basin Plan include:

- overall environmental water resource management objectives and outcomes
- defining separate water resource units within the Basin and sustainable diversion limits for these units, i.e. how much surface water and groundwater can be taken from the Basin, and a mechanism for adjustments to these limits
- an environmental watering plan to protect and restore the Basin's rivers and wetlands
- a water quality and salinity management plan that sets objectives and targets
- identifying the risks to continued water availability in the Basin, and strategies to manage them
- a monitoring and evaluation program, including an annual report on the effectiveness of the Basin Plan
- the preparation of WRPs which implement the management objectives of the Basin Plan for specific areas containing one or several sustainable diversions limits resource units
- limits on the quantity of water that may be taken from the Basin water resources as a whole and from the water resources of each WRP area.

Water quality objectives listed in Schedule 11 of the Basin Plan were developed for surface water and are not considered appropriate for groundwater (NSW Department of Planning, Industry and Environment (DPIE), 2019).

WATER RESOURCE PLANS

WRPs are an integral tool for implementing the objectives of the Basin Plan. They set rules on how much water can be taken from the Basin, ensuring that the sustainable diversion limit is not exceeded. The MDBA works with the state governments to outline how each region aims to achieve community, environmental, economic and cultural outcomes and state water management rules to meet the Basin Plan objectives. Importantly, state governments have had to revise current water management rules, including water sharing plans within NSW (refer to section 2.2.2.2), to ensure they comply with the Basin Plan, including sustainable diversion limit rules on the delivery, protection and monitoring of water for the environment, licence conditions on water access rights, and critical human water needs in extreme circumstances (when triggered). The individual WRP extents match the corresponding water sharing plan boundaries (refer to section 2.2.2.2). The WRPs are behind schedule for accreditation with assessment and negotiation between NSW and the MDBA on-going (MDBA, 2021). Whilst the WRPs have not reached the accreditation stage, the latest water sharing plans are enforced, but will align with finalised WRPs once the WRPs are accredited.

The MDB within NSW is covered by 20 WRPs (nine surface water and 11 groundwater). The groundwater study area includes sustainable diversion limit resource units which indicates how much water, on average, is allowed to be used in a given year, governed by the following relevant groundwater WRPs:

- Murray Alluvium: GW8 WRP area – includes three sustainable diversion limit resource units: Billabong Creek Alluvium, the Upper Murray Alluvium and the Lower Murray Shallow Alluvium. The proposal is situated within the Upper Murray Alluvium and Billabong Creek Alluvium.

- Murrumbidgee Alluvium: GW9 WRP area – includes three sustainable diversion limit resource units: Lake George Alluvium, Mid Murrumbidgee Alluvium and Lower Murrumbidgee Shallow Alluvium. The proposal is situated within the Mid Murrumbidgee Alluvium.

- NSW Murray-Darling Fractured Rock: GW11 WRP area – includes groundwater stored within the fractures, joints, bedding planes, faults and cavities within the geological rock mass of the NSW MDB as well as alluvial sediments that overlie these fractured rock systems that have not been explicitly captured elsewhere. It comprises nine sustainable diversion limit resource units, of which only one (Lachlan Fold Belt) is directly relevant to the proposal.

Water quality objectives for groundwater sources have been developed within the WRPs to address the lack of appropriate groundwater specific water quality targets in the Basin Plan, which includes the groundwater sources within the proposal. Water quality objectives were selected by the NSW Government from the beneficial use categories outlined in the NSW Groundwater Quality Protection Policy (DLWC, 1998) (refer to section 2.2.2) and determined in accordance with procedures set out in Australian and New Zealand Environment and Conservation Council (ANZECC) guidelines (ANZECC, 2000).

2.2 STATE LEGISLATION

2.2.1 *ENVIRONMENTAL PLANNING AND ASSESSMENT ACT 1979*

The EP&A Act and Environmental Planning and Assessment Regulation 2021 (EP&A Regulation) establish a framework for the assessment and approval of developments in NSW. They also provide for the making of environmental planning instruments, including state environmental planning policies (SEPPs) and local environmental plans (LEPs), which determine the permissibility and approval pathway for development proposals and form a part of the environmental assessment process. In accordance with the provisions of the EP&A Act, the proposal is State Significant Infrastructure (SSI). SSI may also be declared to be critical State Significant Infrastructure (CSSI) in accordance with section 5.13 of the EP&A Act, if it is of a category that, in the opinion of the Minister for Planning, is essential for the State for economic, environmental or social reasons. The proposal was declared as CSSI in 2021.

Under section 5.14 of the EP&A Act, the approval of the Minister for Planning is required for SSI (including CSSI), and an EIS has been prepared under Division 5.2 of the EP&A Act.

2.2.2 *WATER ACT 1912 AND WATER MANAGEMENT ACT 2000*

Water resources are administered under the *Water Act 1912* (Water Act) and the *Water Management Act 2000* (WM Act) by the NSW Department of Planning and Environment (DPE). The objective of the WM Act is the sustainable and integrated management of the state’s water sources for the benefit of present and future generations. The WM Act governs the issue of water access licences (WALs) and approvals for those water sources (rivers, lakes, estuaries and groundwater) in NSW where water sharing plans have commenced. Water sharing plans establish rules for sharing water between water users and the environment, and areas rules for water trading. The Water Act is being progressively phased out and replaced with the WM Act. The Water Act continues to apply in those remaining water sources where a water sharing plan has not been enacted. Groundwater resources within the groundwater study area are governed under the WM Act and subject to both water sharing plans, discussed below, and the WRPs discussed in section 2.1.2.

2.2.2.1 LICENSING

Part 2 of the WM Act establishes WALs for the take of water within a particular water management area. These WALs specify the proportion of available water which may be taken from a specified water management area or water source (usually in the form of “units”), usually annually, and the circumstances in which it may be taken. The amount of water which a unit (as specified in a WAL) represents, and therefore, the amount of water which may be taken under each WAL which specifies its allowable take in units, is determined by a Ministerial available water determination, which is issued usually once a year. Water access licences exemptions are described within of Part 1 of Schedule 4, of the *Water Management (General) Regulation 2018*.

Part 3 of the WM Act establishes three types of approvals that a proponent may be required to obtain. These are:

- water use approvals
- water management work approvals (water supply work approvals, drainage work approvals and flood work approvals)
- activity approvals (controlled activity approvals and aquifer interference approvals).

However, under section 5.23(1) of the EP&A Act, approved state significant infrastructure does not require a water use approval under section 89, a water management work approval under section 90 or an activity approval (other than an aquifer interference approval) under section 91 of the WM Act if groundwater extraction activities are assessed and approved as part of State Significant Infrastructure projects. In addition, the provisions relating to aquifer interference approvals have not yet been activated in NSW, so there is currently no requirement to obtain an aquifer interference approval.

Therefore, if the proposals groundwater extraction is assessed and approved as part of the State significant infrastructure proposal, only a WAL may be required. A WAL relevant to the applicable water sharing plan is required for dewatering and any other taking of water from any water source. The WAL will list the entitled water volume (in the form of units) and ordinarily requires a nominated water supply work. ARTC and/or its contractor would determine how water for construction of the proposal would be sourced and, if necessary, would obtain WALs with sufficient unit entitlements to satisfy the proposals water requirements.

2.2.2.2 WATER SHARING PLANS

Water sharing plans within the proposal cover the same areas as the WRPs and incorporate a number of water sources which typically equate directly to the sustainable diversion limits resource areas defined within the WRPs. Available water limits set out in water sharing plans are being negotiated with the MDBA to meet agreed limits within the WRPs. Whilst the WRPs have not reached the accreditation stage, the latest water sharing plans are enforced, but will align with finalised WRPs once the WRPs are accredited. Water sharing plans describe the annual surface water and groundwater recharge volumes for each identified water source and the volumes of water that are available for sharing. Available water volumes are based on calculated long-term average annual extraction limit (LTAAEL), which define the limit of water that can be taken for all purposes (including domestic and stock, urban, industrial, agriculture use and held environmental water) from each water source (DPIE, 2019a). Provisions are made for environmental water allocation, basic landholder rights, domestic and stock rights and native title rights.

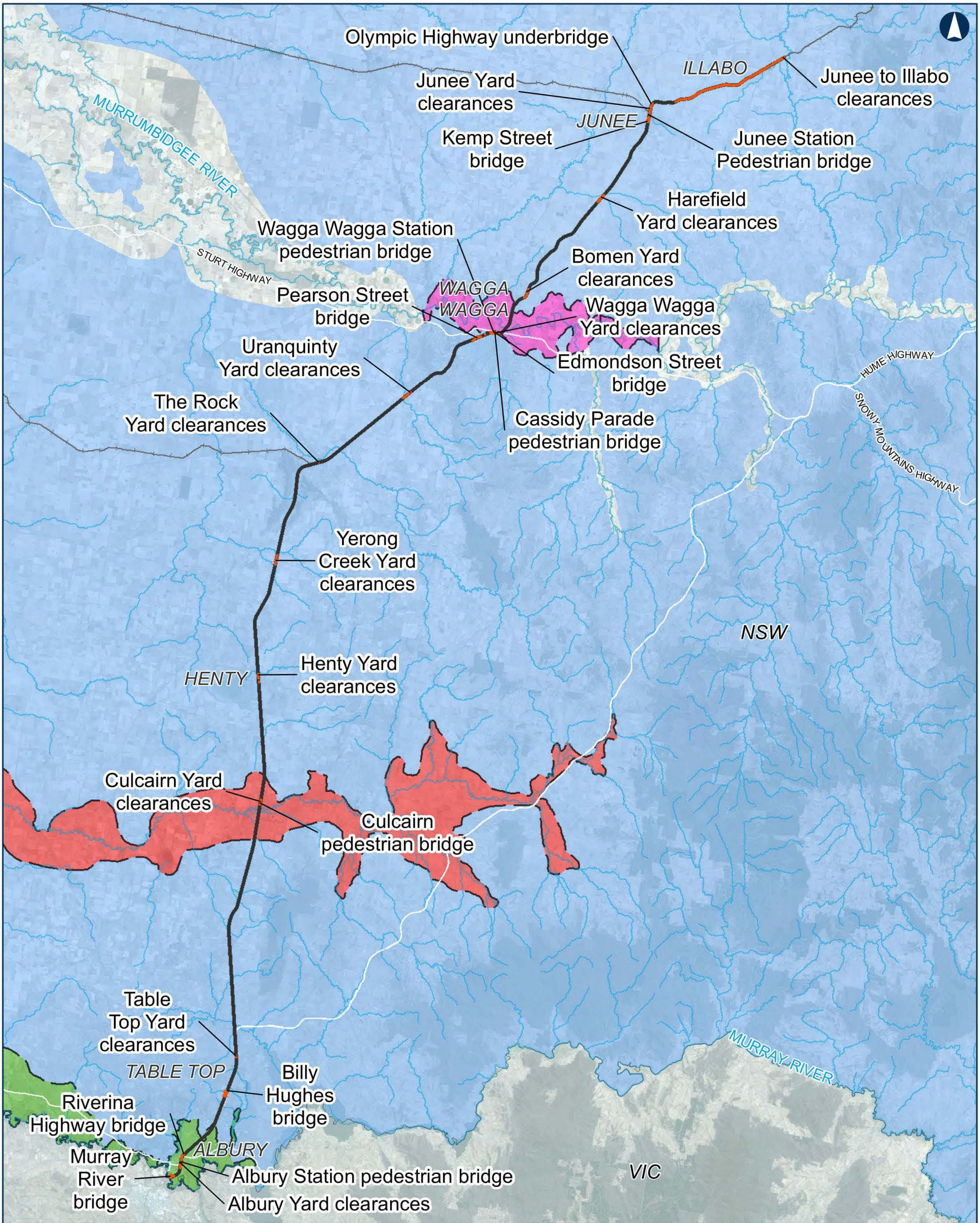
The proposal is overlying several water sharing plans which may overlap each other depending on the depth of the respective groundwater resource, and include:

- Murray Alluvial Groundwater Sources 2020
- Murrumbidgee Alluvial Groundwater Sources 2020
- NSW Murray-Darling Basin Fractured Rock Groundwater Sources 2020.

Table 2.1 lists the groundwater sources within the water sharing plans that are present within the proposal with the spatial extent of each water sharing plan in relation to the groundwater study areas displayed in Figure 2.1. For the purpose of this assessment, the primary groundwater source relates to the shallowest groundwater resource within the groundwater study area. Where groundwater resources overlap, the deeper one has been referred to as secondary.

Table 2.1 Groundwater sources relevant to the proposal

WATER SHARING PLAN	RELEVANT GROUNDWATER SOURCE	MANAGEMENT ZONE	APPROXIMATE LOCATION
Murray Alluvial Groundwater Sources 2020	Upper Murray	N/A	Albury
	Billabong Creek	N/A	Culcairn
Murrumbidgee Alluvial Groundwater Sources 2020	Wagga Wagga Alluvial	N/A	Wagga Wagga
NSW Murray-Darling Basin Fractured Rock Groundwater Sources 2020	Lachlan Fold Belt MDB	Other	Majority of the proposal from Albury to Illabo



Albury to Illabo Figure 2.1: Water sharing plans and their groundwater sources

0 10 20 km

Coordinate System: GDA 1994 MGA Zone 55

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Date: 15/11/2021 Paper: A3
Author: WSP Scale: 1:450,000
Data Sources: ARTC, NSWSS

- Enhancement site
- Albury to Illabo existing railway
- Existing railway
- Watercourse

Outcropping groundwater source
- Billabong Creek (Murray Alluvial Groundwater Sources 2020)
- Lachlan Fold Belt MDB (NSW Murray-Darling Basin Fractured Rock Groundwater Sources 2020)
- Upper Murray (Murray Alluvial Groundwater Sources 2020)
- Wagga Wagga Alluvial (Murrumbidgee Alluvial Groundwater Sources 2020)

Underlying groundwater source
- Lachlan Fold Belt MDB (NSW Murray-Darling Basin Fractured Rock Groundwater Sources 2020)

INLAND RAIL ARTC

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

D:\WSP O365\AU-WKG - Geospatial - AIS - Projects\PS122419_Albury_to_Illabo\Tasks\210_0010_EAP_EISReportFigures\Documents\Groundwater\210_EAP_F0201_WaterSharingPlans_r1v10.mxd

2.2.2.3 WATER MANAGEMENT (GENERAL) REGULATION 2018

The *Water Management (General) Regulation 2018* specifies procedural, technical and licence requirements and exemptions under the WM Act. It also defines the function and powers of water supply authorities. Under this regulation a WAL or a water use approval is exempt if water extraction (such as for excavation to construct or maintain a building, road or infrastructure) is less than three mega litres in any one water calendar year (commencing on 1 July each year). Requirements for this exemption are set out in Clause 21(6) and Schedule 4 of the *Water Management (General) Regulation 2018* and include:

- record the water take within 24 hours in the approved form and manner
- keep the water take records for a period of five years
- provide the water take records to the Minister (or WaterNSW) by no later than 28 July for the year ending 1 July during which the water was taken.

2.3 POLICIES AND GUIDELINES

2.3.1 NSW AQUIFER INTERFERENCE POLICY

The NSW Aquifer Interference Policy (AIP) (DPI, 2012) clarifies the requirements for obtaining water licences and the assessment processes for aquifer interference activities under the WM Act and other relevant legislative frameworks. The AIP also defines considerations in assessing whether more than minimal impacts might occur to a key water-dependent asset.

An aquifer interference activity involves any of the following:

- penetration of an aquifer
- interference with water in an aquifer
- obstruction of the flow of water in an aquifer
- taking of water (referred to as water take) from an aquifer whilst mining or any other activity prescribed by the regulations
- disposal of water taken from an aquifer while mining or any other activity prescribed by the regulations.

While the provisions on the WM Act requiring aquifer interference approvals do not apply at this stage, aquifer interference activities will be considered in the course of the assessment of the proposal under the EP&A Act., of which the AIP is relevant for that assessment.

The WM Act includes the concept of ensuring ‘no more than minimal harm’ for both the granting of water access licences and the granting of approvals. Approvals under the AIP will be granted provided adequate arrangements are in place to ensure that no more than minimal harm will be imposed on any water source or its dependent ecosystems.

For aquifer impact assessments, the AIP divides groundwater sources into ‘highly productive’ and ‘less productive’ based on water quality and yield. Highly productive groundwater sources have total dissolved solids less than 1,500 milligram per litre (mg/L) and can sustain yields greater than 5 litres per second (L/s). On this basis, within the groundwater study area, the Wagga Wagga Alluvial Groundwater Sources is considered as highly productive, while the Lachlan Fold Belt MDB Groundwater Sources and Murray Alluvial Groundwater Sources (Upper Murray and Billabong Creek) are considered less productive. This groundwater impact assessment evaluates the proposal against the AIP minimal impact criteria which considers impacts to the water table, water pressure and water quality (section 5.3.3).

2.3.2 NATIONAL WATER QUALITY MANAGEMENT STRATEGY (ANZECC / ARMCANZ 2018)

The National Water Quality Management Strategy (ANZECC / ARMCANZ 2018) has been developed by the Australian and New Zealand governments in cooperation with state and territory governments. Endorsed by ANZECC, the strategy establishes objectives to achieve sustainable use of the nation's water resources by protecting and enhancing their quality while maintaining economic and social development.

The National Water Quality Management Strategy includes guidelines for protection of water resources across Australia. These guidelines have been used to determine the existing groundwater conditions.

2.3.3 AUSTRALIAN AND NEW ZEALAND GUIDELINES FOR FRESH AND MARINE WATER QUALITY (ANZG 2018)

The Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZG 2018) is a key guideline within the National Water Quality Management Strategy that is used to identify catchment and waterway specific water quality management goals. These guidelines are an updated version of the previous guidelines referred to as the ANZECC 2000 guidelines.

The ANZG 2018 provide a risk-based process for assessing existing water quality condition and developing water quality objectives to sustain current or likely future environmental values for natural and semi-natural water resources. The ANZG 2018 provides default guideline values for water quality indicators for different environmental values. Where default trigger values are currently being devised, the guideline refers to ANZECC 2000 values. These guideline trigger values are considered as generic starting points for assessing water quality in areas where site specific information is not available and have been considered when describing the existing environment (Chapter 4).

2.3.4 NSW GOVERNMENT GROUNDWATER FRAMEWORK DOCUMENTS

The NSW Government Groundwater Policy Framework Document (Department of Land and Water Conservation (DLWC), 1997) aims to manage the State's groundwater resources to sustain their environmental, social and economic uses. The policy has three component policies:

- NSW Groundwater Quality Protection Policy (DLWC, 1998)
- NSW Groundwater Dependent Ecosystems Policy (DLWC, 2002)
- NSW Groundwater Quantity Management Policy (DLWC, undated).

These framework policy documents have been incorporated, where relevant, into generation of the governing policies and legislations discussed above.

2.3.4.1 NSW GROUNDWATER QUALITY PROTECTION POLICY

The NSW Groundwater Quality Protection Policy (DLWC, 1998) has been designed to protect groundwater resources against pollution. This policy provides a protective legislative framework for the sustainability of groundwater resources and their ecosystem support functions during resource management decision making. It will influence the type and selection of management activities and resource development opportunities that will be supported by the State's resource managers, land use planners and regulators. Key policy principles include:

- all groundwater systems should be managed such that their most sensitive identified beneficial use (or environmental value) is maintained
- town water supplies should be afforded special protection against contamination
- groundwater pollution should be prevented so that future remediation is not required
- for new developments, the scale and scope of work required to demonstrate adequate groundwater protection shall be commensurate with the risk the development poses to a groundwater system and the value of the groundwater resource

- a groundwater pumper shall bear the responsibility for environmental damage or degradation caused by using groundwater that is incompatible with soil, vegetation or receiving waters
- groundwater dependent ecosystems will be afforded protection
- groundwater quality protection should be integrated with the management of groundwater quantity
- the cumulative impacts of developments on groundwater quality should be recognised by all those who manage, use, or impact on the resource
- where possible and practical, environmentally degraded areas should be rehabilitated, and their ecosystem support functions restored.

2.3.4.2 NSW GROUNDWATER DEPENDENT ECOSYSTEMS POLICY

The NSW Groundwater Dependent Ecosystems Policy (DLWC, 2002) has been designed to protect valuable ecosystems which rely on groundwater for survival so that, wherever possible, the ecological processes and biodiversity of these dependent ecosystems are maintained or restored, for the benefit of present and future generations. The policy provides practical guidance on how to protect and manage these valuable natural systems through the following key principles:

- The scientific, ecological, aesthetic and economic values of GDEs, and how threats to them may be avoided, should be identified and action taken to ensure that the most vulnerable and the most valuable ecosystems are protected.
- Groundwater extractions should be managed within the sustainable yield of aquifer systems, so that the ecological processes and biodiversity of their dependent ecosystems are maintained and/or restored. Management may involve establishment of threshold levels that are critical for ecosystem health, and controls on extraction in the proximity of GDEs.
- Priority should be given to ensuring that sufficient groundwater of suitable quality is available at the times when it is needed:
  - for protecting ecosystems which are known to be, or are most likely to be, groundwater dependent
  - for GDEs which are under an immediate or high degree of threat from groundwater-related activities.
- Where scientific knowledge is lacking, the Precautionary Principle should be applied to protect GDEs. The development of adaptive management systems and research to improve understanding of these ecosystems is essential to their management.
- Planning, approval and management of developments and land use activities should aim to minimise adverse impacts on GDEs by:
  - maintaining, where possible, natural patterns of groundwater flow and not disrupting groundwater levels that are critical for ecosystems
  - not polluting or causing adverse changes in groundwater quality
  - rehabilitating degraded groundwater systems where practical.

2.3.4.3 NSW GROUNDWATER QUANTITY MANAGEMENT POLICY

The NSW Groundwater Quantity Management Policy (DLWC, 1997) delivers advice for the management of groundwater quantities. This policy helps clarify legislation and management for groundwater users' rights in terms of their long-term access and in relation to the rights of others through the following key principles:

- Total use of groundwater in a water source or zone will be managed within the sustainable yield, so that the groundwater is available for future generations, and dependent ecological processes remain viable.
- Significant GDEs must be identified and protected.
- Total licensed entitlements will not exceed 125 per cent of the sustainable yield in currently over-allocated groundwater sources or zones.
- Groundwater access must be managed in such a way that it does not cause unacceptable local impacts.

- Artificial recharge of groundwater will be strictly controlled.
- Landholders overlying an aquifer will have a basic right to access groundwater for domestic and stock purposes.
- Access to groundwater will be managed according to an established priority of use.
- All rights (except basic land-holder rights) to access and extract groundwater must be licensed and metered.
- In systems that are not subject to a licence embargo or a Ministerial order, groundwater access licenses will be issues on the basis of demonstrated need, within the sustainable yield.
- Groundwater access licence holders have resource stewardship obligations and are required to abide by the conditions of their licence.
- Permanent and temporary transfer of groundwater access will be permitted within sustainable yield constraints, if the transfer does not cause unacceptable impacts on other users, water quality or dependent ecosystems. Inter-aquifer transfers will not be permitted.
- Within environmental and interference constraints, the management of groundwater access should provide business flexibility for existing users through carryover and borrowing provisions on annual entitlements.
- Approvals must be obtained, where required, before any groundwater access licence can be activated at a particular location.
- All activities or works that intersect an aquifer and are not for the primary purpose of extracting groundwater, need an aquifer interference approval. It is noted, however, that the AIP provisions in the WM Act have not been activated yet, so approval is not currently required.

2.3.5 RISK ASSESSMENT GUIDELINES FOR GROUNDWATER DEPENDENT ECOSYSTEMS

In addition to the framework documents listed in section 2.3, the risk assessment guidelines for GDEs (NSW Office of Water, 2012) provides a conceptual framework to:

- assist agency staff support the requirements of the WM Act
- provide methods to identify and value GDEs to assist reporting
- provide a risk assessment framework for GDEs for the National Water Commission Project Coastal Groundwater Quality and GDEs
- detailed methods for defining, identifying and assessing ecological value and risk through a risk analysis conceptual framework for GDEs, with supporting background information.

This document has been used in the development of water sharing plans and WRPs.

3 METHODOLOGY

3.1 OVERVIEW

To achieve the aims and objectives of the SEARs described above (refer to section 1.3), the following key activities were undertaken:

- Characterisation of the existing environment including climate; topography; geology; groundwater occurrence, quality and use; existing groundwater users and GDEs. This was undertaken through a desktop review of publicly available information on the known regional groundwater setting.
- Refinement of the existing environment through field investigations to establish the site-specific conditions considering the local and regional conditions identified in the desktop review. The field investigations comprised the installation of a groundwater monitoring network, groundwater level gauging, groundwater sample collection and measurement of the permeability (hydraulic conductivity) of these groundwater systems.
- Generation of a hydrogeological conceptual model developed from the findings of the desktop assessment and field investigations.
- Quantification of groundwater take and development of a conceptual water balance model for the construction and operation of the proposal.
- Identification of groundwater supply options for construction with consideration of hydrogeological factors such as potential yield and groundwater quality, and legislative considerations.
- A qualitative and quantitative assessment, where practical, of the generated hydrogeological conceptual model and the physical mechanisms that might result in groundwater impacts potentially arising from the proposal during construction and operation against the relevant legislation identified in Chapter 2, particularly the NSW AIP (DPI, 2012) and WRPs.
- Recommendations for monitoring and management of identified impacts and risks, including management and mitigation measures as appropriate.

3.2 STUDY AREA

Impacts from the proposal would occur at the proposal site; however, to adequately characterise hydrogeological conditions for an area, a regional scale understanding is required. Therefore, a larger area termed the groundwater study area has been used to enable understanding and assessment of the potential area of influence of potential impacts to the existing groundwater environment. An additional 2km buffer surrounding each enhancement site has been applied.

Where enhancement sites are in close proximity and are anticipated to share similar groundwater environments, they have been combined for the purpose of establishing the existing groundwater environment (in Chapter 4). Table 3.1 lists the collective enhancement site names used to establish the existing groundwater environment and indicates which enhancement sites have been combined. Each enhancement site has been individually assessed for impact (refer to Chapter 5).

Table 3.1 Enhancement site groupings for establishing the existing groundwater environment

COLLECTIVE ENHANCEMENT SITE NAME USED IN THIS REPORT	RELEVANT ENHANCEMENT SITES
Murray River bridge	— Murray River bridge
Albury Station pedestrian bridge and Yard clearances	— Albury Station pedestrian bridge — Albury Yard clearances
Riverina Highway bridge	— Riverina Highway bridge
Billy Hughes bridge	— Billy Hughes bridge
Table Top Yard clearances	— Table Top Yard clearances
Culcairn pedestrian bridge and Yard clearances	— Culcairn pedestrian bridge — Culcairn Yard clearances
Henty Yard clearances	— Henty Yard clearances
Yerong Creek Yard clearances	— Yerong Creek Yard clearances
The Rock Yard clearances	— The Rock yard clearances
Uranquinty Yard clearances	— Uranquinty Yard clearances
Pearson Street bridge	— Pearson Street bridge
Wagga Wagga Station and surrounds	— Cassidy Parade pedestrian bridge — Edmondson Street bridge — Wagga Wagga Station pedestrian bridge — Wagga Wagga Yard clearances
Bomen Yard clearances	— Bomen Yard clearances
Harefield Yard clearances	— Harefield Yard clearances
Junee Station and surrounds	— Kemp Street bridge — Junee Station pedestrian bridge — Junee Yard clearances
Olympic Highway underbridge	— Olympic Highway underbridge
Junee to Illabo clearances	— Junee to Illabo clearances

3.3 DESKTOP ASSESSMENT

A desktop review of available data was undertaken to develop an understanding of the hydrogeological environment within the groundwater study area and to identify sensitive receptors including waterways, GDEs and registered groundwater bores. The following data and information were used to provide background information for topography, climate, geology and sensitive receptors for the four precincts:

- existing survey information from geotechnical investigations at the site locations
- geological data from the Seamless Geology Project (Colquhoun, Hughes & Deyssing et al., 2019). Additional information was compiled from geotechnical investigations and regional maps
- groundwater dependent ecosystem information from the BOM GDE Atlas
- registered groundwater bore data including groundwater levels, quality and yield, from the BOM National Groundwater Information System (NGIS) and WaterNSW
- climate data including rainfall and evapotranspiration from BOM
- publicly available reports and databases further detailing the existing groundwater, soil, geological, topographical and hydrogeological environments, including surface water and groundwater interaction. Sources include background aquifer descriptions documented in WRPs and water sharing plans, local council management plans, information and reports
- information provided by Wagga Wagga City Council regarding local monitoring bores within their Urban Salinity Management Plan.

Data and information obtained through the desktop review was used to guide site investigations (discussed further below). The combined findings from the desktop assessment and site investigations were then used to determine and conceptualise the existing environmental conditions within the groundwater study area. The existing environment (Chapter 4) presents a description of the existing groundwater conditions, including the key hydrostratigraphic units, groundwater levels, hydraulic properties, groundwater quality, GDEs and groundwater users. Available groundwater information was requested from City of Albury Council, Junee Shire Council, Lockhart Shire Council and Wagga Wagga City Council to support the groundwater impact assessment.

3.4 HYDROGEOLOGICAL SITE INVESTIGATION

The hydrogeological site investigation included the installation of six groundwater monitoring bores to collect baseline data at key locations. The location of the groundwater monitoring bores was devised from the desktop assessment and review of preliminary design information which was used to consider the preliminary risk to the groundwater environment. This preliminary risk assessment was based on a review of the construction and operation activities during the preliminary design stages, particularly ground disturbance works such as track lowering and other work requiring excavation or other work with the potential to impact existing groundwater conditions, based on the available hydrogeological desktop information. The following preliminary risk ratings were applied to each enhancement site:

- Low – the proposal is not anticipated to interfere with the groundwater table or there is sufficient existing information or proposed monitoring as part of this assessment to adequately assess potential impacts to groundwater through a desktop review.
- Moderate – insufficient design information to determine the impact of the proposal at this site against available information, including recent geotechnical investigations.
- High – the presence of a data gap and potential to intersect groundwater that requires hydrogeological site investigations as part of this assessment to adequately address the SEARs.

Table 3.2 summarises the preliminary risk to groundwater identified, and the proposed level of investigation to be completed (desktop or site investigation).

Table 3.2 Enhancement site locations and preliminary risk assessment to the groundwater environment

PRECINCT	ENHANCEMENT SITES	PROPOSED WORKS	PRELIMINARY RISK RATING	PROPOSED LEVEL OF GROUNDWATER INVESTIGATION
Albury	Murray River bridge	Bridge modifications, slew works	Low	Desktop
	Albury Station pedestrian bridge and Yard clearances	Track slews and gantry replacement	High	Hydrogeological site investigation
	Riverina Highway bridge	Track lowering by up to 1.0m	High	Hydrogeological site investigation
	Billy Hughes bridge	Track lowering by up to 1.4m and realignment	Moderate	Desktop
	Table Top Yard clearances	Gantry removal	Low	Desktop
Greater Hume – Lockhart	Culcairn pedestrian bridge and Yard clearances	Track slew, gantry modification, bridge removal	Low	Desktop
	Henty Yard clearances	Track slew and gantry modification	Low	Desktop
	Yerong Creek Yard clearances	Track slew works	Low	Desktop
	The Rock Yard clearances	Gantry modification	Low	Desktop
Wagga Wagga	Uranquinty Yard clearances	Track slew and gantry modification	High	Hydrogeological site investigation
	Pearson Street bridge	Track lowering by up to 1.5m	High	Hydrogeological site investigation
	Wagga Wagga Station and surrounds	Bridge replacement	High	Hydrogeological site investigation
	Bomen Yard clearances	Track slew works	Low	Desktop
Junee	Harefield Yard clearances	Track slew and gantry replacement	Low	Desktop
	Junee Station and surrounds	Bridge replacement, gantry removal and pedestrian bridge removal	Moderate	Desktop
	Olympic Highway underbridge	Track realignment	High	Hydrogeological site investigation
	Junee to Illabo clearances	Track slew works	Low	Desktop

Hydrogeological site investigations included the conversion of six geotechnical boreholes into groundwater monitoring bores to determine baseline groundwater levels and quality.

Three groundwater monitoring events (GMEs) were carried out to preliminary assess the seasonable influences on the hydrogeological environment in 2–5 February (GME 1), 29–31 March (GME 2) and 26–27 May (GME 3). The following was undertaken during the GMEs:

- manual measurement of groundwater levels
- groundwater quality sampling
- installation and download of dataloggers for automatic groundwater level (pressure) recording
- aquifer characteristic testing (rising and/or falling head tests, commonly referred to as slug tests), conducted in GME 1 only.

The limited groundwater monitoring period is considered suitable to assess the impact of the proposal on the hydrogeological environment. Any additional monitoring requirements are addressed in Chapter 7 (Mitigation and management measures).

3.4.1 GROUNDWATER MONITORING NETWORK

Groundwater monitoring bores were installed at areas identified in Table 3.2 as requiring hydrogeological site investigations to adequately address the SEARs. The groundwater monitoring bores were installed under the supervision of suitably qualified personal and constructed in accordance with the latest corresponding Minimum Construction Requirements for Water Bores in Australian 4th edition (NUDLC, 2020). Immediately following installation, the groundwater monitoring bores were developed by the drillers using air injection to remove fines/silts from the screen area. The screened depth was selected based on geological and hydrogeological observations at the time of drilling and identifies the targeted groundwater aquifer for monitoring. The monitoring bores were designed to target the regional groundwater aquifers.

The location of the groundwater monitoring bores is provided in Figure 3.1 with construction details of the monitoring bores provided in Table 3.3.

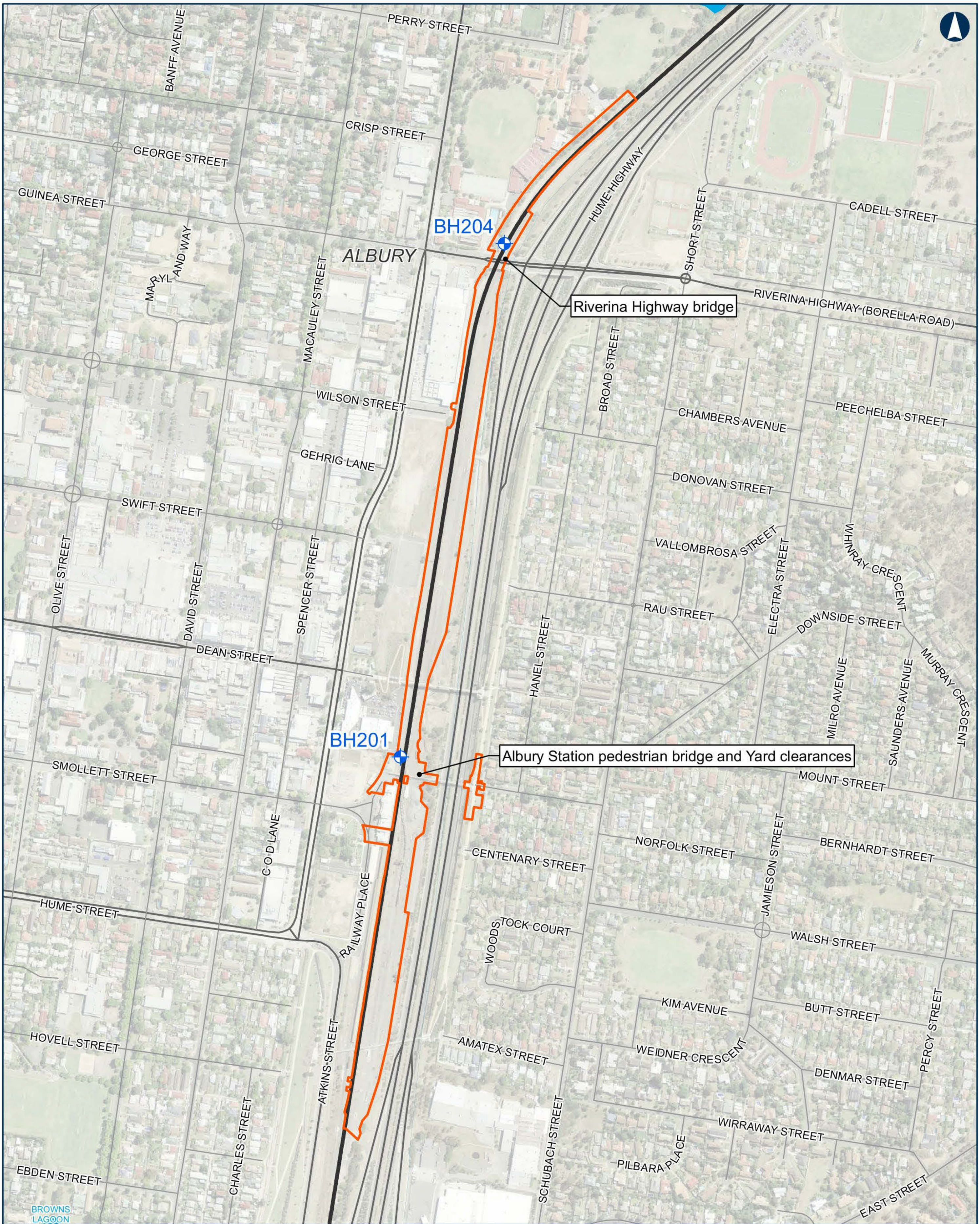
Table 3.3 Groundwater monitoring bore information

PRECINCT	ENHANCEMENT SITE	MONITORING BORE ID[1]	ELEVATION (mAHD[2])	SCREENED DEPTH (mBGL[2])	SCREENED GEOLOGY	GROUNDWATER SOURCE
Albury	Albury Station pedestrian bridge and Yard clearances	BH201	160.64	10.0–16.0	Alluvium	Upper Murray (alluvium)
	Riverina Highway bridge	BH204	161.39	9.0–15.0	Alluvium	Upper Murray (alluvium)
Wagga Wagga	Pearson Street bridge	BH206	186.47	3.5–12.5	Residual soil	Lachlan Fold Belt MDB
	Wagga Wagga Station and surrounds (at Edmondson Street bridge)	BH210	183.67	12.0–18.0	Lachlan fractured rock	Lachlan Fold Belt MDB
Junee	Olympic Highway underbridge	BH215	309.55	24.4-30.4	Lachlan fractured rock	Lachlan Fold Belt MDB
Wagga Wagga	Uranquinty Yard clearances	BH219	198.36	21.0–30.0	Lachlan fractured rock	Lachlan Fold Belt MDB

(1) mAHD = metres Australian Height Datum; mBGL = metres below ground level.

(2) Monitoring bore IDs simplified and corresponded to the following geotechnical boreholes: 210_2_BH201 = BH201; 210_2_BH204 = BH204; 210_2_BH206 = BH206; 210_2_BH210 = BH210; 210_2_BH215 = BH215; 210_2_BH219 = BH219.

Figure 3.1 Groundwater monitoring network

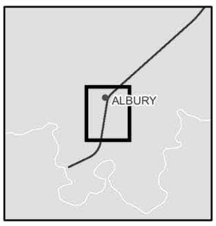


0 50 100 m

Coordinate System: GDA 1994 MGA Zone 55

Date: 11/11/2021 Paper: A3
Author: WSP Scale: 1:6,000
Data Sources: ARTC, NSWSS

- Enhancement site
- Existing railway
- Waterbodies
- Waterways
- Monitoring bore



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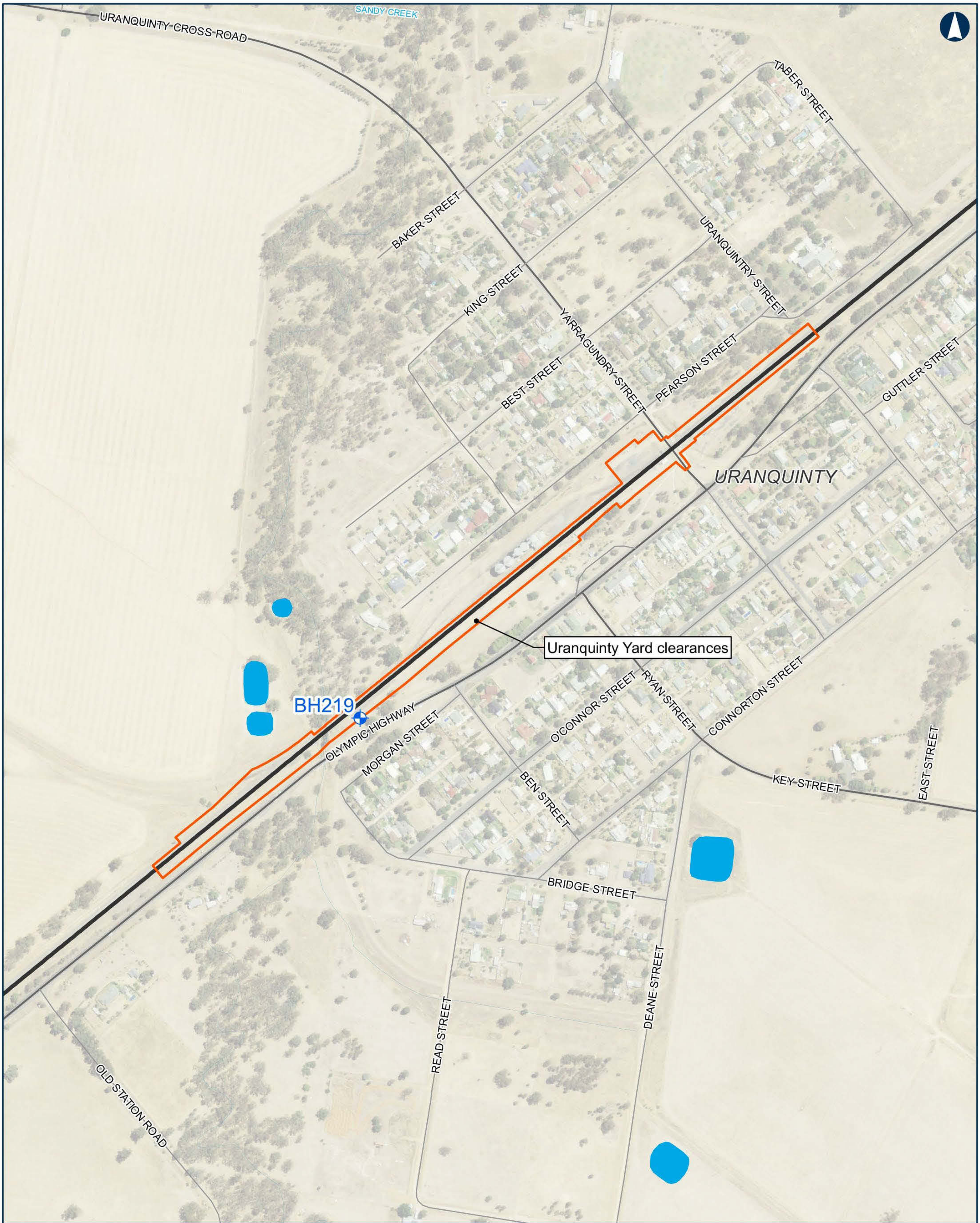


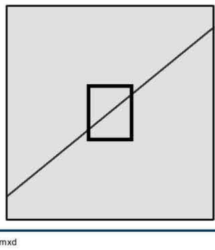
Albury to Illabo — Figure 3.1 Groundwater monitoring network — MAP 2 OF 5

0 50 100 m

Coordinate System: GDA 1994 MGA Zone 55

Date: 11/11/2021 Paper: A3
Author: WSP Scale: 1:5,000
Data Sources: ARTC, NSWSS

- Enhancement site
- Existing railway
- Waterbodies
- Waterways
- Monitoring bore



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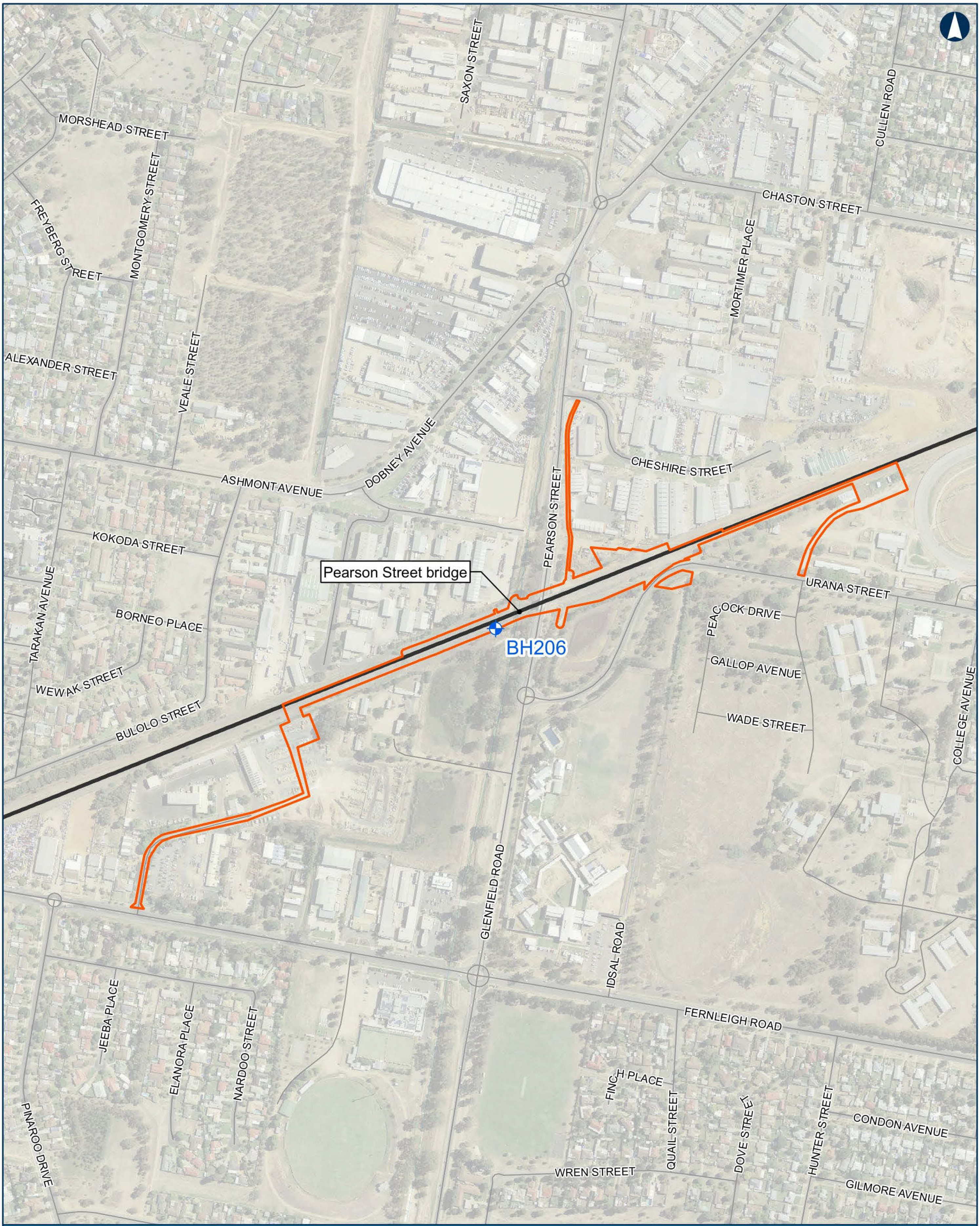


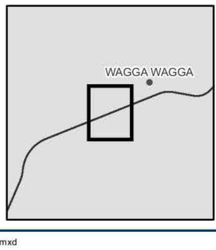
Albury to Illabo Figure 3.1 Groundwater monitoring network MAP 3 OF 5

0 50 100 m

Coordinate System: GDA 1994 MGA Zone 55

Date: 11/11/2021 Paper: A3
Author: WSP Scale: 1:5,000
Data Sources: ARTC, NSWSS

- Enhancement site
- Existing railway
- Waterways
- Monitoring bore



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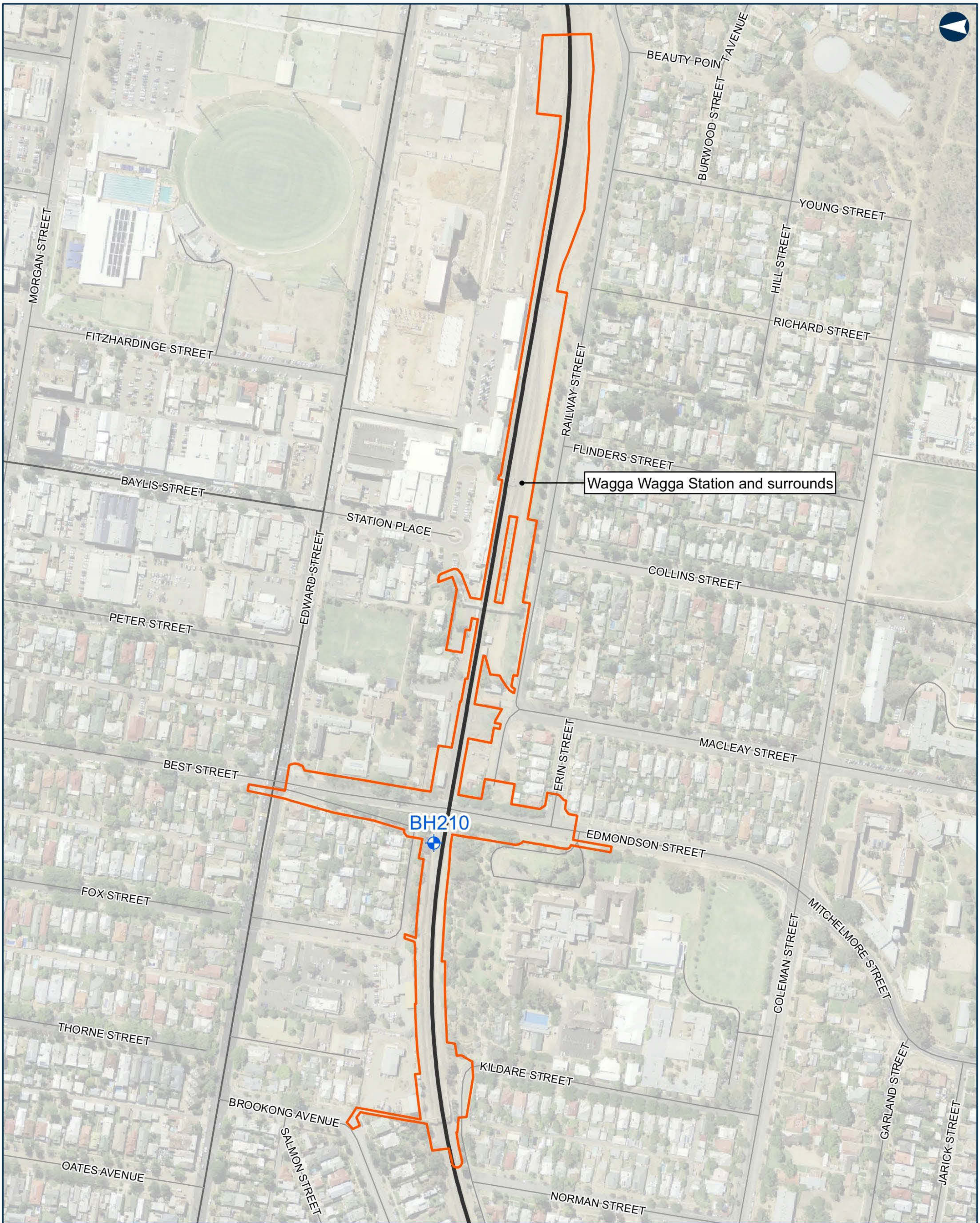


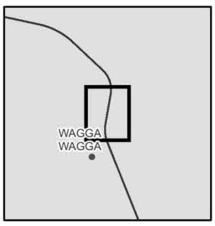
Albury to Illabo Figure 3.1 Groundwater monitoring network MAP 4 OF 5

0 50 100 m

Coordinate System: GDA 1994 MGA Zone 55

Date: 11/11/2021 Paper: A3
Author: WSP Scale: 1:3,500
Data Sources: ARTC, NSWSS

- Enhancement site
- Existing railway
- Waterways
- Monitoring bore



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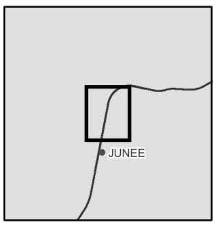
Albury to Illabo | Figure 3.1 Groundwater monitoring network | MAP 5 OF 5

0 50 100 m

Coordinate System: GDA 1994 MGA Zone 55

Date: 11/11/2021 Paper: A3
Author: WSP Scale: 1:5,000
Data Sources: ARTC, NSWSS

- Enhancement site
- Existing railway
- Waterbodies
- Waterways
- Monitoring bore



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3.4.2 GROUNDWATER LEVEL MONITORING

Automated groundwater level monitoring and data recording equipment (dataloggers) were installed in all groundwater monitoring bores during GME 1. Dataloggers were time synchronised and programmed to record at six-hourly intervals.

Two barometric loggers were also installed during GME 1, one at Albury (BH201) and one at Wagga Wagga (BH206), to allow the data to be compensated for atmospheric influences. Additionally, manual groundwater levels were measured during each GME using an electronic dip meter.

3.4.3 GROUNDWATER QUALITY MONITORING

Groundwater sampling was conducted during each GME in boreholes where groundwater was observed. Samples were collected following purging, a 12-volt submersible pump that was positioned adjacent to the screen sections of the groundwater monitoring bores. The pump was decontaminated between each monitoring bore to prevent potential cross-contamination. Where limited groundwater was encountered, the monitoring bore was purged dry and allowed to recover before a disposable plastic bailer was used to obtain a grab sample.

The physiochemical parameters were recorded periodically using a calibrated water quality meter during purging and groundwater samples were obtained following stabilisation of parameters to within 10 per cent (or 0.2°C for temperature), in accordance with *Groundwater Sampling and Analysis – a field guide* (Geoscience Australia, 2009). Where groundwater recovery was slow, the monitoring bore was purged dry and allowed to recharge before sampling.

Groundwater samples were collected in laboratory supplied bottles with appropriate preservation where required in accordance with Australian/New Zealand Standard 5667:2016, *Water Quality – Sampling Guidance on Sampling of Groundwaters* (AS/NZS 5667:2016). Samples collected for dissolved metal analysis were field filtered through a 0.45 micrometre (µm) filter. All groundwater samples were transported under appropriate chain-of-custody protocols in an ice-filled esky to a National Association of Testing Authorities accredited laboratory within holding times.

Table 3.4 details the groundwater field measurements and laboratory analytical suite.

Table 3.4 Groundwater analytical suite

CATEGORY	PARAMETERS[1]		ANALYTICAL METHOD
Physiochemical parameters	EC Temperature DO	pH ORP TDS	Field measurements via calibrated water quality meter. EC was also sent for laboratory analysis with calculated TDS reported.
Major anions	Chloride Bicarbonate	Sulphate	Laboratory analysis
Major cations	Calcium Sodium	Magnesium Potassium	Laboratory analysis
Dissolved metals	Arsenic Cadmium Chromium Copper	Mercury Nickel Lead Zinc	Laboratory analysis

(1) DO = dissolved oxygen; EC = electrical conductivity; ORP = oxidation reduction potential; TDS = total dissolved solids.

Groundwater quality data analysis results are provided in section 4.5.4.4. Laboratory results are listed in water quality tables provided in Appendix C.

3.4.4 HYDRAULIC CONDUCTIVITY TESTING

Hydraulic conductivity was assessed at all monitoring bore locations where groundwater was present during GME 1 to provide an estimate for inflow and drawdown assessments, if required. Hydraulic conductivity testing involved rising or falling head tests, commonly referred to as 'slug tests' or short-term recovery tests depending on groundwater conditions. Slug tests were performed with the insertion and removal of a physical slug tube made of solid acrylic. Where groundwater recovery was limited, the bores were pumped 'dry' using a 12-volt submersible pump and allowed to recover as a short-term recovery test. During hydraulic conductivity testing, groundwater levels were measured using dataloggers.

Hydraulic conductivity results were analysed in AQTESOLV© software using the Bouwer and Rice (1976) solution. Where groundwater conditions resulted in poor or limited data, hydraulic conductivity was qualified within the relevant conceptual hydrogeological model (section 4.8).

3.5 GROUNDWATER QUALITY OBJECTIVES

Groundwater quality describes the condition of water within the groundwater source and its suitability for different purposes, such as whether it can be used for town water, stock and domestic supply or irrigation. One way of assessing groundwater quality is by the salinity of the water resource.

Beneficial use categories are general groupings of groundwater uses based on water quality; primarily based on salinity and the absence or presence of contamination, but can include water quality indicators for sodium absorption ratio, nutrients and pathogens. The overriding principle is that groundwater quality should be maintained within its beneficial use category. Beneficial use is the equivalent of environmental value (ANZECC, 2000). Beneficial use categories:

- was adopted in the NSW Groundwater Quality Protection Policy (DLWC, 1998)
- has been adopted in the NSW AIP (DPI, 2012)
- are used in the relevant WRPs.

Given the above, beneficial use categories based on salinity have been adopted for this assessment and are listed in the relevant WRP's (DPIE, 2019b, 2019c & 2019d). Salinity beneficial use categories are provided in Table 3.5. The placement of a 'tick' indicates the categories suitability for the listed beneficial use.

Table 3.5 Beneficial use categories adopted for assessment (DPIE 2019a, 2019b & 2019c)

BENEFICIAL USE	SALINITY (TDS mg/L)[1]						
	A1	A2	A3	B	C1	C2	D
	0-600	600-900	901-1,200	1,201-3,000	3,001-6,000	6,001-10,000	>10,000
Aquatic ecosystem protection	✓	✓	✓	✓	✓	✓	✓
Primary industries – Irrigation	✓	✓	✓	✓			
Primary industries – Stock drinking water	✓	✓	✓	✓	✓	✓	
Recreation and aesthetics	✓	✓	✓	✓	✓	✓	✓
Raw drinking water	✓	✓	✓				
Industrial water	✓	✓	✓	✓	✓	✓	✓
Cultural and spiritual	✓	✓	✓	✓	✓	✓	✓

(1) Conversion from mg/L to µs/cm (conversion factor of 0.67) is A1 = 0-896, A2 = 897-1,343, A3 = 1,344-1,791, B = 1,792-4,478, C1 = 4,479-8,955, C2 = 8,956-14,925 and D = >14,925.

Salinity targets for GDEs associated with aquatic ecosystems that rely on the surface expression of groundwater, as identified in the WRPs, are listed below:

- 900mg/L (1,343µs/cm) for GDEs identified in section 4.6.2 that are within 100m of the riparian zone
- 3,000mg/L (4,478µs/cm) for remaining GDEs that access fresh water.

For an assessment regarding potential groundwater contamination, refer to Technical Paper 13: Contamination.

3.6 WATER BALANCE MODEL

The NSW Government maintains groundwater models to support groundwater resource management and the development of water sharing plans. These models calculate the groundwater available for sustainable extraction within a groundwater source and are managed through WRPs and water sharing plans. The impact of the proposal on the existing groundwater balance was assessed by identifying any groundwater take resulting from the proposal; including the volume, frequency, duration and source against the relevant sustainable diversion limits and historic groundwater availability.

3.7 WATER SUPPLY

A high-level review of the suitability of groundwater as a water supply for construction purposes was undertaken and considered:

- anticipated groundwater quality and yield identified through the desktop assessment and field investigations
- legislative considerations, such as the long-term average annual extraction limits (LTAAEL), the total number of WALs (which are generally required to extract water from aquifers for use), water made available and water usage for the potential groundwater source.

The review does not take into consideration feasibility or point specific sources, such as extraction or licensing locations.

3.8 IMPACT ASSESSMENT

The following subsections provide an overview for the impact assessment methodology, with the following key impact assessment items: dewatering quantification, groundwater demand and water balance, impact risk ratings and minimal impact consideration, discussed in further detail.

3.8.1 METHODOLOGY

A qualitative assessment of the potential groundwater impacts from the proposal was conducted and considers the findings of the desktop review and site investigations. The primary potential groundwater impact mechanism was determined to occur through construction or operation activities that intersected the permanent regional water table. These activities included bulk excavation earthworks for treatment of foundation soils and track lowering.

The water table for each enhancement site was determined by developing a conceptual hydrogeological model that considered the available groundwater data obtained from the desktop assessment and site investigations.

Enhancement sites where construction and operation activities were determined to potentially intersect the permanent regional water table were considered at higher risk and discussed in further detail.

The following was considered for all enhancement sites:

- the existing hydrogeological environment (water levels and quality, registered bores and GDEs) and hydrogeological conceptual model
- the potential impacts and their risk to the hydrogeological environment from construction and operational activities, including:
  - the risk of penetrating the groundwater table
  - quantitative estimates of dewatering volumes, rates and radius of impact at sites identified at high risk of penetration that would result in groundwater take (where dewatering will be required)
  - potential changes to the availability and water quality for GDEs and registered water supply bores
- the effectiveness of identified mitigation measures
- any residual impacts post-mitigation.

The construction impact assessment aims to identify potential impacts to groundwater based on the current understanding of the likely construction approach and construction methods.

The operational impact assessment identifies potential impacts to groundwater from the operation of the proposal.

3.8.2 DEWATERING QUANTIFICATION

As outlined in the methodology, where the regional water table was identified to be at risk of intersection from the proposal, including requirements for dewatering, a quantitative assessment was undertaken. Table 3.6 lists the analytical groundwater flow equations used to determine quantitative groundwater inflow (dewatering) and radius of influence estimates for the construction and operation of the proposal. The calculated groundwater inflow from each inflow equation (equations 1 to 3) was combined to determine total dewatering volume.

Table 3.6 Groundwater flow equations used for dewatering and radius of influence estimates

EQUATION	FORMULA	PARAMETERS[1]
1 Base flow (Darcy)	$Q_b = \dfrac{KHA}{H+R}$	Q_b = base flow (L/s) K = hydraulic conductivity (m/s) H = dewatering depth (m) A = area (m^2) R = radius (m)
2 Parallel flow (Dupuit-Forchheimer)	$Q_p = \dfrac{0.5KH^2P}{R}$	Q_p = parallel flow (L/s) K = hydraulic conductivity (m/s) H = dewatering depth (m) P = perimeter (m) R = radius (m)
3 Radial flow (Dupuit-Forchheimer)	$Q_r = \dfrac{\pi KH^2}{\ln(R)}$	Q_r = radial flow (L/s) K = hydraulic conductivity (m/s) H = dewatering depth (m) R = radius (m)
4 Radius of influence (Bear)	$R = 1.5\sqrt{\dfrac{KH_{r}t}{S_y}}$	R = radius (m) K = hydraulic conductivity (m/s) H = dewatering depth (m) t = time (day) Sy = specific yield

(1) L/s = litres per second; m/s = metres per second.

3.8.3 GROUNDWATER DEMAND AND WATER BALANCE

An assessment groundwater demand, potential impact and final groundwater balance for each groundwater source relevant to the proposal was undertaken. The required water demand during construction and operation of the proposal was considered, including any groundwater take resulting from dewatering, and the availability of groundwater including:

- availability of the groundwater based on the allocation (share component) of each relevant groundwater source compared to the sustainable diversion limits set in the corresponding water sharing plans
- historic usage of the groundwater sources within each water year (July to June) since 2015/2016.

3.8.4 IMPACT RISK RATINGS

For the purpose of this assessment, four potential impact significance rating categories were assessed with respect to potential impacts relating to the proposal. The assigned impact ratings are:

- negligible, which indicates the impact is considered to cause no perceptible change to the local or regional hydrogeological environment
- low, which indicates a low potential for limited (in extent and/or time) impact to the hydrogeological environment may exist. However, the potential impact would cause no permanent perceptible change to the regional hydrogeological environment including GDEs and registered users
- moderate, which indicates a potential for permanent, but limited impact to the local hydrogeological environment may exist. However, the potential impact would cause no perceivable change to the regional hydrogeological environment
- high, which indicates a potential for permanent impact to the hydrogeological environment at both the local and regional scale. The potential impact could cause significant changes to groundwater availability or quality.

Outcomes of the impact assessment were used to develop mitigation measures to inform future stages of the design, construction and operation of the proposal.

3.8.5 MINIMAL IMPACT CONSIDERATION

An assessment of the proposals impacts from the potential changes in groundwater levels and quality on GDEs, beneficial use category, water supply works (i.e. registered bores), highly connected surface water sources and culturally significant sites, against the minimal impact consideration criteria outlined in the AIP (DPI, 2012), was undertaken in section 5.3.

4 EXISTING ENVIRONMENT

The following sections within this chapter discuss key existing environment features most relevant to the hydrogeological environment. Details on catchments and surface water features are discussed in Technical Paper 11: Hydrology, flooding and water quality, with details on soils provided in the Technical Paper 13: Contamination.

4.1 TOPOGRAPHY

A discussion of the topography relevant to each precinct is provided in the following sections.

4.1.1 ALBURY PRECINCT

The elevation of the enhancement sites in the Albury precinct (Murray River bridge, Albury Station pedestrian bridge and Yard clearances, Riverina Highway bridge, Billy Hughes bridge and Table Top Yard clearances) range from about 150m Australian Height Datum (mAHD) at the Murray River to 230mAHD. The land generally slopes to the south towards the Murray River.

4.1.2 GREATER HUME – LOCKHART PRECINCT

The enhancement sites in Greater Hume – Lockhart precinct (Culcairn pedestrian bridge and Yard clearances, Henty Yard clearances, Yerong Creek Yard clearances and The Rock Yard clearances) are located at about 210 to 220mAHD. The topography generally slopes to the north, west to the Murrumbidgee River, however there are localised high points along the Olympic Highway which drain to various tributaries of the Murrumbidgee River.

4.1.3 WAGGA WAGGA PRECINCT

The enhancement sites in the Wagga Wagga precinct (Uranquinty Yard clearances, Pearson Street bridge, Wagga Wagga Station and surrounds and Bomen Yard clearances) are located at an elevation of about 190 to 200mAHD at the south of the Murrumbidgee River. The topography generally slopes to the north to the Murrumbidgee River, however there are localised high points along the Olympic Highway which drain to various tributaries of the Murrumbidgee River.

The Bomen yard clearance enhancement site is located at about 230 mAHD elevation and generally slopes south to the Murrumbidgee River.

4.1.4 JUNEE PRECINCT

The topography within the Junee precinct (Harefield Yard clearances, Junee Station and surrounds, Olympic Highway underbridge and Junee to Illabo clearances) are discussed below.

The topography generally slopes from the Harefield Yard clearances, located at an elevation of about 250mAHD, up towards Junee with Junee Station and surrounds and Olympic Highway underbridge at elevations of about 300 to 320mAHD. For the Junee to Illabo clearances enhancement site, the elevation varied from 250 in the east to 360mAHD in the west.

Junee Station and surrounds are located in a topographic depression that extends towards the north-northwest, with neighbouring hills to the south, east and west peaking at approximately 360mAHD.

4.2 CLIMATE

Table 4.1 summarises rainfall and evaporation statistics across the four precincts (BOM, 2021).

Table 4.1 Climate data obtained from the Bureau of Meteorology (BOM) across the four precincts

PRECINCT	BOM STATION	CLIMATE DATA	RECORD (mm)	COMMENT
Albury	Albury Airport (#072160)	Mean monthly rainfall (1994–2020)	39.3–65.9	Maximum rainfall typically occurs in winter (June, July and August). Minimum rainfall typically occurs from December to April.
		Historic annual rainfall range (1994–2020)	296.6–916.4	Historic minimum occurred in 2006. Historic maximum occurred in 2010.
		Mean yearly rainfall	609.9	–
	Hume Reservoir (#072023)	Mean monthly evaporation (1965–2020)	30.0–241.8	Maximum evaporation occurs in summer (December, January and February). Minimum evaporation occurs from May to August.
Greater Hume – Lockhart	Henty post office (#074053)	Mean monthly rainfall (1901–2020)	39.0–58.9	Maximum rainfall typically occurs in winter (June, July and August). Minimum rainfall typically occurs between November and April.
		Historic annual rainfall range (1901–2020)	226.5–1053.3	Historic minimum occurred in 1967. Historic maximum occurred in 1974.
		Mean yearly rainfall	589.3	–
		Mean monthly evaporation	–	No historical evaporation data available. Nearest data is from Wagga Wagga AMO (#72150), approximately 55km north.

PRECINCT	BOM STATION	CLIMATE DATA	RECORD (mm)	COMMENT
Wagga Wagga	Wagga Wagga AMO (#72150)	Mean monthly rainfall (1941–2020)	40.1–55.8	Maximum rainfall typically occurs in July or October. Minimum rainfall typically occurs from January to April.
		Historic annual rainfall range (1941–2020)	245.2–1019.2	Historic minimum occurred in 1967. Historic maximum occurred in 2010.
		Mean yearly rainfall	571.4	–
		Mean monthly evaporation (1948–2003)	36.0–313.1	Maximum evaporation occurs in summer (December, January and February). Minimum evaporation occurs in winter (June, July and August).
Junee	Junee Treatment Works (#073019)	Mean monthly rainfall (1892–2020)	37.6–50.3	Maximum rainfall typically occurs in June, July or October. Minimum rainfall typically occurs between December and April.
		Historic annual rainfall range (1892–2020)	198.1–907.1	Historic minimum occurred in 2006. Historic maximum occurred in 1956.
		Mean yearly rainfall	526.0	–
		Mean monthly evaporation	–	No historical evaporation data available. Nearest data is from Wagga Wagga AMO (#72150), approximately 35km south.

4.2.1 LONG TERM RAINFALL TRENDS

Long term cumulative rainfall residual plots provide an indication of the broad scale trends in rainfall pattern behaviour. These plots are formulated by subtracting the average rainfall for the recorded period from the actual rainfall and then accumulating the residual difference over the assessment period. The long term annual cumulative deviation from mean (CDFM) rainfall is a simplistic statistical technique that can identify potential changes in groundwater levels of unconfined aquifers that receive direct recharge through rainfall (Ali et al., 2010). Periods of below average rainfall are represented as downward trending slopes, while periods of above average rainfall are represented as upwards trending slopes. The long term annual CDFM rainfall with total annual rainfall for Albury (BOM station ID #072160) and Wagga Wagga (BOM station ID #072150) are plotted in Figure 4.1 and Figure 4.2, respectively, with the peak of significant droughts (drier climatic conditions) also graphed. These stations were selected due to their location within the proposal and relative history and quality of available data.

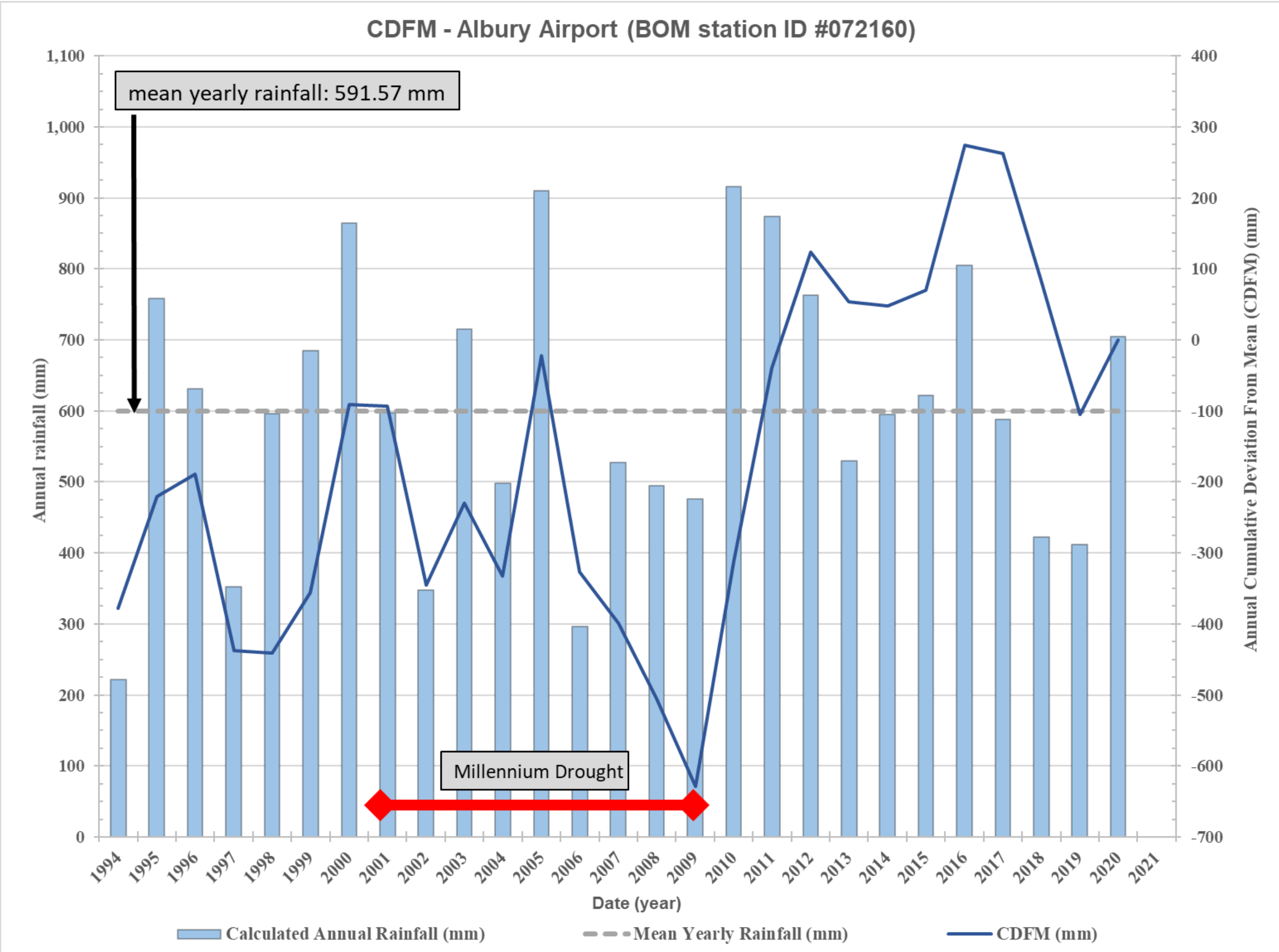


Figure 4.1 Historic annual rainfall recorded at Albury from 1994–2020 (BOM station ID #072160)

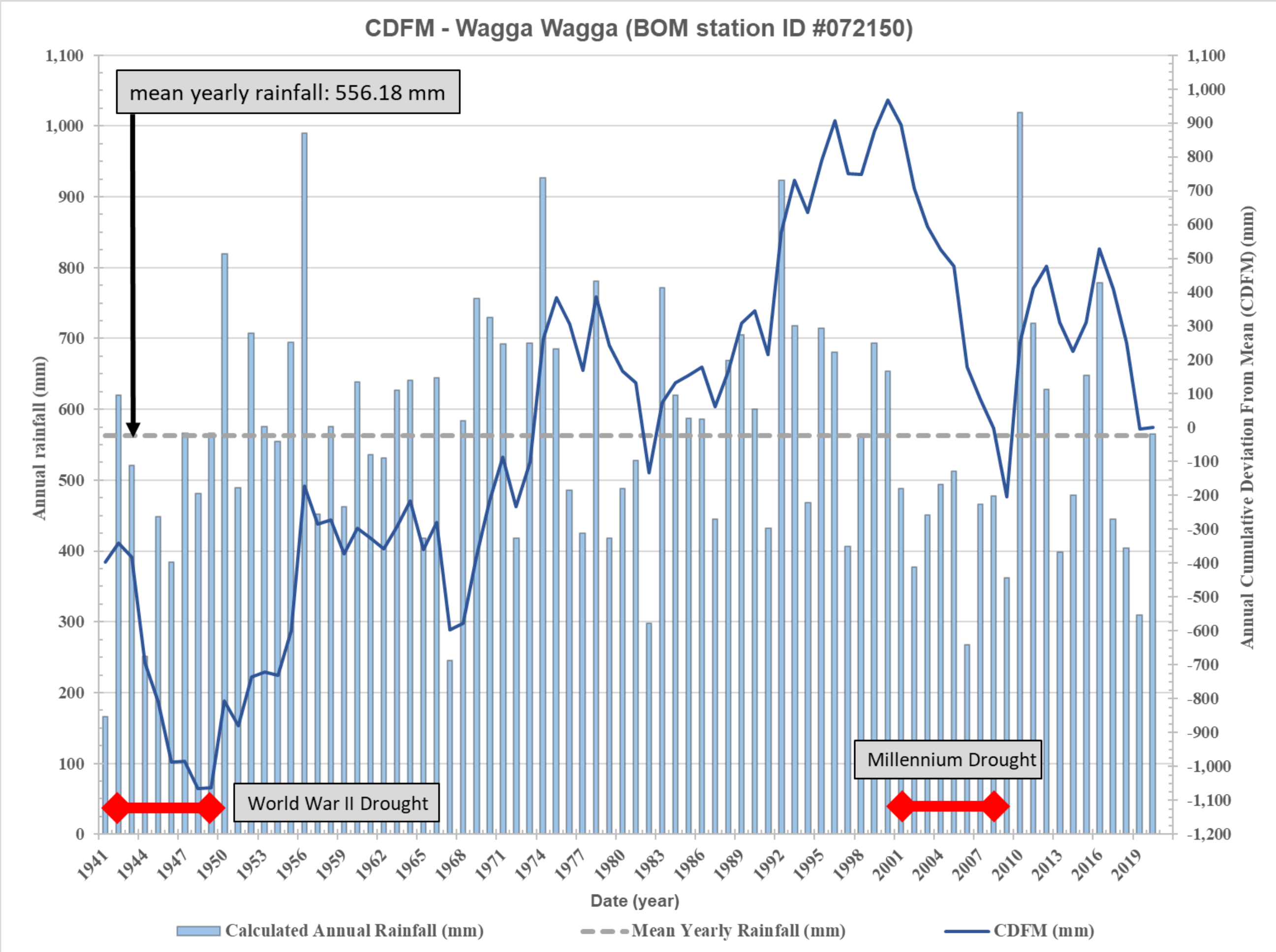


Figure 4.2 Historic annual rainfall recorded at Wagga Wagga from 1941–2020 (BOM station ID #072150)

The two CDFM charts contain similar trends across their overlapping monitoring period from 1994–2020 indicating the sites share similar climatic conditions. Both locations contained below average rainfall conditions witnessed through the millennium drought (2001–2009) and in recent years from 2016–2019 (Wagga Wagga) or 2017–2019 (Albury). They also reveal wetter conditions immediately following the millennium drought. The millennium drought is generally considered to represent the dry climatic conditions from late 1996 to mid-2010, with peak drought conditions occurring between 2001 to 2009 (BOM, 2015).

Wetter climatic conditions were experienced during the most recent full calendar year (2020) and during the groundwater monitoring period in 2021 (refer to section 3.4), evident at both BOM sites. Note the 2021 data is not shown in Figures 4.1 and 4.2 given the incomplete dataset. At the Albury and Wagga Wagga BOM stations, above monthly rainfall averages were experienced from January to June 2021, with a total monthly cumulative rainfall balance of +79.9mm and +142.5mm, respectively.

4.3 GEOLOGY

4.3.1 REGIONAL GEOLOGY

A summary of mapped geological units and features which are shown to underlie the proposal sites are provided in Table 4.2.

Table 4.2 Summary of mapped geological units within the four precincts

PRECINCT	REGIONAL GEOLOGY
Albury	The Albury 1:50,000 Geological Sheet indicates the area is underlain by Quaternary alluvial deposits of sand, silt, clay and gravel in flood and soil plain areas. Underlying rock consists of Devonian Jindera Granites consisting of rhyolite, quartz feldspar porphyry, micaceous quartzite, tuff, and porphyritic biotite granite and granodiorite. The groundwater study area is intersected by and unconformity mapped as a lineament. Zones around the unconformity show schists of the Omeo-Albury Metamorphic Complex including biotite sillimanite schist, mica schist, quartz-mica schist and andalusite-sillimanite-quartz-feldspar gneiss.
Greater Hume – Lockhart	Wagga Wagga 1:250,000 Geological Sheet shows the sites are generally located on Quaternary alluvium deposits comprising of gravel, sand, silty and clay. Underlying bedrock consists of the Devonian Byron Range Group, comprising conglomerate, sandstone, quartzite, reddish shale and siltstone, and the Ordovician Kindra Beds, comprising of quartzite, slate, phylitte, greywacke, hornfels, schist and porphyry.
Wagga Wagga	Wagga Wagga 1:250,000 Geological Sheet shows the area is underlain by deep Quaternary alluvium comprising of gravel, sand, silty and clay. Underlying bedrock consists of the Ordovician Wantabadgery Granite, comprising granodiorite, gneissic granite and gneiss, and the Kiandra Beds, comprising quartzite, slate, phylitte, greywacke, hornfels and schist.
Junee	The Cootamundra 1:250,000 Geological Sheet indicates the area is underlain by Quaternary colluvium/alluvium and alluvium consisting of gravel, sand silt and clay. The underlying rock units are divided by the Gilmore Fault Zone, separating the Wantabadgery Granite consisting of granite/granodiorite (possibly in multiple intrusions) and the Combaning Formation consisting of siltstone, sandstone, shale, conglomerate and minor felsic volcanic rocks.

4.3.2 SITE GEOLOGY

Table 4.3 provides a summary of the geology encountered during intrusive investigations at each enhancement site undertaken as part of geotechnical investigations completed for the proposal. The listed depths provide a summary of the minimum and maximum depth the dominant geology was encountered for all intrusive investigation locations conducted within each enhancement site. Intrusive investigation locations along with regional mapped geology is depicted in Figure 4.3.

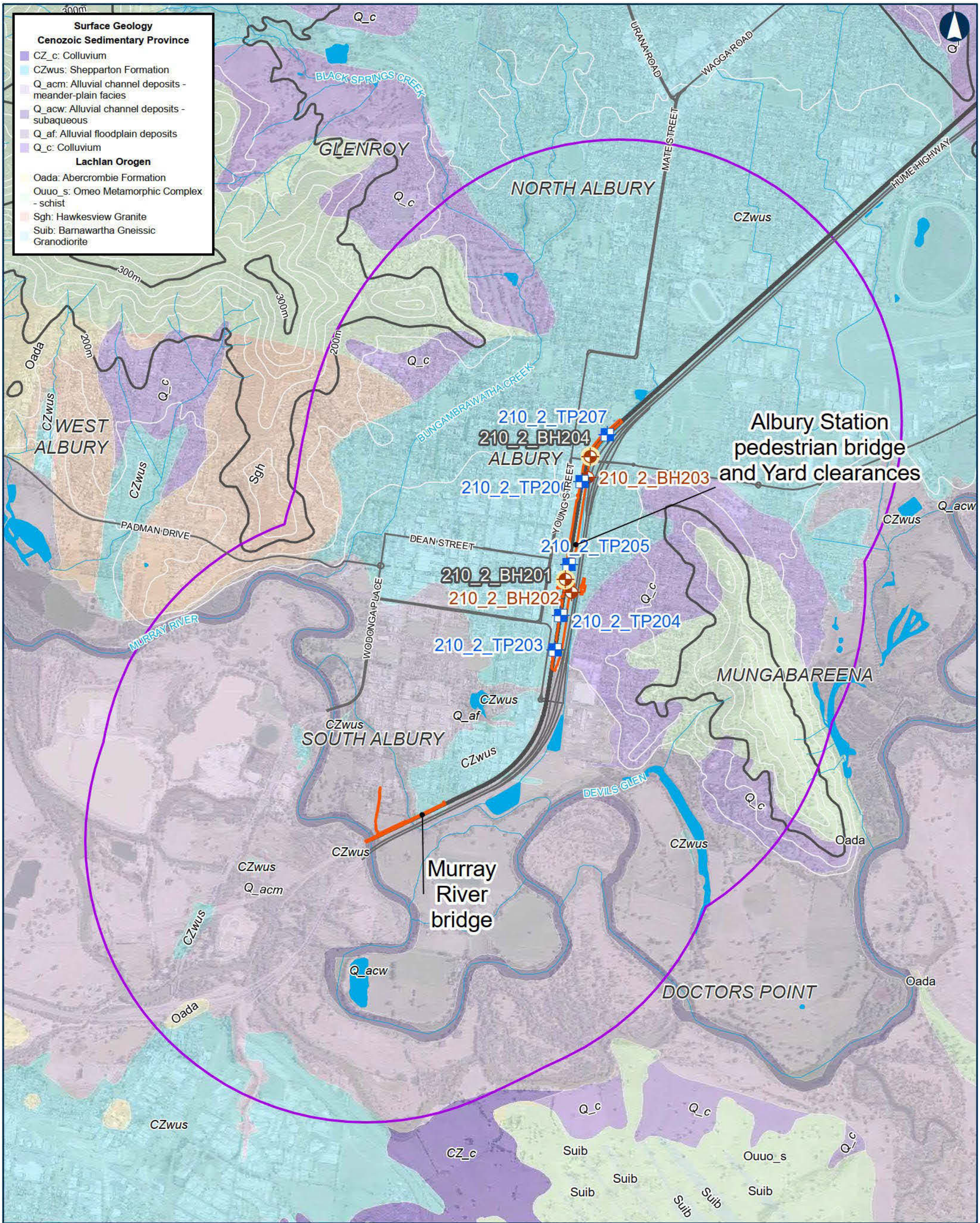
Table 4.3 Encountered geological conditions at enhancement sites

ENHANCEMENT SITE	APPROXIMATE GEOLOGICAL CONDITIONS[1]			
	Material type	Dominant geology	Minimum depth	Maximum depth
Albury precinct				
Murray River bridge	N/A[2]			
Albury Station pedestrian bridge and Yard clearances	Fill	Gravel	Absent	0.3
	Alluvium	Interbedded clays and sands	Surface	24.0
		Interbedded gravel and sands	24.0	30.0+
Riverina Highway bridge	Fill	Clay	Absent	0.3
	Alluvium	Interbedded clays and sands	Surface	15.0+
		Sands	10.0	15.0+
Billy Hughes bridge	Fill	Clays	Absent	0.5
	Residual soil	Clays	Surface	7.1
	Weathered rock	Sandstone, tuff and conglomerate	5.1	13.0
		Claystone	13.0	17.0+
Table Top Yard clearances	N/A[2]			
Greater Hume – Lockhart precinct				
Culcairn pedestrian bridge and Yard clearances	Fill	Gravels	Surface	1.0
	Alluvium	Clays	0.7	2.1+
Henty Yard clearances	Fill	Gravels	Surface	0.8
	Alluvium	Clays	0.7	2.2+
Yerong Creek Yard clearances	Fill	Gravels	Surface	1.3
	Alluvium	Clays	0.9	2.2+
The Rock Yard clearances	Fill	Gravels	Surface	0.8
	Alluvium	Clays	0.8	5.4+

ENHANCEMENT SITE	APPROXIMATE GEOLOGICAL CONDITIONS[1]			
	Material type	Dominant geology	Minimum depth	Maximum depth
Wagga Wagga precinct				
Uranquinty Yard clearances	Fill	Gravels	Absent	1.2
	Alluvium	Clays	Surface	9.3
		Interbedded clays and sands	9.3	17.4
	Residual soil	Clays	17.4	19.0
	Weathered rock	Granite	19.0	30.0+
Pearson Street bridge	Fill	Gravels	Surface	0.3
		Clays	Surface	2.3
	Alluvium	Interbedded clays and sands	Surface	6.0
	Residual soil	Clays	Surface	14.0
	Weathered rock	Meta-siltstone and sandstone	14.0	30.0+
Wagga Wagga Station and surrounds	Fill	Gravels	Surface	0.5
		Clays	Surface	0.2
	Alluvium	Clays	0.1	30.0+
		Interbedded clays, sands and gravels	14.0	28.0
	Residual	Clays	Surface	4.8+
		Sands	0.5	5.5
	Weathered rock	Meta-sandstone	5.5	18.0+
Bomen Yard clearances	Fill	Gravels	Surface	1.3
	Residual	Clays	1.1	2.1+
Junee precinct				
Harefield Yard clearances	Fill	Gravels	Surface	0.9
	Residual	Clays	0.9	2.0+
Junee Station and surrounds	Fill	Clays	Surface	2.6
		Sands	2.6	3.0
	Alluvium	Clays	Surface	5.5
	Colluvium	Clays	0.8	5.9
	Residual	Clays	5.0	29.9+
		Sands	15.5	21.8

ENHANCEMENT SITE	APPROXIMATE GEOLOGICAL CONDITIONS[1]			
	Material type	**Dominant geology**	**Minimum depth**	**Maximum depth**
Olympic Highway underbridge	Fill	Gravels	Surface	1.0
	Residual	Clays	Surface	11.2
		Sands and gravels	11.2	29.3+
	Weathered rock	Basalt	Surface	1.4+
		Granite	27.8	32.9+
Junee to Illabo clearances	Fill	Gravels	Surface	1.2
		Clays and sands	0.6	1.7
	Alluvium	Clays	0.9	2.0+
	Residual	Clays	0.7	2.4+

(1) Geological material type listed has been simplified to a dominant material type. All depths are listed in metres below ground level (mBGL) and where '+' listed indicates depth may exceed investigation termination depth.



Albury to Illabo

Figure 4.3 Regional geology map with geotechnical site investigation locations

MAP 1 OF 14

0 250 500 m

Coordinate System: GDA 1994 MGA Zone 55

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Date: 18/02/2022 Paper: A3
Author: WSP Scale: 1:25,000
Data Sources: ARTC, NSWSS

- Enhancement site
- Existing railway
- Groundwater study area
- Waterways
- Waterbodies
- Main road
- Borehole / monitoring bore
- Borehole
- Test Pit

Contour intervals
- 10m contour
- 50 m contour

ALBURY

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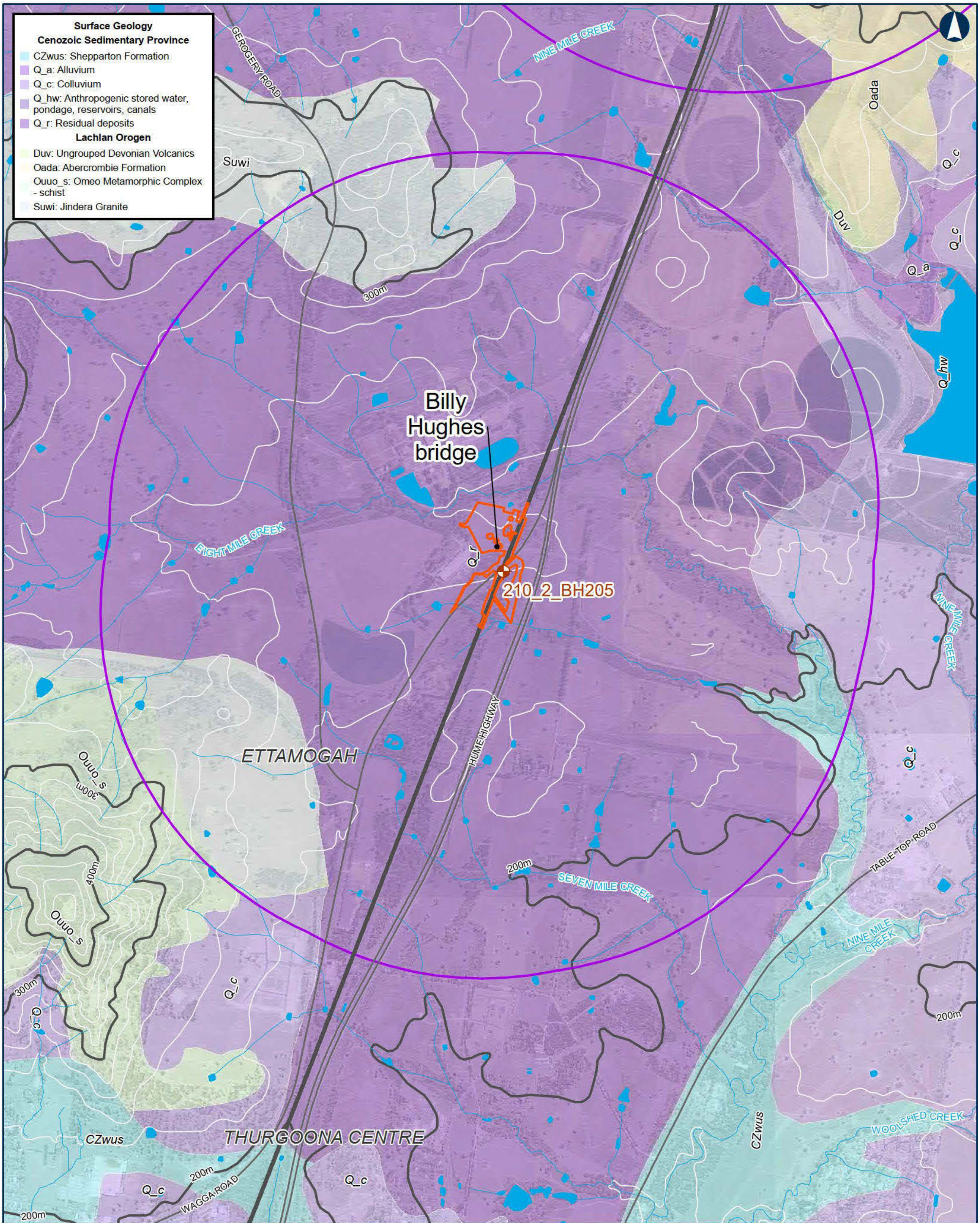

Albury to Illabo

Figure 4.3 Regional geology map with geotechnical site investigation locations

MAP 2 OF 14

0 250 500 m

Coordinate System: GDA 1994 MGA Zone 55

Date: 18/02/2022 Paper: A3
Author: WSP Scale: 1:20,000
Data Sources: ARTC, NSWSS

- Enhancement site
- Existing railway
- Groundwater study area
- Waterways
- Waterbodies
- Main road
- Borehole

Contour intervals
- 10m contour
- 50 m contour

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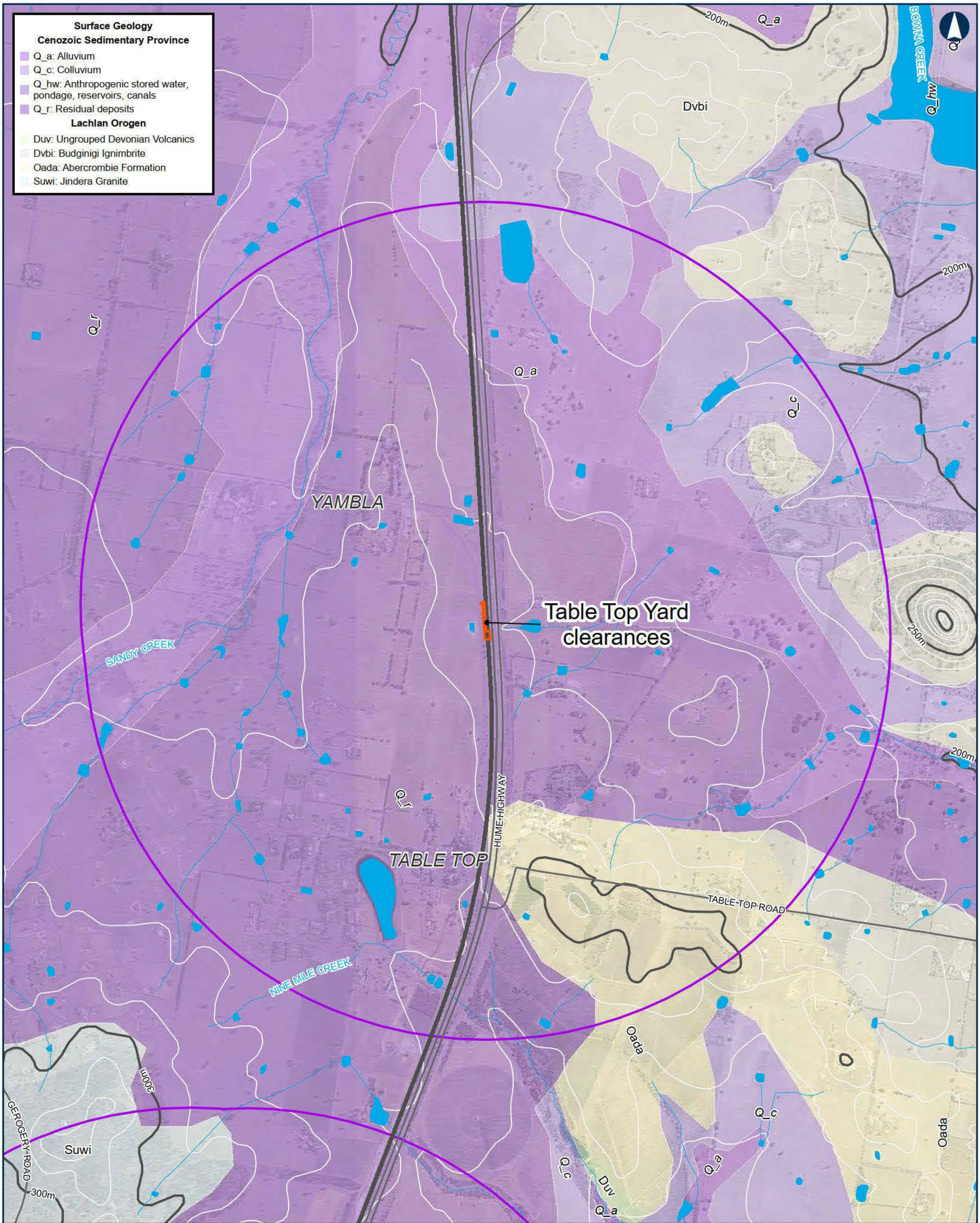

Albury to Illabo — Figure 4.3 Regional geology map with geotechnical site investigation locations — MAP 3 OF 14

0 250 500 m

Coordinate System: GDA 1994 MGA Zone 55

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Date: 18/02/2022 Paper: A3
Author: WSP Scale: 1:17,500
Data Sources: ARTC, NSWSS

- Enhancement site
- Existing railway
- Groundwater study area
- Waterways
- Waterbodies
- Main road

Contour intervals
- 10m contour
- 50 m contour

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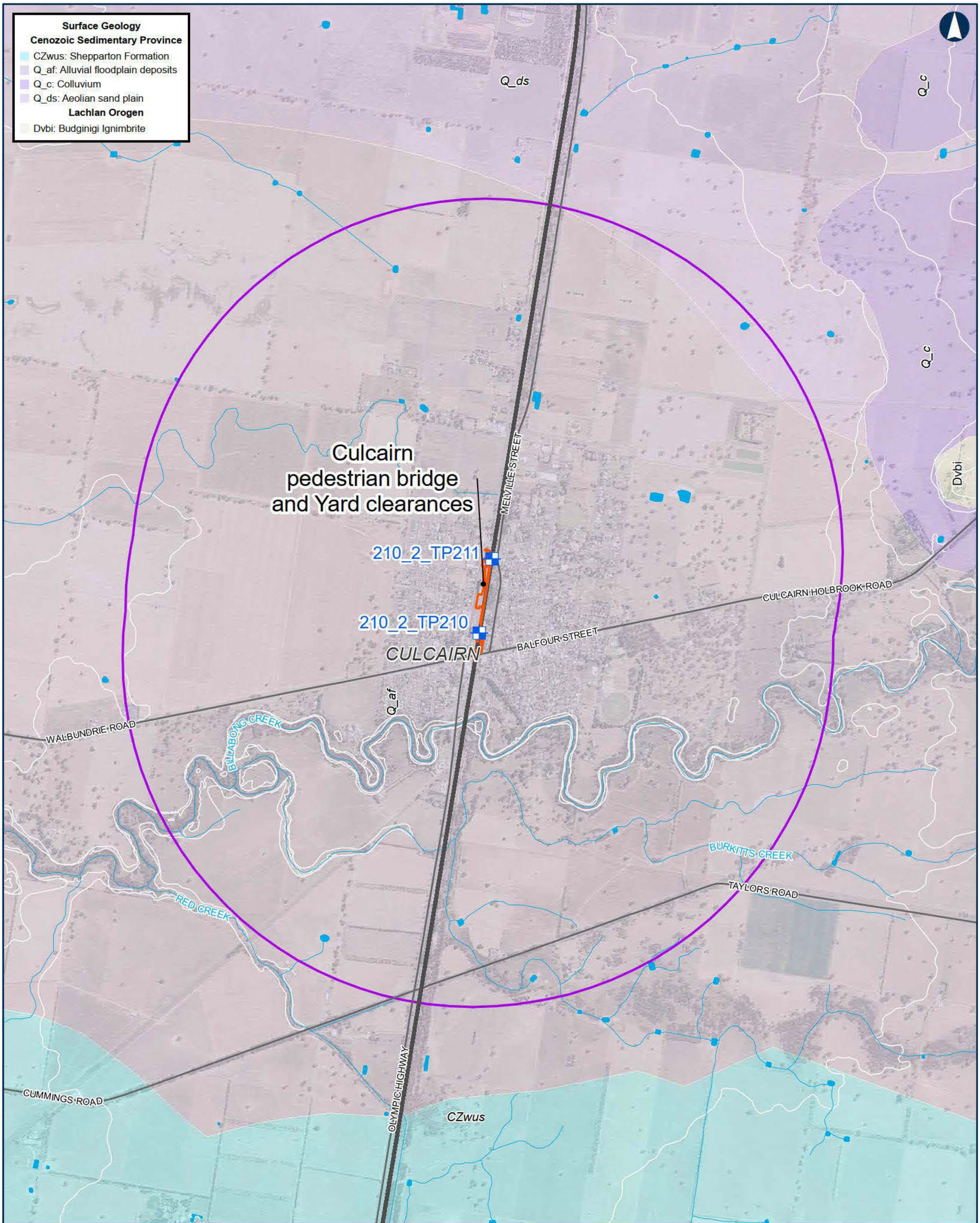


Albury to Illabo

Figure 4.3 Regional geology map with geotechnical site investigation locations

MAP 4 OF 14

0 250 500 m

Coordinate System: GDA 1994 MGA Zone 55

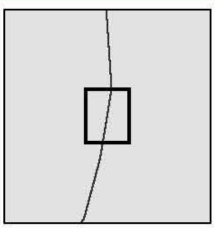
Date: 18/02/2022
Paper: A3
Author: WSP
Scale: 1:20,000
Data Sources: ARTC, NSWSS

Enhancement site
Existing railway
Groundwater study area
Waterways
Waterbodies
Main road

Test Pit

Contour intervals

10m contour



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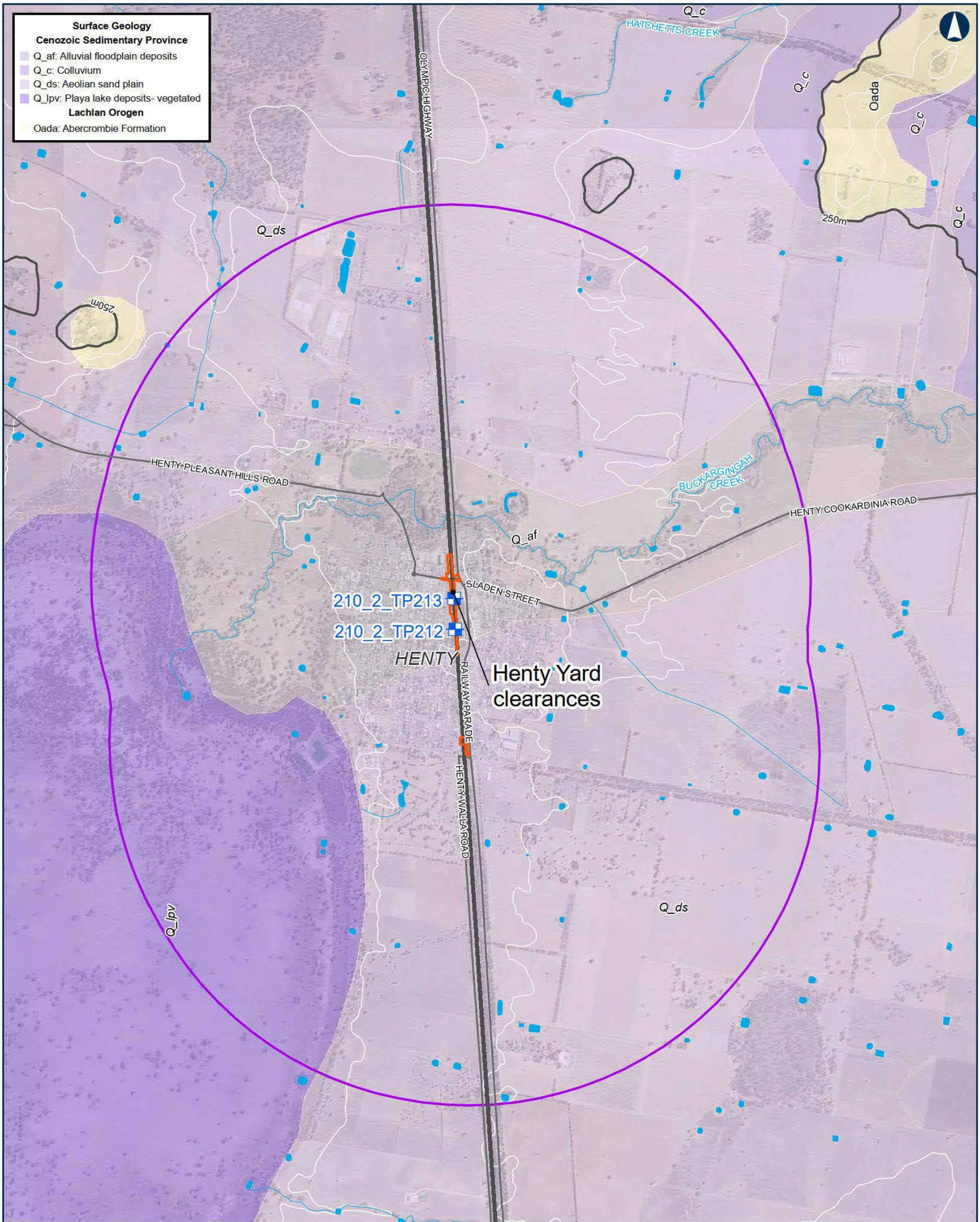

Albury to Illabo Figure 4.3 Regional geology map with geotechnical site investigation locations MAP 5 OF 14

0 250 500 m

Coordinate System: GDA 1994 MGA Zone 55

Date: 18/02/2022 Paper: A3
Author: WSP Scale: 1:20,000
Data Sources: ARTC, NSWSS

- Enhancement site
- Existing railway
- Groundwater study area
- Waterways
- Waterbodies
- Main road
- Test Pit

Contour intervals
- 10m contour
- 50 m contour

HENTY

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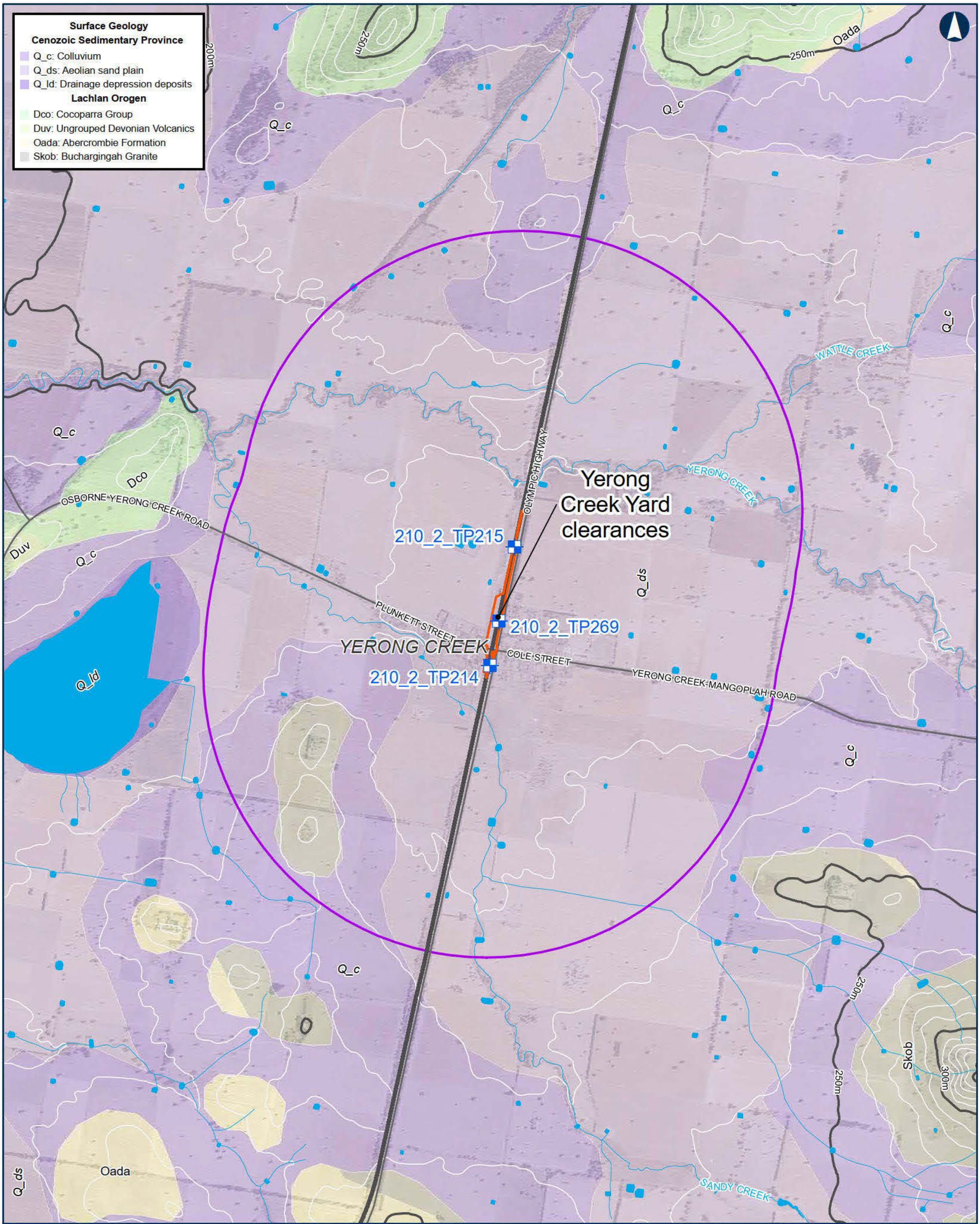

Albury to Illabo

Figure 4.3 Regional geology map with geotechnical site investigation locations

MAP 6 OF 14

0 250 500 m

Coordinate System: GDA 1994 MGA Zone 55

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Author: WSP Scale: 1:25,000
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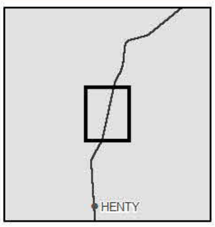
Enhancement site
Existing railway
Groundwater study area
Waterways
Waterbodies
Main road

Test Pit

Contour intervals
10m contour
50 m contour



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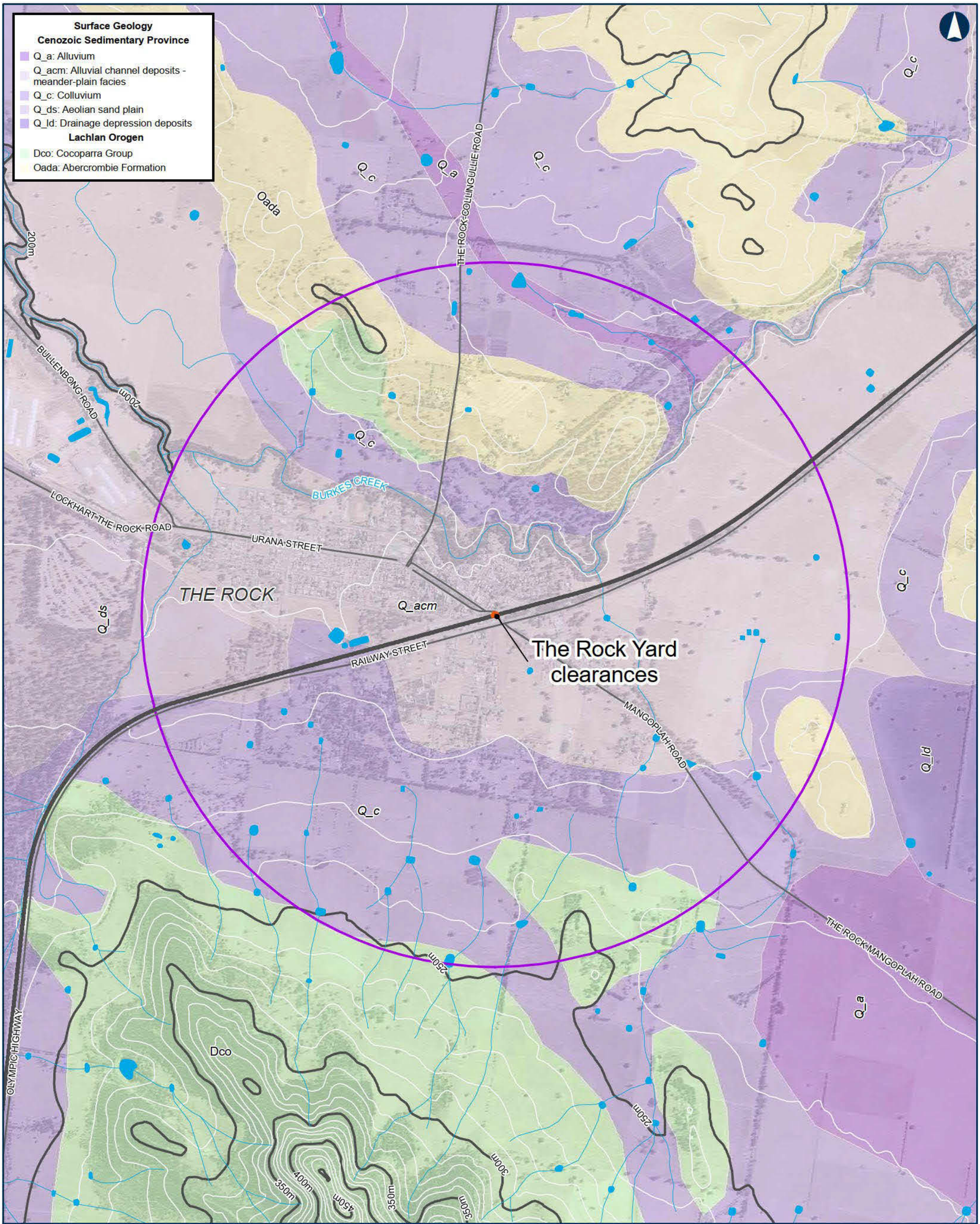

Albury to Illabo

Figure 4.3 Regional geology map with geotechnical site investigation locations

MAP 7 OF 14

0 250 500 m

Coordinate System: GDA 1994 MGA Zone 55

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Data Sources: ARTC, NSWSS

Paper: A3
Scale: 1:20,000

- Enhancement site
- Existing railway
- Groundwater study area
- Waterways
- Waterbodies
- Main road

Contour intervals

- 10m contour
- 50 m contour

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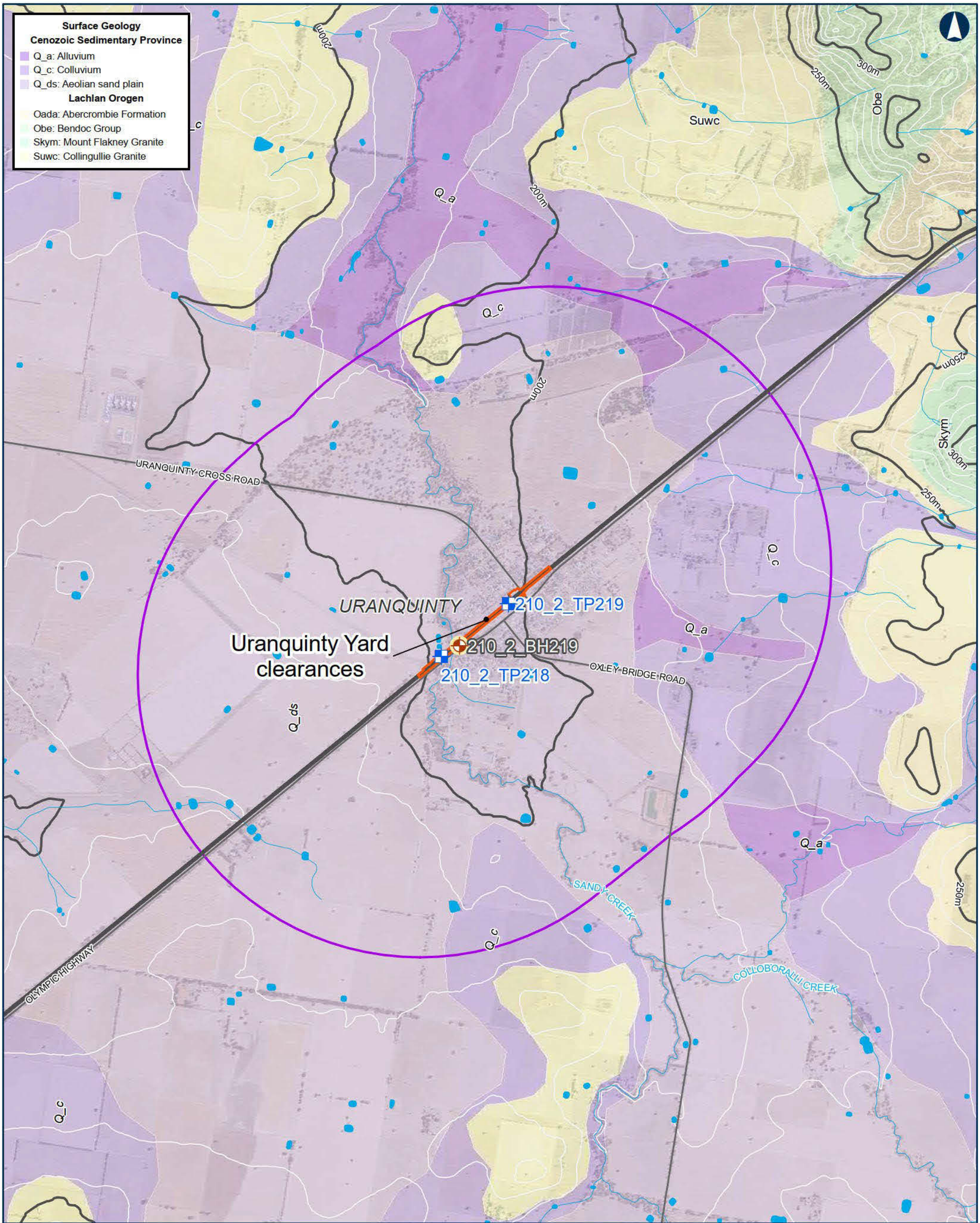

Albury to Illabo Figure 4.3 Regional geology map with geotechnical site investigation locations MAP 8 OF 14

0 250 500 m

Coordinate System: GDA 1994 MGA Zone 55

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Author: WSP Scale: 1:25,000
Data Sources: ARTC, NSWSS

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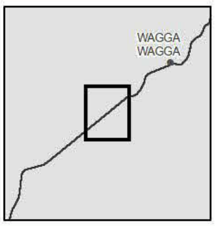
- Waterbodies
- Main road

- Borehole / monitoring bore
- Test Pit

Contour intervals
- 10m contour
- 50 m contour



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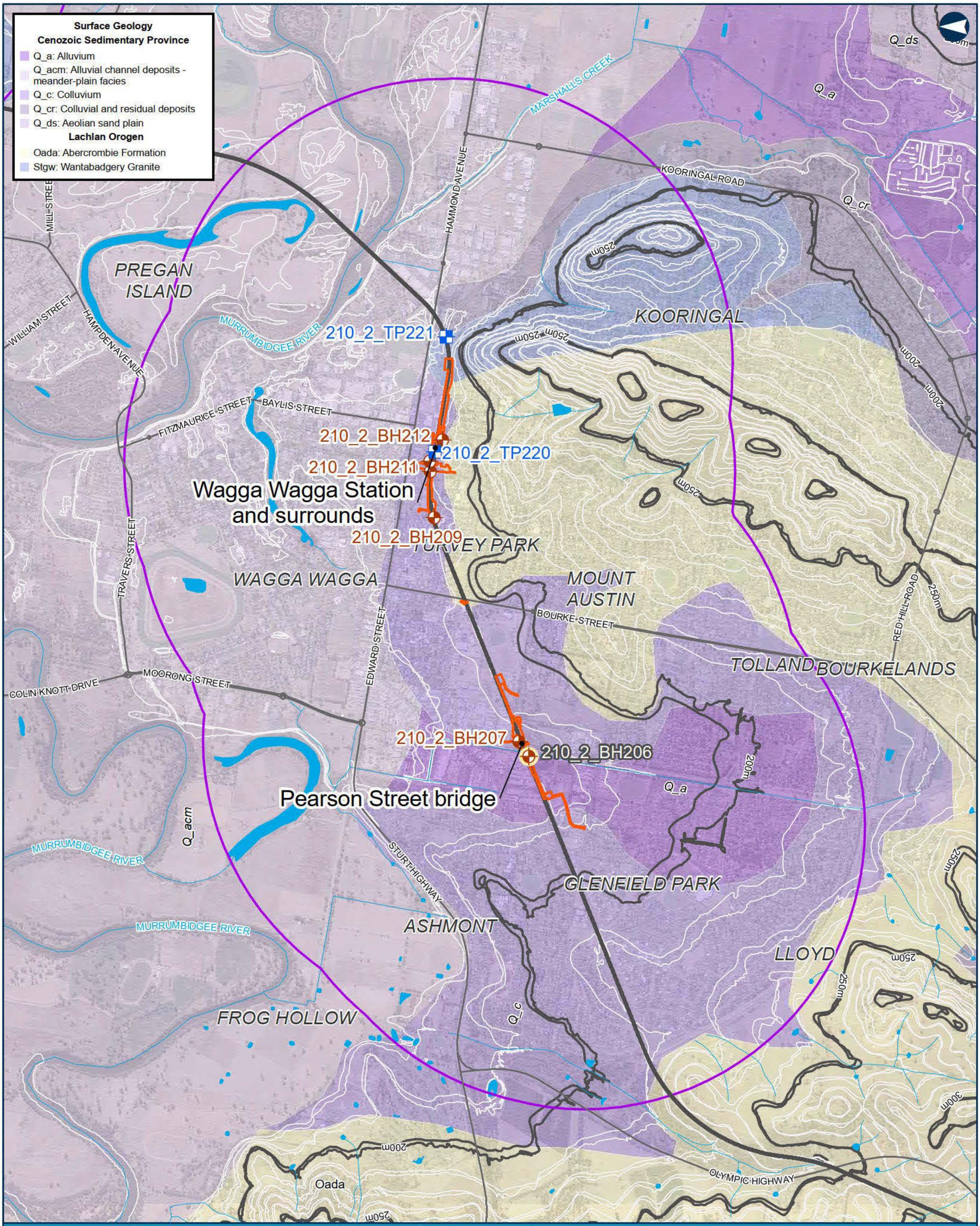

Albury to Illabo Figure 4.3 Regional geology map with geotechnical site investigation locations MAP 9 OF 14

0 250 500 m

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Author: WSP Scale: 1:25,000
Data Sources: ARTC, NSWSS

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- Waterbodies
- Main road
- Borehole / monitoring bore
- Borehole
- Test Pit

Contour intervals
- 10m contour
- 50 m contour

WAGGA WAGGA

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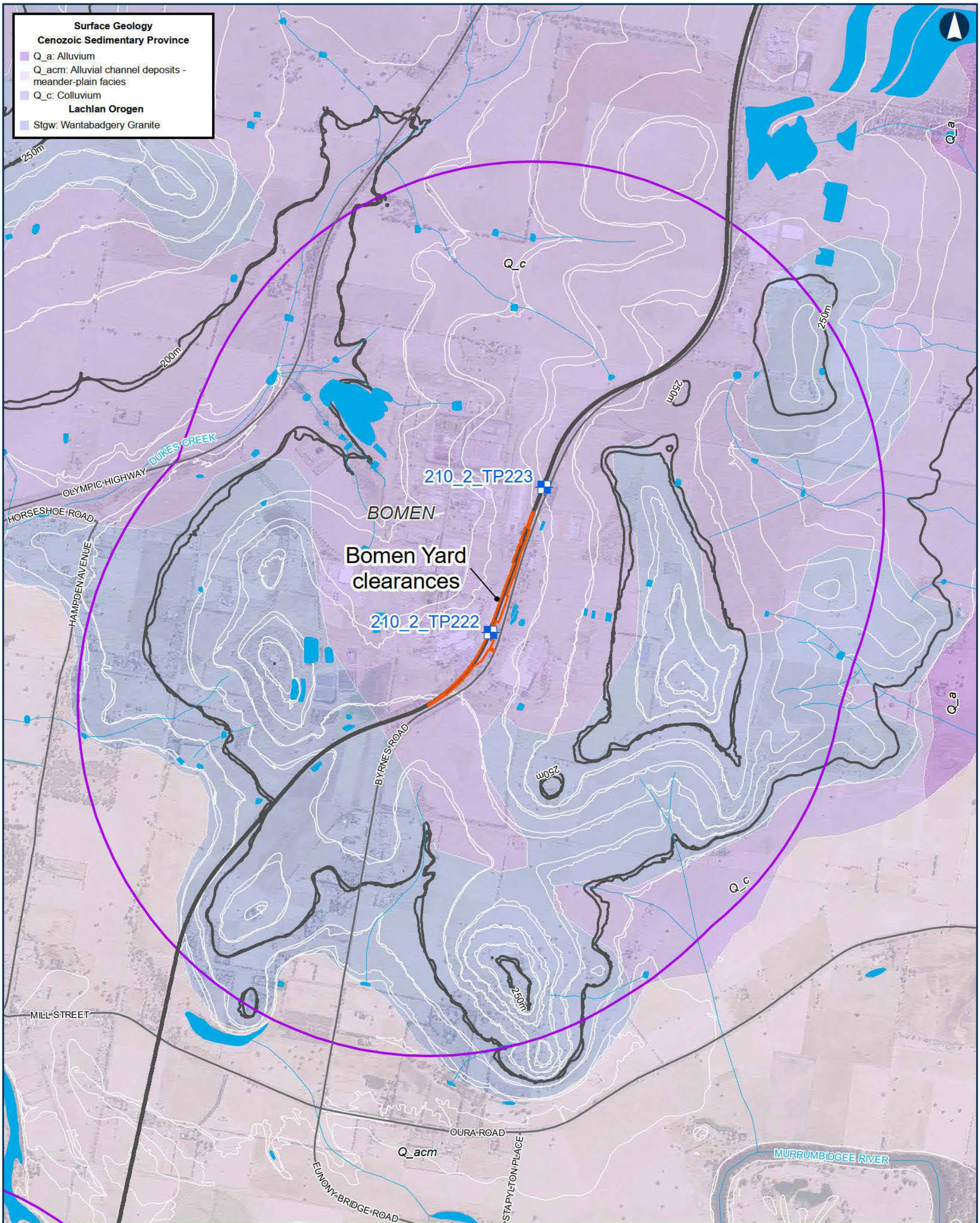

Albury to Illabo Figure 4.3 Regional geology map with geotechnical site investigation locations MAP 10 OF 14

0 250 500 m

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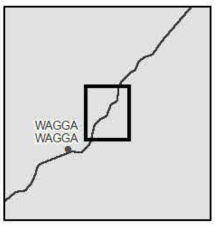
- Enhancement site
- Existing railway
- Groundwater study area
- Waterways
- Waterbodies
- Main road

Test Pit

Contour intervals
- 10m contour
- 50 m contour



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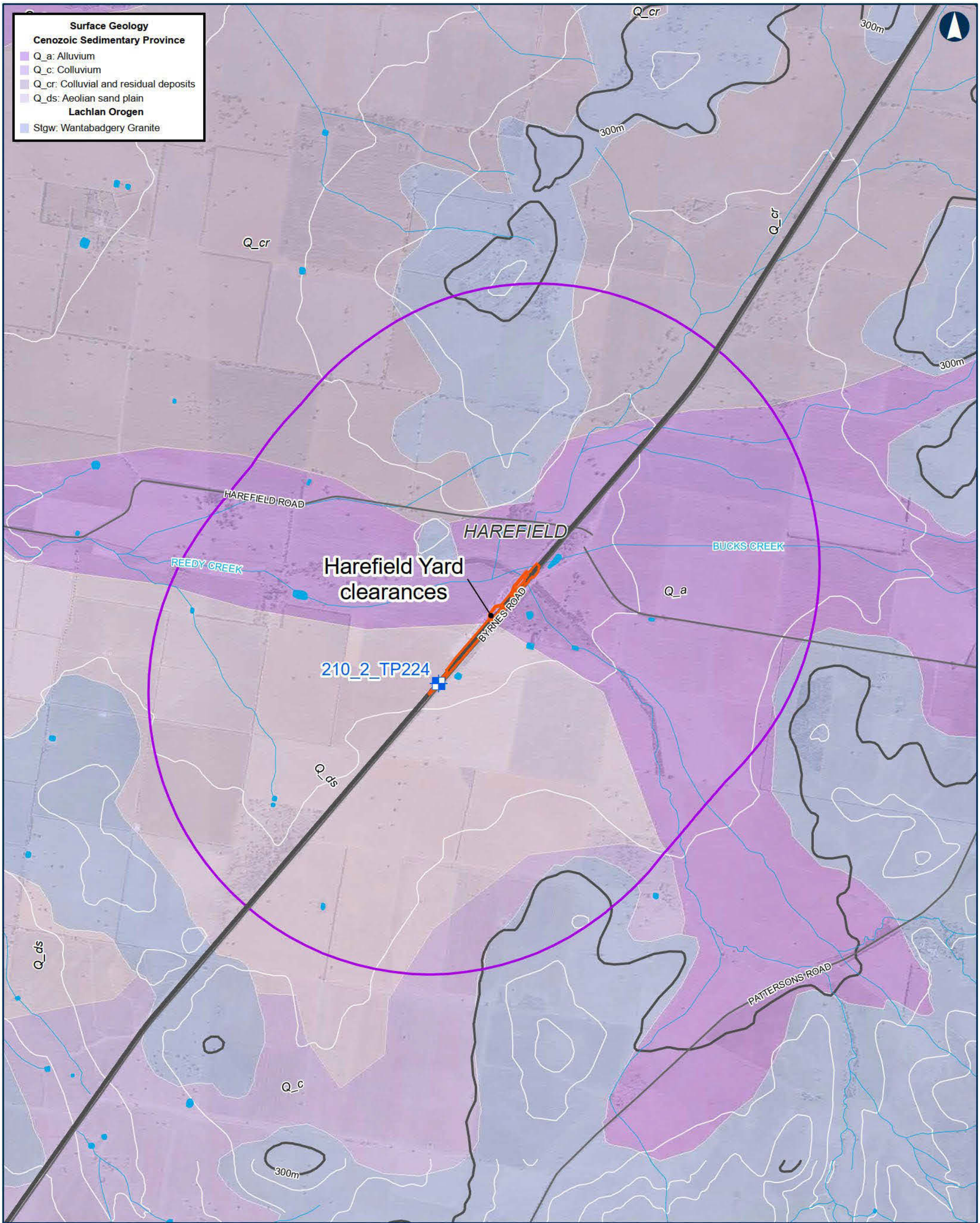

Albury to Illabo Figure 4.3 Regional geology map with geotechnical site investigation locations MAP 11 OF 14

0 250 500 m

Coordinate System: GDA 1994 MGA Zone 55

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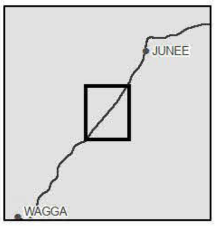
Date: 18/02/2022 Paper: A3
Author: WSP Scale: 1:25,000
Data Sources: ARTC, NSWSS

- Enhancement site
- Existing railway
- Groundwater study area
- Waterways
- Waterbodies
- Main road

- Test Pit

Contour intervals
- 10m contour
- 50 m contour



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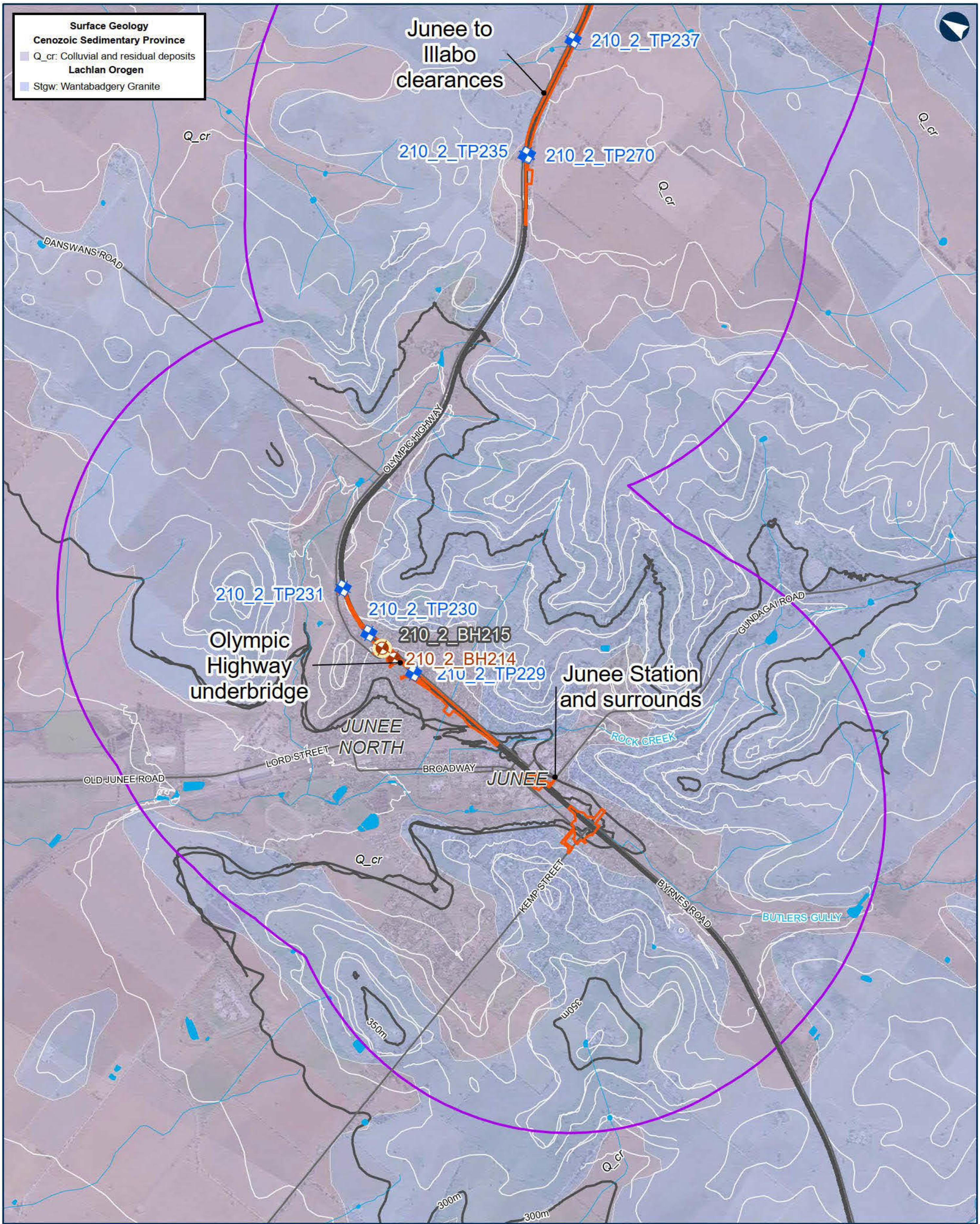

Albury to Illabo

Figure 4.3 Regional geology map with geotechnical site investigation locations

MAP 12 OF 14

0 250 500 m

Coordinate System: GDA 1994 MGA Zone 55

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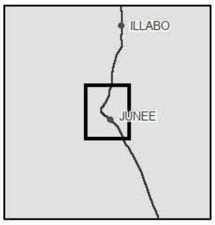
Date: 18/02/2022
Author: WSP
Data Sources: ARTC, NSWSS

Paper: A3
Scale: 1:25,000

- Enhancement site
- Existing railway
- Groundwater study area
- Waterways
- Waterbodies
- Main road
- Borehole / monitoring bore
- Borehole
- Test Pit

Contour intervals

- 10m contour
- 50 m contour



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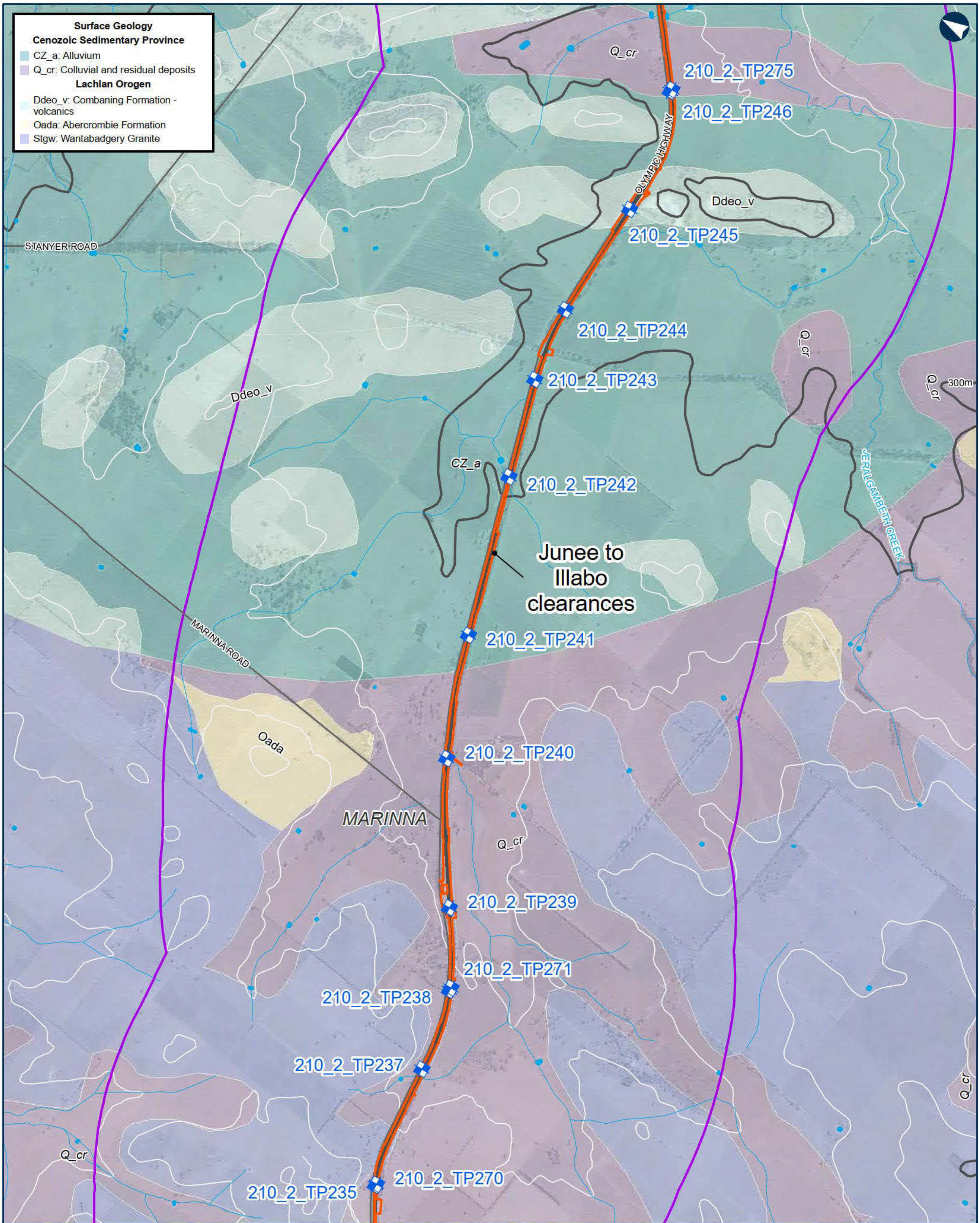
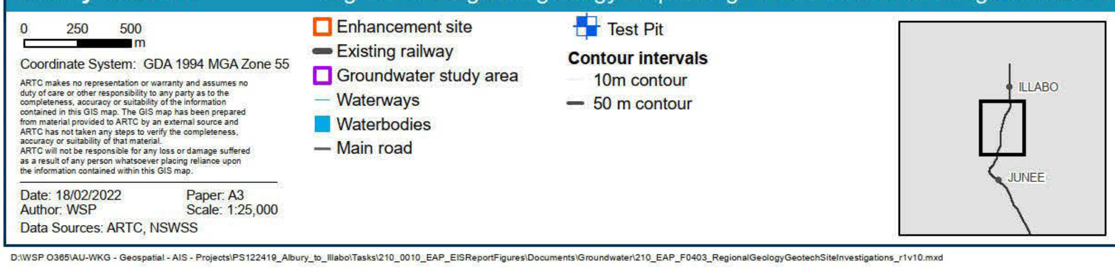


Albury to Illabo Figure 4.3 Regional geology map with geotechnical site investigation locations MAP 13 OF 14



Coordinate System: GDA 1994 MGA Zone 55

Date: 18/02/2022 Paper: A3
Author: WSP Scale: 1:25,000
Data Sources: ARTC, NSWSS

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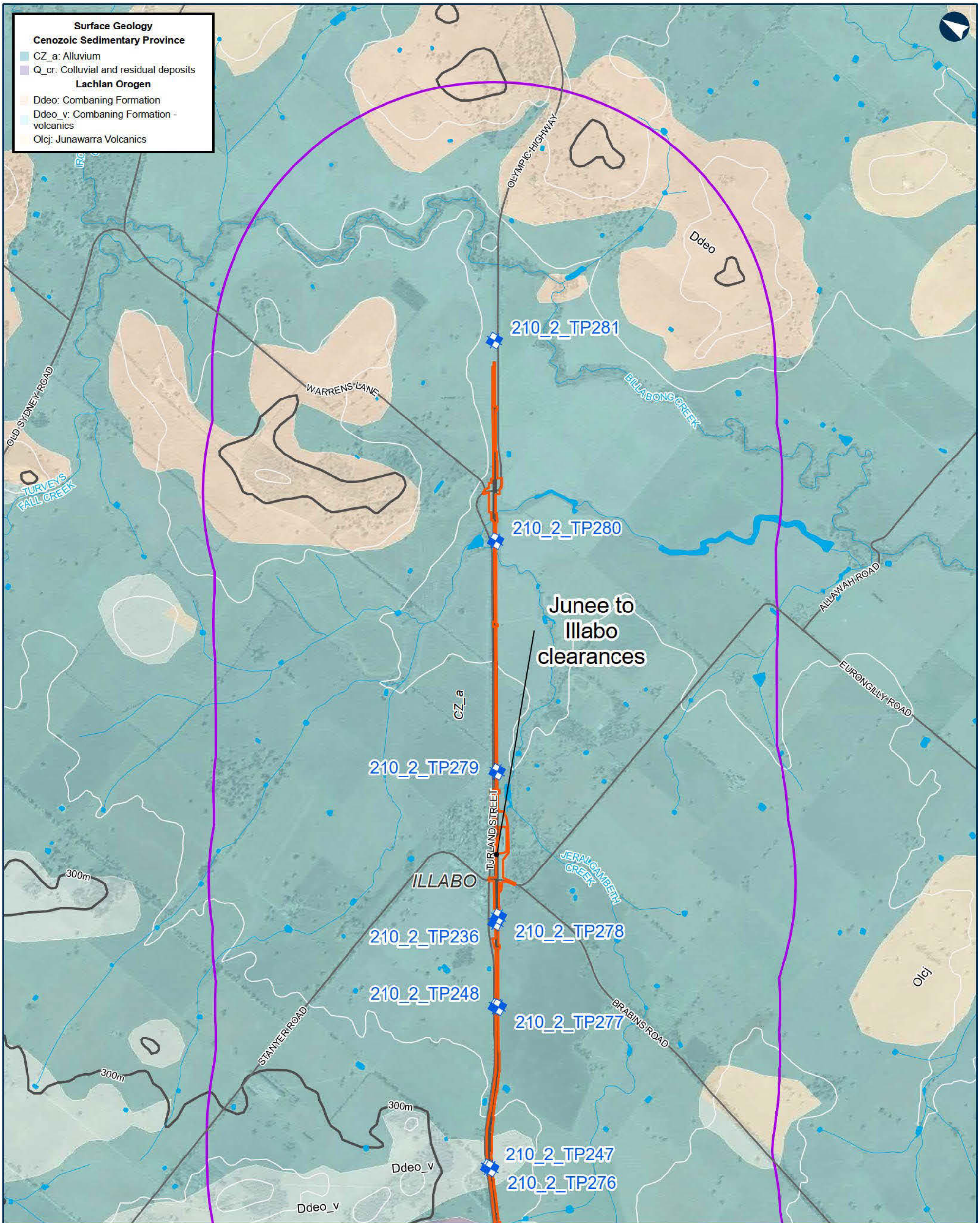

Albury to Illabo | Figure 4.3 Regional geology map with geotechnical site investigation locations | MAP 14 OF 14

0 250 500 m

Coordinate System: GDA 1994 MGA Zone 55

Date: 18/02/2022
Paper: A3
Author: WSP
Scale: 1:25,000
Data Sources: ARTC, NSWSS

- Enhancement site
- Existing railway
- Groundwater study area
- Waterways
- Waterbodies
- Main road
- Test Pit

Contour intervals
- 10m contour
- 50 m contour

ILLABO
JUNEE

INLAND RAIL
ARTC

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4.4 DRYLAND AND URBAN SALINITY

Dryland salinity is the accumulation of salts in the soil surface and groundwater in non-irrigated areas, whereas urban salinity includes dryland salinity and salinity caused by irrigation (DPIE, 2021).

Dryland and urban salinity are caused by widespread land use changes since European settlement, typically through the removal of deep-rooted trees, shrubs and perennial grasses (Wilson, 2004). The change in land use has allowed for high saline water tables, through increased groundwater recharge, that can impact infrastructure, agriculture and the environment by increasing salt loads. Wilson (2004) provides an estimate of the extent of high saline water tables in towns and cities of the Murray-Darling Basin expressed as a percentage of total town area. Within the groundwater study area, Wilson (2004) lists Albury as containing an estimated five percent extent of high saline water table and Wagga Wagga at 50 percent. No other town within the groundwater study area is listed. The presence of a high saline water table at Wagga Wagga is subject to on-going monitoring and management by the City of Wagga Wagga Council. Information from their monitoring program is provided in section 4.5.3.3 and 4.5.4.3.

Junee Shire Council (2021a & 2021b) also identifies urban salinity as a long-standing problem that may be present at the Junee precinct enhancement sites. The council has undertaken multiple mitigation measures including changes to stormwater management, appropriate road construction techniques, revegetation and community education.

Table 4.4 provides a summary of the enhancement sites that contain an increased soil salinity hazard assessed in the Technical Paper 13: Contamination. For further detail regarding soil salinity and the impact from dryland and urban salinity, refer to Technical Paper 13: Contamination.

Table 4.4 Summary of soil salinity hazard (Technical Paper 13: Contamination)

PRECINCT	COMMENT
Albury	Moderate land salinity hazard was identified at Table Top Yard clearances enhancement site.
Greater Hume – Lockhart	Culcairn pedestrian bridge and Yard clearances have a "Low" land salinity hazard but the groundwater and streams have a potential high salinity load making the overall salinity hazard "Very High".
Wagga Wagga	Moderate land salinity hazard at Uranquinty Yard clearances, Pearson Street bridge and Bomen Yard clearances.
Junee	Moderate land salinity hazard at all enhancement sites.

4.5 HYDROGEOLOGY

4.5.1 HYDROSTRATIGRAPHY

Hydrostratigraphy is the classification of the subsurface into distinct hydrogeological units. This section describes the hydrostratigraphic units (HSUs) which underlie the groundwater study areas.

HSUs are defined as geological material of similar hydrogeological properties. HSUs are generally based on stratigraphic units, although units of similar groundwater storage and transmissive properties are often classified together as a single HSU.

For the groundwater study area, HSUs are delineated as per groundwater sources listed within the water sharing plans (section 2.2.2.2) as this provides a consistent classification approach for the groundwater impact assessment. Details on the HSUs, taken from the groundwater resource descriptions (DPIE, 2019b, 219c & 2019d), within the groundwater study area are provided in Table 4.5. Note, the Lachlan Fold Belt MDB groundwater source is henceforth referred to as 'Lachlan fractured rock'. The relationship between HSUs and their corresponding enhancement sites are provided in Table 4.6, section 4.5.2. The encountered depth listed corresponds to the HSU and not exact groundwater levels, which are discussed in section 4.5.2.

Table 4.5 Hydrostratigraphic units within the groundwater study area and their thickness, depths and characteristics (DPIE, 2019a; 2019b and 2019c)

HYDRO-STRATIGRAPHIC UNITS	AQUIFERS	ESTIMATED THICKNESS (m)	ENCOUNTERED DEPTH (mBGL)[1]	CHARACTERISTICS
Upper Murray (alluvium)	Shallow	15–20	0–20	— Unconfined to semi confined aquifer consisting of water bearing sands and gravels. — Groundwater flow is generally southeast to northwest. — Shares a hydraulic connection with major rivers, creeks, irrigation channels and other water bodies and is considered a gaining system at Albury.
	Deep	15–60	20–80	— Semi confined aquifer consisting of water bearing sands and gravels. — Considered the more productive Upper Murray alluvium aquifer with bores containing yields of up to 10ML/day. — Groundwater flow is generally southeast to northwest.

HYDRO-STRATIGRAPHIC UNITS	AQUIFERS	ESTIMATED THICKNESS (m)	ENCOUNTERED DEPTH (mBGL)[1]	CHARACTERISTICS
Billabong Creek (alluvium)	Shallow	10–50	0–50	— Unconfined to semi confined aquifer of poorly sorted sands and gravel with interbedded clay. — Bore yields are generally less than 0.5ML/day. — Shares a hydraulic connection with Billabong Creek and is considered a gaining system at Culcairn. — Groundwater flow is generally east to west.
	Deep	0–50	50–100	— Consisting of water bearing sands and fine gravel. — Considered the more productive Billabong Creek alluvium aquifer with bore yields of up to 5ML/day.
Wagga Wagga Alluvial	Shallow	25–40	0–40	— Unconfined to semi-confined aquifer consisting of water bearing sands and gravels. — Productive aquifer with bore yields of up to approximately 3.5ML/day. — Shares a hydraulic connection with the Murrumbidgee River and alternates between a gaining and losing system depending on geology, topography, river flow and local conditions (such as groundwater extraction). At Wagga Wagga it is considered a gaining system. — Groundwater flow is generally east to west.
	Deep	40–55	40–90	— Semi-confined aquifer consisting of water bearing sands and gravels of the Lachlan Formation. — Considered the more productive Wagga Wagga alluvial aquifer with bore yields of up to 13ML/day. — Groundwater flow is generally east to west. However, flow is locally altered due to groundwater depression cones in areas of heavy extraction around Wagga Wagga and further upstream. — Shares a hydraulic connection with the overlying shallow aquifer.

HYDRO-STRATIGRAPHIC UNITS	AQUIFERS	ESTIMATED THICKNESS (m)	ENCOUNTERED DEPTH (mBGL)[1]	CHARACTERISTICS
Lachlan fractured rock	Shallow	0–30	Can significantly vary	— Unconfined to confined aquifer depending on location and overlying geology. — Groundwater is stored and moves through fractures, joints, bedding plains, faults and cavities within the rock mass or weathered zone (for the shallow aquifer). — Groundwater flow is generally controlled by topography but will be influenced by localised fracture systems and regional geological structures. — Hydraulic connectivity between surface water features, other overlying aquifers and between the shallow and deep Lachlan fractured rock aquifers is limited to the degree of fracturing extending between the aquifers or the bed of the surface water features. — Within all of the groundwater study areas the Lachlan fractured rock aquifers are considered to generally contain low hydraulic connection with overlying aquifers and surface water features.
	Deep	100+	Can significantly vary	

(1) mBGL = metres below ground level.

4.5.2 GROUNDWATER FLOW

Regional groundwater flow directions are provided in Table 4.5, section 4.5.1. Locally, groundwater flow will generally mimic topography and flow towards drainage lines. Groundwater gradients are expected to be higher in regions overlying the Lachlan fractured rock HSU given its variable and undulating topography. Further details pertaining to local groundwater flow at each enhancement site are discussed in the conceptual model subsection (refer to section 4.8).

4.5.3 GROUNDWATER LEVELS

Groundwater levels, considering relevant regional studies, available local information (such as registered bores) and site specific data are provided in the following subsections.

4.5.3.1 REGIONAL GROUNDWATER LEVELS

Indicative regional scale groundwater levels were sourced from WRP groundwater resource descriptions published by DPIE (2019a, 2019b and 2019c) and are provided in Table 4.6.

Table 4.6 Indicative depth to shallowest groundwater aquifers within HSUs based on regional studies (DPIE, 2019a, 2019b and 2019c)

HSU	INDICATIVE DEPTH TO GROUNDWATER[1]	RELEVANT ENHANCEMENT SITES
Upper Murray (alluvium)	2–5mBGL at approximately 155–160mAHD	Albury Precinct: Murray River bridge, Albury Station pedestrian bridge and Yard clearances and Riverina Highway bridge
Billabong Creek (alluvium)	5–10mBGL at approximately 205–210mAHD	Greater Hume – Lockhart Precinct: Culcairn pedestrian bridge and Yard clearances
Wagga Wagga Alluvial	7–15mBGL at approximately 170–175mAHD	Wagga Wagga Precinct: all enhancement sites
Lachlan fractured rock	Varies significantly	All precincts and enhancement sites, including those not previously listed

(1) mBGL = metres below ground level; mAHD = metres Australian Height Datum.

4.5.3.2 GROUNDWATER LEVELS FROM REGISTERED BORES

Key statistics of available groundwater levels obtained from the registered bore search (BOM, 2021), within the groundwater study area (2km) of each enhancement site, is compiled in Table 4.7. The table excludes bores where groundwater level information was not available or determined to be from a non-relevant HSU. The full table of reviewed search results, with individual details per registered bore that contained groundwater level information, are provided in Appendix A. Location of registered bores are provided in Figure 4.5 (section 4.6).

Table 4.7 Registered bores with groundwater levels

ENHANCEMENT SITE[1,2]	INFERRED HSU	GROUNDWATER LEVEL (mBTOC)[3]				
		Number of registered bores[4]	Minimum SWL	Maximum SWL	Average SWL	Median SWL
Murry River bridge and Albury Station pedestrian bridge and Yard clearances	Upper Murray – shallow	26	0.6	18.0	4.4	3.0
	Upper Murray – deep	1	3.0	3.0	3.0	3.0
Billy Hughes bridge	Lachlan fractured rock – deep	3	40.0	47.3	42.4	40.0
Table Top Yard clearances	Lachlan fractured rock – shallow	1	9.0	9.0	9.0	9.0

ENHANCEMENT SITE[1,2]	INFERRED HSU	GROUNDWATER LEVEL (mBTOC)[3]				
		Number of registered bores[4]	Minimum SWL	Maximum SWL	Average SWL	Median SWL
Henty Yard clearances	Lachlan fractured rock – deep	3	52.1	57.9	55.5	56.4
Culcairn pedestrian bridge and Yard clearances	Billabong Creek – shallow	8	4.0	28.0	13.6	13.7
	Billabong Creek – deep	7	6.8	32.9	16.5	16.5
The Rock Yard clearances	Lachlan fractured rock – deep	2	32.9	56.4	44.7	44.7
Yerong Creek Yard clearances	Lachlan fractured rock – deep	2	56.4	66.5	61.5	61.5

(1) Site encompasses the groundwater study area. Where enhancement sites are absent (Uranquinty Yard clearances), no groundwater levels were recorded for the registered bores within their corresponding groundwater study area.

(2) mBTOC = metres below top of casing; SWL = standing water level.

(3) Only includes registered bores with groundwater level records.

4.5.3.3 WAGGA WAGGA CITY COUNCIL MONITORING NETWORK

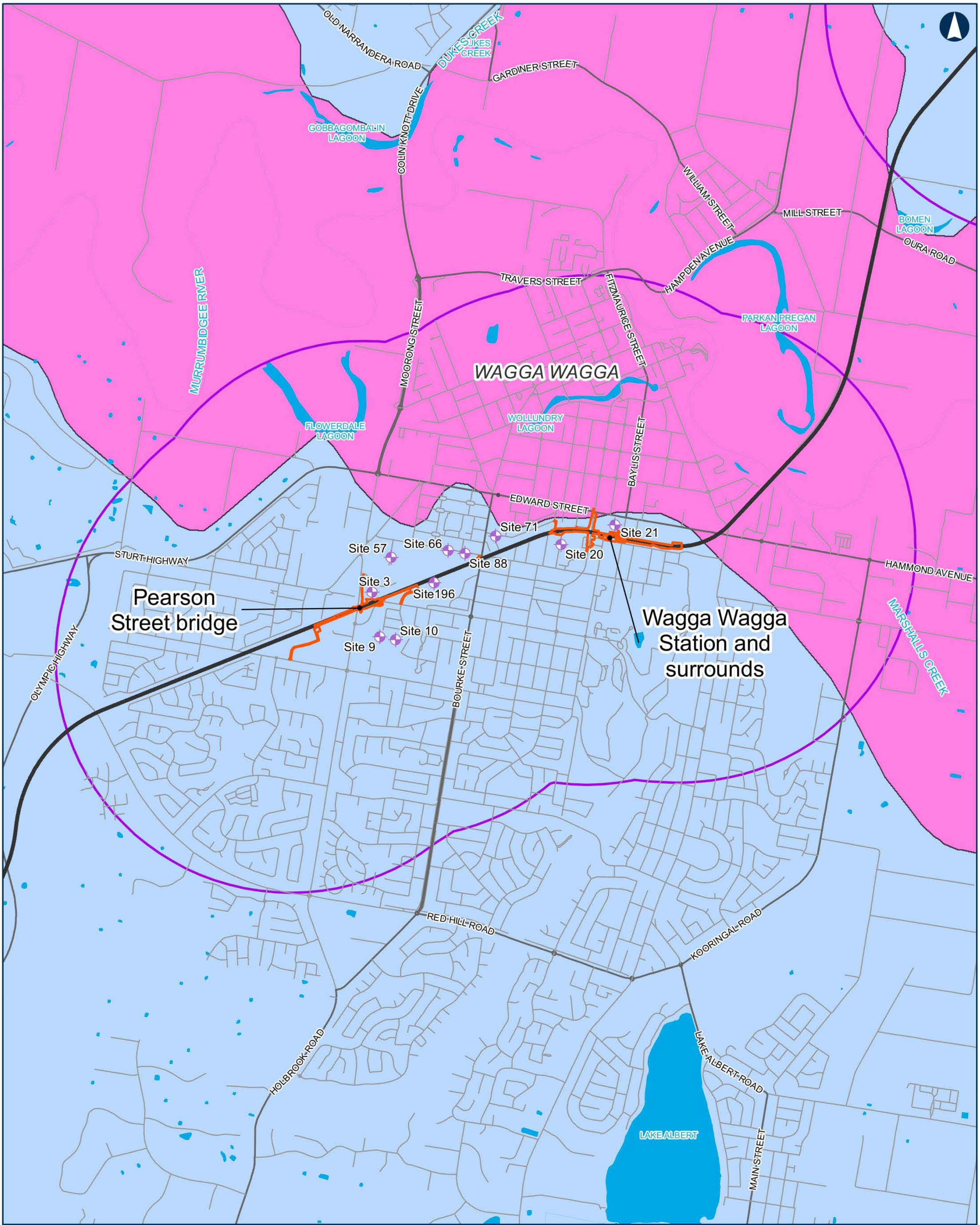
Wagga Wagga City Council maintains around 200 groundwater monitoring bores and dewatering bores that form part of the Council's program for managing urban salinity (Urban Salinity Management Plan), including through the lowering of water tables in discharge areas. The original monitoring network was established in 1998 and has historically been monitored on a monthly, bi-monthly or quarterly basis (Wagga Wagga City Council, 2019 & 2020). Additional groundwater level information obtained from recent technical reports (Wagga Wagga City Council, 2019 & 2020) and excel data provided by Wagga Wagga City Council (2021) for selected monitored bores proximal to the enhancement sites is provided in Table 4.8. All of the listed monitoring bores have been inferred to monitor the shallow Lachlan fractured rock HSU. Locations of the bores listed in Table 4.8 are shown in Figure 4.4.

Table 4.8 Selected groundwater monitoring bores and recorded groundwater levels from Wagga Wagga City Council's urban salinity network within the vicinity of enhancement sites

ENHANCEMENT SITE	COUNCIL BORE ID	MONITORING PERIOD	GROUNDWATER LEVEL (mBGL)[1,2]			GROUNDWATER LEVEL (mAHD)[1,2]		
			Minimum	Maximum	Median	Minimum	Maximum	Median
Pearson Street bridge	3	1994–2011	0.20	0.94	0.71	184.64	185.38	184.87
	9	1994–2021	-0.28[3]	2.10	0.20	187.48	189.86	189.38
	10	1994–2021	0.03	3.43	1.41	188.69	192.12	190.71
	57	1997–2021	0.21	1.45	0.78	179.17	180.41	179.84
	66	1997–2021	0.52	2.23	1.18	184.44	186.67	185.49
	88	1999–2021	1.00	Dry (10.00)	5.23	Dry (178.56)	187.71	182.48
	196	2010–2020	1.93	8.64	4.93	183.24	189.95	186.95
Wagga Wagga Station and surrounds	20	1995–2021	4.50	Dry (14.90)	11.00	Dry (167.94)	182.72	171.74
	21	1995–2020	9.34	Dry (13.00)	10.82	Dry (170.29)	173.95	172.48
	71	2008–2021	1.05	7.05	4.70	177.17	183.17	179.52

(1) mBGL = metres below ground level; mAHD = metres Australian Height Datum; ND = no data; SWL = standing water level.

(2) Negative value indicates the monitoring bore was submerged by ponded surface water during monitoring interval.



Albury to Illabo Figure 4.4: Selected bores from the Wagga Wagga City Council monitoring network (2019, 2020 & 2021)

0 0.25 0.5 km

Coordinate System: GDA 1994 MGA Zone 55

Date: 11/11/2021 Paper: A3
Author: WSP Scale: 1:30,000
Data Sources: ARTC, NSWSS, Wagga Wagga City Council

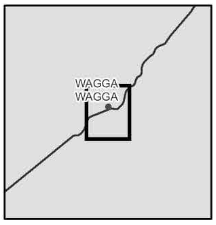
- Enhancement site
- Existing railway
- Groundwater study area
- Main road
- Local road
- Watercourse
- Waterbodies

- Piezometer

Water sharing area (Outcropping groundwater source)

Outcropping groundwater source
- Lachlan Fold Belt MDB Groundwater Source
- Wagga Wagga Alluvial Groundwater Source

Underlying groundwater source
- Lachlan Fold Belt MDB Groundwater Source



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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4.5.3.4 SITE SPECIFIC GROUNDWATER LEVELS

Table 4.9 summarises the locations where groundwater inflow was encountered during geotechnical investigations undertaken between 2016 and 2021 (WSP, 2017a, 2017b, 2017c and 2021; KBR, 2019). It does not include static water level measurements undertaken during GMEs which are listed in Table 4.10. Groundwater inflow was not encountered during geotechnical investigations within the Greater Hume – Lockhart precinct.

Table 4.9 Summary of groundwater observations from geotechnical investigations completed for the proposal (2016–2021)

PRECINCT	SITE	GEOTECHNICAL LOCATION	DATE ENCOUNTERED	INFLOW DEPTH (mBGL)[1]	INFLOW DEPTH (mAHD)[1]
Albury	Albury Station pedestrian bridge and Yard clearances	2100-01-BH2006	11 April 2018	7.25	151.7
	Riverina Highway bridge	210_2_BH204	13 January 2021	9.6	151.8
Wagga Wagga	Pearson Street bridge	2100-01-BH2018	21 March 2018	3.0	183.2
		2100-01-BH2019	15 June 2018	1.4	186.0
Junee	Junee Station and surrounds (at Kemp Street Bridge)	K-BH01	28 November 2016	1.4	298.1
		2100-01-BH2029	27 March 2018	3.3	298.3
		2100-01-BH2030		2.4	298.2
		2100-01-BH2031		6.2	294.4

(1) mBGL = metres below ground level; mAHD = metres Australian Height Datum.

Where water was used during the drilling process, groundwater inflow could not be determined. Manual groundwater level measurements obtained from locations with installed monitoring bores during GMEs (2021) are presented in Table 4.10, with a summary of groundwater level statistics (minimum, maximum and median) obtained from dataloggers provided in Table 4.11. No groundwater level statistics are available for BH219 (Uranquinty Yard clearances) as the bore was 'dry' during the monitoring period. This indicates that groundwater for the regional aquifer was below the base of the monitoring bore at BH219.

Table 4.10 Groundwater levels recorded by manual dip measurements during GMEs

BORE ID	ENHANCEMENT SITE	HSU[1]	GME 1 (FEBRUARY 2021)		GME 2 (MARCH 2021)		GME 3 (MAY 2021)	
			SWL (mBGL)[2]	SWL (mAHD)[2]	SWL (mBGL)[2]	SWL (mAHD)[2]	SWL (mBGL)[2]	SWL (mAHD)[2]
BH201	Albury Station pedestrian bridge and Yard clearances	UM-S	8.11	152.53	8.38	152.26	8.49	152.15
BH204	Riverina Highway bridge	UM-S	7.48	153.91	7.72	153.67	7.66	153.73
BH206	Pearson Street bridge	LFR-S	2.22	184.25	1.98	184.49	2.49	183.98
BH210	Wagga Wagga Station and surrounds (at Edmondson Street bridge)	LFR-S	10.75	172.93	10.45	173.23	11.14	172.53
BH215	Olympic Highway underbridge	LFR-S	9.99	299.56	9.85	299.70	9.72	299.83
BH219	Uranquinty Yard clearances	LFR-S	Dry (>30.00)	Dry (<168.36)	Dry (>30.00)	Dry (<168.36)	Dry (<30.00)	Dry (<168.36)

(1) LFR-S = Lachlan fractured rock shallow; UM-S = Upper Murray shallow.
(2) mBGL = metres below ground level; mAHD = metres Australian Height Datum.

Table 4.11 Groundwater level statistics of the groundwater monitoring network obtained from dataloggers

	BH201	BH204	BH206	BH210	BH215
HSU	Upper Murray Alluvium – shallow	Upper Murray Alluvium – shallow	Lachlan fractured rock – shallow	Lachlan fractured rock – shallow	Lachlan fractured rock – shallow
Minimum SWL (mBGL)	8.20	7.33	1.31	10.29	9.53
Maximum SWL (mBGL)	8.40	7.58	2.47	10.94	9.95
Median SWL (mBGL)	8.32	7.46	2.26	10.70	9.71
Minimum SWL (mAHD)	152.19	153.81	184.00	172.73	299.60
Maximum SWL (mAHD)	152.44	154.06	185.16	173.38	300.02
Median SWL (mAHD)	152.32	153.93	184.24	172.97	299.84

mBGL = metres below ground level; mAHD = metres Australian Height Datum.

4.5.3.5 GROUNDWATER LEVEL VARIATION (HYDROGRAPHS)

Hydrographs were produced from the data collected from the groundwater monitoring network during the GMEs (refer to Table 4.8) and data collected by Wagga Wagga City Council (2021) monitoring bores (refer to section 4.5.4.3) (refer to Appendix B). Observable features from the hydrographs are discussed in Table 4.12. Generally, long-term hydrograph trends correlated to climatic conditions (refer to section 4.2.1).

Table 4.12 Hydrograph trends and observable features

LOCATION	BOREHOLE ID	MONITORING PERIOD (YEAR)[1]	GROUNDWATER LEVEL RELATIVE TREND	CLEAR RESPONSE TO RAINFALL / CLIMATE[2,3]
Enhancement Site				
Albury Station pedestrian bridge and Yard clearances	BH201	2021	Stable	No
Riverina Highway bridge	BH204	2021	Stable	No
Pearson Street bridge	BH206	2021	Influenced by rapid recharge followed by slow discharge	No
Wagga Wagga Station and surrounds (at Edmondson Street bridge)	BH210	2021	Stable	No
Olympic Highway Underbridge	BH215	2021	Increasing	No
Wagga Wagga City Council				
RTA Yard, Cheshire Street	3	1994–2011	— stable from 1994–2000 — declining 2000 to end 2009 — increasing 2010–2011 (end of monitoring)	Major trends correlate to the Millennium Drought and breaking of the Millennium Drought (2001–2009).

LOCATION	BOREHOLE ID	MONITORING PERIOD (YEAR)[1]	GROUNDWATER LEVEL RELATIVE TREND	CLEAR RESPONSE TO RAINFALL / CLIMATE[2,3]
South Campus adjacent Isdal Road	9	1994–2020	— stable from 1994–2003 — declining 2003–2009 — increasing 2010–2011 — stable to slight decline 2011–2020	Trends are subdued but generally correlate to climatic conditions. Most observable trend (declining) correlates to the Millennium Drought. Trends during drier conditions in 2016–2019) are less distinguishable.
South Campus adjacent Pre-School	10	1994–2020	— increasing 1995–1996 — declining 1997–2009 — rapid increase 2010 — declining 2010–2019 — rapid increase 2019–2020	Major trends correlate to climate data with declining trends observed across the Millennium Drought, followed by rapid increase at its end. Declining trend, with less variability was observed during the drier climate in 2016–2019, followed by rapid increase in recent wetter years (2019–2020).
Kildare Catholic College, Kildare Street	20	1995–2020	— declining 1995–2010, with bore going dry from 2007–2010 — slight increase 2010–2010 — declining 2011–2016 — slight increase 2016–2017 — declining 2017–2020	Trends generally correlate to climatic conditions with notable decline through the Millennium Drought followed by rapid increase at its end. Notable rise in 2016 correlates to wetter conditions with following decline matching drier conditions. Recent declining trend (2019–2020) does not correlate to climatic conditions.
South Wagga Public School	21	1994–2020	— declining 1995–2020, with bore going dry or no data from ~2003–2013	Major trend correlates to the Millennium Drought, but lack of consistent data points following 2003 makes it unsuitable to compare against recent climatic conditions.
Mortimer Place	57	1997–2020	— slight increase 1997–2000 — declining 2000–2010 — increasing 2010–2011 — stable 2010–2020	Trends are subdued but generally correlate to climatic conditions. Most observable trend (declining followed by rapid increase) correlates to the Millennium Drought and its end respectively. Recent climatic conditions (2016–2020) are less distinguishable.

LOCATION	BOREHOLE ID	MONITORING PERIOD (YEAR)[1]	GROUNDWATER LEVEL RELATIVE TREND	CLEAR RESPONSE TO RAINFALL / CLIMATE[2,3]
Chaston Street	66	1997–2020	— declining 1997–2010 — slight increase 2010–2011 — declining 2011–2020	Trends are subdued but generally correlate to climatic conditions. Most observable trend (declining followed by rapid increase) correlates to the Millennium Drought and its end respectively. Recent climatic conditions (2016–2020) are less distinguishable.
Roma Street (on Brookong Avenue)	71	2008–2020	— increasing 2008–2011 — declining 2011–2013 — stable 2013–2016 — rapid increase followed by decline during 2016 — declining 2017–2018 — increasing 2018–2020	Slight disparity between groundwater level trends and climatic conditions at the start of monitoring that would correlate to the end of the Millennium Drought. However, noted trends from 2011 correlate to climatic conditions.
2 Chaston Street	88	1999–2020	— declining 1999–2009, with bore going dry from 2003–2008 — increasing 2009–2011 — declining 2011–2014 — increasing 2014–2017 — declining 2017–2019 — increasing 2019–2020	All notable trends correlate to climatic conditions.
Showground (inside trotting track)	196	2010–2020	— increasing 2010–2011 — decreasing 2011–2015 — increasing 2015–2016 — rapid increase followed by decrease during 2016 — decreasing 2017–2018 — stable 2018–2019 — increasing 2020	Correlation of notable trends to climatic conditions is generally low, except for 2016 and recent wetter conditions in 2020.

(1) Based on dates graphed within generated (this report) or published (Wagga Wagga City Council, 2021) hydrographs.

(2) Response to climate is referenced to Figure 4.2 (CDFM plot, Wagga Wagga), section 4.2.1.

(3) A strong correlation of groundwater level trends can be considered as: drier conditions relate to declining groundwater levels and wetter conditions relate to increasing groundwater levels.

4.5.4 GROUNDWATER QUALITY

Groundwater quality, considering relevant regional studies, available local information (such as registered bores) and site specific data are provided in the following subsections.

4.5.4.1 REGIONAL GROUNDWATER QUALITY

The typical regional quality of the groundwater based on the groundwater resource descriptions published by DPIE (2019a, 2019b and 2019c) are provided in Table 4.13.

Table 4.13 Indicative regional groundwater quality (DPIE, 2019a, 2019b and 2019c)

HSU	AQUIFER	QUALITY – SALINITY (EC)
Upper Murray (alluvium)	Shallow	Fresh, generally less than 800µS/cm. Higher values (up to 5,000µS/cm) have previously been recorded. No distinction has been made between shallow or deep aquifer groundwater quality due to limited information.
	Deep	
Billabong Creek (alluvium)	Shallow	Varies from 200 to 12,000µS/cm, with groundwater in the eastern part of the aquifer fresher and in regions with direct river recharge.
	Deep	Typically fresh, 300 to 2,000µS/cm.
Wagga Wagga Alluvial	Shallow	Can vary with the freshest groundwater occurring proximal to the Murrumbidgee River. The EC is generally below 1,660µS/cm.
	Deep	Fresh, around 950µS/cm.
Lachlan fractured rock	Shallow	Significantly varies from fresh to saline based on rock type, fracture density, aquifer depth and climate.
	Deep	

4.5.4.2 GROUNDWATER QUALITY FROM REGISTERED BORE SEARCH

Key statistics of available relevant groundwater quality records obtained from the registered bore search (BOM, 2021) are listed in Table 4.14. The full table of compiled search results are provided in Appendix A. The listed information excludes proposed or planned bores, bores with no quantitative groundwater quality records and groundwater bores within the groundwater study area of Pearson Street bridge and Wagga Wagga Station and surrounds that are inferred to be screened within the Wagga Wagga alluvial groundwater source.

Table 4.14 Registered bores with quantitative groundwater quality records

ENHANCEMENT SITE[1]	INFERRED HSU	NUMBER OF REGISTERED BORES	GROUNDWATER QUALITY – SALINITY (EC µS/cm)[2]					
			Minimum	Maximum	Average	Median	Classification	Category[4]
Murray River bridge and Albury Station pedestrian bridge and Yard clearances	Upper Murray – shallow	2	90	375	233	233	Fresh	A1
Culcairn pedestrian bridge and Yard clearances	Billabong Creek – shallow	4	225	4,500	1,725	1,670	Brackish	A1-C1
	Billabong Creek – deep	2	750	2,240	1,495	1,495	Fresh-brackish	A1-B

(1) Includes sites within 2km of the registered bore.
(2) Values recorded as total dissolved solids (TDS) or parts per million (ppm) were converted to microseimens per centimetre (µS/cm) using a factor of 0.67.
(3) Refer to section 3.5 for water quality category descriptions.

4.5.4.3 WAGGA WAGGA CITY COUNCIL MONITORING NETWORK

Table 4.15 lists the electrical conductivity (EC) (salinity) of the selected relevant bores from the Wagga Wagga City Council's groundwater monitoring network identified in Table 4.8, section 4.5.3.3. All bores are inferred to be screened within the shallow Lachlan fractured rock HSU due to their location and depth. Salinity monitoring data was provided by Wagga Wagga City Council (2021) upon request.

Table 4.15 Selected groundwater monitoring bores and recorded groundwater quality from Wagga Wagga City Council's urban salinity network (Wagga Wagga City Council, 2021)

SITE[1]	COUNCIL BORE ID	MONITORING PERIOD	NUMBER OF SAMPLES	GROUNDWATER QUALITY – SALINITY (EC µS/cm)[2]			
				Range	Median	Classification[3]	Category[4]
PSB	3	1994–2011	138	3,940–20,400	16,560	Moderately saline	D
	9	1994–2021	213	2,650–20,000	8,370	Slightly saline	C1
	10	1994–2021	220	940–16,930	4,300	Brackish	B
	57	1997–2021	254	420–19,530	12,350	Moderately saline	C2
	66	1997–2021	251	2,440–6,620	4,700	Brackish	C1
	88	1999–2021	144	310–24,500	19,850	Moderately saline	D
	196	2010–2020	75	1,010–2.386	1,597	Marginal	A3
WWSP	20	1995–2021	208	1,910–12,850	5,110	Slightly saline	C1
	21	1995–2020	53	880–2,480	1,390	Marginal	A3
	71	2008–2021	88	390–1,660	1,000	Marginal	A2

(1) Proximal location to listed Wagga Wagga City Council bores. WWSP = Wagga Wagga Station and surrounds; PSB = Pearson Street bridge.

(2) µS/cm = microseimens per centimetre.

(3) Based on calculated median value and classification ranges provided in Hounslow (1995).

(4) Refer to section 3.5 for water quality category descriptions.

4.5.4.4 SITE SPECIFIC GROUNDWATER QUALITY OBTAINED FROM GMES

Groundwater quality results obtained from locations with installed monitoring bores during GMEs are presented in Table 4.16. The results of the full analytical suite are provided in Appendix C. No groundwater quality samples were collected at BH219 (Uranquinty Yard clearances) as the bore was dry during each GME. This indicates that groundwater for the regional aquifer was below the base of the monitoring bore at BH219.

Table 4.16 Groundwater quality recorded during GMEs

	GROUNDWATER QUALITY	BH201[4]	BH204[4]	BH206[4]	BH210[4]	BH215[4]
GME 1	Field reading (EC µS/cm)[1]	2,031	1,688	729	547	2,442
	Classification[2]	Brackish	Brackish	Fresh	Fresh	Brackish
	Category[3]	B	A3	A1	A1	B
GME 2	Field reading (EC µS/cm)[1]	1,374	1,591	566	577	2,148
	Classification[2]	Marginal	Marginal	Fresh	Fresh	Brackish
	Category[3]	A3	A3	A1	A1	B
GME 3	Field reading (EC µS/cm)[1]	1,616	1,499	631	580	2,662
	Classification[2]	Marginal	Marginal	Fresh	Fresh	Brackish
	Category[3]	A3	A3	A1	A1	B

(1) µS/cm = microseimens per centimetre.

(2) Based on calculated median value and classification ranges provided in Hounslow (1995).

(3) Refer to section 3.4 for water quality category descriptions.

(4) BH201 is located at Albury Station pedestrian bridge and Yard clearances in the Upper Murray– shallow HSU; BH204 is located at Riverina Highway bridge in the Upper Murray – shallow HSU; BH206 is located at Pearson Street bridge in the Lachlan fractured rock – shallow HSU; BH210 is located within Wagga Wagga Station and Surrounds (at Edmondson Street bridge) in the Lachlan fractured rock – shallow HSU; BH215 is located at Olympic Highway underbridge in the Lachlan fractured rock – shallow HSU.

4.5.5 GROUNDWATER CONTAMINATION

Details on groundwater contamination are provided in Technical Paper 13: Contamination and summarised in Table 4.4. For further information, refer to Technical Paper 13: Contamination.

Table 4.17 Summary of groundwater contamination (Technical Paper 13: Contamination)

PRECINCT	COMMENT
Albury	A review of historical assessments indicates there is potential for hydrocarbon and metal contamination at Albury Station pedestrian bridge and Yard clearances.
Greater Hume – Lockhart	A review of historical assessments did not identify any groundwater contamination.
Wagga Wagga	A review of historical assessments indicates there is a low potential for herbicide contamination at Bowman yard clearances, potential hydrocarbon contamination from underground storage tanks at Wagga Wagga Station and surrounds.
Junee	A review of historical assessments indicates there is a low potential for herbicide contamination at Harefield Yard clearances.

4.5.6 HYDRAULIC CONDUCTIVITY

The results of the rising head slug tests that were considered fit for purpose are presented as estimates of hydraulic conductivity (K) (m/day) in Table 4.18. The results can be summarised as:

- bores screened in the Murray Alluvial HSU recorded K values of 0.88–0.97m/day at Albury Station pedestrian bridge and Yard clearances and 0.078m/day at Riverina Highway bridge, which is within the representative range of silts to fine sands from Domenico and Schwartz (1990)
- BH206 at Pearson Street bridge, screened within residual soils of the Lachlan fractured rock – shallow HSU recorded a K value of 0.08m/day, which is within the representative range of silts from Domenico and Schwartz (1990)
- BH215, screened across the extremely weathered granite profile of the Lachlan fractured rock – shallow HSU recorded a K value of 0.11, which is within the representative range of weathered granite from Domenico and Schwartz (1990).

Table 4.18 Hydraulic conductivity results from rising head 'slug' tests

	BH201		BH204	BH206	BH215
	Test 1	Test 2			
Estimated hydraulic conductivity (K) (m/day)	0.88	0.97	0.08	0.10	0.11

4.6 SENSITIVE RECEIVERS

The closer a receiving environment or receptor is to the proposal, the higher the risk posed from impacts (EPA, 2017). A sensitive receiver for the purpose of this assessment is any identified receiver that utilises groundwater. Registered bores with a registered use as water supply are therefore considered as a sensitive receiver as they rely on the use of the groundwater resource to supply their water requirements across household, stock and domestic, irrigation and commercial uses. GDEs are also classified as a sensitive receiver as they need access to groundwater to meet some or all their water requirements to maintain their communities, processes and ecosystem services.

Registered bores and GDEs are further discussed in the following sections, with the proposals impact to the sensitive receivers assessed in Chapter 5.

4.6.1 REGISTERED BORES

A search of the NGIS (BOM, 2021) and WaterNSW (2021) groundwater databases identified a total of 469 registered groundwater bores across the groundwater study area with the majority located within the Wagga Wagga Precinct. From the 469 registered bores, only one registered bore is located within an enhancement site. The registered bore is GW402492 and occurs within the Olympic Highway underbridge enhancement site within the Junee precinct (refer to Table 4.19).

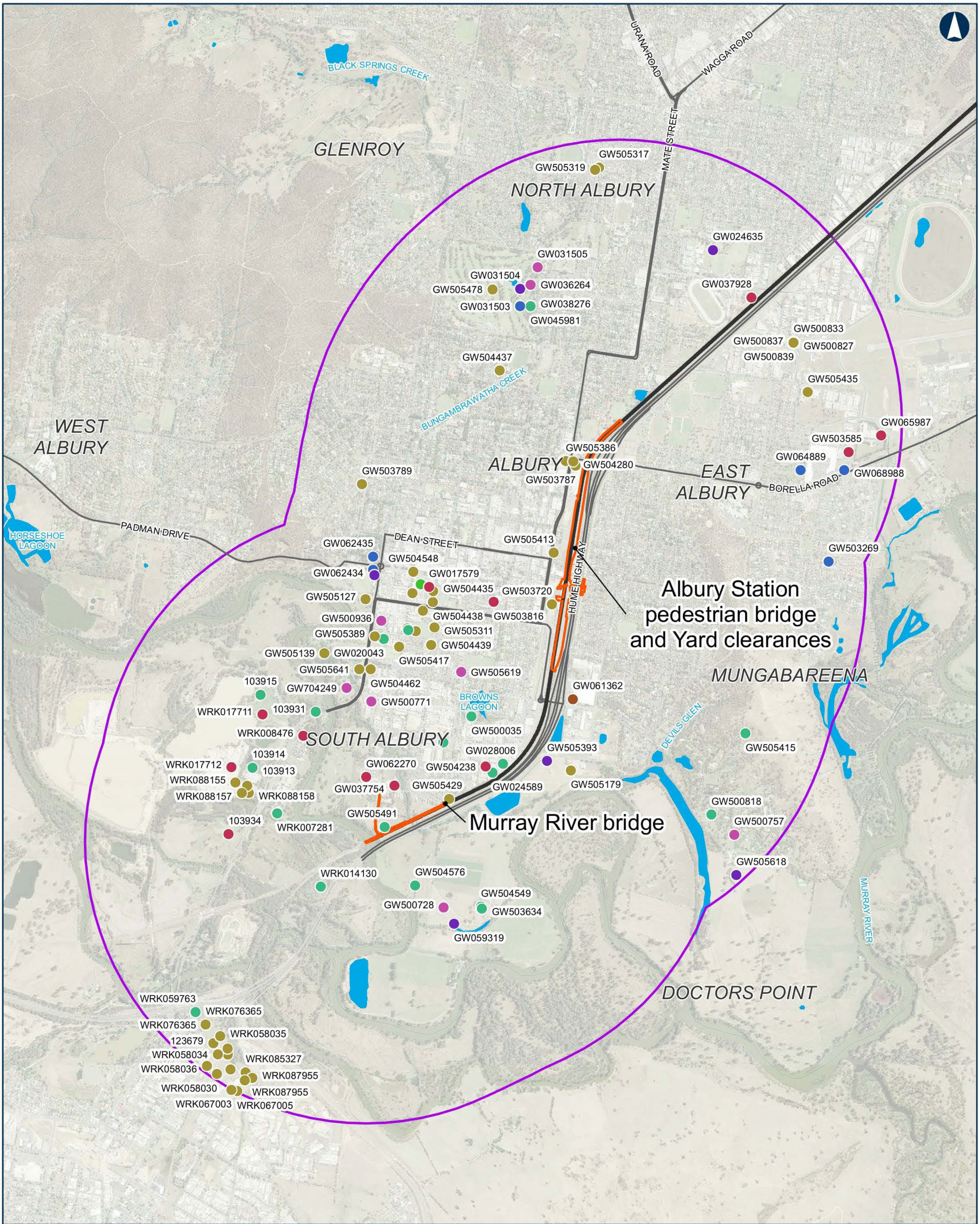
Table 4.19 Registered bores within the Proposals construction impact zones

ENHANCEMENT SITE	BORE ID	STATUS	PURPOSE	DRILLED DEPTH (mBTOC)
Olympic Highway underbridge	GW402492	Unknown	Monitoring/test bore	9.00

Of the 469 bores located within the groundwater study area, the beneficial use of the majority was listed as monitoring or observation (305) followed by water supply (including industry, aquaculture, commercial and household water supply) (91), unknown (32), recreation (15), stock and domestic (11), drainage (11) and exploration (4). Of these bores located within the groundwater study area:

- 142 are functioning or in use
- 292 are in an unknown condition
- 35 bores are either non-functional, proposed, abandoned or removed.

The location of registered bores within the groundwater study area and their purpose is shown in Figure 4.5.



Albury to Illabo Figure 4.5: Registered bores within the groundwater study areas MAP 1 OF 12

0 500 m

Coordinate System: GDA 1994 MGA Zone 55

Date: 25/05/2022 Paper: A3
Author: WSP Scale: 1:25,000
Data Sources: ARTC, NSWSS

- Enhancement site
- Main road
- Existing railway
- Groundwater study area
- Waterbodies
- Waterways

Groundwater monitoring bore function

- Commercial and Industrial
- Dewatering
- Exploration
- Irrigation
- Monitoring
- Other
- Unknown
- Water Supply

ALBURY

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Albury to Illabo Figure 4.5: Registered bores within the groundwater study areas MAP 2 OF 12

0 500 m

Coordinate System: GDA 1994 MGA Zone 55

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Date: 25/05/2022 Paper: A3
Author: WSP Scale: 1:30,000
Data Sources: ARTC, NSWSS

- Enhancement site
- Main road
- Water Supply
- Existing railway
- Groundwater study area
- Waterbodies
- Waterways

Groundwater monitoring bore function

- Monitoring
- Unknown

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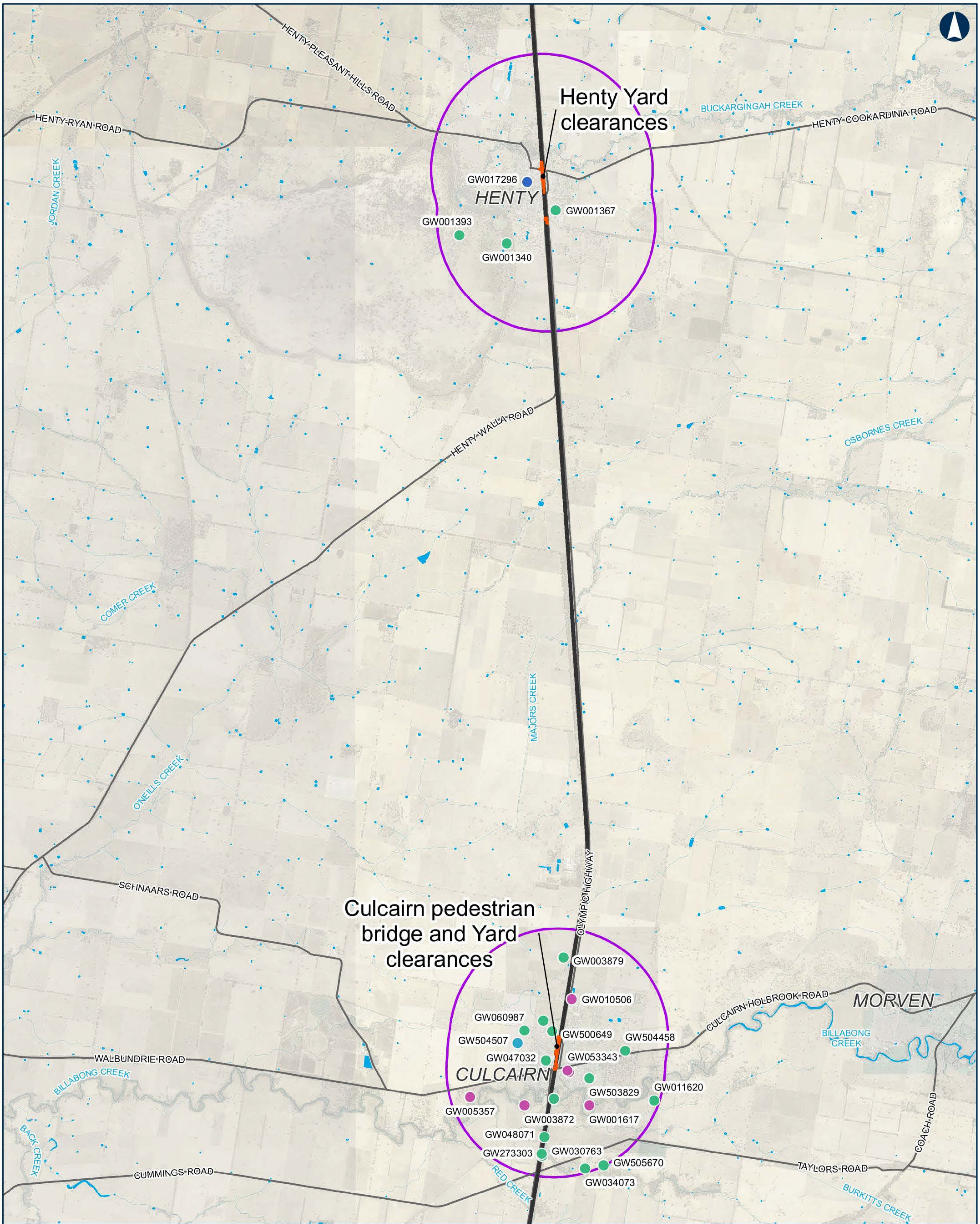

Albury to Illabo Figure 4.5: Registered bores within the groundwater study areas MAP 3 OF 12

0 500 m

Coordinate System: GDA 1994 MGA Zone 55

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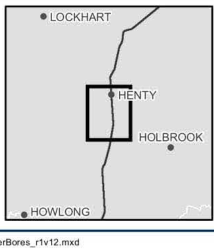
Date: 25/05/2022 Paper: A3
Author: WSP Scale: 1:65,000
Data Sources: ARTC, NSWSS

- Enhancement site
- Existing railway
- Groundwater study area
- Waterbodies
- Waterways
- Main road

Groundwater monitoring bore function

- Other
- Stock and Domestic
- Unknown
- Water Supply



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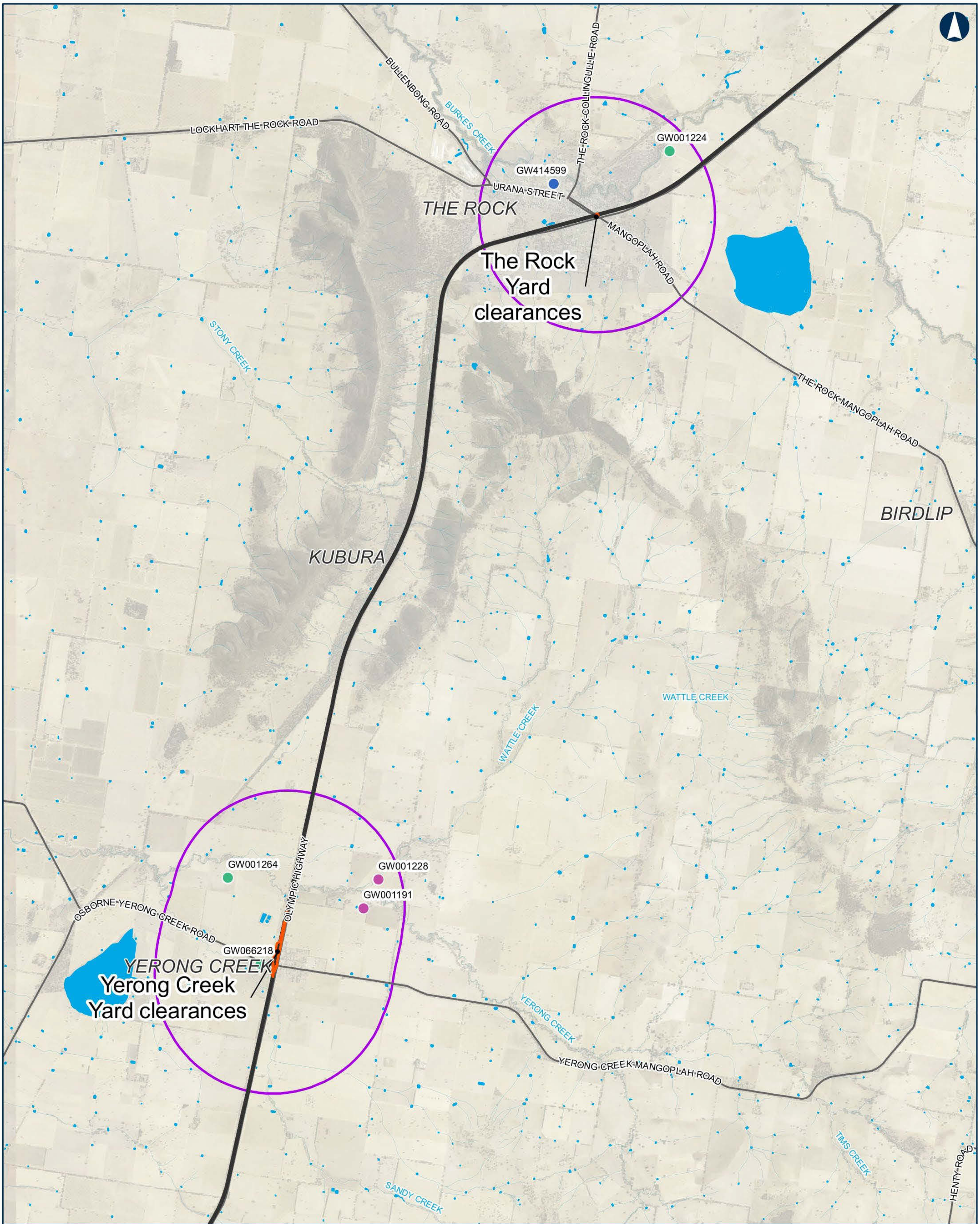

Albury to Illabo Figure 4.5: Registered bores within the groundwater study areas MAP 4 OF 12

0 500 m

Coordinate System: GDA 1994 MGA Zone 55

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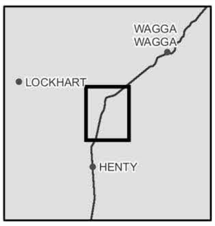
Date: 25/05/2022 Paper: A3
Author: WSP Scale: 1:60,000
Data Sources: ARTC, NSWSS

- Enhancement site
- Main road
- Water Supply
- Existing railway
- Groundwater study area
- Waterbodies
- Waterways

Groundwater monitoring bore function

- Other
- Unknown



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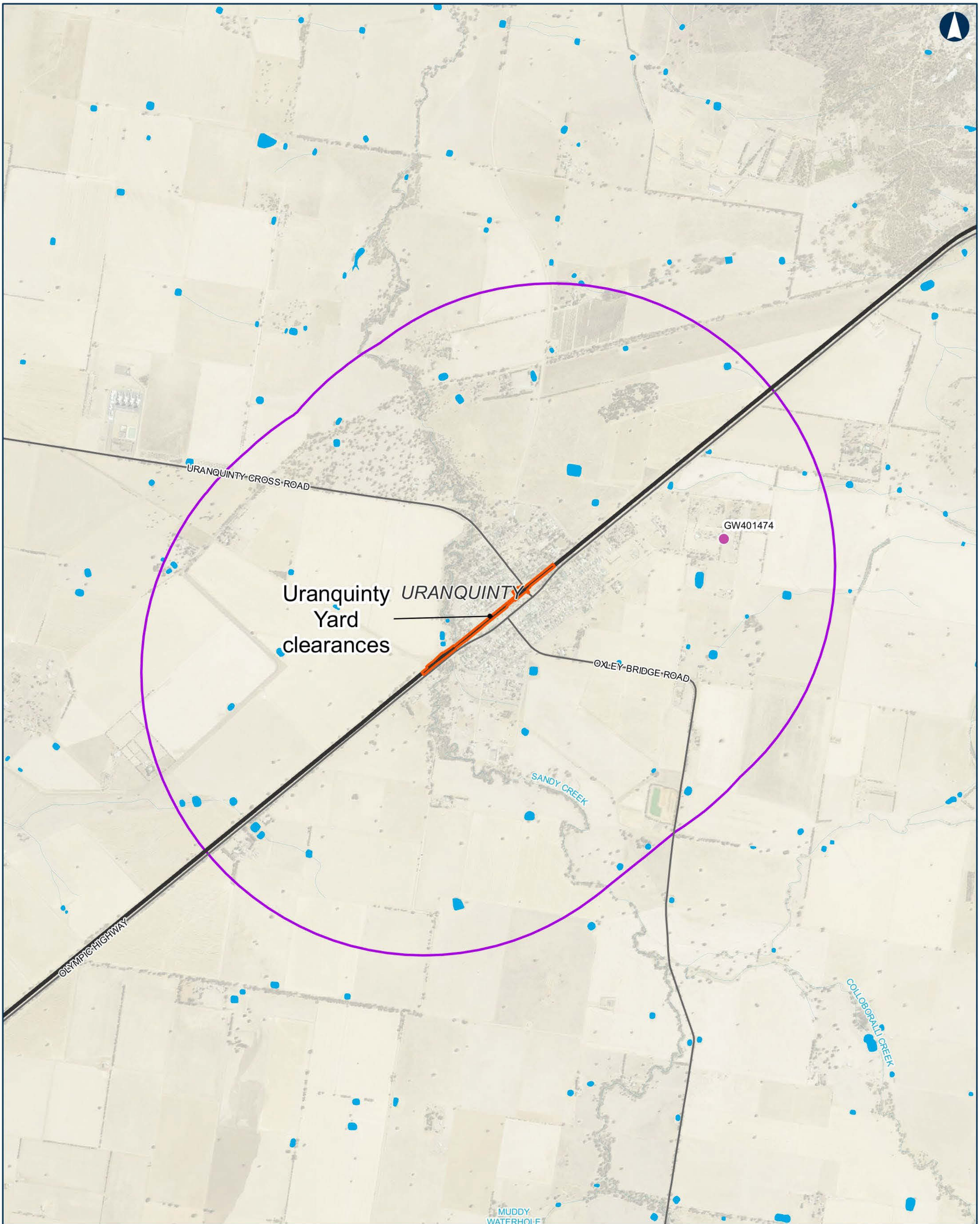


Albury to Illabo Figure 4.5: Registered bores within the groundwater study areas MAP 5 OF 12

0 500 m

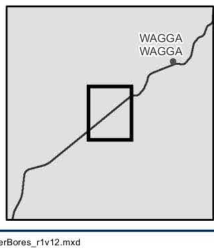
Coordinate System: GDA 1994 MGA Zone 55

Date: 25/05/2022 Paper: A3
Author: WSP Scale: 1:25,000
Data Sources: ARTC, NSWSS

- Enhancement site
- Main road
- Existing railway
- Groundwater study area
- Waterbodies
- Waterways

Groundwater monitoring bore function

- Unknown



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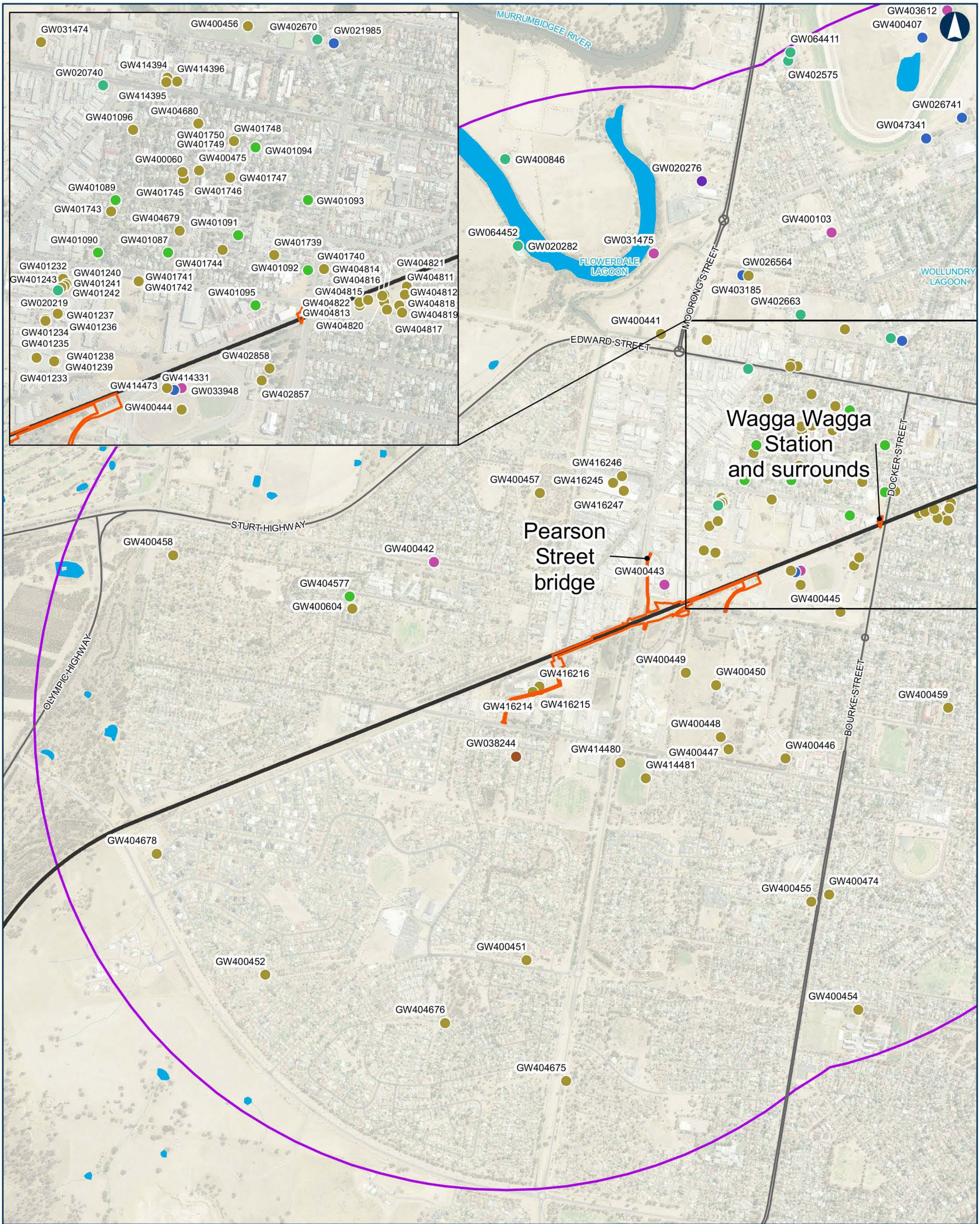

Albury to Illabo Figure 4.5: Registered bores within the groundwater study areas MAP 6 OF 12

0 500 m

Coordinate System: GDA 1994 MGA Zone 55

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Date: 11/11/2021 Paper: A3
Author: WSP Scale: 1:15,000
Data Sources: ARTC, NSWSS

- Enhancement site
- Main road
- Existing railway
- Groundwater study area
- Waterbodies
- Waterways

Groundwater monitoring bore function

- Dewatering
- Exploration
- Irrigation
- Monitoring
- Other
- Unknown
- Water Supply

WAGGA WAGGA

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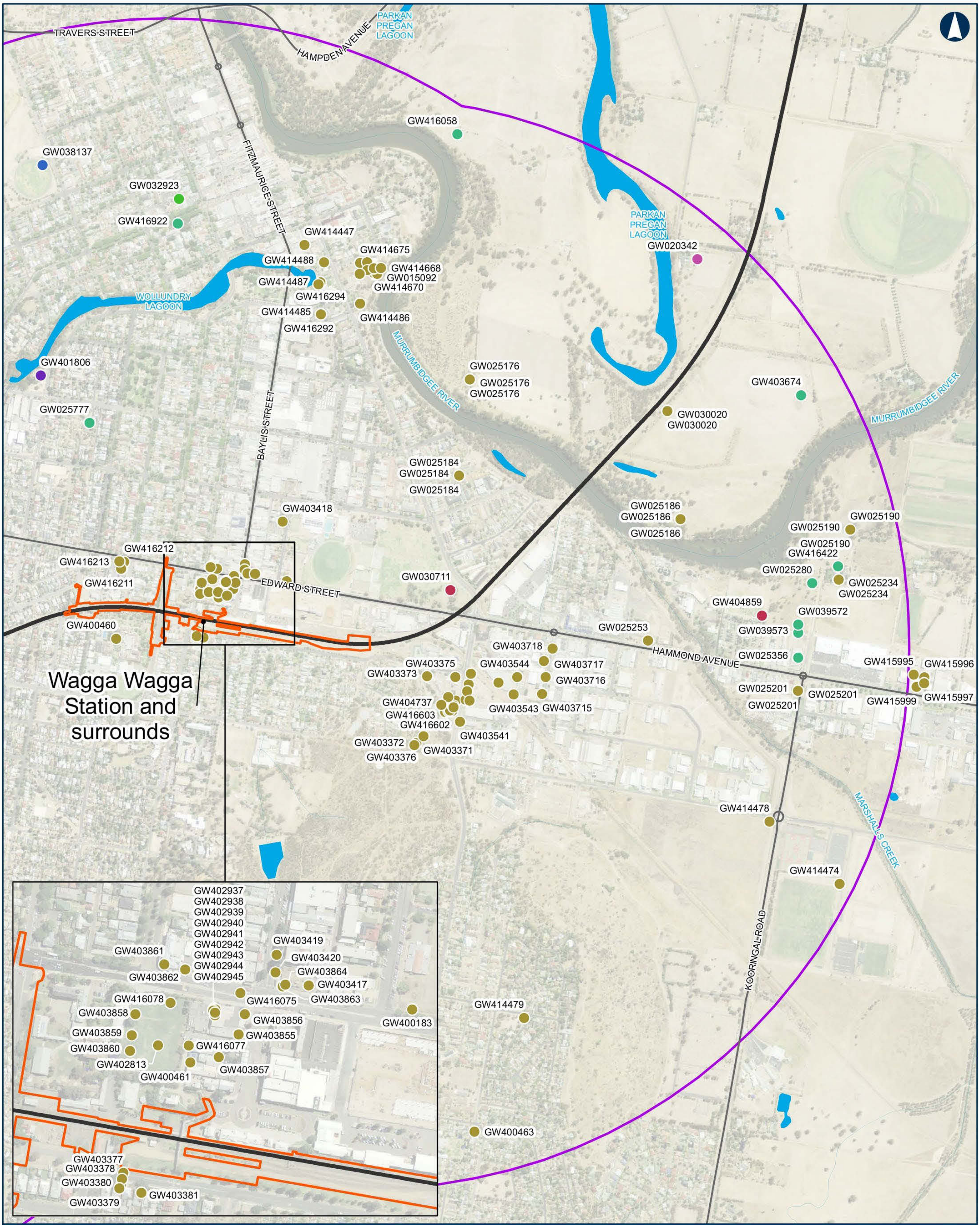

Albury to Illabo | Figure 4.5: Registered bores within the groundwater study areas | MAP 7 OF 12

0 500 m

Coordinate System: GDA 1994 MGA Zone 55

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Author: WSP Scale: 1:13,000
Data Sources: ARTC, NSWSS

- Enhancement site
- Main road
- Existing railway
- Groundwater study area
- Waterbodies
- Waterways

Groundwater monitoring bore function

- Commercial and Industrial
- Dewatering
- Irrigation
- Monitoring
- Other
- Unknown
- Water Supply

WAGGA WAGGA

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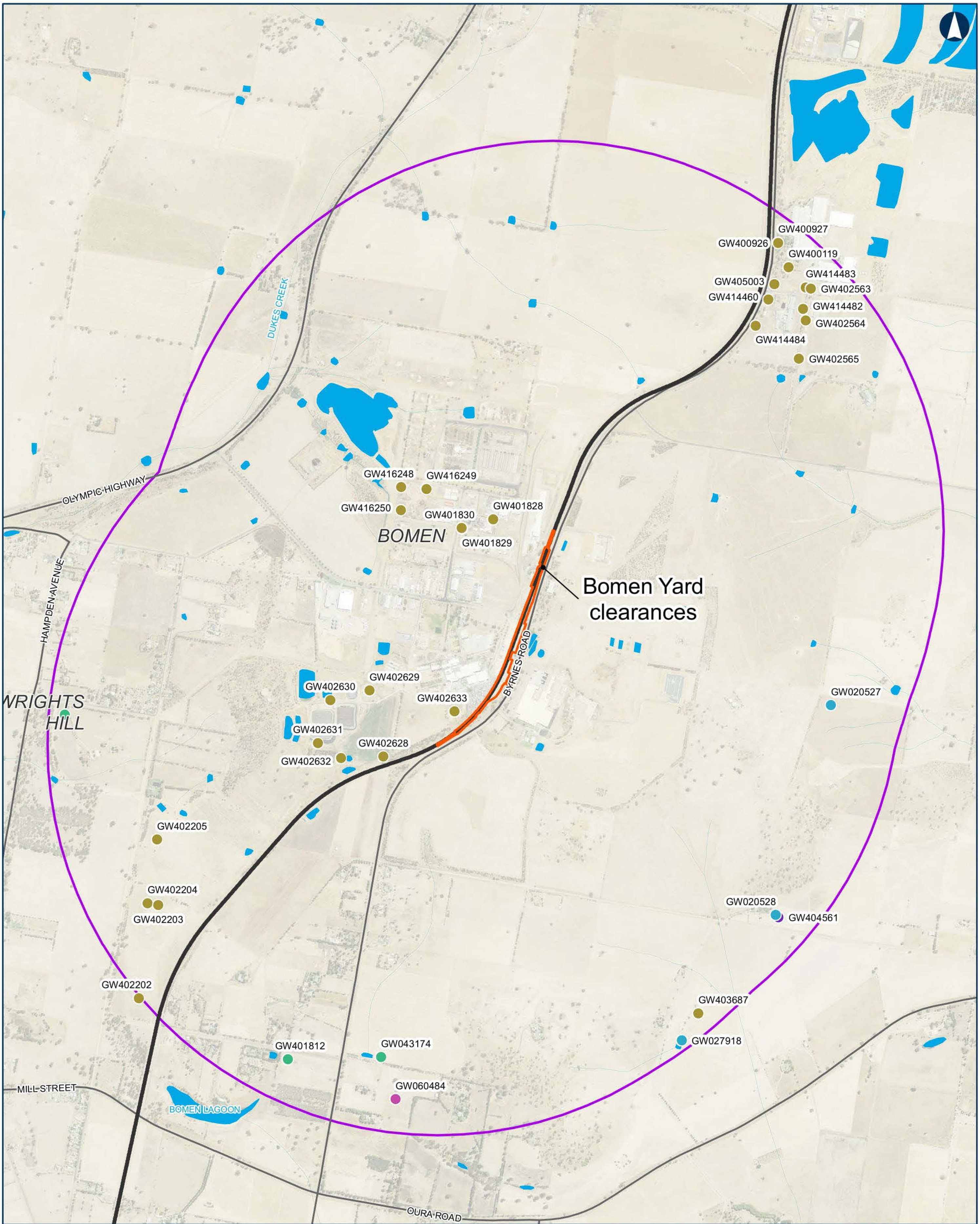

Albury to Illabo Figure 4.5: Registered bores within the groundwater study areas MAP 8 OF 12

0 500 m

Coordinate System: GDA 1994 MGA Zone 55

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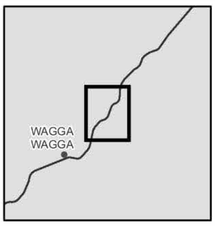
Date: 25/05/2022 Paper: A3
Author: WSP Scale: 1:18,000
Data Sources: ARTC, NSWSS

Enhancement site
Main road
Existing railway
Groundwater study area
Waterbodies
Waterways

Groundwater monitoring bore function
Irrigation
Monitoring
Stock and Domestic
Unknown
Water Supply



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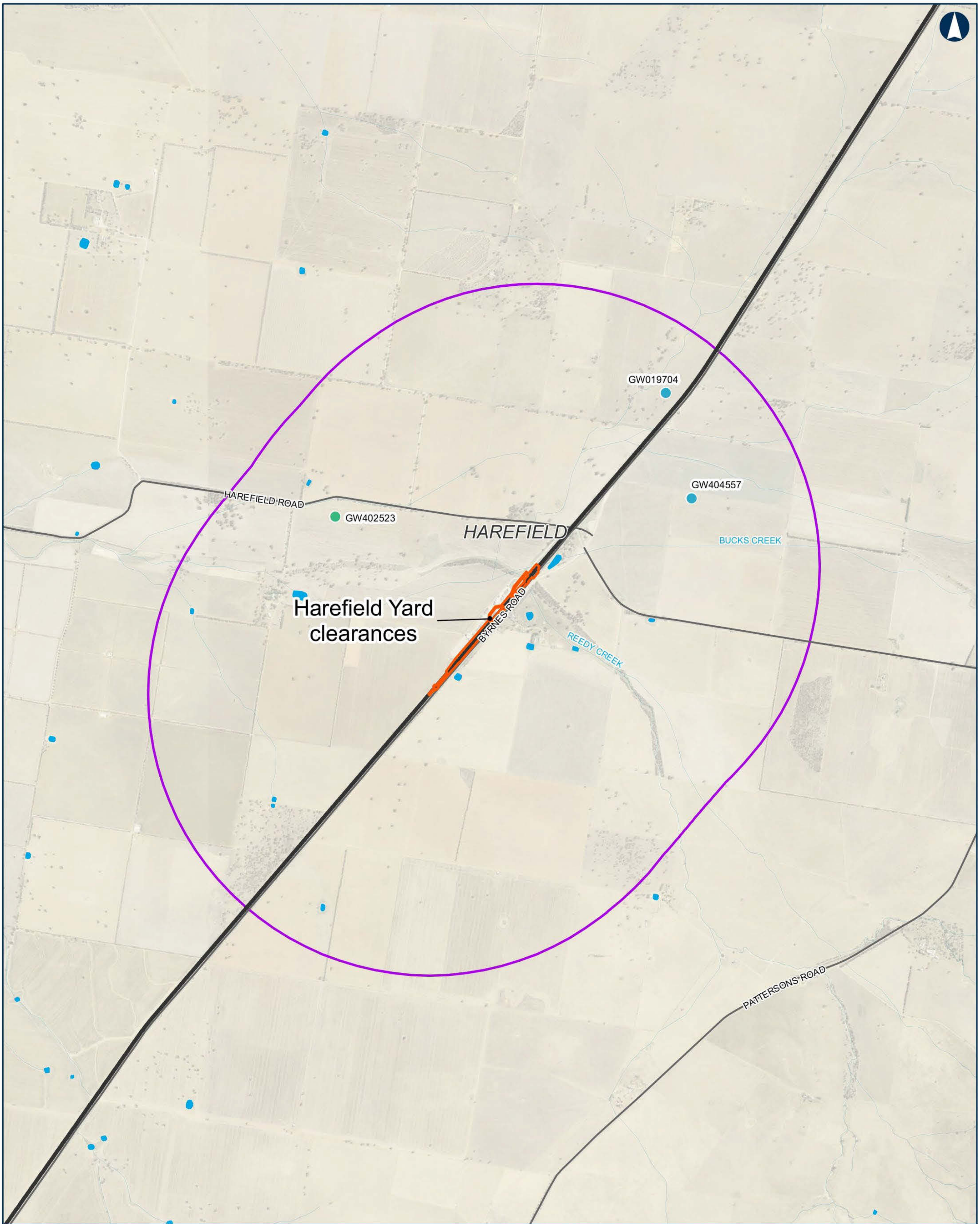

Albury to Illabo

Figure 4.5: Registered bores within the groundwater study areas

MAP 9 OF 12

0 500 m

Coordinate System: GDA 1994 MGA Zone 55

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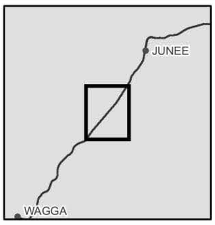
Date: 25/05/2022
Paper: A3
Author: WSP
Scale: 1:25,000
Data Sources: ARTC, NSWSS

Enhancement site
Main road
Existing railway
Groundwater study area
Waterbodies
Waterways

Groundwater monitoring bore function

Stock and Domestic
Water Supply



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Albury to Illabo

Figure 4.5: Registered bores within the groundwater study areas

MAP 10 OF 12

0 500 m

Coordinate System: GDA 1994 MGA Zone 55

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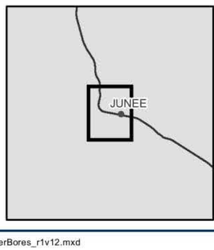
Date: 25/05/2022 Paper: A3
Author: WSP Scale: 1:15,000
Data Sources: ARTC, NSWSS

Enhancement site
Main road
Water Supply
Existing railway
Groundwater study area
Waterbodies
Waterways

Groundwater monitoring bore function

Monitoring
Unknown



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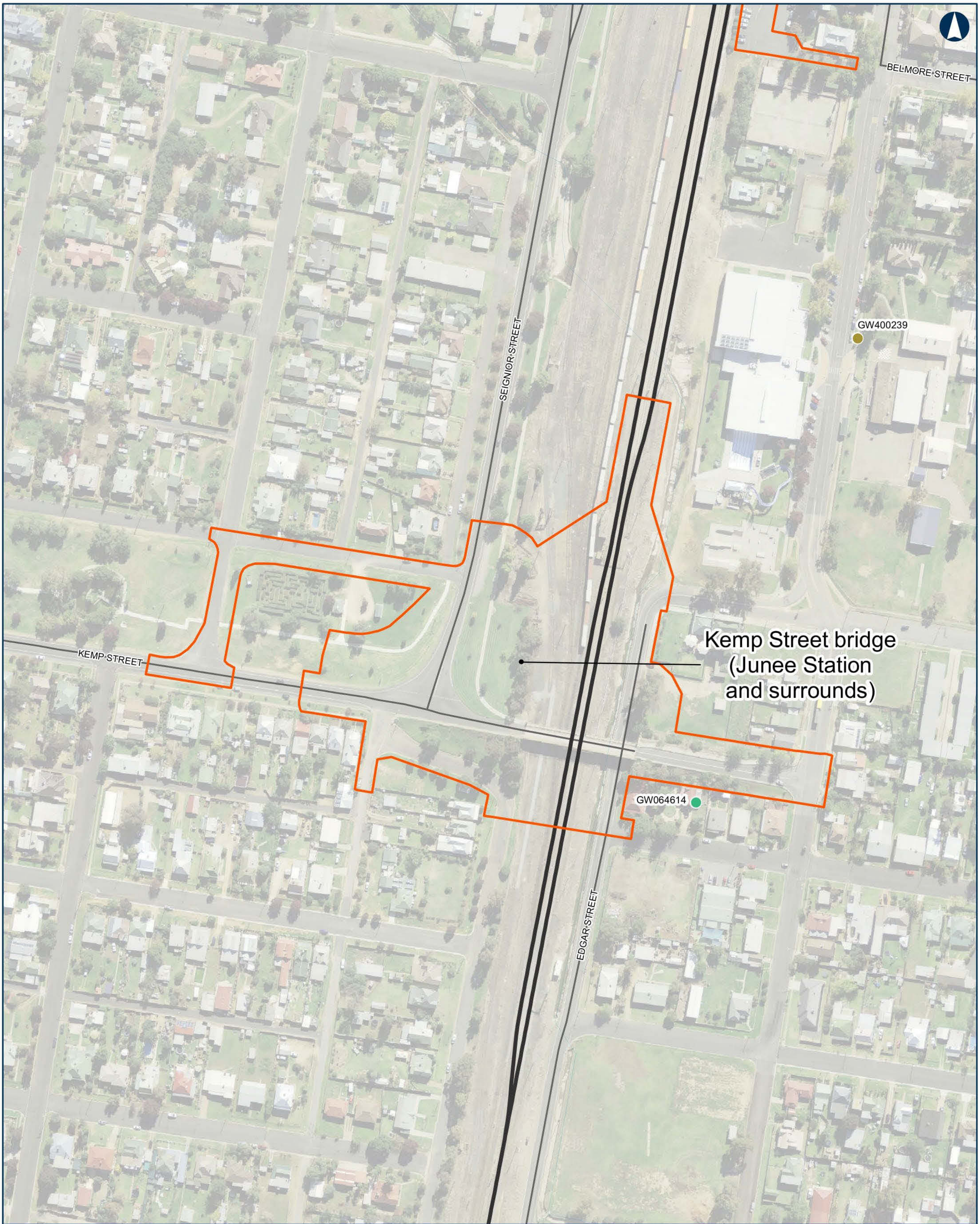


Albury to Illabo — Figure 4.5: Registered bores within the groundwater study areas

MAP 11 OF 12

0 50 m

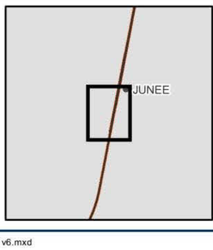
Coordinate System: GDA 1994 MGA Zone 55

Date: 18/02/2022 Paper: A3
Author: WSP Scale: 1:2,000
Data Sources: ARTC, NSWSS

- Enhancement site
- Existing railway
- Main road
- Waterways

Groundwater monitoring bore function

- Monitoring
- Water Supply



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Albury to Illabo Figure 4.5: Registered bores within the groundwater study areas MAP 12 OF 12

0 500 m

Coordinate System: GDA 1994 MGA Zone 55

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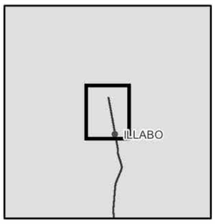
Date: 25/05/2022 Paper: A3
Author: WSP Scale: 1:15,000
Data Sources: ARTC, NSWSS

Enhancement site
Main road
Existing railway
Groundwater study area
Waterbodies
Waterways

Groundwater monitoring bore function

Monitoring
Water Supply



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4.6.2 GROUNDWATER DEPENDENT ECOSYSTEMS

GDE include communities of plants, animals and other organisms that depend on groundwater for survival (DLWC, 2002). A GDE may be either entirely dependent on groundwater for survival or may use groundwater opportunistically or for a supplementary source of water (Hatton and Evans, 1998). The NSW DPI Water Risk Assessment Guidelines for GDEs (NSW Office of Water, 2012) adopts the definition for GDEs as:

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

GDE include wetlands, vegetation, mound springs, river baseflows, cave ecosystems, playa lakes and saline discharges, springs, mangroves, river pools, billabongs and hanging swamps and near-shore marine ecosystems. The GDE Atlas (BOM, 2021) categorises GDEs as aquatic (for surface water bodies) or terrestrial.

Groundwater discharge can be important in maintaining baseflow in rivers and streams, and ecosystems associated with these discharge areas may have a high dependency on groundwater for their water requirements. It should be noted however that some of these ecosystems rely on perched aquifer systems that are shallow, surficial and are largely not connected to the deep regional groundwater system. That is, these ecosystems are largely sustained by recharge-in/recharge-out processes associated with rainfall infiltration which typically characterise the behaviour of shallow perched water systems. Within the groundwater study areas, this relates to GDEs that are located overlying colluvial or residual soils associated with Lachlan fractured rock HSU.

A total of 31 GDEs have collectively been identified across the groundwater study area that rely on the surface expression of groundwater. The location of these GDEs relative to the enhancement sites are presented in Figure 4.6 with key information for each precinct listed in Table 4.20 to Table 4.23.

Table 4.20 GDEs identified within the Albury precinct groundwater study areas

ENHANCEMENT SITE	DESCRIPTION	GDE TYPE	GDE POTENTIAL
Murray River bridge	Murray River.	Aquatic	High
	Bungambrawatha Creek.	Aquatic	High
	Wetlands. Palustrine or Lacustrine.	Aquatic	High
	Riverine Grassy Woodland. Dissected high plateaus on various resistant rocks, with isolated high plains.	Terrestrial – vegetation	High
	Riverine Swampy Woodland Mosaic. Dissected high plateaus on various resistant rocks, with isolated high plains.	Terrestrial – vegetation	High
	River Red Gum. Herbaceous-grassy very tall open forest wetland on inner floodplains.	Terrestrial – vegetation	High
	Floodplain Riparian Woodland. Dissected high plateaus on various resistant rocks, with isolated high plains.	Terrestrial – vegetation	High
	Wetlands. Floodplain water bodies.	Aquatic	Moderate

ENHANCEMENT SITE	DESCRIPTION	GDE TYPE	GDE POTENTIAL
	Plains Grassy Woodland. Ridges and minor tablelands stepping down westwards and breaking into detached hills with intervening alluvial valley floors. Some strong structural control on landforms.	Terrestrial – vegetation	Moderate
Albury Station pedestrian bridge and Yard clearances and Riverina Highway bridge	Murray River.	Aquatic	High
	Bungambrawatha Creek.	Aquatic	High
	Riverine Swampy Woodland Mosaic. Dissected high plateaus on various resistant rocks, with isolated high plains.	Terrestrial – vegetation	High
	River Red Gum. Herbaceous-grassy very tall open forest wetland on inner floodplains.	Terrestrial – vegetation	High
	Tussock grass – Sedgeland fen – rushland – reedland. Wetland in impeded creeks in valleys.	Terrestrial – vegetation	High
	Black Springs Creek.	Aquatic	Moderate
	White box – Blakelys Red Gum – Red Box – Red Stringbark. Shrubby woodland on shallow soils on metamorphic hills.	Terrestrial – vegetation	Low
	Derived grassland of the NSW Western Slopes. Lateritic Plain.	Terrestrial – vegetation	Low
Billy Hughes bridge	Seven Mile Creek.	Aquatic	High
	Eight Mile Creek.	Aquatic	High
	Blakelys Red Gum – Yellow Box. Grassy tall woodland.	Terrestrial – vegetation	High
	Canegrass swamp. Tall grassland wetland of drainage depressions, lakes and pans of the inland plains.	Terrestrial – vegetation	High
	Speargrass – Redleg Grass. Derived grassland on hills.	Terrestrial – vegetation	Moderate and low
	White Box. Grassy woodland.	Terrestrial – vegetation	Low
	Dwyers Red Gum – Black Cypress Pine – Currawang. Shrubby low woodland on rocky hills.	Terrestrial – vegetation	Low

Table 4.21 GDEs identified within the Greater Hume – Lockhart precinct groundwater study areas

ENHANCEMENT SITE	DESCRIPTION	GDE TYPE	GDE POTENTIAL
Table Top Yard clearances	Sandy Creek.	Aquatic	High
	Wetland. Floodplain water body.	Aquatic	High and low
	Blakelys Red Gum – Yellow Box. Grassy tall woodland.	Terrestrial – vegetation	High
	White Box. Grassy woodland.	Terrestrial – vegetation	Low
Culcairn pedestrian bridge and Yard clearances	River Red Gum. Herbaceous-grassy very tall open forest wetland on inner floodplains.	Terrestrial – vegetation	High
	Billabong Creek.	Aquatic	Moderate
Henty Yard clearances	Doodle Corner Swamp.	Aquatic	High
	River Red Gum. Herbaceous-grassy very tall open forest wetland on inner floodplains.	Terrestrial – vegetation	High
	Shallow marsh wetland. Wetland of regularly flooded depressions on floodplains.	Terrestrial – vegetation	High
Yerong Creek Yard clearances	Yerong Creek.	Aquatic	Moderate
The Rock Yard clearances	Burkes Creek.	Aquatic	High

Table 4.22 GDEs identified within the Wagga Wagga precinct groundwater study areas

ENHANCEMENT SITE	DESCRIPTION	GDE TYPE	GDE POTENTIAL
Uranquinty Yard clearances	Sandy Creek.	Aquatic	High
	Blakelys Red Gum – Yellow Box. Grassy tall woodland.	Terrestrial – vegetation	Moderate
	Yellow Box – River Red Gum. Tall grassy riverine woodland.	Terrestrial – vegetation	Moderate
	Western Grey Box – White Cypress Pine. Tall woodland on loam soil on alluvial plains.	Terrestrial – vegetation	Moderate
	White Box – White Cypress Pine – Western Grey Box. Shrub/grassland/forb woodland.	Terrestrial – vegetation	Low

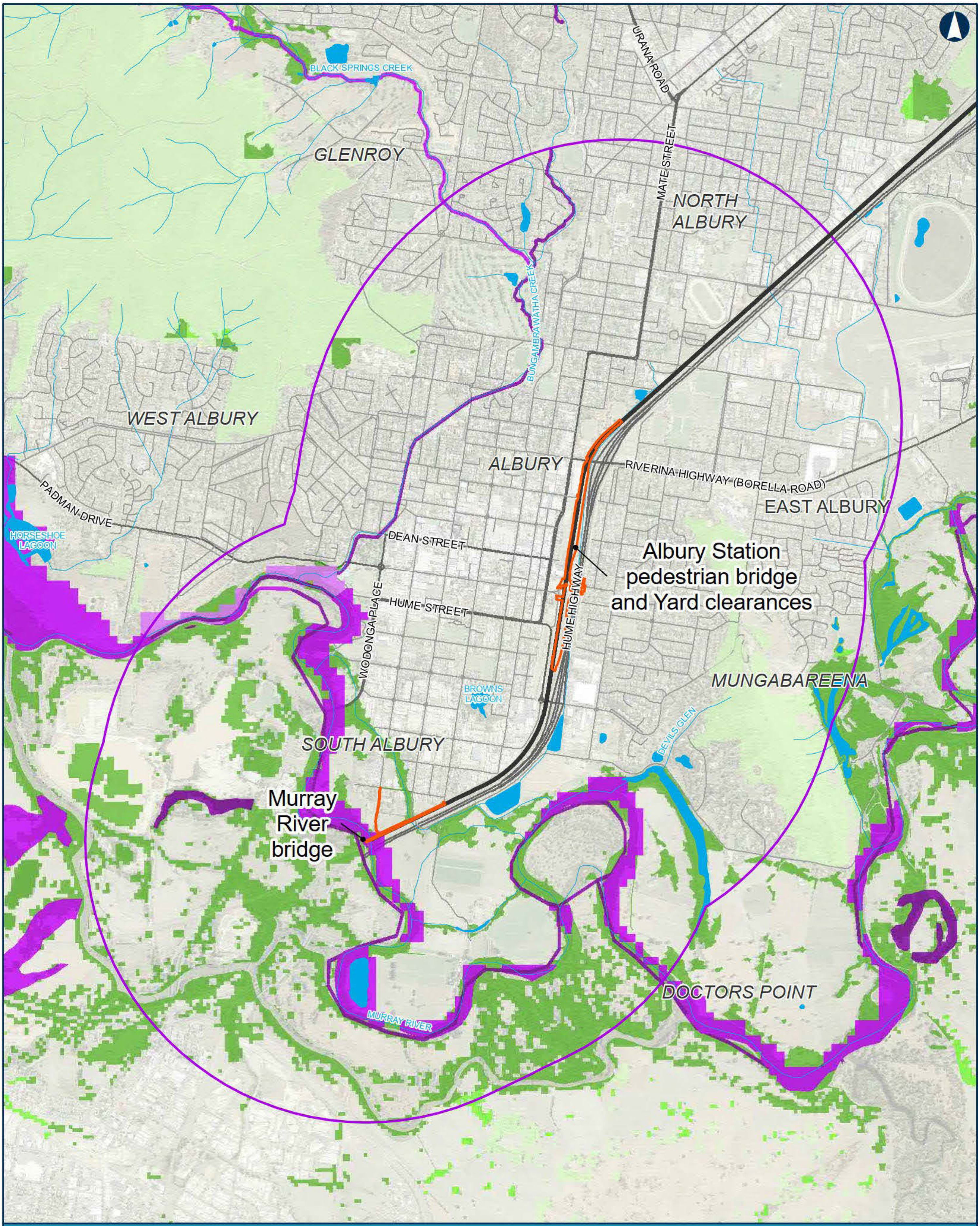
ENHANCEMENT SITE	DESCRIPTION	GDE TYPE	GDE POTENTIAL
	Western Box. Tall grassy woodland.	Terrestrial – vegetation	Low
Pearson Street bridge	River Red Gum. Herbaceous-grassy very tall open forest wetland on inner floodplains.	Terrestrial – vegetation	High
	Blakelys Red Gum – Yellow Box. Grassy tall woodland.	Terrestrial – vegetation	High, moderate and low
	Wetland. Floodplain water body.	Aquatic	Moderate
	White box – Blakelys Red Gum – White Cypress Pine. Shrubby woodland on metamorphic hills.	Terrestrial – vegetation	Low
Wagga Wagga Station and surrounds .	Murrumbidgee River.	Aquatic	High
	Marshalls Creek.	Aquatic	High
	Wetland. Floodplain water body.	Aquatic	High, moderate and low
	Yellow Box – River Red Gum. Tall grassy riverine woodland.	Terrestrial – vegetation	High and moderate
	River Red Gum. Herbaceous-grassy very tall open forest wetland on inner floodplains.	Terrestrial – vegetation	High
	Blakelys Red Gum – Yellow Box. Grassy tall woodland.	Terrestrial – vegetation	High, moderate and low
	White box – Blakelys Red Gum – White Cypress Pine. Shrubby woodland on metamorphic hills.	Terrestrial – vegetation	Low
Bomen Yard clearances	River Red Gum – Wallaby grass. Tall woodland wetland on the outer River Red Gum zone.	Terrestrial – vegetation	High
	River Red Gum. Herbaceous-grassy very tall open forest wetland on inner floodplains.	Terrestrial – vegetation	High
	Blakelys Red Gum – Yellow Box. Grassy tall woodland.	Terrestrial – vegetation	Moderate

ENHANCEMENT SITE	DESCRIPTION	GDE TYPE	GDE POTENTIAL
	White box – Blakelys Red Gum – White Cypress Pine. Shrubby woodland on metamorphic hills.	Terrestrial – vegetation	Low
	Plains Grass. Grassland on alluvial, mainly clay soil.	Terrestrial – vegetation	Low
	White Box – White Cypress Pine – Western Grey Box. Shrub/grassland/forb woodland.	Terrestrial – vegetation	Low

Table 4.23 GDEs identified within the Junee precinct groundwater study areas

ENHANCEMENT SITE	DESCRIPTION	GDE TYPE	GDE POTENTIAL
Harefield Yard clearances	Western Grey Box – White Cypress Pine. Tall woodland on loam soil on alluvial plains.	Terrestrial – vegetation	Low
	Western Grey Box. Tall grassy woodland on alluvial loam and clay soils.	Terrestrial – vegetation	Low
	Yellow Box. Grassy tall woodland on alluvium or loams and clays.	Terrestrial – vegetation	Low
	Plains Grass. Grassland on alluvial, mainly clay soil.	Terrestrial – vegetation	Low
	Blakelys Red Gum – Yellow Box. Grassy tall woodland.	Terrestrial – vegetation	Low
Junee Station and surrounds	Rock Creek.	Aquatic	High
	White Box. Grassy woodland.	Terrestrial – vegetation	Low
	Blakelys Red Gum – Yellow Box. Grassy tall woodland.	Terrestrial – vegetation	Low
	White Box – White Cypress Pine – Western Grey Box. Shrub/grassland/forb woodland.	Terrestrial – vegetation	Low
Olympic Highway underbridge	Rock Creek.	Aquatic	High
	White Box. Grassy woodland.	Terrestrial – vegetation	Low
	Blakelys Red Gum – Yellow Box. Grassy tall woodland.	Terrestrial – vegetation	Low

ENHANCEMENT SITE	DESCRIPTION	GDE TYPE	GDE POTENTIAL
	White Box – White Cypress Pine – Western Grey Box. Shrub/grassland/forb woodland.	Terrestrial – vegetation	Low
Junee to Illabo clearances	Jeralgambeth Creek.	Aquatic	High
	Billabong Creek.	Aquatic	High
	River Red Gum. Shrub/grass riparian tall woodland or open forest wetland.	Terrestrial – vegetation	High and moderate
	Blakelys Red Gum – Yellow Box. Grassy tall woodland.	Terrestrial – vegetation	High, moderate and low
	Western Grey Box – White Cypress Pine. Tall woodland on loam soil on alluvial plains.	Terrestrial – vegetation	Moderate
	Yellow Box. Grassy tall woodland on alluvium or loams and clays.	Terrestrial – vegetation	Moderate
	Western Grey Box. Tall grassy woodland on alluvial loam and clay soils.	Terrestrial – vegetation	Low
	White Box – White Cypress Pine – Western Grey Box. Shrub/grassland/forb woodland.	Terrestrial – vegetation	Low
	White Box. Grassy woodland.	Terrestrial – vegetation	Low



Albury to Illabo Figure 4.6: Potential & priority Groundwater Dependent Ecosystems in the groundwater study areas MAP 1 OF 14

0 0.5 km

Coordinate System: GDA 1994 MGA Zone 55

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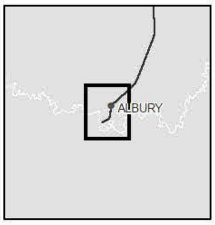
Date: 18/02/2022 Paper: A3
Author: WSP Scale: 1:25,000
Data Sources: ARTC, NSWSS

- Enhancement site
- Existing railway
- Main road
- Local road
- Groundwater study area
- Waterbodies
- Waterways

Terrestrial GDEs
- High potential GDE
- Moderate potential GDE
- Low potential GDE

Aquatic GDEs
- High potential GDE
- Moderate potential GDE
- Low potential GDE



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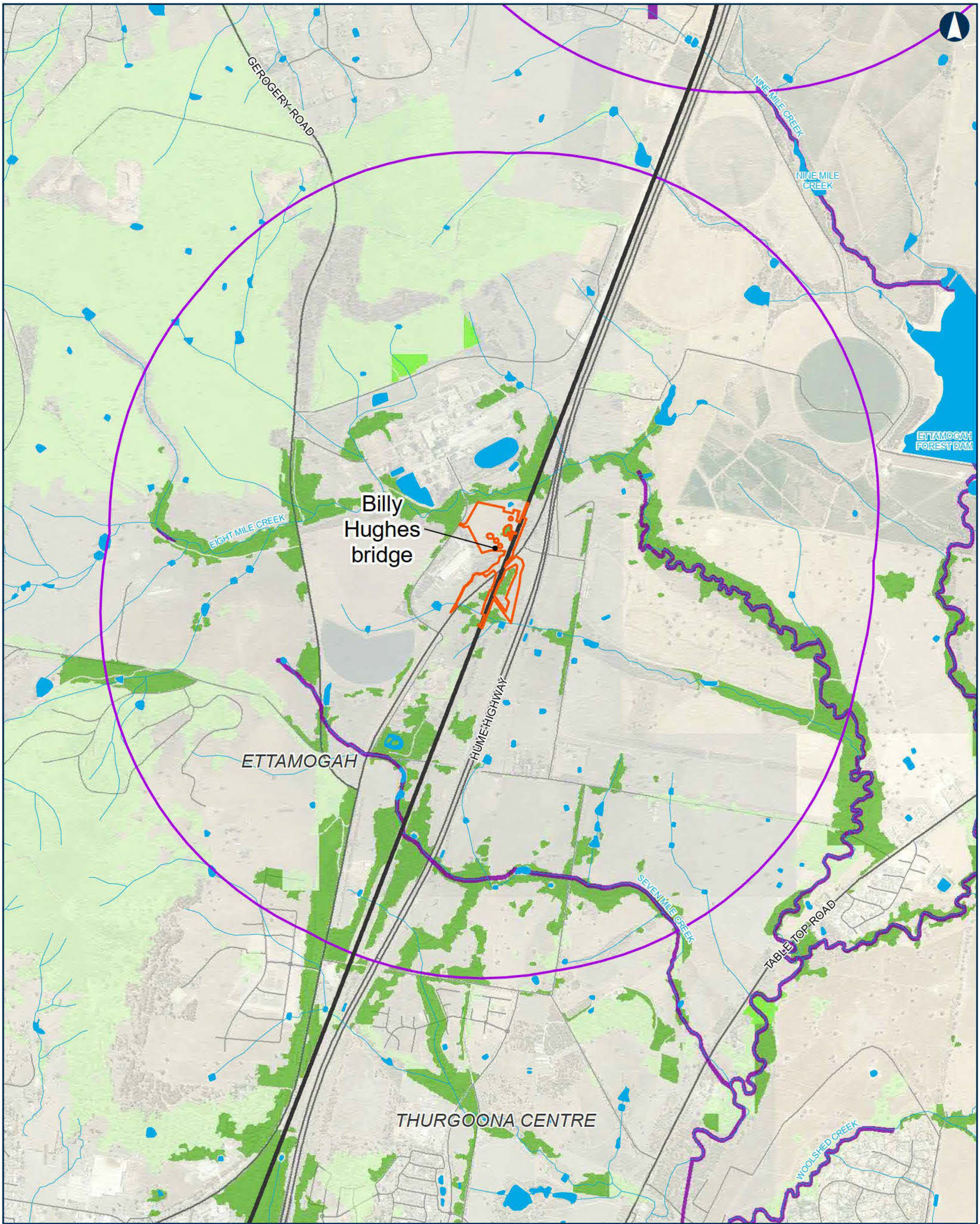

Albury to Illabo Figure 4.6: Potential & priority Groundwater Dependent Ecosystems in the groundwater study areas MAP 2 OF 14

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Data Sources: ARTC, NSWSS

- Enhancement site
- Existing railway
- Main road
- Local road
- Groundwater study area
- Waterbodies
- Waterways

Terrestrial GDEs
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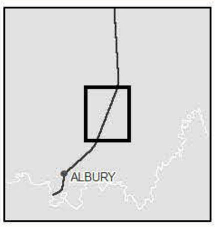
- Moderate potential GDE
- Low potential GDE

Aquatic GDEs
- High potential GDE
- Moderate potential GDE
- Low potential GDE



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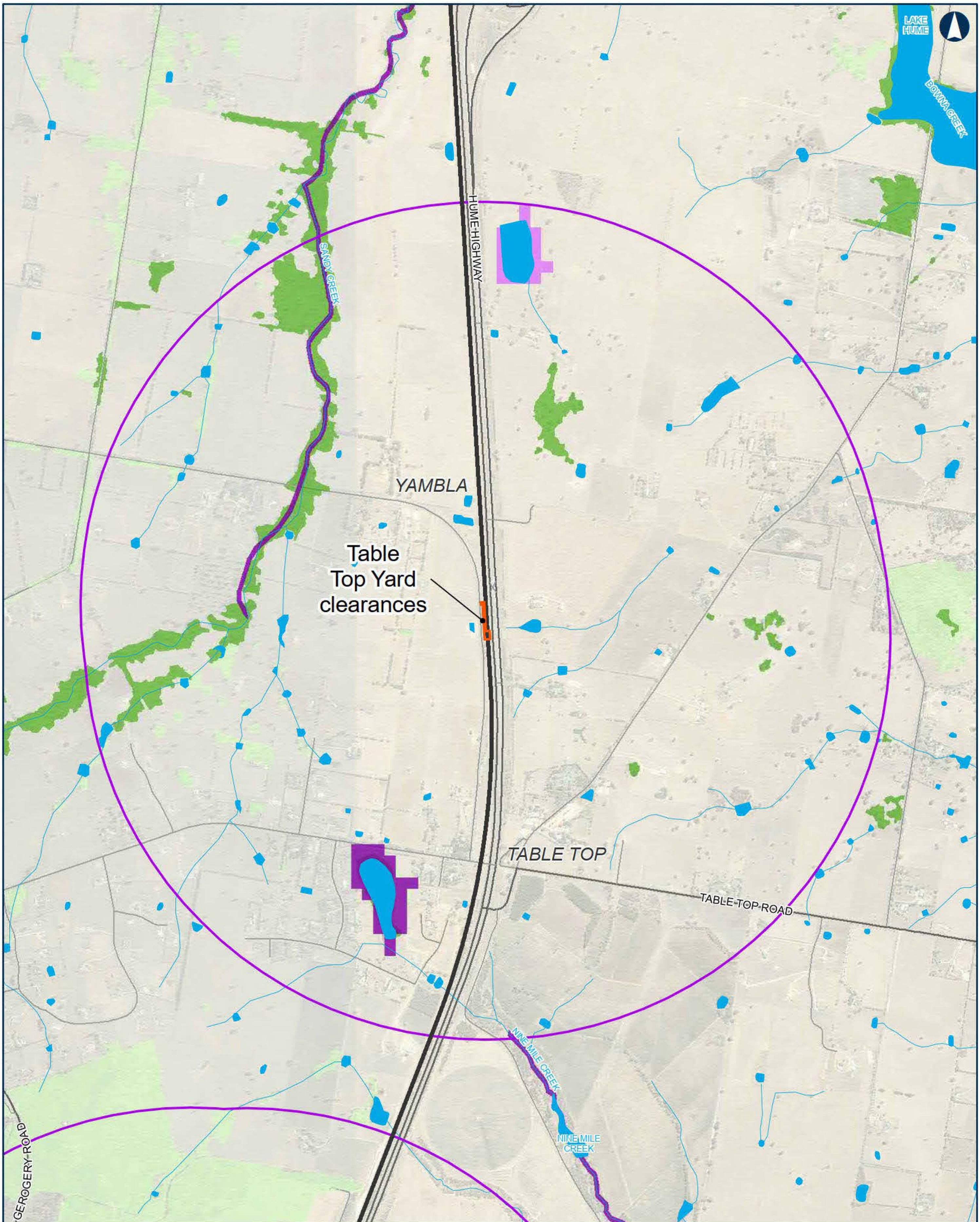

Albury to Illabo Figure 4.6: Potential & priority Groundwater Dependent Ecosystems in the groundwater study areas MAP 3 OF 14

0 0.5 km

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- Enhancement site
- Existing railway
- Main road
- Local road
- Groundwater study area
- Waterbodies
- Waterways

Terrestrial GDEs
- High potential GDE
- Moderate potential GDE
- Low potential GDE

Aquatic GDEs
- High potential GDE
- Moderate potential GDE
- Low potential GDE

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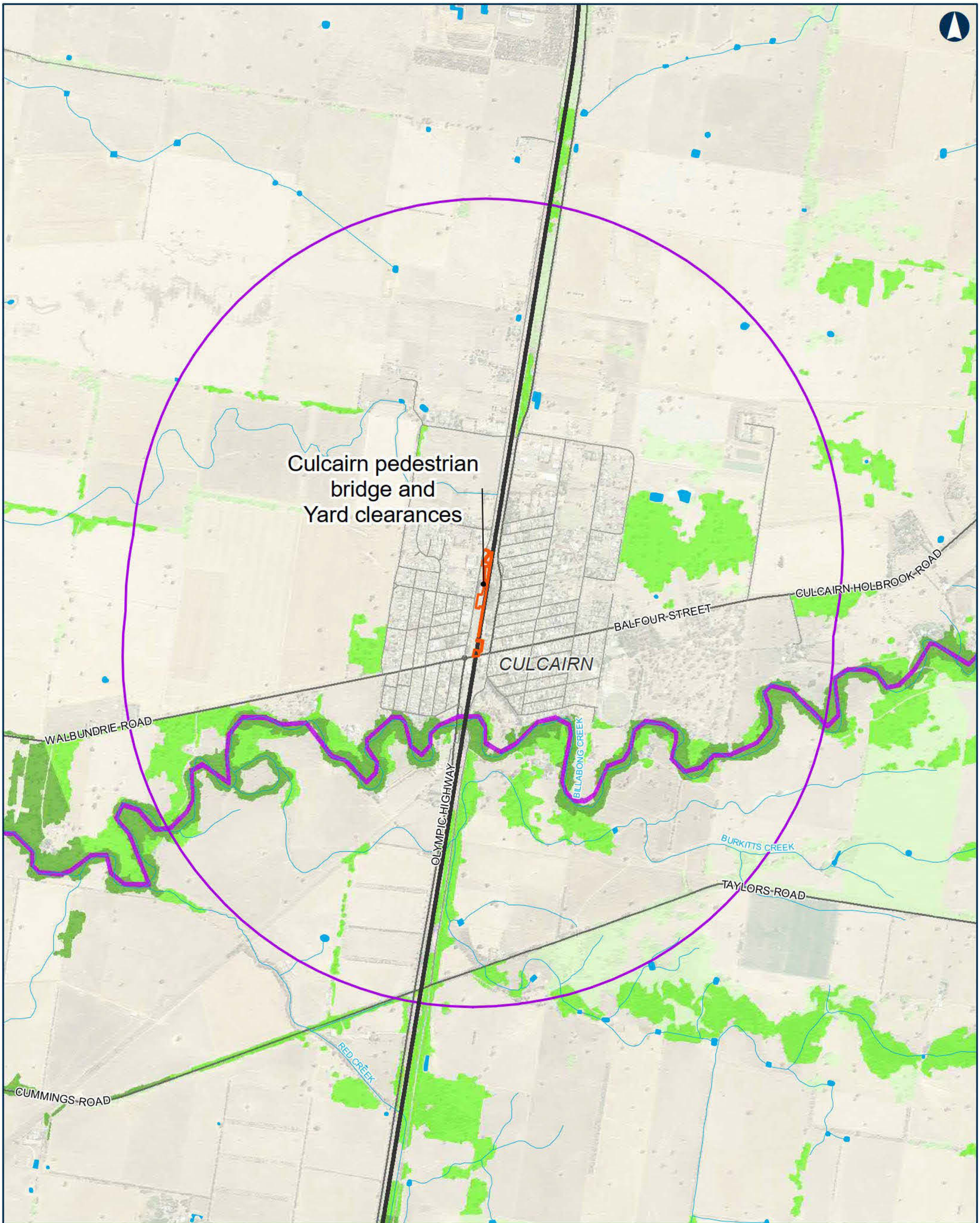

Albury to Illabo

Figure 4.6: Potential & priority Groundwater Dependent Ecosystems in the groundwater study areas

MAP 4 OF 14

0 0.5 km

Coordinate System: GDA 1994 MGA Zone 55

Date: 18/02/2022
Paper: A3
Author: WSP
Scale: 1:20,000
Data Sources: ARTC, NSWSS

- Enhancement site
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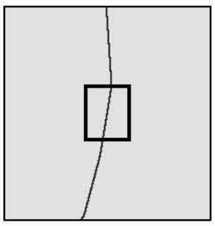
- Waterways

Terrestrial GDEs

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

Aquatic GDEs

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



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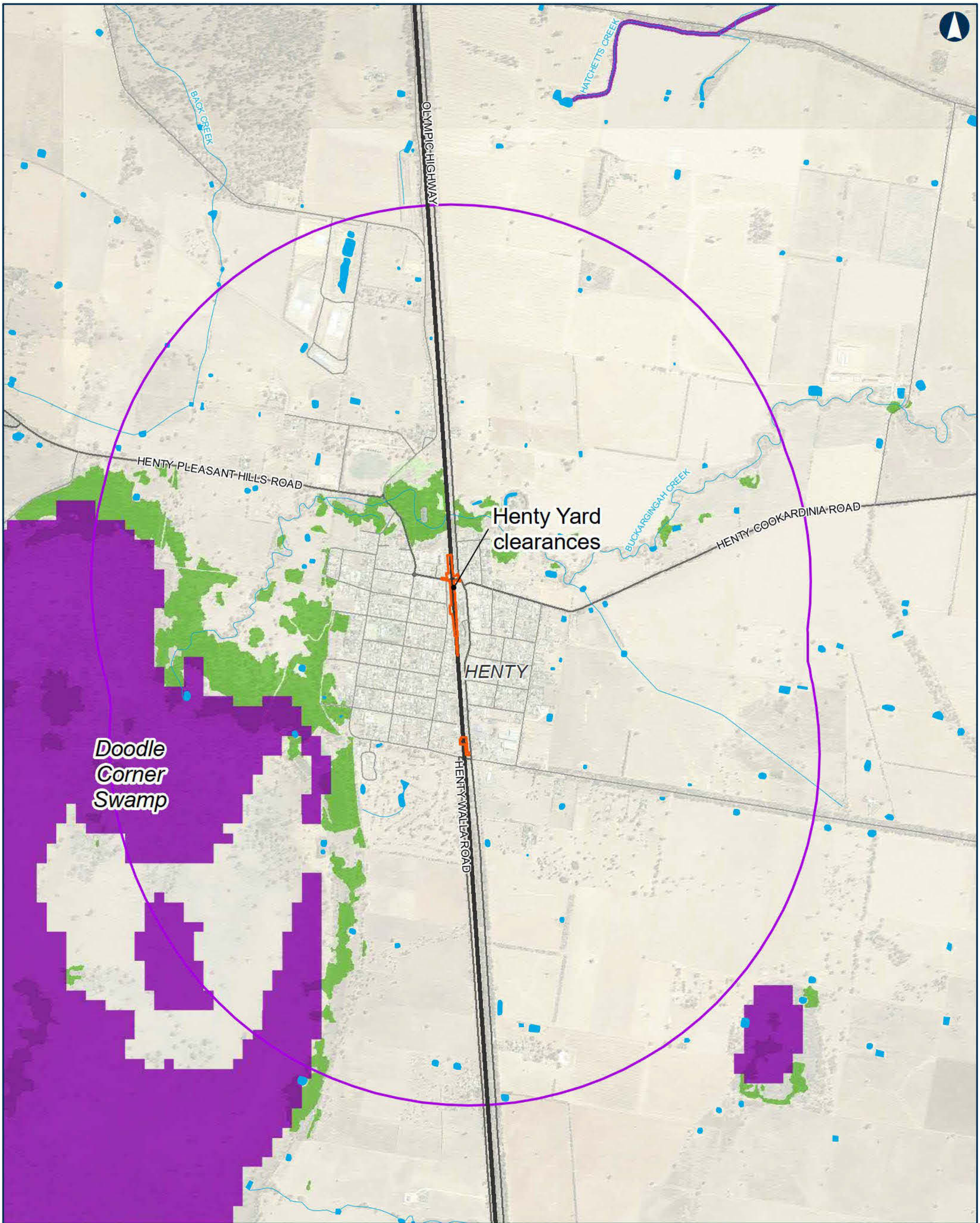

Albury to Illabo Figure 4.6: Potential & priority Groundwater Dependent Ecosystems in the groundwater study areas MAP 5 OF 14

0 0.5 km

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Terrestrial GDEs
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- Moderate potential GDE
- Low potential GDE

Aquatic GDEs
- High potential GDE
- Moderate potential GDE
- Low potential GDE

HENTY

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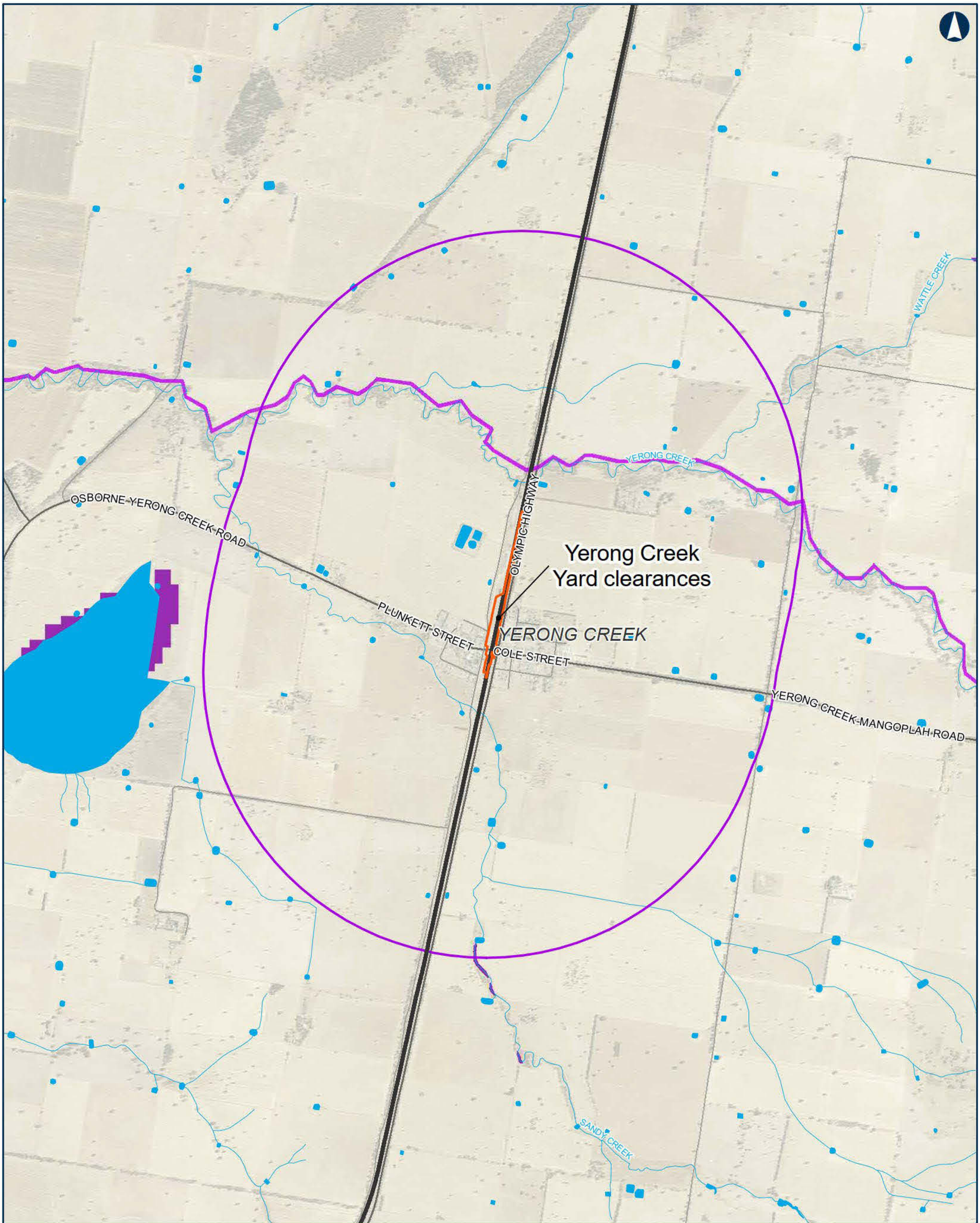

Albury to Illabo Figure 4.6: Potential & priority Groundwater Dependent Ecosystems in the groundwater study areas MAP 6 OF 14

0 0.5 km

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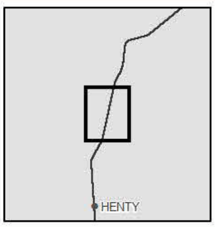
- Low potential GDE



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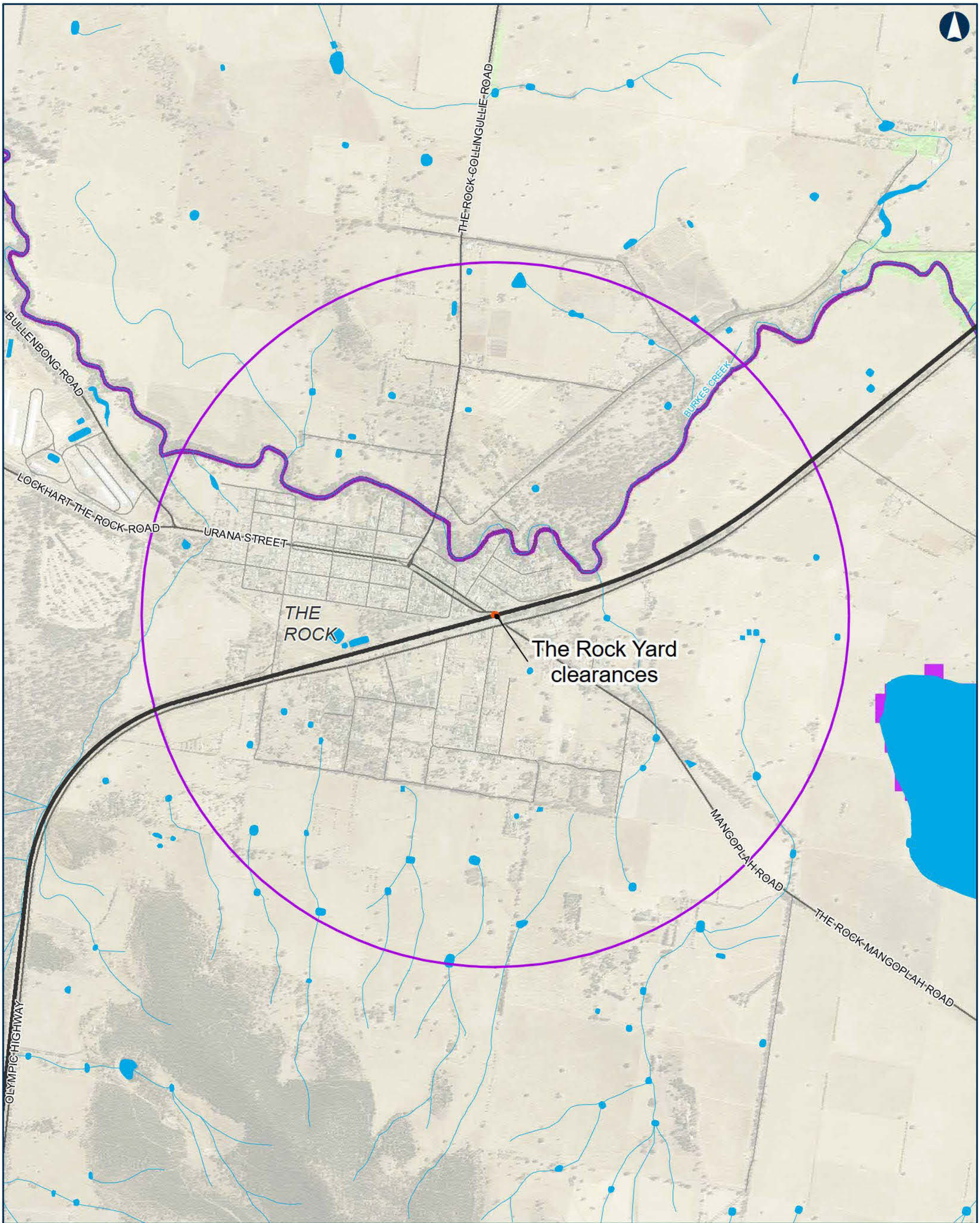

Albury to Illabo Figure 4.6: Potential & priority Groundwater Dependent Ecosystems in the groundwater study areas MAP 7 OF 14

0 0.5 km

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Terrestrial GDEs
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Aquatic GDEs
- High potential GDE
- Moderate potential GDE
- Low potential GDE

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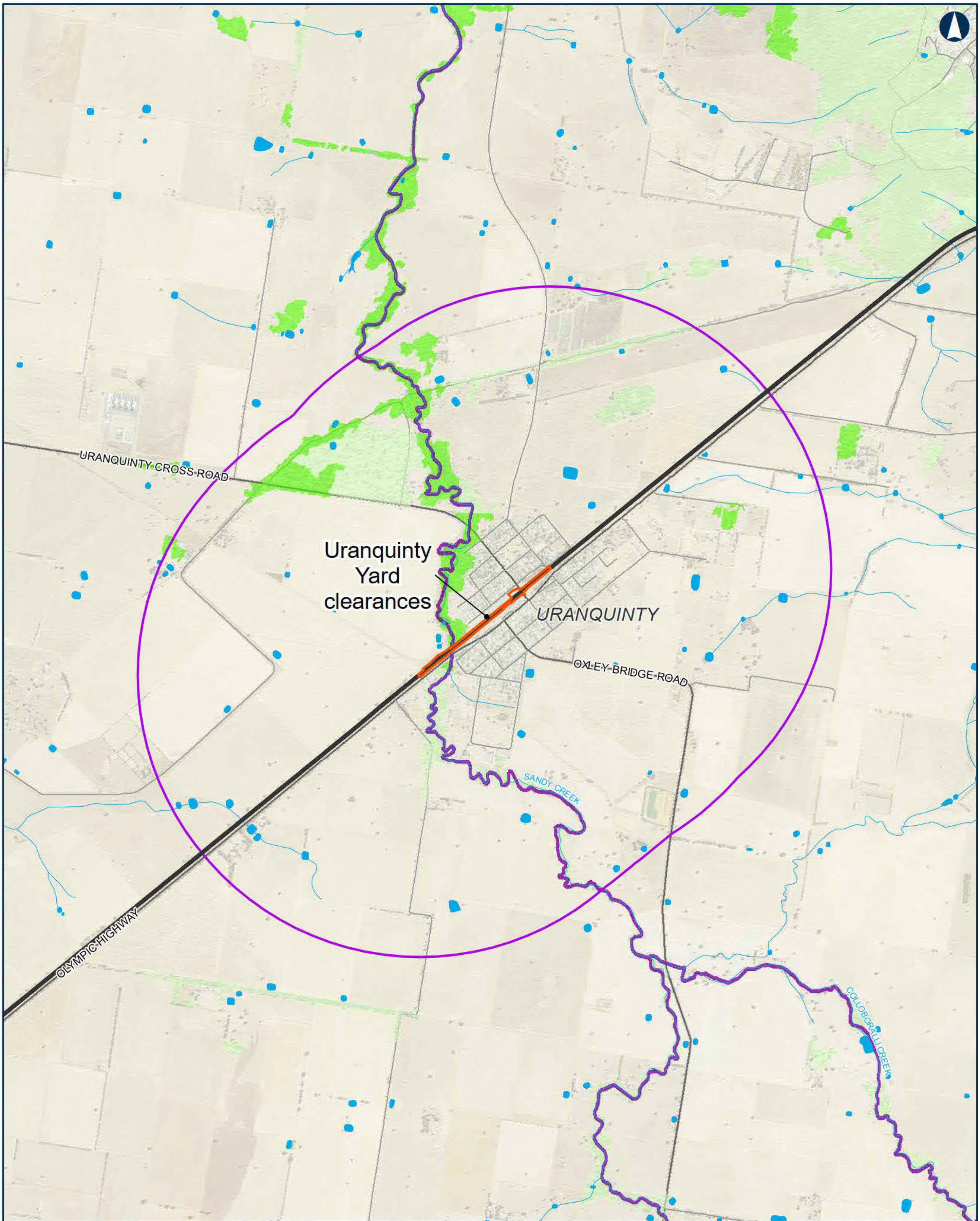
Albury to Illabo

Figure 4.6: Potential & priority Groundwater Dependent Ecosystems in the groundwater study areas

MAP 8 OF 14



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Aquatic GDEs
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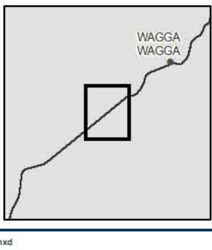

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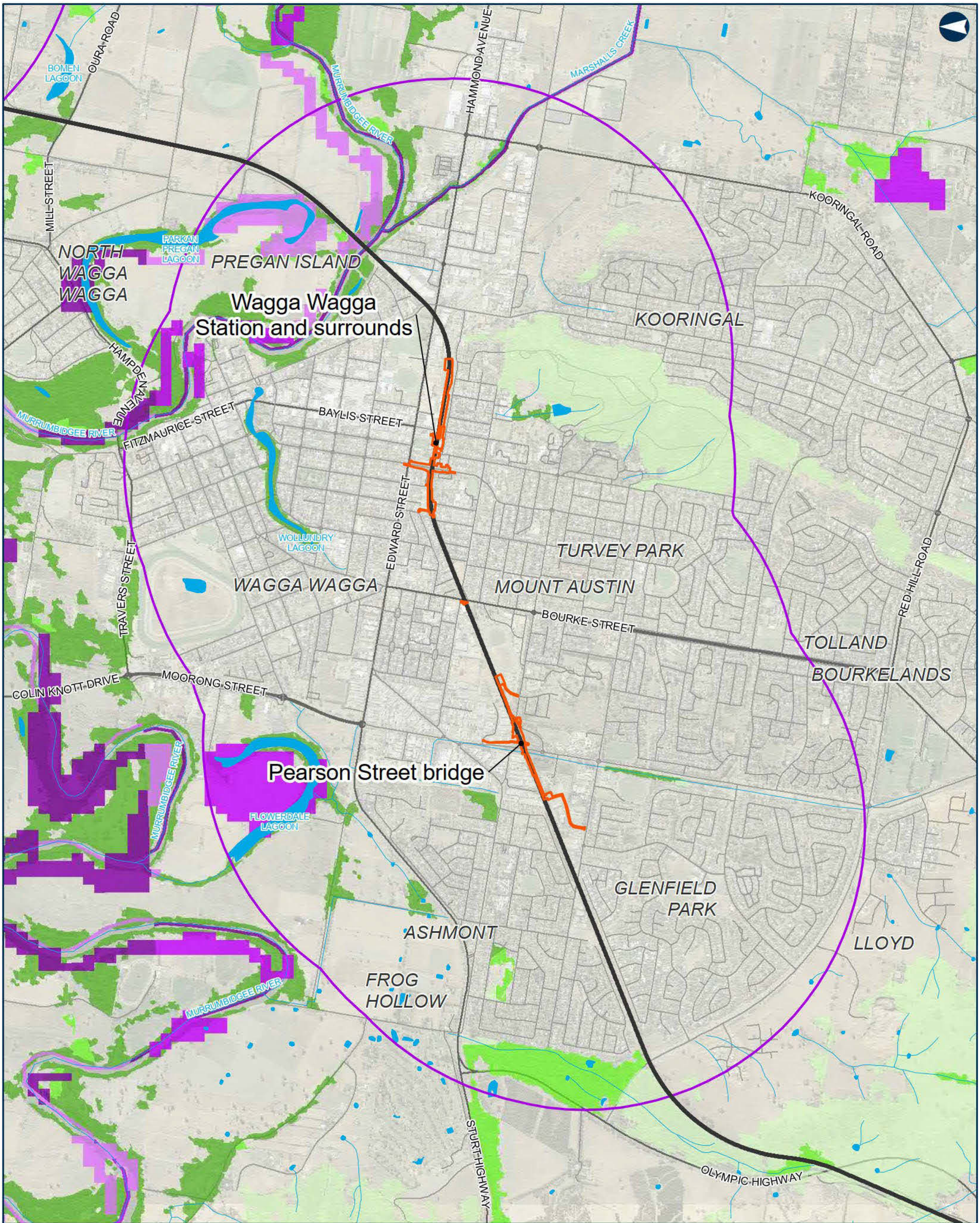

Albury to Illabo Figure 4.6: Potential & priority Groundwater Dependent Ecosystems in the groundwater study areas MAP 9 OF 14

0 0.5 km

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Aquatic GDEs
- High potential GDE
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- Low potential GDE

WAGGA WAGGA

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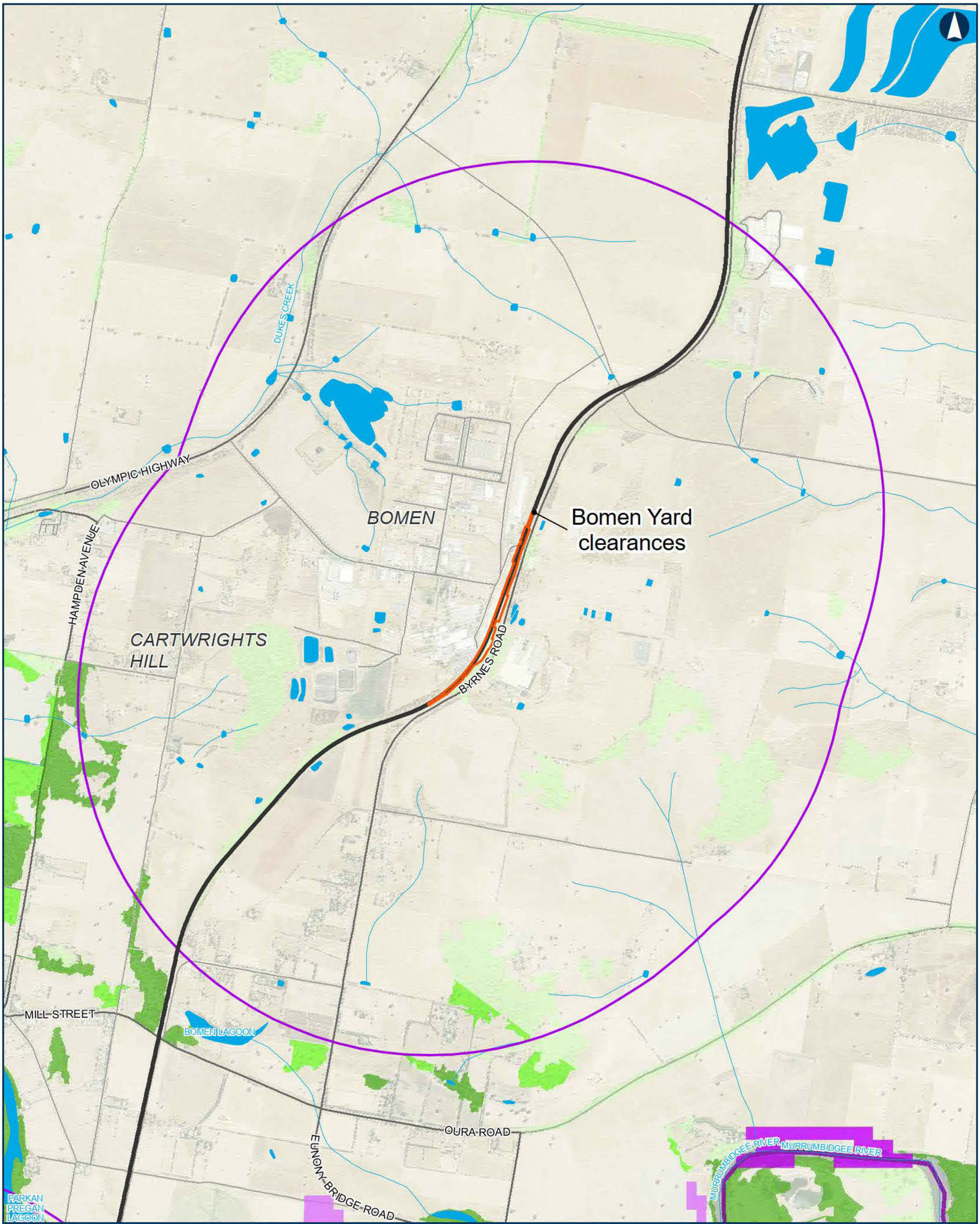

Albury to Illabo Figure 4.6: Potential & priority Groundwater Dependent Ecosystems in the groundwater study areas MAP 10 OF 14

0 0.5 km

Coordinate System: GDA 1994 MGA Zone 55

Date: 18/02/2022 Paper: A3
Author: WSP Scale: 1:20,000
Data Sources: ARTC, NSWSS

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- Low potential GDE

Aquatic GDEs
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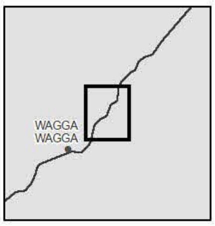
- Moderate potential GDE
- Low potential GDE



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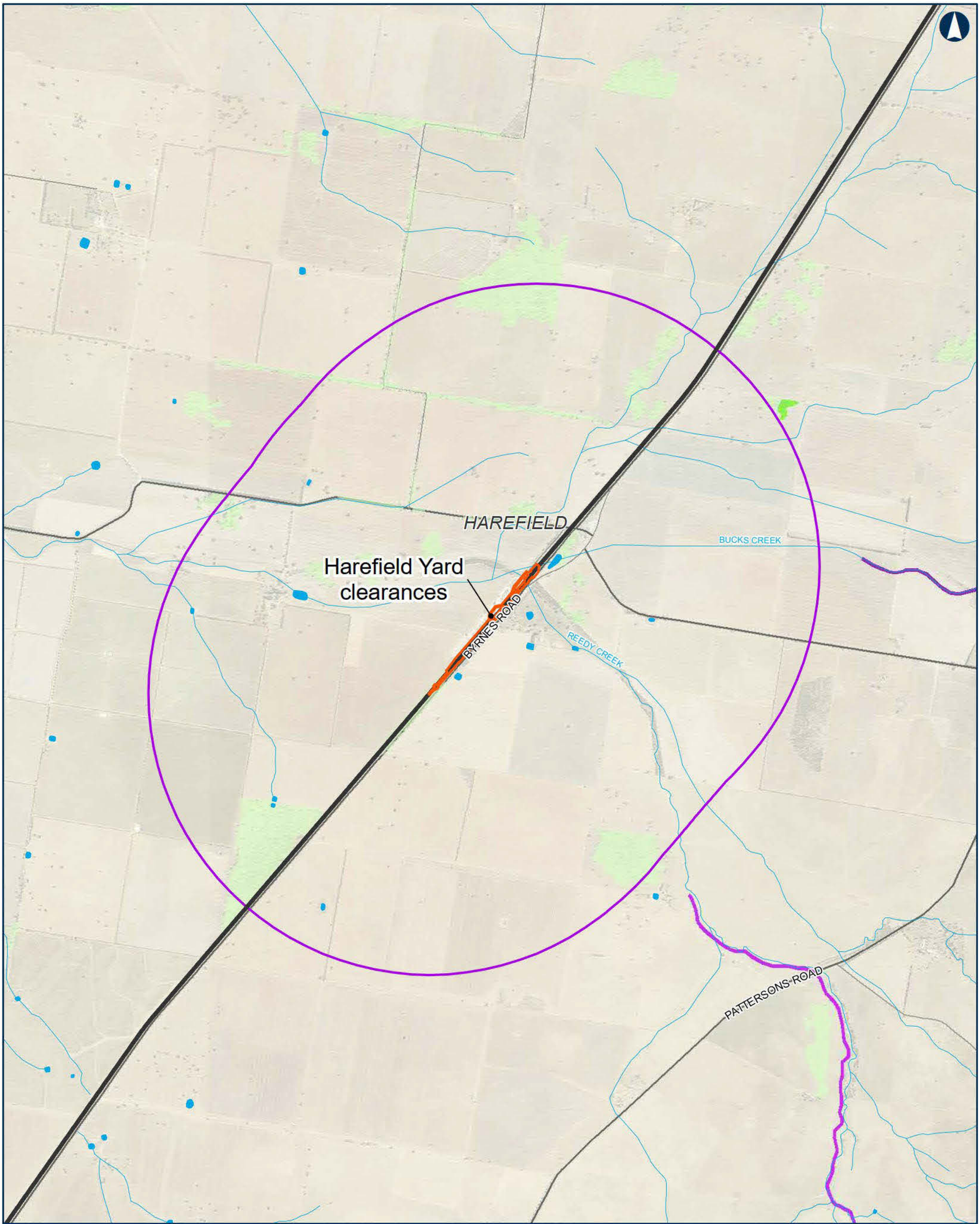

Albury to Illabo

Figure 4.6: Potential & priority Groundwater Dependent Ecosystems in the groundwater study areas

MAP 11 OF 14

0 0.5 km

Coordinate System: GDA 1994 MGA Zone 55

Date: 18/02/2022 Paper: A3
Author: WSP Scale: 1:25,000
Data Sources: ARTC, NSWSS

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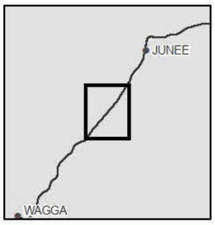
- Low potential GDE



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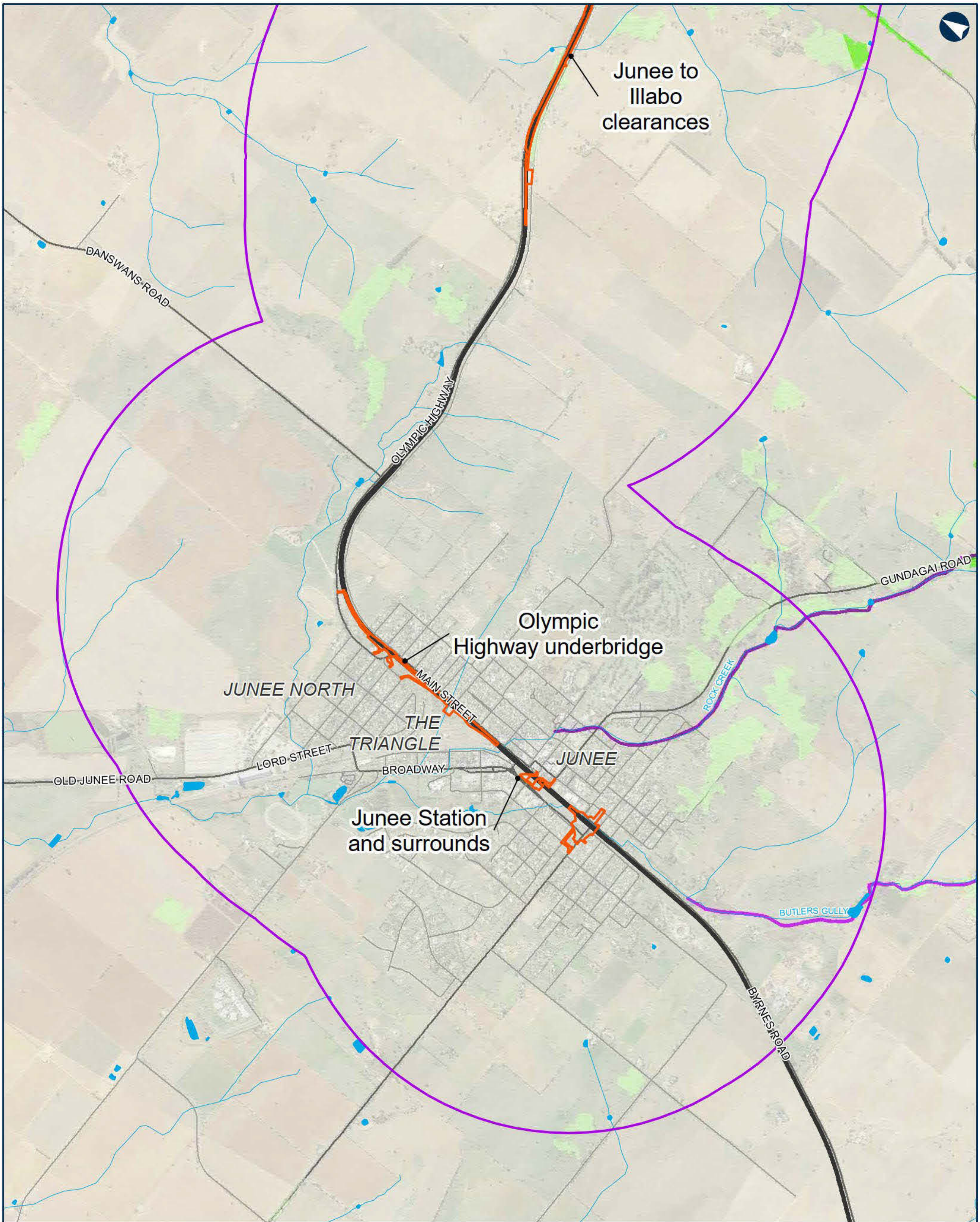

Albury to Illabo — Figure 4.6: Potential & priority Groundwater Dependent Ecosystems in the groundwater study areas — MAP 12 OF 14

0 0.5 km

Coordinate System: GDA 1994 MGA Zone 55

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Date: 18/02/2022
Author: WSP
Paper: A3
Scale: 1:25,000
Data Sources: ARTC, NSWSS

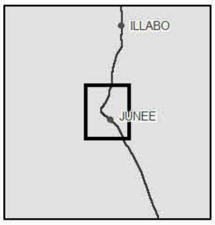
- Enhancement site
- Existing railway
- Main road
- Local road
- Groundwater study area
- Waterbodies
- Waterways

Terrestrial GDEs

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

Aquatic GDEs

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



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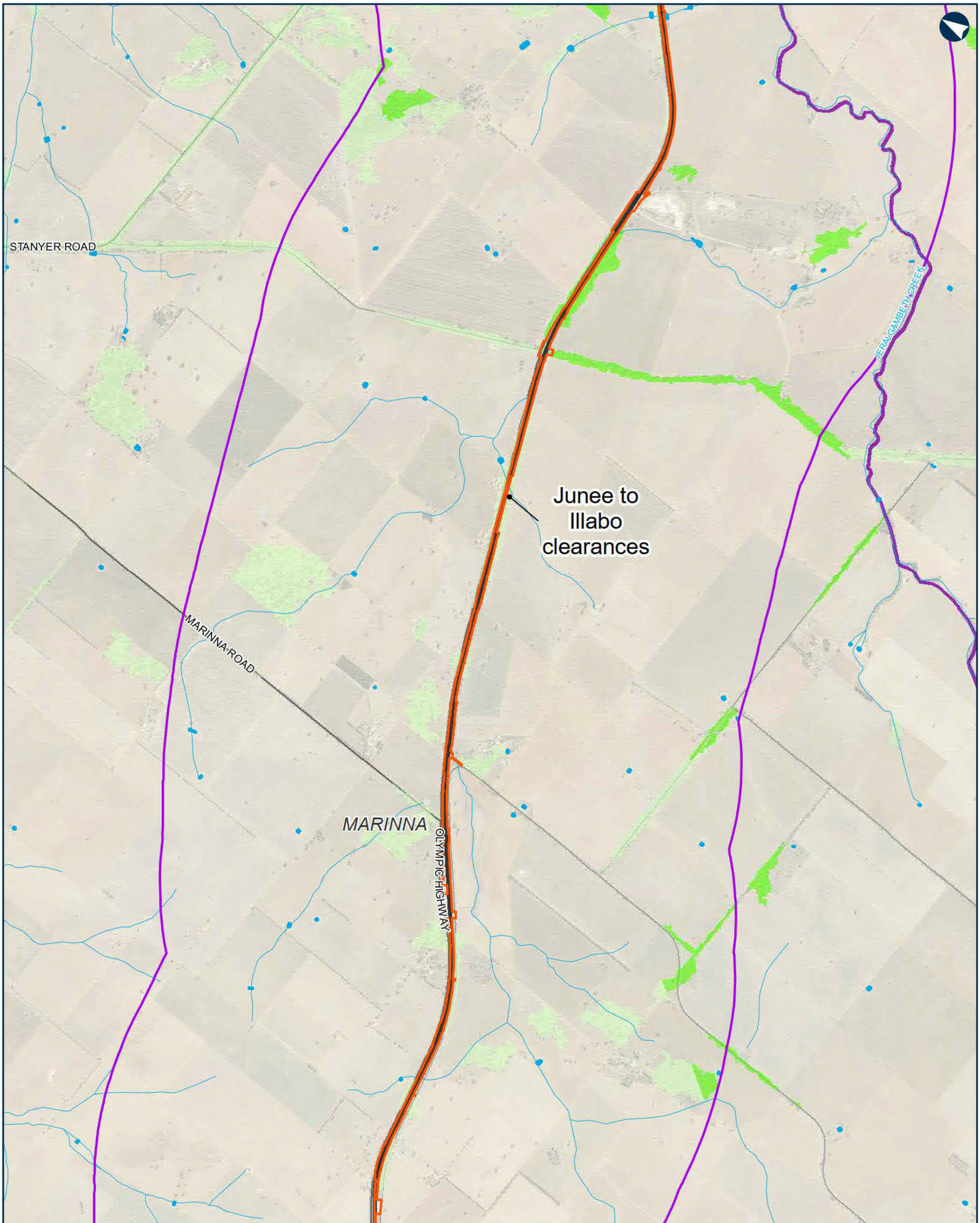

Albury to Illabo Figure 4.6: Potential & priority Groundwater Dependent Ecosystems in the groundwater study areas MAP 13 OF 14

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Coordinate System: GDA 1994 MGA Zone 55

Date: 18/02/2022 Paper: A3
Author: WSP Scale: 1:25,000
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- Enhancement site
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Aquatic GDEs
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- Moderate potential GDE
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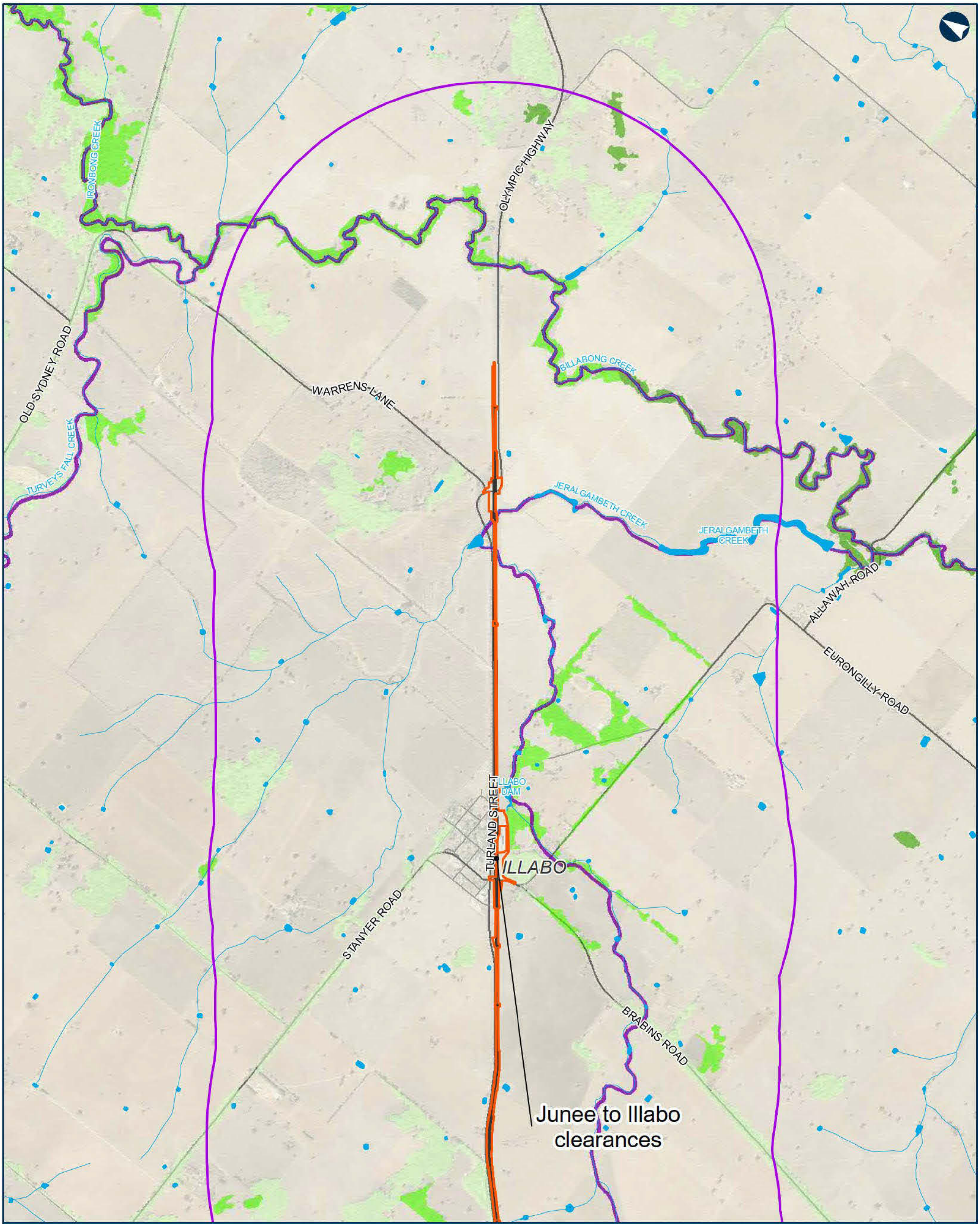

Albury to Illabo

Figure 4.6: Potential & priority Groundwater Dependent Ecosystems in the groundwater study areas

MAP 14 OF 14

0 0.5 km

Coordinate System: GDA 1994 MGA Zone 55

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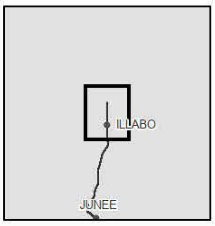

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4.7 WATER ALLOCATIONS AND AVAILABILITY

4.7.1 ALLOCATION AND LONG-TERM AVERAGE ANNUAL EXTRACTION LIMITS

As detailed in section 2.2.2.2, groundwater extraction from groundwater sources in NSW is managed to statutory LTAAEL. The LTAAEL is defined for each individual water source within the relevant water sharing plans (Upper Murray and Billabong Creek within the Murray Alluvial Groundwater Sources 2020; Wagga Wagga Alluvial within the Murrumbidgee Alluvial Groundwater Sources 2020; and Lachlan Fold Belt MDB within the NSW Murray-Darling Basin Fractured Rock Groundwater Sources 2020). For reference (refer to Table 4.6 section 4.5.3.1), the Upper Murray correlates to the Upper Murray (alluvium) HSU, Billabong Creek to the Billabong Creek (alluvium) HSU, Wagga Wagga Alluvial to the Wagga Wagga Alluvial HSU and Lachlan Fold Belt MDB to the Lachlan fractured rock HSU as previously discussed within this report.

Table 4.24 presents the LTAAELs and current licence allocations for the key groundwater sources within the Proposal.

Access licenses specify a volume or a number of "shares" which, under normal circumstances, are equivalent to 1ML each. In sources where average annual extraction over a five year period exceeds the LTAAEL by 5–10 per cent (depending on the source), the value of each share may be set to a volume less than 1ML through an available water determinations at the start of the water year (a water year commences on 1 July). In all but exceptional circumstances, town water supplies and domestic and stock access licenses will maintain their full allocation while lower priority uses may have their share allocations reduced.

The current water allocations have been split by licence category with the combined total presented as the "total share component". This total also includes the estimated annual take under basic landholder rights for stock and domestic purposes.

A simple comparison of the total share component to the LTAAEL for a source indicates whether there is currently any unallocated water for which a licence might be obtained (subject to conditions and necessary approvals). A groundwater source where the total share component is close to or exceeds the LTAEEL can be considered fully allocated. It is clear from the data in Table 4.24 that the groundwater sources are close to or fully allocated, with the exception of the Lachlan Fold Belt MDB (Lachlan fractured rock HSU).

Table 4.24 Groundwater sources – LTAAELs and current entitlements (WaterNSW, 2021)

GROUNDWATER SOURCE	TOTAL SHARE COMPONENT	LTAEEL (ML/YEAR)[1]	LICENCE CATEGORY (NUMBER OF LICENCES)	UNIT SHARES[2]
Upper Murray	41,620	14,109	Aquifer (96)	41,066
			Aquifer – Town water supply (2)	92
			Local water utility (2)	59
			Basic landholder rights	403
Billabong Creek	7,466	7,500	Aquifer (24)	3,826
			Aquifer – Town water supply (1)	30
			Local water utility (4)	1,475
			Salinity and water table management (1)	1,500
			Basic landholder rights	635

GROUNDWATER SOURCE	TOTAL SHARE COMPONENT	LTAEEL (ML/YEAR)[1]	LICENCE CATEGORY (NUMBER OF LICENCES)	UNIT SHARES[2]
Wagga Wagga Alluvial	8,096	3,650	Aquifer (66)	7,939
			Domestic and stock (1)	22
			Basic landholder rights	135
	20,200	16,998	Local water utility (3)	20,200
Lachlan Fold Belt MDB	150,293	253,788	Aquifer (1,056)	7,1843
			Aquifer – Town water supply (6)	467
			Local water utility (36)	3,371
			Local water utility – domestic and commercial (2)	65
			Salinity and water table management (1)	236
			Basic landholder rights	74,311

(1) LTAEEL = long term annual average extraction limits.

(2) Number rounded to nearest integer.

4.7.2 GROUNDWATER USAGE

Whilst the groundwater sources have been identified as close to or fully allocated, with the exception of the Lachlan Fold Belt MDB, actual groundwater usage varies per water calendar year (commencing 1 July and concluding 30 June the following year). Table 4.25 summaries the annual groundwater extraction (assuming complete usage of the allocation for basic landholder rights) for the groundwater sources listed in Table 4.24 from 2015 to 2020. Usage in 2015–2016 was typically under the LTAAELs, with an increase in usage in subsequent years likely as a result of the drought conditions at the time. There were recent exceedances of the LTAAELs in the Upper Murray and Wagga Wagga Alluvial (non-local water utility allocation) groundwater sources.

Table 4.25 Summary of annual groundwater extraction volumes (WaterNSW, 2021)

GROUNDWATER SOURCE	LTAAEL (ML/YEAR)	SHARE COMPONENT (ML/YEAR)	RECORDED USE (ML)	EXTRACTION VOLUME FOR WATER YEAR (ML)[1]				
				2015–2016	2016–2017	2017–2018	2018–2019	2019–2020
Upper Murray	14,109	41,620	Total used	11,183	8,667	14,055	18,787	18,398
			Unused against total shares	30,437	32,953	27,565	22,833	23,222
			Unused against LTAAEL	2,926	5,442	54	-4,678	-4,289
Billabong Creek	7,500	7,466	Total used	3,443	1,892	1,929	4,143	3,925
			Unused against total shares	4,023	5,574	5,537	3,323	3,541
			Unused against LTAAEL	4,057	5,608	5,571	3,357	3,575

GROUNDWATER SOURCE	LTAAEL (ML/YEAR)	SHARE COMPONENT (ML/YEAR)	RECORDED USE (ML)	EXTRACTION VOLUME FOR WATER YEAR (ML)[1]				
				2015–2016	2016–2017	2017–2018	2018–2019	2019–2020
Wagga Wagga Alluvial	3,650	8,096	Total used	1,474	1,623	2,411	3,345	3,981
			Unused against total shares	6,622	6,473	5,685	4,751	4,115
			Unused against LTAAEL	2,176	2,027	1,239	305	-331
	16,998	20,200	Total used	13,394	15,957	16,130	15,453	16,664
			Unused against total shares	6,806	4,243	4,070	4,747	3,536
			Unused against LTAAEL	3,604	1,041	868	1,545	334
Lachlan Fold Belt MDB	253,788	150,293	Total used	78,992	78,097	80,513	80,662	82,363
			Unused against total shares	71,301	72,196	69,780	69,631	37,930
			Unused against LTAAEL	174,796	175,691	173,275	173,126	171,425

(1) A negative (-) value indicates exceedance against the LTAAEL. Values have been rounded to the nearest integer and assumes complete use of basic landholder rights allocations.

4.7.3 WATER TRADING MARKET

The water trading market offers a means of purchasing water access rights within sources that may be fully allocated. However, in the case of groundwater trades, extraction of the water at the desired location would still be subject to the necessary risk assessments, impact assessments and conditions set out in the water sharing plan and the guidelines on assessing groundwater applications.

Under the WM Act, dealings are permitted in access licences, shares, account water and the nomination of supply works. The most common type of dealings between groundwater licences are allocation assignment (temporary trades) and assignment of shares (permanent trades) made under sections 71T and 71Q respectively of the WM Act.

Trading rules permit water trading within the groundwater sources listed in Table 4.24, subject to regulatory assessment. Trades are not permitted into or out of the respective groundwater source to or from a different groundwater source. Trading of water allocations interstate within the Lachlan Fold Belt MDB is not permitted, unless in accordance with administrative arrangements agreed to, and implemented, by NSW and the other State or Territory (and then subject to assessment).

The Natural Resource Access Regulator (NRAR) or Water NSW are the regulatory authority for assessing water licences, water use, and works approvals for government agencies and corporations. For SSI projects, NRAR is the regulatory authority and would defer assessment of any proposed trade by ARTC to DPE – Water group to assess the impact of the proposed trade on other groundwater users and the environment.

4.7.4 GROUNDWATER AS A POTENTIAL SOURCE FOR CONSTRUCTION

This section provides a high-level summary on the suitability of groundwater resources within the groundwater study areas for construction purposes. It takes into brief consideration expected water quality, yields and licensing restrictions. Information regarding water demand and supply is further discussed in sections 5.2.3.1 and 5.3.3.

4.7.4.1 GROUNDWATER QUALITY

Upper Murray and Wagga Wagga Alluvial groundwater sources have high quality water that would generally be suitable for potable requirements through to general construction activities (refer to section 4.5.1).

It is anticipated groundwater from Billabong Creek groundwater source (governed within the Water Sharing Plan for Murray Alluvial Groundwater Sources 2020) would also generally be suitable for potable requirements through to general construction activities. However, groundwater quality is noted to be variable based on distance from Billabong Creek and not all source locations may be suitable for potable requirements.

Water quality within the Lachlan Fold Belt MDB groundwater source is highly variable and its suitability for construction use would be dependent on source location.

4.7.4.2 YIELDS

Based on the HSU characteristics (refer to section 4.5.1), the Wagga Wagga alluvial groundwater source contains the highest yields within its deep HSU. Its shallow HSU, along with the deep HSUs of Upper Murry and Billabong Creek groundwater sources may also provide sufficient yields depending on required water volumes.

Expected yields are low, but variable from the shallow HSUs for the Upper Murry and Billabong Creek groundwater sources and both the shallow and deep HSUs for the Lachlan Fold Belt MDB groundwater sources.

4.7.4.3 LICENSING

Both the Upper Murray and the Wagga Wagga Alluvial groundwater sources are fully allocated indicating that new licenses are unlikely to become available for purchase. In recent years they both were over utilised against the legislative LTAAEL indicating that there could be some restrictions to share allocations and difficulty or higher costs associated with obtaining licenses via trading within these groundwater sources. Whilst Wagga Wagga Alluvial groundwater source was over utilised, the local water utility allocations have historically maintained a portion of available water; use by ARTC may be possible depending on discussions with local water utilities, trading considerations and approvals.

Billabong Creek groundwater source is close to full allocation indicating that new licenses are unlikely to become available for purchase. However, as the groundwater source is not over allocated there is low risk of the groundwater source exceeding its LTAAEL. Therefore, it is unlikely that water share components would be restricted. Historically, the groundwater source has been underutilised, but does contain a large share component for salinity and water table management that is unlikely to be available for use by ARTC. Potential availability of water would have to be secured through trading and require discussions with local water utilities or landholders (aquifer allocations) and be subject to relevant approvals.

The Lachlan Fold Belt MDB groundwater source is under allocated indicating that water share components could be obtained from new licenses, if made available for purchase, or trading, subject to relevant restrictions. The risk of restrictions to share components is low as the groundwater source is utilised.

4.7.4.4 SUMMARY

Whilst most groundwater sources (Upper Murray, Billabong Creek and Wagga Wagga Alluvial) within the groundwater study areas contain expected suitable groundwater quality and yields, licensing restrictions through either full allocation or over utilisation could limit the availability of groundwater as a source for construction. Whilst the Lachlan Fold Belt MDB groundwater source was under allocated and utilised it typically has variable water quality and yields limiting its potential as a suitable source.

4.8 CONCEPTUAL HYDROGEOLOGICAL MODEL

Conceptual hydrogeological models have been generated for each enhancement site based on the data provided in Chapter 4 and are listed in the following sections. The regional permanent groundwater system is conceptualised noting that perched temporary systems can be locally present.

Considering the maximum depth of earthworks required for the proposal (discussed in Chapter 8 of the EIS and Chapter 5 of this report), deeper groundwater systems have been excluded.

4.8.1 ALBURY PRECINCT

4.8.1.1 MURRAY RIVER BRIDGE

The Murray River bridge enhancement site overlies alluvial sediments of the Upper Murray HSU. Given the location of the proposal adjacent to the Murray River, groundwater would be of a comparable elevation and strongly influenced by its hydraulic connection to the river, its surface water levels, flows and quality. High potential GDEs are located within or adjacent to the site and include the Murray River (aquatic) and River Red Gums (terrestrial) and would share connectivity to underlying groundwater.

4.8.1.2 ALBURY STATION PEDESTRIAN BRIDGE AND YARD CLEARANCES

The Albury Station pedestrian bridge and Yard clearances (comprising of the Albury Station pedestrian bridge and Albury Yard clearances enhancement sites) is situated overlying alluvium sediments that contribute to the Upper Murray HSU. The groundwater was determined to be slightly deeper than the regional studies indicated (DPIE, 2019a) with recorded groundwater levels from BH201 at 152.15–152.53mAHD (8.11–8.49m below ground level (mBGL)). The groundwater quality is within the expected quality range (marginal to brackish, A3 to B beneficial use category). Hydraulic conductivity was calculated to be 0.88–0.97m/day.

Groundwater recharge is likely dominated by the Murry River, a losing system proximal to the enhancement site (DPIE, 2019a), which shares a hydraulic connection to the alluvial aquifer. The river would provide recharge to the alluvium and influence its water quality as it flows east to west. A localised topographic ridge to the east of the site may locally influence groundwater flow paths.

Registered bores for water supply purposes and GDEs within the groundwater study area are situated closer to the river than the Albury yard clearance and Albury Station pedestrian bridge enhancement sites, predominately along its riparian corridor and therefore is predicted to be strongly influenced by changes to the river system.

4.8.1.3 RIVERINA HIGHWAY BRIDGE

Similar to the conceptual model for the Albury Station pedestrian bridge and Yard clearances, the groundwater environment underlying the Riverina Highway bridge enhancement site is situated overlying the Upper Murray HSU on alluvium sediments. Groundwater levels monitored at BH204 ranged from 153.67–154.06mAHD (7.33–7.72mBGL) and showed no clear response to daily rainfall. Hydraulic conductivity was calculated to be 0.08m/day.

The groundwater, including levels and quality, is likely influenced by a hydraulic connection to the Murray River. Groundwater is inferred to predominately flow east to west, however groundwater flow towards the Albury pedestrian bridge and Yard clearances is plausible based on limited information regarding groundwater level differences between BH201 (at Albury pedestrian bridge and Yard clearances) and BH204 (at Riverina Highway bridge). A localised topographic high ridgeline exists to the east of the enhancement site that may locally influence groundwater flow paths, particularly between the southern and northern extents. The topographic high will provide localised recharge from infiltration.

Groundwater was of similar quality to Albury pedestrian bridge and Yard clearances with groundwater quality recorded as marginal to brackish (A3 beneficial use category) across the GMEs.

Registered bores for water supply purposes and GDEs within the groundwater study area are situated closer to the river or its tributaries than the Riverina Highway bridge enhancement site, predominately along its riparian corridor and therefore will be more strongly influenced by changes to the river system and localised tributary drainage patterns.

4.8.1.4 BILLY HUGHES BRIDGE

Billy Hughes bridge enhancement site overlies residual clays and underlying volcanic rock that forms part of the Lachlan fractured rock HSU. Given the dominant and deep clay soil type and distance from major surface water features, the permanent groundwater table is anticipated to be below observable groundwater investigation depths of 7.2mBGL (211.7mAHD). Recharge would primarily be from surface water infiltration and localised flows from neighbouring topographic highs. Perched water may exist, particularly at fill and residual soil or residual soil and weathered rock interfaces. Groundwater flow would generally follow local topography, which regionally dips towards the south.

Within the groundwater study area there are four registered bores but only two are drilled within the same geological profile. Groundwater data available from these bores indicates that water bearing zones were intersected from 46–55mBGL and contained low yields of 0.01–0.02 litres per second. Both bores recorded a standing water level of 40m.

Given the lack of registered bores for water supply and their drilled depth, the permanent shallow Lachlan fractured rock aquifer is anticipated to be at depth within the weathered fractured rock and be unsuitable for a resource due to predicted low yields. No information regarding groundwater quality is available.

The presence of high priority GDEs within the groundwater study area and enhancement site typically follows topographic drainage lines, further supporting the discussed recharge mechanisms and the potential for transitory perched groundwater flows.

4.8.1.5 TABLE TOP YARD CLEARANCES

Table Top Yard clearances enhancement site overlies residual soil deposits near a topographic high that forms part of the Lachlan fractured rock HSU. Due to the proposed works (gantry signal works) requiring minimal excavation, no site investigations were conducted. One registered bore used for monitoring purposes was identified. The bore (GW505149) was drilled to 15.5mBGL and recorded a standing water level of 9.0mBGL with yields of 0.1L/s. However, whilst the bore was drilled within the same HSU, it was drilled into mapped alluvial sediments along a topographic low and therefore the available data is considered non-comparable to provide quantitative groundwater levels within the enhancement site. No groundwater quality information is available. Groundwater dependant ecosystems are located greater than 1km from the enhancement site and therefore would contain limited connectivity.

Nevertheless, the bore and lack of available data does allow for the following assumptions regarding the hydrogeological environment:

- infiltration from rainfall would be the dominant recharge mechanism
- groundwater flow within any shallow system, if present, would generally follow topography and flow west to east
- shallow groundwater, if encountered, would likely be perched and temporary, with low yields
- a permanent groundwater source is not anticipated to be close to the ground surface (within half a metre).

4.8.2 GREATER HUME – LOCKHART PRECINCT

4.8.2.1 CULCAIRN PEDESTRIAN BRIDGE AND YARD CLEARANCES

Culcairn pedestrian bridge and Yard clearances (comprising Culcairn pedestrian bridge and Culcairn Yard clearances enhancement sites) overlies alluvium soils that forms part of the Billabong Creek HSU. Numerous registered water supply bores exist within the groundwater study targeting both the shallow (<50m) and deep alluvium systems. Water supply bores within the shallow system are typically greater than 20m deep with recorded groundwater levels of 4.0–34.0mBGL, with the shallower levels within the range listed generally exist in proximity to surface water features like Billabong Creek. The median groundwater level calculated from nine bores within the shallow system is 13.7m. The information generally conforms to the regional Billabong Creek HSU model discussed by DPIE (2019a) where groundwater levels are anticipated to be within 5–10mBGL.

The enhancement site is located within a small urbanised area adjacent to Billabong Creek. Recharge would occur through rainfall infiltration overlying alluvium soils and discharge from Billabong Creek. Groundwater quality is anticipated to be fresh to brackish (WaterNSW, 2021).

Groundwater dependent ecosystem populations tend to be clustered around the riparian corridor of Billabong Creek, which is anticipated to support their populations either through direct contribution or hydraulic connection to the surrounding alluvium. Due to the predicted hydraulic connection between the creek, groundwater flow within the alluvium is predicted to generally flow east to west.

4.8.2.2 HENTY YARD CLEARANCES

Henty Yard clearances enhancement site predominately overlies alluvium soils and to a lesser extent aeolian sands within the southern portion of the site. The alluvium soil is not associated with any mapped dominant waterway within the groundwater study area and falls under the Lachlan fractured rock HSU.

Groundwater was not encountered during geotechnical investigations where clays were encountered as the dominant natural soil profile down to 2.2mBGL.

Four registered water supply bores exist within the groundwater study and were drilled to depths of 61m or greater, targeting the deep Lachlan fractured rock HSU. Three of the four bores contain groundwater levels, with levels of 52.1–57.9mBGL recorded.

Recharge from rainfall infiltration is considered the dominant recharge mechanism. However, urbanisation around the enhancement site may impact localised responses to rainfall events. Groundwater flow is anticipated to generally follow topography, east to west, where it may discharge or support the GDE populations of the topographically low-lying Doodle Corner Swamp, a high potential GDE located approximately 1.6km west of the enhancement site.

Given the available information discussed above, the shallow permanent groundwater system is predicted to be greater than 2.2m within the enhancement site.

4.8.2.3 YERONG CREEK YARD CLEARANCES

Yerong Creek Yard clearances enhancement site overlies mapped aeolian sands of the Lachlan fractured rock HSU. Groundwater was not encountered during geotechnical investigations where alluvium clays were encountered as the dominant natural soil profile down to 2.2mBGL.

Four registered bores (two listed as water supply and two as unknown functions) exist within the groundwater study and were drilled to depths of 60.3m or greater, targeting the deep Lachlan fractured rock HSU. Two of the four bores contain groundwater levels, with levels of 56.4 and 66.5mBGL recorded.

Groundwater flow is anticipated to generally follow topography, generally southeast to northwest, towards and parallel to the ephemeral Yerong Creek. Discharge from Yerong Creek to the underlying and neighbouring sediments during flowing conditions and infiltration from rainfall are anticipated to be the dominant recharge mechanisms. Yerong Creek is the only mapped GDE within the groundwater study area and is classified as moderate potential for groundwater interaction.

Given the available information discussed above, the shallow permanent groundwater system is predicted to be greater than 2.2m within the enhancement site.

4.8.2.4 THE ROCK YARD CLEARANCES

The Rock Yard clearances enhancement site overlies an alluvium channel deposit, likely associated with Burkes River and falls under the Lachlan fractured rock HSU.

Groundwater was not encountered during geotechnical investigations where clays were encountered as the dominant natural soil profile down to 5.4mBGL.

Two registered water supply bores exist within the groundwater study and are drilled to depths of 61m and 71m, targeting the deep Lachlan fractured rock HSU. Groundwater levels of 32.9 and 56.4mBGL were recorded at these bores.

Groundwater is anticipated to follow regional river topography towards the north west as mapped surface elevation within the enhancement site and underlying alluvium channel is generally flat. Discharge from Burkes River to the alluvium during high flow and flooding conditions and infiltration from rainfall are anticipated to be the dominant recharge mechanisms. Burke River is the only mapped GDE within the groundwater study area and is classified as high potential for groundwater interaction.

Given the available information discussed above, the shallow permanent groundwater system is predicted to be greater than 5.4m within the enhancement site under non-flooding river conditions.

4.8.3 WAGGA WAGGA PRECINCT

4.8.3.1 URANQUINTY YARD CLEARANCES

Uranquinty Yard clearances regionally overlies quaternary aged aeolian sediments and granitic Lachlan fractured rocks. However, site investigations encountered a deep alluvium profile dominated by clays in the upper portion to 9.3m and interbedded clays and sands to 17.4m. The alluvium overlies minor residual soil above highly weathered granite. The alluvium is likely related to the deposition of sediments from nearby Sandy Creek.

Groundwater was not intersected or present during field investigations, including BH219, which was dry during the GMEs. In addition, there is limited information from registered bores, with only one bore drilled to 55m located approximately 1.7km north east of the enhancement site. The bore was registered as abandoned and no groundwater information recorded. Therefore, it is inferred that any shallow system, including within the alluvial materials present underlying Sandy Creek, is likely deeper than the observable groundwater depth (8.5mBGL) recorded during site investigations. The deeper aquifer would be located within water bearing structures, such as joints and fractures, and is likely in excess of 30m.

4.8.3.2 PEARSON STREET BRIDGE

The Pearson Street bridge enhancement site is situated overlying the Lachlan fractured rock HSU and predominately within colluvial and residual sediments. However, geological mapping and its proximity to the Wagga Wagga Alluvial HSU suggests the presence of alluvial sediments within the south-western portion of the site, indicating a potential increased connectivity between the two HSUs at this location.

Groundwater levels were monitored at BH206 and ranged from 183.98–185.16mAHD. The groundwater levels are at an elevation above the Murrumbidgee River and associated surface water expression (lagoons and oxbows) of approximately 180mAHD, located to the north. Recorded groundwater quality was fresh, with a beneficial use category of A1. Hydraulic conductivity was calculated at 0.10m/day.

Groundwater underlying Pearson Street bridge would predominately be recharged by direct rainfall or rainfall in areas of topographic highs to the south east and flow towards the north – north west. Groundwater flow would be controlled by localised topography.

Long term groundwater monitoring by Wagga Wagga City Council (2019, 2020 & 2021) showed that groundwater level fluctuations generally contained strong correlation to climatic conditions. However, groundwater level response to recharge and quality (salinity) was shown to be highly variable within approximately 400m of the enhancement site, where groundwater levels varied from as little as 0.74m over 18 years (monitoring bore 3) to 3.40m over 28 years (monitoring bore 10). Groundwater quality was also shown to fluctuate across a wide range of classification and multiple beneficial use categories, such as at monitoring bore 88 which recorded fresh to saline (A1 to D beneficial use category) water quality over 23 years.

In addition, groundwater levels at the site are likely influenced by changes to drainage patterns and dewatering to manage localised groundwater salinity issues within its vicinity (Wagga Wagga City Council, 2019 & 2020). These influences, including the presence of an evaporation pond adjacent to the enhancement site, between Urana Street and Pearson Street to the south, could result in higher fluctuations of groundwater levels and quality than currently monitored.

4.8.3.3 WAGGA WAGGA STATION AND SURROUNDS

Wagga Wagga Station and surrounds (comprising Edmondson Street bridge, Cassidy Parade pedestrian bridge, Wagga Wagga Station pedestrian bridge and Wagga Wagga Yard clearances enhancement sites) is situated overlying the Lachlan fractured rock HSU and predominately within residual soils overlying meta sandstone. Shallow or outcropping granite may be present in the eastern portion of the Cassidy Parade pedestrian bridge enhancement site.

Groundwater levels were monitored at BH210 and ranged from 172.53–173.38mAHD (10.94–11.14mBGL). Groundwater quality was fresh, with beneficial use category A1.

Groundwater underlying Wagga Wagga Station and surrounds would predominately be recharged by direct rainfall or rainfall in areas of topographic highs to the south and flow towards the north. Groundwater flow would be controlled by localised topography. Likely due to urbanisation, the nearest GDEs from the enhancement sites are located more than 600m away and would contain limited connectivity to groundwater within the enhancement site.

Long term nearby groundwater monitoring by Wagga Wagga City Council (2019, 2020 & 2021) showed that groundwater level fluctuations generally contained a degree of correlation to climatic conditions. Groundwater levels in the nearby monitoring bores showed large fluctuations in levels, such as at monitoring bore 20 where groundwater levels ranged from 4.50 to greater than 14.90mBGL between 1995–2021. Groundwater quality was less variable than other Wagga Wagga City Council monitoring bores proximal to Pearson Street bridge enhancement site, with the greatest range in water quality at monitoring bore 20 which was marginal to slightly saline (B to C2 beneficial use category).

Similar to Pearson Street bridge enhancement site, groundwater levels and quality may be influenced by dewatering to manage localised groundwater salinity issues within its vicinity.

4.8.3.4 BOMEN YARD CLEARANCES

Bomen Yard clearances enhancement site overlies colluvial sediment of the Lachlan fractured rock HSU. Recharge from rainfall infiltration is considered the dominant recharge mechanism with groundwater flow likely to follow topography, generally towards the west to north west.

Groundwater was not encountered during geotechnical investigations down to 2.1m. Bore search results (WaterNSW, 2021), particularly from GW402633, located approximately 50m west of the enhancement site indicates the presence of shallow rock (at approximately 3mBGL). The same bore intersected a water bearing zone within the shallow weathered rock profile from 12–15mBGL and contained a groundwater level measurement of 14.50mBGL. This zone is considered representative of the permanent Lachlan fractured rock shallow HSU within this enhancement site. However, perched water may exist at soils and weathered rock interface. Low potential GDEs of Blakely’s Red Gum and Yellow Box grasses occur within and adjacent to the Bomen yard clearance enhancement site, indicating potential limited connectivity.

Given the above, the shallow permanent groundwater table is predicted to be greater than 2.1mBGL.

4.8.4 JUNEE PRECINCT

4.8.4.1 HAREFIELD YARD CLEARANCES

Harefield Yard clearances enhancement site overlies aeolian sand and alluvium deposits of the Lachlan fractured rock HSU. Recharge from rainfall infiltration is considered the dominant recharge mechanism, with additional recharge likely provided through hydraulic connection with Reedy Creek during flowing conditions. Groundwater flow is predicted to follow topography, generally towards the northwest.

Groundwater was not encountered during geotechnical investigations down to 2.0mBGL. Three registered water supply bores exist within the groundwater study and are drilled to depths of 49.4m, 81.0m and 146.0m, targeting the deep Lachlan fractured rock HSU. Recorded groundwater levels ranged between 15.0–25.0mBGL. No information on groundwater quality was available, except for a qualitative statement of ‘very good’ in the records for GW019704 (WaterNSW, 2021).

No high or moderate potential GDEs are present but low potential GDEs of yellow box are located adjacent to the southern end of the enhancement site, indicating potential limited connectivity.

Given the above, the shallow permanent groundwater table is predicted to be greater than 2.0mBGL under non-flooding or high flow creek conditions.

4.8.4.2 JUNEE STATION AND SURROUNDS

Topographically, the Junee Station and surrounds (Kemp Street bridge, Junee Station pedestrian bridge and Junee Yard clearances enhancement sites) occurs within a localised depression filled with minor alluvial and colluvial sediments from the surrounding fractured rock that overlies a deep weathered residual soil profile. The geological profile is dominated by clays with the presence of sands at depth. Recharge would primarily be through infiltration from rainfall from overlying sediments and the surrounding topographic highs located to the east and west, which would influence the groundwater quality and likely be similar to the groundwater quality monitored at Olympic Highway underbridge, Junee (brackish, beneficial use category B). Considering the majority of registered water supply bores within the groundwater study area have been drilled into the deeper Lachlan fractured rock HSU, the use of the shallow groundwater system is limited, possibly indicating a non-permanent groundwater source (perched system) dominated by evaporation, or a groundwater source with limited hydraulic conductivity and yields that would exist within the upper weathered granite profile where a higher proportion of sands and gravels occur. The presence of one nearby (within 20m) water supply bore (GW064614) drilled to 10.7m suggests the later.

Groundwater underlying the Junee Station and surrounds, at the Kemp Street bridge enhancement site has been classified as vulnerable (Junee Local Environmental Plan, 2012), with objectives regarding maintaining the hydrological functions of key groundwater systems and protecting vulnerable groundwater resources from depletion and contamination due to development.

Groundwater flow would follow topography and flow towards the north to north west and is estimated to occur within the enhancement site at around 298–299mAHD. Hydraulic conductivity of the shallow Lachlan fractured rock HSU within weathered granite is anticipated to be comparable (within an order of magnitude) to the value calculated at Olympic Highway underbridge (0.11m/day) given the anticipated similar geological profile. Hydraulic conductivity within the shallow soils near surface is estimated to be around 0.01m/day based on the encountered geology (dominated by clays) and literature values (Domenico and Schwartz, 1990).

Groundwater at Junee Station and surrounds would have limited connectivity with GDEs within the groundwater study area as they are situated to the south east and east, separated by a topographic ridge. No major, non GDE, surface water features are present within the groundwater study area.

4.8.4.3 OLYMPIC HIGHWAY UNDERBRIDGE

The Olympic Highway underbridge enhancement site is located at the edge of a localised depression that overlies colluvial and residual deposits of the Lachlan fractured rock HSU. Recharge would primarily be through infiltration from rainfall from overlying sediments and the surrounding topographic highs. Groundwater flow is expected to follow topography, generally south along the enhancement sites alignment and then towards the west within its southern portion. Similar for the previously discussed Junee precinct enhancement sites, there is predicted to be limited connectivity to GDEs within the groundwater study area.

Groundwater levels were monitored at BH215 and ranged from 299.56–300.02mAHD (9.53–9.99mBGL). Groundwater within the upper weathered rock profile (extremely weathered and fractured granite) was brackish with a B beneficial use category. Whilst groundwater was not observed within the observable depth during geotechnical drilling to 8.5mBGL, perched, temporary water may be present at fill, soil and shallow rock interfaces. Hydraulic conductivity of the weathered granite interface was calculated at 0.11m/day.

Given the above, groundwater is expected to be greater than 9.53mBGL, at approximately 299.56–300.02mAHD.

4.8.4.4 JUNEE TO ILLABO CLEARANCES

The Junee to Illabo clearances enhancement site overlies colluvial and residual deposits and alluvium sediments of the Lachlan fractured rock HSU. Recharge would primarily be through infiltration from rainfall from overlying sediments and the surrounding topographic highs. Groundwater flow is expected to follow topography, generally to the northeast.

Groundwater was not encountered during geotechnical investigations that terminated typically between to 2.0 to 2.4mBGL. A search through WaterNSW (2021) for registered bores identified that the limited registered bores within the groundwater study area were typically drilled into the Lachlan fractured rock deep HSU. Whilst no reviewed records contained groundwater level information, one bore (GW401369) identified water bearing zones starting from 19mBGL within fractured rock. This record also contained a qualitative water quality rating of brackish.

Given the above, groundwater is predicted to be greater than 2.0mBGL.

5 IMPACT ASSESSMENT

Construction and operation of the proposal, if undertaken without adequate management controls in place, has the potential to impact on the identified groundwater resources and environmental values through changes to groundwater availability and groundwater quality. This Chapter identifies the associated risks, impact pathways through construction or operational activities, and qualitative and quantitative impact assessment of the risks at each enhancement site.

5.1 OVERVIEW OF POTENTIAL GROUNDWATER IMPACTS FROM THE PROPOSAL

Table 5.1 identifies the potential risks to the hydrogeological environment resulting from the construction and operation of the proposal. The risks to the hydrogeological environment are the same for both the construction and operation of the proposal but would manifest through different construction or operation activities and for different durations.

For the purpose of assessment, whilst all registered bores have been assessed for potential risk and impact, all identified bores with a registered use for water supply or those listed as unknown have been considered as a sensitive receptor.

Table 5.1 Potential risks to the groundwater environment during construction and operation of the proposal

RISK	DESCRIPTION OF IMPACT AND CAUSE	POTENTIAL CONSTRUCTION ACTIVITY RESULTING IN IMPACT TYPE	POTENTIAL OPERATION ACTIVITY RESULTING IN IMPACT TYPE
Groundwater level decline due to dewatering	Dewatering resulting in groundwater level decline, potential impact to groundwater resources and sensitive receptors	Earthworks for removal of existing infrastructure, foundation improvements, relocating service utilities, piling for bridges and track lowering. Groundwater take for construction water supply.	Continued groundwater take due design levels permanently intersecting the permanent groundwater table.
Changes to groundwater quality (salinity)	Changes to groundwater flow paths, including introduction of groundwater flow barriers or groundwater discharges which may change groundwater quality. Changes to groundwater levels and quality resulting from salinity can impact sensitive receptors such as registered bores and GDEs.	Drainage diversions associated with construction. Piling for bridge foundations. Construction of soil retaining walls.	Drainage diversions associated with operations. Piling for bridge foundations. Construction of soil retaining walls.
Settlement	Changes to surface loading, construction sequencing or soil moisture content causing compression or settlement.	Cuts for the rail alignment that result in dewatering. Whilst the risk could occur during construction, settlement impacts would typically manifest during the operational phase. General construction activities and placement of infrastructure.	Cuts for the rail alignment that result in dewatering. Infrastructure.

RISK	DESCRIPTION OF IMPACT AND CAUSE	POTENTIAL CONSTRUCTION ACTIVITY RESULTING IN IMPACT TYPE	POTENTIAL OPERATION ACTIVITY RESULTING IN IMPACT TYPE
Contamination	Degradation of water quality through the introduction of new contaminants or the movement of potentially existing contamination plumes within the groundwater environment. Impact to existing groundwater contamination, resulting in potential spread to other areas.	Storage, spillage and leaks of hazardous substances used during construction. Cuts for the rail alignment, piling for the bridge foundations and construction of soil retaining walls that alter groundwater flow paths, distributing existing contaminants. Importation and use of contaminated fill.	Storage, spillage and leaks of hazardous substances used during operation. Cuts for the rail alignment, piling for the bridge foundations and construction of soil retaining walls that alter groundwater flow paths, distributing existing contaminants. Leaching of contaminates from contaminated fill.
Changed recharge	Changes to groundwater recharge through altering surface infiltration, degree of evapotranspiration and groundwater seepage along the high wall of cuts leading to changes in groundwater availability and quality for sensitive receptors, including GDEs.	Drainage diversions and general construction activities that result in changes to surface infiltration, such as the creation of construction camps, access paths and removal of vegetation.	Permanent drainage diversions or increased area of impervious surfaces required for operation of the proposal, such as capping or new hard-stand features such as bridges.

The key issue identified for the proposal is the risk associated with permanent proposed cuts that intersect saturated and permanent aquifers. This potential risk occurs at the Riverina Highway bridge, Pearson Street bridge and Billy Hughes bridge enhancement sites as the proposed works involve track lowering. Dewatering of cuts, whether temporary or permanent, for construction or during operational phases of the project have the potential to lower groundwater levels, reducing the availability of groundwater to nearby sensitive receptors such as GDEs or nearby users of groundwater. Where bridge pilings or the construction of soil retaining walls are to occur, impedance to groundwater flow can also occur. This can result in changes to groundwater levels and quality.

Settlement caused by increased surface loading and construction sequencing has been assessed separately within geotechnical and design reports. It is predicted that settlement will be within tolerable limits due to appropriate geological conditions for foundations and finalised design. Risk of settlement from predicted dewatering is discussed in further detail within this chapter.

5.2 CONSTRUCTION

The following sections have been separated based on the assigned level of risk. The risk considers the preliminary risk rating identified in Table 3.2 (section 3.4) as well as additional data obtained during subsequent geotechnical and hydrogeological investigations for the proposal and changes to its design during the assessment period.

5.2.1 ENHANCEMENT SITES WITH NEGLIGIBLE OR LOW RISK OF GROUNDWATER IMPACT

Table 5.2 summarises the assessment considerations for enhancement sites that have been grouped as containing a low risk of groundwater impact where construction activities are not predicted to intersect the permanent water table. Enhancement sites where construction activities are anticipated to intersect the water table during piling only are listed in Table 5.3, but due to the minimal extent of piling and the piling methodology resulting in no groundwater take, the risk is also considered low.

Details on the assessment against the risks identified in Table 5.1 (as relevant to construction) for each enhancement site are provided in Table 5.2 and Table 5.3, but generally consider (in addition to the lack or limited intersection of groundwater due to piling only) the following:

- Limited depth of bulk excavations and/or extent of earthworks compared to expected and predicted groundwater levels:
  - This indicates that the water table will not be intersected, with limited potential connection between construction and the groundwater resource.
- No to minimal change in the current landform that would significantly alter recharge:
  - Through maintaining or minimally altering landforms, including drainage, hard stand areas and landform uses, the risk of changing groundwater levels altered recharge are minimised. The risk of mobilising contaminants or reducing water quality are also reduced.
- Potential minimal and localised groundwater intersection from piling (if required):
  - Piling, whilst potentially intercepting the water table (with no water take), reduces the need for bulk excavations that would require groundwater take, thereby limiting potential impacts associated with groundwater level decline, changes to groundwater quality, settlement and contamination.
- Distance to sensitive receivers: registered water supply bores and/or GDEs:
  - Impacts to sensitive receivers would be dependent on their proximity to the proposal and proposed construction activities with sensitive receivers located further away from the enhancement site typically at lower risk of impacts.
- Registered water supply bores are predicted to take groundwater from the deeper relevant HSU (i.e. a different groundwater source).

Sites that have been identified with potential higher risk ratings are discussed in further detail in the following sections.

Table 5.2 Assessment of enhancement sites that are not predicted to intersect the regional permanent groundwater table

ENHANCEMENT SITE (PRECINCT)	PROPOSED CONSTRUCTION ACTIVITIES	ASSESSMENT CONSIDERATIONS	RISK	IMPACT
Murray River bridge (Albury precinct)	— upgrading infrastructure without excavation or earthworks relating to existing foundations — minimal earthworks for site access, pad preparation and laydown areas for plant equipment and construction materials (such as stripping of topsoil and grading).	— maximum excavation depths of 0.5mBGL which is above the inferred groundwater depth (anticipated to be close to Murray River surface water level) — changes to the landscape impacting recharge would be minimal given construction activities (laydown areas, construction pads) will be minimal in extent and utilise existing rail corridor — inferred strong hydraulic connection to the Murray River would provide a dominant source of water supply to neighbouring GDEs, further limiting potential impacts from changes to recharge.	Negligible	Negligible
Albury Yard clearances (Albury precinct)	— replacing existing track slews and gantry replacement — stripping of topsoil and grading — treatment of foundation material.	— maximum bulk excavation depth of 1.1mBGL — groundwater depth recorded ranged from 8.11 to 8.49mBGL. This is below the maximum bulk excavation depth — identified registered water supply bores are located approximately 400m or greater from the enhancement site — no change in the current landform that would significantly alter recharge.	Low	Low
Table Top Yard clearances (Albury precinct)	— removal of existing gantry structure, if structure can't be removed by de-bolting, minimal earthworks for stripping of surface material to expose existing footing will be required — preparation of access tracks — installation of new post mounted signal.	— maximum excavation depths of 0.5mBGL which is above the predicted groundwater depth — no registered water supply bores located within the groundwater study area — distance to nearest GDEs are approximately 350m (low potential GDE) and 850m (high potential GDE) — no change in the current landform that would significantly alter recharge.	Negligible	Negligible

ENHANCEMENT SITE (PRECINCT)	PROPOSED CONSTRUCTION ACTIVITIES	ASSESSMENT CONSIDERATIONS	RISK	IMPACT
Culcairn Yard clearances (Greater Hume – Lockhart)	— installation of connecting trap loop — gantry modification — stripping of topsoil — treatment of foundation material (for track loop).	— maximum bulk excavation depth of 1.0mBGL to treat foundation material — groundwater is anticipated to be at depths greater than 4.0mBGL, which is deeper than the proposed bulk excavations — identified registered water supply bores are located approximately 140m or greater from the enhancement site — registered water supply bores contain deeper groundwater levels than bulk excavation depths and are inferred to take from the deep Lachlan fractured rock HSU — no change in the current landform that would significantly alter recharge.	Low	Low
Yerong Creek Yard clearances (Greater Hume – Lockhart precinct)	— adjustment of the mainline track horizontally and vertically (track slew) — removal of existing platform and hut — stripping of topsoil — treatment of foundation material.	— maximum excavation depths of 1.0mBGL which is above the predicted groundwater depth — identified registered water supply bores are located approximately 180m or greater from the enhancement site — registered water supply bores are inferred to take from the deep Lachlan fractured rock HSU — distance to identified GDEs, with Yerong Creek (moderate potential GDE) the only mapped GDE in the groundwater study area and is located approximately 400m to the north — no change in the current landform that would significantly alter recharge.	Low	Low

ENHANCEMENT SITE (PRECINCT)	PROPOSED CONSTRUCTION ACTIVITIES	ASSESSMENT CONSIDERATIONS	RISK	IMPACT
The Rock Yard clearances (Greater Hume – Lockhart precinct)	— modification of existing over-track gantry structure via de-bolting or cutting — stripping of topsoil for access tracks, if required.	— maximum excavation depths of 0.5mBGL which is above the predicted groundwater depth — identified registered water supply bores are located approximately 630m or greater from the enhancement site — registered water supply bores are inferred to take from the deep Lachlan fractured rock HSU — distance to identified GDEs, with Burkes River (high potential GDE) the only mapped GDE in the groundwater study area and is located approximately 330m to the north — no change in the current landform that would significantly alter recharge.	Low	Negligible
Uranquinty Yard clearances (Wagga Wagga precinct)	— adjustment of mainline track horizontally and vertically (track slew) — strengthening of Sandy Creek Bridge structure — stripping of topsoil and grading for access tracks — service relocation, if necessary — treatment of foundation.	— maximum excavation depths of 0.5mBGL — groundwater is expected to be deeper than 8.5mBGL within alluvial soils of the shallow Lachlan fractured rock HSU and deeper than 30mBGL in the underlying deep Lachlan fractured rock HSU — identified registered water supply bore is located approximately one kilometre from the enhancement site — registered water supply bore is inferred to take from the deep Lachlan fractured rock HSU — no change in the current landform that would significantly alter recharge.	Negligible	Negligible

ENHANCEMENT SITE (PRECINCT)	PROPOSED CONSTRUCTION ACTIVITIES	ASSESSMENT CONSIDERATIONS	RISK	IMPACT
Wagga Wagga Yard clearances (Wagga Wagga precinct)	— adjustment of mainline track horizontally and vertically (track slew) — treatment of foundation, if necessary.	— maximum bulk excavation depth of 0.5mBGL — groundwater depth recorded ranged from 10.94–11.14mBGL. This is below the maximum bulk excavation depth — identified registered water supply bores are located approximately 550m or greater from the enhancement site — registered water supply bores are inferred to take from a different HSU (Wagga Wagga Alluvial instead of the shallow Lachlan fractured rock) — no change in the current landform that would significantly alter recharge.	Negligible	Negligible
Bomen Yard clearances (Wagga Wagga precinct)	— adjustment of mainline track and loop horizontally and vertically (track slew) — stripping of topsoil and grading for access tracks — service relocation, if necessary — treatment of foundation.	— maximum excavation depths of 1.05mBGL which is above the predicted groundwater depth — nearby registered bores are for monitoring purposes, not water supply — identified registered water supply bores are located approximately 1.5 kilometre or greater from the enhancement site — no change in the current landform that would significantly alter recharge.	Negligible	Negligible
Harefield Yard clearances (Junee precinct)	— adjustment of mainline track horizontally and vertically (track slew) — replacement of gantry structure — adjustment of signals and existing bridge to facility track slews — stripping of topsoil for access tracks — treatment of foundations.	— maximum excavation depths of 1.3mBGL which is above the predicted groundwater depth — identified registered water supply bores are located approximately 850m or greater from the enhancement site — registered water supply bores are inferred to take from the deep Lachlan fractured rock HSU — no change in the current landform that would significantly alter recharge.	Low	Low

ENHANCEMENT SITE (PRECINCT)	PROPOSED CONSTRUCTION ACTIVITIES	ASSESSMENT CONSIDERATIONS	RISK	IMPACT
Junee Yard clearances (Junee precinct)	— adjustment of mainline track horizontally and vertically (track slew).	— identified registered water supply bores are located approximately 450m or greater from the enhancement site — nearest GDE is located approximately 970m from the enhancement site — no change in the current landform that would significantly alter recharge.	Low	Low
Junee Station pedestrian bridge (Junee precinct)	— removal of an existing footbridge — existing bridge foundations to be cut and capped.	— minimal earthworks and excavations are required for the removal of the existing footbridge as the foundations are to be cut and capped.	Negligible	Negligible
Olympic Highway underbridge (Junee precinct)	— adjustment of mainline track horizontally and vertically (track slew) — excavation for service relocation, if required — stripping of soil for access tracks, if required — treatment of foundation material.	— maximum excavation depths of 1.3mBGL which is above groundwater depths recorded between 9.53–9.99mBGL — identified registered water supply bores are located approximately 430m or greater from the enhancement site — nearest GDE is located approximately one kilometre from the enhancement site — no change in the current landform that would significantly alter recharge — one registered bore for monitoring purposes (GW402492) exists within the enhancement site. As groundwater take is not anticipated and the bore is not registered for use as water supply, the risk and impact to the registered bore being unable to continue with its purpose is low. Should the bore be accidently damaged during construction activities, make good provisions would apply.	Low	Low

ENHANCEMENT SITE (PRECINCT)	PROPOSED CONSTRUCTION ACTIVITIES	ASSESSMENT CONSIDERATIONS	RISK	IMPACT
Junee to Illabo clearances (Junee precinct)	— adjustment of mainline track horizontally and vertically (track slew) — full reconstruction of 4.3 kilometres of track — stripping of topsoil for access — service relocation, if required — treatment of foundation material.	— maximum excavation depths of 1.0mBGL which is above the predicted groundwater depth — identified registered water supply bores are located approximately 350m or greater from the enhancement site. — no change in the current landform that would significantly alter recharge.	Low	Low

Table 5.3 Assessment of enhancement sites that are anticipated to intercept the water table due to piling

ENHANCEMENT SITE	PROPOSED CONSTRUCTION ACTIVITIES	ASSESSMENT CONSIDERATIONS	RISK	IMPACT
Albury Station pedestrian bridge (Albury precinct)	— replacing existing bridge — existing bridge foundations to be cut and capped — piling for new bridge foundations.	— anticipated piling depth of up to 20.0mBGL — groundwater depth recorded ranged from 8.11 to 8.49mBGL. This is below the maximum bulk excavation depth — identified registered water supply bores are located approximately 400m or greater from the enhancement site — no change in the current landform that would significantly alter recharge.	Low	Low
Billy Hughes bridge (Albury precinct)	— track lowering by up to 1.4m, including horizontal realignment of the track (by approximately 5m) — installation of soil retaining walls and drainage network — stripping of topsoil and removal of material to design level — treatment of foundation material — piling to support soil retaining walls.	— maximum bulk excavation depth of 2.5mBGL to treat foundation material — anticipated piling depth of up to 15.0mBGL — groundwater is anticipated to be at depths greater than 7.2mBGL, which is deeper than the proposed bulk excavations — identified registered water supply bores are located approximately 220m or greater from the enhancement site — registered water supply bores are inferred to take from the deep Lachlan fractured rock HSU — no change in the current landform that would significantly alter recharge.	Low	Low

ENHANCEMENT SITE	PROPOSED CONSTRUCTION ACTIVITIES	ASSESSMENT CONSIDERATIONS	RISK	IMPACT
Culcairn pedestrian bridge (Greater Hume – Lockhart)	— removal and relocation of an existing footbridge.	— anticipated piling depth of up to 10.0mBGL — groundwater is anticipated to be at depths greater than 4.0mBGL, which is deeper than the proposed bulk excavations — identified registered water supply bores are located approximately 140m or greater from the enhancement site — registered water supply bores contain deeper groundwater levels than bulk excavation depths and are inferred to take from the deep Lachlan fractured rock HSU — no change in the current landform that would significantly alter recharge.	Low	Low
Henty Yard clearances (Greater Hume – Lockhart)	— adjustment of the mainline track by 53.4cm horizontally and 4.9cm vertically (track slew) — removal of an existing track loop — modification of gantry sign — stripping of topsoil — installation of appropriate drainage measures — relocation of services, if required — treatment of foundation material.	— maximum bulk excavation depth of 1.0mBGL to treat foundation material — anticipated piling depth of up to 10.0mBGL — groundwater is anticipated to be at depths greater than 1.0mBGL, which is deeper than the proposed bulk excavations — identified registered water supply bores are located approximately 200m or greater from the enhancement site — registered water supply bores inferred to take from the deep Lachlan fractured rock HSU — no change in the current landform that would significantly alter recharge.	Low	Low

ENHANCEMENT SITE	PROPOSED CONSTRUCTION ACTIVITIES	ASSESSMENT CONSIDERATIONS	RISK	IMPACT
Cassidy Parade pedestrian bridge and Wagga Wagga Station pedestrian bridge, (Wagga Wagga precinct)	— adjustment of mainline track by 54.7cm horizontally and 13.2cm vertically (track slew) — replacement of gantry structure with ground signals — stripping of topsoil and grading for access tracks — service relocation, if necessary — treatment of foundation.	— maximum bulk excavation depth of 0.7mBGL — anticipated piling depth of up to 30.0mBGL — groundwater depth recorded ranged from 10.94–11.14mBGL and is below the maximum bulk excavation depth — identified registered water supply bores are located approximately 550m or greater from the enhancement site — registered water supply bores are inferred to take from a different HSU (Wagga Wagga Alluvial instead of the shallow Lachlan fractured rock) — no change in the current landform that would significantly alter recharge.	Low	Low
Edmondson Street bridge (Wagga Wagga precinct)	— removal of existing bridge — construction of new bridge including bulk excavation for piling benches — adjustment of mainline track by 54.7cm horizontally and 13.2cm vertically (track slew) — installation of drainage — replacement of gantry structure with ground signals — stripping of topsoil and grading for access tracks	— maximum bulk excavation depth of 178.00 mAHD (up to 7.00 mBGL) — anticipated piling depth of up to 30.0mBGL — groundwater depth recorded ranged from 172.53–173.38mAHD (10.94–11.14mBGL) and is below the maximum bulk excavation depth — identified registered water supply bores are located approximately 550m or greater from the enhancement site — registered water supply bores are inferred to take from a different HSU (Wagga Wagga Alluvial instead of the shallow Lachlan fractured rock) — no change in the current landform that would significantly alter recharge.		

5.2.2 ENHANCEMENT SITES WITH INCREASED RISK TO GROUNDWATER

The following enhancement sites were identified to contain a potential risk rating greater than low against one or more of the risks identified in Table 5.1 and therefore have been discussed in further detail within this section.

5.2.2.1 RIVERINA HIGHWAY BRIDGE (ALBURY PRECINCT)

CONSTRUCTION ACTIVITIES

The proposed works at the Riverina Highway bridge enhancement site involves track lowering by up to 1.0m, installation of soil retaining walls and an underground storage tank for the management of stormwater drainage. Typically, bulk excavations up to 2.1mBGL would be required to treat foundation material, however a small area (eight by eight metres squared) would be excavated to about 8.9mBGL using caisson or under excavation methods for installation of the underground storage tank.

REASONING FOR INCREASED RISK RATING

Groundwater is not anticipated to be intersected for the typical bulk excavation depths of up to 2.1mBGL required for track lowering, foundation material improvement and installation of soil retention walls. However, the installation of the underground storage tank to a base excavation level of 152.6mAHD (approximately 8.9mBGL) is below the monitored maximum recorded groundwater level of 154.06mAHD. This would result in approximately up to 1.8m of dewatering during construction for its installation.

EXPECTED GROUNDWATER LEVELS AND QUALITY

Groundwater levels were monitored at BH204 during the GMEs and ranged from 153.67–154.06mAHD (7.33–7.72mBGL). Groundwater quality was recorded as marginal to brackish with a beneficial use category rating of A3.

DEWATERING IMPACT

The methodology for estimating dewatering volumes is provided in section 3.8.2, with the following assumptions:

- construction works for the installation of the underground storage tank would take up to eight weeks, however dewatering would only be required for the last 21 days due to the depth of the water table and construction methodology (caisson or under excavation)
- excavation footprint is eight by 8m long and 8m wide
- groundwater level is constant at 154.1mAHD along the proposed excavation and corresponds to the highest recorded groundwater level during monitoring
- instantaneous excavation of all saturated material to a maximum excavation depth (152.6mAHD)
- maximum excavation depth includes an additional 0.3m sump, thus dewatering will require lowering the water table by an addition 0.3m below the maximum excavation depth (total dewatering depth to 152.3mAHD).

Dewatering rates and volume were calculated using the Darcy equation for base inflow and the Dupuit-Forcheimer for radial and parallel inflows. The calculated groundwater inflow from each equation was then combined for a total dewatering volume. The radius of influence estimate was calculated using the Bear (1979) equation using a specific yield value of 20 per cent. Groundwater equations are provided in section 3.8.2. A hydraulic conductivity of 0.08m/day was used and determined from a slug test conducted at BH204, installed at the Riverina Highway bridge enhancement site, screened between 9–15mBGL. Estimated dewatering rates, volume and radius of influence are provided in Table 5.4.

A total of 0.7ML was estimated to be dewatered during the construction phase with a radius of influence of up to 5.8m based on dewatering for 21 days.

Table 5.4 Estimated dewatering rates and volumes

DEWATERING AREA (m^2)	DEWATERING DEPTH (m)[1]	DEWATERING RATE (L/s)		TOTAL DEWATERING VOLUME (ML)[2]	RADIUS OF INFLUENCE (m)
		At 24 hours	At 14 days		
64.0	1.8	0.1	<0.1	0.7	5.8

(1) Assumes additional 0.3m below excavation required for dewatering.

(2) Assumes dewatering for up to 21 days.

Given the calculated radius of influence, the risk of dewatering impacting sensitive receivers is low. The nearest GDEs are classified as low potential (White box – Blakelys Red Gum – terrestrial) and high potential (Bungambrawatha Creek–aquatic), located approximately 750m to the southeast and 700m northwest, respectively. Their distance is well beyond the estimated 5.8m zone of influence and therefore are not expected to be impacted.

There nearest registered bores are listed for monitoring purpose and are approximately 100m to the west of the dewatering location. As this distance is well beyond the estimated 5.8m zone of influence, no impacts to registered bores are expected.

RISK TO GROUNDWATER QUALITY (SALINITY AND CONTAMINATION)

As groundwater is expected to be dewatered, localised groundwater flow paths and levels will be altered. The changes to groundwater flow paths and levels may disturb and migrate potential existing contamination or saline groundwater. The proposed construction methodology would limit the risk of construction contaminants such as stored chemicals or leachate from spoil entering the groundwater environment as:

- the excavated surface would be within the storage tank walls that would act as an impenetrable barrier (caisson construction methodology), or
- undermining methodology would leave the overlying in situ material that would act as a physical distance buffer to construction contaminants.

Any potential impact is considered low due to the calculated limited radius of influence (5.8m) of dewatering and the minimal time dewatering is required (up to 21 days). Further assessment of groundwater contamination risk and impact is provided in Technical Paper 13: Contamination.

RISK TO SETTLEMENT

As dewatering is temporary, no significant changes to soil moisture content is anticipated and therefore the risk of settlement is considered low.

RISK TO RECHARGE

The required surface area (64 metres squared) for the underground storage tank is minimal and therefore not expected to impact recharge through changes in infiltration or act as a barrier to groundwater flows.

5.2.2.2 PEARSON STREET BRIDGE (WAGGA WAGGA PRECINCT)

CONSTRUCTION ACTIVITIES

The Pearson Street bridge enhancement site includes track lowering by up to 1.5m (to a level of 187.3mAHD) and installation of soil retaining walls. Earthworks will therefore be required as part of the construction activities with excavations predominately involving the removal of material to design levels, installation of retaining walls and treatment of foundation material. Total depth of bulk excavations is anticipated to be up to 2.8mBGL (about 186.0mAHD at deepest extent). Piling will also be required for retaining walls and is anticipated to extend to a maximum of 15mBGL. Earthworks are anticipated to take approximately 30 days for foundation improvements, including track lowering.

REASONING FOR INCREASED RISK RATING

The required depth for bulk excavations (186.0mAHD), whilst above the monitored groundwater levels, is 0.8m from the shallowest recorded groundwater levels at 184.0–185.2mAHD (1.3 to 2.5mBGL). Given the hydrogeological conceptual model indicates that the groundwater level at the enhancement site likely has a strong correlation to climatic conditions and monitored groundwater levels could be influenced from nearby pumping, there is a risk that groundwater levels could be elevated during construction, if wetter climatic conditions occur or there are changes to pumping (if influenced).

Under the above conditions there is an increased risk that potential elevated groundwater levels may be intersected during bulk excavations resulting in groundwater intersection and take.

EXPECTED GROUNDWATER LEVELS AND QUALITY

Recent groundwater monitoring has shown the groundwater at Pearson Street bridge to be approximately 1.3 to 2.5mBGL (184.0 to 185.2mAHD) and of fresh groundwater quality (A1), suitable for use in all beneficial use categories including raw drinking water (refer to Table 3.5, section 3.5). However, long term quarterly to bi-annual monitoring from neighbouring Wagga Wagga City Council monitoring bores has shown groundwater levels can vary by up to 3.4m and approach near ground surface levels as well as having variable and changing water quality (from fresh, beneficial use category A1 to saline, beneficial use category D). In addition, the recent groundwater monitoring has shown the groundwater may be influenced from external factors, possibly nearby pumping.

DEWATERING IMPACT

Given the anticipated groundwater levels under current monitoring conditions, bulk excavations are not anticipated to intercept the water table. As no groundwater take is anticipated, the risk and resulting impacts from dewatering, would be low, including any impacts to GDEs or registered users. However, if groundwater levels at the time of construction are elevated above 186.0mBGL, possibly due to wetter climatic conditions or changes to nearby pumping, groundwater may be intersected during bulk excavations. As this risk transient in nature, no volumes of groundwater take can be appropriately and accurately quantified. It is expected that any potential impact would be limited due to the short time frame required to complete the excavation works.

Further information regarding mitigation and management measures for the increased potential risk of dewatering at this enhancement site are provided in Chapter 7.

RISK TO GROUNDWATER QUALITY (SALINITY AND CONTAMINATION)

There is a low potential risk of impact to groundwater quality given construction activities are not expected to intersect the water table under current monitoring conditions, with no alteration to existing flow paths resulting from dewatering that may disturb and migrate potential existing contamination or saline groundwater.

In addition, the site has already been modified to accommodate rail, including altering drainage patterns, piling for bridge foundations and soil retaining walls. The additional depth for excavation for construction of new soil retaining walls and for track lowering will have negligible impact on the existing conditions, including groundwater levels and flow paths, further limiting the risk of impact to groundwater quality from salinity or contamination.

Further information regarding the risk and impact to the groundwater environment from contamination is discussed in Technical Paper 13: Contamination.

RISK TO SETTLEMENT

Settlement, as a result of dewatering, has a low risk given dewatering is not anticipated to be needed.

RISK TO RECHARGE

Given the proposal is not altering the existing land use (rail) during construction the impact to groundwater recharge is considered low. This is due to the site already being modified to accommodate rail, including altering drainage patterns, piling for bridge foundations and soil retaining walls.

Reduction in rate of surface water infiltration to groundwater is not anticipated.

5.2.2.3 KEMP STREET BRIDGE (JUNEE PRECINCT)

CONSTRUCTION ACTIVITIES

The proposed works at Kemp Street bridge involves bridge replacement and installation of supporting walls. Earthworks will therefore be required to undertake the proposed works and excavations will predominately involve stripping of soil to allow for capping of the existing foundations, installation of supporting walls and treatment of foundation material. Total depth of bulk excavations is anticipated to be up to 5.0mBGL (approximately 297.5mAHD at deepest extent). Piling will also be required to support the new bridge and is anticipated to extend up to 30mBGL. Excavation earthworks are anticipated to take approximately 25 days.

REASONING FOR INCREASED RISK RATING

Given the current design depths required for construction, it is anticipated up to approximately 1.8m of groundwater within the shallow Lachlan fractured rock HSU will be intersected and require dewatering, given the anticipated water table at about 298–299mAHD. Groundwater is predicted to be intersected during excavation required for the treatment of soil foundations and construction of the soil retaining wall. Piling is anticipated to also intersect the shallow Lachlan fractured rock HSU aquifer and potentially the deeper aquifer system if water bearing zones are present at depth, however using appropriate piling techniques, no dewatering resulting from piling is expected to occur.

DEWATERING IMPACT

A conservative approach for estimating dewatering volumes has been applied based on the data available for the site (refer to section 3.8.2).

At Kemp Street bridge enhancement site, the following assumptions, which over-estimate (conservative approach) the calculated dewatering volume, were applied:

- dewatering is required from the first day of excavation for up to 25 days (the total duration of construction)
- dewatering occurs along the total length and width of excavation for the installation of the soil retaining wall (167.29m long x 10m wide)
- groundwater level is constant at 299mAHD along the proposed excavation
- excavation footprint remains rectangular to the total depth of the excavation
- instantaneous excavation of all material to maximum excavation depth (297.48mAHD)
- maximum excavation depth includes an additional one metre below design level for the soil retaining wall for treatment of foundation soils
- dewatering will require lowering the groundwater table an addition 0.3m below the maximum excavation depth (total dewatering depth to 297.182mAHD).

Dewatering rates and volume were calculated using the Darcy equation for base inflow and the Dupuit-Forcheimer for radial and parallel inflows. The calculated groundwater inflow from each equation was then combined for a total dewatering volume. The radius of influence estimate was calculated using the Bear (1979) equation using a specific yield value of 20 per cent. Groundwater equations are provided in section 3.8.2. A hydraulic conductivity of 0.01m/day was selected based on the conceptual hydrogeological model (section 4.8.4.2). Estimated dewatering rates, volume and radius of influence are provided in Table 5.5.

A total of 11.4ML was estimated to be dewatered during the construction phase with a radius of influence of up to 5.1m.

Table 5.5 Estimated dewatering rates and volumes

DEWATERING AREA (m^2)	DEWATERING DEPTH (m)[1]	DEWATERING RATE (L/s)		TOTAL DEWATERING VOLUME (mL)[2]	RADIUS OF INFLUENCE (m)
		At 24 hours	At 14 days		
1,672.9	1.8	1.0	0.4	11.4	5.1

(1) Assumes additional 0.3m below excavation required for dewatering.

(2) Assumes dewatering for up to 25 days.

Given the calculated radius of influence, the risk of groundwater take impacting GDEs and registered bores is low. The nearest GDEs are classified as low potential (White box – terrestrial) and high priority (Rock Creek – aquatic), located approximately 500m to the south and east, respectively, well beyond the estimated 5.1m zone of influence. In addition, these GDEs are situated within different localised topographic terrains from the point of dewatering, further reducing the risk of impact due to reduced groundwater connectivity with the enhancement site.

There is a moderate risk of dewatering impacting a neighbouring water supply bore (GW064614) that is located approximately 7.5m of the dewatering activity. Limited information exists for the registered bore, including its current status, but available information indicates the bore was drilled to 10.7m in 1986 and likely extracts groundwater from the same HSU. However, given dewatering is temporary and for a relatively short duration, the groundwater is expected to recover with no long-term impact. In the event that the bore was significantly impacted (unlikely), make good provisions would apply.

RISK TO GROUNDWATER QUALITY (SALINITY AND CONTAMINATION)

As groundwater is predicted to be dewatered, localised groundwater flow paths and levels will be impacted. The changes to groundwater flow paths and levels may disturb and migrate potential existing contamination or saline groundwater. In addition, as the groundwater table will be close to or at the base of the excavation during earthworks, there is an increased risk of construction contaminants such as stored chemicals or leachate from spoil entering the groundwater environment. Giving groundwater underlying the enhancement site has been classified as vulnerable (Junee Local Environmental Plan, 2012), considerations such as groundwater contamination and impacts to GDE's are specified and have been considered in this impact assessment.

Any potential impact is considered low due to the calculated limited radius of influence (5.1m) of dewatering and the minimal time dewatering is required (up to 25 days). One water supply bore (GW064614) is located just outside the calculated radius (at 7.5m) and is considered at moderate risk of potential impact to groundwater quality. The nearest GDEs are approximately 400m away and are considered to have a low risk based on the conceptual hydrogeological model.

To further limit the risk of potential impact from contaminants entering the groundwater environment, including given the identification of groundwater as vulnerable (Junee Local Environmental Plan, 2012), standard mitigation measures have been identified and are discussed in Technical Paper 13: Contamination and Chapter 7.

RISK TO SETTLEMENT

As dewatering is temporary, no significant changes to soil moisture content are anticipated outside of natural conditions and therefore the risk of settlement and deflection induced by construction dewatering on adjacent infrastructure is anticipated to be low.

RISK TO RECHARGE

Given the proposal is not altering the existing land use (rail) during construction the impact to groundwater recharge is considered low. This is due to the site already being modified to accommodate rail, including altering drainage patterns, piling for bridge foundations and soil retaining walls. In addition, no accommodation camps are required for the enhancement site as the work force can be accommodated within Junee.

Reduction in rate of surface water infiltration to groundwater is not anticipated.

5.2.3 CONSTRUCTION WATER DEMAND, SUPPLY AND BALANCE

5.2.3.1 WATER DEMAND AND SUPPLY

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

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

Preliminary estimates for water requirements for the placement and compaction of engineering fill are summarised in Table 5.6.

Table 5.6 Estimated water demand during construction

PRECINCT	SITE	WATER DEMAND (ML)[1]
Albury	Murray River bridge	0.0
	Albury Station yard clearances	4.5
	Albury Station pedestrian bridge	0.6
	Riverina Highway bridge	2.3
	Billy Hughes bridge	2.3
	Table Top Yard clearances	0.0
	Total	**9.7**
Greater Hume – Lockhart	Culcairn pedestrian bridge	0
	Culcairn Yard clearances	0.6
	Henty Yard clearances	1.1
	Yerong Creek Yard clearances	1.7
	The Rock Yard clearances	0.0
	Total	**3.4**
Wagga Wagga	Uranquinty Yard clearances	2.8
	Pearson Street bridge	0.6
	Cassidy Parade pedestrian bridge	0.0
	Edmondson Street bridge	4.5
	Wagga Wagga Station pedestrian bridge	0.0
	Wagga Wagga Yard clearances	2.8
	Bomen Yard clearances	2.8
	Total	**13.5**

PRECINCT	SITE	WATER DEMAND (ML)[1]
Junee	Harefield Yard clearances	6.1
	Kemp Street bridge	4.6
	Junee Station pedestrian bridge	0.0
	Junee Yard clearances	2.7
	Olympic Highway underbridge	6.5
	Junee to Illabo clearances	10.4
	Total	**30.3**

(1) Excludes any estimated water demand resulting from dewatering (refer to section 5.2.2.3).

Further investigation of options for the provision and storage of construction water would be undertaken during detailed design, in consultation with regulators and landowners. The preferred source of construction water and method of storage would be confirmed prior to construction.

Preferred water sources will depend on:

- climatic conditions in the lead up to construction and associated water availability
- access agreements with landowners for sourcing privately owned water
- access agreements with local governments for sourcing town water.

5.2.3.2 WATER BALANCE AND LICENSING

In the event that groundwater is utilised to supply a percentage of construction requirements, it will be sourced through existing allocations and will not result in additional groundwater take outside of what has already been allocated through available water determination.

Groundwater take resulting from dewatering during construction was identified at Riverina Highway bridge and Kemp Street bridge enhancement sites. Dewatering at Riverina Highway bridge will result in an estimated take of 0.7ML from the Upper Murray groundwater source. The Upper Murray groundwater source is currently over-allocated with a total share component of 41,620ML/year against the LTAAEL of 14,109ML/year. Usage of the groundwater source has varied, with usage less than the LTAAEL occurring in 2015–2016 to 2017–2018, however in 2018–2020 the usage was greater than the LTAAEL by 4,289-4,678ML per water calendar year.

An estimated total of 11.4ML would be additionally removed from the Lachlan Fold Belt MDB groundwater source within one water calendar year. The Lachlan Fold Belt MDB groundwater source is currently under-allocated with a total share component of 150,293ML against the LTAAEL of 253,788ML/year. Usage of the groundwater source between 2015 and 2020 was 171,425–175,691ML/year.

ARTC or its contractor will obtain a relevant WAL with sufficient volume to cover estimated groundwater take resulting from dewatering.

Potential groundwater take resulting from the proposal (including dewatering) will not impact on the current water balance of the Billabong Creek Alluvial, Wagga Wagga Alluvial or Lachlan Fold Belt MDB groundwater sources. Depending on the total usage of the Upper Murray groundwater source during the year construction occurs at the Riverina Highway bridge in Albury, there is potential that the required groundwater take, although low, may contribute to a total groundwater source extraction that is above the sustainable limit.

5.3 OPERATION

Potential operation phase risks are the same as the construction risks identified in Table 5.1, section 5.1, but manifest through different pathways. Generally operational risks and impacts are lower than during the construction phase for the proposal as the operation contains:

- a shallower permanent footprint (with excavation depths during construction typically deeper than the final permanent footprint of the proposals foundations and design level)
- return to pre-existing land use and operation procedures.

Generally, all enhancement sites resulted in minimal vertical change to the alignment except for Riverina Highway bridge, Billy Hughes bridge and Pearson Street bridge enhancement sites as they require permanent track lowering.

Flooding mitigation and drainage design for the proposal will mimic existing discharge conditions at all enhancement sites and therefore the risk of impact to the groundwater environment resulting from flooding mitigation and drainage design is considered comparable and low. Refer to Technical Paper 11: Hydrology, flooding and water quality.

5.3.1 ENHANCEMENT SITES WITH LOW RISK OF GROUNDWATER IMPACT

The following enhancement sites are considered to contain low risk and impact to the groundwater environment as the final land-use, including vertical alignment is comparable to the existing operations. These enhancement sites contain no track lowering and minimal underground infrastructure that may impact or impede groundwater, either due to the depth of groundwater or limited extent of underground infrastructure. Therefore, all risks and impacts identified in Table 5.1 would be similar or lower than those described during the construction and comparable to current operations:

- Murray River bridge (Albury precinct)
- Albury Station pedestrian bridge (Albury precinct)
- Albury Station yard clearances (Albury precinct)
- Table Top Yard clearances (Albury precinct)
- Culcairn pedestrian bridge (Greater Hume – Lockhart precinct)
- Culcairn Yard clearances (Greater Hume – Lockhart precinct)
- Henty Yard clearances (Greater Hume – Lockhart precinct)
- Yerong Creek Yard clearances (Greater Hume – Lockhart precinct)
- The Rock Yard clearances (Greater Hume – Lockhart precinct)
- Uranquinty Yard clearances (Wagga Wagga precinct)
- Edmondson Street bridge (Wagga Wagga precinct)
- Wagga Wagga Station pedestrian bridge (Wagga Wagga precinct)
- Wagga Wagga Yard clearances (Wagga Wagga precinct)
- Bomen Yard clearances (Wagga Wagga precinct)
- Harefield yard clearances (Junee precinct)
- Kemp Street bridge (Junee precinct)
- Junee Station pedestrian bridge (Junee precinct)
- Junee Yard clearances (Junee precinct)
- Olympic Highway underbridge (Junee precinct)
- Junee to Illabo clearances (Junee precinct).

5.3.2 ENHANCEMENT SITES WITH INCREASED RISK OF GROUNDWATER IMPACT

The following enhancement sites contain an increased risk of groundwater impact due to their design requiring track lowering or underground infrastructure that may impact or impede groundwater flow due to its depth or extent.

- Riverina Highway bridge (Albury precinct)
- Billy Hughes bridge (Albury precinct)
- Pearsons Street Bridge (Wagga Wagga precinct).

5.3.2.1 RIVERINA HIGHWAY BRIDGE AND BILLY HUGHES BRIDGE (ALBURY PRECINCT)

At both the Riverina Highway bridge and Billy Hughes bridge enhancement sites, which contain track lowering, the groundwater environment was not anticipated to be impacted during construction. The construction requires deeper excavations and therefore, groundwater is also not anticipated to be intersected during operation. Any underground infrastructure, such as retaining walls, will be above the groundwater table and not impede its flow.

At Riverina Highway bridge, dewatering is required during the installation of an underground storage tank. The storage tank will be partially below the water table during the operation of the proposal. However, it will be constructed with near-impermeable material and given its minor area (64 metres squared), impacts or changes in groundwater levels, quality (contamination and salinity) and recharge is considered low.

For the same reasons outlined in the construction phase and given that operation would be comparable to current operation activities and not require dewatering, all risks and impacts identified in Table 5.1 are considered low.

5.3.2.2 PEARSON STREET BRIDGE (WAGGA WAGGA PRECINCT)

KEY RISK

As listed in Table 5.1, track lowering has the potential to cause continuous impact to the groundwater environment by altering localised flow paths and potential continued groundwater take if the new track elevation intersects the groundwater aquifer. However, this is not anticipated to occur given the final design level for the track lowering at Pearson Street bridge is at 187.3mAHD, 2.1–3.3m above monitored groundwater levels.

Although likely to be limited and transient in nature, there is a moderate risk groundwater will be close to or above the surface level of the track at intermittent periods due to the following:

- Groundwater levels can fluctuate over time and under different climatic conditions. Nearby long-term Wagga Wagga City Council monitoring bores have shown varying degrees of response to climatic and local conditions since monitoring commenced in 1994. Nearby Wagga Wagga City Council bores inferred to be screened within the same groundwater HSU have monitored groundwater fluctuations within the same monitoring bores from 0.74m over 18 years to 3.40m over 28 years. This indicates that groundwater levels and responses are highly localised.
- The current monitoring data (BH206) at Pearson Street bridge indicates groundwater is influenced by local external forces, not just rainfall. This has resulted in the current monitoring period already recording a 1.16m variation between minimum and maximum monitored groundwater levels.

GROUNDWATER LEVEL DECLINE RESULTING FROM DEWATERING

Should groundwater rise to the elevation of the track, this is predicted to be intermittent at most and likely result in seepage through the base of the rail cut and into the installed surface water drainage network. Whilst this would result in potential groundwater take it is not predicted to result in declining groundwater levels as it would only occur under wetter climatic conditions (i.e. when groundwater levels are rising). Therefore, the impact and risk to GDEs and registered water supply bores is considered low.

RISK TO GROUNDWATER QUALITY

Changes in groundwater levels and flow paths may mobilise contaminants or salinity, potentially impacting nearby sensitive receivers. It is anticipated that under wetter climatic conditions where groundwater would be shallower, the quality (salinity) is anticipated to become fresher due to the increased recharge from rainfall infiltration. This would result in negligible risk to GDEs and registered water supply bores.

The presence of shallow, saline groundwater has been considered in the design. Sampling completed as part of the geotechnical investigation for the proposal included consideration of salinity and aggressivity (a measure of the potential for corrosion to occur on concrete or steel structures). Where aggressive soil and groundwater conditions have been recorded, this will be considered during detailed design in the specification of material selection and thickness to allow for adequate durability.

SETTLEMENT

As the operation of the proposal would not result in on-going dewatering, soil moisture contents are not predicted to decrease outside their natural variation. Therefore, the risk of settlement is considered low.

RECHARGE

The operational use at Pearson Street bridge is comparable to existing land-use activities (rail) and flooding and drainage design will mimic existing discharge conditions.. Therefore, no changes to the proposals impact to recharge resulting from its operation is expected.

5.3.3 WATER BALANCE

Groundwater is not required for the operation of the proposal. There is a low-to-moderate risk that groundwater may seep into the rail alignment at Pearson Street bridge under wetter climatic conditions. However, this would be intermittent and limited in extent therefore limiting any impact of the proposal on the existing relevant groundwater sources. The potential groundwater inflows would mix into designed drainage infrastructure with surface water flows and likely form a small component of the total discharge water. Therefore, it is anticipated to have limited impact on the designed discharge quality and volumes.

5.4 MINIMAL IMPACT CONSIDERATION

Interference approvals under the WM Act have yet to commence. However, the aquifer interference policy is used to guide proponents and DPE in assessing aquifer interference activities.

As stated in section 2.2.2.2, the AIP (DPI, 2012) includes minimal impact considerations for assessing the impacts of all aquifer interference activities. NSW groundwater sources need to be categorised as being either highly productive or less productive, based on the general character of the water source meeting or not meeting the criteria of 1,500mg/L total dissolved solids and a bore yield rate of greater than 5L/s. This categorisation applies to a whole groundwater source as it is defined in a water sharing plan, not to the specific groundwater conditions at a specific location. The groundwater resources within the groundwater study area considered to be:

- Less productive:
  - Lachlan Fold Belt MDB (Lachlan fractured rock) groundwater source due to typically low yields and saline groundwater quality
  - Upper Murray groundwater source due to low yields within the shallow aquifer
  - Billabong Creek Alluvial groundwater source due to low yields and saline groundwater quality.
- Highly productive:
  - Wagga Wagga Alluvial groundwater source due to high yields and low total dissolved solids content.

An assessment of the proposals impacts from the potential changes in groundwater levels and quality on GDEs, beneficial use category, water supply works (i.e. registered bores), highly connected surface water source and culturally significant sites is provided in Table 5.7 to Table 5.9.

The assessment of the proposals impacts on aquifers and GDEs in regard to the minimal impact considerations of the NSW Aquifer Interference Policy indicates the proposal complies with Level 1 criteria, which considers the potential impacts as acceptable.

Table 5.7 Aquifer Interference Policy minimal impact consideration for a 'less productive fractured rock aquifer' – Lachlan fractured rock

FEATURE	MINIMAL IMPACT CONSIDERATIONS	RESPONSE
Water table	— Less than or equal to ten per cent cumulative variation in the water table, allowing for typical climatic "post-water sharing plan" variations, 40m from any: — high priority groundwater dependent ecosystem; or — high priority culturally significant site listed in the schedule of the relevant water sharing plan. — A maximum of a two metres decline cumulatively at any water supply work.	There is a low risk of the proposal causing equal to or greater than ten per cent cumulative variation in the water table from any high priority GDE or culturally significant site or over two metre decline cumulatively at any water supply work. Any potential change would be minimal due to the expected groundwater depth, selection of appropriate construction methodologies and final land-use being consistent with current operations. Whilst groundwater take is anticipated for up to 25 days at Kemp Street bridge (Junee), the proposed drawdown for dewatering is anticipated to be less than 2 metres. In addition: — the dewatering would only be temporary, for construction purposes — the calculated radius of dewatering impact is 5.1m — there is a very low potential impact to the high priority GDE Rocks Creeks located approximately 500m east of Kemp Street bridge — no culturally significant sites were identified within a 2 kilometre radius — four registered water supply bores exist within a 2 kilometre radius of Kemp Street bridge. Three are greater than 1 kilometre away (no risk), however one bore (GW064614) is adjacent to the construction impact zone (7.5m from dewatering location). Refer to step 2 for mitigation details. At all other enhancement sites that are situated within the Lachlan fractured rock HSU, a water table change is not anticipated.

FEATURE	MINIMAL IMPACT CONSIDERATIONS	RESPONSE
	— If more than ten percent cumulative variation in the water table, allowing for typical climatic "post-water sharing plan" variations, 40m from any: — high priority groundwater dependent ecosystem; or — 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 two metres decline cumulatively at any water supply work then make good provisions would apply.	In the unlikely event that GW064614 experiences a greater than two metre decline, make good provisions would apply during the construction period.
Water pressure	— A cumulative pressure head decline of not more than a two metres decline, at any water supply work.	Pressure heads are not anticipated to be lowered (or raised) due to the expected depth of the confined aquifers in the groundwater study area and selection of appropriate construction methodologies.
	— If the predicted pressure head decline is greater than Requirement 3 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.	Refer to Item 3 responses that indicates this condition is not triggered.
Water quality	— Any change in the groundwater quality should not lower the beneficial use category of the groundwater source beyond 40m from the activity.	The project is not anticipated to result in a change in groundwater quality which would lower the beneficial use category.
	— 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.	Refer to Item 4 responses that indicates this condition is not triggered.

Table 5.8 Aquifer Interference Policy minimal impact consideration for a 'less productive alluvial water sources' – Billabong Creek Alluvial and Upper Murray

	MINIMAL IMPACT CONSIDERATIONS	RESPONSE
Water table	— Less than or equal to 10% cumulative variation in the water table, allowing for typical climatic "post-water sharing plan" variations, 40m from any: — high priority groundwater dependent ecosystem; or — high priority culturally significant site listing in the schedule of the relevant water sharing plan; or — A maximum of a two metres decline cumulatively at any water supply work unless make good provisions should apply.	There is a low risk of the proposal causing equal to or greater than ten per cent cumulative variation in the water table from any high priority GDE or culturally significant site or over two metre decline cumulatively at any water supply work. Any potential change would be minimal due to the expected groundwater depth, selection of appropriate construction methodologies and final land-use being consistent with current operations. Whilst groundwater take is anticipated within the Upper Murray groundwater source for up to 21 days at Riverina Highway bridge (Albury), the proposed drawdown for dewatering is anticipated to be less than 2 metres. In addition: — the dewatering would only be temporary, for construction purposes — the calculated radius of dewatering impact is 5.8m — there is a very low potential impact to the nearest GDEs, which are located approximately 700m and 750m from the dewatering location — no culturally significant sites were identified within a 2 kilometre radius. At all other enhancement sites that are situated within the Billabong Creek Alluvial or Upper Murray HSU, a water table change is not anticipated.

	MINIMAL IMPACT CONSIDERATIONS	RESPONSE
	— If more than 10% cumulative variation in the water table, allowing for typical climatic "post water sharing plan" variations, 40m from any: — high priority groundwater dependent ecosystem; or — 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 two metres decline cumulatively at any water supply work then make good provisions should apply.	Refer to Item 1 responses that indicates this condition is not triggered.
Water pressure	— 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 of a two metres decline, at any water supply work.	Pressure heads are not anticipated to be lowered (or raised) due to the expected depth of the confined aquifers in the groundwater study area and selection of appropriate construction methodologies.
	— 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.	Refer to Item 3 responses that indicates this condition is not triggered.
Water quality	— Any change in the groundwater quality should not lower the beneficial use category of the groundwater source beyond 40m from the activity; and — No increase of more than 1% per activity in long-term average salinity in a highlight connected surface water source at the nearest point to the activity. Redesign of a highly connected surface water source that is defined as a "reliable water supply" is not an appropriate mitigation measure to meet considerations 1.(a) and 1.(b) above. — No mining activity to be below the natural ground surface within 200m laterally from the top of high bank or 100m vertically beneath (or the three dimensional extent of the alluvial material – whichever is the lesser distance) of a highly connected surface water source that is defined as a "reliable water supply".	The proposal is not anticipated to result in: — a change in groundwater quality which would lower the beneficial use category — increase of more than 1% per activity in long-term average salinity in connected surface water sources. The proposal is not a mining activity.

	MINIMAL IMPACT CONSIDERATIONS	RESPONSE
	— If Condition 1.(a) 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 1.(b) is not met then appropriate studies are required to demonstrate to the Minister's satisfaction that the River Condition Index category of the highly connected surface water source will not be reduced at the nearest point to the activity. — If condition 1.(c) is not met, then appropriate studies are required to demonstrate to the Minister's satisfaction that: — there will be negligible river bank or high wall instability risks — during the activity's operation and post-closure, levee banks and landform designs should prevent the Probable Maximum Flood from entering the activity's site — low-permeability barriers between the site and the highly connected surface water source will be appropriately designed, installed and maintained to ensure their long-term effectiveness at minimising interaction between saline groundwater and the highly connected surface water supply.	Refer to Item 4 responses that indicates this condition is not triggered.

Table 5.9 Aquifer Interference Policy minimal impact consideration for a 'highly productive alluvial water sources' – Wagga Wagga Alluvial

	MINIMAL IMPACT CONSIDERATIONS	RESPONSE
Water table	— Less than or equal to 10% cumulative variation in the water table, allowing for typical climatic "post-water sharing plan" variations, 40m from any: — high priority groundwater dependent ecosystem; or — high priority culturally significant site listing in the schedule of the relevant water sharing plan; or — A maximum of a two metres decline cumulatively at any water supply work.	There is a negligible to low risk of the proposal causing equal to or greater than ten per cent cumulative variation in the water table from any high priority GDE or culturally significant site or over two metre decline cumulatively at any water supply work.
	— If more than 10% cumulative variation in the water table, allowing for typical climatic "post water sharing plan" variations, 40m from any: — high priority groundwater dependent ecosystem; or — 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 two metres decline cumulatively at any water supply work then make good provisions should apply.	Refer to Item 1 responses that indicates this condition is not triggered.
Water pressure	— 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 of a two metres decline, at any water supply work.	Pressure heads are not anticipated to be lowered (or raised) due to the expected depth of the confined aquifers in the groundwater study areas and selection of appropriate construction methodologies. In addition, no groundwater take is anticipated within the groundwater resource during construction or operation of the proposal.
	— 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.	Refer to Item 3 responses that indicates this condition is not triggered.

	MINIMAL IMPACT CONSIDERATIONS	RESPONSE
Water quality	— Any change in the groundwater quality should not lower the beneficial use category of the groundwater source beyond 40m from the activity; and — No increase of more than 1% per activity in long-term average salinity in a highlight connected surface water source at the nearest point to the activity. Redesign of a highly connected surface water source that is defined as a "reliable water supply" is not an appropriate mitigation measure to meet considerations 1.(a) and 1.(b) above. — No mining activity to be below the natural ground surface within 200 m laterally from the top of high bank or 100m vertically beneath (or the three dimensional extent of the alluvial material – whichever is the lesser distance) of a highly connected surface water source that is defined as a "reliable water supply". — Not more than 10% cumulatively of the three dimension extent of the alluvial material in this water source to be excavated by mining activities beyond 200m laterally from the top of high bank and 100m vertically beneath a highly connected surface water source that is defined as a "reliable water supply".	The proposal is not anticipated to result in: — a change in groundwater quality which would lower the beneficial use category — increase of more than 1% per activity in long-term average salinity in connected surface water sources. The proposal is not a mining activity.

	MINIMAL IMPACT CONSIDERATIONS	RESPONSE
	— If Condition 1.(a) 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 1.(b) or 1.(d) is not met then appropriate studies are required to demonstrate to the Minister's satisfaction that the River Condition Index category of the highly connected surface water source will not be reduced at the nearest point to the activity. — If condition 1.(c) or 1.(d) is not met, then appropriate studies are required to demonstrate to the Minister's satisfaction that: — there will be negligible river bank or high wall instability risks — during the activity's operation and post-closure, levee banks and landform designs should prevent the Probable Maximum Flood from entering the activity's site — low-permeability barriers between the site and the highly connected surface water source will be appropriately designed, installed and maintained to ensure their long-term effectiveness at minimising interaction between saline groundwater and the highly connected surface water supply.	Refer to Item 4 responses that indicates this condition is not triggered.

6 CUMULATIVE IMPACTS

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. Cumulative groundwater impacts would predominately relate to increased groundwater take, whether for construction water supply (particularly in the case where construction schedules overlap) or as a result of overlapping dewatering radiuses with other projects that may consequently put increased strain on the groundwater resource and its sustainability. Chapter 26 of the EIS identifies projects with sufficient information to undertake assessment of potential cumulative impacts from the proposal. They include:

- Adjacent sections of Inland Rail, including:
  - Tottenham to Albury (Victoria)
  - Illabo to Stockinbingal.
- Other projects, including:
  - Thurgoona Link Road
  - Nexus Industrial Precinct
  - Jindera Solar Farm
  - Glenellen Solar Farm
  - Walla Walla Solar Farm
  - Culcairn Solar Farm
  - Uranquinty Solar Farm
  - Sandy Creek Solar Farm
  - Gregadoo Solar Farm
  - Solar farm (five MW) – Uranquinty
  - Solar farm (five MW) – Bomen
  - Wagga Wagga Special Activation Precinct
  - Riverina Intermodal Freight and Logistics Hub
  - Olympic Highway intersection upgrades
  - Project EnergyConnect (NSW – Eastern Section)
  - HumeLink
  - Junee Station Upgrade
  - Junee to Griffith Line Upgrade
  - Illabo Solar Farm
  - Grade separating road interfaces.

The location of these projects are shown in Figure 6.1.

Cumulative groundwater impacts are not expected given the distance of the proposal from the above projects and:

- the proposal will result in minimal dewatering with a limited radius of influence
- potential groundwater quality impacts from the proposal will be minimal and highly localised
- impacts from the proposal to settlement are considered negligible
- impact to groundwater recharge from the proposal is minimal and there is no change in the proposals current land use
- there is a low risk to groundwater from the proposal
- groundwater entitlement, including groundwater for construction and dewatering volumes, are legislated by an open trade market and therefore cumulative demand will not adversely impact the environment.

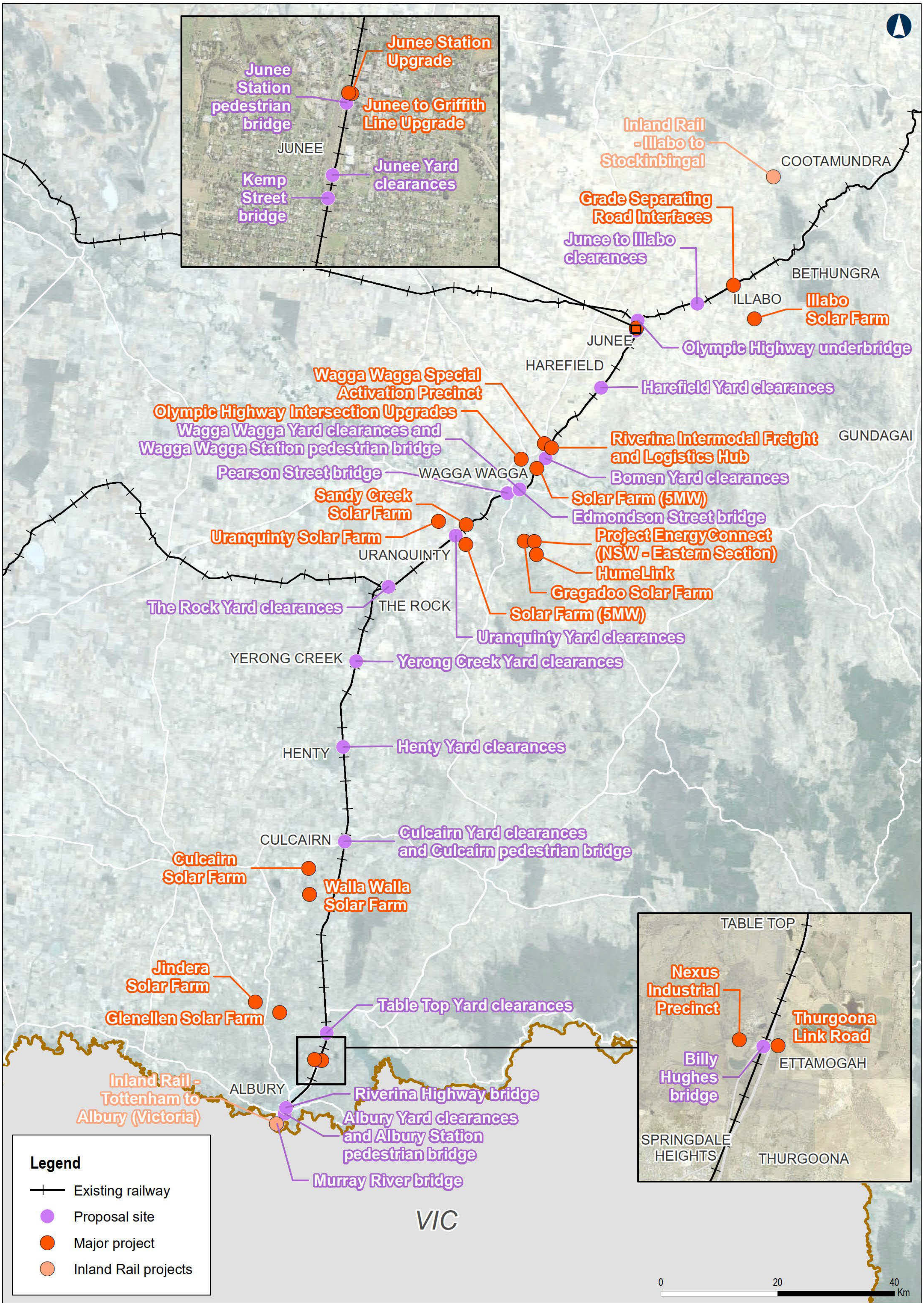

Figure 6-1 Major projects in the vicinity of the proposal

Data Sources: ARTC, NSWSS

Coordinate System: GDA 1994 MGA Zone 55
Scale: 1:850,000
Paper size: A3
Date: 26/05/2022

210_EAP_F0601_MajorProjects_r1v1.mxd

7 MITIGATION AND MANAGEMENT MEASURES

7.1 APPROACH TO MITIGATION AND MANAGEMENT

Environmental management for the proposal would be carried out in accordance with the environmental management approach as detailed in Chapter 27 of the EIS (Synthesis of the environmental impact statement).

Mitigation and management measures have been prepared in the following sections to reduce the risk of the proposals impact to the hydrogeological environment. They target key stages of the projects phase from detailed design, prior to construction, construction and operation.

7.2 GROUNDWATER MANAGEMENT SUB-PLAN

As construction activities have the potential to impact the groundwater environment a groundwater mitigation and management sub-plan (GWMP) would be prepared as part of the Construction Environment Management Plan (CEMP). The GWMP would comply with the Proposal conditions and be implemented to monitor the effectiveness of mitigation and management measures applied during the construction phase of the Proposal. The GWMP would:

- list details of the groundwater monitoring network, frequency of monitoring and test parameters
- be based on baseline studies developed for the Proposal (this report) and establish baseline monitoring reports (proposed)
- contain procedures for the documentation and reporting of results
- list key risks and potential impacts
- provide details on the dewatering protocol, include the disposal, treatment or reuse of extracted groundwater
- provide details on legal and licensing requirements
- include requirements for training, inspections, corrective actions, notification and classification of environmental incidents, record keeping, monitoring and performance objectives for handover on completion of construction.

The GWMP is to be developed by a suitably qualified person and determine the location and number of monitoring bores required to monitor the potential risk from laydown areas, fuel/chemical storage areas etc.

7.3 GROUNDWATER MONITORING PROGRAM

A groundwater monitoring program would be developed following project approval as part of a groundwater mitigation GWMP and would be developed in consultation with NSW DPE and relevant government agencies. A preliminary groundwater monitoring program is provided in the following sections.

7.3.1 SELECTION OF MONITORING SITES AND LOCATIONS

All enhancement sites that require excavations over 0.5m would be subject to preliminary monitoring during detailed design to support design options that can minimise potential impacts to the groundwater environment, particularly groundwater take. Some of the preliminary monitoring sites will require ongoing monitoring during construction as dictated within the GWMP.

The selection of the monitoring location(s) within the monitoring site would be devised by a suitably qualified person and target locations at greatest risk to aquifer interference or impacts to sensitive receivers (such as deep bulk excavations near waterways or high priority GDEs). Existing monitoring bores will be used where practical and suitable.

7.3.2 MONITORING PERIOD

The monitoring period for each identified site would be dictated within the GWMP, but will include at minimum monitoring of groundwater level and quality for period of twelve months prior to construction (baseline monitoring), with groundwater quality and manual groundwater level measurements being undertaken quarterly during baseline monitoring. Monitoring will also be undertaken at least monthly during construction and will continue for the duration of construction and for at least six months (potentially longer) during operation to verify that there are no groundwater impacts, and that management measures are adequate.

7.3.3 MONITORING PARAMETERS

Monitoring of groundwater quality should include the physiochemical parameters (temperature, EC, total dissolved solids, dissolved oxygen, pH, reduction-oxidation potential), major anions and cations (calcium, magnesium, sodium, potassium, bicarbonate, chloride and sulfate) and identified contaminants of concern that reflect the risk being monitored. Monitoring of groundwater levels should be undertaken through dataloggers set at a maximum 6-hour recording interval (3-hourly preferred).

7.4 MITIGATION AND MANAGEMENT MEASURES

The mitigation measures to manage impacts to groundwater from the proposal during detailed design/pre-construction, construction and operation are outlined in Table 7.1.

Table 7.1 Groundwater mitigation measures

IMPACT/ ISSUE	MITIGATION MEASURE	STAGE
Groundwater interaction	Preliminary groundwater monitoring at all enhancement sites requiring excavations greater than 0.5 metres below ground level will be completed to inform detailed design and confirm potential interaction with groundwater at these enhancement sites. This may include design responses such as the installation of appropriate drainage measures and refinement of estimated groundwater take at Kemp Street bridge with an aim to minimise dewatering volumes.	Detailed design/ pre-construction
Groundwater monitoring	A groundwater monitoring program (level and quality), prepared by a suitably qualified person, will be implemented in accordance with the requirements outlined in this assessment prior to construction. This will identify ongoing monitoring requirements following the completion of construction according to the risks to groundwater levels and quality. Ongoing groundwater monitoring (level and quality) will be carried out at the sites for the duration specified in the groundwater monitoring program.	Detailed design/ pre-construction/ construction
Groundwater interaction	Opportunities to use appropriate piling construction methodologies for bridge foundations that minimises groundwater take, such as the use of a tremie system, would be investigated during detailed design and implemented where practicable.	Detailed design/ pre-construction
Groundwater	The quality of groundwater taken during excavation works at Riverina Highway bridge and Kemp Street bridge enhancement sites will be assessed for the suitability for re-use during construction (or by others) or disposed of accordingly.	Detailed design

IMPACT/ ISSUE	MITIGATION MEASURE	STAGE
Groundwater	Registered bore GW402492 at the Olympic Highway underbridge enhancement site will be avoided during construction. If this registered bore is accidently damaged during construction and cannot be used for its intended purpose (monitoring), make good arrangements will apply (such as replacement), subject to discussion with the registered owner.	Detailed design
Groundwater	Site inspection will be carried out to confirm the current viability of registered bore GW064614 (water supply) at Kempt Street bridge enhancement site. In the event that the bore is viable and the AIP minimal impact considerations are temporarily or permanently exceeded, make good provisions will apply.	Construction

7.5 PREDICTED EFFECTIVENESS OF THE MITIGATION AND MANAGEMENT MEASURES PROPOSED

The proposed approach to management measures documented above is considered effective in reducing the potential impacts of the proposal on the groundwater environment, as far as practicable, and providing for the appropriate management of groundwater in the event that it is encountered. Where an identified issue/risk is reduced but not eliminated, it would be assessed further through all project stages to determine if further action is required.

The key residual groundwater impact for the proposal that cannot be eliminated by mitigation relates to dewatering volumes and associated drawdown during construction at Riverina Highway bridge and Kemp Street bridge enhancement sites. Considering the limited dewatering radius of influence and the proposed mitigation measure involving provisions to 'make good' for registered bore GW064614, the residual impact is considered acceptable.

All other groundwater impacts are considered negligible or low and the extent and magnitude of remaining residual impacts would be minimal given the management plans, emergency protocols and no change in the approved land use for the Proposal.

In the context of the strategic benefit of the overall proposal, it is considered that the groundwater impacts are acceptable.

8 CONCLUSION

This report describes the existing groundwater environment for the enhancement sites and assesses the potential groundwater impacts for both the construction and operation phases of the proposal. The potential groundwater impacts were also assessed against the AIP minimal impact considerations.

The proposal overlies the Upper Murray, Billabong Creek alluvium and Lachlan Fold Belt MDB groundwater resources. The proposal's impact on the underlying groundwater sources and hydrogeological environment was assessed as low, and in regard to the minimal impact considerations of the NSW Aquifer Interference Policy (DPI, 2012), the proposal complies with Level 1 minimal impact considerations for impacts on aquifers, registered groundwater users and GDEs.

Aquifer interference is minimal and mainly related to interference from piling for bridge foundations as the majority of construction and operation activities are to be conducted above the permanent regional water table. However, temporary dewatering is expected to occur during construction at two enhancement sites, Riverina Highway bridge, Albury and Kemp Street bridge, Junee. Up to 0.7ML and 11.4ML will be dewatered at Riverina Highway bridge and Kemp Street bridge for installation of an underground storage tank and installation of soil retaining walls, respectively. Both enhancement sites are anticipated to experience drawdowns of 1.8m and a radius of influence of up to 6m. No registered bores or high priority GDEs were located within the dewatering radius of influence. Additionally, a moderate risk of potential dewatering exists at Pearson Street bridge but would be dependent on changes to the existing environment such as wetter climatic conditions or potential neighbouring dewatering schedules. Potential impact under such conditions is expected to be low due to the installation of appropriate drainage measures and the dominance of surface water flows.

Potential impact associated with changes in groundwater quality, settlement and recharge were assessed to be low, primarily due to the proposal not altering the existing approved land use (rail) and the implementation of appropriate management measures, such as a groundwater monitoring program, management plans and emergency protocols, which would further reduce identified risks.

The proposal is not anticipated to impact the groundwater budget for the relevant groundwater resources as groundwater is currently not proposed for use during construction, but if deemed necessary would temporarily occur from existing bores and water allocations. Groundwater take from dewatering would also be appropriately licensed. ARTC or its contractor would also explore the option to re-use the dewatered groundwater for construction activities.

No cumulative impacts were predicted from the construction and operation of the proposal with other neighbouring identified projects.

In conclusion, the overall impact to the groundwater environment resulting from the proposal was considered to be low, meet the Level 1 minimal impact considerations of the AIP, and is acceptable.

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TECHNICAL PAPER 12

Groundwater

Appendix A Registered bore search results

ALBURY TO ILLABO ENVIRONMENTAL IMPACT STATEMENT

A1 REGISTERED BORE SEARCH GROUNDWATER LEVEL RECORDS

Table A.1 Summary of viewed registered bores with groundwater level records

BORE ID[1]	SITE ID[2,3]	INFERRED HSU[4]	DRILLED DEPTH (m)	WATER BEARING ZONES (mBTOC)[5]	GROUNDWATER LEVEL (mBTOC)[5]
GW028006	MRB, AYC	Upper Murray - S	3.70	3.0	2.9
GW503720	MRB, AYC	Upper Murray - S	8.00	–	5.4
GW505307	MRB, AYC	Upper Murray - S	23.00	3.0-21.0	18.0
GW500936	MRB, AYC	Upper Murray - D	46.50	43.0-46.5	3.0
GW505127	MRB, AYC	Upper Murray - S	24.0	2.0-24.0	3.2
GW020038	MRB, AYC	Upper Murray - S	7.60	4.6-7.6	3.7
GW505293	MRB, AYC	Upper Murray - S	21.00	3.5-20.0	2.7
GW505310	MRB, AYC	Upper Murray - S	20.00	4.0-19.0	15.0
GW500035	MRB, AYC	Upper Murray - S	7.00	4.8-7.0	1.8
GW505417	MRB, AYC	Upper Murray - S	6.00	3.0-6.0	2.5
GW505523	MRB, AYC	Upper Murray - S	21.00	–	2.5
GW505311	MRB, AYC	Upper Murray - S	22.00	5.0-22.0	17.0
GW504438	MRB, AYC	Upper Murray - S	4.75	1.8-4.8	1.8
GW505619	MRB, AYC	Upper Murray - S	8.00	3.0-8.0	2.2
GW505491	MRB, AYC	Upper Murray - S	10.00	8.0-9.5	3.3
GW504439	MRB, AYC	Upper Murray - S	5.50	2.0-5.5	1.5
GW504548	MRB, AYC	Upper Murray - S	6.00	2.5-6.0	2.5
GW505179	MRB, AYC	Upper Murray - S	24.00	7.0-15.0	3.5
GW504436	MRB, AYC	Upper Murray - S	5.00	2.3-5.0	1.9
GW505429	MRB, AYC	Upper Murray - S	7.00	4.7-7.0	5.1
GW062932	MRB, AYC	Upper Murray - S	20.00	4.1-10.0 13.0-17.0	3.0
GW037754	MRB, AYC	Upper Murray - S	5.50	0.6-5.4	0.6
GW504238	MRB, AYC	Upper Murray - S	27.00	24.0-27.0	4.0
GW061362	MRB, AYC	Upper Murray - S	36.00	2.5-13.5	1.3
GW504435	MRB, AYC	Upper Murray - S	19.50	3.5-19.5	2.5

BORE ID[1]	SITE ID[2,3]	INFERRED HSU[4]	DRILLED DEPTH (m)	WATER BEARING ZONES (mBTOC)[5]	GROUNDWATER LEVEL (mBTOC)[5]
GW017579	MRB, AYC	Upper Murray - S	36.60	0.0-3.7 6.7-32.0 33.8-39.5	– 3.7 3.7
GW070670	BHB	Lachlan fractured rock - D	88.00	80.0-81.0	47.3
GW504499	BHB	Lachlan fractured rock - D	132.00	46.0-50.0	40.0
GW503809	BHB	Lachlan fractured rock - D	90.00	50.0-55.0	40.0
GW505149	TYC	Lachlan fractured rock - S	15.50	9.5-10.0	9.0
GW001340	HYC	Lachlan fractured rock - D	70.10	61.0	56.4
GW017296	HYC	Lachlan fractured rock - D	88.70	51.8-60.9 82.3-88.7	57.9 52.1
GW001617	CYC	Billabong Creek - D	68.60	37.5	21.9
GW003879	CYC	Billabong Creek - D	76.20	38.1-52.7	32.9
GW048071	CYC	Billabong Creek - S	29.00	14.0-17.7	4.0
GW003872	CYC	Billabong Creek - S and D	67.10	19.1 57.3	16.6 19.8
GW505670	CYC	Billabong Creek - S	30.00	20.0-30.0	4.0
GW500649	CYC	Billabong Creek - S	20.00	–	6.0
GW011620	CYC	Billabong Creek - S	32.00	14.3 17.7 27.7-32.0	13.7
GW273303	CYC	Billabong Creek - D	84.00	77.0-80.0	18.0
GW030763	CYC	Billabong Creek - S and D	88.50	16.0-17.0 29.5-30.0 56.5-57.0 62.5-65.0 66.5-67.5 70.0-70.5 76.5-79.5	6.8 10.0 18.6 14.4 12.4 11.6 16.3
GW504458	CYC	Billabong Creek - S	34.00	31.0-34.0	28.0
GW503829	CYC	Billabong Creek - D	67.00	24.0-26.0 50.0-51.0 63.0-66.0	– – 18.0
GW414599	RYC	Lachlan fractured rock - D	64.40	–	32.9

BORE ID[1]	SITE ID[2,3]	INFERRED HSU[4]	DRILLED DEPTH (m)	WATER BEARING ZONES (mBTOC)[5]	GROUNDWATER LEVEL (mBTOC)[5]
GW001224	RYC	Lachlan fractured rock - D	71.00	61.0-62.5 70.4	– 56.4
GW001264	YCY	Lachlan fractured rock - D	85.30	82.3	65.5
GW400119	BYC	Lachlan fractured rock - S	9.00	–	1.2
GW402629	BYC	Lachlan fractured rock - S	9.10	8.0-10.5	6.3
GW060484	BYC	Lachlan fractured rock - S	17.10	7.9-14.3	5.9
GW402628	BYC	Lachlan fractured rock - S	15.00	14.0-15.0	12.3
GW402631	BYC	Lachlan fractured rock - S	13.10	12.0-13.1	8.0
GW402632	BYC	Lachlan fractured rock - S	10.07	6.0-10.1	5.3
GW401812	BYC	Lachlan fractured rock - S	11.30	7.8-11.3	4.8
GW403687	BYC	Lachlan fractured rock - S	21.00	12.0-20.0	9.0
GW401828	BYC	Lachlan fractured rock - S	13.00	7.0-13.0	3.0
GW402630	BYC	Lachlan fractured rock - S	8.00	6.0-8.0	5.9
GW402633	BYC	Lachlan fractured rock - S	15.03	12.0-15.0	14.5
GW401830	BYC	Lachlan fractured rock - S	18.00	4.0-18.0	4.0
GW403575	BYC	Lachlan fractured rock - S	15.00	Dry	Dry
GW414473	PSB, ESB	Lachlan fractured rock - D	106.00	40.0-41.0 71.0-72.0 90.0-91.0	15.0
GW019704	HFYC	Lachlan fractured rock - D	49.40	22.3 27.4 30.8 46.9 49.4	– – 25.0 19.8 21.9
GW402523	HFYC	Lachlan fractured rock - D	81.00	21.0-50.0	15.0
GW404557	HFYC	Lachlan fractured rock - D	146.00	–	18.0

Notes

(1) Excludes bores with no groundwater level record.

(2) Includes sites within 2 km of the registered bore.

(3) AYC = Albury Station pedestrian bridge and Yard clearances; BYC = Bomen Yard clearances; CYC = Culcairn pedestrian bridge and Yard clearances; ESB = Edmondson Street bridge; HYC = Henty Yard clearances; OHU = Olympic Highway underbridge; PSB = Pearson Street bridge; RHB = Riverina Highway bridge; RYC = The Rock Yard clearances; TYC = Table Top Yard clearances; UYC = Uranquinty Yard clearances; YCY = Yerong Creek Yard clearances, HFYC = Harefield Yard clearances.

(4) S = shallow; D = deep; in reference to corresponding aquifer (refer to section 4.5.1, Table 4.5)

(5) mBTOC = metres below top of casing.

A2 REGISTERED BORE SEARCH WATER QUALITY RECORDS

Table A.2 Summary of viewed registered bores with quantitative groundwater quality records

BORE ID[1]	SITE ID[2,3]	INFERRED HSU[4]	WATER BEARING ZONES	GROUNDWATER QUALITY (µS/cm)[5]
GW504238	MRB, AYC	Upper Murray - S	24.0-27.0	90
GW505179	MRB, AYC	Upper Murray - S	7.0-15.0	375
GW003879	CYC	Billabong Creek - S	38.1-52.7	1,500-4,500
GW505670	CYC	Billabong Creek - S	20.0-30.0	450
GW047032	CYC	Billabong Creek - S	19.0-20.9	1,500-4,500
GW504458	CYC	Billabong Creek - S	31.0-34.0	225
GW503829	CYC	Billabong Creek - D	63.0-66.0	750
GW504507	CYC	Billabong Creek - D	53.0-65.0	2,240

Notes

(1) Excludes proposed or planned bores and bores with no quantitative groundwater quality record.

(2) Includes sites within 2km of the registered bore.

(3) AYC = Albury Station pedestrian bridge and Yard clearances; RHB = Riverina Highway bridge; PSB = Pearson Street bridge; ESB = Edmondson Street bridge; OHU = Olympic Highway underbridge; UYC = Uranquinty Yard clearances.

(4) D = deep; S = shallow; in reference to corresponding aquifer (refer to section 4.5.1, Table 4.5)

(5) Quality refers to salinity. Values recorded as total dissolved solids (TDS) or parts per million (ppm) were converted to microseimens per centimetre (µS/cm) using a factor of 0.67.

A3 REGISTERED BORE SEARCH YIELD RECORDS

Table A.3 Summary of viewed registered bores with yield records (L/s)

BORE ID[1]	SITE ID[2,3]	INFERRED HSU[4]	WATER BEARING ZONES	YIELD (L/s)
GW017579	AYC, MRB, RHB	Upper Murray - S Upper Murray - D	6.7-32.0 33.8-36.5	1.26 1.52
GW037754	AYC, MRB, RHB	Upper Murray - S	0.6-5.4	3.16
GW061362	AYC, MRB, RHB	Upper Murray - S	2.5-13.5	1.00
GW062932	AYC, MRB, RHB	Upper Murray - S	13.0-17.0	1.20
GW500035	AYC, MRB, RHB	Upper Murray - S	4.8-7.0	2.00
GW500936	AYC, MRB, RHB	Upper Murray - D	43.0-46.5	0.80
GW504238	AYC, MRB, RHB	Upper Murray - S	24.0-27.0	1.00
GW504548	AYC, MRB, RHB	Upper Murray - S	2.5-6.0	1.00
GW505179	AYC, MRB, RHB	Upper Murray - S	7.0-15.0	1.50
GW505307	AYC, MRB, RHB	Upper Murray - S	3.0-21.0	2.30
GW505310	AYC, MRB, RHB	Upper Murray - S	4.0-19.0	2.26
GW505311	AYC, MRB, RHB	Upper Murray - S	5.0-22.0	1.70
GW505491	AYC, MRB, RHB	Upper Murray - S	8.0-9.5	1.01
GW505523	AYC, MRB, RHB	Upper Murray - S	3.0-21.0	2.00
GW503816	AYC, MRB, RHB	Upper Murray - D	36.0-40.0	0.60
GW504499	BHB	Lachlan fractured Rock - D	46.0-50.0	0.01
GW503809	BHB	Lachlan fractured Rock - D	50.0-55.0	0.02
GW070670	BHB	Lachlan fractured Rock - D	80.0-81.0	0.02
GW402523	HFYC	Lachlan fractured Rock - D	21.0-50.0	0.18

(1) Excludes registered bores with no yield data.

(2) Includes sites within 2km of the registered bore.

(3) AYC = Albury Station pedestrian bridge and Yard clearances; RHB = Riverina Highway bridge; PSB = Pearson Street bridge; ESB = Edmondson Street bridge; OHU = Olympic Highway underbridge; UYC = Uranquinty Yard clearances; HFYC = Harefield Yard clearances.

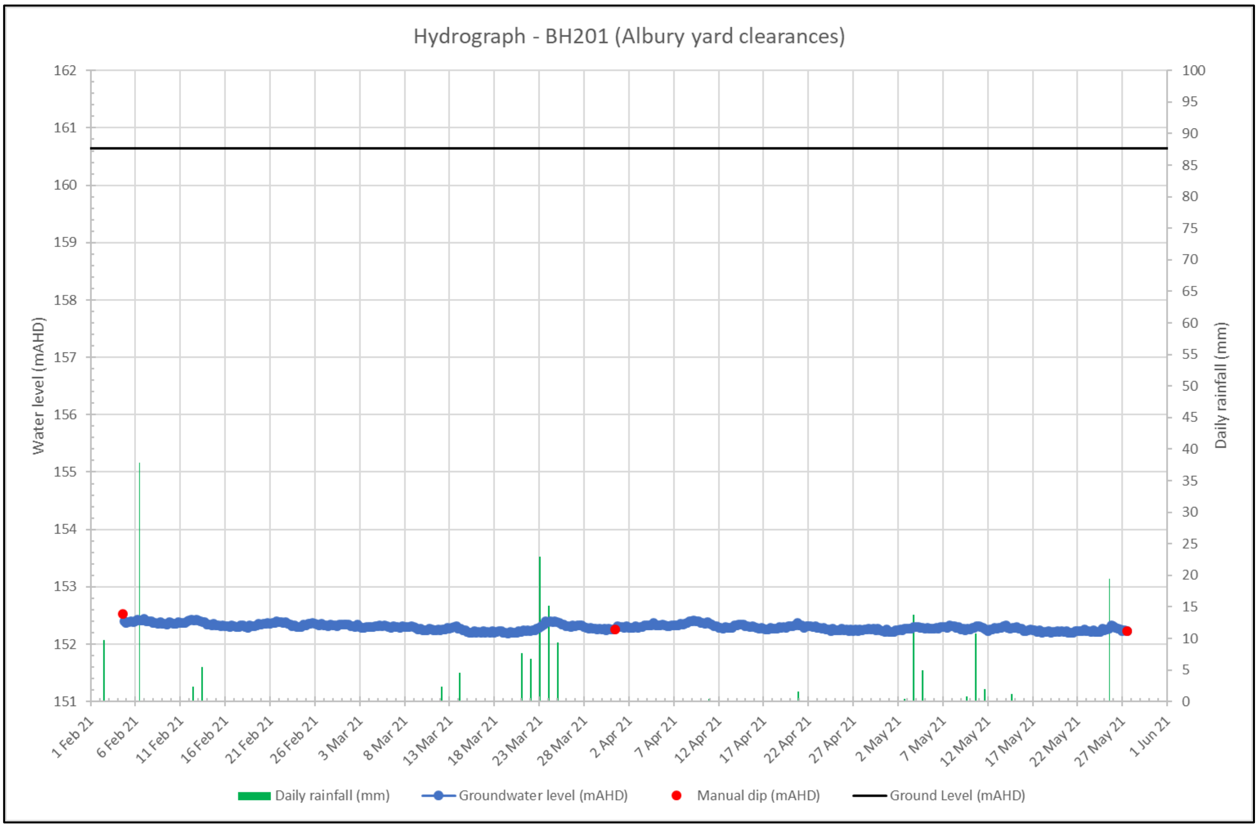
(4) D = deep; S = shallow; in reference to corresponding aquifer (refer to section 4.5.1, Table 4.5).

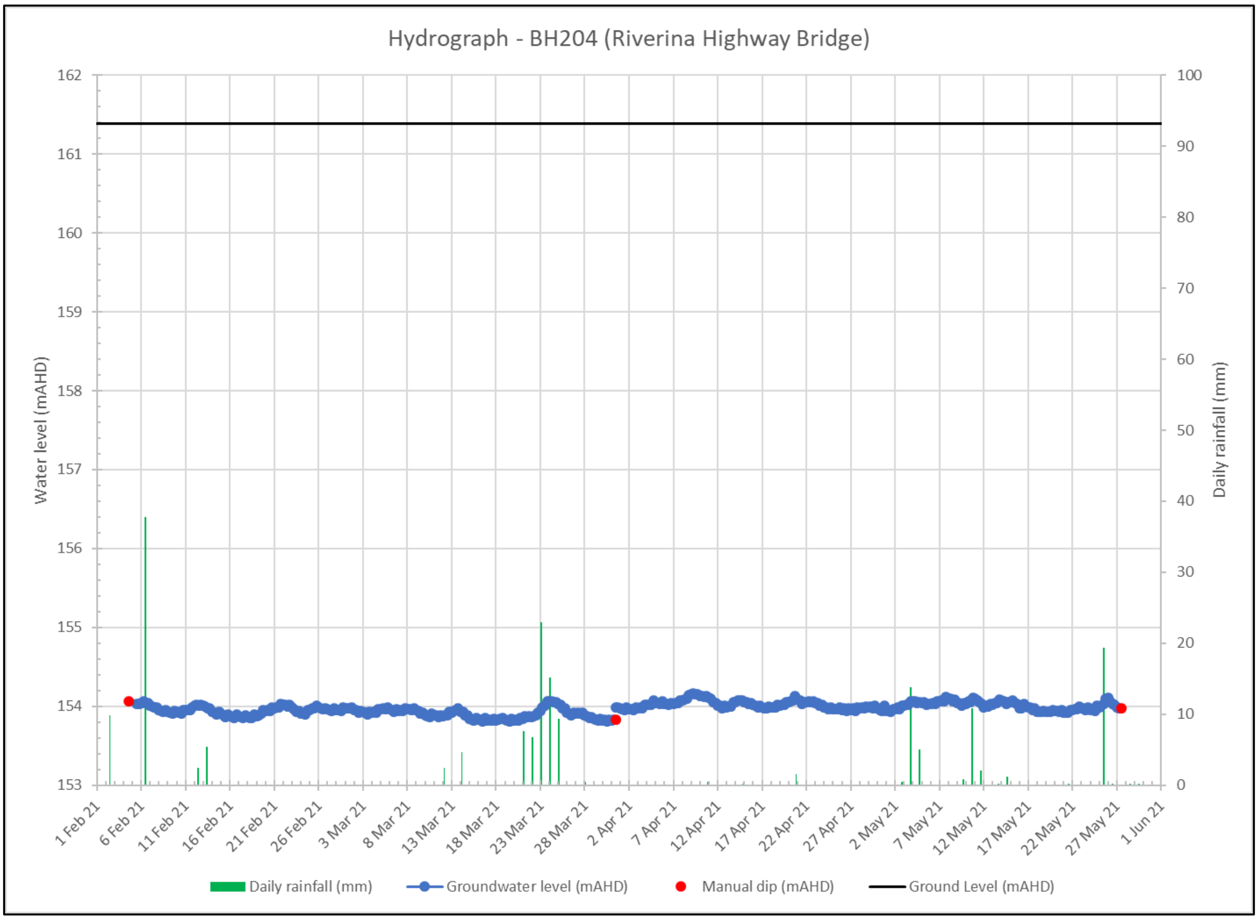
TECHNICAL PAPER 12

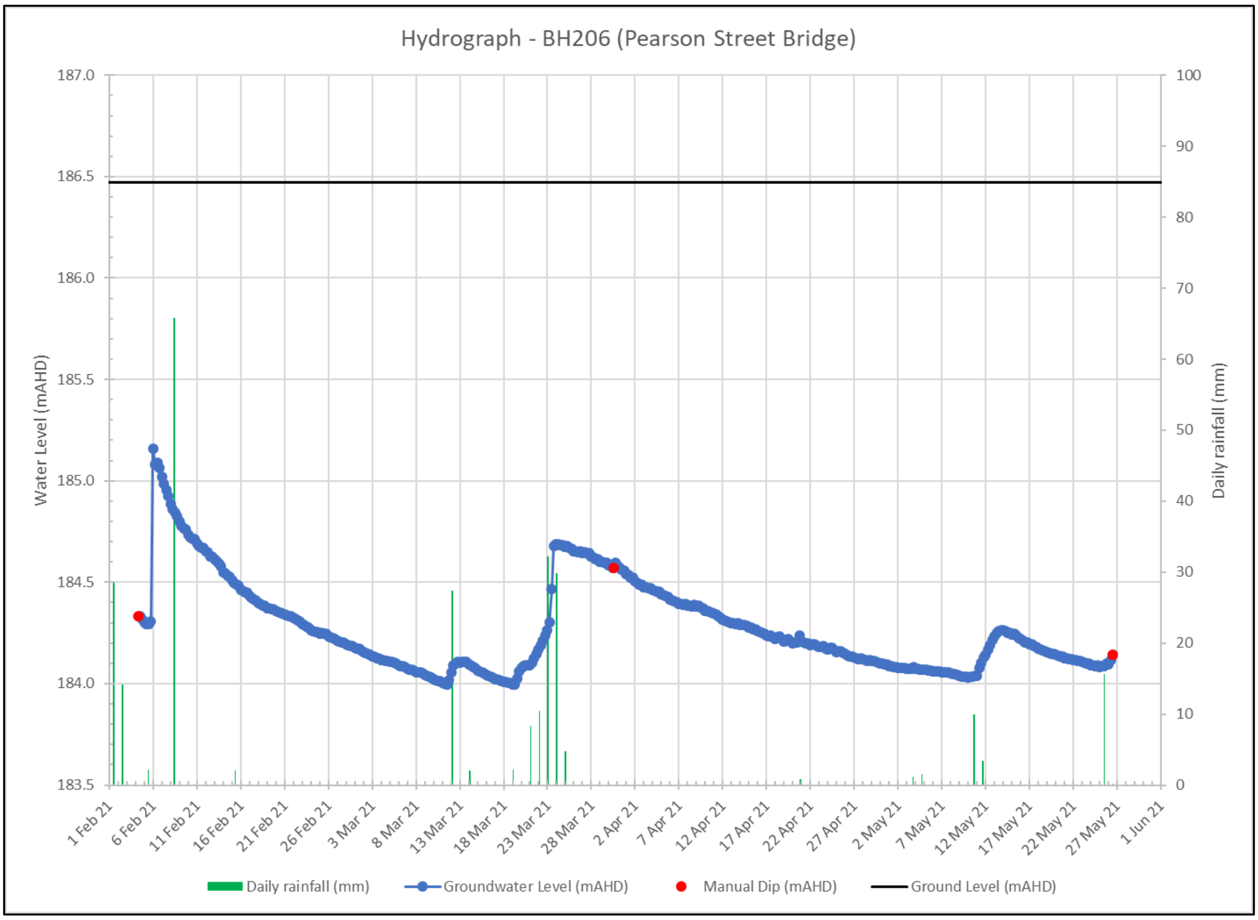
Groundwater

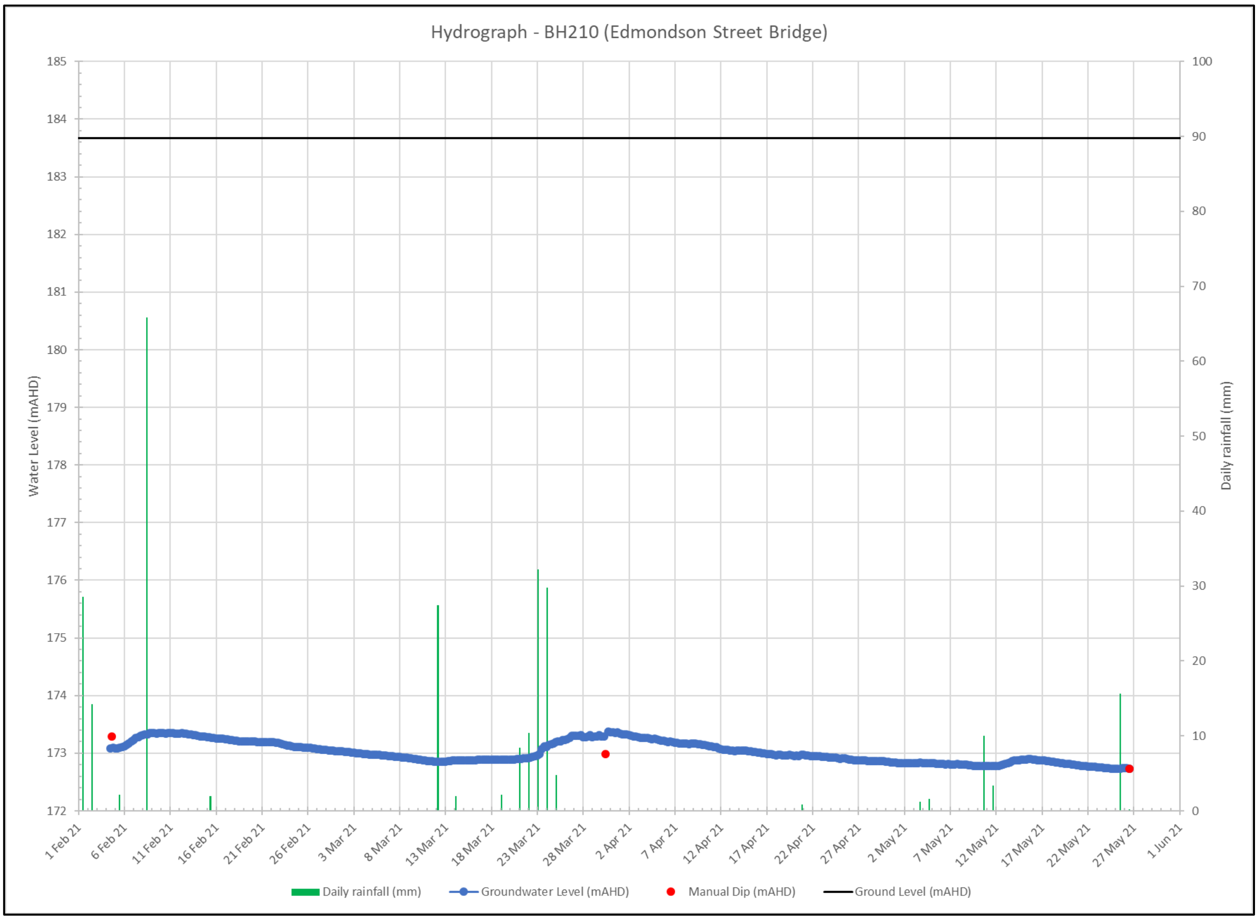
Appendix B Hydrographs

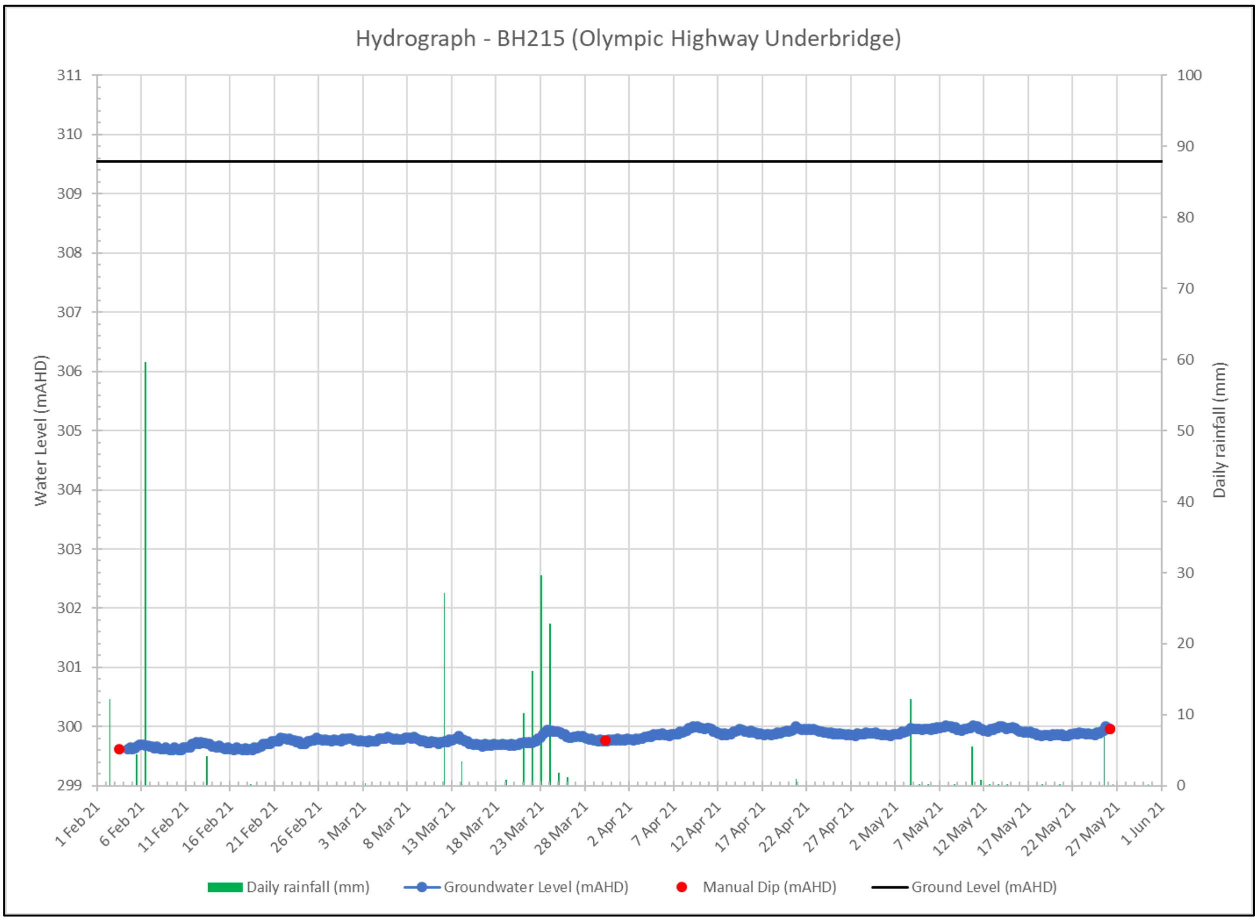
B1 ENHANCEMENT SITE HYDROGRAPHS



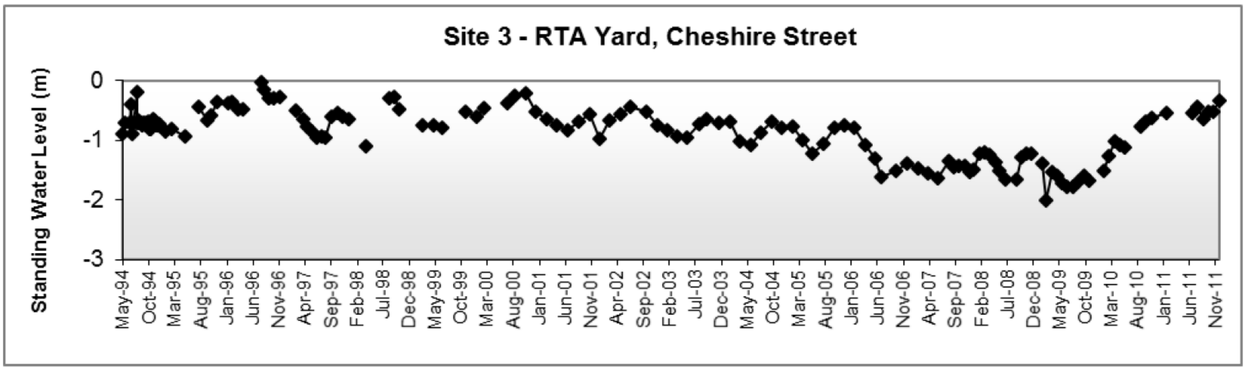

Hydrograph - BH204 (Riverina Highway Bridge)
Water level (mAHD)
Daily rainfall (mm)
162
161
160
159
158
157
156
155
154
153
100
90
80
70
60
50
40
30
20
10
0
1 Feb 21
6 Feb 21
11 Feb 21
16 Feb 21
21 Feb 21
26 Feb 21
3 Mar 21
8 Mar 21
13 Mar 21
18 Mar 21
23 Mar 21
28 Mar 21
2 Apr 21
7 Apr 21
12 Apr 21
17 Apr 21
22 Apr 21
27 Apr 21
2 May 21
7 May 21
12 May 21
17 May 21
22 May 21
27 May 21
1 Jun 21
Daily rainfall (mm)
Groundwater level (mAHD)
Manual dip (mAHD)
Ground Level (mAHD)

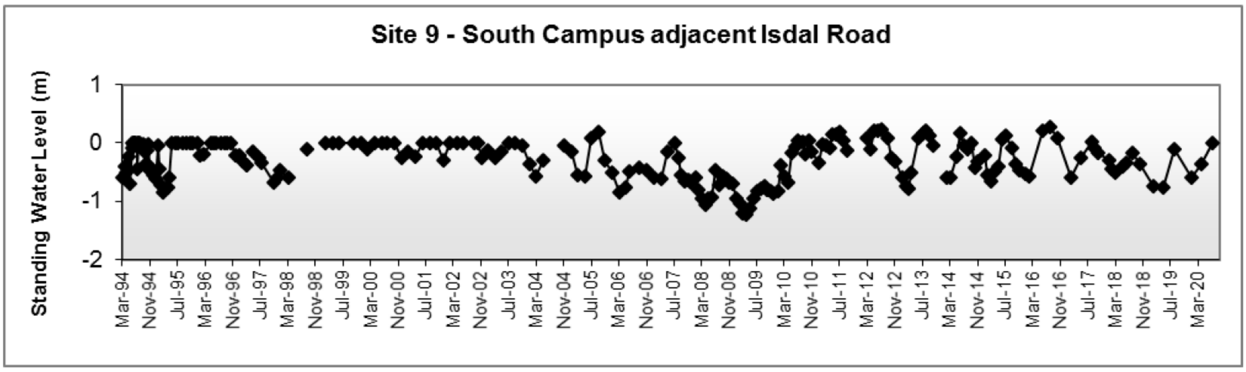

Hydrograph - BH206 (Pearson Street Bridge)
Water Level (mAHD)
Daily rainfall (mm)
187.0
186.5
186.0
185.5
185.0
184.5
184.0
183.5
100
90
80
70
60
50
40
30
20
10
0
1 Feb 21
6 Feb 21
11 Feb 21
16 Feb 21
21 Feb 21
26 Feb 21
3 Mar 21
8 Mar 21
13 Mar 21
18 Mar 21
23 Mar 21
28 Mar 21
2 Apr 21
7 Apr 21
12 Apr 21
17 Apr 21
22 Apr 21
27 Apr 21
2 May 21
7 May 21
12 May 21
17 May 21
22 May 21
27 May 21
1 Jun 21
Daily rainfall (mm)
Groundwater Level (mAHD)
Manual Dip (mAHD)
Ground Level (mAHD)

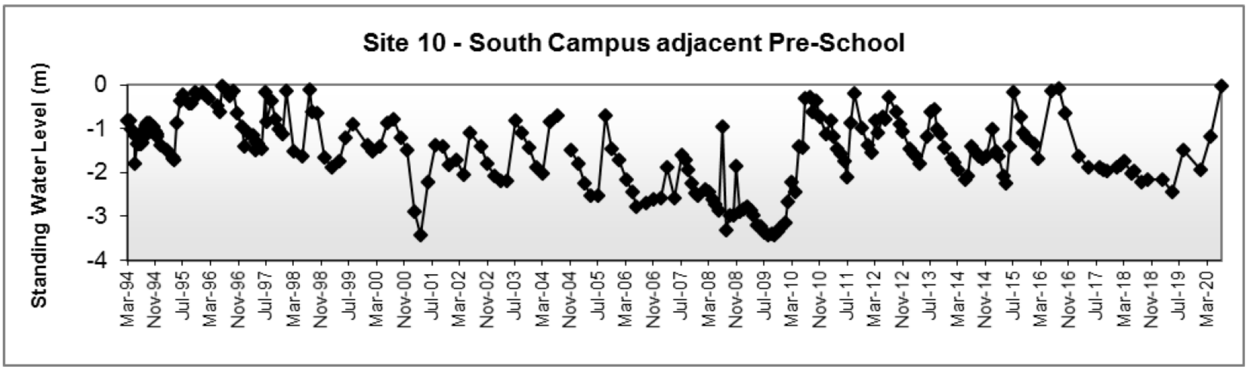

Hydrograph - BH210 (Edmondson Street Bridge)
Water Level (mAHD)
Daily rainfall (mm)
185
184
183
182
181
180
179
178
177
176
175
174
173
172
100
90
80
70
60
50
40
30
20
10
0
1 Feb 21
6 Feb 21
11 Feb 21
16 Feb 21
21 Feb 21
26 Feb 21
3 Mar 21
8 Mar 21
13 Mar 21
18 Mar 21
23 Mar 21
28 Mar 21
2 Apr 21
7 Apr 21
12 Apr 21
17 Apr 21
22 Apr 21
27 Apr 21
2 May 21
7 May 21
12 May 21
17 May 21
22 May 21
27 May 21
1 Jun 21
Daily rainfall (mm)
Groundwater Level (mAHD)
Manual Dip (mAHD)
Ground Level (mAHD)

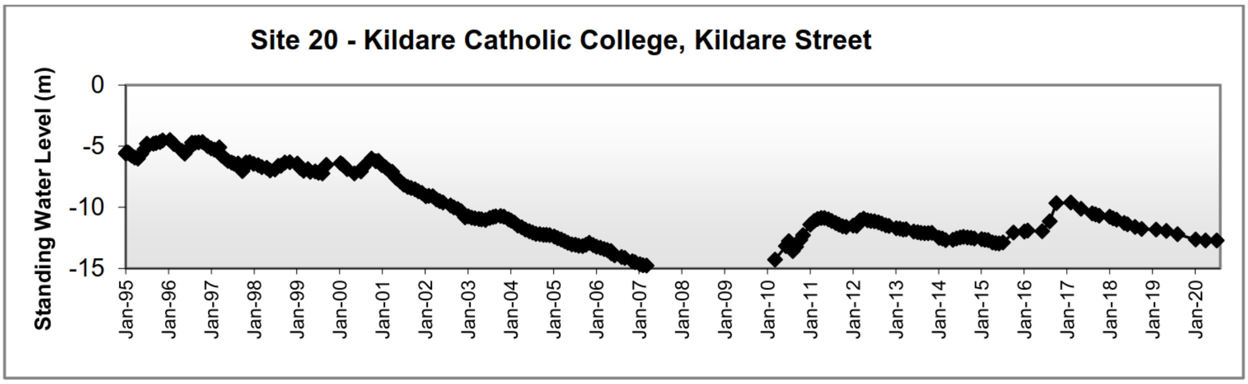

Hydrograph - BH215 (Olympic Highway Underbridge)
Water Level (mAHD)
Daily rainfall (mm)
311
310
309
308
307
306
305
304
303
302
301
300
299
100
90
80
70
60
50
40
30
20
10
0
1 Feb 21
6 Feb 21
11 Feb 21
16 Feb 21
21 Feb 21
26 Feb 21
3 Mar 21
8 Mar 21
13 Mar 21
18 Mar 21
23 Mar 21
28 Mar 21
2 Apr 21
7 Apr 21
12 Apr 21
17 Apr 21
22 Apr 21
27 Apr 21
2 May 21
7 May 21
12 May 21
17 May 21
22 May 21
27 May 21
1 Jun 21
Daily rainfall (mm)
Groundwater Level (mAHD)
Manual Dip (mAHD)
Ground Level (mAHD)

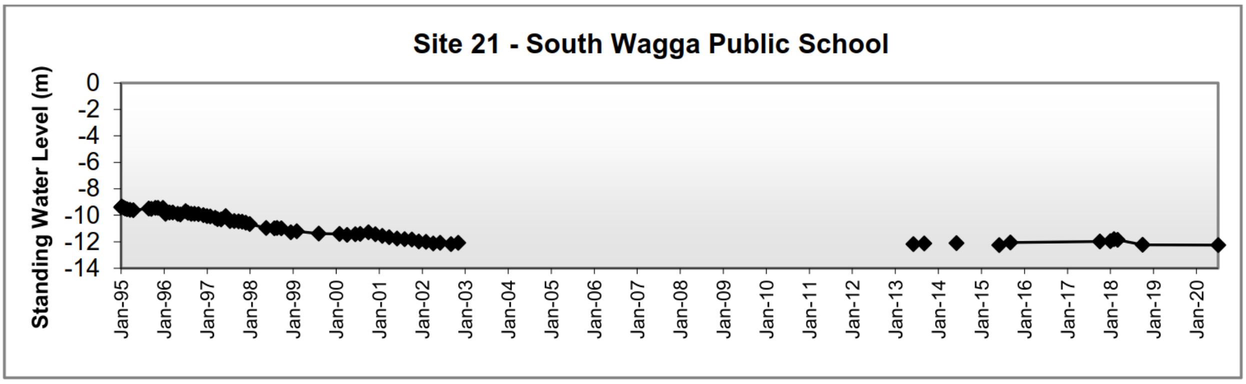
B2 WAGGA WAGGA CITY COUNCIL (2021) HYDROGRAPHS



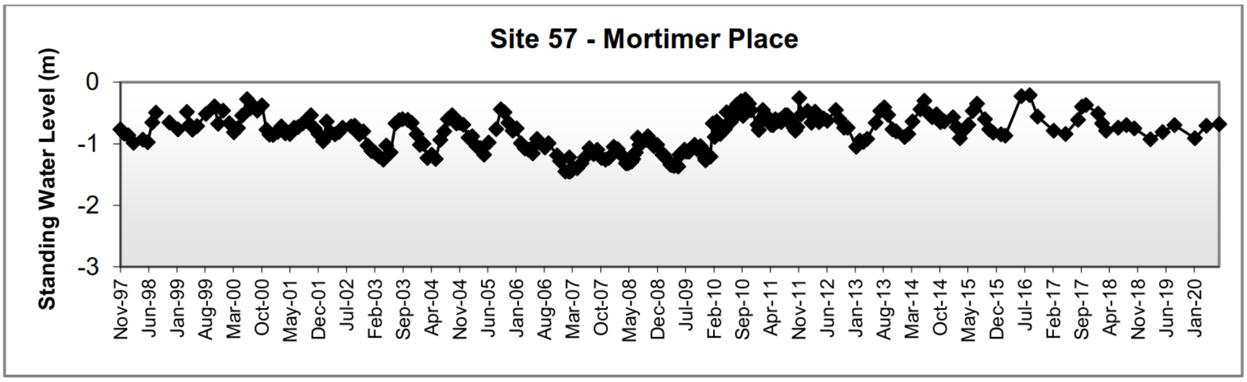




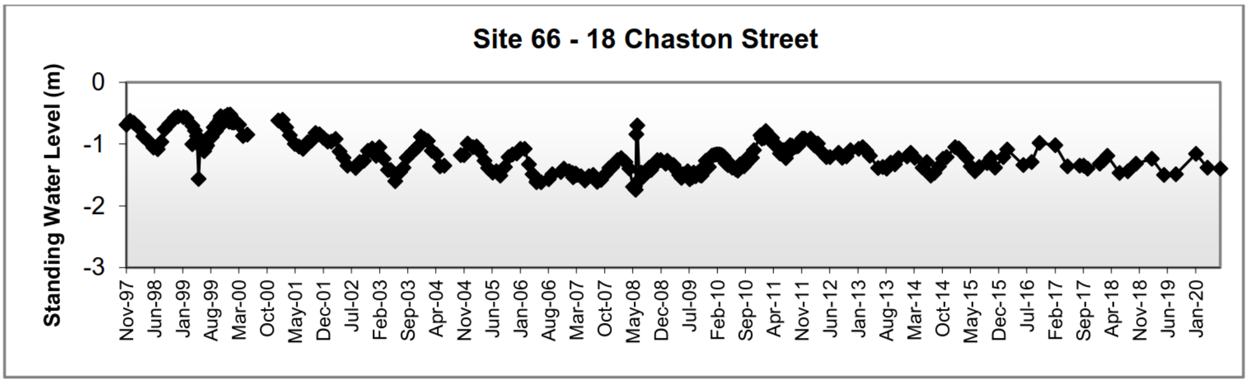




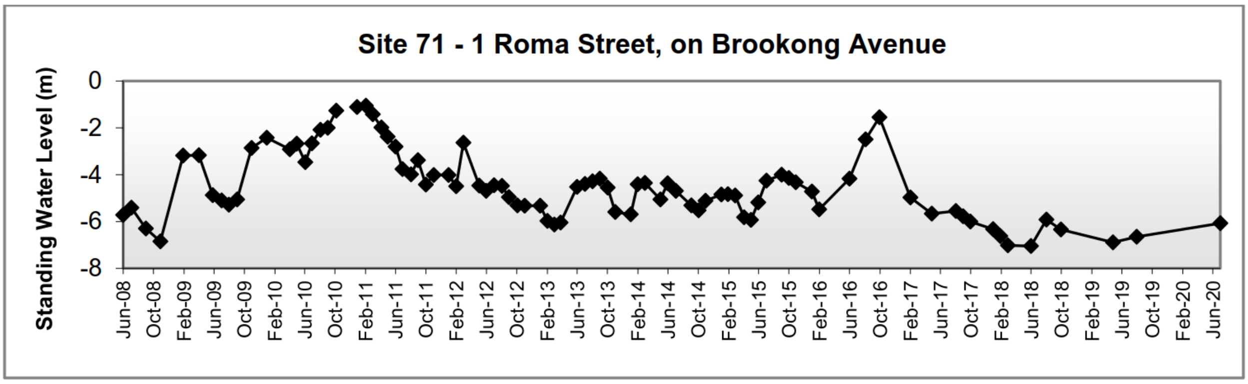
Site 21 - South Wagga Public School
Standing Water Level (m)
0
-2
-4
-6
-8
-10
-12
-14
Jan-95
Jan-96
Jan-97
Jan-98
Jan-99
Jan-00
Jan-01
Jan-02
Jan-03
Jan-04
Jan-05
Jan-06
Jan-07
Jan-08
Jan-09
Jan-10
Jan-11
Jan-12
Jan-13
Jan-14
Jan-15
Jan-16
Jan-17
Jan-18
Jan-19
Jan-20



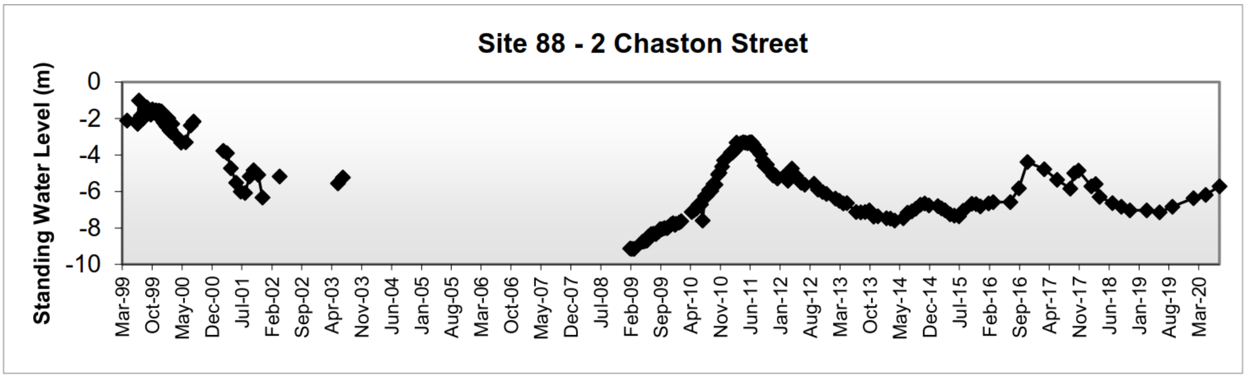
Site 57 - Mortimer Place
Standing Water Level (m)
0
-1
-2
-3

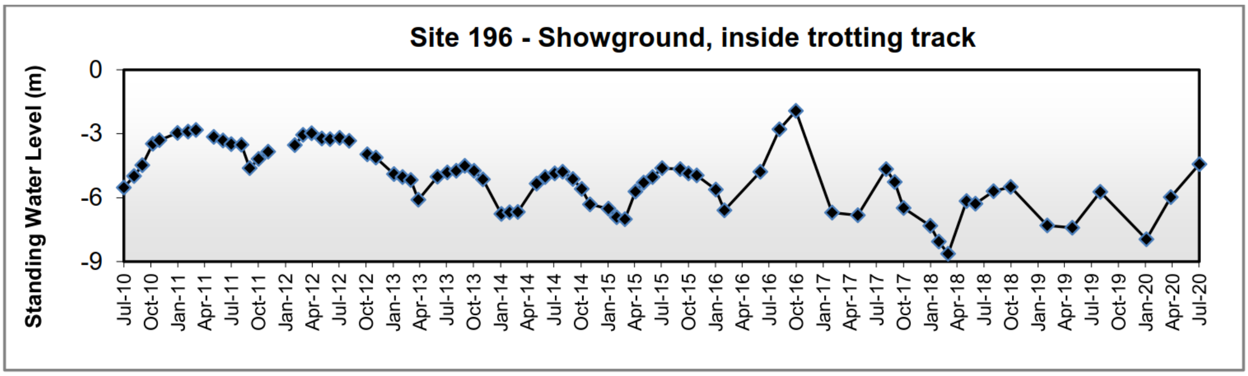


Site 66 - 18 Chaston Street
Standing Water Level (m)
0
-1
-2
-3



Site 71 - 1 Roma Street, on Brookong Avenue
Standing Water Level (m)
0
-2
-4
-6
-8


Site 88 - 2 Chaston Street
Standing Water Level (m)
0
-2
-4
-6
-8
-10
Mar-99
Oct-99
May-00
Dec-00
Jul-01
Feb-02
Sep-02
Apr-03
Nov-03
Jun-04
Jan-05
Aug-05
Mar-06
Oct-06
May-07
Dec-07
Jul-08
Feb-09
Sep-09
Apr-10
Nov-10
Jun-11
Jan-12
Aug-12
Mar-13
Oct-13
May-14
Dec-14
Jul-15
Feb-16
Sep-16
Apr-17
Nov-17
Jun-18
Jan-19
Aug-19
Mar-20


Site 196 - Showground, inside trotting track
Standing Water Level (m)
0
-3
-6
-9
Jul-10
Oct-10
Jan-11
Apr-11
Jul-11
Oct-11
Jan-12
Apr-12
Jul-12
Oct-12
Jan-13
Apr-13
Jul-13
Oct-13
Jan-14
Apr-14
Jul-14
Oct-14
Jan-15
Apr-15
Jul-15
Oct-15
Jan-16
Apr-16
Jul-16
Oct-16
Jan-17
Apr-17
Jul-17
Oct-17
Jan-18
Apr-18
Jul-18
Oct-18
Jan-19
Apr-19
Jul-19
Oct-19
Jan-20
Apr-20
Jul-20

TECHNICAL PAPER

12

Groundwater

Appendix C Groundwater quality tables

Appendix C Water quality results summary

	UNITS	DETECTION LIMITS	BH201			BH204			BH206			BH210			BH215		
			5/2/2021	31/03/2021	5/26/2021	5/2/2021	31/03/2021	5/26/2021	4/2/2021	30/03/2021	5/26/2021	3/2/2021	30/03/2021	5/26/2021	3/2/2021	30/03/2021	5/26/2021
FIELD PARAMETERS																	
pH value	pH Units	-	7.60	7.51	7.47	6.97	6.29	6.60	7.53	6.52	6.62	8.06	7.18	7.29	6.97	6.66	6.90
Electrical conductivity	µS/cm	1	2,031	1,374	1,616	1,688	1,591	1,489	729	566	631	547	577	5,803	2,442	2,148	2,662
Redox potential	mV	0.1	83.7	169.3	152.5	151.9	270.3	151.4	142.3	86.1	113	-47.8	43.1	-12.2	27.6	208.4	98.9
Temperature	^{o}C	0.1	20.1	20.5	19.1	19.9	18.9	18.2	21.1	20.8	16.5	20.8	19.8	17.5	19.5	18.2	17.6
Dissolved oxygen	%	0.1	20	55.5	24.2	33.2	31.2	50.4	59.3	22.6	69.3	1.8	15.7	69.1	17.2	43.7	19.1
MAJOR IONS																	
Electrical conductivity (laboratory)	µS/cm	1	1,920	1,420	-	1,680	2,250	-	690	572	-	529	574	-	2,410	2,200	-
Total dissolved solids (TDS) - calculated	mg/L	1	1,250	923	-	1,090	1,460	-	448	372	-	344	373	-	1,570	1,430	-
Calcium	mg/L	1	25	13	20	31	38	29	46	33	43	16	7	8	138	113	153
Magnesium	mg/L	1	34	18	27	39	60	39	27	18	20	17	8	9	73	62	75
Sodium	mg/L	1	316	278	262	228	373	210	49	43	39	103	110	99	244	258	254
Potassium	mg/L	1	1	<1	<1	4	1	1	4	6	8	24	5	5	8	6	8
Hydroxide as $CaCO_3$	mg/L	1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Carbonate as $CaCO_3$	mg/L	1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Bicarbonate as $CaCO_3$	mg/L	1	330	392	378	262	332	199	244	149	146	256	238	244	474	510	530
Alkalinity as $CaCO_3$	mg/L	1	330	392	378	262	332	199	244	149	146	256	238	244	474	510	530
Sulfate as SO4	mg/L	1	51	52	56	57	285	49	25	22	22	13	18	17	86	87	79
Chloride	mg/L	1	436	207	279	396	515	387	63	67	90	27	23	20	474	378	501
Water type	-	-															
METALS																	
Arsenic	mg/L	0.001	0.002	0.004	0.004	<0.001	<0.001	0.002	<0.001	<0.001	<0.001	0.003	0.003	0.002	<0.001	<0.001	<0.001
Cadmium	mg/L	0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.0002
Chromium	mg/L	0.001	<0.001	<0.001	0.008	<0.001	<0.001	0.007	0.001	<0.001	<0.001	0.025	<0.001	0.002	<0.001	<0.001	<0.001
Copper	mg/L	0.001	<0.001	0.037	0.021	<0.001	0.008	0.012	0.005	0.092	0.001	0.100	0.101	0.006	<0.001	0.002	0.005
Nickel	mg/L	0.001	0.002	0.011	0.013	0.003	0.007	0.012	0.003	0.012	0.001	0.06	0.012	0.024	0.006	0.016	0.022
Lead	mg/L	0.001	<0.001	0.001	0.010	<0.001	<0.001	0.013	0.001	0.002	<0.001	0.011	0.002	<0.001	<0.001	<0.001	<0.001
Zinc	mg/L	0.005	<0.005	0.076	0.041	<0.005	0.033	0.025	0.025	0.166	<0.005	0.186	0.097	0.138	<0.005	0.029	0.010
Mercury	mg/L	0.0001	<0.00004	<0.0001	<0.00004	<0.00004	<0.0001	<0.00004	<0.00004	<0.0001	<0.00004	<0.00004	<0.0001	<0.00004	<0.00004	<0.0001	<0.00004