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DEPARTMENT OF PLANNING AND ENVIRONMENT

DESKTOP HYDROGEOLOGY ASSESSMENT

SPECIAL ACTIVATION PRECINCT, WAGGA WAGGA

APRIL 2021

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Desktop Hydrogeology Assessment
Special Activation Precinct, Wagga Wagga

Department of Planning and Environment

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TABLE OF CONTENTS

CONTENTS (Continued)

LIST OF TABLES

LIST OF FIGURES

GLOSSARY

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.
Australian Height Datum (AHD)	A level datum, uniform throughout Australia, that generally approximates mean sea level.
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.
Clay	Deposit of particles with a diameter of less than 0.002 mm, typically contains variable amounts of water within the mineral structure, and exhibits high plasticity.
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.
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.
Fault	Zone of displacement in rock formations resulting from forces of tension or compression in the earth's crust.
Formation	General term used to describe a sequence of rock layers.
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 resource	Groundwater available for beneficial use, including human usage, aquatic ecosystems and the greater environment.
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).
Hydraulic gradient	Change in the hydraulic head over a certain distance.
(Hydraulic) head	Elevation to which water will rise in a borehole connected to a point in an aquifer.

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.
Investigation area	Includes the area within the Wagga Wagga Special Activation Precinct (SAP) and a 1.5 km buffer around the SAP. In addition, it includes any regional features (such as geological structures) that may influence the Wagga Wagga SAP.
Investigation buffer	The area of land encompassed within a 1.5 km zone adjacent to the Wagga Wagga SAP boundaries.
Lithology	The physical character of rocks.
Modelling	The creation of a computerised model that simulates the natural environment, allows simulations to project future outcomes.
Monitoring bore	A bore used to monitor groundwater levels or quality.
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 (metres per day).
Recharge	*Recharge* is defined as 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.
Regolith	*Regolith* is a layer of loose, heterogeneous material covering solid rock. It includes dust, soil, broken rock, and other related materials.
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.
Semi-confined aquifer	An aquifer that is partly confined by layers of lower permeability material through which recharge and discharge may occur, also referred to as a leaky aquifer.
Stratigraphy	Branch of geology dealing with the classification, nomenclature, correlation, and interpretation of stratified rocks.
SAP Area	The area of land encompassed within the Wagga Wagga SAP boundaries.
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 shallow wells extending a few feet into the zone of saturation and then measuring the water level in those wells.
Watercourse	A river, creek or other stream, including a stream in the form of an anabranch or a tributary, in which water flows permanently or intermittently, regardless of the frequency of flow events. It also includes weirs, lakes and dams.
Yield	The quantity of water removed from a water resource e.g. *yield* of a borehole.

ABBREVIATIONS

1VD	1st derivative (geophysical imagery)
AHD	Australian Height Datum
ANZECC	Australian and New Zealand Environment and Conservation Council
BOM	Bureau of Meteorology
CDFM	Cumulative departure from mean
DOI-W	Department of Industry – Water
DPIE	NSW Department for Planning, Industry and Environment
EMU	Extraction Management Units
EPA	Environment Protection Authority
GDE	Groundwater dependent ecosystem
GMA	Groundwater management area
LTAAEL	Long Term Average Annual Extraction Limit
MBGL	Metres below ground level
MDB	Murray Darling Basin
NGIS	National Groundwater Information System
RTP	Reduction to pole (geophysical imagery)
RWCC	Riverina Water County Council
SAP	Special Activation Precinct
TMI	Total magnetic intensity (geophysical imagery)
WBZ	Water bearing zone

1 INTRODUCTION

1.1 BACKGROUND

In July 2018, the NSW Government announced Regional NSW's first Special Activation Precinct (SAP) at Parkes. A second SAP was announced in January 2019 in Wagga Wagga centred around Bomen Business Park. To date, the City of Wagga Wagga has undertaken work identifying the opportunities and constraints of the existing industrial estate. The Wagga Wagga SAP is investigating a broader area of approximately 4,180 hectares.

SAPs are a place-based approach to 'activate' strategic locations for job creation and regional economic development. SAPs are areas of State or regional significance that are selected based on an assessment of economic enablers, market failures and catalyst opportunities.

The NSW Department of Planning, Industry and Environment (DPIE) has commissioned WSP to prepare an Environmental Assessment for the Wagga Wagga Special Activation Precinct (Wagga Wagga SAP). This assessment is required to support the preparation of a Master Plan. This Environment Assessment includes biodiversity and bushfire, heritage, geology soils and contamination and hydrogeology specialist assessments.

This report provides a hydrogeological desktop assessment for input to the Wagga Wagga SAP.

1.2 OBJECTIVES

The objectives of this desktop hydrogeology assessment are as follows:

- obtain a desktop understanding of the geology, hydrogeology, registered bore users and groundwater dependent ecosystems (GDE)
- identify areas of constraint, where certain land uses should be restricted
- identify potential groundwater source(s) for utilisation as a future SAP resource.

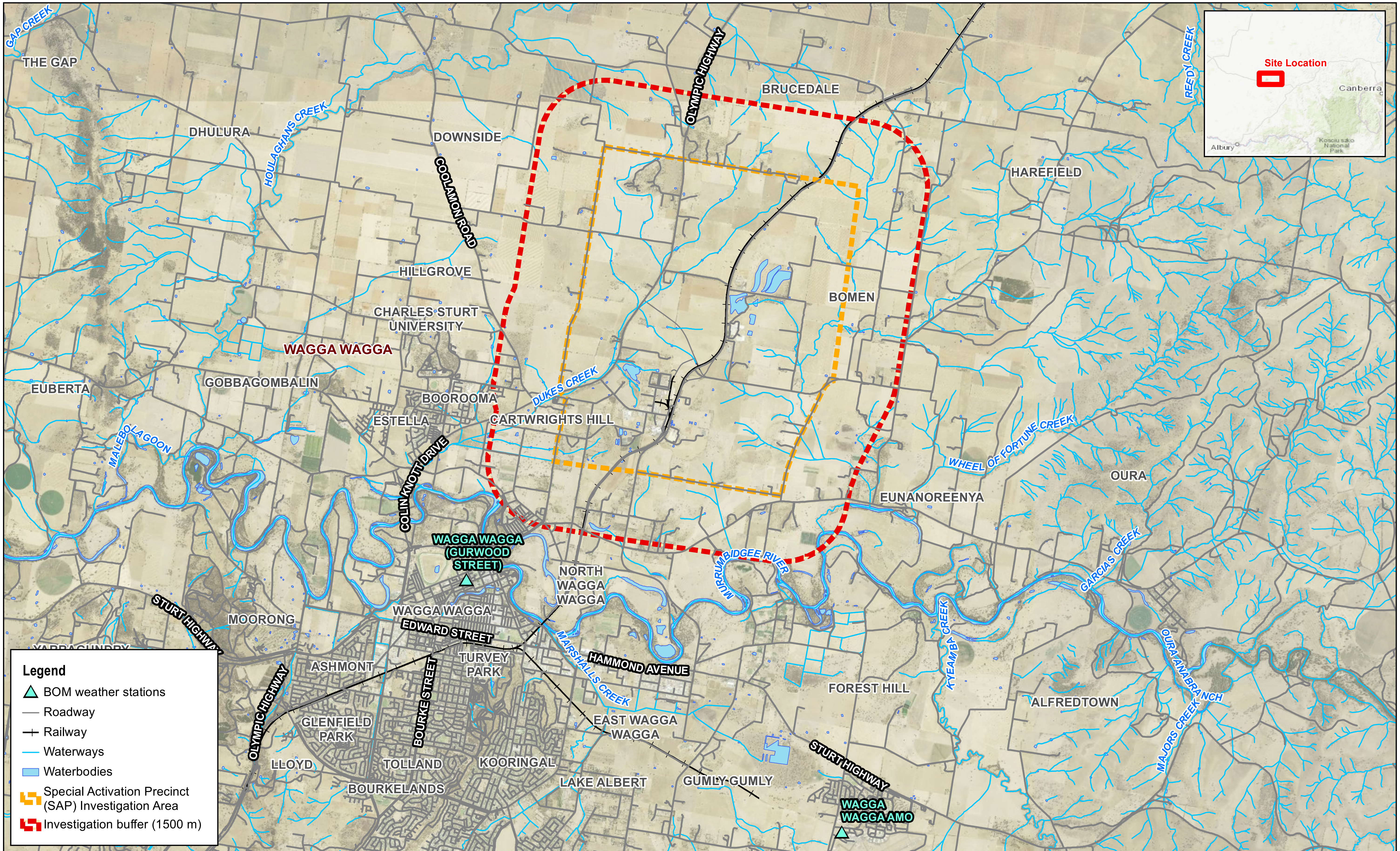
1.3 SCOPE OF WORKS

The scope of works for this desktop hydrogeology assessment includes the following:

- a summary of relevant legislation
- insight into groundwater availability and licensing within the investigation area, defined as the area within the Wagga Wagga SAP (referred to as the SAP within this report), a 1.5 km buffer around the precinct, and any regional features (such as geological structures) that may influence the SAP
- a description of the existing subsurface and groundwater environment within the investigation area
- identification of groundwater related environmental values (registered bore users and GDE's) with a 1.5 km buffer around the SAP (hereafter referred to as the 'investigation buffer') through a review of the following:
  - geological maps, geophysical imagery, Bureau of Meteorology's (BOM) GDE Atlas and National Groundwater Information System (NGIS) database search for registered bores
  - groundwater level and groundwater quality related to the investigation area
  - climatic data (rainfall and evapotranspiration) from the nearest available sources to the investigation area
- identification of possible groundwater systems to be utilised as future resources for the SAP
- identification of recommendations for the SAP Master Plan to ensure protection of the Wagga Wagga alluvium.

Note the investigation area includes the SAP area, and the surrounding environment within a 1.5 km SAP buffer radius. This buffer radius was selected to incorporate the possible influence of the SAP on the Murrumbidgee River and connected alluvial groundwater to the south and east, and surrounding sensitive receptors.

Refer to Figure 1.1 for the location of the SAP, investigation buffer and investigation area.



Map: PS114534_GIS_001_A4	Author: David.Naiken
Date: 11.11.2020	Approved by: Andrea.Madden

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Wagga Wagga SAP

Figure 1.1
Site location map

2 REGULATORY CONTEXT

2.1 COMMONWEALTH LEGISLATION

The *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) is Commonwealth legislation, which guides environmental assessment, biodiversity conservation and the management of protected areas and species, population and communities and heritage items.

Approval from the Commonwealth Minister for the Environment is required for:

- an action which has, would have, or is likely to have a significant impact on 'Matters of National Environmental Significance' (MNES) (or "triggers"). The current MNES include:
  - world heritage properties
  - national heritage places
  - wetlands of international importance
  - listed threatened species and ecological communities
  - migratory species protected under international agreements
  - Commonwealth marine areas
  - the Great Barrier Reef Marine Park
  - nuclear actions (including uranium mines)
  - a water resource, in relation to coal seam gas development and large coal mining development
- an action by the Commonwealth (including a Commonwealth agency or corporation) which has, will have, or is likely to have a significant impact on the environment anywhere in the world
- an action on Commonwealth land which has, will have, or is likely to have a significant impact on the environment
- an action outside Commonwealth land which has, will have, or is likely to have a significant impact on the environment on Commonwealth land.

Impacts on MNES are assessed through a referral process to the Commonwealth Department of Environment and Energy. If the Commonwealth Minister for the Environment determines that a project is likely to have a significant impact on a MNES, then the project becomes a controlled action and approval of the Commonwealth Minister for the Environment would be required before construction works can commence.

2.2 STATE LEGISLATION

2.2.1 WATER ACT 1912 AND WATER MANAGEMENT ACT 2000

Water resources are administered under the *Water Act 1912* and the *Water Management Act 2000* by the NSW Department of Industry – Water (DoI-W). The *Water Act 1912* is being progressively phased out and replaced with the *Water Management Act 2000*. This transition process is largely complete. The *Water Act 1912* still applies to:

- taking water from a water source outside water sharing plan areas
- construction and use of water supply works outside water sharing plan areas
- drainage works in all areas of NSW
- aquifer interference activities in all areas of NSW.

The objects of the *Water Management Act 2000* are to provide for the sustainable and integrated management of the state's water sources for the benefit of present and future generations. The *Water Management Act 2000* governs the issue of water access licences 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 environmental needs of the river or aquifer, and also between different types of water use such as town supply, rural domestic supply, stock watering, industry and irrigation. There are water sharing plans for regulated and unregulated river catchments and groundwater sources in water management areas.

Approval is required under the *Water Management Act 2000* for proposed activities that intersect groundwater (other than water supply bores). The approval may be issued for up to ten years. Part 2 of the *Water Management Act 2000* outlines the entitlements for the holder of an access licence, for the take of water within a particular water management area. Part 3 of the *Water Management Act 2000* outlines three types of approvals that a proponent may be required to obtain, comprising:

- 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).

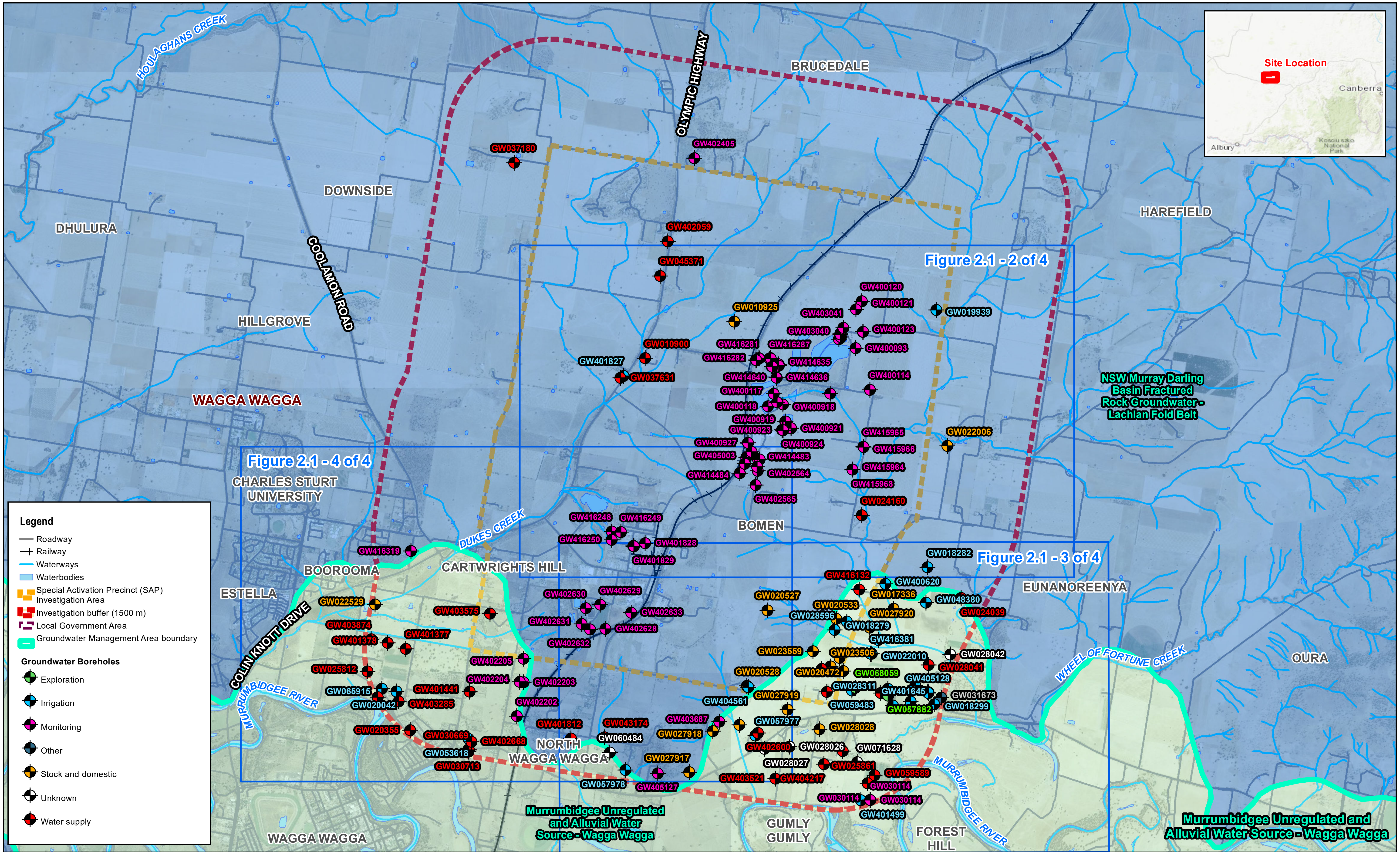
To construct and use a bore for water take, a water supply work approval application form needs to be completed. The form can be downloaded from the WaterNSW website and is to be submitted to WaterNSW. The Water Management (General) Regulation 2018 (a key regulation made under the *Water Management Act 2000*) specifies a number of water supply work approval exemptions, including for monitoring bores (providing certain conditions are met).

2.2.2 WATER SHARING PLANS

As stated in Section 2.2.1, water sharing plans establish rules for sharing water between water users and the environment, and rules for water trading. Water sharing plans describe the annual groundwater recharge volumes for each identified groundwater source and also the volumes of water that are available for sharing (the Long Term Average Annual Extraction Limit (LTAAEL)). Provisions are made for environmental water allocations, basic landholder rights, domestic and stock rights and native title rights. Water sharing plans are typically in place for ten years, however they may be suspended in times of severe water shortages.

Two water sharing plans are currently in place within the investigation area (Figure 2.1):

- NSW Murray-Darling Basin Fractured Rock Groundwater Sources, commenced in January 2012
- Murrumbidgee Unregulated and Alluvial water source, commenced in October 2012.



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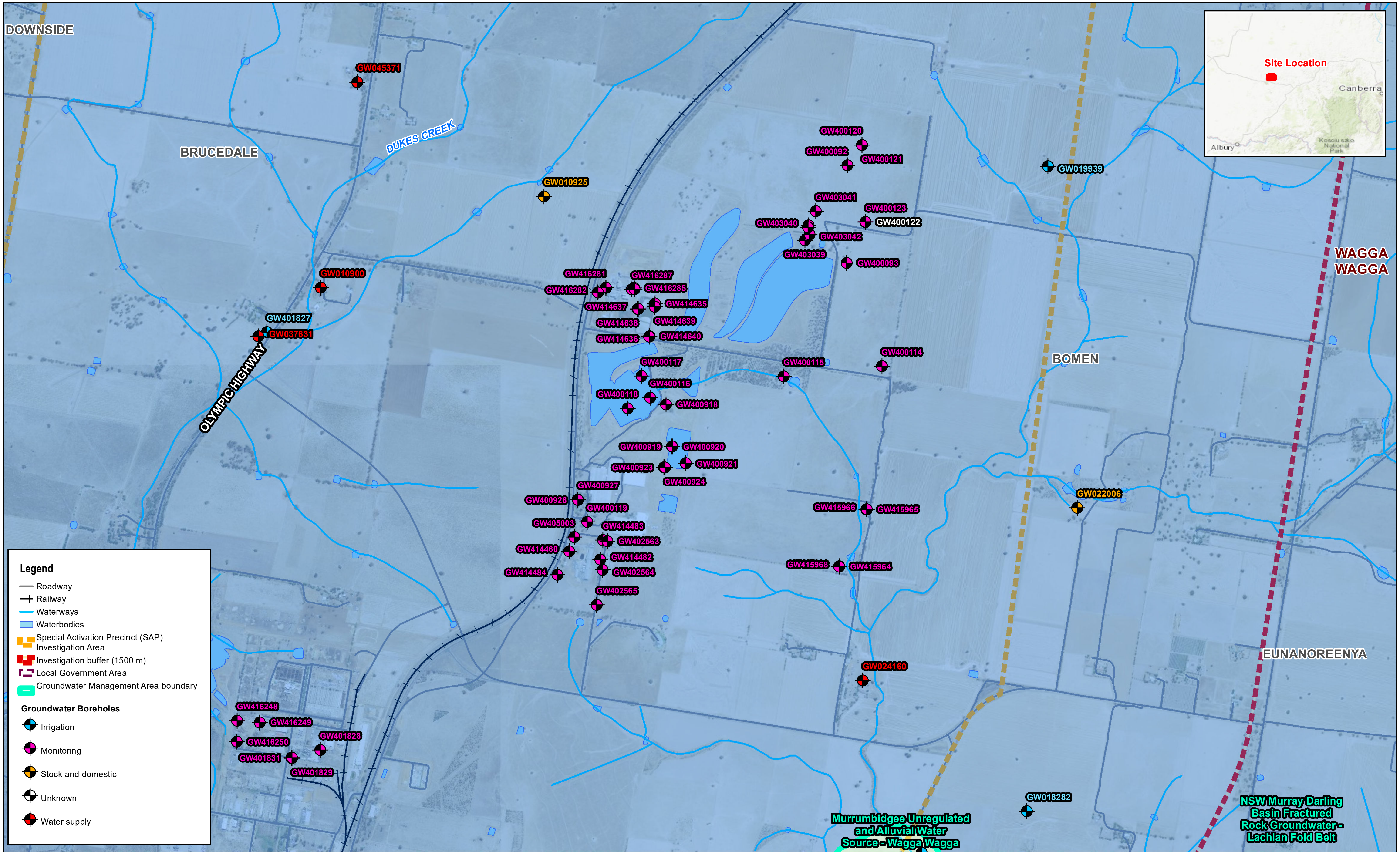
Wagga Wagga SAP

Figure 2.1

Groundwater Management Area and boreholes within the Special activation precinct (SAP) investigation area and investigation buffer

Page 1 of 4



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Wagga Wagga SAP

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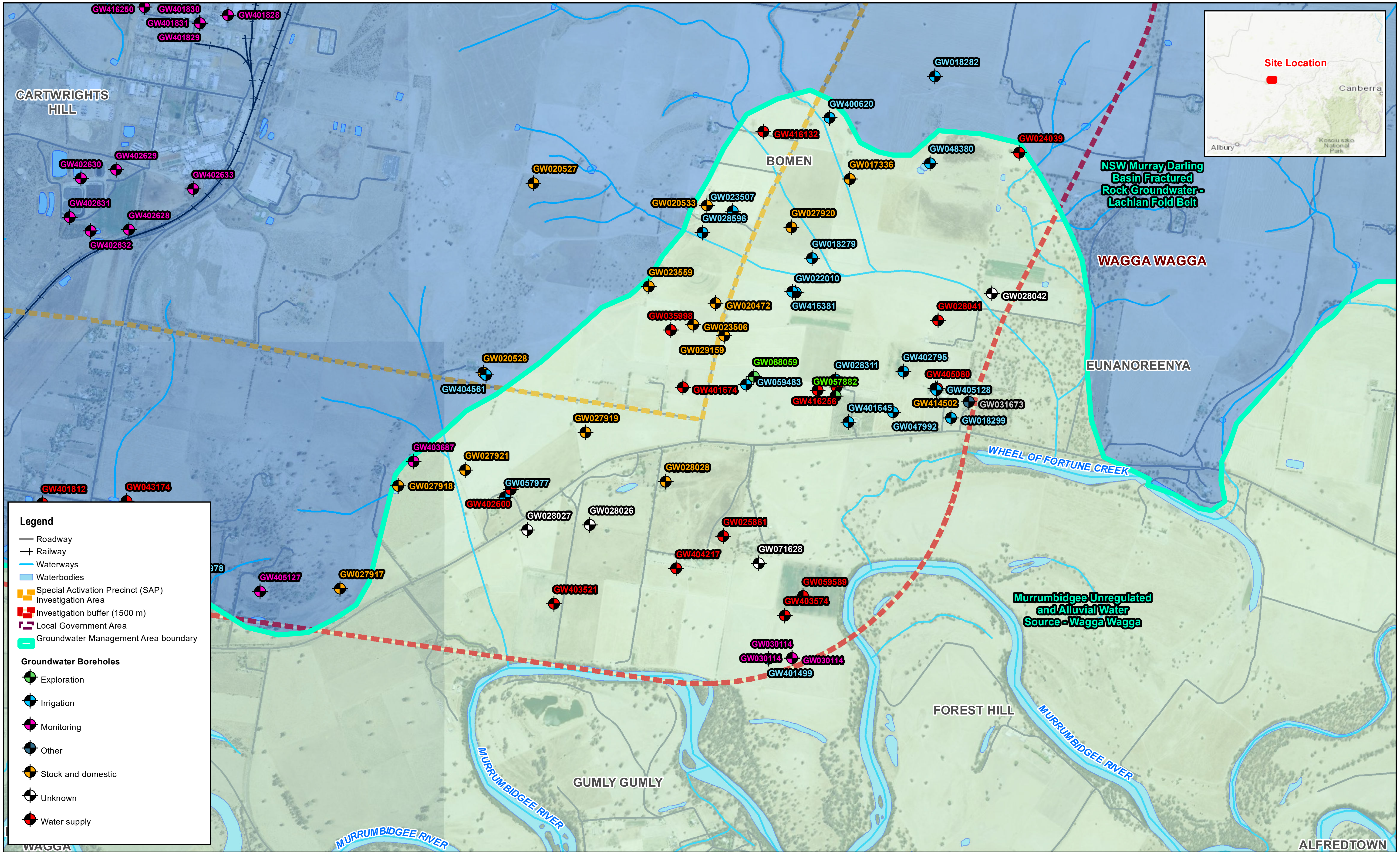

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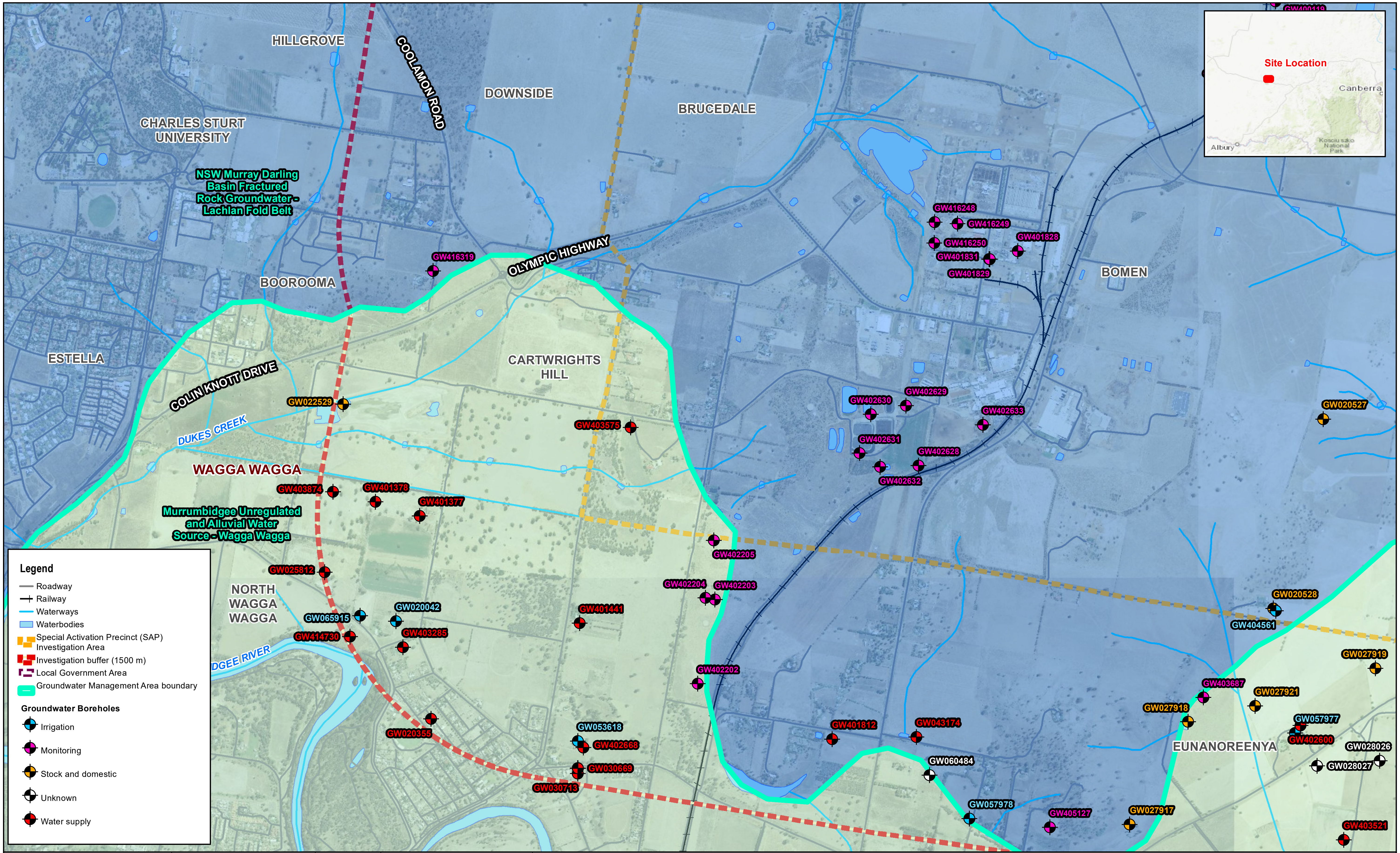

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Wagga Wagga SAP

Figure 2.1

Groundwater Management Area and boreholes within the Special activation precinct (SAP) investigation area and investigation buffer

2.2.2.1 NSW MURRAY-DARLING BASIN FRACTURED ROCK GROUNDWATER SOURCES WATER SHARING PLAN

The water sharing plan for the Murray-Darling Basin (MDB) Fractured Rock Groundwater Sources commenced on 16 January 2012 and covers groundwater sources located within the NSW portion of the MDB, approximately between Broken Hill to the west, Lithgow to the east and extending to the borders of Queensland and Victoria. The water sharing plan comprises ten groundwater sources covering 244,040 km^2 and includes all fractured rock groundwater sources that are not included in other water sharing plans, as well as miscellaneous, unmapped alluvial sediments that overly outcropping fractured rock groundwater sources and porous rock sediments within predominately fractured rock groundwater sources.

The water sharing plan for the NSW MDB Fractured Rock Groundwater Sources establishes a LTAAEL for each groundwater source that is the allowable limit of total extraction for that water source. The LTAAEL is the average annual recharge over a catchment that excludes identified high environmental value areas, and considers aspects such as water for the environment. Each year a provision is made for basic rights to ensure the total extraction from the water source is within the LTAAEL.

The central and northern portions of the investigation area are situated within colluvial and alluvial sediments overlying fractured rock of the Lachlan Fold Belt MDB (other) Groundwater Source zone (Zone 4). The Lachlan Fold Belt MDB is one of the ten groundwater sources within the MDB Fractured Rock Groundwater Sources water sharing plan, and has further been separated into two water management zones, the Lachlan Fold Belt MDB (Mudgee) and Lachlan Fold Belt MDB (other). The Lachlan Fold Belt MDB Groundwater Source encompasses 16,722 km^2 and carries a LTAAEL limit of 821,250 megalitres (ML) per year. Town water supply and stock and domestic users have a higher priority for access to groundwater than other groundwater users. The DoI-W (2017) listed total requirements for basic landholder rights (domestic and stock) as 75,464 ML/year and an additional 5,380 ML/year was allocated to local water utilities.

2.2.2.2 MURRUMBIDGEE UNREGULATED AND ALLUVIAL WATER SOURCES WATER SHARING PLAN

The water sharing plan for the Murrumbidgee Unregulated and Alluvial Water Sources commenced on 4 October 2012 and was amended in July 2016. It provides a legislative framework for all unregulated rivers of the Murrumbidgee River and Billabong Creek catchments; water contained in Tala Lake, Talpee Creek and Five Mile Lagoon, and all alluvial aquifers of the Billabong Creek, Bungendore and Mid Murrumbidgee groundwater management areas. The water sharing plan covers an approximate area of 84,000 km^2, bounded to the east by the Great Dividing Range, to the north by the Lachlan catchment, to the west by the Lower Murray Darling catchment, and to the south by the Murray catchment, and includes the major towns of Balranald, Hay, Griffith, Leeton, Narrandera, Wagga Wagga, Gundagai, Tumut, Cootamundra, Queanbeyan, Yass and Cooma. Within the water sharing plan there are 49 discrete water sources (of which six are groundwater) that have been grouped into 18 management zones governed by four extraction management units (EMU).

The investigation area is located within the City of Wagga Wagga, where a high dependency on groundwater for town water supply exists. This has prompted the generation of an additional, separate management zone, specific to the alluvial sediments surrounding Wagga Wagga, known as the Wagga Wagga Alluvial Groundwater Source. There is currently a draft plan in progress, titled 'Water Sharing Plan for the Murrumbidgee Alluvial Groundwater Sources 2019' (DPI-W 2019c) which updates the current water sharing plan that governs the Wagga Wagga Alluvial Groundwater Source, set for commencement this year. The draft legislation has placed approximately 82% of allowable extraction of the groundwater source for use as town water supply. The LTAAEL was listed as 3,650 ML/year for all licences excluding water utility access licenses and 16,998 ML/year for local water utility access licenses. Maximum entitlement values, which currently are set above the LTAAEL, are provided in Table 2.1.

The southern portion of the investigation area contains groundwater associated with the Wagga Wagga Alluvial Groundwater Source.

2.2.3 WATER LICENSES

The NSW Water Register maintained by the NSW Land Registry Services provides detailed information about water access licences (WALs) within NSW. WALs can be obtained (subject to restrictions outlined within the relevant water sharing plan) through purchasing or trading of an existing WAL. Table 2.1 lists the total number of WALs per licence category within the corresponding water sharing plans. Table 2.1 can be used as an indicative measure only for the potential availability to trade (or purchase, if allowed) a WAL. Where the usage to date is close to the listed available water allocation, a potential difficulty may exist in obtaining the required WALs. WALs for both groundwater sources under the water sharing plans located within the SAP are completely allocated and can only be obtained through trading.

Table 2.1 Total number of WALs per water sharing plan for the 2018 to 2019 financial year (WaterNSW, 2019a)

WATER SHARING PLAN	ACCESS LICENCE CATEGORY	NUMBER OF WAL(S)	AVAILABLE WATER (ML)[1]	USAGE YTD (ML)[2]
NSW MDB Fractured Rock Groundwater Sources Water Sharing Plan – Lachlan Fold Belt MDB Groundwater Source	Aquifer	1027	66726.7	1815.9
	Aquifer (town water supply)	6	467.4	3.3
	Local water utility	35	2370.5	35.6
	Local water utility (domestic and commercial)	1	50	0
	Salinity and water table management	1	236	0
Murrumbidgee Unregulated and Alluvial Water Sources Water Sharing Plan – Wagga Wagga Alluvial Groundwater Sources	Aquifer	63	7939	1797.7
	Domestic and stock	1	22	0
	Local water utility	3	20200	11651.9

(1) Maximum limit set by the corresponding water sharing plan.

(2) 2018-2019 financial year (year to date (YTD)) statistics accessed on 07/04/2019 (WaterNSW, 2019a).

2.3 POLICIES AND GUIDELINES

2.3.1 GUIDELINES

Guidelines relevant to the management of groundwater include:

- *Australian and New Zealand Guidelines for Fresh and Marine Water Quality 2018 revision (ANZG, 2018).* The guidelines provide guidance on the management of water quality in Australia and New Zealand and incorporates setting water quality and sediment quality objectives designed to sustain current, or likely future, community values for natural and semi-natural water resources, including freshwater, groundwater and estuarine and marine waters.
- *Australian and New Zealand Guidelines for Fresh and Marine Water Quality 2000 (ANZECC/ARMCANZ, 2000).* These guidelines provide for the sustainable use of Australia's water resources by protecting and enhancing quality, while maintaining economic and social development.

2.3.2 NSW AQUIFER INTERFERENCE POLICY

The NSW Aquifer Interference Policy (AIP) was introduced in September 2012. The AIP clarifies the requirements for obtaining water licences and the assessment processes for aquifer interference activities under the *Water Management Act 2000* and other relevant legislative frameworks. The AIP also defines considerations in assessing whether more than minimal impacts might occur to key water-dependent assets.

The AIP assists proponents of aquifer interference activities in preparing the necessary information and studies to be used in the assessment of project proposals that have a level of aquifer interference. The AIP forms the basis of assessment and subsequent advice provided by the NSW Government at the various stages of an assessment under the *Environmental Planning and Assessment Act 1979*.

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 from an aquifer while 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.

The *Water Management Act 2000* includes the concept of ensuring 'no more than minimal harm' for the granting of water access licences and the granting of approvals. Aquifer interference approvals will be granted if adequate arrangements are in place to ensure that no more than minimal harm will be imposed on any water source or its dependent ecosystems.

The AIP classifies 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 mg/L and can sustain yields greater than 5 L/s. Highly productive groundwater sources are further grouped into the following categories:

- alluvial
- coastal sands
- porous rock (Great Artesian Basin – Eastern Recharge and Southern Recharge; Great Artesian Basin – Surat, Warrego and Central; and other porous rock)
- fractured rock.

Categories of less productive groundwater sources are alluvial, porous rock, and fractured rock.

The groundwater sources associated with the NSW MDB Fractured Rock Groundwater Sources Water Sharing Plan within the investigation area are considered less productive aquifers due to typical low encountered yield rates. Alluvial sediments associated with the Murrumbidgee River (Wagga Wagga Alluvial Groundwater Sources) are considered as high productivity aquifers due to typical high encountered yield rates and low total dissolved solid content.

Threshold for key minimal impact considerations have been developed for both the highly and less productive groundwater sources. Where the predicted impacts are greater than the minimal impact considerations, additional studies to fully assess the predicted impacts are required. The minimal impact criteria[1] in relation to the investigation area, are summarised as follows:

- Impacts to the water table are considered to be minimal where there is a maximum change of 10% of the cumulative variation in the water table at a distance of 40 m from any GDE or culturally significant site. If the impact is greater, it must be demonstrated that the variation will not prevent the long-term viability of a GDE or culturally significant site.

[1] Refer to the DPI fact sheet for illustrations of the minimum impact criteria: http://www.water.nsw.gov.au/__data/assets/pdf_file/0007/548890/law_key_aquifer_interference_factsheet_4_assessing_the_impacts.pdf

- Impacts to the water table are considered minimal if the cumulative decline in any water supply work (e.g. water bore, water pumps, dams and weirs) is less than 2 m.
- Impacts to water quality are considered minimal if the change in groundwater quality remains within the current beneficial use category of the groundwater source beyond 40 m from the activity. No increase of more than 1% per activity in long term average salinity in a highly connected surface water source at the nearest point to the activity (alluvial water sources only).

2.3.3 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. The policy provides general groundwater and resource management principles including that:

- 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 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 groundwater-dependent ecosystems, and how threats to them may be avoided, should be identified and action taken to ensure that the most vulnerable and the most valuable ecosystems are protected.
- Groundwater 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 groundwater dependent ecosystems.
- 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 groundwater dependent ecosystems 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 groundwater dependent ecosystems. 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 groundwater dependent ecosystems 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.

2.3.5 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 groundwater dependent ecosystems must be identified and protected.
- Total licensed entitlements will not exceed 125% 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 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 issued 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 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.

The above key policies, guidelines and legislation have been considered to provide guidance on the preferred land zoning options for the SAP Master Plan (presented in Chapter 5).

3 PHYSICAL SETTING

3.1 TOPOGRAPHY AND LAND USE

Topography within the investigation area varies due to localised topographic highs with elevations of up to approximately 280 metres relative to Australian Height Datum (mAHD). Topographic highs are associated with the underlying geology (refer to Section 3.5) and includes elevated ridge lines striking north-south near to both the western and eastern boundaries of the investigation area. The area between the ridges slopes generally toward the south-west, with an elevation of approximately 180 mAHD in the south-west of the investigation area. The land located east of the ridgeline that crosses through the Bomen Business Park, slopes toward the Eunony Valley, located in the east of the investigation buffer (Six Maps, 2019).

Land use within the investigation area is dominated by a mixture of light industrial, farmland, and residential properties.

The light industrial land use is centred on the Bomen Business Park located near centre of the investigation area, with the majority to the immediate west of the railway line. Land use includes food processing, fuel distribution, farm supplies stores, transport and animal sales. Further to the north, to the east of the railway line, there are further light industrial properties including a battery recycling facility and a canola oil processing plant (Riverina Oils & Bio Energy [ROBE]). Also within the current industrial area are a wastewater treatment plant (Bomen Industrial Sewage Treatment Facility), and two electrical substations.

Residential properties of varying lot sizes are present in the south-west of the investigation area within the suburb of Cartwrights Hill. There is also a pocket of residential land use in the north-west of the investigation area within Brucedale.

The balance of the investigation area is cleared agricultural land, with associated residential properties.

3.2 CLIMATE

Meteorological data is available from nearby BOM stations, the Wagga Wagga Aeronautical Meteorological Office (AMO) (BOM station 72150) and Wagga Wagga Gurwood Street (BOM station 74127) (Figure 1.1). BOM station 74127 is located closest to the investigation area, at approximately 2 km to the southwest. The long-term rainfall and evapotranspiration data from these stations are summarised in Table 3.1.

Table 3.1 Historic climate data obtained from BOM stations 72150 and 74127 (BoM 2019a)

CLIMATE DATA	RECORD (mm)	COMMENT
Mean monthly rainfall (1942–2018)[1]	39.9–56.9	Minimum rainfall typically occurs in January and April. Maximum rainfall typically occurs in July and October.
Historic rainfall range (1942–2018)[1]	251.2–1019.2	Historic minimum occurred in 1944. Historic maximum occurred in 2010.
Combined yearly rainfall mean (1966–2018)[1]	572.6	–
Monthly mean evapotranspiration (2009–2019)[2]	36.0–252.5	Minimum evapotranspiration typically occurs from June to August. Maximum evapotranspiration typically occurs from December to February.

CLIMATE DATA	RECORD (mm)	COMMENT
Combined yearly evapotranspiration mean (2009–2019)[2, 3]	1,565.8	Rainfall typically exceeds evapotranspiration in June and July. Evapotranspiration greatly exceeds rainfall from September to April.

(1) BOM station 72150 used for 1966 to 2015 rainfall data, due to the historical length of available data compared to BOM station 74127 (2001 – 2018). BOM station 74127 was used for 2016 to 2018 rainfall data, due to data gaps within BOM station 72150 record over this period. The data from both BOM stations is considered acceptable due to their proximity to the investigation area.

(2) Evapotranspiration data obtained from BOM station 72150. Where no data was recorded, daily averages were applied to calculate monthly values.

(3) 2019 data only includes the months of January to May.

Historic monthly average rainfall and evapotranspiration are depicted in Figure 3.1.

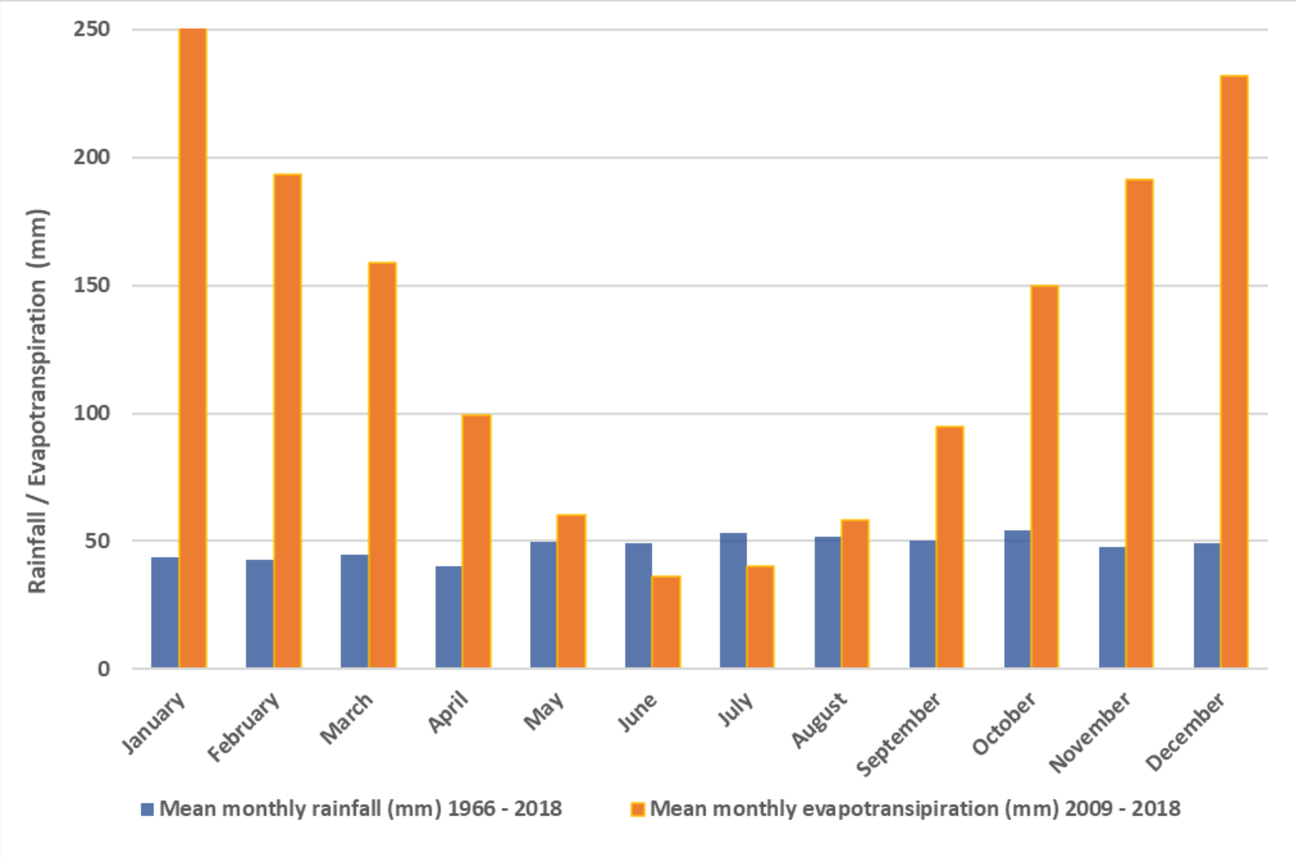


Figure 3.1 Mean monthly rainfall and evapotranspiration recorded at Wagga Wagga (BOM stations 72150 & 74127)

3.2.1 LONG TERM RAINFALL TREND

Long-term cumulative rainfall residual plots provide an indication of the broad scale trends in rainfall pattern behaviour. The plots are formulated by subtracting the average annual rainfall for the recorded period from the actual annual rainfall and then accumulating these residuals 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 1942–2018 is plotted in Figure 3.2.

The cumulative deviation plot starts with a distinct downward sloping trend that corresponds to the national World War 2 drought (DPI-W, 2019a) before a general upward sloping trend from 1950 to 2000, that is punctuated by dry periods, such as in 1967 and 1982. During 2000 to 2009, there was a major drying trend associated with the Millennium Drought (DPI-W, 2019a) that severely impacted the MDB. The record over the following nine years indicates a return to generally average rainfall conditions, with drought conditions currently being experienced.

Figure 3.1 and Figure 3.2 illustrate that the climate at Wagga Wagga, NSW, is characterised by generally consistent, low annual and evenly distributed rainfall, and dominated by evapotranspiration. These climatic factors play a critical role in the investigation areas groundwater resource availability and sustainability (refer Chapter 4).

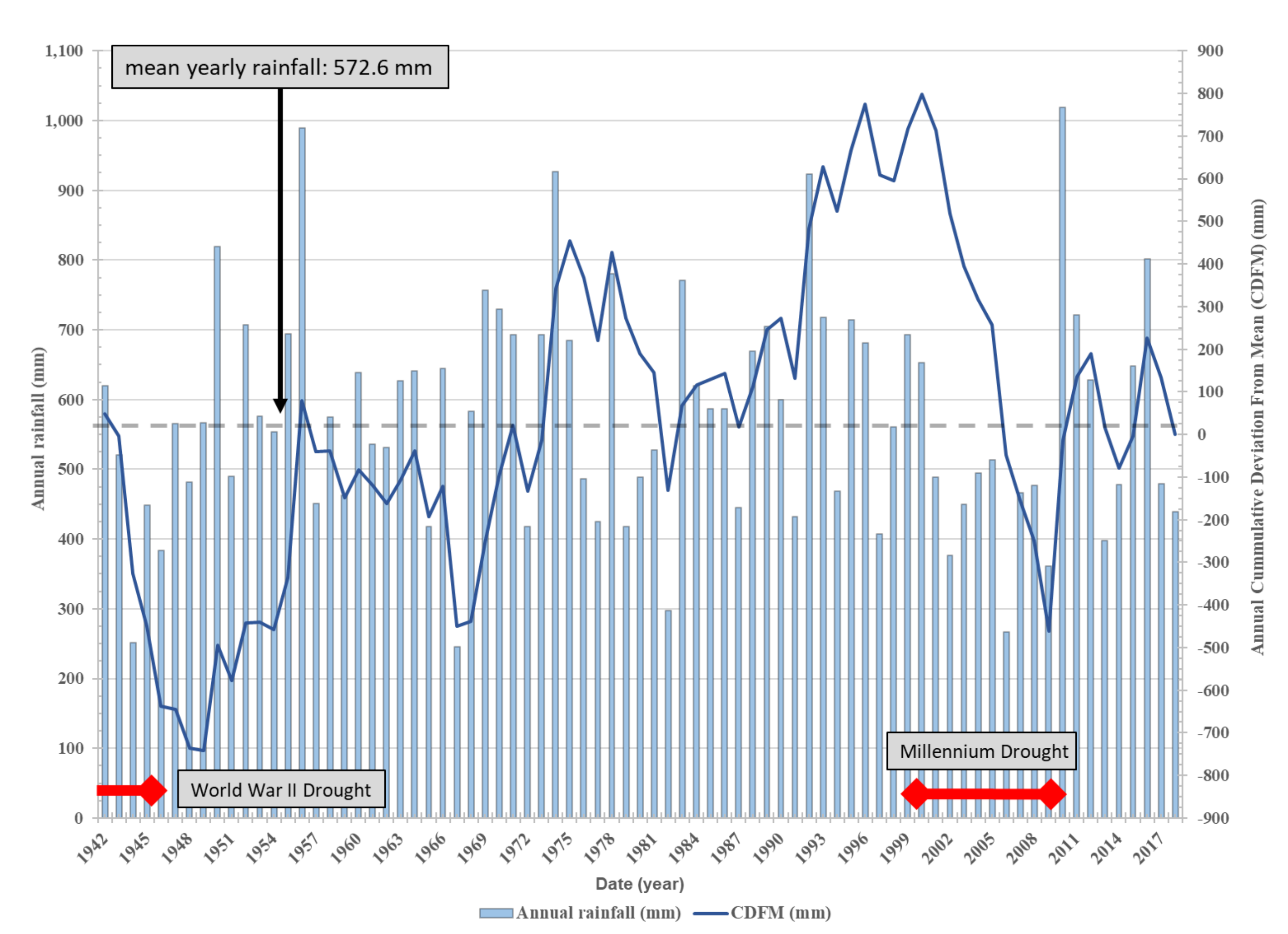


Figure 3.2 CDFM and historic annual rainfall recorded at Wagga Wagga (BOM stations 72150 & 74127)

3.3 DRAINAGE AND SURFACE WATERS

The western portion of the SAP drains to Dukes Creek, an ephemeral surface water body whose main alignment approximately follows the Olympic Highway from north to south through the investigation area. Dukes Creek flows into the Murrumbidgee River approximately 4 km to the south-west of the investigation area.

The catchment of Dukes Creek also discharges to the Gobbagombalin Lagoon, approximately 3 km downstream of the SAP boundary, before ultimately flowing into the Murrumbidgee River. Note water from the Dukes Creek catchment may have additional discharge pathways, such as to the groundwater system and via evapotranspiration (Rhelm, 2020).

In the eastern portion of the SAP, surface water drains into the Kurrajong lagoon on the Wheel of Fortune Creek, which is 3 km to the south-east of the investigation area. This lagoon drains into the Murrumbidgee River.

Major surface water features within the investigation area include ponds associated with the Wagga Wagga Livestock Marketing Centre and the ponds associated with the former wool combing facility to the east of Byrnes Road (Six Maps, 2019).

3.4 SOILS

The soils in the investigation area is summarised as follows (NSW Office of Environment and Heritage, 2018):

- Dominated by the East Bomen Soil Landscape.
- The soils formed on the crests, upper slopes and mid-slopes of the East Bomen Soil Landscape are typically imperfectly drained, mottled eutrophic red dermosols, which consist of a sandy loam topsoil (up to 20 cm) overlying reddish brown clay which lightens to yellow with depth (up to 200 cm).
- The drainage lines are dominated by imperfectly drained, mottled eutrophic brown dermosols, which are characterised by a clay loam surface overlying reddish brown clay which transitions to yellow then orange with depth.
- The East Bomen Soil Landscape is noted to have low limitations for urban development, slight to moderate limitations for cultivation and low limitations for grazing.
- Granitic peaks within the investigation area consist of the Glenmornon Soil Landscape. This soil type is characterised by well-drained red kandosols, which generally consist of a dark red or reddish brown sandy loam surface overlying brown/yellow sandy clay or clay. Bedrock outcrops are common in areas of slope over 20%. The soil type has a high erosion hazard and accordingly has high to extreme risk for foundations and urban capability, high to moderate limitations for grazing and extreme limitations for cultivations. It has areas of soil acidity and aluminium toxicity.

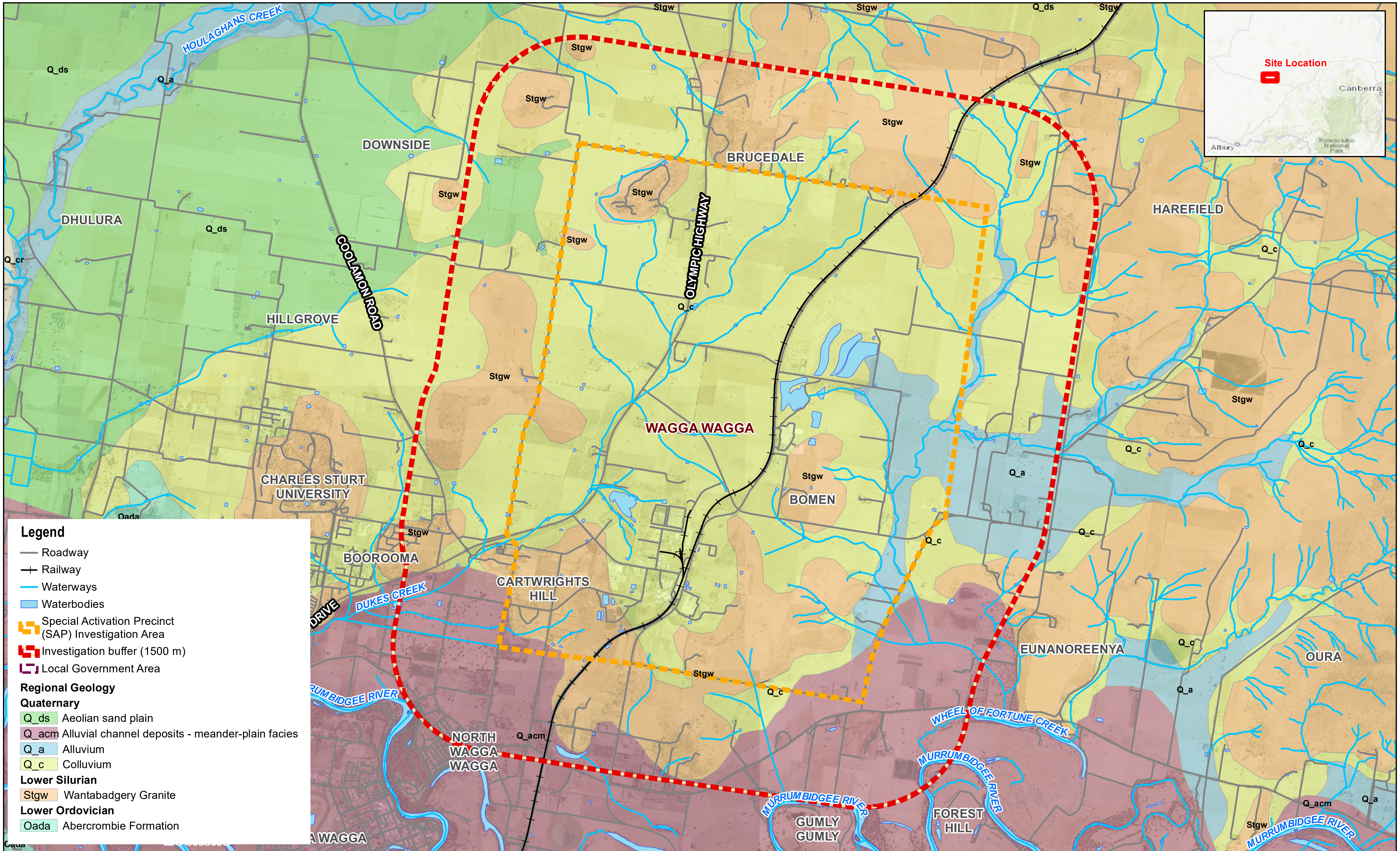
3.5 GEOLOGY

Mapped surface geology within the investigation area comprises multiple Quaternary depositional environments from processes dominated by water (alluvium) to gravitation deposition (colluvial), overlying granites or sandstones that locally outcrop on topographic highs (Colquhoun et al, 2019). Geological units underlying the investigation area are described in further detail in Table 3.2 and their spatial extent is shown in Figure 3.3.

Table 3.2 Mapped geological units (Colquhoun et al, 2019)

AGE	FORMATION	LITHOLOGY AND DESCRIPTION
Quaternary	Alluvium (Q_a)	Unconsolidated humic and micaceous silty clay, quartz with lithic silt, fine to medium grained quartz rich to quartz-lithic sand, polymictic pebble to cobble gravels.
	Alluvium – meander plain facies (Q_acm)	Unconsolidated humic, clayey very fine grained sand, typically overlying light brown clayey silt.
	Aeolian (Q_ds)	Silty to fine grained sand, silty clay at depth; abundant regolithic and pedogenic carbonate.
	Colluvium (Q_c)	Poorly sorted, weakly cemented to unconsolidated colluvial lenses of polymitic conglomerate with medium to very coarse grained sand matrix. Interspersed with unconsolidated clayey and silty sand layers.

AGE	FORMATION	LITHOLOGY AND DESCRIPTION
Silurian (lower)	Wantabadgery Granite (Stgw)	Medium grained, grey, massive to foliated, equigranular to porphyritic granite. Sporadically varies to muscovite-biotite granodiorite. Metasedimentary xenoliths are common.
Ordovician (lower)	Abercrombie Formation (Oada)	Thinly to thickly bedded, fine to coarse grained mica quartz (± feldspar) sandstone, interbedded with laminated siltstone and mudstone. Sporadic chert rich units.



Map: PS114534_GIS_004_A4

Author: David.Naiken

Date: 11.11.2020

Approved by: Andrea.Madden

Coordinate system: GDA 1994 MGA Zone 55
Scale ratio correct when printed at A3

Wagga Wagga SAP

Figure 3.3
Regional geology

3.5.1 GEOLOGICAL STRUCTURES (GEOPHYSICS INTERPRETATION)

Geological structures can act as significant controls to groundwater flow within fractured rock aquifers. Identification of possible controlling structures will therefore help identify regions where the groundwater resource(s) may be more viable for use within the Wagga Wagga SAP or susceptible to risk.

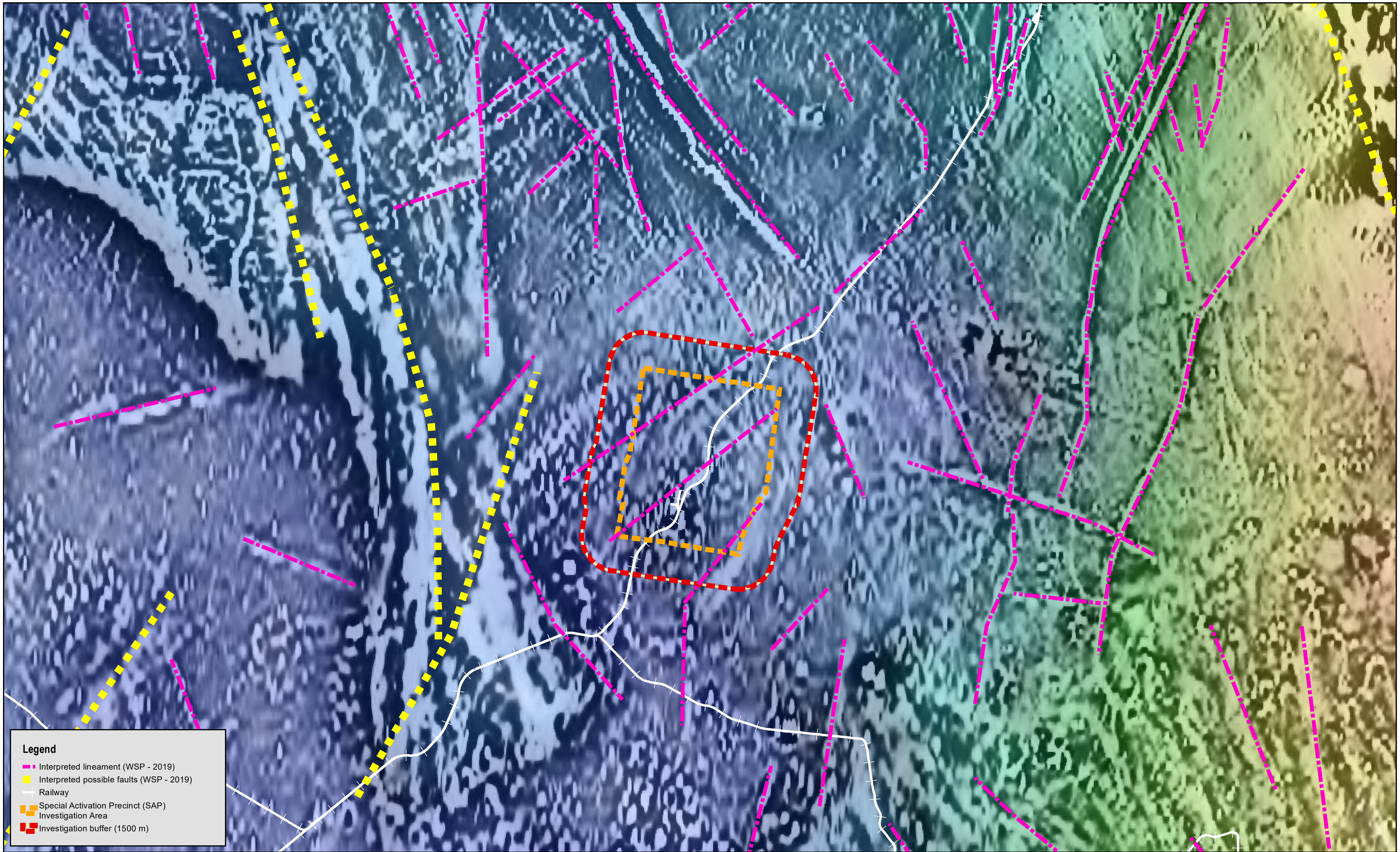
A regional geological structures and geophysical interpretation map (refer to Figure 3.4) was produced from government airborne geophysical data (Mag Geological Survey of NSW, 2016a & 2016b). Lower gravity/density responses displayed as cooler colours and higher gravity/density values are displayed as warmer colours.

Geophysical interpretation of the data indicates that no major regional faults are expected within the investigation area. A few northeast – southwest lineaments occur within the northwest, central and south-eastern portions of the investigation area. These lineaments represent the controlling alignment within the geology and have been expressed as topographic controls (ridgelines and creek flow paths). They may also indicate the presence of localised faults or damage zones adjacent to these regions. The absence of intersecting lineaments combined with the spatial separation between identified structures may impact the groundwater located within bedrock aquifers in the following way:

- reduced spatial extent of potential areas where groundwater within bedrock aquifers may be utilised in significant quantities to be able to contribute to the Wagga Wagga SAP as a resource
- potential lower sustainability of the groundwater within bedrock aquifers, if they are to be utilised as a resource within the Wagga Wagga SAP.

Considering the underlying geology across the investigation area is dominated by the Wantabadgery Granite, the dark blue to blue shading within the investigation area may be interpreted as changes within minerology due to degree of weathering (darker blue indicative of higher degree of weathering compared to light blue regions). Regions experiencing increased weathering are likely to contain a deeper soil profile or regolith and therefore any associated shallow or perched aquifers that exist within the Wagga Wagga SAP may contain more available groundwater within these regions.

For further details on the application of the geophysical interpretation to the assessment of groundwater resources within the Wagga Wagga SAP, refer to Section 4.3.2.2 and Chapter 5.



Map: PS114534_GIS_012_A2	Author: David.Naiken
Date: 11.11.2020	Approved by: Andrea.Madden

0 2,000 4,000 m
1:150,000

Coordinate system: GDA 1994 MGA Zone 55
Scale ratio correct when printed at A3

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Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community © Department Finance, Services and

Wagga Wagga SAP

Figure 3.4
Interpreted regional structures from Total Magnetic Intensity Aeromagnetic (RTP 1VD) with overlain Bouguer Gravity analysis

4 HYDROGEOLOGY

4.1 HYDROGEOLOGICAL UNITS

Based on the reviewed background information (refer Chapter 2 and Chapter 3), the investigation area can be distinguished into two primary hydrogeological units based on the water sharing plan boundaries, each containing an upper and lower groundwater source (aquifer):

- The groundwater in the alluvium associated with the Murrumbidgee River and which is part of the Wagga Wagga Alluvial Groundwater Sources is referred to in this report as the Wagga Wagga alluvium.
- The groundwater in the fractured rock associated with the Lachlan Fold Belt MDB Groundwater Source is referred to in this report as the Lachlan fractured rock and is readily identifiable as underlying the moderately undulating hills.

Note the alluvium (Q_a) described in Section 3.5 is grouped as part of the Lachlan fractured rock rather than the Wagga Wagga alluvium, based on the separation of the alluvium in the two water sharing plans, i.e. the water sharing plan for the NSW MDB Fractured Rock Groundwater Sources includes alluvial sediments that overly outcropping fractured rock (Section 2.2.3). The alluvium (Q_a) is expected to be hydraulically connected and have similar properties to the upper Wagga Wagga alluvium (Cowra Formation) (refer to Section 4.1.1).

4.1.1 WAGGA WAGGA ALLUVIUM

The Wagga Wagga alluvium contains an upper (shallow) aquifer (Cowra Formation) and a lower (deep) aquifer (Lachlan Formation). Expected aquifer characteristics based on regional and local studies are provided in Table 4.1. For SAP specific variance relating to groundwater levels and flow, refer to Section 4.3. The Wagga Wagga alluvium is present within the southern portion of the investigation area. The nominated Wagga Wagga SAP area contains sediments of the upper formation (Cowra Formation) only, with the investigation area containing both the upper and lower aquifers.

Table 4.1 Wagga Wagga alluvium (adopted from Carrara et al, 2004; O'Rouke & Kolstad, 2011; HWA, 2014)

DESCRIPTION	UPPER (SHALLOW) AQUIFER (COWRA FORMATION)	LOWER (DEEP) AQUIFER (LACHLAN FORMATION)
Catchment area	111 km^2	
Unit thickness (m)	Typically 25-40	40-55
Dominant geology	Unconsolidated sediments of clay, silt, sand and gravel	Quartz sands and gravel
Aquifer confinement	Unconfined to semi-confined	Semi-confined to confined
Hydraulic conductivity (m/d)	0.01 – 40	1 – 100
Specific yield	$0.1 – 1 x 10^{-5}$	$0.001 – 1 x 10^{-5}$
Hydraulic gradient and flow	Low gradient (~0.01 m/m) Lateral flow with seepage to underlying aquifer	Low gradient (~0.01 m/m) Lateral flow
Yields (L/s)	Variable, typically 0.1 – 40	Variable, typically 5 – 150
Water quality (TDS) and primary resource use	<1,500 mg/L (fresh to slightly saline); stock and domestic	<500 mg/L (fresh); town water supply and irrigation
Degree of connectedness to the Murrumbidgee River[1]	High	High

(1) High connectedness is classified as more than 70% of the volume of groundwater pumped in one irrigation season is derived from the surface water source.

4.1.2 LACHLAN FRACTURED ROCK

The Lachlan fractured rock is anticipated to contain an upper (shallow) aquifer (weathered regolith) and a lower (deep) aquifer (bedrock). Expected aquifer characteristics based on regional studies are provided in Table 4.2. For Wagga Wagga SAP specific variance relating to groundwater level and flow, refer to Section 4.3. It is expected that both the upper and lower Lachlan fractured rock are present in the nominated SAP and investigation area.

Table 4.2 Lachlan fractured rock aquifer characteristics (DoI-W, 2017; GHD, 2011; GA, 2018)

DESCRIPTION	UPPER (SHALLOW) AQUIFER (WEATHERED REGOLITH)	LOWER (DEEP) AQUIFER (BEDROCK)
Unit thickness (m)	2-5	>1,000
Aquifer confinement	Unconfined	Semi-confined to confined
Hydraulic conductivity (m/d)	0.01 – 40	Variable; dependent on connectedness and aperture of fracture and joint systems.
Yield (L/s)[1]	Low, <1 Possibly unreliable and inconsistent supply.	Typically <3 Where structures are absent, yield will be low (<0.3).
Hydraulic gradient and flow	Low to moderate gradient, dependent upon weathering profile and topography. Gradients can rapidly alter within a short distance. Vertical seepage to lower aquifer and lateral flow through weathered rock. Likely to extend into overlying sediments through capillary action.	Low gradient. Flow confined to secondary flow conduits facilitated by fracture and joint systems.
Water quality (TDS) and primary resource use	<1,500 mg/L (fresh to slightly saline)	<3,000 mg/L (fresh to slightly saline)
Degree of connectedness to the Murrumbidgee River[2]	Low	Low

(1) Source: DoI-W (2017b).

(2) Low connectedness is classified as less than 70% of the volume of groundwater pumped in one irrigation season is derived from the surface water source.

4.2 REGISTERED GROUNDWATER BORES

A search of the BOM's NGIS database registered groundwater bore database (BOM, 2019b) and WaterNSW (2019b) real-time data viewer, identified 86 registered bores within the SAP and an additional 77 bores within the investigation buffer. Bores containing pertinent information to the characteristics of the intersected aquifer(s) are listed in Table 4.3. The location of all registered bores identified through the NGIS search are shown in Figure 2.1.

Table 4.3 List of registered groundwater bores containing pertinent groundwater information located within the investigation area (BOM, 2019b)

BORE NUMBER[1]	EASTING	NORTHING	CONSTRUCTED DEPTH (mBGL)	PURPOSE	YIELD (L/S)	SALINITY (µS/cm)	STANDING WATER LEVEL (mBGL)[2]	SCREENED AQUIFER[3]
GW010925[RT]	538875	6122394	59.1	Stock & domestic	0.15	ND	39.3 (WBZ at 42.0-60.0)	MDFR – L
GW019939	541739	6122566	91.4	Irrigation	0.02	ND	42.9 (WBZ at 42.7 & 78.0)	MDF – L
GW020042	534067	6117146	12.2	Irrigation	ND	ND	8.0	WWA – U
GW020528	539056	6117218	10.4	Stock & domestic	ND	ND	7.0	WWA – U
GW020533	540326	6118167	11.3	Stock & domestic	ND	2600	9.4	WWA – U
GW022006	541907	6120625	36.6	Stock & domestic	ND	ND	17.7-18.3 (WBZ at 24.4)	MDFR – U + L
GW023506	540247	6117707	11.3	Stock & domestic	ND	ND	7.0-8.9	WWA – U
GW023507[RT]	540471	6118136	14.6	Irrigation	ND	ND	6.7	WWA – U
GW023559	538572	6117707	12.8	Stock & domestic	ND	ND	8.7	WWA – U
GW025861	540419	6116288	14.6	Household supply	ND	ND	4.2-11.4	WWA – U
GW027917	538240	6115989	10.4	Stock & domestic	ND	1450	0.9-6.5	WWA – U
GW027918	538572	6116573	7.3	Stock & domestic	ND	ND	1.5-8.2	WWA – U
GW027919	539637	6116877	7.3	Stock & domestic	ND	761	3.2-8.2	WWA – U
GW027920	540807	6118042	10.1	Stock & domestic	ND	1170	4.6-9.8	WWA – U
GW027921	538952	6116664	8.0	Stock & domestic	ND	ND	1.6-7.5	WWA – U

BORE NUMBER[1]	EASTING	NORTHING	CONSTRUCTED DEPTH (mBGL)	PURPOSE	YIELD (L/S)	SALINITY (µS/cm)	STANDING WATER LEVEL (mBGL)[2]	SCREENED AQUIFER[3]
GW028026	539660	6116353	13.7	Unknown	ND	ND	6.9-7.7	WWA – U
GW028028	540091	6116597	7.0	Stock & domestic	ND	515	0.0-3.5	WWA – U
GW028041	541640	6117515	14.9	Household supply	ND	ND	7.5-9.1	WWA – U
GW030114	540810	6115595	79.2	Monitoring	ND	200	U: 8.4–8.7; L: 11.20	WWA – U + L
GW030669[RT]	535102	6116310	58.2	Water supply (municipal)	1.0-10.0	200	5.2-6.0 (WBZ at 9.0, 45.0, 65.0 and 82.0)	WWA – U + L
GW030713	535102	6116279	79.6	Water supply (municipal)	ND	250	6.6 (WBZ at 27.0 to 79.6)	WWA – L
GW043174[RT]	537027	6116487	12.8	General use	0.8	ND	9.4	WWA - U
GW047992[RT]	541384	6116992	16.0	Irrigation	3.8	2250	7.3	WWA – U
GW057977[RT]	539179	6116509	15.2	Irrigation	19.0	534	7.3	WWA – U
GW057978[RT]	537329	6116024	18.0	Irrigation	ND	ND	4.9	WWA – U
GW059483	540549	6117150	18.3	Irrigation	ND	488	ND	WWA – U
GW059589[RT]	540873	6115947	14.0	Household water	3.8	340	8.5	WWA – U
GW060484[RT]	537102	6116271	17.1	Unknown	12.6	ND	5.9	WWA – U
GW400119	539121	6120545	9.0	Monitoring	ND	ND	1.2	MDFR – U
GW401378[RT]	533953	6117825	11.5	Household water	3.0	13[4]	5.5	WWA – U
GW401499	540677	6115591	71.0	Irrigation	50.0	480	12.0 (WBZ at 47.0-71.0)	WWA – L
GW401827[RT]	537301	6121624	41.2	Domestic	ND	ND	5.1	MDFR – U / L
GW401828[RT]	537603	6119250	13.0	Monitoring	0.3	ND	3.0 (WBZ at 7.0)	MDFR – U

BORE NUMBER[1]	EASTING	NORTHING	CONSTRUCTED DEPTH (mBGL)	PURPOSE	YIELD (L/S)	SALINITY (µS/cm)	STANDING WATER LEVEL (mBGL)[2]	SCREENED AQUIFER[3]
GW401829[RT]	537443	6119202	4.0	Monitoring	ND	ND	2.0 (WBZ at 3.0)	MDFR – U
GW401830[RT]	537443	6119205	18.0	Monitoring	0.5	ND	4.0 (WBZ at 4.0)	MDFR – U
GW401831[RT]	537441	6119205	7.0	Monitoring	0.3	ND	3.0 (WBZ at 3.0)	MDFR – U
GW402059[RT]	537925	6123540	111.0	Stock & domestic	66.0	ND	42.67 (WBZ at 57.9 m & 109.7 m)	MDFR – L
GW402405[RT]	538303	6124719	182.9	Test bore	0.02	ND	ND	MDFR – L
GW402628[RT]	537039	6118031	15.0	Monitoring	ND	ND	12.3 (WBZ at 14.0)	MDFR – U
GW402629[RT]	536967	6118371	9.1	Monitoring	ND	ND	6.3 (WBZ at 8.0)	MDFR – U
GW402630[RT]	536767	6118322	8.0	Monitoring	ND	ND	5.9 (WBZ at 6.0)	MDFR – U
GW402631[RT]	536703	6118101	13.1	Monitoring	ND	ND	7.9 (WBZ at 12.0)	MDFR – U
GW402632[RT]	536821	6118024	10.1	Monitoring	ND	ND	5.3 (WBZ at 6.0)	MDFR – U
GW404217[RT]	540151	6116104	29.0	Household water/stock & domestic	1.0	308[4]	10.0 (WBZ at 13.0)	MDFR – U
GW404561	539069	6117206	6.0	Stock & domestic	2.0	ND	ND	WWA – U

(1) RT = real-time data obtained from WaterNSW (2019b).

(2) WBZ = water bearing zone; mBGL = metres below ground level.

(3) MDFR = Murray-Darling Fractured Rock; WWA = Wagga Wagga Alluvial; U – upper; L = lower; ND = no data; inferred screened aquifer.

(4) Converted to µS/cm from total dissolved solids (factor of x 1.54).

4.3 GROUNDWATER LEVELS AND FLOW DIRECTION

4.3.1 WAGGA WAGGA ALLUVIUM

Groundwater flow has been modelled through multiple studies (MA, 2009; GHD, 2011; HWA, 2014; and DPIW, 2016) to regionally flow east to west through the city of Wagga Wagga, mimicking the flow paths of the Murrumbidgee River. Groundwater flow within the investigation area is expected to conform to this regional trend and locally follow the topography, towards the south to south-west. Groundwater flow through the aquifers is expected to be relatively fast. GHD (2011) calculated groundwater migration through the upper portion of the Cowra Formation at up to 36 m per year (based on a hydraulic gradient of 0.01 m/m) during remediation works at the former gas works at Tarcutta Street (approximately 2 km southwest of the investigation area).

Groundwater levels are at approximately 6–9 m below ground level (mbgl). Information obtained from GHD (2011), RWCC (2019) and WaterNSW (2019b) indicate that groundwater within the Wagga Wagga alluvium shows a strong correlation to rainfall and flooding events, with groundwater levels rising to near surface levels (within 2 m of the surface levels within the floodplains) during significant events. Considering the recent climatic trend of below average rainfall (refer to Section 3.2) groundwater levels may drop below 6–9 mbgl, or notably increase following rain and the end of the current drought.

4.3.2 *LACHLAN FRACTURED ROCK*

Groundwater flow within the Lachlan fractured rock will significantly differ between the upper (regolith) aquifer and the lower (bedrock) aquifer.

4.3.2.1 UPPER (REGOLITH) AQUIFER

Groundwater levels within the upper aquifer across the investigation area are between approximately 3–14 mbgl (refer to Table 4.3).

Groundwater within the upper aquifer would be encountered within the regolith (weathered bedrock), where flow will be topographically controlled and influenced by the degree of weathering. As a resource, groundwater within the upper aquifer is not anticipated to be reliable due to expected relatively thin aquifer thickness. Additionally, the aquifer is influenced by topographic (e.g. increased flow gradients) and climatic (e.g. evapotranspiration) controls. Groundwater levels within the upper aquifer are expected to correspond to changes in rainfall.

Groundwater velocity (movement) through the upper aquifer is assumed to be low, at about less than 1 m/year. This is inferred from data obtained at the Bomen Business Park, located within the SAP (WWCC, 2019), and from a site located approximately 2 km to the southwest of the investigation area (GHD, 2011).

Groundwater levels at the Bomen Business Park are strongly influenced by nearby storage dams, which has resulted in localised reversal of groundwater gradients (and flow) on the up-slope side of the storage dams. This highlights the susceptibility of this shallow aquifer to surface activities.

4.3.2.2 LOWER (FRACTURED ROCK) AQUIFER

Groundwater flow direction within the deep (bedrock) aquifer is regionally controlled with flow anticipated towards the west, and minimal groundwater level response to localised rainfall (DPI-W, 2017). Groundwater flow rates are variable and critically controlled by the presence and degree of fractures within the bedrock. Where these structures are absent, there is low fracture density and/or poor connectivity of the fracture network, low groundwater yields would be expected (<0.1 L/s). Locations within the investigation area where inferred structural deformation have been identified (refer Figure 3.4), higher yields are possible, and may account for the high recorded yield of 66 L/s for GW402059 (refer to Table 4.3).

Within the investigation area, bores intersecting the lower aquifer have been drilled up to 182.9 mbgl (GW402405), with water bearing zones typical intersected between 70–100 mbgl. Once fractured rock has been intersected, the confining pressure within the system may cause the groundwater level to rise significantly, with the potentiometric surface to within a few metres of ground surface has been recorded, but it is more common that the potentiometric surface rises in an order of 10 m to 20 m from the intersected depth. The potentiometric surface is anticipated to be around 40 mbgl (refer to Table 4.3).

4.3.3 SURFACE WATER-GROUNDWATER CONNECTIVITY

There is consensus that the Murrumbidgee River recharges the Wagga Wagga alluvium and that within the Wagga Wagga alluvium there is a close connection with a net downward leakage from the upper to lower aquifers (GHD, 2011; HWA, 2014; DPIW, 2016). Riverina Water (J Ip 2019, pers. comm., 11 July) believes there is a high degree of connectivity between the river, lower and upper Wagga Wagga alluvium aquifers, with their extraction from the lower Wagga Wagga alluvium (Lachlan Formation) promoting vertical movement of water from the Murrumbidgee River through the upper aquifer and into the lower aquifer.

Connectivity between the Lachlan fractured rock and alluvium is less defined. GHD (2011) suggested that groundwater may possibly throughflow from the granitic hills into the alluvial sediments as recharge, at the boundary between the groundwater sources. This throughflow connectivity would be limited to the upper aquifer within the Lachlan fractured rock and therefore may act as an impact pathway for potential contamination.

4.4 SENSITIVE RECEPTORS

4.4.1 GROUNDWATER USERS

Based on the NGIS bore database search, 22 registered bores within the SAP and an additional 56 within the investigation buffer can be classified as sensitive receptors. The bores identified as sensitive receptors currently hold licenses for household water supply, municipal water supply, stock and domestic use, irrigation and industry, with six of these bores classified as unknown. All but seven bores identified as sensitive receptors within the investigation buffer are located within the Wagga Wagga alluvium. Four sensitive receptor bores (GW018282; GW027917; GW043174 and GW401812) are located along the boundary (within 200 m of the mapped boundary) of the Wagga Wagga Alluvial Groundwater Sources and MDB Fractured Rock Groundwater Sources. A review of available information (WaterNSW, 2019b), indicates that three of the four bores are likely to be screened within the Wagga Wagga alluvium. There is insufficient information available for GW401812 to determine the groundwater source it is accessing.

The remaining bores listed within the SAP and investigation buffer are licensed as ‘monitoring’ or ‘exploration’ or have a status listed as ‘abandoned’, ‘removed’ or ‘proposed’, and are therefore not classified as a sensitive receptor.

4.4.2 GROUNDWATER DEPENDENT ECOSYSTEMS

Groundwater dependent ecosystems (GDEs) are communities of plants, animals and other organisms whose extent and life processes are dependent on groundwater. These ecosystems range from those entirely dependent on groundwater to those that may use groundwater while not having a dependency on it for survival (i.e. ecosystems or organisms that use groundwater opportunistically or as a supplementary source of water).

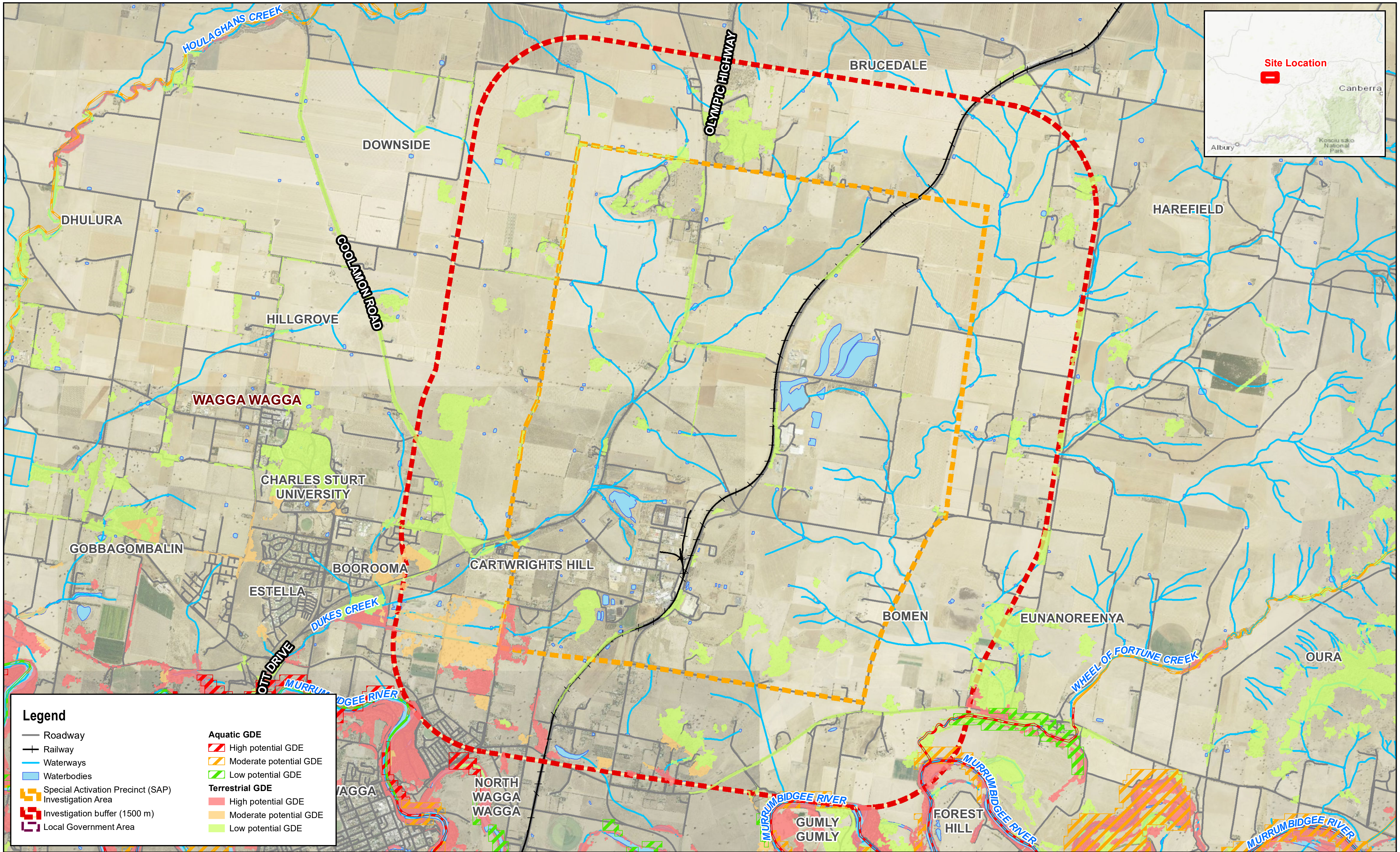
Groundwater dependent ecosystems (GDEs) are described in terms of the ecosystems potential to interact with groundwater. 'Potential' is used to reflect the uncertainty inherent in identifying ecosystems as groundwater-dependant using desktop methods. The classes mapped in the GDE Atlas are high potential for groundwater interaction, moderate potential for groundwater interaction, and low potential for groundwater interaction.

Identified GDE’s found within the investigation area from the BOM GDE Atlas (BOM 2019c) are listed below (refer Figure 4.1):

- three distinct aquatic GDE’s (1 wetland, Wheel of Fortune Creek and Murrumbidgee River) within the investigation area
- nine distinct terrestrial vegetation GDE’s within the Wagga Wagga SAP
- 13 distinct terrestrial vegetation GDE’s within the investigation area.

There are no aquatic GDE’s (ecosystems that rely on the surface expression of groundwater) within the Wagga Wagga SAP. Of the above, only the following high potential GDE’s are present and are spatially clustered towards the southern portion of the investigation area:

- one aquatic GDE (Murrumbidgee River) within the investigation buffer
- one distinct terrestrial vegetation GDE (River Red Gum – Wallaby Grass) within the Wagga Wagga SAP
- two distinct terrestrial vegetation GDE’s (River Red Gum – herbaceous, and River Red Gum – Wallaby Grass) within the investigation area.



Map: PS114534_GIS_002_A4	Author: David.Naiken
Date: 11.11.2020	Approved by: Andrea.Madden

Coordinate system: GDA 1994 MGA Zone 55
Scale ratio correct when printed at A3

Wagga Wagga SAP

Figure 4.1
Aquatic and terrestrial GDEs

4.5 WAGGA WAGGA TOWN WATER SUPPLY

Riverina Water County Council (RWCC) operates water supply to the City of Wagga Wagga and surrounding Riverina, encompassing approximately 15,400 km^2 across four counties (Federation, Lockhart, Greater Hume Shire and Wagga Wagga). Traditionally, water was sourced from the Murrumbidgee River to meet supply demand. However, bore water (groundwater) has become an integral component of the supply network since the late 1960's due to increase in demand as a result of population growth and industry (predominately irrigation).

4.5.1 SUPPLY NETWORK

RWCC have an extensive pipeline that services the surrounding Riverina from Urana in the west, Brucedale to the north, Holbrook to the east and Walla Walla to the south, from their headquarters in Wagga Wagga (Figure 4.2). This pipeline is supplemented by multiple independent water supply locations throughout the Riverina.

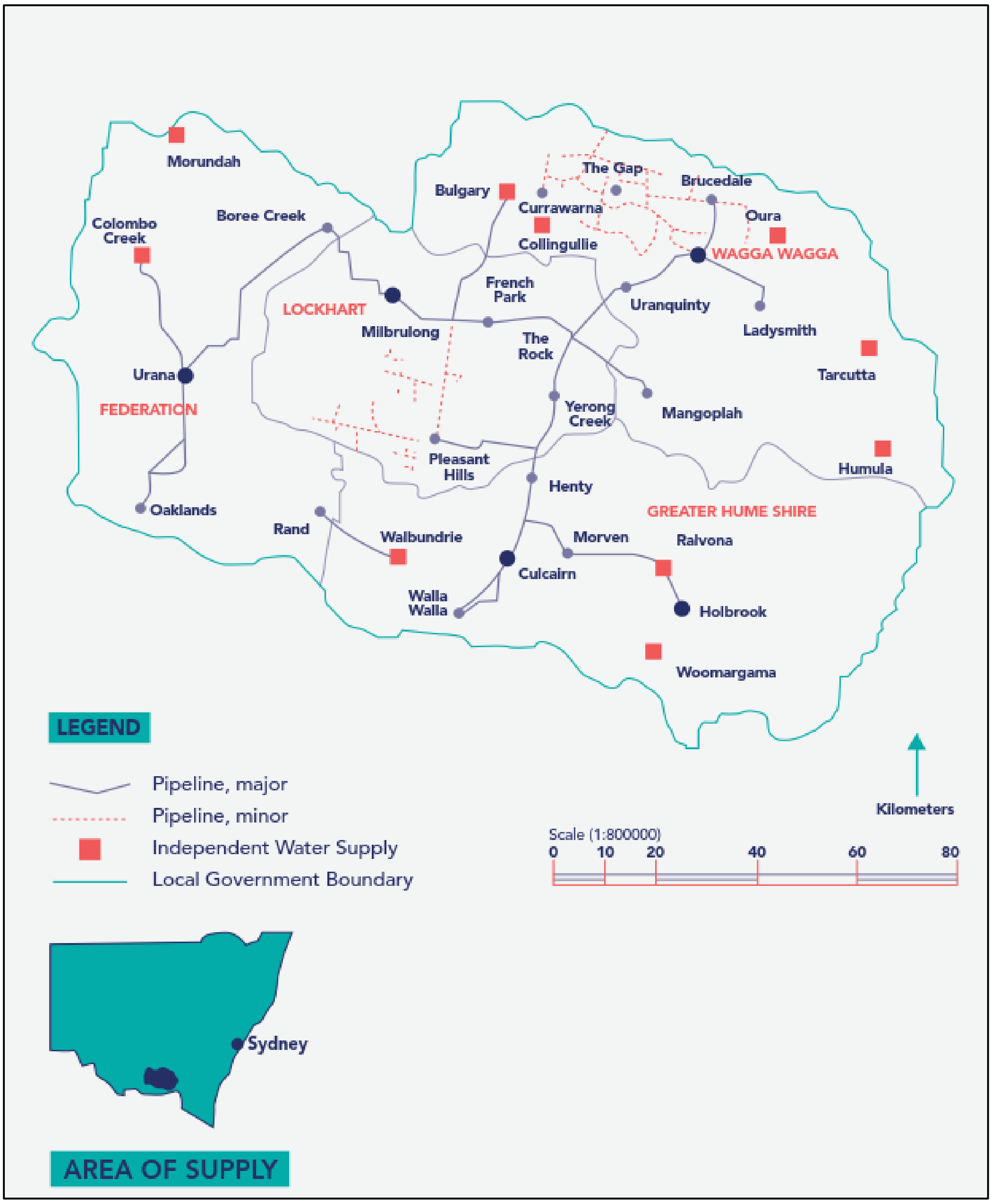


Figure 4.2 RWCC area of supply and supply network (RWCC 2018)

4.5.2 TYPICAL WATER USAGE

Water demand for the Riverina is focused on the City of Wagga Wagga that typically accounts for approximately 80% of water demand since 2012 (RWCC 2018). Water use distribution across the Riverina has been consistent over the past few years with the bulk of annual water distribution used for residential purposes (refer to Table 4.4).

Table 4.4 2017/2018 RWCC annual water supply distribution (RWCC 2018)

USE	CONSUMPTION (ML)	PERCENTAGE
Residential	8,818	59.5
Commercial	2,197	14.8
Commercial unmetered	12	0.1
Industrial	846	5.7
Rural	999	6.7
Institutional	783	5.3
Public parks	553	3.7
Unaccounted[1]	609	4.1

(1) Unaccounted includes flushing, firefighting, unmetered use and discrepancies between meter readings and billed volumes.

Generally peak water use within the Riverina occurs during the summer months of December to February (RWCC 2018). The proportion of groundwater contributing to annual water supply since the 2013/2014 to 2017/2018 financial year ranged from 81.6% to 89.8%, with peak groundwater contribution occurring in 2016/2017 financial year (RWCC 2018).

4.5.3 CITY OF WAGGA WAGGA BORE NETWORK

Groundwater is the preferred source for water supply due to its high quality and reliability (RWCC 2014). Three groundwater bore networks have been established across the City of Wagga Wagga near Kooringal Road (East Wagga bore field), Hinkler Street and Mills Street (North Wagga bore field) and Flowerdale Road and Travers Street (West Wagga bore field). The closest RWCC bore network to the Wagga Wagga SAP is located approximately 2.5 km south (North Wagga bore field) and is governed by the Murrumbidgee Unregulated and Alluvial Water Sources Water Sharing Plan – Wagga Wagga Alluvial Groundwater Sources. A summary of pertinent bore details is provided in Table 4.5.

Table 4.5 Summary of the City of Wagga Wagga RWCC bore network

LOCATION	NUMBER OF BORES[1]	CAPACITY (L/S)	SCREENED DEPTHS (mBGL)[2]	GROUNDWATER SOURCE[3]	REQUIRED TREATMENT[4]
East Wagga bore field	3	Up to 110	27-76, 48-56 and 61-69	Cowra and Lachlan Formation and Lachlan Formation	Aeration, chlorination, fluoride adjustment (sodium silico fluoride dosing) and sodium silicate dosing
North Wagga bore field	3	Up to 150	55-72	Lachlan Formation	
West Wagga bore field	5[4]	Up to 180	50-83	Lachlan Formation	

(1) Only four bores are currently in operational at South Wagga bore field, due to high iron concentrations encountered in one of the bores.

(2) Summary of approximate depths listed. For exact individual bore screened depths refer to RWCC (2014).

(3) Inferred groundwater source based on Table 4.1.

(4) Sodium silicate dosing used at South Wagga bore field for iron stabilisation treatment.

5 POTENTIAL CONSTRAINTS AND OPPORTUNITIES

5.1 GROUNDWATER CONSTRAINTS

Future development within the SAP may result in groundwater contamination, particularly of the Wagga Wagga alluvium.

The Wagga Wagga alluvium, including all registered bores screened within the Wagga Wagga alluvium, would be susceptible (medium to high potential risk) to changes in land practices that may result through the implementation of a SAP Master Plan. This is primarily due to the susceptibility, connectivity and high productivity of the aquifers (upper and lower).

To reduce the potential for future adverse effects on groundwater resources, the SAP Master Plan should try to limit heavy industry and other businesses that have high contamination potential to regions overlying lower productivity and low utilised aquifers, and away from high productivity and highly utilised aquifers.

Figure 5.1 spatially illustrates the areas within the SAP that, from a hydrogeological perspective, should be protected from potentially contaminating development and therefore should be considered for land use restrictions during the development of the SAP Master Plan. The groundwater protection zone (shaded in pink on Figure 5.1) and additional 'area to consider for protection' (shaded in orange on Figure 5.1), was identified based on the following:

- geology and hydrogeology, including the productivity and utilisation of the aquifers
- connectivity and recharge of high productivity aquifers from lower productivity aquifers
- GDE's
- registered bores
- potential errors in geological mapping and water sharing plan boundaries.

The groundwater protection zone includes the Wagga Wagga Alluvial Groundwater Sources, the high-priority GDEs (refer to Section 4.4), any mapped alluvial sediments (refer Figure 3.3) and an indicative 200 m buffer[2] beyond this boundary. This groundwater protection zone also includes identified sensitive receptors, including the registered groundwater bores used for household water supply, municipal water supply, stock and domestic use, irrigation and industry (refer to Section 4.4.1). In addition, it allows for potential discrepancy or inaccuracy of the mapped water sharing plan boundary and associated sediments.

The anticipated slow groundwater velocity of the Lachlan fractured rock within the 200 m buffer between the aquifers (Lachlan fractured rock and the Wagga Wagga alluvium) should allow appropriate time for the early detection of any contamination, assuming an appropriate groundwater monitoring network and program is implemented.

[2] A buffer of 200 metres for the groundwater protection zone boundary is deemed appropriate at this preliminary stage to account for uncertainty due to the desktop nature of this analysis. This buffer should be reassessed as further information on groundwater within the SAP becomes available, such as following intrusive investigations.

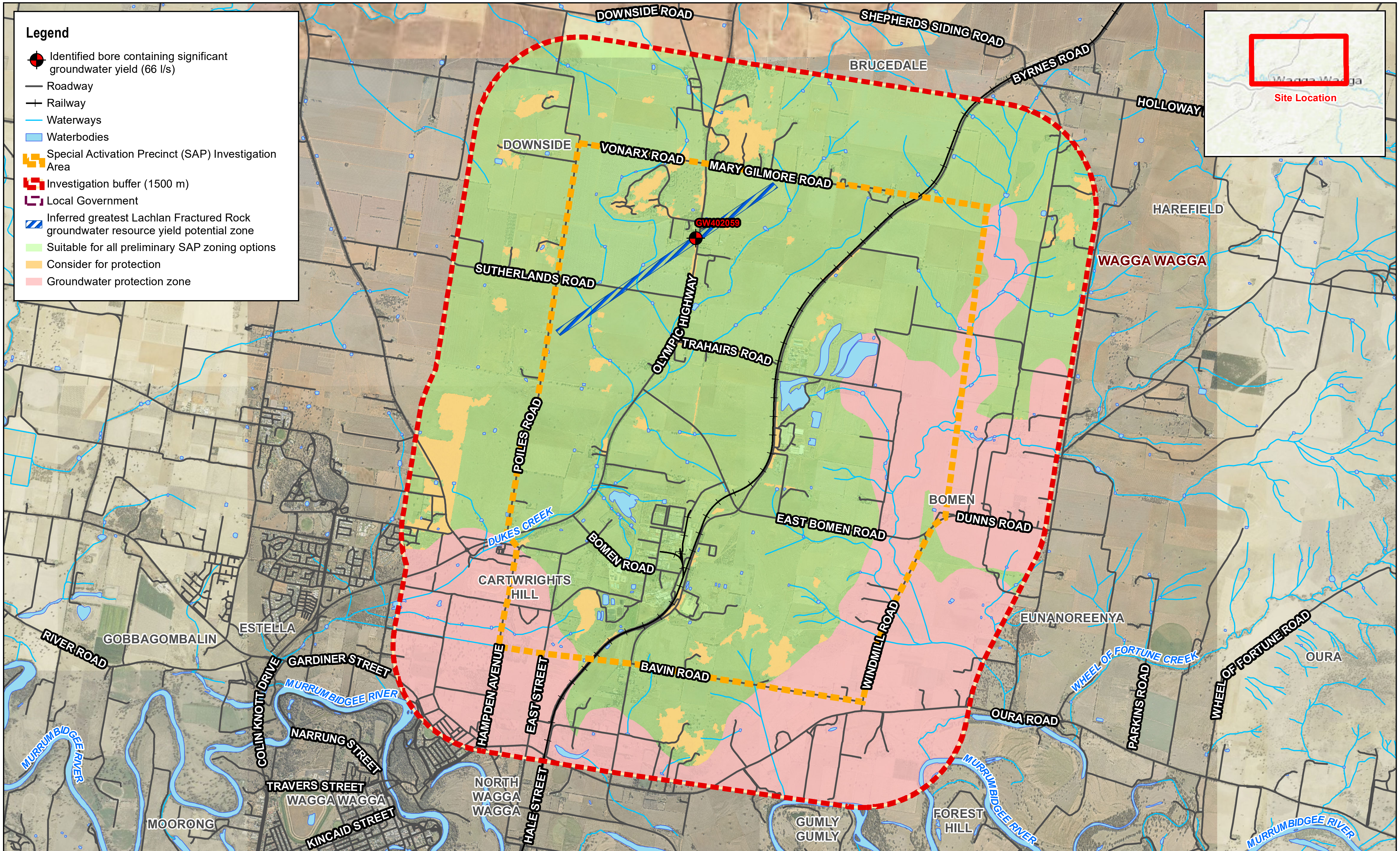
Potential land uses that would be considered unsuitable within the groundwater protection zone (to prevent future groundwater impacts) have been appropriated from the Wagga Wagga Local Environmental Plan (2010) groundwater vulnerability map, and are:

- aquaculture
- industries
- intensive livestock agriculture
- liquid fuel depots
- mines
- rural industries
- service stations
- sewerage systems
- turf farming
- waste or resource management facilities
- water supply systems
- works comprising waterbodies (artificial).

The additional 'area to consider for protection' in Figure 5.1 includes low to medium potential GDE's, which are may be sensitive receptors. Certain types of development within this area may result in adverse groundwater impacts that harm the GDEs, and therefore the SAP Master Plan should include restrictions on the types of land uses that are permitted within this area until further investigations can determine their groundwater dependency. Streams, such as Duke Creek, would also need to be protected, however streams are not specifically considered as part of this hydrogeological assessment.

The remaining area within the SAP, which is shaded green in Figure 5.1, is considered suitable for all preliminary land uses from a hydrogeological perspective. It is noted that the existing registered bores identified within the SAP have not been considered for protection, due to the anticipated appropriation of the bores within land that is purchased as part of the SAP Master Plan process. It is assumed that registered bore use will be discontinued due to future land-use development. Development around any bores identified for continued registered use may require an impact assessment as part of the groundwater management strategy.

Subject to appropriate land use restrictions, in line with the recommendation of this report (shown on Figure 5.1), future development within the SAP is expected to result in a low risk of potential impacts to the highly productive Wagga Wagga alluvium resource and identified sensitive receptors. Following development of the SAP Master Plan, a groundwater management strategy should be developed for the Wagga Wagga SAP that may advocate the requirement for hydrogeological investigations and ongoing groundwater monitoring in certain areas to identify any potential groundwater impacts.



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Date: 11.11.2020 | Approved by: Andrea.Madden

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Wagga Wagga SAP

Figure 5.1
Wagga Wagga SAP Master Plan hydrogeological recommendations

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5.2 GROUNDWATER OPPORTUNITIES

There are two distinct potential groundwater resources within the Wagga Wagga SAP; the lower Lachlan fractured rock aquifer (bedrock) and the upper Wagga Wagga alluvium (Cowra Formation).

The Wagga Wagga alluvium groundwater resource should be prioritised for protection (through land use restrictions in the SAP Master Plan) due to the:

- vulnerable state of the Wagga Wagga alluvium (WWCC, 2010)
- potential difficulty in securing WALs
- high connectivity between the Wagga Wagga alluvium aquifers
- critical reliance on the Wagga Wagga alluvium as a source for town water supply, triggering a key protection objective of the NSW Groundwater Quality Protection policy (DLWC, 1998).

The lower Lachlan fractured rock aquifer includes an identified area of potential high yield located in the north-western portion of the SAP. This area is located across the geophysical lineament interpretation that aligned to within 10.5 m of the high yield bore GW402059 (Figure 5.1, Figure 3.4 and Section 4.4.2). At a desktop review level, extracting groundwater from this location would result in the greatest potential for utilising the lower Lachlan fractured rock aquifer as a groundwater resource for the SAP. However, it is recommended that GW402059 be assessed to ascertain the accuracy of recorded yield values and groundwater levels, including by interviewing the landholder, and further assessment of localised aquifer characteristics (such as groundwater quality and storativity). Additional details on the aquifer are provided in Section 4.3.2.2.

Given the above, the lower Lachlan fractured rock aquifer is the preferred potential groundwater resource for the SAP, should groundwater take be required for future developments within the SAP. However, further hydrogeological investigations should be undertaken to confirm the findings of the desktop assessment. This includes drilling to a depth where significant fractures are intersected and further investigations (such as a pumping test) would be required to confirm the resource potential of the lower Lachlan fractured rock aquifer.

To ensure resource sustainability, if groundwater is proposed to be used for future developments within the SAP, a groundwater management strategy should assess and provide guidance on the management and sustainability of the groundwater resource.

6 KEY CONCLUSIONS

The following list summaries the key findings and recommendations of the hydrogeology desktop assessment:

- Two water sharing plans are in place within the SAP and investigation area:
  - NSW MDB Fractured Rock Groundwater Sources
  - Murrumbidgee Unregulated and Alluvial Water Sources.
- There are multiple groundwater sources within the investigation area, including the:
  - highly productive Wagga Wagga alluvium that is currently heavily utilised for town water supply within the City of Wagga Wagga and surrounding Riverina. The SAP Master Plan should include land use restrictions and groundwater management strategies to protect this resource from any adverse effects from future development within the SAP
  - lower Lachlan fractured rock aquifer that has variability water quality and extraction (yield) potential. However, an area located within the northwest portion of the SAP, identified along a northeast – southwest geophysical lineament interpretation, has the potential to provide a reliable resource with yields recorded by a registered bore (GW402059) of up to 66 L/s. This groundwater resource in its current form should be suitable for use in stock and domestic supply. The resource potential will need to be investigated further. Utilisation of the Lachlan fractured rock aquifer is also subject to license availability (transfer of existing WALs). At the time of reporting, no water access licenses are available for purchase, and licenses must be obtained by trading through a licensed water broker.
- Groundwater protection zone coloured pink (Figure 5.1) should be protected, where possible, through land use restrictions in the SAP Master Plan. This groundwater protection zone includes the following:
  - the Murrumbidgee Unregulated and Alluvial Water Sources water sharing plan that manages the Wagga Wagga Alluvial Groundwater Sources, including a 200 m buffer
  - high priority GDE's located within the investigation area, including a 200 m buffer
  - any additional mapped alluvial sediments, with an associated 200 m buffer.
- Land use restrictions should also be considered for areas shaded by orange in Figure 5.1 (the additional 'area to consider for protection') to prevent potential adverse effects to low and medium potential GDE's.
- A groundwater management strategy should be implemented across the SAP to provide guidance on potential groundwater impacts and sustainability arising from, but not limited to, contamination from industry, potential reversal of groundwater flow gradients and sustainability of the utilised groundwater resources within the SAP:
  - The groundwater management strategy should contain input from a SAP hydrogeological investigation to confirm desktop findings.
  - Depending on the conclusions of the groundwater management strategy, groundwater monitoring may be required in certain areas, to allow for the early identification of possible contamination arising as a result of future development.
- Through the implementation of a groundwater management strategy and alignment of the SAP Master Plan to recommendations of this report (implementation of a groundwater protection zone), there is expected to be a low potential risk to identified sensitive users (beyond the SAP) and sensitive receptors from future development within the SAP.

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8 REPORT LIMITATIONS

SCOPE OF SERVICES

This environmental site assessment report (the report) has been prepared in accordance with the scope of services set out in the contract, or as otherwise agreed, between the client and WSP (scope of services). In some circumstances the scope of services may have been limited by a range of factors such as time, budget, access and/or site disturbance constraints.

RELIANCE ON DATA

In preparing the report, WSP has relied upon data, surveys, analyses, designs, plans and other information provided by the client and other individuals and organisations, most of which are referred to in the report (the data). Except as otherwise stated in the report, WSP has not verified the accuracy or completeness of the data. To the extent that the statements, opinions, facts, information, conclusions and/or recommendations in the report (conclusions) are based in whole or part on the data, those conclusions are contingent upon the accuracy and completeness of the data. WSP will not be liable in relation to incorrect conclusions should any data, information or condition be incorrect or have been concealed, withheld, misrepresented or otherwise not fully disclosed to WSP

ENVIRONMENTAL CONCLUSIONS

In accordance with the scope of services, WSP has relied upon the data and has conducted environmental field monitoring and/or testing in the preparation of the report. The nature and extent of monitoring and/or testing conducted is described in the report.

On all sites, varying degrees of non-uniformity of the vertical and horizontal soil or groundwater conditions are encountered. Hence no monitoring, common testing or sampling technique can eliminate the possibility that monitoring or testing results/samples are not totally representative of soil and/or groundwater conditions encountered. The conclusions are based upon the data and the environmental field monitoring and/or testing and are therefore merely indicative of the environmental condition of the site at the time of preparing the report, including the presence or otherwise of contaminants or emissions.

Also, it should be recognised that site conditions, including the extent and concentration of contaminants, can change with time.

Within the limitations imposed by the scope of services, the monitoring, testing, sampling and preparation of this report have been undertaken and performed in a professional manner, in accordance with generally accepted practices and using a degree of skill and care ordinarily exercised by reputable environmental consultants under similar circumstances. No other warranty, expressed or implied, is made.

REPORT FOR BENEFIT OF CLIENT

The report has been prepared for the benefit of the client and no other party. WSP assumes no responsibility and will not be liable to any other person or organisation for or in relation to any matter dealt with or conclusions expressed in the report, or for any loss or damage suffered by any other person or organisation arising from matters dealt with or conclusions expressed in the report (including without limitation matters arising from any negligent act or omission of WSP or for any loss or damage suffered by any other party relying upon the matters dealt with or conclusions expressed in the report). Other parties should not rely upon the report or the accuracy or completeness of any conclusions and should make their own enquiries and obtain independent advice in relation to such matters.

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WSP will not be liable to update or revise the report to take into account any events or emergent circumstances or facts occurring or becoming apparent after the date of the report.

The scope of services did not include any assessment of the title to or ownership of the properties, buildings and structures referred to in the report nor the application or interpretation of laws in the jurisdiction in which those properties, buildings and structures are located.

ABOUT US

WSP is one of the world's leading engineering professional services consulting firms. We are dedicated to our local communities and propelled by international brainpower. We are technical experts and strategic advisors including engineers, technicians, scientists, planners, surveyors, environmental specialists, as well as other design, program and construction management professionals. We design lasting Property & Buildings, Transportation & Infrastructure, Resources (including Mining and Industry), Water, Power and Environmental solutions, as well as provide project delivery and strategic consulting services. With approximately 48,000 talented people globally, we engineer projects that will help societies grow for lifetimes to come.