Great Northern Highway

Muchea to Wubin Upgrade - Stage 2

MAIN ROADS WESTERN AUSTRALIA

Bindoon Bypass
Environment | Groundwater Assessment

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Glossary

Abbreviation	Description
AASS	Actual Acid Sulfate Soils
ADWG	Australian Drinking Water Guidelines
AHD	Australian Height Datum
AS	Australian Standards
ASJV	Arup Jacobs Joint Venture
ASRIS	Australian Soil Resource Information System
ASS	Acid Sulfate Soils
BAM Act	*Biosecurity and Agriculture Management Act 2007*
BGL	Below ground level
BH	Borehole
BoM	Bureau of Meteorology
CEMP	Construction Environmental Management Plan
Cha	Chainage
CN0X	Contract XX – [Contract Name]
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DAFWA	Department of Agriculture and Food WA
DEM	Digital Elevation Model
DER	Department of Environment and Regulation
DoEE	Department of the Environment and Energy
DPaW	Department of Parks and Wildlife
DSEWPaC	Department of Sustainability Environment Water Planning and Community
DWER	Department of Water and Environmental Regulation
EIA	Environmental Impact Assessment
EMP	Environmental Management Plan
EPA	Environmental Protection Authority
EP Act	*Environmental Protection Act 1986*
EPBC Act	*Environment Protection and Biodiversity Conservation Act 1999*
ESA	Environmentally Sensitive Area
GDA94	Geocentric Datum of Australia 1994
GDE	Groundwater Dependent Ecosystems
GIS	Geographic Information System
GNH	Great Northern Highway
GPS	Global Positioning System
ha	Hectare
IUCN	International Union for Conservation of Nature

Abbreviation	Description
km	Kilometre
m	Metre
Laterite	Iron rich soil derived from strong oxidising and leaching chemical weathering of in-situ rock
Main Roads	Main Roads Western Australia
MGA94	Map Grid of Australia 1994
MNES	Matters of National Environmental Significance
mm	Millimetre
M2W	Muchea to Wubin
M2W team	Muchea to Wubin Integrated Project Team, comprising Main Roads and industry partners Jacobs and Arup
MSDS	Material Safety Data Sheet
PASS	Potential Acid Sulfate Soils
PEC	Protected Ecological Communities
PEIA	Preliminary Environmental Impact Assessment
Project Area	Refers to the entire upgrade project. The project area extends 218 km between Muchea and Wubin along the GNH.
Regolith	Layer of loose material covering the bedrock of the earth and moon, etc, comprising soil, sand, rock fragments, volcanic ash, glacial drift etc.
Saprolite	Extremely weathered rock caused by in-situ chemical weathering
RIWI	Rights in Water and Irrigation (Act)
WA	Western Australia

1. Introduction

In 2014 Main Roads Western Australia (Main Roads WA) established the Muchea to Wubin Integrated Project Team (M2W Team), comprising Main Roads and industry partners Arup and Jacobs (combining to form Arup Jacobs Joint Venture, ASJV) to conduct a comprehensive planning review of the full Muchea to Wubin link along the Great Northern Highway (GNH). This planning review is a critical component of the Great Northern Highway: Muchea to Wubin Upgrade Stage 2, which has been funded with $384.8 million from the Federal and State Governments.

Among the improvements to be considered as part of the planning review were additional passing lanes, flattening crests and easing curves, safer roadsides, more rest stops and additional facilities for heavy vehicles.

The review examined the previous upgrade strategy developed in the 1990s and, having carefully considered current requirements for the movement of people and freight, delivered a revised upgrade strategy.

The M2W team has identified and prioritised construction packages to be delivered over the four-year period from 2015/16 to 2018/19. The construction programme includes the currently funded sections Muchea North / Chittering (13km), Bindoon South (2km), New Norcia (7kms), Lyons East Road to Pithara (46km, including Miling) and Dalwallinu to Wubin realignment (16km) and identifies additional priority packages to be constructed as funding becomes available.

1.1 Description of the project

The project involves the construction of a new 48 km section of the GNH in the Bindoon region, in order to provide a bypass around Bindoon Hill and the town of Bindoon. This section of new road is referred to as the Bindoon Bypass. The Bindoon Bypass will depart from the existing GNH at the Chittering Roadhouse to the railway line just north of Mooliabeenee Road, Mooliabeenee. From here, the road will follow the railway line for approximately 12 km where it will curve to the east and tie into the existing GNH near Calingiri West Road (Figure A.1). The objective of the Bindoon Bypass is to provide an alternative highway route around Bindoon Hill, allow passage of 53.3 m road trains along this section of highway and improve the safety and efficiency of freight transport.

The new Bindoon Bypass will consist of the following elements:

- Approximately 33 km of dual carriage way between Chittering Roadhouse and the Bindoon-Moora Road intersection with a seal width of 9 m on a nominal formation of 11 m and median spacing between carriageways of 30 m.
- Approximately 15 km of single carriageway from the Bindoon-Moora Road intersection to Calingiri West Road intersection with a seal width of 10 m on a nominal formation width of 11 m with a 1 m wide centreline treatment.
- New intersections to connect the Bindoon Bypass to existing local roads.
- Seven northbound and six southbound overtaking lanes.
- Bridge crossing over the Brockman River.
- Installation of culverts for minor creek crossings.
- Fencing of the new road reserve. The road reserve boundary has been developed on the basis of achieving an approximately 120 m reserve along the entire corridor.
- A rail crossing to connect Gingilling and Cullalla Roads to the Bindoon Bypass.
- Relocation and/or re-instatement of driveways and other works as agreed with individual landowners.
- One northbound and one southbound roadside stopping (rest) areas.
- Local service roads to provide controlled access for properties adjacent to the new highway.

- Landscaping and revegetation within the road reserve.
- Relocation of services such as water, power and telecommunications.

1.2 Scope and purpose of this report

This hydrogeology report presents the groundwater assessment for the Bindoon Bypass section of the GNH upgrade to inform a Public Environmental Review (PER). The purpose of this report is to address the hydrogeological processes and inland waters environmental quality components of the Environmental Scoping Document provided by the WA Environmental Protection Authority (EPA) on the 16th November 2017. The scope of this report includes:

- A summary of the existing geological and geomorphological environments in the project area.
- Identification of groundwater users and current water quality.
- Development of a conceptual hydrogeological model.
- Assessment of the potential impacts of the project during construction and operational phases on groundwater and possible residual impacts.
- Identification of possible mitigation measures that may be required to address potential impacts.

1.3 WA and Commonwealth Assessment Requirements

The EPA and the Commonwealth have assessment requirements that must be included in environmental impact statements (EIS). These requirements and where they have been addressed in the document are presented in Table 1-1 and Table 1-2.

Table 1-1: WA EPA environmental impact assessment requirements

WA EPA environmental assessment requirements (EP Act)	Where addressed in document
Identify and describe the values and significance of surface and groundwater hydrological and soil characteristics within the refined development envelope and the immediately adjacent area and describe these values in local, regional and State contexts as appropriate. Identify and describe wetlands within and adjacent to the refined development envelope utilising relevant databases.	Identification and description of the surface water, groundwater and soil value and significance is presented in Section 4. Wetlands are identified and described in Section 4.4.2 and presented in Figure A.7.
Describe and assess the potential impacts (direct and indirect) as a result of both construction and operational elements of the proposal on water quantity and quality in relation to surface and groundwater, waterways and their floodplains and wetlands identified above.	Description and assessment of the potential direct and indirect impacts of the proposal during construction and operation is presented in Section 5 and 6 respectively.
Once the development envelope has been refined, predict the extent, severity and duration of potential impacts, including changes to local and regional groundwater flows and levels, drawdown, local water quality and impacts to other groundwater users identified as a result of construction and operation.	Prediction of the impacts on groundwater during construction and operation is presented in Section 5 and 6 respectively.
Describe any proposed mitigation to reduce the potential impacts of construction and operation of the proposal. Provide maps of and justification for the	Proposed mitigation measures are presented in Section 8.

WA EPA environmental assessment requirements (EP Act)	Where addressed in document
location and number of any proposed culverts. Include any proposed management and/or monitoring plans that will be implemented pre- and post-construction to demonstrate and ensure the EPA's objectives can be met.	
Identify and describe the potential residual impacts (direct and indirect) that may occur following implementation of the proposed mitigation measures and determine the significance of the residual impacts on the identified environmental values with reference to the residual impact model set out in the WA Environmental Offsets Guidelines. Include completed State offset templates as appropriate and propose appropriate offsets package(s) that are consistent with the relevant guidelines set out below. Include spatial data defining the area of any identified significant residual impacts and proposed offsets in relation to the development envelope.	Proposed mitigation measures are presented in Section 8.

Table 1-2: Commonwealth EIS requirement guidelines

Commonwealth EIS Guidelines (Commonwealth EPBC Act)	Where addressed in document
Include a description of the environment of the proposal site and the surrounding areas that may be affected by the proposal. A description of the environment in all areas of potential impact, including all components of the environment as defined in Section 528 of the EPBC Act: • Landscapes and soils • Natural and physical resources, including water resources.	Description of the existing environment is presented in Section 4.
Impacts to the environment (as defined in section 528) should include but not be limited to the following: • Changes to water quality on site and downstream of the site • Changes to siltation • Changes in recreational use and amenity of natural areas.	Description of the impacts to the environment are included in Section 5 and 6.

2. Legislation and policy framework

2.1 Key Legislation, Regulation and Guidelines

The following legislature are applicable for groundwater impact assessments:

- *Water Agencies (Powers) Act 1985.*
- *Rights in Water Irrigation Act 1914.*
- *Country Areas Water Supply Act 1947 and Metropolitan Water Supply, Sewage and Drainage Act 1909.*
- *Country Areas Water Supply (Clearing Licence) Regulations 1981 (CAWS Regs).*
- *Environmental Protection and Biodiversity Conservation Act 1999.*
- Australian Groundwater Modelling Guidelines.
- Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZEC/ARMCANZ 2000).

2.1.1 Water Agencies (Powers) Act 1984

The Department of Water and Environmental Regulation (DWER) leads water resource management in Western Australia by coordinating cross government efforts to protect and manage water resources.

2.1.2 Rights in Water Irrigation Act 1914

The *Rights in Water and Irrigation Act 1914* (RIWI Act) provides the Governor of Western Australia the power to proclaim or prescribe a groundwater area through regulation. Proclaiming or prescribing an area allows comprehensive management of water uses in that area.

For the purposes of groundwater resource management, the state of Western Australia is divided into groundwater areas. The extraction and licencing of groundwater resources are managed within groundwater area.

2.1.3 Country Areas Water Supply Act 1947 and Metropolitan Water Supply, Sewage and Drainage Act 1909

These Acts and associated by-laws protect the state's public drinking water sources (i.e. proclaiming catchment areas, water reserves and pollutions areas (underground pollution control areas).

2.1.4 County Areas Water Supply (Clearing Licence) Regulations 1981 (CAWS Regs)

The clearing of vegetation is controlled by the CAWS Act and CAWS Regs to manage and prevent salinization of water resources in the clearing control catchments.

2.1.5 Environmental Protection and Biodiversity Conservation Act 1999

The *Environmental Protection and Biodiversity Conservation Act 1999 (EPBC)* is administered by the Department of the Environment and Energy (DoEE) and provides a legal framework to protect and manage flora, fauna, ecological communities and heritage places that are of national and international importance. Approval is required under the EPBC Act for any proposed action that is likely to have a significant impact on Matters of National Environmental Significance (MNES).

2.1.6 Australian Groundwater Modelling Guidelines

The *Australian Groundwater Modelling Guidelines* promote a consistent and sound approach to the development of groundwater flow and solute transport models in Australia.

2.1.7 Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZEC/ARMCANZ 2000)

The Australian and New Zealand Environment Conservation Council water quality guidelines (2000) provide a framework for conserving ambient water quality in rivers, lakes, estuaries and marine waters. The ANZEC/ARMCANZ (2000) *National Water Quality Guidelines for Fresh and Marine Water Quality* have been applied to understand the current health of the waterways in the study area and the ability to support certain environmental values, namely the protection of groundwater dependent ecosystems and aquatic ecosystems. The Guidelines provide recommended maximum and minimum values which have been applied to understand the existing water quality.

2.2 Other regulatory requirements

Other regulatory requirements for groundwater impact assessments include:

- *Environment Protection and Biodiversity Conservation Act 1999*
  - Matters of National Environmental Significance: Significant Impact Guidelines 1.1
  - Matters of National Environmental Significance: Significant Impact Guidelines 1.2 Actions on, or impacting upon, Commonwealth Land and Actions by Commonwealth Agencies
- *Environmental Protection Act 1986*
  - Guidance for the Assessment of Environmental Factors No. 6 Rehabilitation of Terrestrial Ecosystems
  - Guidance Statement 12: Minimising Greenhouse Gases
  - Acid Sulfate Soils Guideline Series: Identification and Investigation of Acid Sulfate Soils and Acidic Landscapes
  - Acid Sulfate Soils Guideline Series: Treatment and management of soils and water in acid sulphate soil landscapes
  - WA Government Environmental Offset Guidelines
- *Waterways Conservation Act 1976*
  - Waterways Conservation Regulations 1981
  - A Guide to Managing and Restoring Wetlands in Western Australia

2.2.1 Policies and position statements

The following policies and position statements are applicable for groundwater impact assessments:

- State Planning Policy 2.9 Water Resources
- Western Australian Environmental Offsets Policy 2011
- Gingin Groundwater Areas Allocation Plan, Water Resource Allocation and Planning Series Report no. 53
- Water Quality Protection Notes:
  - No. 44 – Roads Near Sensitive Water Resources
  - No. 36 – Protecting Public Drinking Water Source Areas
  - No. 6 – Vegetation Buffers to sensitive water resources

2.2.1.1 State Planning Policy 2.9 Water Resources

The State Water Strategy for Western Australia seeks to develop and protect water resources in an economically and environmentally responsible way by providing a whole government framework for setting strategies and plans for water resources. The objective of the policy is:

- To protect, conserve and enhance water resources that are identified as having significant economic, social, cultural and/or environmental values.
- Ensure that suitable water resources are available to maintain requirements for human and all other biological life.
- Promoting and assisting in the management and sustainable use of water resources

2.2.1.2 Western Australian Environmental Offsets Policy 2011

The Western Australian Environmental Offsets Policy is designed to compensate for residual environmental impacts and achieve long-term outcomes by ensuring economic and social development may occur while supporting long term environmental and conservation values.

2.2.1.3 Gingin Groundwater Areas Allocation Plan, 2015

The *Gingin Groundwater Allocation Plan* has been developed to manage groundwater resources in the Gingin plan area in the context of the drying climate and high levels of demand. There has been an updated allocation of limits and licencing rules which will maintain the reliability of groundwater for productive use and reduce the risks to the groundwater dependent environment.

2.2.1.4 Water Quality Protection Notes

Roads Near Sensitive Water Resources provides a general guide on issues of environmental concern, and offers potential solutions. It offers the Department's views on road siting, construction and management, guidance on acceptable practices for water resource protection and a basis for the development of a multi-agency code or guideline.

Protecting Public Drinking Water Source Areas implements the document, National Water Quality Management Strategy No. 6: *Australian Drinking Water Guidelines* and *State Water Quality Management Strategy*. It describes how and why Public Drinking Water Source Areas are protected, the roles of stakeholders in their protection and delivers clarity, consistency and equity for land use planning decision-making.

Vegetation Buffers to sensitive water resources offers the Department's views on establishing and maintaining protective vegetated buffers to vulnerable surface and underground waterbodies to help sustain their values.

2.3 Decision making authorities and approval requirements

2.3.1 Environment Protection and Biodiversity Conservation Act 1999

Referral under the Act is required in respect of the impact on MNES. The PER this report supports will be assessed by DoEE to obtain the necessary environmental approval.

2.3.2 Environmental Protection Act 1986 – Part IV

Referral under the Act is required if the proposal will have a significant environmental impact. The PER this report supports will be used by the EPA as part of the assessment of the proposal.

2.3.3 Rights in Water and Irrigation Act 1914

The Department of Water and Environmental Regulation (DWER) is responsible for the *Rights in Water and Irrigation Act 1914.*

A Section 5C licence to take groundwater may be required for construction purposes.

A Section 26D licence to construct a well for dewatering may be required for construction purposes. This application will be dependent on the location of dewatering.

3. Methodology

Environmental impact assessment guidelines provided by both the WA and Commonwealth Governments have been consulted to develop this hydrogeology report. The guidelines provide guidance on factors that should be considered in the assessment of environmental impacts, which may require mitigation measures during the construction and operation phases of the project to minimise impacts. The follow methodology was adopted to assess the potential impacts upon groundwater caused by the proposed project:

- Review of existing literature relating to the project area including geological and environmental maps (regional and structural geology, regional hydrogeology and acid sulphate soils (ASS)), published journal articles and government reports, proclaimed areas (groundwater, surface water, environmentally sensitive areas, environmental protection policy lakes, groundwater dependent ecosystems, public drinking water source areas), available groundwater level, quality and flow data (WA WINsite database searched within 2 km of the project alignment), and recent geotechnical investigation data to aid subsurface condition interpretation.
- Review of surface water and groundwater allocation sharing plans
- Development of a conceptual groundwater model
- Review of the conceptual groundwater model to assess potential impacts upon groundwater during construction and operation phases of the project

The conceptual hydrogeological model was developed in consultation with the following public sources and published literature:

- WA WINsites groundwater bore online database
- Perth 1:250,000 scale geological series sheet (Geological Survey of Western Australia, 1978)
- Department of Water, Reinterpretation of the Hydrogeology of the Leederville Aquifer Report (Leyland, 2012)
- Outline of the Hydrogeology of the Perth Region (Commander P. , 2003)

4. Existing Environment

4.1 Landform and landscape

The project is located within the Darling Plateau and Dandaragan Plateau, where the Darling Plateau is part of the Yilgarn Craton and the Dandaragan Plateau is part of the Perth Basin. The boundary between the Darling Plateau and the Dandaragan Plateau is delineated by the Darling Fault, running sub-parallel to the western side of the proposed alignment. The Darling Fault is expressed at the ground surface as the Darling Scarp, which has an average elevation of 300 m AHD and has retreated during the cretaceous period 1 to 3 km inland of the fault line (Gozzard, 2007). The Dangaran Plateau has an average elevation of 200 m AHD and extends west to the Gingin Scarp (Gozzard, 2007).

The Darling Plateau features a hills and valleys landscape created by streams and rivers eroding the overlying lateritic material and exposing the Archean rocks in the valley floors (Gozzard, 2007). The landscape of the Darling Plateau has been divided into three distinct subdivisions: lateritic uplands, deeply incised valleys (common on the western side of the plateau) and wide valleys with intervening low hills that are prevalent on the eastern side of the plateau (Anand & Butt, 2003). The Dandaragan Plateau has fewer rivers and streams relative to the Darling Plateau, so minimal erosion has occurred in the lateritic sand material that overlies the Cretaceous sedimentary rocks in this region (Gozzard, 2007).

The proposed alignment alternates between running along the ridge of sub-catchments and lower lying middle reaches of the sub-catchments. The main watercourses in the project area are the Brockman River that flows in a generally southerly direction along the eastern side of the proposed alignment and the Lennard Brook flowing in a westerly direction from the southern end of the project. The proposed alignment intersects the Brockman River where it begins to run in a north-east direction and the Brockman River runs sub parallel to this alignment to the north. Valleys created by tributaries of the Brockman River generally align in a west-east direction and there are many farm dams along these watercourses.

The land-use in the area is rural with cleared and vegetated fields and pockets of rural townships.

4.2 Regional geology

The geological series sheet for the project area indicates that the alignment is underlain by Cainozoic geology of the Perth Basin, generally on the western side of the proposed alignment, and Archean rocks of the Yilgarn Craton on the eastern side of the alignment (Figure A.2) (Geological Survey of Western Australia, 1978). The boundary between the Perth Basin and the Yilgarn Craton is delineated by the Darling Fault, which strikes approximately north-south in the project area and the proposed alignment intersects several times. The most recent significant activity along the fault is thought to have occurred between 430 and 130 million years ago (early Silurian to early Cretaceous) (Geological Survey of Western Australia, 1990). The proposed alignment also intersects a doleritic dyke that strikes approximately north-south and intersects the alignment perpendicularly in its northern portion (Geological Survey of Western Australia, 2015). North-south striking lineaments are common features in the western area of the Yilgarn Craton (Geological Survey of Western Australia, 2015).

The Perth Basin geology in the project area comprises Quaternary aged colluvium and alluvium with localised areas of Tertiary aged laterite (Geological Survey of Western Australia, 1978). These Cainozoic sediments are underlain by sedimentary Mesozoic formations, which were deposited during infilling of the Perth Basin rift valley (Commander P. , 2003) and form many of the aquifers within the Perth region due to the interbedding of sandstone, siltstone and shale members.

The Darling Range is an uplifted plateau developed on the western margin of the Yilgarn Craton (Anand & Butt, 2003). In the project area, the geology of the Darling Range typically comprises laterite over gneiss, schist, migmatites and granites associated with the Chittering Metamorphic Belt (Geological Survey of Western Australia, 1978). The Darling Range of the Yilgarn Craton is a stable Archaen nucleus which has allowed ancient and variable weathering profiles to develop and these weathering profiles can extend in excess of 20 m below ground surface (Anand & Butt, 2003).

The geological units encountered along the route alignment are presented in Table 4-1.

Table 4-1: Geological units within the project area

Geological unit (code)	Description
Quaternary colluvium (Qpo)	Colluvium, soil and undifferentiated sand over laterite of Coastal Plain includes minor alluviated areas
Quaternary colluvium (Qrc)	Colluvium, including valley-fill deposits, variably lateritized and podsolized
Quaternary alluvium (Qra)	Clay, sand and loam
Quaternary alluvium (Qa)	Alluvium and minor colluvium developed on laterite of the Darling Range
Tertiary laterite (Czl)	Chiefly massive, but includes overlying pisolithic gravel and lateritized sand
(Czs)	Sand overlying laterite Yellow, white or grey and often associated with drainage courses
(Alb)	Archean quartz-mica schist, biotite generally in excess of muscovite
(Agn)	Archean gneissic granite, with cataclastic foliation

4.3 Soil landscapes

4.3.1 Acid Sulphate Soils (ASS)

The Atlas of Australian Acid Sulfate Soils indicates that the proposed project area is primarily underlain by soils with an extremely low (1 – 5 % chance) probability occurrence of ASS (Figure A.3) (CSIRO, 2011). Near the Bindoon-Moora Road interchange the proposed alignment intersects an area with a low probability (6 – 70 % chance) of ASS occurrence, which is likely to be associated with wetlands identified in this area. An isolated area with a high probability (> 70 % chance) of ASS occurrence is located within the project area at Lake Nangar near Mooliabeenee Road. As these soils have the potential to oxidise, but oxidation has not occurred, they are referred to as potential acid sulfate soils (PASS) and are sensitive to changes in groundwater levels and disturbance.

4.3.2 Salinity

The project area covers two areas of mapped salinity risk, the Dandaragan Plateau and the Eastern Darling Range, in a report card completed by the Western Australian Department of Agriculture and Food. The report card identifies the Dandaragan Plateau at high risk of dryland salinity expansion, where recent trends indicate the condition of the Dandaragan Plateau are degrading due to rising groundwater levels and high quality of agricultural land available (Simons, George, & Raper, 2013). The Eastern Darling Range was identified at moderate risk of dryland salinity expansion where generally stable groundwater levels were observed (Simons, George, & Raper, 2013).

Limited groundwater salinity data available from WINsites indicates the groundwater quality varies from fresh to saline, where the majority of results are less than 3000 mg/L i.e. non-saline (Figure A.4) (Australian Water Resource Council, 1976). These results are limited in their quantity and spatial extent, where the closest location is approximately 9 km from the project alignment. Generally for aquifers within the Perth basin the groundwater salinity increases in the direction of flow (typically south in the project area) and with depth in the aquifer (Appleyard, 2003).The *Gingin Groundwater Allocation Plan 2015* provides the total dissolved solids (TDS) typically encountered within the aquifers located in the project area and are presented in Table 4-2. The aquifers presented are discussed in further detail in Section 4.5 of this report.

Table 4-2: Extract of typically TDS of groundwater aquifers within the project area (Department of Water, 2015)

Aquifer	TDS (mg/L)	General classification
Surficial	< 1000	Fresh

Aquifer	TDS (mg/L)	General classification
Mirrabooka	< 1000	Fresh
Fractured rock	Variable	Variable
Leederville - Parmelia	< 1000	Fresh

4.4 Surface water features, catchments and flow

The project area is primarily located within the Swan River System and borders the Gingin Brook Catchment Area in the north-west portion of the alignment. Both the Swan River System and Gingin Brook Catchments are proclaimed RIWI Act 1914 surface water areas (Figure A.5). The Brockman River that runs sub-parallel to most of the proposed alignment is a tributary of the Avon River and ultimately the Swan River which flows through the centre of the Perth metropolitan area, south east of the project area. The Gingin Brook is a tributary of the Moore River located west of the project area. Both river systems provide economic and environmental benefits in their catchments for tourism, agriculture and groundwater dependent ecosystems.

The proposed alignment traverses through a number of sub-catchments part of the greater Brockman River and Gingin Brook catchments (Figure A.6) where the alignment is within relatively close vicinity of several unnamed tributaries of the Brockman River. The Brockman River and its tributaries including the Udumung Brook and two unnamed tributaries are intersected in the northern portion of the proposed alignment. The Lennard Brook Bindoon Branch is intersected in the southern portion of the alignment where in addition a relatively short section of the alignment is located within the Ellen Brook catchment area.

Water flows in the Brockman sub-catchments are generally in an easterly direction relative to the north-south section of the proposed alignment. Where the alignment runs approximately west-east, flow in the Brockman sub-catchment are generally in a westerly direction relative to the alignment. Water flows in the Gingin Brook sub-catchments are typically in a westerly direction.

4.4.1 Environmental protection policy lakes

The Swan Coastal Plain Lakes are identified under the *Environmental Protection Act 1986* as an environmentally sensitive area which the *Environmental Protection (Swan Coastal Plain Lakes) Policy 1992* applies. The Swan Coastal Plain Lakes are intersected by and within the vicinity of the project area (Figure A.7). The lakes are identified as conservation category wetlands (the most environmentally significant), resource enhancement wetlands or multiple use wetlands.

4.4.2 Wetlands

Two wetlands in the vicinity of the project area are listed on the Directory of Important Wetlands in Australia: the Wannamal Lake system and the Chittering-Needonga Lake system (Figure A.7) (Australian Nature Conservation Agency, 1993). The Wannamal Lake system is located approximately 3.3 km north of the north-west corner of the proposed alignment within a Brockman River sub-catchment. The Chittering-Needonga Lake system is approximately 4 km east of the southern section of the proposed alignment, and is located along the Brockman River.

4.4.3 Mound Springs

No mound springs have been identified within or surrounding project area.

4.4.4 Surface water allocation plan

Part of the southern portion of the project area falls within the *Gingin Surface Water Allocation Plan 2011.* The Plan relates to the Gingin Brook and its tributaries, which have been divided into sub-areas. The project alignment intersects the Moondah Brook and Lennard Brook sub-areas, which have allocation limits presented in Table 4-3 to maintain reliability of current supply levels and minimise risk to the riverine environment (Department of Water, 2011).

Table 4-3: Excerpt of allocation limits for selected Gingin surface water resources from Department of Water, 2011

Resource	Allocation limit (kL/year)	Allocation limit components (kL/year)	
		Unlicensable (exempt use, including riparian rights)	Licensable (general licensing)
Lennard Brook	2,434,310	25,000	2,409,310
Moondah Brook	808,651	1,000	807,651

4.5 Groundwater

4.5.1 Groundwater occurrence, levels and flow

Four aquifers are present within the project area including an unconfined surficial aquifer, the Mirrabooka semi-confined aquifer west of the Darling Fault, a fractured rock aquifer east of the Darling Fault and the semi confined Leederville-Parmelia aquifer east of the Darling Fault (Department of Water, 2015). An excerpt of the Perth Basin stratigraphy and corresponding aquifers are presented in Figure 4-1. It is anticipated that the project will primarily interact with the surficial, Mirrabooka and fractured rock aquifers, which may have indirect impacts upon the Leederville-Parmellia aquifer.

The surficial aquifer in the project area comprises colluvium and lateritised soil profiles including a combination of colluvial and lateritic clays, sands, ferricrete and gravels that are intersected by alluvial deposits associated with natural drainage lines. The aquifer is thin and often unsaturated (Department of Water, 2015). Surface expressions of the aquifer include the wetlands and lakes that are common in the vicinity of the project area.

The Mirrabooka aquifer is comprised of the Lancelin Formation which includes variably lateritised glauconitic sands and clays, and the Osbourne Formation that includes glauconitic siltstone, claystone, shale and sandstone, where the Kardinya Shale Member acts as a basal aquitard (Geological Survey of Western Australia, 1978) (Commander P. , 2003). The aquifer is hydraulically connected to the surficial aquifer and is recharged in the north of the Perth Basin (Commander P. , 2003) The Mirrabooka aquifer contributes to the summer flows in the headwaters of the Gingin Brook and maintains summer flows in the Moore River (Department of Water, 2015).

The fractured rock aquifer comprises fractured and weathered crystalline bedrock with small groundwater storage capacity (Department of Water, 2015). Low groundwater yields can be obtained from the base of the weathered zone in the saprolite, generally around 25 m depth, however water-bearing fractures in the granitic rock are widely spaced and springs can occur below the laterite (Commander P. , 2003). It is anticipated that this aquifer is recharged by the surficial aquifer.

The Leederville-Parmelia aquifer is an interconnected aquifer of the Leederville Formation and Parmelia Group comprising of sandstone and shale aquitards, which is semi confined and recharged by the Gnagara mound approximately 15 km west of the project area before becoming confined to the south of the Gingin proclaimed groundwater area (Department of Water, 2015). The Leederville aquifer is also referred to as the ‘shallow artesian aquifer’ and is used for public water supply (Commander P. , 2003). Similar to the Mirrabooka aquifer, the Leederville-Parmelia contributes to the baseflow of the Gingin Brook and is important for maintaining summer flow in the Moore River (Department of Water, 2015).

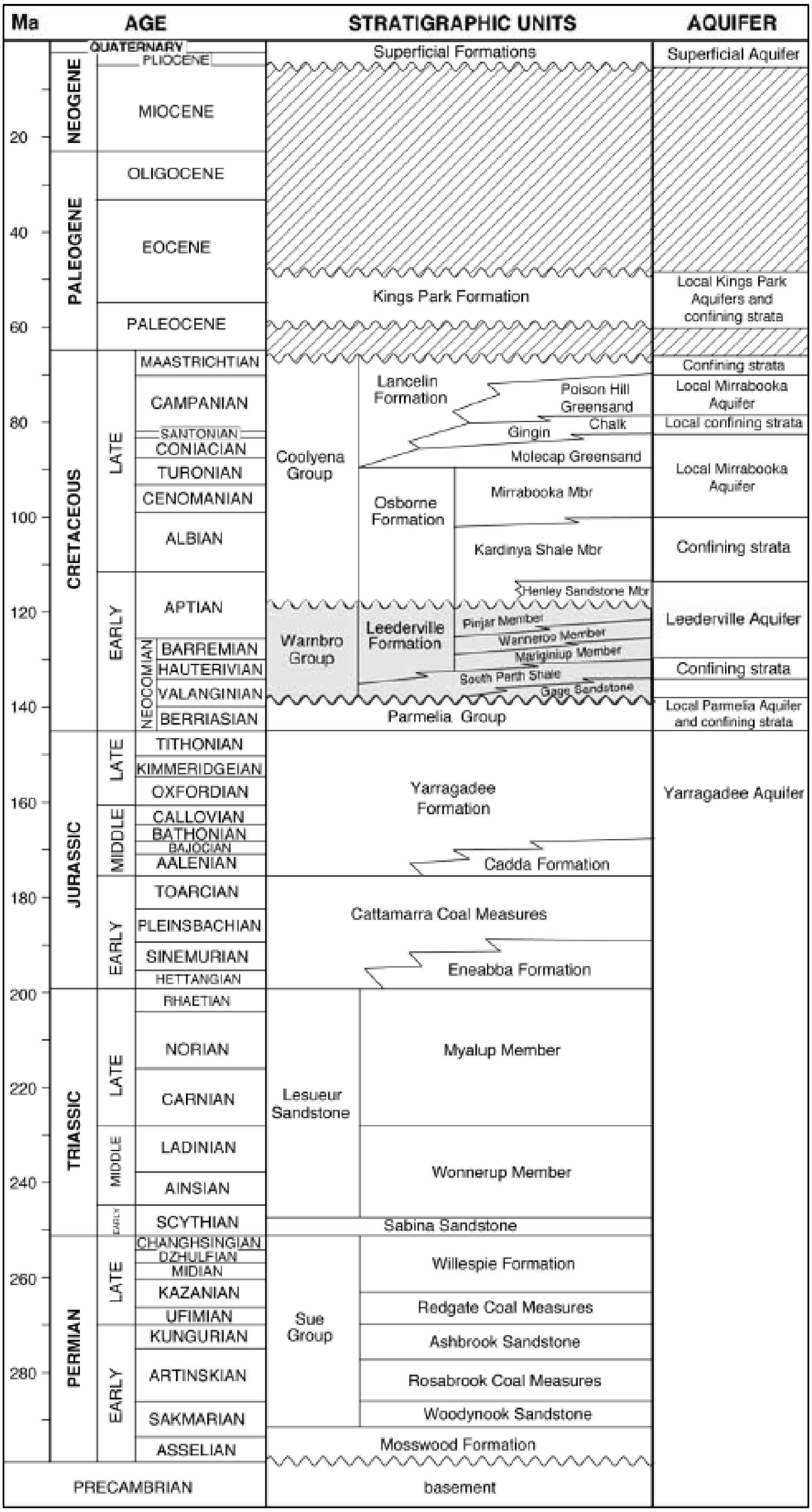


Figure 4-1: Stratigraphy of the Perth Basin and aquifers (Leyland, 2012)

Table 4-4: Extract of typical of groundwater bore yields within the project area (Department of Water, 2015)

Aquifer	Yield (kL/day)	Description of yield
Surficial	< 100	Small
Mirrabooka	-	Highly variable
Fractured rock	< 500	Very low
Leederville - Parmelia	3000	Good

A search of the Water Information (WIN) Sites dataset of groundwater bores within WA was conducted for a 2 km buffer from the project alignment and included 19 bore locations with flow data available. Of the search results 16 bores within the surficial aquifer had flows between 0 and 80 kL/day. Within the Leederville-Parmelia aquifer two bores had flows equal to 1360 kL/day each (used for town water supply). In the Yarradee aquifer one bore in this aquifer had a flow of 55 kL/day.

4.5.2 Groundwater quality

Limited groundwater quality testing is available for the aquifers in the project area. The Chittering borefield abstracts groundwater from the Leederville aquifer to supply town water to Bindoon and Chittering. An extract the aesthetic and health related detections for this supply based on the 2004 Australian Drinking Water Guidelines (ADWG) (NHMRC, 2004) are presented in Table 4-5.

Table 4-5: Extract of aesthetic and health related detections for the Chittering borefield (Department of Water, 2007)

Parameter	Unit	ADWG guideline value	Chittering borefield raw source	
			Range	Median
Aesthetic detections				
Aluminium unfiltered	mg/L	NA	<0.008 – 0.032	<0.008
Chloride[1]	mg/L	250	145 – 160	152.5
Colour – True	TCU	15	<1 – 10	2
Conductivity at 25ºC	mS/m	NA	51 – 89	56
Hardness as CaCO3	mg/L	200	45 – 48	46.5
Iron unfiltered	mg/L	0.3	3.2 – 13	7.5
Manganese unfiltered	mg/L	0.1	0.055 – 0.18	0.101
pH	–	6.5 – 8.5	5.73 –6.16	5.94
Sodium[1]	mg/L	180	82 – 86	84
Sulphate[1]	mg/L	250	18	18
TFSS[1]	mg/L	500	334 – 350	342
Turbidity	NTU	5	<0.1 – 90	0.6
Health related detections				
Barium[1]	mg/L	0.7	0.03 – 0.035	0.03
Boron[1]	mg/L	4	<0.02 – 0.034	0.03
Fluoride	mg/L	1.5	0.3 – 0.35	0.325
Manganese unfiltered	mg/L	0.5	0.055 – 0.18	0.101

Parameter	Unit	ADWG guideline value	Chittering borefield raw source	
			Range	Median
Nitrate as nitrogen[1]	mg/L	11.29	0.039 – 0.21	0.1245
Nitrite as nitrogen[1]	mg/L	0.91	0.007 – 0.011	0.009
Sulphate[1]	mg/L	500	18	18

Note: 1. Limited sampling available

4.5.3 Groundwater users

A search of the WIN Sites dataset of groundwater bores within WA was conducted for a 2 km buffer of the project alignment, where 81 bores were identified within the search area. The bores are owned by a variety of asset owners including state government, commercial agriculture, private owners and a number that currently have no owner or no asset owner was identified. The purpose of the bore installations included household/domestic use, production, irrigation, livestock, exploration and monitoring. A summary of the WIN Sites dataset is tabulated in Appendix B and the bore locations are presented in Figure A.8.

4.5.4 Groundwater allocation plan

The north-south alignment of the project area is located within the *Gingin Groundwater Allocation Plan 2015* (Figure A.9). The Plan covers several aquifers within the project area including the Perth surficial aquifer, the Mirrabooka aquifer (west of the Darling Scarp), fractured rock aquifer (east of the Darling Scarp) and the Leederville-Parmelia aquifer (west of the Darling Scarp) discussed previously. The amount of groundwater abstracted for water supply from the Leederville-Parmelia aquifer within the project area is presented in Table 4-6 and the allocation limits for the surficial, Mirrabooka and Fractured Rock aquifers within the project area are presented in Table 4-7.

Table 4-6: Excerpt of volumes license to water service providers servicing towns within the Gingin plan area (Department of Water, 2015)

Town	Subarea	Aquifer	Total license volume (ML/year)	Volume abstracted 2012-13 (ML/year)
Dandaragan, Gingin, Bindoon and Chittering	Cowalla	Leederville-Parmelia	1382.7	197.6

Table 4-7: Excerpt of allocation limits for the Gingin plan area (Department of Water, 2015)

Sub area	Aquifer	Allocation limit components (ML/year)				
		Allocation limit	Licensable		Unlicensable	Reserved water
			General	Public water supply	Exempt	Public water supply
Bindoon	Surficial	2400	1925	0	475	0
Central Scarp	Mirrabooka	1500	1135	0	365	0
	Fractured Rock	50	50	0	0	0
Southern Scarp	Mirrabooka	800	285	0	515	0
	Fractured Rock	50	50	0	0	0

Groundwater remaining in the aquifers after the allocation limit were set to support groundwater dependent environments and social values, support baseflows in the Gingin Brook and Moore River and protect aquifers from seawater intrusion (Department of Water, 2015). The estimated percentage of recharge left in these aquifers is presented in Table 4-8.

Table 4-8: Excerpt of percentage of recharge retained in aquifers within the Gingin plan area (Department of Water, 2015)

Aquifer	Percentage of recharge left in the aquifer
Surficial	20
Mirrabooka	80
Leederville-Parmelia	10

4.6 Conceptual hydrogeological model

A conceptual hydrogeological model for the site is presented in Figure A.10. Five systems have been considered in the hydrogeological model: surface water, surficial groundwater, two regional aquifers and an artesian aquifer.

The conceptual model comprises four aquifers that may be directly and indirectly impacted upon by the project including:

- A surficial aquifer comprising localised perched groundwater flows within colluvial and lateritic sediments and localised alluvial deposits comprising a variable mixture of clays, silts, sands, gravels and bands of ferricrete. It is anticipated that the proposed road cuttings (up to approximately 16.1 m height) will intercept perched flow and that high proposed fill areas (up to approximately 17.2 m height) may locally redistributed flow paths and flow rates of the surficial aquifer. Recharge of the aquifer is due to rainfall events, where discharge from the system goes to surface water drainage lines and infiltrates to the Mirrabooka and fractured rock aquifers.
- The Mirrabooka aquifer is one of two regional aquifers in the project area which comprises variably lateritised sand and clay geological units underlain by siltstones, claystone, shale and sandstone on the western side of the Darling Fault. The Mirrabooka aquifer may be intercepted by proposed road cuttings and the lateritised units will have variable zones of permeability and flow paths due to the heterogeneous nature of lateritised material. Recharge to the aquifer is from the surficial aquifer and from the northern area of the Mirrabooka aquifer, which induces groundwater flow to the south and south east. The aquifer discharges to the Gingin Brook and superficial aquifer near the Swan River (Commander P. , 2003). The aquifer is used for a number of purposes including irrigation, domestic and livestock due to its typically non-saline water quality and zones of relatively higher yield.
- The fractured rock aquifer is the second of two regional aquifers in the project area that comprises variably lateritised granitic and metamorphic rock, which predominantly weathers to clay material and the degree of weathering decreases with depth to a saprolitic profile. The permeability and yield of the aquifer is anticipated to be relatively low with groundwater typically at the base of the saprolite (up to approximately 25 m depth below ground) and in some bedrock fractures (Commander P. , 2003). Groundwater springs being recorded at the base of the laterite (Commander P. , 2003). The aquifer also supports groundwater dependent wetlands along the Brockman River. Proposed road cuttings are anticipated to intercept the fractured rock aquifer, particularly within the laterite and saprolite profiles, and proposed fill areas may also cause localised consolidation within the aquifer closer to the ground surface and redistribute flow paths. The aquifer is primarily used for domestic use due to its variable saline content and low yields.
- The Leederville-Parmelia aquifer represents the deeper semi-confined aquifer which becomes confined towards the south. The aquifer is used for Perth's metropolitan water supply and locally to the project area it is pumped to supply town water to Bindoon due to its relatively higher yields and non-saline

water quality. Earthworks for the project are not anticipated to intercept this aquifer as it is typically between 150 and 250 m below the ground surface in the project area, however the aquifer is recharged from the surficial aquifer approximately 15 km west of the project area where the overlying aquitard is absent.

4.6.1 Surrounding groundwater users

A search of the WIN Sites dataset of groundwater bores within WA was conducted for a 2 km buffer of the project alignment, where 88 bores were identified within the search area and are used for a variety of purposes including household/domestic use, production, irrigation, livestock, exploration and monitoring. The bores are primarily founded within the surficial, Mirrabooka and fractured rock aquifers, however their current operational status is unknown.

4.6.2 Surrounding water access licenses

The WA DWER has designated a wellhead protection zone around the Bindoon-Chittering water reserve. The 300 m wellhead protection zone is intended to protect the drinking water from contamination and is proclaimed under the *Country Areas Water Supply Act 1947*. The proposed alignment is approximately 950 m east of the wellhead protection zone boundary, and there are no other known operational water supply bores within 2 km of the project area.

4.7 Groundwater dependent ecosystems

A review of the BoM Groundwater Atlas indicates the proposed alignment intersects several Groundwater Dependent Ecosystems (GDE). The ecosystems intersected include aquatic and terrestrial ecosystems which are described as (Commonwealth of Australia, 2017):

- Aquatic ecosystems – rely on the surface expression of groundwater, which includes surface water ecosystems which may have a groundwater component, such as rivers, wetlands and springs.
- Terrestrial ecosystems – rely on the subsurface presence of groundwater, which includes all vegetation ecosystems

Many of aquatic GDEs in the project have been identified under the *Environmental Protection (Swan Coastal Plain Lakes) Policy 1992.* The Gingin Groundwater Allocation Plan also indicates that the Moore River, Gingin Brook and Moondah Brook are dependent upon groundwater base flow from aquifers that the proposed alignment intersects. The aquatic and terrestrial ecosystems that are dependent on groundwater are presented in Figure A.11 and Figure A.12.

5. Assessment of potential construction impacts

The construction of the proposed alignment may impact upon aspects of groundwater including:

- Levels, flow, connectivity, and groundwater storage; particularly due to the influence of road cuttings and fill areas.
- Groundwater chemistry, from pollution caused by spills and leakages of plant on site or water usage practices on site. Excavation across aquifer boundaries can also lead to cross contamination of aquifers.
- Groundwater users, due to interference with the current groundwater regime where anthropogenic users and groundwater dependent ecosystems are dependent upon particular groundwater levels and quality.

5.1 Impact on groundwater levels, flow and connectivity

The proposed alignment has road cuttings up to 16.1 m height and fill areas up to 17.2 m height, which may intersect and/or locally affect the surficial aquifer's current groundwater regime characteristics and further impact upon the regional aquifers. The preparation of the cut and fill foundations will include compaction of the surficial materials that may comprise suitable existing in-situ material or imported engineered fill to replace unsuitable in-situ material. This foundation preparation is likely to create areas of lower permeability of the road foundation relative to the existing subsurface, which may reduce the infiltration of surface runoff to the surficial aquifer.

When the groundwater table is temporarily raised, such as due to rainfall recharge, the surficial aquifer may cause seepage out of the cut faces. Common practice is to capture this seepage in the temporary construction drainage network, which may be reused on-site or treated and disposed of. The capturing of groundwater seepage and surface waters will reduce the amount of infiltration and flow to the surficial aquifer and underlying regional aquifers. Free drainage of groundwater to the cut face will also locally reduce the groundwater level to the cutting.

The placement of temporary and permanent fill during construction may cause localised consolidation of the surficial aquifer, which can reduce or increase groundwater flow rates, redistribute flow paths and affect the connectivity of the surficial aquifer to the regional aquifer depending on the material used and the degree of compaction applied. The consolidation can create a zone of lower or higher permeability that could raise the groundwater level in the adjacent higher permeability areas, particularly following a rainfall recharge event.

Groundwater dewatering may be required to facilitate construction activities, where the groundwater levels are relatively close to the surface and/or interfering with construction, such as the construction of the Brockman River bridge. It is likely that dewatering will more likely be required in lower lying areas where GDEs are common and sensitive to changes in groundwater. Similarly consideration of the duration and quantity of groundwater abstraction for construction will have a varying impact upon the groundwater levels and the effects on groundwater dependent ecosystems. Both dewatering and abstraction locally reduce the groundwater table in a conical shape around the extraction point, and induce flow towards this point.

Additional water used for construction activities such as dust suppression or subsurface drilling, is considered unlikely to affect the surficial aquifer as they are typically limited in their extent and duration.

5.2 Impact on groundwater chemistry

During construction there is the potential for hydrocarbon spills or leaks to contaminate the surficial aquifer and potentially contaminate the regional aquifers. Depending upon the hydrocarbon type this contamination may float on top of the groundwater table or sink to the base of the regional aquifer. Contamination from hydrocarbons is typically mitigated with storage safeguards, mandatory spill kits and plant maintenance which are discussed in Section 8 of this report.

Depending on the depth of excavation there is potential for cross aquifer contamination. Most of the cuts will occur in the rock containing the surficial aquifer. Given the surficial aquifer likely drains into the underlying aquifer it is considered unlikely that any cuts would greatly impact the underlying water quality. Any free draining water from the cut would likely be captured into surface storages and would be given minimal opportunity to infiltrate into the underlying aquifer.

PASS are present in the project area and could oxidise if the groundwater level changes during construction particularly due temporary activities such as dewatering or groundwater abstraction, or due to permanent earthworks. If the PASS oxidise to become actual acid sulfate soils (AASS), plumes of acidic groundwater may be released into the environment impacting upon GDEs and other groundwater user's ability to utilise their allocated resources. If the groundwater level is to be altered, the zone of influence of the drawdown curve should be considered. This is particularly relevant for the construction of the bridge and cuttings located in an area of low probability (6-70% chance) of ASS around the Brockman River.

If groundwater is abstracted and used on site for construction activities, consideration should be given to the salinity levels of the water, cumulative volume required and where the water is to be disposed of. Limited groundwater salinity data is available for the project area, but generally more saline groundwater is anticipated towards the southern end of the site. If relatively more saline groundwater from the southern end of the site is used in areas of lower salinity, additional salts will be introduced into the subsurface profile that can leach into less saline groundwater affecting the water quality.

5.3 Impact on groundwater users

Impacts to groundwater users are anticipated if groundwater levels are reduced within the vicinity of groundwater dependent ecosystems or PASS sites due to potential environmental degradation or adverse changes in groundwater chemistry. Otherwise considering the relatively low and variable yields of the aquifers that may be affected by the construction, no other significant impacts on groundwater users are anticipated.

6. Assessment of potential operational impacts

During the operational phase of the project, the groundwater regime is unlikely to be greatly affected by the project as minor changes in the groundwater regime caused by project earthworks are anticipated to have reached an equilibrium. Rainfall recharge events are likely to cause the most change in groundwater levels and flow.

The operational phase of the project may impact upon aspects of groundwater including:

- Levels, flow and connectivity, due to potential redistributed flow paths.
- Groundwater chemistry, from pollution caused by spills and leakages of road user vehicles or drainage maintenance issues.
- Groundwater users, due to interference with the current groundwater regime where anthropogenic users and groundwater dependent ecosystems are dependent upon particular groundwater levels and quality.

6.1 Groundwater levels, flows and connectivity

No major effects on groundwater levels, flows or connectivity are anticipated during the operational phase of the project. Recharge to the surficial aquifer is still anticipated to be primarily due to rainfall, with a slight reduction in infiltration to the surficial and regional aquifers due to the impermeable and drained nature of the road surface area, which the equivalent area would have normally contribute to infiltration prior to construction. Minor zones of reduced permeability which may be created by fill areas are not anticipated to have a great impact upon the surrounding groundwater level, and any changes in groundwater level due to these zones are anticipated to be short term following rainfall recharge.

6.2 Impact of groundwater chemistry

There are no major impacts expected upon groundwater chemistry during the operational phase of the project. It is anticipated that minor hydrocarbon leakages from road users will be captured as runoff by the project drainage network, where any impacts are likely to be minor and short term. As dewatering measures are not for operational activities, impacts upon PASS are not anticipated.

6.3 Impact on groundwater users

As dewatering activities are not required for the operational phase of the project, major impacts are not anticipated to affect groundwater users, including groundwater dependent ecosystems.

7. Proposed mitigation measures

Mitigation measures are required to minimise the impact of the project's construction and operation on groundwater. Controls to be implemented for groundwater protection are listed below for construction and operational phases respectively.

7.1 Construction phase groundwater controls

The most significant changes in groundwater regime are anticipated to be from dewatering or abstraction activities, where the main impacts are anticipated to be in relation to:

- ASS and GDEs
- Groundwater salinity

7.1.1 ASS and GDEs

During the construction phase there maybe impacts upon GDEs and groundwater quality due to PASS becoming AASS during dewatering/abstraction activities. Additionally these construction activities could impact upon GDEs, which would degrade if the groundwater levels are significantly altered. To minimise impacts upon GDEs and PASS, dewatering and abstraction should be limited in both its spatial and temporal extents. Dewatering and abstraction activities should give consideration to the following:

- The drawdown curve zone of influence
- Duration of dewatering
- Depth and extent of PASS within the anticipated zone of influence
- Distance to GDEs from the abstraction point

7.1.2 Groundwater salinity

During construction if groundwater is to be abstracted for construction activities, consideration should be given to the source groundwater salinity levels and the salinity levels of groundwater where the abstracted water is to be used. The abstracted groundwater salinity should not be significantly higher than the salinity levels of the groundwater in the area it is to be used. In order to minimise significant introduction of salts to groundwater with relatively lower salinity levels, which may affect GDEs and other groundwater users.

7.1.3 Other controls

Due to the low yields of aquifers in the project area, no other specific groundwater controls are anticipated. However, groundwater quality and levels should be regularly monitored during construction.

7.2 Operational phase groundwater controls

No specific groundwater controls are required for the operational phase of the project. Ongoing operational groundwater monitoring should be continued from the construction phase. In particular monitoring should remain in place at sites in close proximity to Deep cutting/fill locations, groundwater dependent ecosystems, where significant clearing of vegetation has occurred or if a local groundwater used has been affected.

8. Safeguards, management and mitigation

While the aquifers in the project area are anticipated to have low yields and variable levels, groundwater may be encountered during works, particularly minor seepage from cut faces and if dewatering or abstraction activities occur. If groundwater is encountered during the works, a Groundwater Management Plan should be implemented. Other safeguards and mitigation measures to be adopted before and during construction are presented in Table 8-1.

Table 8-1: Safeguards and mitigation measures

Impact	Environmental safeguard	Responsibility	Timing
Water pollution	• All fuels and chemical are to be stored in a secure, impervious bunded area at least 50 m from drainage receptors in the construction compound and in accordance with MSDS • All construction plant are to be equipped with spill kits and a Spill Response Procedure should be established for the project • A designated refueling zone for construction plant should be established in a impervious, bunded area in the construction compound • On site drainage measures should include bunds, basins, levees to manage clean and dirty water separately with run-off water reused where possible • Additional groundwater salinity testing should be conducted to establish the pre-construction salinity regime • A Groundwater Management Plan should be developed for the site and implemented if groundwater is encountered during the works	Contractor	Pre-construction and construction
Disturbance of PASS	• Minimise changes in groundwater levels, particularly within high probability ASS areas • Develop an ASS Management Plan to be triggered when ASS are disturbed	Contractor	Pre-construction and construction
Disturbance of GDEs	• Minimise changes in groundwater levels in GDE areas	Contractor	Construction

9. Residual Impacts

Following the implementation of the proposed mitigation measures, safeguards and management procedures discussed in Section 7 and 8 there may be some residual impacts from the construction and operation of the project. Anticipated residual impacts during construction and operation phases are discussed below, however these are not anticipated to be significant.

9.1 Construction phase

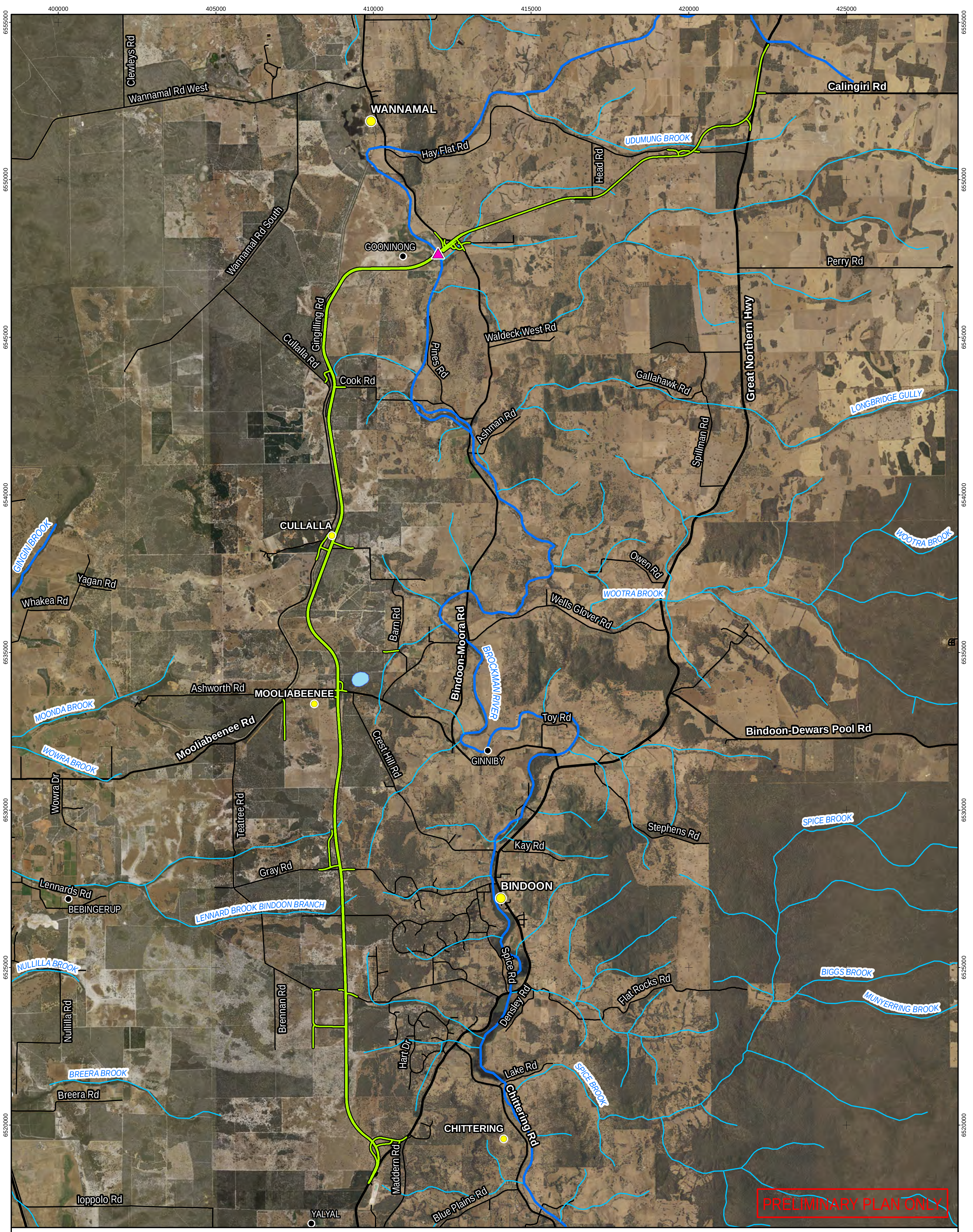
During construction hydrocarbon leaks and spills may occur on site, which could contaminate groundwater if clean-up or containment procedures are not implemented before the contaminate reaches the construction or natural drainage network. However, considering the mitigation measures and procedures that should be implemented for leaks and spills, it is unlikely that this event will occur and if it does occur impacts are likely to be minor.

9.2 Operation phase

During the operation phase there are unlikely to be significant residual impacts on groundwater. Contamination could occur in the event of a significant leak or spill, such as from a vehicular accident where the contaminated cannot be contained and clean-up prior to being received by the road or natural drainage network. However, as the project is designed to improve motorists safety, the likelihood of a major vehicular accident is anticipated to be low.

Appendix A. Figures

Figures



Legend

- Proposed Bindoon Bypass Bridge
- Proposed Bindoon Bypass Centreline (10-05-2018)
- Town or Centre
- Populated Locality
- Locality
- Major Watercourse
- Minor Watercourse
- Lake
- Highway
- Major Road
- Minor Road

Data Source: Main Roads WA, Landgate, DMP

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0 1,000 2,000
Metres

Scale at A3
1:110,000

Coordinate System: GDA 1994 MGA Zone 50

ARUP TRADING AS ASJV
JACOBS

Main Roads Western Australia
Client

Project
Great Northern Highway
Muchea to Wubin Upgrade Stage 2

Figure A-1
Project alignment

Drawing No	Issue
GNH-CN12-RW01-GIS-0018	B

Task No	Drawing Status / Other
1717	Draft / Other Info

Date	By	Chkd	Appd
22/06/2018	BS	TR	JW

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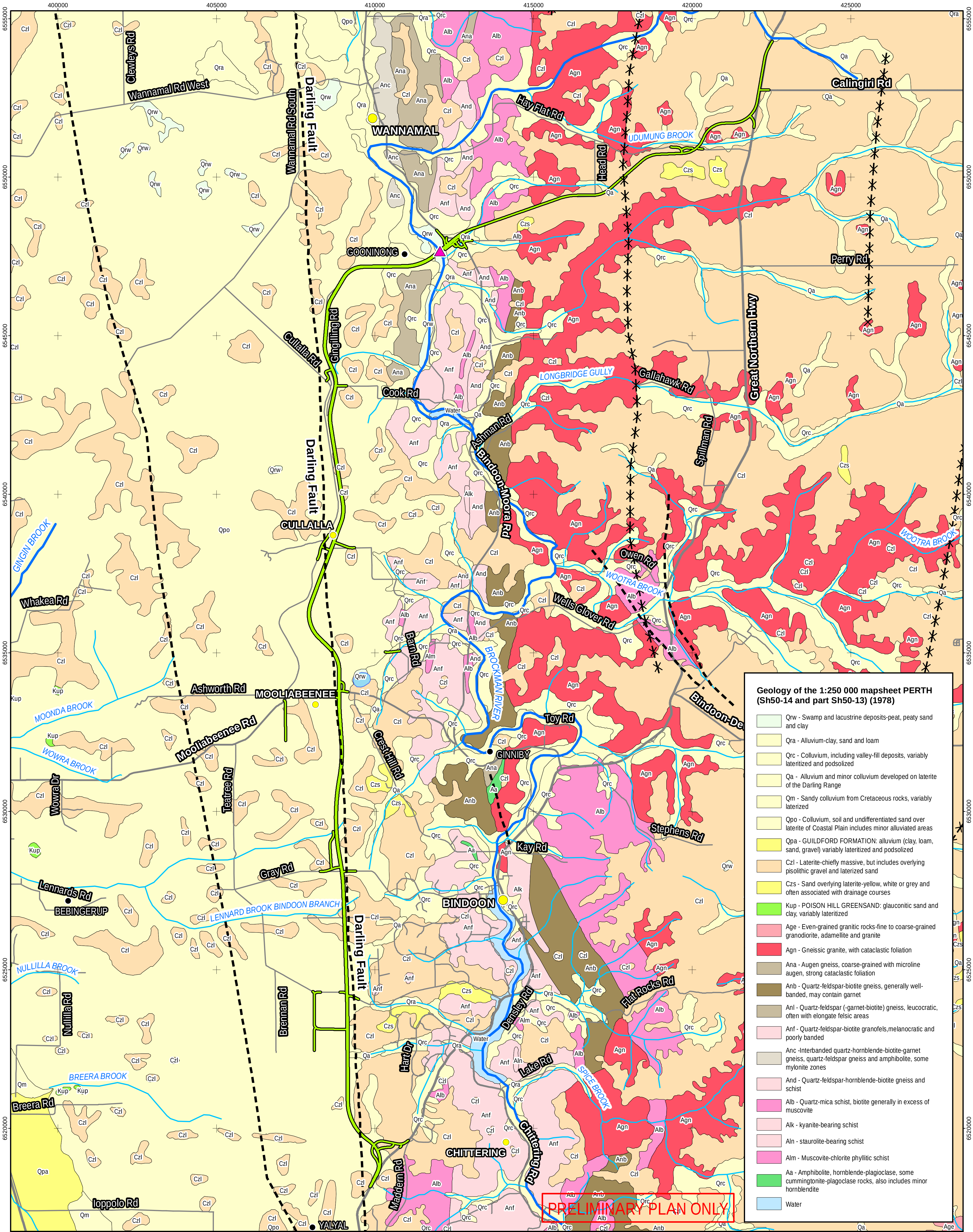

Legend

- 2.5m Interpolated Dyke
- Linear Structure
- Proposed Bindoon Bypass Bridge
- Proposed Bindoon Bypass Centreline (10-05-2017)
- Town or Centre
- Populated Locality
- Locality
- Major Watercourse
- Minor Watercourse
- Lake
- Highway
- Major Road
- Minor Road

Data Source: Main Roads WA, Landgate, DMP

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0 1,000 2,000
Metres

Scale at A3
1:110,000

Coordinate System: GDA 1994 MGA Zone 50

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Main Roads Western Australia
Client

Project
Great Northern Highway
Muchea to Wubin Upgrade Stage 2

Figure A-2
Regional geology

Drawing No	Issue
GNH-CN12-RW01-GIS-0019	C

Task No	Drawing Status / Other
1717	Draft / Other Info

Date	By	Chkd	Appd
22/06/2018	BS	TR	JW

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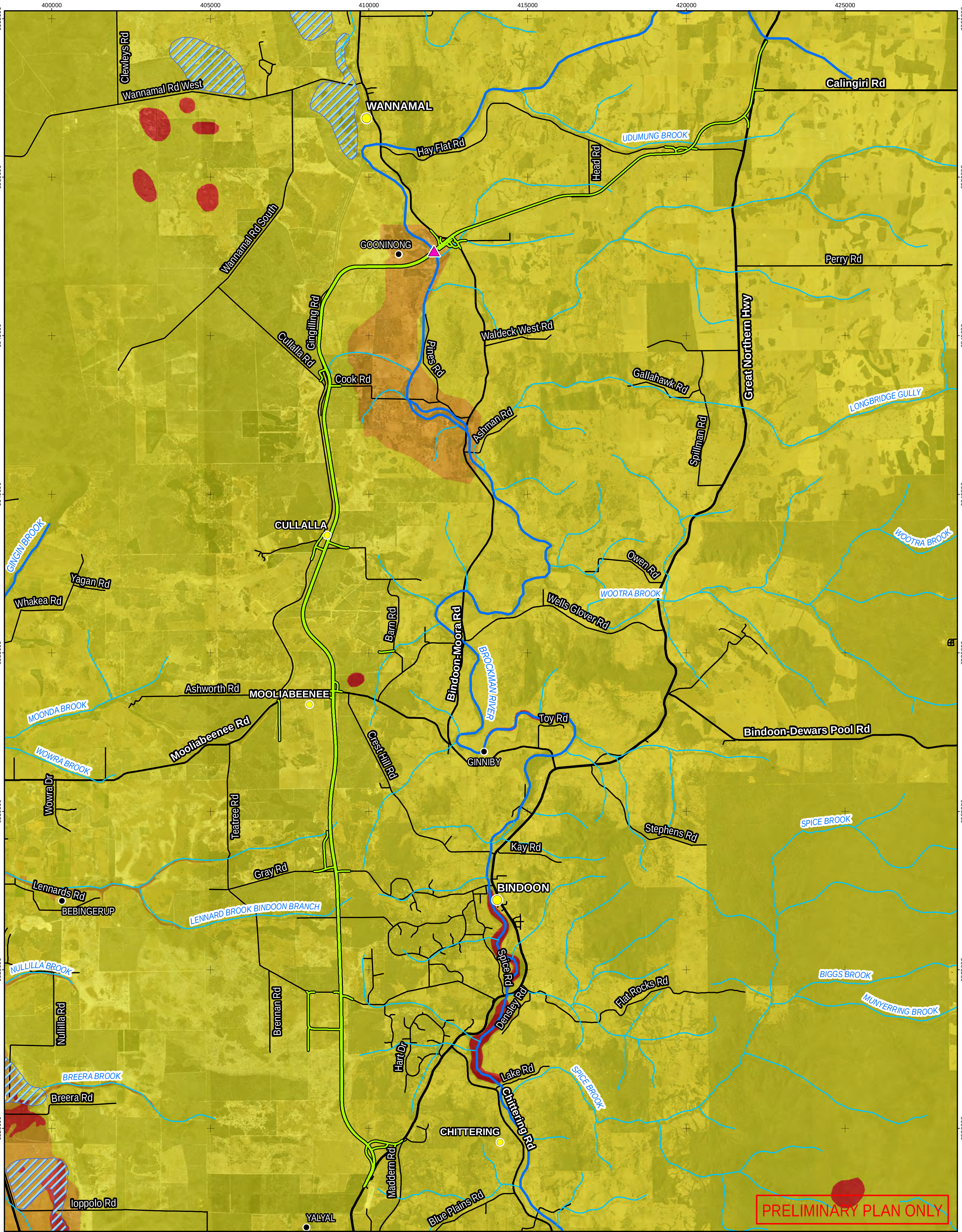

Legend

Atlas of Australian Acid Sulfate Soils (19-02-13)

Probability of Occurrence

- A: High; >70% chance
- B: Low; 6-70% chance
- C: Extremely low; 1-5% chance
- Proposed Bindoon Bypass Bridge
- Proposed Bindoon Bypass Centreline (10-05-2018)

- Town or Centre
- Populated Locality
- Locality
- Major Watercourse
- Minor Watercourse
- Flat
- Highway
- Major Road
- Minor Road

Data Source: Main Roads WA, Landgate, DMP

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0 1,000 2,000
Metres

Scale at A3
1:110,000

Coordinate System: GDA 1994 MGA Zone 50

TRADING AS ASJV

Main Roads Western Australia
Client

Project
Great Northern Highway
Muchea to Wubin Upgrade Stage 2

Figure A-3
Acid sulfate soils

Drawing No	Issue
GNH-CN12-RW01-GIS-0020	B

Task No	Drawing Status / Other
1717	Draft / Other Info

Date	By	Chkd	Appd
22/06/2018	BS	TR	JW

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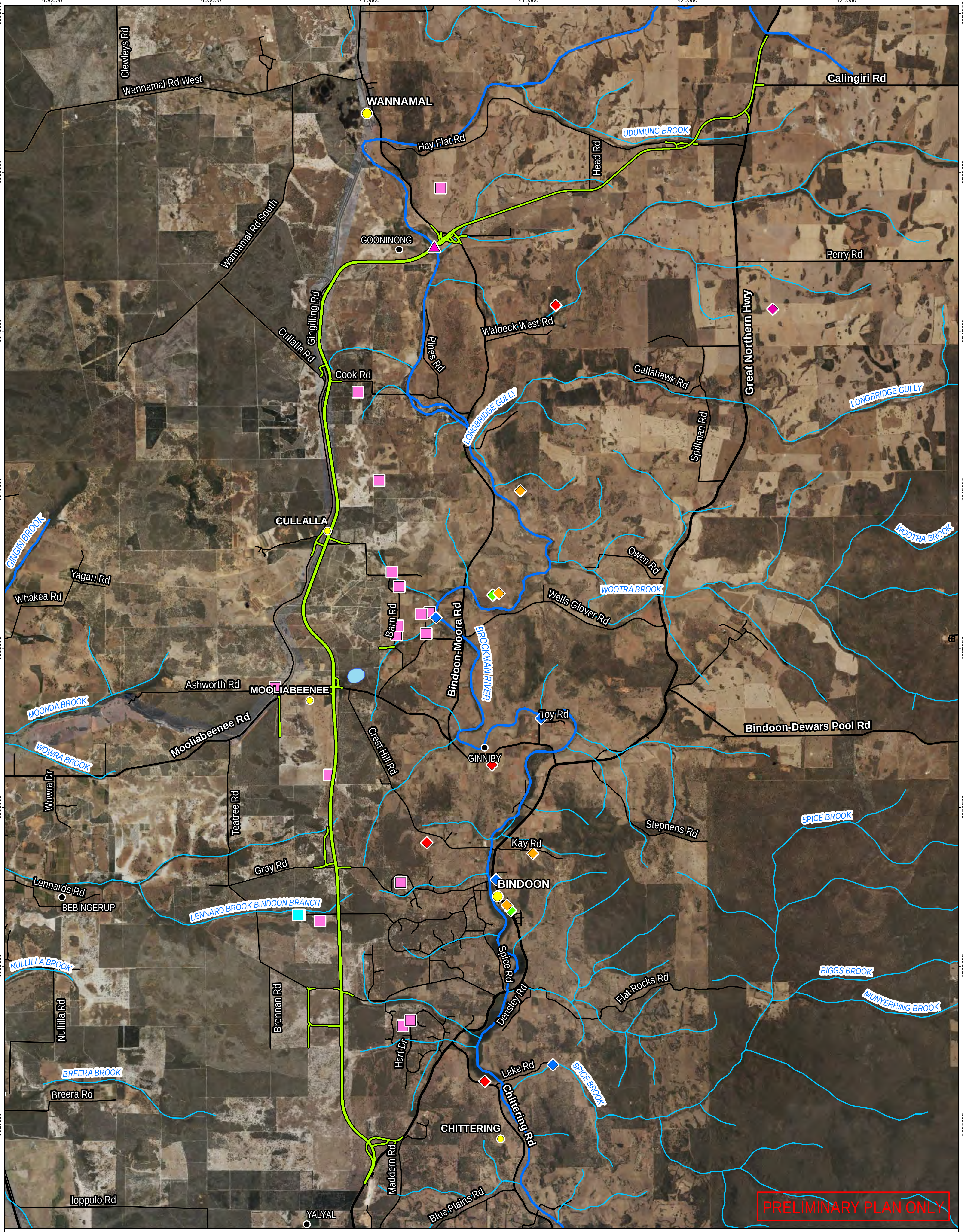

Legend

Groundwater bores classified by salinity
- Less than 500mg/L
- 500 - 1000mg/L
- 1000 - 3000mg/L
- 3000 - 7000mg/L
- Greater than 7000mg/L

Groundwater bores classified by flow
- 0 - 100 KL/day
- >1000 kL/day
- Proposed Bindoon Bypass Bridge
- Proposed Bindoon Bypass Centreline (10-05-2018)

- Town or Centre
- Populated Locality
- Locality
- Major Watercourse
- Minor Watercourse
- Lake
- Highway
- Major Road
- Minor Road

Data Source: Main Roads WA, Landgate, DMP

Joint Venture Partners:

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Metres

Scale at A3
1:110,000

Coordinate System: GDA 1994 MGA Zone 50

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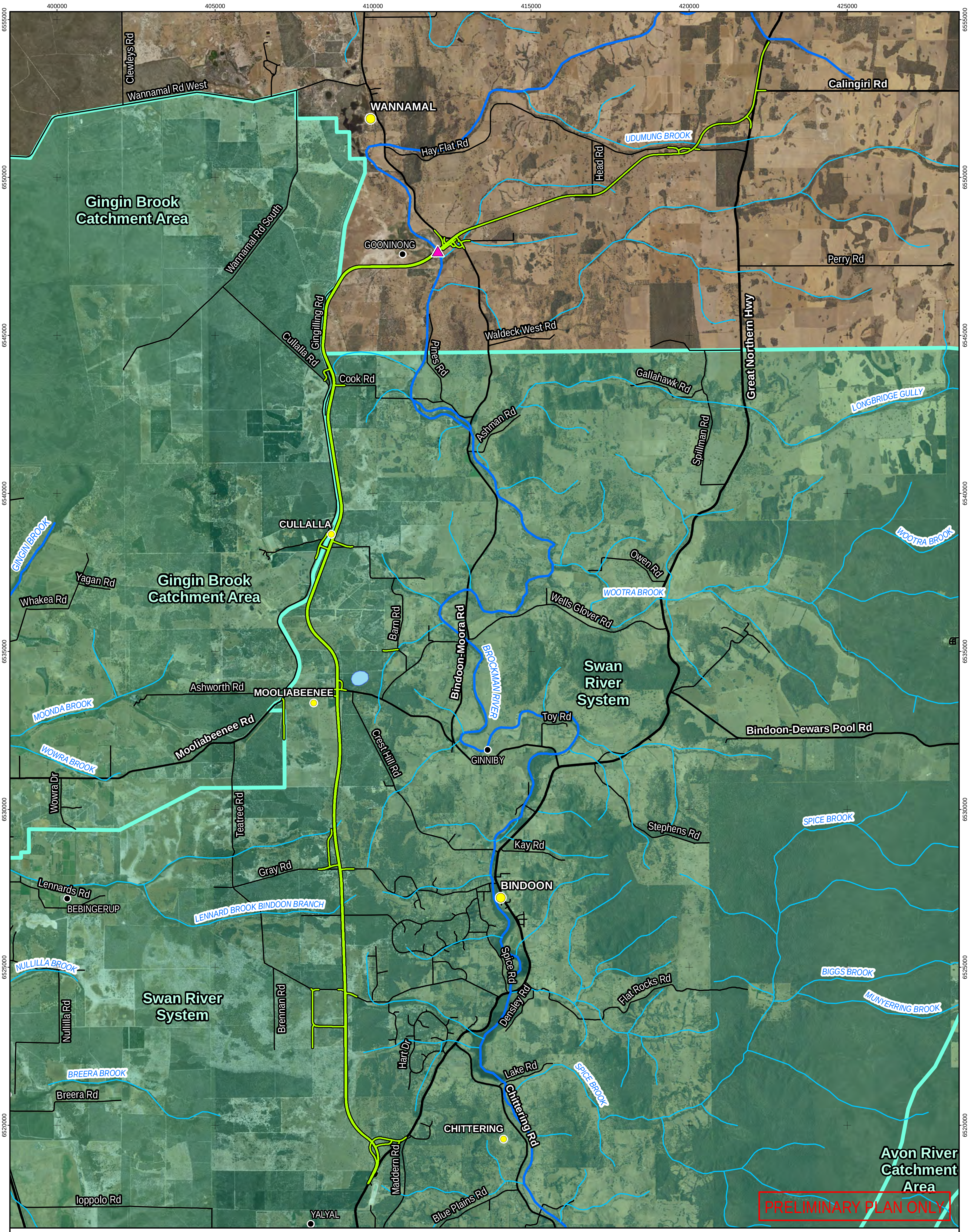
Muchea to Wubin Upgrade Stage 2

Figure A-4
Groundwater salinity and flow (WIN Site database)

Drawing No	Issue
GNH-CN12-RW01-GIS-0021	C

Task No	Drawing Status / Other
1717	Draft / Other Info

Date	By	Chkd	Appd
28/06/2018	BS	TR	JW



Legend

RIWI Act Surface Water Areas And Irrigation Districts

- Surface Water Area
- Proposed Bindoon Bypass Bridge
- Proposed Bindoon Bypass Centreline (10-05-2018)
- Town or Centre
- Populated Locality
- Locality
- Major Watercourse
- Minor Watercourse
- Lake
- Highway
- Major Road
- Minor Road

Data Source: Main Roads WA, Landgate, DMP

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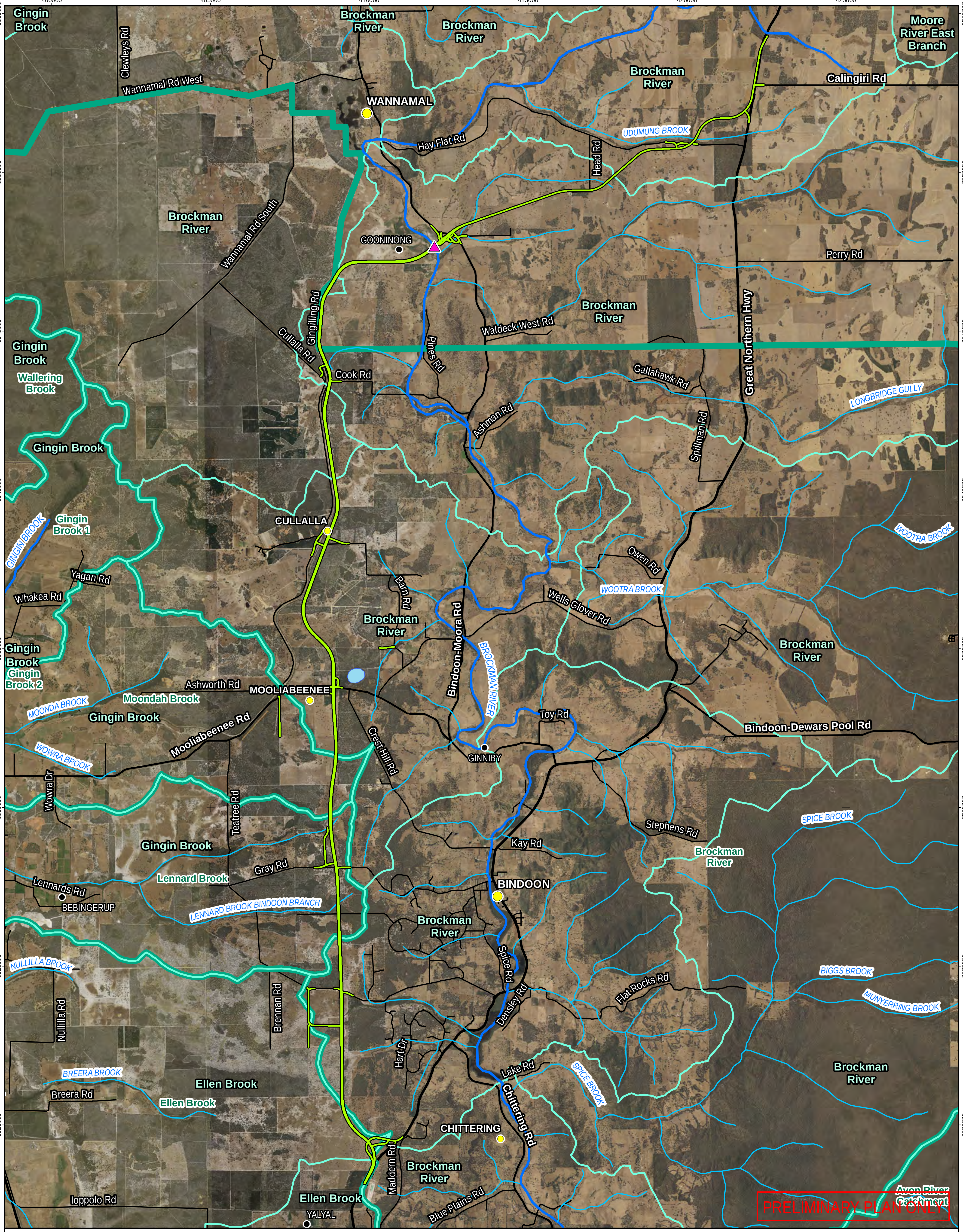
Figure A-5
RIWI proclaimed area

Drawing No			Issue
GNH-CN12-RW01-GIS-0022			C
Task No	Drawing Status / Other		
1717	Draft / Other Info		
Date	By	Chkd	Appd
22/06/2018	BS	TR	JW

MXD Location: \\Jacobs.com\PERProjects\PBIF\Projects\PB50732\Technical\GIS\ArcMap\RoadWorks\CN12\GNH-CN12-RW01-GIS-0022-C.mxd



Legend

- Surface Water Resource Proclaimed Portions (DWAID)
- Subcatchments (DoW)
- Proposed Bindoon Bypass Bridge
- Proposed Bindoon Bypass Centreline (10-05-2018)
- Town or Centre
- Populated Locality
- Locality
- Major Watercourse
- Minor Watercourse
- Lake
- Highway
- Major Road
- Minor Road

Data Source: Main Roads WA, Landgate, DMP

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Muchea to Wubin Upgrade Stage 2

Figure A-6
Surface water sub-catchments

Drawing No	Issue
GNH-CN12-RW01-GIS-0023	B

Task No	Drawing Status / Other
1717	Draft / Other Info

Date	By	Chkd	Appd
22/06/2018	BS	TR	JW

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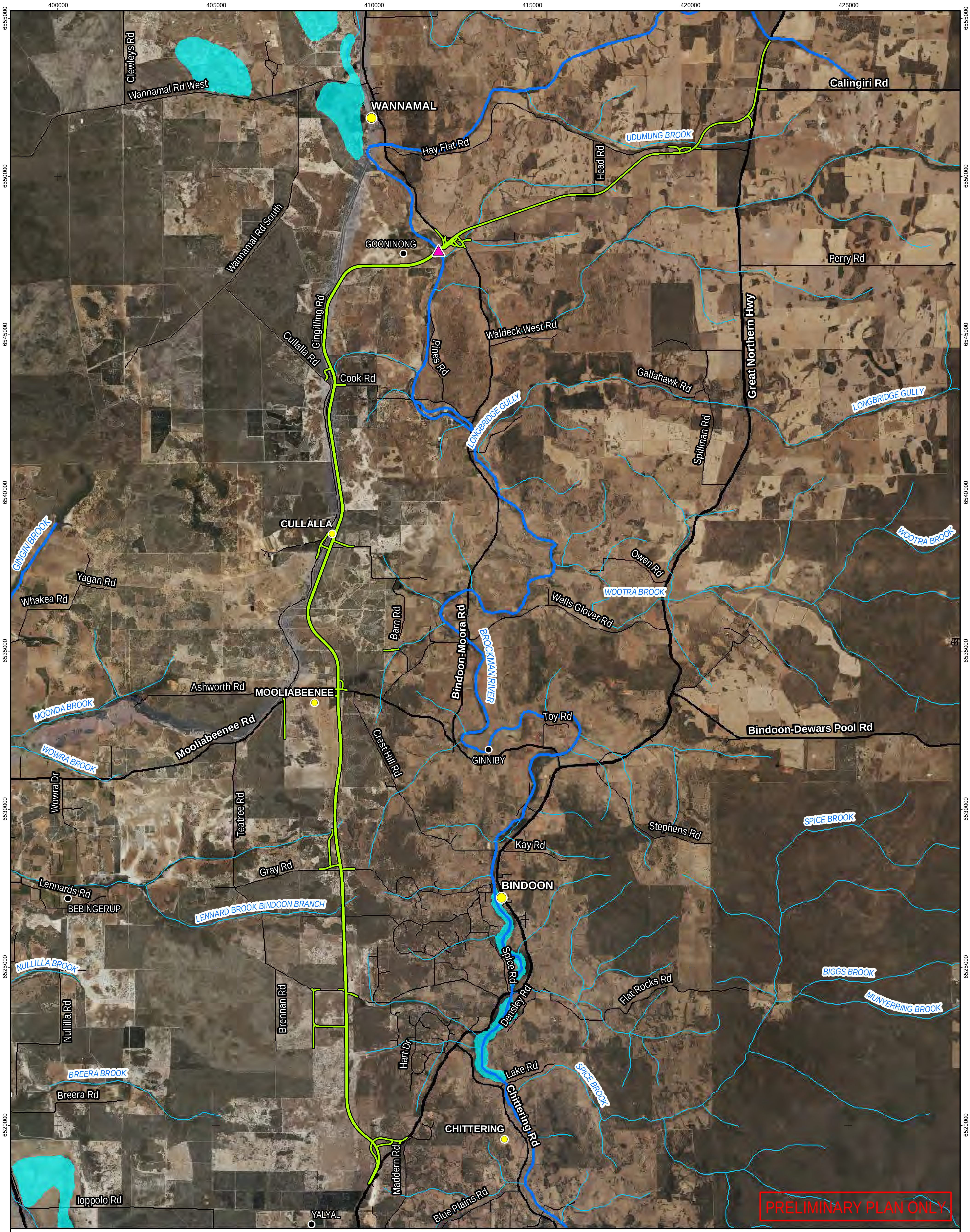

Legend

- Proposed Bindoon Bypass Bridge
- Proposed Bindoon Bypass Centreline (10-05-2018)
- Directory of Important Wetlands in Australia
- Major Watercourse
- Minor Watercourse
- Town or Centre
- Populated Locality
- Locality
- Highway
- Major Road
- Minor Road

Data Source: Main Roads WA, Landgate, DMP

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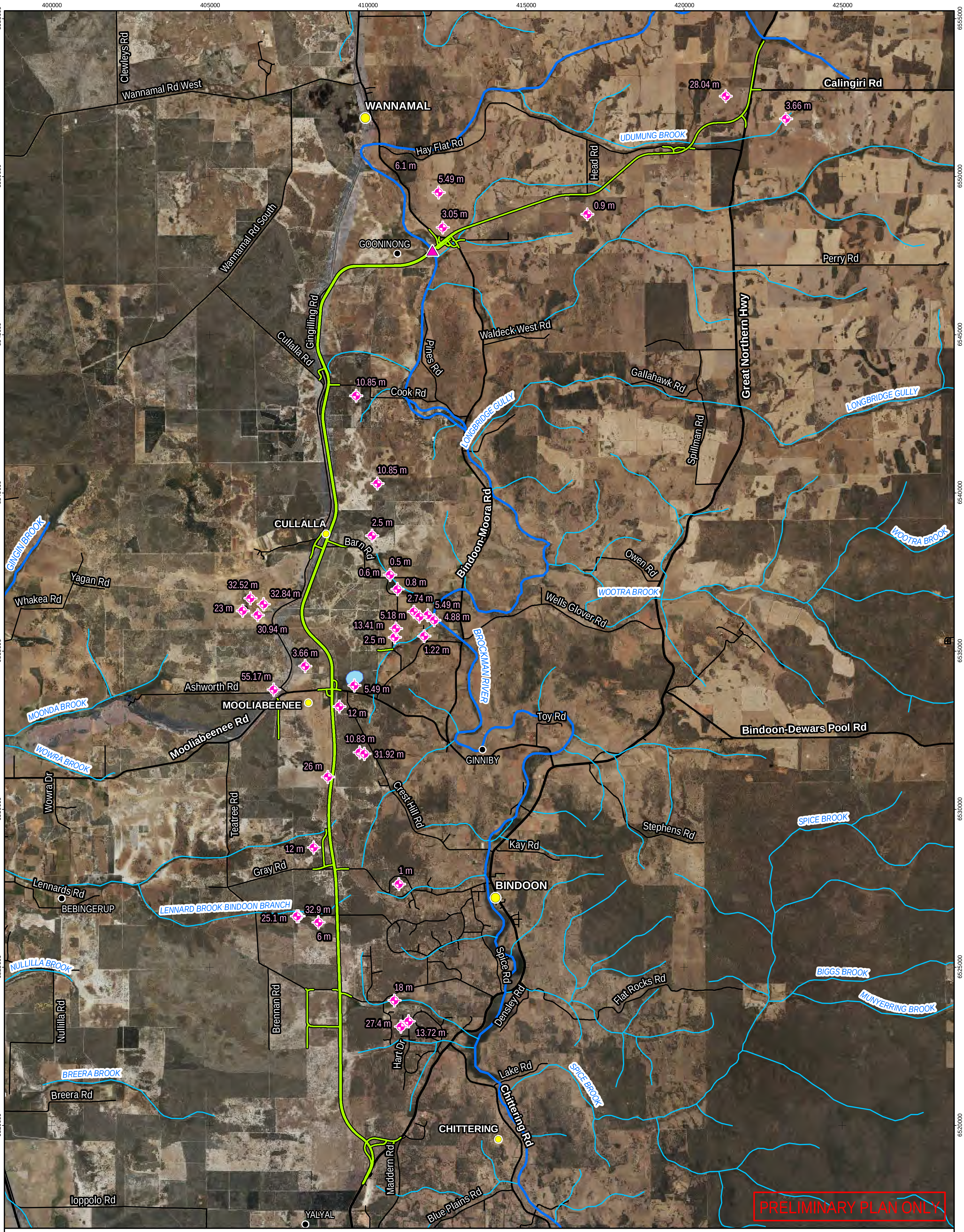
Great Northern Highway
Muchea to Wubin Upgrade Stage 2

Figure A-7
Directory of Important Wetlands in Australia

Drawing No	Issue
GNH-CN12-RW01-GIS-0024	D

Task No	Drawing Status / Other
1717	Draft / Other Info

Date	By	Chkd	Appd
16/07/2018	BS	TR	JW



Legend

- WIN Sites within 2km of Bypass with water levels
- Proposed Bindoon Bypass Bridge
- Proposed Bindoon Bypass Centreline (10-05-2018)
- Town or Centre
- Populated Locality
- Locality
- Major Watercourse
- Minor Watercourse
- Lake
- Highway
- Major Road
- Minor Road

Data Source: Main Roads WA, Landgate, DMP

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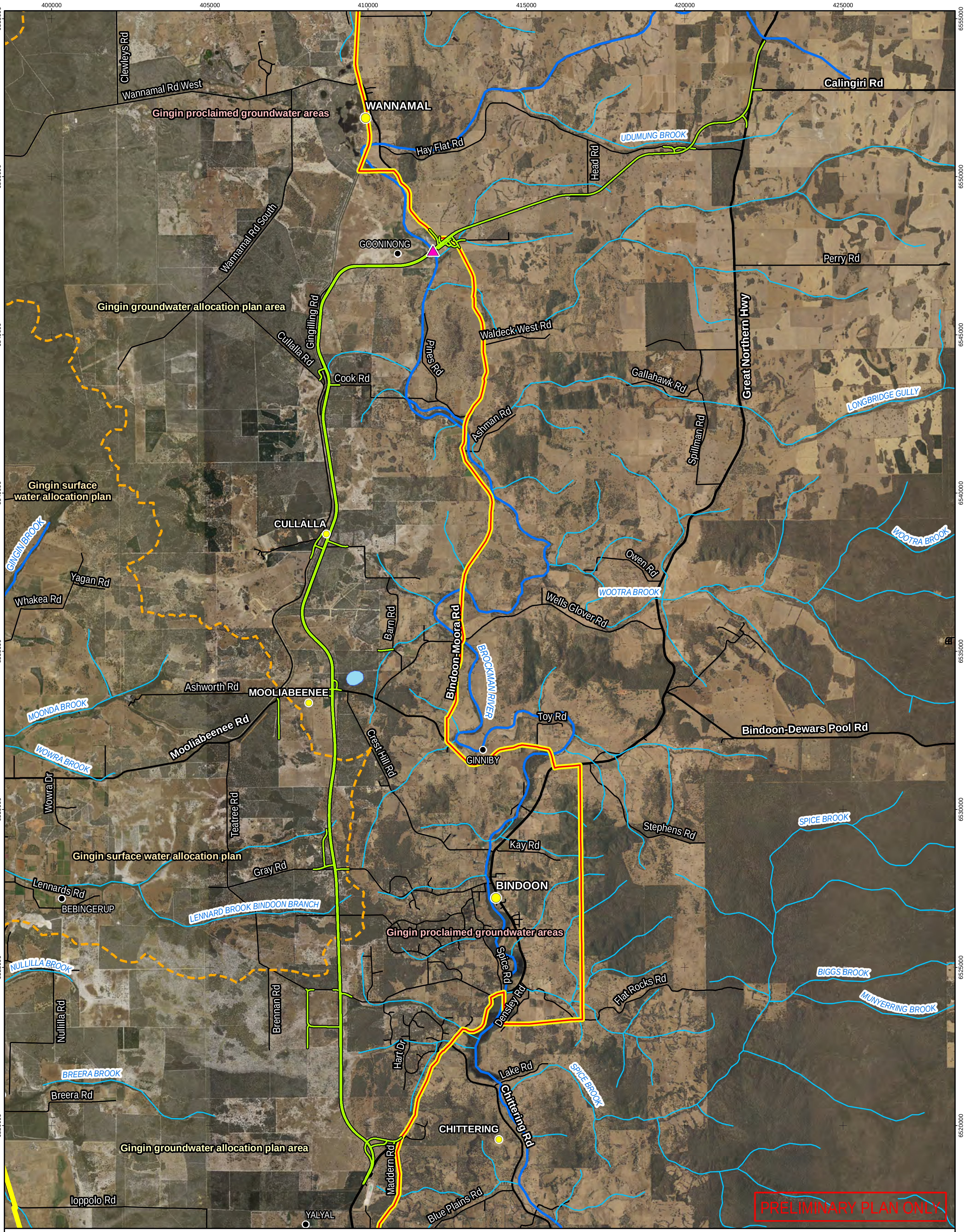
Figure A-8
WIN Site bore locations and groundwater levels

Drawing No	Issue
GNH-CN12-RW01-GIS-0025	B

Task No	Drawing Status / Other
1717	Draft / Other Info

Date	By	Chkd	Appd
16/07/2018	BS	TR	JW



Legend

- Gingin surface water allocation plan
- Gingin proclaimed groundwater areas
- Gingin groundwater allocation plan area
- Proposed Bindoon Bypass Bridge
- Proposed Bindoon Bypass Centreline (10-05-2018)
- Town or Centre
- Populated Locality
- Locality
- Major Watercourse
- Minor Watercourse
- Lake
- Highway
- Major Road
- Minor Road

Data Source: Main Roads WA, Landgate, DMP

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Coordinate System: GDA 1994 MGA Zone 50

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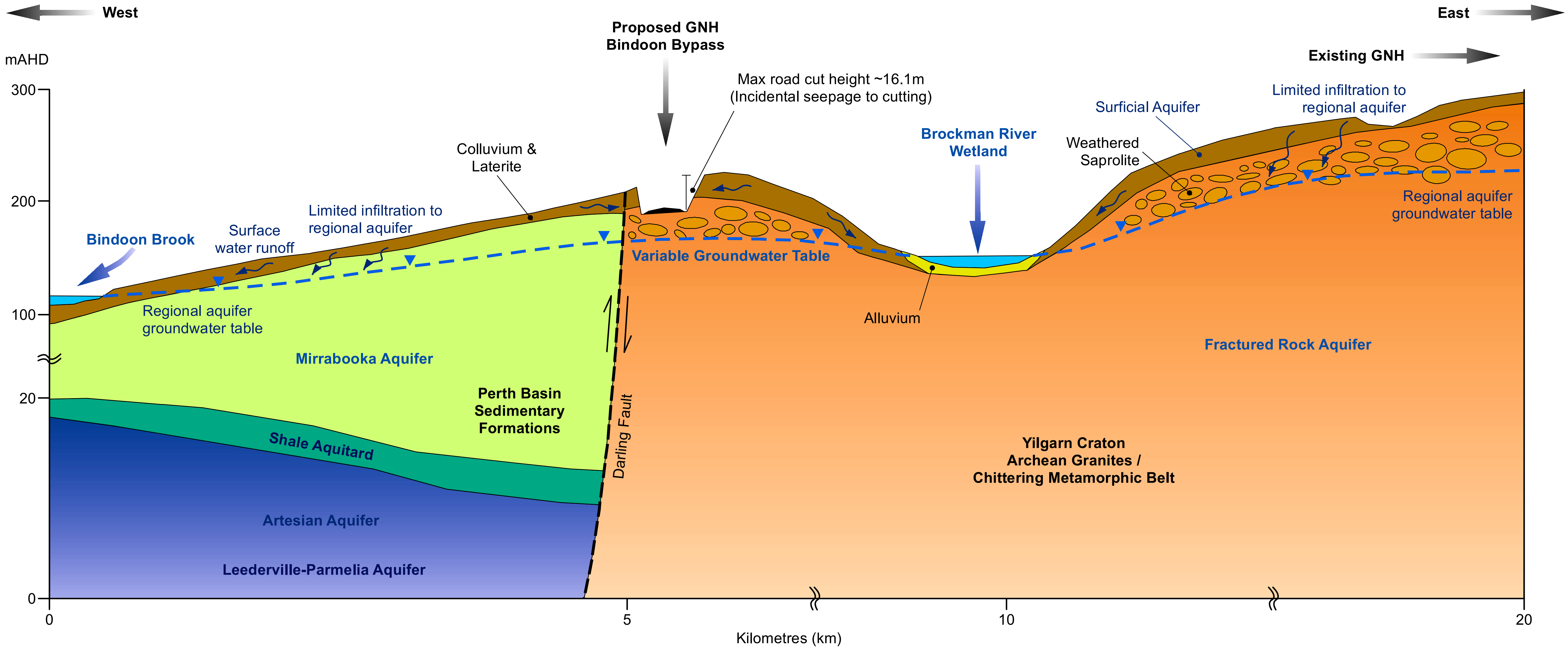
Figure A-9
Groundwater licensing areas

Drawing No	Issue
GNH-CN12-RW01-GIS-0026	B

Task No	Drawing Status / Other
1717	Draft / Other Info

Date	By	Chkd	Appd
22/06/2018	BS	TR	JW



PRELIMINARY PLAN ONLY

Legend

Conceptual hydrogeology

- Surface Water
- Weathered Saprolite
- Alluvium
- Shale Aquitard
- Surficial Aquifer
- Leederville-Parmelia Aquifer
- Mirrabooka Aquifer
- Fractured Rock Aquifer
- Fault
- Groundwater Level (GWL)

Data Source: Arup 2017

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Figure A-10
Conceptual hydrogeological model

Drawing No	Issue
GNH-CN12-RW01-GIS-0017	C

Task No	Drawing Status / Other
1717	Draft / Other Info

Date	By	Chkd	Appd
7/12/2017	BS	XX	XX

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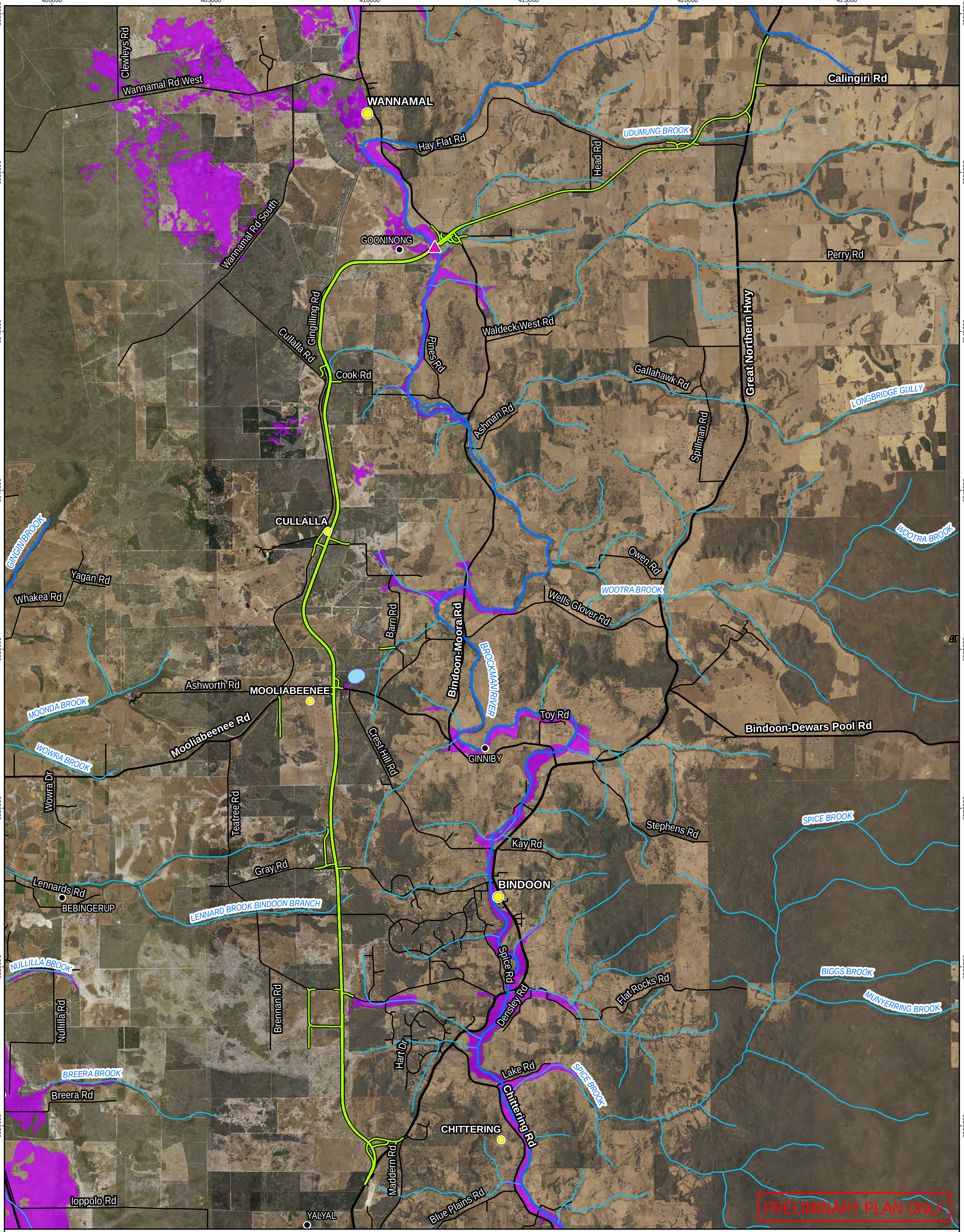

Legend

- Groundwater dependent ecosystems - Aquatic
- Proposed Bindoon Bypass Bridge
- Proposed Bindoon Bypass Centreline (10-05-2018)
- Town or Centre
- Populated Locality
- Locality
- Major Watercourse
- Minor Watercourse
- Lake
- Highway
- Major Road
- Minor Road

Data Source: Main Roads WA, Landgate, DMP

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Figure A-11
Groundwater dependent ecosystems - Aquatic

Drawing No	Issue
GNH-CN12-RW01-GIS-0027	B

Task No	Drawing Status / Other
1717	Draft / Other Info

Date	By	Chkd	Appd
22/06/2018	BS	TR	JW

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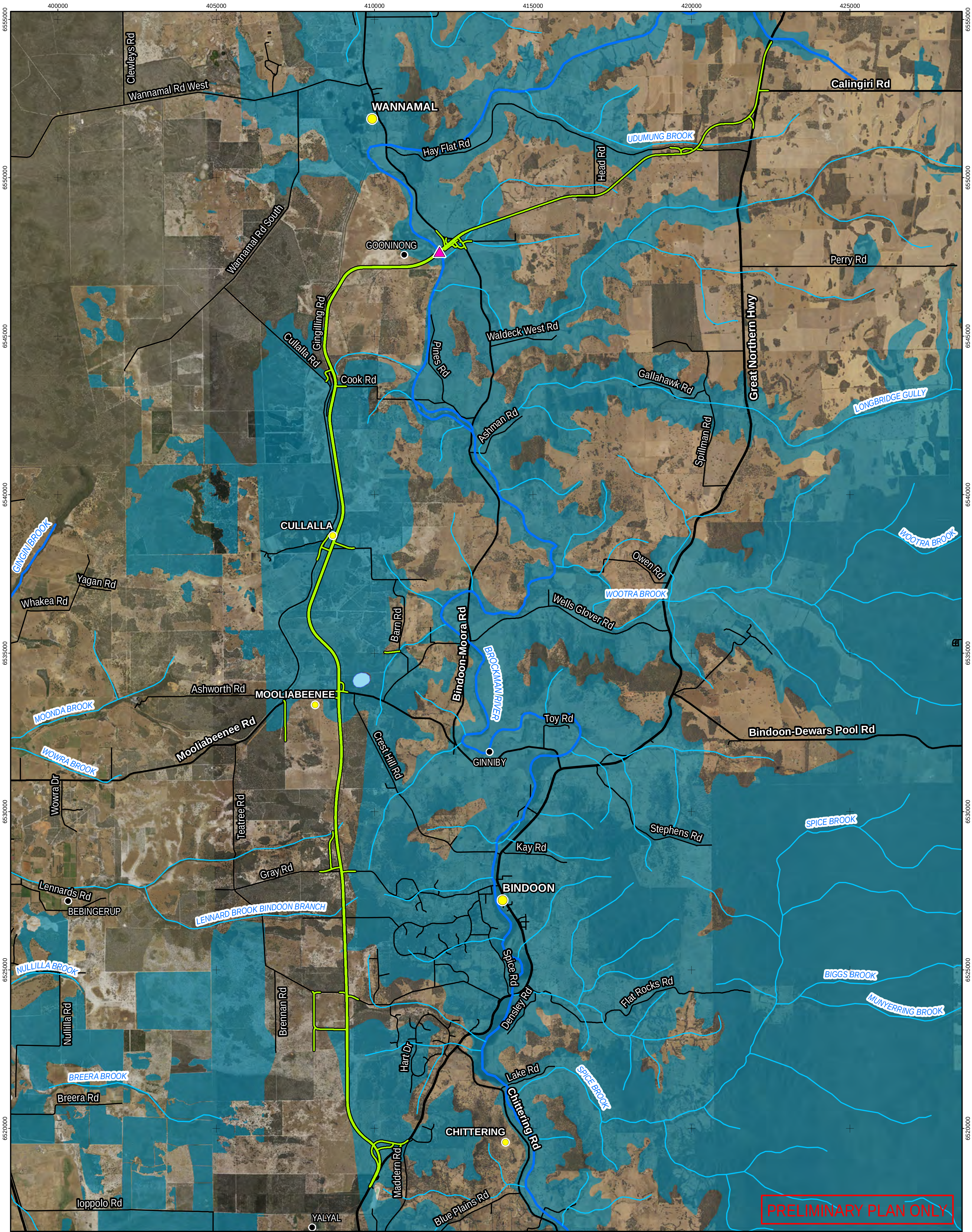

Legend

- Groundwater dependent ecosystems - Terrestrial
- Proposed Bindoon Bypass Bridge
- Proposed Bindoon Bypass Centreline (10-05-2018)
- Town or Centre
- Populated Locality
- Locality
- Major Watercourse
- Minor Watercourse
- Lake
- Highway
- Major Road
- Minor Road

Data Source: Main Roads WA, Landgate, DMP

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Coordinate System: GDA 1994 MGA Zone 50

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Figure A-12
Groundwater dependent ecosystems - Terrestrial

Drawing No	Issue
GNH-CN12-RW01-GIS-0028	B

Task No	Drawing Status / Other
1717	Draft / Other Info

Date	By	Chkd	Appd
22/06/2018	BS	TR	JW

Appendix B. WIN sites database

Type	Bore ID	Easting	Northing	Asset Owner	Current Purpose	Current Status	Date Drilled	Drilled Depth (m below ground level)	Response zone (below ground level) and aperture	Water Supply (m^3/day)	Static Water Level (m below ground level)	Total Dissolved Solids (mg/L)
Bore or Well	61710649	408501	6531749	Private Owner	Production	Unknown	20-09-2010	42	23-41m Inlet - Screen; Ap:1mm			
Bore or Well	61609423	410704	6537409	No Current Owner		Unknown	01-01-1900	14.3		20.7	0.	460
Bore or Well	61642035	409639	6538349	Private Owner		Unknown						
Bore or Well	61642443	406854	6538087	Private Owner	WRL linked	Unknown						
Bore or Well	61642447	408536	6539098	Private Owner	WRL linked	Unknown						
Bore or Well	61700696	406510	6525177	Department of Water		Proposed						
Bore or Well	61671492	408728	6534493	Private Owner		Unknown	01-09-1999	11.25				
Bore or Well	61609425	410937	6536954	No Current Owner		Unknown	01-01-1900	8.1		16.4	0.8	640
Bore or Well	61671490	408839	6534544	Private Owner		Unknown	01-09-1999	12.85				
Bore or Well	61609391	410693	6530820	No Current Owner	Exploration	Unknown	15-10-1978	9.5				
Bore or Well	61609508	410839	6523949	No Current Owner	Livestock	Unknown	21-05-1995	30	18-30m Inlet - Slotted		18.0	
Bore or Well	61609504	410978	6527635	No Current Owner		Unknown	02-05-1988	16	10-16m Inlet - Slotted	44.0	1.0	
Bore or Well	61615106	406614	6525106	Department of Water	Monitoring; Groundwater Assessment Network	Operational	30-06-1981	810	603-609m Inlet - Perforated		126.6	
Bore or Well	61609434	411788	6535477	No Current Owner		Unknown	30-06-1974	20.12		38.2	1.2	
Bore or Well	61700697	406522	6525169	Department of Water	Groundwater Assessment Network; Monitoring	Operational						
Bore or Well	61612040	410952	6522997	Private Owner	Domestic/Hou sehold	Unknown	01-02-1989	35.052	33.528-35.052m Inlet - Screen; Ap:.762mm			
Bore or Well	61609426	410853	6535437	No Current Owner		Unknown	01-01-1900	17.5		19.6	2.5	190
Bore or Well	61609437	411630	6536086	No Current Owner		Unknown	30-06-1978	7.01		32.7	5.2	328
Bore or Well	61609436	411898	6536138	No Current Owner		Unknown	30-06-1946	6.1		1.1	5.5	1372

Type	Bore ID	Easting	Northing	Asset Owner	Current Purpose	Current Status	Date Drilled	Drilled Depth (m below ground level)	Response zone (below ground level) and aperture	Water Supply (m^3/day)	Static Water Level (m below ground level)	Total Dissolved Solids (mg/L)
Bore or Well	61609550	412243	6549505	No Current Owner	Livestock	Unknown	30-06-1951	15.54		36.4	5.5	
Bore or Well	61740229	408286	6528788	Private Owner	Investigation	Unknown	05-04-2002	18	12-18m Inlet - Slotted; Ap:.5mm		12.0	
Bore or Well	61740268	408437	6526421	Private Owner	Domestic/Household	Unknown	12-04-1994	21	15-21m Inlet - Slotted; Ap:.635mm	43.2	6.0	2000
Bore or Well	61671489	408431	6534487	Private Owner		Unknown	01-09-1999	11.5				
Bore or Well	61712968	409889	6531749	No Current Owner	Irrigation	Unknown	25-03-1995	38.37	32.37-38.37m Inlet - Slotted; Ap:.508mm		31.9	500
Bore or Well	61609446	409739	6531799	No Current Owner	Irrigation	Unknown	13-04-1995	17.8	11.8-17.8m Inlet - Slotted; Ap:.508mm		10.8	90
Bore or Well	61609947	409103	6533247	No Current Owner	Irrigation	Unknown	11-01-1998	44	37-43m Inlet - Slotted; Ap:.5mm		12.0	
Bore or Well	61609388	410762	6536707	No Current Owner		Unknown	01-01-1900	4.88				758
Bore or Well	61642445	407407	6538360	Private Owner	WRL linked	Unknown						
Bore or Well	61612064	409630	6543080	Private Owner	Irrigation	Unknown	27-05-1995	31.394	16.459-31.394m Inlet - Slotted; Ap:1.27mm; 14.63-16.459m Inlet - Slotted; Ap:.508mm; 11.278-12.497m Inlet - Slotted; Ap:.762mm	38.2	10.9	200.0
Bore or Well	61609484	411552	6517750	No Current Owner		Unknown	30-06-1958	3.66			0.0	7150.0
Bore or Well	61642197	408453	6538328	Private Owner	WRL linked	Unknown						
Bore or Well	61612059	408018	6534521	Private Owner	Livestock	Unknown	26-03-1994	24.384	18.288-24.384m Inlet - Slotted; Ap:.508mm		3.7	
Bore or Well	61609379	409064	6533331	No Current Owner		Unknown	01-01-1900	6.1				
Bore or Well	61609396	410693	6530820	No Current Owner		Unknown	15-11-1978	41.1				
Bore or Well	61612053	409001	6542274	Private Owner		Unknown	28-11-1990	32	20-32m Inlet - Slotted			
Bore or Well	61609554	410299	6540299	No Current Owner	Irrigation; Domestic/Household	Unknown	27-05-1995	33.8	17.7-33.8m Inlet - Slotted; Ap:1.27mm; 12.14-13.45m Inlet - Slotted; Ap:1.27mm; 13.8-17.7m Inlet - Slotted; Ap:.508mm	38.2	10.9	200.0
Bore or Well	61609414	410890	6535720	No Current Owner	Livestock; Garden Irrigation;	Unknown	15-03-1980	17.98		7.6	13.4	1160.0

Type	Bore ID	Easting	Northing	Asset Owner	Current Purpose	Current Status	Date Drilled	Drilled Depth (m below ground level)	Response zone (below ground level) and aperture	Water Supply (m^3/day)	Static Water Level (m below ground level)	Total Dissolved Solids (mg/L)
					Domestic/Household							
Bore or Well	61612057	411293	6523287	Private Owner	Domestic/Household	Unknown	29-08-1992	21.336	13.411-20.117m Inlet - Slotted	32.7	13.7	
Bore or Well	61609458	411548	6521029	No Current Owner		Unknown					0.0	1750.0
Bore or Well	61619503	407759	6526619	Water Corporation	Production	Unknown	19-10-1985	244	138-153.1m Inlet - Screen; Ap:.635mm; 153.1-159.1m Inlet - Screen; Ap:.5mm	1360.0	25.1	418.0
Bore or Well	61611987	406518	6536133	Wildcross Pty Ltd	Monitoring	Unknown	28-10-2010	52	39-51m Inlet - Slotted		30.9	
Bore or Well	61740138	408741	6531026	Private Owner	Production	Unknown	05-09-2010	36	29-35m Inlet - Screen; Ap:2mm	28.0	26	420.0
Bore or Well	61609454	411114	6524051	No Current Owner		Unknown						929.0
Bore or Well	61609377	407172	6536995	No Current Owner		Unknown	01-01-1900	6.1				
Bore or Well	61609390	410708	6532318	No Current Owner		Unknown	01-01-1900	2.44				144.0
Bore or Well	61609505	411050	6523125	No Current Owner		Unknown	01-02-1989	35		54.0	27.4	
Bore or Well	61609394	410693	6530820	No Current Owner	Exploration	Unknown	15-11-1978	3				
Bore or Well	61609555	408839	6542749	No Current Owner	Irrigation	Unknown	29-07-1997	22.5	16.5-22.5m Inlet - Slotted; Ap:.5mm			
Bore or Well	61609438	411456	6536247	No Current Owner		Unknown	30-06-1979	5.79			2.7	328.0
Bore or Well	61642446	406987	6538107	Private Owner	WRL linked	Unknown						
Bore or Well	61611990	406048	6536274	Wildcross Pty Ltd	Monitoring	Unknown	28-10-2010	32	20-32m Inlet - Slotted		23.0	
Bore or Well	61609539	415353	6547903	No Current Owner		Unknown						2603.0
Bore or Well	61671491	408823	6534586	Private Owner		Unknown	01-09-1999	11				
Bore or Well	61618732	409366	6516645	Private Owner		Unknown						8800.0
Bore or Well	61611988	406706	6536484	Wildcross Pty Ltd	Monitoring	Unknown	29-10-2010	48	36-48m Inlet - Slotted		32.8	
Bore or Well	61611991	406288	6536671	Wildcross Pty Ltd	Monitoring	Unknown	29-09-2010	51	39-51m Inlet - Slotted		32.3	

Type	Bore ID	Easting	Northing	Asset Owner	Current Purpose	Current Status	Date Drilled	Drilled Depth (m below ground level)	Response zone (below ground level) and aperture	Water Supply (m^3/day)	Static Water Level (m below ground level)	Total Dissolved Solids (mg/L)
Bore or Well	61642444	406798	6538034	Private Owner	WRL linked	Unknown						
Bore or Well	61612054	410955	6528061	Private Owner	Domestic/Household	Unknown	04-07-1990	56				3500.0
Bore or Well	61619504	407809	6526619	Water Corporation	Production	Unknown	26-10-1985	171	150.19-160.25m Inlet - Screen; Ap:.5mm; 138-150.19m Inlet - Screen; Ap:.625mm	1360.0	32.9	662.0
Bore or Well	61609483	411228	6517632	No Current Owner		Unknown	30-06-1949	4.57			0.0	7693.0
Bore or Well	61609424	410704	6537409	No Current Owner		Unknown	01-01-1900	2.9			0.6	280.0
Bore or Well	61712967	407026	6533780	No Current Owner		Unknown	30-06-1970	163.98		54.6	55.2	185.0
Bore or Well	61609395	410693	6530820	No Current Owner	Exploration	Unknown	15-11-1978	21	17.98-19.5m Inlet - Screen	27.0		460.0
Bore or Well	61609453	411114	6524051	No Current Owner		Unknown						960.0
Bore or Well	61609455	411114	6524051	No Current Owner		Unknown						786.0
Bore or Well	61609378	407662	6533715	No Current Owner		Unknown	01-01-1900	30.48				
Bore or Well	61612060	410139	6538649	Private Owner		Unknown	20-10-1993	25.5	7-25m Inlet - Slotted; Ap:.762mm		2.5	
Bore or Well	61609552	408866	6542663	No Current Owner	Domestic/Household; Irrigation	Unknown	15-01-1988	24.4		80.0		160.0
Bore or Well	61609389	410708	6532318	No Current Owner		Unknown						2188.0
Bore or Well	61609392	410693	6530820	No Current Owner		Unknown	15-11-1978	6				
Bore or Well	61609393	410693	6530820	No Current Owner		Unknown	15-11-1978	20.2				
Bore or Well	61609397	409774	6533412	No Current Owner		Unknown	15-11-1978	22		0.0		
Bore or Well	61609551	412373	6548397	No Current Owner	Livestock	Unknown	30-06-1930	11.58			3.1	3575.0
Bore or Well	61609532	416944	6548814	No Current Owner		Unknown	01-01-1900	22.3			0.9	260.0
Bore or Well	61609422	407209	6534163	No Current Owner	Livestock	Unknown	01-01-1900					

Type	Bore ID	Easting	Northing	Asset Owner	Current Purpose	Current Status	Date Drilled	Drilled Depth (m below ground level)	Response zone (below ground level) and aperture	Water Supply (m^3/day)	Static Water Level (m below ground level)	Total Dissolved Solids (mg/L)
Bore or Well	61609435	412003	6535692	No Current Owner		Unknown	30-06-1973	10.06		38.2	0.0	3231.0
Bore or Well	61609531	423220	6551828	No Current Owner		Unknown	30-06-1975	14.63			3.7	1029.0
Bore or Well	61609949	410719	6537281	No Current Owner		Unknown	13-05-1999	18				
Bore or Well	61611340	409359	6516669	Salinity and Land Use Impacts Branch		Unknown						
Bore or Well	61642804	411048	6535166	Private Owner	WRL linked	Unknown						
Bore or Well	61609530	421323	6552547	No Current Owner	Domestic/Household; Livestock	Unknown	30-06-1962	39.01			28.0	1287.0