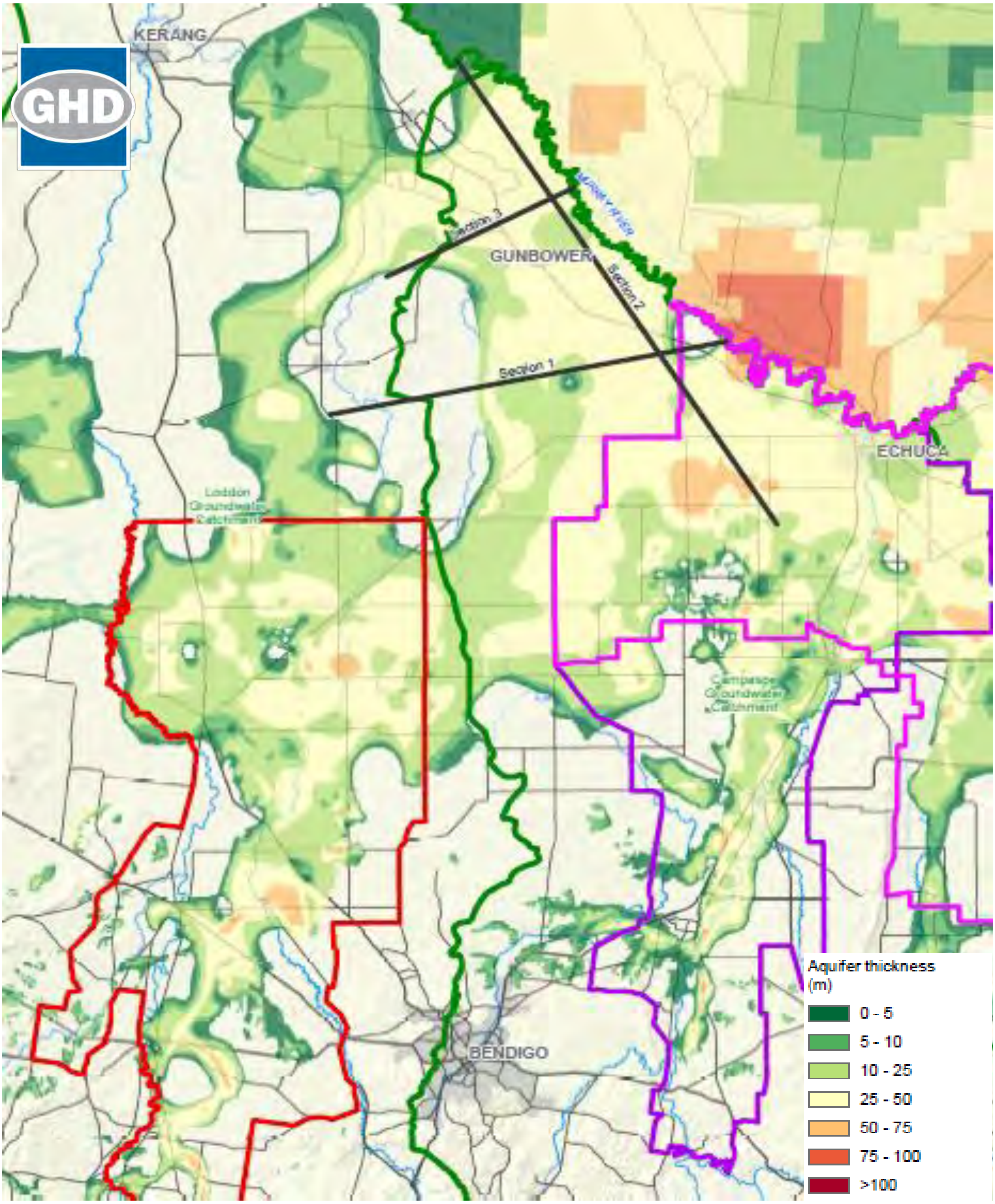

Goulburn Murray Water

Gunbower Area
Hydrogeological Assessment

July 2020

Executive summary

Project Objective

GHD was engaged by Goulburn-Murray Water (GMW) to undertake a desktop hydrogeological assessment for the Gunbower area, to assist in developing a sustainable yield (SY) estimate for the Deep Lead aquifer (i.e. Calivil Formation and/or Renmark Group) for this unincorporated area.

The project is driven by an increase in licence applications for extraction from the Deep Lead aquifer around the township of Gunbower. The recent increase in groundwater exploration and use of this aquifer is driven by the current dry conditions, and in some locations the opportunity to shandy the groundwater with fresher water supplies (i.e. from the surface water irrigation/channel systems).

Methodology

To meet the project objectives, GHD completed a hydrogeological data review, developed a Conceptual Hydrogeological Model (CHM) and then calculated the annual throughflow in the Deep Lead aquifer in the Gunbower area, to provide a first pass assessment of the sustainable yield of the resource. Based on the CHM and current aquifer response, GHD also identified the risks associated with increased groundwater extraction in the Gunbower area and qualitatively rated these risks.

Conclusions

Based on the calculated throughflow estimations, groundwater available for extraction in the Gunbower area is estimated to be approximately **8,000 ML/year**, with a low confidence rating due to the limited availability of aquifer information in the area and recognising the risks identified at this stage. The identified risks incorporate:

- Drawdown may ultimately impact on the adjacent Lower Campaspe Valley WSPA resource, under certain climate and extraction conditions (i.e. dry climate, high extraction).
- The potential for significant increase in groundwater salinity in the Gunbower region from additional extraction given that existing salinity is fresher than the surrounding areas.

As an initial approach, in consideration of potential risks of over allocation and the uncertainties associated with local aquifer parameters, an allocation cap of less than 8,000 ML/yr is considered appropriate. The recommended initial allocation volume is 5,600 ML/yr, which represents 70% of the estimated median throughflow within the target aquifer.

The potential exists that additional licences volume may be able to be allocated, however further ongoing monitoring, pumping tests and assessment work will need to be undertaken to provide a more technically rigorous assessment of sustainable yield in the area and associated impacts, prior to issuing any further entitlements beyond this volume.

Recommendations

1. Limit entitlements to 5,600 ML/year in this unincorporated area while further investigations are completed to assess the potential impacts of additional extraction in the area and to provide a more technically rigorous sustainable yield estimate.

2. Undertake further technical investigation including:
    a. Pumping tests: As a priority, pumping tests should be completed using the existing production bores, or as a requirement of new production bores, to better understand the aquifer parameters in this area and further inform the throughflow estimations.
    b. Numerical groundwater modelling to assess the potential impact of additional extraction on existing groundwater users (i.e. nearby management areas and across the border), overlying aquifer system and surface water features. Based on this work:
        i. further assess the sustainable yield
        ii. establish a new groundwater management area
        iii. establish a management plan.
    c. Monitoring of quality in surrounding and adjacent observation bores to identify any longer term changes, prior to impacts to users.
3. Licencing considerations. Any new licences should consider including conditions to assist in addressing datagaps, such as completion of pumping tests (including observation bores if needed), groundwater quality monitoring and the ability to reduce entitlements if unexpected impacts occur.
4. Further work to be completed in regards to the Murray Darling Basin plan and the implications in regards to Sustainable Diversion Limits, and also the management of the groundwater resource in NSW.

This report is subject to, and must be read in conjunction with, the limitations set out in section 10 and the assumptions and qualifications contained throughout the Report.

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Appendices

1. Introduction

1.1 Background and purpose of the study

GHD Pty Ltd (GHD) was engaged by Goulburn-Murray Water (GMW) to undertake a desktop hydrogeological assessment for the Gunbower area, to assist in an immediate need to determine a sustainable yield estimate for the deep lead aquifer in the area.

The project is driven by an increase in exploration and licence applications for extraction from the deep lead sediments (i.e. Calivil Formation and/or Renmark Group) around the township of Gunbower, which is located close to the Murray River. The recent increase in groundwater exploration and use is driven by the on-going dry conditions and demand for water security, primarily for irrigation purposes. In some locations the opportunity to shandy the groundwater with fresher water supplies (i.e. from the surface water irrigation/channel systems) is being proposed.

The deep lead aquifer system in the Gunbower area is currently in an unincorporated area (i.e. not covered by a Groundwater Management Unit), therefore, currently there is no Permissible Consumptive Volume (PCV) or local management plans in place for the resource. If development of this localised area of the deep lead aquifer continues without consideration of the sustainable yield of the system, there is a risk of unsustainable development, where groundwater levels continually decline and environmental impacts may potentially occur. There is also the potential that the groundwater resources in adjacent GMAs (i.e. Mid-Loddon GMA and Lower Campaspe WSPA) may be impacted.

1.2 Project objectives

The primary objective of this study is to inform the development of a sustainable yield (SY) for the deep lead aquifer in the Gunbower region. This assessment and development of a resource limit will allow GMW to make determinations on existing and future applications for extraction of groundwater and establish volumes that can potentially be licenced from the area.

The methodology applied for the determination of a SY can vary depending on the amount of data available (i.e. first principles, water balances or integrated numerical models) and the budget (often related to the economic value of the groundwater resource). To address the immediate need and objectives, this is a first stage assessment, using desktop information, and should be used to inform further detailed work in regards to a SY assessment of the deep lead aquifer in this area and potentially the entire groundwater resource. In addition the assessment may also inform and the development of groundwater management, such as the interaction with nearby GMAs, and any requirements for the Murray Darling Basin management plans.

This report includes:

- A desktop review of the available hydrogeological information in the area.
- Development of a conceptual hydrogeological model (CHM).
- A preliminary estimate of the SY.
- Identification of any key data gaps with respect to estimating a SY.
- Recommend a methodology for further sustainable yield assessment for the aquifer system/s based on available data.

2. Scope of Works

2.1 Project Scope

The scope of works for this project are detailed in the proposal dated 19th December 2019 (GHD ref 12523464-39473) and included the following:

- Task 1: Project Inception Meeting.
- Task 2: Hydrogeological Data Review:
  - Gather all available hydrogeological data and identify any key data gaps.
- Task 3: Hydrogeological Conceptualisation:
  - Based on the available data develop the Conceptual Hydrogeological Model (CHM) for the aquifer system in this area, including identification of the impacts of extraction and interaction with the other GMUs. The CHM will also be used to identify suitable boundaries for a management area.
- Task 4: Preliminary estimate of aquifer recharge (throughflow):
  - As first past assessment of the limits of the resource, GHD propose to assess the throughflow in the aquifer system.
- Task 5 : Reporting
  - Including identification of data gaps, and recommendation on the methodology to complete a more technically defensible SY within the data limitations and for the hydrogeological setting.

2.2 Assumptions

This desktop assessment has relied on a number of data sources including:

- Publically accessible geological and hydrogeological information and data, including that contained in:
  - Department of Environment, Land, Water and Planning (DELWP) Groundwater Management System (WMIS) database.
  - DELWP groundwater resource reports.
  - GMW Local Management Plans.
  - GMW Groundwater Management Assessment reports.
  - GMW bore information.
  - Published geological and hydrogeological mapsheets and reports. .

These data sources have been referenced, where relevant, throughout this report.

A complete list of references is provided in Section 9 this report.

3. Study Area Characterisation

3.1 Background and Study Area

The **regional** study area is shown in Figure 1, which includes the **focus area** around the township of Gunbower, but also encompasses the broader region to include the following features:

- The adjacent Lower Campaspe Valley and Mid Loddon GMUs
- The Murray River to the north.

Within the focus area there are 3 existing licenced users and 11 new licence applications to extract groundwater from the Deep Lead aquifer system, between the townships of Wee Wee Rup, Gunbower and Welton (refer Section 4.4.2) adjacent the Murray River.

This Deep Lead aquifer system in the focus area, based existing bore logs, can generally be characterised as:

- Present at a depth of around 90-100m , and in the order of 50-60m thick with the coarser sediment commonly being intersected in the basal sands of the unit.
- High yielding, with bore yields often greater than 25 L/sec.
- Groundwater salinity is generally in the order of 2,000-5,000 mg/L TDS (although GMW has reported salinity as low as 1,900 mg/L TDS based on recent information provided by licence applicants).
- Commonly confined by overlying clays, although there is varying degrees of connection between the deep lead aquifer and the overlying Shepparton Formation aquifer system (which commonly forms the water table aquifer).
- Currently in an unincorporated area (i.e. not covered by a Groundwater Management Unit), and therefore currently there is no Permissible Consumptive Volume (PCV) or local management system in place for the resource.

If development of this localised area of the Deep Lead aquifer continues without consideration of the sustainable yield of the system, there is a risk of unsustainable development, where groundwater levels continually decline and environmental impacts may potentially occur.

GMW therefore required a local groundwater sustainable yield (SY) assessment for the deep lead aquifer in the Gunbower region, to initially allow GMW to make decisions on the volumes that can potentially be licenced from the area and secondly identify further work that is likely to be required to improve the SY assessment and interaction with entire groundwater resource and existing Groundwater Management Units (GMUs).

3.2 Topography and Surface Water Features

The study area (Figure 1) covers the southernmost portion of the Murray Darling Basin, and includes the central and lower sections of the Loddon and Campaspe River and groundwater catchments.

The study area is topographically varied, with hilly areas in the south containing the Loddon and Campaspe River headwaters, declining steeply downstream to the relatively flat Loddon and Campaspe valleys, which continues to flatten towards the Murray River.

The Loddon River, runs south from the regulated Cairn Curran Reservoir (ground RL around 320m) to the north via Kerang to the confluence with the Murray River (ground RL around 80m).

Adjacent to the township of Gunbower is Gunbower Creek and Kow Swamp, a large swamp feed by Mount Hope Creek, a tributary of the Loddon River. Bullock Creek is another major tributary of the Loddon River.

The Campaspe River, runs south from Lake Eppalock (ground RL around 240m) to the north via Echuca to the confluence with the Murray River (ground RL around 90m). Other significant surface water features include the Waranga Western Channel and the Mount Pleasant Creek.

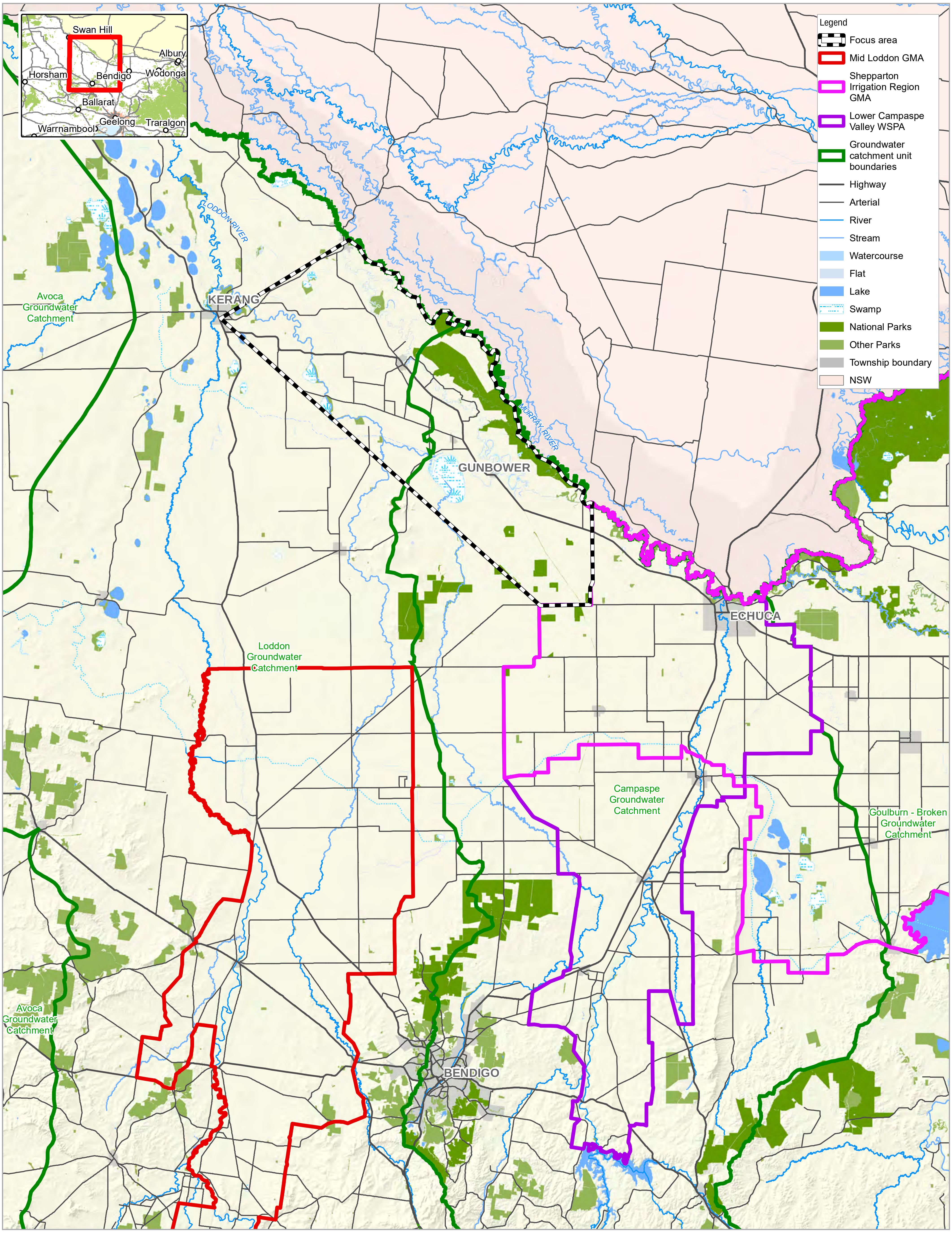
Groundwater Dependent Ecosystem (GDEs)

Data obtained from the Bureau of Meteorology Groundwater Dependent Ecosystems (GDE) Atlas is presented in Figure 2.

This shows there is typically low potential for interaction with groundwater along the lower reaches of the Loddon and Campaspe Rivers. However there is moderate to high potential for interaction with groundwater along Bullock Creek and Mount Hope Creek.

To the north of Gunbower, there is also high potential for groundwater interaction along the Gunbower Creek and moderate potential for groundwater interaction along the Murray River and the associated flood plains. Fresher groundwater around the Murray River suggests the river is a losing system, at least during high flow/flood periods and providing some recharge to the local water table aquifer.

Kow Swamp is not classified as a GDE, reflecting that the main recharge to the swamp is surface water runoff during relatively wet periods.



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Kilometres

Map Projection: Lambert Conformal Conic
Horizontal Datum: GDA 1994
Grid: GDA 1994 VICGRID94

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Goulburn Murray Water
Gunbower and Lower Loddon Hydrogeological Models

Study area
overview plan

Project No. 12523464
Revision No. 0
Date 03/07/2020

Figure 1

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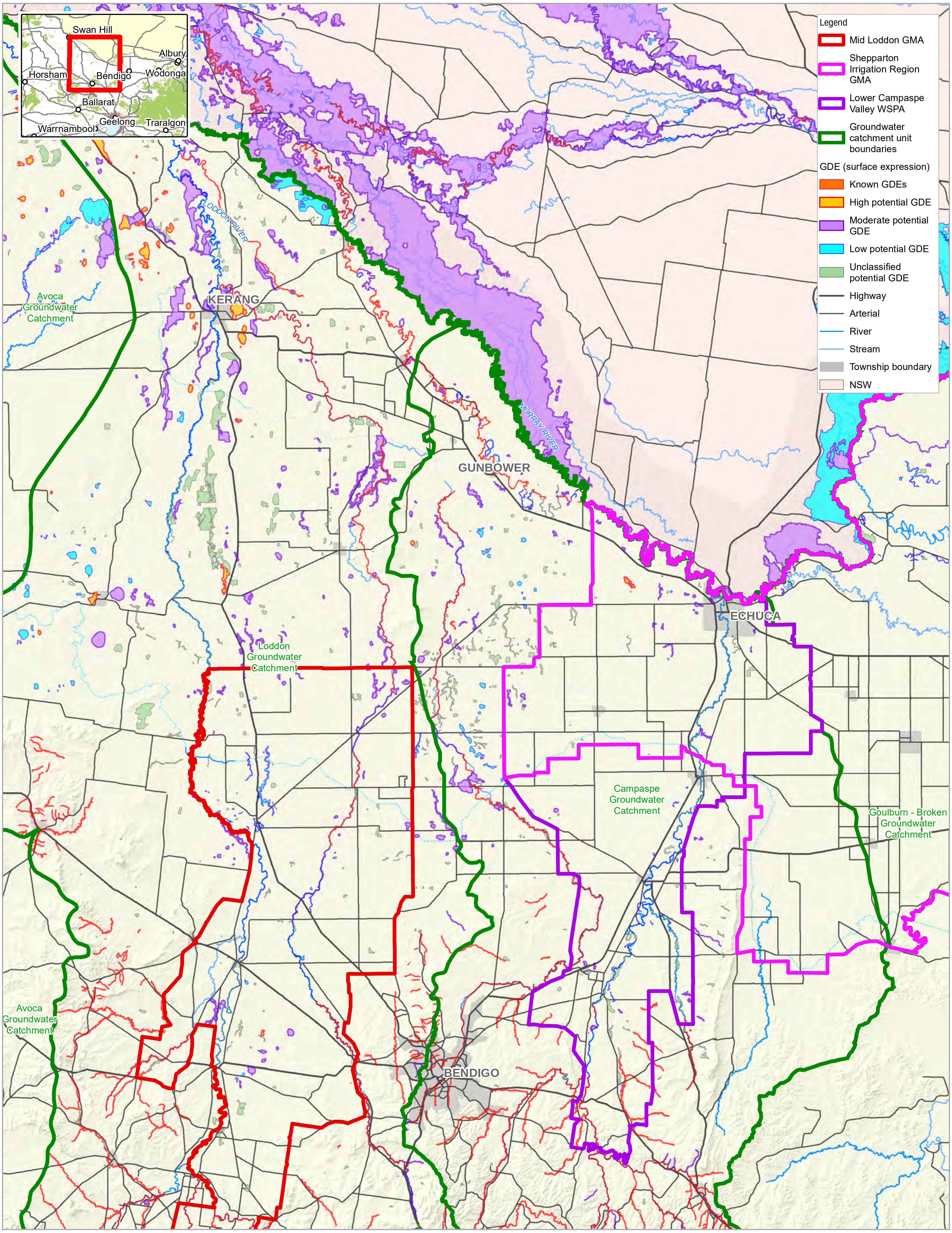
Data source: DELWP, VicMap, 2020; DELWP, SAFE data, 2012 Created by: bsmyth



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Kilometres

Map Projection: Lambert Conformal Conic
Horizontal Datum: GDA 1994
Grid: GDA 1994 VICGRID94

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GHD

Goulburn Murray Water
Gunbower and Lower Loddon Hydrogeological Models

Project No. 12523464
Revision No. 0
Date 03/07/2020

Current GMUs and GDEs

Figure 2

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Data source: DELWP, VicMap, 2020; DELWP, SAFE data, 2012 Created by: bsmyth

3.3 Climate

Climate information was obtained from SILO for Gunbower gee tee stud station 80020.

Average climate data from 1990 has been summarised in Table 3-1. Monthly rainfall along with cumulative deviation from the mean monthly rainfall (1990 to 2020) and long term average (1900 to 2020) is shown in Figure 3.

Table 3-1 Average climate summary

Month	Average Rainfall (mm) (1990-2020)	Average Max Temp (1990-2020)	Average Min Temp (1990-2020)	Average Rainfall (mm) (LTA)	Average Max Temp (LTA)	Average Min Temp (LTA)
January	26.2	32.3	15.8	25.3	31.4	15.3
February	23.3	31.4	15.6	24.4	30.9	15.4
March	20.0	28.0	13.0	26.1	27.5	13.1
April	24.5	23.2	9.3	25.3	22.5	9.5
May	29.5	18.4	6.4	36.3	17.9	6.8
June	36.6	14.9	4.5	35.9	14.5	4.6
July	36.7	14.2	3.7	36.6	13.8	3.8
August	32.8	15.9	4.1	36.9	15.7	4.7
September	34.4	19.2	5.9	35.0	18.7	6.3
October	32.8	23.3	8.3	36.4	22.5	8.7
November	37.0	27.0	11.4	27.6	26.4	11.3
December	27.3	29.9	13.7	26.2	29.4	13.6
Annual	361.1			372.2		

Figure 3 Cumulative deviation from mean monthly rainfall

4. Hydrogeological Characterisation

4.1 Geology

The outcrop geology of the regional area is shown in Figure 5.

The Victorian portion of the Murray Basin consists of five main groups of sediments, as old as the Late Tertiary (Palaeocene) period. During the Late Tertiary, a cycle of deposition began when surface water features deposited sediments along drainage lines from the Great Dividing Range in central Victoria towards what is now the Murray River. These sediments, mostly consist of fluviatile and lacustrine sand, silt and carbonaceous layers of the Renmark Group, deposited on top of the existing Palaeozoic Basement rocks (sandstone, siltstone, metamorphosed sediments, volcanics and granite),which was subsequently overlain by fluvial sediments of the Calivil and Shepparton Formations.

Further up catchment and in the highlands, the Calivil Formation were deposited directly on the Basement rocks. The northern extent of the Tertiary fluvial sediments was controlled by the marine transgression into the Murray Valley system, in which the marine Parilla Sands were deposited. Quaternary sediments associated with the current drainage system overlie the Shepparton Formation.

4.2 Hydrostratigraphy

A summary of the interpreted regional stratigraphy has been provided in Table 4-1, from youngest to oldest. The geological units have been subdivided into key aquifer systems under the Victorian Aquifer Framework (VAF). The key attributes of the aquifer systems, including their lithology, are summarised in Table 1, with further details in regards to their distribution provided in the following sections.

Table 4-1 Regional Hydrostratigraphy

Period	Sub period	Geological formation	Hydrostratigraphic unit (VAF)	Lithology	Aquifer type/Condition	Present in Gunbower local area
Quaternary	Holocene / Pleistocene	Alluvial sediments/ Coonambidgal Formation	Quaternary Aquifer (QA)	sand, gravel, clay, silt	Sedimentary /Unconfined	Yes - along Murray River /Kow Swamp
Quaternary /Upper Tertiary	Pleistocene - Pliocene	Newer Volcanics	Upper Tertiary / Quaternary Basalt (UTB)	basalt	Fractured rock/ Unconfined-semiconfined	No - upper Mid Loddon GMA/Campaspe GMA
Quaternary – Upper Tertiary	Pleistocene to Pliocene	Shepparton Formation	Upper Tertiary / Quaternary Aquifer (UTQA)	Shoestring sand, gravel, clay, silt	Sedimentary/semi-confined- unconfined	Yes
Upper Tertiary	Pliocene	Parilla Sands	Upper Tertiary Aquifer (marine) (UTAM)	Sand, cemented sands, minor clay, silt	Sedimentary/semi-confined- unconfined	No - north west
Tertiary	Late Miocene to Early Pliocene	Calivil Formation / Deep Lead	Upper Tertiary Aquifer (fluvial) (UTAF)	Unconsolidated sands/gravels and clay layers	Sedimentary/ Semi-confined to confined	Yes
Tertiary		Geera Clay	Upper Middle Tertiary Aquitard (UMTD)	Clay	Aquitard	No – at Kerang
Tertiary	Eocene to Miocene	Renmark Group (also often referred to as Deep Lead)	Lower Tertiary Aquifer (LTA)	Unconsolidated, carbonaceous sand, silt, clay	Sedimentary/ Semi-confined to confined	Yes
Palaeozoic	Ordovician to Permian	Basement	Basement rocks Aquifer (BSE) & Cretaceous and Permian sediments (CPS)	Sedimentary and igneous rocks	Fractured rock/Unconfined , semi-confined, confined	Yes – at depth

4.2.1 Basement rock aquifers

These pre-Tertiary basement rocks have variable aquifer potential, owing to their varied geological composition. The bedrock aquifer units comprise steeply dipping Ordovician sandstones, siltstones, shales and slates, outcropping Lower-Middle Devonian granites, flat-lying Upper Devonian sediments and acid volcanics, Permian mudstones and minor conglomerates occurring primarily in the deep subsurface, with broad areas of geological outcrop along the Great Dividing Range.

Across the Murray Basin, the basement rock aquifers have relatively unpredictable, but generally limited permeability, yield and storage potential.

The surface elevation of the Basement rock aquifer is shown in Figure 6 and Figure 7 (for Cretaceous and Permian rocks thickness). The basement rocks generally deepen towards the north, into the Murray Basin. Of note is the basement high, forming the Terrick Terrick Ranges to the south-west of Gunbower.

Around Gunbower the bedrock elevation is variable, however it is approximately -50 to -100m RL, at the township. Ground surface is around 80m AHD, and therefore the basement depth is around 130-180m.

4.2.2 Deep Lead Aquifer (Renmark Group Aquifer and Calivil Formation Aquifer)

Renmark Group aquifer (LTA)

Distribution

The extent and thickness of the Renmark Group aquifer in the regional study area is shown in Figure 8. The Renmark Group aquifer (LTA) is relatively extensive across much of the Murray Basin, mostly consisting of sand, silt and carbonaceous layers deposited through fluvial and lacustrine processes.

The aquifer is present in the Mid Loddon and Lower Campaspe Valley Groundwater Management Units (GMU) areas and is generally <50m thick , except in the north, close to the Murray River.

In the Loddon Valley, the aquifer does not extend north past Mitiamo, however it extends across to the east, around the Terrick Terrick Ranges and has continuity with the aquifer in the adjacent Campaspe Valley.

In the Gunbower area, the aquifer thickness is generally 25-75m, getting thicker towards the north and north west. A number of cross-sections (Figure 15, Figure 16 and Figure 17) have also been completed through the Gunbower area to show the aquifer systems in this local area.

The Renmark Group aquifer is overlain by the Calivil Formation aquifer and these aquifers are generally considered to be hydraulically connected and confined by the clays within the overlying Shepparton Formation. Macumber, 2011 completed a review of the nested bores screened in the Calivil Formation and Remark Group across the Riverine Plain, incorporating the Mid Loddon, Katunga and Lower Campaspe Valley GMUs. He found these bores show a near identical groundwater response indicating a strong connection between the two aquifer systems (GMW, 2012). This is consistent with observations from the state observation bores near Gunbower, which show near identical groundwater heads in the two aquifer systems (refer Section 4.4.4).

The combined Renmark Group and Calivil Formation aquifers are generally referred to as the Deep Lead aquifer system in this region (i.e. Macumber, 2008) and the term will be used in this report to refer to the combined aquifer systems.   Approximately 80% of the Deep Lead aquifer consists of gravel and sand, the remainder being clayey sand or clay (Nolan ITU, 2003).

Quality and Yields

The groundwater salinity in the Renmark Group aquifer is shown in Figure 18.

There is generally an increasing salinity trend in the down hydraulic gradient direction. The lowest salinity is recorded in the mid to upper sections of the Campaspe deep lead (i.e. <500 mg/L TDS) and in the mid-Loddon deep lead area (<3,500mg/L TDS) (i.e. the areas predominately covered by the existing Mid-Loddon and Lower Campaspe GMUs). Further down basin, closer to the Murray River, the salinity is interpreted to be 3,500 mg/L to 13,000 mg/L TDS.   Due to the higher salinity, the groundwater resources were not highly developed outside of the current GMAs (i.e. in the lower Loddon and Gunbower areas). Recent bores installed in the Gunbower area, in the deep lead aquifer, recorded salinity of 2,600 mg/L TDS and 3,700 mg/L TDS, and although marginal for many uses can be shandied with other water supplies.

Bore yields in the deep lead aquifer in the Gunbower area were classified as > 25 L/sec (DITR, 1985), and at least two bores installed in the Gunbower area have recorded yields of between 50 and 250 L/sec. Aquifer parameters are described in Section 4.6.

Calivil Formation aquifer (UTAF)

Distribution

The extent and thickness of the Calivil Formation aquifer in the regional study area is shown in Figure 9. The Calivil Formation is a significant aquifer in northern Victoria, consisting of alluvial sands/gravels and clay layers.

The distribution of the aquifer is similar to the Renmark Formation in the northern region, however the sediments extend further south into elongate historic drainage channels, where they are typically deposited directly on the Basement.

The aquifer is generally less than 50m thick along the Mid Loddon and Lower Campaspe valley, although is up to 75m thick in some places.

In the Loddon Valley, the sediments continue north past Mitiamo (and the northern boundary of the Mid Loddon GMA), however they are narrower, thinner and lower in permeability. This results in groundwater flow being restricted and forced upwards to the Shepparton Formation aquifer in this area and around Bear Lagoon, which has resulted in high groundwater heads in the Shepparton Formation and historically caused soil salinisation issues. The aquifer extends to the east, similar to the Renmark Group aquifer and has continuity with the aquifer in the adjacent Campaspe Valley.

In the Campaspe Valley, the aquifer generally thickens and widens to the north and the Murray River.

In the Gunbower area, the aquifer thickness is generally less than 50m (also refer cross sections (Figure 12, Figure 13 and Figure 14).

It is noted that for the Renmark Group and and Calivil Formation, the thickness and extent figures were extend into NSW (beyond the extent of the VAF layers). The thickness of these units in NSW was calculated using top of layer elevation data from the Murray Darling Basin Commissions, Basin in a Box dataset. The top of layer elevations are a contour dataset and thus were converted to a surface in order to calculate the thickness; by doing this data was interpolated between the contour lines. From the top of layer elevations, the thickness was calculated by subtracting the top of layer elevation of the next underlying unit in the dataset from the top of layer elevation of the unit in questions

Groundwater Flow

As noted above, the Renmark Group and the Calivil Formation are generally considered to be hydraulically connected, and the combined unit will be referred to as the Deep Lead aquifer. The general groundwater flow direction in the Deep Lead aquifer system is shown in Figure 4 (Macumber, 1999). Groundwater generally flows from the upland areas of both catchments in the south towards the north. Groundwater flows around the Terrick Terrick ranges, where the deep Lead is absent, and a groundwater divide was noted between the main Loddon Deep Lead and the east.

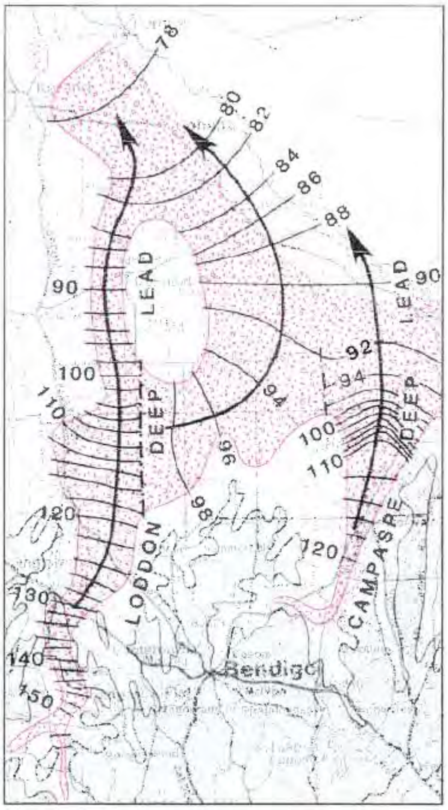


Figure 4 Groundwater flow direction in the Loddon and Campaspe Deep Lead System (Macumber, 1999)

Groundwater quality and Yields

The groundwater salinity in the Upper Tertiary aquifer (i.e. Calivil Formation aquifer) is shown in Figure 19.

As expected, with the hydraulic connection, the salinity trends are very similar to the Renmark Group aquifer, with an increasing salinity trend in the down hydraulic gradient direction.

In the Gunbower area, to the north along the Murray River, the Calivil Formation aquifer has a fresher pod of groundwater in comparison to the underlying Renmark Group aquifer. This fresher zone (1,000-3,500 mg/L TDS) is basically between the Murray River and Gunbower Creek, where the existing two high yielding irrigation bores are located, and the salinity recorded from the bores is indicative that they are probably screened in the Calivil Formation (i.e. upper part of the Deep Lead aquifer).

The fresher groundwater zone in deep Lead aquifer in this area is likely to be related to recharge from the Murray River, particularly during high flow and flood events. This is reflected in the salinity of the water table aquifer in this general area as well (Figure 20), which records relatively fresh groundwater in the water table aquifer around the Murray River (i.e.as low as 500mg/L), a particularly south-east of Gunbower. Groundwater recharge from the Murray River will be dependent on many factors such as the head difference between the water table aquifer and the river level, and the vertical permeability of the river bed sediments. As noted above, significant flood events where there is extensive induration along the Murray River/ Gunbower Creek flood plains are likely to provide a significant contribution to the water table recharge in this area.

There is a downwards vertical groundwater gradient from the water table aquifer (i.e. Shepparton Formation) to the underlying Deep Lead aquifer (refer Section 4.4.4), which will result in some vertical leakage of the low salinity groundwater to the Deep Lead aquifer system, resulting in the relative freshening of the groundwater in this area close to the Murray River.

Recharge and discharge mechanism

Recharge to the Deep Lead aquifer system is primarily through leakage from the overlying Shepparton Formation (Nolan-ITU, 2003). The salinity of the deep lead aquifer will therefore be influenced by the quality of the overlying Shepparton Aquifer system (as discussed above).

It is noted (Nolan-ITU, 2003) that in the Campaspe Catchment, seepage from the Shepparton Formation in the northern reaches originates from rainfall and irrigation, while in the southern reaches it is also from leakage from the Campaspe River, which is reflected by the low salinity Deep Lead aquifer groundwater in the vicinity of Elmore.

4.2.3 Shepparton Formation aquifer (UTAM)

Distribution

Figure 11 shows the thickness and spatial distribution of the Shepparton Formation aquifer.

The Shepparton Formation is regionally extensive, and outcrops across much of the regional study area. The Shepparton Formation aquifer system generally consists of silts and clays with ‘shoe string’ lenses of sands and gravels that generally have lower hydraulic conductivities and yields than the underlying Deep Lead aquifer system. The ‘shoe-string’ sands of the Shepparton Formation can be limited in lateral and vertical extent with considerable variation in permeability. A higher permeability zone, referred to as the ‘Shepparton Formation sand sheet’ (Macumber, 2007) is present across the central north area of the Mid-Loddon GMA, and commonly utilised for groundwater supply.

Around Gunbower and to the north, the Shepparton Formation is commonly >75m thick, with some areas exceeding 100m (refer cross sections also).

Groundwater Flow

Groundwater flows is generally from a south to north direction, and in many areas, the water table within the Shepparton Formation aquifer is within a few metres of ground surface, and the aquifers are essentially unconfined.

Aquade, 2011 reported that generally the proportion of clay and continuity of clays in the Shepparton Formation increased from the south to the north (at least in the Campaspe catchment), and therefore the vertical conductance of the Shepparton Formation also decreased from south to north. Inter-aquifer connection between the Shepparton Formation and the underlying Deep Lead aquifer is generally less towards the north.

AGSO, 1993 indicates the Shepparton Formation is low yielding in the vicinity of Gunbower (i.e. <0.5 L/sec) and DITR, 1985 indicates that the average aquifer thickness (i.e. sand thickness) in this area is only around 1m (although the complete unit thickness is often >75m).

Recharge and discharge processes

Recharge to the Shepparton Formation aquifer is via rainfall recharge, as well as recharge through stream bed leakage from water courses and the channels. In addition, recharge occurs as a result of irrigation practices.

In some areas there is upflow from the underlying Deep Lead aquifer, particularly during wet climatic periods, results in groundwater discharge in local areas (i.e. as noted previously around Bears Lagoon).

Discharge from the Shepparton Formation occurs to the underlying Deep Lead aquifer, as the potentiometric heads in the Deep Lead system are generally lower than the Shepparton Formation aquifer, forming a downward vertical gradient (Nolan, 2003). In the Gunbower area, the head difference between the systems in approximately 2m (refer Section 4.4.4). Groundwater also discharges, in some areas into waterways, such as the lower reaches of the Campaspe River, or the adjacent Coonambidgal Formation.

Groundwater Quality

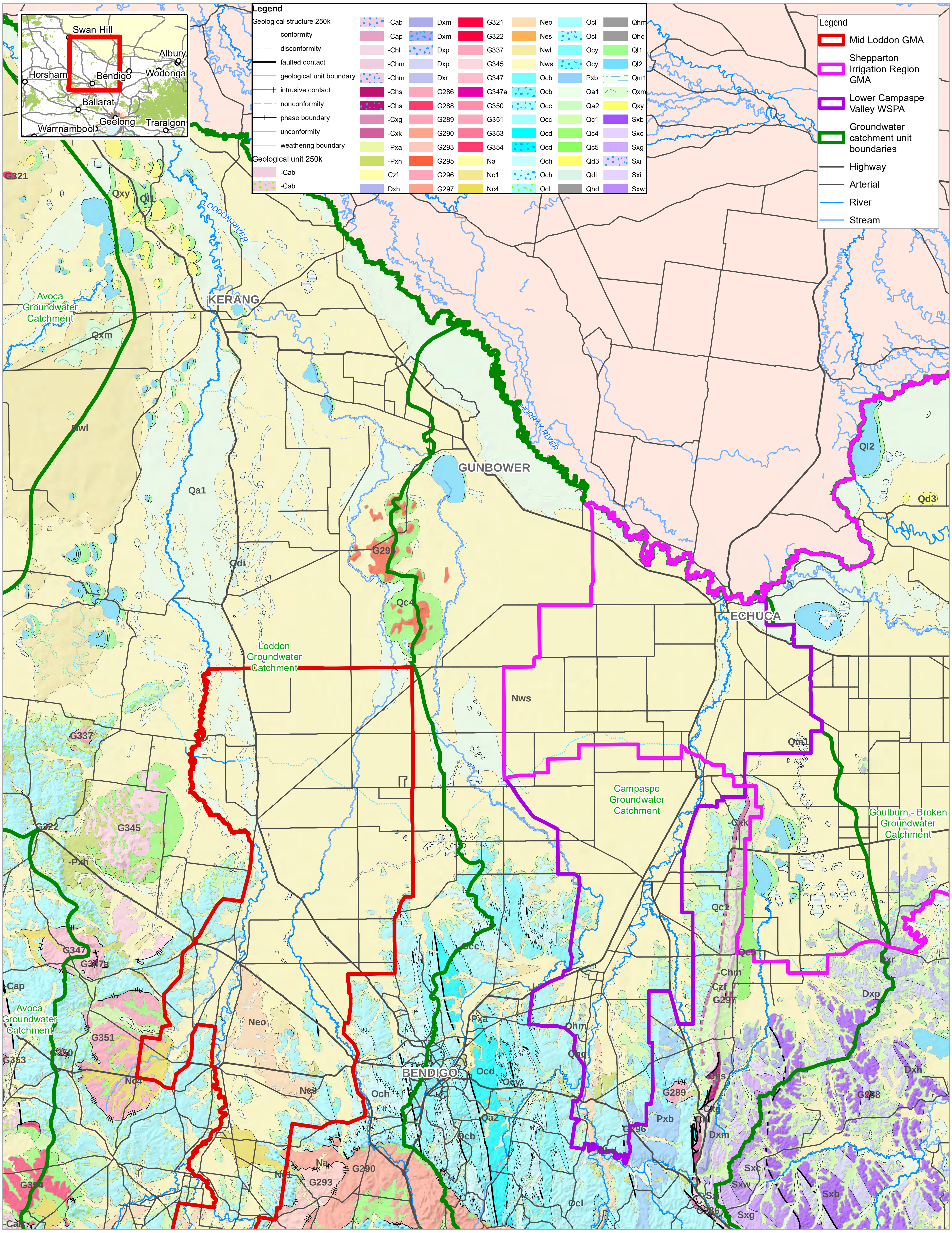
The groundwater salinity in the water table aquifers (i.e. the Shepparton Formation and Coonambidgal formation) is shown in Figure 20 .

The salinity is generally >3,500 mg/L TDS in the direct vicinity of Gunbower, however as discussed previously the salinity of the Shepparton Formation aquifer is variable, with lower salinity occurring in the vicinity of additional groundwater recharge sources such as losing waterways or current/ previous irrigation areas (i.e. south-east of Gunbower). The groundwater quality of the Shepparton Formation aquifer influences the quality of the underlying deep lead aquifer, the degree of which, and the lag, depends on the vertical leakage (i.e. dependent on head difference, vertical conductivity etc.) and the throughflow in the Deep Lead.

4.2.4 Quaternary Aquifer (QA)

The Quaternary Aquifers system is present along the major drainage lines (refer Figure 13. It consists of relatively thin (i.e. <10 m) alluvial and colluvial deposits of sand, silts and clays are present, and include the Coonambidgal Formation in places along the Campaspe and Murray Rivers.

In the vicinity of Gunbower, the Quaternary aquifer is most extensive along the Murray River (<10m thick) and around Kow Swamp (<10m thick). Along the Murray River, this aquifer has a high degree of connection with the surface water system and as discussed previously there is areas where the water table aquifer is relatively fresh due to groundwater recharge from the Murray River during at least some periods, probably high flows and flood conditions. The Water table aquifer quality is shown in Figure 20, and AGSO, 1991 indicated groundwater salinity in the Quaternary aquifer directly north of Gunbower Creek as being in the range of 1,500 mg/L to 3,000 mg/L TDS (i.e. larger fresher groundwater zone than shown in in Figure 20)



Paper Size ISO A3

0 4.5 9 13.5 18

Kilometres

Map Projection: Lambert Conformal Conic
Horizontal Datum: GDA 1994
Grid: GDA 1994 VICGRID94

N

Goulburn Murray Water
Gunbower and Lower Loddon Hydrogeological Models

Outcrop geology and geological structures

Project No. 12523464
Revision No. 0
Date 03/07/2020

Figure 3

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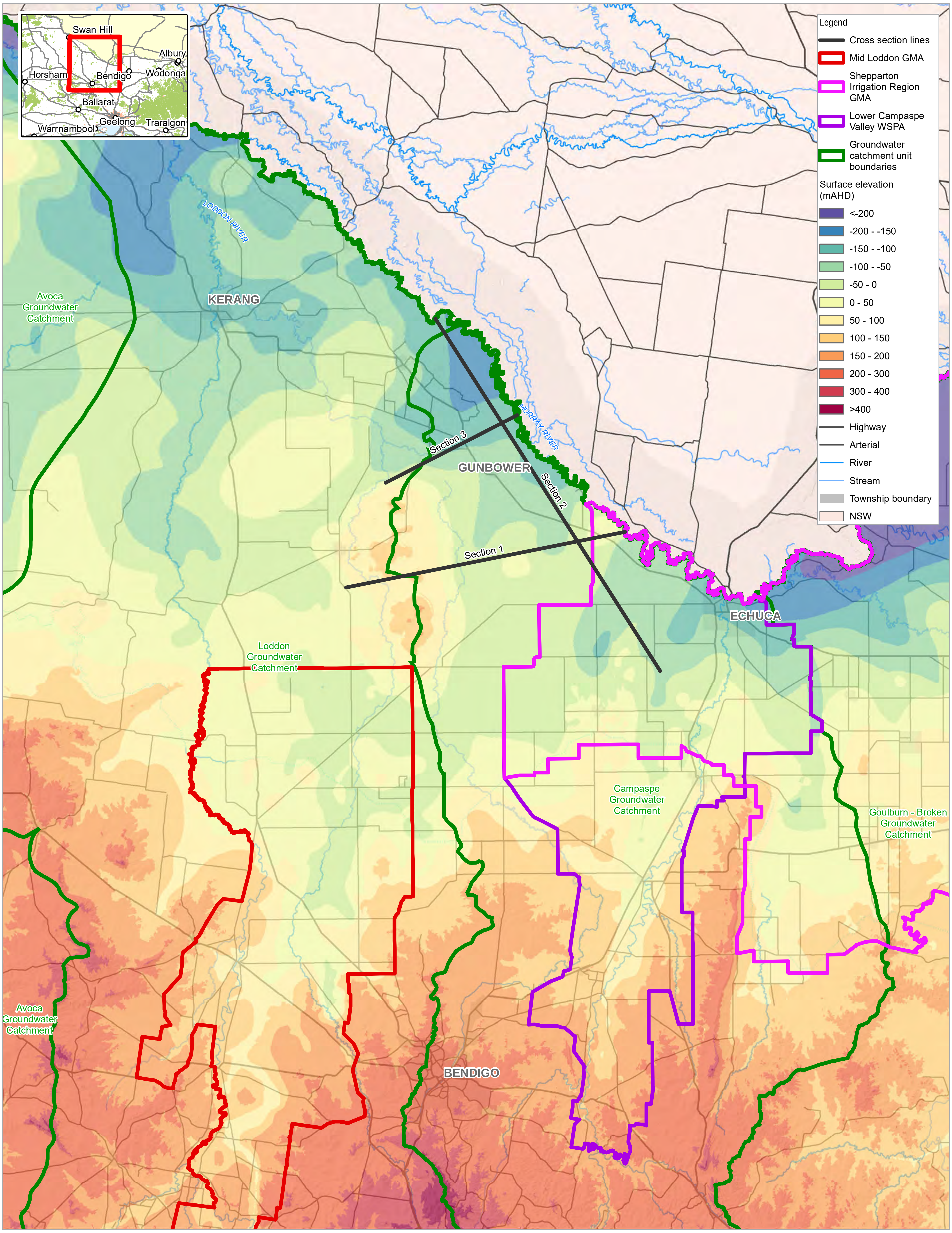

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Kilometres

Map Projection: Lambert Conformal Conic
Horizontal Datum: GDA 1994
Grid: GDA 1994 VICGRID94

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Goulburn Murray Water
Gunbower and Lower Loddon Hydrogeological Models

Aquifer surface
Mesozoic and Palaeozoic Bedrock (114)

Project No. 12523464
Revision No. 0
Date 03/07/2020

Figure 6

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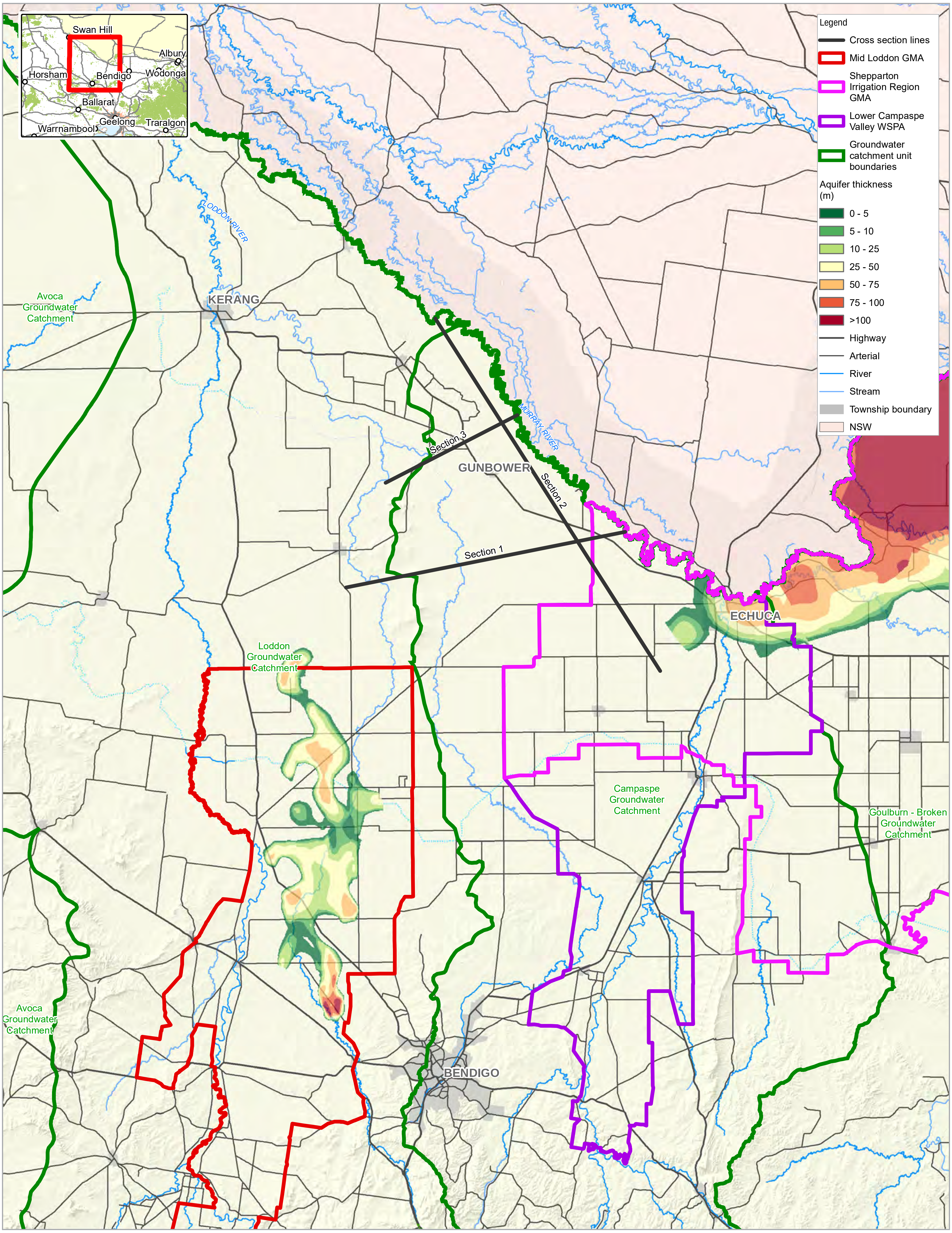

Paper Size ISO A3

0 4.5 9 13.5 18

Kilometres

N

Map Projection: Lambert Conformal Conic
Horizontal Datum: GDA 1994
Grid: GDA 1994 VICGRID94

GHD

Goulburn Murray Water
Gunbower and Lower Loddon Hydrogeological Models

Project No. 12523464
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Date 03/07/2020

Aquifer thickness
Cretaceous and Permian Sediments (113)

Figure 7

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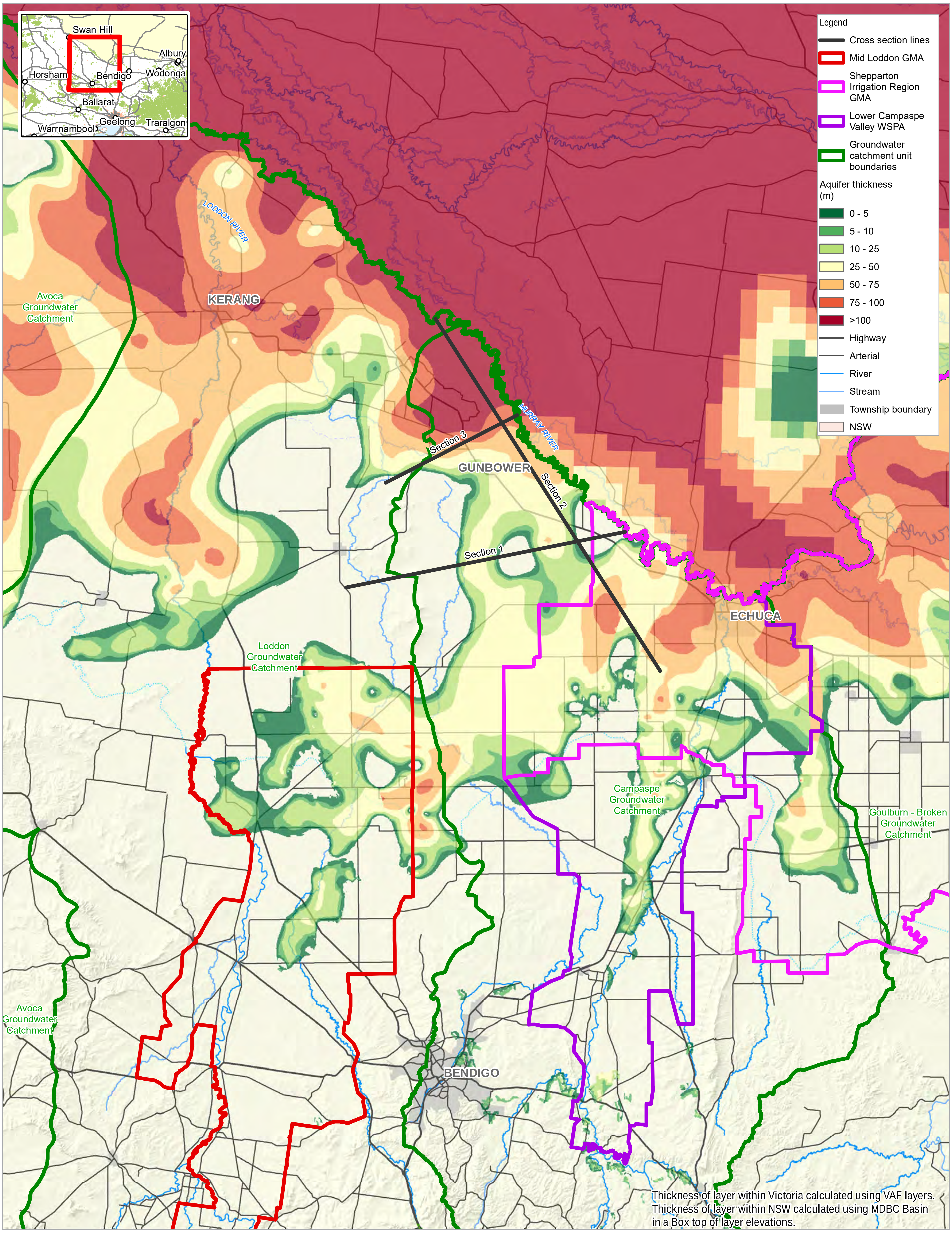

Paper Size ISO A3

0 4.5 9 13.5 18

Kilometres

Map Projection: Lambert Conformal Conic
Horizontal Datum: GDA 1994
Grid: GDA 1994 VICGRID94

N

Goulburn Murray Water
Gunbower and Lower Loddon Hydrogeological Models

Aquifer thickness
Lower Tertiary Aquifer (111)

Project No. 12523464
Revision No. 0
Date 03/07/2020

Figure 8

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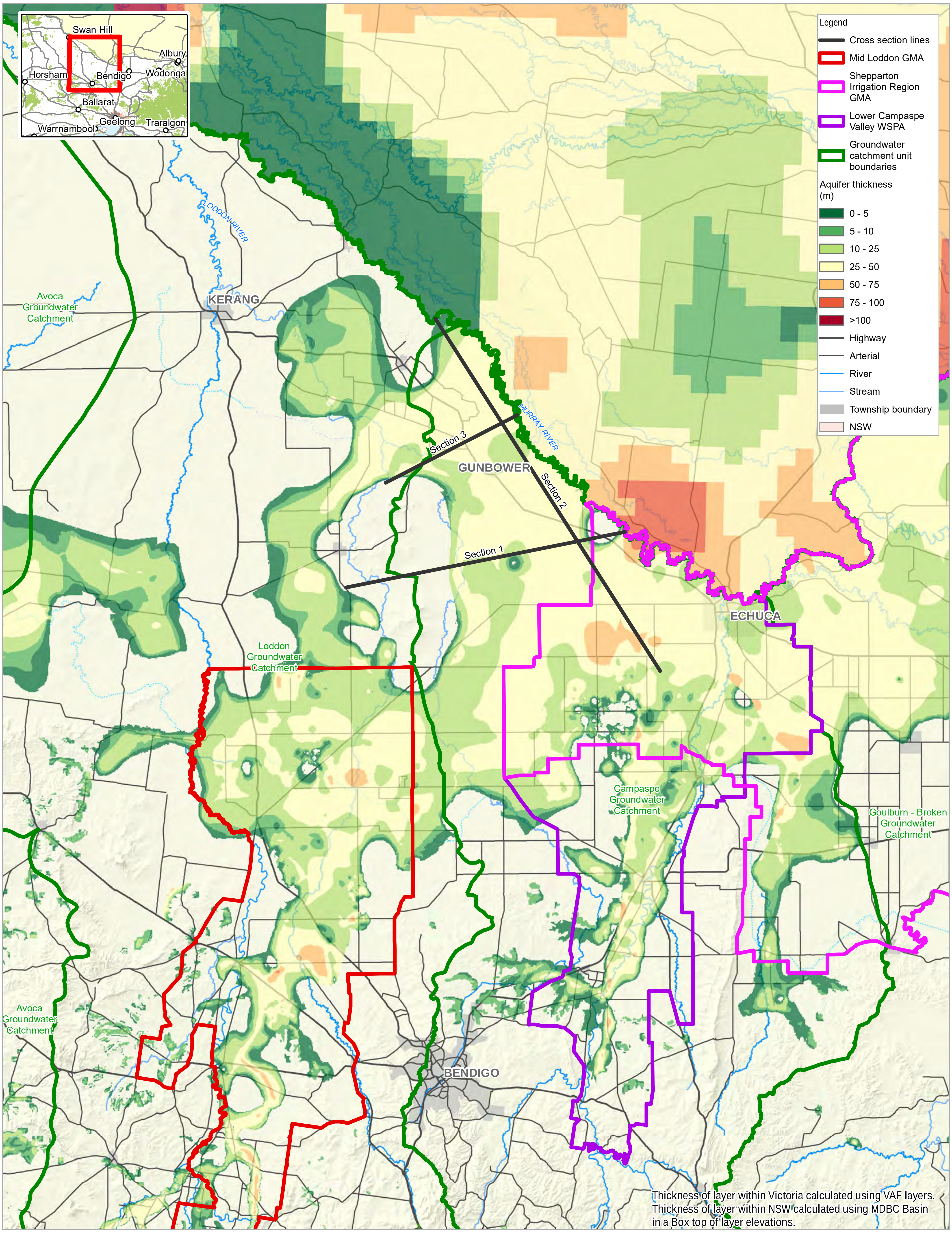

Paper Size ISO A3

0 4.5 9 13.5 18

Kilometres

Map Projection: Lambert Conformal Conic
Horizontal Datum: GDA 1994
Grid: GDA 1994 VICGRID94

N

Goulburn Murray Water
Gunbower and Lower Loddon Hydrogeological Models

Aquifer thickness
Upper Middle Tertiary Aquifer (Fluvial) (105)

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Revision No. 0
Date 03/07/2020

Figure 9

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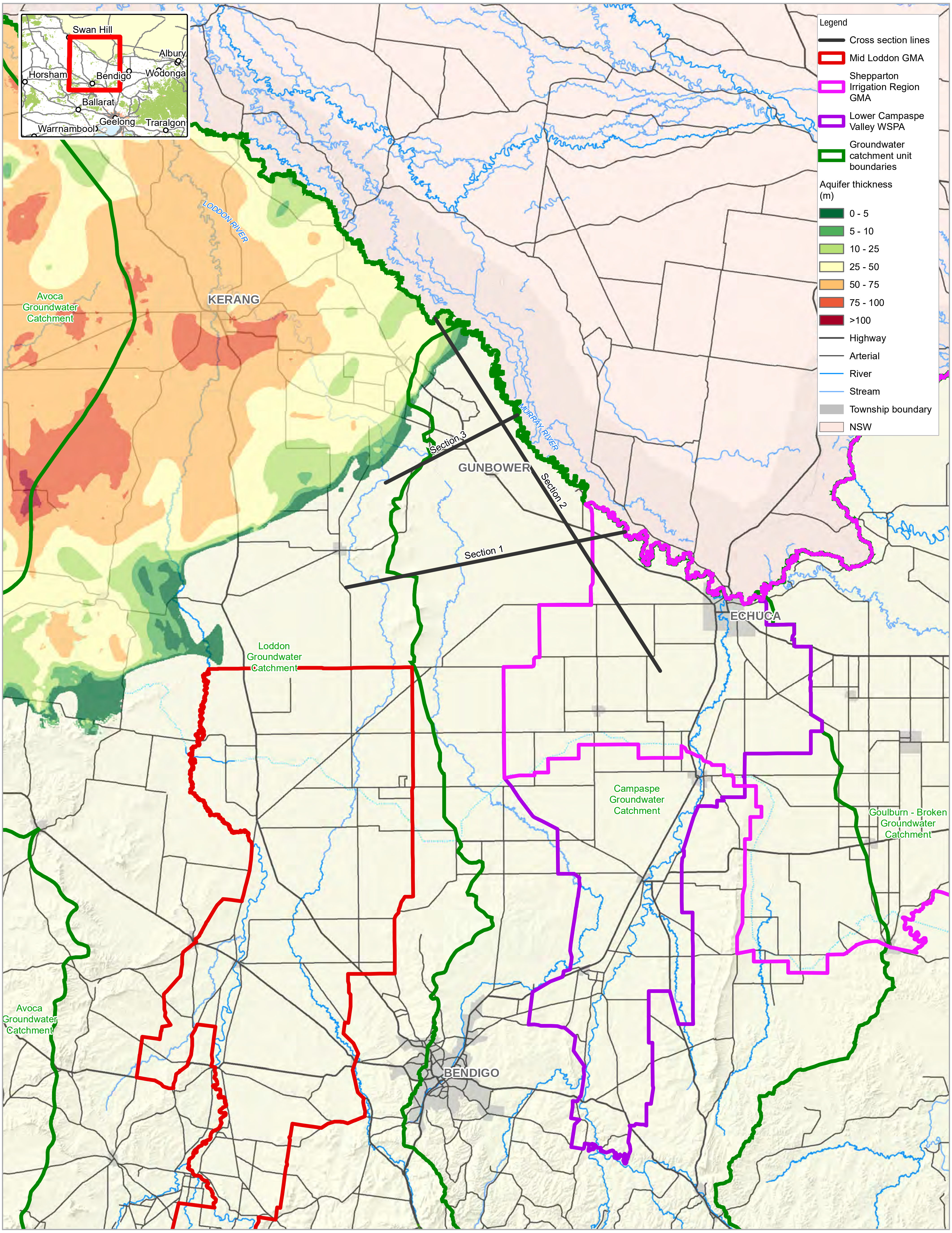

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Kilometres

Map Projection: Lambert Conformal Conic
Horizontal Datum: GDA 1994
Grid: GDA 1994 VICGRID94

N

Goulburn Murray Water
Gunbower and Lower Loddon Hydrogeological Models

Aquifer thickness
Upper Middle Tertiary Aquifer (Marine) (104)

Project No. 12523464
Revision No. 0
Date 03/07/2020

Figure 10

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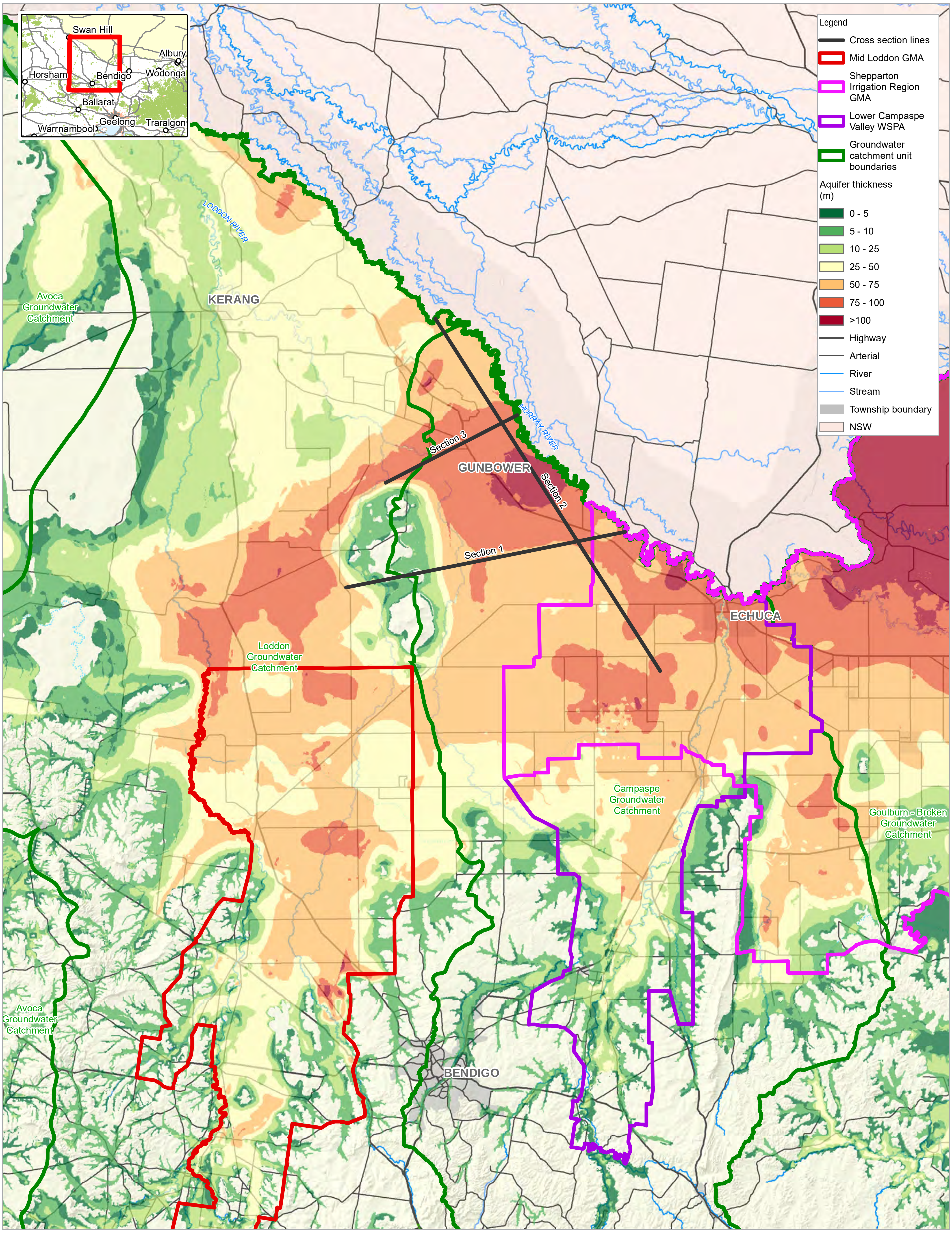

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Kilometres

Map Projection: Lambert Conformal Conic
Horizontal Datum: GDA 1994
Grid: GDA 1994 VICGRID94

N

Goulburn Murray Water
Gunbower and Lower Loddon Hydrogeological Models

Aquifer thickness
Upper Tertiary Quaternary Aquifer (102)

Project No. 12523464
Revision No. 0
Date 03/07/2020

Figure 11

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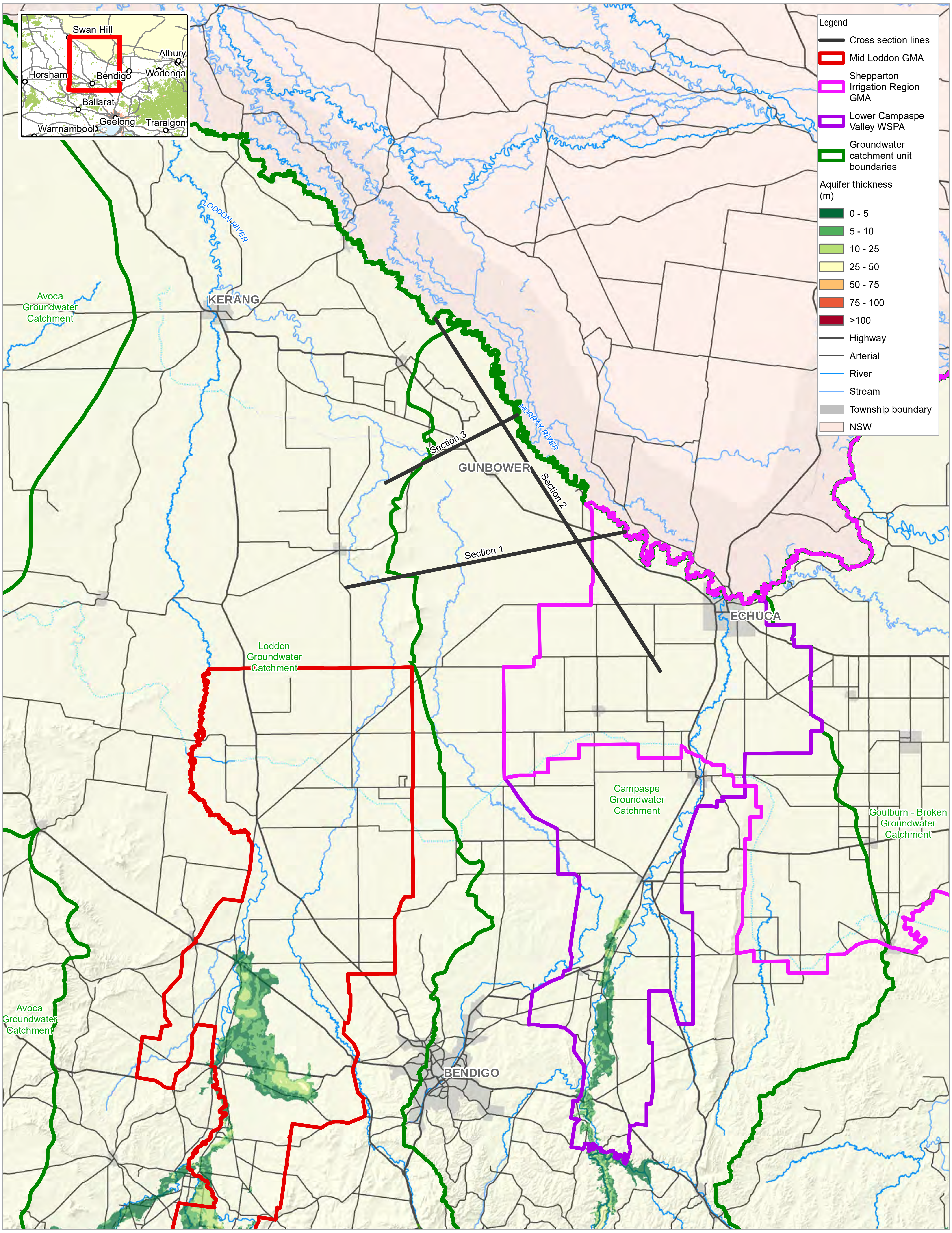

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Kilometres

Map Projection: Lambert Conformal Conic
Horizontal Datum: GDA 1994
Grid: GDA 1994 VICGRID94

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Goulburn Murray Water
Gunbower and Lower Loddon Hydrogeological Models

Aquifer thickness
Upper Tertiary Basalts (101)

Project No. 12523464
Revision No. 0
Date 03/07/2020

Figure 12

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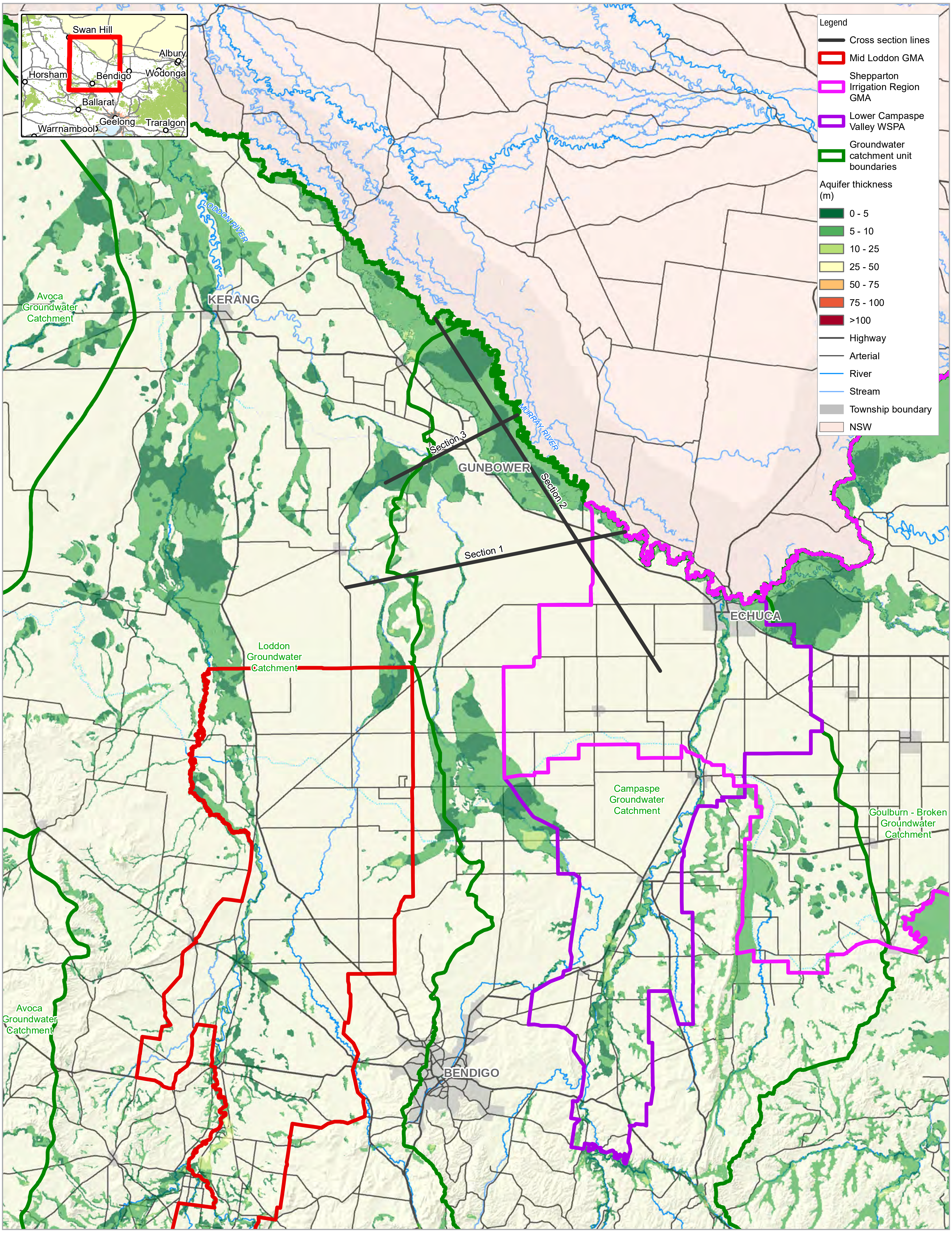

Paper Size ISO A3

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Kilometres

Map Projection: Lambert Conformal Conic
Horizontal Datum: GDA 1994
Grid: GDA 1994 VICGRID94

N

Goulburn Murray Water
Gunbower and Lower Loddon Hydrogeological Models

Aquifer thickness
Quaternary Aquifer (100)

Project No. 12523464
Revision No. 0
Date 03/07/2020

Figure 13

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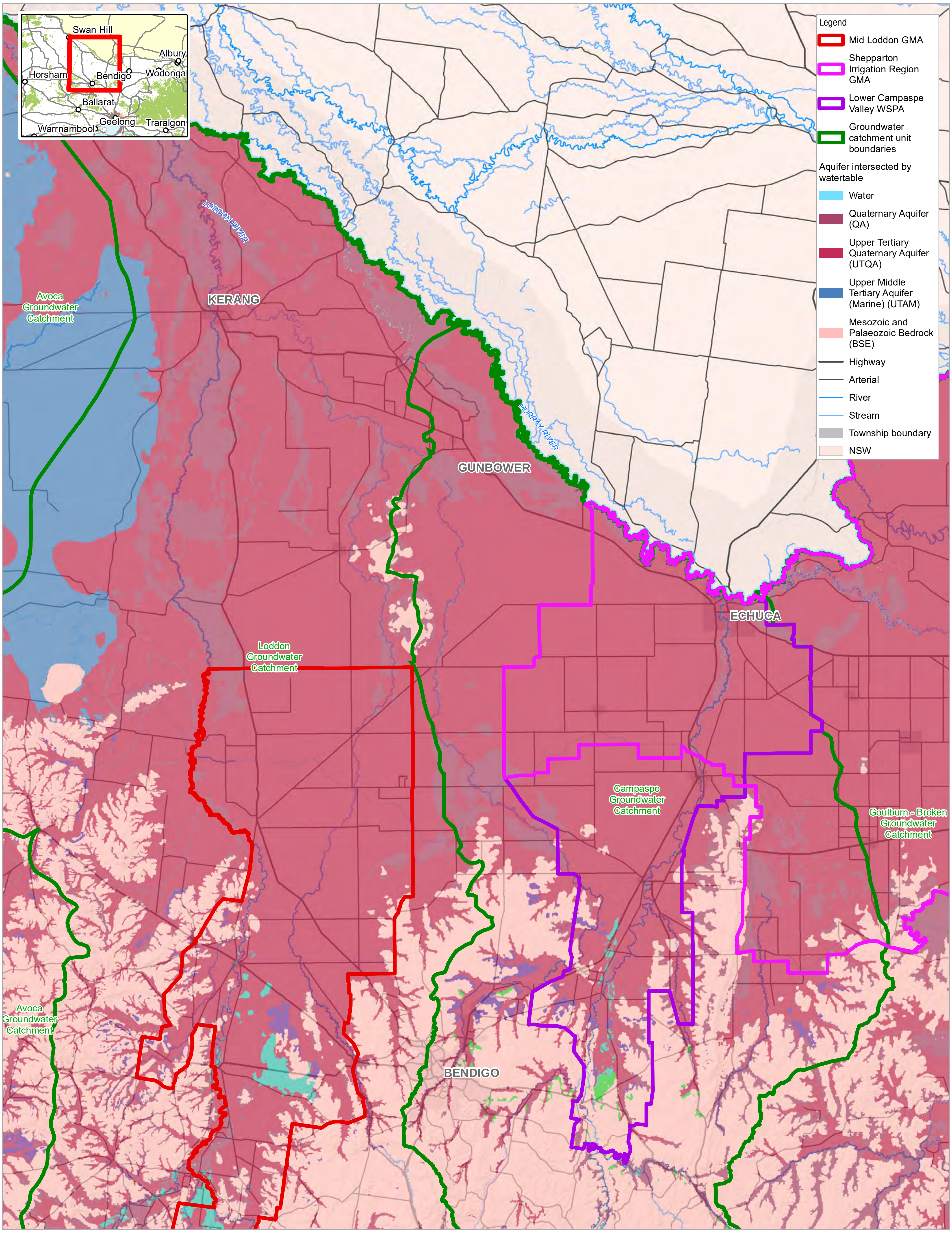

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Kilometres

Map Projection: Lambert Conformal Conic
Horizontal Datum: GDA 1994
Grid: GDA 1994 VICGRID94

N

Goulburn Murray Water
Gunbower and Lower Loddon Hydrogeological Models

Aquifer intersected by Water Table

Project No. 12523464
Revision No. 0
Date 03/07/2020

Figure 14

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0 1 2 4
Kilometres

Map Projection: Lambert Conformal Conic
Horizontal Datum: GDA 1994
Grid: GDA 1994 VICGRID94

LEGEND- SECTION VIEW
- Basement
- QA
- UTQA
- UTAF
- LTA

LEGEND- PLAN VIEW
- Section Line Plan View
- Major road
- Stream
- Channel
- Drain/Channel/Ot...
- Watercourse
- Lake
- Swamp

UTAF Aquifer thickness (m)
- 0 - 5
- 5 - 10
- 10 - 25
- 25 - 50
- 50 - 75
- 75 - 100

Goulburn Murray Water
Gunbower and Lower Loddon
Hydrogeological Models

Job Number 31-12523464
Revision 0
Date 03 Jul 2020

Cross section 1

Figure 15

180 Lonsdale Street Melbourne VIC 3000 Australia T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com W www.ghd.com

G:\31\12523464\GIS\Maps\Deliverables\31_12523464_001_Cross_section_A1L_Section1_Rev0.mxd

Data source:DEWLP, Vicmap, 2020; cross section GHD, 2020 ;DPIPWE, VAF layers and VicMap data, 2020 Data Custodian, Data Set Name/Title, Version/Date. Created by:bsmyth

Paper Size A1

0 1 2 4

Kilometres

Map Projection: Lambert Conformal Conic
Horizontal Datum: GDA 1994
Grid: GDA 1994 VICGRID94

LEGEND- SECTION VIEW

QA
UTQA
UTAM
UTAF
LTA
Basement

LEGEND- PLAN VIEW

Section line
Highway
Arterial
Watercourse
Lake
Swamp

UTAF Aquifer thickness (m)

0 - 5
5 - 10
10 - 25
25 - 50
50 - 75

Goulburn Murray Water
Gunbower and Lower Loddon
Hydrogeological Models

Job Number 12523464
Revision 0
Date 03 Jul 2020

Cross Section 2

Figure 16

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Data source: DPIPWE, VAF layers and VicMap data, 2020. Created by:bsmyth

Paper Size A1

0 0.5 1
Kilometres

Map Projection: Lambert Conformal Conic
Horizontal Datum: GDA 1994
Grid: GDA 1994 VICGRID94

LEGEND- SECTION VIEW

- Basement
- UTAF
- LTA
- UTQA
- QA

LEGEND- PLAN VIEW

- Major road
- Township area
- Watercourse
- Lake
- Swamp
- Stream
- Channel
- Drain/Channel/Other

UTAF Aquifer thickness (m)

- 0 - 5
- 5 - 10
- 10 - 25
- 25 - 50

GHD

Goulburn Murray Water
Gunbower and Lower Loddon
Hydrogeological Models

Job Number 31-12523464
Revision 0
Date 03 Jul 2020

Cross section 3

Figure 17

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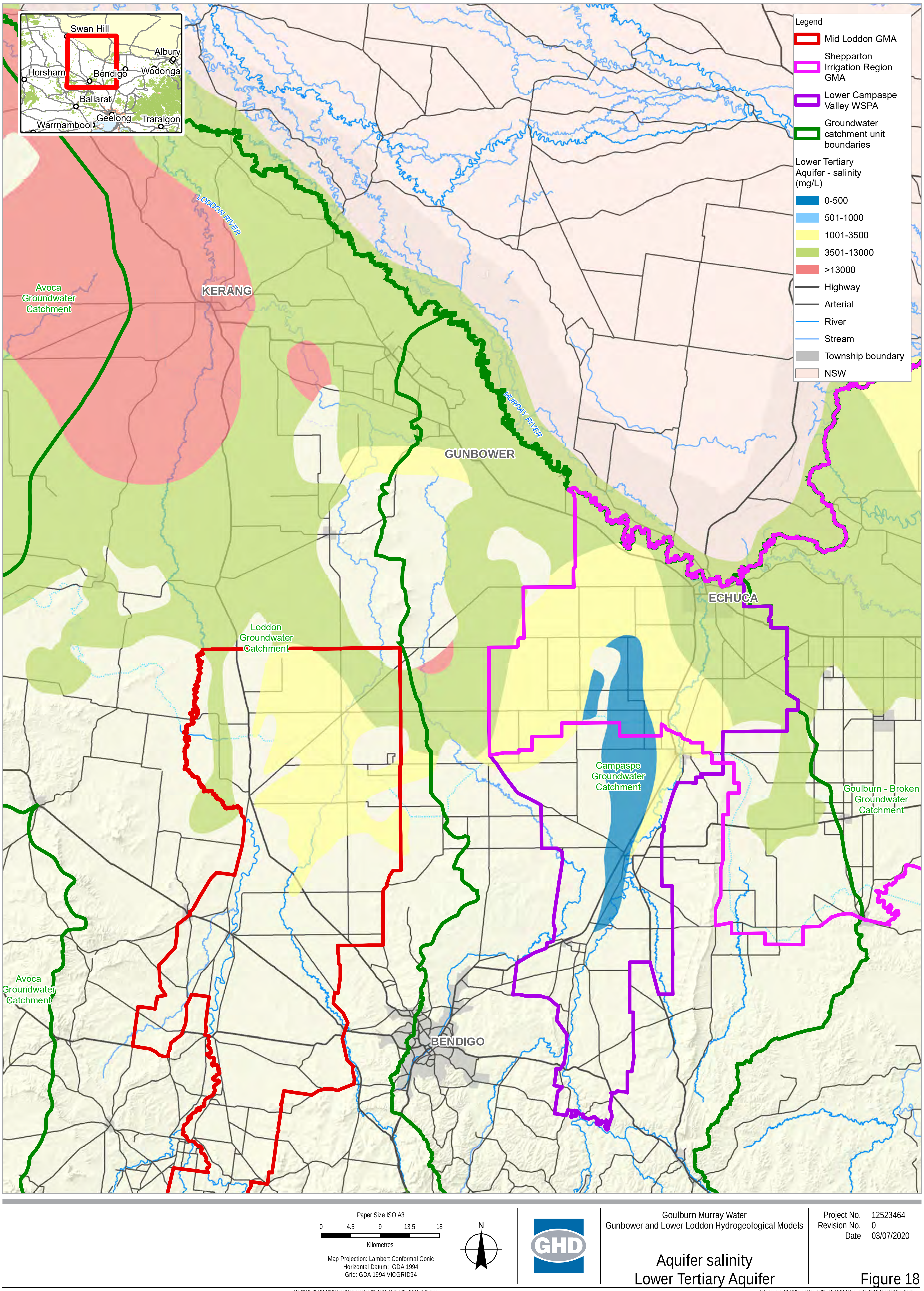

Goulburn Murray Water
Gunbower and Lower Loddon Hydrogeological Models

Project No. 12523464
Revision No. 0
Date 03/07/2020

Aquifer salinity
Lower Tertiary Aquifer

Figure 18

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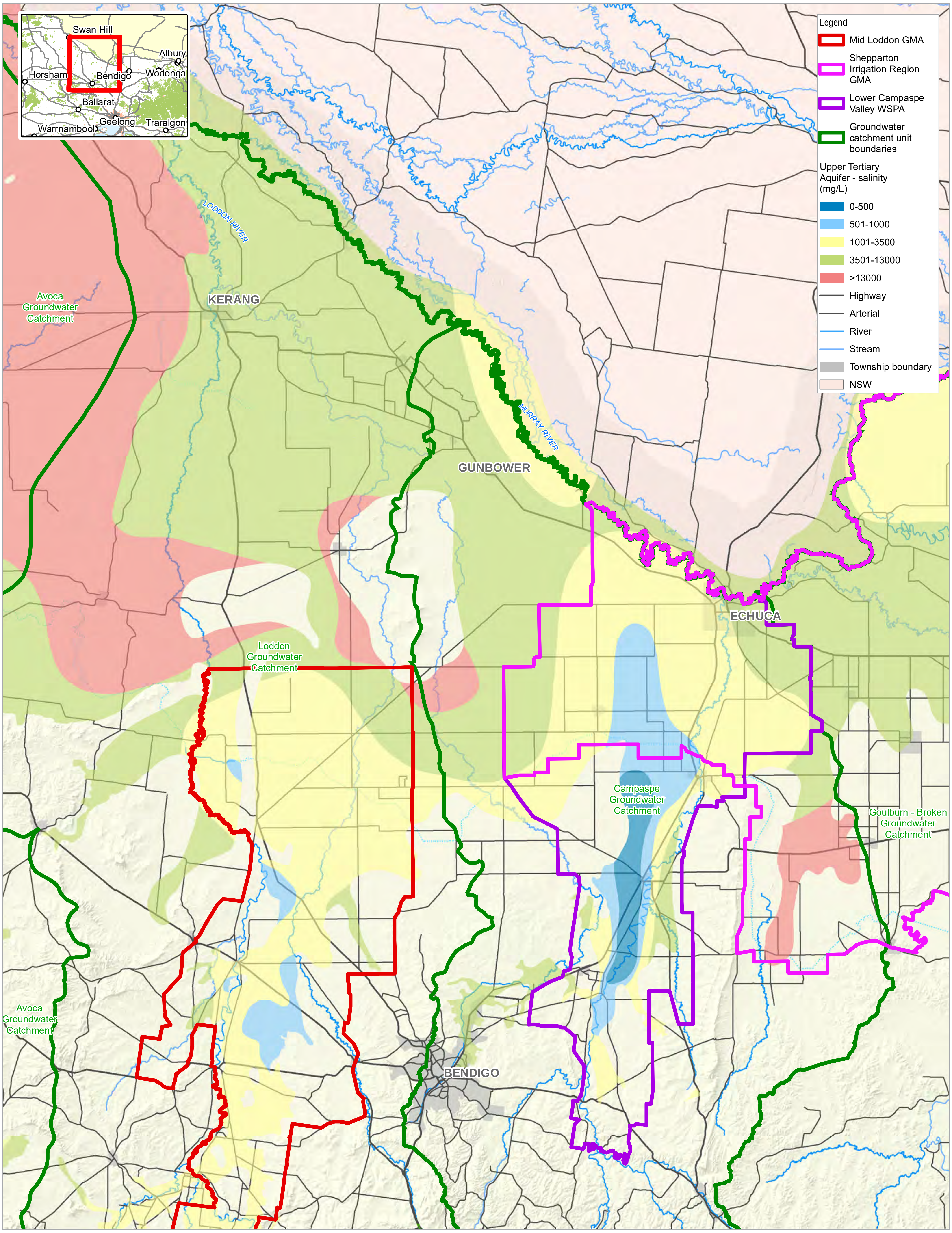

Paper Size ISO A3

0 4.5 9 13.5 18

Kilometres

Map Projection: Lambert Conformal Conic
Horizontal Datum: GDA 1994
Grid: GDA 1994 VICGRID94

N

Goulburn Murray Water
Gunbower and Lower Loddon Hydrogeological Models

Project No. 12523464
Revision No. 0
Date 03/07/2020

Aquifer salinity
Upper Tertiary Aquifer

Figure 19

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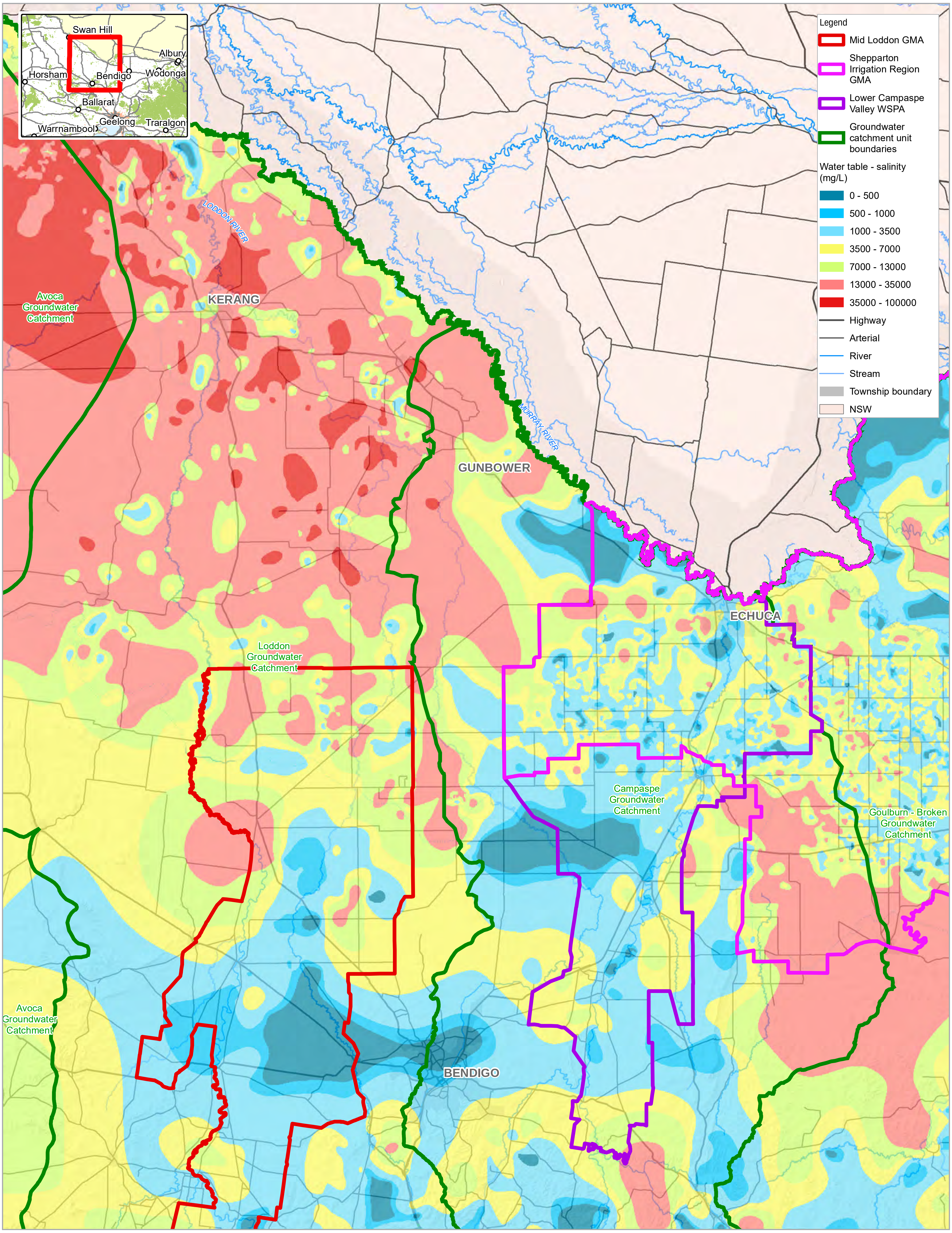

Paper Size ISO A3

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Kilometres

Map Projection: Lambert Conformal Conic
Horizontal Datum: GDA 1994
Grid: GDA 1994 VICGRID94

N

GHD

Goulburn Murray Water
Gunbower and Lower Loddon Hydrogeological Models

Aquifer salinity
Water Table Salinity

Project No. 12523464
Revision No. 0
Date 03/07/2020

Figure 20

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Print date: 03 Jul 2020 - 13:09

Data source: DELWP, VicMap, 2020; DELWP, SAFE data, 2012 Created by: bsmyth

4.3 Groundwater Management Areas and PCVs

4.3.1 Background

The Victorian Department of Environment, Land, Water and Planning (DELWP) has divided the State into 5 groundwater basins, e.g. Goulburn-Murray Basin. Each basin comprises one or more groundwater catchments within a geological basin, e.g. Loddon, Campaspe, Goulburn-Broken, Ovens and Upper Murray (refer Figure 1).

The principle management unit for groundwater resources in Victoria is the Groundwater Management Unit or GMU. A GMU may be a Groundwater Management Area (GMA), a Water Supply Protection Area (WSPA) or an Unincorporated Area. An unincorporated area is a region falling outside of a GMA or WSPA.

Under the Water Act 1989, the Minister for Water may declare the total volume of groundwater (and/or surface water) which may be taken in an area. This is termed the Permissible Consumptive Volume (PCV). The total volume of water allocated under the PCV became a trigger for declaration of a GMA (or WSPA).

The Water Act (1989) requires that all persons who wish to extract groundwater (except domestic and stock users) apply for a groundwater licence. Groundwater licences are issued to protect the rights of licence holders, ensure that water is shared amongst users, and to ensure that environmental requirements are protected. The Victorian Water Register was established as a public register of all water-related entitlements.

Within WSPAs, caps or moratoriums on the issue of additional extraction licenses are often present. Owing to the implications on groundwater development, Ministerial approval, including the development of management plans, were required to convert a GMA to a WSPA. In the late 1990s approximately 50 GMAs were established across the State.

DELWP delegates the management of the Water Act (1989) to Goulburn Murray Water (GMW) in this region, i.e. GMW is the licensing authority responsible for allocation of the groundwater (and surface water) resources. GMW has been releasing Local Management Plans (LMPs). LMPs are incorporating smaller GMUs into larger groundwater catchments for management purposes, but local rules are retained to address specific issues, and water trading arrangements. LMPs are considered to be more responsive that statutory management plans as they can be revised and updated with changing (local) groundwater conditions

4.3.2 Management Units in Study Area

In the regional study area (Figure 1) there are the following management areas are present :

- **Mid Loddon GMA**

The Mid Loddon GMA was established primarily to manage the groundwater resources in the main Loddon Valley Deep Lead aquifer which was, historically, the highly utilised zone of the aquifer systems. The key aquifer systems covered by the Mid-Loddon GMA are the:

- Quaternary Basalt Aquifer
- Quaternary /Upper Tertiary Shepparton Formation Aquifer
- Upper Tertiary Calivil Formation (Deep Leads) Aquifer (UTAF)

The GMA boundary pertains to all formations below the surface (i.e. all depths).

The Mid-Loddon GMA is divided into three management zones; Jarklin Zone, Laanecoorie-Serpentine Zone and Moolort Zone

Mid-Loddon GMA Local Management Rules (Goulburn-Murray Rural Water Corporation, 2009) outline the specific management measures relevant to the GMA, including a trigger levels in Bore 88214, which can result in pumping restrictions, and other requirements.

Groundwater in this GMU is extracted for domestic and stock use and for licensable uses such as irrigation, commercial (watering of intensive poultry farms) and urban supply. Central Highlands Water has a borefield constructed into the Deep Leads underlying the Moolort Plains however sustained extraction from the borefield is yet to commence

- **Lower Campaspe Valley (LCV) WSPA**

The Lower Campaspe Valley (LCV) WSPA was established primarily to manage the groundwater resources in the main Campaspe Valley Deep Lead aquifer, which was also historically the highly utilised aquifer system. The key aquifer systems covered by the GMU include:

- Quaternary /Upper Tertiary Shepparton Formation aquifer.
- Upper Tertiary Calivil Formation and Lower Tertiary Renmark Group (Deep Lead) aquifer.

The LCV WSPA is divided into four management zones; Barnadown, Elmore-Rochester, Bamawm and Echuca.

The WSPA Groundwater Management Plan (GMW, 2012) outline the specific management measures relevant to the WSPA, including two triggers for restrictions, and other requirements:

- Bore 79324: maintain net flow over the NSW border, and prevent higher salinity groundwater inflow.
- Bore 62589: maintain the resource, prevent long term decline

Groundwater in this GMU is predominately used for domestic and stock use and for licensable uses such as irrigating dairy pastures and agricultural crops, as well as urban supply for Elmore township.

- **Shepparton Irrigation Region (SIR) WSPA**

The Shepparton Irrigation Region (SIR) WSPA covers the groundwater resources in the Shepparton Formation aquifer to a depth of 25m. Groundwater extraction from this aquifer system is primarily for salinity control, and for irrigation (shandied with channel water). In wetter conditions, there is additional surface water available and the groundwater demand declines, however groundwater levels can rise causing issues with land productivity.

The WSPA Groundwater Management Plan (GMW, 2015) outline the specific management measures relevant to the WSPA. It is noted that there is no cap on groundwater entitlement defined in the Plan in order for new licences to be developed to maximise the opportunity for pumping of shallow groundwater, with the objective to assist with the management of shallow water table impacts.

- **Unincorporated Area (UA)**

  The zone, north of the Mid Loddon GMA and between then Mid Loddon and LCV WSPA. The Gunbower zone of interest is in this Unincorporated Area.

4.3.3 Permissible Consumptive Volumes and Available Allocations

The permissible consumptive volume (PCV), entitlements and recent usage (2017-2018) is summarised in Table 4-2 below.

It is noted that the adjacent GMUs are fully allocated, and usage from the GMUs is also high at 73% of the PCV for Mid Loddon and 67% for the LCV WSPA. Therefore these GMUs, and particularly the LCV WSPA may be sensitive to impacts from extraction from the Gunbower zone.

In addition, GMW, 2012, completed a water balance for LCV WSPA, which calculated there was around 25 GL/year available for extraction if throughflow was minimised. This calculated sustainable level of extraction was around 45% of the licenced entitlements, and therefore it can be concluded that the WSPA is potentially under considerable stress now (and particularly under dry climate scenarios). GMW,2011 also noted that if groundwater levels fall below triggers then additional recharge is likely to occur; being river leakage, leakage from the Shepparton Formation and additional lateral flows.

Additional use data (over a number of years) is included in Section 4.4.

Table 4-2 GMU PCV, allocation and use summary

Information	Mid Loddon GMA	Lower Campaspe Valley WSPA	Shepparton Irrigation region WSPA
PCV (ML/year)	34,037	55,875	Not Set
GMA aquifer depth limits (m)	All formations below ground surface	All formations below ground surface	<25m
Number of licenses	100	133	
No. of D & S Bores	328	520	
Licensed entitlement (ML) 2017-18	33,877	55,860	188,446
Entitlement as % of PCV	99.5% (fully allocated)	100% (fully allocated)	n/a
Total licensed groundwater use (ML) 2017-18	24,721	37,432	76,610
Total estimated non-metered groundwater use (ML) 2017-2018	656	1,040	-
Estimated average Total Use (All.+ S&D) (ML) 2017-2018	25,377	38,472	76,610
Trend in allocations (2004-2018 data)**	Stable / Flat	Stable / Flat	Stable/flat
Trend in use (2004-2018 data)**	Rising	Rising	Variable -Rising (since 2011)
Use as % of entitlements (2017-2019)	73	67	41
Use as % of PCV (2017-2018)	73	67	n/a

Notes:

* Data range between 2017 and 2018 used,

**Source: GHD (2018)

- **SIR WSPA**

It is noted that the Basin Plan includes limits on groundwater extraction defined for the SIR GMA. A groundwater Sustainable Diversion Limit (SDL) of 244,100 ML is specified in the Basin Plan for the SIR GMA (GMW, 2015). This limit has been set at a high level, based on a historic level of entitlement, and in recognition that the main purpose of groundwater management in the SIR is to support the mitigation of impacts from high water tables, rather manage resource extraction. Compliance with the SDL is based on average usage over a period of 5 or 10 years. It is higher unlikely that the SDL will be a constraint in the SIR GMA based on historical use and the resource capability of the shallow aquifers.

4.4 Groundwater Use

4.4.1 Existing Groundwater Bores

A search of the DELWP Water Measurement Information System (WMIS) database was undertaken to identify and characterise groundwater use in the region. All bore locations are shown in Figure 21, and a summary of bore type in the 4 key zones; Mid Loddon, Lower Campaspe, Shepparton irrigation district (SID) and Unincorporated; are included in Table 4-3.

Table 4-3 Groundwater Bore Summary

Bore type	Mid Loddon	Lower Campaspe	SIR	SIR and Lower Campaspe	Unincorporated
Commercial	12	12	13	6	29
Dairy	3		13	7	
Dewatering	1	20	2	7	36
Disposal	3				
Domestic	21	36	46	53	62
Dryland salinity bore network	147	24	5		729
Groundwater investigation	96	625	2870	1459	1393
Industrial	25	14	4	19	126
Investigation				3	8
Irrigation	127	136	329	297	82
Miscellaneous	4	2	12		2
Non groundwater	456	327	113	19	1639
Not known	184	158	902	614	512
Not used	1	3	12	10	4
Observation	134	527	2537	752	2522
SEC bore		1		2	3
State Observation Bore	132	118	75	58	281
Stock	207	122	42	50	110
Stock and domestic	281	337	356	412	790
Urban		2			1

Groundwater bores are predominately used for observation and investigation purposes in each for the four zones. In terms of extractive uses, stock / domestic / stock and domestic are the most common extractive uses followed by irrigation. There are only three bores in the area that are used for urban consumptive use.

As noted in Section 4.3, a combination of use for stock and domestic, as well as licensable uses such as irrigation, commercial and urban supply. Groundwater use will be primarily from the Deep Lead system and the Shepparton Formation, however in some areas the basalt aquifer and Quaternary aquifer will be developed

Gunbower Area

Figure 22 focuses on the bores around the township of Gunbower.

This shows two existing irrigation bores (WRK091289, WRK115717) to the east of Gunbower and also shows a number of additional proposed bore locations (based on current applications to GMW).

4.4.2 Licensed Entitlements

Licensed entitlements across the region are shown in Figure 24, which indicates:

- Entitlements are commonly used for irrigation in the Mid-Loddon, LCV and SID GMUs, with some commercial/industrial use.
- There is limited entitlements in the Unincorporated Area between the Mid Loddon and LCV GMUs with the following notable exceptions:
  - Dewatering extraction around Bendigo, assumed to be associated with former mines.
  - Dewatering extraction at Pyramid Hill for salt interception schemes.
  - Irrigation extraction in the Gunbower Area (discussed further below).

Gunbower Unincorporated Zone users

In the Gunbower focus area, there are currently three bores with entitlement, the details are shown in Table 4-4 below. These three bores have similar depths, around 130-140m and screen the Deep Lead aquifer system.

Table 4-4 Gunbower Area Existing Groundwater Entitlements

Information	Bore ID WRK091289	Bore ID WRK115717	Bore ID WRK118233	Comment
Total depth (m)	136	138	132	
Screened interval (m DBNS)	119.5-135	99-113; 120-132	107-129	
Bore constructed	14/06/2016	21/09/2019	13/1/2020	
Groundwater salinity (sample date; source)	~4000 EC (bore owner)	3600 EC (21/09/2019; Driller) 5730 EC (7/08/2019; ALS Lab) 3950 EC (16/01/2020; GMW)"	3000 EC	
TDS mg/L (est)	2600	3725 (lab based)		
Groundwater licence issued	5/12/2016	2/12/2019	unknown	
Licence volume (ML/yr)	505	840	600	

Information	Bore ID WRK091289	Bore ID WRK115717	Bore ID WRK118233	Comment
Max daily volume (ML)	15	14	unknown	
2019/20 use (ML)	300.3 (to 7/01/2020)	406 (to 23/01/2020)	n/a	
2018/19 use (ML)	275.6	n/a	n/a	First year of extraction
Yield from drill log L/sec	250	50	170	

As noted previously, these bores are high yielding (14-15 ML/day, or 170-180 L/sec) and although the salinity is marginal at 2,600 to 3,700 mg/L TDS can be used by shandying with other water sources.

Gunbower Zone: New Entitlement Applications

Figure 22, shows the approximate location of 11 entitlement applications for the Gunbower area.

The application volumes (and the existing issued entitlements) are summarised in Table 4-5. New applications total 10,612 ML/year, around 5 times the existing entitlements.

Table 4-5 Gunbower: Summary of New Applications and Existing Entitlements

Bores	Application / Entitlement Volume (ML/year)
Applications	
BGW0836-19	1,000
BGW0995-19	850
BGW0977-19	1,120
BGW0982-19	840
BGW0997-19	840
BGW1038-19	1,000
BGW1053-19	1,000
BGW0006-20	500
BGW0088-20	1,500
BGW0099-20	600
BGW0111-20	1,022
WRK091289	200(1)
WRK115717	140(1)
Total Applications	**10,612**

Bores	Application / Entitlement Volume (ML/year)
Entitlements Issued	
WRK091289	505
WRK115717	840
WRK118233	600
Total Entitlements	**1,945**
Applications + Entitlements	***12,557***

Note (1) Application to increase volumes

4.4.3 Groundwater Use

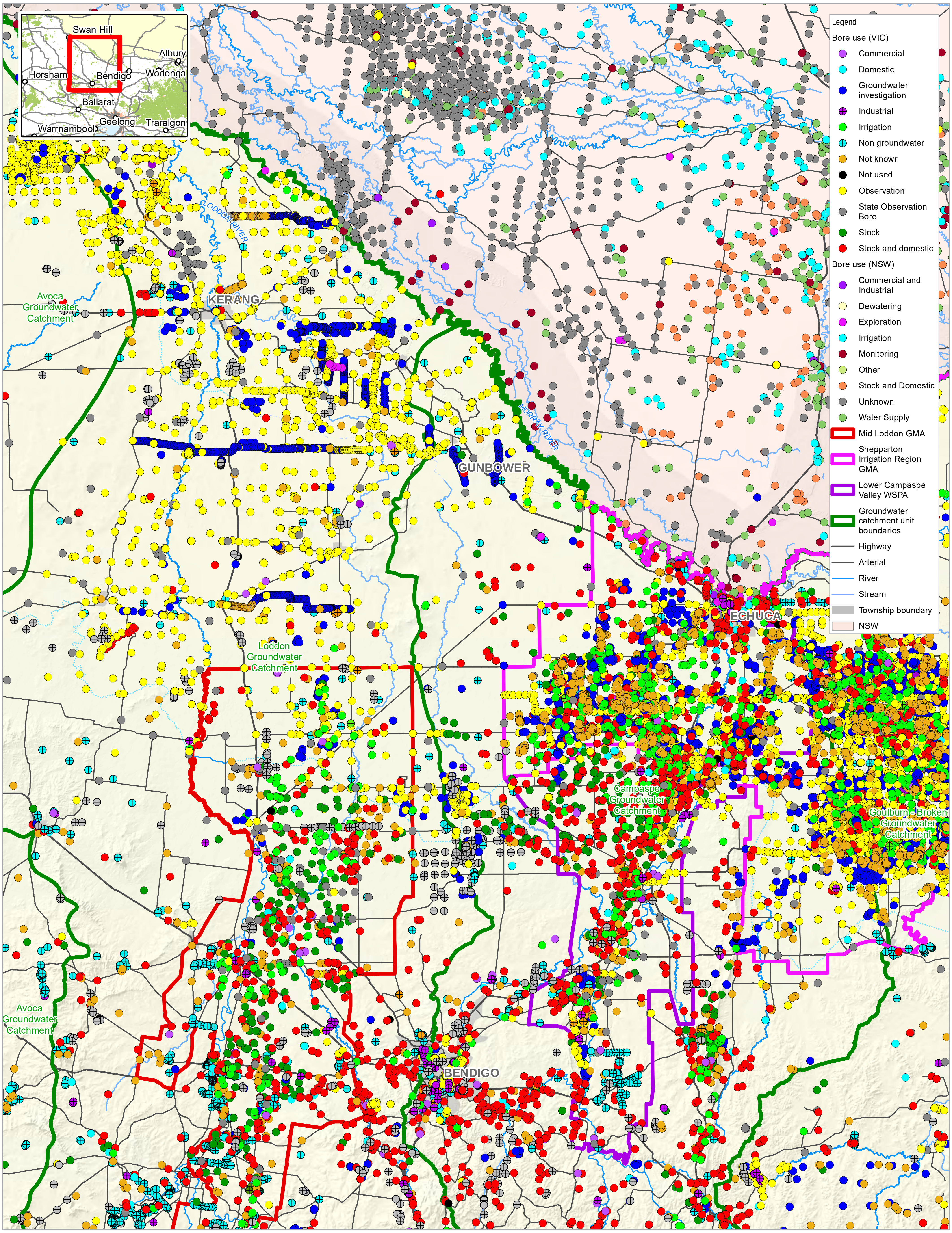
Groundwater entitlement and use is shown in Table 4-6 for the four water system sources:

- Mid-Loddon Groundwater Management Area (GMA)
- Lower Campaspe Valley Water Supply Protect Area (WSPA)
- Shepparton Irrigation Region Groundwater Management Area (SIR GMA)
- Unincorporated areas

Groundwater use was highest in 2018/19 for each water system source with the lowest year of groundwater use being 2016/17; it is noted that 2016/17 was a wetter year compared to the other four summarised.

Table 4-6 Groundwater entitlement and use

Water System Source	Current licenced volume (ML)	2014/15 (ML)		2015/16 (ML)		2016/17 (ML)		2017/18 (ML)		2018/19 (ML)	
		Volume (ML)	% licenced volume	Volume (ML)	% licenced volume	Volume (ML)	% licenced volume	Volume (ML)	% licenced volume	Volume (ML)	% licenced volume
Lower Campaspe Valley WSPA	55,860	36,057	65%	44,994	81%	24,383	44%	37,409	67%	50,259	90%
Mid Loddon GMA	33,927	17,165	51%	25,249	74%	12,285	36%	24,152	71%	30,300	89%
Shepparton Irrigation Region GMA	185,321	71,690	39%	79,448	43%	54,220	29%	76,610	41%	93,828	51%
Unincorporated	34,748	3,165	9%	2,217	6%	1,816	5%	3,008	9%	4,061	12%
Grand Total	**309,856**	**128,077**	**41%**	**151,908**	**49%**	**92,704**	**30%**	**141,179**	**46%**	**178,448**	**58%**



Paper Size ISO A3

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Kilometres

Map Projection: Lambert Conformal Conic
Horizontal Datum: GDA 1994
Grid: GDA 1994 VICGRID94

N

GHD

Goulburn Murray Water
Gunbower and Lower Loddon Hydrogeological Models

Regional bore locations

Project No. 12523464
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Date 03/07/2020

Figure 21

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Print date: 03 Jul 2020 - 13:00

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Kilometres

Map Projection: Lambert Conformal Conic
Horizontal Datum: GDA 1994
Grid: GDA 1994 VICGRID94

GHD

Goulburn Murray Water
Gunbower and Lower Loddon Hydrogeological Models

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Date 03/07/2020

Bore use
Gunbower area

Figure 22

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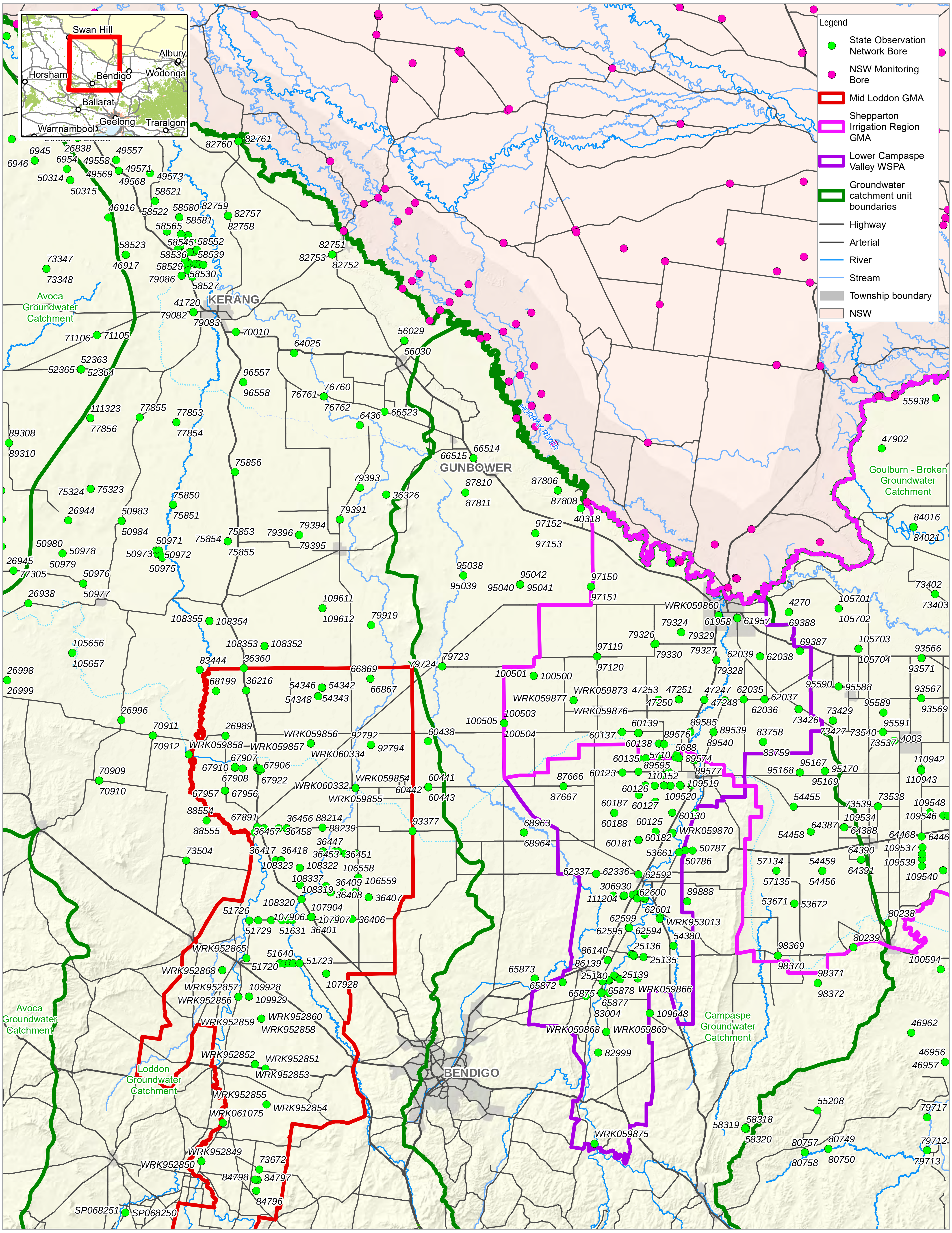
Data source: DELWP, VicMap, 2020; DELWP, WMIS, 2020; GMW, application bores, 2020 Created by: bsmyth



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Kilometres

Map Projection: Lambert Conformal Conic
Horizontal Datum: GDA 1994
Grid: GDA 1994 VICGRID94

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GHD

Goulburn Murray Water
Gunbower and Lower Loddon Hydrogeological Models

State observation bores Regionally

Project No. 12523464
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Date 03/07/2020

Figure 23

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Print date: 03 Jul 2020 - 14:15

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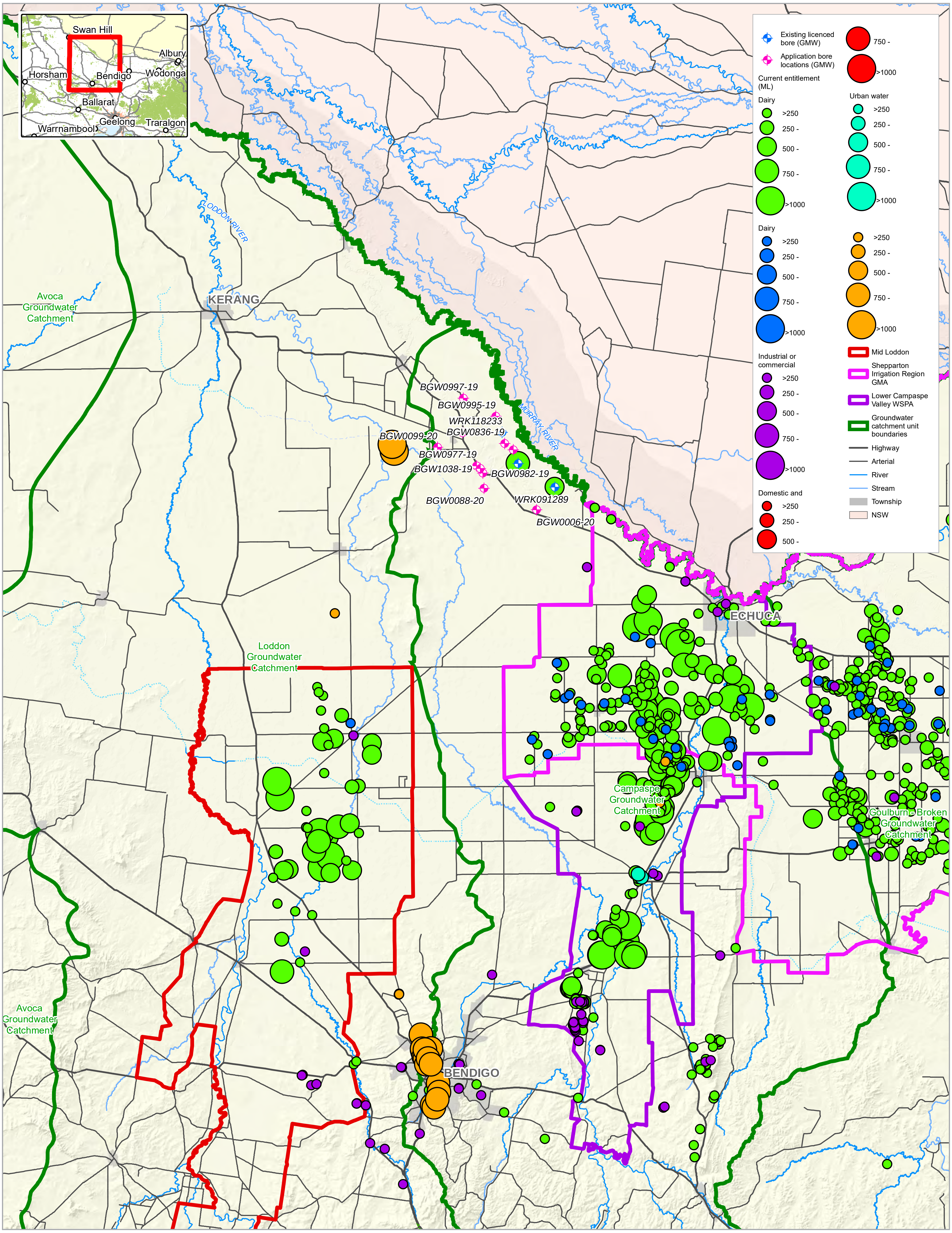

Paper Size ISO A3

0 4.5 9 13.5 18

Kilometres

Map Projection: Lambert Conformal Conic
Horizontal Datum: GDA 1994
Grid: GDA 1994 VICGRID94

N

GHD

Goulburn Murray Water
Gunbower and Lower Loddon Hydrogeological Models

Groundwater use and entitlement

Project No. 12523464
Revision No. 0
Date 03/07/2020

Figure 24

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Print date: 03 Jul 2020 - 13:10

Data source: DELWP, VicMap, 2020; GMW, bore use, 2020; GMW, application bores, 2020 Created by: bsmyth

4.4.4 Groundwater Monitoring Network and Level Trends

State Observation Network (SON) Bores in the region are shown in Figure 23. These bores generally have either monthly or quarterly groundwater level monitoring frequencies, and this can provide a source of longer term groundwater level information for the region.

In the Gunbower area the most relevant bores area tabulated in Table 4-7

Table 4-7 State Observation Bores in Gunbower Area

Bore ID	Distance from Gunbower (km)	Aquifer Monitored	Bore depth (m)	Screen From (m)	Screen To (m)	Associated nested bores
66515	4.0	102	17.5	7	14	66514
66514	4.0	105	178	116.2	123.5	66515
87810	5.0	111	133.9	96.85	99.85	87811
87811	5.0	102	17.5	4	16	87810
97152	10.5	105	145	107	110.3	97153
97153	10.5	102	20.5	11.5	17.5	97152
54342	40.4	111	151.79	31.89	32.65	54343, 54346, 54347, 54352
54343	40.4	105	100.28	88.4	94.5	54346, 54347, 54342, 54352
54346	40.4	102	69	0	0	54343, 54342, 54347, 54352
54348	41.7	111	125.5	119.5	125.5	54350, 54349, 54351
95039	15.5	102	12.5	7.5	12.5	95038
95038	15.5	105	157	86.7	90.05	95039
95042	16.6	102	28	20	26	95040, 95041
95041	16.6	105	75	66	69	95040, 95042
95040	16.6	105	120	82.5	85.5	95041, 95042
97150	21.8	105	147.7	75	81	97151
97151	21.8	102	22.5	15	20	97150
56029	23.9	111	190	122.49	128.61	56030
56030	23.9	104	63	50.26	56.46	56029
54349	41.7	105	110	95	105	54348, 54350, 54351
54350	41.7	102	46	35	45	54348, 54349, 54351
54352	40.4	102	36	0	0	54342, 54343, 54346, 54347
76760	27.7	111	123.5	113	116	76761, 76762
76761	27.7	105	80.5	73	74.5	76760, 76762
76762	27.7	102	26.5	17.9	21.8	76760, 76761

Bore ID	Distance from Gunbower (km)	Aquifer Monitored	Bore depth (m)	Screen From (m)	Screen To (m)	Associated nested bores
87806	9.6	111	196.6	156	162	87807, 87808, 87809
87807	9.6	105	135.35	122	128	87806, 87808, 87809
87808	9.6	102	62	50	60	87806, 87807, 87809
87809	9.6	102	20	12	15	87806, 87807, 87808
79324	36.0	105	170	78	84	79329
79329	36.0	102	6	0.1	6	79324
100500	30.2	111	138.85	113	133	100501
100501	30.2	105	121.2	85	96	100500
102827	29.2	105	185	108	114	102828, 102829, 102830, 102831
102828	29.2	111	178	160.21	166.78	102827, 102829, 102830, 102831
102829	29.2	102	80.5	70.5	73.5	102827, 102828, 102830, 102831
102830	29.2	102	27.8	16	22	102827, 102828, 102829, 102831
102831	29.2	114	195	177	195	102827, 102828, 102829, 102830
88214	57.9	105	128.02	53.6	112.2	88238, 88239
88238	57.9	102	30	25	29	88214, 88239
88239	57.9	102	14	8	12	88214, 88238

The hydrographs for all these 41 SON bores are included in Appendix A, with select hydrographs included, and trends discussed below:

- **Nested Bores 87806/07/08/09:**

The hydrograph is shown in Figure 25 and includes monitoring of the Shepparton Formation \Calivil Formation and Renmark Group aquifers. This is the closest SOB bore to the existing irrigation extraction bores in the Gunbower area (i.e. WRK091289) .

This hydrograph shows that there is a strong correlation of groundwater trends (in all aquifers) with climatic trends (i.e. rainfall) with a general decline in groundwater levels in all aquifers since 1995 and a marked decline from around 2000-2010 during the Millennium drought. In the Shepparton Formation the decline was around 3m during this period, and while a similar pattern of response in the Deep Lead aquifer the decline was around 5m over the same period. This decline likely to be greater due to pumping from the Deep Lead aquifer in the adjacent LCV WSPA.

This hydrograph, as noted previously, indicates there is a downwards vertical hydraulic gradient from the Shepparton Formation aquifer to the Deep Lead aquifer. The differing magnitude of climatic/extraction induced variation, and head differences reflects the hydraulic separation between the aquifer systems in this area.

The Renmark Group and Calivil Formation aquifers have near identical hydrographs, again reflecting the high degree of connection of these units of the Deep Lead aquifer system.

There is a notable decline in the Deep Lead Aquifer in late 2018/2019, where ground water levels have declined around 2m in the last 2 years. This has occurred during a drier climate however it does also correspond with the commencement of extraction from the nearby licenced bore (WRK091289) in 2018/19 and then additional extraction from WRK115717 (further away) starting in 2019/2020. A comparison with the nested SON Bores in the LCV WSPA (Figure 26), which also shows a sharp decline around the same period, indicating it is more likely to be a regional response to climate/extraction rather than a local response to the relatively new extraction bores.

- **General: Groundwater trends in the Deep Lead aquifer**

In the Gunbower area there has been a general decline in Deep Lead aquifer levels of around 5-6m from around 1995 and through the Millennium drought to 2010, or around 0.4m/year (refer hydrographs Figure 25: 87806/07/08/09 and Figure 27: 66514/15). The declining trend during this dry period indicates that the aquifer recharge/discharge processes are not in equilibrium and groundwater is being taken from storage. Continuing declines in groundwater levels are not sustainable, and there is no obvious flattening of the drawdown during this period.

However in this area, when rainfall returns to close to average (combined with lower use), the groundwater levels rebound and stabilise from 2010 through to 2019. After 2019 as noted previously there appears to be further decline in groundwater levels associated with dry conditions.

Overall the hydrographs indicate that the Deep Lead aquifer system is stable under average climate conditions, however under dry conditions when there is greater use and potentially less recharge, groundwater is being removed from storage and the aquifer is under more stress. It is noted that there is significant available drawdown available for the deep lead aquifer in this area (i.e. 40-80m), and additional vertical recharge may occur to the Deep Lead aquifer over time, due to the additional drawdown and provides a new equilibrium in the water balance at some stage.

- **General: Vertical flow direction**

It is noted that although there is a downward vertical flow direction from the Shepparton Formation aquifer to the Deep Lead aquifer in the Gunbower area, the difference between groundwater pressures has generally increased significantly since around 1995 and through the Millennium drought. In addition there are some areas to the south of Gunbower (i.e. nested bores 95038/39 or 95040/41/42), where upward gradients have been consistent pre 2005. However, since this relatively dry period, gradients have been reversed or levels are now similar.

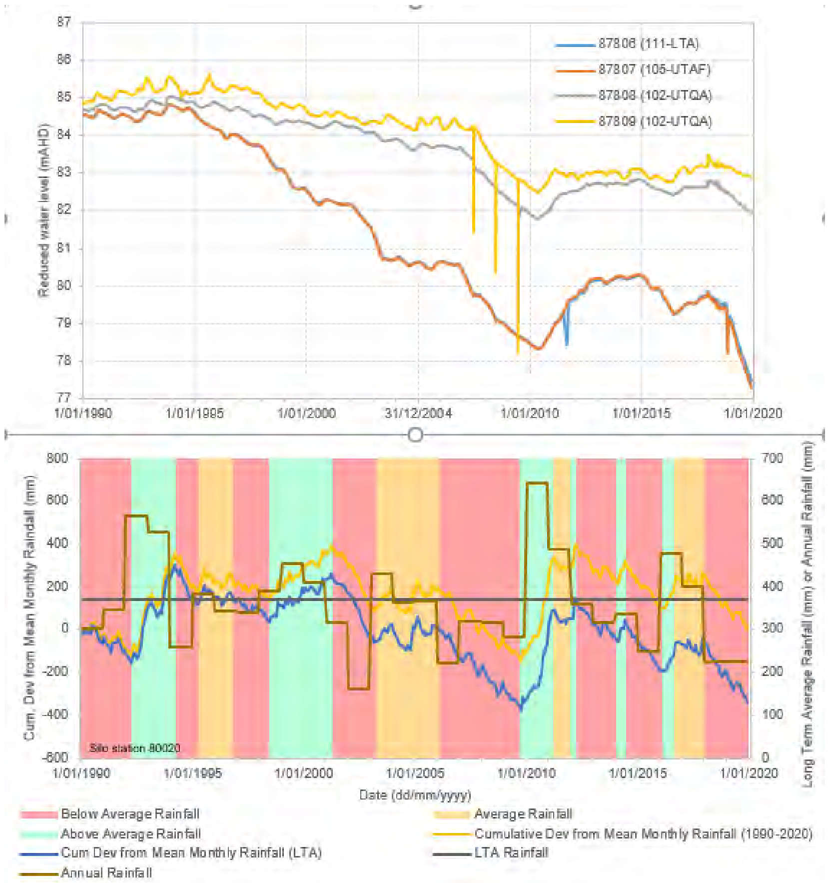


Figure 25 Hydrograph (Gunbower) Nested Bores: 87806/07/08/09

Figure 26 Hydrograph (LCV WSPA) Nested site

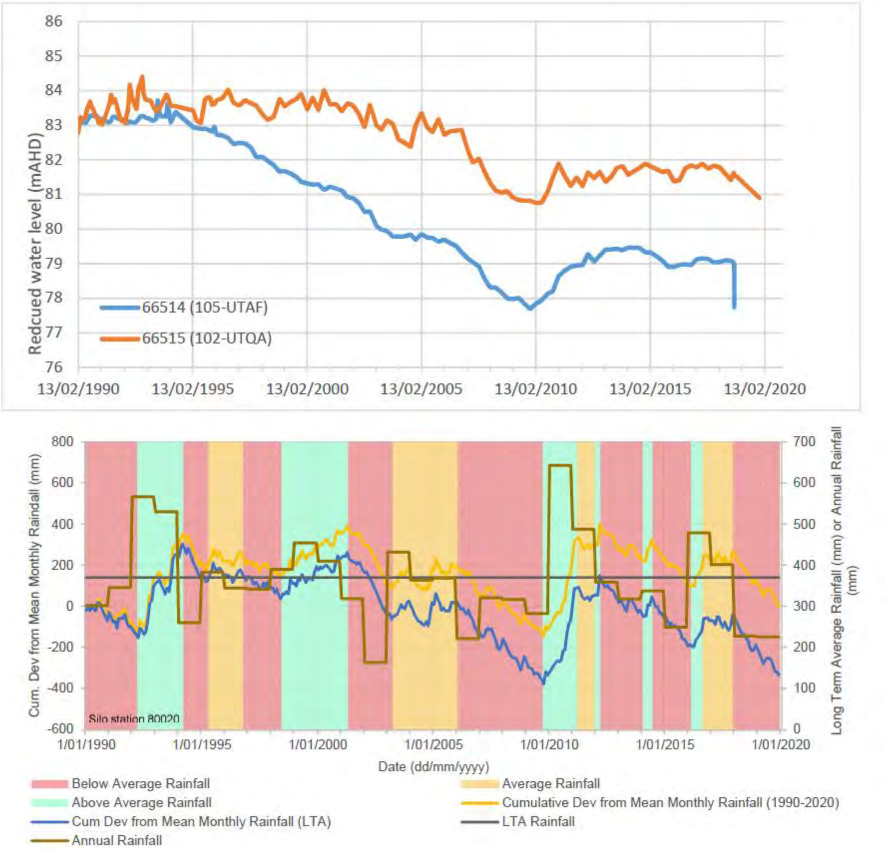


Figure 27 Hydrograph Gunbower) Nested Bores: 66514/15

4.5 Groundwater Potentiometric Contours and Flow direction

GHD has constructed potentiometric surfaces for the key aquifer systems based on the SOBN bores to assist in identifying any flow patterns which may indicate connection, or otherwise, between the GMUs and the Gunbower area, and for groundwater gradient estimations:

- Shepparton Formation aquifer: Figure 28.
- Deep Lead aquifer:
  - Calivil Formation: Figure 29.
  - Renmark Group: Figure 30.
  - Deep Lead (combined): Figure 31.

Groundwater levels used for the interpreted potentiometric surfaces were generally from 2019, the exception being some data points from 2015 (last data available).

4.5.1 Shepparton Formation aquifer

The groundwater contours in Figure 28 show the following trends:

- Noticeable drawdown cones in the Mid Loddon GMA (sand sheet area) and the LCV WSPA due to groundwater extraction.
- Regional groundwater flow is generally south to north.

4.5.2 Deep Lead Aquifer

The Deep Lead aquifer interpreted potentiometric surfaces, show the following:

- In the Gunbower area, there is generally a downwards vertical gradient from the Shepparton Formation aquifer to the Deep Lead aquifer, this is also shown in the hydrographs (Appendix A).
- Groundwater flow is general from south to north towards the Murray River.
- There appears to be a groundwater divide between the flows in the Mid-Loddon GMA and the Deep lead sediments that are present further east around the Terrick Terrick Ranges.
- Groundwater flows north–south on the eastern side of the Terrick Terrick Ranges, where there is another groundwater divide. This divide approximates the western boundary of the LCV WSPA. At the divide groundwater either flows towards the LCV WSPA or further north towards the Gunbower area through a defined trough of deep lead sediments of around 60-80m in thickness (refer cross section 1 : Figure 15). The divide is driven by groundwater drawdown in the LCV WSPA. It is noted that there will also be another divide to the north in NSW (as documented by Macumber, 2008) again caused by extraction form the LCV WSPA, and the flow direction may be reversed seasonally when extraction ceases in the wetter months.
- Groundwater that flows towards Gunbower, thorough this trough then flows to the north-west, basically paralleling the path of the Murray River, where the Deep Lead sediments become thicker and more extensive, extending across the Victorian border (refer cross section 3: Figure 17, and Figure 8).
- The aforementioned groundwater divide indicates that currently the groundwater flowing towards Gunbower is generally not sourced from the LCV WSPA, but from further south and possibly from the north (across the Murray River). It is noted that intensive pumping from the Gunbower area however could move this divide further into the WSPA and result in some flow from the WSPA.

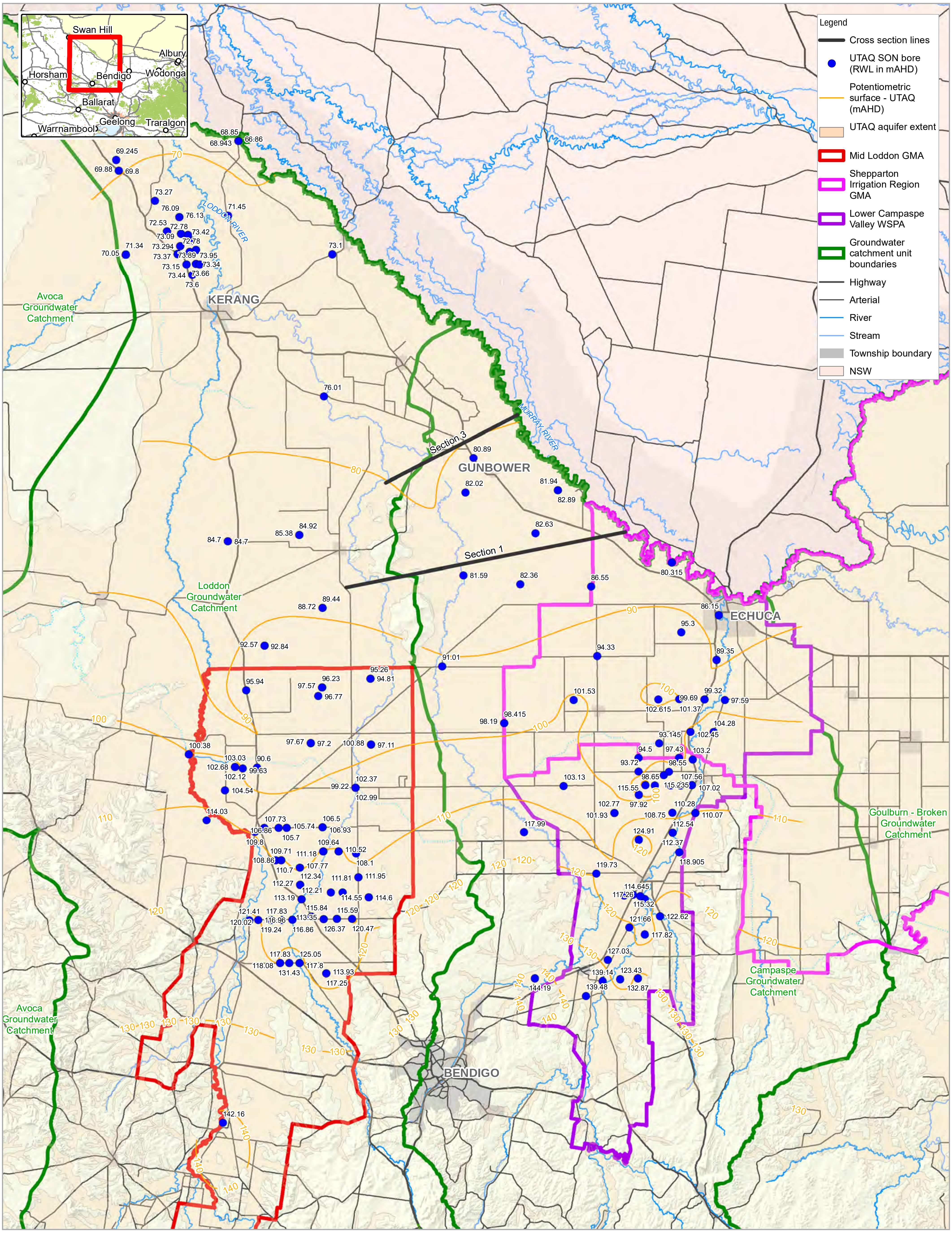
- Groundwater gradient in the Remark Group was calculated to be 0.0004 around cross section 1, and flattened further north–west to approximately 0.0001 at cross section 2. Overall the hydraulic gradients from the Renmark Group, are considered more accurate than the Calivil Formations in the northwest due to the more extensive network of SOBN bores.

It is noted, that across the border in NSW, GHD has shown some historical AGSO (1992) contours/flow directions for context, as although NSW bores were interrogated the aquifer screen could not be clearly distinguished between the Calivil Formation or the Renmark Group. Data from these deeper observation bores in NSW has been used in the combined Deep Lead potentiometric surface (Figure 31) to provide flow directions across the border. The NSW bores included are summarised in Table 4-8.

Table 4-8 NSW Groundwater Bore Summary

Bore ID	Distance from Gunbower (km)	Bore depth (m)
GW036765.3.3	23.2	199.0
GW036775.4.4	34.3	276.0
GW036644.3.3	38.8	190.0
GW036747.3.3	40.4	291.0
GW036772.3.3	44.4	205.0
GW036582.2.2	44.7	190.0
GW273088.1.1	54.6	202.0
GW036589.3.3	55.0	206.0
GW088540.2.2	55.3	145.0
GW036766.1.1	58.7	160.0
GW036102.1.1	62.0	121.9
GW273085.2.2	62.5	192.0
GW036486.1.1	67.3	241.1
GW036490.1.1	67.3	286.0
GW036557.1.1	69.9	330.0
GW036682.1.1	69.9	330.0
GW036653.1.1	69.9	305.0
GW036095.1.1	69.9	224.3
GW036683.1.1	69.9	331.0
GW036558.1.1	70.2	313.0
GW040979.2.2	70.3	111.0
GW036201.1.1	72.0	114.3
GW036587.4.4	72.1	190.0
GW273087.1.1	72.2	131.0
GW036564.1.1	74.0	313.0
GW036588.4.4	74.0	158.0

Bore ID	Distance from Gunbower (km)	Bore depth (m)
GW041081.2.2	75.3	198.0
GW036823.4.4	76.7	215.0
GW273026.1.1	77.1	207.0
GW036871.3.3	77.2	218.0
GW036742.3.3	82.7	322.0
GW500444.2.2	83.4	195.0
GW036822.3.3	90.2	299.0



Paper Size ISO A3

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Kilometres

Map Projection: Lambert Conformal Conic
Horizontal Datum: GDA 1994
Grid: GDA 1994 VICGRID94

N

Goulburn Murray Water
Gunbower and Lower Loddon Hydrogeological Models

Project No. 12523464
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Date 03/07/2020

Potentiometric surface
Upper Tertiary Quaternary Aquifer (102)

Figure 28

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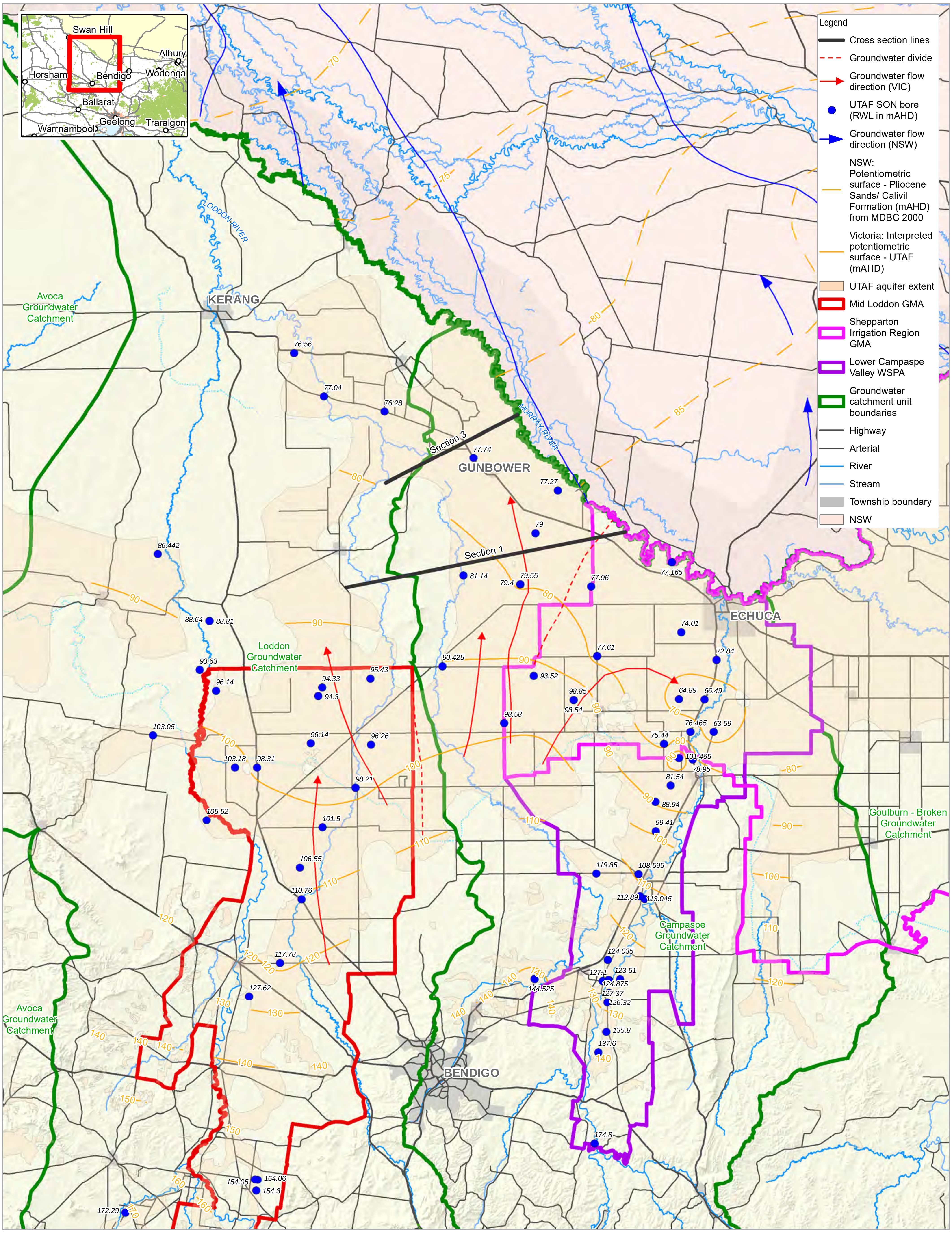

Paper Size ISO A3

0 4.5 9 13.5 18

Kilometres

Map Projection: Lambert Conformal Conic
Horizontal Datum: GDA 1994
Grid: GDA 1994 VICGRID94

N

Goulburn Murray Water
Gunbower and Lower Loddon Hydrogeological Models

Project No. 12523464
Revision No. 0
Date 03/07/2020

Potentiometric surface
Upper Middle Tertiary Aquifer (Fluvial) (105)

Figure 29

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Print date: 03 Jul 2020 - 14:14

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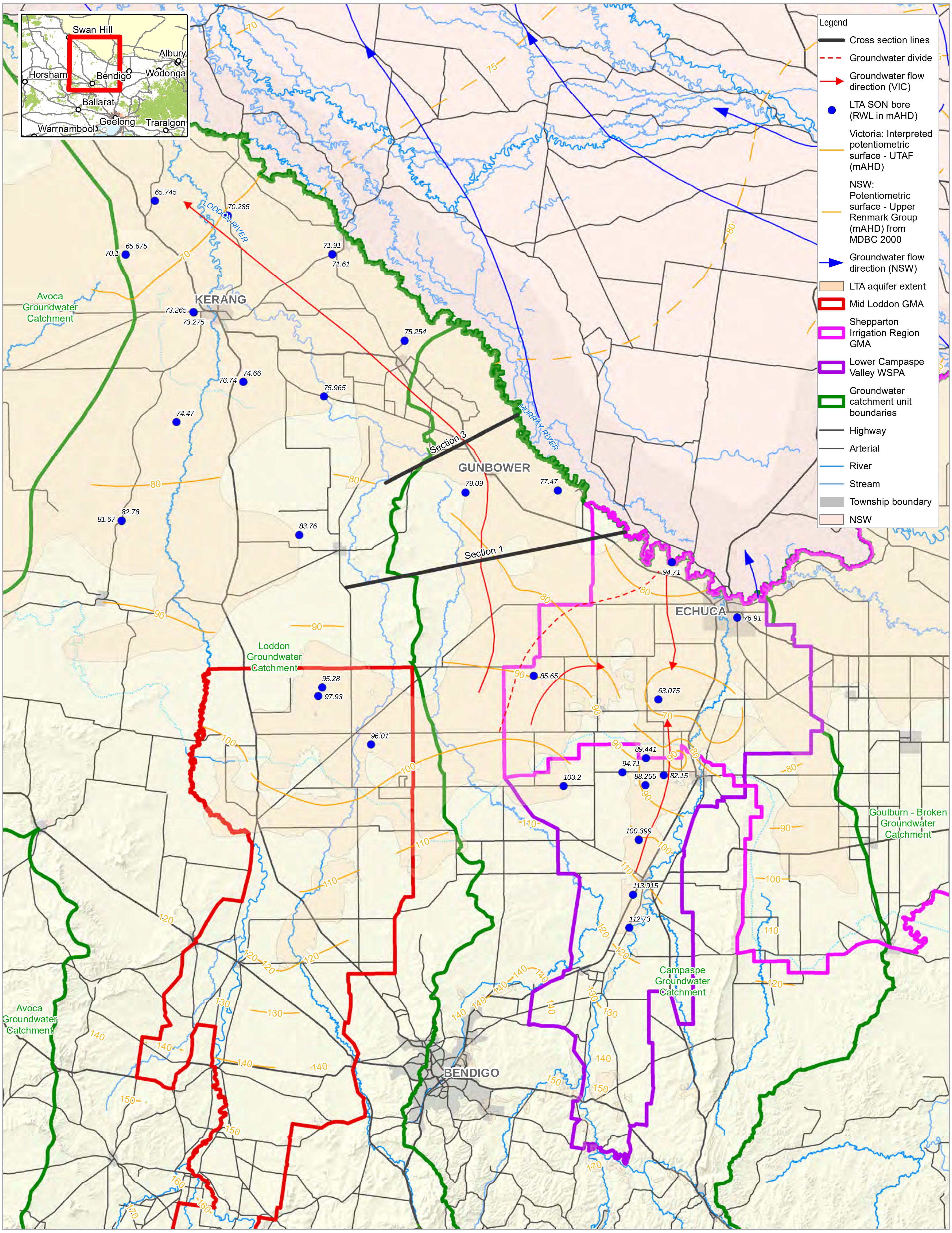

Paper Size ISO A3

0 4.5 9 13.5 18

Kilometres

Map Projection: Lambert Conformal Conic
Horizontal Datum: GDA 1994
Grid: GDA 1994 VICGRID94

N

Goulburn Murray Water
Gunbower and Lower Loddon Hydrogeological Models

Potentiometric surface
Lower Tertiary Aquifer (111)

Project No. 12523464
Revision No. 0
Date 03/07/2020

Figure 30

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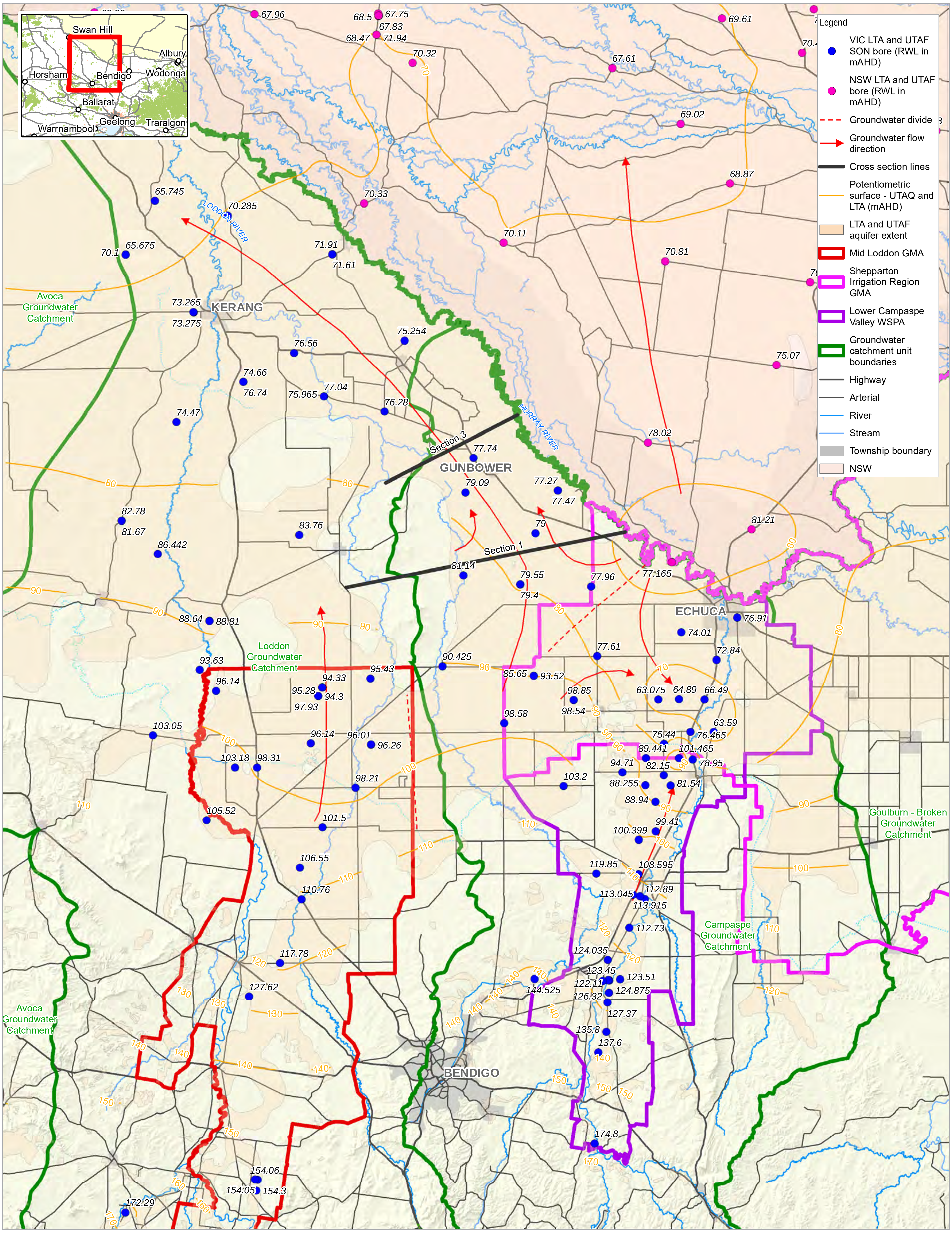

Paper Size ISO A3

0 4.5 9 13.5 18

Kilometres

Map Projection: Lambert Conformal Conic
Horizontal Datum: GDA 1994
Grid: GDA 1994 VICGRID94

N

GHD

Goulburn Murray Water
Gunbower and Lower Loddon Hydrogeological Models

Potentiometric surface
LTA and UTAF combined

Project No. 12523464
Revision No. 0
Date 03/07/2020

Figure 31

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Print date: 03 Jul 2020 - 13:16

Data source: DELWP, VicMap, 2020; DELWP, WMIS, 2020; GHD, contours, 2020; DELWP, VAF, 2013; BOM, NGIS data, 2019 Created by: bsmyth

4.6 Aquifer Parameters

4.6.1 Shepparton Formation aquifer

Nolan ITU, 2003 reports hydraulic conductivities generally in the range of 0.5 to 8.0 m/day, and specific yields ranging from 0.02 to 0.01.   Thicker sections can have hydraulic conductivities up to 30m/day. The presence of the shoe string sands result in significant anisotropy in groundwater flow.

4.6.2 Deep Lead aquifer

Nolan-ITU, 2003 reported that in the Campaspe valley the deep lead hydraulic conductivities range from 10-200 m/day but are typically around 100 m/day in the south, grading to lower values in the north. However, it was noted that values can increase markedly in the extreme north, where hydraulic conductivities of 185 m/day have been recorded associated with the Murray Trench (Nolan ITU, 2001a). As a result of the considerable thickness and permeability of the sediments , high transmissivities are expected and found, ranging between 500 and 10,000 m^2/day (Nolan-ITU, 2011a).

Nolan ITU, also reported storage co-efficient within the Deep Lead range from 5 $x10^{-4}$ to 5 $x10^{-3}$ (Dudding et al 1991).

Aquade, 2011 and CDM-smith, 2016 also collated and summarised regional aquifer properties in the Lower Campaspe Valley WSPA area, with the results being summarised in Table 4-9.

Table 4-9 Deep Lead aquifer hydraulic conductivity

Aquifer Unit	Source	Range	Hydraulic Conductivity, K (m/day)	Transmissivity , T (m^2/day)	Area
Deep Lead aquifer	Aquade (2011)	Min	25	740	Lower Campaspe WSPA
		Max	260	16,000	
		typical	40-140	2,000-6,000	
Renmark Formation	CDM-Smith (2017)	Min	10	212	West of Echuca
		Max	138	2,200	
		Mean	60	1,194	
Calivil	CDM-Smith (2017)	Min	0.3	746	West of Echuca
		Max	276	9,381	
		Mean	116	3,863	

4.7 Conceptual Hydrogeological Model

4.7.1 Regional CHM

On a regional scale, the conceptual hydrogeological model for the Lower Campaspe Valley WSPA is shown in Figure 32 (from GMW, 2012). This shows the relationship and flow systems of the Deep Leads, Shepparton Formation, basalt (in the upper valley area) and bedrock aquifer systems.

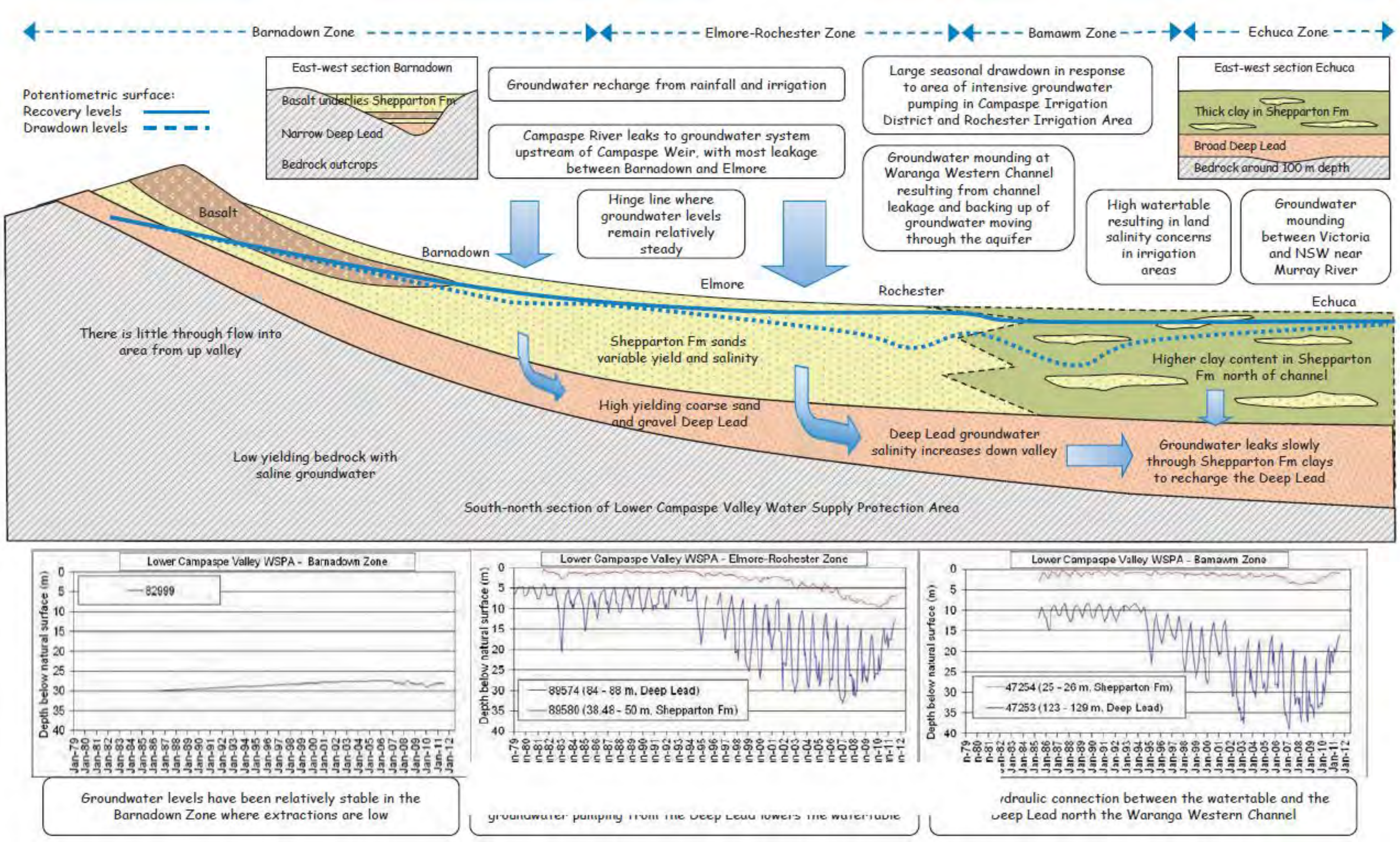
4.7.2 Gunbower Area

On a local scale, the conceptual hydrogeological model for the Gunbower area is shown in Figure 33, and the recharge and discharge processes are summarised in Table 4-11.

Table 4-10 Summary of Aquifer Recharge and Discharge Processes

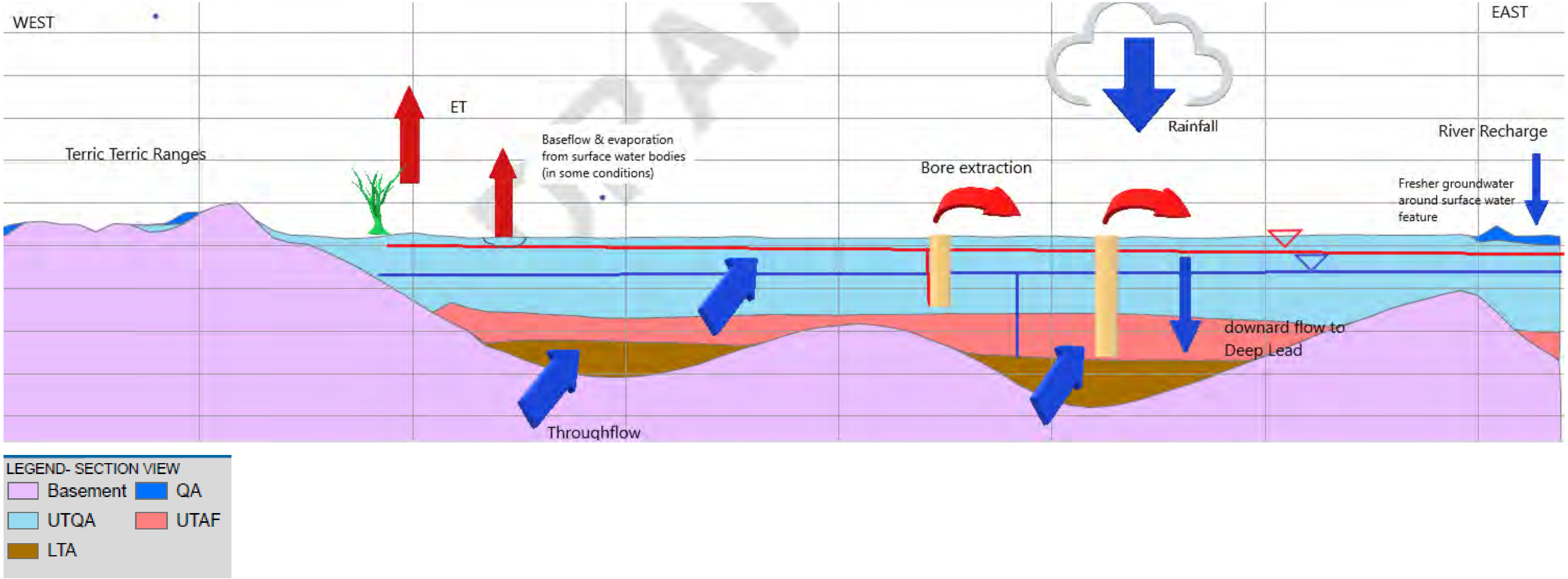
Aquifer System	Recharge Process	Discharge Process	Comments
Shepparton Formation	Direct rainfall infiltration	Evapotranspiration	
	Surface Water (leakage) recharge (i.e. rivers, channels, ephemeral lakes)	Baseflow to streams/surface water features (in some locations/wet conditions)	i.e. Murray River generally losing
	Throughflow from adjacent areas	Throughflow to adjacent areas	
	Upwards leakage from underlying Deep lead aquifer	Leakage to underlying Deep Lead aquifer	Generally downwards leakage, particularly since 1995. Some areas to the south have upwards gradient in some climatic conditions
		Extraction	
Deep Lead	Downward Leakage from Shepparton Formation aquifer	Upwards Leakage to underlying Deep Lead aquifer (some conditions)	As above generally downwards Aquifer is confined in this area and Shepparton Formation is relatively clayey and low permeability
	Throughflow from adjacent areas/GMUs	Throughflow to adjacent areas (i.e. further into Murray Basin/NSW)	
		Extraction	

Figure 32 Conceptual Hydrogeological Model: Regional Lower Campaspe Valley WSPA



Source : GMW, 2012

Figure 33 Conceptual Hydrogeological Model: Local Gunbower Area



Notes: Not to scale

4.7.3 Risks associated with additional extraction (Gunbower Area)

Based on the Conceptual Hydrogeological Model and current aquifer response, GHD has identified the risks associated with increased groundwater extraction in the Gunbower area in Table 4-11, and also qualitatively rated these risks.

The objective of this is to identify key risks that may require prioritisation for further investigation, technical assessment or focus for monitoring plans, when GMW consider additional applications. Licence requirements may be tailored to focus on the higher risks, particularly if entitlements issued are approaching the estimate of annual recharge of the area (refer Section 5).

A non-technical risk associated with additional large scale extraction from the Gunbower area may be stakeholder and/or public perception associated with potential interaction with the nearby GMUs.

Table 4-11 Potential Risk of additional groundwater extraction

Risk	Specific Risk Pathway	Qualitative Risk Rating	Potential Management or Mitigation Options
Impact on Deep Lead aquifer sustainability (Gunbower Area)	Long term continued groundwater level decline due to additional extraction. • Groundwater levels are stable during average climate/use periods to date, however during drought period there was a continuing downwards groundwater level trend suggesting the aquifer is under stress. Under additional extraction further groundwater decline will occur, however it will only stabilise if a sustainable volume. The decline noted in the past dry periods may stabilise over extended time but this was not seen in the hydrographs. • Groundwater levels may also be impacted by extraction from adjacent LCV WSPA and flow directions/groundwater divides shift in dry periods.	Low: average climate Moderate: dry climate	Assessment of sustainable yield on a regional scale (i.e. with LCV and Mid Loddon GMUs) under various climate scenarios. Declare a GMU for this area, develop a PCV limit and local management plan. Improved monitoring. Improved understanding of aquifer parameters Develop level triggers based on acceptable drawdown limit Ability to reduce entitlements based on aquifer response
	Groundwater quality decline (is salinity increase) due to additional extraction. • This area of potential development is relatively fresh compared with surrounding areas. It is pod of fresher water, possibly related to leakage from the Murray Flood plains to the overlying Shepparton Formation. Vertical leakage is expected to be minor compared to lateral flow in the aquifer and therefore intensive development could impact the groundwater salinity (i.e. saline intrusion from adjacent areas of the Deep lead aquifer).	High	Monitoring of quality in surrounding and adjacent existing / new observation bores to identify any longer term changes, prior to impacts to users, and then restrict extraction. Water quality on annual basis from existing new licenced bores Develop quality triggers based on quality baseline information Ability to reduce entitlements based on aquifer response.
Impact on Shepparton Formation aquifer sustainability (Gunbower Area)	Long term continued groundwater level decline due to additional extraction in the underlying Deep Lead aquifer. • The Deep Lead aquifer is confined in this region, and there is significant hydraulic separation with shoestring sands within the clayey Shepparton Formation. This is reflected in the differing hydrograph responses. • There is a generally a downwards gradient and therefore vertical leakage over large area, however this is expected to be a minor component of the water balance in comparison to throughflow/ rainfall and surface water accession recharge.	Low	Continued monitoring of groundwater levels and quality in the Shepparton Formation aquifer

Risk	Specific Risk Pathway	Qualitative Risk Rating	Potential Management or Mitigation Options
	Groundwater quality decline (i.e. salinity increase) due to additional extraction in the underlying aquifer. • As above, inter-aquifer drawdown impacts are expected to be minimal therefore quality impacts are also expected to be minimal. Quality will primarily be impacted by rainfall recharge and surface water accessions	Low	Continued monitoring of groundwater levels and quality in the Shepparton Formation aquifer
Impact on surface water features and GDEs	Groundwater decline reducing baseflows or accessibility of groundwater for GDEs. This includes local creeks/lakes and the Murray River. • As above, inter-aquifer drawdown impacts are expected to be minimal therefore impacts to surface water features (i.e. baseflows) or GDEs is also expect to be minimal. • Groundwater levels in the Shepparton Formation aquifer are expected to be primarily driven by rainfall recharge/ surface water accessions. • Any decline that may occur may be considered beneficial in terms of reduction of saline groundwater baseflow or minimising soil salinisation/improving land productivity.	Low	Continued monitoring of groundwater levels and quality in the Shepparton Formation aquifer
Impact on Deep Lead aquifer sustainability **(Adjacent LCV WSPA**)	Long term continued groundwater level decline due to additional extraction from the Gunbower Area. • The WSPA is fully allocated and use is round 70% of the PCV in 2017/2018 (i.e. highly utilised). GMW, 2012 also completed a water balance assessment which suggested the sustainable level of extraction was around 45% of the licenced entitlements, and therefore it can be concluded that the WSPA is potentially under considerable stress now (and particularly under dry climate scenarios). The WSPA currently has trigger levels to restrict extraction if groundwater level declines. • The interpreted potentiometric surfaces show a groundwater divide close to the existing WSPA boundary and therefore throughflow to Gunbower was not primarily sourced from the WSPA. However it is recognised that under drier climate/more extraction scenarios, the groundwater divide will likely move and more drawdown impacts may occur on the existing WSPA associated form extraction in the Gunbower area.	High	Assessment of sustainable yield on a regional scale (i.e. with LCV and Mid Loddon GMUs) under various climate scenarios (i.e. numerical modelling of drawdown and water balances of different areas under different scenarios). Further assessment of drawdown limits associated with large scale extraction from Gunbower area. Limit extraction from Gunbower area based on technical assessment of sustainable yield (i.e. modelling above) Ability to reduce entitlements in Gunbower based on aquifer response

Risk	Specific Risk Pathway	Qualitative Risk Rating	Potential Management or Mitigation Options
	• The aquifer is already stressed, triggers are in place so the management of this resource will be sensitive to any changes associated with Gunbower additional extraction.		
	Groundwater quality decline (is salinity increase) due to additional extraction. The main flow path is south to north through the WSPA, potential relatively small flow direction changes or drawdowns at the northern end associated with additional extraction at Gunbower is not expected to have a significant impact on groundwater salinity in the WSPA.	Low	Continued monitoring of groundwater quality to identify any longer term changes, prior to impacts to users, and then restrict extraction. Ability to reduce entitlements in Gunbower area based on aquifer response.
Impact on Deep Lead aquifer sustainability **(Adjacent Mid Loddon WSPA**)	Long term continued groundwater level decline due to additional extraction from the Gunbower Area. • The WSPA is fully allocated and use is round 70% of the PCV in 2017/2018 (i.e. highly utilised). • The deep lead aquifer continuity between Gunbower area and the Mid-Loddon GMA is limited by the Renmark Group aquifer grading out directly north of the Mid-Loddon WSPA and the Calivil Formation having low transmissivity and yield directly north of the Mid Loddon GMA. • A groundwater divide is also interpreted on the eastern side of the Mid Loddon GMA , indicating that groundwater flow, in the main northern flow path, east around the Terrick Terrick Ranges and further north towards Gunbower is not predominantly sources from the Mid Loddon GMA Impacts on this resource from extraction in the Gunbower Area are considered likely to be low/minimal. However as the aquifer is stressed and triggers are in place, minor changes may be significant to the resource sustainability.	Moderate/ Low	Assessment of sustainable yield on a regional scale (i.e. with LCV and Mid Loddon GMUs) under various climate scenarios (i.e. numerical modelling of drawdown and water balances of different areas under different scenarios). Further assessment of drawdown limits associated with large scale extraction from Gunbower area. Limit extraction from Gunbower area based on technical assessment of sustainable yield (i.e. modelling above). Ability to reduce entitlements in Gunbower based on aquifer response.
	Groundwater quality decline (is salinity increase) due to additional extraction. As above, drawdown interference is expected to be low/minimal and therefore impact on waste quality is considered low.	Low	Continued monitoring of groundwater quality to identify any longer term changes, prior to impacts to users, and then restrict extraction. Ability to reduce entitlements in Gunbower area based on aquifer response.

Risk	Specific Risk Pathway	Qualitative Risk Rating	Potential Management or Mitigation Options
Impact on Deep Lead aquifer sustainability **(In NSW**)	Long term continued groundwater level decline due to additional extraction from the Gunbower Area. • Extraction from the Gunbower area will cause drawdown across the border and impact flow paths (i.e. more flow towards Victoria and south rather than contoured flow to the north-west) • Depending on the use, stress and groundwater management framework in place this may be significant • Groundwater quality generally decline to the north west of Gunbower, which may limit use from the aquifer over the border Impacts on this resource from extraction in the Gunbower Area will occur. The significance to other water management plans need to be assessed further.	Moderate	Assessment of sustainable yield on a regional scale (i.e. with LCV and Mid Loddon GMUs) under various climate scenarios (i.e. numerical modelling of drawdown and water balances of different areas under different scenarios). Further assessment of drawdown limits associated with large scale extraction from Gunbower area. Further work to assess : • Groundwater use and demand in NSW • The implications under the MDB plan and SDL.
	Groundwater quality decline (is salinity increasing) due to additional extraction.	Low	Continued monitoring of groundwater quality to identify any longer term changes, prior to impacts to users, and then restrict extraction. Ability to reduce entitlements in Gunbower area based on aquifer response.
Impact on existing Deep Lead aquifer bores (Gunbower area)	Bore interference (drawdown) impact existing bore performance (i.e. yields or pump requirements). Although the aquifer has a high transmissivity, and over a 20 km area, the applications are relatively high.	Moderate	Bore density rules or local impact assessments as part of the licensing process.
Impact on existing Shepparton Formation aquifer bores (Gunbower area)	Bore interference (drawdown) impact existing bore performance (i.e. yields or pump requirements). • As above, inter-aquifer drawdown impacts are expected to be minimal therefore impacts on any Shepparton Formation aquifer bores is expected to be minimal. • Shepparton Formation aquifer is low yielding, generally poor quality and not highly utilised in this area.	Low	Bore density rules or local impact assessments as part of the licensing process.

Risk	Specific Risk Pathway	Qualitative Risk Rating	Potential Management or Mitigation Options
Climate Change	Potential to influence groundwater recharge and long term sustainability of Deep Lead aquifer system (Gunbower area and other GMUs).	High	Assessment of sustainable yield on a regional scale (i.e. with LCV and Mid Loddon GMUs) under various climate scenarios (i.e. numerical modelling of drawdown and water balances of different areas under different climate scenarios).

5. Estimate of Aquifer Throughflow

5.1 Throughflow

Method

As a first pass assessment of the sustainable yield of the resource, the annual throughflow in the deep lead aquifer in the Gunbower area has been calculated.

The annual throughflow in an aquifer system is generally considered to be an estimate of the available water for extraction, as it reflects the annual discharge from the aquifer system under natural flow conditions. Extraction from the aquifer system at rates higher than the annual throughflow are likely to result in continued drawdown in the aquifer system, a reduction in aquifer storage and eventually associated impacts such as inter-aquifer flow, changes in groundwater quality or reduced groundwater availability for the environment.

Two cross sections were used for throughflow estimations:

- Cross Section 1: Up hydraulic gradient of the Gunbower potential extraction area, to assess the throughflow from the south-west, in a well-defined channel between 2 bedrock highs (refer Figure 15 cross section and section location with respect to the Renmark Group and Calivil Formation distribution in Figure 8 and Figure 9).
- Cross Section 3: Down hydraulic gradient of the township of Gunbower in the central region of the potential extraction area. This is the main throughflow area on the Victorian side of the Murray, although the Deep Lead aquifer extends beneath the Murray and into NSW. The cross section is shown in Figure 17.

The throughflow estimate is based on the Darcy Equation:

- ***Q (Flow) = K (hydraulic conductivity) x A (cross sectional area) x I (hydraulic gradient***).

Throughflow calculations for these sections are included in Appendix B with the following inputs:

- **Hydraulic Conductivity (K):**

To assess the throughflow sensitivity two K cases were assumed:

- Median K:
  - Calivil Formation: 60 m/day. Median from CDM smith, 2016 (refer Table 4-9).
  - Renmark formation: 116 m/day. Median from CDM smith, 2016 (refer Table 4-9).
- High K :
  - Calivil and Renmark Formation: 185 m/day. Applicable to Murray trench (Nolan ITU, 2001a) refer Table 4-9, and considered realistic based on existing bore yields in the area (ie >50 L/sec to 250 L/sec).

- Throughflow area:

This was calculated from the cross sections for the Renmark and Calivil Formation using GIS methods and are shown in Table 5-1 below.

Table 5-1 Cross Sectional Areas

Section	Renmark Formation Area (m2)	Calivil Formation (m2)
Section 1	319,875	597,955
Section 3	1,197,740	589,673

- **Hydraulic Gradient**

Hydraulic gradients across the cross sections were based on interpreted contours or available bore data. The hydraulic gradient calculations are included in Appendix B, and varied between 0.0004 and 0.00009.

Results

The throughflow estimates are summarised in Table 5-2.

Table 5-2 Throughflow Estimation Summary

Component	Median K Case	High K Case
(a) Up-gradient Throughflow (Section 1) (ML/year)	5,103	12,276
(b) Down-gradient Throughflow (Section 3) (ML/year)	7,221	17,240
(b-a) Difference in Throughflow	2,118	4,964
(c) Existing Extraction (Licenced) in area	700	700
(b+c) Estimated Available Throughflow	7,920	17,940

Throughflow at Section 3, in the central region of the extraction area is considered most applicable. As a conservative approach, and considering the likely variability of the hydraulic conductivity of the deep lead aquifer, the median K case is also considered most applicable. Therefore, throughflow in the Gunbower area is estimated to be approximately 8,000 ML/year.

The following is noted:

- This is flow component on the Victoria side of the border only, however extraction in the area will obviously result in drawdown across the border and flow to be directed to the Victoria side. Extraction of this volume will reduce flow down basin (and potentially to other users).
- As a more conservative approach, and just considering flow coming into the area from Section 1, a lower bound of groundwater availability would be 5,100 ML/year. This is basically the current throughflow into the area under current condition (i.e. with the current groundwater divide and groundwater extraction in the adjacent WSPA) and ignoring additional recharge downstream of this section.

Based on these throughflow estimations, groundwater available for extraction in the Gunbower area is approximately 8,000 ML/year, with a low confidence rating. Groundwater decline will occur in the Gunbower area associated with the additional extraction and, as noted in the risk assessment (Section 4.7.3), there are potential impacts that are considered high risk at this stage and require further review:

- Drawdown may ultimately impact on the adjacent LCV WSPA resource, under certain climate and extraction conditions (i.e. dry climate, high extraction for both areas).
- Groundwater salinity in the Gunbower region may increase due to additional extraction as it is slightly fresher than the surrounding area.

The throughflow calculation has a low confidence rating, the main reason being the uncertainty in regards to the aquifer parameters with no local pumping tests to validate the aquifer parameters used in the assessment. Local pumping tests should therefore be undertaken as a priority to substantiate the aquifer parameters in the local area.

Therefore as an initial approach, considering the uncertainties associated with local aquifer parameters, GHD recommends restricting licensing to 70% of the median throughflow at Gunbower (i.e. 5,600 ML/year), accepting the risks identified and also considering groundwater declines noted in the Millennium drought. This suggested volume also approximates the inflow into the area, which is considered to be a lower bound for groundwater availability in the area, based on the assumed aquifer parameters.

Additional technical work may reveal that the throughflow is higher than the estimations discussed above. If so, the implications and associated impacts, would need to be assessed via an appropriate technique to determine whether this may mean that a larger volume of extraction could be sustainable. This is discussed in section 6.

5.2 Predicted Drawdown Associated with extraction from the Gunbower Area

Existing Bore

To assess the potential drawdown from an existing irrigation at the LCV WSPA boundary, an analytical well field model developed by GHD has been used. It is based on the non-equilibrium Theis (1936) solution to the well equation and superposition of cones of depression.

The spreadsheet relies on the use of hydraulic properties (i.e. transmissivity and storage co-efficient) of the aquifer and its accuracy is dependent on the representativeness of these inputs and the validity of Theis' assumptions with respect to aquifer behaviour. It assumes the aquifer is homogeneous and laterally continuous, with a flat hydraulic gradient, which is a limitation as the aquifer extent is variable and boundary conditions may be intersected during pumping. However this will provide a guide in regards to the likely magnitude of drawdown that may occur.

The model used the following inputs:

- Hydraulic conductivity (K)= 88 m^2/day (average of the mean for Renmark and Calivil Formation)
- Aquifer thickness (b)= 60m (average aquifer thickness)
- Transmissivity (T)= K x b= 5,280 m^2/day
- Storativity (S)= 0.0005

Pumping was assumed from a single bore at 28 L/sec continually for 4 months (i.e. 2.5 ML/day for 4 months = a total of around 300 ML = approximate use from existing irrigation bores in 2019/2020).

The predicted drawdown cone with this extraction scenario is shown in Figure 34 and the results included in Appendix C.

The predicted 0.1m drawdown cone extends approximately 13,000m. At 7,000m, the approximate distance of the LCV WSPA boundary, the drawdown is predicted to be around 0.15m.

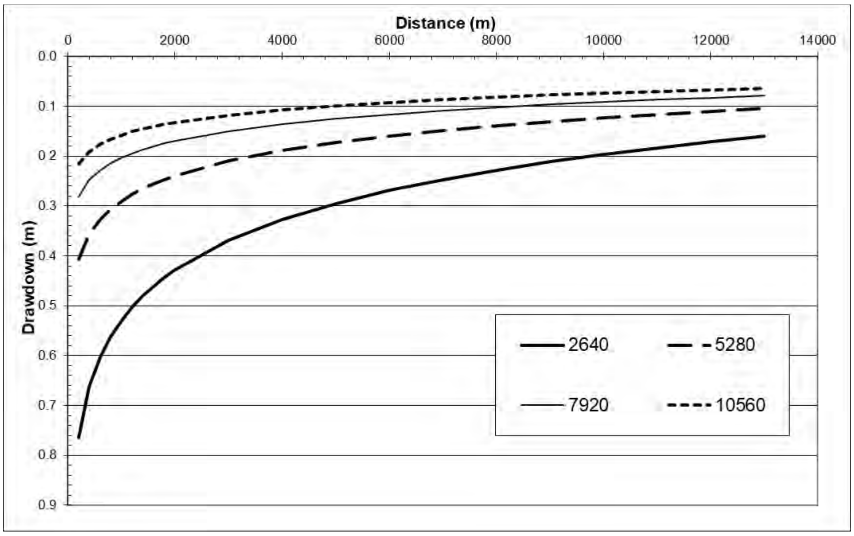


Figure 34 Predicted Drawdown Cone (single bore extraction)

Combined Extraction

Using the same spreadsheet and aquifer parameters, the drawdown associated with extraction from the three existing bores and eleven new applications has been modelled to approximate the drawdown at the WSPA boundaries and existing trigger bores (refer Appendix C). It is assumed that the full allocation is used from each bore over a 4 month period of continual pumping.

The drawdown predicted is shown in Table 5-3 and indicates that drawdown at the LCV WSPA could be in the order of 3.5m with all bores pumping continually over the 4 month period and using their full entitlements. If only 50% of the entitlements are used over a 4 month period the drawdown predicted is approximately half the results shown in Table 5-3, with the drawdown at the LCV WSPA estimated to be in the order of 1.7m.

Drawdown impacts are predicted at trigger bores in the LCV WSPA, however at these distances the accuracy of these predictions are further limited due to the variable extent, thickness and conductivity of the aquifer system, as well as groundwater gradients (i.e. drawdown cones will propagate along preferential paths).

Table 5-3 Calculated Drawdown Impacts on WSPA Boundaries/Bores

Bore	Radial Distance from Existing Pumping Bore WRK091289 (m)	Pumping rate assumed (L/sec)	Drawdown Predicted (after 120 days pumping) (m)	Comment
WRK091289	0	47	6.10	Note full allocation all bores

Bore	Radial Distance from Existing Pumping Bore WRK091289 (m)	Pumping rate assumed (L/sec)	Drawdown Predicted (after 120 days pumping) (m)	Comment
WRK115717	6,431	51	7.95	
WRK118233	11,198	57	8.37	
BGW0836-19	9,798	96	9.64	
BGW0995-19	13,587	81	8.35	
BGW0977-19	11,949	108	10.38	
BGW0982-19	10,807	81	9.76	
BGW0997-19	18,813	81	7.46	
BGW1038-19	11,316	96	10.28	
BGW1053-19	15,819.8	96	8.85	
BGW0006-20	4,672.8	48	6.25	
BGW0088-20	10,444.0	144	10.47	
BGW0099-20	18,261.1	57	7.09	
BGW0111-20	8,220.6	98	9.49	
Trigger Mid Loddon 88214	60,872		0.54	Limited connection and changing aquifer parameters
Trigger LCV WSPA 79324	28,421		1.39	
Trigger LCV WSPA 62589	61,286		0.38	
Border Mid Loddon	30,000		1.30	
Border LCV WSPA	7,000		3.47	

6. Data gaps and Relevant Information

6.1 Data gaps

In the throughflow estimation the following data gaps identified were:

- Aquifer parameters in this Gunbower area:

  This area may be significantly higher hydraulic conductivity than the median used in the calculations. This has significant impactions to the throughflow calculations as shown in Table 5-2, where the higher K case results in at least double the throughflow estimate.

  The parameters will also be relevant to assessing bore interference for new applicants.

  It is recommended pumping tests are completed using the existing bores, or as a requirement of new bores, to better understand the aquifer parameters in this area.

- Groundwater levels in NSW.

  Although some data was reviewed, and there are observation bores over the border, the screened formation needs to be confirmed and data further assessed to improve the continuity of level data over the border. Relevant state observation bores should be sourced from Water NSW, in particular confirmation of the screened aquifer.

6.2 Relevant Information

There is a significant amount of groundwater data and studies undertaken in the Gunbower area and the surrounding GMUs, which could be used to better assess sustainable yield of the deep lead aquifer, in conjunction with the adjacent GMUs and NSW management areas. Some are listed below:

- Hydrogeological conceptualisation reports:
  - Campaspe Valley Conceptual Hydrogeological Model (Hyder, 2006)
  - Campaspe Valley Conceptual Groundwater Model (Nolan, ITU, 2003)
  - Mid Loddon: Stage 2 Conceptual Model refinement (URS 2006)
- Numerical models:
  - Beverly and Hocking (2014) Northern Victoria Groundwater Model Technical Report. Department of Environment and Primary Industries. If digital data is available it will provide seamless aquifer thickness and extent data across the border.
  - Hocking et al. (2010c) North Central CMA – Transient model development report (Ensym ecoMarkets Model).
  - CSIRO (2008) Water availability in the Campaspe and Loddon-Avoca.
  - CSIRO (2010) Groundwater Modelling Report – Southern Riverine Plains: Used for SDLs.
- State observation bores:
  - numerous bores (in the order of 400) in multiple aquifers, with long term trend data, including when the aquifers were under stress in the Millennium drought, which can be used in numerical model calibration.
- Victorian Aquifer Formation (VAF) Layers.

Ultimately this existing work could be used to develop a numerical groundwater model including the GMUs suitable to predict impacts under different extraction and climate scenarios, and the relationship between the management areas.

7. Conclusions

GHD was engaged by GMW to undertake a desktop hydrogeological assessment for the Gunbower area, to assist in developing a sustainable yield estimate for the Deep Lead aquifer (i.e. Calivil Formation and/or Renmark Group) in this area.

Hydrogeology

In the Gunbower area, the hydrogeology consists of two main aquifer systems:

- **Shepparton Formation aquifer**: This aquifer is in the order of 40-80m thick, consisting of thin shoestring sands, and is generally low yielding in the Gunbower area and salinity is generally >3,500 mg/L.
- **Deep Lead aquifer**: This aquifer has variable thickness but is generally >60m in the Gunbower area, confined and high yielding (>50 L/sec).

  Recharge to the Deep Lead aquifer system is primarily through leakage from the overlying Shepparton Formation. The salinity of the deep lead aquifer will therefore be influenced by the quality of the overlying Shepparton Aquifer system.

  In general the aquifer salinity is >3,500 mg/L TDS, however there is a fresher (1,000-3,500 mg/L TDS) pod of groundwater basically between the Murray River and Gunbower Creek, around Gunbower where two existing high yielding irrigation bores are located. The fresher groundwater zone in Deep Lead aquifer in this area is surmised to be related to recharge to the overlying aquifer systems from the Murray River, particularly during high flow and flood events.

  Groundwater flow in the Deep Lead aquifer is generally from south to north in the Loddon and Campaspe groundwater catchments. In Gunbower area, northern groundwater flow on the eastern side of the Terrick Terrick Ranges, moves through a defined tough and then flows north-west down basement, basically paralleling the path of the Murray River, where the Deep Lead sediments become thicker and more extensive, extending across the Victorian border.

Groundwater Management

The Gunbower area is an unincorporated area. To the south-east, around 30 kms away is the Mid Loddon GMA and to the east, around 7 kms away, is the Lower Campaspe Valley WSPA, which both cover the groundwater resources in the Deep Lead.

Both these management areas are fully allocated with the Mid Loddon GMA PCV at 34,037 ML/year and the Lower Campaspe Valley WSPA PCV at 55,875 ML/year. Groundwater is highly utilised with around 70% of entitlements being used in 2017/18.

Risks Associated with additional extraction form then Gunbower Area

Based on the conceptual hydrogeological model and current aquifer response, GHD has identified the risks associated with increased groundwater extraction in the Gunbower area and qualitatively rated these risks (refer Table 4-11). A number of high risks were identified:

- Groundwater quality decline (i.e. salinity increase) due to additional extraction.

  The area of potential development near Gunbower is relatively fresh compared with surrounding areas. It appears to be a pod of fresher groundwater, potentially related to leakage from the Murray Flood plains to the overlying Shepparton Formation. Vertical leakage is expected to be minor compared to lateral flow in the aquifer and therefore intensive development could impact the groundwater salinity (i.e. saline intrusion from surrounding areas of the Deep lead aquifer), and at some stage it may not be suitable for the users purposes (i.e. irrigation and shandying with alternative supplies to meet water quality purposes).

- Impact on Deep Lead aquifer sustainability in the adjacent Lower Campaspe Valley WSPA.

  The interpreted potentiometric surfaces show that there is a groundwater divide close to the existing WSPA boundary and therefore throughflow to Gunbower is not primarily sourced from the WSPA. However, it is recognised that under drier climate and/or more extraction scenarios, the groundwater divide will likely move and more drawdown impacts may occur on the existing WSPA associated form extraction in the Gunbower area. Although the volumetric impact may be relatively small from the WSPA compared to the PCV, this WSPA is potentially under stress and already has triggers that can restrict groundwater entitlements for these users.

Estimate of Aquifer Throughflow

As a first pass assessment of the sustainable yield of the resource, the annual throughflow in the deep lead aquifer in the Gunbower area was calculated between 5,000 and 8,000 ML/year for a median hydraulic permeability case and 12,000 to 18,000 ML/year for a high hydraulic permeability case.

Based on these throughflow estimations, groundwater available for extraction in the Gunbower area is estimated to be approximately 8,000 ML/year, with a low confidence rating and recognising the high risks noted above.

As an initial approach, considering the uncertainties associated with local aquifer parameters, GHD recommends restricting licensing to 70% of the median throughflow at Gunbower (i.e. 5,600 ML/year), accepting the risks identified and also considering groundwater declines noted in the Millennium drought. This suggested volume (i.e. 5,600 ML/year) also approximates the estimated inflow into the area, which is considered to be a lower bound for groundwater availability in the area, based on the assumed average aquifer parameters.

However as the throughflow calculation has a low confidence rating, pumping tests should be undertaken as a priority to confirm the aquifer parameters in this area. Further ongoing monitoring, pumping tests and potentially assessment work will need to be undertaken to provide a more technically rigorous assessment of sustainable yield in the area and associated impacts, prior to issuing any further entitlements beyond this volume.

8. Recommendations

Based on the work completed, the following recommendations are made:

1. Limit entitlements to 5.600 ML/year in this unincorporated area while further investigations are completed to assess the potential impacts of additional extraction in the area and to provide a more technically rigorous sustainable yield estimate.
2. Further technical investigation including:
   a. Pumping tests: As a priority, pumping tests should be completed using the existing bores, or as a requirement of new bores, to better understand the aquifer parameters in this area and further inform the throughflow estimations. Pumping tests should be designed appropriately to allow the aquifer parameters to be accurately assessed (i.e. sufficient monitoring bores) and also to assess other risk factors (i.e. boundary conditions due to aquifer geometry, groundwater quality changes or inter-aquifer flows).
   b. Numerical groundwater modelling to assess the potential impact of additional extraction on existing groundwater users (i.e. nearby management areas and across the border), overlying aquifer system and surface water features. The potential high risk impacts include the nearby LCV WSPA, which warrants a more rigorous technical assessment, to quantify the sustainable yield as a connected resource. As there is significant complexity in groundwater flow regimes, multiple aquifers and assessment of cumulative impacts under different extraction and climate scenarios will be required, numerical groundwater modelling is considered the most robust methodology. In addition, GMW has collected significant data over the last 20 years that can be utilised to calibrate the model and provide technically defensible results. Numerical modelling will allow water balance components between management areas to be quantified.

      Alternatively water balances from existing numerical models (i.e. Ensym ecoMarkets Model) could be utilised to provide improved assessment of water balances between management areas.

      - Based on this work, establishment of a new groundwater management area or extension of existing area should be considered for the connected resource. A management area extending north of the Mid Loddon GMA to the Murray and as far east as the LCV WSPA may be applicable, subzones would be needed to distinguish between the high yielding area around Gunbower and the relatively low yielding (and limited use) area directly north and east of the Mid Loddon GMA.
      - Based on this work develop management plans (i.e. PCV, triggers or bore density rules etc.) to manage impacts.

   c. Monitoring of quality in surrounding and adjacent observation bores to identify any longer term changes, prior to impacts to users.
3. Licencing considerations

   It is expected that individual licence application will need to be considered under the current GMW pumping impact assessment process (i.e. individual bore interference) which will identify individual bore application risks.

Some general licence conditions which may assist with data gaps and management could include:

- Water quality on annual basis from existing/ new licenced bores to provide baseline conditions and assess any changes.
- Pumping tests (as noted above) on any new production bore and results reported to GMW. Potentially an observation bore installed (if SON bores cannot be utilised).
- Ability to reduce entitlements if unexpected impacts occur.

4. Further work to be completed in regards to the Murray Darling Basin plan and the implications in regards to Sustainable Diversion Limits, and also the management of the groundwater resource in NSW.

9. References

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URS (2006) *Mid Loddon WSPA Groundwater Model, Stage 2 - Conceptual Model Refinement.* Report prepared for Goulburn-Murray Water. 1 June 2006

10. Limitations

This report: has been prepared by GHD for Goulburn Murray Water and may only be used and relied on by Goulburn Murray Water for the purpose agreed between GHD and the Goulburn Murray Water as set out in section 2 of this report.

GHD otherwise disclaims responsibility to any person other than Goulburn Murray Water arising in connection with this report. GHD also excludes implied warranties and conditions, to the extent legally permissible.

The services undertaken by GHD in connection with preparing this report were limited to those specifically detailed in the report and are subject to the scope limitations set out in the report.

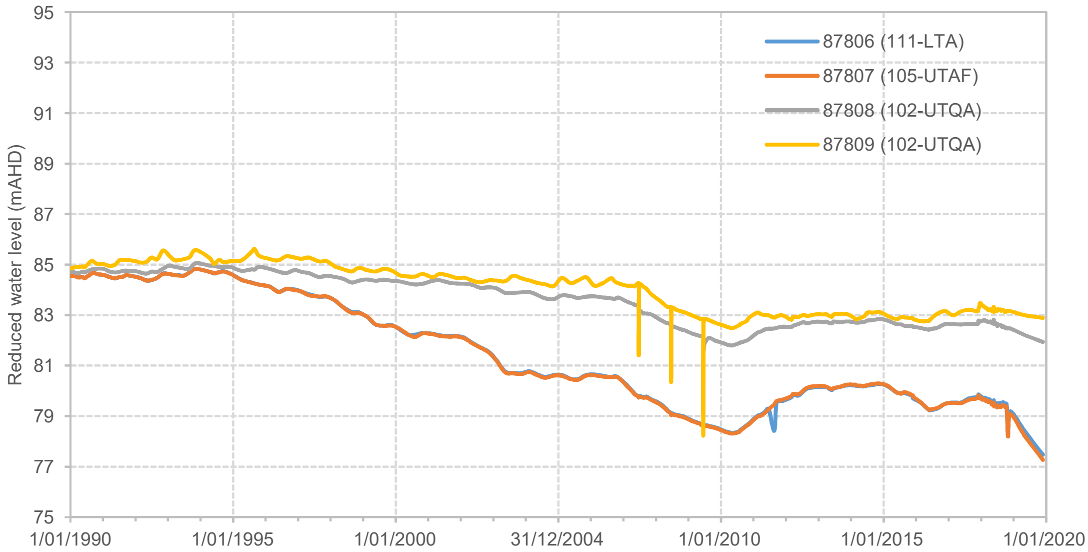
The opinions, conclusions and any recommendations in this report are based on conditions encountered and information reviewed at the date of preparation of the report. GHD has no responsibility or obligation to update this report to account for events or changes occurring subsequent to the date that the report was prepared.

The opinions, conclusions and any recommendations in this report are based on assumptions made by GHD described in this report (refer section(s) 2.2. of this report). GHD disclaims liability arising from any of the assumptions being incorrect.

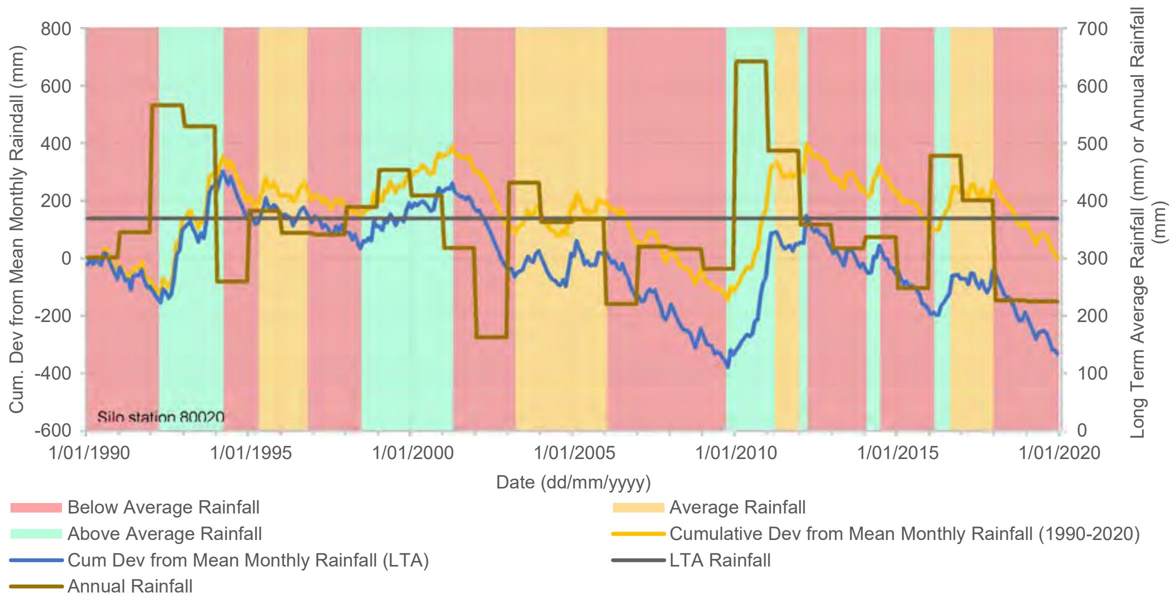
GHD has prepared this report on the basis of information provided by Goulburn Murray Water and others who provided information to GHD (including Government authorities)], which GHD has not independently verified or checked beyond the agreed scope of work. GHD does not accept liability in connection with such unverified information, including errors and omissions in the report which were caused by errors or omissions in that information.

Appendices

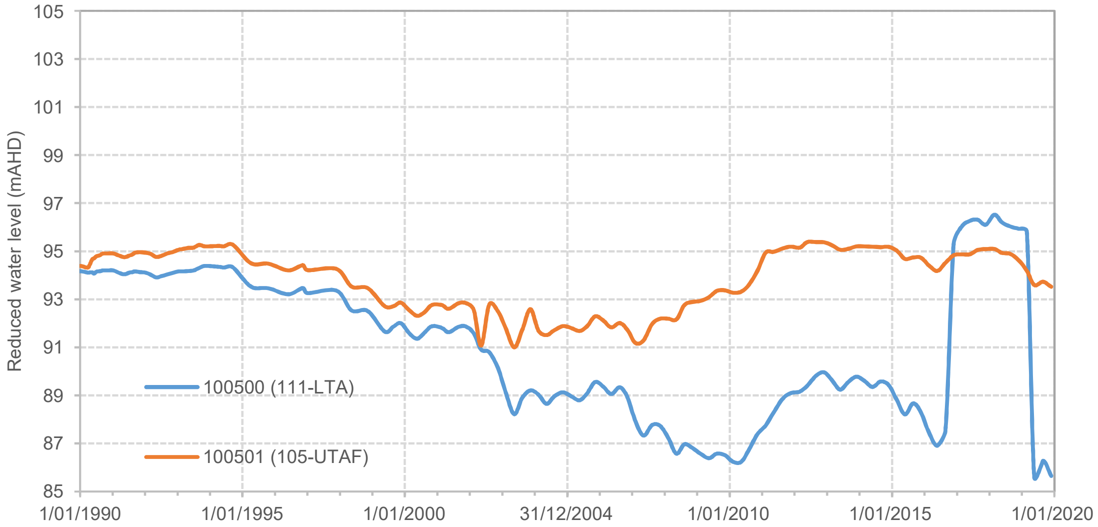
Appendix A – Bore Hydrographs



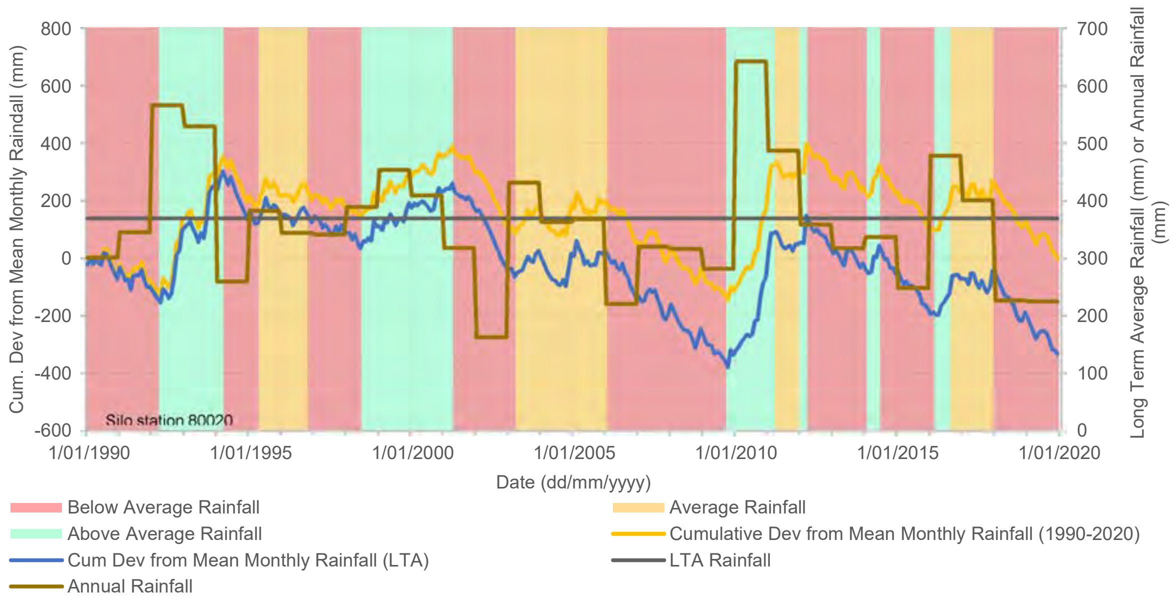
87806 (111-LTA)
87807 (105-UTAF)
87808 (102-UTQA)
87809 (102-UTQA)
Reduced water level (mAHD)
95
93
91
89
87
85
83
81
79
77
75
1/01/1990
1/01/1995
1/01/2000
31/12/2004
1/01/2010
1/01/2015
1/01/2020



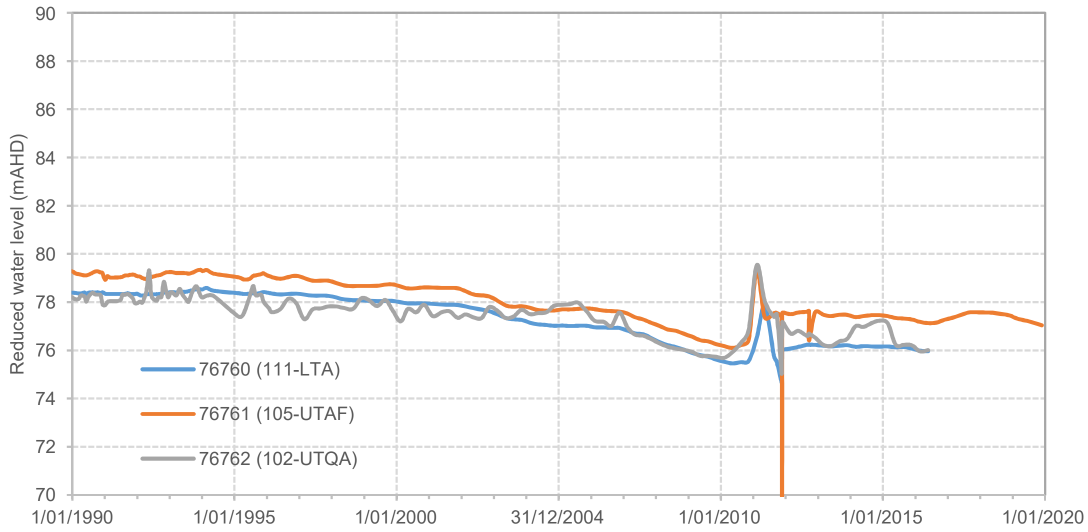
Cum. Dev from Mean Monthly Raindall (mm)
Long Term Average Rainfall (mm) or Annual Rainfall (mm)
Silo station 80020
800
600
400
200
0
-200
-400
-600
700
600
500
400
300
200
100
0
1/01/1990
1/01/1995
1/01/2000
1/01/2005
1/01/2010
1/01/2015
1/01/2020
Date (dd/mm/yyyy)
Below Average Rainfall
Average Rainfall
Above Average Rainfall
Cumulative Dev from Mean Monthly Rainfall (1990-2020)
Cum Dev from Mean Monthly Rainfall (LTA)
LTA Rainfall
Annual Rainfall



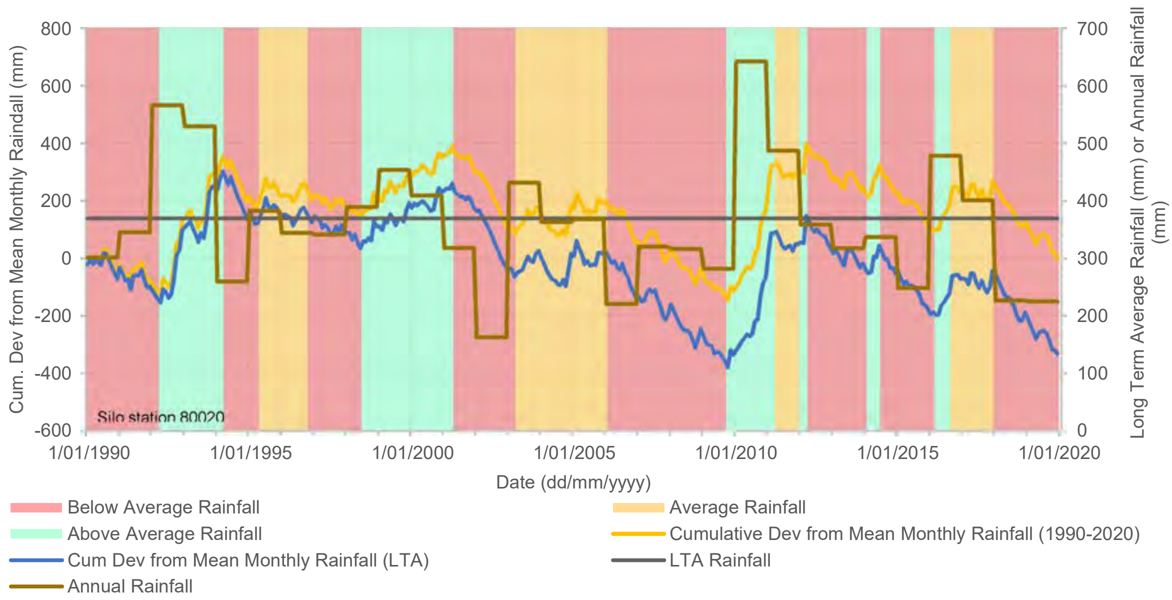
Reduced water level (mAHD)
100500 (111-LTA)
100501 (105-UTAF)
1/01/1990
1/01/1995
1/01/2000
31/12/2004
1/01/2010
1/01/2015
1/01/2020



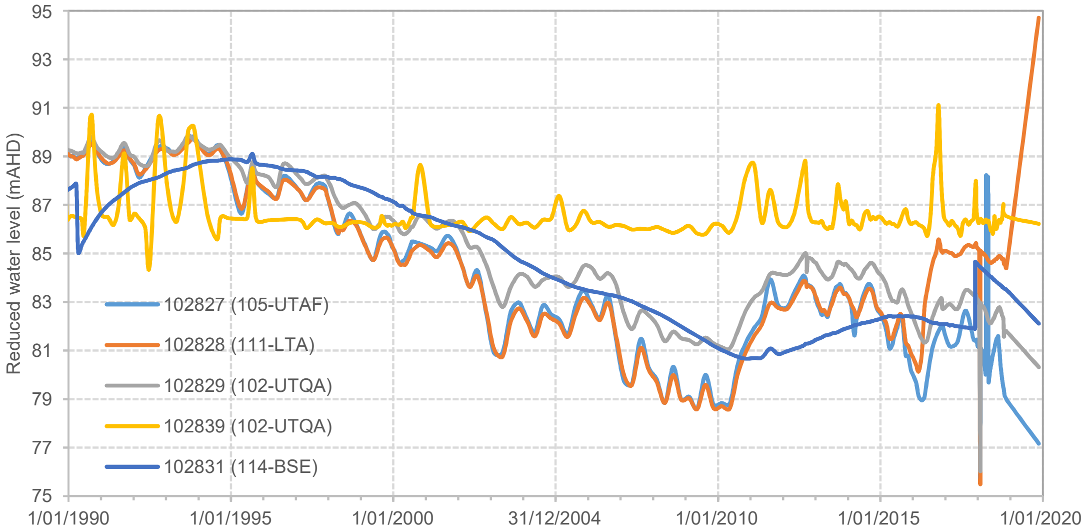
Cum. Dev from Mean Monthly Raindall (mm)
Long Term Average Rainfall (mm) or Annual Rainfall (mm)
Silo station 80020
Date (dd/mm/yyyy)
Below Average Rainfall
Above Average Rainfall
Cum Dev from Mean Monthly Rainfall (LTA)
Annual Rainfall
Average Rainfall
Cumulative Dev from Mean Monthly Rainfall (1990-2020)
LTA Rainfall

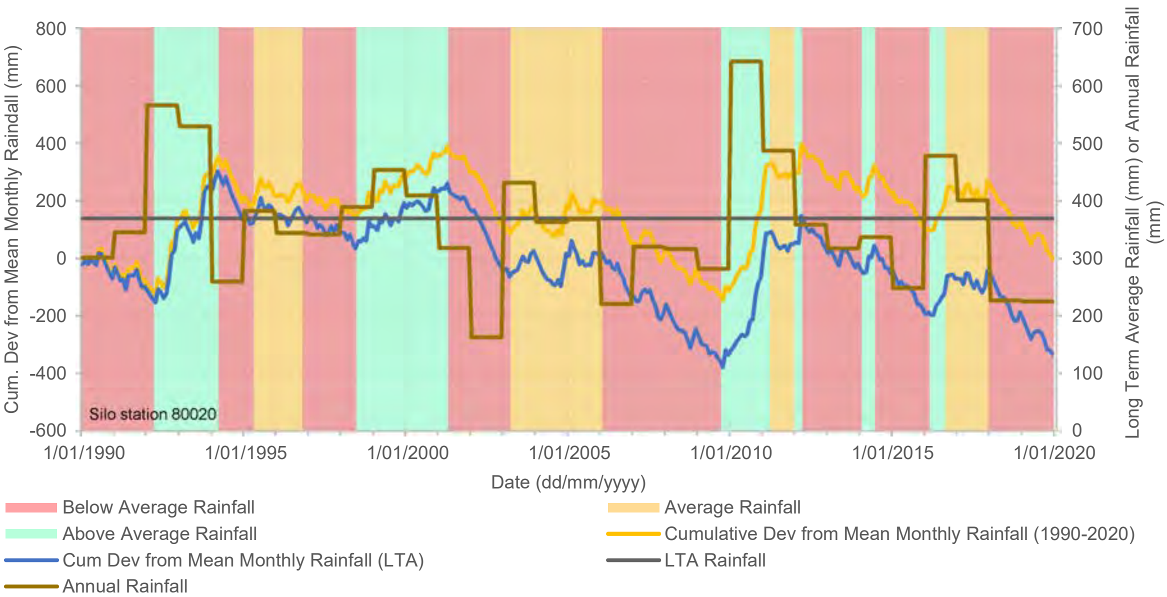


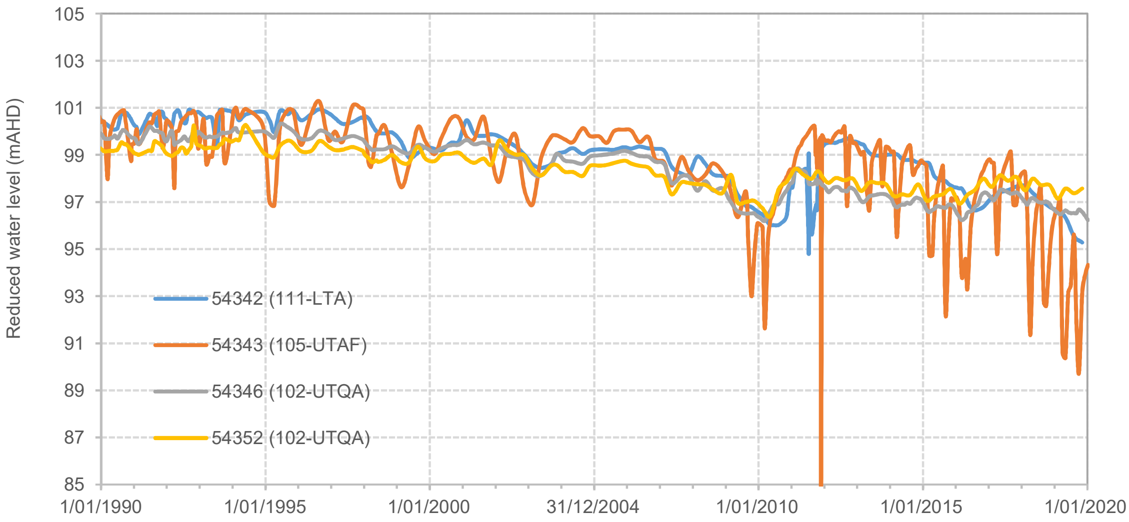
Reduced water level (mAHD)
90
88
86
84
82
80
78
76
74
72
70
76760 (111-LTA)
76761 (105-UTAF)
76762 (102-UTQA)
1/01/1990
1/01/1995
1/01/2000
31/12/2004
1/01/2010
1/01/2015
1/01/2020



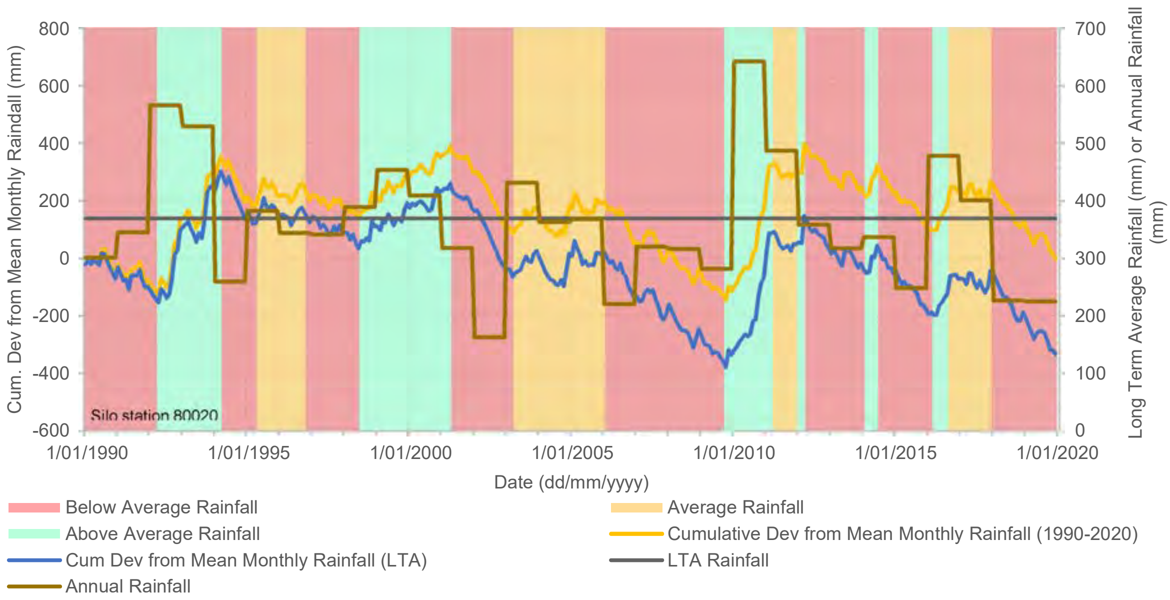
Cum. Dev from Mean Monthly Raindall (mm)
800
600
400
200
0
-200
-400
-600
Long Term Average Rainfall (mm) or Annual Rainfall (mm)
700
600
500
400
300
200
100
0
Silo station 80020
1/01/1990
1/01/1995
1/01/2000
1/01/2005
1/01/2010
1/01/2015
1/01/2020
Date (dd/mm/yyyy)
Below Average Rainfall
Above Average Rainfall
Cum Dev from Mean Monthly Rainfall (LTA)
Annual Rainfall
Average Rainfall
Cumulative Dev from Mean Monthly Rainfall (1990-2020)
LTA Rainfall


95
93
91
89
87
85
83
81
79
77
75
Reduced water level (mAHD)
102827 (105-UTAF)
102828 (111-LTA)
102829 (102-UTQA)
102839 (102-UTQA)
102831 (114-BSE)
1/01/1990
1/01/1995
1/01/2000
31/12/2004
1/01/2010
1/01/2015
1/01/2020

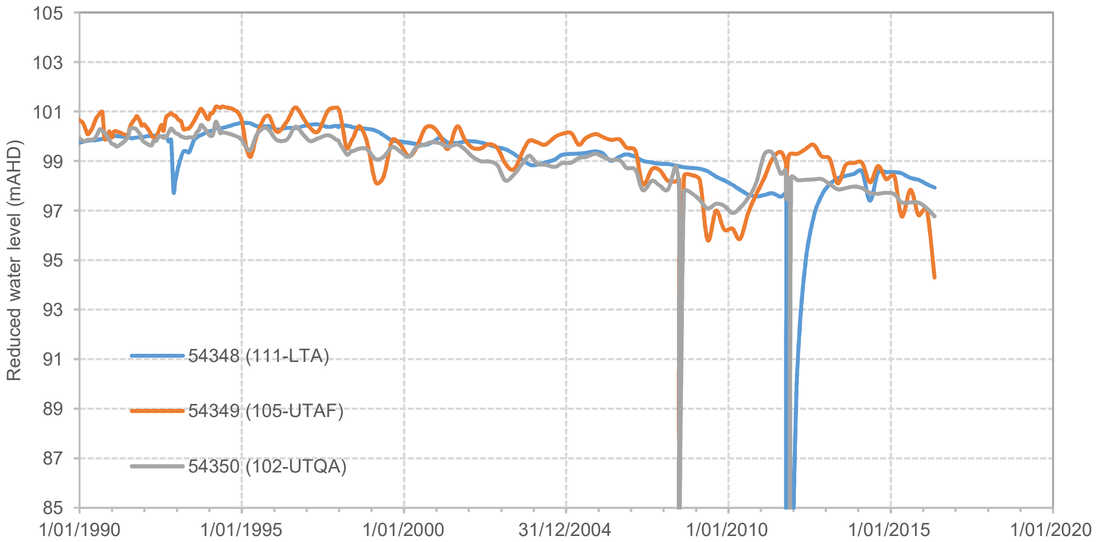

800
600
400
200
0
-200
-400
-600
Cum. Dev from Mean Monthly Raindall (mm)
700
600
500
400
300
200
100
0
Long Term Average Rainfall (mm) or Annual Rainfall (mm)
Silo station 80020
1/01/1990
1/01/1995
1/01/2000
1/01/2005
1/01/2010
1/01/2015
1/01/2020
Date (dd/mm/yyyy)
Below Average Rainfall
Above Average Rainfall
Cum Dev from Mean Monthly Rainfall (LTA)
Annual Rainfall
Average Rainfall
Cumulative Dev from Mean Monthly Rainfall (1990-2020)
LTA Rainfall



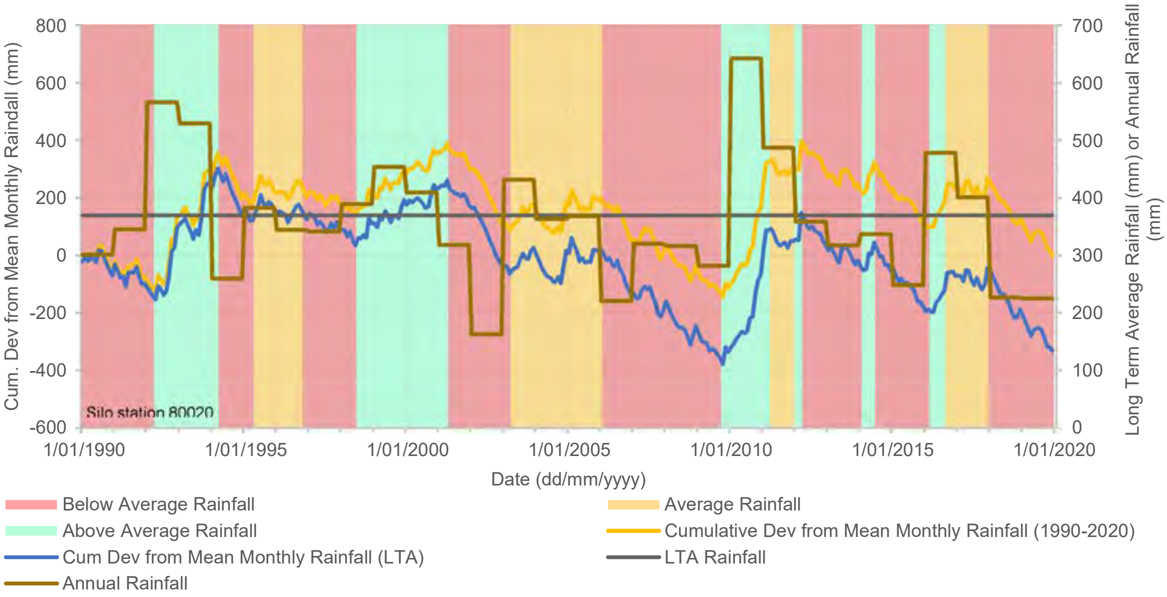
Reduced water level (mAHD)
105
103
101
99
97
95
93
91
89
87
85
1/01/1990
1/01/1995
1/01/2000
31/12/2004
1/01/2010
1/01/2015
1/01/2020
54342 (111-LTA)
54343 (105-UTAF)
54346 (102-UTQA)
54352 (102-UTQA)



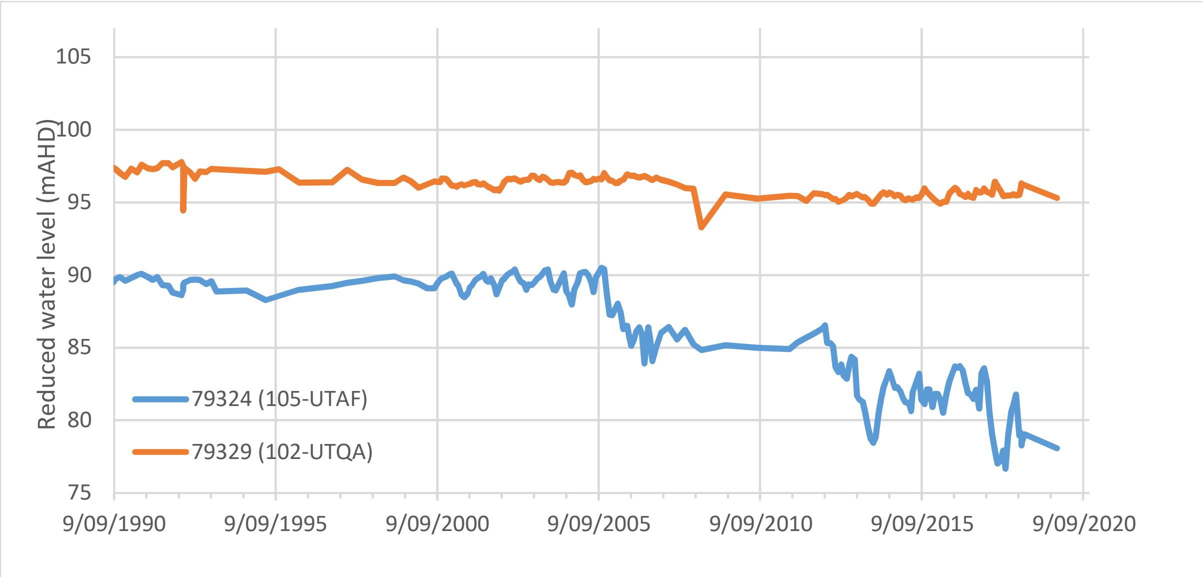
Cum. Dev from Mean Monthly Raindall (mm)
800
600
400
200
0
-200
-400
-600
Long Term Average Rainfall (mm) or Annual Rainfall (mm)
700
600
500
400
300
200
100
0
Silo station 80020
1/01/1990
1/01/1995
1/01/2000
1/01/2005
1/01/2010
1/01/2015
1/01/2020
Date (dd/mm/yyyy)
Below Average Rainfall
Above Average Rainfall
Cum Dev from Mean Monthly Rainfall (LTA)
Annual Rainfall
Average Rainfall
Cumulative Dev from Mean Monthly Rainfall (1990-2020)
LTA Rainfall



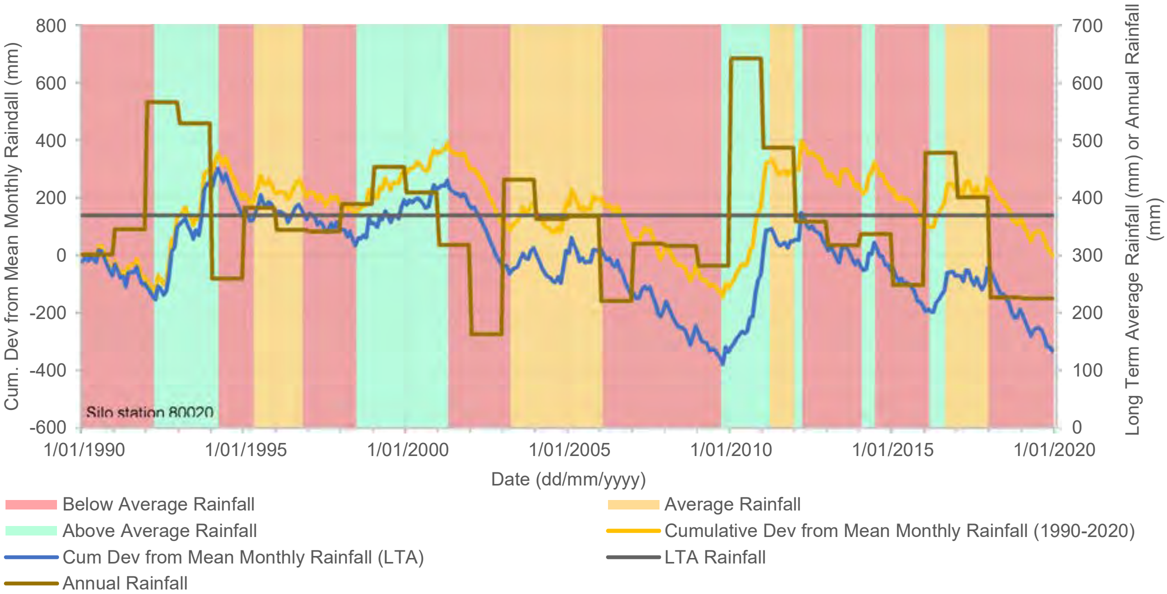
105
103
101
99
97
95
93
91
89
87
85
Reduced water level (mAHD)
54348 (111-LTA)
54349 (105-UTAF)
54350 (102-UTQA)
1/01/1990
1/01/1995
1/01/2000
31/12/2004
1/01/2010
1/01/2015
1/01/2020



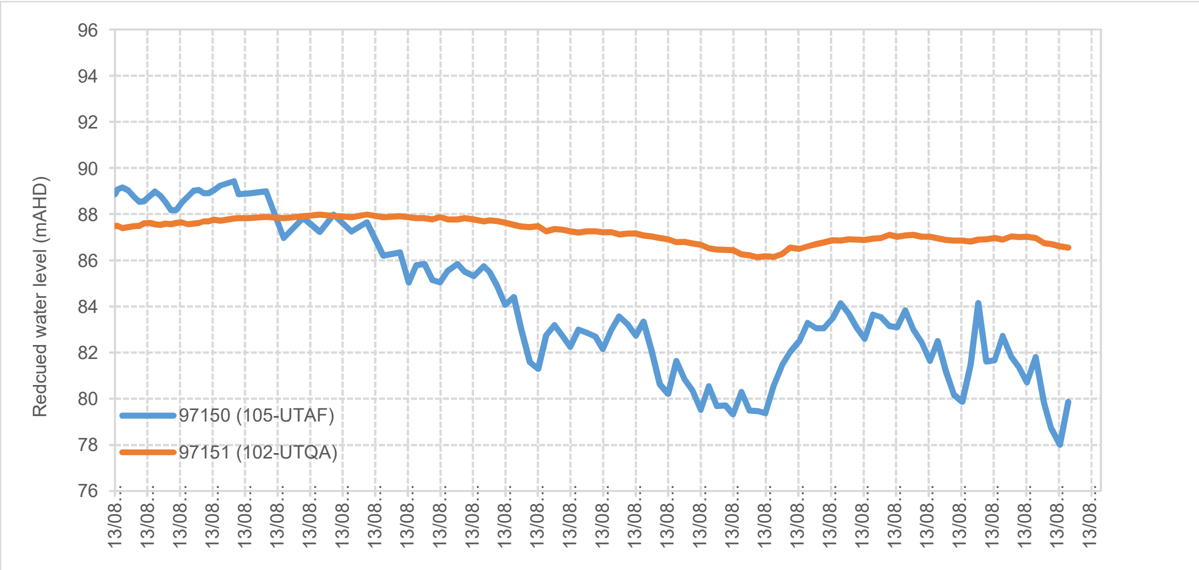
800
600
400
200
0
-200
-400
-600
Cum. Dev from Mean Monthly Raindall (mm)
700
600
500
400
300
200
100
0
Long Term Average Rainfall (mm) or Annual Rainfall (mm)
Silo station 80020
1/01/1990
1/01/1995
1/01/2000
1/01/2005
1/01/2010
1/01/2015
1/01/2020
Date (dd/mm/yyyy)
Below Average Rainfall
Average Rainfall
Above Average Rainfall
Cumulative Dev from Mean Monthly Rainfall (1990-2020)
Cum Dev from Mean Monthly Rainfall (LTA)
LTA Rainfall
Annual Rainfall



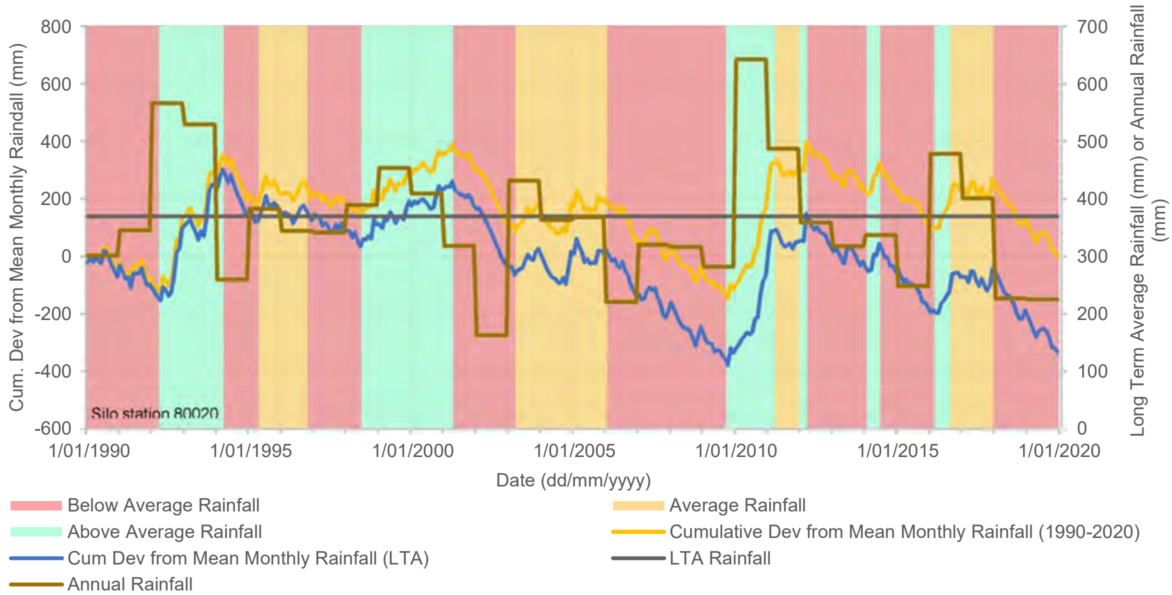
Reduced water level (mAHD)
105
100
95
90
85
80
75
79324 (105-UTAF)
79329 (102-UTQA)
9/09/1990
9/09/1995
9/09/2000
9/09/2005
9/09/2010
9/09/2015
9/09/2020



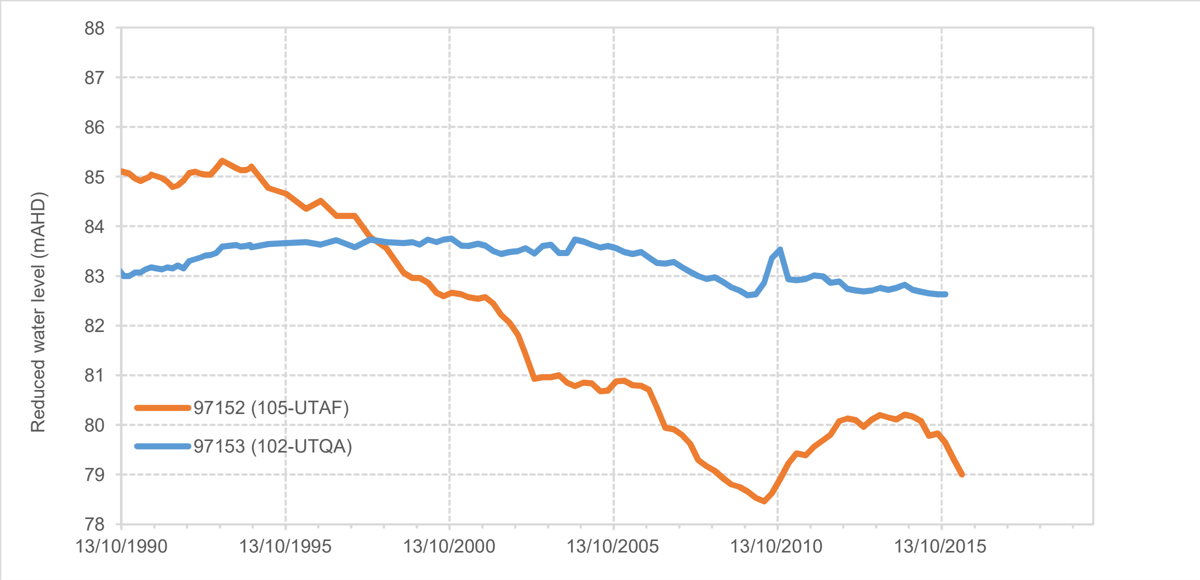
Cum. Dev from Mean Monthly Raindall (mm)
800
600
400
200
0
-200
-400
-600
Long Term Average Rainfall (mm) or Annual Rainfall (mm)
700
600
500
400
300
200
100
0
Silo station 80020
1/01/1990
1/01/1995
1/01/2000
1/01/2005
1/01/2010
1/01/2015
1/01/2020
Date (dd/mm/yyyy)
Below Average Rainfall
Above Average Rainfall
Cum Dev from Mean Monthly Rainfall (LTA)
Annual Rainfall
Average Rainfall
Cumulative Dev from Mean Monthly Rainfall (1990-2020)
LTA Rainfall



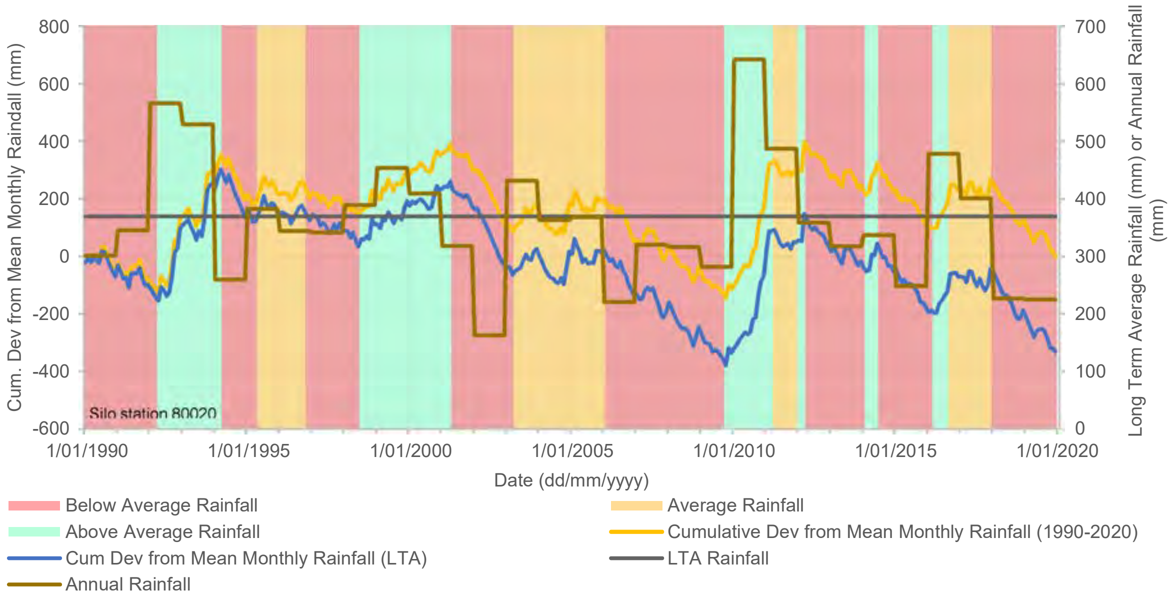
Redcued water level (mAHD)
97150 (105-UTAF)
97151 (102-UTQA)
13/08...



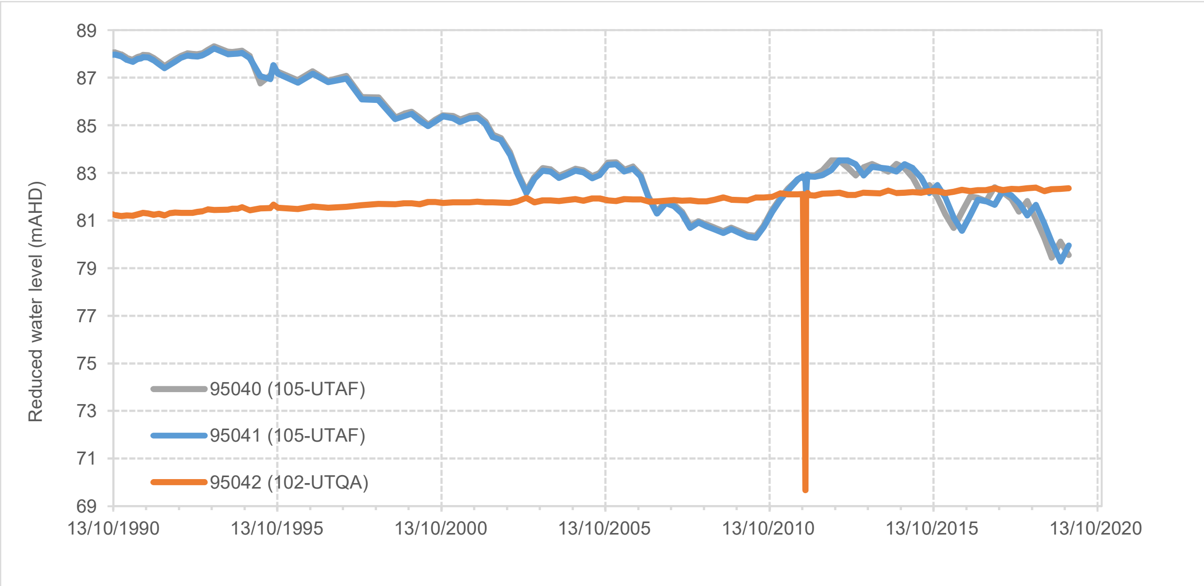
Cum. Dev from Mean Monthly Raindall (mm)
Long Term Average Rainfall (mm) or Annual Rainfall (mm)
Silo station 80020
Date (dd/mm/yyyy)
Below Average Rainfall
Above Average Rainfall
Cum Dev from Mean Monthly Rainfall (LTA)
Annual Rainfall
Average Rainfall
Cumulative Dev from Mean Monthly Rainfall (1990-2020)
LTA Rainfall



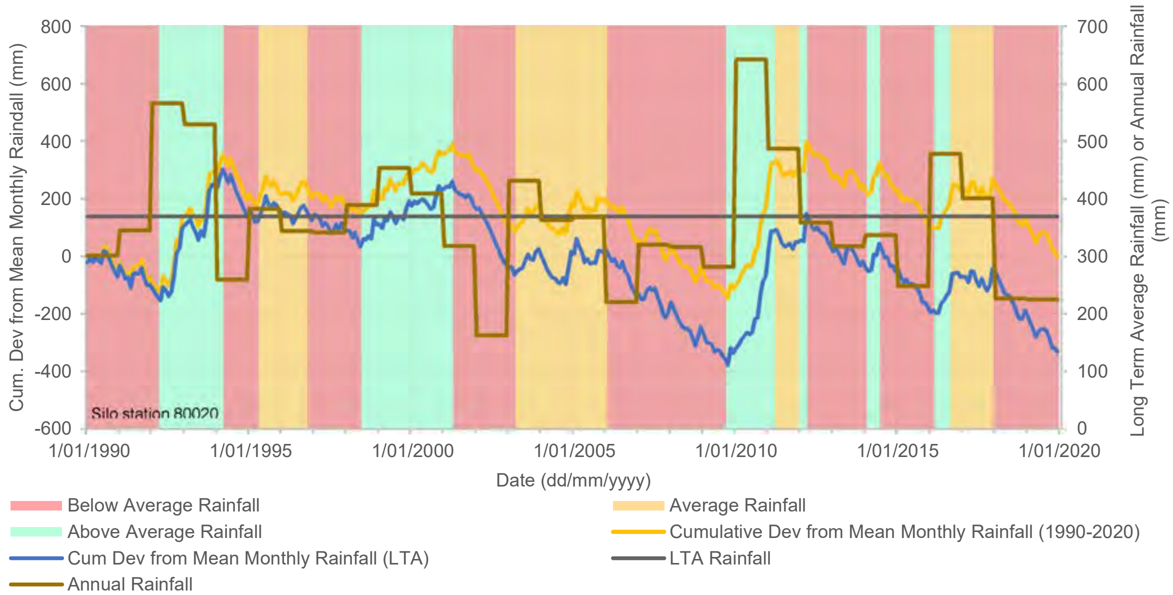
Reduced water level (mAHD)
88
87
86
85
84
83
82
81
80
79
78
13/10/1990
13/10/1995
13/10/2000
13/10/2005
13/10/2010
13/10/2015
97152 (105-UTAF)
97153 (102-UTQA)



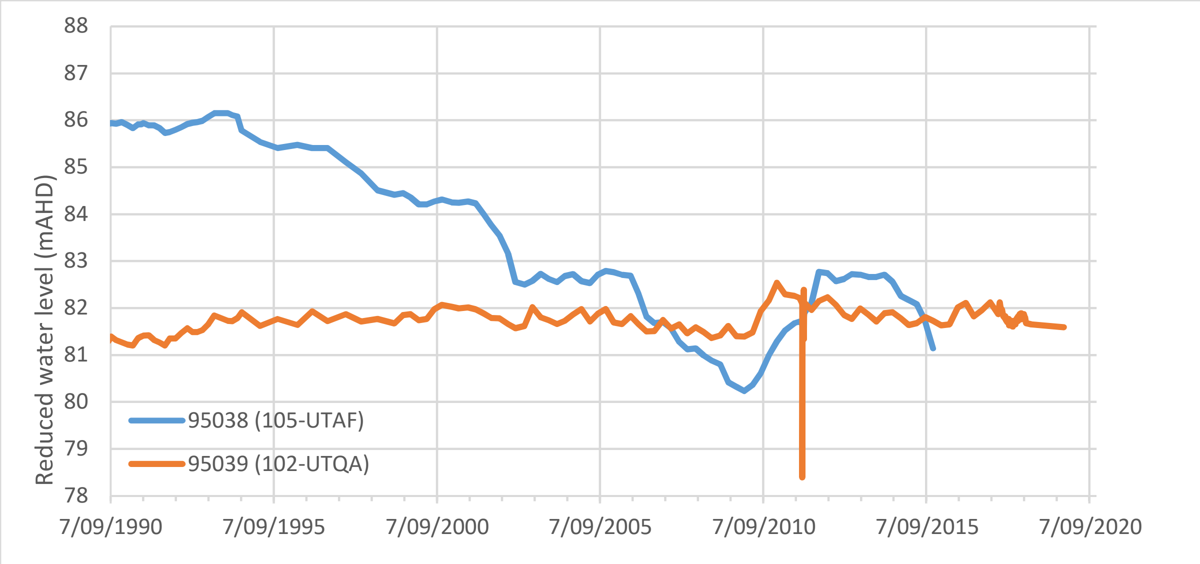
Cum. Dev from Mean Monthly Raindall (mm)
800
600
400
200
0
-200
-400
-600
Silo station 80020
700
600
500
400
300
200
100
0
Long Term Average Rainfall (mm) or Annual Rainfall (mm)
1/01/1990
1/01/1995
1/01/2000
1/01/2005
1/01/2010
1/01/2015
1/01/2020
Date (dd/mm/yyyy)
Below Average Rainfall
Above Average Rainfall
Cum Dev from Mean Monthly Rainfall (LTA)
Annual Rainfall
Average Rainfall
Cumulative Dev from Mean Monthly Rainfall (1990-2020)
LTA Rainfall



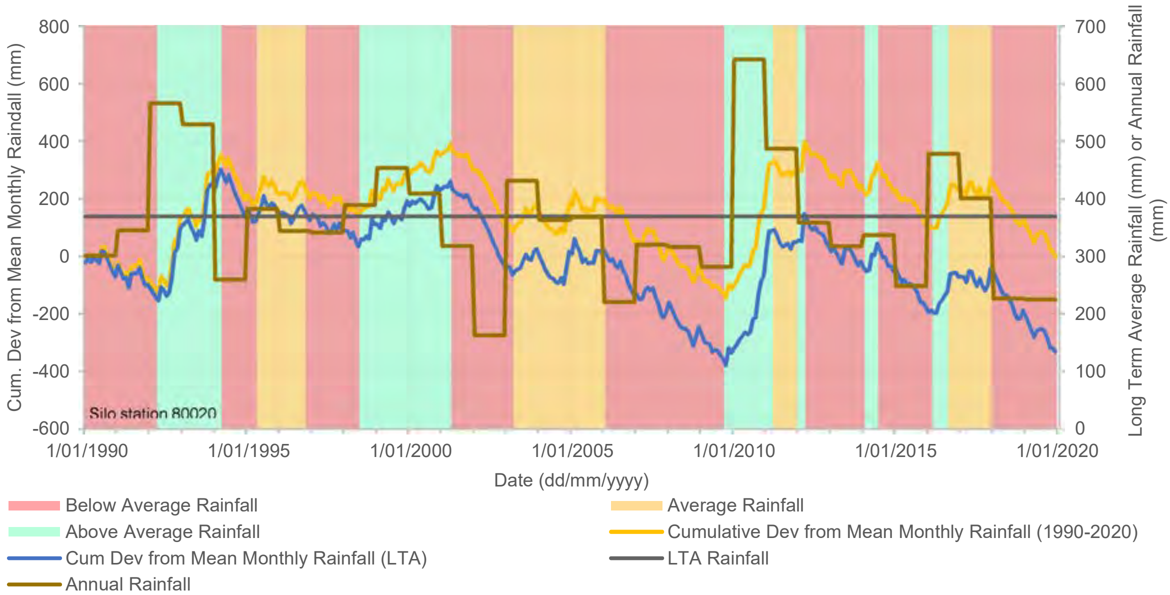
Reduced water level (mAHD)
89
87
85
83
81
79
77
75
73
71
69
95040 (105-UTAF)
95041 (105-UTAF)
95042 (102-UTQA)
13/10/1990
13/10/1995
13/10/2000
13/10/2005
13/10/2010
13/10/2015
13/10/2020



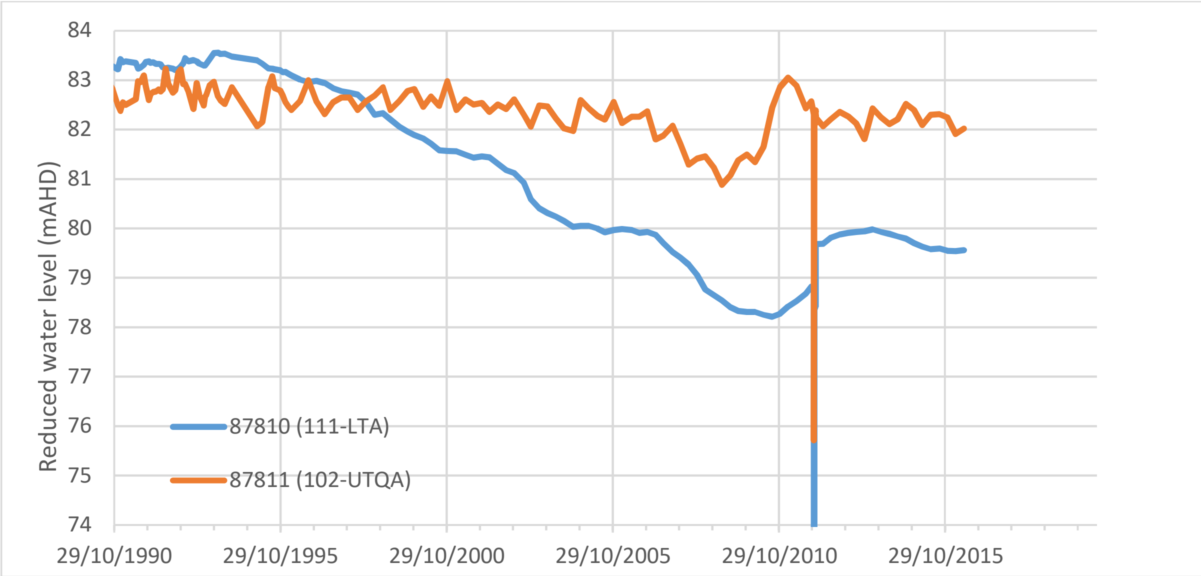
Cum. Dev from Mean Monthly Raindall (mm)
800
600
400
200
0
-200
-400
-600
Silo station 80020
Long Term Average Rainfall (mm) or Annual Rainfall (mm)
700
600
500
400
300
200
100
0
1/01/1990
1/01/1995
1/01/2000
1/01/2005
1/01/2010
1/01/2015
1/01/2020
Date (dd/mm/yyyy)
Below Average Rainfall
Average Rainfall
Above Average Rainfall
Cumulative Dev from Mean Monthly Rainfall (1990-2020)
Cum Dev from Mean Monthly Rainfall (LTA)
LTA Rainfall
Annual Rainfall



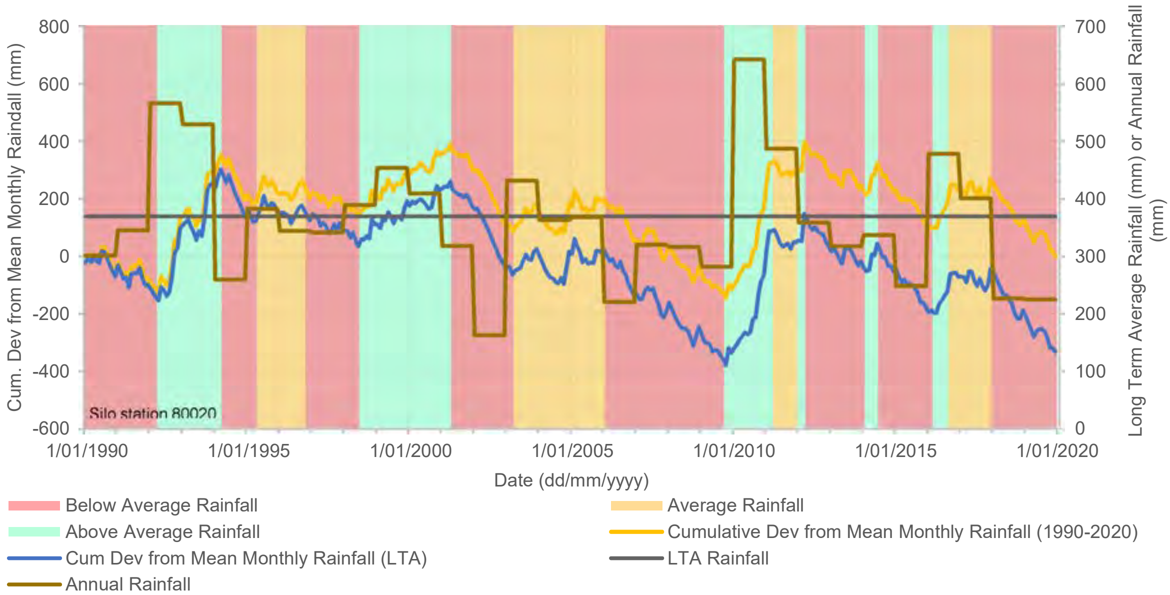
Reduced water level (mAHD)
88
87
86
85
84
83
82
81
80
79
78
7/09/1990
7/09/1995
7/09/2000
7/09/2005
7/09/2010
7/09/2015
7/09/2020
95038 (105-UTAF)
95039 (102-UTQA)



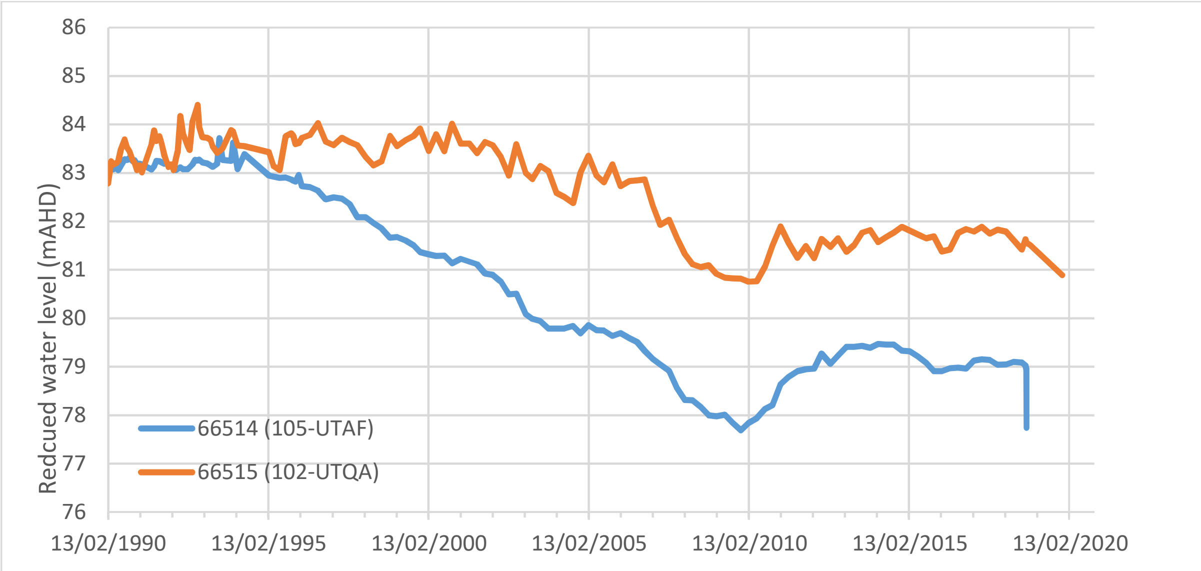
Cum. Dev from Mean Monthly Raindall (mm)
800
600
400
200
0
-200
-400
-600
Silo station 80020
1/01/1990
1/01/1995
1/01/2000
1/01/2005
1/01/2010
1/01/2015
1/01/2020
Date (dd/mm/yyyy)
700
600
500
400
300
200
100
0
Long Term Average Rainfall (mm) or Annual Rainfall (mm)
Below Average Rainfall
Above Average Rainfall
Cum Dev from Mean Monthly Rainfall (LTA)
Annual Rainfall
Average Rainfall
Cumulative Dev from Mean Monthly Rainfall (1990-2020)
LTA Rainfall



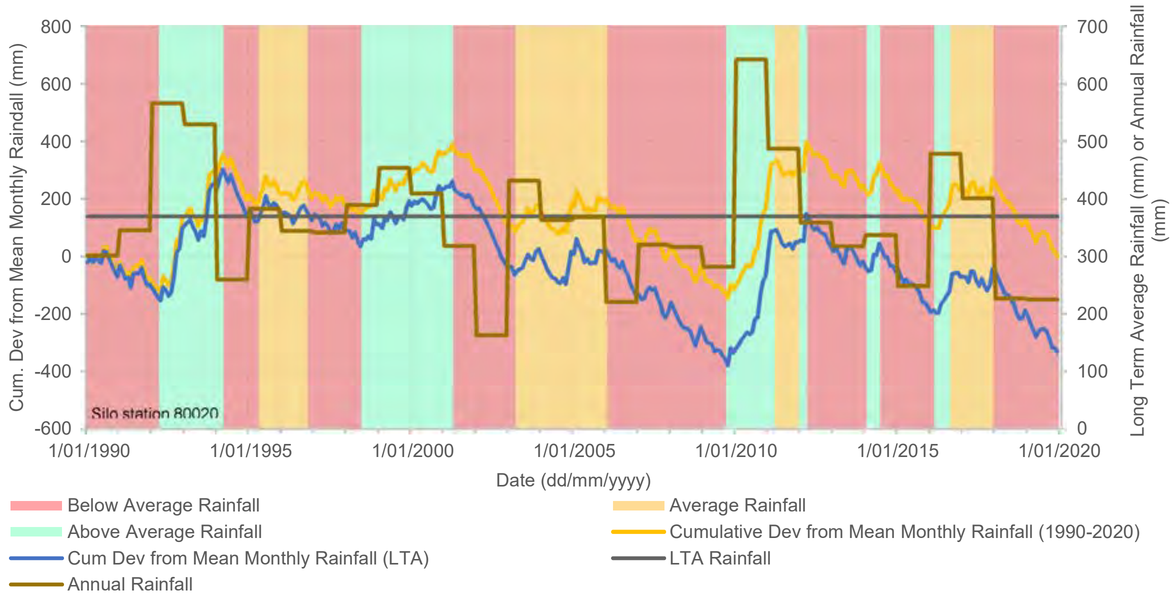
Reduced water level (mAHD)
84
83
82
81
80
79
78
77
76
75
74
87810 (111-LTA)
87811 (102-UTQA)
29/10/1990
29/10/1995
29/10/2000
29/10/2005
29/10/2010
29/10/2015



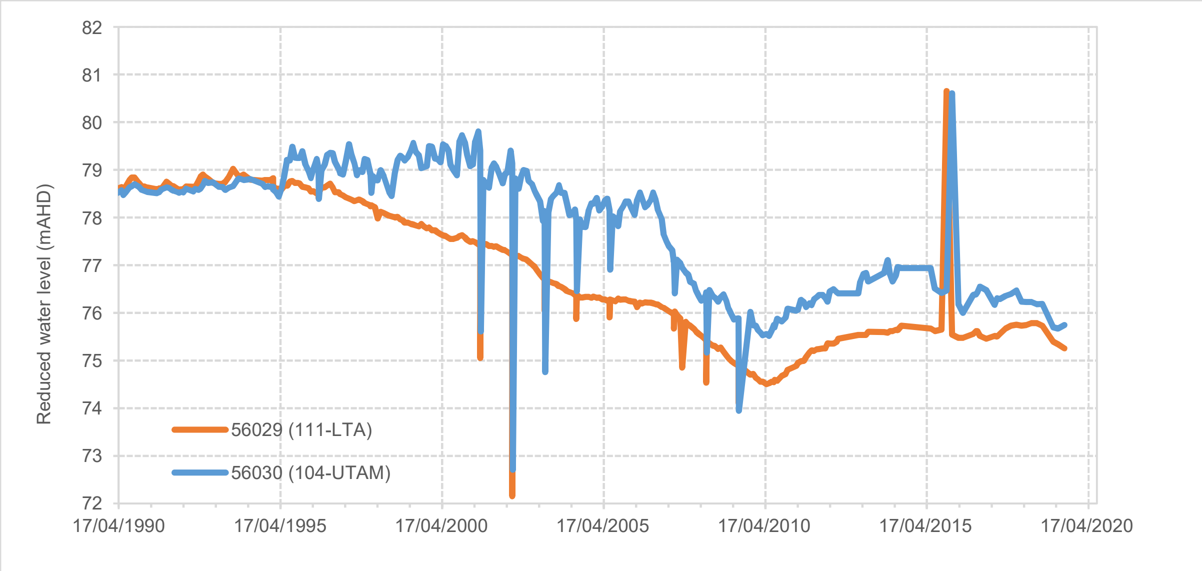
Cum. Dev from Mean Monthly Raindall (mm)
800
600
400
200
0
-200
-400
-600
Silo station 80020
700
600
500
400
300
200
100
0
Long Term Average Rainfall (mm) or Annual Rainfall (mm)
1/01/1990
1/01/1995
1/01/2000
1/01/2005
1/01/2010
1/01/2015
1/01/2020
Date (dd/mm/yyyy)
Below Average Rainfall
Average Rainfall
Above Average Rainfall
Cumulative Dev from Mean Monthly Rainfall (1990-2020)
Cum Dev from Mean Monthly Rainfall (LTA)
LTA Rainfall
Annual Rainfall



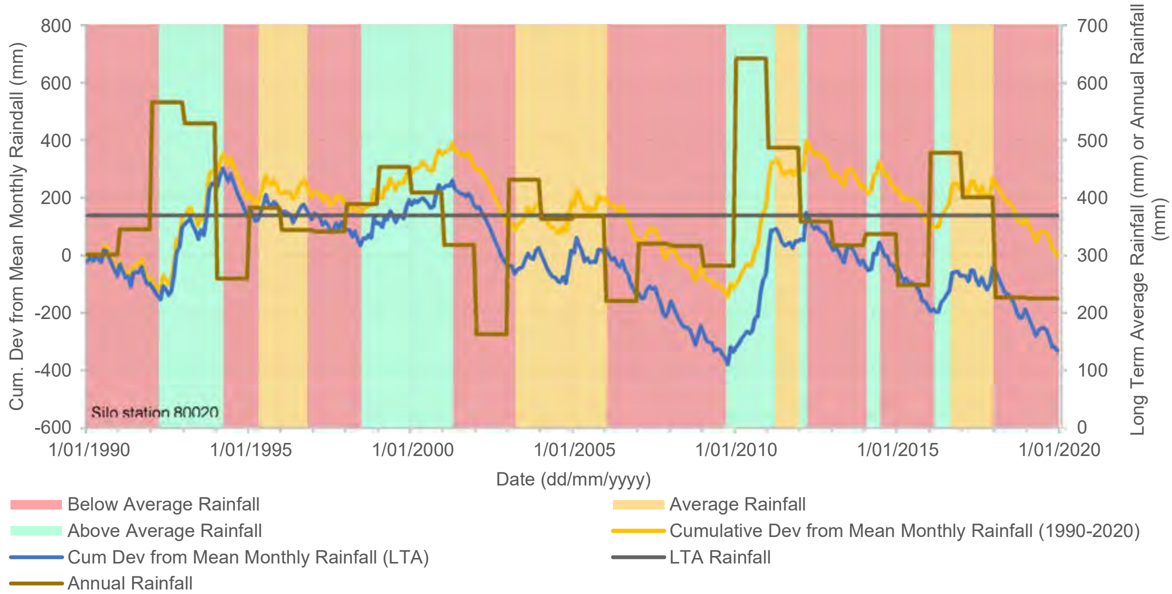
86
85
84
83
82
81
80
79
78
77
76
Redcued water level (mAHD)
66514 (105-UTAF)
66515 (102-UTQA)
13/02/1990
13/02/1995
13/02/2000
13/02/2005
13/02/2010
13/02/2015
13/02/2020



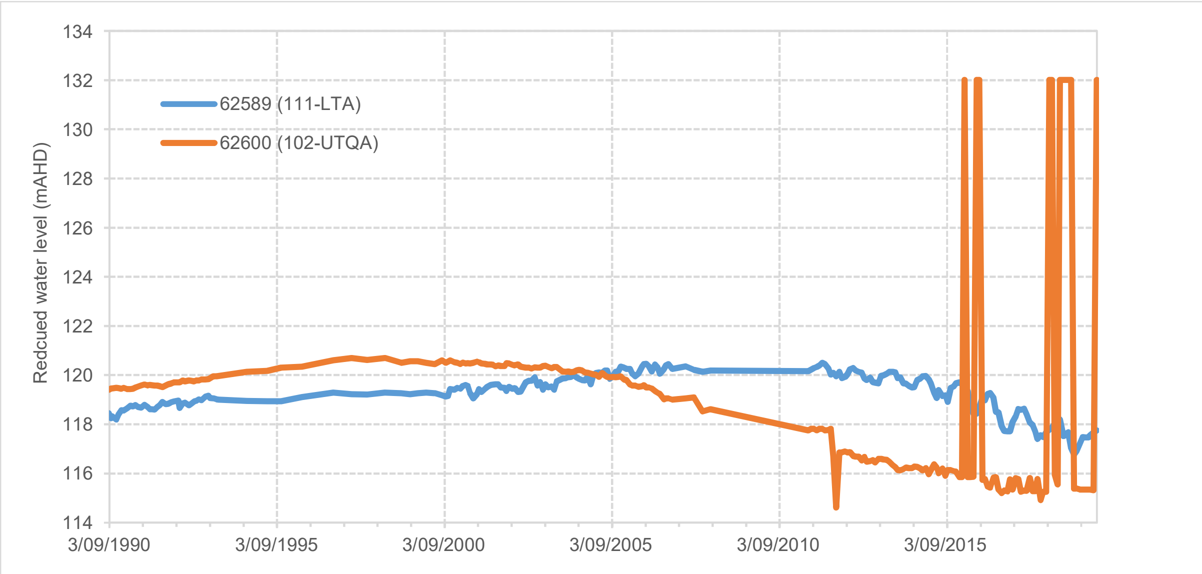
Cum. Dev from Mean Monthly Raindall (mm)
800
600
400
200
0
-200
-400
-600
Long Term Average Rainfall (mm) or Annual Rainfall (mm)
700
600
500
400
300
200
100
0
Silo station 80020
1/01/1990
1/01/1995
1/01/2000
1/01/2005
1/01/2010
1/01/2015
1/01/2020
Date (dd/mm/yyyy)
Below Average Rainfall
Above Average Rainfall
Cum Dev from Mean Monthly Rainfall (LTA)
Annual Rainfall
Average Rainfall
Cumulative Dev from Mean Monthly Rainfall (1990-2020)
LTA Rainfall

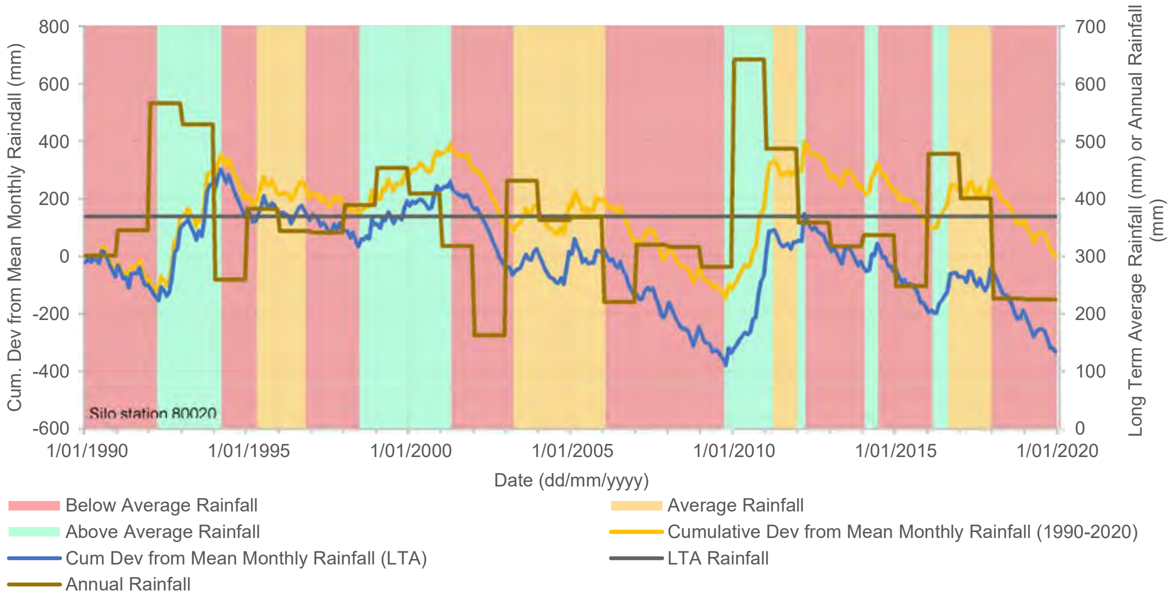


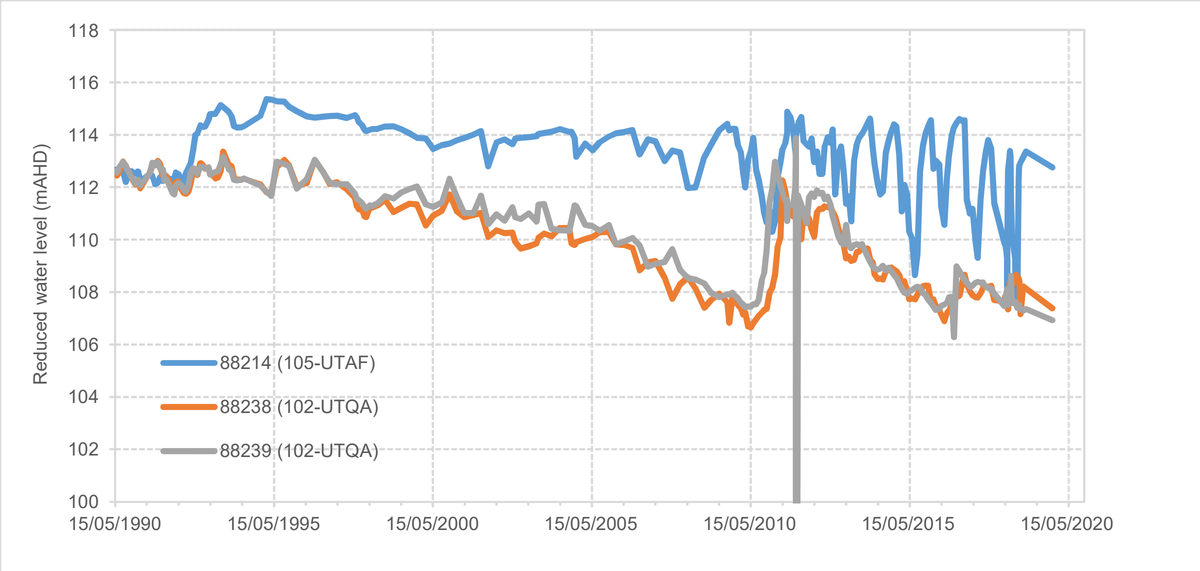
Reduced water level (mAHD)
82
81
80
79
78
77
76
75
74
73
72
17/04/1990
17/04/1995
17/04/2000
17/04/2005
17/04/2010
17/04/2015
17/04/2020
56029 (111-LTA)
56030 (104-UTAM)



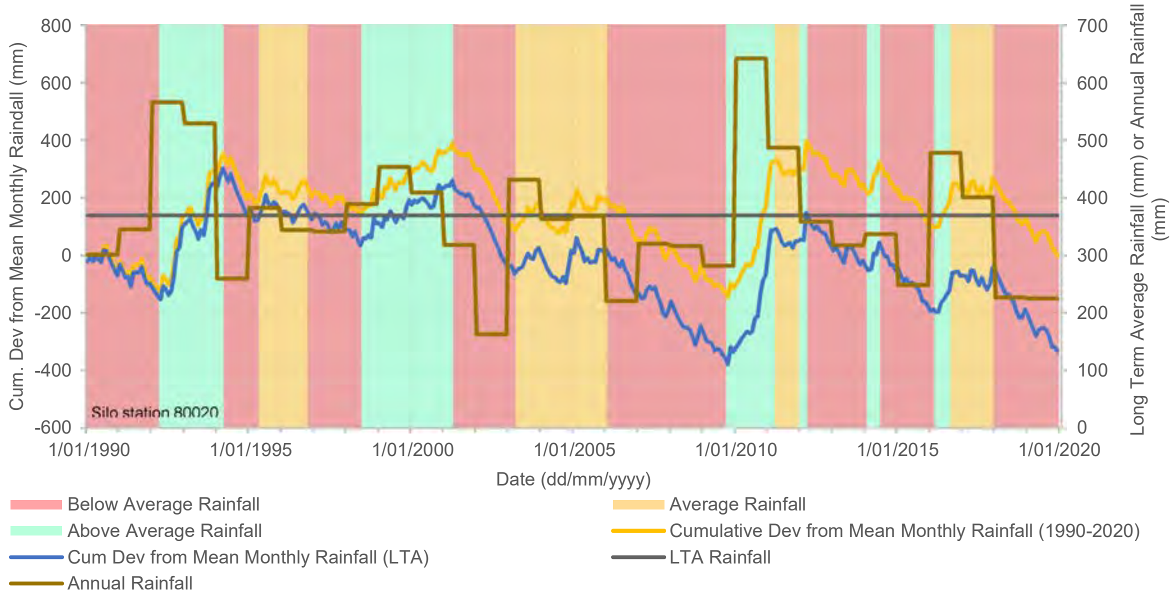
Cum. Dev from Mean Monthly Raindall (mm)
800
600
400
200
0
-200
-400
-600
Silo station 80020
700
600
500
400
300
200
100
0
Long Term Average Rainfall (mm) or Annual Rainfall (mm)
1/01/1990
1/01/1995
1/01/2000
1/01/2005
1/01/2010
1/01/2015
1/01/2020
Date (dd/mm/yyyy)
Below Average Rainfall
Average Rainfall
Above Average Rainfall
Cumulative Dev from Mean Monthly Rainfall (1990-2020)
Cum Dev from Mean Monthly Rainfall (LTA)
LTA Rainfall
Annual Rainfall


62589 (111-LTA)
62600 (102-UTQA)
Redcued water level (mAHD)
134
132
130
128
126
124
122
120
118
116
114
3/09/1990
3/09/1995
3/09/2000
3/09/2005
3/09/2010
3/09/2015


Cum. Dev from Mean Monthly Raindall (mm)
Long Term Average Rainfall (mm) or Annual Rainfall (mm)
800
600
400
200
0
-200
-400
-600
700
600
500
400
300
200
100
0
Silo station 80020
1/01/1990
1/01/1995
1/01/2000
1/01/2005
1/01/2010
1/01/2015
1/01/2020
Date (dd/mm/yyyy)
Below Average Rainfall
Average Rainfall
Above Average Rainfall
Cumulative Dev from Mean Monthly Rainfall (1990-2020)
Cum Dev from Mean Monthly Rainfall (LTA)
LTA Rainfall
Annual Rainfall



Reduced water level (mAHD)
118
116
114
112
110
108
106
104
102
100
15/05/1990
15/05/1995
15/05/2000
15/05/2005
15/05/2010
15/05/2015
15/05/2020
88214 (105-UTAF)
88238 (102-UTQA)
88239 (102-UTQA)



Cum. Dev from Mean Monthly Raindall (mm)
800
600
400
200
0
-200
-400
-600
Long Term Average Rainfall (mm) or Annual Rainfall (mm)
700
600
500
400
300
200
100
0
Silo station 80020
1/01/1990
1/01/1995
1/01/2000
1/01/2005
1/01/2010
1/01/2015
1/01/2020
Date (dd/mm/yyyy)
Below Average Rainfall
Average Rainfall
Above Average Rainfall
Cumulative Dev from Mean Monthly Rainfall (1990-2020)
Cum Dev from Mean Monthly Rainfall (LTA)
LTA Rainfall
Annual Rainfall

Appendix B – Throughflow Calculations

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UPSTREAM

GMW Gunbower — Version 2

Throughflow calculations — X Section: section 1 :Upstream

Darcy Equation Q=KiA — Type: K Median 88

SECTION 1 UPSTREAM

Cross Section ID		Unit	AQ1 LTA	AQ2 UTAF	Area 3	Total Area	Notes
Cross Sectional Area		m^2	319,875	597,955	0	917,830	Perpendicular to flow lines
Gradient							
	Initial Water Level	m	80	79.55	0		
	Final Water Level	m	70	77.77	0		
	Change in Head	m	10	1.78	0		
	Distance	m	25200	19400	1		
	Gradient	m/m	0.00040	0.00009	0.0000		
Hydraulic Conductivity		m/day	60	116	0		
Throughflow		m3/day	7,616	6,364	0		
		ML/year	**2,780**	**2,323**	**0**		
Calculated Throughflow		**ML/year**	**5,103**				

GMW Gunbower — Version 2

Throughflow calculations — X Section: section 1 :upstream

Darcy Equation Q=KiA — Type: K high 185

SECTION 1 UPSTREAM

Cross Section ID		Unit	AQ1 LTA	AQ2 UTAF	Area 3	Total Area
Cross Sectional Area		m^2	319,875	597,955	0	917,830
Gradient						
	Initial Water Level	m	80	79.55	0	
	Final Water Level	m	70	77.77	0	
	Change in Head	m	10	1.78	0	
	Distance	m	25200	19400	1	
	Gradient	m/m	0.00040	0.0001	0.0000	
Hydraulic Conductivity		m/day	185	185	0	
Throughflow		m3/day	23,483	10,150	0	
		ML/year	**8,571**	**3,705**	**0**	
Calculated Throughflow		**ML/year**	**12,276**			

DOWNSTREAM

GMW Gunbower — Version 2

Throughflow calculations — X Section: section 3 :Downstream

Darcy Equation Q=KiA — Type: K Median 88

SECTION 3 DOWNSTREAM

Cross Section ID		Unit	AQ1 LTA	AQ2 UTAF	Area 3	Total Area
Cross Sectional Area		m^2	1,197,740	589,673	0	1,787,413
Gradient						
	Initial Water Level	m	80	77.74	0	
	Final Water Level	m	75.25	76.28	0	
	Change in Head	m	4.75	1.46	0	
	Distance	m	32400	10800	1	
	Gradient	m/m	0.00015	0.00014	0.0000	
Hydraulic Conductivity		m/day	60	116	0	
Throughflow		m3/day	10,536	9,247	0	
		ML/year	**3,846**	**3,375**	**0**	
Calculated Throughflow		**ML/year**	**7,221**			

GMW Gunbower — Version 2

Throughflow calculations — X Section: section 3 :downstream

Darcy Equation Q=KiA — Type: K high 185

SECTION 3 DOWNSTREAM

Cross Section ID		Unit	AQ1	AQ2	Area 3	Total Area
Cross Sectional Area		m^2	1,197,740	589,673	0	1,787,413
Gradient						
	Initial Water Level	m	80	77.74	0	
	Final Water Level	m	75.25	76.28	0	
	Change in Head	m	4.75	1.46	0	
	Distance	m	32400	10800	1	
	Gradient	m/m	0.00015	0.0001	0.0000	
Hydraulic Conductivity		m/day	185	185	0	
Throughflow		m3/day	32,485	14,747	0	
		ML/year	**11,857**	**5,383**	**0**	
Calculated Throughflow		**ML/year**	**17,240**			

Upstream throughflow	ML/year	5,103	
Downstream throughflow	ML/Year	7,221	
Difference	ML/Year	2,118	
Estimated Pumping	ML/Year	700	
Estimated throughflow	ML/year	7,920.66	0.64

Upstream throughflow	ML/year	12,276
Downstream throughflow	ML/Year	17,240
Difference	ML/Year	4,964
Estimated Pumping	ML/Year	700
Estimated throughflow	ML/year	17,939.78

Appendix C – Bore interference and drawdown estimates

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Theis Equation Spreadsheet

Inputs (fill in yellow boxes only)

Project	Gunbower
Location	Gunbower
Project No.	12523464

CALCULATOR

L/s	Imp.gal/hr	m3/day	
28		2419.2	original rate

Hydraulical Conductivity	88	m/day	
Aquifer Thickness	60	m	
Calculated Transmissivity	5280	m^2/day	
Estimated Storativity	0.0005	m/m	lower S
Pumping Rate	2419	m^3/day	
Pumping Duration	120	days	
Minimum Radial Distance	200	m	

Drawdown after 120 days		**Transmissivity**									
		52.8	**528**	**1320**	**2640**	**3960**	**5280**	**6600**	**7920**	**9240**	**10560**
Radial Distance (m)	200	23.946	3.234	1.427	0.764	0.529	0.407	0.332	0.281	0.244	0.216
	400	18.901	2.729	1.225	0.663	0.462	0.357	0.292	0.248	0.216	0.191
	600	15.958	2.433	1.107	0.604	0.422	0.327	0.268	0.228	0.199	0.176
	800	13.881	2.223	1.023	0.562	0.394	0.306	0.252	0.214	0.187	0.166
	1000	12.279	2.061	0.958	0.529	0.373	0.290	0.238	0.203	0.177	0.158
	1200	10.981	1.928	0.905	0.503	0.355	0.277	0.228	0.194	0.170	0.151
	1400	9.894	1.816	0.860	0.480	0.340	0.265	0.219	0.187	0.163	0.145
	1600	8.963	1.719	0.821	0.461	0.327	0.256	0.211	0.180	0.158	0.140
	1800	8.151	1.634	0.787	0.444	0.316	0.247	0.204	0.175	0.153	0.136
	2000	7.436	1.558	0.756	0.428	0.305	0.239	0.198	0.169	0.148	0.132
	3000	4.817	1.266	0.638	0.369	0.266	0.210	0.174	0.150	0.132	0.118
	4000	3.166	1.061	0.555	0.328	0.238	0.189	0.158	0.136	0.120	0.107
	5000	2.071	0.904	0.491	0.295	0.216	0.173	0.145	0.125	0.110	0.099
	6000	1.34	0.78	0.44	0.27	0.20	0.16	0.13	0.12	0.10	0.09
	7000	0.85	0.68	0.40	0.25	0.18	0.15	0.13	0.11	0.10	0.09
	8000	0.52	0.59	0.36	0.23	0.17	0.14	0.12	0.10	0.09	0.08
	9000	0.31	0.51	0.33	0.21	0.16	0.13	0.11	0.10	0.09	0.08
	10000	0.18	0.45	0.30	0.20	0.15	0.12	0.10	0.09	0.08	0.07
	11000	0.07	0.39	0.27	0.18	0.14	0.12	0.10	0.09	0.08	0.07
	12000	0.00	0.35	0.25	0.17	0.13	0.11	0.09	0.08	0.07	0.07
	13000	0.00	0.30	0.23	0.16	0.13	0.10	0.09	0.08	0.07	0.06

Source: Fetter, C.W., 1988: 'Applied Hydrogeology' 2nd Edition, Macmillan Publishing Company

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Programmed: Tim Anderson

Numerically unstable for drawdowns greater than 600 m

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380 Lonsdale Street Melbourne Vic 3000

Project: Gunbower
Client:GMW

ENTER INPUT DATA IN SHADED CELLS

Aquifer Parameters

Transmissivity	5280	m^2/day
Storativity	0.0005	m/m
Pumping Bore Min.Radius	0.1	m

Modelling Periods

Period 1	30	days
Period 2	60	days
Period 3	90	days
Period 4	120	days
Period 5		day
Period 6		day

	Bore Name / Descriptor	Bore ID	Location Easting	Location Northing	Radial Distance from WRK091289	Pumping Rate L/s	Pumping Rate m^3/day	SWL	Pump Depth (m)	Available drawdown (m)	Graphing Code (m)
1	Applicant's Existing Lic	WRK091289	271,681	6,016,119	1.0	47	4,060.8	1	101	100	2
2	Applicant's Existing Lic	WRK115717	266,197	6,019,479	6,431.5	51	4,406.4	1	101	100	2
3	Applicant's Existing Lic	WRK118233	263,740	6,024,015	11,198.5	57	4,924.8	1	101	100	2
4	Applicant's Proposed B	BGW0836-19	264,160	6,022,400	9,798.8	96	8,294.4	1	101	100	1
5	Applicant's Proposed B	BGW0995-19	262,772	6,026,378	13,587.4	81	6,998.4	1	101	100	1
6	Applicant's Proposed B	BGW0977-19	260,089	6,019,018	11,949.0	108	9,331.2	1	101	100	1
7	Applicant's Proposed B	BGW0982-19	261,032	6,017,961	10,807.1	81	6,998.4	1	101	100	1
8	Applicant's Proposed B	BGW0997-19	257,913	6,028,941	18,813.9	81	6,998.4	1	101	100	1
9	Applicant's Proposed B	BGW1038-19	260,644	6,018,617	11,316.2	96	8,294.4	1	101	100	1
10	Applicant's Proposed B	BGW1053-19	257,884	6,023,859	15,819.8	96	8,294.4	1	101	100	1
11	Applicant's Proposed B	BGW0006-20	268,513	6,012,684	4,672.8	48	4,147.2	1	101	100	1
12	Applicant's Proposed B	BGW0088-20	261,244	6,015,736	10,444.0	144	12,441.6	1	101	100	1
13	Applicant's Proposed B	BGW0099-20	254,271	6,021,629	18,261.1	57	4,924.8	1	101	100	1
14	Applicant's Proposed B	BGW0111-20	265,455	6,021,487	8,220.6	98	8,467.2	1	101	100	1
15	State Observation / Inv	rigger Mid loddon 8821	238,422	5,965,135	60,872.9		-				12
16	State Observation / Inv	rigger LCV WSPA 7932	290,749	5,995,044	28,421.4		-				12
17	State Observation / Inv	rigger LCV WSPA 6258	284,434	5,956,174	61,286.6		-				12
18	State Observation / Inv	Border Mid Loddon	301,681	6,016,119	30,000.0		-				12
19	State Observation / Inv	Border LCV WSPA	278,681	6,016,119	7,000.0		-				12
20	<< BLANK >>				-		-				8
21	<< BLANK >>				-		-				8
22	<< BLANK >>				-		-				8
23	<< BLANK >>				-		-				8
24	<< BLANK >>				-		-				8
25	<< BLANK >>				-		-				8
26	<< BLANK >>				-		-				8

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Project: Gunbower
Client:GMW

Calculated Drawdowns (Expressed as total drawdown (m) or % of available drawdown)

	Bore	Radial Distance from WRK091289	Available Drawdown (m)	Pumping Rate (L/s)	30 days		60 days		90 days		120 days		days		days	
					Total Drawdown at Bore (m)	% of Available Drawdown	Total Drawdown at Bore (m)	% of Available Drawdown	Total Drawdown at Bore (m)	% of Available Drawdown	Total Drawdown at Bore (m)	% of Available Drawdown	Total Drawdown at Bore (m)	% of Available Drawdown	Total Drawdown at Bore (m)	% of Available Drawdown
1	WRK091289	1.0	100.0	47	4.16	4.2	5.11	5.1	5.69	5.7	6.10	6.1	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
2	WRK115717	6,431.5	100.0	51	5.93	5.9	6.93	6.9	7.53	7.5	7.95	7.9	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
3	WRK118233	11,198.5	100.0	57	6.35	6.4	7.36	7.4	7.95	7.9	8.37	8.4	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
4	BGW0836-19	9,798.8	100.0	96	7.61	7.6	8.62	8.6	9.22	9.2	9.64	9.6	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
5	BGW0995-19	13,587.4	100.0	81	6.34	6.3	7.33	7.3	7.92	7.9	8.35	8.3	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
6	BGW0977-19	11,949.0	100.0	108	8.35	8.3	9.36	9.4	9.95	10.0	10.38	**10.4**	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
7	BGW0982-19	10,807.1	100.0	81	7.73	7.7	8.74	8.7	9.33	9.3	9.76	9.8	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
8	BGW0997-19	18,813.9	100.0	81	5.50	5.5	6.46	6.5	7.04	7.0	7.46	7.5	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
9	BGW1038-19	11,316.2	100.0	96	8.25	8.3	9.26	9.3	9.86	9.9	10.28	**10.3**	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
10	BGW1053-19	15,819.8	100.0	96	6.84	6.8	7.84	7.8	8.43	8.4	8.85	8.9	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
11	BGW0006-20	4,672.8	100.0	48	4.31	4.3	5.26	5.3	5.84	5.8	6.25	6.3	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
12	BGW0088-20	10,444.0	100.0	144	8.46	8.5	9.45	9.5	10.05	**10.0**	10.47	**10.5**	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
13	BGW0099-20	18,261.1	100.0	57	5.11	5.1	6.09	6.1	6.67	6.7	7.09	7.1	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
14	BGW0111-20	8,220.6	100.0	98	7.47	7.5	8.48	8.5	9.07	9.1	9.49	9.5	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
15	Trigger Mid loddon 88214	60,872.9			0.00	#VALUE!	0.17	#VALUE!	0.35	#VALUE!	0.54	#VALUE!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
16	Trigger LCV WSPA 79324	28,421.4			0.27	#VALUE!	0.72	#VALUE!	1.09	#VALUE!	1.39	#VALUE!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
17	Trigger LCV WSPA 62589	61,286.6			0.00	#VALUE!	0.09	#VALUE!	0.23	#VALUE!	0.38	#VALUE!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
18	Border Mid Loddon	30,000.0			0.23	#VALUE!	0.65	#VALUE!	1.01	#VALUE!	1.30	#VALUE!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
19	Border LCV WSPA	7,000.0			1.68	#VALUE!	2.53	#VALUE!	3.08	#VALUE!	3.47	#VALUE!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
20		-														
21		-														
22		-														

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12523464-45734-16/https://projectsportal.ghd.com/sites/pp17_04/gmwgunbowerandlowerl/ProjectDocs/12523464_REP_DRAFT_C_ Gunbower Area Hydrogeological Assessment.docx

Document Status

Revision	Author	Reviewer		Approved for Issue		
		Name	Signature	Name	Signature	Date
1	J Morgan B Smyth	G Jones		G Jones		7/7/2020

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