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MURRAY–DARLING BASIN AUTHORITY

Murray–Darling Basin Plan Groundwater Methods Report

Determining the groundwater baseline and sustainable diversion limits

November 2020

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Acknowledgement of the Traditional Owners of the Murray–Darling Basin

The Murray−Darling Basin Authority pays respect to the Traditional Owners and their Nations of the Murray−Darling Basin. We acknowledge their deep cultural, social, environmental, spiritual and economic connection to their lands and waters.

The guidance and support received from the Murray Lower Darling Rivers Indigenous Nations, the Northern Basin Aboriginal Nations and our many Traditional Owner friends and colleagues is very much valued and appreciated.

Aboriginal people should be aware that this publication may contain images, names or quotations of deceased persons.

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Abbreviations

ASGE – Achieving Sustainable Groundwater Entitlements program

Basin – Murray–Darling Basin

Basin state – Queensland, New South Wales, Victoria, South Australia or Australian Capital Territory

BDL – baseline diversion limit

CSG – coal seam gas

CSIRO – Commonwealth Scientific and Industrial Research Organisation

ESLT – environmentally sustainable level of take

GAB – Great Artesian Basin

GDE – groundwater dependent ecosystem

GMA – groundwater management area

GMU – groundwater management unit

Guide – the Guide to the Basin Plan (October 2010)

KEA – key environmental assets

KEF – key ecosystem functions

KEO – key environmental outcomes

MDB – Murray–Darling Basin

MDBA – Murray–Darling Basin Authority

PB – productive base

PEL – preliminary extraction limit

RCL – resource condition limit

RRAM – Recharge Risk Assessment Method

S&D – stock and domestic

SAFE – Secure Allocations, Future Entitlements

SDL – sustainable diversion limit

SF – sustainability factor

SIS – salt interception scheme

SKM – Sinclair Knight Merz

WAVES – Water Vegetation Energy and Solute model

WRP – water resource plan

WSPA – water supply protection area

Introduction

The Murray–Darling Basin Authority (MDBA) has a vision of a healthy working Basin that has vibrant communities, productive and resilient industries, and healthy and diverse ecosystems. One of the key actions to achieve this vision is ensuring a balance between the water needs of communities, industries and the environment, while protecting and restoring the ecological and other values of water-dependent ecosystems so they remain healthy.

The Basin Plan aims to do this through the establishment of long-term average sustainable diversion limits (SDLs). They came into effect in 2019, along with a range of other measures that will improve the management of water in the Basin. SDLs are limits on the volumes of water that can be taken for human uses from both surface water and groundwater systems across the Basin. This also includes domestic, urban and agricultural use. The *Water Act 2007 (Cwlth)* requires that these new limits reflect an environmentally sustainable level of take (ESLT).

This groundwater methods report is aimed at groundwater practitioners and other informed readers to support understanding of the Basin Plan and its amendments (MDBA, 2018) in the development of sustainable level of diversion limits. The report details the history and technical detail behind the methods and assessments used to determine both the groundwater baseline diversion limits (BDLs) and sustainable diversion limits (SDLs) for the Basin Plan. It provides details for the quantification of recharge, risk assessments and numerical modelling used to determine SDLs, as well as the information used to determine the BDL.

The report reflects Basin Plan amendments in 2018, and consolidates and combines information published previously by the MDBA, including:

- the *Groundwater Methods Report* (MDBA 2012b);
- *Addendum* (MDBA, 2012c); and
- the *Groundwater SDL Methodology for the Murray–Darling Basin Plan* (CSIRO and SKM, 2010a).

As part of the amendments in 2018 the Authority made several changes to how groundwater is managed under the Basin Plan. The changes were based on several drivers including:

- the outcomes of groundwater reviews specified in the Basin Plan; and
- requests by Basin states to improve alignment of the water planning boundaries in the Basin Plan with their state water management plans.

There were three main areas in which changes to the Basin Plan groundwater provisions were made: SDLs and mandatory local management rules in the review areas, the groundwater compliance method and groundwater SDL unit boundaries. These are discussed in this report.

This report also has a companion document, the 2020 ‘report cards’ (available on the MDBA website), which provides information on each individual SDL resource unit including how the BDL and SDL have been determined. This replaces the previously published version of the report cards report (CSIRO and SKM, 2010; MDBA, 2012).

Each Basin state has a groundwater management framework in place. In developing the Basin Plan, the MDBA considered the state frameworks and drew on the expertise and knowledge held by the states. Significantly, since the Basin Plan was established, for the first time there was:

- a limit on groundwater use established across the whole Basin (in contrast to surface water, where a cap has been in place since the mid-1990s); and
- a consistent set of management arrangements to be applied across all the Basin's groundwater resources.

The groundwater resources in the Basin have been split into 19 groundwater water resource plan (WRP) areas, which are further divided into 80 SDL resource units (Schedule 4 of the Basin Plan). The boundaries of SDL resource units were determined to reflect state planning boundaries and accommodate the level of connectivity of various groundwater resources. There is an SDL volume determined for each SDL resource unit in the Basin Plan. Several SDL resource units have also been vertically or horizontally separated. This was to reflect that water is or can be extracted from different aquifers within the same area.

The requirement to set SDLs is just one element of the 2012 Basin Plan and its amendments in 2018. SDLs are considered to work in parallel to other water resource management elements (e.g. water quality management plans under Chapter 10 of the Basin Plan), required to deliver a healthy working Basin.

The Basin Plan and groundwater management

The Basin Plan, and its framework for managing groundwater and surface water resources through SDLs and accredited WRPs, came into force in late 2012.

Enforcement of SDLs commenced on 1 July 2019. Determining SDLs was an iterative process. Basin states provided information and comments to refine SDLs based on the best available science and information. The timeline of the Basin Plan with major milestones, followed by detailed explanation, is provided as follows.

2010 - 2012

- **Initial groundwater SDLs were agreed with Basin states**

November 2012

- **Basin Plan commenced**

November 2014

- **Groundwater SDL reviews completed**
  SDL reviews completed for Goulburn–Murray (Vic), Western Porous Rock (NSW) and Eastern Porous Rock (NSW) WRP areas and recommendations made to the MDBA

July 2018

- **Basin Plan amendments**
  Amendments included boundary changes, changes recommended from SDL reviews, other minor BDL/SDL updates and changes to the groundwater compliance method.

July 2019

- **SDLs commence**
  SDLs commenced in all groundwater SDL resource units on 1 July 2019

Basin Plan commenced in November 2012

The Basin Plan commenced on 24 November 2012. Schedule 4 of the Basin Plan lists the characteristics for groundwater areas, including SDL resource unit groundwater names and definitions, BDLs and SDLs.

SDL reviews completed in November 2014

When the Basin Plan was finalised in 2012, concerns were raised by the NSW and Victorian Governments in relation to the SDLs for the Western Porous Rock SDL resource unit (GS50), the Eastern Porous Rock WRP area (GW16) (comprising of the Gunnedah-Oxley Basin MDB (GS17) and the Sydney Basin MDB (GS41) SDL resource units) and the Goulburn-Murray: Sedimentary Plain SDL resource unit (GS8c). In response, the Basin Plan included a requirement that the SDLs for these areas would be reviewed (Section 6.06(6) to (9)).

Review panels were established to undertake the reviews and a consultant was appointed to synthesise the relevant information for each review. The review and synthesis reports are available on the MDBA website:

- Western Porous Rock - https://www.mdba.gov.au/publications/research-report/western-porous-rock-sdl-resource-unit-review (Review, Forbes et al, 2014; Synthesis report, Evans, 2014)
- Eastern Porous Rock - https://www.mdba.gov.au/publications/independent-reports/eastern-porous-rock-water-resource-plan-area-review (Review, Forbes et al, 2014; Synthesis report, Evans, 2014)
- Goulburn-Murray: Sedimentary Plain - https://www.mdba.gov.au/publications/research-report/goulburn-murray-sedimentary-plain-sdl-resource-unit-review (Review, Forbes et al, 2014; Synthesis report Wade, 2014)

These three reviews recommended that the SDLs under consideration could be increased 'once assurances have been given by the relevant state to demonstrate that the resource will be managed by state policies and plans so as to limit impacts to acceptable levels'. This outcome reflected the view of the review panels, that a less conservative approach to setting SDLs could be considered if suitable management actions are in place to manage the potential impacts of increased groundwater take.

Basin Plan amendment in July 2018

The Basin Plan was amended on 3 July 2018 (MDBA, 2018b). The proposed amendments were open for public comment from 22 November 2016 to 24 February 2017.

The amendments:

- Addressed boundary issues to reflect alignment with state water management plans to reduce complexity and administrative burden:

    - NSW Western Porous Rock WRP area (GW6) and Eastern Porous Rock WRP area (GW16) were amalgamated into the NSW Murray–Darling Basin Porous Rock WRP area (GW6).
    - Lachlan and South Western Fractured Rock WRP area (GW11) and New England Fractured Rock and Northern Basalts WRP area (GW17) were amalgamated into the NSW Murray–Darling Basin Fractured Rock WRP area (GW11).
    - WRP area boundary changes in Darling Alluvium (GW7), Murray Alluvium (GW8), Murrumbidgee Alluvium (GW9), Macquarie-Castlereagh Alluvium (GW12) and Namoi Alluvium (GW14). These area changes are less than 1% of the NSW Murray–Darling Basin area and do not change the SDLs in the SDL resource units.
    - Vertical boundary changes to some NSW groundwater SDL resource units to align with state plans and allow separate accounting for buried resources (where one SDL resource unit is buried by another).
    - Queensland Border Rivers WRP area (GW19) and Moonie WRP area (GW20) were amalgamated into the Queensland Border Rivers-Moonie WRP area (GW19);
- Incorporated the recommendations from the SDL reviews for the Western Porous Rock SDL resource unit (GS50) (NSW), Eastern Porous Rock WRP area (GW16) (NSW) and Goulburn-Murray: Sedimentary Plain SDL resource unit (GS8c) (Vic) to a combined total increase of groundwater SDL from 3,334 GL/y to 3,494 GL/y in these areas. Details are summarised in Table 1. The increases in extraction limits have been assessed to have minimal potential impacts on the environment; and
- Transferred 2.14 GL/y of entitlement associated with a salt interception scheme from the BDL of the Mallee (Murray Group Limestone) (GW3) SDL resource unit to the BDL of the SA Murray Salt Interception Schemes (GS7) SDL resource unit. There was no change to the SDL of the SA Murray Salt Interception Schemes SDL resource unit as the current SDL allows for more take than the current BDL.
- Revised the BDL for the Australian Capital Territory (ACT) SDL resource unit (GS52) to account for additional water used by the Commonwealth in the ACT in 2009 than what was estimated.
- Changed the groundwater compliance methodology (MDBA, 2018a). After consulting the Basin states, the Authority proposed a 10-year rolling average compliance method to be used for groundwater SDL resource units. Under the proposed method, each year from 1 July 2019, the Basin states are required to report on the volume of water extracted during a water year (annual actual take) from a surface or groundwater SDL resource unit; and the volume that is allowed to be extracted during a water year (annual permitted take) from the same surface or groundwater SDL resource unit as well as the difference between both volumes. A non-compliance with a groundwater SDL in a water year will occur if the average annual actual take over the ten year period ending with that water year is greater than a) the average annual permitted take over the same period, and b) the Basin state does not have a reasonable excuse for the excess.
  Moved groundwater water quality from Part 4 to Part 7 of Chapter 10.

Table 1: Groundwater BDL and SDL changes in Schedule 4 of the Basin Plan, as a result of 2018 amendments (MDBA, 2018)

Basin state	WRP area	SDL resource unit	Basin Plan BDL (GL/y)	BDL (GL/y)	Basin Plan SDL (GL/y)	SDL (GL/y)	SDL change (GL/y)	State Plan Limit
NSW	NSW Western Porous Rock (GW6)	Western Porous Rock (GS50)	63.1	No change	116.6	226.0	+109.4	530.5
		Gunnedah-Oxley Basin (GS17)	22.1	No change	114.5	127.5	+13.0	205.6
		Sydney Basin (GS41)	3.12	No change	17.2	19.1	+1.9	60.4
VIC	Goulburn-Murray (GW2)	Goulburn-Murray: Sedimentary Plain (GS8c)	203.5	No change	203.5	223.0	+19.5	223.0
		Goulburn-Murray: Highlands (GS8b)	38.3	No change	50.5	68.7	+18.2	41.6
	Wimmera-Mallee (GW3)	Wimmera-Mallee: Sedimentary Plain (GS9b)	68.9	No change	190.7	190.1	-0.6	68.9
		Wimmera-Mallee: Highlands (GS9a)	1.26	No change	2.14	2.75	+0.6	1.26
SA	South Australian Murray Region (GW4)	Mallee (Murray Group Limestone) (GS3b)	65.7	63.6	65.7	63.6	-2.1	63.6
		SA Murray Salt Interception Schemes (GS7)	11.1	13.2	28.6	28.6	No change	13.2
		Total					**+159.9**	

SDLs commenced 1 July 2019

SDLs commenced in all groundwater SDL resource units on 1 July 2019. WRPs are the main mechanism for giving effect to SDLs and the Basin Plan. The 2019–2020 water year is the first year where water accounting and compliance is applied by the MDBA across the Basin. Prior to this, from 2012–13 'transition period water take reports' have been published by MDBA consistent with the framework, processes and procedures for assessing SDL compliance. They also trialled how water accounting and compliance reports will be presented. Transition period water take reports are available on the MDBA website (https://www.mdba.gov.au/publications/mdba-reports/transitional-sdl-water-take-reports).

WRP areas and SDL resource unit boundaries

Groundwater boundaries pre-Basin Plan

Prior to the Basin Plan, a groundwater management unit (GMU) was defined by the 2000 National Land and Water Resources Audit as a 'hydraulically connected groundwater system that is defined and recognised by Territory and State agencies' (Richardson et al., 2008; NLWRA, 2001).

There were 96 GMUs located across the Murray–Darling Basin, with major differences in definition and size. For example, across New South Wales, all areas were within at least one GMU, while other states have large unincorporated areas for which GMUs do not exist. GMUs were three dimensional in nature and often associated with a geological formation or aquifer. The aquifers may overlie one another.

Defining boundaries for the Basin Plan

Mandatory content in the *Water Act 2007 (Cwlth)* (Section 22 (1) item 2) framed the definition of boundaries for WRP areas and SDL resource units. Basin states were included in the process for defining WRP areas and SDL resource units.

For WRP areas, the approach was to:

- preserve Basin state management areas as much as possible;
- have fewer and larger WRP areas to enable flexible management approaches; and
- ensure a commonality between WRPs for surface water and groundwater resources wherever possible.

For SDL resource units, the approach was to:

- preserve Basin state management boundaries where possible;
- include unincorporated areas into hydrogeological or surface water catchment-based units; and
- aggregate very detailed management areas into larger areas that allow Basin states some flexibility of management without over-burdening the Basin Plan with too much detail.

The Basin has been divided into 19 groundwater WRP areas. The boundaries of these areas are shown in . The WRP areas cover the entire Basin, including those areas not previously subject to water planning arrangements.

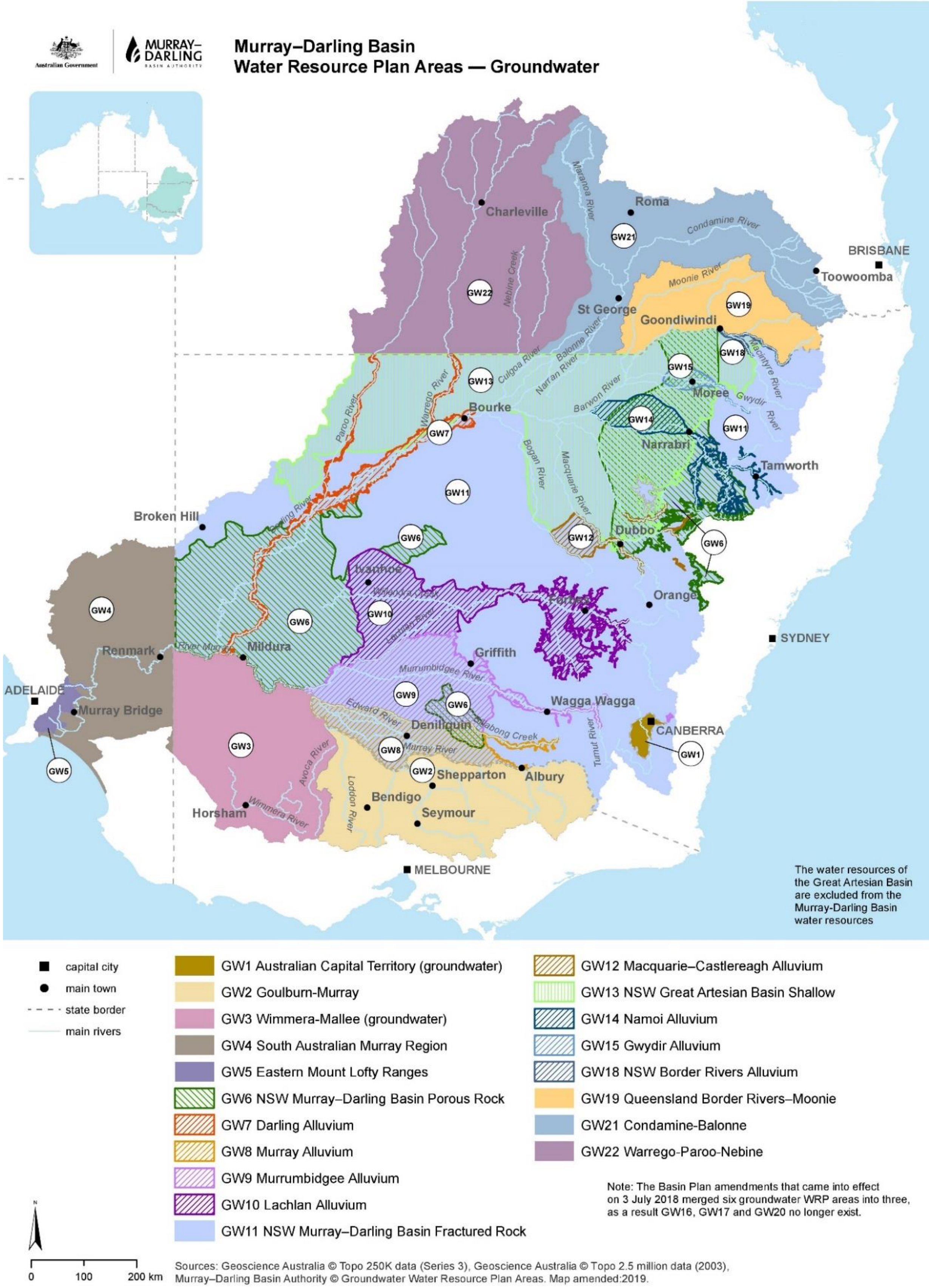


Figure 1: Water resource plan areas – Groundwater

Within these WRP areas there are 80 SDL resource units (Figure 2). There is an SDL volume for each SDL resource unit.

Excluded areas

The *Water Act 2007 (Cwlth)* specifically excludes water resources of the Great Artesian Basin (GAB) from being considered as Basin water resources. As such, the GAB is not covered by a WRP.

The following water resources were excluded from the Murray–Darling Basin (MDB) water resources by regulation:

- groundwater resource of the Tintinara-Coonalpyn Prescribed Wells Area;
- groundwater resources of the Victorian West Wimmera Groundwater Management Area; and
- groundwater and surface water resources of specified areas in South Australia.

These water resources were excluded by the MDB boundary defined under Section 18A of the *Water Act 2007 (Cwlth)*. Section 18A of the *Water Act 2007 (Cwlth)* informs the definition of Basin water resources, which were originally determined based on states' surface water planning areas. The excluded water resources are on the edge of non-MDB state water planning areas or fall partially inside and partially outside of the MDB boundary. The SDL for the Victorian Wimmera-Mallee: Sedimentary Plain SDL resource unit was modified to account for the exclusion.

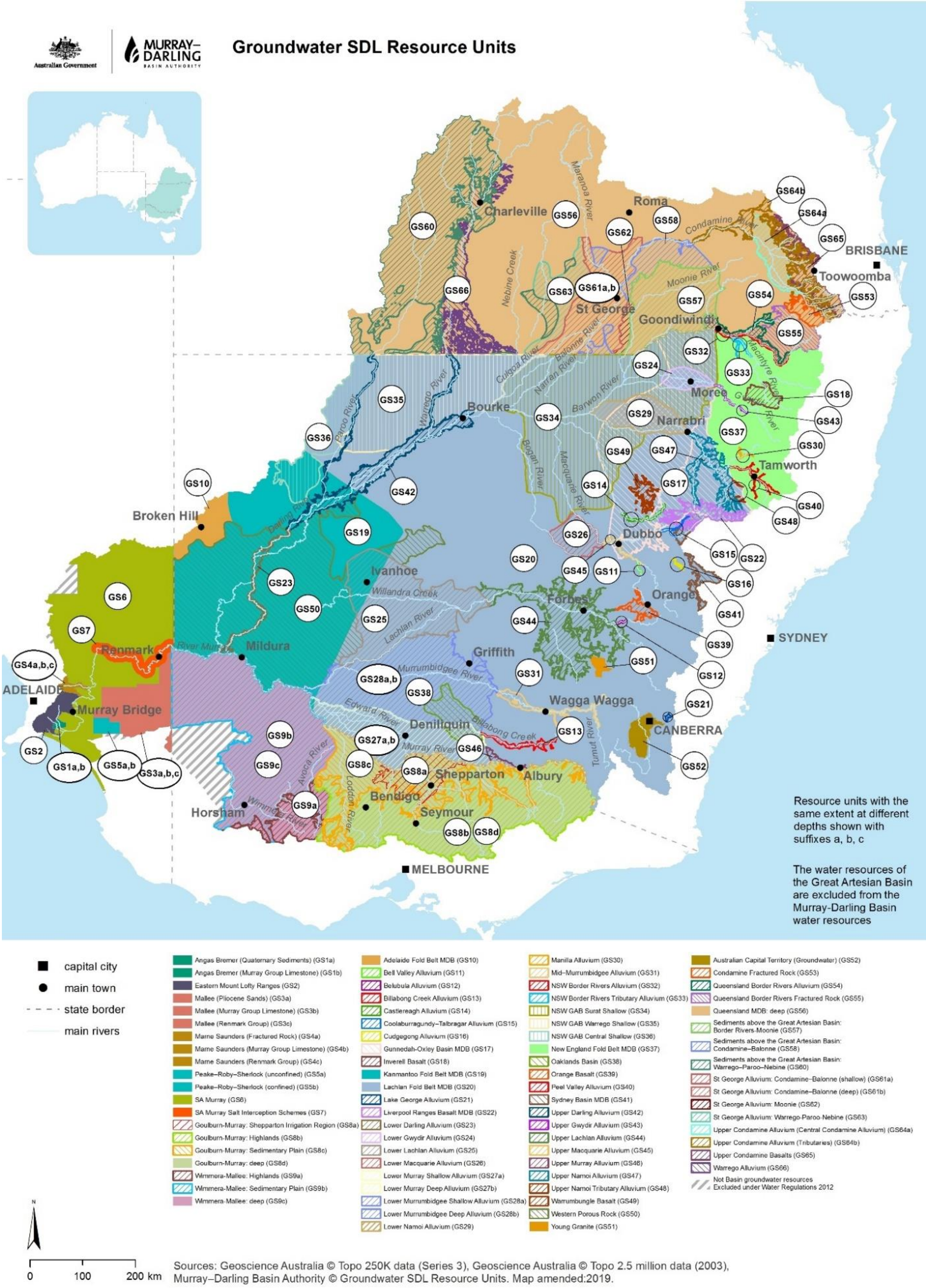


Figure 2: Groundwater SDL resource units

Baseline diversion limits

Specifying a baseline diversion limit (BDL) for each SDL resource unit is required under Section 78 of the *Water Act 2007 (Cwlth).* BDLs provide the baseline against which SDLs are assessed. BDLs were a common starting point for discussions with Basin states and communities on the groundwater SDLs. In surface water, the 1995 Cap on diversions (often referred to as 'The Cap') effectively provided a common starting point for much of the Basin. However, for groundwater, no similar arrangement was in place prior to the development of the Basin Plan.

Setting the baseline diversion limits

The specification of BDLs has implications for the Commonwealth's commitment to water recovery programs. It is important to have a Basin-wide policy for setting BDLs that accurately reflects the potential limit of diversions in place at the making of the Basin Plan. The BDL for each SDL resource unit was determined on the following basis:

- where a water management plan or proposed plan existed, the BDL is the plan limit unless the plan limit is greater than the level of entitlement, in which case the BDL is set as the entitlement volume;
- where there is no plan, the BDL is the entitlement volume along with the effect of any rules managing extraction[1]; and
- where there is a cross-border agreement for groundwater management, the extraction limit under the agreement is the BDL.

Basin states provided the information used by the MDBA to determine BDLs. During the development of the Basin Plan, some Basin states reviewed and updated the baseline information they had initially provided. This new information represented the most up-to-date understanding of the level of groundwater water access rights and basic landholder rights (the taking of water for stock and domestic use).

Except for the ACT, groundwater extraction under basic landholder rights is not metered in the Basin. Each state has a different definition of basic landholder right use and applies different methods to estimate basic landholder right take volumes. The MDBA used these state estimates to determine the basic landholder rights volumes within the BDLs.

[1] For the Upper Condamine Alluvium, metered use from 2002-03 to 2007-08 for 5 sub-areas of the Queensland management area was used to estimate the limit imposed by the management arrangements.

Assessment to determine groundwater SDLs

Groundwater SDLs

Under the *Water Act 2007 (Cwlth)* (Section 22(1) Item 6), the Basin Plan must include SDLs for:

- the Basin water resources as a whole; and
- the water resources, or parts of the water resources, of each water resource plan area.

Groundwater SDLs were informed by numerical modelling or an analytical risk assessment. Numerical modelling was carried out in 12 SDL resource units where there were fit for purpose numerical models available. The analytical risk assessment, known as the recharge risk assessment method (RRAM), was developed for the MDBA (CSIRO and SKM 2010a), to inform the SDLs. Both the numerical groundwater modelling and the RRAM derived preliminary estimates of the SDL for consumptive use which is known as the preliminary extraction limit (PEL).

The PEL represents the MDBA's numerical assessment of the level of groundwater extraction that can be maintained in an aquifer while preserving its environmentally sustainable level of take characteristics. To determine the final groundwater SDLs the MDBA applied an analytical framework taking other factors into account that were not considered in determining the PEL (see Groundwater Assessment Framework).

The groundwater SDLs are a limit and not a target. In some areas due to poor water quality and difficulty in accessing groundwater, it is unlikely that extraction will approach the SDL in the medium term (20 to 30 years).

Environmentally sustainable level of take

The SDLs reflect the environmentally sustainable level of take (ESLT) for a water resource. The ESLT is defined as the level at which water can be taken from that water resource which, if exceeded, would compromise:

- key environmental assets (KEA) of the water resource; or
- key ecosystem functions (KEF) of the water resource; or
- the productive base (PB) of the water resource; or
- key environmental outcomes (KEO) for the water resource.

For groundwater resources specifically, the ESLT is the level at which water can be taken from a groundwater resource which, if exceeded, would compromise:

- groundwater dependent ecosystems; or
- surface water – groundwater connectivity; or
- the productive base of the resource; or
- water quality.

Groundwater dependent ecosystems

Some Basin ecosystems are completely groundwater dependent. Others rely on groundwater for part of the time.

The *Water Act 2007 (Cwlth)* defines environmental assets as those that include water-dependent ecosystems and sites with ecological significance and ecosystem services. As part of the RRAM, MDBA identified and mapped environmental assets of ecological significance. The determination of dependence on groundwater and sensitivity to groundwater take of these assets was largely based on the understanding, conceptualisation and local knowledge of hydrogeologists with extensive experience of the groundwater resources of the Basin. State based groundwater management plans were also used to identify groundwater dependent ecosystems.

Surface water–groundwater connectivity

Surface water and groundwater are components of one hydrologic system. Connected systems can be described as those where there is a zone of continuous saturation between a stream and the aquifer. If the connection between these components is strong, groundwater extraction may directly affect stream flow by inducing leakage to groundwater. Similarly, groundwater extraction may intercept potential groundwater-derived base flows to streams.

The MDBA used the following classification system to describe connectivity for the purposes of the Basin Plan:

- gaining stream: groundwater flows to surface water;
- losing stream: surface water flows to groundwater;
- maximum losing stream: surface water flows to groundwater, however, the groundwater and stream are not connected; and
- disconnected stream: there is no connection between the surface water and groundwater.

Preservation of the productive base

The preservation of the productive base means the maintenance of the groundwater resource availability and quality, to allow uses to continue, e.g. for:

- supporting environmental assets and ecosystem functions;
- providing water for irrigation; and
- providing drinking water for people and stock.

Water quality

For Basin groundwater resources, the key environmental outcome is the protection of groundwater resources from salinisation. Groundwater salinisation can occur via multiple processes including excessive groundwater take. However, groundwater salinisation from groundwater take is not a threat in all Basin groundwater resources.

Groundwater recharge

An important input into the development of the PEL is groundwater recharge. Across the Basin, there are many small-scale recharge studies. However, little information is known about recharge to groundwater at an SDL resource unit scale. A recharge assessment was undertaken to establish recharge volumes across the Basin in a repeatable and uniform manner. The assessment also investigated the impact of climate change and climate variability on estimates of groundwater recharge across the Basin.

CSIRO developed the Water Vegetation Energy and Solute (WAVES) model for the Murray–Darling Basin Sustainable Yields project (CSIRO 2008). The WAVES model was subsequently updated and used to determine recharge for the Basin. The recharge assessment using the WAVES model is described in full in the CSIRO/SKM technical report on dryland diffuse groundwater recharge modelling across the Murray–Darling Basin (CSIRO 2010c).

The MDBA continues to work in collaboration with Basin states and industry partners to increase the understanding of groundwater recharge processes in the Basin and estimation techniques. The MDBA will examine the information used in setting limits and incorporate new information where available, as part of the Basin Plan review in 2026. Regular 10 yearly reviews of the Basin Plan are required, which allow for emerging climate change patterns, new information, tools and techniques to be considered. These reviews could result in changing water limits or other water management arrangements.

Modelled SDL resource units

In developing SDLs, the MDBA found there were 11 numerical groundwater models available that cover 13 SDL resource units (Figure 3). The numerical groundwater models are predominately alluvial groundwater systems with high levels of take in NSW, Victoria and Queensland. These models were developed or modified for the CSIRO Murray–Darling Basin Sustainable Yields Project (CSIRO, 2008). All NSW numerical models were originally developed and calibrated by the New South Wales Department of Planning, Industry and Environment – Water (or its predecessors).

The models cover all or parts of the following groundwater SDL resource units:

- Upper Condamine Alluvium (Qld);
- Lower Gwydir Alluvium (NSW);
- Lower Namoi Alluvium (NSW);
- Upper Namoi Alluvium (NSW;
- Lower Macquarie Alluvium (NSW);
- Upper Macquarie Alluvium (NSW);
- Lower Lachlan Alluvium (NSW);
- Upper Lachlan Alluvium (NSW);
- Lower Murray Shallow Alluvium (NSW);
- Lower Murray Deep Alluvium (NSW);
- Lower Murrumbidgee Alluvium (NSW);

- Mid-Murrumbidgee Alluvium (NSW); and
- Goulburn-Murray Sedimentary Plain (Vic).

The models represent groundwater systems that covered 73% of the groundwater extracted in the Murray–Darling Basin in 2007-08. The MDBA used the above modelling results as an input to determine the SDLs. Other evidence was also considered, including groundwater hydrographs and extraction information.

The results from the South Australian numerical model for the Angas–Bremer were used to confirm the SDL for Angas-Bremer SDL resource unit.

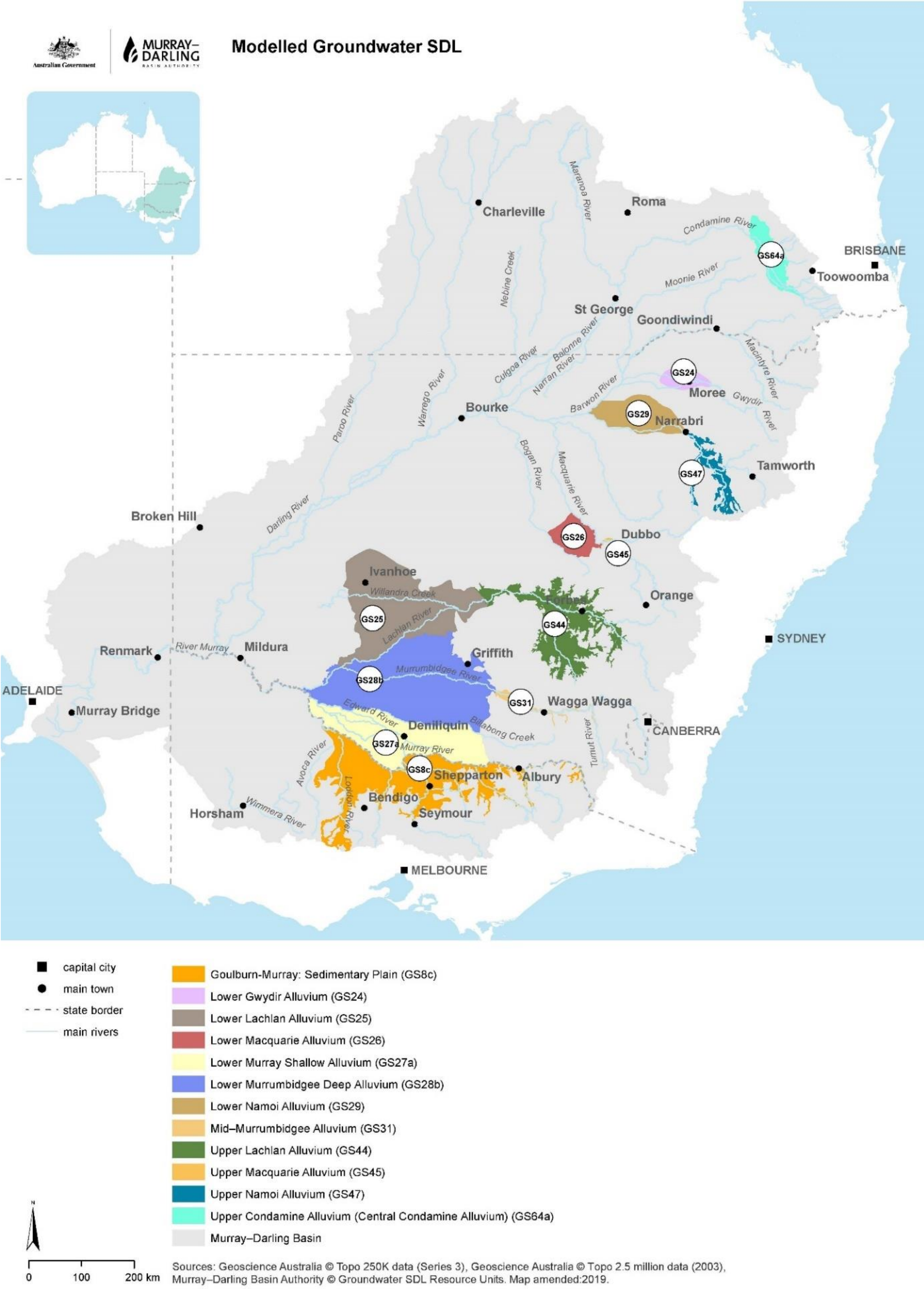


Figure 3: Modelled groundwater SDL

Recharge risk assessment method

The recharge risk assessment method (RRAM) is a risk assessment process used to determine the PEL for SDL resource units without a numerical groundwater model. The method was developed by the MDBA, CSIRO and Sinclair Knight Merz (SKM) specifically for the Basin Plan (CSIRO and SKM, 2011).

The method establishes a sustainability factor (SF) by assessing the level of risk that groundwater take poses to the ESLT characteristics of the groundwater system. The PEL is then determined by applying the SF to the volume of rainfall recharge received by the SDL resource unit. The PEL can therefore be expressed as a fraction of the recharge that can be taken, with all the groundwater in storage reserved for the environment.

The RRAM is described in four steps, as follows:

> **Step 1:** Rainfall recharge across the Basin was determined using the WAVES model. Upscaling techniques developed for the Murray–Darling Basin Sustainable Yields project, subsequently refined for the Basin Plan, were also used (CSIRO and SKM, 2010a, 2010c). Additional recharge information was also used where it was made available by Basin states.

Basin wide recharge modelling explored several historic and future climate scenarios. Of these scenarios, the median historic climate recharge scenario was used for all SDL resource units. Prior to the draft Basin Plan in November 2011, the historic dry climate recharge scenario was used for all SDL resource units where the PEL was greater than the BDL. For the draft Basin Plan the median historic climate recharge scenario was used. The decision to use the median historic climate recharge scenario was made in response to recommendations from a peer review of the methodology conducted during the development of the Basin Plan.

To inform the review of the Basin Plan in 2026, the MDBA will work collaboratively with Basin states and industry partners to collect new and updated scientific data and information on groundwater recharge across the Basin. To further improve the RRAM assessment and the risks to the ELST characteristics, the MDBA also aims to improve its knowledge of salinity, water levels and surface-groundwater connectivity.

Risks to the four ESLT characteristics

The next three steps determined the SF using a risk matrix that assessed:

- risks to the four ESLT characteristics; and
- the level of uncertainty within an SDL resource unit.

> **Step 2:** Criteria were developed to assess the level of risk that groundwater extraction represents to compromise one of the ESLT characteristics. A higher risk resulted in a lower SF, with the following risk rankings used:

- High risk – 10% of recharge;
- Medium risk – 50% of recharge; or
- Low risk – 70% of recharge.

Step 3: The risk of groundwater extraction compromising groundwater quality was assessed separately. Where there is a risk of groundwater extraction compromising groundwater quality, the SF was further reduced. Each SDL resource unit was separated into four salinity classes:

Table 2: RRAM salinity classes

Salinity Class	Salinity (mg/L)
Class 1	0 – 1,500
Class 2	1,500 – 3,000
Class 3	3,000 – 14,000
Class 4	14,000+

Where groundwater extraction created a risk of compromising salinity Class 1 or 2 groundwater, the following factors were applied to the SF determined in Step 2:

- Class 1 – 80% of the available recharge volume (from Step 1);
- Class 2 – 90% of the available recharge volume (from Step 1); or
- Class 3 and 4 – 100% of the available recharge volume (from Step 1).

The level of uncertainty within an SDL resource unit

Step 4: The level of uncertainty reflects the quantity and quality of information and data that was used in the assessment. It also reflects the level of understanding of groundwater processes in an SDL resource unit. Where there is high uncertainty regarding the groundwater system, the SF was further reduced. The reduction was determined by the level of risk to the ESLT characteristics determined in Step 2:

- Risk to ESLT characteristics is high or medium – SF reduced by 50%; or
- Risk to ESLT characteristic is low – SF reduced by 25%.

The resulting SF from the above steps was then applied to the available recharge volume calculated in Step 1, to determine the PEL.

Figure 4 shows an example of a graphical representation of the four steps in the RRAM process used to determine the PEL (potential volume that can be taken), prior to other assessments used to inform SDLs.

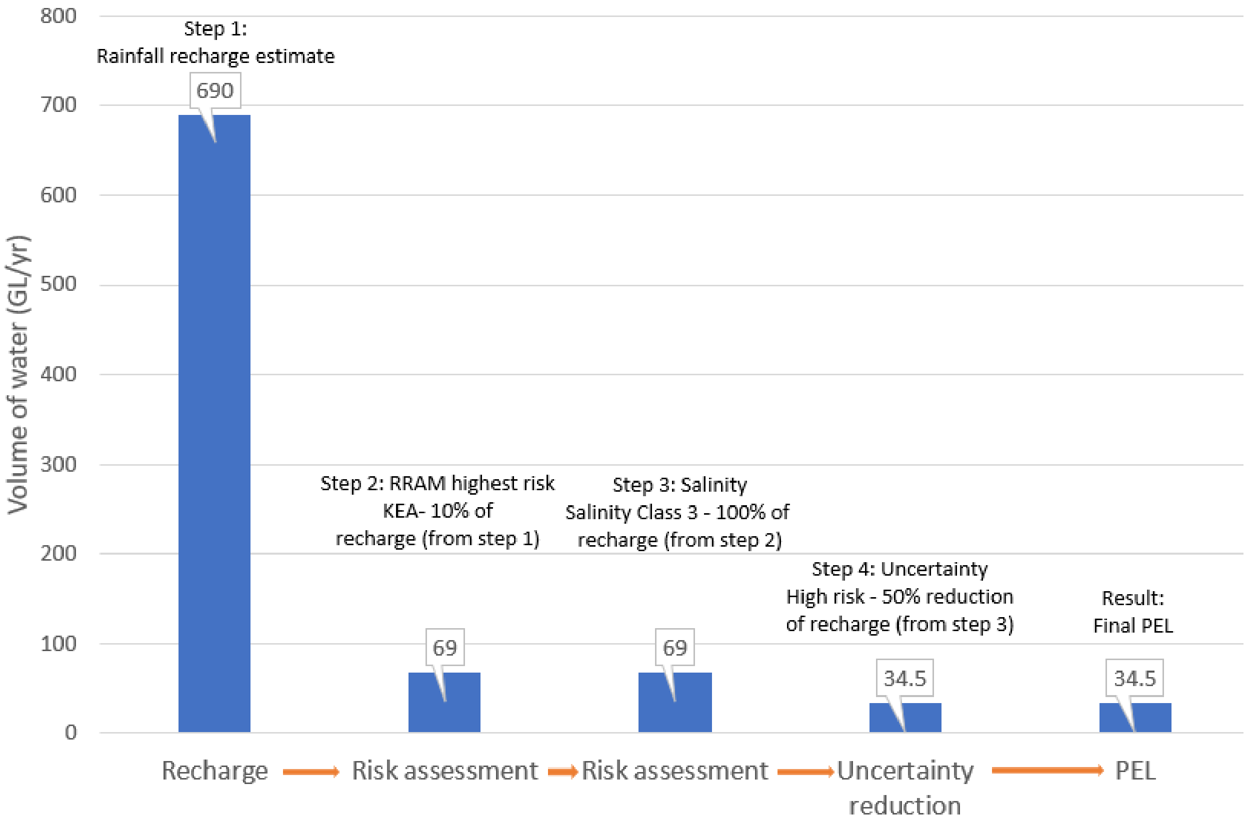


Figure 4: Example of the RRAM process showing the reduction in groundwater volume (GL/y) after each assessment step to determine the PEL

Groundwater assessment framework

The MDBA developed a groundwater assessment framework, building on PEL values, to determine groundwater SDLs that reflect the ESLT. This framework was developed and refined during the development of the Basin Plan.

Applying the assessment framework

In applying the groundwater assessment framework, a two-stage approach was taken. The first stage considered characteristics (geology, recharge, ESLT characteristics etc.) of the individual groundwater resource units. Each groundwater SDL resource unit was characterised as either:

- Deep groundwater;
- Non-renewable groundwater;
- Connected to surface water resources; or
- Not connected to surface water resources.

The second stage assessed the BDL in relation to the PEL and the groundwater management arrangements in place to determine the SDLs in the connected and non-connected resource units.

The assessment then considered if:

- there was an existing reduction program in place (e.g. Achieving Sustainable Groundwater Entitlements program);
- the BDL was greater than the PEL and whether there was a need for an entitlement reduction program;
- better science or knowledge of the resource existed; or existing or proposed water management arrangements were in place and how they related to the BDL and PEL. If there was, the SDL was set to the BDL; or
- the BDL was less than the PEL and if the resource unit was:
    - connected to surface water resources; and whether
    - the SDL was equal to the BDL; or
    - the SDL was greater than the BDL (unassigned groundwater); or
    - there was no connection to surface water resources (unassigned groundwater).

Figure 5 outlines the process of assessment used to determine which assessment was applied to the PEL for each SDL resource unit. The 2020 Report Cards provide summaries of the assessment that has been applied to individual groundwater SDL resource units.

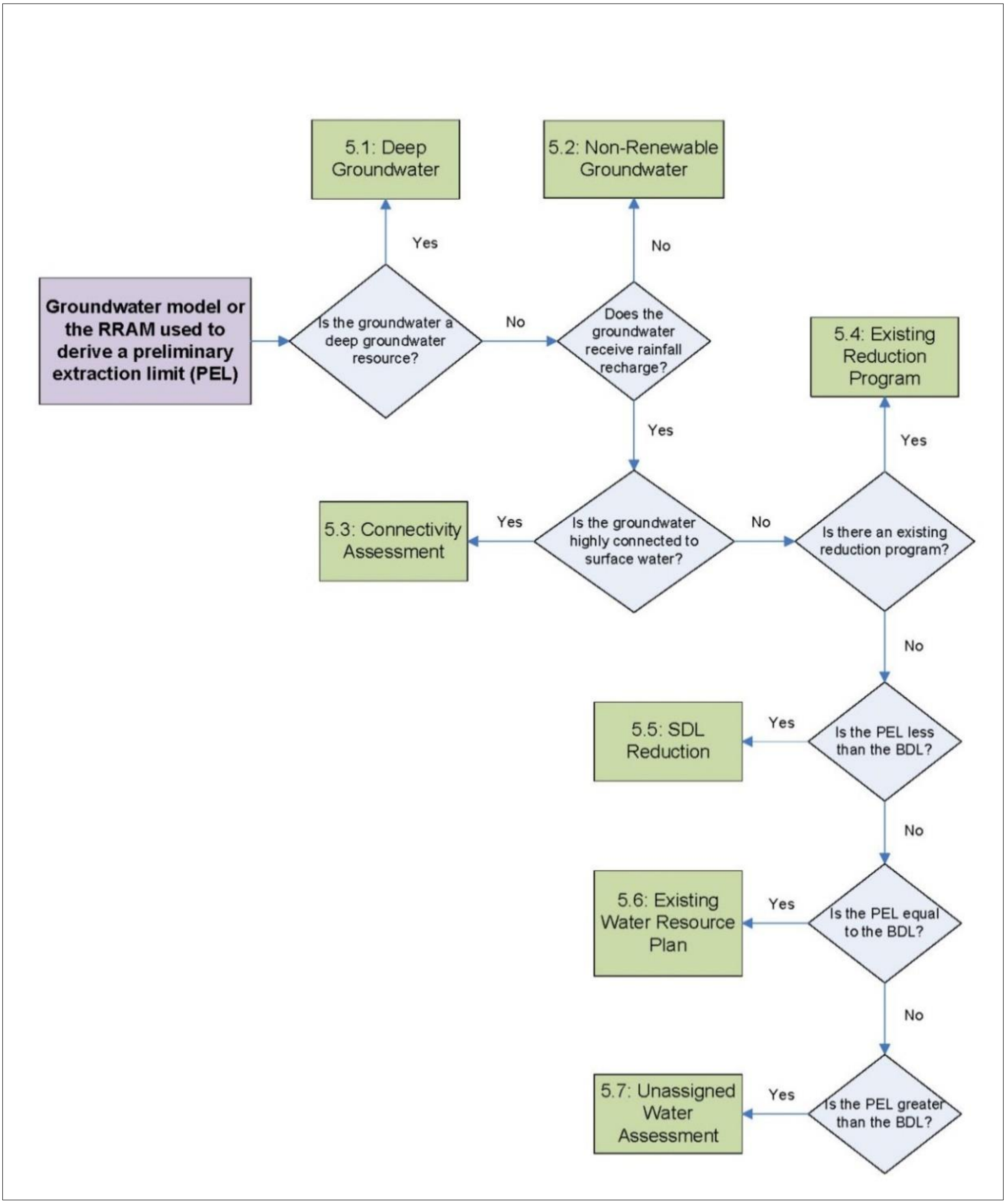


Figure 5: Groundwater assessment framework decision tree

SDL resource unit categories

The application of the framework resulted in seven categories in which the groundwater SDL resource units can be assigned. The categories are outlined in the following sections of this report:

- Deep groundwater;
- Non-renewable groundwater;
- Connected resources;
- Achieving Sustainable Groundwater Entitlements program (now ceased);
- SDL resource units with reduction;
- Existing planning arrangements and up to date science; and
- Unassigned groundwater.

Deep groundwater resources

Deep groundwater resources are described as the groundwater resources below those currently accessed for productive use and stock and domestic (S&D) needs. Deep groundwater resources are not usually accessed for agricultural purposes due to the costs associated with bore construction or poor water quality.

Interest in groundwater extraction has extended to several deep groundwater resources that are considered Murray–Darling Basin water resources under the *Water Act 2007 (Cwlth)*. The incorporation of deep groundwater in the Basin Plan was an outcome of the MDBA's improved knowledge regarding these systems. Each Basin state was consulted during the development of the deep groundwater assessment.

Deep groundwater SDL resource units are attributed to either the WRP area where the deep groundwater resource outcrops or, if the deep groundwater is fully sub-cropped, the WRP area that the majority of the deep groundwater resource underlies (i.e. Oaklands Basin SDL resource unit). Note that the outcrop areas of deep groundwater resources are considered part of the deep groundwater resource unit and not the overlying resource. The SDL volumes are based on the available knowledge of these deep aquifers. It is possible that new knowledge may inform a change to these SDLs as part of future reviews of the Basin Plan. There are seven deep SDL groundwater resource units in the Basin Plan (Figure 6), described below. The total of deep groundwater SDLs are 291.1 GL/y, which represents about 8.3% of the total of groundwater SDLs (3,494 GL/y).

Australian Capital Territory

There are no deep groundwater SDL resource units in the Australian Capital Territory pursuant to the Basin Plan.

New South Wales

In NSW, there are three deep groundwater SDL resource units: Gunnedah-Oxley Basin MDB (GS17), Sydney Basin MDB (GS41) and Oaklands Basin (GS38) (Figure 6).

The Gunnedah-Oxley Basin MDB SDL resource unit is in northern NSW and has been defined in the Basin Plan as all rocks of Permian, Triassic, Jurassic, Cretaceous or Tertiary age; and all alluvial sediments within the outcropped areas. The SDL for the Gunnedah-Oxley Basin SDL resource unit is 127.5 GL/y. This SDL resource unit is part of the NSW Murray–Darling Basin Porous Rock WRP area.

The Sydney Basin MDB SDL resource unit lies in the eastern part of the NSW MDB. Basin Plan defines it as all rocks of Permian, Triassic, Jurassic, Cretaceous or Tertiary age; and all alluvial sediments within the outcropped areas. The Sydney Basin MDB SDL resource unit has an SDL of 19.1 GL/y. It is part of the NSW Murray–Darling Basin Porous Rock WRP area.

The Oaklands Basin SDL resource unit lies in southern NSW and has been defined as the water resources within the Oaklands geological Basin. Oaklands Basin receives negligible volumes of recharge and could be classified as a non-renewable groundwater resource. It is buried underneath other SDL resource units and the MDBA has classified it as a deep resource. The SDL for the resource is 2.5 GL/y, which represents 0.0006% of the storage. Oaklands Basin is included in the NSW Murray–Darling Basin Porous Rock WRP area.

Queensland

There are four deep geological basins within the Queensland MDB. These are the Bowen, Galilee, Adavale and Drummond Basins. These basins contain groundwater resources in excess of 2,000 m depth that lie within the MDB boundary and beneath the GAB.

MDBA assigned a single SDL resource unit, Queensland MDB deep (GS56), with an SDL of 100 GL/y, for all groundwater resources below the GAB in Queensland. Given the geographic extent of the area, the volume was set to allow for future development. It may be reviewed should more information about water resources in these geological basins become available.

South Australia

South Australia has one deep groundwater resource called the Renmark Group. The MDBA established a separate deep groundwater SDL resource unit for the Renmark Group in the Mallee grouping of SDL resource units (GS3). The Mallee (Renmark Group) (GS3c) SDL resource unit has an SDL of 2 GL/y, as determined by the deep groundwater assessment process. South Australia manages this SDL resource unit under the SA Murray Region WRP. The decision to assign the Renmark group to the Mallee SDL resource unit is consistent with the requirement of the *Water Act 2007 (Cwlth)*, to align boundaries as much as practical with existing water management boundaries.

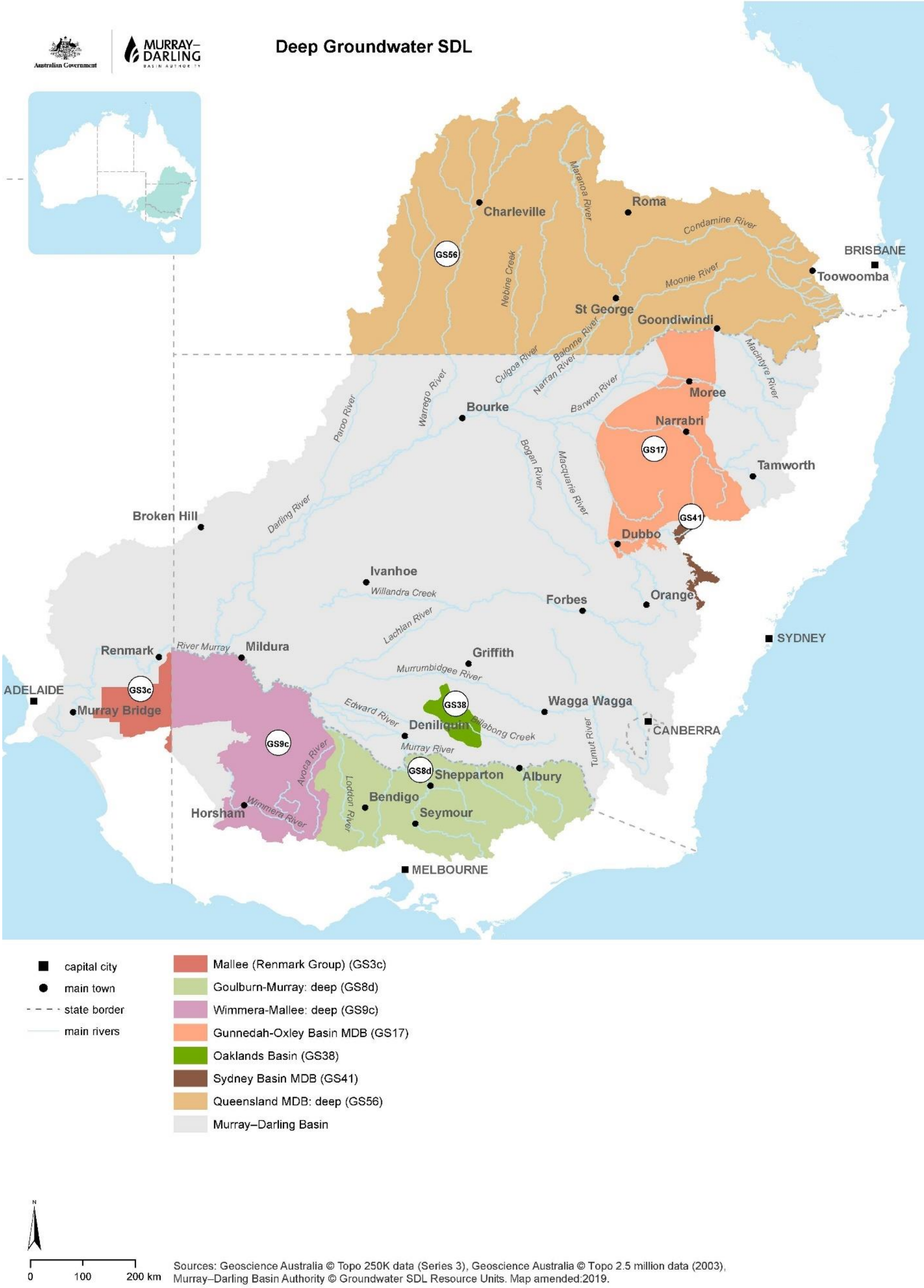


Figure 6: Deep groundwater SDL resource units

Victoria

There are two deep groundwater SDLs in Victoria the Murray–Goulburn: deep (GS8d) and Wimmera-Mallee: deep (GS9c) SDL resource units. There is little information available regarding the groundwater resources of these two deep resource units. Each SDL was set to 20 GL/y. This volume will enable any potential water users to extract groundwater while further collecting information to refine the deep groundwater SDLs.

Non-renewable groundwater

A non-renewable groundwater resource is a semi-confined or confined aquifer receiving negligible recharge. Groundwater contained in these units was recharged during different climatic periods and is several thousand or more years old. Non-renewable groundwater resources can have very large storages which, to a certain point, can be extracted with minimal environmental consequences.

Within the Basin, there are two groundwater SDL resource units that have been categorised as non-renewable resources: the Mallee (Murray Group Limestone) (GS3b) SDL resource unit in South Australia and the Wimmera-Mallee: Sedimentary Plain (GS9b) SDL resource unit in Victoria (Figure 7: Non-renewable groundwater SDL resource units). These SDL resource units straddle the South Australian and Victorian Border and the water is extracted from the Murray Group Limestone Aquifer. The SDL for the Mallee (Murray Group Limestone) (GS3b) SDL resource unit is 63.6 GL/y. The SDL for the Wimmera-Mallee: Sedimentary Plain (GS9b) SDL resource unit is 190.1 GL/y. This SDL also includes a sub-area with unassigned water.

The extraction of groundwater along the border is regulated by a cross-border agreement pursuant to both South Australian and Victorian legislation (the *Groundwater (Border Agreement) Act 1986* (SA and Vic.)). This agreement allows for groundwater in the designated area, a 40 km-wide strip centred on the South Australian–Victorian border, to be depleted by approximately 15% in 200 years.

In setting the SDLs for the non-renewable resource units, the MDBA adopted the limits set by the South Australian and Victorian cross-border agreement. The SDLs for non-renewable groundwater resources reflect the maximum permitted rate of groundwater decline under the state acts for the Border Groundwaters Agreement area. The principles used in the Border Groundwaters Agreement area were applied to the surrounding Mallee groundwater, which is also considered a non-renewable water. Additionally, the groundwater resources of the Victorian West Wimmera Groundwater Management Area are excluded by regulation from this WRP area due to limited hydrologically connectivity to the rest of the Murray–Darling Basin. Approximately half of the West Wimmera GMA is outside the Basin, so exclusion of this GMA fits with Victoria's reporting requirements and allows for all of the West Wimmera to be managed and reported as one resource. Notwithstanding this, the Section 10.05 of the Basin Plan requires Victoria to identify in relevant water resource plans, the effect of the use of this resource on Basin water resources (and if required, undertake management actions).

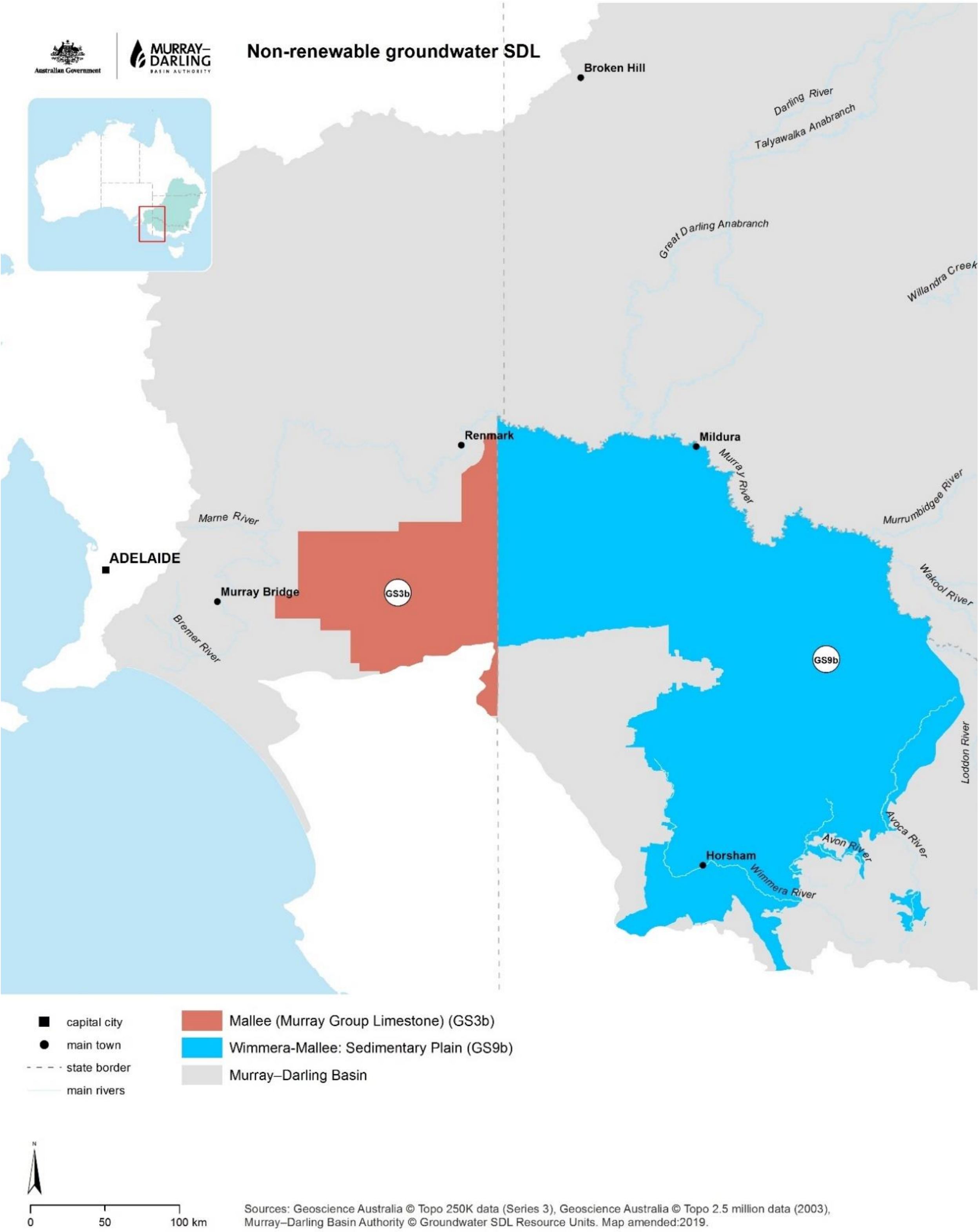
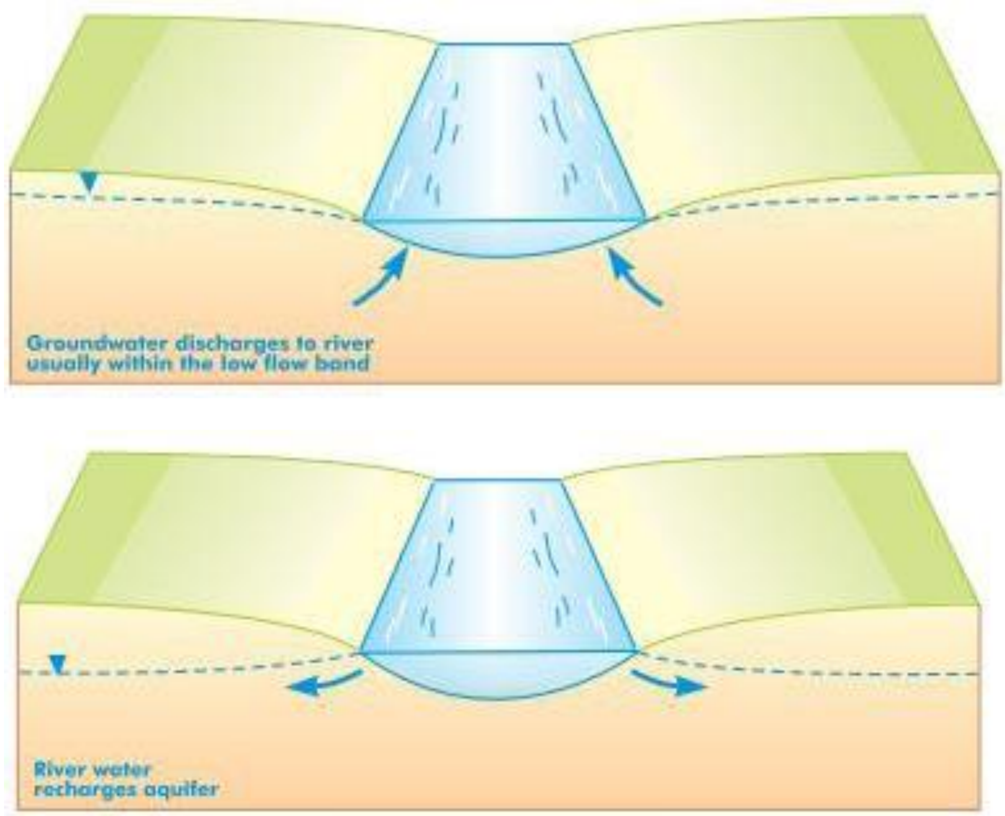


Figure 7: Non-renewable groundwater SDL resource units

Connected Systems

Surface and groundwater systems are not separate resources; they are components of one hydrologic system. Where the connection between surface and groundwater is strong, groundwater extraction may directly affect surface-water stream flow. The effects can include inducing leakage to groundwater, or intercepting groundwater-derived base flow over both short and long timeframes. Conversely, excessive surface water extraction may reduce recharge to groundwater systems. Connected systems are described as those where there is a zone of continuous saturation between the river and the aquifer. Connectivity between streams and groundwater can vary along stream reaches i.e. in a given section of a stream, there can be gaining and losing sections. Changes can also occur over time as changes in groundwater levels can change streams from gaining streams to losing. Traditionally, classifications of connectivity focussed on classifying streams according to the direction of flux between surface and groundwater, particularly whether the rate of flux is influenced by groundwater abstraction. Classification systems have typically defined up to four different stream types on this basis; classified as connected or disconnected and gaining or losing.

The MDBA used the following classification system to describe connectivity for the purposes of the Basin Plan (Figure 8):



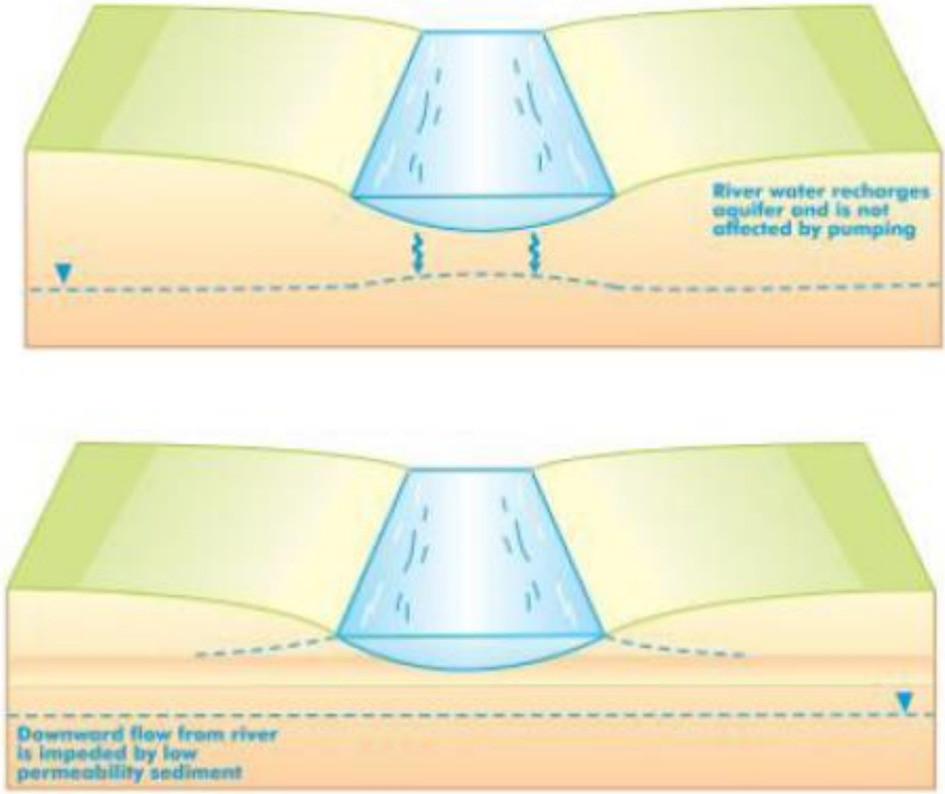


Figure 8: Classifications of connected groundwater and surface water (sourced from Parsons Brinckerhoff, 2009)

The connectivity between groundwater and surface water varies across the Basin. Connected systems can be further classified based on geomorphology and similarities in the connectivity between surface and groundwater in the following way (Figure 9):

- fractured rock systems (e.g. Lachlan Fold Belt) – variable connectivity due to the nature of the geology of these systems;
- shallow alluvial aquifers (e.g. Belubula Alluvium) – typically highly connected system with the stream both losing and gaining water from the groundwater;
- mid-valley alluvial aquifer systems (e.g. Mid-Murrumbidgee Alluvium) – generally losing streams;
- floodplain alluvial aquifer systems (e.g. Lower Namoi Alluvium) – streams are mostly disconnected from the aquifer and lose water to the groundwater at a maximum rate; and
- end of system aquifers (e.g. SA Murray) – typically a mixture of gaining, losing and disconnected streams but discharge is usually saline.

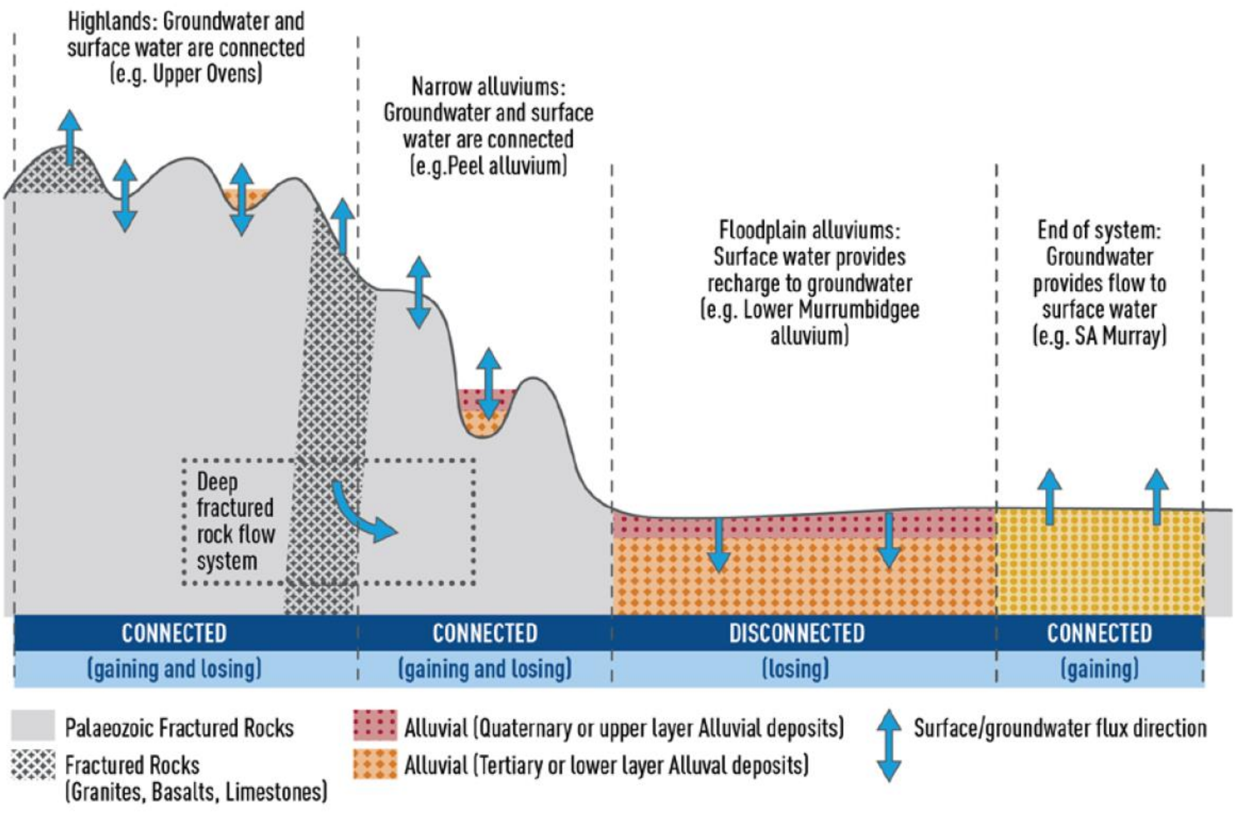


Figure 9: Connected systems classification (adopted from Braaten and Gates, 2003) showing the connectivity between surface and groundwater considering geology and topography

The connectivity between groundwater and surface water resources was considered for every SDL resource unit, through the methods to develop the PEL. The MDBA considered an SDL resource unit to be highly connected, if during the RRAM process, the risk of groundwater extraction to impacts on the surface water streams was determined to be high or medium. The criteria used to assess the risk to surface water streams were:

- high – In the current state, groundwater discharge provides base flow to the unregulated river reach. Groundwater extraction is likely to result in stream flow depletion;
- medium – rivers in the SDL resource unit are regulated and highly connected to the groundwater system (i.e. >50% of the groundwater pumped would have contributed to stream flow within 50 years); or
- low – rivers in the SDL resource unit are regulated or unregulated and they have low-moderate connection with the groundwater system (i.e. <50% impact of pumping on stream flow within 50 years).

Using the risk classification in relation to the connectivity assessment, the MDBA set SDLs for the Basin Plan, in systems with:

- high or medium levels of risk to surface water resources, where the SDL was set at the BDL. This ensures that, in these systems, groundwater extraction will have no further impact on surface water resources beyond the level accounted for within the BDL; and
- low levels of risk to surface water systems, where a different assessment is used compared to high and medium risk assessments.

Additional decisions were made considering connectivity and associated risks to surface water resources, in relation to floodplain alluvial aquifer systems, groundwater extraction for salinity management and fractured rock systems, as follows:

Floodplain alluvial aquifer systems were informed by numerical groundwater models. The models accounted for connectivity between surface and groundwater.

Take from saline groundwater systems is beneficial for connected surface water resources as it reduces salt entering rivers and streams. The MDBA determined that groundwater extraction from these systems is low risk to the groundwater system and beneficial to the connected surface water resource. The MDBA set the SDL for these resource units on the maximum volume of existing entitlements and incorporated a future growth allowance.

Additional groundwater was made available above the BDL in seven fractured rock systems, due to the large size of the systems and variability of connectivity (unassigned groundwater). Additional protection of surface water resources in fractured rock systems will be provided through inclusion of local management rules in the state developed water resource plans.

There are 20 groundwater SDL resource units classified as highly connected (Figure 10). The total of the SDLs is 365.3 GL/y, which represents 10.5% of the total of groundwater SDLs.

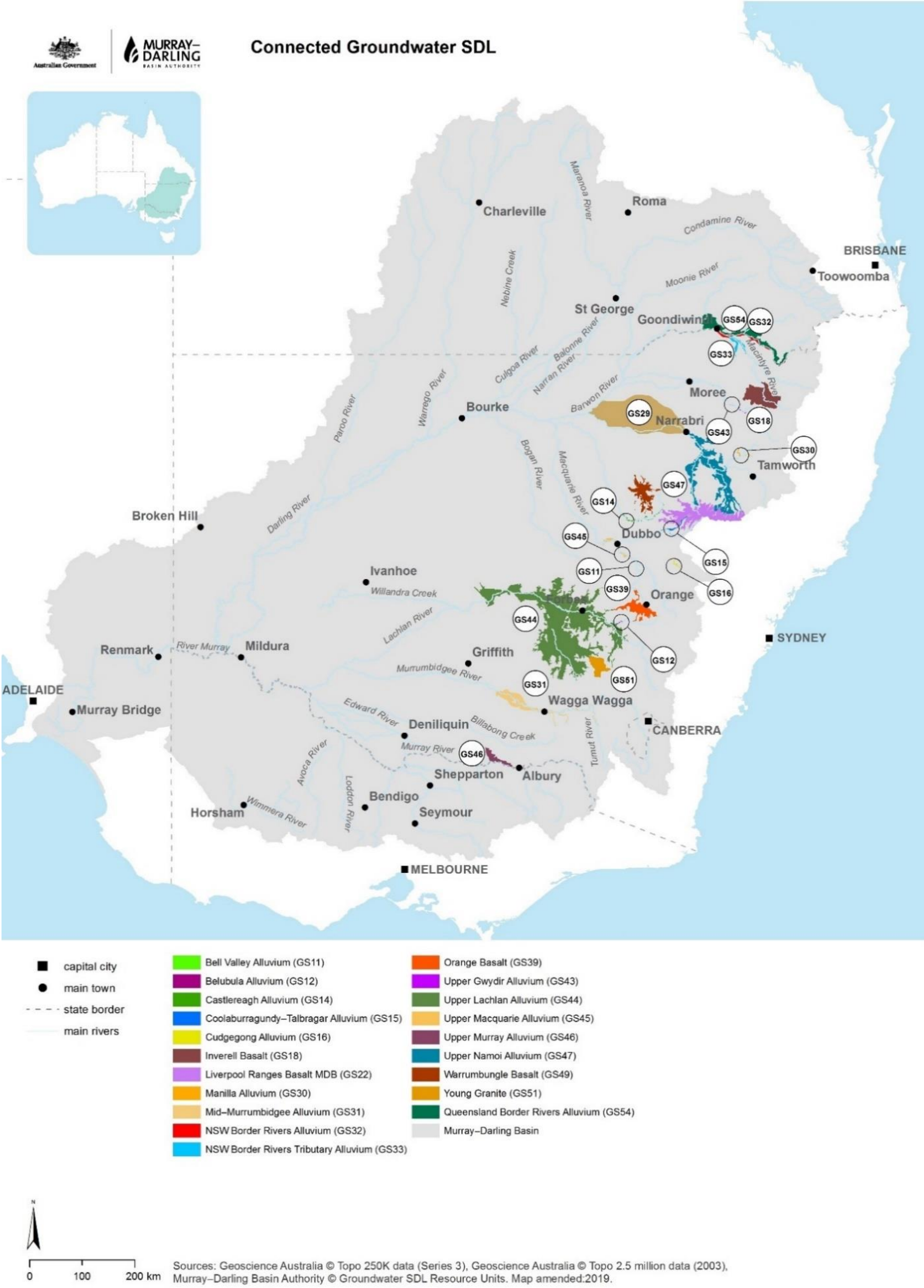


Figure 10: Connected groundwater SDL resource units

In determining groundwater SDLs for connected systems, the MDBA assessed potential volumetric impacts on surface water associated with increases above the groundwater BDL (BDL to SDL).

Based on volumes of unassigned water, the location and extent of potential increases in groundwater commitments are mainly in the northern and western areas of the Basin. Further, the Basin Plan does not allow for increased extraction in the large alluvial systems.

The MDBA assessment (MDBA, 2012b) categorised unassigned groundwater SDL resource units based on potential impacts of increased groundwater extraction into three broad systems based on their hydrogeological characteristics:

- Lachlan Fold Belt: a fractured rock system that lies under several surface water catchments and shallow alluvial aquifers, spanning the width of the Basin from Albury to Bourke;
- Highland aquifer systems: fractured and porous rock systems with overlying small shallow alluvial aquifers, located in the eastern and southern elevated parts of the Basin; and
- Western aquifer systems: fractured or porous rock systems stretching from the southwest to the north of the Basin, with relatively flat terrain and mostly saline resources that can be difficult to access.

For each of the broad systems the MDBA used the assumptions regarding connectivity from the Murray–Darling Basin Sustainable Yields project (CSIRO, 2008) and applied those assumptions to SDL increases in the Basin Plan. The MDBA calculated a potential reduction of between 29 and 58 GL/y in surface water resources from additional groundwater extraction in the Lachlan Fold Belt and Highland systems (MDBA, 2012c). It is essential to note the time span of potential impacts can vary from a few years to hundreds of years, and in some cases may never be realised. Therefore, the MDBA finds this to be an acceptable risk.

For the western aquifer systems, the MDBA determined minimal or no connectivity. In areas where there was groundwater flowing to the river systems, it was saline and any extraction could potentially reduce the flux of salt into the river. Considering these factors coupled with a lack of information, the MDBA did not calculate a potential reduction in surface water resources from additional groundwater extraction in the western aquifers systems.

Of the remaining SDL resource units, there are three where groundwater is managed to control salinity, water logging and the flow of saline groundwater to surface water resources:

- Lower Murray Shallow Alluvium (GS27a);
- Lower Murrumbidgee Shallow Alluvium (GS28a); and
- Goulburn-Murray: Shepparton Irrigation Region (GS8).

In these units a reduction in saline groundwater flow to surface water resources is considered to be beneficial. The BDL was set at the entitlement levels (625.6 GL/y) to ensure maximum flexibility to manage salinity and water logging. The total difference between the BDL and estimated take in the three areas is 212.7 GL/y. This represents a considerable portion (34%) of the total potential for increased groundwater take within the Basin wide BDL. In setting the BDLs for these systems, the MDBA did not include potential impacts on surface water from any increases in groundwater take.

The MDBA implemented this approach to setting BDLs with the view to most accurately reflect limits of groundwater take in groundwater planning at the time of the making of the Basin Plan. While there remains a potential impact on surface water from groundwater use within the BDL, the MDBA views that potential impact as pre-existing risk. That risk has been incorporated into surface water and groundwater planning under the Basin Plan.

Achieving Sustainable Groundwater Entitlements program (now ceased)

The Achieving Sustainable Groundwater Entitlements program (ASGE) was introduced in 2005. The program was funded by the NSW government and the Australian Government under the National Water Initiative (NWI). ASGE was introduced to achieve the sustainable use of groundwater resources in seven alluvial groundwater systems in NSW (later designated as SDL resource units in the Basin Plan) (Figure 11):

- Lower Gwydir;
- Lower Lachlan;
- Lower Macquarie;
- Lower Murray;
- Lower Murrumbidgee;
- Upper Namoi; and
- Lower Namoi.

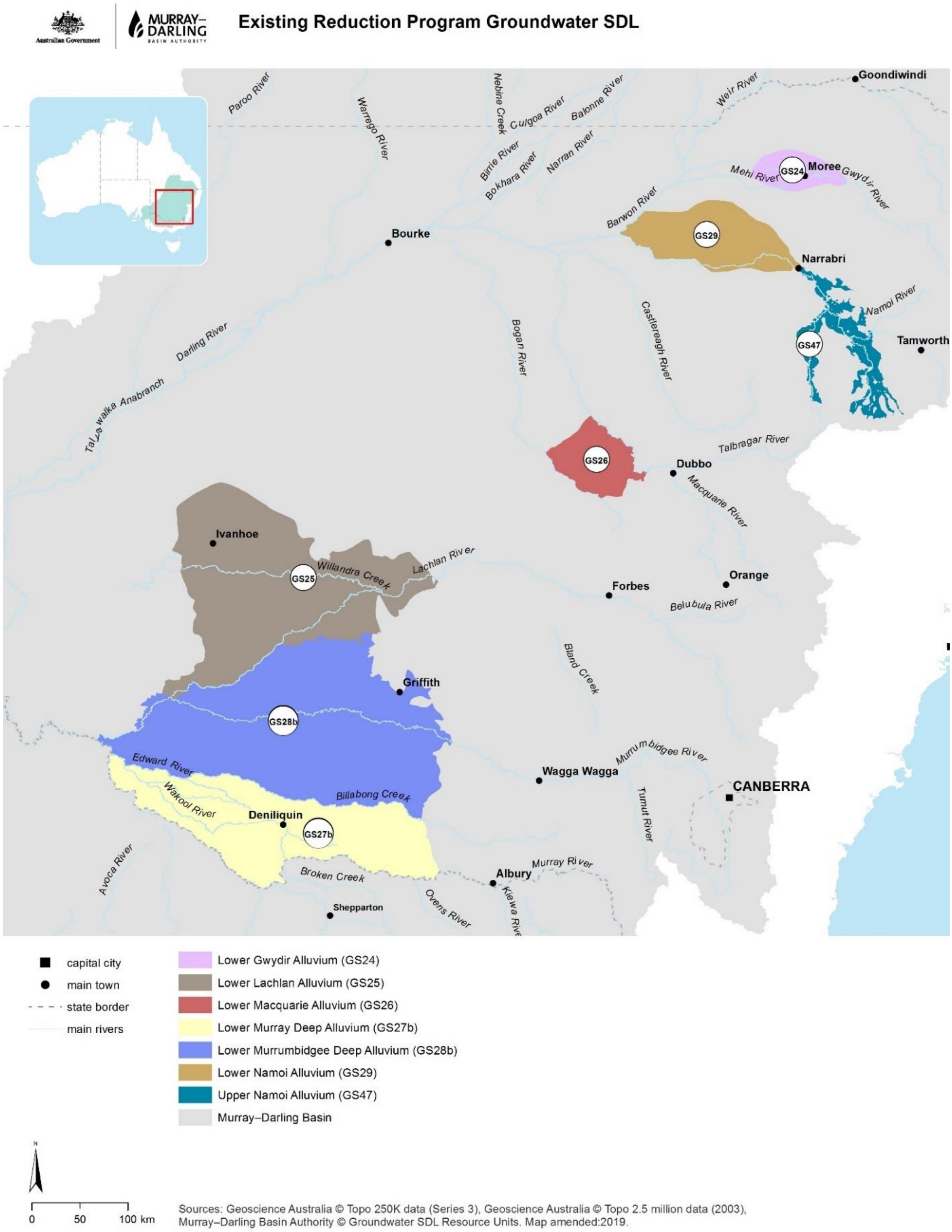


Figure 11: Existing reduction program groundwater SDL resource units. Note that reduction programs are now finalised; at the time of publication, the term “existing reduction program” is used as an historical category name

These systems were identified as over-allocated and most of them were also over-used. Reductions in entitlement were required to achieve sustainable levels of take. The program was put in place through the development and introduction of water sharing plans in the seven areas. Table 3 details the ASGE reductions in entitlements, which ranged from 46% to 69% across the various SDL resource units. The total of groundwater SDLs for these seven SDL resource units, after reductions and Basin Plan amendments, was 771.4 GL/y.

Table 3: Effect of the ASGE program on groundwater entitlements

Groundwater SDL resource unit	Initial Entitlement (GL)	Reduction Volume (GL)	Entitlements (excluding S&D) at completion of ASGE (GL)	Reduction (%)	Completion date
GS24 Lower Gwydir Alluvium	70.7	38.4	32.3	54.3%	30 Jun 17
GS25 Lower Lachlan Alluvium	212.3	104.3	108.0	49.1%	30 Jun 18
GS26 Lower Macquarie Alluvium	136.8	67.5	69.3	49.3%	30 Jun 17
GS27b Lower Murray Deep Alluvium	267.6	183.9	83.7	68.7%	30 Jun 17
GS28b Lower Murrumbidgee Deep Alluvium	514.6	244.6	270.0	47.5%	30 Jun 17
GS29 Lower Namoi Alluvium	172.2	86.2	86.0	50.1%	30 Jun 17
GS47 Upper Namoi Alluvium	301.9	179.8	122.1	59.6%	30 Jun 17
Total	**1,676.1**	**904.9**	**771.4**		

Numerical groundwater modelling of the ASGE areas indicated that in four areas the PEL was less than the BDL. The modelling recommended *further* reductions in diversion limits in these units. However, the MDBA received feedback from Basin states and through peer review on the use of numerical modelling in the ASGE areas. The feedback questioned the need for further reductions to the SDL before the ASGE program was completed and outcomes from the program realised.

After receiving this feedback, the MDBA further considered the following:

- risks to ESLT characteristics for the resources;
- peer review of the numerical models; and
- assessment of additional information supplied by both the NSW government and water users.

The MDBA also considered additional uncertainties associated with modelling in those groundwater systems and the associated changes in groundwater take. Additionally, these resource units had large groundwater storages estimated to be available for a minimum of 200 years at current levels of take. There was a low risk of depleting the volume of groundwater stored in these aquifers from implementing the Basin Plan in 2012 and its review in 2026.

Considering these factors, the MDBA adopted an approach that allowed the reduction program to reach completion and the outcomes be determined before considering any changes to the SDL. For the seven NSW SDL resource units in the ASGE program, the SDLs were set at the final water sharing plan limit. The MDBA will continue to monitor and assess the impacts of groundwater take in these systems with the aim of reviewing the plan limits on an ongoing basis.

SDL resource unit with a reduction in entitlement

In most groundwater SDL resource units in the Basin Plan, SDLs were set equal to or greater than BDL. The exception is the Upper Condamine Alluvium SDL resource unit grouping (GS64), located in the headwaters of the Condamine River, and extending from Killarney in the south-east to downstream of Chinchilla in the west (Figure 12). It is an alluvial groundwater system being heavily utilised to irrigate crops.

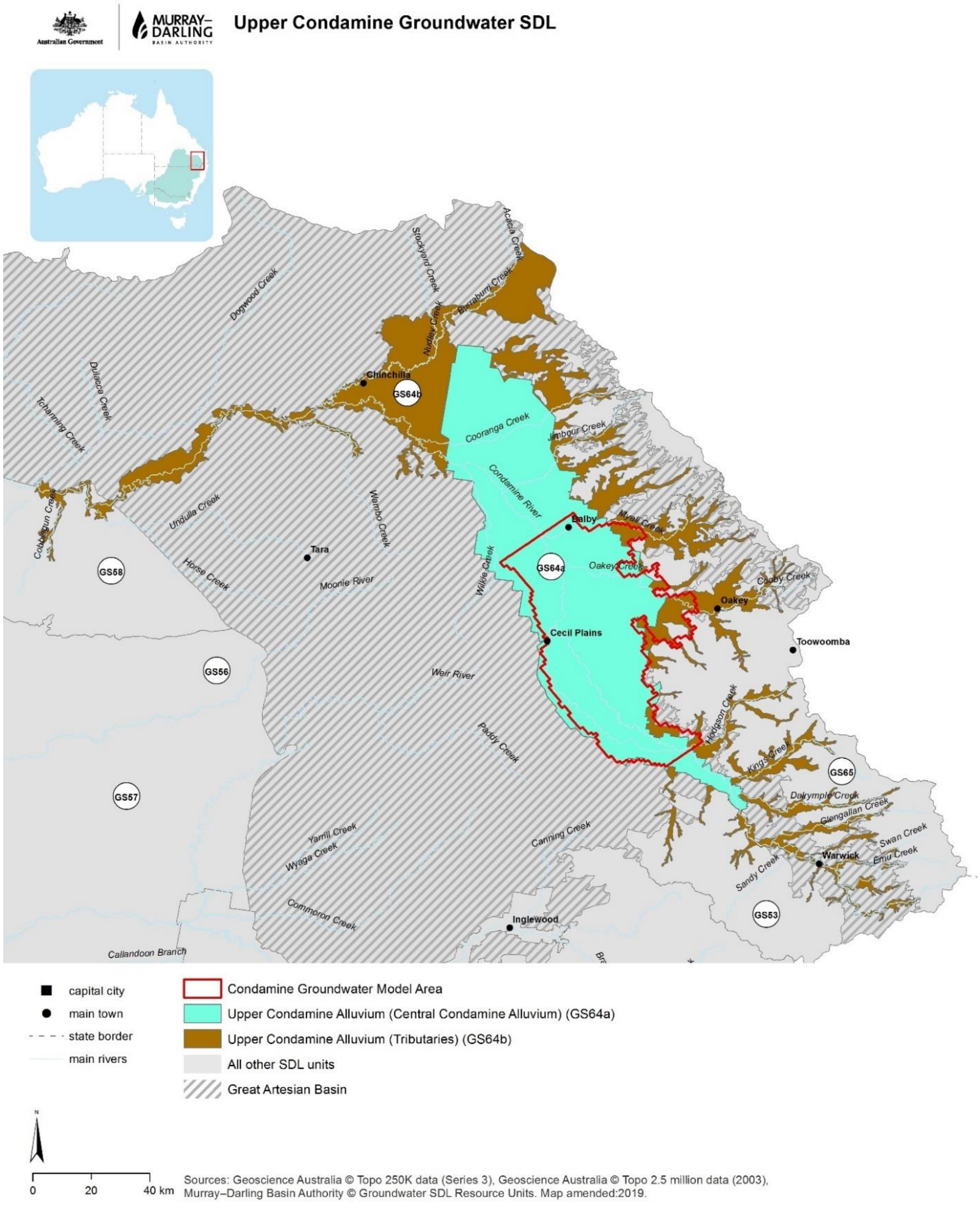


Figure 12: Upper Condamine Alluvium including the Upper Condamine Alluvium (Central Condamine Alluvium) (GS64a) and the Upper Condamine Alluvium (Tributaries) (GS64b)

Initially, the MDBA assessed the Upper Condamine Alluvium (GS64) as having a higher BDL than SDL. To determine the BDL and SDL, the MDBA divided the Upper Condamine Alluvium into two SDL resource units, the Upper Condamine Alluvium (Central Condamine Alluvium) (GS64a) (which matches Queensland's management area) and the Upper Condamine Alluvium (Tributaries) (GS64b) (the area outside the Central Condamine Alluvium) (CCA)). The Queensland Government has managed extraction in the CCA through regulation. These regulations were formalised in August 2012 through the *Water Management Plan for the Upper Condamine Alluvium Sustainable Diversion Limit Area* (August 2012).

Upper Condamine Alluvium (Central Condamine Alluvium, CCA) SDL resource unit (GS64a)

At the time of setting the SDLs, the CCA consisted of eight sub-areas. Five of the sub-areas (1, 2, 3, 4 and 5) made up the former Condamine Groundwater Management Area (CGMA), which corresponded to the model domain used to determine part of the SDL. The remaining three sub-areas (6, 7 and 8) of the CCA were not within the model domain.

The original CCA BDL of 81.4 GL/y was based on the MDBA BDL policy of using entitlement in addition to basic landholder rights, along with the effect of any rules managing extraction (Section 3). The BDL breakdown was:

- 52.6 GL/y of metered take for the five sub-areas of the former CGMA. Metered take was used in this case to estimate the limit imposed by the current arrangements; plus
- 22.8 GL/y, which is 100% of entitlement for sub-areas 6, 7 and 8; plus
- 6.0 GL/y of basic landholder rights for the whole CCA.

Note: Entitlement, rather than current take, was used for sub-areas 6, 7 and 8 because there was no metering in these zones at the time of preparing the Basin Plan. Metering was introduced into sub-areas in the 2010-11 water year.

Prior to the enactment of the Basin Plan, the Queensland Government consulted with groundwater users in the CCA and agreed upon an extraction limit of 40.0 GL/y for the entire CCA. The MDBA assessed this volume as meeting the ESLT and adopted this number as the SDL. An estimate for basic landholder rights take of 6.0 GL/y was added to make the total SDL 46.0 GL/y (Table 4). This SDL represents a reduction of 35.4 GL/y from the BDL of 81.4 GL/y.

To reduce groundwater use from the BDL to SDL in the CCA the Australian Government has purchased groundwater entitlements under its water recovery program 'Bridging the Gap'. The status of the recovery is reported on the Department of Agriculture, Water and the Environment's website.

Upper Condamine Alluvium (Tributaries) SDL resource unit (GS64b)

At the time of setting the SDLs, there was no plan or information on metering in the Upper Condamine Alluvium (Tributaries). The BDL of 45.5 GL/y was based on entitlement of 42.0 GL/y plus basic landholder rights of 3.5 GL/y (Table 4).

For the Tributaries area, the PEL of 40.5 GL/y was determined using the RRAM. The PEL represents the volume assessed to meet the ESLT requirements and has been adopted as the SDL. This volume which is 5 GL/y below the BDL was set due to the high risk of salinisation and the high level of uncertainty associated with the Tributaries area.

Table 4: Summary table of Upper Condamine Alluvium SDL resource unit

SDL resource unit	Entitlement (GL/y)	Stock and domestic (GL/y)	Basin Plan BDL (GL/y)	Basin Plan PEL (GL/y)	Basin Plan SDL (GL/y)
Upper Condamine Alluvium (Central Condamine Alluvium) (GS64a)	86.2	6.00	81.4	46.0	46.0
Upper Condamine Alluvium (Tributaries) (GS64b)	42.0	3.50	45.5	40.5	40.5
Total	**128.2**	**9.50**	**126.9**	**86.5**	**86.5**

For the Upper Condamine Alluvium as a whole (GS64a and GS64b), the BDL is 126.9 GL/y and the SDL is 86.5 GL/y, representing a reduction of 40.4 GL/y, or 32%.

To reduce groundwater use from the BDL to SDL in the Tributaries the Australian Government has purchased groundwater entitlements under its water recovery program ‘Bridging the Gap’. The status of the recovery is reported on the Department of Agriculture, Water and the Environment’s website.

Existing planning arrangements and up-to-date science

There are 16 SDL resource units or sub-units where the MDBA adopted a transitional or interim water resource plan limit as the SDL (Figure 13). Of these, there are five in NSW, seven in SA, two in Queensland and two in Victoria. The total of groundwater SDLs for the resource units and sub-units is 714.9 GL/y, which represents 20.5% of the total of groundwater SDLs.

To determine if a Basin state plan limit reflected an ESLT, the MDBA assessed the plan extraction limit against the PEL. The assessment considered whether the state extraction limit and the science underpinning it represented the most up to date scientific knowledge (i.e. a more thorough assessment than RRAM, while also being consistent with the *Water Act 2007 (Cwlth))*.

This approach acknowledges that there are areas in the Basin where the Basin states have invested considerable resources into understanding the groundwater system.

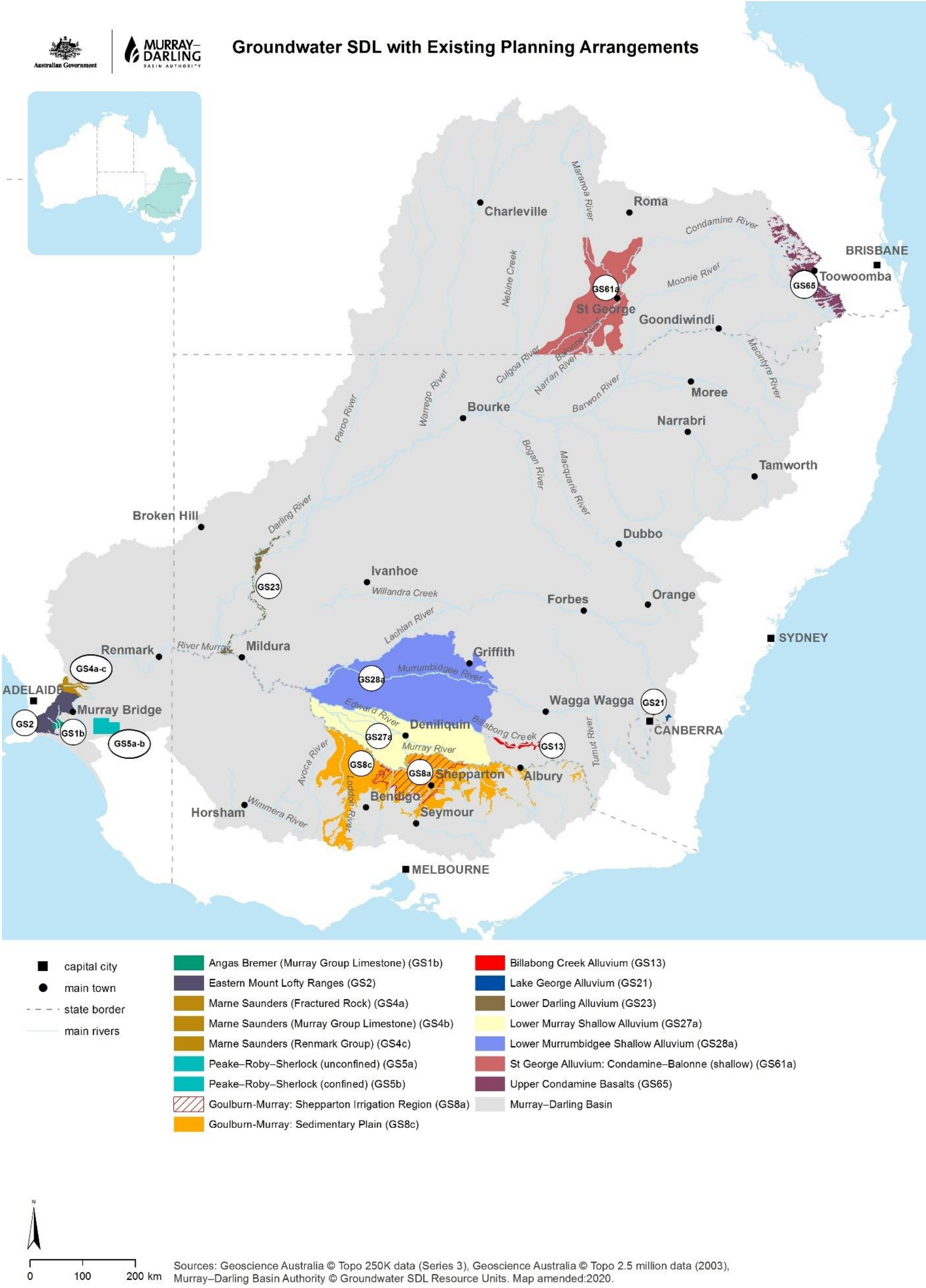


Figure 13: Groundwater SDL resource units with existing planning arrangements being adopted as the SDL

Unassigned groundwater

There are groundwater SDL resource units with low volumes of water access rights and take relative to the size of the groundwater system, resulting in a higher SDL than BDL. The total of unassigned groundwater SDLs is 1,142.6 GL/y and represents 32.7% of the overall Basin wide total of groundwater SDLs. The low use volumes in these systems are associated with difficulty accessing groundwater, either due to the system's geology and/or poor water quality. In these systems the BDL reflects the volume of water access rights, not the volume of groundwater that can be taken without compromising ESLT characteristics. The SDL in these systems is higher than the BDL. The additional volume making the SDL greater than the BDL is known as 'unassigned water'. Using the RRAM (Section 4), unassigned groundwater was identified when the preliminary extraction limit (PEL) exceeded the BDL. In unassigned water areas, groundwater may be suitable for stock and domestic use, salt interception schemes, mining and industrial activities. There are 23 SDL resource units that contain unassigned water. For many of these SDL resource units with unassigned water this is the first time an extraction limits has been implemented. Of these 23 resource units with unassigned water, there are nine in NSW, two in SA, one in Victoria, 10 in Queensland and one in the ACT (Figure 14).

Unassigned water assessment

The assessment of unassigned water is a precautionary approach to develop groundwater resources. The SDLs were determined by allowing a percentage of the water between the BDL and the PEL to be made available for consumptive use. The amount available is determined by applying an 'unassigned groundwater factor' to the total volume of unassigned water.

In the draft Basin Plan, for groundwater systems where unassigned water was identified, half or all of the amount between the BDL to the PEL was allowed (i.e. an unassigned groundwater factor of 0.5 or 1.0 was applied). For the final version of the Basin Plan in 2012, the MDBA adopted a conservative unassigned groundwater factor of 0.25 due to unknown potential impacts. An exception was made for two groundwater SDL resource units, the SA Murray Salt Interception Scheme and the NSW Adelaide Fold Belt. In both cases, the PEL was adopted as the SDL. For the SA Murray Salt Interception Scheme, this enables additional groundwater take where the take is purely for beneficial salinity control in the River Murray. In the Adelaide Fold Belt SDL resource unit, the PEL was adopted as the SDL recognising the nature of this system.

The precautionary approach adopted for unassigned groundwater will allow development to occur in areas with unassigned groundwater without negatively impacting on surface water resources or allowing the over-extraction of groundwater resources. As better knowledge becomes available, particularly in resource units where data is currently poor, the MDBA will reassess and may revise the SDLs. This is a key consideration in those resource units with high uncertainty and limited amounts of data and information.

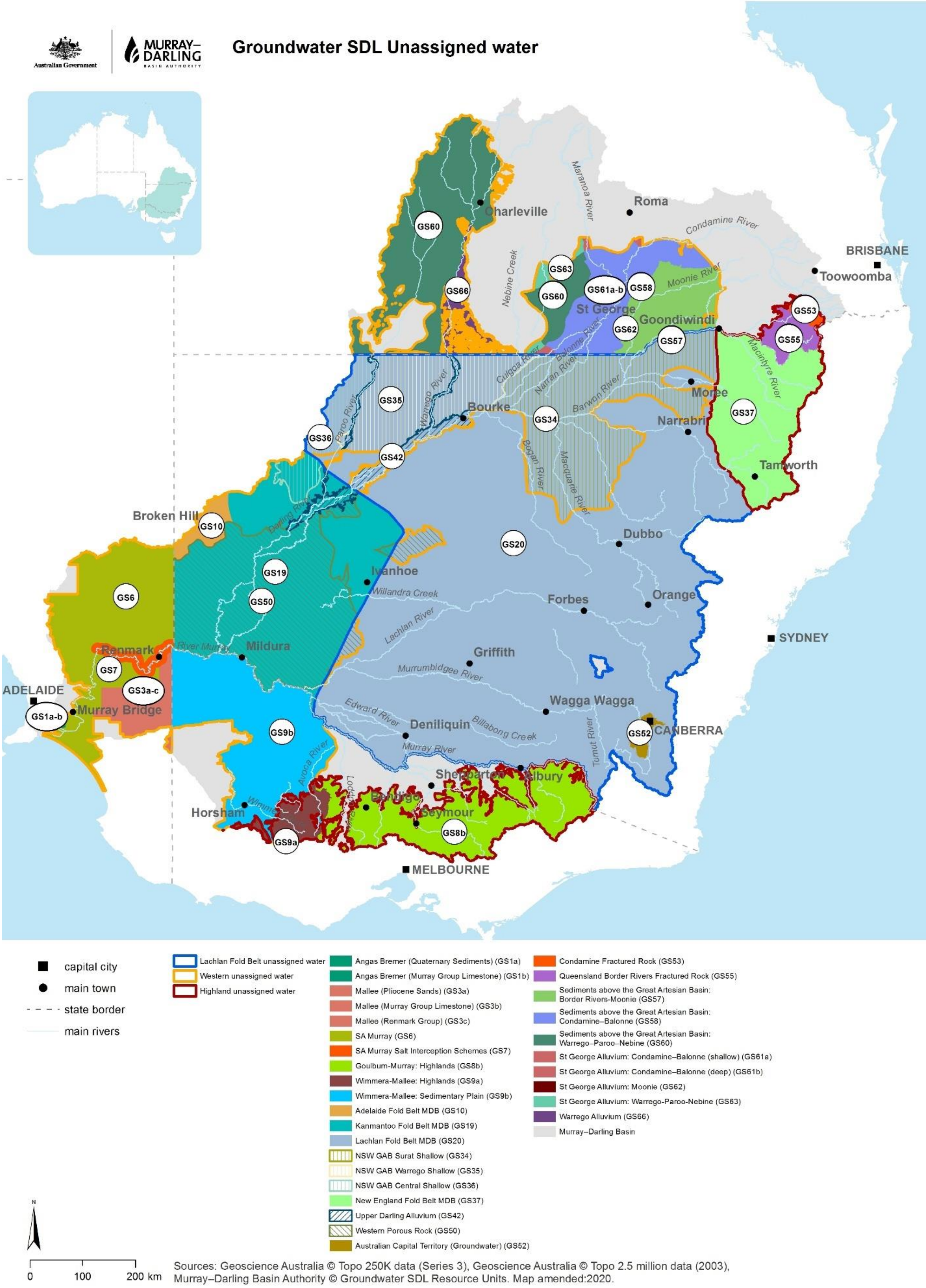


Figure 14: Unassigned groundwater SDL resource units

Potential impacts on surface water of growth in groundwater extraction

The MDBA understood that that the actual take in several SDL resource units could be below the BDL. Where this occurred in groundwater SDL resource units that are connected to surface water resources, there was potential for increased groundwater take, up to the BDL, which may have an impact on surface water resources.

The MDBA quantified the potential surface water impact of increased groundwater take within the BDL, based on an estimate of take against the BDL. There are several issues and assumptions used to estimate groundwater take across the Basin:

- at the time of making the 2012 Basin Plan, the most up to date Basin-wide groundwater take information held by the MDBA was for the period 2003-04 to 2007-08. This information was sourced from the Basin states;
- metered data is concentrated in areas of high groundwater take where -
  - approximately 75% of the annual average groundwater extraction in the Basin occurs across 40% of the SDL resource units;
  - take is generally at least 50% of the BDL in these areas; or
  - the quality of water take data in most of these areas is considered reasonable with lower levels of uncertainty and
- in the non-metered SDL resource units, take was estimated as 60% of the volume of entitlement plus an estimate of S&D take. The quality of water take data for these areas is highly variable and has high levels of uncertainty.

Considering these issues, the MDBA estimated average take across the Basin for the period 2003-04 to 2007-08 to be 1,745 GL/y. The BDL in the Basin Plan is 2,386 GL/y, which is 641 GL/y higher than the estimated average use in the 2003-04 to 2007-08 period.

The MDBA estimated the potential impact of this increased groundwater take on surface water within the BDL by applying the same assessment method as outlined previously. To determine the potential impact, the method applied the connectivity ratio for the relevant system to the difference between estimated take and the BDL.

At the time of the 2012 Basin Plan, the potential Basin wide impact on surface water, of increased take within the BDL under this method, was estimated to be 56 GL/y. This impact related to potential increases in 24 SDL resource units where the connectivity assessment was used to determine the SDL. In the remaining SDL resource units, either the connectivity assessment was not used, or no increases were possible as take was already at the BDL.

The MDBA commissioned an independent review investigating the potential impacts of groundwater SDL under three different growth scenarios and irrigation efficiency projects on river flow volume under the Basin Plan (Wang et al., 2018). The growth scenarios were no growth, 2%/y growth and 4%/y growth. These scenarios give credence to the expectation that any future growth will be from commitments prior to the Basin Plan (i.e. BDLs) rather than the 'unassigned' water resulting from the high SDLs. The analysis has also assessed the impact of extraction growth to the full SDLs. Although there is no evident trend in historic use, plausible growth scenarios over the next 40 years indicate that the total groundwater use will almost all be from prior commitments within the BDL. The impact on river flow under these scenarios is in the range of 0 to 360 GL/y, with 170 GL/y as the most likely. The high uncertainty is associated with the growth in groundwater extraction and ground-surface water connectivity factors. Impacts are likely to be significant for low flow during extended dry periods and would affect both quantity and quality. The estimated reduction under this review differs from the previous estimate by the MDBA mainly because the ground-surface water connectivity factor used in this review is higher than by MDBA.

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