THE BASIN PLAN IMPLEMENTATION

Lachlan Alluvium Groundwater Resource Description

GW10 Water Resource Plan Area

NSW Department of Planning and Environment | dpie.nsw.gov.au

Published by NSW Department of Planning and Environment

dpie.nsw.gov.au

Title: Lachlan Alluvium Groundwater Resource Description

Subtitle: GW10 Water Resource Plan area

First published: August 2019

Department reference number: INT22/31961

More information

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Glossary

Term	Meaning
Alluvial aquifer	A groundwater system whose geological matrix is composed of unconsolidated sediments consisting of gravel, sand, silt and clay transported and deposited by rivers and streams.
Alluvium	Unconsolidated sediments deposited by rivers or streams consisting of gravel, sand, silt and clay, and found in terraces, valleys, alluvial fans and floodplains.
Aquifer	Under the *Water Management Act 2000* an aquifer is a geological structure or formation, or an artificial landfill that is permeated with water or is capable of being permeated with water. More generally, the term aquifer is commonly understood to mean a groundwater system that can yield useful volumes of groundwater. For the purposes of groundwater management in NSW the term 'aquifer' has the same meaning as 'groundwater system' and includes low yielding and saline systems.
Anabranch	Stable multi-thread channels that are intermediate between single thread and braided channels characterised by vegetation or otherwise stable alluvial islands that divide flows at discharges up to nearly bank-full.
Artesian	Groundwater which rises above the surface of the ground under its own pressure by way of a spring or when accessed by a bore.
Archean	The Archean Era spanned 4.56 to 2.5 billion years ago.
Australian Height Datum (AHD)	Elevation in metres above mean sea level.
Available water determination	A determination referred to in section 59 of the *Water Management Act 2000* that defines a volume of water or the proportion of the share component (also known as an 'allocation') that will be credited to respective water accounts under specified categories of water access licence. Initial allocations are made on 1 July each year and, if not already fully allocated, may be incremented during the water year.
Baseflow	Discharge of groundwater into a surface water system.
Basement (rock)	See Bedrock
Basic landholder rights (BLR)	Domestic and stock rights, harvestable rights or native title rights.
Bedding	Discrete sedimentary layers that were deposited one on top of another.
Bedrock	A general term used for solid rock that underlies aquifers, soils or other unconsolidated material. .
Beneficial use (category)	[1]A general categorisation of groundwater uses based on water quality and the presence or absence of contaminants. Beneficial use is the equivalent to the 'environmental value' of water.

[1] As defined in '*Macro water sharing plans – the approach for groundwater*' (NSW Office of Water, 2011)

Term	Meaning
Bore (or well)	A hole or shaft drilled or dug into the ground.
Brackish water	Water with salinity between 3,000 and 7,000 mg/L total dissolved solids.
Cenozoic	The Cenozoic Era spanned from 66 million years ago to present.
Confined aquifer	An aquifer which is bounded above and below by impermeable layers causing it to be under pressure so that when the aquifer is penetrated by a bore, the groundwater will rise above the top of the aquifer.
Connected water sources	Water sources that have some level of hydraulic connection.
Development (of a groundwater resource)	The commencement of extraction of significant volumes of water from a water source.
Discharge	Flow of groundwater from a groundwater source.
Drawdown	The difference between groundwater level/pressure before take and that during take.
Dual porosity	Where a groundwater system has two types of porosity; primary porosity resulting from the voids between the constituent particles forming the rock mass, and secondary porosity resulting from dissolution, faulting and jointing of the rock mass.
Electrical conductivity (EC)	Ability of a substance to conduct an electrical current. Used as a measure of the concentration of dissolved ions (salts) in water (i.e. water salinity). Measured in micro-Siemens per centimetre (µS/cm) or deci-Siemens per metre (dS/m) at 25^{o} C. 1 dS/m = 1000 µS/cm
Environmental Value	[2]Particular values or uses of the environment that are important for a healthy ecosystem or for public benefit, welfare, safety or health and which require protection from the effects of contamination, waste discharges and deposits.
Fractured rock	Rocks with fractures, joints, bedding planes and cavities in the rock mass.
Geological sequence	A sequence of rocks or sediments occurring in chronological order.
Groundwater	Water that occurs beneath the ground surface in the saturated zone.
Groundwater-Dependent Ecosystem (GDE)	[3]Ecosystems that require access to groundwater to meet all or some of their water requirements so as to maintain their communities of plants and animals, ecological processes and ecosystem services.
Geological formation	A fundamental lithostratigraphic unit used in the local classification of strata and classified by the distinctive physical and chemical features of the rocks that distinguish it from other formations.

[2] As defined in '*Guidelines for Groundwater Quality Protection in Australia 2013'* published by the National Water Quality Management Strategy.

[3] Kuginis L., Dabovic, J., Byrne, G., Raine, A., and Hemakumara, H. 2016, *Methods for the identification of high probability groundwater dependent vegetation ecosystems.* NSW Department of Primary Industries—Water, Sydney, NSW.

Term	Meaning
Groundwater equilibrium	A state where the forces driving groundwater flow have reached a balance in a groundwater system, for example where groundwater inflow equals groundwater outflow.
Groundwater system	Any type of saturated sequence of rocks or sediments that is in hydraulic connection. The characteristics can range from low yielding and high salinity water to high yielding and low salinity water.
Hydraulic conductivity	The capacity of a porous medium to transmit water. Measured in meters/day.
Hydraulic connection	A path or conduit allowing fluids to be connected. The degree to which a groundwater system can respond hydraulically to changes in hydraulic head.
Hydraulic head	The height of a water column above a defined point, usually expressed in metres.
Hydrogeology	The branch of geology that relates to the occurrence, distribution and processes of groundwater.
Hydrograph	A plot of water data over time.
Kriging	A method of interpolation using a weighted average of neighbouring samples to estimate an 'unknown' value at a given location to create surfaces.
Long-term average annual extraction limit (LTAAEL)	The long-term average volume of water (expressed in megalitres per year) in a water source available to be lawfully extracted or otherwise taken.
Igneous rock	Rocks which have solidified from a molten mass.
Infiltration	The movement of water from the land surface into the ground.
Ion	Mineral species dissolved in groundwater.
Make good provisions (in reference to a water supply work)	The requirement to ensure third parties have access to an equivalent supply of water through enhanced infrastructure or other means for example deepening an existing bore, funding extra pumping costs or constructing a new pipeline or bore.
Management zone	A defined area within a water source where a particular set of water sharing rules applies.
Mesozoic	The Mesozoic Era spanned 252 to 66 million years ago
Metamorphic rock	Rocks that result from partial or complete recrystallisation in the solid state of pre-existing rocks under conditions of temperature and pressure.
Minimal impact considerations	Factors that need to be assessed to determine the potential effect of aquifer interference activities on groundwater and its dependent assets.

Term	Meaning
Monitoring bore	A specially constructed bore used to measure groundwater level or pressure and groundwater quality at a specific depth. Not intended to supply water.
Ongoing take	The take of groundwater that occurs after part or all of the principal activity has ceased. For example extraction of groundwater (active take) entering completed structures, groundwater filling abandoned underground workings (passive take) or the evaporation of water (passive take) from an abandoned excavation that has filled with groundwater.
Outcrop	Rocks which are exposed at the land surface.
Piezometric or Potentiometric head	The pressure or hydraulic head of the groundwater at a particular depth in the ground. In unconfined aquifers this is the same as the water table.
Palaeozoic	The Palaeozoic Era spanned 541 to 252 million years ago.
Perched water table	A local water table of very limited extent which is separated from the underlying groundwater by an unsaturated zone.
Permeability	The capacity of earth materials to transmit a fluid.
Porous rock	Consolidated sedimentary rock containing voids, pores or other openings in the rock (such as joints, cleats and/or fractures).
Pre-development	Prior to development of a groundwater resource.
Proterozoic	The Proterozoic Era spanned 2.5 billion to 541 million years ago.
Recharge	The addition of water into a groundwater system by infiltration, flow or injection from sources such as rainfall, overland flow, adjacent groundwater sources, irrigation, or surface water sources.
Recovery	The rise of groundwater levels or pressures after groundwater take has ceased. Where water is being added, recovery will be a fall.
Recovery decline	Where groundwater levels or pressures do not fully return to the previous level after a period of groundwater removal or addition.
Reliable water supply	[4]Rainfall of 350 mm or more per annum (9 out of 10 years); or a regulated river, or unregulated rivers where there are flows for at least 95% of the time (i.e. the 95th percentile flow of each month of the year is greater than zero) or 5th order and higher rivers; or groundwater aquifers (excluding miscellaneous alluvial aquifers, also known as small storage aquifers) that have a yield rate greater than 5L/s and total dissolved solids of less than 1,500mg/L.
River Condition Index (RCI)	This is a spatial tool used to measure and monitor the long- term trend of river condition, but also reports on instream values and risk to instream values from extraction and geomorphic disturbance.

[4] As defined by Strategic Regional Land Use Plans

Term	Meaning
Salinity	The concentration of dissolved minerals in water, usually expressed in EC units or milligrams of total dissolved solids per litre (mg/L).
Salt	A mineral which in a liquid will readily dissociate into its component ionic species for example NaCl into Na^+ and Cl^- ions.
Saturated zone	Area below the water table where all soil spaces, pores, fractures and voids are filled with water.
Sedimentary rock	A rock formed by consolidation of sediments deposited in layers, for example sandstone, siltstone and limestone.
Share component	An entitlement to water specified on an access licence, expressed as a unit share or for specific purpose licences a volume in megalitres (e.g. local water utility, major water utility and domestic and stock).
Sustainable Diversion Limits	The volume of water that can be taken from a Sustainable Diversion Limit resource unit as defined under the Murray– Darling *Basin Plan 2012*.
Unassigned water	Exists where current water requirements (including licensed volumes and water to meet basic landholder rights) are less than the extraction limit for a water source.
Unconfined aquifer	A groundwater system usually near the ground surface, which is in connection with atmospheric pressure and whose upper level is represented by the water table.
Unconsolidated sediment	Particles of gravel, sand, silt or clay that are not bound or hardened by mineral cement, pressure, or thermal alteration of the grains.
Unsaturated zone	Area above the water table where soil spaces, pores, fractures and voids are not completely filled with water.
Water balance	A calculation of all water entering and leaving a system.
Water resource plan	[5]A plan made under the *Commonwealth Water Act 2007* that outlines how a particular area of the Murray–Darling Basin's water resources will be managed to be consistent with the Murray–Darling Basin Plan. These plans set out the water sharing rules and arrangements relating to issues such as annual limits on water take, environmental water, managing water during extreme events and strategies to achieve water quality standards and manage risks.
Water sharing plan	[6]A plan made under the *Water Management Act 2000* which sets out the rules for sharing water between the environment and water users within whole or part of a water management area or water source.

[5] www.mdba.gov.au/basin-plan-roll-out/water-resource-plans 21/03/17

[6] As defined in '*Macro water sharing plans – the approach for groundwater*' (NSW Office of Water, 2011)

Term	Meaning
Water source	Defined under the *Water Management Act 2000* as 'The whole or any part of one or more rivers, lakes or estuaries, or one or more places where water occurs naturally on or below the surface of the ground and includes the coastal waters of the State'. Individual water sources are more specifically defined in water sharing plans.
Water table	Upper surface of groundwater at atmospheric pressure, below which the ground is saturated.
Water year	Twelve-month period from 1 July to 30 June.
Yield	The amount of water that can be supplied over a specific period.

1 Introduction

The NSW Government is developing water resource plans as part of implementing the Murray–Darling Basin Plan 2012 (the Basin Plan). Water resource plans align Basin-wide and state-based water resource management in each water resource plan area. The water resource plans recognise and build on the existing water planning and management frameworks that have been established in NSW.

Under the Murray–Darling Basin Plan, individual water resources are known as sustainable diversion limit (SDL) resource units and each water resource plan covers a number of SDL resource units within an area.

The Lachlan Alluvium Water Resource Plan area is shown in Figure 1 and is located within the Lachlan catchment that forms part of the Murray–Darling Basin in northern NSW. The Lachlan catchment covers around 90,000 km² and represents about eight per cent of the Murray–Darling Basin.

The groundwater resources of the Lachlan Alluvium include all of the main alluvial deposits associated with the Lachlan River. The Lachlan Alluvium Water Resource Plan area extends from approximately 40 km upstream of Cowra at its eastern extent to Oxley and Ivanhoe at its western extremity.

The Lachlan Alluvium Water Resource Plan area (GW10—Murray–Darling Basin reference number) is composed of three SDL resource units: the Lower Lachlan Alluvium (GS30), the Upper Lachlan Alluvium (GS48) and the Belubula Alluvium (GS12) shown in Figure 1. Within the Upper Lachlan Alluvium, there are eight management zones which are also shown on Figure 1. These SDL resource units correlate directly to groundwater sources currently covered by water sharing plans. They are the:

- Lower Lachlan Groundwater Source (Lower Lachlan Alluvium) managed under the *Water Sharing Plan for the Lower Lachlan Groundwater Source 2003,* and the
- Belubula Valley Alluvial Groundwater Source and Upper Lachlan Alluvial Groundwater Source (Belubula Alluvium and Upper Lachlan Alluvium) managed under the *Water Sharing Plan for the Lachlan Unregulated and Alluvial Water Sources 2012.*

This report describes the location, climate and physical attributes of the groundwater resources of the Lachlan Alluvium water resource plan area, and explains their geological and hydrogeological context, environmental assets, groundwater quality and management. It also presents the current status of these groundwater resources including groundwater rights, accounts, dealings, take, groundwater behaviour and modelling.

2 History of groundwater management

2.1 Early groundwater management

The *Water Act 1912* was introduced at a time when the development of water resources for agriculture and regional development were the priority of government (DLWC, 1999). Under this Act, water entitlement was linked to land rights, and licences for bores and wells were granted for a fixed term, with no restriction on the volume that could be extracted. Bore licences were initially required only for bores greater than 30 m depth in the western half of NSW.

After World War II, there was a drive to expand irrigation and promote economic development in inland NSW. In 1955, the *Water Act 1912* was amended to require all bores to be licensed irrespective of depth or location. By the 1970s, the rapid expansion of the irrigation industry, increasing competition for water resources and extended periods of drought were affecting the reliability of water supplies in inland NSW.

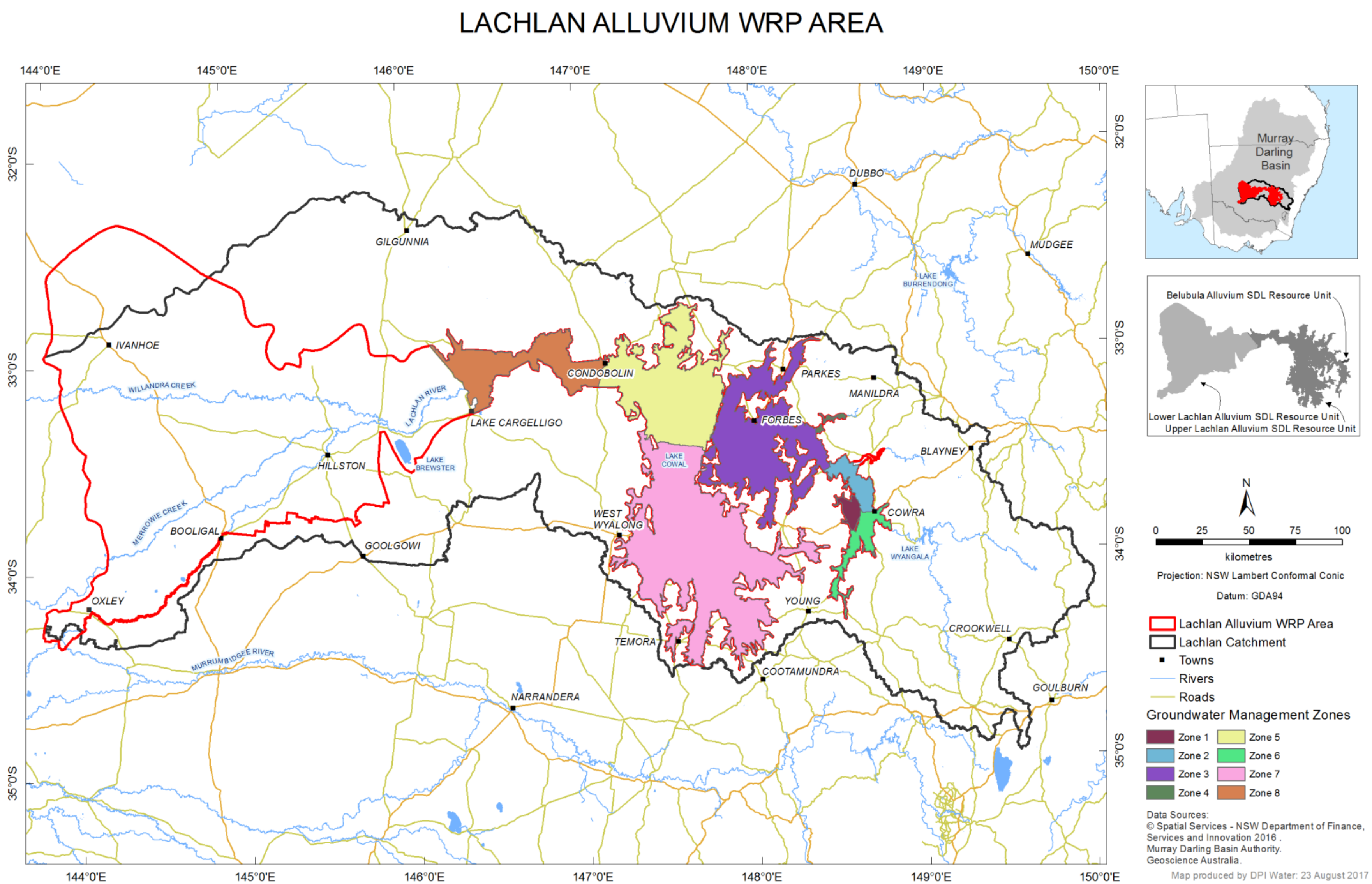

Figure 1 Location of the Lachlan Alluvium water resource plan Area and SDL Resource Units

Acknowledging that groundwater was a finite resource, from 1972 to 1983 new irrigation licences were issued based on the size of the area being irrigated. These licences had to be renewed every five years, but still had no volumetric limit on extraction (Gates et al, 1997).

From 1984, all new high yield bores and wells (greater than 20 ML/yr), except those in the Great Artesian Basin, were given a volumetric entitlement and old area-based licences were progressively converted. Volumetric entitlements were generally issued based on historical usage, property area or bore capacity.

From 1986, comprehensive volumetric groundwater allocation policies were introduced throughout the state.

The objectives were to more effectively manage development in those groundwater systems where the resource was fully committed and to encourage the use of groundwater where it was underutilised.

2.2 NSW water reforms

In 1994, the Council of Australian Governments (COAG) endorsed a strategic framework for reform of the Australian water industry. The framework included identifying and recovering the costs of water management and supply from beneficiaries, recognising the environment as a water user through formal allocations and ensuring that water rights could move by trade to where they would generate the highest value.

By the late 1990s, NSW had embarked on a major program of water policy reforms. This included the development of the NSW State Groundwater Policy Framework Document, the NSW Groundwater Quality Protection Policy, and an assessment of risk to the state's groundwater systems from over-extraction and/or contamination. The NSW State Groundwater Dependent Ecosystems Policy was released in 2002.

The 1990s policy reforms drove the development of the *Water Management Act 2000*. This Act establishes water for the environment as a priority while also providing licence holders with more security through perpetual licences and greater opportunities to trade through the separation of water access rights from the land.

The *Water Management Act 2000* considers other users of water such as groundwater dependent ecosystems, and aquifer interference activities; cumulative impacts; climate change; Aboriginal cultural rights and connectivity between groundwater and surface water. The *Water Management Act 2000* also sets up the framework for developing statutory plans to manage water.

Water sharing plans are the principle tool for managing the state's water resources including groundwater. These ten-year plans manage groundwater resources at the 'water source' scale, define the long-term average annual extraction limit (LTAAEL), establish rules for sharing groundwater between users and the environment, establish basic landholder rights and set rules for water trading.

Priority for developing water sharing plans was based on the groundwater systems identified by the risk assessment as being at highest risk. The first groundwater sharing plans in the Murray–Darling Basin commenced between 2006 and 2008 across six large alluvial groundwater systems in the Murray–Darling Basin, which included the Lower Lachlan Groundwater Source. Access to groundwater was reduced to the extraction limit over the ten-year plan using an approach that recognised historical extraction.

Since 2007, water sharing plans for unregulated rivers and groundwater systems in NSW have been completed using a 'macro' approach to cover most of the remaining water sources across NSW. Each groundwater macro plan covers a number of water sources of a particular type of groundwater system (for example, fractured rock).

In 2008, two embargo orders covering the remaining inland groundwater resources were made under the *Water Act 1912* on new applications for groundwater licences in 22 groundwater sources within the Murray–Darling Basin. These embargoes remained in effect until the commencement of water sharing plans for the groundwater sources that they covered.

A groundwater management committee was first established for the Lachlan valley in 1999. This group contributed to the development of water sharing plans for the valley. The Lower Lachlan Water Sharing Plan commenced in 2003 and the Lachlan Unregulated and Alluvial Water Sharing Plan commenced in 2012.

In 2012, the 'NSW Aquifer Interference Policy' was released. The purpose of this policy is to explain the water licensing and assessment requirements for aquifer interference activities under the *Water Management Act 2000* and other relevant legislative frameworks.

2.3 Belubula and Upper Lachlan Alluvium

The first gazetted groundwater volumetric allocation policy was introduced for the Belubula and Upper Lachlan Alluvium in November 1984 (NSW Government Gazette, 1984). Prior to this, an interim volumetric policy existed for these water sources (WRC, 1983) allowing new bore applications to receive volumetric entitlement. The November 1984 Gazette stipulated that all new high yield bores were given an annual volumetric entitlement and existing licences were to be converted to an annual volumetric entitlement.

In December 1989, an interim management plan for the Belubula Alluvium was introduced. It set out entitlement allocation guidelines which stipulated that entitlement be calculated based on property area overlying the resource subject to a property ceiling of 486 ML/yr. In February of 2007, an embargo was placed on new applications for groundwater licences within the Belubula Alluvium.

In August 1995, an allocation policy was introduced for the Upper Lachlan Alluvium (DLWC, 1995). It stipulated that entitlement be calculated based on property area overlying the resource subject to a property ceiling of 972 ML/yr. From June 1997, the Upper Lachlan Alluvium progressively had moratoriums and embargoes limiting further issue of new groundwater licences. In May 2003, a final embargo on new applications for groundwater licences was issued within the Upper Lachlan Alluvium.

The embargoes on the Belubula and Upper Lachlan Alluvium remained in place until the commencement of the *Water Sharing Plan for the Lachlan Unregulated and Alluvial Water Sources 2012*.

2.4 Lower Lachlan Alluvium

The first volumetric groundwater allocation policy for the Lower Lachlan Valley was introduced in March 1984 called the *Licensing Policy for High Yield Bores in the Lower Lachlan Valley and other valleys (WRC, 1984)*. Under this policy, the existing unrestricted area based licences were converted to an annual volumetric entitlement and new licences were given an annual volumetric entitlement.

An embargo on new groundwater entitlements was imposed in October 1998 (NSW Government Gazette, 1998) and no new entitlement was issued for new or replacement bores until the embargo was replaced by the *Water Sharing Plan for the Lower Lachlan Groundwater Source 2003*, in February 2008.

Total entitlements in the Lower Lachlan Alluvium were reduced from approximately 215,000 ML to the 108,000 ML under the water sharing plan that commenced in 2008. Access to supplementary licences was progressively reduced over the ten-year life of the plan. Supplementary licences were cancelled at the end of the 2017–18 water year.

3 Regional setting

3.1 Topography

The Lachlan River system and its floodplain are the main topographic features of the Lachlan catchment (Figure 2). From its headwaters near Gunning, at around 700 m above sea level, the Lachlan River flows north-west through tablelands and steep-sided valleys into Wyangala Dam.

Wyangala Dam was completed in 1971 and is the valley's major water storage facility with a capacity of 1,220,000 ML that provides water for town water supplies, irrigation, stock and domestic use, industry, and environmental flows. Wyangala Dam is located on the Lachlan River about 38 km east of Cowra.

The flow regime of Lachlan River has been substantially altered by the construction of Wyangala Dam and weirs/regulators that divert water along the Lachlan including a distributary channel system called the Jemalong scheme (Figure 3).

Downstream of the dam, the river continues flowing north-west through an alluvial valley before it enters the flat western plains near Condobolin.

The Lachlan River reaches its maximum capacity at Forbes where the mean daily flow is 3,197 ML per day. After this, the main channel of the Lachlan begins to lose its flow to the many anabranches and effluent channels that characterise the lower part of the catchment.

Downstream of Forbes, the Lachlan River splits into numerous effluent creeks that rejoin the river again downstream of Condobolin. The major effluent creek is the Wallamundry–Wallaroi Creek system, which may carry up to 30% of the river's flow depending on flow conditions and operation of regulators (DWR 1990)[7]. Connected to Wallaroi Creek is Banar Lake (located south of Condobolin), which forms an extensive area of shallow water and habitat for large numbers of waterbirds when full (Figure 3).

Between Forbes and Condobolin lays Lake Cowal, the largest lake in the catchment. During moderate floods, water from the Lachlan River enters the lake via two major floodways. The lake also receives water from Bland Creek catchment, which flows into it from the south. Once full, the water from Lake Cowal flows across a low saddle into the adjoining Nerang Cowal basin. Further downstream of Lake Cowal, Bogandillon Swamp is another large basin flooded directly from the Lachlan, or from overflow from Nerang Cowal. These lakes and swamp wetland systems are not groundwater-dependant.

Downstream from Lake Cargelligo, the valley widens and the landscape changes to alluvial floodplains where three main effluent channels flow westward from the Lachlan River: the Willandra, Middle and Merrowie Creeks.

Between Hillston and Booligal, the Merrimajeel and Muggabah Creek system flows away from the Lachlan River, forming one of the most valuable wetland habitats in the valley, known as the Booligal Wetlands. These wetlands support large breeding colonies of ibis and other colonial water birds during moderate flows (DWR 1990).

Downstream of the small village of Oxley, the Lachlan River enters the Great Cumbung Swamp. The Great Cumbung Swamp comprises a diversity of habitats including reed swamp, river red gum forest, black box woodlands, shallow marshes and open water wetlands. The movement of water within the swamp is controlled by a series of banks and regulators operated by the local landholders. Water generally does not reach the Murrumbidgee River except in large floods.

7 Department of Water Resources 1990, Draft Water Management Plan for the Wetlands of the Lachlan Valley Floodplain

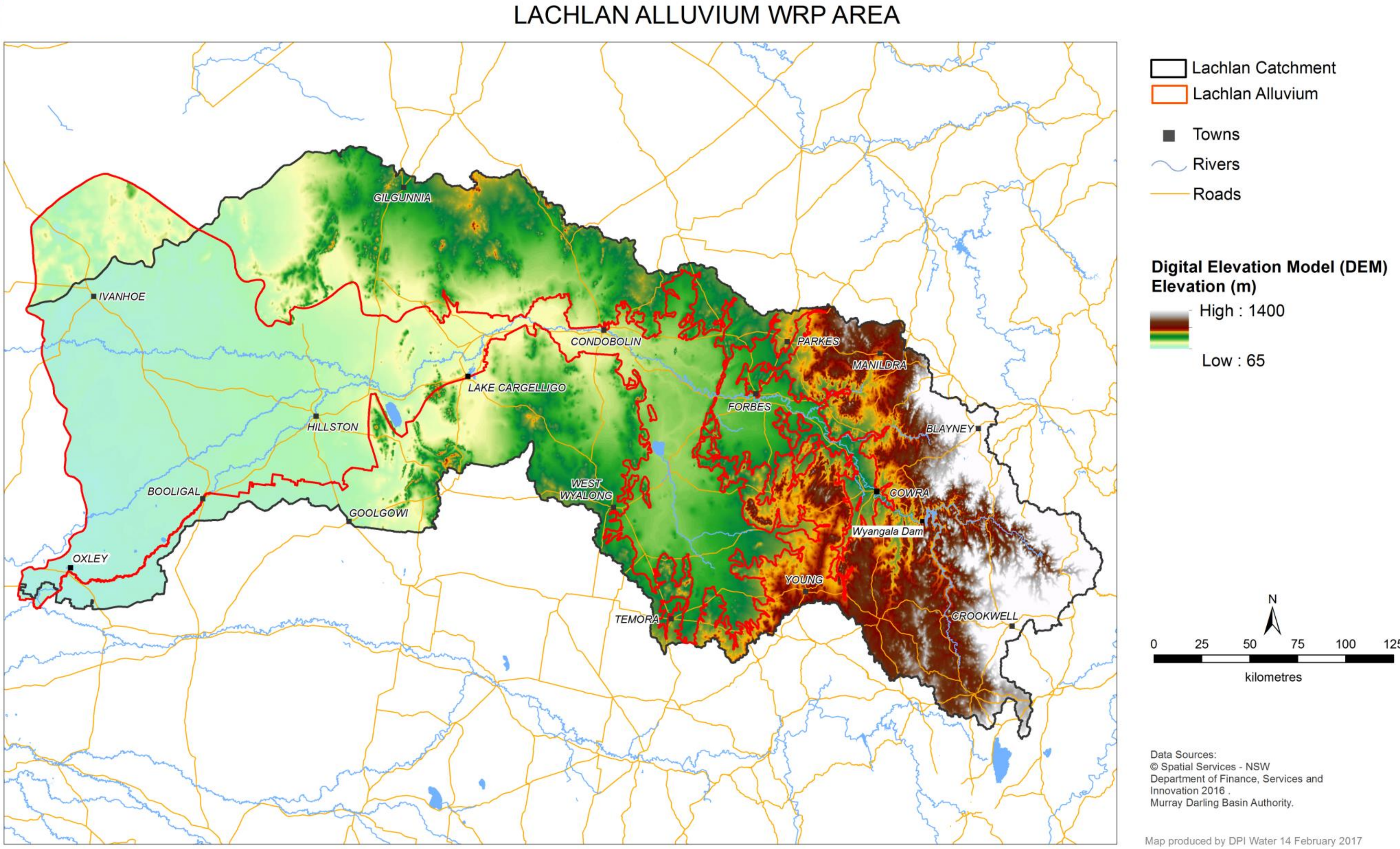

Figure 2 Topography and elevation map of the Lachlan catchment (Gallant *et al*, 2009)

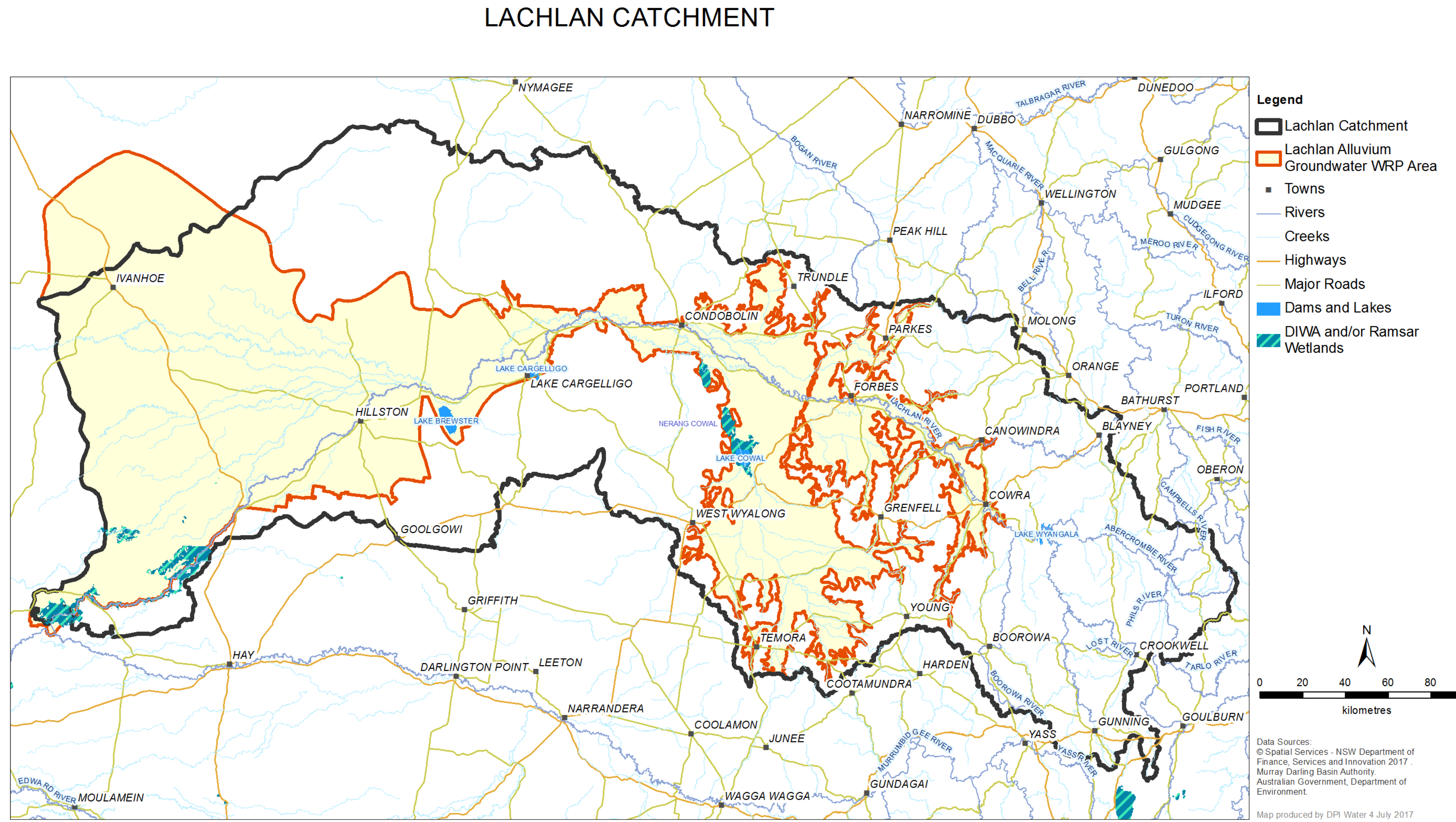

Figure 3 Surface water map of the Lachlan catchment

3.2 Climate

The Lachlan catchment has a temperate climate, with a considerable gradient from east (cooler and wetter) to west (hotter and drier).

The temperature extremes across the Lachlan catchment can range from –9°C in the winter to 46°C in the summer. The average maximum temperature is 34°C and the average minimum is 0°C.

Average annual rainfall varies from 860 mm at Crookwell at the eastern part of the catchment to around 300 mm at Ivanhoe (Figure 4).

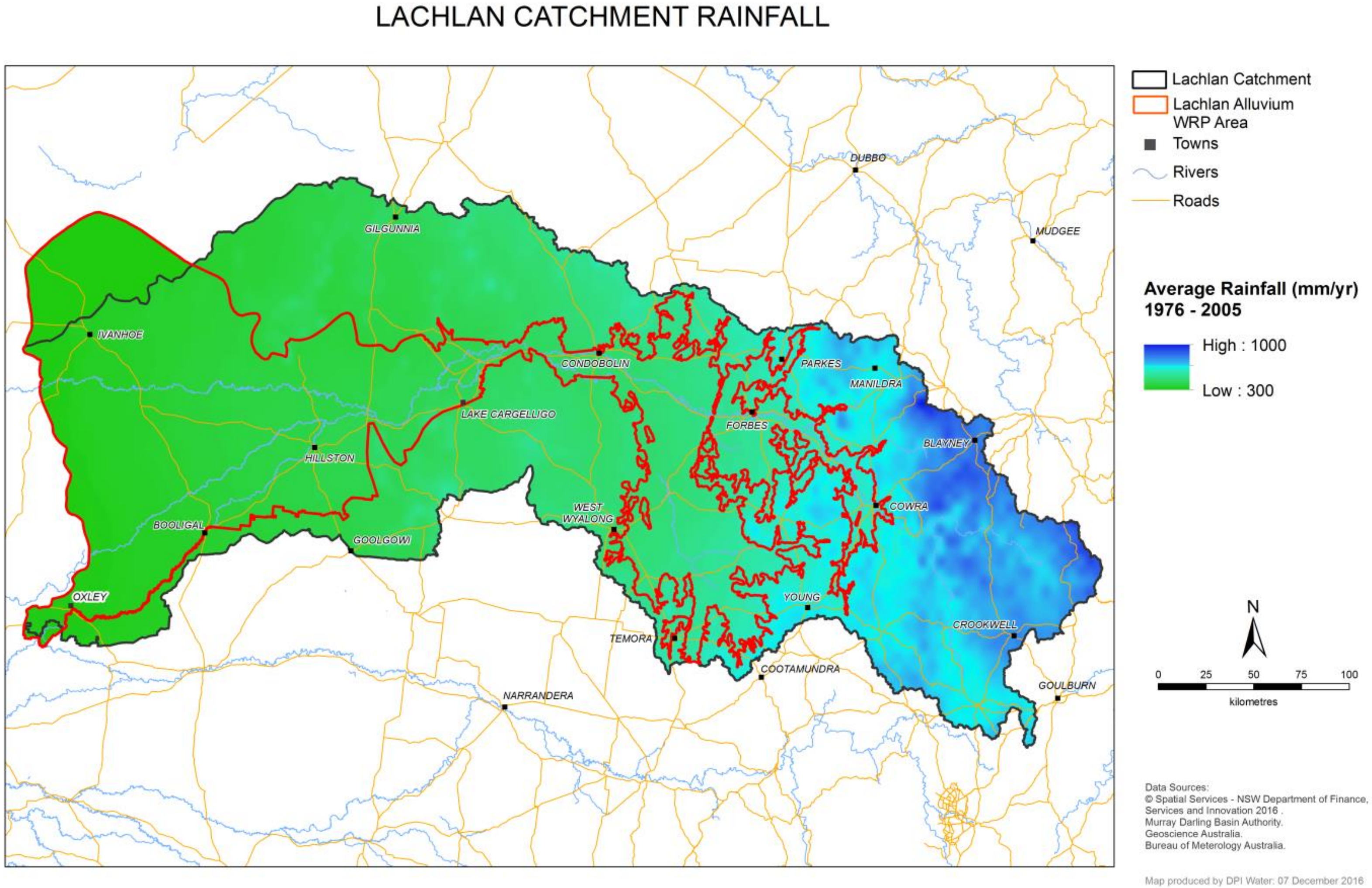

Figure 4 Average annual rainfall map of the Lachlan catchment (Bureau of Meteorology—BOM, 2008)[8]

[8] The average rainfall period 1976–2005 displayed in this map is the current standardised average conditions gridded data set available from the Bureau of Meteorology.

Rainfall is generally winter dominant in the more elevated area in the eastern portion of the catchment (to the south and east of Cowra) whereas in the western portion (west of Cowra) monthly rainfall is relatively consistent throughout the year.

Within the Lachlan Alluvium, summer and winter rainfall is not significantly different (Figure 5). Rainfall is typically 34–50 mm per month at Forbes, and 28–40 mm per month at Hillston.

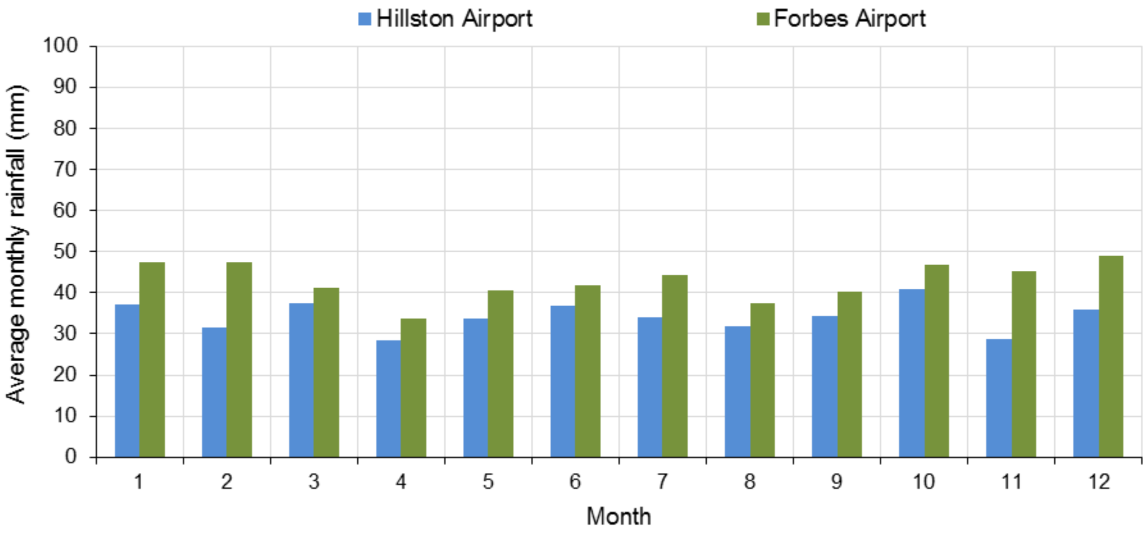

Figure 5 Average monthly rainfall for Hillston and Forbes 1972–2016 (BOM). This period corresponds to the period of record for groundwater monitoring within the Lachlan Alluvium.

Evaporation (Class A pan evaporation) in the Lachlan catchment has a strong east-west gradient (Figure 6). Yearly evaporation varies from around 1,380 mm in the east to 2,200 mm in the west.

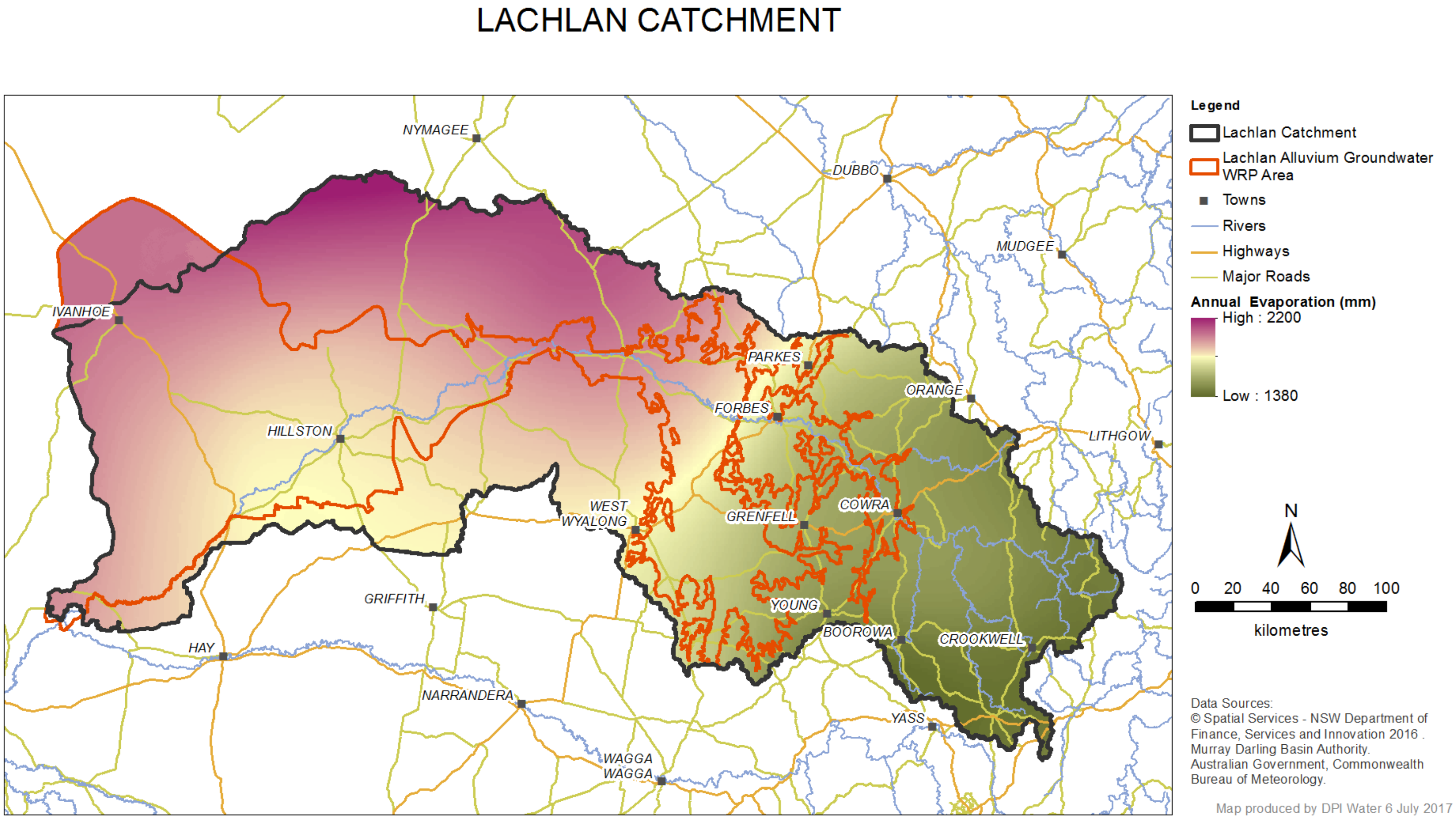

Figure 6 Average annual evaporation map of the Lachlan catchment (BOM, 2008)[9]

[9] The average evaporation period 1976–2005 displayed in this map is the standardised average conditions gridded data set available from the Bureau of Meteorology.

Evaporation is strongly seasonal (Figure 7), varying from 40–75 mm a month over winter (June–August). Evaporation significantly exceeds average monthly rainfall during the year, with the exception of June and July. The greatest exceedance occurs over the summer months (December–February), when up to 300 mm of evaporation occurs per month, compared to up to 50 mm of rainfall per month for the same period.

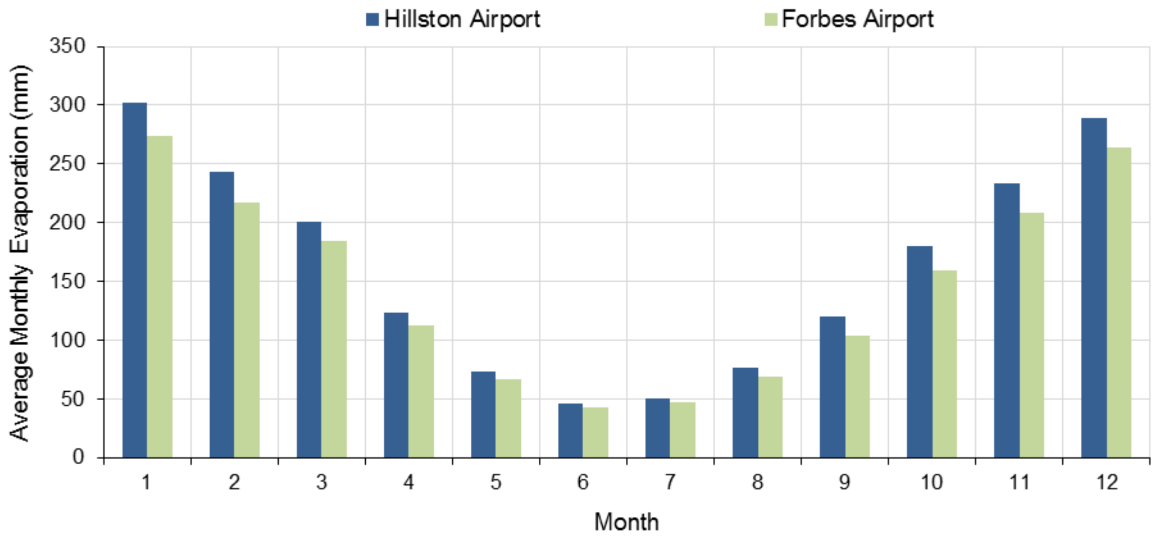

Figure 7 Average monthly evaporation for Hillston and Forbes 1972–2016 (BOM)

Residual rainfall plots have been constructed for the Lachlan using daily data sourced from the Scientific Information for Land Owners (SILO) database. The rainfall residual mass graph plots the cumulative difference from the monthly average rainfall and provides a visual representation of the rainfall history in an area. A falling trend indicates a period of lower than average rainfall; a rising trend showing periods of above average rainfall.

Figure 8 shows the residual mass graph of average monthly rainfall from 1972 to 2016 at Forbes and Hillston. This period corresponds to the period of groundwater monitoring in the Upper and Lower Lachlan Alluvium.

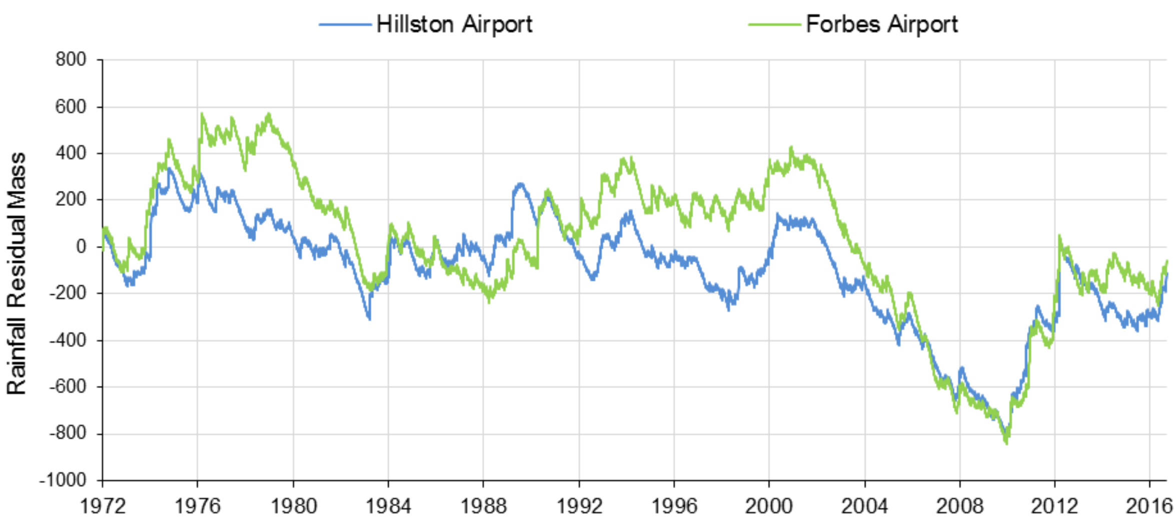

Figure 8 Hillston and Forbes Airport rainfall residual mass graph 1972–2016 (BOM)

Figure 8 shows a below-average rainfall trend during the millennium drought from 2002 to 2010, followed by an above-average spike between 2011 and 2012, and then a below-average trend to present.

3.3 Land use

The Nari Nari, Ngiyampaa, Wiradjuri, Barkandji and Yita Yita people were the original inhabitants of the Lachlan catchment. The land and waters of the Lachlan catchment contain places of deep significance to Aboriginal people and are central to their spiritual and religious belief systems, and are often celebrated in ritual, ceremony, story, dance and art work.

European settlement of the valley was encouraged by the discovery of gold at Forbes in the 1860s. However, since the 1900s, land use within the valley has been largely agricultural.

Today, the main land uses across the Lachlan catchment are livestock grazing and dryland agriculture, which together account for some 75% of land use (Green et al, 2011). The grazing land is distributed throughout the catchment. The majority of dryland cropping is carried out downstream of Wyangala Dam and through the middle and lower reaches of the catchment where moderate winter rainfalls occur.

While economically important within the region, irrigated crops cover only 1.4%of the catchment area. The main crops under irrigation are cereals, lucerne and cotton. Other irrigated crops include oilseeds, vegetables, wine grapes and stone fruits. Irrigation is concentrated mainly within the area of the Lower Lachlan Alluvium around Hillston; however significant crop irrigation also occurs at and downstream from Cowra (Figure 9).

Approximately 3,800 km^2 (4.4% of total catchment) of conservation land in the Lachlan catchment consist of national parks and nature reserves (Green et al, 2011). In the Upper Lachlan Alluvium at and immediately downstream from Lake Cowal lays an area of conservation land associated with wetlands (Lake Cowal and Bogandillon Swamp). In the Lower Lachlan Alluvium, two wetlands can be found immediately downstream from Booligal (Booligal wetlands) and downstream from Oxley (Great Cumbung Swamp). These are listed as important wetlands in the Directory of Important Wetlands in Australia.

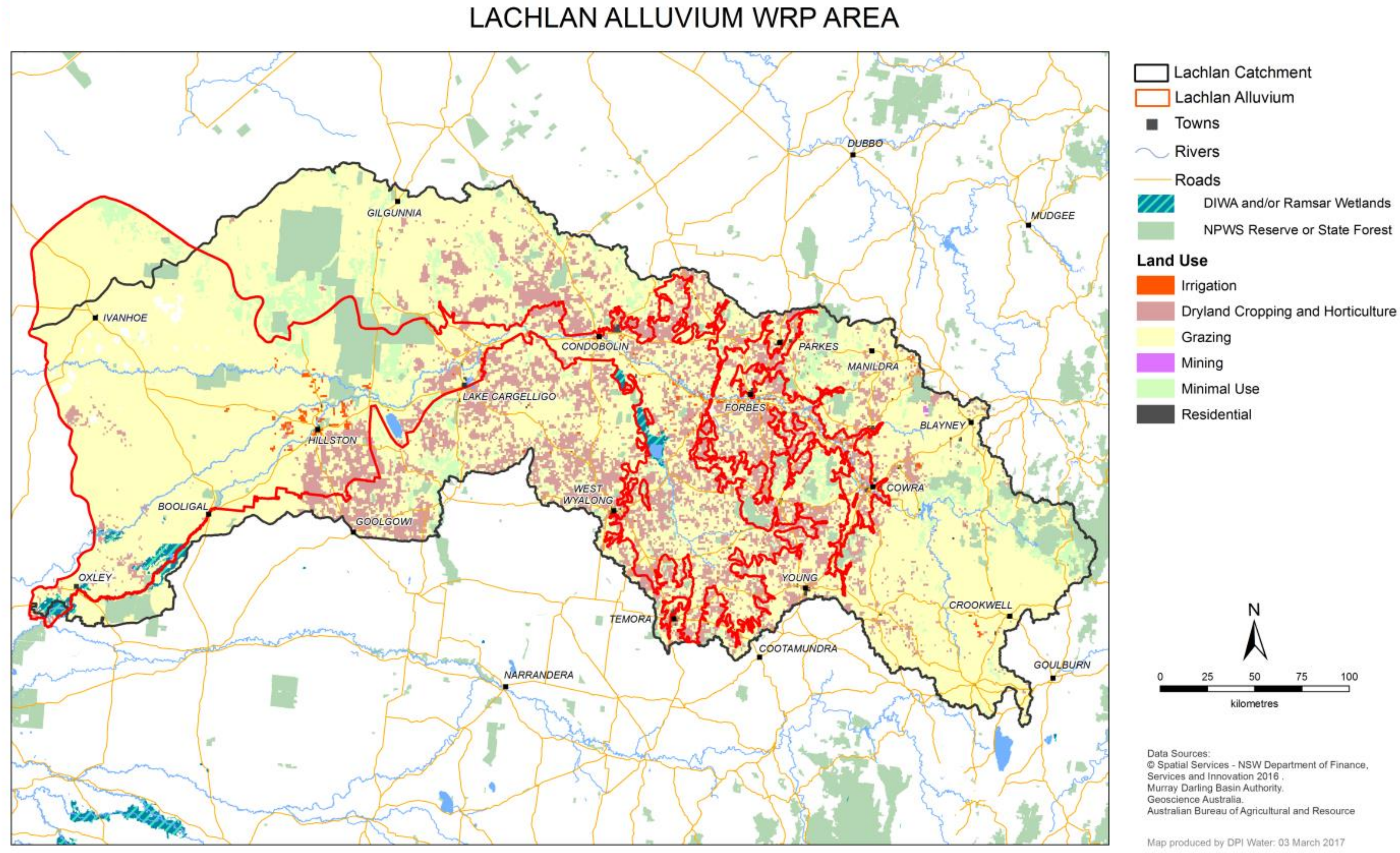

Figure 9 Land use map of the Lachlan catchment (Smart, 2016)

Over 106,000 people live within the Lachlan catchment (Green et al, 2011). The largest town within the catchment is Parkes (12,000 people).

4 Geology

The surface geology of the Lachlan catchment is distributed across four main geological sequences including the Palaeozoic Lachlan Fold Belt, the Mesozoic sedimentary rocks (ungrouped), the Cenozoic unconsolidated sediments, and the Cenozoic volcanics (Figure 10).

The Lachlan Fold Belt in the Lachlan catchment primarily consists of the complex sedimentary, volcanic and plutonic associations of early to mid-Silurian to Late Devonian (Coney, 1992). It is expressed at the surface as hills and outcrops, particularly in the eastern portion of the catchment. The Lachlan Fold Belt is extensively faulted due to tectonic events during the Devonian period (around 400 million years ago).

The Lachlan Fold Belt is unconformably overlain by ungrouped Mesozoic sedimentary rocks. These Mesozoic sedimentary rocks outcrop west of Parkes and consist of sandstones and conglomerates with rare mudstone.

The Lachlan Fold Belt and Mesozoic rocks are overlain by unconsolidated Cenozoic sediments that cover the majority of the area west of Cowra and include the Upper and Lower Alluvium. These sediments extend outside of the Lachlan catchment to cover the majority of western NSW.

The Cenozoic unconsolidated sediments are made up of clay, silt, sand, and gravels generally deposited by river systems (alluvial deposits) or as wash from hill slopes (colluvial deposits). The sediments were deposited in a fluvial and lacustrine environment immediately downstream of Young to Lake Cargelligo. Downstream from Lake Cargelligo, they were deposited as a large alluvial fan.

Occasional Cenozoic extrusive volcanic rocks may be found on some peaks in the Lachlan catchment. The Orange Basalt is an example of these extrusive volcanic rocks. These rocks were formed by Cenozoic volcanic events and include basalts that were erupted during widespread volcanic activity throughout the eastern part of the state over the last 65 million years.

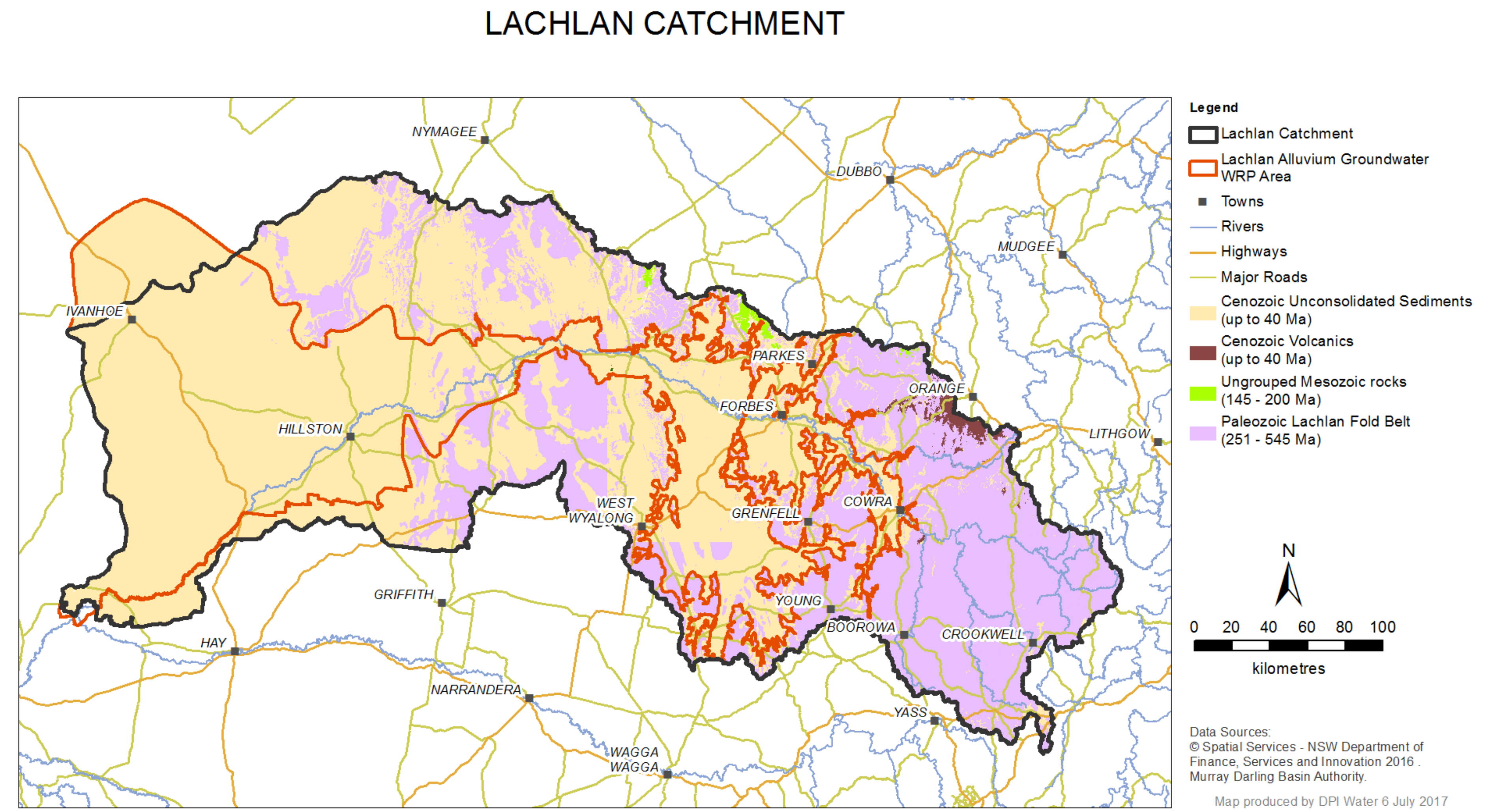

Figure 10 Geology of the Lachlan catchment

5 Hydrogeology

5.1 Regional context

The Lachlan Alluvium is a continuous sequence of unconsolidated sediments deposited as valley fill in the upper areas of the catchment and grades into broader valley and floodplain sediments in the mid catchment. The Lower Lachlan Alluvium in turn grades into the Murray Geological Basin (MGB) sediments, which also incorporates the Western Porous Rocks SDL resource unit on the western boundary of the Lachlan Alluvium and the Lower Murrumbidgee Alluvium SDL resource unit on its south western boundary.

Whilst the geometry of the alluvium is varied over the 1,400 plus kilometres of valley length, there is no break in the sedimentation. Consequently, groundwater through flow is uninterrupted down valley and there is hydraulic connection across contiguous boundaries between the Lachlan Alluvium and the MGB sediments.

The Lachlan Alluvium sits over and adjacent to the fractured rock management units of the Lachlan Fold Belt and the Kanmantoo Fold Belt. The permeability of the underlying fractured rocks is many orders of magnitude lower than that of the alluvium. Groundwater exchange between the alluvium and the underlying rock is expected to be insignificant in the context of the groundwater resources of the alluvium. Consequently, these fractured rock systems are not considered hydraulically connected in a resource management sense to the groundwater resources in the alluvium.

The boundaries of the three SDL resource units within the Lachlan Alluvium, and the management zones within them, reflect areas of similar hydrogeological characteristics. There is hydraulic connection across contiguous boundaries within and between the management units. The characteristics of each of the SDL resource units are presented in the following sections.

5.2 Belubula Alluvium

The Belubula Alluvium (Figure 11) is made up of Cenozoic (Pleistocene) valley fill alluvial sediments. It extends from approximately 12 km upstream to 10 km downstream of Canowindra and is up to 2 km wide. The alluvial sediments of the Belubula Alluvium become thicker to the west until they merge with the Upper Lachlan Alluvium at the water source boundary. The Belubula Alluvium is comprised of clay, silt, sand and gravel generally less than 40 m thick.

Groundwater contained within the Belubula Alluvium is generally considered to be unconfined or semi-confined and has a high level of hydraulic connection with the Belubula River along its length. Conceptually, the dominant recharge processes are direct rainfall infiltration and leakage from the Belubula River and overbank flood waters (SKM, 2010[10]).

Groundwater flows parallel to the Belubula River from east to west and is understood to discharge directly into the Upper Lachlan Alluvium to the west of the water source boundary (Figure 12).

A cross-section through the Belubula Alluvium is shown in Figure 13 and its location shown in Figure 12. Note that this cross section is displayed at a different scale to the sections shown for the Upper Lachlan and Lower Lachlan Alluvium; however the vertical to horizontal ratios are the same.

Available information for the Belubula Alluvium indicates that bores can yield up to 500 megalitres per year.

[10] Surface Water–Groundwater interactions in the Belubula Catchment. October 2010. Paper prepared for Department of Sustainability, Environment, Water, Population and Communities

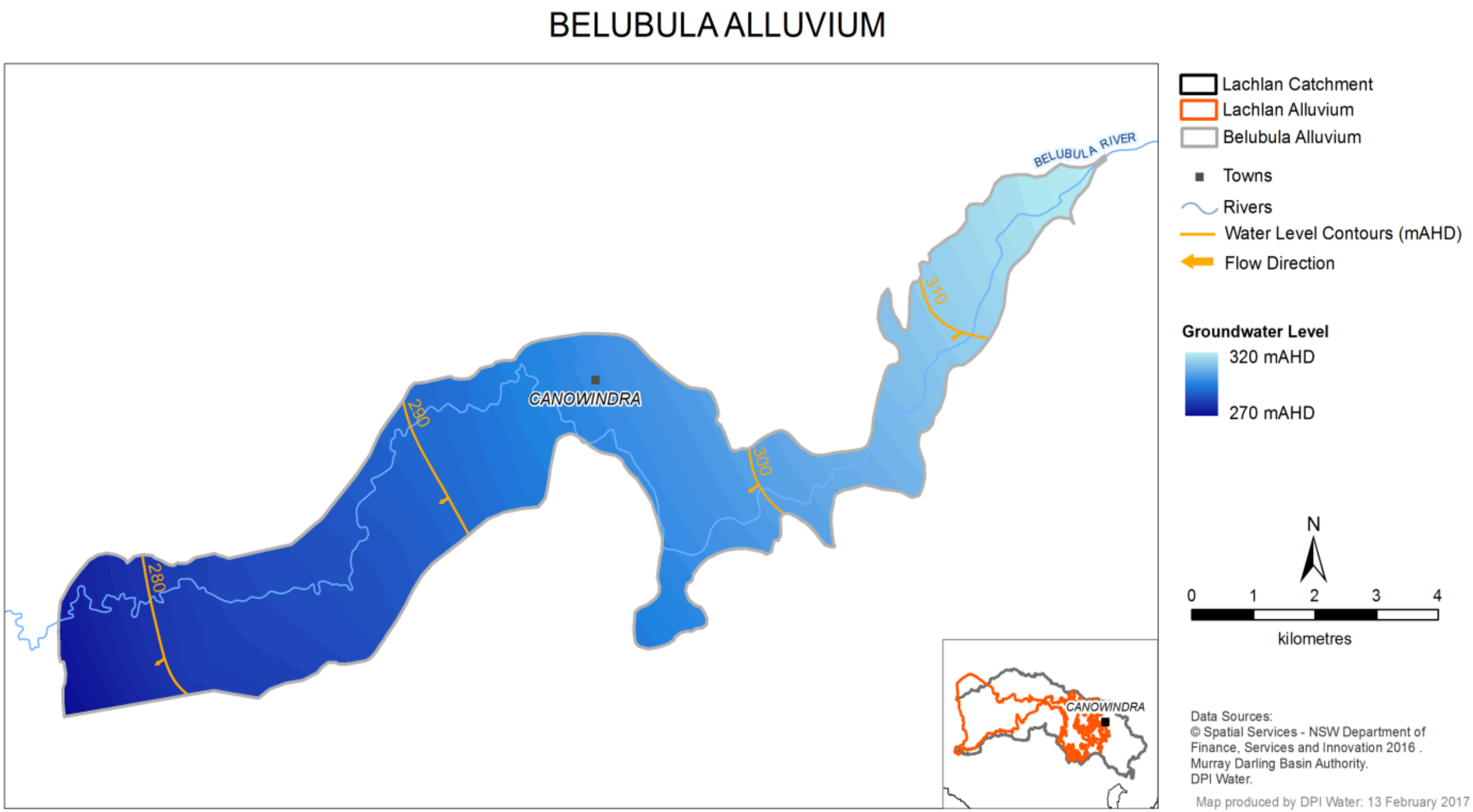

Figure 11 Location map of the Belubula Alluvium showing groundwater flow direction

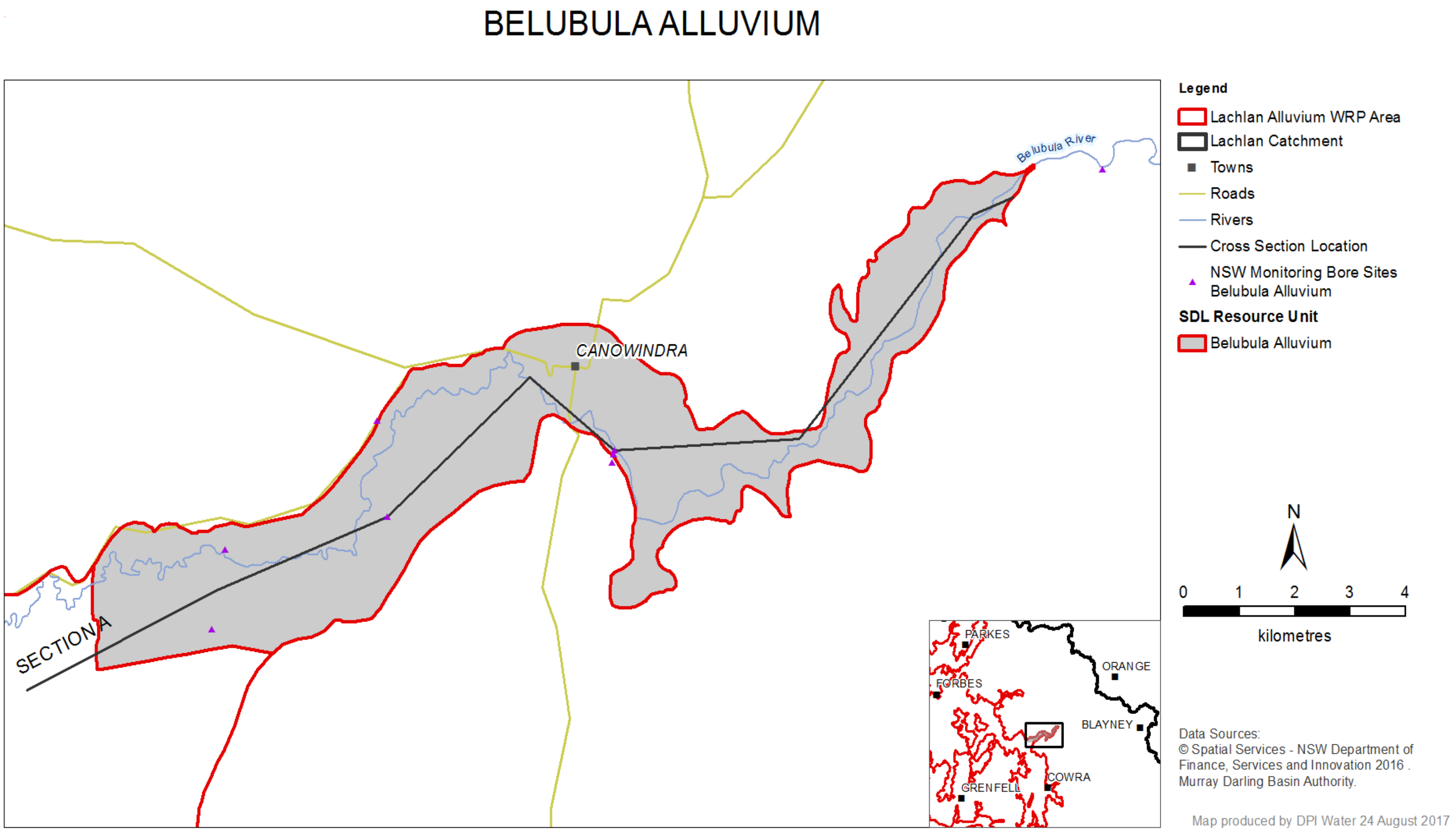

Figure 12 Cross-section location map of the Belubula Alluvium

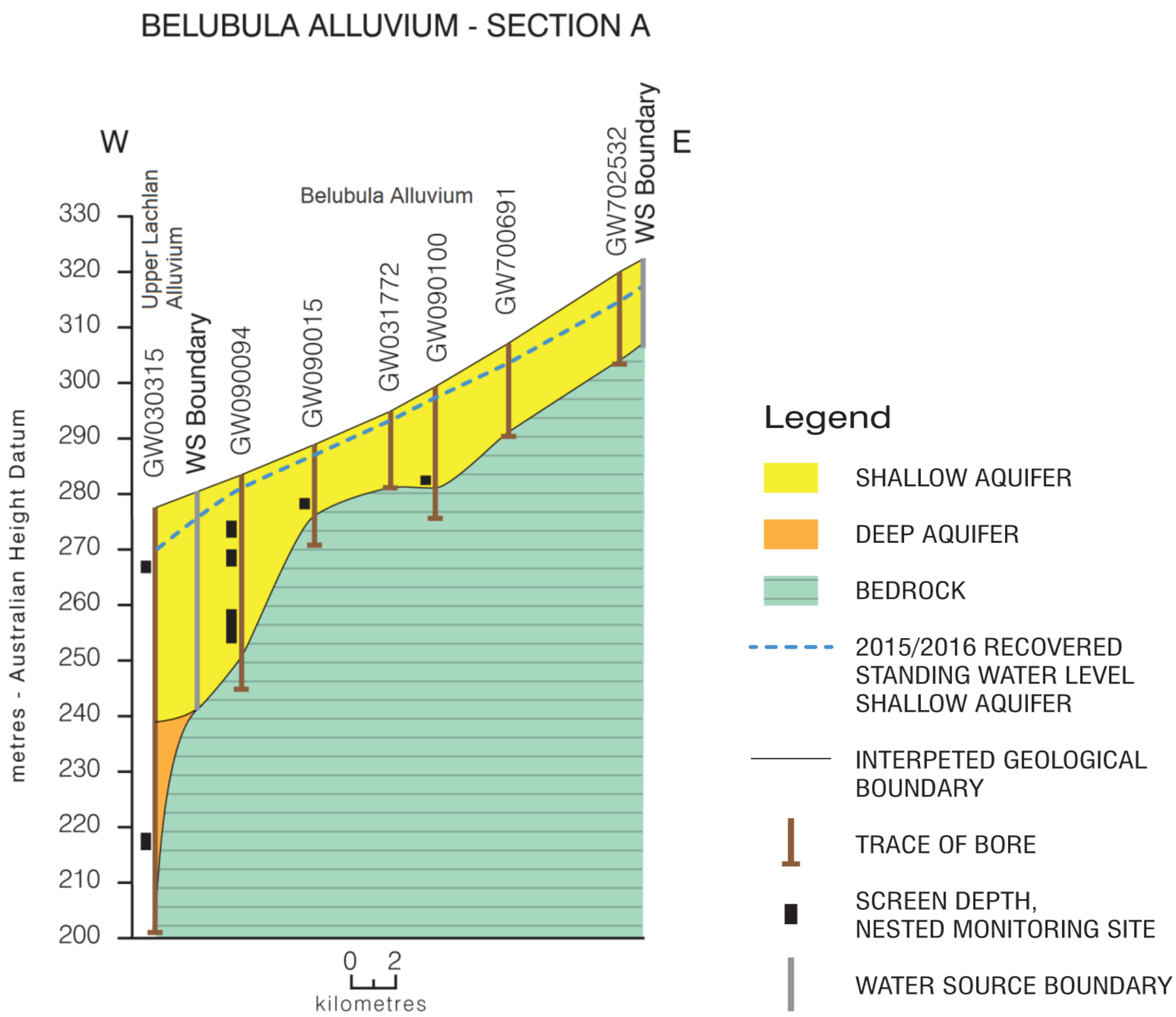

Figure 13 East-west long section through the Belubula Alluvium - Section A

5.3 Upper Lachlan Alluvium

The Upper Lachlan Alluvium (Figure 14) is made up of Cenozoic valley fill alluvial sediments. It extends from approximately 13 km to the northeast of Young through to Lake Cargelligo. The Upper Lachlan Alluvium was deposited in deep paleo-valleys that follow the track of the Lachlan River and its main tributaries reaching a maximum width of approximately 60 km.

The water-bearing sands and gravels within the alluvial sediments of the Upper Lachlan Alluvium are broadly divided into two main aquifer systems: a shallow aquifer system between 35 and 60 m deep, and a deep aquifer system up to a maximum of 150 m deep. The shallow unconfined/semi-confined aquifer is referred to as the Cowra formation[9] and the deeper semi confined (and in some cases confined aquifer) is referred to as the Lachlan formation[11]. The shallow aquifer system is in hydraulic connection with the Lachlan River and its tributaries (with exception of Bland Creek) along their length. The dominant recharge processes are direct rainfall infiltration, leakage from the Lachlan River and overbank flood waters (NSW Department of Primary Industries—Water, 2012).

[11] The ‘Cowra and Lachlan formations’ are not recognised as official formation names by the Australian Stratigraphic Commission.

In general, groundwater flows parallel to the Lachlan River system from east to west, as shown on Figure 14 (deep aquifer). An exception occurs immediately northeast of Lake Cowal where pumping has resulted in local groundwater level drawdown.

Figure 15 displays the locations of four geological cross-sections that have been produced for the Upper Lachlan Alluvium. These sections are shown in Figures 16 and 17.

The deep aquifer within Upper Lachlan Alluvium is reported to have the highest yields and is generally considered to have a lower salinity. Within the Upper Lachlan Alluvium, bores constructed in the deeper aquifer system can yield up to 3,400 ML/year. However, the majority of high yield bores produce supplies in the range of 200–1,200 ML/year. The highest yielding bores are located south and immediately west of Forbes.

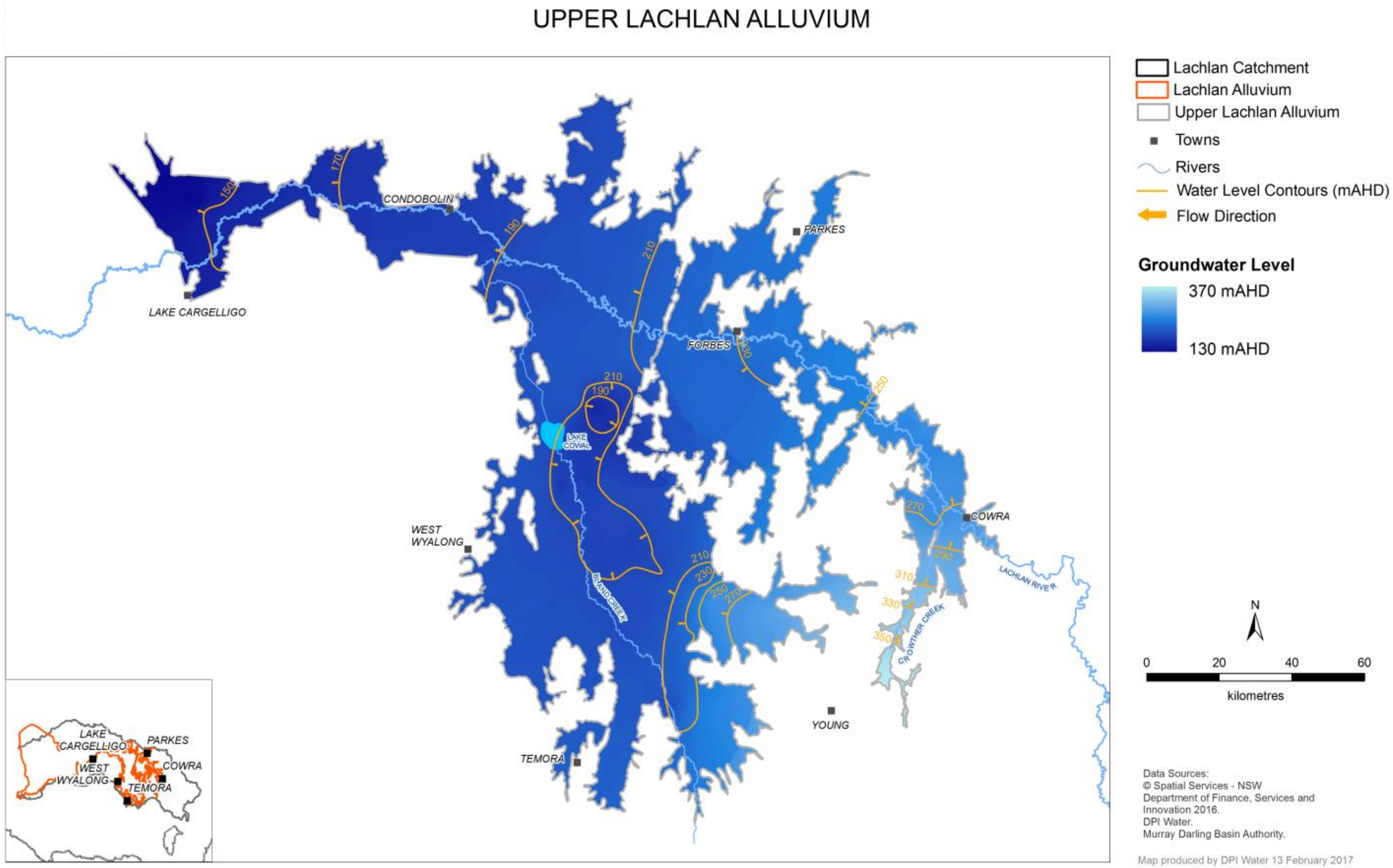

Figure 14 Location map of the Upper Lachlan Alluvium showing groundwater flow direction (deep aquifer)

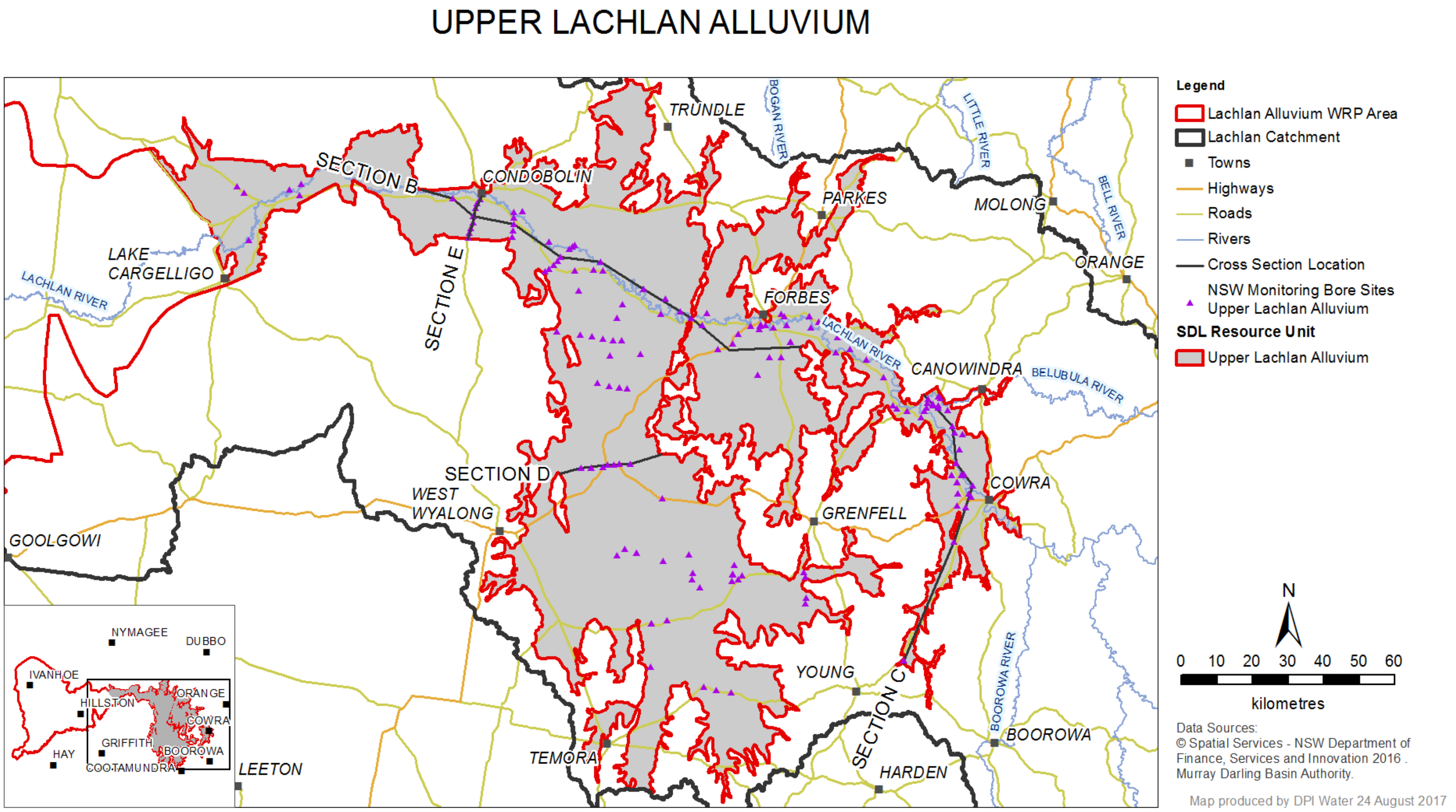

Figure 15 Cross section location map of the Upper Lachlan Alluvium

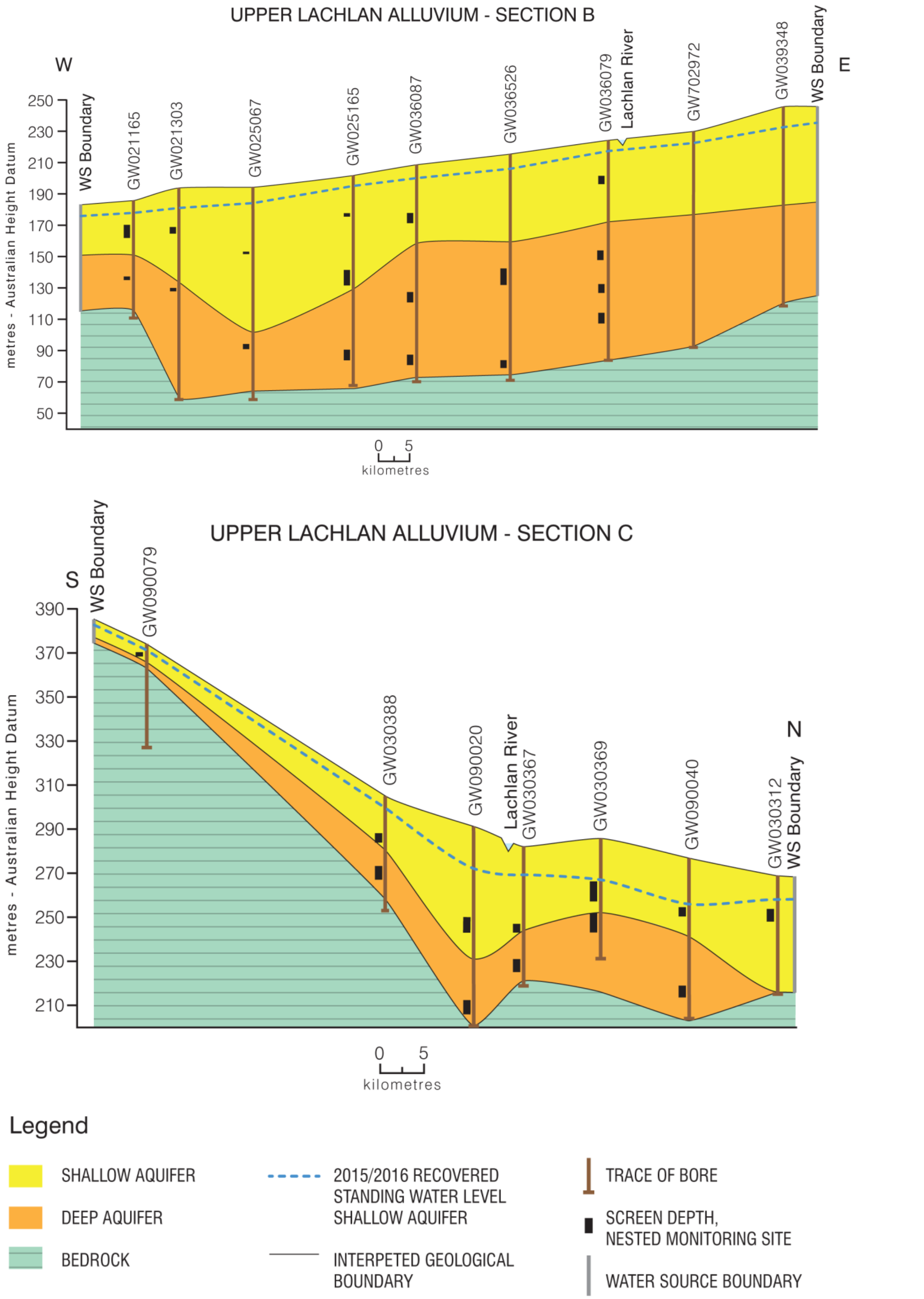

Figure 16 East-west section (Section B) and north-south section (Section C) through Upper Lachlan Alluvium

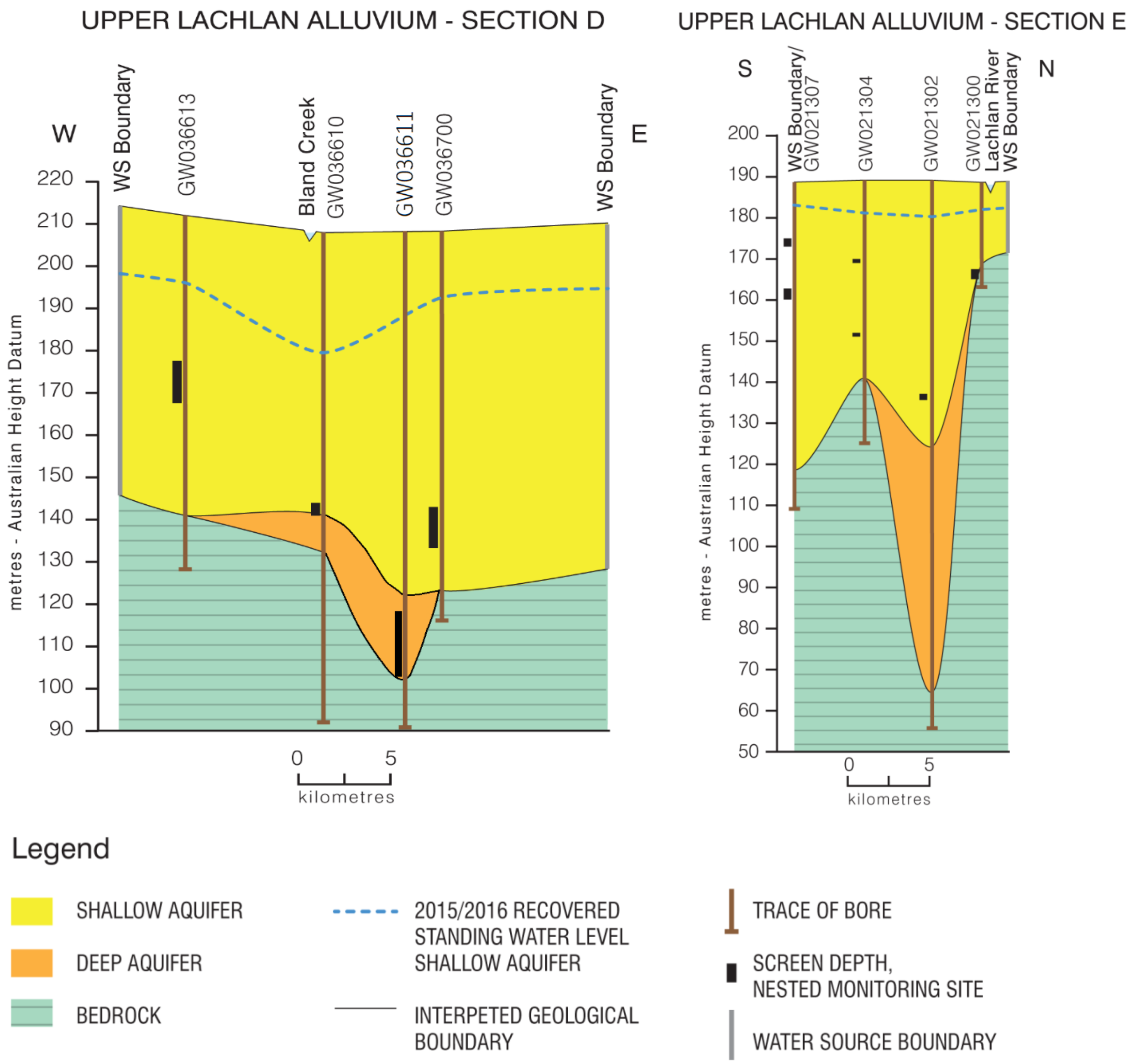

Figure 17 East-west section (Section D) and north-south section (Section E) through Upper Lachlan Alluvium

5.4 Lower Lachlan Alluvium

The Lower Lachlan Alluvium is made up of the Cenozoic alluvial sediments extending from Lake Cargelligo to approximately 25 km west of Ivanhoe and Oxley. These sediments form an extensive alluvial fan deposited by the Lachlan River and its tributaries, comprised of clay, silt, sand and gravel.

The water-bearing sands and gravels within the alluvial sediments of the Lower Lachlan Alluvium are broadly divided into two main aquifer systems: a shallow aquifer system between 55 and 90 m depth, and a deep aquifer system up to a maximum depth of 400 metres. Groundwater flow direction in the deep aquifer is generally to the west (Figure 18).

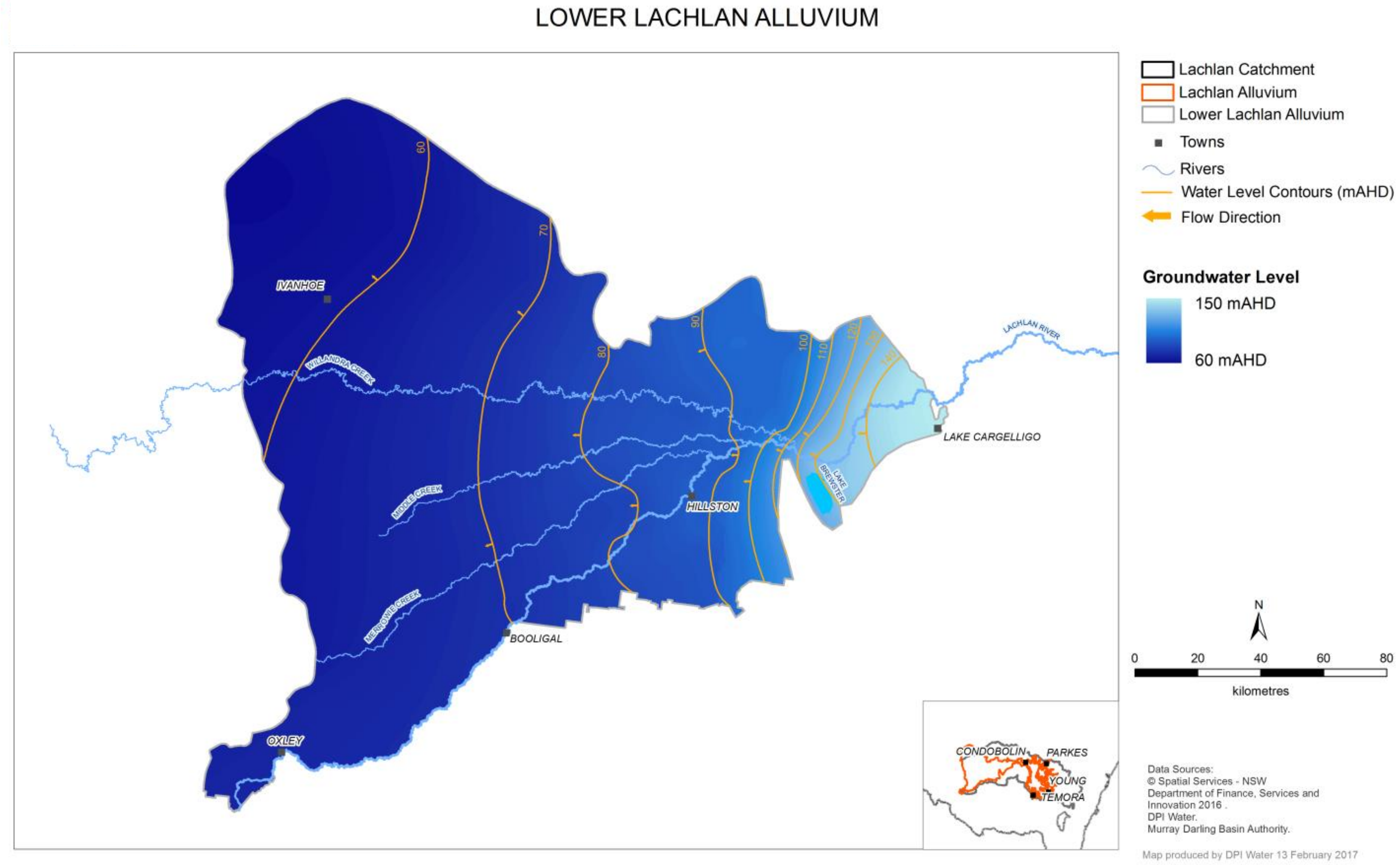

Figure 18 Location map Lower Lachlan Alluvium showing groundwater flow direction (deep aquifer)

There is no laterally continuous horizon or marker layer to define a distinct boundary between the shallow and deep systems; however there is generally some form of hydraulic disconnection at 50 to 70 m that justifies the separation.

Where the boundary occurs, the shallow system is generally separated from the deep system by a relatively impermeable layer of sandy/gravelly clay of variable thickness. The shallow unconfined/semi-confined aquifer is within the Calivil Formation and the deeper semi-confined/confined aquifer is within the Renmark Group sediments. The overlying Shepparton Formation is mostly unsaturated within the Lower Lachlan Alluvium, except in the eastern upper reaches of the water source. No licenced production bores are reported to be installed within the Shepparton Formation.

Figure 19 shows the location of four geological cross-sections that have been produced for the Lower Lachlan Alluvium:

- a long-section through the Lower Lachlan Alluvium that extends across the entire length of the water source (Section F, Figure 20). The water level height can be seen to follow the east to west groundwater flow direction previously mapped.
- Figures 21 a north-south section, section G; and,
- Section H (Figure 22) and the Hillston section also displayed in Figure 22.

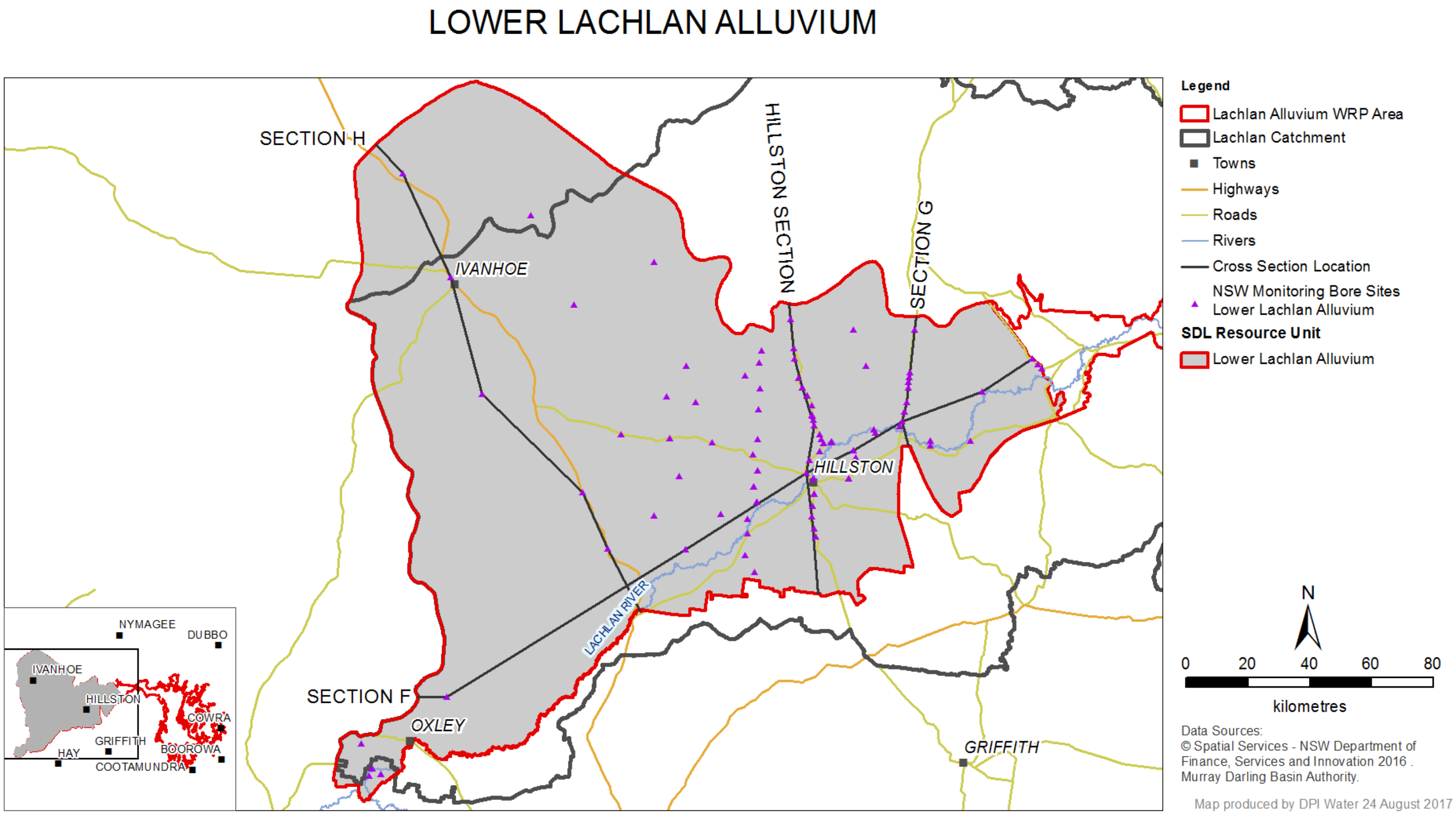

Figure 19 Cross section location map of the Lower Lachlan Alluvium

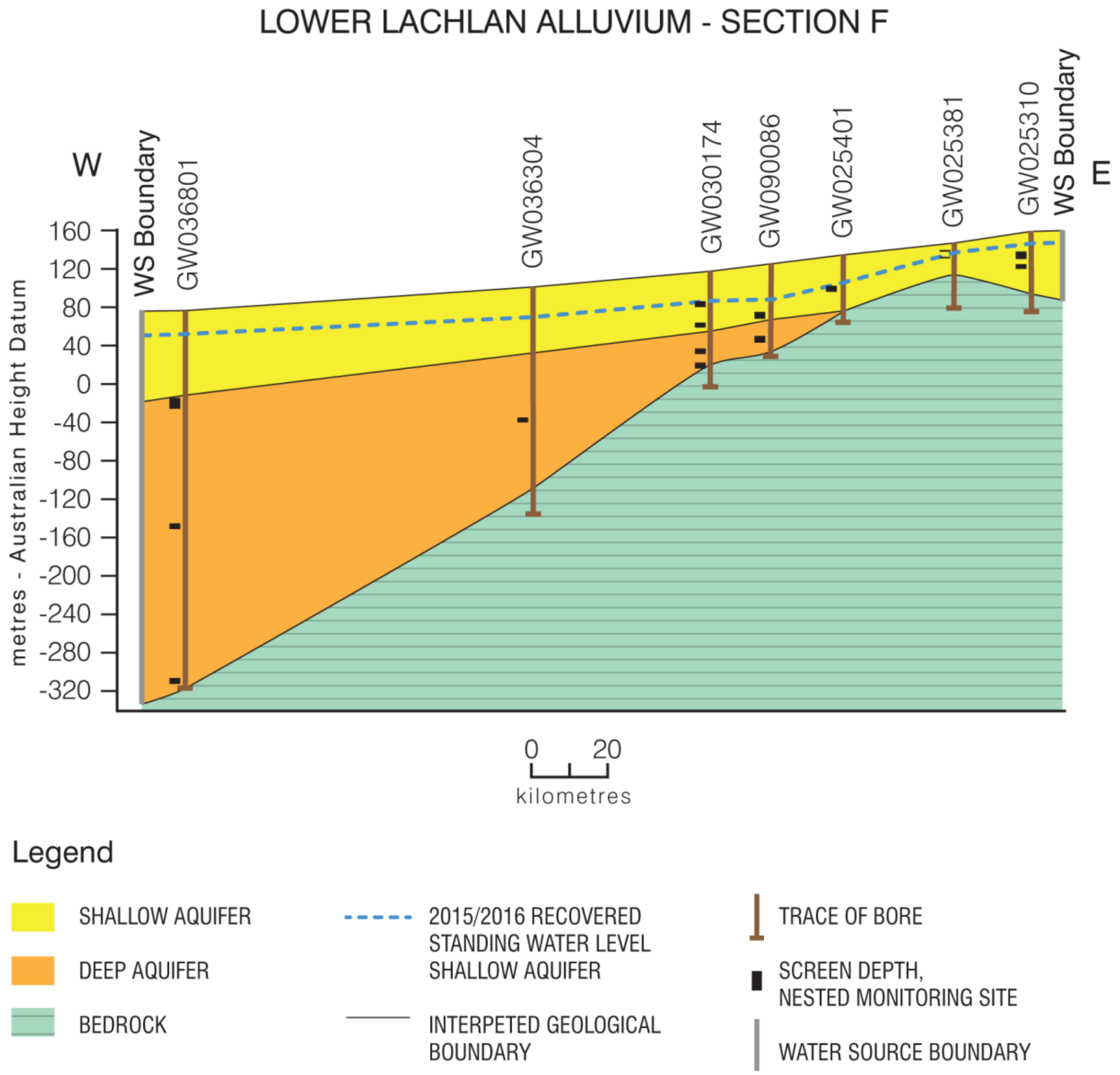

Figure 20 East-west section (Section F) through Lower Lachlan Alluvium

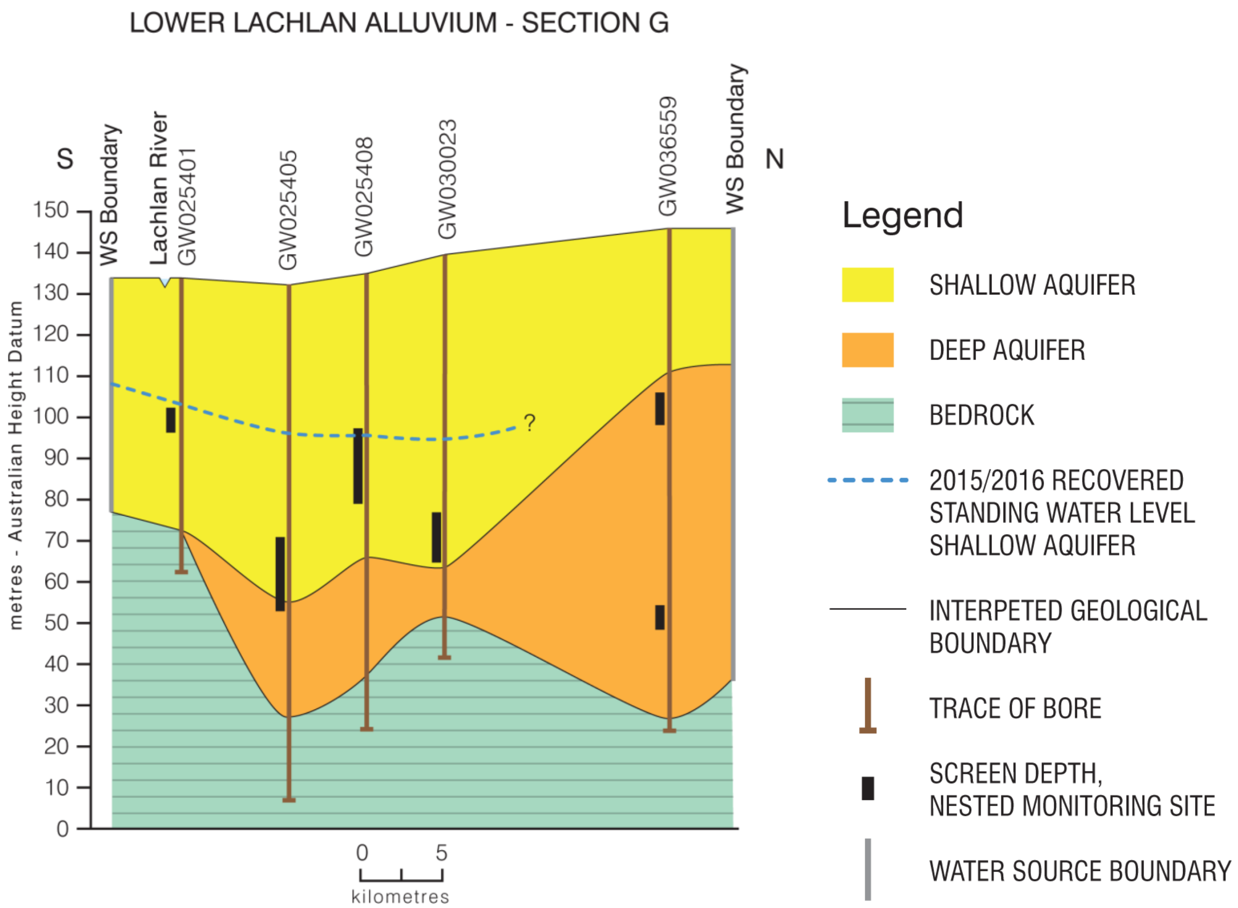

Figure 21 North-south section (Section G) through Lower Lachlan Alluvium

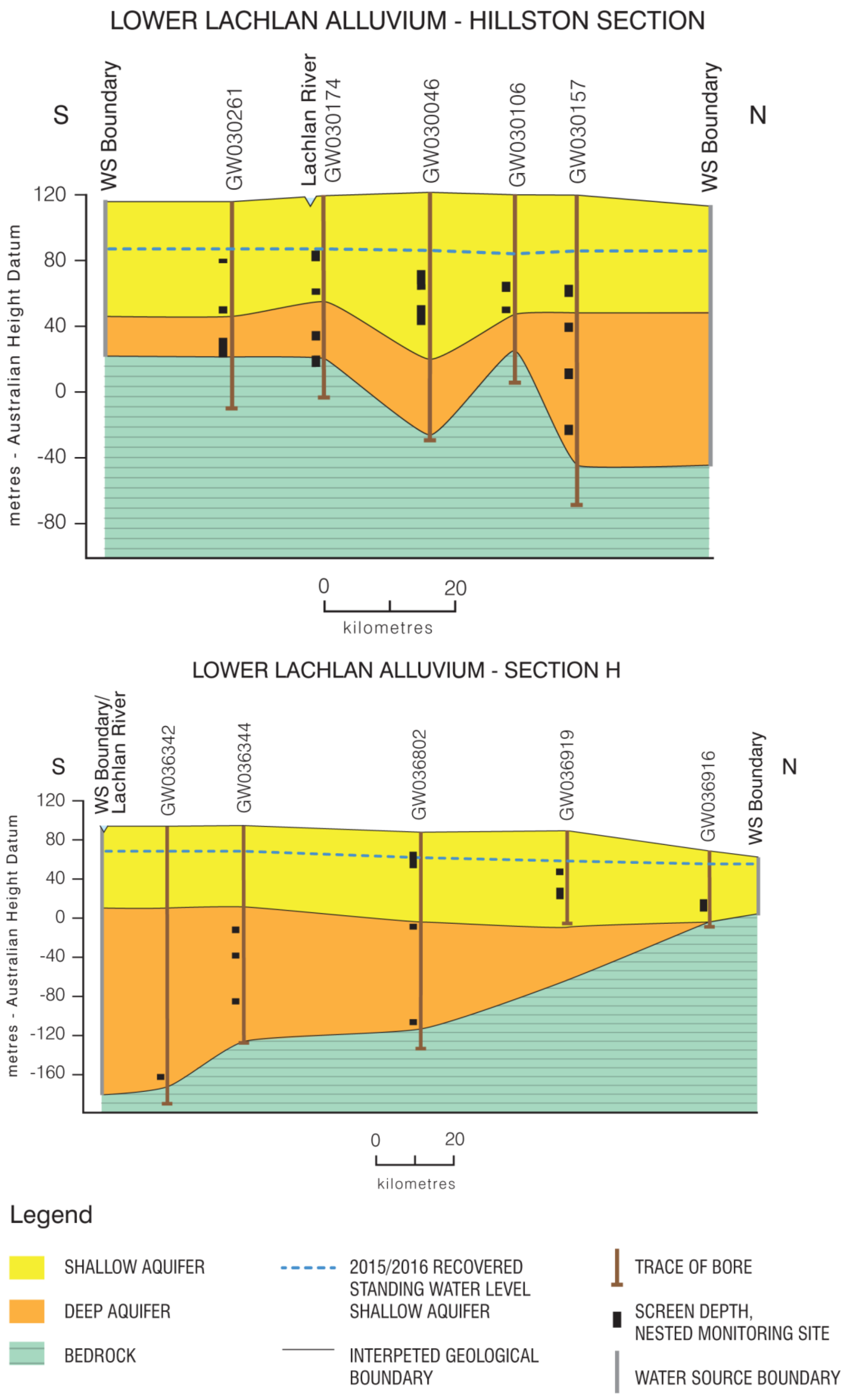

Figure 22 North-south sections (Hillston Section and Section H) through Lower Lachlan Alluvium

Within the Lower Lachlan Alluvium bores constructed in the deeper aquifer system have reported yields of up to 7,000 ML/yr. However, the majority of high yield bores produce supplies in the range of 1,100 ML/yr of low salinity water suitable for irrigation purposes. The highest yielding bores are located in the area near Hillston.

Conceptually, the dominant recharge process for the Lower Lachlan Alluvium is direct rainfall infiltration and river/flood leakage.

The main discharge in the Lower Lachlan Alluvium is extraction for irrigation and through flow towards the west.

5.5 Connection with surface water

The Belubula Alluvium is considered to be highly connected to the regulated Belubula River. Data from monitoring site GW090014 (refer to Section 10.3) shows the groundwater responds quickly to changes in the river levels. It demonstrates the connectivity between the surface and groundwater resources within the Belubula Alluvium. This high level of hydraulic connection is recognised in the Water Sharing Plan rules for the Belubula Alluvium resource unit.

In the Upper Lachlan Alluvium, the Lachlan River varies between losing and gaining conditions along its length, depending on geology, topography, local conditions and prevailing long-term climatic conditions. Although the Lachlan River is considered to be hydraulically connected with the Upper Lachlan Alluvium, due to the depth and width of the alluvium, groundwater pumping impacts at the river are subdued and/or delayed. This lag time of groundwater pumping impacts is acknowledged in setting the extraction limit of the resource; however the Upper Lachlan Alluvium is managed independently from the river.

The greater depth to the regional water table in the Lower Lachlan Alluvium results in the Lachlan River and its tributaries to be largely hydraulically disconnected from the groundwater for much of their reaches. That is, whilst the Lachlan River would lose water into the underlying alluvium, the rate of loss is not influenced by groundwater pumping. Further analysis of the interconnection between surface water and groundwater in the Lower Lachlan Alluvium near Hillston is given by Lamontagne et al (2011).

6 Groundwater-Dependent Ecosystems

Groundwater-dependent ecosystems (GDEs) are defined as '*ecosystems that require access to groundwater to meet all or some of their water requirements so as to maintain their communities of plants and animals, ecological processes and ecosystem services*' (modified from Richardson et al, 2011).

The NSW Department of Planning and Environment has developed a method for the identification of high probability groundwater-dependent vegetation ecosystems (Kuginis et al, 2016) and associated ecological value (Dabovic et al. in preparation). This process has identified a number of vegetation GDEs in the upper and lower parts of the Lachlan catchment. Expected ecological value of these vegetation GDEs identified within the Lachlan catchment is shown in Figure 23.

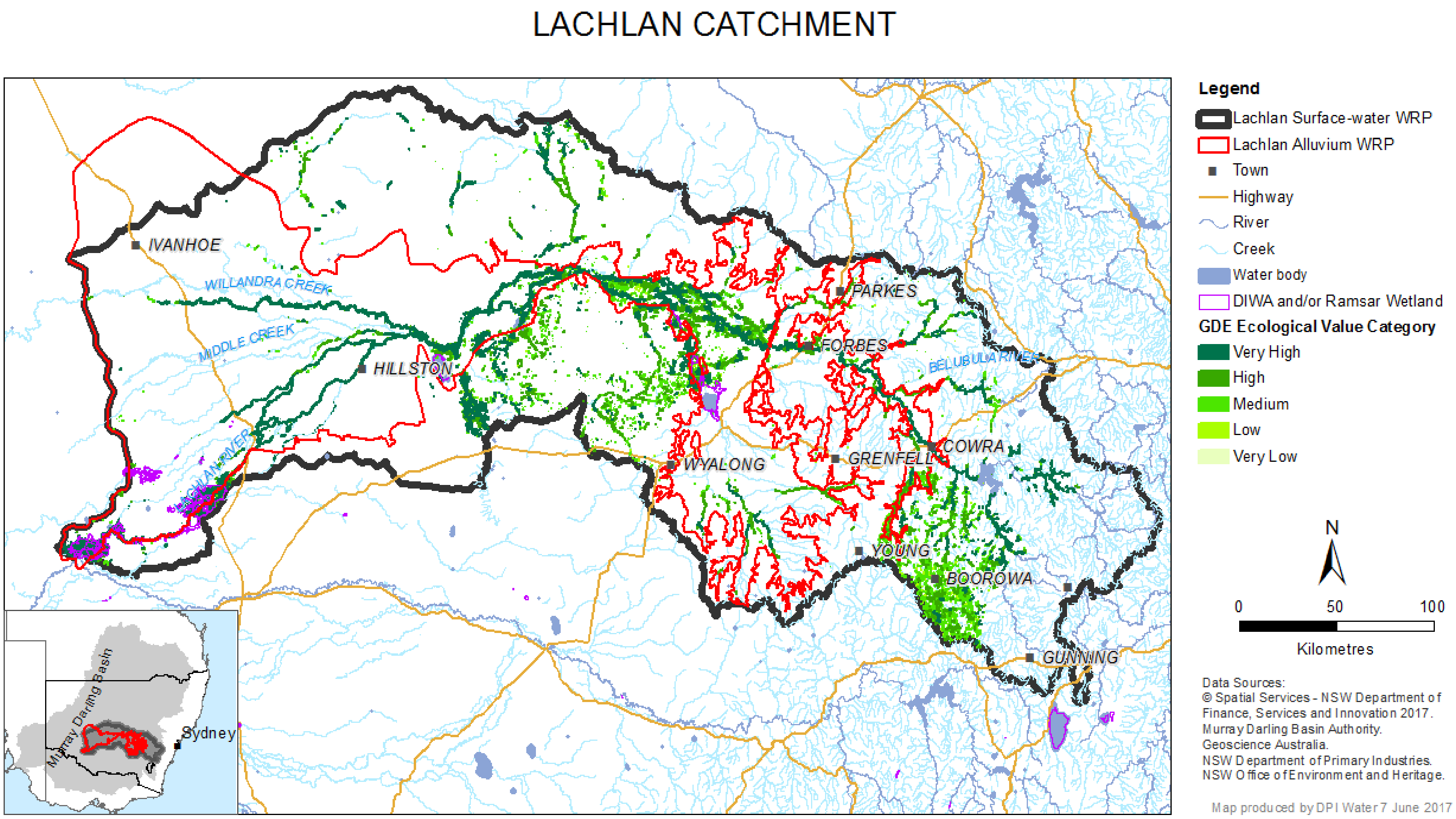

Figure 23 Ecological value for high probability groundwater-dependent vegetation ecosystems of the Upper Lachlan

According to the mapping exercise, the Lachlan Alluvium supports significant GDEs of ecological value including endangered ecological communities (EECs), threatened species, vegetation, and base flow ecosystems.

The high probability existence GDEs in the Lachlan Alluvium WRP area (Figure 23) are classified as high to very high ecological value across the Upper and Lower Lachlan alluvium.

River Red Gum—Lignum and River Red Gum—Black Box communities dominate both Upper and Lower Lachlan alluvium in the riparian and floodplain. There is a high number of recorded threatened bird and flora species. The Lachlan River EEC, Inland Grey, Yellow and Red Box Woodland are also located within these groundwater sources. Habitat diversity is also very high in this area, providing extensive riparian corridors as vital habitat for important bird and mammal species. Vital habitat and naturalness is higher in the Lower Lachlan Alluvium, with very high and high values, whilst in the Upper Lachlan Alluvium there are medium to low values (Dowsley K, 2012).

7 Groundwater Quality

Water quality describes the condition of water within a water source and its related suitability for different purposes. The water quality characteristic of a groundwater system influences how that water is used by humans i.e. for town water or stock and domestic supply, or for commercial purposes such as farming and irrigation. If water quality is not maintained, it can impact on the environment as well as the commercial and recreational value of a groundwater resource.

One measure of quality most relevant to the end use is the level of salt present in groundwater, or groundwater salinity. This is determined by measuring the electrical conductivity (EC) and is generally reported in microsiemens per centimetre (µS/cm). An EC value of 2,500 µS/cm approximates 1,500 mg/L TDS, which is the recognised upper threshold for drinking water supply.

In NSW, groundwater salinity levels can range from that of rainwater (<250 µS/cm) to greater than that of sea water (~60,000 µS/cm). Groundwater with salinity suitable for a range of productive uses is generally found in the large unconsolidated alluvial systems associated with the major westward draining rivers.

Groundwater suitability can be changed by contaminants infiltrating into the groundwater system. This can be from spills or leaks onto the land surface but it can also occur more broadly from the overlying land use. Seasonal variations and longer-term changes in climate as well as groundwater extraction can all affect groundwater quality.

7.1 Belubula and Upper Lachlan Alluvium

The NSW Government monitoring bores were sampled for salinity at the time of their construction; however groundwater quality data collection from the Belubula and Upper Lachlan Alluvium has subsequently been sporadic.

Groundwater quality data in the Belubula Alluvium based on groundwater samples from monitoring bores at the time of construction is very fresh (< 1,500 uS/cm), similar to quality in the Belubula River. This indicates that groundwater is suitable for drinking water supply.

Across the Upper Lachlan Alluvium, salinity in groundwater samples from groundwater monitoring bores at the time of construction ranged from100 µS/cm close to the rivers to more than 40,000 µS/cm on the outer limits of the alluvium. The quality in the shallow and deep aquifers is quite variable, but is generally < 2,500 µS/cm upstream from the village of Fairholme. Downstream and to the south from Fairholme the salinity in the shallow aquifer is variable and generally > 2,500 µs/cm.

7.2 Lower Lachlan Alluvium

Groundwater salinity in both the shallow and deep aquifers of the Lower Lachlan Alluvium is low and generally less than 2,500 µS/cm east of the Cobb Highway. The lowest salinity groundwater occurs closest to Lachlan River near Hillston. To the west salinity increases, exceeding 40,000µS/cm.

The former NSW Office of Water and the National Water Commission commissioned groundwater quality analysis (Parsons Brinkerhoff, 2011) that involved water quality and isotope sampling from select group of monitoring bores in the Lower Lachlan Alluvium, centred on the township of Hillston between October 2009 and January 2011.

Groundwater samples were taken on a monthly basis at seven sites, with an additional 16 sites monitored on a three-monthly basis. Surface water sampling was undertaken at two locations on the Lachlan River on a monthly basis. In total, 233 groundwater samples and 18 surface water samples were analysed.

The main finding of this study relating to salinity is that groundwater in both aquifer systems in the study area is fresh (271 -1,795 µS/cm in the shallow aquifer and 456 -1,350 µS/cm in the deep aquifer), and is suitable for multiple beneficial uses including drinking water supply, irrigation and stock water supply. No significant long-term increasing trends in salinity were identified.

8 Groundwater Management

Whilst the Lachlan Alluvium forms a large laterally continuous and hydraulically connected system, for management purposes it has been subdivided into three separate management units.

Groundwater in the Upper Lachlan Alluvium and Belubula Alluvium are managed under the *Water Sharing Plan for the Lachlan Unregulated and Alluvial Water Sources 2012*. Groundwater in the Lower Lachlan Alluvium is managed under the *Water Sharing Plan for the Lower Lachlan Groundwater Source 2003.* The Belubula Valley Alluvial, Upper Lachlan Alluvial and the Lower Lachlan groundwater sources in these water sharing plans correlate directly to the three SDL resource units in the Lachlan WRP.

The Lachlan Alluvium sits over and adjacent to the fractured rock management units of the Lachlan Fold Belt and the Kanmantoo Fold Belt. These fractured rocks have very different hydrogeological characteristics and are not considered to be hydraulically connected in a resource management sense to the groundwater resources in the alluvium. Groundwater in these management units are managed under the Water Sharing Plan for the NSW Murray–Darling Basin Fractured Rock Groundwater Sources 2011.

8.1 Access rights

Groundwater access licenses for the Belubula Alluvium, Upper Lachlan Alluvium and the Lower Lachlan Alluvium are shown in Table 1.

Supplementary water access licences were issued to some licence holders in the Lower Lachlan Alluvium that provided temporary access to water to adjust to the reduction in entitlements at the commencement of the water sharing plan. The volume of water available under the supplementary water access licences have gradually decreased each year. These licences will be cancelled at the end of the 2017–18 water year.

The local water utility access licences are held by local government for town water supply purposes and the share component is for a specified volume of groundwater. The share components of aquifer access licences and aquifer access licence (high security) are issued for a specified number of unit shares (Table 1).

Table 1 Access licences in the Lachlan Water Resource Plan Area (at May 2017).

Access Licence Category	Belubula Alluvium Share Component	Upper Lachlan Alluvium Share Component	Lower Lachlan Alluvium Share Component
Local Water Utility (ML/year)	0	7,848	2,922
Aquifer (unit shares)	0	165,538	105,078
Aquifer (High Security) (unit shares)	8,250	0	0

Owing to the high level of connection of the alluvium with the regulated Belubula River, groundwater available under the licence category 'aquifer access licence (high security)' in the Belubula Alluvium is linked to the availability of high security allocations in the regulated Belubula River.

8.2 Extraction limits

Extraction in a groundwater source is managed to the long-term average annual extraction limit (LTAAEL) set by the water sharing plan.

Water resource plans will set limits, in the same way as water sharing plans, on the quantities of water that can be taken from Basin water resources. These limits are known as sustainable diversion limits (SDLs). Under the water resource plans, NSW will continue to manage extractions to the LTAAEL, ensuring compliance with the SDLs.

Table 2 lists the LTAAEL (including basic landholder rights) for the Belubula Alluvium, Upper Lachlan Alluvium and the Lower Lachlan Alluvium as well as the SDL for each area. The SDL for Lower Lachlan Alluvium includes a revised estimate for basic landholder rights.

Table 2 LTAAEL for the Belubula, Upper Lachlan Alluvium and Lower Lachlan Alluvium compared to the SDL (at May 2017)

Water Source	LTAAEL ML/yr	SDL ML/yr
Belubula Alluvium	2,883	2,883
Upper Lachlan Alluvium	94,168	94,168
Lower Lachlan Alluvium	112,000	117,000

To manage any growth in extraction in excess of the LTAAEL, water sharing plans set a trigger for complying with the extraction limit.

Figures 24, 25 and 26 show the annual groundwater extraction from the Belubula, Upper Lachlan and Lower Lachlan respectively since commencement of the water sharing plans. The data includes basic landholder rights. The figures also display for comparison, the LTAAEL and the trigger set by each respective water sharing plan to initiate a management response to ensure there is no growth in extraction above the LTAAEL in the long term.

The *Water Sharing Plan for the Lachlan Unregulated and Alluvial Water Sources 2012* allows an additional 10% extraction above LTAAEL in the Belubula Valley Alluvial and Upper Lachlan Alluvial groundwater sources before triggering a reduced available water determination.The *Water Sharing Plan for the Lower Lachlan Alluvial Water Sources 2006* only allows an additional 5% above LTAAEL before triggering a reduced available water determination. In addition, the average annual extraction for the Belubula and Upper Lachlan Alluvium are calculated based on a ‘rolling’ average of the preceding five water years (including years prior to the commencement of the plan). For the Lower Lachlan Alluvium, average annual extraction is calculated based on a three-year ‘rolling’ average of the previous three years, excluding years prior to the commencement of the plan.

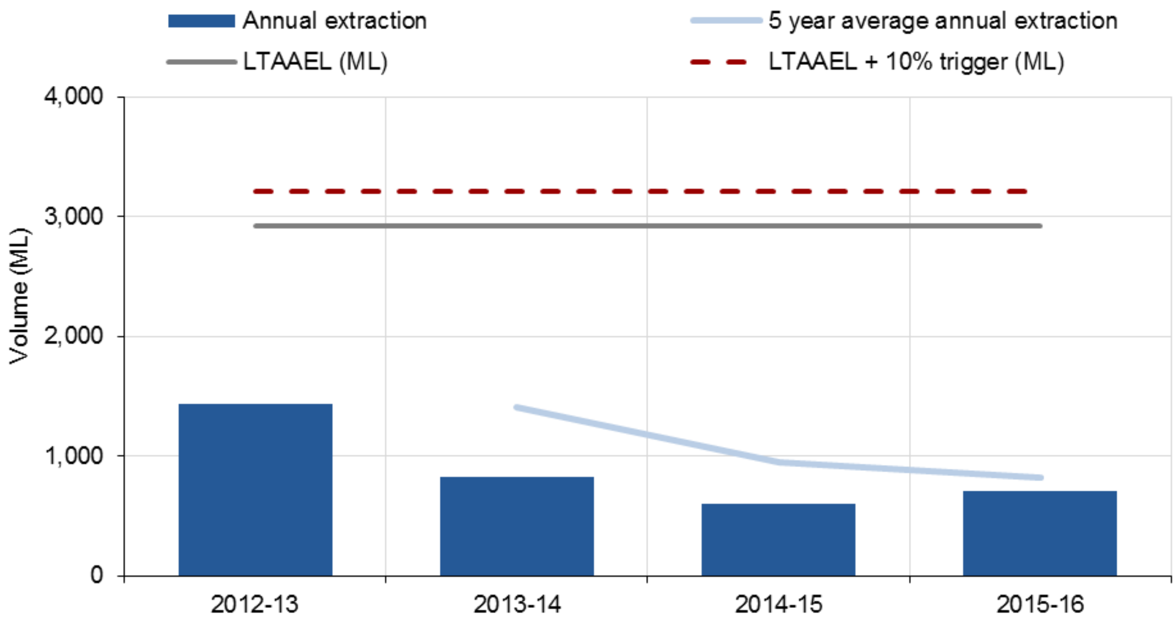

Figure 24 Belubula Alluvium annual extraction compared to the LTAAEL

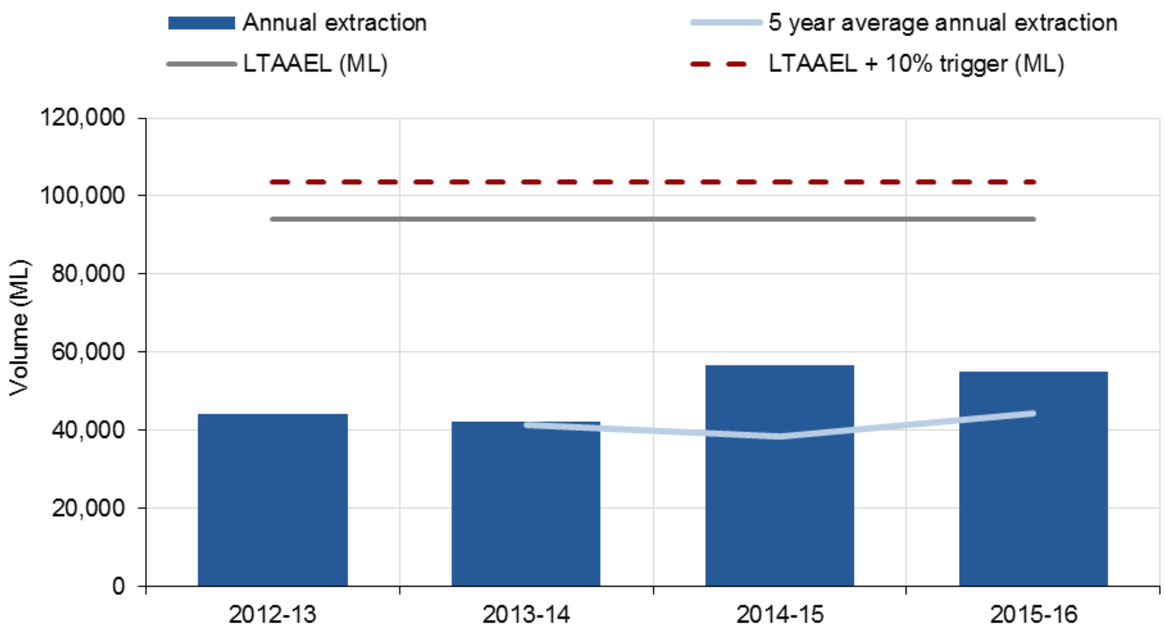

Figure 25 Upper Lachlan Alluvium annual extraction compared to the LTAAEL

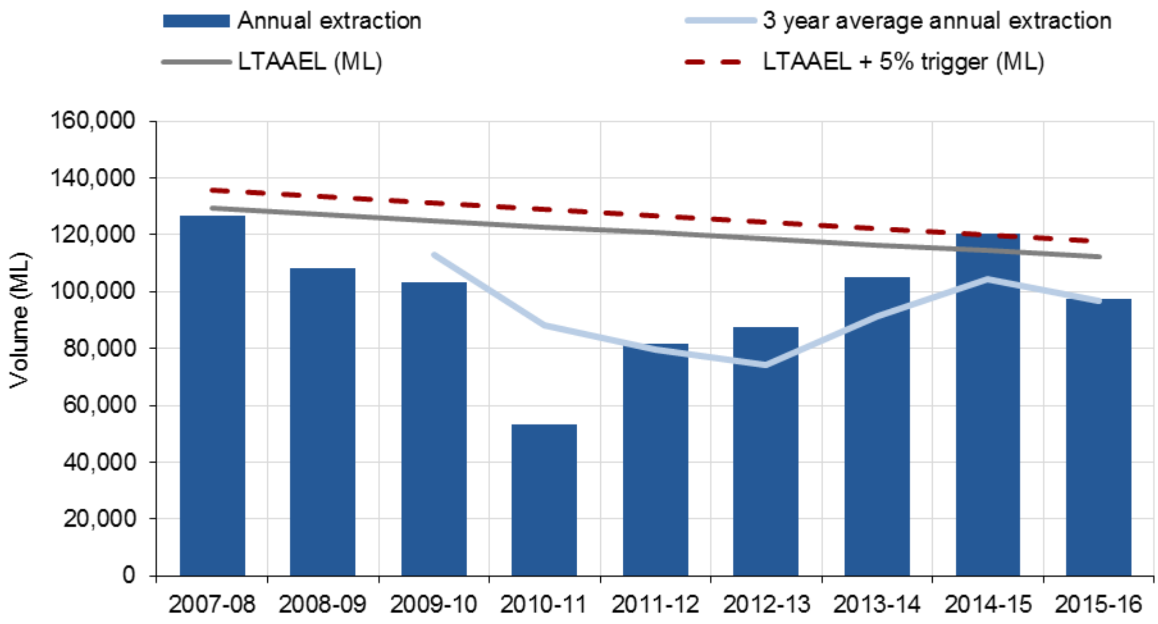

Figure 26 Lower Lachlan Alluvium annual extraction compared to the LTAAEL

8.3 Available water determinations

An available water determination is made at the start of each water year that sets the allocation of groundwater for the different categories of access licence.

The available water determination for high security aquifer access licences in the Belubula Alluvium is linked to the available water determination for the high security regulated river licences. Since the commencement of the water sharing plan this has been 100% access, therefore the available water determination for aquifer access (high security) licences in the Belubula Alluvium has remained at one megalitre per share.

The available water determination for aquifer access licences in the Upper Lachlan Alluvium has been set at one megalitre per share (i.e. 100% access) every year since the commencement of the water sharing plan. The local water utility access licences have been set at 100% every year for the same periods.

The available water determination for each licence category in the Lower Lachlan Alluvium for each year since commencement of the water sharing plan is shown in Figure 27. The available water determination for aquifer access licences has been set at one megalitre per share and for local water utility access licences has been set at 100% every year since the water sharing plan commenced.

The available water determination for supplementary water access licences (SWAL) in the Lower Lachlan Alluvium has been set by the water sharing plan for each year of the plan until 2017–18. Supplementary water access licence allocations decreased each year from 2007–08 to 2017–18.

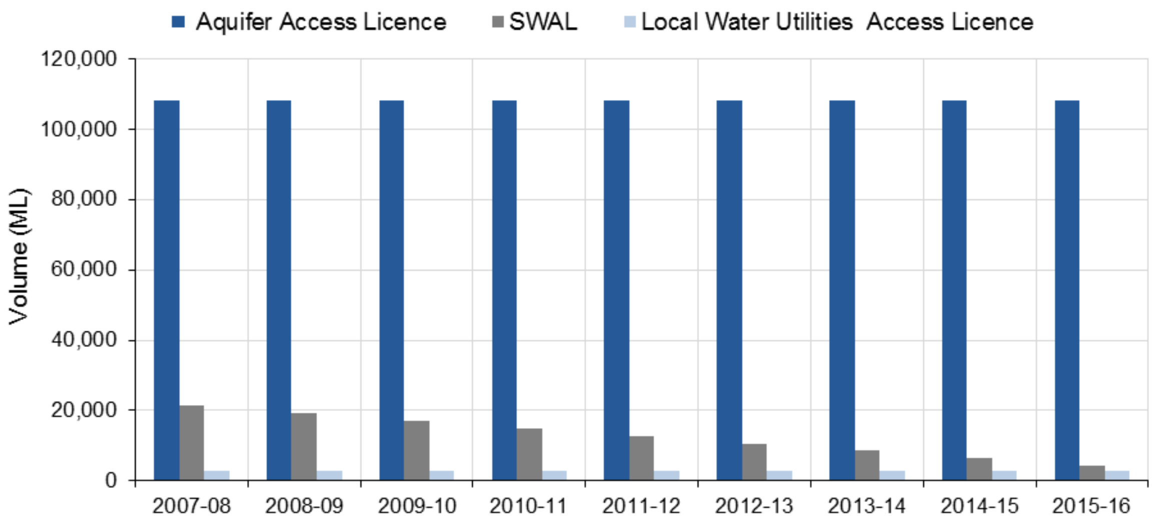

Figure 27 Annual allocations for the Lower Lachlan Alluvium

8.4 Groundwater accounts

Under a water sharing plan, a water allocation account is established for each water access licence. Water is credited to the account when an available water determination is made or when water is traded in, and debited from the account when water is physically taken or traded out.

The water sharing plans allow for accrual of unused allocation in aquifer access licence accounts. This includes the yearly allocations for the aquifer access licences made through available water determinations, plus any carryover of unused allocation up to a maximum of:

- 1 ML per unit of share component for Lower Lachlan Alluvium,
- 0.25 ML per unit of share component for Belubula Alluvium, and
- 0.20 ML per unit of share component for Upper Lachlan Alluvium.

Local water utility and domestic and supplementary access licences do not have any provisions for carryover. The maximum amount of water that can be debited from an account in any one water year (i.e. account take limit) in the Lower Lachlan Alluvium cannot exceed 1.5 ML per unit share component plus any allocation transferred in, and minus any allocation transferred out. This means that metered extraction plus transfers out cannot exceed 150 % of the of share component, unless water is transferred in. For Belubula and Upper Lachlan Alluvium, the yearly extraction cannot exceed 125% and 120% respectively unless water is transferred in. Figures 28, 29 and 30 show the volumes held in water accounts for the Belubula, Upper Lachlan and Lower Lachlan Alluvium since commencement of the water sharing plans.

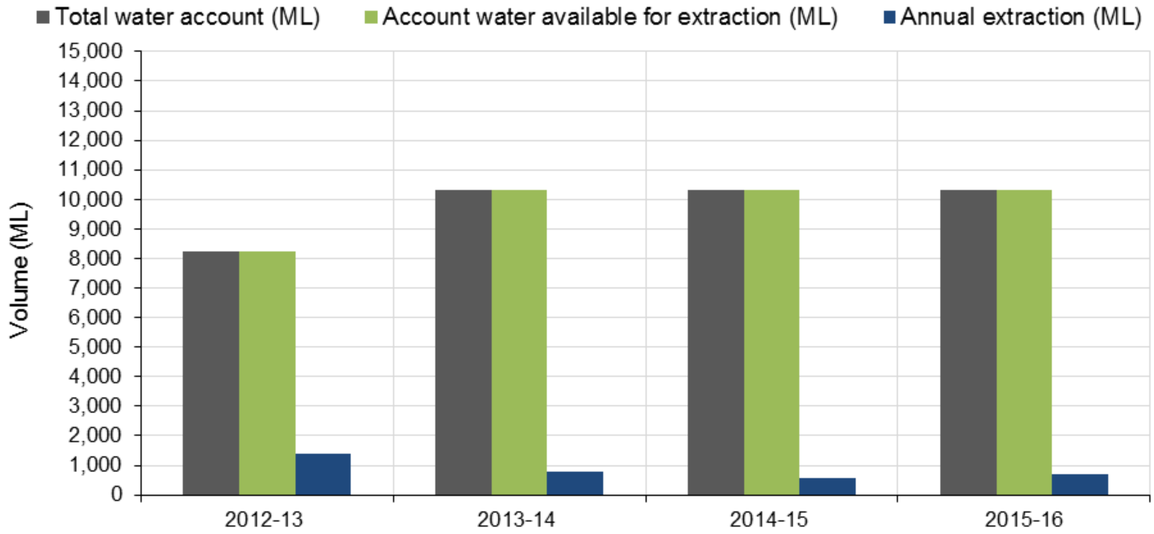

Figure 28 Water accounts since the commencement of the water sharing plan for the Belubula Alluvium

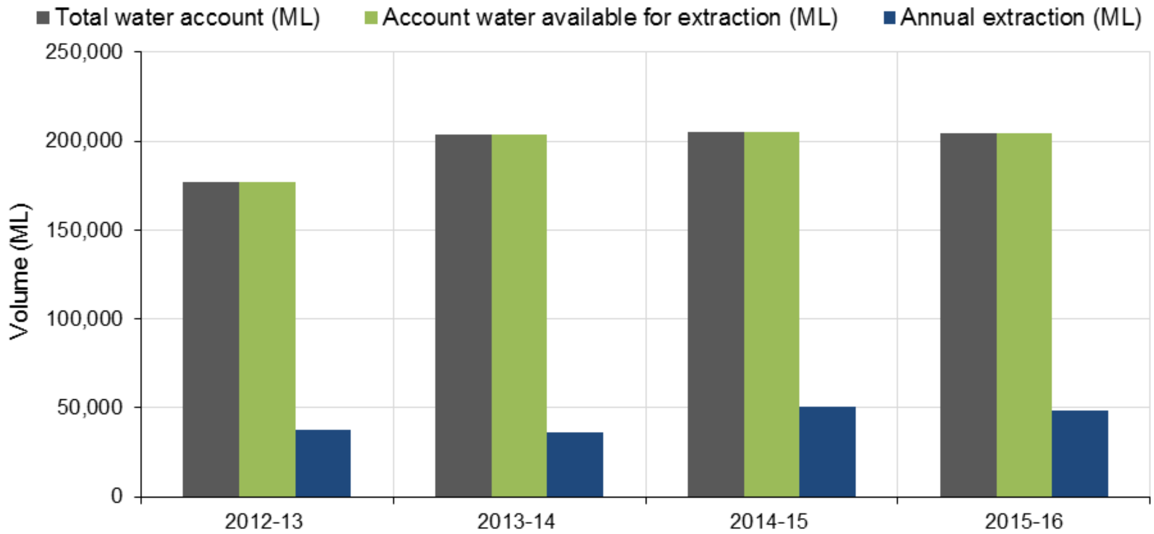

Figure 29 Water accounts since the commencement of the water sharing plan for the Upper Lachlan Alluvium

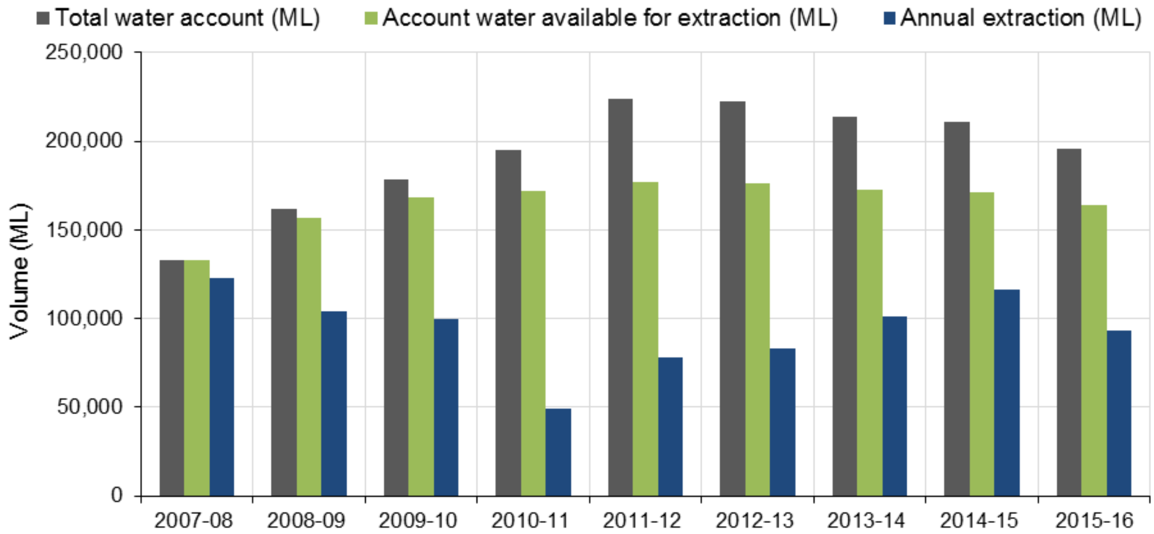

Figure 30 Water accounts since the commencement of the water sharing plan for the Lower Lachlan Alluvium

8.5 Groundwater take

Groundwater is taken and used in the Lachlan valley for productive purposes such as irrigation and industry, as well as for water supply for local water utilities and stock and domestic use. Figures 31, 32 and 33 illustrate the distribution of water supply bores across the Lachlan groundwater resources.

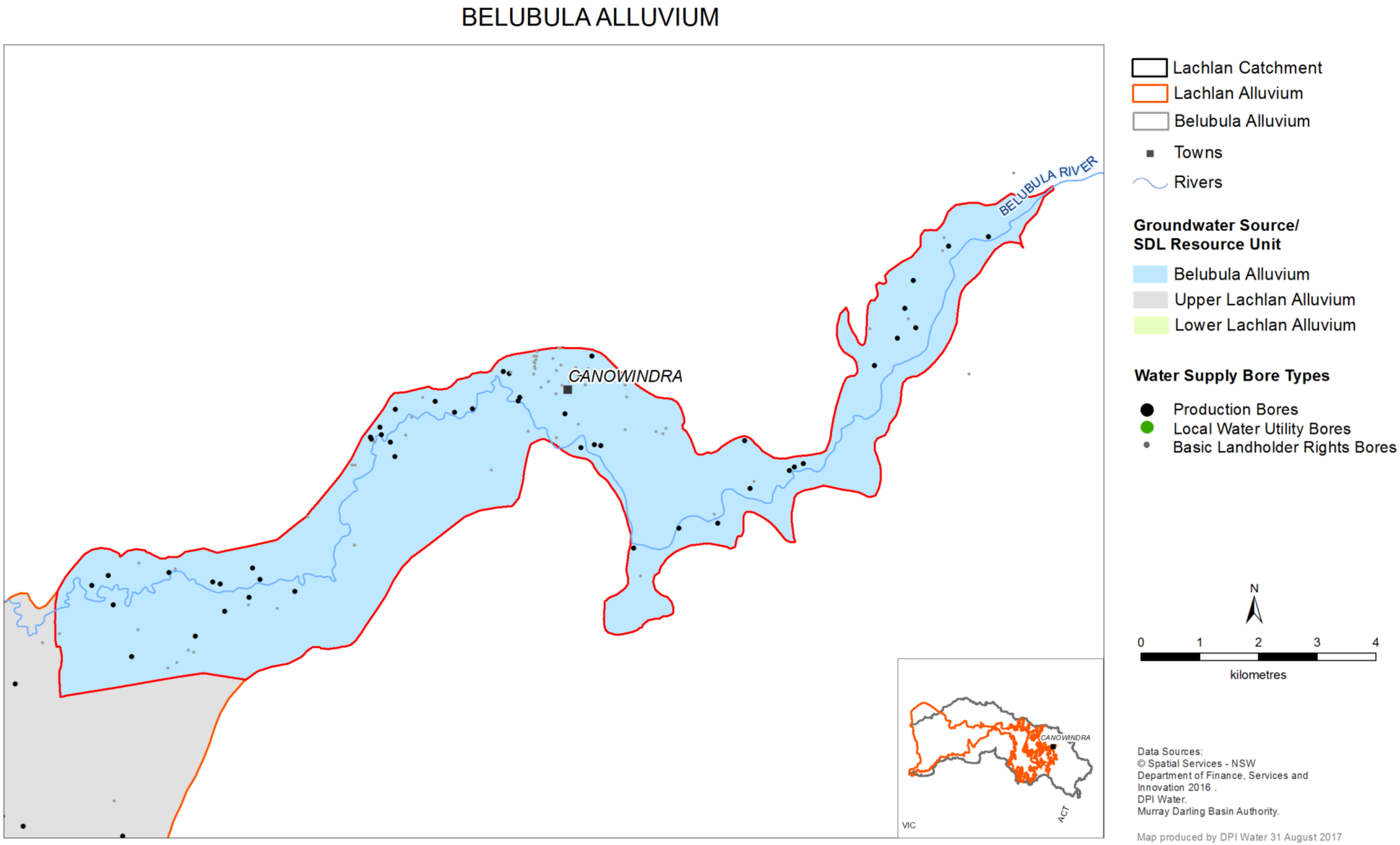

Figure 31 Registered bores in the Belubula Alluvium

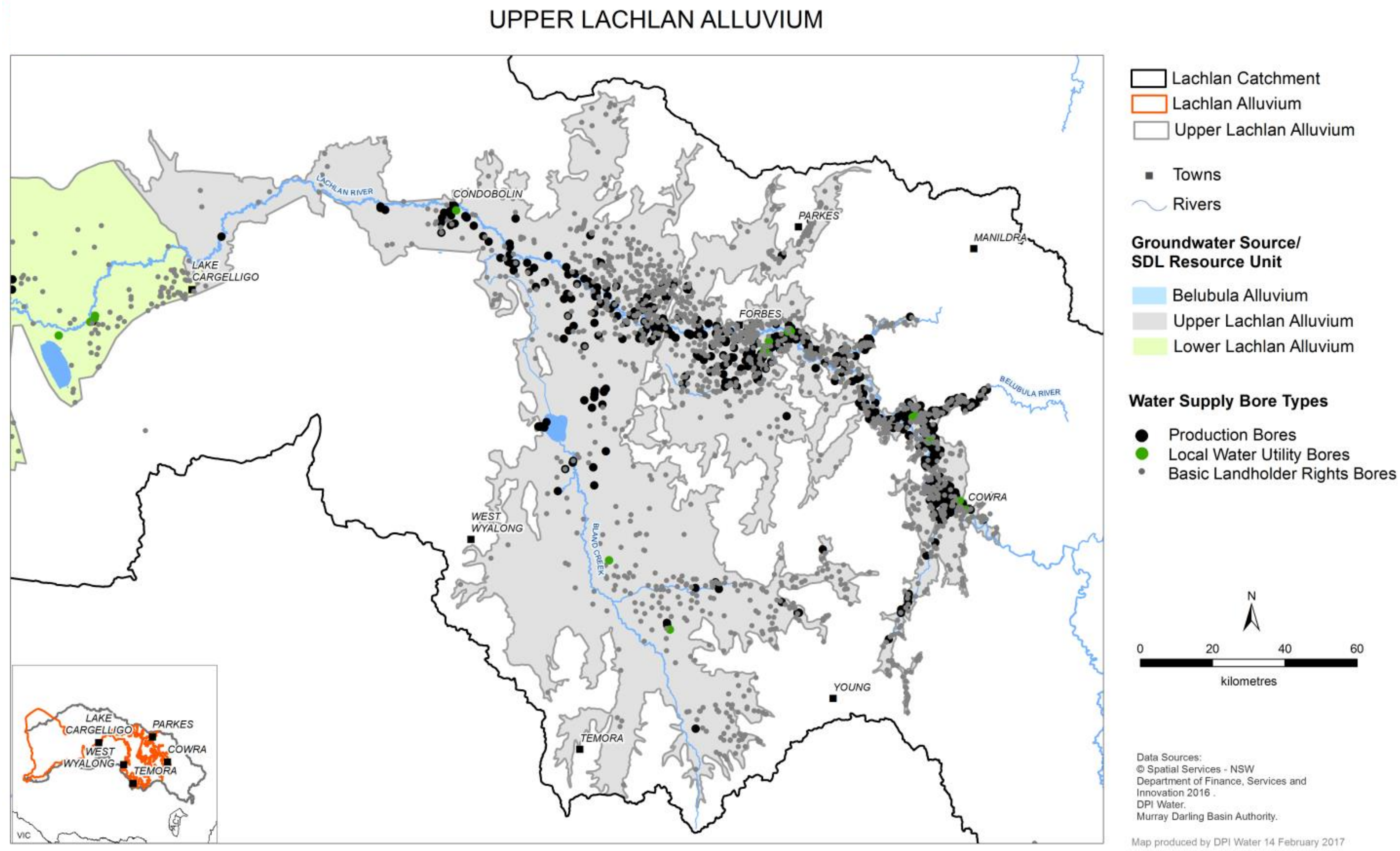

Figure 32 Registered bores in the Upper Lachlan Alluvium

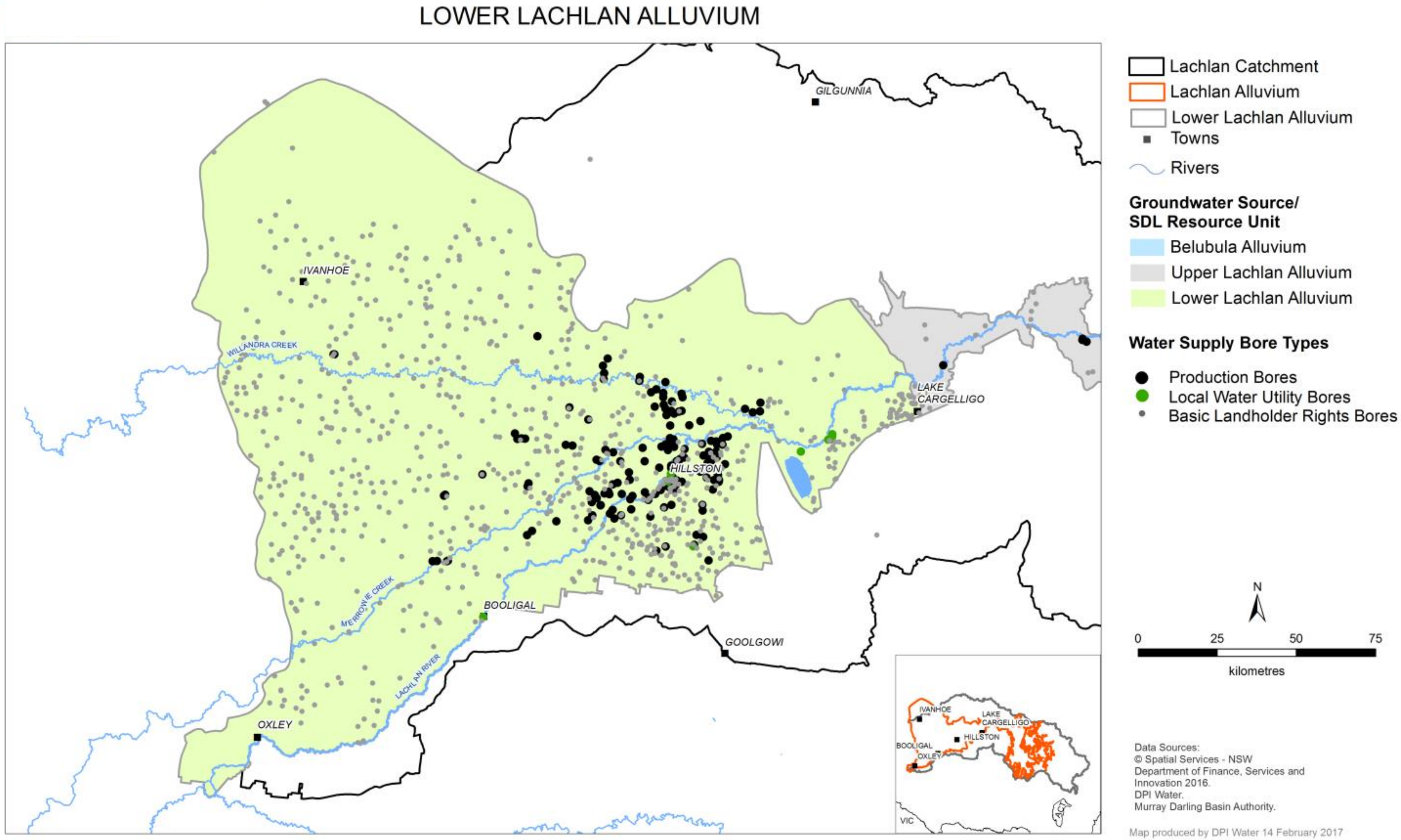

Figure 33 Registered bores in the Lower Lachlan Alluvium

Groundwater use is influenced by climate and access to surface water. Reliance on groundwater increases in drier years and when there is reduced access to surface water.

There are over 100 and 2,400 registered bores in the Belubula Alluvium and Upper Lachlan Alluvium, respespectively. In each water source, the majority are used for stock and domestic purposes. Within the Upper Lachlan Alluvium, there is significant reliance on groundwater for irrigation, the majority concentrated along the Lachlan River. The towns of Forbes, Parkes and Condobolin use groundwater from the Upper Lachlan Alluvium as water supply for local water utility.

There are over 1,000 registered bores in the Lower Lachlan Alluvium, the majority used for stock and domestic purposes. There is significant reliance on groundwater for irrigation with approximately 178 production bores, the majority concentrated in the area surrounding Hillston. The town of Hillston uses groundwater for its water supply.

Whilst production bores in the Upper Lachlan Alluvium utilise significant volumes of water those of the Lower Lachlan Alluvium are relied on to a greater extent and pump greater volumes, as shown in Figure 34.

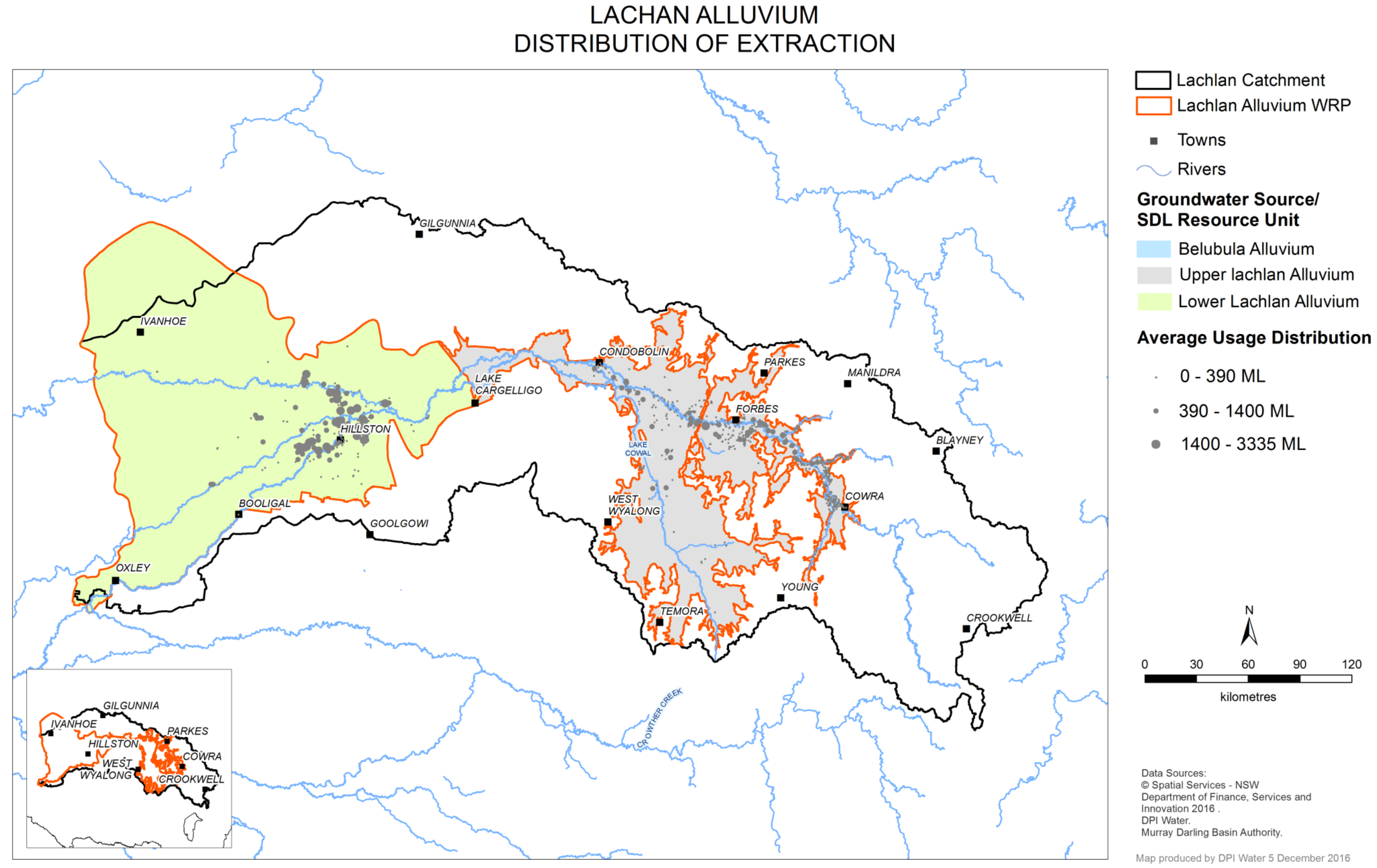

Figure 34 Lachlan Alluvial Water Resource Plan Area distribution of extraction

Annual metered groundwater extraction since 2000 for the Belubula, Upper Lachlan and Lower Lachlan Alluvium is shown in Figures 35, 36 and 37, respectively. The annual extraction limit since commencement of the respective water sharing plans is also provided. Records of extraction prior to 2000 from the Lachlan Alluvium water sources were obtained mostly through licence holder written reports to the department (where available) and may not represent a complete record of total pumping.

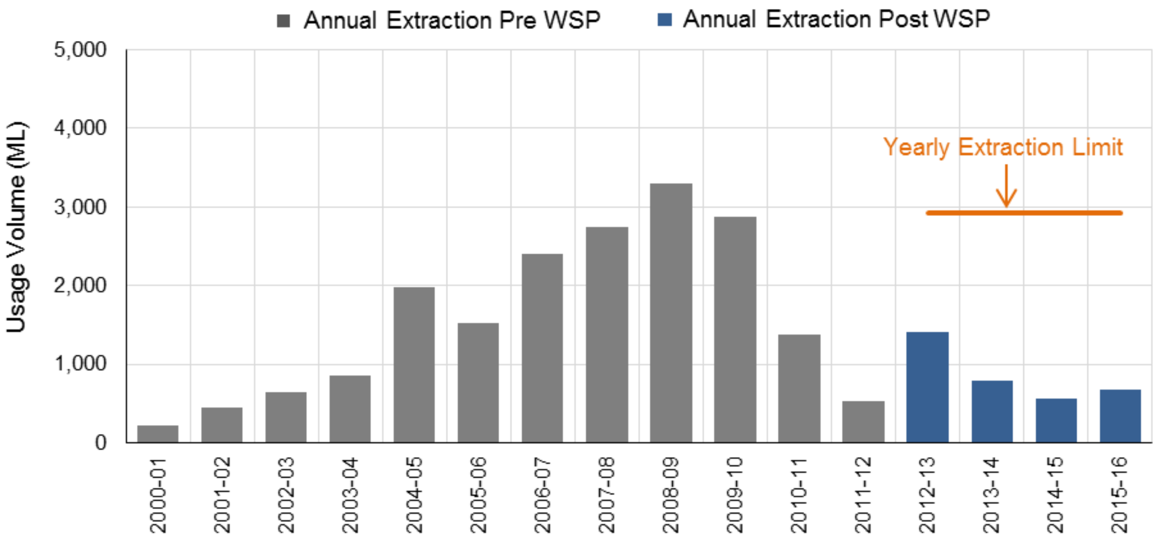

Figure 35 Metered extraction for the Belubula Alluvium

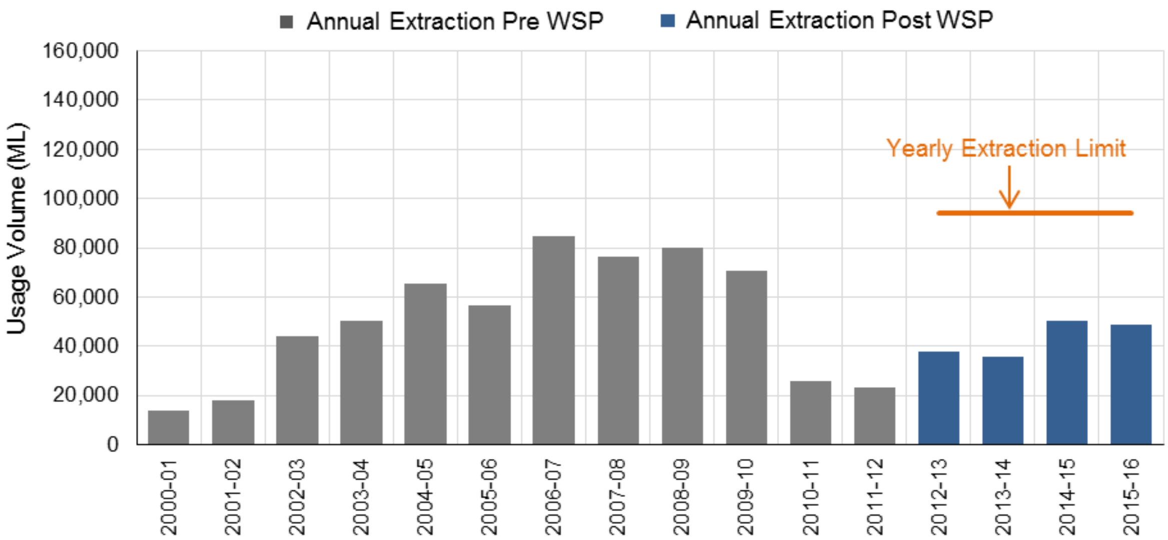

Figure 36 Metered extraction for the Upper Lachlan Alluvium

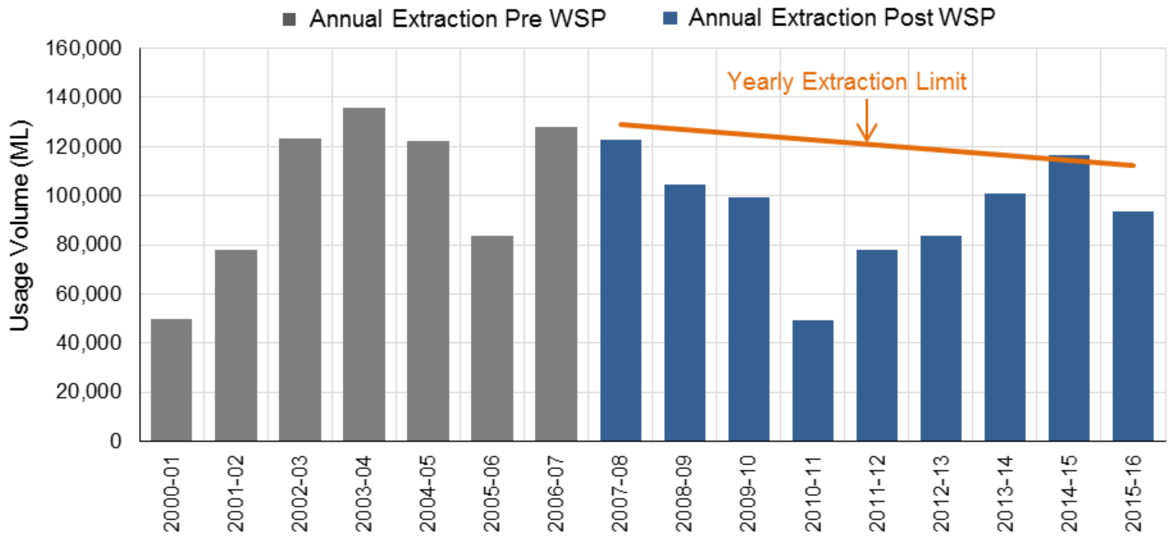

Figure 37 Metered extraction for the Lower Lachlan Alluvium

Average extraction from the Belubula and Upper Lachlan Alluvium pre-water sharing plan , particularly between 2006 and 2010, was 2,800 ML/yr and 78,000 ML/yr respectively. This is higher than post-plan extractions for the two sources (860 ML/yr for Belubula Alluvium and 43,000 ML/yr for Upper Lachlan Alluvium). The larger groundwater extraction volumes experienced pre water sharing plan is due to the dry climatic conditions and reduced surface water access that occurred during the time.

Average extraction from the Lower Lachlan Alluvium has fluctuated over time in response to climatic conditions. Whilst surface water is used in the Lower Lachlan for irrigation, many properties do not have access to surface water and therefore must rely entirely on groundwater for their supply. It is for this reason that average extraction pre comencement of water sharing plan does not vary significantly from post water sharing plan.

8.6 Groundwater dealings

Under the *Water Management Act 2000*, dealings are permitted in access licences, shares, account water and the nomination of supply works.

The Upper Lachlan Alluvium has eight management zones. Dealings are permitted within but not between zones.

There are no restrictions for dealings in the Belubula Alluvium or Lower Lachlan Alluvium.

8.6.1 Temporary

The most common type of dealings between groundwater licences are allocation assignments (temporary trades) made under section 71T of the *Water Management Act 2000*. The volumes traded in the Upper Lachlan Alluvium have increased since 2012; however the average price remains generally consistent (Figure 38). The business-to-business trades worth less than $1/ML show a similar trend, as shown in Figure 39.

The volumes traded in the Lower Lachlan Alluvium fluctuate in response to demand, which is greater during dryer periods (2007–10 and recently since 2013) as shown in Figure 40. The average price increases in general during the dryer periods; conversely it is cheaper in wetter periods (Figure 40). The business-to-business trades worth less than $1/ML show a similar trend, as shown in Figure 41. To date, there have been no applications for temporary dealings in the Belubula Alluvium since water sharing plan commencement.

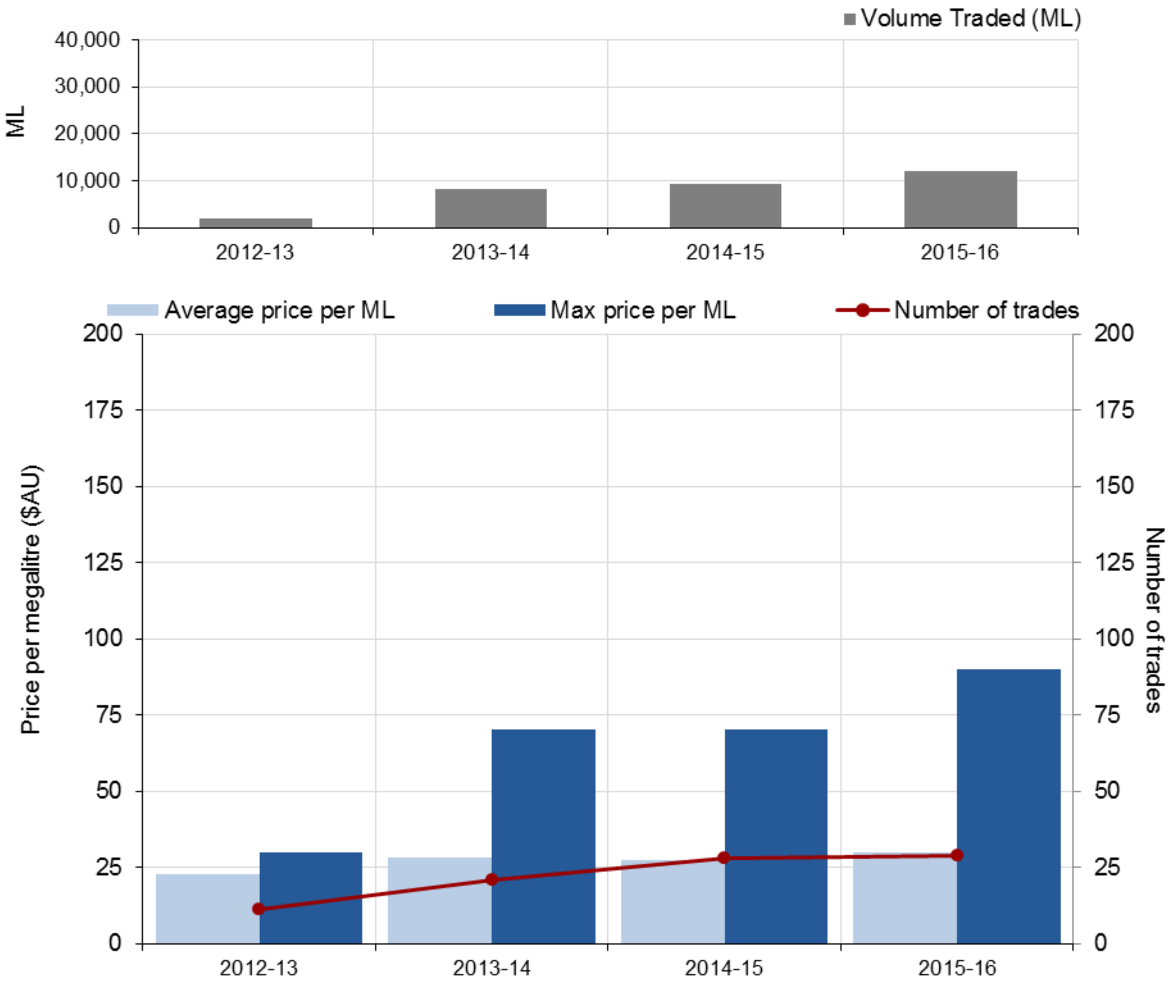

Figure 38 Upper Lachlan Alluvium 71T dealings since commencement of the water sharing plan

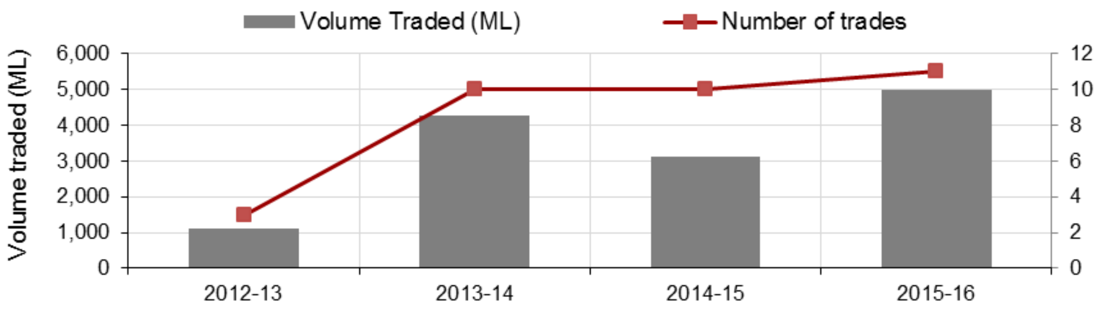

Figure 39 Upper Lachlan Alluvium < $1/ML 71T dealings since commencement of the water sharing plan

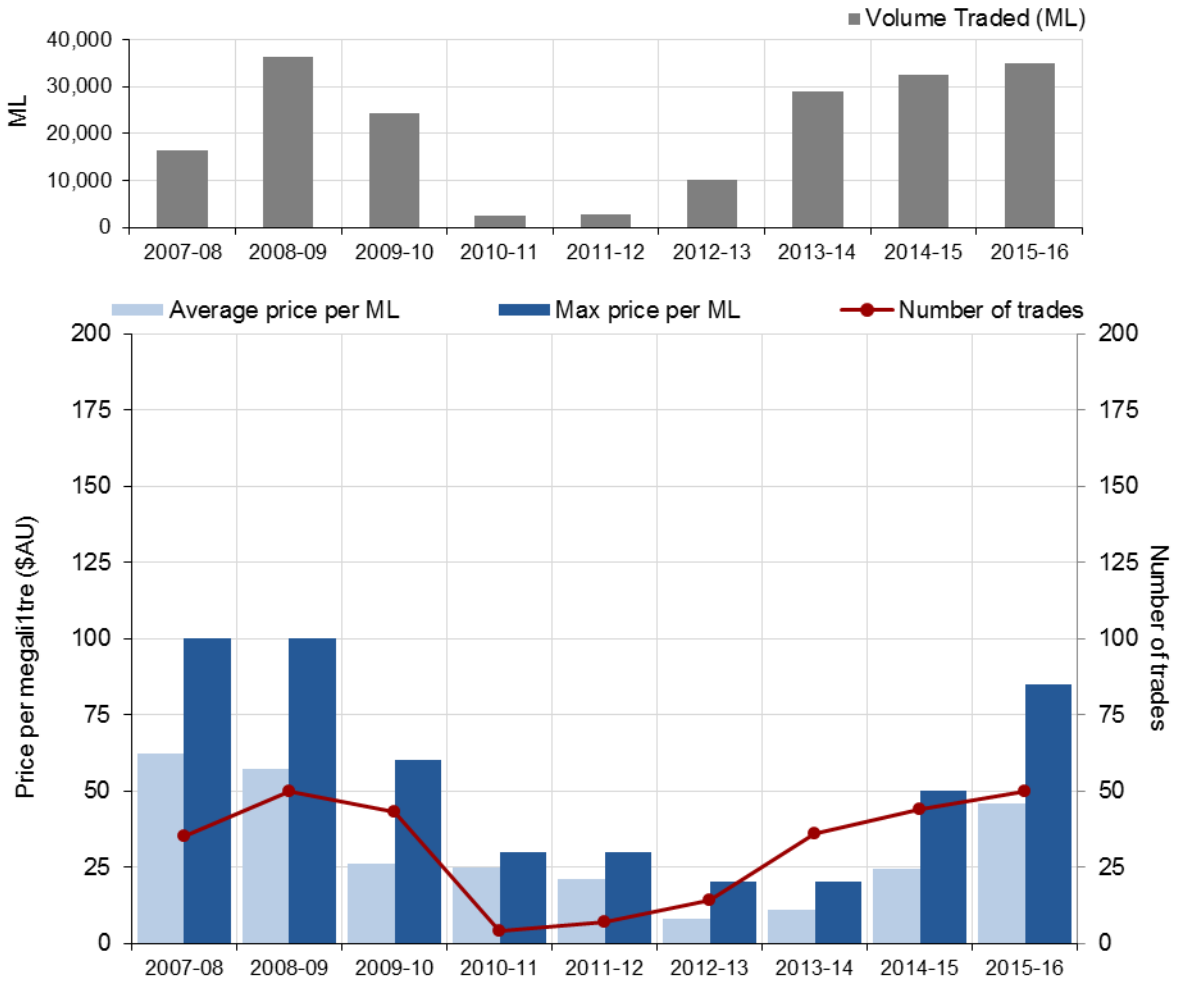

Figure 40 Lower Lachlan Alluvium 71T dealings since commencement of the water sharing plan

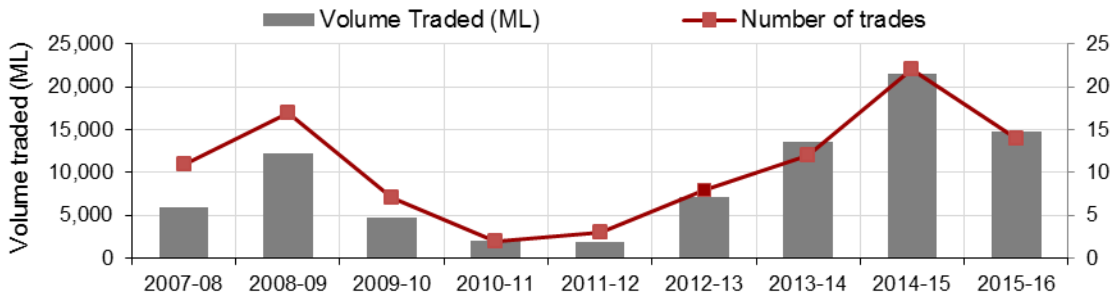

Figure 41 Lower Lachlan Alluvium < $1/ML 71T dealings since commencement of the water sharing plan

8.6.2 Permanent

Other dealings for groundwater licences are made under sections 71M (licence transfer), 71N (term licence transfer), 71P (subdivision/consolidation), 71Q (assignment of shares) and 71W (nomination of works) of the *Water Management Act 2000*.

Dealings that can result in a change in the potential volume that can be extracted from a location and therefore have the potential to cause third-party impacts are subject to a hydrogeological assessment and may be approved, subject to conditions being placed on the nominated work or combined approvals such as bore extraction limits to minimise potential impact on neighbouring bores.

Figure 42 shows the statistic for permanent dealings since commencement of the water sharing plan in the Upper Lachlan Alluvium. 71M dealings are not included as these are a change in ownership only and therefore have no potential for additional third-party impacts. To date, there have been no applications for any type of permanent dealing in the Belubula Alluvium. The total volume of dealing has been increasing for the Upper Lachlan Alluvium. No trend can yet be established for the number of dealings in these water sources.

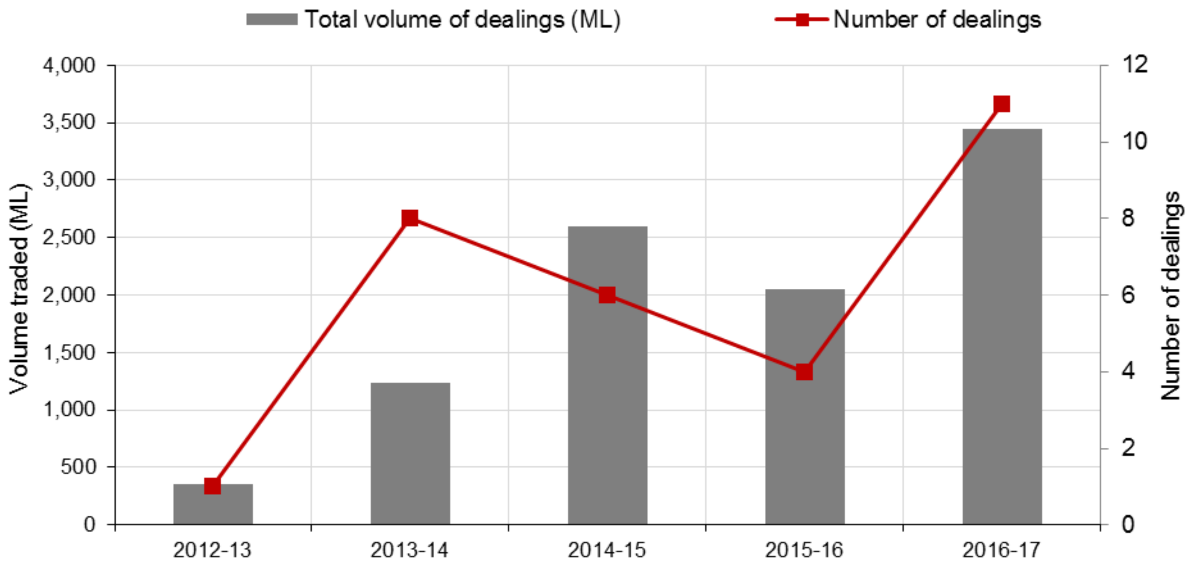

Figure 42 Upper Lachlan Alluvium permanent dealings since commencement of the water sharing plan, 71M dealings not included.

Figure 43 shows the statistic for permanent dealings since commencement of the water sharing plan in the Lower Lachlan Alluvium.

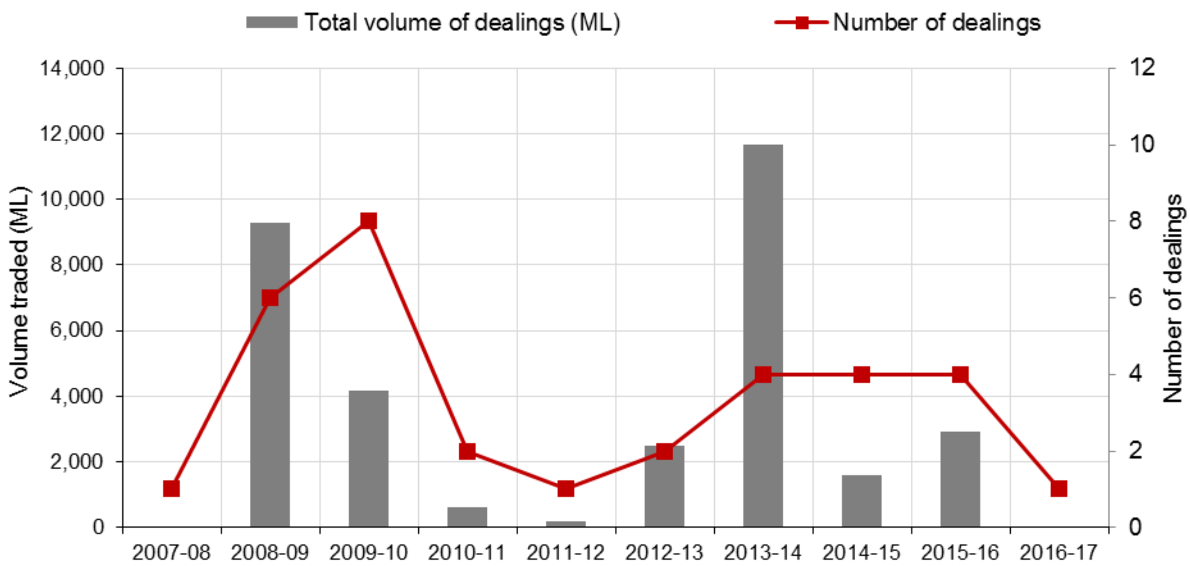

Figure 43 Lower Lachlan Alluvium permanent dealings since commencement of the water sharing plan, 71M dealings not included.

9 Groundwater Monitoring

Water NSW monitors groundwater level, pressure and quality through its network of groundwater observation bores across New South Wales. The groundwater monitoring network plays an important role in:

- assessing groundwater conditions;
- managing groundwater, including groundwater access and extraction; and
- providing data for the development of groundwater sharing plans.

Figure 44 shows a generalised conceptualisation of a layered groundwater system illustrating how the water level height in bores in an area can vary, depending on the depth of the screened interval of the bore.

Groundwater systems typically include a number of aquifers that may be confined or unconfined. An unconfined aquifer is an aquifer whose upper water surface (water table) is at atmospheric pressure.

A confined aquifer is completely saturated with water and is overlain by impermeable material (aquitard), causing the water to be under pressure. If the hydraulic head of groundwater is plotted and contoured on a map, this is referred to as the potentiometric surface.

Figure 44 also illustrates the difference between stock and domestic, production and monitoring bores. Stock and domestic bores are often constructed into the shallowest aquifer and have a relatively small diameter and limited extraction capacity. Because they are typically shallow they can be more susceptible to climatic fluctuations in water levels and influence from surrounding pumping.

Production bores are generally much larger diameter and have significantly larger extraction capacity. They are usually constructed into the deepest most productive part of a groundwater system and can be screened in multiple aquifers.

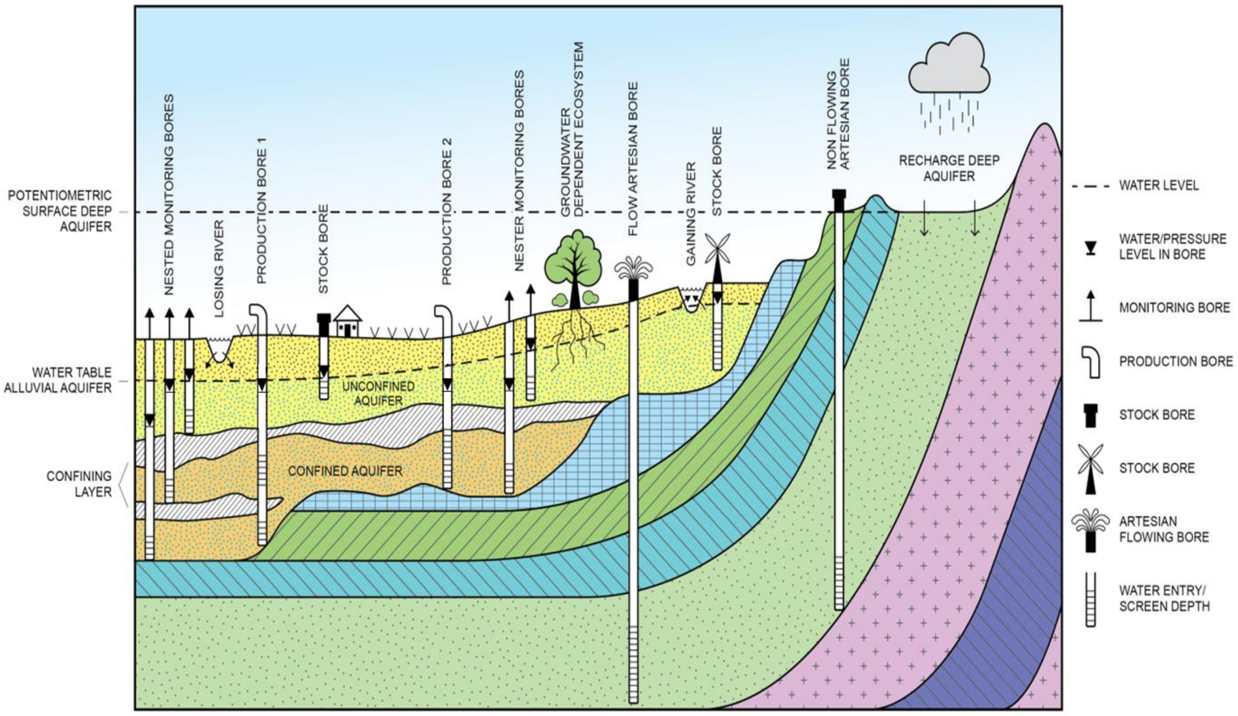

Figure 44 Schematic diagram of different types of aquifers

Monitoring bores are designed to monitor a specific aquifer for water levels and water quality and are generally relatively small in diameter. At some monitoring bore locations, there are multiple monitoring bores that are screened at different depths to observe the hydraulic relationship between different aquifers.

Figure 44 illustrates how the water level in some of the monitoring bores can be at different levels to nearby production and stock bores. This is because the monitoring bores are screened at a single depth and the water level represents the water table or hydraulic head at that depth, whereas the water level in a multiple screened production bore is a composite water level, influenced by the hydraulic head in all screened aquifers.

Groundwater level and pressure data collected from monitoring bores can be plotted and analysed at a water source scale to assess long and short-term changes in the system. This data is used to identify areas where there may be a potential management issue.

The monitoring bores in each of the Lachlan Alluvium water sources have been monitored continuously since installation. The Belubula Alluvium currently has 14 bores at 8 sites and the Upper Lachlan Alluvium has 295 bores at 152 sites, as shown in Figures 45 and 46, respectively. Monitoring in the Belubula Alluvium commenced in 2007 with the installation of three sites. Between 2009 and 2011, five new sites were added and incorporated into the monitoring network. Installation of sites in the Upper Lachlan Alluvium commenced in the early 1960s, and by 1985 almost 80% (120 out of 152 sites) of the current network was complete. The final eight bores were added and incorporated into the Upper Lachlan Alluvial monitoring network between 2009 and 2011.

The Lower Lachlan Alluvium currently has 189 observation bores at 90 sites (Figure 47). Installation of sites in the Lower Lachlan Alluvium commenced in the late 1960s, and by 1995 80% (74 out of 90 sites) of the current network was complete. The final seven bores were added and incorporated into the Lower Lachlan Alluvial monitoring network between 2008 and 2009.

The manually monitored sites are read every four to eight weeks. Data is available for three groundwater monitoring sites in Belubula Alluvium, 18 in Upper Lachlan Alluvium and 20 in Lower Lachlan Alluvium, in real-time via telemetry from realtimedata.water.nsw.gov.au/water.stm

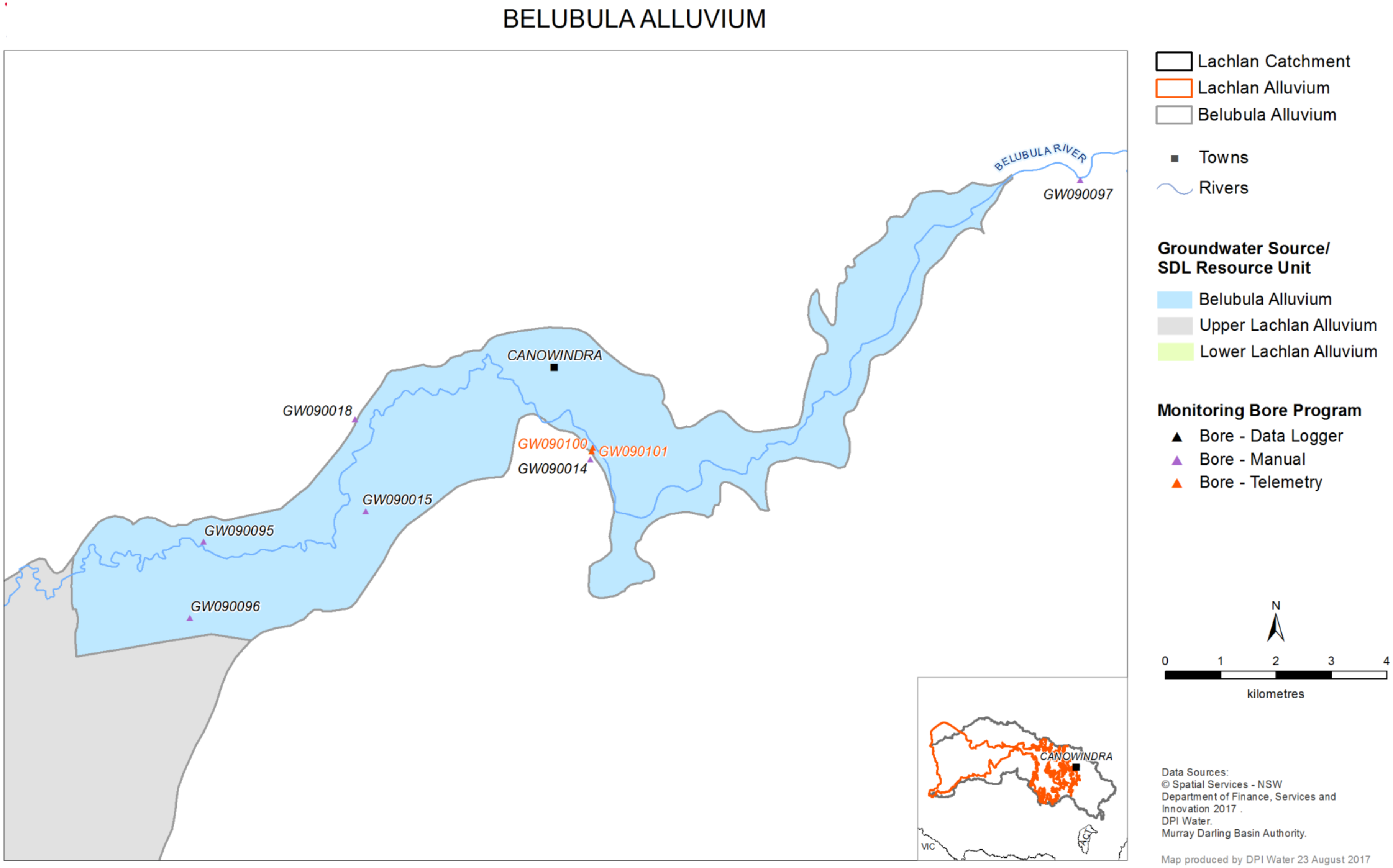

Figure 45 Location map of monitoring bores in the Belubula Alluvium

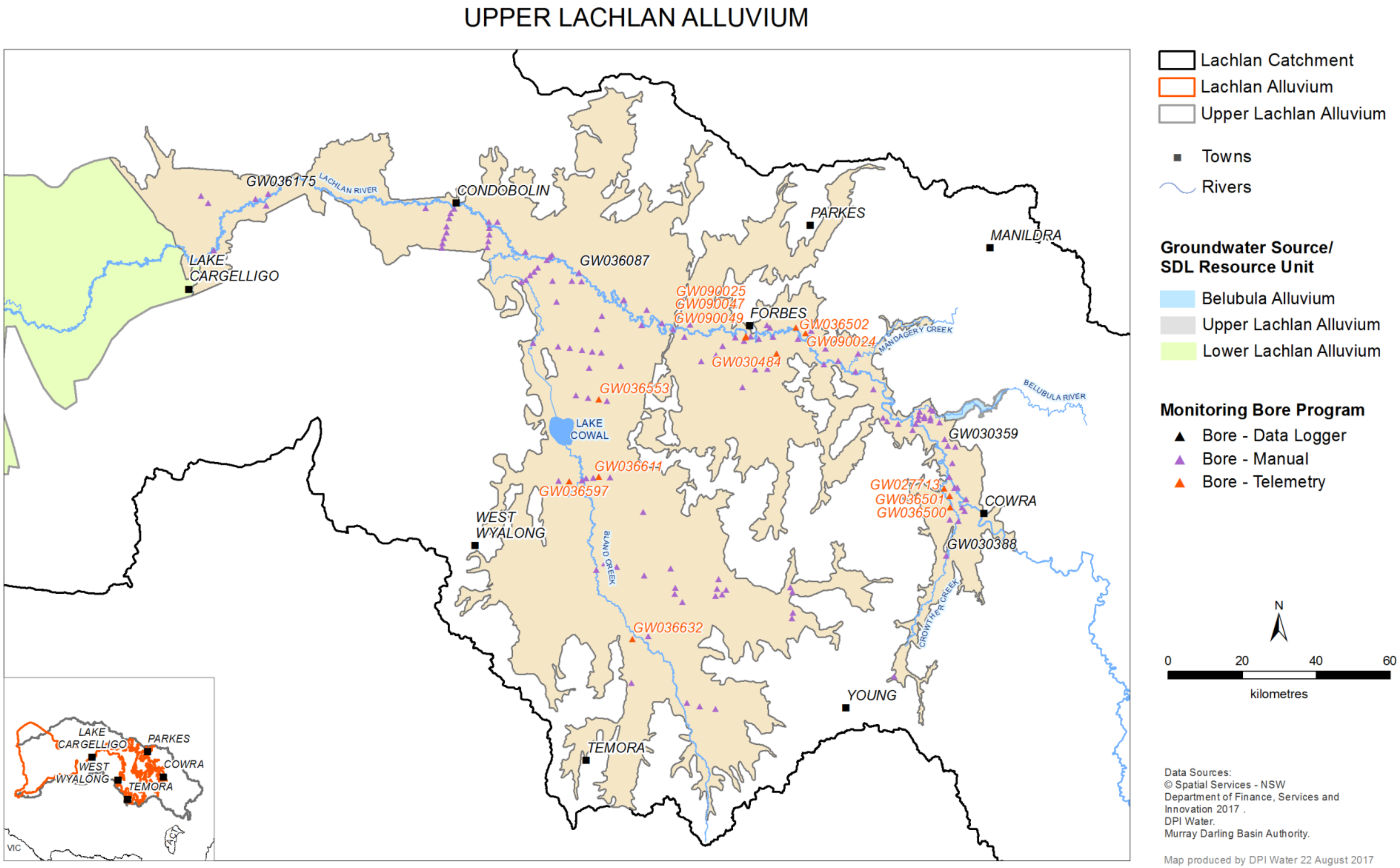

Figure 46 Location map of monitoring bores in the Upper Lachlan Alluvium

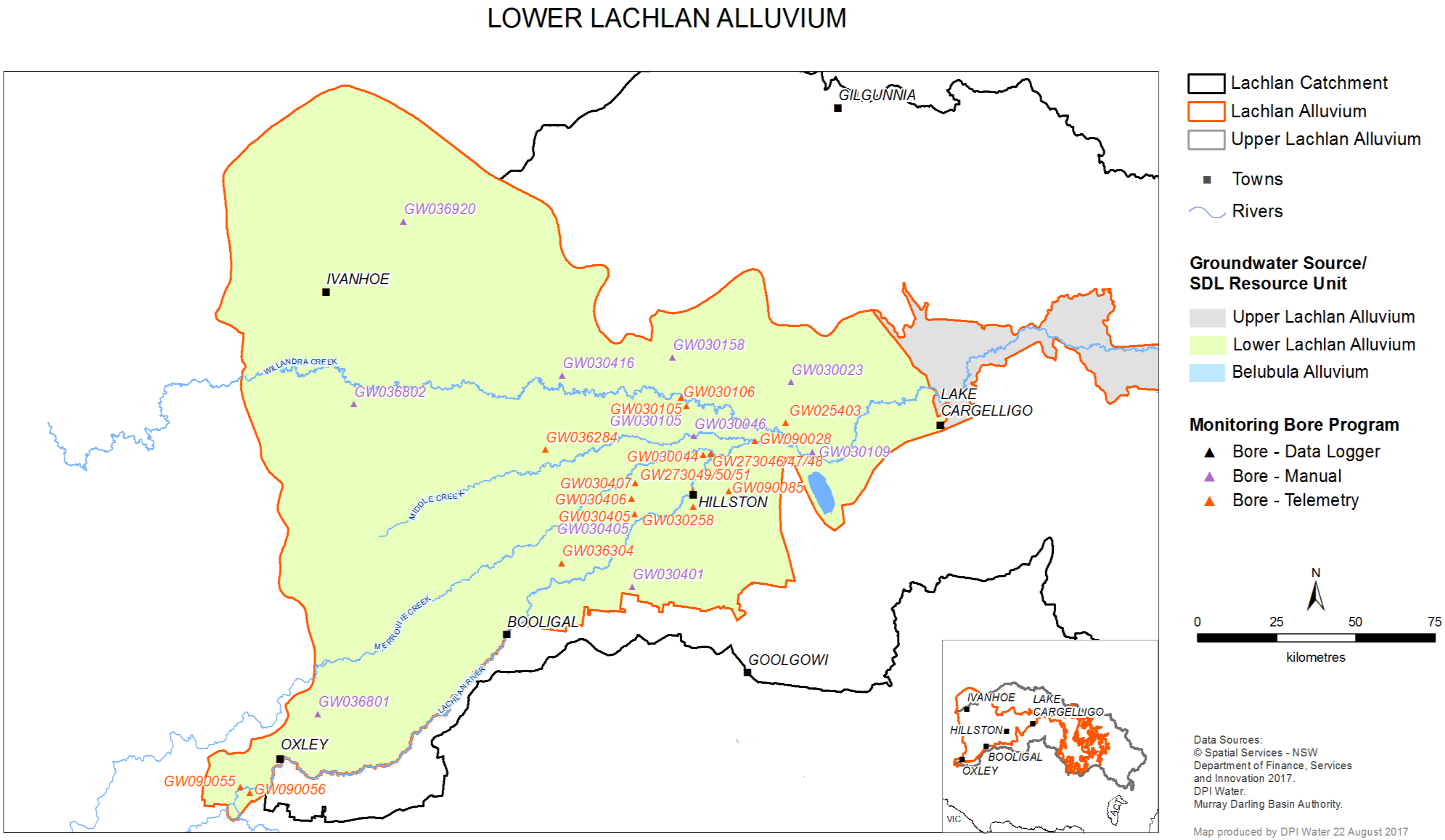

Figure 47 Location map of monitoring bores in the Lower Lachlan Alluvium

10 Groundwater Behaviour in the Lachlan Alluvium

10.1 Introduction

All monitoring bores in the Belubula Alluvium are constructed within the shallow, unconfined aquifer system, which has a high degree of hydraulic connection to the Belubula River. The majority of monitoring bores in the Upper Lachlan Alluvium are constructed within the unconfined/semi-confined aquifer system that has some degree of hydraulic connection to existing rivers and creeks. Most monitoring bores in Lower Lachlan Alluvium are considered to be within the semi-confined/confined aquifer system that has little to no hydraulic connection to existing rivers and creeks.

The reference condition to which long-term trends are compared is the ‘pre-development’ water level (prior to any significant groundwater extraction). The Belubula Alluvium does not have any monitoring bores installed pre-development, therefore groundwater level data in this water source is entirely post-development. In the Upper and Lower Lachlan Alluvium, the ‘pre-development’ is defined as the average recovered water level from 1984 to 1989. Changes in groundwater levels in the water sources of the Lachlan Alluvium are discussed in the following sections presenting data from hydrographs and groundwater head maps.

10.2 Hydrographs

A hydrograph is a plot of groundwater level or pressure from a monitoring bore over time (Figure 48). Hydrographs can be used to interpret influences on groundwater such as rainfall, floods, drought and climate change, as well as interpret aquifer response to groundwater extraction.

Figure 48 explains the trends that can be observed in groundwater hydrographs. Both short and longer term water level trends can be identified. In unconfined and semi-confined aquifers, groundwater can be in hydraulic connection with the surface. Where this occurs, groundwater levels rise in response to recharge such as rainfall or flooding and decline during periods of reduced rainfall.

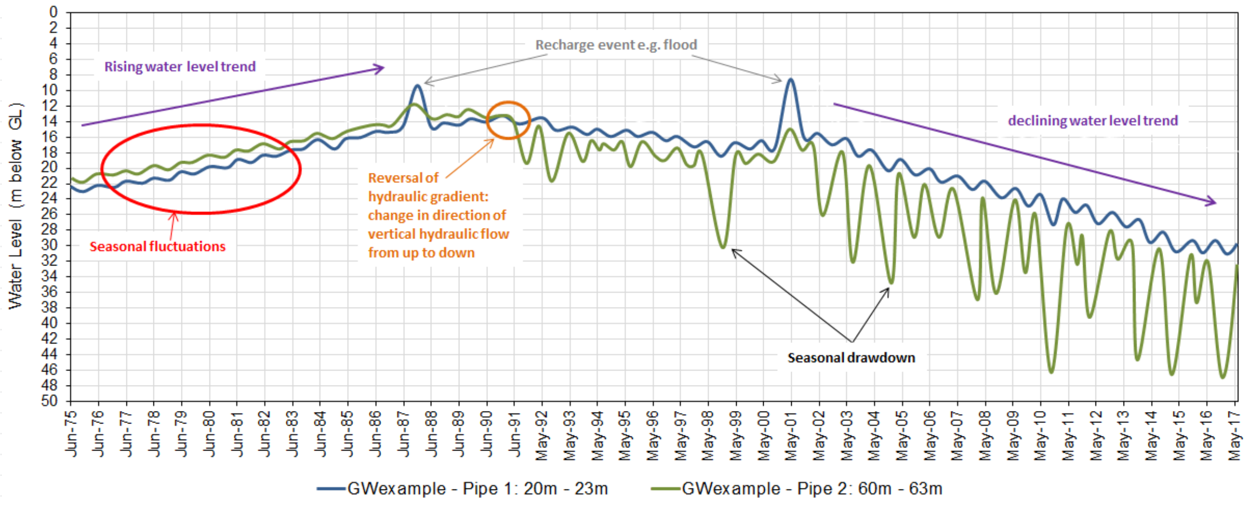

Figure 48 Example of a groundwater hydrograph identifying trends in groundwater responses to pumping and climate.

Significant recharge events such as floods can be identified in hydrographs as peaks in the groundwater level record while droughts tend to result in a slow gradual decline in groundwater levels.

In areas where groundwater extraction occurs, hydrographs show a seasonal cyclic pattern of drawdown and recovery. Drawdown is the maximum level to which groundwater is lowered in a bore due to pumping. It is followed by recovery when pumping has ceased or reduced.

Review of the recovered groundwater level over time can be used to assess how a groundwater system is responding to climate and pumping impacts in the long-term. The recovered groundwater level is the highest point to which groundwater has risen in a particular year.

Drawdown can be used to assess more short-term seasonal impacts in a groundwater system. In areas where drawdown occurs, groundwater recovery may not return to the level of the previous year before pumping resumes, resulting in a long-term reduction in the recovered groundwater levels.

10.3 Review of groundwater levels

Hydrographs from representative groundwater monitoring sites across the Belubula Alluvium (one site), Upper Lachlan Alluvium (three sites) and Lower Lachlan Alluvium (three sites) are presented below. The locations of these sites are shown in Figures 49, 50, and 51 respectively. For ease of comparison, the Upper and Lower Lachlan hydrographs are plotted using the same scales. Due to the size and behaviour of the aquifer systems, the hydrograph scale for the Belubula Alluvium is displayed using a different scale compared to that of the other two water sources.

As described in Section 5, the Belubula Alluvium becomes deeper from east to west. The Upper Lachlan Alluvium thickness varies depending on proximity to the centre of the paleo-valley in which it was deposited. The thickest portion of paleo-valley has been encountered in management zones 3 and 5, that is, along the Lachlan River floodplain between Forbes and Condobolin.

The Lower Lachlan Alluvium becomes deeper from east to west. Its shallow and deep aquifer systems become more defined west of Kidman Way.

Groundwater levels in the Belubula Alluvium respond almost instantaneously, with high flows/flood events indicating a high degree of connection to the Belubula River (Figure 52). The long-term water level trend in this water source is generally stable.

With the exception of management zone 7 in the Bland Creek catchment, groundwater levels in the Upper Lachlan Alluvium in all locations responded to the flood event of 1990.

Groundwater levels in the Lower Lachlan Alluvium have a delayed response to recharge from flood events, except the area to the east of monitoring bore GW025401 (Figure 51).

During the period 1995–2000, groundwater levels at most locations in Upper and Lower Lachlan Alluvium began to decline in response to development and reached its lowest point during the period 2007–10. Groundwater levels started to recover and have remained relatively stable since this time. This is attributed higher rainfall and reduced extractions.

The most significant drawdowns in Upper Lachlan Alluvium occurred in management zones 1 (Back Creek catchment near Cowra) and zone 7 (Bland Creek catchment), which were identified as locally impacted areas in 2005–06. Figure 55 shows a hydrograph for typical water declines that have occurred within the locally impacted area of Zone 7. Community consultation and local impact management has since been implemented in these zones.

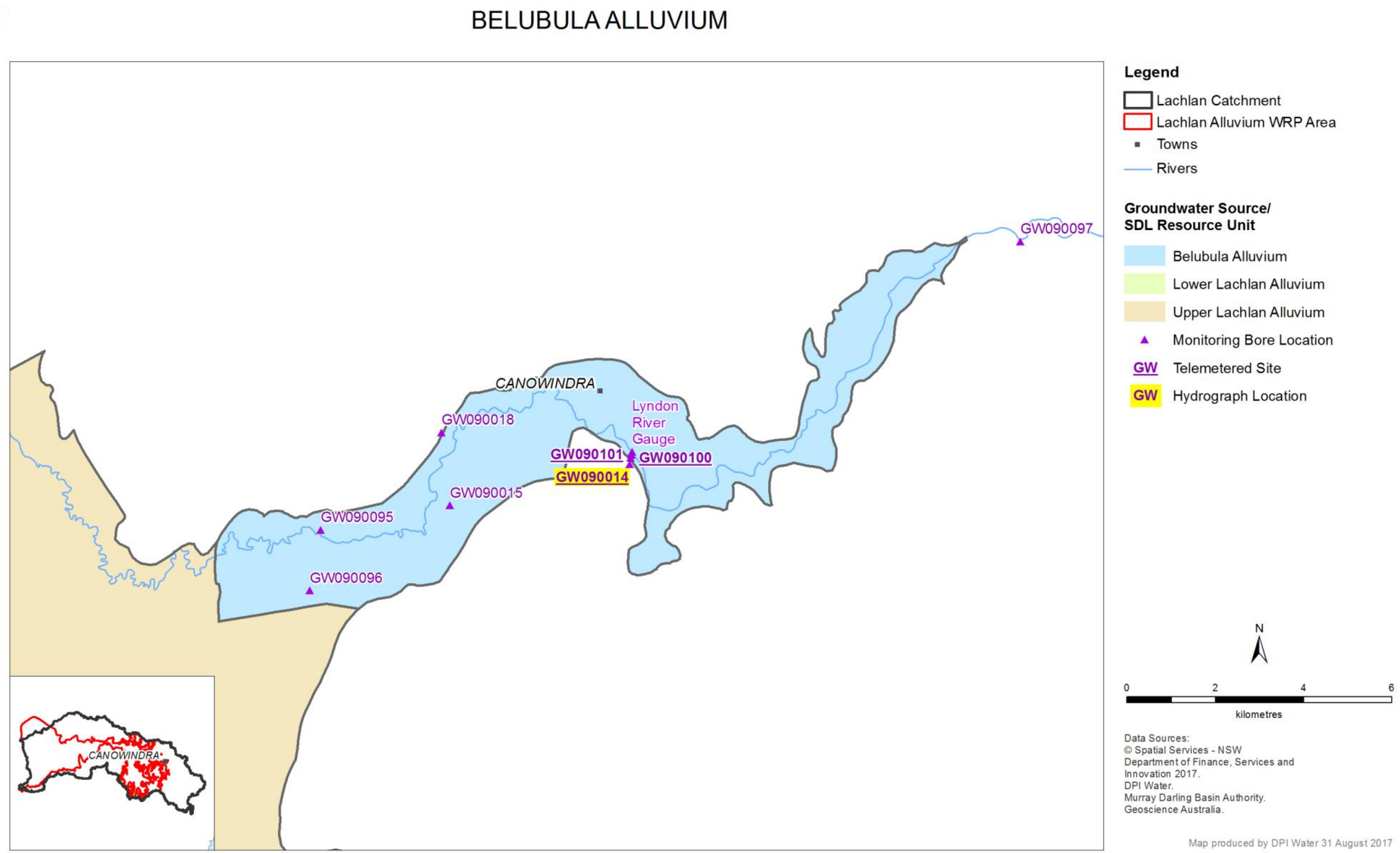

Figure 49 Belubula Alluvium hydrograph locations

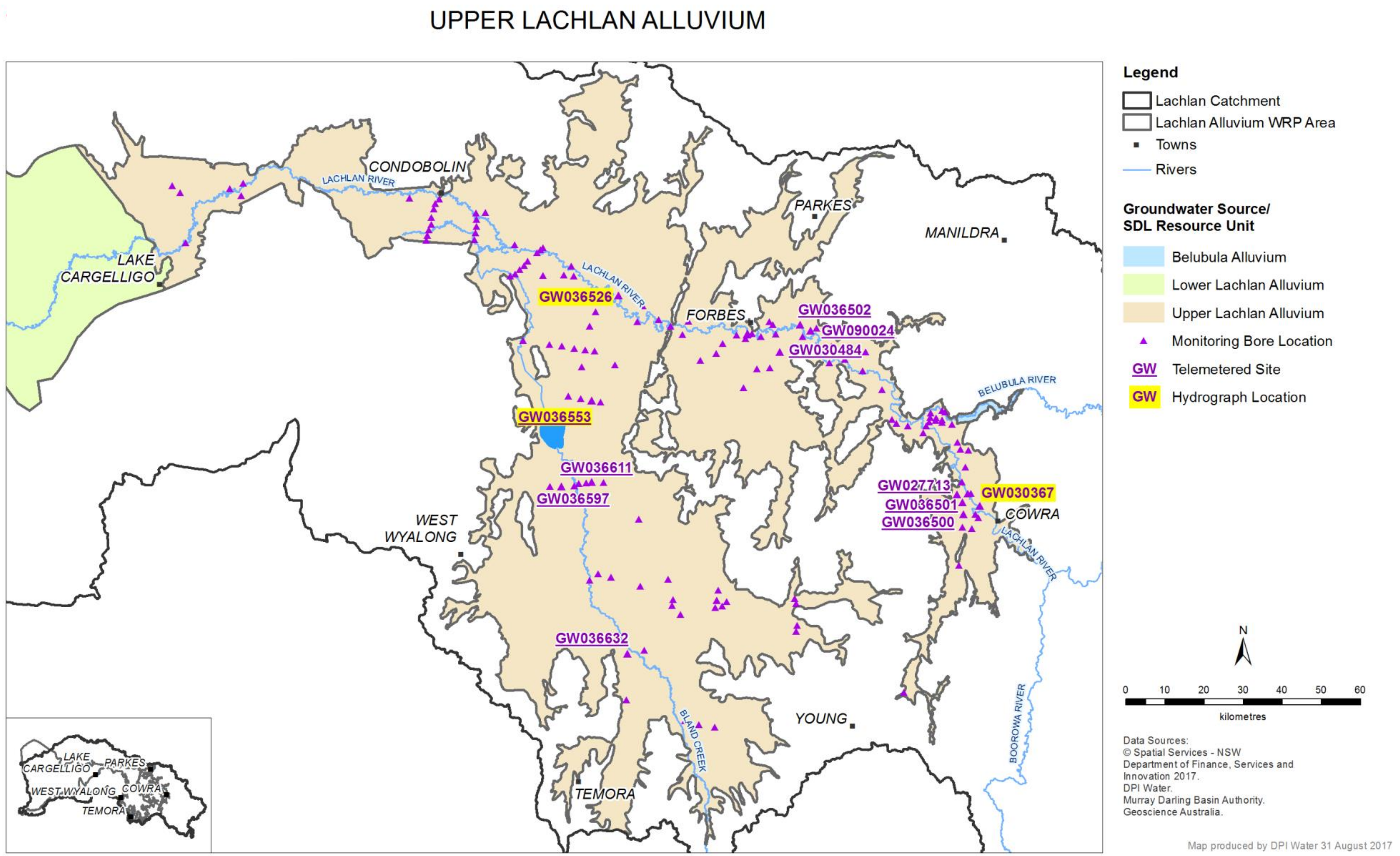

Figure 50 Upper Lachlan Alluvium hydrograph locations

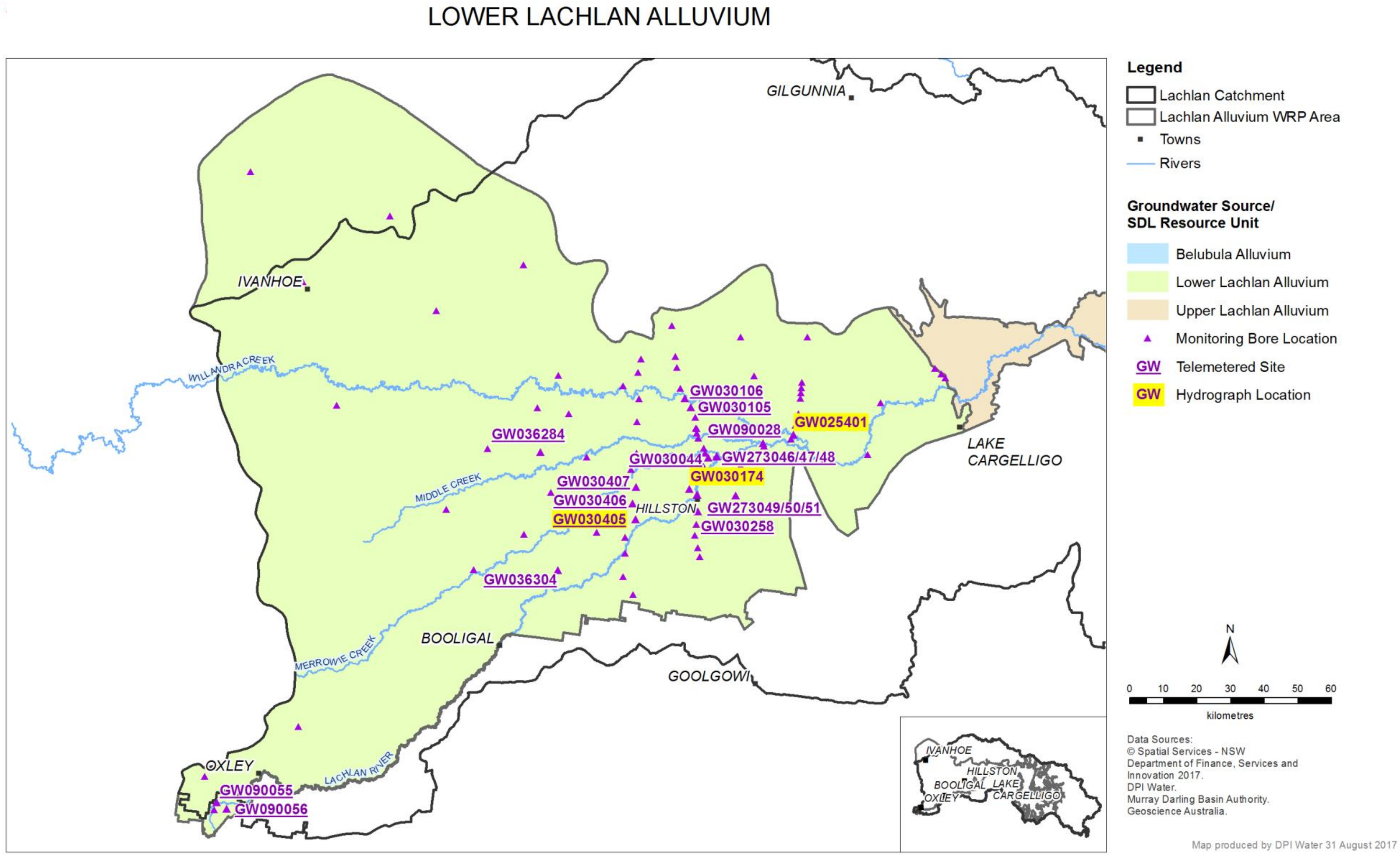

Figure 51 Lower Lachlan Alluvium hydrograph locations

Since 2010, groundwater levels in Upper Lachlan have stabilised or risen slightly in response to increased rainfall and reduced groundwater extraction. The stabilisation of levels also occurred in locally impacted areas within management zones 1 and 7. Hydrograph for monitoring bore GW03653 (management zone 7) shows a large decline in water levels commencing 2002 and then stabilising around 2006 when local impact management was negotiated with the local users.

Groundwater levels have experienced ongoing decline since the early 2000s in the area around Hillston (Figure 57). The ongoing declines have been observed both to the north and south of Hillston to the edge of the Lower Lachlan Alluvium. To date, the declines have not been excessive and groundwater has remained accessible to all users. Whilst declines have been larger to the west of Hillston, particularly in the vicinity of monitoring site GW030405 (Figure 58), it has stabilised since 2004–05. At monitoring site GW025401 (Figure 57) and to the east of this location, water level trends are stable.

On the peripheral edges and in the far west of the Lower Lachlan Alluvium, water level responses show stable to rising water level trends.

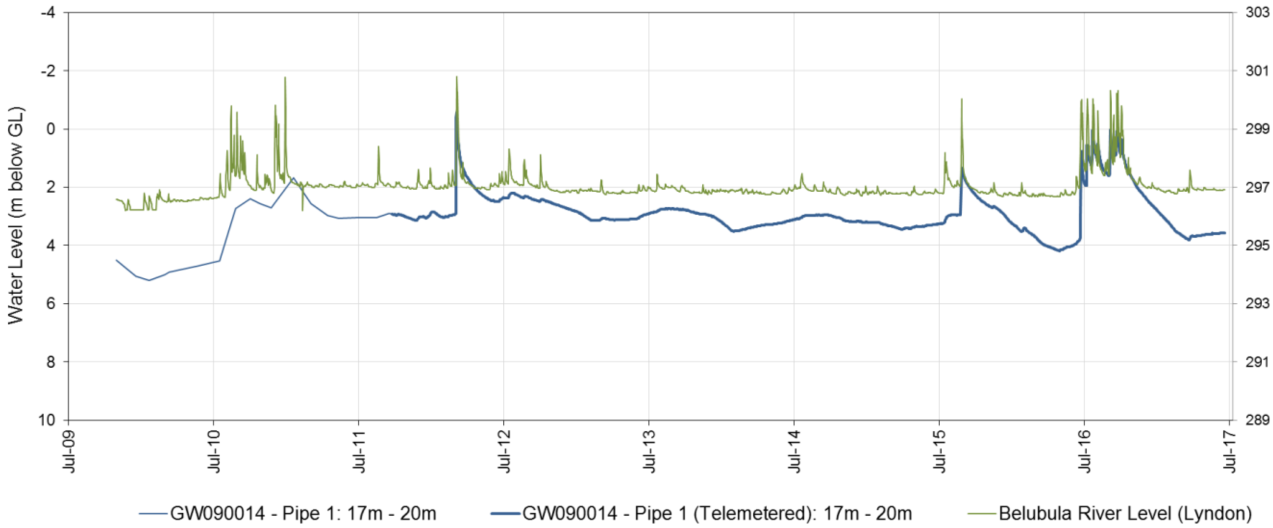

Figure 52 Hydrograph for monitoring bore site GW090014 – adjacent to Lyndon gauge station (Belubula Alluvium)

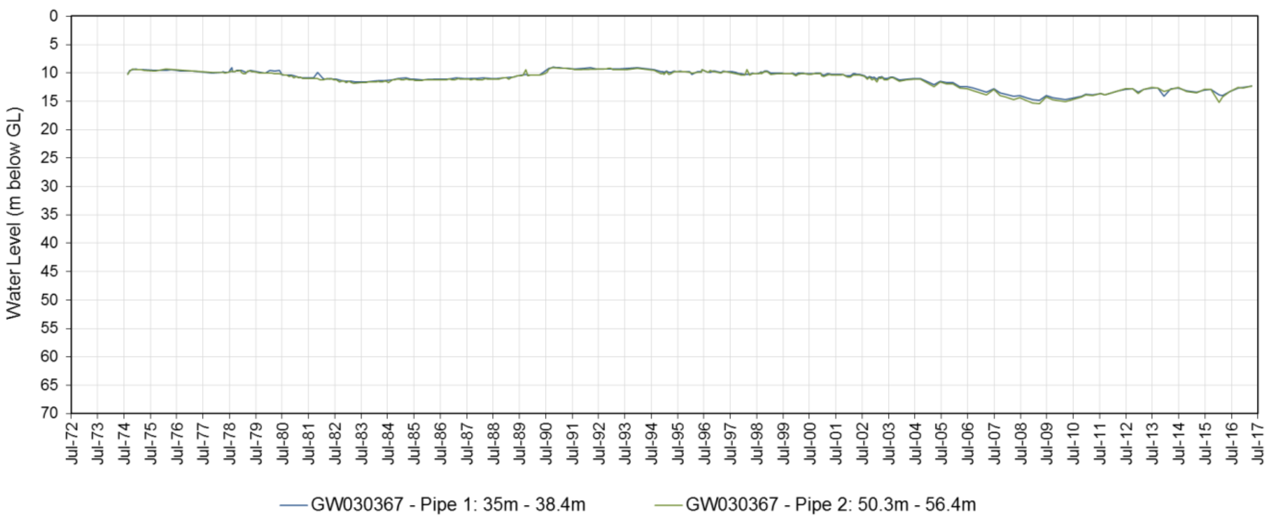

Figure 53 Hydrograph for monitoring bore site GW030367 – Section C (Upper Lachlan Alluvium)

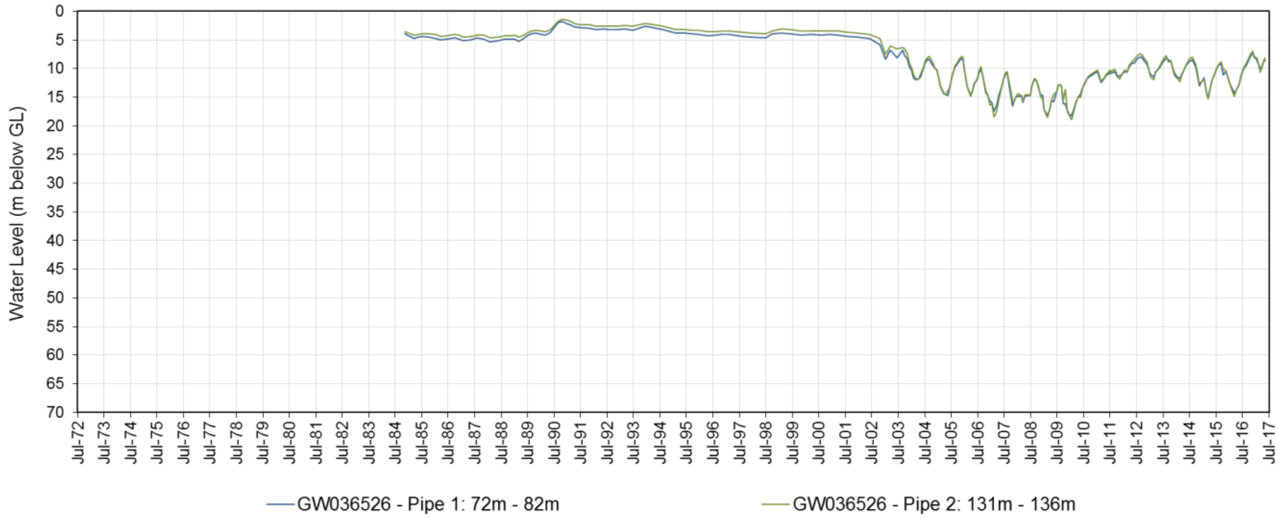

Figure 54 Hydrograph for monitoring bore site GW036526 – Section B (Upper Lachlan Alluvium)

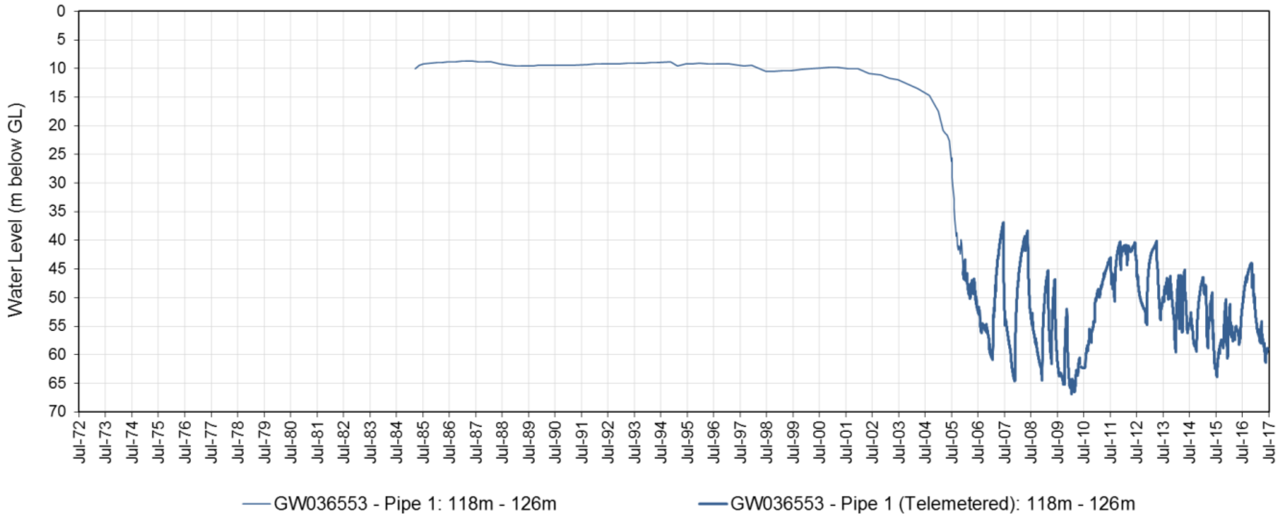

Figure 55 Hydrograph for monitoring bore site GW036553 – Upper Lachlan Alluvium

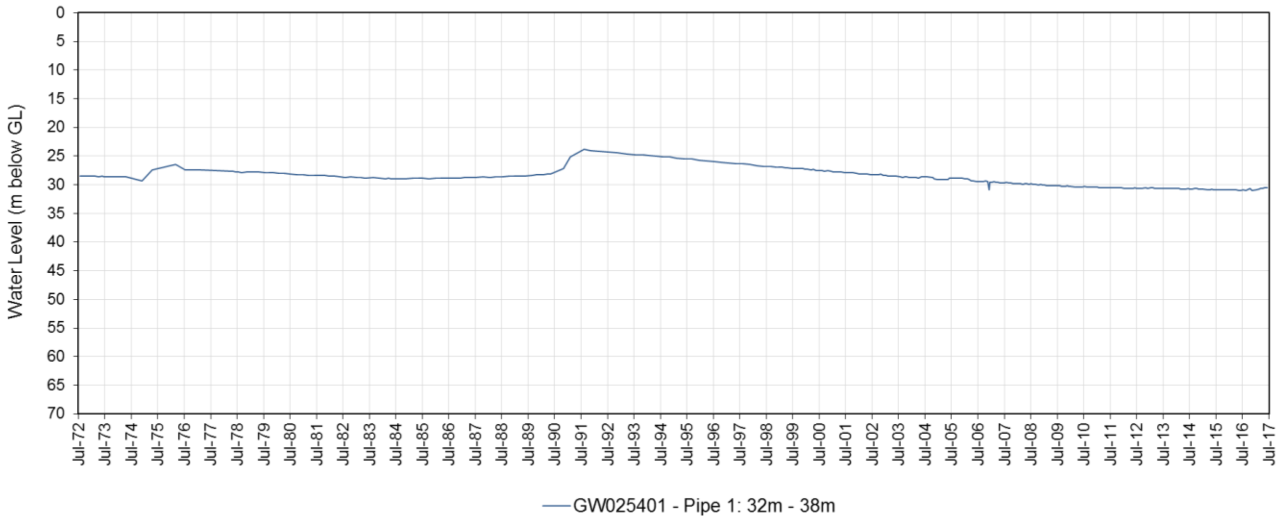

Figure 56 Hydrograph for monitoring bore site GW025401 – Section F (Lower Lachlan Alluvium)

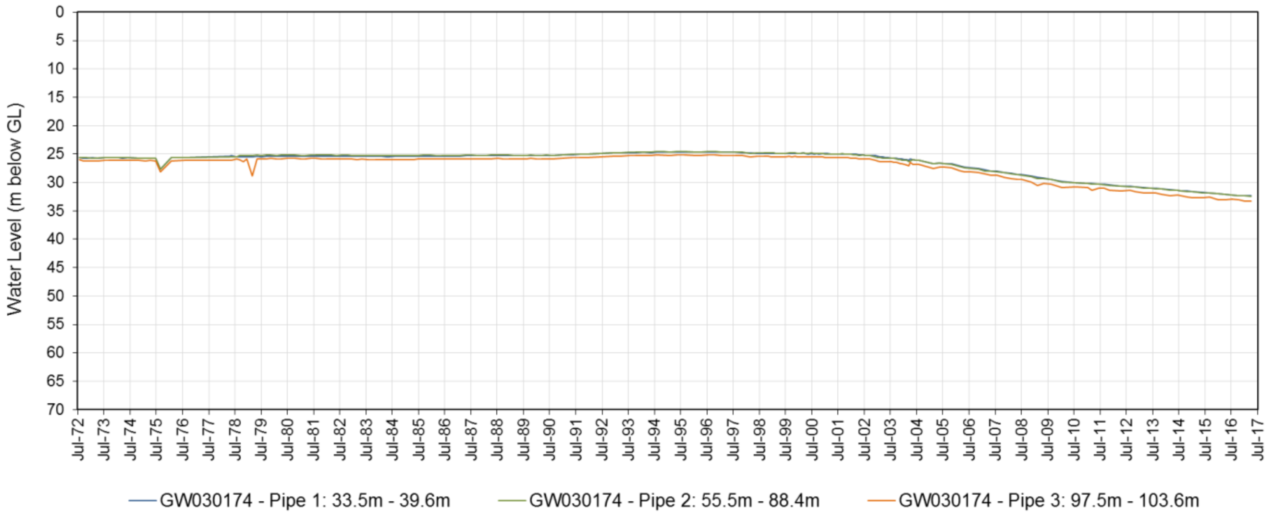

Figure 57 Hydrograph for monitoring bore site GW030174 – Section F (Lower Lachlan Alluvium)

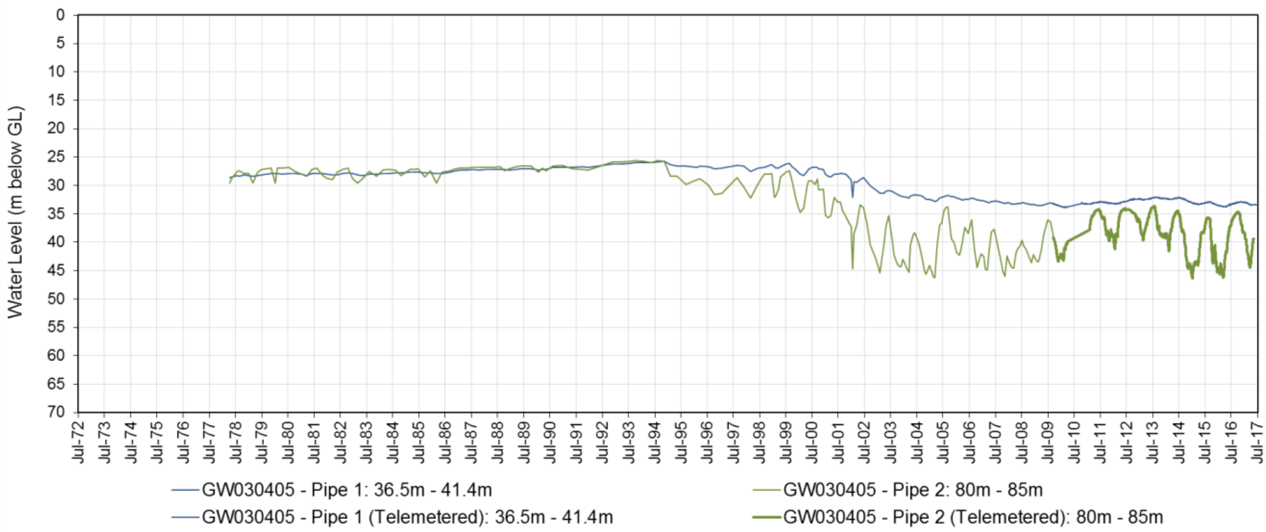

Figure 58 Hydrograph for monitoring bore site GW030405 – Adjacent to Section F (Lower Lachlan Alluvium)

10.4 Groundwater contour maps

Groundwater level contour maps are used to display the distribution of groundwater levels or pressures from a specific aquifer and indicate groundwater flow direction which is perpendicular to the contour lines.

For comparison purposes, contour maps have been prepared at maximum recovery level at pre-development (average 1984–89), 2005–06 and 2015–16 in both the shallow and deep aquifer systems of the Upper and Lower Lachlan Alluvium. Comparison maps were not constructed for the Belubula Alluvium because it does not have pre-development water level records. Contours are displayed in metres Australian Height Datum (m AHD), which provides a reference level for the measurement of groundwater level or pressure that is independent of topography.

Maximum drawdown contours have been prepared for the shallow and deep systems of the Upper and Lower Lachlan Alluvium for 2015–16. These are compared with the maximum recovery of these systems for the same year to demonstrate the change in flow direct that can occur during the pumping season.

Groundwater level contours of recovered water levels show the regional groundwater flow direction across the Upper and Lower Lachlan Alluvium is east to west (Figures 59 to 62).

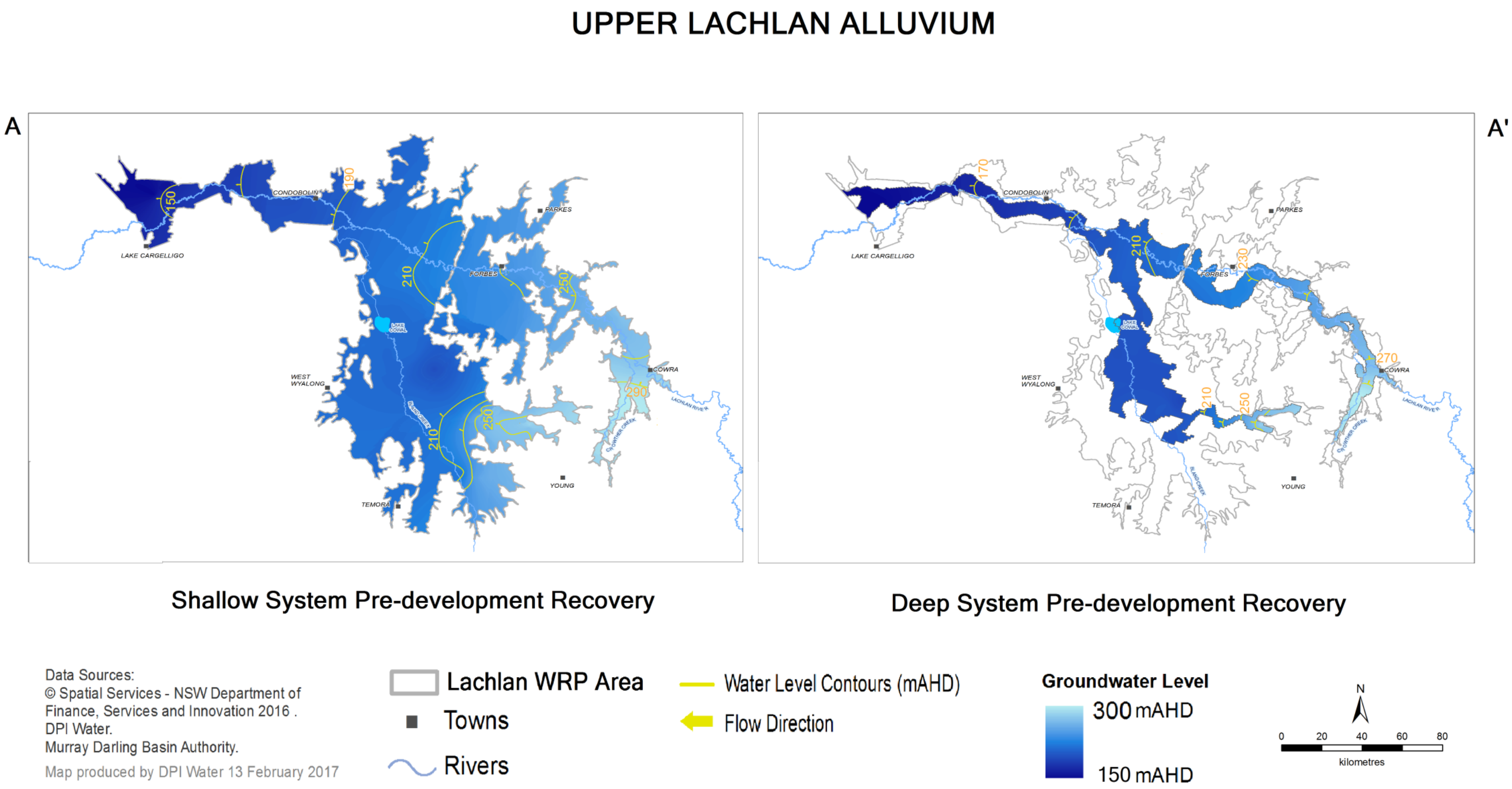

Figure 59 Recovered groundwater level contours for pre-development (1984–89 for the shallow and deep aquifer systems of Upper Lachlan Alluvium.

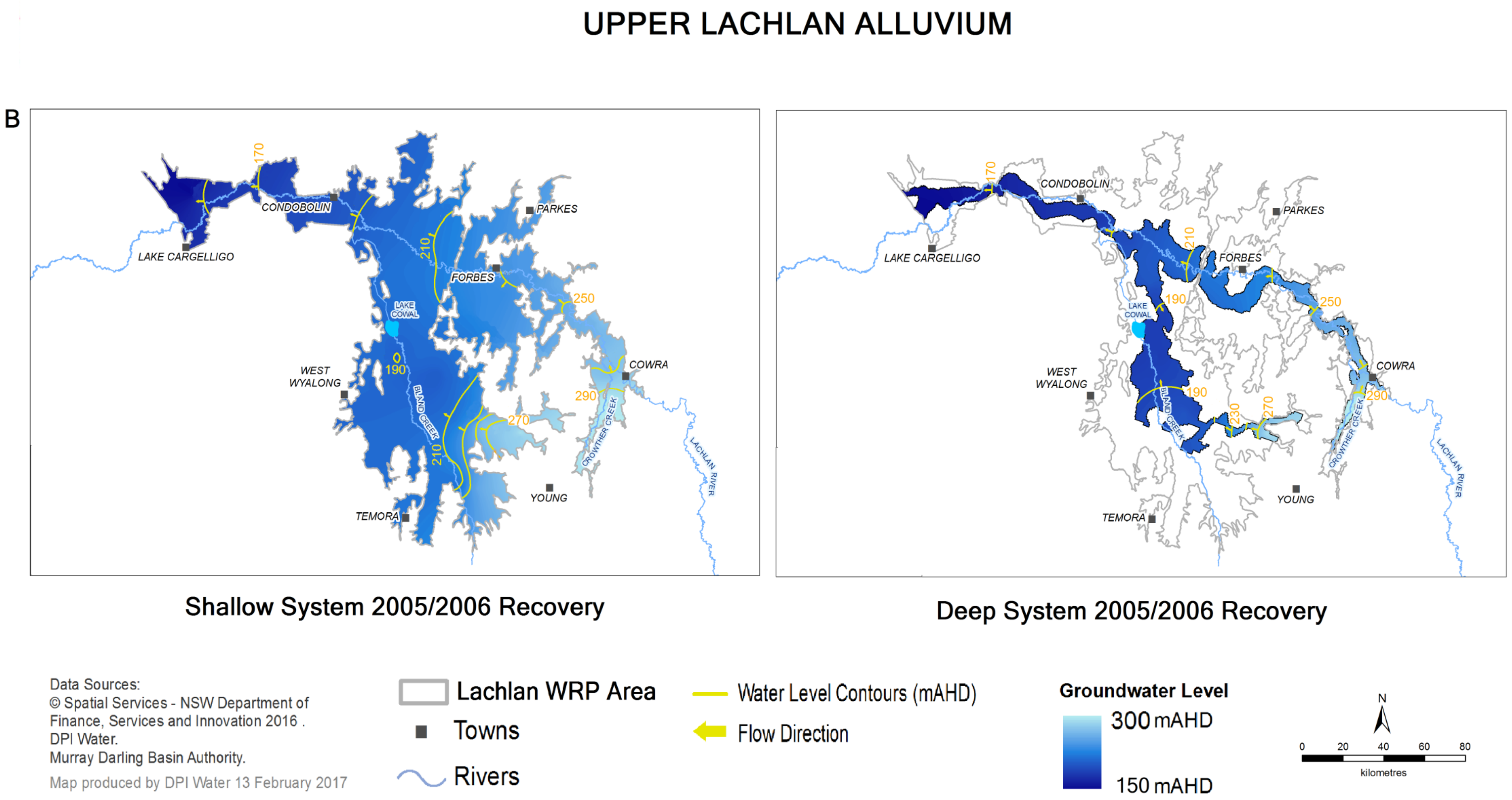

Figure 60 Recovered groundwater level contours for 2005–06 for the shallow and deep aquifer systems of Upper Lachlan Alluvium.

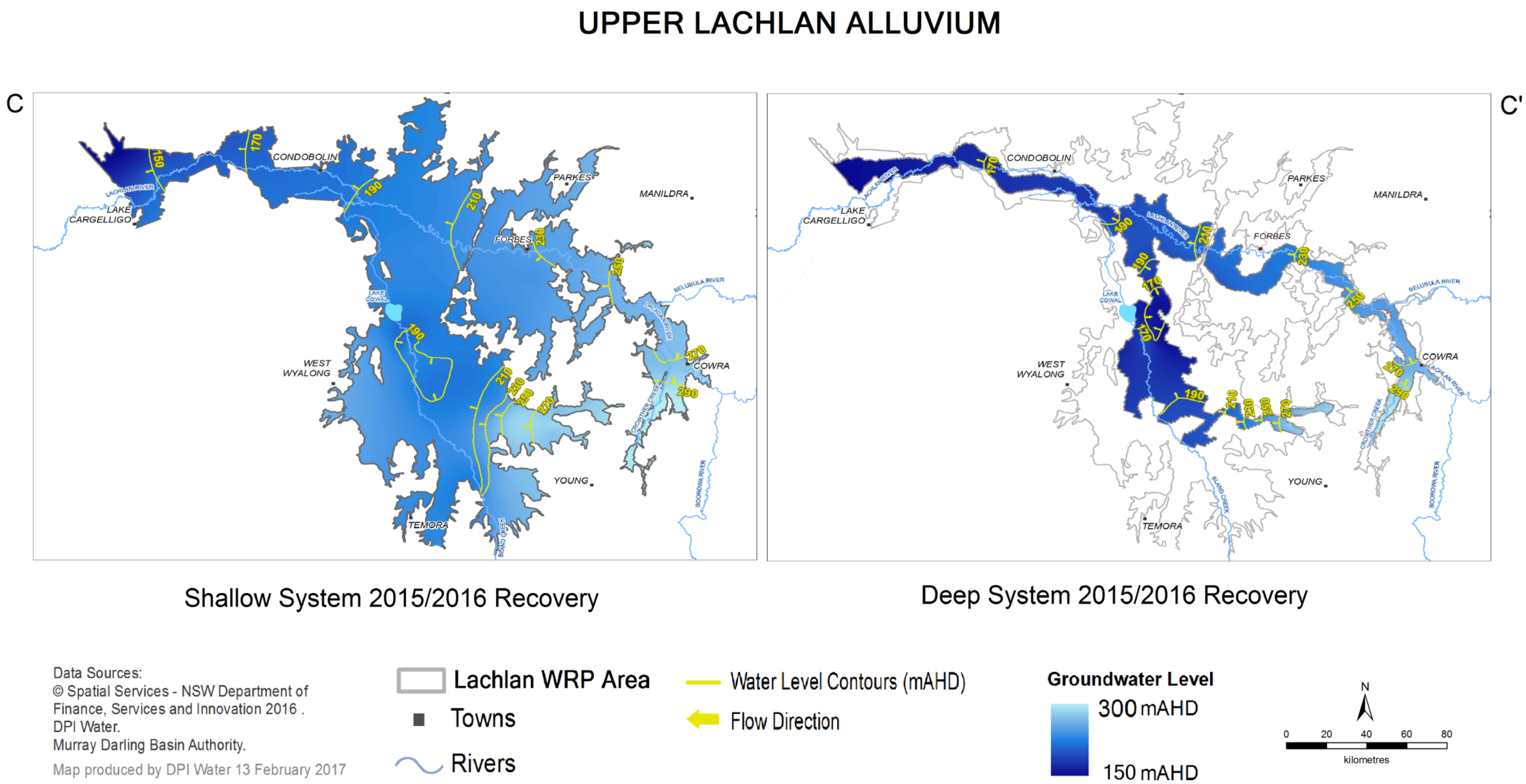

Figure 61 Recovered groundwater level contours for 2015–16 for the shallow and deep aquifer systems of Upper Lachlan Alluvium

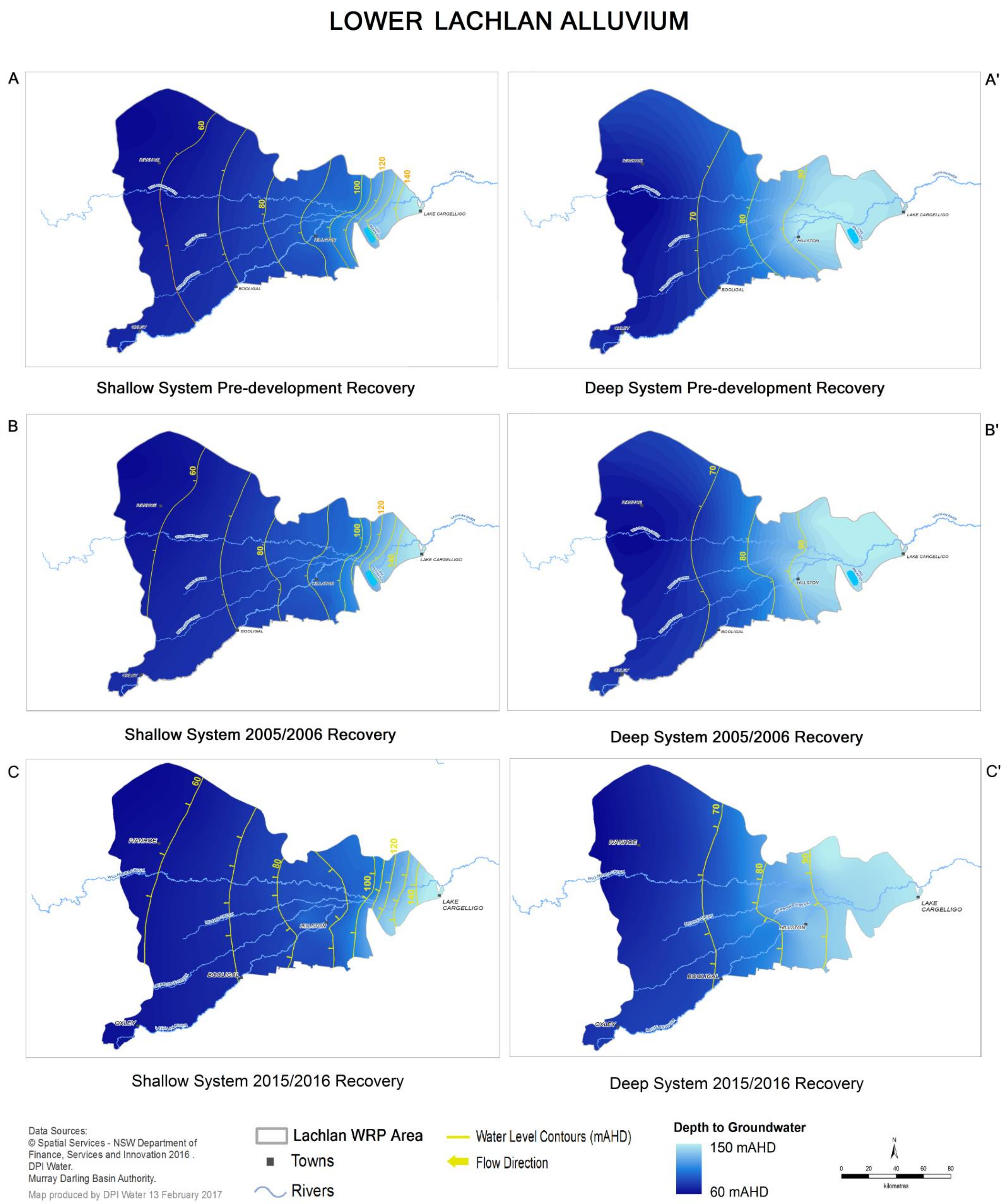

Figure 62 Recovered groundwater level contours for the pre-development period (1984–89), 2005–06 and 2015–16 for the shallow and deep aquifer systems, Lower Lachlan Alluvium

Prior to development of the Upper Lachlan Alluvium, particularly in the shallow aquifer system, (Figure 59 A) groundwater contours bulge north and westward along the rivers (with exception of the lower portions of the Bland Creek), indicating that Lachlan River and upper reaches of the Bland Creek are losing water to the groundwater system. Comparison of the pre-development contour map (Figure 59) and the post-development 2005–06 and 2015–16 contour maps (Figures 60 and 61) show this effect reducing over time in areas to west of Forbes.

Prior to development of the Lower Lachlan Alluvium, groundwater contours in both the shallow and deep aquifer systems (Figure 62 A and A¹) gently curve westward. Post-development (2005–06 and 2015–16) this trend has reversed, in vicinity and downstream from Hillston. This indicates that groundwater pumping has influenced regional flow trends and caused a lowering of groundwater levels in this area. A small area of intense drawdown ‘hotspot’ can be noted in 2015–16 from the deep aquifer downstream from Hillston.

Figure 63 compares the recovered water levels in the Belubula Alluvium with the corresponding maximum drawdown water level in 2015–16. The minor variation observed indicates that pumping had minimal influence on groundwater levels.

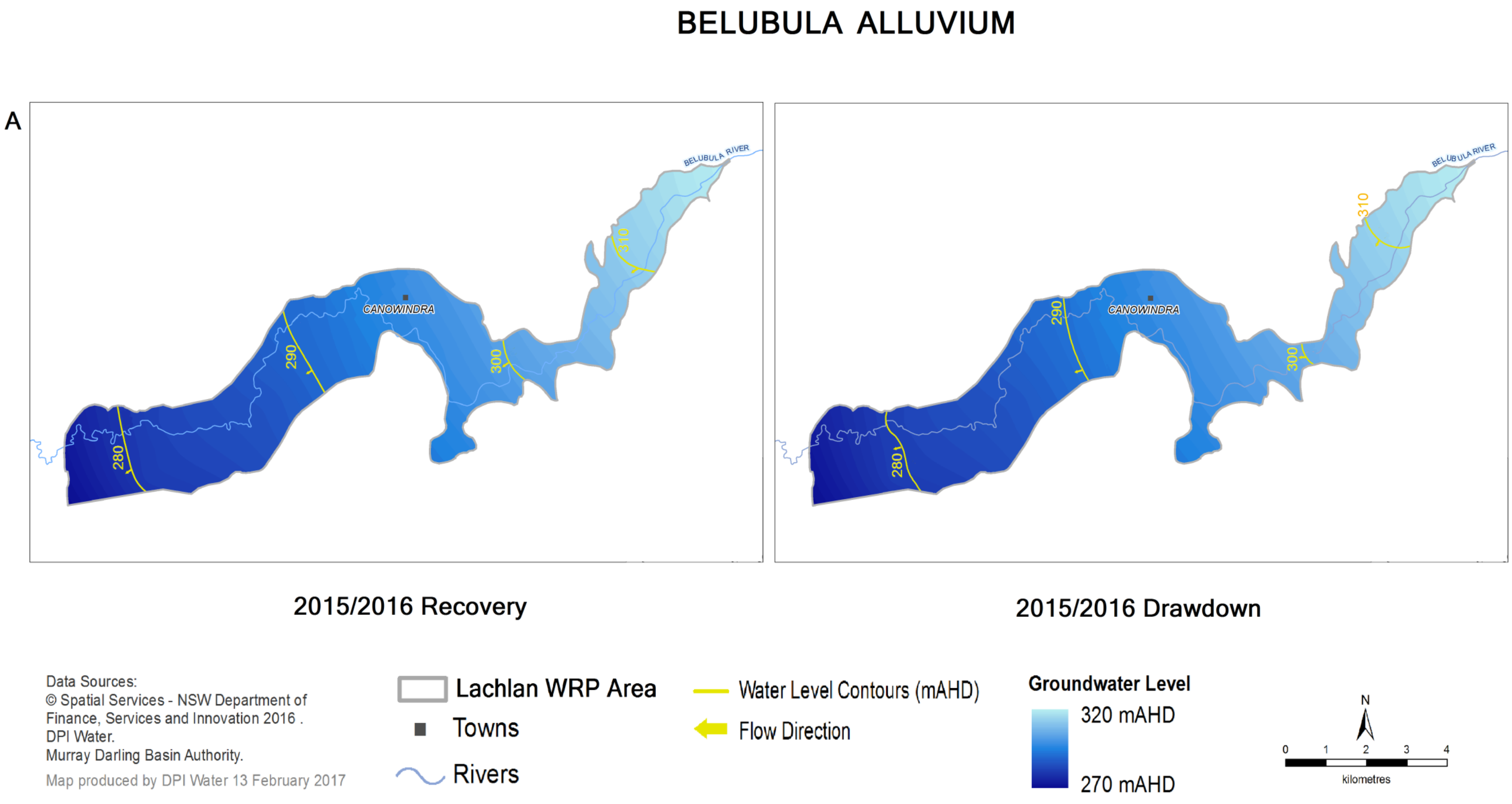

Figure 63 Groundwater level contours for the maximum recovery and maximum drawdown in 2015/2016; Belubula Alluvium.

Figure 64 compares the recovered water levels in the deep aquifer system of the Upper Lachlan Alluvium with the corresponding maximum drawdown water level in 2015–16. It highlights the change of pattern in the flow direction over a season in areas where extraction occurs. The area of greatest extraction impacts is adjacent to Lake Cowal, where drawdown ‘hotspots’ have developed. This area of lowered groundwater levels persists throughout the year but is larger and more pronounced during summer. Such areas of extraction impacts are also observed in localised areas between Cowra and Condobolin (Figure 64).

Figure 65 compares the recovered water levels in the deep aquifer system of the Lower Lachlan Alluvium with the corresponding maximum drawdown water level in 2015–16. It highlights the change of pattern in the flow direction over a season in areas where intense extraction occurs. The area of greatest extraction impacts occurs west of Hillston, where groundwater drawdown has developed lasting throughout the year but is larger and more pronounced during summer.

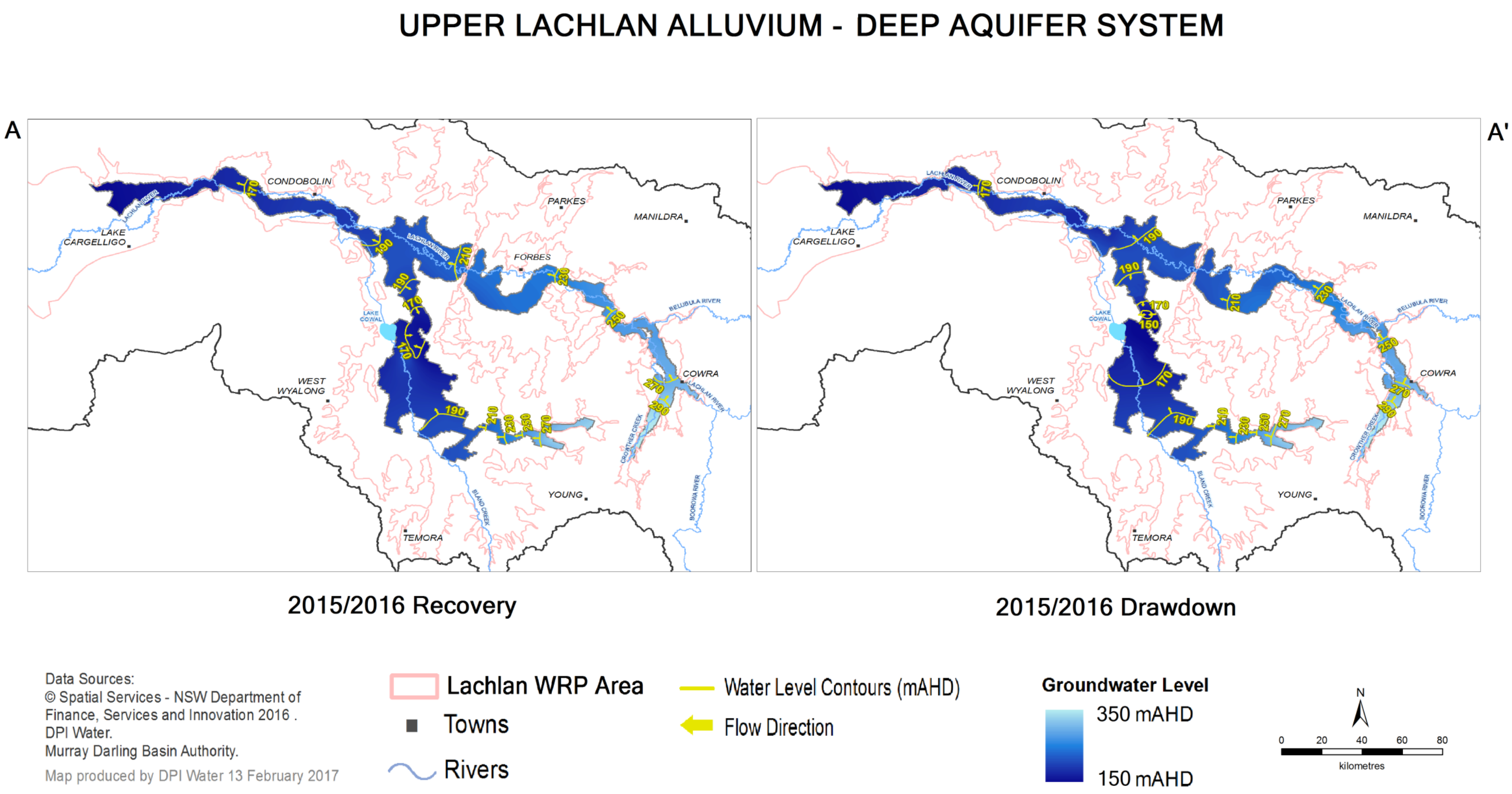

Figure 64 Groundwater level contours for the maximum recovery and maximum drawdown in 2015–16; deep aquifer system, Upper Lachlan Alluvium.

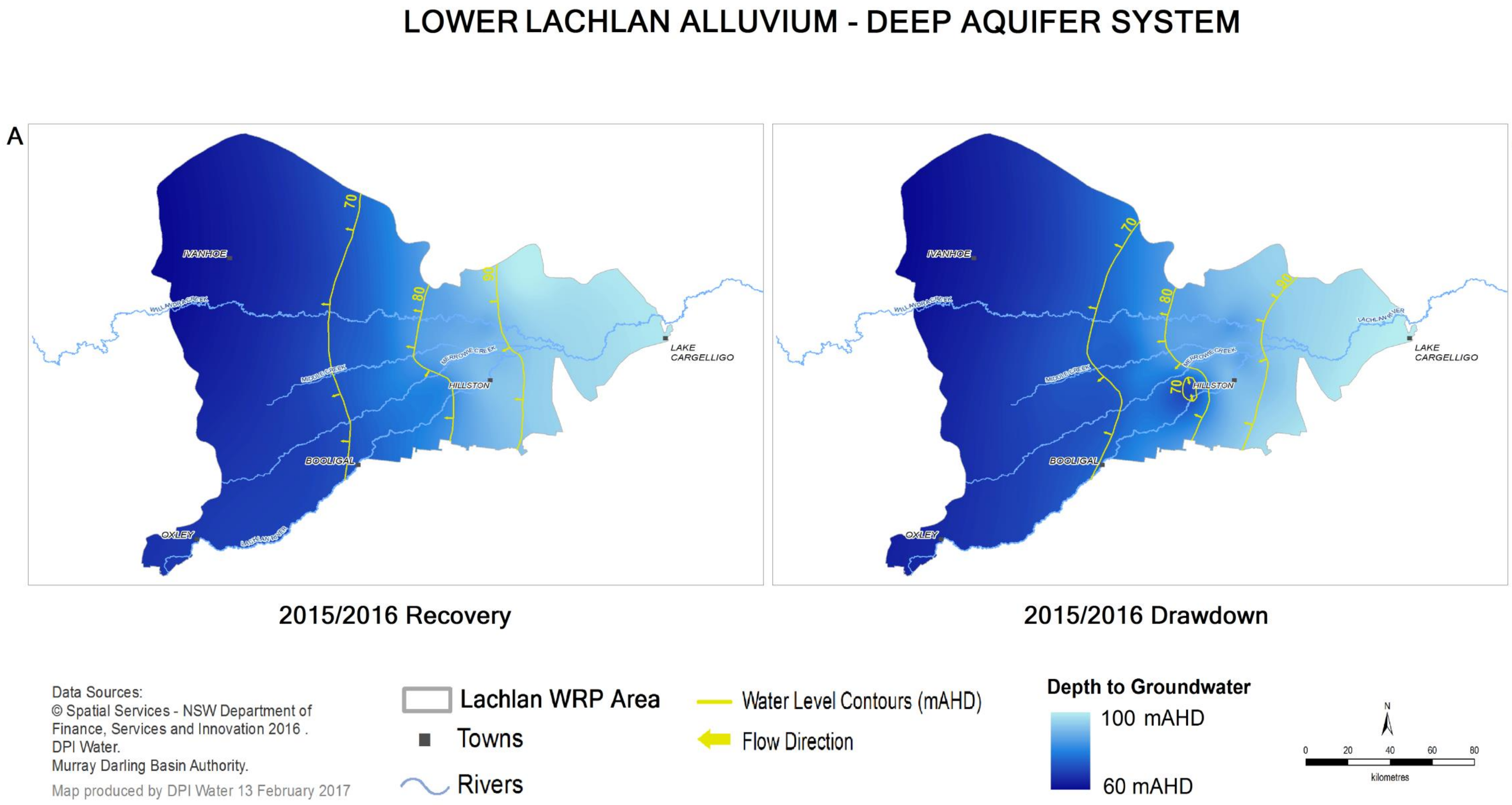

Figure 65 Groundwater level contours for the maximum recovery and maximum drawdown in 2015–16; shallow/deep aquifer system, Lower Lachlan Alluvium.

10.5 Long-term changes

Change in recovered groundwater levels between 2005–06 (pre-water sharing plan) and 2015–16 (post-water sharing plan) in the shallow and deep aquifer systems of the Upper Lachlan and Lower Lachlan Alluvium are shown in Figures 66 and 67, respectively. This comparison was not undertaken for the Belubula Alluvium since water levels from 2005–06 are not available.

The decline in the Upper Lachlan Alluvium (shallow and deep) has been observed mainly where pumping has been occurring with exception of:

- an area east of Forbes; and
- an area to the east of West Wyalong and Bland Creek where water levels have risen.

Across most of the Upper Lachlan Alluvium, water level declines are minimal (less than 4 m). However, in the region adjacent to Lake Cowal in both the shallow and deep systems, significant declines have occurred that are consistent with known areas of localised impacts. It is believed that the rise in water levels to the east of Forbes is possibly due to pressure equilibration and reduced pumping over the last 5 to 6 years. The cause of the observed rise in water levels to the north east of Young is not certain but likely due to local recharge from surface water.

Between 2005–06 and 2015–16, water level decline has been observed in both the aquifer systems (shallow and deep) of the Lower Lachlan Alluvium in areas where pumping has been occurring (Figure 67). The largest drawdowns have occurred in the vicinity of Hillston, in particular to the north of the town where development pressure has been the greatest.

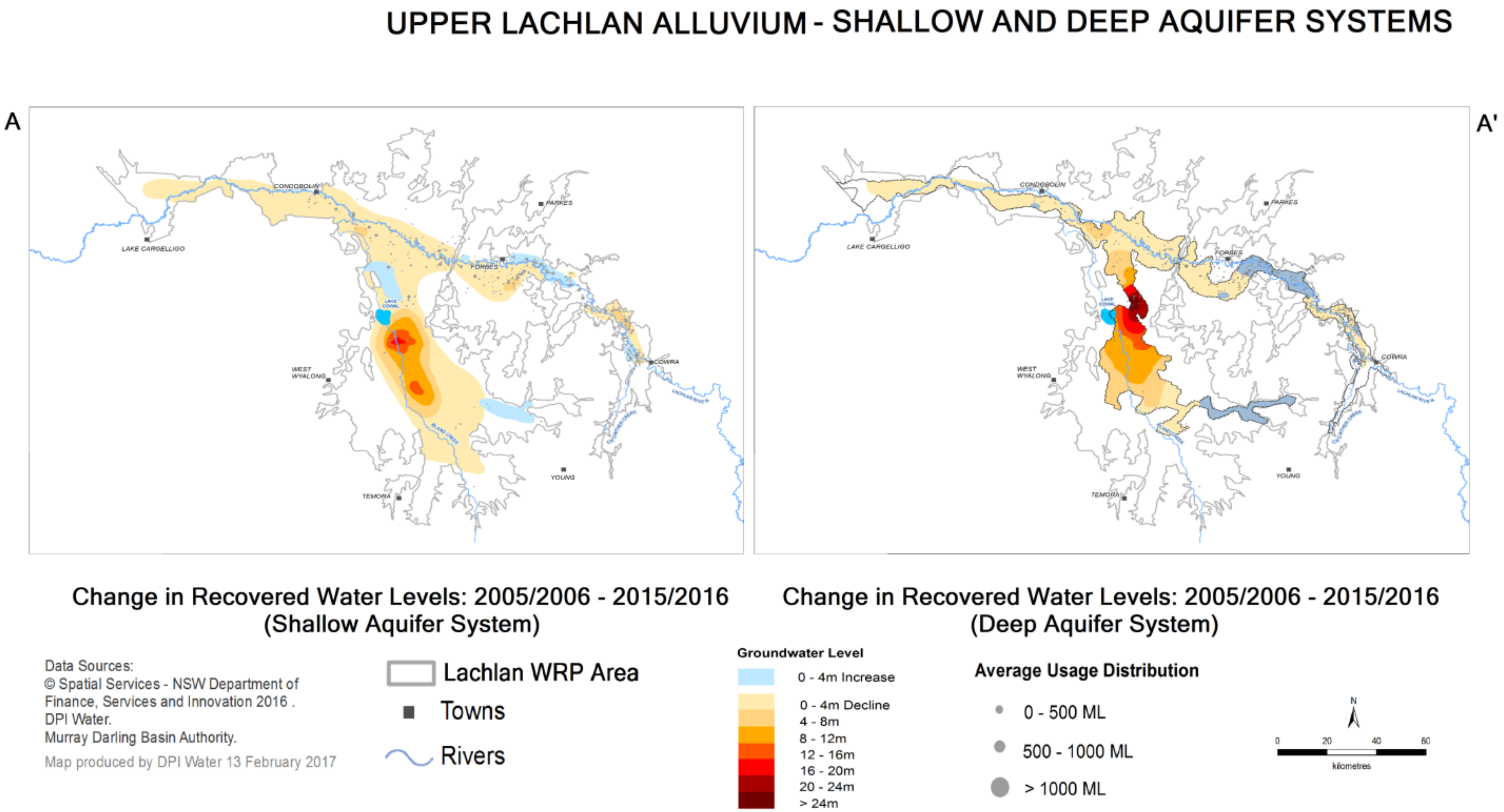

Figure 66 Upper Lachlan Alluvium – shallow and deep aquifer systems; change in recovered water level between 2005–06 and 2015–16.

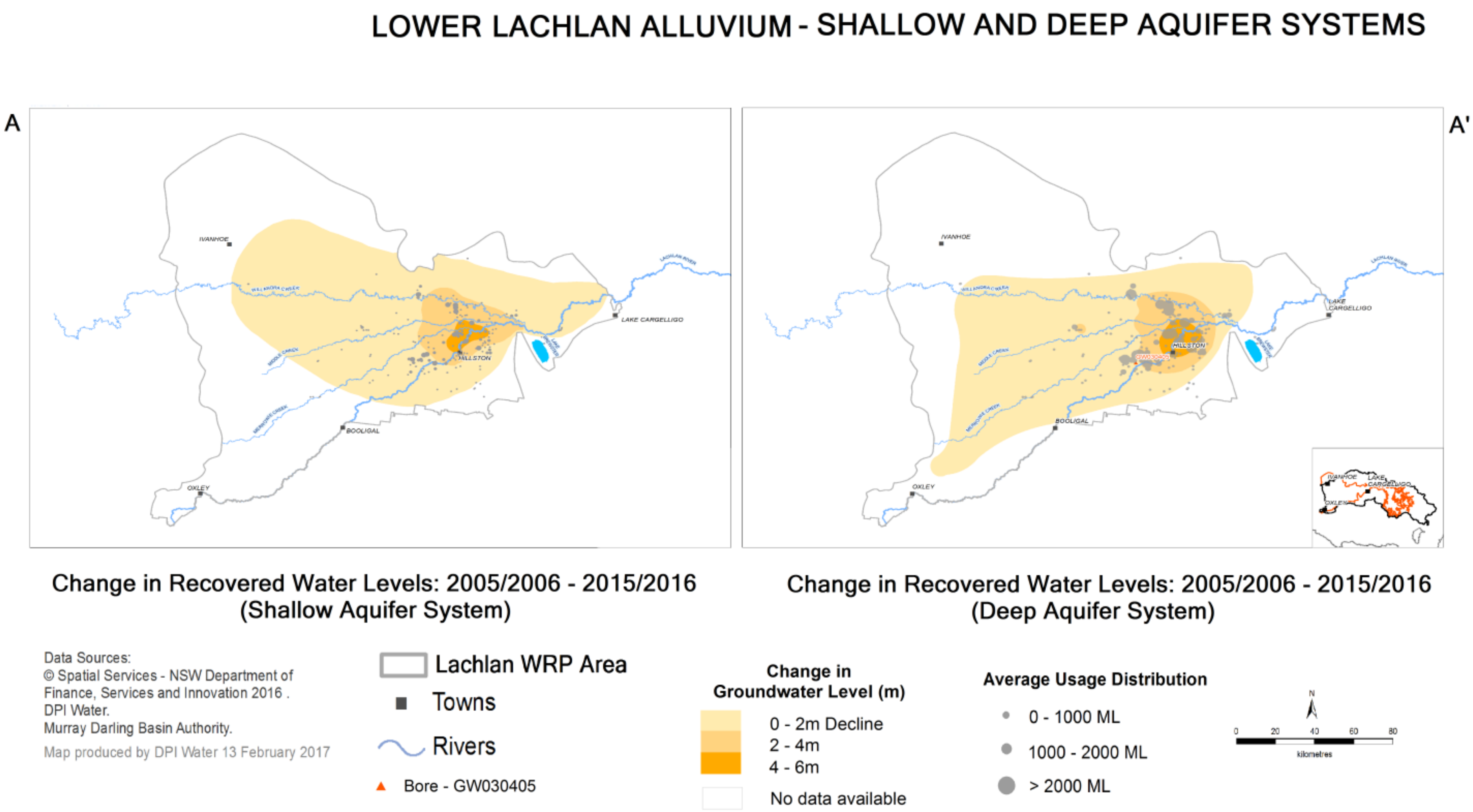

Figure 67 Lower Lachlan Alluvium – shallow and deep aquifer systems; change in recovered water level between 2005–06 and 2015–16.

11 Groundwater Model

A groundwater model is any computer-based method that simulates a groundwater flow system.

Groundwater models enable spatial and temporal prediction estimates based on simulation of inputs (rain, floods, irrigation, rivers) and outputs (pumping, rivers, evaporation) to and from the groundwater system.

There are many computer programs which model groundwater systems. The NSW Government generally uses a commonly used and worldwide-accepted standard code called MODFLOW, developed by the United States Geological Survey (USGS).

The modelling process involves several stages such as data collation, hydrogeological system conceptualisation, software selection, model design and model calibration against measured and observed data. A sensitivity analysis is also undertaken to evaluate the influence of parameters uncertainty on model outputs.

In 2006, the groundwater model for the Lower Lachlan Alluvium was finalised to support resource management. It was updated in 2016 with refined modelled area and a calibration period from 1986 to 2015 (Bilge et al, 2016, in Prep).

Figure 68 shows the cumulative water budget output from the 2016 Lower Lachlan Alluvium groundwater model for the period 2006–07 to 2015–16.

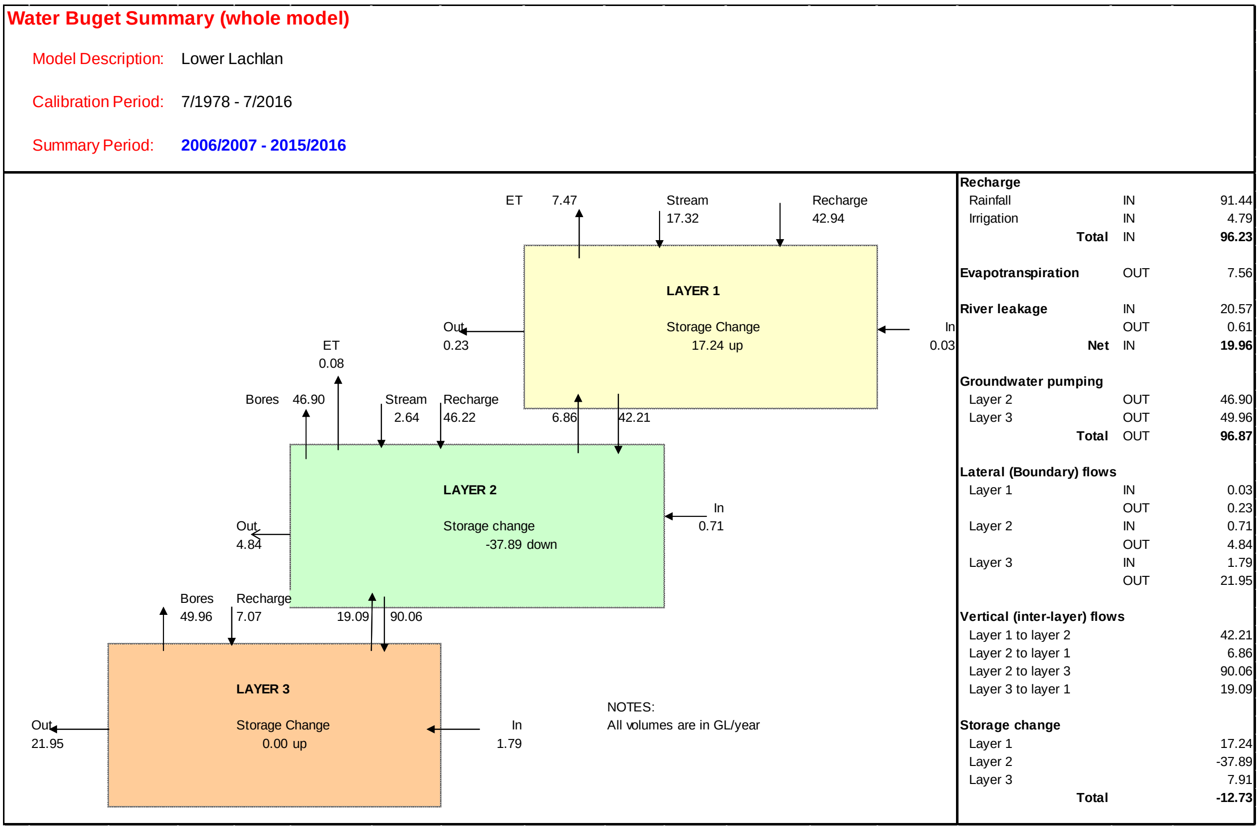

Figure 68 Lower Lachlan Alluvium groundwater flow model water budget output 2006–07 to 2015–16.

The water budget provides an estimate of the bulk change to the volume of groundwater in storage. If the total outputs such as extraction, and loss to the rivers are greater than the inputs (estimated recharge) over time then there is a net loss of the amount of water stored in the aquifer. No change in storage implies that the level of pumping is potentially sustainable into the future.

Figure 68 shows that since the commencement of the water sharing plan in 2006–07, the modelled total net groundwater in storage in the Lower Lachlan Alluvium has decreased (storage change –12.73 GL) over the ten years of the dataset.

In NSW, groundwater management aims to ensure that long-term extraction does not impact on the sustainability of the resource. Annual groundwater extraction volumes may exceed the plan's extraction limit during periods of high demand, provided the resource is able to recover over the longer term.

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