NSW BORDER RIVERS ALLUVIUM WATER RESOURCE PLAN

NSW Border Rivers Alluvium Water Resource Plan - Groundwater Resource Description

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Published by NSW Department of Planning, Industry and Environment

dpie.nsw.gov.au

Title: NSW Border Rivers Alluvium Water Resource Plan - Groundwater Resource Description

First published: July 2019

Department reference number: INT19/2797

NOTE: On 1 July 2019, NSW Department of Industry became part of NSW Department of Planning, Industry and Environment. Any references to Department of Industry in this document, except where made in a historical context, can be taken to refer to Department of Planning, Industry and Environment.

More Information

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Glossary

Note: these terms are presented in the context that they are used for groundwater.

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.
Aquitard	A confining low permeability layer that retards but does not completely stop the flow of water to or from an adjacent aquifer, and that can store groundwater but does not readily release it.
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. .

Term	Meaning
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.
Bore (or well)	A hole or shaft drilled or dug into the ground...
Brackish water	Water with a 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.

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

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

Term	Meaning
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.
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.

[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 Industry, Sydney, NSW.

Term	Meaning
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.
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.

Term	Meaning
Reliable water supply	[4]Rainfall of 350mm 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) which 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.
Salinity	The concentration of dissolved minerals in water, usually expressed in EC units or milligrams of total dissolved solids per litre.
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 (eg. 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.

[4] As defined by Strategic Regional Land Use Plans

Term	Meaning
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 set out the rules for sharing water between the environment and water users within whole or part of a water management area or water source.
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.

[5] https://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)

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 NSW Border Rivers Alluvium Water Resource Plan (WRP) area is shown in Figure 1 and is located within the Border Rivers catchment that forms part of the Murray-Darling Basin in northern NSW. The Border Rivers catchment in NSW covers approximately 24,500 km^2 and represents about two percent of the Murray-Darling Basin; the main rivers being the Dumaresq River, Macintyre River Severn River and the Barwon River.

The groundwater resources of the NSW Border Rivers Alluvium WRP area include all of the main alluvial deposits associated with the Dumaresq River, the Macintyre River and Ottleys Creek. The WRP area extends downstream from Mingoola along the Dumaresq and Macintyre Rivers to approximately 20 km downstream of Boggabilla. It also includes the alluvium along the Macintyre River from approximately 20 km upstream of Yetman to its confluence with the Dumaresq River and a 44 km reach of the Ottleys Creek upstream of its confluence with the Macintyre River.

The New South Wales Border Rivers Alluvium WRP area (GW18 - Murray-Darling Basin reference number) is composed of two SDL resource units: the NSW Border Rivers Alluvium (GS32); and the NSW Border Rivers Tributary Alluvium (GS33) shown in Figure 1 inset map. These two SDL resource units correlate to four groundwater sources currently covered by the *Water Sharing Plan for the NSW Border Rivers Unregulated and Alluvial Water Sources 2012 (BR WSP 2012),* refer to Table 1.

Table 1 New South Wales Border Rivers Alluvium Water Resource Plan area (GW18)

SDL Resource Unit	Water Source
The NSW Border Rivers Alluvium (GS32)	NSW Border Rivers Upstream Keetah Bridge Alluvial Groundwater Source NSW Border Rivers Downstream Keetah Bridge Alluvial Groundwater Source
NSW Border Rivers Tributary Alluvium (GS33)	Macintyre Alluvial Groundwater Source Ottley's Creek Alluvial Groundwater Source

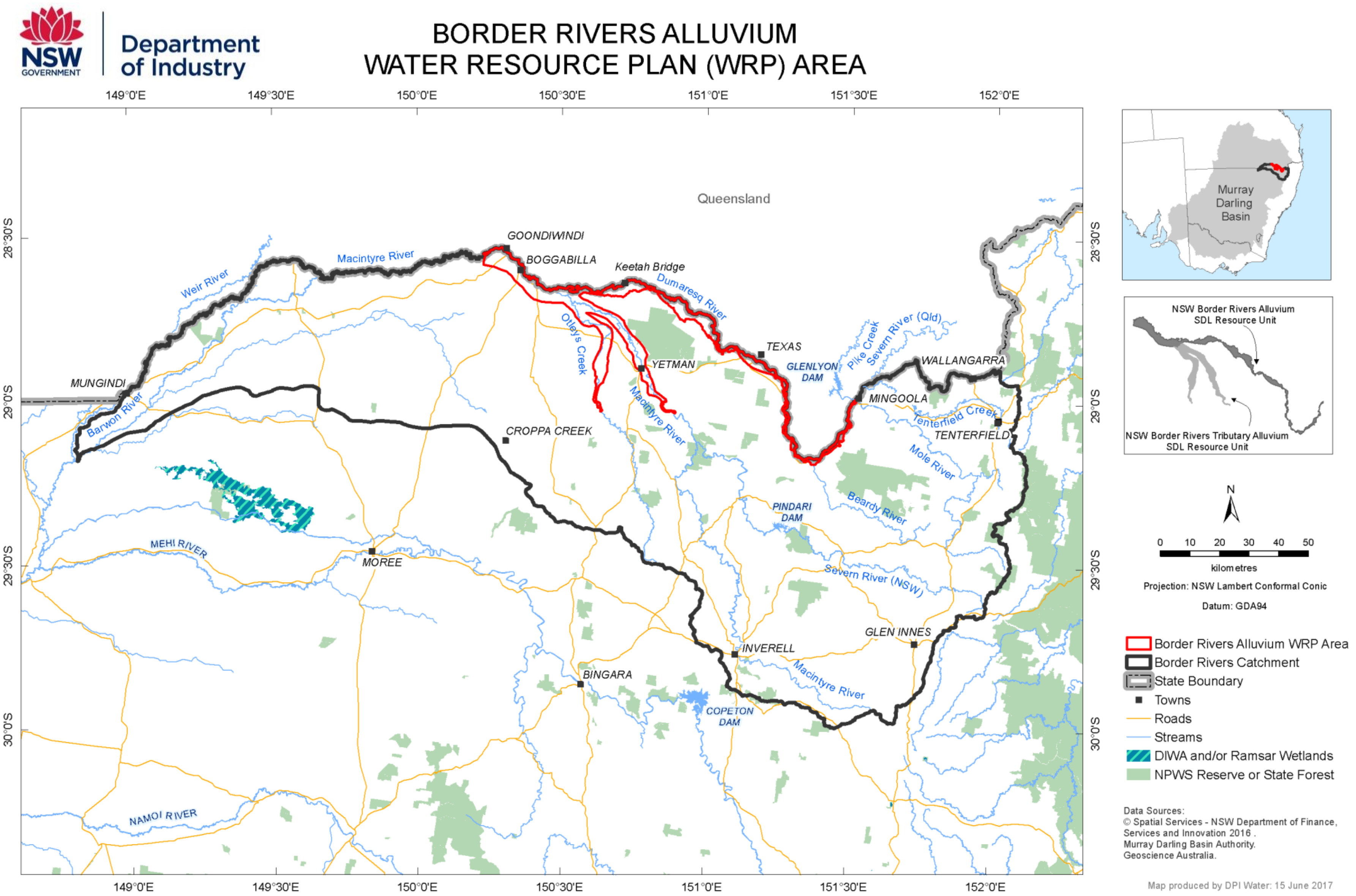

Figure 1 Location of the New South Wales Border Rivers Alluvium water resource plan area and SDL Resource Units

This report describes the location, climate and physical attributes of the groundwater resources of the NSW Border Rivers Alluvium WRP, 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 *Water Act 1912* water entitlement was linked to land rights. Licences were granted for bores and wells for a fixed term with no restriction on the volume that could be extracted. Bore licences were initially required only in the western half of NSW for bores greater than 30 m in depth.

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. 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 (WMA 2000)*. The *WMA 2000* 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 *WMA 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 *WMA 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. 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 covers a number 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.

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 *WMA 2000* and other relevant legislative frameworks.

2.3. Groundwater management in the Border Rivers Alluvium

In 1948 the Dumaresq-Barwon Border Rivers Commission (BRC) was established (DBBRC, 2011b) under an agreement made in November 1946 ratified by legislation in both states.

The Border Rivers Commission recommended that, as the alluvial groundwater system traverses the state boundary, it should be shared equally. It was agreed that the Border Rivers Commission would be responsible for assessing the bulk volumes of groundwater and recommending groundwater sharing arrangements to the States. However, each State would continue to be responsible for managing groundwater on its own side of the border, through its own legislation but along agreed guidelines (Water Resources, 1990).

In 1984 the NSW Water Resources Commission proclaimed the Border Rivers Region as a Restricted Sub-Surface Water Area under Section 117A of the Water Act 1912 (Kalaitzis P., De Silva H., 1994). This enabled controls to be put on the quantity of water pumped from any licensed bore, including those bores and wells whose licence did not specify a volumetric limit.

In 1986 an embargo for new groundwater licences was introduced pending the development of management plan (Water Resources, 1989). This embargo was lifted in 1990 with the introduction of the Interim Management Plan for the Groundwater Resources Contained in the Alluvial Sediments of the Border Rivers System (Water Resources, 1990). This facilitated the conversion of area based licences to a volume and also provided for a conjunctive component in dry times to make up for reduced surface water access for those licensees that held surface water licences.

In 1990 the States agreed through the Border Rivers Commission that the maximum allocation of groundwater be capped at 15,000 ML in each state for the reach of alluvium upstream of Keetah (DBBRC, 1990).

In 2005, conjunctive licences were converted to groundwater only volumes for licences upstream of Keetah Bridge.

Since 1 June 2012 the groundwater resources have been managed under the Water Sharing Plan for the NSW Border Rivers Unregulated and Alluvial Water Sources 2012.

3. Regional Setting

3.1. Topography

The NSW Border Rivers river system and its floodplain are the main topographic features of the WRP area (Figure 2). The headwaters of the Border Rivers tributaries which start at around 1,200 m above sea level are on the western side of the Great Dividing Range north of Glen Innes. The tributaries flow north-west through tablelands to the flood plain downstream of Boggabilla.

There are three dams that regulate river flows and provide water for town water supplies, irrigation, stock and domestic use, industry and environmental flows.

Pindari Dam, located on the Severn River in NSW, was completed in 1969 and enlarged in 1995 to 312,000 ML capacity. Glenlyon Dam, situated in Queensland on Pike Creek completed in 1976 with a 245,000 ML capacity, regulates the flow along the Dumaresq River. Coolmunda Dam is located on the Macintyre Brook in Queensland was completed in 1968 with 69,000 ML capacity.

The flow regime of Dumaresq, Severn, Macintyre and Barwon Rivers has been substantially altered by the operation of these three dams and various weirs along the river systems (Figure 3). The river flow is regulated downstream to Mungindi.

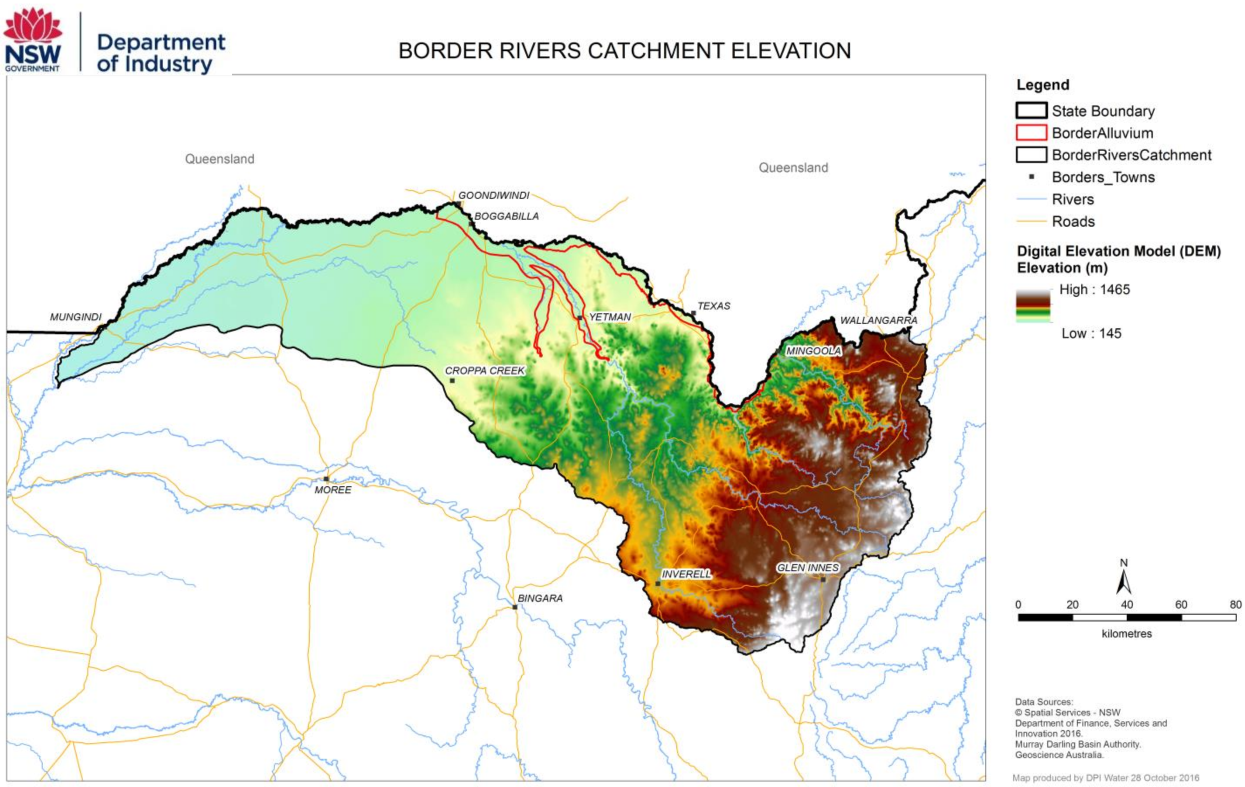

Figure 2 Topography and elevation map of the New South Wales Border Rivers catchment (Gallant *et al*, 2009)

The Dumaresq River commences about 5 to 6 km upstream of Mingoola at the confluence of the Severn River (Queensland) and Tenterfield Creek (NSW). The Dumaresq River flows westerly and is regulated downstream from the confluence of Pike Creek at Mingoola. About 25 km upstream of Boggabilla Dumaresq River joins the Macintyre River. The mean daily flow in the Dumaresq River is 1,041 ML (1934 – 2010) at Bonshaw Weir (Green et al, 2012).

The Macintyre River's headwaters are about 40 kilometres upstream of Inverell. It is regulated downstream from the confluence of the Severn River. The mean daily flow at Boggabilla is 2,459 ML (1885-2010) (Green et al, 2012).

The Macintyre River changes name to Barwon River at the confluence of Weir River from Queensland. The Barwon River is regulated to Mungundi with a mean daily flow of 1,645 ML (1889-2010) (Green et al, 2012).

A detailed description of the catchment's surface water systems is provided in the New South Wales Border Rivers Surface Water Resource Description (September 2017, in prep).

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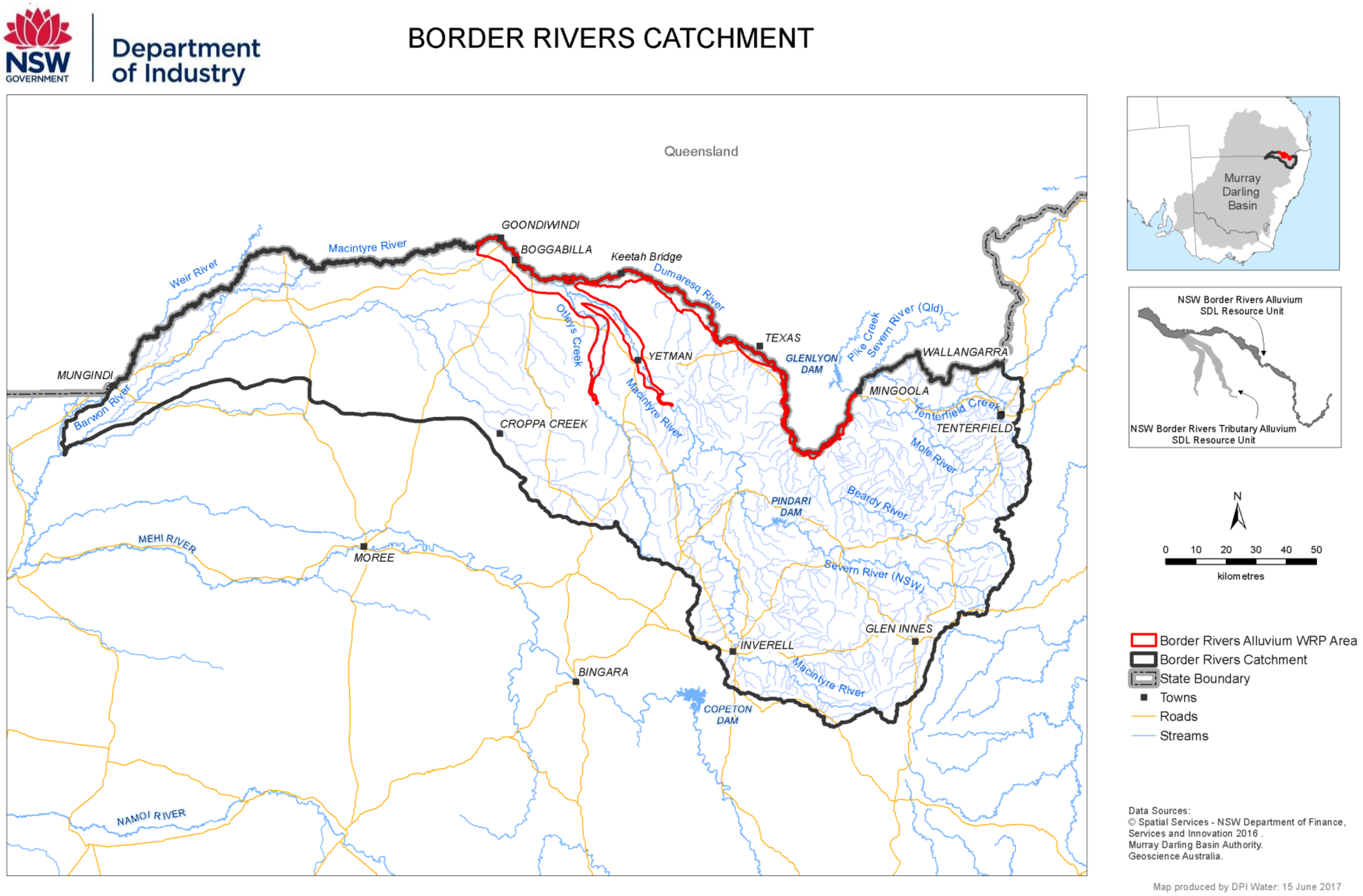


Figure 3 Surface water map of the New South Wales Border Rivers catchment

3.2. Climate

The NSW Border Rivers catchment has a temperate to sub-tropical climate, with a considerable gradient from east (cooler and wetter) to west (hotter and drier).

The temperature extremes across the catchment can range from -9.4°C in the winter to 48.2°C in the summer. Average maximum temperature is 23.8°C and average minimum 11°C. The average temperature is similar across the catchment.

Average annual rainfall varies from over 860 mm near Glen Innes at the top of the catchment to around 500 mm in the far west (Figure 4).

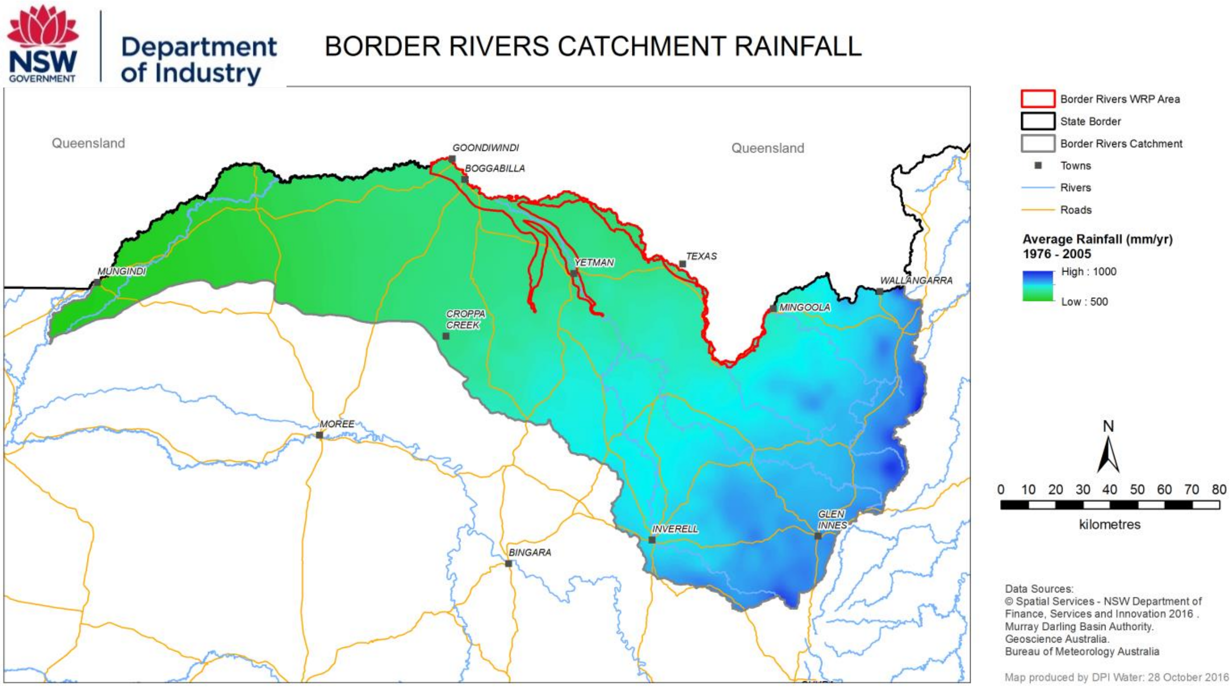


Figure 4 Average annual rainfall map of the New South Wales Border Rivers catchment (BOM, 2008) [7]

The rainfall and evaporation data (sourced from Scientific Information for Land Owners (SILO)) below is reported from 1987 to 2016 inclusive matching the dataset of regular groundwater level measurements for the area.

Annual rainfall across the catchment decreases westward. Texas in the central part of the plan area receives an average yearly rainfall of 698 mm while at Goondiwindi in the western area has an average of 621 mm. Rainfall is generally summer dominant with the heaviest rainfall occurring from October to March (Figure 5). Summer rainfall is typically 65-107 mm per month at Texas, and 45-95 mm per month at Goondiwindi.

[7] The average rainfall period 1976 - 2005 displayed in this map is the current standardised average conditions gridded dataset available from the Bureau of Meteorology.

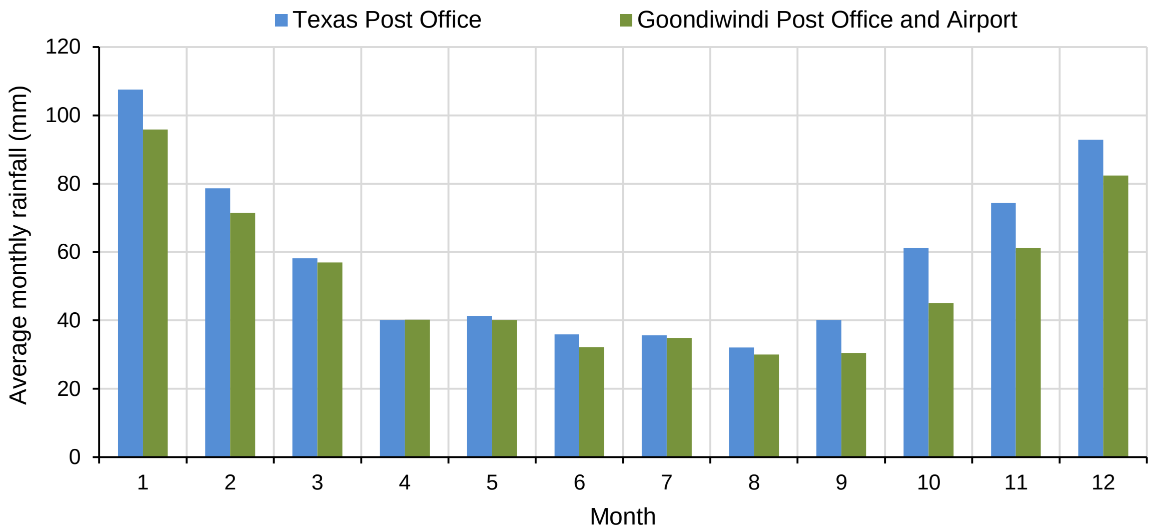


Figure 5 Average monthly rainfall 1987 – 2016 for Texas and Goondiwindi

Evaporation (Class A pan evaporation) in the catchment has a strong east-west gradient (Figure 6). Yearly evaporation varies from around 1,400 mm in the east to over 2,000 mm in the west.

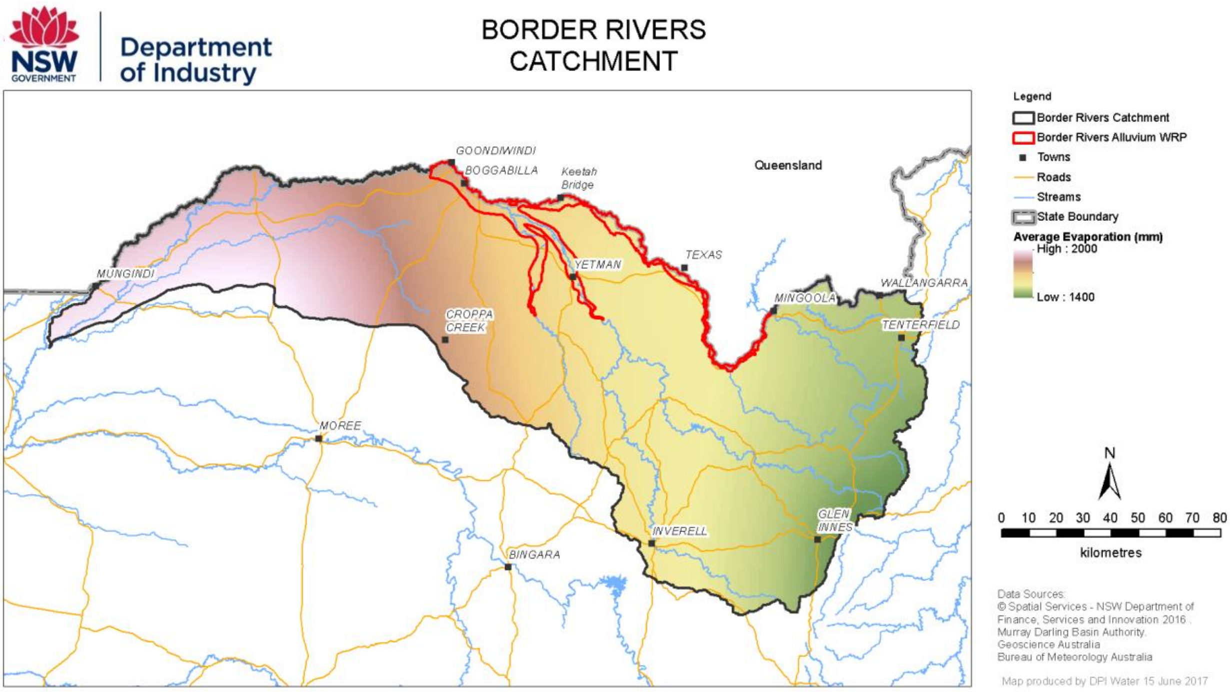


Figure 6 Average annual evaporation map of the New South Wales Border Rivers catchment (BOM, 2008) [8]

Evaporation is strongly seasonal (Figure 7) varying from 65 - 80 mm a month over winter (June/July) to 235 – 290 mm over the summer (December/January). Evaporation significantly exceeds average monthly rainfall over the year. The greatest exceedance occurs over the summer months (December/January), when up to 288 mm of evaporation occurs per month compared to up to 107 mm of rainfall per month for the same period.

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

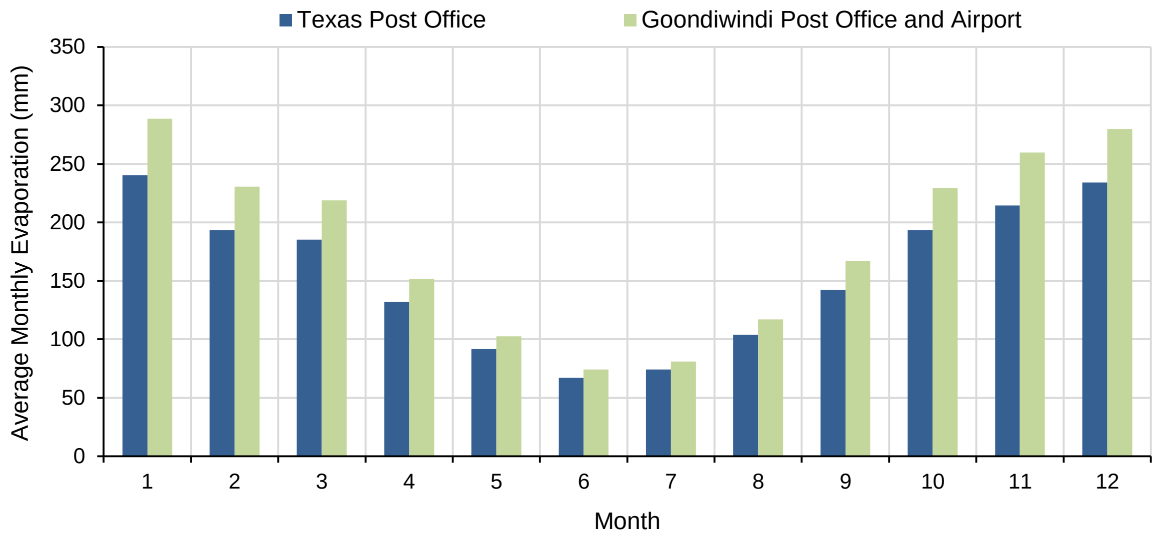


Figure 7 Texas and Goondiwindi average monthly evaporation 1987 – 2016

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 1987 to 2017 at Texas and Goondiwindi. This period corresponds to the period of groundwater monitoring in the Border Rivers Alluvium which commenced around 1987 in NSW.

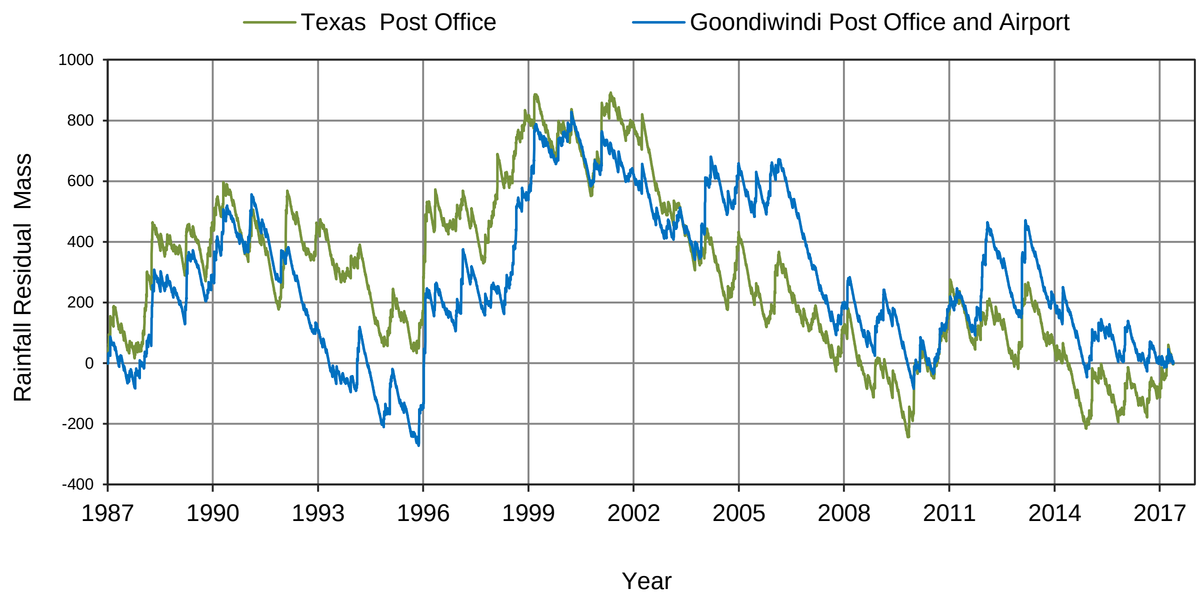


Figure 8 Texas and Goondiwindi rainfall residual mass graph 1987 - 2017

Figure 8 shows a below average rainfall trend during the millennium drought from 2002 to 2010, followed by an above average spike over the 2011-2013 period then a below average trend to present.

3.3. Land use

The Bigambul, Kamilaroi and Ngarabal people were the original inhabitants of the New South Wales Border Rivers catchment. The land and waters of the NSW Border Rivers 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 Border Rivers dates back to the 1840's when Texas Queensland was first settled by the McDonald brothers. Tobacco was predominant crop in the Border Rivers Alluvium from the late 1800's to the 1950's when it was finally phased out in 1986.

"*Land use in the Border Rivers catchment is dominated by extensive agriculture with approximately 67 per cent of the catchment used for grazing and 18 per cent used for dryland cropping. Grazing occurs right throughout the catchment while dryland cropping occurs predominantly on the central plains south of Goondiwindi and Boggabilla. The principal crops are winter cereals, summer grain and oilseed. Approximately two per cent of land has been developed for irrigation, mostly in the west of the catchment between Goondiwindi and Mungindi. Cotton accounts for around 85 per cent of all irrigated crops, covering around 40,000 hectares of the NSW catchment, and having an economic value of around $150 million per annum (DWE 2009a). Other irrigated crops include fruit, vegetables, wine grapes, lucerne, cereal crops, corn, peanuts, and fodder for feedlots*" (Green et al, 2012). Most of the irrigation is along the alluvium associated with the regulated rivers, with the predominant groundwater use upstream of Keetah Bridge. More recently pecans have been trialed as a permanent planting.

Figure 9 shows land use information across the catchment based on the Australian Bureau of Agricultural and Resource Economics and Sciences 2010-2011 land use data (Smart, 2016). There is over 500 km^2 of conservation areas and National Parks. These include the Torrington State Conservation Area (300 km^2), the Sundown National Park, situated on the NSW-Queensland border, the Kwiambal National Park (71 km^2), the Severn River Nature Reserve (57 km^2) and the Kings Plains National Park (69 km^2) (Green et al 2012)

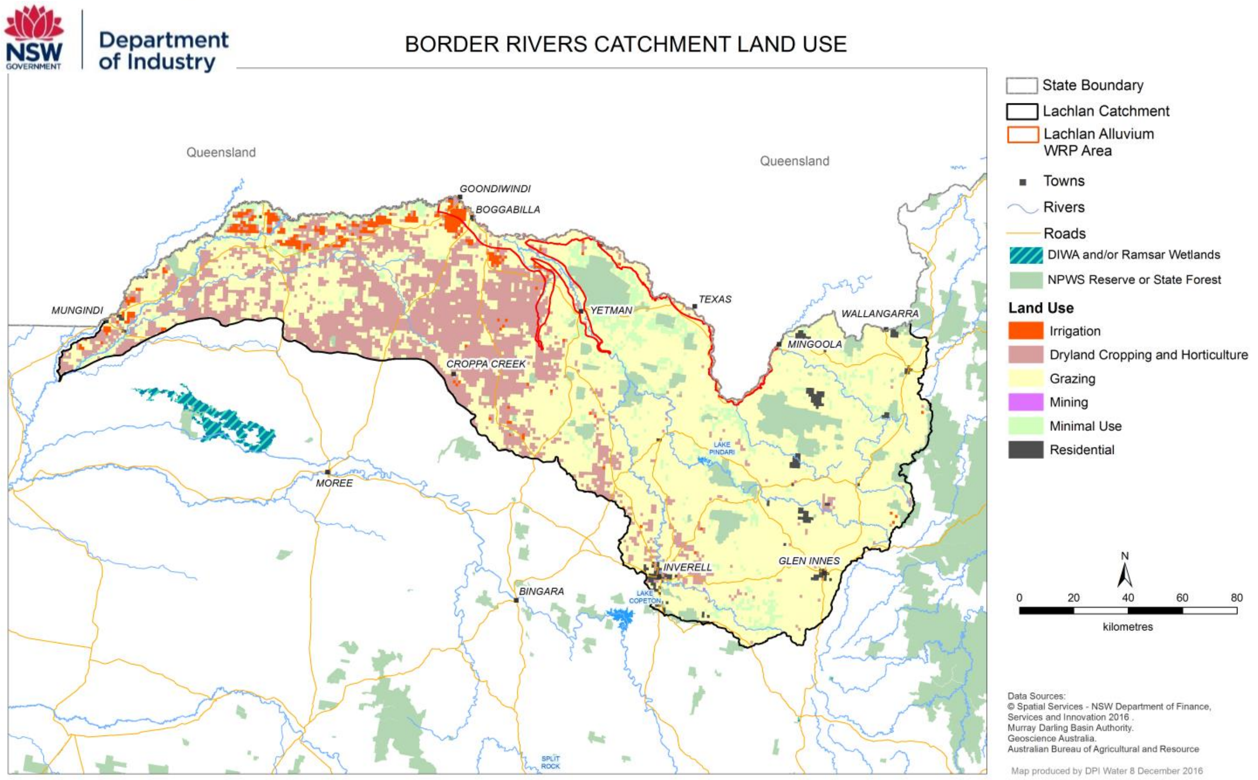


Figure 9 Land use map of the New South Wales Border Rivers catchment (Smart, 2016)

There are over 30,000 people living within the NSW Border Rivers catchment (Green et al, 2011). The largest town and commercial centre within the catchment is Inverell (population 9,347, 2011 census).

Boggabilla is the largest settlement (population 626) in the NSW Border Rivers Alluvium and Yetman (population 178) is the largest settlement located within the NSW Border Rivers Tributary Alluvium.

4. Geology

The geology of the NSW Border Rivers catchment is made up of four main geological sequences including; the Palaeozoic/Mesozoic New England Fold Belt, the Mesozoic Great Artesian Basin, the Cenozoic unconsolidated sediments, and the Cenozoic extrusive volcanics (Figure 10).

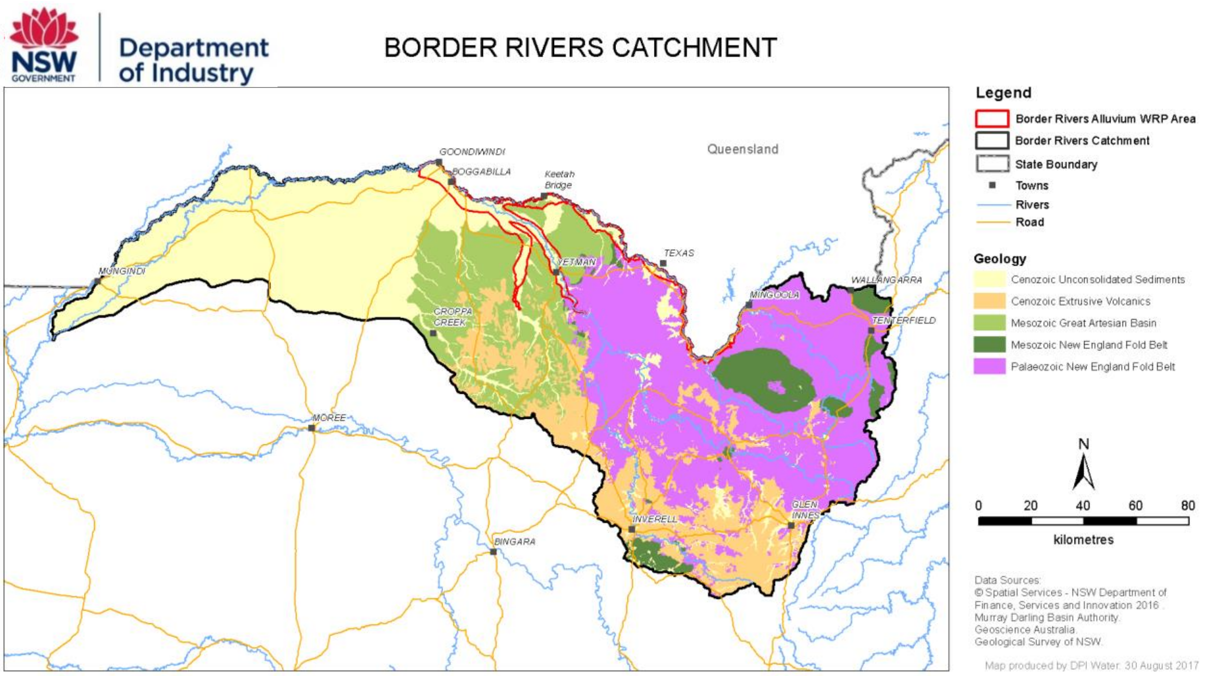


Figure 10 Geology of the New South Wales Border Rivers catchment

The Palaeozoic New England Fold Belt is the oldest rock assemblage in the area and consists of sedimentary, metamorphic and igneous rocks. The New England Fold Belt is extensively faulted due to tectonic events around 200 million years ago. South of Inverell and north of Glen Innes, younger Mesozoic aged granites crop out within the New England Fold Belt.

The late Palaeozoic Gunnedah Basin is a sedimentary coal basin that occurs only at depth, and does not outcrop at the surface within the New South Wales Border Rivers catchment.

The Gunnedah Basin is overlain by the Mesozoic Great Artesian Basin. The Great Artesian Basin is Australia's largest groundwater basin covering approximately 22% of Australia across four states including NSW, South Australia, the Northern Territory and Queensland. It is comprised of sequences of shale, conglomerate and sandstone.

West of Croppa Creek and Boggabilla the Great Artesian Basin is overlain by extensive Cenozoic unconsolidated sediments that cover the majority of the area. These sediments extend west beyond the catchment and cover the majority of north western NSW.

The Cenozoic unconsolidated sediments are made up of mud, silt, sand, and gravels generally deposited by river systems (alluvial deposits) or as wash from hill slopes (colluvial deposits). The Border Rivers Alluvium is Cenozoic valley infilled sediments.

Near Inverell and Glenn Innes Cenozoic extrusive volcanic rocks, predominately basalts, are widespread. The basalts are the result of volcanic eruptions throughout the eastern part of the state over the last 65 million years.

5. Hydrogeology

5.1. Regional Context

The NSW Border Rivers Alluvium mostly overlies or is adjacent to the New England Fold Belt, the Great Artesian Basin (GAB), and the continuation of the Border Rivers alluvium into Queensland.

The upper part of the alluvium is underlain by the fractured rock of New England Fold Belt. The permeability of these fractured rocks is many orders of magnitude less 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 middle sections of the Border Rivers Alluvium are underlain by the Great Artesian Basin. There is very little groundwater extraction from the GAB in this area and consequently this extraction would not compromise water availability or access rights in the alluvium. There is upward gradient from the GAB into the overlying alluvium.

The downstream boundary of the Border Rivers Alluvium adjoins the NSW GAB Surat Shallow groundwater source. The alluvium in this groundwater source is the continuum of the Border Rivers Alluvium.

The NSW Border Rivers Alluvium is hydraulically connected to the Queensland Border Rivers Alluvium in the north. Both alluvium units are of the same origin composition and structure, only administratively separated by the state border.

5.2. NSW Border Rivers Alluvium

The NSW Border Rivers Alluvium (GS32) extends along a 250 km continuous reach of the Dumaresq and Macintyre Rivers as shown in Figure 1. Within the alluvium a shallow and a deep aquifer system can be identified. In NSW, the deeper aquifer only occurs upstream of Keetah Bridge. The deeper aquifer extends downstream from Keetah Bridge on the northern side of the Dumaresq River in Queensland.

From upstream of Keetah Bridge to Mingoola, the alluvium is comprised of sediments ranging from large boulders to cobbles, gravels, silts and clays. Bore yields of up to 60L/s can be obtained along this reach (NSW Office of Water 2012b). The floodplain is up to 4.5 km wide and the sediments have a maximum thickness of 100 metres. Conceptually the dominant recharge process is rainfall and flooding, side slope run off and streamflow leakage from the regulated Dumaresq River.

The shallow aquifer is generally 30 m thick with maximum recorded thickness of 40 metres. At the base of the shallow aquifer, there is a layer up to 5 m thick comprising of cobbles and boulders larger than 200 mm in diameter. This cobble boulder horizon has made drilling difficult in the past, and many older bores did not penetrate through this horizon. During the groundwater investigations of the late 1950’s and early 1960’s this boulder horizon was penetrated and deeper alluvium up to 100 m deep was found. There is a non-continuous aquitard of clay that is generally less than 10 m thick, but is up to 40 m thick in places, separating the two aquifer systems.

The deep aquifer is in a palaeochannel that ranges from a narrow gorge less than 300 m wide to up to 1.5 km wide. The current channel of the Dumaresq River does not coincide with the deep palaeochannel. The palaeochannel meanders below the floodplain between NSW and Queensland (IWSCQ 1965).

In the upstream eastern end of the alluvium the two aquifer systems are hydraulically connected with little or no clay separating them. From east to west the hydraulic separation becomes more pronounced and from downstream of Texas the deeper aquifer becomes more confined. From this point the deeper aquifer does not respond to the surface water flows and flood events that are reflected in the shallow aquifer system responses.

Figure 11 and Figure 12 shows the direction of the groundwater flow in the shallow and deep aquifers is down valley following the topography of the floodplain.

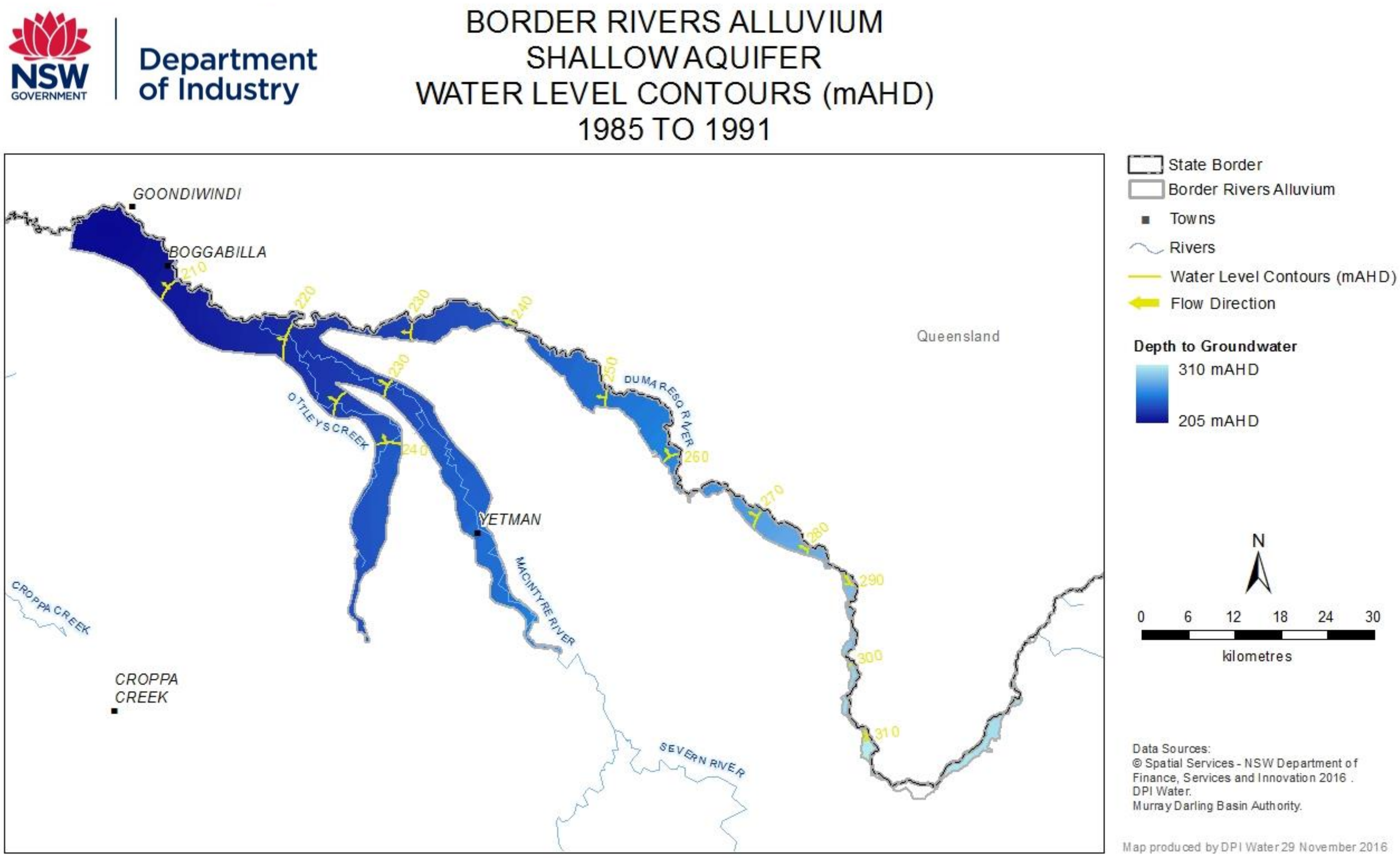


Figure 11 Location map of the Border Rivers Alluvium showing groundwater flow direction in the shallow aquifer system

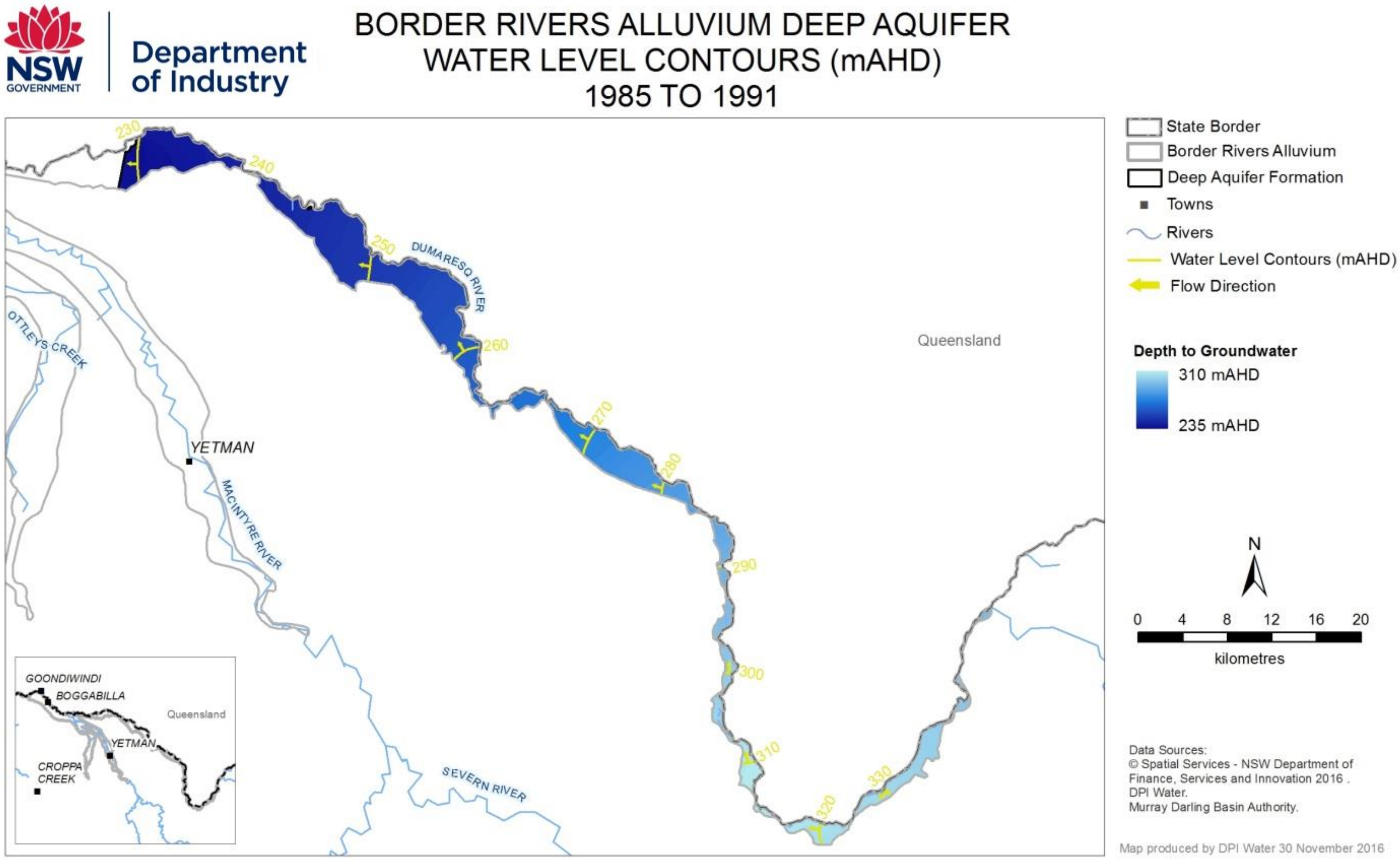


Figure 12 Location map New South Wales Border Rivers Alluvium showing groundwater flow direction in the deep aquifer system

Figure 13 shows the location of the geological cross section shown in Figure 14 through the alluvium from the west to east. The cross section (Figure14) illustrates the narrowest section of the deep palaeochannel and relative depth of the aquifers.

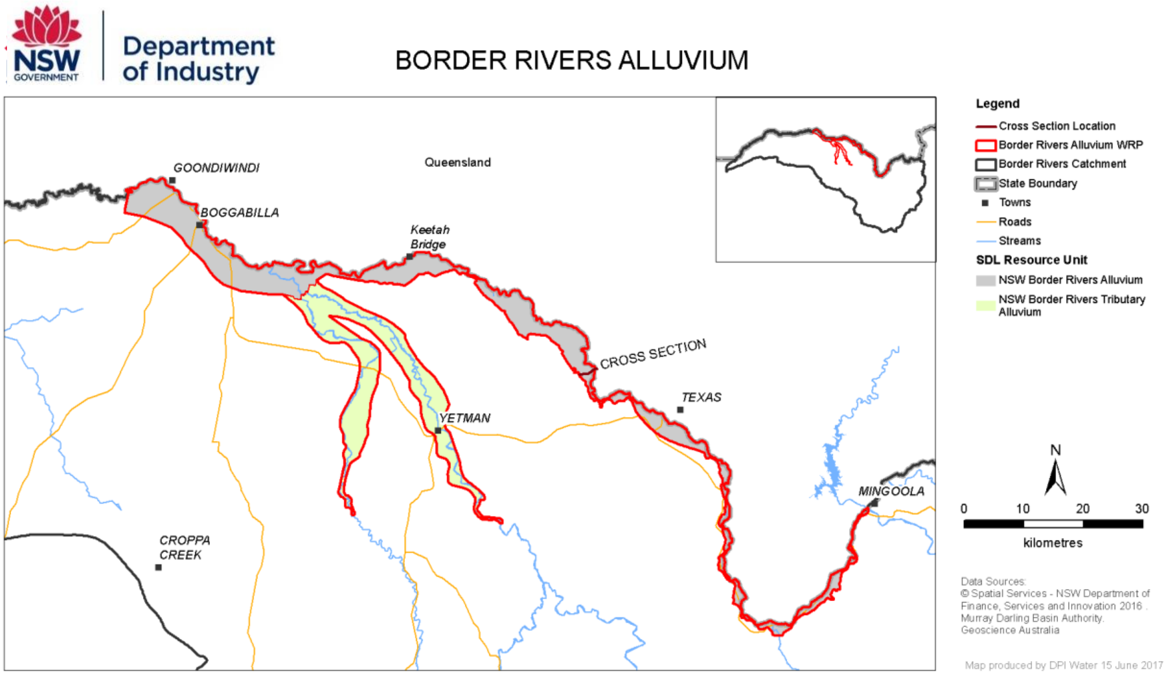


Figure 13 Cross section location map New South Wales Border Rivers Alluvium

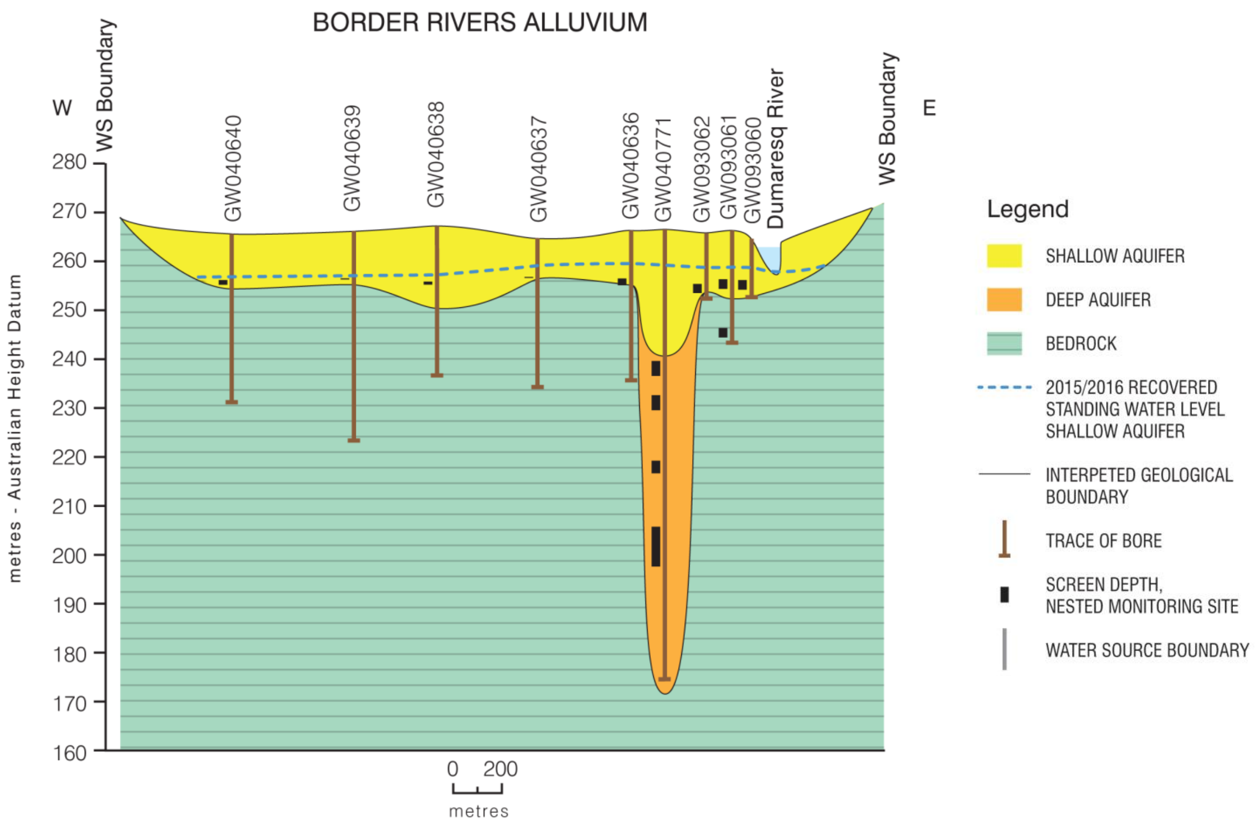


Figure14 West - East cross section through the NSW Border Rivers Alluvium

Downstream of Keetah Bridge, the NSW Border Rivers Alluvium is comprised of sediments ranging from cobbles to gravels, sands, silts and clays. Bore yields are low, up to 4.5 L/s (NSW Office of Water 2012b). The floodplain width ranges from 500 m to 7 km and the sediments have a maximum thickness of 35 metres. There is no deep aquifer in this part of the alluvium. Conceptually the dominant recharge process in the alluvium is by rainfall, some side slope run off and streamflow leakage from the regulated Dumaresq and Macintyre Rivers.

5.3. NSW Border Rivers Tributary Alluvium

NSW Border Rivers Tributary Alluvium is the alluvium along the Macintyre River and Ottleys Creek. It commences on the Macintyre River about 9 km upstream of the confluence of the Macintyre River and the Dumaresq River.

The alluvium along the Macintyre River is comprised of sediments ranging from cobbles to gravels, sands, silts and clays. Bore yields are generally low, up to 11.3 L/s (NSW Office of Water 2012b). The floodplain ranges from 700 m to 4.8 km wide and the sediments have a maximum thickness of 42 metres. Conceptually, the dominant recharge is from rainfall and flooding, some side slope run off and streamflow leakage from the regulated Macintyre River.

The alluvium along Ottleys Creek is comprised of sediments ranging from gravels to sands, silts and clays. There are no production bores in this aquifer as bore yields are low, up to 1.3 L/s (NSW Office of Water 2012b). The floodplain width ranges from 230 m to 4.7 km and the sediments have a maximum thickness of 24 metres. Conceptually the dominant recharge process in the alluvium is by rainfall, some side slope run off and streamflow leakage from Ottleys Creek.

5.4. Connection with surface water

The NSW Border Rivers Alluvium upstream of Keetah Bridge is considered to be hydraulically connected to the regulated Dumaresq River. The rivers change between losing and gaining conditions along its length depending on the geology, topography, and local conditions. The hydrographs (Figure 30 and Figure 31) show the shallow aquifer responds to high river flows.

Further analysis of the interconnection between the Dumaresq River and groundwater downstream of Texas is provided in Lamontagne et al (2011).

Downstream of Keetah Bridge the relationship between the groundwater and the surface water is not as well understood. The groundwater shows higher salinity levels than the river indicating that the river and groundwater are not well connected.

In the NSW Border Rivers Tributary Alluvium the alluvium along the regulated Macintyre River is considered to be highly connected.

There is no surface water gauging station within the reach of the unregulated Ottleys Creek coinciding with the NSW Border Rivers Tributary Alluvium so that the relationship between the groundwater and Ottleys creek has not been characterised.

6. Groundwater Dependent Ecosystems

Groundwater dependant 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).

Department of Planning, Industry 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 prep). This process has identified a number of vegetation GDEs in parts of the NSW Border Rivers catchment. The determined ecological value of vegetation GDEs within the NSW Border Rivers catchment is shown in Figure 15.

When the first groundwater water sharing plans were developed, no systematic mapping of GDEs had occurred in NSW. The department has since put in place a program to identify and monitor GDEs, so they can be considered in water planning decisions.

The identification of GDEs in NSW is separated into two key projects. The first project was to identify the probability of an ecological community being groundwater-dependent. The department has since completed a comprehensive program of mapping high probability GDEs (see – water.nsw.gov.au/__data/assets/pdf_file/0011/691868/High-Probability-GDE-methodreport.pdf).

The second project prioritised GDEs for management purposes. A method to assign an ecological value to the high probability GDEs has been developed based on the High Ecological Value Aquatic Ecosystem (HEVAE) framework (Aquatic Ecosystems Task Group 2012).

After applying the two approaches to existing data, a subset of high probability and high value GDEs is identified. The risks to these GDEs from extraction will be further considered to determine if any controls are required to manage the risks and what monitoring or further information may be required.

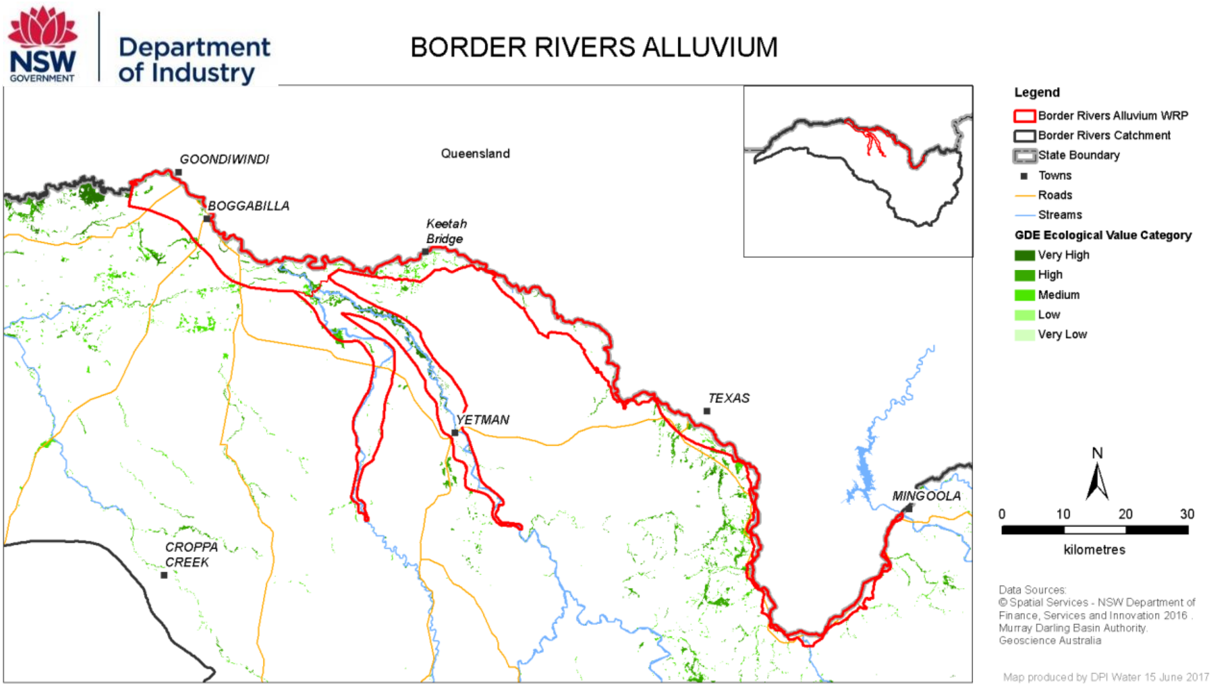


Figure 15 Ecological value for high probability groundwater dependent vegetation ecosystems

The NSW Border Rivers alluvial groundwater resource supports significant GDEs of ecological value including endangered ecological communities (EECs), threatened species, vegetation, and base flow ecosystems.

GDE ecological value in the WRP area for high probability of existence GDEs (Figure 15) are mainly medium to high. The method for GDE identification (Kuginis et al. 2016) identifies that these GDEs areas are dominated by river red gum riparian woodland and coolibah -river coobah -lignum woodland vegetation GDE communities. These communities are generally characterised by having threatened bird species present, extensive connected riparian corridors and vegetation patches which contribute to the very high and high habitat diversity, naturalness and vital habitat (Figure 15). These communities are also Basin target species. The Border Rivers Alluvium has two Endangered Ecologically Communities (EECs) in the area, with coolibah -river coobah -lignum woodland communities present. The EECs include the "*Coolibah-Black Box Woodland in the Darling Riverine Plains, Brigalow Belt South, Cobar Peneplain and Mulga*

Lands Bioregion" EEC; and the "*Darling River*" EEC. The area also has small areas of threatened Lignum communities

6.1. 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 influence 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).

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.

Changes in land use, impact of industry, seasonal variations, and longer-term changes in climate as well as groundwater extraction can all affect groundwater quality.

There is no routine monitoring of groundwater quality in the NSW Border Rivers Alluvium WRP area. Groundwater samples were taken at the time of bore construction for most of Department of Planning, Industry and Environment's monitoring bores (over 60 years ago for some bores in this WRP area). Please et al (2000) summarised water quality analysis collected from some of the monitoring bores in both Queensland and NSW in 1994 and 1995. Baskaran et al 2004 summarised others work (O'Rourke 2015).

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.

6.2. NSW Border Rivers Alluvium

Groundwater from the NSW Border Rivers Alluvium is mainly used for irrigating field crops and pastures, basic rights (stock and/or domestic) and local water utility (town water supply) use with the exception of Downstream Keetah Bridge Alluvium which is of poor quality for irrigation.

The salinity in the NSW Border Rivers Alluvium upstream of Keetah Bridge in the shallow aquifer is <600 µS/cm close to the river and 800 µS/cm to 1,800 µS/cm away from the river. In the deep aquifer the salinity is <1,500 (Baskaran et al 2004; O'Rourke 2015). Downstream of Keetah Bridge the groundwater quality ranges from 14,000 µS/cm to 50,000 µS/cm (Baskaran et al 2004; O'Rourke 2015).

6.3. NSW Border Rivers Tributary Alluvium

Groundwater from the NSW Border Rivers Tributary Alluvium is mainly used for irrigating field crops and pastures, basic rights (stock and/or domestic) and local water utility (town water supply) use.

The salinity in the NSW Border Rivers Tributary Alluvium ranges from 870 µS/cm to 1,040 µS/cm in the Macintyre Alluvium and from 660 µS/cm to 1,460 µS/cm in the Ottleys Alluvium (Baskaran et al 2004; O'Rourke 2015).

7. Groundwater Management

For management purposes the NSW Border Rivers Alluvium has been subdivided into two separate management units.

Groundwater in the Border Rivers Alluvium is managed under the Water Sharing Plan for the NSW Border Rivers Unregulated and Alluvial Water Sources 2012. The plan commenced on 1 June 2012.

The NSW Border Rivers Alluvium sits over and adjacent to the fractured rocks of the New England Fold Belt which is managed under the Water Sharing Plan for the NSW Murray-Darling Basin Fractured Rock Groundwater Sources 2011.

Similarly the Great Artesian Basin underlies and is adjacent to the Border Rivers Alluvium in the mid-section of the WRP area. It is managed under the Water Sharing Plan NSW Great Artesian Basin Groundwater Sources 2008 (GAB).

Further west the adjoining NSW GAB Surat Shallow groundwater source is managed under the Water Sharing Plan NSW Great Artesian Basin Shallow Groundwater Sources 2011. .

The alluvium of the NSW Border Rivers Alluvium and the Queensland Border Rivers Alluvium are effectively the one resource that is divided by the NSW Queensland border. .

7.1. Access rights

Groundwater access licenses for the NSW Border Rivers Alluvium and the NSW Border Rivers Tributary Alluvium are shown in Table 2.

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 2).

Table 2 Access licence share components in the New South Wales Border Rivers Water Resource Plan Area (at June 2017).

SDL Resource Unit	Groundwater Source	Local Water Utility (ML/year)	Aquifer (Unit Shares)	Aquifer (High Security) (Unit Shares)
NSW Border Rivers Alluvium (GS32)	NSW Border Rivers Upstream Keetah Bridge Alluvial Groundwater Sources	10	15,392	0
	NSW Border Rivers Downstream Keetah Bridge Alluvial Groundwater Sources	0	485	0
NSW Border Rivers Tributary Alluvium (GS33)	Macintyre Alluvial Groundwater Sources	35		1,558
	Ottleys Creek Alluvial Groundwater Sources	0	0	0

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

7.2. 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 3 lists the LTAAEL for the NSW Border Rivers Alluvium and the NSW Border Rivers Tributary Alluvium as well as the SDL for each area.

Table 3 LTAAEL for the NSW Border Rivers Alluvium and NSW Border Rivers Tributary Alluvium compared to the SDL (at June 2017)

SDL Unit	LTAAEL ML/yr	SDL ML/yr
NSW Border Rivers Alluvium	8,401.7	8,400
NSW Border Rivers Tributary Alluvium	402.7	410

Whilst Table 1Table 3 presents the combined LTAAEL for the SDL resource units, Table 4 shows the LTAAEL for each of the four groundwater sources. The estimated volumes for basic landholder rights that are for domestic and stock purposes are also included in the volumes quoted.

Table 4 The water sharing plan LTAAEL for the groundwater sources incorporated into the NSW Border Rivers Water Resource Plan area

Water Source	LTAAEL ML
NSW Border Rivers Upstream Keetah Bridge Alluvial Groundwater Sources	8,085.3
NSW Border Rivers Downstream Keetah Bridge Alluvial Groundwater Sources	316.4
Macintyre Alluvial Groundwater Sources	373
Ottleys Creek Alluvial Groundwater Sources	29.7

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

Figure 16 and Figure 17 shows the annual metered extraction since commencement of the water sharing plan. These figures include the daily basic rights extraction requirements converted to an annual volume. The extraction for the entire water year 2011-2012 is shown here even though the water sharing plan commenced on the 1 June 2012. The figures also shows the LTAAEL and the trigger set by the water sharing plan to initiate a management response to ensure there is no growth in extraction above the LTAAEL in the long term.

On Figure 16 and Figure 17 the five year average extraction from 2011-2012 to 2015-2016 is plotted. Only in the 2015-2016 year can an average be calculated and shown.

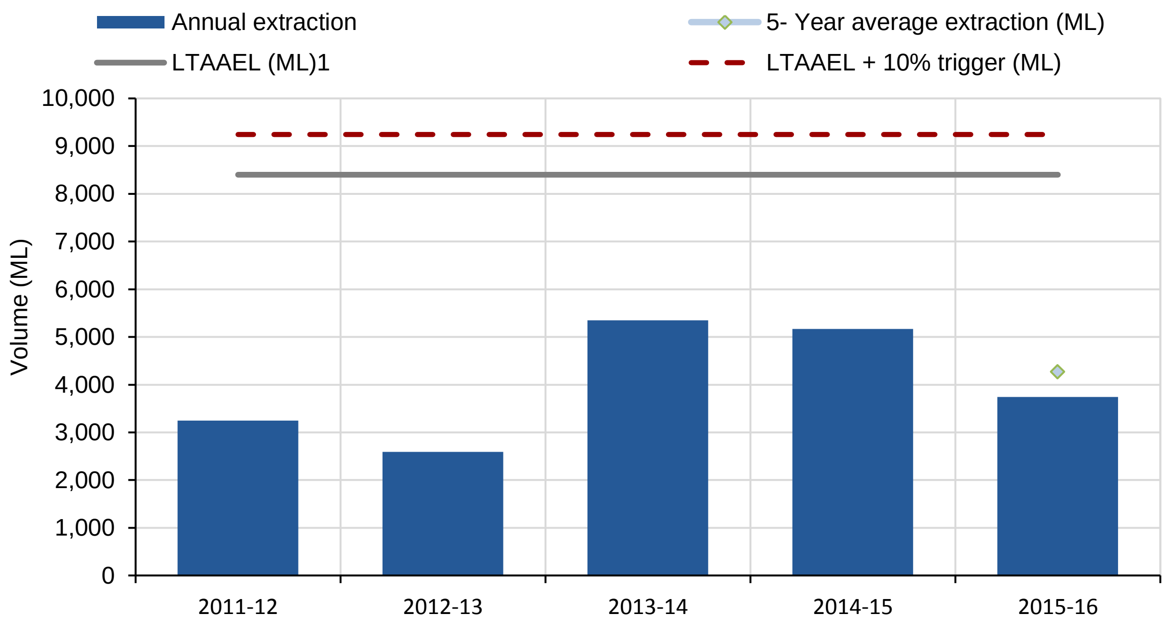


Figure 16 NSW Border Rivers Alluvium annual extraction compared to the LTAAEL

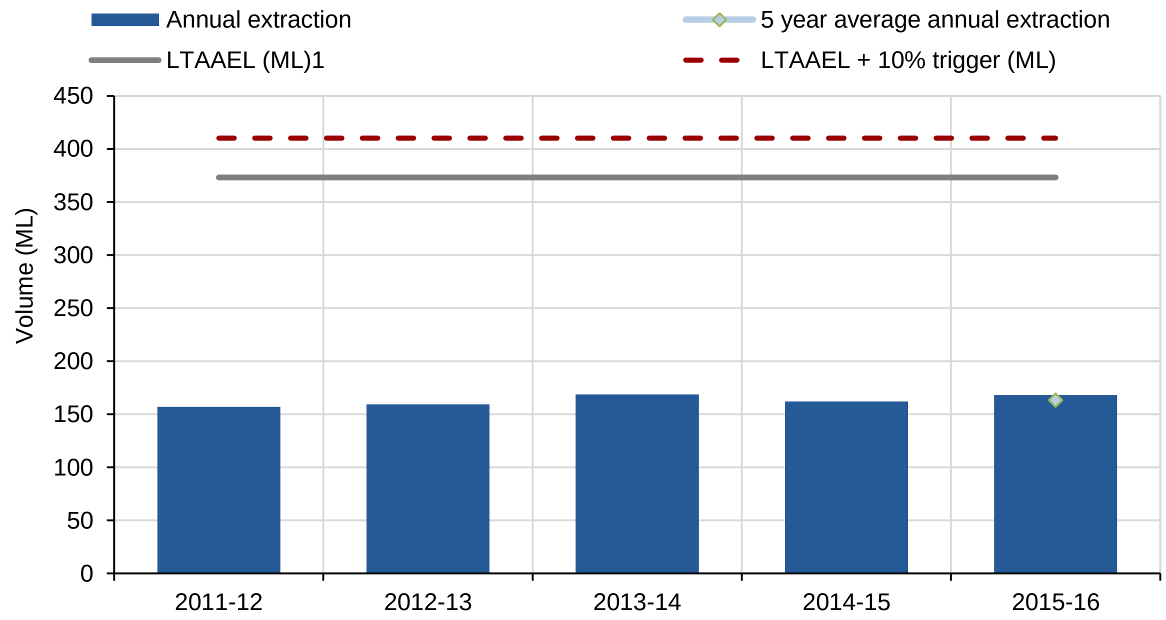


Figure 17 NSW Border Rivers Tributary Alluvium annual extraction compared to the LTAAEL

The risk of extraction in the Border Rivers Alluvium exceeding the LTAAEL is low, as the groundwater development usage has historically been well below the LTAAEL.

7.3. Available water determinations

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

The annual AWD for aquifer access licences in the NSW Border Rivers Alluvium is not linked to the AWD determination for the general security or the high security regulated river licences. The AWD is linked to the five year rolling average of cumulative use commencing in year 6 of the plan. If the five year rolling average exceeds the LTAAEL by more than 10%, then a reduced available water determination is triggered. Since the commencement of the water sharing plan there has been 100% access, therefore the available water determination for aquifer access licences in the NSW Border Rivers Alluvium has remained at 1 ML per share or 100% access.

The available water determination for each licence category in the NSW Border Rivers Alluvium for each year since commencement of the water sharing plan is shown in Figure 18. The available water determination for aquifer access licences has been set at 1 ML per share and for local water utility access licences has been set at 100% every year since the water sharing plan commenced. Note the Local Water Utility entitlement on Figure 18 is 10 ML.

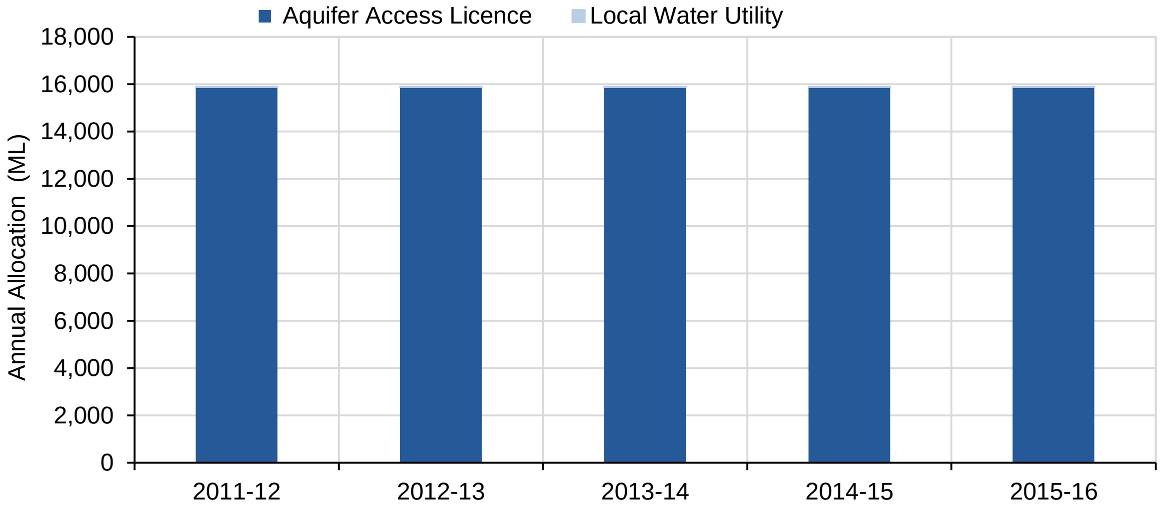


Figure 18 Annual allocations for the NSW Border Rivers Alluvium

The annual available water determination for high security aquifer access licences in the NSW Border Rivers Tributary 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 NSW Border Rivers Tributary Alluvium has remained at 1 ML per share or 100% access.

In addition to the annual available water determination linked to the high security regulated water licence. The available water determination is linked to the five year rolling average of cumulative use commencing in year 6 of the plan. If the five rolling average usage exceeds the LTAAEL by more than 10% an available water determination is triggered.

The available water determination for each licence category in the NSW Border Rivers Tributary Alluvium for each year since commencement of the water sharing plan is shown in Figure 19. The available water determination for aquifer access licences has been set at 1 ML per share and for local water utility access licences has been set at 100% every year since the water sharing plan commenced. Note the Local Water Utility entitlement on Figure 19 is 35 megalitres.

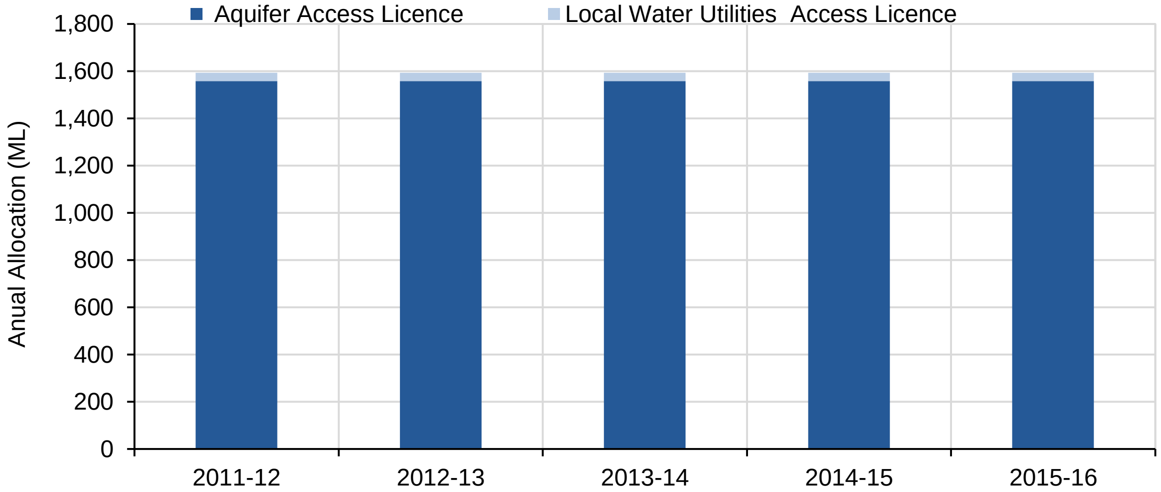


Figure 19 Annual allocations for the NSW Border Rivers Tributary Alluvium

7.4. Groundwater accounts

Under the 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 water is traded in, and debited from the account when water is physically taken or traded out.

For licences in both the NSW Border Rivers Alluvium and the NSW Border Rivers Tributary Alluvium the water sharing plan has no maximum limit that can be held in an account. Water held in the account includes the yearly allocation for aquifer access licences made through available water determinations plus all allocation transferred in, minus any allocation transferred out.

Carryover of allocation is not permitted in the NSW Border Rivers Alluvium and the NSW Border Rivers Tributary Alluvium for any licence category.

Figure 20 shows the water accounts since the commencement of the water sharing plan for the NSW Border Rivers Alluvium. Figure 21 shows the water accounts since the commencement of the water sharing plan for the NSW Border Rivers Tributary Alluvium.

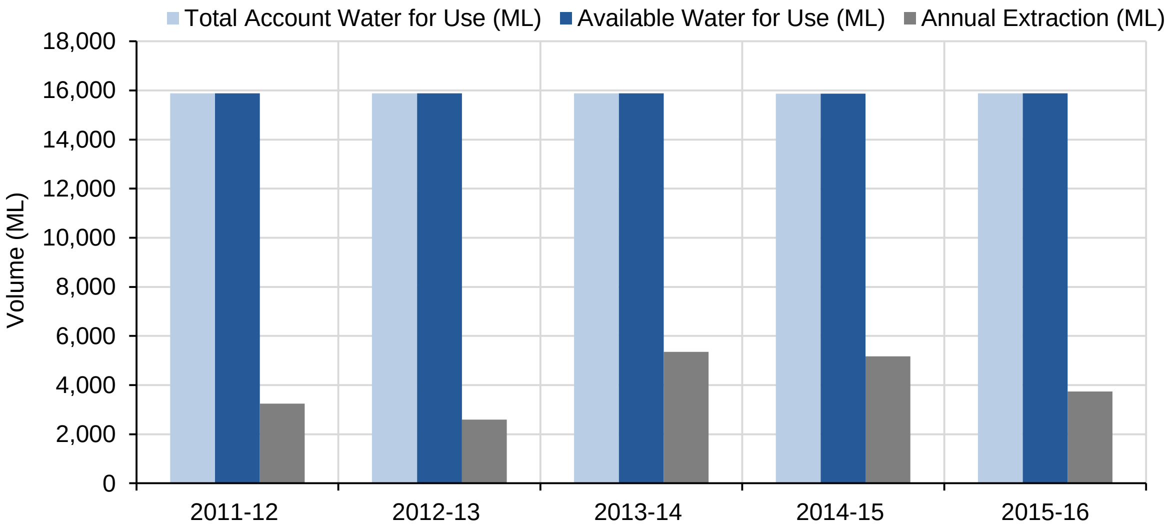


Figure 20 Water accounts since the commencement of the water sharing plan for the NSW Border Rivers Alluvium.

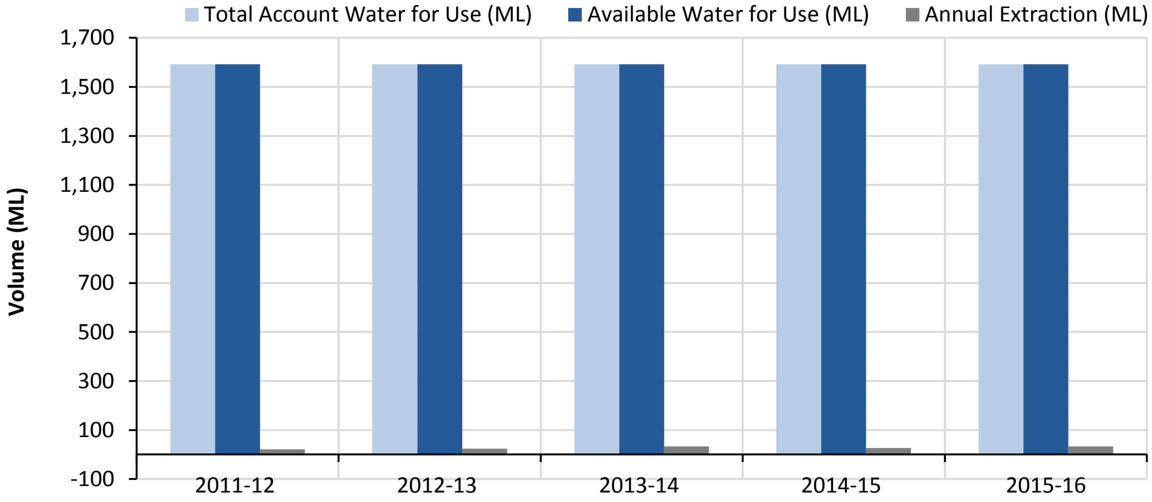


Figure 21 Water accounts since the commencement of the water sharing plan for the NSW Border Rivers Tributary Alluvium

7.5. Groundwater take

Groundwater is taken and used in the Border Rivers Alluvium for productive purposes such as irrigation and industry as well as for water supply for local water utilities and stock and domestic use. Figure 22 shows the distribution of water supply bores across the Border Rivers Alluvium groundwater resources.

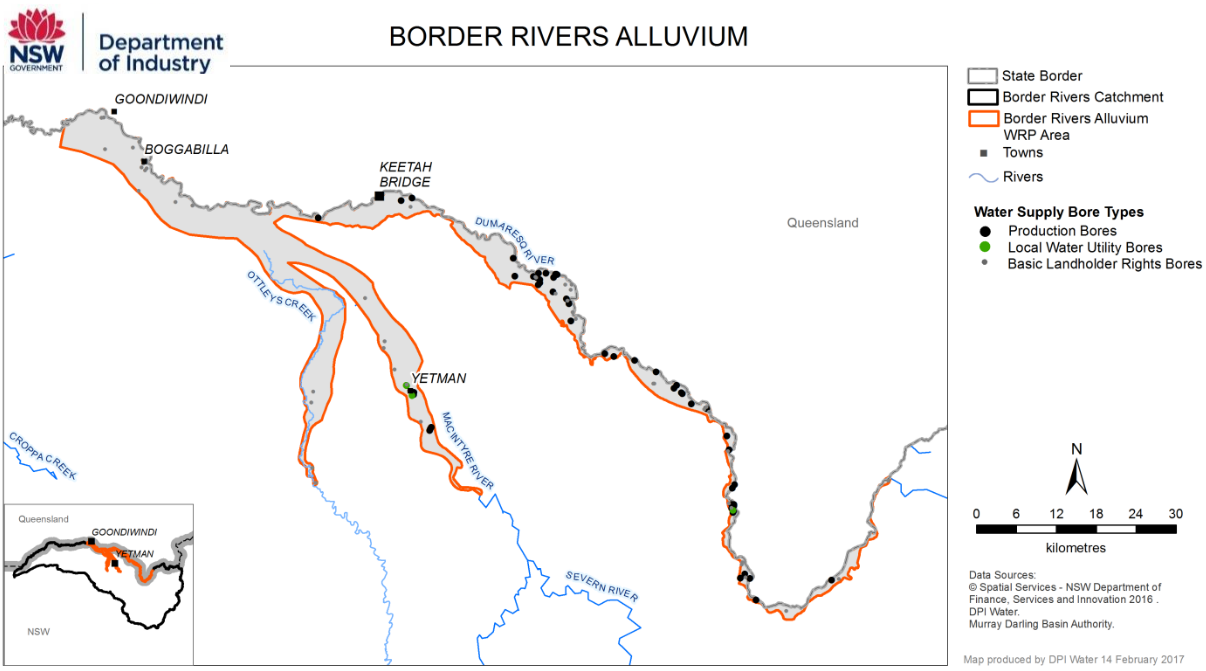


Figure 22 Registered bores in the Border Rivers Alluvial Water Resource Plan Area.

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 193 registered bores in the NSW Border Rivers Alluvium, and majority of the bores are used for stock and domestic purposes. There are 52 production bores for irrigation purposes which are mostly concentrated in the alluvium upstream of Keetah Bridge. The township of Bonshaw relies on groundwater as part of its main water supply for local water utility.

Bores constructed in the deeper more productive aquifer system upstream of Keetah have historically extracted up to 1,000 ML per year, but since 2012 the maximum bore extraction has reduced to about 450 ML per year. Average extraction from a bore completed in the deep aquifer is about 360 ML/yr (Figure 23). The reduction in use is attributed to favourable climatic conditions and surface water being available resulting in less groundwater being pumped

There are 39 registered bores in the NSW Border Rivers Tributary Alluvium, the majority of groundwater is used for stock and domestic purpose, with six production bores and three local water utility bores for the town of Yellarbon. Historically only the local water utility has extracted groundwater. There are no production bores or local water utilities in the alluvium along Ottelys Creek.

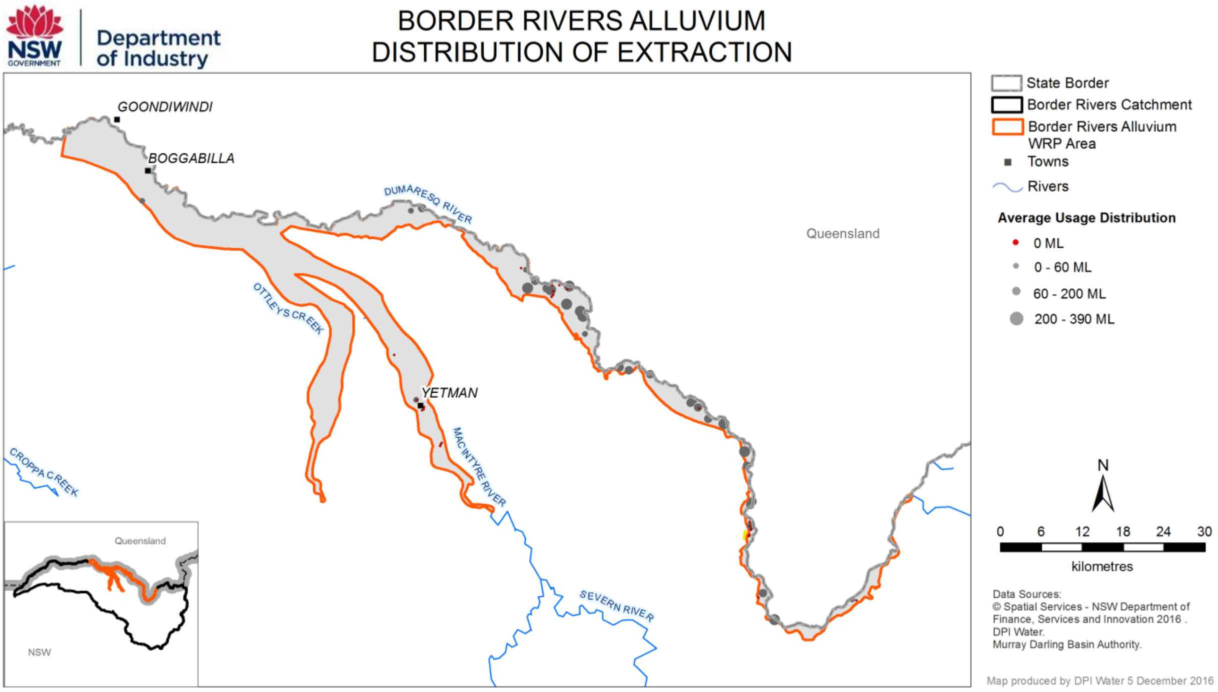


Figure 23 Border Rivers Alluvial Water Resource Plan Area distribution of extraction

Annual recorded groundwater extraction since under access licences since 1990-1991 and the annual extraction limit for the NSW Border Rivers Alluvium since the commencement of the water sharing plan is provided in Figure 24.

Annual groundwater extraction since under access licences since 1991-1993 and the annual extraction limit for the NSW Border Rivers Tributary Alluvium since the commencement of the water sharing plan is provided in Figure 25. In some years there is no record of use. Considering that all recorded groundwater use is for Local Water Utility use it can be concluded that there may have been some usage for Local Water Utility in the years where none was recorded.

Take associated with basic landholder rights in not included in Figures 24 and 25.

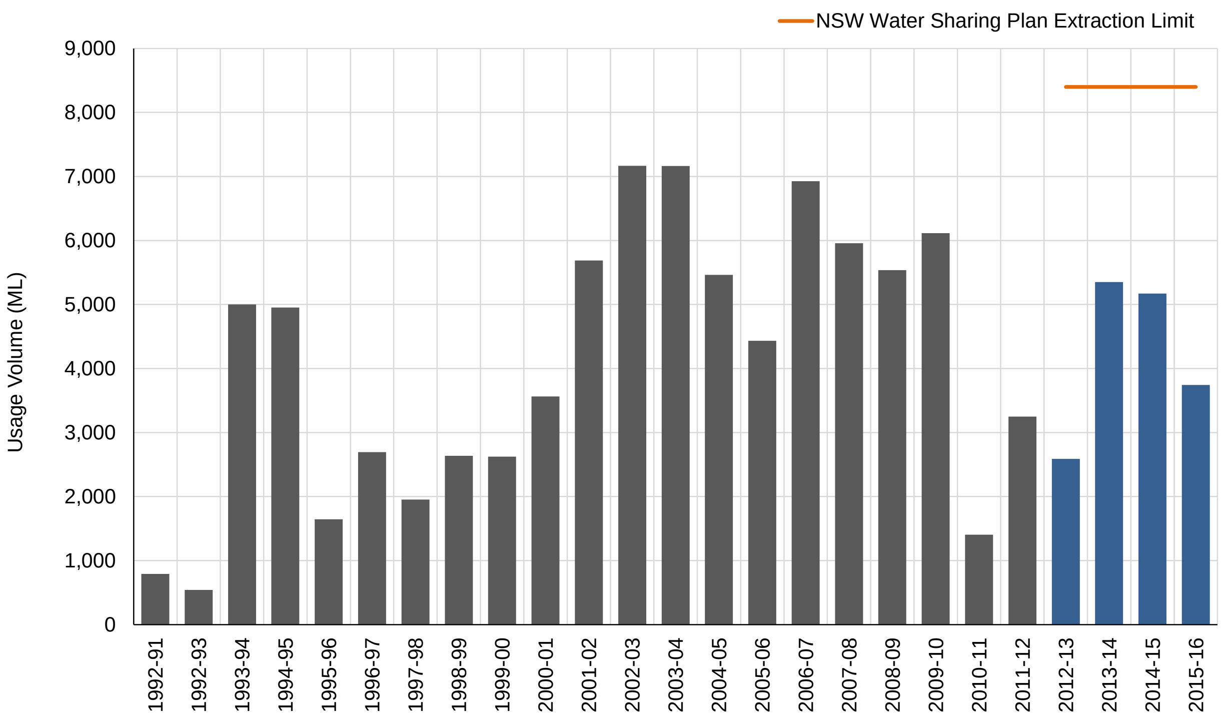


Figure 24 Metered extraction for the NSW Border Rivers Alluvium

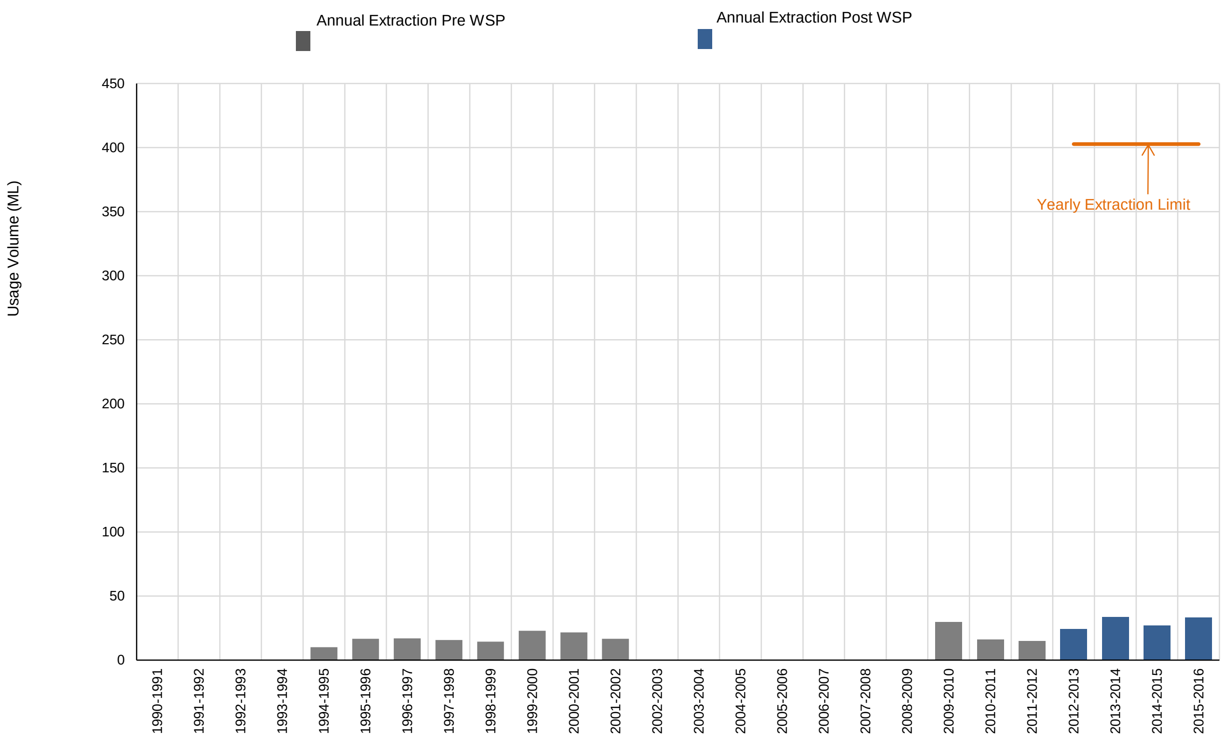


Figure 25 Metered extraction for the NSW Border Rivers Tributary Alluvium

7.6. Groundwater dealings

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

7.6.1. Temporary dealings

Temporary trades of groundwater allocations within this WRP area have been permitted since an announcement on 29 April 2008 that allowed temporary trades up to 100 ML per annum. Since then there has been only one temporary trade for 100 ML in the NSW Border Rivers Alluvium in the 2008/2009 water year. These temporary trade rules were replaced by water sharing plan rules on 1 June, 2012.

Since the commencement the Water Sharing Plan there has been one temporary dealing in the NSW Border Rivers Alluvium in the 2014/2015 water year for 150 ML.

To date there have been no applications for temporary dealings in the NSW Border Rivers Tributary Alluvium.

7.6.2. Permanent dealings

Permanent dealings for groundwater licences are made under sections 71M (licence transfer), 71N (term licence transfer), 71P (subdivision/consolidation), 71Q (assignment of share) and 71W (nomination or 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.

Since the commencement of the Water Sharing Plan there has been no permanent dealings registered in the NSW Border Rivers Alluvium or the NSW Border Rivers Tributary Alluvium.

8. Groundwater monitoring

WaterNSW 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 26 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 which may be confined or unconfined. An unconfined aquifer is an aquifer whose shallow 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 26 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.

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

Figure 26 illustrates how the water level in some of the monitoring bores can be at different levels to nearby production and stock bores 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.

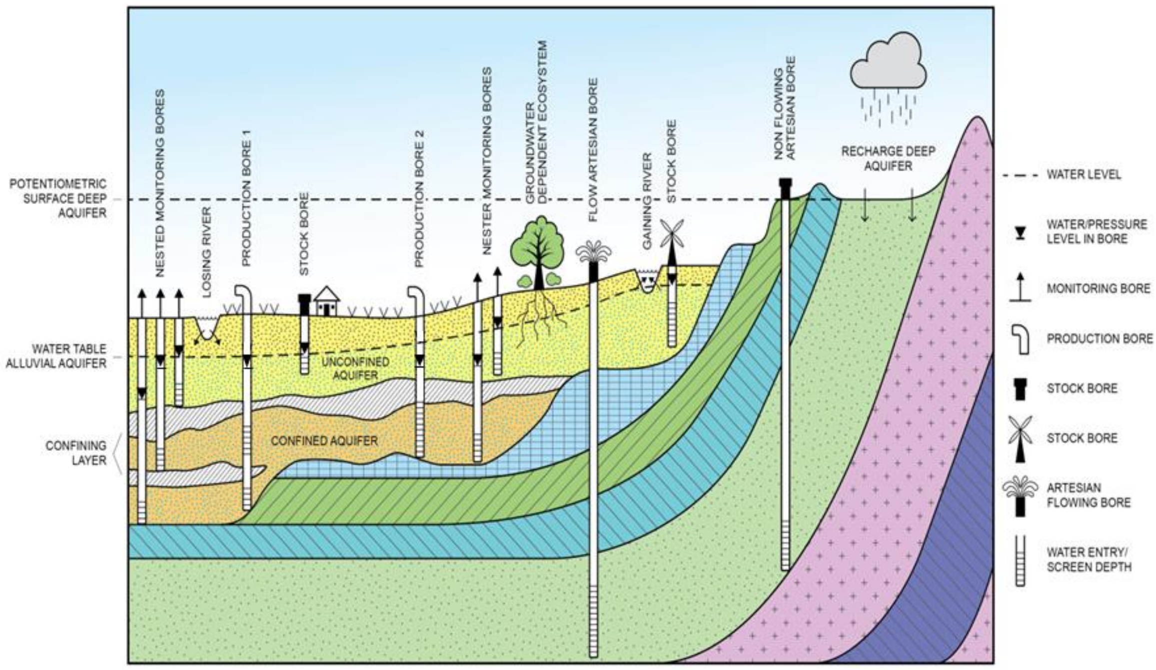


Figure 26 Schematic diagram of different types of aquifers

Across the NSW Border Rivers Alluvium WRP area there are 35 monitoring bores at 29 sites (Figure 27). The first monitoring bores were installed in the late 1950’s early 1960’s with more monitoring bores installed in 1987, 1994, 1997 and 2009. Monitoring of groundwater levels and pressures commenced in 1987 initially at five of the sites, with a continuous record of measurement since then. Groundwater monitoring for the monitoring bores installed in the late 1950’s early 1960’s commenced in 1991. Monitoring bores drilled in 1997 and 2009 have been monitored since their installation.

Upstream of Keetah Bridge the monitoring bores in the alluvium are currently manually monitored every three months. For the bores in the rest of the NSW Border Rivers Alluvium WRP area they are manually monitored about every two months. There are no sites equipped with data loggers. However, GW036691.2.2 a monitoring bore situated within the NSW Border Rivers Alluvium footprint, equipped with a telemetered data logger, monitors the underlying

Great Artesian Basin. Real time data for this bore is available from: *http://realtimedata.water.nsw.gov.au/water.stm*.

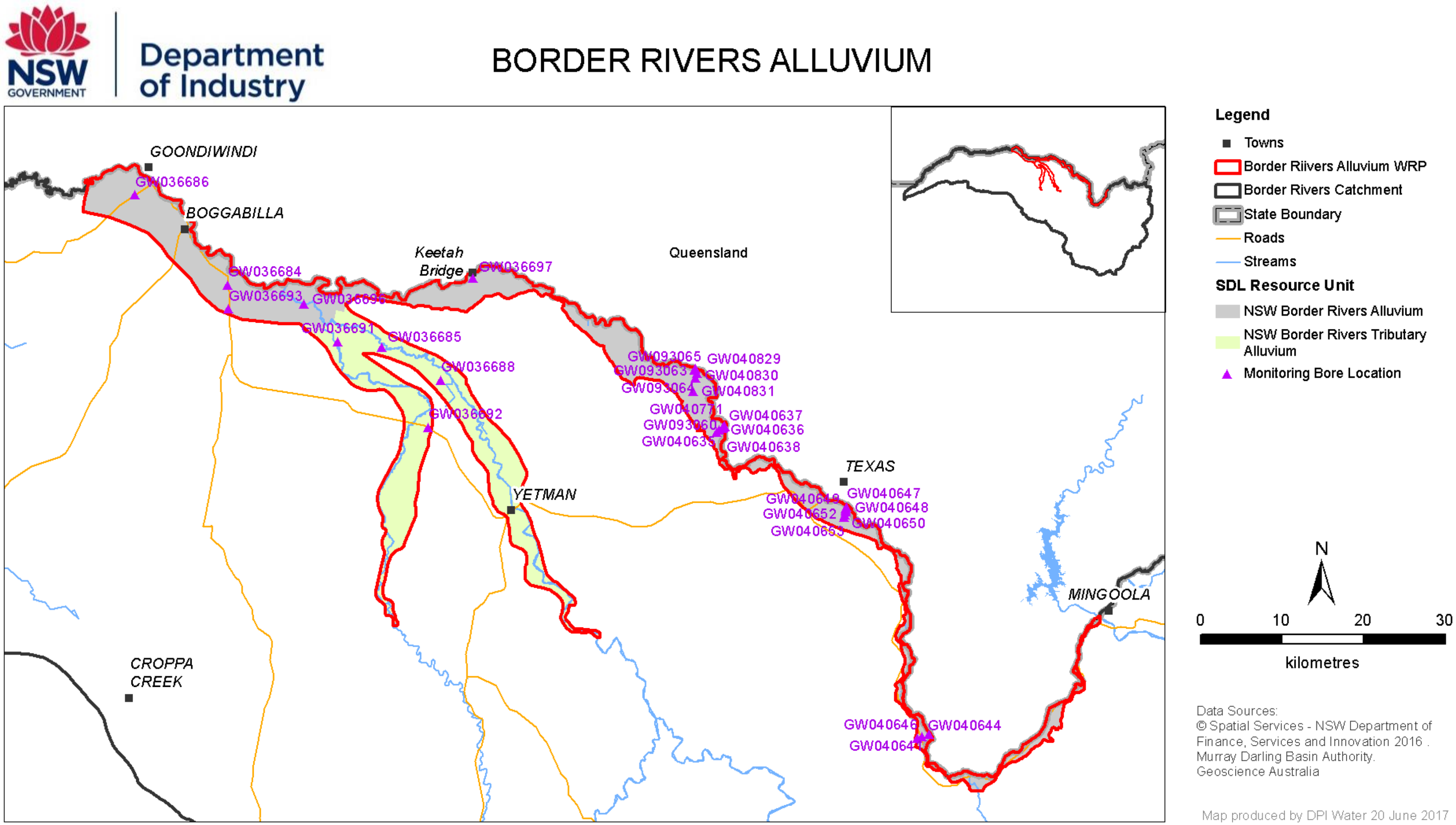


Figure 27 Location map of monitoring bore in the Border Rivers Alluvium

9. Groundwater Behaviour in the Border Rivers Alluvium

9.1. Introduction

In the NSW Border Rivers Alluvium monitoring bores constructed in the alluvium upstream of Keetah Bridge screen both the shallow alluvium and the deep alluvium. Bores which are screened less than 25 m deep are considered to be within the unconfined shallow aquifer system; while monitoring bores constructed deeper than 25 m have been assessed to be in the deep semi confined/confined aquifer system.

Monitoring bores GW036688 Pipe 2, GW036691 Pipe 2 and GW036692 Pipe 2 are screened in the underlying Great Artesian Basin.

The reference condition to which long term trends are compared is the ‘pre-development’ water level. For this WRP area the ‘pre-development’ is defined as the average recovered water level from 1985 to 1991.

Water level data of monitoring bores from both New South Wales and Queensland were used to determine the pre-development water level of the alluvium upstream of Keetah Bridge. Only water level data in New South Wales have been presented. Changes in groundwater levels are discussed in the following sections presenting data from hydrographs and groundwater level maps.

9.2. Hydrographs

A hydrograph is a plot of groundwater level or pressure from a monitoring bore over time (Figure 28). 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 28 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.

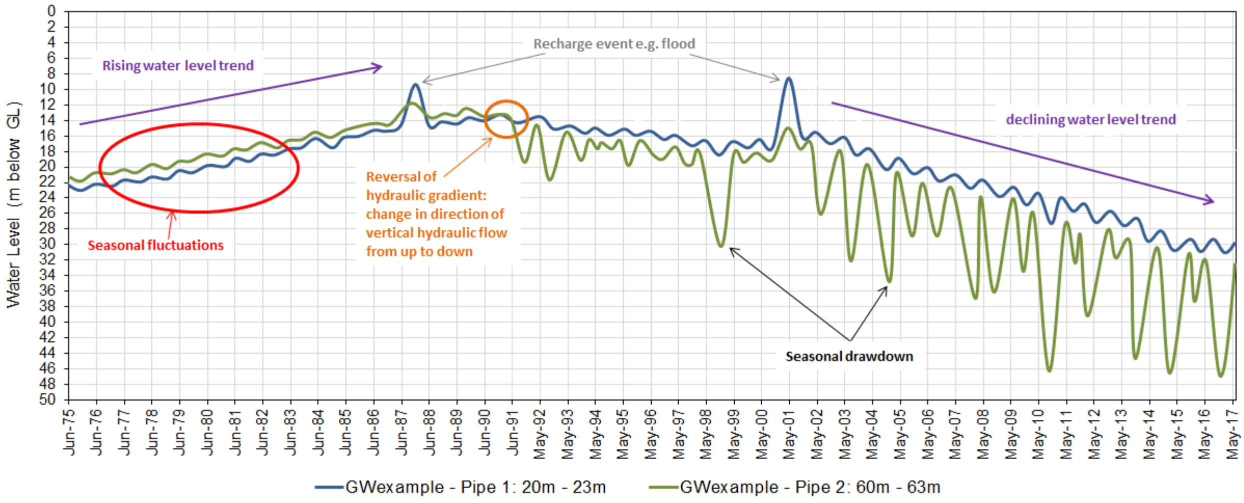


Figure 28 Example of a groundwater hydrograph identifying trends in groundwater responses to pumping and climate.

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.

9.3. Review of groundwater levels

Hydrographs from five representative groundwater monitoring locations (Figure 29) across the NSW Border Rivers Alluvium WRP area are presented below. Each hydrograph is displayed on the same scale for ease of comparison. These hydrographs show monitoring data from the NSW Border Rivers Alluvium at bore sites GW040641 and GW040644 (Figure 30); GW040831 and GW040829 (Figure 31); GW036684 (Figure 32), and from the NSW Border Rivers Tributary Alluvium at bore sites GW036685 (Figure 33) and GW036692 (Figure 34).

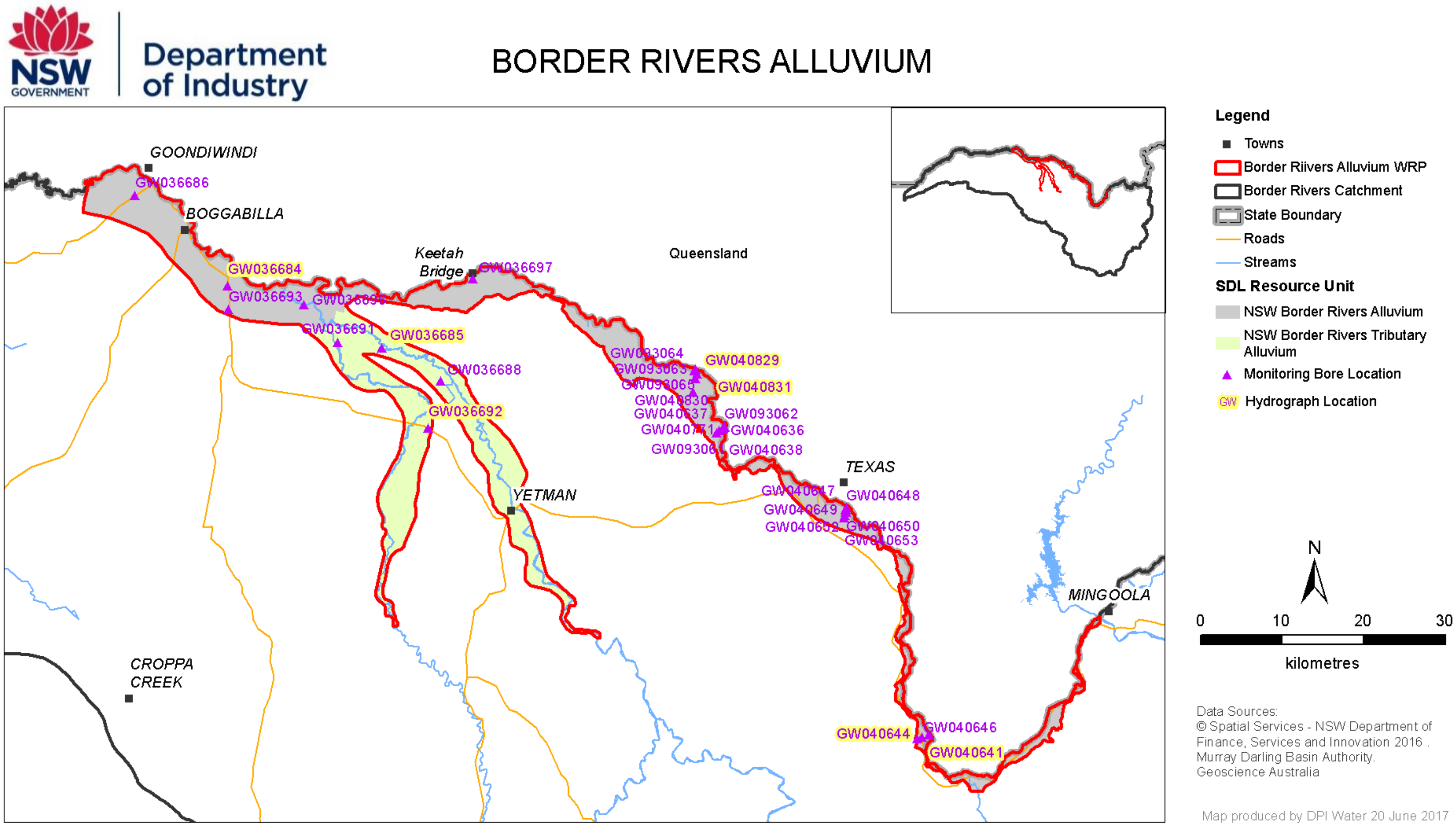


Figure 29 Border Rivers Alluvium hydrograph locations

9.3.1. NSW Border Rivers Alluvium groundwater levels

As described in Section 5.2, the deeper aquifer in the NSW Border Rivers Alluvium upstream of Keetah Bridge progressively becomes more confined in down gradient direction.

Figure 30 shows groundwater level responses upstream of Texas in the deep aquifer system at bore GW040641 and the shallow aquifer at GW040644. These two sites are 900 m apart on the same transect. In the vicinity of these monitoring bores groundwater development commenced in 1995/96.

Prior to activation of pumping, the deeper aquifer had a pressure level similar to the water level of the shallow aquifer. Since pumping commenced, the seasonal drawdown and recovery responses to pumping can be seen in the water levels of the deeper aquifer but this is not reflected in the shallower aquifer. The recovered water levels returned to non-pumping levels after the 2011 flood and reduced pumping.

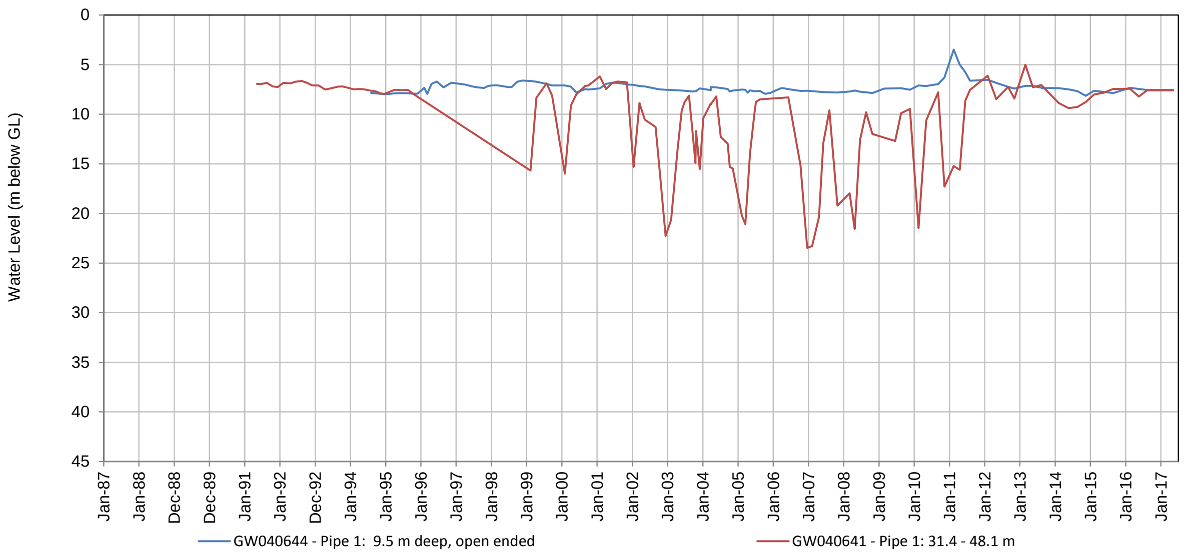


Figure 30 Hydrograph for monitoring bore site GW040641 and GW040644 - Upstream of Texas

Figure 31 shows groundwater level responses downstream of Texas in the deep aquifer system at bore GW040831 and the shallow aquifer at GW040829. These two sites are 2,233 m apart on the same transect. Figure 31 shows pumping impacts on the groundwater levels in the deeper aquifer at site GW040831 that are not reflected in the shallow groundwater levels monitored at site GW040829. Groundwater extraction commenced in 1994/95 which was prior to commencement of monitoring. The hydrograph shows that the shallow aquifer responds to high river flows that occurred in the 2011 flood. The deep aquifer shows some pressure response to the flood and reduced pumping due to wetter times.

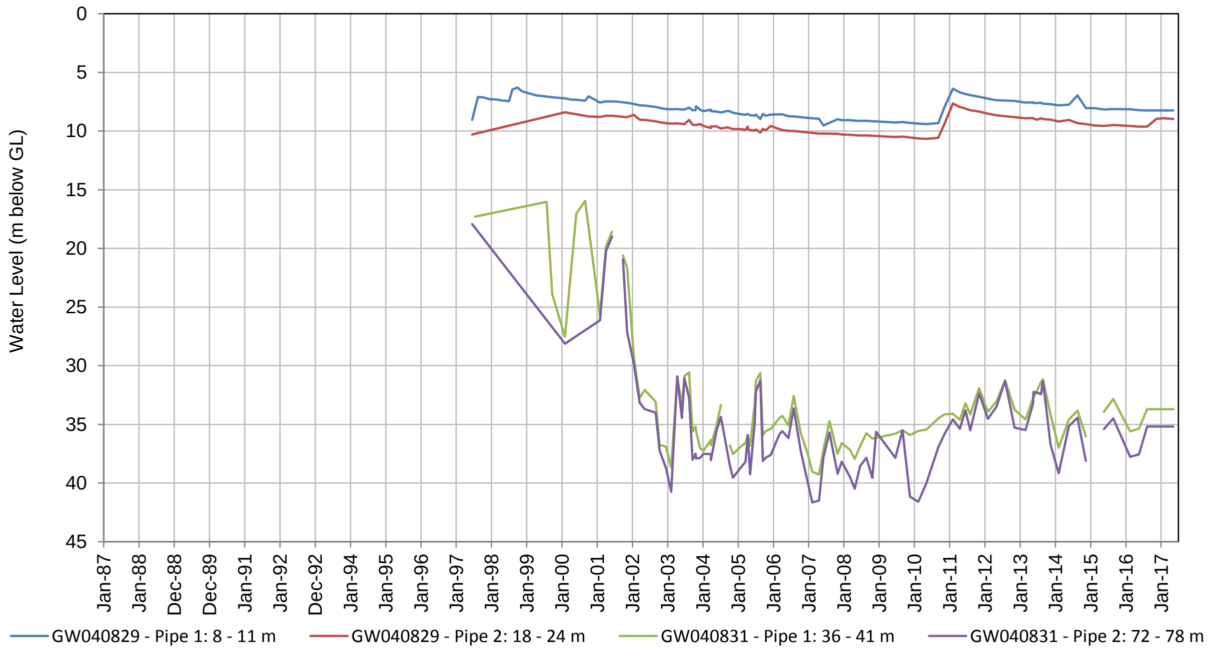


Figure 31 Hydrograph for monitoring bore site GW040829 and GW040831 - Downstream of Texas

The water level for the area downstream of Keetah Bridge is represented by GW036684 (Figure 32). This hydrograph demonstrates that the aquifer has minimal response to climatic conditions and flood events of 2011.

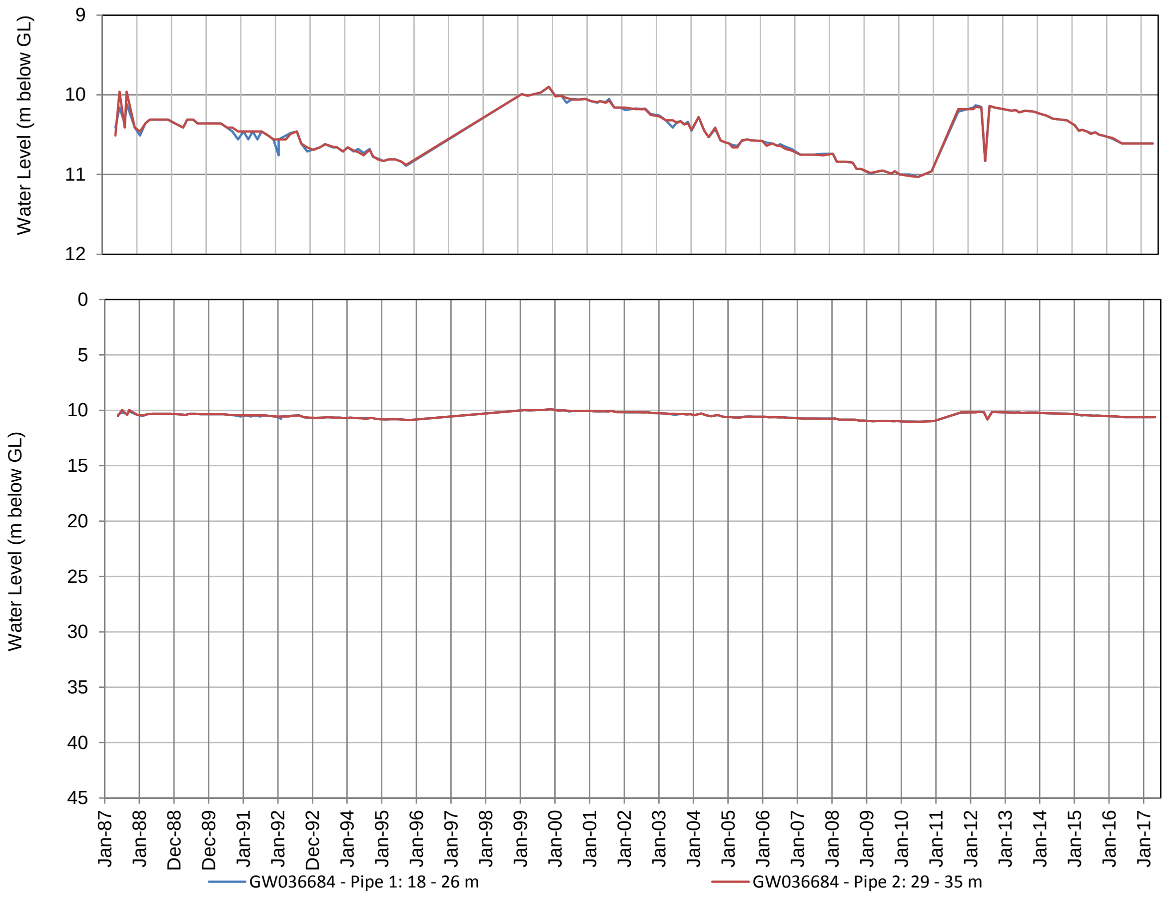


Figure 32 Hydrograph for monitoring bore site GW036684 - Downstream of Keetah Bridge

9.3.2. NSW Border Rivers Tributary Alluvium groundwater levels

In the NSW Border Rivers Tributary Alluvium the water level for the area in the Macintyre Alluvium is represented by GW036685 (Figure 33). This hydrograph illustrates the aquifer's response to climatic conditions and the flood events of 2001 and 2011.

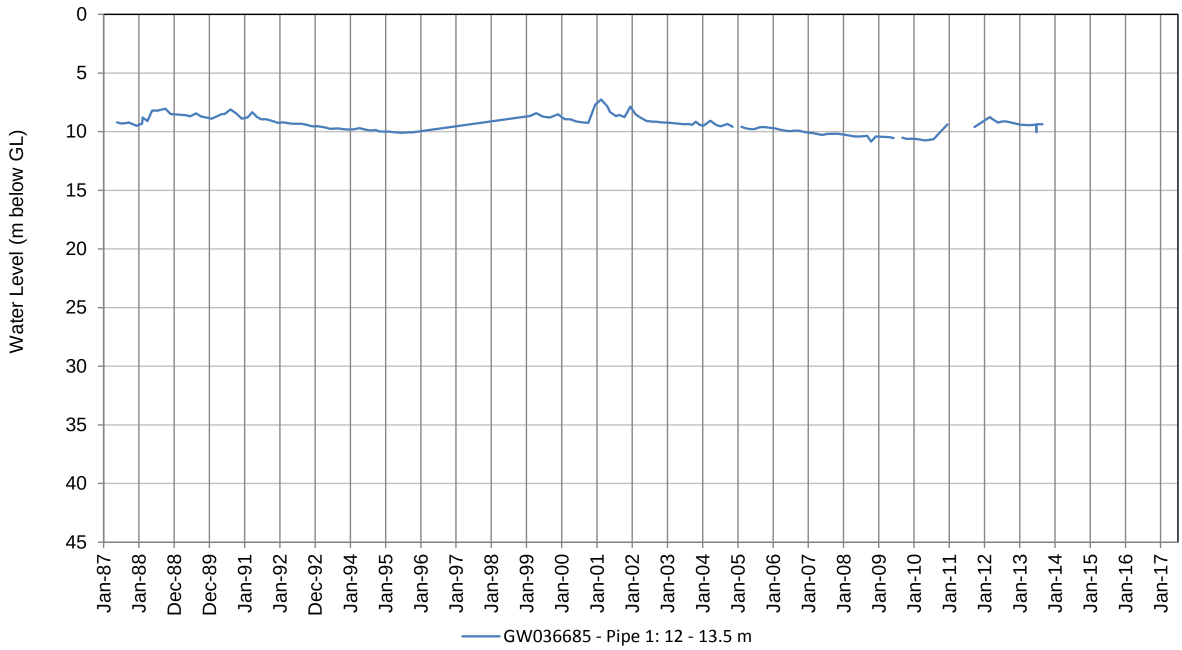


Figure 33 Hydrograph for monitoring bore site GW036685 – Macintyre Alluvium

Groundwater levels in the alluvium associated with Ottleys Creek is represented in the hydrograph from Pipe 1 (slotted interval 11-13m) at GW036692 (Figure 34). Pipe 2 (slotted interval 32-34m) is constructed in the Great Artesian Basin at this location and the hydrograph shows there is a continuing slight downward trend in water levels.

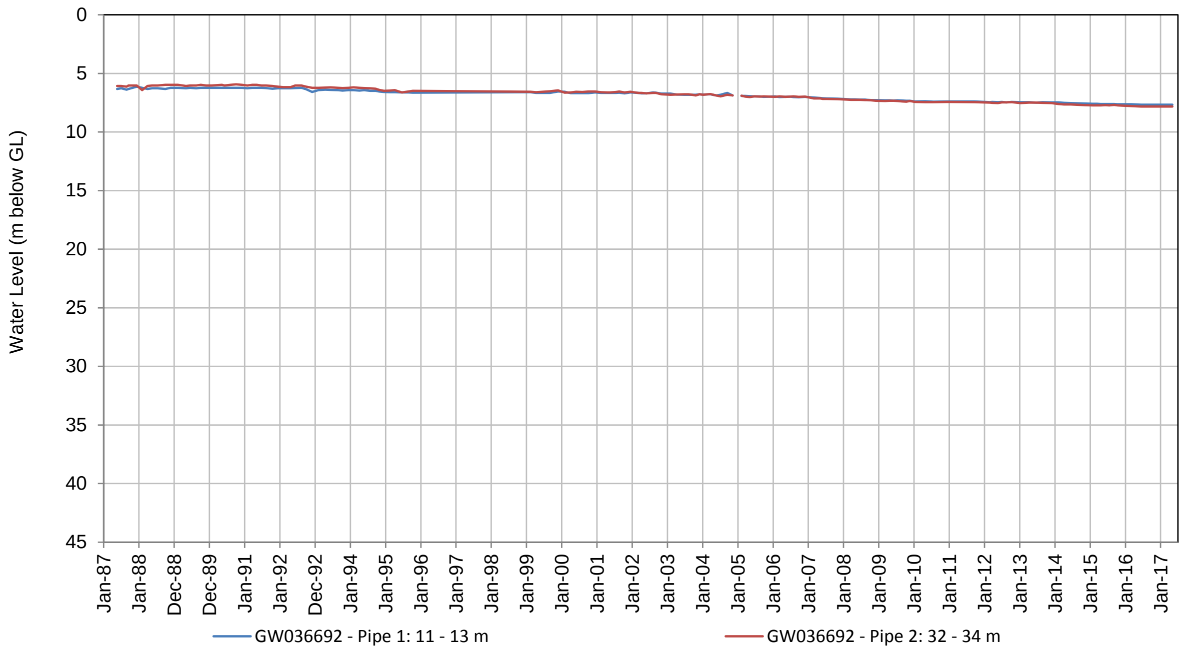


Figure 34 Hydrograph for monitoring bore site GW036692 – Ottleys Creek Alluvium

9.4. 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.

Groundwater level and pressure contour maps have been prepared for the shallow and deep groundwater systems by hand contouring the data.

BORDER RIVERS ALLUVIUM

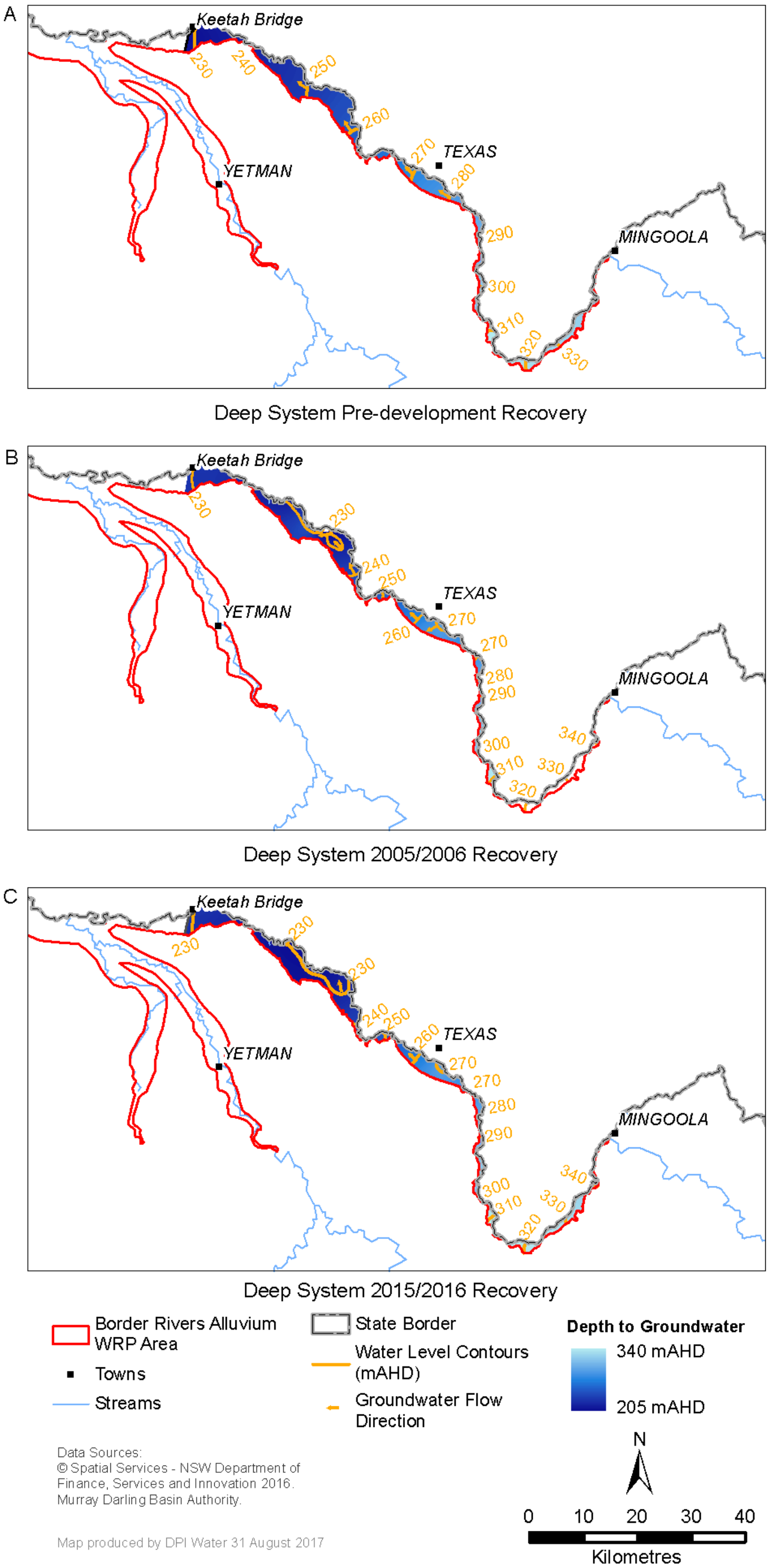


Figure 36 shows the shallow aquifer and

BORDER RIVERS ALLUVIUM

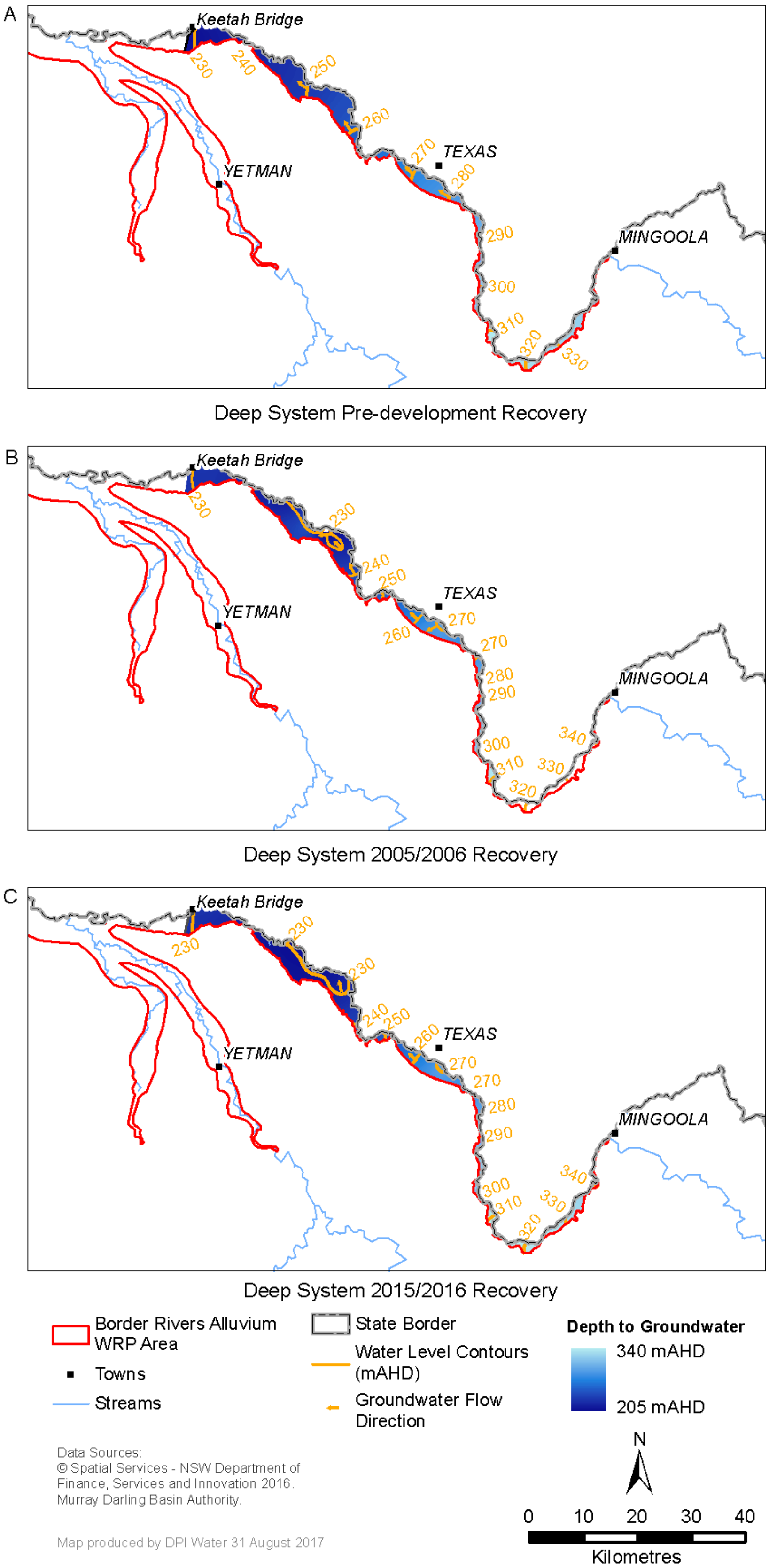


Figure 36 shows the deep aquifer.

For comparison purposes, contour maps have been prepared at maximum recovery level at ten year intervals commencing with pre-development (average 1985 - 1991).

BORDER RIVERS ALLUVIUM

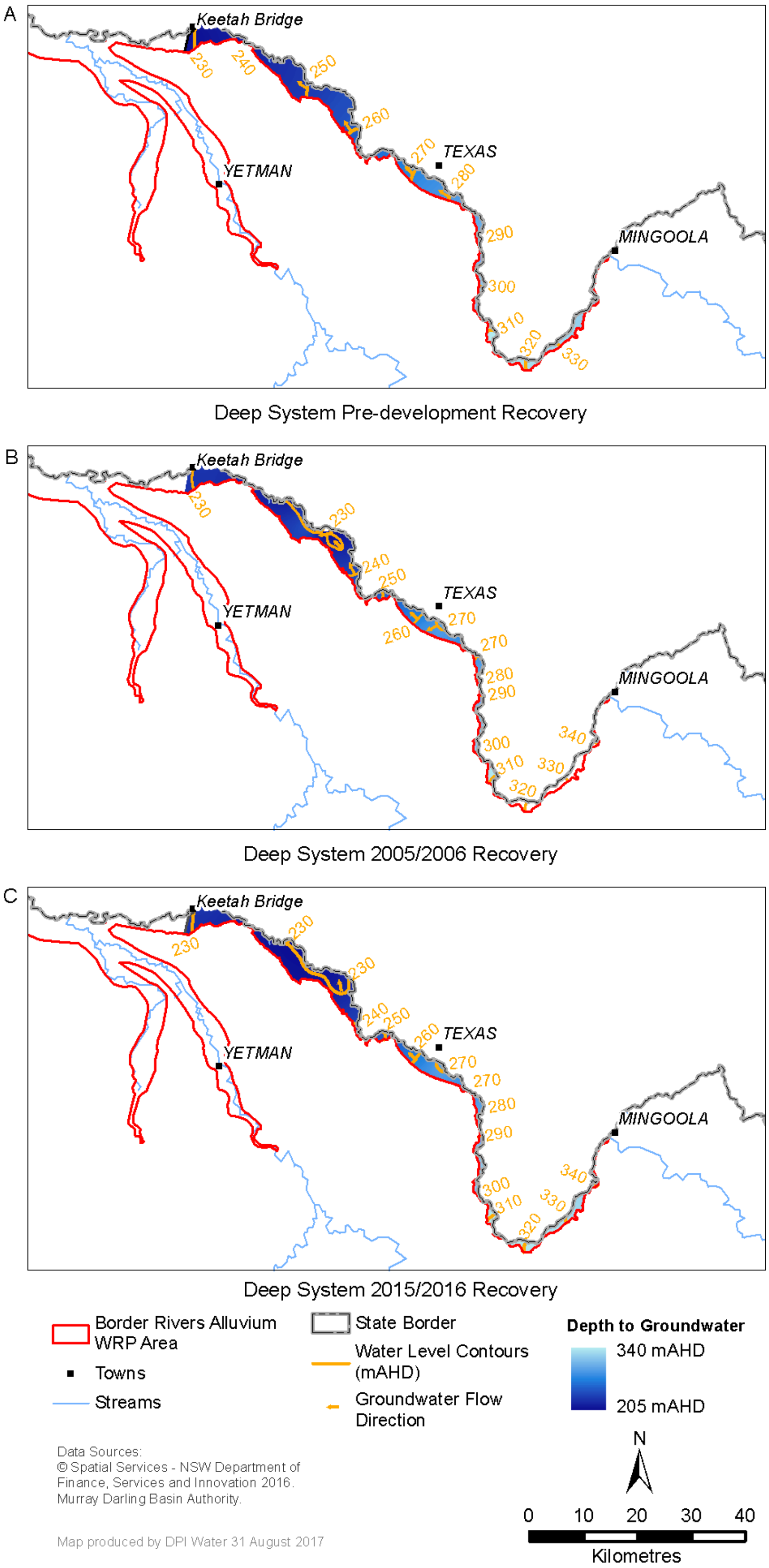


Figure 36 A shows the pre-development level for the shallow aquifer over the WRP area.

BORDER RIVERS ALLUVIUM

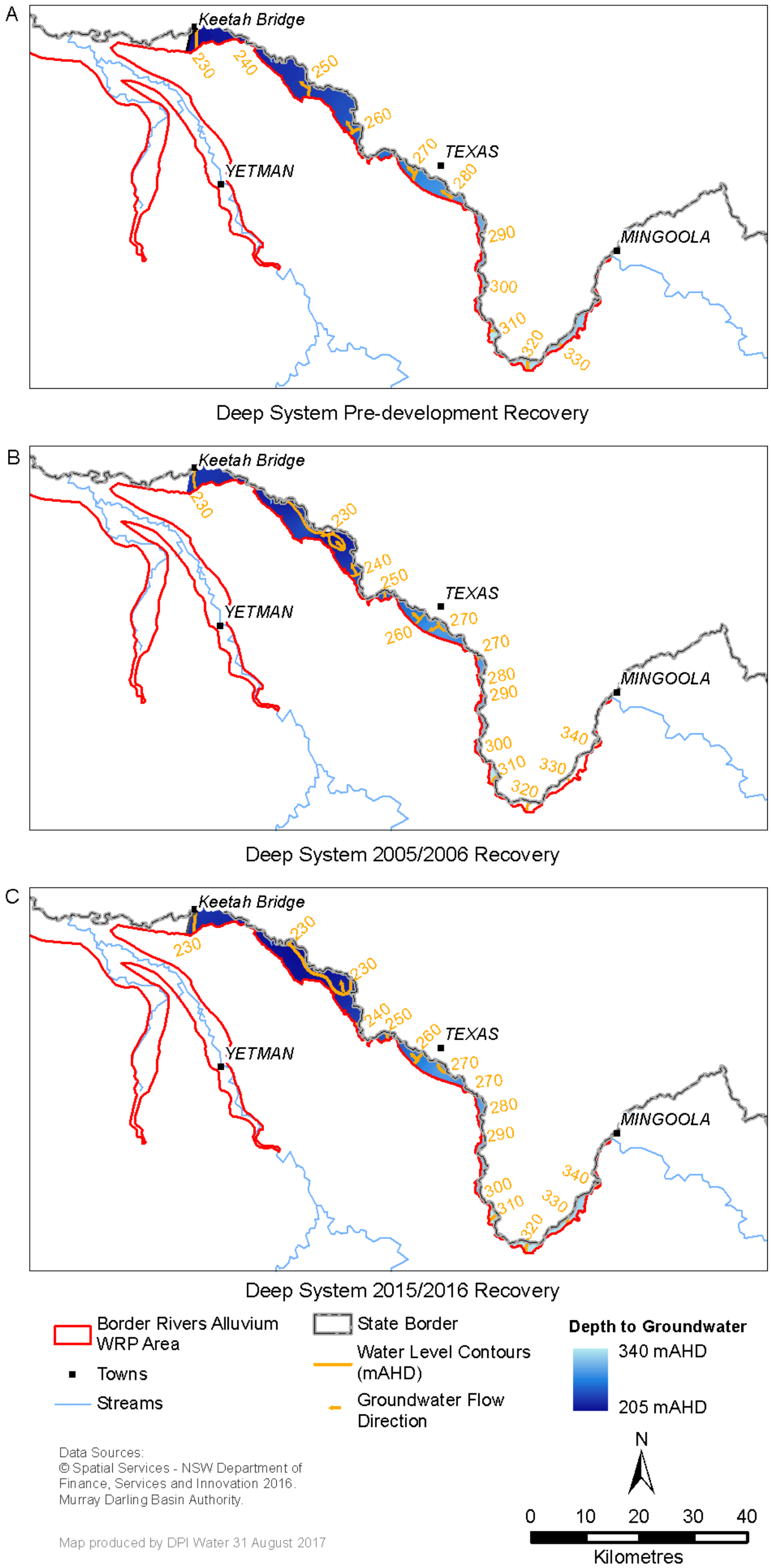


Figure 36 A shows the pre-development level for the deep aquifer system upstream of Keetah Bridge. Contours are displayed in metres Australian Height Datum (m AHD) which provides a reference level for the measurement of groundwater level or pressure that is independent of topography.

Prior to development of the resource in both the shallow (

BORDER RIVERS ALLUVIUM

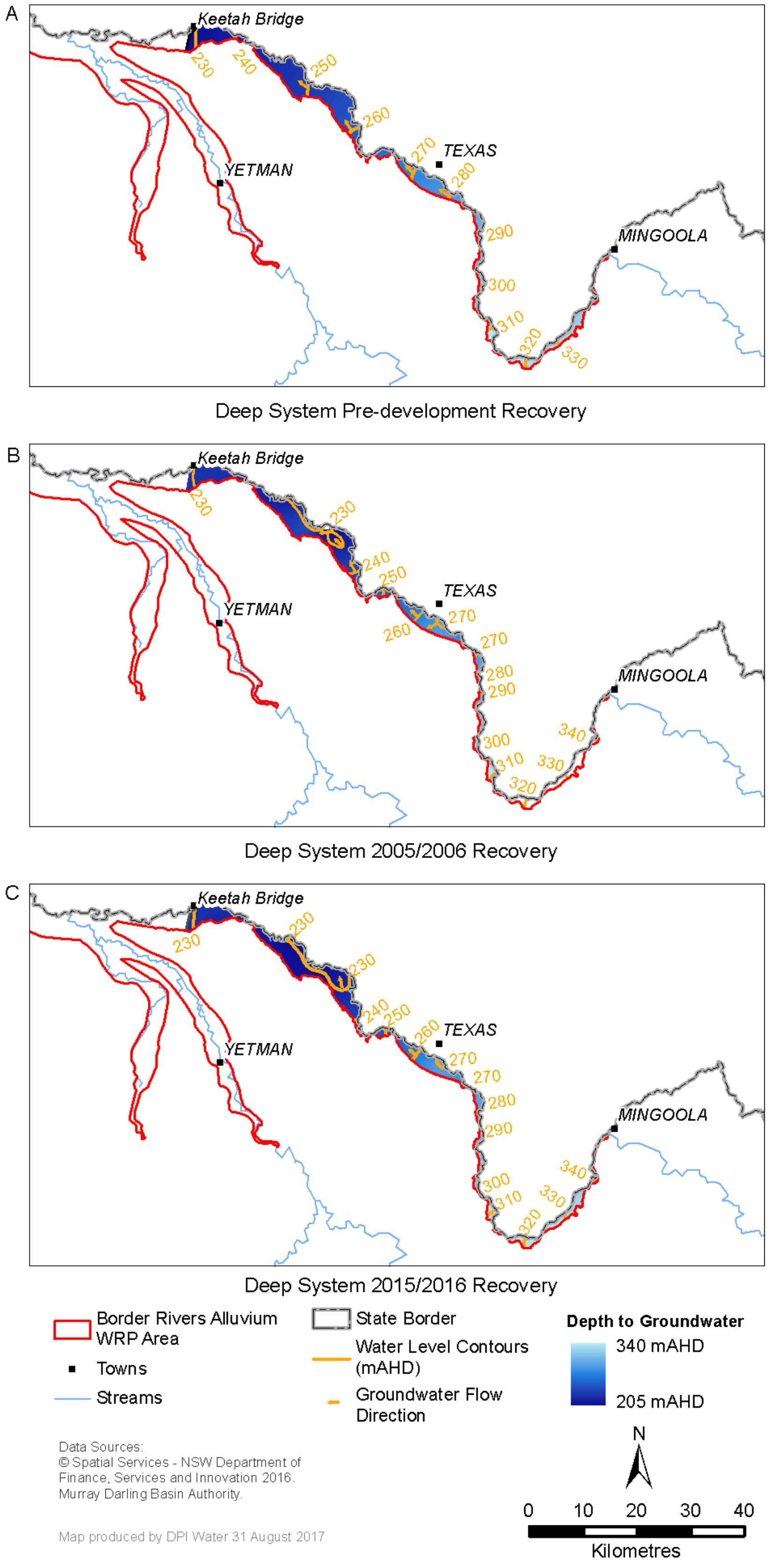


Figure 36 A) and deep systems (

BORDER RIVERS ALLUVIUM

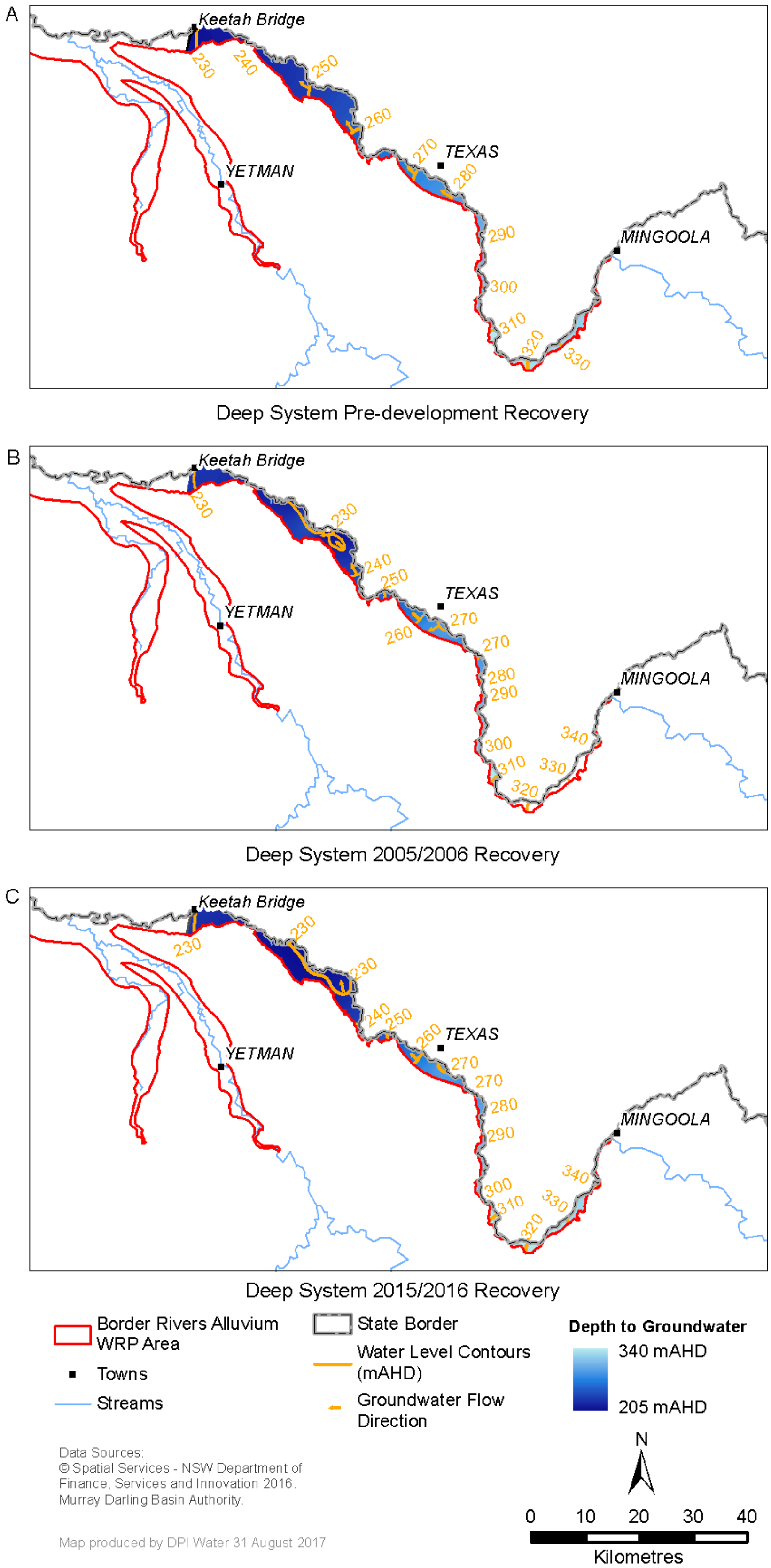


Figure 36 A), groundwater contours show a groundwater gradient that is consistent with the topographic surface. The contour maps for the shallow alluvium in 2005/06 (

BORDER RIVERS ALLUVIUM

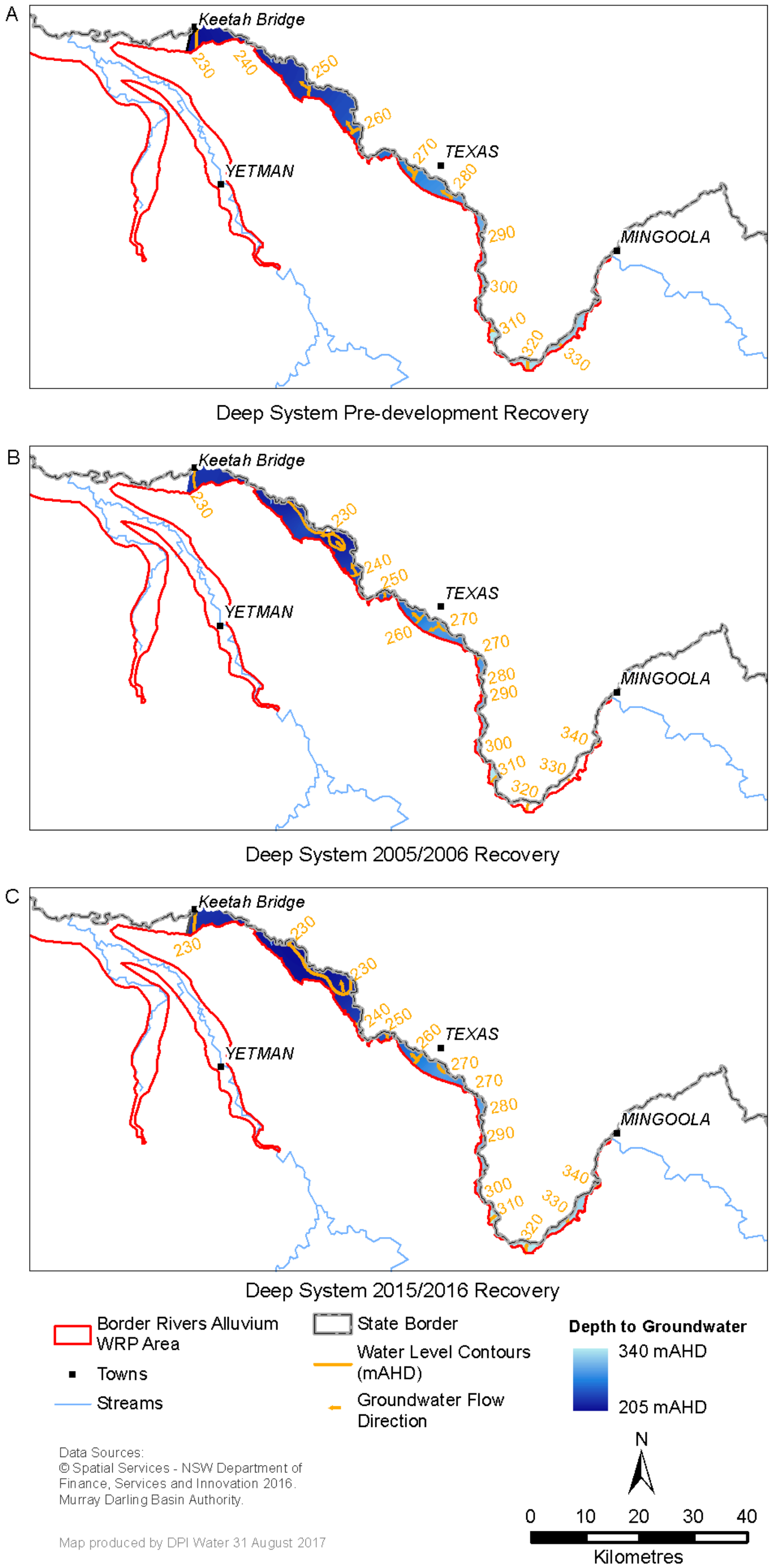


Figure 36 B) and in 2015/16 (

BORDER RIVERS ALLUVIUM

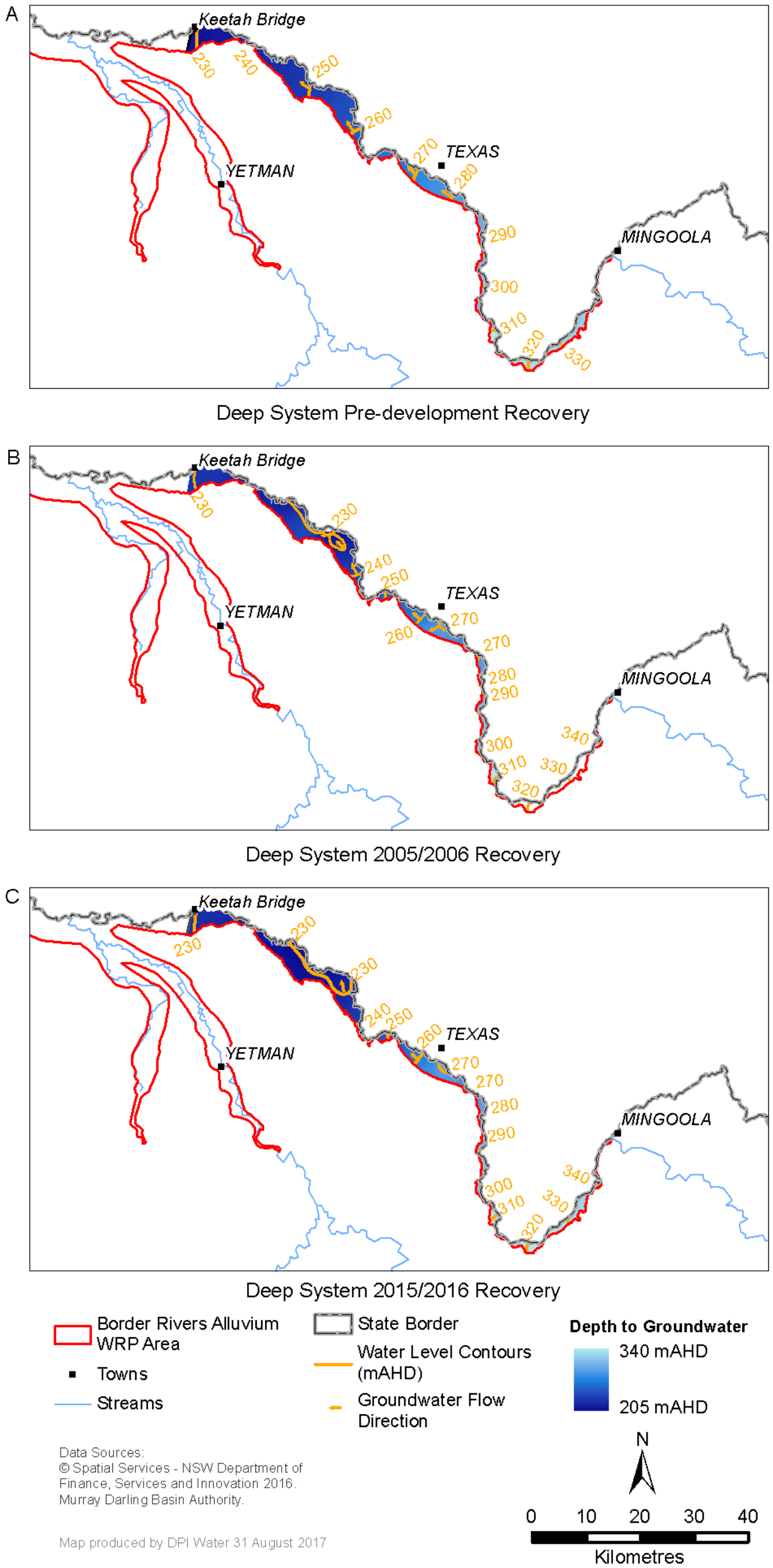


Figure 36 C) show very similar groundwater conditions.

The contour maps for the deeper aquifer show an area where the groundwater levels are not fully recovering during the non-pumping period about 16 km upstream of Keetah Bridge in 2005/06 (

BORDER RIVERS ALLUVIUM

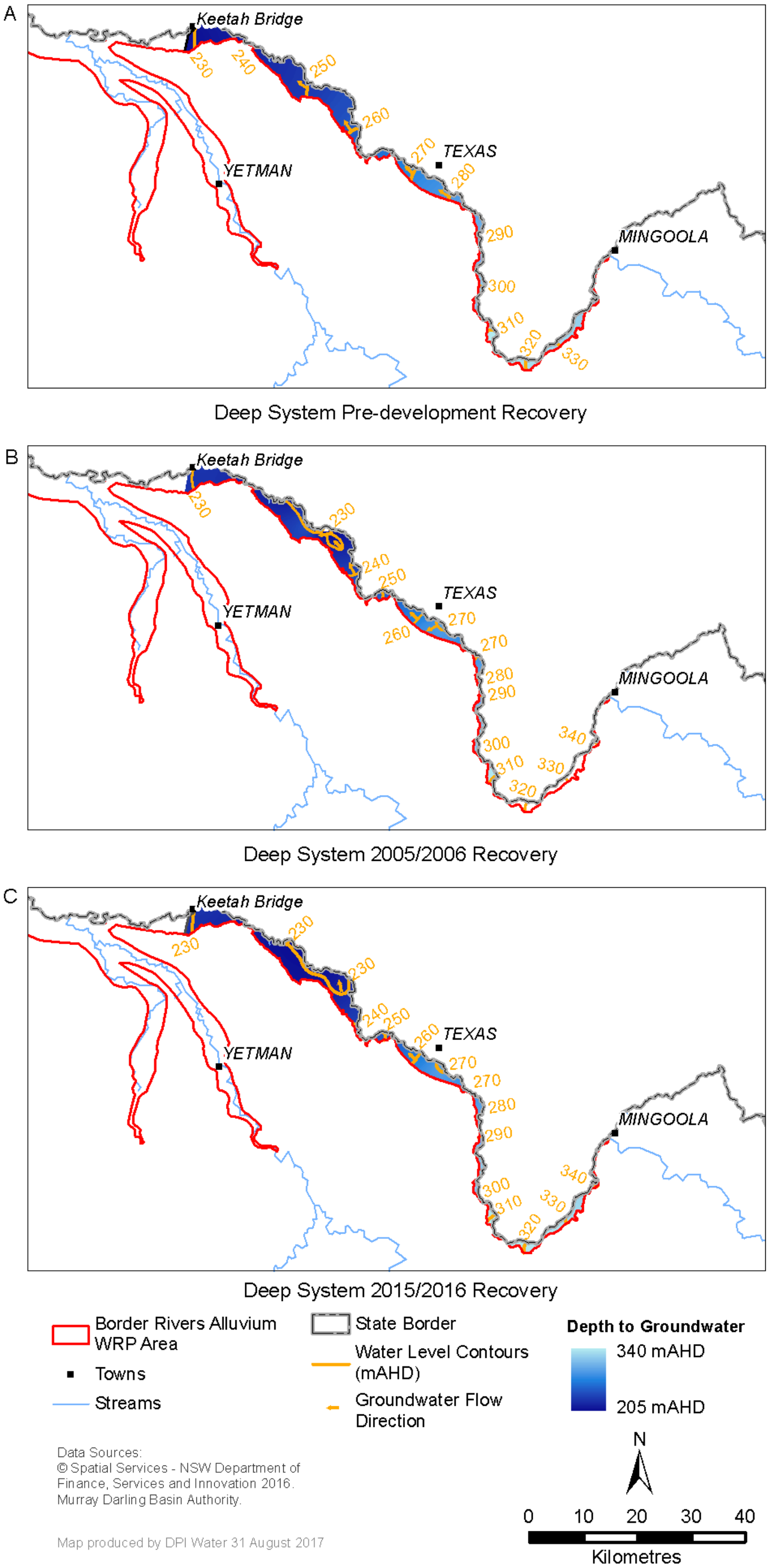


Figure 36 B). This area has increased in size by 2015/16 (

BORDER RIVERS ALLUVIUM

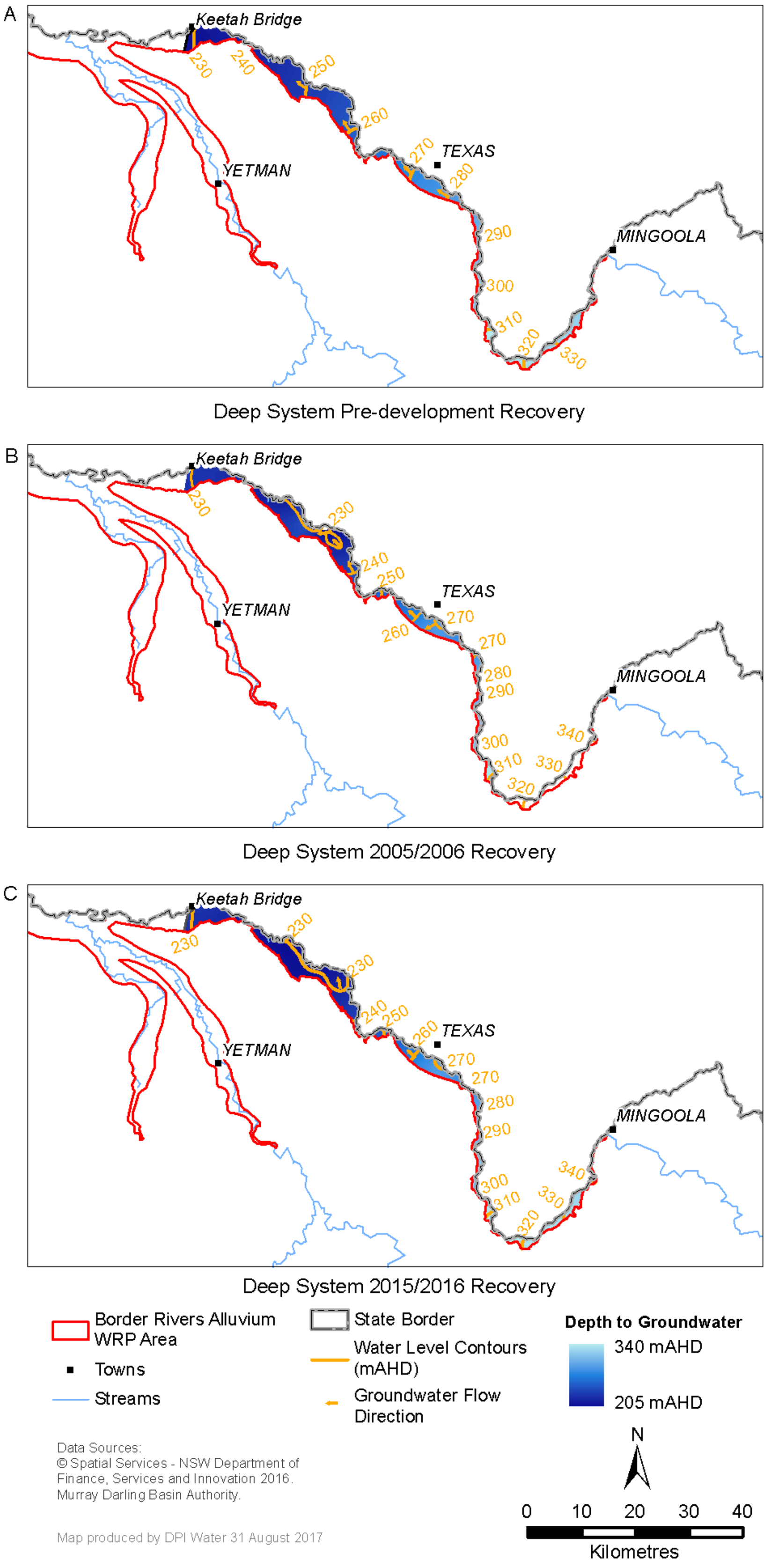

A
Keetah Bridge
230
240
250
260
270
TEXAS
280
YETMAN
290
MINGOOLA
300
310
320
330
Deep System Pre-development Recovery
B
Keetah Bridge
230
230
240
250
TEXAS
270
YETMAN
260
270
280
290
MINGOOLA
340
300
310
330
320
Deep System 2005/2006 Recovery
C
Keetah Bridge
230
230
230
240
250
260
TEXAS
270
YETMAN
270
280
290
MINGOOLA
340
300
310
330
320
Deep System 2015/2016 Recovery
Border Rivers Alluvium WRP Area
Towns
Streams
State Border
Water Level Contours (mAHD)
Groundwater Flow Direction
Depth to Groundwater
340 mAHD
205 mAHD
N
0
10
20
30
40
Kilometres
Data Sources:
© Spatial Services - NSW Department of Finance, Services and Innovation 2016.
Murray Darling Basin Authority.
Map produced by DPI Water 31 August 2017

Figure 36 C).

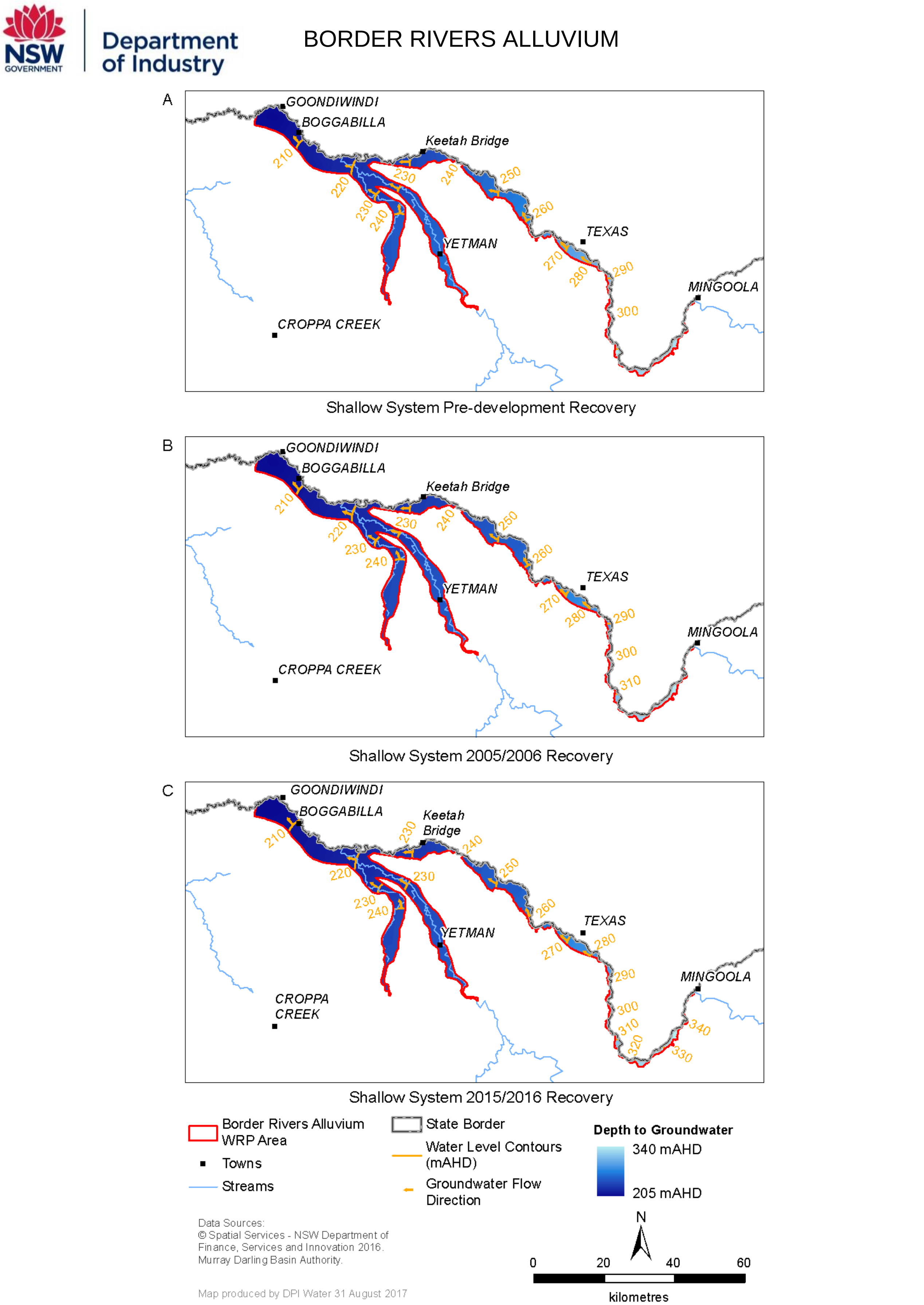


Figure 35 Groundwater level contours for the maximum recovery period, every 10 years starting from the pre-development period for the shallow aquifer systems, Border Rivers Alluvium.

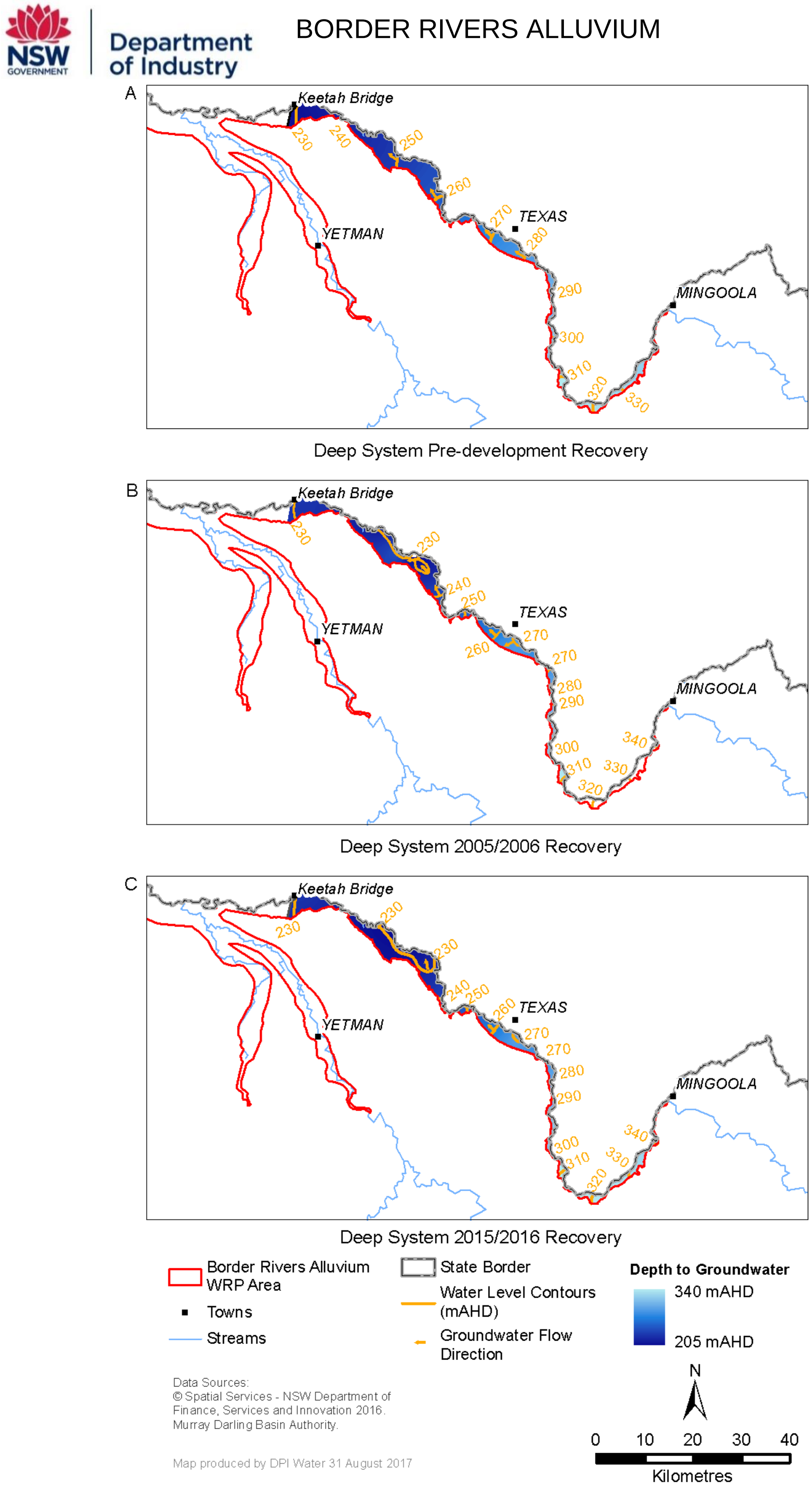


Figure 36 Groundwater level contours for the maximum recovery period, every 10 years starting from the pre-development period for deep aquifer systems, Border Rivers Alluvium.

Figure 37 compares the recovered water levels in the deep aquifer system with the corresponding maximum drawdown water level in 2015/2016. Figure 37 highlights the change of pattern in the flow direction over a season in areas where extraction occurs. The area of greatest extraction impacts is between Keetah Bridge and Texas where a drawdown low has developed over the pumping season Figure 37 A which then recovers slightly Figure 37 B.

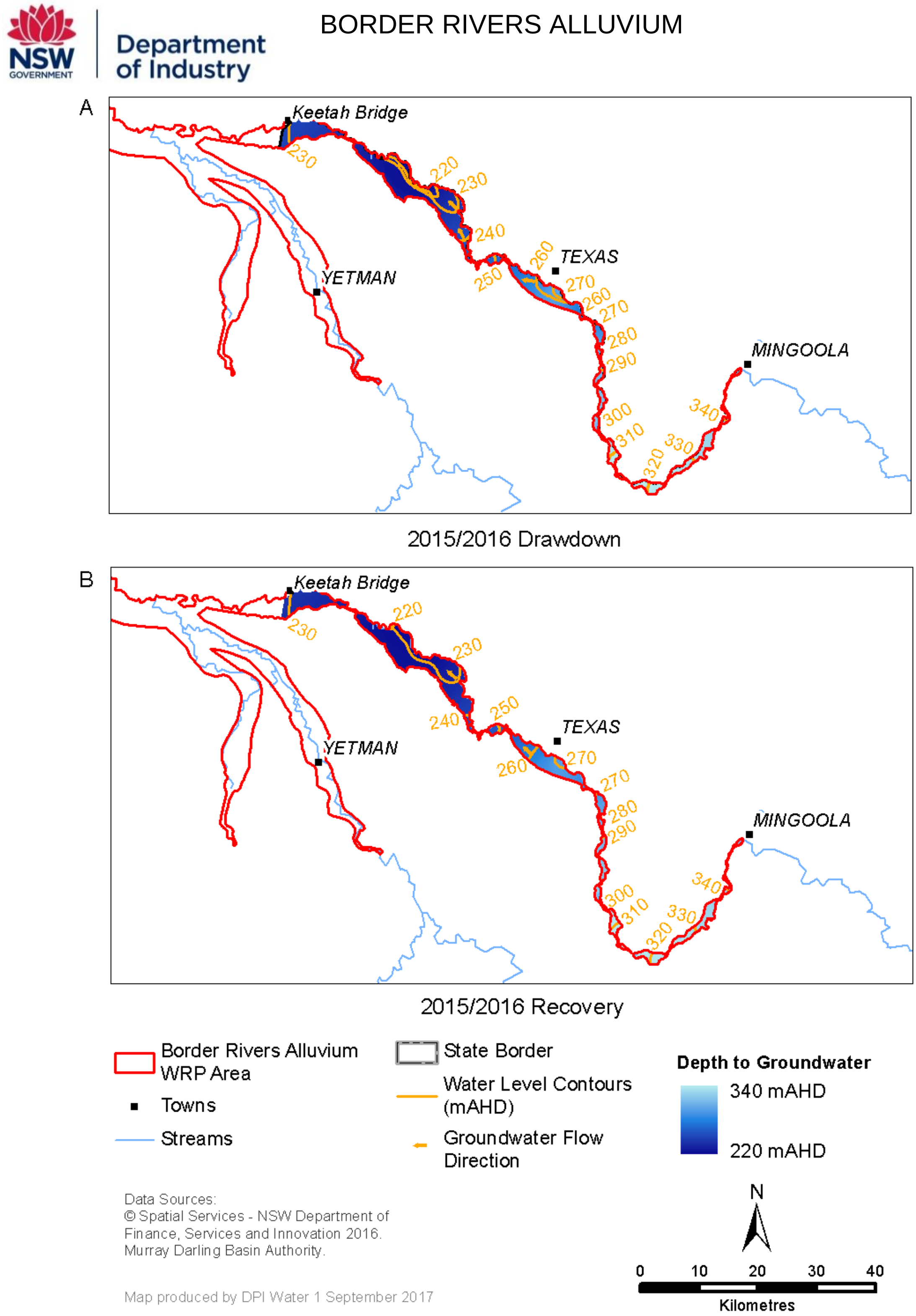


Figure 37 Groundwater level contours for the maximum recovery and maximum drawdown period in 2015/2016; deep aquifer system, Border Rivers Alluvium.

9.5. Long term changes

Change in recovered groundwater levels from 2006 to 2016 is shown in Figure 38 A for the shallow aquifer system and in Figure 38 B for the deeper aquifer system. These show very little change over this period in the shallow aquifer and a maximum change up to four metres rise upstream of Texas and a four metres fall down stream of Texas in the deeper aquifer system. This change is due to pumping induced drawdowns and reduced pumping and flooding in the rises.

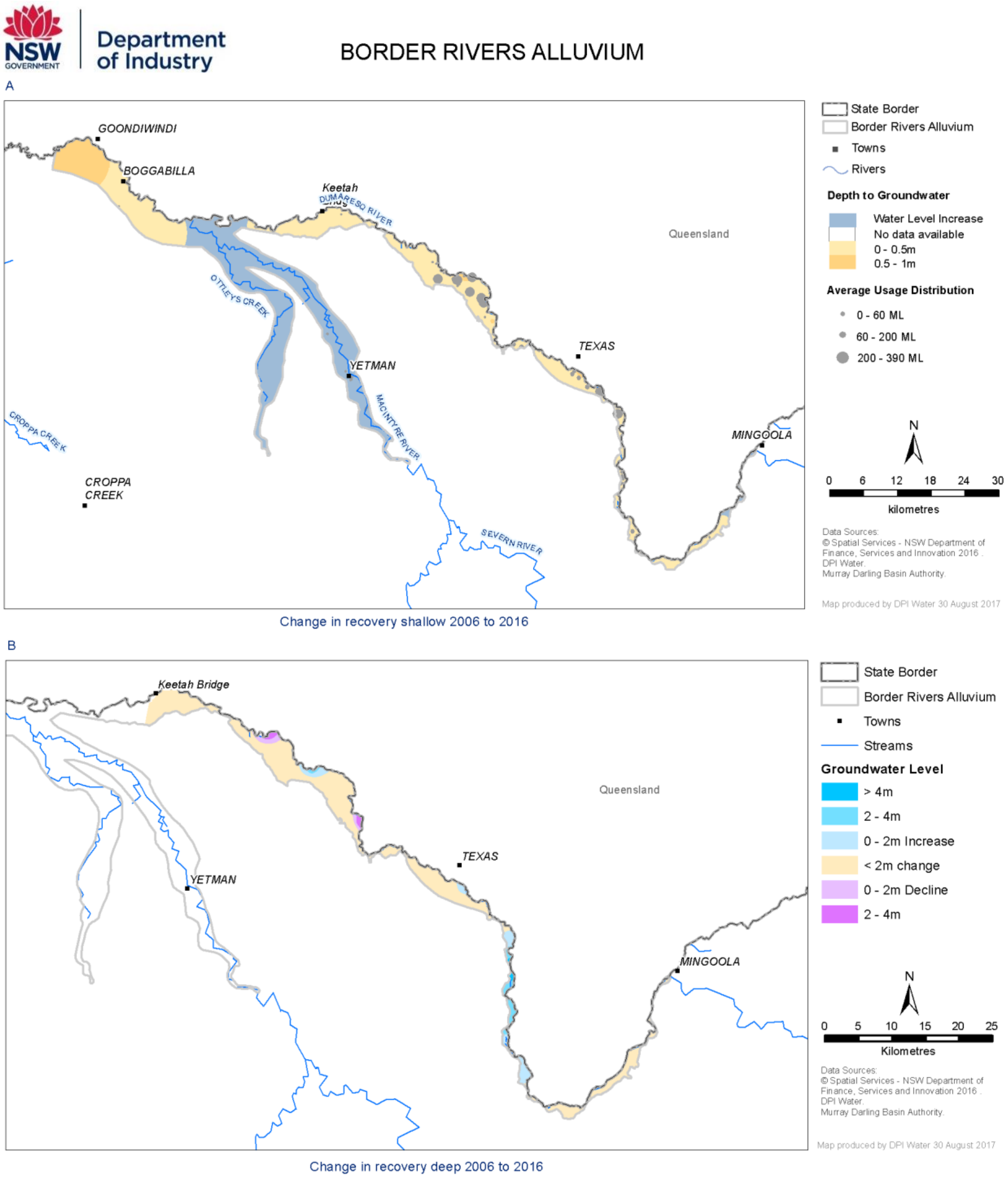


Figure 38 Border Rivers Alluvium – shallow and deep aquifer system; two maps showing the change in recovered water level between 2006 and 2016.

10. 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 2002 a groundwater model for the shared resource in both states upstream of Keetah Bridge was finalised to support shared resource management. A final model report was completed in January 2003 (Chen 2003).

In 2013 an upgrade of the existing model was required to satisfy legislative requirements in Queensland. As there was a further 13 years of data available and improvements in modelling techniques since the 2002 model a new model was determined to be the best option.

Queensland Department of Natural Resources and Mines (DNRM) developed the new groundwater model using the USGS Modflow Unstructured Grid format on behalf of both New South Wales and Queensland. The new model has been constructed, calibrated (peer reviewed) and scenario runs undertaken. The final model is expected to be available to both agencies upon final completion scheduled in 2019.

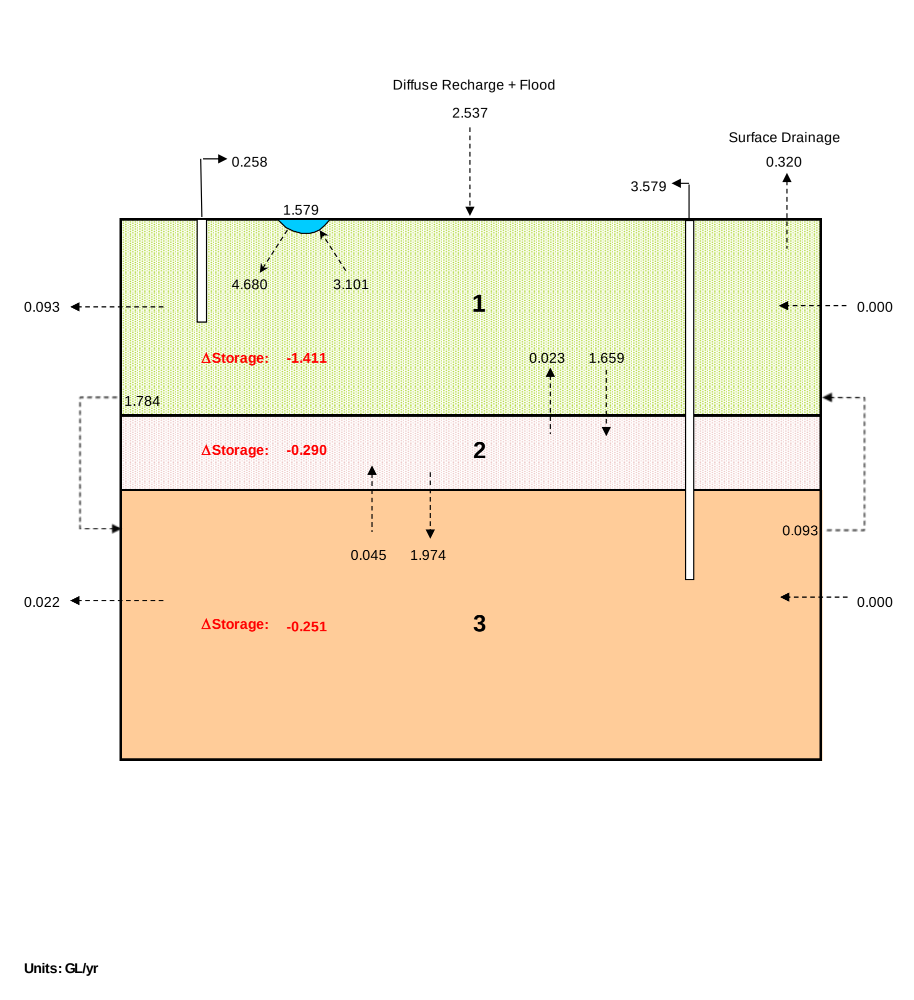
Figure 39 shows the cumulative water budget output for the NSW side of the alluvium from 1 June 2012 to 31 December 2015. This corresponds to the period since commencement of the water sharing plan to the end of the model calibration period.

Water Budget Summary (NSW Only)

Model Description: Border Rivers (Dumaresq)

Calibration Period: 1/1990 - 12/2015

Summary Period: **6/2012 - 12/2015**



Recharge		
Net Diffuse + Flood	IN	2.537
Total	IN	**2.537**
River exchange	IN	4.680
	OUT	3.101
Net	IN	**1.579**
Surface Drains	OUT	0.320
Groundwater pumping		
Layer 1	OUT	0.258
Layer 3	OUT	3.579
Total	OUT	**3.837**
Lateral (Boundary) flows		
Layer 1	IN	0.000
	OUT	0.093
Layer 3	IN	0.000
	OUT	0.022
Vertical (inter-layer) flows		
Layer 1 to layer 2		1.659
Layer 1 to layer 3		1.784
Layer 2 to layer 1		0.023
Layer 2 to layer 3		1.974
Layer 3 to layer 1		0.093
Layer 3 to layer 2		0.045
From QLD to Layer 1		*1.666*
From Layer 1 To QLD		*3.192*
From QLD to Layer 2		*0.003*
From Layer 2 To QLD		*0.002*
From QLD to Layer 3		*3.147*
From Layer 3 To QLD		*3.415*
Storage change		
Layer 1		-1.411
Layer 2		-0.290
Layer 3		-0.251
Total		**-1.952**

Figure 39 Border Rivers Alluvium groundwater flow model water budget output 1/06/2012 to 31/12/2015.

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 39 shows that since the commencement of the water sharing plan on 1 June 2012 to 31 December 2015, the modelled total net storage volume in the Border Rivers Alluvium has decreased (storage change -1.952 GL) over this 3 years 7 month period. It should be noted that this period coincides with three and half pumping seasons but only three non-pumping, or recovery periods. Therefore this deficient in storage cannot be extrapolated as an indicator of the long term response of the system to the current level of pumping stresses.

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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