

# **Upper Condamine Basalts**

## **Groundwater Background Paper**

**July 2018**

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# Contents

<b>Introduction .....</b>	<b>2</b>
<b>Location .....</b>	<b>2</b>
<b>Land use.....</b>	<b>3</b>
<b>Climate and rainfall .....</b>	<b>3</b>
<b>Geology and hydrogeology.....</b>	<b>3</b>
Major rock formations.....	3
Recharge and discharge .....	4
Water resource connections .....	5
Transmissivity and specific yield.....	5
Groundwater quality .....	6
<b>Groundwater dependant ecosystems (GDEs).....</b>	<b>6</b>
<b>Entitlements and use .....</b>	<b>7</b>
<b>Management arrangements .....</b>	<b>7</b>
Proposed future management – new water plans in 2019 .....	9
<b>Overall status .....</b>	<b>9</b>
<b>References .....</b>	<b>9</b>
<b>Attachment A: Land use.....</b>	<b>11</b>

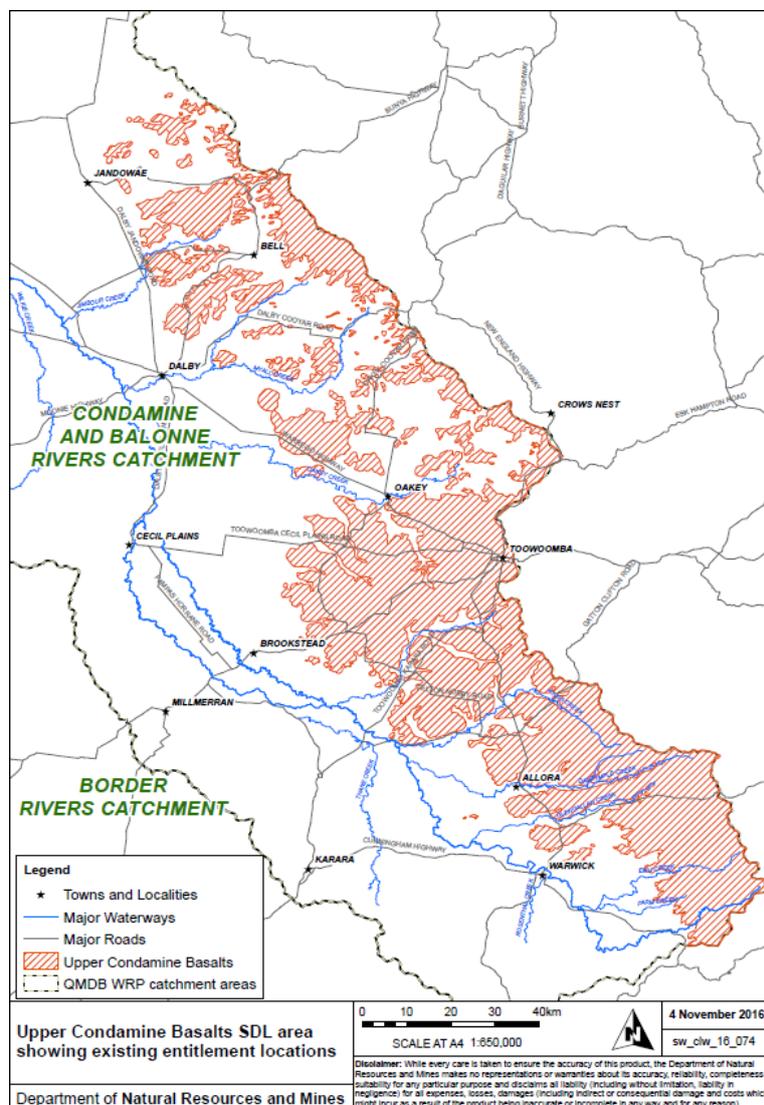
# Introduction

This paper relates to the Upper Condamine Basalts (the UCB) sustainable diversion limit resource unit (GS65) located within the Condamine – Balonne water plan area. The unit is part of the Main Range Volcanics aquifer system composed of basaltic fractured rock aquifers.

This paper summarises the UCB groundwater system, including location, land use, climate, geology, hydrogeology, key environmental assets, use and management arrangements.

# Location

The UCB is located west of the Great Dividing Range in the Darling Downs region within the local government areas of Western Downs, Toowoomba and Southern Downs Regional Councils, bordering New South Wales. It stretches from Killarney to Jandowae and spans an area of ~5800 km<sup>2</sup>.



**Figure 1: Upper Condamine Basalts SDL resource unit (GS65)**

## Land use

Across the Condamine – Balonne area the land use is dominated by cattle and sheep grazing on dryland pasture (Figure A Attachment A). Grain and cotton crops are significant contributors to the regional economy, and are grown under dryland and irrigated farming, respectively. Within the Upper Condamine irrigated and dryland agriculture are the dominant land uses followed by grazing and forestry, town and industrial uses (DSITI 2016, OGIA 2016).

## Climate and rainfall

Climate in the UCB is classified as warm and temperate. Average annual rainfall, according to the Bureau of Meteorology, is 724 mm, which peaks in the warm season. The annual rainfall ranges from 600 mm in the west (Dalby and Warwick) to 1000 mm in the east (Toowoomba). The majority of rain falls from November to March, with January and February being the peak rainy months<sup>1</sup>.

## Geology and hydrogeology

The unit is located on the Toowoomba Plateau – a basaltic plateau supporting highly weathered bedrock and soil on bedrock surfaces. The plateau is composed of volcanic rock deposit known as the Main Range Volcanics (MRV) formation which comprises predominantly basalt<sup>2</sup> (extrusive igneous rock), agglomerates, shales and dolomites. Figure A shows the distribution of outcrops of the MRV geology. The UCB overlies formations of the Great Artesian Basin (GAB), including Walloon Coal Measures (Clarence Moreton Basins) and Marburg Sandstone. The unconformity between basalts of the UCB and GAB formations generally occurs at 440–460 m AHD<sup>3</sup>, indicating a nominal thickness of basalt of 200 m, with a maximum thickness of approximately 280 m beneath high upland areas (Brodie and Green, 2002).

The terrain of the Main Range Volcanics is dominated by the steep-sided, east-facing escarpment that runs from north to south, and the gently-sloping, west-facing terrain.

## Major rock formations

Groundwater in the UCB occurs within the basalts of the MRV. Basalt weathers and oxidises relatively fast in comparison to other rock types. It has highly variable porosity and may form aquifers that store and transmit groundwater through the vesicles, fractures and weathered zones of the basalt.

Basaltic aquifers of the unit are primarily located along the eastern margin of the Condamine river basin. The basalts do not consist of a single homogeneous basalt flow or one single aquifer. Rather, the basalt sequence consists of many overlapping basalt flows with a maximum thickness of approximately 10 m each (Brodie and Green, 2002), which are stacked together and commonly separated by lower permeability layers including the clay-rich weathering profiles that developed between periods of volcanic activity.

These different zones of varying permeability affect the capacity of different basalt flows to store and transmit groundwater. At the top and the base of the basalt flows, zones consisting of broken vesicles commonly occur, and these provide considerable primary pore space that can contain and transmit groundwater. At the edge of the basalt flows, at the interface of the higher permeability basalts and the lower permeability overlying alluvial aquifers, groundwater discharges to the surface as springs, and these may feed streams (Brodie and Green, 2002).

Located along the eastern margin of the Condamine river basin at depths of between 11 and 41 m, the aquifers in the UCB generally consist of an upper unconfined weathered and fractured zone with a lower, more limited in extent, semi-confined fractured zone. Average aquifer thicknesses are in the

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<sup>1</sup> Data sourced from the Bureau of Meteorology monthly climate statistics (all years); [www.bom.gov.au](http://www.bom.gov.au)

<sup>2</sup> Mainly, olivine basalt

<sup>3</sup> i.e., metres on the Australian Height Datum

order of 28 m (Skelt et al., 2004). Small parts of the UCB are covered by alluvial deposits of the Upper Condamine Alluvium.

The presence of numerous small, overlapping lava flows and columnar joints creates vertical and horizontal hydraulic discontinuities. The upper weathered basalt layers are important for groundwater recharge during heavy precipitation events, with a delay period of about a month between rainfall and recharge. This major recharge zone feeds creekbeds incised into the permeable pallid base of the weathered layers, even during dry periods (Willey, 2003). The dominant stream alluvium in upper valleys is cracking clay; baseflow here relates to springs discharging at the edges of streambed aquitards.

In the east of the Upper Condamine, the basalts are hydraulically connected with the alluvium and the GAB intake beds. Streams forming on the basalts began to incise and deposit alluvium within small valleys. This process of incision continues until the streams incised down to the GAB intake beds. Therefore, all three geological formations may be in direct hydraulic contact with each other at different locations in the tributary valleys.

## Recharge and discharge

Aquifers of the UCB generally exhibit relatively dynamic and rapid water level variations in response to rainfall recharge and pumping events, and natural depletion. Recharge may occur via direct rainfall infiltration to fractured and weathered zone of the basaltic aquifers and/or leakage from overlying alluvial sediments, where there is sufficient connection (Table 1).

**Table 1: Table 1. Rates of recharge for the UCB resource unit (Figure 2) (CSIRO (2008)).**

GMU	Recharge (GL/Year)
Nobby Restricted Area	2.4
Toowoomba City Basalts	1.8
Toowoomba North Basalts	13.3
Toowoomba South Basalts	7.8
Upper Hodgson Creek	1.1
Warwick Basalts	8.8

Local and intermediate groundwater flow systems occur in the aquifers of the UCB. The top of the UCB is important for groundwater recharge during heavy precipitation events, where there is a delay period of approximately a month between rainfall and recharge.

In some areas, the upper weathered basalt (the major recharge zone) feeds creek beds even during dry periods (Willey, 2003). Groundwater recharge occurs following rainfall rates of 100–150 mm/month, with 3–6 days delay between rainfall events and peak groundwater levels in the upper catchments, and lag times of the order of 4–7 months in bores in basalt beneath deep clay alluvia (Silburn et al., 2006). Deep drainage recharges aquifers within several months and excess groundwater is transferred down-gradient to the land surface or streams within a year (Cresswell et al., 2006). Surface permeability has decreased across the Toowoomba Plateau through urban expansion, for example sealed roads and rooftops now intercept rainfall and reduce recharge.

Due to the discontinuous nature of the permeability in the distribution of the fractures and joints in the basalts, there are varying degrees of connectivity between the various groundwater areas of the UCB. Generally groundwater flow direction is from the east to the west (i.e. away from the area of recharge).

Rainfall recharge to groundwater could either increase or decrease as a result of climate change. However, it is anticipated that the change would not exceed 10 per cent (CSIRO, 2008) and impact of this on groundwater resources would be minor in comparison to the impacts of groundwater extraction.

Discharge of groundwater is common around the contact between basalt and less permeable underlying geologies including bands of rhyolite and mudstone. Groundwater discharge to the surface

may occur via seepage to baseflows, springs and evapotranspiration. Discharge may also occur into overlying alluvial (upwards discharge) or underlying GAB (downward discharge) aquifers, recharging them.

Overall, water levels in the UCB are directly linked to:

- size and amount of fractures
- proximity of fractures to the surface
- interconnections between fractures in any given area.

An accurate potentiometric surface is difficult to determine due to the discontinuous nature of the distribution of the fractures and joints in the basalts.

## Water resource connections

The relatively high rainfall of the UCB in the east (around 1000 mm) and resultant runoff and deep drainage amounts to 35.2 gigalitres per year (GL/year) of recharge to the main groundwater UCB management areas (Table 1). This water is an important source of inflows to two connected groundwater resources and stream baseflows within the Condamine – Balonne area, namely:

- the Upper Condamine Alluvium Tributaries (GS64b) (UCAT)
- the Central Condamine Alluvium (GS64a) (CCA)
- the Condamine River and tributaries system (SS26).

Table 2 summarises connectivity status of groundwater in the UCB with other, adjacent water resources, particularly whether connection is significant or not.

**Table 2: Hydrologic connectivity between the UCB and other water resources**

Connected resource units	Significant connection*
Upper Condamine Alluvium Tributaries (GS64b)	Yes
Central Condamine Alluvium (GS64a)	Yes
Condamine Balonne (SS26) (surface water)	Yes

\* Two water resources are considered to have a significant hydrological connection to one another if both water from a resource is physically able to move to the other resource and activities in one resource may have a material impact on the state or condition of the other. "No" status was assigned in case there was no evidence of significant, or high, connectivity between the resources based on hydrological studies or local, expert knowledge.

## Transmissivity and specific yield

Permeability within the UCB aquifers consists of both primary and secondary (fracture) porosity, with the latter having the dominant influence. The aquifers exhibit local and intermediate groundwater flow systems. Bore yields are highly variable due to the complex and irregular nature of high permeability networks, which control the movement of groundwater. Sub-horizontal water-bearing zones are predominantly hosted in weathered or vesicular basalt, commonly in the upper parts of individual layers. Significant sub-vertical discontinuities also provide important fluid pathways within the UCB; these include faults and fractures, columnar or radial joint networks, and the overlapping edges of terminal palaeo-lava flows.

Transmissivity is highly variable, ranging between 10 and 1000 m<sup>2</sup>/day (QGC, 2009), due to the discontinuous nature of the basalts. Yields to the south of Toowoomba range up to 19 L/sec, however yields up to 35 L/sec have been obtained in localised areas (Departmental data, 2017).

Overall, aquifers in the UCB offer high potential as groundwater storages. They generally exhibit relatively dynamic and rapid water level variations in response to rainfall recharge, pumping events, and natural depletion. Monitoring data reveal that the trend of water levels in basaltic aquifers has

close correlation with rainfall and in general does not indicate either a rising or falling trend. The dynamic nature of the groundwater system is evident in bores with seasonal water level variations of 1 to greater than 3 m and, in some cases, water level variations in the order of 11 m between periods of high rainfall and drought.

For a case study, watertable depths in the Upper Hodgson Creek subarea range from less than 2 to 50 m below ground level. The watertable height decreases from 517 m to 426 m AHD over a distance of ~25 km, a hydraulic gradient of 0.003. Groundwater salinity increases progressively down-gradient, indicating continuity of the flow path (Cresswell et al., 2006).

Hodgson Creek is a 'gaining stream', receiving discharging groundwater as streamflow, although dry periods may see a reversal, with streambeds locally recharging underlying strata. The presence of baseflow is strongly influenced by the depth of stream incision. Baseflow no longer occurs in several streams, for example, in Hodgson Creek downstream of Cambooya, below the area of greatest groundwater use (Reid et al., 2007). Depth of stream incision and groundwater use for irrigation largely control the presence or absence of baseflow, e.g., groundwater is generally not far beneath the creek bed in non-irrigation areas. The system is strongly predisposed to groundwater-surface water interaction. The Kings Creek system shares similar characteristics (Huxley 1982).

## Groundwater quality

Chemical composition of groundwater depends on the original composition of rocks, aquifer depth and groundwater flow patterns. Groundwater quality in the basaltic aquifers may vary in the UCB, due to the complexity of mineralisation of the rocks and irregular weathering processes.

In general, basalts in the UCB have a weakly to strongly alkaline composition. Chemical composition of groundwater in the unit is dominated by (in decreasing order) Mg, Ca, Na: HCO<sub>3</sub>, Cl and SO<sub>4</sub>, reflecting the influence of weathering of the basaltic host rocks and rainfall infiltration.

Groundwater in the UCB is of low salinity, having total dispersion solids (TDS) concentrations mostly in the range zero to 1500 mg/L, increasing slightly in the north to 1500 to 3000 mg/L. Water quality is generally suitable for all purposes, with salinity in the range from 500 to 1500 mg/L (CSIRO, 2008). Occurrence of Na-Cl rich groundwater in the lower slopes may relate to evaporative and flow related concentrations of salts in groundwater on its down gradient flow (Cresswell et al., 2006). More Na-Cl-rich groundwaters observed in the upper slopes may relate to evaporative concentration of infiltrated rainfall stored in the upper weathered unit at the top of the catchments.

Groundwater in the UCB flows predominately from east to west. The quality generally appears to be better in the east towards Toowoomba and groundwater salinity increases progressively down gradient to the west, indicating continuity of the flow path (Cresswell et al., 2006).

In general, salinisation is a minor problem in the UCB. Typically, saline outbreaks may occur where groundwater flow is restricted at:

- impermeable interbeds in the MRV or where there are permeability contrasts between different basalt layers
- the boundary between basalt and underlying Walloon Coal Measures in lower parts of sub-catchments
- creeks incised into alluvial aquifers where the hydraulic conductivity of a valley is very low, causing groundwater levels to rise (Kalma 1995).

A notable saline outbreak occurs in the upper part of Umbiram Creek (near Cambooya) where a constriction in the MRV inhibits groundwater flow.

## Groundwater dependant ecosystems (GDEs)

Discharge of groundwater is common around the contact between basalt and less permeable underlying geologies. Technical assessments conducted as part of water plan development identified the following types of GDEs in the UCB unit: baseflows to watercourses, springs, and groundwater dependent terrestrial vegetation and non-riverine wetlands. The maps showing the distribution of

these GDEs across the unit are provided in Appendix 6 the Ecological Risk Assessment report submitted for water resource plan accreditation (DSITI 2017).

## Entitlements and use

Table 3 summarises entitlement statistics (the number of groundwater licences and the allocated volumes) for each management area. Overall, more than 77 per cent of the licensed take of groundwater is for irrigation and urban use comprises at least 11 per cent of the total allocated volume in the UCB. As authorisations are not required for constructing bores and taking water for stock and domestic use, actual groundwater take is not known for this unit.

**Table 3: Entitlement statistics**

GMA	# of licences	Allocated volume, ML	Allocated volume, %
Nobby Restricted Area	51	3034	5
Toowoomba City Basalts	112	6040	10
Toowoomba North Basalts	186	8576	14
Toowoomba South Basalts	564	27 987	46
Upper Hodgson Creek	121	5754	9
Warwick Basalts	228	9677	16
Total	1262	61 068	100

## Management arrangements

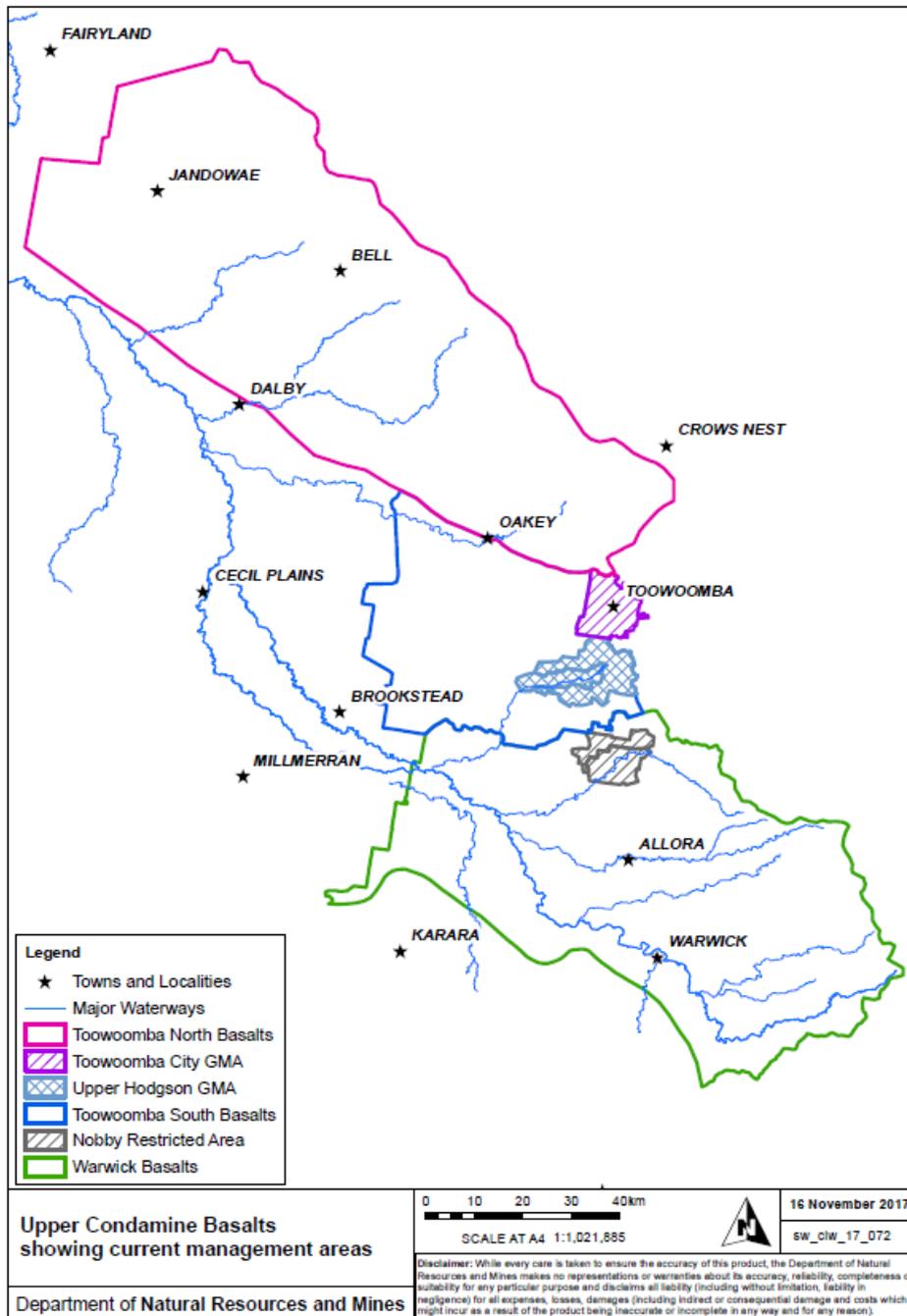
The groundwater in the UCB is currently managed under the State's *Water Act 2000*, *Water Regulation 2002* and the *Water Plan (Condamine and Balonne) 2004*. Table 4 provides a summary of the existing management arrangements in the unit.

**Table 4: Current management arrangements in the UCB (GS65)**

Management measure	Status
Water resource plan	<i>Water Plan (Condamine and Balonne) 2004</i>
Moratorium	No
Declared subartesian area	No
Groundwater management area	Yes for some areas only (Toowoomba City, Upper Hodgson Creek)
Metering take	Only in the Toowoomba City Basalts and the Upper Hodgson Creek GMAs
Water licences	Required for all purposes other than stock and domestic
Development permit for works	Required for all purposes other than S&D
Water sharing rules	Only in the Upper Hodgson Creek GMA
Announced entitlements	Only in the Upper Hodgson Creek GMA
Carry over	Only in the Upper Hodgson Creek GMA
Forward draw	Only in the Upper Hodgson Creek GMA
Seasonal water assignment	Only in the Toowoomba City Basalts and the Upper Hodgson Creek GMAs
Consultation committee	Only in UHCGMA

Management measure	Status
Limitations on take	Yes (under s29 of the Act) <sup>4</sup> – except for UHCGMA
Pumping hours restrictions	No
Monitoring	Yes

For management purposes, the UCB is divided into six management areas: Toowoomba North Basalts, Toowoomba South Basalts, Toowoomba City Basalts, Upper Hodgson Creek, Warwick Basalts and Nobby Restricted Area Basalts (Figure 2). Groundwater take in the Toowoomba City Basalts and the Upper Hodgson Creek is managed under water sharing rules and/or seasonal water assignment rules prescribed under the regulation.



<sup>4</sup> Water Act 2000 s29 provides the ability for the Chief Executive to impose restrictions on the take of water

**Figure 2: Groundwater management areas in the Upper Condamine Basalts (GS65) including the management areas.**

Groundwater monitoring in the UCB is undertaken by the department as part of the state's groundwater ambient water quality network and groundwater level network, to assist planning and management of groundwater resources<sup>5</sup>. Water quality and salinity sampling frequency varies from one to three years and water level measurement frequency varies between two and four times a year depending on location.

## **Proposed future management – new water plans in 2019**

Draft new water plans and water management protocols for the Condamine and Balonne and the Border Rivers and Moonie catchments were released in April 2018. Due for finalisation in early 2019, these new statutory planning instruments include revised management arrangements for the QMDB.

## **Overall status**

The aquifers of the UCB typically consist of an upper unconfined weathered and fractured zone and a lower fractured zone that is semi-confined and of limited extent. These zones may not be hydraulically connected. Groundwater is stored in the fractures, joints, bedding planes and cavities of the rock mass.

Groundwater is discontinuous, variable and of limited supply and thus sensitive to exploitation. Because of the complexity and lateral discontinuity of the aquifers, meaningful water table contours cannot be compiled for the UCB. These basaltic aquifers are classified as comprising local groundwater flow systems.

The hydrographic data indicate that groundwater condition in the unconfined sections of the UCB are representative of a fractured rock aquifer response to recharge, seasonality and use. In some areas the hydrographs reveal no significant head differences between bores at different elevations which suggests that areas at lower elevations are not dependant on down-gradient recharge from higher elevations in maintaining groundwater levels.

Hydrographs for the semi-confined aquifer of the Nobby Restricted Area demonstrate however sharp declines in water level (of up to 35 m within a year), which indicates that the groundwater resources in that area are at risk from over extraction.

Groundwater authorisations are currently required for all, but stock or domestic take. It is anticipated that stock and domestic use will grow in the future, particularly in and peri-urban areas, and will require continued monitoring.

Overall, major groundwater issues include the following:

- limited supplies, some scope for further development
- water level declines
- minor salinity issues emerging.

Demand for new water for industrial is high in Toowoomba and the surrounding areas. The impact on town water supply bores of nearby extractions is also an issue of concern.

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<sup>5</sup> Monitoring is focused on priority groundwater areas including the GAB, Condamine Alluvium, Border Rivers Alluvium, the St George Alluvium and basalts of the Main Range Volcanics Formation.

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# Attachment A: Land use

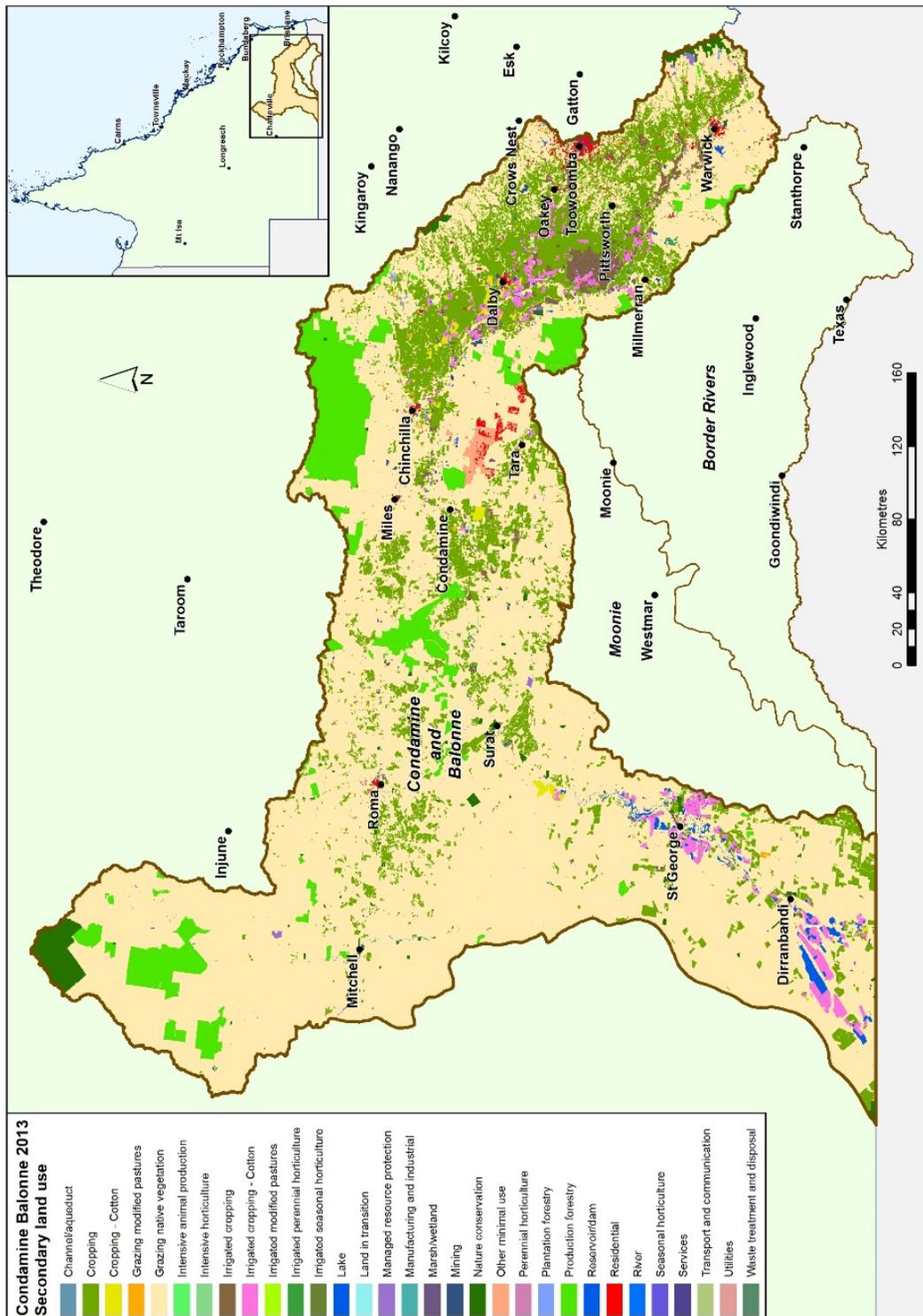


Figure A: Condamine and Balonne land use. The Upper Condamine land use is dominated by cropping and grazing, represented by the area between Chinchilla and Warwick (DSITI 2016).

