Water bores and groundwater use in the Surat and southern Bowen basins

A research update paper

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1.0	January 2024	Steven Flook

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The work presented in this document provides an update on a component of OGIA's ongoing research to support the assessment and management of resource development impacts. It is not a statutory document. Conclusions are subject to further review and changes ahead of the preparation of the next Underground Water Impact Report and other statutory reporting as needed.

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1 Introduction

1.1 Audience

This document is primarily targeted to a scientific audience. Additional detail on the methodology for estimating groundwater use is provided in a separate technical note (OGIA 2024). Fundamental understanding of geology, groundwater flow and coal seam gas (CSG) production processes is assumed. Detailed discussions of these topics are provided in OGIA (OGIA 2016, 2021, 2023).

1.2 Purpose

The groundwater resources in the Surat Cumulative Management Area (CMA) are extensively developed for a range of purposes including stock and domestic (S&D), town water supply, irrigation and stock-intensive operations. Understanding the location and volume of groundwater extracted is a critical component of groundwater conceptualisation and a key input to modelling of petroleum and gas (P&G) extraction in the Surat CMA.

Outside of major alluvial resources – such as the Condamine Alluvium – there is limited metering data, therefore reliable estimates of groundwater use are necessary. The purpose of this document is to provide details about the location of water supply bores and the current estimate of groundwater use for each formation across the Surat CMA.

1.3 Scope

Specifically, the scope of this document includes the following components:

- a synthesis of previous research to improve groundwater use estimates
- a description of the location, construction and increase in number of water supply bores in the Surat CMA
- a synthesis of the new data and changes in methodology for the estimation of groundwater use across the Surat CMA
- a synthesis of the results from the current approach to this estimation.

Due to the ongoing evolution of knowledge and the progressive nature of research, findings in this document will be periodically updated as new data and understanding becomes available.

1.4 Linkages with other research

The work presented here is a component of a broader ongoing research program to improve the understanding of the groundwater systems and impacts from P&G development in the Surat CMA. The location and estimated volume of groundwater use is a key input to a range of other research activities, such as groundwater level trend analysis.

1.5 Terminology

For the purposes of this document, the following terminology and definitions apply:

- **Groundwater use** – extraction of groundwater via authorisations, water licences and entitlements under Chapter 2 of the *Water Act 2000* (Water Act) for agricultural, irrigation, industrial, town water supply and S&D purposes. The extraction of groundwater for domestic use (household purposes and garden area <0.5 ha) and a number of stock nominally depastured on the land (excluding stock-intensive operations) are considered S&D purposes.

- **Non-associated groundwater use** – extraction of groundwater by resource tenure holders for consumptive purposes, such as camp water supply and road construction. This use requires a water licence or equivalent under Chapter 2 of the Water Act. Non-associated groundwater use volume is very small in comparison to associated extraction.
- **Associated water extraction** – incidental extraction of groundwater to ensure safe operation of resource development and to produce resources, including the depressurisation of coal measures during CSG production, dewatering of coal seams for coal mining, and conventional oil and gas development. The right for this extraction is provided through the *Petroleum and Gas (Production and Safety) Act 2004* and the *Petroleum Act 1923* (collectively referred to here as the P&G Acts) and the Mineral Resource Act 1989 (MR Act).

2 Background

2.1 Cumulative assessment

The Office of Groundwater Impact Assessment (OGIA) is responsible for the independent assessment and management of cumulative groundwater impacts from resource development within the Surat CMA. Comprehensive reporting is provided in the form of an Underground Water Impact Report (UWIR), released each three years. This includes an assessment of impacts to aquifers and water supply bores in the Surat and southern Bowen basins. The most recent UWIR was released in 2021 and approved in 2022.

2.2 Major groundwater systems

Information about water bore location, construction and source aquifers, as well as estimates of groundwater use and extraction, are key elements in the conceptualisation of the groundwater system and for the calibration of groundwater flow models. These datasets are also critical to inform the understanding of system responses to the principal stressors on the system, this understanding being a key component of impact assessment.

This document presents groundwater use and extraction across the entire Surat CMA. As it is focused on understanding impacts in and around resource development areas, the UWIR 2021's reporting of groundwater use and extraction is focused on the immediate area of interest – defined as within 15 km of resource development tenures.

There are three primary groundwater systems in the Surat CMA. The distribution of water bores and P&G wells, and estimates of use and extraction, are reported based on these groundwater systems:

- **Surat Basin:** a Jurassic to Cretaceous hydrogeological basin comprising alternating aquifers and aquitards of various geologic formations of Surat Basin sediments and their equivalents, including the Walloon Coal Measures – a CSG and coal mining resource.
- **Bowen Basin:** Permian to Triassic aquifers and aquitards of the Bowen Basin formations underlying the Surat Basin, including the Bandanna Formation – a CSG reservoir.

- **Alluvium and basalt:**
    - *Alluvium:* Quaternary unconsolidated surficial aquifers, the most prominent being the Condamine Alluvium, which overlies the Surat Basin sediments in the southeast of the Surat CMA in the central plain of the Condamine River.
    - *Basalt:* Cenozoic consolidated surficial aquifers, the most prominent being the Main Range Volcanics, which overlies the Surat Basin sediments along the Great Dividing Range (GDR) in the southeast of the Surat CMA.

2.3 Evolution of the approach

Since the initial UWIR in 2012, the approach for the identification of water supply bores and for the estimation of groundwater use has significantly evolved. Additional details are provided in subsequent chapters of this document.

The primarily repository for the location of water supply bores is the Queensland Groundwater Database (GWDB). Since 2012, more than 5,000 bore and baseline assessments have been completed by tenure holders at water supply bores considered to be potentially affected by resource development. These assessments have increased confidence in the accuracy of water supply bore locations and status in priority areas within the Surat CMA. This information is periodically updated on the GWDB as the point-of-truth dataset in Queensland.

The approach to estimation of groundwater use has also progressively evolved since the initial UWIR in 2012 (see chapter 4), for which a nominal use value was assigned for S&D bores and 100% of the entitlement volume was applied for non-S&D bores. The S&D component evolved for the UWIR 2016, with a demand-based approach developed that utilised property grazing potential to estimate stock demand. In parallel, the University of Queensland (UQ) commenced a metering project in 2016 at 34 properties to provide additional data and information on groundwater use for S&D purposes.

Since the UWIR 2021, OGIA has evolved the workflow further, integrating new datasets, information and analysis. As described in chapter 4, this includes revisions to stock rates, reductions in the daily consumption for stock, and incorporation of spatial-temporal climatic variability into the annual estimates of groundwater demand for S&D purposes.

3 Water bores

This chapter provides background context on water supply bores in the Surat CMA and includes a summary of the distribution and construction, hydraulic conditions, and the increase in construction of water bores over time.

3.1 Distribution and construction

Under the Water Act, water bores must be constructed by a licensed water bore driller in accordance with construction standards, which specify both construction materials and minimum design standards (Department of Natural Resources Mines and Energy 2017). The point of the standard is to ensure water bores are constructed to a high standard and the groundwater resource is protected.

A development permit is generally required for the construction of a water bore for any purpose in Great Artesian Basin (GAB) aquifers. The exception is one area – the Eastern Downs sub-area between Toowoomba and Dalby – where water bores are exempt if constructed for S&D purposes. In the Condamine Alluvium, water bores for purposes other than S&D require development permits under the *Planning Act 2016.*

Upon completion of a water bore, a driller's log must be submitted to Department of Regional Development, Manufacturing and Water (DRDMW), describing the bore's construction and geology intersected by the bore and including groundwater level information. DRDMW uploads this information to the GWDB.

The physical status of a water bore may change over time. The status recorded in the GWDB is not routinely updated, as there is no specific requirement for bore owners to provide updated bore status information to DRDMW. Bore status information recorded elsewhere may also be more contemporary, such as in DRDMW's Water Management System (DRDMW WMS), in baseline and bore assessments completed at potentially affected water bores in accordance with Chapter 3 of the Water Act, or in decommissioning information provided directly to OGIA by resource tenure holders.

To increase confidence in the water bore dataset, OGIA has established a hierarchical workflow that assigns a status to each bore within the Surat CMA. The workflow considers the reliability and currency of the various datasets available for the Surat CMA. A hierarchical logic is applied to the available data to determine bores that are 'Abandoned and destroyed' (AD), 'Abandoned but useable' (AU) and 'Existing' (EX). Rules are developed and applied in order of decreasing confidence.

A bore's physical status is important for the assessment of impact from resource development. Where there is ambiguity, OGIA cross-verifies this bore status information through a desktop assessment and aerial photography analysis, as well as field investigations and discussions with bore owners where necessary. As the level of effort in verifying information is prioritised based on a bore's proximity to existing and planned resource development, assumptions are sometimes made about the status of water bores in areas remote from development. These assumptions and limitations are discussed in section 4.3.2.2.

There are approximately 27,000 existing water bores in the Surat CMA, of which around 10,000 are screened in formations of the Surat Basin, just over 1,500 are in the Bowen Basin, about 270 are within basement rocks and the remainder – approximately 15,000 – are in the overlying shallow alluvium and basalt (Figure 3-1).

More than 80% of these water bores are interpreted to be screened across single formations. The remaining are interpreted to be multiple-aquifer water bores and were generally constructed prior to the introduction of contemporary water licensing and minimum construction standards, which commenced in Queensland in the late 1990s.

Figure 3-1 shows the spatial distribution of water bores and largely reflects the availability of the groundwater resources within the key regional development areas. There is extensive groundwater development in the central Surat CMA, near Roma, and in eastern areas, near Dalby and Toowoomba. In these areas, the Bowen Basin is at significant depths and the majority of groundwater use is therefore from the overlying Surat Basin or Cenozoic units (where present).

The majority of water bores accessing formations in the Bowen Basin either are located outside the Surat Basin extent or are relatively shallow – less than 200 m in depth. There are only limited areas within the Surat Basin extent – in the north, on the eastern and western flanks of the Mimosa Syncline – where the aquifers of the Bowen Basin are present at shallow depths. In other areas, productive supplies can generally be sourced from overlying Surat Basin or Cenozoic units. The majority (~85%) of water bores in the Surat CMA are constructed to depths of less than 200 m (Figure 3-2).

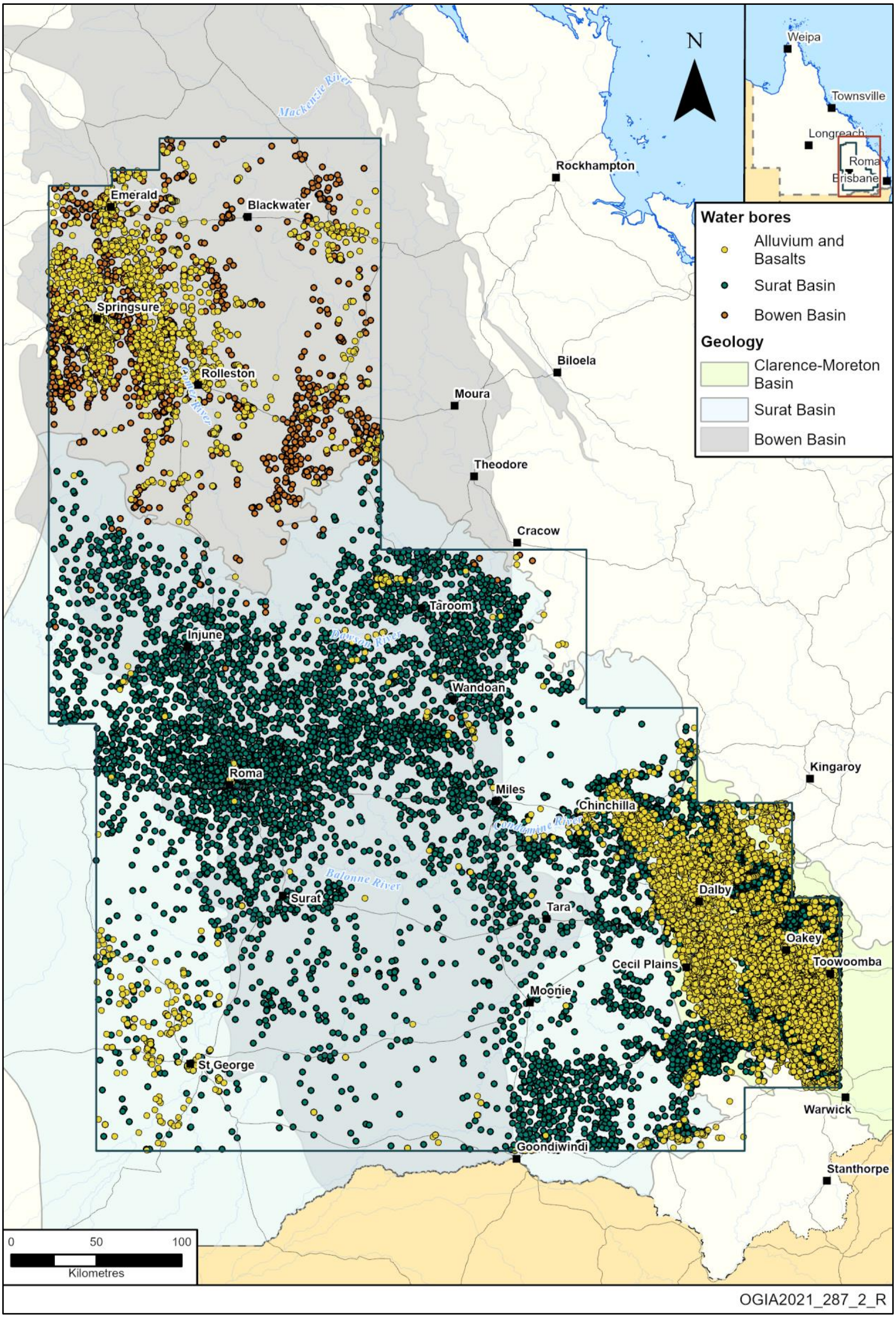

Figure 3-1: Distribution of water bores in the Surat CMA

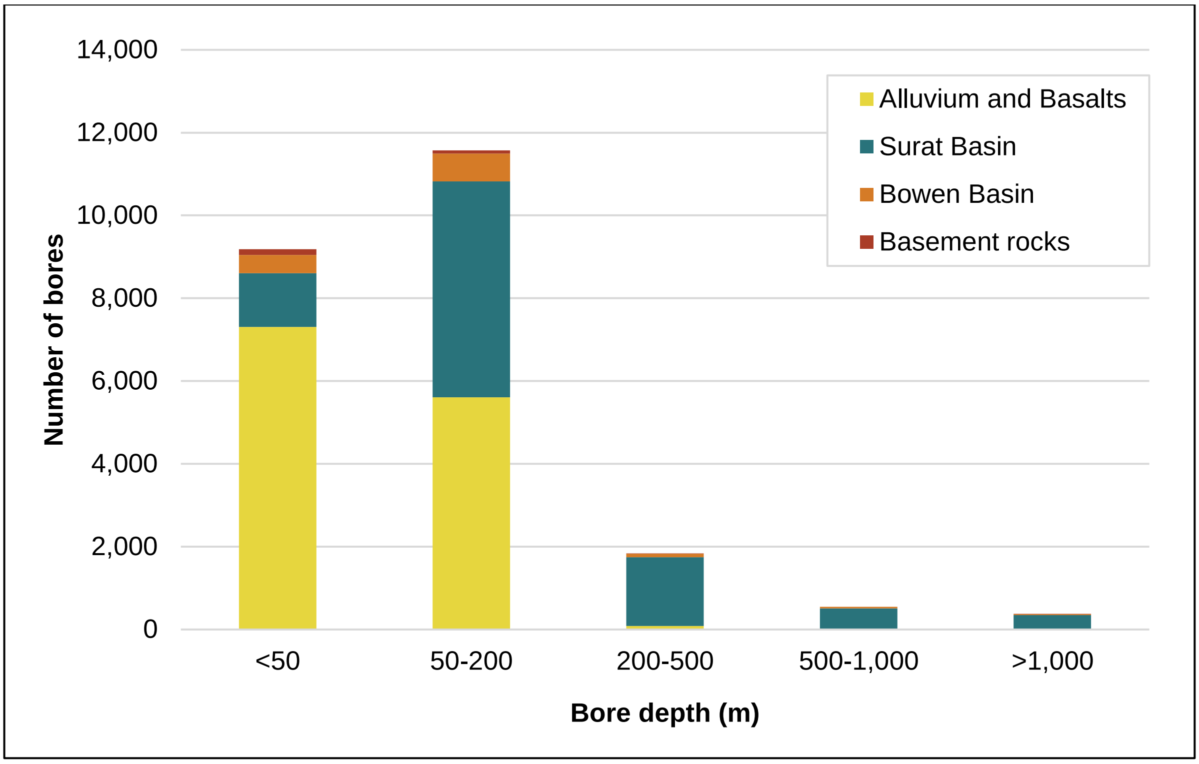

Figure 3-2: Water bores by depth and groundwater flow system

3.2 Aquifer attribution

Aquifer attribution for a water bore is the determination of the aquifer 'tapped' by the water bore, which is critical information required to support the assessment in the UWIR and to characterise groundwater use. The process involves the compilation and verification of bore location and construction details – to determine the portion of the bore that is 'screened' or open (intake depth) – and the intersection of this with the depths of the geological formations at the same location, taken from the geological model.

There are significant challenges in implementing this fundamental process: uncertainties in recorded bore locations and matching registered numbers (RNs); lack of information on bore depths and screened depths (there are about 2,200 existing water supply bores without recorded depths); and insufficient construction information. Where a water bore intersects multiple formations, there can be uncertainty about which contributing aquifer is dominant. Additional details of the methodology for assigning aquifers to water bores is available in an additional technical note (OGIA 2024).

3.3 Hydraulic conditions

Hydraulic conditions vary accross the Surat CMA. Where artesian conditions are present, groundwater will flow naturally to the surface. Under sub-artesian conditions, a pump is necessary to enable water to reach the surface. The GWDB is the primary dataset for information about hydraulic conditions. Table 3-1 provides a summary of pressure conditions of existing water bores by groundwater system.

The majority (85%) of water bores in the Surat and Bowen basins are sub-artesian. About 4% have an unknown status; the remainder (11%) are recorded as artesian – of which approximately 2% are recorded as 'uncontrolled flow', 76% as 'controlled flow', 15% as 'ceased to flow', 6% as 'condition unknown' and <0.1% as 'seasonal flow'.

Table 3-1: Existing number of water bores and hydraulic conditions

Condition		Groundwater system: Alluvium & Basalts	Surat Basin	Bowen Basin	Basement rocks	Total
Artesian	Condition unknown (AB)	1	79	2	-	82
	Ceased to flow (AC)	1	193	5	-	199
	Controlled flow (AF)	6	857	116	1	980
	Seasonal flow (AS)	-	1	-	-	1
	Uncontrolled flow (AU)	2	20	7	-	29
Sub-artesian (SF)		14,431	8,618	1,407	267	24,723
Unknown status		345	384	60	5	794
Total		**14,786**	**10,152**	**1,597**	**273**	**26,808**

As shown in Figure 3-3, water bores recorded as artesian are distributed west of Chinchilla and in areas associated with lower topographic relief, in contrast to higher areas where formations outcrop and receive recharge. As a result, there are few artesian water bores in areas surrounding the GDR, which dissects the CMA north of Roma and Chinchilla.

A significant number of artesian water bores are north of the GDR, along the Dawson River. This is due to the dissected landscape resulting in shallow confinement of artesian aquifers, as well as the northerly groundwater flow directions in both the Precipice and Hutton sandstones. The majority of artesian water bores in the areas south and west of Roma are associated with the Gubberamunda Sandstone.

The artesian water bores in the north, within the Bowen Basin, are associated with the Clematis Sandstone. In this area, the formation is recharged on the western margin within the Expedition Range National Park. Groundwater flows east and is confined by the overlying Moolayember Formation. There are limited Cenozoic aquifers in this area and water bores are therefore often constructed in the deeper, confined and artesian Clematis Sandstone aquifer of the Bowen Basin.

Figure 3-4 shows the hydraulic conditions of water bores and their depths. The majority of bores that are very shallow (<50 m) extract from the unconfined Cenozoic basalts and alluvium, including the Condamine Alluvium. Increased confinement with depth is observed – at depths of more than 200 m, most bores are screened in the Surat Basin under confined aquifer conditions.

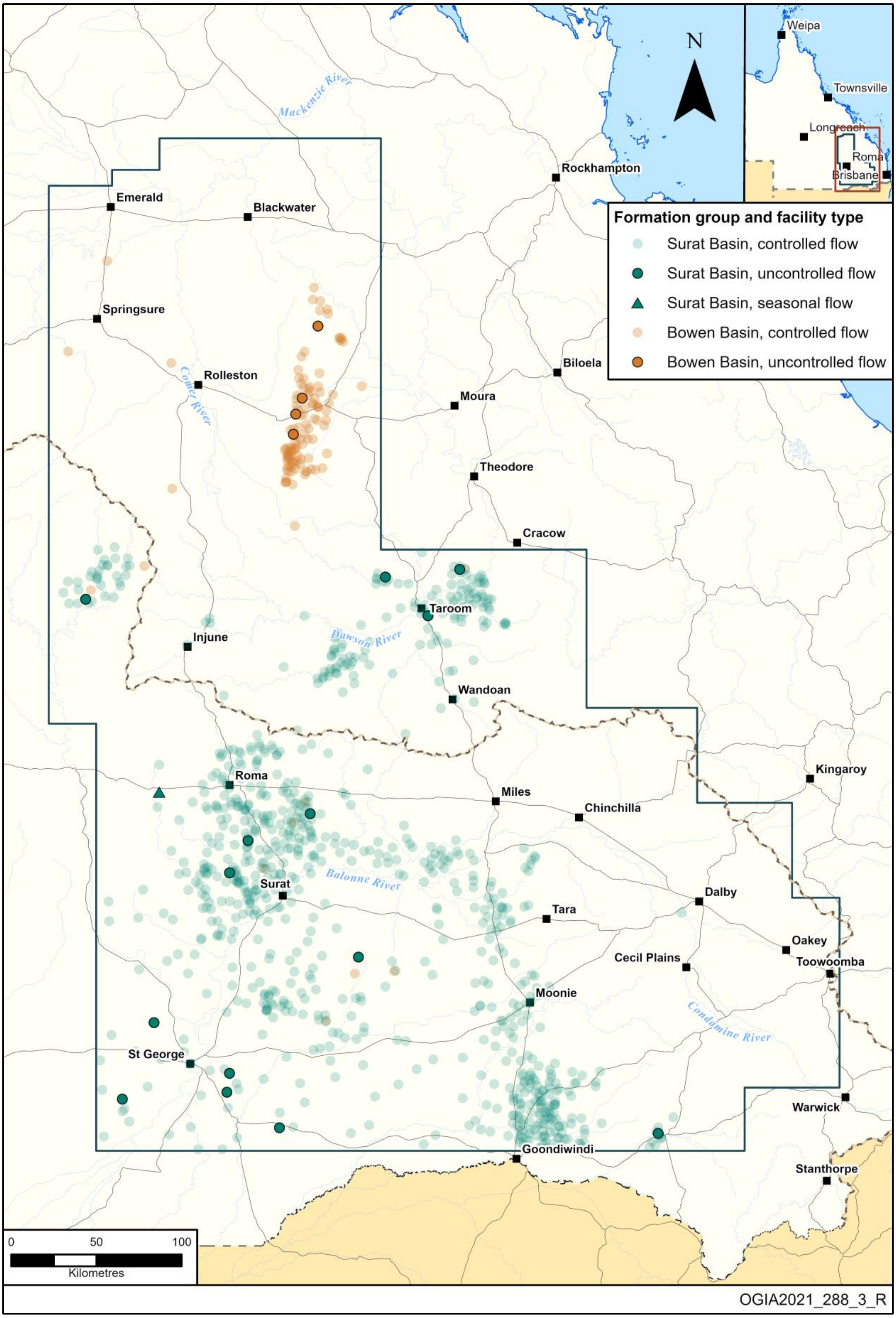

Figure 3-3: Distribution of artesian water bores in the Surat CMA

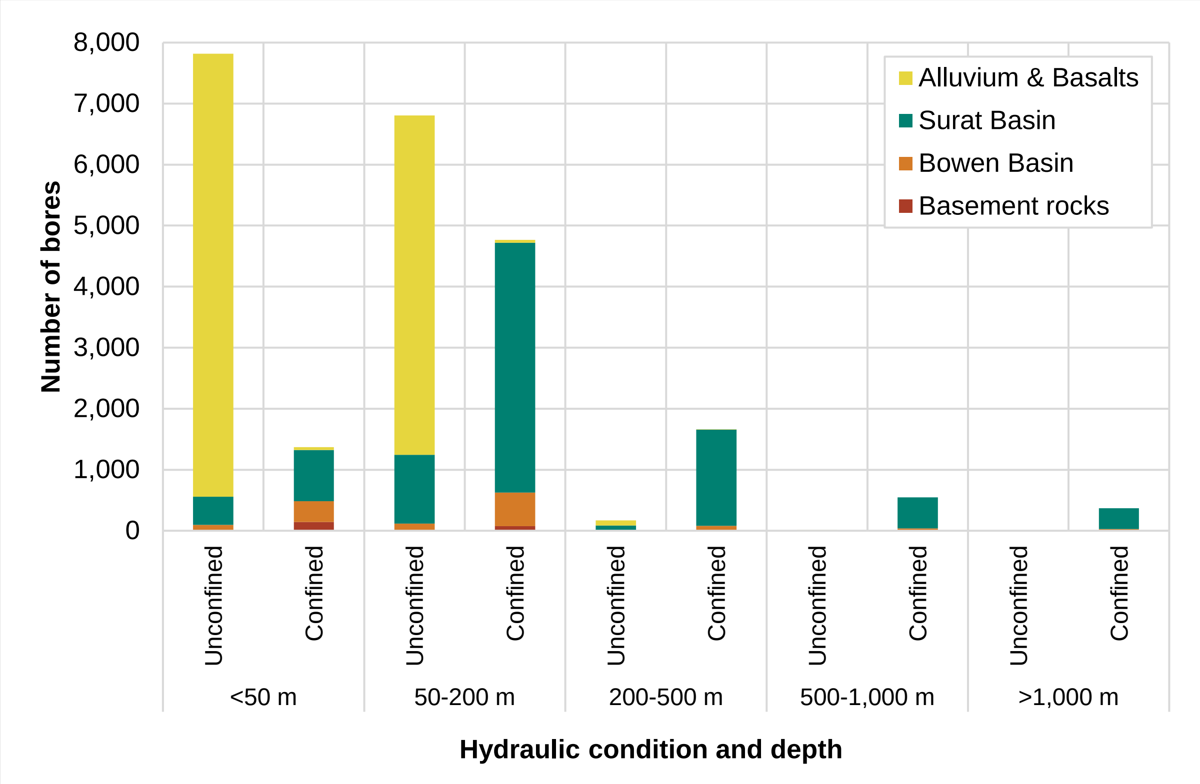

Figure 3-4: Number of water bores, depth and aquifer hydraulic condition

3.4 Purposes of groundwater use

Aquifers of the Surat Basin are significantly developed for groundwater use. The Bowen Basin has much less groundwater development compared to the Surat Basin aquifers. The largest groundwater extraction in the Bowen Basin is from the Clematis Group and its equivalents (OGIA 2016).

Alluvial groundwater systems in the Surat CMA are associated with several river systems overlying the regional groundwater flow systems. The Condamine Alluvium is the most significant of these and is extensively developed for irrigation, domestic and town water supply. In the east of the Surat CMA, basalts of the Main Range Volcanics overlie the Walloon Coal Measures and Hutton Sandstone and are in turn overlain by alluvium of the tributaries of the Condamine River. Basalts of the Main Range Volcanics contain significant aquifers used for irrigation, S&D and town water supply purposes.

Figure 3-5 shows water bore depths and purposes. Approximately 85% of water bores are constructed for S&D purposes, where the primary objective is typically to obtain an adequate supply for domestic use and grazing demands. Bores with authorisations for non-S&D purposes, such as irrigation or town water supply, generally have larger volume extraction entitlements. This often necessitates the construction of deeper water bores to secure supply and avoid interference with other groundwater users or groundwater-dependent ecosystems.

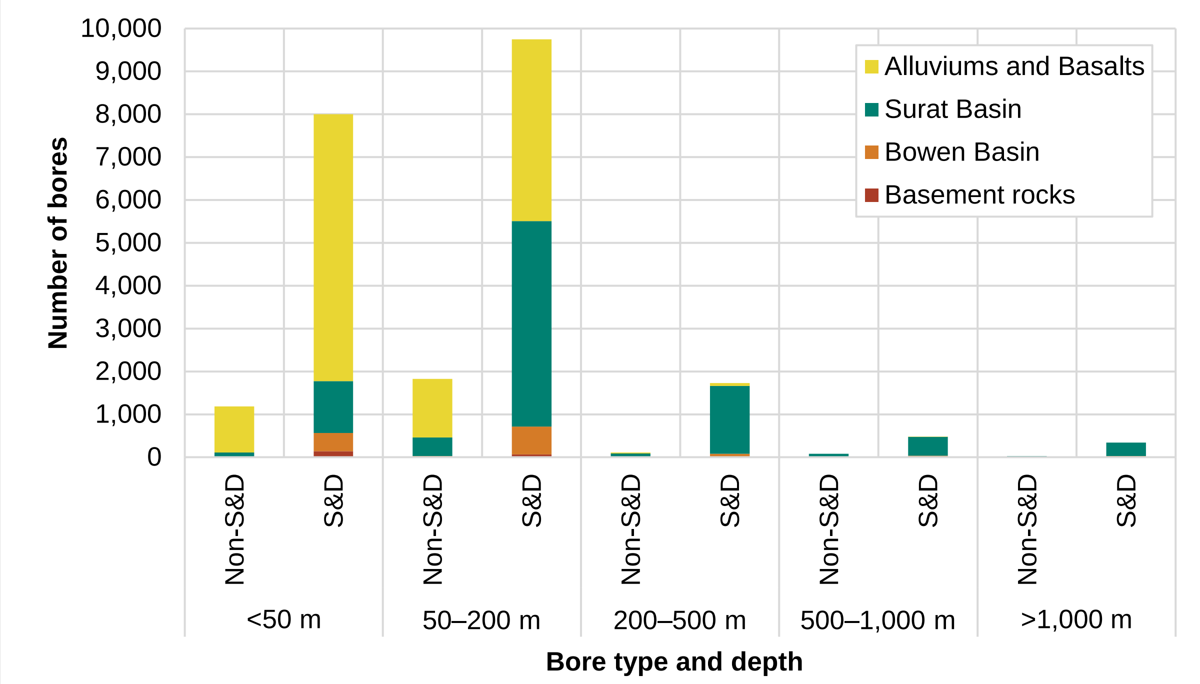

Figure 3-5: Number of water bores by groundwater use purpose and bore depth

3.5 Water bore development over time

The construction of water bores in the Surat CMA commenced in the late 1800s. The majority of water bores were initially constructed in the shallower alluvium and basalt, likely reflecting the accessibility of shallow supplies and early construction techniques. Between the 1930s and 1950s, construction grew steadily in the alluvium and basalt units and the Surat Basin, at between 40 and 60 bores per year. From the 1960s onwards, there was a notable step up in groundwater development. In the alluvium and basalt, construction increased to around 190 bores per year, reflecting a period of rapid development in the Condamine Alluvium on the eastern Darling Downs.

Across the Surat Basin, observed construction rates post-1960 are around 170 bores per year. Development of groundwater resources in the Bowen Basin commenced in the 1960s and has been increasing on a comparatively minor scale. Figure 3-6 shows the growth in water bores from 1900 to 2022 across the three major groundwater flow systems.

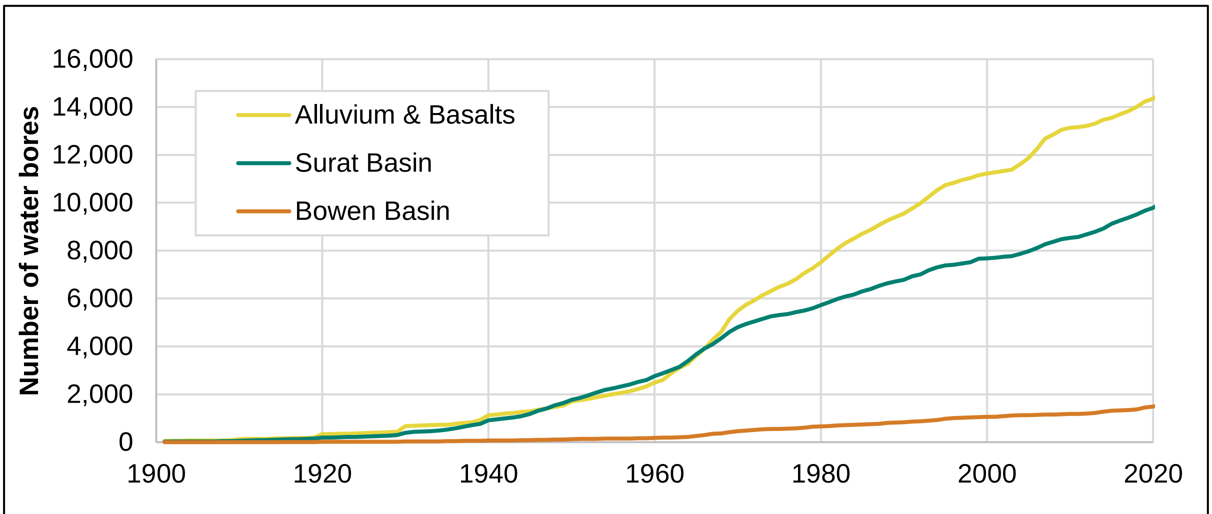

Figure 3-6: Growth of water bores in the Surat CMA

4 Groundwater use

This chapter provides a summary of authorisations to take, measure and report groundwater use, followed by a discussion on the evolution of OGIA's approach to estimating groundwater use. An overview of the current estimation methodology is provided, including recent research and subsequent updates, as well as a summary of assumptions and limitations. Further details of the current methodology and its implementation in a Python-based workflow is provided a separate technical note (OGIA 2024).

4.1 Authority to take and metering

DRDMW administers the licensing provisions of the Water Act. Information about water licences, authorised volumetric limits and uses is recorded in the DRDMW WMS. Information about water bores is recorded in the GWDB, however it may not contain records of all water bores that take water under statutory authorisations. Historically, some bore records may not have been submitted to DRDMW.

Within the Surat CMA, groundwater use for town water supply, irrigation, agriculture, industrial and stock-intensive purposes is licensed under volumetric entitlement. In some cases – such as in the Condamine Alluvium – water bores for these purposes are also metered and the volume of groundwater use is therefore known with a reasonable level of accuracy. Where metering is unavailable, there is uncertainty with regard to the timing and volume of groundwater use.

A volumetric entitlement is not required for S&D purposes. There is limited metering for the majority of non-S&D entitlements in the Surat and Bowen basins. In some cases, water bores have been accessed by P&G tenure holders for non-associated groundwater use purposes – such as construction or camp water supply. Tenure holders are required to report the volumes of groundwater extracted. In these instances, the reported volumes replace the estimated volumes (see chapter 4).

Table 4-1 provides a summary of water bores and groundwater use for metered and unmetered bores in the alluvium and basalts and the Surat and southern Bowen basins, excluding the basement rocks.

Table 4-1: Summary of metered and unmetered groundwater use in the Surat CMA (ML/year)

Groundwater system		Water use type					
		Metered (DRDMW WMS)		Unmetered (volumetric entitlement)		Unmetered (S&D)	
		Bores	Volume	Bores	Volume	Bores	Volume
Alluvium & Basalts	Condamine Alluvium	405	32,766	266	4,943	2,437	1,243
	Other	301	6,332	1,725	57,004	9,652	7,144
Surat Basin		44	797	768	31,710	9,340	16,401
Bowen Basin		2	43	39	1,814	1,556	3,029
Total		**752**	**39,938**	**2,798**	**95,471**	**22,985**	**27,817**

4.2 Estimating groundwater use

OGIA has developed a methodology to estimate annual groundwater consumption from 1900 to present within the Surat CMA. The resulting dataset is used to: support the assessment of cumulative groundwater impacts from P&G activities; provide an estimate of groundwater use for model calibration; and support the analysis of trends in monitoring data.

Requirements vary for the measurement and reporting of groundwater use in the Surat CMA. S&D groundwater use does not require metering; for other purposes, there is limited (less than 1%) metering outside of the Condamine Alluvium and Main Range Volcanics.

In the absence of metering data, indirect methods are required to estimate groundwater use. Metering data was largely unavailable when OGIA prepared the first UWIR in 2012. A method for estimating groundwater use in the Surat CMA was initially developed by OGIA in 2012 and has since been refined based on additional data and information.

Some sporadic metered data has gradually become available, which has helped OGIA to reconcile groundwater use estimates and build uncertainty bounds around the estimates in varying climatic conditions. Since the UWIR 2021 was published, additional research has led to further refinements of the methodology, including:

- data and analysis from a collaborative bore metering program between UQ and OGIA
- development of a spatiotemporal rainfall dataset, which supports the identification of below-average (dry), average and above-average (wet) rainfall years for all properties in the Surat CMA.

The following sections summarise the evolution of the approach to estimating unmetered groundwater use, a description of the post-UWIR 2021 research and an overview of the current methodology, which incorporates the latest understanding.

4.2.1 Evolution of the approach

This section provides an overview of the previous methods and approaches, used by OGIA and others, to estimate groundwater use in the Surat CMA.

4.2.1.1 Prior to 2011

Approaches to estimate groundwater use prior to 2011 are summarised in (Lowe et al. 2009) and (Parsons Brinckerhoff 2011), which discuss existing methods across Australia and internationally. The approaches can be categorised into three groups:

- **direct measurement** – water extraction metered or estimated through landholder surveys
- **demand assessment** – estimates based on the volumetric requirements for S&D, area-based irrigation and town water supply purposes
- **supply assessment** – estimates based on available water supplies – groundwater and farm dams (Lowe et al. 2009), noting:
    - licensed take cannot exceed the licensed volume
    - estimated water use from farm dams is based on the number of dams and the average proportion of the dam volume used.

Approaches to estimating S&D and entitlement-based groundwater use in Queensland have evolved in recent years. CSIRO and SKM (2010) estimated S&D groundwater use in the Queensland portion of the Murray-Darling Basin based on the number of S&D bores and assigning 1 ML/year to each bore (SKM, CSIRO & BRS 2010). The then Department of Environment and Resource Management also assessed the number of S&D bores and used an expert elicitation approach to determine and assign an average volume of groundwater use for each water bore (Parsons Brinckerhoff 2011).

Parsons Brinckerhoff (2011) discusses a multifaceted approach to estimate groundwater use through application of several techniques using data from a small number of landholder surveys. This estimation of S&D groundwater use was subjective, dependent on the judgement of the surveyed landholders. Indicating a large variation in estimates of groundwater use, the limited survey results were averaged and multiplied by the estimated number of bores, contributing to significant uncertainty in the resultant estimates of groundwater use (Parsons Brinckerhoff 2011).

4.2.1.2 UWIR 2012 and 2016

For the initial UWIR in 2012, OGIA (then part of the Queensland Water Commission) applied the following demand-based approach to estimating groundwater use (Queensland Water Commission 2012):

- For domestic bores, groundwater use estimates were 1 ML/year in urban areas, 2 ML/year in peri-urban areas and 3–5 ML/year for S&D bores.
- The range in estimates considered the availability of reticulated supply at the location, stocking rates, estimated requirements for grazing and cropping water uses, surface water availability, rainfall, temperature, aquifer yield and quality.
- Artesian S&D bore groundwater use was estimated based on the latest available bore discharge rates or each constructed bore's designed flow rate.
- Bores with volumetric entitlements were assigned 100% of the entitlement volume, distributed evenly between linked water bores.

The estimates of groundwater use in the UWIR 2012 were for each existing bore for an average rainfall year. For the UWIR 2016, while the same approach was applied to bores with volumetric entitlements, a demand-based approach was developed to estimate S&D groundwater use. The method provided 'high', 'medium' and 'low' grazing demand scenarios based on property scale grazing potential, enabling the estimation of quantities of livestock for individual properties (OGIA 2016). These estimates resulted in a significant decrease in estimated groundwater use from S&D bores. As reported in subsequent sections, this method has further evolved to inform the UWIR 2021.

4.2.1.3 University of Queensland

In 2016, UQ commenced a project to estimate long-term groundwater use within the extent of OGIA's numerical groundwater model domain. A statistical model to estimate groundwater use was developed by incorporating metered volumes, temperature and rainfall data, and property-level information from farm surveys, such as property size, number of livestock and bores, and availability of surface water.

The method for volumetric entitlement estimates used similar spatial information as well as the volumetric entitlement. The distribution of groundwater use between bores within each property was estimated based on average empirical distributions of groundwater use between active bores. The groundwater use estimates from the UQ study (212,410 ML/year) were similar to those from the UWIR 2016 (203,092 ML/year).

In exploring statistical methods for estimating groundwater use, UQ has also been collecting additional field data through the installation of ultrasonic flow meters on around 57 bores in the Surat Basin. Since 2020, OGIA has partnered with UQ on this project to integrate knowledge, contextual information and data, in order to improve the estimates of S&D groundwater use in the Surat CMA.

4.2.1.4 Klohn Crippen Berger

OGIA's 2016 methodology was applied by Klohn Crippen Berger (2016) more broadly across the Eromanga and Carpentaria basins to support a review of the Queensland *Water Resource (Great Artesian Basin) Plan 2006*. An important enhancement to the method for these areas was the inclusion of and accounting for uncontrolled (flowing) bores and drains.

4.2.2 Post-UWIR 2021 research

4.2.2.1 UQ-OGIA collaborative metering project

As discussed in section 4.2.1.3, UQ commenced a research project in 2016 to develop a method for estimating water extraction in and around the Surat CMA, using metered volumes. This work produced a new dataset and information on groundwater extraction for S&D purposes (Keir, Bulovic & Mcintyre 2019). In 2020, OGIA funded a three-year extension of the project to gain a better understanding of S&D groundwater use and to improve the accuracy of the current estimates.

Meters were installed on a total of 48 water bores on 34 properties. Data collected from the meters was processed to produce annual volumes. Interview data was also obtained from landholders, which included answers to questions around surface water availability, livestock numbers, bore usage and de-stocking rates (Rochford et al. 2022, 2023).

Over the course of the project, the metered volumes and interview data were analysed and compared with OGIA's estimates. Based on the data and analysis, the following refinements have been made to OGIA's approach to estimating S&D use:

- application of a stocking rate of 0.25 to the total grazing area on each property; in the previous approach, grazing areas were divided into low, medium and high grazing potential areas, with stocking rates of 0.05, 0.15 and 0.3 respectively.
- a reduction in the daily consumption per animal from 60 to 40 L/day
- a spatiotemporal climate analysis (see section 4.2.2.2) defining below (dry), average and above-average (wet) rainfall years and assigning appropriate estimates based on year type.

The above refinements have been implemented since the UWIR 2021. The resulting annual groundwater use estimates show an improved alignment with annual metered volumes from the project.

4.2.2.2 Climate analysis

Prior to the recent analysis (post-UWIR2021) water supply bores were assigned three annual groundwater use estimates – high, medium and low to account for below-average (dry), average and above-average (wet) rainfall years. This enabled a comparison of the differences in estimated groundwater use during different climatic periods and likely changes in demand. The average groundwater use estimate was used for OGIA's conceptualisation and modelling activities in the UWIR 2021.

Recent analysis of metered use data and rainfall indicated that there is an opportunity to incorporate a spatiotemporal climate component into the current methodology. To support further refinement, annual rainfall trends throughout the Surat CMA were analysed from gridded data obtained from SILO (www.longpaddock.qld.gov.au/silo). Climatic zones were defined for each grid cell based on annual average rainfall, using the criteria defined in Table 4-2.

Table 4-2: Criteria for assigning climate zones to grid cells

Average annual rainfall (mm)	Climate zone
Less than 500	One
Between 500 and 550	Two
Between 550 and 600	Three
Between 600 and 700	Four
Greater than 700	Five

Figure 4-1 shows the spatial distribution of defined climate zones. As expected, higher annual rainfall is observed in the northern and eastern areas of the Surat CMA. Within each climate zone, the annual rainfall is compared with the long-term average. Where annual rainfall is within 30% of the long-term average, the year is classified as an average rainfall year. Where the annual rainfall is more than 30% below or above the long-term average, it is classified as a below-average (dry) or above-average (wet) rainfall year respectively. This 30% deviation value was derived from analysis of metering data and rainfall trends. When years were classified as wet, average or dry using a 30% threshold, this provided the best match to the increasing and decreasing trends observed in annual metered volumes. These annual classifications (wet, average, dry) are assigned to each property within the Surat CMA, enabling the appropriate groundwater use estimate to be applied at each annual timestep.

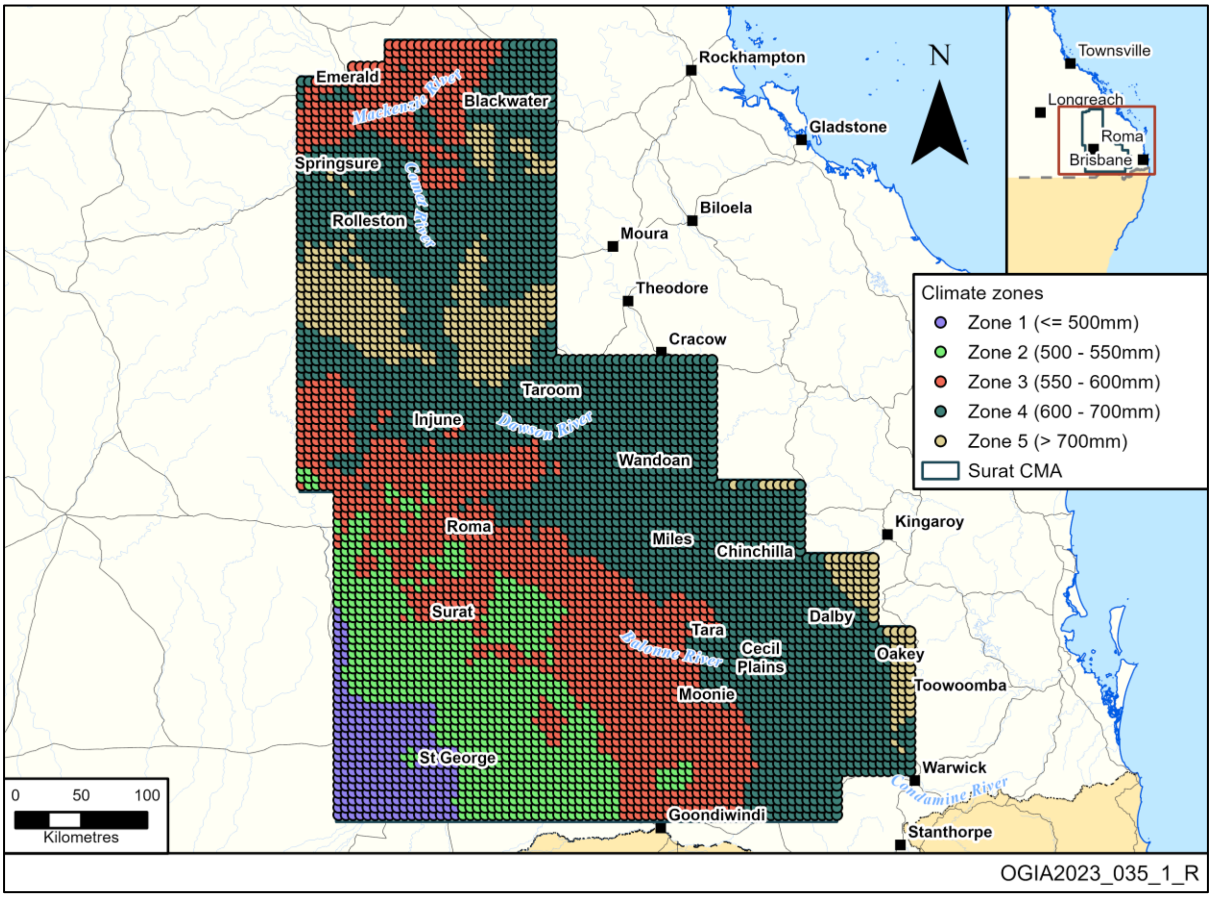

Figure 4-1: Climate zones defined from average annual rainfall

4.3 Current methodology

4.3.1 Methodology overview

The methodology applied to estimate groundwater use varies primarily based on the purpose of take, which largely reflects the availability of data for different industries. Importantly, the resulting estimates include upper and lower bounds – scenarios for groundwater use in below-average, average (dry) and above-average (wet) rainfall years. A summary of the methodology is provided in Figure 4-2.

For S&D groundwater use, the underlying principle of the method is that the deficit between the water demand and availability of surface water supplies is met by groundwater. Demand is estimated based on grazing potential (stock-carrying capacity), property size and climatic variability.

For non-S&D groundwater use, metered data is used where available (predominantly in the Condamine Alluvium). Where metered data is not available – the majority of the GAB – groundwater use is estimated by applying a percentage – termed an ‘uptake coefficient’ – to the licensed annual volumetric limit (entitlement volume) for specific purposes. Where multiple bores are linked to a single entitlement, the total entitlement volume is distributed based on the relative yield of each bore – i.e. a bore with a larger yield is assumed to use a higher percentage of the entitlement.

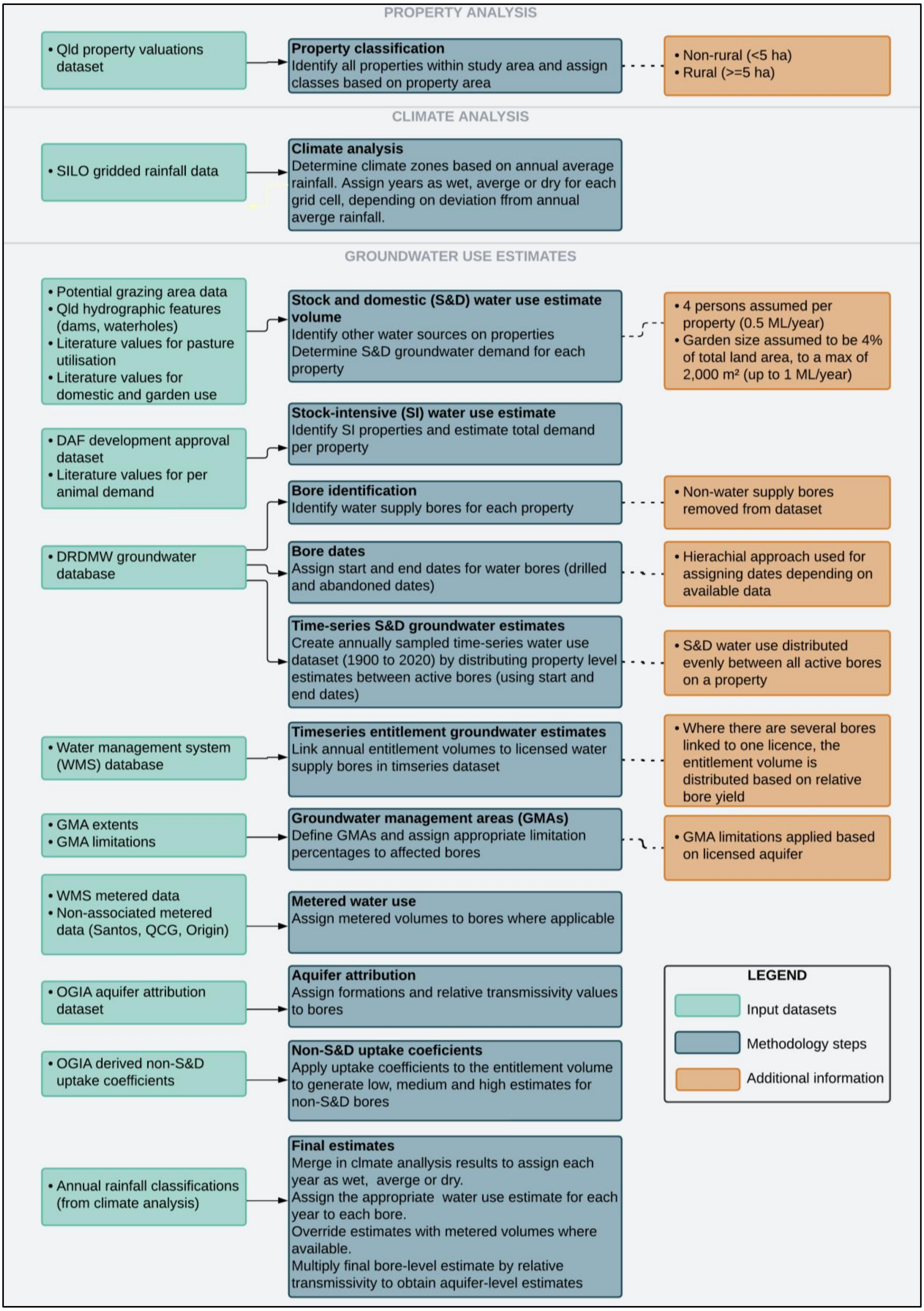

Figure 4-2: Summary of the methodology to estimate groundwater use

Limitations apply to the nominated volumes of water authorisations within certain zones of the Condamine Alluvium, basalts and some GAB aquifers – termed 'groundwater management areas'

(GMA). The extents and limitation percentages of GMAs have changed over time. A bore within a GMA and licensed to source water from the aquifer to which the GMA limitation applies has the limitation percentage applied to the entitlement volume. The limitation percentages range from 50% to 95% and are only applicable to non-S&D bores.

For bores that are used for stock-intensive activities – including cattle feedlots, piggeries and poultry enterprises – an additional demand-based estimate is calculated. The stock-carrying capacity of the stock-intensive operation is known based on the development approval and a likely range of water use per animal is assigned based on industry standards and literature.

Each bore is assigned a low, medium and high groundwater use estimate for each year, to account for wet, average and dry rainfall years respectively. For S&D bores, these values are determined by adjusting the surface water availability – average dam fullness is assumed in wet and average rainfall years, while dams are assumed to be empty in dry years. For non-S&D (entitlement) bores, the uptake coefficient is adjusted and differs according to bore purpose – for example, for town water supply, a value of 0.7, 0.8 and 0.9 is applied for the above-average (wet), average and below-average (dry) rainfall years respectively.

The relevant estimate is then applied for each bore at each annual timestep, according to the climate zone in which the bore lies and the assigned year type – wet, average or dry (see section 4.2.2.2 for details on climate zones and year types).

4.3.2 Assumptions

The methodology to estimate groundwater use incorporates several assumptions, contributing to uncertainty in the results. The key assumptions and their interpreted influences on results are discussed in this section.

4.3.2.1 Distribution of estimated use on properties with multiple water bores

For properties with more than one active water bore, property-scale S&D demand is distributed equally to all active bores on the property. For unmetered bores linked to a non-S&D entitlement – such as irrigation – the groundwater use estimate is distributed based on the relative yield of all bores linked to the entitlement. This assumes the higher yielding bores extract a larger volume of groundwater than lower yielding bores. In the absence of metering data or details of which bores are actually in use, the above assumptions may incorrectly distribute demand.

To assess the significance of this approach, the S&D groundwater use dataset was analysed. Around 60% of properties with S&D water bores have one water bore each and distribution therefore does not affect the use estimates of bores or aquifers at these properties. There are more than 4,000 properties with two or more S&D bores. For around 60% (2,381) of these multiple-bore properties, all bores on each property are screened across the same aquifer and equal distribution therefore does not reduce accuracy in aquifer use totals. For the remaining (1,776) properties, where multiple bores are screened across various aquifers, the majority (1,762) have <50 ML/year groundwater use. Of the 13 properties that have >50 ML/year groundwater use, only 8 have more than 100 ML/year.

In summary, for S&D purposes, the distribution of property-scale demand is unlikely to have a significant influence on the accuracy of groundwater use estimates at an aquifer level.

4.3.2.2 Number and status of water bores

OGIA uses the GWDB to identify water bores; it is assumed that all water bores with 'Existing' status are active. It is unlikely that the actual number of existing water bores is an exact match to the GWDB. It is also unlikely that all bores on all properties are in use. Using the demand-based approach means that while variances in the number and status of bores would not affect the property-scale groundwater use estimates, such variances would influence the individual bore estimates, due to the distribution of demand to all active bores on a property.

Previous survey results (Parsons Brinckerhoff 2011) indicated 0–20% variance between the numbers of water bores on surveyed properties and the numbers recorded in the GWDB. This is also generally consistent with the number of unregistered water bores – around 10% – identified during baseline assessments. Reliability of data is greater for water bores that require water authorisations (non-S&D) than for S&D water bores, for which it is common that the only recorded information is from the time of drilling. It is likely that any incorrect bore counts and/or status would be for S&D bores, where groundwater use is generally small. Taking this into account, as well as the above-mentioned survey results, it is likely that incorrectly recorded bore counts and status would have a minimal impact on groundwater use estimates at an aquifer level.

4.3.2.3 Climate and availability of other water sources

The methodology assumes that the availability of surface water in dams, creeks and rivers in average and above-average rainfall years will reduce the demand for groundwater for livestock purposes during those years. Dams larger than 1,875 m^2 are identified from the Queensland Dam Waterbody Database, which uses LandSat imagery to classify waterbodies in a time series since 1986. Non-dam waterbodies are mapped from other datasets and all waterbodies are assumed to have an average depth of 1.5 m (a conservative approach, generally average depth of a farm dam is around 2-3 m, but assuming 50% loss in surface evaporation). Based on this data, the methodology applies the following assumptions:

- Surface water is unavailable to livestock in below-average rainfall years (dry).
- A percentage is applied, derived from the number of years during which waterbodies contain water, to determine the surface water available to livestock in average rainfall years.
- Waterbodies are at full capacity and available for livestock in above-average rainfall years.

Based on the above assumptions, the groundwater demand is reduced in above-average and average rainfall years on properties where waterbodies are identified. Uncertainties in this approach include limited knowledge about the quality of surface water, accessibility of water sources, volume of water sources and localised climate conditions. In most cases, the average-rainfall-year estimate is likely to provide the most reliable results and hence has been used for the majority of data analysis.

4.3.2.4 Non-S&D uptake coefficients

The available metering data from non-S&D bores indicates that groundwater use is generally less than the nominal entitlement volumes, particularly in average and wet rainfall years. To generate an estimate of groundwater use for non-S&D purposes, climate-dependent coefficients are applied to each bore's assigned nominal entitlement volume – or the share thereof in instances where multiple bores are linked to an entitlement.

The uptake coefficients are derived by comparing the total annual metered volume for a bore to the nominal volume on the entitlement (or share thereof) over multiple years. The results are analysed by purpose – such as town water supply and irrigation – with each year classified as having above-average (wet), average or below-average rainfall (dry). For each purpose, the mean ratio of entitlement to metered volume is calculated in above-average (wet), average and below-average (dry) rainfall years. These ratios – 'uptake coefficients' – are then incorporated into the workflow to estimate non-S&D groundwater use where metered data is unavailable.

Due to the lack of available metering data for non-S&D bores, there is significant uncertainty in determining the uptake coefficients. As more metering data becomes available, the uptake coefficients will be further refined.

4.4 Results

The methodology described in section 4.3.1 has been applied to generate a range of estimates for groundwater use across the Surat CMA. Results are compiled for each water bore and for the formations each bore is interpreted to be tapping.

As previously noted, the estimation approach incorporates a spatiotemporal climate analysis to account for varying climatic conditions. For each bore, a 'low', 'medium' or 'high' use estimate is produced based on the bore location (climate zone) and the corresponding rainfall classification for the year.

A hierarchical approach is used to assign final estimates based on the available data. For example, where metered data is available (predominantly non-S&D bores in the Condamine Alluvium), the metered volume overrides the estimated volume.

In the absence of metered data and knowledge of how individual groundwater users access groundwater, the range of estimates provides a degree of uncertainty in unmetered groundwater use.

Results are represented in terms of the primary purpose of groundwater use. The Department of regional development manufacturing and water (DRMDW) water management system (WMS) provides details of the purposes of bores associated with water entitlements. DRDMW WMS data has been translated by OGIA into the following categories for this document and includes the following:

- **town water supply** – includes supplies for schools and similar institutions; reticulated domestic supply systems operated by groups of individuals; and some commercial and industrial use where the water is delivered through town water reticulation systems
- **irrigation** – includes private, commercial and industrial irrigation
- **industrial** – includes industrial, commercial and mining use
- **stock-intensive** – includes cattle, pig and chicken feedlot facilities
- **other agriculture** – includes aquaculture, dairy farming and combinations of these uses with stock watering and domestic supply.

The above water supply use purposes fall under the general category of non-S&D bores. Water bores located on rural properties and not attached to entitlements are assumed to be used for S&D purposes. Extraction volumes for bores accessed by P&G tenure holders for non-associated purposes (such as construction) are provided by the tenure holders. In these cases, the reported volumes replace the estimated volumes in OGIA's methodology.

4.4.1 Current groundwater use

Table 4-3 provides a summary of the annual estimated groundwater use for 2022 in the Surat CMA, including bores used for non-associated extraction by P&G tenure holders.

There are 26,808 existing water bores in the Surat CMA, of which 87% (23,407) are for S&D purposes. Estimated groundwater use for 2022 is 163,765 ML, which includes 32,406 ML (20%) for S&D purposes. Approximately 30% of groundwater use in the Surat CMA is from the Surat Basin, with a further 67% from the alluvium and basalt – including the Condamine Alluvium and Main Range Volcanics. The remaining 3% of extraction volume is from the Bowen Basin and basement rocks.

With an estimated groundwater use of 16,797 ML for 2022, the Hutton Sandstone is the most heavily used formation in the Surat Basin, followed by the Precipice and Gubberamunda sandstones, with 8,165 ML and 6,855 ML respectively.

Compared to the other groundwater systems, groundwater use in the Bowen Basin is relatively minor, which generally reflects the accessibility of shallower aquifers in the more populated areas of the Surat CMA.

Irrigation is the largest sectoral user, with the vast majority of extraction coming from the alluvium and basalts. Agricultural use is primarily from the shallow non-GAB formations and is the second largest overall groundwater use purpose. Town water supply and industrial groundwater use are slightly higher in the GAB than in alluvium and basalts, while S&D and stock-intensive groundwater use is consistent across both of these groundwater systems.

S&D is the largest groundwater use purpose across the GAB formations, although the combined non-S&D use is just over 60% of all use in the GAB.

Table 4-3: Summary of annual groundwater use in the Surat CMA (2022)

Formation	Groundwater use (ML)			Number of bores		
	S&D	Non-S&D	TOTAL	S&D	Non-S&D	TOTAL
Cenozoic Sediments	755	6,599	7,354	477	21	498
Condamine Alluvium	1,536	37,416	38,952	2,450	658	3,108
Main Range Volcanics	3,770	37,725	41,496	6,332	1,553	7,885
Other Alluvium	5,071	12,688	17,759	1,850	288	2,138
Other Basalts	1,182	2,688	3,870	1,110	47	1,157
Alluvium & Basalts subtotal	*12,315*	*97,117*	*109,431*	*12,219*	*2,567*	*14,786*
Upper Cretaceous formations	550	838	1,388	189	8	197
Wallumbilla Formation	352	13	366	132	2	134
Bungil Formation	656	29	685	239	2	241
Mooga Sandstone	2,326	669	2,995	689	19	708
Orallo Formation	1,918	1,596	3,515	845	26	871
Gubberamunda Sandstone	2,697	4,158	6,855	980	86	1,066
Westbourne Formation	139	5	144	75	1	76

Formation	Groundwater use (ML)			Number of bores		
	S&D	Non-S&D	TOTAL	S&D	Non-S&D	TOTAL
Springbok Sandstone	344	194	538	231	12	243
Walloon Coal Measures NPZ	23	8	30	15	0	15
Upper Juandah Coal Measures	283	459	741	219	15	234
Lower Juandah Coal Measures	643	2,119	2,761	663	70	733
Taroom Coal Measures	380	1,898	2,278	607	84	691
Durabilla Formation	116	128	245	116	7	123
Hutton Sandstone	4,444	12,353	16,797	3,500	392	3,892
Evergreen Formation	965	440	1,404	467	9	476
Precipice Sandstone	909	7,257	8,165	406	46	452
Surat Basin subtotal	*16,743*	*32,165*	*48,908*	*9,373*	*779*	*10,152*
Moolayember Formation	354	88	442	163	2	165
Clematis Group	724	305	1,029	168	6	174
Rewan Group	586	27	613	350	2	352
Bandanna Formation	183	192	375	120	4	124
Cattle Creek Formation	51	0	51	27	0	27
Upper & Lower Permian	1,175	1,201	2,377	730	25	755
Bowen Basin subtotal	*3,072*	*1,814*	*4,886*	*1,558*	*39*	*1,597*
Metamorphic/igneous/old basement rocks	276	264	540	257	16	273
TOTAL	**32,406**	**131,359**	**163,765**	**23,407**	**3,401**	**26,808**

Notes:

- Sums may differ due to rounding

4.4.2 Historical groundwater use

This section provides a summary of estimated historical groundwater use. The purpose of this analysis is to determine how groundwater demand has changed over time, which will assist the quantification and assessment of the historical use's possible influence on aquifer systems. This is an important dataset to inform evaluation of groundwater level trends and to support calibration of groundwater flow models.

The estimate of annual groundwater use for the period 1900 to 2022 across the three major groundwater systems is shown in Figure 4-3, along with the annual average rainfall for the Surat CMA. This time-series plot integrates the construction and decommissioning timeframes for individual bores, and shows the groundwater use estimate based on average rainfall. There is a significant increasing trend from the 1960s across the region, particularly evident in the alluvium and basalts but also in the Surat Basin.

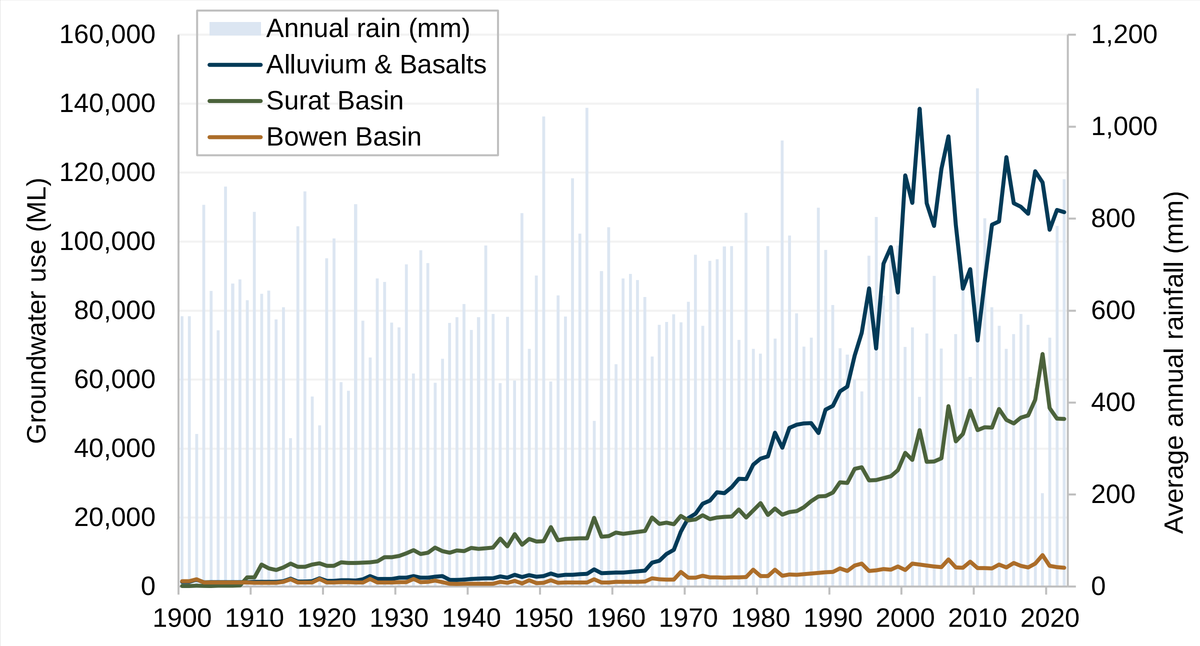

Figure 4-3: Historical growth in groundwater use by major formation group

Groundwater use between 1965 and 2010 increased at the rate of approximately 3 ML/year in the alluvium and basalts, and approximately 1 ML/year in the Surat Basin. Groundwater use in the Bowen Basin has remained relatively stable over time.

Metering commenced in the alluvium and basalts around 1990, resulting in a 'staggered' effect in the graph from variations in annual metered volumes. The sudden decrease in 2010 corresponds to an increase in annual rainfall combined with restrictions on entitlements, hence reduced groundwater use. An increase in groundwater post-2010 corresponds to below-average rainfall years.

The time series of estimated annual groundwater use and number of bores across all formations is shown in Figure 4-4 by bore purpose. The estimated volumes for S&D and non-S&D bores have metered volumes applied where available.

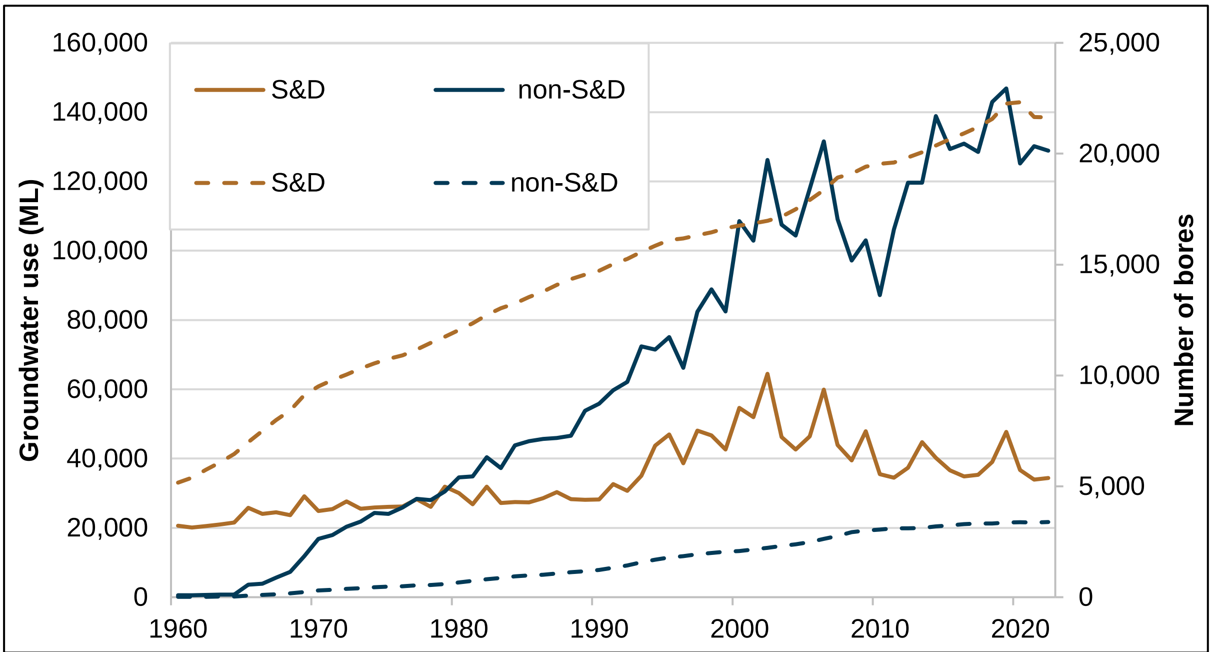

Figure 4-4: Annual estimate of groundwater use and bore count (1960 to 2022)

S&D groundwater use has increased at a steady rate, corresponding to bore development. As more metering and contextual information becomes available, the estimation method will continually evolve and reduce the bounds of uncertainty.

5 Conclusion

This document provides a summary of water bores and groundwater use in the Surat CMA. The groundwater use estimates inform the conceptual understanding of the groundwater flow system and provide a key dataset to understand system responses to various stressors.

Information on water bores – such as location, hydraulic condition and source aquifer – play a key role in groundwater use estimates. The bore purpose – S&D or non-S&D (town water supply, irrigation, etc.) determines the approach used to estimate groundwater use.

OGIA's methodology for estimating groundwater use has evolved since the initial UWIR 2012, as more data and information become available. Since the UWIR 2021, the approach to groundwater use estimation has been revised following an analysis of metered volumes and landholder interview data from a collaborative metering project between UQ and OGIA. The major revisions based on findings from metered and interview data are as follows:

- A spatiotemporal climate analysis was incorporated, whereby the estimates for each year are dependent on bore location and annual rainfall.
- Daily consumption per animal was reduced from 50L/day to 40L/day.
- A stocking rate of 0.25 was applied to the total grazing area for each property – for the UWIR 2021, rates of 0.05, 0.1 and 0.3 were applied for low, medium and high grazing areas respectively.

The latest groundwater use estimates for the Surat CMA indicate a total extraction of around 164,000 ML for 2022, from approximately 27,000 water supply bores.

As additional information, datasets and metering become available, OGIA will continue to evolve the methodology for estimating groundwater use. Potential further developments may include:

- review and update of non-S&D uptake coefficients
- alternative datasets to define grazing areas and pasture quality
- review of stocking rates and daily consumption volumes, with consideration of pasture quality
- review of surface water availability and linkages with climate variation.

References

CSIRO & SKM 2010, *Sustainable extraction limits derived from the recharge risk assessment method - Queensland*, CSIRO, Canberra.

Department of Natural Resources Mines and Energy 2017, *Minimum standards for the construction and reconditioning of water bores that intersect the sediments of artesian basins in Queensland*, WSS/2016/3189, Department of Natural Resources, Mines and Energy.

Keir, G, Bulovic, N & Mcintyre, N 2019, ‘Stochastic modeling of groundwater extractions over a data-sparse region of Australia’, *Groundwater*, vol. 57, no. 1, pp. 97–109.

Klohn Crippen Berger 2016, *Hydrogeological assessment of the Great Artesian Basin: Characterisation of aquifer groups. Eromanga Basin*, Report prepared for Department of Natural Resources and Mines, July 2016, Brisbane.

OGIA 2016, *Hydrogeological Conceptualisation Report for the Surat Cumulative Management Area*, OGIA, Department of Natural Resources and Mines, Brisbane, accessed from <https://www.ogia.water.qld.gov.au/publications-reports>.

OGIA 2021, *Underground Water Impact Report 2021 for the Surat Cumulative Management Area*, accessed from <https://www.ogia.water.qld.gov.au/publications-reports>.

OGIA 2023, *Analysis of groundwater trends to identify impacts from coal seam gas and coal mining in the Surat and southern Bowen basins (OGIA21CD14)*, Brisbane, Queensland, accessed from <https://www.ogia.water.qld.gov.au/publications-reports>.

OGIA 2024, *Methodology for the assignment of aquifers to bores in the Surat and southern Bowen basins*, Brisbane, Queensland, accessed from <https://www.ogia.water.qld.gov.au/publications-reports>.

Parsons Brinckerhoff 2011, *Queensland Murray-Darling Basin. Methodology for estimating the take of groundwater for stock and domestic purposes*, accessed August 9, 2018, from <https://www.mdba.gov.au/sites/default/files/pubs/22-Parsons-Brinckerhoff-2011-Method-estimating-stock-domestic-groundwater-take-D16-40858.pdf>.

Queensland Water Commission 2012, *Underground Water Impact Report*, Queensland Water Commission, Brisbane, accessed from <https://www.dnrm.qld.gov.au/__data/assets/pdf_file/0016/31327/underground-water-impact-report.pdf>.

Rochford, LM, Ordens, CM, Bulovic, N & McIntyre, N 2022, ‘Voluntary metering of rural groundwater extractions: understanding and resolving the challenges’, *Hydrogeology Journal*, vol. 30, no. 8, pp. 2251–2266, accessed from <https://doi.org/10.1007/s10040-022-02548-8>.

SKM 2014, *Developing an Improved Monitoring Approach for Springs in the Surat CMA, Stage 1 & 2 Progress Report. A report prepared for the Office of Groundwater Impact Assessment.*, Sinclair Knight Merz, Brisbane.

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