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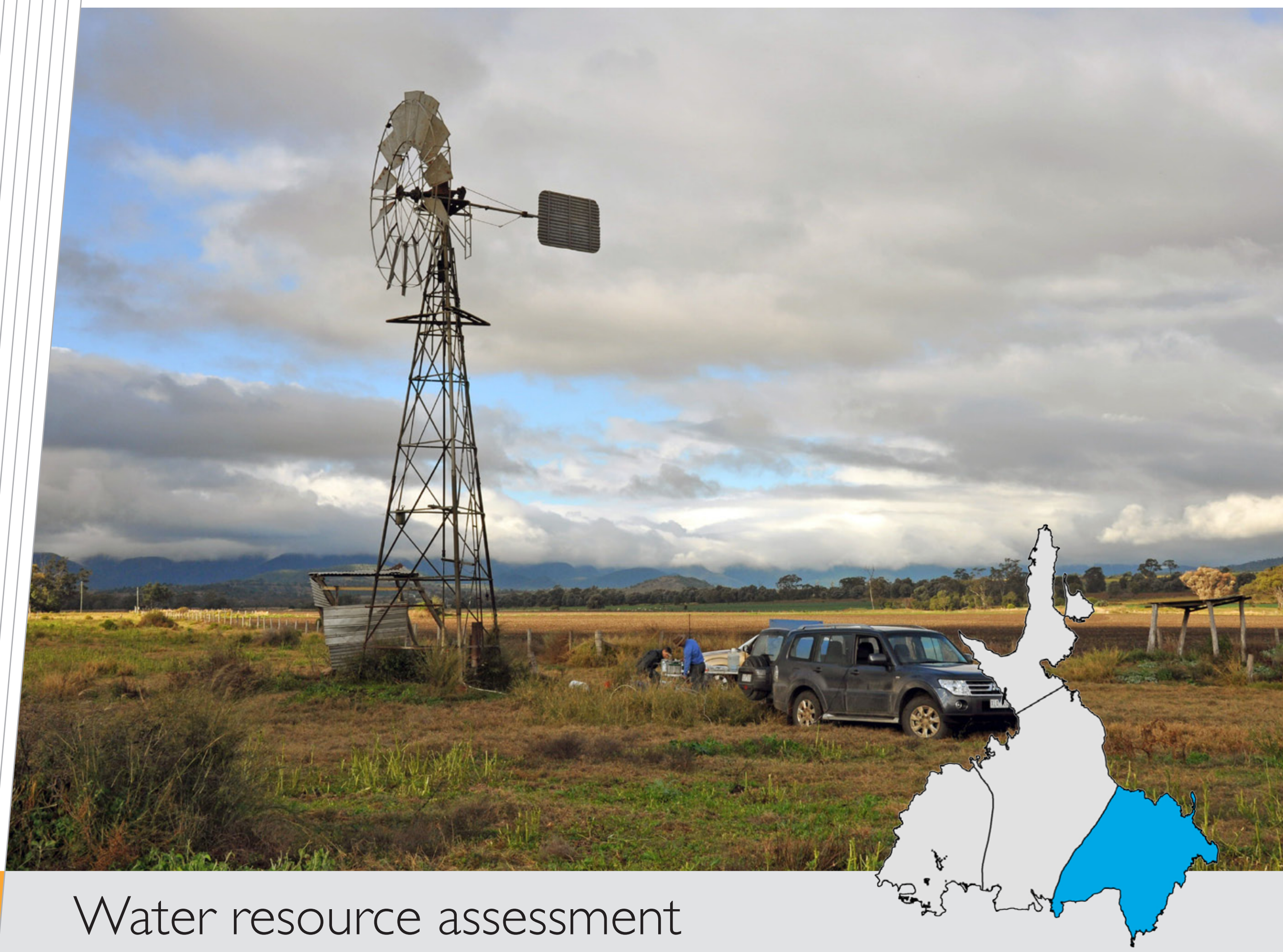

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Water resource assessment for the Surat region

Summary of a report to the Australian Government from the CSIRO Great Artesian Basin Water Resource Assessment

Smerdon BD, Marston FM and Ransley TR

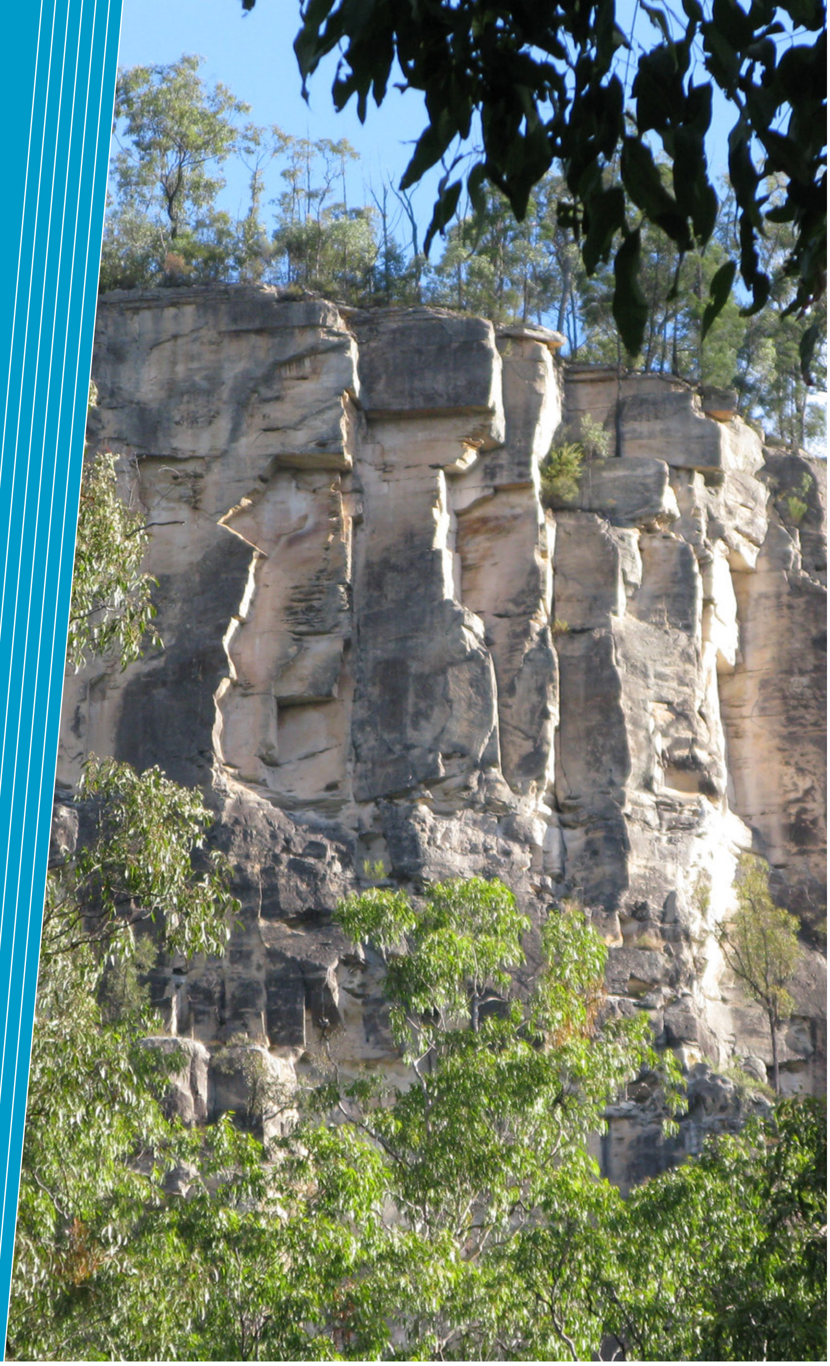
21 December 2012

Australian Government
Department of Sustainability, Environment, Water, Population and Communities
National Water Commission

About the project

Since 2007, CSIRO has been undertaking groundbreaking scientific assessments of current and future water availability in major water systems across Australia through its Sustainable Yields projects. To date, rigorous assessments of the anticipated impacts of climate change, catchment development and increasing groundwater extraction on the availability and use of water resources have been completed for the Murray-Darling Basin, northern Australia, south-west Western Australia and Tasmania. The underlying aim has been to provide consistent water resource assessments to guide water policy and water resources planning.

Determinations of sustainable water resource development and allocations require choices by governments and communities about the balance of outcomes (environmental, economic and social) sought from water resource management and use. These choices are best made on the basis of sound scientific information, particularly a robust description of the extent, variability and nature of the water resource. Consistent with the previous Sustainable Yields projects, the Great Artesian Basin Water Resource Assessment (the Assessment) provides an analytical framework to assist water managers in the Great Artesian Basin (GAB) to meet National Water Initiative commitments.



> Precipice sandstone, Carnarvon Gorge (Geoscience Australia)

Great Artesian Basin Water Resource Assessment acknowledgments
The Assessment was prepared by CSIRO for the Australian Government under the *Water for the Future* initiative and the National Water Commission (NWC) Raising National Water Standards Program. Geoscience Australia was a significant contributor to the Assessment. Important aspects of the work were undertaken by Sinclair Knight Merz, Flinders University, South Australian Department for Water and Natural Resources (formerly Department for Water), and MA Habermehl Pty Ltd.

The Assessment was guided and reviewed by a Steering Committee, which had representatives from the following organisations: Australian Government Department of Sustainability, Environment, Water, Population and Communities; National Water Commission; Australian Bureau of Agricultural and Resource Economics and Sciences; New South Wales Office of Water; the Queensland Department of Natural Resources and Mines (formerly the Department of Environment and Resource Management); Queensland Water Commission; South Australia Department of Environment, Water and Natural Resources (formerly Department for Water); and Northern Territory Department of Land Resource Management (formerly Northern Territory Department of Natural Resources, The Arts and Sport - NRETAS).

Valuable input into this report was provided by the Technical Reference Panel. The Panel included representatives from the same organisations as on the Steering Committee, plus representatives from the following organisations: Australian Government Bureau of Meteorology; CSIRO; and Geoscience Australia.

Citation
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Cover photograph
Sub-artesian bore 40 km north of Dalby, Queensland. Courtesy of Geoscience Australia.

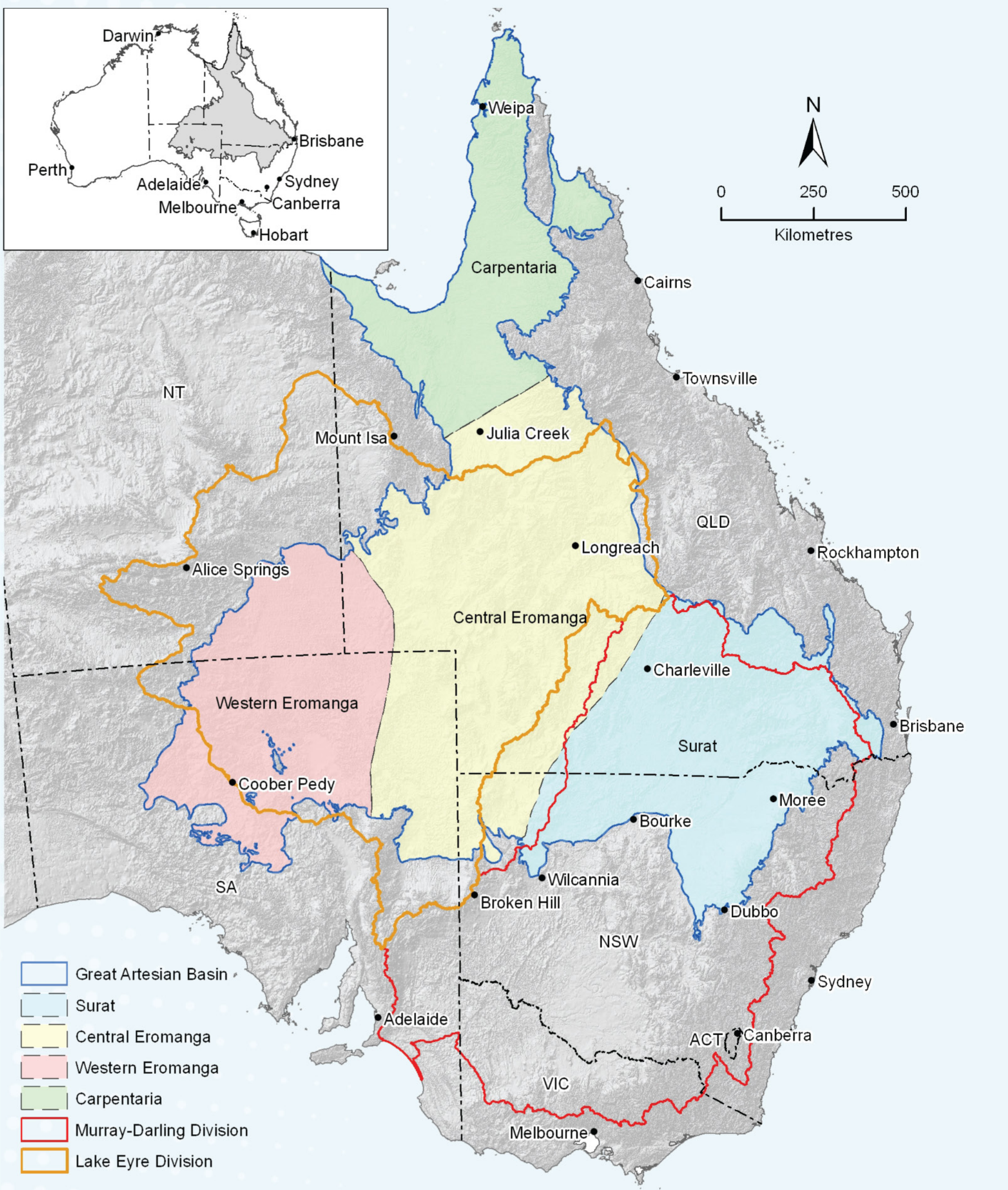
Assessing groundwater resources in the Great Artesian Basin

Overview

The Great Artesian Basin (GAB) is Australia's largest groundwater basin. It underlies arid and semi-arid regions and extends across one-fifth of Australia, across parts of Queensland, New South Wales, South Australia and the Northern Territory. The Great Artesian Basin Water Resource Assessment (the Assessment) outlines the current status of groundwater resources in the GAB and the potential impacts of climate change and resource development on those water resources. It focuses only on aquifers of the Jurassic and Cretaceous periods, which are present across the entire GAB. For reporting purposes, individual regions – generally aligned with geological basins – were defined: the Surat, Central Eromanga, Western Eromanga and Carpentaria regions (Figure 1).

This report summarises the findings of the Assessment for the Surat region – detailed analysis is presented in the companion region report. Further reporting of the Assessment is covered by a range of products including four region reports that focus on the four reporting regions. In addition, there is a whole-of-GAB report. The region reports are summarised in 16-page summary reports for a general audience. Similarly, the whole-of-GAB report is summarised as a synthesis for a general audience. Four technical reports provide additional scientific detail underpinning the region reports. Other scientific outputs include a computer-coded groundwater flow model, data used and produced in the Assessment (housed at Geoscience Australia), and a three-dimensional (3D) visualisation of the GAB.

> Figure 1. Geographic extent of the Great Artesian Basin, selected overlying surface water drainage divisions and reporting regions of the Assessment



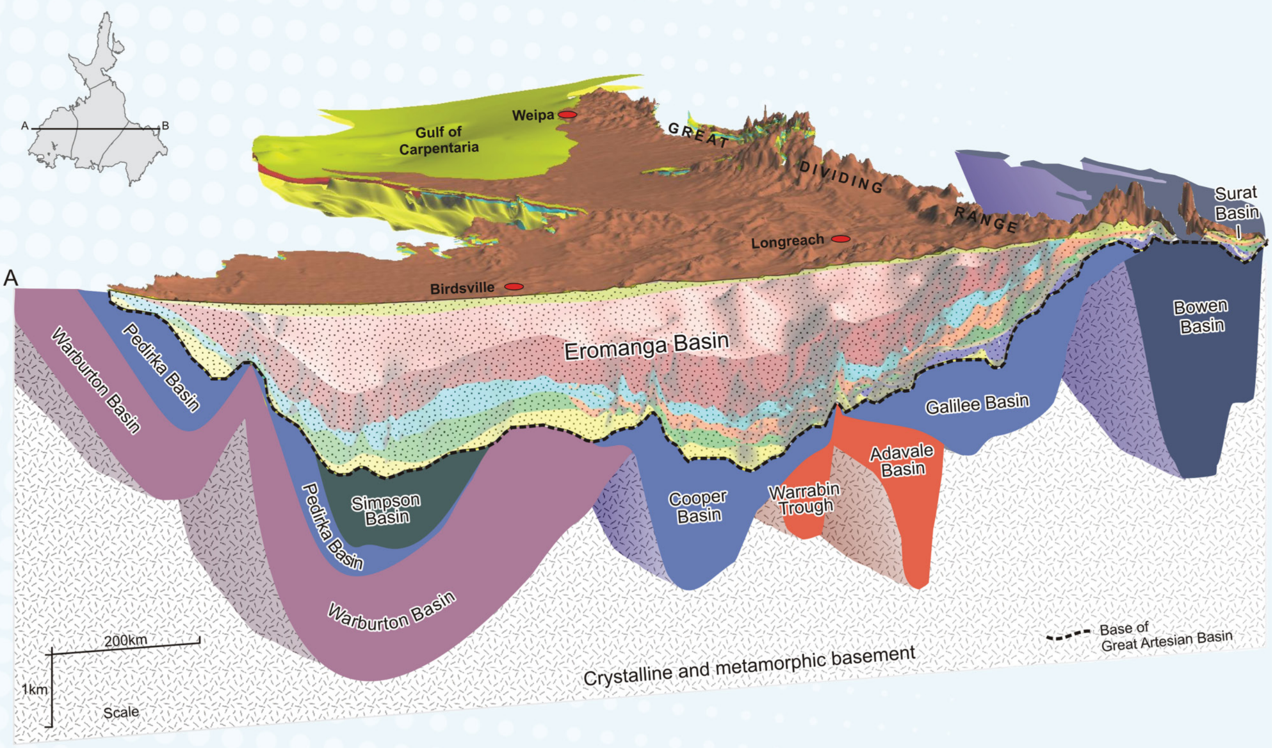
The Great Artesian Basin

The GAB is a complex groundwater entity that is difficult to visualise and challenging to describe. To help describe the GAB and improve knowledge of groundwater resources, this summary report uses technical terms that may be unfamiliar to many readers – **definitions** of these terms are provided on the back page.

The GAB is a **groundwater basin** made of rock layers that form **aquifers** (the permeable layers that readily transmit water) and **aquitards** (the **confining layers** that restrict **groundwater flow**). Because the GAB is defined as a groundwater basin, it encompasses several **geological basins** that were deposited at different times in Earth's history, from 200 to 65 million years ago, in the Jurassic and Cretaceous periods. These geological basins sit atop deeper, older geological basins and, in turn, have newer surface **drainage divisions** situated on top of them (e.g. the Lake Eyre and Murray-Darling river basins). In this context – as a groundwater basin – the GAB is a vast groundwater entity stretching across one-fifth of Australia (Figure 1).

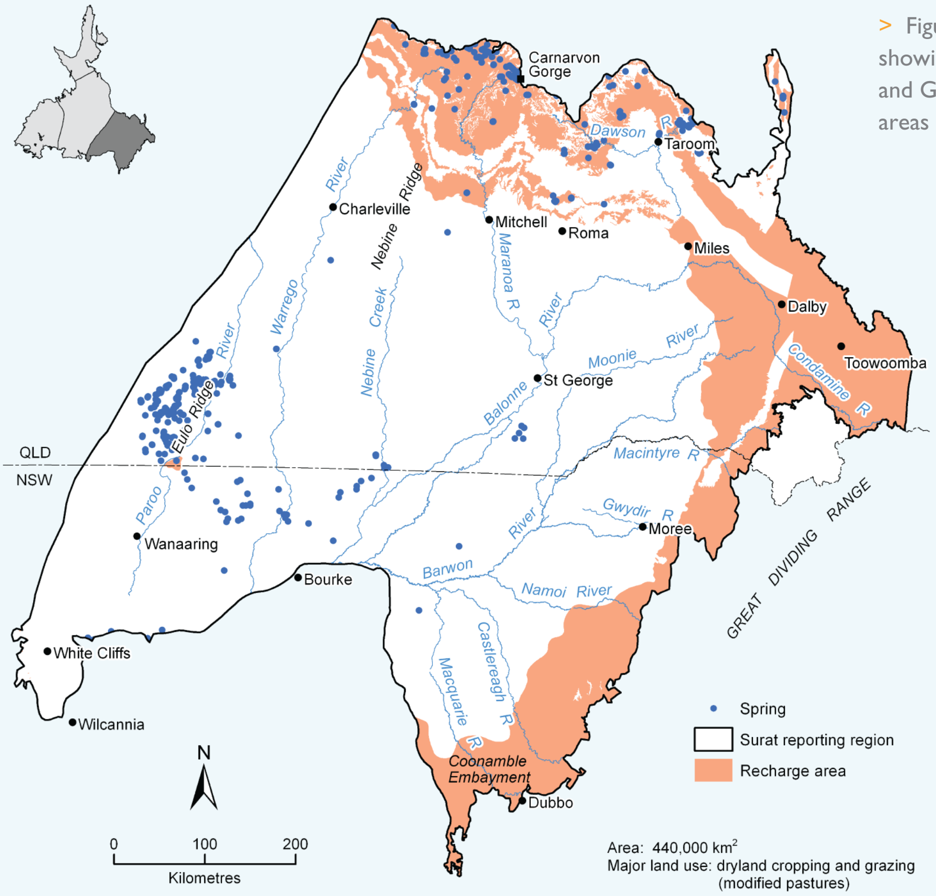
Groundwater resources in the GAB support many activities including pastoral, agricultural, mining and extractive industries and inland population centres – and the demand for groundwater is growing. Properly managing these groundwater resources, for often competing interests, requires a better understanding of how the groundwater basin works. In addition to groundwater flow occurring in the aquifers and aquitards of the GAB, there are connections with **geological formations** underneath, on top of, and beside the GAB (Figure 2).

The Assessment investigated the latest geological and hydrogeological information and developed a comprehensive description of the GAB aquifers, including the geological history, structure of the rock layers, and three-dimensional (3D) visualisation of aquifers and aquitards. **Groundwater flow models** were used to assess the effects of future climate and groundwater development on water levels in the Cadna-owie – Hooray Aquifer, which is the main aquifer in the GAB, and potential impacts to groundwater-dependent ecosystems.



> Figure 2. Three-dimensional illustration of a slice through geological basins, including the Eromanga Basin that hosts the Great Artesian Basin (GAB). This diagram shows aquifer layers of the GAB and underlying geological basins. Because the GAB is a groundwater entity, some of the GAB aquifers may be in contact with groundwater in underlying basins

The Surat region



> Figure 3. The Surat region showing selected rivers and springs and Great Artesian Basin recharge areas (intake beds)

- Some of the rock layers that form aquifers in the GAB are exposed along the western slopes of the Great Dividing Range.
- In these areas, rainfall and river water percolate into the ground, becoming groundwater in the GAB.
- These are referred to as areas of 'groundwater recharge' or the 'intake beds' for the GAB.

Region facts and figures	
Geology	The Surat region is bounded by the Great Dividing Range to the east and the Eulo and Nebine ridges to the west. The extent is defined by the exposure (outcrop) of the Jurassic-aged sediments in the north and the Coonamble Embayment in the south. The region is approximately centered on the geological Surat Basin, which sits atop of the older Bowen Basin. The region's surface water is drained by tributaries of the Darling River, which originate in the higher areas along the eastern margin of this region. The tributaries of these rivers, and associated alluvial valleys, are highly productive agricultural land.
Climate	The climate of the Surat region is generally sub-tropical with warm, wet summer months and cooler, drier winter months. Average annual rainfall across the region is variable, increasing west to east from 500 mm/year in Charleville to 627 mm/year in Dalby, and increasing south to north from 350 mm/year in Bourke to 675 mm/year in Taroom. Variation in climate from south to north and seasonality control the rate and timing of **groundwater recharge** to the GAB along the western slopes of the Great Dividing Range.
Groundwater use	Primarily, groundwater use in the region has been for pastoralism, with increasing use for stock, town water and irrigation over the past century. More recently, mining interest has expanded from coal to the potential for coal seam gas (CSG). Extraction of CSG requires pumping groundwater to release gas from the coal, which can lead to decreased water levels in overlying and underlying aquifers. Groundwater resources are managed by two jurisdictions (New South Wales and Queensland), each having different legislation.
History	Springs and wetlands of the GAB have played an important role in providing habitat for a range of species in the region. The springs have also been valued by Aboriginal people for thousands of years, as a water source of strong cultural and spiritual value. Early European explorers, including John Oxley (in 1818) and Thomas Mitchell (in 1846), travelled the Macquarie, Balonne, and Warrego river systems and observed the springs and marshes that were features of the GAB. The first artesian bores tapped the GAB in the late 1870s and by 1910 there were over 850 artesian bores in the GAB.

Modelling groundwater levels from 2010 to 2070

An existing large-scale groundwater model was used to estimate the impact of climate and development on groundwater levels in the GAB by 2070. The model – originally developed for the Great Artesian Basin Sustainability Initiative (GABSI) in 2006 – simulates groundwater levels in the Cadna-owie – Hooray Aquifer as a single layer spanning the GAB and does not include any of the geological complexities discovered by the Assessment. The model represents the uppermost artesian aquifer – which has been eroded by natural processes over geological time along the eastern boundary – so the spatial extent does not cover the north-eastern portion of the Surat region. It is the only model to consider the main aquifers across the GAB and shown to represent the change in groundwater levels at such a large scale.

The modelling considered scenarios with different combinations of climate conditions and levels of groundwater development.

The modelling considered current (circa 2010) climate as well as three possibilities for future climate: a wet extreme, median and dry extreme future climate. In these three future possibilities, the rainfall and evaporation vary, which would result in different groundwater recharge rates at the **intake beds** in 2070. The groundwater recharge rates span between 38 percent lower than existing rates for the dry extreme future climate and 54 percent higher for the wet extreme future climate.

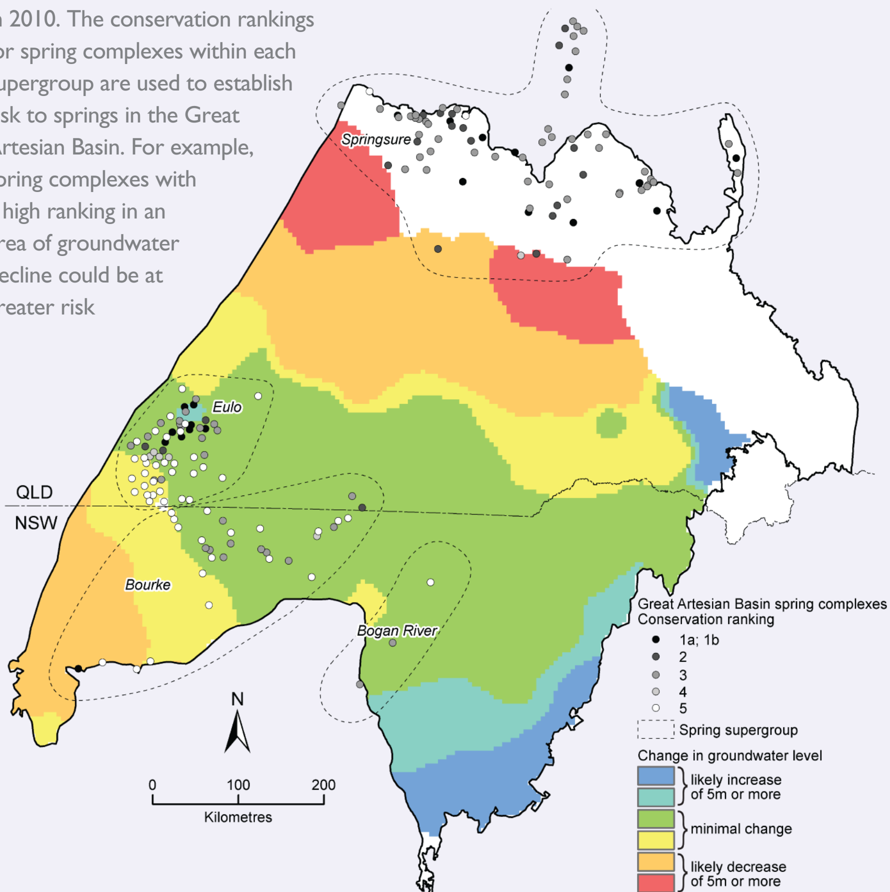
The modelling considered both current (circa 2010) and future levels of groundwater development, as represented by changing rates in groundwater extraction. In the Surat region, these future changes include a reduction in extraction due to bore rehabilitation under GABSI. Future groundwater development from conventional petroleum wells and other extractive industries is assumed to be negligible. Modelling of increased groundwater extractions related to coal seam gas (CSG) development are described on page 6 (Figure 8).

Figure 4 shows the change in groundwater levels from 2010 to 2070 under the scenario with median future climate and current groundwater development. Under current groundwater development, GASBI and previous Government programs had achieved approximately 75 percent of the total expected groundwater savings, and it is assumed that GABSI had been concluded in 2010. Under the future climate and current groundwater development scenario, groundwater development from bores is 232 GL/year and groundwater levels decrease in the north and south-west. Under the median future climate and wet extreme future climate, groundwater levels increase in the south-east because groundwater recharge is greater than discharge. Under the dry extreme future climate, groundwater levels decrease in the south-east (due to lower groundwater recharge rates) and the level of groundwater extraction is greater than replenishment.

Figure 5 shows the change in groundwater levels from 2010 to 2070 under the median future climate and future groundwater development scenario. Under future groundwater development, GABSI is assumed to run to full completion, achieving 100 percent of the total expected groundwater savings. Under the future climate and future groundwater development scenario, groundwater development from bores is 141 GL/year. Under the median future climate and future groundwater development scenario, groundwater levels gradually recover for at least 50 percent of the region (assuming GABSI continues to completion and that all eligible artesian bores remaining to be controlled at 2010 are controlled).

The modelled estimates of groundwater levels are sensitive to rates of groundwater recharge and groundwater extraction. The key difference between Figures 4 and 5 is attributed to 25 percent of the total expected groundwater savings under GABSI. There is some uncertainty in future groundwater extraction rates, which leads to uncertain results in some locations. For example, although the modelled impacts appear to be greatest in the south-eastern Coonamble Embayment, these results are not supported by sufficient data.

> Figure 4. Change in groundwater levels from 2010 to 2070 under median future climate and the continuation of current development, where GABSI groundwater savings are concluded in 2010. The conservation rankings for spring complexes within each supergroup are used to establish risk to springs in the Great Artesian Basin. For example, spring complexes with a high ranking in an area of groundwater decline could be at greater risk



- Within an aquifer, groundwater moves from areas where groundwater levels are higher to areas where groundwater levels are lower. Changes in climate – the amount of rainfall – lead to changes in groundwater level. Similarly, changes in groundwater extraction lead to a change in groundwater level.
- Management of GAB groundwater relies on groundwater levels. Future conditions were assessed by considering different scenarios of the climate in 2070 and estimates of future groundwater extraction.

Risks to Great Artesian Basin springs

Many ecosystems depend on groundwater from the GAB aquifers. These groundwater-dependent ecosystems range in size from small vents to large mounds and may be surrounded by wetlands. **Spring complexes** that are located in major regional clusters are referred to as **supergroups**, with thirteen supergroups found in the GAB and four in the Surat region.

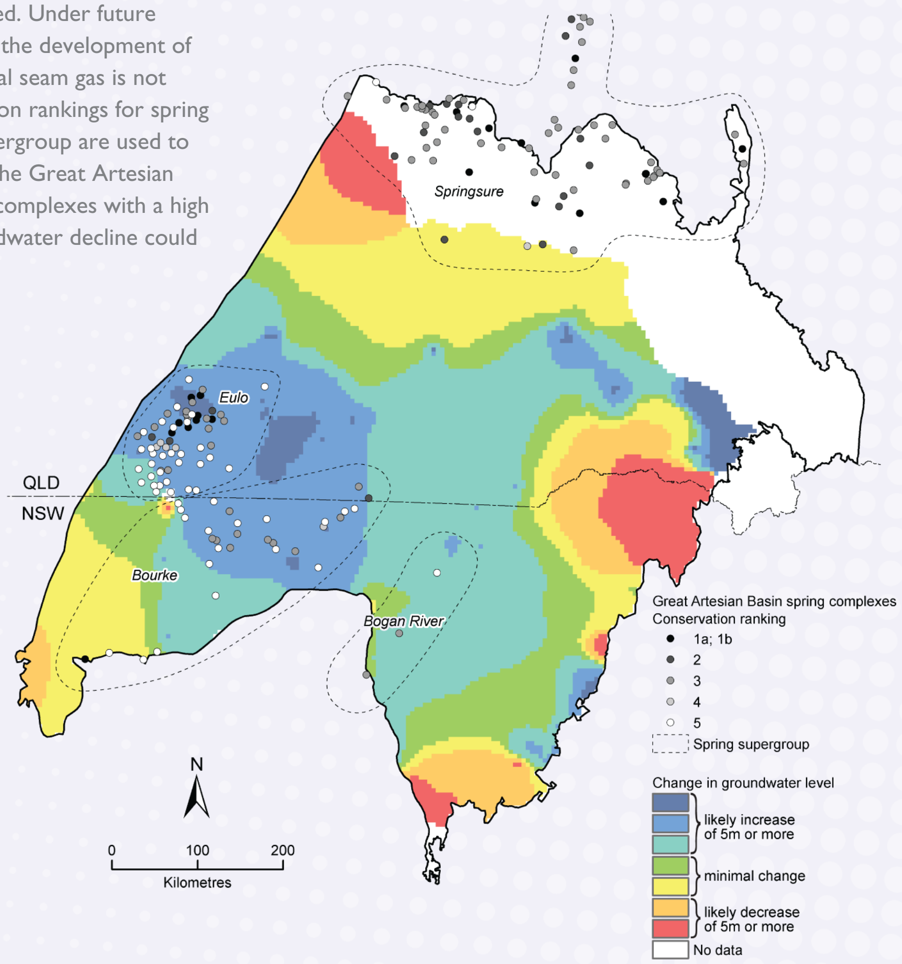
The Assessment determined the likely risk and opportunity to springs in the GAB based on the modelled change in groundwater levels from 2010 to 2070 and the conservation value of the spring complexes. High risk means that loss of spring ecological values is highly likely, due to a high likelihood that a spring complex would cease to flow. Low risk means loss of ecological values is unlikely. Assessment of impact considers both the likelihood of decline in groundwater level and likelihood of recovery of flow to a spring complex.

Under the future climate and the current level of groundwater development (Figure 4), some spring complexes are likely to be affected by a decrease in groundwater levels. In the Bourke and Eulo supergroups, many of the spring complexes are currently inactive, so a further decline will not lead to higher risk. However, at the highest ranked spring complex in the Bourke supergroup – Peery Springs complex (ranking 1b) – groundwater levels are likely to decline under the future climate.

Under the future climate with future development (Figure 5), the majority of spring complexes (94 percent) are located in areas where the groundwater level is likely to increase assuming continuation of the GABSI. In the region, only six spring complexes are at risk from a decline in groundwater level, of which only one is active (Peery Springs complex, Bourke supergroup).

- Groundwater modelling estimates groundwater levels in the GAB in the future, from which the risks to groundwater-dependent ecosystems were determined.

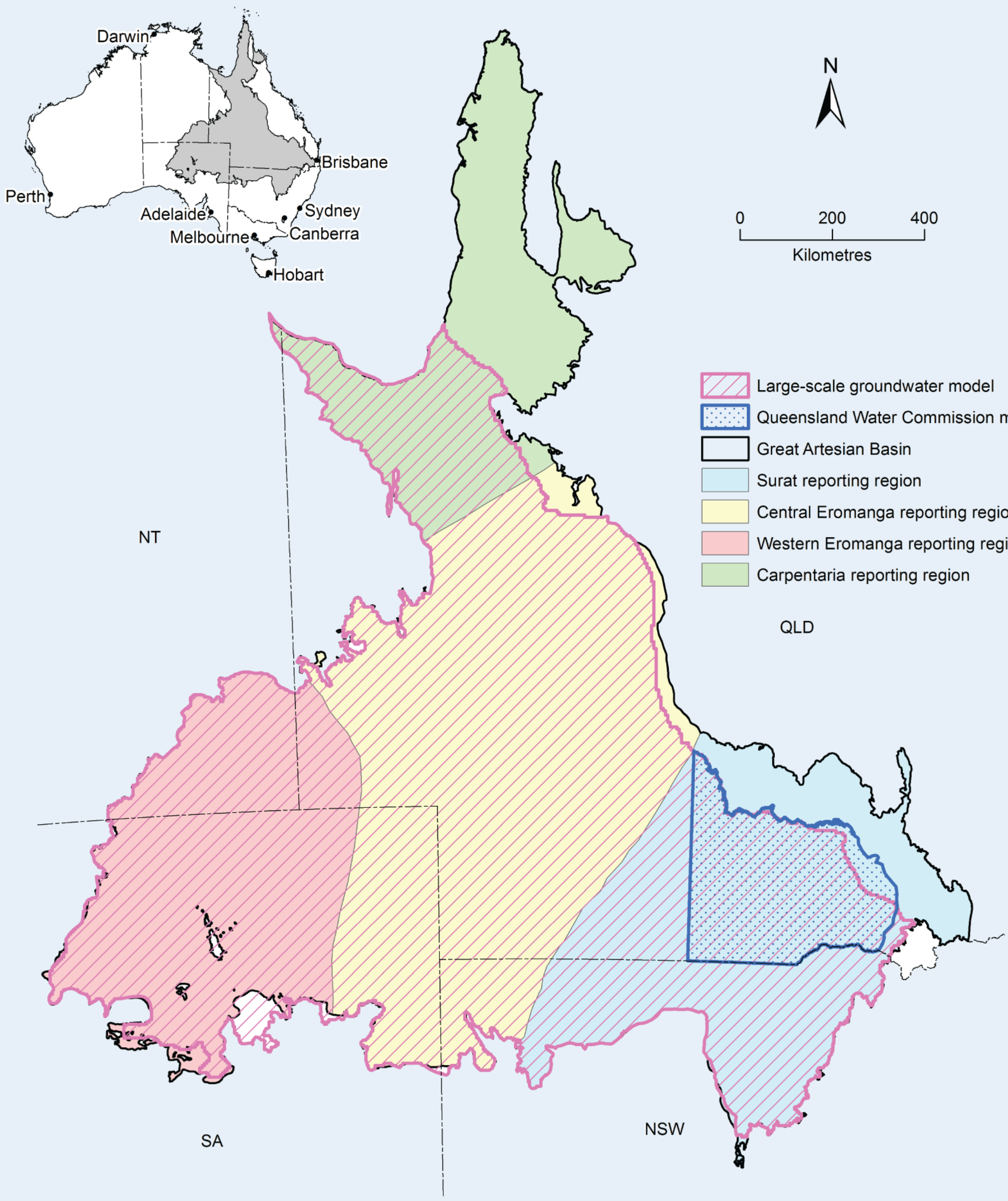
> Figure 5. Change in groundwater levels from 2010 to 2070 under median future climate and future levels of groundwater development. Under future development the GABSI program is run to full completion whereby all eligible uncontrolled artesian bores are controlled. Under future development the impact of the development of petroleum resources or coal seam gas is not considered. The conservation rankings for spring complexes within each supergroup are used to establish risk to springs in the Great Artesian Basin. For example, spring complexes with a high ranking in an area of groundwater decline could be at greater risk



Modelling the effect of coal seam gas development

The large-scale groundwater model was suitable for estimating the effects of future climate and development across the GAB (Figure 6), but not the effects of groundwater extraction related to coal seam gas (CSG) development. CSG development requires extracting groundwater to release gas from the coal. These groundwater extractions occur in different geological formations than are represented in the large-scale groundwater model. For the Surat region, a partnership with the Queensland Water Commission (QWC) was established to use results from the existing groundwater flow model developed by the QWC (Figure 6) for assessing the impact of future CSG development.

The groundwater model developed by QWC covers part of the Surat reporting region. Rather than simulating groundwater levels in the Cadna-owie – Hooray Aquifer as a single layer, the QWC model has multiple layers to represent different rock layers in the Surat region – the aquifers and aquitards. The groundwater extraction for CSG occurs in a formation called the Walloon Coal Measures. Impacts on other layers from CSG-related development are likely to occur by changes to the rate of groundwater movement between different layers (vertical leakage), which will cause changes in groundwater levels where groundwater is extracted and in layers above and below.



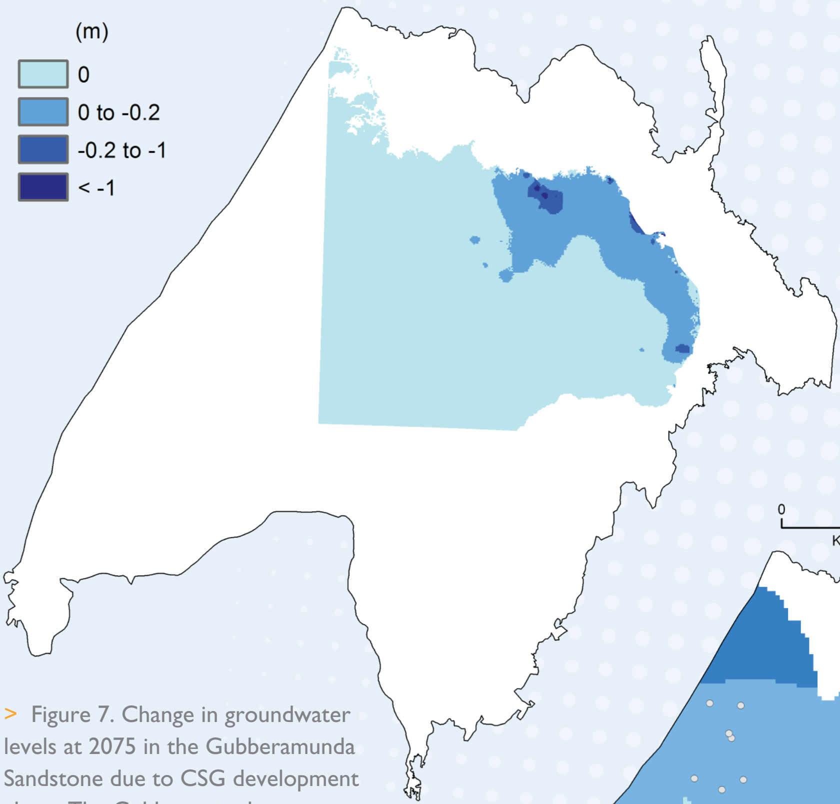
> Figure 6. Extent of the large-scale single-layer groundwater model that spans the Great Artesian Basin and extent of the layer representing the Gubberamunda Sandstone in the groundwater model developed by the Queensland Water Commission

To compare the results of the QWC modelling with those of the large-scale modelling described on pages 4 and 5, the representative Gubberamunda Sandstone layer of the QWC model was selected, chosen as it is equivalent to the single layer of the large-scale model.

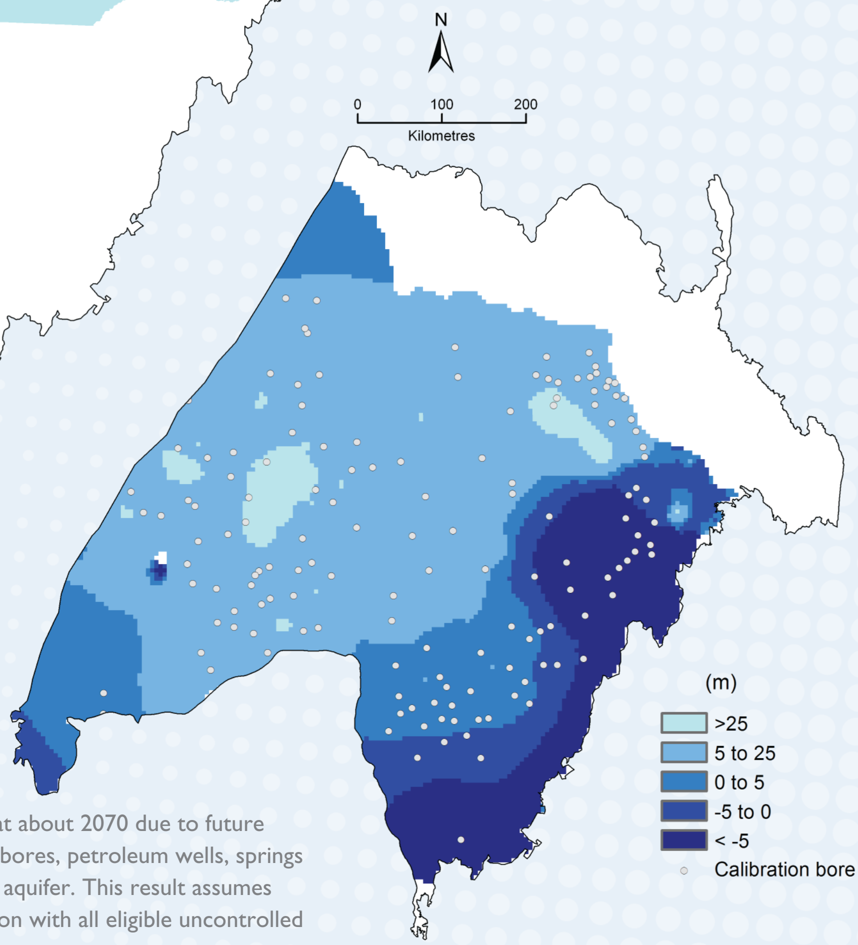
The QWC model estimated changes groundwater levels in 2075 for CSG development alone. CSG development is simulated by reducing the groundwater level to 40 metres above the top of the productive coal seam. CSG development is expected to cease by 2050, so groundwater extraction for CSG development reduces to zero before 2070. In the Gubberamunda Sandstone, the estimated groundwater levels are predominantly less than 0.2 metres lower over more than three quarters of the model area (Figure 7).

The combined effect of all future groundwater development – including reduction in extraction due to bore rehabilitation under GABSI and increased extractions related to CSG development – are shown in Figure 8. Compared to the increase in groundwater levels resulting from GABSI running to full completion, whereby all eligible uncontrolled artesian bores are controlled, the estimated decrease in groundwater levels from CSG development is relatively small.

- To assess the effects of groundwater extraction related to coal seam gas development, a multi-layered groundwater model developed by QWC was used.
- The majority of groundwater extraction is expected to be finished by 2050.
- The estimated groundwater level decrease from coal seam gas development is less than the potential groundwater level increase assuming GABSI is run to completion.



> Figure 7. Change in groundwater levels at 2075 in the Gubberamunda Sandstone due to CSG development alone. The Gubberamunda Sandstone layer from the QWC model is equivalent to the single layer large-scale model

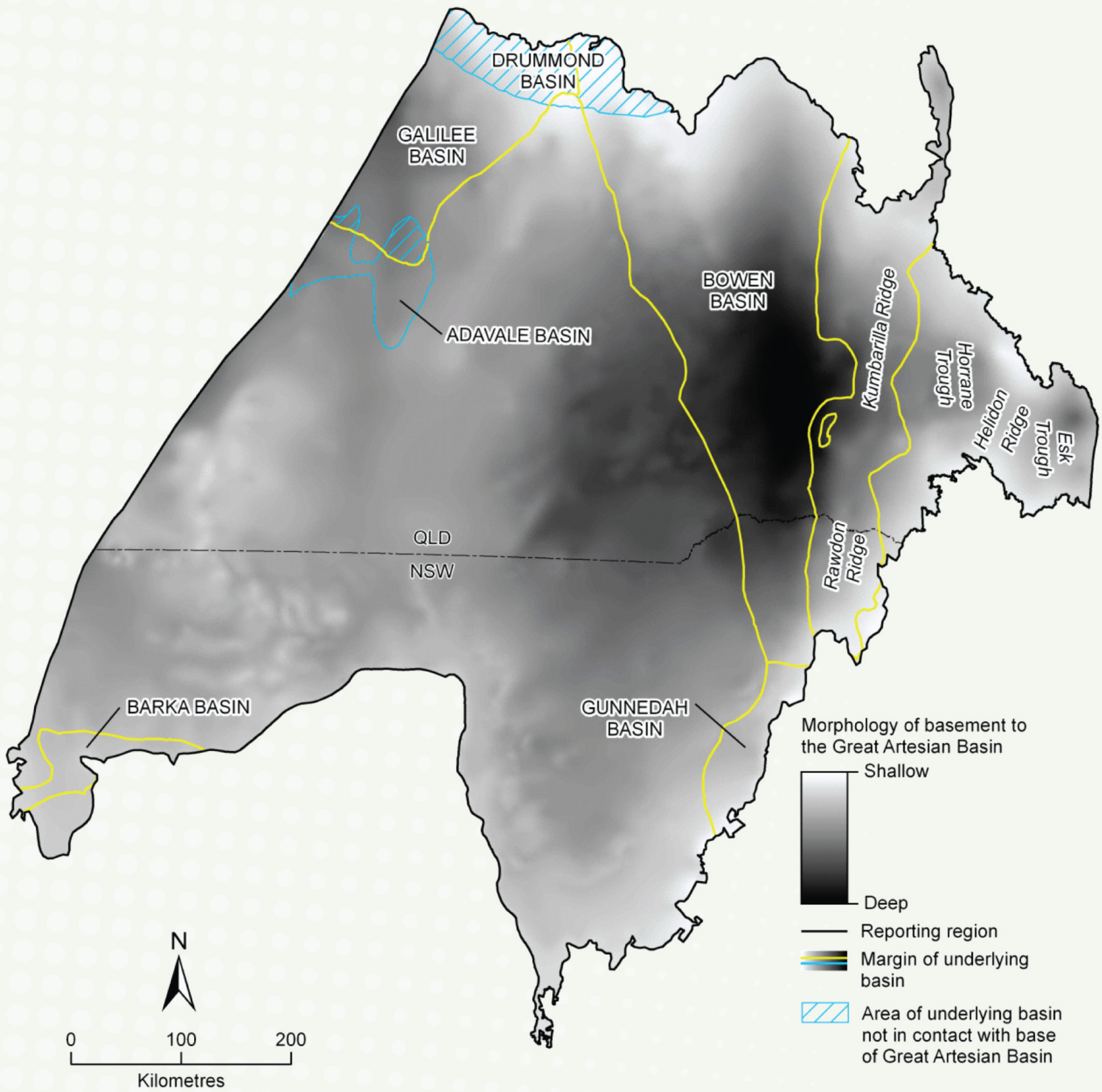


> Figure 8. Change in groundwater levels at about 2070 due to future groundwater development including water bores, petroleum wells, springs and CSG development in the main artesian aquifer. This result assumes that the GABSI program is run to completion with all eligible uncontrolled artesian bores controlled

The Great Artesian Basin and deeper, older geological basins: critical connections

The Jurassic to Middle Cretaceous age sediments in the Surat region were deposited on top of older geological basins. It is these underlying basins that cause the GAB to have its structure and general shape. Below the deepest part of the Surat Basin, the older Permian-Triassic Bowen Basin is located within a north-to-south trough that extends southward to the Gunnedah Basin (Figure 9).

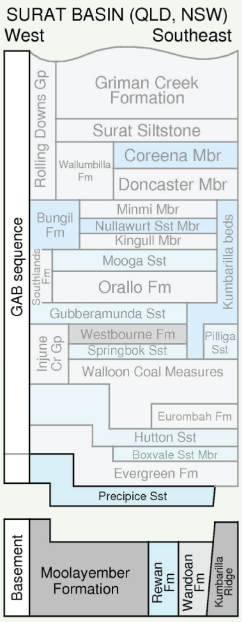
Because the GAB is situated on top of these deeper geological basins, there are some locations where GAB aquifers are potentially connected to aquifers in the deeper basins. The connections form a patchwork across the Surat region (Figure 10).



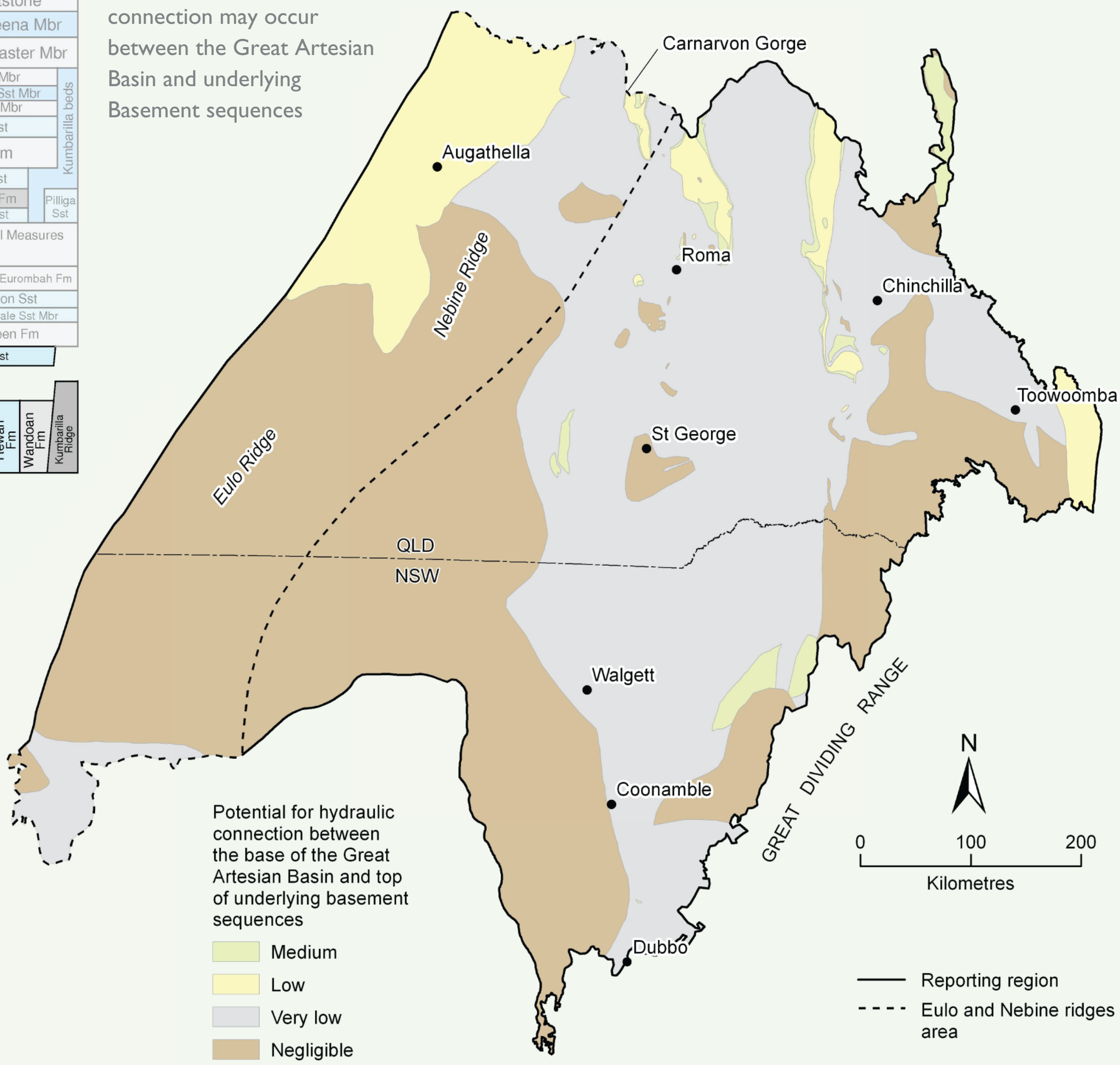
> Figure 9. Depth of rock layers in the Great Artesian Basin and outline of deeper, older geological basins

> Artesian bore intersecting Hutton Sandstone, north of Goondiwindi, Queensland (Geoscience Australia)

- There exists the potential for hydraulic connectivity at the boundary of aquifers at the base of the GAB and the underlying partial aquifers and leaky aquitards that form the upper sequences of the deeper, older geological basins.
- In the areas where aquifers at the base of the GAB are connected, there may be groundwater moving from one basin to another.

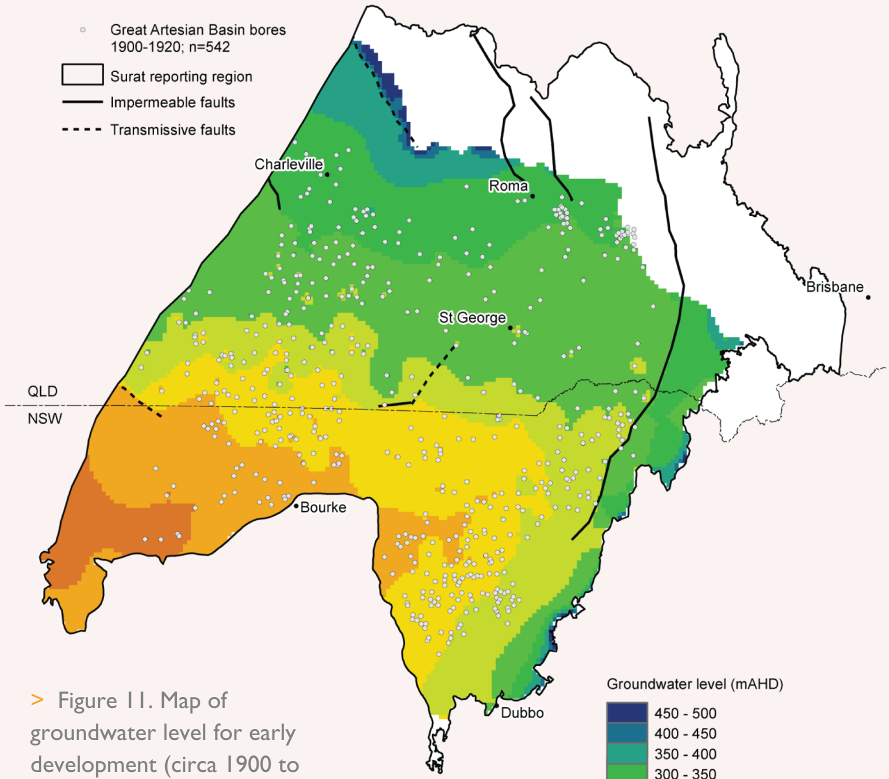


Regional stratigraphic sequence of the Surat Basin showing the boundary where possible hydraulic connection may occur between the Great Artesian Basin and underlying Basement sequences



> Figure 10. Potential areas of hydraulic connection between the base of the Great Artesian Basin and underlying basement sequences in the Surat and Clarence-Moreton basins.
Note: map does not imply connection above formations at the base of the GAB e.g. Evergreen formation and above.

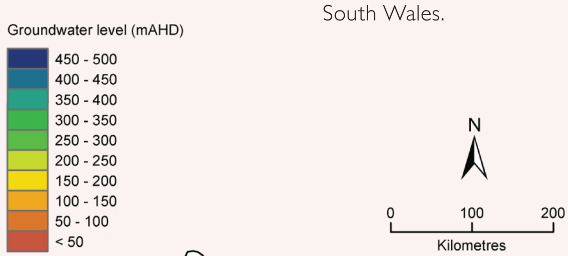
Measuring groundwater levels: the change since 1900



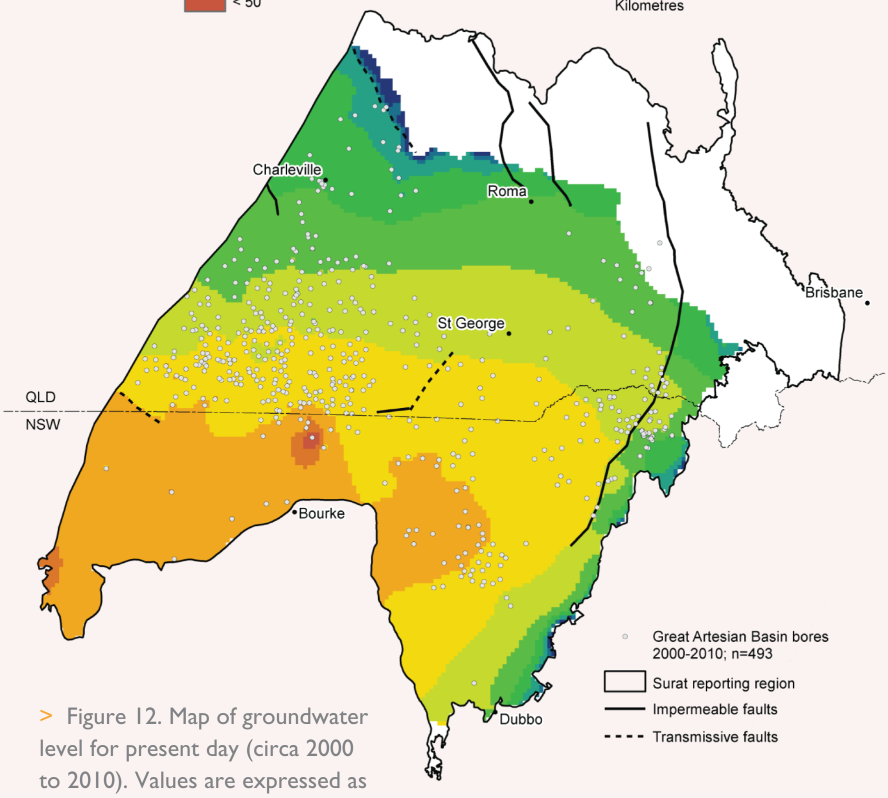
> Figure 11. Map of groundwater level for early development (circa 1900 to 1920). Values are expressed as an elevation (mAHD)

Groundwater levels have been measured in the GAB since the early 1900s. Now, for the first time, groundwater levels at 20-year intervals have been mapped for the Cadna-owie – Hooray Aquifer for the period 1900 to 2010. This shows changes in measured groundwater levels from early development (circa 1900) (Figure 11) to the present day (circa 2010) (Figure 12).

Groundwater levels in the Surat region are highest along the northern, eastern and southern margins of the region, where the aquifers are exposed near the intake beds. Groundwater flow is towards the south in Queensland, and towards the west and north-west in the Coonamble Embayment in New South Wales.



> Injune town bore (Geoscience Australia)



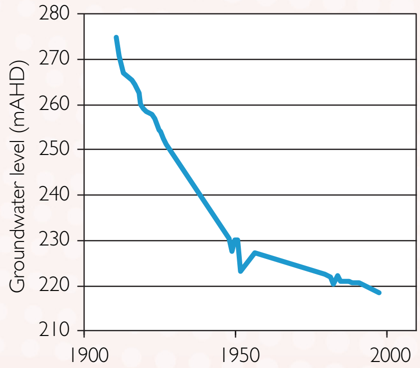
> Figure 12. Map of groundwater level for present day (circa 2000 to 2010). Values are expressed as an elevation (mAHD)

The differences between groundwater levels measured at specific bores provide an opportunity to plot a map of change (Figure 13). From 1900 to 2010 groundwater levels have declined over much of the region. The largest decline is located in the northern half of the region. However, groundwater level recovery can be seen in some areas due to the Great Artesian Basin Sustainability Initiative.

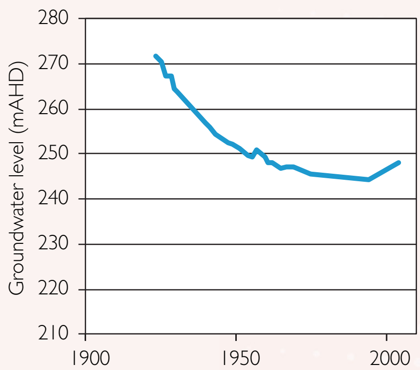
During the early stages of development in the 1900s, a large number of free-flowing bores discharged significant volumes of groundwater from the GAB. Such a high initial discharge from these bores during the early years of development was mainly the result of the release from groundwater storage. These significant decreases in groundwater levels may not be recoverable. Deeper aquifers in the Surat region, which had previously not been heavily developed, have been tapped in recent times as alternatives.

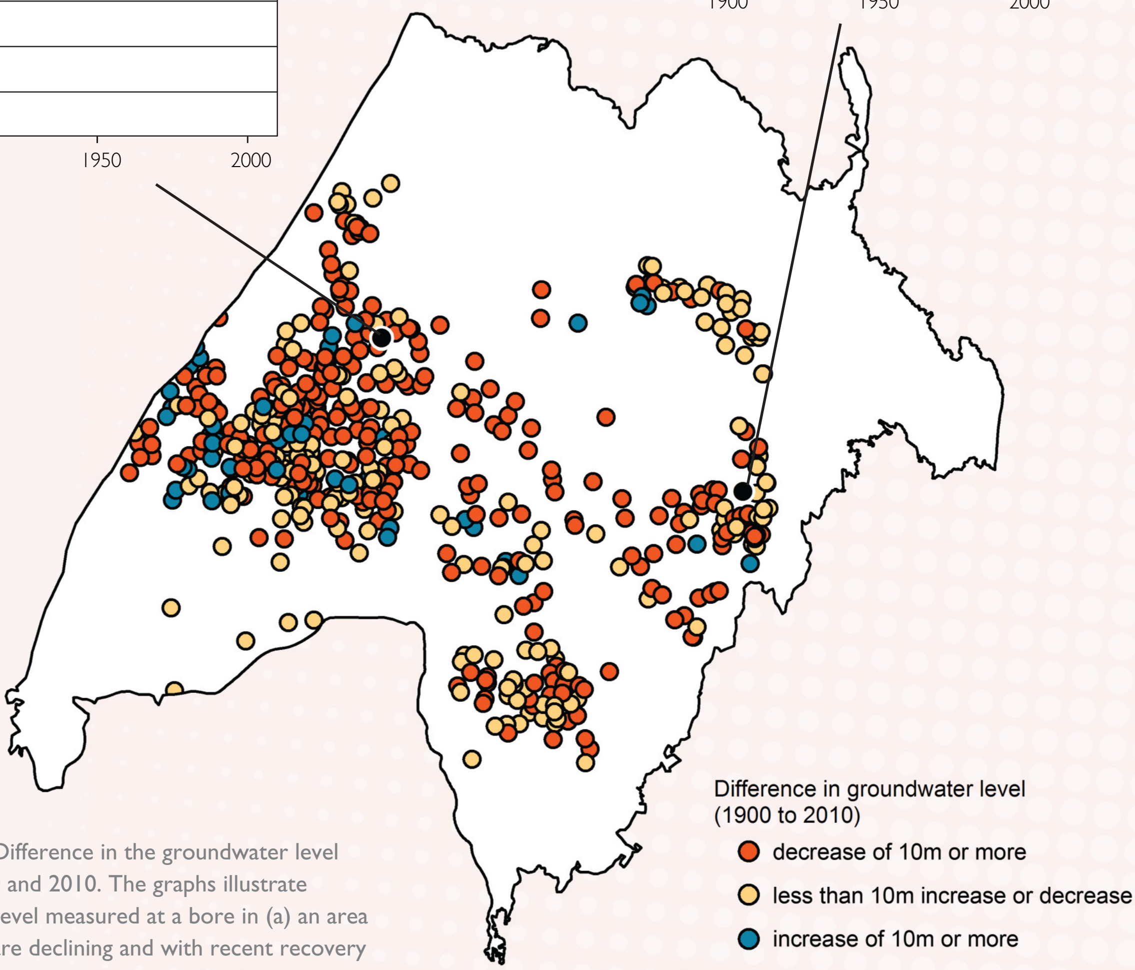
- Groundwater levels have decreased across the region since the early 1900s.
- It is likely that widespread development of the GAB has released pressure from long-term storage.
- Groundwater level recovery can be seen in some water bores.

(b) Declining groundwater levels



(a) Declining groundwater levels with recent recovery





> Figure 13. Difference in the groundwater level between 1900 and 2010. The graphs illustrate groundwater level measured at a bore in (a) an area where levels are declining and with recent recovery and (b) an area where levels are declining and with no recovery. Values are expressed as an elevation (mAHD)

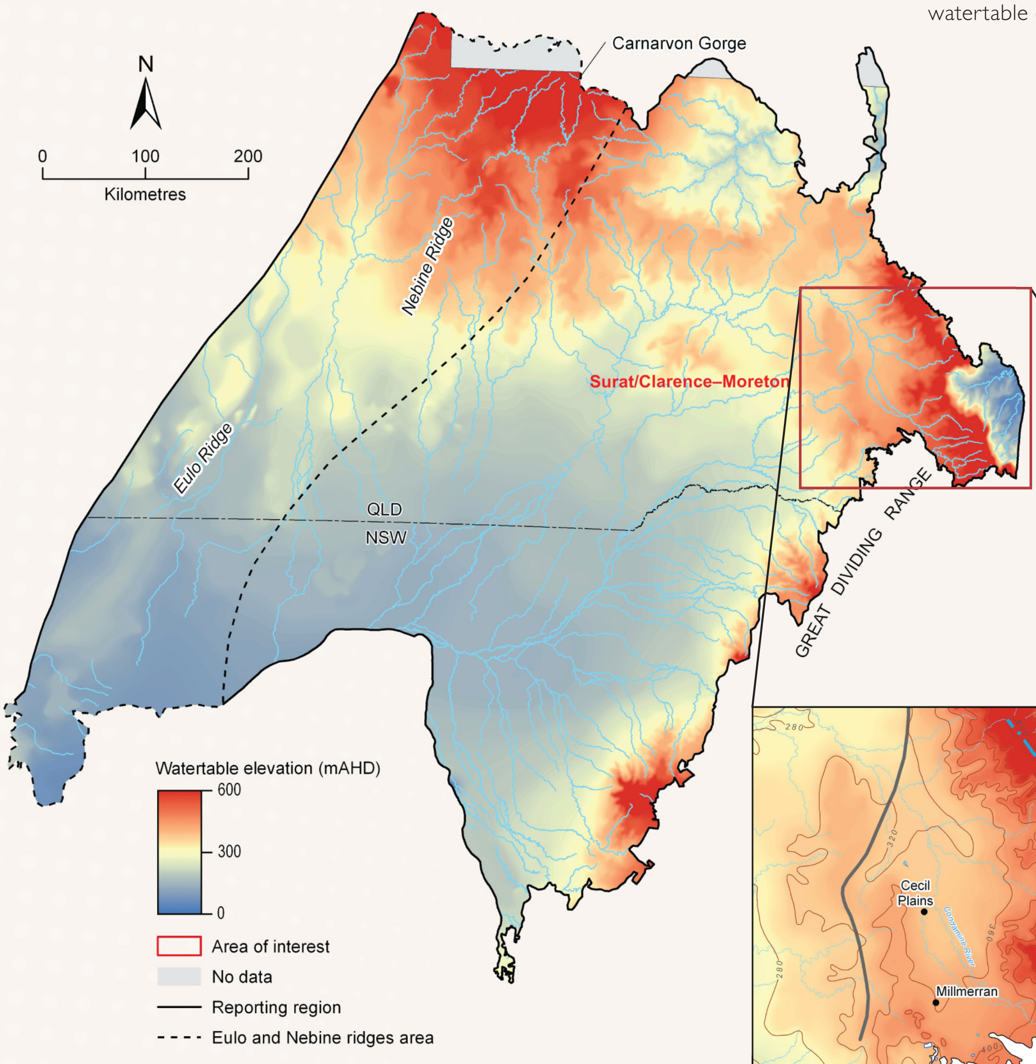
The Surat and the Clarence-Moreton basins: finding the groundwater divide

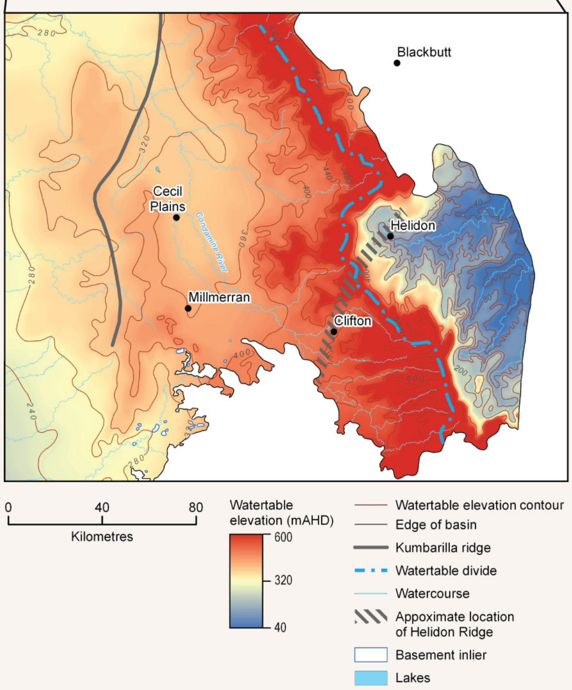
Just as the Great Dividing Range marks the boundary between catchments that flow eastward to the Pacific Ocean or westward into the Murray-Darling Basin, a groundwater divide marks the boundary between two groundwater basins beside each other. The groundwater divide between the Surat and the Clarence-Moreton basins is complex.

Figure 14 shows the approximate **watertable** elevation for the Surat region.

The shape of the watertable contours is similar to a topographic map. Groundwater will flow from higher watertable elevations toward lower watertable elevations.
For the eastern edge of the GAB a groundwater divide was found in the watertable (Figure 14). On the west side of the watertable divide, shallow groundwater will flow west into the Surat Basin.
On the east side of the watertable divide, shallow groundwater will flow east, into the Clarence-Moreton Basin.

For deeper layers in the GAB, there is a different groundwater divide. This is due to influences from deeper, older geological structures underneath the GAB. The Jurassic-age rock layers between the Surat Basin and the Clarence-Moreton Basin drape across a deeper geological structure called the Helidon Ridge (Figure 9). This ridge is expected to influence groundwater flow in the deeper aquifers in the GAB and form a different groundwater divide than occurs in the watertable (Figure 14).





> Figure 14. Map of the approximate watertable elevation, defined as the shallowest groundwater in the uppermost geological formations. The area where the Surat Basin and the Clarence-Moreton Basin are connected is shown in detail. Two groundwater divides are shown for shallow and deeper groundwater
Note: to show greater detail, area of interest inset uses different scales and watertable elevation ranges

Water budget components

A water budget describes the amount of groundwater inflow and outflow. For a complex groundwater system – such as the GAB – there could be several different components for inflow and outflow. There is a degree of uncertainty about each component of the water budget. This can lead to a range of values – that have either been determined from a single method (having a range of uncertainty) or from using the findings from different studies.

The known water budget components for the Cadna-owie – Hooray Aquifer, which is the main aquifer in the GAB, are shown in the table below. Although not all values are known for certain, the water budget components indicate outflows are greater than inflows for the region.

Groundwater Recharge	Occurs through the intake beds located on the western slopes of the Great Dividing Range. Inflow rates are estimated by a method called the chloride-mass-balance using groundwater data or from the results of groundwater modelling.	Estimates vary from 157 GL/year (this Assessment) to 295 GL/year (previous studies) using the chloride-mass-balance. The large-scale groundwater model (page 4) found recharge to be 185 GL/year.
Spring Discharge	Naturally occurring groundwater discharge at the ground surface. Measured rates of spring flow are known for some individual springs that have been studied, but not all springs in the region.	Estimated to be 14 GL/year based on an extensive study undertaken in 1982.
Bore Extraction	The combination of free or controlled artesian flow and pumped extraction from water bores drilled into the aquifers. Measured rates of bore extraction are not known for all bores in the region.	Estimated to be 232 GL/year in the large-scale groundwater model (page 4).
Diffuse Discharge	Slow vertical leakage from the aquifers upwards to the regional watertable. In some locations, leakage may be enhanced by the presence of preferential pathways – such as faults. Estimated by a method using Darcy's Law assuming that preferential pathways cover a varying amount of the region.	Estimated to be 46 GL/year assuming that 5 percent of the region has preferential pathways, 92 GL/year assuming that 10 percent of the region has preferential pathways, and 139 GL/year assuming that 15 percent of the region has preferential pathways. The exact amount of preferential pathways is unknown.

So what does it all mean?

The Assessment modelling shows that future groundwater conditions are driven largely by changes in groundwater extraction.

- Under most future scenarios considered, increases in groundwater level are attributed to the remaining 25 percent of the total expected groundwater savings under GABSI.
- The majority of groundwater extraction for CSG development is expected to be finished by 2050, so the decline in groundwater levels caused by CSG development in the Cadna-owie – Hooray Aquifer, is estimated to be less than 0.2 meters by 2070 over much of the region.
- Many springs in the Bourke and Eulo supergroups are currently inactive. Further decreases in groundwater levels will not increase risk to these springs, but could affect currently active springs in the Bourke supergroup.

Historical groundwater levels show the impact of significant groundwater extraction from the region.

- From 1900 to 2010 groundwater levels declined over much of the region with the largest decline in the northern half of the region.
- The recovery of groundwater levels can be seen in some areas recently due to bore rehabilitation under GABSI.

> Precipice Sandstone Moolayember Formation (boundary between Jurassic and Triassic aged layers), Carnarvon Gorge (Geoscience Australia)

Understanding groundwater

Basic terms and concepts

Aquifer: a permeable geological material that can transmit significant quantities of water to a bore, spring, or surface water body. Generally, 'significant' is defined based on human need, rather than on an absolute standard.

Aquitard (sometimes called '**confining layers**'): a saturated geological unit that is less permeable than an aquifer, and incapable of transmitting useful quantities of water. Aquitards often form a confining layer over an aquifer.

Artesian aquifer (artesian bore): an artesian aquifer has enough natural pressure to allow water in a bore to rise to the ground surface. The groundwater level of an artesian aquifer is higher than the ground surface. A bore completed in an artesian aquifer is referred to as an artesian bore.

Geological basin: layers of rock that have been deformed by mega-scale geological forces to become bowl-shaped. Often these are round or oblong (troughs) with a depression in the middle of the basin.

Groundwater level: the equivalent elevation in meters relative to the Australian Height Datum (mAHD).

Geological faults: a large fracture or discontinuity in one or more rock layers. Faults are caused by tectonic forces and result in horizontal or vertical displacement.

Geological formation: geological formations consist of rock layers that have common physical characteristics (lithology) deposited during a specific period of geological time.

Groundwater (hydrogeology): water that occurs within the zone of saturation beneath the Earth's surface. The study of hydrogeology focuses on movement of fluids through geological materials (e.g. layers of rock).

Groundwater basin: a non-geological delineation for describing a region of groundwater flow. Within a groundwater basin, water enters through recharge areas and flows toward discharge areas.

Groundwater flow: within a groundwater basin, the path from a recharge area to a discharge area is referred to as a groundwater flow system, where travel time may be as short as days or longer than centuries, depending on depth. The mechanics of groundwater flow are governed by the structure and nature of the sequence of aquifers.

Groundwater flow model: a computer simulation of groundwater conditions in an aquifer or entire groundwater basin. The simulations are representations based on the physical structure and nature of the sequence of aquifers and rates of inflow (from recharge areas) and outflow (through springs and wells).

Groundwater recharge and discharge: recharge occurs where rainfall or surface water drains downward and is added to groundwater (the zone of saturation). Discharge occurs where groundwater emerges from the Earth, such as springs or seepage into rivers.

Intake beds: areas where the major aquifers of the GAB are exposed at the ground surface and become recharged. The GAB intake beds are generally located along the western slopes of the Great Dividing Range.

Spring complex: clusters of springs that share similar water chemistry and geomorphological setting, which are related to common geological features; clusters of spring complexes are referred to as '**supergroups**'.

Watertable: the surface where the groundwater level is balanced against atmospheric pressure. Often, this is the shallowest water below the ground.

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