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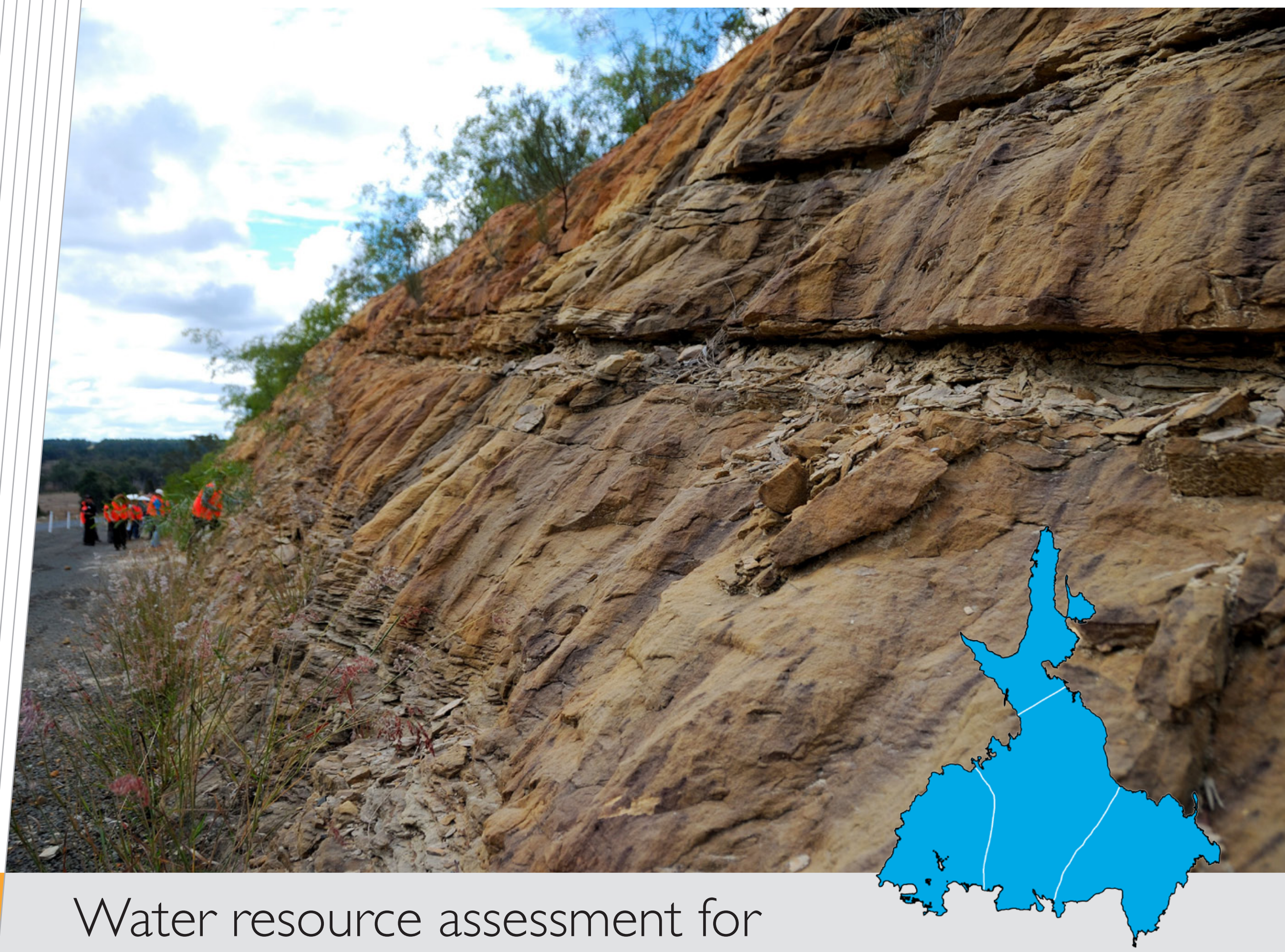

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Water resource assessment for the Great Artesian Basin

Synthesis 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.

> Area of groundwater discharge in the Great Artesian Basin, South Australia (CSIRO)

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Great Artesian Basin Water Resource Assessment acknowledgments

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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 the 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.

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Cover photograph

Exposure of the Hutton Sandstone Formation in Queensland, which forms a major aquifer in the Great Artesian Basin.
Courtesy of CSIRO Land and Water.

Assessing groundwater resources in the Great Artesian Basin

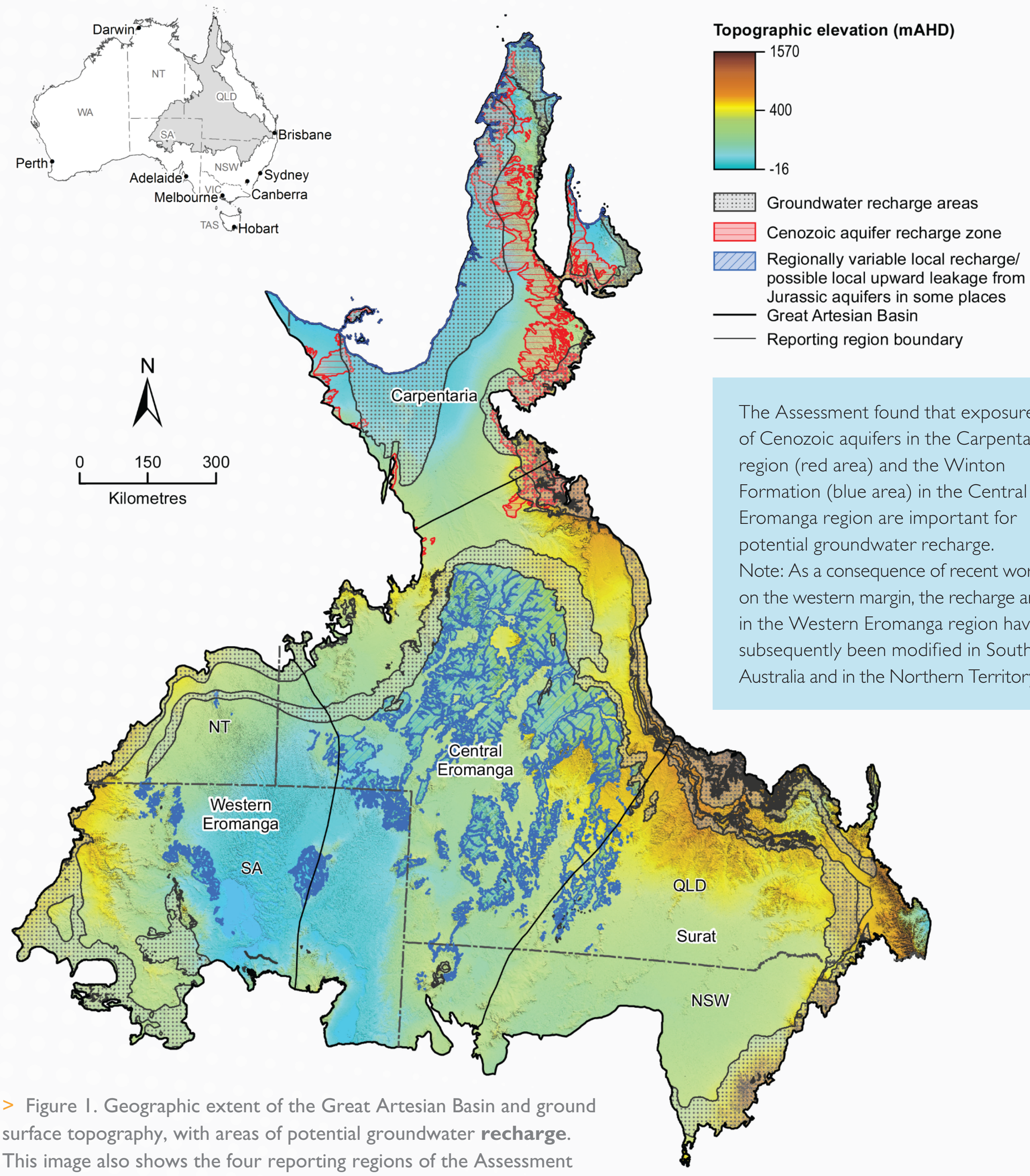
The Great Artesian Basin (GAB) is Australia's largest groundwater basin. It underlies arid and semi-arid regions and extends across one-fifth of Australia, across parts of Queensland, New South Wales, South Australia and the Northern Territory (Figure 1). The Great Artesian Basin Water Resource Assessment (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.

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 synthesis report uses technical terms that may be unfamiliar to many readers – definitions of these terms are provided on the back page.

This report synthesises the findings of the Assessment, which advances the conceptual understanding of water resources of the GAB by:

- carefully evaluating the geological framework
- describing how the geology translates into hydrostratigraphy (the ability of specific layers to store and transmit water)
- characterising groundwater conditions.

The resulting improved understanding of the GAB can underpin assessments of water availability and guide water policy and water resource planning.



The Assessment found that exposure of Cenozoic aquifers in the Carpentaria region (red area) and the Winton Formation (blue area) in the Central Eromanga region are important for potential groundwater recharge.
Note: As a consequence of recent work on the western margin, the recharge areas in the Western Eromanga region have subsequently been modified in South Australia and in the Northern Territory.

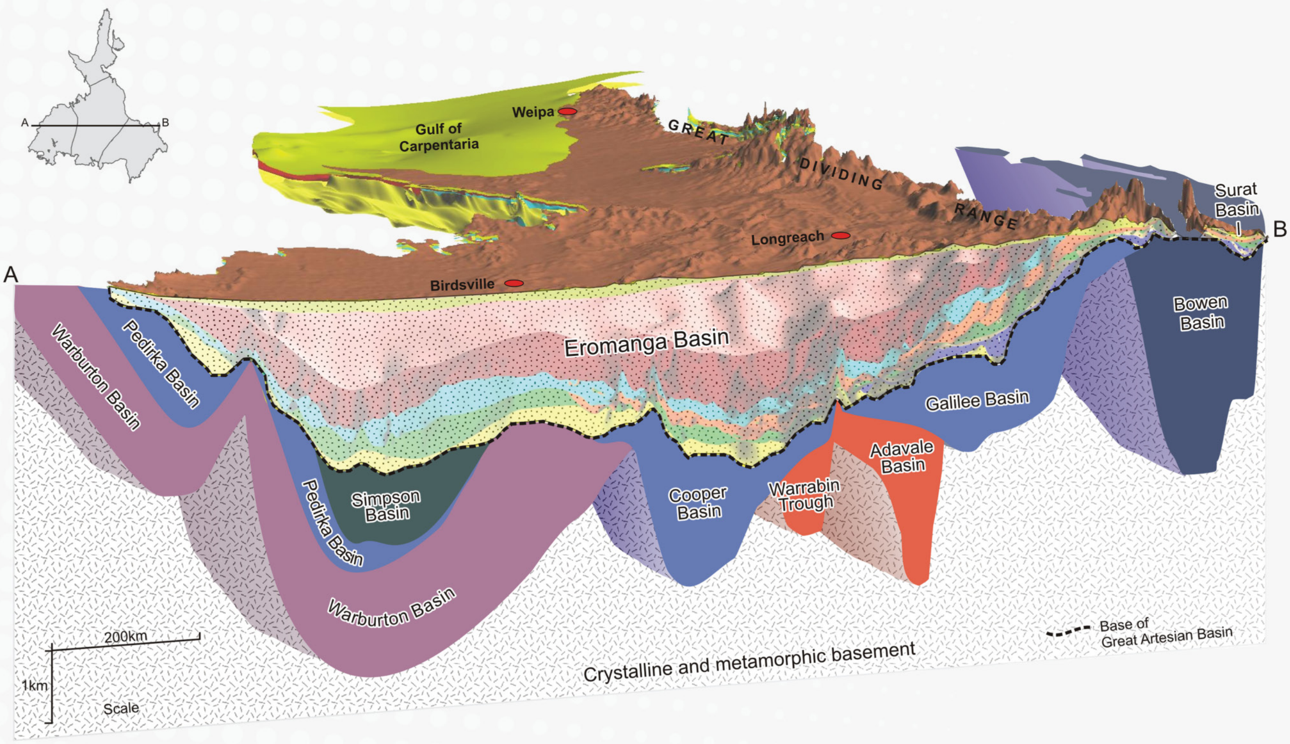
> Figure 1. Geographic extent of the Great Artesian Basin and ground surface topography, with areas of potential groundwater **recharge**. This image also shows the four reporting regions of the Assessment

The Great Artesian Basin

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 on top of 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.

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. The findings of these aspects of the Assessment are presented in companion reports that are tailored for each of the four reporting regions shown on Figure 1. These are aligned with major geological basins and include the Surat, Central Eromanga, Western Eromanga and Carpentaria regions.



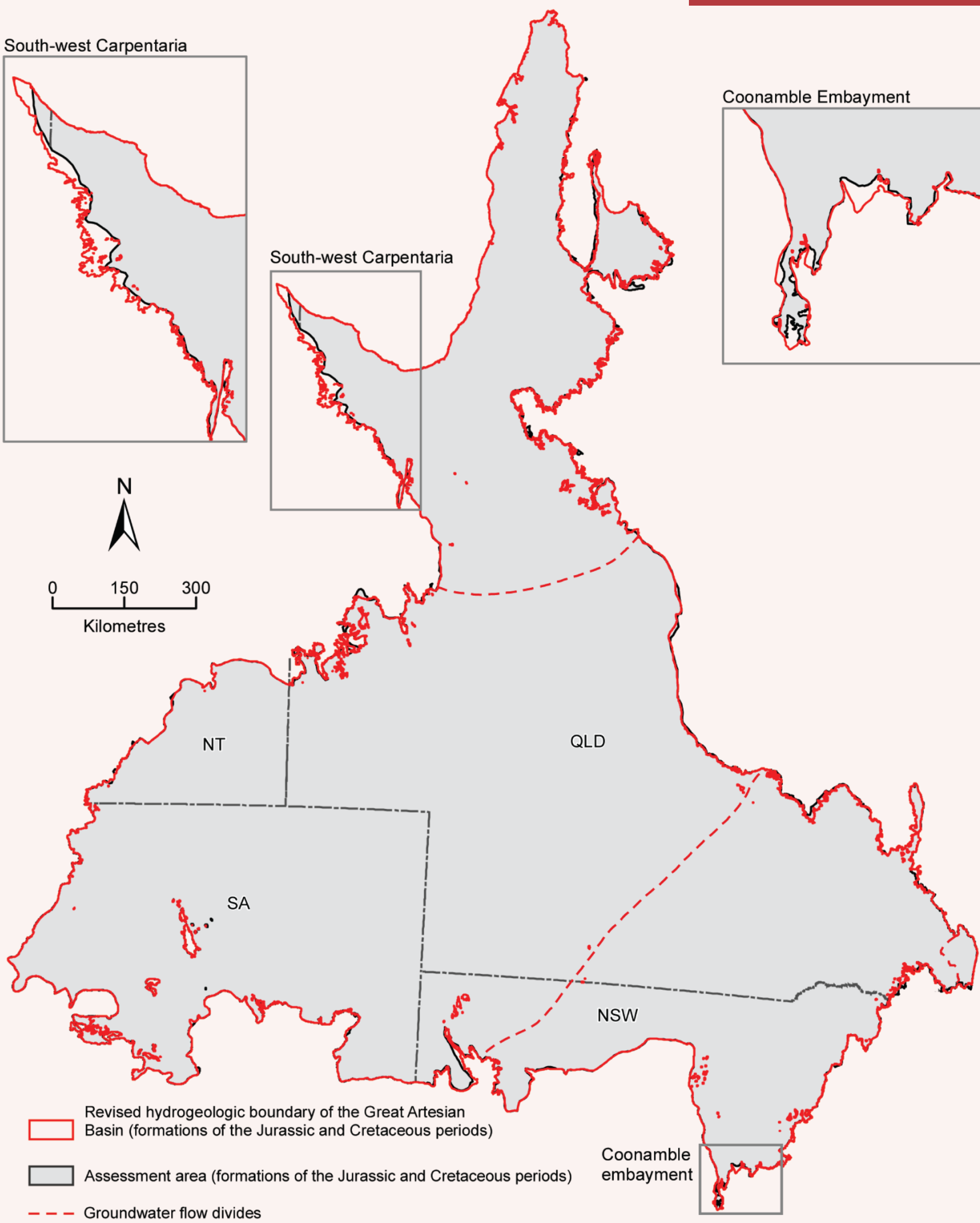
> Figure 2. Three-dimensional illustration of a slice through geological basins, including the Eromanga Basin that hosts the Great Artesian Basin (GAB). This diagram shows aquifer layers of the GAB and underlying geological basins. Because the GAB is a groundwater entity, some of the GAB aquifers may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

Updating the boundary of the Great Artesian Basin

Working with the most recent information enabled the Assessment to reinterpret the geological framework, hydrostratigraphy and groundwater conditions of the GAB. Consequently revisions to the hydrogeological boundary of the GAB have been made in the Coonamble Embayment and along the western margin near the Gulf of Carpentaria (Figure 3).

In the Coonamble Embayment, the boundary has been shifted 10 to 30 km eastward and the southern extent approximately 60 km further south. In the South-west Carpentaria, the updated boundary lies up to approximately 35 km further west than previously described.

- As a result of reinterpreting the geological framework, hydrostratigraphy and groundwater conditions, several modifications of the boundaries have been proposed for the Jurassic-Cretaceous sediments of the GAB.
- These changes are based on the most up-to-date information and could inform groundwater management in Queensland and New South Wales.



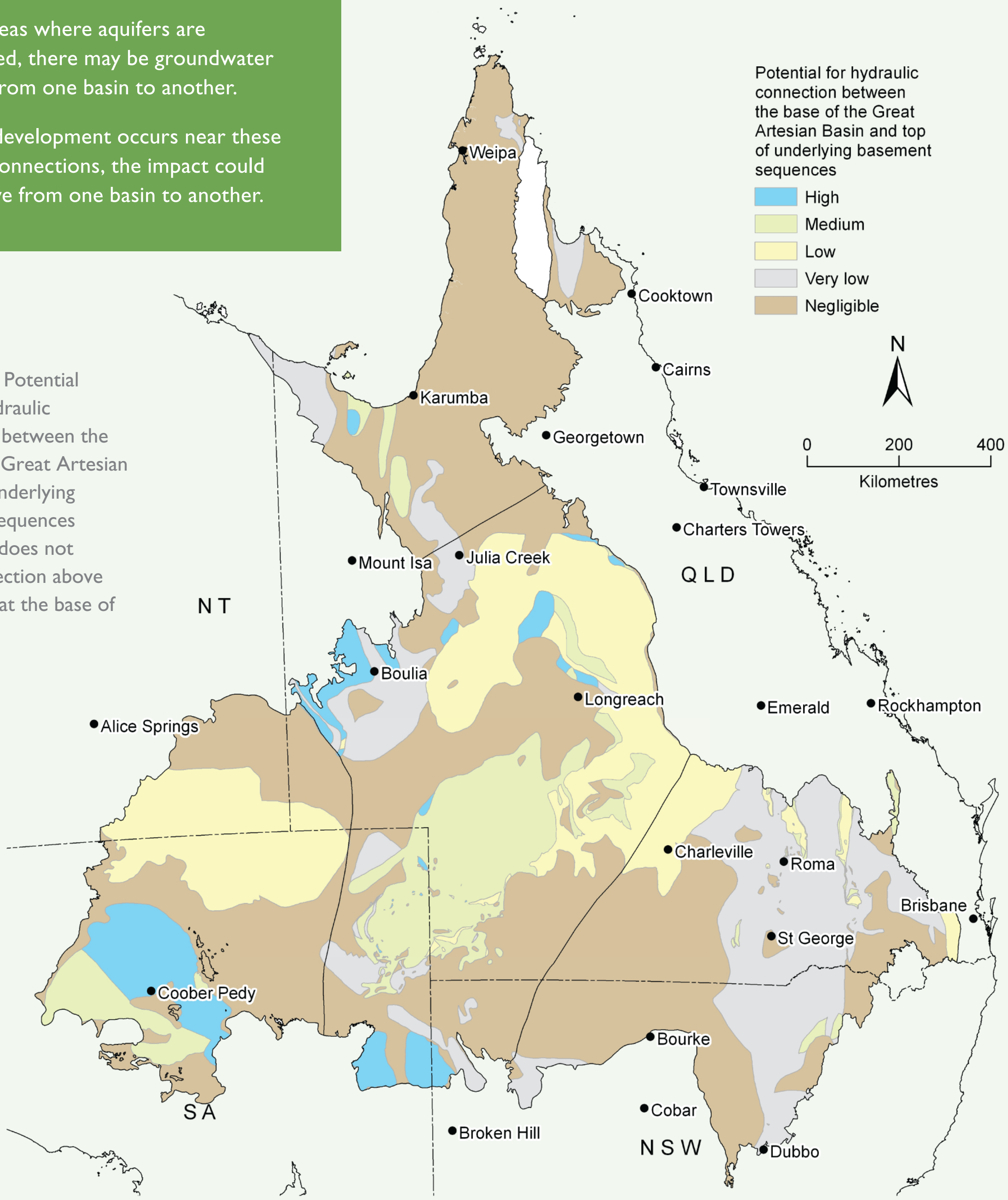
> Figure 3. Revised hydrogeological boundary of the Great Artesian Basin
Note: the outliers in South Australia represent protrusion of older rocks through the GAB

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

The Jurassic to Middle Cretaceous age sediments in the GAB were deposited on top of older geological basins (Figure 4). It is these underlying basins that cause the GAB to have its structure and general shape. Basins that underlie the GAB include the Bowen, Cooper, Galilee, Pedirka, Simpson and Arckaringa basins.

Because the GAB is situated on top of these deeper geological basins, there are some locations where GAB aquifers are connected to aquifers in the deeper basins. The connections form a patchwork across the GAB, with approximately 50 percent overlap of the Eromanga Basin, 10 percent of the Surat Basin, and 5 percent of the Carpentaria Basin. In Queensland, there are sections of the Warang and Clematis sandstone formations in the Galilee Basin that are also **artesian**, which creates a potential for groundwater inflow to the GAB.

- Aquifers in the GAB are potentially connected with aquifers in deeper, older geological basins that lie beneath the GAB.
- In the areas where aquifers are connected, there may be groundwater moving from one basin to another.
- Where development occurs near these critical connections, the impact could also move from one basin to another.

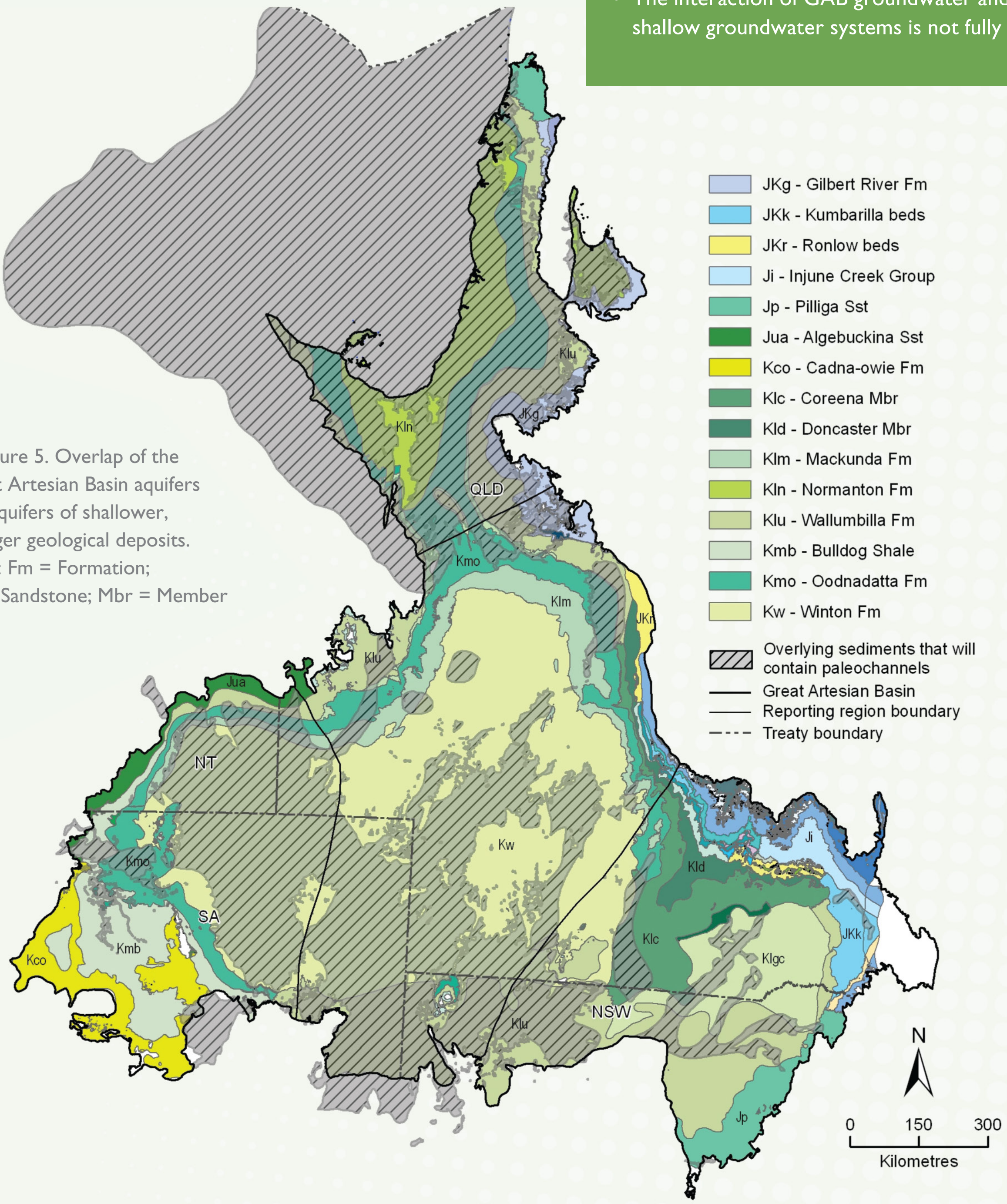


> Figure 4. Potential areas of hydraulic connection between the base of the Great Artesian Basin and underlying basement sequences
Note: map does not imply connection above formations at the base of the GAB

The Great Artesian Basin and shallower, younger geological basins: additional critical connections

In addition to the underlying, deeper geological basins, the GAB is also overlain by shallower geological basins. Extensive Cenozoic age sedimentary basins have covered the Jurassic and Cretaceous sediments of the GAB (Figure 5). The Cenozoic deposits contain at least two significant features that influence the vertical connectivity between the GAB and surface water systems (including shallow alluvial groundwater systems). The development of **paleochannels** create permeable pathways that potentially increase the vertical connections. The reworking of sediments by erosion and deposition could reduce vertical connections.

- Aquifers in the GAB are potentially connected with geological deposits in shallower, younger geological basins that sit on top of the GAB.
- The overlying deposits contain complex shallow groundwater systems that are sometimes used for domestic and agricultural purposes.
- Potential connectivity occurs where overlying sediments containing paleochannels interact with formations at the top of the GAB.
- The interaction of GAB groundwater and these shallow groundwater systems is not fully known.



> Figure 5. Overlap of the Great Artesian Basin aquifers and aquifers of shallower, younger geological deposits. Note: Fm = Formation; Sst = Sandstone; Mbr = Member

Geological faulting and groundwater flow

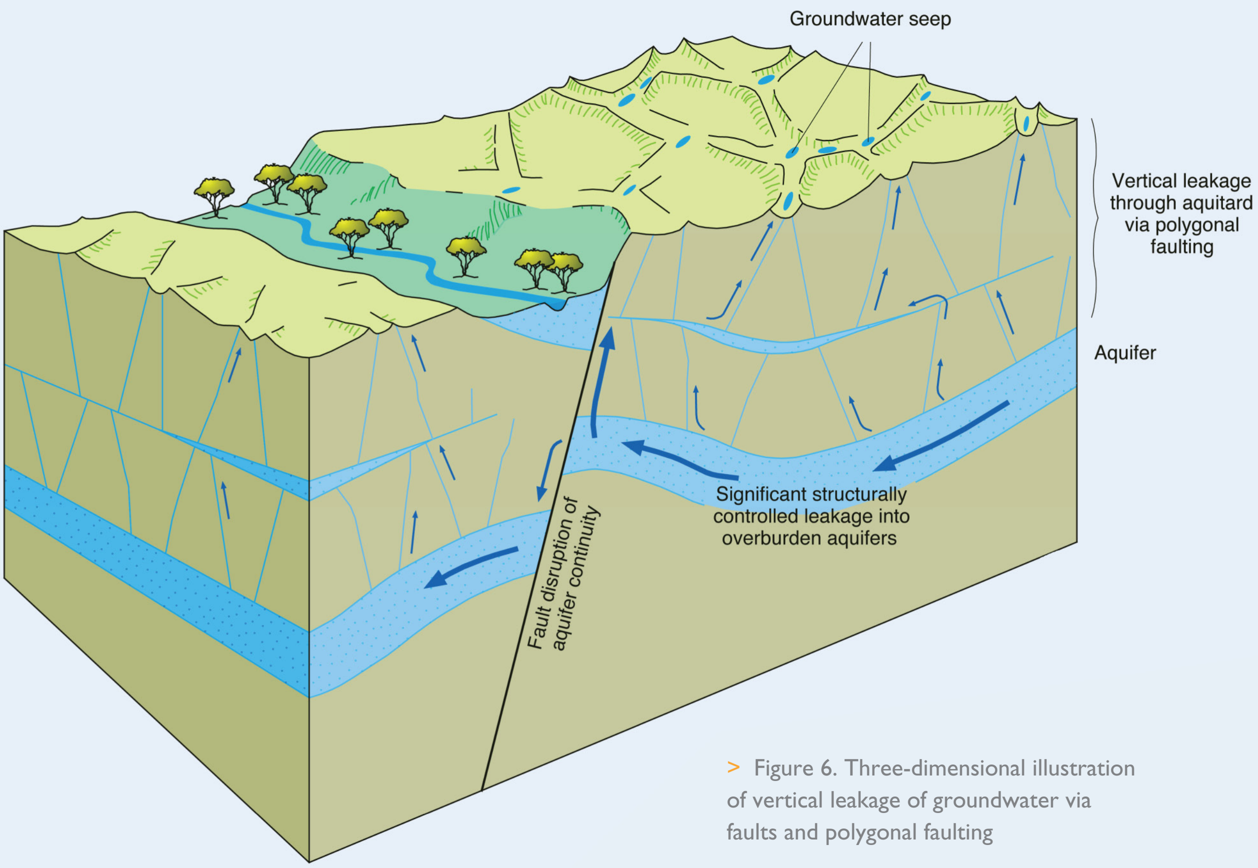
The structure and shape of the rock layers in the GAB have resulted from continental-scale stresses that have occurred over geological time. Beginning 65 million years ago – when the last sediments were deposited that would eventually become aquifers in the GAB – these geological forces have shifted rock layers. The end result seen today is rock layers that have been folded, bent and (in many locations) **faulted**. These geological faults are present across the GAB (Figure 6) and affect groundwater levels.

In many locations the faulting has caused a single rock layer to be disrupted and displaced. The amount of displacement can be mapped from geological and geophysical data.

Across the GAB, displacement can vary from tens of metres to hundreds of metres. For a small amount of displacement, a rock layer that forms an aquifer may still have lateral connection across the faulted area. However, in some locations, a large amount of displacement results in a disconnection. Large displacements could create barriers to groundwater flowing through the GAB. Accurately determining the effect of this large-scale geological faulting on groundwater flow in the GAB is an ongoing challenge for scientists.

However, adding to the body of new knowledge about the GAB, the Assessment found that smaller-scale polygonal faulting is present in the Rolling Downs Group – a thick sequence of aquitards and partial aquifers overlying the Cadna-owie – Hooray Aquifer in the Eromanga Basin. These unique features have formed potential conduits for upward leakage from the GAB aquifers. The complete effect of polygonal faulting on the groundwater conditions of the GAB is unknown.

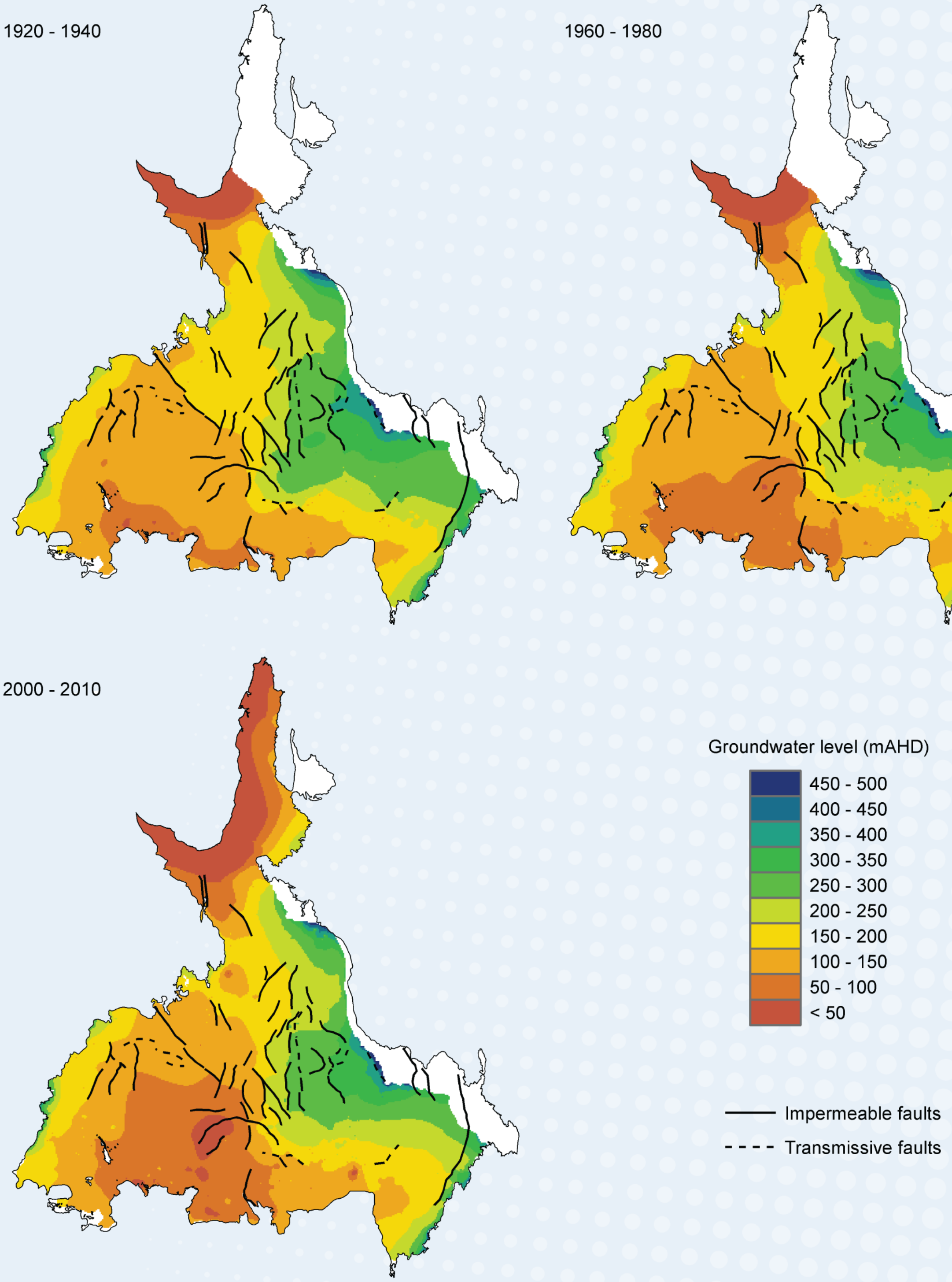
- Across the GAB, the layers have been disrupted by geological faulting.
- Faulting creates a disconnection, where an aquifer layer terminates abruptly against a different layer that has been moved because of faulting.
- These abrupt changes create barriers to groundwater flow, which could cause unexpected changes in groundwater level where groundwater development occurs. A decrease in level caused by groundwater extraction may go unnoticed in a nearby water bore if there is a fault.



> Figure 6. Three-dimensional illustration of vertical leakage of groundwater via faults and polygonal faulting

The presence of faults could create barriers for flowing groundwater, which can be seen in the maps of groundwater levels (Figure 7). The location and direction of the faults are a controlling factor of the spatial distribution of groundwater levels, which in turn is the controlling factor for groundwater flow direction and rate – groundwater moves from areas where groundwater levels are higher to areas where groundwater levels are lower.

Groundwater levels in the GAB are highest along the northern and eastern margins, where the aquifers are exposed near the **intake beds**. Groundwater levels diminish towards the north-west, west, south-west and south.

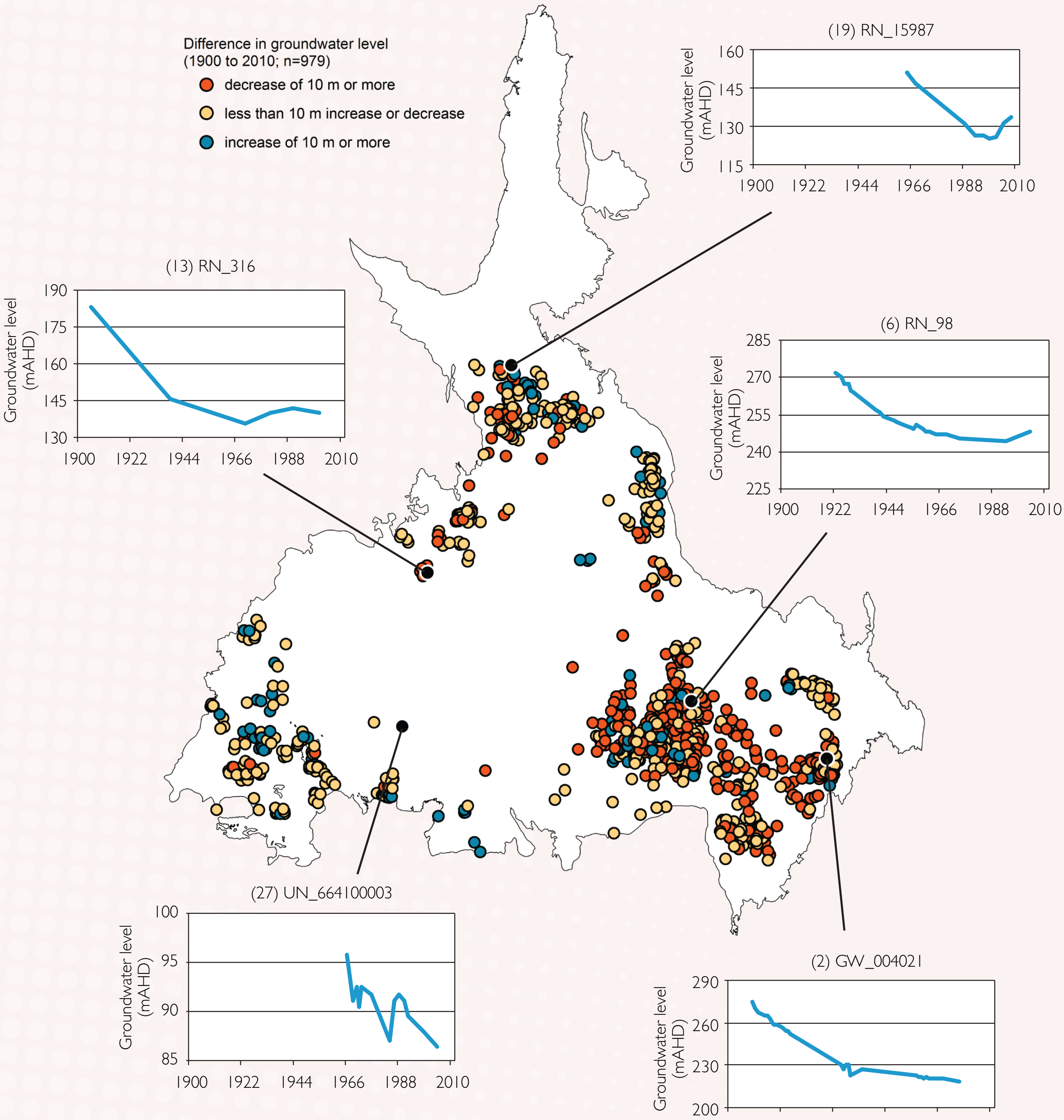


> Figure 7. Groundwater level maps for the Cadna-owie – Hooray Aquifer across the Great Artesian Basin for different time periods since the start of groundwater development in Great Artesian Basin aquifers. Note: the most recent map (2000 to 2010) includes results from modelling of equivalent aquifers in the Cape York region, which has insufficient measured data to create groundwater levels as was done for the remainder of the Great Artesian Basin

Measuring groundwater levels: the change since 1900

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 beginning in 1900. Assessment of groundwater level maps for 20-year intervals and trends in some individual bores clearly illustrates the decline in groundwater levels in the early part of the last century, but more recently an increase (recovery) of groundwater levels is evident from bore capping and water piping activities (Figure 8).

- Groundwater levels have decreased across the GAB since the early 1900s.
- Groundwater level recovery can be seen in some water bores as a result of rehabilitation under the Great Artesian Basin Sustainability Initiative.



> Figure 8. Difference in groundwater levels from pre-development (circa 1900) to the present day (circa 2010)

Advancing the conceptual understanding of the Great Artesian Basin

The conceptual understanding of the GAB has grown steadily since the late 19th Century. A long-accepted view of the GAB is as a single, large, contiguous groundwater flow system in which aquifers are considered to be laterally continuous across the extent of the entire GAB. However, this view does not adequately reflect what is now understood about the hydrogeological complexity that governs groundwater movement in the GAB.

The new knowledge and findings of the Assessment confirm that the GAB must be viewed as an extensive and complex groundwater basin, rather than a simple, laterally continuous aquifer. As the conceptual understanding of the GAB is the foundation for assessing water availability and provides guidance to water policy and water resource planning, key complexities of the groundwater system must now be considered, including:

- Categorisation of GAB layers into 'aquifer, partial aquifers, leaky aquitards, tight aquitards and aquicludes', which better represent the variability of geological formations.
- Connection with underlying and overlying geological basins. At present, the rate of groundwater movement between the GAB and these basins is unknown and requires further research.
- The presence of faults and either the potential disruption or enhancement of vertical groundwater movement in the GAB.

With the addition of these geological complexities, a more complete representation of groundwater conditions in the GAB is possible.

The conceptual understanding of the GAB should be incorporated into the next generation of groundwater models for the GAB. Groundwater modelling provides a rigorous method to evaluate the conceptual understanding of a groundwater system, where the real-world complexity is balanced against its certainty and requirement to accurately represent groundwater conditions. Inclusion of multiple layers, connectivity with overlying and underlying geological formations, and the presence of faults could potentially improve the predictive ability under future scenarios of climate change and groundwater development.

Assessment reporting

Details of these findings can be found in the reporting of the Assessment in a range of products including four region reports (with companion summaries), a whole-of-GAB report and in a number of technical reports that 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.

All of the Assessment reporting is available online at <http://www.csiro.au/science/Great-Artesian-Basin-Assessment>.

> The Bubbler mound spring in South Australia (CSIRO)

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 that 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 metres 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.

Paleochannel: remnant of an inactive river or stream channel that has been either filled or buried by younger sediments.

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