Independent Expert Scientific Committee
on Coal Seam Gas and Large Coal Mining Development

Australian Government
Department of the Environment

Knowledge report

Ecological and hydrogeological survey of the Great Artesian Basin springs - Springsure, Eulo, Bourke and Bogan River supergroups

Volume 1: history, ecology and hydrogeology

This report was commissioned by the Department of the Environment on the advice of the Interim Independent Expert Scientific Committee on Coal Seam Gas and Coal Mining. The review was prepared by UniQuest and revised by the Department of the Environment following peer review.

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Disclaimer

Contents

Summary

This project report describes the surveys of 848 springs in four Great Artesian Basin (GAB) supergroups: 252 in Springsure, 436 in Eulo, 145 in Bourke and 7 in Bogan River. The surveys included all of the likely *Environment Protection and Biodiversity Conservation Act 1999* (Cwlth)– (EPBC Act–) listed springs. A further eight spring locations in the Eulo, Bourke and Bogan River supergroups, and 105 in the Springsure supergroup, have not yet been surveyed but are considered unlikely to be EPBC Act related.

The project team surveyed 503 springs in 94 spring complexes that had not previously been surveyed; and extended the current knowledge base of other previously surveyed springs.

This report is presented as two volumes:

- *Ecological and hydrogeological survey of the Great Artesian Basin springs - Springsure, Eulo, Bourke and Bogan River supergroups. Volume 1: history, ecology and hydrogeology, Knowledge report* (**this report**), which is divided into two main sections:
  - Part 1: Cultural history and ecological values of Great Artesian Basin springs in the Springsure, Eulo, Bourke and Bogan River supergroups—provides information on the history and ecology of the spring supergroups.
  - Part 2: Hydrogeological survey of the Great Artesian Basin springs in the Springsure, Eulo, Bourke and Bogan River supergroups—provides information on the hydrogeology of the spring supergroups, including identification of source aquifers and an analysis of the potential impacts of coal seam gas development on the springs.
- *Ecological and hydrogeological survey of the Great Artesian Basin springs - Springsure, Eulo, Bourke and Bogan River supergroups. Volume 2: hydrogeological profiles, Knowledge report* (CoA 2014), which includes a database of GAB springs and hydrogeological profiles for springs with both a high-conservation ranking and EPBC Act listing in the targeted supergroups.

Springs have been classified into discharge (EPBC Act–listed community), and recharge or watercourse (not EPBC Act–listed community) springs. Fifteen GAB spring-specific conceptual models were developed to describe the hydrogeological setting of springs and to clarify the definition of discharge springs that identifies EPBC-listed springs. Nine of these conceptual models describe EPBC Act–listed springs (Appendix E, types C to K).

All 92 EPBC Act–listed discharge springs in the Springsure supergroup have been surveyed. The unsurveyed springs are elevated in the landscape and unlikely to be affected by coal seam gas activities. Habitat for EPBC Act–listed species *Eriocaulon carsonii* is present in 23 springs in the Springsure supergroup, habitat for *Arthraxon hispidus* in 24 springs and habitat for *Thelypteris confluens* in two springs. Species listed under the *Nature Conservation Act 1992* (Qld) (NCA Act) occur in 56 springs of the Springsure supergroup.

In the Eulo supergroup, there are 177 active EPBC Act–listed discharge springs with four springs at one location providing habitat for the EPBC Act–listed species *Eriocaulon carsonii.* A further two springs in the Eulo supergroup contain species listed under the NCA Act, and 22 springs contain species endemic to spring wetlands.

In the Bourke supergroup, there are 51 active EPBC Act–listed discharge springs with six springs at one location providing habitat for the EPBC Act–listed species *Eriocaulon carsonii*, which is also listed under the *Threatened Species Conservation Act 1995* (NSW). No other springs in the Bourke supergroup support endemic species. There are no active springs in the Bogan River supergroup.

The importance of springs to Indigenous people for the past thousands of years is evident in the archaeological record, although stories relating to individual springs in the regions studied in this project have mostly not been told.

The Eulo and New South Wales springs were similarly vital to early pastoralists as the only reliable sources of water across large semi-arid expanses. However, as bores were drilled since the late 1800s and the extent of the GAB became known, springs became redundant. Many springs dried up as artesian aquifer pressures were drawn down by flowing artesian bores, and spring locations were eventually forgotten.

Due to the loss of springs, and the local impacts of excavation, piping, and feral and domestic herbivores, many populations of endemic species were lost, and it is likely that some spring-dependent species became extinct.

The ability to identify source aquifers for springs is dependent on the quantity and quality of data for nearby waterbores. The lack of bore screen data at the Eulo supergroup, and interpreted stratigraphy for New South Wales bores and springs, limited our ability to determine source aquifers for springs of the Eulo, Bourke and Bogan River supergroups with certainty.

Springs in the Springsure group are most likely to be impacted by current coal seam gas development. Of particular concern are the Lucky Last and Scotts Creek springs, with a predicted (modelled) artesian pressure drawdown of more than 0.2 metres, due to hydraulic connectivity between targeted coal seams and their likely source aquifer. These two discharge spring clusters (hence, EPBC Act–listed communities), provide habitat for the EPBC Act–listed species *Eriocaulon carsonii* and they have high-conservation value. Other springs that may be impacted, although with a predicted (modelled) drawdown of less than 0.2 metres, include Spring Rock Creek, Abyss and possibly Dawson River 8. It should be noted that the drawdown risk threshold of 0.2 metres—as set in s. 379 (3) of the *Water Act 2000* (Qld), and used to assess and rank springs likely to be impacted by coal seam gas—is more a reflection of the predictive capability of the groundwater model than the level of drawdown that would have an impact on a spring's ecological values.

Coal seam gas development and extraction is currently remote from active springs in the Eulo, Bourke and Bogan River supergroups, and is of less concern than large free-flowing artesian pastoral bores in proximity to springs that have not as yet been rehabilitated and regulated.

Springs supporting endemic species must be the focus of ongoing conservation efforts. Particularly urgent is the rehabilitation of remaining high-flow artesian bores that occur within 50 kilometres of high-value spring groups. Fencing, secure tenure agreements and strategic ongoing pest control will also be important.

Groundwater data collection and modelling capabilities need to be improved to more accurately predict the impact of coal seam gas extraction on aquifers that source springs in the Springsure supergroup.

The database presented as part of the project report and any updated version, need to be extended to include all springs throughout the Basin. This will assist the priority setting for conservation efforts and inform regulatory decision-making in the regions of coal seam gas and large coal mining activities, and allow consideration of their impacts on surface and groundwater resources.

This report should be read in conjunction with complementary work recently completed by the Queensland Water Commission (QWC 2012b, *Underground water impact report for the Surat Cumulative Management Area*) and by the National Water Commission (NWC 2013, *Allocating water and maintaining springs in the Great Artesian Basin*).

Further background information can be found in work completed by the Queensland Herbarium (2012 *Ecological and botanical survey of springs in the Surat Cumulative Management Area*) and by the Queensland Water Commission (QWC 2012a, *Hydrogeological attributes associated with springs in the Surat Cumulative Management Area*).

Abbreviations

General abbreviations	Description
DERM	Queensland Government Department of Environment and Resource Management (ceased operations in 2012)
DNR	Queensland Department of Natural Resources
EPBC Act	*Environment Protection and Biodiversity Conservation Act 1999*
GAB	Great Artesian Basin
GWDB	Groundwater Database
L/s	litres per second

Glossary

Term	Description
Alkalinity	The quantitative capacity of aqueous media to react with hydroxyl ions. The equivalent sum of the bases that are titratable with strong acid. Alkalinity is a capacity factor that represents the acid-neutralising capacity of an aqueous system.
Anthropogenic	Relating to, or resulting from, the influence of human beings on nature.
Anticline	In structural geology, an anticline is a fold that is convex up and has its oldest beds at its core.
Aquifer	Rock or sediment in formation, group of formations or part of a formation, that is saturated and sufficiently permeable to transmit quantities of water to wells and springs.
Aquifer connectivity	The degree to which groundwater can transfer between two adjacent aquifers or to the surface.
Aquifer discharge	Water leaving an aquifer.
Aquifer recharge	The amount of water replenishing an aquifer over a given time period.
Aquitard	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 artesian aquifer.
Artesian	Pertaining to a confined aquifer in which the groundwater is under positive pressure (i.e. a bore screened into the aquifer will have its water level above ground).
Aquatic ecosystem	Any watery environment from small to large, from pond to ocean, in which plants and animals interact with the chemical and physical features of the environment.
Bore/borehole	A narrow, artificially constructed hole or cavity used to intercept, collect or store water from an aquifer, or to passively observe or collect groundwater information. Also known as a borehole, well or piezometer.
Casing	A tube used as a temporary or permanent lining for a bore. *Surface casing*: the pipe initially inserted into the top of the hole to prevent washouts and the erosion of softer materials during subsequent drilling. Surface casing is usually grouted in and composed of either steel, PVC-U or composite materials. *Production casing*: a continuous string of pipe casings that are inserted into or immediately above the chosen aquifer and back up to the surface through which water and/or gas are extracted/injected.
Coal seam	Sedimentary layers consisting primarily of coal. Coal seams store both groundwater and gas and generally contain saltier groundwater than aquifers that are used for drinking water or agriculture.
Coal seam gas	A form of natural gas (generally 95–97 per cent pure methane, CH_4) typically extracted from permeable coal seams at depths of 300–1000 m.
Confined aquifer	An aquifer bounded above and below by confining units of distinctly lower permeability than that of the aquifer itself. Pressure in confined aquifers is generally greater than atmospheric pressure.

Term	Description
Cretaceous period	A period of geologic time, 145 million to 66 million years ago.
Depressurisation	The lowering of static groundwater levels through the partial extraction of available groundwater, usually by means of pumping from one or several groundwater bores.
Dewatering	The lowering of static groundwater levels through complete extraction of all readily available groundwater, usually by means of pumping from one or several groundwater bores.
Diffusion	Process whereby ionic or molecular constituents move under the influence of their kinetic activity in the direction of their concentration gradient.
Drawdown	The reduction in groundwater pressure caused by extraction of groundwater from a confined formation, or the lowering of the watertable in an unconfined aquifer.
Fault	A planar fracture or discontinuity in a volume of rock, across which there has been significant displacement along the fractures as a result of earth movement.
Fracture	The separation of an object or material into two or more pieces under the action of stress.
Geologic stratum	A layer of sedimentary rock or soil with internally consistent characteristics that distinguish it from other layers. The 'stratum' is the fundamental unit in a stratigraphic column and forms the basis of the study of stratigraphy.
Geological layer	A layer of a given sample. An example is Earth itself. The crust is made up of many different geological layers which are made up of many different minerals/substances. The layers contain important information about the history of the planet.
Groundwater	Water occurring naturally below ground level (whether in an aquifer or other low-permeability material), or water occurring at a place below ground that has been pumped, diverted or released to that place for storage. This does not include water held in underground tanks, pipes or other works.
Hydraulic conductivity	The rate at which a fluid passes through a permeable medium.
Hydraulic fracturing	Also known as 'fracking', 'fraccing' or 'fracture simulation', is the process by which hydrocarbon (oil and gas) bearing geological formations are 'stimulated' to enhance the flow of hydrocarbons and other fluids towards the well. The process involves the injection of fluids, gas, proppant and other additives under high pressure into a geological formation to create a network of small fractures radiating outwards from the well through which the gas, and any associated water, can flow.
Hydraulic gradient	The change in hydraulic head between different locations within or between aquifers or other formations, as indicated by bores constructed in those formations.
Hydraulic head	The potential energy contained within groundwater as a result of elevation and pressure. It is indicated by the level to which water will rise within a bore constructed at a particular location and depth. For an unconfined aquifer, it will be largely subject to the elevation of the watertable at that location. For a confined aquifer, it is a reflection of the pressure that the groundwater is subject to and will typically manifest in a bore as a water level above the top of the confined aquifer, and in some cases above ground level.

Term	Description
Hydraulic pressure	The total pressure that water exerts on the materials comprising the aquifer. Also known as pore pressure.
Hydrogeology	The area of geology that deals with the distribution and movement of groundwater in the soil and rocks of Earth's crust (commonly in aquifers).
Hydrology	The study of the movement, distribution and quality of water on Earth and other planets, including the hydrologic cycle, water resources and environmental watershed sustainability.
Jurassic period	The period of geologic time 201.3 million to 145 million years ago.
Lineaments	Linear surface expressions of subsurface fracture zones, faults and geological contacts.
Permeability	The measure of the ability of a rock, soil or sediment to yield or transmit a fluid. The magnitude of permeability depends largely on the porosity and the interconnectivity of pores and spaces in the ground.
Physicochemical parameters	Relating to both physical and chemical characteristics.
Pore-fluid pressure/pore pressure	*See* Hydraulic pressure.
Porosity	The proportion of the volume of rock consisting of pores, usually expressed as a percentage of the total rock or soil mass.
Potentiometric surface	An imaginary surface representing the static head of groundwater and defined by the level to which water will rise in a tightly cased well.
Production well	A well drilled to produce oil or gas.
Quaternary	The period of geologic time 2.5 million to zero million years ago.
Saturated zone	That part of Earth's crust beneath the regional watertable in which all voids, large and small, are filled with water under pressure greater than atmospheric.
Screen	The intake portion of a bore, which contains an open area to permit the inflow of groundwater at a particular depth interval, while preventing sediment from entering with the water.
Sediment	A naturally occurring material that is broken down by processes of weathering and erosion, and is subsequently transported by the action of wind, water or ice, and/or by the force of gravity acting on the particle itself.
Stratigraphy	A branch of geology that studies rock layers (strata) and layering (stratification).
Stratification	The formation of density layers (either temperature or salinity derived) in a water body through lack of mixing. It can create favourable conditions for algal blooms and lower dissolved oxygen levels in the bottom layers with the associated release of nutrients, metals and other substances.
Tertiary	A geologic period (from 66 million to 2.588 million years ago) that is no longer recognised as a formal unit by the International Commission on Stratigraphy, but is still widely used.

Term	Description
Tilt	The change in the slope of the ground as a result of differential subsidence. It is calculated as the change in subsidence between two points divided by the distance between those points. Tilt is usually expressed in units of millimetres per metre (mm/m), or as a ratio of rise to run (mm:mm). A tilt of 1 mm/m is equivalent to a change in grade of 0.1 per cent.
Triassic	The period of geologic time 248 million to 206 million years ago.
Unconfined aquifer	An aquifer that has the upper surface connected to the atmosphere.
Vadose zone	The 'unsaturated' zone, extending from the top of the ground surface to the watertable. In the vadose zone, the water in the soil's pores is at atmospheric pressure.
Water quality	The physical, chemical and biological attributes of water that affect its ability to sustain environmental values.
Watertable	The upper surface of a body of groundwater occurring in an unconfined aquifer. At the watertable, pore water pressure equals atmospheric pressure.
Well	A human-made hole in the ground, generally created by drilling, to obtain water. *See also* Bore
Yield	The rate at which water (or other resources) can be extracted from a pumping well, typically measured in litres per second (L/s) or megalitres per day (ML/d).

Part 1: Cultural history and ecological values of Great Artesian Basin springs in the Springsure, Eulo, Bourke and Bogan River supergroups

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1 Introduction

‘If it could be wished that any superstition should remain among us, it is that which attached a peculiar sacredness to the pure spring.’

© Copyright, Anon. (1858, p. 352)

Springs occur where water flows naturally to the earth’s surface from underground. They take many forms, depending on underlying geology and hydrology. Some feed great rivers, while others create tiny desert pools. The maxim *nullus enim fons mon sacer*—‘there is in fact no spring that is not sacred’—has been attributed to the ancient Roman King Servius, and indeed it is likely that for every spring there is a custodian and a story.

This maxim reflects the universal sanctity of water as a primordial, life-giving element (Strang 2004). However, there is something unique—astounding, even—about clear pure water rising out of earth or rock. Groundwater is by definition invisible and mysterious; we can only experience it directly once it has left its realm (Schwalbaum 1997). Perhaps then it is not surprising that springs, the surface expression of this vast and hidden world, are revered as sources of mystery and magic, healing and renewal, wisdom and transcendence; and are beloved of poets, romantics and mystics (Chapelle 1997; Dowden 2000). At the same time, terrors and passages to the underworld can lurk beneath their calm surfaces (Bowman 1998), stirring an undercurrent of ambivalence in human relations to groundwater.

In ancient times, imagination was virtually all people had to draw on when trying to explain the source and behaviour of springs, resulting in the development of elaborate mythologies that remain embedded in our associations with groundwater today (Chapelle 1997). Springs assume a special aura in desert environments due to their necessity for life and the sharp contrast with surrounding ‘inhospitable wastes’. The recurring paradisal vision in the Bible is of a desert made fruitful, blooming into a garden oasis, through the blessing of divine waters (Smith 1912; Dickson 1987). The miraculous nature of desert springs is encapsulated in Isaiah’s prophesy:

‘Then shall the lame man leap as a deer, and the tongue of the dumb shall sing: for in the wilderness shall waters break out and stream into the desert. And the glowing land shall become a pool, and the thirsty ground springs of water.’

© Copyright, (35:6)

Australia is the driest vegetated continent and has the smallest area of land surface covered by wetland of any continent. Inland Australia has been described as the ‘dead heart’, a ‘wide brown land’ and the ‘vast central desert’ (Finlayson 1935; Madigan 1946). When people imagine the interior, it is often as a dry, harsh and dusty place—the ‘great grey plain’ of Henry Lawson, a land of ‘ever-receding horizons, lonely graves’ (Durack 1959) and ‘pitiless skies’ (Duncan-Kemp 1934). In the midst of this aridity, springs provide vital physical as well as psychological succour. Their tiny surface area relative to the immensity of the surrounding landscape belies their immense ecological, cultural, economic and social significance.

1.1 Great Artesian Basin springs—background

Although there are springs throughout inland Australia, the largest clusters are those emanating from the Great Artesian Basin (GAB). Underlying one-fifth of mainland Australia, it comprises numerous aquifers. Springs occur where the potentiometric surface of the aquifer from which the water issues is above the ground surface (Habermehl 1982). Major regional clusters of spring complexes with some consistent hydrogeological characteristics form 12 ‘supergroups’ in the Basin (Figure 1).

Great Artesian Basin springs can be divided into two categories: recharge and discharge (Fensham & Fairfax 2003). Recharge springs occur within outcrop areas of sandstone formations on the eastern margins of the Basin, before the aquifer rocks dip underground. Water drains out of the rocks under gravity or through the intersection of the ground surface with a saturated aquifer, rather than welling upwards under artesian pressure. The water has a relatively short residence time in the aquifer, and tends to be neutral or slightly acidic with low levels of dissolved solids. Spring flows in recharge areas exhibit dynamism related to recent rainfall history.

Discharge springs emanate where the confining bed or aquitard is thin or weakened by faults or folds, and where aquifers abut against impervious basement rocks, mainly in relatively arid areas remote from the recharge zones. Spring flows are not related to recent rainfall, although the size of a spring wetland may fluctuate depending on seasonal conditions. Waters are generally alkaline with high levels of dissolved solids, reflecting the long residence time of the groundwater within the aquifer and because the groundwater gains salts during the upward movement from the artesian aquifer through the overlying, predominantly clayey aquitards. There are three broad types of discharge springs: peat, mud and water; the distinction between the two latter types is considered in detail in Chapter 3.

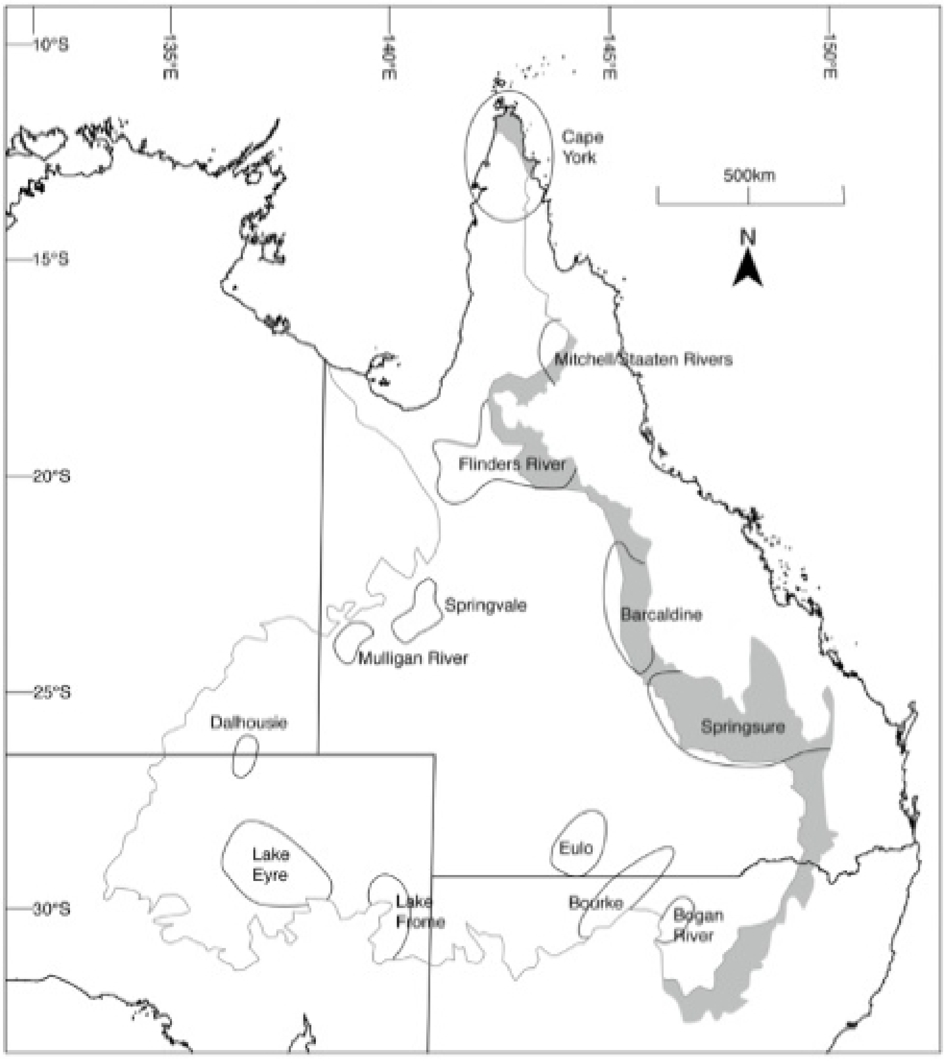


Figure 1 Great Artesian Basin, showing spring supergroups and recharge areas (shaded). The supergroups surveyed for this project are Springsure, Bogan River, Bourke and Eulo.

1.2 Cultural history

1.2.1 Aboriginal

Great Artesian Basin springs have been intimately known, used and cared for by Aboriginal people for millennia. The Aboriginal names of some springs have been preserved across the Basin—Pigeongah, Mommedah, Muk Quibunya, Bookera and Allawonga, to name a few of the more poetic—but the stories and significance of most individual springs have not been revealed in Queensland. Indigenous belief systems have parallels with spring mythologies worldwide, including the presence of supernatural beings and oracles, and the healing power of the waters. Rainbow Serpents of Aboriginal Australia remain an ongoing, living presence in some springs, keeping the water pure and punishing anyone who transgresses laws or rites (McDonald et al. 2005). In Western Australia, springs, soaks and wells are all viewed as being connected to the underlying groundwater, which is referred to as *kurtany*—literally, ‘mother’ (Yu 2002).

Dalhousie Springs in South Australia are collectively known as *Irrwanyere*, or ‘the healing spring’ (Ah Chee 2002), whereas an oracle dwelt in a purportedly bottomless spring near the Mulligan River in far western Queensland. This ‘big fellow masser’ was consulted in a peculiar manner, as recounted by surveyor Twisden Bedford:

> *‘ …one Aboriginal taking a big stone in each hand, dived head first into the bubbling water. A second Aboriginal jumped in immediately afterwards, and catching hold of his predecessor’s legs, which appeared above the surface of the water, forced him further down. A third Aboriginal then jumped in and forced the second down, all remaining under the water for as long a time as they could hold their breath in abeyance. They then all came to the surface, when the leading native gravely announced that he had interviewed the big fellow masser, and that big fellow flood come up along a one-fellow moon. And what is more, the flood did come in another month as predicted.’*
>
> © Copyright, Bedford (1886)

As well as being intrinsically sacred, springs were of vital importance in an arid land, as camp sites and nodes in continent-wide trade and communication routes (Boyd 1990; Harris 2002). Archaeological remains associated with one camp site at Dalhousie extend for almost three kilometres (Bayly 1999), whereas the scalded plain surrounding Youleen Springs in south-western Queensland has a rich and complex surface archaeology dating back at least 13 000 years (Robins 1998). In May 1876, explorer William Hodgkinson met a group of 30–40 people west of the Diamantina River near a group of permanent springs, possibly Pathungra Springs. The country was showing signs of drought and people were congregating around the few remaining permanent waters (Hodgkinson 1877). Stone tools are abundant across the claypans surrounding Pathungra Springs and other springs along the Hamilton River. Mysteriously, artefacts are in very low densities at other springs, including a large group in waterless country north of Aramac in central Queensland.

1.2.2 European

Pastoral settlement of inland Australia was profoundly limited by the availability of water. Pioneering squatters concentrated their runs and grazing activities on permanent waterholes along major rivers and the sparse network of artesian springs. Beyond these tiny nodes, however, vast tracts of land remained ‘untrodden by hoof’ (Jack 1900). The GAB springs to the west and south of Lake Eyre played a vital role in ‘opening up’ the country (Harris 2002). Explorer John McDouall Stuart was the first to describe the extent and importance of the springs in 1859. He perceived them as important stepping stones to the interior and used them on his six expeditions. His eventual triumphant transcontinental crossing in 1861–62 was only successful because of these springs (Bailey 2006). The reliable water supply provided by the springs, coupled with favourable reports of grazing land, soon enticed pastoralists into the region. Later, two significant infrastructure developments, the Overland Telegraph Line (started in 1870, completed in 1872) and the Central Australian Railway (commenced in 1878, completed in 1929) followed the arc of mound springs from the south to north-west of Lake Eyre (Gibbs 2006).

Similarly, many roads and tracks in Queensland and New South Wales follow lines of springs. Although not as numerous or widespread as riverine waterholes (Silcock 2009), where springs do occur, they were considered a vital pastoral resource, especially during drought. One correspondent described a ‘fine spring’ in the vicinity of the Hamilton River: ‘one of many on the run that would ensure that in a drought stock would be watered’ (Nolan 2003). When taking stock from the Channel Country to the *Gulf* of Carpentaria, droving parties used Parker [Elizabeth] Springs as a vital stopover between the Diamantina and Georgina rivers, and a man was engaged for the specific duty of maintaining the groundwater supply and its delivery through a network of drains (Nolan 2003).

Water was not merely a vital resource; it was also a blessed relief from the inland heat and the silence, holding out ‘the sweet, cool promise that things could be otherwise’ (Cathcart 2009). Nevertheless, the utilitarian focus on springs almost completely nullified the sacred. Rather than ‘building altars and offering sacrifices’ as counselled by Roman philosopher Seneca, springs were drilled, drained and dug out in attempts to ‘improve’ them, although many were also fenced to stop stock becoming bogged. Although the honest yeomanry of the frontier were not by nature given to superstition, their interferences with springs did sometimes seem to awaken dark spirits of the earth. In a letter to the *Sydney Morning Herald* in 1882, JE Kelley provided a vivid description of his attempts at ‘improving’ a mud spring through drilling into a mound about 60 centimetres below its base:

> *‘All went well till the outside crust and sound ground were tunnelled through; but at the first dive of the bar into the “pudden” the whole mound groaned and surged like a large hole in agony, and the first thing I saw was my man floating out the mouth of the drive at the rate of 10 knots on a small sea of cold, white, watery lava. The whole hill continued to groan and shake as it appeared to gather vent, and after every groan it discharged ton upon ton of this white batter from the drive. A superstitious person would have believed that the thing was alive.’*
>
> © Copyright, Kelley (1882)

Springs also provided tantalising clues as to the existence of a vast supply of water below the parched inland, and played a wider role in the discovery, development and scientific understanding of the Basin. They were in effect tacit participants in their own demise. The 1884 New South Wales Royal Commission on water conservation collected information on springs to examine the potential extent of groundwater supplies (Gilliat 1885). Initially, shallow bores were sunk near the springs where success was assured—the first of these was in 1879 at Wee Wattah Spring north of the Darling River and others soon followed (Percy 1906). Although clean flowing water from these early bores could be conveniently directed into drains and troughs, this was only a modest improvement on springs, and failed to capture public imagination or provide adequate proof for groundwater theorists.

More adventurous drilling to greater depths and at further distances from the springs through the 1880s gradually revealed a vast underground basin stretching from Richmond in Queensland to Oodnadatta in South Australia and Moree in New South Wales. Water was obtained at Thurulgoona Station south of Cunnamulla in 1886 and this success was quickly mirrored in other areas (Powell 2012). This seemingly providential and boundless aquifer would come to be known as the Great Artesian Basin and delivered precious water from the bowels of the earth at enormous pressure.

Sinking of bores increased rapidly following severe stock losses in the Federation Drought (1898– 1902) and it was a condition of pastoral leases by 1918 that artesian bores must have been sunk. However, bore drilling remained an expensive and imprecise operation, and it was not until the 1950s that the combination of favourable seasons, high wool prices, improved technology and government subsidies gave pastoralists the opportunity to invest extensively in bores (Noble et al. 1998). By 1960, 18 000 (flowing artesian, and nonflowing artesian or subartesian) bores had been drilled across the Basin, resulting in a drastic loss of pressure in the aquifer. Total recorded discharge from free-flowing artesian bores in the Basin was more than 2000 megalitres per day from 1700 bores in 1916, but by 1998, less than 1000 megalitres per day were discharging from 3400 bores (GABCC 2000).

Spring flows across, and in the discharge areas of, the Basin declined similarly. Data indicate that some 40 per cent of discharge spring groups in Queensland have become completely inactive since pastoral settlement, whereas some springs within another 14 per cent of groups are inactive (Fairfax & Fensham 2002; Fensham et al. 2004). The loss of springs in Queensland, as a result of aquifer drawdown has been most severe in the Flinders River, Bourke, Springvale, Barcaldine and Eulo supergroups (Figure 1).

Though the springs continued to be used by pastoralists, the seemingly inexhaustible supplies obtained from flowing and nonflowing artesian bores meant that springs played an increasingly peripheral role. Bores were celebrated in both folklore and the annals of the colonial scientific literature. The vision of towering rigs (Figure 3) became the stuff of legends, as powerfully encapsulated in Banjo Paterson's poem *Song of the artesian water* (Paterson 1896). The miracle of groundwater was easier to appreciate in the form of clear, gushing fountains as opposed to muddy, wobbling quagmires. Springs, once the lifeblood of early settlement, faded into obscurity, a mere footnote in the historical development of one of the world's largest artesian basins.

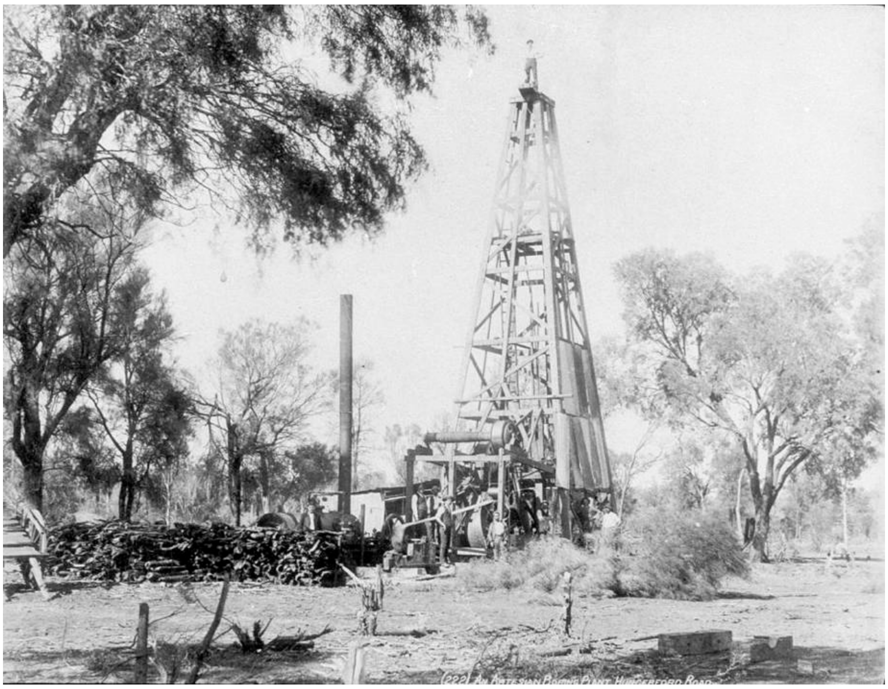


Figure 2 Drilling rig located along the Bourke–Hungerford road, circa 1895.

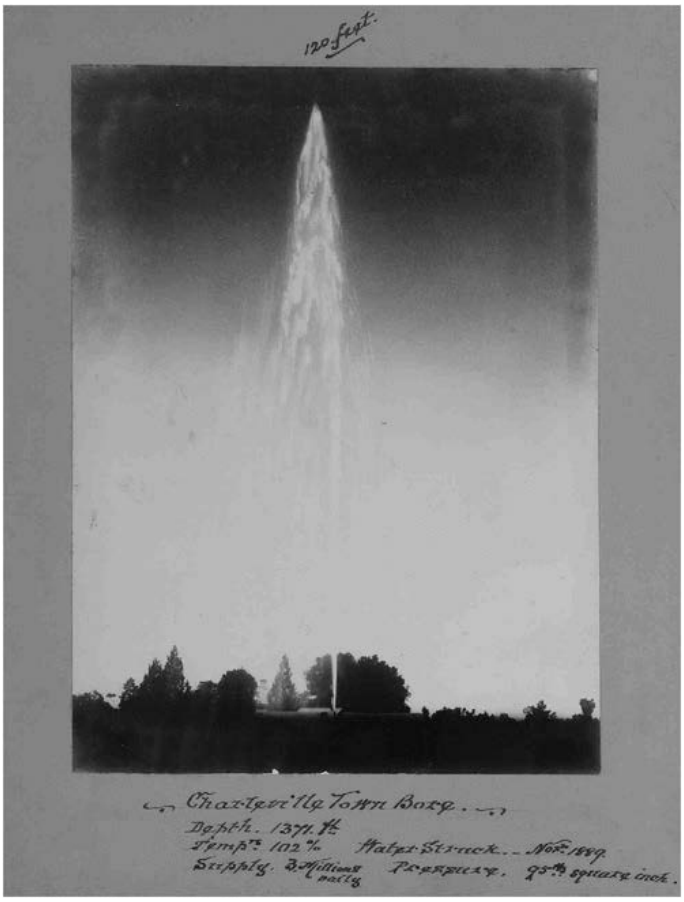


Figure 3 Charleville town bore, circa 1902. Caption reads that the bore depth is 1371 feet (418 m), yielding three million gallons (13 638 m^3) per day. Temperature is recorded at 102 °F (38.9 °C) with water pressure at 95 pounds per square inch (655 002 Pa). Turned on at the bore head, the water reaches 120 feet (36.6 m).

In some respects, mirroring the global resurgence of spring pilgrimages, well dressings and health spas, Australia's GAB springs have re-entered the public and scientific consciousness during the past three decades. Desert springs in South Australia, notably Blanche Cup, The Bubbler and Dalhousie Springs (Schmiechen 2004) have become popular tourist destinations, whereas elsewhere artesian spas (Moree, New South Wales), artesian mud baths and nature drives have been established. Traditional owners and pastoralists continue to tell stories about the springs, and there are even (unconfirmed) nymph sightings from time to time. Springs have also become the focus of biological surveys, which have revealed an astounding diversity of specialised and strange life forms.

1.3 Overview of ecological values

Globally, wetlands tend to have low levels of endemism, and favour plants and animals that are mobile or readily dispersed (Junk 2006; Horwitz et al. 2009), because they are relatively ephemeral ecosystems. Wetlands that have persisted through glacial periods of aridity provide habitat for relictual species that were more widespread in wetter times (De Deckker 1986; Davis et al. 1993; Murphy et al. 2010). GAB discharge springs are distinctive wetlands that have (Fensham et al. 2011b):

- permanent and relatively constant water levels

- an unusual water chemistry
- great antiquity
- isolation from other wetlands.

These factors have combined to create a remarkable concentration of specialised endemics from this habitat, which have persisted despite the extinction of many springs and more recent local disturbances from excavation, invasive species and introduced herbivores. GAB discharge spring wetlands are listed as a nationally endangered ecological community under the *Environment Protection and Biodiversity Conservation Act 1999* (Cwlth).

Thirteen vascular plant species are endemic to GAB discharge spring wetlands. Some are widespread across numerous supergroups (e.g. *Eriocaulon carsonii, Myriophyllum artesium*), and others are restricted to a single spring or spring complex (e.g. *Eriocaulon giganteum* and *E. aloensis* in the Pelican Creek complex) (Davies et al. 2007). As permanently wet habitats in an arid land, discharge springs also support extremely disjunct populations of some plant species, including *Gahnia trifida* and *Baumea juncea* in South Australia, and *Cenchrus purparascens* (formerly *Pennisetum alopecuroides*) in south-west Queensland (Fensham et al. 2010).

Sodic and salty groundwater scalds are often associated with discharge springs, and these areas have a specialised non-aquatic flora. Three species endemic to this habitat are highly restricted in the Barcaldine supergroup: *Gunniopsis* species (RJ Fensham 5094) is known from three populations totalling just 80 plants within a two-square-kilometre area on Edgbaston Reserve. *Chloris* species (Edgbaston RJ Fensham 5694) and *Sphaeromorphaea major* have small populations around the springs at Edgbaston and Doongmabulla. The near threatened *Sporobolus partimpatens* is known from groundwater scalds across five supergroups, and the Eulo and Barcaldine supergroups are each home to endemic, undescribed *Calocephalus* species.

Eight fish species are endemic to the GAB: five are recorded only from Dalhousie in South Australia (Glover 1989), two are restricted to a single spring complex in the Barcaldine supergroup and one to Elizabeth Springs in the Springvale supergroup (Wager 1995; Fairfax et al. 2007; Fensham et al. 2012). The radiation of molluscs is especially remarkable, with 38 species endemic to GAB discharge springs, including 26 that are restricted to a single spring group (Ponder et al. 1989; Ponder & Clark 1990; Ponder 1995; Worthington Wilmer et al. 2008; Fensham et al. 2010). Discharge springs are also centres for other specialised biota, including spiders, beetles, leeches, crustaceans and flatworms, many of which have very restricted distributions (Zeidler 1997; Fensham et al. 2010). Bacteria-like organisms occur in GAB aquifers (Kanso & Patel 2003); however, spring microorganisms remain extremely poorly characterised.

In contrast, the neutral or acidic water chemistry, and greater temporal fluctuations of GAB recharge springs seem to have limited the evolution of specialised endemics. These springs tend to emanate from sandstone gullies and are dominated by generalist wetland species from this habitat, including a variety of ferns and sedges (Fensham et al. 2011a). They do, however, provide habitat for very isolated populations of species otherwise restricted to much wetter climates, but some in the Springsure supergroup contain endemic species as discussed in Chapter 2.

1.4 Outline of report

This project focused on 4 of the 12 GAB supergroups: Springsure, Eulo, Bourke and Bogan River in Queensland and New South Wales (Figure 1). The Springsure group is very different from the others, consisting mostly of recharge springs located outside the semi-arid zone. The other groups comprise mostly discharge springs occurring in areas receiving more than 500 millimetres of average annual rainfall, although the source aquifers of some of the New South Wales spring groups remains uncertain. For each supergroup, the historical record is reviewed and the results of our surveys presented. The cultural significance and natural values are discussed based on a review of the historical and ecological literature, and field survey results.

1.5 Methods

For each supergroup, this project aimed to:

1. assess the location and status of all springs mentioned in historical sources
2. record the history and cultural values of springs
3. assess their contemporary biological values
4. determine any signs of recovery with bore capping and potential for habitat restoration.

Firstly, historical records of springs were systematically analysed. Several sets of historical maps were examined, including original pastoral run surveys, (1860–1880), historical map sheets (1880–1940) as well as more recent topographic maps (1964–2008). Historical literature relevant to the spring areas was reviewed, including explorer journals, newspaper articles, reports of government geologists and land/water inspectors, official government reports and books. People with long-term historical knowledge of these areas were interviewed where possible.

This historical analysis formed the basis of a comprehensive on-ground survey of springs in the Eulo, Bourke and Bogan River supergroups. A further survey of priority springs in the Springsure group was carried out, which added to information gathered through a recent Queensland Water Commission project (Fensham et al. 2012). Once a spring had been located in the historical record, we used a combination of computer-based mapping software (ArcGIS 10.1) and Google Earth satellite imagery to interpret the spring's location in the landscape and obtain its approximate coordinates. In New South Wales, John Pickard's report on New South Wales' artesian springs (Pickard 1992) was invaluable for many springs, whereas the Eulo surveys built on the 1999–2000 surveys initiated by Rod Fensham and Russell Fairfax (Fairfax & Fensham 2003; Fensham & Fairfax 2003).

During the field survey, the combination of the assigned coordinates and the local knowledge of landholders was usually sufficient to identify the spring's location or its possible remnants. Springs can often be detected through a series of visual cues, including:

- soil dampness (indicating the spring is potentially active)
- mounding
- scalded terrain (due to carbonate and salt deposits)
- sunken depressions.

Evidence of both Aboriginal (stone flakes and cores, hearths, grindstones) and European occupation (e.g. old fences or yards, ruins of huts, bottles, tin) in an otherwise waterless area may also indicate the presence of a now-inactive spring.

At all sites, the landscape position and surrounding vegetation were described and photos taken. Each vent location in a spring group was determined with a handheld global positioning system (GPS) unit and its activity status recorded. The elevation of the main vent/s was recorded using an OmniSTAR differential GPS. This gave an ellipsoidal height reading, which was converted to actual height (Australian Height Datum) using a geoid–ellipsoid separation (N value) calculated from the Geoscience Australia website (www.ga.gov.au/ausgeoid/nvalcomp.jsp).

For active springs, soak and wetland area (defined as more than 50 per cent cover of wetland vegetation), excavation damage (wells, pipes, bores, direct excavation), and impacts of stock and feral animals were recorded. Where a spring remained active only through excavation below the aquifer surface (e.g. Nulty, Kullyna and Toulby Springs), it was classified as inactive. All plant species present in the spring wetland were recorded, and the wetland was surveyed for fish, molluscs and other invertebrates. Unidentified and significant plant species were vouchered and these collections have been lodged at the Queensland Herbarium. For rare and threatened species (Silcock et al. 2011), detailed assessments of habitat, population size, extent and threats were made (Keith 2000). In springs with free water, pH, conductivity and temperature measurements were taken. If the spring wetland area was more than 10 metres in length, readings were taken at the vent and then every 10 metres to the edge of the wetland.

In addition to indicating the differences in water chemistry between springs, this also helped interpret whether the water was artesian or of run-on origin. Artesian water tends to be basic with high conductivity, while rainwater tends to be neutral or slightly acidic with lower conductivity. Nevertheless, the presence of run-on water from recent rainfall or flooding sometimes made it difficult to differentiate between active spring vents and inactive vents, or nonspring depressions such as gilgais and hollows. In most instances, landholder interviews provided sufficient information to make this distinction. Where this local knowledge was not available, assessments were made based on the field characteristics of the site. The problem of identifying permanent springs was particularly pronounced in the Springsure supergroup, where recent above-average rainfall years meant that ephemeral springs were abundant across the sandstone slopes visited during the survey.

All historical and ecological data collected for the four supergroups were entered into a Microsoft Access database (refer to metadata in Appendix A for full details). The database also incorporates the existing SPRLOC database compiled and maintained by the Queensland Herbarium, and new ecological and botanical data on springs in the Surat Cumulative Management area (Fensham et al. 2012). Separate water chemistry and vegetation species databases were also created, which are linked to the main database. Fauna collections were made, but are mostly retained as unidentified samples. Likely endemic mollusc species are identified. Other endemic fauna have been identified, but only where taxonomic advice has been available. Photos are contained in a linked photo library. A report was compiled for each spring group and these are located in an ‘Additional information’ library, along with available historical information and hydrogeological reports. An example of a spring report is provided in Appendix B. Springs that are considered to be non-GAB in origin remain in the database; however, their records can be filtered out using the field ‘GAB’ (true or false).

In the Access database each record (row) is referred to as a 'spring' and refers to an individual vent. In some cases, multiple vents feed an individual wetland, and this is captured by a separate 'wetland' field.

The field surveys conducted of the three southern supergroups were almost comprehensive and six additional priority springs in the Springsure supergroup were visited. The springs not visited were either inaccessible at the time of survey or were unable to be located with any degree of precision from historical records (refer to Appendix C). All databases and spring reports have been compiled and submitted with the present report. The historical record, cultural and biological values for each supergroup are discussed in Chapters 2–5.

The report refers to individual springs and these are not identified on the figures. The database needs to be used in conjunction with this report to identify individual localities.

2 Springsure supergroup

The Springsure supergroup is the most easterly in the Great Artesian Basin (GAB) (Figure 1 in Chapter 1) and comprises mostly recharge springs along the Great Dividing, Expedition, Dawson and associated mountain ranges. More than 250 individual recharge vents have been recorded across 83 spring groups, and 10 groups encompassing 93 documented vents are classified as discharge springs. A section of the Springsure supergroup was the subject of a recent project managed through the Queensland Water Commission in the Surat Basin (Fensham et al. 2012). Given this recent work, and the fact that only a handful of priority springs were visited for this project, the cultural significance and biological values are only briefly summarised here.

2.1 Historical record

More than 40 survey run plans and historical maps drafted between 1863 and 1936 were inspected. In contrast to the New South Wales and Eulo supergroups, most springs are not marked on any plans or maps, probably because their occurrence in a wetter climate with more surface water meant that they were not as critical to early pastoralists. Springs are marked on pastoral run plans L42217 (1889) and L42207 (1900) in the Taroom, Boggomoss and Mt Rose area, where there are numerous springs across a small area and none are referred to individually. Pastoral Run Plan L42217 (1889) depicts springs in the Salvator Rosa area (Figure 4). Top and Belinda Springs are named, whereas numerous unnamed springs are marked along Louisa Creek, and between Mt Flat Top and Fred's Hill. Belinda Springs is also marked on the four-mile series 6d map (1921).

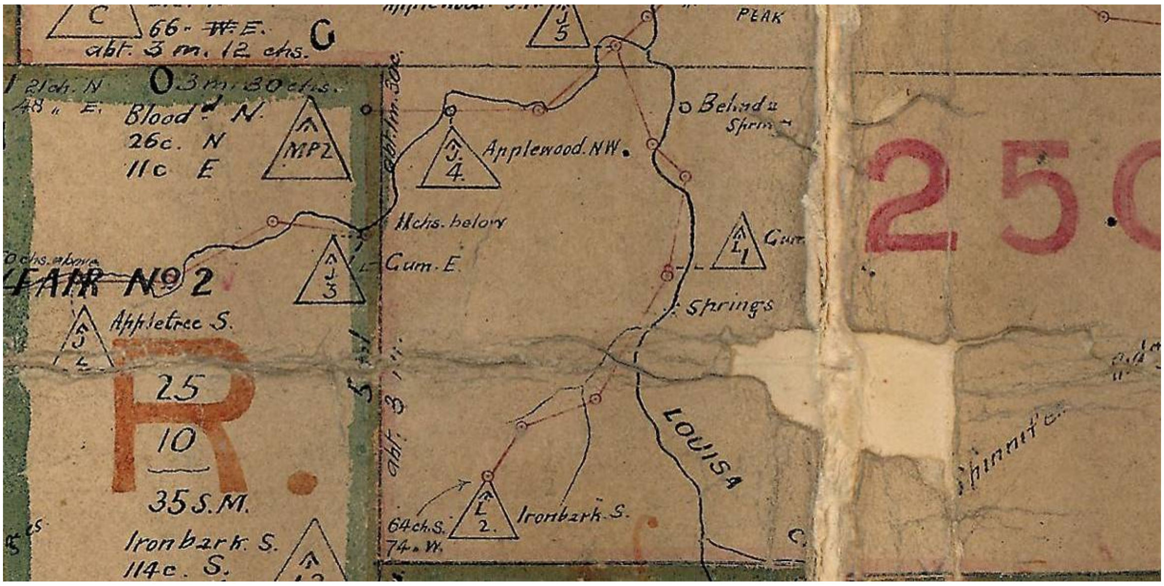


Figure 4 Pastoral Run Plan L42217 (1889) showing Belinda Springs and unnamed springs along Louisa Creek. This is one of the few run surveys to show springs in the Springsure supergroup.

Major Thomas Mitchell provided the first written record of the Springsure springs, compiled as he advanced north in search of a route to the Gulf of Carpentaria. On 27th June 1846, he found ' ... an extensive valley … bounded by the fine trap range of Hope's Table Land … [which] contained springs, in various ravines along its sides' (Mitchell 1847). Geo-referencing of Mitchell's route suggests that Mitchell was referring to GAB recharge springs on present-day Babbiloora in the Carnarvon Ranges north-east of Augathella. Three days later, Mitchell recorded that Mr Stephenson found a 'copious spring' in a valley east of Mt Hopeless. Bevan Spring is eight kilometres to the east of Mt Hopeless, and Mitchell may have been referring to this or another spring on Farraday or Curnalong creeks, or their tributaries. Visits to springs in this area and comparison of features with Mitchell's descriptions will be required to ascertain which springs his party visited.

However, a more momentous discovery was the line of springs along Louisa Creek in what is now Salvator Rosa National Park. Mitchell first encountered these springs on 2 July 1846 while scouting ahead of his party to secure both water and a suitable route forward:

> *'Returning with two men and Yuranigh to the valley where I had been yesterday, I followed it downwards, and soon found that it widened very much, and contained dry ponds, with the traces of a deep current of water at some seasons…Further on, I perceived reeds in the hollow of the valley, and Yuranigh said there must be a spring, upon which he walked in amongst them, but still found the earth dry. The reeds at length covered an extensive flat, so green, that I sent Corporal Graham to examine that point. He emerged from the reeds with a face that, at a distance, made Douglas, my other man, say, "He has found water". He had found a running stream, to which he had been guided by its own music, and taking a tin pot, he brought me some of it. The water was clear and sparkling, tasting strongly of sulphur, and Yuranigh said that this was the head of a river that never dried up. In this land of picturesque beauty and pastoral abundance, within eighty miles of the tropics, we had discovered the first running stream seen on this journey.'*
>
> © Copyright, Mitchell (1847).

What is now known as Major Mitchell's Spring consists of an extensive peat deposit confined by the valley margins (Figure 5). There are numerous springs along Louisa Creek, which runs into the Nogoa River. Having discovered a secure water supply, Mitchell brought the expedition forward. By 5 July 1846, they encamped on the right bank of the 'reedy rivulet' near the 'Pyramids' where he established a depot marked XLIV (Figure 6); from here Mitchell explored north. Travelling down the bank of the stream on 6 July, Mitchell observed that it was:

> *'Flowing, and full of sparkling water to the margin. The reeds had disappeared, and we could only account for the supply of such a current, in such a country, at such a season, by the support of many springs. We made sure of water now for the rest of our journey; and that we might say of the river "Labitur et labetur in omne volubilis aevum".'*
>
> © Copyright, Mitchell (1847).

Mitchell's lyrical optimism for this stream that seemed to 'glide on … rolling forever' was destroyed by his realisation that the Nogoa, and then the Belyando, were taking his party towards the east coast, rather than the Gulf of Carpentaria. He returned to his 'swamp with the spring' on 5 September 1846 before heading west in search of the north-westerly flowing stream of his dreams. Mitchell took four men on this western journey, while the remainder of the party stayed at a depot at the springs. The water from the spring-fed swamp 'had a sulphureous taste, and nausea and weak-stomach were complained of by some of the men' (Mitchell 1847).

Figure 5 Major Mitchell spring, a singular example of a recharge spring that forms a large bed of peat in a sandstone gully.

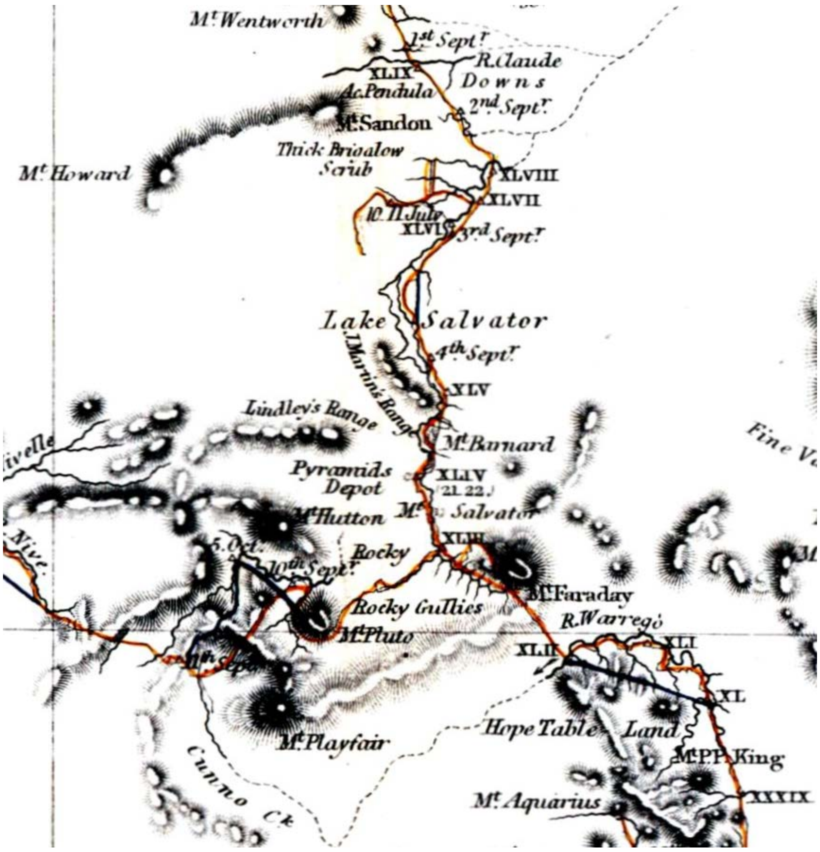


Figure 6 Mitchell's route through the Salvator Rosa area, showing Pyramids Depot (Camp XLIV) at Major Mitchell's Spring, south of Lake Salvator.

Few other historical references to the Springsure springs were found. There is a reference to a spring on Crystalbrook in the Chesterton Range north of Mitchell in the *Queensland Government Mining Journal* in 1918. Government geologist Lionel C Ball described the spring as approximately 100 metres in maximum diameter rising three metres above a black soil flat. If this is correct, the mound has shrunk considerably since then. In 1999, the mound was described as just 30 metres long and 0.4 metres high. According to Ball (1918), the substance of the mound was an extremely fine black mud and bright ‘sulphur yellow’ lichen was growing on the surface. When dry, the material could be easily ignited. Before taking over the property, the manager claimed that the mound had been on fire ‘during a period of eighteen months’. The daily flow of the spring did not exceed 90 800 litres per day. The water was described as being quite clear, odourless and free from gas bubbles, although it had a slightly ‘astringent’ taste and a faint small of sulphur dioxide could be detected downwind. Locally it was regarded as poisonous, highly corrosive and avoided by stock, though ‘birds were observed by us drinking it’. Jensen (1926) also noted the presence of ‘sulphur springs’ on Crystalbrook.

2.2 Project surveys and reassessment of spring status

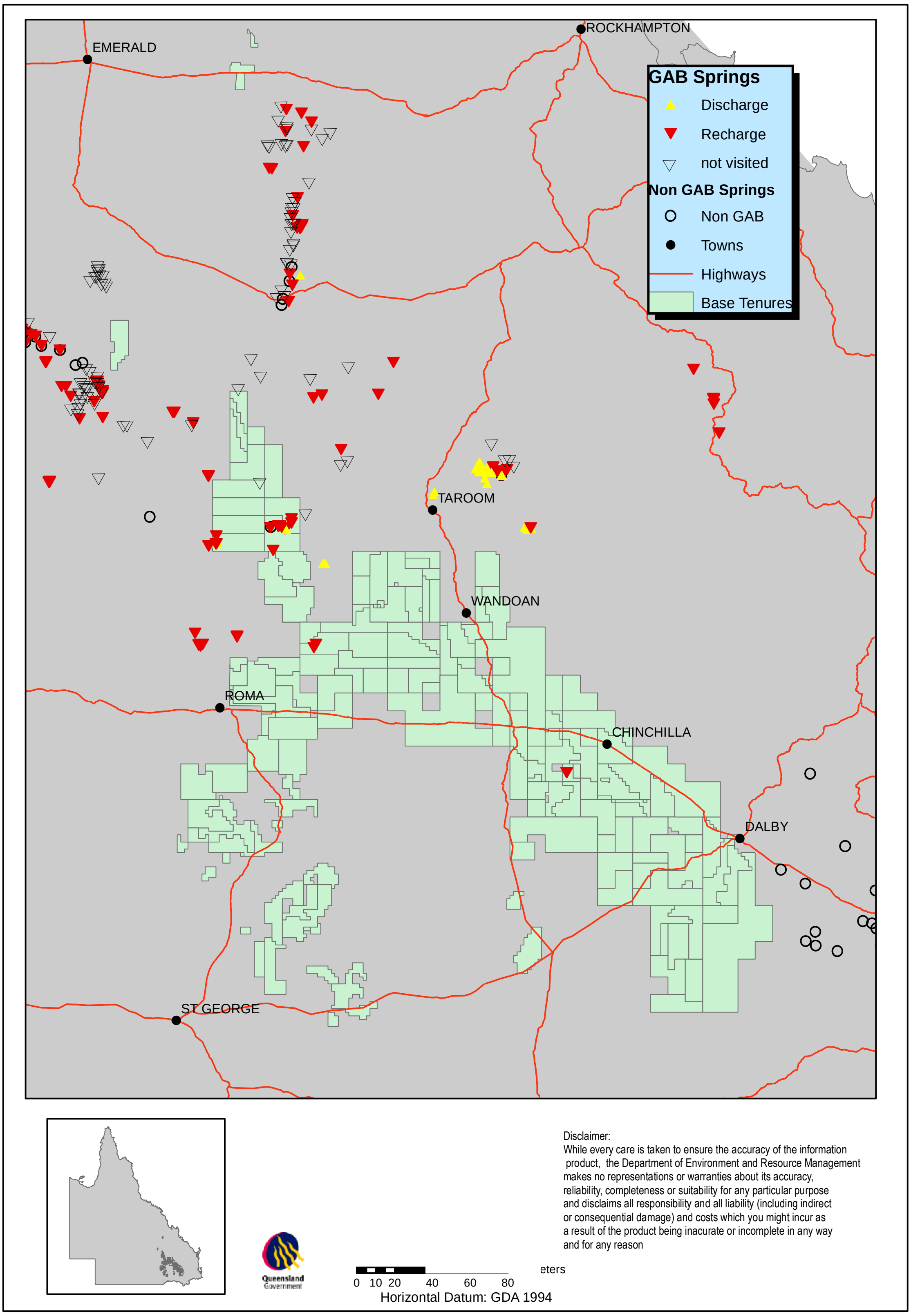
This project targeted springs within the Springsure supergroup that were identified as having potentially high biological values, low to medium elevation in the landscape, proximity to petroleum tenure, and relatively easy access and good return for effort. We visited an additional seven springs meeting these criteria in the Expedition Range and Blackdown Tableland areas between Taroom and Blackwater in September 2012.

In the Expedition Tableland, Turtle Creek spring on Coorada (Figure 7 a) and Bracklyn Spring on Stonecroft are permanent springs emanating from creek beds, the latter in a steep gorge near the head of Roundstone Creek. They run Turtle and Roundstone creeks, respectively, for several kilometres. An almost-permanent spring on Spring Creek was surveyed (Figure 7 b); however, it went dry during the drought in 2009. All other springs on Glen Elgin, including those documented along Stockyard, Peach and Black Gin creeks, also went dry in 2009. Many of the springs are dynamic and appear in different sections of the creeks in different seasons.

Three springs on Blackdown Tableland were visited: Rainbow Falls (Figure 7 c), Ballamoo Cliffs and Cleanskin Paddock (Figure 7 d). At the two former sites, preceding wet seasons meant that water was gushing from many places along the creek lines, rendering it impossible to locate the permanent springs. Cleanskin Paddock spring, near the south-eastern boundary of Blackdown Tableland National Park, has one of two inland populations of the endangered swamp orchid *Phaius australis*, as discussed in Section 2.4.

Most of the remaining unvisited springs in the Springsure supergroup are not regarded as high priorities for survey, because they are high in the landscape and are probably not discharging under artesian pressure (type A and B springs, as well as non-GAB types L–M in the hydrogeological report). Thus, they are unlikely to be affected by coal seam gas activities (Figure 8; also see supporting spreadsheet, Appendix C).

Figure 7 (a) Source of the permanent Turtle Creek spring on Coorada, (b) Spring Creek spring, the most permanent spring on Glen Elgin, (c) Jeremy Drimer and Carlin Burns near the source of Rainbow Falls; however, the amount of water flowing down these creeks in September 2012 made it difficult to locate the permanent springs, and (d) Cleanskin Paddock spring, a one-hectare swampy area dominated by ferns and sedges, and supporting a highly disjunct population of *Phaius australis*.



GAB = Great Artesian Basin.

Figure 8 Map showing visited and unvisited springs in Springsure supergroup. Most unvisited springs are high in the landscape and not likely to be affected by coal seam gas activities.

2.3 Cultural history

The mountain ranges within which the Springsure springs lie have a long and rich Aboriginal history, as evidenced by the many habitation, burial and rock art sites (Mulvaney & Joyce 1965; Godwin 2001). Numerous rock art shelters, including on Carnarvon National Park, Mt Moffatt and Dooloogarah, occur near recharge springs, which would have provided vital water during dry times. During this project, rock art sites were documented on an overhang along Roundstone Creek downstream of the spring vent and above Rockland Spring (unvisited) on Blackdown Tableland.

Early pastoral settlement was not intimately tied to the Springsure springs, as it was in more arid areas. Nevertheless, most springs in more accessible areas were, and in many cases continue to be, used as stock water. Many have been excavated or piped, and yards have been built adjacent to some springs. A small number of springs, including one on Carnarvon Station, are known to have supplied Chinaman's gardens in the early days of pastoral settlement.

2.4 Biological values

Discharge springs of the Springsure supergroup contain populations of two spring endemics, *Eriocaulon carsonii* (recorded from 15 spring wetlands) and *Myriophyllum artesium* (recorded from 5 spring wetlands). An undescribed *Dimeria* species is recorded only from one recharge spring in Salvator Rosa National Park. The boggomoss snail (*Adclarkia dawsonensis*) is listed as Critically Endangered under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) and occurs adjacent to one 'boggomoss' spring, but is not an aquatic species (Stanisic pers. comm. 2011). The endemic hydrobiid snail *Jardinella carnarvonensis* is widespread in the springs and associated perennial streams within Carnarvon Gorge. In addition, 40 species are known to have isolated disjunct distributions at GAB springs (defined as being more than 250 kilometres from the nearest nonspring record) (Fensham et al. 2012).

Disjunct populations of the endangered swamp orchid *Phaius australis* occur at springs in Carnarvon Gorge and Blackdown Tableland National Park, while three other listed species are recorded from GAB recharge springs (Table 1). The *Phaius* population surveyed at Blackdown for this project covered an area of 100 metres × 50 metres on a spongy seep adjacent to a running creek in a steep valley. It occurred patchily amongst ferns and sedges with scattered shrubs and trees, including *Schoenoplectus mucronatus*, *Baumea rubiginosa, Cyperus lucidus, Lygodium microphyllum, Blechnum indicum, Pteridium esculentum, Melastoma malabathricum* subsp. *malabathricum*, *Sacciolepis indica* and *Viola betonicifolia* subsp. *betonicifolia*. Total population size was estimated to be at least 500 plants. All were healthy and about to burst into flower in September 2012 (Figure 9). No other endemic, disjunct or listed species were recorded at springs surveyed for this project.

Table 1 Spring endemic and listed species in the Springsure supergroup, under the *Environment Protection and Biodiversity Conservation Act 1999* (Cwlth) and the *Nature Conservation Act 1992* (Qld).

Species	R/D	Spring endemic?	EPBC Act	NCA	Notes on occurrence in supergroup
Plants					
Eriocaulon carsonii	D	Y	E	E	15 spring wetlands
Myriophyllum artesium	D	Y	–	E	5 spring wetlands
Phaius australis	R	N	E	E	1 spring wetland
Arthraxon hispidus	R	N	V	V	17 spring wetlands
Thelypteris confluens	R	N	–	V	2 spring wetlands
Livistona nitida	R	N	–	NT	7 spring wetlands
Dimeria sp. (Salvator Rosa RJ Fensham 3643)	R	Y	–	–	1 spring wetland
Molluscs					
Jardinella carnarvonensis	R	N	–	–	Widespread in Carnarvon Gorge

– = not listed, D = discharge, E = endangered, EPBC Act = *Environment Protection and Biodiversity Conservation Act 1999* (Cwlth), N = no, NCA = *Nature Conservation Act 1992* (Qld), NT = near threatened, R = recharge, V = vulnerable, Y = yes.

Figure 9 *Phaius australis* at Cleanskin Paddock spring, Blackdown Tableland, September 2012.

The impact of coal seam gas extraction on springs is reviewed in the hydrogeological section of this report. Using modelling, there are six spring complexes that are predicted to suffer a greater than 0.2-metre drawdown with cumulative prospective development. Of these, individual wetlands in the Lucky Last (Figure 10a) and the Scotts Creek complex (Figure 10b) have high biological values (

Table 2). They are also discharge springs and are thus protected under the EPBC Act. The other spring complexes predicted to be affected do not have substantial biological values, mainly because they occur in watercourses that are regularly scoured by floodwaters.

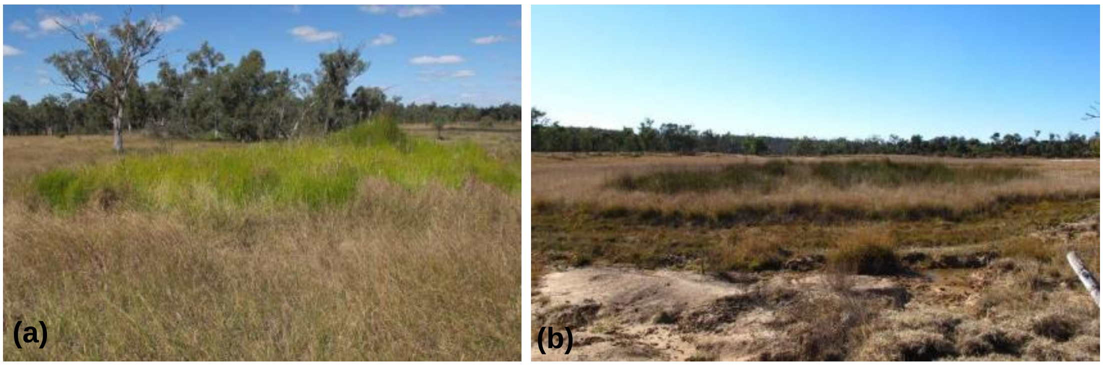


Figure 10 Discharge springs in the Springsure supergroup with high biological values predicted to suffer drawdown due to coal seam gas activities: (a) Lucky Last and (b) Scotts Creek.

Table 2 Biological values of spring complexes predicted to suffer a more than 0.2-metre drawdown with cumulative prospective coal seam gas developments.

Spring complex	**Listed species**	**Disjunct populations**[a]
Lucky Last	*Eriocaulon carsonii* (6)	*Cenchrus purpurascens* (3), *Isachne globosa* (6)
Scott's Creek	*Eriocaulon carsonii* (4)	*Cenchrus purpurascens* (2), *Cyperus laevigatus* (4), *Eriocaulon carsonii, Schoenus falcatus* (1)
311	None	*Ampelopteris prolifera* (1), *Isachne globosa* (2)
Barton	None	None
Spring Rock Creek	None	None
Yebna Boggomoss	None	None

a Number of populations of listed and disjunct populations (> 500 km from the nearest known population) in each complex is shown in brackets.

3 Eulo supergroup

Springs comprising the Eulo supergroup occur across a 150 kilometre × 100 kilometre area roughly bounded by the towns of Eulo, Hungerford and Thargomindah in south-western Queensland. The Eulo and Bourke supergroups lie within the Great Artesian Basin (GAB) Warrego management zone, in which average pressure has decreased by 39 metres (0–120 metres)—the greatest loss of pressure in the GAB. The Eulo springs as a group currently discharge about one-third of their early 20th century output (Fairfax & Fensham 2003). The springs were first surveyed by bore inspectors Ogilvie and Edwards in 1911–12. This historical record was examined by Fairfax & Fensham (2003), and Fensham et al. (2004) surveyed the active springs. Four spring groups are located south of Hungerford in New South Wales and were surveyed by Pickard (1992).

3.1 Historical record

Half of the 111 spring groups documented in the Eulo supergroup are marked on the four-mile series drafted between 1916 and 1931. Only 25 are marked on survey plans drawn between 1870 and 1964. Some large spring groups are not marked on any maps or plans, including the Dead Sea (although the block is called 'The Springs') and Tunga. Nine springs, including eight not marked on other maps, are marked on 1:250 000 geology maps (Table 3). A map dated circa 1900 of Tinneburra Resumed Area drawn by FH Biden shows Garrawin and Pitherty mud springs, while a railway plan from 1886 depicts Bingara Old Station and Dewalla Springs.

Table 3 Springs marked on historical maps and plans in the Eulo supergroup.

Map/Plan inspected	Springs marked
Original survey of runs W51.59 (c. 1870)	Carpet Springs, Roses Paddock
Original survey of runs W51.40 (c. 1870)	Bingara Springs, Dead Sea springs (as 'The Springs' block), Wiggera, Wirrarah
Perambulator survey of runs on Bundilla, Acklands, Bingara and Dewalla Creeks W.51.41 (1876)	Bingara, Dewalla, Granite, Tunca, Wirrarah, Wiggera, Wombula
Warrego District Plan showing survey of runs between Lower Paroo and Warrego rivers to 29th Parallel W51.52 (1880)	None
Perambulator survey of runs on Lower Paroo and tributaries W.51.51 (c. 1880)	Curracunya Springs
Original survey of runs W51.62 (1886)	Baroona Springs
Original survey plan B144.198, B144.155 (c. 1890)	Dewalla
Survey plan NL.5 (c. 1900)	Ningaling, Thorlindah Outstation

Map/Plan inspected	Springs marked
Survey plan NL.8 (1913)	Jubilee (Corina) Springs, Muntha Napper (Bull)
Railway survey plan, Cunnamulla–Thargomindah (1896)	Dewalla and Bingara Old Station
Tinnenburra Resumed Area (FH Biden, c. 1900)	Garrawin mud spring, Pitherty well and mud spring
Pastoral run of Brindingabba (1886)	Jacombe, Picnic Sandhill, Tynghynia,
County of Irrara (1964)	Tynghynia
NSW pastoral holding index map (1888)	Warroo
4-mile maps: Series 1 sheets 2D (1928), 3A (1916), 3C (1931); Series 2 sheets 6 (1964), 7 (1959), 15 (1961), 16 (1940)	Barb Tank, Baroona, Basin, Bingara Bore, Bingara Old Station (and mounds), Bush, Bokeen, Boorara Woolshed, Bullenbilla, Burtanya, Dewalla, Cainawarra Bore, Carpet, Curracunyah, Goonerah, Gooringara, Granite, Fish, Jubilee, Kopanyu, Little Kopanyu/Kapingee, Masseys (Horseshoe), Minyeburra, Muntha Napper, Myrton Bore, Nowanee, Ooliman, Oonunga, Parally Mill and Spring, Pether[a], Riley[a], Taleroo, Tarko (Fish), Thorlindah Outstation, Tilberry Outstation, Tunca, Tunkata, Twomanee, Umatcha, Waihora, Wanco, Wandilla, Wiggera, Wirrarah, Wombula, Wooregym[a], Youleen, Yowah Creek mud springs and hot spring
Geology maps	Boundary, Pitherty Road, Police Paddock, Farnham North, Farnham South, Town Common C, Springvale mounds, Tunkata West, Wombula

c. = circa. NSW = New South Wales.
a Pether and Riley springs both marked on series 2, but not series 1 maps; Wooregym marked on series 1 but not series 2.

Between October 1911 and April 1912, the Queensland Government's bore inspectors Ogilvie and Edwards inspected artesian water supplies in the Eulo area, recording about 60 spring groups. These records are contained in unpublished artesian reports, volumes VIII, IX and VI, held by the Queensland State Archives (reference numbers RSI 3037-1-8, 9 and 16). Ten were deemed unimportant and not visited, and it can be assumed that their flow rates were negligible. Oligive and Edwards' descriptions of six groups of dry mounds suggest that they may have been mostly inactive before the first artesian bores being sunk in the district in the 1880s. They described most of the springs visited, sometimes including vegetation and wetland area, and measured flow rates for 22 groups. As well as these descriptions and some maps of individual spring groups (see spring reports), Ogilvie gave the following overview:

> *'The important springs are almost all in the valley of Boorara Creek, hemmed in on either side by sandstone ridges about 250 ft high, which seems to support the view that the water is of local origin (as the lower beds of this series are very porous) … On the other hand, the temperature of the springs (where the actual outlet is accessible) varies between 79 ° and 105 °F, which is higher than one would expect from local supplies. There is also generally a small alkaline deposit in the vicinity of springs similar in appearance to that found on the bore drains of the district … At Youleen one of the springs possesses a very slight odour of sulphur. It and the taste of the springs of this*

district resemble that of the local bore water. In most of the springs the evaporative effect is very marked, and especially at the main Horseshoe Spring … '

© Copyright, Ogilvie (1912).

Wiggera and Youleen Springs had the largest flows in the district, and were considered the principal springs. From the descriptions of Ogilvie and Edwards, a further 19 groups had considerable flows and often supported large wetlands, while 25 were visited but seem to have been small and were regarded as 'unimportant' (Table 4).

Table 4 Springs in the Eulo group visited or mentioned, but not visited by Ogilvie and Edwards, in 1911–12.

Important	**Unimportant**	
	Visited	**Unvisited**
Baroona	Springs 13 kilometres north of Currawinya (Basin Bore)	Boomerang[a]
Bingara Old Station	Barb Tank	Burtanya[a]
Bullenbilla	Bingara Bore	Springs 8 kilometres north-west of Colanya (Corina house springs)
Bush	Bingara Old Station mounds	North-west corner of The Springs block (Dead Sea group)
Corina (Jubilee)	Bokeen	Gourminya[a]
Dewalla	Boorara Woolshed	Kapingee
Gooning	Boundary	Nowanee
Granite	Cainawarro Bore	Between Tunca and Boundary
Horseshoe (Masseys)	Caiwarro mud springs (Bodalla and Mooning mud springs)	Taleroo Bore
Kopanyu	Colanya Bore	Wonko (Wanco)
Ooliman	Curracunya	
Oonunga	Currawinya Station	
Tarko (Fish)	Fish	
Tilberry	Goonerah	
Tunga	Kungie	
Tunkata	Little Granite	
Twomanee	McNichol's (Apex mud springs)	
Wiggera	Minyeburra	
Wirrarah	Myrton Bore	
Wooregym	Pitherty mud springs	
Youleen	Tareen Outstation	
	Thorlindah Oustation	
	Tunca	

Important	Unimportant	
	Visited	Unvisited
	Tunkata South	
	Umatcha	

a Not located on the ground in 2012.
Note: Where Oligive and Edwards referred to sites by a different name, the current name is given in brackets.

3.2 Project surveys and reassessment of spring status

From previous surveys (Fairfax & Fensham 2003; Fensham et al. 2004), historical sources, geology maps and local knowledge, 111 spring groups (defined as vents situated more than one kilometre apart or in a different landscape setting) were compiled. A total of 105 springs (encompassing 436 separate vents) were surveyed between October and December 2012. This included 43 spring groups that had not been visited in previous surveys. All springs emanate from the Basin with the probable exception of Kungie Lake spring. Situated approximately 100 metres west of Kungie No. 1 bore, Ogilvie described it as being marked by a small boggy area in 1912. A small rocky area on the dry lake bed may be the old spring (Andrew Campbell 2012, pers. comm.; Figure 11a), but the area does not have the appearance of a GAB spring and is not considered in this report.

Currawinya Station Spring is somewhat ambiguous, because it does not have scalded ground around it and now lies beneath a bore-fed pool (Figure 11b). However, there are other small springs in similar landscape settings (e.g. Parally mill and the spring on Boorara), and Edwards' description (23/2/1912) is consistent with an artesian source:

> *'Situated at Currawinya Station and 2 ½ chains S of the creek. A well 4 feet × 4 feet has been sunk to a depth of 12 feet and timbered. The water is of excellent quality and cold. The spring just overflows at the surface keeping a hole (10 gallon capacity) filled. The water is used for domestic purposes at the station and the supply is reckoned at 600 gpd …. As the supply kept up throughout the drought and the well water rises above this level in the creek there appears to be a source of supply other than soakage.'*
>
> © Copyright, Edwards (2012).

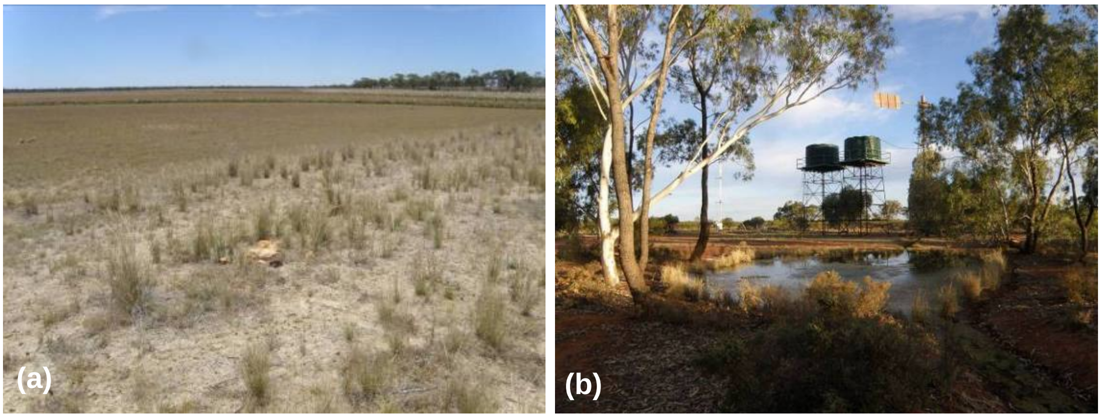


Figure 11 (a) Site of Kungie Lake Spring, west of Tinnenburra No. 1 bore, but long inactive and probably not emanating from the Great Artesian Basin, and (b) Currawinya Station Spring, ambiguous but assumed to be a small, now-inactive Basin spring.

Springs in the Eulo supergroup are loosely clustered in three lines aligned south or south-west, and a south-eastern line running into New South Wales, and can be classified as either mud or water springs (Figure 12). Mud springs form where the groundwater has mixed with fine sediment to form a slurry emanating from the spring vent. The slurry may not flow to the surface for long periods and dry surface layers can form a 'skin' across the soupy interior material. In contrast, water springs have clear water and their permanent soak areas often support wetland vegetation. The water emanates from a discrete vent or vents, and saturates the surface across an extent determined by flow and evaporation. Within the vegetation, there may be pools of free water formed where the vegetation or sediment has created an obstruction to flow, forming a dam. All springs east of the Paroo River from Farnham Plains to Pitherty are mud springs. Mud and water springs are interspersed throughout the central and western lines, which run from the Dead Sea to Karto and Bingara to Wombula, respectively. Two isolated groups of inactive water springs occur west of the Warrego River on Baroona, which are here considered eastern outliers of the Eulo supergroup. At least some springs in 63 groups remain active.

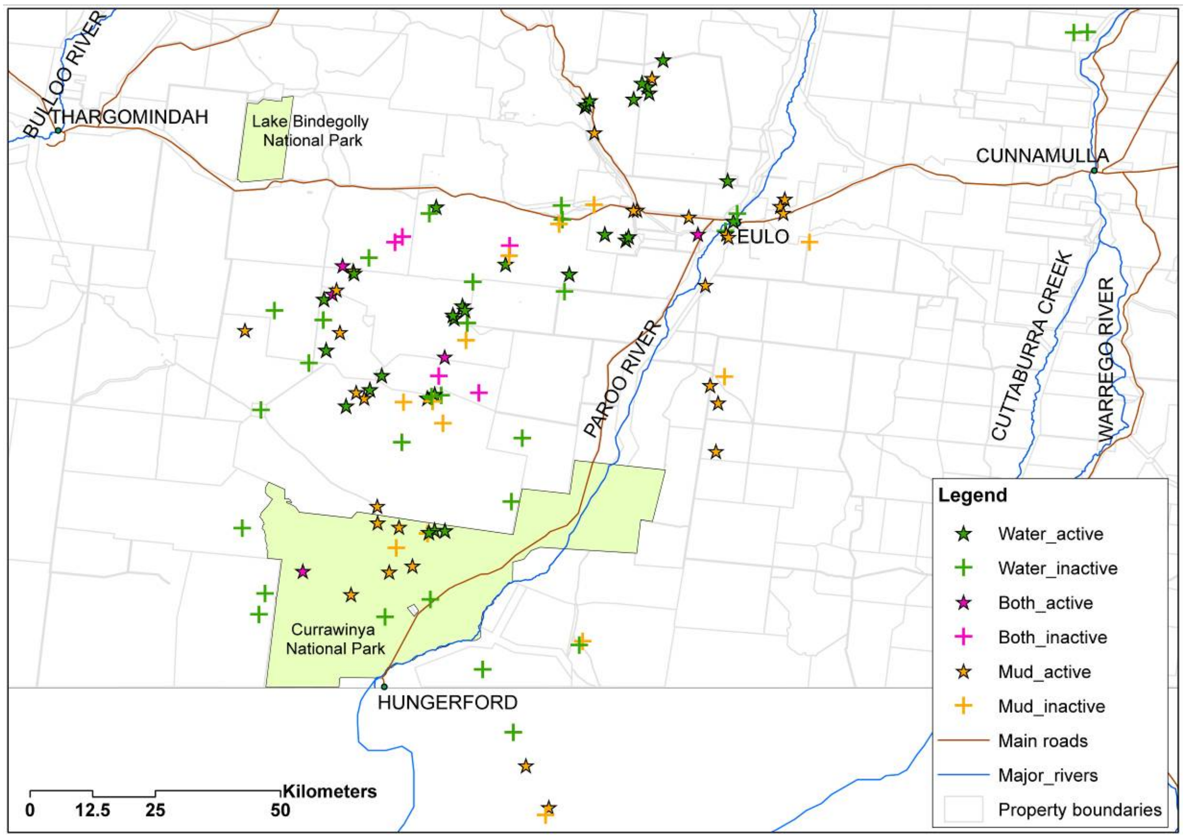


Figure 12 Eulo supergroup, showing active and inactive mud and water springs. 'Both' means that active and inactive springs occur together.

Thirty-six spring groups are comprised solely of mud springs, and 75% of these contain at least some active springs (Table 5). Most mud springs are mounded and can occur as single isolated mounds, in small clusters or cover large areas up to 10-square kilometres containing hundreds of vents (Figure 13 a–c). The largest mound spring areas occur in a line from Currawinya to Boorara west of Hoods Range, and at Jubilee, Corina and Tunkata springs near the Boorara–Corina springs boundary. Many mounds were probably inactive before European settlement, based on the historical record, local knowledge and the consolidated, pebbly nature of the mounds, some with large trees growing out of them. Of the nine completely inactive groups, only three—Waihora, Garrawin and Tunga mound—show signs of recent activity and may have ceased flowing due to aquifer drawdown. Five mud spring groups comprise flat, unvegetated muddy slurries or puddles; all of these remain active, although the flow of Bokeen Spring has probably declined since Edwards visited in 1912. Seven groups contain a mixture of active and inactive depressions and mounds (Table 5).

Whether flat or mounded, mud springs seem to be inherently dynamic. The Wandilla Springs on the Paroo floodplain can fill with water overnight without any rainfall and dry back in a similarly inexplicable fashion (Carmel Meurant 2012, pers. comm.). Mounds in the Eulo area have popped up within the past decade (Mick Beresford & Ian Pike 2012, pers. comm.), whereas others 'spew' out mud sporadically, but may lie dormant for years (Figure 14). There are reports of mud springs 'exploding' with 'loud bangs' in the Eulo area and on Currawinya (Anon. 1904; Pickard 1992; Deveson 2004).

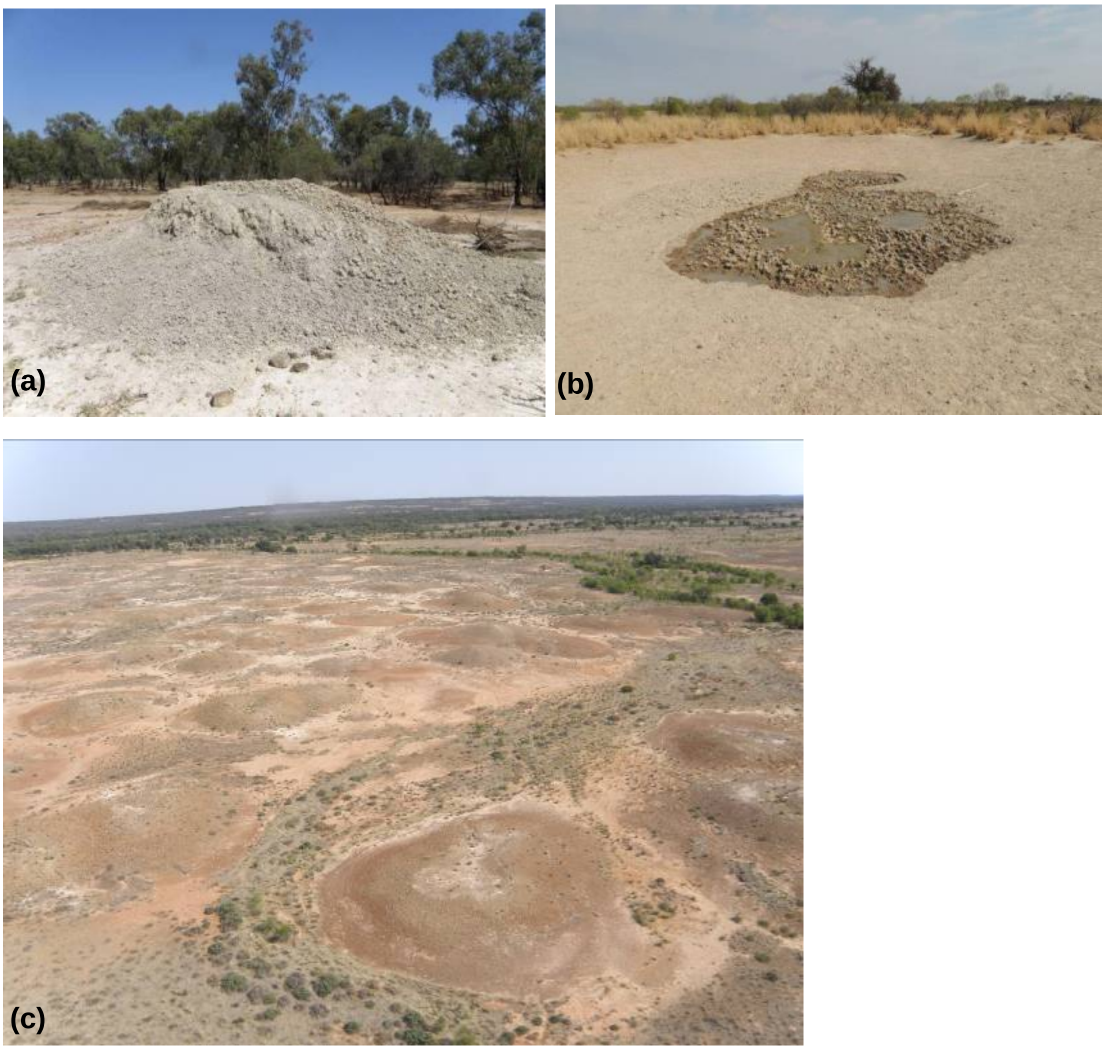


Figure 13 (a) Active mounded mud spring on the Paroo River floodplain, Farnham South group, (b) Big Bog mud spring, in a small scalded depression in the Dead Sea, Penaroo, and (c) mound spring landscape at Jubilee Springs from the air; this cluster covers 2 kilometres × 1.5 kilometres along the eastern side of Boorara Creek and comprises hundreds of vents, most of which were apparently inactive before European settlement.

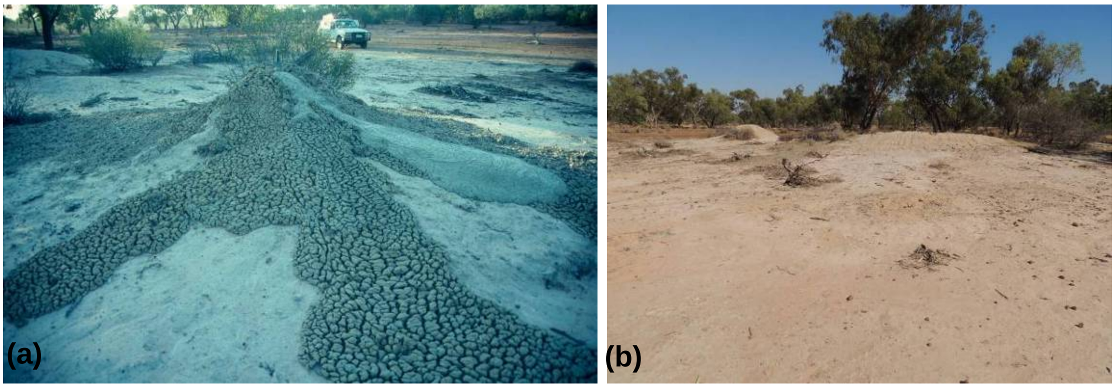


Figure 14 Mud spring on a claypan west of Springvale house, (a) with plumes flowing to the west of the mound in February 1999, and (b) active but with no surface mud in December 2012.

At some sites, mud and water springs occur in close proximity. Within a large basin known as the Dead Sea north-west of Eulo, the southern and northern spring groups are comprised of water springs, while the central group contains only mud springs. Bingara Bore, Bullenbilla, Springvale Claypan, Corina House, Fish (Ogilvie and Edwards' 'Tarko'), Jubilee, Tunca, Wirrarah and Yarraman springs all have mud and water springs situated on the same claypan.

Of the 71 water springs documented, 36 remain active (Table 5). The two largest springs of the district, Wiggera and Youleen, are completely inactive (Figure 15). Where there are historical descriptions from Ogilvie and Edwards, a decline in flow and wetland area is often evident even when springs remain active, for example at Tunga, Myrton Bore and Gooning Springs. Water springs in the Eulo group can either be vegetated and form the 'carpet springs' as described by Ogilvie and Edwards, or be unvegetated pools (Figure 16). Although it can be difficult to tell which category an inactive spring would have fallen into, based on field characteristics and the historical record, we consider that 51 water springs would have been vegetated and 18 unvegetated.

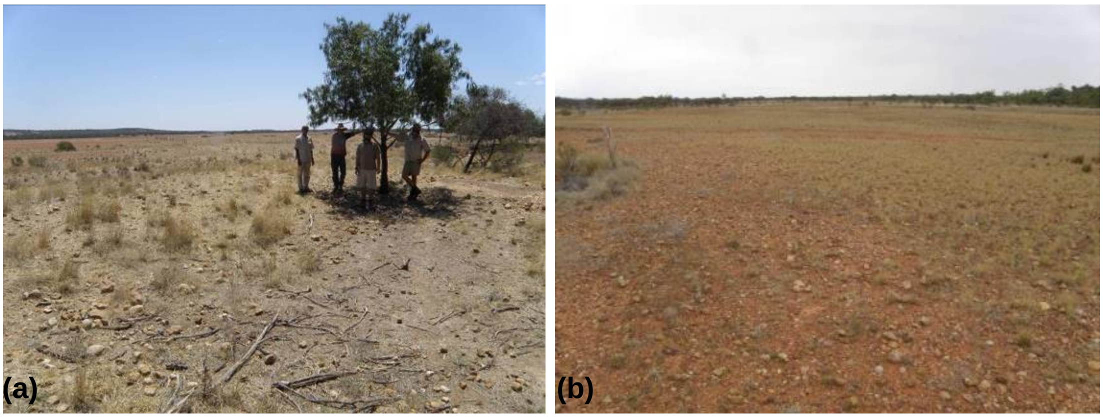


Figure 15 Described in 1912 as the two largest springs in the Eulo supergroup, both Wiggera and Youleen are now extinct. (a) Wiggera stopped flowing in the 1950s, while water was being pumped out of Youleen Springs via a windmill until the 1960s, and (b) the five-hectare formerly swampy area created by springs south of Youlaingee Creek.

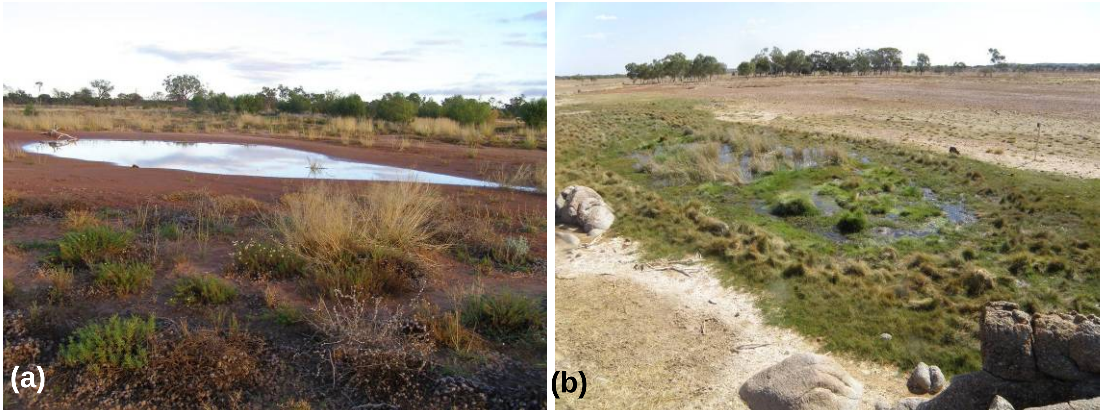


Figure 16 (a) Poached Egg Spring in Basin Bore group, Currawinya National Park, a typical unvegetated water spring, and (b) Massey Spring wetland, showing carpets of spring vegetation interspersed with shallow pools of free water.

Table 5 Active and inactive springs by spring type, Eulo supergroup.

Spring type	Active	Inactive	Total	Proportion active (%)
Mud	25	9[a]	36	69
Mounds	12	9	21	57
Depressions	5	0	5	100
Mounds and depressions	10	0	10	100
Water	36	35	71	51
Carpet	29	24	53	55
Unvegetated	7	11	18	39
Total	61	44	107	57

a Includes six that were probably inactive before pastoral settlement.
Note: 'Active' includes spring groups with at least some active springs. The character of three unsurveyed inactive springs (Cainawarro bore, Tunkata West and Gourminya) is unknown and they are not included in the table.

The dynamism of mud springs and their relative immunity to aquifer drawdown stands in stark contrast to the water springs, which have been greatly affected by loss of pressure in the aquifer. This suggests that mud and water springs may result from different hydrogeological processes; however, much remains to be understood about spring formation and behaviour.

3.3 Cultural history

The Kunja, Budgiti, Kullilli and Mardigan people have lived in the Eulo–Hungerford area for at least 14 000 years (McKellar 1984; Robins 1999). Many of the springs in the Eulo supergroup have retained Aboriginal names, including Gourminya, Tunkata, Curracunyah, Goonamurra, Minyeburra, Muntha Napper, Oonunga and Wirrarah. Although the stories associated with these places have mostly been lost, Aboriginal artefacts were recorded at all except 2 of the 105 spring groups surveyed, testament to the long and rich association between people and springs.

Robins (1993) investigated the archaeology of the Currawinya Lakes area and documented a high density of artefacts at Youleen (Youlain), Bokeen, Kopanyu (Kaponyee) and Riley Springs. Excavations at Youleen revealed an especially rich and complex archaeology dating back at least 13 000 years, including silcrete tools (cores, flakes and retouched flakes), a piece of ochre, hearths and bone fragments—the only ones observed in association with archaeological material in the area (Robins 1998). Youleen Springs, formerly one of the largest in the district and just five kilometres west of the huge salt Lake Wyara, has by far the highest density and variety of archaeological material recorded at any spring in the Eulo supergroup. The two main camp sites correspond to Robins' western and eastern sites, and each cover about 10 hectares on the scalded flats adjacent to Youlaingee Creek (Figure 17).

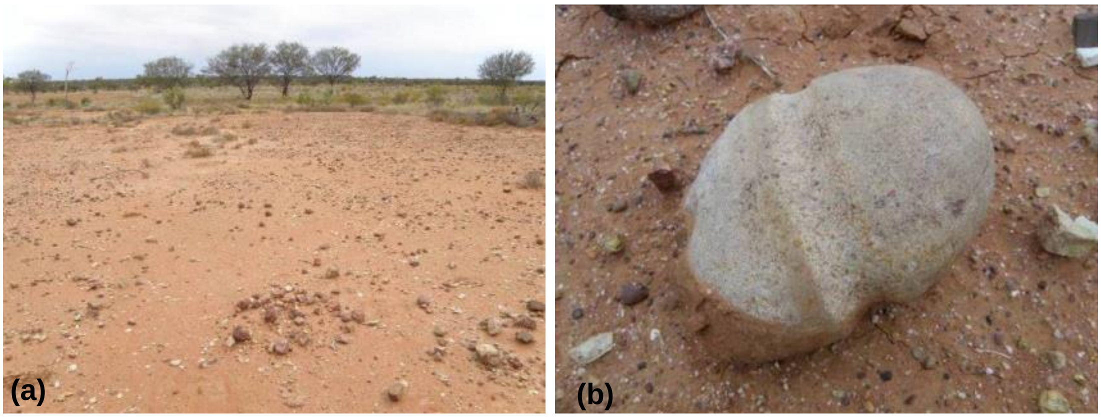


Figure 17 (a) Robins' western site, showing high density of stone artefacts across claypan with intact hearth in foreground, and (b) an axe measuring 15 centimetres across.

An additional 27 springs visited for this project had high densities of artefacts, similar to Bokeen and Kopanyu as recorded by Robins (1997). These sites typically include a range of silcrete flakes, reworked flakes, cores, grindstone fragments, hammerstones and/or hearths, suggesting more intensive and consistent usage (Veth 1993, Witter 2004). In general, sites south-west of Eulo have higher artefact densities than the eastern line, probably reflecting the supply of fresh water provided by these larger spring groups, as well as their proximity to the Currawinya Lakes and permanent waterholes of the Paroo River. Distribution of artefacts is also dependent upon distance to sources of siliceous rock, mostly sourced from hard mulga country and dissected residuals (Robins 1997; Holdaway et al. 2000). Most springs south-west of Eulo occur close to granite outcrops and/or stony hills that include silcrete, so are close to both water and stone sources. The recorded density of artefacts on claypans at least partially reflects the ease of visibility and their exposure through erosive processes (Robins & Swanson 2006).

Stone tools and hearths are abundant on claypans throughout the five spring groups along the Currawinya–Boorara road, probably reflecting their position between a large quarry site in Hoods Range to the east and the almost-permanent freshwater Lake Numalla to the west. The largest and still-active mud spring of the Barb Tank group was itself a quarry site, with boulders and larger rocks thrown up by the mud spring used as core stones (Figure 18a). The artefact scatter at Warroo Springs includes a high density of stone tools and intact stone hearths (Figure 18b), and extends at least one kilometre. Even relatively small and isolated springs such as Burtanya, Colanya, Goonerah, Tareen and Waihora have high densities of stone tools, cores and hearths on their surrounding claypans. Conversely, the large water springs along Yowah Creek are characterised by a mysteriously low density of artefacts, although a thorough exploration of the area could reveal sites situated away from the main wetlands.

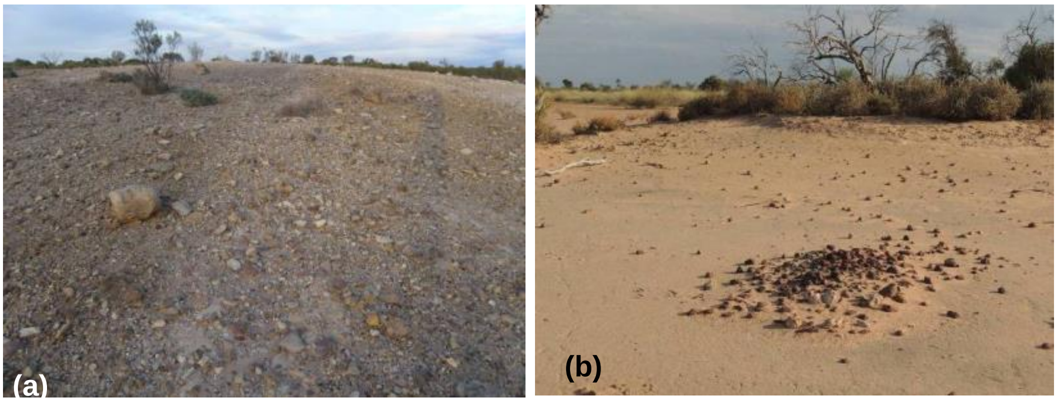


Figure 18 (a) Large active mud spring in Barb Tank group, Currawinya National Park, measuring 30 metres × 20 metres × 2 metres; larger rocks thrown up by the spring were used as core stones for making tools, and many flakes remain strewn across the mound, and (b) intact stone hearth at Warroo Springs south-east of Hungerford.

Aside from the springs, there are only three permanent natural water bodies (i.e. have not been dry since pastoral settlement) across the 150 kilometres × 100 kilometres area encompassing the Eulo supergroup—all waterholes on the lower Paroo on Currawinya National Park and Ningaling (Silcock, unpublished data). Semipermanent waterholes are scattered along the channels of the Paroo and Yowah Creek. However, with the notable exception of the almost-permanent freshwater Lake Numalla, GAB springs are the only lasting surface water between the Paroo and Bulloo rivers, a distance of almost 200 kilometres. Not surprisingly, the water springs and some mud springs were used extensively by early settlers, as traveller stopovers, sites for huts and stations, and vital watering points for livestock.

The line of springs from Fords Bridge to Hungerford formed critical stepping stones for the pioneer pastoralists, as discussed in the Bourke supergroup chapter. The main road still follows this line of springs, and old cart tracks are visible beside the main road on a hard patch of red earth 10 kilometres west of Warroo Springs (Figure 19). In 1865, John Costelloe[1] and his family followed these springs through the dry country north-west of Bourke with 200 cattle and 15 horses. They set up a depot at the most north-westerly spring, 16 kilometres south-east of present-day Hungerford, which they named 'Warroo Springs'. Mary Durack describes their arrival at the springs in *Kings in grass castles*:

> *'Feeling their way up the inconsistent stream of the Warrego and across the Cuttaburra , they moved on to the sandy, timeless plains of the Paroo into an area of seemingly permanent springs, which they judged to be fair horse country but of little use for the cattle.'*
>
> © Copyright, Durack (1959, p. 88)

However, by 1867, these 'permanent' springs had 'almost given out' (Durack 1959; p. 102–103). When the Costelloe's relatives, the Duracks, arrived at Warroo Springs, the party moved to a good waterhole John Costelloe had found on Moble Creek some 450 kilometres to the north. By 1875, the Costelloe–Durack pastoral empire covered nearly all the land between Kyabra Creek and the Diamantina River in Queensland's Channel Country, and they later owned stations across northern Australia. Thus, Warroo Springs played a key role

[1] Costello, John (1838–1923), in *Australian dictionary of biography*, National Centre of Biography, Australian National University, Canberra.

in the pastoral history of inland Australia. The first generation of the Dunk family to take up the Brindingabba lease also initially lived at the springs. The remains of an old hut lie on a sandy rise near the bore, above the now-inactive spring.

Figure 19 Wagon tracks remain beside the current road, a sign of early travellers who followed the line of springs.

People travelling between Eulo and Thargomindah used the Dewalla and Old Bingara Springs until at least 1920. A drover travelling west in search of work in March 1881 described the gardens at Bingara as ‘well laid-out, with small tanks for watering, and a large tank outside for the horses, all supplied from the springs’ (Nameerf 1881). Edwards (1911) recorded that ‘a single mud spring at [Old Bingara] was the main supply for the old station and is now used at the accommodation house for coach travellers.’ The garden edging remains at Old Bingara, along with pipes, tanks, concrete slab, posts and piles of bottles. There are three graves of early settlers nearby: Fitzherbert Brooke (died 1887), Dolly Martyr (aged 17) and an unmarked grave (Figure 20 a–b).

Curracunya Town Reserve and Hotel are marked on the four-mile map of 1916, and were established to serve thirsty travellers on the stock route between Hungerford and Thargomindah (Figure 21). The ruins and the old road remain on a stony rise above the now-dry springs (Figure 20c). Gooning Spring was ‘the only good supply for travelling stock between Dynevor and Boorara’ (Edwards 1912), while Tarko (now known as Fish) Springs provided a drink for travellers between Granite Springs and Boorara. The few main roads through the area now take the most direct route between towns, and these old tracks have become disused and mostly impassable, fading relicts of a time when the springs dictated movements of people as they had for millennia.

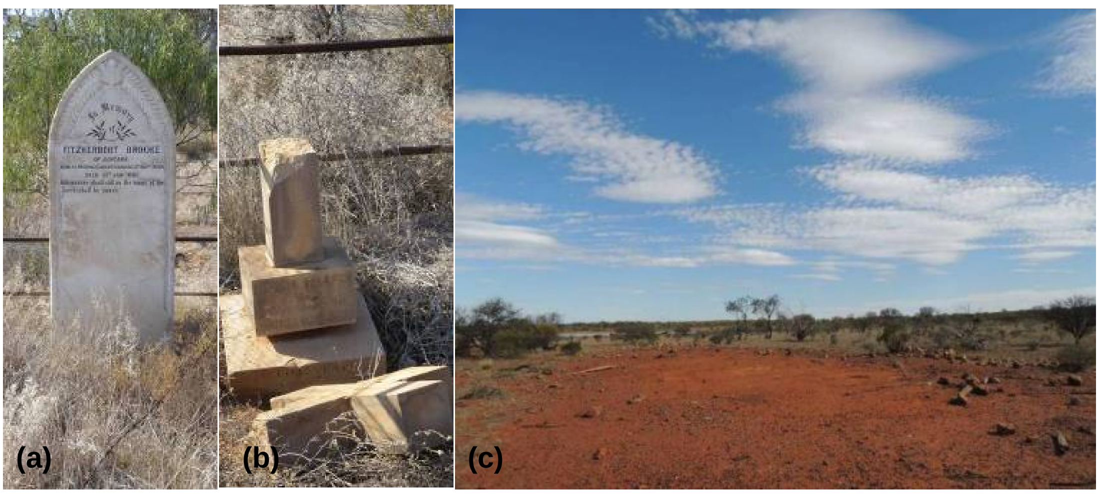


Figure 20 (a) Grave of Fitzherbert Brooke, who died in 1887, (b) undated grave of Dolly Martyr, aged 17 years, near Old Bingara Station, and (c) ruins of Curracunya Hotel on a stony ridge above the basin with now-extinct springs.

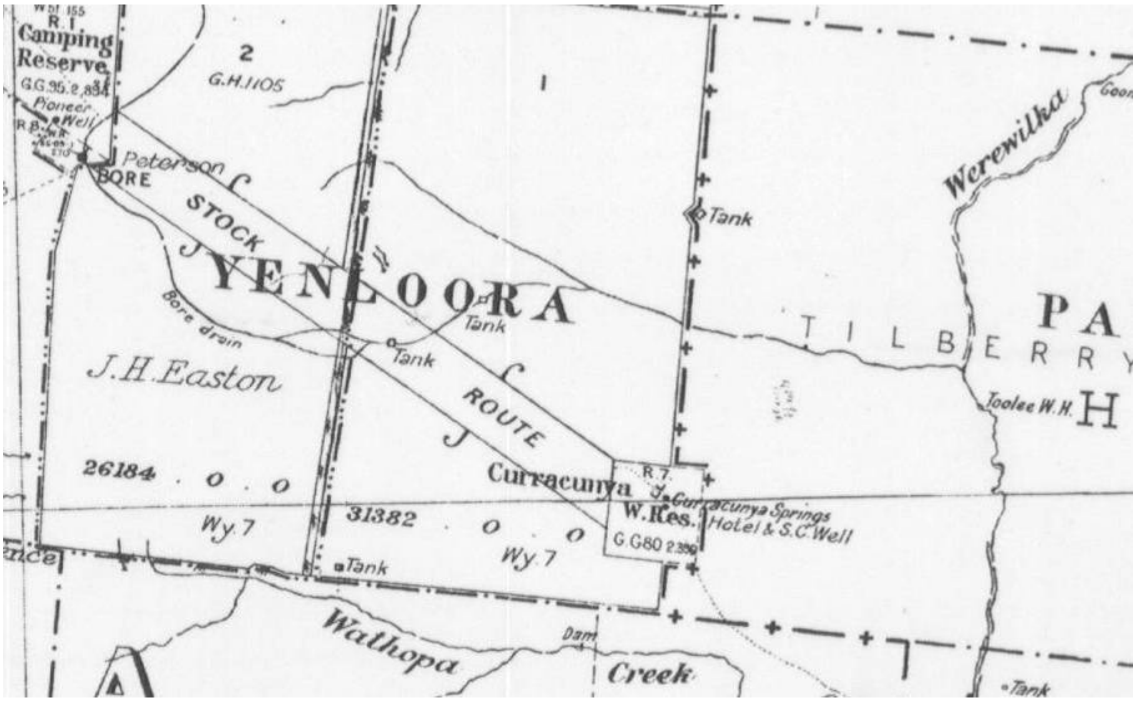


Figure 21 Four-mile series 1 sheet 3C (1931), showing Curracunya Springs Hotel and Well, an important stopover on the stock route between Hungerford and Thargomindah.

Newspaper reports from travellers in the 1880s to early 1900s refer to the ‘celebrated’ or ‘famous’ mud springs on the Eulo–Thargomindah Road west of Yowah Creek, south of the present-day Merimo homestead. They seem to have been a minor tourist attraction, as well as providing water for a town reserve, hut and stock. A drover looking for work travelled from the Balonne to the Bulloo in 1881 and recounted his travels to *The Queenslander*, including a detailed description of emerging from mulga ridges onto:

> *‘ … a fine open plain, on the opposite extremity of which are seen what appear to be a collection of huts. These are the Springs. What seemed to be a field of green maise is*

> *the main spring, fenced to keep off cattle or horses, which if they once get bogged could not be very easily extricated. There are numerous springs, which a Mr Riordan, who is contractor with Mr Bradley for fencing, opened, and having made channels running into the lower creek, has succeeded in obtaining an unfailing supply of splendid water, quite sufficient to water his horses and bullocks and for household purposes. Riordan has a good hut at the Springs, which he makes his headquarters. Leaving the Springs, I got onto Bingara … '*
>
> © Copyright, Nameerf (1881)

Three years later, *The Brisbane Courier's* 'special representative' to the 'never-never country' went on a coach journey between Eulo and Thargomindah, writing:

> *'An hour or so, however, saw the coach over [Yowah Creek] and into mulga country with here and there a small sand ridge. The celebrated mud springs were then come to, and were observed with interest. From these volcano shaped mounds, some of them 20 feet high, came trickling streams of clear water, filling the numerous billabongs in their vicinity … '*
>
> © Copyright, Anon. (1894)

Correspondent 'HFO', despite being glad to have left behind the 'dirty looking and dirty smelling' township of Eulo with its 'evil reputation as a place where a man could be "lambed down" as quickly as in any part of Queensland' and 'where no one who could possibly help it would remain an hour longer than necessary', was less impressed by the springs:

> *'Distant twenty miles from Eulo is the Springs Station … Here I got my first experience of the mud springs of Australia. They are conical excrescences upon the surface of the earth, looking like piles of dug up loose soil. It is better to inspect—admire them you cannot—from a short distance as a too close acquaintance is likely to lead to unpleasant if not dangerous consequences.'*
>
> © Copyright, Anon. (1889)

Fourteen huts, three of which became stations, were built on springs. Springs, or wells dug on or near springs, provided the only surface water for boundary riders at Bokeen, Myrton Bore, Oonunga and Tynghynia, and for outstations at Corina Springs, Goonerah (Figure 22), Granite Springs, Tareen (Figure 23), Tilberry and Wooregym. Many of these springs would have had much greater flow rates to support these now-abandoned habitations. The ruins of an extensive homestead—including concrete foundations, elaborate piping and plumbing, tanks, animal cages, garden edging and timber yards—lie beside Goonamurra spring and waterhole north of Eulo, while the remains of a small hut, apparently occupied by a band of outlaw horse-duffers, are nestled amongst the granite boulders behind Twomanee Spring (Figure 24a). The location of Oonunga Springs and hut on Bingara, described in detail by Ogilvie and Edwards, remains a mystery after extensive searching.

A cook's galley and shearers hut were located on a sandhill above the Baroona Springs north of Cunnamulla. The woolshed and hut as described by Edwards were relocated to a nearby bore that was sunk in 1907 and, ultimately, to their present site near the Baroona house (Bora Schmidt 2012, pers. comm.). An old mud oven remains on a low dune above the now-inactive springs under a huge coolabah. A silted-up well marks the site of a mud spring at the Boorara woolshed, which was cleaned out each year to provide water at shearing time (Figure 24b).

Figure 22 Two boxed wells mark the site of the inactive spring at Goonerah on Boorara, which once supplied the outstation. A rusty bucket still with the wire attached lies near the well (left) and was probably last used by Ruby and Jack McKellar, who lived there until the 1950s. The outstation ruins are on a low dune overlooking the claypan and spring (right).

Figure 23 Well built on small spring (left) at the abandoned Tareen Outstation, in the northern portion of Boorara (right).

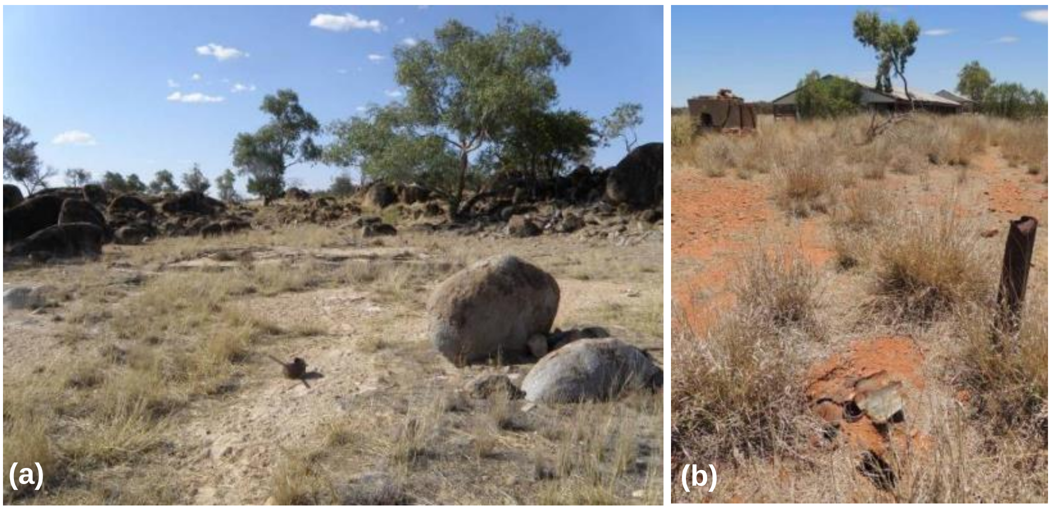


Figure 24 (a) The remains of a hidden hut among granite boulders behind Twomanee Spring, Granite Springs, and (b) silted-up well marking the site of old mud spring, with Boorara shearers quarters in the background.

The Eulo springs were highly valued and used for stock water by early pastoralists. Ogilvie and Edwards several times quoted the number of stock able to be watered at a spring as a measure of its importance. Wiggera Spring was discharging a precious 180 kilolitres per day in 1911, and had been the subject of litigation between the owners of Dynevor and Boorara. To the south, Gooning Springs provided the main watering place for a 1300 hectare paddock and was viewed as a 'valuable asset [to Dynevor] owing to its proximity to Mitchell grass plains south of the spring' (Edwards 1912). A correspondent to the *South Australian Register* reported that improved springs provided 'splendid, never-failing reservoirs of water … and by this means mostly all the stock on the Springs Station [now Carpet Springs/Merimo] and Dynevor Downs are watered' (Anon. 1889, p. 332).

Most water springs and some mud springs have wells, usually silted up and dry, sunk in or near them (Figure 25a). The supply obtained at a long-dry well near Pitherty mud spring (Figure 25b) south of Eulo was especially large: in 1912, Ogilvie (1945) described how 'after baling for 1¼ hours the level had been lowered by only 2 feet, 6 inches, whereas in an ordinary well about 10 feet would have been taken out'. Many water springs have been excavated to provide better access for stock. Excavating mud springs tends to be perilous and unsuccessful, so they were often simply fenced or, in the case of Jacombe Spring on Warroo, lined with timber corduroy to prevent stock becoming bogged. The remains of old yards lie near some springs, including the impressive beefwood yards at Minyeburra Springs on Tarko (Figure 26a). In Taleroo Paddock, on Karto north-west of Hungerford, a partially buried sheep yard near a spring marked on the 1916 four-mile map provides the only clue that there was once permanent water in the vicinity (Figure 26b).

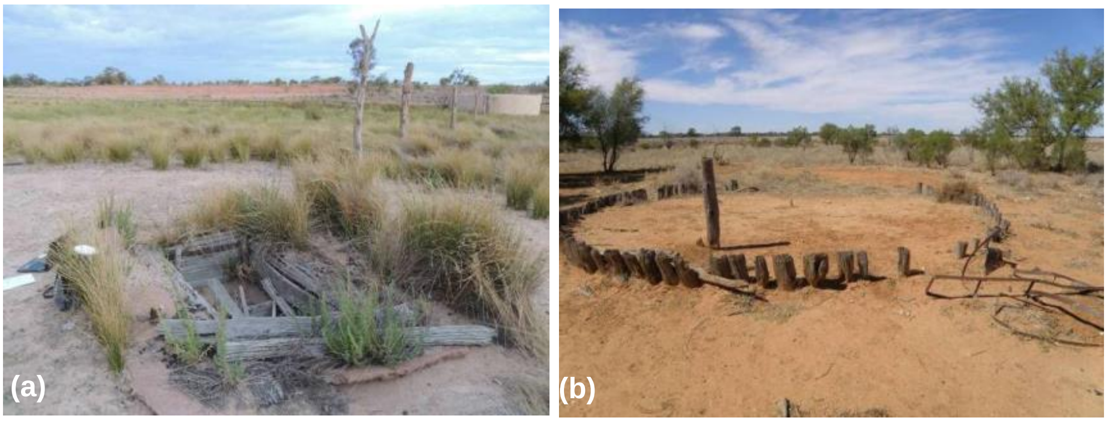


Figure 25 (a) One of two timbered dry wells, marking the site of an inactive spring at Bush Springs, Wombula, and (b) Pitherty Well, 400 metres south of an active mud spring, has been dry for at least 50 years, but once had a huge flow rate.

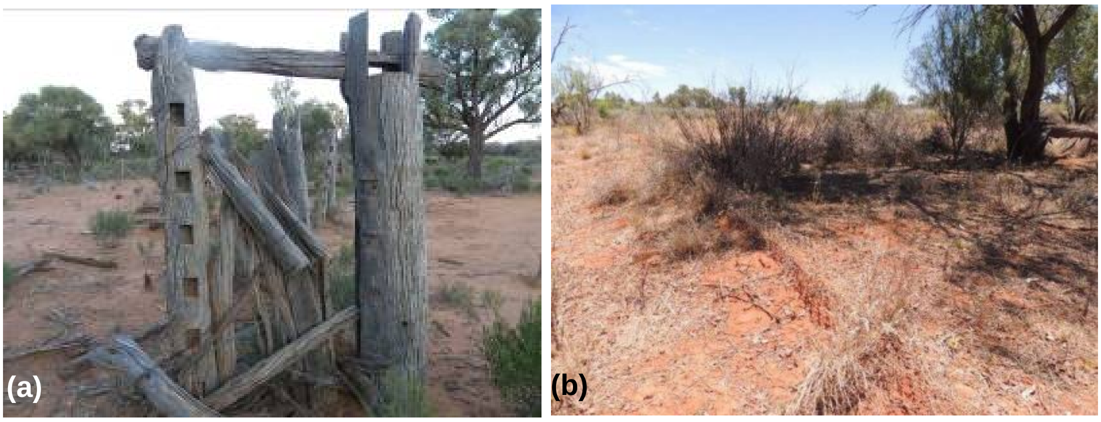


Figure 26 (a) Beefwood yards near Minyeburra springs and hand bore, Tarko, and (b) half-buried low sheep netting fence in vicinity of spring marked on a four-mile map, Karto.

Today, many active springs continue to be used for stock water. Recent years have seen the establishment of some 'groundwater tourism', including the Eulo mud baths, suitably paired with a date winery, and a tourist drive and interpretative signage at the Springvale Mound Springs Nature Refuge. The name Picnic Sandhill Mud Spring hints at some private recreational use and enjoyment of springs by landholders and visitors. Numerous spring groups now fall under nature refuges and national parks, in recognition of their outstanding biological values.

3.4 Biological values

The Eulo supergroup is probably the most biologically significant of the four spring groups considered for this project, despite the substantial losses with aquifer drawdown and the fact that only nine spring groups still support endemic species. Spring endemics include six plants, three crustaceans and seven molluscs, many with very restricted distributions (Table 5). In particular, seven molluscs are endemic to single spring groups (four to Yowah Creek, and one each to Granite, Tunga and Paroo River springs). Two crustaceans, *Ponderella ecomanufactia* and *P. bundoona* are known only from the Paroo River and Yowah Creek springs, while the latter complex contains the only known populations of an undescribed crustacean (*Austrochiltonia* sp. AMS P68160), spider (*Mamersella* sp. AMSKS85341) and flatworm (*Weissius capaciductus*). *Eragrostis fenshamii* is known from four Eulo spring groups, *Hydrocotyle dipleura* from five, *Sporobolus pamelae* and *Eriocaulon carsonii* from two each, and *Isotoma* sp. (Myross RJ Fensham 3883) from Yowah Creek only. *Myriophyllum artesium* occurs at seven spring groups and is also known from bore drains in the area.

None of the previously unsurveyed springs surveyed in 2012 contained spring endemic species; however, an additional population of the vulnerable *Hydrocotyle dipleura* was found at Little Granite Springs. This species is known only from eight spring complexes in the Eulo and Barcaldine supergroups. The Granite Springs group were very heavily grazed in the 1999 and 2004; however, their wetlands had recovered with reduced grazing pressure in 2012 (Figure 27). The species assemblages of other spring wetlands have generally remained constant between 1999–2000 and 2012. However, Tunga Spring was very heavily grazed in 2012, and there was no sign of its endemic snail *Jardinella* sp. AMS C.156780 or the tiny annual forb *Triglochin nana* (Figure 28). Massey Spring and the recently fenced Fish Springs show that spring wetlands can recover rapidly once grazing pressure is relieved. However, this does not mean that some species have not been lost, as discussed later in this section.

Figure 27 Massey Spring in the Granites Spring group, heavily grazed in 2004 (left), and spring wetland vegetation recovered in 2012 (right).

Figure 28 Tunga Spring in August 2000 with dense wetland vegetation (left), and spring wetland much diminished by goats in October 2012 (right).

Yowah Creek is the biological jewel of the Eulo supergroup with 15 spring endemics, including 4 molluscs and 1 crustacean known only from this group, and numerous disjunct (Table 6). It is third only to the Pelican Creek complex north of Aramac and Dalhousie in South Australia in its concentration of endemics. There are five springs, most containing multiple vents, in a narrow band running south-west across the Yowah Creek channels. Site 223 has the largest wetland area, and supports all endemic and disjunct species recorded, including the only population of *Isotoma* sp. (Myross RJ Fensham 3883) in the Eulo supergroup (Figure 29). This species is known only from eight springs in the Pelican Creek complex and this spring, where it is patchily abundant with the total population numbering more than 500 plants.

Table 6 Spring groups containing endemic species and/or disjunct populations in the Eulo supergoup.

Spring group	**Endemic species only known from spring complex**	**Species endemic to GAB spring wetlands**	**Disjunct populations**
Yowah Creek	Crustacea: *Austrochiltonia* sp. AMS P68160; Molluscs: *Jardinella* sp. AMS C.400131, *Jardinella* sp. AMS C.400130, *Jardinella* sp. AMS C.400133 , *Jardinella* sp. AMS C.400132	Plants: *Eragrostis fenshamiii, Eriocaulon carsonii, Hydrocotyle dipleura*, *Isotoma* sp. (Myross RJ Fensham 3883), *Myriophyllum artesium, Sporobolus pamelae* Crustacea: *Ponderella ecomanufactia, Ponderella bundoona* Other invertebrates: *Mamersella* sp. AMS KS85341; *Weissius capaciductus*	Plants: *Cenchrus purpurascens, Phragmites australis, Schoenus falcatus, Spirodela punctata, Utricularia caerulea*
Paroo River	Molluscs: *Jardinella* sp. AMS C.410721	Plants: *Eragrostis fenshamiii, Myriophyllum artesium* Crustacea: *Ponderella ecomanufactia, Ponderella bundoona* Other invertebrates: *Weissius capaciductus*	None
Masseys (Horseshoe)	Molluscs: *Jardinella eulo*	Plants: *Eragrostis fenshamiii, Myriophyllum artesium*	Plants: *Utricularia caerulea*
Tunga	Molluscs: *Jardinella* sp. AMS C.156780	Plants: *Myriophyllum artesium*	Plants: *Schoenus falcatus, Triglochin nana, Utricularia dichotoma*
Dead Sea (including Dead Sea South and Little Bundoona)	None	Plants: *Eragrostis fenshamii, Hydrocotyle dipleura, Sporobolus pamelae*	None
Little Granite	None	Plants: *Hydrocotyle dipleura, Myriophyllum artesium*	Plants: *Utricularia caerulea*
Merimo (Site 238)	None	Plants: *Eragrostis fenshamii, Myriophyllum artesium*	Plants: *Phragmites australis*
Wooregym	None	Plants: *Hydrocotyle dipleura, Myriophyllum artesium*	Plants: *Triglochin nana*
Tungalla	None	Plants: *Myriophyllum artesium*	None

GAB = Great Artesian Basin.

Figure 29 Spring wetland of Site 223, the biggest spring of the Yowah Creek group and containing all endemic species recorded from the group, including the extremely restricted aquatic forb *Isotoma* sp. (Myross RJ Fensham 3883).

Based on the descriptions of Ogilvie and Edwards, and knowledge of the species assemblages of active springs, it is possible to gain a picture of some spring wetlands before their extinction. Most of the descriptions refer to 'clumps of tall rushes', 'green feed', 'grassy bogs' or 'carpet springs' (Table 7). *Cyperus laevigatus* dominates many active carpet springs in the supergoup, and was probably a common component of the extinct spring wetlands. Long-term resident Ian Pike recognised *Eriocaulon carsonii* from Wiggera Spring, which suggests that it was also present in the other large spring groups where Ogilvie and Edwards describe 'grassy bogs' and 'carpet springs', including Baroona, Youleen and Dewalla, and possibly Gooning, Ooliman and Myrton Bore. These larger spring wetlands are also most likely to have contained the other endemic species, although *Hydrocotyle dipleura, Eragrostis fenshamii* and *Sporobolus pamelae* can grow on small soaks (e.g. at the Dead Sea and Little Granite springs). The mat-forming aquatic forb *Myriophyllum artesium* seems most likely to be the 'vegetable growth' giving the water a 'weedy taste' at Dewalla, and was probably present in many of the larger springs with free water.

Baroona Springs seems to have had an especially diverse wetland assemblage, with 'the whole surface thickly coated with duckweed, mosses, rushes and other vegetation [growing] so thickly … that the cattle do not bog' (Edwards 1912). The descriptions of the large, grassy bogs at numerous springs are especially tantalising, and raise the possibility that localised endemic plants and fauna from this supergroup are now extinct. Given the extremely restricted distribution of most snail species (Ponder 2004), it seems certain that some were lost as springs became extinct. Figure 30 shows the inferred distribution of spring endemics, based on the historical record, species composition of active springs and characteristics of inactive springs surveyed. It appears that the biggest losses would have been in the western springs from Dewalla to Youleen, as well as at Baroona.

Table 7 Vegetation descriptions of Ogilvie and Edwards, 1911–1912.

Spring	Description
Baroona West	*'There are several small springs not flowing, but within 100 yards of the main spring their presence being noticeable on account of the clumps of tall rushes.'*
Baroona East	*' … the whole surface is thickly coated with duckweed, mosses, rushes and other vegetation. So thickly are these growing that the cattle do not bog … '*
Bullenbilla Group 1	*'About 6 of the [mound] springs overflow slightly and form small patches of green feed … '*
Bullenbilla Group 2	*' … 5 very large mounds and 2 small carpet springs in the bed of a watercourse … '*
Bush Springs	*' … the whole [spring, well and trough] being enclosed in a very dense clump of reeds.'*
Curracunyah	*'The springs do not overflow to any extent and merely render a few acres of the flat almost impassable.'*
Dewalla	*'The discharge of the main spring is probably about 500 g.p.d…it is absorbed in a grassy bog about 1 chain wide. In large springs decaying vegetable growths have given the water a weedy taste … '*
Gooning[a]	*'The quality of the water is excellent being quite free from odour or taste in spite of a dense growth of reeds around the spring.'*
Ooliman [a]	*'The main spring of this group is situated 1¼ chains south west of the bore and is surrounded by a grassy bog about 20 foot wide.'*
Fish (Tarko) [a]	*'The main spring has at some time been fenced in and the remains of some troughing are alongside, but at present no use is made of the spring, which has become overgrown with reeds.'*
Myrton Bore [a]	*'The surplus forms a small swamp in the bed of the claypan and this is overgrown with the reed peculiar to the spring area.'*
Tunkata [a]	*' … and the water [in the spring/well] was protected by growths of tall reeds.'*
Wiggera	*'A few reeds flourish on the edge of the pool, and good feed is growing in the watercourse, which, however, is rather boggy.'*
Wiggera (carpet)	*'A few small carpet springs occur at the main spring and 4 or 5 about 15 chains west.'*
Youleen	*'The water here spreads over an area of a few acres causing swamps. A growth of green grass has attracted the cattle with the result that the whole area is now a bog and consequently a proper estimate of the flow is difficult to arrive at.'*

a Denotes active springs in 2012.

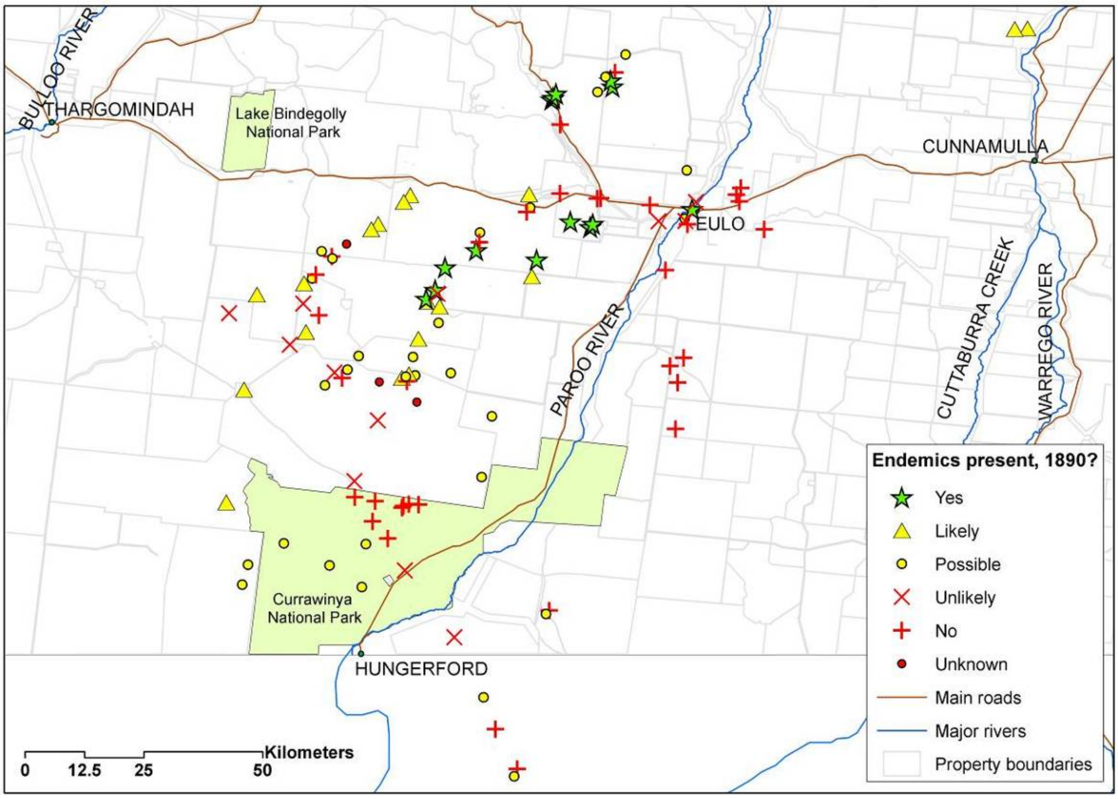


Figure 30 Likely distribution of endemic species, as inferred from historical record and field surveys.

Although lacking specific references to vegetation, the descriptions of Ogilvie and Edwards indicate that Bingara Bore, Curracunya, Kopanyu/Kaponyee, Minyeburra and central Wirrarah springs were also water springs with sizeable wetlands and possibly endemic species. It is also likely that many still-active springs have lost endemic species through drawdown, excavation, and/or grazing and trampling. For example, the 'grassy bog about 20 foot wide' (Ogilvie 1912) at Ooliman Spring has been completely obliterated by goats and pigs (Figure 31a), while the 'small swamp in the bed of the claypan … overgrown with the reed peculiar to the spring area' (Edwards 1912) at Myrton Bore is non-existent. The description of Kopanyu as 'the best spring on [Currawinya] and second only to Youleen and Wiggera in the district' (Ogilvie 1912) seems incongruous with its current local name of the 'stinking spring'—a single pool of black water with a patch of *Cyperus laevigatus* on one side (Figure 31b). This pool is surrounded by scalds, mounds and depressions, and it seems that it was a bigger complex supporting extensive wetlands before bore drilling. Ogilvie also states that the flow, and presumably wetland area, of Tunga Spring was much larger before the bore was sunk (Oligvie 1912).

The centre of large springs is often inaccessible to herbivores, and the shrinking of spring wetlands with aquifer drawdown would have not only reduced habitat, but also exposed the wetland to grazing and trampling. The fleshy endemic *Eriocaulon carsonii* is especially vulnerable to destruction by pigs, which dig up its roots in their feeding frenzies. *Triglochin nana*, currently known in Queensland from just three springs, was collected at Goonamurra by Queensland Government botanist Selwyn Everist in 1938 (Queensland Herbarium database). In December 2012, this spring was active, but very heavily grazed and trampled by cattle, and *Triglochin* sp. were not found.

Many springs, including Tungalla (Figure 31c), Fish (Ogilvie and Edwards' 'Tarko'), Double Well, Tunkata and Wanco, have been excavated, sometimes repeatedly, to provide better access to water for stock. These disturbed wetlands are usually dominated by *Cyperus laevigatus*, sometimes with *Myriophyllum artesium*, and it is possible that the original spring assemblages may have been richer, including, for example, *Eragrostis fenshami, Sporobolus pamelae* and/or *Eriocaulon carsonii*. In other cases, excavation has completely obliterated spring wetlands—for example, at Rose and Bullock Paddock springs in the Dead Sea group.

Despite considerable progress of the *Great Artesian Basin Sustainability Initiative*, including rehabilitation and regulation of 27 bores with flows of more than 0.5 litres/second within 50 kilometres of high-value springs, there remain flowing bores (Figure 31d) within close proximity of high-value springs, some of which have large flows (Table 8; Figure 32).

Table 8 High-flow bores[a] in close proximity to high-value springs in the Eulo supergroup that have not been capped and should be a priority for rehabilitation.

Property (run)	**Latitude**	**Longitude**	**Flow (L/sec)**	**Distance to (km) and name of high-value spring**
Tilbooroo (RN4538)	–27.76330	144.94310	38.00	20 (Dead Sea)
Jandell (RN4902)	–27.81610	144.49140	35.32	31 (Yowah Creek)
Bingara (RN5006)	–28.11110	144.61690	13.28	14 (Tunga)
Strathlea (RN2273)	–28.24010	145.48810	5.09	45 (Paroo River)
Yowah town (RN4976)	–27.97310	144.63610	3.36	13 (Yowah Creek)
Moonjaree (RN4547)	–28.05440	145.47470	1.92	46 (Paroo River)
Gumahah (RN4561)	–28.47110	145.33330	1.68	45 (Paroo River)
Tarko (RN6750)	–28.34140	144.74310	1.50	16 (Tunga)
Werai Park (RN5329)	–28.56640	144.94530	1.39	40 (Wooregym)
Wandilla (RN5409)	–28.31640	145.07030	1.19	18 (Paroo River)
Werai Park (RN1821)	–28.60440	144.92390	0.97	43 (Wooregym)
Currawinya National Park (RN7408)	–28.75860	144.41600	0.81	49 (Little Granite)
Gumahah (RN4552)	–28.50390	145.24690	0.76	43 (Paroo River)
Moonjaree (RN4541)	–27.99530	145.33680	0.56	37 (Paroo River)
Springvale (RN6574)	–28.20530	144.91110	0.56	7 (Merimo)

Property (run)	Latitude	Longitude	Flow (L/sec)	Distance to (km) and name of high-value spring
Jandell (RN4901)	–27.73560	144.41030	0.54	42 (Yowah Creek)
Carpet Springs (RN5538)	–28.16810	144.86890	0.50	6 (Merimo)
Springvale (RN2546)[b]	–28.18690	144.98860	0.47	5 (Paroo River)
Goonamurra (RN5047)[b]	–28.04420	144.87500	0.44	13 (Dead Sea)
Wittenburra (RN6207)[b]	–28.39500	144.67970	0.25	17 (Wooregym)
Turn Turn (RN9094)[b]	–28.30390	144.82170	0.20	9 (Wooregym)
Springvale (RN12202)[b]	–28.18940	144.97750	0.20	7 (Paroo River)
Paddabilla (RN4546)[b]	–28.20220	145.09140	0.17	7 (Paroo River)

a High flow is defined as more than 0.5 megalitres (ML)/day.
b These bores have a flow of <0.5 ML/day, but are <20 kilometres from high-value springs.
Source: Unpublished Queensland GABSI records.

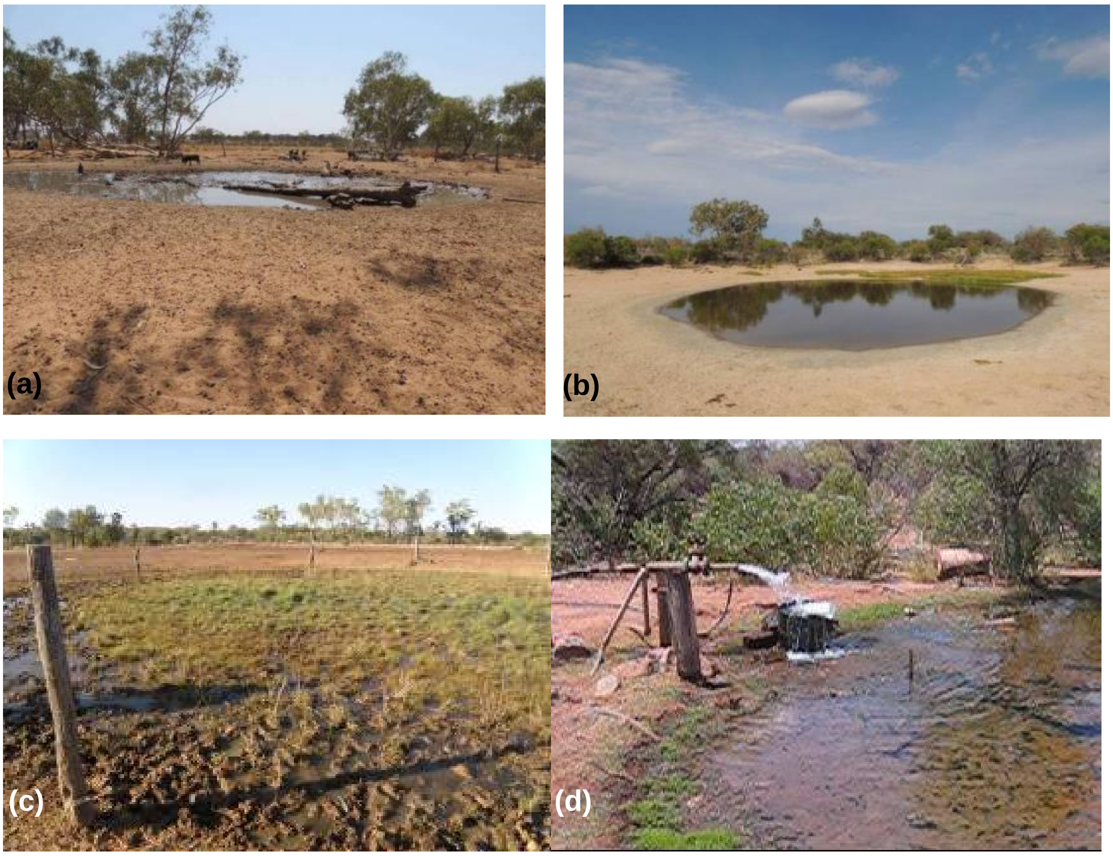


Figure 31 Spring wetland destruction. (a) Ooliman Spring, Ogilvie's 'grassy bog' completely obliterated by goats and pigs, (b) Kopanyu Spring pool, now referred to as the 'stinking spring', but formerly regarded as the third-best spring in the district, (c) Tungalla Spring wetland, excavated in the 1950s and 1970s, possibly supported a more diverse wetland assemblage, and (d) Werewilka bore, situated in the western Eulo supergroup, 13 kilometres west of the high-value Granite Springs group, which has now been capped under the *Great Artesian Basin Sustainability Initiative*.

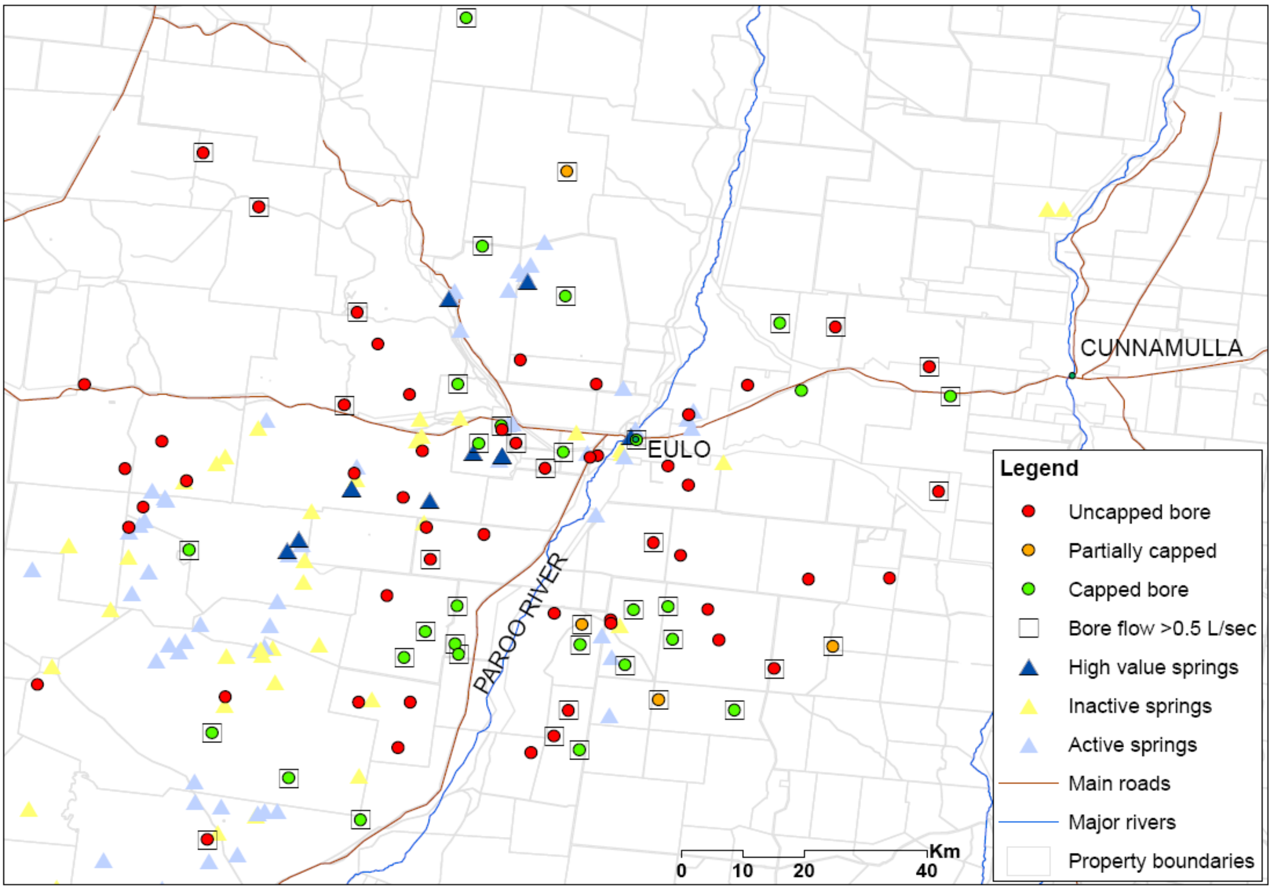


Figure 32 Status of bores within 50 kilometres of high-value springs; high-flow bores that should be a focus of rehabilitation are represented by red and orange circles, enclosed by squares. Uncapped bores are free-flowing without rehabilitation, partially capped bores have been rehabilitated but are still free flowing.

A comprehensive survey of *Calocephalus* sp. (Eulo ME Ballingall MEB2590), a daisy endemic to groundwater scalds and the sides of mound springs in the Eulo supergroup, was also conducted between October and December 2012. This species is listed as near threatened, but this survey has resulted in it being recommended for listing as vulnerable under the *Nature Conservation Act 1992* (Qld) (Appendix D). Eighteen populations were found across a 7000-square-kilometre area (Figure 33a), but with an area of occupancy of just 3.2 square kilometres (Keith 2000). The total population size was estimated to be 15 000 individuals. The largest population, at Basin Bore on Currawinya National Park, contained more than 5000 plants, while some populations contained only 50 individuals. However, population size is known to vary substantially with seasonal conditions, with episodes of mass death and germination.

The species is highly palatable, and 13 of the 18 populations were heavily grazed, usually by goats and/or cattle. Plants were typically cropped to ground level, although most still had a few flowers. Ungrazed plants (usually in fenced areas) have a very different growth form to grazed plants, spreading to 40 centimetes tall and up to 80 centimetres across, and being laden with flowers (Figure 33b). It seems likely that the species was more abundant before the introduction of feral and domestic herbivores, and continued grazing pressure is likely to result in further declines in the abundance and fecundity of the species. However, plants can survive and produce seedlings, even under very heavy grazing pressure, and ongoing monitoring of fenced and unfenced sites at Granite Springs and Currawinya will shed further light on the long-term effects of grazing.

Other species associated with groundwater scalds and representing highly disjunct populations were also recorded, including *Sporobolus partimpatens* (recorded at 7 sites), *Trianthema* sp. (Coorabulka RW Purdie 1404; 23 sites) and *Xerochloa barbata* (8 sites). Aquifer drawdown does not affect the habitat of these species, as scalds remain present even after the extinction of the springs.

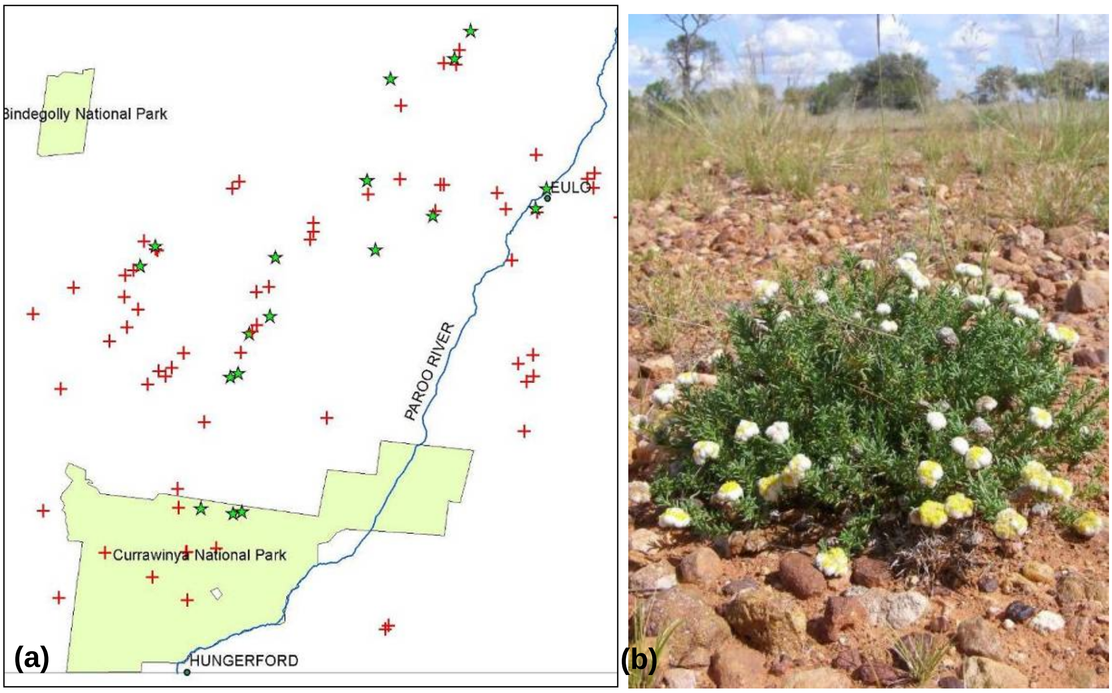


Figure 33 (a) Distribution of *Calocephalus* sp. (Eulo ME Ballingall MEB2590) based on 2012 surveys (green stars = species present, red crosses = species absent), and (b) an ungrazed specimen inside a fenced area at Basin Bore, Currawinya National Park.

The Eulo springs are also valuable for their fossil and archaeological deposits. Megafauna fossils, including some of the best-preserved Diprotodon skeletons in Australia were recently excavated by the Queensland Museum at old springs between Rose and Bullock Paddock springs on Bundoona. Crocodile and Diprotodon teeth were found at Riley Spring (Robins 1999), and bone fragments excavated at Youleen Spring included:

- a brushtail possum (*Trichosurus vulpecula*) mandible
- a phalanx form a pademelon-sized animal
- the jaw of the now-extinct crescent nail-tail wallaby (*Onychogalea lunata*), dated securely to the Pleistocene
- a right maxillary fragment from a small rock-wallaby sized wallaby
- a dentary from spectacled hare-wallaby (*Largorchestes conspicillatus*)
- a mandible from a southern brown bandicoot (*Isoodon obseulus*) (Robins 1998).

4 Bourke supergroup

Rade (1954) noted the association of springs with faults or very shallow basement rock in western New South Wales, especially where an impervious bed blocks an artesian aquifer on the side of the fault opposite to the prevailing direction of water flow. Habermehl (1982) described the Bourke supergroup as extending from White Cliffs in south-west New South Wales and extending across northern New South Wales to Culgoa Floodplain National Park just across the Queensland border. Pickard (1992) documented about 45 sets of springs occurring in the Western Division of New South Wales, mostly within the Bourke supergroup, and visited 29 of these.

4.1 Historical record

Most springs in New South Wales are marked on county map sheets and/or pastoral run surveys drafted between 1860 and 1964 (Table 9). Eight springs identified for this project were not marked on historical maps; however, Hawkes Spring Bore is marked on modern 1:250 000 topographic maps. Vincent Dowling's 1860s sketch map from his diary and reproduced in Bourke and District Historical Society (1969), shows the approximate location of many springs (spelling as per Dowling): Yantabulla, Cullawillalee (Mother Nosey), Wapweela, Boongunyarra, Thooro, Pullamonga, Coonbilly, Youngarinnia, Yarranongany, Kullyna, Native Dog, Bunnavinyah, Gurrera, Old Morton Plains, Gooroomere, Sandy, Tooloomi, Cumborah and Thully. References to certain springs also appear in various newspaper articles and government reports; these are considered in Section 4.3. Queensland Government bore inspectors Ogilvie and Edwards visited Tego and Towry springs in 1911, and provided descriptions and a 'mud map'.

Table 9 Springs marked on historical maps and plans, western New South Wales.

Map/Plan inspected	Springs marked
Four-mile series, 1920	Deadman, Log, Tego, Towry, Tin
County of Gunderbooka (1905)	Kullyna, Native Dog, Sledgehammer (WR31), Thully, Yarrongany
Corella Pastoral Run (c. 1886)	Thully
County of Irrara (1903)	Boongunyarrah, Coonbilly, Mother Nosey, Tanawanta, Thooro Mud, Thooro, Yantabulla, Youngerina
County of Irrara (1964)	Lake Eliza, Mascot, Tanawanta, Thooro, Yantabulla
Lissington pastoral run no. 90 (c. 1870)	Bunnavinyah, Colless, Nulty, Old Gerara
Pirillie pastoral run no. 53 (c. 1870)	Pullamonga
Weilmoringle pastoral run no. 3 (c. 1870)	Gooroomero, Sandy, Tooloomi, Yotomi
Toorale pastoral run no. 257 (c. 1870)	Goonery
County of Barrona (1913)	Goonery
Maranoa pastoral run no. 62 (c. 1870)	Yantabulla
County map of Narran (1914)	Coorigul

Map/Plan inspected	Springs marked
Pastoral holdings index NSW (1886)	Cuddie, Cumborah
Llanillo pastoral run no. 242 (c. 1860)	Cumborah
Wyabray pastoral run (1859)	Cuddie
Momba pastoral run no. 55 (c. 1870)	Bathing, Peery Lake Springs (western and eastern groups)
Tarella pastoral run (1878)	Paralna, Yoorltoo
County of Killara (1912)	Mulyeo, Wee Wattah
Dunlop pastoral run no. 240 (c. 1870)	Mulyeo
Lila Springs pastoral run no. 247 (c. 1870)	Lila
Multagoona pastoral run no. 228 (c. 1870)	Sweetwater
County of Yantara (1906)	Bingewilpa
County of Culgoa (1914)	Old Gerara, Bunnavinyah, Gooroomero

c. = circa, NSW = New South Wales.

4.2 Project survey and reassessment of status of springs

Of the 50 spring groups collated in our database, 26 had been visited in previous surveys (21 by Pickard in 1992, and six by Fensham and Fairfax in 2000) and were revisited. Three sites visited by Pickard and assigned as springs—Youngerina (Little Bore), Boongunyarrah and Gooroomero—were not located despite extensive searching. Seven sites documented but not visited by Pickard were surveyed in 2012, whereas eight previously or recently unknown springs were located from the historical record and/or local knowledge. We searched for but could not locate three springs marked on historical maps (Paralna, Sandy and Yotomi), and five springs were not searched for in the field. The locations of two of these (Old Morton Plains and Brenda Spring) remain obscure, whereas Yantabangee on the Paroo Overflow was underwater at the time of survey in 2012.

We consider that many of the springs in the line from Culgoa Floodplain to Lila Springs are unlikely to emanate from the Great Artesian Basin (GAB) (Figure 37). Nulty, Scrubber and Colless Springs are associated with the Tertiary land surface, which outcrops east of Enngonia and are assumed to be type O (non-GAB) springs (see conceptual diagrams in Appendix E). All seem to be permanent, although Nulty is the largest and its excavated pool maintains a constant water level (Brian Bambrick 2012, pers. comm.; Figure 34b). Colless and Scrubber are soaks emanating from rocky ground, and both fluctuate with recent rainfall. In November 2012, Colless was a tiny soak in a rocky creekline, while Scrubber had contracted in the past month but still covered an area of about 20 metres × 15 metres on the upper slope of a high rocky ridgeline (Figure 34b). Deadman Spring on Culgoa National Park is also associated with the Tertiary surface but was probably never permanent (Andy Coward 2012, pers. comm.).

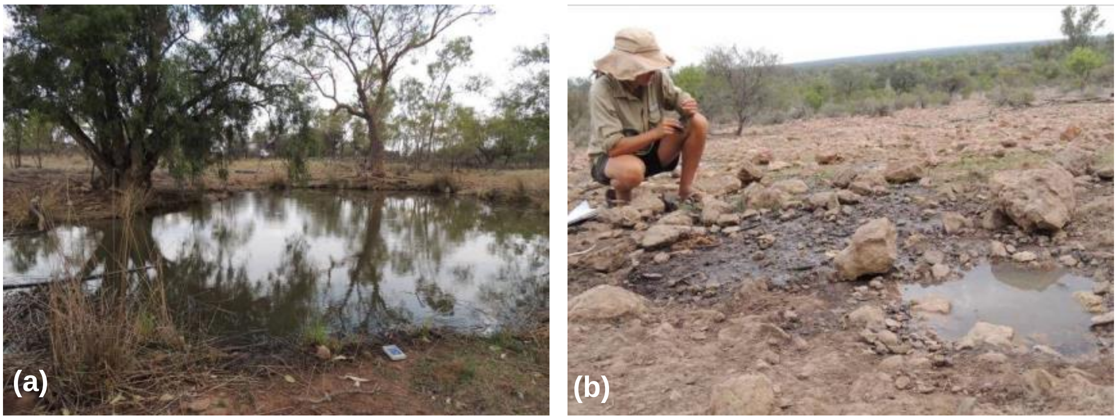


Figure 34 (a) Nulty Spring feeds an excavated pool, and (b) scrubber emanates from the upper slopes of a rocky ridge. Both appear to be associated with the Tertiary land surface rather than the underlying Great Artesian Basin.

The remainder of this line—Tin, Log, Bernard's, Gooroomero, Toolami, Bunnavinyah and Old Gerara, and probably Sandy and Yotomi, which were not located during the field survey—appear to be associated with a watertable close to the surface. Further interpretation is required to determine the association of these springs with the GAB or Tertiary aquifers. However, based on their character (in particular, a lack of groundwater scalds), the long-standing excavations at many sites and the historical description of WE Abbott, we have assumed that they were mostly small and did not support permanent wetlands. Abbott travelled the western districts to appraise pastoral land on behalf of the New South Wales Government in 1880 and wrote:

> *'Gerrarra, or Gerrarra Springs, belongs to a Mr. Shearer (who is a very old resident in that part of the country), and is only remarkable for the springs from which the run takes its name. There are two springs situated within about a mile and a half of each other in a line running about north-east and south-west, and Mr. Shearer told me they form part of a line of springs extending in the same general direction, which were known to him for a distance of 150 miles, the springs being in some cases like those at Gerrara, close together and in others separated by long intervals of waterless country. Some of the springs in this line overflow and some, as those at Gerrara, only rise to within a short distance of the surface. Mr. Shearer has made an excavation in the rock at the mouth of each of the springs of which he is the owner, and draws the water out by horse power for his stock … and as the springs do not supply water as fast as it is drawn out, I had an opportunity of examining the formation both above and below where the water is coming out of the rock. I found that near the surface there was about 4 feet of a soft coarse red sandstone, unlike anything I had seen anywhere else on the Darling, with apparently a slight dip to the south-west, and under this about 4 feet of a coarse light coloured sand cemented slightly together, out of which the water was coming. The cemented sand was resting on a very hard conglomerate, composed chiefly of quartz pebbles; in fact, the same conglomerate which has already been described in this paper under the name of the murrillo conglomerate.'*
>
> © Copyright, Abbott (1881)

Abbott describes the 'murrillo conglomerate' as '[showing] in the banks of the Grawin, and … lying on a white rather soft rock, almost as light as meerschaum … In some places, this underlying rock is so soft as to be easily cut with a knife, and in others as hard as flint' (Abbott 1881). Mr Bagot, a long-term resident on the Moonie River near the Queensland–New South Wales border, informed Abbott that:

' …all the springs about the Narran that are known to him are found in the murrillo conglomerate; some of them rising above the surface and some, like Gerarra, only coming to the surface. This seems to confirm the opinion which I have already formed, that the murrillo conglomerate, where it shows in the north-western part of the Colony, is very much older than the western plains, being part of an older continent, and from the Barwon River to beyond the Warrego forms a sort of bar which obstructs the flow of the underground water to the south-west and so causes it to rise up to or near the surface in many places, by flowing along the surface of the conglomerate whenever there is a slight deposit of sand between the clay and the conglomerate, as at Gerarra.'

© Copyright, Abbott (1881)

From these descriptions, it seems that water never rose to the surface as a natural spring at Old Gerara and Bunnavinyah; rather, excavations were made to reach a shallow watertable (Figure 35 a–b). The first cartographic reference to these 'springs' appears on the County of Culgoa map of 1914, by which time there was indeed water at the ground surface. The area around Gooroomero Spring is dotted with wells dug into a porous, friable rock layer, and water can be obtained in other places by digging. Water flows out of these rocks during rain periods, so that shallow puddles retain water for a long time, and the ground has a hollow sound at times (JD Davies 2012, pers. comm.). The three small springs on Culgoa National Park—Log, Tin and Bernard's—are situated between the larger GAB spring groups Towry and Tego. However, they do not have extensive scalds and are more similar in appearance to the springs in the Gooroomero area. Although their origin is uncertain, they do not appear to have ever been permanent springs.

Toulby and Lila springs (both now inactive, although Toulby maintains an excavated hole; Figure 36) are the only springs in this line that appear to have been permanent GAB springs, and are characterised by large scalded areas created by groundwater precipitates. The standing water level of bore RN 004579 near Toulby has declined about 15 metres since 1950, suggesting that the spring once had a much larger flow. The three Tertiary springs discussed above are assumed to be the 'overflowing' springs described to Abbott in 1881.

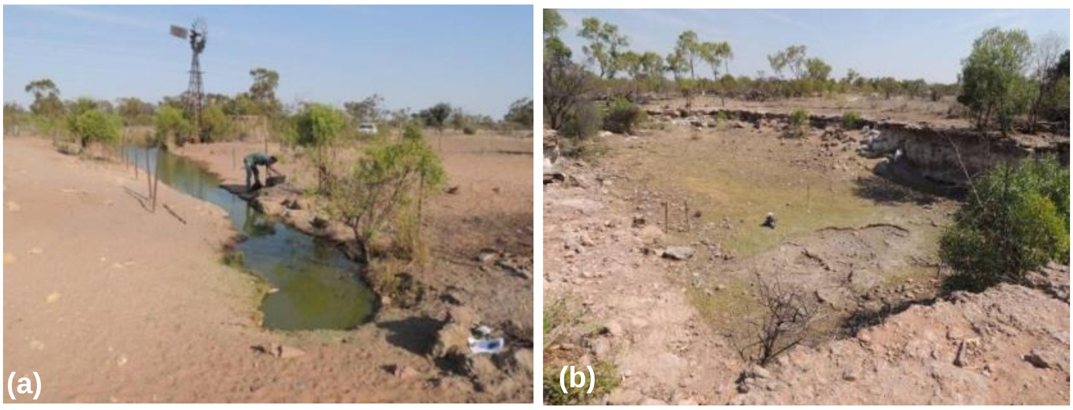


Figure 35 Excavations into a shallow watertable at (a) Old Gerara and (b) Bunnavinyah.

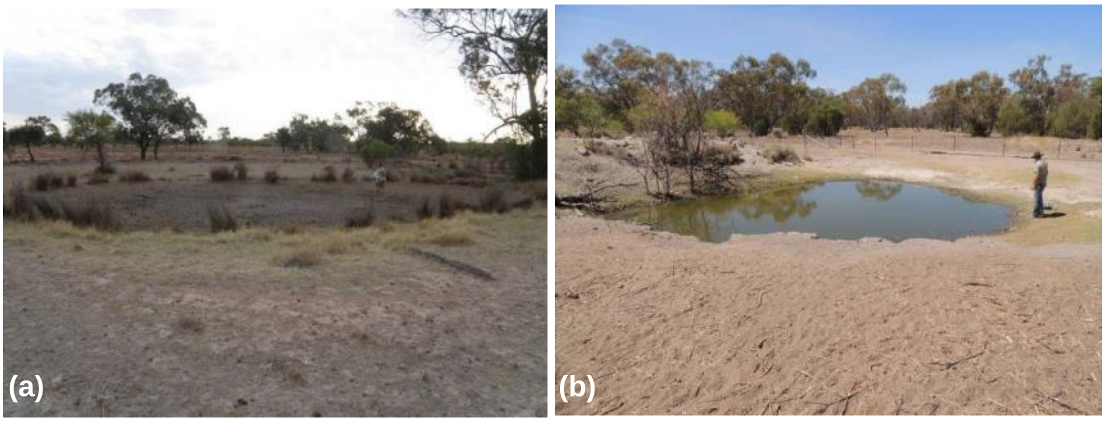
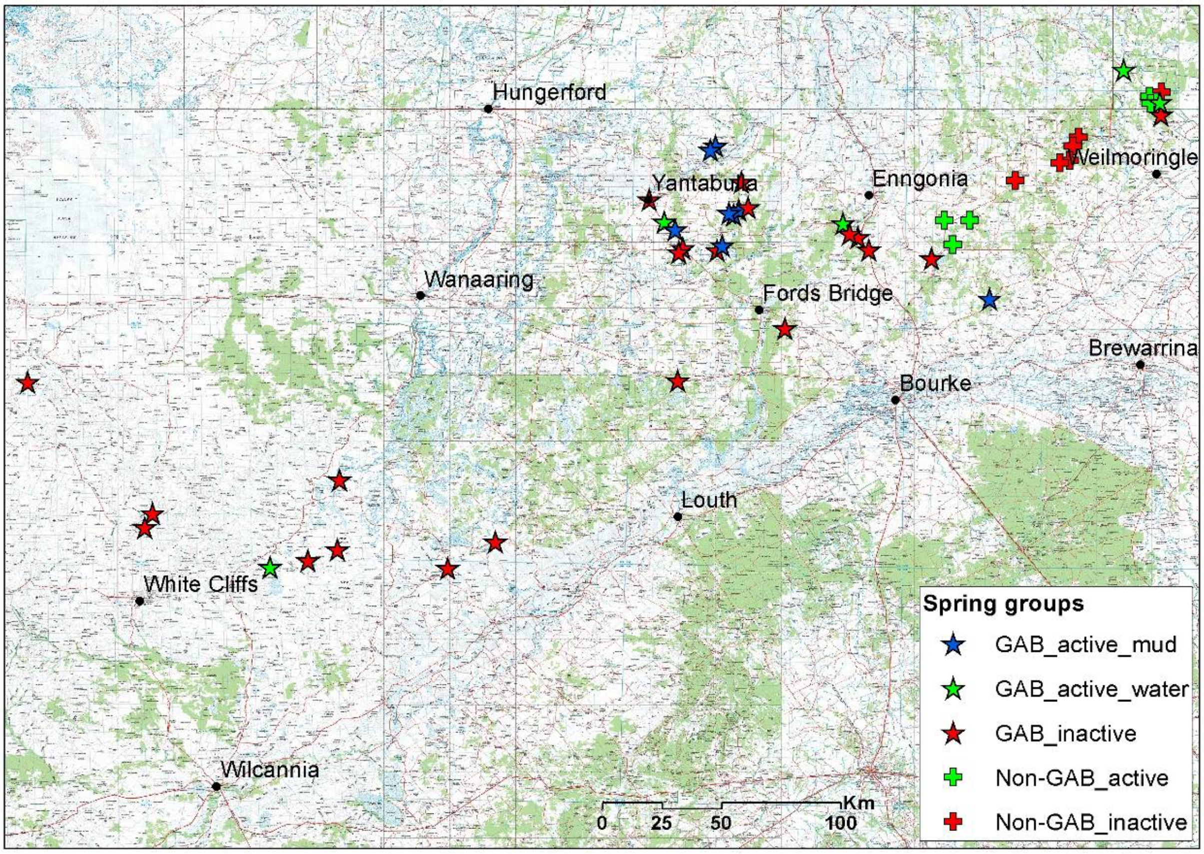


Figure 36 (a) Lila Spring, showing extensive groundwater scald, and (b) excavated spring at Toulby house.

Northwest of Bourke, we were unable to find any trace of Boongunyarrah Spring, which Pickard (1992) photographed as a dry, shallow ditch on a stony rise near Mother Nosey Spring. A stony rise is an unlikely location for a GAB spring. Even before deep artesian drilling, this 'spring' had been dug out, and seems to have been a well tapping the watertable close to Mother Nosey Spring. According to Gilliat:

> *'All indications of the old mud spring, if there was one, have disappeared. The present basin has at some time been dug out, and apparently has been poached by the trampling of cattle that the overflow I noticed four years ago has ceased, and the water stands about 6 inches below the edge of the basin, an occasional bubble indicating the presence of water from below.'*
>
> © Copyright, Gilliat (1885)

Our interpretation leaves 34 GAB spring groups (Figure 37; Table 10). Fourteen groups are comprised of single vents. Peery is by far the biggest group, with at least 130 documented vents. Tego, Towry, Native Dog, Thooro Mud Springs, Coonbilly and Mooroonowa South all have more than seven vents. Sixty-five per cent of GAB spring groups are now inactive, leaving only 12 groups with some active springs (Table 10), although the flow of at least some of these is greatly diminished (Figure 38 a). Some vents documented may have been inactive before European settlement, particularly in the Native Dog, Thooro Mud and Mooroonowa South groups (Figure 38 b).



GAB = Great Artesian Basin.

Figure 37 Springs formerly classified as part of the Bourke supergroup, north-central New South Wales. Non-Great Artesian Basin (GAB) springs include Tertiary springs and those in the line east of Enngonia.

Table 10 Great Artesian Basin spring vents and those identified as active in the Bourke supergroup.

Spring	Total vents identified	Active vents	Notes
Coonbilly	11	0	Large spring complex, probably mostly water
Goonery	1	0	Mud springs
Hawkes	1	0	Now site of bore
Kullyna	2	0	One spring excavated plus inactive mud spring area
Lake Eliza	7	7	Small soaks across claypan
Lila	2	0	Excavated ditch plus mound spring area
Mascot	3	2	Active flat mud springs on claypan; possibly other inactive vents on edges of claypan
Mooroonowa	5	2	Two active mud springs plus at least 3

Spring	Total vents identified	Active vents	Notes
North			inactive mud springs
Mooroonowa South	~11	2	Two small active mud springs; other scalded depressions across claypan—possibly pre-European extinct?
Mother Nosey	1	1	Active mud spring
Mulyeo	1	0	Now site of bore
Native Dog	~16	0	Mounds, craters and depressions
Peery Lakes	~130	~130	Many vents, mostly underwater in 2012; data from Jowett & Christie (2008)
Pullamonga	1	0	Active mud spring
Sledgehammer	1	0	Likely to have been a tiny, isolated spring
Sweetwater	1	1	Flow and wetland area probably much reduced
Tanawanta	1	1	Active mud spring; water is close to surface on other claypans in area
Tego	~20	~20	Six main vents, others dynamic
Thooro	1	0	On claypan; underwater in 2012
Thooro Mud	21	12	Mud springs; some inactive mounds probably inactive pre-European settlement
Thully	2	2	Mud springs on claypan
Toulby	1	0	Excavated spring
Towry	7	6	Four main vents, one excavated plus numerous small vents
Wapweelah	1	0	Now site of bore; impossible to inspect old spring area
Wee Wattah	1	0	Spring was located on scalds 50 m west of bore; water spring with *Eriocaulon carsonii* present
Yantabangee	1	0	Mound spring surveyed by Pickard; underwater in 2012
Yantabulla	>10	0	Number of vents based on 1887 town plan
Yarrongany	>2	0	'Springs' marked on historic maps
Yoorltoo	1	0	Inactive depression
Youngerina	3	0	Site of bore; apparently one of largest springs in NSW

Spring	Total vents identified	Active vents	Notes
Youngerina (Little Bore)	2	0	Not located in 2012

~ = approximately, m = metre, NSW = New South Wales.
Note: Springs not located by Pickard (1992) or in 2012 surveys (Paralna, Bingewilpa, Bathing) are not included.

A cluster of springs north-west of Fords Bridge are mostly active mud springs and some inactive water springs, and are associated with fault lines intersecting with an underlying granite basement. Springs in the Yantabulla area occur along the eastern margin of a granitic basement horst, and small faults connect Kullyna – Native Dog and Coonbilly–Youngerina springs (Rade 1954). Goonery, Sledgehammer and Thully are single isolated springs; only Thully is still active.

A separate cluster occurs on the Paroo Overflow near the south-western edge of the GAB, all of which are extinct except the Peery Lake springs. Three previously undocumented springs were located on survey plans and county maps west of Peery, representing the most westerly springs in New South Wales (Figure 39). The far-western outlier, Bingewilpa, was not searched for during this project, but its location based on David (1891) and the County of Yantara map (1906) seems fairly certain to be Bingewilpa bore.

Figure 38 (a) Diminished but still active spring and wetland at Sweetwater Spring south of Enngonia, and (b) an example of a pebbly mound that was probably extinct before pastoral settlement, Native Dog Springs.

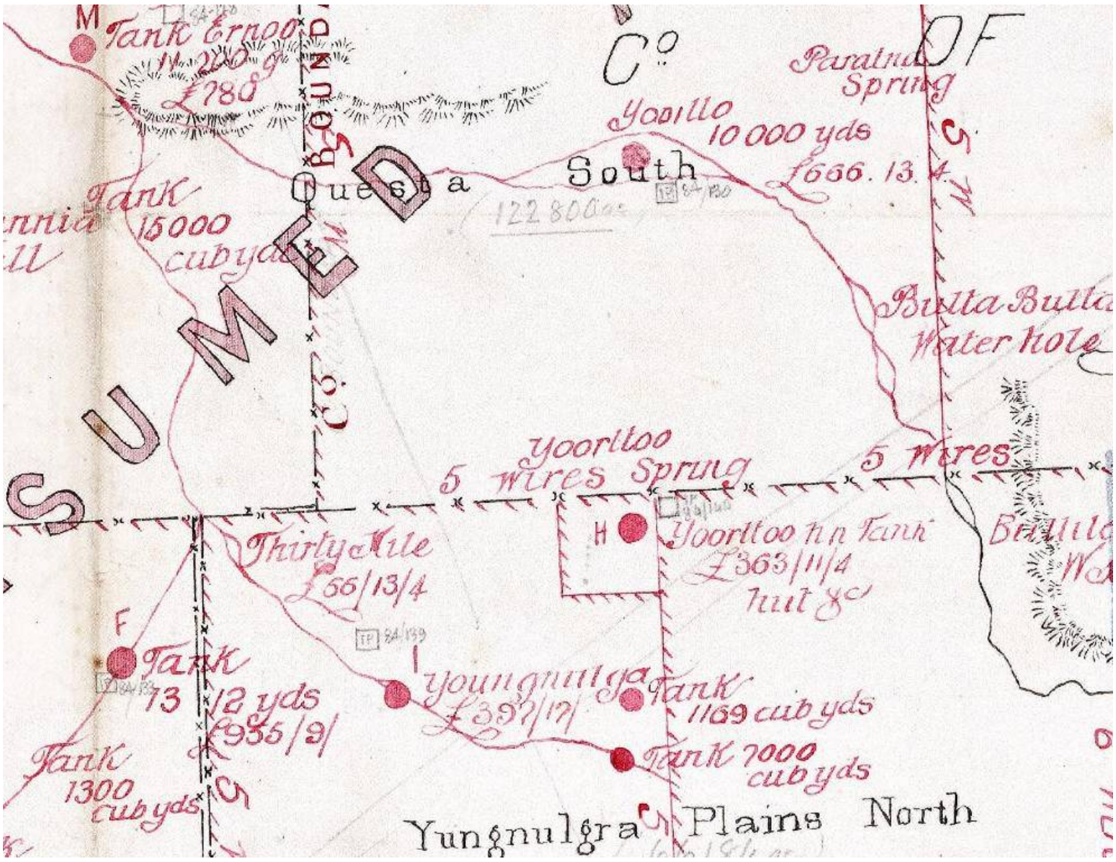


Figure 39 Section of Tarella pastoral run map (1878) showing Yourltoo and Paralna springs.

4.3 Cultural history

Many springs in western New South Wales have Indigenous names, including Yantaboollaboola (Yantabulla), Bunnavinyah, Yanaranah (Youngerina), Culla–Willalee (Mother Nosey), Boongunyarrah, Goonarah (Goonery), as well as the impressive but mysterious Widgegelahgambone, which was mentioned by Kelley (1882) but was not located on any survey plans. The name Yantabulla apparently comes from an Aboriginal word meaning ‘stones around a spring’ (Geographic Names Board of NSW 2012). Unfortunately the original pronunciation, translation and stories attached to these places have mostly been lost. However, the surface archaeological record hints at the long and rich Aboriginal association with these springs. Stone tools were found at all except two of the spring groups surveyed, and were in high densities and spread across large areas at 14 sites. These sites typically include a range of reworked silcrete flakes, cores, grindstone fragments and/or hearths, suggesting more intensive and consistent usage (Veth 1993; Witter 2004).

Aboriginal artefacts are abundant at nearly all spring areas west of Bourke, while most sites to the north-east of Bourke have only scattered stone flakes. The notable exception is Tego Springs in Culgoa Floodplain National Park, where there is a high density of artefacts on a sandy ridge about 500 metres north of the springs. A grindstone and numerous stone flakes have also been found at the nearby Log Spring (Andy Coward 2012, pers. comm.). Artefact scatters are typically associated with scalded areas and claypans adjacent to springs, which partly reflects visibility in these landscapes (Robins & Swanson 2006). Especially rich and dense surface archaeology was noted on the groundwater scalds surrounding Coonbilly, Goonery (Figure 40 a), Hawkes, Kullyna, Lake Eliza (Figure 40 b) and Native Dog Springs.

At Youngerina, stone tools are scattered across the spring area but become abundant on bare areas in stony mulga immediately to the south. Stone flakes, cores and grindstones are abundant in patches along the western shore of Peery Lake, but the major concentration of artefacts, including numerous large grindstones, occurs at the base of a lunette on the eastern shore (Figure 41). This reflects proximity to the ephemeral freshwater lake, where people would congregate when the lake was filled from Paroo River floods. However, the relatively tiny but permanent springs would have provided a reliable drought refuge.

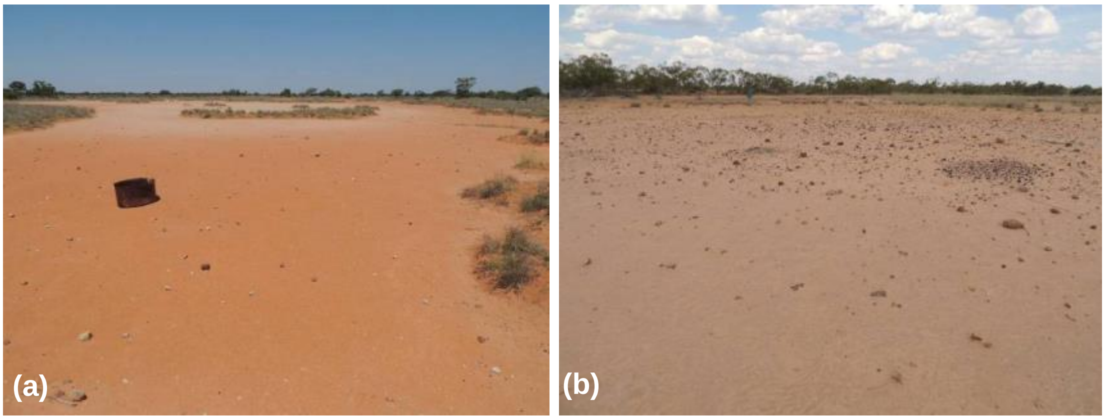


Figure 40 (a) Claypans to the east of Goonery Spring, typical of sites with high density of artefacts, and (b) high density of stone tools and intact stone hearths near springs on Lake Eliza.

Figure 41 Large grindstone on the eastern shore of Peery Lake close to Peery East spring, which was underwater in October 2012.

Aboriginal artefacts often lie alongside relics of more recent European occupation. An eroding shrubby sandhill 300 metres west of the inactive Wee Wattah spring seems to have been the focus for both Aboriginal and early European activity. Stone flakes, cores and grindstone fragments are intermingled with old wheels, wire, crockery, bottles and a half-buried cart (Figure 42-a). A similar situation exists at Yantabulla, where stone tools and European detritus including (mostly) bottles, wire and tin are strewn across the claypans on the eastern outskirts of the now-abandoned village (Figure 42b).

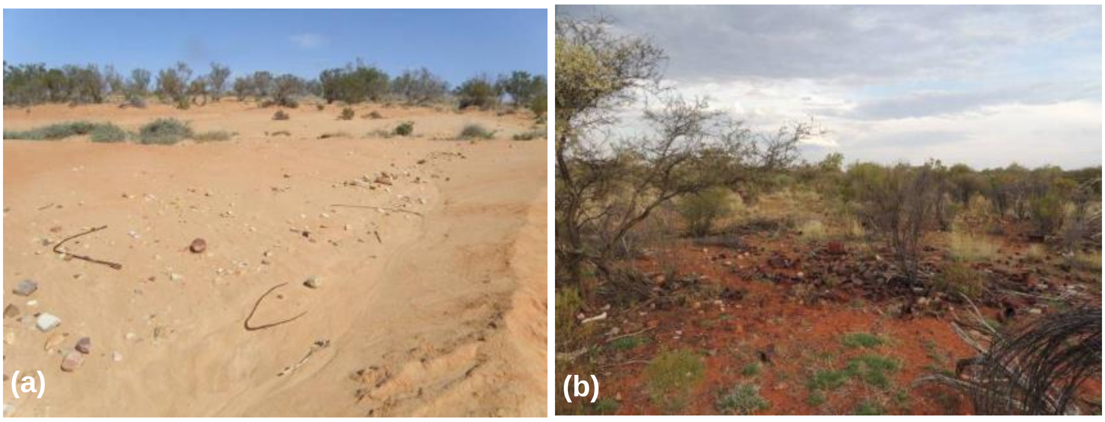


Figure 42 Aboriginal and European history occur together (a) on a sandhill west of Wee Wattah Spring, and (b) on the outskirts of Yantabulla.

Lack of dependable surface water was the major impediment to pastoral settlement of north-western New South Wales. Most goods travelling to Queensland arrived from Bourke, via a tenuous passage easily broken by floods or drought. During the 1860s drought, the *Maitland Mercury* rued that:

> *' … the only obstacle which throws Bourke from the sure line of rapid progress is the almost total absence of water northwards … stations [on the Warrego] are now turning east to Roma and other places for supplies and if the rain doesn't come trade to the Warrego will stop.'*
>
> © Copyright, Maitland Mercury (1865)

South of Cunnamulla, the Warrego River dwindles to a mostly dry sandy channel, and there are only a couple of reliable waterholes along Cuttaburra Creek and the Paroo River. In this waterless country, the small but permanent artesian springs assumed enormous importance and were routinely declared public water reserves, even if they remained too far off of tracks to ever be used as such. Historical maps explicitly reveal the close associations between the early pastoral economy and springs. The Bourke to Hungerford route, trod by historical luminaries such as the Duracks and Henry Lawson, as well as countless unknown shearers and swaggies, follows Youngerina, Mother Nosey, Lake Eliza, Yantabulla and Warroo springs (Figure 39). With the exception of Mother Nosey and Lake Eliza, these springs are no longer active and certainly not modern tourist attractions. However, they would have been critical stopovers for thirsty stock, bullock drivers and travellers. A secondary track from Youngerina to Pullamonga and Coonbilly Springs is also depicted on the 1903 County of Irrara map (Figure 43).

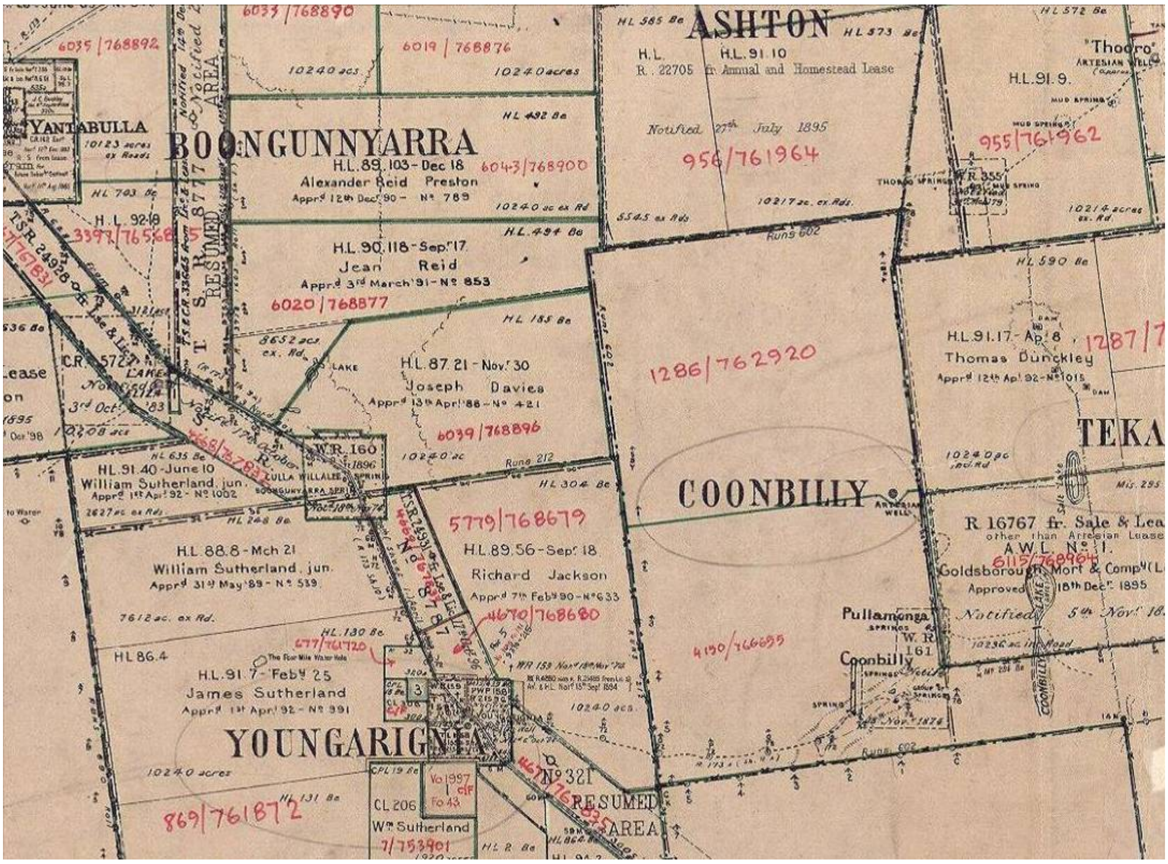


Figure 43 County of Irrara sheet map (1903), depicting section of the Bourke to Hungerford route heading north-west, linking Youngarignia (Youngerina), Boongunyarrah/Culla Willalee (Mother Nosey) and Yantabulla Springs, all marked as square water reserves. The dotted line heading east from Youngarignia marks a secondary track connecting Coonbilly and Pullamonga Springs, then heading north to Thoroo Springs and the mud springs to the north-east.

Similarly, Queensland's four-mile map series from 1913 shows the original Brewarrina–Cunnamulla road clearly following Towry, Log and Tego springs. This road no longer exists, but old wagon tracks are still visible in places. Tego Springs, the most northerly in the line, provided water for the township of Tego. A well was sunk adjacent to the main spring (Ogilvie 1912) and this water supplied a Cobb & Co station and a hotel. Although no buildings remain, the location of the main street has been marked with steel pickets based on the old town plan (Andy Coward 2012, pers. comm.). Further west, Cobb & Co stations and the requisite drinking establishments were also located at Lila and Native Dog springs.

In 1861, pioneer squatter Vincent Dowling established a station at Yantabulla, 100 metres from the most westerly spring, which he used as a base for his explorations into Queensland's Paroo and Bulloo River country. Dowling's homestead later became the site of the Yantabulla Hotel, and the town a centre of commerce with telegraph station, post office and Cobb & Co change station, and even a lemonade factory. The 1887 town plan shows numerous spring vents, and a Chinese garden near a large vent (Figure 44). In his evidence to the 1885 Royal Commission on Water Conservation, HA Gilliat described how about 300 cubic metres had been excavated from this vent. During this process, the blue mud issuing forth had forced the 'old Chinaman' out several times until he carted in a load of stones. According to the local publican, 9 or 10 shafts had been put down around town, all of which yielded salt water with the exception of a well sunk to 12 metres on a spring vent (Gilliat 1885).

Yantabulla has been abandoned since its last residents, Keith and Nora Roberts, left in the mid-1990s. A few dilapidated buildings and diffuse piles of bottles and other detritus of habitation remain (Figure 45a). The springs have not flowed since at least the 1930s (Pickard 1992). There are no obvious signs of springs along the depression running north-west to south-east as depicted in the 1887 plan, although some coolibah-lined depressions may be old springs. A shallow (two metre) abandoned well was found on a sandy rise east of town (Figure 45b). The springs that fed the Chinese garden are dry depressions with scalded rims dotted across a scalded coolibah swamp just north of town (John Stephenson 2012, pers. comm.; Figure 45c).

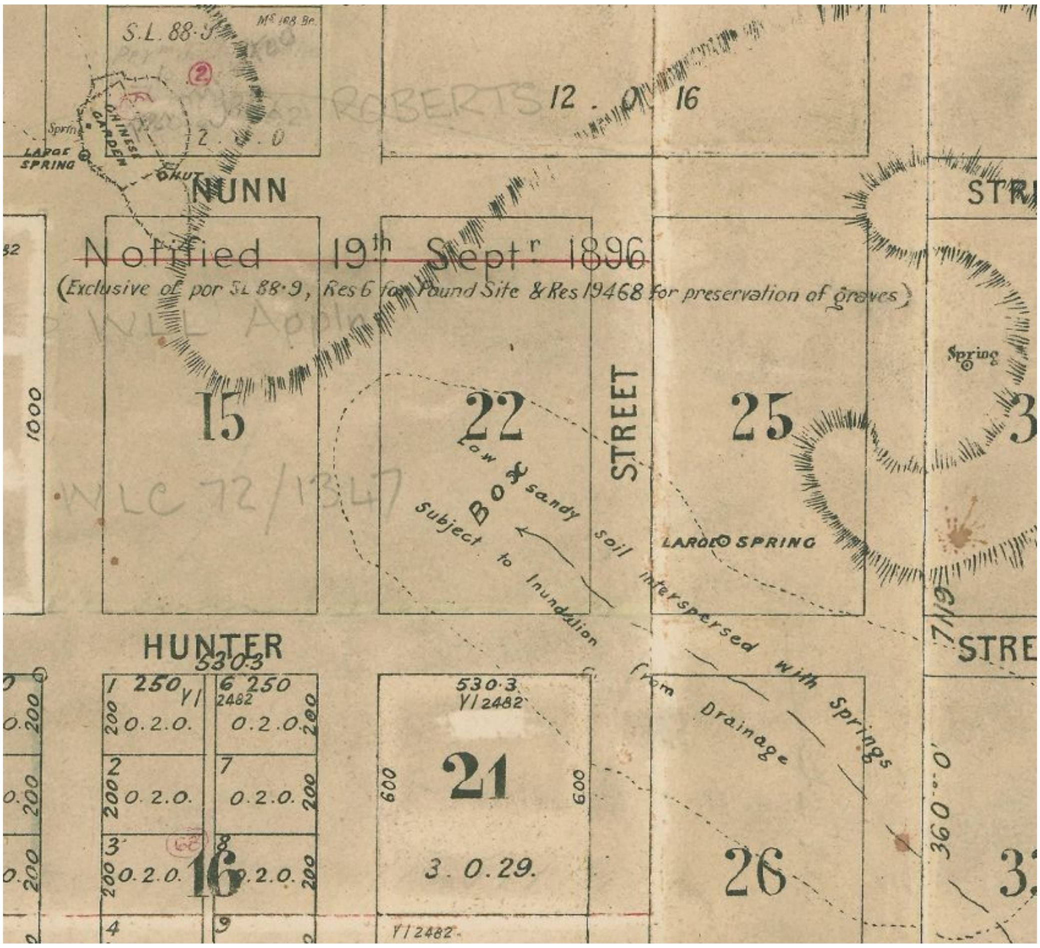


Figure 44 Yantabulla town plan 1887, showing streetscape and location of several springs and a Chinese garden.

Figure 45 (a) The last occupied buildings of the abandoned town of Yantabulla, (b) abandoned well shaft on the eastern outskirts of the town, and (c) large inactive spring vent on the western edge of a coolibah claypan north of town, which once supported a Chinese garden.

Huts and homesteads were often built near springs. Ruins in various states of disrepair were present at one-quarter of springs surveyed in the Bourke supergroup. The ruins of a cypress pine hut lie near the Tertiary Colless Spring and well east of Enngonia (Figure 46a). It is uncertain who lived in the hut or what it was used for, but there were apparently rifle slots in the walls, giving rise to its local name of the 'bushranger's hut' (Brian Bambrick 2012, pers. comm.). The stone ruins of Youldoo homestead and abandoned well sit on a barren rise above the inactive and confusingly named Yourltoo Spring (Yourltoo is another abandoned homestead to the north; Figure 46b). West of Weilmoringle, stone foundations remain adjcent to a dry excavated depression known as the site of Tooloomi Spring (Figure 46c). Other homesteads, such as those at Toulby and Nulty springs, have only been abandoned in the past decade.

Woolsheds were built at Old Gerara (Figure 46d) and Pullamonga springs, and there are remains of old yards, fences and troughs at many springs. Even where such structures are absent, old bottles, wire, tin, assorted contraptions and, at Wee Wattah, a half-buried cart, testify to an early pastoral presence. Even at Bernard's Spring, a small soak in a mulga gully on Culgoa National Park that is not marked on any historical maps and was 'discovered' in the 1950s, a poplar box stump has been cut with an axe and there are old horse yards nearby. Where springs are no longer active, relics of European industry remain isolated discords in an arid landscape, and a reminder of past human activity once nourished by groundwater.

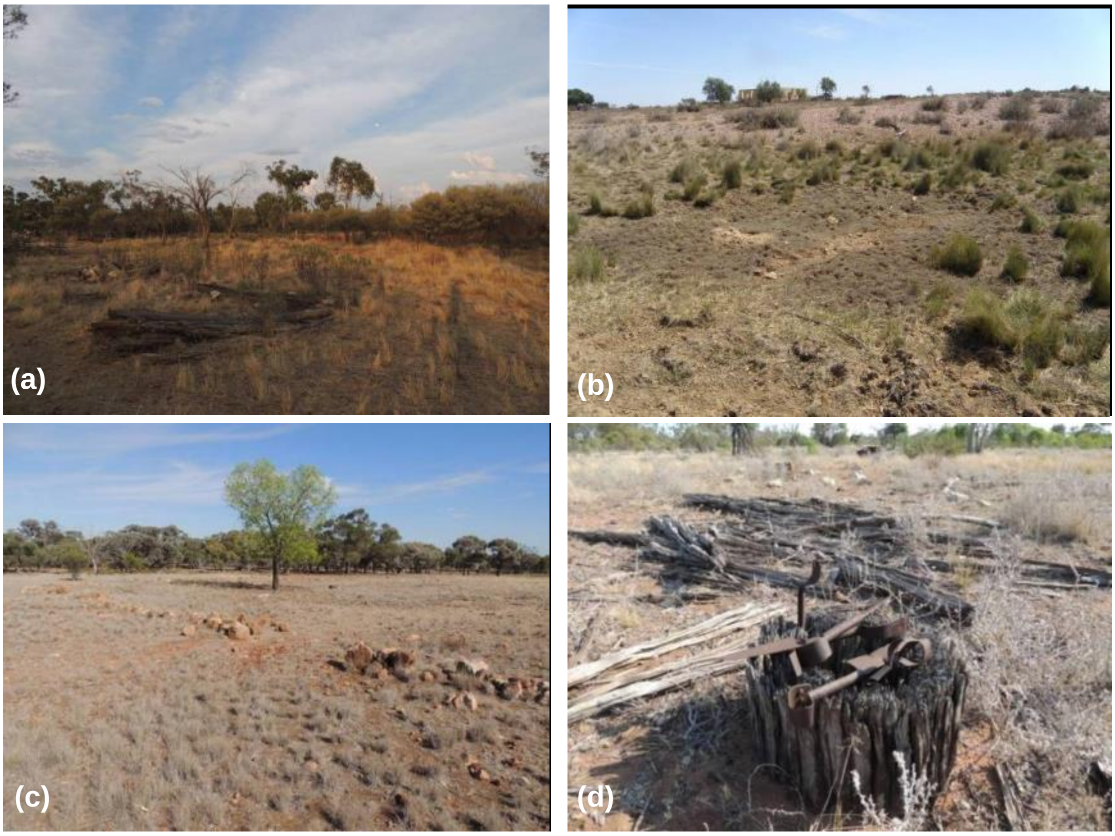


Figure 46 (a) Ruins of the ‘bushranger’s hut’ at Colless Spring, Stanbert, (b) Yourltoo Spring with homestead ruins in the background, (c) stone foundations and lone kurrajong near Tooloomi Spring, Glenora, and (d) hand shears on a stump at Old Gerara, near site of old woolshed.

The Bourke springs played a central role in the discovery and development of the Basin. Springs along stock and trade routes were targeted as sites of early drilling. According to WB Henderson, Superintendent of Diamond Drills, the bore sunk at Goonery Springs on the otherwise dry Bourke–Wanaaring track eventually yielded a supply of 4550 litres a day at 24 metres. The shaft was sunk roughly 400 metres from the springs that ‘were not giving out much water when we started the bore’ (Gilliat 1885). A large flowing bore was also sunk at Native Dog Springs, a public watering place north of Bourke (Figure 47). Simultaneously, private interest sought to increase stock carrying capacities and, in 1879, drilling at Wee Wattah Spring on the Killara Station purportedly led to the first artesian bore (Percy 1906), closely followed by bores at the nearby Mulyeo Spring.

Figure 47 Glass negative, imperial plate, 'Artesian Bore, Native Dog, Barringun District', circa 1884–1917.

In a pattern repeated across the GAB, bores ultimately rendered springs redundant and many were completely forgotten as they dried up. Today, Peery Springs are protected as part of the Paroo–Darling National Park and recognised for their natural and cultural values, as are Towry and Tego in Culgoa Floodplain National Park in Queensland. Other springs lie mostly dry and completely forgotten, except in some cases by pastoralists and local townsfolk.

4.4 Biological values

Only Towry, Tego and Peery springs have vents with measurable flows and support substantial wetlands. Both Tego and Towry consist of numerous vents dominated by *Cyperus laevigatus* on scalded plains (Figure 48a–b). One spring at Tego has a dense mound of *Phragmites australis*, representing a disjunct population of this mostly more mesic species, and providing habitat for echidnas and small birds. Scald endemic *Sporobolus partimpatens* was abundant at one vent at Tego in September 2003 and March 2004, but grasses were very dry and not seeding in October 2012. Towry Flat contains a disjunct population of groundwater specialist *Trianthema* sp. (Coorabulka RW Purdie 1404). Both groups of springs are underwater during floods, and the introduced mosquito fish *Gambusia holbrooki* has invaded the springs. Snails have been collected from the vent with *Phragmites* by Craig Eddie, but only old shells were observed in October 2012. Tego Springs were fenced by Queensland Parks and Wildlife in 2003, and were heavily impacted by cattle, sheep, goats and pigs before this. Towry Bore, situated about 500 metres from the springs, was controlled in 2006, but no effect on the springs has been observed (Andy Coward 2012, pers. comm.).

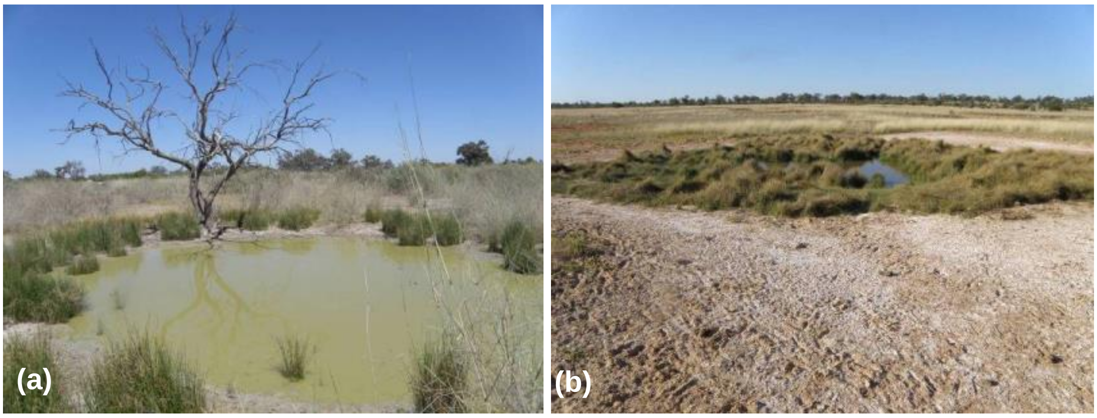


Figure 48 (a) Spring wetland at Tego Springs; dark green clumps are *Cyperus laevigatus*, and (b) one of three main vents on Towry Flat, dominated by *Cyperus laevigatus* with a central shallow pool.

Peery Lake contains the most biologically significant springs in the Bourke supergroup. This ephemeral freshwater lake was full in 2012, and all except 7 of the 130 vents documented by Jowett and Christie (2007) along the north-western shore were underwater (Figure 49a). *Cyperus laevigatus* dominates most spring wetlands, although large areas had died at exposed vents in 2012 due to pelicans roosting on these 'islands' (Figure 49b). In 1992, Pickard found the endangered spring endemic *Eriocaulon carsonii* on one mound, but by 2003 it had spread to adjacent mounds (NSW NPWS 2003). Jowett and Christie (2007) recorded *E. carsonii* on six mounds; we found mostly just one clump, with large populations at two springs. All six *Eriocaulon* springs were underwater in October 2012 and none was found at vents surveyed. The observations at the Peery Springs indicate that *E. carsonii* can survive prolonged flooding, and that its distribution may be dynamic within the spring group across decadal scales. *Utricularia dichotoma* was recorded in 18 spring wetlands (Jowett & Christie 2007) and *Schoenoplectus pungens* can be locally common (Bowen & Presey 1993), both representing highly disjunct western populations.

Figure 49 (a) Small *Cyperus laevigatus* island in Peery Lake in October 2012; a cluster of three springs with *Eriocaulon carsonii* recorded in 2007 are more than 50 metres to the west of this spring (towards the shore) but were submerged in October 2012, and (b) mounded vent, showing dead *Cyperus laevigatus*, apparently due to pelicans using the island as a roosting site.

Cyperus laevigatus is also present at Sweetwater Spring, Wapweelah bore and, unexpectedly, Scrubber Spring on a stony hill. Although this species can be locally common in bore drains in western New South Wales, it occurs in isolated disjunct populations dependent on groundwater-fed wetlands. The only other wetland species recorded at springs were the common grass *Leptochloa fusca* and the introduced grass *Cynodon dactylon*. No snails or fish were observed in any springs. With the exception of *Sporobolus partimpatens* at Tego and *Trianthema* sp. (Coorabulka RW Purdie 1404) at four springs, no scald specialists were found.

What were the biological losses due to spring extinction in western New South Wales? The type specimen of *Eriocaulon carsonii* (Figure 50a) was collected at Wee Wattah Spring (Figure 50b) in 1888 (NSW NPWS 2003), and is the only documented local extinction. At least 10 spring groups are or were comprised solely of mud springs, which by their nature do not support vegetated wetlands. Of the remaining 25 groups, Mulyeo and Hakes Spring bore are located within 50 kilometres of Wee Wattah in similar landscape settings, and it seems likely that their spring wetlands once supported endemic species such as *Eriocaulon carsonii*. Two spring groups that remain partially active—Lake Eliza and Sweetwater—would once have supported larger spring wetlands, possibly with endemic species. The large inactive spring areas of Native Dog (Figure 50c), Coonbilly (Figure 50d), Yantabulla, Youngerina (including Little Bore) and Goonery also seem likely to have supported substantial spring wetlands.

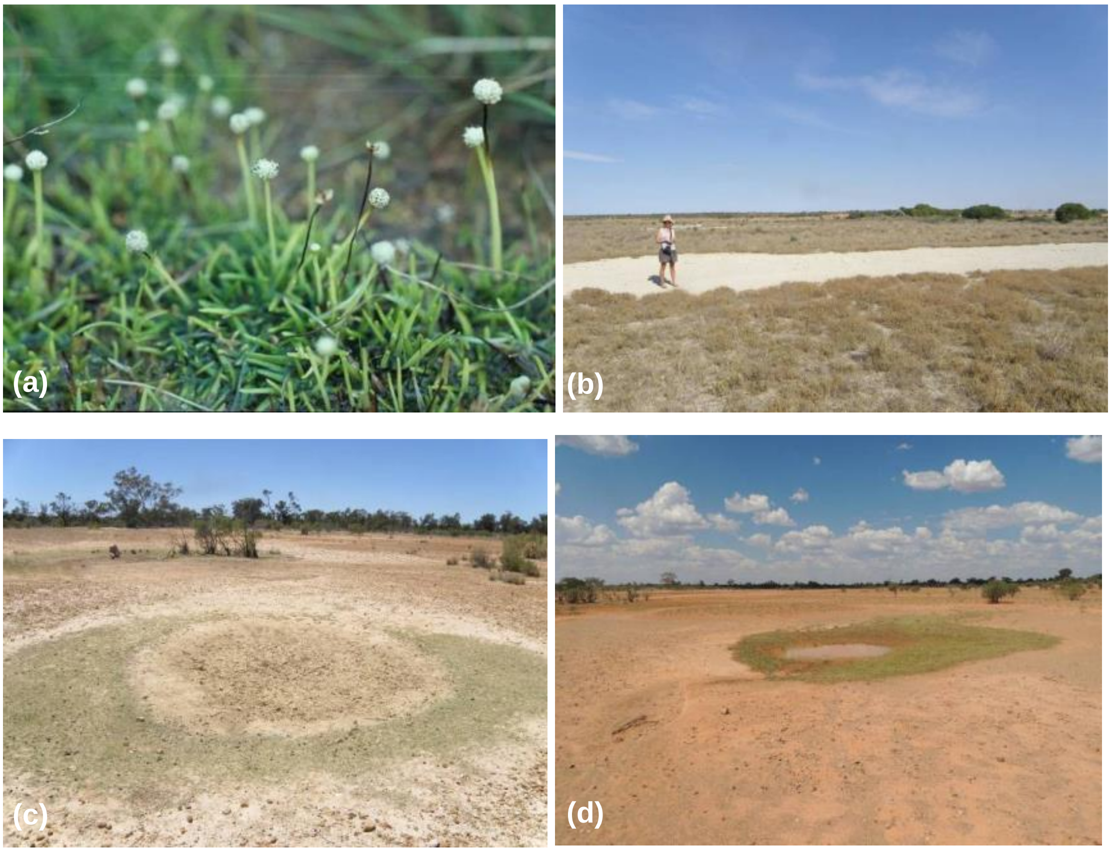


Figure 50 (a) Salt pipewort, *Eriocaulon carsonii*, (b) site of the now-inactive Wee Wattah spring where the type specimen was collected in 1888, (c–d) old springs in the inactive Native Dog (c) and Coonbilly (d) spring complexes, which probably supported substantial spring wetlands and possibly endemic species.

As for the Eulo group, there remain flowing bores within close proximity of high-value springs, some of which have large flows (Table 11; Figure 51). However, the current status of most bores is not known. Data on the status of bores and their flow rates need to be collected, and bores prioritised for rehabilitation accordingly.

Table 11 Flowing bores within 50 kilometres of Peery Springs; all were flowing at some stage but their current status is unknown.

Work number (name)	Latitude	Longitude	Flow notes	GABSI status	Flow (L/sec) (year measured)
GW004350	–30.88319	143.59597	Flowing at some stage	Not specified	–
GW004354 (Momba no. 4)	–30.65958	143.82513	Flowing at some stage	Not specified	0.20 (1965)
GW004581 (Tongo)	–30.34736	143.83984	Flowing at some stage	Not specified	0.20 (1964)
GW004733 (Kallara no. 22)	–30.55763	144.03818	Flowing at some stage	Not specified	–
GW010384	–30.63486	143.92096	Flowing at some stage	Not specified	–
GW010490 (Mackeon's)	–30.52625	143.72179	Flowing at some stage	Expression of interest received for funding, but project unlikely to go ahead	1.30 (1956)
GW010579 (Klondyke)	–30.65152	143.71568	Flowing at some stage	Expression of interest received for funding, but project unlikely to go ahead	0.52 (1987)
GW010580 (Jock's)	–30.59736	143.79318	Flowing at some stage	Not specified	0.88 (1987)
GW010582 (Mac's)	–30.61625	143.73290	Flowing at time of drilling	Expression of interest received for funding, but project unlikely to go ahead	0.61 (1987)
GW010800 (North Tongo)	–30.43652	143.82790	Flowing at some stage	Not specified	0.10 (1961)
GW010804 (Middle)	–30.59986	143.83374	Flowing at some stage	Not specified	1.00 (1975)
GW010869 (Mt Jack)	–30.81264	143.66958	Flowing at the time of drilling	Not specified	–
GW011198 (Palooka)	–30.66375	143.68402	Flowing at the time of drilling	Expression of interest received for funding, but project unlikely to go ahead	1.53 (1987)
GW013049 (Ram)	–30.62375	143.68624	Flowing at some stage	Expression of interest received for funding, but project unlikely to go ahead	0.40 (1987)
GW014316 (Yantabangee)	–30.53791	143.75124	Flowing at some stage	Expression of interest received for funding, but project unlikely to go ahead	2.40 (1987)

Work number (name)	Latitude	Longitude	Flow notes	GABSI status	Flow (L/sec) (year measured)
GW014329 (Klondyke no. 2)	–30.65652	143.80068	Flowing at some stage	Not specified	–
GW014330 (Klondyke no. 3)	–30.66069	143.85652	Flowing at some stage	Not specified	0.10 (1960)
GW014331	–30.68819	143.70596	Flowing at the time of drilling	Not specified	–
GW014458 (Kiwi)	–30.63180	143.78040	Flowing at some stage	Expression of interest received for funding, but project unlikely to go ahead	0.12 (1987)
GW014705 (Coorpooka)	–30.73319	143.65596	Flowing at some stage	Not specified	0.21 (2004)
GW016685	–30.56597	143.70652	Flowing at the time of drilling	Not specified	–
GW016954 (Glasson's)	–30.49041	143.74429	Flowing at some stage	Not specified	0.3 (1975)
GW019373 (Peery)	–30.67653	143.62430	Flowing at some stage	Not specified	1.60 (2008)
GW019977 (Klondyke no. 4)	–30.62514	143.70985	Flowing at some stage	Expression of interest received for funding, but project unlikely to go ahead	0.52 (1987)
GW020164	–30.49541	143.93929	Flowing at the time of drilling	Not specified	–
GW022750 (Top Flow)	–30.73652	143.66680	Flowing at some stage	Not specified	0.26 (1987)
GW022751 (Bottom Flow)	–30.84041	143.62346	Flowing at some stage	Not specified	–

– = unknown, GABSI = Great Artesian Basin Sustainability Initiative.

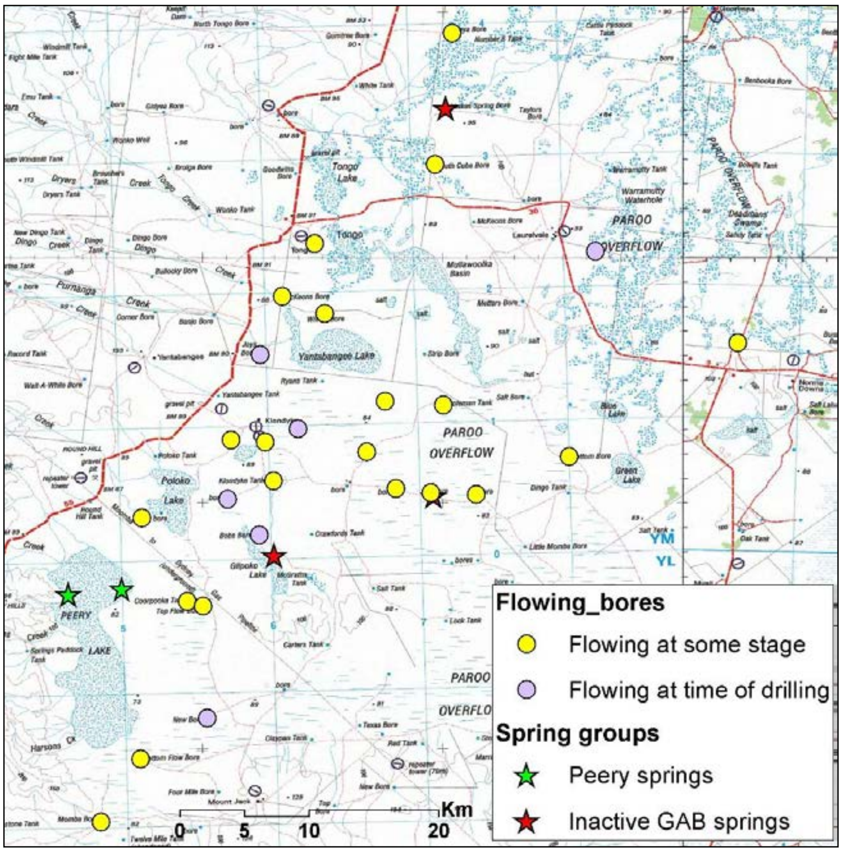


Figure 51 Flowing Great Artesian Basin (GAB) bores within 50 kilometres of Peery Springs; all were flowing for some period after drilling but their current status is unknown. Any that are still flowing should be a priority for rehabilitation.

5 Bogan River supergroup

Rade (1955) considered these springs to be associated with the eastern margin of a peninsula-like basement prominence that forms the western margin of the Coonamble Basin or Embayment. Habermehl (1982) identified the Bogan River supergroup as comprising three widely spaced springs along a 150 kilometre line from Coolabah to Walgett. Pickard (1992) visited and documented Cumborah Spring, but did not visit Coolabah and Cuddie. Cuddie Spring is famous as a site of Pleistocene megafauna fossils, which were discovered when a well was sunk in the 1870s. Some of these were sent to Sydney and analysed by WB Clark, and extensive archaeological investigations commenced in 1933 (see Field 2006 for an overview of the site and research conducted). Coorigul is marked on 1:250 000 topographic maps; however, it had not been documented in previous surveys.

5.1 Historical record

All springs except Coolabah are located on historical maps: Coorigul on the county map of Narran (1914); Cumborah on the Llanillo pastoral run survey 242 and pastoral holdings index of New South Wales map (1886); and Cuddie on the Wyabray pastoral run survey (1859) and pastoral holdings index of New South Wales map (1886). Although Coolabah Spring is not shown on maps or plans, the Mayfield property used to be called 'The Springs' and The Springs Tank is marked to the east of the spring on 1:250 000 topographic maps. Maps included in the reports of the Interstate Conferences on Artesian Water (1913, 1914, 1922, 1924 and 1925) and Interstate Conference on Water Conservation and Irrigation (1939) show most of these springs.

Major Thomas Mitchell passed through the area in March 1847 en route to the Balonne, and was taken to some springs on a plain south-south-east of Narran Lakes. His journal entry for 5 March reads:

> *'Our guides brought us at length to some waterholes, amongst some verdant grass on a plain, where no stranger would have looked for water; and here we encamped fifteen good miles from the Barwan. The ponds were called "Carawy," and were vitally important to us, enabling us to pass on towards the Narran, which was still, as we had been informed, twenty-five miles off. As we approached these springs, I saw some natives running off, and I sent one of the guides after them to say we should do them no harm, and beg them to stop, but he could not overtake them.'*
>
>

There are no springs marked on plans or maps, no likely signatures on Google Earth, and the landholders we spoke to had no knowledge of springs in this area. It is possible that Mitchell's use of the term 'springs' is loose and they were simply pools of rain or flood water, or small ephemeral soaks, or that the springs are now extinct and forgotten.

5.2 Project survey and reassessment of spring status

Four springs were surveyed in November 2012 (Figure 52). Coorigul Spring on the Queensland – New South Wales border is an intermittent Tertiary spring, similar in appearance to Tertiary springs near Dirranbandi to the north-east. It is situated in a hollow in low stony hills where the local watertable is very close to the surface (Dick & Kate Bucknell 2012, pers. comm.; Figure 53a). These factors, as well as the water-quality data (pH 6.43, 28.0 °C, 468 microsiemens per cm, compared with a pH of 11 at the house bore water, which comes from 900 metres), suggest that this spring is emanating from a local Tertiary aquifer rather than the Great Artesian Basin (GAB).

Cumborah Springs are situated at the junction of Tertiary sandstone and the Griman Creek Formation, which is both a Basin aquifer and aquitard. Habermehl (1982) considered that they might be related to the Tertiary sediments and thus not part of the GAB. Based on geological evidence and the appearance of the springs, we interpret them as non-GAB type O springs, with downward flow through the Tertiary material discharging at the junction of the Griman Creek Formation. Water present in March 1992 and November 2012 is probably run-on water, and the vegetation is dominated by generalist wetland species (Figure 53b).

During the drought of 1877, a well was sunk to 8.4 metres in the centre of the lake at Cuddie Spring (Figure 53c), and water flowed up at a rate of 11 360 litres per day (Abbott 1881). There is broad consensus among geomorphologists that Cuddie was never a true spring with free water on the surface, at least not in recent history. This is based on the fact that the upper 3 metres of the sediments are lacustrine clays and there are no precipitate salts (Judith Field 2012, pers. comm.). However, the historical record suggests otherwise. Abbott recorded that:

> *'When the country was first taken up, the cuddie was simply a bog-hole, which never dried up—always, even in the greatest droughts, affording water to the aboriginals when they scooped it out, but forming a dangerous trap for cattle … '*
>
> © Copyright, Abbott (1881)

The district surveyor provided evidence about the site to the 1885 Royal Commission of Water Conservation:

> *'It was originally a mud spring. It is in a hollow 100 yards across or more, and in the hollow a well has been sunk to a depth of 28 feet. Great difficulty was experienced in sinking the well, owing to the way the sides fell in, but timber was used to keep up the sides. The water now trickles over the top of the timber, which is several feet above the surface of the ground.'*
>
> © Copyright, Gilliat (1885)

The Wyabray pastoral run survey (1859) and pastoral holdings index of New South Wales map (1886) both show 'Cuddie Spring'. Anderson and Fletcher (1934) reported that the spring had been inactive ever since a nearby bore had been sunk at the turn of the century. Based on this historical evidence, we consider Cuddie to have been a single isolated mud spring emanating from the Basin. Anderson and Fletcher (1934) also found bullock and horse remains 0.6 metres deep, an indication that this thickness of sediments was deposited during the past 200 years according to Watkins and Meakin (1996). These authors also refer to a stratigraphic hole drilled by the Geological Survey of New South Wales at Cuddie Springs in 1990, with Rolling Downs Group sediments encountered at 41 metres and overlain by Quaternary sands. Although Cuddie Springs and its immediate surroundings do not give the appearance of a true artesian basin spring, there is the (slight) possibility that groundwater was derived from the Pleistocene units (Trangie Formation). Alternatively, it could have been derived from the Lower Cretaceous – Jurassic Keelindi beds, the latter being the equivalent of the Mooga Sandstone, or even from the Pilliga Sandstone. This artesian groundwater could have risen to the surface along one of the many lineaments, or interpreted or intersecting faults derived from geophysical data and Landsat imagery

(Figures 18–20, 22 and 23) shown in Watkins and Meakin (1996), and on the side map and geological cross-section at the Walgett SH 55-11 Geological Series map sheet 1:250 000.

The site of Coolabah Spring was marked with a steel picket by the previous lessee, who described it as a small permanent seep (Pickard 1992). In November 2012, the shallow depression on a flood-out of Turners Creek was filled with rainwater (Figure 53d). The site did not have the appearance of a GAB spring; however, scalds of extinct springs on floodplains can be easily obscured over time. The area surrounding 'The Springs tank' marked on topographic maps one kilometre to the east of the marked spring was also inspected, and had numerous depressions and scalds. The presence of The Springs tank and the fact that Mayfield used to be called 'The Springs' indicates that there were springs present in the area, either on the floodplain at the marked site or at the tank. Like Cuddie Spring, the site is situated along the margin of the Coonamble Embayment, and we consider it most likely to be an extinct type K GAB spring (see conceptual diagrams in Appendix E).

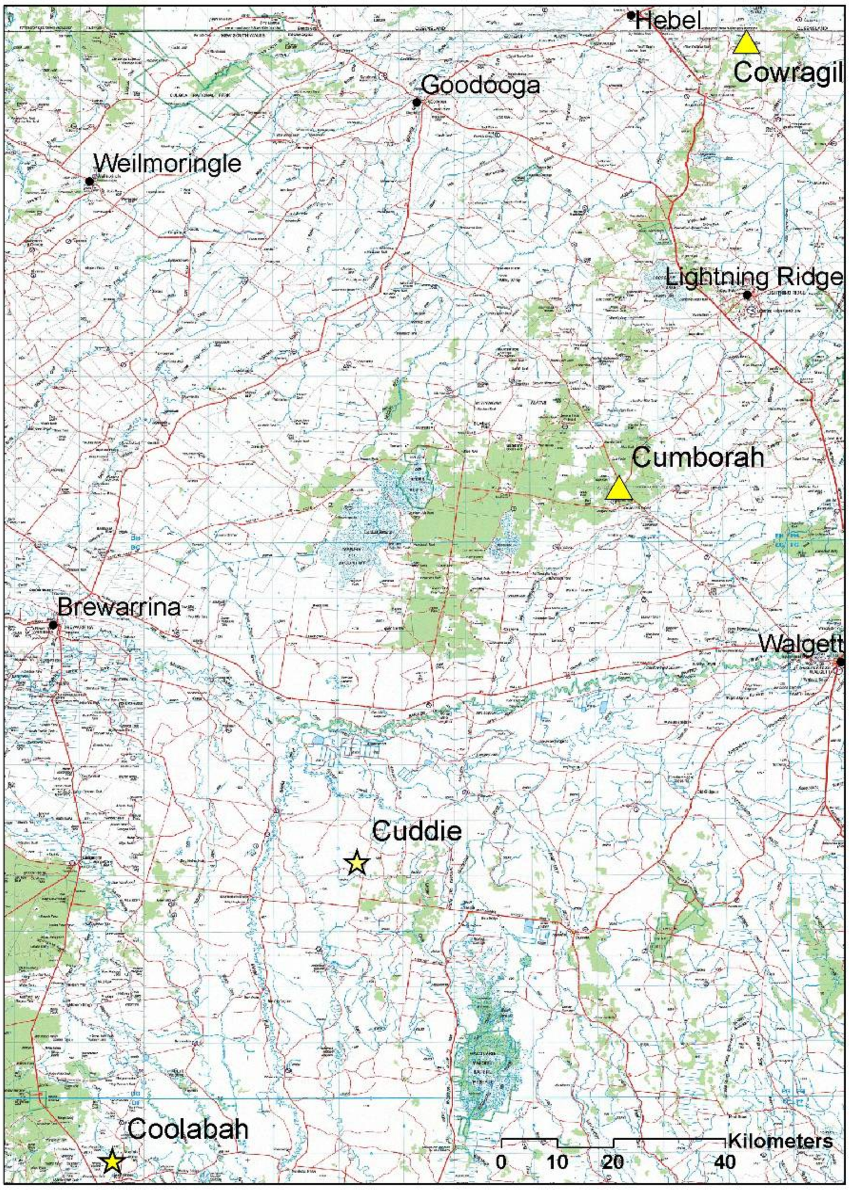


Figure 52 Springs in the Bogan River district, New South Wales. Cuddie and Coolabah are considered to be Great Artesian Basin springs based on available historical and hydrogeological evidence.

Figure 53 The four springs in the Bogan River 'supergroup'. (a) Coorigul, a small pool in a hollow in low stony hills, (b) Cumborah, a damp depression in a hollow at the junction of Tertiary sandstone and the Griman Creek Formation, (c) Cuddie, the site of an old well sunk on an ephemeral lakebed; pickets and disturbance in the centre of the lake are from archaeological excavations, and (d) Coolabah, a muddy puddle on Turners Creek floodplain.

5.3 Cultural history

The archaeological record at Cuddie Springs shows the presence of people in the area from about 35 000 years ago (Field et al. 2002, Trueman et al. 2005). Cuddie is one of the few springs in the Basin where an Aboriginal creation myth has survived in the historical record. According to WE Abbott, who visited in 1881, Cuddie meant 'bad water', although he conceded that this term may have been commonly used by Aboriginal people to describe a number of locations. While reporting on archaeological investigation at Cuddie Springs the early 1930s, Anderson and Fletcher (1934) recounted an Aboriginal legend that purportedly explained the remains of so many skeletons, as well as perhaps the connotation of 'bad water':

> *'Long ago there was an immense gum tree, miles in height, which grew on the bank of the Geerah waterhole on the Barwon River, eleven miles north of Cuddie Springs. Near it was an Aboriginal camp, and in its branches a pair of huge eagles had built their nest, whither they used to carry the little black babies to feed their young. At last the blacks decided to get rid of these troublesome neighbours by cutting down the tree. When it was done the trunk was found to be hollow, and, in defiance of the laws of hydrostatics, the water ran along this huge pipe, emerging from the top end, where it fell at Cuddie Springs, the escaping water making a deep hollow in which were deposited the bones of the animals which had formed the food of the eaglets. So, according to the legend, did Cuddie Springs come into being, and this is the origin of the bones found there.'*
>
> © Copyright, Anderson and Fletcher (1934)

Coorigul Spring also features in Aboriginal mythology, as the start of a dreaming track following the Bogan River. This story has been recorded by anthropologists and is painted as a mural at a Lightning Ridge service station. There is a stone arrangement on the slope above the spring. It was obscured by tall grass at the time of our visit, but Kate Bucknell described it as consisting of large stones arranged in wavy lines (pers. comm., 2012). There are stone flakes scattered throughout the area. Traditional owners continue to visit the site. Stone flakes are also scattered in the hollow containing Cumborah Springs, but no artefacts were seen on the cracking clay floodplain around Coolabah Spring.

Mitchell's description of the mysterious Caraway Springs on 6 March 1847 suggests it was a major habitation site for the local people, and sounds a prescient warning about the fate that was to befall inland springs:

> *'I found near the ponds, several huts made of fresh branches of trees and the remains of fires, doubtless the deserted home of the fugitives of yesterday. At these fires I found the roasted pods of the acacia already mentioned (Munumula) [Acacia stenophylla]. The water was surrounded by fresh herbage, and such was the simple fare of those Aborigines, such the home whence they fled. As I looked at it in the presence of my sable guides, I could not but reflect that the white man's cattle would soon trample these holes into a quagmire of mud, and destroy the surrounding verdure and pleasant freshness for ever. I feared that my good-natured but acute guides thought as much, and I blushed inwardly for our pallid race.'*
>
> © Copyright, Mitchell (1847)

Cumborah Well is situated adjacent to the springs and continues to provide water for the village of Cumborah. The ruins of an old cottage, possibly of a boundary rider, lie near Coorigul Spring. The old well at Cuddie Spring was not located. Based on Abbott's description, it was situated in the middle of the lake close to where the most recent archaeological excavations have been conducted. About 100 metres away, on the edge of the claypan, stand the remains of an old timber tankstand and a line of 20-centimetre-high timber posts running towards the centre of the claypan for about 50 metres. This probably represents the remnants of old troughing and piping that carried water for stock to firmer ground (Abbott 1881).

5.4 Biological values

No spring endemics or listed species were recorded at the four springs visited. Plant species present were generalist wetland or terrestrial species, including *Alternanthera angustifolia*, *Bothriochloa decipiens*, *Centipeda crateriformis*, *Eleocharis plana*, *Fuirena ciliaris*, *Glossostigma diandrum, Juncus aridicola, Juncus polyanthemos*, *Malvastrum americanum*, *Nymphoides crenata* and *Schoenus apogon*; and the introduced species *Anagallis arvensis*, *Aster subulatus*, *Cynodon dactylon, Echinochloa colona*, *Juncus bufonius*, *Soliva anthemifolia* and *Xanthium occidentale*. No fish or snails were found in any springs.

6 Conclusions and recommendations

All except eight known Great Artesian Basin (GAB) spring groups in the Eulo, Bourke and Bogan River supergroups, and nearly all priority springs in the Springsure group, have now been surveyed and historical and biological values documented. Cuddie and Coolabah springs now stand alone in the Bogan River supergroup. They lie only 120 kilometres south-east of the nearest GAB spring (Thully) in the Bourke supergroup and could be regarded as outliers of this group. The springs on the Paroo Overflow are almost 100 kilometres south of Goonery and separated by a large expanse of Quaternary dunefields (Figure 34 in Section 4.2). A case could be made for placing them in a new supergroup. Conversely, the Eulo springs and the line from north-west of Fords Bridge are close to being one supergroup, especially as both are related to granitic basement structures. Nevertheless, any groupings in southern Queensland and northern NSW will remain somewhat arbitrary, and we have persisted with the supergroup domains defined by Habermehl (1982).

Although many wetlands, populations and most likely some species have been lost as a result of artesian aquifer pressure drawdown and local disturbances, especially in the Eulo supergroup, the active springs continue to provide habitat for endemic species and disjunct populations. It is critically important to preserve the springs that remain. Preservation and conservation effort must be directed to the nine spring groups south-west of Eulo that still support endemic species (Table 7 in Section 3.4) and Peery Lake in New South Wales. The remaining active springs may be candidates for rehabilitation in the future, but are not a priority for action until the high-value springs have been secured.

The Great Artesian Basin Sustainability Initiative artesian bore rehabilitation program has made considerable progress, but massive flowing bores remain very close to high-value springs, including the Yowah Creek group (Table 8 in Section 3.4). There is an urgent imperative to rehabilitate the bores that may be critical for the preservation of the last remaining springs.

Other strategies must be site specific, but will include fencing, feral animal control and tenured protection agreements (Table 12). Priority sites for fencing are Masseys and Little Granite on Granite Springs, Wooregym and Tunga on Bingara Springs, and the southern group in the Dead Sea on Penaroo Springs. Other sites with endemics are situated on floodplains where fencing is not practical or are not heavily impacted by herbivores. The desirability and practicalities of fencing need to be negotiated with landholders for individual sites. In most cases, fencing to exclude both stock and feral animals is desirable despite the extra cost and maintenance required, given the high densities of goats and pigs. Fatchen (2000) has reviewed the effects of fencing on the natural values of springs and clearly demonstrates results peculiar to individual sites. The consequences of fencing should be monitored to determine the effects. A gate in a fence provides flexibility for future management.

Table 12 Conservation recommendations for high-value springs.

Spring group	Fencing (feral and stock-proof)	Nature refuge	Feral animal control
Yowah Creek	Impractical	High priority	Pigs
Paroo River	Impractical, as in creek channels	On Town common	Stock are more of an issue than ferals
Masseys (Horseshoe)	High priority	Priority	
Tunga	High priority, but would be challenging due to adjacent creekline and run-off from surrounding hills	Priority	Goats and pigs
Dead Sea (including Dead Sea South and Little Bundoona)	High priority, but would be a very large fence	Existing	Goats and pigs
Little Granite	High priority	Priority	Goats and pigs
Merimo (Site 238)	Impracticable, as in creek channels	Priority	Pigs
Wooregym	High priority	Priority	Goats and pigs
Tungalla	Lower priority, as has been excavated in past and is not as heavily impacted by herbivores	Lower priority, as excavated in past	Pigs

Notes:
Bore rehabilitation applies to all springs.
Yowah Creek, Paroo River, Masseys and Tunga springs all contain species not known from any other locations; all other springs contain spring endemics.

The high-value springs Yowah Creek, Paroo River, Masseys and Tunga are located on four properties or amalgamations, currently owned by three landholders. All value the springs and are sympathetic to conservation efforts. However, secure tenure agreements will protect against future destruction should the properties change hands. In Queensland, Nature Refuge Conservation Agreements are signed between landholders and the state. These agreements may allow for continued production and land management activities such as sustainable grazing and water use, but prohibit further excavation, the introduction of exotic species to the springs and groundwater extraction that will impact on spring flows. It is possible for extension officers to undertake property assessments, negotiation of the conservation agreement, and provide follow-up advice and assistance with management. The Dead Sea Springs on Penaroo already are included under a Nature Refuge Conservation Agreement.

A bore swap initiative that allowed for a 100 per cent government subsidy for bore rehabilitation and regulation on properties with high-value springs in exchange for secured agreements on the springs has been partially successful. Similar initiatives could be developed to complete bore rehabilitation and regulation in the vicinity of high-value springs.

There is a responsibility to ensure that demands for groundwater, whether it be for its own sake or as a by-product of another resource, do not cause further degradation to the already-debilitated GAB springs. Rather, there are opportunities through coordinated and targeted restoration to enhance the cultural and biological values of the last remaining springs. Priorities for future action are:

- ensure restoration of artesian aquifer pressures in areas containing high-value artesian springs, particularly in the Eulo and Bourke supergroups
- enhance groundwater modelling capabilities for the prediction of impacts of coal seam gas extraction on artesian springs, including timing, extent, duration and possible eventual recovery in the Springsure supergroup
- complete the database for springs throughout the GAB to further refine priority action
- develop tenure-secure agreements to implement best-practice management at important spring locations.

6.1 Acknowledgements

The hospitality and assistance of all landholders, managers and rangers in Queensland and New South Wales is gratefully acknowledged: Brian Bambrick (Stanbert), Kerry and Cally Hayes (Ellavale), Patrick Gain (Mascot), JD and Kaz Davies (Glenora), Andy Coward (Culgoa Floodplain National Park), Shirley Meyer (New South Wales National Parks, White Cliffs), Dick and Kate Bucknell (Calooma/The Springs), Paul and Adele Friend (Waratah), Glen Knight (Bundy), Bully Hayes (Box Vale), Justin and Julie McClure (Killara), John Dunk and John Stephenson (Warroo), Lorraine Lewis (Springvale/Lochangar), Dan Munster (Congarrara), Bruce and Christine Sharpe (Comeroo/Maranoa), Mark Pritchard (Meulleyarra/Thoura), Leon Zanker (Laurel Vale), Jan Currey and the Johnstones (Cuddie Spring), Graeme Pfitzner (Werewilka/Granite Springs), Dick O'Connell (Wombula), James Hatch (Wombah), Shane, Peta, Gordon and Tim Warner (Merimo/Bingara), Reb and Matt Price and family (Wittenburra), Ken Looker (Karto), David and Carmel Meurant (Wandilla), Rupert and Nikki Schmidt (Mooning), Andrew and Jane Campbell (Pitherty), Greg and Tony Sherwin (Kilcowera), Mick Beresford (Farnham Plains), John and Cherry Gardiner (Garrawin), Ian and Kerry Canning (Ningaling), Jake Berghofer (Springvale), Ross Campbell (Waihora), Bora and Sally Schmidt (Baroona), Randall and Cheryl Newsham (Bundoona), Carly Atkins (Coorada), Kelvin Hahn (Stonecroft), Mark Driscoll (Glen Elgin) and Carlin Burns (Blackdown Tableland National Park).

Eric and Kate Beresford, Ian Pike and Dan McKellar shared their knowledge of springs in the Eulo area. Dan and Shiralee McKellar, and Moc and Sheree Parker are thanked for their interest and hospitality during the Eulo surveys. Steve Peck from Charleville National Parks, accompanied by Joel d'Souza, assisted with surveys and vehicle recovery at some springs in the Eulo group. John Pickard's work on the New South Wales springs was invaluable and is gratefully acknowledged. Tracy Wattz provided photos of Poached Egg Spring and its eponymous daisy, and patiently assisted in trip preparation for the Eulo springs.

Part 2—Hydrogeological survey of the Great Artesian Basin springs in the Springsure, Eulo, Bourke and Bogan River supergroups

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7 Introduction to the springs of the Great Artesian Basin

Great Artesian Basin (GAB) springs have been divided into 12 regional supergroups (Habermehl 1982, Fairfax & Fensham 2003). They are generally present along the margins of the GAB, and occur in Queensland, New South Wales and South Australia (Figure 54).

The Basin's springs can be classified as either recharge or discharge springs. Recharge springs are supplied by groundwater from an aquifer or aquifers that are unconfined in the spring region, and occur in the recharge areas of the GAB. Water drains out of the aquifer either by the saturated aquifer intersecting with the surface or through the force of gravity. Recharge springs occur along the eastern margin of the Basin, where the aquifers are outcropping.

Discharge springs are fed by groundwater welling upwards under artesian pressure through thin confining beds or along faults. These springs occur near the western and southern margins of the GAB, but some are also present in and near the eastern margin, such as some in the Springsure supergroup. Artesian groundwater residence times for discharge springs are much longer than for recharge springs and, as a result of a longer time in contact with aquifer sediments, the water has high levels of dissolved solids and is more alkaline. Discharge springs form either water or mud springs. Mud springs are formed where artesian groundwater collects and mixes with fine sediments from the overlying aquitards, so that a mud slurry comes out of the spring vent, creating a mound on selected springs. Clear water emanates from the vents of water springs, sometimes creating pools of water that can support vegetation (Habermehl 1982).

These two basic spring types (discharge and recharge) can be further refined into 15 different conceptual models (Appendix E), which describe the mechanism by which the groundwater reaches the surface. Appendix E sets out diagrams depicting each of these conceptual models. All of the 15 conceptual models are represented in the GAB. Springs types shown within nine of the conceptual models (C–K) are discharge springs protected under the *Environment Protection and Biodiversity Conservation Act 1999* (Cwlth) (EPBC Act) and are descriptive of the springs investigated in this report, with the exception of the Coorigul and Cumborah supergroups.

Conceptual models D–F describe artesian discharge springs related to a fault or faults (E and F), or anticline or monocline (D), allowing artesian groundwater from a confined aquifer or aquifers to reach the ground surface. Models C, G and H describe situations where artesian water from a confined aquifer is able to flow to the surface through confining beds that are relatively thin since deposition or have been thinned by erosion (C); or are thin as the sedimentary units, including the aquifers and aquitards that covered basement rocks, were compacted (G and H). Springs emanating from the contact between outcropping basement sediments and onlapping sediments from the aquifer or multiple aquifers are described in conceptual models I and J. Model I shows an artesian spring fed from the top aquifer; model J shows an artesian spring being fed from a mixture of artesian groundwater from the lower and upper confined aquifers, or along the contact with the basement rocks. Lastly, conceptual model K describes the situation where spring water emanates from an artesian discharge spring located at the limit of the confining bed at the western or southern edges of the GAB, though most artesian springs in these areas are associated with faults and basement abutments.

The volume of water discharged by GAB recharge springs is highly variable. Springs located next to one another, with the same likely source aquifer can have very different flow rates, probably depending on the ease of or resistance to vertical throughflow of artesian groundwater through the confining beds. Most springs produce less than 10 litres per second (L/s); however, some springs have been recorded to have flow rates of up to 85 L/s and and as large as 150 L/s (Habermehl 1982). In 1982, the estimated combined discharge from 600 Basin springs amounted to 1500 L/s, about 5 per cent of modelled GAB recharge (Habermehl 1982).

Historical exploitation of GAB aquifers has, however, greatly reduced spring discharge and many springs have become extinct. For example, springs in the Eulo supergroup currently discharge one-third of their early 20th century volumes, and 62 per cent of springs have become inactive. A regime of rehabilitation of bores and regulating flow, such as capping flowing bores and improvements in the efficiency of water usage, has been implemented through the Great Artesian Basin Sustainability Initiative to address the dramatic decline in spring flow caused by the drawdown of source artesian aquifers (Fairfax & Fensham 2003).

Potential new threats to springs may, however, be posed by the coal seam gas industry operating in the Basin. This report investigates the hydrogeology of the GAB springs to assess whether the coal seam gas industry and coalmining pose threats to some of the GAB springs, and what those threats may be.

This report provides an overview for high-value springs in the Springsure supergroup—they have been investigated in great depth by the Queensland Water Commission (QWC 2012a). This part 2, in conjunction with part 1 of the *Ecological and hydrogeological survey of the Great Artesian Basin springs—Springsure, Eulo, Bourke and Bogan River supergroups*, *Volume 1: history, ecology and hydrogeology* provides the most in-depth investigation for the Springsure, Bourke, Eulo and Bogan River supergroups to date.

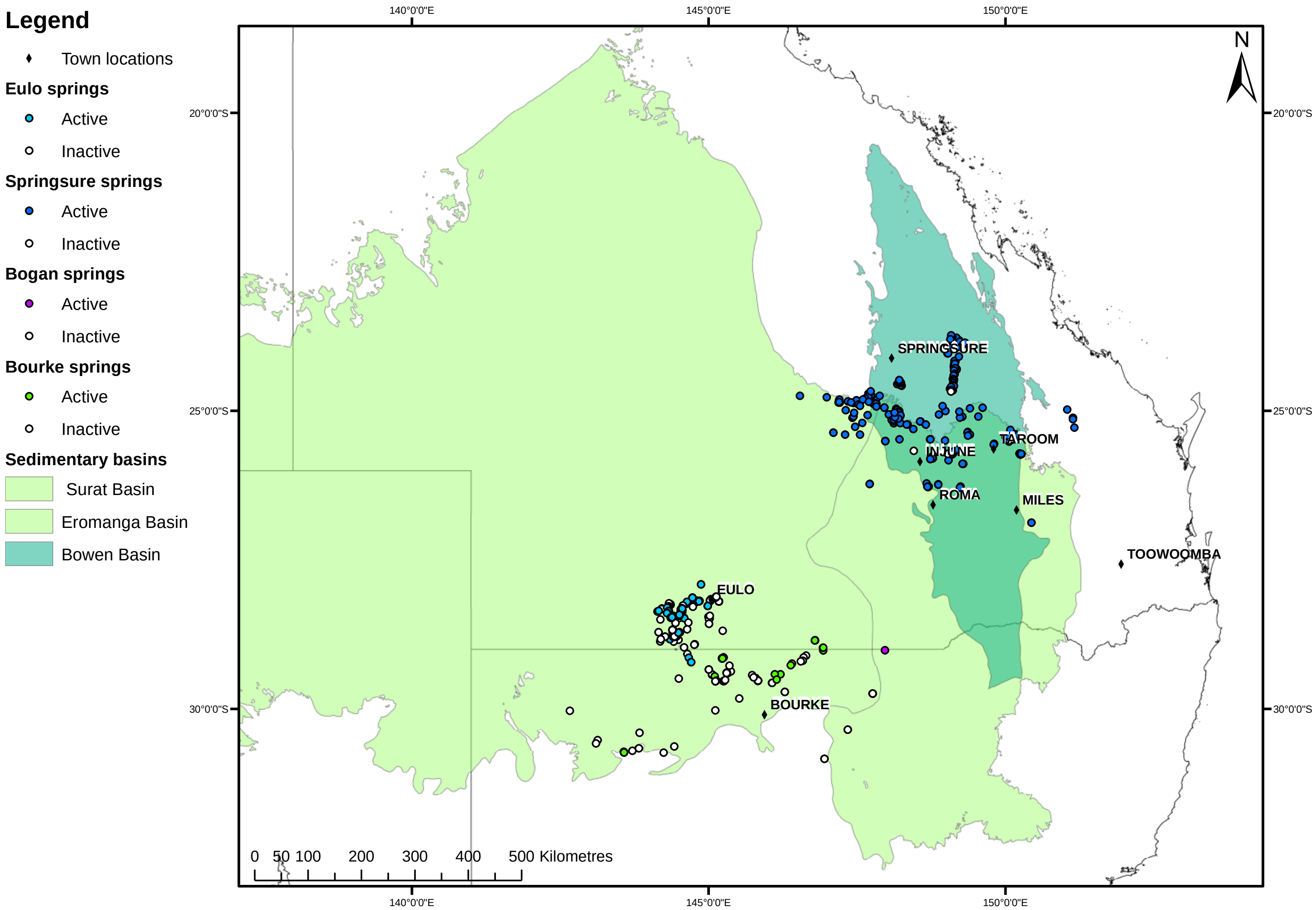


Figure 54 Sedimentary basins and artesian springs of the Springsure, Eulo, Bourke and Bogan River supergroups.

7.1 Project aim and scope

Through the collation and interpretation of regional geological, hydrogeological and water-quality information, this report aims to:

- identify the most likely source aquifers for springs in the Springsure, Eulo, Bourke and Bogan River supergroups that are listed in the EPBC Act
- classify the investigated springs into conceptual spring types
- assess the potential threats to the springs posed by coal seam gas development.

To limit the scope of this project, we only investigated the springs that are EPBC Act–listed and were ranked with a high conservation status in an earlier survey (Fensham et al. 2010) or by the survey conducted in Part 1 (Table 13). For the Springsure and Eulo supergroups, springs with a conservation ranking of 1a or 1b as determined according to Fensham et al. (2010) were investigated. As there were few springs with a high-value ranking in Bourke, springs with a conservation ranking of 1a—4a were investigated. All Bogan River springs are included in this report. For each spring complex investigated, a hydrogeological profile of the area has been compiled and is detailed in Volume 2 of this report. A summary of the major hydrogeological findings for each supergroup is provided in chapters 10–13.

Table 13 Spring complexes investigated in this report.

Supergroup	Spring complex
Bogan River	Coorigul, Cumborah, Cuddie and Coolabah
Bourke	Peery Lakes, Sweetwater, Thooro Mud, Tego and Towry
Eulo	Yowah Creek, Dead Sea, Carpet, Eulo Town, Merimo, Granite, Tunga and Wooregym
Springsure	Lucky Last and Abyss, Scott’s Creek, Cockatoo Creek, Boggomoss, Dawson River 6, Dawson River 2, Dawson River 8

7.2 Methodology

To determine the source aquifer for the springs, geological, hydrogeological and hydrochemical methods were used, as defined in Parsons Brinkerhoff Australia’s report for the Queensland Department of Environmental and Resource Management (DERM 2010):

- Geological methods. Develop an understanding of the geology in the area using surface geological maps, subsurface geometry of formations, geological structure information, bore locations and bore logs (including driller’s logs, geologists’ interpretations and lithology logs), and stratigraphic elevations.
- Hydrogeological methods. Use hydrogeological information to improve the understanding of the geology, including hydrogeological maps, groundwater and potentiometric level for waterbores that had been adequately identified, spring elevation, spring flow information, historic rainfall records, and temperature of spring and aquifer waters.
- Hydrochemical methods. Use hydrochemical information to identify the source aquifer of the spring. These data include physiochemical parameters, major ion chemistry, minor

elements chemistry, isotope geochemistry, as well as geothermometer data and anthropogenic substances if required and where available.

The above methods defined by Parsons Brinkerhoff build upon work undertaken to identify source springs by Environmental Hydrology Associates (EHA 2009), where the source aquifers were assessed for a limited selection of spring complexes within the Springsure and Eulo supergroups.

7.2.1 Geological methods

Geological data for the area surrounding each spring complex were collated, including information on:

- Surface lithology. For example, the 1:250 000 map sheet series and regional geological features, such as mapped faults and other geological boundaries obtained from Queensland Interactive Resources and Tenure Maps, and the New South Wales Department of Trade & Investment and Geoscience Australia. Literature on the geology of the Basin was also used.
- Groundwater bore locations and stratigraphic logs obtained from the DERM Groundwater Bore Database (GWDB) for Queensland bores (DERM 2012) and PINNEENA for New South Wales bores (NSW OoW 2010), as well as geophysical logs of waterbores by Habermehl (2001).
- Stratigraphic boreholes obtained from Queensland Interactive Resources and Tenure Maps.
- Spring vent locations obtained during field surveys of the springs as reported in Part 1.

This information was also used to map each spring complex using ArcGIS 10.1. The understanding of the regional geology was applied to identify aquifers within the region of the target spring complex.

7.2.2 Hydrogeological methods

Published literature on regional potentiometric elevations, for potential source aquifers and hydrogeology of the GAB, was then used to refine the understanding of the hydrogeology, identify potential source aquifers for the investigated spring complex and classify it into a conceptual spring type.

Information on potentiometric elevations for GAB aquifers was obtained from Quarantotto (1989) and the Queensland Department of Natural Resources (DNR 1996). These data were only available for the Springsure and Eulo region. Current and historical waterbore standing water levels and flow rates from the DERM GWDB or PINNEENA were used to identify artesian aquifers where potentiometric information was not available, or as an additional source of information.

7.2.3 Hydrochemical methods

The physicochemical parameters of water samples taken from the springs were compared with waterbore hydrochemical data available in the DERM GWDB and from QWC (2012a). Major ion composition of spring water and waterbores were also compared. This information was combined with casing information for waterbores to try and identify source aquifers.

Spring water chemistry data for the Springsure supergroup was obtained from the QWC (2012a), fieldwork conducted in 2011, and DNR (1996). Data from EHA 2009 and the GAB Springs Database was used for the Eulo springs. Only basic physicochemical information was available for springs in the Bourke and Bogan River supergroups and waterbores in New South Wales. This was collected during the spring surveys undertaken in 2012 for Part 1 of this report, which were conducted at the same time as the desktop assessments. As a result, the process for identifying potential source aquifers for the Bourke and Bogan River supergroups was largely limited to geological and hydrogeological methods.

Minor element chemistry and isotope geochemistry data were only occasionally available for springs and waterbores.

7.2.4 Synthesis of methods

The results and outputs from the geological, hydrogeological and hydrochemical methods were combined into a report for each spring complex (see Volume 2). The results were then compared with those obtained by EHA (2009) and the information provided by the QWC (2012a) report to identify any inconsistencies, and ensure the work would be compatible with and add to previous work on the spring complexes.

By combining the results from each method, it was possible to identify potential source aquifers for each of the spring complexes. Data gaps and ambiguities could be identified that impact on the ability of this methodology to accurately identify a spring's source aquifer.

Unfortunately, some key data on waterbores were missing for bores at the Eulo, Bourke and Bogan River supergroups. At the Eulo supergroup, there are little data on bore screening. For example, for many of the bores within 10 kilometres of the spring complexes investigated in this report, only information on steel piping is provided, with no data on where or whether there is screening at different depths, or whether the bore taps a single aquifer at the bottom of the pipe. In addition, often no information on which aquifers are contributing to the bore is provided. There are also a number of bores that source water from multiple aquifers. This made it difficult to determine which aquifer/s were the source of the spring, as one could not presume that bores without screening information were only tapping one aquifer. For the Bourke and Bogan River supergroups, the ability to identify a source aquifer was limited, due to the lack of interpreted stratigraphy and lack of bore water chemistry data. Where information was lacking, best estimates were made using the available data, and uncertainties were flagged.

8 Hydrogeological overview of the Great Artesian Basin

The Great Artesian Basin (GAB) is an extensive and complex groundwater system underlying about one-fifth of Australia. A long-accepted view of the GAB is that it is 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 findings of the GAB water resources assessment (Smerdon et al. 2012) confirm that the GAB is not a simple, laterally continous aquifer. Key geological complexities include multiple layers with varying groundwater flow rates, connections with overlying and underlying geological basins, and the presence of faults. In general, the aquifer sediments outcrop as sandstone and siltstone along its eastern margin where they are recharged by rainwater (Habermehl 1980, Habermehl 1982, Radke et al. 2000) and, to a lesser extent, along the western margin where they outcrop. Groundwater generally flows from the eastern margin towards the southern, western and northern margins of the Basin, and from the western margin towards the south-west (Figure 55). Some artesian groundwater in the GAB is more than one million years old and, generally, groundwater recharge rates and travel or residence times are reasonably well understood (Habermehl 2001).

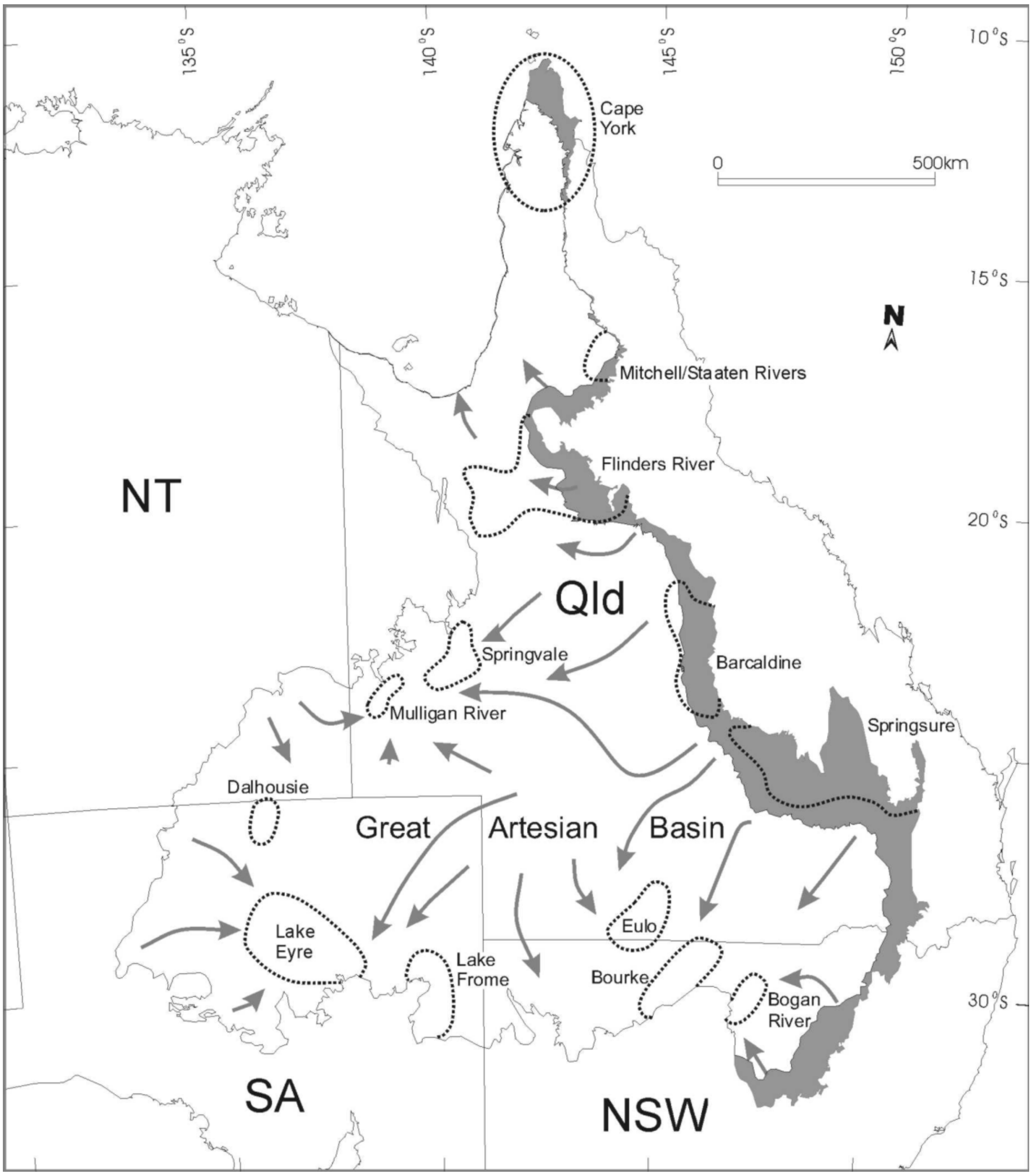


Figure 55 Map of the Great Artesian Basin. The shaded grey area indicates the eastern recharge areas. Dominant flow directions are indicated by arrows. Spring supergroups are represented by dotted lines.

8.1 Geological basins

The GAB comprises the Eromanga, Surat and Carpentaria basins, as well as parts of the underlying Bowen and Gallilee basins (Figure 54 in Chapter 7). The Euroka Arch separates the Eromanga and Carpentaria basins, and the Nebine Ridge in Queensland separates the Eromanga Basin and northern part of the Surat Basin (Habermehl 1980). The basins formed in a downwarp of continental crust during Jurassic times and west of a volcanic system during the Cretaceous. The volcanic system was located offshore of the present coastline, on the eastern Australian Plate boundary. The basins accumulated continental sediments during the Jurassic and Early Cretaceous, and marine and continental sediments later during the Cretaceous (Shaw 1990).

The constituent sedimentary basins of the GAB are continuous across the shallow basement ridges and platforms of older sedimentary, metamorphic and igneous rocks. The basin consists of aquifers made up of sheet-like quartzose sandstone deposits. These aquifers are of mostly continental origin from the Triassic, Jurassic and Cretaceous ages, and alternate with confining beds of siltstone and mudstone with low permeability. The aquifers of the GAB are bound by the Winton Formation at the top and the Rewan Group at the bottom. Not all sequences are present across the whole basin (Habermehl 1980, 2001; see also Figure 56).

The Eromanga and Surat basin sediments originate from many large-scale cycles of sediment deposition by rivers and streams (fluvial), and by lake and river environments (fluviolacustrine). Fluvial deposits created widespread sandstone units that make up important aquifers, including the Wyandra Sandstone Member of the Cadna-owie Formation, and the Hooray, Adori, Hutton and Precipice sandstones and their stratigraphic equivalents. Units of fluviolacustrine origin are generally aquitards made up of siltstone, mudstone and fine-grained sandstone. They include the lower parts of the Cadna-owie Formation, large parts of the Wallumbilla Formation as, well as the Westbourne, Birkhead and Evergreen formations (Habermehl 2001).

8.2 Aquifers and aquitards of the Great Artesian Basin

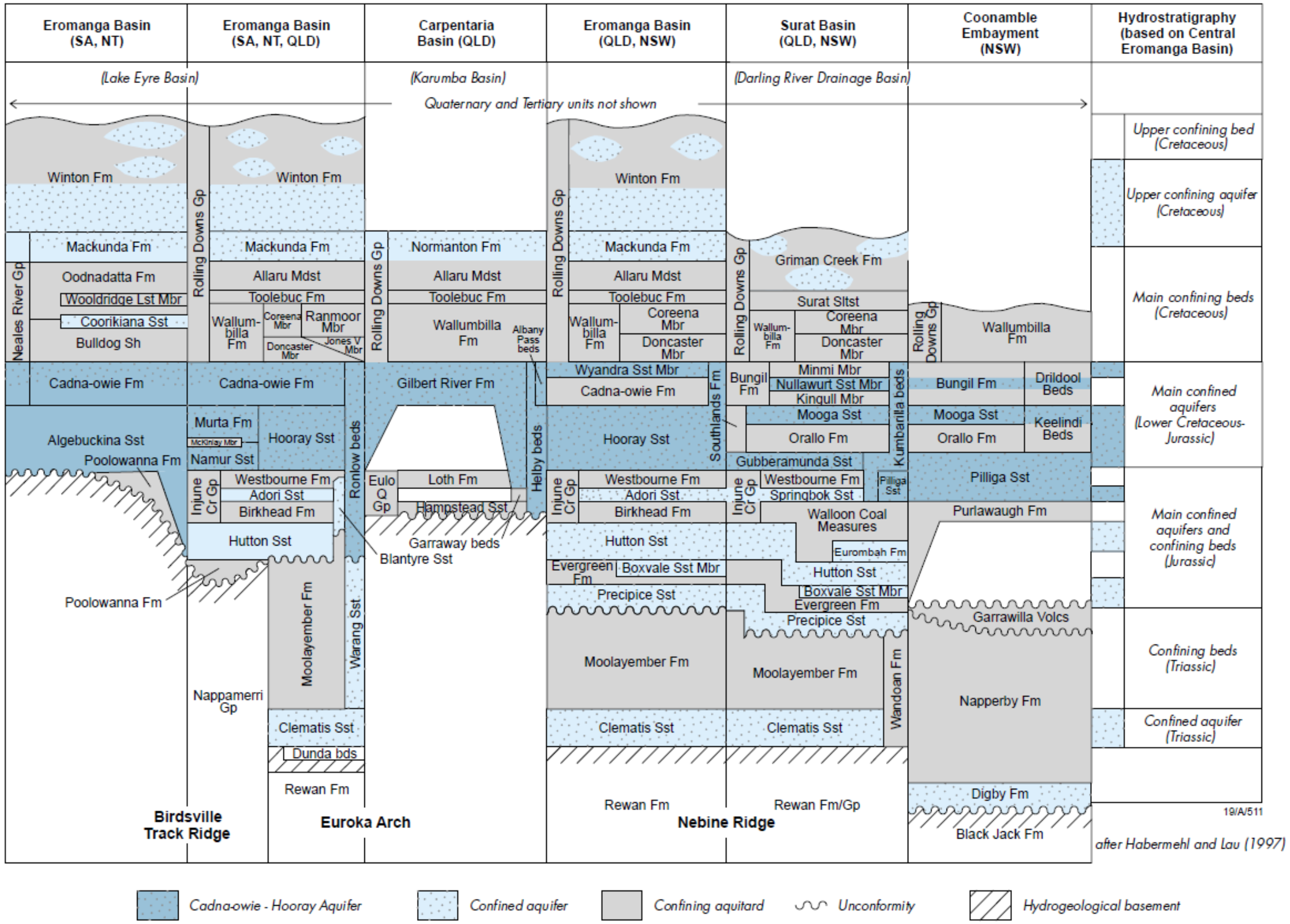
The Clematis, Precipice, Hutton, Adori and Hooray sandstones; the Wyandra Sandstone Member of the Cadna-owie Formation; and the Winton–Mackunda Formations and their equivalents contain aquifers (Habermehl 1980, 2001; Figure 56). Most artesian waterbores in the GAB tap these aquifers (Habermehl 2001), with most flowing artesian waterbores tapping the Jurassic – Lower Cretaceous aquifers (Hooray Sandstone and Wyandra Sandstone Member). The Mackunda and Winton formations form the shallowest aquifers of the Cretaceous Rolling Downs Groups. Figure 56 shows the basic hydrostratigraphic sequence of the GAB, including the Eromanga Basin and Surat Basin sequence, and the stratigraphic equivalents in the Coonamble Embayment of the Surat Basin in New South Wales.

Major confining beds include the Rewan Group, Moolayember, Evergreen, Birkhead, Westbourne, Wallumbilla and Toolebuc formations; and Allaru Mudstone and their equivalents. Parts of the Mackunda and Winton formations also consist of aquitards (Habermehl 1980, 2001).

The aquifers are continuous across large extents of the GAB. Faults locally displace or disconnect aquifers, and obstruct part or all of the groundwater flow in the main Lower Cretaceous – Jurassic aquifers. Faults can act as permeable or impermeable barriers to groundwater flow or to hydrocarbons migrating in the sandstones (Radke et al. 2000).

Before exploitation of the aquifers began in around 1880, the potentiometric surface of the artesian aquifers in the Lower Cretaceous and Jurassic sequence (e.g. Hooray Sandstone and equivalents) was above the ground surface across almost the entire basin (Habermehl 1980, 1982). Discharge from waterbores caused the regional potentiometric surface of the exploited aquifers to drop dramatically in heavily developed areas. In some areas, near the margins and in the south-east to central part of the Basin, the potentiometric surface has fallen below the ground surface (Habermehl 1980, 2001).

Rainfall along the western and part of the eastern slopes of the Great Dividing Range provides recharge to the GAB aquifers. Most of the Jurassic and Cretaceous sandstone aquifers outcrop on the eastern margin, allowing rainwater to enter directly or to flow into the aquifer through overlying sandy surface sediments (Habermehl 1980, 2001). Recharge also occurs along the western marginal zone, where aquifer sandstones are exposed or subcrop. Drainage systems such as the Finke River contribute substantial seasonal recharge within this arid zone. Discharge occurs in the southern, south-western and north-western regions of the GAB (see Figure 55).



cr = creek, fm = formation, gp = group, mbr = member, mdst = mudstone, NSW = New South Wales, NT = Northern Territory, Qld = Queensland, SA = South Australia, sst = sandstone.

Figure 56 Hydrostratigraphic sequence of the Great Artesian Basin

9 Hydrochemistry of the Great Artesian Basin

The range of recharge mechanisms and environmental processes within the Great Artesian Basin (GAB) means that the basin's hydrochemistry is not homogeneous, both among the constituent sedimentary basins, and within regional recharge zones and within the aquifers throughout the Basin (Herczeg et al. 1991, Radke et al. 2000). Hydrochemical change occurs during water infiltration into an aquifer and within the aquifers. As water flows through the aquifer rocks, ions in the water react with the rocks. The chemical characteristics of spring water reflect the characteristics of the aquifer or aquifers from which the water originates.

Regions and individual aquifers can broadly classify groundwater within the GAB. Hydrochemical differences delineate the eastern flow system from the western flow system. The westward flowing water is of a Na-HCO_3-Cl type. The eastward-flowing water is of the Na-Cl-SO_4 type (Habermehl 1980, 2002, Herczeg et al. 1991). Artesian groundwater in the eastern and central parts of the GAB flows westward (Na-HCO_3-Cl type waters). Carbon dioxide dissolves into water at the eastern marginal recharge zone as rainwater flows through near-surface soil. Water interactions with silicate and carbonate minerals in rock results in ion exchange. This contributes to elevated calcium and magnesium ion concentrations, and elevated alkalinity levels (Herczeg et al. 1991).

As the groundwater flows towards the Basin, sodium cations associated with the aquifer sediments are exchanged with calcium and magnesium cations in the water. The removal of calcium and magnesium from the groundwater by exchange with sodium in clay minerals within the aquifer framework may also cause hydrogen ions to be released. This further promotes carbonate dissolution (Herczeg et al. 1991, Radke et al. 2000). Further, diffusion of sodium and chlorine ions, and some calcium, magnesium and sulfate ions from overlying aquitards increases total ion concentration and influences the groundwater type.

Through the ion-exchange processes described above, the chemistry of the groundwater evolves from Ca-Mg-HCO_3-Cl groundwater towards Na-HCO_3-Cl. Na-HCO_3-Cl type water is characterised by higher alkalinity and sodium dominance. It cannot, however, be confirmed that Ca-Mg-HCO_3-Cl groundwater is a precursor of the Na-HCO_3-Cl groundwater (Radke et al. 2000). This is because groundwater mixing and evolution make it difficult to accurately model ion exchange.

In the southwest part of the Basin, the eastward-flowing groundwater is characterised by Na-Cl-SO_4- and Na-Ca-Cl-SO_4-type waters. These higher calcium and sulfite concentrations are acquired from recharge and, possibly, from diffusion from overlying mudstones (Habermehl 1980, 2001, Radke et al. 2000).

9.1 Salinity

Typically, deeper Jurassic–Cretaceous or Jurassic aquifers have lower salinity (as measured by electrical conductivity) levels than younger Cretaceous aquifers (Habermeh 1980, 2001, Radke et al. 2000, EHA 2009). Salinity also varies both spatially and temporally within the same aquifer. Areas closer to the recharge source are generally fresher than deeper sections of the same aquifer. The general trend in the main Lower Cretaceous – Jurassic aquifer (Hooray Sandstone and Wyandra Sandstone Member of the Cadna-owie Formation aquifer system) is for salinity to increase down the potentiometric gradient from the recharge zones. Areas of deeper aquifer burial are characterised by relatively higher salinity groundwater. This trend may also be explained by mixing of fresher recharge waters with saline waters in deeper parts of the Basin, along with the dissolution carbonates and ion exchange with clay minerals into the groundwater along the flow path (Herczeg et. al. 1991). The differences in salinity between aquifers and the change in salinity levels along flow paths make salinity one of the indicators for determining the source aquifer for GAB springs.

9.2 Total dissolved solids

Total dissolved solids (TDSs) in the Lower Cretaceous – Jurassic aquifer ranges from less than 200 milligrams per litre (mg/L) to more than 10 000 mg/L, with higher TDS values in the deeper parts of the GAB. Generally, TDS ranges between 500 mg/L and 1500 mg/L in most of the GAB (Habermehl 1980, 2001). It is lowest in the Pilliga region of the Coonamble Embayment, the recharge zones of the northern Eromanga Basin and the northern part of the Carpentaria Basin. TDS is highly variable in the eastern Eromanga Basin recharge zone. It is consistently higher in all other recharge areas, especially in the western Eromanga Basin, which exceeds 1500 mg/L, though near the Finke River region salinities decrease to 400 mg/L (Radke et al. 2000).

TDS values of up to 10 000 mg/L can be found in the central Eromanga Depocentre and its southward extension. The central Eromanga Depocentre is separated from the western Eromanga Basin flow system by an arcuate zone of relatively lower TDS. The western Eromanga Basin flow system extends from the eastern recharge zone to the southern discharge zone, and around the northern and western margins of the Eromanga Depocentre. It is characterised by an increase in TDS from 300 mg/L to 1300 mg/L. Groundwaters have a TDS range of 300–1000 mg/L from the Cheepie Shelf and across the Eulo–Nebine Ridge area. Eastwards into the western Surat Basin and south in the Coonamble Embayment, TDS ranges from 600 mg/L to1000 mg/L; TDS is higher (up to 2000 mg/L) in the eastern Surat Basin (Radke et al. 2000).

9.3 Temperature and pH

Temperature can indicate the origin of discharged waters. The slow flow rate of spring water from the aquifer to the surface means that spring water temperature will usually be lower than groundwater temperatures from bores that tap the same aquifer. If spring water temperatures are significantly higher than groundwater temperature measured in nearby bores, then it is likely that the spring is sourced from a deeper aquifer than that of the bore (EHA 2009).

Surface temperatures for groundwater bores that tap the Lower Cretaceous – Jurassic sequence usually range from 30 °C to 100 °C. Springs usually have temperatures around 20–45 °C. Groundwaters near basin margins have temperatures of up to 40 °C. Groundwaters in deeper parts of the GAB have warmer temperatures, between 60 °C and 100 °C, but these temperatures can also be found at shallower depths, as the aquifer and groundwater temperatures are determined by the local geothermal gradients (Habermehl 2001).

Groundwater pH measurements can be used to compare groundwater chemistry, but the accuracy of pH values for comparison are not always reliable, as pH is easily affected by environmental and physical changes (Parsons Brinckerhoff Australia Pty Ltd 2010). Confined aquifers from the Lower Cretaceous – Jurassic usually contain groundwater with pH values ranging between 7.5 and 8.5 (Habermehl 2001, Radke et al. 2000).

9.4 Ion composition

The concentrations and ratios of major and minor ions are a good source of information for identifying source aquifers. Major ions include sodium, calcium, magnesium, potassium, chloride, bicarbonate, carbonate and sulfate. The relative concentrations of these ions are used to indicate the type of water and the possible flow pattern.

Chloride is a reliable indicator of influences from recharge, and subsequent diffusion and mixing processes. This is due to its low reactivity in water and rock (Radke et al. 2000). The main Lower Cretaceous – Jurassic aquifer (Hooray Sandstone and Wyandra SandstoneMember of the Cadna-owie Formation) has chloride concentrations ranging from 25 mg/L to more than 10 000 mg/L. The normal trend of a steady increase in chloride concentration down potentiometric gradients is only apparent in the northern Eromanga Basin and Coonamble Embayment. Groundwater adjacent to the Eulo supergroup springs and within the Pilliga region of the eastern Coonamble Embayment is predominantly less than 200 mg/L, with regions of significantly lower chloride concentrations (Radke et al. 2000).

9.5 Alkalinity

Alkalinity is also a reliable indicator of groundwater evolution in confined flow systems. Total alkalinity has distinctive Basin-wide trends. Most recharge zones have waters with low alkalinity (less than 200 mg/L). Alkalinity increases down the potentiometric gradient away from the recharge zones and into the confined aquifer.

9.6 Environmental isotopes data

Isotopes data, both stable and radioactive, can also be used to determine the origin and age of groundwater, as seen in Table 14.

Table 14 Isotopes used to identify groundwater origins.

Isotope type	Isotope	Description
Stable	Oxygen-18 and deuterium	• Affected by meteorological processes that provide a fingerprint of their origin. • Used to infer recharge conditions, calculate mixing between waters, interpret palaeoclimatic conditions and assess evaporation.
Stable	Carbon-13	• Interpretation of geochemical and microbiological processes in groundwater. • Used as tracers of discharge contributions of different flow paths to streams.
Radiogenic	Carbon-14	• Used for dating regional and intermediate flow systems. • Half-life of 5730 years, which covers a timescale of 500 to 30 000 years.
Radiogenic	Chlorine-36	• Half-life of approximately 301 000 years. • Used for dating deeper, more mature groundwater with an age range of 46 000 to 1 000 000 years old.

Isotope type	Isotope	Description
Stable	Helium-3	• Indicator for mixing of endogenic fluids and groundwater. • Used to determine sources of recharge.

Carbon-14 has been used extensively on waterbores in the GAB to determine groundwater ages, and residence times or travel times along artesian groundwater flow lines. It is, however, only present above background levels within 200 kilometres of the GAB recharge zones due to its relatively short half-life (Bentley et al. 1986, Radke et al. 2000). It is therefore useful for determining whether springs in deeper parts of the Basin are receiving water from a local source, rather than from the deeper aquifers where carbon-14 concentration would be low or undetectable due to the age of the water (Parsons Brinckerhoff Australia Pty Ltd 2010). Anthropogenic substances such as chlorofluorocarbons and tritium can be used as tracers and dating tools for relatively young (less than 50-year-old) groundwater (Parsons Brinckerhoff Australia Pty Ltd 2010).

Chlorine-36 has been used in the GAB to determine groundwater ages, and residence times or travel times along artesian groundwater flow lines (Bentley et al. 1986, Torgersen et al. 1991, Radke et al. 2000, Mahara et al. 2009). Most of the chlorine-36 applications have been carried out on waterbores in the Eromanga and Carpentaria basins, and Coonamble Embayment. Chlorine-36 is well suited for the determination of the long groundwater residence times in the GAB because of its long half-life. Carbon-14 and chlorine-36 isotopes have confirmed the recharge, regional groundwater movement rates, directions and patterns determined from hydrogeological data. Carbon-14 and chlorine-36 samples from springs originate mainly from artesian springs in the south-western part of the Eromanaga Basin in South Australia.

Helium-3/helium-4 ratios can be used to determine the origin of helium in artesian groundwater (Torgersen et al. 1987, 1991, 1992, Mahara et al. 2009, Love et al. 2010). Discharge springs and bores from the GAB have been found to show persistent but variable inputs of endogenic (deeply derived) fluids that contain helium-3 from Earth’s mantle. Up to 40 per cent of the helium in some GAB groundwater may be from the mantle (Love et al. 2010). These findings indicate that water quality in the aquifer is a product of groundwater evolution along flow paths, as well as local input of fluids from deeper rock strata.

10 Springsure supergroup springs, Queensland

The Springsure supergroup consists of 71 active and inactive spring complexes, located in central to eastern Queensland, south of the town of Springsure (Figure 57, Table 15 and Table 16), within the Surat Basin. The Springsure supergroup lies within the Surat North Management Area of the *Water Resources (Great Artesian Basin) Plan 2006* (Qld), and is the most easterly of the spring supergroups. Springs within this supergroup are the most likely springs to be affected by coal seam gas development and production, because they are closest to coal seams in the Walloon Coal Measures of the Injune Creek Group and Bandanna Coal Measures currently being exploited. The Springsure supergroup comprises mostly recharge springs, although some discharge springs are present, sometimes in the same area as recharge spring vents.

Hydrogeological profiles of the Lucky Last Spring Rock Creek and Abyss, Scott's Creek, Cockatoo Creek, Boggomoss, Dawson River 2, Dawson River 6 and Dawson River 8 spring complexes are detailed in Volume 2, pages 3–101 of this report. The locations of these spring complexes are highlighted in Figure 57.

Table 15 Inactive spring complexes of the Springsure supergroup, Queensland (Springs Database).

Inactive	Complex no.
325	325
Castle	253
Timor	587

Table 16 Active spring complexes of the Springsure supergroup, Queensland (Springs Database).

Active[a]	Complex no.	Active[a]	Complex no.
16	16	Dawson River 8	8
16 mile	238	Den Springs	245
254	254	Eddy Owen	255
267	267	Eden Vale	76
296	297	Elgin	307
302	302	Exped Range	304
306	306	Goodlife	248
308	308	Googenya	242
309	309	Hell hole	234
310	310	Ladybird	246
311	311	Lenore Hills	583
326	326	Lonely Eddie	339
327	327	Lucky Last	230
328	328	Lc1	599
331	331	Lc2	600
332	332	Lc3	601
334	334	Lc4	602
335	335	Lc5	603
336	336	Lc6	604
337	337	Major Mitchell	241
35	35	Manan	258
78	78	Marburg 1	598
Abercorn	261	Marlong	236
Abyss	592	Merivale	589
Barngo	562	Moffat	235
Barton	283	Moffat Basalt	595
Bevan	268	Moolayember	233
Big Tree	247	Newton	85
Binnalong	509	Oaky 1	597
Boggomoss	5	Paddy's	237
Bowenvale	585	Ponies	229
Boxvale	586	Prices	580
Buckland	563	Rainbow Spring	1
Bunbunc	240	Rock Art	263

Active[a]	Complex no.	Active[a]	Complex no.
Bunya	596	Scott's Creek	260
Carnarvetc	297	SF212	68
Canaveron George	296	Spa	262
69Cera	264	Spring Grove	298
Channin	564	Springwood	588
Cleanskins	510	Spring Rock Creek	561
Cockatoo 3	593	Spring Ridge	506
Cockatoo Creek	9	Surveyor's	262
Conom	84	Top	243
Crystal ball	232	Unfairplay	272
Dam dyke	256	VI mile	507
Dawson River 2	2	Wambo	584
Dawson River 3	3	Yebna	74
Dawson River 4	4	Yebna 2	591
Dawson River 6	6		

a Note that active spring complexes often contain inactive vents and some of the numbered complexes are generally included in other complexes.

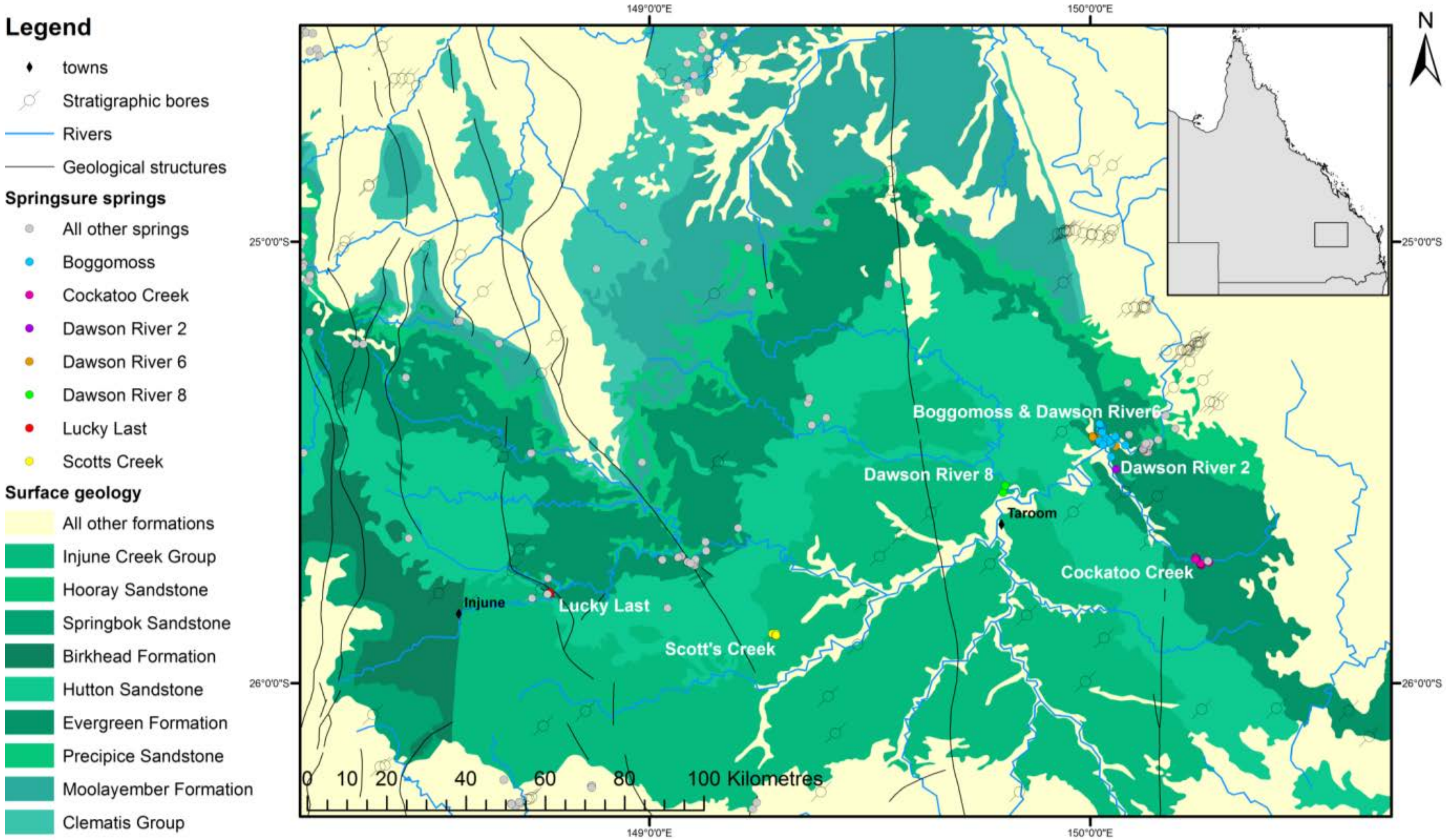


Figure 57 The Springsure supergroup springs investigated in this report.

10.1 Regional geology

The springs of the Springsure supergroup lie on the eastern margin of the Great Artesian Basin (GAB), where the major aquifers are present at or close to the surface. The distribution of Jurassic rocks, which include all the main artesian aquifers in the region, is controlled by the underlying Permian Bowen Basin and Taroom Trough, on which Triassic and Jurassic GAB sediments were deposited. Folding and faulting resulted in many north–south-directed structures, including anticlines, synclines and faults. Late Cainozoic uplift of the Great Dividing Range increased the Basin-ward tilt towards the south-west, after which the GAB remained stable and the northen margin was extensively eroded (Exon 1976, DNR 1996). As a result, the spring complexes of the Springsure supergroup have a range of geological settings, depending on which formation is present at the surface. The folding and faulting has caused a large number of major and minor faults in the region, with most springs in the area believed to be associated with faults.

10.2 Regional aquifers and aquitards

10.2.1 Injune Creek Group

The Injune Creek Group of Middle to Late Jurassic age comprises three distinct formations that cover most of the Springsure supergroup region: the Westbourne Formation, the Adori Sandstone/Springbok Sandstone and Birkhead Formation. It also includes the Eurombah Formation and the Walloon Coal Measures. The Injune Creek Group consists of calcareous lithic sandstone, siltstone, mudstone, coal and conglomerate (DNRM 2005, GA 2012).

10.2.1.1 Westbourne Formation

The Westbourne Formation is primarily a confining bed consisting of fine-grained sandstone, siltstone and mudstone. It ranges in thickness from 50 metres to 120 metres (DNRM 2005, GA 2012).

10.2.1.2 Springbok Sandstone

The Springbok Sandstone is the main aquifer of the Injune Creek Group in the Surat Basin, and comprises fine- to medium-grained sandstone, siltstone, mudstone and minor pebble layers (DNRM 2005, GA 2012).

10.2.1.3 Birkhead Formation

The Birkhead Formation acts mainly as a confining bed, and consists of fine-grained sandstone, siltstone and mudstone, with some coal. Where sandstone is present, it acts as a minor aquifer (DNRM 2005, GA 2012).

10.2.2 Hutton Sandstone

The Early Jurassic Hutton Sandstone contains a major GAB aquifer and overlies the Evergreen Formation. It consists of poorly sorted coarse- to medium-grained sandstone at its base, and fine-grained, well-sorted quartzose sandstone at the top of the formation. Minor amounts of carbonaceous siltstone, mudstone and coal are also present. The formation produces high yields of water (up to 50 L/s) and reaches maximum thicknesses in the centre of the Eromanga Basin of about 250 metres (DNRM 2005, GA 2012).

10.2.3 Evergreen Formation

The Early Jurassic Evergreen Formation represents a predominantly confining bed. It consists of sandstone, carbonaceous mudstone and siltstone. The formation includes the Boxvale Sandstone Member and Westgrove Ironstone Formation (DNRM 2005, GA 2012).

10.2.3.1 Boxvale Sandstone Member

The Boxvale Sandstone Member of the Evergreen Formation consists of fine- to medium-grained quartz sandstone and fossil wood. It varies in thickness from 45 metres to 90 metres, and produces water of good quality and high yields (DNRM 2005, GA 2012).

10.2.4 Precipice Formation

The Jurassic Precipice Sandstone and its equivalents are the deepest Jurassic aquifer in the Surat Basin and part of the eastern Eromanga Basin. The Precipice Sandstone consists of thick, cross-bedded and pebbly quartzose sandstone, siltstone and mudstone laid down in the Early Jurassic. Thickness of the formation varies from 45 metres to 150 metres. Water quality is also variable and often influenced by geological structures such as faults. The Precipice Sandstone aquifer recharges along the eastern margin of the GAB and springs occur in this area (DNRM 2005, GA 2012).

10.2.5 Clematis Sandstone

The Clematis Sandstone aquifer, which this report includes in the GAB, is the oldest aquifer in this region and forms the only major Triassic aquifer in the Surat Basin part of the GAB. It comprises medium- to coarse-grained quartzose sandstone interbedded with siltstone and mudstone, as well as granule- to pebble-sized conglomerate. Waterbores tap the Clematis Sandstone where it outcrops along the eastern edge of the GAB. Towards the centre of the Basin, it is deep and not usually tapped (DNRM 2005, GA 2012).

10.3 Hydrogeological summary

10.3.1 Conceptual spring types

The occurrence of the Springsure supergroup is attributable primarily to its location near the eastern margin of the GAB, where major confined aquifers are close to the surface, but also have a high-enough artesian pressure for groundwater to come to the surface through any confining beds, usually along faults.

Lucky Last, Abyss and Spring Rock Creek complexes, located alongside each other, are located near a major fault and sit on top of a smaller fault that forms a geological boundary between the Hutton Sandstone and the Evergreen Formation. The conceptual spring type for Lucky Last and Spring Rock Creek would therefore be a discharge spring emanating from an artesian aquifer through a fault (conceptual spring type E and F). The Abyss Complex is likely a recharge spring emanating from the Hutton Sandstone.

The geological complexity of the region makes it difficult to attribute conceptual spring types to all of the spring complexes. Other spring complexes, including Cockatoo Creek, Boggomoss, Dawson River 6 and Dawson River 2 are most likely associated with unmapped faults (EHA 2009). Another conceptual model that may apply to these springs is for discharge springs where the confining layer has been thinned by erosion and the underlying artesian aquifer is able to flow to the surface (see conceptual spring type C at Appendix E).

Scott's Creek spring complex lies on the eastern limb of the Arcadia Anticline. The likely conceptual model for Scott's Creek is therefore spring discharge resulting from an anticline elevating the aquifer relative to the surface (see conceptual spring type D in Appendix E).

10.3.2 Potential source aquifers

Source aquifers for the Springsure spring complexes vary depending on their geological setting. Volume 2 of this report gives a detailed examination of each spring complex. The predominant source aquifer for the investigated springs is likely to be the Precipice Sandstone, which is known to have a potentiometric surface of about 250 metres (AHL) in the area, while the springs are located at about 244–245 m Australian Height Datum. Cockatoo Creek, Boggomoss, Dawson River 6 and Dawson River 2 are all likely to have the Precipice Sandstone as their source. Chemical analysis of spring groundwater and water from waterbores supports the conclusion that Cockatoo Creek is sourced from Precipice Sandstone. Waterbore chemistry varies spatially in the area of Boggomoss and Dawson River 6 spring complexes, making any attribution of a source aquifer less certain. In some instances, mixing with overlying aquifers in the Boxvale Member of the Evergreen Formation might also occur. Dawson River 8 spring complex is likely sourced from the Hutton Sandstone, with influence from the overlying Birkhead Formation.

Scott's Creek and Lucky Last spring complexes are located on younger Jurassic sediments. Hutton Sandstone is therefore a potential source aquifer for these springs. A comparison of water chemistry for Scott's Creek springs and waterbores within a 10-kilometre radius suggests Hutton Sandstone as the likely source aquifer. However, again, there may be a contribution from a minor aquifer in the Birkhead Formation, which overlies Hutton Sandstone.

Hydrochemical analysis suggests that artesian groundwater from spring vents in the Lucky Last, Spring Rock Creek and Abyss (located next to Lucky Last, see Figure 57) complexes may have different source aquifers, depending on their location. For example, springs 287 and 340 (Lucky Last) are located on an outcrop of Evergreen Formation, and are thought to be associated with a fault that allows upward migration of groundwater from the Precipice Sandstone or adjacent Hutton Sandstone. On the other hand, springs 286 and 716 (Abyss) are underlain by Hutton Sandstone and located near the contact between the Hutton Sandstone and Birkhead Formation. The springs are thought to be fed by groundwater from the Hutton Sandstone emerging at the edge of the Birkhead Formation, making them recharge springs. Springs 287, 286 and 716 do have similar water chemistry, suggesting that they are all fed by Hutton Sandstone (see Volume 2 of this report).

Although likely source aquifers for the Springsure supergroup can be identified with more confidence than for the Eulo supergroup, it is not certain whether the Hutton and Precipice sandstones are the only source aquifers. This is due to a lack of chemical and potentiometric data for the Clematis Sandstone Group, as well as the Boxvale Sandstone Member and Birkhead Formation.

11 Eulo supergroup springs, Queensland

The Eulo supergroup consists of 53 active and inactive spring complexes, located in southern Queensland south-west of the town of Eulo (Figure 58, Table 17), within the Eromanga Basin.The Eulo supergroup lies within the Warrego Management Area of the *Water Resources (Great Artesian Basin) Plan 2006* (Qld). This region has experienced the greatest loss of pressure in the Great Artesian Basin (GAB); on average, the water level has decreased by 39 metres and ranges from 0 metres to 120 metres across the supergroup (Habermehl 1980, Fairfax & Fensham 2003). Collectively, these springs are considered to currently discharge about one-third of their early 20th century output (Fairfax & Fensham 2003). Many bores were sunk adjacent to springs in the region, typically within a few metres. Springs in the region have been reported to experience notable natural variation in flow rates. Although some springs were recorded to have a constant flow rate, others have been noted to fluctuate daily (e.g. Twomanee Springs), and others show intermittent spring activity for a longer time. Intermittent spring activity may be attributed to changes to the permeability and/or the chemical precipitates in the vertical pathways (EHA 2009). Anecdotal evidence does, however, suggest a link between weather patterns, such as high- and low-pressure systems, and short-term variation in spring flow.

Hydrogeological profiles of the Carpet, Dead Sea, Eulo Town, Granite, Merimo, Tunga, Wooregym and Yowah Creek spring complexes have been completed, and are included in Volume 2, pages 102–189 of this report. The names and location of these spring complexes are in Figure 58.

11.1 Regional geology

The Eulo Springs overlie the Eulo Ridge, an area of granitic bedrock exposures and regionally shallow depth to the granite basement. The Eulo Ridge is characterised by a marked thinning of the Eromanga Basin sedimentary sequence (Senior et al. 1971). Wireline-logged waterbores in the region (Habermehl 2001) indicate that the Eromanga Basin aquifers beneath the Hooray Sandstone are not present within the vicinity of the spring complexes (EHA 2009). Outcrops of the Winton Formation, and the Doncaster and Coreena Members of the Wallumbilla Formation are present in the region. Several spring complexes, most notably the Dead Sea complex, are coincident with mapped geological fault structures (see Toompine 1:250 000 SG55-13 geological map sheet series—Ingram and Senior 1970).

Table 17 Spring complexes of the Eulo supergroup, Queensland.

Active[a]	Complex no.	Inactive	Complex no.
Bokeen	n/a	Banger	146
Car Window	113	Baroona	159
Carpet	148	Bush	134
Corina	123	Curracunya	123
Dead Sea	157	Currawinya	108
Dewella	150	Goonerah	117

Active[a]	Complex no.	Inactive	Complex no.
Eulo Town	144	Kungie	115
Fish	110	Minyeburra	141
Fish (Tarko) (formerly Jubilee)	129	Ningaling	271
Garrawin	57	Riley	105
Goonamurra	153	ShellRam	151
Gooning	130	Shire Tank	121
Granite	133	Taleroo	109
Jacombe	n/a	Thorlindah	104
Jubilee	129	Thorlindah Mud	n/a
Kopanyu	111	Tynghynia	n/a
Magic Wand	137	Waihora	143
Merimo	142	Warroo	n/a
Muddy	145	Wiggera	138
Ooliman	149	Woolshed	116
Panic Sandhill	n/a	Youleen	114
Pikes	147		
Pitherty	118		
Tareen	124		
Tilberry	132		
Tunca	135		
Tunga	139		
Tunkata	125		
Wacno	131		
Wooregym	136		
Yowah Creek	156		
Yowah Mud	155		

n/a = not applicable.
a Note that active spring complexes often contain inactive vents.

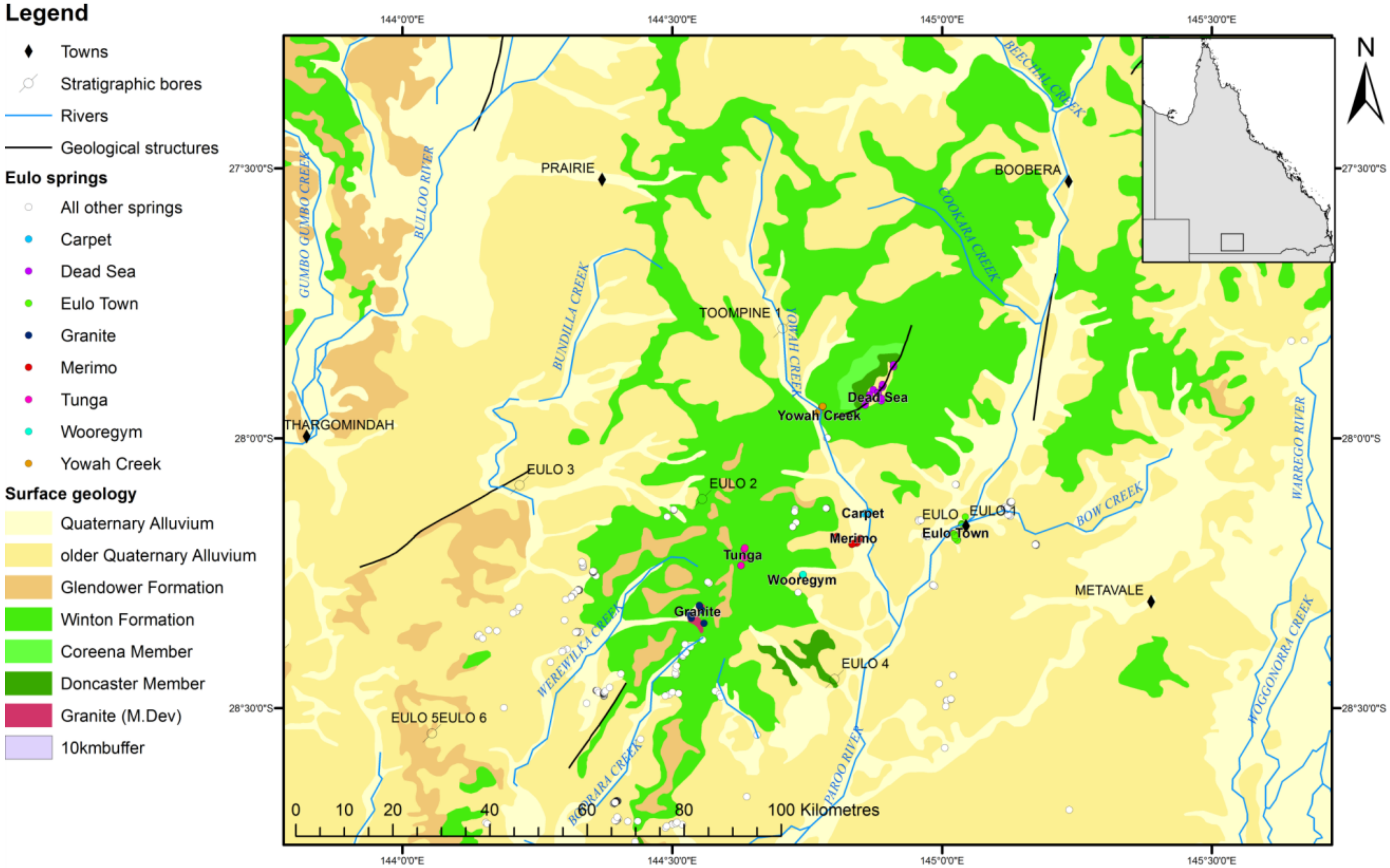


Figure 58 The Eulo supergroup springs in the Eromanga Basin investigated in this report.

11.2 Regional aquifers

The major GAB aquifers present in the Eulo supergroup region include the Hooray Sandstone and the Wyandra Sandstone of the Cadna-owie Formation. Local artesian aquifers also occur in the shallow Winton Formation, and within the Coreena and Doncaster members of the Wallumbilla Formation in the south-eastern part of the Eromanga Basin. However, the latter is generally referred to as a confining bed by Habermehl (2001) (see Figure 56 in Section 8.2).

11.2.1 Winton/Mackunda Formation

The Winton Formation of the Rolling Downs Group is a Cretaceous formation located in central to western Queensland, South Australia and the Northern Territory across a large part of the GAB. It consists of sedimentary rocks including sandstone, siltstone and claystone. The average depth to the top of the water-bearing strata is 77 metres, with an estimated average saturated thickness of 6 metres in the Eulo area. The Winton Formation reaches a maximum thickness of 400 metres.

The Mackunda Formation of the Rolling Downs Group conformably underlies the Winton Formation, and consists of labile sandstone, mudstone and calcareous siltstone. The average depth to the top of the water-bearing strata in the Mackunda Formation is 179 metres with an average thickness of 6 metres across its extent. The Winton/Mackunda Groundwater Management Unit consists of two nonflowing or subartesian aquifer systems. The (semi-)confined aquifers occur within laterally discontinuous or lenticular sandstone deposits (Habermehl 1980, Australian Natural Resource Atlas 2009).

11.2.2 Wallumbilla Formation

The Cretaceous Wallumbilla Formation of the Rolling Downs Group is a sedimentary unit comprised dominantly by mudstone and siltstone with grey limestone and minor sandstone. The average thickness of the formation is 250 metres, and ranges from 100 metres to 600 metres (Radke et al. 2003). Aquifers within the Wallumbilla Formation (Coreena and Doncaster members) are generally lenticular with an uncertain hydraulic connection between adjacent aquifers. Yields are low and salinity is typically high, ranging from 1500 microsiemens per centimetre (µS/cm) to more than 10 000 µS/cm. The named beds include the Coreena, Doncaster, Jones Valley, Ranmoor and Trimble members, although only the Coreena and Doncaster members occur in the Eulo area. It reaches a maximum thickness of 600 metres. The Coreena and Doncaster members also contain sandstone and form minor aquifers. The Wallumbilla Formation overlies the Wyandra Sandstone Member of the Cadna-owie Formation in the Eromanga Basin (DNRM 2005, GA 2012).

11.2.2.1 Coreena Member

The Coreena Member comprises siltstone and fine sandstone interbedded with mudstone. It has a maximum thickness of 165 metres (DNRM 2005, GA 2012).

11.2.2.2 Doncaster Member

The Doncaster Member comprises mudstone, siltstone, minor quartz sandstone in part glauconitic, silty limestone and gypsum (Eromanga and Surat basins). It has a maximum thickness of 275 metres (DNRM 2005, GA 2012).

11.2.2.3 Wyandra Sandstone (Cadna-owie Formation)

The Wyandra Sandstone Member of the Cadna-owie Formation forms a significant aquifer in parts of Queensland, overlying the Cadna-owie Formation in the Eromanga Basin. It is the shallowest artesian aquifer producing flowing artesian waterbores in the Basin, though some flowing bores are also known from the Correna–Doncaster aquifers. The formation is a medium- to coarse-grained quartzose sandstone, generally less than 20 metres in thickness (DNRM 2005, GA 2012).

11.2.2.4 Hooray Sandstone

The Hooray Sandstone and its hydrogeological equivalents are generally the shallowest major artesian aquifer intercepted by flowing artesian waterbores in the GAB in Queensland. The Hooray Sandstone comprises fine-to-coarse white quartzose sandstone with a kaolinitic matrix. This is the most highly developed artesian aquifer across a large extent of the Eromanga Basin, except in the centre of the basin where it is too deep for economic development by waterbores. It typically produces very good yields (DNRM 2005, GA 2012).

11.3 Hydrogeological summary

11.3.1 Conceptual spring types

The Eulo spring complex is primarily attributable to the shallowing of the GAB aquifers due to elevated granitic basement structures. The Granite and Eulo Town spring complexes are situated directly adjacent to granite outcroppings, and may be considered as discharge spring complexes emanating from contact between onlapping sediments and outcropping basement structures (see conceptual spring types I and J at Appendix E and Figure 59).

The Carpet, Merimo and Wooregym spring complexes occur at greater distances from mapped granite outliers, although are likely still associated with elevated granite basement in the region. The most likely conceptual spring model for these vents are discharge springs associated with weakness or thinning, and, possibly, the fracturing-associated basement structure (conceptual spring types G and H, Appendix E).

The Dead Sea spring complex is one of the most active spring complexes in the Eulo region, with 24 active vents recorded during the 2012 field surveys. This spring group lies directly above the Boondoona fault (see conceptual spring type E and F, Appendix E), although the elevated basement structure also should be considered as a relevant conceptual spring type for this complex (type I and J). The Yowah Creek spring complex may also be associated with the extension of the Boondoona Fault, and the Tunga spring complex may be associated with an unmapped fault or fracture system, because there is a fault running through the inlier of granite at the headwaters of Boorara and Twomanee creeks (EHA 2009).

Senior et al. (1971) refers to carbonate coatings and deposits of tufa in the Eulo area. These are likely to be similar to carbonate deposits found on artesian GAB springs in northern New South Wales, western Queensland and in the south-western part of the GAB in South Australia.

Figure 59 Granite spring complex—Massey Spring.

11.3.2 Potential source aquifers

The likely source aquifers of the Eulo Spring groups are considered to be the Wyandra Sandstone Member of the Cadna-owie Formation and/or the Hooray Sandstone, although it is likely that some of these waters mix with shallower aquifers en route to surface (e.g. type J springs). Although considered less likely, there is insufficient evidence to discount conclusively the shallower aquifers of the Winton Formation, and the discontinuous aquifers present in the Doncaster and Coreena Members of the Wallumbilla Formation as being potential source aquifers for some of the Eulo springs. This is due to:

- the artesian status of several bores in the region tapping these shallow aquifers
- no differentiation between the water chemistry of springs in the region and groundwater bores, regardless of which aquifer the bores are recorded to be tapping (see, for example, Carpet in Figure 60).

All waterbores known to be tapping either the Wyandra Sandstone Member of the Cadna-owie Formation or the Hooray Sandstone with available standing water-level data assessed in this report have maintained artesian pressure over time. Although there are many examples of shallower waterbores with artesian pressure tapping either the Winton or Wallumbilla formation, there are also several examples of waterbores tapping these aquifers being recorded as nonflowing or subartesian upon drilling, or being recorded as ceasing to flow post-drilling. EHA (2009) postulate that there may be sufficient interconnection between the deeper aquifers (the Wyandra Sandstone and the Hooray Sandstone) and the shallower aquifers (Wallumbilla and Winton formations) to allow for the development of artesian conditions in the upper formations that are not regionally considered to produce flowing artesian waterbores.

Water-quality analyses of spring and bore water did not conclusively attribute or discount source aquifers for the Eulo spring complexes analysed here. This could be explained by the waterbores in the region lacking casing information, such as missing information as to whether the bore had screens or used only an open hole at the bottom of the casing, and which aquifers were contributing water. A number of bores also tap multiple aquifers and the major ion composition of water from bores in the area is similar, regardless of what aquifers they are tapping (Figure 60). This could result in groundwater mixing, thereby erasing any water-quality signatures. An alternative explanation is that these waterbores and springs could be sourced from the same aquifer. There is currently no data to confirm whether the water chemistry for these waterbores differs from the groundwater chemistry for overlying or underlying aquifers.

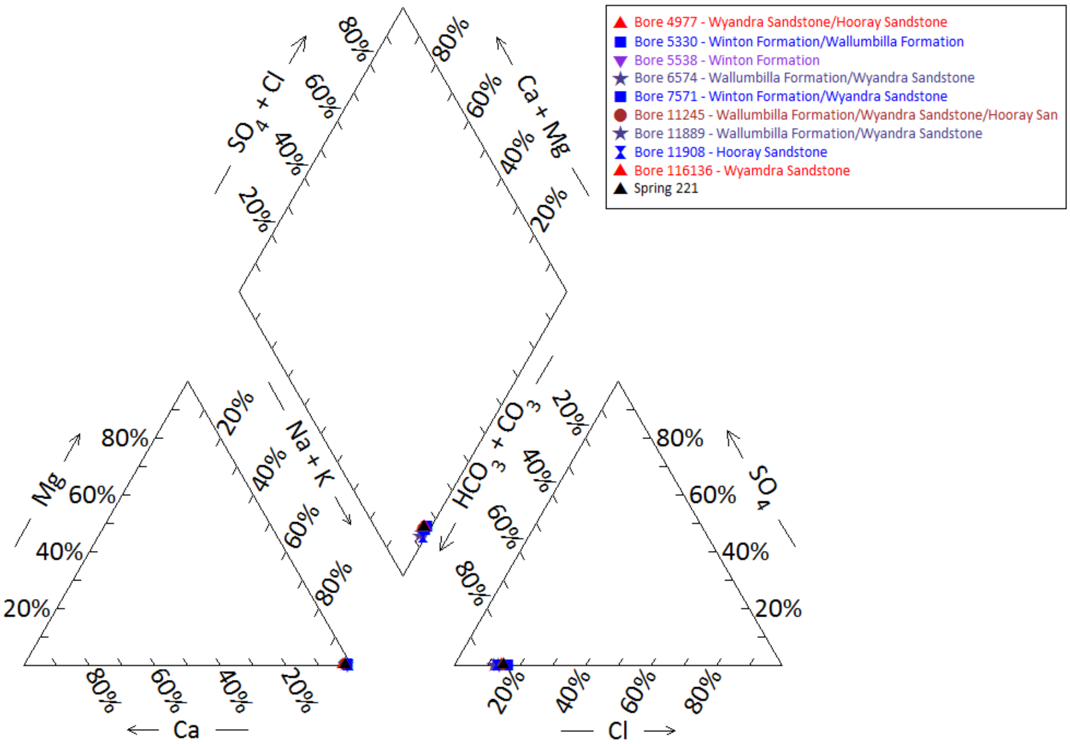


Figure 60 Carpet spring complex—Piper plot of the spring water and bore water chemistry.

12 Bourke supergroup springs, New South Wales

The Bourke supergroup consists of 53 active and inactive discharge spring complexes, located in northern New South Wales, near the town of Bourke (Figure 61 and Table 18), within the Eromanga Basin part of the Great Artesian Basin (GAB). Tego and Towry are located in Queensland. Most of the springs in this area are inactive. In comparison to the Springsure and Eulo supergroups, there are very few Bourke spring complexes with high-value rankings (see Part 1) and many spring wetland areas have been excavated.

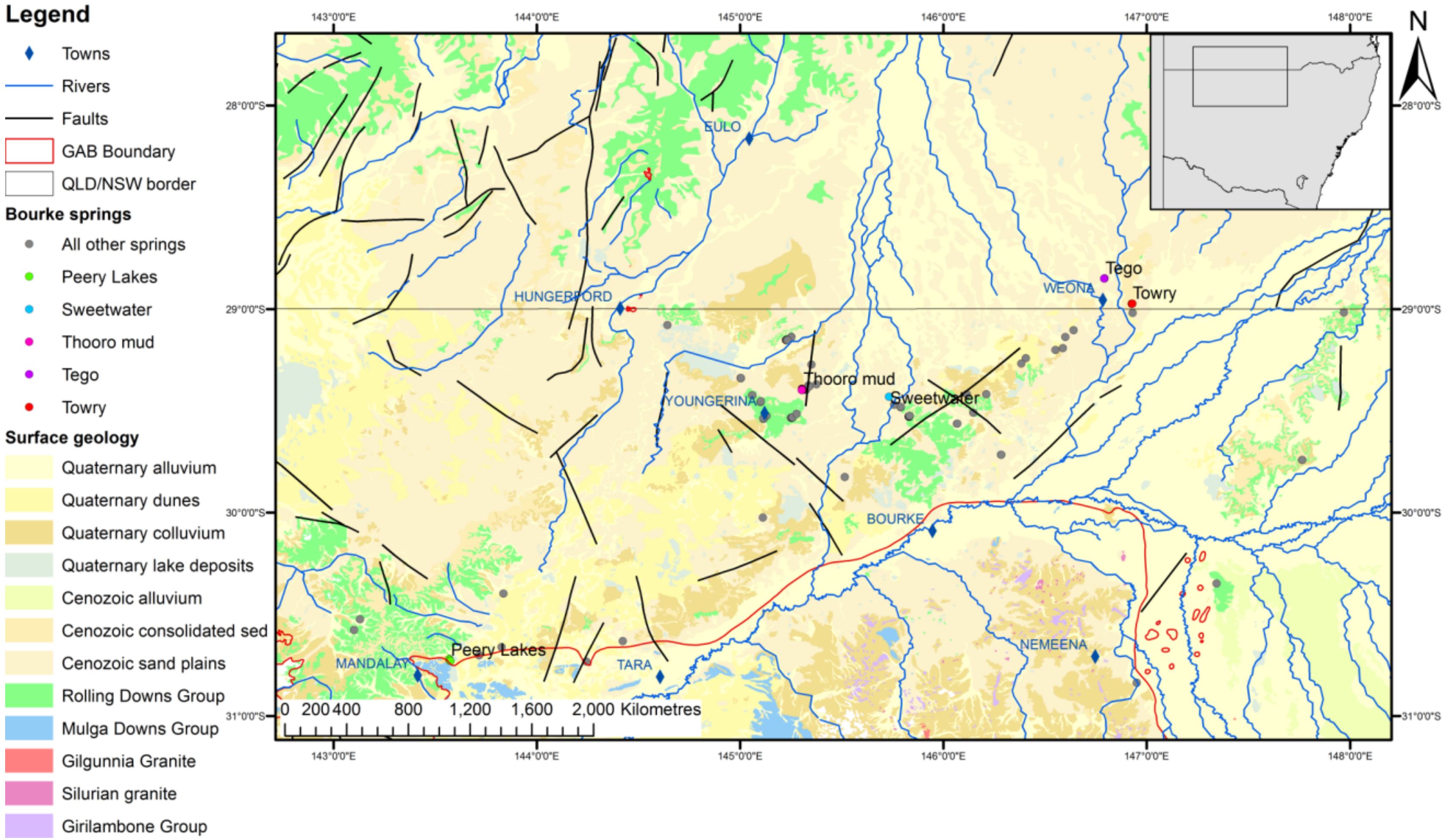
Hydrogeological profiles of the spring complexes with conservation rankings 1a—4a; Peery Lakes, Sweetwater, Thooro mud Tego, and Towry, have been completed and are found in Volume 2 of this report. The locations of these spring complexes are shown in Figure 61.

Table 18 Spring complexes of the Bourke supergroup.

Spring complexes with active springs	Inactive spring complexes	
Boongunyarrah	Bathing	Sandy
Colless	Bingewilpa	Sledgehammer
Lake Eliza	Coonbilly	Sweetwater
Mascot	Gerara	Thooro
Mooronowa North	Goonery	Thully
Mooronowa South	Gooroomero	Tooloomi
Nulty	Hawkes	Wapweela
Peery Lakes	Kallara	Yantabangee
Scrubber	Kullyna	Yantabulla
Tego	Lila	Yoorltoo
Throo Mud	Native Dog	Yotomi
Toulby	Peery	Youngerina
Towry	Pullamonga	

12.1 Regional geology

The Bourke spring complex lies near the southern edge of the Eromanga Basin in New South Wales, and just north of the New South Wales – Queensland border. Interpreted stratigraphy for this area is not as detailed as the stratigraphy available for the areas around the Springsure and Eulo supergroups. Available stratigraphic information indicates that the geological units present in the area include the Rolling Downs Group and Hooray Sandstone. Deeper GAB aquifers such as Hutton or Precipice Sandstone are not present (Kuske et al. 2010). Many geological structures, including faults and lineaments, are evident in the region, and many of the springs appear to be associated with these geological features (Figure 61).



GAB = Great Artesian Basin.

Figure 61 Bourke supergroup, Eromanga & Surat basins, New South Wales (NSW) and Queensland (Qld).

12.2 Regional aquifers

12.2.1 Wallumbilla Formation

The Cretaceous Wallumbilla Formation is a sedimentary unit comprised mainly of mudstone and siltstone with grey limestone and minor sandstone. It is the lowest stratigraphic unit in the Rolling Downs Group. The average thickness of the formation is 250 metres, and ranges from 100 metres to 600 metres (Radke et al. 2000). The Coreena Member comprises siltstone and fine sandstone interbedded with mudstone. It has a maximum thickness of 165 metres (DNRM 2005, GA 2012). The Doncaster Member comprises mudstone, siltstone, minor quartz sandstone in part glauconitic, silty limestone and gypsum (Eromanga and Surat basins). It has a maximum thickness of 275 metres (DNRM 2005, GA 2012).

Aquifers within the Wallumbilla Formation are generally lenticular with an uncertain hydraulic connection between adjacent aquifers. Yields are low and salinity is typically high, ranging from 1500 microsiemens per centimetre (µS/cm) to more than 100 000 µS/cm. The aquifers include the Coreena and Doncaster members, which are present in the Bourke area. The Wallumbilla Formation overlies the Wyandra Sandstone Member of the Cadna-owie Formation in the Eromanga Basin (DNRM 2005, GA 2012).

12.2.2 Wyandra Sandstone (Cadna-owie Formation)

The Wyandra Sandstone Member of the Cadna-owie Formation forms a significant aquifer, overlying the Cadna-owie Formation in the Eromanga Basin, and is the shallowest artesian aquifer in the GAB that generally produces flowing artesian waterbores, though some flowing bores also originate from the Wallumbilla Formation. The formation is a medium- to coarse-grained quartzose sandstone, generally less than 20 metres in thickness (DNRM 2005, GA 2012).

12.2.3 Hooray Sandstone

The Lower Cretaceous – Jurassic Hooray Sandstone and its hydrogeological equivalents are also generally the shallowest major artesian aquifers in the GAB, producing flowing artesian waterbores in the Eromanga Basin. The Wyandra Sandstone Member of the Cadna-owie Formation and the Hooray Sandstone are often considered as a single aquifer unit. The Hooray Sandstone comprises fine-to-coarse white quartzose sandstone with a kaolinitic matrix. This is the most highly developed artesian aquifer across a large extent of the Eromanga Basin, except in the centre where it is too deep for economic waterbore development. The Hooray Sandstone typically produces very good yields (DNRM 2005, GA 2012).

12.3 Hydrogeological summary

12.3.1 Conceptual spring types

Peery Lakes spring complex and other spring complexes on the edge of the GAB are likely to be springs emanating from a downgradient at the edge of the Basin (see conceptual spring type K at Appendix E).

The extensive faulting and other geological structures, including lineaments in the area, suggest that most of the spring complexes in the Bourke supergroup are discharge springs emanating from an artesian aquifer through a fault (conceptual spring types E and F). For example, there are a number of faults and lineaments running north-west to south-east, and lines of springs running parallel to them, such as the line of springs running from Youngerina to Bourke (Rade 1954). A line of springs, including Sweetwater, also follow a fault trending northeast to southwest (Figure 61).

It is harder to attribute a conceptual spring type to Tego and Towry spring complexes, because they lie on the Cunnamulla Shelf in an area with very few geological features and no mapped basement highs (Cunnamulla 1:250 000 geological sheet SH55-2, 1st edition; Senior & Thomas 1971). Nevertheless, the most likely conceptual types to apply would be springs emanating from a fault (type E or F), or a spring resulting from anticline or monocline elevating the aquifer relative to the surface (type D).

12.3.2 Potential source aquifers

The likely source aquifer for most spring complexes in the Bourke supergroup—including Peery Lakes, Sweetwater and Thooro Mud—is the Hooray Sandstone. It is possible that the springs are fed from shallower aquifers including the Wyandra Sandstone Member of the Cadna-owie Formation, or minor aquifers in the Coreena and Doncaster members of the Wallumbilla Formation. The Wyandra Sandstone Member of the Cadna-owie Formation is also a likely aquifer for Tego and Towry springs, as the Hooray Sandstone is at some depth in this area.

Although considered less likely, there is insufficient evidence to discount the discontinuous aquifers present in the Wallumbilla Formation as being potential source aquifers for the Bourke springs, due to:

- the artesian status of waterbores in the region tapping these shallow aquifers
- no interpreted stratigraphy to determine what aquifers the waterbores are tapping
- little to no groundwater chemistry data to distinguish between aquifers and assign a source aquifer for a spring.

Many of the Bourke springs are now inactive, suggesting that whatever aquifer was their source no longer has sufficient artesian pressure for groundwater to reach the surface and produce artesian springs. The springs are located in the region extending across a large part of southern Queensland and northern New South Wales that has experienced extensive drawdown due to large-scale exploitation of artesian groundwater since the late 1890s (Habermehl 1980).

13 Bogan River supergroup springs, New South Wales

The Bogan River supergroup consists of four active and inactive discharge spring complexes, located in northern New South Wales (Figure 62 and Table 19). The spring complexes extend in a line running south-south-west to north-north-east starting near the New South Wales town of Colossal and ending near the Queensland town of Hebel. The most southerly complex (Coolabah) lies on the edge of the Great Artesian Basin (GAB). Cumborah, Cuddie and Coorigul are located in the Coonamble Embayment of the Surat Basin. The geology and characteristics of Coorigul and Cumborah spring complexes indicate that they are not GAB springs, but sourced by local aquifers.

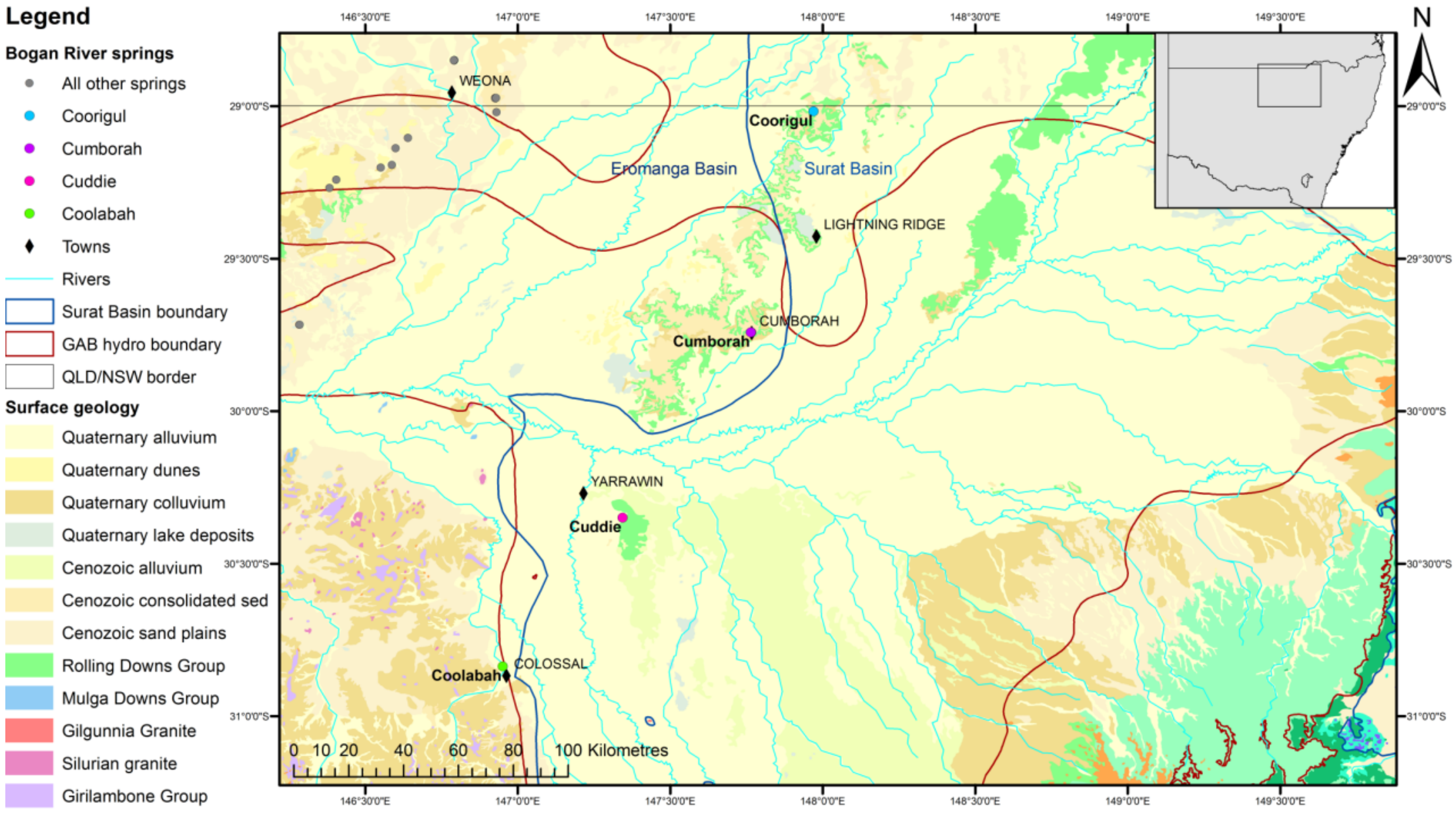
Hydrogeological profiles of all spring complexes have been completed and are in Volume 2, pages 235–264 of this report. The location of these spring complexes is shown in Figure 62 and Figure 63.

Table 19 Spring complexes of the Bogan River supergroup, New South Wales.

Spring complexes with active springs	Inactive spring complexes
Coorigul	Coolabah
	Cuddie
	Cumborah

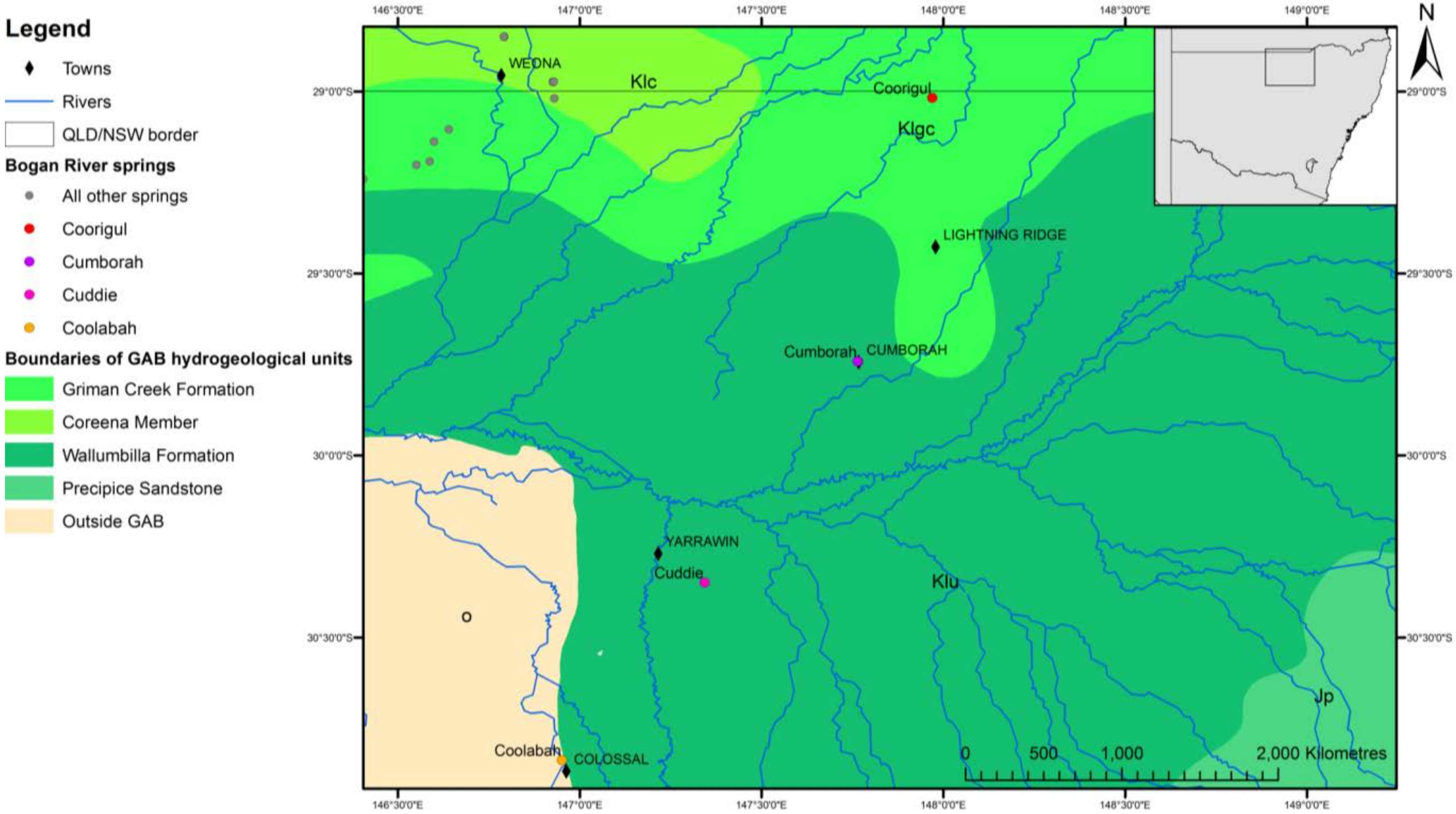
13.1 Regional geology

The Bogan River springs extend from the north-western part of the Coonamble Embayment into the Surat Basin (Figure 63). The geology for each of the spring complexes is based on the stratigraphy of the Surat Basin and Coonamble Embayment. Coorigul and Cumborah spring complexes are located along a ridge of sedimentary rocks that contain opal. The town of Lightning Ridge, famous for its opals, is located about halfway between Coorigul and Cumborah. Drillers' logs from waterbores and mapped depths of the Hooray Sandstone and its hydrogeological equivalents indicate that Mooga Sandstone and Gubberamunda Sandstone are underlying the Cuddie, Cumborah and Coorigul springs. Coolabah Spring is likely located at the edge of the GAB—shown within a small triangle shown as Surat Basin on the geological framework side map as part of the Bourke 1: 250 000 SH 55-10 Geological Series map sheet (Brunker 1971) and on the edge of the GAB hydrogeological unit boundary map produced by Habermehl and Lau (1997) (Figure 62). However, it maps just outside the boundary of Surat Basin using Australian Geological Provinces (sedimentary basins) maps (Stewart et al. 2013) (Figure 63).



GAB = Great Artesian Basin, QLD = Queensland.

Figure 62 Bogan River supergroup—Eromanga and Surat basins, New South Wales (NSW).



GAB = Great Artesian Basin, QLD = Queensland.

Figure 63 Boundaries of GAB hydrogeological units in northern New South Wales (NSW)—Bogan River supergroups.

13.2 Regional aquifers

13.2.1 Bungil Formation

The Bungil Formation occurs in the Surat Basin and the Coonamble Embayment. It consists of three members: the Minmi Member, the Nullawurt Sandstone Member and the Kingulli Member, and comprises sandstone, siltstone and mudstone. The Kingull Member is mostly a confining bed. The Minmi Member is primarily a confining bed, but does contain minor aquifers. The Nallawurt Sandstone Member is the main aquifer and comprises a quartzose, and lithic sandstone and siltstone. The Bungil Formation is a lateral equivalent of the Cadna-owie Formation in the Eromanga Basin and, along with the Mooga Sandstone, is informally divided into the Drildool beds and Keelindi beds in the Coonamble Embayment. It provides water of generally good quality with yields of more than 1.5 litres per second (L/s) (DNRM 2005, GA 2012). The Bungil Formation is informally known as the Drildool beds in the southern Coonamble Embayment to delineate the limit of marine influenced sediments (Watkins & Meakin 1964).

13.2.2 Mooga Sandstone

Mooga Sandstone is a hydrogeological equivalent of the Hooray Sandstone. The formation is thin but continuous throughout the Surat Basin and the Coonamble Embayment, and supplies artesian groundwater of good quality with yields of up to 35 L/s. The formation occurs between only the Nebine Ridge and the Kumbarilla Ridge. Mooga Sandstone comprises fluvial quartzose to sublabile sandstone. It is thinly bedded with siltstone and mudstone (DNRM 2005, GA 2012). The Mooga Sandstone has informally been named the Drildool and Keelindi beds in the Coonamble Embayment due to the difficulty in distinguishing the Mooga Sandstone from the Orallo Formation in the southern Coonamble Embayment (Watkins & Meakin 1964).

13.2.3 Gubberamunda Sandstone

The Gubberamunda Sandstone is also a hydrogeological equivalent of the Hooray Sandstone and laterally equivalent to the Pilliga Sandstone in the Coonamble Embayment. It comprises fluviatile sandstone, siltsone, mudstone and minor conglomerate. The Gubberamunda Sandstone provides artesian flows of good-quality water (DNRM 2005, GA 2012).

13.3 Hydrogeological summary

13.3.1 Conceptual spring types

The Coorigul and Cumborah spring complexes are most likely non-GAB springs emanating from the base of Tertiary sandstone where it contacts a confining layer.

Cuddie spring complex lies in the Coonamble Embayment, in an area with a number of lineaments trending north-south and east-west (NSW DTIRE 2004). The conceptual spring types that would describe the mechanism for discharge would be a discharge spring emanating from an artesian aquifer through a fault (see conceptual spring types E and F at Appendix E).

According to available stratigraphy and the mapped extent of the GAB by Habermehl & Lau (1997), Coolabah spring complex lies just on the edge of the GAB and the Lachlan Fold Belt.

As it appears to be a GAB spring, the most likely conceptual spring type would be a spring emanating from a downgradient at the edge of the Basin (see conceptual spring type K in Appendix E).

13.3.2 Potential source aquifer

The likely source aquifers for the GAB springs of the Bogan River supergroup (Cuddie and Coolabah) located in the Coonamble Embayment include the Mooga Sandstone (informally named the Drildool beds and Keelindi beds), the Bungil Formation and the Pilliga Sandstone.

The Cuddie spring complex is located in the Surat Basin. Mooga Sandstone is the most likely source aquifer for the Cuddie spring. It appears as though most bores in the area tap the Mooga Sandstone. Some bores are very deep, and appear to extend beyond the depth of Mooga Sandstone to deeper GAB aquifers such as the Pilliga Sandstone.

As the Coolabah spring complex is located near the southern edge of the GAB, where the Mooga Sandstone (Drildool beds and/or the Keelindi beds) come to the surface, one or more of these aquifers is the most likely source aquifer for springs in this complex. The Pilliga Sandstone appears to thin out to the east between Marra Creek and Macquarie River, and does not extend as far west as Bogan River (geological cross-section on Walgett SH 55-11 Geological Series map sheet 1:250 000 by Meakin et al. 1996), leaving the Mooga Sandstone as the most likely option.

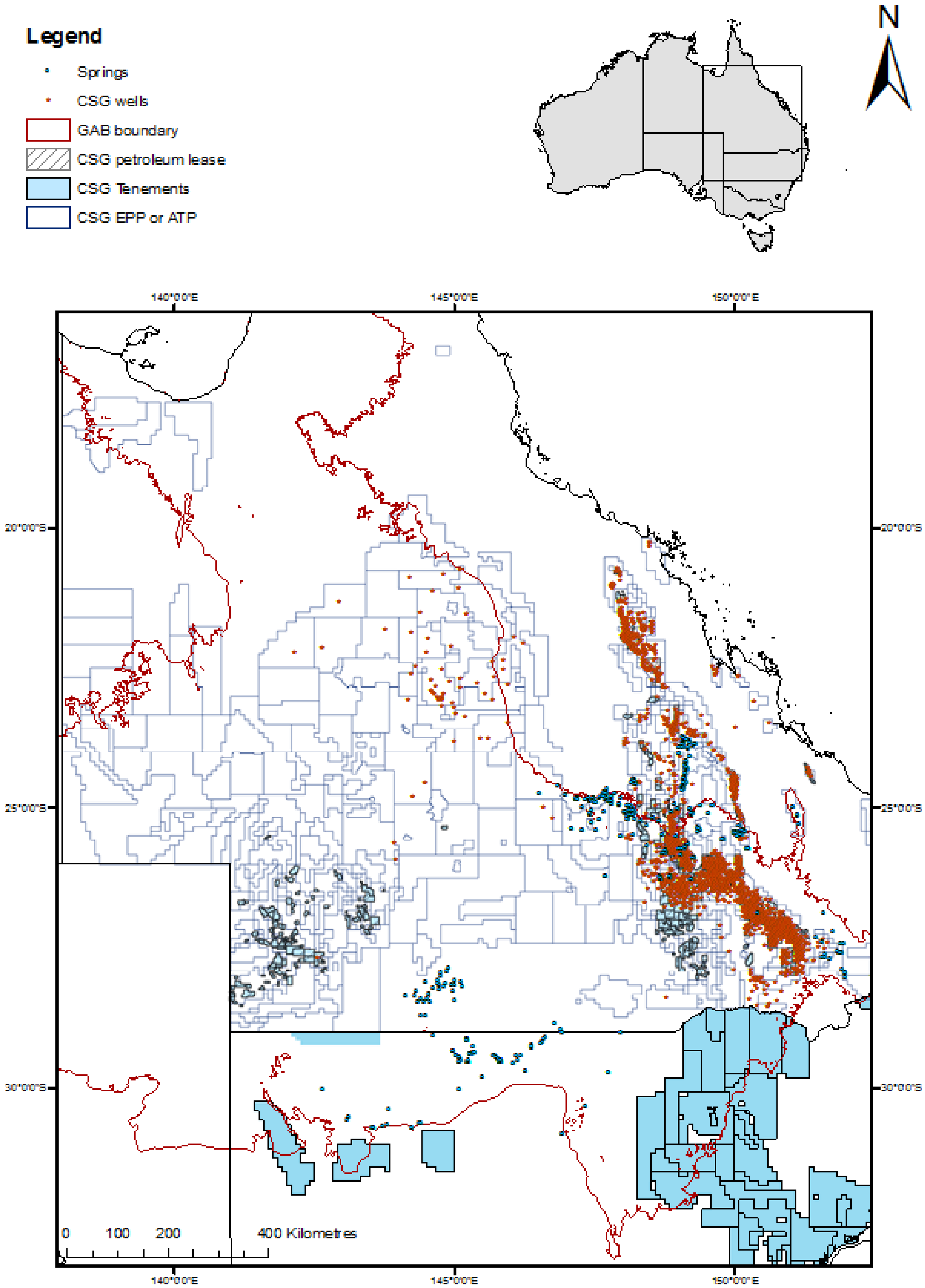
14 Risk assessment

Coal seam gas extraction in the Surat and Bowen basins may pose a threat to Great Artesian Basin (GAB) springs through the depressurisation of the coal seams in the Walloon Coal Measures (Surat Basin) and the Bandanna Coal Measures (Bowen Basin), and the subsequent effects of depresurisation on overlying and underlying aquifers.

The process of depressurising a coal seam involves pumping out groundwater to lower the artesian pressure in the coal seams. Gas then desorbs from the coal and can be extracted. Groundwater from overlying and underlying aquifers may then flow into the depressurised coal seams (QWC 2012a). The extent to which the coal seams and adjacent aquifers are hydraulically connected determines the resulting decrease in artesian groundwater pressure of those aquifer(s). Where a formation containing a targeted coal seam is separated from an aquifer by low-permeability rocks, such as siltstone and mudstone, groundwater flow between the coal seams and aquifer will be greatly reduced and coal seam gas extraction could have a limited impact on the aquifer.

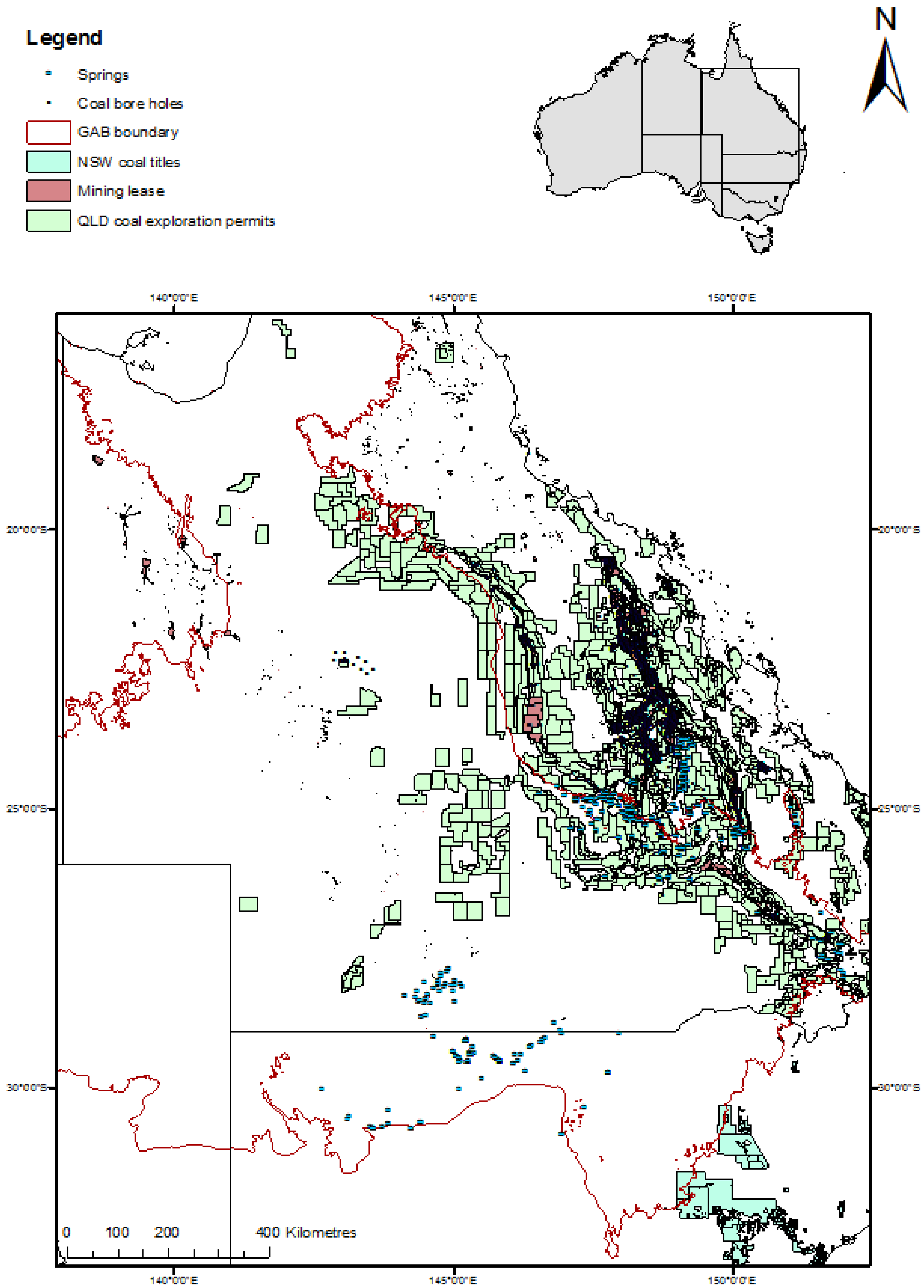
Coalmining has the potential to impact GAB springs through similar mechanisms. To prevent groundwater from infiltrating mine pits and underground mine shafts, water is pumped out of surrounding formations. This creates a cone of depression around a mine. Like a depressurised coal seam, water from overlying or underlying aquifers (and from formations surrounding the depressurised zone) may flow into the depressurised zone.

Any reduction of the artesian groundwater pressure in an aquifer may result in a decrease in the artesian groundwater levels of in a waterbore or spring that is fed by the aquifer (QWC 2012a). The closer a GAB spring is to coal seam gas production wells or coalmines, the greater the likelihood of the spring being affected, if coal seam gas extraction or mine dewatering has an effect on the source aquifer. Figure 64 shows the location of the Springsure, Eulo, Bourke and Bogan River supergroups in relation to current coal seam gas production wells, coal seam gas tenements and potential future sites of coal seam gas production. Figure 65 shows the location of the Springsure, Eulo, Bourke and Bogan River supergroups in relation to current coalmining leases and coal exploration permit titles. From these figures, it can be seen that the Springsure supergroup is in close proximity to coal seam gas and coalmining activity. The other supergroups (Eulo, Bourke and Bogan River) are relatively isolated and are not likely to be impacted from current activities. However, it should be noted that groundwater impacts can be slow to manifest and the springs should be monitored to ensure that negative effects do not develop, particularly through cumulative impacts of groundwater extraction for both groundwater bores, and coal and gas development.



ATP = authority to prospect, CSG = coal seam gas, EPP = exploration permit for petroleum, GAB = Great Artesian Basin.

Figure 64 Coal seam gas tenures and springs of the Springsure, Eulo, Bourke and Bogan River supergroups.



GAB = Great Artesian Basin, NSW = New South Wales, Qld = Queensland.

Figure 65 Coal tenures and springs of the Springsure, Eulo, Bourke and Bogan River supergroups.

The Walloon Coal Measures in the Surat Basin and the Bandanna Formation in the Bowen Basin are the two formations currently targeted for coal seam gas extraction (DERM 2010). They are not major aquifers of the GAB; however, some bores do tap the Walloon Coal Measures and, on occasion, water is extracted from the Bandanna Formation for agricultural purposes.

For most of the extent of the Walloon Coal Measures, low-permeability mudstones and siltstones are present at the top and bottom of the formation. The siltstone and mudstones at the bottom of the formation are quite thick in some areas and act as an aquitard separating the Walloon Coal Measures from the Hutton Sandstone below. The Queensland Water Commission (QWC 2012a) predicted the maximum impact on Hutton Sandstone to be less than five metres drawdown across most of its extent. There are, however, areas where the maximum drawdown may be up to 18 metres. The confining siltstone and mudstone at the top of the Walloon Coal Measures is much thinner and, in some places, has been eroded away. Connectivity between the Walloon Coal Measures and the overlying Springbok Sandstone aquifer is therefore highly variable and poorly understood at this stage (QWC 2012a). The QWC (2012a) predicted the maximum impact on the Springbok Sandstone across most of its extent to be less than a 20-metre drawdown; however, drawdown in an area south of Miles may reach more than 90 metres.

Depressurisation of the Bandanna Formation is unlikely to affect underlying formations, as they have very low permeability. It is also unlikely to affect overlying aquifers across most of its extent, because it is separated from overlying aquifers by the Rewan Group, which is made up of mudstones with very low permeability (QWC 2012a). The Rewan Group and overlying Clematis Sandstone were eroded away in a narrow zone that trends north-south and is situated east of Injune. The Precipice Sandstone in that location is in direct contact with the Bandanna Formation and the two formations are likely to have a high degree of interaction. The QWC predicted a maximum drawdown of 10 metres in this area, which is also close to the Fairview and Spring Gully coal seam gas production fields.

The potential for drawdown of tens of metres in adjacent aquifers in some areas resulted in the QWC investigating the potential effects of the predicted drawdowns on springs in the Springsure supergroup, which is in the vicinity of coal seam gas production fields. The QWC (2012a) has identified springs in the Fairview and Spring Gully coal seam gas production field areas as the springs most likely to be affected by coal seam gas extraction. The Surat underground water impact report (QWC 2012a) gave Lucky Last, Scott's Creek and Yebna 2 spring complexes a risk assessment score of five out of five based on the likelihood of a reduction in the artesian groundwater flow from springs (drawdown of more than 0.2 metres) and the consequences of a reduced flow on ecological values.

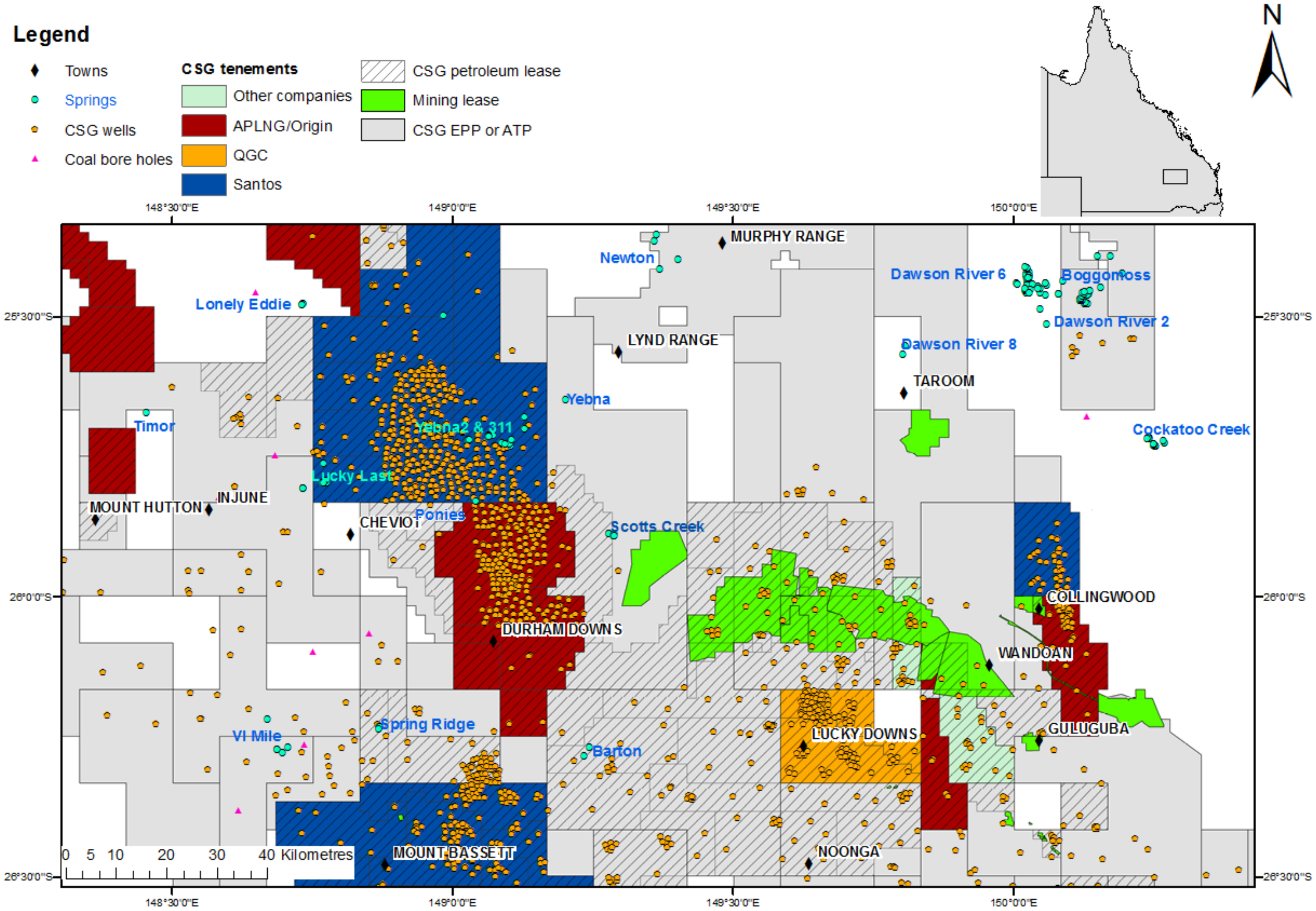
Lucky Last and Scott's Creek spring complexes are of particular concern, because they have a high-value ranking (as per Fensham et al. 2010) and a high likelihood of being affected by coal seam gas activities. Figure 66 shows the location of Lucky Last and Scott's Creek spring complexes in relation to coal seam gas tenures and wells in the area. Spring complexes predicted to be impacted, but with a lower risk rank (e.g. because drawdown is predicted to be less than 0.2 metres) include Dawson River 8, Yebna, Ponies, Barton, 311, Spring Ridge, VI Mile, Spring Rock Creek, Wambo and Abyss. Other springs of concern include Dawson River 8, 311 and Spring Rock Creek, because they have fairly high-risk rankings and are discharge springs. The drawdown risk threshold of 0.2 metres—as set in s. 379(3) *Water Act 2000* (Qld)—used to assess and rank springs likely to be impacted by coal seam gas is, however, more of a reflection on the predictive capability of the QWC's groundwater model, as opposed to the actual level of drawdown that would have an impact on a spring's ecological values.

Lucky Last spring complex is predicted to have a reduction in artesian groundwater pressure of 1.0–1.5 metres in the next 40–60 years, with an estimated timeframe of 5–40 years before the impact is predicted to exceed 0.2 metres (QWC 2012a). This is because the Precipice Sandstone (with some contribution from the Boxvale Sandstone Member of the Evergreen Formation) has been identified as the source aquifer for Lucky Last Springs, and there is a high degree of connectivity between artesian groundwater in the Precipice Sandstone and the Bandanna Coal Formation in this area. This is also the case for Yebna 2 spring complex. Once the drawdown exceeds 0.2 metres, the 'make good obligations' under the *Water Act 2000* (Qld) will be triggered.

Scott's Creek spring complex is predicted to have a reduction in artesian groundwater pressure of 0.2–0.5 m in the next 30–35 years. It is estimated that it will take 20–40 years before the predicted impact will exceed 0.2 metres (QWC 2012a). The Hutton Sandstone has been identified as the source aquifer for Scott's Creek spring complex. In the area of Scott's Creek, the lower Walloon Coal Measures aquitard is thin, and there would therefore be greater connectivity between the Hutton Sandstone and Walloon Coal Measures.

The QWC has developed a Spring Impact Management Strategy (SIMS) (QWC 2012a) as part of the underground water impact report. Along with identifying potentially affected artesian springs and assessing the connectivity of underlying aquifers, the SIMS also provides for a monitoring program and spring impact mitigation strategy. The spring mitigation strategy is currently focused on investigating potential actions to mitigate or prevent the predicted impacts at spring locations. Petroleum tenure holders are required to implement a spring monitoring program and a spring mitigation program for springs with a predicted impact of more than 0.2 metres under the *Water Act 2000* (Qld). The spring complexes that fall under this requirement include Lucky Last, Scott's Creek, Barton, Spring Rock Creek and 311/Yebna 2. The other springs investigated in this report had a predicted drawdown of less than 0.2 metres and are therefore unlikely to be significantly impacted by coal seam gas extraction. Further investigation into Dawson River 8 would be advisable, because it is of high conservation value. One bore in the area, with similar groundwater chemistry to the spring, is listed as tapping the Walloon Coal Measures (see Hydrogeological profile of Dawson River 8), although this may be an error. Table 20 shows the risk assessment score (QWC 2012b) for the Springsure spring complexes given a conservation ranking of 1a or 1b by Fensham et al. (2010) and focused on in this report. Springs listed as 'not potentially impacted' are in an area where no underlying aquifer has a predicted drawdown of more than 0.2 metres, and are at least 10 kilometres from an area with a predicted drawdown of more than 0.2 metres.

All springs likely to be affected by coal seam gas development are located in the Surat Basin, although some of them, such as Lucky Last spring complex, may be impacted by drawdown in underlying Bowen Basin Sediments. All springs located in the Bowen Basin, with the exception of Elgin 2 are recharge springs—conceptual types A or B (Figure 67). Recharge springs are supplied by groundwater from an unconfined GAB aquifer. Water drains out of the aquifer either by the water intersecting and running along a layer of low permeability or a fracture, or where the saturated zone of the aquifer intersects with the surface. Water residence time in the outcropping aquifer is fairly short. Spring flow is dynamic and correlated to recent rainfall (Habermehl 1982). For this reason recharge springs are less likely to be affected by dewatering though coal seam gas activity or mining than discharge springs, as spring flow is less dependent on artesian pressure.



APLNG = Australian Pacific LNG, ATP = authority to prospect, CSG = coal seam gas, EPP = exploration permit for petroleum.

Figure 66 Coal seam gas tenures and wells near Lucky Last and Scott's Creek spring complexes.

Table 20 Risk assessment results for Springsure spring complexes with 1a and 1b conservation ranking.

Spring complex name	QWC complex number	Risk assessment score (1–5)[a]
Lucky Last	230	5
Scott's Creek	260	5
Dawson River 8	8	3
Cockatoo Creek	9	Not a potentially impacted spring
Boggomoss	5	Not a potentially impacted spring
Dawson River 6	6	Not a potentially impacted spring
Dawson River 2	2	Not a potentially impacted spring

QWC = Queensland Water Commission.
a As assessed in QWC (2012a).

As only a few spring complexes within the Springsure supergroup are likely to be affected by coal seam gas extractions, it is unlikely that spring complexes further away such as Eulo, Bourke and Bogan River will be affected in the short term. However, exploration permits for petroleum (EPPs) and authorities to prospect (ATPs) have been granted for areas close to the Eulo and Bourke supergroups (Figure 64). Because the QWC, now the Office of Groundwater Impact Assessment, has a defined area of jurisdiction (currently the Surat Cumulative Management Area), spring complexes other than Springsure are outside of the area of modelled impact by coal seam gas development on groundwater. No model currently exists in enough detail to predict drawdown caused by coal seam gas development or coalmining for the Eulo, Bourke and Bogan River supergroups. Any effects that future coal seam gas extraction might have on springs in the Eulo and Bourke supergroups will depend on the hydraulic connectivity between the targeted coal seams and the Cadna-owie–Hooray aquifer and equivalent Surat Basin aquifers, the distance between the springs and coal seam gas extraction sites, and scale of the groundwater level drawdown (QWC 2012a). However, given the long distances between current coal seam gas and coalmining activity, impacts from drawdown are not expected. Potential effects of coal seam gas extraction and coalmining on the Bogan River supergroups are even less likely. Should coal seam gas or coalmining activities occur in closer proximity to these spring complexes, the risk assessment should be revisited.

Other impacts, such as drawdown caused by the use of flowing artesian waterbores; excavation; trampling and grazing by domestic stock, and native and feral species; and introduced pests, also pose a threat to the GAB springs. Historically, decreased aquifer pressure caused by the use of artesian waterbores has resulted in a dramatic reduction in artesian spring flows and a loss of many springs in the GAB (Fairfax & Fensham 2003). The Eulo, Bourke and Bogan River supergroups and the communities of native species dependent on their flows are more likely to be threatened by these land-use practises than by coal seam gas extraction.

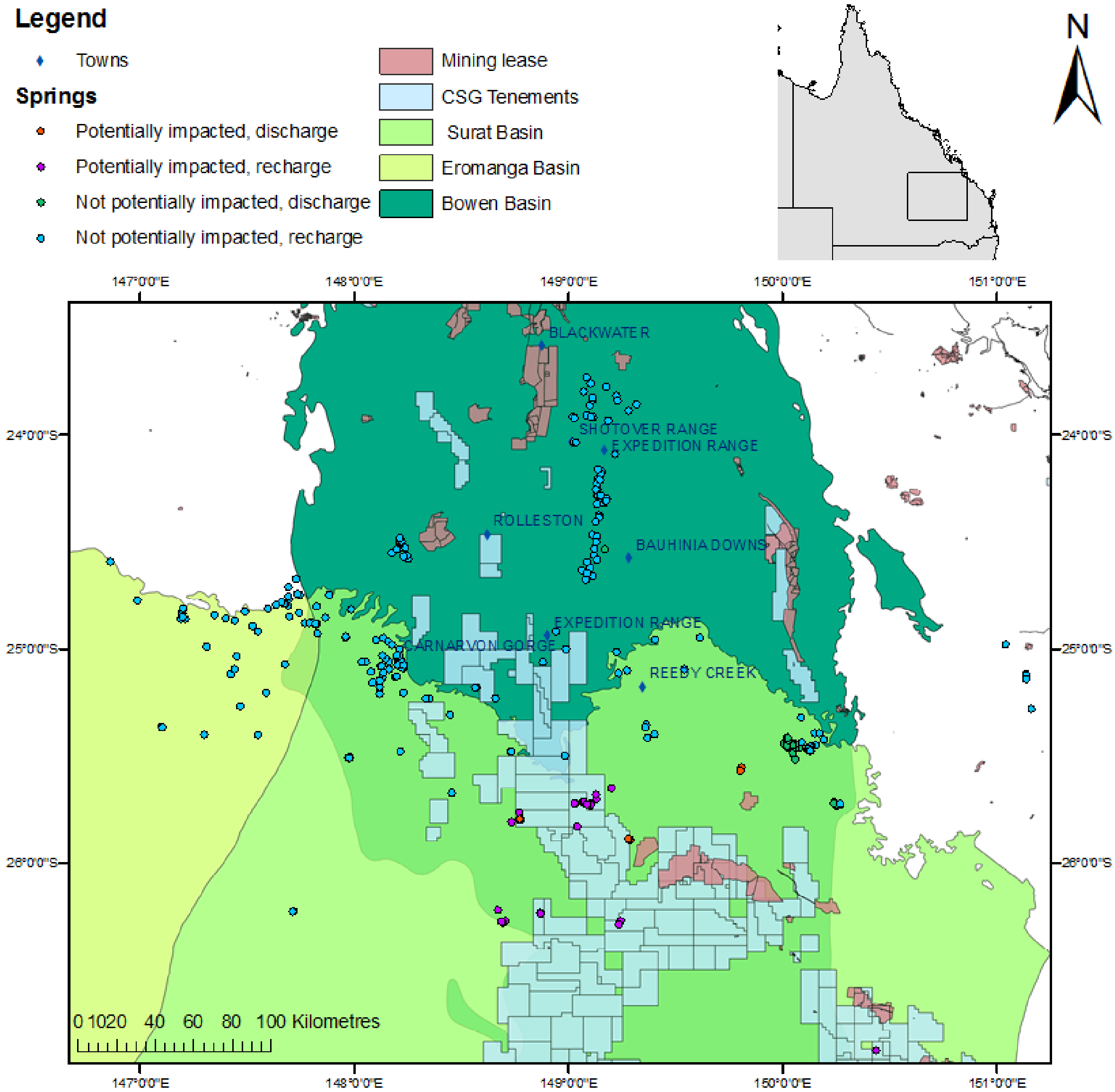


Figure 67 Discharge and recharge springs of the Springsure supergroup with coal seam gas (CSG) and mine tenements in the Bowen and Surat basins.

Bore rehabilitation and regulation was suggested as the most useful strategy for the recovery of artesian springs in the Eulo and Bourke supergroups (Smerdon et al. 2012). Any successful strategy aimed at protecting GAB springs must therefore take into account the historical and local threats to particular spring supergroups and complexes.

15 Concluding remarks

Identification of the source aquifer/s for the spring complexes in the Springsure supergroup was achieved with a fair degree of confidence. Ample information was available for these springs, because they have been the subject of in-depth investigation by Klohn Crippen Berger (QWC 2012c) for the Queensland Water Commission (QWC) for the *Underground water impact report for the Surat Cumulative Management Area* (QWC 2012a). The QWC report (2012a) provides a detailed discussion on how spring complexes have been identified as being vulnerable to coal seam gas impacts. The detailed discussion and analysis by the QWC were relied upon for informing the risk analysis.

Identification of some potential source aquifers was possible for the Eulo, Bourke and Bogan River supergroups. Our ability to identify a particular source aquifer for the springs in the Eulo supergroup was limited, because there is the potential for mixing of artesian groundwater from different aquifers before the spring water comes to the ground surface. Further limitations include the reduced amount of bore-screening data, and the similarity in hydrochemistry between all waterbores and springs. Identifying a source aquifer with any high degree of certainty for the Bourke and Bogan River supergroups was not possible due to the lack of bore water chemistry data, and sufficiently detailed and reliable stratigraphic information for the areas.

The methodology defined by Parsons Brinckerhoff (2010) allowed for a comprehensive investigation to determine the artesian source aquifer for a spring. Processes such as vertical mixing of artesian groundwater do, however, restrict the conclusions that can be drawn from some steps in the methodology, such as hydrochemistry analysis. Although the methodology involved using a variety of data and sources of information, the ability to successfully identify a spring's source aquifer/s is heavily dependent on the availability of certain key pieces of information.

The ability to identify artesian source aquifers for springs is highly dependent on information about waterbores in the vicinity of the artesian spring. Both the type of information and quality is important. To identify a source aquifer with any confidence, information on the drillers' logs, geological and geophysical logs, stratigraphy, bore data (including screening and casing, contributing aquifers, depth of groundwater cut in nearby waterbores), as well as the hydrochemistry of groundwater from the bores is essential. For example, in the Springsure supergroup, more information on waterbore screens was available, and the information about 'screening' (i.e. the interval where the slots appear in the casing or were an open hole exists below the bottom of the casing) was more specific. This made it easier to use this information— along with the interpreted stratigraphy of the bore's drilling log, and other geological or hydrogeological information—to come to a conclusion as to what aquifer the bore was tapping.

In contrast, little screening information was available for the Eulo supergroup area. For example, the information on bore casing did not include information on screening and did not specify whether the bore was accessing water via an open hole at the bottom. The information on aquifers encountered during drilling of the bore often did not specify which aquifers were contributing to the bore. Given the Queensland *Department of Environment and Resource Management's* Groundwater Database had codes to specify whether a bore was accessing water via an open hole at the bottom and specify contributing aquifers, assumptions were not made regarding the contributing aquifers in the absence of this information. The bores at Eulo also passed through several aquifers, making it difficult to determine whether the bores were sourcing groundwater from one or more artesian aquifers. Without the information about what aquifer or aquifers a bore is tapping, any hydrochemistry data are less valuable, as it cannot be linked to a specific aquifer and used to identify a spring's aquifer.

The lack of sufficiently detailed stratigraphic information made it very difficult to identify potential source aquifers for the artesian springs of the Bourke and Bogan River supergroups. No waterbores in New South Wales had interpreted stratigraphy from bore drilling logs. The New South Wales Department of Trade and Investment, Division of Resources and Energy 1:250 000 geological maps provided some interpreted stratigraphy for the area. These maps often did not indicate the presence of Great Artesian Basin aquifers, such as the Hooray Sandstone or its equivalents in the Surat Basin, including the Pilliga and Mooga Sandstones, which are known to be present in the area of the Bourke and Bogan River supergroup springs (H Haridharan 2013, pers. comm.). Stratigraphy provided from one of the stratigraphic bore in the Bourke area and stratigraphy from Queensland waterbores near the border with New South Wales was more relied on, along with published literature on the geology of the region, such as that by Habermehl (2001), Exon (1976), and Hawke and Cramsie (1984). To identify source aquifers for the Bourke and Bogan River supergroup springs in the future, more detailed information on stratigraphy and the waterbores in the area is needed.

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Appendix A: Metadata for Queensland Springs Database

Dataset COMPILERS

C Pennay, J Drimer, O Powell, R Fensham, R Rossini

Dataset DATE

March 2013

Dataset CUSTODIAN

Queensland Herbarium, Department of Science, Information Technology, Innovation and the Arts

Dataset JURISDICTION

Queensland

Description ABSTRACT

The information in this dataset is an inventory of permanent springs within the Eulo, Springsure, Bourke and Bogan River regional supergroups (Habermehl 1982) of springs in the Great Artesian Basin in Queensland. The dataset is current at March 2013, and includes information for all springs on: location; status (active/inactive); grouping (complex), and where available information on: physical properties; general morphology; water chemistry; floristic composition; disturbance; faunal composition; survey effort; photographic documentation; historical descriptions. Where sufficient information was available, springs have been given a conservation ranking at both the individual spring and complex levels.

Description SEARCH WORD(S)

Spring, spring wetland, wetland, Queensland, Great Artesian Basin, GAB

Description GEOGRAPHIC EXTENT NAMES(S)

Access STORED DATASET FORMAT(S)

Point locations

PROJECTION: Universal Transverse Mercator (UTM)

DATUM: Geocentric Datum of Australia (GDA94) or Australian Geodetic Datum (AGD84)

ACCESS AVAILABLE FORMAT TYPE(S)

Microsoft Access database

Data Quality LINEAGE

Table A1 Site details

Field name	Description	Allowed values
Site number	Unique identifier for spring wetland	>0
Preliminary site number	Preliminary unique identifier given to spring wetlands during field survey	>0 (mandatory)
Data source	Source of data for individual spring wetland	text, blank
Date	Most recent date spring wetland visited (see Historical data for a list and report from all previous visits)	text, blank
Recorders	Name of person(s) who recorded data	text, blank
Site name	Unique site name	text, blank
Property name	Name of property/pastoral station/national park on which spring wetland is located	text, blank
Flora species list	If TRUE there is a link to a list of plant taxa associated with this spring wetland, a list of species records for a spring wetland is necessary to undertake a conservation ranking. This can contain data from numerous trips. If the spring has not been surveyed yet, or is inactive must equal FALSE.	true/false
Adjacent environment RE	Field description of vegetation adjoining spring wetland including regional ecosystem (RE) code(s). For a full description of regional ecosystem codes refer to www.derm.qld.gov.au/wildlife-ecosystems/biodiversity/regional_ecosystems/index.php	text, blank
Spring RE	Regional ecosystem (RE) code for the spring wetland. For a full description of regional ecosystem codes refer to www.derm.qld.gov.au/wildlife-ecosystems/biodiversity/regional_ecosystems/index.php	single RE code
Notes	Additional information	text, blank
Complex name	Name of spring complex to which spring wetland belongs. A complex represents a group of springs or spring groups such that no adjacent pair of springs or spring-groups is more than about 6km distant and all springs within the spring complex are in a similar geomorphic setting. Geomorphic setting includes geological unit, landform, landscape position or soil type. Complexes can contain both active and inactive springs.	text, blank
Complex number	Unique numerical identifier for spring complex	any integer >0, blank
Supergroup name	Name of spring supergroup to which spring wetland belongs. A supergroup represents a major regional cluster of spring complexes with some consistent hydrogeological characteristics as defined by Habermehl (1982), Ponder (1986), GABCC (1998) and Fensham et al. (2003)	text, blank

Field name	Description	Allowed values
Discharge	A spring emanating from the Great Artesian Basin (GAB) aquifers other than those within outcrop areas of the following sandstone formations on the eastern margins of the GAB: Adori, Blantyre, Boxvale, Clematis, Expedition, Gilbert River, Gubberamunda, Hampstead, Hooray, Hutton, Mooga, Namur, Nullawurt, Precipice, Springbok, Warrang and Wyandra sandstones, the Bulimba, Bungil, Digby, Eurombah, Glenidal, Pilliga and Murta formations, and the Albany Pass, Drildool, Helby, Kumbarilla and Ronlow beds.	true/false
Active	The spring wetland is actively expressing water to maintain the spring wetland in a damp condition	true/false
GAB	Spring wetland derived from aquifers associated with Great Artesian Basin (GAB)	true/false
Region	Non-GAB Region (EG Carnarvon Basalt)	text, blank
Latitude (decimal degrees)	Latitude, recorded as decimal degrees to 7 decimal places (0.01 m accuracy). Negative values indicate location in southern hemisphere	(mandatory)
Longitude (decimal degrees)	Longitude, recorded as decimal degrees to 7 decimal places (0.01 m accuracy). Positive values indicate location in eastern hemisphere	(mandatory)
Horizontal coordinate system	Coordinate system used for horizontal location. 1. Australian Geodetic Datum of 1984 (AGD84), 2. Map Grid of Australia 1994 (MGA1994)	AGD84, MGA1994
Zone	Zone within Map Grid of Australia 1994 (MGA1994) coordinate system	54, 55, 56
Easting	Metres east within zone, recorded to 2 decimal places (0.1 m accuracy), MGA1994 coordinate system	(mandatory)
Northing	Metres north within zone, recorded to 2 decimal places (0.1 m accuracy), MGA1994 coordinate system	(mandatory)
Location precision	Indication of the precision (accuracy) of location data (horizontal coordinates, latitude and longitude). 1. OmniSTAR Differential GPS has a mean horizontal positional error of ± 0.1 m. 2. Handheld GPS units have a mean horizontal positional error of ± 10 m. 3. Other measures of location have been given a horizontal positional error range from 0.1–10 km. 4. Some spring wetland locations have had their location masked to protect populations of endangered species, these have been given a horizontal positional error of >10 km.	OmniSTAR Differential ~0.1 m accuracy, Garmin handheld ~10 m accuracy, Other 0.1–10 km accuracy, Masked >10 km accuracy
Vertical coordinate system	Australian Height Datum (AHD)	Australian Height Datum (AHD), blank

Field name	Description	Allowed values
Elevation—AHD (metres)	Mean elevation referenced to Australian Height Datum (AHD). Calculated from ellipsoidal height using AUSGeoid09 V1.01 (11 April 2011) www.ga.gov.au/earth-monitoring/geodesy/geodetic-datums/geoid.html (accessed 27/09/2011). Recorded in metres to 2 decimal places (0.1 m accuracy).	>0, blank
Dominant surface composition	Field description of the dominant surface composition of the vent. 1. Peat, 2. Mud (exuded), 3. Rocky seep (fractured), 4. Sand/Silt, 5. Carbonate (travertine), 6. Water/soak, 7. Other	Peat, Mud (exuded), Rocky Seep (fractured), Sand/Silt, Carbonate (travertine), Water/soak, Other, blank
General morphology	Field description of the general morphology of the vent. Mound, Flat, Closed depression (concave), Open depression (watercourse) bed, Open depression (watercourse) bank, Terraced, Other	Mound, Flat, Closed Depression (concave), Oped Depression (watercourse) bed, Open Depression (watercourse) bank, Terraced, Other, blank
Mound length (metres)	Visual estimate of the length (metres) of mound	>0, blank
Mound width (metres)	Visual estimate of the width (metres) of mound	>0, blank
Relative mound height (metres)	Visual estimate of the relative height (metres) of mound to the adjoining non-mounded area	>0, blank
Soak Length (metres)	Visual estimate of the length (metres) of the saturated spring wetland	>0, blank
Soak width (metres)	Visual estimate of the width (metres) of the saturated spring wetland	>0, blank
Spring wetland area (square metres)	Area (square metres) covered by ≥50% spring wetland vegetation	>0, blank
Area derivation	Method used to calculate 'Spring wetland area'. (a) Differential GPS–GIS polygon. Field traverse of the spring wetland boundary (defined as having ≥50% cover of perennial wetland plant species) using differential GPS to generate a GIS polygon feature for which an area could be calculated using Albers equal areas projection. (b) Visual estimate—multiplication of values recorded for spring wetland length and width	Differential GPS–GIS polygon, visual estimate, blank

Field name	Description	Allowed values
Estimated spring flow (L/min)	Estimated discharge rate (litres per minute) of water from spring wetland	>0, blank
Flow derivation	Method used to calculate 'Estimated spring flow'. (a) Fatchen model based on vegetated area (spring wetland area), for details refer to Fatchen (2001) Vegetated wetland area as an index of mound spring flows. *Proceedings of the 4th Mound Spring researchers forum* Friday 23 February 2001, Department of Environment and Heritage, Adelaide, pp. 5–8, accessed 10 March 2008, www.gabcc.org.au/tools/getFile.aspx?tbl=tblContentItem&id=47.(b) Visual estimate. Field estimate of visible flow rate.	Fatchen, visual estimate, blank
Water sample taken	Field water sample collected from site if free water was available. If TRUE, links to a separate water chemistry database containing estimates of all water chemistry measures. This database can contain measurements on numerous dates.	true/false
Morphological type (landscape situation)	Field description of the landscape situation of the spring wetland using morphological types as defined in CSIRO (2009)	crest, hillock, ridge, simple slope, upper slope, mid-slope, lower slope, flat, open depression, closed depression, blank
Landform (landscape) element	Field description of landform element (landform with 20-m radius) of the spring wetland using landform element types described and defined in CSIRO (2009, pp. 34–35)	Refer to CSIRO (2009)
Erosional landform pattern	Field description of erosional pattern (landform with 300-m radius) of the spring wetland using erosional landform pattern classes described in CSIRO (2009, pp. 47–48)	Refer to CSIRO (2009)
Landform pattern 2	Field description of landform pattern (landform with 300-m radius) of the spring wetland using landform pattern types described and defined in CSIRO (2009. p. 49)	Refer to CSIRO (2009)
Surface geology	Field description of surface geology with reference to 1:250,000 geology mapping units	text, blank

Field name	Description	Allowed values
Excavation damage (proportion)	Visual estimate of excavation damage recorded as one of five classes based on proportion of wetland area affected	0=none; 1=adjacent to spring wetland; 2=spring wetland less than 50% effected; 3=spring wetland more than 50% effected, but not totally eradicated; 4=spring wetland totally eradicated, blank
Excavation damage (type)	Description of excavation damage to site. 1. Bored, 2. Milled, 3. Dammed, 4. Drained, 5. Boxed well, 6. Pumped, 7. Other	text, blank
Pig damage	Visual estimate of pig damage recorded as one of four classes based on proportion of wetland area affected	0=absent; 1≤10% affected; 2=10–50% affected; 3=>50% affected, blank
Stock damage	Visual estimate of stock damage recorded as one of four classes based on proportion of wetland area affected	0=absent; 1≤10% affected; 2=10–50% affected; 3=≥50% affected, blank
Macroinvertebrate survey	Five-minute sweep of vegetated spring wetland area with 15-cm sieve (1 mm mesh). If TRUE, links to a separate macroinvertebrate database containing abundance data for all macroinvertebrates on all sampling occasions.	true/false
Molluscs survey	Where surveyed a five-minute sweep of vegetated spring wetland area with 15 cm sieve (1 mm mesh). If molluscs have been found and the macroinvertebrate survey conducted see previous field for abundance information.	Surveyed and found, surveyed and not found, not surveyed
Fish survey	Presence or absence of fish gauged by visual investigation	Surveyed and found, surveyed and not found, not surveyed
Inundation frequency	Known or inferred inundation history, based on information from landholders and floristic composition of spring wetland (perennial obligate wetland species)	Ephemeral, Intermittent, Seasonal, Permanent, Unknown, blank
Spring endemic	Presence in spring wetland of flora and/or fauna taxa endemic to GAB springs	true/false
Endemic details	List of flora and/or fauna taxa present in spring wetland endemic to GAB springs. For a full list of flora you can also link to the Flora database, connected to the field 'Flora species list'	List of endemic species, blank

Field name	Description	Allowed values
Scald endemic	List of flora taxa present in any scald associated with the spring	List of endemic species, blank
EPBC community	Spring wetland falls within the definition of *The community of native species dependent on natural discharge of groundwater from the Great Artesian Basin* listed as a threatened ecological community under the *Environment Protection and Biodiversity Conservation Act 1999* (Cwlth)	true/false
EPBC spp.	Presence in spring wetland of flora and/or fauna taxa listed as threatened under the *Environment Protection and Biodiversity Conservation Act 1999* (Cwlth)	TRUE/FALSE
EPBC spp. detail	Presence in spring wetland of flora and/or fauna taxa listed as endangered or vulnerable or near threatened under the *Environment Protection and Biodiversity Conservation Act 1999* (Cwlth)	List of EPBC species, blank
NCA spp.	Presence in spring wetland of flora and/or fauna taxa listed as endangered or vulnerable or near threatened under the *Nature Conservation Act 1992* (Qld)	true/false
NCA spp. detail	List of flora and/or fauna taxa present in spring wetland and listed as endangered or vulnerable under the *Nature Conservation Act 1992* (Qld)	List of NCA species, blank
Invasive species	Presence in spring wetland of invasive flora and/or fauna (i.e. Invasive species refers to flora and fauna species that have adetrimental effect on spring wetlands and associated biological values)	true/false
Invasive species detail	List of invasive flora and/or fauna taxa present in spring wetland	List of invasive species, blank
Disjunct/isolated population	Occurrence of populations of plant and/or animal taxa not known from habitat other than spring wetlands within 250 km, listed in Appendix R. Based on confirmed species records held in the Queensland Herbarium HERBRECS database	true/false

Field name	Description	Allowed values
Conservation Ranking 2012 (vent level)	Spring wetland conservation ranking applied at individual spring wetland/vent level as per the following ruleset: Category 1a: Contains at least one GAB endemic species not known from any other location beyond this spring complex. Category 1b: Contains endemic species known from more than one spring complex; or has populations of threatened species listed under state or Commonwealth legislation that do not conform to Category 1a. Category 2: Provides habitat for populations of plant and/or animal species not known from habitat other than spring wetlands within 250km. Category 3: Spring wetland vegetation without isolated populations (Category 2) with at least one native plant species that is not a weedy cosmopolitan plant species (Appendix R). Category 4: a) Spring wetland vegetation comprised of exotic and/or only native weedy cosmopolitan wetland plant species (Appendix R) or a spring devoid of vegetation or b) the original spring wetland is destroyed by impoundment or excavation. The probability of important biological values being identified in the future is very low. No other wetland species. Category 5: All springs inactive. Conservation ranking can only be applied to spring wetlands which have associated flora and fauna records	1a, 1b, 2, 3, 4a, 4b, 5
Conservation Ranking rationale 2012 (vent level)	Detail of the attribute which results (trigger) in the spring receiving a particular conservation rank. Refer to field Conservation Ranking 2012 (Vent Level)	text, blank
Conservation Ranking 2012 (complex level)	Spring wetland conservation ranking aggregated to the spring complex level. All spring wetlands within a spring complex are given the highest rank (Conservation Ranking (spring wetland/vent)) achieved by any constituent spring wetlands	1a, 1b, 2, 3, 4a, 4b, 5
Conservation Ranking rationale 2012 (complex level)	Detail of the attribute which results (trigger) in the spring complex receiving a particular conservation rank. Refer to fields Conservation Ranking 2012 (complex level) and Conservation Ranking 2012 (vent level)	text, blank
Additional Info	Directory path to the folder containing all additional information regarding this spring (e.g. Hydrogeological report, historical information, survey plans)	text, blank

Table A2 Photo details

Field name	Description	Allowed values
Site number	Unique identifier for spring wetland	≥0 (mandatory)
Preliminary site number	Preliminary unique identifier given to spring wetlands during field survey	≥0
Description	Caption describing photo (keep short, less than 100 characters)	text, blank
Date taken	Date photo was taken (can be gathered from EXIF data for recent digital camera images), for older photos where exact date not known default to the 1st day of known month or 1st day of known year	text, blank
File name	Unique identifier for site photo; full file name including extension (e.g. QWC_1044.jpg)	text (mandatory)
Locality	Brief text describing locality (e.g. property name)	text, blank
Direction	Azimuth of photo direction measured clockwise in degrees from magnetic north (e.g. 270)	0–360
Regional ecosystem	Regional ecosystem (RE) code for the spring wetland. For a full description of regional ecosystem codes refer to www.derm.qld.gov.au/wildlife-ecosystems/biodiversity/regional_ecosystems/index.php>	single RE code
Latitude (decimal degrees)	Latitude at point photo taken, recorded as decimal degrees to 4 decimal places. Negative values indicate location in southern hemisphere	–29.5 to –9.5
Longitude (decimal degrees)	Longitude at point photo taken, recorded as decimal degrees to 4 decimal places. Positive values indicate location in eastern hemisphere	137.9 to 154.0
Photographer	Name of person(s)/institution who took the photo (e.g. JS Smith)	text, blank
Bioregion	3 letter code indicating bioregion as per Sattler and Williams (1999)	BBN, BBS, CYP, CHC, CQC, DEU, EIU, GUP,MGD, NWH, MUL, NET, SEQ, WET, blank
Supergroup	Name of spring supergroup to which spring wetland belongs. A supergroup represents a major regional cluster of spring complexes with some consistent hydrogeological characteristics as defined by Habermehl (1982), Ponder (1986), GABCC (1998) and Fensham et al. (2003)	text, blank

Table A3 Flora records

Field name	Description	Allowed values
Record number	Unique record number for all flora records	autonumber (mandatory)
Site number	Unique identifier for spring wetland	≥0 (mandatory)
Preliminary site number	Preliminary unique identifier given to spring wetlands during field survey	≥0
Taxon number	Unique identifier for floristic taxa—equivalent to BC_NR in Queensland Herbarium HERBRECS database	≥0 (mandatory)
Taxon name	Accepted taxon name, without author details	text
Date	Date taxa recorded at spring wetland (i.e. date of floristic survey)	text (mandatory)
Supergroup	Name of spring supergroup to which spring wetland belongs. A supergroup represents a major regional cluster of spring-complexes with some consistent hydrogeological characteristics as defined by Habermehl (1982), Ponder (1986), GABCC (1998) and Fensham et al. (2003)	text, blank

Table A4 Flora taxa

Field name	Description	Allowed values
Taxon ID	Unique identifier for floristic taxa equivalent to BC_NR in Queensland Herbarium HERBRECS database	≥0 (mandatory)
Taxon name including author	Accepted full taxon name including author(s)	text (mandatory)
Taxon name	Accepted full taxon name excluding author(s)	text (mandatory)
Taxa with isolated population	Taxon occurs as isolated populations in spring wetlands (i.e. not known from habitat other than spring wetlands within a radius of 250 km, though may be common elsewhere), Based on confirmed species records held in the Queensland Herbarium HERBRECS database	true/false
Spring endemic	Taxon endemic to GAB springs	true/false
NCA	Taxon listed under *Nature Conservation Act 1992* (Qld)	true/false
EPBC	Taxon listed as threatened under the *Environment Protection and Biodiversity Conservation Act 1999* (Cwlth)	true/false
Naturalised	Taxon recognised by Queensland Herbarium as naturalised	true/false
Widespread colonisers	Taxon recognised as common and widespread in a broad range of wetland habitats (cosmopolitan wetland taxa)	
Non-wetland incidental taxa	Taxon not normally associated with wetland habitats	true/false
Invasive taxa	Naturalised taxon recognised as potentially invasive in	true/false

Field name	Description	Allowed values
	wetland habitats (e.g. ‘ponded pasture’ taxa)	

Table A5 Water chemistry

Field name	Description	Allowed values
Record number	Unique record number for all water chemistry records	autonumber (mandatory)
Site number	Unique identifier for spring wetland	≥0
Date	Date spring wetland water data collected	Any date, blank
Distance from vent (m)	The distance (metres) from main spring vent to the point at which water chemistry data was collected	≥0
pH	Hydrogen ion potential of field water sample	0–14, blank
Temperature	Water temperature in degrees Celsius (recorded to 1 decimal place)	>0, blank
Conductivity	Measure of electrical conductivity. Measured in microsiemens per centimetre.	>0, blank
Chemistry data source	1. Data collected by Herbarium staff; 2. Data collected by others	1, 2, blank
Hydrogeological report exists	A hydrogeological report exists for the spring or an associated bore	true/false
Notes	Additional information	text, blank

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Metadata Date METADATA DATE

06 March 2013

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Appendix B: Example spring report, Wiggera Spring, Eulo supergroup

WIGGERA SPRING

Status: Inactive

Location: –28.26836°S, 144.56864°E (Wiggera), –28.26625°S, 144.56600°E (Wiggera Carpet Springs)

Property: Granite Springs

Preliminary site #: 381B, 381Dnv

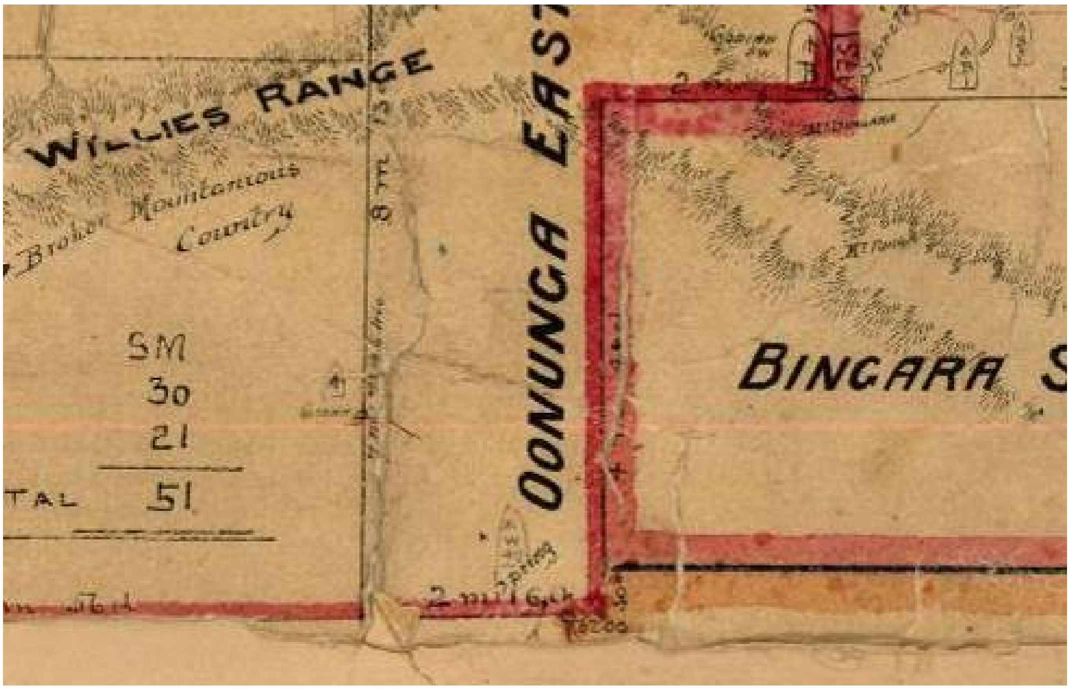
Site #: 905 (Wiggera), 905.1 (Wiggera carpet springs)

Field survey date: 18 October 2012

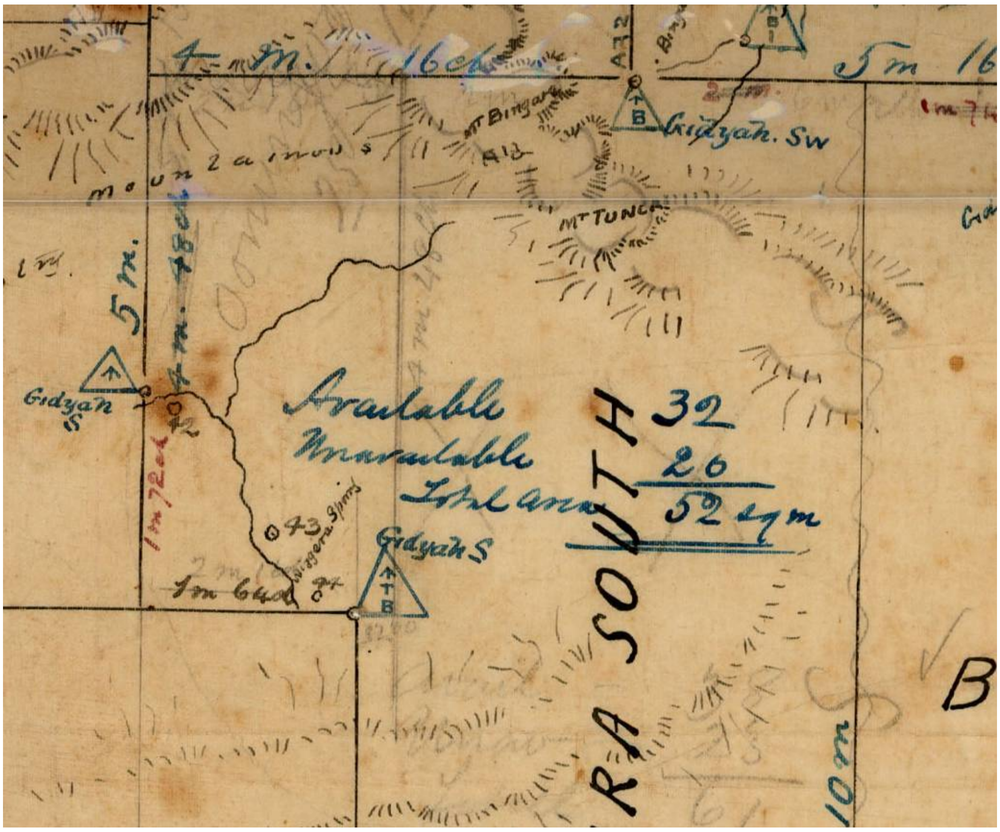
Informant: Graeme Pfitzner, Ian Pike, Gordon Warner

Inspected plans: Perambulator Survey of Runs on Bundilla, Acklands, Bingara and Dewalla Creeks, Warrego District, 21 February (1876); survey plan W.51.40 (c.1870); 4 mile series 1 sheet 3C (1931); 4 mile series 2 sheet 7 (1959)

Marked on survey plan W51.40 (1870) as unnamed spring, Perambulator Survey of Runs on Bundilla, Acklands, Bingara and Dewalla creeks, Warrego District (1876); and four-mile maps. The *Adelaide Chronicle* reported on extensive mud springs between Eulo and Thargomindah and that ‘a hot lake is found near the southern boundary of the (Dynevor) run’ (24 May 1919, p. 5). This probably relates to the area formerly flooded by Wiggera Spring.



Survey plan W.51.40 (1870), with Wiggera Spring marked in bottom centre of image.



Perambulator Survey of Runs on Bundilla, Acklands, Bingara and Dewalla creeks, Warrego District, 21 February (1876), showing Wiggera Spring.

Four-mile series 1, sheet 3C (1931) showing Wiggera Spring.

Bore inspectors Ogilvie and Edwards visited Wiggera Spring. Ogilvie wrote:

> *'Situated at the head of Wiggera Crek in the south-east corner of Dynevor Downs. The surrounding country on all sides consists of very steep desert sandstone ridges. The water issues from several holes in a basin about 10 foot wide and 2 or 3 feet deep and runs the flat bed of the watercourse for about ½ mile. A few reeds flourish on the edge of the pool, and good feed is growing in the watercourse, which, however, is rather boggy. The temperature is 95°F (also 96°F) and the water of good quality. 42,100 gpd. measured.*
>
> *A few small carpet springs occur at the main spring and 4 or 5 about 15 chains west, but these are barely noticeable and do not overflow.'*
>
>

Edwards (13/12/1911) described Wiggera as:

> *'Situated in the centre of a basin about ½ mile in width and almost surrounded by desert sandstone ranges. Wiggera Spring is one of the largest and most valuable in the district and was at one time the subject of litigation between the owners of Dynevor Downs and Boorara runs as their division boundary passed through the spring. I made a rough estimate of the flow which is about <u>40,000 g.p.d.</u> In winter this runs Wiggera Creek for 3 miles. The bottom of the spring is of loose free sand and has numerous 'pipes' or fissures up which water and gas rise. Reaching as far as possible down these 'pipes' I secured some water-worn stones which belong to the white sandstone and quartzites of the desert sandstone series.*
>
> *Improvements in Boorara- 200 foot of 2 inch piping leading to about 75 foot of troughing for watering of stock. In Dynevor a short length of drain has been made to lead water into Wiggera Creek. A strong flow of gas has been given off from the spring.*
>
> *Quality: in taste similar to Wooregym bore water the H_2S being noticeable; other gases are probably present but impart no taste to the water. Temperature about 96°F. Wiggera Spring water is hotter than both Tunga and Wooregym bores and almost as*

> *hot as Bingara. This evidence together with the great similarity in taste and presence of H_2S gas seems to indicate an artesian source of supply for the spring.'*
>
> © Copyright, Edwards (1912)

[Vide note WIGGERA SPRINGS, Rpt No. 13 p.15] in Edwards 18/2/12:

> *'The supply is now very small but a boundary rider who was on the run before the adjacent bore was sunk states that the spring gave out when the bore first struck water. Originally the spring maintained the same length of drain as the bore now does. Quality: excellent.'*
>
> © Copyright, Edwards (1912)

The site of Wiggera Spring is a dry, stony clay depression at the southern end of a vast barren plain between low hills. It sits in a shallow dry creekline vegetated with *Geijera parviflora, Acacia tetragonophylla* and *Atalaya hemiglauca*. The only sign of its former considerable outflow is a rusty pipe emanating from this depression. Sections of the pipe are scattered across the adjacent stony flat. Just to the north is a depression that appears to have been scraped out with a drain leading to the north-west. Numerous old fencelines converge at the site. Long-term residents of the area remember Wiggera as an active spring until about the 1940s, when it was no longer regularly maintained by scooping out and it went dry.

The Carpet Springs described by Ogilvie are evident as dry, shallow depressions fringed by sedges near the main spring at –28.26835, 144.56828 and 300 m to the west-north-west on the edge of the vast pebbly plain, where there are about five such depressions across a small area. Ian Pike remembers *Eriocaulon carsonii* growing in the Wiggera Spring wetland in the 1940s, while the groundwater indicator species *Sporobolus partimpatens, Calocephalus* sp. (Eulo) and *Trianthema* sp. (Coorabulka RW Purdie 1404) are still common at the site. Aboriginal stone flakes are scattered across the area.

(A) Site of Wiggera spring, now a dry, shallow depression in the bed of Wiggera Creek *(Photo 109)*, (B) rusty, old pipe emanating from the spring depression *(Photo 110)* and lying on the adjacent pebbly flat *(Photo 113)*, (C) the only sign of the former 40 000 gpd flow that emanated from the spring and flowed Wiggera Creek for five kilometres, and (D) shallow depressions on stony, barren flat between hills, filled with sedges and *Sporobolus partimpatens*; the Carpet Springs west of the main Wiggera Spring, as described by Ogilvie in 1912 *(Photo 116)*.

Appendix C: Survey status; Springsure, Eulo and Bourke supergroups

Table A6 Survey status for Springsure, Eulo and Bourke supergroups, March 2013, with notes on distance to tenure (petroleum production leases), elevation and access

Site	Supergroup	Latitude	Longitude	Elevation (m)	EPBC community	EPBC-listed species	EPBC species	NCA-listed species	NCA species	Distance to tenure (km)	Access
1	Springsure	–25.4341	150.0253	186.36	Yes	Yes	*Arthraxon hispidus*	Yes	*Arthraxon hispidus*	44.58	Surveyed
2	Springsure	–25.4576	150.0215	175.5	Yes	No	n/a	No	n/a	41.95	Surveyed
3	Springsure	–25.4525	150.0292	177.88	Yes	No	n/a	No	n/a	42.51	Surveyed
4	Springsure	–25.4458	150.0237	179.42	Yes	Yes	*Arthraxon hispidus*	Yes	*Arthraxon hispidus*	43.27	Surveyed
5	Springsure	–25.4455	150.0260	187.85	Yes	Yes	*Arthraxon hispidus*	Yes	*Thelypteris confluens*, *Arthraxon hispidus*	43.30	Surveyed
6	Springsure	–25.4275	150.0227	197.56	Yes	Yes	*Arthraxon hispidus*	Yes	*Arthraxon hispidus*	45.32	Surveyed
7	Springsure	–25.4268	150.0282	203.03	Yes	Yes	*Arthraxon hispidus*	Yes	*Arthraxon hispidus*	45.40	Surveyed
8	Springsure	–25.4154	150.0237	208.68	Yes	No	n/a	No	n/a	46.68	Surveyed
9	Springsure	–25.4148	150.0236	210.31	Yes	No	n/a	No	n/a	46.74	Surveyed
10	Springsure	–25.4125	150.0209	212.54	Yes	No	n/a	No	n/a	47.01	Surveyed

Site	Supergroup	Latitude	Longitude	Elevation (m)	EPBC community	EPBC-listed species	EPBC species	NCA-listed species	NCA species	Distance to tenure (km)	Access
11	Springsure	–25.4512	150.0436	173.37	Yes	No	n/a	No	n/a	42.67	Surveyed
12	Springsure	–25.4414	150.0563	173.38	Yes	No	n/a	No	n/a	43.77	Surveyed
13	Springsure	–25.4409	150.0563	174.6	Yes	No	n/a	No	n/a	43.82	Surveyed
14	Springsure	–25.4476	150.0427	170.98	Yes	No	n/a	No	n/a	43.06	Surveyed
15	Springsure	–25.4435	150.0337	188.23	Yes	No	n/a	No	n/a	43.53	Surveyed
16	Springsure	–25.4484	150.1541	158.929	No	No	n/a	No	n/a	43.30	Surveyed
17	Springsure	–25.4604	150.1331	171.835	No	No	n/a	No	n/a	41.75	Surveyed
18	Springsure	–25.4603	150.1301	163.134	No	No	n/a	No	n/a	41.74	Surveyed
19	Springsure	–25.4564	150.1341	161.424	No	No	n/a	No	n/a	42.21	Surveyed
20	Springsure	–25.4614	150.1321	172.229	No	No	n/a	No	n/a	41.63	Surveyed
21	Springsure	–25.4554	150.1351	160.631	No	No	n/a	No	n/a	42.33	Surveyed
22	Springsure	–25.4280	150.0275	199.67	Yes	Yes	*Arthraxon hispidus*	Yes	*Arthraxon hispidus*	45.26	Surveyed
23	Springsure	–25.4359	150.0256	188.14	Yes	Yes	*Arthraxon hispidus*	Yes	*Thelypteris confluens*, *Arthraxon hispidus*	44.38	Surveyed
24	Springsure	–25.4384	150.0256	185.01	Yes	Yes	*Arthraxon hispidus*	Yes	*Arthraxon hispidus*	44.10	Surveyed
25	Springsure	–25.4368	150.0233	184.86	Yes	Yes	*Arthraxon hispidus*	Yes	*Arthraxon hispidus*	44.27	Surveyed
26	Springsure	–25.5524	149.8071	190	Yes	No	n/a	No	n/a	31.32	Surveyed

Site	Supergroup	Latitude	Longitude	Elevation (m)	EPBC community	EPBC-listed species	EPBC species	NCA-listed species	NCA species	Distance to tenure (km)	Access
27	Springsure	–25.4323	150.0254	191.59	Yes	Yes	*Arthraxon hispidus*	Yes	*Arthraxon hispidus*	44.79	Surveyed
28	Springsure	–25.5524	149.8071	190	Yes	No	n/a	No	n/a	31.32	Surveyed
29	Springsure	–25.4516	150.0205	178.17	Yes	No	n/a	No	n/a	42.62	Surveyed
30	Springsure	–25.4423	150.0055	181.33	Yes	Yes	*Arthraxon hispidus*	Yes	*Arthraxon hispidus*	43.66	Surveyed
31	Springsure	–25.4409	150.0049	183.16	Yes	Yes	*Arthraxon hispidus*	Yes	*Arthraxon hispidus*	43.82	Surveyed
32	Springsure	–25.4412	150.0260	182.94	Yes	Yes	*Arthraxon hispidus*	Yes	*Arthraxon hispidus*	43.79	Surveyed
33	Springsure	–25.4591	150.0286	177.98	Yes	No	n/a	No	n/a	41.77	Surveyed
34	Springsure	–25.4584	150.1231	163.104	No	No	n/a	No	n/a	41.91	Surveyed
35	Springsure	–25.4594	150.1251	162.707	No	No	n/a	No	n/a	41.81	Surveyed
36	Springsure	–25.4564	150.1261	164.178	No	No	n/a	No	n/a	42.15	Surveyed
37	Springsure	–25.4608	150.0797	174.76	Yes	No	n/a	No	n/a	41.59	Surveyed
37.1	Springsure	–25.4608	150.0798	174.76	Yes	No	n/a	No	n/a	41.58	Surveyed
38	Springsure	–25.5685	149.8021	182.67	Yes	No	n/a	No	n/a	29.51	Surveyed
39	Springsure	–25.4764	150.1271	177.162	No	No	n/a	No	n/a	39.92	Surveyed
40	Springsure	–25.4753	150.1287	179.88	Yes	Yes	*Eriocaulon carsonii*	Yes	*Eriocaulon carsonii*, *Livistona nitida*	40.06	Surveyed
41	Springsure	–25.4767	150.1309	180.43	Yes	Yes	*Eriocaulon*	Yes	*Eriocaulon*	39.91	Surveyed

Site	Supergroup	Latitude	Longitude	Elevation (m)	EPBC community	EPBC-listed species	EPBC species	NCA-listed species	NCA species	Distance to tenure (km)	Access
							carsonii		*carsonii*, *Livistona nitida*		
42	Springsure	–25.5150	150.0586	181.47	Yes	No	n/a	No	n/a	35.51	Surveyed
43	Springsure	–25.4633	150.0567	172.83	Yes	No	n/a	No	n/a	41.31	Surveyed
44	Springsure	–25.4586	150.0476	221	Yes	No	n/a	No	n/a	41.83	Surveyed
45	Springsure	–25.4714	150.1221	172.22	No	No	n/a	No	n/a	40.45	Surveyed
46	Springsure	–25.4713	150.1201	173.037	No	No	n/a	No	n/a	40.45	Surveyed
47	Springsure	–25.4709	150.1175	169.86	No	No	n/a	No	n/a	40.49	Surveyed
47.1	Springsure	–25.4710	150.1181	168.23	No	No	n/a	No	n/a	40.47	Surveyed
47.2	Springsure	–25.4711	150.1181	178	No	No	n/a	No	n/a	40.46	Surveyed
47.3	Springsure	–25.4712	150.1182	177	No	No	n/a	No	n/a	40.45	Surveyed
47.4	Springsure	–25.4714	150.1183	177	No	No	n/a	No	n/a	40.44	Surveyed
47.5	Springsure	–25.4710	150.1184	167.32	No	No	n/a	No	n/a	40.48	Surveyed
47.6	Springsure	–25.4705	150.1183	166.99	No	No	n/a	No	n/a	40.54	Surveyed
47.7	Springsure	–25.4705	150.1177	167.44	No	No	n/a	No	n/a	40.54	Surveyed
47.8	Springsure	–25.4699	150.1178	167.13	No	No	n/a	No	n/a	40.60	Surveyed
47.9	Springsure	–25.4696	150.1178	166.95	No	No	n/a	No	n/a	40.63	Surveyed
48	Springsure	–25.4721	150.1187	174.74	No	No	n/a	Yes	*Livistona nitida*	40.36	Surveyed
49	Springsure	–25.4714	150.1191	173.891	No	No	n/a	No	n/a	40.44	Surveyed
50	Springsure	–25.4696	150.1186	166.18	No	No	n/a	No	n/a	40.63	Surveyed

Site	Supergroup	Latitude	Longitude	Elevation (m)	EPBC community	EPBC-listed species	EPBC species	NCA-listed species	NCA species	Distance to tenure (km)	Access
51	Springsure	–25.4684	150.1201	169.779	No	No	n/a	No	n/a	40.78	Surveyed
52	Springsure	–25.4773	150.1257	181.42	Yes	Yes	*Eriocaulon carsonii*	Yes	*Eriocaulon carsonii*	39.81	Surveyed
53	Springsure	–25.4549	150.0210	174.82	Yes	No	n/a	No	n/a	42.25	Surveyed
54	Springsure	–25.4454	150.0591	170.34	Yes	No	n/a	No	n/a	43.32	Surveyed
55	Springsure	–25.4219	150.0227	202.18	Yes	No	n/a	No	n/a	45.95	Surveyed
56	Springsure	–25.4247	150.0217	197.05	Yes	No	n/a	No	n/a	45.63	Surveyed
56.1	Springsure	–25.4246	150.0210	196.57	Yes	No	n/a	No	n/a	45.65	Surveyed
57	Springsure	–25.4202	150.0265	201.4	Yes	No	n/a	No	n/a	46.14	Surveyed
58	Springsure	–25.4225	150.0271	201.61	Yes	No	n/a	No	n/a	45.88	Surveyed
59	Springsure	–25.4421	150.0235	182.32	Yes	Yes	*Arthraxon hispidus*	Yes	*Arthraxon hispidus*	43.69	Surveyed
60	Springsure	–25.4302	150.0216	190.99	Yes	Yes	*Arthraxon hispidus*	Yes	*Arthraxon hispidus*	45.02	Surveyed
61	Springsure	–25.4544	150.0274	172.43	Yes	No	n/a	No	n/a	42.31	Surveyed
62	Springsure	–25.4311	150.0252	193.45	Yes	No	n/a	No	n/a	44.91	Surveyed
63	Springsure	–25.4502	150.0464	171.64	Yes	No	n/a	No	n/a	42.78	Surveyed
64	Springsure	–25.7177	150.2409	223.08	No	Yes	*Eriocaulon carsonii*	Yes	*Myriophyllum artesium*, *Eriocaulon carsonii*	18.86	Surveyed
64.1	Springsure	–25.7178	150.2407	217.29	Yes	No	n/a	No	n/a	18.83	Surveyed

Site	Supergroup	Latitude	Longitude	Elevation (m)	EPBC community	EPBC-listed species	EPBC species	NCA-listed species	NCA species	Distance to tenure (km)	Access
65	Springsure	–25.7165	150.2391	219.2	Yes	Yes	*Eriocaulon carsonii*	Yes	*Myriophyllum artesium*, *Eriocaulon carsonii*	18.82	Surveyed
65.1	Springsure	–25.7163	150.2390	218.29	Yes	No	n/a	No	n/a	18.83	Surveyed
65.2	Springsure	–25.7162	150.2391	222.13	Yes	No	n/a	No	n/a	18.84	Surveyed
66	Springsure	–25.7194	150.2381	217.928	Yes	No	n/a	No	n/a	18.52	Surveyed
67	Springsure	–25.4755	150.1272	176.92	Yes	No	n/a	No	n/a	40.02	Surveyed
68	Springsure	–25.4312	150.0270	196.09	Yes	Yes	*Arthraxon hispidus*	Yes	*Arthraxon hispidus*	44.91	Surveyed
68.1	Springsure	–25.4312	150.0267	197.07	Yes	Yes	*Arthraxon hispidus*	Yes	*Arthraxon hispidus*	44.90	Surveyed
69	Springsure	–25.4644	150.1221	184.274	No	No	n/a	No	n/a	41.23	Surveyed
157	Springsure	–25.2797	151.1614	175.16696	No	No	n/a	No	n/a	121.67	Surveyed
158	Springsure	–25.1197	151.1358	197.85609	No	No	n/a	No	n/a	130.03	Surveyed
159	Springsure	–25.1156	151.1347	199.84569	No	Yes	*Arthraxon hispidus*	Yes	*Arthraxon hispidus*	130.24	Surveyed
160	Springsure	–25.1208	151.1372	201.69513	No	Yes	*Arthraxon hispidus*	Yes	*Arthraxon hispidus*	130.06	Surveyed
161	Springsure	–24.8675	147.4419	592.86096	No	No	n/a	No	n/a	82.55	Surveyed
162	Springsure	–24.8242	147.4897	586.63873	No	No	n/a	No	n/a	77.77	Surveyed
163	Springsure	–24.8414	147.3467	593.59277	No	No	n/a	No	n/a	92.05	Surveyed
164	Springsure	–24.8597	147.1892	456.66693	No	Yes	*Arthraxon*	Yes	*Arthraxon*	107.79	Surveyed

Site	Supergroup	Latitude	Longitude	Elevation (m)	EPBC community	EPBC-listed species	EPBC species	NCA-listed species	NCA species	Distance to tenure (km)	Access
							hispidus		*hispidus*		
165	Springsure	–24.8458	147.1947	443.65741	No	Yes	*Arthraxon hispidus*	Yes	*Arthraxon hispidus*	107.23	Surveyed
166	Springsure	–24.8267	147.1942	436.55573	No	No	n/a	No	n/a	107.30	Surveyed
167	Springsure	–24.8339	147.1989	438.87662	No	No	n/a	No	n/a	106.83	Surveyed
168	Springsure	–24.8106	147.2022	435.22226	No	No	n/a	No	n/a	106.51	Surveyed
169	Springsure	–24.8247	147.4900	588.13892	No	No	n/a	No	n/a	77.74	Surveyed
170	Springsure	–24.7975	147.6911	831.58331	No	No	n/a	No	n/a	57.65	Surveyed
171	Springsure	–24.7886	147.6772	764.51538	No	No	n/a	No	n/a	59.04	Surveyed
172	Springsure	–24.7886	147.6711	761.77777	No	No	n/a	No	n/a	59.66	Surveyed
173	Springsure	–24.7808	147.6583	766.88861	No	No	n/a	No	n/a	60.94	Surveyed
174	Non–GAB	–24.8034	147.8591	942	No	No	n/a	No	n/a	40.85	Surveyed
175	Non–GAB	–24.7894	147.8461	883	No	No	n/a	No	n/a	42.16	Surveyed
176	Springsure	–24.8006	147.8236	834.99377	No	No	n/a	No	n/a	44.40	Surveyed
177	Non–GAB	–24.7439	147.7473	838	No	No	n/a	No	n/a	52.06	Surveyed
178	Springsure	–25.3625	147.1003	475.22223	No	No	n/a	No	n/a	123.91	Surveyed
179	Springsure	–25.3667	147.1036	476.04626	No	No	n/a	No	n/a	123.76	Surveyed
180	Springsure	–25.1172	147.4231	725.67926	No	No	n/a	No	n/a	85.62	Surveyed
181	Springsure	–25.0942	147.4411	711.4538	No	No	n/a	No	n/a	83.43	Surveyed
182	Springsure	–24.8797	147.7689	802.58954	No	No	n/a	No	n/a	49.88	Surveyed
183	Springsure	–24.8731	147.7961	823.37347	No	Yes	*Arthraxon*	Yes	*Arthraxon*	47.20	Surveyed

Site	Supergroup	Latitude	Longitude	Elevation (m)	EPBC community	EPBC-listed species	EPBC species	NCA-listed species	NCA species	Distance to tenure (km)	Access
							hispidus		*hispidus*		
184	Springsure	–26.2334	148.8686	406.38	No	No	n/a	No	n/a	11.11	Surveyed
185	Springsure	–26.2321	148.8694	404.16	No	No	n/a	No	n/a	11.25	Surveyed
186	Springsure	–26.2367	148.8690	398.72	No	No	n/a	No	n/a	10.73	Surveyed
187	Springsure	–26.2190	148.6703	382.7	No	No	n/a	No	n/a	20.61	Surveyed
188	Springsure	–26.2695	148.7054	368	No	No	n/a	No	n/a	14.56	Surveyed
189	Springsure	–25.8915	149.2860	245.61	Yes	Yes	*Eriocaulon carsonii*	Yes	*Eriocaulon carsonii*	6.75	Surveyed
190	Springsure	–25.8884	149.2874	244.35	Yes	Yes	*Eriocaulon carsonii*	Yes	*Eriocaulon carsonii*	6.90	Surveyed
191	Springsure	–25.8918	149.2875	244.45	Yes	Yes	*Eriocaulon carsonii*	Yes	*Eriocaulon carsonii*	6.90	Surveyed
192	Springsure	–25.8890	149.2790	244.85	Yes	Yes	*Eriocaulon carsonii*	Yes	*Eriocaulon carsonii*	6.07	Surveyed
192.1	Springsure	–25.8881	149.2792	247	Yes	No	n/a	No	n/a	6.08	Surveyed
193	Springsure	–26.2244	147.7164	453.4198	No	No	n/a	No	n/a	110.58	Surveyed
194	Springsure	–26.2264	147.7119	444.99689	No	No	n/a	No	n/a	110.79	Surveyed
196	Bourke	–28.8502	146.7913	140	Yes	No	n/a	No	n/a	238.30	Surveyed
196.1	Bourke	–28.8501	146.7914	135.093	Yes	No	n/a	No	n/a	238.28	Surveyed
196.2	Bourke	–28.8500	146.7917	140	Yes	No	n/a	No	n/a	238.25	Surveyed
196.3	Bourke	–28.8496	146.7919	135.681	Yes	No	n/a	No	n/a	238.22	Surveyed
196.4	Bourke	–28.8488	146.7921	140	Yes	No	n/a	No	n/a	238.16	Surveyed

Site	Supergroup	Latitude	Longitude	Elevation (m)	EPBC community	EPBC-listed species	EPBC species	NCA-listed species	NCA species	Distance to tenure (km)	Access
196.5	Bourke	–28.8493	146.7909	135.075	Yes	No	n/a	No	n/a	238.29	Surveyed
197	Bourke	–28.9708	146.9237	134.606	Yes	No	n/a	No	n/a	233.33	Surveyed
197.1	Bourke	–28.9716	146.9255	134.245	Yes	No	n/a	No	n/a	233.22	Surveyed
197.2	Bourke	–28.9707	146.9251	134.154	Yes	No	n/a	No	n/a	233.21	Surveyed
197.3	Bourke	–28.9732	146.9262	135.108	Yes	No	n/a	No	n/a	233.25	Surveyed
197.4	Bourke	–28.9743	146.9268	136.019	Yes	No	n/a	No	n/a	233.26	Surveyed
197.5	Bourke	–28.9746	146.9263	136.131	Yes	No	n/a	No	n/a	233.33	Surveyed
197.6	Bourke	–28.9728	146.9292	136.163	Yes	No	n/a	No	n/a	232.98	Surveyed
198	Bourke	–28.9491	146.8874	133.803	Yes	No	n/a	No	n/a	235.16	Surveyed
199	Bourke	–28.9781	146.8917	138.076	No	No	n/a	No	n/a	236.40	Surveyed
200	Bourke	–28.9690	146.9088	144.764	No	No	n/a	No	n/a	234.47	Surveyed
201	Eulo	–28.3333	144.5354	185	Yes	No	n/a	No	n/a	412.51	Surveyed
202	Eulo	–28.3275	144.5329	185	Yes	Yes	*Hydrocotyle dipleura*	Yes	*Hydrocotyle dipleura*, *Myriophyllum arteisum*	412.56	Surveyed
203	Eulo	–28.3108	144.5501	194	Yes	Yes	*Eragrostis fenshami*	Yes	*Myriophyllum artesium*, *Eragrostis fenshami*	410.43	Surveyed
203.1	Eulo	–28.3095	144.5504	196	Yes	No	n/a	No	n/a	410.37	Surveyed
204	Eulo	–28.4682	144.5794	172	Yes	No	n/a	No	n/a	412.95	Surveyed
204.1	Eulo	–28.4737	144.5878	167	Yes	No	n/a	No	n/a	412.38	Surveyed

Site	Supergroup	Latitude	Longitude	Elevation (m)	EPBC community	EPBC-listed species	EPBC species	NCA-listed species	NCA species	Distance to tenure (km)	Access
204.2	Eulo	–28.4790	144.5900	164	Yes	No	n/a	No	n/a	412.36	Surveyed
204.3	Eulo	–28.4851	144.5891	163	Yes	No	n/a	No	n/a	412.67	Surveyed
205.1	Eulo	–28.4026	144.5177	174	Yes	No	n/a	No	n/a	416.39	Surveyed
205.2	Eulo	–28.4023	144.5176	174	Yes	No	n/a	No	n/a	416.38	Surveyed
205.3	Eulo	–28.4022	144.5174	174	Yes	No	n/a	No	n/a	416.40	Surveyed
205.4	Eulo	–28.4032	144.5182	174	Yes	No	n/a	Yes	*Myriophyllum artesium*	416.36	Surveyed
205.5	Eulo	–28.4031	144.5179	174	Yes	No	n/a	No	n/a	416.38	Surveyed
205.6	Eulo	–28.4039	144.5198	176	Yes	No	n/a	No	n/a	416.24	Surveyed
205.7	Eulo	–28.4012	144.5198	174	Yes	No	n/a	No	n/a	416.14	Surveyed
205.8	Eulo	–28.3974	144.5253	177	Yes	No	n/a	No	n/a	415.51	Surveyed
205.9	Eulo	–28.3861	144.5338	178	Yes	No	n/a	No	n/a	414.35	Surveyed
206.1	Eulo	–28.4378	144.5076	170	Yes	No	n/a	No	n/a	418.50	Surveyed
206.2	Eulo	–28.4379	144.5063	170	Yes	No	n/a	No	n/a	418.62	Surveyed
206.3	Eulo	–28.4352	144.5054	170	Yes	No	n/a	No	n/a	418.62	Surveyed
206.4	Eulo	–28.4254	144.5065	171	Yes	No	n/a	No	n/a	418.18	Surveyed
206.5	Eulo	–28.4215	144.5083	172	Yes	No	n/a	No	n/a	417.89	Surveyed
207	Eulo	–28.3905	144.3054	135.778	Yes	No	n/a	No	n/a	435.69	Surveyed
207.1	Eulo	–28.3933	144.2979	134.321	Yes	No	n/a	No	n/a	436.47	Surveyed
207.2	Eulo	–28.3950	144.2960	141	Yes	No	n/a	No	n/a	436.70	Surveyed
208	Eulo	–28.2897	144.3166	143.239	Yes	No	n/a	No	n/a	431.62	Surveyed

Site	Supergroup	Latitude	Longitude	Elevation (m)	EPBC community	EPBC-listed species	EPBC species	NCA-listed species	NCA species	Distance to tenure (km)	Access
208.1	Eulo	–28.2880	144.3179	149	Yes	No	n/a	No	n/a	431.46	Surveyed
208.2	Eulo	–28.2932	144.3133	149	Yes	No	n/a	No	n/a	432.03	Surveyed
208.3	Eulo	–28.2941	144.3129	149	Yes	No	n/a	No	n/a	432.10	Surveyed
209	Eulo	–28.1767	145.0221	155.897	Yes	No	n/a	No	n/a	362.31	Surveyed
210	Eulo	–28.7185	144.4899	136.475	Yes	No	n/a	No	n/a	430.70	Surveyed
211.1	Eulo	–28.6729	144.3962	129	Yes	No	n/a	No	n/a	437.31	Surveyed
211.1	Eulo	–28.6720	144.3975	129	Yes	No	n/a	No	n/a	437.16	Surveyed
211.1	Eulo	–28.6721	144.3970	129	Yes	No	n/a	No	n/a	437.20	Surveyed
211.1	Eulo	–28.6718	144.3969	130	Yes	No	n/a	No	n/a	437.20	Surveyed
211.1	Eulo	–28.6719	144.3963	130	Yes	No	n/a	No	n/a	437.26	Surveyed
211.1	Eulo	–28.6716	144.3960	130	Yes	No	n/a	No	n/a	437.28	Surveyed
211.2	Eulo	–28.6721	144.3957	130	Yes	No	n/a	No	n/a	437.32	Surveyed
211.2	Eulo	–28.6723	144.3960	130	Yes	No	n/a	No	n/a	437.30	Surveyed
211.2	Eulo	–28.6725	144.3959	129	Yes	No	n/a	No	n/a	437.32	Surveyed
211.2	Eulo	–28.6725	144.3954	130	Yes	No	n/a	No	n/a	437.36	Surveyed
211.2	Eulo	–28.6724	144.3950	130	Yes	No	n/a	No	n/a	437.40	Surveyed
211.2	Eulo	–28.6727	144.3963	129	Yes	No	n/a	No	n/a	437.29	Surveyed
211.2	Eulo	–28.6727	144.3951	130	Yes	No	n/a	No	n/a	437.39	Surveyed
211.2	Eulo	–28.6729	144.3954	129	Yes	No	n/a	No	n/a	437.38	Surveyed
211.2	Eulo	–28.6732	144.3951	129	Yes	No	n/a	No	n/a	437.42	Surveyed

Site	Supergroup	Latitude	Longitude	Elevation (m)	EPBC community	EPBC-listed species	EPBC species	NCA-listed species	NCA species	Distance to tenure (km)	Access
211.2	Eulo	–28.6735	144.3951	129	Yes	No	n/a	No	n/a	437.43	Surveyed
211.2	Eulo	–28.6737	144.3949	129	Yes	No	n/a	No	n/a	437.45	Surveyed
211.3	Eulo	–28.6734	144.3945	129	Yes	No	n/a	No	n/a	437.48	Surveyed
211.3	Eulo	–28.6739	144.3945	129	Yes	No	n/a	No	n/a	437.50	Surveyed
211.3	Eulo	–28.6745	144.3940	125.696	Yes	No	n/a	No	n/a	437.57	Surveyed
211.3	Eulo	–28.6748	144.3930	129	Yes	No	n/a	No	n/a	437.67	Surveyed
211.3	Eulo	–28.6750	144.3931	129	Yes	No	n/a	No	n/a	437.67	Surveyed
211.3	Eulo	–28.6727	144.3965	129	Yes	No	n/a	No	n/a	437.27	Surveyed
211.3	Eulo	–28.6759	144.3918	129	Yes	No	n/a	No	n/a	437.82	Surveyed
211.3	Eulo	–28.6759	144.3914	130	Yes	No	n/a	No	n/a	437.86	Surveyed
211.3	Eulo	–28.6766	144.3909	129	Yes	No	n/a	No	n/a	437.93	Surveyed
211.3	Eulo	–28.6768	144.3918	129	Yes	No	n/a	No	n/a	437.86	Surveyed
211.3	Eulo	–28.6762	144.3930	129	Yes	No	n/a	No	n/a	437.73	Surveyed
211.4	Eulo	–28.6759	144.3930	128	Yes	No	n/a	No	n/a	437.71	Surveyed
211.4	Eulo	–28.6758	144.3937	129	Yes	No	n/a	No	n/a	437.64	Surveyed
211.4	Eulo	–28.6757	144.3939	129	Yes	No	n/a	No	n/a	437.62	Surveyed
211.4	Eulo	–28.6754	144.3942	129	Yes	No	n/a	No	n/a	437.59	Surveyed
211.4	Eulo	–28.6752	144.3941	129	Yes	No	n/a	No	n/a	437.59	Surveyed
211.4	Eulo	–28.6725	144.3987	129	Yes	No	n/a	No	n/a	437.07	Surveyed
211.4	Eulo	–28.6747	144.3942	129	Yes	No	n/a	No	n/a	437.56	Surveyed

Site	Supergroup	Latitude	Longitude	Elevation (m)	EPBC community	EPBC-listed species	EPBC species	NCA-listed species	NCA species	Distance to tenure (km)	Access
211.5	Eulo	–28.6722	144.3991	129	Yes	No	n/a	No	n/a	437.01	Surveyed
211.6	Eulo	–28.6716	144.3982	129	Yes	No	n/a	No	n/a	437.07	Surveyed
211.7	Eulo	–28.6714	144.3981	130	Yes	No	n/a	No	n/a	437.08	Surveyed
211.8	Eulo	–28.6720	144.3982	129	Yes	No	n/a	No	n/a	437.09	Surveyed
211.9	Eulo	–28.6723	144.3979	129	Yes	No	n/a	No	n/a	437.12	Surveyed
212	Eulo	–28.4769	144.4870	161	Yes	No	n/a	No	n/a	421.74	Surveyed
213	Eulo	–28.4702	144.5003	166	Yes	No	n/a	No	n/a	420.29	Surveyed
214	Eulo	–28.4725	144.5117	170	Yes	No	n/a	No	n/a	419.32	Surveyed
215	Eulo	–28.4360	144.4051	147	Yes	No	n/a	No	n/a	427.91	Surveyed
216	Eulo	–28.4617	144.3840	134.48	Yes	No	n/a	No	n/a	430.71	Surveyed
217	Eulo	–28.7139	144.5063	134.085	Yes	No	n/a	No	n/a	429.04	Surveyed
218	Eulo	–28.7114	144.5086	131.897	Yes	No	n/a	No	n/a	428.73	Surveyed
219	Eulo	–28.7156	144.5186	133.491	Yes	No	n/a	No	n/a	428.00	Surveyed
220	Eulo	–28.1563	144.7296	177.598	Yes	No	n/a	No	n/a	389.10	Surveyed
220.1	Eulo	–28.1642	144.7234	183	Yes	No	n/a	No	n/a	389.90	Surveyed
220.2	Eulo	–28.1639	144.7231	185	Yes	No	n/a	No	n/a	389.93	Surveyed
221.1	Eulo	–28.1375	144.8635	160	Yes	No	n/a	No	n/a	376.00	Surveyed
221.2	Eulo	–28.1381	144.8629	160	Yes	No	n/a	No	n/a	376.07	Surveyed
221.3	Eulo	–28.1391	144.8624	160	Yes	No	n/a	No	n/a	376.14	Surveyed
221.4	Eulo	–28.1387	144.8630	160	Yes	No	n/a	No	n/a	376.08	Surveyed

Site	Supergroup	Latitude	Longitude	Elevation (m)	EPBC community	EPBC-listed species	EPBC species	NCA-listed species	NCA species	Distance to tenure (km)	Access
221.5	Eulo	–28.1386	144.8637	159	Yes	No	n/a	No	n/a	376.01	Surveyed
221.6	Eulo	–28.1387	144.8632	159.661	Yes	No	n/a	No	n/a	376.06	Surveyed
221.7	Eulo	–28.1363	144.8649	160	Yes	No	n/a	No	n/a	375.83	Surveyed
222	Eulo	–28.0857	145.0261	159.519	Yes	No	n/a	No	n/a	359.27	Surveyed
222.1	Eulo	–28.0856	145.0251	162	Yes	No	n/a	No	n/a	359.35	Surveyed
223	Eulo	–27.9521	144.7699	171.457	Yes	No	n/a	No	n/a	380.24	Surveyed
224	Eulo	–27.9535	144.7696	171.591	Yes	No	n/a	No	n/a	380.30	Surveyed
225	Eulo	–27.9487	144.7731	172.089	Yes	No	n/a	No	n/a	379.87	Surveyed
225.1	Eulo	–27.9486	144.7734	174	Yes	No	n/a	No	n/a	379.84	Surveyed
226	Eulo	–27.9424	144.7774	172.209	Yes	No	n/a	No	n/a	379.32	Surveyed
227	Eulo	–27.9412	144.7784	172.152	Yes	No	n/a	No	n/a	379.20	Surveyed
227.1	Eulo	–27.9408	144.7790	176	Yes	No	n/a	No	n/a	379.13	Surveyed
227.2	Eulo	–27.9407	144.7788	176	Yes	No	n/a	No	n/a	379.15	Surveyed
228	Eulo	–27.9100	144.8724	179.768	Yes	No	n/a	No	n/a	369.57	Surveyed
228.1	Eulo	–27.9100	144.8724	180	Yes	No	n/a	No	n/a	369.57	Surveyed
229	Eulo	–27.9384	144.8575	173.816	Yes	No	n/a	No	n/a	371.60	Surveyed
229.1	Eulo	–27.9323	144.8588	178	Yes	No	n/a	No	n/a	371.34	Surveyed
229.2	Eulo	–27.9384	144.8575	178	Yes	No	n/a	No	n/a	371.60	Surveyed
230.1	Eulo	–27.9275	144.8852	180.288	Yes	No	n/a	No	n/a	368.71	Surveyed
230.2	Eulo	–27.9282	144.8849	178.981	Yes	No	n/a	No	n/a	368.75	Surveyed

Site	Supergroup	Latitude	Longitude	Elevation (m)	EPBC community	EPBC-listed species	EPBC species	NCA-listed species	NCA species	Distance to tenure (km)	Access
230.3	Eulo	–27.9279	144.8849	178.47	Yes	No	n/a	No	n/a	368.75	Surveyed
230.4	Eulo	–27.9286	144.8859	179.269	Yes	No	n/a	No	n/a	368.66	Surveyed
230.5	Eulo	–27.9299	144.8871	177.88	Yes	No	n/a	No	n/a	368.58	Surveyed
230.6	Eulo	–27.9305	144.8877	178.16	Yes	No	n/a	No	n/a	368.54	Surveyed
230.7	Eulo	–27.9258	144.8874	180.447	Yes	No	n/a	No	n/a	368.47	Surveyed
231.1	Eulo	–27.8678	144.9102	184.847	Yes	No	n/a	No	n/a	365.09	Surveyed
231.2	Eulo	–27.8674	144.9099	185.057	Yes	No	n/a	No	n/a	365.11	Surveyed
231.3	Eulo	–27.8636	144.9102	188	Yes	No	n/a	No	n/a	365.00	Surveyed
232.1	Eulo	–27.9162	144.8816	181	Yes	No	n/a	No	n/a	368.81	Surveyed
232.2	Eulo	–27.9151	144.8811	178.206	Yes	No	n/a	No	n/a	368.84	Surveyed
232.3	Eulo	–27.9154	144.8812	178.144	Yes	No	n/a	No	n/a	368.84	Surveyed
232.4	Eulo	–27.9157	144.8810	178.255	Yes	No	n/a	No	n/a	368.86	Surveyed
233.1	Eulo	–27.9058	144.8888	178.87	Yes	No	n/a	No	n/a	367.91	Surveyed
233.2	Eulo	–27.9023	144.8907	178.774	Yes	No	n/a	No	n/a	367.65	Surveyed
233.3	Eulo	–27.9014	144.8902	179.082	Yes	No	n/a	No	n/a	367.68	Surveyed
233.4	Eulo	–27.9013	144.8905	182	Yes	No	n/a	No	n/a	367.65	Surveyed
233.5	Eulo	–27.9004	144.8897	179.011	Yes	No	n/a	No	n/a	367.71	Surveyed
234	Eulo	–28.1585	145.0363	157.34	Yes	Yes	*Eragrostis fenshamii*	Yes	*Eragrostis fenshamii*, *Myriophyllum artesium*	360.42	Surveyed
235.1	Eulo	–28.1390	144.8570	160	Yes	No	n/a	No	n/a	376.65	Surveyed

Site	Supergroup	Latitude	Longitude	Elevation (m)	EPBC community	EPBC-listed species	EPBC species	NCA-listed species	NCA species	Distance to tenure (km)	Access
235.2	Eulo	–28.1390	144.8570	157.877	Yes	No	n/a	No	n/a	376.65	Surveyed
235.3	Eulo	–28.1397	144.8558	160	Yes	No	n/a	No	n/a	376.79	Surveyed
236	Eulo	–28.1817	144.8056	161.051	Yes	No	n/a	No	n/a	382.70	Surveyed
237	Eulo	–28.1923	144.8434	153.892	Yes	No	n/a	No	n/a	379.47	Surveyed
237.1	Eulo	–28.1942	144.8423	155.968	Yes	No	n/a	No	n/a	379.63	Surveyed
237.2	Eulo	–28.1949	144.8359	155.984	Yes	No	n/a	No	n/a	380.25	Surveyed
237.3	Eulo	–28.1962	144.8333	155.822	Yes	No	n/a	No	n/a	380.53	Surveyed
237.4	Eulo	–28.1958	144.8335	155.271	Yes	No	n/a	No	n/a	380.50	Surveyed
238	Eulo	–28.1864	144.8481	157	Yes	Yes	*Eragrostis fenshamii*	Yes	*Eragrostis fenshamii*, *Myriophyllum artesium*	378.86	Surveyed
238.1	Eulo	–28.1853	144.8484	155.006	Yes	No	n/a	No	n/a	378.79	Surveyed
239	Eulo	–28.1820	144.9727	153.799	Yes	No	n/a	No	n/a	367.08	Surveyed
239.1	Eulo	–28.1819	144.9736	157	Yes	No	n/a	No	n/a	366.99	Surveyed
239.2	Eulo	–28.1799	144.9681	155.972	Yes	No	n/a	No	n/a	367.44	Surveyed
284	Springsure	–25.8296	149.0414	356.98	No	No	n/a	No	n/a	0.00	Surveyed
285	Springsure	–25.7627	148.7698	356.81	No	No	n/a	No	n/a	0.00	Surveyed
286	Springsure	–25.7982	148.7691	348.2	Yes	Yes	*Eriocaulon carsonii*	Yes	*Eriocaulon carsonii*	0.00	Surveyed
286.1	Springsure	–25.7982	148.7703	350	No	No	n/a	No	n/a	0.00	Surveyed
286.2	Springsure	–25.7980	148.7702	350	No	No	n/a	No	n/a	0.00	Surveyed

Site	Supergroup	Latitude	Longitude	Elevation (m)	EPBC community	EPBC-listed species	EPBC species	NCA-listed species	NCA species	Distance to tenure (km)	Access
286.3	Springsure	–25.7976	148.7687	351	No	No	n/a	No	n/a	0.00	Surveyed
287	Springsure	–25.7981	148.7756	349.48	Yes	Yes	*Eriocaulon carsonii*	Yes	*Eriocaulon carsonii*	0.00	Surveyed
299	Springsure	–24.7475	146.5372	490.38879	No	No	n/a	No	n/a	173.08	Surveyed
300	Springsure	–24.7736	146.9881	507.26233	No	No	n/a	No	n/a	127.96	Surveyed
301	Springsure	–24.8569	147.3997	611.38898	No	No	n/a	No	n/a	86.75	Surveyed
302	Springsure	–25.0710	147.6760	808	No	No	n/a	No	n/a	59.88	Surveyed
303	Springsure	–24.8781	147.7903	812.33026	No	No	n/a	No	n/a	47.75	Surveyed
304	Non–GAB	–24.8534	147.8631	861	No	No	n/a	No	n/a	40.44	Surveyed
305	Springsure	–24.8817	147.8239	791.61115	No	Yes	*Arthraxon hispidus*	Yes	*Arthraxon hispidus*	44.38	Surveyed
306	Springsure	–24.8844	147.8208	786.18518	No	No	n/a	No	n/a	44.67	Surveyed
307	Springsure	–24.8825	147.8186	789.55554	No	Yes	*Arthraxon hispidus*	Yes	*Arthraxon hispidus*	44.90	Surveyed
308	Springsure	–24.9281	147.8264	784.70679	No	No	n/a	No	n/a	44.08	Surveyed
309	Springsure	–24.9434	147.9611	786.5	No	No	n/a	No	n/a	30.62	Surveyed
310	Springsure	–24.9464	147.9581	784.411	No	No	n/a	No	n/a	30.92	Surveyed
311	Non–GAB	–24.8684	147.9391	1016	No	No	n/a	No	n/a	32.92	Surveyed
312	Non–GAB	–24.8244	147.9111	1032	No	No	n/a	No	n/a	35.65	Surveyed
313	Non–GAB	–24.8154	147.8891	983	No	No	n/a	No	n/a	37.85	Surveyed
314	Non–GAB	–24.8894	148.0261	904	No	No	n/a	No	n/a	24.16	Surveyed
315	Springsure	–24.9424	147.9601	785.611	No	No	n/a	No	n/a	30.72	Surveyed

Site	Supergroup	Latitude	Longitude	Elevation (m)	EPBC community	EPBC-listed species	EPBC species	NCA-listed species	NCA species	Distance to tenure (km)	Access
316	Springsure	–25.1064	148.0781	720.111	No	No	n/a	No	n/a	23.52	Surveyed
316.1	Springsure	–25.0604	148.0551	742.608	No	No	n/a	No	n/a	22.98	Surveyed
316.2	Springsure	–25.0604	148.0341	754.756	No	No	n/a	No	n/a	24.92	Surveyed
317	Springsure	–25.5054	147.9771	481.232	No	No	n/a	No	n/a	65.44	Surveyed
317.1	Springsure	–25.5064	147.9781	490.736	No	No	n/a	No	n/a	65.49	Surveyed
317.2	Springsure	–25.5084	147.9731	485.55	No	No	n/a	No	n/a	65.92	Surveyed
318	Springsure	–25.5084	147.9771	482.361	No	No	n/a	No	n/a	65.74	Surveyed
319	Springsure	–25.7255	150.2689	228.83	Yes	No	n/a	Yes	*Myriophyllum artesium*	20.36	Surveyed
320	Springsure	–25.7318	150.2519	227.64	Yes	No	n/a	Yes	*Myriophyllum artesium*	18.65	Surveyed
320.1	Springsure	–25.7319	150.2520	232	Yes	No	n/a	No	n/a	18.64	Surveyed
321	Springsure	–25.7294	150.2500	225.62	Yes	Yes	*Eriocaulon carsonii*	Yes	*Myriophyllum artesium*, *Eriocaulon carsonii*	18.70	Surveyed
321.1	Springsure	–25.7297	150.2499	224.85	Yes	No	n/a	No	n/a	18.67	Surveyed
321.2	Springsure	–25.7297	150.2500	224.5	Yes	No	n/a	No	n/a	18.67	Surveyed
321.3	Springsure	–25.7298	150.2501	224.99	Yes	No	n/a	No	n/a	18.68	Surveyed
321.4	Springsure	–25.7296	150.2499	225.39	Yes	No	n/a	No	n/a	18.67	Surveyed
321.5	Springsure	–25.7294	150.2498	225.4	Yes	No	n/a	No	n/a	18.68	Surveyed
321.6	Springsure	–25.7293	150.2501	225.47	Yes	No	n/a	No	n/a	18.70	Surveyed

Site	Supergroup	Latitude	Longitude	Elevation (m)	EPBC community	EPBC-listed species	EPBC species	NCA-listed species	NCA species	Distance to tenure (km)	Access
321.7	Springsure	–25.7289	150.2501	225.17	Yes	No	n/a	No	n/a	18.74	Surveyed
321.8	Springsure	–25.7287	150.2502	225.99	Yes	No	n/a	No	n/a	18.76	Surveyed
322	Springsure	–24.8922	147.5239	636.61108	No	No	n/a	No	n/a	74.31	Surveyed
340	Springsure	–25.7940	148.7732	350.06	Yes	Yes	*Eriocaulon carsonii*	Yes	*Eriocaulon carsonii*	0.00	Surveyed
380	Eulo	–28.1328	144.5029	171.571	Yes	No	n/a	No	n/a	409.86	Surveyed
380.1	Eulo	–28.1326	144.5029	174	Yes	No	n/a	No	n/a	409.85	Surveyed
380.2	Eulo	–28.1317	144.5028	174	Yes	No	n/a	No	n/a	409.84	Surveyed
381	Eulo	–28.2356	144.6275	201	Yes	No	n/a	Yes	*Myriophyllum artesium*	400.95	Surveyed
381.1	Eulo	–28.2357	144.6274	201	Yes	No	n/a	No	n/a	400.96	Surveyed
381.2	Eulo	–28.2357	144.6274	201	Yes	No	n/a	No	n/a	400.96	Surveyed
381.3	Eulo	–28.2214	144.6338	199	Yes	No	n/a	No	n/a	399.94	Surveyed
382.1	Eulo	–28.2537	144.7417	167.532	Yes	No	n/a	Yes	*Myriophyllum artesium*	390.82	Surveyed
382.2	Eulo	–28.2536	144.7421	167.581	Yes	No	n/a	Yes	*Myriophyllum artesium*	390.78	Surveyed
382.3	Eulo	–28.2530	144.7420	167.7	Yes	No	n/a	Yes	*Myriophyllum artesium*	390.77	Surveyed
382.4	Eulo	–28.2527	144.7421	167.569	Yes	No	n/a	Yes	*Myriophyllum artesium*	390.75	Surveyed
382.5	Eulo	–28.2524	144.7424	167.318	Yes	No	n/a	No	n/a	390.72	Surveyed
382.6	Eulo	–28.2521	144.7424	167.477	Yes	No	n/a	No	n/a	390.70	Surveyed

Site	Supergroup	Latitude	Longitude	Elevation (m)	EPBC community	EPBC-listed species	EPBC species	NCA-listed species	NCA species	Distance to tenure (km)	Access
383	Eulo	–28.1309	144.7278	178	Yes	No	n/a	No	n/a	388.58	Surveyed
383.1	Eulo	–28.1331	144.7273	178	Yes	No	n/a	No	n/a	388.69	Surveyed
383.2	Eulo	–28.1359	144.7269	180	Yes	No	n/a	No	n/a	388.80	Surveyed
385	Eulo	–28.2740	144.9861	151.075	Yes	No	n/a	No	n/a	368.77	Surveyed
385.1	Eulo	–28.2716	144.9826	151.463	Yes	No	n/a	No	n/a	369.02	Surveyed
385.2	Eulo	–28.2720	144.9840	156	Yes	No	n/a	No	n/a	368.90	Surveyed
386.1	Eulo	–28.3199	144.2126	143.203	Yes	No	n/a	No	n/a	442.24	Surveyed
386.2	Eulo	–28.3207	144.2112	148	Yes	No	n/a	No	n/a	442.39	Surveyed
386.3	Eulo	–28.3131	144.2161	143.095	Yes	No	n/a	No	n/a	441.71	Surveyed
386.4	Eulo	–28.3240	144.2049	143.721	Yes	No	n/a	No	n/a	443.07	Surveyed
387	Eulo	–28.4990	144.1883	146.191	Yes	No	n/a	No	n/a	450.03	Surveyed
408	Springsure	–25.1795	148.5704	335.28	No	No	n/a	No	n/a	26.31	Surveyed
497	Springsure	–25.1410	151.1370	193	No	No	n/a	No	n/a	128.63	Surveyed
498	Springsure	–24.9790	151.0410	295	No	No	n/a	No	n/a	133.69	Surveyed
499	Springsure	–25.7002	149.1289	248.27	No	No	n/a	No	n/a	0.00	Surveyed
500	Springsure	–25.7198	149.1048	257.84	No	No	n/a	No	n/a	0.00	Surveyed
500.1	Springsure	–25.7282	149.1005	251.01	No	No	n/a	No	n/a	0.00	Surveyed
534	Springsure	–25.7326	149.1028	264.24	Yes	No	n/a	No	n/a	0.00	Surveyed
535	Springsure	–25.7202	149.0275	289	No	No	n/a	No	n/a	0.00	Surveyed
536	Springsure	–25.7145	149.0654	275.28	No	No	n/a	No	n/a	0.00	Surveyed

Site	Supergroup	Latitude	Longitude	Elevation (m)	EPBC community	EPBC-listed species	EPBC species	NCA-listed species	NCA species	Distance to tenure (km)	Access
536.1	Springsure	–25.7136	149.0654	270.78	No	No	n/a	No	n/a	0.00	Surveyed
536.2	Springsure	–25.7155	149.0648	278.61	No	No	n/a	No	n/a	0.00	Surveyed
537	Springsure	–25.7283	149.0939	254.29	No	No	n/a	No	n/a	0.00	Surveyed
538	Springsure	–25.3544	149.3631	262	No	No	n/a	Yes	*Lobelia membranacea* listed under former name *Pratia podenzanae*	27.72	Surveyed
539	Springsure	–25.0994	149.2731	410	No	No	n/a	Yes	*Lobelia membranacea* listed under former name *Pratia podenzanae*	31.84	Surveyed
539.1	Springsure	–25.1134	149.2331	480	No	No	n/a	No	n/a	27.63	Surveyed
540	Springsure	–24.5341	149.1696	212.82	Yes	No	n/a	No	n/a	66.32	Surveyed
541	Springsure	–24.3159	149.1678	220	No	No	n/a	No	n/a	77.51	Surveyed
542	Springsure	–24.2984	149.1791	222	No	No	n/a	No	n/a	76.08	Surveyed
543	Springsure	–24.3144	149.1551	233	No	No	n/a	No	n/a	76.92	Surveyed
544	Springsure	–24.3084	149.1741	261	No	No	n/a	No	n/a	76.94	Surveyed
544.1	Springsure	–24.3094	149.1701	219	No	No	n/a	No	n/a	76.91	Surveyed
544.2	Springsure	–24.3094	149.1741	213	No	No	n/a	No	n/a	77.05	Surveyed
544.3	Springsure	–24.3084	149.1751	210	No	No	n/a	No	n/a	76.98	Surveyed

Site	Supergroup	Latitude	Longitude	Elevation (m)	EPBC community	EPBC-listed species	EPBC species	NCA-listed species	NCA species	Distance to tenure (km)	Access
545	Springsure	–24.1724	149.1561	248	No	No	n/a	No	n/a	62.17	Surveyed
546	Springsure	–24.2574	149.1347	248	No	No	n/a	Yes	*Lobelia membranacea* listed under former name *Pratia podenzanae*	70.22	Surveyed
547	Springsure	–23.8174	149.2231	213	No	No	n/a	No	n/a	36.34	Surveyed
548	Springsure	–23.7754	149.1751	213	No	No	n/a	No	n/a	29.92	Surveyed
549	Springsure	–23.8614	149.1001	737	No	No	n/a	No	n/a	29.50	Surveyed
550	Springsure	–23.7594	149.1041	750	No	No	n/a	No	n/a	22.70	Surveyed
551	Springsure	–24.0344	149.0221	308	No	No	n/a	No	n/a	42.99	Surveyed
552	Springsure	–24.0354	149.0351	547	No	No	n/a	No	n/a	43.47	Surveyed
553	Springsure	–25.0794	148.2296	573	No	No	n/a	Yes	*Lobelia membranacea* listed under former name *Pratia podenzanae*	11.58	Surveyed
554	Springsure	–25.0435	148.2009	575	No	No	n/a	Yes	*Lobelia membranacea* listed under former name *Pratia podenzanae*	9.61	Surveyed
554.3	Springsure	–25.0354	148.2042	653	No	No	n/a	No	n/a	8.74	Surveyed

Site	Supergroup	Latitude	Longitude	Elevation (m)	EPBC community	EPBC-listed species	EPBC species	NCA-listed species	NCA species	Distance to tenure (km)	Access
555	Springsure	–25.0574	148.2101	536	No	No	n/a	No	n/a	10.25	Surveyed
556	Springsure	–25.0573	148.2136	521	No	No	n/a	No	n/a	10.05	Surveyed
675	Springsure	–25.1792	148.5640	323.97	No	No	n/a	No	n/a	26.94	Surveyed
676	Springsure	–25.1795	148.5635	325.89	No	No	n/a	No	n/a	27.00	Surveyed
677	Springsure	–25.0378	148.2000	619.03	No	No	n/a	Yes	*Livistona nitida*	9.23	Surveyed
678	Springsure	–25.0372	148.2013	624.83	No	No	n/a	Yes	*Livistona nitida*	9.09	Surveyed
679	Springsure	–26.2785	148.6959	353.6	No	No	n/a	No	n/a	14.96	Surveyed
680	Springsure	–26.2731	148.6868	366.46	No	No	n/a	No	n/a	16.02	Surveyed
680.1	Springsure	–26.2736	148.6873	364.69	No	No	n/a	No	n/a	15.95	Surveyed
681	Springsure	–25.4361	150.0230	185.63	Yes	Yes	*Arthraxon hispidus*	Yes	*Arthraxon hispidus*	44.36	Surveyed
682	Springsure	–25.8081	148.7342	355.6	No	No	n/a	No	n/a	1.68	Surveyed
683	Springsure	–25.4531	150.0206	175.74	Yes	No	n/a	No	n/a	42.45	Surveyed
684	Springsure	–25.7258	150.2694	229.73	Yes	No	n/a	No	n/a	20.37	Surveyed
685	Springsure	–25.7231	150.2665	219.16	No	No	n/a	No	n/a	20.36	Surveyed
686	Springsure	–25.7948	148.7734	346.86	Yes	No	n/a	No	n/a	0.00	Surveyed
687	Springsure	–25.7948	148.7738	351.97	Yes	Yes	*Eriocaulon carsonii*	Yes	*Eriocaulon carsonii*	0.00	Surveyed
687.1	Springsure	–25.7946	148.7738	348.58	Yes	No	n/a	No	n/a	0.00	Surveyed
687.2	Springsure	–25.7946	148.7738	348.4	Yes	No	n/a	No	n/a	0.00	Surveyed

Site	Supergroup	Latitude	Longitude	Elevation (m)	EPBC community	EPBC-listed species	EPBC species	NCA-listed species	NCA species	Distance to tenure (km)	Access
687.3	Springsure	–25.7942	148.7736	348.96	Yes	No	n/a	No	n/a	0.00	Surveyed
687.4	Springsure	–25.7941	148.7735	349.22	Yes	Yes	*Eriocaulon carsonii*	Yes	*Eriocaulon carsonii*	0.00	Surveyed
687.5	Springsure	–25.7937	148.7733	350.65	Yes	No	n/a	No	n/a	0.00	Surveyed
687.6	Springsure	–25.7936	148.7733	350.31	Yes	Yes	*Eriocaulon carsonii*	Yes	*Eriocaulon carsonii*	0.00	Surveyed
688	Springsure	–25.7951	148.7737	348.91	Yes	No	n/a	No	n/a	0.00	Surveyed
689	Springsure	–25.7940	148.7728	348.47	Yes	Yes	*Eriocaulon carsonii*	Yes	*Eriocaulon carsonii*	0.00	Surveyed
690	Springsure	–25.4370	150.0880	181.837	No	No	n/a	Yes	*Livistona nitida*	44.25	Surveyed
691	Springsure	–25.4873	150.0471	170.93	Yes	No	n/a	No	n/a	38.62	Surveyed
692	Springsure	–25.7260	149.1037	219.48	No	No	n/a	No	n/a	0.00	Surveyed
693	Springsure	–25.7207	149.0296	279.75	No	No	n/a	No	n/a	0.00	Surveyed
694	Springsure	–25.7124	149.0726	271.13	No	No	n/a	No	n/a	0.00	Surveyed
695	Springsure	–25.7254	149.0869	267.57	No	No	n/a	No	n/a	0.00	Surveyed
696	Springsure	–25.7255	149.0869	266.06	No	No	n/a	No	n/a	0.00	Surveyed
697	Springsure	–25.7256	149.0867	267.97	No	No	n/a	No	n/a	0.00	Surveyed
698	Springsure	–25.7256	149.0867	268.21	No	No	n/a	No	n/a	0.00	Surveyed
699	Springsure	–25.7258	149.0866	267.68	No	No	n/a	No	n/a	0.00	Surveyed
700	Springsure	–25.2107	148.1189	611.01	No	No	n/a	No	n/a	29.64	Surveyed
701	Springsure	–25.2043	148.2292	564.79	No	No	n/a	No	n/a	25.23	Surveyed

Site	Supergroup	Latitude	Longitude	Elevation (m)	EPBC community	EPBC-listed species	EPBC species	NCA-listed species	NCA species	Distance to tenure (km)	Access
702	Springsure	–26.2703	149.2433	338.42	No	No	n/a	No	n/a	0.00	Surveyed
703	Springsure	–26.2853	149.2345	359.72	No	No	n/a	No	n/a	0.00	Surveyed
704	Springsure	–25.6797	149.1273	255.39	No	No	n/a	No	n/a	0.00	Surveyed
705	Springsure	–25.2303	148.6591	380.48	No	No	n/a	No	n/a	17.46	Surveyed
706	Springsure	–25.4791	148.7315	398.7	No	No	n/a	No	n/a	2.91	Surveyed
707	Springsure	–25.4787	148.7321	399.55	No	No	n/a	No	n/a	2.91	Surveyed
708	Springsure	–25.4785	148.7326	401.24	No	No	n/a	No	n/a	2.89	Surveyed
709	Springsure	–25.4785	148.7335	402.48	No	No	n/a	No	n/a	2.83	Surveyed
710	Springsure	–24.6597	149.1141	295.22	No	No	n/a	No	n/a	51.20	Surveyed
711	Springsure	–26.8742	150.4371	289.2	No	No	n/a	No	n/a	0.00	Surveyed
711.1	Springsure	–26.8740	150.4372	289.65	No	No	n/a	No	n/a	0.00	Surveyed
712	Springsure	–25.1312	148.1904	455.62	No	Yes	*Phaius australis*	Yes	*Phaius australis*	18.43	Surveyed
713	Springsure	–25.0907	148.2290	455.62	No	No	n/a	Yes	*Livistona nitida*	12.80	Surveyed
714	Springsure	–25.0888	148.2238	820.29	No	No	n/a	No	n/a	12.77	Surveyed
715	Springsure	–25.0338	148.2046	677	No	No	n/a	No	n/a	8.59	Surveyed
716	Springsure	–25.8077	148.7340	358.21	No	No	n/a	No	n/a	1.70	Surveyed
850	Springsure	–25.0960	149.5413	316.24	No	No	n/a	No	n/a	52.62	Surveyed
851	Springsure	–24.9467	149.6135	289.32	No	No	n/a	No	n/a	68.14	Surveyed
852	Springsure	–23.9330	149.1860	344.26	No	Yes	*Phaius australis*	Yes	*Phaius australis*	41.26	Surveyed

Site	Supergroup	Latitude	Longitude	Elevation (m)	EPBC community	EPBC-listed species	EPBC species	NCA-listed species	NCA species	Distance to tenure (km)	Access
900	Eulo	–28.2856	144.7332	162	Yes	No	n/a	No	n/a	392.61	Surveyed
901	Eulo	–28.2031	144.6347	202	Yes	No	n/a	No	n/a	399.33	Surveyed
901.1	Eulo	–28.2058	144.6334	208	Yes	No	n/a	No	n/a	399.53	Surveyed
902	Eulo	–28.2523	144.3553	146	Yes	No	n/a	No	n/a	426.94	Surveyed
902.1	Eulo	–28.2549	144.3588	158	Yes	No	n/a	No	n/a	426.68	Surveyed
903	Eulo	–28.3735	144.5564	187	Yes	No	n/a	No	n/a	411.84	Surveyed
903.1	Eulo	–28.3817	144.5237	181	Yes	No	n/a	No	n/a	415.14	Surveyed
904	Eulo	–28.3425	144.5586	199	Yes	No	n/a	No	n/a	410.64	Surveyed
905	Eulo	–28.2684	144.5686	216	Yes	No	n/a	No	n/a	407.42	Surveyed
905.1	Eulo	–28.2663	144.5660	212	Yes	No	n/a	No	n/a	407.60	Surveyed
906	Eulo	–28.3186	144.5547	196	Yes	No	n/a	No	n/a	410.25	Surveyed
907	Eulo	–28.4834	144.4964	163	Yes	No	n/a	No	n/a	421.11	Surveyed
908.1	Eulo	–28.2464	144.3536	155	Yes	No	n/a	No	n/a	426.94	Surveyed
908.1	Eulo	–28.2470	144.3545	154	Yes	No	n/a	No	n/a	426.87	Surveyed
908.1	Eulo	–28.2465	144.3547	154	Yes	No	n/a	No	n/a	426.84	Surveyed
908.1	Eulo	–28.2459	144.3548	155	Yes	No	n/a	No	n/a	426.82	Surveyed
908.1	Eulo	–28.2458	144.3549	155	Yes	No	n/a	No	n/a	426.80	Surveyed
908.1	Eulo	–28.2459	144.3533	156	Yes	No	n/a	No	n/a	426.96	Surveyed
908.2	Eulo	–28.2462	144.3530	156	Yes	No	n/a	No	n/a	426.99	Surveyed
908.3	Eulo	–28.2464	144.3529	156	Yes	No	n/a	No	n/a	427.01	Surveyed

Site	Supergroup	Latitude	Longitude	Elevation (m)	EPBC community	EPBC-listed species	EPBC species	NCA-listed species	NCA species	Distance to tenure (km)	Access
908.4	Eulo	–28.2476	144.3530	155	Yes	No	n/a	No	n/a	427.03	Surveyed
908.5	Eulo	–28.2477	144.3532	155	Yes	No	n/a	No	n/a	427.02	Surveyed
908.6	Eulo	–28.2485	144.3536	154	Yes	No	n/a	No	n/a	427.00	Surveyed
908.7	Eulo	–28.2482	144.3540	154	Yes	No	n/a	No	n/a	426.95	Surveyed
908.8	Eulo	–28.2480	144.3541	154	Yes	No	n/a	No	n/a	426.93	Surveyed
908.9	Eulo	–28.2477	144.3539	154	Yes	No	n/a	No	n/a	426.95	Surveyed
909.1	Eulo	–28.2386	144.3348	149	Yes	No	n/a	No	n/a	428.49	Surveyed
909.2	Eulo	–28.2369	144.3342	149	Yes	No	n/a	No	n/a	428.51	Surveyed
909.3	Eulo	–28.2353	144.3344	150	Yes	No	n/a	No	n/a	428.44	Surveyed
909.4	Eulo	–28.2310	144.3342	149	Yes	No	n/a	No	n/a	428.35	Surveyed
909.5	Eulo	–28.2290	144.3328	150	Yes	No	n/a	No	n/a	428.43	Surveyed
910.1	Eulo	–28.1442	145.1260	162.348	Yes	No	n/a	No	n/a	351.61	Surveyed
910.2	Eulo	–28.1443	145.1262	161.588	Yes	No	n/a	No	n/a	351.60	Surveyed
910.3	Eulo	–28.1442	145.1263	165	Yes	No	n/a	No	n/a	351.58	Surveyed
910.4	Eulo	–28.1424	145.1242	164	Yes	No	n/a	No	n/a	351.72	Surveyed
910.5	Eulo	–28.1416	145.1223	161.497	Yes	No	n/a	No	n/a	351.88	Surveyed
911	Eulo	–28.1876	145.0274	156.071	Yes	No	n/a	No	n/a	362.15	Surveyed
911.1	Eulo	–28.1877	145.0282	160	Yes	No	n/a	No	n/a	362.07	Surveyed
911.2	Eulo	–28.1881	145.0284	160	Yes	No	n/a	No	n/a	362.07	Surveyed
911.3	Eulo	–28.1893	145.0283	160	Yes	No	n/a	No	n/a	362.12	Surveyed

Site	Supergroup	Latitude	Longitude	Elevation (m)	EPBC community	EPBC-listed species	EPBC species	NCA-listed species	NCA species	Distance to tenure (km)	Access
912	Eulo	–28.1815	145.0237	160	Yes	No	n/a	No	n/a	362.31	Surveyed
912.1	Eulo	–28.1852	145.0240	161	Yes	No	n/a	No	n/a	362.39	Surveyed
912.2	Eulo	–28.1804	145.0240	160	Yes	No	n/a	No	n/a	362.24	Surveyed
913	Eulo	–28.4543	144.9946	150.292	Yes	No	n/a	No	n/a	374.54	Surveyed
914	Eulo	–28.4970	145.0070	151	Yes	No	n/a	No	n/a	375.11	Surveyed
914.1	Eulo	–28.4857	145.0088	148.725	Yes	No	n/a	No	n/a	374.49	Surveyed
914.2	Eulo	–28.4856	145.0091	148.324	Yes	No	n/a	No	n/a	374.46	Surveyed
914.3	Eulo	–28.4832	145.0164	148.678	Yes	No	n/a	No	n/a	373.70	Surveyed
914.4	Eulo	–28.4828	145.0165	148.727	Yes	No	n/a	No	n/a	373.68	Surveyed
915	Eulo	–28.4391	145.0205	152.842	Yes	No	n/a	No	n/a	371.60	Surveyed
916.1	Eulo	–28.1967	145.1730	167	Yes	No	n/a	No	n/a	348.90	Surveyed
916.1	Eulo	–28.1973	145.1732	167	Yes	No	n/a	No	n/a	348.90	Surveyed
916.1	Eulo	–28.1971	145.1732	167	Yes	No	n/a	No	n/a	348.89	Surveyed
916.2	Eulo	–28.1963	145.1730	167	Yes	No	n/a	No	n/a	348.89	Surveyed
916.3	Eulo	–28.1962	145.1739	166	Yes	No	n/a	No	n/a	348.80	Surveyed
916.4	Eulo	–28.1955	145.1743	167	Yes	No	n/a	No	n/a	348.74	Surveyed
916.5	Eulo	–28.1967	145.1735	167	Yes	No	n/a	No	n/a	348.85	Surveyed
916.6	Eulo	–28.1969	145.1738	167	Yes	No	n/a	No	n/a	348.83	Surveyed
916.7	Eulo	–28.1972	145.1741	167	Yes	No	n/a	No	n/a	348.81	Surveyed
916.8	Eulo	–28.1977	145.1744	167	Yes	No	n/a	No	n/a	348.80	Surveyed

Site	Supergroup	Latitude	Longitude	Elevation (m)	EPBC community	EPBC-listed species	EPBC species	NCA-listed species	NCA species	Distance to tenure (km)	Access
916.9	Eulo	–28.1974	145.1738	167	Yes	No	n/a	No	n/a	348.85	Surveyed
917.1	Eulo	–28.1319	145.1204	163	Yes	No	n/a	No	n/a	351.76	Surveyed
917.1	Eulo	–28.1300	145.1200	163	Yes	No	n/a	No	n/a	351.74	Surveyed
917.1	Eulo	–28.1294	145.1205	163	Yes	No	n/a	No	n/a	351.68	Surveyed
917.1	Eulo	–28.1294	145.1214	164	Yes	No	n/a	No	n/a	351.59	Surveyed
917.1	Eulo	–28.1290	145.1214	164	Yes	No	n/a	No	n/a	351.58	Surveyed
917.2	Eulo	–28.1315	145.1205	163	Yes	No	n/a	No	n/a	351.74	Surveyed
917.3	Eulo	–28.1321	145.1178	164	Yes	No	n/a	No	n/a	352.01	Surveyed
917.4	Eulo	–28.1285	145.1152	165	Yes	No	n/a	No	n/a	352.14	Surveyed
917.5	Eulo	–28.1284	145.1160	165	Yes	No	n/a	No	n/a	352.07	Surveyed
917.6	Eulo	–28.1281	145.1160	165	Yes	No	n/a	No	n/a	352.06	Surveyed
917.7	Eulo	–28.1281	145.1167	165	Yes	No	n/a	No	n/a	351.99	Surveyed
917.8	Eulo	–28.1273	145.1172	165	Yes	No	n/a	No	n/a	351.92	Surveyed
917.9	Eulo	–28.1306	145.1197	163	Yes	No	n/a	No	n/a	351.79	Surveyed
918.1	Eulo	–28.1174	145.1267	163	Yes	No	n/a	No	n/a	350.73	Surveyed
918.1	Eulo	–28.1189	145.1286	163	Yes	No	n/a	No	n/a	350.60	Surveyed
918.1	Eulo	–28.1182	145.1285	163	Yes	No	n/a	No	n/a	350.59	Surveyed
918.1	Eulo	–28.1182	145.1278	163	Yes	No	n/a	No	n/a	350.66	Surveyed
918.1	Eulo	–28.1174	145.1287	162	Yes	No	n/a	No	n/a	350.55	Surveyed
918.2	Eulo	–28.1174	145.1262	163	Yes	No	n/a	No	n/a	350.79	Surveyed

Site	Supergroup	Latitude	Longitude	Elevation (m)	EPBC community	EPBC-listed species	EPBC species	NCA-listed species	NCA species	Distance to tenure (km)	Access
918.3	Eulo	–28.1184	145.1268	163	Yes	No	n/a	No	n/a	350.76	Surveyed
918.4	Eulo	–28.1191	145.1270	163	Yes	No	n/a	No	n/a	350.76	Surveyed
918.5	Eulo	–28.1191	145.1264	163	Yes	No	n/a	No	n/a	350.82	Surveyed
918.6	Eulo	–28.1193	145.1268	163	Yes	No	n/a	No	n/a	350.78	Surveyed
918.7	Eulo	–28.1193	145.1276	163	Yes	No	n/a	No	n/a	350.71	Surveyed
918.8	Eulo	–28.1190	145.1277	163	Yes	No	n/a	No	n/a	350.69	Surveyed
918.9	Eulo	–28.1191	145.1279	163	Yes	No	n/a	No	n/a	350.68	Surveyed
919	Eulo	–28.5733	145.0051	153	Yes	No	n/a	No	n/a	378.45	Surveyed
919.1	Eulo	–28.5734	145.0048	152	Yes	No	n/a	No	n/a	378.48	Surveyed
920	Eulo	–28.6883	145.2356	146	Yes	No	n/a	No	n/a	363.35	Surveyed
921	Eulo	–28.9662	144.5862	142	Yes	No	n/a	No	n/a	433.29	Surveyed
922.1	Eulo	–28.9154	144.7658	138	Yes	No	n/a	No	n/a	415.23	Surveyed
922.2	Eulo	–28.9150	144.7660	138	Yes	No	n/a	No	n/a	415.19	Surveyed
922.3	Eulo	–28.9152	144.7657	138	Yes	No	n/a	No	n/a	415.23	Surveyed
922.4	Eulo	–28.9155	144.7656	138	Yes	No	n/a	No	n/a	415.25	Surveyed
923	Eulo	–28.9222	144.7596	136	Yes	No	n/a	No	n/a	416.10	Surveyed
924	Eulo	–28.5497	144.6572	147	Yes	No	n/a	No	n/a	408.86	Surveyed
925	Eulo	–28.7117	144.1545	137	Yes	No	n/a	No	n/a	460.71	Surveyed
925.1	Eulo	–28.7140	144.1573	136	Yes	No	n/a	No	n/a	460.54	Surveyed
926	Eulo	–28.7889	144.2635	124.98	Yes	No	n/a	No	n/a	453.93	Surveyed

Site	Supergroup	Latitude	Longitude	Elevation (m)	EPBC community	EPBC-listed species	EPBC species	NCA-listed species	NCA species	Distance to tenure (km)	Access
926.1	Eulo	–28.7887	144.2659	127	Yes	No	n/a	No	n/a	453.70	Surveyed
926.2	Eulo	–28.7890	144.2656	127	Yes	No	n/a	No	n/a	453.74	Surveyed
926.3	Eulo	–28.7890	144.2658	127	Yes	No	n/a	No	n/a	453.72	Surveyed
926.4	Eulo	–28.7877	144.2661	127	Yes	No	n/a	No	n/a	453.64	Surveyed
926.5	Eulo	–28.7868	144.2669	126.329	Yes	No	n/a	No	n/a	453.53	Surveyed
926.6	Eulo	–28.7870	144.2667	127	Yes	No	n/a	No	n/a	453.55	Surveyed
927	Eulo	–28.6639	144.6378	142	Yes	No	n/a	No	n/a	415.16	Surveyed
928.1	Eulo	–28.7048	144.4002	132	Yes	No	n/a	No	n/a	438.22	Surveyed
928.1	Eulo	–28.7083	144.3953	129	Yes	No	n/a	No	n/a	438.79	Surveyed
928.1	Eulo	–28.7085	144.3951	129	Yes	No	n/a	No	n/a	438.82	Surveyed
928.1	Eulo	–28.7080	144.3937	129	Yes	No	n/a	No	n/a	438.92	Surveyed
928.1	Eulo	–28.7018	144.3978	130	Yes	No	n/a	No	n/a	438.30	Surveyed
928.2	Eulo	–28.7049	144.3983	131	Yes	No	n/a	No	n/a	438.39	Surveyed
928.3	Eulo	–28.7064	144.3971	130	Yes	No	n/a	No	n/a	438.55	Surveyed
928.4	Eulo	–28.7072	144.3973	130	Yes	No	n/a	No	n/a	438.57	Surveyed
928.5	Eulo	–28.7075	144.3973	130	Yes	No	n/a	No	n/a	438.59	Surveyed
928.6	Eulo	–28.7076	144.3962	130	Yes	No	n/a	No	n/a	438.68	Surveyed
928.7	Eulo	–28.7078	144.3960	130	Yes	No	n/a	No	n/a	438.71	Surveyed
928.8	Eulo	–28.7082	144.3960	129	Yes	No	n/a	No	n/a	438.73	Surveyed
928.9	Eulo	–28.7089	144.3964	130	Yes	No	n/a	No	n/a	438.72	Surveyed

Site	Supergroup	Latitude	Longitude	Elevation (m)	EPBC community	EPBC-listed species	EPBC species	NCA-listed species	NCA species	Distance to tenure (km)	Access
929	Eulo	–28.8400	144.4923	134	Yes	No	n/a	No	n/a	435.69	Surveyed
930	Eulo	–29.1391	144.6640	123	Yes	No	n/a	No	n/a	435.39	Surveyed
931.1	Eulo	–29.2304	144.6982	120.4	Yes	No	n/a	No	n/a	437.47	Surveyed
931.1	Eulo	–29.2282	144.6993	123	Yes	No	n/a	No	n/a	437.26	Surveyed
931.1	Eulo	–29.2285	144.6994	123	Yes	No	n/a	No	n/a	437.26	Surveyed
931.1	Eulo	–29.2289	144.7000	123	Yes	No	n/a	No	n/a	437.23	Surveyed
931.1	Eulo	–29.2289	144.6996	123	Yes	No	n/a	No	n/a	437.27	Surveyed
931.1	Eulo	–29.2283	144.7004	123	Yes	No	n/a	No	n/a	437.16	Surveyed
931.2	Eulo	–29.2282	144.7000	123	Yes	No	n/a	No	n/a	437.19	Surveyed
931.2	Eulo	–29.2303	144.6983	123	Yes	No	n/a	No	n/a	437.45	Surveyed
931.3	Eulo	–29.2306	144.6980	123	Yes	No	n/a	No	n/a	437.49	Surveyed
931.4	Eulo	–29.2299	144.6977	123	Yes	No	n/a	No	n/a	437.48	Surveyed
931.5	Eulo	–29.2270	144.6980	123	Yes	No	n/a	No	n/a	437.29	Surveyed
931.6	Eulo	–29.2264	144.6966	123	Yes	No	n/a	No	n/a	437.38	Surveyed
931.7	Eulo	–29.2263	144.6981	118.664	Yes	No	n/a	No	n/a	437.25	Surveyed
931.8	Eulo	–29.2277	144.6990	123	Yes	No	n/a	No	n/a	437.25	Surveyed
931.9	Eulo	–29.2279	144.6993	123	Yes	No	n/a	No	n/a	437.23	Surveyed
932.1	Eulo	–29.2142	144.7051	119.136	Yes	No	n/a	No	n/a	435.99	Surveyed
932.2	Eulo	–29.2144	144.7054	119.136	Yes	No	n/a	No	n/a	435.98	Surveyed
933	Eulo	–29.0792	144.6412	121	Yes	No	n/a	No	n/a	434.19	Surveyed

Site	Supergroup	Latitude	Longitude	Elevation (m)	EPBC community	EPBC-listed species	EPBC species	NCA-listed species	NCA species	Distance to tenure (km)	Access
934	Eulo	–28.8714	144.4110	127.013	Yes	No	n/a	No	n/a	444.28	Surveyed
935.1	Eulo	–28.8307	144.3499	126.03	Yes	No	n/a	No	n/a	447.93	Surveyed
935.2	Eulo	–28.8307	144.3499	128	Yes	No	n/a	No	n/a	447.93	Surveyed
935.3	Eulo	–28.8304	144.3500	128	Yes	No	n/a	No	n/a	447.91	Surveyed
936	Eulo	–28.8670	144.1846	155.673	Yes	No	n/a	No	n/a	464.23	Surveyed
936.1	Eulo	–28.8294	144.1956	138	Yes	No	n/a	No	n/a	461.68	Surveyed
937.1	Eulo	–28.7806	144.4623	139	Yes	No	n/a	No	n/a	435.77	Surveyed
937.1	Eulo	–28.7859	144.4517	133	Yes	No	n/a	No	n/a	436.94	Surveyed
937.1	Eulo	–28.7873	144.4380	132	Yes	No	n/a	No	n/a	438.22	Surveyed
937.1	Eulo	–28.7891	144.4361	131	Yes	No	n/a	No	n/a	438.47	Surveyed
937.1	Eulo	–28.7857	144.4347	130	Yes	No	n/a	No	n/a	438.45	Surveyed
937.1	Eulo	–28.7857	144.4356	131	Yes	No	n/a	No	n/a	438.37	Surveyed
937.2	Eulo	–28.7838	144.4361	131	Yes	No	n/a	No	n/a	438.24	Surveyed
937.2	Eulo	–28.7817	144.4403	132	Yes	No	n/a	No	n/a	437.79	Surveyed
937.2	Eulo	–28.7799	144.4629	140	Yes	No	n/a	No	n/a	435.69	Surveyed
937.3	Eulo	–28.7792	144.4623	140	Yes	No	n/a	No	n/a	435.72	Surveyed
937.4	Eulo	–28.7794	144.4601	141	Yes	No	n/a	No	n/a	435.92	Surveyed
937.5	Eulo	–28.7801	144.4594	139	Yes	No	n/a	No	n/a	436.01	Surveyed
937.6	Eulo	–28.7817	144.4604	137	Yes	No	n/a	No	n/a	435.98	Surveyed
937.7	Eulo	–28.7837	144.4595	136	Yes	No	n/a	No	n/a	436.16	Surveyed

Site	Supergroup	Latitude	Longitude	Elevation (m)	EPBC community	EPBC-listed species	EPBC species	NCA-listed species	NCA species	Distance to tenure (km)	Access
937.8	Eulo	–28.7840	144.4577	136	Yes	No	n/a	No	n/a	436.33	Surveyed
937.9	Eulo	–28.7866	144.4561	135	Yes	No	n/a	No	n/a	436.58	Surveyed
938	Eulo	–28.7473	144.4311	134	Yes	No	n/a	No	n/a	437.16	Surveyed
939	Eulo	–28.7094	144.4361	142	Yes	No	n/a	No	n/a	435.16	Surveyed
939.1	Eulo	–28.7096	144.4179	134	Yes	No	n/a	No	n/a	436.81	Surveyed
940.1	Eulo	–28.7875	144.4022	125	Yes	No	n/a	No	n/a	441.43	Surveyed
940.1	Eulo	–28.7892	144.4162	128	Yes	No	n/a	No	n/a	440.26	Surveyed
940.1	Eulo	–28.7893	144.4167	127	Yes	No	n/a	No	n/a	440.21	Surveyed
940.1	Eulo	–28.7901	144.4161	127	Yes	No	n/a	No	n/a	440.31	Surveyed
940.1	Eulo	–28.7902	144.4185	126.895	Yes	No	n/a	No	n/a	440.09	Surveyed
940.1	Eulo	–28.7902	144.4193	127	Yes	No	n/a	No	n/a	440.02	Surveyed
940.2	Eulo	–28.7888	144.4173	128	Yes	No	n/a	No	n/a	440.14	Surveyed
940.2	Eulo	–28.7845	144.4230	129	Yes	No	n/a	No	n/a	439.45	Surveyed
940.2	Eulo	–28.7879	144.4040	126	Yes	No	n/a	No	n/a	441.29	Surveyed
940.3	Eulo	–28.7869	144.4051	126.333	Yes	No	n/a	No	n/a	441.15	Surveyed
940.4	Eulo	–28.7870	144.4087	125	Yes	No	n/a	No	n/a	440.83	Surveyed
940.5	Eulo	–28.7868	144.4090	125	Yes	No	n/a	No	n/a	440.80	Surveyed
940.6	Eulo	–28.7865	144.4089	125	Yes	No	n/a	No	n/a	440.79	Surveyed
940.7	Eulo	–28.7869	144.4099	126	Yes	No	n/a	No	n/a	440.72	Surveyed
940.8	Eulo	–28.7865	144.4097	126	Yes	No	n/a	No	n/a	440.72	Surveyed

Site	Supergroup	Latitude	Longitude	Elevation (m)	EPBC community	EPBC-listed species	EPBC species	NCA-listed species	NCA species	Distance to tenure (km)	Access
940.9	Eulo	–28.7893	144.4157	127	Yes	No	n/a	No	n/a	440.31	Surveyed
941	Eulo	–28.7147	144.5000	134.487	Yes	No	n/a	No	n/a	429.63	Surveyed
941.1	Eulo	–28.7152	144.5003	137	Yes	No	n/a	No	n/a	429.63	Surveyed
942	Eulo	–28.7215	144.4874	140	Yes	No	n/a	No	n/a	431.05	Surveyed
943	Eulo	–28.5571	144.4413	142.062	Yes	No	n/a	No	n/a	428.81	Surveyed
944.1	Eulo	–28.3668	144.1398	150.887	Yes	No	n/a	No	n/a	450.41	Surveyed
944.2	Eulo	–28.3667	144.1395	154	Yes	No	n/a	No	n/a	450.43	Surveyed
944.3	Eulo	–28.3663	144.1398	149.805	Yes	No	n/a	No	n/a	450.39	Surveyed
944.4	Eulo	–28.3639	144.1422	150.394	Yes	No	n/a	No	n/a	450.10	Surveyed
944.5	Eulo	–28.3709	144.1488	158	Yes	No	n/a	No	n/a	449.69	Surveyed
944.6	Eulo	–28.3552	144.1596	149.473	Yes	No	n/a	No	n/a	448.22	Surveyed
944.7	Eulo	–28.3567	144.1748	152	Yes	No	n/a	No	n/a	446.84	Surveyed
945.1	Eulo	–28.2824	144.3238	151	Yes	No	n/a	No	n/a	430.74	Surveyed
945.1	Eulo	–28.2809	144.3260	150	Yes	No	n/a	No	n/a	430.49	Surveyed
945.1	Eulo	–28.2812	144.3254	150	Yes	No	n/a	No	n/a	430.56	Surveyed
945.1	Eulo	–28.2813	144.3252	150	Yes	No	n/a	No	n/a	430.58	Surveyed
945.2	Eulo	–28.2818	144.3260	150	Yes	No	n/a	No	n/a	430.53	Surveyed
945.3	Eulo	–28.2814	144.3278	150	Yes	No	n/a	No	n/a	430.34	Surveyed
945.4	Eulo	–28.2811	144.3277	150	Yes	No	n/a	No	n/a	430.34	Surveyed
945.5	Eulo	–28.2808	144.3276	150	Yes	No	n/a	No	n/a	430.34	Surveyed

Site	Supergroup	Latitude	Longitude	Elevation (m)	EPBC community	EPBC-listed species	EPBC species	NCA-listed species	NCA species	Distance to tenure (km)	Access
945.6	Eulo	–28.2805	144.3268	150	Yes	No	n/a	No	n/a	430.41	Surveyed
945.7	Eulo	–28.2798	144.3268	150	Yes	No	n/a	No	n/a	430.40	Surveyed
945.8	Eulo	–28.2805	144.3261	150	Yes	No	n/a	No	n/a	430.47	Surveyed
945.9	Eulo	–28.2809	144.3264	150	Yes	No	n/a	No	n/a	430.46	Surveyed
946	Eulo	–28.2989	144.3016	139.616	Yes	No	n/a	No	n/a	433.30	Surveyed
947	Eulo	–28.3370	144.3002	137.545	Yes	No	n/a	No	n/a	434.54	Surveyed
948.1	Eulo	–28.3595	144.3246	145	Yes	No	n/a	No	n/a	432.94	Surveyed
948.1	Eulo	–28.3582	144.3243	146	Yes	No	n/a	No	n/a	432.93	Surveyed
948.1	Eulo	–28.3579	144.3238	145	Yes	No	n/a	No	n/a	432.96	Surveyed
948.1	Eulo	–28.3582	144.3232	145	Yes	No	n/a	No	n/a	433.03	Surveyed
948.1	Eulo	–28.3583	144.3234	145	Yes	No	n/a	No	n/a	433.01	Surveyed
948.1	Eulo	–28.3597	144.3212	144	Yes	No	n/a	No	n/a	433.26	Surveyed
948.2	Eulo	–28.3589	144.3271	146	Yes	No	n/a	No	n/a	432.69	Surveyed
948.3	Eulo	–28.3590	144.3295	146	Yes	No	n/a	No	n/a	432.47	Surveyed
948.4	Eulo	–28.3588	144.3299	146	Yes	No	n/a	No	n/a	432.43	Surveyed
948.5	Eulo	–28.3590	144.3305	147	Yes	No	n/a	No	n/a	432.38	Surveyed
948.6	Eulo	–28.3591	144.3230	145	Yes	No	n/a	No	n/a	433.08	Surveyed
948.7	Eulo	–28.3589	144.3233	145	Yes	No	n/a	No	n/a	433.05	Surveyed
948.8	Eulo	–28.3585	144.3237	145	Yes	No	n/a	No	n/a	432.99	Surveyed
948.9	Eulo	–28.3584	144.3241	141.127	Yes	No	n/a	No	n/a	432.95	Surveyed

Site	Supergroup	Latitude	Longitude	Elevation (m)	EPBC community	EPBC-listed species	EPBC species	NCA-listed species	NCA species	Distance to tenure (km)	Access
949.1	Eulo	–28.4670	144.3592	138	Yes	No	n/a	No	n/a	433.18	Surveyed
949.1	Eulo	–28.4690	144.3624	136	Yes	No	n/a	No	n/a	432.95	Surveyed
949.1	Eulo	–28.4671	144.3612	136	Yes	No	n/a	No	n/a	433.00	Surveyed
949.1	Eulo	–28.4711	144.3640	137	Yes	No	n/a	No	n/a	432.88	Surveyed
949.2	Eulo	–28.4672	144.3592	138	Yes	No	n/a	No	n/a	433.19	Surveyed
949.3	Eulo	–28.4673	144.3596	138	Yes	No	n/a	No	n/a	433.16	Surveyed
949.4	Eulo	–28.4675	144.3600	137	Yes	No	n/a	No	n/a	433.12	Surveyed
949.5	Eulo	–28.4674	144.3609	137	Yes	No	n/a	No	n/a	433.04	Surveyed
949.6	Eulo	–28.4677	144.3613	136	Yes	No	n/a	No	n/a	433.01	Surveyed
949.7	Eulo	–28.4680	144.3614	137	Yes	No	n/a	No	n/a	433.01	Surveyed
949.8	Eulo	–28.4680	144.3616	136	Yes	No	n/a	No	n/a	432.99	Surveyed
949.9	Eulo	–28.4679	144.3619	136	Yes	No	n/a	No	n/a	432.96	Surveyed
950.1	Eulo	–28.4772	144.3736	136	Yes	No	n/a	No	n/a	432.19	Surveyed
950.1	Eulo	–28.4738	144.3731	136	Yes	No	n/a	No	n/a	432.13	Surveyed
950.1	Eulo	–28.4734	144.3733	136	Yes	No	n/a	No	n/a	432.10	Surveyed
950.1	Eulo	–28.4735	144.3735	136	Yes	No	n/a	No	n/a	432.08	Surveyed
950.1	Eulo	–28.4738	144.3734	136	Yes	No	n/a	No	n/a	432.10	Surveyed
950.1	Eulo	–28.4742	144.3743	136	Yes	No	n/a	No	n/a	432.03	Surveyed
950.2	Eulo	–28.4734	144.3744	136	Yes	No	n/a	No	n/a	431.99	Surveyed
950.2	Eulo	–28.4726	144.3727	135	Yes	No	n/a	No	n/a	432.12	Surveyed

Site	Supergroup	Latitude	Longitude	Elevation (m)	EPBC community	EPBC-listed species	EPBC species	NCA-listed species	NCA species	Distance to tenure (km)	Access
950.2	Eulo	–28.4723	144.3730	135	Yes	No	n/a	No	n/a	432.09	Surveyed
950.2	Eulo	–28.4719	144.3730	136	Yes	No	n/a	No	n/a	432.07	Surveyed
950.2	Eulo	–28.4714	144.3726	136	Yes	No	n/a	No	n/a	432.09	Surveyed
950.2	Eulo	–28.4764	144.3734	136	Yes	No	n/a	No	n/a	432.18	Surveyed
950.2	Eulo	–28.4712	144.3731	136	Yes	No	n/a	No	n/a	432.04	Surveyed
950.2	Eulo	–28.4711	144.3736	136	Yes	No	n/a	No	n/a	431.99	Surveyed
950.2	Eulo	–28.4707	144.3738	136	Yes	No	n/a	No	n/a	431.96	Surveyed
950.2	Eulo	–28.4705	144.3745	136	Yes	No	n/a	No	n/a	431.88	Surveyed
950.2	Eulo	–28.4684	144.3759	136	Yes	No	n/a	No	n/a	431.68	Surveyed
950.3	Eulo	–28.4755	144.3736	136	Yes	No	n/a	No	n/a	432.14	Surveyed
950.4	Eulo	–28.4758	144.3732	136	Yes	No	n/a	No	n/a	432.18	Surveyed
950.5	Eulo	–28.4764	144.3730	135	Yes	No	n/a	No	n/a	432.22	Surveyed
950.6	Eulo	–28.4766	144.3732	132.555	Yes	No	n/a	No	n/a	432.21	Surveyed
950.7	Eulo	–28.4760	144.3734	136	Yes	No	n/a	No	n/a	432.17	Surveyed
950.8	Eulo	–28.4745	144.3731	136	Yes	No	n/a	No	n/a	432.15	Surveyed
950.9	Eulo	–28.4739	144.3727	135	Yes	No	n/a	No	n/a	432.17	Surveyed
951	Eulo	–28.4910	144.3411	130.17	Yes	No	n/a	No	n/a	435.66	Surveyed
952	Eulo	–28.4146	144.2744	132.782	Yes	No	n/a	No	n/a	439.32	Surveyed
953.1	Eulo	–27.9994	144.7868	172	Yes	No	n/a	No	n/a	379.70	Surveyed
953.2	Eulo	–27.9993	144.7867	172	Yes	No	n/a	No	n/a	379.71	Surveyed

Site	Supergroup	Latitude	Longitude	Elevation (m)	EPBC community	EPBC-listed species	EPBC species	NCA-listed species	NCA species	Distance to tenure (km)	Access
953.3	Eulo	–27.9992	144.7876	173	Yes	No	n/a	No	n/a	379.62	Surveyed
953.4	Eulo	–27.9993	144.7876	173	Yes	No	n/a	No	n/a	379.61	Surveyed
954.1	Eulo	–28.1295	144.7861	171	Yes	No	n/a	No	n/a	383.06	Surveyed
954.2	Eulo	–28.1295	144.7855	171	Yes	No	n/a	No	n/a	383.11	Surveyed
954.3	Eulo	–28.1296	144.7852	166.519	Yes	No	n/a	No	n/a	383.15	Surveyed
955.1	Eulo	–28.1509	144.9569	160	Yes	No	n/a	No	n/a	367.62	Surveyed
955.2	Eulo	–28.1511	144.9565	160	Yes	No	n/a	No	n/a	367.67	Surveyed
955.3	Eulo	–28.1533	144.9576	160	Yes	No	n/a	No	n/a	367.63	Surveyed
955.4	Eulo	–28.1532	144.9570	160	Yes	No	n/a	No	n/a	367.68	Surveyed
955.5	Eulo	–28.1518	144.9611	157.222	Yes	No	n/a	No	n/a	367.25	Surveyed
956	Eulo	–28.1457	145.0434	156.979	Yes	No	n/a	No	n/a	359.38	Surveyed
957	Eulo	–27.8185	145.6715	198.513	Yes	No	n/a	No	n/a	291.32	Surveyed
958	Eulo	–27.8194	145.6474	195.694	Yes	No	n/a	No	n/a	293.64	Surveyed
959	Eulo	–28.4748	144.4943	163	Yes	No	n/a	No	n/a	421.00	Surveyed
960.1	Bourke	–29.5294	145.8310	–	Yes	No	n/a	No	n/a	355.56	Surveyed
960.1	Bourke	–29.5244	145.8339	–	Yes	No	n/a	No	n/a	355.04	Surveyed
960.1	Bourke	–29.5249	145.8338	–	Yes	No	n/a	No	n/a	355.07	Surveyed
960.1	Bourke	–29.5277	145.8301	–	Yes	No	n/a	No	n/a	355.53	Surveyed
960.1	Bourke	–29.5279	145.8298	–	Yes	No	n/a	No	n/a	355.57	Surveyed
960.1	Bourke	–29.5280	145.8294	–	Yes	No	n/a	No	n/a	355.61	Surveyed

Site	Supergroup	Latitude	Longitude	Elevation (m)	EPBC community	EPBC-listed species	EPBC species	NCA-listed species	NCA species	Distance to tenure (km)	Access
960.2	Bourke	–29.5277	145.8284	–	Yes	No	n/a	No	n/a	355.68	Surveyed
960.2	Bourke	–29.5278	145.8282	–	Yes	No	n/a	No	n/a	355.69	Surveyed
960.2	Bourke	–29.5287	145.8313	–	Yes	No	n/a	No	n/a	355.50	Surveyed
960.3	Bourke	–29.5269	145.8325	–	Yes	No	n/a	No	n/a	355.29	Surveyed
960.4	Bourke	–29.5264	145.8329	–	Yes	No	n/a	No	n/a	355.23	Surveyed
960.5	Bourke	–29.5261	145.8331	–	Yes	No	n/a	No	n/a	355.20	Surveyed
960.6	Bourke	–29.5256	145.8325	–	Yes	No	n/a	No	n/a	355.22	Surveyed
960.7	Bourke	–29.5254	145.8329	–	Yes	No	n/a	No	n/a	355.17	Surveyed
960.8	Bourke	–29.5254	145.8332	–	Yes	No	n/a	No	n/a	355.15	Surveyed
960.9	Bourke	–29.5249	145.8336	–	Yes	No	n/a	No	n/a	355.09	Surveyed
961	Bourke	–29.7160	146.2843	–	Yes	No	n/a	No	n/a	330.84	Surveyed
961.1	Bourke	–29.7162	146.2849	110.829	Yes	No	n/a	No	n/a	330.81	Surveyed
962	Bourke	–29.4570	145.1003	130	Yes	No	n/a	No	n/a	414.23	Surveyed
963	Bourke	–29.4540	145.1013	122.883	Yes	No	n/a	No	n/a	414.00	Surveyed
964	Bourke	–29.2410	146.4054	136.628	No	No	n/a	No	n/a	291.66	Surveyed
965	Bourke	–29.2677	146.3830	131.292	No	No	n/a	No	n/a	295.02	Surveyed
966	Bourke	–29.1922	146.5875	128.304	No	No	n/a	No	n/a	273.80	Surveyed
967	Bourke	–29.1040	146.6200	149	No	No	n/a	No	n/a	266.12	Surveyed
967.1	Bourke	–29.0957	146.6540	144	No	No	n/a	No	n/a	262.81	Surveyed
968	Bourke	–29.4181	146.1150	154.611	No	No	n/a	No	n/a	325.74	Surveyed

Site	Supergroup	Latitude	Longitude	Elevation (m)	EPBC community	EPBC-listed species	EPBC species	NCA-listed species	NCA species	Distance to tenure (km)	Access
969	Bourke	–29.4188	146.2112	140.364	No	No	n/a	No	n/a	317.88	Surveyed
970	Bourke	–29.5096	146.1470	156.976	No	No	n/a	No	n/a	328.48	Surveyed
971	Bourke	–30.0238	145.1099	101.816	Yes	No	n/a	No	n/a	443.13	Surveyed
972	Bourke	–29.8258	145.5143	120.874	Yes	No	n/a	No	n/a	398.62	Surveyed
973	Bourke	–29.5246	145.1296	122.994	Yes	No	n/a	No	n/a	415.00	Surveyed
973.1	Bourke	–29.5395	145.1149	–	Yes	No	n/a	No	n/a	417.01	Surveyed
974.1	Bourke	–29.5351	145.2476	123.972	Yes	No	n/a	No	n/a	405.31	Surveyed
974.1	Bourke	–29.5328	145.2568	123.972	Yes	No	n/a	No	n/a	404.40	Surveyed
974.1	Bourke	–29.5326	145.2566	–	Yes	No	n/a	No	n/a	404.41	Surveyed
974.1	Bourke	–29.5319	145.2553	–	Yes	No	n/a	No	n/a	404.49	Surveyed
974.1	Bourke	–29.5320	145.2576	–	Yes	No	n/a	No	n/a	404.30	Surveyed
974.1	Bourke	–29.5318	145.2580	123.102	Yes	No	n/a	No	n/a	404.25	Surveyed
974.2	Bourke	–29.5312	145.2592	–	Yes	No	n/a	No	n/a	404.12	Surveyed
974.2	Bourke	–29.5323	145.2590	–	Yes	No	n/a	No	n/a	404.19	Surveyed
974.2	Bourke	–29.5323	145.2597	–	Yes	No	n/a	No	n/a	404.13	Surveyed
974.2	Bourke	–29.5318	145.2606	–	Yes	No	n/a	No	n/a	404.03	Surveyed
974.2	Bourke	–29.5303	145.2617	–	Yes	No	n/a	No	n/a	403.86	Surveyed
974.2	Bourke	–29.5365	145.2491	–	Yes	No	n/a	No	n/a	403.73	Surveyed
974.2	Bourke	–29.5289	145.2624	–	Yes	No	n/a	No	n/a	405.25	Surveyed
974.3	Bourke	–29.5345	145.2493	–	Yes	No	n/a	No	n/a	405.13	Surveyed

Site	Supergroup	Latitude	Longitude	Elevation (m)	EPBC community	EPBC-listed species	EPBC species	NCA-listed species	NCA species	Distance to tenure (km)	Access
974.4	Bourke	–29.5325	145.2551	–	Yes	No	n/a	No	n/a	404.54	Surveyed
974.5	Bourke	–29.5324	145.2555	–	Yes	No	n/a	No	n/a	404.50	Surveyed
974.6	Bourke	–29.5324	145.2557	–	Yes	No	n/a	No	n/a	404.48	Surveyed
974.7	Bourke	–29.5327	145.2559	–	Yes	No	n/a	No	n/a	404.47	Surveyed
974.8	Bourke	–29.5334	145.2565	–	Yes	No	n/a	No	n/a	404.46	Surveyed
974.9	Bourke	–29.5330	145.2570	–	Yes	No	n/a	No	n/a	404.40	Surveyed
975	Bourke	–29.5147	145.2780	121.843	Yes	No	n/a	No	n/a	401.69	Surveyed
976.1	Bourke	–29.3917	145.3041	138	Yes	No	n/a	No	n/a	393.43	Surveyed
976.1	Bourke	–29.3976	145.3064	137	Yes	No	n/a	No	n/a	393.52	Surveyed
976.1	Bourke	–29.3974	145.3067	137	Yes	No	n/a	No	n/a	393.48	Surveyed
976.1	Bourke	–29.3976	145.3070	137	Yes	No	n/a	No	n/a	393.46	Surveyed
976.1	Bourke	–29.3974	145.3077	138	Yes	No	n/a	No	n/a	393.40	Surveyed
976.1	Bourke	–29.3970	145.3079	132.64	Yes	No	n/a	No	n/a	393.36	Surveyed
976.2	Bourke	–29.3968	145.3073	137	Yes	No	n/a	No	n/a	393.40	Surveyed
976.2	Bourke	–29.3966	145.3070	137	Yes	No	n/a	No	n/a	393.42	Surveyed
976.2	Bourke	–29.3953	145.3067	137	Yes	No	n/a	No	n/a	393.38	Surveyed
976.2	Bourke	–29.3933	145.3057	137	Yes	No	n/a	No	n/a	393.37	Surveyed
976.2	Bourke	–29.3937	145.3063	137	Yes	No	n/a	No	n/a	393.34	Surveyed
976.2	Bourke	–29.3918	145.3042	131.148	Yes	No	n/a	No	n/a	393.41	Surveyed
976.2	Bourke	–29.3921	145.3046	138	Yes	No	n/a	No	n/a	393.43	Surveyed

Site	Supergroup	Latitude	Longitude	Elevation (m)	EPBC community	EPBC-listed species	EPBC species	NCA-listed species	NCA species	Distance to tenure (km)	Access
976.3	Bourke	–29.3918	145.3044	138	Yes	No	n/a	No	n/a	393.42	Surveyed
976.4	Bourke	–29.3922	145.3040	137	Yes	No	n/a	No	n/a	393.46	Surveyed
976.5	Bourke	–29.3924	145.3044	137	Yes	No	n/a	No	n/a	393.44	Surveyed
976.6	Bourke	–29.3926	145.3048	137	Yes	No	n/a	No	n/a	393.42	Surveyed
976.7	Bourke	–29.3937	145.3048	129.609	Yes	No	n/a	No	n/a	393.47	Surveyed
976.8	Bourke	–29.3948	145.3038	136	Yes	No	n/a	No	n/a	393.60	Surveyed
976.9	Bourke	–29.3968	145.3029	136	Yes	No	n/a	No	n/a	393.78	Surveyed
978	Bourke	–29.3972	145.3215	130.263	Yes	No	n/a	No	n/a	392.19	Surveyed
978.1	Bourke	–29.3977	145.3230	130.05	Yes	No	n/a	No	n/a	392.09	Surveyed
978.2	Bourke	–29.3963	145.3207	133.784	Yes	No	n/a	No	n/a	392.22	Surveyed
979	Bourke	–29.3801	145.3405	125.384	Yes	No	n/a	No	n/a	389.72	Surveyed
979.1	Bourke	–29.3748	145.3371	133	Yes	No	n/a	No	n/a	389.76	Surveyed
980	Bourke	–29.3695	145.3755	129.758	Yes	No	n/a	No	n/a	386.18	Surveyed
981	Bourke	–29.2731	145.3510	129.244	Yes	No	n/a	No	n/a	383.76	Surveyed
982.1	Bourke	–29.1368	145.2519	128.356	Yes	No	n/a	No	n/a	386.44	Surveyed
982.2	Bourke	–29.1370	145.2517	133	Yes	No	n/a	No	n/a	386.48	Surveyed
982.3	Bourke	–29.1372	145.2516	133	Yes	No	n/a	No	n/a	386.49	Surveyed
982.4	Bourke	–29.1374	145.2516	127.467	Yes	No	n/a	No	n/a	386.52	Surveyed
982.5	Bourke	–29.1386	145.2514	132	Yes	No	n/a	No	n/a	386.60	Surveyed
983.1	Bourke	–29.1511	145.2326	130	Yes	No	n/a	No	n/a	388.88	Surveyed

Site	Supergroup	Latitude	Longitude	Elevation (m)	EPBC community	EPBC-listed species	EPBC species	NCA-listed species	NCA species	Distance to tenure (km)	Access
983.1	Bourke	–29.1508	145.2280	130	Yes	No	n/a	No	n/a	389.24	Surveyed
983.1	Bourke	–29.1526	145.2338	130	Yes	No	n/a	No	n/a	388.87	Surveyed
983.2	Bourke	–29.1512	145.2276	130	Yes	No	n/a	No	n/a	389.29	Surveyed
983.3	Bourke	–29.1512	145.2272	130	Yes	No	n/a	No	n/a	389.33	Surveyed
983.4	Bourke	–29.1516	145.2262	130	Yes	No	n/a	No	n/a	389.43	Surveyed
983.5	Bourke	–29.1527	145.2255	130	Yes	No	n/a	No	n/a	389.55	Surveyed
983.6	Bourke	–29.1530	145.2265	130	Yes	No	n/a	No	n/a	389.49	Surveyed
983.7	Bourke	–29.1525	145.2273	130	Yes	No	n/a	No	n/a	389.40	Surveyed
983.8	Bourke	–29.1518	145.2284	130	Yes	No	n/a	No	n/a	389.26	Surveyed
983.9	Bourke	–29.1523	145.2280	130	Yes	No	n/a	No	n/a	389.32	Surveyed
989.1	Bourke	–29.4235	145.0590	124.083	Yes	No	n/a	No	n/a	416.25	Surveyed
989.2	Bourke	–29.4236	145.0593	131	Yes	No	n/a	No	n/a	416.22	Surveyed
989.3	Bourke	–29.4237	145.0591	131	Yes	No	n/a	No	n/a	416.24	Surveyed
989.4	Bourke	–29.4237	145.0592	131	Yes	No	n/a	No	n/a	416.24	Surveyed
989.5	Bourke	–29.4238	145.0593	131	Yes	No	n/a	No	n/a	416.23	Surveyed
989.6	Bourke	–29.4238	145.0594	131	Yes	No	n/a	No	n/a	416.22	Surveyed
989.7	Bourke	–29.4235	145.0594	131	Yes	No	n/a	No	n/a	416.21	Surveyed
989.8	Bourke	–29.4235	145.0596	131	Yes	No	n/a	No	n/a	416.19	Surveyed
990	Bourke	–29.3398	145.0033	120.494	Yes	No	n/a	No	n/a	417.35	Surveyed
991	Bogan River	–29.5289	145.2624	174.989	No	No	n/a	No	n/a	403.73	Surveyed

Site	Supergroup	Latitude	Longitude	Elevation (m)	EPBC community	EPBC-listed species	EPBC species	NCA-listed species	NCA species	Distance to tenure (km)	Access
992	Bogan River	–29.7411	147.7644	153.608	No	No	n/a	No	n/a	237.01	Surveyed
992.1	Bogan River	–29.7411	147.7647	–	No	No	n/a	No	n/a	236.99	Surveyed
992.2	Bogan River	–29.7413	147.7644	–	No	No	n/a	No	n/a	237.02	Surveyed
992.3	Bogan River	–29.7412	147.7646	–	No	No	n/a	No	n/a	237.00	Surveyed
993	Bogan River	–30.3486	147.3434	123.225	Yes	No	n/a	No	n/a	316.06	Surveyed
994	Bogan River	–30.8338	146.9499	141.107	Yes	No	n/a	No	n/a	381.91	Surveyed
995	Bourke	–30.6615	143.8270	–	Yes	No	n/a	No	n/a	584.53	Surveyed
996	Bourke	–29.0193	146.9304	141.762	Yes	No	n/a	No	n/a	235.54	Surveyed
997	Bourke	–29.1377	146.5993	136	No	No	n/a	No	n/a	269.72	Surveyed
998	Bourke	–29.2014	146.5510	133	No	No	n/a	No	n/a	277.34	Surveyed
1000	Bourke	–30.7201	143.5694	–	Yes	No	n/a	No	n/a	608.93	Surveyed
1000	Bourke	–30.7208	143.5700	–	Yes	No	n/a	No	n/a	608.92	Surveyed
1000	Bourke	–30.7286	143.5733	–	Yes	Yes	*Eriocaulon carsonii*	Yes	*Eriocaulon carsonii*	609.08	Surveyed
1000	Bourke	–30.7287	143.5738	–	Yes	No	n/a	No	n/a	609.06	Surveyed
1001	Bourke	–30.7294	143.5739	–	Yes	No	n/a	No	n/a	609.08	Surveyed
1001	Bourke	–30.7289	143.5743	–	Yes	No	n/a	No	n/a	609.02	Surveyed
1001	Bourke	–30.7288	143.5744	–	Yes	No	n/a	No	n/a	609.01	Surveyed
1001	Bourke	–30.7300	143.6130	–	Yes	No	n/a	No	n/a	605.91	Surveyed
1001	Bourke	–30.5772	143.1014	–	Yes	No	n/a	No	n/a	640.51	Surveyed
1002	Bourke	–30.5250	143.1304	–	Yes	No	n/a	No	n/a	635.46	Surveyed

Site	Supergroup	Latitude	Longitude	Elevation (m)	EPBC community	EPBC-listed species	EPBC species	NCA-listed species	NCA species	Distance to tenure (km)	Access
1003	Bourke	–30.3984	143.8354	–	Yes	No	n/a	No	n/a	569.37	Surveyed
1004	Bourke	–30.7317	144.2435	–	Yes	No	n/a	No	n/a	555.26	Surveyed
1005	Bourke	–30.6315	144.4223	–	Yes	No	n/a	No	n/a	534.92	Surveyed
1006	Bourke	–29.5635	146.0671	–	Yes	No	n/a	No	n/a	338.19	Surveyed
1006	Bourke	–29.5634	146.0687	–	Yes	No	n/a	No	n/a	338.05	Surveyed
1007	Bourke	–29.4823	145.7902	137	Yes	No	n/a	No	n/a	356.38	Surveyed
1007	Bourke	–29.4799	145.7898	136	Yes	No	n/a	No	n/a	356.28	Surveyed
1008	Bourke	–29.4697	145.7577	129	Yes	No	n/a	No	n/a	358.43	Surveyed
1009	Bourke	–29.4308	145.7323	129	Yes	No	n/a	No	n/a	358.53	Surveyed
1010	Bourke	–28.9347	146.9332	140.033	No	No	n/a	No	n/a	230.53	Surveyed
1011	Springsure	–24.5303	149.1203	221.47	No	No	n/a	No	n/a	65.02	Surveyed
1012	Springsure	–24.5834	149.1321	264.59	No	No	n/a	No	n/a	59.80	Surveyed
301A	Springsure	–24.5920	146.8610	489.5	No	No	n/a	No	n/a	141.88	Surveyed
nv10	Springsure	–24.7480	147.7460	831	No	No	n/a	No	n/a	52.19	High-elevation recharge
nv11	Springsure	–24.8300	147.7420	768.40002	No	No	n/a	No	n/a	52.55	No vehicle access; Remote
nv12	Springsure	–24.7430	147.7330	859	No	No	n/a	No	n/a	53.49	High-elevation recharge
nv126	Eulo	–28.1454	144.4906	179	Yes	No	n/a	No	n/a	411.34	No vehicle

Site	Supergroup	Latitude	Longitude	Elevation (m)	EPBC community	EPBC-listed species	EPBC species	NCA-listed species	NCA species	Distance to tenure (km)	Access
											access; Remote
nv13	Springsure	–24.7111	147.6921	753	No	No	n/a	No	n/a	57.74	No vehicle access; Remote
nv14	Springsure	–24.7660	147.6950	965	No	No	n/a	No	n/a	57.28	High-elevation recharge
nv15	Springsure	–24.7550	147.6920	898	No	No	n/a	No	n/a	57.58	High-elevation recharge
nv16	Springsure	–25.2033	147.5883	629.61121	No	No	n/a	No	n/a	72.16	No vehicle access; Remote
nv17	Springsure	–25.4000	147.5500	558.75	No	No	n/a	No	n/a	85.50	No vehicle access; Remote
nv18	Springsure	–25.2667	147.4667	640.5061	No	No	n/a	No	n/a	86.01	No vehicle access; Remote
nv19	Springsure	–25.0333	147.4500	602.85413	No	No	n/a	No	n/a	81.81	No vehicle access; Remote
nv2	Springsure	–24.1814	149.1511	268	No	No	n/a	No	n/a	62.89	No vehicle access; Remote
nv20	Springsure	–25.4000	147.3000	502.5	No	No	n/a	No	n/a	107.21	No vehicle

Site	Supergroup	Latitude	Longitude	Elevation (m)	EPBC community	EPBC-listed species	EPBC species	NCA-listed species	NCA species	Distance to tenure (km)	Access
											access; Remote
nv21	Springsure	–24.8600	147.2100	557	No	No	n/a	No	n/a	105.71	No vehicle access; Remote
nv22	Springsure	–24.8500	147.2000	461.5	No	No	n/a	No	n/a	106.70	No vehicle access; Remote
nv3	Springsure	–24.2834	149.1341	296	No	No	n/a	No	n/a	72.96	No vehicle access; Remote
nv329	Springsure	–25.6484	149.2011	314	No	No	n/a	No	n/a	3.31	Not permanent
nv331	Springsure	–25.3984	149.4011	245.035	No	No	n/a	No	n/a	30.98	Not permanent
nv332	Springsure	–25.4154	149.3681	245.035	No	No	n/a	No	n/a	27.28	Not permanent
nv337	Springsure	–23.9134	149.1125	697	No	No	n/a	No	n/a	34.78	No vehicle access; Remote
nv339	Springsure	–23.7314	149.0841	372	No	No	n/a	No	n/a	19.54	No vehicle access; Remote
nv340	Springsure	–23.9154	149.0201	413	No	No	n/a	No	n/a	30.33	<5 km hike
nv341	Springsure	–23.8404	149.2291	432	No	No	n/a	No	n/a	38.13	No vehicle access;

Site	Supergroup	Latitude	Longitude	Elevation (m)	EPBC community	EPBC-listed species	EPBC species	NCA-listed species	NCA species	Distance to tenure (km)	Access
											Remote
nv343	Springsure	–23.9214	149.0281	423	No	No	n/a	No	n/a	31.26	<5 km hike
nv348	Springsure	–24.1614	149.1391	284	No	No	n/a	No	n/a	60.35	No vehicle access; Remote
nv349	Springsure	–24.2074	149.1361	257	No	No	n/a	No	n/a	65.02	No vehicle access; Remote
nv350	Springsure	–24.2284	149.1331	249	No	No	n/a	No	n/a	67.11	No vehicle access; Remote
nv351	Springsure	–24.2554	149.1291	257	No	No	n/a	No	n/a	69.83	No vehicle access; Remote
nv352	Springsure	–24.2834	149.1411	265	No	No	n/a	No	n/a	73.18	No vehicle access; Remote
nv353	Springsure	–24.2104	149.1461	238	No	No	n/a	No	n/a	65.69	No vehicle access; Remote
nv354	Springsure	–24.2824	149.1491	254	No	No	n/a	No	n/a	73.34	No vehicle access; Remote
nv355	Springsure	–24.3224	149.1321	242	No	No	n/a	No	n/a	77.05	<5 km hike
nv356	Springsure	–24.3764	149.1431	248	No	No	n/a	No	n/a	82.17	<5 km hike
nv357	Springsure	–24.3854	149.1431	248	No	No	n/a	No	n/a	81.20	<5 km hike

Site	Supergroup	Latitude	Longitude	Elevation (m)	EPBC community	EPBC-listed species	EPBC species	NCA-listed species	NCA species	Distance to tenure (km)	Access
nv358	Springsure	–24.4054	149.1261	253	No	No	n/a	No	n/a	78.58	<5 km hike
nv359	Springsure	–24.4669	149.1148	287	No	No	n/a	No	n/a	71.65	Not permanent
nv363	Springsure	–24.8154	147.9841	754	No	No	n/a	No	n/a	28.35	No vehicle access; Remote
nv365	Springsure	–23.9094	149.0861	674	No	No	n/a	No	n/a	32.88	No vehicle access; Remote
nv366	Springsure	–23.9164	149.1051	587	No	No	n/a	No	n/a	34.62	No vehicle access; Remote
nv367	Springsure	–23.8864	149.2811	374	No	No	n/a	No	n/a	45.31	No vehicle access; Remote
nv368	Springsure	–23.8374	149.1121	388	No	No	n/a	No	n/a	28.43	No vehicle access; Remote
nv369	Springsure	–23.8274	149.1121	439	No	No	n/a	No	n/a	27.69	No vehicle access; Remote
nv370	Springsure	–25.0134	149.2241	428	No	No	n/a	No	n/a	31.50	No vehicle access; Remote
nv371	Springsure	–24.0904	149.2171	229	No	No	n/a	No	n/a	57.06	No vehicle access; Remote

Site	Supergroup	Latitude	Longitude	Elevation (m)	EPBC community	EPBC-listed species	EPBC species	NCA-listed species	NCA species	Distance to tenure (km)	Access
nv372	Springsure	–24.4660	149.1110	291	No	No	n/a	No	n/a	71.64	Not permanent
nv373	Springsure	–24.4740	149.1320	262	No	No	n/a	No	n/a	71.38	Not permanent
nv374	Springsure	–24.9564	149.4031	303	No	No	n/a	No	n/a	50.42	No vehicle access; Remote
nv379	Springsure	–24.5952	149.0859	313	No	No	n/a	No	n/a	57.04	Not permanent
nv383	Springsure	–25.0009	148.9881	337	No	No	n/a	No	n/a	11.46	Unreliable source; Remote
nv384	Springsure	–25.0610	148.8801	426	No	No	n/a	No	n/a	2.33	Unreliable source; Remote
nv385	Springsure	–25.4994	148.9831	435	No	No	n/a	No	n/a	0.00	No vehicle access; Remote
nv386	Springsure	–23.8574	149.3181	282	No	No	n/a	No	n/a	46.91	High-elevation recharge
nv387	Springsure	–24.9484	148.1351	1134	No	No	n/a	No	n/a	13.24	High-elevation recharge
nv388	Springsure	–24.9654	148.1581	1057	No	No	n/a	No	n/a	10.95	High-elevation recharge

Site	Supergroup	Latitude	Longitude	Elevation (m)	EPBC community	EPBC-listed species	EPBC species	NCA-listed species	NCA species	Distance to tenure (km)	Access
nv389	Springsure	–24.9804	148.1751	1041	No	No	n/a	No	n/a	9.25	High-elevation recharge
nv390	Springsure	–25.0014	148.2111	1065	No	No	n/a	No	n/a	6.07	High-elevation recharge
nv391	Springsure	–24.9594	148.1001	1046	No	No	n/a	No	n/a	16.74	High-elevation recharge
nv392	Springsure	–25.0504	148.2161	465	No	No	n/a	No	n/a	9.26	No vehicle access; Remote
nv394	Springsure	–25.0314	148.2111	728	No	No	n/a	No	n/a	7.93	No vehicle access; Remote
nv395	Springsure	–25.0744	148.2021	823	No	No	n/a	No	n/a	12.28	High-elevation recharge
nv396	Springsure	–25.0284	148.1991	649	No	No	n/a	No	n/a	8.62	No vehicle access; Remote
nv399	Springsure	–25.0544	148.1561	815	No	No	n/a	No	n/a	13.80	No vehicle access; Remote
nv4	Springsure	–23.7984	149.0711	827	No	No	n/a	No	n/a	22.44	<5 km hike
nv400	Springsure	–25.0594	148.1621	685	No	No	n/a	No	n/a	13.67	No vehicle access;

Site	Supergroup	Latitude	Longitude	Elevation (m)	EPBC community	EPBC-listed species	EPBC species	NCA-listed species	NCA species	Distance to tenure (km)	Access
											Remote
nv401	Springsure	–25.0454	148.1461	729	No	No	n/a	No	n/a	14.08	No vehicle access; Remote
nv402	Springsure	–25.3929	150.1486	184	No	No	n/a	No	n/a	49.43	No vehicle access; Remote
nv403	Springsure	–25.3192	150.0847	226	No	No	n/a	No	n/a	57.46	No vehicle access; Remote
nv404	Springsure	–25.3933	150.1714	263	No	No	n/a	No	n/a	49.65	No vehicle access; Remote
nv405	Springsure	–25.4235	150.1926	185	No	No	n/a	No	n/a	46.66	No vehicle access; Remote
nv408	Springsure	–24.9170	147.5500	710	No	No	n/a	No	n/a	71.68	No vehicle access; Remote
nv425	Springsure	–24.9900	147.3100	575	No	No	n/a	No	n/a	95.60	No vehicle access; Remote
nv426	Springsure	–24.6726	147.7284	580	No	No	n/a	No	n/a	54.63	No vehicle access; Remote
nv427	Springsure	–24.7930	147.6346	692	No	No	n/a	No	n/a	63.30	No vehicle access;

Site	Supergroup	Latitude	Longitude	Elevation (m)	EPBC community	EPBC-listed species	EPBC species	NCA-listed species	NCA species	Distance to tenure (km)	Access
											Remote
nv428	Springsure	–24.8113	147.5964	638	No	No	n/a	No	n/a	67.11	No vehicle access; Remote
nv429	Springsure	–24.8484	147.6968	770	No	No	n/a	No	n/a	57.06	No vehicle access; Remote
nv435	Springsure	–25.0754	148.2311	552	No	No	n/a	No	n/a	11.11	High-elevation recharge
nv437	Springsure	–25.3070	148.4478	580	No	No	n/a	No	n/a	37.02	No vehicle access; Remote
nv438	Springsure	–25.4784	148.2158	477	No	No	n/a	No	n/a	53.24	No vehicle access; Remote
nv5	Springsure	–24.9184	148.9411	451.5	No	No	n/a	No	n/a	18.45	Unreliable source; Remote
nv6	Springsure	–25.2314	148.3511	823.838	No	No	n/a	No	n/a	28.42	Unreliable source; Remote
nv600	Springsure	–25.1312	148.1312	673	No	No	n/a	No	n/a	21.59	Surveyed
nv601	Springsure	–25.1762	148.1182	620	No	No	n/a	No	n/a	26.41	Surveyed
nv602	Springsure	–25.1555	148.0844	632	No	No	n/a	No	n/a	26.71	Surveyed
nv603	Springsure	–25.1477	148.1190	654	No	No	n/a	No	n/a	23.79	Surveyed

Site	Supergroup	Latitude	Longitude	Elevation (m)	EPBC community	EPBC-listed species	EPBC species	NCA-listed species	NCA species	Distance to tenure (km)	Access
nv604	Springsure	–25.0795	148.1230	809	No	No	n/a	No	n/a	18.12	High-elevation recharge
nv605	Springsure	–25.1286	148.1972	660	No	No	n/a	No	n/a	17.89	Surveyed
nv606	Springsure	–25.0813	148.1263	774	No	No	n/a	No	n/a	17.99	High-elevation recharge
nv607	Springsure	–25.1104	148.1371	713	No	No	n/a	No	n/a	19.44	Surveyed
nv608	Springsure	–25.0962	148.1626	879	No	No	n/a	No	n/a	16.57	High-elevation recharge
nv609	Springsure	–24.5778	148.2525	286	No	No	n/a	No	n/a	19.18	No vehicle access; Remote
nv610	Springsure	–24.5633	148.2464	351	No	No	n/a	No	n/a	20.85	No vehicle access; Remote
nv611	Springsure	–24.5680	148.2306	386	No	No	n/a	No	n/a	20.56	No vehicle access; Remote
nv612	Springsure	–24.5252	148.2210	386	No	No	n/a	No	n/a	25.44	No vehicle access; Remote
nv613	Springsure	–24.5276	148.2368	398	No	No	n/a	No	n/a	24.94	High-elevation recharge

Site	Supergroup	Latitude	Longitude	Elevation (m)	EPBC community	EPBC-listed species	EPBC species	NCA-listed species	NCA species	Distance to tenure (km)	Access
nv614	Springsure	–24.5324	148.2068	406	No	No	n/a	No	n/a	24.96	No vehicle access; Remote
nv615	Springsure	–24.5516	148.1758	540	No	No	n/a	No	n/a	23.89	High-elevation recharge
nv616	Springsure	–24.5324	148.1989	434	No	No	n/a	No	n/a	25.17	No vehicle access; Remote
nv617	Springsure	–24.5083	148.2141	418	No	No	n/a	No	n/a	27.43	High-elevation recharge
nv618	Springsure	–24.4987	148.2102	415	No	No	n/a	No	n/a	28.56	High-elevation recharge
nv619	Springsure	–24.4967	148.2194	390	No	No	n/a	No	n/a	28.62	High-elevation recharge
nv620	Springsure	–24.4811	148.2120	407	No	No	n/a	No	n/a	30.46	High-elevation recharge
nv621	Springsure	–24.6317	149.0629	381	No	No	n/a	No	n/a	52.47	No vehicle access; Remote
nv622	Springsure	–24.6225	149.1018	310	No	No	n/a	No	n/a	54.65	No vehicle access; Remote

Site	Supergroup	Latitude	Longitude	Elevation (m)	EPBC community	EPBC-listed species	EPBC species	NCA-listed species	NCA species	Distance to tenure (km)	Access
nv623	Bourke	–30.7020	143.7163	–	Yes	No	n/a	No	n/a	595.88	No vehicle access; Remote
nv624	Bourke	–30.0300	142.6610	–	Yes	No	n/a	No	n/a	651.66	No vehicle access; Remote
nv625	Eulo	–28.6840	144.3090	125	No	No	n/a	No	n/a	445.63	Unable to locate
nv626	Eulo	–28.1870	144.4420	207	No	No	n/a	No	n/a	417.01	Unable to locate
nv627	Eulo	–28.5230	144.5150	206	No	No	n/a	No	n/a	420.82	Unable to locate
nv628	Eulo	–28.5230	144.5150	206	No	No	n/a	No	n/a	420.82	Unable to locate
nv7	Springsure	–25.2314	148.3341	758.773	No	No	n/a	No	n/a	28.17	No vehicle access; Remote
nv8	Springsure	–25.0314	148.1311	757	No	No	n/a	No	n/a	14.73	No vehicle access; Remote
nv9	Springsure	–24.7484	147.8811	777.25	No	No	n/a	No	n/a	38.67	No vehicle access; Remote
SP1	Springsure	–27.6024	151.9395	667.12	No	No	n/a	No	n/a	50.88	Non–GAB
SP10	Springsure	–27.8998	151.9456	452.29	No	No	n/a	No	n/a	57.74	Non–GAB

Site	Supergroup	Latitude	Longitude	Elevation (m)	EPBC community	EPBC-listed species	EPBC species	NCA-listed species	NCA species	Distance to tenure (km)	Access
SP11	Springsure	–28.0253	151.9794	476.16	No	No	n/a	No	n/a	67.96	Non–GAB
SP15	Springsure	–27.5701	151.8476	510.57	No	No	n/a	No	n/a	41.92	Non–GAB
SP2	Springsure	–26.8771	151.5959	579.7	No	No	n/a	No	n/a	42.24	Non–GAB
SP3	Springsure	–27.3946	151.5736	376	No	No	n/a	No	n/a	19.16	Non–GAB
SP37	Springsure	–27.9521	151.9928	491.97	No	No	n/a	No	n/a	64.57	Non–GAB
SP38	Springsure	–27.9596	151.9998	493.52	No	No	n/a	No	n/a	65.58	Non–GAB
SP4	Springsure	–27.3278	151.4570	360	No	No	n/a	No	n/a	11.98	Non–GAB
SP42	Springsure	–27.6036	151.9110	597.99	No	No	n/a	No	n/a	48.10	Non–GAB
SP43	Springsure	–27.5815	151.8899	548.08	No	No	n/a	No	n/a	46.05	Non–GAB
SP44	Springsure	–27.4265	151.9071	502.82	No	No	n/a	No	n/a	48.45	Non–GAB
SP45	Springsure	–27.4393	151.9561	621.86	No	No	n/a	No	n/a	52.97	Non–GAB
SP5	Springsure	–27.2186	151.7609	457	No	No	n/a	No	n/a	41.86	Non–GAB
SP6	Springsure	–27.6213	151.6208	384.09	No	No	n/a	No	n/a	19.80	Non–GAB
SP7	Springsure	–27.6854	151.6235	462.83	No	No	n/a	No	n/a	20.18	Non–GAB
SP8	Springsure	–27.6651	151.5749	460.04	No	No	n/a	No	n/a	15.32	Non–GAB
SP9	Springsure	–27.7107	151.7254	469.34	No	No	n/a	No	n/a	30.41	Non–GAB
x328	Springsure	–25.3654	149.3591	245.035	No	No	n/a	No	n/a	27.32	Not permanent
x346	Springsure	–25.4754	150.1271	181	No	No	n/a	No	n/a	40.03	No spring found
x375	Springsure	–24.4995	149.1287	278	No	No	n/a	No	n/a	68.56	No spring found

Site	Supergroup	Latitude	Longitude	Elevation (m)	EPBC community	EPBC-listed species	EPBC species	NCA-listed species	NCA species	Distance to tenure (km)	Access
x377	Springsure	–24.5637	149.1189	281	No	No	n/a	No	n/a	61.42	No spring found
x380	Springsure	–24.6464	149.0871	317	No	No	n/a	No	n/a	51.63	No spring found
x381	Springsure	–24.6764	149.0811	352	No	No	n/a	No	n/a	48.26	No spring found
x431	Springsure	–25.7206	149.0285	287	No	No	n/a	No	n/a	0.00	No spring found
x436	Springsure	–25.6718	148.4547	455	No	No	n/a	No	n/a	29.40	No spring found

Appendix D: Nomination form and guidelines for changing the conservation status of a species under the *Nature Conservation Act 1992* (Qld)

Species nomination form and guidelines for adding or changing the category of a native species listing under the Queensland *Nature Conservation Act* 1992 (NCA Act)

For: Calocephalus sp. (Eulo ME Ballingall MEB2590)

General notes

The purpose of this document is to nominate a species for assessment under the NCA by the Department of Environment and Resource Management Species Technical Committee (STC) for its consideration and subsequent advice to the Minister for Climate Change and Sustainability.

Please use one nomination form for each species. The form may be submitted electronically, however, the original, signed, hard copy must also be lodged. Lodgement instructions are provided at the end of the form. The STC will not consider nominations submitted in any other format.

Each section of the form needs to be completed with as much detail as possible, and indicate when there is no information available. Identify your references / information sources, document reasons and supportive data. Indicate the quality of facts/information, for example was it based on research or anecdotal data; on observed data or estimated or inferred from data; or suspected to be the case. Identify confidential material and explain the sensitivity.

The STC will not consider incomplete nominations or nominations with insufficient information. Your nomination will be returned to you if inadequate information is provided.

Your nomination must be supported with referenced summaries of relevant information from the scientific literature. Full bibliographic details are to be provided. The opinion of appropriate scientific experts may also be cited, provided they authorise you to do so. The names of the expert(s), their qualifications and full contact details must also be provided if they are cited.

The STC assesses nominations against the IUCN Red List Categories and Criteria (version 3.1) for the categories of extinct in the wild, endangered, vulnerable, near threatened and least concern. The IUCN updates its red list guidelines regularly and the STC uses the most recent version (version 8.0). This form will be updated in accord with revisions of IUCN criteria, if necessary. A full description of the IUCN categories and criteria can be found in: IUCN 2001. IUCN Red List Categories: Version 3.1. Prepared by the IUCN Species Survival Commission. IUCN, Gland, Switzerland and Cambridge, UK.

www.iucnredlist.org/documents/redlist_cats_crit_en.pdf
http://www.iucnredlist.org/documents/RedListGuidelines.pdf .

- Species—applies to the entity nominated under the *Nature Conservation Act*
- Population—refers to populations within a species or total population numbers for a species.

Section 1. Summary

1.1 Scientific and common name of species (or subspecies)
***Calocephalus* sp. (Eulo ME Ballingal MEB2590)**
1.2 If the species is not conventionally accepted, please provide: • a taxonomic description of the species in a form suitable for publication in conventional scientific literature. State where this description has been submitted for publication; or • evidence that a scientific institution has a specimen of the species and a written statement signed by a person who is a taxonomist with relevant expertise (has worked, or is a published author, on the class of species nominated) that the species is new. Details of the qualifications and experience of the taxon expert need to be provided. For a specimen lodged at a museum or herbarium, state where the specimen is held, the collector name, collection date and collection/voucher number.
Specimens are currently on loan to DNA (Alice Springs) to Phillip Short who is revising the group.
1.3 If a population is being nominated, justify why the population should be considered separately from the species as a whole. This will generally require evidence why the nominated population is considered genetically distinct and/or geographically separate and/or severely threatened in comparison with all other populations of the species.
1.4 Please provide a description of the species or population that is sufficient to distinguish it from other species or populations.
Differs from all other *Calocephalus* and similar species in the area by the stems and leaves that are completely glabrous and glandular (microscopic); compound heads broader than long and much wider than *C. sonderi*, with a whitish appearance from very dense white woolly bracts, with florets pale yellow and barely topping the woolly bracts.
1.5 Current conservation status under Nature Conservation Act 1992 and the EPBC Act
NCA: NT EPBC: none
1.6 Proposed conservation status under the *Nature Conservation Act 1992* and the EPBC Act
Vulnerable
1.7 IUCN Criteria under which the species is eligible for listing. The species should be judged against the criteria described in Attachment B: Categories and criteria used for assessing the status of species. The categories for extinct in the wild, endangered, vulnerable and near threatened use the most recent version of IUCN criteria.
Vulnerable (D2)

Section 2. Species ecology/biology

2.1 Is this species conventionally accepted? If not, explain why. Is there any controversy on the taxonomy?
Accepted but awaiting formal description (Phillip Short ms.)

2.2 Give a brief description of the species': appearance, including size and/or weight, and sex and age variation if appropriate; social structure and dispersion (e.g. solitary/clumped/flocks)
Annual tufted herb, with multiple stems to 20 cm high. Stems and leaves glabrous, with minute scattered gland dots (microscopic). The leaves are alternate or sub-opposite, linear–oblong, 4–10 mm long and up to 1 mm wide, with a rounded apex. The compound heads are depressed globosa to 13 mm wide, and white woolly, the general involucral bracts are green. The partial heads have 5 to 7 pale yellow florets and about the same number of woolly bracts with flat white tips and often a green central strip at the base. Achenes to 1 mm long, hairy, and with a pappus of with 6–8 separate plumose bristles (Queensland Herbarium 2012).
2.3 Describe the species' habitat (e.g. aspect, topography, substrate, climate, forest type, associated species, sympatric species).
Associated only with Great Artesian Basin (GAB) springs in the Eulo Supergroup (Habermehl 1982). The species occurs on scalded claypans and plains, and low lunettes which typically surround GAB springs, and on the sides of inactive and active mound springs.
2.4 What is the species' generation length? Note: Generation length is the average age of parents of the current cohort (i.e. newborn individuals in the population).
The species is short-lived but has a large, woody taproot and can behave as a perennial in good seasons.
2.5 Is there any other information regarding the species ecology or biology relevant to a conservation status assessment?
Only associated with GAB springs. Flowers in spring and summer. Widespread death of mature plants occurs most years, followed by mass germination under the dead plants.

Section 3. Conservation status

3.1 Describe the species' distribution in Australia and attach a map of known localities. Please include details of which Natural Resource Management and IBRA Bioregions the species occurs in.
Confined to south-western Queensland in the Mulga Lands IBRA region. It occurs in a band west of Eulo, extending to Bundoona/Yowah Creek in the north, Granite Springs in the west and Currawinya National Park in the south. Map 1 shows all records of the species, as well as absences, based on a comprehensive 2012 survey of springs in the Eulo supergroup.
3.2 What is the species' total extent of occurrence (in km^2) (see Attachment A)
The species occurs in an area (rectangle) of 7000 km^2 (100 km × 70 km).
3.3 What is the species' total area of occupancy (in km^2) (see Attachment A)
The estimated area of occupancy is 3.2 km^2. The area occupied by each of the 18 known populations ranged from 800 m^2 to 1 km^2. The total area of occupancy is a tiny fraction of the extent of occurrence, as the species is confined to springs and their surrounds, often in very small patches.
3.4 What is the species' total population size in terms of number of mature individuals?
In spring–summer 2012, the total estimated population size was about 15 000 individuals. At large populations, density of plants in a subset of the population and the total area of occupancy were used to estimate population size. The largest population encountered contained >5000 plants, while some populations contained only 50 individuals. However, population size is known to vary substantially with seasonal conditions (see below).
3.5 How many locations do you consider the species occurs in and why? Where are these located? Note: The term 'location' defines a geographically or ecologically distinct area.

The species occurs at 18 distinct locations. While it is likely that a handful of populations were missed in large spring areas (such as on Currawinya NP and Granite Springs), these data are based on a comprehensive survey of all spring groups in the Eulo Supergroup in Qld and NSW. (Prior to the 2012 surveys, the species was known from five localities, but there were no data on population size or area of occupancy; all these known locations were visited in 2012, so the old records are not included in the table below.)

3.6 For flora, and where applicable, for fauna, detail the location, land tenure, survey date, estimated number of individuals and area of occupancy. This is optional for taxa nominated as near threatened or least concern. Summary distribution information such as a map and list of localities should be provided for taxa nominated as near threatened or least concern.

Location	Land tenure	Date of most recent survey	Number of individuals at location	Area of occupancy at location (km^2)
Fenced spring complex, Currawinya National Park, 13 km north of ranger headquarters	National Park	5/12/2012	5000	0.25
Dead Horse Spring, Currawinya National Park, 13km north of ranger headquarters	National Park	5/12/2012	300	0.04
West of Yowah Creek, Merimo	Private	16/10/2012	200	0.0008
Wooregym Bore and springs, Bingara	Private	16/10/2012	500	0.50
Fish Springs (fenced), Granite Springs	Private	18/10/2012	2000	0.25
Near Bull Spring, Granite Springs	Private	18/10/2012	200	0.25
Wiggera Spring, Granite Springs/Bingara boundary	Private	18/10/2012	200	1.00
Double Well and spring, Boorara, just south of Granite Springs boundary	Private	19/10/2012	200	0.04
Tunkata Well and spring, Boorara, just south of Granite Springs boundary	Private	19/10/2012	500	0.04
Boundary Springs, Granite Springs – Dynevor Downs boundary	Private	19/10/2012	100	0.005
Dewalla Springs, Bingara	Private	20/10/2012	50	0.20
Eulo Town Common, west of Pitherty road, 2.5 km south-west of town	Town common	20/10/2012	200	0.04
East of Shire Tank, Currawinya National Park	National Park	5/12/2012	2500	0.25
Wombula–Granite springs boundary, north-east of Tunca Spring	Private	8/12/2012	50	0.003
Yowah Creek Springs, Bundoona	Private	10/12/2012	2000	0.01

Little Bundoona Springs, Dead Sea, Penaroo	Private	11/12/2012	200	0.25
Pretty Plains Springs, Tilbooroo	Private	12/12/2012	200	0.05
1.7 km north of Eulo, on western side of Paroo River	Town Common	13/12/2012	300	0.0002

3.7 Is the species' distribution severely fragmented? If so, what is the cause of this fragmentation? Note: Severely fragmented refers to the situation in which increased extinction risk to the taxon results from most individuals being found in small and relatively isolated populations (in certain circumstances this may be inferred from habitat information). These small populations may go extinct, with a reduced probability of recolonisation
Distribution is naturally fragmented, confined to springs and their immediate surrounds.
3.8 Does the species undergo extreme natural fluctuations in population numbers, extent of occurrence or area of occupancy? To what extent and why? Note: Extreme fluctuations can be said to occur in a number of taxa when population size or distribution area varies widely, rapidly and frequently, typically with a variation greater than one order of magnitude (i.e. a tenfold increase or decrease).
The extent of occurrence and area of occupancy remain relatively constant. However, population numbers undergo large natural fluctuations in response to prevailing seasonal conditions. For example, a population on Currawinya National Park that has been visited repeatedly during the past five years fluctuates from occurring as scattered plants to forming the dominant groundcover across a couple of hectares. It seems to respond to winter–spring rainfall in particular. Nearly all mature plants in any population can die off simultaneously, and such events are usually followed by mass germination of seedlings, often under the standing remains of dead plants.
3.9 What data are there to indicate past trends in the species' population size, distribution, extent or quality of habitat? (if available, include data that indicates the percentage decline over the past 10 years or 3 generations whichever is longer)?
The collecting record does not indicate a decline in this species across its range. Transect data from the past two years inside and outside fenced areas documents substantial natural population fluctuations (see section 3.8 above), and an increase in the abundance and fecundity of the species when grazing pressure is removed. Thus it is likely that the species was more abundant prior to the introduction of feral and domestic herbivores.
3.10 What data are there to indicate future changes in the species' population size, distribution, extent or quality of habitat? (if available, include data that indicates the percentage decline over 10 years or 3 generations whichever is longer (up to a maximum of 100 years in the future) where the time period is a continuous period that may include a component of the past?
Spring habitats are extremely vulnerable to habitat degradation, through aquifer drawdown, concentrated grazing and trampling pressure, excavation and sowing of introduced pasture species (Fensham & Fairfax 2003). With the exception of grazing pressure, these impacts don't affect the habitat of *Calocephalus* sp., as it occurs in scalded country adjacent to springs which remains suitable even after damage or destruction of springs. However, concentrated pressure from goats, sheep, cattle and, to an extent, native macropods, is likely to result in continued degradation of habitat and a decline in the abundance and fecundity of the species.
3.11 Has the species been reasonably well surveyed? Is the species' current known distribution and/or population size likely to be its actual distribution and/or population size?
Eighty-six spring group, representing all but three groups in the Eulo supergroup, were surveyed between October and December 2012. Surveys were also undertaken on springs in the Bourke and Bogan River supergroups (NSW) and all supergroups in Queensland. Thus, current estimates are likely to closely reflect the actual distribution, area of occupancy and population size. However, it is probable that a small number of populations that occur in large spring areas, such as on Currawinya National Park and Granite Springs, have been missed.

3.12 For species considered eligible for listing as extinct or extinct in the wild, please provide details of the most recent known collection, or authenticated sighting of the species in the wild and whether additional populations are likely to exist.

4. Threats and threat abatement

4.1 Identify past, current and future threats indicating whether they are actual or potential. For each threat describe: a. how and where it impacts on this species b. what its effect has been so far (indicate whether it is known or suspected; does it only affect certain populations) c. what is its expected effect in the future (is the threat only suspected; does it only affect certain populations)
Habitat destruction through aquifer drawdown, excavation of habitat, elevated grazing pressure, feral pig damage and introduced pasture species are observed threats to spring-dependent species (Silcock et al. 2011). However, these impacts do not affect the persistence of *Calocephalus* sp., which grows around even long-extinct (potentially pre-European) springs. The major threat to this species is high-grazing pressure. It is highly palatable and is nearly always heavily grazed by feral animals (goats) and domestic livestock (cattle and sheep). Macropods may also contribute to this grazing pressure. In 13 of the 18 known populations, plants were heavily grazed, usually by goats and/or cattle. Plants were typically cropped to ground level, although most still had a few flowers. Ungrazed plants (usually in fenced areas) have a very different growth form to grazed plants, spreading to 40 cm tall and up to 80 cm across, and being laden with flowers. Transects inside and outside fenced areas show a clear effect of grazing on fecundity and abundance of this species in areas where grazing pressure is high. However, plants survive and can produce seedlings even under very heavy grazing pressure. Thus, the long-term effects of grazing on the persistence of this species are unknown. Ongoing monitoring of these transects will shed further light on these grazing impacts.
4.2 Where possible, provide information on threats for each occurrence/location. This is optional for taxa nominated as near threatened or least concern. Summary information should be provided for taxa nominated as near threatened or least concern.

Location/population	**Grazing pressure (as recorded October–December 2012)**
Fenced spring complex, Currawinya National Park, 13 km north of ranger headquarters	All plants outside fence very heavily grazed by goats, cropped to ground level; plants inside fenced area recovered rapidly and form dominant groundcover after winter–spring rain
Dead Horse Spring, Currawinya National Park, 13 km north of ranger headquarters	All plants outside fence very heavily grazed by goats, cropped to ground level; fence only completed in September 2012, so no signs of recovery yet
West of Yowah Creek, Merimo	Some plants grazed by goats and macropods
Wooregym Bore and springs, Bingara	Most plants heavily grazed and trampled by cattle, but some still flowering
Fish Springs (fenced), Granite Springs	Plants outside fence heavily grazed by goats and cattle, but some seedlings still present; seedlings also present inside fenced area
Near Bull Spring, Granite Springs	Some plants grazed by goats
Wiggera Spring, Granite	Plants all very dry and shrivelled at time of survey, so

Springs/Bingara boundary	difficult to assess grazing pressure
Double Well and spring, Boorara, just south of Granite Springs boundary	Some plants grazed by goats
Tunkata Well and spring, Boorara, just south of Granite Springs boundary	Some plants grazed by goats
Boundary Springs, Granite Springs – Dynevor Downs boundary	Plants look healthy/leafy, although most are heavily grazed by goats and cattle
Dewalla Springs, Bingara	Not heavily grazed
Eulo Town Common, west of Pitherty road, 2.5 km south-west of town	Very healthy, large plants, mostly ungrazed
East of Shire Tank, Currawinya National Park	Woody plants, all very heavily grazed by goats
Wombula – Granite Springs boundary, north-east of Tunca Spring	All plants grazed to <5 cm high
Yowah Creek Springs, Bundoona	All plants grazed to ground level, but some still flowering
Little Bundoona Springs, Dead Sea, Penaroo	All plants grazed to ground level by goats and sheep, but some still flowering
Pretty Plains Springs, Tilbooroo	Heavily grazed by goats and cattle; some older plants have recently died and seedlings to <3 cm (as yet ungrazed) are growing up underneath standing dead plants
1.7 km north of Eulo, on western side of Paroo River	Not heavily grazed despite high cattle grazing pressure at site; mostly young plants in population, including tiny seedlings to <3 cm

4.3 Identify and explain any additional biological characteristics particular to the species that are threatening to its survival.

None known.

4.4 Give an overview of how threats are being abated/could be abated and other recovery actions under way/proposed. Identify who is undertaking these activities and how successful the activities have been to date.

Two populations on Currawinya National Park and one population on Granite Springs have been recently fenced to exclude all large herbivores (the fenced populations are identified in Section 3.6 above). Fencing has been undertaken under a Caring for Country project led by Stephen Peck from Charleville National Parks. Permanent monitoring transects have been established inside and outside the fences to examine the effects of removal of grazing pressure on the species. Continued monitoring will shed further light on population dynamics and grazing effects.

There is a Nature Refuge agreement over the Dead Sea springs, which contains a population of the species, however, the area remains very heavily grazed by goats, macropods and sheep. Concerted and ongoing goat control across the area, through aerial mustering and targeted on-ground shooting, will alleviate much of the grazing pressure on this species. Wooregym Springs on Bingara would benefit from fencing, which would protect the *Calocephalus* and other spring endemics from grazing and trampling by cattle.

4.5 Identify key management documentation for the species (e.g. recovery plans, conservation plans,

threat abatement plans).
The species is not mentioned in the Currawinya National Park Management Plan (2001).
4.6 Are there any management or research recommendations from the documents mentioned in 4.5 or otherwise, that will assist in the conservation of the species?
No.

5. Compilers, referees and references

5.1 Compiler(s) details		
Name(s)	Ailsa Holland	
Organisation(s)	Queensland Herbarium	
Contact details		
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Date	9 October 2012	
5.2 Has this document been refereed? If so, indicate by whom		
5.3 Reference List		

Fensham RJ & Fairfax RJ 2003, Spring wetlands of the Great Artesian Basin, Queensland, Australia’, *Wetlands Ecology and Management*, vol. 11, pp. 343–62.

Habermehl MA 1982, *Springs in the Great Artesian Basin, Australia: their origin and nature*,. Bureau of Mineral Resources, Geology and Geophysics, Canberra.

Queensland Herbarium 2012, HERBRECS, specimen label information, accessed 11 October 2012.

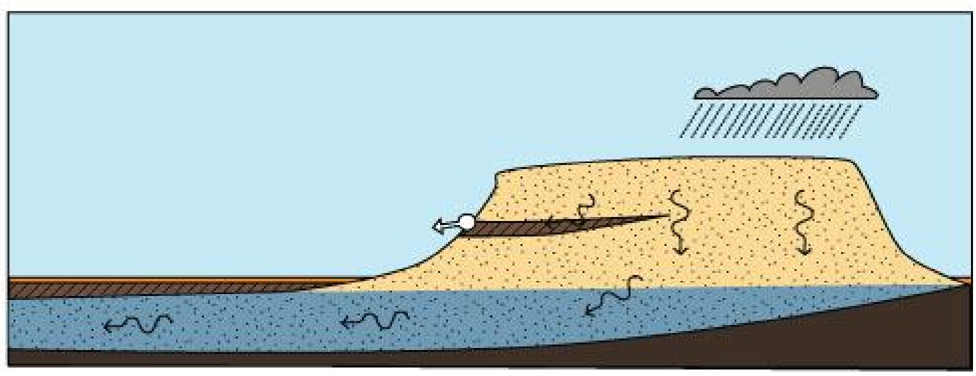
Silcock JL 2011, ‘Assessing rarity and threat in an arid-zone flora’, *Australian Journal of Botany*, vol. 59, pp. 336–50.

Appendix E: Conceptual diagrams of Great Artesian Basin spring types

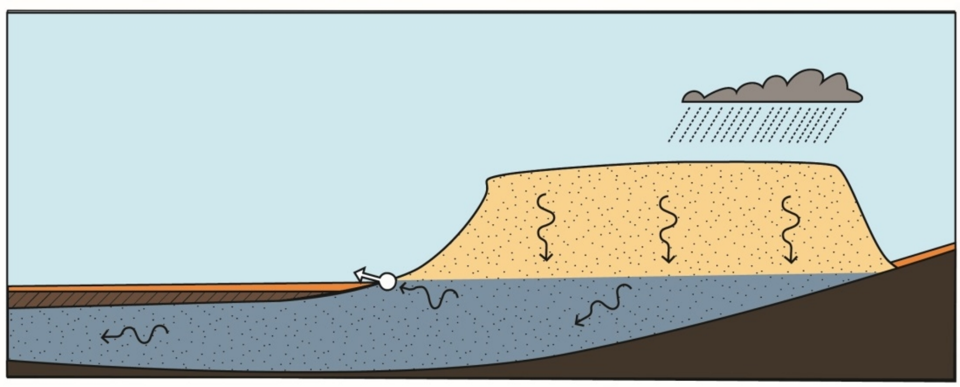
For all diagrams:

EPBC = *Environment Protection and Biodiversity Conservation Act 1999* (Cwlth)

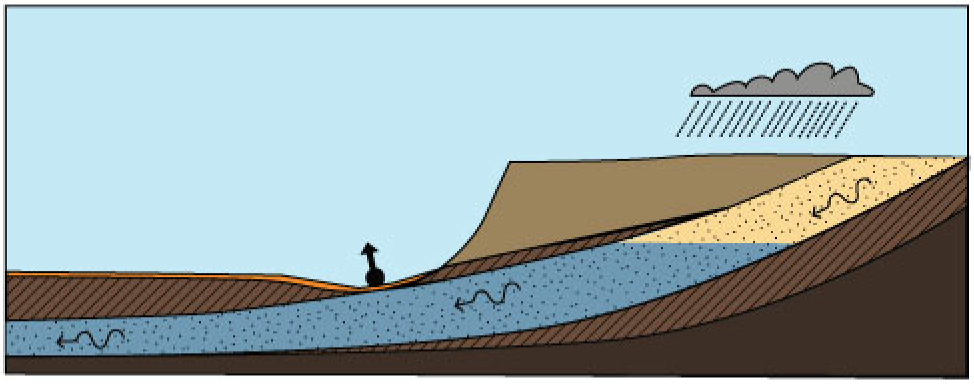
GAB = Great Artesian Basin.



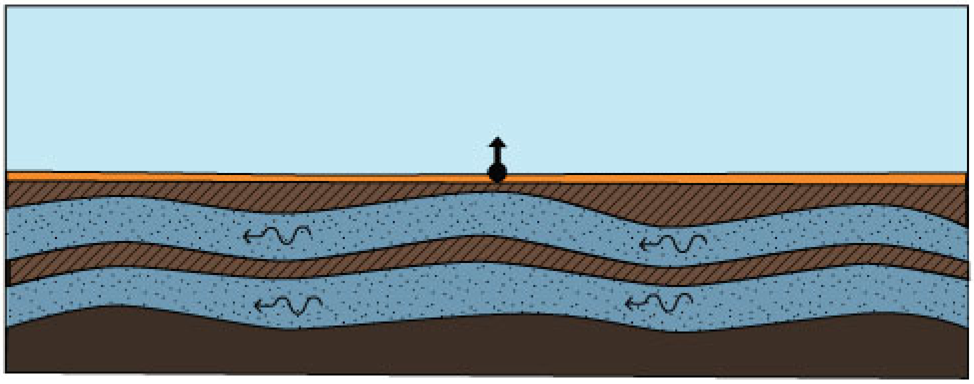
Type A. Springs emanating from outcropping sediments of the GAB. Water is not flowing to the spring under aquifer pressure. Water flows to the spring either along low-permeability layer or through a fracture. These springs occur in areas of high relief in the landscape and springs (GAB springs, but not EPBC listed).



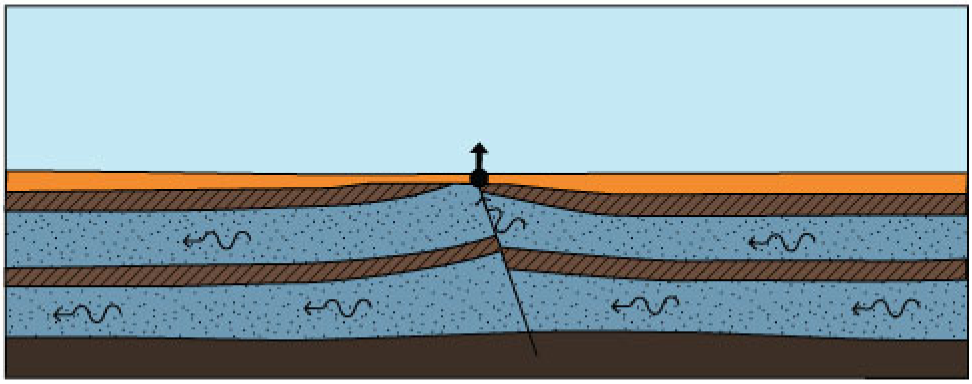
Type B. Spring emanating from outcropping sediments of the GAB where the saturated zone of the aquifer (watertable) intersects with the ground surface. These springs are in gullies or valleys. (GAB recharge springs, not EPBC listed) .



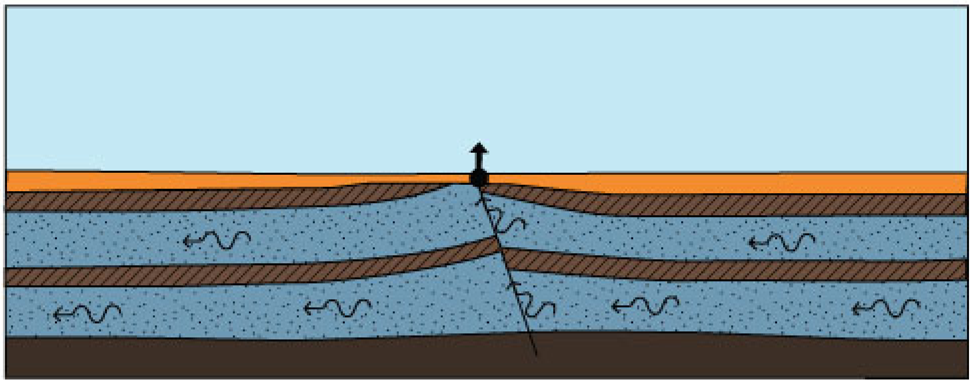
Type C. A discharge spring where the confining layer (aquitard) has been thinned by erosion and the underlying artesian aquifer is able to flow to the surface (GAB springs, EPBC listed).



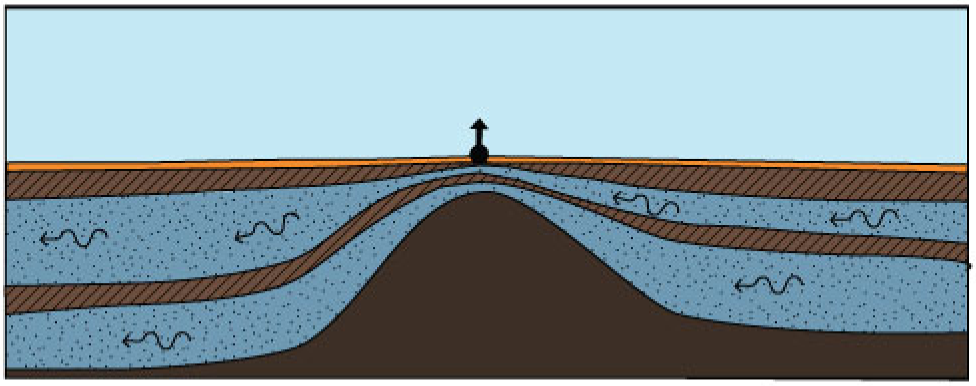
Type D. Discharge spring resulting from an anticline or a monocline elevating the aquifer relative to the surface (GAB springs, EPBC listed).



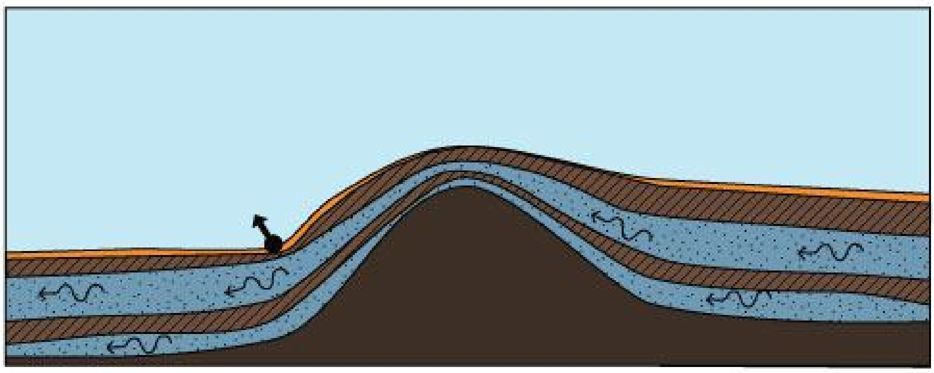
Type E. Discharge spring emanating from uppermost artesian aquifer through fault (GAB springs, EPBC listed).



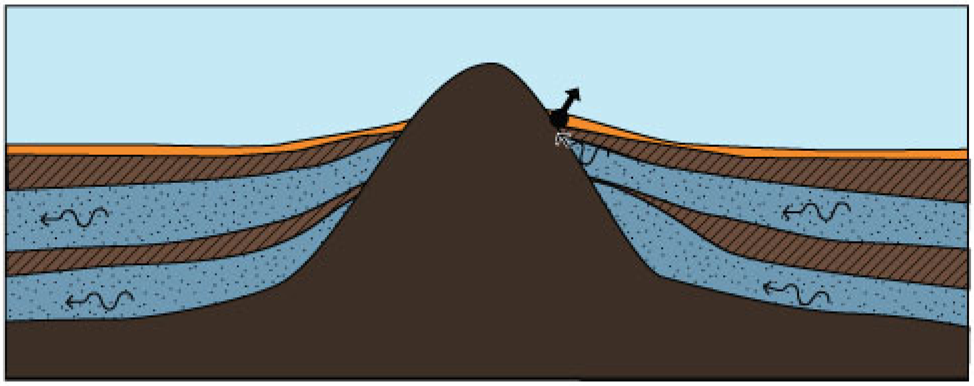
Type F. Discharge spring emanating from deep artesian aquifer where the fault is sufficiently transmissive to allow discharge from sequences beneath the uppermost aquifer layer (GAB springs, EPBC listed).



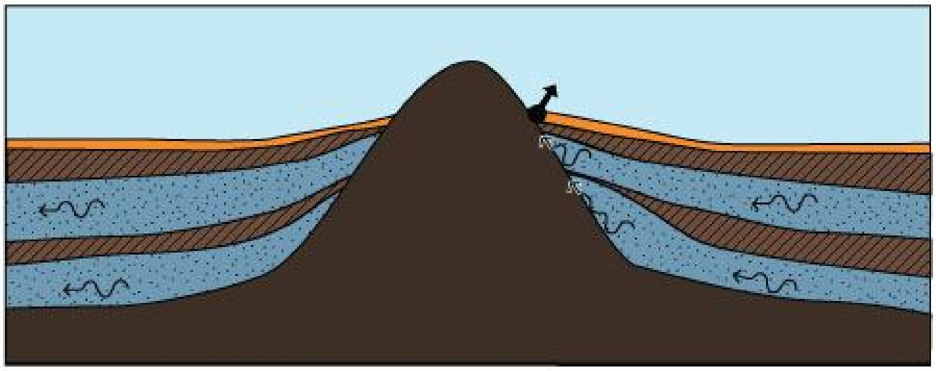
Type G. Discharge spring occurring on the top of the basement dome, ridge or platform, where the aquitards has been weakened or fractured (GAB springs, EPBC listed).



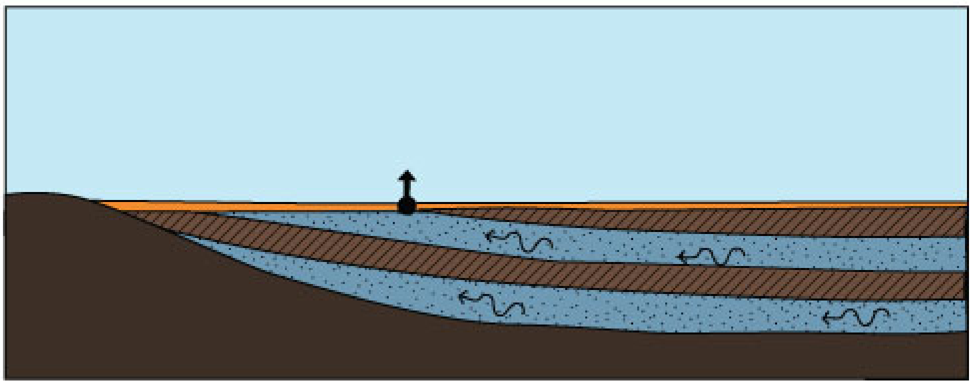
Type H. Discharge spring associated with weakness or thinning, and possibly the fracturing of the aquitard associated with basement structure (GAB springs, EPBC listed).



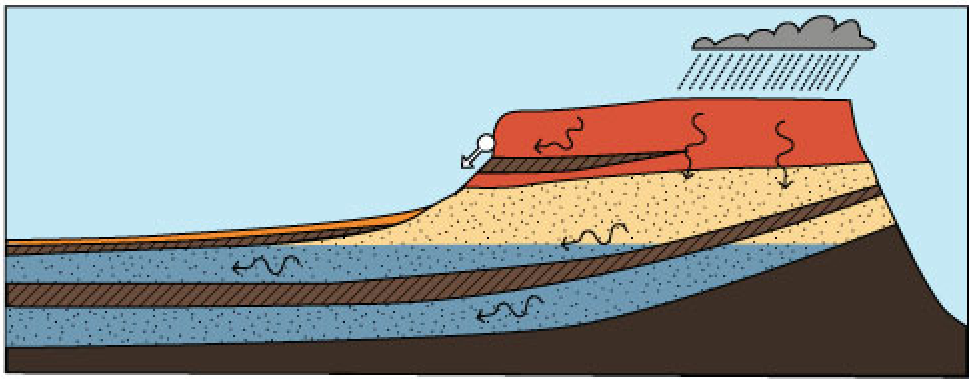
Type I. Spring emanating from contact between onlapping sediments and outcropping basement where the groundwater source is the upper-most aquifer (GAB springs, EPBC listed).



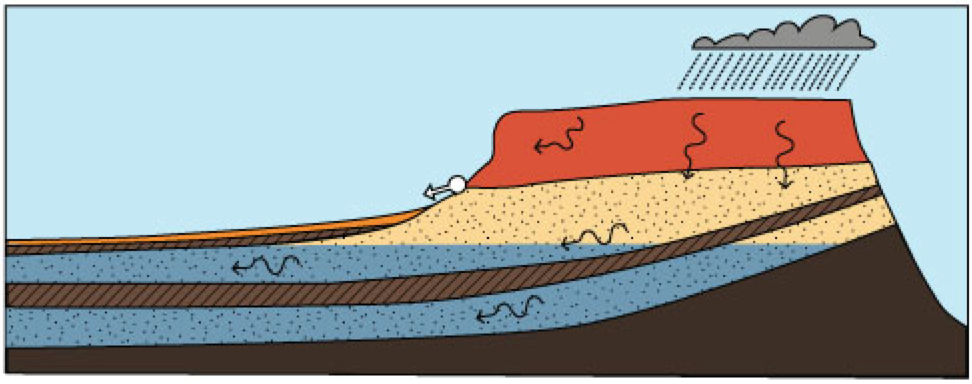
Type J. Spring emanating from contact between onlapping sediments and outcropping basement with mixing of the groundwater from multiple aquifer sequences (GAB springs, EPBC listed).



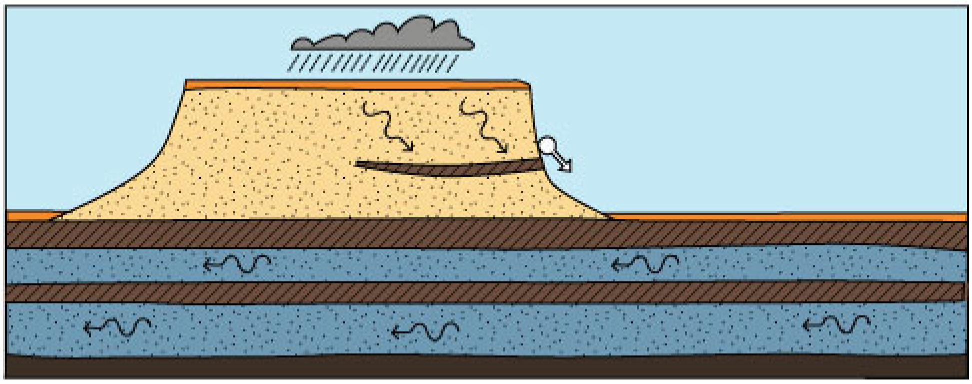
Type K. Spring emanating from downgradient (western or southern) edge of the GAB (GAB springs, EPBC listed).



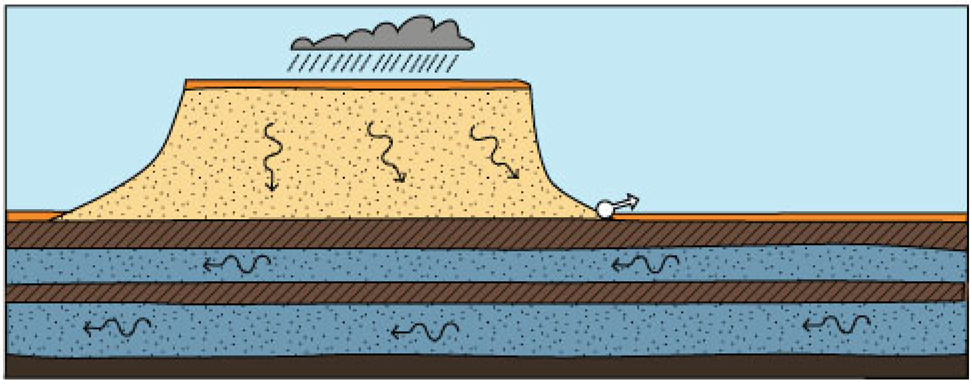
Type L. Springs emanating from within volcanic capping above outcropping sediments, often from porous layers in the basalt (non-GAB springs, not EPBC listed).



Type M. Springs emanating from contact between volcanic capping and outcropping sediments (non-GAB springs, not EPBC listed).



Type N. Springs emanating from within Tertiary sandstone overlying the GAB. Water flows to the spring either along a low-permeability layer or through a fracture (non-GAB springs, not EPBC listed).



Type O. Springs emanating from the base of Tertiary sandstone where it contacts the confining layer above aquifer sediments (non-GAB springs, not EPBC listed).