Groundwater

Historical Note/

Oases to Oblivion: The Rapid Demise of Springs in the South-Eastern Great Artesian Basin, Australia

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Introduction

Since the advent of powerful rock boring equipment in the late nineteenth century, ground water extraction for towns, mining, and agriculture has had significant impacts on aquifers across the globe. In areas where surface water is scarce, human demands on artesian supplies have been particularly acute, demonstrated by declines in the pressure surface of aquifers and subsequent loss of artesian springs. The springs and the wetlands they support have important natural values, providing habitat for specialized plants and animals, many of which are endemic to their idiosyncratic habitat (Ponder 1986; Patten et al. 2008). Springs are also significant cultural places, embodying traditional folk-lore, and mythology (Idris 1996; Park and Ha 2012) and supporting settlements along ancient trade routes (Aldumairy 2005). While the exploitation of groundwater and loss of springs, together with their natural resource and cultural values, has been repeated across the continents from Australia (Fairfax and Fensham 2002), the United States (Keleher and Rader 2008; Brune 1981), China (Jiao 2010) and North Africa (Roberts and Mitchell 1987; Idris 1996) there have been few comprehensive historical studies which piece together the details of their decline.

In recent decades there have been attempts to resurrect the forgotten cultural history of the Australian Great Artesian Basin (GAB) springs. There are broad cultural and historical examinations of the GAB, its folk-lore and its significance to the historical geography of central Australia (Powell 2012; Powell 1991; Blake and Cook 2006) however, these studies pay limited attention to springs. The position and status of lost springs have been reconstructed in some regions (Fairfax and Fensham 2002; Fensham and Fairfax 2003; Pickard 1992) but these studies do not reveal their cultural significance prior to when many of them became extinct. A study of the South Australian mound springs highlighted their biological values, significance to indigenous people as well as their critical role in European exploration, pastoralism, and the establishment of the trans-continental telegraph line (Harris 1981), but there was little systematic analysis of how the springs were affected by the exploitation of groundwater.

This article identifies both the cultural significance of the springs under European management as well as the processes that brought about their demise. In charting transformation of springs from “oases to oblivion” this article illustrates the critical role the springs played, not only in supporting human occupation of the semi-arid zone, but in facilitating nascent understanding of the GAB and groundwater processes, which finds parallels in other colonial settings (Davis and Davis 1997). The largely forgotten cultural and economic significance of the springs is resurrected and, in so doing, illuminates a watershed period in Australian environmental history concerning the development of one of the world’s largest artesian basins.

Hydrogeology and Springs

The GAB underlies approximately 22% of the Australian land mass (Figure 1). Comprised of quartzose sandstone of late Triassic to early Cretaceous age, aquifers are confined by alternating layers of marine mudstone and siltstone (Herczeg et al. 1991). Water enters the basin along uplifted sandstone intake beds located mainly along the eastern margin. Water percolates slowly through the sandstone aquifer and groundwater in the furthest extremities from the intake beds have been dated from 200,000 to more than 1 million years (Bentley et al. 1986; Torgersen et al. 1991; Collon et al. 2000; Lehmann et al. 2003). Prior to the development of the Basin

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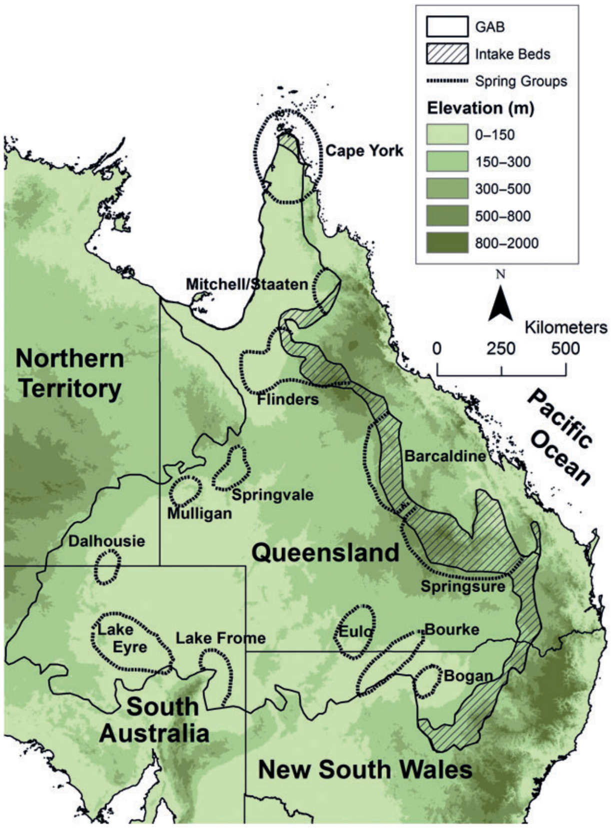

Figure 1. Great Artesian Basin, showing spring supergroups and recharge areas along elevated outcrops. The supergroups discussed in this paper include Bogan River, Bourke, and Eulo.

and proliferation of bores, springs provided a natural outlet for the GAB. Clustered in so-called "supergroups" (Habermehl 1982), GAB springs emerge along the edges of the basin, near Palaeozoic intrusions and through fault lines which breach the confining layers (Rade 1954).

This study area comprises the south-eastern portion of the GAB including the Eulo, Bourke, and Bogan River supergroups (Figures 1 and 2). Since European settlement in the mid-19th century, economic activity has focused mainly on the grazing of sheep, cattle and, more recently, goats. The region is semi-arid with mean rainfall ranging from 300 to 500 mm per annum. There are also aquifers in the Tertiary sandstone overlying the GAB, and some of these outcrops have perennial springs.

Apart from the springs, natural permanent surface water is restricted to the south, east, and northern extremes of the study area. The Darling River is a permanent downstream from Brewarrina. The Warrego River supports numerous permanent waterholes (here defined as those which have not gone dry since pastoral settlement; see Fensham et al. 2011) although the stream dissipates into anabranches south of Cunnamulla. Cuttaburra Creek diverts flood waters from the Warrego River and forms just two permanent waterholes in New South Wales (NSW). The Paroo River contains just three permanent waterholes between Eulo and Hungerford. During floods, the Warrego and Culgoa may flow and join the Darling River, while Cuttaburra Creek and the Paroo River terminate in extensive floodplains and ephemeral lakes.

Groundwater History

Indigenous History

Throughout the study area, Aboriginal hunting, gathering, and ceremonial activities were concentrated along watercourses and pathways linking permanent water (Humphries 2007; McKellar 1984) while dispersal was facilitated by intermittent rainfall, shallow native wells, and a sparse networks of springs. Archeological investigations at Youleen Springs (Robins 1995) and Cuddie Springs (Field 2006; Trueman et al. 2005) revealed utilization extending back to the Pleistocene.

Many springs and waterholes throughout the study area have retained their Aboriginal names, or at least anglicized versions, although their precise meaning and stories seem to be lost. Aboriginal people considered springs to be the creation of powerful spirits and ancestral beings and thus possessed potent spiritual and cultural meaning. One Aboriginal narrative asserts that the "Yanta" spirits saw people dying during drought and sought to protect mankind by excavating springs across the landscape (Langloh 1905). The spirits began at Yantabulla springs which are purportedly named after them (Langloh 1905), though some accounts suggest that Yantabulla means "stones around a spring" (Geographical Names Board NSW 2013). The "Yanta" then went out to the "Kinggle" Plain to create a permanent lake, however gradually died of exhaustion. "Kinggle" is an obscure, unknown place name which does not appear on any maps. According to Langloh (1905) Aboriginal people would no longer cross this plain for fear of disturbing their graves "resting above the springs" (Langloh 1905).

According to one account the Aboriginal etymology of Cuddie Spring meant "bad water" though it was also conceded that this word may have been applied to a number of locations in the Brewarrina district (Abbott 1881). During an archeological investigation at Cuddie Springs in the 1930s (Anderson and Fletcher 1934), an Aboriginal legend was recounted which explained the fossilized bones of extinct giant marsupials found in the spring (Field 2006; Trueman et al. 2005) 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, wither 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

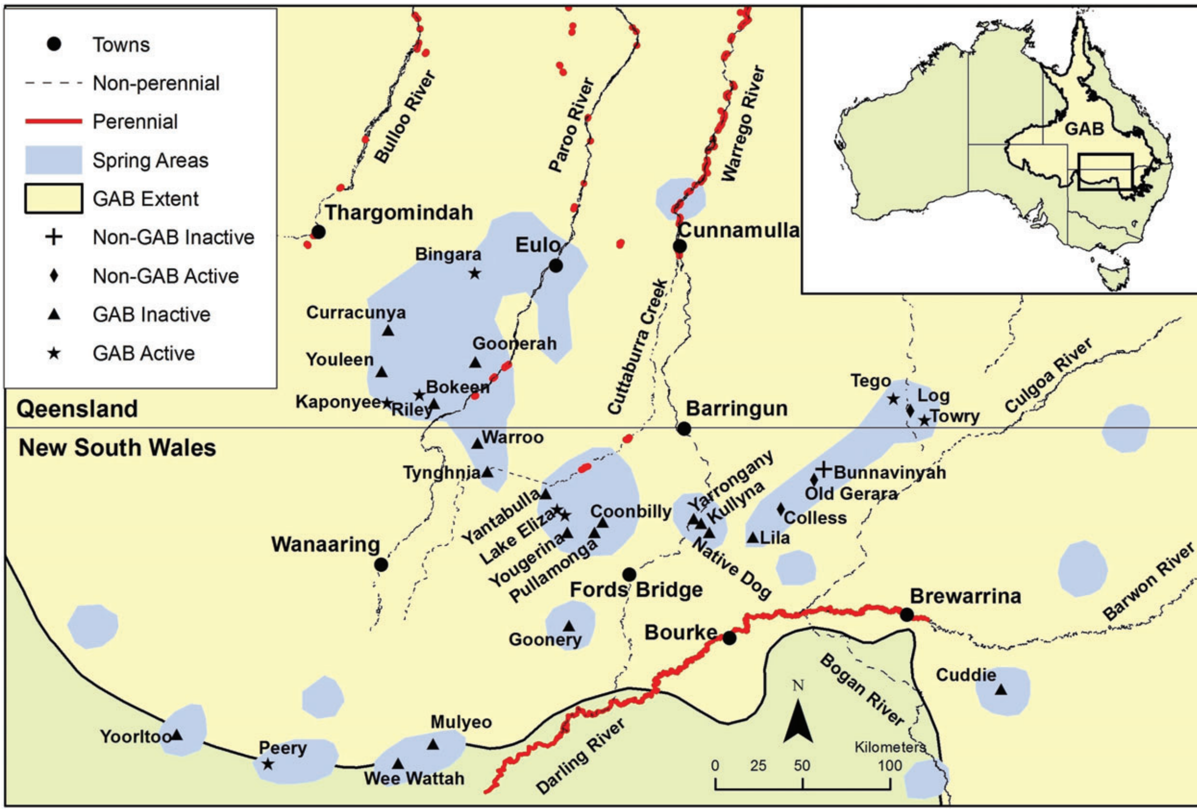

Figure 2. The study area showing the extent of the GAB, non perennial streams, surface water and spring areas and springs mentioned in the text.

> 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.

As places of intense economic and cultural activity, it is not surprising that springs are rich sites of indigenous material culture. Artifact scatters consisting of stone flakes, cores, grindstones, axes, and hearths are typically associated with scalded areas and claypans adjacent to springs, which partly reflects their obvious visibility in these landscapes (Robins 1993). The field records of the authors reveal especially rich and dense surface archeology on the groundwater scalds surrounding Coonbilly, Goonery, Kullyna, Lake Eliza, Warroo, Peery Lakes, and Native Dog Springs in New South Wales and at 30 spring groups in Queensland, including Bokeen, Kaponyee, Riley and Youleen as documented by Robins (1993).

Exploration and Early Settlement

In 1828, Charles Sturt explored the Darling River along its permanent reaches during a severe drought whereby its diminished level enabled him to observe brackish seepage discharging into the river (Sturt 1982). Sturt's record of the parched landscape and unpotable waters created an unfavorable impression which discouraged immediate settlement of the area. Thomas Mitchell explored the Darling River Region in 1835 and 1836, however, his instructions were to establish its southern outlet to the ocean and he therefore ignored the dry country to the north (Mitchell 1839). In 1847, Edmund Kennedy traced the Warrego River south until it ran dry below Cunnamulla, forcing him to make a desperate march without water to the Culgoa River (Beale 1983). European pastoralists followed the eastern tributaries of the Darling River and began selecting land in the 1850s, concentrating their runs along the reaches of permanent and semi-permanent water (Heathcote 1965) (Figure 2).

The artesian springs provided the only perennial water source between the Darling River and the enduring waterholes on the ephemeral streams in southern Queensland (Figure 2) and were important stepping stones for the pioneering squatters. Thomas Dangar was one of the first who established a station on a waterhole of the Warrego River to the north of Cunnamulla in 1859. Kullyna Spring was a "perfect oasis in the desert" (Anon 1868) and, during one dry period, a local Bourke correspondent commented that "were it not for the springs on this route [Native Dog, Yarrongany, and Kullyna], all communication with the north must stop" (Anon 1865).

While conducting explorations into Queensland's Paroo and Bulloo River country in 1861, Vincent Dowling discovered several springs including Yantabulla where he later established a station (Dowling 1861). In the early 1860s, while prospecting west of the Darling River, Bloxham (1885), found Goonery Springs, which would later form a link to the lower Paroo River. In 1865, John Costelloe and his family drove 200 cattle and 15 horses through the dry country north-west of Bourke relying on a depot at "Warroo Springs" (O'Neill 1969). This later became a launch pad for his family's expansion into Queensland's channel country and the foundation of a vast pastoral empire (Durack 1959).

Artesian springs became sites of towns and isolated "bush shanties," as well as the basis for early stock routes which later became main roads. The Bourke-Hungerford road traces a line of springs once followed by historical luminaries including Dowling, Costelloe, the celebrated "bush poet" Henry Lawson, as well as countless unknown shearers and swaggies. The Bourke-Wanaaring road leads directly to Goonery Springs before turning north-west to the Paroo River. The Bourke-Barringun-Cunnamulla route leads directly to Native Dog Springs and passes within 2 km of Kullyna Spring. Queensland's 4 mile map series from 1913 shows the original Brewarrina-Cunnamulla road following Towry, Log, and Tego Springs. This road no longer exists, but old wagon tracks are still visible in places.

Vincent Dowling's homestead at Yantabulla became a hotel and by 1887 a town plan depicted neatly gridded streets based around numerous springs (Figure 3). The "Whip Spring" with a wetland of roughly 2023 m^2 (Gilliat 1885) was probably the most important source of water, but another spring, yielding a supply estimated to be 600 to 700 buckets per day, watered a Chinese market garden (Gilliat 1885). In the early 1880s, the Youngerina Hotel, named after the local spring, was established along the side of the Bourke-Hungerford road (Anon 1932). Lake Eliza is thought to contain several muddy soaks supported by artesian water (Pickard 1992). There was a hotel at one point (Anon 1961) and while not mentioning the springs this "lonely pub in mulga scrub" featured in Henry Lawson's poem "Lake Eliza" (Lawson 1893). In search of the lost explorer Ludwig Leichhardt, in 1865 Duncan McIntyre followed the Paroo River and camped at Curracunya Spring (Anon 1866) which became a mail stop and later a small township with an inn. An inn and small settlement also existed at Tego Springs. A well was sunk adjacent to the main spring (Ogilvie 1911) and this water supplied a Cobb & Co station, post office, and numerous houses.

Financial investment in fledgling pastoral operations in the 1860s and 1870s accelerated pastoral development (Cain and Com 1962). Artesian springs were immune to the ravages of drought and were critical assets within the burgeoning enterprise of tanks, dams, wells, stockyards, buildings, and roads, as well as hundreds of miles of new fencing. The soupy substrates of springs were a death trap for stock and their supplies were often limited. Excavations, trenches, and shafts were necessary to redirect and increase their flows.

Cuddie Spring was described as a "bog hole" which never dried up "even in the greatest of droughts" (Abbott 1881), however, during one dry period in the late 1870s, the area dried sufficiently to enable the local manager to fence the spring and sink a well. This first excavation revealed that numerous sheep, cattle, and horses had suffered the same fate as the Australian mega-fauna that preceded them (Abbott 1881; Anderson and Fletcher

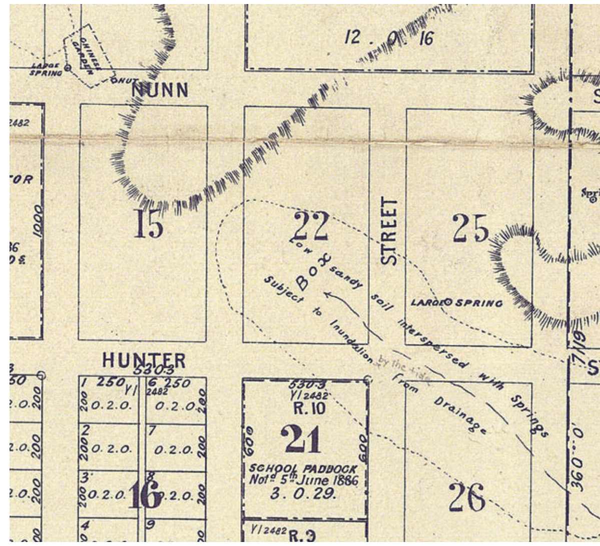

Figure 3. Town plan of Yantabulla depicting numerous springs including 'Chinese Garden' near a 'large' spring (source: Yantabulla Town Plan, 1887, Land and Properties Information, NSW Government).

1934). The water rose to the surface at the rate of 11,365 L/day and was channeled to stock on firmer ground (Abbott 1881).

Youngerina was one of the largest springs along the Bourke-Hungerford route comprising an area of 80.5 m^2 and rising in a 0.9-m mound. After installing shafts and trenches the estimated flow was between 6819 and 8183 L/day (Gilliat 1885). After discovering Goonery Springs, E.J. Bloxham excavated detritus from a hole he found in a mound of reeds. Although it was "a splendid looking spring" supporting a lush wetland, it could only fill a 200 gallon (909 L) cask in 24 h (Bloxham 1885). Later "improvements" to Goonery and Lila Springs meant that both were capable of watering around 8000 sheep in any season (Kelly 1882). Evidence of European attempts to increase spring flow is still evident in the excavated Tertiary sandstone around Old Gerara and Bunnavinya Springs.

Signposts to the Aquifer

Aboriginal people had strong prescriptions for the sustainable exploitation of resources as well as profound reverence of watering places. Under European management, focus shifted from the sacred to the utilitarian, but the Europeans created their own secular story with the "discovery" of the artesian water source (Powell 2012). The exploitation of artesian springs by pastoralists, in conjunction with sinking shallow wells, identified the extent of groundwater supplies as well as highlighting the influence of local geology on both water quality and quantity. Throughout the study area, shallow groundwater associated with unconsolidated Cainozoic stratum is often brackish (Williams et al. 1994). The fresh, potable sources of water from the artesian springs indicated that another more substantial source of groundwater might exist at greater depth.

At Yantabulla, shallow wells encountered salty water until a deeper well sunk to 12.2 m on the site of a dormant spring "bottomed out in a sandy drift," with fresh water rising 3 m from the surface yielding approximately 682 L/day (Gilliat 1885). At Warroo Springs the manager sank a 6-m shaft and encountered brackish water, but struck a good supply at 18 m depth (Gilliat 1885). Tynghynia Springs was described as yielding an excellent supply sufficient for a boundary rider's hut though a nearby well yielded salt water from a "white drift and water worn boulders" (Gilliat 1885).

With the introduction of shallow boring plants in the region (see Wood 1883), springs signposted access points to the artesian aquifer. The first deep bore came about through a private drilling operation at Wee Wattah Springs (Figure 4) on Killara station south-west of Bourke in 1878 (Wilkinson 1882; Percy 1906). At a depth of 43 m, the bore initially yielded 326,880 L/day until the shaft became choked with sand and flows diminished. At Mulyeo Spring, also on the Killara holding, four bores were put down though three were later abandoned due to their low supply (Wilkinson 1882). On Dunlop station, a government bore contractor described his intention to sink a shaft at Goonery Springs along the Bourke-Wanaaring Track in which he felt "not the slightest doubt that we will get the artesian water at 100 feet [30.5 m]" (Anon 1883).

During the NSW Royal Commission of Water, considerable evidence was collected on springs and bores, contributing to a fledgling understanding of the artesian system in north-west NSW. The Superintendent of Diamond Drills, reported that the artesian water from the bore at Goonery Springs came from three different levels, the last being from a "blue gray flinty-sandstone" (Henderson 1885). The formation of the springs was associated with a shallow granite basement at 58.5 m which forced water "through the weak points in the clay" (Ford 1885). The government geologist, H.L. Brown, argued that all of the mud springs in the district were in the "same position geologically, the water coming from below the Cretaceous marl and shale deposit which occupies so large a portion of the country" (Brown 1885). Wilkinson (1885) recognized that the Cretaceous formation was of "great importance" and made the prescient suggestion that deep bores could supply the entire district in the future. The Bourke district surveyor, Edward MacFarlane, noted that the springs of north-west NSW ran a general line south-west to north east, which roughly describes the general layout of the Bourke Supergroup (Figures 1 and 2). Indicating the extent of the GAB, he reported that similar artesian flows south of the Darling River were unknown (MacFarlane 1885).

Figure 4. A low mound and carbonate scald 70m south-east of Wee Wattah bore possibly represents the site of the original spring. The raised area on the left horizon is the site of the bore.

Discovering the GAB

Early artesian wells and bores were only modest improvements on springs, due to the lack of experienced bore contractors and technological limitations, as well as the prohibitive costs of deep drilling beyond the upper Cretaceous layers (Powell 2012). Powerful machines had been developed in North America (Darley 1884), but conservative public servants were skeptical of the value and highlighted the risks of introducing cumbersome and expensive plants to the remote districts (Henderson 1885). Severe drought and ambitious private investment, however, eventually provided the catalyst for discovering "secure" artesian supplies. This was a high risk enterprise because bore drilling operations had not ventured from the immediate vicinity of the springs where reliable supplies at relatively shallow depths seemed almost guaranteed.

In 1886, the year after the Queensland Government's failed attempt to establish a deep test bore in central Queensland, a private contractor on the Thurulgoona property, north-west of Barringun, used a large North American style rig and struck a supply of 363,680 L/day at just over 305 m (Powell 2012). The success on Thurulgoona was quickly mirrored across the NSW border as the managers of the Kerribree Station sank the first "deep," artesian bore in NSW at a depth of 310 m yielding a supply of 1,636,592 L/day (Anon 1888). The Kerribree No. 2 bore watered a fruit orchard and a paddock of cereals while the fourth bore yielded a supply of 7,273,774 L/day (Anon 1892).

The deep bore logs (Figure 5) generated a better understanding of the GAB as well as its potential for broad scale exploitation (David 1893; Symmonds 1912; Cox 1902). It was reasoned that Palaeozoic rocks probably formed a barrier to the southern outlet of the GAB in NSW and that the springs often occur along the junction of the Cretaceous strata and bedrock which "formed the margin of the Cretaceous ocean" (David 1891). A similar observation associating springs with the edge of the Basin (e.g., Wee Wattah, Mulyeo, and Peery Lakes) was made during the First Interstate Conference on Artesian water in 1912 (Pittman et al. 1913). Because the springs occurred at the margins of the basin or near granite intrusions, bores drilled in their vicinity were generally found to yield modest supplies (Pittman and David 1903). The fossils from deep bores located further from the basin's

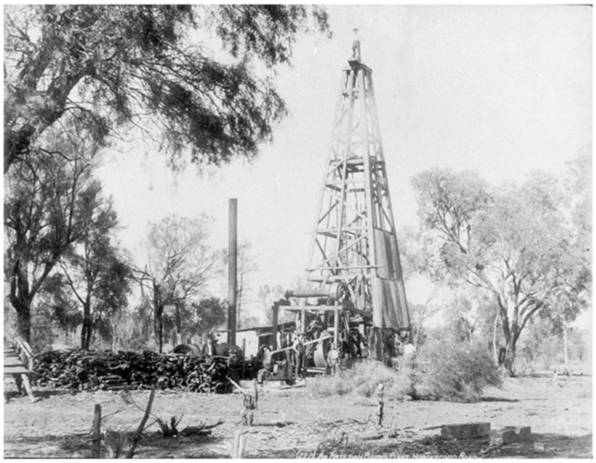

Figure 5. Drilling rig located along the Bourke-Hungerford road c.1895. This road once followed a line of springs which are now mostly inactive (source: State Library of NSW, item 03632).

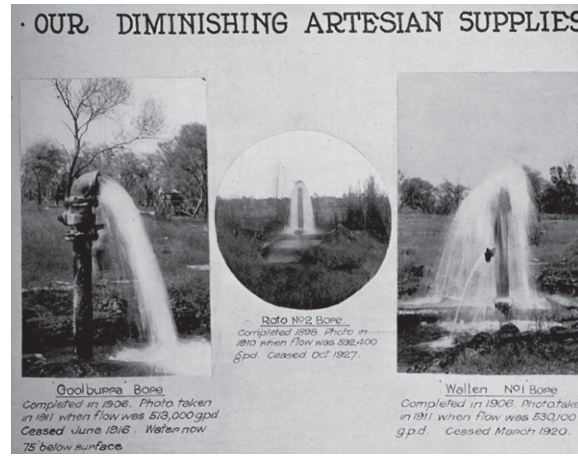

Figure 6. Diminution of artesian supply from select bores in the Warrego River and Paroo River region (source: Queensland Artesian Water Investigation Committee 1955).

Figure 7. Abandoned houses in the old township of Yantabulla, once the site of numerous active springs.

edge subsequently revealed artesian water to be derived from sedimentary layers other than the Cretaceous leading to speculation that the "porous strata of the Trias-Jura formation may constitute the *chief* storage beds of the artesian water supply of Australia" (Pittman 1895).

Oases to Oblivion

Through mostly private investment, artesian bores proliferated (Powell 2012) and water was diverted into miles of excavated bore drains which opened up vast stretches of new grazing country. Much of the water was wasted through seepage and evaporation. By the turn of the 20th century, surface pressures across the south-eastern portion of the GAB declined significantly (Pittman et al. 1913). Overshadowed by diminishing supply from bores and, in some cases, complete bore failure (Figure 6) records for the extinction of springs are scant. Wee Wattah Spring included a wetland of 12.2 m diameter (Wilkinson 1882), and ceased immediately after the nearby bore was established (Pittman and David 1903) while Cuddie Springs suffered a similar fate when a local bore was put down at the turn of the 20th century (Anderson and Fletcher 1934). As the bores diminished aquifer pressure, springs flows declined or ceased throughout the district (Figure 2). A recent survey by the authors revealed that around 55% of spring groups across the Eulo, Bourke, and Bogan River supergroups have been rendered inactive due to groundwater extraction, while many of the remaining springs have diminished in flow. Just 13 spring groups in NSW and 47 in Queensland remain active (see Table S1).

The extinction and declining relevance of springs is graphically illustrated by their abandonment and gradual disappearance from the modern cartographic record. Deserted houses (Figure 7), as well as extensive scatterings of Aboriginal and European cultural artifacts indicate that Yantabulla was once nourished by numerous springs but they are not indicated on current maps. The remains of old woolsheds can be found at Old Gerara and Pullamonga springs. The vestiges of a tumbled down hut lie beside the Tertiary Colless Spring. The stone ruins of Youldoo homestead and abandoned well sit on a barren rise above the inactive Yourltoo Spring, while abandoned outstations mark the sites of Goonerah, Old Bingara, and Bokeen springs in Queensland. The old shanties and road side settlements similarly faded from history as the springs dried up and new forms of mechanized transport reduced the need for stop overs when traveling across the vast distances of dry country.

Under the Great Artesian Sustainability Initiative (GABSI) and other related bore-capping programs, considerable progress has been made in restoring aquifer pressure. By mid-2008, more than 1000 bores had been controlled across the GAB and close to 17,700 km of earthen drains have been replaced with pipe, resulting in estimated water savings of around 284 GL per year (GABCC 2009).

Previously "subartesian" bores have begun flowing again in south-west Queensland (see Powell 2011). However, much work remains to be done to close the remaining network of open bores. As this important project progresses it is plausible that springs may also be reactivated, but there is no evidence of springs returning from "oblivion to oases" yet. The rapid demise of the springs across the south-eastern GAB is a powerful illustration of the dramatic transformations that have occurred within dry land environments over the last century.

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Supporting Information

Additional Supporting Information may be found in the online version of this article:

Table S1. Activity and spring attributes in the Bogan, Bourke, and Eulo Supergroups.

References

Abbott, W.E. 1881. Notes of a journey on the Darling. *Journal and Proceedings of the Royal Society of NSW* 15: 41–70.

Aldumairy, A. 2005. *Siwa: Past and Present*. Alexandria, Egypt: Yasso.

Anderson, C., and H.O. Fletcher. 1934. [title illegible] *Nambour Chronicle and North Coast Advertiser*, February 16, 1934, 2. http://trove.nla.gov.au/ndp/del/page/7640898?zoomLevel=1 (accessed November 20, 2013).

Anon. 1932. The old pioneering days: In the years when Bourke was young. *The Land*, September 30, 1932, 24. http://trove.nla.gov.au/ndp/del/page/11237115?zoomLevel=1 (accessed November 20, 2013).

Anon. 1883. Water prospecting by boring. *Australian Town and County Journal*. http://trove.nla.gov.au/ndp/del/page/5054983?zoomLevel=1 (accessed November 20, 2013).

Anon. 1892. Bourke. *Australian Town and Country Journal*, 29 October, 1892, 13. http://trove.nla.gov.au/ndp/del/page/5236865?zoomLevel=1 (accessed November 20, 2013).

Anon. 1888. Water struck on Kerribree Run. *Sydney Morning Herald*, November 24, 1888, 15. http://trove.nla.gov.au/ndp/del/page/1388274?zoomLevel=1 (accessed November 20, 2013).

Anon. 1868. The Upper Darling and the Warrego. *The Queenslander*, 10 April, 1868, 8. http://trove.nla.gov.au/ndp/del/page/2049229?zoomLevel=1 (accessed November 20, 2013).

Anon. 1866. The Leichhardt Expedition [from the Riverine Herald], April 6, 1866, 3. *The Sydney Morning Herald*. http://trove.nla.gov.au/ndp/del/page/1472014?zoomLevel=1 (accessed November 20, 2013).

Anon. 1865. Bourke. *The Maitland Mercury and Hunter River General Advertiser*, March 28, 1865, 3. http://trove.nla.gov.au/ndp/del/page/140027?zoomLevel=1 (accessed November 20, 2013).

Anon. 1961. All those Hotels. *Western Herald*, May 12, 1961, 11. http://trove.nla.gov.au/ndp/del/page/10637501?zoomLevel=1 (accessed November 20, 2013).

Beale, E. 1983. *Kennedy the Barcoo and Beyond 1847*. Hobart, Australia: Blubber Head press.

Bentley, H.W., F.M. Phillips, S.N. Davis, M.A. Habermehl, P.L. Airey, G.E. Calf, D. Elmore, H.E. Gove, and T. Torgersen. 1986. Chlorine 36 dating of very old groundwater: 1. The Great Artesian Basin, Australia. *Water Resources Research* 22, no. 13: 1991–2001.

Blake, T., and M. Cook. 2006. *Great Artesian Basin Historical Overview*. Brisbane, Australia: Queensland Government Natural resources, Mines and Water.

Bloxham, E.J. 1885. Royal Commission of Water: Evidence of Mr. E.J. Bloxham. *Votes and Proceedings of the Legislative Council* 6: 762–767.

Brown, H.Y.L. 1885. Royal Commission on Water: Evidence of Mr H.Y.L. Brown. *Votes and Proceedings of the Legistlative Council* 6: 413.

Brune, G. 1981. *Springs of Texas*. Austin: Texas A&M University Press.

Cain, N., and B. Com. 1962. Companies and squatting in the Western Division of New South Wales. In *The Simple Fleece Studies in the Australian Wool Industry*, ed. A. Barnard, 435–456. Melbourne, Australia: Melbourne University Press.

Collon, P., W. Kutschera, H.H. Loosli, B.E. Lehmann, R. Purtschert, A. Love, L. Sampson, D. Anthony, D. Cole, B. Davids, D.J. Morrissey, B.M. Sherrill, M. Steiner, R.C. Pardo, and M. Paul. 2000. 81Kr in the Great Artesian Basin, Australia: A new method for dating very old groundwater. *Earth and Planetary Science Letters* 182, no. 1: 103–113.

Cox, W.G. 1902. The Artesian water-supply of Australia from a geographical standpoint. *The Geographical Journal* 19 no. 5: 560–571.

Darley, C.W. 1884. *Notes on Drilling and Boring Artesian Wells: As Practiced in the United States of America*. Sydney, Australia: Thomas Richards, Government Printer.

David, T.W. 1893. Notes on Artesian water in New South Wales and Queensland. *Journal and Proceedings of the Royal Society of NSW* 27: 408–443.

David, T.W. 1891. Artesian water in New South Wales. *Journal and Proceedings of the Royal Society of NSW* 25: 286–296.

Davis, S.N., and A.G. Davis. 1997. Saratoga Springs and early hydrogeochemistry in the United States. *Ground Water* 35, no. 2: 347–356.

Dowling, V. 1861. Vincent J. Dowling papers, 1859–1861; Exploration and rough survey of the Paroo River in 1861. Manuscript 1643, Mitchell Library, Sydney.

Durack, M. 1959. *Kings in Grass Castles*. Sydney, Australia: Thomas C. Lothian Pty Ltd.

Fairfax, R., and R. Fensham. 2002. In the footsteps of J. Alfred Griffiths: A cataclysmic history of Great Artesian Basin springs in Queensland. *Australian Geographical Studies* 40, no. 2: 210–230.

Fensham, R.J., J.L. Silcock, A. Kerezsy, and W. Ponder. 2011. Four desert waters: Setting arid zone wetland conservation priorities through understanding patterns of endemism. *Biological Conservation* 144: 2459–2467.

Fensham, R.J., and R.J. Fairfax. 2003. Spring wetlands of the Great Artesian Basin, Queensland, Australia. *Wetlands Ecology and Management* 11, no. 5: 343–362.

Field, J.H. 2006. Trampling through the Pleictocene: Does taphonomy matter at Cuddie Springs. *Australian Archaeology* 63: 9–20.

Ford, H.W. 1885. Royal Commission of Water: Evidence of Mr. H.W Ford. *Votes and Proceedings of the Legislative Council* 6: 771–774.

GABCC. 2009. *Great Artesian Basin Strategic Management Plan: Progress and Achievements to 2008*. Canberra, Australia: GABCC.

Geographical Names Board of NSW. 2013. http://www.gnb.nsw.gov.au/

Gilliat, H.A. 1885. Royal Commission of Water: Notes on the mud springs and some shafts and borings of underground supply on the road between Ford's Bridge (on the Warrego

River) and Hungerford (on the Paroo River). *Votes and Proceedings of the Legislative Council* 6: 827–828.

Habermehl, M.A. 1982. *Springs in the Great Artesian Basin, Australia: Their Origin and Nature*. Canberra, Australia: Bureau of Mineral Resources, Geology and Geophysics.

Harris, C.R. 1981. Oases in the desert: The mound springs of northern South Australia. *Royal Geographical Society of Australia, South Australia Branch* 81: 26–39.

Heathcote, R.L. 1965. *Back of Bourke: A Study of Land Appraisal and Settlement in Semi-arid Australia*. London, England; New York: Melbourne University press.

Henderson, W.B. 1885. Royal Commission of Water: Evidence of Mr W.B. Henderson. *Votes and Proceedings of the Legislative Council* 6: 631–634.

Herczeg, A.L., T. Torgersen, A.R. Chivas, and M.A. Habermehl. 1991. Geochemistry of ground waters from the Great Artesian Basin, Australia. *Journal of Hydrology* 126, no. 3–4: 225–245.

Humphries, P. 2007. Historical indigenous use of aquatic resources in Australia's Murray-Darling Basin, and its implications for river management. *Ecological Management & Restoration* 8, no. 2: 106–113.

Idris, H. 1996. Springs in Egypt. *Environmental Geology* 27, no. 2: 99–104.

Jiao, J.J. 2010. Crescent Moon Spring: A disappearing natural wonder in the Gobi Desert, China. *Ground Water* 48, no. 1: 159–163.

Keleher, M.J., and R. Rader. 2008. Bioassessment of artesian springs in the Bonneville Basin, Utah, USA. *Wetlands* 28, no. 4: 1048–1059.

Kelly, J.E. 1882. Well Sinking, water storing and irrigation in the interior. *Sydney Morning Herald*. http://trove.nla.gov.au/ndp/del/page/1419174?zoomLevel=1 (accessed November 20, 2013).

Langloh, K. 1905. *The Euahlayi Tribe: A Study of Aboriginal Life in Australia*. London, England: Constable.

Lawson, H. 1893. Lake Eliza. *The Bulletin* 13, no. 722: 20.

Lehmann, B.E., A. Love, R. Purtschert, P. Collon, H.H. Loosli, W. Kutschera, U. Beyerle, W. Aeschbach-Hertig, R. Kipfer, S.K. Frape, A. Herczeg, J. Moran, I.N. Tolstikhin, and M. Gröning. 2003. A comparison of groundwater dating with 81Kr, 36Cl and 4He in four wells of the Great Artesian Basin, Australia. *Earth and Planetary Science Letters* 211, no. 3–4: 237–250.

MacFarlane, E. 1885. Royal Commission of Water: Evidence of Mr. Edward MacFarlane. *Votes and Proceedings of the Legislative Council* 6: 669–771.

McKellar, H. 1984. *Matya-Mundu*. Cunnamulla, Australia: Cunnamulla Australian Native Welfare Association.

Mitchell, T. 1839. *Three Expeditions into the Interior of Eastern Australia: with Descriptions of the Recently Explored Regions of Australia Felix, and of the Present Colony of New South Wales*, 2nd ed. London, England: T. & W. Boone.

Ogilvie, C. 1911. *Artesian Bore Reports of Inspector: C. Ogilvie*. Queensland State Archives Item ID291259, Reports-Inspection.

O'Neill, S. 1969. Costello, John (1838–1923). In *Australian Dictionary of Biography*. Canberra, Australia: National Centre of Biography, Australian National University.

Park, W.-B., and K. Ha. 2012. Spring water and water culture on Jeju Island. *Ground Water* 50, no. 1: 159–165.

Patten, D., L. Rouse, and J. Stromberg. 2008. Isolated spring wetlands in the Great Basin and Mojave Deserts, USA: Potential response of vegetation to groundwater withdrawal. *Environmental Management* 41, no. 3: 398–413.

Percy, A. 1906. *The Drought Antidote for the North-West: Or, the Utilisation of the Artesian Resources of New South Wales*. Sydney, Australia: Government Printer.

Pickard, J. 1992. *Artesian Springs in the Western Division of New South Wales*. Sydney, Australia: Maquarie University.

Pittman, E.F. 1895. On the occurrence of artesian water in rocks other than the cretaceous. *Journal and Proceedings of the Royal Society of NSW* 29: 408–415.

Pittman, E.F., J.B. Henderson, A.G. Maitland, A.S. Keyon, L.K. Ward, H.H. Dare, R.F. Jenkins, and J.E. Slade. 1913. *Report of the Interstate Conference on Artesian Water*. Sydney, Australia: William Applegate Gullick, Government Printer.

Pittman, E.F., and T.W. David. 1903. Irrigation geologically considered with special reference to the artesian area of New South Wales. *Journal and Proceedings of the Royal Society of NSW* 37: CIII–CLIII.

Ponder, W.F. 1986. Mound springs of the Great Artesian Basin. In *Limnology in Australia*, Vol. 61, ed. P. Deckker and W.D. Williams, 403–420. Houten, Netherlands: Springer. http://link.springer.com/chapter/10.1007%2F978-94-009-4820-4_25

Powell, O. 2012. Song of the artesian water: Aridity, drought and disputation along Queensland's pastoral frontier in Australia. *The Rangeland Journal* 34: 305–317.

Powell, O. 2011. Warrego Country: Water, people, landscape. PhD thesis, University of Queensland, Australia.

Powell, J.M. 1991. *Plains of Promise Rivers of Destiny*. Brisbane, Australia: Boolarong Publications.

Queensland Artesian Water Investigation Committee. 1955. *Artesian Water Supplies in Queensland*. Brisbane, Australia: Government Printer.

Rade, J. 1954. Geology and sub-surface waters of the area north of the Darling River between longitudes 145° and 149°E. *Journal and Proceedings of the Royal Society of NSW* 88, no. 24–32.

Roberts, C.R., and C.W. Mitchell. 1987. Spring Mounds in southern Tunisia. *Geological Society London, Special Publications* 35: 321–334.

Robins, R. 1995. Archaeological investigations at Youlain Springs, Southwest Queensland. *Memoirs of the Queensland Museum* 1, no. 1: 57–74.

Robins, R. 1993. Archaeology and the Currawinya Lakes: Towards a prehistory of arid lands of southwest Queensland. PhD thesis, Griffith University, Australia.

Sturt, C. 1982. *Two Expeditions into the Interior of Southern Australia, during the Years 1828, 1829, 1830, and 1831: With Observations on the Soil, Climate, and general Resources of the Colony of New South Wales*. Sydney, Australia: Doubleday Australia.

Symmonds, R.S. 1912. *Our Artesian Waters: Observations in the Laboratory and in the Field*. Sydney, Australia: William Applegate Gullick, Government Printer.

Torgersen, T., M.A. Habermehl, F.M. Phillips, D. Elmore, P. Kubik, G.B. Jones, T. Hemmick, and H.E. Gove. 1991. Chlorine 36 Dating of very old groundwater: 3. Further studies in the Great Artesian Basin, Australia. *Water Resources Research* 27, no. 12: 3201–3213.

Trueman, N.G., J.H. Field, J. Dortch, B. Charles, and S. Wroe. 2005. Prolonged coexistence of humans and megafauna in Pleistocene Australia. *PNAS* 102, no. 23: 8381–8385.

Wilkinson, C.S. 1885. Royal Commission of Water: Evidence of Mr. Edward MacFarlane. *Votes and Proceedings of the Legislative Council* 6: 588–596.

Wilkinson, C.S. 1882. Notes on the occurrence of artesian wells in the Albert District, New South Wales. *Proceedings of the Linnean Society of NSW* 6: 155–157.

Williams, R.M., D.R. Wooley, R.S. Abell, P. Please, and W.R. Evans. 1994. Darling basin hydrogeological map land and water management issues. In *Water Down Under 94*, Vol. 1. Adelaide, Australia: Institution of Engineers.

Wood, A.P. 1883. Tanks and wells of New South Wales, water supply and irrigation. *Journal and Proceedings of the Royal Society of NSW* 17: 149–186.