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THE SUSTAINABILITY OF MOUND SPRINGS IN SOUTH AUSTRALIA : IMPLICATIONS FOR OLYMPIC DAM

Gavin M Mudd
Victoria University of Technology [1]

ABSTRACT

The Mound Springs of South Australia are unique groundwater discharge features of the Great Artesian Basin, a deep regional groundwater system that covers 22% of the Australia continent. They are the principal sources of water in the arid and semi-arid inland heart of Australia, and have great ecological, scientific, anthropological and economic significance. Excessive development of the Great Artesian Basin over the past century by European activity has seen an overall decline in the flows from the springs, and recent development of the water supply borefields for the WMC Olympic Dam copper-uranium mine in the midst of the most important spring groups has exacerbated this problem. A review of the history of the Olympic Dam borefields, an analysis of the impacts on the mound springs, and future recommendations for the return of environmental flows and protection of the springs is presented.

Keywords : Mound Springs, Great Artesian Basin, Olympic Dam (Roxby Downs)

1 INTRODUCTION

The Olympic Dam (Roxby Downs[2]) polymetallic copper, uranium, gold and silver deposit in northern South Australia was discovered in 1975 by Western Mining Corporation (now WMC) and contains the largest known uranium ore body in the world. The deposit was developed as a joint venture between WMC and BP. After the operation of pilot plant studies in the mid-1980's, a commercial mine began operation in 1988 and is currently nearing completion of a major expansion. WMC acquired full ownership of the mine in 1993 and it is presently ranked seventh as a world producer of uranium (Uranium Institute, 1998).

The Olympic Dam mine currently produces about 85,000 tonnes per annum (tpa) of refined copper, 1,600 tpa of uranium oxide (U_3O_8), 13 tpa of silver and 850 kg per year of gold (Kinhill, 1997). The State and Commonwealth governments approved the development of the mine in 1983. In 1997, a formal proposal to further expand production was received (Kinhill, 1997) and approved by State and Commonwealth governments for levels of 200,000 tpa of copper, 4,630 tpa of uranium oxide, 23 tpa of silver and 2 tpa of gold. The ore reserves of the multi-mineral deposit are quite large by any standard, with 11.4 million tonnes (Mt) of copper, 340,000 tonnes of uranium (as U_3O_8), 2,790 tonnes of silver and 400 tonnes of gold (Kinhill, 1997). The expanded production rates will allow production from the mine for at least the next 50 to 100 years or longer.

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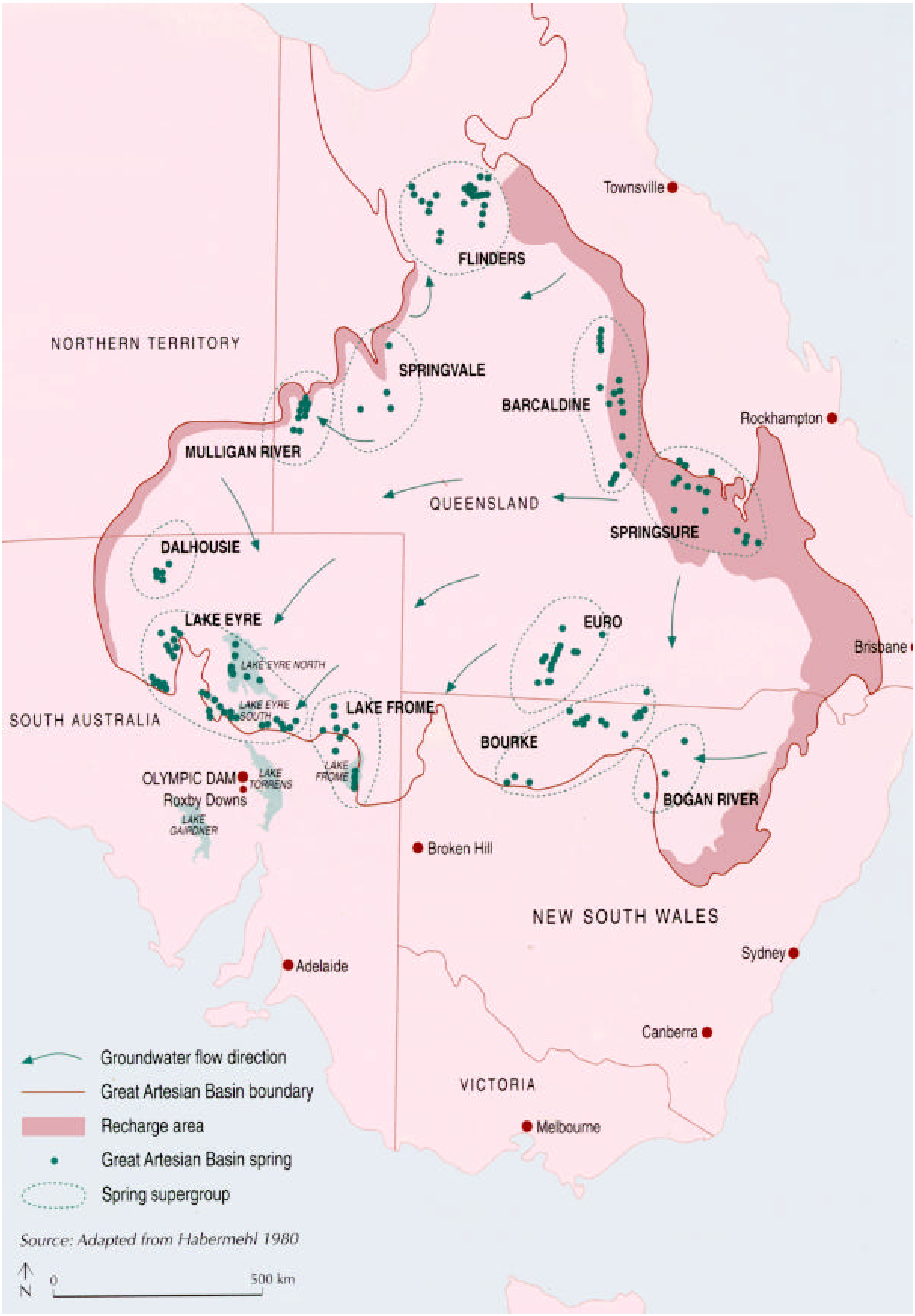
[1] - School of the Built Environment, Victoria University of Technology (Footscray)
c/o P.O. Box 81, Watsonia, VIC 3087, Australia (Email - angelb@netspace.net.au) - all views expressed herein are those of the author, and are not meant to convey the views of any other person, organisation or company.

[2] - Roxby Downs is the name of the township, while Olympic Dam is the formal name of the mine, although it is colloquially known as Roxby Downs.

Figure 1 - Location of the Olympic Dam Project and Extent of the Great Artesian Basin, Flowpaths and Spring Groups (Kinhill, 1997)



Source: Adapted from Habermehl 1980

The process and potable water supply for the Olympic Dam mine and Roxby Downs township is derived from two borefields located approximately 150 to 200 km to the north, near the southern margins of the Great Artesian Basin near Lake Eyre South. Since the start of pilot plant operations and the commercial mine, the amount of water extracted has steadily increased, with extraction during 1996 averaging about 15 Ml/day (ODC, 1997). The borefields are located directly within or near the Lake Eyre supergroup of mound springs, and the original 1982 Environmental Impact Statement (EIS) (Kinhll, 1982) and 1997 Expansion Project EIS (Kinhll, 1997) predicted impacts on the springs as well as other users of GAB water in the region. However, the actual impacts have been markedly different.

The northern regions of South Australia are arid to semi-arid, with evapotranspiration generally exceeding rainfall by an order of magnitude or more (Allan, 1990; Badman *et al.*, 1996). The surface landscape has seen dramatic change over the past 500 million years, varying from shallow seas with active volcanoes, glaciers and ice caps, rich humid and tropical forests, to the dry arid landscape now present (Krieg *et al.*, 1990). Each climate has left distinctive marks on the landscape.

The availability and careful management of water supplies is thus critical to the overall project and it's related environmental impacts.

2 THE GREAT ARTESIAN BASIN

2.1 Overview

The Great Artesian Basin (GAB) is one of the world's largest and oldest groundwater system, underlying 22% of the Australian continent or 1,711,000 km^2 (Hillier, 1996). It consists of several contiguous sedimentary basins with confined aquifers of Triassic, Jurassic and Cretaceous continental quartzose sandstones, underlain by an impervious pre-Jurassic base (Habermehl, 1996). The aquifers are confined by the Rewan Group at the bottom and the Winton Formation at the top (Habermehl, 1980). The maximum total thickness of about 3,000 metres occurs in the Mesozoic sedimentary sequence in the central GAB. The Basin forms a large synclinal structure, uplifted and exposed along it's eastern margin, leaving the overall Basin tilted southwest (Keane, 1997).

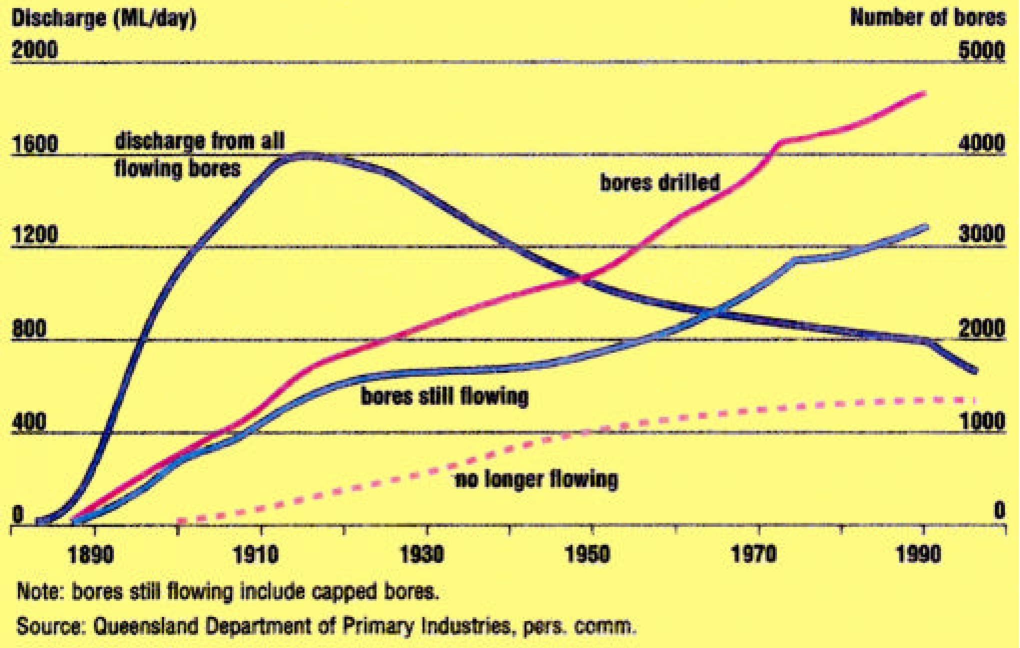
Recharge to the GAB occurs primarily along the uplifted eastern margins and also on the western margins where the aquifers are exposed or overlain by sandy sediments (Habermehl, 1980). Environmental isotope and other hydrochemical studies of groundwater from across the Basin confirm the assumptions of continuous recharge from geological to modern times, and that the water is of meteoric origin (Airey *et al.*, 1983; Bentley *et al.*, 1986; Torgersen *et al.*, 1991; Habermehl, 1996). The age of the groundwater, determined from extensive carbon-14 and chlorine-36 studies and correlated with hydraulic modelling studies, ranges from several thousands of years near recharge areas to nearly two million years around the southwest of the GAB near Lake Eyre (Habermehl, 1996).

Natural discharge from the GAB occurs via two principal processes - vertical leakage towards the regional water table and concentrated outflow from springs around the margins (Habermehl, 1996). Since the onset of European development of the GAB for the pastoral industry late in the 19TH century, and more recently the mining and resource extraction industries, discharge via free or controlled artesian bores and pumped abstraction from non-artesian bores has now become the primary discharge mechanism (Keane, 1997).

The hydrochemistry of the majority of GAB is dominated by sodium-bicarbonate-chloride waters, although waters around the western margin are of a sodium-sulphate-chloride type (Habermehl, 1980). The water quality generally increases with the depth of the aquifer being tapped, with the Lower Cretaceous-Jurassic aquifer holding good quality water with a TDS from 500 to 1,000 mg/l, while the shallower Cretaceous aquifers have higher salinities up to a TDS of 10,000 mg/l (Habermehl, 1980).

The first bore to tap the GAB was in 1878, drilled near Burke, NSW (Habermehl, 1980). Initially, bores were drilled near springs as these were known sources of artesian water, but the extensive areal nature of the GAB quickly became established and further deep bores were drilled in the central parts of the GAB (Habermehl, 1980). Estimates of the overall water balance for the GAB, although trending downward due to lower artesian pressures, vary widely and reflect both the difficulty of calculations on such a large scale and the scarcity of reliable regional data (Keane, 1997). The total number of bores is still increasing, although an increasing proportion of these are no longer free flowing and require pumping (Hillier, 1996). The vast majority of the extracted water is wasted, up to 95%, due to uncontrolled bore flows and inefficient open earth drain distribution systems (Hillier, 1996; PMSEC, 1996). Bore rehabilitation programs and water conservation measures are now being implemented across the GAB to improve efficiency and long term sustainability (Sampson, 1996).

Figure 2 - GAB Bore Discharge and Bores Drilled Summary (SoE, 1996)



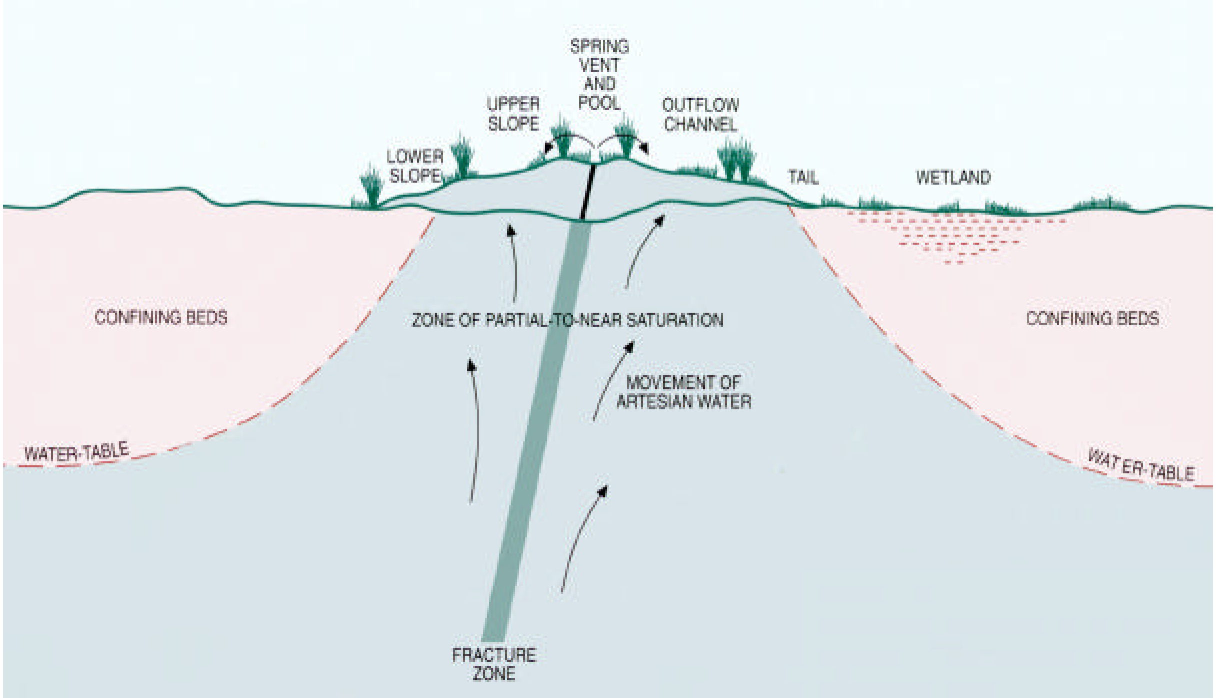
Note: bores still flowing include capped bores.
Source: Queensland Department of Primary Industries, pers. comm.

2.2 Mound Springs in the GAB

A unique feature of the GAB is the large numbers of springs it supports. There are considered to be 11 main groups totalling about 600 individual springs, with the Lake Eyre supergroup around the south-western margin containing the largest concentration of active and unique springs (Habermehl, 1982). The location of springs is controlled by local geology, such as faults or erosion of confining beds (Boyd, 1990; Keane, 1997). The flow rates from individual springs is highly variable, with values ranging from 0.1 to 14 Ml/day, with the majority being less than 0.5 Ml/day (Habermehl, 1982 & 1996).

The persistence of spring flows over geologic time has seen the accumulation and carbonate cementation of sand, silt and clay, building a characteristic mound. Hence these particular springs, found only in the Lake Eyre supergroup, are referred to as Mound Springs. A typical mound consists of a central pool of water, an outer rim of reeds and vegetation, an outflow channel, and successive layers of carbonate. The mounds may be up to 8 m in height and up to 30 m in diameter across (although the extinct Hamilton Hill Spring is about 40 m above ground level, suggesting that artesian pressures have been higher in the GAB over recent geologic time) (Habermehl, 1982). A wetland and sometimes a small creek are formed by the outflow from a spring. The flowrate from a spring has been shown to be directly proportional to the area of wetland vegetation a spring supports (Williams & Holmes, 1978).

Figure 3 - Cross Section of a Typical Mound Spring (Kinhill, 1997)



2.3 Aboriginal Heritage

The springs were a vital resource for the Aboriginal inhabitants of the region for many thousands of years and remain so to this day (Keane, 1997; Hercus & Sutton, 1985; PMSEC, 1996; Noble *et al.*, 1998). This is evidenced by the abundance of stone chips, grinding stones and other traditional tools in the vicinity of the springs, and also by the rich mythological and oral history of the springs in Aboriginal culture (DHAE, 1983; Hercus & Sutton, 1985). The springs in the Lake Eyre region are recognised as being the traditional responsibility and custodianship of the Arabanna people (Hercus & Sutton, 1985; Keane, 1997).

All individual springs and complexes are known to hold significance to Aboriginal people, and it is impossible in modern times to predict, with any confidence, that an individual mound spring does not have any significance due to similarities with other springs in an area (Noble *et al.*, 1998). Hercus & Sutton (1985) emphasize that "the springs are considered so important that the large-scale deterioration of any group of springs would cause great distress to at least some Aboriginal people, whether their associations with the sites are direct or indirect."

2.4 Ecological Importance of the Mound Springs

The Mound Springs are the only permanent source of water in the arid interior of South Australia and a delicate yet intricate ecological balance has been established (Keane, 1997). Due to their prolonged isolation the mound springs contain many endemic and rare species that have undergone genetic differentiation and speciation (PMSEC, 1996; Kinhill, 1997). The springs are important as drought refuge areas for many wildlife and as wetlands for migratory birds, recognised as being of national importance (DHAE, 1983; ANCA, 1993).

The rare and endemic species include plants, fish, hydrobiids, isopods, amphipods and ostracods, many of which occupy specialised areas within a spring such as the open pool, outer rim or the rocky outflow channel (Ponder & Jenkins, 1983; Keane, 1997). Despite the linear correlation of flow rate with wetland area, a minor reduction of flow of the order of 20% can impact animal populations by up to 70%, although current monitoring only counts total population and not individual species dynamics (Ponder & Zeidler, 1997). Many species are only found within a particular mound spring or spring complex (PMSEC, 1996). The mound springs provide unique opportunities for prehistoric, evolutionary, ecological and biogeographical studies.

2.5 European Heritage

The mound springs quickly established themselves as a principal water resource for the arid interior of Australia during the early years of European exploration and settlement. The springs were invaluable in the early exploration trails of Edward John Eyre in 1839 and followed by Benjamin Herschel Babbage, Peter Egerton Warburton and by John McDouall Stuart in 1862 (Kinhill, 1984). These journeys paved the way for pastoralists such as Philip Levi, Francis Dunbar Warren, John Howard Angas, Thomas Elder and Sidney Kidman, eager to exploit the land (Kinhill, 1984). The mound springs were seen as crucial in the success of pastoral ventures (Kinhill, 1984). The building of the overland telegraph in the late nineteenth century was one of the greatest engineering and logistical feats of nineteenth century Australia, with the route closely following that of Stuart’s 1862 journey through spring country (Kinhill, 1984). The transcontinental railway, constructed from the late nineteenth to the early twentieth centuries from Adelaide to Alice Springs, subsequently followed the overland telegraph route through the springs (Kinhill, 1984). Thus the region of the springs also contains much of the rich and diverse struggles and themes of early Australia.

3 THE OLYMPIC DAM WATER SUPPLY BOREFIELDS

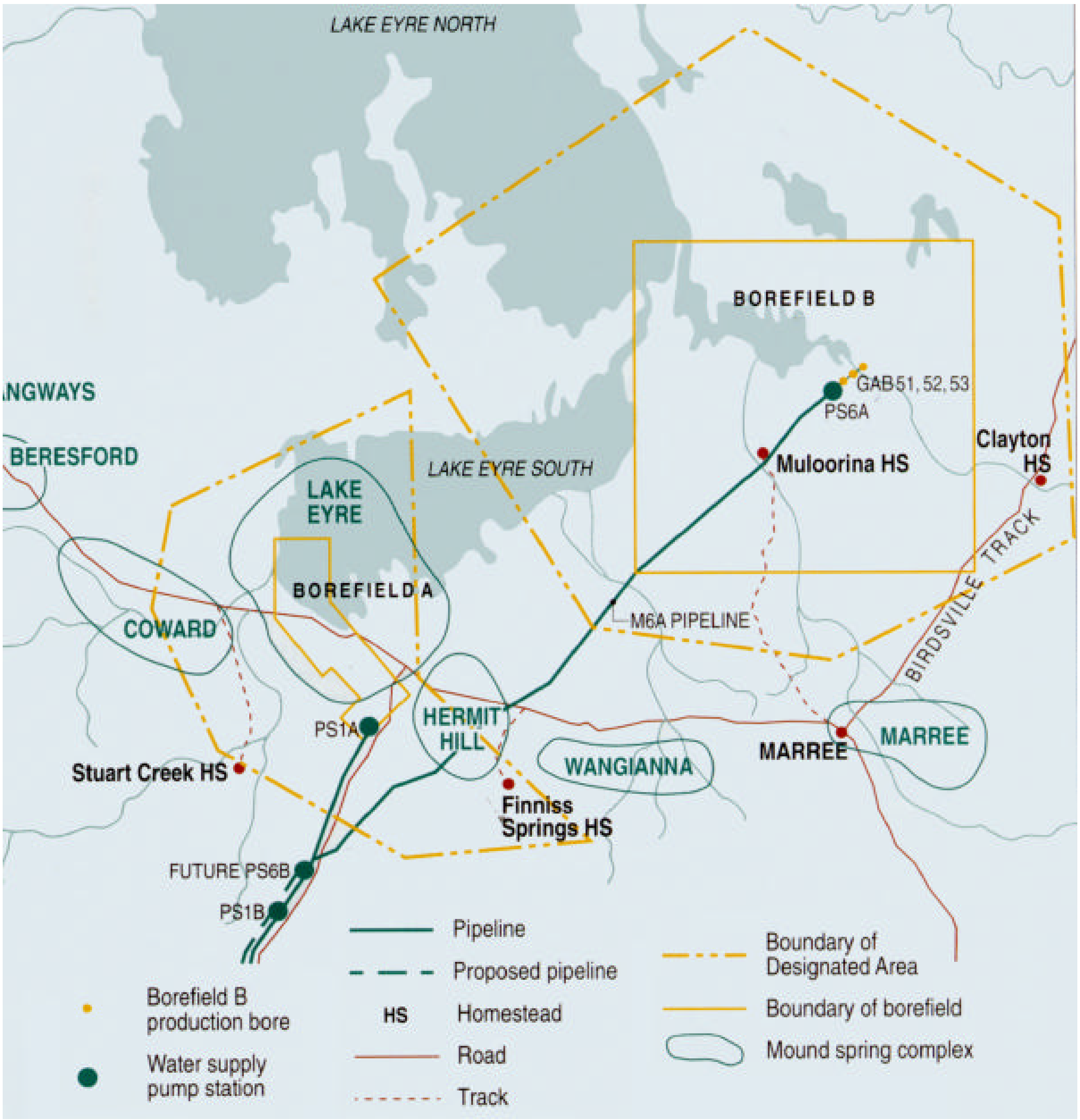
3.1 Overview of Borefields Development

A brief review of the history of water extraction for the Olympic Dam Project is warranted to understand the environmental impacts associated with the mound springs. The water supply is presently derived from two borefields located amidst the springs around the southern margins of the GAB near Lake Eyre South, known as Borefields A and B. The original Draft Environmental Impact Statement in 1982 (Kinhill, 1982) proposed extraction rates of 6 Ml/day and 27 Ml/day from Borefields A & B via 5 bores and 7 to 10 bores respectively, pumped via buried pipeline to the mine and township. It is explicitly stated in Kinhill (1982) that Borefield A, developed during initial mine construction, would not be able to supply the total demand for water upon commencement of commercial mining operations and that Borefield B would be necessary for such a scale of operations.

Table 1 - Average Extraction Rates from the Olympic Dam Borefields (Kinhill, 1997)

Years	Borefield A (Ml/day)				Borefield B	**Total**
	Southern	Central	Northern	Total	Ml/day	**Ml/day**
1982-86	1.30	0	0	1.30	0	**1.30**
1986-87	2.30	0	0	2.30	0	**2.30**
1987-88	2.34	2.08	0	4.42	0	**4.42**
1988-89	4.27	4.56	0	8.83	0	**8.83**
1989-90	5.68	4.30	0	9.98	0	**9.98**
1990-91	6.25	4.39	0	10.64	0	**10.64**
1991-92	5.67	4.39	1.57	11.63	0	**11.63**
1992-93	5.60	3.98	3.01	12.59	0	**12.59**
1993-94	4.50	3.14	4.46	12.10	0	**12.10**
1994-95	4.72	4.37	4.43	13.52	0	**13.52**
1995-96	4.67	5.40	4.92	14.99	0	**14.99**
1996-97	n/a	n/a	n/a	6.9	7.8	**15.20**

Figure 4 - Location of Borefields A & B and Mound Spring Complexes (Kinhill, 1997)



It would appear that the original intention of Borefield A was within a sub-basin thought to be hydraulically separated from the mound springs by the North-west Fault zone (Berry & Armstrong, 1995 & 1996), although this approach is not explicit in Olympic Dam Project literature (eg - Kinhill, 1982 & 1997). By commissioning of the mine in 1988, however, investigation, design and development of Borefield B was yet to begin. It was clear that the demand for water and the average extraction rate from Borefield A would exceed the original projection. A new proposal was approved by the South Australian government in 1991 to allow expansion of Borefield A with new limits on drawdowns at the designated boundary until construction of Borefield B (WMC, 1995). Three new extraction bores were commissioned in January 1992 on the southern shores of Lake Eyre South (Kinhill, 1995a).

Planning and investigation for the construction of Borefield B finally commenced in 1992 and field geophysics indicated that the original site would be unsuitable due to various geologic constraints, such as no hydraulic barrier and excessive impacts on springs (Berry & Armstrong, 1996). A new site was selected based upon existing exploration seismic data 50 km to the north-east of the original site, where the GAB thickens and becomes more permeable (Berry & Armstrong, 1996). Operation of the first bore from Borefield B began in November 1996 supplying approximately 9-10 Ml/day from one bore, and extraction from Borefield A was subsequently reduced to 5 to 6 Ml/day (Kinhill, 1997).

3.2 Impacts on Mound Springs

By the early 1990's it was apparent that impacts on the mound springs were underestimated in Kinhill (1982). By 1990 the spring vents at Priscilla and Venables had ceased flowing, and there were visible reductions in flows and wetland area at other spring complexes, notably Hermit Hill, Beatrice and Bopeechee (Keane, 1997). The approach of Kinhill (1997) for the proposed expansion of Olympic Dam and the borefields was to compare all spring flow rates to 1996 levels, and not pre-borefield levels. It is unclear why this was done, but the relatively small changes presented do not compare to the larger changes from background flows. The predicted graphs of spring flows in Kinhill (1997) display downward trends after three years, with the relative reduction from 1996 levels ranging up to 17%.

A comprehensive table has yet to be compiled comparing background, current and predicted flows from springs and bores, although background data is incomplete. A brief compilation is attempted below for some of the more important springs, although it can only be considered indicative until a more thorough compilation of monitoring data is undertaken.

Table 2 - Reduction in Mound Spring Flows - Predicted and Actual[3] (Kinhill, 1997)

Spring Complex	Spring Name	Predicted Flow Reductions (%)		Actual Flow Reduction (%)
		Impermeable	Semi-permeable	
Hermit Hill	Beatrice	100	100	40
	Bopeechee	<2	20	43
	Hermit Hill	<1	<1	36
	Old Finnis	<2	<2	marginal increase
	Venable	100	100	100 (extinct May 1990)
Wangianna	Davenport	<1	<1	close to 0
Lake Eyre	Emerald	3	3	close to 0
	Fred	6	17	50
	Priscilla	75	60	100 (extinct late 1990)

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[3] - predictions based on the northwest fault zone being impermeable or semi-permeable.

Table 3 - Select Background and Current Spring Flows[1] (kl/day)

Spring	1974	1981	1985[2]	1988	1991	1992	1993	1996	1997
Venable (pastoral bore)	-	-	180	124	24.4	11.6	2.6	n/a	0.0
Hermit Hill Complex	130	30	45.4	31.1	36.3	36.9	37.1	30.2	-
Old Finnis	-	-	14.2	14.7	13.0	13.0	13.8	13.0	11.2
Beatrice (pastoral bore)	130	25	63.1	58.8	39.7	27.1	34.6	n/a	25.9
Bopeechee	130	25	54.4	42.5	33.7	33.5	31.7	24.2	13.9
Fred	40	10	15.6	4.3	9.1	4.7	12.0	n/a	-

There are a number of complex mitigating factors in determining the reasons for the variability and reductions in spring flow. However, it is clear that the location and subsequent expansion of Borefield A in the midst of the springs hastened the demise of some springs and flow reductions in others.

Some key considerations in discerning the impact of Borefield A on the springs are :

- it was widely recognised at the time of the Draft EIS that there was a significant deficiency in the amount of knowledge and data on the hydrogeology of the southern margins of the GAB, especially the mound springs (eg - Kinhill, 1982; DEP, 1983; DHAE, 1983);
- original projections of spring flow reduction did not include a significantly expanded rate of extraction from Borefield A;
- flow across the Northwest Fault zone was assumed to be impermeable, whereas operation of Borefield A demonstrated a degree of hydraulic connection (Berry & Armstrong, 1995). It is hypothesised that the higher extraction rates created an increased pressure difference across the fault zone than early field testing and operation achieved, and thus the system was not stressed to the point of becoming permeable until Borefield A was expanded;
- the interpreted geological structure based on aerial photography presented in ODO (1993) shows that, like many springs across the GAB, several springs in the vicinity of Lake Eyre South are located directly above or near fault zones (eg - McLachlan, Smith and Fred Springs) - suggesting that faults are at least semi-permeable across the region;
- the rehabilitation of pastoral bores in the Lake Eyre region is improving efficiency of water extracted for pastoral purposes, reducing demand from this source and associated impacts on spring flows (Sampson, 1996);
- Woods (1990), using environmental isotope techniques to study the evaporative loss from the water table which receives vertical leakage from the GAB aquifer, concluded that the sustainable yield of Borefield A was approximately 9 Ml/day (the average extraction during 1990 was 10.6 Ml/day);
- pastoral bores are generally low yield bores spread diffusely across a large area while the borefields contain high yield bores in the concentrated region of the mound springs;
- the extraction of water by production bores is via pumps, thereby exacerbating drawdowns, whereas pastoral bores flow under natural artesian conditions.

3.3 Alternative Borefield Configurations

It has long been recognised that continued overdevelopment of the GAB would lead to the extinction of flows at the mound springs. This scenario was first put forward by the Public Works Department in Queensland in 1954 when they assessed the sustainable supply of artesian water (DPW, 1954), and presented below in diagrammatically.

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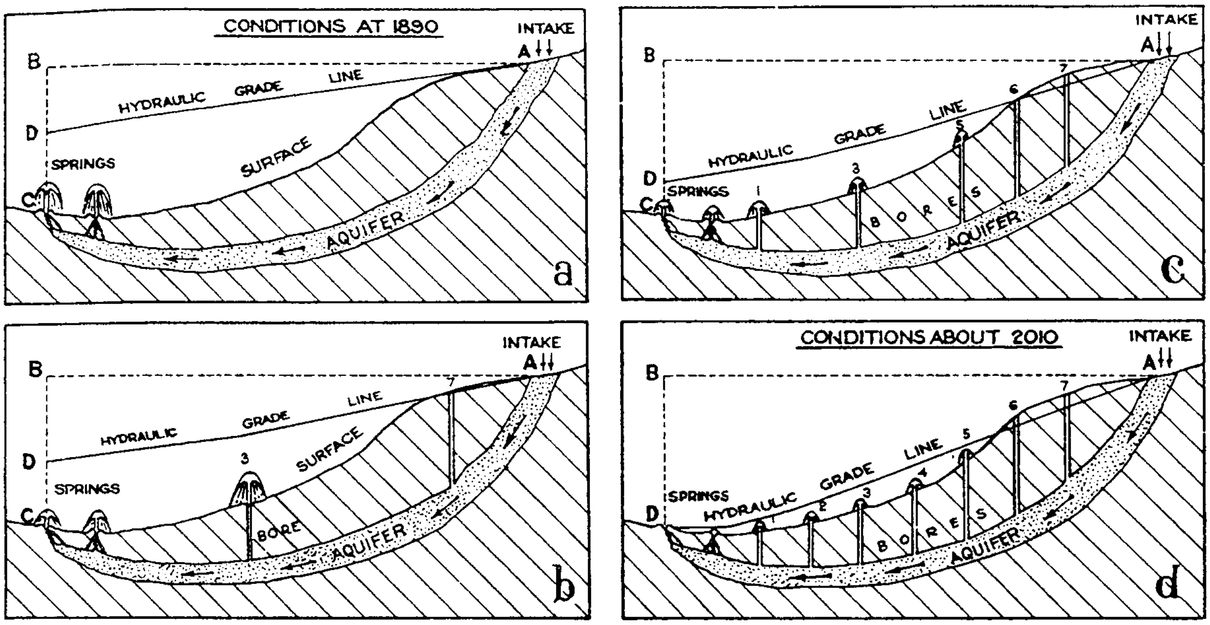
[1] - compiled from Kinhill (1982), Lad (pers. comm.) and Annual Environmental Management Reports by WMC.

[2] - reference flows used by WMC for comparison.

In words, it suggests that before European development of the GAB, artesian pressures and spring flows were relatively high. As bores were developed around the margin of the GAB and gradually in the centre, the overall artesian pressure begins to fall and spring flows decline, although initial artesian bore flows are reasonable. Finally, the GAB is developed with an extensive series of bores that each provide small relative flows, the artesian pressure of the GAB is exhausted and near ground level and there is no flow emanating from the mound springs. The current situation in South Australia is approaching the final stage of the above prediction - one made thirty years before the construction of the Olympic Dam water supply borefields.

Figure 5 - GAB Cross Section : Projection of Bores, Pressure and Spring Flow (DPW, 1954)



There has been limited assessment of the effect of closing Borefield A on spring flow. These demonstrated that while Borefield B was still operating at full extraction capacity there would be no recovery of springs in the long term, with flows predicted to remain low or decrease from 1996 levels by up to 17% (Kinhill, 1995b; Berry & Armstrong, 1995). This can be considered to be due to the decrease in artesian pressure to the north due to Borefield B and no effective recovery mechanism for artesian pressure around Borefield A.

The regional contours of transmissivity and GAB aquifer thickness presented in Berry & Armstrong (1995) and Armstrong & Berry (1997) show that a further 100 to 200 km to the north and north-east of Borefield B, the GAB aquifer is relatively thick at about 300 to 400 m, is more permeable and reaches a transmissivity of 3,000 to 4,000 m^2/day. The aquifer thickness and transmissivity at Borefield A ranges from 10 to 25 m and 20 to 200 m^2/day, respectively. A borefield located in this new region would likely result in relatively lower drawdowns and occupy a smaller area compared to that from Borefield A. The potential for drawdown effects on the springs is therefore smaller than the current location of Borefield's A and B. A borefield located in this region would therefore be more sustainable for both spring flow and the long term life of the mine's water supply due to it's higher potential yield.

The prospect of a third borefield has been recognised with the current phase of expansion, and WMC will consider constructing it further into the GAB (Kinhill, 1997), as the properties just highlighted would suggest is appropriate.

However, despite the more favourable hydrogeologic properties, a "Borefield C" would thus be at a further distance from the mine but the GAB aquifer is also deeper in this area. The overall costs of a new pipeline and deeper drilling could inhibit the timing and commitment by WMC to a new borefield. It is unclear whether Borefield A would be closed under this scenario.

4 CONCLUSIONS AND RECOMMENDATIONS

The question of adverse environmental impacts on the springs from the operation of the water supply borefields for the Olympic Dam copper-uranium mine is complex. It is clear from available hydrogeologic data that the location of Borefield A in the midst of the Lake Eyre supergroup of mound springs has hastened the demise of some springs and exacerbated flow declines at others. No comprehensive data set yet exists documenting the long term changes over recent time of the springs and the complex factors that influence spring behaviour. The 20 year projections of Kinhill (1997) still predict long term flow decreases.

However, given the Olympic Dam Project is estimated to operate well in excess of 50 years, the environmentally sustainable supply of water for ongoing operations should be considered crucial in successful and pro-active environmental management. The construction of a large borefield in the midst of environmentally and culturally important mound springs, especially given the more hydrogeologically favourable sites to the north-east, should not be regarded as having environmental merit. To merely discuss the demise and extinction of springs is an unwanted and unwelcome Faustian bargain that should never be forced upon any government or local community. The only way to ensure the long term ecological integrity of mound springs and associated wildlife is to protect the quality and quantity of water flowing to individual springs - not averages over large spring groups which mask declines and impacts.

It is recommended that WMC :

- work towards the permanent and rapid closure of Borefield A;
- immediately commence studies into a new Borefield "C", located a further 100 to 200 km to the north-east of Borefield B; and
- begin investigations for remedial options of all affected springs in the Lake Eyre region and initiate programs to ensure that background flows of all affected springs are achieved within a reasonable time frame.

This will ensure the ecological and mythological integrity of the mound springs for indigenous custodians and all future Australians, and that environmental flows and values are maintained sustainably.

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