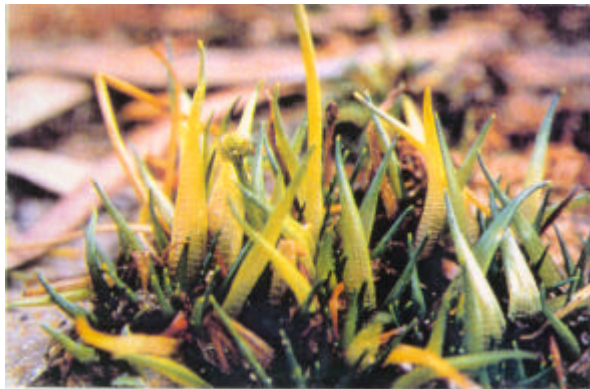


**The sustainability of use of groundwater from the south-western edge of the Great Artesian Basin, with particular reference to the impact on the mound springs of the borefields of Western Mining Corporation.**



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EV 403 - Environmental Engineering Design 4  
Department of Civil and Geological Engineering Investigation Project 1997

**Supervisor : Paulino Piotto**  
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# **The sustainability of use of groundwater from the south-western edge of the Great Artesian Basin, with particular reference to the impact on the mound springs of the borefields of Western Mining Corporation.**

Submitted by Daniel Keane 9103764V  
Supervisor : Paulino Piotto

The investigation has been prepared with extra supervision from Philip Keane and Gavin Mudd.

Front Cover Photographs:

“The Bubbler”, one of many mound springs in the north of South Australia, with the extinct mound spring, Hamilton Hill, in the background.

(Photo : Linda Marks, 1991)

Salt pipewort, one of the threatened endemic species of plant which grows on the edges of some mound springs.

(Photo : Colin Harris)

Aboriginal grinding stone located near McLachlan Springs.

(Photo : Eric Miller, 1988)

## **Table of Contents**

|       |                                                         |    |
|-------|---------------------------------------------------------|----|
| 1.    | Introduction                                            | 1  |
| 1.1   | Investigative Procedures                                | 2  |
| 2.    | The Great Artesian Basin                                | 3  |
| 2.1   | Geology                                                 | 3  |
| 2.2   | Hydrogeology                                            | 5  |
| 2.2.1 | Hydraulic Characteristics                               | 5  |
| 2.2.2 | Recharge                                                | 8  |
| 2.2.3 | Discharge                                               | 8  |
| 2.2.4 | Groundwater Age                                         | 10 |
| 2.3   | Hydrochemistry                                          | 11 |
| 2.4   | Early Exploration and Present Development               | 11 |
| 2.5   | The GAB Well and Drain Rehabilitation Program           | 12 |
| 3.    | Springs                                                 | 14 |
| 3.1   | The Springs of the GAB                                  | 14 |
| 3.2   | Mound Springs of South Australia's North East Desert    | 16 |
| 3.3.1 | Geological Controls on Mound Spring Location            | 21 |
| 3.3.2 | Hydrogeological Significance                            | 23 |
| 3.3.3 | Aboriginal Significance                                 | 23 |
| 3.3.4 | Tourism Potential of Mound Springs and Environs         | 24 |
| 3.3   | Biological and Ecological Significance of Mound Springs | 24 |
| 3.3.1 | Vegetation                                              | 25 |
| 3.3.2 | Fish                                                    | 27 |
| 3.3.3 | Hydrobiids (small, dark coloured snails)                | 27 |
| 3.3.4 | Ostracods (crustaceans)                                 | 28 |
| 3.3.5 | Isopods                                                 | 28 |
| 3.3.6 | Amphipods                                               | 28 |
| 3.4   | The Impact of Pastoralism on the Mound Springs          | 30 |
| 3.5   | Recommendations for Protection of Mound Springs         | 31 |
| 4.    | Olympic Dam Operations                                  | 32 |
| 4.1   | Present Operations                                      | 32 |
| 4.2   | The Expansion Proposal                                  | 32 |
| 4.3   | GAB Water Supply                                        | 34 |
| 4.3.1 | Borefield A                                             | 36 |
| 4.3.2 | Borefield B                                             | 38 |
| 4.3.3 | Future BorefieldBorefield C                             | 38 |
| 4.4   | Water Use                                               | 40 |
| 4.5   | Water Costs                                             | 41 |
| 4.6   | Abstraction Licences held by WMC                        | 42 |
| 4.6.1 | Special Water Licence for Borefield A                   | 42 |
| 4.6.2 | Special Water Licence for Borefield B                   | 42 |
| 4.7   | Impact on Mound Springs due to WMC's Borefields         | 43 |
| 4.7.1 | ODO Draft EIS, 1982 Predictions                         | 43 |
| 4.7.2 | ODO Expansion Project EIS, 1997                         | 45 |

|     |                                                                           |    |
|-----|---------------------------------------------------------------------------|----|
| 5.  | Other Industrial Developments in the Region                               | 47 |
| 5.1 | Cooper Basin Gas and Oil Fields (Moomba)                                  | 47 |
| 5.2 | Future Developments                                                       | 47 |
| 6.  | Water Balance                                                             | 48 |
| 7.  | Field Work                                                                | 51 |
| 7.1 | Introduction                                                              | 51 |
| 7.2 | Comments of Impacts on the Mound Springs                                  | 51 |
| 7.3 | Interview with Ila Marks and Eric Miller                                  | 53 |
| 7.4 | Visits to the Mound Springs                                               | 55 |
| 7.5 | Summary of Interview with Reg Dodd                                        | 56 |
| 8.  | General Discussion, Conclusions and Recommendations                       | 60 |
| 8.1 | Water Balance in the South Australian Portion of the Great Artesian Basin | 60 |
| 8.2 | Importance of Mound Springs                                               | 60 |
| 8.3 | Impact of WMC Borefields on Mound Springs                                 | 61 |
| 8.4 | Summary of Recommendations                                                | 65 |
| 9.  | Bibliography                                                              | 66 |

#### List of Tables

|    |                                                                                                                                 |    |
|----|---------------------------------------------------------------------------------------------------------------------------------|----|
| 1  | Expansion Project Production Rates                                                                                              | 32 |
| 2  | Summary of Abstraction from Borefield A                                                                                         | 36 |
| 3  | Borefield A & B Extraction Predictions                                                                                          | 40 |
| 4  | Estimates of Reduction in Bore Discharge, 1982                                                                                  | 43 |
| 5  | Estimates of Reduction in Spring Discharge, 1982                                                                                | 44 |
| 6  | Springs impacted by Borefield A                                                                                                 | 44 |
| 7  | Predicted and actual impacts on mound springs and observed impacts on endemic mound spring fauna                                | 46 |
| 8  | Water Balance for Great Artesian Basin                                                                                          | 48 |
| 9  | Water Balance of the South Australian Portion of the GAB                                                                        | 49 |
| 10 | Expert parties and summaries of their concerns about the potential adverse impact on the mound springs due to WMC's Borefield A | 51 |

## List of Figures

|     |                                                                                                                         |    |
|-----|-------------------------------------------------------------------------------------------------------------------------|----|
| 1   | The Great Artesian Basin                                                                                                | 3  |
| 2   | Recharge and natural discharge (springs) areas and directions of regional groundwater flow in the Great Artesian Basin  | 4  |
| 3   | Lateral extent of simplified hydrogeological (model) units and cross-section                                            | 6  |
| 4   | Example of an artesian basin                                                                                            | 7  |
| 5   | Great Artesian Basin schematic flow system                                                                              | 7  |
| 6   | Artesian bores in the Great Artesian Basin                                                                              | 9  |
| 7   | The <sup>36</sup> Cl defined age structure in the Jurassic aquifer in the Great Artesian Basin                          | 10 |
| 8   | Generalised surface geology, and well and spring locations for the South Australian portion of the Great Artesian Basin | 13 |
| 9   | Location of Springs in the Great Artesian Basin                                                                         | 15 |
| 10a | Location of Mound Springs in South Australia                                                                            | 17 |
| 10b | Location of Mound Springs in South Australia                                                                            | 18 |
| 10c | Location of Mound Springs in South Australia                                                                            | 19 |
| 11  | Cross-section of a Typical Mound Spring                                                                                 | 20 |
| 12  | Blanche Cup a Typical Mound Spring                                                                                      | 20 |
| 13  | Diagrammatic geological section of the mound springs of the Strangways area                                             | 22 |
| 14  | Diagrammatic geological section showing the location of mound springs east of Peake and Denison Ranges                  | 22 |
| 15  | A relationship between the area of a spring-fed swamp and the discharge from that spring                                | 26 |
| 16  | Differentiation of hydrobiid habitats at Blanche Cup Spring                                                             | 29 |
| 17  | Location of Olympic Dam                                                                                                 | 33 |
| 18  | Location of ODO Borefields A & B                                                                                        | 35 |
| 19  | Borefield A plan                                                                                                        | 37 |
| 20  | Borefield B plan                                                                                                        | 39 |
| 21  | Gosse bore Blowout, 1988                                                                                                | 58 |
| 22  | Cattle damage                                                                                                           | 58 |
| 23  | WMC pumping station                                                                                                     | 59 |
| 24  | WMC bore, Lake Eyre South                                                                                               | 59 |
| 25  | Davenport Springs                                                                                                       | 59 |
| 26  | Eriocaulon carsonii (salt pipewort or Button grass)                                                                     | 59 |

## **1. Introduction**

The Great Artesian Basin (GAB) is the world's largest and oldest groundwater system, underlying 22% of the Australian continent. The natural outflows of these waters have long had great significance for Aboriginal people inhabiting the dry heart of the continent. In particular, the mound springs that are formed on the south-western edge of the Basin have been of great importance. The emergence of water from these springs has resulted in the deposition and accumulation of calcium carbonate, creating rocky mounds with springs emerging from the top and associated, unique, water-dependent vegetation. These springs are still of great cultural and spiritual significance to local Aboriginal people, and have potential as the basis of outback tourism ventures run by Aboriginal communities.

Since European settlement this groundwater resource has been crucial for the development of Central Australia, particularly the pastoral industry. This has involved the use of natural outflows such as mound springs, which often suffered degradation through the trampling of stock, as well as a large number of bores drilled since 1878.

In more recent times, mining and resource extraction companies have come to rely heavily on this water for mining and processing operations. Examples include the copper, uranium oxide, gold and silver mine, run by the WMC (Western Mining Corporation) subsidiary Olympic Dam Operations (ODO), and the Santos oil and gas production fields in the Coongie Lakes district. ODO currently takes 15 ML/day from the southern margins of the GAB near Lake Eyre South (Borefields A and B). With ODO's expansion program, and plans being developed for other large mining ventures in northern South Australia, there is clear potential for a threat to the sustainability of this resource and for conflict between the various users of the water.

Evidence based on environmental isotope studies suggests that the GAB groundwater is "fossil water" that has accumulated in past eons. Therefore there is an urgent need for a thorough, independent assessment of the sustainability of the resource, especially in relation to the impact on the spectacular mound springs and other springs in the region. Such an assessment involves a development of a water balance for the region. The studies on the sustainability of the water resource of the GAB in the South Australian portion have mainly been carried out by ODO. The few independent reports of data relevant to the question of sustainability of the resource are couched in complex jargon that is difficult to interpret and understand. It is the aim of this review to summarise in an objective and comprehensible way the data on the sustainability of the water resource of the GAB particularly in relation to impacts on the mound springs by the nearby borefields of WMC.

## 1.1 Investigation Procedures

The investigation will focus on the south western portion of the basin and the mound springs found in an arc westward from Marree along the Oodnadatta Track in north central South Australia.

The relative and absolute use of the groundwater by pastoral and mining interests will be investigated from published data. Anecdotal evidence will be accumulated through interviews with people living in the region. The evidence for replenishment of the resource will also be assessed from published sources.

Evidence of decline in the activity of mound springs will be accumulated from interviews with people who have a long experience of visiting the springs.

The management of any groundwater system cannot ignore the complete system, especially as most of the recharge is thought to occur on the eastern edges of the Basin. By the end of the investigation a water balance will be developed to give an indication of the sustainability of the groundwater.



**PROPOSED EXPANSION OF THE OLYMPIC DAM OPERATIONS NEAR ROXBBY DOWNS, SOUTH AUSTRALIA**

**ENVIRONMENTAL IMPACT STATEMENT**

WMC (Olympic Dam Corporation) Pty Ltd propose to expand the Olympic Dam Operations near Roxby Downs, South Australia from 150,000 t/a to 350,000 t/a of copper and associated products. An Environmental Impact Statement (EIS) has been prepared by WMC (Olympic Dam Corporation) Pty Ltd to describe the proposal and to evaluate the potential environmental, social and economic impacts of the proposed expansion. The EIS has been prepared in accordance with the provisions of the South Australian Development Act, 1982 and the Commonwealth Environment Protection (Impact of Proposals) Act, 1974.

**Public Comment Invited**

The Minister for Housing and Urban Development invites interested persons and organisations to submit written comments on the EIS. The proponent will provide a publicly available response to all submissions received. Both the South Australian Department of Housing and Urban Development, and Environment Australia, Environment Protection Group (Commonwealth), on behalf of their respective Ministers, will also take the submissions into account in their assessments of the proposal.

The EIS will be available for inspection and public comment from Wednesday, 14 May 1987 to Friday, 11 July 1987 at the following locations:

**Department of Housing and Urban Development**  
3rd Floor Corner  
Library (1st Floor)  
138 North Terrace  
Adelaide SA 5000

**Municipal Council of Roxby Downs**  
Council Office  
Richardson Place  
Roxby Downs SA 5725

**State Public Libraries in Adelaide, Brisbane, Darwin, Hobart, Melbourne, Perth and Sydney.**

**The Environment Protection Group**  
Tourism House Library  
40 Balaclava Street  
Barton ACT 2600

**The Conservation Centre**  
120 Wakefield Street  
Adelaide SA 5000

The Executive Summary of the EIS is available at no cost. Copies of the EIS may be purchased at a cost of \$25 from those locations marked with an asterisk (\*) or by mail order for \$30 per copy (includes postage) from the Department of Housing and Urban Development, telephone (08) 8303 0724.

Comments on the EIS should be clearly identified as a 'public submission on the Proposed Expansion of the Olympic Dam Operations' be preferably on A4 sized paper and in black ink to facilitate copying, and be forwarded by 5.00 pm on Friday, 11 July 1987 to:

**The Minister for Housing and Urban Development**  
Attention: Manager, Environmental Impact Assessment Branch  
Department of Housing and Urban Development  
138 North Terrace  
Adelaide SA 5000

Submissions will be treated as public documents unless confidentiality is requested.

The South Australian Department of Housing and Urban Development, and the Commonwealth Environment Protection Group will be organising a number of meetings for public consultation during the public comment period and will advertise details of the meetings closer to the time they will be held.



**Environment Australia**

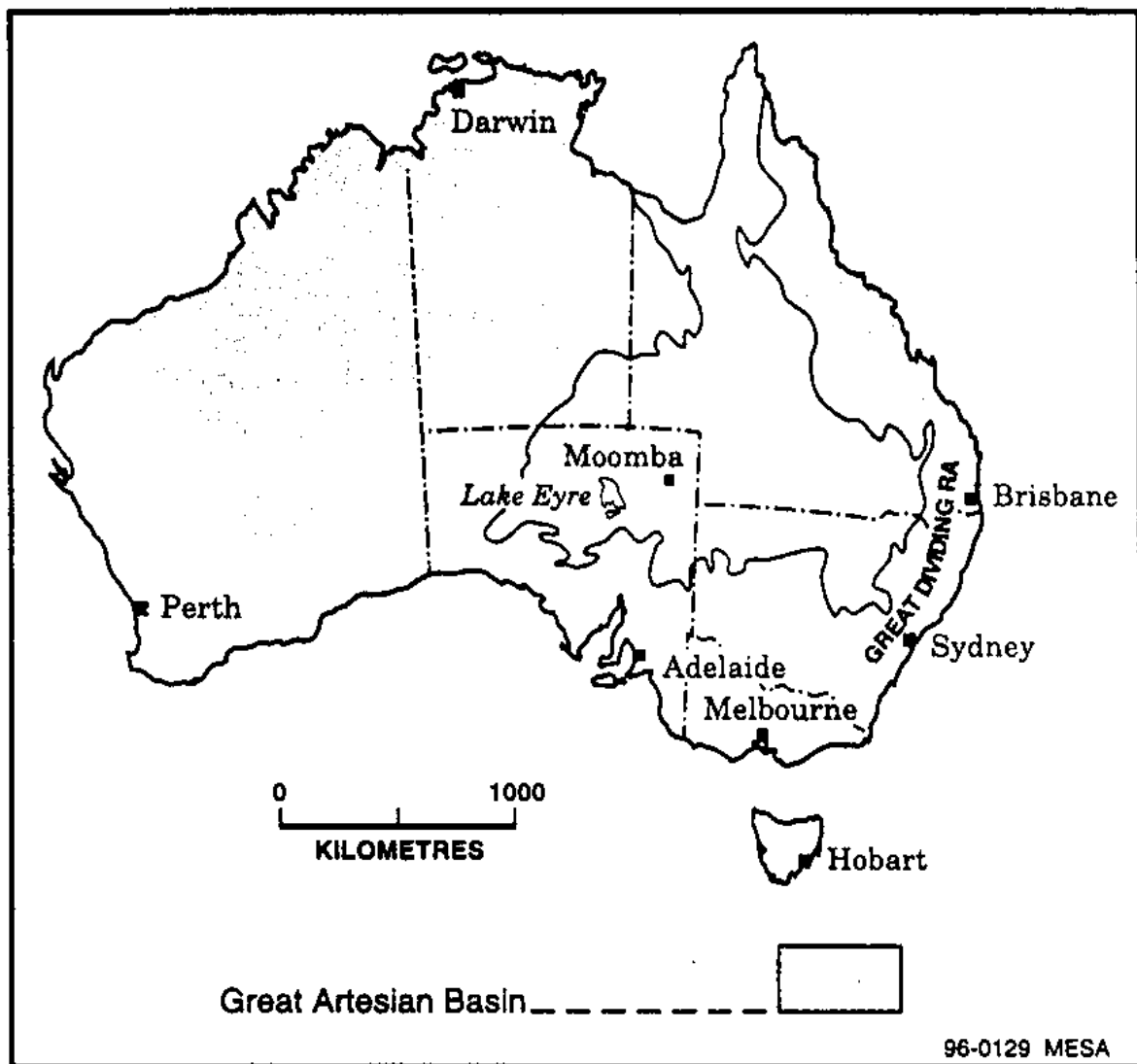
**DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT  
PLANNING DIVISION**

## 2. The Great Artesian Basin

### 2.1 Geology

The Great Artesian Basin (GAB) is the largest artesian groundwater basin in the world, underlying parts of Queensland, New South Wales, the Northern Territory and South Australia and occupying approx.  $1.7 \times 10^6 \text{ km}^2$  (Figure 1). It consists of several contiguous sedimentary basins, including the Eromanga Basin, with confined aquifers of Triassic, Jurassic and Cretaceous continental sandstone, underlain by an impervious pre-Jurassic base (Habermehl, 1980). The maximum total thickness of about 3000m occurs in the Mesozoic sedimentary sequence in the central GAB.

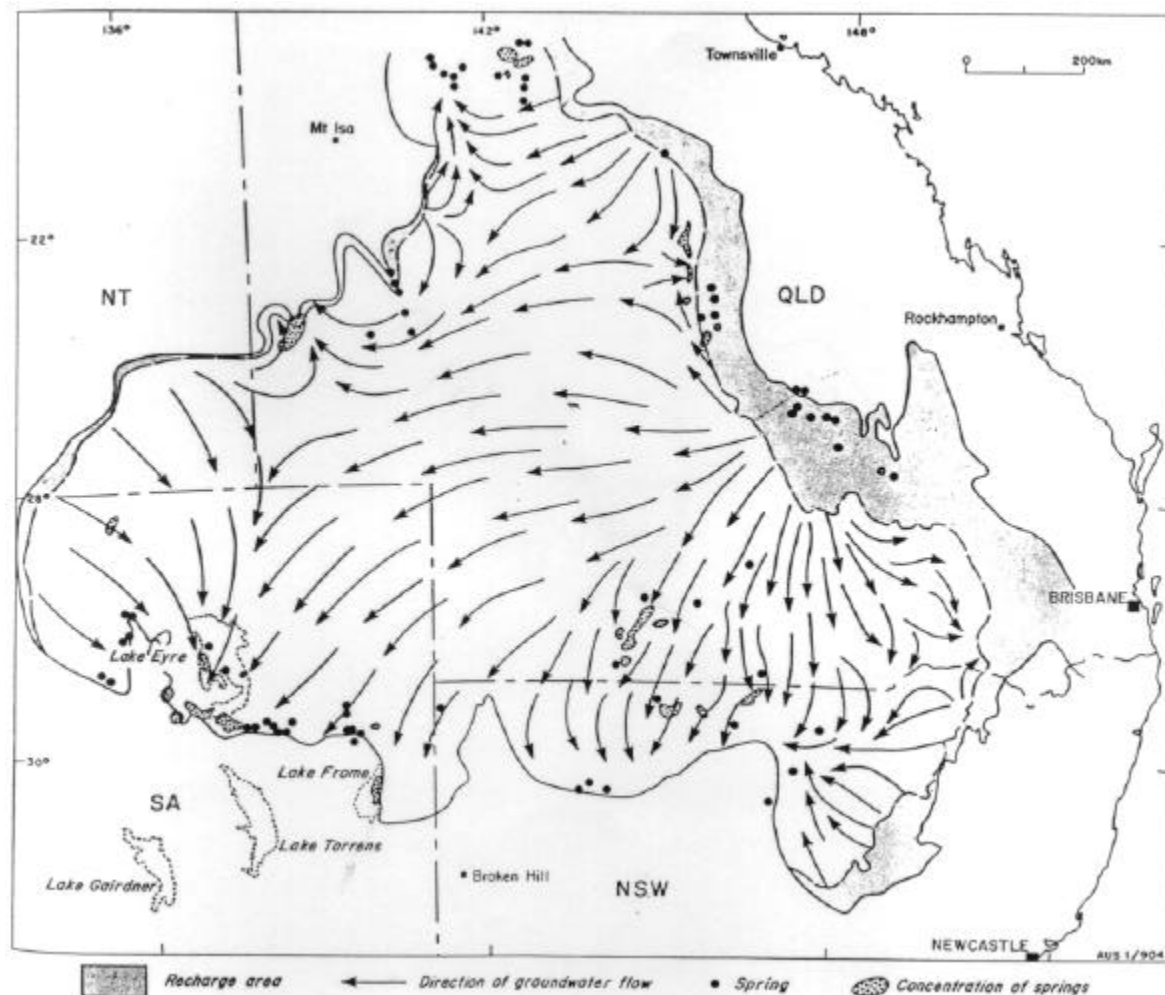
Figure 1 - The Great Artesian Basin  
Source: Sibenaler, 1996.



The basin is tilted slightly towards the south west, which accounts for the predominant flow of groundwater in that direction (Figure 2). Its asymmetry and groundwater flow is due to tertiary uplift along the eastern margin and subsidence in the central and south western parts of the basin. The Eromanga Basin, which occupies an area of 1 million square kilometres, is the one that feeds the mound springs on the south western extremity of the GAB and from which ODO is extracting large quantities of water through two large borefields on the southern rim of Lake Eyre. Major fault and fold systems have formed across the whole basin, but these faults don't have a broad scale effect on the regional patterns of water flow.

Figure 2 - Recharge and natural discharge areas (springs) and directions of regional groundwater flow in the Great Artesian Basin.

Source: Habermehl, 1980.



## 2.2 Hydrogeology

The GAB consists of aquifers which are continuous and hydraulically connected throughout the geological basins. These aquifers are bounded by the Winton formation at the top and the Rewan Group at the bottom (Habermehl, 1980). Impervious sedimentary, metamorphic or igneous rock form the hydrogeological basement which acts as an aquitard or no flow boundary. The upper, mostly unconfined, aquifers in the Tertiary and Quaternary sedimentary rocks are not considered part of the GAB.

The GAB primary artesian aquifer is the Lower Cretaceous-Jurassic system (known as the “J” aquifer). It consists of approximately 600 m of sandstone with 400m of intervening siltstone and mudstone. The Cretaceous aquifer (known as the “K” aquifer) sits above the J aquifer and is considerably more saline (Figures 3). For this reason the lower J aquifer has been the most exploited for its better quality water.

An example of an artesian basin is illustrated in Figure 4 along with the schematic flow system of the GAB which shows the approximated reduction in potentiometric head since 1880.

### 2.2.1 Hydraulic Characteristics

Since the early exploitation of the GAB many tests have been carried out to determine the hydraulic characteristics of the confined aquifers. In recent years rock samples and petroleum exploration wire-line logs have given more information on these characteristics (Habermehl, 1980). Hydraulic conductivity values range from 0.1 to 10 m/day with the majority of the values being in the lower part of that range. The State Water Authorities have conducted periodic systematic tests to determine transmissivity values ranging from 1 to 6,000 m<sup>2</sup>/day, with the majority of values being in the lower range. The water from the recharge areas on the eastern edge percolates through the basin at a rate of only 1-5 m/year (groundwater velocity) (Habermehl, 1980). Petroleum log data has been used to calculate storage coefficient values ranging from 10<sup>-4</sup> to 9x10<sup>-5</sup>. Intrinsic permeability ranges from several tens to several thousands of millidarcys. Porosity values range from 10 to 30 percent and the average vertical leakage conductivities of the leaky, very low permeability, confining beds range from 10<sup>-1</sup> to 10<sup>-4</sup> m/day.

Figure 3 - Lateral extent of simplified hydrogeological (model) units and cross-section of GAB. Source: Habermehl, 1980.

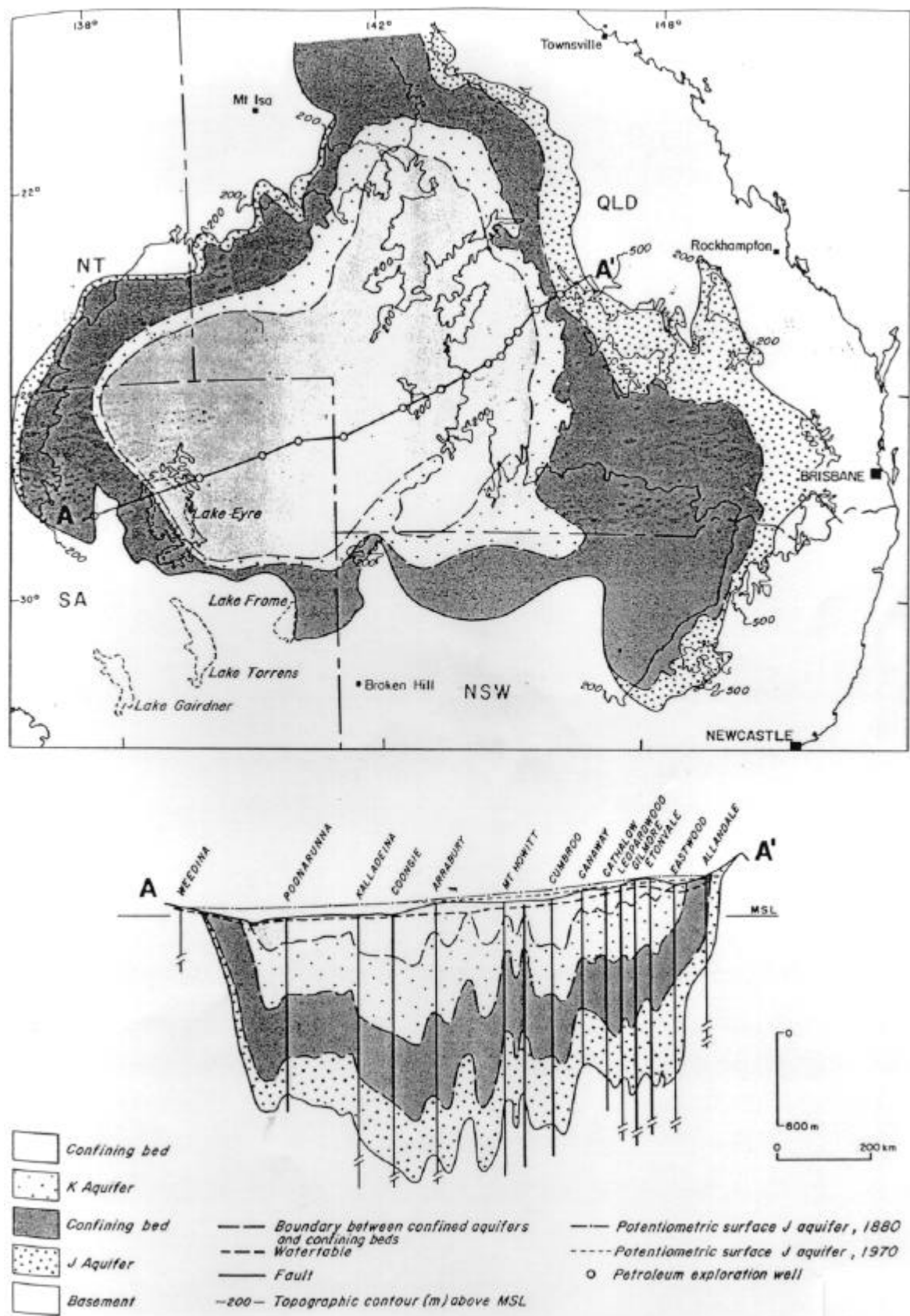


Figure 4 - Example of an artesian basin  
Source: ODO Expansion Project EIS, 1997.

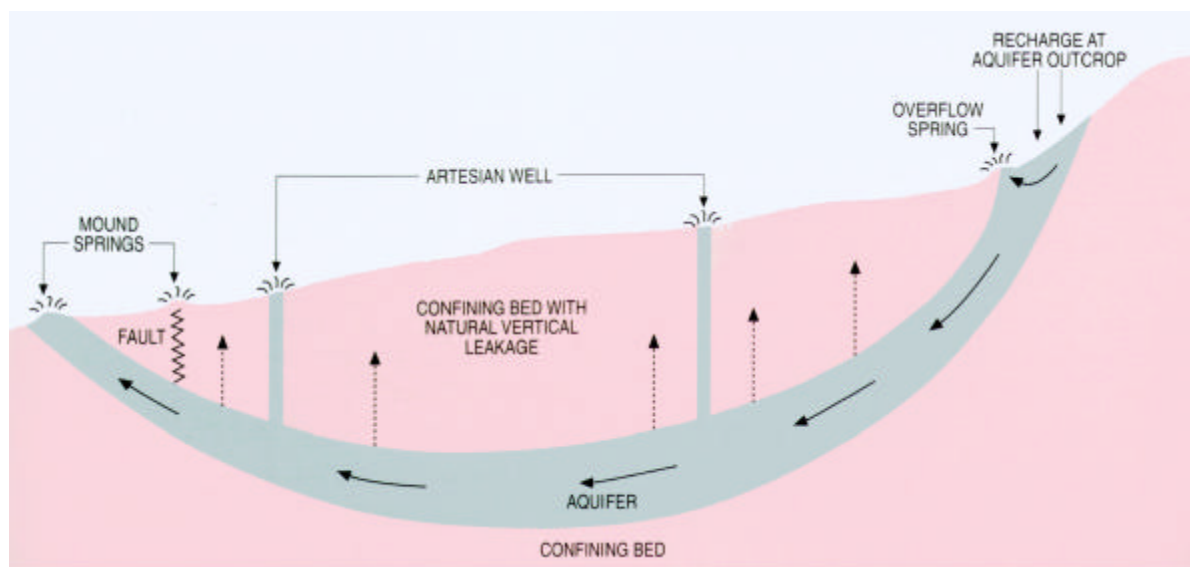
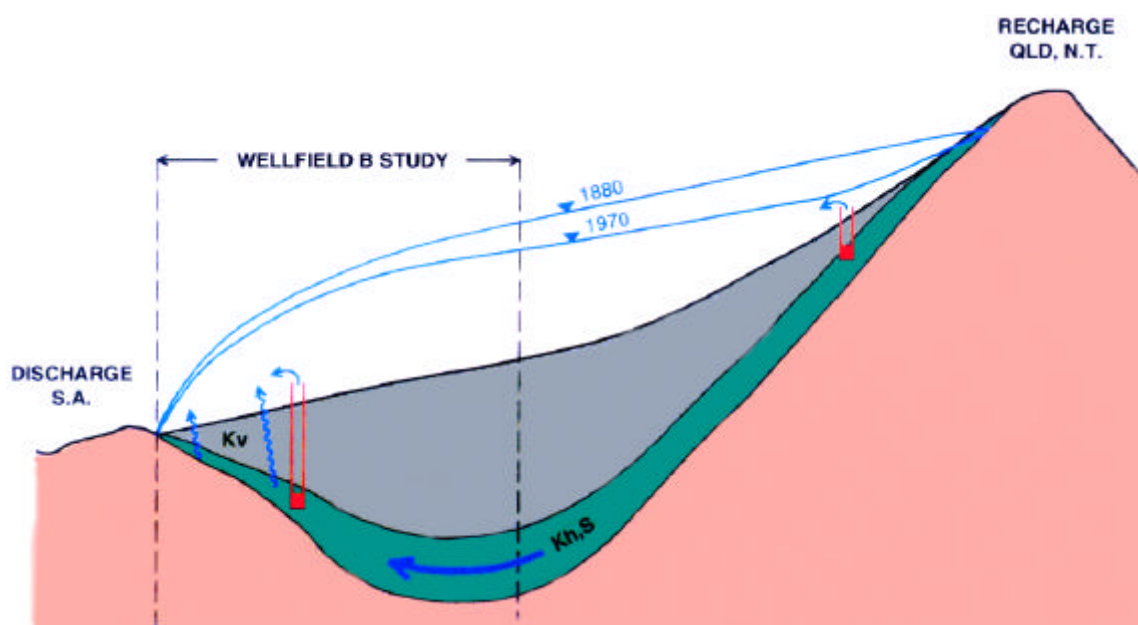


Figure 5 - Great Artesian Basin schematic flow system  
Source: Berry & Armstrong, 1995.



### 2.2.2 Recharge

The majority of recharge occurs on the western slopes of the Great Dividing Range in Queensland or the eastern elevated margins of the GAB in Queensland and New South Wales (Habermehl, 1980). Rainfall infiltrates through outcrop areas of unconsolidated sediments. In the arid western regions of the basin, in the Northern Territory, some recharge also takes place where aquifers are exposed or overlain by sandy sediments (Figure 2).

Through isotope analyses it has been confirmed that recharge has occurred from geological to modern times. Sophisticated analytical techniques are now available to measure environmental isotopes in groundwater, which include radioactive carbon-14 and chlorine-36, and stable isotopes such as oxygen-18 and deuterium (hydrogen-2). These techniques aid in the understanding of groundwater age, the interaction of groundwater with lakes and reservoirs, and the effects of evaporation on infiltration. Other hydrochemical studies have allowed the calculation of flow rates and flow patterns of the groundwater in the GAB (Habermehl, 1996).

### 2.2.3 Discharge

Discharge from the GAB occurs in four ways - natural concentrated outflow from springs, vertical leakage towards the regional watertable, subsurface outflow into neighbouring basins, and artificial discharge from artesian bores or pumped extraction from waterbores drilled into the aquifers (Habermehl, 1980). The basin was in a natural steady-state condition before European settlement, ie. there was no difference between recharge and natural discharge from the springs and vertical leakage. The natural discharge has decreased since European settlement, mainly due to the loss of hydraulic pressure following the opening up of the first bores (Habermehl, 1980). The reduction in flows from springs has been a visible indication of this.

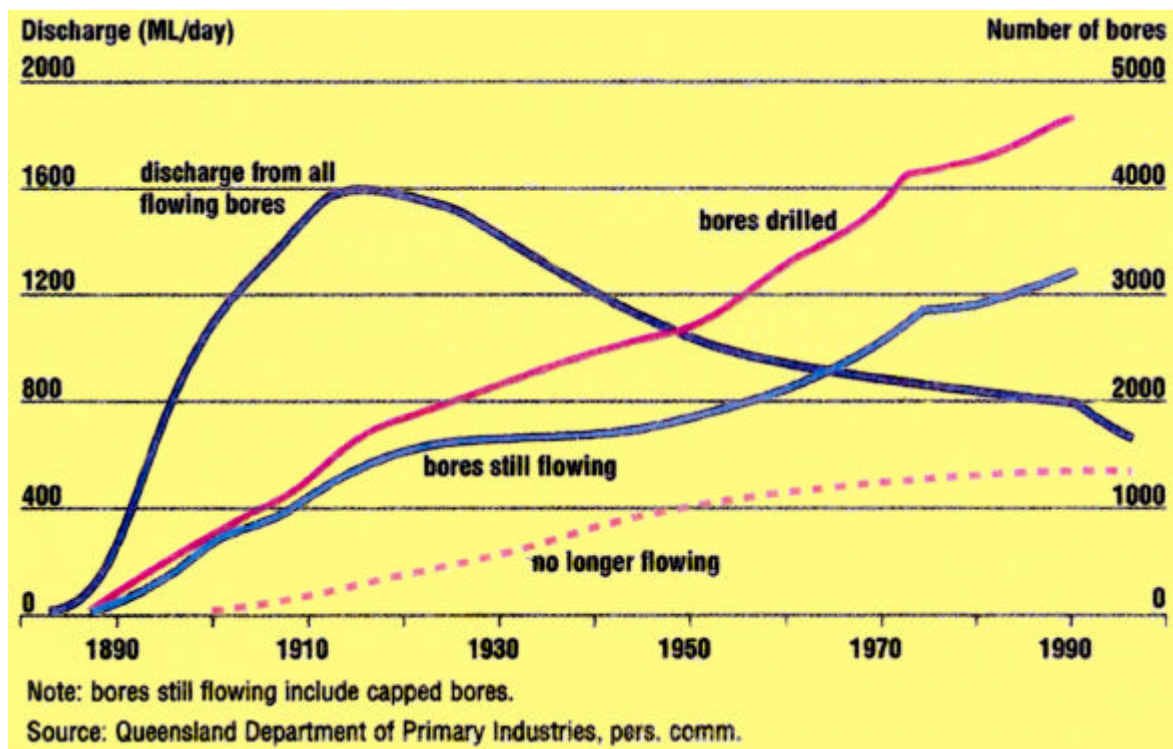
Rates of discharge from springs are generally low but highly variable, ranging from less than 0.09 ML/day to 13 ML/day. This will be discussed further in the section on springs (Section 3.2).

Vertical leakage upwards through the semi-pervious confining beds accounts for a considerable volume of groundwater movement throughout the basin. Estimates suggest 1,300 ML/day for the GAB as a whole (Kinhill Engineers, 1997), although as hydraulic pressures are decreased, vertical leakage rates will subsequently decline. It should be noted that accurate estimates of vertical leakage are hard to obtain due to processes such as high evaporation rates, a deep phreatic surface and surface water inflow from intermittent river systems, large swamps and lakes (Habermehl, 1980). As of 1980, no detailed studies have attempted to quantify the hydraulic properties of the confining units, with standard values based on rock type being used to calculate approximate values of vertical hydraulic conductivity, and thereby vertical leakage (Habermehl, 1980).

The first bore to tap into the GAB was put down near Bourke, N.S.W, in 1878. Since then thousands of bores have been drilled. These allowed the pastoral industry to be established in the predominantly semi-arid to arid areas that overlie the GAB. Some 4700 flowing artesian waterbores have been drilled into the basin. These bores average 500m in depth, with some up to 2000m. The accumulated discharge of these waterbores in 1970 was about 1500 ML/day (Habermehl, 1980). A summary of the flow history, number of bores drilled and those still flowing was recently compiled for the State of the Environment Australia (1996) report, reproduced below in Figure 6. It shows an early maximum peak discharge of approximately 1,600 ML/day in 1915. An important point to note is the continuing steady increase in bores being drilled and bores ceasing to flow. Non-flowing windmill operated bores numbered about 20,000 in 1980, supplying an average of 0.01 ML/day (Habermehl, 1980). These bores tap into the upper aquifers of the Winton and Mackunda Formations.

Figure 6 - Artesian bores in the Great Artesian Basin

Source: Australia State of the Environment 1996.





### 2.3 Hydrochemistry

The groundwater of the main basin area, which constitutes the westerly flows, mainly carries the ions  $\text{Na}^+$ ,  $\text{HCO}_3^-$  and  $\text{Cl}^-$ . More than 90% of the total ionic strength is due to these ions. The easterly flowing water is comprised of  $\text{Na}^+$ ,  $\text{Cl}^-$  and  $\text{SO}_4^{2-}$  water type. These two types of water meet and mix within the basin. However, in the south western part of the basin the groundwater is characterised by the Na-Cl- $\text{SO}_4$  water type (Habermehl, 1980).

The aquifers in the Lower Cretaceous-Jurassic sequence generally contain about 500-1000 mg/L total dissolved solids (500 mg/L is drinking water), and pH values range from 7.5 to 8.5 (Habermehl, 1980). This is good quality water suitable for domestic and town water supply, but it is chemically incompatible with the soils, making it unsuitable for irrigation. The Cretaceous aquifers have higher salinities, Cl values, and an overall poorer quality than the lower aquifers, although their water is still suitable for stock water. Hydrochemical differences distinguish the J and K aquifers. Fluoride values in the basin are commonly up to 10 mg/L and more. This is quite high and therefore presents a problem for domestic and stock water supplies.

Temperatures of the Lower Cretaceous-Jurassic groundwaters range from 30°C to 100°C. The presence of uranium and thorium in the earth's crust in the region is attributed to the heat flow within the basin (Torgersen *et al.*, 1991).

### 2.4 Early Exploration and Present Development

The extent of the GAB was well defined within twenty years of the first bore being sunk into its groundwaters. In Queensland, 670 bores had been drilled by 1900, with an estimated total flow of 1,000 ML/day (Hillier, 1996). The majority of the flows were quite small but it wasn't unusual for individual bores to exceed 10 ML/day (more than 100 L/s). In 1918 the maximum flow rate was 2,000 ML/day from 1500 flowing artesian waterbores (Habermehl, 1980). It quickly became evident that the high initial flowrates were declining. As a consequence, interstate conferences were held between 1912 and 1928 to address the problem. These conferences ended with an agreement on geology, the effects of elastic storage on diminution of flows and probable long term steady state basin discharge, although a GAB management plan wasn't developed. In 1954 the Queensland Government published a comprehensive report on the Artesian Water Supplies in Queensland. The report encouraged the use of pipelines from new bores and the licensing of artesian bores. The report didn't consider water conservation or the rehabilitation of existing bores as important issues for the basin.

There was and still is much wastage in the distribution of water from flowing artesian bores. This is largely due to the use of open-earth drains or ditches ("bore drains") which may run for tens of kilometres across station properties to provide water for the stock. Of the water distributed, estimates of livestock consumption vary from about 10% (Tandy, 1939, 1940) to 1 to 2% (Ker, 1963). The wastage of more than 90% of the extracted groundwater is mainly due to seepage, transpiration and evaporation of the water.

In recent years the mining and petroleum industry has become increasingly dependent on groundwaters from the GAB. These include Olympic Dam Operations (ODO) and the town of Roxby Downs in South Australia, several mines in the North West of the GAB, and oil and gas production in the North East of South Australia, South West Queensland and Eastern Queensland. These developments have placed a heavy burden on the resource of the GAB as the companies expand their operations. ODO are on the verge of increasing their water extraction rate from 15 to 42 ML/day, with talk of increasing this extraction rate even further by the year 2010. The extraction of large quantities of water from a concentrated region in the south western extremity of the GAB has greatly affected the position of hydrogeologic equilibrium in this portion, to the detriment of all uses of the water. With increases in extraction rates the springs are under greater threat.

## 2.5 The GAB Well and Drain Rehabilitation Program

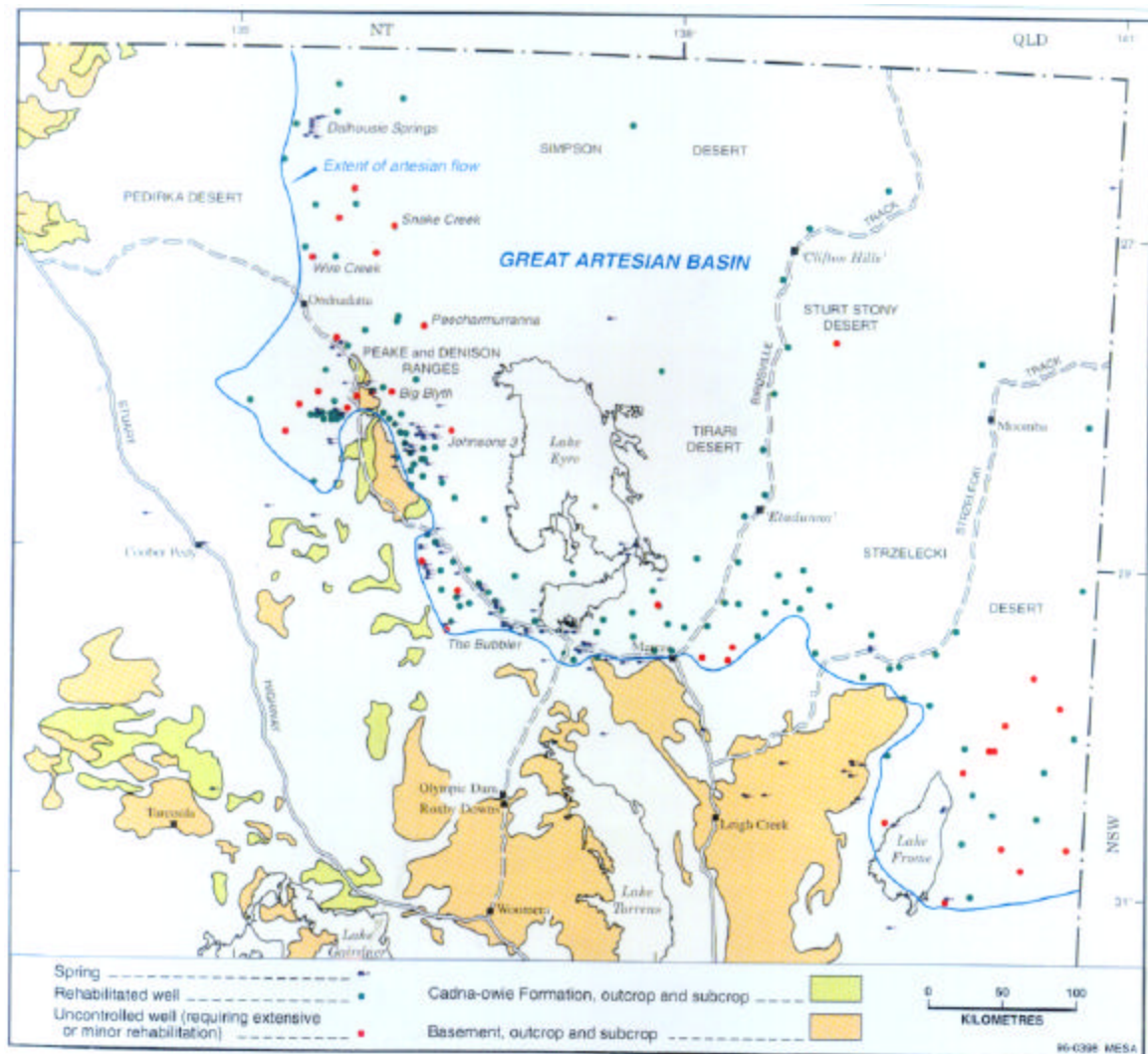
In 1977 the South Australian Water Resources Council highlighted the important issue of water wastage from uncontrolled wells. This began the rehabilitation program in South Australia. Queensland and N.S.W commenced a similar program in 1989. Three rehabilitation methods are used throughout the entire basin. These include:

- Complete abandonment, where wells are filled with cement through PVC or polythene pipe;
- Rehabilitation in which the existing well is re-lined with PVC or FRP casing to the top of the aquifer and pressure cemented to depth.
- Replacement of well. The old well is abandoned and a new well is drilled next to the old well or on a higher elevation.

Since the South Australian rehabilitation program began, 192 wells have been rehabilitated (78 plugged and abandoned, 73 rehabilitated, and 41 replaced). This amounts to an estimated water saving of 105 ML/day. A further 40 ML/day can be saved through the rehabilitation of 30 more wells which will occur over the next 5-8 years. Currently there are 220 wells in South Australia flowing at a rate of 169 ML/day (this includes ODO's 15 ML/day and Moomba's 22 ML/day). Figure 8 illustrates wells that have been rehabilitated and wells requiring extensive or minor rehabilitation. There are no uncontrolled wells in the vicinity of WMC's Borefield A.

Part of the GAB Rehabilitation Program in Queensland involves the introduction of polythene piping to replace open earth drains (Hillier, 1996). These pipes reduce water wastage and the demand on flowing artesian bores. In Cunnamulla, Queensland, improvements in artesian pressure have already been observed following the change from open channels to pipes. It has been estimated that the present outflow from the Queensland portion of the basin has been reduced to 420 ML/day (Hillier, 1996). The environmental benefits include reduction of land degradation, reduced spread of introduced weeds, shrubs and trees, and reduction in the numbers of feral and native animals that had become dependent on the open water drains, with a consequent improvement in the quality of vegetation in the vicinity.

Figure 8 - Generalised surface geology, and well and spring locations for the South Australian portion of the GAB.  
Source: Sampson, 1996.



### **3. Springs**

Springs occur where groundwater naturally flows to the surface. Artesian springs form when the potentiometric surface of the aquifer is above the ground surface, allowing the groundwater from the aquifer to rise to the surface.

#### **3.1 The Springs of the GAB**

Springs and areas of seepage occur throughout the marginal areas of the GAB. There are about 600 spring locations which are concentrated into eleven groups (Figure 9). The southern, south central, south western, north western and northern margins of the basin contain the largest concentrations of springs. The south western region, south west and north west of Lake Eyre, contains the largest number of springs, the most active springs, and the most unique springs (known as “mound springs”). These are the springs relevant to this investigation.

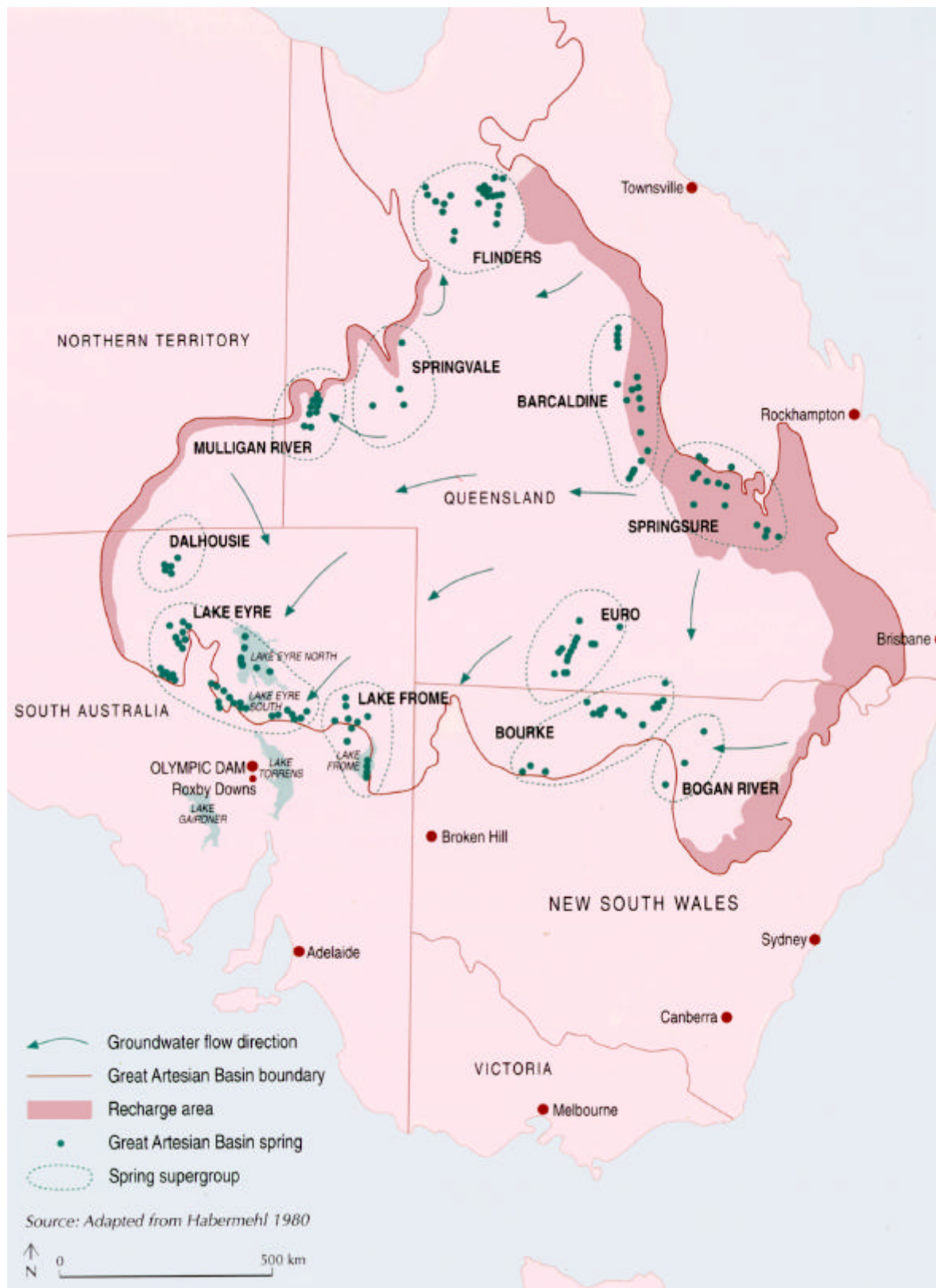
The springs are the natural discharge points from the ‘J’ and ‘K’ aquifers which make up the GAB. Many of the springs are associated with faults or fault zones, and pronounced deformation zones in the sedimentary cover. In the south, south west, and north west many of the springs have formed when water under pressure has broken its way through thin confining beds, making a path for water flow to the surface. Some springs in the east of the basin form when nearby aquifers overflow.

The springs support a varying density of vegetation immediately around them or along discharge lines. The discharges may form small creeks which vary from a few hundred metres to several kilometres long. The mound spring known as the Bubbler is one example. The majority of the springs in the GAB produce small discharges, although large discharges occur from the Dalhousie group of springs in South Australia (58 ML/day from about 80 spring outlets)(Habermehl, 1982). The accumulated spring discharge (from 600 spring complexes) is estimated at 130 ML/d (Habermehl, 1982).

Most of the springs were discovered by the early explorers of Central Australia in the middle and latter part of the nineteenth century. The springs were invaluable watering holes for these early explorers and indicated to the early settlers that there was artesian water underlying a large portion of inland Australia. Many of the first bores were sunk near springs. The development of the basin since that time, involving extraction of water from the aquifer through bores, has resulted in many of the spring flows ceasing or being reduced to seepages. Observations of reduced flows from springs began to be reported as early as 1893 (David, 1893; Pittman & David, 1903; Jensen, 1926; all cited in Habermehl, 1982). The reduction in spring flow in the north west, north, and east as a result of well development has been documented (Interstate Conf. on Artesian Water, 1913; Queensland Government, 1954 etc.).

Figure 9 - Location of Springs in the Great Artesian Basin

Source: ODO Expansion Project EIS, 1997.



### 3.2 Mound Springs of South Australia's North East Desert

Natural springs, known as “mound springs”, occur on the south western margins of the GAB in isolated desert environments where they support a diverse range of flora and fauna, some species of which are endemic and rare. They occur in a loop from Marree, under the southern tip of Lake Eyre, to Oodnadatta further north west. The South Australian Department of Environment and Planning in 1986 classified the several hundred springs into 22 groups. This is illustrated in the maps enclosed (Figures 10 a, b & c). Approximately 120 km to the north of Oodnadatta is the Dalhousie Spring complex.

The mounds which are characteristic of these springs are formed by the accumulation and carbonate cementation of sand, silt and clay (Figure 11). Calcium carbonate layers form on top of the mounds. The mounds vary in height up to 8 m, and cover areas of a few square metres to hundreds of square metres. Blanche Cup Spring is a classic mound spring structure, being about 6 m above the ground surface with a flat crater rim about 30m across (see Figure 12). Situated in the middle of the elevated surface is a circular pool. This is an example of a single outlet spring, which is not common since most of the springs have multiple outlets at different levels. There are three main sources of the sedimentary material that forms the mounds, these being chemical precipitates derived from dissolved solids near the spring exit, wind blown clastic material which is trapped in the vegetation around the spring, and clastic material brought to the surface by groundwater. Mounds may form when precipitates and clastics are deposited together. It has been estimated that a small spring with a discharge in the order of 0.06 L/sec and a solute concentration of 4 g/L deposits 170 tonnes of calcium carbonate in 1,000 years, enough to build a 3m high mound (Williams & Holmes, 1978). Carbonate rock and salt-encrusted plains surround many of the mound springs.



Figure 10 b - Location of Mound Springs in South Australia (cont.)

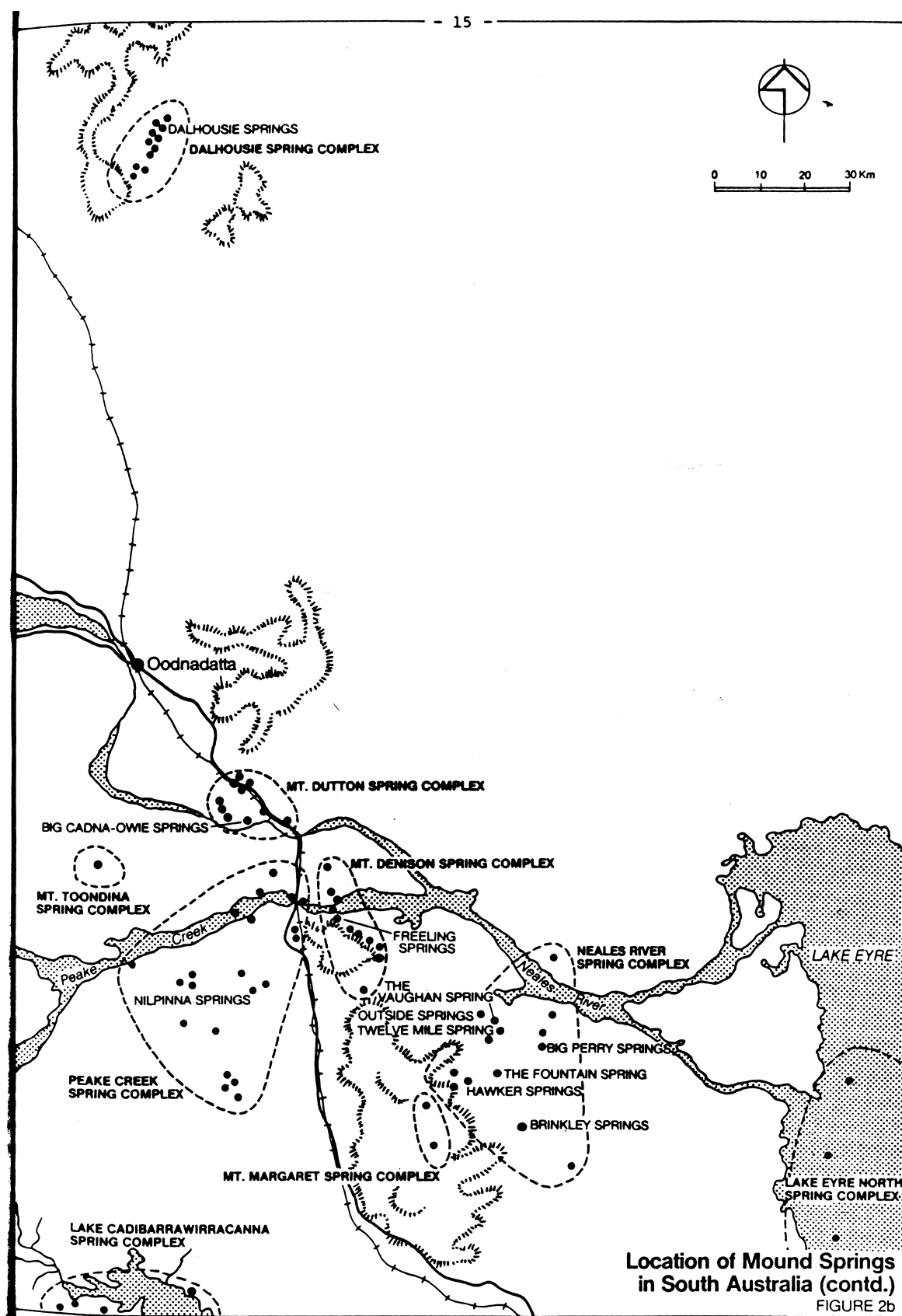


Figure 10 c - Location of Mound Springs in South Australia (cont.)

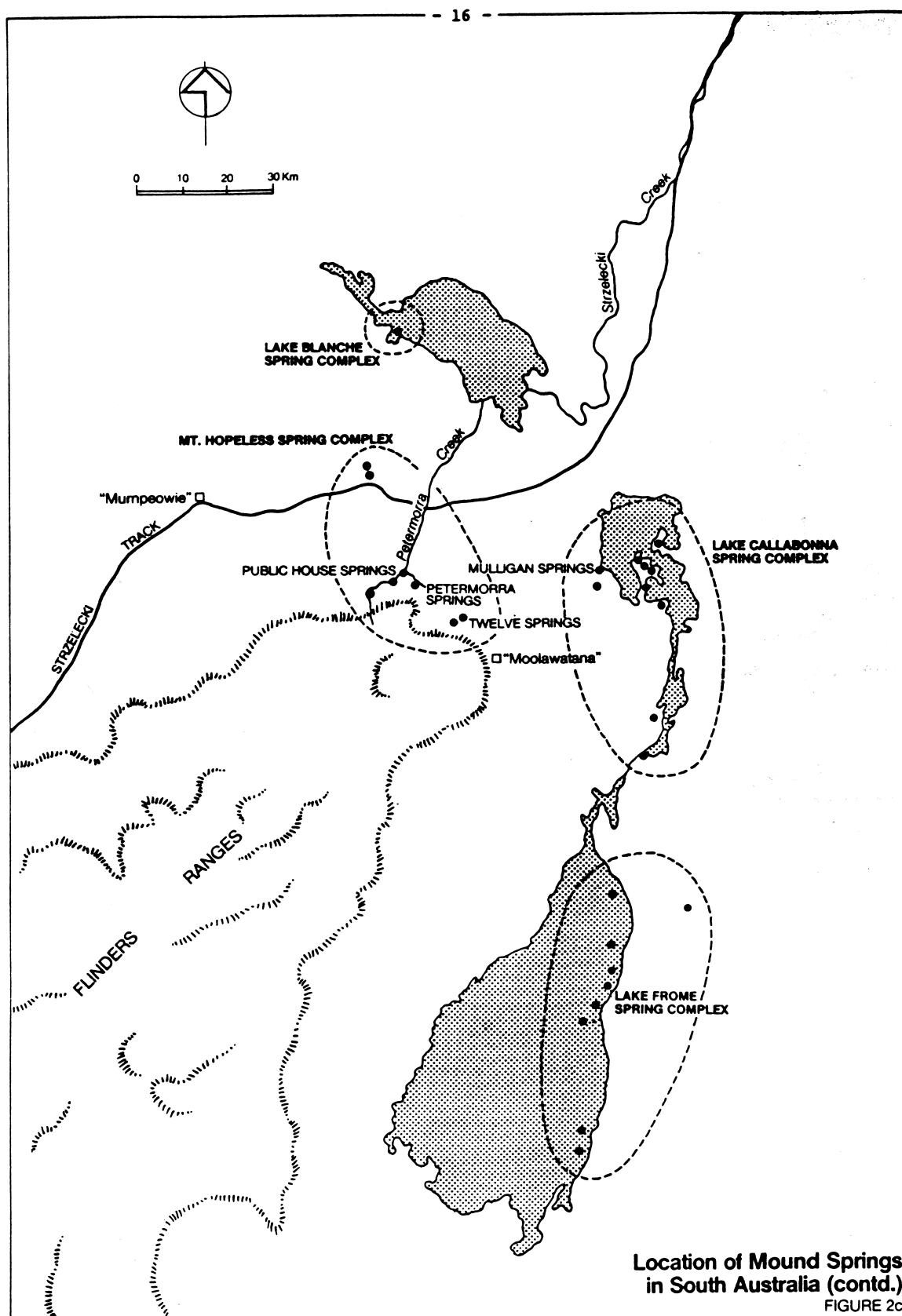


Figure 11 - Cross Section of a Typical Mound Spring  
Source: Williams & Holmes, 1978.

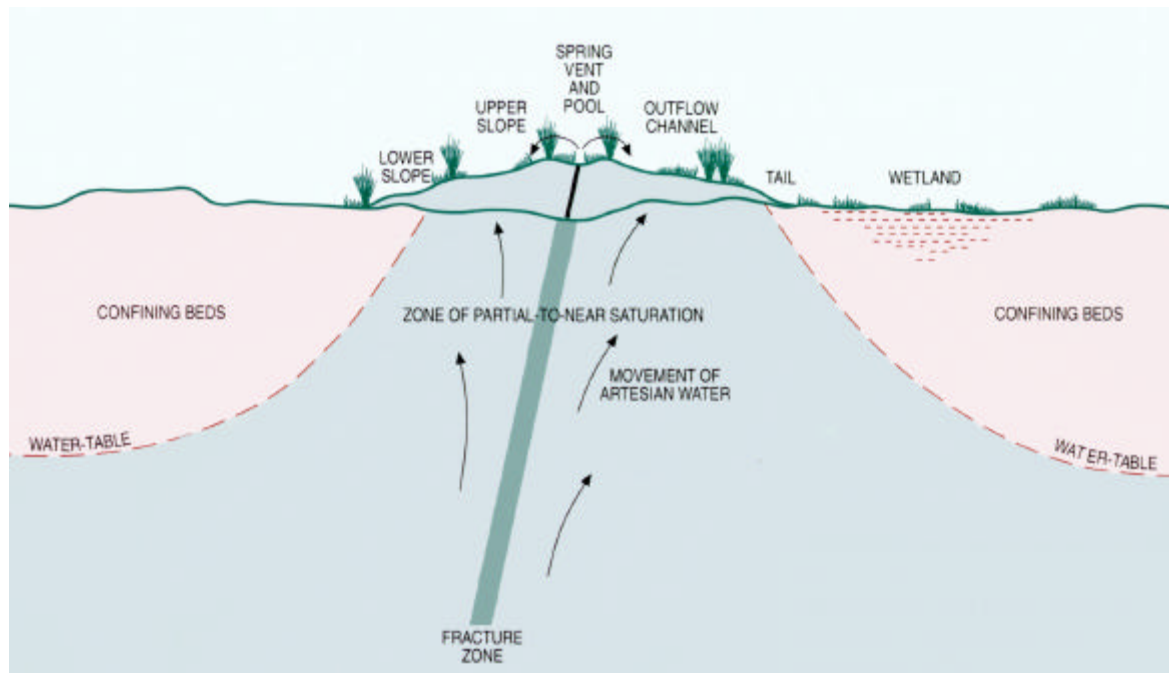


Figure 12 - Blanche Cup a Typical Mound Spring  
Source: Photo: Dan Keane, 1997



The Dalhousie Spring complex accounts for 80-90% of the natural discharge in the South Australian portion of the basin (Williams, 1979). The largest discharge from an individual spring in this complex is 14 ML/day. The discharges from the rest of the springs in South Australia are generally quite small, less than 0.09 ML/day. The Bubbler has the largest discharge outside the Dalhousie Springs of 0.65 ML/day.

Based on the anecdotal evidence of long term residents of the area, the drilling of wells has definitely reduced the spring discharges in the South Australian portion of the GAB. However, there are few records of this diminution in spring discharges. The evidence is largely based on the reduction in flowing artesian wells which were drilled near the springs, and the lowering of the potentiometric surface. Evaporation has a significant effect on the amount of vegetation which is supported by the mound springs. In the Dalhousie Spring complex it has been estimated that during the colder months the water discharge supports an area of vegetation three and a half times that supported in the warmer months (Holmes, 1975). This is equivalent to an evaporation loss of about 0.07 ML/day.

Extinct mound springs can be seen among the active mound springs, one example being Hamilton Hill, near the Bubbler and Blanche Cup, which is a huge mound rising about 40m above the present land surface. These extinct springs are remnants of past land surfaces and are protected from wind erosion by the carbonate-cemented sediments formed by the old mound springs (Figure 13). They are also an indication of how high the potentiometric surface was thousands of years ago. It has been estimated that the mound springs were active and forming sediments 80,000 - 40,000 years ago (Wopfer & Twidale, 1967). The present mound springs are generally found in the floors of valleys or broad creek channels. Davenport, Bopeechee, Beatrice and Priscilla Springs are all examples of this. Other spring outlets form at the base of hills, an example being the Hermit Hill Spring complex.

### 3.2.1 Geological Controls on Mound Spring Location

It has been recognised that there are five major geological controls on the formation of mound springs. The first two relate to the erosion of confining beds, allowing the groundwater to get closer to the surface. The confining beds may also outcrop, also due to erosion, allowing groundwater to reach the surface if the pressure is great enough. The next three controls relate to three types of faulting occurrences, basement wrench faults, trapdoor faults where two faults intersect, or topographical lows. Examples of all five of these controls are found in the South Australian region. The geological controls of the mound springs to the east of the Peake and Denison Ranges is illustrated in Figure 14.

Figure 13 - Diagrammatic geological section of the mound springs of the Strangways area illustrating the topographic relationships between active and extinct mound springs. Note that the top of Hamilton Hill lies approximately 28 metres above the surface upon which the modern mound springs site.

Source: Thomson & Barnett, 1985, cited in Boyd.

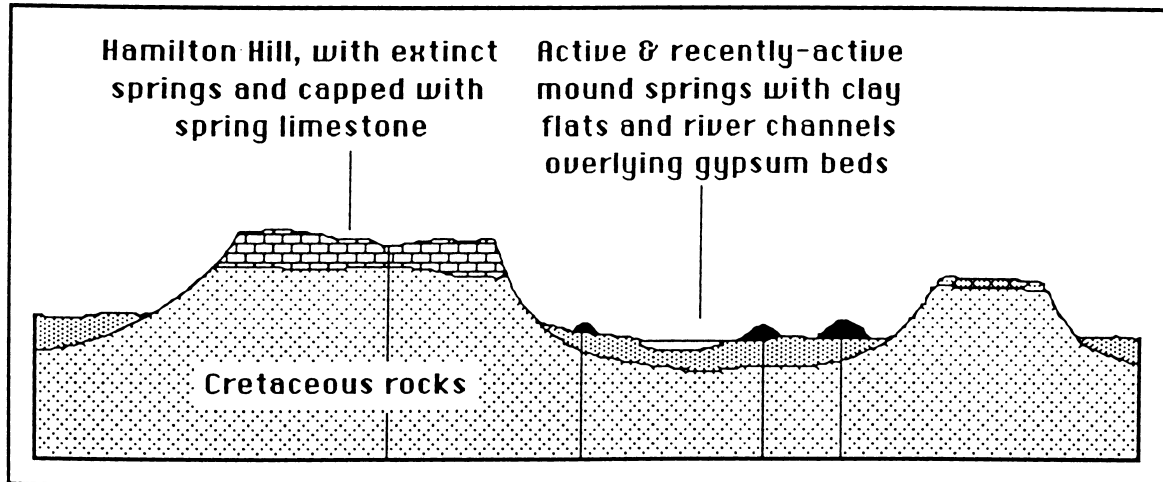
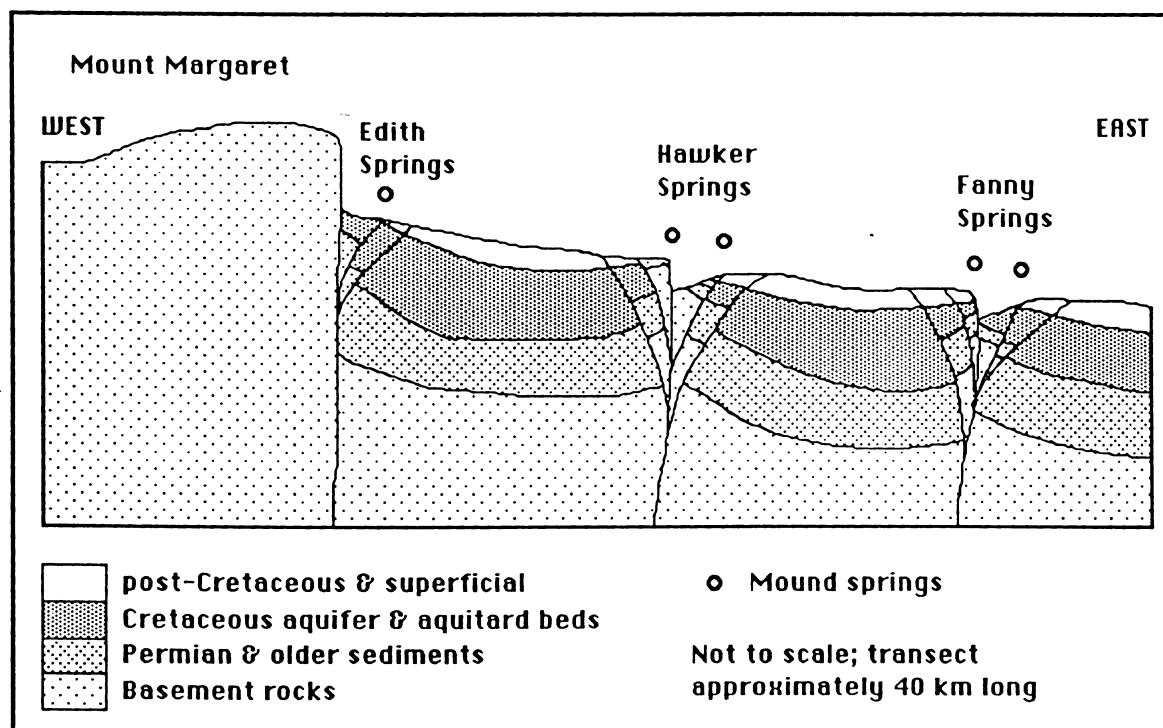


Figure 14 - Diagrammatic geological section showing the location of the mound springs east of the Peake and Denison Ranges, and illustrating the role of the structural control over mound spring location, in this case with springs located along echelon fault systems.

Source: Aldam & Kuang, 1988, cited in Boyd.



### 3.2.2 Hydrogeological Significance

The mound springs have been described as ‘oases in the desert’ (Harris, 1980-81) and must have been considered so for thousands of years by aboriginal inhabitants of the desert region. They represent the final flow of groundwater through the world’s largest artesian water basin. The water that reaches the South Australian portion of the GAB flows from the two recharge areas, the majority from the western slopes of the Great Dividing Range in Queensland and a small quantity from the Western Desert in the Northern Territory. The eastern water is carbonated and relatively rich in sodium and fluorine while the western water is rich in calcium, poor in sodium and fluorine, and sulphated, making it hard and corrosive. It has been estimated that these waters mix between the Wangianna and Francis Swamp spring complexes (Kinhill Stearns, 1984) (Figure 10). The natural discharge which occurs at the Wangianna, Hermit Hill, and Lake Eyre Spring complexes takes place after the water has been underground for almost two million years, and derives from the easterly flowing groundwater (Sibenaler, 1996; Torgersen *et al.*, 1991). This is the longest retention time of any of the waters in the GAB.

Hence any changes to the position of hydrogeologic equilibrium within the GAB, and in particular the South Australian portion with the most significant springs, will have lasting impacts for many future generations. Viewed from this perspective, the springs have immense hydrogeological significance.

### 3.2.3 Aboriginal Significance

The springs were important centres for Aboriginal communities probably beginning about 5000 years ago (Kinhill Stearns, 1985a - Assessment of Aboriginal Archaeological Significance of Mound Springs in South Australia), as shown by the huge abundance of stone chips and other artifacts in their vicinity. They remain of great spiritual and practical significance for Aboriginal communities. The majority of the springs in South Australia (about 116 springs in all) lie in Arabanna country and the Arabanna have traditional custodianship of the land and mound springs (Hercus and Sutton, 1985). Much of the oral history traditions ("the long lines of histories that traverse the country") relate to the mound spring sites (Hercus and Sutton, 1985). For example, the Bubbler is described by Aboriginal people as the convulsions of the ganmari snake which was killed by a Guyani ancestor.

One can’t emphasise strongly enough the fundamental importance of these mound springs to the traditional inhabitants. All springs have significance, and the deterioration of any group of springs will cause great distress to Aboriginal people (Hercus and Sutton, 1985). As these authors say, "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." We are now starting to realise, based on our limited scientific understanding of the country gleaned over the last 100 years, that the environmental health of inland Australia is vital to the wellbeing of all Australians. The Aboriginal people have learned this from their association with the land for millenia, leading to their appreciation of the sacredness of the mound springs and to the centrality of the springs in their mythology.

The Arabanna people have considered measures to protect the springs, having in the past had to watch while many of them were damaged and nearby sites and sacred trees were destroyed by the settlers. They again recognise major threats to these sites from mining, road building, pipeline building and tourism, and have expressed to Hercus and Sutton (1985) a desire to have Arabanna people trained as rangers and to be involved in periodic surveys of the sites, and to see the most endangered sites fenced. The hopes of the people will again be in vain if the lack of consultation of WMC with the local Arabanna community leaders in Marree over the construction of the pipeline from Borefield B to Roxby Downs is anything to go by (R. Dodd, personal communication; see section 7.5).

#### 3.2.4 Tourism Potential of Mound Springs and Environs

The mound springs have been assessed as having great potential for ecotourism (Rosewarne and Macdonald, 1993). Ornithologists have shown the greatest interest in them, but they also have great interest for botanists and students of invertebrates and fish. The Arabanna Community Centre in Marree attracts about 4000 visitors per year, and most of these are interested in visiting the mound springs. The local Arabanna community, which has suffered great deprivation since the closure of the Ghan railway line through Marree and the decline of the pastoral industry, has begun a tourism venture based on these springs and the surrounding desert wilderness. Ecotourism is likely to be the major future source of employment for people in the region, if it is not so already. Placed in this perspective, it is evident that the actively flowing mound springs, quite apart from their intrinsic worth, are likely to provide far more economic benefit to the people of the region than the huge, city-based investments such as mines.

### 3.3 Biological and Ecological Significance of Mound Springs

The mound springs have a unique biological and ecological significance due to their isolation in a desert environment. This uniqueness is based on the number of endemic and rare species of plants, fish, hydrobiids (small snails), and isopods, amphipods and ostracods (crustacea) they support. More than 40 species of unique Australian aquatic invertebrates inhabit artesian springs and rely for their continued existence on the continued flow of water from these springs (Ponder, 1994). The existence of many of these species is threatened by reduction in flows from mound springs.

Many birds, macropods, terrestrial invertebrates and other native animals use the springs frequently, but are not totally dependent on them due to their mobility. They are important as a drought refuge for many species (Australian Nature Conservation Agency, Directory of Important Wetlands in Australia, 1993). The South Australian Ornithological Association has suggested that an extensive survey of avifauna associated with the springs be undertaken. Since the springs are important drought refuge areas for birdlife, this life is a valuable indicator of the health of the spring. In fact all life associated with the springs is likely to be a very sensitive indicator of a decline in the quantity and quality of their water flow.

The springs have great potential for further evolutionary and ecological studies. The following springs have been listed as the highest priority for protection on the basis of their biological value and vulnerability to degradation (Biological Assessment of the South Australian Mound Springs, 1985). In the longer-term the conservation of all the springs needs to be considered.

1. Dalhousie Springs
2. Freeling Springs
3. Hermit Springs
4. Old Finnis Springs
5. West Finnis Springs
6. Blanche Cup and Bubbler Springs Group
7. Strangways Springs (Telegraph Reserve)
8. Nilpinna Springs
9. Bopeechee Springs
10. The Fountain or Big Perry Springs
11. Big Cadna-owie Springs
12. Twelve Springs
13. Coward Springs
14. Davenport Springs

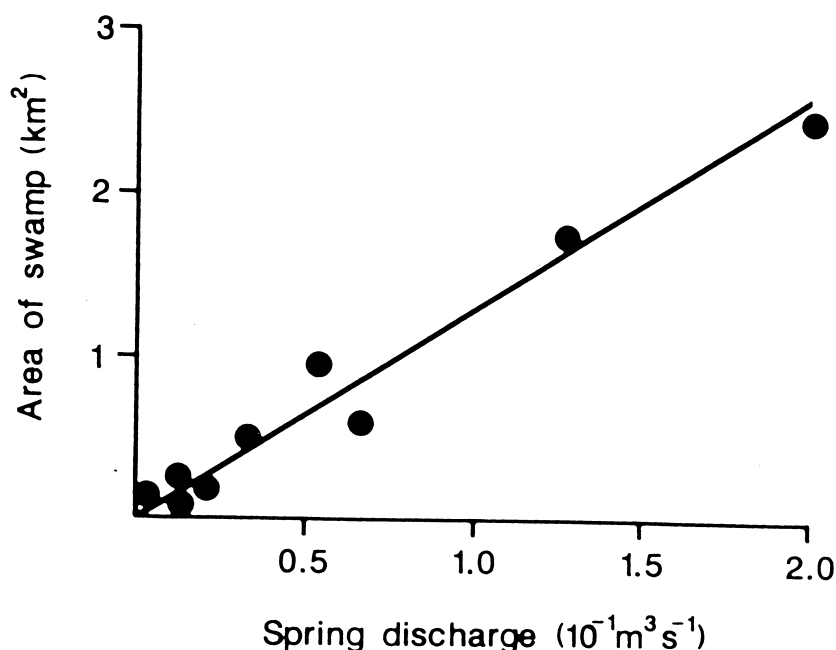
### 3.3.1 Vegetation

The vegetation associated with the springs has received the least attention but is the most diverse component of the spring communities, and of course the component on which all other species depend for food and habitat (McLaren *et al.*, 1985). The area of vegetation supported by a spring can be used as a measure of the rate of water discharge from the spring on a broad scale, as shown in Figure 15, although on a local scale for monitoring the short term reductions in flows associated with bore water extraction it has proved less useful (Fatchen and Fatchen, 1993). Loss of certain components of the vegetation is likely to mean loss of habitat for other species that depend on these components, resulting in their extinction.

Many of the mound springs contain endemic and relic plant species (Fatchen and Fatchen, 1993). Some plants of the springs are common and widespread near rivers and bores (eg. the bullrush *Typha domingensis* (cumbungi), the sedges *Cyperus laevigatus* and *C. gymnocaulos*, the common reed *Phragmites australis*, and the rush *Juncus krausii*) (McLaren *et al.*, 1985). Others are dependent on the springs for their survival in the north (eg. cutting grass *Gahnia trifida*, bare-twigh rush or spikerush *Baumea juncea*, spike rush *Eleocharis geniculata*, and fringe rush *Fimbristylis dichotoma*, while others are rare and endangered (eg. button grass or salt pipewort *Eriocaulon carsonii*, *Polygonum salicifolia*, *Goodenia anfracta*, *Zygophyllum crassissimum* and *Myporum* aff. *refractum*).

Figure 15 - Relationship between the area of a spring-fed swamp (ie. area of vegetation) and the rate of discharge from the spring.

Source: Williams and Holmes, 1978.



Button grass is a special example because it is limited to a few springs (see front cover and Figure 26). It was rediscovered in the Hermit Hill spring complex in 1978, after having been reported only twice before, once from a spring in western N.S.W. from which it is now extinct due to the incursion of cattle. *Eriocaulon* forms a dense mat in the outflow of the springs at Hermit Hill and is invariably covered by a thin layer of clear, flowing water. It occurs as natural populations in seven spring groups, these being Hermit, Northwest, Gosse, Old Finniss, West Finniss, Petermorra and Twelve. The presence of cattle apparently favours the salt pipewort by depressing the populations of larger plants that outcompete the pipewort (Fatchen and Fatchen, 1993).

Bare twig-rush, cutting grass and sea rush in the mound springs are not rare or endangered but are of biogeographic significance because of their disjunct occurrence in the springs in relation to other populations.

Different springs may have very different floristics, even though they may appear physically similar. This appears to be due to the fact that plant colonisation of the springs is a matter of chance distribution of particular species. Extinction of plants at the springs is also a matter of chance.

During a survey by the Nature Conservation Society of South Australia in 1978 (Symon, 1985), severe degradation of the vegetation of many springs by cattle was noted. While nine aquatic and semi-aquatic plants were noted in some intact springs, as few as one, two or three were found in springs damaged by cattle. *Phragmites australis* is often present in heavily grazed areas, which may be due to its size and greater resistance to grazing than other species such as *G. trifida*, *B. juncea*, *F. dichotoma* and *E. carsonii*.

It has been reported (Fatchen and Fatchen, 1993; Symon, 1985; EIS 1997, p. 7-51) that there is little similarity between the species composition of the vegetation around mound springs and around bores; therefore, to conserve that plants of the mound springs, it is necessary to conserve the mound springs themselves.

A survey of several springs has shown the existence in them of 35 taxa of algae, including 1 red alga and many green algae, diatoms and cyanobacteria (blue-green algae) in roughly equal proportions. About 8 -12 species of algae occur in any one spring, indicating a degree of variation between springs.

### 3.3.2 Fish

The South Australian Museum, under the direction of C.J.M. Glover, has reviewed the data on occurrence of fish in the springs of the GAB, and this data is summarised in the Supplement to the Draft Environmental Impact Statement for the Olympic Dam Project (Kinhill Stearns, 1983, pp. 49 - 50). Seventeen of 35 springs surveyed were inhabited by fish, with up to 6 species at any one locality. There are 9 species in the mound springs (Biological Assessment of South Australian Mound Springs, Heritage of the Mound Springs, 1986). All are likely to be affected by drawdown from the borefields. Eight of these are indigenous and one (the mosquito fish, *Gambusia affinis*) is introduced (in fact, a pest). All except one are found in artesian bores as well as natural springs, although springs are their basic niche. The fish appear to show a wide tolerance to fluctuations in water temperature, salinity and oxygen levels to which their habitats are prone. Therefore, although top consumers such as fish are often sensitive to deteriorating habitat conditions and therefore function as good indicators of such conditions, these fish may not be so useful in this respect. However, any gross deterioration in the quality and quantity of water flows in the springs would be expected to be reflected in declining fish populations.

### 3.3.3 Hydrobiids (small, dark coloured snails)

Extensive studies of the snail populations associated with the mound springs have been undertaken by the Australian Museum, under the direction of W.F. Ponder. These are reviewed in the Supplement to the Draft Environmental Impact Statement for the Olympic Dam Project (Kinhill Stearns, 1983, pp. 50 - 58). Collections have revealed two undescribed and endemic genera and a total of at least 11 species of snail (several undescribed) in the mound springs between Oodnadatta and Marree. Some species are confined to particular springs. At least one species is endemic to the eastern-most springs (including Davenport and Welcome Springs). Two springs (Coward and Billa Kalina) contain species endemic to them alone. Wider sampling has shown that the species in the springs of the Oodnadatta - Marree region are confined to this region. Within a spring there may be up to 5 species, with each occupying a different habitat within the spring and associated outflow (Figure 16). Most cannot tolerate standing water and none have been observed in swamps associated with bore outflows. While moderate cattle damage in many of the springs has reduced but not eliminated the snail and crustacean fauna in many springs, in others heavy damage has eliminated the fauna.

It appears that hydrobiids are likely to be a much more sensitive indicator of the environmental health of the springs than the fish. Flow reductions in springs have been documented to result in loss of snail fauna. For example, three species were collected from Horse Spring in 1970, whereas following reduced flows only one species was found there in 1981. The Supplement to the EIS recognises that because the hydrobiids lack a mechanism of widespread dispersal, "localised habitat loss may result in loss of species not represented elsewhere --- whether this is the case or not is not known" (p. 58).

There is now clear evidence that degradation of the springs has led to the extinction of hydrobiid snails at certain mound springs and threats to their extinction in others (Ponder and Hershler, 1984).

#### 3.3.4 Ostracods (crustaceans)

A unique crustacean, *Ngarawa dirga*, has been described from most of the mound springs in the Strangeways-Curdimurka group (eg. Blanche Cup, Coward, The Bubbler) (De Deckker, 1979; Supplement to the Draft Environmental Impact Statement for the Olympic Dam Project, Kinhill Stearns, 1983, p. 56). It is so unusual that it has been described as a new species, genus and sub-family. These organisms are usually found buried in the sediment in shallow flows. It is likely that as collections are studied further more species, unique to particular springs, will be described (McLaren *et al.*, 1986).

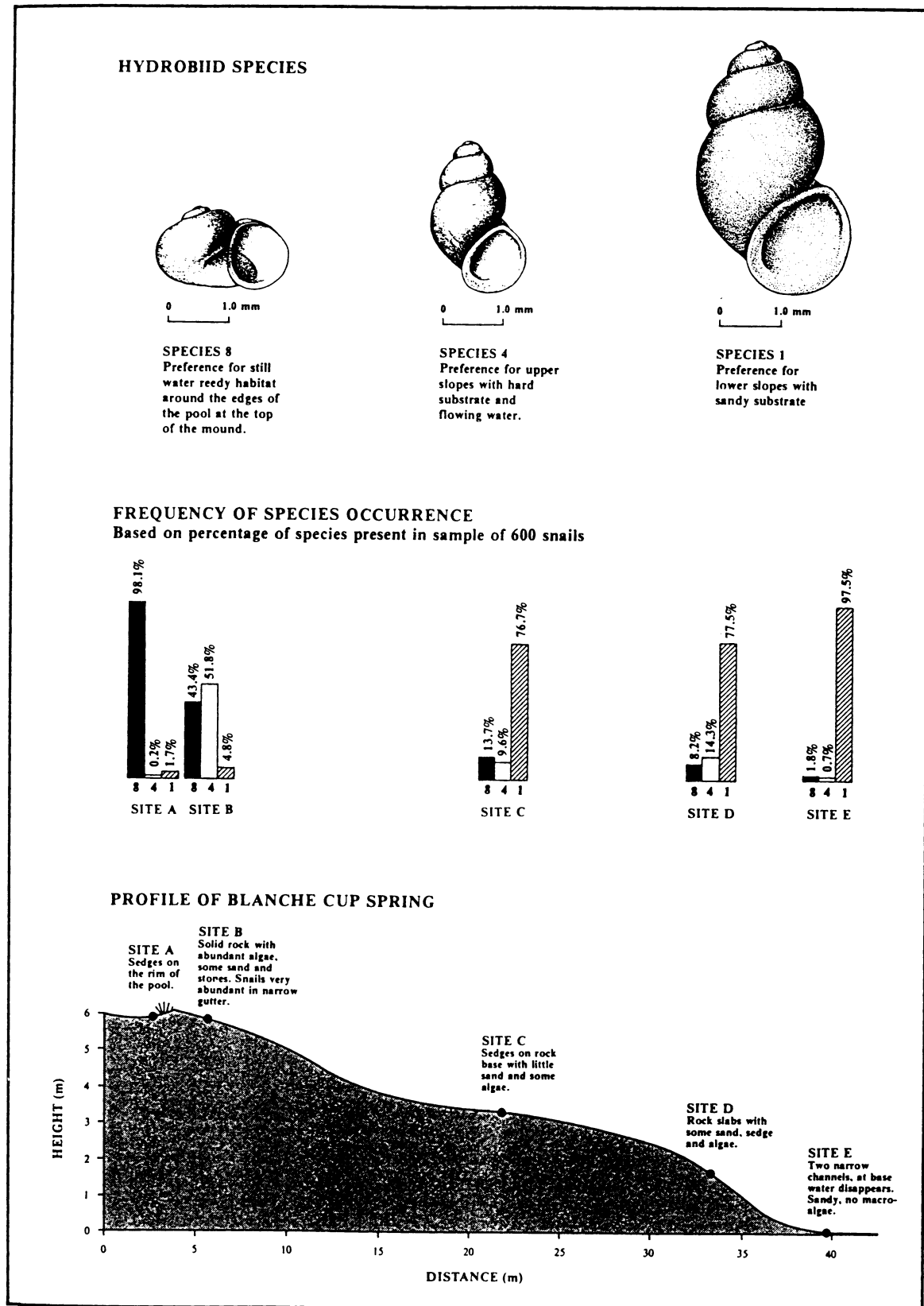
#### 3.3.5 Isopods

The most common crustacean inhabiting the mound springs is the isopod *Phreatomerus latipes*, which was first discovered at Hergott Springs in 1920. Interestingly, it is now extinct there because the water flow has stopped due to withdrawal of water to supply the nearby town of Marree (McLaren *et al.*, 1985). The adults prefer the shallow, slow flowing water at the end of the outflows, while the juveniles are more common in the faster flowing water near the source.

#### 3.3.6 Amphipods

It is likely that several species in this group occupy the springs, with certain species being unique to particular springs (McLaren *et al.*, 1985).

Figure 16 - Differentiation of hydrobiid habitats at Blanche Cup Spring  
Source: W.F. Ponder and B.W. Jenkins, 1989



### 3.4 The Impact of Pastoralism on the Mound Springs

Until this century, the mound springs remained relatively undisturbed despite centuries of use by Aboriginal communities and native animals. Initially the early pastoralists caused little damage also, since they generally fenced the springs to prevent stock fouling the water. Unfortunately, as pastoralists came to rely more on bores for stock water, the mound springs were neglected. Fences fell down and stock trampled the delicate structures of the springs, leading to degradation of the biotic communities (Harris, 1981). Single springs such as Blanche Cup and the Bubbler have in the past suffered more damage by cattle than the more dispersed spring complexes such as Hermit Hill, where the activities of cattle are distributed over a wider area, giving a lower intensity of damage for any single spring (McLaren *et al.*, 1985). Cattle damage is illustrated clearly in Figure 28 (Section 7).

There is conflicting evidence over whether the extraction of water through bores for pastoral use has impacted adversely on the mound springs. There is evidence that following the first rush of bore sinking in the outback in the early part of this century, the general groundwater pressure in the GAB declined (Habermehl, 1982). This was evident in a declining flow from the early bores. Habermehl (1980, 1986), using computer models of groundwater flows, concluded that during the early period of bore sinking spring discharge and vertical leakage both decreased in response to the increasing discharge through bores. It was contended that, as a result of the pressure decline, recharge of the aquifer increased by about 25%, compensating somewhat for the decline in natural discharges. However, Boyd (1990) maintains that there is little evidence that the spring flow has been affected during historical time by the discharge from bores. The few measurements that have been made over the last 100 years provide no evidence of a decline in flow rates. In 1860 a flow rate of 1.1 L/sec was recorded at Emerald Spring (cited in Boyd, 1990). A flow rate of 2.7 L/sec was recorded in 1923 and again in 1960.

The conflict may arise from confusion between flows from a few selected springs such as Emerald Spring, which because of local conditions (eg. perhaps little competition from nearby bores) may suffer little reduction in flow rate, and the general picture over the whole GAB for which a total of 3000 bores (Sibenaler, 1996) are contributing to water extraction. In South Australia there are at present 220 bores functioning primarily for the pastoral industry and flowing at a total rate of about 132 ML/day (Sampson, 1996), less than 10% of which is used effectively by the industry. The bulk of water is wasted through poorly functioning old bores and use of earth drains to distribute water.

### 3.5 Recommendations for Protection of Mound Springs

As a result of a study of the cultural and biological significance of the mound springs commissioned by the South Australian Department of Environment and Planning, the following measures were recommended to protect the mound springs (Biological Assessment of the South Australian Mound Springs, 1985) -

- fencing of springs as appropriate and provision of watering troughs at a distance from the springs as a substitute for direct access to stock;
- capping of uncontrolled bores in the vicinity of valuable springs; and
- assessment of future bore licence applications to ensure that their drawdown will not adversely affect valuable springs.

These recommendations contain an implication that springs can be classified as "valuable" and "less valuable", which is unfortunate given the uniqueness of the whole system and the great variation between springs in their hydrogeology, cultural significance, environmental relationships, biology, accessibility, and vulnerability to damage. This same implication permeates all ODO's EIS documents, and is a classic tactic of developers which allows attrition of sites as a result of economically-driven short cuts in development, when more considered development planned from a long term perspective could avoid damage to the entire system.

## **4. Olympic Dam Operations**

### **4.1 Present Operations**

Olympic Dam Operations (ODO) are located 580 km north-north-west of Adelaide in South Australia (Figure 17). Roxby Downs is the town that services the mine and where the majority of the workforce lives. The operations are wholly owned and run by WMC (Olympic Dam Corporation) Pty Ltd, which is a wholly owned subsidiary of WMC Limited. The mine site is considered to be one of the world's largest multi-mineral discoveries and one of the world's largest uranium deposits. ODO currently processes about 3 Mt/annum of ore, for the recovery of 85,000 t/a of refined copper, 1,500 t/a of uranium oxide, 850 kg/a (30,000 oz/a) of gold and 13,000 kg/a (460,000 oz/a) of silver. The mine and plant have been in production since August 1988. In December 1996 the workforce consisted of 963 workers at ODO and 319 support staff in Melbourne and Adelaide, giving a total of 1,282 workers, including 537 contract staff.

### **4.2 The Expansion Proposal**

The first stage of the expansion is to increase copper output to 150,000 t/a by the year 1999. This production rate has been approved and the construction works began in January 1996. The current Olympic Dam Expansion Project Environmental Impact Statement is directed to obtaining approval for an increased rate of copper production of 200,000 t/a by the year 2000. These dates are expected to be brought forward by an accelerated construction and mine development program. After the year 2000, it is planned for copper production to increase to 285,000 t/a. The proposed expansions in production rates of copper, uranium oxide, gold, and silver are illustrated in Table 1. A further expansion in capacity by the year 2010 would give a maximum total copper production rate of 350,000 t/a. Construction for this phase would start in 2008.

Table 1 - Expansion Project Production Rates

| Mineral                               | Existing operations          | Approved operations <sup>1</sup> | Expansion Project             |                                            |                              |
|---------------------------------------|------------------------------|----------------------------------|-------------------------------|--------------------------------------------|------------------------------|
|                                       |                              |                                  | First phase                   | After first phase                          | Second phase                 |
| COPPER                                |                              |                                  |                               |                                            |                              |
| From Olympic Dam ore <sup>2</sup>     | 85,000 t/a<br>(3.0 Mt/a ore) | 150,000 t/a<br>(6.5 Mt/a ore)    | 200,000 t/a<br>(9.0 Mt/a ore) | 200,000 t/a<br>(9.0 Mt/a ore) <sup>3</sup> | 350,000 t/a<br>(17 Mt/a ore) |
| From imported concentrates/other ores | -                            | -                                | -                             | 85,000 t/a                                 | -                            |
| <b>Nominal copper production rate</b> |                              |                                  | <b>200,000 t/a</b>            | <b>285,000 t/a</b>                         | <b>350,000 t/a</b>           |
| ASSOC. PRODUCTS                       |                              |                                  |                               |                                            |                              |
| Uranium oxide <sup>2</sup>            | 1,500 t/a                    | 3,420 t/a <sup>5</sup>           | 4,630 t/a                     | 4,630 t/a                                  | 7,730 t/a                    |
| Gold <sup>4</sup>                     | 850 kg/a                     | 1,640 kg/a <sup>5</sup>          | 2,050 kg/a                    | 2,920 kg/a <sup>6</sup>                    | 3,630 kg/a                   |
| Silver <sup>4</sup>                   | 13,000 kg/a                  | 18,000 kg/a <sup>5</sup>         | 23,000 kg/a                   | 32,800 kg/a <sup>6</sup>                   | 49,600 kg/a                  |

1 - 1983 EIS Approval is based on copper production rate

2 - Nominal values. Quantity varies depending on copper-uranium grade in ore processed

3 - Olympic Dam ore. Other South Australian ores may supplement this figure

4 - Nominal values. Quantity varies depending on gold-silver grade in ore and concentrates processed.

5 - Expected production rates. 1983 EIS indicative rates were 3,000 t/a U<sub>3</sub>O<sub>8</sub>, 3,400 kg/a gold and 23,000 kg/a silver.

6 - Assumes imported concentrate gold-silver grade is similar to Olympic Dam concentrate.

Source: ODO Expansion Project EIS, 1997.

Figure 17 - Location of Olympic Dam  
 Source: ODO Expansion Project EIS, 1997.



### 4.3 GAB Water Supply

The ODO and Roxby Downs township obtain water for potable and process uses from two borefields (Borefields A & B) in the south western part of the GAB. Until June 1996, 15 ML/day of water was extracted from Borefield A, with 1.5 ML/day of this being for the Roxby township (Dwyer, 1997). With the completion of Borefield B, WMC is entitled to extract 42 ML/day free of charge under an agreement made between the company and the S.A. Minister for Mines and Energy (Special Water Licences). This accounts for 9-25% of the total artificial extraction from the south western portion of the GAB and not the 3% claimed in the Report of the Senate Select Committee on Uranium Mining and Milling, 1997. Borefield A is located 107 km north of the mine while the new Borefield B is located a further 100 km away to the east of Lake Eyre (Figure 18).

Figure 18 - Location of ODO Borefields A & B  
Source: ODO Expansion Project EIS, 1997.



#### 4.3.1 Borefield A

Borefield A consists of nine production bores and nineteen observation bores located on the south western edge of the GAB, right in the middle of the most significant GAB springs (Figure 19). At this point the depth of the aquifer is only approximately 100 metres and the aquifer thickness varies from 15 - 25 metres (Berry, 1995). Six production bores flowing under artesian pressure were constructed between 1982 and 1987. In 1987 pumps were fitted to these bores. Three additional bores were constructed on the southern shore of Lake Eyre South in 1992 in a slightly thicker portion of the aquifer (see Figure 24, Section 7.4). A summary of abstraction from Borefield A since 1983 is given in Table 2. The water from these bores is pumped to the mine site via two pumping stations (see Figure 23, Section 7.4) along the pipeline. The current abstraction rate has been reduced from 15 ML/day to 5-6 ML/day with the construction of Borefield B.

Table 2 - Summary of Abstraction from Borefield A

| Period  | Average abstraction rates (ML/d) |                                |                                 |              |
|---------|----------------------------------|--------------------------------|---------------------------------|--------------|
|         | Southern bores<br>GAB6, 15, 16   | Central bores<br>GAB12, 14, 18 | Northern bores<br>GAB30, 31, 32 | <b>Total</b> |
| 1983-86 | 1.30                             | 0                              | 0                               | <b>1.30</b>  |
| 1986-87 | 2.30                             | 0                              | 0                               | <b>2.30</b>  |
| 1987-88 | 2.34                             | 2.08                           | 0                               | <b>4.42</b>  |
| 1988-89 | 4.27                             | 4.56                           | 0                               | <b>8.83</b>  |
| 1989-90 | 5.68                             | 4.30                           | 0                               | <b>9.98</b>  |
| 1990-91 | 6.25                             | 4.39                           | 0                               | <b>10.64</b> |
| 1991-92 | 5.67                             | 4.39                           | 1.57                            | <b>11.63</b> |
| 1992-93 | 5.60                             | 3.98                           | 3.01                            | <b>12.59</b> |
| 1993-94 | 4.50                             | 3.14                           | 4.46                            | <b>12.10</b> |
| 1994-95 | 4.72                             | 4.37                           | 4.43                            | <b>13.52</b> |
| 1995-96 | 4.67                             | 5.40                           | 4.92                            | <b>14.99</b> |

GAB- Great Artesian Basin

Source: ODO Expansion Project EIS, 1997.

Figure 19 - Borefield A Plan

Source: ODO Expansion Project EIS, 1997.



#### 4.3.2 Borefield B

The second Borefield was developed to accommodate the increased water needs as a result of the proposed mine expansion at ODO. It has been placed 100 km from Borefield A further towards the centre of the GAB, where the aquifer is much deeper and wider (Figure 20). It is interesting to note that Borefield B and its pipeline were approved and constructed well before the EIS was published. WMC's public affairs adviser, Terry Dwyer, describes the pipeline as "a new environmental benchmark."

The borefield has been installed to depths of 700-800 metres where the aquifer has a thickness of approximately 100 metres (Berry, 1995). Borefield B consists of three bores, each expected to deliver an average yield of 11 ML/day at artesian pressure to a pump station. At the present time only one bore is connected, pumping at a rate of 9-10 ML/day. When all three bores are connected, a new pumping station, located where the water from Borefields A and B meet, and a larger pipeline running to the mine, will be constructed. With a cost of \$40 million, this is the largest construction activity undertaken in the South Australian outback in the past five years. Initially, the Borefield B pipeline was going to be 55 km shorter. The added length increased the cost by \$5 million (Dwyer, 1997).

#### 4.3.3 Future Borefield - Borefield C

WMC's long term plan of obtaining copper production rates of 350,000 t/a by the year 2010 will involve water extraction greater than the present maximum supply of 42 ML/day. WMC has stated that another borefield would be required to fulfil these production rates. This extra borefield would be subject to a separate public consultation and government assessment.

Figure 20 - Borefield B Plan

Source: ODO Expansion Project EIS, 1997.



#### 4.4 Water Use

Water use at ODO is expressed as a function of the tonnage of ore milled (L/t). This is the water required for the mine and metallurgical plant. Due to water minimisation programs this value has declined from 2,100 L/t in the 1989-90 period to 1,570 L/t in 1995-96. It is expected that a further 21% reduction (to 1,240 L/t) will occur when copper production reaches 200,000 t/a. The following table has been prepared to demonstrate the expected use of water from the GAB (Table 3). The water use figures are based on two sets of estimates - WMC's 1997 economic modelling of copper production and groundwater modelling of borefield extraction. The table demonstrates that there are large discrepancies between these two sets of figures in the ODO Expansion Project EIS, especially for the higher levels of copper production.

Table 3 - Borefield A and B Extraction Predictions

| Period    | Copper production | Total Ore Milled (Mt/a) | Water use <sup>1</sup> (ML/day) | Water use <sup>2</sup> (ML/day) |
|-----------|-------------------|-------------------------|---------------------------------|---------------------------------|
| 1996-1998 | 85,000 t/a        | 3                       | 17                              | 13-17                           |
| 1998-1999 | 150,000 t/a       | 6.5                     | 20                              | 22-28                           |
| 1999-2010 | 200,000 t/a       | 9                       | 34                              | 32-42                           |
| 2010-2011 | 285,000 t/a       | >9                      | 39                              | >42                             |
| 2011-2016 | 350,000 t/a       | 17                      | 42                              | 58-75                           |

1 - Based on borefield extraction used for groundwater modelling.

2 - Based on economic modelling of copper production rates, 1,240- 1,570 litres of water is used per tonne of ore mined. Includes Roxby Downs township, mine & metallurgical plant.

The nature of uranium mining, with its requirement for dust suppression to reduce the level of radioactive contamination of plant and personnel, makes it a heavy and wasteful consumer of water, quite apart from heavy consumption during on-site processing. For example, under the heading "Mine Dust Control" in the Supplement to the Draft Environmental Impact Statement for the Olympic Dam Project (Kinhill Stearns 1983, p. D10) it is stated that "Water will be used for dust suppression. This will include water injection during drilling, water sprays after blasting, washing down of walls, and wetting of piles of broken ore before moving. Sprays will also be used at ore passes and chutes and at the crushers."

#### 4.5 Water Costs

In the ODO Expansion Project EIS, WMC claim they deserve to obtain water 'free of charge' since they pay for all of their own operating costs.

In the inner city of Melbourne an average two person household pays \$100 /year for water or \$0.65/kL (including sewage water) and \$1000 /year for supply costs. The operating costs (capital and reticulation) are ten times the cost of the actual water. WMC considers their operating costs to be so enormous that they don't need to pay for the water at all. Remember that this water is two million years old and a very precious desert resource. Melbourne's water supply is sustainable.

The present water supply of 15 ML/day is divided into desalinated or potable water and untreated process water. The potable water amounts to 6 ML/day and the process water to 9 ML/day. Roxby Downs township uses 1.5 ML/day with domestic households being charged \$0.88/kL. The industrial mine pays nothing for water while the mine workers and their families in the town pay \$0.23 more than the cost of water in Melbourne. At a rough estimate WMC receive \$4.3 million/year of water free of charge (13.5 ML/day).

On top of this pastoralists in the region are now being charged for their GAB water supply (Dr Denis Matthews, Stephen Baker and Robert Kelly, cited in Senate Select Committee on Uranium Mining and Milling, Vol. 1, 51/52).

#### 4.6 Abstraction Licences Held by WMC

An indenture exists between WMC and the South Australian Government which forms the legal framework for the development and operation of Olympic Dam. Special water licences are issued under this indenture allowing WMC to abstract groundwater from the borefields up to agreed maximum drawdown levels at the boundaries of the designated areas (Figure 19 & 20). Ms Cherry Hoyle (Friends of the Earth) and Professor Denis Matthews (Conservation Council of South Australia) have stated that there is no public scrutiny of the operations due to the Indenture Act and it does not represent current thinking (Senate report, Vol. 2, 13).

##### 4.6.1 Special Water Licence for Borefield A

The Borefield A agreed limits are :

1. The drawdown at the observation bores GAB8 and HH2 located at the boundary of the designated area shall not exceed 4m.
2. Drawdown at Jackboot bore shall not exceed 5m

The licence also requires WMC to prevent adverse effects on the Hermit Hill, The Bubbler and the Blanche Cup mound spring complexes. Water pressures and spring flow must be monitored on a monthly basis.

##### 4.6.2 Special Water Licence for Borefield B

This licence places maximum drawdown limits of 5m at the five corner locations of the designated area. Regular monitoring is also required.

#### 4.7 The Impact on the Mound Springs due to WMC's Borefields

Borefield A was located right within the Lake Eyre and Hermit Hill Spring Complex, immediately to the south of Lake Eyre South. This location now seems astounding, given our awareness of the localised impact of water extraction and the hydrological, environmental, cultural and economic sensitivity of the mound springs.

##### 4.7.1 ODO Draft EIS, 1982 Predictions

Reductions in artesian flow expressed as percentages in response to extractions of water through these borefields were predicted in the 1982 Draft EIS using a computer model (Kinhill Stearns, 1982). These are summarised in Tables 4 & 5, and are based on a 33 ML/day extraction rate from Borefields A and B. In this EIS it was stated that 6 ML/day would be extracted from Borefield A and 27 ML/day from Borefield B. The proposed Borefield B in the 1982 Draft EIS was located 55 km south-west of the Borefield B currently under construction (1997).

Table 4 - Estimates of Reduction in Bore Discharge, 1982

| Bore                           | Present head<br>(approximate metres<br>above ground level) | Reduction in head<br>(metres) | Reduction in<br>artesian flow (%) |
|--------------------------------|------------------------------------------------------------|-------------------------------|-----------------------------------|
| In vicinity of<br>Borefield A: |                                                            |                               |                                   |
| Venable                        | 15                                                         | 15                            | 100                               |
| Bopeechee                      | 25                                                         | 20                            | 80                                |
| Beatrice                       | 25                                                         | 20                            | 80                                |
| New Years Gift                 | 25                                                         | 20                            | 80                                |
| Curdimurka                     | 30                                                         | 4                             | 13                                |
| In vicinity of<br>Borefield B: |                                                            |                               |                                   |
| Charles Angas                  | 45                                                         | 8                             | 18                                |
| Morris Creek                   | 50                                                         | 15                            | 30                                |
| Cooranna                       | 50                                                         | 30                            | 60                                |
| Crow's Nest                    | 70                                                         | 70                            | 100                               |
| Big Bore                       | 70                                                         | 40                            | 57                                |

Source: Olympic Dam Project Draft EIS, 1982.

Table 5 - Estimates of Reduction in Spring Discharge, 1982.

| Spring                         | Present head<br>(approximate metres<br>above ground level) | Reduction in<br>head (metres) | Reduction in<br>discharge (%) |
|--------------------------------|------------------------------------------------------------|-------------------------------|-------------------------------|
| In vicinity of<br>Borefield A: |                                                            |                               |                               |
| Priscilla                      | 20                                                         | 20                            | 100                           |
| Gosse                          | 40                                                         | 10                            | 25                            |
| McLachlan                      | 40                                                         | 10                            | 25                            |
| Smith                          | 40                                                         | 10                            | 25                            |
| Hermit Hill                    | 30                                                         | 5-10                          | 17-33                         |
| In vicinity of<br>Borefield B: |                                                            |                               |                               |
| Davenport                      | 30                                                         | 3                             | 10                            |
| Wangianna                      | 30                                                         | 3                             | 10                            |
| Welcome                        | 30                                                         | 3                             | 10                            |

Source: Olympic Dam Project Draft EIS, 1982.

The 1982 EIS contained a very slim understanding and appraisal of the impact on the mound springs. These tables are in effect all WMC came up with- a meager effort. Venable, Bopeechee and Beatrice Springs are referred to as a “bore or well adjacent to spring” and excluded from the reduction in spring discharge (Table 5). So, in reality it was predicted that there would be four springs (Venable, Bopeechee, Beatrice and Priscilla) receiving flow reductions of between 80 and 100% and another four springs having their flow reduced by around 25%. In the near vicinity of Borefield A there are four spring complexes containing 45 different spring groups (Table 6). Each spring group has unique geological formations, hydrogeologic conditions and biotic communities. The EIS with its simplistic hydrogeologic models and subsequent analysis of its results (Tables 4 & 5) is a very limited environmental impact study. However, it does document that the company knew that Borefield A would have a strong impact on mound springs in its vicinity.

Table 6 - Springs Impacted by Borefield A

| Spring complex | No. of spring<br>groups in<br>complex | Reduction in<br>flow (%) |
|----------------|---------------------------------------|--------------------------|
| Hermit Hill    | 13                                    | ?                        |
| Lake Eyre      | 17                                    | ?                        |
| Wangianna      | 4                                     | ?                        |
| Coward         | 11                                    | ?                        |

Source: Heritage of Mound Springs, 1986.

#### 4.7.2 ODO Expansion Project EIS, 1997

It is important to note that the monitoring of the springs, and hence the impact on the mound springs, presented in the 1997 EIS has been developed and implemented by WMC and its consultants. There has been no independent confirmation of these data.

The 1997 EIS gives an analysis of the predicted and actual percentage flow change for 6 of the total of 45 spring groups associated with Borefield A (Table 7). The observed change in endemic fauna is also noted. As an example, Davenport Springs are considered to be of 'low conservation value owing to low species diversity and the absence of species, or suites of species, of conservation significance' (ODO EIS, 1997). This is contrary to the Heritage of the Mound Springs document of 1986 which places Davenport on the list of highest priority springs. Davenport is comprised of 10 springs and contains one endemic hydrobiid sub-species (also found in Welcome Springs). WMC sources predict a 3-4.5% decrease in flow at Davenport Springs. It is also significant that Priscilla Springs, predicted to have a 60-75% reduction in flow, is outside the computer model domain.

The Australian Nature Conservation Agency, in its Directory of Important Wetlands in Australia (1993), considers that "Increasing amounts of water being taken from the aquifer is considered to have a detrimental effect and may cause extinction of some springs."

Table 7 - Predicted and actual impacts on WMC monitored spring groups and observed impacts on endemic mound spring fauna.

Source: ODO Expansion Project EIS, 1997.

| Spring Complex | Spring group        | Flow change                    |                                                     | Observed change in endemic fauna                       |
|----------------|---------------------|--------------------------------|-----------------------------------------------------|--------------------------------------------------------|
|                |                     | Predicted flow reduction, 1984 | Actual, 1995                                        |                                                        |
| Hermit Hill    | Venable (bore)      | 100%                           | 100%                                                | total loss of endemic fauna 1991 (extinct)             |
|                | Bopeechee           | 20-30%                         | 43%                                                 | decline in all endemic fauna                           |
|                | Bopeechee (bore)    | 80%                            | 80%                                                 | -                                                      |
|                | Dead Boy            | 10-17%                         | no recording                                        | decline in all endemic fauna                           |
|                | Sulphuric           | 8-15%                          | insufficient data                                   | decline in all endemic fauna                           |
|                | West Finniss        | 10-13%                         | no or insufficient data                             | decline in all endemic fauna                           |
|                | West Finniss (bore) | no data                        | 20%                                                 | -                                                      |
|                | Hermit Springs      | 5-33%                          | no or insufficient data                             | decline in all endemic fauna                           |
|                | Hermit (bore)       | no data                        | 36%                                                 | -                                                      |
|                | Old Woman           | <3%                            | no or insufficient data                             | decline in all endemic fauna                           |
|                | Old Finniss         | <2%                            | no or insufficient data                             | decline in all endemic fauna                           |
| Lake Eyre      | Goose               | 5-25%                          | no or insufficient data                             | ostracods present, insufficient data to analyse trends |
|                | Priscilla           | 60-75%                         | 100%                                                | Total loss of endemic fauna                            |
| Wangiana       | Davenport           | 1-10%                          | Virtually zero at one spring recording <sup>2</sup> | decline in all endemic fauna                           |
| Coward         | Blanche Cup         | no data                        | no data                                             | -                                                      |

## **5. Other Industrial Developments in the Region**

### **5.1 Cooper Basin Gas and Oil Fields (Moomba)**

Approximately 200 km to the east of Lake Eyre is the Santos owned oil and gas extraction operation (Figure 1). It includes gas pipelines which run to Sydney and Adelaide from the service and operations town, Moomba. Water from the GAB is extracted from this site at a rate of 22-35 ML/day (ABARE, 1996; Berry & Armstrong, 1995). Santos spent \$600 million on development, operating and capital costs in the two year period between 1995 and 1996. This company and others are in the process of further exploration. Santos is expected to spend \$200 million on 125 exploration wells between 1996-98 (Frears, 1996). These large scale developments will have a further impact on the equilibrium of the GAB.

### **5.2 Future Developments**

A significant development of coal and iron ore mining at Cooper Pedy has been proposed and is expected to extract 25 ML/day from the GAB (ABARE, 1996). Other less advanced developments include a new proposed uranium mine at Beverley on the western edge of the Lake Frome Embayment. The Beverley mine is proposing in-situ leaching to extract uranium using water from the extremities of the GAB on the eastern edges of Lake Frome, where the significant Lake Frome Spring complex is found.

## 6. Water Balance

An important part of any hydrogeological study is to estimate an overall water balance for the basin under investigation. There have been numerous studies that derive overall flow rates for different processes within the GAB, and there is wide variation among the many published rates. These have been compiled to facilitate comparison between the GAB as a whole, and the particular portion of South Australia under close scrutiny in relation to impact on the mound springs (Tables 8 & 9).

Table 8 - Water Balance of the GAB (ML/day)

| Ref                 | Recharge                     | Bores              | Vertical Leakage | Springs | Total Discharge |
|---------------------|------------------------------|--------------------|------------------|---------|-----------------|
| 1918 <sup>(3)</sup> |                              | 1,600              |                  |         |                 |
| 1968 <sup>(3)</sup> |                              | 289 *              |                  |         |                 |
| 1974 <sup>(1)</sup> | 1,123                        |                    |                  |         | 1,441 #         |
| 1975 <sup>(2)</sup> |                              |                    |                  |         | 1,480           |
| 1980 <sup>(3)</sup> | 3,024                        | 1,500              | 1,394            | 130     | 3,024           |
| 1982 <sup>(4)</sup> | 3,100                        | 1,500 <sup>1</sup> | 1,400            | 200     | 3,100           |
| 1982 <sup>(5)</sup> | 2,600 to 13,000 <sup>2</sup> | -                  | -                | 130     | -               |
| 1996 <sup>(6)</sup> |                              | 1,500              |                  |         |                 |
| 1997 <sup>(7)</sup> | 2,630 to 2,930               | 1,200 to 1,500     | 1,300            | 130     | 2,630 to 2,930  |

\* - Flow for combined bore flows for NSW only.

# - State flows : Qld - 904, NSW - 356, SA - 205, NT - 2.74.

<sup>1</sup> - Water used for domestic purposes and stock watering is <150 ML/day; water lost by evaporation or seepage into shallow sediments >1,350 ML/day.

<sup>2</sup> - Calculated based on the assumptions of spring flow accounting for <1% to 5% of total inflow to the GAB.

(1) Australian Water Resources Council, 1975.

(2) Australian Water Resources Council, 1976.

(3) Habermehl, 1980.

(4) Kinhill Stearns Roger, 1982 (ODO Draft EIS).

(5) Habermehl, 1982.

(6) Habermehl, 1996.

(7) Kinhill Engineers, 1997 (ODO Draft Expansion EIS; based on Habermehl, pers. comm.).

Some important points will be made about the above data. Firstly, it appears that total discharge from the GAB has stabilised overall, although the proportions for each type of discharge are still changing. For instance, there has been a marked reduction in spring flows over the past 100 years, based on anecdotal evidence (the table doesn't show this).

Table 9 - Water Balance of the South Australian portion of the GAB (ML/day)

| Ref                  | Inflow     | Pastoral  | Springs  | Oil & Gas | Vertical Leakage | ODO      | Total Discharge |
|----------------------|------------|-----------|----------|-----------|------------------|----------|-----------------|
| 1982 <sup>(1)</sup>  | -          | 210       | 80       |           | 250              |          | 540             |
| 1997 <sup>(2)</sup>  | 450        | 130 (29%) | 66 (15%) | 22 (5%)   | 217 (48%)        | 15 (3%)  | 450             |
| 1997 <sup>(3)</sup>  | 425        | 132       | 66       | 22        | 190              | 15       | 425             |
| 1995 <sup>(4)</sup>  | 350 to 400 |           |          | 35        |                  |          | 350 to 400      |
| 1995* <sup>(4)</sup> | 76         | 36 (47%)  | 2 (3%)   |           | 24 (32%)         | 14 (18%) | 76              |

(1) Kinhill Stearns Roger, 1982 (ODO Draft EIS)

(2) Dwyer, 1997.

(3) Kinhill Engineers, 1997 (ODO Draft Expansion EIS, based on Sibenaler 1996).

(4) Berry & Armstrong, 1995 (ODO Report HYD T044; \* Lake Eyre Region only)

For all the estimates, it is clear that an underlying assumption is that recharge = discharge. Accordingly, vertical leakage is only estimated as the difference between estimated total inflow and the sum of known discharges from springs and all bores - not from hydrogeologic data. Attempts have been made by ODO to instrument some bores to allow calculation of vertical leakage. The data obtained to date is inconclusive and leads to “significant errors” when included in modelling predictions (Berry & Armstrong, 1995).

The recent figures are derived from a computer model used by Berry and Armstrong. Several comments on this model will be made:

- The estimates are based on 50% of the South Australian portion of the GAB. The inflow into this reduced portion is approximated at 76 ML/day. This is a very small estimate when compared to 425 ML/day for the water balance of South Australia as a whole.
- It underestimates vertical leakage (32% of total flow compared with 48% in Dwyers estimate - Table 9), leading to higher groundwater flow through the aquifer units. This results in an over-estimate of the potential bore flows that actually occur in the field. Presumably the greatly reduced figure for spring flow is due to the exclusion of Dalhousie Springs. These data are only estimates.
- The analysis of the Lake Eyre portion of the basin in South Australia puts the ODO water extraction into proper perspective. It shows it as being 18% of the total water movement in the local region. If the ODO usage expands to 42 ML/day as planned (Sections 2.4, 4.4 & Table 3) this will represent 55% of the water movement through the region.

- The model incorporates an assumption that GAB is in steady state, ie. there are no changes over time. This is based on the classic Habermehl paper of 1980, which claimed that the basin is in equilibrium - “provided no new major developments occur which will affect this equilibrium situation, discharge and potentials will not change significantly”. In the seventeen years since this statement was made many large scale developments have occurred in South Australia and the basin as a whole. The assumption of equilibrium let alone steady state needs much scrutiny and critique. Equilibrium, unlike steady state is a balance between opposing processes where the dynamic position is able to change.

There is no doubt that these models are at best very rough estimates. The flows for the overall basin are not useful when discussing large-scale extraction in a localised area of the basin, especially in a far extremity of the basin such as the Lake Eyre South region. The more localised analysis of Berry and Armstrong (1995) is an attempt to develop a local model for the region affected by the ODO extraction. However, even here there are some gross inadequacies that need to be corrected by collection of data and independent analysis. For example, the flows from the springs and pastoral bores in the region must be accurately measured, and the pressures in bores measured over several years to determine whether or not the system is in equilibrium.

The limited model of Berry and Armstrong does show that the ODO extraction is a significant proportion of the total water flow, and must be considered very carefully in relation to the flows in the mound springs in the region. This applies particularly to the proposed extraction of 42 ML/day (55% of the total flows for the local region). That the flows from these springs are small (3% of the total) in this model only serves to emphasise the delicate situation of the springs: diminution of large flows may not have a great impact on biota, but further reduction of small and already diminished flows will be catastrophic.

A further unknown in the development of a water balance for a localised region is the extent to which any drawdown in a local region is replaced by inflow from the broader basin. The replenishment is likely to be slow, given hydraulic conductivity values as low as 2 m/day and velocity values of 1-5 m/year (Section 2.2.1).

## **7. Field Work**

### **7.1 Introduction**

This involved compilation of expressions of concerns of a range of expert parties about the impact of Borefield A on the mound springs, an interview with two people who have been visiting the mound springs twice a year for ten years, and reports of two visits to the region of the mound springs during which observations were made on some of the springs and some of the WMC installations of Borefield A, and a local Aboriginal elder was interviewed about the impact of the borefields.

### **7.2 Comments on Impacts on the Mound Springs**

In the Supplement to the Draft Environmental Impact Statement for the Olympic Dam Project (Kinhill Stearns 1983), there is a list of submissions by various expert parties universally expressing concern about the location of Borefield A in the vicinity of springs which will be adversely affected along with their associated unique flora and fauna. The main parties and their concerns are summarised in Table 10.

Table 10 - Expert parties and summaries of their concerns about the potential adverse impact on mound springs due to WMC's Borefield A. Source: Draft Environmental Impact Statement for the Olympic Dam Project (Kinhill Stearns, 1983), p. A1 - A12.

#### **The S.A. Ornithologists Assoc.**

Concerned at effect of drawdown of mound springs on avifauna.  
Mound springs are important as drought refuge areas.  
Recommended intensive survey be carried out.

#### **Dr. David Symon, University of Adelaide**

Concern in relation to impact of drawing water from GAB.  
Concern over survival of *Eriocaulon carsonii* known to occur at Hermit Hill.

#### **Wolfgang Zeidler, S.A. Museum**

Concern about the siting of bores and their effect on the mound springs.  
Fauna has not been studied in sufficient detail for ecological assessment.  
Constant seepage is essential to maintain fauna.  
Species vary from top of mound to bottom and from mound to mound.  
Requested consideration of alternative bore sites; Hermit Hill to be preserved.

#### **Nature Conservation Soc. of S.A.**

Concern about localised effect of Borefield A on mound springs.  
Lack of adequate baseline data for mound springs.  
Computer model fails to account for characteristics peculiar to mound springs.  
Fauna depend on flow rather than ponding, and therefore maintenance of flow rates is essential to survival.  
Mitigation measures for the mound springs require closer attention.  
Insufficient justification for Borefield A in particular.

**C.J.M. Glover, S.A. Museum**

Mound springs are habitat for indigenous and endemic Australian fishes.  
 Mound springs are important as avifauna habitat.  
 Preservation of certain springs desired.

**W.F Ponder, Australian Museum**

Expressed concern about effects of Borefield A, and possibly Borefield B.  
 Results of research on mound springs

- there are localised species
- fauna from groups of springs varies
- within springs, each species is habitat specific
- species do not colonise bore outflows
- cattle damage had reduced fauna associated with mound springs
- need to retain flow for species to survive
- difficult to maintain habitat artificially
- springs still of value despite degradation due to cattle

Fauna composition was understated in EIS.  
 Mound springs are a unique habitat containing a variety of organisms found nowhere else.

**Environmental Protection Council**

Concern re mound springs.  
 Urges implementation of baseline studies, control of bores, conservation of springs, definition of state/proponent responsibilities.

**Friends of the Earth/Great Artesian Basin Association**

Concern over detrimental effects on other bores and mound springs.  
 Concern at inadequacy of GABHYD (Great Artesian Basin Hydrology) computer model.

**Nature Conservation Council of NSW**

Mound springs support a unique biota.  
 Opposes the development of Borefield A considering the unusual nature of the mound springs.

### 7.3 Interview with Ila Marks and Eric Miller

Ila and Eric are members of Friends of the Earth and first visited the mound spring region in 1987, and have returned twice yearly during the subsequent ten years, staying for an average of two weeks each visit. They have collected many photos depicting changes in the springs coinciding with the period of impact of Borefield A on the mound springs. They are on good terms with the traditional owners of Finnis Springs station, through which the pipeline from Borefield B runs. I asked Ila and Eric what sort of impact they have seen since their first visit to the springs?

Ila - "In 1987 Bopeechee Spring had a long tail which ran like a creek. Since then I have never seen the tail running like a creek, even in wet times or after heavy rain. In '87 & '88 access to Finnis West Swamp, Old Woman Swamp and Finnis Spring was very difficult due to mud around the actual springs created by strong water flows. Since then we haven't encountered this situation, even after heavy rains, indicating a decline in flows from these springs."

Eric - "Overall, there has been quite a noticeable reduction in the amount of service water and flow."

Ila - "There are also fewer reeds, noticable at Bopeechee and Hermit Hill. Hermit Hill has a noticable reduction in flow. Smaller unnamed springs where reeds used to exist no longer have reeds. This certainly indicates reduced flows from these springs."

Eric - "The area of swamp at Hermit Hill has shrunk since our early visits."

Ila - "When we first visited Beatrice Spring in 1990, there was water seeping out of the spring; now water only comes from the bore near the spring. The same with Venable Spring, except that now water is pumped into the spring by WMC."

Ila - "Gosse bore is an example of WMC interfering with springs. In 1987 a test bore was drilled too close to Gosse Spring resulting in a blow out of a large uncontrolled water flow creating a huge wetland (Figure 21). The bore wasn't capped until nine years later. This test bore is not mentioned in the 1997 EIS. The flow in Gosse spring has improved since the bore was capped, although WMC do not acknowledge that this improvement is due to the repairing of their faulty bore (p. 7-52)."

Ila - "We have seen evidence of WMC transplanting rare and endemic plants. WMC have denied this for many years. In the 1997 EIS they admit to it, and describe it as a success (1997 EIS, p. 7-52; Appendix Table K-4). Reg Dodd from Marree Arabanna Peoples' Committee has seen button grass at Sulfuric Springs and West Springs, places where it never existed before."

Q: “The reeds look quite tall in some of your earlier photographs?”

Ila - “Part of the succession process is the growth, death and regrowth of reeds. The traditional owners told us that they would swim in the springs and clean the reeds away from the vents, as part of caring for them. I’m not sure exactly why, probably to allow water to flow more freely. The problems caused by WMC interfering with Aboriginal groups has made people reluctant to visit the springs. WMC don’t consult with the right people; if they did they would know more about the springs and how to care for them. They have consulted with only one section of the descendants of Francis Dunbar Warren, the original owner of Finnis Springs Station, and have ignored another group, the ones running the Arabanna Community Centre in Marree (led by Reg Dodd), who seem to be more strongly attached to the land and concerned about its protection.”

Q: “WMC claim in the 1997 EIS that Davenport is of low conservation significance in terms of its wetland vegetation.”

Ila - “It is a unique spring as far as visual presentation and geology is concerned. It obviously had great significance for Aboriginal people judging from the huge amount of rock chips on the mesas overlooking the springs. There are small snails and water scorpions. The actual spring is not monitored by WMC; only the bore drain is monitored, and we wonder about this anomaly. There are interesting fossils and artefacts at Davenport and a series of rock pools in an old creek bed. Seepage throughout the area forms interesting salt formations.”

Eric - “I’m concerned about WMC’s assumption in the 1997 EIS (p. 4-20) that they will be able to produce copper at a rate of 350,000 t/a within the infrastructure capacity of 42 ML/day of water.”

Eric - “WMC do all the surveys and you never see the raw data, only cleaned up environmental reports. These reports are the only information from the company, a company which makes millions of dollars profit. It is like having the fox looking after the chicken hatch. The Department of Minerals and Energy are the only people that have access to the raw data. It’s the fox and the ferret looking after the chicken hatch.”

#### 7.4 Visits to the Mound Springs

I visited the area of the mounds springs in the vicinity of Borefield A twice, in September 1996 and April 1997. The first visit was a 33 person Friends of the Earth sponsored tour conducted under the guidance of Ila, Eric and Jan Whyte along with others who have frequently visited the area. I also visited the ODO Mine site and took part in a guided tour of the mine. Here we saw water trucks watering down the road outside the mine. In Marree we had the privilege of meeting and talking with two traditional owners, Reg Dodd and Kevin Buzzacott, and some of their family. Reg Dodd is a Marree Arabanna People's Committee representative. They claim that they were not consulted over water extraction on their traditional land.

##### *Visit September 1996*

1. Visited Lake Eyre South and WMC bore. The lake was dry.
2. Visited Venable Springs which was completely dry. The bore located close to the spring was almost dry. WMC's reinjection project was in operation. It consisted of a solar powered pump which injected water into the vicinity of the bore.
3. Visited Beatrice Springs. It was in a similar state to Venable Springs. Small amounts of water were evident while there was practically no vegetation.
4. Visited Hermit Hill Spring. A spectacular spot where we saw the endemic species of button grass.
5. Visited Bopeechee and Davenport Springs. There was a series of quite deep ponds in an old creek bed at Davenport. Interesting geological faults. It was amazing exploring this site.

##### *Visit April 1997*

1. Visited WMC pumping station (PS1A) on the Borefield road (Figure 23).
2. Visited WMC bore close to Lake Eyre South (Figure 24). On this visit the lake was filled with water. It was unusual as Lake Eyre North had no water while Lake Eyre South was filled.
3. Visited Coward Bore, and bathed in outlet of a recently reconditioned bore and observed large wetlands with great ornithological significance.
4. Visited Blanche Cup spring (Figure 12, Section 3.2). Observed lush growth of sedges and algae.
5. Visited The Bubbler Spring (Cover & Figure 25). Observed lush growth of sedges and algae.
6. Visited extinct spring, Hamilton Hill (Cover).

7. Visited Coward Springs and observed damage from cattle and long, creek like tail to the spring with many invertebrates (Figure 26).
8. Visited Davenport Spring and observed large quantities of Aboriginal artifacts, and a succession of large, deep clear pools that would have been of great value for Aboriginal communities (Figure 27).
9. Visited the Big Spring in the Hermit Hill complex. Observed the rare and endangered plant *Eriocaulon carsonii* (salt pipewort or button grass)(Figure 28 and Cover), large reed beds, and many Aboriginal artefacts.

#### 7.5 Summary of Interview with Reg Dodd

Reg Dodd is the leader and spokesperson of the Arabanna people, who are acknowledged as the traditional custodians of the region containing the mound springs south of Lake Eyre (see Section 3.2.3), and especially the Finnis Springs Station, the leasehold of which was left to the community on the death of the original owner, Francis Dunbar Warren, who was married to an Arabanna woman. There has been a dispute about who represents the traditional owners of this region, with WMC preferring to deal with a group who refer to themselves as the “Dieri Mitha Council”. This group appears to have little to do with the Arabanna Community Centre, led by Reg Dodd, in Marree, which is the main organisation catering for the cultural, recreational and educational needs of the Aboriginal community in Marree. Reg Dodd is the ATSIC councillor for the area and, from my observations was a leader with great concern for his community and their interests. He has organised an impressive museum of artefacts at the Community Centre, and is leading his community in conducting ecotourism groups to the region.

The Dieri Mitha Council appear to be a splinter group directly supported by WMC. This conflict erupted into violence on 12 January 1995 when the Dieri Mitha Council apparently brought a group of men into Marree from groups further north in an attempt to conduct an initiation ceremony. In the course of the night many people associated with the Arabanna community in Marree were terrorised with guns. The police had been warned by Reg Dodd of the likelihood of violence but chose to do nothing until a member of the invading group was killed by an Arabanna man defending his home and family in Marree. It appeared that the Dieri Mitha group had been well financed, arriving in Marree in 4WD vehicles.

On 20 June 1994, about 80 elders from all over Central Australia met at Davenport, Port Augusta to sort out the conflicting claims of the Dieri Mitha Council and the Arabanna community. The meeting made clear that the Arabanna People are the traditional custodians of the land and appointed a Committee of Elders and spokespeople for the area. Reg Dodd was one of the five spokespeople appointed. Despite that, WMC still insists on dealing only with the Dieri Mitha Council and refuses to deal with the community led by Reg Dodd.

As an outsider, it is difficult to understand why WMC refuse to deal with the Arabanna community and have instead promoted a splinter group which has perpetrated violence against the peaceful Arabanna community in Marree. It was clear to me during my visits that the Arabanna Community Centre led by Reg Dodd is the only cultural and community centre in Marree. It has a substantial presence in the main street, consisting of a well curated museum, well equipped offices and a centre for communal activities. When I was there a visiting potter was instructing women in pottery, and I saw strong community participation by men and women from the town, including whites. Indeed, the Centre appeared to be the only cultural or community centre in the town, apart from the hotel. During my visit I saw no evidence of the Dieri Mitha Council - no building, no cultural centre, no museum.

Reg Dodd is a very knowledgeable and moderate leader. In discussions with me he explained his association with Finnis Springs Station, which was owned by his grandfather, Francis Dunbar Warren. While the property is traditional Arabanna land, the leasehold was bequeathed to the Arabanna descendants of Warren, including Reg and his close relatives. Thus Reg and his people had two claims on the Station, a traditional one and a modern legal one. Reg stated to me that there had been a dispute between two branches of the family as to what to do with the property. One group wanted to sell the leasehold, while Reg's family refused to sell, claiming that under Aboriginal tradition he couldn't sell traditional land. As he said, "We couldn't sell the graves of our ancestors." The solution put to the Federal Government by Reg was for the leasehold to be resumed and the Station to be developed as a National Park to be run by the Arabanna community. This appears to have been a problem for WMC, who wanted to put the pipeline from Borefield B through the Station. It appears that, under pressure from WMC, Reg's quite reasonable and generous proposal has been stalled.

I saw at first hand the preparations of Reg's community for ecological and cultural tourism based on the old Finnis Springs Station and the nearby mound springs. The station has been destocked and the vegetation has recovered considerably compared with neighbouring properties. Reg has sponsored many visits by Friends of the Earth groups, who assist with the communities' commercial tourism ventures and independent monitoring of the mound springs. His community has bought a former Ghan Railway siding building (Alberrie Creek) as a centre for tourism. Reg stated that his community had no intention of interfering with WMC's pipeline plans, "but would have liked to have been consulted." It was clear to me that Reg is a person with very close links to the land and would have been the ideal person to have advised the company on the sites of cultural, historical and biological significance in relation to the route for the pipeline. For example, while at the Arabanna Community Centre I saw a large collection of photographs taken by Reg over many years of the mound springs and associated flora and fauna in the region. There is no doubt that Reg is a man with a great and genuine interest in the region. I also talked with Reg's brother, Ken Dodd, who is also strongly involved in the Arabanna Community Centre and has a deep concern for the traditional land and situation of the people.



Figure 21 - Gosse Bore Blowout, 1988



Figure 22a - 'Little Bubbler Spring' July 1989



Figure 22b - 'Little Bubbler Spring' July 1991

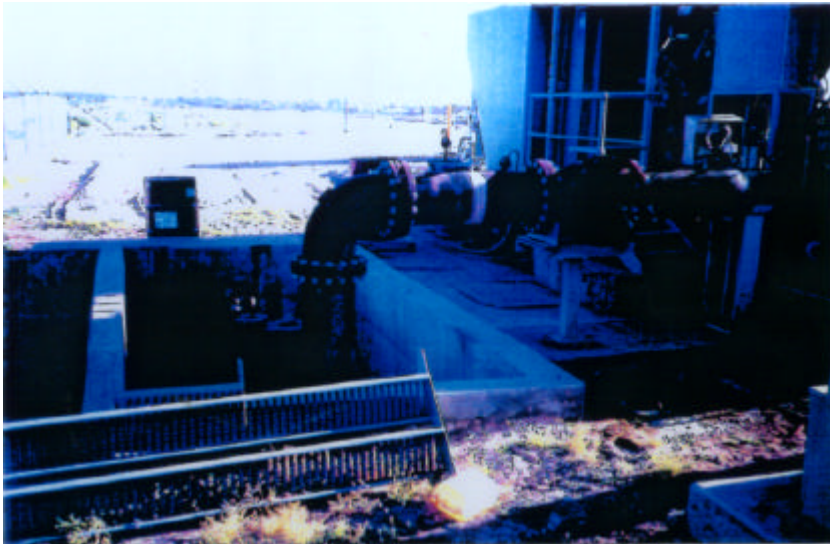


Figure 23 - WMC Pumping Station



Figure 24 - WMC Bore, Lake Eyre South



Figure 25 - Davenport Springs

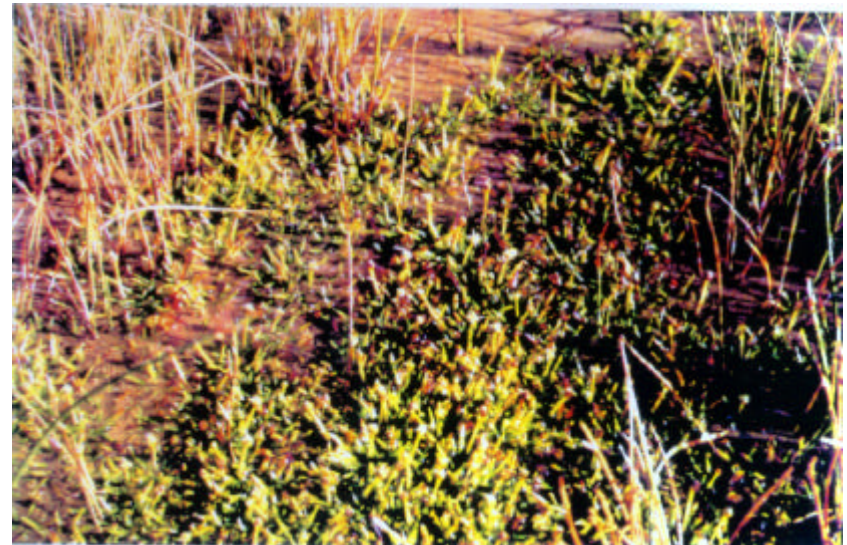


Figure 26 - *Eriocaulon carsonii* (Salt Pipewort or Button Grass)

## **8. General Discussion, Conclusions and Recommendations**

### **8.1 Water Balance in the South Australian Portion of the GAB**

It is evident from the data compiled in Section 6 that there is wide variation in the figures placed on the various components of the water flows in the GAB as a whole and in the South Australian part in particular. All water budgets calculate vertical leakage only by subtraction, assuming that total inflow is equal to total discharge. There is thus much work to be done in measuring the various water flows (including vertical leakage) before an assured water budget is determined. This needs to be considered in making predictions about the impact of greatly expanded water extractions.

The latest water budget calculated for the Lake Eyre Region of South Australia (Berry and Armstrong, 1995) puts the water extraction by WMC into proper perspective, given that the major impacts of water extraction are felt locally. This budget shows that the current WMC extraction of 15 ML/day amounts to 18% of the total water flows (76 ML/day) of this region; when the extraction expands to 42 ML/day, this will represent 55% of the total flow.

### **8.2 Importance of the Mound Springs**

There is no doubt that the mound springs in the region of Lake Eyre South are of national heritage importance. They have great significance for the Aboriginal Community in the region, and the most culturally active group have developed an ecotourism venture based on the springs. These people deserve the greatest support in their endeavours to protect the springs and to build a sustainable livelihood based on their knowledge of the land and its features. At the moment they appear to receive only neglect, if not hindrance, from WMC, the overwhelming enterprise in the region. It is astounding that this great company, which professes such strong concern for environment and Aboriginal issues, has offered no assistance to the Arabanna Centre, the only genuine cultural centre from Marree to Woomera to Oodnadatta, and the cultural expression of the people most affected by the borefields.

The biological significance of the springs is also unquestioned. They are a refuge for many birds and animals, and support unique populations of plants and invertebrate. They are “oases in the desert” and thus provide a unique opportunity for evolutionary studies.

### 8.3 Impact of WMC Borefields on Mound Springs

In Appendix 3 "Commitments to Undertake Mitigation Measures" of the Supplement to the Draft Environmental Impact Statement for the Olympic Dam Project (Kinhill Streamns 1983, p. D14) WMC states that "Mound springs are of environmental, archaeological, anthropological, historical and scientific importance as some support rare vegetation and aquatic invertebrate fauna. Pumping will reduce the flows in eight springs. Further studies of mound springs and the development of measures to mitigate the effects on significant mound springs will be conducted with the relevant government Department." This is an interesting statement because it shows that in 1983 it was known that water extraction would reduce flows in some mound springs. It also reveals an underlying attitude that omits from consideration the cultural and spiritual value of the mound springs for the Aboriginal inhabitants of the region, which is reflected in the rather manipulative dealings of the company with the Aboriginal people most directly affected by the borefields (see section above). The statement also implies that some springs are "significant" while others, by implication, are "insignificant". This prepares the public to accept the loss of some springs, which can then be classified as "insignificant". In fact an attitude pervades the EIS that some springs are less important than others, and can therefore be sacrificed.

The Supplement to the Draft EIS (1983) also states that the "Joint Venturers recognise that concern exists in respect of the effect of the water supply borefields on the mound springs. They have therefore in consultation with the relevant specialists prepared a programme that will enable a more detailed assessment of these effects. It is recognised that the present level of knowledge of both hydrogeological and ecological aspects of the springs and the southern portion of the GAB is limited (p 60). An extensive program of research into these areas is proposed in the Supplement (Section 6.3, pp. 58-59). The Supplement then goes on to say that " Final decisions as to the safe and sustainable yield from the proposed borefields on both hydrogeological and environmental grounds can be better assessed at the conclusion of the programme -- [ie. the extensive programme of research] --- Final planning decisions as to the siting of the borefields can be made at that time." It is evident that the development of Borefield A in the locality of the mound springs proceeded very soon after, without improved knowledge of the hydrogeology and ecology of the springs. It appears that, at the very least, Borefield A commenced operation in the midst of the mound springs with incomplete knowledge of the likely consequences, if not disregard for the likely consequences. As stated in the Draft EIS, 1982 (p 10-66), "insufficient data is currently available to enable a proper assessment to be made of the effect which such a reduction in discharge would have on the ecology of the Hermit Hill Springs," which were predicted to suffer a 17-33% reduction in discharge due to the extraction.

The other crucial point about the predictions made in the Draft 1982 EIS is that they were based on an extraction rate of 6 ML/day (p 10-44) when up to 15 ML/day were actually extracted. How was this gross expansion in extraction rate allowed to occur, given that the smaller rate was predicted to have serious consequences for the springs? This makes a mockery of the EIS as a process to ensure public accountability of the company in its dealings with the environment.

In the summary of the EIS for the Olympic Dam Expansion Project, 1997, the adverse (catastrophic, in some cases) impact of water extraction on certain mound springs is freely admitted - "Recently, water abstraction by WMC has been identified as the probable cause of an adverse habitat change at the Bopeechee and Hermit Springs spring groups. This impact has been remedied by the reinjection of water adjacent to these spring groups and a reduction since November 1996 in water abstraction in Borefield A from 15 ML/d to 6 ML/day." (p. 11) This amounts to an admission that Borefield A is an environmental disaster, and a quite predictable disaster based on estimates given in the 1982 Draft EIS (see Section 4.7.1) and the known hydrogeology of the south western portion of the GAB. Borefield A was sited in the middle of the mound springs of the Lake Eyre South region despite the knowledge of the intrinsic value of the springs and the likely impact of water extraction of 15 ML/day. This appears to be a classic case of a mining company ignoring the best advice of its own consultants and other experts regarding environmental impact, and making a mockery of the EIS process, in the name of short term cost reduction. It is evident that even without further expansion of the mine, the company would have had to develop another borefield in a deeper part of the GAB to supply its water requirements. Why then wasn't a borefield with a more sustainable yield in a region more remote from the mound springs developed in the first place? The 55km of extra pipeline between the original location of Borefield B to its present location was approximately \$5 million (Dwyer, 1997). What would the extra cost have been? What is the cost of the drying up of some, or even one, of the unique mound springs? Within the vast expanse of the GAB, occupying 22% of the continent, the major unique sites of cultural and biological interest are the mound springs situated in a very localised area to the south of Lake Eyre. Why, oh why, then, was the initial borefield sited right in their midst??

The 1997 EIS for the mine expansion (p. 4-15) discusses the 1984 predictions and the actual outcomes for the impact of Borefield A on the mound springs. It reports that the early modelling, used as the basis for predictions in the Draft 1982 EIS for the initial mine, contemplated an extraction rate from Borefield A of only 6 ML/day (p. 4-16). The predicted impacts in the Draft 1982 EIS were "mound spring discharges along the southern margin of the Great Artesian Basin would be reduced by 100% in the case of Priscilla, and up to 10-33% for others, with effects more marked in close proximity to the borefields and less marked further afield. In addition, localised impacts on discharge rates were predicted at existing bores, particularly Venable Bore in Borefield A and Crows Nest Bore in Borefield B, which were both predicted to experience a 100% reduction in artesian flow." It should be noted that Venable Bore is adjacent to Venable Spring, which presumably was also expected to become extinct. (Bopeechee Bore and Spring both showed a considerable reduction, also). In the event, Beatrice, Fred, Venable and Priscilla springs were dried up (EIS 1997, p. 4-25). This statement reveals that WMC was fully aware of the likely localised rather than regional impact of a borefield, which makes it even more culpable in its development of a borefield within the area of the springs and in a locality where the GAB aquifer is narrow, and therefore likely to suffer greater proportional drawdown, rather than further towards the centre of the basin and well away from the mound springs.

Presumably the only difference in cost would have been the extra pipeline and pumping station, and depth of bores required. In fact the company eventually has had to build another deeper and more remote borefield (Borefield B) and a longer pipeline, in addition to the pipeline to and bores at Borefield A, the cost of which can now be seen as wasted expenditure in the total, long-term purview of the project. The company could then have avoided all the problems over the fate of the mound springs, which in the event has been the major local environmental concern hanging over the project.

The predicted (1984) and actual impacts on mound springs given in the 1997 EIS are shown in Table 7 (Section 4.7.2).

Another important point made in the 1997 EIS (p. 4-17) is that "data for springs with very low flow rates sometimes contain erroneous values owing to measurement difficulties." This makes it even more important that impact on such springs be considered very carefully. Not only is the data about the springs, and therefore the predictions concerning their fate, more prone to error, but they are more prone to extinction with small impacts from a nearby borefield. It must be emphasised, in this age when the dominant culture is "big is beautiful", that from a cultural, biological, aesthetic and conservationist viewpoint, small springs may be as important as larger springs. This point is supported by the conclusion of Fatchen & Fatchen (1993) that, "Other influences, including local or regional drought, increased evaporation or evapotranspiration rates, and stock damage can mask the long term changes associated with drawdown and prevent the predictive use of the data. Records of spring extinctions in the past have shown that an extinction can occur without early warning; that is, without a significant reduction in the vegetated area or flow rate prior to extinction." (1997 EIS, p 7-55).

The predictions for further impact on the mound springs (1997 EIS, p. 4-17), in comparison with flows in 1994, are that "discharge rates at mound springs within the Bopeechee Spring group would decline a further 10-15%, the Welcome and Hergott spring groups would decline 10-15%, and the Hermit Springs and Davenport spring groups would decline up to 10-15% following combined extraction from Borefields A and B." In the actual flows reported for 1994, the Bopeechee group had already declined by 43%, and the Hermit Springs group by 36%. On these predictions, it appears that even now the company has not sited its new borefield far enough from the springs, especially given that Hermit Springs, Bopeechee Springs and Davenport Springs are listed in Biological Assessment of the South Australian Mound Springs (1985) among the 14 springs with highest priority for protection based on their biological value and vulnerability to degradation (see Section 3.3).

It is evident that mitigation of damage to the mound springs requires heavy further expenditure, which could have gone more profitably into extending the initial pipeline. For example, since 1995 WMC has been injecting water obtained from Borefield A back into the aquifer at a rate of 0.2 (initially) to 0.4 ML/day (since June 1996) to increase groundwater pressure in the vicinity of the Bopeechee group. ReInjection also at Venable was observed on a field trip (September 1996, Section 7.4). As the total extraction from Borefield A is now 6 ML/day, this reinjection amounts to about 7% of the water from Borefield A.

Whether this reinjection program has been successful in restoring the flow rates of the springs is still open to question, partly because of the relatively short time since reinjection commenced and partly because of the natural variability in flow rates from the monitored springs. Flow rate in spring HBO 004 fluctuated about 0.22 L/sec until March 1996, then increased to 0.39 L/sec in August 1996 and to a high of 0.66 L/sec in January 1997. The flow rate at HHS 170 in June 1995 was 0.47 L/sec, declined to 0.15L/sec in January 1996, increased to 0.42L/sec in June 1996, but dropped back to 0.21 L/sec in January 1997.

It is evident that the location of Borefield B is in response to several factors, including the requirement for a much greater supply of water for the mine expansion, the unsustainability of the water supply from Borefield A, and the environmental damage to the springs in the vicinity of Borefield A associated with the drawdown of water in that region of the GAB. It appears that the location of Borefield A was in fact a major blunder by WMC: it was an unsustainable borefield, even in the narrow terms of the requirement of water for the mining and processing operation, and it has been an ecological disaster in relation to the water flows in some of the springs.

In the light of the unfortunate location of Borefield A and the clear evidence of its impact on the mound springs in its vicinity, requiring reinjection by WMC of large amounts of water to try to restore the flow in one of the most important springs, it would be wise to eliminate further extraction of water from this borefield, and rely entirely on Borefield B. The new borefield has a much greater capacity and sustainability of yield, being in a thicker part of the aquifer. It has less saline water than that from Borefield A, and thus requires less treatment to reduce salinity and flouride content (Draft EIS, 1982, p 10-48). It also has much smaller impact on the mound springs, being more remote from them. However, there is still some impact of Borefield B on mound springs closest to it. In the 1997 EIS, WMC already begins to contemplate the possibility of having to build yet another borefield further inland, possibly to supply even greater quantities of water for an expanded mine with an output of 350,000 tonne/annum. Given the bad experience with Borefield A, and the predicted impacts of Borefield B and the possibility that it might not be able to supply sufficient water for further expansion of the mine, consideration should be given to developing a third borefield further inland, where impact on the springs would be reduced to negligible levels, the yield and sustainability of water flows would be assured and the water is likely to be of higher salinity. This applies particularly in light of the real possibility of more extensive mining and processing developments in northern South Australia, all requiring extraction of large quantities of water from the south western portion of the GAB. The data and research presented in the present study provide overwhelming evidence that the siting of Borefield A right in the midst of the mound springs was short sighted on both environmental and economic grounds. It shows a fundamental flaw in the EIS process whereby the company, for what appears to be short term economic gain, was able to ignore the expert advice gathered together in the Draft 1982 EIS and in the Supplement summarising responses to the Draft EIS. The Government appeared to be powerless to enforce a more environmentally sound development (eg. development of a borefield at a site further into the GAB and away from the mounds springs).

#### 8.4 Summary of Recommendations

- (i) In the interests of protection of the mound springs, Borefield A in the midst of the springs be closed.
- (ii) In the interest of protection of mound springs, and of establishing a sustainable water supply of less saline water, Borefield B be supplemented by a borefield further into the GAB.
- (iii) Further research is required to establish accurate water budgets for the South Australian portion of the GAB, and for the Lake Eyre Region most relevant to the WMC borefields.
- (iv) WMC, as the major business enterprise in the Lake Eyre South region, support the most culturally and environmentally aware Aboriginal community in the region, based on the Arabanna Community Centre in Marree. This centre is endearing to establish tourism and cultural enterprises to provide a sustainable, productive livelihood for their people.

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