CHAPTER 1: INTRODUCTION

The terms “mound spring”, “spring mound” and “mound” have been used locally and internationally to describe a number of spring-related morphologies in a variety of hydrological and topographic settings (e.g. Adkim and Julia, 2005; Chafetz and Guidry, 2003; Kele et al., 2008). The specifics of mound formation and composition encompassed by these terms can vary. For example, Crombie et al. (1997) describe calcareous spring deposits found in the Western Desert region of Egypt that appear as mounds due to topographic inversion, while Acworth and Timms (2003) describe small, ephemeral mud structures with no apparent flowing discharge, located on the Liverpool Plains of New South Wales, Australia. Additionally, the term “mound spring” is popularly used in Australia to describe a variety of environments and morphological features developed and supported by naturally discharging springwater from the Great Artesian Basin (GAB).

The definition used here is the one adopted by Habermehl (1989), Linares et al. (2010), Pentecost and Viles (1994) as well as Williams and Holmes (1978) to describe accumulations of predominantly calcium carbonate ($CaCO_3$) in dome or shield-like structures around the vent of a spring (Figure 1.1a and 1.1b). Springwater first emerges into a pool located at the summit of the mound (Figure 1.1c), while the discharge zone that forms a wetland at the base of the mound is called a spring tail (Figure 1.1d). Mound spring environments may develop complexities related to variations in either their spatial extent or velocity of flow. Cobb (1975), Forbes (1961) and Habermehl (1982) have described mounds with either singular or multiple outflows and springwater discharge as varying from actively flowing to simple seeps. Examples of such mound springs are common in the Lake Eyre South region of South Australia (SA), where they are recognised as wetland environments of great cultural and ecological value (AhChee, 2002; Cohen, 1989; Harris, 1989; Ponder, 2002).

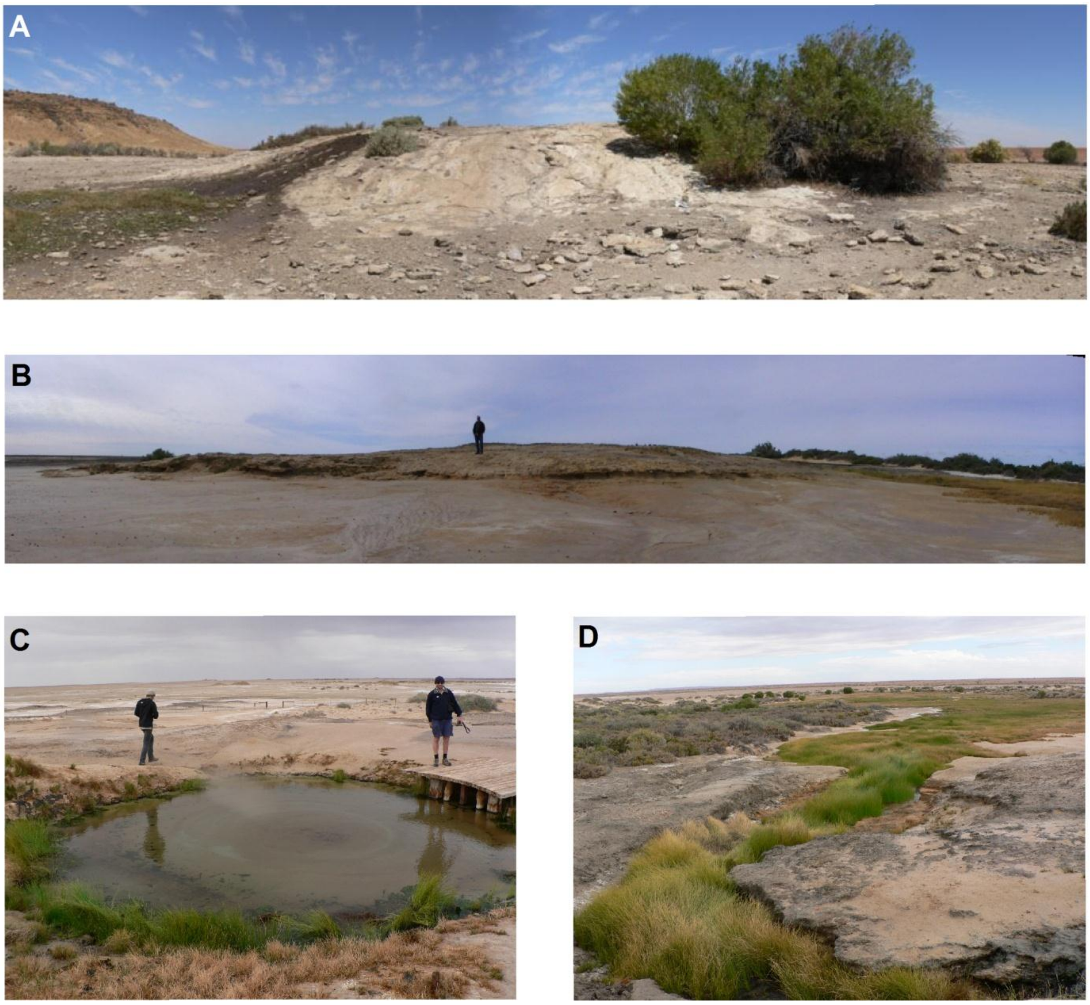

Figure 1.1: Typical morphological characteristics of Lake Eyre South mound spring environments. A) Composite photograph of a dome-like mound spring structure, Beresford spring. B) Composite photograph of a shieldlike mound spring structure, The Bubbler. Both Beresford Spring and The Bubbler have mounds composed primarily of calcareous spring deposits. C) The spring pool at the centre of the mound at The Bubbler. D) Discharging springwater forming a spring tail and associated wetland, The Bubbler

Despite previously published descriptive definitions, few intensive studies of the formation and ongoing evolution of mound spring structures exist and consequently, little testing of the assumptions concerning the factors important to the formation of these structures has been undertaken (Linares, et al., 2010; Pentecost, 2005; Pentecost and Viles, 1994). Specifically, there has been little work with respect to either determining or verifying the hydrochemical and environmental factors critical to mound formation. There has also been little explanation of how spring flow is maintained once a mound structure has been built. Consequently, the primary objective of this thesis is to produce a detailed conceptualisation of how calcareous mound springs found in the Lake Eyre South region form and evolve.

An in-depth knowledge of the formation and evolutional of mound spring environments and the factors critical to this are important for both scientific and conservation management reasons: In relation to the former, terrestrial structures of grossly similar composition have been used elsewhere as data sources for palaeoclimatic, palaeohydrologic and neotectonics studies (e.g. Andrews, 2006; Hancock et al., 1999; Miner et al., 2007). It has been recognised that the effectiveness of such studies is improved if assumptions concerning the formation of the studied structures and deposits are well constrained (e.g. Andrews et al., 2000; Jones, 2010). Consequently, it is critical to establish the influence of formational factors on data before such studies are attempted. Similarly, environments like mound springs can have high conservation value, particularly with respect to provision of habitat for aquatic and migratory species (Australian Government Department for Environment, Water, Heritage and the Arts (DEWHA), 2011a); effective conservation management of such environments benefits greatly if information regarding life expectancy, stability and environmental factors most influential in either maintaining or changing current day spring flow, water quality or wetland extent is known (e.g. Forbes et al., 2010). These features inherent within mound spring environments may affect the development of endemism, ecological dependency on water supplies and the structural integrity of the mounds. This information may also aid the determination of how vulnerable such spring-fed wetland ecologies and structures are to both natural and artificial change in spring flow.

1.1 Composition of mound springs and the importance of water chemistry

Jones and Renaut (2010) describe the terminology used in the international literature to classify terrestrial calcareous spring deposits similar to that found in mound springs as diverse. Given this diversity, this thesis adopts the carbonate facies and morphotype classification systems by Ford and Pedley (1996), which is one of the most cited systems found in the international literature (e.g. Arenas et al., 2000; Carthew et al., 2003; Forbes et al., 2010; Jones and Renaut, 2010; Ozkul et al., 2010; Viles et al., 2007.)

However, the use of an existing facies and morphotype classification system like Ford and Pedley (1996) to place mound spring structures and related sediments into the broader context of terrestrial calcareous spring deposits is not without issue; mound spring structures are not discussed within Ford and Pedley (1996), while other systems inclusive of mound structures (e.g. Goldenfeld et al., 2006; Kerr and Turner, 1996; Nelson et al., 2007; Pentecost, 1995; Pentecost and Viles, 1994), make assumptions concerning carbonate precipitation and prevailing thermogene conditions that are note whole applicable with respect to examples found in the Lake

Eyre South region. A summary of conceptual models with respect to calcareous mound spring formation is provided in Table 1.1, while a summary of the Ford and Pedley (1996) carbonate facies and morphotype classification systems and the difficulties in applying these and other classification systems to the Lake Eyre south mound springs is provided in Chapter 3. Chapter 3 also provides a response to this issue by outlining a conceptual model for the formation of mound spring structures that respects the prevailing environmental conditions found.

The water chemistry responsible for carbonate precipitation in terrestrial spring environments is of critical importance with respect to the formation of calcareous spring-related structures such as mound springs. Consequently, the topic of carbonate precipitation from terrestrial springwaters has been covered in some detail in the international literature. In general, terrestrial carbonate precipitation is dependent upon the evolution of carbonate hydrochemistry in an environment that has a number of inherent properties that either enhance or inhibit carbonate precipitation. A detailed summary of previous work into environmental factors critical with respect to terrestrial spring carbonate precipitation is provided in Chapter 4. In brief however, $CaCO_3$ precipitation and carbon dioxide (CO_2) degassing from $CaCO_3$-enriched emergent springwater is primarily controlled by a chemical disequilibrium caused by dissimilar physio-chemical conditions between the aquifer and spring wetland environment (Barnes, 1965; Holland et al.,1964; and Langmuir, 1971). In addition, environmental conditon inherent in the surface environment, such as the relative turbulence of water flow (e.g. Chen et al. 2004; Dreybrodt and Buhmann, 1991; Kano et al., 1999), the presence of microbial or macrophyte biota (e.g. Lee, 2003; Pedley and Rogerson, 2010; Pentecost, 2005; Spiro and Pentecost, 1991) and relative rates of evaporation (e.g. Pedley et al., 1996; Radke, 1990; Wright, 2000) may enhance rates of carbonate precipitation, while kinetic inhibition may have the opposite effect (e.g. Herman and Lorah, 1987; Lebron and Suarez, 1996; Meyer, 1984).

Table 1.1: Summary of publications relating to conceptual models for mound spring formation

Key Publication	Model Description	Data gap
Williams and Holmes 1978)	Identified the importance of faulting in providing spring conduits. Described formation as involving the accumulation of sediment and precipitate around the vent of a spring.	
Mabbutt (1977), Reeves (1968)	Theorised that the hydrostatic head and its relationship to spring flow are important to mound formation. Hydrostatic head must be higher than the spring opening	
Linares et al. (2010)	Stated that a flat topography is necessary to allow carbonate-precipitating waters to pool around the spring conduit.	
Goldenfeld et al. (2006), Kerr and Turner (1996), Nelson et al. (2007), Pentecost (1995), Pentecost and Viles (1994)	Suggested thermogene spring conditions are important with respect to driving carbonate precipitation. Assumed instantaneous precipitation of $CaCO_3$ upon springwater emergence.	Required temperature differential between emergent springwater and ambient conditions not apparent in Lake Eyre South examples.
Radke (1990)	Suggested evaporation was an important factor.	Lack of geochemical or hydrochemical evidence to support importance of evaporation.
Kerr and Turner (1996)	Laboratory-based experiments using Na_2CO_3 replicated many features observed in mound springs, including crater and “break-out” development.	Although such features are observed on mound springs, Na_2CO_3 has different thermodynamic properties compared to $CaCO_3$.
Bourke et al. (2007), Nelson et al. (2007), Linares et al., (2010), and Pentecost (2005), Williams and Holmes (1978)	Relationship between hydrostatic head and spring flow is a limiting factor; spring flow will slow and eventually cease when hydrostatic head and mound height become similar.	Thermoluminescence dating published by Prescott and Habermehl (2008) suggests spring activity may be longer lived than the time required for mound construction.

Despite this, little work with respect to hydrochemistry has been undertaken to determine how mound spring structures form. Past hydrochemical studies of mound springs have primarily focussed on groundwater hydrochemistry rather than the interaction of emergent springwater with the ambient environment (e.g. Cobb et al., 1975; Howe et al., 2008; Kinhill Stearns, 1984) or are based on laboratory experiments using sodium carbonate (Na_2CO_3) rather than $CaCO_3$ (Kerr and Turner, 1996). This feature of past hydrochemical studies is a limitation when seeking to clarify the role of water chemistry in the formation and evolution of mound springs; the previous investigations into carbonate-depositing springs demonstrate that a wide area of spring-supported hydrology, inclusive of both the spring vent and the wider spring-supported discharge environment, is required for analysis (e.g. Chen et al., 2004; Herman and Lorah, 1987; Kano et al., 1999; Liu et al., 1995; Lorah and Herman, 1988; Lu et al., 2000; Zhang et al., 2001). Such an inclusive survey of a number of mound spring environments is presented and discussed in Chapter 4.

1.2 Mound springs of the Lake Eyre South region

The explorer John McDougal Stuart (1865) provided the first European recordings of mound springs in the Lake Eyre South region and their potential importance in establishing pastoral and transport routes through Australia. More recently, the importance of these springs as a natural and cultural resource to local indigenous and non-indigenous populations has been discussed by Ah Chee (2002) and Leek (2002). The mound springs provide unique habitats for a number of endemic flora and fauna species and are a crucial resource for migratory species (Ponder, 2002).

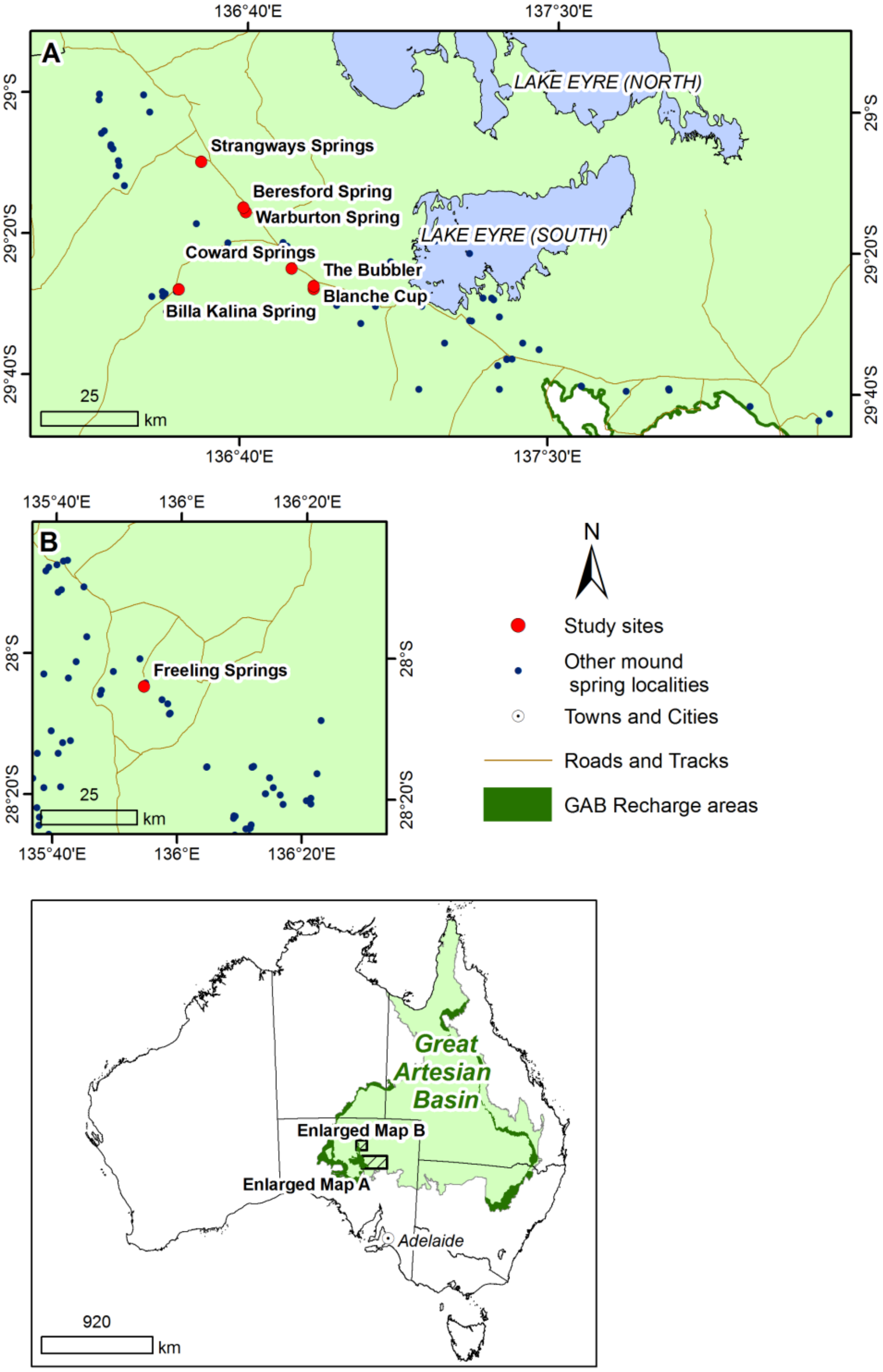

Figure 1.2: Location map of mound spring study sites.

Consequently, the springs are protected federally under the Environment Protection and Biodiversity Conservation Act 1999, which aims to protect and manage nationally and internationally important flora, fauna, ecological communities and heritage places (DEWHA, 2011a; DEWHA, 2011b). The GAB mound springs within South Australia occur in an arc that extends from Dalhousie Springs, located approximately 40 km south of the South Australia/ Northern Territory border to Lake Frome (Figure 1.2). The mound springs included in this study are primarily located within the Lake Eyre South region, approximately 620 km north-northwest of Adelaide and within a 70 km radius to the south and west of Lake Eyre South (Figure 1.2). Access to the region is obtained via the Oodnadatta track.

Ambrose and Flint (1981), Jessup and Norris (1971), Krieg et al. (1991), Radke (1990) Thomson and Barnett (1985) and Wopfner and Twidale (1967) noted that many mounds in the Lake Eyre South region are composed predominantly of $CaCO_3$. Radke (1990) described algal limestone as being widespread and noted goethite as well as minor amounts of manganese oxide in many carbonate samples, while Krieg et al. (1991) and Radke (1990) described the common occurrence of reed castings and bioclasts. Habermehl (1990), Radke (1990) and Williams and Holmes (1978), interpreted the detrital sediments associated with mound structures to be sourced from either discharging groundwater or from aeolian activity.

Similarly to mound spring structure internationally, little in the way of interpreting the specifics of the depositional environment responsible for mound spring formation has been completed. The most comprehensive attempt was made by Radke (1990), who suggested evaporation was an important factor, citing the arid climate in which mound springs were found and petrographic and geochemical evidence for evaporate mineral impregnation. However, no hydrochemical evidence was used in formulating this theory and the samples collected were largely form bore holes located either near the perimeter of mound spring systems or in locations of unknown relationship to the spring conduits, rather than from specific mound spring structures themselves.

Williams and Holmes (1978) estimated that a spring with a small discharge of 0.06 L/sec and a solute concentration of 4.0 g/L could precipitate approximately 170 tonnes of $CaCO_3$, which would be enough to build a typical 3 m high mound in approximately 1,000 years, while Radke (1990) suggested that as a consequence of evaporate mineral impregnation during carbonate precipitation that “very old” mound spring carbonate structures were susceptible to deflation and therefore likely to have been destroyed. In contrast, Prescott and Habermehl (2008) published the most comprehensive study to date concerning the age of calcareous mound spring structures from both active and relict structures; using thermoluminescence methodology, they found age variations from 10,900 +/- 1,500 years to 740,000 +/- 120,000 years. Jessup and Norris (1971) and Wopfner and Twidale (1967) used the geomorphic relationship between spring deposits and other sedimentological features to determine relative ages between 40,000 and 80,000 years, while Miller (1987) and Symons (1985) used faunal communities to suggest that spring activity commenced at the end of the Tertiary. In the Dalhousie Spring area, approximately 230 km northwest of Lake Eyre, Krieg (1989) used stratigraphic relationships between spring-related sediments and other sediment types to interpreted a maximum age for spring activity of between one and two million years.

Such a discrepancy between the measured ages of sediments associated with mound springs and the estimated time taken to build a mound might be explained by inferring episodic spring activity. The best evidence for this theory came after an analysis of core samples by Radke (1990), who identified erosion and denudation features, dissolution of carbonate surfaces and formation of clastic deposits as evidence for episodic deposition. However, limitations to interpreting episodic deposition associated with an individual spring vent based on Radke (1990) include the inability to link core samples with either episodic deposition related to an individual springs or deposition events from multiple springs within a wider spring complex. Additionally, it was not possible to discount whether carbonate erosion and dissolution could occur concurrently on structures associated with an active spring, as would be the case if carbonate sedimentation was lobate in form. Consequently, neither episodic deposition attributable to individual mound springs or defined periods of dormancy and accumulation via detailed age dating of mound spring sequences has been conclusively established. Another possibility to explain the age discrepancy that is novel to this study involves a shifting of mound spring-related deposition away from the vicinity of the mound due to spatial and temporal dynamics inherent in the carbonate precipitation reaction; this theory will be discussed in subsequent chapters.

Flows from springs in the Lake Eyre South region are typically less than 10 L/sec with little annual variation (Boyd, 1990). Boyd (1990) suggested that there was inconclusive evidence for spring flow decline related to groundwater exploitation, but indicated this latter point was due to the invalidity of early records. In contrast and more recently, Mudd (2000) concluded that groundwater extraction associated with the Olympic Dam mining operations in the vicinity of Lake Eyre South had led to the extinction of a number of springs and exacerbated the decline of several more.

However, a caveat was added that the factors responsible for spring behaviour were considered complex and poorly understood; therefore little more could be said in relation to predicting future influence other than a continuation of long term decline in flow with ongoing extraction.

Williams and Holmes (1978) suggested that spring discharge could be reasonably predicted remotely by determining the areal extent of the supporting wetland with allowance for water loss through evaporation based on work conducted at Dalhousie Springs. However, Holmes et al. (1981) found that application of this method was problematic when applied to a number of mound springs located in the Lake Eyre South region. Despite this, the method has been used in relation to discharge estimation, given the difficulty in both accessing springs in remote areas and determining discharge accurately (Fatchen, 2001b). A key issue central to the difficulty of application of the Williams and Holmes (1978) model is that the rate of surface water evaporation has never been actively measured within the spring wetland environment. Also, despite the generally abundant hydrophyte communities and surrounding gravelly and sandy regolith conditions associated with many springs, transpiration and infiltration were never discussed as potentially significant draws on surface water.

1.3 The Great Artesian Basin: Relationship to mound springs

The Great Artesian Basin (GAB) covers approximately 1.7 million km^2 of the Australian landmass in largely arid and semi-arid parts of the continent (Habermehl, 1980), with recharge areas primarily located in the vicinity of the Great Dividing Range and central Australia (Figure 1.2). More recently, Wohling et al. (2012) also found evidence using hydrochemistry-based mixing models for mountain system recharge of GAB aquifers via interconnectivity with fractured rock aquifers within underlying basement units in the vicinity of the Peake and Denison Inlier and Marla. The GAB is cited as the primary source of groundwater for the mound springs that occur within its vicinity, inclusive of the Lake Eyre South region (Habermehl, 1980; Habermehl, 1982) and consequently the management of the GAB groundwater resource is seen as directly impacting springwater supply to these environments (Mudd, 2000; Thomson and Barnett, 1985). A detailed summary of the geological and hydrogeological characteristics of the GAB, with particular emphasis on the southwestern corner, is provided in Chapter 2.

A summary of current water users within the South Australian portion of the GAB is provided as Table 1.1 (SAAL NRMB, 2009). Given its location in arid and semi-arid parts of Australia, groundwater resources associated with the GAB often provide the only reliable water source for pastoral, mining and domestic use. Groundwater extraction for such purposes may reduce the groundwater pressure head; potentially impacting upon the supply of groundwater to dependent environments such as mound springs (Kinhill Stearns, 1984; Mudd, 2000). SAAL NRMB (2009) predicts that groundwater demand from mining, power generation and commercial interests will increase in the future. Such increases are expected to have an adverse impact on groundwater dependant ecosystems such as mound springs if not managed sustainably.

Table 1.2: Indicative water demand in the Far North Prescribed Wells Area (SAAL NRMB, 2009).

Purpose	Artesian GL/year	Non-Artesian GL/year
Stock and Domestic	18.3	3.7
Mining	12.2	
Petroleum	6.2	
Power Generation	0.4	
Wetlands	4.4	
Town Water Supplies	0.9	0.5
Road Maintenance	0.3	
Industrial and Tourism	0.7	
Commercial	-	
Springs	24.1	
Total	**67.5**	**4.0**

1.4 Objectives of thesis

As stated previously, the primary objective of this thesis is to produce a detailed conceptualisation of how calcareous mound springs found in the Lake Eyre South region of South Australia form and evolve. Such a task requires a multi-disciplinary approach, because elements such as the geological setting, hydrology, hydrochemistry of both emergent spring and spring tail wetland water and biota of spring environments all conceivably impact on their formation and ongoing evolution.

By using a multi-disciplinary approach, the complexity of the interaction between the surface environment and springwater that ultimately leads to the formation of mound structures can be described sufficiently so that determinations concerning mound spring longevity and sensitivity to environmental change can be formulated. Such work will have important ramifications for the ongoing management of mound spring environments and how they may be approached in relation to future studies. The objectives of this study can be summarised as follows:

1. To describe the sediments of mound spring environments in sufficient detail to establish a clear picture concerning the environment of formation. By doing this, limitations on the possible depositional and hydrochemical conditions required to construct and maintain mound spring environments can be established and so constrain the possibilities concerning the development of conceptual models for mound spring formation and evolution.
2. To determine the controls on $CaCO_3$ precipitation in the modern environment in order to establish what hydrochemical and environmental conditions are important.
3. To ascertain the temporal variability or otherwise of the hydrochemical and environmental conditions important to mound construction.
4. To develop a hydrochemical model that can effectively describe the controls on carbonate precipitation, occurring both today and during initial formation.
5. To develop a conceptual model for the initial formation, growth and evolution of mound spring environments, which is based on detailed petrological and hydrochemical sampling as well as hydrochemical modelling.
6. To review the possible role tectonics has in the morphological development and maintenance of mound springs through a synthesis of new and existing data.

Most petrological, experimental and hydrochemical work was completed at the Beresford Hill Spring Complex and the Billa Kalina Spring Complex (Figure 1.2).

Specifics concerning work completed at each study site detailed in Figure 1.2 and the methodologies employed are included within individual chapters.

1.5 Organisation and contributions of thesis

Chapter 1 provides an introduction to this thesis and describes the aims and objectives being addressed, while Chapter 2 provides an overview of the study area including a review of the tectonic setting of the region (Objective 6) and the influence this may have on spring formation. Chapters 3 to 5 and Appendix 1 are written to be self-contained and address specific objectives. The final chapter (Chapter 6) provides a summary of the thesis and highlights scope for further work. A brief description of Chapters 3 to 6 is provided below:

Chapter 3 contains a detailed petrological description and interpretation of samples from examples of Lake Eyre South mound spring limestone, from which a facies nomenclature for the mound spring sediments is developed. This nomenclature is based on those developed from international examples of calcareous spring deposits. Additionally, the results of a field based experiment and hydrochemistry data are presented to provide information on the rate and form of carbonate accumulation. This chapter establishes that the formation of calcareous mound spring structures are highly dependent upon the evolution of carbonate hydrochemistry within springwaters in the surface environment and that this rate of evolution appears dynamic over time. Finally, a conceptual model for mound spring formation is presented, which has potential application to other mound structures found internationally (Objectives 1, 2, 3 and 5).

Chapter 4 discusses major ion and stable isotope concentrations from water samples collected from three mound spring wetlands. A reactive-transport model was developed using the hydrochemistry modelling package PHREEQC-2 (Parkhurst and Appelo, 1999) with the WATEQ4 database (Truesdell and Jones, 1974). Consequently, the environmental and hydrochemical conditions important to carbonate precipitation in modern mound spring wetlands are determined and the proportion of evapotranspiration to infiltration within the wetlands studied is estimated (Objectives 2, 3 and 4).

Chapter 5 describes how the reactive-transport model developed in Chapter 4 can be modified and used to predict the initial mound spring hydrochemical conditions and subsequently used to describe how the maximum spatial extent of the mound base or mound “footprint” is established through an interaction between hydrochemistry and flow conditions. By applying this model, mound springs structures may be used in palaeohydrological studies to predict the necessary flow required for mound footprint formation (Objectives 3 and 4).

Chapter 6 provides a summary of findings, a discussion concerning the potential impacts of this research and a summary of potential future research stemming from this study.

Additionally, Appendix 1 presents evidence for structural deformation of mound spring structures and argues that the formation and ongoing activity of mound springs of the Lake Eyre South region are closely linked with active tectonism that also affects the supplying aquifer and associated basin (Objective 6).

Data used to develop the interpretations and conclusions reached in this thesis, as well as detailed petrological interpretations are provided in additional appendices.

This thesis attempts to make the following contributions to the understanding of calcareous mound spring hydrodynamics and resultant sedimentology, as well as to the fields of carbonate sedimentology and hydrochemistry in terrestrial environments:

- Describes a new conceptual model for carbonate mound spring formation in non-thermogene conditions using facies description, hydrochemistry and experimental data as a basis for construction.

- Presents the first detailed hydrochemical survey of a mound spring wetland formed from a non-thermogene spring environment. Consequently, its examination of the evolution of springwaters from calcite under-saturation to over-saturation and the spatial and temporal dynamics of carbonate hydrochemistry in spring mound environments is unique in the international literature.

- Demonstrates the importance of carbonate-fixing microbial activity in the formation of mound structures through the use of experimental data and petrology to an extent not previously seen.

- Uses a novel reactive-transport modelling approach to theorise the important environmental influences on carbonate hydrochemistry in a spring environment. In particular, the use of a reactive transport model to assess the relative impacts of infiltration and evapotranspiration on the water balance and to identify the possible influence heterotrophy has on the mound spring wetland is unique.

- Adapts this reactive-transport modelling approach further so as to uniquely provide a quantitative framework through which past mound spring activities can be constrained and potentially used as a tool to study palaeohydrology.

- Presents for the first time the role of structural deformation on mound spring morphologies in the Lake Eyre South region.

A summary of fieldworks conducted during the course of this study is provided as Table 1.3

Table 1.3: Summary of field work undertaken during this study.

Date	Sites visited	Purpose
4-8 June 2008	Wabma Kadarbu NP (Blanche Cup and the Bubbler) Beresford Hill Spring complex	Field reconnaissance first pass mapping and rock sampling
3-7 July 2008	Wabma Kadarbu NP (Blanche Cup and the Bubbler) Beresford Hill Spring complex, Freeling Springs, Billa Kalina springs, Coward Springs, Strangways Springs, other spring localities	Field reconnaissance first pass mapping and rock sampling, site selection for more detailed work. First pass springwater sampling from vents
1-7 October 2008	Beresford Hill Spring complex, Billa Kalina Spring, other spring localities	Detailed field mapping, structural mapping, rock sampling and water sampling of wetland and bores (2 days each site). Initial placement of microcosms. Some hydrochemistry data rejected from this field trip based on QAQC concerns.
11-17 March 2009	Beresford Hill Spring complex, Billa Kalina Spring, other spring localities	Detailed follow-up field mapping, rock sampling and water sampling of wetland (2 days each site). Collection and placement of microcosms. One field site subsequently not included in final study (non-calcareous spring site).
14-17 June 2009	Beresford Hill Spring complex, Billa Kalina Spring, other spring localities	Follow-up field mapping, Structural mapping, rock sampling and water sampling of wetland (1-2 days each site). Collection and placement of microcosms.

Table 1.3: Summary of field work undertaken during this study (cont.).

Date	Sites visited	Purpose
27 July – 2 August 2009	Beresford Hill Spring complex, Billa Kalina Spring, Wabma Kadarbu NP (The Bubbler), Freeling Springs , Strangways Springs.	Follow-up field mapping, Structural mapping, rock sampling and water sampling of wetland (The Bubbler). Collection and placement of microcosms. (1-2 days each site)
16-18 July 2010	Beresford Hill Spring complex, Freeling Springs	Follow-up field mapping, Structural mapping (1 day each). Collection of microcosms.