ENVIRONMENTAL HISTORY OF THE WILLUNGA BASIN 1830s to 1990s

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ABSTRACT

Environmental History is a relatively new field of study which seeks to establish historic trends relative to environmental change and to use the insight gained to assist future management. As yet there are few such Australian studies on a detailed regional basis. The Willunga Basin is an important region within South Australia in physical, economic and social terms, but it currently experiences a variety of environmental problems, including a minimal amount of native vegetation, winter flooding and gully erosion. It was perceived that these problems could benefit from some knowledge of the area's environmental history. Therefore, using a range of sources and methods, historical trends were established in the key aspects of rainfall, surface and groundwater drainage, gully erosion, vegetation, population, settlement and land use, and these trends were then compiled to provide this Environmental History of the Willunga Basin from the 1830s to the 1990s. It was ascertained that the Willunga Basin environment had changed significantly in some respects since the first Europeans moved into the area in the 1830s. The nature, timing and magnitude of various changes were compared to provide some explanation of the contemporary environmental problems. These were found to have resulted from both human and non-human forces. Although one significant non-human change was a long-term decline in average annual rainfall over the 155 years from 1839 to 1993, European land use activities introduced since settlement in 1840 had often combined with natural processes and events to produce change. Extensive and intensive land use changes had made the environment more susceptible to change or had accelerated natural change in a particular direction.

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CHAPTER 1

INTRODUCTION

In 1864 George Perkins Marsh wrote:

> "Man [*sic*] is everywhere a disturbing agent. Wherever he plants his foot, the harmonies of nature are turned to discords ... the destructive agency of man becomes more and more energetic and unsparing as he advances in civilisation, until the impoverishment, with which his exhaustion of the natural resources of the soil is threatening him, at last awakens him to the necessity of preserving what is left, if not of restoring what has been wantonly wasted". (Marsh, 1864:36, 39-41).

Although it is now acknowledged that the Aboriginal inhabitants of pre-European Australia must have had some effect on the environment, the nature, magnitude and rate of human impacts have changed considerably since European arrival, influenced by a different perception of, and attitude to, the land (Hanley & Cooper, 1982; Whitelock, 1985; Nance & Speight, 1986; Heathcote, 1988; Bolton, 1992). For some decades now, awareness of the human impact on the environment has been growing worldwide, but only since the 1980s has there been sufficient concern to translate this into widespread action. This has been encouraged by reports on the state of the environment at different levels and the recognition that positive management is needed to maintain the basis of our environmental, social and economic support systems (eg Department of the Arts, Sports, the Environment, Tourism and Territories (DASETT), 1991; Department of Environment & Planning (South Australia), 1991a, 1991b; Lawrence, Vanclay & Furze, 1992).

One of the milestones in encouraging action in Australia since the mid-1980s has been the development of the grass-roots movement known as Landcare. This is "a unique national program which is a partnership of government, farmers, conservationists and community groups" aimed at "constructive, long-term, practical action at a community level for tackling environmental (and increasingly social and economic) problems" (Campbell, 1994:1-2). However, whilst the need for widespread action is acknowledged and encouraged, more information is needed for future management. If the present has its roots in the past, then effective management of any area and the provision of solutions to current problems cannot occur without knowing how past factors and processes have contributed to the present situation and "successful maintenance and development of Australia's land, water and vegetation resources [therefore] relies increasingly on good knowledge of the environmental past" (Chappell, 1985:216).

Although "an environmental issue without a past is altogether as mysterious as a person without a past" (Dovers, 1994:4), many studies concerned with environmental management concentrate only on the present and future and ignore the past. The aim of this thesis is to establish the Environmental History of a small part of the South Australian landscape from the time of the earliest European accounts of the area in the 1830s to the present, to use those findings to explain how the environment came to be in its present condition and to provide information for present and future environmental management.

1.1 LITERATURE REVIEW

1.1.1 Definition, aims and uses of Environmental History

During the 1980s Environmental History emerged as a new, integrative and rapidly growing field of study (Worster, 1988; Brimblecombe & Pfister, 1990; Bolton, 1992). Dovers (1994:4) offered two working definitions of Environmental History which both relate to this thesis. In simple terms, Environmental History is the field of study which tries to explain how the environment came to be in its present condition, with a more formal definition being "the investigation and description of previous states of the biophysical environment, and the study of the history of human impacts on and relationships with the non-human setting". Environmental History therefore aims "to examine the past as it relates to environmental and resource issues in the present" (Dovers, 1994:6), and it can, like Palaeoenvironmental Studies, "help understand the trajectory which a particular environmental system is following, and hence aid in its management" (Roberts, 1989:187). As well as contributing to formal management, Environmental History can, according to Cronon (1993) and Lewis (1993) also:

- encourage consideration of human-environment relationships and learning from the past;

- emphasise the human capacity for environmental change and the power of "nature" to respond;
- encourage action with care, since the complexity and unpredictability of "nature" means that human action often has unforeseen consequences;
- remind people that "there is not One Big Problem called The Environment" (Cronon, 1993:20) but many smaller problems needing attention locally; and
- improve understanding of human environmental impact and therefore play a role in the struggle to reshape a sustainable human future.

1.1.2 The interdisciplinary nature of Environmental History

An enormous amount of Environmental History work is currently underway and is a direct consequence of concerns about environmental change which arose in the 1970s and 1980s, a time of worldwide cultural reassessment and reform (Worster, 1988; Goudie, 1992). Ecosystem studies had become popular in the scientific community by the 1950s, influenced by a key paper (von Bertalanffy, 1951) which developed General Systems Theory as a framework for understanding nature and reality as a whole. Once the complexity of ecosystems was acknowledged, it was appreciated that interdisciplinary approaches needed to replace earlier studies of only a few isolated components (van Dyne, 1969). An early achievement in this respect was *"Water, Earth and Man: A Synthesis of Hydrology, Geomorphology and Socio-Economic Geography"* (Chorley, 1969), in which the physical and human environments were seen to be intimately linked through the water-cycle. Although Environmental History is a relatively new field of study it has a basis in earlier fields such as Historical Geography, Historical Demography, Industrial History and Social History (Blaschke, 1990), and, as Moore (1993) indicated, is born of one of the oldest interdisciplinary alliances of modern academic times, that between History and Geography, which themselves live astride the boundaries between the social sciences, and respectively, the humanities and the natural sciences. Environmental History is differentiated from other fields of study by its concern with the whole combined system of nature, society and culture (Blaschke, 1990).

1.1.3 Geographers and Environmental History

The characteristics of Environmental History make it a suitable field of research for geographers. Historical Geography first began in Australia in the 1950s (Jeans, 1988) and some Historical Geographers had similar goals to Environmental History researchers through their belief that "one cannot understand the landscape of the present without going back to the history that lies behind it" (Williams, 1974). Jeans (1988:110) outlined some other aspects of Historical Geography which are similar to Environmental History, particularly the "eclectic, imaginative and wide-ranging" nature of the field. Historical geographers were prominent among those preventing the human-environment theme from disappearing in Geography, while studies by well-known Australian geographers, such as Powell, Heathcote, Jeans and Davies, began to focus more on environmental perception and management after the mid-1970s (Jeans, 1988). Since the 1970s biogeographers and physical geographers had also been heavily committed to "the historical elucidation of environmental change" (Stoddart, 1986:272). Since the non-specialist is particularly suited to the "eclectic enterprise" of Environmental History (Dovers, 1994:12), geographers are well placed to analyse and synthesise the temporal and spatial elements of environmental history, particularly since, as Simmons (1990) suggests, geographers have a traditional interest in human-environment interactions and are trained to consider a range of temporal and spatial scales. Geographers researching Environmental History can help re-emphasise the integration of physical and human geography to address fundamental world problems, something which leading geographers have been calling for over the last ten years (Massey, 1984; Goudie, 1986a; Stoddart, 1986; Powell, 1988; Newson, 1992) and which is particularly relevant since "some of the most challenging problems on earth lie at the interface between the natural system and the human scene, problems often created by earlier misunderstandings of nature" (Orme, 1985:265).

1.1.4 Environmental History and environmental management

Environmental History which aims to provide information for environmental management has become important only recently, since environmental management itself only recently moved away from focussing purely on the economics of resource use to considering human impacts on the environment. The first proper study to consider the effects and potential consequences of human environmental impact was "*Man & Nature: Physical Geography as Modified by Human Action*" written by George Perkins Marsh in 1864 (Goudie, 1986b), while Gill wrote a paper in 1893 about the European impact on South Australia through deforestation (Gill, 1893). However, human environmental impact was given relatively little academic attention until the 1960s, partly due to the disciplinary isolation of Geomorphology and Physical Geography from more anthropocentric areas of study. In 1964 Leopold, Wolman and Miller wrote *"Fluvial Processes in Geomorphology"*, one of the earliest textbooks to consider human environmental impact. It was ascertained that the magnitude of variables involved in geomorphic processes could be changed by humans despite the processes themselves remaining the same, although any need to manage this impact was ignored. The possible disruption of environmental processes by land management practices was also given passing mention by Bormann & Likens in 1967.

The increasing attention to human environmental impact was probably attributable to its growing public recognition in the 1960s through works such as *"Silent Spring"* by Rachel Carson. During the 1970s and early 1980s earlier intellectual developments were consolidated and the need for environmental management was further emphasised (eg Chorley & Kennedy, 1971; Hasler, 1975; Schumm, 1977; Tivy & O'Hare, 1981). This meant that by the early 1980s it had become appropriate for those working in fields of study which took a historical perspective to consider the application of their work to environmental management.

1.1.5 General studies in Environmental History

Since Environmental History is a relatively new field of study, a coherent theoretical framework is lacking and key issues still have to be submitted to scholarly debate. Some groups have been formed to address these matters, such as the European Association for Environmental History which was formed in 1988 (Brimblecombe & Pfister, 1990). The content of Environmental History studies varies considerably. Some researchers concentrate more on history than environment, addressing social, economic and political change, while others take an ecological focus and look more at environment than history (Dovers, 1994:8-9). Some studies are based strictly on scientific evidence, some are more humanistic and yet others combine the two (Simmons, 1993).

Studies address many different timescales, but Goudie (1992) defined Environmental History as the history of the time during which humans have inhabited the earth (ie the last two to three million years). Studies can cover both short-term and longer-term environmental change, from tens of years to several million years. For example, the book entitled "*Late Quaternary Environmental Change: Physical and Human Perspectives*" by Bell &

Walker (1992) covered thousands of years and the European impact in North America was addressed in just one paragraph. At a much shorter timescale Paetzel, Schrader & Croudace (1994) looked at increased metal enrichment of soils from sewage outfall since 1969 against a background history from 1800 to 1991. Environmental History in Australia can essentially address any or all of three major periods, as defined by Dovers (1994): *Biophysical Australia* which evolved over millions of years, *Aboriginal Australia* which existed for thousands of years, and *European Australia* which began just over 200 years ago. The last 200 years are particularly important in both Australian and European Environmental History since this period has seen the most severe and dramatic environmental changes related to population expansion and industrial development (Oldfield & Clark, 1990; Dovers, 1994). It is the latter period which this thesis will address.

Some of the earliest work in Environmental History emerged from North America in the 1970s, since environmental matters had long received attention there (Worster, 1988; Brimblecombe & Pfister, 1990). However, the field is very new to many places. In China, for example, recent political, social and economic reform are only now arousing environmental concerns which could be addressed by Environmental History (Wenhui Hou, 1990). On a global scale, North American and European researchers have dominated the field. Andrew Goudie (Professor of Geography at Oxford) and Ian Simmons (Professor of Geography at Durham) in particular have produced key texts on the topic since the early 1980s. Although the evolution of environments over time was a long-established component of environmental research, in the early 1980s physical geographers in particular began to address "new subjects" which had a focus on chronological investigation, notable amongst which were Simmons & Tooley's *"The Environment in British Prehistory"* (1981) and Goudie's *"The Human Impact: Man's Role in Environmental Change"* (1981) (Gregory, 1985). Although the latter concentrated on human impact and is now in its fourth Edition (Goudie, 1993, which was retitled in its second edition with gender awareness as *"The Human Impact on the Natural Environment"*), Goudie also wrote *"Environmental Change"* (Goudie, 1992, 3rd edition) which addressed purely physical changes in different regions at different times during the last two to three million years. Simmons has also covered a range of timescales, from a study of human development and associated environmental change over two million years (Simmons, 1989) to a reassessment of human environmental impact over the last 10,000 years (Simmons, 1993). A 700-page volume entitled "*The Earth as Transformed by Human Action*" (Turner, *et* *al*, 1990) is comparable with Simmons' (1989) work in scope, but addressed only the last 300 years. As a compilation of symposium papers, Turner *et al* (1990) brought together worldwide contributions addressing Geography, History, Population and World Resources, which aimed at understanding the environmental history of different areas to improve future management.

1.1.6 Studies in Australia and South Australia

Dovers (1994) outlined the background of Environmental History in Australia. He set Meinig's 1962 work *"On the Margins of Good Earth"* as the starting point of Australian Environmental History and observed that in contrast to North America, Australian studies were mainly done by scientists, particularly geographers. Although many works came from Regional History or Historical Geography, "works that could clearly be described as Environmental History are not numerous" because many have a limited scope (Dovers, 1994:7). Following general developments worldwide, Environmental History in Australia was still very new in 1981 when Bolton produced a study of Australia-wide Environmental History through a description of changing human-environment relationships and impacts (Bolton, 1992). More recently, in acknowledging the diversity within the field, *"Australian Environmental History"* (Dovers, 1994) has brought together several essays and case studies, and in this respect is similar to Brimblecombe and Pfister's (1990) compilation of essays on European Environmental History. Dovers (1994) has also helped to develop Environmental History in Australia by including a chapter on its scope, aims and content as a field of study. Australia was also included in Dodson's (1992) book on environmental change in the South-West Pacific, which took a more scientific approach to human-environment interaction over the longer-term (the last 25,000 years), using environmental records and archaeological evidence as sources.

It appears that much more work in the field of Environmental History has been carried out in South Australia than in other states. The topic was addressed by historical geographers in the 1960s and 1970s but focussed on the development of settlement and only considered some associated environmental impacts, rather than synthesising environmental change (eg Harris, 1968; Bourman, 1969-70; Williams, 1974). Nevertheless, by the mid- to late 1970s a few more comprehensive studies appeared, such as an article on landscape change on the South Coast of the Fleurieu Peninsula since European settlement (Bourman, 1975), and a study on the land use and groundwater history of the Northern Adelaide Plains (Smith, 1979) which aimed to provide information for management. *"Conquest to Conservation: History of Human Impact on the South Australian Environment"* (Whitelock, 1985) was probably the first comprehensive book on South Australian Environmental History. It took a chronological and descriptive approach, looking at Aboriginal and European human-environment interactions and perceptions. *"A Land Transformed: Environmental Change in South Australia"* (Nance & Speight, 1986) also covered environmental change at the state level but was intended as a textbook and therefore took a more thematic approach.

Dovers (1994:8) maintains that "rigorous and detailed regional studies of environmental change are a rarity" (Dovers, 1994:8). This is perhaps because regional studies, particularly in Geography, became less popular as positivism rose to prominence in the 1950s and 1960s, rejecting the study of unique places and concentrating on understanding general processes. However, more recently it has been recognised that in seeking to understand society and the environment it is necessary to combine the two and that "the region" can provide a useful basis upon which to study the reciprocality of general processes and unique places (Massey, 1984; Johnston, 1991). Furthermore, regions can be seen as ecosystems and therefore can be useful in environmental management (Slocombe, 1993).

1.1.7 Sources and methodology for Environmental History

As is evident from the foregoing review, Environmental History studies can have different thrusts depending on the background and aims of the researcher. Since the environment is complex, Environmental History must by definition also consider a range of factors. It is therefore commonly accepted practice to adopt a range of methods to suit the individual study and to use multiple sources, including interviews and oral history, survey records, sketches and paintings, photographic records, historic maps, historic observations and botanical collections, present-day field observations, scientific analysis, hypothesis and speculation (Bourman, 1975; Smith, 1979; Nance & Speight, 1986; Jeans, 1988; Blaschke, 1990; Goudie, 1992; Dovers, 1994). The material used by Environmental History researchers has therefore often existed for decades or centuries but is being reorganised in light of recent experience (Worster, 1988). Most work is largely descriptive, is based on documentary evidence and is therefore more 'history' than 'environment'. However, a few recent studies have concentrated on environmental records. Archaeological evidence, climate records, pollen and sediment analysis have been used to compare changes before and after human presence or human-induced change over the last few hundred years (eg Kershaw & Strickland, 1989; Paetzel, Schrader & Croudace, 1994). Although palaeoenvironmental work usually covers much longer-term change, such studies can be termed Environmental History when they focus on recent history and seek to identify present-day problems (Oldfield & Clark, 1990). Other recent studies have sought to combine environmental records with document-based history such as population and agricultural statistics, descriptions by early settlers, and land use and settlement information (eg Gell, 1989; Lawrence, 1994; Ren Mei-e & Zhu Xianmo, 1994; MacCameron, 1994). The combined method will be adopted in this thesis.

In any study of Environmental History it is important to define the field of enquiry because 'a real history of the environment would include too much' (Dovers, 1994:5). In writing about a completely different field of study Hägerstrand, a well-known Swedish geographer, made a comment very appropriate to Environmental History, that it is more desirable to isolate a few crucial factors which go a long way toward substantially explaining the phenomena in question, before the rough edges of the analysis are smoothed off by consideration of other factors (Hägerstrand, 1953). In terms of the temporal aspect of change, sequent occupance studies were popular in relation to Regional Geography (eg Bourman, 1969-70), but these were replaced by a view of time as an ongoing process rather than time slices. This resulted from the growing interest in time in geographical studies in the late 1960s and early 1970s after the work of Hägerstrand and others (Chorley & Haggett, 1967).

The present study will therefore seek to establish continuous trends over time, wherever possible, and will focus on the environment. It will consider land use history as just one of several factors, while complementing a scientific approach with a humanistic view, therefore combining 'environment' and 'history'. It will also adopt four principles for Environmental History outlined by Dovers (1994): to explain the landscape through its history; to accept the complexities in processes of change; to explain the context of change; and not to apportion blame but to identify causes and explain their relevance for future decision-making.

1.1.8. Potential problems of conducting Environmental History research

It is important to acknowledge potential problems in researching Environmental History. For example, Smith (1979) based a vegetation reconstruction on nineteenth century South Australian survey records complemented by historic accounts, and "surveyors' notes have been the most practical and the most common source for vegetation reconstruction in North America", but they are not without their deficiencies (Tracie, 1992:261). Furthermore, Livingstone (1992) emphasised the inherent difficulties of attempting historical reconstruction which might not accurately represent reality. The principle of uniformitarianism, that "relationships which can be observed at the present time also held good in the past" (Roberts, 1989:21) will be adopted when attempting to explain the environmental history of the Willunga Basin and is probably not a controversial assumption with timeframes under 200 years.

Philosophical developments over the past 20 years have suggested that objective knowledge is no longer achievable (Bowen, 1981; Thomas, 1994). It is therefore important to be aware that any historical work is influenced by the characteristics of the original event and its recording, as well as the researcher's background and their interpretations (Oldfield & Clark, 1990; Thomas, 1994). Furthermore, quantitative cause-and-effect relationships can seldom be established because interactions between different components of different environmental systems are complex and lags often occur between a change and its effects, both in spatial and temporal terms (Goudie, 1981:283-4). Whilst these problems are acknowledged, it is felt that in many cases the information located is all that exists. However, awareness of the pitfalls and comparison of information from a number of different sources (where possible) can overcome these problems sufficiently to provide useful knowledge. In the face of such dilemmas and the vastness and importance of the task, Dovers (1994:6) calls for those entering into Environmental History research to do so with humility, and "the realisation that their perspective can only offer partial answers at best".

1.2 ENVIRONMENTAL HISTORY AND THE WILLUNGA BASIN

Detailed regional studies of environmental change are rare in the field of Environmental History, but such studies have the potential to assist present and future management. The Willunga Basin in South Australia was identified as a region which could benefit greatly from Environmental History research. The Willunga Hills Face Landcare Group initially expressed a desire to establish an integrated land management plan which included local landholders and the community in addressing contemporary environmental problems. It was felt that knowledge of the Environmental History of the Willunga Basin since the time of European settlement would help explain what factors and processes had contributed to these problems and that this knowledge would be invaluable in designing an appropriate management plan. Chapter 2 will outline the background to the study area before explaining the problems which need addressing and establishing the aims of the thesis.

CHAPTER 2

BACKGROUND TO THE STUDY AREA AND AIMS OF THE THESIS

2.1 BACKGROUND TO THE STUDY AREA

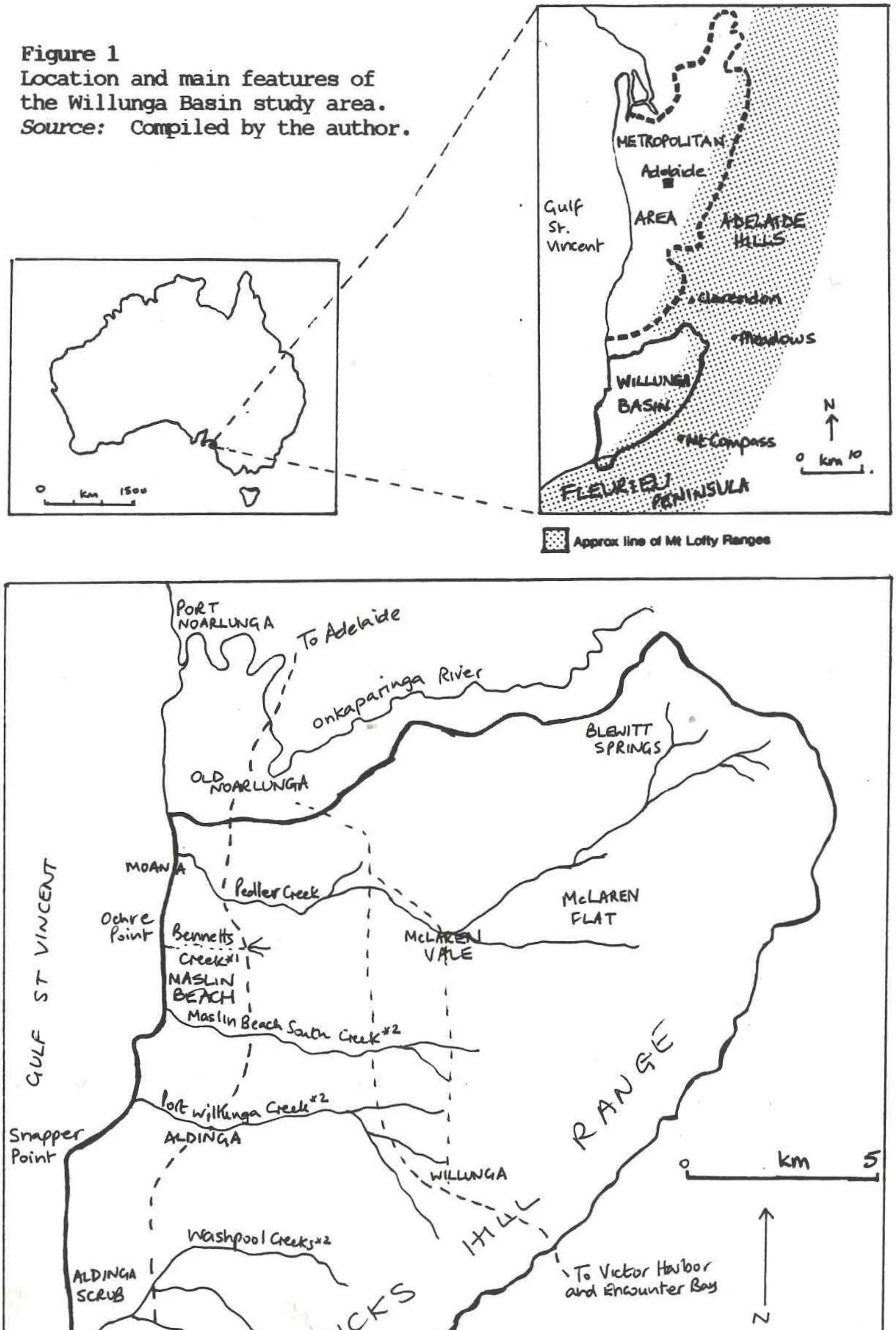
The Willunga Basin lies approximately 40 kilometres south of the centre of Adelaide and covers about 100,000 hectares (Overton, 1993a). The area is characterised by a wide range of rural and urban land uses, including vineyards and almond orchards, cropping and grazing land, residential, light industrial and recreation areas. These aspects are not only significant locally but are also important to the people and the economy of the Adelaide region as well as the state of South Australia.

2.1.1 Location and boundaries

Figure 1 shows the location and main features of the study area. A boundary based on surface catchments was felt to be the most appropriate for an environmental history study, since the catchment can be seen as "an easily appreciated plan projection of the ecosystem" (Newson, 1992:242). In addition, catchment management, which integrates biophysical and socio-economic resources and resource uses within a catchment, is widely accepted as an appropriate tool to address contemporary environmental problems (National Workshop on Integrated Catchment Management, 1988; Water Authority of Western Australia, 1989; Hart, 1991; Burton, 1992; Greening Australia, undated) and Landcare groups which have been established in the Willunga Basin are also catchment based. The study area was therefore delineated by the watershed between the Onkaparinga River and Pedler Creek in the north, the top of the Sellicks Hill Range to the east and south, and the coast to the west. It is important to note that the term "Willunga Basin" also refers to a geological basin and a groundwater province in the area and that while these overlap the study area, they do not coincide completely. When the Willunga Basin is mentioned it will refer to the study area as defined above, unless otherwise stated.

Earlier studies in the Willunga region were not always based on boundaries suitable for environmental studies and sometimes used Council boundaries or

Figure 1
Location and main features of the Willunga Basin study area.
Source: Compiled by the author.



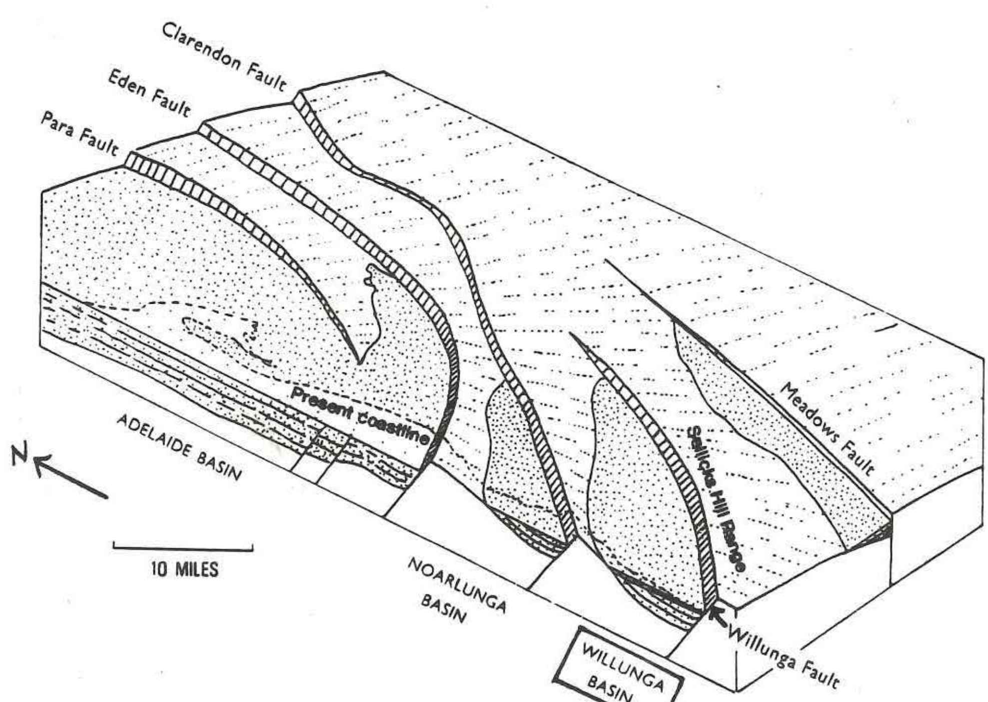
what appear to be arbitrarily selected areas. Turner & Associates (1982), for example, concluded that some environmental problems could not be addressed without attention to events occurring elsewhere in the catchment but outside their study area. Appendix 1A shows the relationship of the boundary used for this thesis to other boundaries which relate to the Willunga Basin.

2.1.2 Geology, soils and topography

The Willunga Basin is a term which also describes a tectonic basin in the southern Mount Lofty Ranges, bounded on the south-east by the Willunga Fault and on the north by sediments onlapping onto a ridge of basement rocks adjacent to the Onkaparinga River, known as 'the Onkaparinga Ridge' (Bowering, 1979). Differential block movements along the Willunga and Clarendon Faults produced the Basin and the fault block which forms the Sellicks Hill Range (Talbot & Nesbitt, 1968) (Figure 2).

The Willunga Basin has a complex geological history. Figure 3 shows that the Sellicks Hill Range is composed of basement rocks between 500 million

Figure 2
Simplified block diagram of the Adelaide region showing uplifted fault blocks and Tertiary Basins, of which the Willunga Basin is an example. *Source:* Talbot & Nesbitt (1968:16, Fig 2.4), augmented by the author.



QUATERNARY (To 2MY BP)

HOLOCENE (10,000 BP To PRESENT)

MODERN ALLUVIUM AND FOREDUNE	Qrm
WALDEILA FORMATION	Qrw
NGANKIPARI SAND	Qrn

LATE PLEISTOCENE

CHRISTIES BEACH FORMATION	Qpc
TARINGA FORMATION	Qpt
NGALTINGA CLAY	Qpn
KURRAJONG FORMATION	Qpk

EARLY PLEISTOCENE

OCHRE COVE FORMATION	Qpo

TERTIARY (2 MA To 60 MA)

PLIOCENE (2MA To 10 MA)

SEAFORD FORMATION	Tps
HALLETT COVE SANDSTONE	Outcrop not shown

UPPER EOCENE TO MIOCENE (±15MA To 40 MA)

CALCAREOUS SANDS, MARLS, LIMESTONE	Te–m

EOCENE (±40MA To 55MA)

NORTH MASLIN SAND	Te

PALAEOZOIC

250MA PERMIAN

(Erosion) TILLITE, FLUVIOGLACIAL SANDS AND CLAYS	Outcrop not shown

500MA CAMBRIAN

LIMESTONE, ARGILLACEOUS LIMESTONE, BASAL ARKOSE	Є

PROTEROZOIC (500 MA To 1 BILLION YEARS AGO)

ADELAIDE SYSTEM

MARINOAN SERIES	
Upper	Pmu
Lower (Upper Glacial Sequence)	Pml
STURTIAN SERIES	
Upper (Interglacial Sequence)	
Brighton Limestone	Psub
Tapley Hill Slate	Psut
Lower (Lower Glacial Sequence)	Psl
TORRENSIAN SERIES	Pt

ROADS	
RAILWAY	
COUNTY BOUNDARY	
HUNDRED BOUNDARY AND NAME	KUITPO
MILITARY SHEET BOUNDARY AND NAME	MILANG
TRIANGULATION STATION	△
CLIFFS	
QUARRIES	
SAND	Beach / Dune
ABORIGINAL LOCALITY	"Parnanga"

Dates from Daily, Firman, Forbes & Lindsay (1976).
MYBP = Million years before present.
MA = Million years ago.

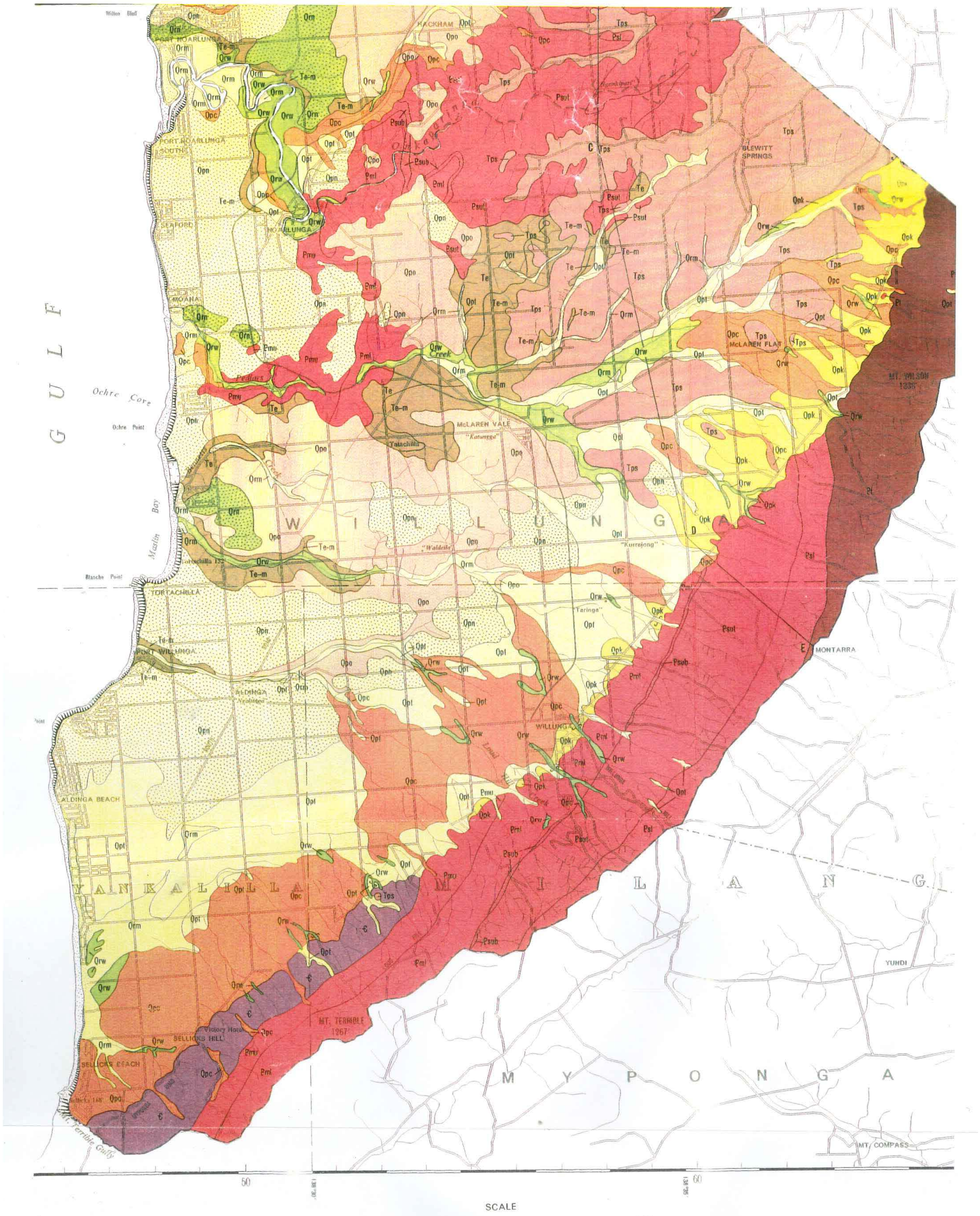

GULF
Ochre Cove
Ochre Point
Maslin Bay
Blanche Point
Witton Bluff
PORT NOARLUNGA
PORT NOARLUNGA SOUTH
NOARLUNGA
SEAFORD
MOANA
HACKHAM
BLEWITT SPRINGS
McLAREN FLAT
McLAREN VALE
MT. WILSON 1335
TORTACHILLA
PORT WILLUNGA
ALDINGA
ALDINGA BEACH
WILLUNGA
MONTARRA
SELLICKS BEACH
SELLICKS HILL
Victory Hotel
MT. TERRIBLE 1267
Terrible Gully
YUNDI
MT. COMPASS
W I L L U N G A
Y A N K A L I L L A
M Y P O N G A
50
60
138°30'
138°35'
SCALE
CHAINS 80 40 0 1 2 MILES
1 INCH TO 1 MILE
1 : 63,360

Figure 3

Geology of the Willunga Basin.

Source: Extract from Ward's (1966) Geology Map.

Key on facing page.

and one billion years in age, which are predominantly folded Proterozoic slates, quartzites, calcareous siltstones and tillites, with Cambrian calcareous sandstones, limestones and phosphatic shales (Ward, 1966; Pain & Hiern, 1970). These basement rocks are overlain by Permian glacial beds and Tertiary deposits (Ward, 1966). Deposits from the period between 250 and 500 million years ago are not found anywhere in the Adelaide region, which implies that this was a time of erosion (Daily, Firman, Forbes & Lindsay, 1976:6). Block faulting began approximately 45 million years ago and Tertiary marine transgressions, which lasted from approximately 40 to 15 million years ago, deposited sands, gravels, marls and calcareous sandstones in the Willunga Basin, while another Tertiary marine transgression 5 million years ago deposited marine sands and clays (Ward, 1966; Selby, 1984). These have since been overlain by recent Quaternary alluvial sediments. Another period of folding, faulting and block movement occurred during the Pleistocene (from approximately 2 million to 10 thousand years ago) (Talbot & Nesbitt, 1968). The present coastline formed about 6,000 years ago (Ross, 1984). The sediments of the Willunga Basin are thickest in the south-west near Aldinga, where 340 metres was penetrated by drilling; the succession thins in a northerly and north-easterly direction where it is terminated by the Onkaparinga Ridge (Bowering, 1979). This increasing shallowness is evident in Figure 2.

Figure 4 indicates that within the Willunga Basin there are forty-four textural types of soils. Soil differences result from variations in parent material, climate and drainage, duration of exposure to weathering and differences in soil process (Ward, 1966). Surface soils vary from sands to clays and most are intermediate in texture, ranging through sands, sandy loams, loams, silt loams and clay loams (Turner & Associates, 1982). Soils in the lowest part of the basin floor have a wave-like irregular surface micro relief termed 'gilgai' or 'Bay of Biscay' which causes irregular water infiltration and slow drainage when the soils are fully wet to some depth (Turner & Associates, 1982).

The topography of the Willunga Basin is shown in Figure 5. By comparing this with Figure 6 the relationship between geology, soils and the main physical features of the Basin become evident: ie the main range, the plains and the low hills to the north. The land which was uplifted to the south east of the Willunga Fault during the Pleistocene today forms the Willunga Scarp (Talbot & Nesbitt, 1968). Its north-west facing slope rises to just over 400m within a short distance and forms the hills face zone of

SOILS WITH WELL DEVELOPED HORIZONS
(Non-calcareous A and B horizons)

SOILS FORMED ON ERODED PRIOR SOILS

CHANDLER LOAMY SAND	1
BLEWITT SPRINGS – McLAREN FLAT COMPLEX	2 [illegible]

SOILS FORMED ON FRESH ROCK

VERY WEAK TEXTURE CONTRAST

NGANKIPARI LOAMY SAND	3
ONKAPARINGA STEEPLAND SOILS	4S
WALDEILA LOAM	5
WALDEILA LOAM, Saline phase	[illegible]
WALDEILA CLAY LOAM	5b
SELLICKS BEACH SILT LOAM	6

WEAK TEXTURE CONTRAST

KURTANDILA SILT LOAM	7H
KATUNGGA SANDY LOAM	8
NORTHFIELD SANDY LOAM	9
NORTHFIELD SILT LOAM	9a 9b
DARLINGTON LOAM	10 10H
SEACOMBE SILT LOAM	11
NOARLUNGA LOAM	12

[illegible] TO MODERATE TEXTURE CONTRAST

[illegible] HILLS ASSOCIATION	13 13H
[illegible] LOAM	13 14H
[illegible] LOAMY SAND	15
[illegible] SANDY LOAM	15a
[illegible] SANDY LOAM	16
[illegible] STONY LOAM	17
[illegible] SILT LOAM	17a
[illegible] SILT LOAM, Saline phase	17b
[illegible] LOAMY SAND	18

MODERATE TEXTURE CONTRAST

[illegible] ASSOCIATION	19 19H
[illegible] LOAMY SAND	20
[illegible] SANDY LOAM	21

STRONG TEXTURE CONTRAST

[illegible] SANDY LOAM	22
[illegible] BEACH SAND	23
McLAREN FLAT SAND	24
STONYFELL ASSOCIATION	25 25H
MAUNDABILLA LOAMY SAND	26
HIGHBURY LOAMY SAND	27
GLENALTA LOAMY SAND	28
KUITPO LOAMY SAND	29

SOILS WITHOUT WELL DEVELOPED HORIZONS
(Calcareous throughout, except where developed on non-calcareous parent material)

WITH GILGAI

ASSOCIATED WITH DIFFERENTIATED SOILS

SEAVIEW CLAY LOAM	30
KURRAJONG CLAY LOAM	31
CLAREMONT CLAY LOAM	32
CLAREMONT CLAY LOAM, Saline phase	[illegible]

NOT ASSOCIATED WITH DIFFERENTIATED SOILS

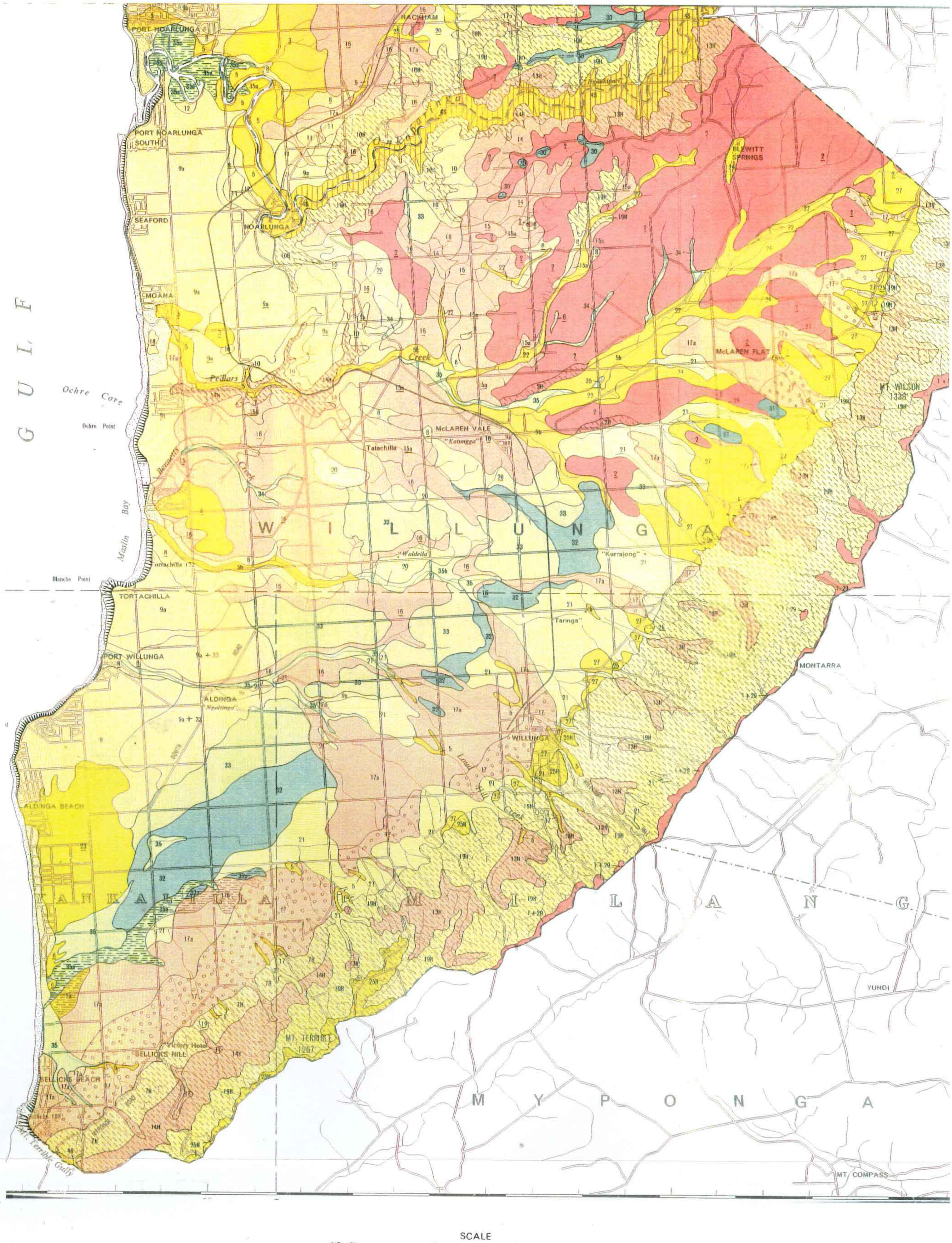
PARADISE CLAY LOAM	33

WITHOUT GILGAI

HAPPY VALLEY LOAMY SAND	34
PORT WILLUNGA LOAM	35
PORT WILLUNGA LOAM, Saline phase	[illegible]
PORT WILLUNGA CLAY LOAM	35b

The symbols for soils that occur on rolling and gently rolling land are underlined. The letter "H" indicates that the topography is hilly, and "S" indicates steep land. The remaining soils occur on gently sloping and flat land.

ROADS	
RAILWAY	
COUNTY BOUNDARY	
HUNDRED BOUNDARY AND NAME	KUITPO
MILITARY SHEET BOUNDARY AND NAME	MILANG
TRIANGULATION STATION	
CLIFFS	
QUARRIES	
SAND	Beach Dune
ABORIGINAL LOCALITY	"Parnanga"



SCALE

INS 80 40 0 1 2 MILES

1 INCH TO 1 MILE 1 : 63,360

Figure 4

Soils of the Willunga Basin.
Source: Extract from Ward's
(1966) Soils Map.

Key on facing page.

Figure 5
Topography of the Willunga Basin.
Source: Compiled by the author, with the base map obtained from the Willunga Basin Geographical Information System (GIS).

Note: Contour interval is 25m.

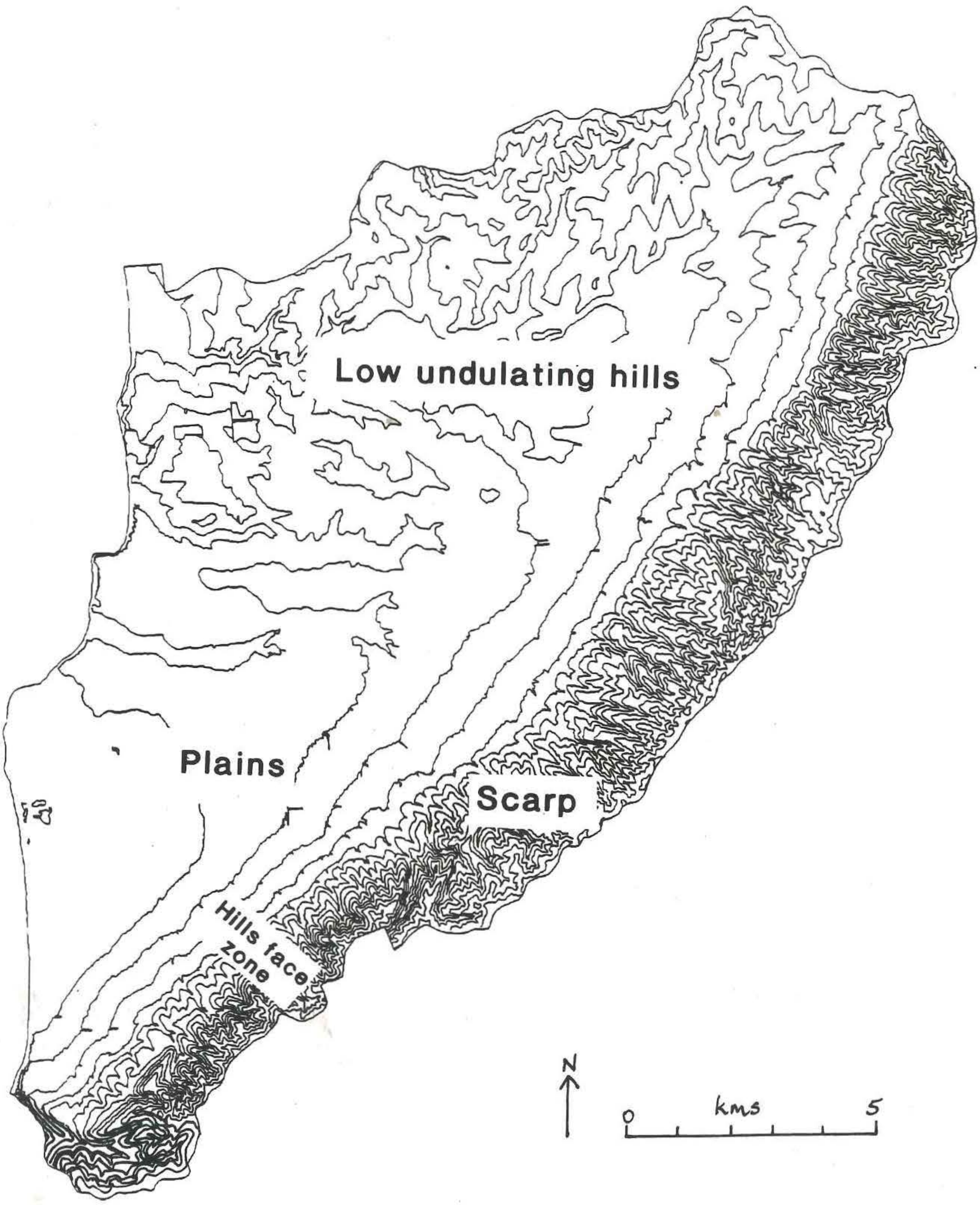
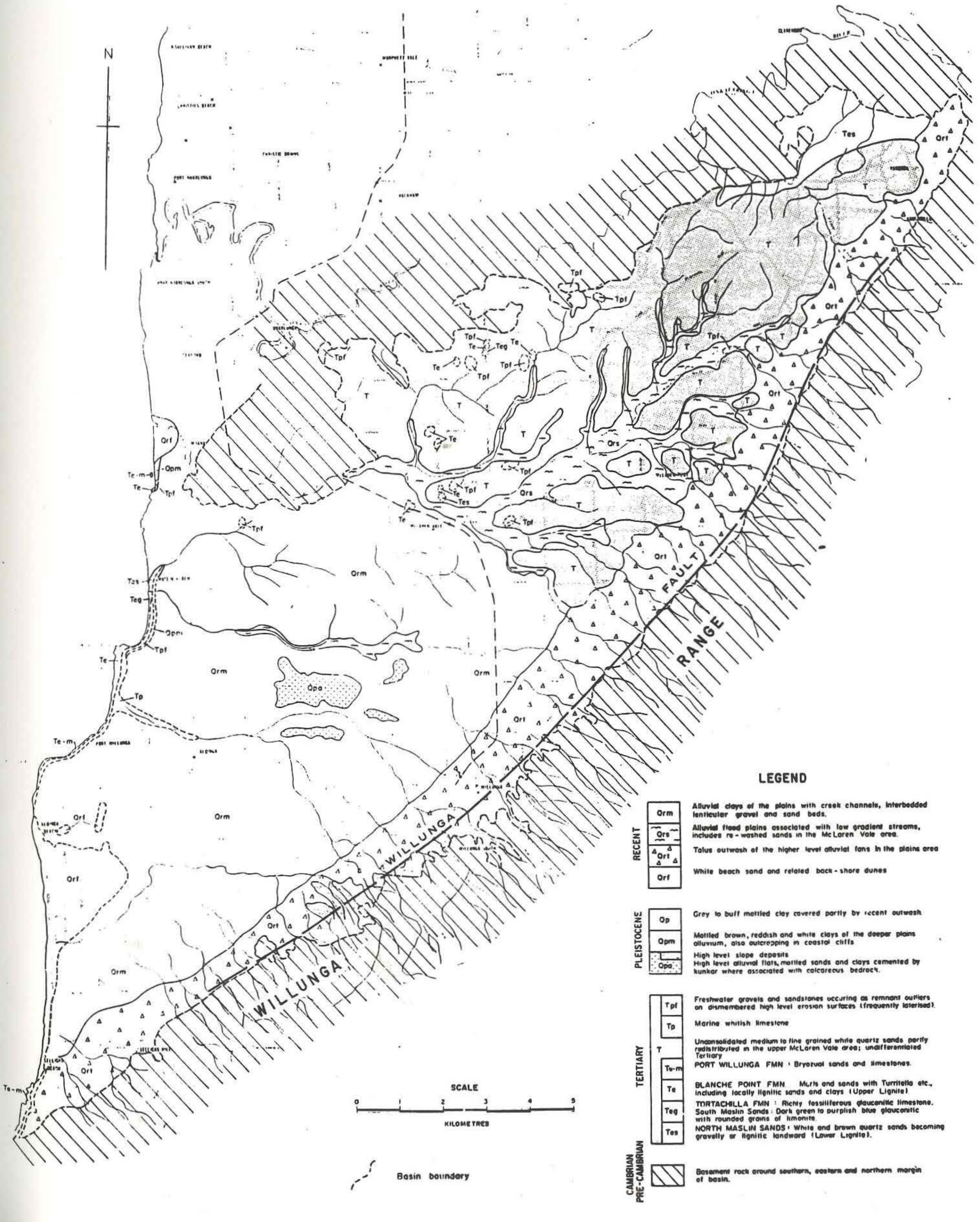


Figure 6
Simplified map of geology and soils in the Willunga Basin.
Source: Bowering (1979:fig 6).

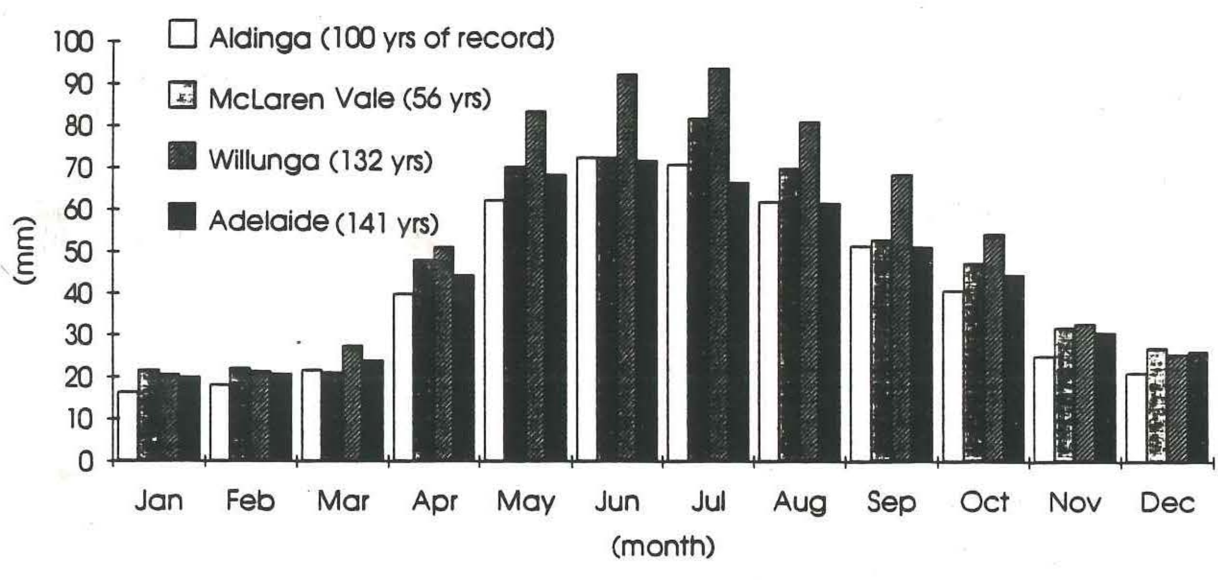


the Sellicks Hill Range in the south and east. The range and the outwash alluvial fans at the scarpfoot provide a backdrop to the plains of the south-west which are composed of recent sediments and which slope gently toward the coast. In the northern half of the Willunga Basin lie undulating hills of Tertiary sands and loams interspersed with recent alluvial material.

2.1.3 Climate, surface hydrology and groundwater

The Willunga Basin has a Mediterranean climate with warm dry summers and cool moist winters (Bowering, 1979:3). The mean monthly temperatures (minimum and maximum) are 9.4° to 27.9° in January and 2.1° to 14.9° in July (Overton, 1993a:9). Prolonged dry periods of up to two months often occur in summer when continental airmasses move south associated with relatively high mean pressure over the Adelaide region, but occasional thunderstorms occur in January and February, particularly on the plains (Schwerdtfeger, 1976; Linacre & Hobbs, 1977). Figure 7 shows that high rainfall is concentrated in the winter months. This results from lows moving in across the sea from the west (Linacre & Hobbs, 1977). The airstreams rise on meeting the ranges, resulting in orographic rainfall for eight months of the year (Schwerdtfeger, 1976). Rainfall increases significantly from March to May but decreases less rapidly during spring. Comparison of the rainfall at Aldinga in the western part of the Basin with the Willunga totals confirms that the western part receives less rainfall

Figure 7
Mean monthly rainfall in the Willunga Basin. *Source:* Compiled by the author from data supplied by the Commonwealth of Australia Bureau of Meteorology. Note: Adelaide has been included for comparison.



than the east (Turner & Associates, 1982). This is determined largely by proximity to the coast and topography, since rainfall increases with altitude. Figure 8 shows the isohyets for the region.

There are seven main surface sub-catchments within the Willunga Basin, as shown in Figure 9. There is virtually no permanent natural surface water (Turner & Associates, 1982), as the four major creeks (Pedler, Maslin Beach South, Port Willunga and Washpool Creeks) are largely ephemeral. This is not unusual within Australia as its unique hydrological conditions mean that over half the continent has intermittent or episodic flow regimes (Boulton & Suter, 1986; McComb & Lake, 1990:57). Surface drainage in the Basin is south and westward, due to the tilt of the Willunga Block and the erosion of soft Pleistocene strata (Cochrane, 1956). The main creeks rise on the Sellicks Hill Range and, after flowing down the escarpment, make their way westwards across the plains to the sea. They are fed periodically by rainfall-generated surface runoff and from springs in the Sellicks Hill Range. Some ephemeral, steep-sided escarpment streams debouch onto the plain and terminate within a short distance of the range in alluvial outwash fans (Bowering, 1979:2).

Flooding problems in the Willunga Basin occur roughly every five years when creeks burst their banks and the lower-lying areas become boggy (Boulden, pers comm, 1994). The first attempt at flood area mapping occurred in 1992 but more detailed mapping at a scale of 1:2,500 was deemed necessary (Planning Advisory Services, 1992). The five main areas noted as flood-prone are outlined in Table 1.

Table 1
Areas prone to flooding in the Willunga Basin.
Source: Planning Advisory Services (1992:27).

1. Pedler Creek: A floodplain at least 300m wide through and adjacent to McLaren Vale.

2. Maslin Beach South Creek: Floods land immediately adjacent to the boundary of the urban area. 4000m upstream it requires a flood reserve 500m wide.

3. Port Willunga Creek: Requires a flood reserve 300m wide.

4. Creeks to the east of Sellicks Beach: Flood over land immediately adjacent to the boundary of the urban area.

5. Blue Lagoon/Washpool area: Has a total catchment of approximately $38km^2$ and needs to be reserved for drainage purposes. Incoming drains/creeks need land to be reserved for drainage purposes also.

Figure 8
Rainfall map of the Adelaide Region and Fleurieu Peninsula. *Source:* Extract from the Rainfall Map of South Australia, Commonwealth of Australia Bureau of Meteorology.

Note: Rainfall is in millimetres, calculated from all years of record, ending April 1992.

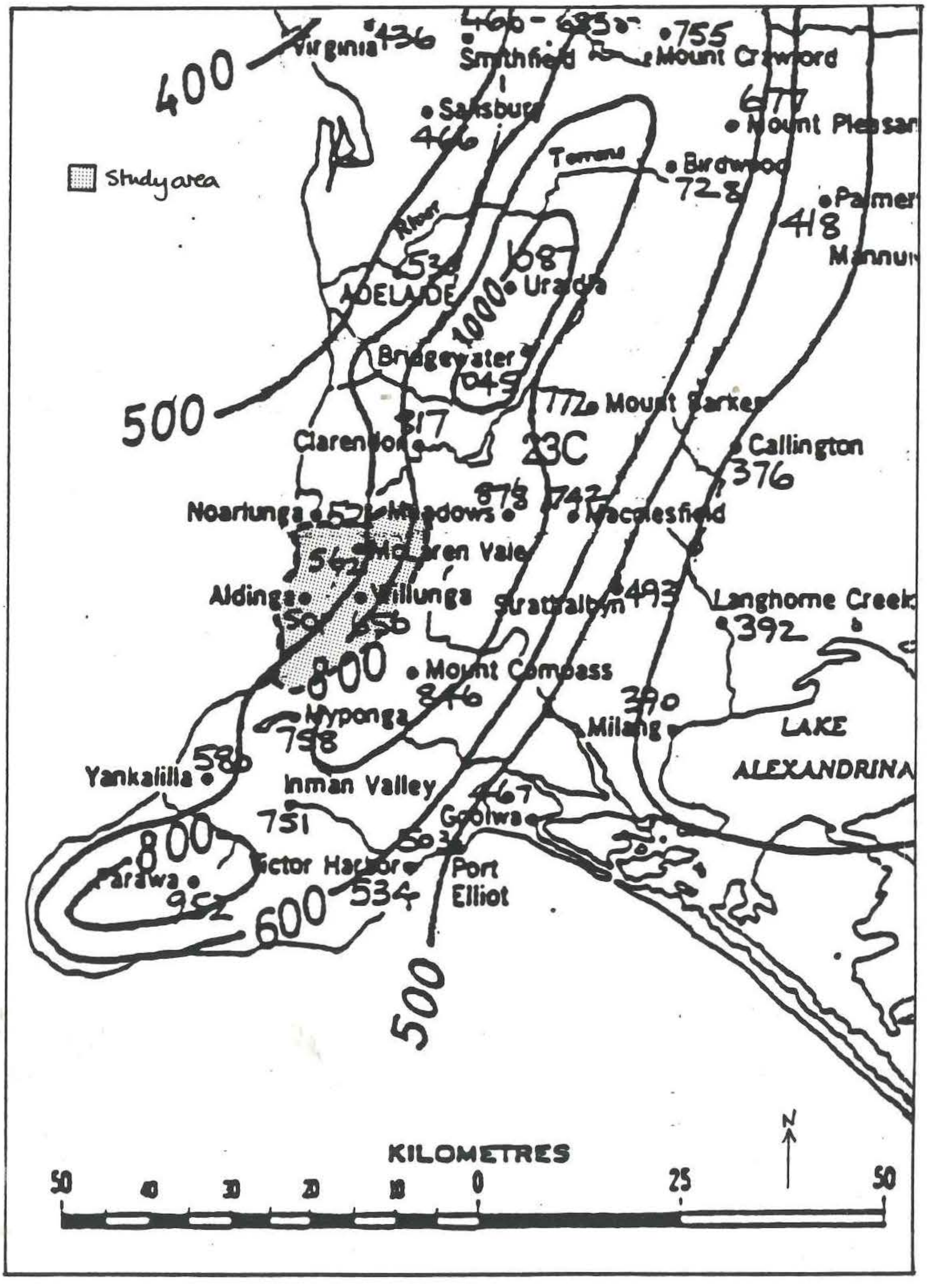
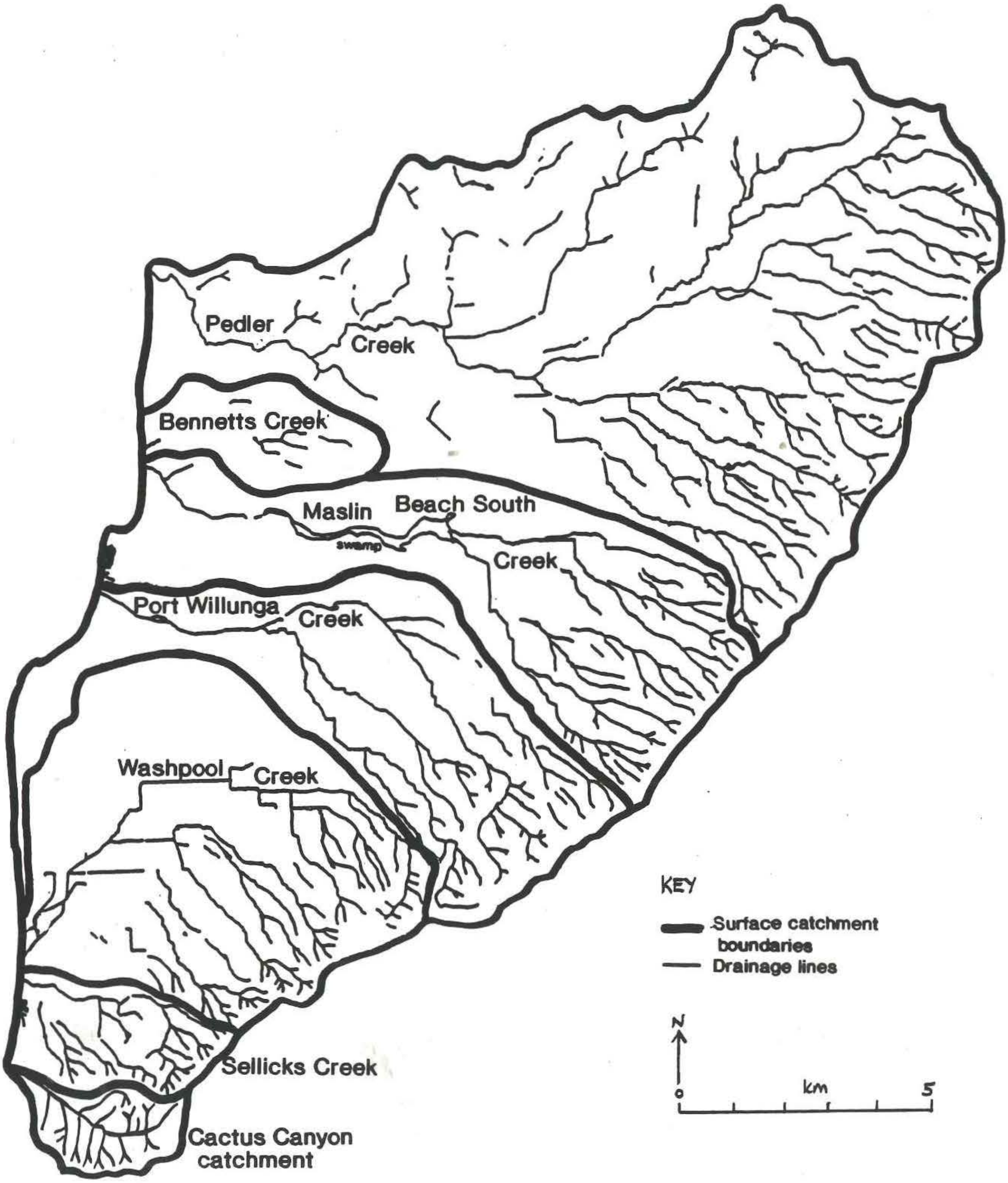


Figure 9
Surface drainage and catchment boundaries in the Willunga Basin 1992.
Source: Adapted by the author from Planning Advisory Services (1992) and the 1992 surface drainage coverage from the Willunga Basin GIS.



The term Willunga Basin also denotes a groundwater basin bounded on the south and east by the Willunga Fault (Figure 10). The geology of the area has produced four aquifer systems, comprising two major deep sedimentary aquifers known as the Port Willunga Formation and the Maslin Sands aquifers, fractured basement rock aquifers underlying the Sellicks Hill Range, and shallow Quaternary alluvial aquifers of a limited areal extent on the plains (Bowering, 1979:5; Selby, 1984:8). Figure 11 shows the relationship between the geology and the aquifer systems, while Figure 12 shows the major outcrop and recharge zones. The recharge zones for the main aquifers are the main range and the low hills in the north-east.

During years of average rainfall there is no surplus of rainfall over evapotranspiration and soil-moisture deficit requirements to provide recharge over much of the plains. However, the scarp streams contribute groundwater inflow via the hardrock aquifers into the sedimentary aquifers on the plains, and through surface flow into the basin (Bowering, 1979:24). It is difficult to obtain a three-dimensional idea of aquifer depths, thicknesses, relationships or connections. Figure 12, for example, does not show that the Maslin Sands aquifer extends over the entire Willunga Basin (Bowering, 1979:8), while Figure 11 does not show that there is probably some interconnection between the two major sedimentary aquifers around McLaren Vale and McLaren Flat (Bowering, 1979:6).

In some places the presence of groundwater is manifested in the form of springs and soaks. For example, springs emanate from the basement rocks at the foot of the Willunga Range (Bowering, 1979:9). Shallow alluvial aquifers are probably responsible for the presence of ephemeral waterholes and 'native wells' on the margins of the Aldinga Scrub area. Freshwater springs also occur on the coast at Red Ochre Cove, Port Willunga and Sellicks Hill, and were related in Aboriginal mythology to tears shed by Tjilbruke, an ancestral hero, as he sat on the beach (Gara, 1988). This story accounted for the presence of freshwater springs below the high-tide mark, which probably came from groundwater aquifers extending below sea level, as is evident in Figure 2. These springs still exist.

2.1.4 Vegetation and fauna

Although there is only limited information on the prehistory of the Adelaide region vegetation, there is evidence, for example in the Maslin Bay flora deposits, that vegetation types in the past were different from

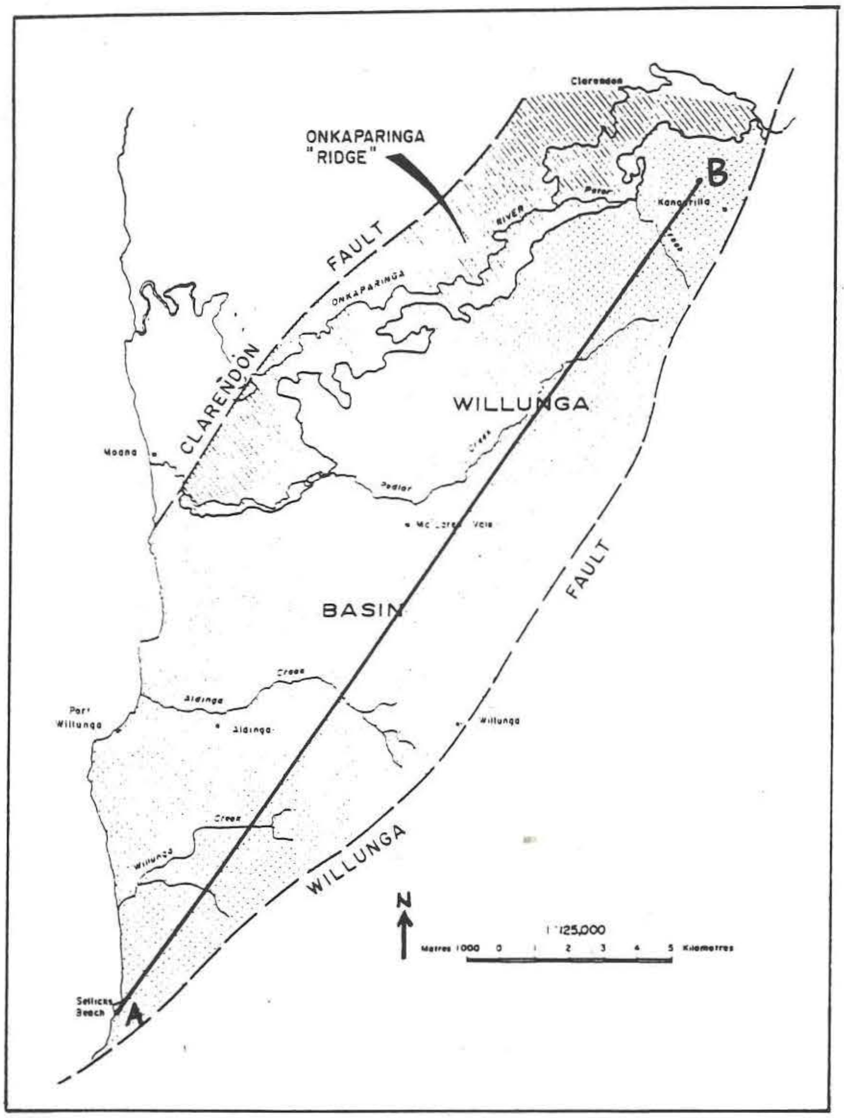


Figure 10
The Willunga Basin in groundwater terms.
Source: Bowering (1979:fig 2).

Figure 11
Cross-section showing the aquifer systems of the Willunga Basin.
Source: Adapted by the author from Selby (1984:fig 16).

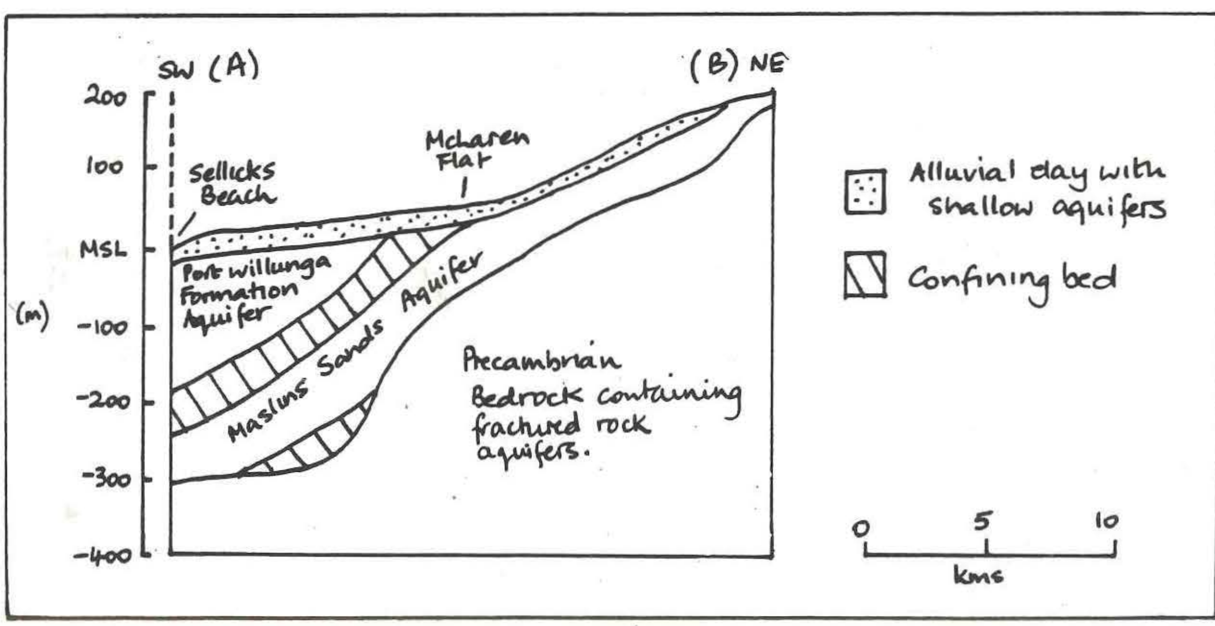
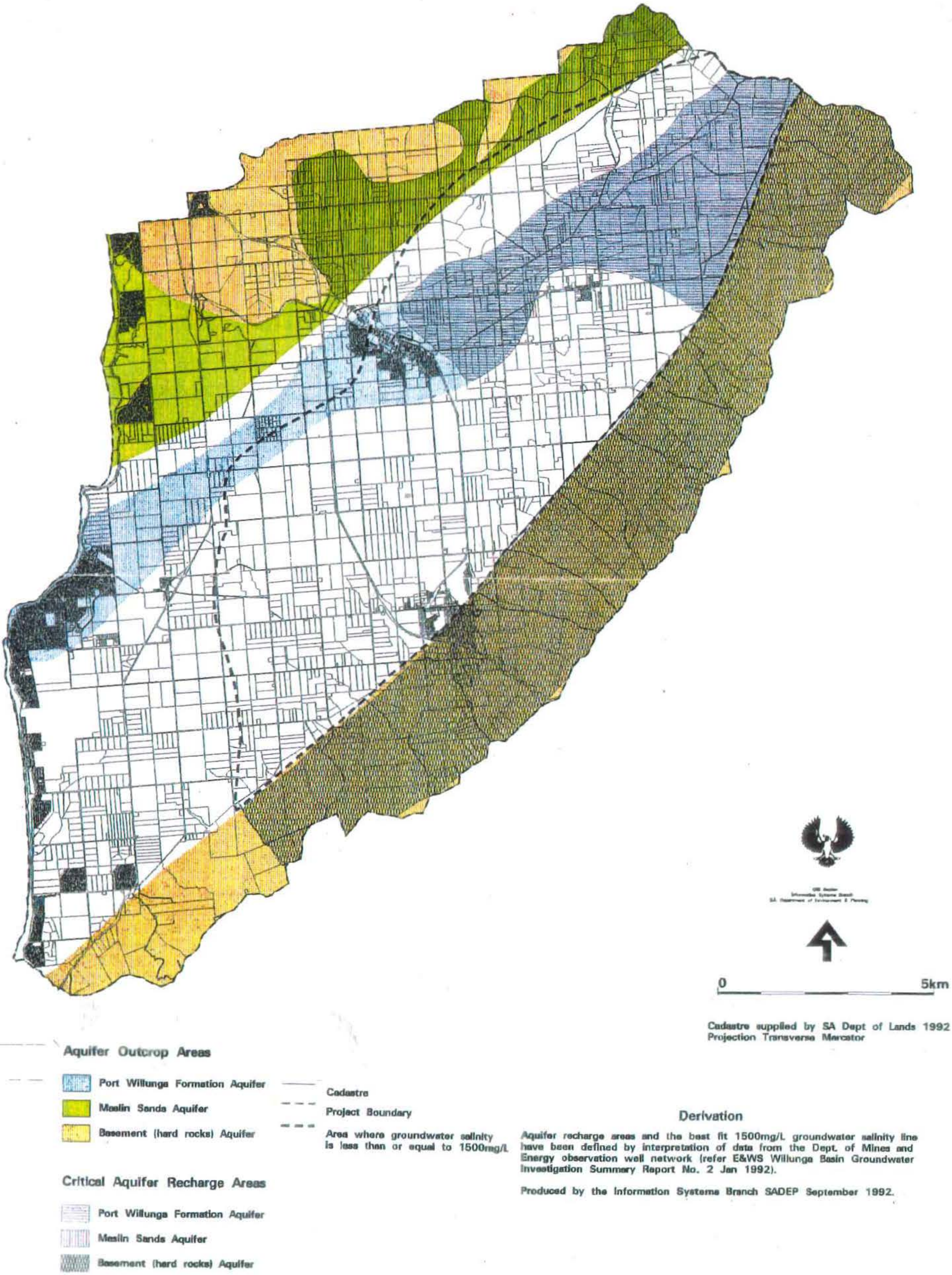


Figure 12
Aquifer outcrop areas and recharge zones.
Source: Planning Advisory Services (1992: fig 2.3).



today (Lange, 1976). From the Cretaceous to the early Tertiary much of South Australia was covered by warm temperate rainforest, such as is found today in the Lamington area of Southern Queensland, and the present eucalypt-dominated vegetation only developed as the climate became drier (Boomsma & Lewis, 1980). Currently there are only small isolated patches of native vegetation remaining in the Willunga Basin. A floristic vegetation map compiled by the Office of Planning and Urban Development (in Overton, 1993b) showed that native tree cover was limited and was represented by three types of woodland, three types of low woodland and one type of open forest, as shown in Table 2.

Table 2
Types of woodland found in the Willunga Basin today.
Source: Overton (1993b).

Type	Dominant species
Woodland	*Eucalyptus obliqua/E. fasciculosa* with *Pultenaea daphnoides/Lomandra dura* understorey
	E. leucoxylon/E. fasciculosa/E. odorata with *Ehrharta longifolia* (introduced species) understorey
	E. microcarpa, E fasciculosa with *Acacia rotundifolia* understorey
Low Woodland	*E. fasciculosa* with *Callitris preissii, Hibbertia virgata/Kunzea pomifera* understorey
	E. obliqua/E. fasciculosa with *Acacia verticillata* and *Xanthorrhoea semiplana* understorey
	E. baxteri/E cosmophylla with *Pteridium esculentum* understorey
Open Forest	*E. obliqua* with *Triflium campestre* (introduced) understorey

The total area of woodland and forest remnants is approximately 700 hectares (Planning Advisory Services, 1992) which is less than 1% of the Basin's area. Only two major areas of native vegetation remain, one near Blewitt Springs in the north-east and the other being the 300 hectares of Aldinga Scrub Conservation Park in the south-west (National Parks & Wildlife Service (NPWS), 1993). Small remnants of woodland with understorey are scattered along the top of the range and in the north. Some roadside remnants also occur, and patches of wetland vegetation exist along major creeklines and in a drainage reserve south of Aldinga Scrub.

Many weed species occur in the Willunga Basin (Overton, 1993a:27). Olive (*Olea europaea*) is particularly visible along roadsides in the north-east. Other exotics include woody weeds, which are invading native understorey on some roadsides, and African grasses. The present state of the native vegetation is addressed further in the Chapter on Vegetation History.

Knowledge of the native fauna of the Willunga Basin is limited since the only large scale studies which have been done have covered the Adelaide Hills in general (Overton, 1993b). The more obvious species in the Hills are the mammals, of which only five species are listed: the Yellow-footed Antechinus (*Antechinus flavipes*), the Western Grey Kangaroo (*Macropus fuliginosus*), the Bush Rat (*Rattus fuscipes*), the Common Brushtail Possum (*Trichosurus vulpecula*) and the Short-beaked Echidna (*Tachyglossus aculeatus*) (Overton, 1993b). More specific information is available for Aldinga Scrub, since it is a Conservation Park. Here over 166 bird species have been recorded, along with 18 butterfly species, 540 species of other insects, the Common Brushtail Possum, Short-beaked Echidna, bats, geckoes, skinks and snakes (NPWS, 1993). Wetland birds are also associated with the lagoons which sometimes form south of the Scrub (Friends of the Earth, 1991). Three major animal pests occurring in the Willunga Basin are the Fox (*Vulpes vulpes*), the Cat (*Felix catus*) and the Rabbit (*Oryctolagus cuniculus*) which between them spread exotic weed seeds, and prey on or compete with native fauna (Overton, 1993a:17).

2.1.5 Aboriginal and European history

The Aboriginal history of the Willunga Basin, based largely on ethnohistoric and archaeological material, is well covered (Ellis, 1976; Ross, 1984; Gara, 1988; Clarke, 1991). Carbon-14 dates suggest that Aboriginal people have inhabited the Fleurieu Peninsula for at least the last 10,000 years and possibly longer (Ross, 1984). There is evidence of continuous Aboriginal occupation at Moana, on the coast, from about 6,000 years ago, with over fourteen campsites and activity areas found between Snapper Point and Sellicks Beach, and eighteen campsites located on the margins of Aldinga Scrub (Ross, 1984). The Aborigines of the Willunga Basin belonged to the Kaurna tribe who occupied the coastal lands from Port Wakefield north of Adelaide to the southern tip of the Fleurieu Peninsula (Ross, 1984). Although the total Kaurna population in 1842 was estimated at 700 (Ellis, 1976), smallpox had spread west and decimated Aboriginal communities along the Murray River even before European arrival in South Australia and evidence of the disease was noted around Adelaide in 1840 (Gara, 1988). This fact surely makes it difficult to estimate the Aboriginal population of the Adelaide region or the Willunga Basin just prior to European settlement.

Early Europeans made some references to Aboriginal people in the Willunga Basin. For example, Giles (1838) listened to a corroborree whilst camped out one night. In 1842 it was recorded that six out of a large party of 'natives' from Encounter Bay were employed to help harvest corn near McLaren Vale (*South Australian*, 16 December 1842). Eight 'natives' were also recorded as having lived in Aldinga Scrub until about 1914 (Wollaston & Kraehenbuhl, 1986:6). Kaurna people probably ceased to live in the Willunga Basin shortly after this, although people from other tribes continued to visit. Kaurna descendants today live mostly in other parts of South Australia as a result of dispersal to missions largely during the 1880s (Gara, 1988; Clarke, 1991).

Features of the physical environment were prominent in Aboriginal physical and spiritual life. For example, Red Ochre Cove on the coast south of Pedler Creek and the coastal freshwater springs feature in the well-known Tjilbruke myth (Gara, 1988). In the summer months people would fish on the coast and cure animal skins whilst obtaining water from springs, and in winter would camp in the woodlands and foothills (Ross, 1984). Aboriginal people are thought to have had an impact on the environment by using certain plants more selectively than others, creating dams and channels along rivers to divert water to lakes and swamps to support fish and birds, and through burning the vegetation (Ellis, 1976; Gale, 1986; Clarke, 1991). Gale (1986:1) concluded that "the landscape of South Australia was moulded and changed by its first settlers, the Aborigines; European settlers did not come to an entirely natural landscape, as they believed, but to one established through thousands of years of Aboriginal occupation and utilization".

Matthew Flinders first sighted and named the Mount Lofty Ranges in 1802. Further explorations occurred in 1830 and 1831 after which British interest focused on establishing settlement along Gulf St Vincent and Encounter Bay (Marsden, 1986). After 1803 isolated whaling and sealing bases were established intermittently on Kangaroo Island and at Encounter Bay

(Heathcote, 1986:15). Although the establishment of South Australia had been projected in 1831, Colonel Light, as Surveyor-General, did not land on Kangaroo Island until 1836 (Worsnop, 1878) and only on 28 December 1836 did the first Europeans arrive on the mainland, at Glenelg west of Adelaide, to establish permanent settlement. For ease of reference later, Table 3 details nineteenth century visitors to the Willunga Basin who recorded various aspects of the environment. European settlement and land use in the Willunga Basin will be addressed in Chapter 7.

2.1.6 Current land uses and environmental problems

Figure 13 indicates the range of current land uses in the Willunga Basin. Agriculture dominates, with grazing on the hills, and cropping and grazing on the red and black clays of the plains. The Willunga Basin is famous for its almond orchards, and the wineries and vineyards in the north-east which constitute the Southern Vales wine region centred at McLaren Vale. Some large companies, including Seaview and Hardy's, and over twenty smaller wineries make an important contribution of high quality products, particularly Shiraz, to the South Australian wine industry. Some quarrying occurs in the Maslin Beach and Sellicks Hill areas and small light industrial areas have been established around McLaren Vale and Aldinga. The Willunga Basin holds landscape and heritage attractions for tourists and provides a recreation and leisure environment for the people of Metropolitan Adelaide. Residential areas are mainly limited to the coast and townships of Willunga and McLaren Vale. However, large-scale residential developments have recently appeared on the north-west coast and the resident population is expected to increase as the area absorbs some of the future growth from Metropolitan Adelaide.

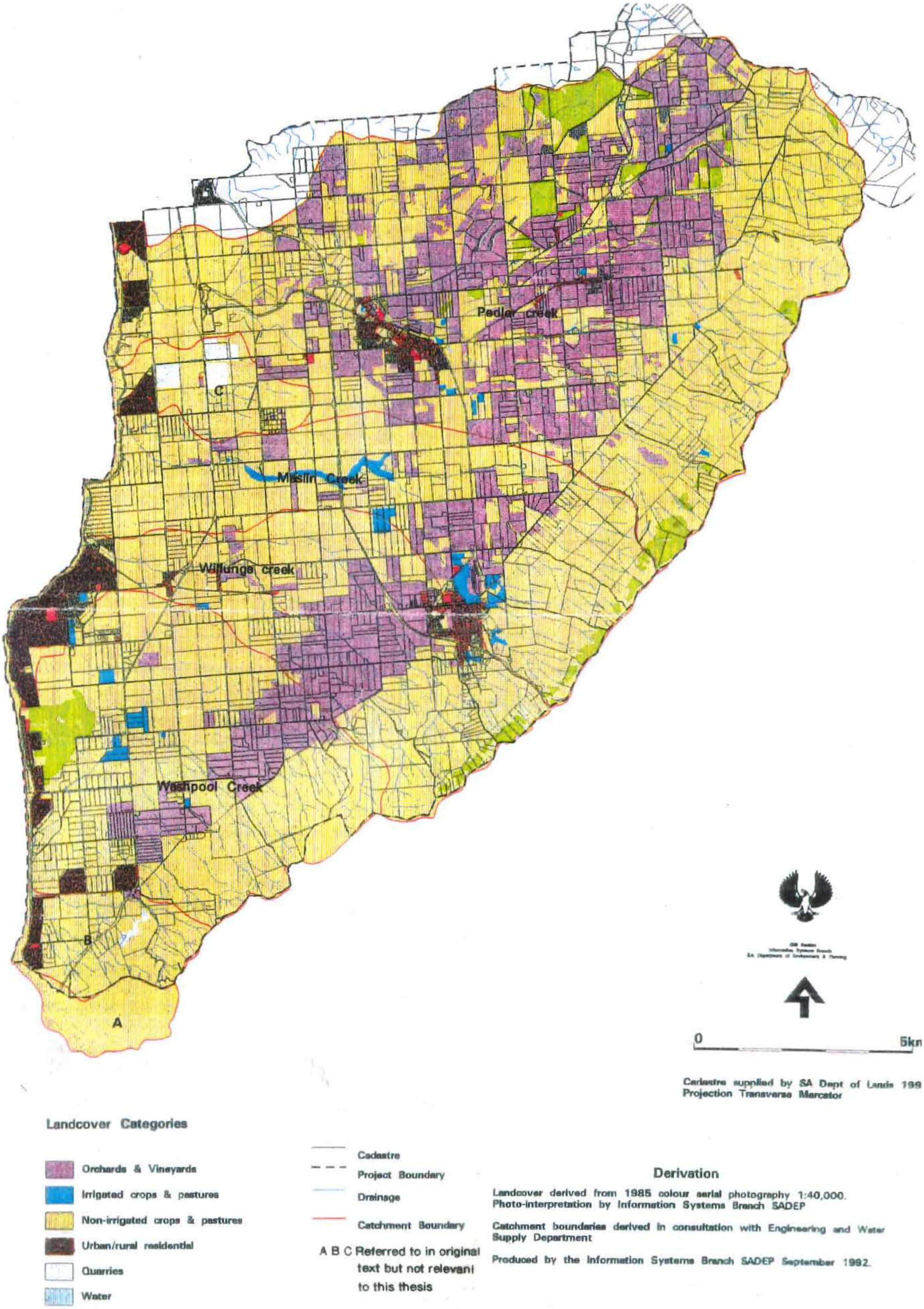
Due to its location and major land uses the Willunga Basin plays an important role in the social and economic welfare of the Basin's residents and also of the people of Adelaide and South Australia. However, these facets have also made the environment subject to increasing pressures and several major environmental problems in the Basin currently require attention. These are:

- a lack of native vegetation;
- flooding problems on the plains in winter and soil salinity problems; and
- gully erosion, which in some cases is severe.
(Overton, 1993a:7; Campbell, pers comm 1994).

Table 3
Nineteenth century visitors whose accounts, recollections and sketches included reference to the Willunga Basin. *Source*: Compiled by the author.

Date	Name	Comment
Mar 1802	Matthew Flinders	Sailed up St Vincent's Gulf in 1802. Made notes and maps of the coast in ship's log. *Source*: Cooper (1953).
Sep 1836	William Light	Wrote a diary and drew a sketch map of the coastal lands whilst surveying and searching for a site for Adelaide. *Source:* Elder (1984).
Nov 1836	John Morphett	Wrote a lengthy letter reporting his observations whilst accompanying mainland surveying expeditions from Kangaroo Island. Included descriptions of the McLaren and Aldinga Plains. *Source:* Morphett (1836).
May 1838	William Giles	Giles' diary of a visit to the area included comments on the Aldinga Plains. *Source:* Giles (1838).
1839	James Hawker	Hawker worked on the first surveys in the Willunga Basin in 1839. Beginning as fourth officer employed to survey sections, by October 1839 he had become Assistant Surveyor. He reminisced about the Willunga environment and the difficulties it caused for surveyors. *Source:* Hawker (1899).
1840	Edward Frome	As Surveyor General, Frome sketched scenes whilst out surveying and exploring the new colony. He painted a scene at McLaren Vale, probably in 1840. *Source:* Auhl & Marflett, (undated:34), Appleyard (1972).
Mar 1844	Unnamed writer with the initials "L.P." in *The Observer*	Wrote a lengthy report of a tour through the Onkaparinga and Willunga Districts and made many comments on the environment and early settlement. *Source: Observer* (1844)
1846	F Dutton	Described the Mt Lofty Ranges in general, early life and natural resources in South Australia, to inform people in Britain who, Dutton felt, knew nothing about South Australia. *Source:* Dutton (1846).
1847	George French Angas	Descriptions included the Mt Lofty Ranges and Adelaide Hills. *Source:* Angas (1847a).
Feb 1850	Edward Snell	Wrote an illustrated diary of his adventures in Australia from 1849 to 1859, including a visit to Willunga. *Source:* Griffiths (1988).
1889	George Sutherland	Provided descriptions of travels between the Noarlunga, McLaren Vale and Willunga areas. *Source:* Sutherland (1889).

Figure 13
Landcover in the Willunga Basin 1985.
Source: Adapted slightly from Planning Advisory Services (1992:fig 2.3).



2.2 AIMS OF THE THESIS

The main aim of this thesis is to establish the Environmental History of the Willunga Basin between the 1830s and the present and to use this to help explain some of the current environmental problems. Furthermore, Overton (1993a) emphasised that some knowledge of the Environmental History of the area needed to be ascertained in order for an integrated management plan to be developed. There is some existing work which examines the environment of the Willunga Basin, but these works are lacking either because only one aspect of the environment was studied (eg Dragovic, 1966; Chapple, 1991; Withers, 1993) or because reports were part of a planning process and addressed current problems but with little or no reference to the past (eg Turner & Associates 1982; Savarton 1990; Planning Advisory Services, 1992). For example, the original vegetation of the Willunga Basin was addressed to some extent in Savarton (1990), in relation to revegetation strategies for the Southern Region of Councils, but it was noted that there was a lack of detailed knowledge regarding the composition, density and location of the original plant communities. Savarton's primary guide to the original distribution of indigenous species was based on a soils map (Ward, 1966) and recent surveys undertaken by various environmental/conservation groups in the area, rather than on historical evidence. The work entitled *"Cradle of Adversity: A History of the Willunga District"* (Linn, 1991) addressed the human struggle with the environment of the Willunga Basin but was written for general readership. As such, it was more descriptive than analytical, emphasised social history rather than giving any detailed investigation of environmental change, and did not provide any insight for future management.

The timeframe for this study is set by the earliest European accounts of the area in the 1830s. It is intended that this study concentrate on vegetation, hydrology and land use, which are felt to be the main factors influencing the Willunga environment. The five major objectives of this thesis which relate to these aspects are as follows:

- both to establish rainfall trends since the 1830s so as to differentiate wetter and drier periods, and to calculate flood probabilities to date large rainfall events and determine their order of magnitude;

- to establish trends in the history of the surface and groundwater drainage and to determine the surface drainage pattern at the time of the first surveys, along with the timing, nature and magnitude of any change. Trends in groundwater levels and salinity will also be investigated;

- to establish the spatial distribution of gullying at the time of European settlement, and the onset of gully erosion, paying particular attention to the Sellicks Creek Gully, which is currently one of the largest gullies;

- to determine the general spatial pattern of vegetation in the Willunga Basin at the time of the first surveys and to establish the timing, nature and magnitude of any change; and

- to establish a history of temporal and spatial trends in population and major land use activities.

Sources to be researched and analysed to provide quantitative data and complementary qualitative information are historical and contemporary records available in Australia. The main sources to be researched are original survey records, historic maps and official statistics, complemented by material such as historical accounts, sketches and photographs. Although the works noted in Table 3 provide much historic source material on the Willunga Basin environment, it is recognised that the people listed are all white European males (except possibly Sutherland) and that they could have recorded a biased view of the environment. However, their work is used in the absence of alternative documentary evidence since it relates to many aspects which are important to this thesis.

Since a variety of sources and methods were used in this thesis, as is common in Environmental History research, these are discussed in detail at the beginning of the relevant chapters. Five chapters follow which will look at the Willunga Basin's rainfall and flood history, surface drainage and groundwater history, history of gully erosion, vegetation history and European population, settlement and land use history. The length of each chapter reflects the amount of information available.

CHAPTER 3

RAINFALL AND FLOOD HISTORY

When researching environmental history, it is important to establish climatic trends over the study period because they provide a background against which to assess other trends. The aim of this Chapter is to establish rainfall trends in the Willunga Basin from 1839 to 1993 and to identify periods which have been wetter and drier than normal. An analysis of large rainfall events will also be made so as to identify years of major flood events.

3.1 RAINFALL TRENDS

3.1.1 Obtaining reliable rainfall records for the Willunga Basin

To establish rainfall trends for the Willunga Basin, computerised monthly and annual data for all years of record were obtained from the Bureau of Meteorology for stations in and near the Basin. The extent of the data is summarised in Table 4. The data were processed using Unix-SPSS and Microsoft Excel to derive a useable record of annual data for the eight stations. Of the three stations actually in the Willunga Basin, the Willunga record covers the longest period. Therefore, it was desirable to

Table 4
Summary of rainfall records available for stations in and near the Willunga Basin. *Source:* Compiled by author from data supplied by Commonwealth of Australia Bureau of Meteorology.

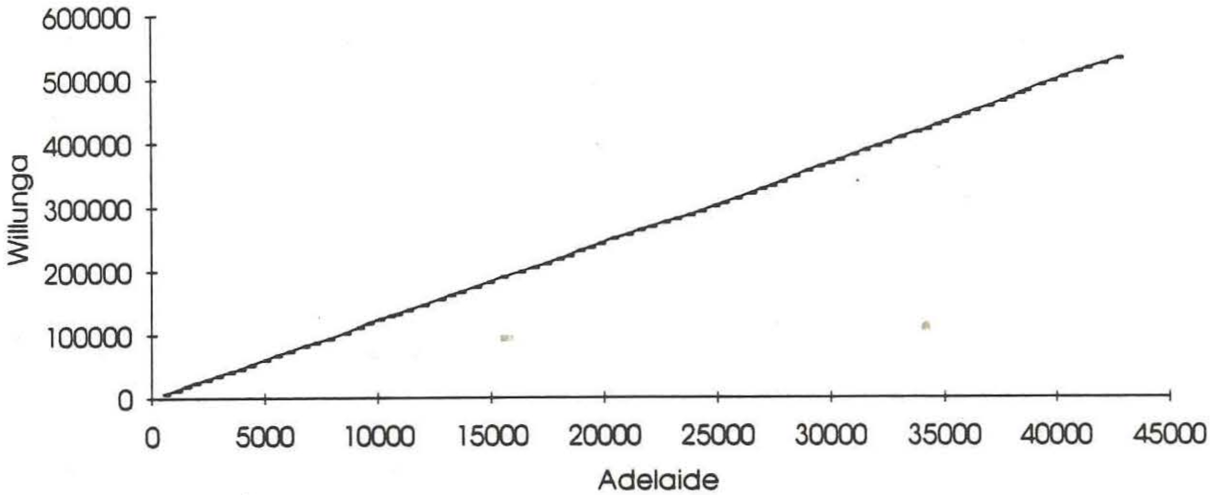
	Station	Dates of Record
1	Willunga	Jan 1862 - Dec 1993
2	Aldinga P O	Dec 1893 - Mar 1992
3	Old Noarlunga	Sep 1876 - Dec 1993
4	Meadows	May 1887 - Jun 1991 (incomplete)
5	Clarendon	Jan 1867 - Nov 1993 (incomplete)
6	Adelaide (West Tce)	Jan 1839 - Feb 1979
7	Mt Compass	Sep 1922 - Dec 1929 Jan 1934 - Nov 1992
8	McLaren Vale P O	Jul 1938 - Dec 1993

use the Willunga data to ascertain rainfall trends for the whole Basin, if the record could be shown to be consistent over time. There was no rainfall data collected at Willunga between 1839 and 1861 or for 1975, so it was deemed appropriate to test the consistency of the Adelaide record to see whether it could be used to provide proxy data for Willunga for the missing years. If the Adelaide data were suitable, then a continuous rainfall record would be available for the Willunga Basin since the time of the first surveys in 1839.

The Double Mass Curve method outlined by Searcy & Hardison (1960) was used to establish whether the Adelaide and Willunga records had been consistent over time. This allowed comparison of the Adelaide and Willunga records with data from the other six stations. The underlying principle of the Double Mass Curve method is that "the graph of the cumulative data of one variable versus the cumulative data of a related variable is a straight line so long as the relation between the variables is a fixed ratio" (Searcy & Hardison, 1960:31). Data was used for the first six stations listed in Table 4 for the period 1894 to 1974, over which continuous records existed. The annual data for each of the six stations during this period was cumulated in chronological order and the mean of the cumulative rainfall for all six stations was computed in order to provide the pattern against which individual stations could be checked. Since less than ten stations were used in this analysis each one was plotted against the averaged pattern to check for consistency. The resulting Double Mass Curves are given as Appendices 2A and 2B. Searcy & Hardison (1960) suggest that stations whose curves show significant breaks in slope should be eliminated from the average. It was felt that, on this basis, Clarendon, Old Noarlunga and Meadows should be eliminated. A three-station average was then calculated from the remaining stations of Willunga, Aldinga and Adelaide. The new double-mass curves plotted for Willunga and Adelaide are given as Appendix 2C.

It can be seen that the curves for Adelaide did not show any significant breaks, indicating that the annual rainfall at Adelaide had been consistent between 1894 and 1974. Cornish (1954:334) examined the Adelaide rainfall record between 1839 and 1950 and also found the data to be statistically consistent. However, the Willunga curve did show a break in 1946 against both the six-station and three-station patterns. In order to test whether this break was statistically significant, the F-Test (variance-ratio test) was applied, as suggested by Searcy & Hardison (1960). The workings for this are given in Appendix 2D. The break was found not to be statistically significant. Figure 14 shows the relationship between the Willunga and Adelaide data from 1894 to 1974. The straight line obtained indicates a consistent relationship between the two records.

Figure 14
Cumulated annual rainfall: Willunga and Adelaide 1894-1974.
Source: Compiled by the author from data supplied by the Commonwealth of Australia Bureau of Meteorology.



In order to predict the Willunga rainfall for 1839 to 1861, and 1975, from the Adelaide record of the same period, the statistics for a linear regression were calculated on Unix-SPSS for Willunga and Adelaide annual data from 1894 to 1974. The correlation coefficient was 0.84 and the coefficient of determination (R^2) was 0.71. The data from the two stations for the whole period of coincidence, 1862 to 1978, was also transformed into a linear regression plot which gave the same results. Appendix 2E shows the regression plots and the associated statistics. On this basis the missing Willunga data was derived from the Adelaide data using the formula:

Willunga missing data = (Adelaide data x 1.0585) + 98.36906.

Thus, the collected rainfall data for Willunga and Adelaide between 1894 and 1974 is consistent and the Adelaide record has been used to extend the Willunga record back from 1861 to 1839, giving a total period of 155 years.

3.1.2 Rainfall trends in the Willunga Basin 1839-1993

Once the annual data series was completed for Willunga, 25-year and 11-year moving averages were calculated and plotted, as shown in Figures 15 and 16. Figure 17 also shows the 11-year moving average for Willunga plotted with the annual data. The moving averages smooth the annual data and show the rainfall trends in the Willunga Basin over the period of record. The 25-year moving average (Figure 15) depicts a continual downward trend for the

Figure 15
Rainfall in the Willunga Basin: 25-year moving average 1839-1993.
Source: Compiled by the author from data supplied by the Commonwealth of Australia Bureau of Meteorology.

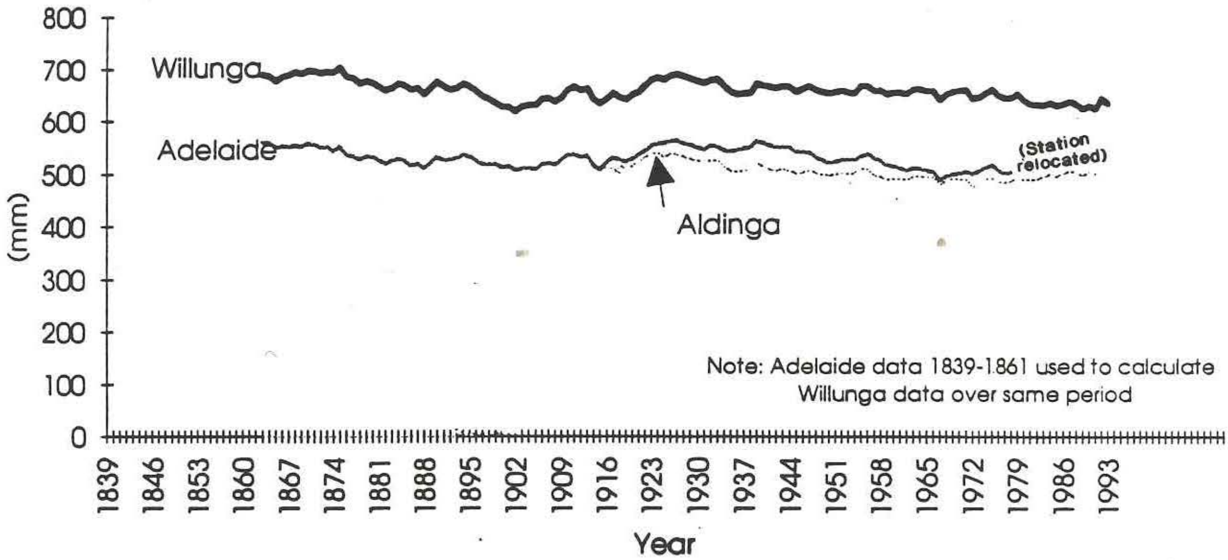


Figure 16
Rainfall in the Willunga Basin: 11-year moving average 1839-1993.
Source: Compiled by the author from data supplied by the Commonwealth of Australia Bureau of Meteorology.

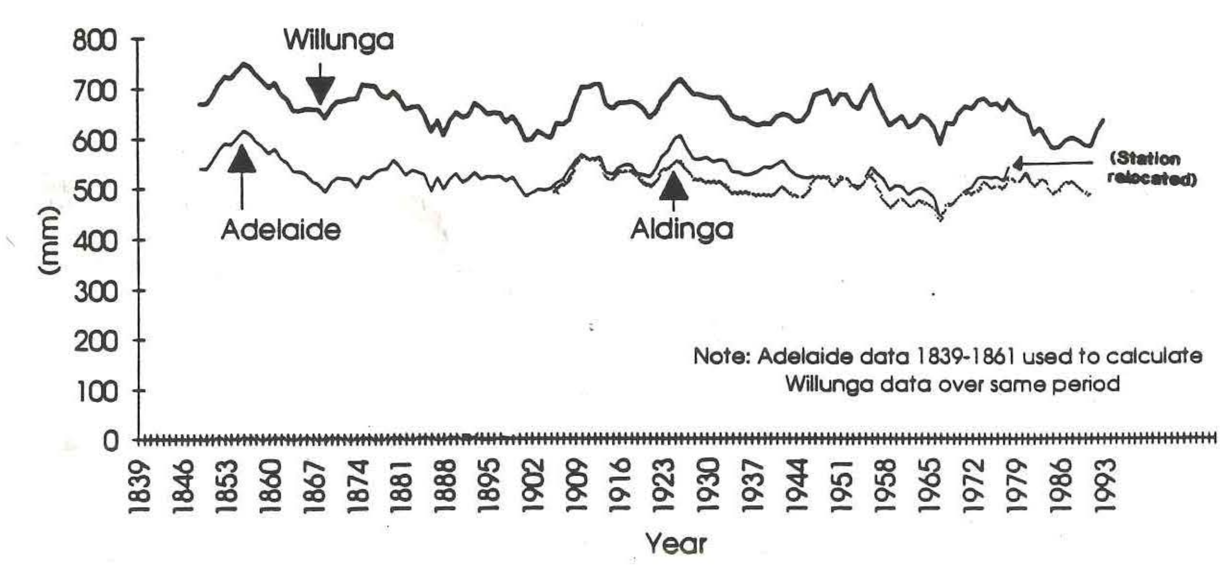
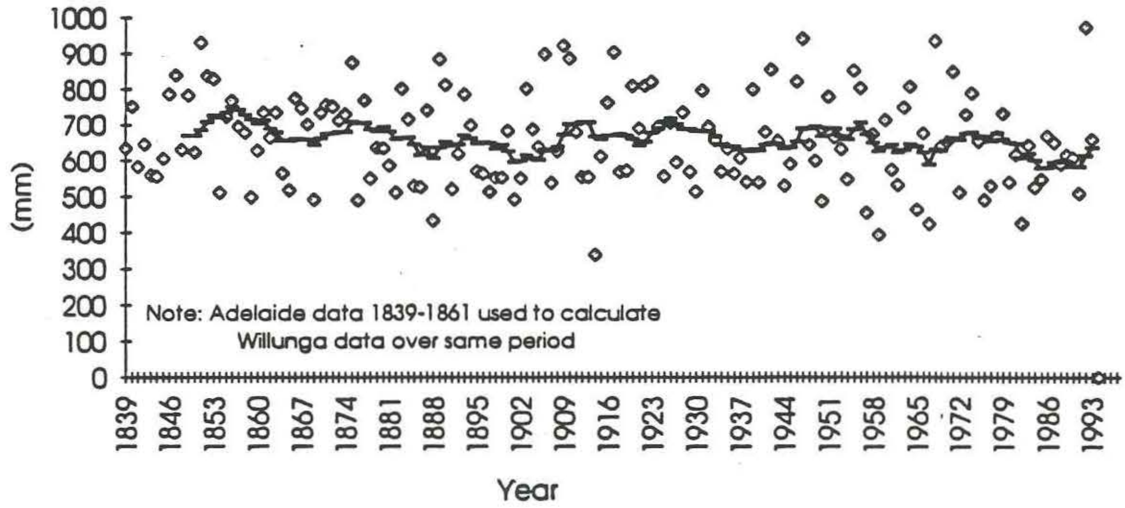


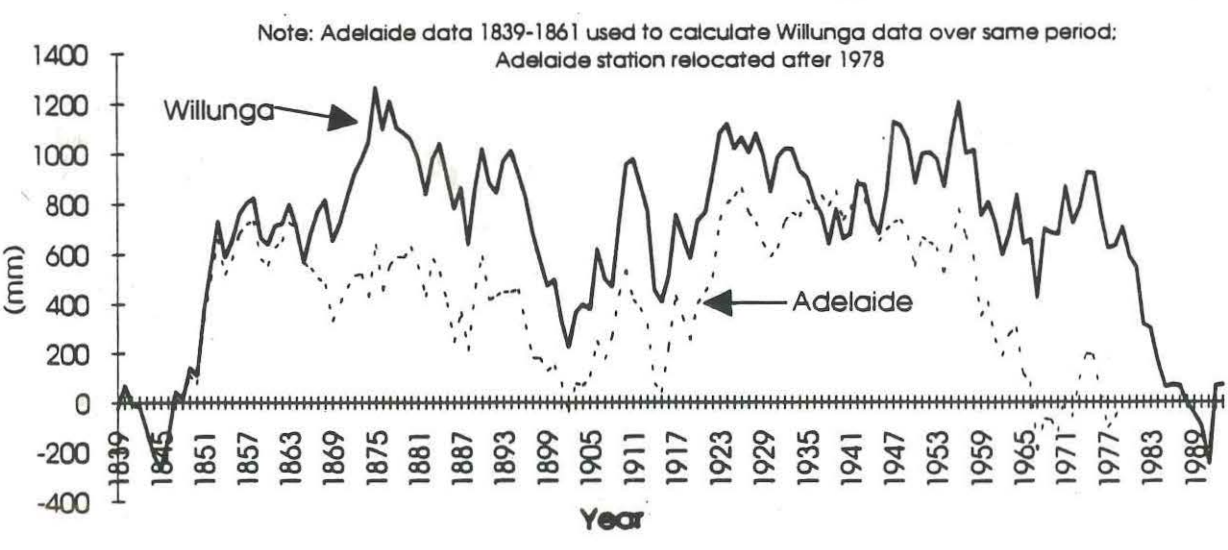
Figure 17
Willunga annual rainfall and 11-year moving average 1839-1993.
Source: Compiled by the author from data supplied by the Commonwealth of Australia Bureau of Meteorology.



average annual rainfall at Willunga over the period of record. The 25-year average was around 700mm in the 1860s and 1870s and had dropped by just under 15% to 600mm in the 1980s. The downward trend was reversed temporarily by an upward climb in the first two decades of this century. The 11-year moving average in Figure 16 is more detailed and shows that within the overall downward trend Willunga experienced periods of higher and lower annual rainfall.

Cumulative residual mass graphs were also compiled for Willunga and Adelaide to identify periods of greater than, or less than, average rainfall. These are shown in Figure 18. Cumulative residual graphs were

Figure 18
Cumulative residual plot of Willunga and Adelaide annual rainfall 1839-1993. *Source:* Compiled by the author from data supplied by the Commonwealth of Australia Bureau of Meteorology.



the main basis of Foley's (1957) comprehensive study of droughts in South Australia. The cumulative residual plot indicates the major periods of increasing and decreasing rainfall at Willunga as follows:

- Decreasing for the first five years after the initial surveys
- Increasing from 1845 to 1875
- Decreasing from 1875 to 1900
- Increasing from 1900 to 1925
- Decreasing from 1925 to 1945
- Increasing from 1945 to 1960
- Decreasing from 1960 to 1993

By closely comparing Willunga's annual rainfall record with the detailed climatic analysis given in Foley (1957) for the period 1839-1945, Willunga's trends were found to mirror the fluctuations experienced generally in the agricultural areas of South Australia extremely well (Foley examined ten rainfall stations between Strathalbyn and Orroroo). The two major periods where Willunga's rainfall declined, from the mid-1870s to the 1900s and from the mid-1920s to the 1940s, also coincided with similar changes further afield. The period of particularly low rainfall at the beginning of this century, evident in Figures 15 and 18, was highlighted by Foley who stated that "rainfall deficiencies in the years 1896 to 1902 culminating in the extremely dry conditions of 1902 were far greater than anything previously experienced since rainfall records commenced" (Foley, 1957:164). This drought period which eastern Australia experienced from 1896 to 1915 was also felt world-wide in tropical and east coast regions, affecting the semi-arid western part of New South Wales, the east coast of North America, other dry regions such as Arabia, the east coast of South Africa, and East Asia to a lesser extent (Kraus, 1955:439). Based on Foley's work and the Willunga data presented here, it also appears to have affected parts of South Australia.

Another drought period affected south-eastern Australia between 1939 and 1944 but was shorter and more limited geographically than the drought at the turn of the century (Kraus, 1955:439). Pittock (1975:501) demonstrated that this drought affected areas from Central Queensland to Bass Strait and Figure 18 also illustrates that it was experienced at Willunga. However, Adelaide did not record the same trend. Kraus (1963) attributed the widespread coincidence of rainfall variations at this time to changes in general atmospheric circulation, since a long-term correlation was found between rainfall regions both north and south of the Equator. He also pointed out that such similarities became obvious only by looking at longer-term trends so that random and local effects were averaged away. Interestingly, Willunga's declining rainfall trend from 1974 to 1991 was longer than the previously worst recorded period of declining rainfall at the turn of the century.

No reference to a long-term declining average rainfall trend over the past 155 years could be located in other research. Hobbs (1988) examined rainfall trends for nineteen South Australian stations between 1891 and 1983 (most stations did not have earlier records). He concluded that "the evidence for any sustained long-term climatic change, at least as far as rainfall is concerned, is unclear" (Hobbs, 1988:295). However, his own work, and other work which he reviewed, aimed to provide information for agricultural purposes. The focus was therefore on seasonal rainfall change and did not include long-term annual trend analysis. Hence, it is not known whether the long-term declining rainfall trend at Willunga and Adelaide is a local or more widespread phenomenon.

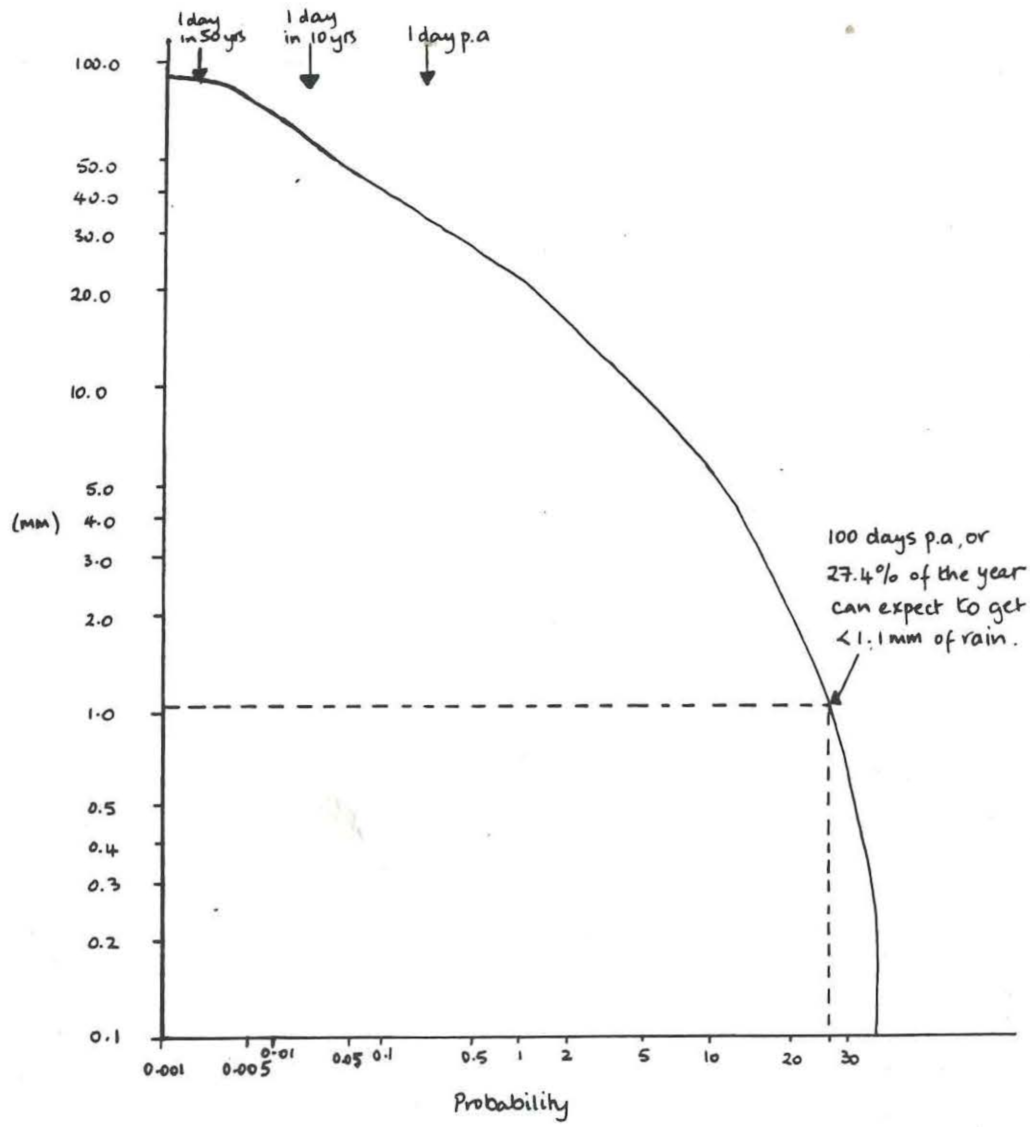
3.2 FLOODING

3.2.1 Sources and method for obtaining flood probability information

The best method for obtaining flood probability information is to use streamflow records from a gauging site. The probability of the occurrence of floods of different magnitude is ascertained by transforming peak discharge data via a probability function to a frequency-magnitude distribution (Wasson & Clark, 1985). However, there are no historic streamflow records for the Willunga Basin (Overton, 1993a:32). In the 1970s stream gauges were proposed and sites selected for a groundwater recharge investigation, but surface flow measurements were later deemed unnecessary and so gauging never began (Bowering, 1979:21). Such a lack of water and sediment discharge monitoring was not unusual in Australia before the 1980s, and gauges were usually installed only to monitor water use (Warner, 1984:137). Rainfall data was therefore used as a proxy to establish a flood history for the Willunga Basin.

The computerised daily rainfall data for Willunga was obtained from the Bureau of Meteorology and was prepared on Unix-SPSS for flood analysis. This included adjusting the raw data set to give a rainfall figure for every day of record, from 1 January 1884 to 28 February 1994. Where there were instances of one or two days of missing data followed by a cumulated total for that time period, the cumulative total was averaged over the associated number of days. Of course, this means that heavy rainfall events which occurred on, say, one day alone were averaged out and became less significant. Averaged figures occurred more frequently after 1974, where two or three days per week were often accounted for by one rainfall amount. However, there was no alternative to distributing these averages if a flood probability graph were to be produced. A frequency distribution was calculated for all data and classes were established over a range from 0.1mm to 100mm. The classed data were plotted on log probability paper to provide the flood probability graph in Figure 19.

Figure 19
Probability of heavy rainfall events at Willunga.
Source: Compiled by the author from daily data, for 1 January 1884 to 28 February 1994, supplied by the Commonwealth of Australia Bureau of Meteorology.



3.2.2 Extreme rainfall events at Willunga 1884-1994

On the basis of the data used, Figure 19 shows that a one in ten year rain event (a probability of 0.0274% or less) occurs in the Willunga Basin when 53mm or more falls in 24 hours; that rain occurs approximately 33% of the time (or once every three days); and that 100 days per year are likely to record under 1.1mm of rain. The days which have had a rainfall event of one in ten year magnitude or greater are presented chronologically in Figure 20 and by order of magnitude in Table 5.

Figure 20
Timeline of 1 in 10 year rainfall events at Willunga 1884-1994.
Source: Compiled by the author from daily data supplied by the Commonwealth of Australia Bureau of Meteorology.

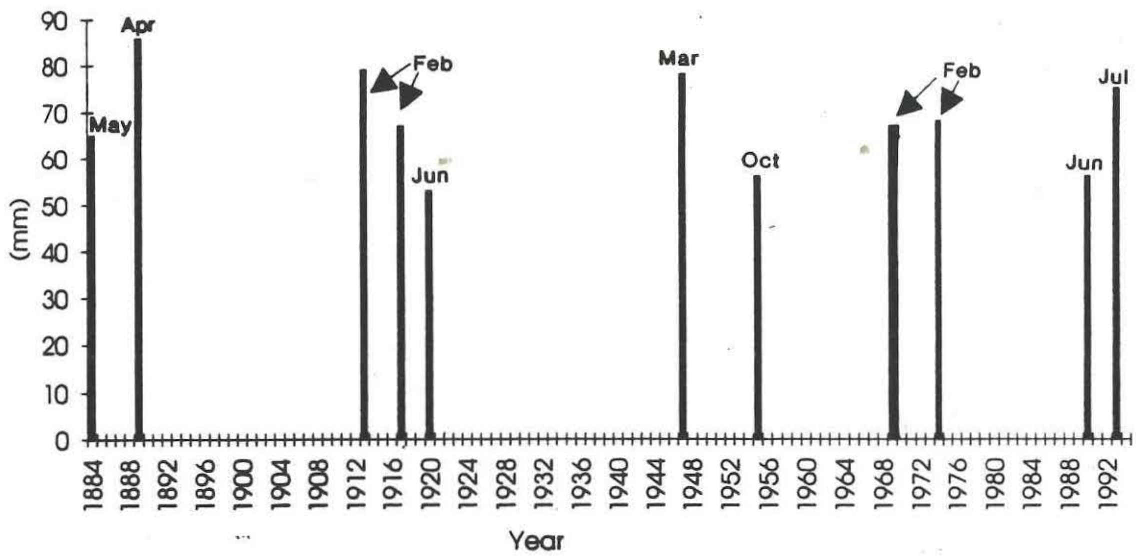


Table 5
Rainfall events of 1 in 10 year magnitude or greater occurring at Willunga 1 January 1884 to 28 February 1994, by order of magnitude.
Source: Compiled by author from daily data supplied by Commonwealth of Australia Bureau of Meteorology.

Amount of rain	Date
86mm	2 Apr 1889
79mm	14 Feb 1913
78mm	28 Mar 1947
75mm	8 Jul 1993
68mm	1 Feb 1974
67mm	14 Feb 1917
67mm	9 Feb 1969
67mm	10 Feb 1969
65mm	12 May 1884
56mm	20 Oct 1955
56mm	27 Jun 1990
53mm	1 Jun 1920

From Figure 20 it is clear that the nine largest daily rainfall events (except for July 1993) occurred between February and April. That storms are most frequent at these times of year is confirmed by research at the Waite Agricultural Research Institute (Turner & Associates, 1982:9) and often one intense summer thunderstorm in the Adelaide region can provide a substantial percentage of the annual total rainfall (Schwerdtfeger, 1976:77). The Willunga daily records also show that late summer rains often followed extended dry periods. On 2 April 1889 Willunga experienced its largest rain event ever since daily records began. This occurred at the end of a ten-year drought. Foley (1957) wrote that 1889 and 1890 were very wet years which followed the dry period which began in 1879 and culminated in the 1888 drought.

3.2.3 Flood history for the Willunga Basin 1839-1994

The flood probability analysis is a useful benchmark for measuring claims of extreme hydrological events. A short list of floods mentioned in some historic accounts is given in Table 6 (the list is not exhaustive). It can be seen that three large floods occurred after daily rainfall records began in 1884 which were not accounted for in Table 5, ie in January 1889, December 1912 and July 1986. Therefore, the printout of daily rainfall was consulted and a note was made where rainfalls of over 30mm occurred on one day, which amounted to over 70mm over two or more days, in an attempt to account for significant events which might have been removed by the averaging procedure and the selection of heavy falls on one day alone. This resulted in the additional list of rainfall periods shown in Table 7. By adding these to the events identified by the rainfall record a new table of large rainfall events was constructed (Table 8). With the additional events included, it was found that 75% of the periods recording 67mm or more had occurred between 1 January and 24 April. It was also evident that large rainfall amounts in winter tended to result from several days' rain, while large amounts in summer and autumn were more likely to come from heavy falls on one day.

By including the large rainfall amounts which accrued over two or more days the floods of 1/2 January 1889 and July 1986 were accounted for, but the December 1912 flood was not. This was puzzling, since the December 1912 flood was said to be bigger than the January 1889 flood (Dunstan, 1978:37). According to meteorological records, 73mm fell in two days in January 1889, whereas the maximum amount of rain in December 1912 was 18mm on 7 December and only 1mm on 10 December. The account of the December flood also

Table 6
Floods which were reported in historic accounts.
Source: Compiled by the author from sources as indicated.

Date	Event	Source
End May to 3 Jun 1851	Flood after heavy rain in one day at Willunga carried away fences and a huge log which had taken twenty bullocks to move, destroyed several acres of newly sown wheat and completely washed away topsoil.	*The Register* 3 Jun 1851
23 May 1860	Localised thunderstorm on Loud's Hill south-west of Willunga. Produced torrential flow which moved downhill then north-west via Aldinga towards the sea. "The most extraordinary floods experienced for many years" followed continuous and heavy rain which exceeded soil infiltration capability and stream capacity. Ploughed land was washed away and sub-soil laid bare.	*The Chronicle* 26 May and 2 Jun 1860
Late Aug/ Sep 1875	Flood at McLaren Vale	*The Observer* 4 Sept 1875
1 Jan 1889	Large floods at Willunga	'Floods at Willunga' Dunstan (1978:37).
10 Dec 1912	A flood bigger than any in living memory, including floods of Jan 1889	'Floods at Willunga' Dunstan (1978:37).
Jul 1986	Rains of one in ten year severity	Wollaston & Finger (1986:15); Friends of the Earth (1991)

Table 7
Rainfall totals over one in ten year magnitude recorded over two to five days, which could have contributed to flooding but which were not accounted for in Table 5. *Source:* Compiled by the author from daily data supplied by the Commonwealth of Australia Bureau of Meteorology.

A= average value as appeared in original data set

Period	Day 1	Day 2	Day 3	Day 4	Day 5	Total
1-2 Jan 1889	73mmA					73mm/2 days
27-31 May 1893	31mm	39mmA		28mm	10mm	108mm/5 days
8-9 Mar 1903	69mmA					69mm/2 days
23-24 Apr 1905	67mmA					67mm/2 days
24-26 Mar 1906	38mm	73mmA				111mm/3 days
5-7 Mar 1910	27mm	80mmA				107mm/3 days
23-25 Jun 1915	32mm	15mm	26mm			73mm/4 days
16-18 Apr 1938	28mm	58mmA				86mm/3 days
17-18 Feb 1946	96mmA		13mm			109mm/3 days
9-10 Feb 1969	134mmA					134mm/2 days
1-7 Jul 1986	27mm	11mm	44mm	25mmA		107mm/5 days
25-27 Jun 1990	27mm	6mm	56mm			89mm/3 days

Table 8
Large rainfall events occurring at Willunga over one to five days between 1 January 1884 and 28 February 1994. *Source:* Compiled by author from daily data supplied by Commonwealth of Australia Bureau of Meteorology.

Rain fell on one day only unless stated as:
*2 = possibly over two days (gauge only read on 2nd day)
*3 = over three days; *4 = over four days; *5 = over five days

Amount	Date
134mm*2	9-10 Feb 1969
111mm*3	24-26 Mar 1906
109mm*3	17-18 Feb 1946
108mm*5	27-31 May 1893
107mm*3	5-7 Mar 1910
107mm*5	3-7 Jul 1986
89mm*3	25-27 Jun 1990
86mm	2 Apr 1889
86mm*3	16-18 Apr 1938
79mm	14 Feb 1913
78mm	28 Mar 1947
75mm	8 Jul 1993
73mm*2	1/2 Jan 1889
73mm*4	23-25 Jun 1915
68mm	1 Feb 1974
69mm*2	8-9 Mar 1903
67mm*2	23-24 Apr 1905
67mm	14 Feb 1917
67mm	9 Feb 1969
67mm	10 Feb 1969
65mm	12 May 1884
56mm	20 Oct 1955
56mm	27 Jun 1990
53mm	1 Jun 1920

mentioned that floodwaters rose 18" (0.45m) over a bridge on the main road to Adelaide, that metal from several macadamised roads and scores of tons of hay on the Aldinga Plains were completely swept away, and that the Delabole Quarry above Willunga resembled a waterfall. There are photographs of floods at McLaren Vale in 1912 which record that flooding was quite extensive there too (Mortlock Library Historic Photograph Collection, SLL:M B32358 and B32355). The discrepancy between the rainfall data and the historic account might be explained by the fact that occasionally intensely localised thunderstorms occur in summer in the Adelaide region (Schwerdtfeger, 1976:77). One such event occurred in May 1860, where a single black cloud over the Sellicks Hill Range produced "an immense body of water ... such as had never before been witnessed" by any resident in the district (*The Chronicle*, 2 June 1860). Water flowed down between the hills and rose up to fifteen feet (five metres), until it reached the plains and spread out "in greater or lesser streams of water" making its way to the coast at a speed of up to twelve miles an hour (20km/hour). The force of water carried trees, great stones and fences away although the intensity had diminished within three hours. It is therefore possible that a rainfall event which was not recorded at Willunga may have caused the December 1912 flood.

Care is therefore needed in interpreting flood probability data based on rainfall records because factors other than rainfall can contribute to flooding, including soil type and pre-rain soil moisture level, depth and width of stream channels (which can be reduced by siltation, resulting for example from certain land use practices) and the type of vegetation intercepting the rain. Two falls of the same amount in one location could therefore produce a different outcome under different conditions. No official rainfall recording station exists on the Sellicks Hill Range but rainfall recorded over an eighteen month period by a local landholder shows that the amount of rain received monthly on the top of the range can differ considerably from that recorded at Willunga (Table 9). The December 1912 flooding might therefore have resulted from rain which fell on the hills but not at Willunga, or from a combination of other factors.

Table 9
Monthly rainfall recorded at the top of the Sellicks Hill Range above Willunga compared with Willunga rainfall, August 1992 to February 1994 *Source:* John Carey and Commonwealth Bureau of Meteorology.

Date	Willunga	Top of Range	Hills as % of Willunga	Hills rain compared
Aug 92	119mm	158mm	133%	+39mm
Sep 92	135mm	171mm	127%	+36mm
Oct 92	85mm	66mm	78%	-19mm
Nov 92	106mm	33mm	31%	-73mm
Dec 92	112mm	102mm	91%	-10mm
Jan 93	19mm	26mm	137%	+7mm
Feb 93	19mm	20mm	105%	+1mm
Mar 93	20mm	27mm	135%	+7mm
Apr 93	1mm	1mm	100%	equal
May 93	58mm	71mm	122%	+13mm
Jun 93	94mm	111mm	118%	+17mm
Jul 93	145mm	151mm	104%	+6mm
Aug 93	66mm	69mm	105%	+3mm
Sep 93	75mm	72mm	96%	-3mm
Oct 93	73mm	87mm	119%	+14mm
Nov 93	30mm	41mm	137%	+11mm
Dec 93	57mm	93mm	163%	+36mm
Jan 94	24mm	47mm	196%	+23mm
Feb 94	14mm	17mm	121%	+3mm
Total	1252mm	1363mm	109%	

3.3 SUMMARY OF FINDINGS

Rainfall trends between 1839 and 1993 were established for the Willunga Basin based on the Willunga and Adelaide records. Over the long-term, average annual rainfall has been on a continual downward trend. However, in the short-term the annual rainfall has fluctuated. Two particularly dry periods were experienced, from the 1890s to the 1900s and from the 1920s to the 1940s, both of which reflected drought patterns elsewhere in Australia and overseas. From 1974 until 1991 the Willunga Basin experienced its longest period of decreasing rainfall yet, surpassing the length of the previously worst recorded drought period at the turn of the century.

On the basis of daily rainfall records from 1884 to 1994 a flood probability graph was constructed for Willunga which showed that a one in ten year flood occurred when 53mm fell in 24 hours. A chronology of floods equal to or greater than a one in ten year magnitude was compiled, which was also amended to include large rainfall events which had occurred over two to five days. Many of the largest events on record were found to have occurred in late summer and the largest fall recorded in one day was 86mm on 2 April 1889 after a ten-year drought.

A table of historic references to floods in the Willunga Basin was compiled which showed that devastating floods had occurred in 1851 and 1860, as well as three large flood events after 1884 which had not been accounted for in the daily records. The amended table of rainfall events which had occurred over two to five days accounted for two of these, showing that floods can result from more than just heavy falls in one day. However, the other flood could not be accounted for and may have been caused by a particular combination of environmental factors, or localised rainfall which was not recorded at the Willunga station. The rainfall and flood trends which have been established in this Chapter will be compared in Chapter 8 with other changes in the Willunga Basin since the 1830s.

CHAPTER 4

SURFACE DRAINAGE AND GROUNDWATER HISTORY

The hydrology of an area is interdependent with many other factors, including its geology, soils and vegetation, and in turn it affects other environmental aspects, including habitat suitability both for humans and other species. The aim of this Chapter is to establish the history of the surface and groundwater drainage of the Willunga Basin and to see whether any changes in these parameters have occurred since the 1830s. It is intended that the surface drainage pattern at the time of the earliest surveys be determined, along with the timing, nature and magnitude of any changes. Trends in groundwater levels and salinity will also be examined and a brief investigation will be made into the wetlands area on the Aldinga Plains, since coastal wetlands are a rarity in the Adelaide Metropolitan area today.

4.1 SURFACE DRAINAGE

4.1.1 Sources and method for establishing a history of the surface drainage

In order to establish the surface drainage history of the Willunga Basin at the time of the first surveys in 1839/40 and to determine whether any changes had occurred since, maps of the surface drainage pattern at different dates were needed. Whilst conducting research in the State Library of South Australia, eight maps were found in the Map Collection which, as well as showing the sections surveyed in the Willunga Basin at different times, also indicated the surface drainage pattern. There was an 1840 map by McLaren (supplied as Appendix 3 and henceforth referred to as the 1840 McLaren map) and seven maps of the Hundred of Willunga for 1873, 1883, 1896, 1915, 1926, 1959 and 1963 (the latter was the last Hundred Map published for Willunga). Maps were also located for the Hundreds of Kuitpo (1872, 1886, 1962) and Myponga (1881, 1896, 1959) to cover the small areas in the far north-eastern and far southern parts of the Willunga Basin. Although the dates did not coincide exactly with those for Willunga, the Kuitpo and Myponga maps showed little change in drainage patterns. A 1992 coverage on the Willunga Basin Geographical Information System (GIS), housed at the Geography Department, University of Adelaide, provided the most up-to-date surface drainage pattern for the Willunga Basin.

Although the historic maps appeared to be very useful, it was felt that care was needed in using them to chart changes in the drainage pattern, especially since much of the surface drainage in the Willunga Basin is ephemeral. It cannot be known on what basis the mapping took place, nor what techniques were used. For instance, some creeks on the 1840 map were not marked on the 1873 and 1883 maps. This might have reflected actual changes in the amount of surface water present or could have been the result of poor mapping. It was also possible that maps were completed in more detail as time went by, leading to an apparent but not real change.

In spite of the potential limitations with the maps, it was felt that no other information was likely to be located. Therefore, the drainage patterns from the maps between 1840 and 1963 were digitised onto the Willunga Basin GIS using ArcInfo and were then transformed and registered to the same scale as the 1992 map before being printed out. The maps constitute the first historic coverages added to this GIS, which is being developed as a land management tool. The Willunga Basin was not completely mapped until 1883, so that the 1840 map omitted the hills and the north-east area which had not been surveyed, while the 1873 map included the hills, but still omitted the north-east area which was not surveyed until 1879. Therefore, three areas were delineated on the computerised maps: the area mapped in 1840, the extra area mapped in 1873, and the area added in 1883 which completed the mapping of the whole Willunga Basin. The GIS was then used to provide measurements of the total length of drainage channels for each year from 1840 to 1992, as well as breaking the total length up by separate areas to allow comparisons over time and space. It was then easy to compare the drainage pattern from different dates by overlaying different maps together on the computer screen. This method revealed that mapping at each date had in fact been quite accurate, as channels which appeared in maps at two different dates usually coincided well, even when comparing the 1840 and 1992 maps. It was also found that the total length of channels had decreased between 1963 and 1992 which showed that even if mapping techniques had become more refined over time the maps still indicated surface changes.

4.1.2 Surface drainage in the Willunga Basin 1839/40

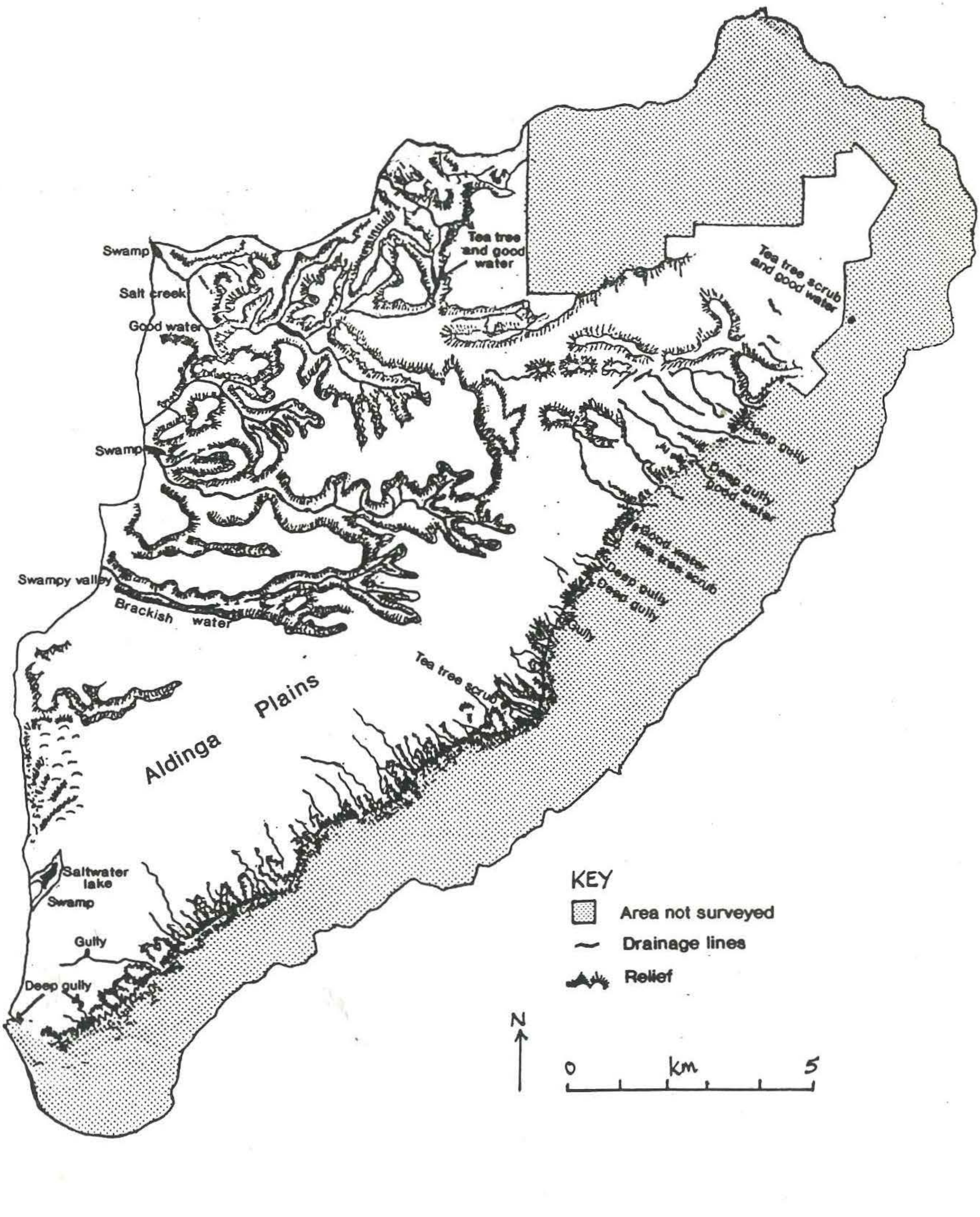
The 1840 McLaren map provides as complete a picture as is likely to be found for the surface drainage of the area surveyed in 1839/40. Figure 21 has been compiled from the drainage and relief features shown on this map along with comments relating to the hydrology mentioned in the 1839/40 survey records, which were researched at the Survey Records Department of the Department of Environment & Natural Resources. Based on Figure 21, four major areas can be delineated in terms of the 1839/40 surface drainage: 1) an area known as the Aldinga Plains in the south-west of the Willunga Basin, which had no drainage channels marked; 2) the Sellicks Hill Range (which was not mapped); 3) the stream channels flowing from the Sellicks Hill Range which often passed through deep gullies and which did not extend very far onto the plains; and 4) the four major creeks in the north-west of the Basin.

There were doubts as to the accuracy of the 1840 map so references to the early surface drainage of the Willunga Basin were located. Early written accounts supported the 1840 map, particularly in relation to the lack of water on the Aldinga Plains. In 1844 the Aldinga Plains and the McLaren Plains (between the sites of McLaren Vale and Willunga) were said to have "an irregular surface ... formed by the heavy rains beating on a surface *which has not an effectual drainage*" (*The Observer*, 13 April 1844, emphasis added). This describes the poorly drained gilgai soils of these areas. Since both areas were deficient in surface water, the *Observer* article detailed a scheme for supplying water to the McLaren Plains from the springs in the ranges via a network of wooden pipes. The lack of water on the Aldinga Plains had also been noted by Colonel Light in September 1836, who thought that the land looked good although no brooks of water could be seen (Light, 1836), and by William Giles in May 1838, who noted that no water could be found there (Giles 1838). *The Observer* (13 April 1844) also noted on more than one occasion that surface water was scarce on the Aldinga Plains in summer and that Aldinga was really deficient in surface water. The fact that Colonel Light could see no brooks of water in the area in September may indicate that 1836 was a particularly dry winter.

In contrast to the waterless plains, permanent water was obtainable in the 1830s in the swampy area of reeds and teatree in the middle reaches of Maslin South Creek. Good water was mentioned three times where tea-tree

Figure 21
Hydrological and relief features in the Willunga Basin 1839/40.
Source: Compiled by the author from drainage lines and relief on the 1840 McLaren map, along with comments from the 1839/40 survey records.

Note: The comments about the edge of the hills appeared adjacent to surveyed sections in the field notebooks.



scrub was found, once on Section 115 north-west of the McLaren Vale area, and in two locations along the hills (Figure 21). The area around Willunga also had "water all year round" (*The Register*, 21 December, 1839) which is probably a reference to the spring-fed streams and soaks in the gullies on the scarpfoot (G Vaudrey, pers comm July 1994). In addition, most of the ravines in the range contained water in the winter but "the little rivulets soon [ran] to waste and after a few warm days they [would] dry up", causing the early settlers difficulties in finding water and necessitating the sinking of wells (*The Observer*, 13 April 1844). By 1851 the water shortage had presumably been overcome by digging wells or using springwater, since a visitor remarked that in and near the Willunga district water was abundantly found even though some of it tended to be brackish (*South Australian Register*, 26 March 1851).

4.1.3 Changes in surface drainage since the 1830s

A comparison of the drainage patterns in Figure 22 shows that significant changes occurred between 1840 and 1992. These include an increase in the number of streams in some areas, as well as stream disappearances in others. Figure 23 is a comparison of the total length of drainage channels at each date. The first map to cover the whole area, drawn in 1883, depicted 260km of channels. By comparison, in 1992 there were 397km of channels, representing an increase of over 50%. However, comparison of the 1959 map with the 1963 and 1992 maps shows that the latter two apparently gave much more detail on small tributaries and thus may overestimate the increase in overall length. Nevertheless, if the 1959 map is used instead of the 1963 map, then the difference with 1883 is 362km as compared to 260km, which is still an increase of 40%.

The increase in the extent of drainage channels on the Aldinga Plains, which was described in early accounts as lacking in surface water, is particularly striking. Between 1840 and 1883 stream channels marked at the scarpfoot had shortened although these streams regained their former extent in 1896. Until 1926 there was no further change but by 1959 there had been a significant extension of channels westwards across the Plains, with several rather straight channels appearing. By 1963 the channels reaching onto the Aldinga Plains had extended further westwards and by 1992 they had become completely joined to the wetland area south of Aldinga Scrub. The Port Willunga Creek and Maslin South Creek became extensions of scarpfoot

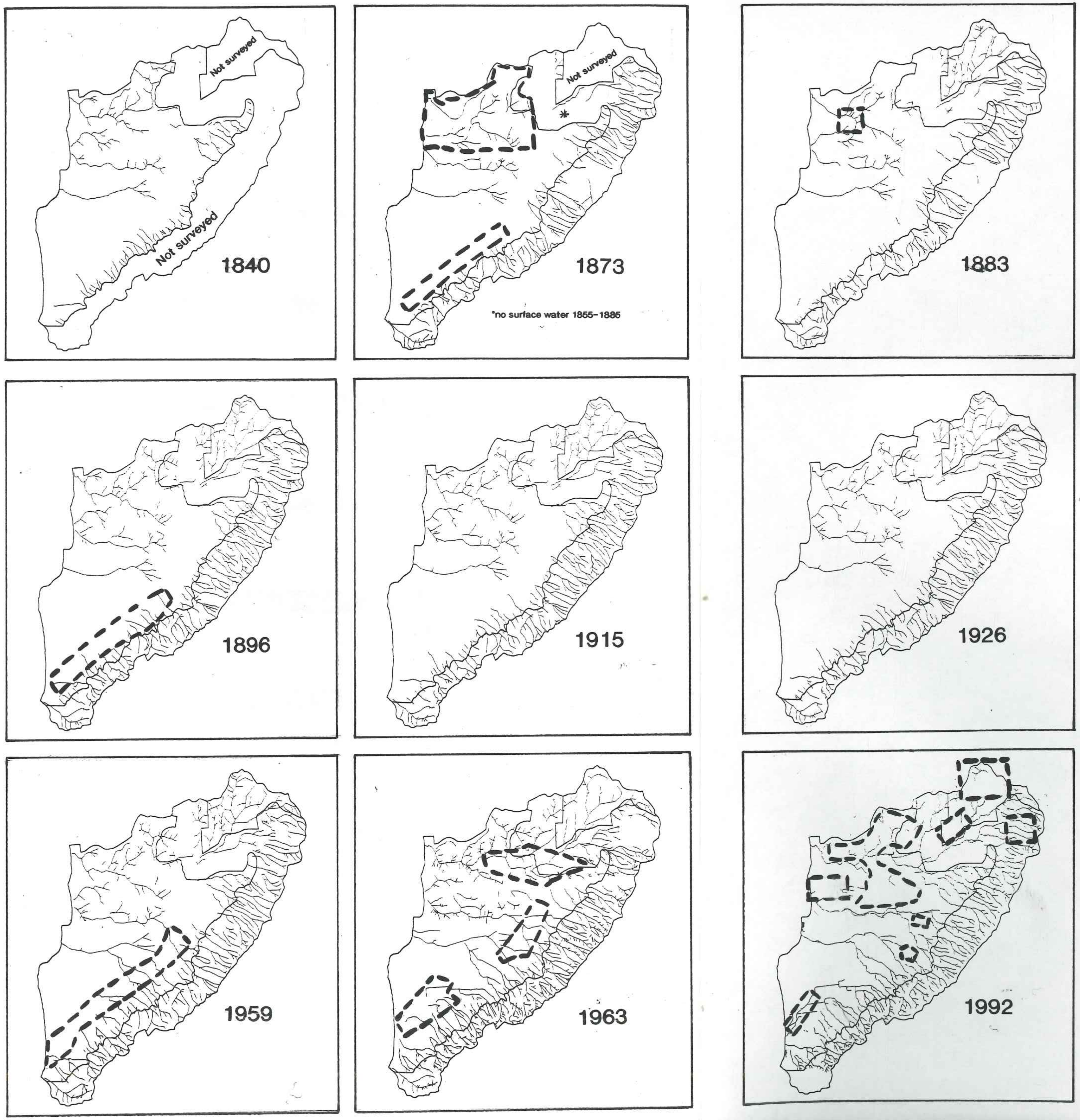
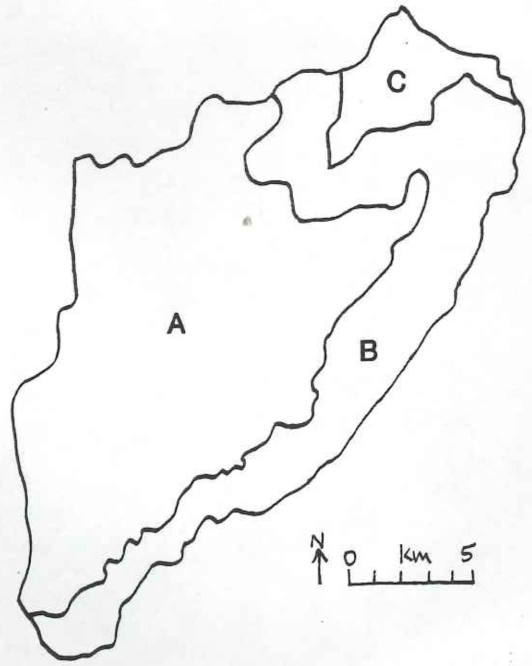


Figure 22
Surface drainage patterns in The Willunga Basin 1840-1992.
Source: Compiled by the author from the 1840 McLaren Map, maps of The Hundreds of Willunga, Kuitpo and Myponga, with the Willunga Basin GIS 1992 surface drainage coverage.

KEY



A Area mapped since 1840
B Area mapped since 1873
C Area mapped since 1883

Areas of major change over previous date

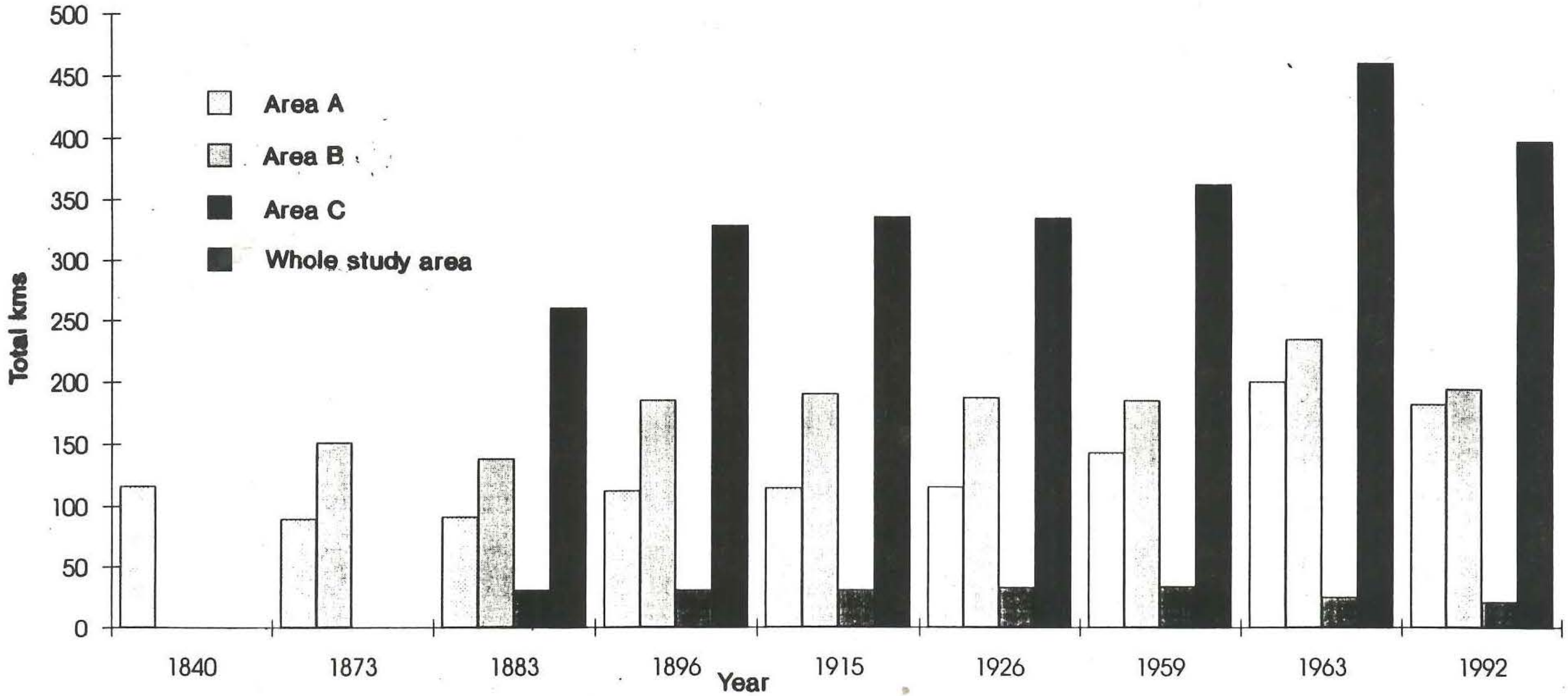


Figure 23
Total length of drainage channels mapped 1840-1992.
Source: Compiled by the author from measurements computed on the Willunga Basin GIS for the coverages shown in Figure 22.

streams between 1926 and 1959 and the Pedler Creek had been joined by streams from the north-east by 1963. The trend of increasing stream lengths on the plains in general is shown in changes in the total length of drainage channels for area A in Figure 23. There were 116km of channels in 1840, which dropped to 90km between 1883 and 1896, then returned to 112km by 1896. This remained constant until 1959, when an increase of 28% occurred, taking the total to 143km. By 1963 stream length had increased to 200km, but dropped again to 182km by 1992. The overall increase between 1840 and 1992 was 57%.

By contrast, there has been a decrease in the extent of surface drainage channels in some areas. Bennetts Creek had been marked on all maps since 1840 but disappeared between 1963 and 1992. A large number of streams in the north, around Pedler Creek also disappeared, as well as some in the north-east. Figure 23 shows that total stream length in the north-east (area C) declined between 1840 and 1992, from 31km to 21km. The streams in the most northerly part of the map in the north-east corner also became cut off so that in a 1992 study (Planning Advisory Services, 1992) the catchment boundary was drawn to its south since it no longer appeared to be connected to other streams in the Willunga Basin. However, on the basis that it had been connected up to and including 1963, the catchment boundary for this study was extended to include this area.

On the basis of the evidence presented here, the changes in the surface drainage pattern of the Willunga Basin since 1840 have been significant. Of particular note was the appearance of stream channels on the Aldinga Plains after 1926, where earlier there had been none.

4.2 GROUNDWATER

4.2.1 Sources and method for establishing a history of the groundwater

Discussions were held with staff at the Department of Mines & Energy SA (DMESA) and the Engineering & Water Supply Department (EWS) to ascertain what information was available on the groundwater of the study area. Unfortunately, there was no quantitative data available with which to compile a comprehensive history of changes in the groundwater and water tables in the Willunga Basin (Aldam, pers comm, 1994). What information was available was largely limited to reports written since the 1970s. The

"Willunga Basin Observation Network" (a computerised drillhole database at DMESA) was checked for the period 1900-1955. Although eight bores were found with a depth of 0-25m whose water levels could have been a reflection of aquifer levels, none of the bores had any corresponding post-1970s observations to provide a historic trend. In addition, there were only one or two readings for most wells and bores such that historic trends could not be established (DMESA staff, and Stokes, pers comm 1994) and most of the observation wells for which data had been recorded since the 1970s related only to the confined aquifers, not the shallow aquifers, because the confined aquifers were of particular interest, being the Basin's major groundwater resources.

In 1974, at a time when the groundwater resources of the area were being developed rapidly, the Willunga Basin Investigation Progress Report Number 1 was written, summarising work up to December 1973. The authors found that there was a distinct lack of groundwater information for the area and commented that so little information was available that "groundwater reserves in the basin could be totally over-exploited at this stage without the Department of Mines having any knowledge of that state of affairs" (Waterhouse & Barnett, 1974:2). In addition, no water table contours were available and "although a considerable amount of drilling [had] been carried out in the area over a long period of time, almost no useful information [had] resulted" (Waterhouse & Barnett, 1974:4). Work had been considerably frustrated and delayed by the lack of basic borehole information, and geological logs, water cuts, water levels and drawdown measurements were almost never available (Waterhouse & Barnett, 1974:8). To further complicate matters, the third Willunga Basin Groundwater Investigation Report found that although contour plans were available they were composites of all aquifers (Bowering, 1979:14).

4.2.2 <u>Groundwater trends in the Willunga Basin</u>

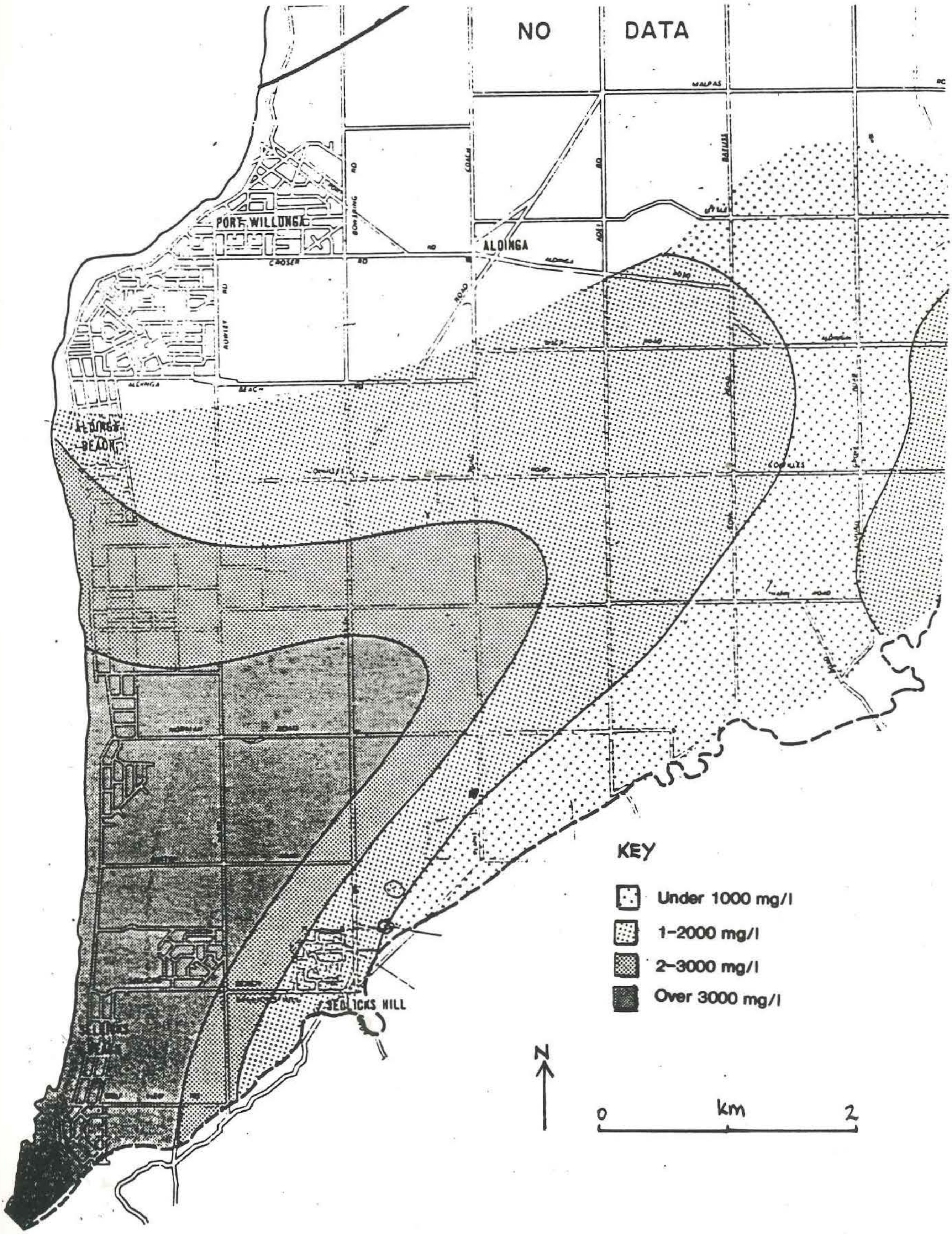
Due to the limitations outlined it was only possible to establish a fragmentary groundwater history for the study area. By 1979, five years of groundwater investigations had at least led to a better understanding of the geological framework of the groundwater basin (Bowering, 1979:1) (see Figure 11). The Port Willunga Formation aquifer and the Maslin Sands aquifer were the two main groundwater zones which were separated in most areas by a confining bed. They occur in tilted rocks and their extent varies (Selby, 1984:44).

Over the five years of investigation prior to 1979 there had been no serious depletion of groundwater resources in general and local declines in water levels were attributed to three years of below average rainfall (Bowering, 1979). Over the past 20 to 30 years the upper aquifer, the Port Willunga Formation, has generally maintained its level and the lower aquifer, the Maslin Sands, has shown no overall major change; the latter trend has occurred despite some interference between bores, where some individual bore levels have declined due to the aquifer being naturally slow yielding and therefore having difficulties coping with heavy withdrawals in a short space of time (Stokes pers comm, 1994).

Despite the above, it has been noted that water levels have generally been declining in the aquifer systems of the Basin (Planning Advisory Services, 1992:31). Bowering (1979:15) reported a slow decline in water levels in the northern part of the Basin and other reports point to a particular decline in the south-west. For example, in 1926, despite a decade of increasing rainfall, there were reports of wells in the Sellicks Hill area going dry and others turning salty, with the springs drier in the summer of 1926 than in the 1914 season (which came after several years of decreasing rainfall) (*Advertiser*, 13 January 1926). Bowering (1979:15) also noted a significant decline between 1975 and 1978 in the potentiometric level of a well in the Port Willunga Formation. A decline in groundwater levels in the south-west may also be supported by evidence of the drying out of the Aldinga Scrub area. This aspect is covered in the Section which follows about the Wetlands on the Aldinga Plains.

Although historical salinity data is also poor, there are some indications that salinity may be increasing in the Maslin Sands and Port Willunga Formation aquifers (Planning Advisory Services, 1992:31). The 1926 article noted wells turning salty in the Sellicks Hill area and changes in groundwater salinity levels were noted in 1979 in the south-western part of the Basin near to the Aldinga wetlands (Bowering, 1979:8). Figure 24 shows salinity zones in the Port Willunga Formation aquifer in 1979. A decline in water levels in the Port Willunga Formation was also a potential cause for concern since "a reversal in the head difference between that aquifer and the Maslin Sands would allow an upward migration of highly saline water" (Bowering, 1979:8).

Figure 24
Salinity zones in the Port Willunga Formation aquifer in the south-west of the Willunga Basin in 1979. *Source:* Bowering (1979: Fig 19).



4.3 THE WETLANDS ON THE ALDINGA PLAINS

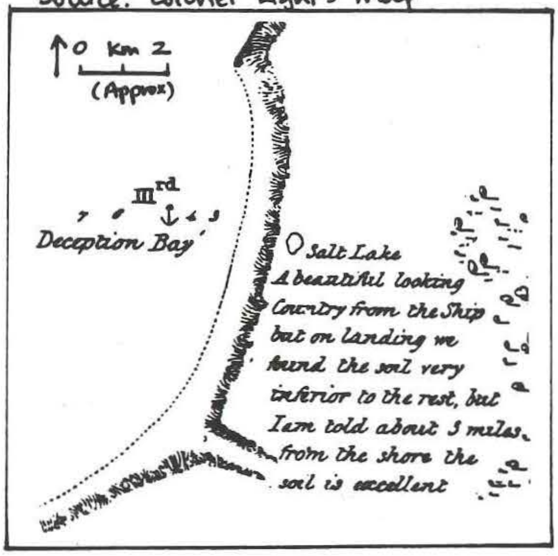
4.3.1 The wetlands in the 1830s

Wetland areas were marked in several places on low-lying land, particularly near the coast, on the 1839 survey records and 1840 McLaren map (see Figure 21). At that time, the valley of the Port Willunga Creek was swampy 1.5km inland, as was the mouth of Maslin Beach South Creek. The mouth of Pedler Creek was marked as a salt creek in the lower reaches, and as swampy at the mouth and part way inland, while a large saltwater lake surrounded by swampland was marked near the coast on the Aldinga Plains, south of the Aldinga Scrub area. This must have been a significant landmark because it was noted on several historic maps and in early accounts. It had formed in a depression where drainage was cut off from the coast by dunes, in an area which was the last remnant of "what was in the near past the outlet of the Onkaparinga River", before its diversion 20km to the north (Howchin, 1923:307). Colonel Light's map of the coast in 1836 showed a salt lake in this area (Figure 25: 1836 map extract). Light also wrote in late September 1836 that this area presented "a most beautiful appearance" but that, on going ashore, he "felt some disappointment at the appearance of the land, as it looked so luxuriant from the ship; we could find no fresh water; a lake of some extent on the high ground above the beach proved, on reaching it, to be salt" (Elder, 1984). Morphett, who accompanied Colonel Light on various surveying expeditions, also recorded in November 1836 that "the lower part [of the plains] is impregnated with salt, being beneath the level of the sea at spring tides, and this imparts a brackish taste to the rains which collect there during the winter months, and form a small lake" (Morphett, 1836:7). The references to the lake being saltwater contradict Ross's claim that early references clearly stated that the water in the Washpool (as the area was known) was fresh (Ross, 1984:17). References to freshwater might have been written after heavy rains flushed the lagoon of saltier water, or could have related to nearby waterholes which were fed by localised shallow aquifers and which were used by Aborigines.

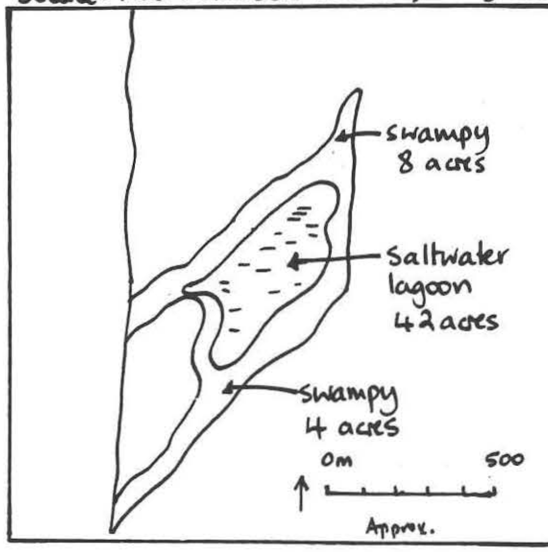
Figure 25 provides a comparison of various maps of the major wetlands area between 1840 and 1986. The 1839 survey sketch recorded a swampy area of twelve acres (five hectares) surrounding a 42 acre (17 hectare) saltwater lagoon. Water apparently built up east of the Aldinga Scrub area during the winter months and drained south around the dunes into two lagoons south

Figure 25
The wetlands area on the Aldinga Plains 1836-1986.
Source: Compiled by the author from extracts from various sources as indicated.

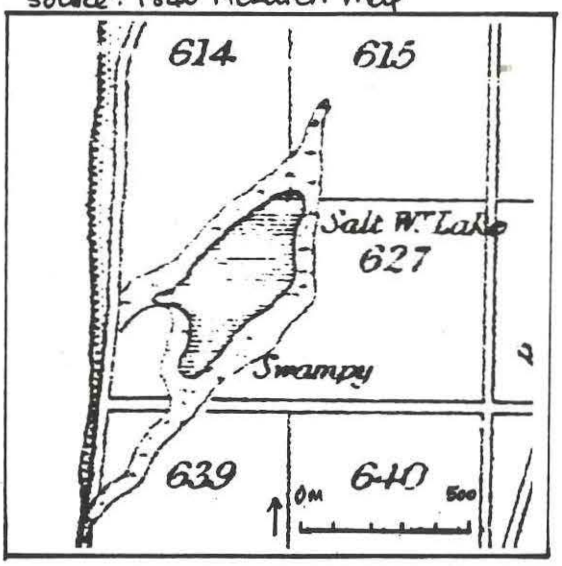
1836 (Approx September)
Source: Colonel Light's map



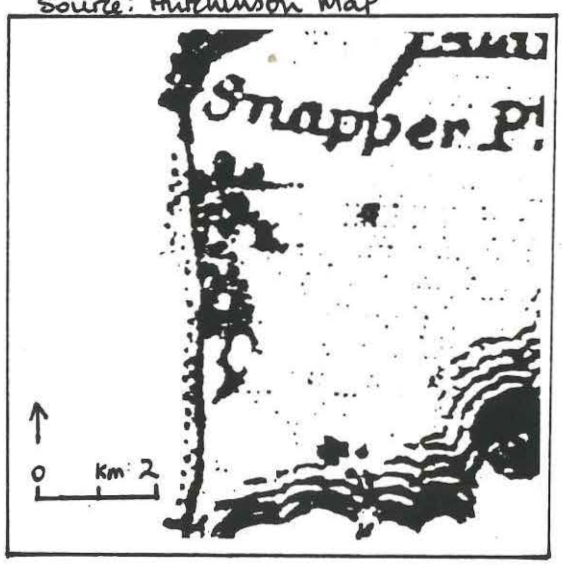
1839 (Approx October)
Source: Field Notebook 102:63, Survey Records



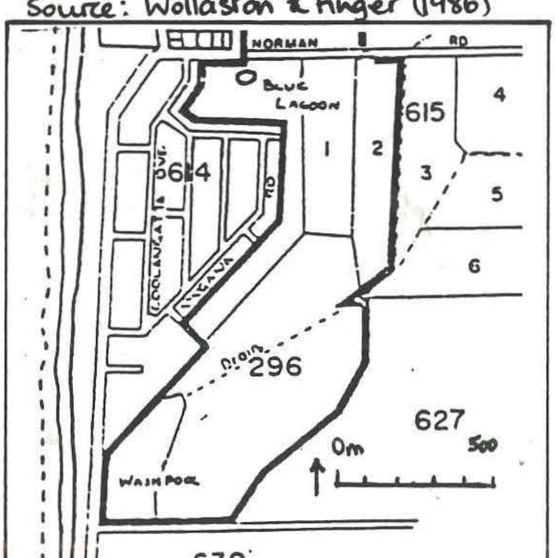
1840
Source: 1840 McLaren Map



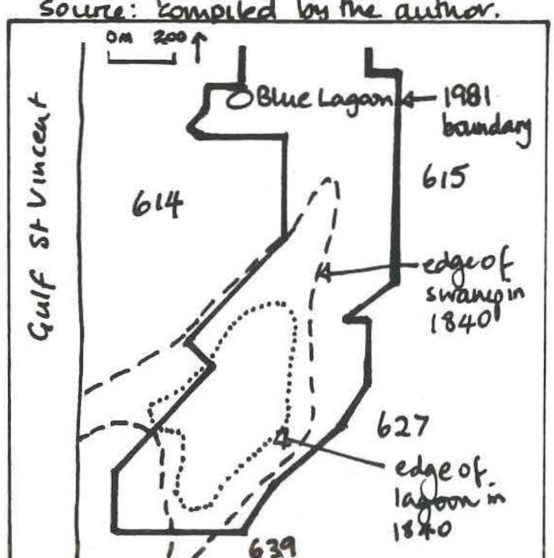
1863-73
Source: Hutchinson Map



1986
Source: Wollaston & Finger (1986)



1840 compared to 1986
Source: compiled by the author.



of the Scrub area, known as the Blue Lagoon and the Washpool (Ross, 1984:17). The 1840 to 1986 comparison map shows that the main lagoon noted in the survey records was the Washpool, while the Blue Lagoon lay to its north. While early accounts and maps from 1836 to 1844 only mention one lagoon, Hutchinson's map (1863-73) seems to show two lagoons, but then an 1876 Atlas only referred to the "Aldinga Big Lagoon, ... a swampy lagoon lying in the Aldinga Plains at a distance 1.5 miles [2.5km] northwest by west of Sellicks Hill" (Carroll, 1876:11). The reference to different numbers of lagoons may be because the lagoons were seasonal and evaporated in summer (*The Observer*, 13 April 1844; Howchin, 1923). That the Aldinga wetlands were seasonal is further supported by the fact that the lagoon reportedly attracted quite a range of wetland birds (Hay, quoted in Linn, 1991). The seasonal flooding of the wetlands would make them more fertile than permanent wetlands due to the high biological fertility and high nutrient turnover maintained by regular drying and reflooding (Briggs, 1981). In addition, Aborigines in the area had waited for muds to become exposed on the southern edge of the Washpool lagoon during the summer to prepare and cure animal skins (Gara, 1988:6).

4.3.2 Changes in the wetlands

The former wetlands area has changed since the 1840s. The Blue Lagoon was originally three to five metres deep but it gradually became silted up and was drained after World War II (Ross, 1984). Today it remains as an area of dark soil supporting a dense cover of reeds. The Washpool is now a grassy drainage reserve which acts as a settling area during heavy rainfall events and as long as the lagoon does not overflow into the sea it prevents much sediment from entering the Gulf St Vincent (Friends of the Earth, 1991). Both lagoons now fill with water only after heavy rains.

Wollaston & Kraehenbuhl (1986) and Friends of the Earth (1991) mention that the Aldinga Scrub and the associated wetlands area are drying out. It is possible that the changes in the groundwater mentioned in Section 4.2.2 may be causing this. Although the lagoons are seasonal, a salt lake was marked on all Hundred Maps from 1873 to 1926, but in 1959 it was marked as a salt pan and by 1963 had become a drainage reserve. A hydrogeological report on the Aldinga Scrub area noted that the most important hydrogeological units from Port Willunga to Sellicks Hill are the Port Willunga Formation aquifer and a Quaternary aquitard containing perched water (Skelt, 1989, in Friends of the Earth, 1991). The report also gave evidence that several permanent waterholes once existed in and near Aldinga Scrub, including the Blue Lagoon and Cliff's Lagoon (a waterhole in the north-east corner of the Scrub, used by Aborigines: Gara, 1988:5), but that these had dried up, while the perched groundwater is now only found in the north-western corner of the scrub during winter. Blackfellows Waterhole near the western side of Aldinga Scrub also once contained permanent water but has since been covered by drifting sands (Gara, 1988:5).

4.4 SUMMARY OF FINDINGS

In this Chapter the surface drainage features of the area which was surveyed in 1839/40 were examined, along with the drainage pattern at eight other dates to 1992. It was demonstrated that the surface drainage had changed significantly over 154 years. There were two periods when some streams had disappeared, ie between 1873 and 1883, and between 1963 and 1992 in the north and north-east. Bennetts Creek ceased to exist between 1963 and 1992 but other areas had experienced a dramatic increase in the number of stream channels. There was no obvious surface drainage pattern on the Aldinga Plains until 1959, but after that time scarpfoot streams extended much more towards the coast. Combining this knowledge with the historic accounts of floodwaters in Section 3.2.3, this suggests that prior to 1959 any water arriving on the plains either flowed overland in sheets or in very shallow channels towards the low-lying wetlands (rather than in obvious surface channels which could be mapped), or filtered down into the shallow aquifers on the plains. The changes which have been observed suggest that the maps were predominantly showing the presence of stream channels with water. This was probably because channels were difficult to distinguish from normal undulating land when water was not present. As such, the early surveyors appear to have been recording changes in the amount of surface water in the Willunga Basin.

The groundwater history of the Willunga Basin was less easy to determine due to a lack of information. Nevertheless, indications were found of a general decline in water levels in the Basin's aquifers, particularly in the north-east and south-west, where the most obvious changes in the surface waters had also occurred. Although the water levels in the main aquifers may have declined in the past, they have generally held their levels over the past twenty years, but the shallow aquifers, at least in the south-west, have been drying up. In addition, rising salinity levels had been indicated in the south-west in the Maslin Sands and Port Willunga Formation aquifers. A general history of the wetlands on the Aldinga Plains was also compiled to illustrate changes in the surface and groundwater drainage. The area which was one of seasonally flooded lagoons and swamps had also experienced declining water levels over time. The groundwater levels in the north-east have therefore generally declined while the number of channels mapped also declined between 1963 and 1992. By contrast, the groundwater levels in the south-west have declined while the number of channels has increased.

CHAPTER 5
HISTORY OF GULLY EROSION

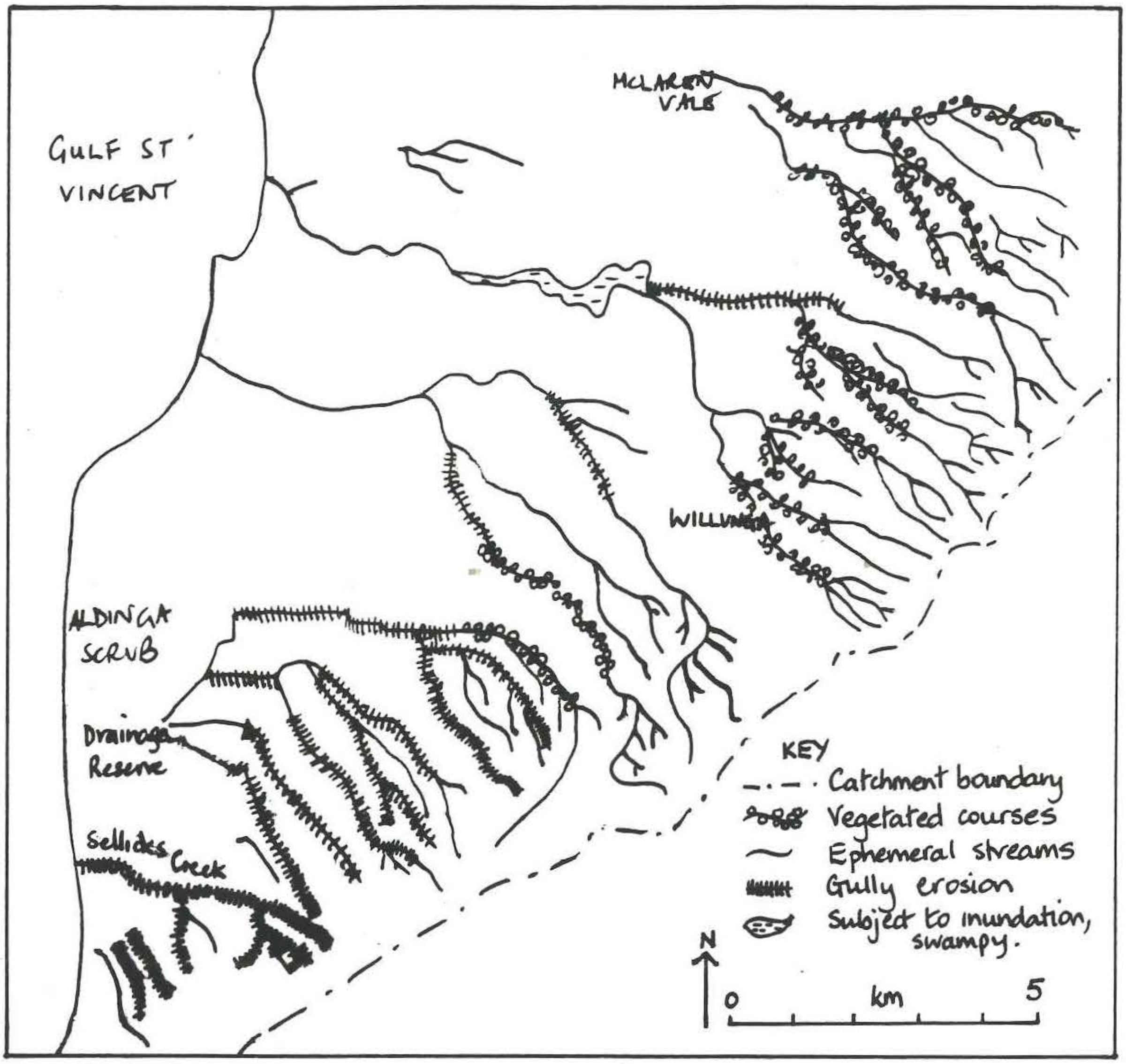
A gully may be defined as "a narrow channel worn in the earth" (Clark, 1985:264-5). Gully erosion occurs when water action either cuts new channels or extends already existing channels, particularly in soil or soft rock. Parts of the Willunga Basin currently suffer severe gully erosion, with large deep scars cutting through the landscape causing soil loss and a reduction in the areal extent of farmland. This Chapter aims to establish the spatial distribution of gullies in the area in earlier times, as well as the onset of gullying, which will be compared with other historic trends in an attempt to explain the present situation in Chapter 8. The Sellicks Creek Gully will be highlighted to illustrate gullying in general.

5.1 SOURCES AND METHOD FOR ESTABLISHING A HISTORY OF GULLY EROSION

The worst gully erosion in the Willunga Basin today is evident on the alluvial apron at the base of the Willunga Scarp, and on the plains, particularly south-west of Willunga. Here "a number of ephemeral streams ... [have experienced] deepening of their beds, severe bank erosion and collapse, and scouring of the soil immediately adjacent" (Turner & Associates, 1982:15). The extent of the problem in this area is indicated on Figure 26.

A history of gullying in the Willunga Basin has been pieced together from comments in the earliest survey records (Figure 21), along with comments and accounts from later years. Work by Dragovic (1966), Twidale (1976a, 1976b) and Chapple (1991) provided some background to the history of gullying, while Turner & Associates (1982) commented on current gullying problems. One difficulty encountered whilst researching gullying is the interpretation of the word. It can mean simply a steep dip between hills along which creeks may run, as is frequently used in place names (eg "Beltunga Gully" above Willunga), whereas a gully can also be a deep scar caused by water erosion. The latter type of gully will form the focus of this Chapter.

Figure 26
Current extent of major gully erosion in the Willunga Basin.
Source: Adapted by the author from Turner & Associates (1982).



There is geomorphological evidence of sequences of gullying and infilling in the Willunga Basin throughout the late Quaternary (Dragovic, 1966; Chapple, 1991). Infilled channels, dissected alluvial fans and fluvial terraces are visible today in the morphology and soil sequence of some of the deeper gullies. Shallow abandoned valleys, such as one south-east of Sellicks Gully, are also evidence of different drainage patterns in the past. Evidence of pre-European gullying phases are widespread in South Australia in various topographic and geological settings, suggesting that they were caused by late Pleistocene and early Recent climatic change and glacio-eustatic sea level change (Twidale, 1976a; Chapple, 1991). In the Willunga Basin fires associated with the presence of Aborigines (who have lived in the area for at least the last 10,000 years) may have contributed to pre-European gullying by removing vegetation cover and making the soils vulnerable to erosion, and this was acknowledged by Twidale (1976b:57). However, there is also evidence in Canada of phases of cutting and filling occurring before humans were ever present (Goudie, 1990).

5.2 GULLIES IN THE WILLUNGA BASIN IN 1839/40

Figure 21, which indicated the hydrological and relief features of the Willunga Basin in 1839/40, shows that four deep gullies had been noted along the scarpfoot. However, these probably referred only to the deep valleys between the hills (as described by Morphett, 1836:10). A deep gully was indicated in the far south-west corner of the Willunga Basin, now known as Cactus Canyon, along with another deep gully on the alluvial apron nearby. A gully was also noted on what is now known as Sellicks Creek, in the vicinity of the foothills.

Deep watercourses on or near the plains were mentioned in a few early accounts. In 1839, Hawker was out hunting kangaroo six kilometres from his camp at McLaren Plains "where the timber was not too thick for the horses to gallop safely". His companion was thrown forwards over the top of his horse when it stopped abruptly at the edge of a watercourse about 20 feet (six metres) deep with very steep banks (Hawker, 1899:46). Speaking generally, Dutton (1846:86-7) mentioned very deep water holes with steep sides occurring in creeks and riverbeds, particularly on the River Light, which had caused the loss of many valuable horses when the sides had collapsed.

5.3 GULLIES SINCE THE 1830s

There is no doubt that in some parts of the Willunga Basin gullying has either continued or been initiated since European settlement in 1840. Chapple (1991:16) researched gullying on the Willunga Scarp over several thousand years and along with geomorphological evidence of pre-European gullying also provided evidence of post-European gullying, such as fences which had been undermined and the shaft of a brick-lined well which had become exposed by the widening of the Sellicks Creek Gully. Twidale

(1976a:234) also photographed a seven-metre-deep gully on the alluvial apron fronting the Willunga scarp where a well opened only about one metre away from the gully. The inference made was that early settlers would not have dug a well if water had been accessible in the gully. These examples show that gullying has either continued or increased since European settlement. Despite the above, it was difficult to ascertain when gullying had been initiated or further developed. Dragovic (1966) contended that the most recent major period of gully initiation and development on the Willunga Scarp occurred between 1860 and 1910 to 1920, while Twidale (1976a) argued that further gullying had occurred in 1915 and 1944 in certain areas.

There is some indirect evidence which points to periods of gully extension in the south-west part of the Willunga Basin between the 1830s and 1990s. The maps which show changes in the surface drainage pattern between 1840 and 1992 (Figure 22), for example, indicate that some channels which were not marked on maps between 1840 and 1883 re-appeared on the 1896 map, while other channels had extended in length. Channels also extended across the Aldinga Plains between 1926 and 1959, 1963 and 1992, and particularly between 1959 and 1963. A curious point about the mapped extensions is that many extended towards the sea rather than increasing upstream by headward erosion. Such an extension of channels in the downstream zone would lower the base level of all other points upstream and could therefore initiate or increase gully erosion (Dragovic, 1966:80). One area which did not experience any change in the extent of channels between 1850 and 1963 was the small catchment area feeding into the very large gully called Cactus Canyon. However, in the upper parts of that catchment tunnel erosion extending upstream of some minor gully erosion is visible today. Another indication of soil erosion in this catchment are sediment plumes which have been observed, since at least the 1960s, extending into the Gulf from Cactus Canyon after heavy rains (G Vaudrey, pers comm 1994).

Following are some of the rare historic reports of the occurrence of gullying. In 1889 Sutherland noted that very deep channels had been cut along the roadside between McLaren Vale and Willunga (Sutherland, 1889:7). However, the cause of the cutting was not clear. Although he mentioned that "tremendous torrents" came off the hills during heavy rains, suggesting water erosion along the roadside, Sutherland also said that slate had been used to pave the channels, which could indicate that they had been deliberately cut by humans. He could have been talking about erosion channels similar to one which is developing on the east side of Justs Road, south of where it crosses Sellicks Creek Gully, and which is only about five centimetres deep at present.

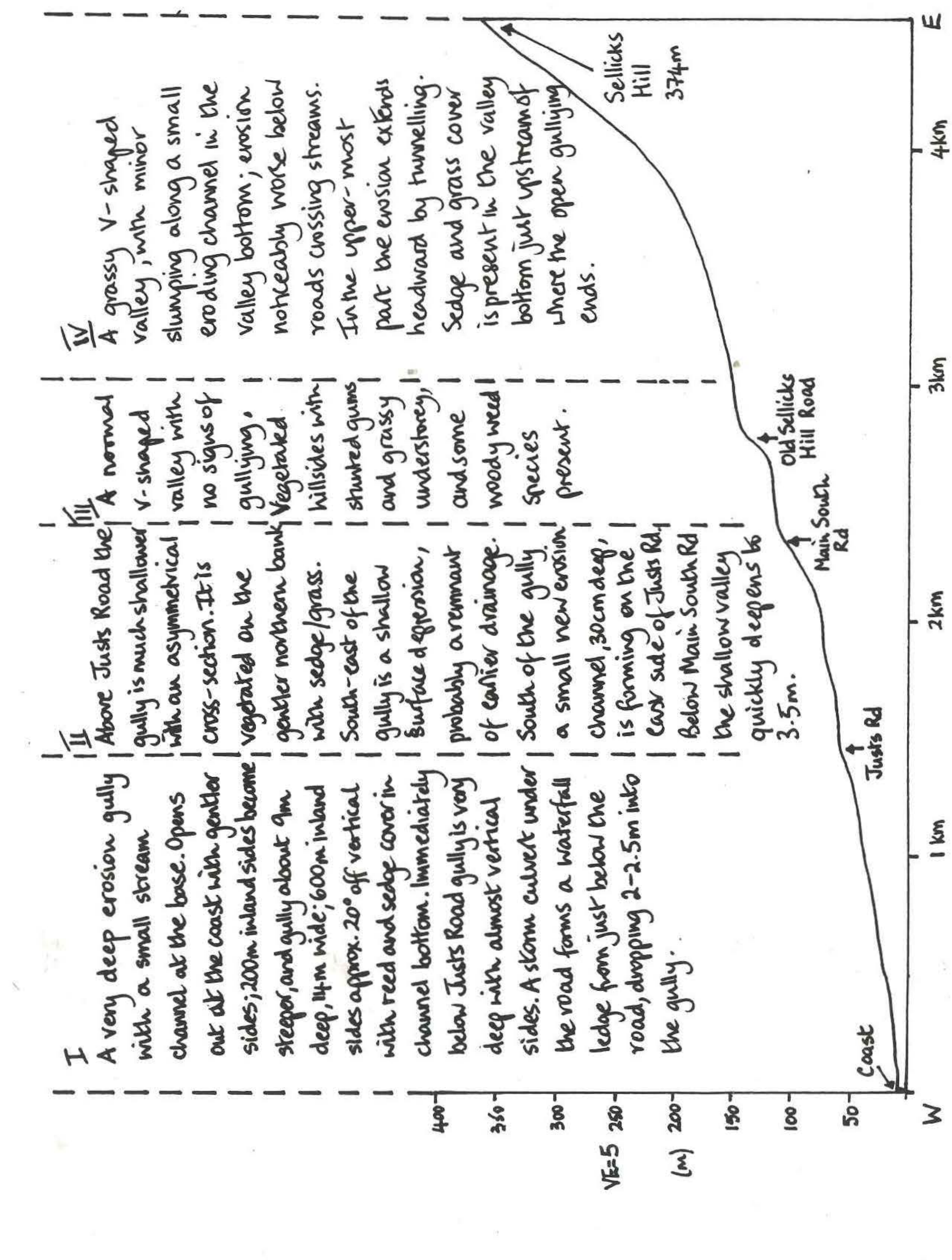
A relationship between gully erosion and the channel extensions shown on the maps in Figure 22 is suggested by changes on Section 472 east of McLaren Vale. No channels were marked near this section up to and including 1883 but by 1896 a channel crossed the section. Furthermore, in 1938 a watercourse two to six metres deep there was noted in survey records. On the property of a Mr Longbottom (Section 267 in Willunga) a gully had developed by 1892 (Hallack, 1892). This gully was located in the north-east corner of the section and grew from the depth of a plough furrow to being four to five metres deep (G Vaudrey, great nephew of Mr Longbottom, pers comm, 1994). Another short channel also appeared on drainage maps between 1883 and 1896. It entered from the south-east side of the section, but the 1892 extension was not drawn to the northern boundary until 1959. That gullies can often develop along plough furrows was mentioned both by Bourman (1975), Twidale (1976a) and Vogt (1990).

5.4 THE SELLICKS CREEK GULLY

The Sellicks Creek Gully is one of the most prominent gullies now seen in the Willunga Basin and will be highlighted here to illustrate gully development generally. Today the Sellicks Creek Gully can be divided into four distinct sections along its course, as shown in Figure 27. Section I between Justs Road and the sea is a wide gully approximately fifteen metres deep, with the walls closing in with distance from the coast to form vertical cliffs at Justs Road. This section has been called the "Sellicks Beach Ravine" (Potter & Associates, 1994). The gully has obviously widened since European settlement because the Sellicks Beach Road has been realigned to avoid it falling into the gully. A "serious washout", which was seven and a half metres deep in places, had developed at the lower end of the road by 1923 (Howchin, 1923: 307) and a 1930's aerial photograph showed the road realignment and the gully at a size not much different from today (Fitzpatrick, pers comm 1994). Section II exhibits cutting downstream of Main South Road and filling upstream of Justs Road, while infilling on the upstream side of Main South Road occurs in Section III with very little active erosion. Section IV exhibits headward gully growth

Figure 27
Annotated long profile of Sellicks Creek Gully from the coast, along Old Sellicks Hill Road, to the hilltop 1994. *Source:* Compiled by the author based on field observations in September 1994 and the Yankalilla 1:50,000 map (Department of Lands, 1987).

Note: Elevations are taken from the topographic map and do not represent the actual gully floor.

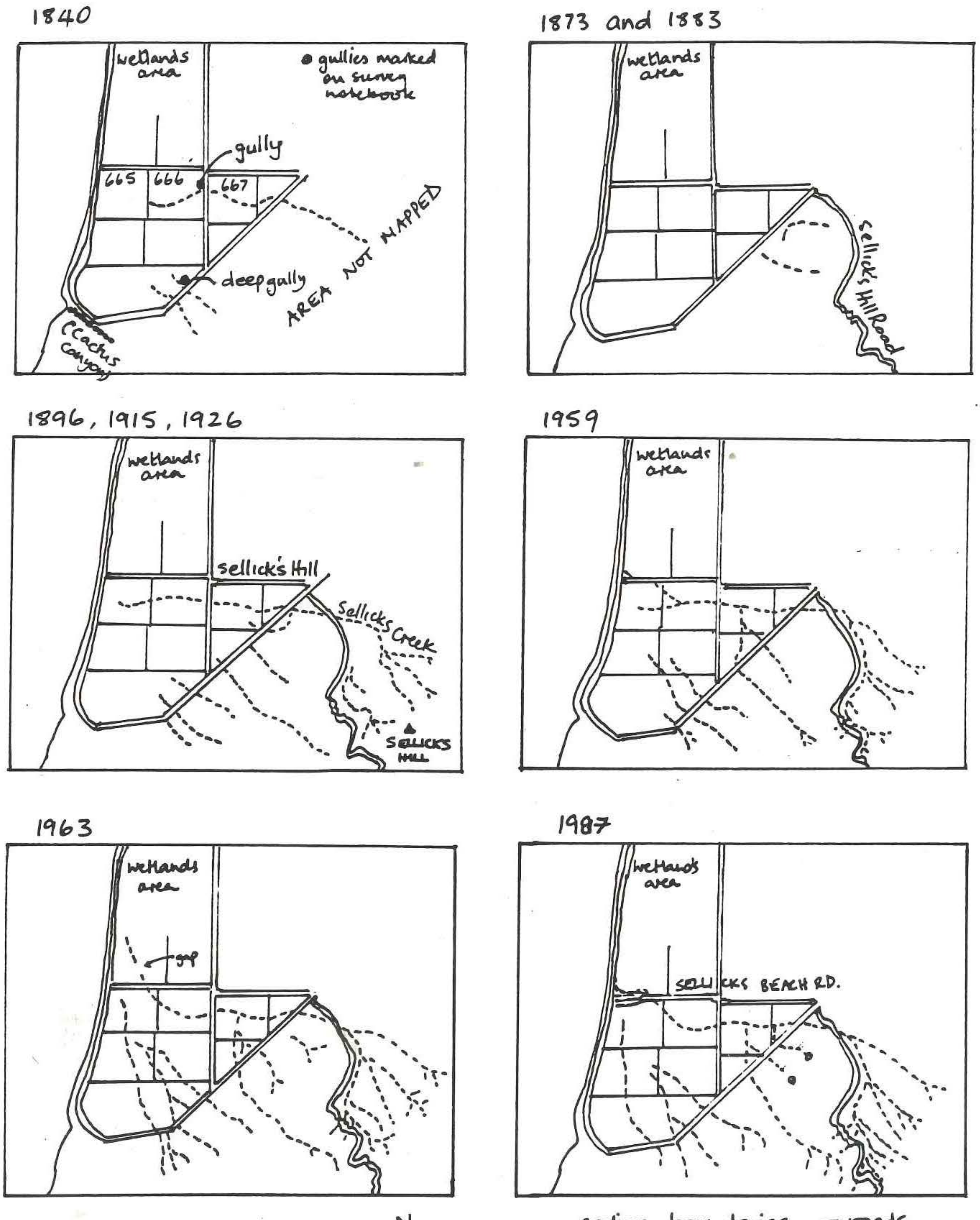


via tunnel erosion on the steep slopes of the Sellicks Hill Range. The gully is so deep and wide in Section I that the Willunga Council recently commissioned a study (Potter & Associates, 1994) to consider suitable erosion control measures. Soil loss from this gully has resulted in sediment plumes extending from the mouth of the gully into the sea during and after heavy rainfall events since at least the 1960s (G Vaudrey, pers comm, 1994) and during heavy rains in July 1986 (Friends of the Earth, 1991).

Surface drainage changes in the Sellicks Creek area between 1840 and 1987 are shown in Figure 28. It is evident that some creeks or gullies have appeared and some have disappeared at various times, while others have changed their path. Several changes have also occurred on the main Sellicks Creek. In 1840 the main channel headed westwards from the range and terminated about one kilometre from the coast in Section 666. A deep gully was noted between Sections 666 and 667 in the survey notebook. However, in 1873 and 1883 no creek was marked. It has already been established that the maps showed only obvious creeks containing water. By 1896 the Sellicks Creek reappeared and had extended westwards another five hundred metres. Three new creeks had also appeared on the scarpfoot to the south. By 1959 the main creek had captured an extra tributary from the south-east, which had been joined by another creek in Section 667. Two other creeks to the south-west of Sellicks Creek had also extended north-westwards. A short channel was also mapped meeting the coast just north of Sellicks Beach. Although a small channel appeared between the end of Sellicks Creek and the wetlands in 1963, and the most southerly creeks had almost extended right to the coast, the gully alongside the road only became evident on the 1987 topographic map.

The fact that historic maps show Sellicks Creek terminating before the coast is supported by reports that floodwaters in this area used to spread out over the land and flow towards the low-lying wetlands area, rather than being channelled to the sea (Fitzpatrick, pers comm, 1994). It is precisely in this area near the coast just north of, and adjacent to, Sellicks Beach Road that the deepest section of the Gully is today. It is puzzling that this section of the gully did not appear on maps until 1959 because it had run alongside the road at least since the 1930s, according to the aerial photograph. Perhaps the gully was too close to the road to be drawn. The Sellicks Creek Gully seems to have increased substantially

Figure 28
Drainage patterns in the area of Sellicks Creek 1840-1987.
Sources: Extracts compiled by the author from 1840 McLaren map; Hundred of Willunga maps 1873-1963; 1:50,000 topographic map (Department of Lands, 1987).



in size within the last 100 years. Two different residents interviewed by Dragovic (1966) claimed that their parents recalled that it was possible to jump across Sellicks Creek in the mid-1880s. Figure 28 shows that in the mid-1880s the creek may not have been a major channel. However, by 1966 the gully was at one site about fourteen metres wide and twelve metres deep (Dragovic, 1966:80). Potential causes of gullying will be addressed in Chapter 8.

5.5 SUMMARY OF FINDINGS

It was difficult to establish a history of gully erosion in the Willunga Basin since evidence of gully development since the 1830s was only patchy. Nevertheless, it has been determined that some deep watercourses and gullies already existed at the time of European arrival in the Willunga Basin and that others had originated or developed further since then. Dragovic (1966) established that the major period of recent gullying was between 1860 and 1910 to 1920 and that the Sellicks Creek Gully had probably been initiated and developed during this period. Some evidence was found to suggest that the initiation of gullying was probably most pronounced in the 1880s and 1890s. The fact that channel changes did not appear on maps until later may suggest that small gullies were not mapped as stream channels until they developed to a substantial width and depth. The extension of channels on the plains at various times, mapped in Figure 22, was probably also related to gully erosion. The Sellicks Creek Gully was used as one example of gully erosion in the Willunga Basin and was found to have developed substantially in the past 100 years. Whereas the channel used to terminate before the coast and surface water spread out towards the wetlands, water now reaches the coast via a wide, deep gully in the lowest section on the plains, and deposits plumes of sediment into Gulf St Vincent after heavy rains.

CHAPTER 6
VEGETATION HISTORY

Vegetation type is usually determined by factors such as latitude, altitude, aspect, climate, soil type and hydrology. Vegetation therefore acts as an important indicator of general environmental conditions, and changes in an area's vegetation can often be related to changes in other factors. This Chapter aims to determine the general pattern of vegetation in the Willunga Basin at the time of the first surveys and then to describe the timing, nature and magnitude of any changes since then.

6.1 SOURCES AND METHOD FOR ESTABLISHING A HISTORY OF THE VEGETATION

To establish the vegetation pattern of the 1830s and subsequent years, survey records, historic accounts and historic visual material was consulted. Although Prescott (1929), Specht (1972) and Williams (1974) addressed the original vegetation of South Australia, their work was too general to be useful for this thesis. No map was available at a suitable scale showing the general distribution of vegetation cover in the Willunga Basin at the time of the earliest European surveys. Nevertheless, the first field surveys of the Hundred of Willunga were carried out from 1839 to January 1840. Fortunately for Environmental History researchers, His Excellency the Resident Commissioner of the time, "wishing to give every possible facility to buyers of land" instructed the Surveyor General to ensure that all plans sent in had "the features ... of the country, such as hills, valleys, flats, rivers, or chains of ponds, to enable applicants for land to form the best estimate of its value and to afford them all the guidance we can, in the selection of it" (Hawker, 1899:44). Indications of the early vegetation of the Willunga Basin were available in these historical records.

The first step taken to determine the 1839 vegetation of the Willunga Basin was to consult the original survey records. Lange (1976:100) said that although the early surveyors' work took a loose approach to plant names the records were of great importance in research, but had been largely neglected by contemporary researchers. They were invaluable for this study. Landscape descriptions noted in Mr Richard Counsell's original Field Notebook of 1839/40 (Field Notebook No 102 at the Survey Records Department, Department of Environment & Natural Resources, Adelaide), along with details from other Field Notebooks and Diagram Books, are the only records available covering the whole Willunga Basin which could give any indication of the spatial extent of the original vegetation cover.

The extent and quality of environmental information in the survey records varies considerably, presumably depending on the capabilities of individual surveyors and time pressures. The differences are illustrated in Table 10 which shows how emphasis changed over time, making comparisons difficult.

Table 10
Difference over time in descriptions of sections in Willunga's nineteenth century survey records. *Source:* Compiled by the author from original survey records in the Survey Records Department at the Department of Environment & Natural Resources.

Survey dates	Predominant Descriptions
1839/1840	Plains/open plains Forest land Sandy/sandy hills/sandy and scrubby Good section, good soil Occasionally: valley, gully, deep gully, teatree scrub, bare hill, saltwater lake, swamp.
1849-1862	Good pasture/good grazing Good arable/good agricultural Hilly pasture/hilly arable (sometimes with reference to water, scrub, and whether the section was wooded or timbered: well/thickly/ thinly).
1879-1893	Descriptions containing reference to: Timber, stringybark, gums, sheoaks, timber gums, blackwood, blackoaks, peppermint, bastard gums, stunted gums, scrub gums, bushes, wattles, grasstree, yacca, wire grass, scrub, ferns, grassy flats, honeysuckle, thick undergrowth of bushes.

In 1839 simple descriptions covered many sections, although they were sometimes accompanied by artistic impressions, with stippling used to indicate some vegetation types. By the 1850s comments on farming potential appeared, and after 1879 far fewer but more detailed descriptions were given. A major problem with using this information was the lack of a descriptive standard, which caused difficulties in interpretation.

Descriptions such as 'scrub', 'timber', 'good land', 'bad land' must be seen as selective interpretations of the Australian landscape by Europeans. Survey Records staff mentioned that the Willunga survey records were not as good as others as far as detailed landscape information was concerned. However, at least they postdate the fire which occurred in the Adelaide Office in January 1839 which destroyed many maps and documents of other areas surveyed early on (Grenfell Price, 1935:82). Other problems included difficulties reading the tiny faded pencil script in the original Field Notebooks, while some information had been lost where pages had been frequently thumbed, and diagrams and amendments were not always clearly dated.

The difficulties in using the survey records are acknowledged, but it was felt that the historic information contained in such a data source was essential for this project and could not be obtained elsewhere. The survey information relating to the Willunga Basin was therefore compiled in Appendix 4 and a generalised vegetation map was drawn. The result is shown in Figure 29. For each section within the Willunga Basin the date of the earliest survey was noted with any landscape descriptions. Where a general description covered several sections, a note was only made for sections where the wording or artistic impression actually crossed them, in order to avoid inaccurate extrapolation. The survey information was augmented with details shown on Colonel Light's 1836 map and the 1840 McLaren map. Figure 30 was compiled from landscape descriptions given in surveys after 1840. It helped to complete the picture of the early vegetation on the ranges, which were not surveyed until the 1850s. It also added further detail to some rather loose descriptions in earlier surveys about the types of native vegetation found in some sections. (An overlay showing sections and section numbers is included on the inside back cover).

Historic descriptions by early travellers and settlers were also located to complement the information given in the maps, and a search was made for any sketches, paintings or photographs which depicted the vegetation of the Willunga Basin in these early days. The South Australian Historic Pictures Index, the pictorial collections of the Mortlock Library, the Willunga National Trust, and collections of local residents in the Willunga Basin were all examined. George French Angas' *South Australia Illustrated* (Angas, 1847b) and a catalogue of the sketches of Edward C Frome (Appleyard, 1972) were consulted. Only one early sketch was found, drawn by Edward Frome at McLaren Vale, probably in 1840.

Figure 29
Vegetation and landcover in the Willunga Basin 1839/40.
Source: Compiled by the author from information contained in original survey records as given in Appendix 4; drainage lines from 1840 McLaren map; 'wooded hills' reference from Light's 1836 map and 1850's surveys.

Note: Words written over areas where descriptions occur on survey records.

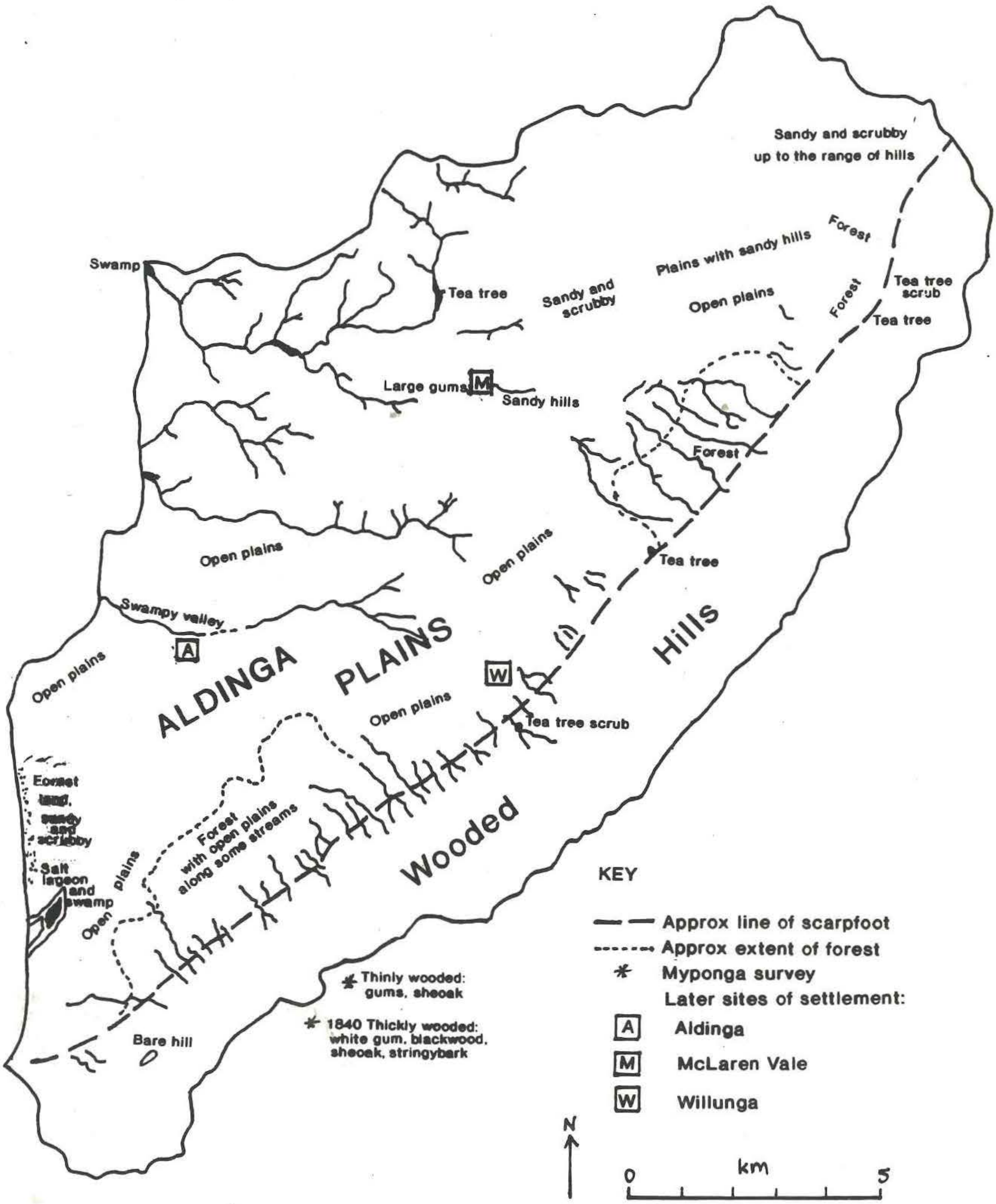
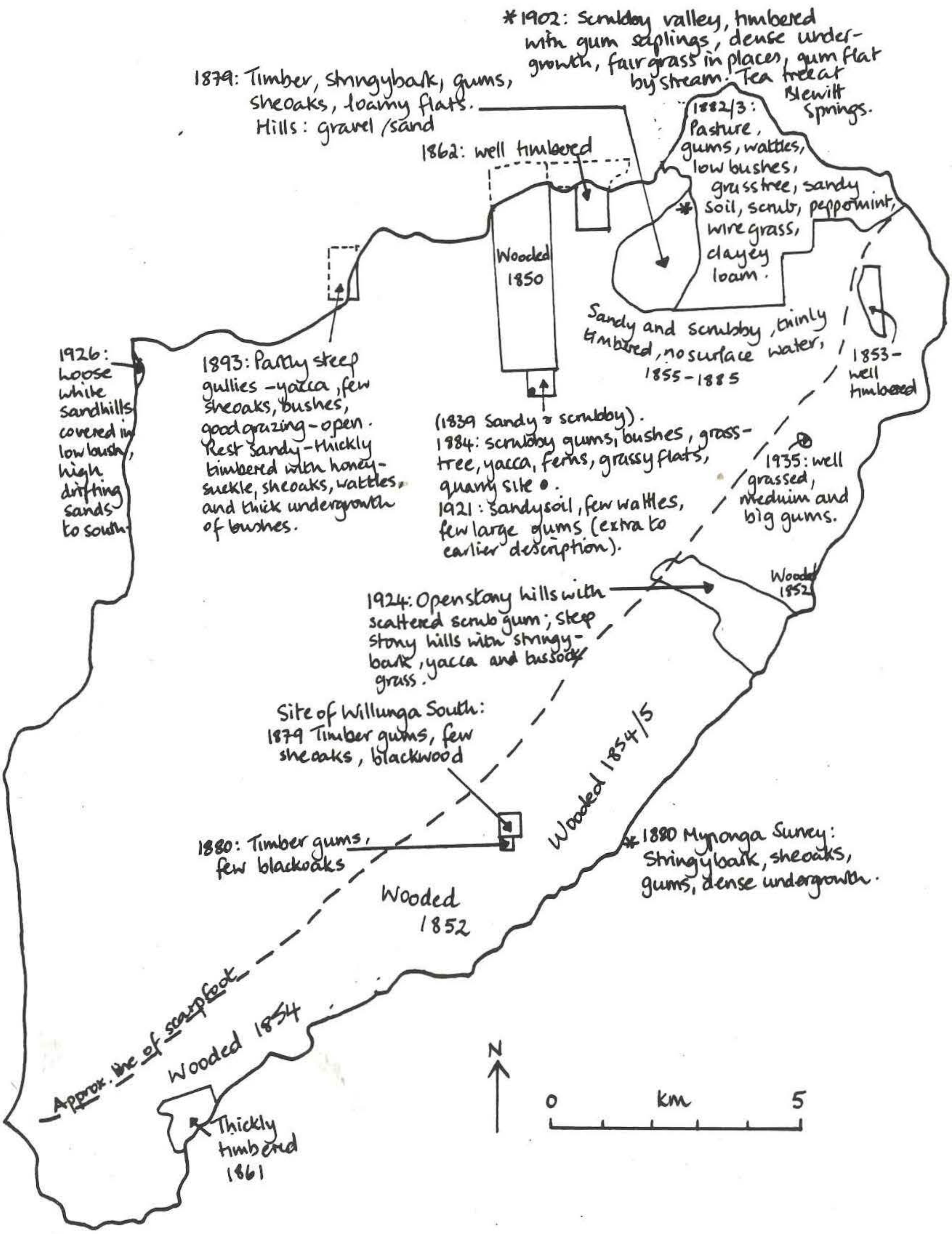


Figure 30
Vegetation and landcover in the Willunga Basin 1850-1935.
Source: Compiled by the author from information contained in original survey records as given in Appendix 4.



6.2 THE VEGETATION IN THE WILLUNGA BASIN IN 1839/40

6.2.1 The Sellicks Hill Range and other timbered sites

The Sellicks Hill Range was not surveyed until the 1850s so information on the 1839/40 vegetation of that area must come from other sources. Nevertheless, many of the sections surveyed in the 1850s on the hills from east of Willunga to the sea were noted as wooded, with one section surveyed in 1861 noted as "thickly timbered". Since these sections are today bare grassy hills it was felt important to compile the map shown in Figure 31 to emphasise the earlier extent of 'wooded' land on the ranges. Colonel Light's 1836 map (Figure 32) described the high ground east of the Aldinga lagoon as appearing well wooded and very rich, perhaps as the wooded area around Mt Lofty appears today from the coast. The Sellicks Hill Range is the southern-most outlier of the Mt Lofty Ranges so some general comments about the latter are probably applicable to the Sellicks Range. In the 1840s the Mt Lofty Ranges were described as "moderately high and steep hills, mostly covered with different kinds of timber, and in parts thickly wooded, in others more bare, ... throughout ... covered with verdant sward" (Dutton, 1846:83). Angas (1847a:44), talking generally about the Mt Lofty Ranges from Glen Osmond on the south-eastern outskirts of Adelaide towards Mt Barker, mentioned that because the ranges retained moisture for a long time and the trees gave shelter and shade (presumably meaning that they reduced evaporation losses) the grass looked green and verdant through the summer, whereas on the plains from January to March the grass was sere and yellow from the scorching heat.

The 'wooded' cover of the Sellicks Hill Range probably consisted, at least on the higher slopes, of stringybark forest. Indeed, the name Willunga is thought to come from the Aboriginal word "Willangga" meaning either 'place of green trees' (Tindale, undated; Cockburn, 1984:239) or "scrub place" or "scrub forest" (Tindale, undated). Stringybark forest is typical of the higher rainfall areas of the southern Mt Lofty Ranges and Fleurieu Peninsula (Adamson & Osborn, 1924:96-97; Barker, 1986). It was the only real forest in South Australia in ecological terms (it had trees over five metres high with a bole at least half the height, whereas woodland trees are over five metres high but with a bole under half the height) and was dense but rarely tall, with the dominant species being Messmate Stringybark (*Eucalyptus obliqua*) and Brown Stringybark (*Eucalyptus baxteri*) (Boomsma & Lewis, 1980). In 1839 it was recorded that "the Stringybark Forest [was]

Figure 31
Areas with sections noted as timbered or wooded in surveys 1850-1862.
Source: Compiled by the author from original survey records as given in Appendix 4.

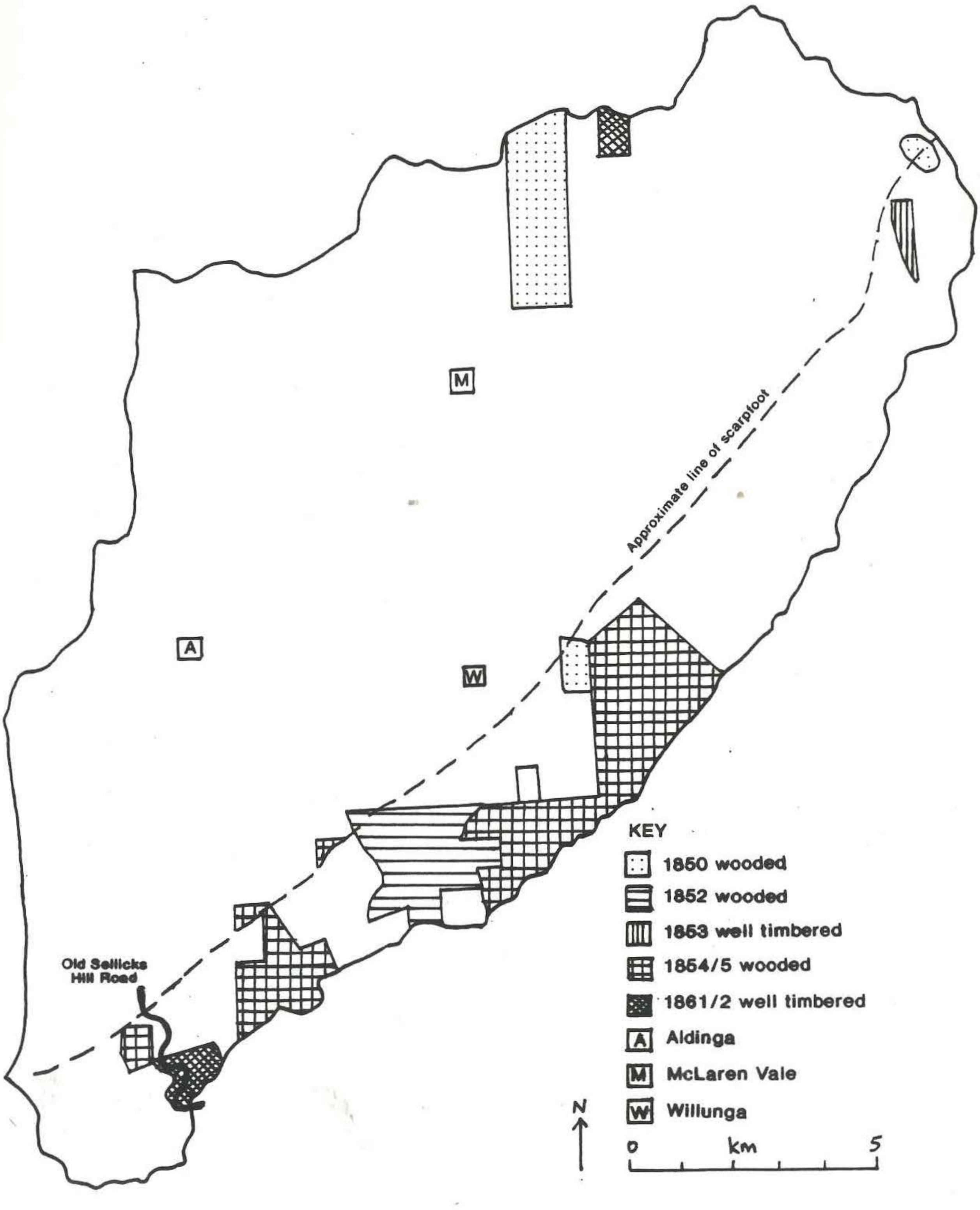
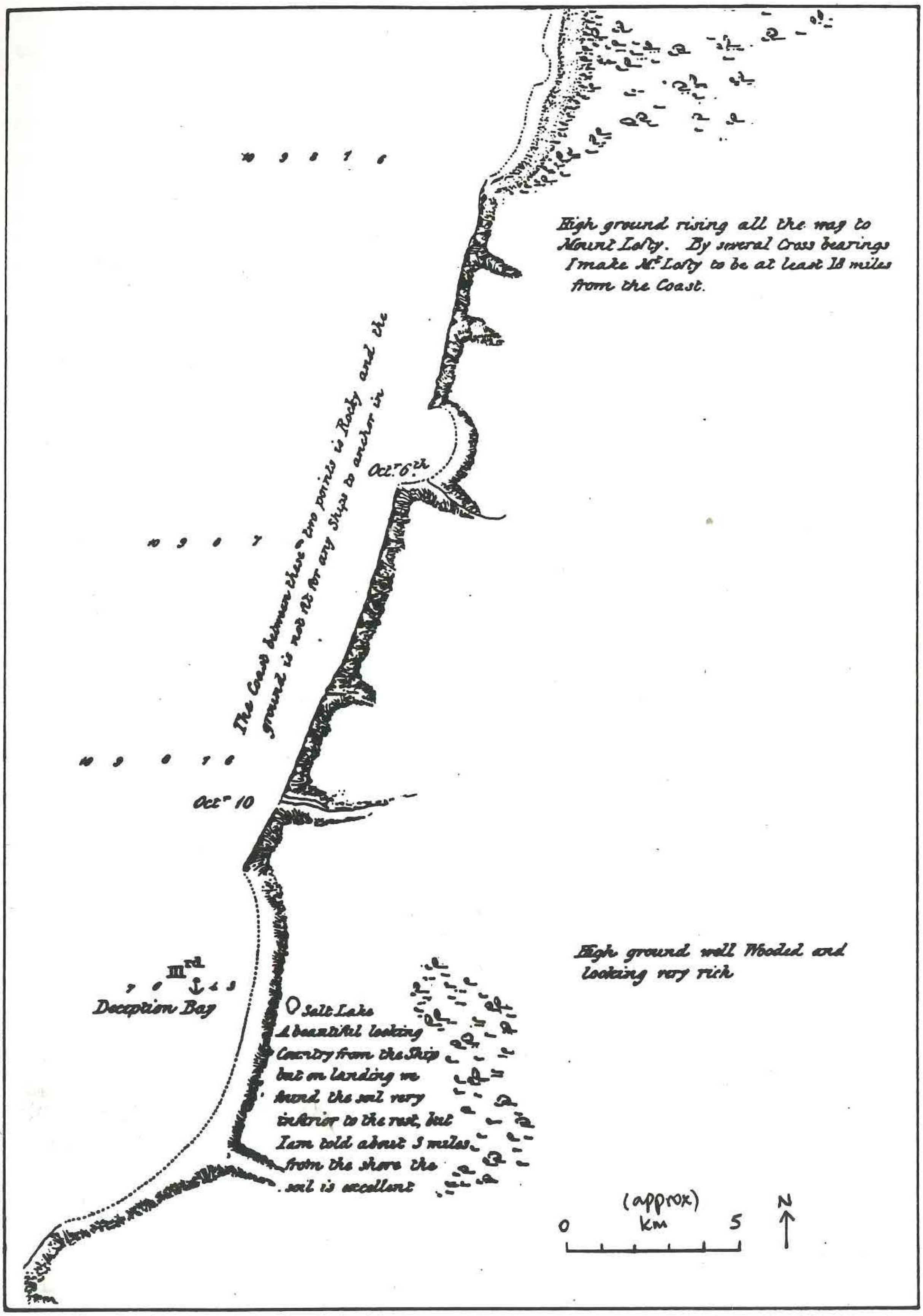


Figure 32
Extract from Colonel Light's 1836 map "A survey of the coast on the east side of St Vincent's Gulf" showing a lagoon on the Aldinga Plains and the wooded hills. (*Note:* Deception Bay is now called Aldinga Bay).
Source: Map Library, Geography Department, University of Adelaide.



within one mile" (1.5km) of Willunga township (Dunstan, 1977:14), which would locate it half way up the scarp. Indeed, in the same year the range behind the Willunga police station and depot was said to be covered in a thick forest of stringybark and scrub (Hawker, 1899:48). The 1879 and 1880 surveys of the site of Willunga South recorded "timber gums", which also suggests stringybark forest, since this type of tree and forest was often mentioned in reference to timber supplies (eg Dutton, 1846:84; Angas, 1847a:43; Hawker 1899:14). A 1924 survey also noted stringybark growing with yacca and tussockgrass on steep stony hills in the central-northern part of the range (Figure 30). The wooded cover was sufficient for early travellers to perceive an abundance of timber in the Willunga area (*The Observer*, 13 April, 1844) and an "unlimited supply of wood" in the Mt Lofty Ranges in general (Dutton, 1846:202).

More detail on the woodland vegetation was available from an 1840 survey just east over the hilltop in the Hundred of Myponga, where the black soils were thickly wooded with white gum, sheoak, blackwood and stringybark, while the thin light soils were thinly wooded with gums and sheoak (Figure 29). Descriptions on the Willunga side of the range in 1879 and 1880 mentioned similar species (Figure 30) as well as a few black oaks (black oak is *Casuarina cristata* according to Lange, 1976:107). However, the tops of the ridges were sometimes noted as bare and rocky where the soil had gradually been washed away (Dutton, 1846). This probably accounts for the survey description of one hilltop on the far south of the range as a bare hill.

In the north of the ranges and nearer to the Onkaparinga River a somewhat different vegetation cover was described where the hills were open, steep and stony. Two descriptions from 1893 and 1924 in those areas mentioned a cover of stringybark with scrub gum, yacca and tussock grass. The field notebooks also noted two "forest" areas extending onto the plains at the scarpfoot, with open areas along some streams. Figure 29 shows that the forest south-east of the site of McLaren Vale covered approximately six square kilometres and the one to the south-west of Willunga about twelve square kilometres. They appeared to coincide with the two areas where streams were mapped as extending onto the plains. *The Observer* (13 April 1844) and Tindale's map of Aboriginal place names (Tindale, undated) referred to the forest near present-day McLaren Vale as "Mullawirra", meaning 'dry forest'. This was felt to be "an appropriate name" (*The*

Observer, 13 April 1844) and perhaps suggested it was a savannah forest formation of peppermint gum (*Eucalyptus odorata*) which occurred on the drier foothills above the Adelaide plains and became dried up and dormant to a very large extent in summer (Adamson & Osborn, 1924:130-132). The Aldinga Plain was "surrounded by finely wooded eminences" (Morphett, 1836:9) and "bounded by small but dense forests on *either* side" (emphasis added); the forest to the east was the Mullawirra just described, while that to the west was called the South-West Corner, due to its position from Willunga, and was well known to kangaroo hunters (*The Observer*, 13 April 1844). The writer in *The Observer* described a journey northwards keeping to the coast, but it is not clear whether this second forest was the one on the scarpfoot directly south-west of Willunga or was in fact the forest land of Aldinga Scrub.

Worsnop, writing generally in 1878 about the hills running from Adelaide 30 to 40 miles (50 to 60 kilometres) south to the sea said that "the country along their base is well timbered, nearer the coast it is open and level" (Worsnop, 1878). There may have been forest all along the foothills in the Willunga Basin: the sections within a kilometre or two of Willunga along the McLaren Vale-Willunga road were noted in the survey records as open plains (Figure 29) but Hawker recalled that, while surveying and clearing this road, working southwards from McLaren Vale they had to skirt the plains because "the last mile [one and a half kilometres] before Willunga was thickly timbered" (Hawker, 1899:52). This area may have been covered with woodland or open forest, relatively taller than the stringybark forest of the higher areas, and which, according to Boomsma & Lewis (1980), occurred on the valleys and foothills of the Mt Lofty Ranges. The foothills and lower parts of these Ranges were generally covered with blue gum forest (*Eucalyptus leucoxylon*) while the floors, sides and upper flanks of steep valleys draining through the western foothills face of the Adelaide region carried river red gum (*Eucalyptus camaldulensis*), blue gum and pink gum (*Eucalyptus fasciculosa*) respectively (Lange, 1976:107). The sheltered valleys of the Sellicks Hill Range still contain remnant blue gum and pink gum with sheoak (Savarton, 1990:21).

Only a few areas of large gums were mentioned on the plains. In the 1839/40 survey records there was one reference to "large gums" on a creek in the south-west corner of the site of McLaren Vale, while an area on a creek one and a half kilometres south east of McLaren Vale was called

"Wirra Wirra", meaning "in the midst of red gum trees" (Tindale, undated). In addition, "large quantities of red gum" were reportedly obtained from forests near Aldinga in the 1880s (McLean, 1886:14). In the absence of other reports of river red gum forests, these may have come from the red gum forest which, according to Ross (1984), used to be at the north-east corner of Aldinga Scrub and which may be indicated by the large trees at this location on the 1863-73 Hutchinson map (Figure 25). No other forest land was mentioned near Aldinga in the early surveys.

From the evidence collected it seems that originally the Willunga Basin carried the three main types of *Eucalyptus* forest detailed by Adamson & Osborn (1924:131) as found in the Mt Lofty Ranges: the stringybark forest (sclerophyll woodland) which occurred on the higher slopes where winter rainfall was over 750mm; the savannah forest (or woodland) found on lower slopes where rainfalls of 375mm to 875mm occurred, and which had two sub-formations of blue gum forest and peppermint forest; and the red gum forest which occurred on creeklines or where deep soils held water.

6.2.2 The low undulating hills of the north and north-east

The area of low undulating hills in the north of the Willunga Basin was surveyed early in 1839 but no landscape descriptions were recorded in the Diagram Book, and unfortunately the "Number 1 Sketch Book" mentioned in the Field Notebooks, which may have given such information, had not been heard of and could not be located by staff at the Survey Records Department. The hills between McLaren Vale and the Horseshoe (Old Noarlunga) were described as "wattle hills" (*The Observer*, 13 April 1844), with "timber chiefly of sheaoak [*sic*]" (Hawker, 1899:51). A description of a section in this area in 1893 was complementary and mentioned an area thickly timbered with sheoak, wattle, a thick undergrowth of bushes and honeysuckle, while yacca, bushes and a few sheoaks covered the steep gullies. Honeysuckle was the name for *Banksia integrifolia* (*The Observer*, 13 April 1844:8; *The South Australian Register*, 26 March 1851).

The sketch in Plate 1 shows some detail of early vegetation. It was drawn at McLaren Vale, probably in 1840, and the site was easily recognised by a local resident who provided the photograph in Plate 2, which was taken at roughly the same location. The 1840 sketch looked north-east towards the main Sellicks Hill Range and indicated that in 1840 there was a good cover

Plate 1
McLaren's Vale by E C Frome, probably in 1840. *Source:* Art Gallery of South Australia. (Caption and further explanation in footnote 1 on next page).

Plate 2
Photograph taken in 1992 near the site of the 1840 sketch in Plate 1. The photograph shows the upper Pedler Creek in flood in August 1992 near to the McLaren Vale caravan park. *Source:* Ruth Baxendale, McLaren Vale.

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[1] **E C Frome**
Australia 1802-1890
McLaren's Vale
Watercolour
17.8 x 26.4 cm
Art Gallery of South Australia
South Australian Government Grant, Adelaide City Council and Public Donations, 1970.

The sketch is not dated, but Appleyard (1972) put it at 1840 based on the location, the type of paper used and the style. Going by Hawker's reminiscences and dates on the original survey records, the initial surveys in and near McLaren Vale had taken place in 1839 before Lieutenant Frome first set foot in Australia in the September as the new Surveyor General (Hawker, 1899:52). This means that the sketch was not done in April 1839 or while the first surveys were being done. Frome travelled to the Murray Lake and Coorong in 1840 (Auld & Marflett, undated) and may have painted McLaren Vale whilst travelling through on the new road from Old Noarlunga to Willunga.

Frome tended to illustrate scenes he saw whilst out surveying or exploring the new colony (Auhl & Marflett, undated:34; Appleyard, 1972). This scene is typical of several sketched by him, showing the landscape along with a tent and a two-wheeled cart. It gives an indication of the early extent of tree cover in the McLaren Vale area.

of trees on the left-hand hill and tree cover extending onto the flat at the base of the hills. The tree cover behind the tent had the appearance of sheoaks. Hawker commented that in 1839 sheoaks were plentiful around McLaren Vale and were easy to clear to make way for the new road (Hawker, 1899:51-52). The 1992 photograph shows that the camp in the sketch was set up on a grassy flat by the side of a flood channel. In the 1840 sketch the main range of hills in the background had a blue tinge and if this is an artistic representation of eucalyptus haze, it further supports the evidence that the main range was wooded in 1839/40. It would seem unusual for a European to paint hills blue and if they had been grass-covered it would be expected that the artist would use green, brown or yellow colours, as for the campsite area. The 1992 photograph also shows a difference between the dark green/blue green areas where tree cover remains on the hills and the brighter green of the grass.

The low hills in the north-east of the Willunga Basin appear to have carried a variety of vegetation types, including the only areas not near the main range which were mentioned early on as being wooded or timbered (Figures 30 and 31). By comparing these Figures and presuming that the vegetation described later is applicable to 1839, the thinly timbered and "poor" sandy hills, which lacked surface water, appeared to have been interspersed with open plains and grassy loamy flats suitable for pasture near the streams, with an area sandy and scrubby up to the hills in the far east. A section surveyed in 1884 in this area noted the vegetation as scrubby gums, bushes, grasstree, yacca and ferns with grassy flats, while in 1921 a few wattles and a few large gums were also mentioned. The substantial area which was not surveyed until 1879 generally contained stringybark, bastard gum (peppermint gum: Adamson & Osborn, 1924), sheoaks, wattles, low bushes, grasstree, and wiregrass on sandy soil and clayey loams, with teatree occurring at the Blewitt Springs site. The country around the Port Willunga Creek (called the Tartarchilla Gully in 1844) was also lightly timbered with sheoak, with "honeysuckle" in any little hollows or gullies (*The Observer*, 13 April 1844).

6.2.3 <u>The plains</u>

The wording "Aldinga Plains" appeared several times in both the original Field Notebooks and on Arrowsmith's map (1841). According to these and

Morphett (1836:9-10), the extent of the Aldinga Plains appeared to be a roughly triangular area in the south-west of the Willunga Basin, bordered by the coast, the foothills and the Maslin South Creek. In 1836 John Morphett accompanied several official mainland surveying expeditions from Kangaroo Island. His description of the 'Aldinghi Plains' [*sic*] suggested completely open grassland:

> "This place has a very singular and interesting aspect from the sea. The sloping grass-land in front, *without a single tree for three or four miles square* ... is surrounded by finely wooded eminences, and a bold range of hills beyond" (Morphett, 1836:9, emphasis added).

Light's 1836 map (Figure 32) gave the impression of the area further inland being grassland with a sparse tree cover, perhaps on the soils three miles (five kilometres) from the shore and beyond the plains, where, he noted, the soil was supposed to be excellent.

More information is available about another open plains area, between the present sites of McLaren Vale and Willunga. The area near to McLaren Vale was called the McLaren Plains in the early days. It can be located with reasonable accuracy because a Mr McLeod purchased sections on the northern side of the McLaren Plains in 1839 (Hawker, 1899:52) and his name was recorded on Sections 116, 117, 126 and 127 just north of the site of McLaren Vale on the 1840 McLaren map. The area of about seven kilometres between these Plains and Willunga was "called at that time Bay of Biscay ground because it was composed of little hillocks and indents like small waves of the sea ... very unpleasant for driving over" (Hawker, 1899:52). This area on the road from McLaren Vale to Willunga was described separately from the plain at Aldinga, as "a beautiful open plain" (*The Observer*, 13 April 1844). When Hawker was sent to survey and clear the first road from The Horseshoe (Old Noarlunga) to Willunga in 1839 he recorded that "emus were just as plentiful as kangaroos on the McLaren Plains ... On many occasions when riding without my dogs in pretty open ground, I came across a large flock of emus" (Hawker, 1899:49). The native fauna provided food for the early surveyors who had to "put up with salt provisions and kangaroo meat, varied now and then with emu" since mutton was unobtainable (Hawker, 1899:45). *The Observer* (13 April, 1844) also commented on the abundance of game in this area, with kangaroos and emus being very numerous, and particularly mentioned the fine large trees and close sward which gave a park-like appearance to the McLaren Vale area.

Morphett's 1836 description of the country north of the Aldinga Plains also seemed to describe the McLaren Plains. Morphett mentioned the abundance of kangaroo and emu and the park-like appearance of the plains, and, having talked about the Aldinga Plains, went on to say:

> To the north the level country stretches for miles; it is of the richest character, and is covered with so long and thick an herbage that it is quite laborious to walk through it. There are numerous woods ... of a very open description, and some spots where the scenery resembles an English gentleman's park ... Here was a most luxuriant soil, in some places level and commanding an extensive view; in others having vistas through rows of elegant trees ... I have seen a greater number of kangaroos and emus here than in any spot along the coast (Morphett, 1836:9-10).

The length of the grass on the McLaren Plains in 1839 was also noted in an article in *The Observer* (13 April 1844). It mentioned that the grass was so high and wet that after a mile's walk (1.5km) the writer was as wet as if they had waded into a pond (*The Observer*, 13 April 1844). This long grass was probably kangaroo grass (*Themeda spp*), of which Hawker (1899:37) commented that colonists of the late nineteenth century could "have no idea of the wonderful length to which it grew in the rich valleys, where the pasture had never been disturbed, except by an occasional bushfire". He also pointed out that it was so named because of the height to which it grew; in his "long experience of the kangaroo" he had never known them feed on it but on a short, fine kind which they preferred when it was green (Hawker, 1899:37).

The 1836 Light and 1840 McLaren maps depict the Aldinga and McLaren Plains areas with tree symbols dotted over the landscape, which could be interpreted as savannah woodland. Such woodland is defined as having trees more widely-spaced than the dense stands found in forests, and frequently with a grassy understorey (Barker, 1986:26-27). To some extent the tree symbols do conform with the stippling labelled "forest" in the field notebooks, but the tree symbols on the maps do not occur any closer together to represent the forest or thick timber noted on the foothills and also occur where Morphett's 1836 description indicated treeless plains. It was therefore concluded that the symbols were generalised impressions added by the mapmaker. However, Riddle (1981) investigated in detail the relationship between such symbols and real tree cover in the Adelaide area and found a good correspondence. Perhaps a more detailed study of historic botanical records for the Willunga Basin could explain this apparent discrepancy.

6.2.4 The Aldinga Scrub area

From the vegetation map in Figure 29, it appears that the area now known as Aldinga Scrub was not connected to other areas of similar vegetation in 1839/40. The area's distinctiveness was given special attention on early maps, and in the 1839 Field Notebook was labelled "Forest Land" with the words "sandy and scrubby" written faintly below. The early descriptions of the vegetation of the Aldinga Scrub area seem to indicate sclerophyll woodland, mallee communities and sandy coastal vegetation which have also been mentioned in recent studies (Gent *et al*, 1980; Wollaston & Finger, 1986). Ross (1984) also recorded that stands of river red gums had at some time existed in the north-east corner of the Scrub at Cliffs Waterhole (discussed in Section 6.2.1). The existence of red gums in this area may be explained by the presence of poorly drained depressions which border the entire landward margin of Aldinga Scrub, of which the northern part once flooded seasonally up to one metre (Gent *et al*, 1980). The hydrological aspects of the Aldinga lagoons were covered earlier in Section 4.3.

6.2.5 Wetland and estuarine vegetation

The early surveys and accounts often noted swampy areas along streamcourses. Of particular note was Port Willunga Creek (previously Tartarchilla Gully) where water was recorded as brackish in the last two kilometres before the coast. *The Observer* (13 April 1844) noted that Pedler Creek (previously Turneeyundingga Gully) which received drainage from McLaren Vale was originally called Salt Water Creek because the sea occasionally flowed into it. In the 1839 survey the estuary was labelled as swamp, and Maslin South Creek (Cunyanyapella Gully) appeared to terminate in a small swamp just before the coast. In 1844 large teatrees (*Melaleuca linariifolia*) and reeds were mentioned as occurring along Maslin South Creek where water was permanent (*The Observer*, 13 April 1844) (in its midcourse on the plains this creek was marked as a swampy area in the 1987 1:50,000 topographic map: Department of Lands, 1987). Also in 1839, swampy areas were shown at two sites along Pedler Creek (in Section 115 and near Sections 120 and 130), of which one was associated with tea tree scrub. As Figure 29 shows, tea tree scrub was noted as occurring away from the coast, particularly in gullies where streams left the hills, for example between the sites of Willunga and Willunga South. "Good water" was often indicated where teatree scrub was mentioned. The other major swamp area indicated in 1839 surrounded the lagoon on the Aldinga Plains. The types of wetland vegetation found there today include red gum, sedge (*Gahnia filum*) and lignum (*Muehlenbeckia cunninghamii*) swamps in the north-east corner, along with areas of bulrush (*Typha* spp) and reeds (*Phragmites* spp) (Friends of the Earth, 1991).

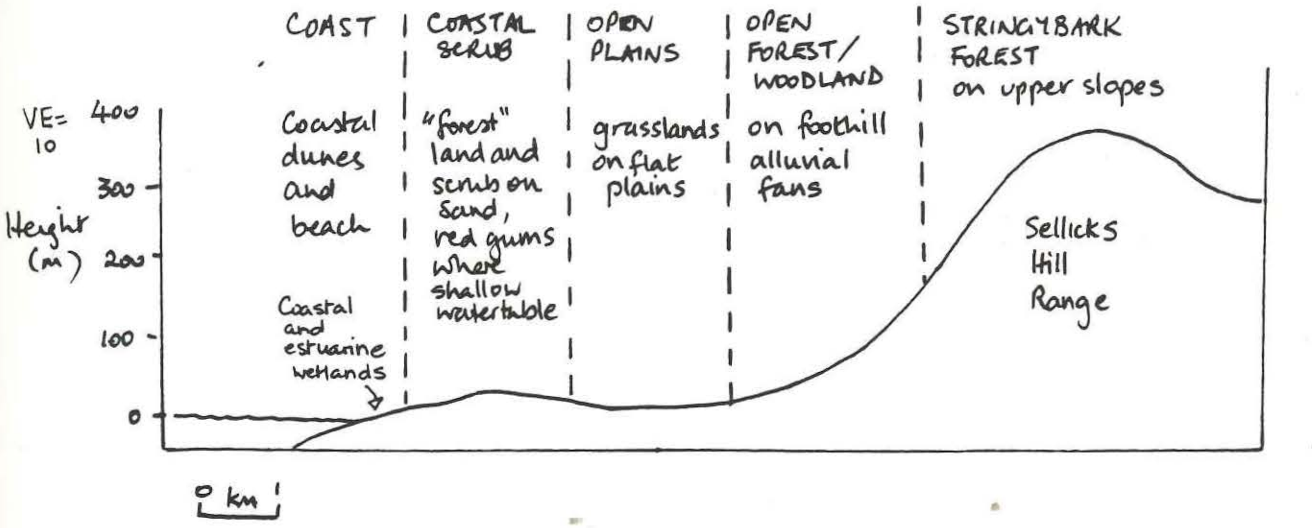
6.2.6 Explanation of the early vegetation distribution

On the basis of the evidence so far, it appears that at the time of early European settlement the Willunga Basin had several different landscape types. It was bordered by a high wooded scarp face on the east, with the open grasslands of the Aldinga Plains to the west and the McLaren Plains near the centre. More tree and understorey cover occurred on both the undulating plains to the north and north-east, and in the unique Aldinga Scrub area to the south-west with its associated lagoon and swamp.

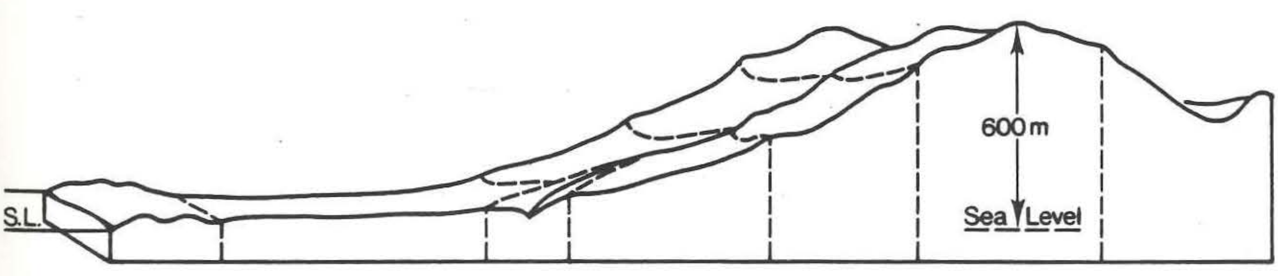
By comparing the maps of geology, soils, topography and rainfall (Figures 3, 4, 5 and 8) with the location of the broad areas just mentioned, it seems sensible to agree with Maud (1972) who commented that in the Adelaide Region in general "the available information strongly suggests that the soils and the climate have determined the distribution of the vegetation". (However, Maud pointed out that no detailed ecological studies had been done to map vegetation, soil and climate to compare relationships). Some relationship between these factors in the Willunga Basin can be interpreted as follows. The upper slopes of the ranges which received higher rainfall were forested, while the lower slopes were wooded. The low-lying gently sloping plains, which received less rain than the hills, but which were subject to seasonal flooding, carried open grassland and savannah woodland, while Aldinga Scrub was a patch of forested and scrubby land isolated due to its location on an island of sandy soil surrounded by land subject to inundation. Lagoons and swamps occurred on low-lying land near the coast which was cut off from the sea by dunes, while wetland vegetation also occurred along streamcourses. This variety of landscapes is summarised in Figure 33a and is compared with a cross-section indicating the original vegetation of the Mt Lofty Ranges (Figure 33b).

Figure 33

(a) Cross-section from the coast near Aldinga Scrub to the top of the Sellicks Hill Range showing topography and vegetation in 1839.
Source: Compiled by the author from information in Figure 29, with topography based on a section from Aldinga Reef to Pages Flat Road taken from Department of Lands (1987 and 1990).



(b) Major changes in the main site factors and original vegetation communities between the coast and the Mt Lofty Ranges.
Source: Boomsma & Lewis (1980:figure 1).



	COAST	ADELAIDE PLAINS		FOOTHILLS	MOUNT	LOFTY	RANGES
TOPOGRAPHY	Sandhills	Plains	Creek	Lower slopes	Mid-slopes	Upper slopes	Elevated valley
ANNUAL RAINFALL (mm)	475	500		600	650	700	650
SOILS	Dune sand	Calcrete and shallow red-brown earths	Alluvial	Red-brown earths	Grey-brown podsols	Grey and yellow podsols	Meadow podsols
VEGETATION FORMATION	Shrubs and scattered trees	Low open woodland to woodland	Open woodland	Open woodland	Open woodland to woodland	Woodland to open forest	Open woodland to open forest
DOMINANT TREE OR TALL SHRUB SPECIES	*Acacia sophorae* *Leucopogon parviflorus* *Casuarina stricta*	*Eucalyptus porosa* *Casuarina stricta*	*Eucalyptus camaldulensis*	*Eucalyptus microcarpa porosa*	*Eucalyptus fasciculosa leucoxylon*	*Eucalyptus baxteri fasciculosa leucoxylon obliqua viminalis* (aff) *viminalis*	*Eucalyptus camaldulensis leucoxylon rubida viminalis*

With respect to the plains grasslands, which were often noted for their abundance of kangaroo and emu, there are suggestions that such open landscapes could have been created by frequent Aboriginal firing of the vegetation (eg Barker, 1986:26-27; Gale, 1986; Clarke, 1991:59). Writing of South Australia in general, Gale (1986) argued that the greatest impact that Aboriginal people had on the landscape was probably through the regular and calculated use of fire in hunting and food gathering:

> Regular fires encouraged grass to grow across areas that would otherwise be covered by trees or scrub. These induced grasslands provided suitable habitats for the various grazing animals which formed such an important part of the Aboriginal diet (Gale, 1986:10).

Clarke (1988:74) mentioned several instances where early settlers recorded that Aboriginal people deliberately lit fires, especially in the dry season or late summer, to encourage new grass and to facilitate hunting. The fact that Matthew Flinders' noted "much smoke on the low land" and "also great smokes rising from the hills further up" as he sailed along the Adelaide coast in 1802 (Cooper, 1953) is sometimes quoted to support the notion of Aboriginal burning (eg Clarke, 1991), although Flinders' notes did not indicate that Aborigines were responsible for any of these fires (Cooper, 1953). Ellis (1976) has suggested that such explanations for the existence of grasslands on the mainland are supported by the absence of grasslands and presence of eucalypt shrublands on Kangaroo Island. At the time of early European settlement Kangaroo Island was not inhabited by Aboriginal people and therefore would not have been subject to intentional burning. Barker (1986) contended that intentional burning may therefore have suppressed the shrubby understorey on the mainland.

In addition to possible deliberate burning by Aborigines, fires would have broken out spontaneously in late summer when the vegetation was dry. Dutton (1846:246) noted that ravaging bushfires occurred when the grass had become very dry during the summer heat and Angas (1847a:43) mentioned "tremendous fires" that swept through the stringybark forests of the Adelaide Hills and which blazed for days over many miles "usually during the dry heats of summer". When rains occurred after a bushfire, "beautiful green young grass" quickly sprang up again, the fire having passed over too quickly to injure the roots (Dutton, 1846:246). Angas made reference to many Aboriginal practices in his 1847 book entitled "*Savage Life & Scenes* *in Australia and New Zealand*", but neither he nor Dutton connected summer bushfires with Aboriginal people. The Aboriginal use of fire in the Adelaide region before European arrival is hard to assess, especially since European presence may have increased the occurrence of fires. Hawker (1899:45) commented that "as the country got populated very severe bush fires, often caused by great carelessness, occurred".

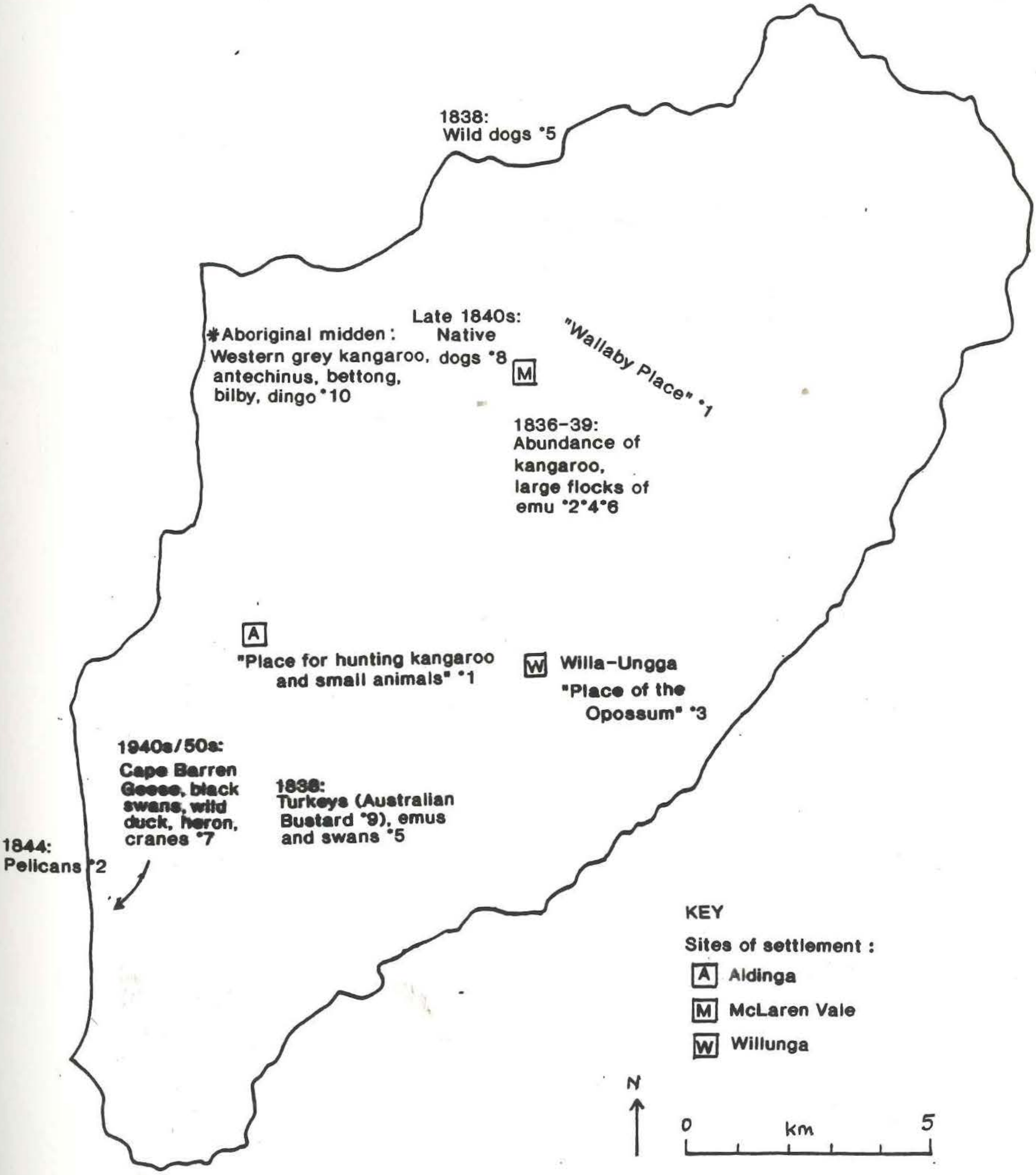
Although the grassland vegetation seems at first to be related to climate and soils, it is possible that human and non-human forces working together created the grassland plains. This would make tree and shrub regeneration more difficult than grass regeneration under frequent firing on a low-rainfall plain. However, the firing theory does not explain how the forest of the foothills and the Aldinga Scrub area, which both adjoin the plains, were not converted to grassland before European arrival. Only if Aboriginal people were able to maintain good control over fires could the Aldinga Scrub area have been deliberately protected. The margins of Aldinga Scrub were used as camping areas (eighteen Aboriginal campsites have been located: Ross 1984) and this could have motivated the Aborigines to preserve the scrub. Alternatively, it could have been naturally protected from fires on the open plains by the presence of the lagoon and swamp areas bordering it, although these were often dry in summer.

6.2.7 Habitat for native fauna

There is little information available about native fauna in the Willunga Basin in earlier times. However, Figure 34 has been compiled from what scant information is available. Unfortunately most early observers only noted the larger and more obvious species, and did not make reference to small or medium-sized mammals, many of which were thought to have been present at the time of European settlement. The references to native fauna are mainly related to the habitat types provided by the vegetation in the Willunga Basin.

An abundance of unspecified game, kangaroo and emu, on the open and grassy McLaren Plains, has already been mentioned (Morphett, 1836; *The Observer*, 13 April 1844; Hawker, 1899). In addition, two references indicated the presence of dingos in the northern part of the Willunga Basin. In 1838 "wild dogs" were noted near the Onkaparinga River (Giles, 1838): this is one of the common names for the dingo (Strahan, 1983). "Plenty of native

Figure 34
Locational references to native birds and animals in the Willunga Basin 1836-1950s. *Source:* Compiled by the author from *1 Tindale (undated); *2 *The Observer* (13 April 1844); *3 Dunstan (1978:114); *4 Hawker (1899); *5 Giles (1838); *6 Morphett (1836); *7 Hay (1942-51 in Linn, 1991); *8 Hewett (late 1840s, in Linn, 1991:23); *9 Whitelock (1985:102); *10 Ross (1984).



dogs" were also reported in the late 1840s, probably in the McLaren Vale area. The latter comment was made by a resident of McLaren Vale but it was not clear whether they were making a local reference or a general comment (Hewett in Linn, 1991:23). While the term "native dog" was not directly related to the dingo it is likely that it referred to dingos because the dogs were said to be a threat to sheep. Dingos in south-eastern Australia today favour areas where forest meets grassland or heathland (Strahan, 1983) and comparison of Figures 29 and 34 shows that the area in which they were noted in the Willunga Basin would have provided such habitat.

Although no historic references to smaller mammals were located, some animal remains were found in a midden near an Aboriginal hearth site at Moana, just south of Pedler Creek. Although the species could have inhabited the Willunga Basin they could equally have been brought from elsewhere. The findings are listed in Table 11. The presence of kangaroo and dingo is supported by the historical observations, while the other finds are interesting particularly because wild bettongs and bilbies are no longer found in the Adelaide region.

Table 11
Animal remains found in a midden near an Aboriginal hearth site at Moana. *Source:* Compiled by the author based on Ross (1984) and other references as indicated.

Species found	Comments
Rabbit-eared bandicoot (or bilby: *Macrotis lagotis*)	Once inhabited most of arid and semi-arid Australia in savannah woodlands and shrub grasslands (Strahan, 1983) and once quite common on the Adelaide Plains (Tyler *et al*, 1976).
Kangaroo rat or bettong (scientific name unspecified)	Two types of rat-kangaroo were common on the Adelaide Plains: the Brush-tailed Bettong (*Bettongia penicillata*) and the Lesuer's or Burrowing Bettong (*Bettongia lesueur*) (Tyler *et al*, 1976).
Small carnivorous marsupials (*Dasyurid*, *Antechinus* or *Sminthopsis* species)	The Yellow-footed Antechinus (*Antechinus flavipes*) is found today in the Adelaide Hills (Overton, 1993b).
Dingo (*Canis familiaris dingo*)	Once common throughout Australia (Strahan, 1983).
Western grey kangaroo (*Macropus fuliginosus*)	Found today in the Adelaide Hills (Overton, 1993b).

References to arboreal mammals were limited to possums. These references were made to areas known to have had some tree cover. In 1915, P O'Grady of Wright Street Adelaide wrote to *The Chronicle* to say that on early visits to "native camps" the "old chaps" had been pestered for native names of familiar objects and they had told O'Grady that "Willa" meant opossum. Therefore, O'Grady concluded that the native name for Willunga could be "Willa Unga", meaning "Place of the Opossum" (Dunstan, 1978:114). According to Tindale (undated) the native name for the main Aldinga lagoon was Wangkondanangko which meant "possum place". However, the interpretation of Aboriginal place names requires some caution. Although "possum place" may indicate the presence of live possums in the area (brush-tail possums are found today in Aldinga Scrub: NPWS, 1993) it may also refer to a place for pegging out possum skins to cure them for making skin cloaks, as noted by Tindale (undated). Aboriginal people could have obtained skins from possums living in trees on the hills or in the Scrub, or could have brought them from outside the Willunga Basin. Nevertheless, since possum references were made to areas in or near to woodland it is likely that possums did occur in or close to those areas.

There were some early references to large birds in the Willunga Basin. In early May 1838 "numbers of turkeys, swans and emus" were observed on the Aldinga Plains even though no water was seen (Giles, 1838). "Turkeys" were probably Australian Bustards (*Eupodotis australis*) because Whitelock (1985:102) said that Australian Bustards were called "wild turkeys" by early settlers. These birds are now absent from settled areas in South Australia and are relatively rare even in the north of the state (Aslin, 1986). It is possible that the Bustard would have been found on the Aldinga Plains since it is a ground-nesting grassland bird (Slater, Slater & Slater, 1989).

Many waterbirds were associated with the Aldinga wetlands. A long-time resident of Willunga recalled that in the 1930s flocks of Cape Barren Geese often flew over Willunga from the coastal lagoon but had difficulty ascending the scarp face due to headwinds (G Vaudrey, pers comm July 1994). Another local resident in the 1940s recalled that Cape Barren Geese frequented the swamp in the middle of Aldinga Scrub, along with black swans, wild ducks, herons, cranes and "all manner of swamp birds" (Hay quoted in Linn, 1991:148). The presence of waterbirds on the Aldinga wetlands is explained by the suitability of the habitat. Briggs (1981:355) explained that waterbirds do not occur on all wetland types but that they are common in lignum shrublands, reed grasslands, bulrush grasslands, and flooded red gum forests. Where lignum shrublands with a sedge and aquatic herb understorey occur under red gums a large number of waterbirds, particularly ducks, can be found. The seasonal flooding of the low-lying Aldinga Plains wetlands would have brought nutrients from the surrounding area to increase the biological productivity and food supply for such birds.

6.3 CHANGES IN THE VEGETATION SINCE THE 1830s

6.3.1 General changes

Figure 35 shows that in 1992 very little native vegetation remained in the Willunga Basin. The main remnants were small patches of woodland and forest, occurring in the Blewitt Springs area in the north-east and at Aldinga Scrub in the south-west, with scattered patches along the hilltop immediately north and south of Willunga. In 1958 and 1977 the pattern of remnant native vegetation on the plains was similar to 1992. However, the 1977 and 1992 maps indicated some patches of native vegetation which had not been marked in the preceding maps. Figure 35 shows that the native vegetation which was already very limited in extent in 1958 has become even more fragmented since then. Unfortunately the 1958 and 1977 landuse maps did not cover the hills, and time limitations for this project precluded a direct analysis of the relevant aerial photographs. While it was felt that the cover mapped at the three dates shown in Figure 35 was comparable and represented the major remnants of native tree cover with understorey, two other maps were found which were based on recent aerial photographs and other information (Planning Advisory Services, 1992: Environmental Opportunities and Constraints map - Floristic Vegetation category; Withers, 1993: Overlay 4). The Planning Advisory Services (1992) map included exactly the same categories as the 1992 category in Figure 35, except for the addition of "possible treecover", which was described as native tree species with little or no understorey. The spatial pattern of the Planning Advisory Services (1992) map was very similar to Withers (1993), which is shown as Figure 36. Many small extra patches are visible which did not appear on Figure 35. Since the pattern in Figure 36 can be confirmed to some extent by field observations and topographic maps (Department of Lands 1984, 1990), particularly in relation to the more frequent occurrence of

Figure 35
Remnant vegetation in the Willunga Basin 1958, 1977 and 1992.
Source: Compiled by the author based on information extracted from Bowering (1979, volume 2, Figs 4 and 5); Willunga Basin GIS 1992 Remnant Vegetation coverage.

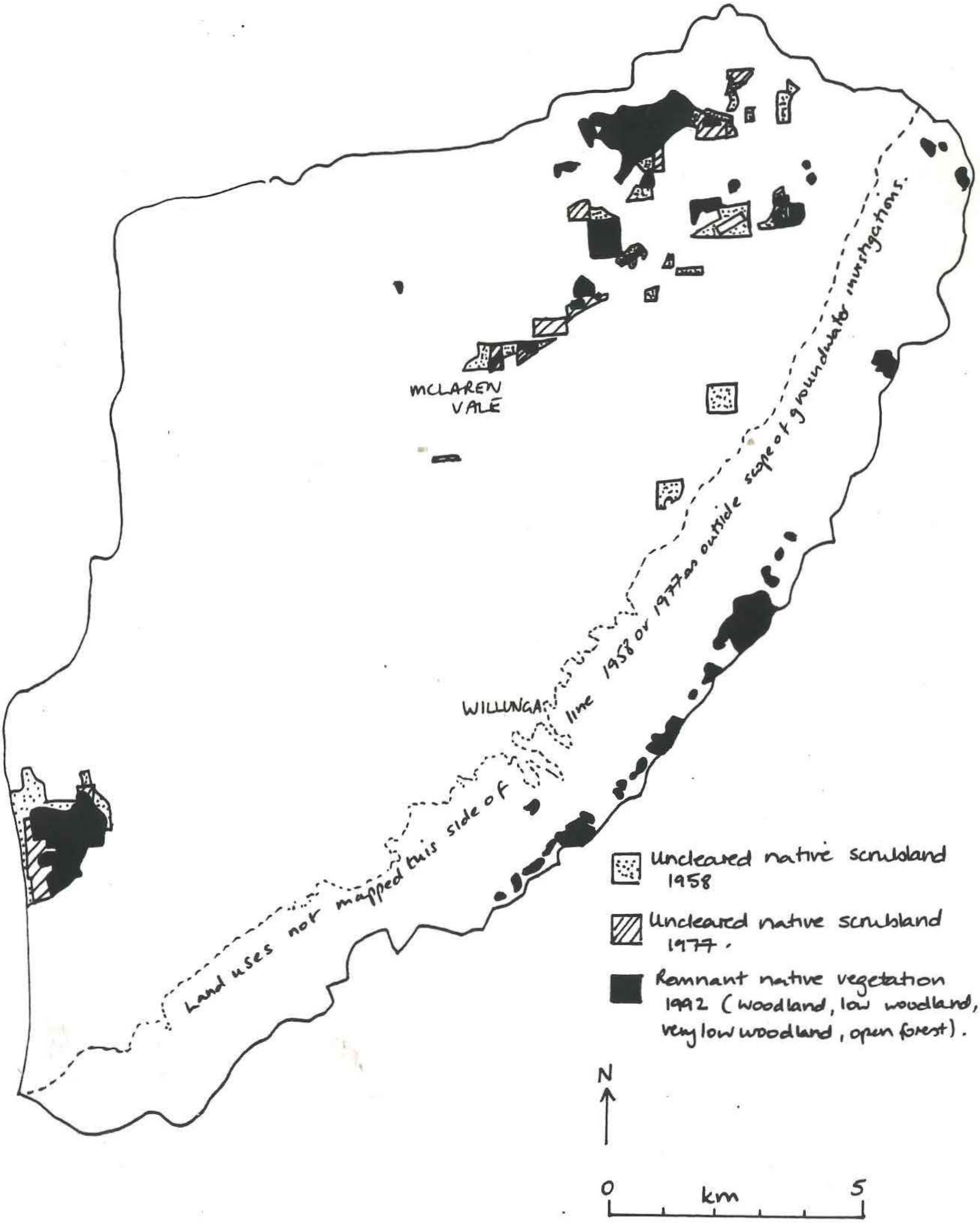
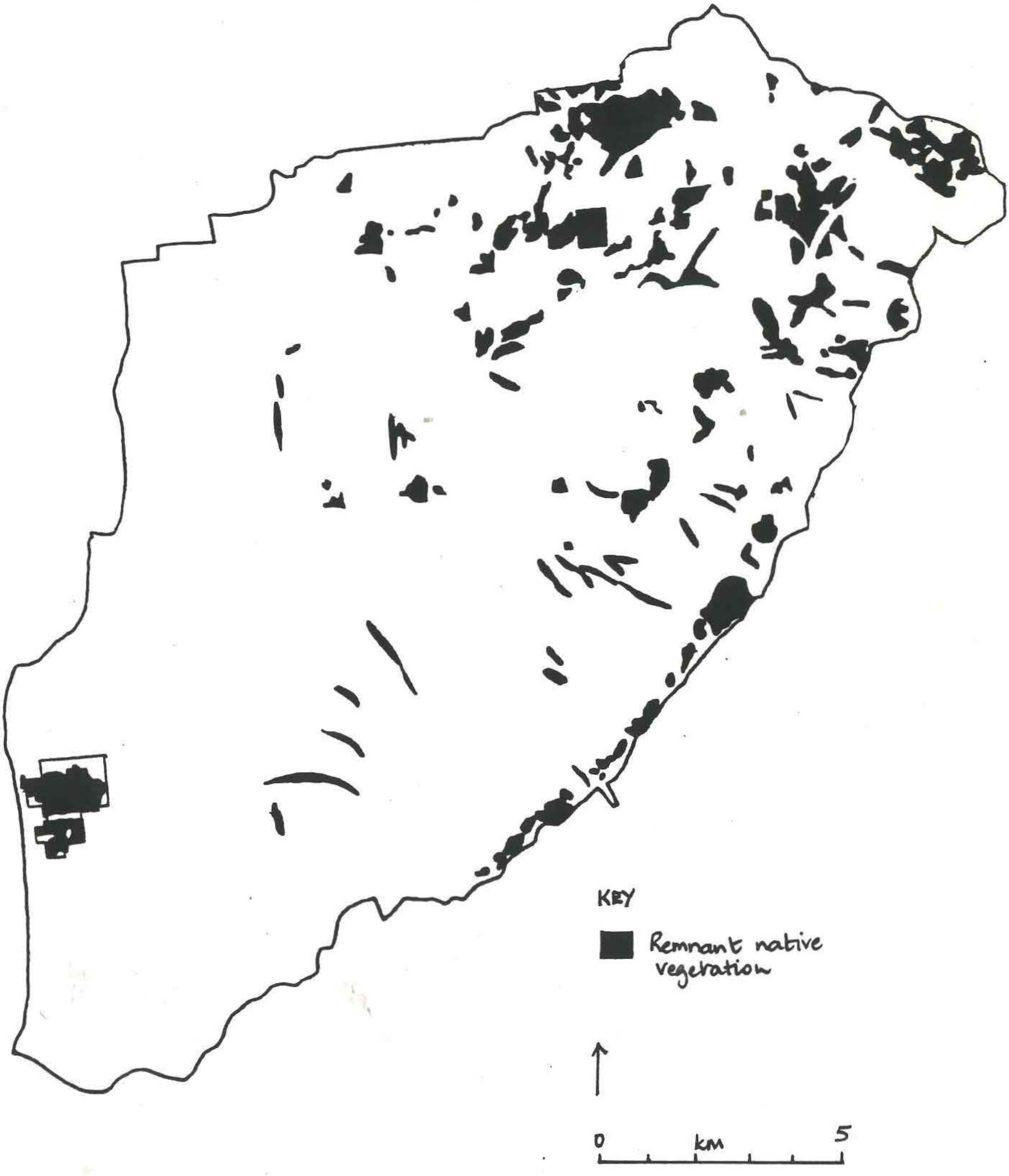


Figure 36
Remnant vegetation in the Willunga Basin 1991.
Source: Withers (1993, Overlay 4: mapped from 1991 aerial photographs 1:40,000 and 1986 aerial photographs 1:80,000).



tree cover in the north-east (also visible in Plate 2), it was concluded that many of the patches which were not shown in Figure 35 were treecover without native understorey. However, this does not explain the absence from the maps in Planning Advisory Services (1992) and Withers (1993) of a substantial patch of gums on grazed land at the bottom of the Old Sellicks Hill Road, which were already large trees in the 1949 aerial photographs.

6.3.2 Changes on the plains

Plate 3 shows a scene of the plains in 1870, thirty years after the first surveys. At this time, the plains had an open appearance, with scattered trees and belts of trees, both on the plains and the foothills. The main band of trees on the plains may have lined one of the major creeks. It is impossible to say what the general understorey cover was but the darker patches of vegetation were possibly swamp vegetation or crops. Comments by Sutherland (1889) suggest that fifty years after the first surveys were made substantial changes had occurred to land cover on the plains. In a rather romantic description of the countryside scene, Sutherland (1889) described the view from McLaren Vale, with hayfields stretching as far as the eye could see and wide expanses of grassy paddocks between. He wrote of:

> ... haystacks, and cottages with their neat gardens and porches covered with creepers ... to be seen in every direction ... tidy fruit-plots and plantations [growing] luxuriantly here and there; and ... Thomas Hardy's extensive vineyards covering hundreds of acres (Sutherland, 1889:4).

In the 1880s, there were belts and clumps of trees around McLaren Vale and it was recorded that people were creating wattle plantations, particularly to make use of the poor hilly land (Sutherland, 1889:4). This was in the same area between Noarlunga and McLaren Vale where the wattle hills were mentioned in 1839. The road from McLaren Vale to Willunga was described as passing through pleasant open, grassy country (Sutherland, 1889:7) but Sutherland did not specify whether this was open plains covered with native grasses or introduced pasture. In any case, there was no mention of the tall grasses which so impressed the earlier travellers. Indeed, in 1873 it was noted that although kangaroo grass had flourished on the plains areas of the Adelaide region 35 years previously, by 1873 not a blade was to be seen (Harris, 1986:38). In general, the long kangaroo grass was initially replaced by shorter wallaby and spear grasses (*Danthonia* spp and *Stipa*

Plate 3
A view down the main street of Willunga towards the plains to the north-west, c1870.
Source: Mortlock Library SSL:M B7192.

spp), then by annuals from the Mediterranean region and South Africa (Harris, 1986). The plains have also received introduced exotic weed species. Star Thistle (*Centaurea calcitrapa* L) and Bathurst Burr (*Xanthium spinosum* L) were reported in the 1880s (Linn, 1991:118) and 1926 survey records noted Scotch Thistle (*Onopordum acanthium* L) and Boxthorn (*Lycium ferocissimum*) on a neglected orchard covering three sections near McLaren Vale. Today exotic weeds such as boneseed (*Chrysanthemoides monilifera*) are found in some areas, including on landslips in the lower section of the Sellicks Creek Gully.

6.3.3 Changes on the hills

The early records of the 1830s indicated that the Sellicks Hill Range was generally wooded and it remained so at least until the time of the first hills surveys in the early to mid-1850s. Edward Snell, who visited Willunga in February 1850, noted a "fine background of hills which at the base slope off to the sea, the whole covered with trees through which the roads wind" (Griffiths, 1988:78). Indeed, Plate 4 records that tree cover remained right down to Willunga at least until the 1860s. From Plate 5 it appears that around 1870 the hills behind Willunga still had good tree cover with large gum trees surrounding Willunga township at the foot of the scarp. A French map was found, dated 1878, which seemed to suggest that the hills were still wooded in the mid-1870s (Hutchinson, Howard, Guy, Goalen and Roxby, 1878). However, the appearance of two earlier maps (Hutchinson's 1863-73 map and an 1874 Admiralty map by Captain J F Evans in the Royal Geographical Society's map collection) suggested that the French map had been compiled from the earlier maps rather than being an 1878 representation of the area.

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[2] The date of Plate 4 is important in establishing how long the tree cover remained on the hills around Willunga. Although the Mortlock Library dates the photography as c1885, two large trees are seen growing outside the same house in Plate 7, which was taken around 1889. The trees could not have grown to such a size by 1889 if they had not even been there five years earlier. Linn (1991:54) dated Plate 4 as the 1850s. However, local resident D Vaudrey, who has researched the history of the Sara family, dates the photograph as late as the 1860s, based on the fact that the site was unimproved and owned by H Malpas until 1858 (D Vaudrey, pers commm, July 1994). If the photograph was taken in the 1860s, the trees in Plate 7 could then be 20-30 years old. Thus, from this evidence tree cover remained on the hills behind Willunga to the 1860s.

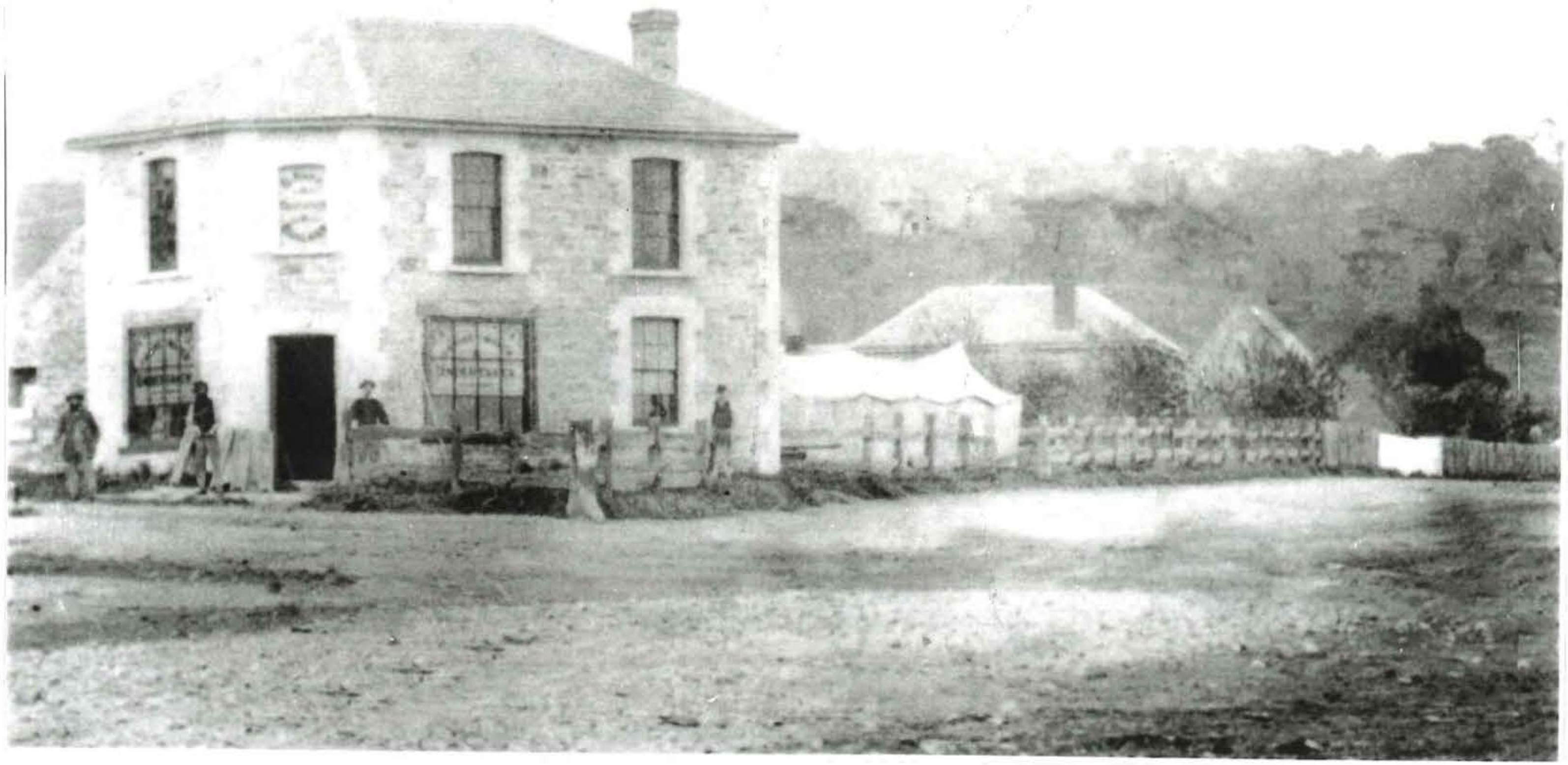

Plate 4
A view of George Sara's shop on Section 59 at the corner of High Street and St Andrew's Terrace in Willunga, Probably in the 1860s. Further explanation is given in footnote 2 on the previous page. *Source*: Mortlock Library SSL:M B45282.

Plate 5
Willunga Township c1870 looking south-east up Willunga Hill (the Police Station on the left and the Post Office on the right). *Source:* Mortlock Library SSL:M B7193.

By the 1880s the tree cover on the hills behind Willunga had almost completely disappeared, as shown in Plates 6 and 7. Plate 6 indicates that in 1880 a limited area of the hills above Willunga near the quarries did not have tree cover. Plate 7, which was taken around 1889, depicts only scattered trees remaining at a distance from Willunga. The 1889 photograph is supported by a description, from about the same time, of the long range of hills which passes by Willunga being "very sparsely wooded, but grassy ... for the most part either quite bald and bare, or very sparsely covered with low stunted trees" (Sutherland, 1889:5-7).

A decline in tree cover also occurred on the hills along the Old Sellicks Hill Road between 1870 and 1909. The 1850's surveys recorded that the hills area generally had been wooded, and in 1861 the area along the higher part of this road was interpreted as thickly timbered. However, Plates 8 and 9 show that tree cover there declined between 1870 and 1909. The landcover in Plate 8 was about 60% tree canopy and 40% grass. The trees appeared to be healthy, and low bushes covered parts of the hillside and gully bottom. However, Plate 9 shows that by 1909 the tree cover was much reduced and grasscover dominated. There were some dead and dying trees, and what may be terracettes on the slope below the road. Low bushes still grew in the gully bottom but the trees on the distant hilltops had largely gone. Today this area along the Old Sellicks Hill Road has only grasscover, with a few isolated sheoaks, wattles and yacca in rocky roadside crevices.

In summary, it appears that the tree cover on the Sellicks Hill Range probably began to disappear sometime during the late 1860s to early 1870s. The tree cover continued to decline throughout the 1870s, and by the 1880s had disappeared almost completely across a substantial part of the hills.

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[3] The view in Plate 9 was photographed from a similar location to that in Plate 8. The Aldinga Scrub area is visible as a dark shadow on the horizon, with the lagoon to its south appearing as a white patch. The tree cover had declined significantly over the forty years since the 1870 photograph was taken, as had the sedge or bush cover in the gully. In the area from the centre of the photo towards the right there are only three dying trees today with a limited amount of sedge still remaining in the valley. The top of the hill in the centre of the photo is now bare rock. On these hilltops today a fifteen centimetre layer of soil lies between the grass cover and baserock. There are more sheoaks today on the left side of the road than is evident in this photograph.

Plate 6
Martin's Quarry in the hills above Willunga, c1880. Note the absence of trees on the hillside. *Source*: Martin Dunstan.

Plate 7
The crossroads at Willunga, c1889. The house in Plate 4 appears again in this photograph. Dunstan (1977:117) stated that by this time the building had become the chemist's shop and that, regrettably, it was later demolished.
Source: Mortlock Library SSL:M B12374.

Plate 8
Old Sellicks Hill Road c1870. This road runs alongside the top part of the Sellicks Creek Gully in the hills about eight kilometres south-west of Willunga. Although the tree cover was not continuous in 1870, this photograph is significant, since the area is today almost completely devoid of tree cover. *Source:* Mortlock Library SSL:M B26739/14.

Plate 9
Old Sellicks Hill Road c1909. Further explanation is given in footnote 3 on page 106. *Source:* Mortlock Library SSL:M B26196.

6.3.4 The Aldinga Scrub area

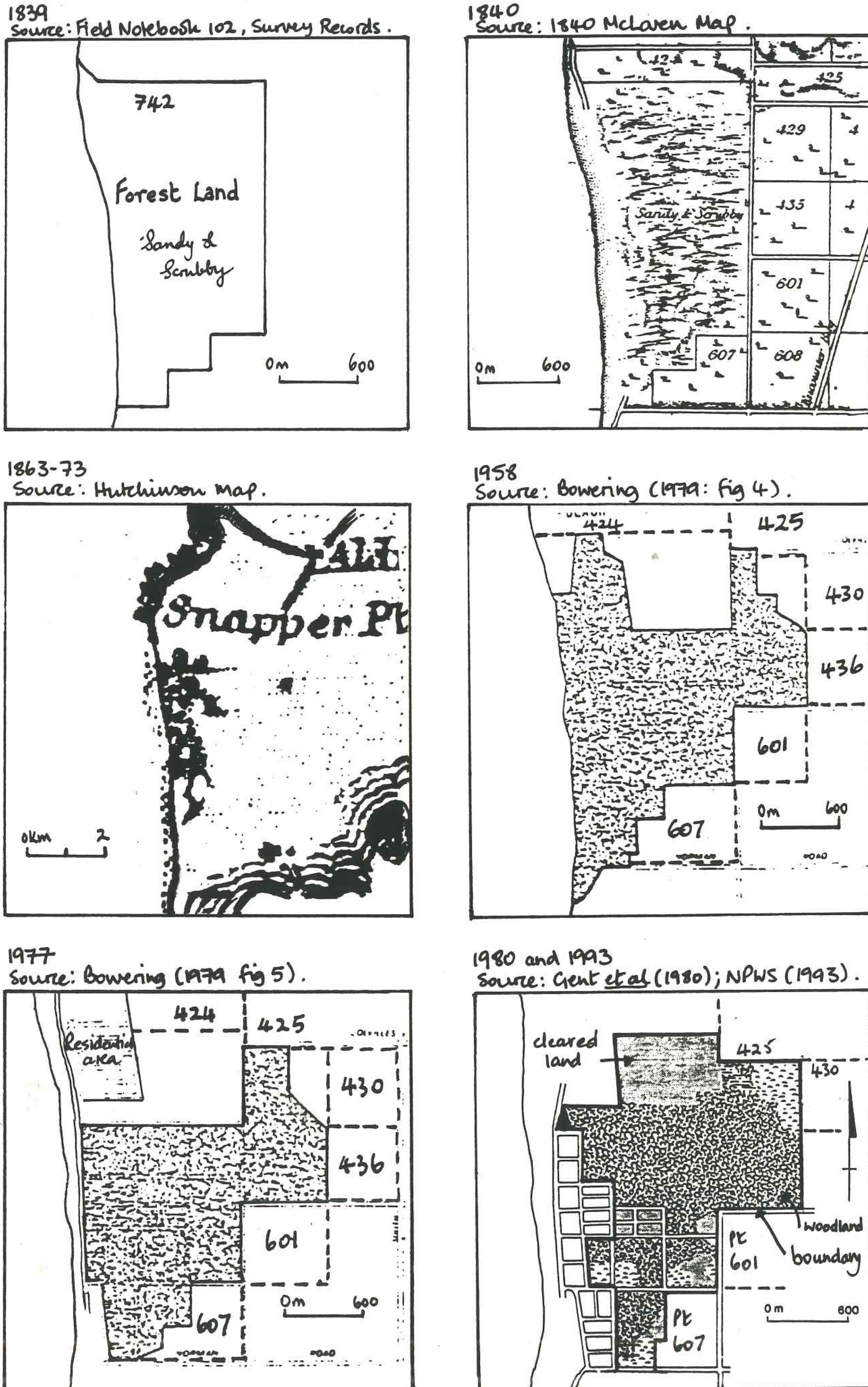
The scrub and woodland vegetation of the Aldinga Scrub has declined in area since the first surveys, so that by the early 1990s it covered only approximately 300 hectares (NPWS, 1993). A comparison of the area of Aldinga Scrub in 1839 and at later dates is shown in Figure 37. Both the 1949 aerial photographs and the 1958 landuse map depict the Scrub area as a continuous unit to the beach, as it had been on the 1840 McLaren map. By the time the 1977 landuse map was drawn, the seaward dunes had been subdivided for housing development, which isolated the Scrub from the beach. The red gums in the north-east corner disappeared at an unknown date (Ross, 1984).

Despite the modifications to the Aldinga Scrub vegetation over the years, it is still a valuable remnant because it is the only substantial area of natural bushland still surviving along the coastal plain in the vicinity of Adelaide. Today the Scrub exhibits an unusual combination of sclerophyll woodland, mallee and sandy coastal type vegetation (Wollaston & Kraehenbuhl, 1986:6). However, there are contemporary reports that the vegetation around the Scrub is changing. In swampy areas bulrushes and reeds were once common but have disappeared; large gums in the lower-lying areas have also been showing signs of dieback, and red gums on the margins of the Scrub have not regenerated (Fatchen & Associates 1986, quoted in Friends of the Earth, 1991).

6.4 SUMMARY OF FINDINGS

In this Chapter a general map of the 1839/40 vegetation pattern in the Willunga Basin was compiled and historic accounts were examined in order to assemble a picture of the vegetation at the time of the first surveys. The historic accounts, photographs and maps indicated that the vegetation pattern had changed substantially since the 1830s. A map of the remnant native vegetation in the Willunga Basin depicts very little remaining in 1992. In particular, there was a considerable amount of forest and woodland cover on the Sellicks Hill Range and at the foot of the scarp until the late 1860s, but by the late 1880s the hills had taken on their present-day appearance of being completely devoid of trees and grassy in most places, with only a few stands of trees remaining. The plains in the south-west and centre of the Basin had generally been open grasslands,

Figure 37
The changing shape of Aldinga Scrub 1839-1993.
Source: Compiled by the author from sources as indicated.



surrounded by wooded areas at the foot of the scarp and a forested sandy area near the coast on the present-day site of Aldinga Scrub. South of Aldinga Scrub lay an area of wetland vegetation in the swamps and lagoons. The Aldinga Scrub area was found to have been different from its surroundings since 1839, and had declined in area since then, while some individual species within it had also declined in numbers and extent. Although it had not been a specific objective to identify fauna species in the Willunga Basin since the 1830s, some information was found which enabled a map to be compiled. It was important to record this because there is little information on native fauna in the Willunga Basin. It was seen that the vegetation at the time of European settlement provided a range of habitat types. Changes in the vegetation since then probably led to an associated local decline in native biota which was dependent on the previous vegetation cover for its existence. This will be addressed further in Chapter 8.

CHAPTER 7

EUROPEAN POPULATION, SETTLEMENT AND LAND USE HISTORY

European settlement and associated European land use activities in South Australia have occurred within the relatively short timeframe of 160 years, compared with the many thousands of years Aboriginal people have lived in Australia. The Willunga Basin was one of the first areas in South Australia to be surveyed by Europeans because it lay close to Adelaide and its natural environment seemed to hold potential for settlement and production. This Chapter aims to establish a history of general trends in the population and land use in the Willunga Basin since the 1830s.

7.1 SOURCES AND METHOD FOR ESTABLISHING A HISTORY OF POPULATION, SETTLEMENT AND LAND USE

There was no comprehensive record of land use or population statistics for the Willunga Basin as a whole. Therefore, in order to establish population trends since the 1830s a time-series of statistics was compiled from census data in the *South Australian Government Gazette* (SAGG) (1844-1855), the *South Australian Government Gazette and Statistical Register* (1861-1976), the Australian Bureau of Statistics' (ABS) Local Government Area Statistics (1977 onwards) and the ABS Census of Population and Housing (1981). To determine land use trends after 1840 (except for mining and quarrying) statistics were compiled from the *Adelaide Chronicle* of 26 August 1840, the Willunga Public Library Statistics File, the *South Australian Register* of 26 March 1851, the *SA Government Gazette and SA Statistical Register* 1857-1976, ABS Divisional Statistics 1976-1988 and ABS Local Government Area Statistics 1991. It was found that official statistics were published at varying frequencies so statistics were obtained for approximately every five years for the period 1840-1991. Separate tables were assembled for all years for which data was available between 1840 and 1911 to give maximum detail for that period. Graphs were then produced to show trends for the Aldinga District Council (DC), Willunga DC and the Willunga Basin as a whole. Discussion will focus on trends for the whole Willunga Basin, except where significant differences were noticed for separate DCs.

Research of population and land use statistics (other than mining and quarrying) was complicated by the fact that statistical data was mainly recorded by DC and that the Willunga Basin had at various times been covered by several DC areas. Further problems arose due to changing statistical boundaries and the fact that data collection had both changed and increased in complexity over time. Some background to the changing administrative and statistical boundaries relating to the study area are explained in Appendices 1B to 1D, along with the areas to which population and land use statistics relate. Although statistics were collected and compiled separately for the DC areas, they were aggregated to represent the Willunga Basin in general. Only about half of the Noarlunga DC area lies within the Basin so the Noarlunga statistics were simply halved and added to the Aldinga and Willunga figures. It is admitted that this is a very crude method of data breakdown, since land uses and population vary spatially, but it was done in the absence of any better way of representing the Noarlunga DC's contribution to trends in the Basin. Willunga DC used to be divided into two parts and the figures collected were those recorded for the part which lay in the Hundred of Willunga. Since the other part lay to the east of the Sellicks Hill Range, and remained largely uncleared until the late 1920s (Dunstan, 1977:10; G Vaudrey, pers comm, 1994), the Willunga statistics should only relate to changes west of the main range at least until the 1930s. Even by 1981 the eastern portion had a very small proportion of the whole population (ABS Census of Population and Housing, 1981).

Statistics for mining and quarrying in the Willunga Basin were researched at the Department of Mines and Energy SA (DMESA). The main products that have been mined and quarried from the Willunga Basin are construction materials. Since 1971 all producers have sent six-monthly returns to DMESA. However, no comprehensive production records of these materials were kept before this date, since they were not considered valuable by comparison with copper and gold. Hence it was impossible to build a complete picture of mining in the area from 1840 to 1993 (Drew and Pain pers comms, 1994). Nevertheless, what information was available on production was collected. A map and corresponding "Record of Mines - Summary Cards" provided most of the pre-1970 data, but this data set was not all-inclusive. For example, production figures for the Bangor Mine, which operated between 1840 and 1957, were only given for 1955 to 1957. Also, DMESA had no record that Loud's Quarry had existed. It was established in 1840 on Sections 747 and 750 (Linn, 1991:41-42). What data was available on mining and quarry production between 1840 and 1993 is given in Appendix 5A and production by product type from all locations from 1971 to 1993 is given in Appendix 5B.

Despite the problems encountered it is felt that the statistics collected provided a valuable indication of general trends in settlement and land use, and in the discussion of the data to follow the statistics are supported by qualitative information from historic and contemporary sources wherever possible. Some background to the settlement of the Willunga Basin is provided to set the context, followed by presentation and analysis of the information collected on population and settlement trends, mining, timber use, agricultural land uses, and drainage and irrigation.

7.2 BRIEF BACKGROUND TO EUROPEAN SETTLEMENT OF THE WILLUNGA BASIN, AND POPULATION AND SETTLEMENT TRENDS FROM THE 1830s TO THE 1990s

Once the new colony of South Australia was established, the authorities were keen to quickly survey as much land as possible. The surveyors moved southwards from Adelaide, and by March 1839 had moved south of the Onkaparinga River to continue surveying the district known as District C (Hawker, 1899:38), which covered most of the Willunga Basin. The order in which surveying progressed has been mapped in Appendix 1E and the survey dates and section numbering are further explained in Appendix 1F. By December 1839 almost all the plains had been surveyed into sections but the hills were not surveyed until the first half of the 1850s and most of the north-east was left until the early 1880s. Although any area could have been subjected to some land use activities before it was surveyed and sectioned, Appendix 1E gives an indication of the timing of the preparation for organised European settlement.

Figure 38 shows population trends for the Willunga Basin from 1844 to 1993, while Figure 39 highlights further detail for the 1844 to 1961 period. There were no official population figures prior to 1844 although some information can be gleaned from other sources. Appendices 1E and 3 indicate that almost the whole plains had been surveyed and opened for settlement by 1840. Of the 408 sections marked out on the 1840 map (Appendix 3), 25% (107 sections) had been earmarked with a purchaser's name, in the areas mostly around what is now McLaren Vale and along the

Figure 38
District Council area population trends 1844-1993.
Source: Compiled by the author from statistics collected from various sources as indicated in the Section 7.1.

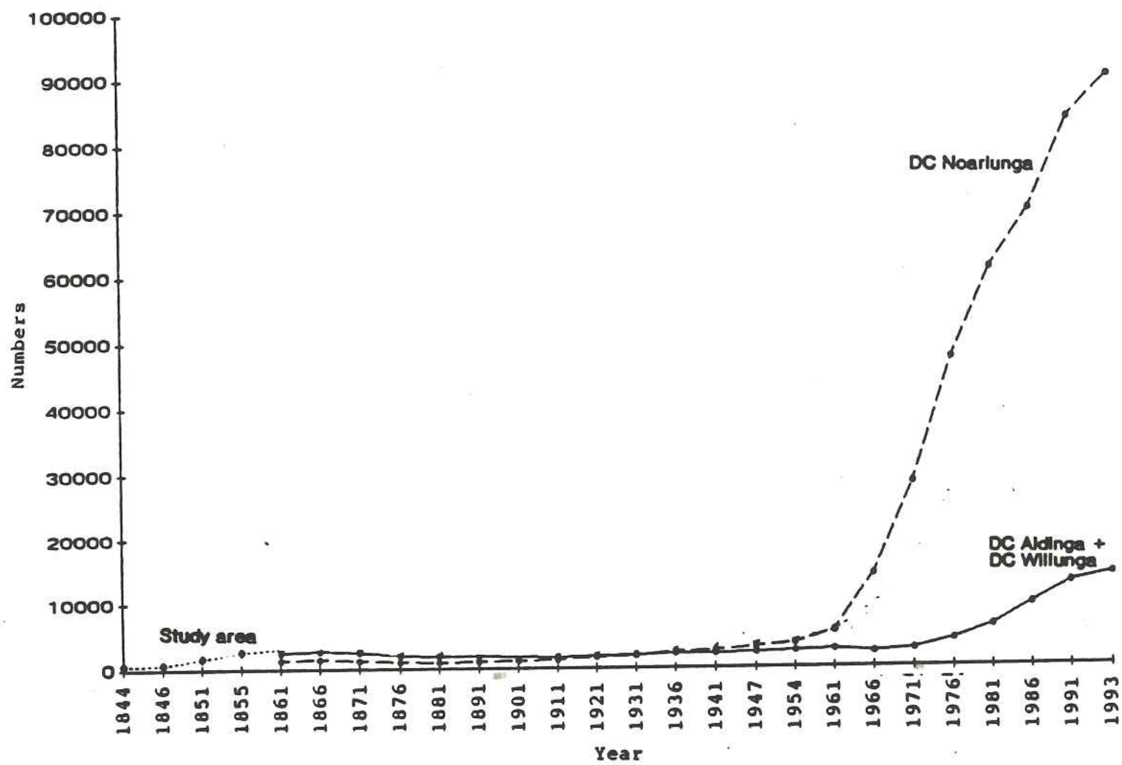
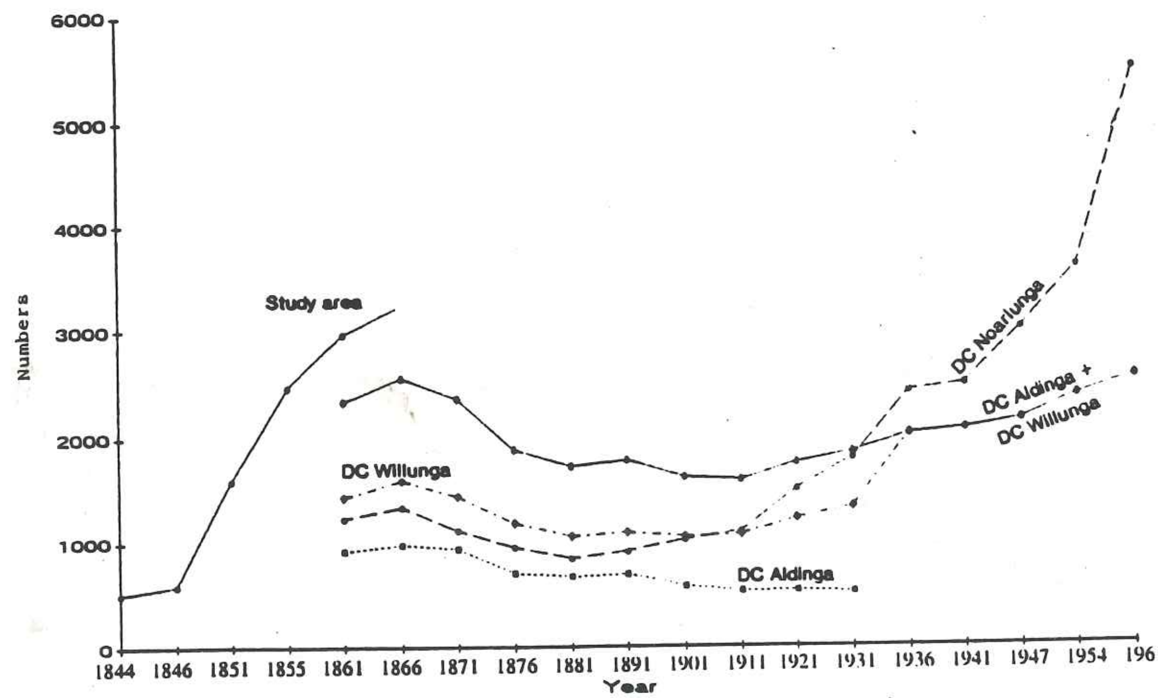


Figure 39
Population trends in the Willunga Basin 1844-1961.
Source: Compiled by the author from statistics collected from various sources as indicated in Section 7.1.



foothills just south-west and north-east of Willunga. However, in 1840 settlement was only just beginning, with McLaren Vale having only twelve settlers (*Adelaide Chronicle*, 26 August 1840). Even by 1844 the town of Willunga existed "more in name than in reality" with only two brick buildings, four government huts and two or three private settlers' buildings (*The Observer*, 13 April 1844:7), and there were only 500 people in the whole area south of the Onkaparinga River to the Willunga Hills (SAGG, 1 April 1844:61). Nevertheless, by 1843 Hawker (1901:15) was surprised at "the number of stations in these districts and the great increase of population since [he had been] on the survey there in 1839".

By 1851 the population had increased, heading towards a minor peak of just over 3000 in the mid-1860s (Figure 39). All land in and near the Willunga township had been purchased, 60 or 70 settlers had just over 2000 hectares under cultivation, and settlement on the Aldinga Plains was increasing rapidly (*South Australian Register*, 26 March 1851). However, a population decline began in 1866 with losses attributed to the attraction of people to the Victorian goldfields and the newly opened agricultural districts in other parts of South Australia (Miller, 1895:78). Between the 1870s and 1930s population numbers remained at between 2000 and 4000 but then began to rise slowly.

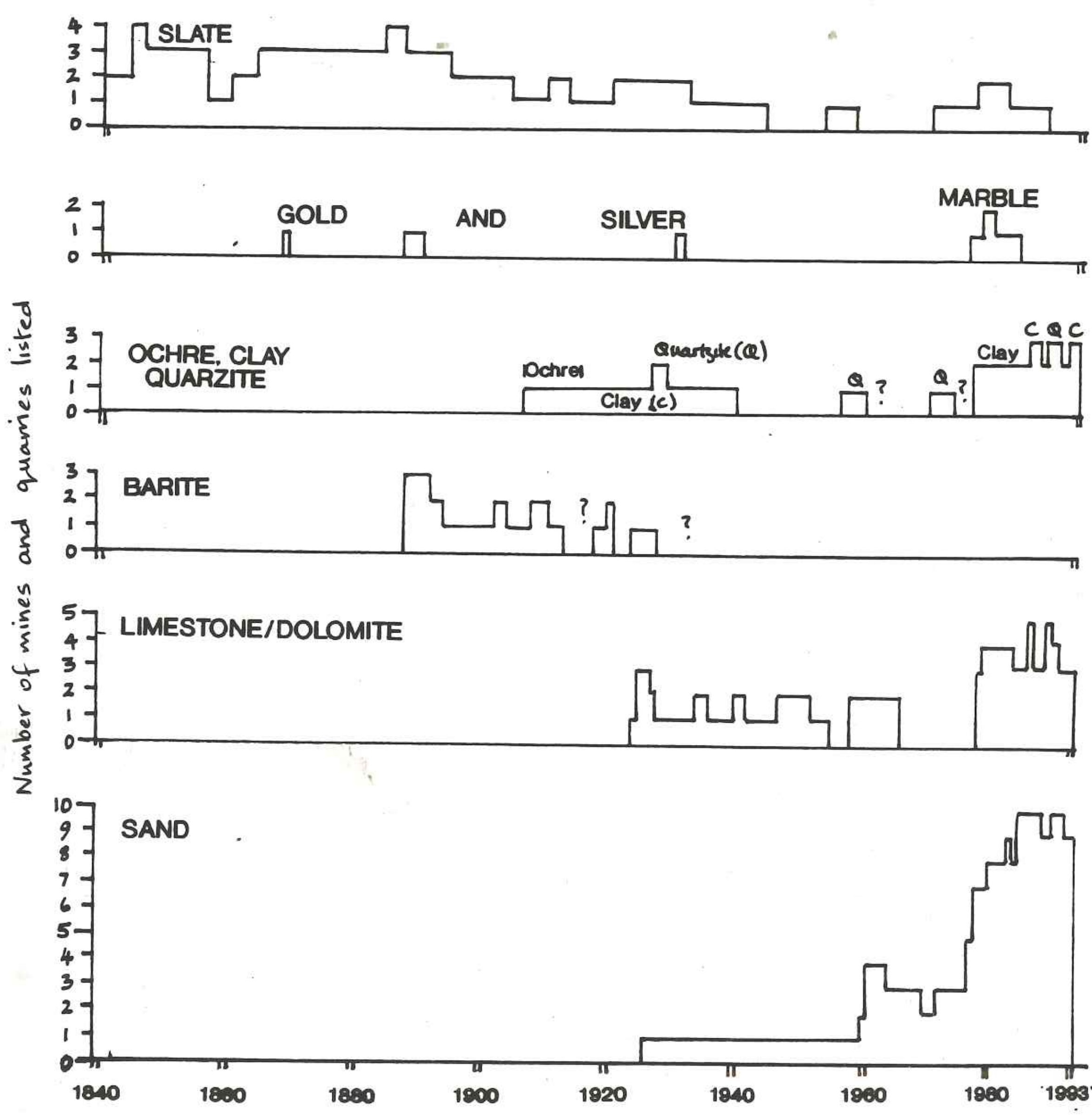
In the early 1960s the population of the DC Noarlunga began to increase more rapidly, largely due to the urban sprawl southwards from Adelaide. However, this occurred in the part of the DC area which lies north of and outside the Willunga Basin. The southward sprawl has continued until the present, with urban residential developments such as Seaford and Glenview now occurring on the coast south of the Onkaparinga River in the Willunga Basin. Population numbers in the DC areas of Aldinga and Willunga have also risen since the 1970s, but at lower rates, and are a reflection of the area's attraction for people seeking a semi-rural lifestyle only 40 kilometres from the centre of Adelaide. A general trend in rural population growth related to lifestyle changes began in the 1970s and continued in Australia well into the 1980s; it was felt most in "a few coastal non-metropolitan divisions on the east, south-east and south-west coasts on the edge of major metropolitan centres or just beyond their commuting zones" (Hugo, 1989:72).

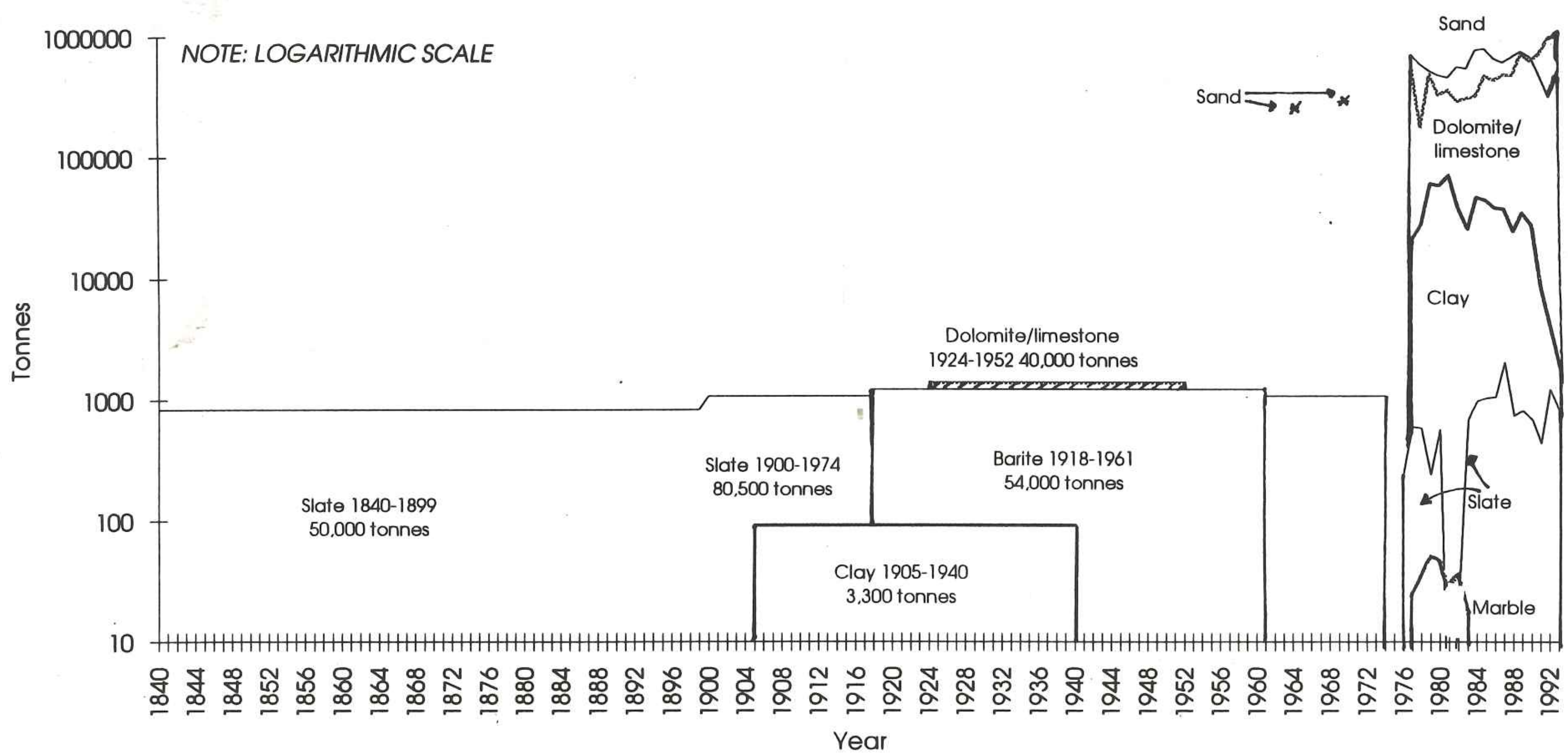
7.3 LAND USE TRENDS FROM THE 1830s TO THE 1990s

7.3.1 Mining and quarrying

Quarrying was one of the first European land uses in the Willunga Basin, with Loud's Quarry opening in 1840. Figure 40 was constructed to indicate general trends in the minimum numbers of quarries and mines which have operated in the area. Some indication of the scale of production is also given in Figure 41, while Figure 42 depicts both the location and types of mines in the Willunga Basin between 1840 and 1993 as well as the scale of production. Quarrying and mining in the Willunga Basin have been limited

Figure 40
General trends in the number of mines and quarries operating in the Willunga Basin 1840-1993 (may be incomplete due to limitations of original sources). *Source:* Compiled by the author from data in Appendices 5A and 5B.



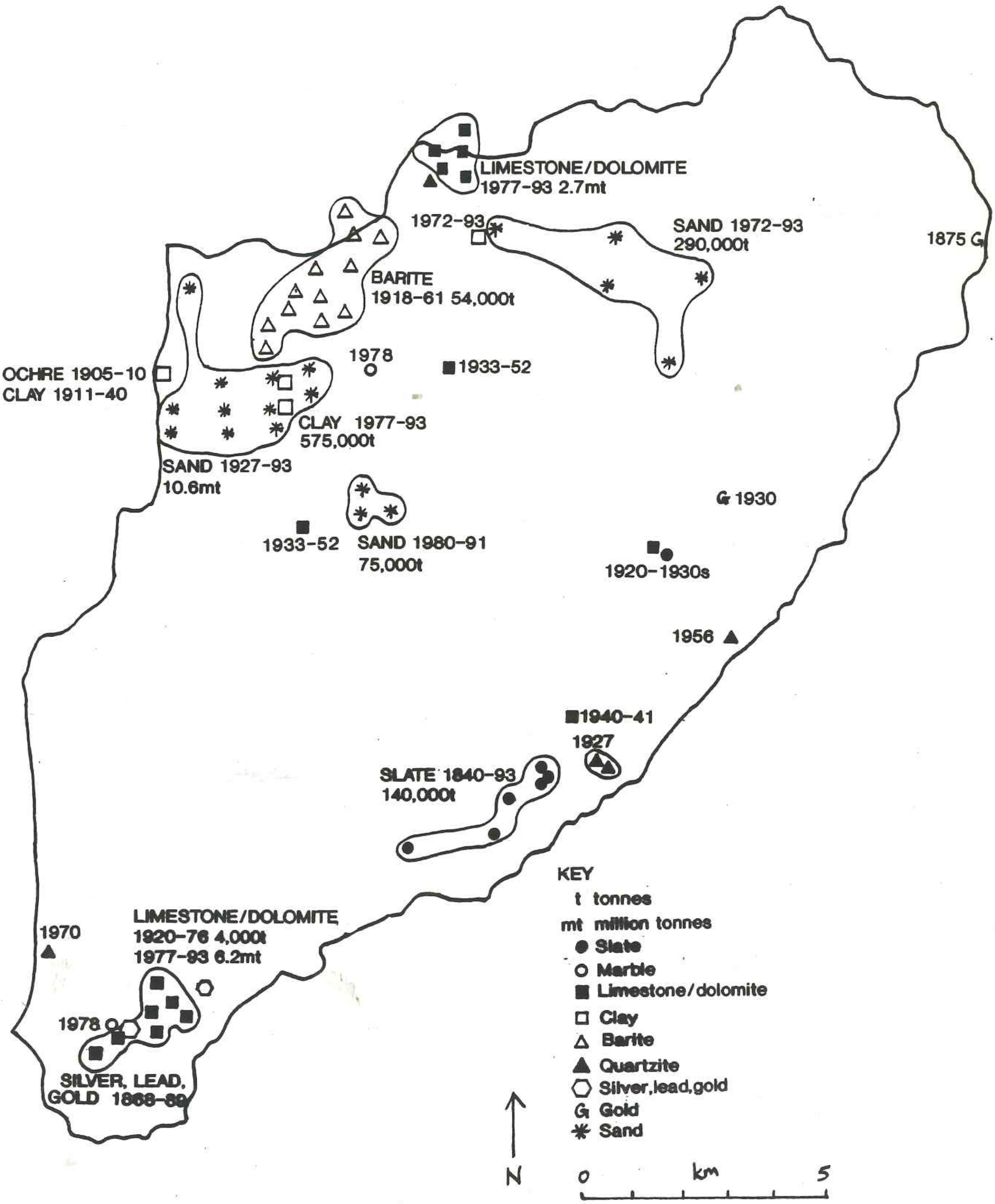


Note: Figures from 1840 to 1974 are averages for whole periods. These were calculated by dividing the total production amount over any period by the number of years. Figures after 1974 are plotted per annum.

Figure 41
Mine and quarry production in the Willunga Basin 1840-1993.
Source: Compiled by the author from data in Appendices 5A and 5B.

Figure 42
Main locations of mining and quarrying activity in the Willunga Basin 1840-1993, with dates between which the main operations occurred and indications of the scale of production. *Source:* Compiled by the author from data in Appendices 5A and 5B, and DMESA mine maps.

Note: Mapped at precise location within sections for dates before 1970; mapped in section generally for dates after 1970.



in their geographical extent. Slate has been quarried from the hills above Willunga, limestone/dolomite mined from around Sellicks Hill, sand quarried mostly near the coast in the Maslins area, and barite and limestone/dolomite produced from the far north and north-west of the Willunga Basin.

Slate was the first product developed in the Willunga Basin (Figures 40 and 41), and the earliest quarry was opened in the hills above Willunga in 1840. The Willunga Slate Quarries were the major Australian source of roofing slate from 1840 to 1933 (Ludbrook, 1980:142). Slate from these quarries was used, for example, to roof the General Post Offices in Melbourne and Adelaide, several University of Adelaide buildings, some public buildings in Perth, as well as local churches and houses, and to pave the streets of Adelaide (Lamshed, 1971:43). Some of the earliest settlers in Willunga lived in the Piltongga gully near the quarries (*The Observer*, 13 April 1844:7). The quarries were worked sporadically until slate became replaced by corrugated iron roofing and asphalt and bitumen paving (*The Register*, 18 August 1927). The slate industry declined after a peak in the late 1880s but it was revived in the 1920s (Shepherd, 1950) and, as Figure 41 shows, between 1900 and 1974 the quarries produced more slate per annum than prior to 1900, possibly due to the use of modern machinery. Smaller scale production since the 1970s has continued to provide paving, ornamental stone and replacement roofing for historic buildings. Waste slate has been powdered for industrial filler (Appendix 5A; Ludbrook, 1980). The two scenes in Plates 10 and 11 show that the quarry workings at the Bangor site were quite limited in their spatial extent and that between 1922 and 1974 the mine did not increase much in area.

Other materials mined from the Willunga Basin included gold, silver, lead, marble, barite, ochre, clay, quartzite, sand and limestone/dolomite. Gold and silver deposits in the hills were worked on a very limited basis between 1868 and 1930. A small amount of marble was produced in the late 1970s and early 1980s and barite was produced from the 1890s to the 1930s. Some ochre, clay and quartzite have been extracted periodically from the 1900s to the present, with clay production being the largest of these. However, the largest scale operations in terms of the numbers of quarries and the volume of material quarried has been sand extraction since the 1960s and limestone/dolomite mining since the 1970s (Figures 40 and 41).

Plate 10
Bangor Quarry 1922.
Source: Mortlock Library SSL:M B55748.

Plate 11
Bangor Quarry 1974.
Source: Department of Mines & Energy SA Historic Pictures Library, Photograph Number 26652.

A few changes are obvious since the 1922 photograph (Plate 10), including a new gum tree in the lower left hand corner and soil instability in the form of landslumps along the road behind the chimney and on the waste dump.

This increase was foreshadowed in 1970 by Pain and Hiern (1970:101) who emphasised both that the Willunga DC area contained one of the Adelaide Metropolitan area's two main sand sources and enormous reserves of limestone which could be exploited for coarse aggregate for the future southward expansion of the metropolitan area. In the past year public attention has been drawn to the presence of dolomite caves near the Sellicks Hill limestone/dolomite quarries (Buswell, 1994). These caves could be geomorphologically significant as well as holding potential for tourism. A potential source of glass-making and foundry sand mapped in 1970 was the Aldinga Scrub area (Pain and Hiern, 1970:103 Fig 2).

In summary, a wide range of mine and quarry materials have been produced in the Willunga Basin since 1840. Slate production was the earliest and has been the most continuous, but other materials have been produced since the turn of the century. There was a large increase in the scale of production from the 1970s onward, which may to some extent reflect the better recording system implemented, but which undoubtedly reflects increased demand for industrial and construction materials. However, although mining and quarrying has been locally intense, operations have been very limited in their spatial extent.

7.3.2 Timber use

No information is available which directly indicates the amount of timber felled or used in the early days of settlement before most of the tree cover in the Willunga Basin was cleared. Timber was probably extracted from some areas even before the surveyors or settlers arrived. "Tiersmen" or "Splitters" roamed the Stringy Bark Tiers (the Mt Lofty Ranges) splitting wood for posts and rails and palings for fencing (Dutton, 1846:202; Angas, 1847a:44; Hawker, 1899:14) and the stringybark forests were seen as an unlimited supply of wood for building and "the other thousand-and-one purposes of the settler" (Dutton, 1846:84). Stringybark was easy to split and work, made good roofing shingles and fencing, and along with peppermint gum provided fuel (Harris, 1986). Indeed, a settler arriving in Adelaide in 1847 noted that wood was the only fuel (Miller, 1895:26).

Clearing the tree cover not only made the land suitable for agriculture but also supplied wood to fence that land. Many thousands of acres in South Australia were only lightly wooded, particularly the plains, and so were suitable for grazing and cultivation without the need for clearance, (Morphett, 1836:9; Dutton, 1846:84), but denser tree cover could be removed cheaply and at leisure by ringbarking, enabling a whole field to be cultivated within one year (Dutton, 1846:202). The ghost gums and scattered dead timber shown in Plate 12 suggest that intentional tree clearance occurred in the hills above Willunga while the presence of standing ghost gums may indicate that ringbarking was practiced there. It is not known when the trees died.

Plate 12
Bangor Quarry 1911 or earlier. *Source:* Department of Mines & Energy SA Historic Pictures Library, Photograph Number 2905.

This undated photograph appeared in a 1911 Mines Review publication. It shows that large gums were cleared on the hills above Willunga, probably to remove the canopy cover and encourage grass growth. Low understorey species appear to have survived on the hillside behind the building.

Early settlers were "constantly ploughing or cutting and getting home wood for fencing or building" (Colton, January 1840 quoted in Linn, 1991:21), although the farmers of Willunga could not afford to fence their land in the early 1840s (Linn, 1991:32). Land in South Australia generally began to be fenced from 1850 onwards (Williams, 1988). In a sketch of Willunga drawn in 1850 (Plate 13) settlers houses were "stuck about among the trees" (Griffiths, 1988:78) and the tree stumps left in the fenced paddocks perhaps suggested newly enclosed fields. The following year the occupied land around Willunga was said to be substantially enclosed and the fencing almost entirely post and rail (*South Australian Register*, 26 March 1851). The Willunga DC requested some Timber Licenses in October 1853, possibly for this very purpose (Willunga DC Minute No 22, 1 October 1853).

Plate 13
Willunga, February 1850.
Source: A sketch by Edward Snell in Griffiths (1988), *The Life & Adventures of Edward Snell. The Illustrated Diary of an Artist, Engineer & Adventurer in the Australian Colonies 1849 to 1859.* Published by Angus & Robertson and the Library Council of Victoria.

This is one of the earliest sketches of Willunga to show the landscape in any detail. The view is down the main street of the township towards the coast, with the first Bush Inn situated on the right (Baxendale, pers comm, 1994). Tree stumps still remained in the paddocks, suggesting recent fencing activities. What appear to be grasstrees (yacca) are also visible in the foreground. They may be remnants of the native understorey which was cleared to prepare the land for cultivation.

By 1858 the amount of land enclosed had risen rapidly to 16,000 hectares. This correlates with the extensive amount of wooden post and rail fencing in Willunga by 1872, when the photograph shown in Plate 14 was taken. Both sides of the Old Sellicks Road had also been fenced in this manner by 1870 (Plate 8). The timber requirements of early settlers had the potential to remove a huge number of trees, since according to Dutton (1846:203) about 4,500 pieces of timber were required to enclose a standard 80-acre section with a three rail fence. Paddocks much smaller than this were fenced in the township of Willunga, as shown in Plate 14, and therefore could have necessitated the cutting of even larger amounts of timber.

Another reason for land clearance was road-making. Some roads were marked out and cleared of timber during the 1839 surveys, including the road from Old Noarlunga via McLaren Vale to Willunga. Hawker (1899:51-2) remarked how easy the sheoak was to clear along this road and also described unsuccessfully trying to blow up the larger timber with gunpowder to facilitate its removal, after which the surveyors resorted to clearing the trees manually by sawing them off a metre from the ground. In 1862, a "contract for grubbing [removing stumps and roots] and clearing at the top of the hill" was discussed in reference to road development in Willunga (Dunstan, 1977:60), although the size of the area in question is unclear.

Timber was probably also used as fuel to produce steam power for both flour mills, mines and quarries. Steam flour mills operated in the Willunga Basin from the 1840s to the 1870s, including two mills in McLaren Vale, one in Willunga (Baxendale, pers comm, 1994) and White's Mill near Aldinga which was built in 1844 (Dunstan, 1977:35). Although much use was made of timber for adit reinforcement and smelting in South Australian mines, such as at Burra, the open cast quarrying and mining in the Willunga Basin did not require this. Nevertheless, the area around most mines was probably cleared to some extent to improve access. Steam driven equipment was introduced at Martin's Quarry in 1881, possibly fuelled by local wood, and at Bangor Quarry in 1920 (Appendix 5A), by which time the wood supplies around Willunga had been exhausted.

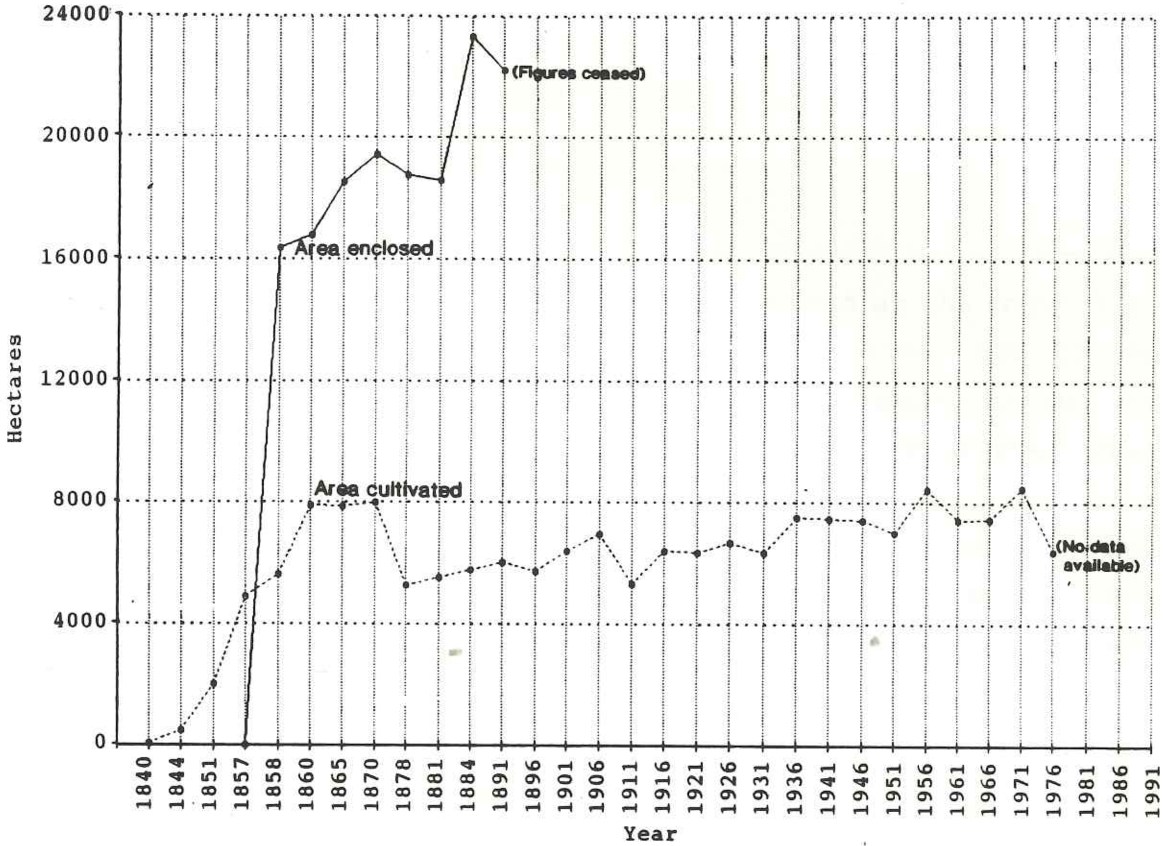
7.3.3 Area enclosed and cultivated

The area of land in the Willunga Basin which was cultivated rose rapidly between 1840 and 1860 (Figure 43). By 1858 a peak of 8,000 hectares was reached and 16,000 hectares of land was enclosed. Agricultural expansion

Plate 14
Willunga township c1872.
Source: Mortlock Library SSL:M B10598.

This view of Willunga shows the extensive use of wooden post and rail fencing by the 1870s. Note also the tall, large eucalypt trees found on the foothills where Willunga was established.

Figure 43
Trends in the area cultivated and the area enclosed in the Willunga Basin 1840-1991. *Source:* Compiled by the author from statistics collected from various sources as indicated in Section 7.1.



proceeded so quickly that by 1858 it was thought that the supply of new ground in the area would soon be exhausted (*The Chronicle*, 24 July 1858). Only twenty years after the first surveyors had struggled through the scrub, several thousand people were living in the Willunga District, and they had transformed the landscape, as proudly described in an 1858 newspaper report thus:

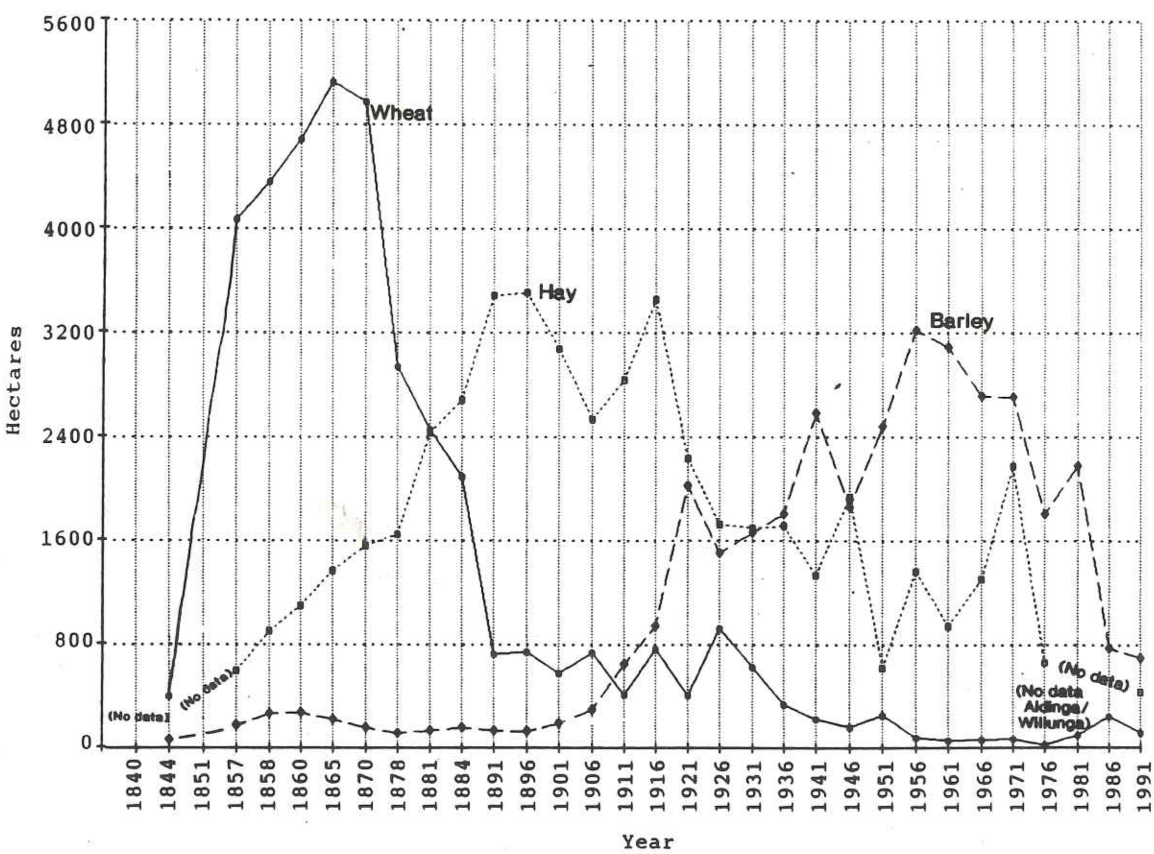
> "The country round Willunga is one of the oldest agricultural districts in the colony, and the quantity of arable land under cultivation will bear a fair comparison with the most important wheat producing portions of the province.... The numerous thriving farms striking out in every direction are particularly gratifying, being mapped out into paddocks and sections with geometrical regularity, the alternating colours which their various crops in seasons present to the eye being especially pleasing" (*The Chronicle*, 24 July 1858).

By 1865 the amount of land enclosed covered approximately 60% of the study area but figures ceased after 1891, probably because most land was enclosed by then. However, while the amount of land enclosed continued to rise to a peak of almost 24,000 hectares by 1884, the area cultivated declined in the 1870s, reflecting population trends. Unlike the population which did not recover until the 1930s, the area cultivated increased gradually again between 1878 and the 1950s and then remained more or less unchanged after that time.

7.3.4 Crops

The trends in the area under crops such as wheat, hay and barley from 1840 to 1991 are shown in Figure 44. Wheat quickly developed as the major crop in 1844 and by 1865 covered about 5,000 hectares (over 60% of the cultivated land), but the area planted then decreased rapidly to only 800 hectares 25 years later. After only a relatively short period under wheat the soils on the plains had become exhausted, resulting in declining yields (Linn, 1991:80). Furthermore, 'red rust' crippled crops (Shepherd, 1950) and there was competition from larger wheat-growing farms in newly developing parts of the state (Bourman, 1975). Wheat acreage has declined

Figure 44
Trends in the area under wheat, hay and barley in the Willunga Basin 1840-1991. *Source:* Compiled by the author from statistics collected from various sources as indicated in Section 7.1.

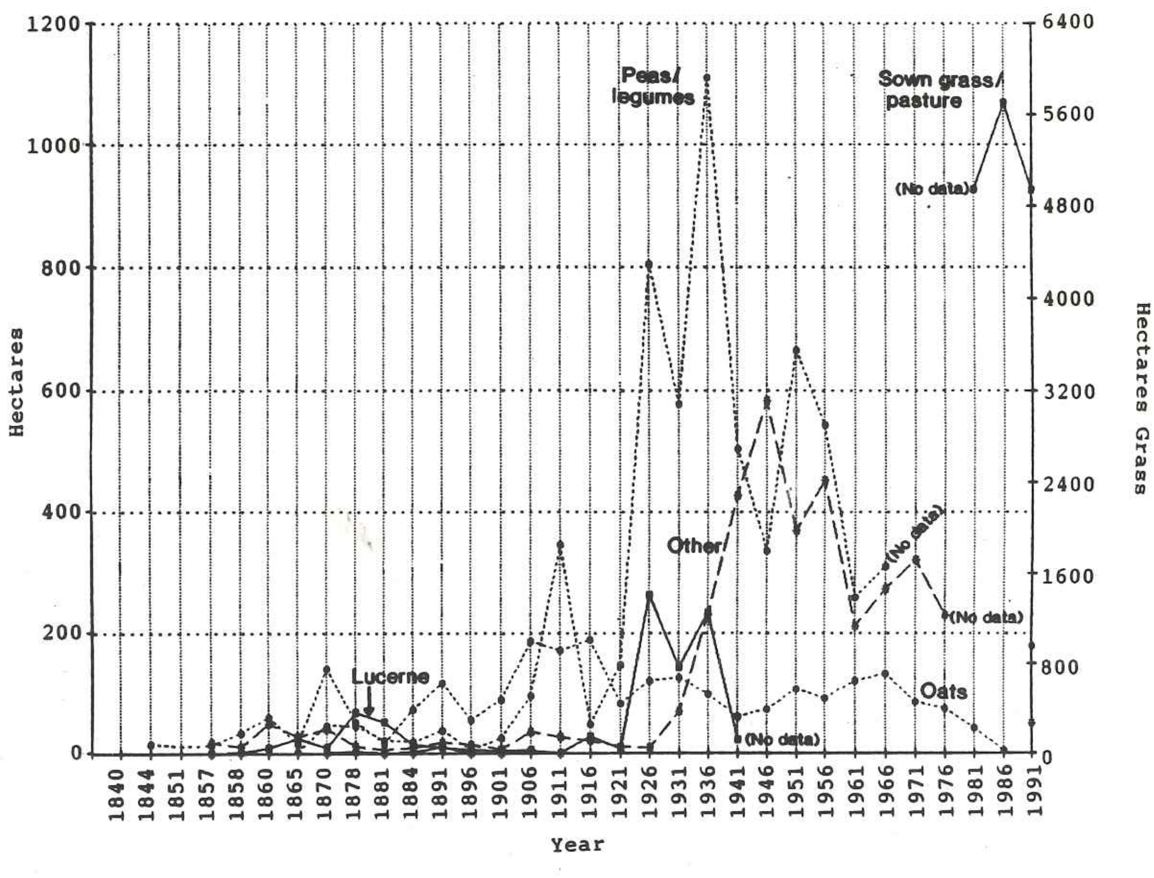


ever since 1870 and wheat is now only grown on a few hundred hectares. Hay emerged as a more important crop than wheat in 1881, particularly in the Aldinga and Willunga DCs. Hay was favoured over wheat for its better financial returns, but declined when the need for horse feed diminished early this century (Pim, 1939). In the early days, barley had not been worth growing because distillation was more or less prohibited (Dutton, 1846:204) but barley became more important after the turn of the century so that the maximum area under barley was reached in the mid-1950s.

In 1991 the area under these major crops was very limited. A variety of other crops have always been grown in the Willunga Basin, including oats, peas and beans, lucerne, flax, green forage, potatoes and market garden produce. Figure 45 shows the trends in the area under these crops. Of particular note is the swift increase in the acreage under peas and beans after the 1900s. The area under sown grass (also called pasture) increased substantially between the 1940s and the 1980s.

Figure 45
Trends in the area under crops other than wheat, hay and barley in the Willunga Basin 1840-1991. *Source:* Compiled by the author from statistics collected from various sources as indicated in Section 7.1.

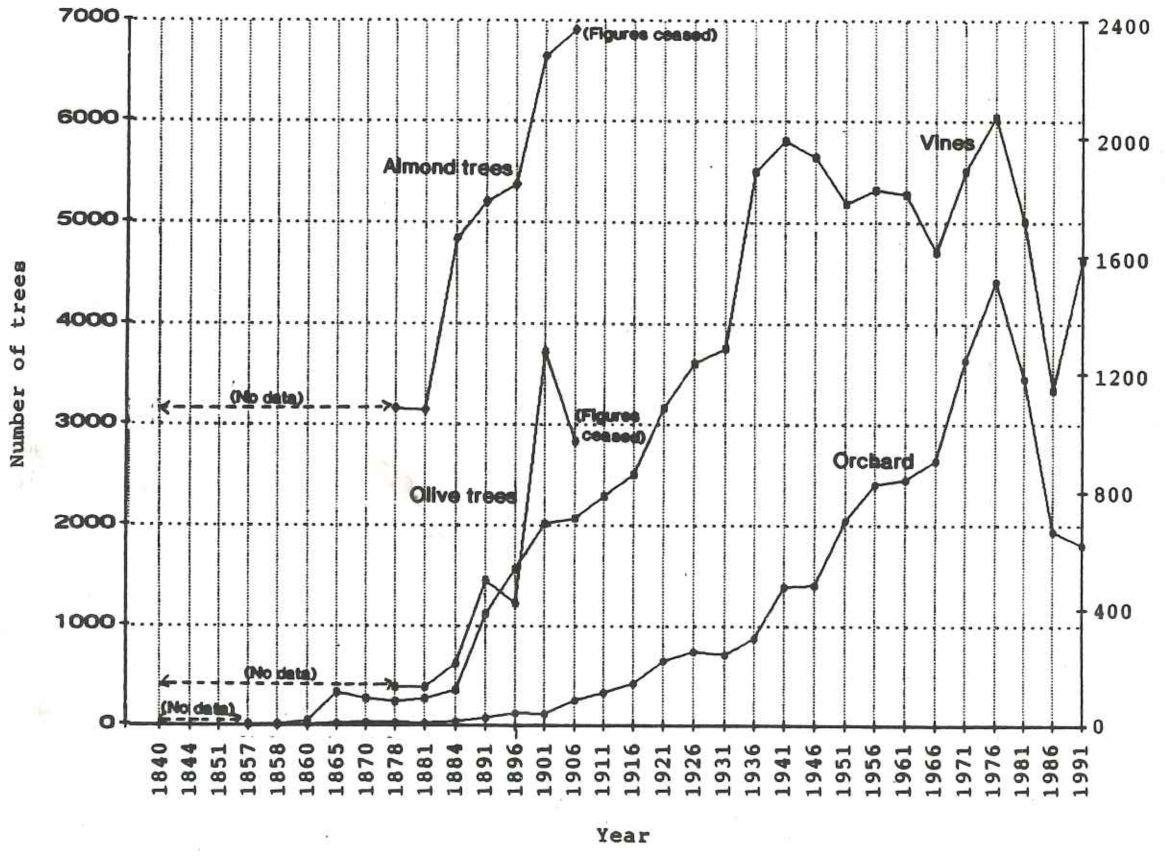
Note: "Other" includes potatoes, green forage, flax, garden, vegetables and 'other'.



7.3.5 Vines, almonds, orchards and olives

The Willunga Basin is well-known for its vines, almonds and orchards. As Figure 46 shows, there was a striking increase in the number of almond and olive trees grown in the district between the late 1870s and the turn of the century, but figures for these products were not recorded by DC after 1906. Figure 46 hides the fact that the majority of the increase in the number of almond trees by 1901 occurred in the Aldinga and Willunga DCs (approximately 5000 trees out of 6600). The overall area planted to vines increased rapidly from the 1880s and reached a peak in the 1940s, then declined somewhat, before rising again in the 1970s. Over half the vineyards were in the Noarlunga DC, undoubtedly accounted for by the Southern Vales wineries to the north and north-east of McLaren Vale. Although the foundations of viticulture and winemaking in this area had been laid in the 1850s, in 1888 "vine mania" swept over the whole of South Australia and viticulture in the state began to assume the importance it has today (Halliday, 1985). Since the area under vines generally increased in the Aldinga and Willunga DCs from the mid-1970s, the area in Noarlunga DC must have declined, probably due to vineyard conversion to residential

Figure 46
Trends in the area under fruit and nut production in the Willunga Basin 1840-1991. *Source:* Compiled by the author from statistics collected from various sources as indicated in Section 7.1.



land mainly outside the Willunga Basin and nearer to Adelaide. In the mid-1980s the area under vines began to increase again, and new vineyards are appearing today in the McLaren Vale and Willunga areas, spurred on by the increasing popularity of South Australian wines.

7.3.6 Livestock and grazing

An insight into land use in the Willunga Basin before agricultural and livestock statistics were collected can be seen in census information for 1844 to 1855 (SAGG), as presented in Table 12. Some grazing obviously occurred in the Willunga Basin before settled farmers became established. However, the rapid rise in the amount of land enclosed probably accounts for the decline in shepherd numbers from sixteen in 1846 to none by 1851.

Table 12
Indication of land use activity 1844-1855 in the area "South of the Onkaparinga River to the Willunga Hills". *Source*: Occupation data in the census returns included in SA Government Gazettes.

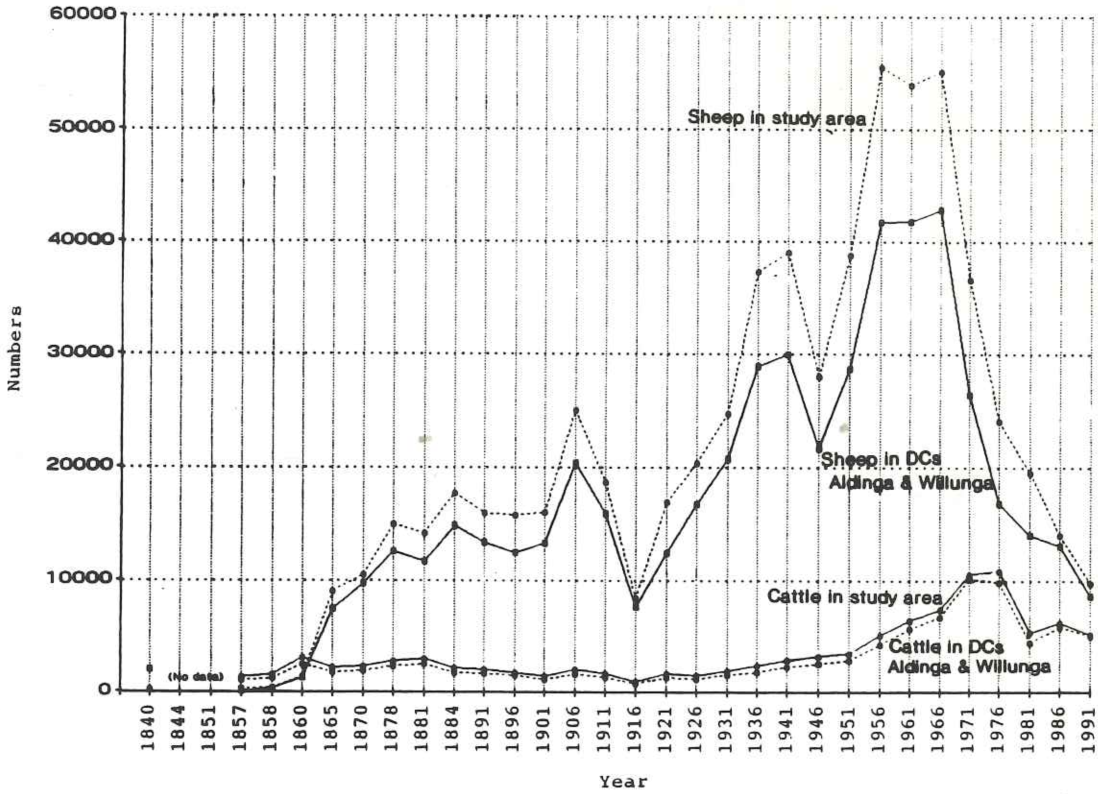
Date	Shepherds and others in care of sheep	Stockmen and others in care of cattle	Gardeners farm servants others in agriculture farm labourers	Farmers
1844	24	16	120	N/A
1846	16	0	14	N/A
1851	0	1	N/A	196
1855	2	0	227	258

Cattle numbers have always been at relatively low levels, although they increased from the mid-1950s (Figure 47). Bullocks were preferred over horses in the early days for breaking new ground (Dutton, 1846:203) and some of the earliest statistics gave figures for these. Although the figures for all cattle are aggregated to be consistent with earlier data, dairy cows predominated until the 1950s, but beef cattle took over in the 1960s and accounted for most of the increase through the 1970s. This trend is probably associated with the rapid increase in the area sown to grass between the 1940s and 1980s, indicated in Figure 45.

Sheep numbers remained low until 1858. Although 2000 sheep were reported in the McLaren Vale area in 1840, official numbers for 1857 and 1858 were only a few hundred. However, by 1865 numbers had reached 9,000, peaking in

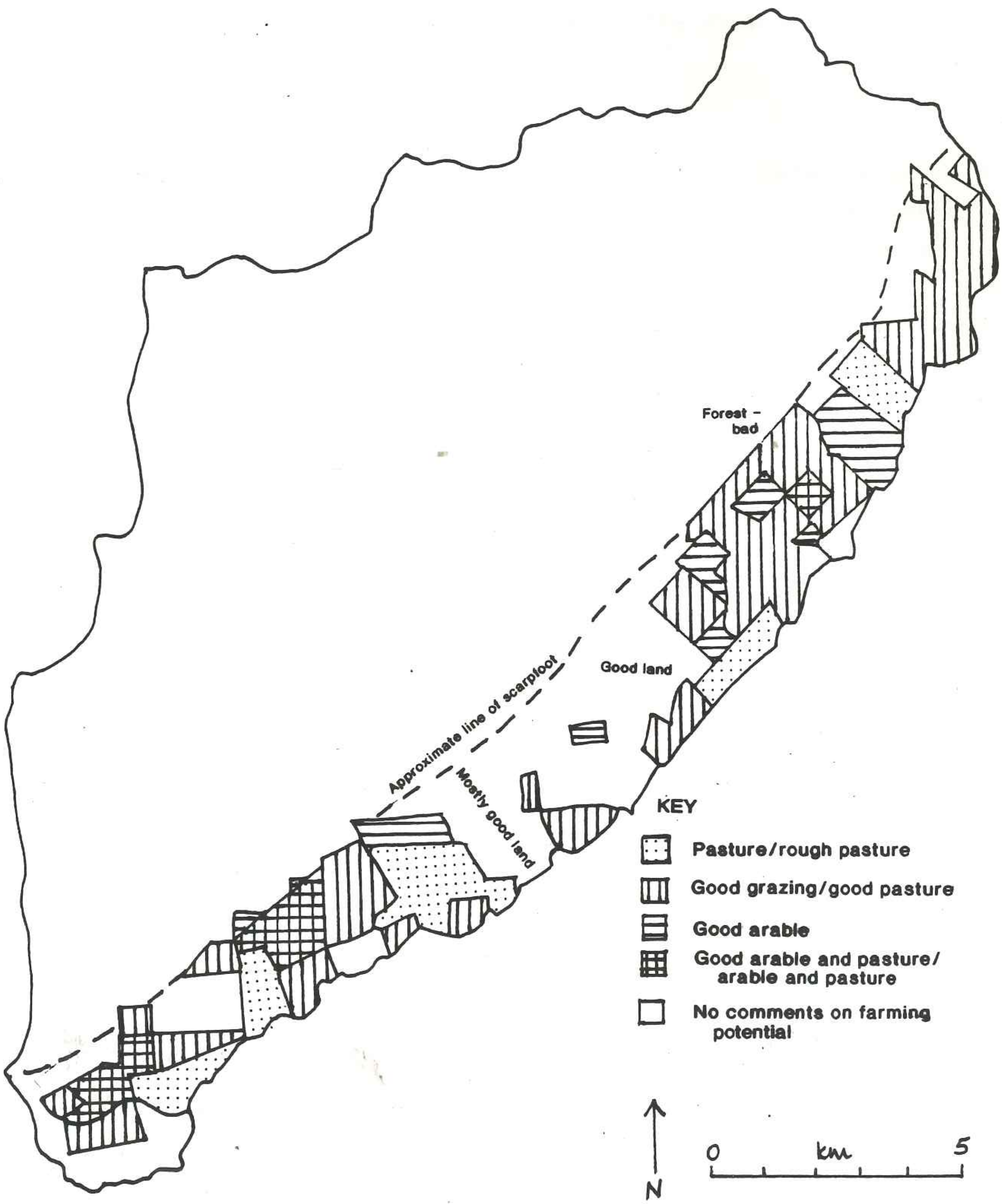
Figure 47
Trends in cattle and sheep numbers in the Willunga Basin 1840-1991.
Source: Compiled by the author from statistics collected from various sources as indicated in Section 7.1.

Note: 'cattle' excludes bullocks, as bullock numbers were only given for the earliest years. The category 'cattle' initially covered 'horned cattle' but later became 'cows and calves'. Up to 1935 'sheep' represents 'sheep including lambs', from 1935 it was 'total sheep'.



1867 in Aldinga and Willunga DCs. Most of the livestock were counted in the Aldinga and Willunga DC areas. Until the 1890s livestock numbers in Aldinga DC fluctuated between approximately 5,000 and 9,000 and in Willunga DC between 3,000 and 13,000. Surveyors of the hills sections between 1850 and 1856 had noted that large areas were suitable for grazing and pasture, as shown in Figure 48. Between 1860 and 1884 sheep numbers in the Willunga Basin increased at least twelve-fold to over 17,000. Many of these may have been grazed on the main range because in 1889 it was reported that a large number of sheep were depastured on the bare grassy hills around Willunga, although the undulating hills west of McLaren Vale were also used for grazing (Sutherland, 1889:4-7). Sheep numbers declined during World War I but then increased to an all-time high of around 55,000 head between the mid-1950s and mid-1960s, following the Australia-wide trend as wool

Figure 48
Farming potential on the Sellicks Hill Range as noted in survey records from 1851 to 1862. *Source:* Compiled by the author from survey records as given in Appendix 4.



prices rose, partly associated with increased demand for woollen army clothing during the Korean war. Sheep and fat lamb breeding had taken over from hay production in the 1930s as superphosphate applications and pasture cultivation aided the sheep industry (Pim, 1939). Sheep numbers declined from the late 1960s to only 10,000 in 1991, probably due to the fact that the Willunga environment was more suited to other land uses which would have become more attractive as the fortunes of the sheep industry changed.

7.3.7 Drainage and Irrigation

Settlement in the Willunga Basin was initially located adjacent to accessible water supplies, as was often the case in early Australian settlement, but those areas sometimes proved to be too wet or too dry for comfortable living, necessitating drainage or irrigation measures. This Section will examine the consequence of human settlement on the environment in terms of the drainage and irrigation works carried out in the Willunga Basin. Enquiries were directed to the Engineering Department of the Willunga DC and local history researchers G & D Vaudrey to determine the dates of construction of drainage channels in the area. It was found that no consolidated official records existed because most of the drainage works were constructed by private landholders. However, evidence of problems with surface drainage in the 1850s was found in the minutes of the Willunga District Road Board and the Willunga DC, along with references to court actions and complaints by the Council and landholders. Early settlers felt a need to construct drainage channels to protect their housing and crops. Properties around Willunga were affected by water flowing from teatree swamps and springs, and heavy flood runoff from the hills, while other properties became inundated when floodwaters spread out over the plains.

The problems caused by channel cutting on private land were highlighted by attempts to prevent interference with the "natural course" of any surface water. In the 1850s, the Willunga DC insisted that landholders confine the water running through their land "to the natural course" and gave notice to others that they must "not turn any stream of water from its natural course" (letters dated 3 October 1853, Willunga DC Minutes). Nevertheless, landholders did cut plough furrows along their fencelines to redirect surface water, such as occurred on the south side of Section 257, where a plough furrow was cut along the road to take water away from a swampy area (G Vaudrey, pers comm, 1994).

Settlers in the Willunga Basin had tried to control excess surface water at least since the 1850s and the cutting of channels was often seen as the answer to this problem. Large volumes of water were said to run off the hills during heavy rains (*The Chronicle*, 2 June 1860; Sutherland, 1889) and some excess water also resulted from the clearance of tea-tree swamps from the springs and gullies at the foot of the range (*The Observer*, 13 April 1844:8; Aldam Private Papers, undated). In 1851 Hewett drew attention to the need to cut a "main large drain or canal" through the flat lands near McLaren Vale to take floodwaters away from the plains to the sea. He complained that such water inundated large areas of wheat, killed or weakened the crop, injured "the land from immediate working to sow maize" and brought with it "seeds of various sorts of the worse description - drake, wild oats, etc" (Hewett, 1851). A direct channel to the sea was favoured over the natural "serpentine course" of the streams which rendered more land than necessary subject to overflows.

The authorities could not avoid their responsibilities regarding surface drainage indefinitely. In 1850 the Commissioner of the Willunga Road Board received a complaint about water being diverted from its original course by certain landholders in the Willunga area. The complainants feared that the diverted water would damage the roads, overflow onto their own land in winter, and generally damage their crops (Willunga Road Board Minutes, 1850). The origin of the problem was explained during legal investigations into the precise powers of the Road Board Commissioners for cutting new drains or watercourses to take water away from the roads onto land where no water course could be traced. It was stated that:

> Before the lands where [*sic*] inhabited at the floods, and generally at other times, as (the water) flowed over the surface and not being confined it did not leave any tracing and of course ran into the lowest land. But now by fencing it has obtained a regular course to a certain distance and where parties are interested they have turned it to answer their own purpose and in many instances to the great injury of the roads (George Stephens, Barrister at Law, 10 July 1851 Adelaide, Willunga District Road Board Minutes).

A notable dispute about the management of one watercourse occurred in the early 1860s (outlined in Miller, 1895:89-90; Vaudrey, 1991). A widow living in Willunga wanted the water from a nearby spring to be conducted onto her property to irrigate her market garden so she could derive some income, but she also wanted floodwaters from a large gully to be kept out.

The widow's late husband had cut a channel to conduct water away from its "natural course" towards the garden whilst mixing materials to build their cottage. To help settle the dispute the Reverend Miller suggested that another drain should be cut to take floodwaters away from the property. The widow took legal action against the Willunga DC for depriving her of water, and the case continued unsettled with delays and court actions until the late 1870s. Eventually the widow's property went to her lawyers in repayment of the legal fees, although she was allowed to continue living there. The lawyers then sued the Council in her name and a drain was eventually built, but by this time the spring and soak had dried up (Vaudrey, 1991).

Most of the major drainage channels on the Aldinga Plains were built after the 1930s (Boulden, pers comm, 1994) and appear as straight lines on surface drainage maps (Figure 22). These channels gradually extended westwards between 1926 and 1963 until they had reached the coast by 1992. In addition to the efforts directed at removing excess water, considerable trouble has also been taken more recently to acquire water for agriculture and pastoral activities. This has probably only occurred on a large scale since the early 1970s. The changeover to irrigated vineyards and orchards began sometime between 1958 and 1977 (Bowering, 1979:3) and the first investigation into the groundwater resources of the Willunga Basin only occurred in 1974 (Waterhouse & Barnett, 1974). Some surface water has been directed away from natural drainage lines into farm dams, particularly in the Blewitt Springs area in the north-east of the Basin. This became apparent between 1963 and 1984 when a series of dams were developed, particularly in vineyard areas, and resulted in discontinuous streamcourses (Figure 22 and Department of Lands, 1984). The Port Willunga Formation aquifer was most extensively developed for irrigation in an area bounded by McLaren Vale, McLaren Flat and Willunga, and the Maslin Sands aquifer provided good yields between McLaren Flat, Blewitt Springs and Kangarilla. Limited groundwater supplies were also obtained for stock and domestic use from the shallow Quaternary aquifers underlying most of the plains (Bowering, 1979:7-8). The rate of natural recharge of the Basin is now deemed to be equal to the current rate of extraction, and in order to control future groundwater use the Basin became a Proclaimed Well Area on 1 January 1991 (Planning Advisory Services, 1992).

7.4 SUMMARY OF FINDINGS

The Willunga Basin has had one of the longest histories of land use in South Australia, with settlement and quarrying beginning in 1840, only four years after the official establishment of the colony. The population increased after 1840 and was associated with rapid agricultural development. Early settlers cut timber for many purposes and also saw a need to cut drainage channels to reduce surface water and prevent flooding. Channel construction on a larger scale occurred from the 1930s, particularly on the Aldinga Plains. The population remained at relatively low levels for decades although it peaked in the mid-1860s but then declined again so that the 1860's level was not reached again until the 1930s. By 1991 all of the previously extensive major land uses accounted for only a small area within the Willunga Basin. Since the 1880s the rising dominance of more intensive land uses has been reflected in the fortunes of the various industries and since the 1960s has occurred alongside a rapid population increase, as more extensive land uses continued to move to areas further from Adelaide. A range of mining and quarry products has been extracted from the Willunga Basin since 1840, but production has occurred on a much larger scale at a number of localised sites since the 1970s. With such a range of land uses occurring in the Basin several planning studies at local and state government levels have been completed in recent years with the aim of controlling and directing future development trends to ensure they are suitable and beneficial for the area.

Although sequent occupance studies are no longer popular, since the division of the past into discrete categories is often arbitrary or does not coincide in all factors studied, the method is still useful to summarise major periods of settlement. Bourman (1975) identified four major modes of land occupance on the South Coast Region of South Australia. The Willunga Basin also experienced these major modes but with some slight differences, which are identified in Table 13.

Table 13
Bourman's four modes of land occupance in the South Coast Region of South Australia compared with the Willunga Basin. *Source:* Compiled by the author, based on Bourman (1975).

Mode of Occupance	South Coast	Willunga Basin
1 Primitive Occupance	Until 1836	Until 1840
2 Pioneer Occupance, with whaling and subsistence agriculture	1836-1855	1840-1845, no whaling
3 Commercial Grain Farming and Trading Occupance	1860-1900	1846-1880
(Intensive Farming Occupance)	Not experienced	Since 1880
4 Pastoral and Recreational Occupance	Since 1920	Pastoral since 1920 Recreational since 1970

CHAPTER 8

DISCUSSION AND CONCLUSION

The aim of this thesis was not only to establish major trends in the Environmental History of the Willunga Basin since the 1830s but also to use that information to explain some of the main environmental problems currently experienced in the area. The problems were outlined in Section 2.1.6 as a minimal amount of remnant native vegetation in the Willunga Basin, flooding on the plains in winter, and gully erosion in some parts of the area. The historic trends which have been established from the research are summarised in a relative context in Figure 49. This allows comparison of the nature, timing and magnitude of change for the discussion which now follows.

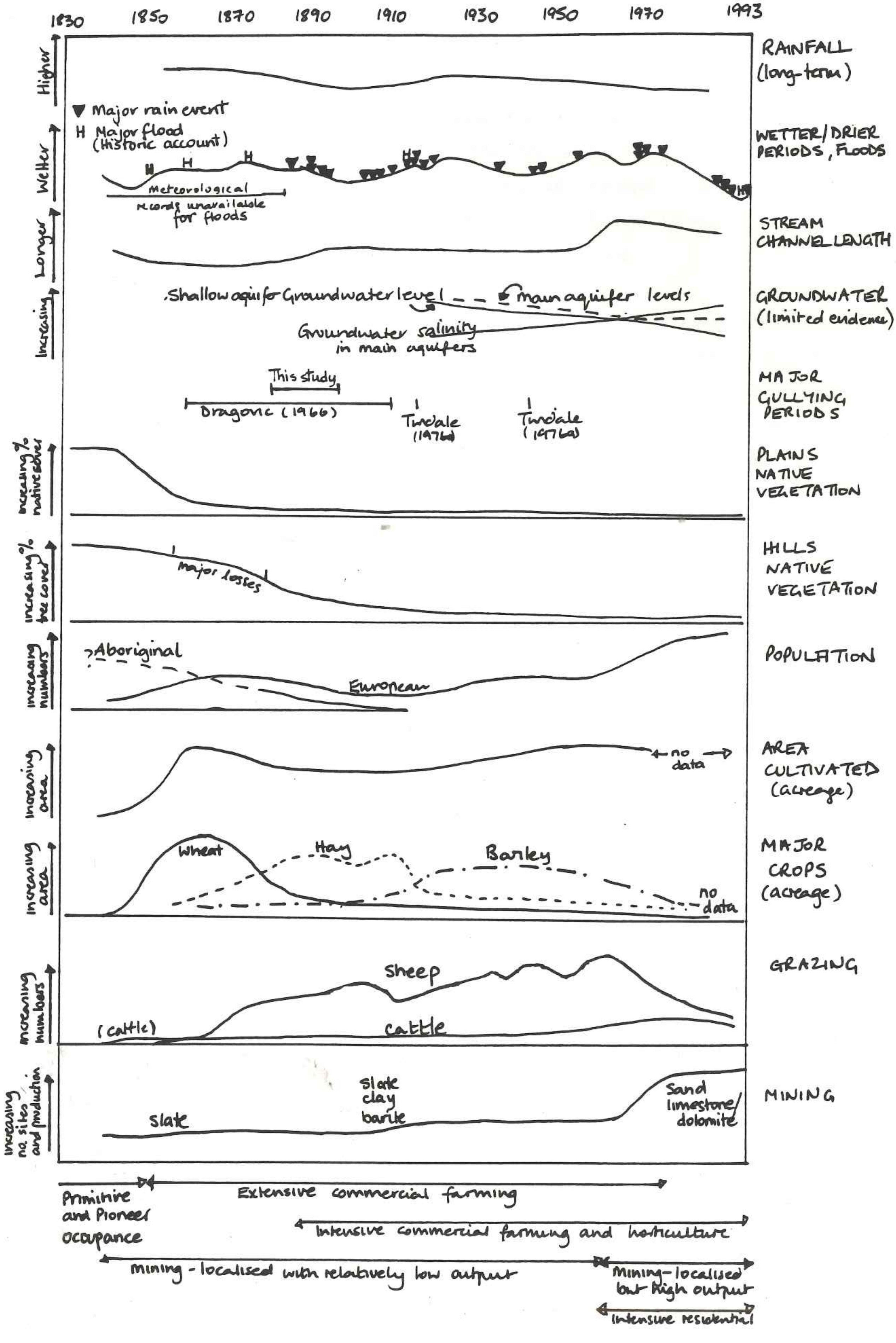
8.1 VEGETATION

8.1.1 Discussion of the vegetation history

Vegetation plays a key role in the environment and so vegetation change can influence other factors, including soil erosion, hydrology and fauna. Only small pockets of native vegetation remain in the Willunga Basin today, but this is not surprising considering the extent to which the area was rapidly developed for extensive European agriculture. Timber use and agriculture on the Mt Lofty Ranges and Adelaide Plains in general resulted in 95% of the native vegetation being cleared by 1976 (Williams, 1988). However, since the Willunga Basin was one of the first areas to be settled in South Australia its plains vegetation had already been largely replaced by agricultural land uses by 1860, while the almost complete denudation of tree cover on the main range and foothills was achieved by the late 1880s.

The large-scale loss of native vegetation on the plains can be linked to the rapid increase in the extent of cultivated land between 1840 and 1860 when wheat was the predominant crop. The plains were undoubtedly surveyed first because they were easier to convert to farmland than the hills. The order in which native vegetation was cleared in Australia was generally determined by the amount of physical effort involved, with light timber

Figure 49
Summary diagram of historic trends in the Willunga Basin from the 1830s to the 1990s. *Source:* Compiled by the author.



and scrub being removed before larger trees (Williams, 1988). The demise of native grassland on the plains would have resulted partly from trampling and grazing by introduced stock, since native grasses (*Themeda* species in particular) have only slight powers of regeneration after being closely grazed (Adamson & Osborn, 1924). Scattered trees may have survived longer on the plains than on the hills because those trees were originally more dispersed. Trees on the plains in the Adelaide region were often far enough apart for farmers to be able to plough around them, negating the need for removal (Dutton, 1846; Harris, 1986). Large trees also survived in and around the townships and along some creeklines.

A combination of factors probably caused the decline in tree cover on the Sellicks Hill Range, which occurred mainly between the 1860s and 1880s. Firstly, timber cutting for many domestic purposes occurred from the earliest days of settlement. It was responsible for quickly removing the entire tree cover from locations around Adelaide (Harris, 1986) and was undoubtedly exacerbated by the early settlers' perception that timber supplies were inexhaustible. Secondly, fencing of land on the plains and foothills, which increased particularly around Willunga from the 1850s onwards, required large amounts of wood and this was probably obtained initially from the foothills and then from the higher slopes.

Thirdly, when the wooded hills were first surveyed in the 1850s many areas were noted as suitable for grazing or arable farming. The open canopy and grass-like flora of the open forests and woodlands on the lower slopes of the Mount Lofty Ranges were indicative of pasture land to early settlers and so were used for grazing (Adamson & Osborn, 1924). By 1858 large-scale clearance of the Sellicks Hill Range for grazing and farming would have been more attractive because land availability on the plains had been exhausted. It is significant that a twelve-fold increase in sheep numbers occurred between 1860 and 1884, coinciding with the major period of tree losses on the range. Grazing may have increased on the range to partially compensate for decreasing wheat yields on the plains, associated with declining soil fertility in the 1860s. Grazing can affect tree cover because, prior to the introduction of cattle and sheep by Europeans, the Australian vegetation was not subjected to concentrated close-grazing by herbivores (Adamson & Osborn, 1924). This directly and indirectly contributed to tree decline because the seedlings of many species were palatable fodder, and overgrazing and trampling would have prevented germination by making the ground hard (Gill, 1893).

Once the main timber trees had been removed, much of the remaining native vegetation may have been cleared to encourage pasture development and to prepare arable land. Rusty farm implements and stones cleared to the side of fields are evidence that the hills were cropped at some time (Campbell, pers comm, September 1994). The ringbarking of trees to encourage grass growth would also have prevented regeneration by killing seed trees (Gill, 1893; Adamson & Osborn, 1924). Grazing was not carried out in the stringybark forests as much as in lower altitude forests because the undergrowth plants of the stringybark forests lacked nutrient value (Adamson & Osborn, 1924). However, many stringybark trees on the Sellicks Hill Range must have been completely removed for timber, or felled and burnt to prepare farm land, since stringybark regenerates readily from stumps unless these are killed by burning following clearing (Adamson & Osborn, 1924). Burning was used to clear the hills near Adelaide for farming (Gill, 1893) and may have been used in the Willunga Basin. As well as timber use and farming, the conversion of the hills to grassland by the late 1880s may have been assisted by the ten-year drought which lasted from 1879 to 1888, as it would have intensified grazing pressure and reduced the possibility of natural regeneration.

Fourthly, mining may have contributed to declining tree cover on the hills. The area around the Willunga slate mines was probably cleared to improve access from 1840, and the earliest settlers who lived in the gullies near the quarries probably obtained wood from the hillside. Martin's Quarry reopened in 1863 and steam sawing equipment was introduced by 1881. This quarry might have used local timber as fuel until supplies ran out, which could account for the completely bare hillside above the quarry by 1880 (Plate 6). By comparison, the Bangor Quarry was not reported as having steam equipment until 1920, and in 1911 there were still scattered trees, ghost gums and fallen scattered timber on the surrounding hillsides (Plate 12). The hills between Willunga and the sea are today almost completely denuded of tree cover while the hills north-east of Willunga still have some remnants. The early presence of quarries immediately south-west of Willunga could have contributed to this contrast. Underlying geological differences could also have played some role, as well as the fact that the hills to the south-west are steeper. This could have affected soils and therefore possibly natural regeneration. However, there may be other contributing factors which have not been covered in this thesis.

The evidence presented indicates that the main factors leading to the conversion of the Sellicks Hill Range from woodland to almost complete grassland by the late 1880s were the gradual loss of trees for timber use from the earliest days of settlement, tree clearance around mine sites and settlers' homes from 1840, the intentional clearing of trees for extensive farming from the 1860s, and the continual prevention of natural regeneration and the loss of seed trees due to the grazing of regenerating seedlings by introduced stock from the 1860s. The drought conditions of the 1880s would also have exacerbated the impact of these land uses.

8.1.2 Explanation of the remaining native vegetation

Native vegetation in the Willunga Basin has been highly fragmented by European land use and the present-day remnants seem to have survived only because their location was unsuitable for other uses. The small remnants in the north-east of the Basin occur on land which was labelled in the early survey records as sandy and scrubby and which was not surveyed until 40 years after the plains. Although in 1958 the native vegetation in this area was only patchy, it became even more fragmented by 1977 as new vineyards were established. The largest remnant of native vegetation today, the Aldinga Scrub, was also specifically designated as "forest land, sandy and scrubby" in 1839, suggesting poor farming potential. However, although the Scrub area still survives it has declined in areal extent since 1839, as it was sub-divided before World War I, was then subjected to several unsuccessful attempts to farm it (NPWS, 1993) and was encroached upon by urban development in the 1960s. Its survival today is largely attributable both to its location on sandy soils in an area subject to inundation (Wollaston & Kraehenbuhl, 1986:6) and to the Willunga Council's concern in the 1960s that sub-division would cause soil erosion. As a result it was purchased by the Council between 1965 and 1982 as Open Space and was declared a Conservation Park in 1985 (NPWS, 1993).

The scattered woodland remnants along the top of the Sellicks Hill Range may remain today because stringybark forest was known to occupy the least valuable soils and because these forests were not particularly suitable for grazing (Adamson & Osborn, 1924). These remnants lie near to much larger remnants which exist just outside the Willunga Basin, to the east over the hilltop in the Hundreds of Myponga and Kuitpo. In contrast to the Willunga side of the range, the area to the east remained as largely wooded and uninhabited scrub until the 1930s and when the Willunga railway was commenced in 1913 timber supplies had to come from the Hundreds of Myponga and Kuitpo because no timber remained around Willunga (G Vaudrey, pers comm, July 1994). Timber from this area to the east was also taken to mines at Broken Hill during World War I when American timber imports were restricted (G Vaudrey, pers comm 1994). Other remnants of native vegetation in the Willunga Basin survive along roadsides, on a few small private properties, in swampy areas along creeks, or scattered over the hills. Their plant communities are in various states of completeness.

8.1.3 The effect of vegetation change on native fauna

Although in pre-European Australia the distribution of native fauna was determined to some extent by Aboriginal people, for example through the introduction of the dingo and the firing of some vegetation types (Aslin, 1986), European settlement and land use activities have had a much greater impact in a much shorter time. In the Willunga Basin European arrival rapidly resulted in the widespread loss of grasslands and woodlands. This contributed to the eventual loss of some species which had once been recorded in the area, as set out in Table 14. The losses were accelerated by direct killing for food, sport, profit or as pests, and competition from other species and predators (native and introduced), particularly as protective vegetation cover was removed (Aslin, 1986).

Some native species have survived although the number of individuals has declined. Cape Barren Geese were reported on the Aldinga wetlands in the 1930s and still visited that area in the 1980s (Friends of the Earth, 1991). However, their numbers in South Australia were substantially reduced by the 1950s due to habitat loss, hunting and conflict with farmers, but special management action allowed numbers in the state to rise and stabilise at around 3000 to 4000 by the mid-1980s (NPWS, 1988). The fact that these geese have been noted in the Aldinga area is not surprising for it lies directly on the route outlined by the NPWS (1988) from the major breeding ground near the Eyre Peninsula to the main summering areas around Lakes Alexandrina and Albert at the mouth of the Murray River. Any future plans to reintroduce species formerly found in the Willunga Basin, or to encourage the number of individuals of any species to increase, would depend largely on the provision of adequate habitat range and type, and protection from predators and competitors.

Table 14
Current status of fauna species in the wild which were identified in Section 6.2.7 as formerly inhabiting the Willunga Basin. *Source:* Compiled by author based on information gathered in Chapter 6, and other sources as stated.

Species	Current status
Dingo (*Canis familiaris dingo*)	Largely excluded now from southern South Australia by the 'Dog Fence' built to protect the grazing industry (Strahan, 1993).
Brush-Tailed Bettong (*Bettongia penicillata*)	Extremely common in South Australia until the 1920s, are now completely absent from the state and almost all mainland Australia (except in sanctuaries) due to hunting for sport, predation by cats and foxes and habitat loss (Aslin, 1986)
Rat-kangaroo ?Lesuer's or Burrowing Bettong (*Bettongia lesueur*)	Had one of the largest geographic ranges of any Australian mammal, now extinct on the mainland possibly due to predation by cats and foxes (Strahan, 1983).
Bilby (or Rabbit-eared Bandicoot (*Macrotis lagotis*)	Sudden and widespread contraction of range at the turn of the century, now limited to central deserts (Strahan, 1983). Killed for its fur (Aslin, 1986).
Emu (*Dromaius novaehollandiae*)	Now rare or vanished from the Adelaide Region. Killed as pests (Aslin, 1986).
Australian Bustard (*Eupodotis australis*)	Once a common nomad on plains, grasslands and open woodlands throughout Australia (Slater *et al*, 1989). Now disappeared from settled South Australia and relatively rare even in the north of the state (Aslin, 1986) due to habitat loss, use as food and hunting for sport.

8.1.4 Implications for management and further research

The use of indigenous native species in revegetation strategies to replicate the pre-European vegetation cover is currently popular and is being encouraged (Savarton, 1990; Kraehenbuhl, pers comm 1994). Although this thesis has established the general spatial distribution of major vegetation types in the Willunga Basin at the time of European settlement, more details are needed on particular species and their former extent. The historic evidence suggests that the plains were, at least in part, open grasslands and that the hills vegetation clearly differed from that of the open plains. However, despite acknowledging Morphett's 1836 description of the Aldinga Plains as treeless grasslands, Savarton concluded that the plains (which he called the Willunga Plains Unit) supported woodland and that the slopes of the Sellicks Hill Range were "*likely* to have been covered with a woodland of similar species to that of the plains" (Savarton, 1990:16 and 20-22, emphasis added). Savarton's findings differ from those presented here because he used soil types and present day remnant vegetation to infer original vegetation types. The fact that vegetation and soils may not have a straightforward relationship can be seen by comparing the map of the 1839/40 vegetation (Figure 29) with the soils map (Figure 4). The open plains areas, for example, coincided with a range of soil types, while the forested foothills occurred both on loamy sand and stony loam. Aboriginal firing could also have interfered with the vegetation-soil relationship. There are major problems with using present day remnants to infer past vegetation, since the present remnants are several generations removed from the "original" and have often undergone significant changes related to European land uses (Smith, 1979:9). In light of the conflicting conclusions and the popularity of revegetation with "original" species, further detailed study on the vegetation history of the Willunga Basin is warranted. An investigation of particular species recorded in the area could be based on the format adopted by Riddle (1981) who researched historical and modern references to plants collected or observed in the historical landscape, reports of early Field Naturalists' field trips and botanical collections to establish the vegetation of the Adelaide Metropolitan area in 1836.

The area under native vegetation in the Willunga Basin may increase in future as a result of revegetation strategies recently adopted, for example by Landcare members and Friends of the Earth. Some encouraging comments have been found with respect to the regenerative capacity of the native vegetation. For example, in the absence of stock-grazing, stringybark forest can in some cases rapidly recapture cleared ground after it has been abandoned and the apparently stable grass community which had been maintained by grazing gradually disappears as the stringybarks regenerate (Adamson & Osborn, 1924:125). A case in point occurred on a private property near Port Willunga where limestone soil was disturbed and several native understorey species appeared from seeds which had lain dormant in the soil for several decades (Kraehenbuhl, pers comm, 1994). Whilst revegetation with indigenous species helps to conserve biodiversity, it must be acknowledged that the environment is undergoing constant change and cannot be held static in time. Some vegetation species in Aldinga Scrub are known to have declined in extent and numbers, which may be partly attributable to changes associated with European land uses, such as reduced water inflow due to its diversion in drainage channels. However, vegetation change may also be linked to the declining rainfall trend since European settlement, or even longer-term changes because:

> the [Australian] landscape, taken over at the time of European settlement, was not in a state of universal equilibrium. Many landform, hydrologic and biotic systems were still adjusting to the major climatic and sea level changes which occurred during the decline of the last Ice Age and the response time in some systems is several thousand years (Chappell, 1985:216).

The future of native vegetation in the Willunga Basin is an issue which needs immediate attention. A cooperative research project was recently established between the University of Adelaide's Geography Department and the University of South Australia's Surveying Department, of which the Willunga Basin Geographical Information System is the focus. The Surveying Department is currently digitising aerial photographs to provide an orthophotographic coverage of the Willunga Basin. The delineating and digitising of land uses from the 1949, 1958, 1977 and 1992 aerial photographs would provide coverages which could be compared with the vegetation history compiled here. It would then be possible to determine how long remnant patches have been isolated and to compare the biological status of patches which have been isolated for different amounts of time. A map linking remnant native vegetation and revegetation sites to land tenure would also allow the long-term security of these sites to be determined.

8.2 HYDROLOGY

In considering the hydrology of the Willunga Basin three major points will be discussed: the changes which have occurred in the surface drainage pattern, changing groundwater and salinity levels, and the flooding problems. It is important to note in this respect that the long-term declining rainfall trend does not appear to have been addressed by other researchers. Unlike most other changes in the Willunga Basin, rainfall cannot be controlled by management strategies but must be taken into consideration as a major factor in environmental change.

8.2.1 Discussion of the surface drainage history

The characteristics of surface drainage in the Willunga Basin changed dramatically between 1840 and 1992 and included an overall increase in the total length of drainage channels. It could be presumed that this was related to increasing rainfall or to increased runoff associated with the clearance of native vegetation. However, the situation is more complex because although there was a large increase in the extent of channels on the Aldinga Plains, there was also an overall reduction in the extent of channels in the northern half of the Basin. The discussion of a number of factors is therefore necessary. Firstly, the decreased number of surface drainage channels between 1873 and 1883 may have been a reflection of decreased rainfall, which would have made it difficult for surveyors to differentiate dry stream channels from surface undulations. However, the reappearance and extension of channels in 1896 occurred at a time when rainfall was decreasing and so is more likely to have been related to the intentional cutting of channels and increased gully erosion than mapping anomalies. The extension of channels on the Aldinga Plains and the joining of scarpfoot streams to the major creeks between 1959 and 1963 also occurred at a time of decreasing rainfall and is probably linked to drainage works and the continued direction of surface water along ploughlines and fences (indicated by the straightness of the lines) rather than rainfall trends. Thus, it appears that rainfall was not a major determinant in stream channel extension.

Secondly, reduced native vegetation cover may have caused changes in water yield and therefore changes in runoff, streamflow and the length of stream channels mapped. A review of paired catchment experiments worldwide found that the replacement of eucalypt forest cover with low cover, coppice, grass or weeds generally resulted in an increased water yield of approximately 40mm per year per 10% change in cover (Bosch & Hewlett, 1982). These authors also found that the maximum increase in yield occurred in the first five years after forest clearance (following which the hydrological balance adjusted), that greater changes occurred in higher rainfall areas and that reductions in cover of less than 20% had little effect. The replacement of forest with pasture or crops has often been found to result in some increase in water available for runoff, but the main change has usually been an increase in baseflow and more perennial seepage into streams in the first few years after clearance, due to reduced interception and evapotranspiration (Gilmour, 1977; Mein, Bieniaszewska-

Hunter & Papworth, 1988; Sharma, Johnston & Barron, 1982). It is impossible to determine whether runoff from the Sellicks Hill Range increased after its woodland cover was cleared because no historic reports were found which mentioned this change and quantitative data was unavailable. However, regardless of whether runoff changed, a number of other factors are implicated in the surface drainage changes in the Basin.

In some instances surface drainage changes were probably related to groundwater changes. In the north-east of the Basin the Pedler Creek had been joined by streams to its east by 1963, which could have resulted from drainage channels being cut to remove floodwaters, as recommended by Hewett in 1851. However, by 1992 the surface drainage in this area had become so discontinuous that in a 1992 study (Planning & Advisory Services, 1992) the northernmost area was excluded from the surface catchment as it appeared not to be connected. The loss of surface channels may be related to declining groundwater levels, which Bowering (1979:16) attributed to pumping from the Maslin Sands aquifer above McLaren Flat. A large increase in the use of groundwater for irrigation occurred between 1958 and 1977 when vineyard and orchard owners began to irrigate with groundwater to reduce their reliance on rainfall (Bowering, 1979:3). The area of vineyards and orchards irrigated with groundwater increased by 50% between 1987 and 1990 to 3,150 hectares (Planning Advisory Services, 1992:31). The loss of surface water could also be linked to its diversion into local farm dams, and to the long-term declining rainfall trend. The disappearance of Bennetts Creek between 1963 and 1992 could be related to falling groundwater levels, but may be related to the increase of sand quarrying activities in the area since the mid-1970s.

It is unusual that the extension of most channels since 1840 has been towards the sea, rather than headwards as would normally occur if base level (ie sea level) remained constant. However, this phenomenon can be explained by land use changes. From the 1850s landholders diverted floodwater away from their land, which passed it on downslope until eventually channels developed or were constructed to take excess surface water to the coast. The attempts to control the surface water around the township of Willunga must have had relatively minor effects on the development of obvious channels because little increase in channel extent was apparent there on the maps between 1840 and 1959. In summary, the general changes in surface drainage which occurred in the Willunga Basin between 1840 and 1992 have largely resulted from drainage and irrigation practices, although changes in rainfall were an indirect factor in some cases.

8.2.2 Discussion of the groundwater history

On the basis of limited evidence, groundwater levels in the Willunga Basin were found to have declined somewhat in the past, while groundwater salinity levels had probably increased. Although water levels in the shallow aquifers had dropped, the main aquifers had maintained their levels for the past few decades. The groundwater changes could be related to several factors, which may be different in each aquifer system. These may include: reduced recharge associated with the long-term downward rainfall trend, the quicker removal of surface water in drainage channels except during excessive flooding, and the increased withdrawal of groundwater for irrigation.

A relationship between rainfall and recharge in the Willunga Basin was determined by Bowering (1979) who attributed reduced groundwater levels in a bore, which had experienced little use as a groundwater resource, to decreased rainfall over three years. He also noted that during years of average rainfall there was no surplus of rainfall over evapotranspiration and soil-moisture deficit requirements to provide groundwater recharge over much of the plains. The long-term declining rainfall trend in the Willunga Basin has therefore probably affected groundwater resources on the plains, particularly the shallow alluvial aquifers of limited areal extent such as the one which once existed in the north-east of Aldinga Scrub.

The drying out of Aldinga Scrub has been variously attributed to the natural drying of a remnant of a moister environment (Wollaston & Finger, 1986:5), the siltation of the low-lying areas which reduced the amount of surface water inflow, falling groundwater levels, and a reduced volume of surface water draining towards the swamps (Wollaston & Kraehenbuhl, 1986:14). The Washpool area does act as a siltation pond during heavy rain events and increased soil erosion which has occurred since European settlement, and which is particularly associated with heavy rains, has reduced its natural siltation capacity. Major drains have also been constructed since the 1930s which divert surface water past the Scrub to the coast. This has concentrated the water which once spread out over the land into channels, thereby reducing the amount of water available to recharge surficial aquifers. The loss of red gums at the north-east corner of the Scrub may be attributable to the fact that they were felled for timber, while a lack of regeneration may be due to falling groundwater levels or decreased surface runoff. Although it is not known whether runoff and recharge in the Willunga Basin changed after much of the native vegetation was cleared, reduced recharge of surficial aquifers could have resulted from decreased surface runoff from the hills if the hydrological balance was altered by vegetation clearance. This may have resulted in more rainfall becoming baseflow, which then entered the deeper sedimentary aquifers or flowed away in drainage channels. The fact that the Willunga Basin aquifers are fed by surface and underground flow from the Sellicks Hill Range and that groundwater levels are not known to have increased in the past, implies that even if water yield from the hills has increased, it has been offset by other factors, such as groundwater pumping or the long-term declining rainfall trend.

The factors which are contributing to the drying out of Aldinga Scrub have affected the former wetlands area, which is now dry most of the year. The loss of the seasonal wetlands is significant because hardly any such areas remain in the Adelaide Metropolitan area today. The most well-known area was 'The Reedbeds', a flat swampy area of lagoons behind the beach dunes, stretching inland three kilometres from Glenelg and extending fifteen kilometres up the coast to Port Adelaide (Holmes & Iversen, 1976:91). These used to support large flocks of waterbirds but were totally destroyed by drainage works and residential development (Tyler *et al*, 1976; Holmes & Iversen, 1976). There were suggestions in the 1980s that the Aldinga wetlands should be recreated, with the construction of a freshwater lake in the Washpool area and the reinstatement of the Blue Lagoon, but the plans were shelved due to a lack of funding and higher priorities being given to other matters (Wollaston & Finger, 1986). The reconstruction idea has recently been revived (Friends of the Earth, 1991). The changes which have occurred in Aldinga Scrub and the associated wetlands were probably a result of natural processes (eg siltation and climatic change) which were accelerated by European land use activities. Future research could investigate soil erosion rates and the longer-term drainage history of the wetland area by examining sediment cores. The Blue Lagoon site, which has silted up since European settlement, would be ideal for this.

Groundwater salinity levels have been increasing in the south-west of the Basin. However, this is a low-lying area near the sea with naturally saline soils (Figure 4) and saline groundwater (Figure 24). The lagoons there were reported to be saltwater in the 1830s, and in 1889 it was suggested that the area was "indeed the last remaining portion of an arm of the sea which at one geological period must have covered the whole of the limestone country including the plains of Adelaide and Aldinga right down as far as Sellick's Hill" (Sutherland, 1889:8). It has been suggested that the Maslin Sands aquifer in this area contains connate water derived from an evaporative environment (Bowering, 1979) which means that saline water is trapped in the rocks. Even if the area was naturally saline in the past, salinity levels still appear to have increased. This could be associated with declining water levels in the upper aquifer, allowing an upward migration of highly saline water, which Bowering (1979) thought would result from a reversal in the head difference between that aquifer and the Maslin Sands aquifer. However, it is difficult to see how this could occur unless the confining bed between the aquifers is discontinuous in this area, or if the upper aquifer is experiencing saltwater incursions from the sea associated with overwithdrawal now or in the past.

Salinity problems in the south-west of the Basin could be exacerbated by reduced flushing of the soils. There is now an average of 100mm less rain per year than 155 years ago, and although the Aldinga Plains were always deficient in surface water except during floods, the water which previously spread out over the plains and flushed the soils has now been largely directed through confined channels. The area may also be receiving more salts via silt deposition associated with increased soil erosion, which could increase salinity further after the water has been evaporated. The high salinity zones of the Port Willunga Formation aquifer extend about five kilometres inland (Figure 24) so that any additional increase in salinity levels would affect areas further inland and could impact on land use activities. In summary, it seems likely that salinity levels in this naturally saline environment are rising through a combination of natural processes and European land use practices. The complexity of the groundwater and salinity situation warrants further research.

8.2.3 Discussion of flooding problems

Landholders in the Willunga Basin are concerned about flooding which occurs on the plains about once every five years (Boulden, pers comm 1994). It is commonly assumed that vegetation clearance not only caused an increase in the volume of water on the basin floor due to less water being used by crops, compared with the previous native vegetation cover, but that the clearance of the woodland cover on the hills also resulted in larger volumes of runoff occurring sooner after rain events (Turner & Associates, 1982; Savarton, 1990). However, the environmental history of the area suggests that the situation is more complex, for the following reasons. Firstly, certain parts of the Willunga Basin are naturally prone to flooding. Historic accounts and maps indicate that the low-lying plains and the areas around McLaren Vale and Willunga have been swampy and subject to periodic flooding ever since settlement. A surplus of rainfall over runoff occurs mostly in late winter and early spring (Turner & Associates, 1982:9) and would contribute to flooding at these times. The gilgai soils of the McLaren and Aldinga Plains have a poor infiltration capacity and downward drainage is slow when these soils are wet. In addition, the natural channels of ephemeral streams are too small to take the volume of floodwaters resulting from occasional heavy rains so that excess water overflows onto the relatively flat land of the plains. Considering the current gullying problems in the Basin, it is ironic that flooding in the early days was more severe along well-vegetated stream channels whose capacity could not be enlarged by water erosion (Hewett, 1851).

Secondly, although it is impossible to determine whether vegetation changes in the Willunga Basin resulted in increased runoff from the hills, changes in runoff do not necessarily affect flood flow. It was recorded that devastating floodwaters ran off the hills in the Willunga Basin well before the hills vegetation was cleared. This observation seems to be comparable to some experiments which measured the relationship between vegetation change and runoff in different parts of Australia. Gilmour (1977) and Leitch & Flinn (1986) found that in tropical Queensland and North-East Victoria, respectively, flood high flows were determined more by soil moisture conditions and the timing and volume of rainfall than by major vegetation changes. The conversion of the Sellicks Hill Range from woodland to grassland may therefore have had a minimal impact on flood flow, since heavy rains in a short space of time can contribute large volumes to surface runoff under most vegetation types (Aldam, pers comm 1994). It is important to remember that the effects of clearing on runoff and flooding are highly variable (Leitch & Flinn, 1986) and that no studies of this nature have been conducted in the Willunga Basin.

Nevertheless, vegetation clearance could have contributed indirectly to flooding. Angas (1847a) stated that the Mount Lofty Ranges retained moisture for a long time, which may mean that the soils at the time of settlement had good infiltration and storage capacities and that vegetation cover reduced evaporation levels. Increased seepage was associated with the clearance of tea-tree swamps around Willunga but this would have had minimal effects on flooding if seepage flow was removed in drainage channels. There is also no evidence that the replacement of the plains vegetation by introduced grassland and crops contributed to higher soil moisture levels by using any less water than the open plains grasslands. However, increased seepage or the direction of water into channels may have caused higher soil moisture levels in those channels, thus reducing infiltration capacity and increasing the likelihood of flooding. A decline in soil structure resulting from the changeover from woodland to grassland on the hills may also have reduced infiltration capacities, which along with reduced evapotranspiration, could cause more continuous seepage and more quickflow during and after heavy rain events.

Some European land uses have undoubtedly contributed to flooding problems. The use of groundwater for irrigation may have resulted in higher soil moisture levels in some parts of the Basin at certain times of the year. The joining of the major creeks to the streams coming from the east between 1926 and 1963 probably also allowed floodwaters to move downstream faster and to overflow more rapidly. Soil erosion, which has increased since European settlement, may have contributed to channel infilling through deposition in some places, and even the drainage channels which have been constructed would not restrict overflows during particularly large floods. These artificial channels have largely prevented surface water from being distributed over the plains but obviously cannot accommodate all the water during heavy rain events. The confinement of surface water to channels and the long-term decline in rainfall may also have increased the period during which the plains appear to be dry, giving people the impression that flooding has worsened.

8.2.4 Implications for management and further research

Over the past 155 years the hydrology of the Willunga Basin has changed as a result of natural change as well as human-induced or human-accelerated change. This has important ramifications for native vegetation management, revegetation, the reconstruction of coastal wetlands, land use capability assessment and the longer-term condition of groundwater resources. It is impossible to say whether the long-term declining rainfall trend will be reversed in the near future, or whether it is part of an ongoing decline. The period 1839 to 1993 is very short, speaking in terms of environmental change, and the trends determined over this period have been viewed detached from the longer-term context. Future researchers could compare the 155-year rainfall trend in the Willunga Basin with other records to see whether the Willunga trend corresponds with Greenhouse predictions, to suggest what the impact of Greenhouse conditions might be on rainfall-runoff-recharge relationships in the Basin and to see whether the Willunga pattern is related in any way to the El Niño Southern Oscillation. The identification of the long-term declining rainfall trend shows the importance of considering both human and non-human factors in environmental change. With groundwater resources, for example, groundwater levels could still decline in the Willunga Basin despite restricted groundwater usage if recharge is being affected by the long-term downward rainfall trend.

The perception that the clearance of the hills caused increased runoff, which led to increased erosion and flooding, has resulted in suggestions that the hills be revegetated (Savarton, 1990; Withers, 1993). However, it has been shown that the vegetation-runoff-recharge-flooding relationship in the Willunga Basin is not straightforward. Whilst revegetation could have multiple benefits, such as reduction of sheet erosion, a new visual appearance and the provision of habitat, it must be recognised that flooding is a natural phenomenon associated with the particular climate, topography and soils of the area. Flooding may have been exacerbated by some land use changes, but if runoff has not increased since the hills were cleared then revegetation of the hills may not have the desired effect. Any decision to revegetate the Sellicks Hill Range should also take the following into account. If the area were revegetated and runoff were also reduced, then salinity and groundwater levels could be further affected by reduced groundwater recharge and the reduced flushing of soil salts. Since the hard rock aquifers underlying the Sellicks Hill Range are thought to provide significant sub-surface inflow to the two main aquifers, it has been suggested that land uses in the recharge zone, which covers most of the hills except for the south-west corner, should not be allowed to significantly reduce recharge volumes or rates (Planning Advisory Services, 1992:30). However, even if revegetation reduced the volume of water and sediment entering streams and thereby reduced gully erosion and flooding downstream, it might not affect groundwater recharge if this comes mainly from floodwaters (Aldam, pers comm, 1994). The complexities involved suggest that further detailed study is needed to establish the relationship between vegetation cover, soil moisture condition, infiltration capacity, runoff, flooding and groundwater recharge in the Willunga Basin. The establishment of paired catchment experiments could help determine the effect of various vegetation cover types on these relationships.

The investigation of the Environmental History of the Willunga Basin and the explanation of contemporary environmental problems has been limited by the lack of hydrological data. It would be useful to establish a series of stream gauges on water courses in the hills and plains areas to enable a more precise study of hydrological interactions in the Basin. The study of flood flow, discharge and sediment load would allow the mechanics of flooding and stream erosion to be examined. Flood hydrographs could be constructed from streamflow records and combined with rainfall data to establish lag-times between rainfall and flood pulses. Rainfall-runoff differences under a range of vegetation types could be considered. Stream gauges should be installed as a matter of urgency. It would also be useful to have an official rain recording station on the Sellicks Hill Range to collect data for use in calculations of rainfall, runoff and groundwater recharge. Bowering (1979:25), for example, was limited to using the Willunga rainfall record when calculating water balances for catchments above Willunga, but it was demonstrated in Chapter 3 that the amount of rain falling on the Sellicks Hill Range can sometimes differ substantially from that at Willunga.

Considering that the level of shallow water tables is related to soil moisture levels, it would also be useful to monitor shallow aquifer levels, in addition to the major aquifers, in order to see how they relate to flooding and vegetation change. In the long-term, data on the aquifers, perhaps from the DMESA Willunga Observation Well Network, could be combined with geological data on the Willunga Basin GIS to provide a three-dimensional computerised model of the aquifers in the Basin. This would help monitor changes and their effects on other aspects of the local environment and increase the understanding of how the environment is functioning, as well as allowing a range of alternative management strategies to be modelled to see their likely effects on different variables.

8.3 GULLYING

8.3.1 Discussion of the history of gully erosion

There is a common perception that vegetation clearance in the Willunga Basin has led to gully erosion on the scarp and plains due to reduced vegetative protection and increased runoff. This case is supported by correlating unvegetated stream courses with the incidence of gully erosion, and by comparing differences in erosion north-east and south-west of Willunga (Turner & Associates, 1982). Whilst it is well-known that buffer strips minimise the impact of land use on streams (Graynoth, 1979), Figure 26 shows that the relationship is not simple, since gullying has not developed on some courses which are still unvegetated. This Environmental History study suggests that gully erosion is worse in areas where no major channels had existed in 1840. In those areas the cutting of ploughlines and channels for drainage initiated gully erosion, while channels which existed at the time of settlement have maintained stable banks. This is evident on the Aldinga Plains and on some of the channels which now connect the Port Willunga and Maslin South Creeks to the scarpfoot streams. The removal of the "forest" on the scarpfoot south-west of Willunga probably made this area particularly vulnerable to erosion, especially since the land slopes more steeply than the land north-east of Willunga. It is also significant that gullying is most pronounced on the unconsolidated late Pleistocene fanglomerates which are highly susceptible to erosion (Talbot & Nesbitt, 1968; Twidale, 1976a).

Vegetation clearance and replacement by crops and grassland has undoubtedly made the soils vulnerable to erosion due to both the removal of the binding roots of trees and shrubs and the reduction of canopy and leaf litter, which previously reduced rainsplash and contributed organic matter to the soils. However, other factors are also implicated. Firstly, grazing by introduced hard-hoofed animals (compared to the soft-footed native animals) can weaken soil structure. Local people have also suggested that warrens dug by introduced rabbits have coalesced in some cases and widened gullies (Campbell, pers comm 1994). Secondly, road building across channels has changed the local base level of streams and concentrated streamflow through culverts so that it emerges on the downstream side with great force. The cliff-like sides of the lower section of Sellicks Gully, downstream of Justs Road, are evidence of this. Thirdly, regardless of whether runoff from the Sellicks Hill Range has increased since clearance, surface water is now being directed into a few vulnerable channels rather than spreading out over the plains as previously occurred. The deliberate cutting of ploughlines or channels to divert water away from properties has resulted in the seaward extension of many of the surface channels and has created a new base level for creeks, thereby initiating or increasing gully erosion. Fourthly, the Willunga Council may also have contributed to gullying up until the 1950s by removing gravel for use as road metal from creekbeds along the Willunga Scarp, and particularly from Sellicks Creek (G Vaudrey, pers comm 1994).

The main period of gully initiation and development in the Willunga Basin was dated by Dragovic (1966) as sometime between the 1854 surveys and 1910 or 1920, with gully formation most likely after drought-breaking rains. Often one specific rainfall or flood event cannot be correlated with gully initiation because there is usually a lag between the time when a land surface becomes vulnerable to erosion and the actual initiation of gullying. In other words, physical processes take time to change soils and this is complicated by the fact that rainfall distribution is spatially and seasonally nonuniform (Twidale, 1976a). Gullying which occurred in the Willunga area in June 1915 and 1944 (Twidale, 1976a) can be related to the fact that both periods were preceded by several dry years, as well as a reduction in sheep numbers, which probably reflected increased grazing pressure in the immediately preceding period. While the findings in this thesis agree with Twidale (1976a) that 76mm falling over four days in June 1915 was probably related to the gullying which occurred then, the Willunga daily rainfall data did not support Twidale's (1976a) claim that the 1944 gullying was related to 70mm falling over two days. Of course, it is possible that 70mm was recorded somewhere other than Willunga. It is also of note that other heavy or heavier rainfall events are known to not have initiated gullying (Twidale, 1976a).

The evidence in this thesis suggests that within the major period of gullying proposed by Dragovic (1966) a combination of conditions made gully initiation and development particularly likely in the 1880s and 1890s, when gullying and channel extension is known to have occurred in several areas. Firstly, wheat had been the major crop from the 1840s until the late 1870s, and, unlike barley which is the dominant cereal today, wheat requires relatively long fallow periods (Turner & Associates, 1992:15), leaving soils open to erosion. Between 1870 and 1878 the area cultivated dropped from 8,000 hectares to roughly 5,000 hectares, suggesting that large areas would have been vulnerable to erosion if they were left fallow. Soil structure would probably have declined as topsoil was lost during floods in the 1850s, and soil fertility also declined after the 1860s. The rate of organic depletion in soils varies, but tends to occur in a matter of decades, and is increased by fallowing because this causes rapid oxidation (Twidale, 1976a). Secondly, summer-growing native grasses had probably afforded more protection from late summer downpours than introduced unirrigated crops and pastures which probably provided minimal cover, particularly during drought. Finally, about forty years after the plains were converted for agriculture and ten to twenty years after the hills were cleared, there was a ten-year drought. This ended with heavy rains in 1888 and 1889, including Willunga's largest recorded rainfall in one day: 86mm on 2 April 1889. Although there are no meteorological records to determine heavy rainfalls prior to 1884, the combination of land use changes outlined would have slowly increased the soils' erodibility over several decades and along with the heavy rainfall events after the drought would have made gully erosion particularly likely during the 1880s and 1890s.

8.3.2 Discussion of the Sellicks Creek Gully

The initiation of the Sellicks Creek Gully probably occurred during the major gullying period of the 1880s and 1890s. People could jump over the Creek in the mid-1880s but it had increased considerably in depth near to the coast by 1923. Apparently the gully grew quickly after a few heavy rains, after which the dimensions remained essentially the same (Fitzpatrick pers comm, 1994: information passed down by grandfather). That gullies can develop rapidly is supported by the example of a six metre deep gully which grew in just three years at Modbury North (Bourman & Harvey, 1986). The initiation of erosion in the lowest section of the Sellicks Creek Gully was probably encouraged by land use practices. It is thought that a plough furrow was at some time cut to divert water directly towards the sea (Fitzpatrick, pers comm, 1994) and that water was diverted from a field onto Sellicks Beach Road by an adjacent landowner (Howchin, 1923:307). These actions would account for the straightness of the gully in the lowest section because the diverted water would have been able to erode along the side of the straight road. They would also have lowered the base level of the creek and led to renewed downcutting, whilst limiting surface water to one particular line of weakness.

Downcutting in the lowest section of the Sellicks Creek Gully might be related to the appearance of a small gully at the very top of the range between 1870 and 1909 (Plates 8 and 9). More channels were mapped in this area in 1896, suggesting that channels either became more visible or that gullying had occurred. However, the different sections along the Sellicks Creek are isolated by roads so that shallow gullying near the hilltop might be more related to the localised vegetation loss and soil erosion, shown by the development of terracettes between 1870 and 1909, rather than to downcutting in the lowest section. Quarry operations at Sellicks Hill cannot be related to the initiation of the Sellicks Creek Gully since quarrying did not commence until the 1920s, and probably remained on a small scale until operations increased in the 1970s. Even if mine tailings contributed sediment to the gully, increasing the likelihood of erosion and deposition, the impact was probably much less than the cutting of channels on the plains and the increasing erodibility of the soil related to early European farming practices. The current impact of the mine beside the gully is difficult to ascertain without a further investigation of the movement of sediments and materials from the tailings dumps.

Dragovic (1966) concluded that post-European gullying in the Willunga Basin could not be directly correlated with periods of land clearance. However, the findings in this thesis support Twidale's (1976a) conclusions that land uses both initiated and accelerated gully erosion, albeit with a considerable time lag during which the environment gradually became more vulnerable to erosion until a suitably dramatic rain event initiated the gullying. Similar situations have led to gully initiation elsewhere in South Australia (Dragovic, 1966; Twidale, 1976a; Bourman & Harvey, 1986) and overseas. The creation of large fields (out of smaller parcels of land) which were left fallow over winter, and the practice of surficial ploughing on plains and lower mountain areas in Western Europe in the eighteenth and nineteenth centuries also caused deep gullying (Vogt, 1990), while in Canada many broad valleys and plains became deeply gullied between 1865 and 1915 (Goudie, 1990:227-229). The coincidence of white settlement and gully initiation in Canada during the 1880s led to the conclusion that human action was the main cause of gullying, although changes in rainfall intensity and amount had probably worked in the same direction (Goudie, 1990). It may be pure coincidence that the main period of gullying in Willunga also spanned the 1880s. Since there is no evidence to implicate climatic trends in the post-European phase of gullying at Willunga

(Twidale, 1976a:227) it seems that land use activities rendered soils more vulnerable to natural erosive processes and increased the erosive power of streamflow by directing waters into specific channels.

8.3.3 Implications for management and further research

Some of the gullies in the Willunga Basin are stabilising today (Aldam, pers comm, 1994; field observations, September 1994). Landcare members are also encouraging stabilisation by modifying land use practices. This includes the fencing out of stock, revegetating creekbanks, and stacking newspapers in gullies to trap sediment. The lower section of the Sellicks Creek Gully may also be stabilising where vegetation is establishing naturally near the coast, while in Section 666 the situation has improved since sheep were fenced out (Fitzpatrick, pers comm, 1994). The European experience outlined by Vogt (1990) is encouraging in this respect since it showed that changes in land use practices can effectively stabilise gullies. A recent report on the Sellicks Gully also determined that the lower section was stabilising but suggested further reinforcing the banks with various materials and deflecting the streamflow at strategic points (Potter & Associates, 1994). This report did not mention any need to address floodflow or runoff from the hills. However, it might be worth researching the impact of heavy rain events on newly stabilising gullies. It would also be useful to investigate the likely effects of gully stabilisation on flooding, because infilling could reduce channel capacity over time if flood volumes are not reduced. Attention should also be paid to creeks which currently do not have gullying problems, because these could become vulnerable in future. These creeks could be mapped and their erosion potential and surrounding land uses assessed so that measures can be taken to prevent new gullying problems.

8.4 CONCLUSION

The main aim of this thesis was to establish the Environmental History of the Willunga Basin since the 1830s in order to help explain some of the current environmental problems and provide insight for future management. The five specific objectives were:

- both to establish rainfall trends since the 1830s so as to differentiate wetter and drier periods, and to calculate flood probabilities to date large rainfall events and determine their order of magnitude;

- to establish trends in the history of the surface and groundwater drainage and to determine the surface drainage pattern at the time of the first surveys, along with the timing, nature and magnitude of any change. Trends in groundwater levels and salinity were also to be investigated;

- to establish the spatial distribution of gullying at the time of European settlement, and the onset of gully erosion, with particular consideration of the Sellicks Creek Gully, which is currently one of the largest gullies;

- to determine the general spatial pattern of vegetation in the Willunga Basin at the time of the first surveys and to establish the timing, nature and magnitude of any change; and

- to establish a history of temporal and spatial trends in population and major land use activities.

The extent to which these have been achieved will now be addressed.

Rainfall trends between 1839 and 1993 were established for the Willunga Basin and average annual rainfall was found to have been on a continual downward trend. It was suggested that future research could compare this trend with longer-term records to see whether it corresponded with Greenhouse predictions and to suggest what the impact of Greenhouse conditions might be on rainfall-runoff-recharge in the Willunga Basin, as well as whether there is any relationship with the El Niño Southern Oscillation. In the shorter term, wetter and drier periods had been experienced which reflected climatic fluctuations elsewhere in Australia and overseas. In the absence of streamflow data, calculations of flood probabilities were made using rainfall records. This enabled the dating and magnitude of large rainfall events to be determined since daily rainfall records began in 1884, although some additional floods before and after 1884 were established from historical accounts. It was found that the low-lying plains and the areas around McLaren Vale and Willunga had been naturally swampy and subject to seasonal flooding ever since European settlement and that large devastating floods had occurred in the Willunga Basin since at least the 1850s.

The surface drainage pattern of the Willunga Basin at nine dates was mapped, including the pattern at the time of the first surveys. This indicated that significant changes had occurred between 1840 and 1992. Streams had disappeared, reappeared and extended at various times, while channel length had increased overall. Channels constructed in some areas on the plains had largely confined the surface flow, whereas it had previously been more distributary. The groundwater history proved more difficult to establish because only limited information was available, but it was concluded that shallow aquifer levels had fallen, while levels in the two main aquifers had dropped in the past, even though they had held steady over the last few decades. Changes in groundwater and surface drainage in the north-east were positively correlated. Surface water had been diverted into dams, while groundwater levels had fallen due to decreased rainfall and the increased use of groundwater for irrigation. In the south-west, surface drainage and groundwater trends were negatively correlated because groundwater levels had fallen due to changes in rainfall and land use, while drainage construction and gully erosion had created more channels. Salinity levels had increased in the south-west corner of the Willunga Basin while the Aldinga coastal wetlands had contracted since European settlement, reflecting the restricted surface flows and falling groundwater levels in that area. Due to the apparent complexities and importance of hydrology in the Willunga Basin it was suggested that further study was warranted.

It was not easy to establish trends in gully erosion, again because information was limited. Nevertheless, it seemed probable that a major period of gullying had occurred in the 1880s and 1890s, which narrowed down the 60-year period suggested by Dragovic (1966). It also seemed likely that the Sellicks Creek Gully had been initiated during this period.

In order to compare hydrological changes with vegetation changes, the general spatial pattern of vegetation at the time of the first surveys in 1839 was established from survey records and historic accounts. Further research determined that native vegetation cover had rapidly declined on the plains within the first twenty years of settlement (by the 1860s) and that most of the hills had been converted from woodland to grassland between the 1860s and 1880s, leaving only small remnant patches of native vegetation today. Extra information collected allowed a preliminary map to be compiled and comments to be made on some of the native fauna species which had existed in the Willunga Basin in the past. With respect to native fauna, numbers of individuals and species have generally declined over time and some species are no longer found in the area today.

The seventh Chapter established a history of temporal and spatial trends in population and land use. The Willunga Basin has had one of the longest histories of settlement and land use in South Australia, with surveys and settlement beginning only four years after the colony's creation. Although slate mining started immediately, extensive commercial farming only began after ten years of pioneer occupance. Extensive timber usage and drainage construction were also associated with European settlement. The range of land use activities changed and expanded after the 1880s to include more intensive commercial farming and horticulture. By the 1970s land use pressure began to rise as the area's popularity for rural living close to Adelaide increased. More recently, intensive residential development has occurred in the north-west. The output and numbers of mining operations has also increased over time, although the spatial extent remains limited.

The historic trends identified in this Environmental History of the Willunga Basin since the 1830s were discussed and used to explain current environmental problems, and potential implications for future management and research were identified. The most significant non-human change was the long-term decline in average annual rainfall, which has not been considered by other researchers. The Basin's major environmental problems had resulted from a combination of both natural processes and events and European land use activities. Land use had either made the environment more susceptible to change or had accelerated change in a particular direction. In most cases, environmental changes had resulted from a combination of several factors, often with unforeseen or delayed effects. This highlights the complexity of the physical environment and the need to better understand how general processes function within the unique environment of the Willunga Basin. It also became clear that some problems were more complicated than previously thought, suggesting that future management strategies should consider a number of factors in relation to any one problem, but particularly the major components of vegetation, hydrology and land use. This would help minimise the creation of new problems while others are being solved. The long-term effects of past changes and ongoing natural change should also be considered and in order to assist future management it was suggested that some long-term environmental monitoring projects be established.

The area to which management should apply also needs further consideration. While a surface catchment has been used to define the Willunga Basin in this thesis, many other boundaries overlap the area and could cause difficulties when attempting to address pressing environmental, social and economic problems, by causing funding or commitment obstacles. While

Landcare groups operate at the catchment and sub-catchment level, consideration should be given as to whether other physical, social and administrative boundaries coincide appropriately. Questions could be asked, such as to what extent do state and local government boundaries coincide with Landcare catchments, how far do either of these coincide with community identity or groundwater catchments and how do the different boundaries affect management and sustainability in the region. This question of defining areas and boundaries for the purposes of practical management and sustainability has been addressed only in recent years (eg Newman, 1991; Roberts, 1992; Slocombe, 1993) and would be an interesting subject for future research. It might be appropriate to consider the suitability of the "bioregion" concept, which combines the biophysical and socio-economic aspects of sustainability at different levels through ecosystem-based management (Newman, 1991; Slocombe, 1993).

Despite some problems encountered in the process of investigating and compiling this thesis, it is felt that a small but important contribution to knowledge of the Willunga Basin has been made, by documenting the major aspects of its Environmental History since the 1830s. It has also explained and discussed the influence of major historic trends on present day environmental problems and has suggested some implications for management. It is hoped that this thesis will assist in shaping a management strategy for a sustainable environment, economy and society within the Basin, as well as providing a starting point for further research.

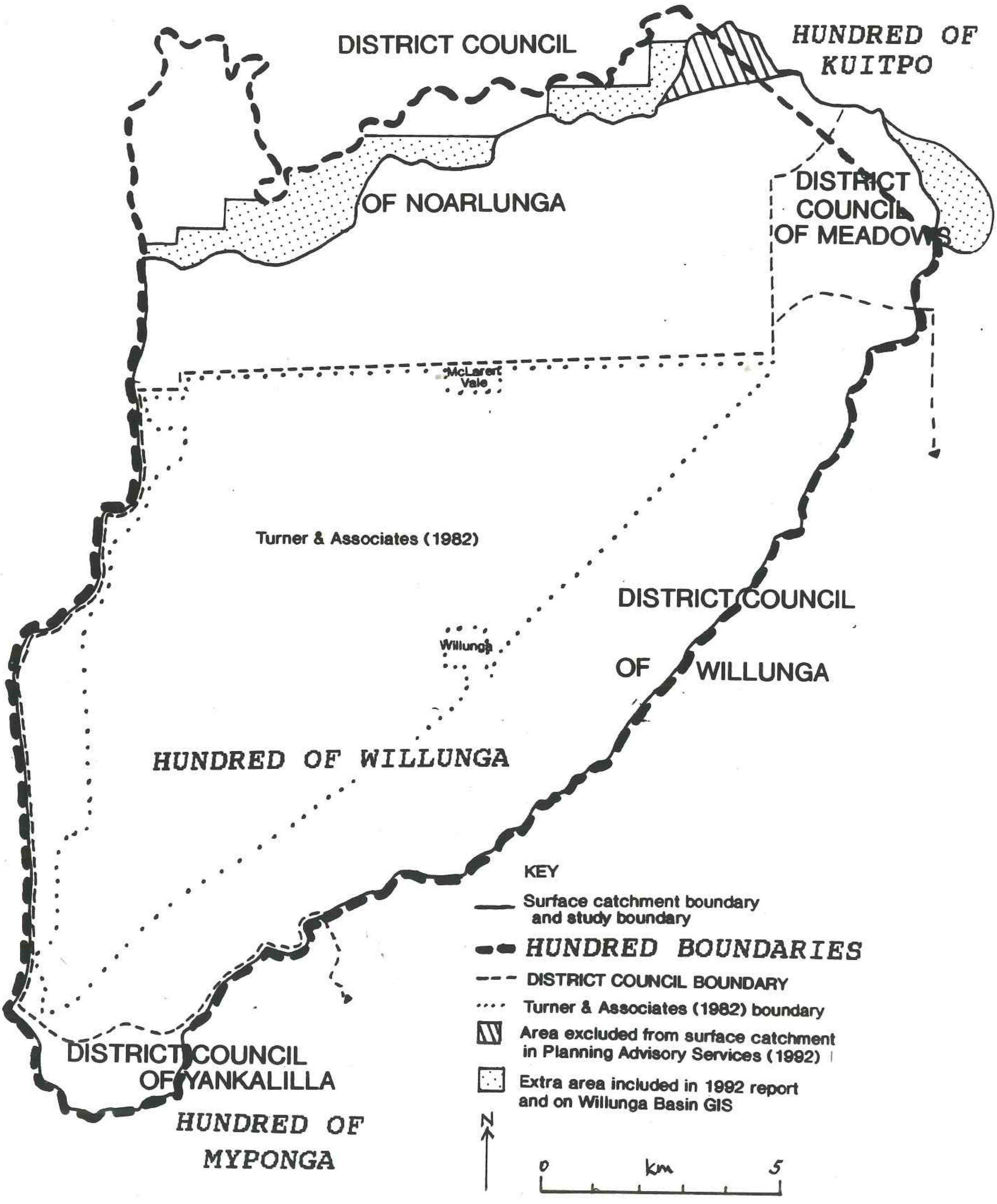
APPENDICES

AND

BIBLIOGRAPHY

APPENDIX 1A

Map showing various boundaries which relate to the Willunga Basin.
Source: Compiled by the author based on boundaries shown in Hundred of Willunga map (1963); Turner & Associates (1982); Department of Lands (1984, 1987, 1990); Planning & Advisory Services (1992).



APPENDIX 1B

BACKGROUND TO ADMINISTRATIVE AND STATISTICAL BOUNDARIES RELATING TO THE WILLUNGA BASIN

Source: Compiled by the author from SA Government Gazette 13 November 1856:1016-7; SA Government Gazette 31 January 1861:84; Research papers of G & D Vaudrey.

Until 1850	The Hundred or District of Willunga was administered from Adelaide.
1850	District Road Board of Willunga established. The first meeting was on 7 January.
1852	South Australian Council Act (Act No 16) established.
1853	Willunga District Council established, first meeting minutes dated 2 September.
1856	21 August Noarlunga DC split away. It comprised the area north of McLaren Vale up to Morphett Vale and Hackham.
1857	21 January Aldinga DC split away. It comprised the area approximately west of a line from Sections 155 to 751.
1932	Aldinga and Willunga DCs amalgamated again.

EXTENT OF THE DISTRICT COUNCIL AREAS

The boundaries of the District Councils changed as areas were added from or ceded to other Council areas. Although in later years there were descriptions of how much land had been gained or lost, no maps were found which indicated boundary changes. Statistics could therefore not be amended accordingly and as such could only be collected for the standard statistical areas. The areal extent of the DCs, where given with returns in the SA Statistical Register, SAGG and LGA statistics, was as set out in the table over the page. The largest change was for Noarlunga DC between 1931 and 1936. However, this did not appear to cause any related changes in the population and land use trends graphed during this period. Although the area of the DCs changed over time, it was felt that the statistical trends established were the best available for the Willunga Basin and in many cases were supported by information from other sources and knowledge of the area. The "western part" of Willunga DC is further explained in the footnotes to Appendix 1C and the maps in Appendix 1D.

Areal extent of the District Councils (converted to hectares)

Year	Aldinga	Willunga	Noarlunga
1866	7,880	15,540 (Western part)	11,900
1876	8,800	15,540 (Western part)	10,100
1901	8,800	17,600 (Western part)	10,100
1931	8,800	25,490 (Western part)	10,100
1936	Joined Willunga	26,680 (Western part plus Aldinga DC)	16,320
1971	-	19,130 (Western part)	16,600

APPENDIX 1C

AREAS TO WHICH POPULATION AND LAND USE STATISTICS RELATE

Year	Area
1844	South of the Onkaparinga River to the Willunga Hills (SAGG 11 April 1844:91)
1846	South of the Onkaparinga River to the Willunga Hills, bounded by the sea coast and extending to the east as defined by a sketch (SAGG 23 April 1846:139); no such sketch could be found (Miller, 1983).
1851	Willunga District (SAGG 20 March 1851:189)
1855	District of Willunga (SAGG 2 August 1855:565)
From 1861	District Councils of Aldinga, Willunga (part of*1) and Noarlunga (SAGG and Statistical Registers)
From 1936	District Councils of Willunga (part of) and Noarlunga
1976	Local Government Areas (LGAs) of Willunga (part of), and Noarlunga (Australian Bureau of Statistics LGA Statistics)
From 1981	Local Government Areas Willunga (Part A: west of range*2) and Noarlunga (Australian Bureau of Statistics Census of Population and Housing)
From 1985	Local Government Areas Willunga (whole DC) and Noarlunga (Australian Bureau of Statistics LGA Statistics)

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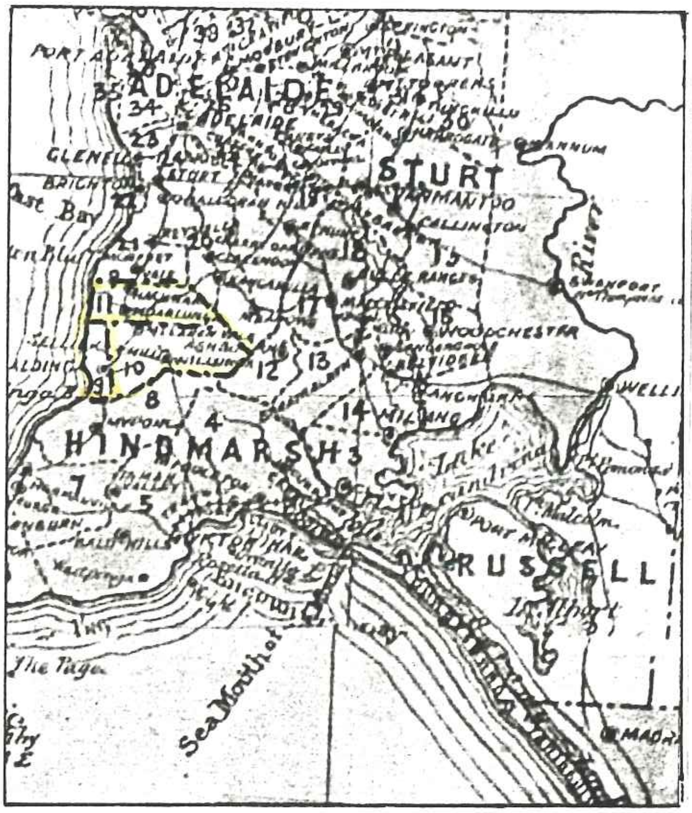
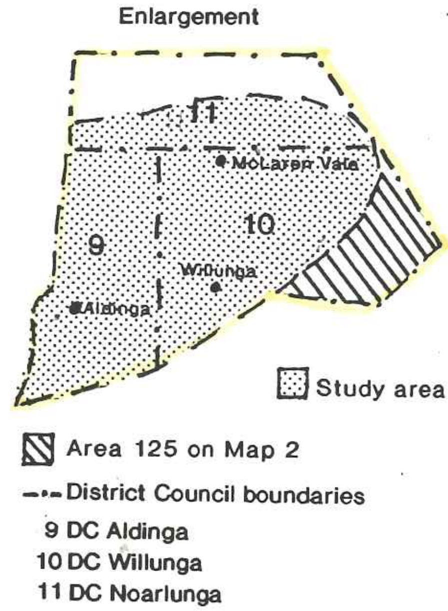
*1 The District Council of Willunga was divided into two parts in 1861. Statistics for the purpose of this thesis were collected for the western part, which lay in the Hundred of Willunga. This is shown on map 1 in Appendix 1D and was defined as follows: "Bounded on the west by the District of Aldinga; on the north by District of Noarlunga; and on the south-east by the boundary of the Hundreds of Willunga and Kuitpo" (SAGG 31 January 1861:84).

*2 Part B's population in 1981 was only 396 compared to 6146 in Part A. Part B appears to be the section south-east of the Hundred boundary, as shown on the accompanying map. From 1985 the only figures given were for the whole DC of Willunga, but the map 2 in Appendix 1D, and other information, indicated that this was a relatively small area with a small proportion of the overall population. The change in 1985 did not seem to affect the general trends in population or land use.

APPENDIX 1D

MAP 1

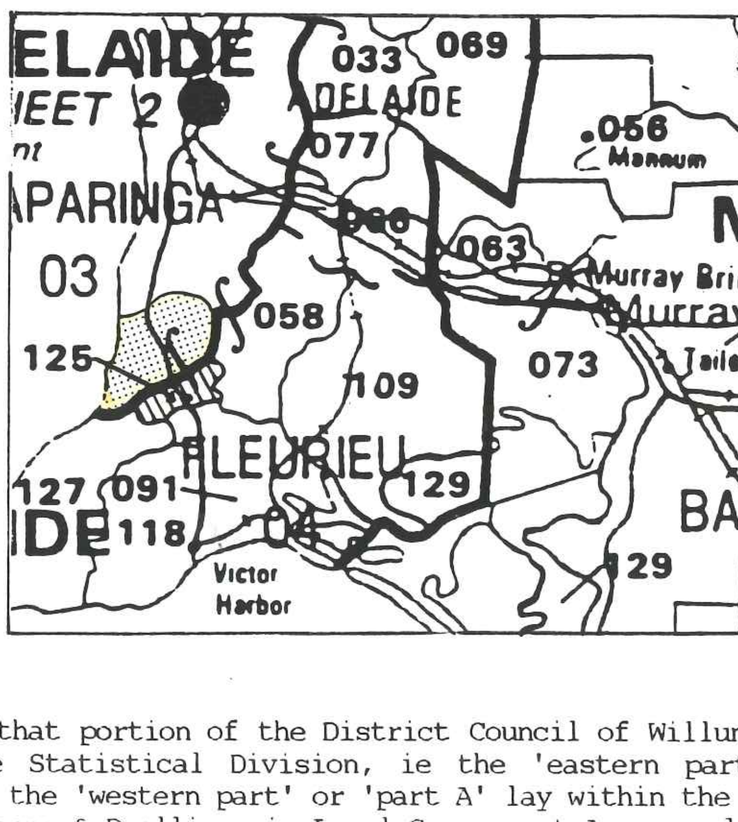




Map showing the District Council areas relating to the Willunga Basin. *Source:* Whitworth (1867).

MAP 2

Study area

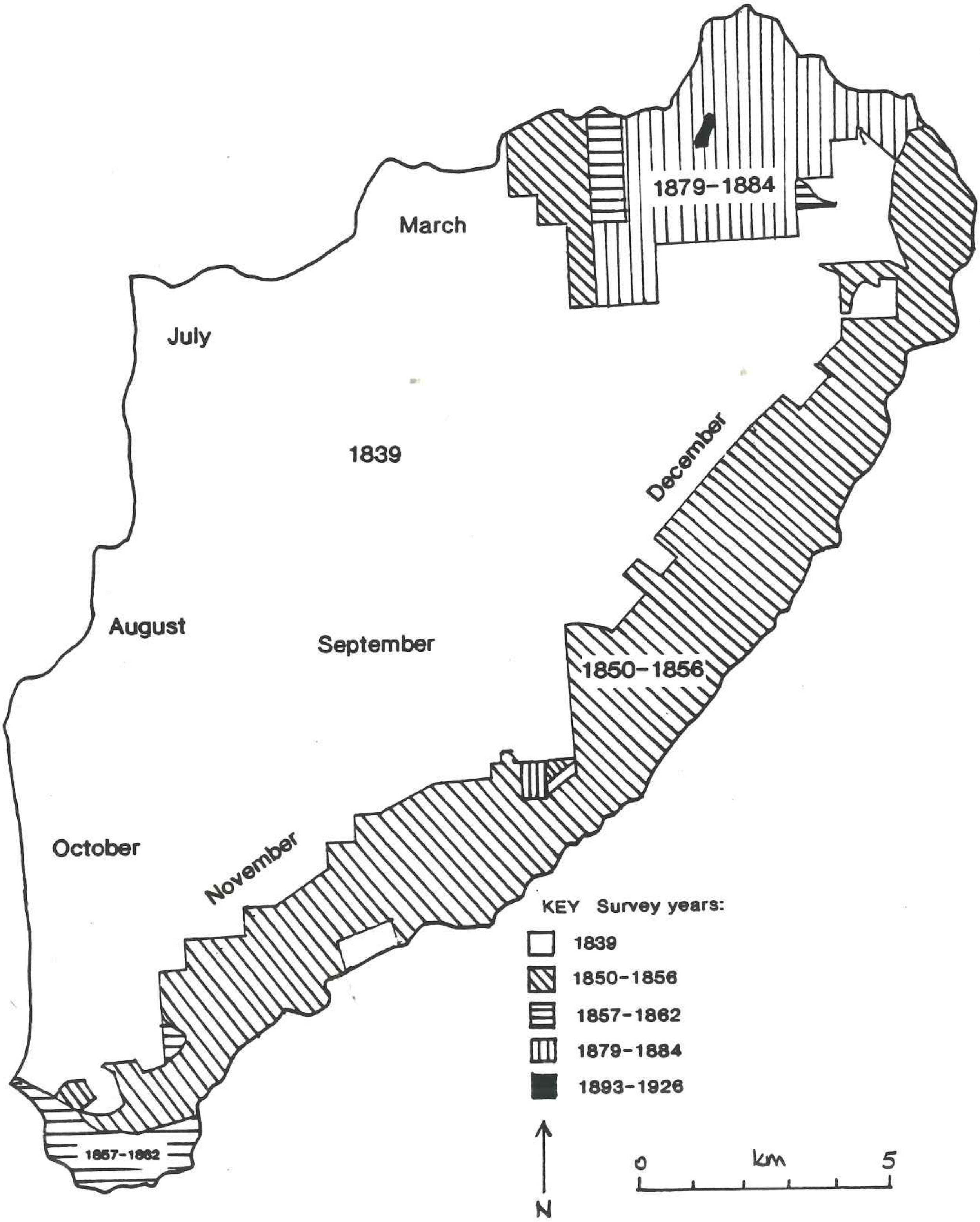


Area 125 is that portion of the District Council of Willunga lying outside the Adelaide Statistical Division, ie the 'eastern part' or 'part B', showing that the 'western part' or 'part A' lay within the Willunga Basin. *Source:* Persons & Dwellings in Local Government Areas and Urban Centres in South Australia, (Australian Bureau of Statistics 1982).

APPENDIX 1E

Map dating the first surveys of sections in the Willunga Basin.
Source: Compiled by the author from information in original survey records, researched at the Survey Records Department, Department of Environment & Natural Resources; Hawker (1899) and checked against Hundred maps for Willunga, Kuitpo and Myponga of various dates.

Note: Further explanation is given in Appendix 1F.



APPENDIX 1F

FURTHER EXPLANATION OF THE SURVEYING SEQUENCE IN THE WILLUNGA BASIN

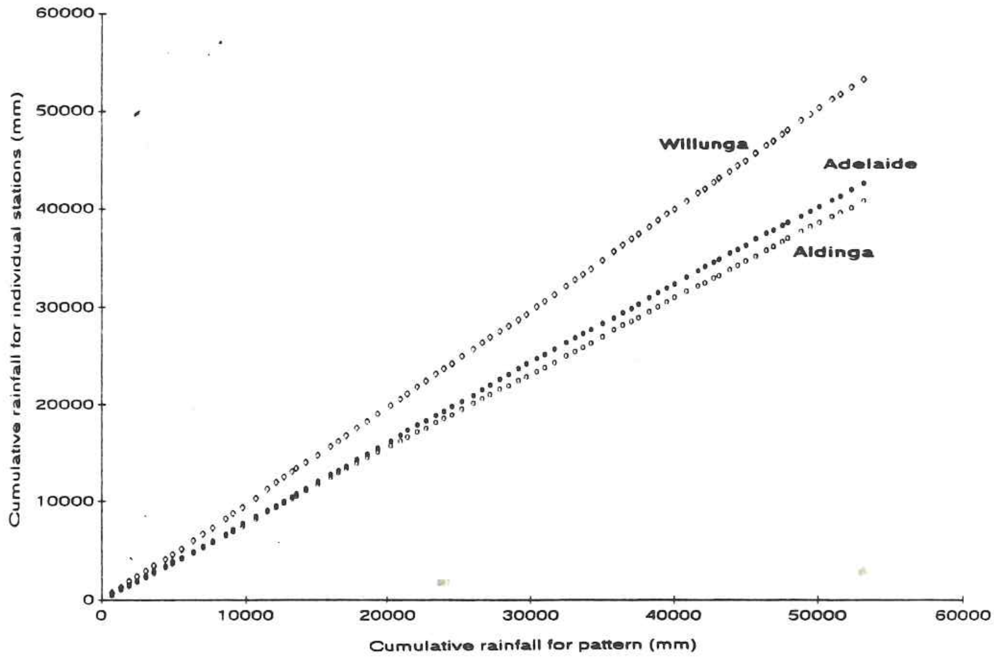
To understand the sequence of section numbering within the Willunga Basin it is important to realise that when the first surveys were done the Hundreds did not exist. Adelaide was divided into Districts from A to H. The boundary of these districts was as follows:

> The Preliminary boundary is an imaginary line passing over Mt Lofty and running due South, [which] strikes upon the sea at Encounter Bay. The country to the West of this line, and bounded by the coast, was reserved for holders of Preliminary Land Orders, and no Special Survey allowed to be taken therein... The Preliminary Districts are eight in number and are lettered from A to H (*The Observer*, 13 April 1844:7).

The division between Districts B and C ran east-west just north of the Onkaparinga River, and the division between Districts C and D was in the far south of the Willunga Basin (visible on the 1840 McLaren Map, Appendix 3). Numbering for District C started north of the Onkaparinga River with Section 1. Therefore when the Hundred of Willunga was formed, mostly out of the former District C, the earliest surveyed sections commenced not with Section 1, but with numbers in the 50s, sections with numbers lower than this lying north outside the Hundred. This is made clear in the 1840 McLaren Map (Appendix 3). Consequently, the lowest numbers which had not been used within the area which later became Hundred of Willunga were used to fill in the number sequence after the Hundred was formed and were allocated to sections declared later. This explains why some of the lowest section numbers occur in the north-east of the Willunga Basin, which was not surveyed until 1879. Contrary to what would be expected, the lowest numbers therefore do not indicate that this area was surveyed first, but last.

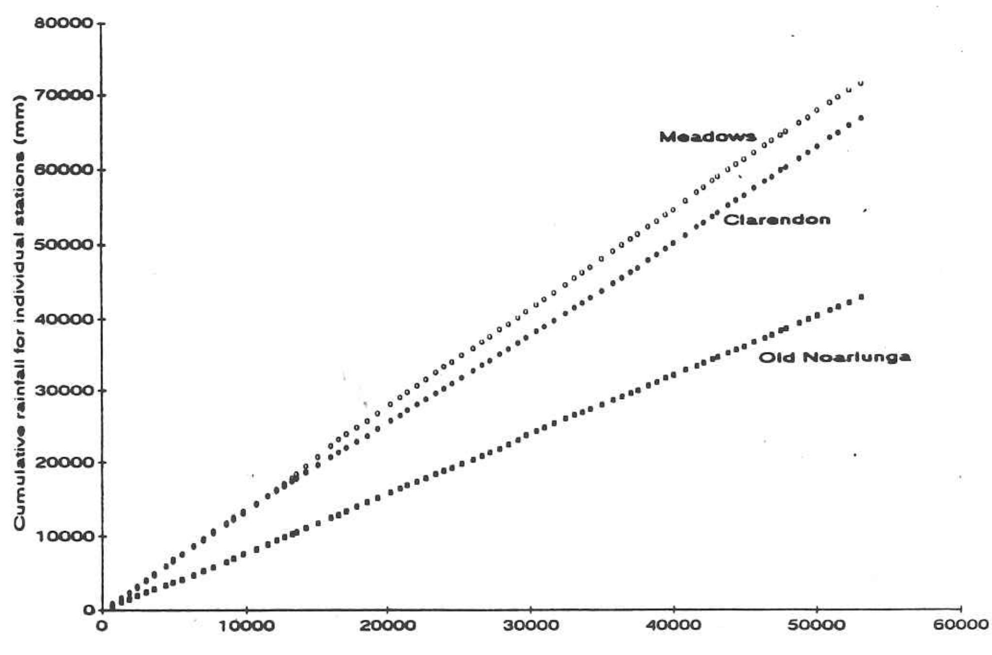
APPENDIX 2A

Rainfall Double Mass Curves for Adelaide, Aldinga and Willunga 1894-1974 against the 6-station pattern. *Source:* Compiled by the author from data supplied by Commonwealth of Australia Bureau of Meteorology.



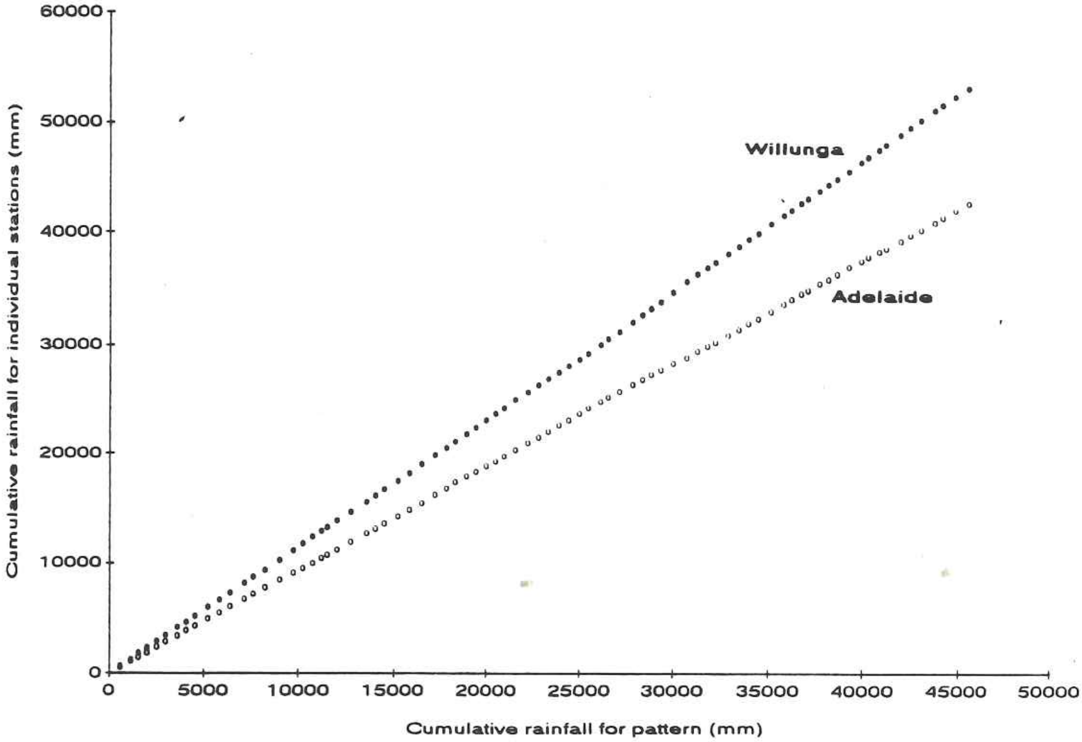
APPENDIX 2B

Rainfall Double Mass Curves for Clarendon, Meadows and Old Noarlunga 1894-1974 against the 6-station pattern. *Source:* Compiled by the author from data supplied by Commonwealth of Australia Bureau of Meteorology.



APPENDIX 2C

Rainfall Double Mass Curves for Willunga and Adelaide against the 3-station pattern 1894-1974. *Source:* Compiled by the author from data supplied by Commonwealth of Australia Bureau of Meteorology.



APPENDIX 2D

Statistics for the F-test on the Willunga Double Mass Curve.

F-TEST: TWO-SAMPLE FOR VARIANCES (MICROSOFT EXCEL)

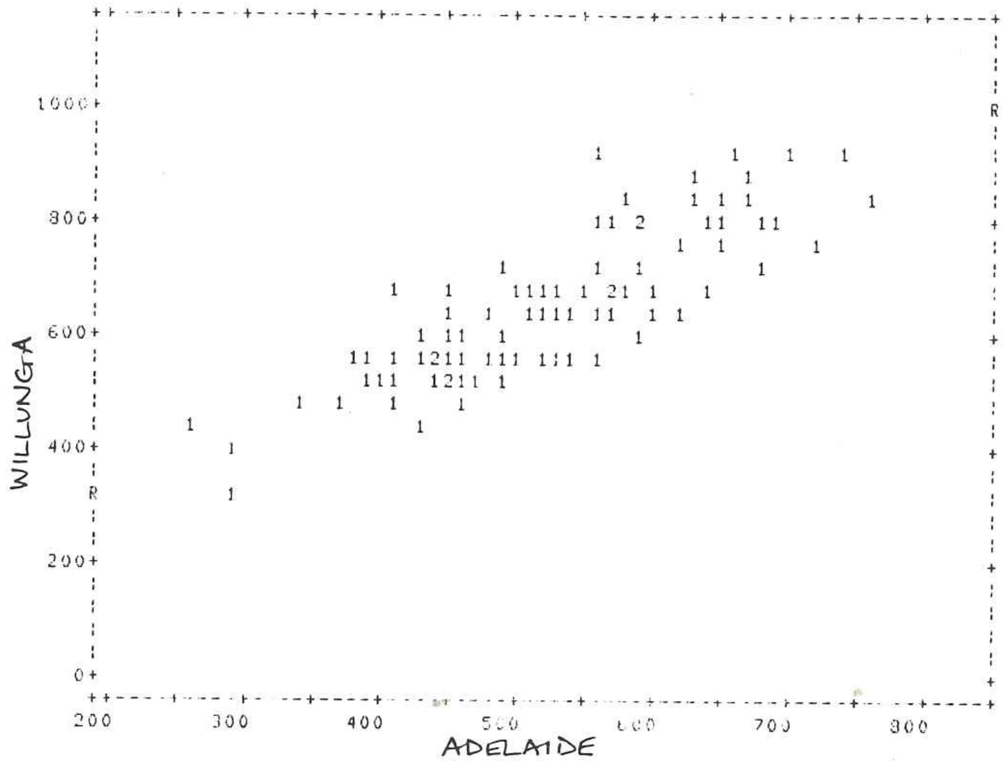
	1894-1945	1946-1974
	Variable 1	*Variable 2*
Mean	651.3653846	665.4827586
Variance	15704.98152	22883.54433
Observations	52	29
df	51	28
F	1.457088269	

H_0 = Means of each sample of the population are equal.
H_a = Means of each sample of the population are not equal.

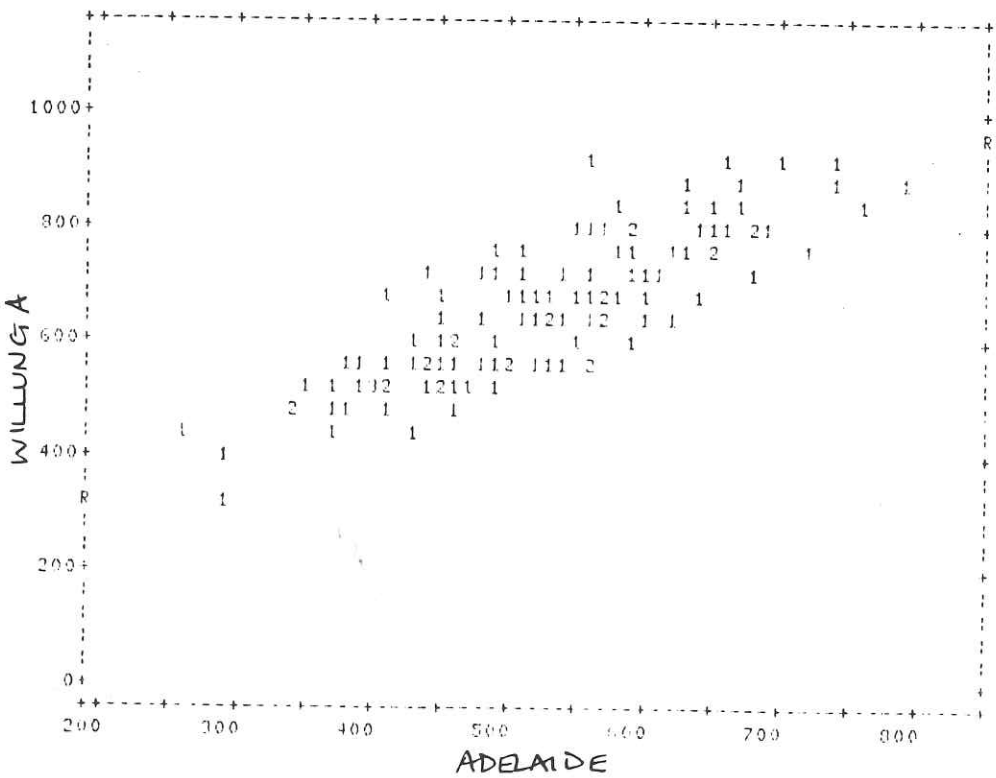
If F is $\leq$ 0.05 then H_0 is rejected. In this instance F was 1.46 and therefore was $\geq$ 0.05 so H_0 was not rejected and the conclusion was that the means of each sample of the population were equal.

APPENDIX 2E

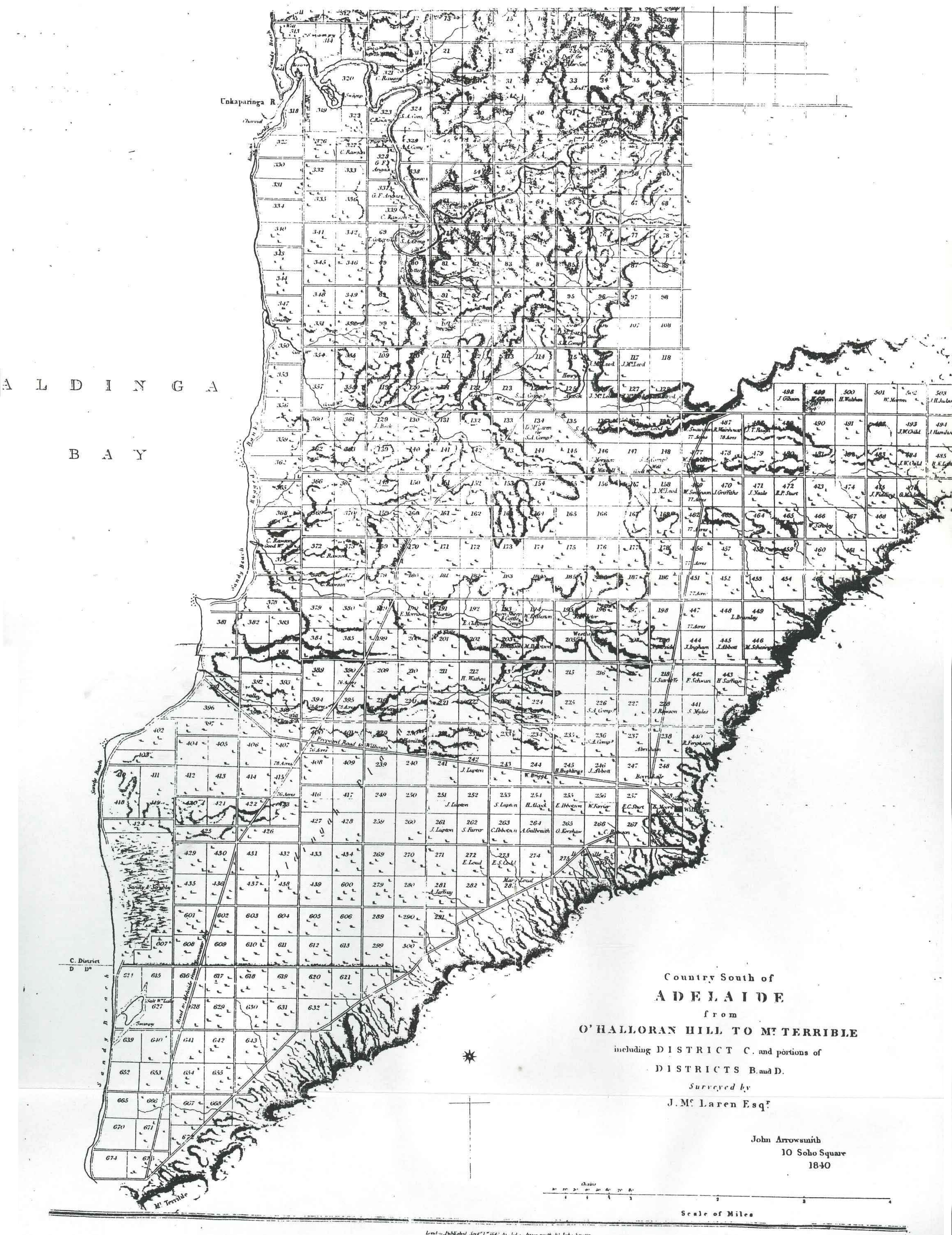
Linear regression plots and statistics - Willunga rainfall on Adelaide rainfall.



1894-1974
Statistics: Correlation 0.84; R^2 0.71; Slope: 1.05850
Intercept 98.36906



1862-1978
Statistics: Correlation 0.84; R^2 0.71 ; Slope 1.01315
Intercept 125.26067



Country South of
ADELAIDE
from
O'HALLORAN HILL TO Mt. TERRIBLE
including DISTRICT C. and portions of
DISTRICTS B. and D.
Surveyed by
J. Mc. Laren Esqr.
John Arrowsmith
10 Soho Square
1840
ALDINGA
BAY
Unkaparinga R.
Mt. Terrible
C. District
D. Do.
Sandy Beach
Scale of Miles

APPENDIX 3

Extract from the 1840 McLaren Map which shows the Willunga Basin as surveyed in 1839/40.

Source: McLaren (1840), State Library of South Australia, Map Collection

APPENDIX 4

INDEX TO SECTIONS: COMMENTS NOTED IN SURVEY RECORDS RELATING TO THE ENVIRONMENT WITHIN THE WILLUNGA BASIN.

Source: Compiled by the author January-February 1994 from original surveyors' field notebooks and diagram books held in the Survey Records Department, Department of Environment & Natural Resources.

Notes:

Sections in the Hundred of Willunga are given first, followed by the Hundred of Kuitpo and the Hundred of Myponga. The latest Hundred Maps (Willunga 1963, Myponga, 1959 and Kuitpo, 1962) are used as a base.

ALL sections on these maps were investigated. If a section was recorded in more than one place in the same year, only the records giving information are noted. Only one entry appears to give a year where several records in one year give no information (eg if the Diagram Books recorded no details from the Field Notebook of the same year, the Diagram Book is not referred to, especially since many Diagram Book pages were not clearly datable). No environmental information was available after the 1930s. Survey records after this date only give changes to section boundaries or subdivisions. Dates and information are as accurate as records permit and are cross-checked to other records where possible. Missing numbers in the sequence indicate that the section number is not in use (according to the Section Index in Diagram Book 1), or could not be found in the diagrams.

Information was lacking for the sections south and south-east of Noarlunga. Field Notebook 102 said to see No 1 Sketch Book for this area, but Survey Records staff could not locate it. However, the sections appear in an undated copy of the original in Diagram Book A, but part of the number sequence also occurs in the 1839 books, therefore allowing the survey year to be established.

The overlay provided in the inside back cover of the thesis can be used to locate sections on the larger maps within the body of the text.

KEY:

Sources: * FNB = Field Notebook number/page
DBK = Kuitpo Diagram Book number/page
DBM = Myponga Diagram Book number/page
DBW = Willunga Diagram Book number/page
DBA/B/C = Diagram Books A, B or C/page

Compass points used in abbreviated form, eg NW = northwest
+ = Section no. at equivalent location on 1963 Hundred map
Date? = Date not clear/not given in surveys (but often inferrable by reference to adjacent sections)

HUNDRED OF WILLUNGA

Section No.	Date	Source (*)	Description/ artistic representation
1) 2) 3) 4) 5) 6) 7) 8) 9) 10)	1879	DBW1/29	"Willunga South" Grazing Land. Timber gums and a few sheaoaks and blackwood
1	1883	DBW1/35	Pasture land, gums, wattles, bushes, grasstree, sandy soil
2	1883	DBW1/35	Gums, peppermint, wattles, bushes, grasstree, sandy soil
3	1883	DBW1/35	Gums, scrub bushes, grasstree, sandy soil
Pt 4	1883	DBW1/36	Rough pasture, gums, wattles, peppermint, bushes, grass tree, wire grass, sandy soil, brown clayey loam in places
5	1883	DBW1/36	Pasture land, stunted gums, scrub, wire and grass tree, sandy soil, clayey in places
Pt 6	1883	DBW1/36	Pasture land, stunted gums, scrub, wire and grass tree, sandy soil, clayey in places
Pt 7	1883	DBW1/36	Pasture land, gums, bushes, grasstree, wiregrass, sandy soil
8	1883	DBW1/36	Pasture land, gums, bushes, grasstree, wiregrass, sandy soil
9	1883	DBW1/36	Stunted scrub, grasstree, wiregrass, sandy soil
10	1883	DBW1/37	Poor sandy country, gums, wattles, grasstree, red clayey soil near creek
11	1883	DBW1/37	Gums, wattles, bushes, grasstree, wiregrass, sandy on creek, red clay
12) 13) 14) 15) 16)	1883	DBW1/37	Gums, bushes, scrub, grasstree, wiregrass, sandy soil, red clay on creeks, wattles
17	1883	DBW1/35	Gums, wattles, bushes, sandy soil
18	1883	DBW1/35	Gums, wattles, bushes, sandy soil wiregrass, grasstree
19) 20)	1893	DBW1/39	Partly steep gullies, covered with yacca bushes, good grazing, rest sandy country timbered with honeysuckle, sheaoak and bushes, ironstone on surface, red clay in gullies.
	1893	FNB1820/6	N steep gullies, good grazing, open with low bushes and a few sheaoaks, ironstone on surface, S thickly timbered with honeysuckles, sheaoaks and wattles, undergrowth of bushes and yacka
21) 22)	1893	DBW1/39	Mostly red sandy soil, thickly timbered with honeysuckle, sheaoak, wattles and bushes. Arable land
23	1893	DBW1/39	Soil brown sandy loam, 6-15" deep, honeysuckle, sheaoak, wattles, bushes. Arable land. Thick undergrowth of bushes.
24	1893	DBW1/39	Soil brown sandy loam, 6-15" deep, honeysuckle, sheaoak, wattles, bushes. Thick undergrowth of bushes. Good arable.
25	1839	FNB102/29	All sandy and scrubby
	1884	DBW1/38	Scrub gums, bushes, grasstree, sandy portion near reserve, good dark loam, grassy flat, gums. At 25c: quarrying for sand and gravel
	1887		4 sections (25/26/27/28) dedicated as stone reserve
	1921	DBW1/43	Poor sandy soil, timbered with scrub gums, various bushes, yacca and ferns. Rubble ironstone for roadmaking and repairing has been excavated from top of hill (was stone reserve)
26	1839	FNB102/29	All sandy and scrubby
	1884	DBW1/38	Scrub gums, bushes, grasstree, sandy portion near reserve, good dark loam, grassy flat, gums.
	1887		4 sections (25/6/7/8) dedicated as Stone reserve
	1921	DBW1/43	3/5 fairly good arable land, sandy soil, scrub gums, a few wattles, various bushes and yacca. Rest poor scrubby sandy soil country with small scrub gums, bushes, yaccas and ferns.
27	1839	FNB102/29	All sandy and scrubby
	1884	DBW1/38	Scrub gums, bushes, grasstree, sandy portion near reserve, good dark loam, grassy flat, gums.
	1887		4 sections (25/6/7/8) dedicated as Stone reserve
27 contd	1921	DBW1/43	3/5 fairly good arable land, sandy soil, scrub gums, a few wattles, various bushes and yacca. Rest poor scrubby sandy soil country with small scrub gums, bushes, yaccas and ferns.
28	1839	FNB102/29	All sandy and scrubby
	1884	DBW1/38	Scrub gums, bushes, grasstree, sandy portion near reserve, good dark loam, grassy flat, gums.
	1887		4 sections (25/6/7/8) dedicated as Stone reserve
	1921	DBW1/43	3/10 rich loamy flat cleared of all timber, planted with trellised vines, open vines and various fruit trees, all in good bearing. 3/10 fair arable land with scrub gums, a few wattles, various bushes, yacca and ferns. 4/10 poor sandy soil, timbered as above. 2 wells on map.
29	1921	DBW1/43	3/4 rich loamy flat, a few large gum trees, 1/4 fair to good sandy soil, various bushes, fern, yacca
30	1921	DBW1/43	Fairly good arable, sandy soil, scrub gums, few wattles, various bushes and yacca
31	1883	DBW1/36	Pasture land, gums, bushes, grasstree, wiregrass, sandy soil
32	1883	DBS1/36	Rough pasture, gums, wattles, peppermint, bushes, grass tree, wire grass, sandy soil, brown clayey loam in places
	1924	DBW1/18	(Pt of 4)
33	1854	DBW1/17	(As 551/2/3) Good pasture
	1924	DBW1/45	1/5 rich loamy slopes suitable for vines. Good grazing. 2/5 open stony hills with scattered scrub gum. Good grazing. Rest steep stony hills covered with stringybarks, yacca, teatree and tussocked grass. Fair grazing.
34	1924	DBW1/45	Nearly all rich loamy slopes, suitable for vines, good grazing
35	1924	DBW1/46	
36	1924	DBW1/46	
37	1883	DBW1/36	Pasture land, gums, bushes, grasstree, wiregrass, sandy soil
	1923	DBW1/18	(Pt of 7)
38+	1839	FNB102/32	Sandy and scrubby and barren "up to the range of hills"
	1859	DBW1/21	Part good arable, part dense scrub, thinly timbered, no surface water
39	1839	FNB102/34	Forest land
	1859	DBW1/21	Part good arable, part dense scrub, thinly timbered, no surface water
40	1859	DBW1/21	Part good arable, part dense scrub, thinly timbered, no surrace water
41	1839	FNB102/31	Sandy and sandy hills, plains
	1859	DBW1/21	Part good arable, part dense scrub, thinly timbered, no surface water
42	1839	FNB102/31	Plains in N, sandy and sandy hills in S
	1859	DBW1/21	Part good arable, part dense scrub, thinly timbered, no surface water
43	1859	DBW1/22	Part good arable, part good grazing land, thickly timbered
44	1839	DBA/4	(Noarlunga)
45	1839	DBA/4	(Noarlunga)
46	1926	DBW2/51	N loose white sandhills covered in low bushes
46 (pt 350/347)	1926	DBW2/51	Patches of bare windswept clay and limestone subject to change according to winds. Peglers Creek - inundation marked in corner of 347 where joins 350/46
47	1839	DBA/4	
48	1839	DBA/4	
49	1839	DBA/4	
50	1839	DBA/4	
51	1839	DBA/4	
52	1839	DBA/4	
53	1839	DBA/4	
54	1839	DBA/4	(Noarlunga)
55	1839	DBA/4	(Noarlunga)
56	1839	DBA/4	
57	1839	DBA/4	Water in SE where creek enters
58	1839	DBA/4	
59	1839	DBA/4	
60	1839	DBA/4	
61	1839	DBA/4	(Part in Noarlunga)
62	1902	DBW1/41	Scrubby valley timbered with gum saplings, dense undergrowth, light sandy loam 2-8" deep over gravel, fair grass in places. Gumflat by stream, teatree near Blewitt's spring
63	1839	DBA/4	
64	1839	DBA/4	
65	1839	DBA/4	
66	1839	DBA/4	
67	1839	DBA/4	
68	1839	DBA/4	
69	1839	FNB102/20	
70	1839	DBA/4	
71	1839	DBA/4	
72	1839	DBA/4	
73	1839	DBA/4	
74	1839	DBA/4	
75	1839	DBA/4	
76	1839	DBA/4	
77	1839	DBA/4	
78	1839	DBA/4	
79	1839	FNB102/20	
80	1839	DBA/4	
81	1839	DBA/4	
82	1839	DBA/4	
83	1839	DBA/4	

84	1839	DBA/4	
85	1839	DBA/4	
86	1839	DBA/4	
87	1839	DBA/4	
88	1839	DBA/4	
89	1839	FNB102/20	
90	1839	DBA/4	
91	1839	DBA/4	
92	1839	DBA/4	
93	1839	DBA/4	
94	1839	DBA/4	
95	1839	DBA/4	
96	1839	DBA/4	
97	1839	DBA/4	
98	1839	DBA/4	
99	1839	FNB102/20	
100	1839	DBW1/1	
101	1839	DBW1/1	
102	1839	DBA/4	
103	1839	DBA/4	
104	1839	DBA/4	
105	1839	DBA/4	Where creek enters= "good water"
106	1839	DBA/4	
107	1839	DBA/4	
108	1839	FNB102/29	
109	1839	FNB102/20	
110	1839	DBW1/1	
111	1839	DBW1/1	
112	1839	DBW1/1	
113	1839	DBA/4	
114	1839	DBA/4	
115	1839	DBA/4	Teatree along stream, good water
116	1839	DBA/4	
117	1839	DBA/4	
118	1839	FNB102/29	
119	1839	DBA/4	Water on stream just W of boundary
120	1839	DBW1/1	
121	1839	DBW1/1	
122	1839	DBW1/1	
123	1839	DBA/4	"Water" where creek crosses W boundary
124	1839	DBA/4	
125	1839	DBA/4	
126	1839	DBA/4	
127	1839	DBA/4	
128	1839	FNB102/29	
129	1839	DBA/4	Good water marked middle of creek
130	1839	DBW1/1	
131	1839	DBW1/1	
132	1839	DBW1/1	
133	1839	DBA/4	
134	1839	DBA/4	
135	1839	DBA/4	
136	1839	DBA/4	
137	1839	DBA/4	
138	1839	FNB102/29	
139	1839	FNB102/20	
140	1839	DBW1/1	
141	1839	DBW1/1	
142	1839	DBW1/1	
143	1839	DBA/4	
144	1839	DBA/4	
145	1839	DBA/4	
146	1839	DBA/4	
147	1839	DBA/4	SW corner - large gum trees
148	1839	FNB102/29	
149	1839	FNB102/20	
150	1839	DBA/4	
151	1839	DBA/4	
152	1839	DBA/4	
153	1839	DBA/4	
154	1839	DBA/4	
155	1839	DBA/4	
156	1839	DBA/4	
157	1839	DBA/4	
158	1839	FNB102/29	
159	1839	FNB102/20	
160	1839	DBA/4	
161	1839	DBA/4	
162	1839	DBA/4	
163	1839	DBA/4	
164	1839	DBA/4	
165	1839	DBA/4	
166	1839	DBA/4	
167	1839	DBA/4	
168	1839	FNB102/29	
169	1839	FNB102/20	
170	1839	DBA/4	
171	1839	DBA/4	
172	1839	DBA/4	
173	1839	DBA/4	
174	1839	DBA/4	
175	1839	DBA/4	
176	1839	DBA/4	
177	1839	DBA/4	
178	1839	FNB102/29	
179	1839	FNB102/19	
180	1839	DBA/4	
181	1839	FNB102/25	
182	1839	FNB102/25	
183	1839	FNB102/25	
184	1839	FNB102/25	
185	1839	FNB102/25	
186	1839	FNB102/25	
187	1839	FNB102/27	Open plains
188	1839	FNB102/27	Open plains
189	1839	FNB102/23	
190	1839	FNB102/23	
191	1839	FNB102/23	
192	1839	FNB102/25	
193	1839	FNB102/25	
194	1839	FN102/25	
195	1839	FNB102/25	Aldinga Plains
196	1839	FNB102/25	Aldinga Plains
197	1839	FNB102/27	Open plains
198	1839	FNB102/27	Open plains
199	1839	FNB102/23	
200	1839	FNB102/23	
201	1839	FNB102/23	
202	1839	FNB102/23	
203	1839	FNB102/25	
204	1839	FNB102/25	
205	1839	FNB102/25	
206	1839	FNB102/25	Aldinga Plains
207	1839	FNB102/25	Aldinga Plains
208	1839	FNB102/27	Open plains
209	1839	FNB102/23	
210	1839	FNB102/23	
211	1839	FNB102/23	
212	1839	FNB102/23	
213	1839	FNB102/25	
214	1839	FNB102/25	Open plains
215	1839	FNB102/25	Open plains
216	1839	FNB102/25	
217	1839	FNB102/25	
218	1839?	DBW1/11	
219	1839	FNB102/23	
220	1839	FNB102/23	
221	1839	FNB102/23	
222	1839	FNB102/23	
223	1839	FNB102/25	
224	1839	FNB102/25	
225	1839	FNB102/25	
226	1839	FNB102/25	NE open plains, rest forest
227	1839	FNB102/25	
228	1839	FNB102/27	Open plains
229	1839	FNB102/23	
230	1839	FNB102/23	
231	1839	FNB102/23	
232	1839	FNB102/25	Aldinga Plains
233	1839	FNB102/25	Aldinga Plains
234	1839	FNB102/25	
235	1839	FNB102/25	
236	1839	FNB102/25	
237	1839	FNB102/25	
238	1839?	DBW1/11	
239	1839	FNB102/23	Plains
239	1839	FNB102/33	Open plains
240	1839	FNB102/23	Plains
		FNB102/33	Open plains
241	1839	FNB102/23	
242	1839	FNB102/25	
243	1839	FNB102/25	Aldinga Plains
244	1839	FNB102/25	Aldinga Plains
245	1839	FNB102/25	
246	1839	FNB102/25	
247	1839	FNB102/25	
248	1839	FNB102/27	
249	1839	FNB102/33	Open plains
250	1839	FNB102/33	Open plains
251	1839	FNB102/33	Open plains
252	1839	FNB102/33	Open plains
253	1839	FNB102/35	Open plains
254	1839	FNB102/35	Open plains
255	1839	FNB102/38	Open plains
256	1839	FNB102/38	Open plains
257	1839	FNB102/38	Open plains
258	1839	FNB102/38	Open plains
259	1839	FNB102/33	Open NW, forest SE
260	1839	FNB102/33	Forest
261	1839	FNB102/23	Forest SW, open NE
262	1839	FNB102/33	Open plains
263	1839	FNB102/35	Open plains
264	1839	FNB102/38	Open plains
265	1839	FNB102/38	Open plains
266	1839	FNB102/38	Open plains
267	1839	FNB102/38	Teatree scrub across stream, plains NW, forest SE and S
268	1839	DBW1/4	
269	1839	FNB102/43	Forest
270	1839	FNB102/43	Forest
271	1839	DBW1/4	
272	1839	DBW1/4	
	1936	DBW2/91	In July marked as fence washed away in top NW corner
273	1839	DBW1/4	
274	1839	DBW1/4	
275	1839	FNB102/38	Open plains NW
276	1839	DBW1/4	
277	1839	DBW1/4	
278	1848	DB1/7	
279	1839	FNB102	Open W, lightly wooded E
	1848	DB1/7	
280	1839	FNB102	Lightly wooded
281	1839	DBW1/4	
282	1839	DBW1/4	
283	1839	DBW1/4	
284	1854	DBW1/34	
285	1883	DBW1/36	Pasture land, stunted gums, scrub, wire and grass tree, sandy soil, clayey in places
286	1937?	DBW2/106	Council Purposes Reserve (coast)
287	1883	DBW1/36	Rough pasture, gums, wattles, peppermint, bushes, grass tree, wire grass, sandy soil, brown clayey loam in places
288	1902	DBW1/41	Was water reserve
289	1839	DBW1/4	
290	1839	DBW1/4	
291	1839	DBW1/4	
292	1938	DBW3/108	Watercourse 20' deep along N boundary
293	1925?	DBW1/65	
294	1925?	DBW1/65	
295	1959	DBW2/124	(was section 482)
296	1839	DBW1/4	Swamp, saltwater lake
		FNB102/61	Swamp surrounding lagoon
297	1949?	DBW2/122	
298	1926	DBW2/56	Chiefly deep black clayey soil, in places covered by yellow silt. Subject to inundation. Orchard of assorted fruit trees (fig and orange chiefly) in a neglected state.
299	1839	DBW1/4	
300	1839	DBW1/4	
301	1854	DBW1/34	
302	1850	DBB/45	
303	1850	DBB/45/101	
304	1850	DBB/45	
305	1839	FNB102/28	Teatree scrub along stream, good water
306	1851	DBA/35	Hilly, wooded, water
307	1851	DBA/35	RC Glebe
308	?	DBW2/136	(Location not clear)

309	1967	DBW2/139	Preservation of Natural Features Reserve (coast)
310) 311)	1973	DBW3/139	Caravan park and recreation reserve created in SW corner of Sec 742 ("Aldinga Scrub")
312	1857	DBW2/122	Subdiv of Sec 701
313) 314)	1883	DBW1/37	Poor sandy country, gums, wattles, grasstree, red clayey soil near creek
315	1854	DBW1/13	Govt Reserve, sand and scrub well in top NE corner
	1891	DBW1/13	Water Reserve
	1950s/ 60s	DBW1/13	Enquiries to use as recreation reserve or caravan park (Cancelled)
316	?	DBW1/19	
318	1839	FNB102/21	
319	1839	FNB102/21	
320	1839	FNB102/21	
322	1839	FNB102/21	
323	1839	FNB102/21	
325	1839	FNB102/21	
326	1839	FNB102/21	
327	1839	FNB102/21	
328	1839	FNB102/21	
330	1839	FNB102/7	
331	1839	FNB102/7	
332	1839	FNB102/21	
333	1839	FNB102/21	
334	1839	FNB102/7	
335	1839	FNB102/21	
336	1839	FNB102/21	
337	1839	FNB102/21	
339	1839	FNB102/21	
340	1839	FNB102/7	
341	1839	FNB102/20	
342	1839	FNB102/20	
343	1839	FNB102/3	
344	1839	FNB102/3	
345	1839	FNB102/20	
346	1839	FNB102/20	
347	1839	FNB102/3	
348	1839	FNB102/20	
349	1839	FNB102/20	
350	1839	FNB102/20	Salt water creek
351	1839	FNB102/20	
352	1839	FNB102/20	
353	1839	FNB102/21	
354	1839	FNB102/20	
355	1839	FNB102/20	
356	1839	FNB102/4	
357	1839	FNB102/20	Good water
358	1839	FNB102/20	
359	1839	FNB102/4	
	1928	DBW2/63	Open country, light brown sandy loam
360	1839	FNB102/20	
361	1839	FNB102/20	
362	1839	FNB102/4	
363	1839	FNB102/20	
364	1839	FNB102/20	
365	1839	FNB102/4	
366	1839	FNB102/20	
367	1839	FNB102/20	
368	1839	FNB102/4	
	1928	DBW2/62	Deep ravine NW, cutting under rnad towards W (road marked as opened 3.3.1970)
369	1839	FNB102/20	
370	1839	FNB102/20	
371	1839	DBA/3	Fresh water (near coast)
372	1839	FNB102/20	
373	1839	FNB102/20	
374	1839	FNB102/4	
375	1839	FNB102/4	
376	1839	FNB102/19	
377	1839	FNB102/19	
378	1839	FNB102/4	
379	1839	DBW1/5	
380	1839	FNB102/23	
381	1839	DBW1/5	
382	1839	DBW1/5	
383	1839	DBW1/5	
384	1839	DBW1/5	
385	1839	FNB102/23	
386	1839	DBW1/5	
387	1839	DBW1/5	
388	1839	FNB102/37	Open plains
389	1839	DBW1/5	
390	1839	FNB102/37	Open plains
391	1839	FNB102/37	Water brackish in stream
392	1839	FNB102/37	Water brackish in stream
393	1839	FNB102/37	Water brackish in stream
394	1839	DBW1/5	
395	1839	FNB102/23	
396	1839	DBW1/5	
397	1839	DBW1/5	
398	1839	DBW1/5	
399	1839	FNB102/37	Water brackish
400	1839	DBW1/5	
401	1839	FNB102/23	
402	1839	DBW1/5	
403	1839	DBW1/5	
404	1839	DBW1/5	
405	1839	DBW1/5	
406	1839	FNB102/37	Plains
407	1839	FNB102/37	Plains
408	1839?	DBW1/5	
409	1839	FNB102/33	Open plains
410	1839	FNB102/39	Open plains
411	1839	FNB102/39	Open plains
412	1839?	DBW1/5	
413	1839?	DBW1/5	
414	1839	FNB102/37	
414	1839	FNB102/37	Open plains
415	1839	FNB102/37	Open plains
416	1839?	DBW1/5	
417	1839	FNB102/23	Open plains
418	1839	DBW1/5	
419	1839	DBW1/5	
420	1839	DBW1/5	
421	1839	DBW1/5	
422	1839	DBW1/5	
423	1839	DBW1/5	
424	1839	DBW1/5	
425	1839	DBW1/5	
426	1839	DBW1/5	
427	1839	DBW1/5	
428	1839	FNB102/23	Aldinga Plains
429	1839	DBW1/4	
430	1839	FNB102/43	Open plains
431	1839	FNB102/43	Open plains
432	1839	FNB102/43	Open plains
433	1839	FNB102/43	Open plains
434	1839	FNB102/43	Plains
435	1839	FNB102	
436	1839	FNB102/43	Open plains
437	1839	FNB102/43	Open plains
438	1839	FNB102/43	Open plains
439	1839	FNB102/43	Open plains
440	1839	FNB102/27	Open plains
441	1839	FNB102/27	Open plains
442	1839	FNB102/27	Open plains
443	1839	FNB102/27	Open plains
444	1839	FNB102/27	Open plains
445	1839	FNB102/27	Open plains
446	1839?	DBW1/6	
447	1839	FNB102/29	Open plains
448	1839	FNB102/29	Open plains
449	1839	FNB102/29	Open plains
450	1839	FNB102/29	Open SW 2/3, forest NE 1/3
451	1839	FNB102/29	Open plains
452	1839	FNB102/29	Open plains
453	1839	FNB102/29	Open SW, forest NE
454	1839	FNB102/29	Forest
455	1839	FNB102/29	Forest
456	1839	FNB102/29	
457	1839	FNB102/29	Open plains
458	1839	FNB102/29	Open plains
459	1839	FNB102/29	Forest
460	1839	FNB102/29	Forest
461	1839	FNB102/31	Forest land
462	1839	FNB102/29	Plains
463	1839	FNB102/29	Plains SW, sandhills NW
464	1839	FNB102/29	Plains
465	1839	FNB102/29	Plains
466	1839	FNB102/29	Plains
467	1839	FNB102/31	Forest land
468	1839	FNB102/31	Forest land, water
469	1839	FNB102/29	Plains
470	1839	FNB102/29	N part plains
471	1839	FNB102/29	Good section
471	1839	FNB102/31	Forest land, plains in N
472	1839	FNB102/29	Good section, plains in N
	1938	DBW3/108	Watercourse 6-20' deep marked on NW boundary
473	1839?	DBW1/6	
474	1839	FNB102/31	Forest land - bad
475	1839	FNB102/31	Forest land - bad
476	1839	FNB102/31	Forest land - bad
477	1839?	DBW1/6	
478	1839	FNB102/31	Forest land. Bad
479	1839	FNB102/29	Sandy
480	1839	FNB102/29	Sandy
481	1839	FNB102/29	Sandy
482	1839?	DBW1/6	
483	1839?	DBW1/6	
484	1839	FNB102/31	Forest
485	1839	FNB102/31	Open plains
486	1839?	DBW1/6	
487	1839	FNB102/29	Plains, water to be got 50'(?)
488	1839	FNB102/29	Plains, water to be got 50'(?)
489	1839	FNB102/29	Sandy hills
490	1839	FNB102/29	Sandy hills
		FNB102/31	Open plains
491	1839	FNB102/31	Open plains
492	1839	FNB102/31	Open plains
493	1839	FNB102/31	Open plains
494	1839?	DBW1/6	
495	1839	DB1/12/38	
496	1839	FNB102/29	Sandy hills NW, plains SE
	1884	DBW1/38	Wells and spring in SE corner, "water reserve (fresh)"
497	1839	FNB102/29	NW sandy hills, SE good section
	1884	DBW1/38	Open flat between streams
498	1839	FNB102/29	Plains
499	1839	FNB102/29	Plains
500	1839?	DBW1/6	
501	1839	FNB102/31	Open plains
502	1839	FNB102/31	Open plains
503	1839	FNB102/31	Open plains, sandy hill
503	1839	FNB102/32	Good soil
504	1884	DBW1/38	Gums, good grassy flat, black clayey loam
505	1839	FNB102/27	Deep gully
	1850	DBA/28	
506	1839	FNB102/29	Sandy hills in S
	1850	DBA/30	Good undulating, wooded
507	1839	FNB102/31	Open plains
	1854	DBA/28	
508	1879	DBW1/27	Good land
509	1839	FNB102/29	Good section
	1839	FNB102/31	Open plains
	1879	DBW1/27	Glebe
510	1839	FNB102/31	Open plains
511	1839	FNB102/31	Open plains/sandy
512	1839	FNB102/31	Sandy/sandy hills
513) 514) 515) 516) 517) 518) 519)	1850?	DBA/30	Good undulating, wooded
520	1850	DBA/30	
521	1839	FNB102/31	Plains in N, sandy/sandy hills in S
522	1982	DBW3/147	Commonage and public camping
523	1851	DBW1/9	Good pasture
524	1851	DBW1/9	Good pasture
525	1851	DBW1/9	Good pasture
526	1852	DBW1/9	Good pasture
527	1852	DBW1/9	Good pasture
528	1852	DBW1/9	Good pasture
	1849	DBW1/8	Good pasture
529	1852	DBW1/9	Good pasture
530	1852	DBW1/9	Good pasture
530A	1839	FNB102/34	Good water, teatree scrub along stream, some forest in NW

531	1839	FNB102/32	Deep gullies noted
	1839	FNB102/34	Teatree scrub along stream, good water
532) 533)	1853	DBC/11	Well timbered, some creeks running with water from springs
534	1854	DBW1/14	Good arable land, wood
536	1855	DBW1/15	Good arable, wooded
537	1852	DBW1/9	Good pastoral
538	1852?	DBW1/9	Ground water to be got by sinking to about 30 feet
539	1854	DBW1/14	Some arable, mostly pasture, hilly
540	1854	DBW1/14	Hilly pasture, wood
541	1854	DBW1/14	Hilly pasture, wood
542	1854	DBW1/14	Hilly arable and pasture, wood
543	1854	DBW1/14	Good arabla
544	1854	DBW1/14	Hilly arable and pastureland, water
545	1852	DBW1/15	Good pasture, rather hilly
546	1854	DBW1/17	Mostly rough pasture
547	1854	DBW1/17	Good pasture
548	1854	DBW1/17	Good agriculture
549	1854	DBW1/17	Good agriculture
550	1854	DBW1/17	Good grazing
551-554 & 566 were section 33			
551	1854	DBW1/17	Good pasture
552	1854	DBW1/17	Good pasture
553	1854	DBW1/17	Good pasture
554	1854	DBW1/17	Rough pasture
555	1854	DBW1/17	
556	1854	DBW1/17	Good pasture
557	1854	DBW1/17	Good pasture
558	1854	DBW1/17	Good agricultural
559	1854	DBW1/17	Good pasture
560	1854	DBW1/17	Good pastureland
561	1854	DBW1/17	Good arable, pasture
562	1854	DBW1/17	Good pasture
565	1854	DBW1/17	Good pasture
566	1854	DBW1/17	Good pasture
567	1854	DBW1/17	Good agriculture
568	1856	DBW1/20	Good pasture
569	1856	DBW1/20	Good hilly pasture
570	1856	DBW1/20	Good hilly pasture
571	1856	DBW1/20	Good hilly pasture
572+	1839	FNB102/32	Sandy and scrubby and barren "up to the range of hills"
	1856	DBW1/20	Scrubby, sandy
573	1856	DBW1/20	Hilly pasture, water reserve in SW corner
574	1839	FNB102/32	Scrubby
	1839	FNB102/34	Sandy and sandy hills
	1856	DBW1/20	Mostly sandy
575	1855	DBW1/19	Midling good land
577	1840	FNB9	(Myponga survey)
578	1840	FNB9	(Myponga survey)
579	1855	DBW1/19	Thick scrub and sand
	1879	DBW1/27	Very poor land, parts in gullies good
580	1855	DBW1/19	Mostly scrub and sand
	1879	Resurvey	Very poor land/parts in gullies good
581	1855	DBW1/19	Good agricultural
582	1855	DBW1/19	Good agricultural
583	1855	DBW1/19	Good agricultural
584	1855	DBW1/19	Good agricultural
	1862	DBW1/24	Good arable and pasture, well timbered
585	1855	DBW1/19	Good agricultural
	1862	DBW1/24	Good arable and pasture, well timbered
586	1855	DBW1/19	Good agricultural
	1862	DBW1/24	Good arable and pasture, well timbered
587	1935	DBW2/87	Sharply undulating country of brown loam over stone, mostly well grassed, timbered with medium and big gums
589	1939	DBW2/51	Public Recreation Reserve (coast)
591	?	DBW1/16	(Location not clear)
592	1883	DBW1/37	Gums, bushes, scrub, grasstree, wiregrass, sandy soil, red clay on creeks, wattles
593	1883	DBW1/37	Gums, bushes, scrub, grasstree, wiregrass, sandy soil, red clay on creeks, wattles
596	1839	FNB102/31	Sandy hills NW, plains SE
	1856	DBW1/20	A little good, mostly sandy
600	1839	DBW1/4	
601	1839	FNB102/43	Sandy and scrubby
602	1839	FNB102/43	Open plains
603	1839	FNB102/43	Open plains
604	1839	FNB102/43	Open plains N, forest S
605	1839	FNB102/43	Lightly wooded N, forest S
606	1839	DBW1/4	
607	1839	FNB102/43	Open plains
608	1839	FNB102/43	Open plains
609	1839	FNB102/43	Open plains
610	1839	FNB102/43	Open plains NW, forest SE
611	1839	FNB102/43	Forest land
612	1839	FNB102/43	Forest land
613	1839	FNB102/43	Forest SW, rest open plains
614	1839	DBW1/4	
615	1839	FNB102/41	Open plains
616	1839	FNB102/41	Open plains
617	1839	FNB102/42	Open plains
618	1839	FNB102/42	Forest N and E, rest open plains
619	1839	FNB102/42	Open plains in centre of forest
620	1839	FNB102/42	Forest
621	1839	FNB102/42	Open in NE, rest forest
623	1883	DBW1/37	Gums, bushes, scrub, grasstree, wiregrass, sandy soil, red clay on creeks, wattles
624	1958	DBW2/129	(Noarlunga?)
625	1902	DBW1/41	Was water reserve
627	1839	FNB102/41	Open plains
628	1839	DBW1/4	
	1902	DBW1/41	Was water reserve
629	1839	FNB102/42	Forest S, open in N
630	1839	FNB102/42	Partly forested SW, rest forest
631	1839	FNB102/42	Forest N, lightly wooded S
632	1839	FNB102/42	Forest
633) 634) 635) 636) 637) 638)	1879	DBW1/29	Grazing land. "Willunga South" Timber gums and a few sheaoaks and blackwood
639	1839	FNB102/41	Open plains
640	1839	DBW1/4	
641	1839	DBW1/4	
642	1839	FNB102/42	Forest?
643	1839	FNB102/42	Forest land
644) 645) 646) 648) 649)	1879	DBW1/29	Grazing land, "Willunga South" Timber gums, a few sheaoaks and blackwood
650) 651)	1880	DBW1/30	Good grazing land, soil read and brown loam, ironstone slate and gravel. Timber gums, a few blackoaks
652	1839	DBW1/4	
653	1839	DBW1/4	
654	1839	DBW1/4	
655	1839	FNB102/42	Forest land
656) 657) 658) 659) 660) 661)	1880	DBW1/30	Good grazing land, soil read and brown loam. Ironstone slate and gravel. Timber gums and a few blackoaks
665	1839	DBW1/4	
666	1839	DBW1/4	
667	1839	DBW1/4	
668	1839	DBW1/8	Good pasture ground
670	1839	DBW1/4	
671	1839	DBW1/4	
672	1839	DBW1/4	
674	1839	FNB102/64	Deep gully marked across SW corner to sea
675	1839	FNB102/64	Deep gully marked entering from SE hills
678	1854	DBW1/14	Hilly pasture, water
	1861	DBW1/33	Pasture very hilly and rocky
679	1854	DBW1/14	Hilly pasture, water
	1861	DBW1/33	Thickly timbered, surface water
680	1861	DBW1/23	Pasture, very hilly and stony
681	1862	DBW1/25	Good arable and pasture, well timbered
682	1862	DBW1/25	Good arable and pasture, well timbered
683	1862	DBW1/25	Part arable, part sand and scrub
684	1862	DBW1/25	Part arable, part sand and scrub
685	1879	DBW1/26	Portions fair arable, soil in gullies, good black loam
686	1879	DBW1/26	Hills very gravel and sand, soil in gullies
687	1879	DBW1/26	Flats good rich loam,
	1879	DBW1/28	Timber, stringybark, gums, sheaoaks
688	1879	DBW1/26	Hills very poor sand and gravel
	1879	DBW1/28	Timber, stringybark, gums, sheaoaks
689	1879	DBW1/27	Portions fair arable, soil in gullies rich black loam, hills sand
690	1879	DBW1/27	Sand, black and brown loam in gullies
691	1879	DBW1/27	Sand, black and brown loam in gullies
692	1879	DBW1/28	Timber, stringybark, gums, sheaoaks
693	1879	DBW1/28	Timber, stringybark, gums, sheaoaks
694	1902	DBW1/41	Scrubby valley timbered with gum saplings, dense undergrowth, light sandy loam 2-8" deep over gravel, fair grass in places. Gumflat by stream, teatree near Blewitt's spring
695	1902	DBW1/41	As 694
700	1839?	DBW1/3	
701	1839	DBW1/12	
702	1839	DBW1/12	
703	1839	FNB102/27	
704	1839	FNB102/27	Open plains
705	1839	FNB102/27	Open plains
706	1839	FNB102/27	Open plains
707	1839	FNB102/28	
708	1839	FNB102/31	Stippled for forest
709	1839	FNB102/31	Forest land
710	1839	FNB102/31	Forest land - bad
711	1839	FNB102/31	Forest
712	1839	DB1/12	
713	1839	FNB102/31	Open
714	1839	FNB102/31	
715	1839	FNB102/31	
716	1839	FNB102/32	Good soil
	1839	FNB102/31	Open plains
717	1839	FNB102/31	
718	1839	FNB102/32	Sandy
719	1839	FNB102/31	
720	1854	DBW1/34	
721	1839	FNB102/32	Open plains with sandhills
722	1839	FNB102/32	Open plains with sandhills
723) 724)	1839	FNB102/34	Forest land, in hills to east teatree scrub and good water
725	1839	FNB102/32	Plains
726	1839	FNB102/32	Plains
726	1839	FNB102/34	Plains in W, sandy in E
727	1854	DBW1/14	Hilly arable and pastureland, water
728	1854	DBW1/14	Hilly, good grazing, wood
730	1854	DBW1/14	Hilly, good grazing, wood
731	1854	DBW/14	Hilly, good grazing, wood
732	1839	FNB102/44	Bare hill at top
732	1854	DBW1/14	Arable and pasture, wooded
733	1854	DBW1/14	Good pasture, wood, water
	1861	DBW1/23	Pasture, very hilly and stony
734	1854	DBW1/14	Good arable and pasture
735	1839	FNB102/44	Bare hill
	1854	DBW1/14	Good arable and pasture
736	1854	DBW1/14	Good pasture, wood, water (later Sec 680 and 733)

737	1854	DBW1/14	Good hilly arable, pastureland
	1861	DBW1/23	Pasture, very hilly and stony
740	1839	DBW1/1	
	1850	DBA/30	Good, undulating, wooded
741	1839	FNB102/41	Forest land, sand and scrub
741+	1839	DBW1/4	Sandy and scrubby soil
	1854	DBW1/13	Sand and scrub
742	1854	DBW1/13	Sand and scrub
743	1852	DBW1/15	Good arable land, wooded Good sandstone quarry
744	1852	DBW1/15	Good arable land, wooded
745	1852	DBW1/15	Good arable land, wooded
746	1852	DBW1/15	Hilly arable and pasture, wooded Good sandstone quarry
747	1852	DBW1/15	Hilly pasture, wooded, little water
748	1852	DBW1/15	Hilly pasture, wooded
749	1852	DBW1/15	Hilly pasture, wooded
750	1852	DBW1/15	Hilly pasture, wooded, little water
751	1852	DBW1/15	Hilly pasture wooded
752	1852	DBW1/15	Good pasture, rather hilly
753	1854	DBW1/16	Good red loam, rather hilly
754	1852	DBW1/15	Good pasture, rather hilly
755	1854	DBW1/16	Mostly good land, rather hilly, water reserve in N corner
756	1854	DBW1/16	Mostly good land, rather hilly, wooded
757	1854	DBW1/16	Mostly good land, rather hilly, wooded, slate quarry
758	1854	DBW1/16	Hilly, pasture, wooded
759	1854	DBW1/16	Good grazing land, wooded, hilly
760	1854	DBW1/16	Good grazing land, wooded, hilly
761	1854	DBW1/16	Good arable, rather hilly
762	1854	DBW1/16	Good land, hilly, wooded
763	1854	DBW1/16	Good pastureland, hilly, wooded
764	1854	DBW1/16	Good pasture land, hilly, wooded
765	1854	DBW1/16	Good arable, a little hilly
766	1854	DBW1/16	Good land, hilly, wooded
767	1854	DBW1/16	Good land, hilly, wooded
768	1854	DBW1/16	Good land, hilly, wooded
769	1854	DBW1/16	Good land, hilly, wooded
770	1854	DBW1/16	Good land, hilly, wooded
771	1854	DBW1/17	Good agriculture and ?
772	1854	DBW1/16	Hilly, pasture, wooded
773	1854	DBW1/17	Rough pasture
774	1854	DB1/16	Cemetery
775) 776) 777) 778) 779) 780) 781) 782) 783) 784) 785)	1926	DBW2/53	"McLaren Vale" V deep rich black and chocolate sandy loam, planted with peaches, nectarines, apricots, apples, pears, with border of almonds. Boxthorn on fences
786	1926	DBW2/53	V deep rich black and chocolate sandy loam, well grassed, boxthorn and scotch thistles. House and sheds in poor order
787	1926	DBW2/54	Chiefly deep black clayey soil, in places covered by yellow silt. Subject to inundation (2 creeks ran through). Partly planted with pears north of creek. Well grassed, scotch thistles.
788	1926	DBW2/56	Chiefly deep black clayey soil, in places covered by yellow silt. Subject to inundation. Orchard of assorted fruit trees (fig and orange chiefly) in a neglected state.
789	1921	DBW1/58	(Repurchased for soldier)
790	1921	DBW1/58	(Repurchased for soldier)
791	1920	DBW1/65	(Repurchased for soldier)
792	1948	DBW2/118	(McLaren Vale)
793	1883	DBW1/37	Gums, bushes, scrub, grasstree, wiregrass, sandy soil, red clay on creeks, wattles
794	1883	DBW1/36	Pasture land, gums, bushes, grasstree, wiregrass, sandy soil
795	1856	DBW1/20	Stone Reserve
796	1971	DBW2/137	(Subdiv of 10)
797	1962	DBW2/135	(McLaren Vale)
798	1975	DBW2/142	(McLaren Vale)
799	?	DBW2/141	Coastal Recreation Reserve
800	?	DBW2/141	Coastal Recreation Reserve
801	?	DBW2/141	Coastal Recreation Reserve
802	?	DBW2/141	Coastal Recreation Reserve
804	?	DBW1/20	Wickham Hill
805	?		(McLaren Vale)
806	?		(McLaren Vale)
807	?	DBW1/5	Coastal reserve
808	?	DBW1/4	Reserve where swamp enters sea
809	?	DBW1/14	Mt Terrible
810	1854	DBW1/14	Water reserve
811	1854	DBW1/14	Water reserve
812	1854	DBW1/17	Spring
813	?	DBW2/115	Water reserve
814	?	DBW1/2	(block by coast
815	?	DBW1/2	(block by coast
816	?	DBW1/5	Reserve on coast
818	1967	DBW2/139	Caravan Park Reserve
834)	1839?	DBA/7	(Just S of Onkaparinga)
836	1879	DBW1/32	(N of Onkaparinga) Very superior pasture land - rough stony granite slate ironstone, soil red and brown loam in places, timber gum and peppermints, with chimney and shaft marked
846	1879	DBW1/32	(N of Onkaparinga) Very superior pasture land - rough stony granite slate ironstone, soil red and brown loam in places, timber gum and peppermints
847) 856) 858) 859) 860) 861)	1839?	DBA/7	(originals in FNB102 so presume datable as 1839) just S of Onkaparinga
862	1959?	DBW1/4	(Subdiv on coast)
1007	1854	DBB3/17	
1008	1842	DBW1/3	Slate quarries
1150	1854	DBB/16/17	
1151	1847	FNB100	
1241	1854	DBB/22/100	
1242	1854	DBB/22	

HUNDRED OF KUITPO

Section No.	Date	Source (*)	Description/ artistic representation
196	1882	DBK2/68	Gums, low scrub, grasstree, bushes, sandy soil.
197	1882	DBK2/68	Mostly low scrub, gums, grasstree and bushes, sandy soil, wiregrass. Western part Bay Biscay soil, peppermint, grassy, gums, wattles.
202) 203) 538) 539)	1882	DBK2/68	Low scrub, grasstree and bushes, sandy soil.
1641	1855	DBK1/10	Good land, wooded
1642	1855	DBK1/10	Mostly good land, wooded
1643	1855	DBK1/10	Hilly grazing
1646	1855	DBK1/10	Hilly pasture
1647	1855	DBK1/10	(illegible)
1650	1855	DBK1/10	Good hilly land

HUNDRED OF MYPONGA

Section No.	Date	Source (*)	Description/ artistic representation
272	1858	DBM1/9	Water reserve
273	1858	DBM1/9	
274	1858	DBM1/9	
276	1858	DBM1/9	
277	1858	DBM1/9	
301	1854	DBM1/7	Good arable and pastureland
302	1854	DBM1/7	Good pasture land
303	1854	DBM1/7	Good pasture land, wood
545	1858	DBM1/9	
546	1858	DBM1/9	
548	1858	DBM1/9	
551	1858	DBM1/9	
552	1858	DBM1/9	

Other side of study boundary, top of hills

3	1880	DB1/20	Sheoak, stringybark
	1880	DB1/20	
4	1881	DB1/28	High hills covered with stony spurs covered with stringybark and gums, dense undergrowth

APPENDIX 5A

MINES HISTORY OF THE WILLUNGA BASIN

The information in this chart can be used in conjunction with the section overlay (provided on the inside back cover of the thesis) and Figure 43 to compare the sites of individual mines, the minimum periods of operation and the scale of production.

Source: Compiled by the author from Department of Mines SA (DMESA) "Record of Mines - Summary Cards"; Mines Registration Branch Production Reports 1971-93; A M Pain (pers comm 1994).

Note: Production figures are as complete as the records allow, but are not all inclusive since complete returns were not kept before 1971. All figures given in tons have been converted to tonnes.

PM = Private Mine (any part of section can be mined).

MLE = Extractive Mineral Lease (often have restrictions on which part of the section can be mined).

Products are listed in the following order:

Slate
Barite
Dolomite/limestone
Quartzite
Silver, lead, gold
Sand products
Marble

PRODUCT: SLATE

Name	No	Section	Prodn Date	Prodn Amount	Comments
Loud's Quarry		747 750	1840-41		Only produced for 1 or 2 years since slate found to be poor quality (Vaudrey, pers comm, 1994)
Delabole Mine	8	1150			1840-1846 worked 1860 reopened, small village established 1873 10 men, increasing to peak in 1891 1891 slate industry declined 1903 closed
			1955-57	1,016 tonnes	1953-1957 reopened, worked since intermittently on small scale
PM265	-	1150	1976-91	882 tonnes	Private Mine
Bangor Mine or Australian Slate Quarry	2	756			1842 opened 1856 - quarry caved in, abandoned, new one opened nearby 1884 sold, worked 3 years, slate industry peaked 1887 1900s closed when industry slumped 1911 - main working face 120', 80' high 1917 new company opened new pit below old quarry floor 1920-21 steam dressing plant and new buildings/machines
			1924-44	7,027 tonnes	1924 - Face 200' above quarry floor, pit 70' below 1927 new quarry opened, 50' high, 30' wide, continued until 1944 1976 held as Private Mine
PM273	-	756	1983-93	8,732 tonnes	

Name	No	Section	Prodn Date	Prodn Amount	Comments
Bastian's Mine	3	1008			Large quarry 1846 opened and steady production until closed in 1893 when industry and demand declined rapidly.Reworked at various times with Martin's Quarry. Since 1970 - paving and ornamental stone 1976 - roofing slate from Martin's and Bastian's.
Martin's Quarry	23	1008			Deepest face 100'. 1846 opened, worked on tribute in 1850s 1863 opened, using steam sawing plant by 1881. 1873 15 men 1912 closed 1920s reworked 1925 onwards - intermittently worked with Bastian's 1976 being worked
		With Bastian's	1925-47	17,000 tonnes Ballast	
			1949	5 tonnes Roofing	
			1938-74	31,000 tonnes Flagging	
PM117	-	1008/ 1242	1977-83	2,411 tonnnes	
MLE5775	-	1242	1992	770 tonnes	
AV Jennings Mine	16	1007	1949	1,746 tonnes	Worked 1949 only?, for building stone.
Mrs Brown	N23	305	1933) 1934) 1939)	685 tonnes	

THE WILLUNGA SLATE QUARRIES (Nos 2, 3, 8, 16 & 23) - The only significant source of roofing slate in Australia. Began in 1840 and has since produced 22 million roofing slates (± 68,000 tonnes). The slate industry peaked 1887 and declined after 1891.

Production from nos. 2, 3, 8, 16 and 23 together: 1840-1974

		No. slates (millions)	Roofslate (tonnes)	Flagging, paving, walling (tonnes)
1840-1899	Export	4	13,000	10,000
	Local	5	17,000	10,000
1900-1974		13	38,000	40,000
1840-1974	TOTAL	22 million	68,000 tonnes	60,000 tonnes

PRODUCT: BARITE

Name	No	Section	Prodn Date	Prodn Amount	Comments
Adelaide Barytes Syndicate	-	92 93	1918-52	33,367 tonnes	Largest barite producer
Budgens	N25	101	1918-21 1922 1944-47	1,457 tonnes 269 tonnes 368 tonnes	1918-1921 first worked 1939-40 reworked, shaft sunk to 30' 1944-1947 reworked
Noarlunga Barytes	N99	110,101 111,120	1918-61	18,737 tonnes	1918-21 Secs 101,110 lots of shafts/adits put down; "Mining in a slipshod manner"! Second largest barite mine.
Coleman or Riddle	N34	129			1920s 2 mines prospected 1940 2 mins worked for few months only - low grade ores, small lodes only
Willunga Barytes	N154	122			1922-23 little work
Sutter Bros	?	120			1936-1940 worked on and off.

PRODUCT: DOLOMITE/LIMESTONE (Leases in Sellicks Hill area)

Name	No	Section	Prodn Date	Prodn Amount	Comments
Aldinga DC	Y3	668	1929 1931	102 tonnes 51 tonnes	1920s-1930s intermittent workings for ballast
Hillsley	Y12	678 679 680 727 773	1925-26	3,861 tonnes	Considered as source of limestone for cement in 1925.
Local Government	Y15	680			To 1954 worked for road metal Small quarry 70' long, 60' wide, to 30' high Main quarry 180' long, 180' wide, to 65' high
Norton Minerals	Y23	735			1980s - worked for ornamental grey marble
			1960s		Some of the quarries possibly operated by Highways Department (Pain and Vaudrey, pers comms, 1994). Southern Quarries commenced in the early 1970s.
PM163	-	680/732 678	1977-89	4,132,379 tonnes	Dolomite/limestone
MLE5054	-	735	1989-91	1,029,782 tonnes	Dolomite/limestone
MLE5440	-	735	1992-93	1,040,776 tonnes	Dolomite/limestone
PM151	-	735	1977-83	206 tonnes	Marble
PM237	-	734			No production to date

PRODUCT: DOLOMITE/LIMESTONE (not in Sellicks Hill area)

Name	No	Section	Prodn Date	Prodn Amount	Comments
Mrs Brown	N23	305	1924 1927	295 tonnes 5000 yards	1927 Quarry 60' wide, 200' long, 50' deep 1927 22 men working, of which 15 in rock breaking
Willunga DC	N155	135,136 190	1933-52	34,458 tonnes	1933-1952 (and after?)
Willunga Works	48	701	1940-41	252 tonnes	
PM61	-	65,66	1977 1988-93	141,359 tonnes 551,578 tonnes	Worked 1977, 1988-1993.
PM303	-	58	1978-87	579,688 tonnes	
MLE5273	-	75	1986-90	264,601 tonnes	
MLE5272	-	76	1986/87) 1989-93)	1,175,362 tonnes	

PRODUCT: QUARTZITE

Name	No	Section	Prodn Date	Prodn Amount	Comments
Willunga Council	45	760 1242	-		1927 worked intermittently, 6 men employed. Quarry 45' wide, 200' long, 40-50' deep
Dasborough Mine	7	773	-		1956 opened, used by Willunga Council for roads
SA Silicates	Y25	652	-		1970 - intermittent working of pebble beds extending from low coastal cliffs in Sec 652 used as grinding pebbles for ball mills
MLE5273	-	75	1990	22,000 tonnes	Produced 1990 only

PRODUCT: SILVER, LEAD, GOLD

Name	No	Section	Prodn Date	Prodn Amount	Comments
Sellicks	Y28	732,727			1868 silver/gold found in hills behind Sellicks Hill 1869 gold mined one year: underground adits worked 1887-1889 unsuccessful reworking of northern section
Wickham Hill	N153	122			1875 shafts sunk, small amounts gold obtained
Hardy's Claim	N68	33			1930 - quartz reef discovered and gold worked 1 year

PRODUCT: SAND PRODUCTS AND LOAM

Name	No	Section	Prodn Date	Prodn Amount	Comments
Readymix	N106	365 368	1964 1969	168,098 tonnes 121,926 tonnes	1927-1978 continuous. First sand production area.
PM40	-	365	1977-91	433,188 tonnes	1977-1991 (according to production returns)
Albert's Sandpit	N3	366	1964 1969	117,887 tonnes 69,375 tonnes	Quarry in North Maslins Sands to 50' below surface. Mined 1960 onwards.
PM20	-	366	1977-93	4,728,264 tonnes	Operated 1977-1993 (production returns)
Readymix	N118	139	1969	57,898 tonnes	1961 test drilled, stopped after several years 1972 reopened
PM17	-	139	1977-92	2,170,565 tonnes	Operated 1977-1992 for sand and clay
Christies Sands	N32	149	1964 1969	24,385 tonnes 124,974 tonnes	1961 opened. Sand pit for construction projects, dams, Torrens Island Project (ETSA).
PM265		149	1977-93	1,619,961 tonnes	Operated 1977-93 (production returns)
Monier Besser	N89	364 363			1965 boring tests
PM241	-	509	1977-78	641 tonnes	Only operated 1977-78.
PM279	-	97	1978-92	66,572 tonnes	Operated 1977-93 for sand and clay
Fricker	N55	97	1979	15,071 tonnes	1979 mentioned only
MLE4608	-	481	1978-91	15,197 tonnes	Operated 1978-1991
Moana Sands	N88	350	1979	3,317 tonnes	Only operated 1979
MLE4831	-	182	1980-88	47,619 tonnes	Operated 1980-1988 only
MLE4678	-	193	1980-93	26,299 tonnes	Operated 1980-1993
MLE4846	-	193	1983	1,008 tonnes	Operated 1983 only
MLE5051	-	580	1985-93	193,070 tonnes	Operated 1985-93
NLE5217	-	159	1985-93	995,637 tonnes	Operated 1985-93
MLE5609	-	192	1990-91	18,901 tonnes	Operated 1990-91 only
PM244	-	140/ 150	1992-93	800 tonnes	Operated 1992-1993 only
Readymix	N119	119			No information available
Brighton Garden Supplies	N21	579			No information available

PRODUCT: MARBLE

PM151	-	735	1977-83	206 tonnes	
PM161	-	142	1978	37 tonnes	1978 only

PRODUCT: CLAY

Name	No	Section	Prodn Date	Prodn Amount	Comments
Eclipse (Ochre & Clay)	N47	359	1905-10 1911-16 1908-40	35 tonnes ochre 1,016 tonnes clay 2,234 tonnes clay	1905-1947 worked continuously 1947 onwards - worked by others
PM279	-	97	1977-93	189,229 tonnes	Operated 1977-93 for clay and sand
PM17	-	139	1978-92	382,381 tonnes	Operated 1978-92
PM 65 (265?)	-	149	1987-93	3,586 tonnes	Sand and clay quarried. Clay produced 1987/88-and 1992/93

MINES FOR WHICH LEASES ARE HELD BUT WHICH HAVE NOT PRODUCED SINCE THE PRIVATE MINES ACT (1970s)

PM43	-	363/4
PM232	-	367
PM275	-	141
PM293	-	95
PM289	-	143
PM165	-	305
MLE4847	-	193
MLE5767	-	369

APPENDIX 5B

MINE AND QUARRY PRODUCTION IN THE WILLUNGA BASIN JUNE 1971-DECEMBER 1993

Source: Compiled by the author from Branch Production Reports for individual Extractive Mineral Leases and Private Mines, supplied by the Minerals Registration Branch, Department of Mines & Energy SA.

NOTE: Whilst operating all tenements are required to send in 6-monthly production figures to Mines & Energy, SA; "slate" includes dimension stone, aggregate and rubble; "sand" includes garden, filling packing, concrete, plastering, bricklaying, bitumen, foundry and unspecified sand, and gravel; "marble" includes aggregate, decorative and dimension stone; "clay products" includes red and white plastic clay and shale.

YEAR	SAND PRODUCTS OR LOAM (tonnes)	DOLOMITE/ LIMESTONE (tonnes)	CLAY OR CLAY PRODUCTS (tonnes)	QUARTIZE/ SANDSTONE (tonnes)	SLATE (tonnes)	MARBLE (tonnes)
1976	0.00	0.00	0.00	0.00	250.00	0.00
1977	721,191.00	567,503.00	21,384.00	0.00	599.00	26.00
1978	603,527.00	178,626.00	28,066.00	0.00	587.00	36.00
1979	528,907.00	489,697.00	60,991.00	0.00	244.00	52.00
1980	483,797.00	333,795.00	58,901.00	0.00	570.00	47.00
1981	465,393.00	367,610.00	71,095.00	0.00	0.00	27.00
1982	567,139.00	298,230.00	38,450.00	0.00	20.00	37.00
1983	552,930.00	313,308.00	25,738.00	0.00	688.00	17.00
1984	782,402.00	329,102.00	47,408.00	0.00	980.00	0.00
1985	811,831.00	478,552.00	44,860.00	0.00	1,036.00	0.00
1986	666,048.00	442,925.00	38,662.00	0.00	1,050.00	0.00
1987	620,029.00	489,371.00	37,683.00	0.00	2,044.00	0.00
1988	685,928.00	486,847.00	24,741.00	0.00	742.00	0.00
1989	770,552.00	730,160.00	34,975.00	0.00	820.00	0.00
1990	691,643.00	644,403.00	27,827.00	22,000.00	686.00	0.00
1991	480,115.00	738,730.00	8,474.00	0.00	444.00	0.00
1992	324,484.00	998,796.00	4,069.00	0.00	1,226.00	0.00
1993	495,005.00	1,027,870.00	1,872.00	0.00	809.00	0.00
TOTALS	10,250,921.00	8,915,525.00	575,196.00	22,000.00	12,795.00	242.00
Maximum No. locations operating at any time:	10	5	3	1	3	1

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OVERLAY SHOWING SECTION BOUNDARIES

Source: 1963 Hundred of Willunga Map, 1963 Hundred of Kuitpo Map and 1959 Hundred of Myponga Map: State Library Map Collection