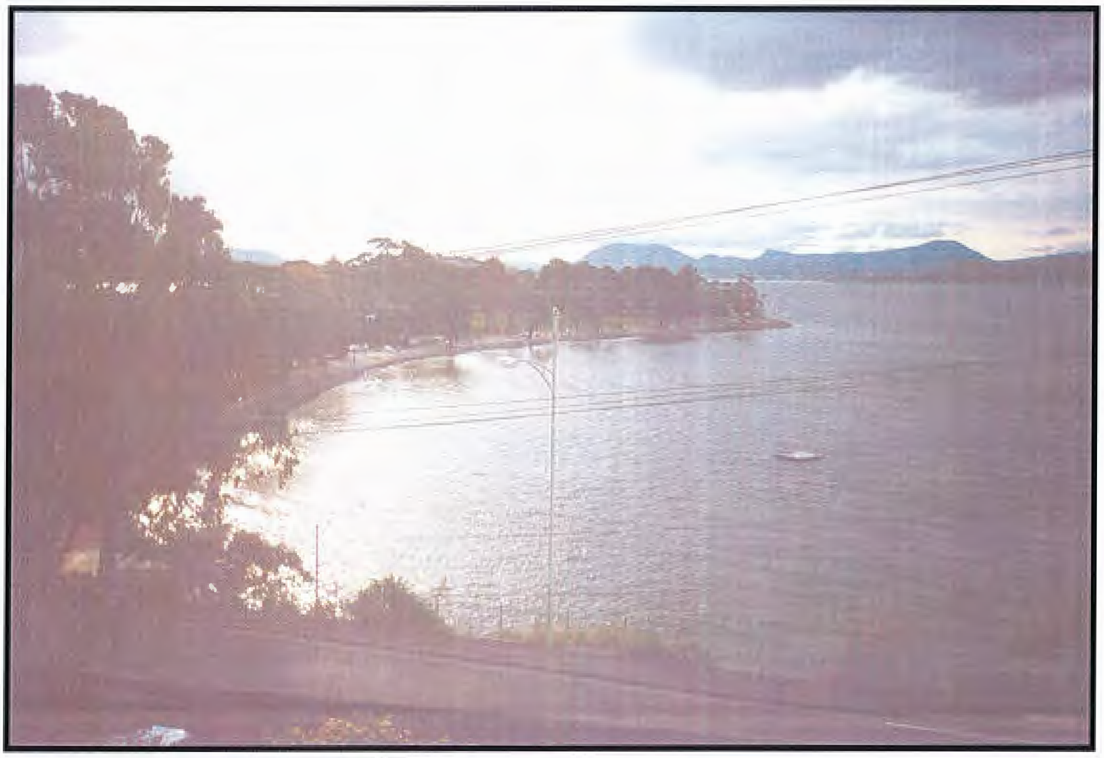
THE MORPHOLOGY AND LONG TERM SHORELINE CHANGES

OF LONG BEACH, SANDY BAY

Stuart J. Anstee



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Declaration

This thesis contains no material that has been submitted for credit in any other degree or graduate diploma in any tertiary institution. To the best of the author's knowledge, this thesis contains no material previously published or written by other persons, except when due reference is made in the text of the thesis.

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Abstract

This project has analysed the long term changes in shoreline position and morphology of Long Beach, located 3 kilometres south of the Hobart CBD in southern Tasmania. Also of interest was the effect of the seawall on shoreline recession rates on Long Beach, offshore bathymetry and the sediment cycling in the area.

Aerial photography and Geographic Information Systems (GIS) is used to create graphical change maps of the study area from 1947 to 1998, in order to interpret regions of change. This information was interpreted to obtain numerical values for the rates of recession or accretion. The changes in offshore bathymetry were also investigated through the production of a digital elevation model. Spot height data was analysed and interpolated in order to effectively locate offshore sand stores.

Results have shown extensive shoreline retreat from 1947, with sand loss being most severe on the mid-regions of Long Beach and on Long Point to the north. In comparison, accretion is prevalent on Nutgrove Beach indicated by a developed dune system. Rates of recession have averaged 2 metres/year during periods of maximum erosion. This figure is comparable to other shoreline studies completed in the region. The variations in sediment supply were analysed in relation to the effect of coastal processes and various coastal engineering structures.

It was found that the erosion on Long Beach has been a direct result of a combination of natural and human-induced changes.

- A shift in the balance of northerly and southerly winds has altered the sediment equilibrium that existed prior to the 1950s, as a result sediment is no longer able to reach Long Beach from the northern beach.
- The extension of a sewage outfall pipe on Blinking Billy Point has possibly restricted sediment movement from the south.
- The presence of the seawall on Long Beach combined with a narrow beach has resulted in waves impacting on the beach during storm events resulting in increased erosion due to wave reflection and scouring.
- Foreshore development, the presence of bridges to the north and damming of the Derwent River may all have influenced wind patterns and sediment supply to Long Beach which has resulted in the poor condition of the beach.

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CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

The coastal environment is constantly changing. The influence of numerous coastal processes leads to the development or erosion of coastal landforms at several spatial and temporal scales. To understand the dynamic nature of coastal regions we must first investigate the factors that lead to these changes. To successfully manage and protect the coastal environment for present and future use, and for aesthetic reasons, we must understand the nature of the change in order to address the problems.

Sandy beaches are one such coastal environment that are constantly changing in response to coastal processes. Beaches occur on all sedimentary shorelines exposed to waves and are amongst the most dynamic physical systems on the earth's surface (Davies, 1980). Worldwide, the estimate of sandy beach coastline ranges from 11 % (53 000 km) to 34 % (170 000 km) (Short, 1999). In Australia, sandy beaches account for approximately 60 % of the total coastline (Short, 1999).

Both wind and water act on the sandy coastline in the form of aeolian transport, waves and currents to remove or deposit sediment within the coastal environment. Beaches are dependent on waves and sediment but are independent of all other surface processes, as a result beaches occur at all latitudes around the globe (Short, 1999). Beaches are modified by a range of processes including tide and wind, and parameters such as sediment type, biota, air and water temperature, and water chemistry (Short, 1999).

Tasmania has 4792 km of coastline, however, of this only 100 km of coastline is protected within National Parks (Watt, 1999). As a result, the majority of Tasmania's coastline and sandy beaches are subject to the ever increasing impacts resulting from human use and development, and also natural coastal processes.

For several decades the Tasmanian coastline has been influenced by human use through: the construction of coastal defence structures; recreational activities; sand extraction; and the introduction of exotic sand binding flora (Davies, 1980). These factors have contributed greatly to the changes witnessed along the majority of the Tasmanian coastline. Efforts have been made to manage and conserve Tasmania's coastal environment, however without a proper understanding of the nature of change many of these efforts have proven futile (Davies, 1980).

Human-induced pressures accelerate rates of change and highlight the need for management and conservation of coastal areas (Baily, 1996). The increasing number of people utilizing the coastal zone is resulting in greater impacts on sandy beaches. Dune erosion, foreshore development and the construction of coastal defence structures, to halt shoreline retreat and protect foreshore regions, are just some of the impacts which are accelerating changes to the coast.

An increase in demand, and a subsequent rise in value, of land in the coastal zone has placed a strong dependence on the protection of sandy beaches. In many cases the presence of the coastal foreshore is a major factor in the location of resorts and tourism facilities, and reflects the high real estate value of those areas.

The need to protect the coastal foreshore has resulted in the wide-spread use of coastal defence structures. The implementation of coastal engineering structures has severely restricted the dynamic nature of the coastal environment (Cooke and Doornkamp, 1990). Beaches are no longer able to change in response to the seasonal conditions or the dominant wave climate. The cyclic nature of sediment transport has been altered through the development of the foreshore and the presence of defence structures (Viles and Spencer, 1995).

Engineering structures can lead to changes in sediment transport within a system and can have severe impacts on the nourishment of beaches (Bailey et al. 1996). In many cases in Australia, and in the rest of the world, the construction of coastal defence structures has not only failed to resolve the particular problem but has contributed to the deterioration of the situation and the instigation of numerous secondary effects (Evans, 1992). The failure of numerous coastal defence structures has been related to a lack of understanding of the geomorphological processes in operation.

Long Beach is a small, sandy beach located on the western shore of the Derwent River, three kilometres south of Hobart in south east Tasmania, as can be seen in Figure 2.1. Long Beach is subject to a range of coastal processses including: southerly swell and wind waves, northerly wind waves, longshore currents and tidal currents. A combination of tide and swell induced currents, seawall scouring, and a dominance of southerly winds has resulted in large scale erosion of Long Beach since the early 1950s.

In March of 1908 the first timber seawall was constructed on the foreshore of Long Beach, Sandy Bay in an attempt to halt coastal erosion. In 1940 a longer concrete seawall was constructed. Since the initial construction of these coastal defence structures, constant repairs have been required due to wave impact. It appears that the construction of the original concrete seawall caused Long Beach to change from a stable beach system, consistently recovering from erosion events, to an undernourished, unstable beach. From these early stages of coastal engineering several efforts have been made to restore Long Beach to its original condition.

The main objective of coastal engineering structures is to prevent the erosion or flooding of the coastal zone, while the fundamental objective of coastal management is to satisfy the demands on coastal resources without degrading the coastal environment (Evans, 1992). To successfully manage and maintain the coastal environment in the present day, both human and natural processes impacting on a region must be addressed and a solution found that ensures the long term presence and amenity of coastal areas.

1.2 PREVIOUS STUDIES ON THE AREA

Several studies have been carried out on the Long Beach and Nutgrove Beach (Sandy Bay Beach) coastal foreshore areas of Sandy Bay and reports produced. A number of studies have been commissioned by the Hobart City Council (HCC) in an attempt to identify the coastal processes operating and total sediment movement occurring within the Long Beach-Nutgrove Beach system. Previous geomorphological studies have examined the long term erosion problems present on Long Beach and suggested possible means to halt the retreat of the shoreline and protect the valuable foreshore. The earliest study of the region was carried out by Cruise (1978). This report provided predominantly historical information as far back as 1834 in relation to meteorological data, hydrographic data, tidal data, map summaries and major accretion and erosion occurrences. The report by Cruise (1978) included a detailed engineering chronology of the Nutgrove Beach, Long Beach foreshore and reserve from 1834 to 1977, and also made mention of possible reasons for the decline in form of Long Beach. Here, it was suggested that a shift in the balance between northerly and southerly winds resulted in a net sediment movement north, towards Nutgrove Beach. In addition, it was suggested that land reclamation at Blinking Billy Point may have reduced sediment supply onto Long Beach from the south.

Further geomorphological studies into the estuarine beaches of Sandy Bay have been conducted by Carpenter (1984). The report summarises the work, up to that point, investigating beach erosion, and suggests methods to maximise foreshore protection and appearance. Included in the suggestions were several options and designs for sloped seawalls, and a range of costs for various rehabilitation options. The Carpenter report also mentions the significance of sand lost to the onshore system and the problems brought about by wave reflectance from a vertical seawall. Outlined in the report is a discussion of the processes related to turbulence and scouring associated with seawalls.

More recent investigations into Long Beach include those by Kinhill Engineers (1994) and Patterson and Britton (1998). The first such report was the Sandy Bay Beach Redevelopment Study undertaken in 1994 by Kinhill Engineers Pty Ltd. This report involved a high degree of on-site field work resulting in detailed bathymetric charts, current measurements and seabed sampling. A primary focus of the report was the development of new ideas on the coastal processes acting in the region. These included detailed measurement and interpretation of the tidal currents operating in the study area, wind analysis and seabed sampling. The Redevelopment Study also contained views from the local population as to the possible causes of the erosion problems and possible solutions.

A further study is the Sandy Bay Beach Rehabilitation Report produced in 1998 by Patterson, Britton and Partners Pty Ltd. This report provided much more detailed information on the coastal processes acting in the area, summarised in both conceptual and numerical models. The Rehabilitation Report also detailed multiple rehabilitation options, optional works and numerical models of the preferred option. Included in the possible rehabilitation options were suggestions for the construction of a groyne and breakwater, and beach nourishment. In addition, the report included detailed information on the study area, including: historical shoreline behaviour, wave climate, currents, bathymetry, sediment types and distribution and the influence of seawalls on Long Beach.

1.3 AIMS AND OBJECTIVES

The principal aim of this thesis is to study the long term morphology and shoreline change of Long Beach and surrounding areas, and investigate the relationship between form and process in the study area. In addition to this primary objective there exist several objectives:

1) to effectively utilise aerial photography and Geographic Information Systems to monitor the changes in shoreline position of Long Beach during the period 1947 to 1998;

2) to assess the rate of change in shoreline position of Long Beach by analysing the rate of sediment movement within the Long Beach-Nutgrove Beach system; and

3) to investigate the effect of the seawall on rates of erosion on Long Beach, and to study the possible effects resulting from the construction of further coastal defence structures.

1.4 STRUCTURE OF THE THESIS

This thesis consists of six chapters. The first chapter includes a background to the coastal environment, with emphasis on the Tasmanian coastline and in particular the estuarine beaches of Sandy Bay. A brief history and overview of the erosion problem will be provided, outlining significant occurrences in the history of Long Beach. Chapter One also provides a brief overview of previous studies conducted in the Long Beach-Nutgrove Beach system, and identifies the objectives of the thesis.

The second chapter of the thesis provides a background to the study area. This chapter presents the location of the study area; regional setting; climatic conditions; vegetation; and past and present land use. Geological and geomorphological information will also be included in this chapter.

Chapter Three details information related to the coastal processes operating within estuarine beach systems and the formation of coastal landforms. The third chapter also outlines the various methods used to measure, monitor and predict coastal processes and coastal landforms. Also included in this chapter is a discussion regarding the influence of specific processes on the morphology of Long Beach.

The methods and techniques used during the investigation into the long term changes in shoreline position of Long Beach since 1947 are presented in Chapter Four. Provided in this chapter is an overview of the methods used and sources of data inaccuracy and error within the methodology. Within the discussion of these results the more significant changes in the shoreline position will be linked with the chronology provided in the report by Cruise (1978).

Chapter Five contains the results of the study. Included in this chapter is the graphical output generated using GIS, including shoreline change maps and Digital Elevation Models. In addition a discussion of the results is presented. Also included in this chapter is a discussion on the possible influence of coastal processes and engineering structures on the shoreline of Long Beach.

Finally, Chapter Six summarises the results of the study and makes recommendations for the future management of Long Beach, including the preferred rehabilitation option identified by Patterson and Britton and its possible effects on Long Beach.

CHAPTER 2

BACKGROUND TO STUDY AREA

This chapter provides an outline and description of the study area. Included is information related to the location and physical environment of the study area, incorporating discussions on climate and geological characteristics, past and present land use, and flora and fauna.

2.1 LOCATION AND ACCESS

Long Beach is located in lower Sandy Bay on the western shore of the Derwent River, approximately 3 kilometres south of the Hobart CBD as shown in Figure 2.1. Long Beach is located between Blinking Billy Point to the south and Sandy Bay Point (Long Point) to the north, forming Little Sandy Bay.

Long Beach is orientated in a north-south direction. The headlands to the north and south of the beach therefore provide some protection from the wind and swell waves from the north, north west and south east (Plate 2.2). Swell waves from the south have been shown to refract around Blinking Billy Point and impact on the shoreline, causing erosion (Patterson and Britton, 1998).

The deep water channel of the Derwent River passes close to Sandy Bay Point forming a sharp dropover from the foreshore into the channel (Kinhill, 1994). As a result, Sandy Bay Point is severely eroded during periods of significant swell from the dominant directions of the north and southeast. However, wind blown sand from Long Beach and Nutgrove Beach has been stabilised in vegetated dune systems on Sandy Bay Point.

Long Beach is located off Sandy Bay Road and has a road and carpark located behind the seawall over the majority of its length (Plate 2.3). A walking track is located along the entirety of the seawall from Sandy Bay Point to Blinking Billy Point and is used for recreational purposes. Wrestpoint Casino is located on the western end of Nutgrove Beach, while Sandy Bay Sailing Club, Regatta Pavilion and Prossers Restaurant are situated on Sandy Bay Point (Figure 2.2).

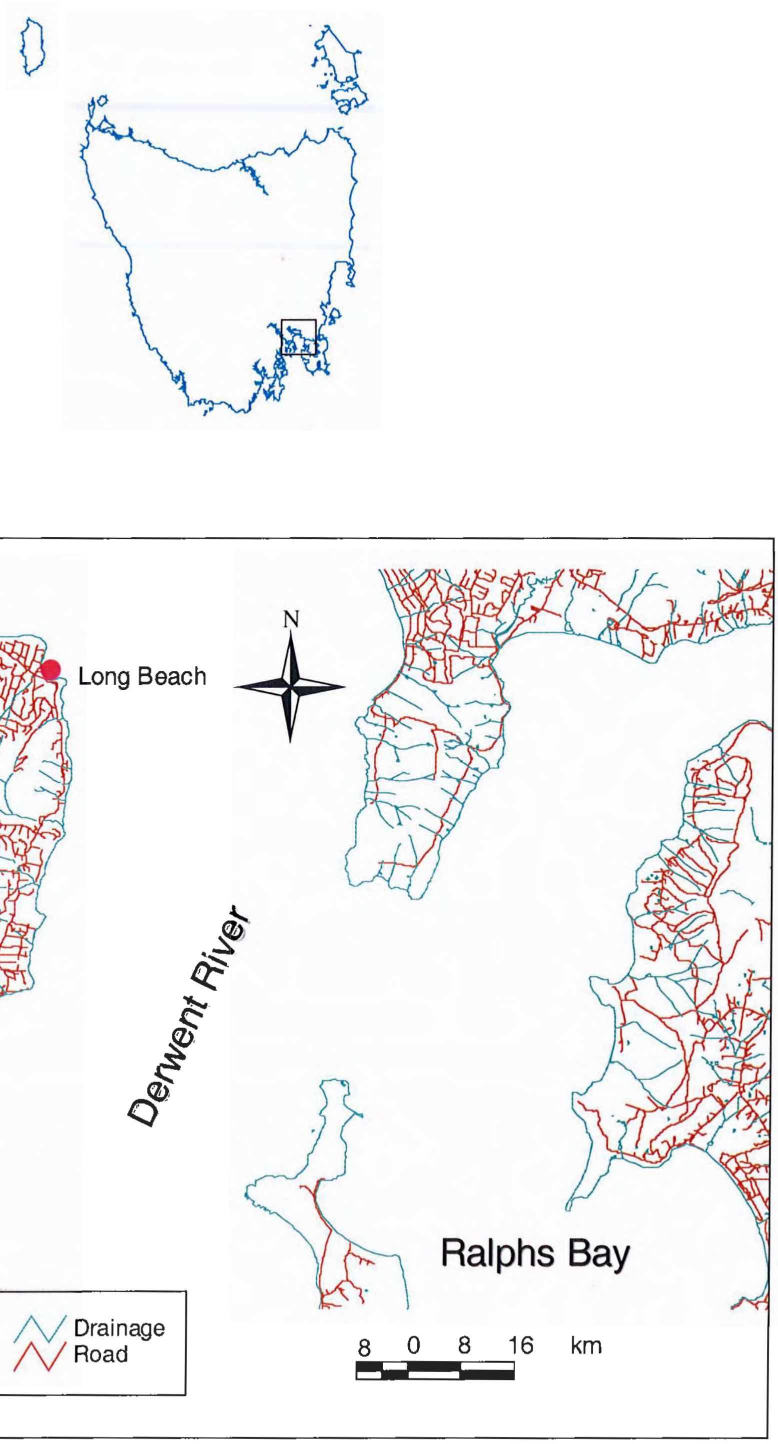

Figure 2.1 Location of Study Area (DPIWE, 2000).

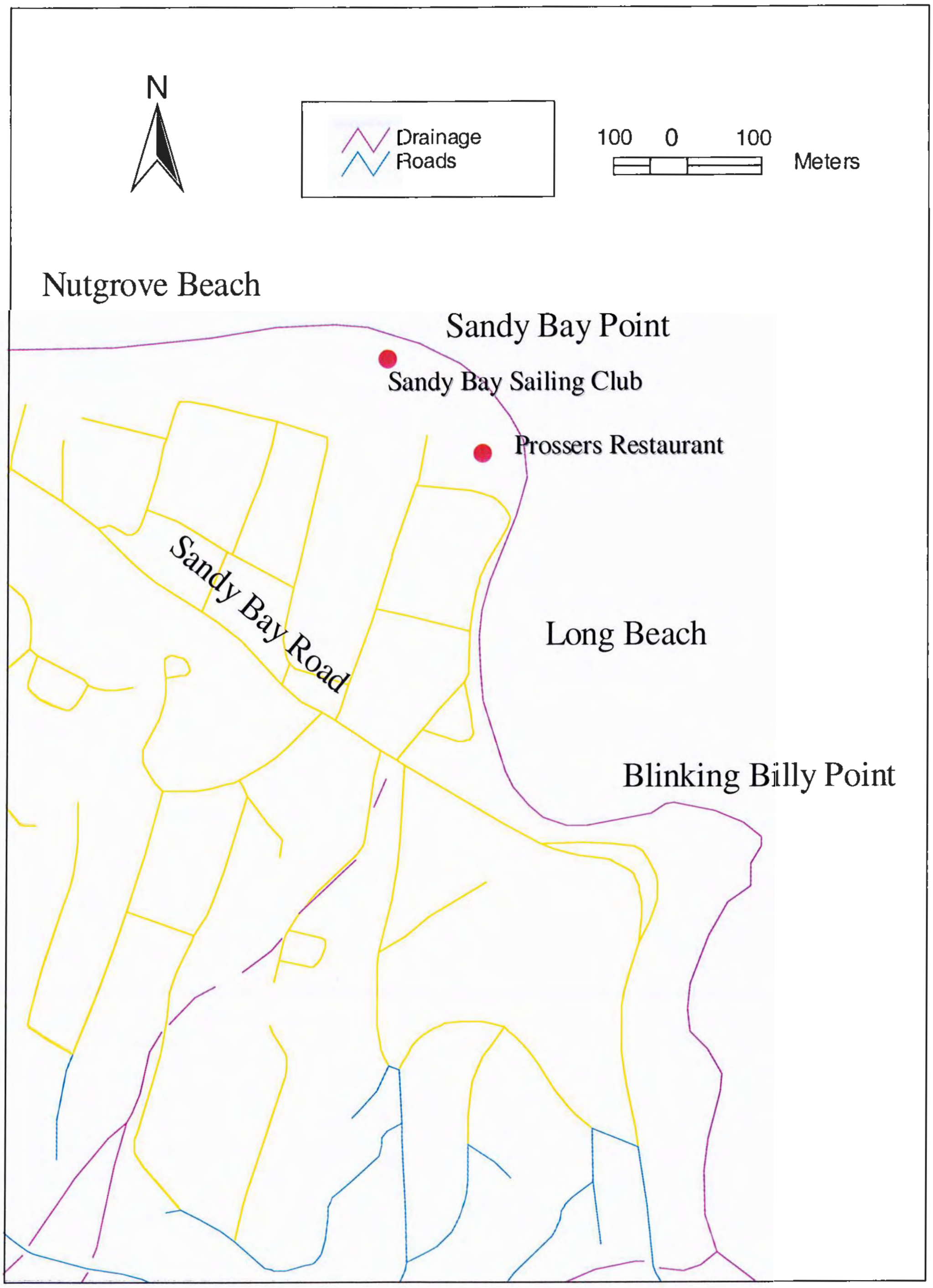

Figure 2.2 Study Area (DPIWE, 2000).

Nutgrove Beach is located to the north of Sandy Bay point and, in addition to Long Beach, Blinking Billy Point and Sandy Bay Point form a closed system in which sediment is transported (Carpenter, 1984). Nutgrove Beach is aligned in a northerly orientation and increases in width with proximity to Sandy Bay Point, the western end of the beach is predominantly rock with limited patches of sand (Plate 2.1).

Plate 2.1 Aerial Photograph of Long Beach and surrounding regions, 1998.
Scale 1: 12, 500.

Plate 2.2 View from Long Point to Blinking Billy Point, Sandy Bay.

Plate 2.3 View from the southern end of Long Beach towards Long Point, Sandy Bay.

2.2 CLIMATIC CONDITIONS

The climate of south-eastern Tasmania, including the Sandy Bay region, is considered to be temperate maritime, with an above average evaporation rate resulting in the net loss of water (Tasmanian Conservation Trust, 1978). Climate data for the study area was obtained from the Ellerslie Road weather station, located 3 km north west of Long Beach (42.53° S; 147.19° E).

Temperature averages recorded at the Ellerslie Road weather station range from an average maximum of 22°C in February to 12°C in July; and minimum average temperatures of 12°C in February and 4°C in July. The highest average temperature maximum was 25°C recorded in February; the lowest recorded average minimum temperature was 3°C in June and July (Figure 2.2).

Rainfall within the south-eastern Tasmania region has been recorded at approximately 600 mm per annum, but can vary greatly with distance to the south and east. An average annual rainfall of 621 mm has been recorded at Ellerslie Road station over the period 1882 to 2000. Extreme annual precipitation has been recorded as high as 1104 mm and as low as 390 mm. In Figure 2.3 it can be seen that the average precipitation is highest in October, however there is little variation in precipitation between months.

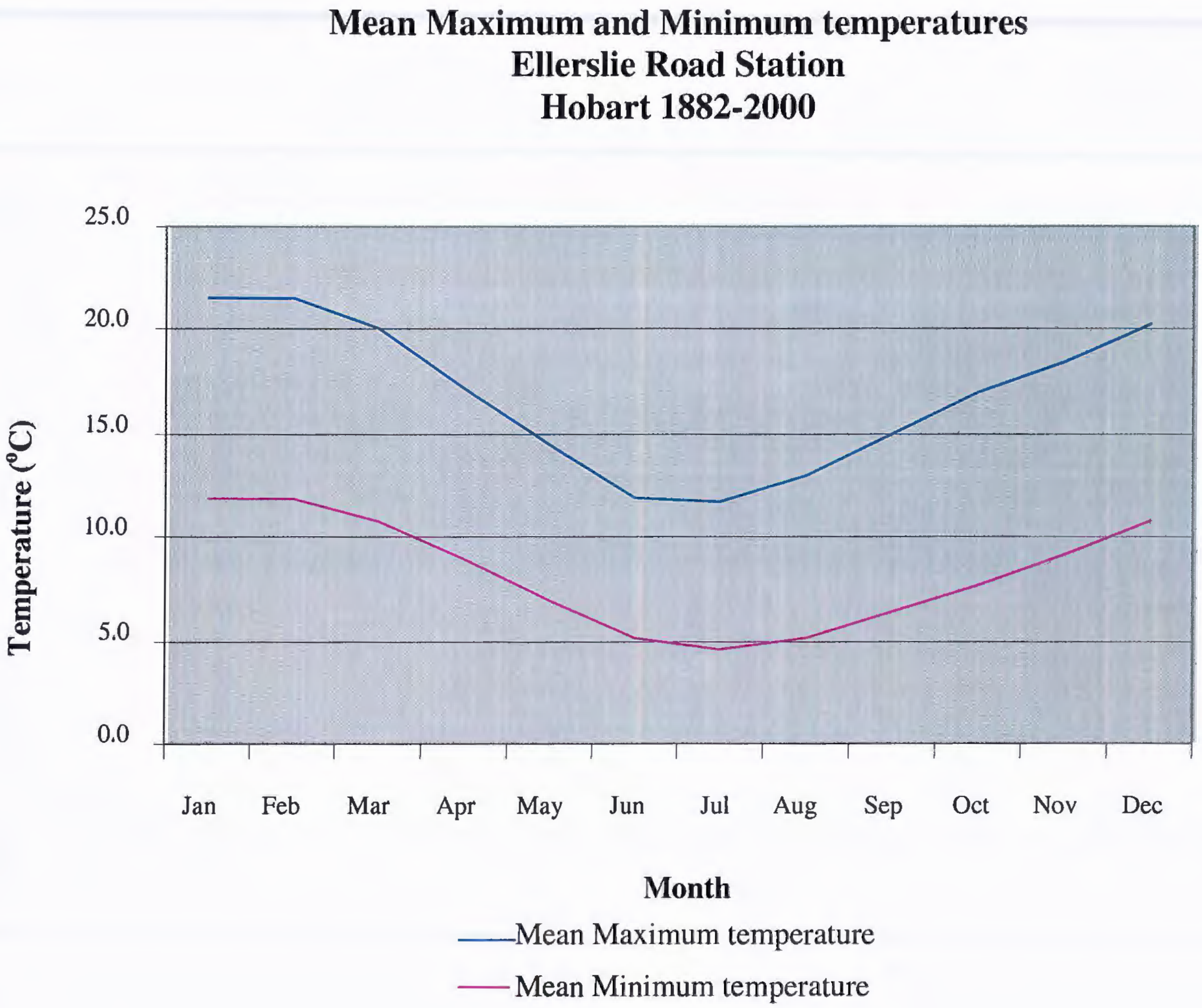

Figure 2.3 - Average monthly maximum and minimum temperatures between 1882 and 2000, Ellerslie Road (Bureau of Meteorology, 2000).

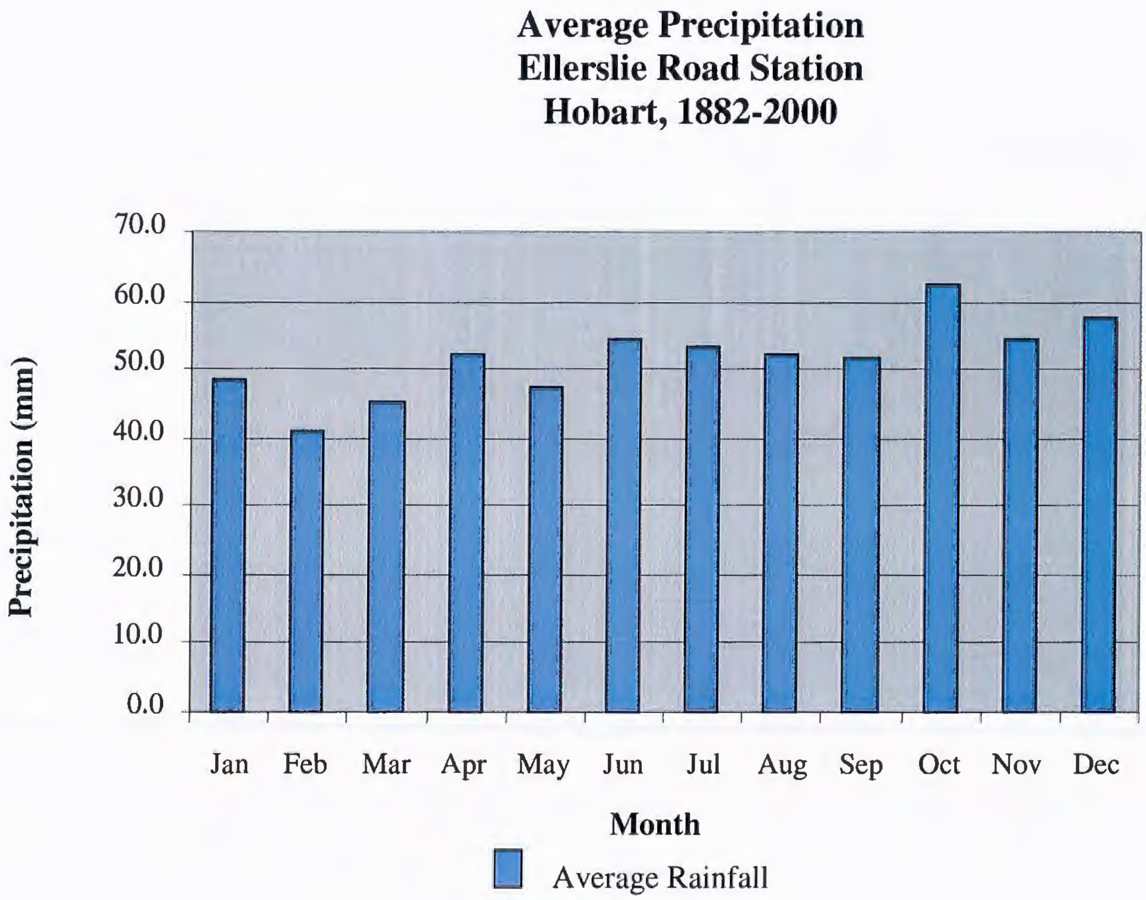

Figure 2.4 - Average monthly precipitation for Ellerslie Road weather station, 1882-2000 (Bureau of Meteorology, 2000).

Winds recorded at the Ellerslie Road weather station show significant daily variation, however detailed studies by Cruise (1978) showed that dominant wind directions are from the north-west and south-west quadrants with a south-east sea breeze during the summer months.

2.3.1 Wave Climate

Swell data was recorded by the CSIRO from wave buoys near Wedge Island in Storm Bay, however only one year of data has been recorded (1993). Wave data is included in Table 2.1. The data compares a range of swell periods in seconds (Tz) to the probability, in percentage, of wave height ranges occurring. The data may be used to gain an understanding of the frequency of waves of varying size impacting on Long Beach – and the resulting erosion potential of the waves. Interpreting the data, it can be seen that incoming waves reduce as wave height increases and wave period increases.

Table 2.1 Joint wave height – wave period occurrence (percentage) for Wedge Island (CSIRO, 1993).

Tz (s)	**Significant Wave Height (m)**								
	0.00-0.75	**0.75-1.50**	**1.50-2.25**	**2.25-3.00**	**3.00-3.75**	**3.75-4.50**	**4.50-5.25**	**5.25-6.00**	**Total**
2.0 - 3.0	0.04	0	0	0	0	0	0	0	0.04
3.0 - 4.0	1.93	1.05	0	0	0	0	0	0	2.98
4.0 - 5.0	4.69	5.78	1.13	0	0	0	0	0	11.6
5.0 - 6.0	4.18	14.37	4.58	0.36	0	0	0	0	23.49
6.0 - 7.0	2.11	14.62	5.6	1.6	0.07	0	0	0	24
7.0 - 8.0	1.53	11.86	6.51	2.15	0.51	0.11	0	0	22.67
8.0 - 9.0	0.58	4.51	3.16	1.24	0.65	0.18	0.25	0	10.57
9.0 - 10.0	0.18	1.56	1.27	0.36	0.15	0.04	0	0.04	3.6
10.0 - 11.0	0	0.18	0.18	0.25	0.11	0.04	0	0	0.76
11.0 - 12.0	0	0.07	0.15	0.07	0	0	0	0	0.29
Total	**15.24**	**54**	**22.58**	**6.03**	**1.49**	**0.37**	**0.25**	**0.04**	**100**

It can be seen that the most prevalent wave setup acting in the area is low wave height with mid-range wave period. Wind roses, constructed using data from Ellerslie Road weather station between 1944 and 2000, are presented in Figure 2.5.

2.3.1.1 Swell Waves

Swell generated in the Southern Ocean travels into Storm Bay, refracts in the area of the John Garrow Light and impacts upon the shoreline of Long Beach (Patterson and Britton, 1998). Although no long term swell data records exist, pictures and video of swell at Long Beach have shown that breaking waves of up to 1 metre in height have occurred. Numerical modelling conducted by Lawson and Treloar (1998) estimated severe swell heights to be in the range of 1 to 1.2 metres.

2.3.1.2 Wind Waves

Wind waves in the study area can be largely interpreted from the wind roses presented in Figure 2.4. The wind roses show that the dominant wind direction is from the north and north west during all months. North west winds are strongest during late autumn and during winter and weakest during the summer months. Southerly sector winds are minimal during the whole year except December and January where south east winds are stronger.

This data suggests that during the year there is a very high north to south wind ratio. Given the short northerly wind fetch in the study area, the strong north and north west winds would produce wind waves with high erosion potential. Given the high strength and frequency of northerly sector winds, resulting currents would suggest sediment is being transported from the north to the south, removing sediment from Nutgrove Beach to Nourish Long Beach.

The low proportion of southerly waves cannot be directly linked to the frequency of southerly swell waves occurring. Swell waves are generated over long distances from where the data used in this study was recorded.
From this wind data it could be hypothesised that there is a large north to south movement of sediment within the study area. However, due to the influence of currents and tides within the region, this is not the case, and will be discussed further in chapters three and five.

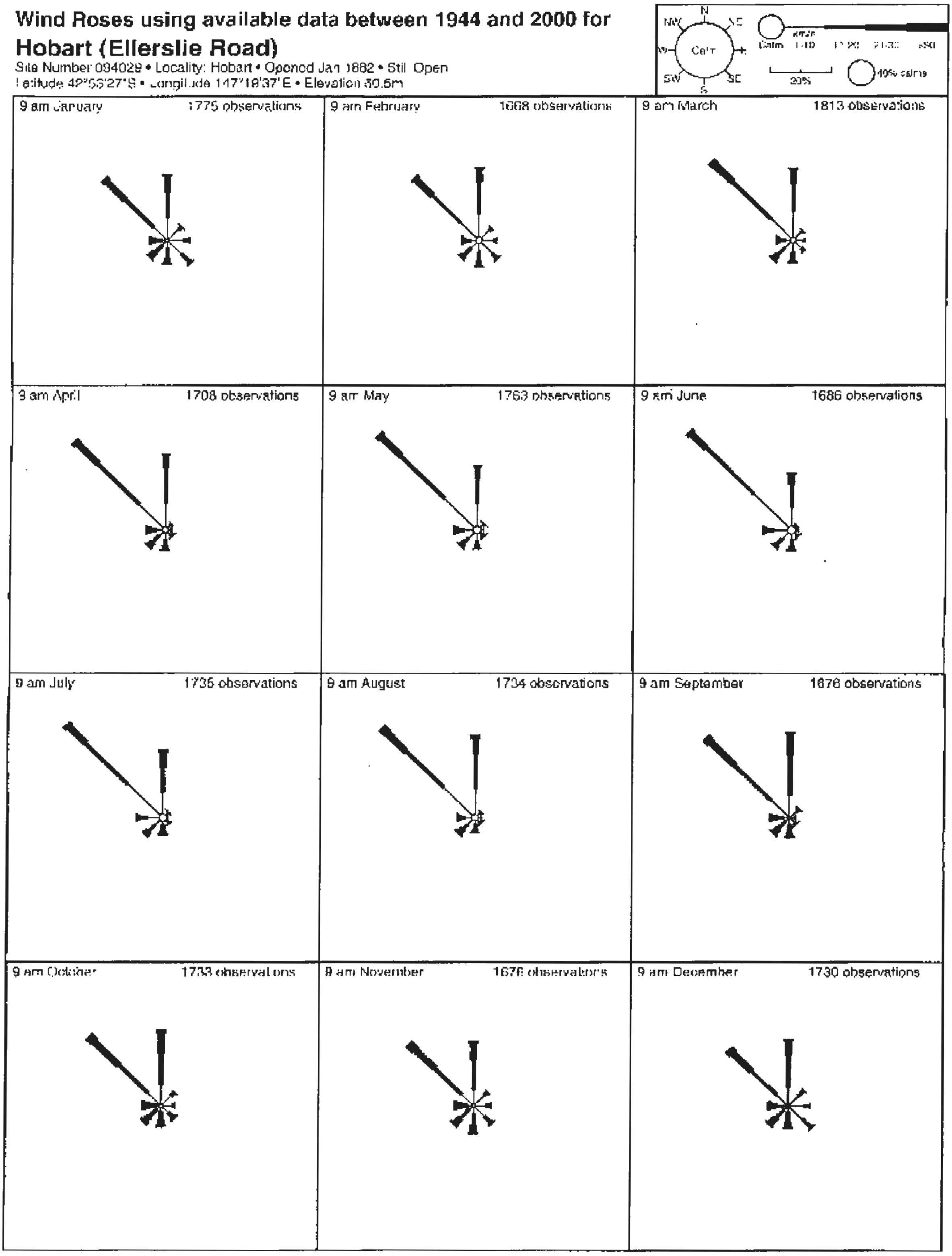

Figure 2.5 Wind Rose data for the Ellerslie Road Weather Station between 1944 and 2000 (Bureau of Meteorology, 2000).

2.3 GEOLOGY AND SOILS

A brief description of the geology of Long Beach and surrounding areas was included in studies conducted by Carpenter (1984) and later by Patterson and Britton (1998). Several detailed studies into the geology of the region have been carried out, the ease of access to the study area and the presence of large road cuttings and wave-cut platforms has lead to numerous reports. The first geological reference to the region was by Darwin (1844), who noted the presence of basaltic lava and brecciated scoria on the west side of Storm Bay (Spry, 1955). Further studies were carried out by Johnston (1881), White and Macleod (1898), Petterd (1910), Noetling (1913), Aurousseau (1926), Edwards (1949) and also Carey and Banks (1955).

Sandy Bay Point, in the north of the study area, has been defined as an estuarine cuspate foreland containing deep sand and shell deposits (Carpenter, 1984). To the south of Long Beach, Blinking Billy Point is characterised by complex deposits of basaltic rock, possibly volcanic in origin (Spry, 1955). Triassic sandstone deposits are common throughout the study area and have been suggested as a possible sand source (Spry, 1955).

The geology of the study area is described as being a combination of coarse and fine-grained pyroclastics overlying Tertiary lacustrine beds, with a thick layer of Tertiary rock forming a faulted block (Spry, 1955). The presence of Permian and Triassic sediments and Jurassic Dolerite has also been noted (Spry, 1955). The various geological strata present in the Long Beach region are illustrated in Figure 2.6.

The boulder bed exposed at the large road cutting at Blinking Billy Point is indicative of the Tertiary rock system present in the area. Permian sediments, pebbles and also, to a lesser extent, sand are present within this region varying in size from clay to boulders, with a wide size distribution (Spry, 1955). The texture of the Tertiary material is typical of till, landslide debris or mudflow material (Spry, 1955).

The wave-cut platform on the promontory south of Blinking Billy Point has exposed a diverse range of volcanic rock. Basanite, tuff and volcanic breccia have all been recorded and are strongly folded (Spry, 1955). The pocket beaches to the north and south of Sandy Bay Point have been shown to contain a shingle layer at a depth of 1 to 2 metres, which acts as a buffer in the event of severe erosion (Carpenter, 1984).

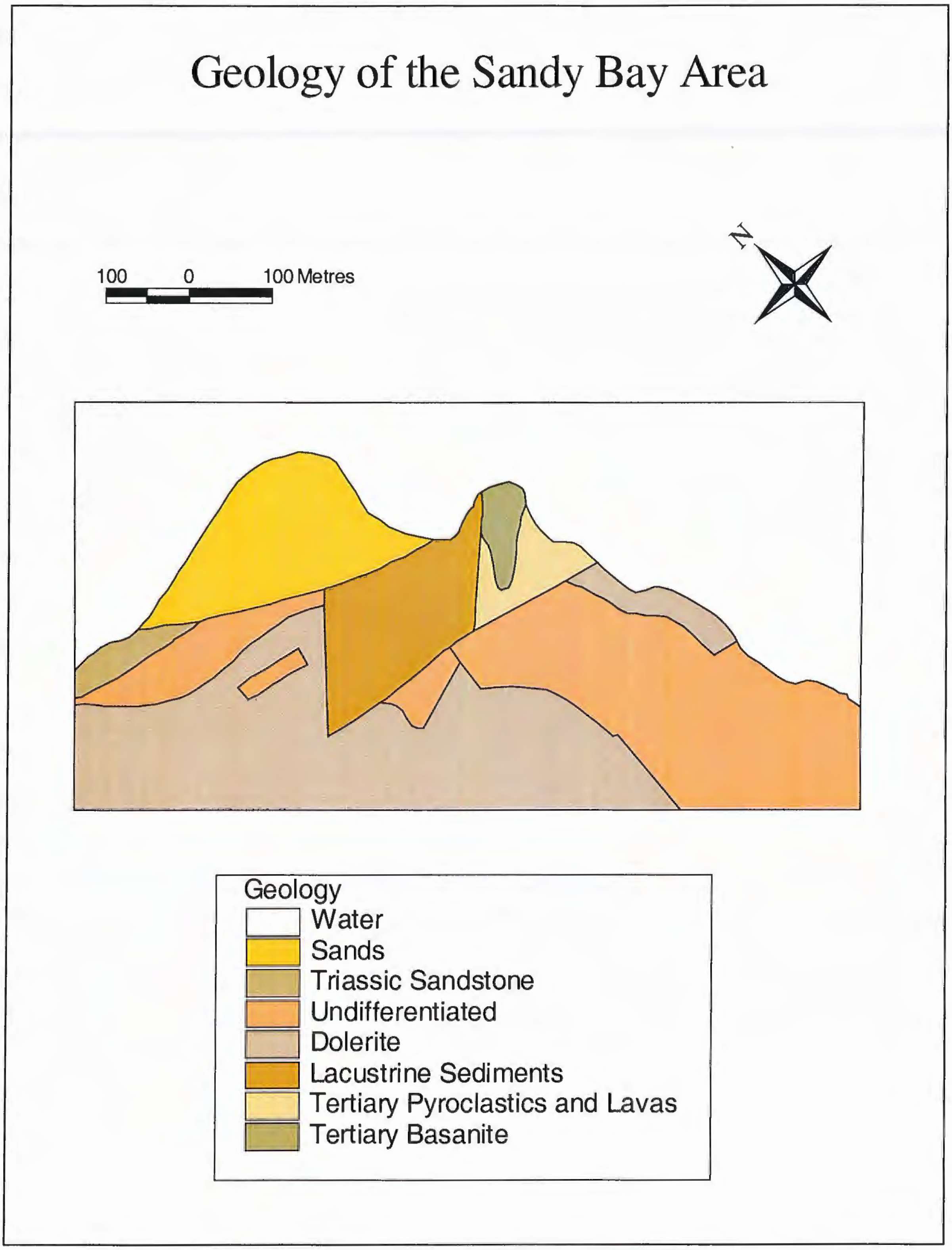

Figure 2.6 Geology map of the Study Area (Spry, 1955).

During the last sea level rise 6000 years ago sand was transported onto the present day coastline and into the lower reaches of the Derwent River estuary (Davies, 1980). Over the past 6000 years since the initial sand deposition, the shoreline has been shaped by the dominant southerly swell, resulting in the movement of sediment to the north. The presence of rocky outcrops to the south of Blinking Billy Point, to the north of the study area and to the west of Sandy Bay Road suggests the sand plain is a depositional feature (Spry, 1955). Past survey plans have noted the presence of remnant dunes over the sandy plain, supporting the suggestion that the sand plain is a depositional feature. The growth of the frontal dune on Nutgrove Beach over the last forty years indicates that the formation of the sandy plain is still continuing. Estimations indicate that over the last 6000 years, 1.5 million m^3 of sand has accreted to form this landform - an average annual sand supply of 250 m^3/year (Patterson Britton and Partners, 1998).

2.4 HISTORY OF LAND USE

2.4.1 Commercial Operations

In 1813 land in the Nutgrove Beach-Long Beach area was bought and farmed, the first landholders in the area being documented as Messrs Walford, Cropper, Fisher, Cartwright and Pitcairn (Cruise, 1978). The purchase of 2 units of land at the southern end of Long Beach in 1815 signified the importance with which the Crown viewed the beaches.

Early reports indicate that the backdune area of Sandy Bay Point was extensively logged during the mid 1800s removing much of the native vegetation (Carpenter, 1984).

2.4.2 Recreation

The beaches of Sandy Bay, and in particular Long Beach, were used extensively for recreational purposes during the 19th and 20th centuries. Horse racing was conducted in the area as early as 1816 in order to "ease the dull monotony of Hobart Town," as was reported in 1827 (Cruise, 1978). Horse racing was a common past time up until 1844 (Carpenter, 1984).

The extension of the Sandy Bay tram system to include Long Beach and Nutgrove beach in 1913 resulted in an increased number of people using the beach area. In 1919 further developments of the Sandy Bay foreshore were made in the construction of croquet lawns, bathing boxes, tea rooms, diving platforms and sanitary facilities (Cruise, 1978). In 1924-25, a bowling green and two grass tennis courts were constructed, increasing the recreational value of the area (Cruise, 1978).

2.5 PRESENT LAND USE

The Long Beach-Nutgrove Beach foreshore has been developed considerably and is now used by a number of user groups to address a range of needs. The foreshore is used frequently throughout the year for a range of recreational purposes, while the region to the rear of the beach extending back to Sandy Bay Road has grown into a significant retail and commercial center, providing the residents of lower Sandy Bay with goods and services.

2.5.1 Commercial and Residential landuse

In 1932 sub-division of the land behind Nutgrove beach began (Cruise, 1972). Since the initial construction of residential properties, building has spread along the entire foreshore of Nutgrove Beach and Blinking Billy Point. Long Beach and Long Point have not been subdivided and remain the property of the Crown. As previously mentioned, the area to the rear of Long Beach and Nutgrove Beach has been developed extensively and includes several small shops and commercial operations.

In recent decades commercial properties have extended from the central zone of Sandy Bay Road, down Beach Road towards the Long Beach foreshore. Several commercial operations exist within the boundaries of the study area.

2.5.2 Recreation

Recreation is perhaps still the most common use of the Sandy Bay foreshore. The region is used year-round for a range of activities including: sailing, walking, jogging, windsurfing and general relaxation. The decline in the water quality of Little Sandy Bay due to upstream pollution has resulted in a decline in the use of the beaches for water based activities, such as swimming and fishing. The gradual widening of Nutgrove Beach and the development of its dune system over past decades has resulted in an attractive beach environment which is popular with the people of Hobart. However, the increase in accretion of Nutgrove Beach has come as a result of increased erosion of Long Beach. The narrowing of Long Beach has also lead to a shift in beach use to Nutgrove Beach. The walking tracks on Blinking Billy Point and Long Beach foreshores are regularly used by local residents for the walking of dogs and other activities. The Sandy Bay Sailing Club is located on the northern side of Long Point and is one of the largest sailing clubs in greater Hobart.

2.6 VEGETATION

Intensive logging of Long Point and surrounding areas between 1834 and 1860 resulted in the loss of much of the native vegetation. However, from notes included in the report by Cruise (1978) early vegetation species present in the Nutgrove Beach, Sandy Bay Point area included honey suckle (*Banksia marginata*), coast wattle (*Acacia sophorae*) and several *Eucalyptus* species.

Although intensive development of the hind-dune area of Long Beach and Nutgrove Beach has seen the construction of car parks, roads, seawalls and buildings there still remain small pockets of remnant vegetation.

The developed dunes on the eastern end of Nutgrove Beach have been stabilised to a significant degree by the presence of the introduced species marram grass (*Ammophila arenaria*), which in some areas has been replaced by coast wattle (*Acacia sophorae*) through succession. The origin of the marram grass (*Ammophila arenaria)* is believed to be from a funded planting along the foreshore in 1921 (Cruise, 1978). Coast wattle is the dominant vegetation type throughout the dune system, however species diversity is low within the study area. Behind the seawall on Long Beach an area of the foreshore has been fenced and marram grass (*Ammophila arenaria*) planted in an attempt to develop a dune system and hence a buffer for the protection of the seawall.

Throughout the study area isolated blue gum (*Eucalyptus globulus*) specimens have been left during development. Their size indicates an origin from the late 19th century or early 20th centrury. In addition to the natives already mentioned, there exists a large range of exotic species, the most prolific species being the pine (*Pinus radiata*). Stands of pine are found in the parkland to the rear of Long Point and also behind the seawall of Long Beach.

2.7 HUMAN IMPACTS

Human impacts on the Sandy Bay foreshore since early European settlement have resulted in a number of changes in the study area, particularly to the coastal environment. The construction of buildings, concrete roads and carparks and the use of both timber and concrete seawalls to protect the foreshore have resulted in vast changes in the orientation and width of Long Beach and Nutgrove Beach.

The first recorded shoreline position of 1834 indicated that Long Beach was 30 metres wider than it is today and that Nutgrove Beach was at the same position as today (Cruise, 1978). Some thirty years later, the centre of Nutgrove Beach had receded by 100 metres, this sand widening the southern end of Long Beach (Cruise, 1978).

In 1908 the first seawall constructed from timber was erected along Long Beach at the high tide mark (Cruise, 1978). Immediately after, Beach Road was constructed behind the seawall. The excavation required for the construction of Beach Road resulted in large amounts of sand being pushed onto Long Beach. Between August 1906 and March 1908, 15 000 cubic yards of sand had been deposited (Cruise, 1978). The construction of the seawall greatly altered the natural cycles of erosion and deposition that previously existed on Long Beach. Scouring and wave reflection from the vertical structure resulted in increased erosion during storm events.

The subdivision and property development along the Nutgrove Beach foreshore in 1932 greatly impacted on the closed sediment cycle existing within the study area. The construction of fences and cut-off walls at the seaward boundaries of properties resulted in sand being trapped within this region and not being recycled to renourish other regions in the system. The construction on Nutgrove Beach resulted in the beach being unable to respond to variations in climatic conditions (Kinhill, 1994). The construction of housing on the Nutgrove Beach foreshore also lead to the problem of wind blown sand being transported onto these properties. To alleviate this problem sand trapping fences were constructed and vegetation planted. As a result the frontal dune along Nutgrove beach was stabilised.

Between 1938 and 1940 the seawall at Long Beach was replaced with a concrete seawall. In 1960, ninety metres of the seawall was damaged resulting in the reconstruction of the wall with

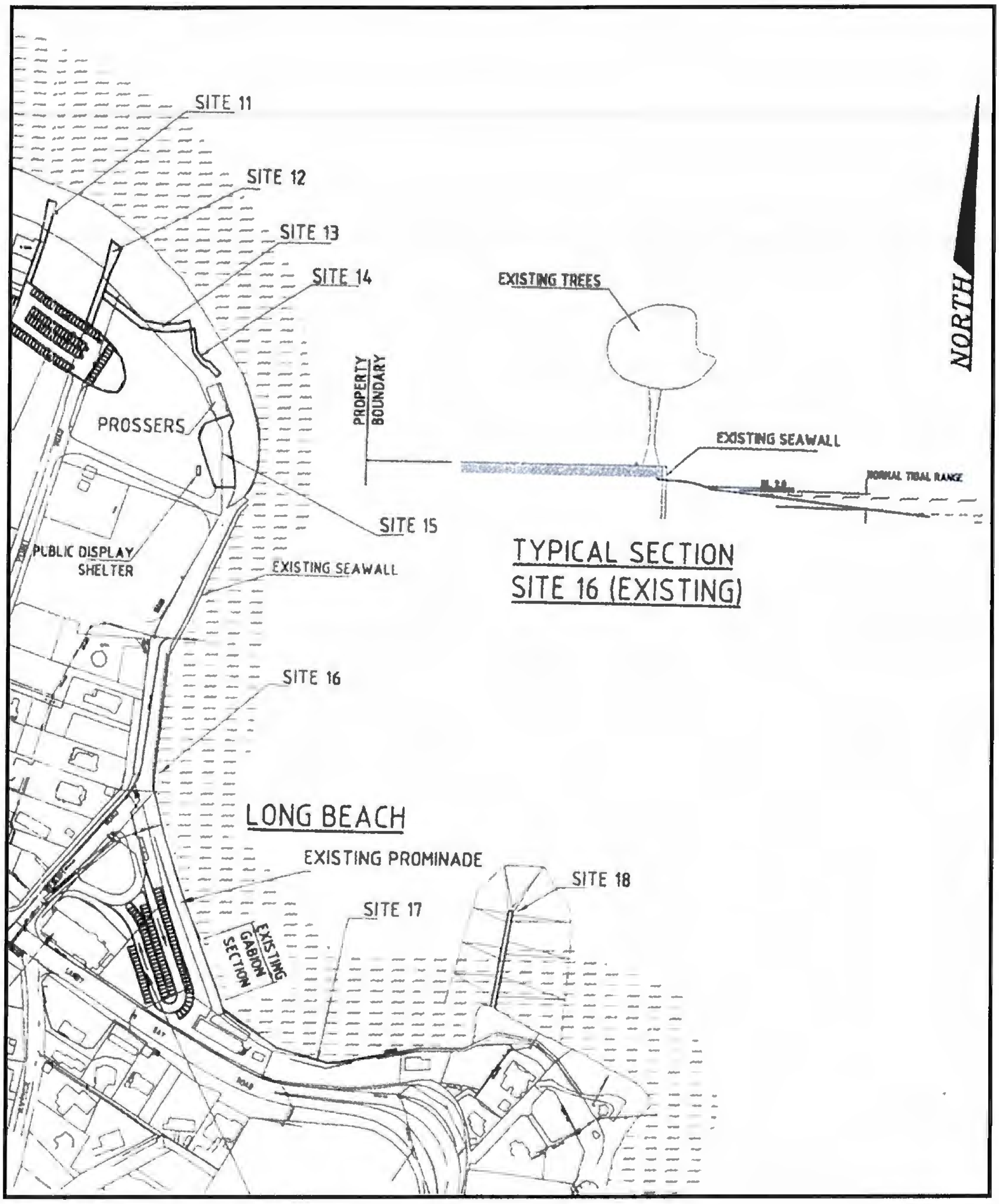

Figure 2.7 Diagram of Long Beach and surrounding areas, showing the location of the seawall, existing gabion section and a cross-sectional profile of Long Beach (Patterson and Britton, 1998).

an additional sixty metres to protect the Regatta Pavillion (Cruise, 1978). Since the initial repairing of the seawall, several storm events have occurred which necessitated further repair work.

Further construction work was carried out on Long Beach in 1961. Land reclamation at Blinking Billy Point, for the construction of an extended sewerage outfall, resulted in Blinking Billy Point protruding further into the Derwent River. As a result, southerly swell waves were refracted around the point. The realignment of incoming swell impacting on the beach resulted in erosion from different regions of Long Beach (Cruise, 1978).

2.8 CHAPTER SUMMARY

The Sandy Bay foreshore, including Long Beach and Nutgrove Beach and adjacent points, has a range of geological, climatic and biological characteristics that are unique to the area. The past and present land uses of the area have created a degree of cultural significance that has sustained interest in the region.

The vegetation of the study area is limited due to intensive development, however native species including blue gum (*Eucalyptus globulus*) and coast wattle (*Acacia sophorae*) are common, as are the exotic species marrum grass (*Ammophila arenaria*) and pine (*Pinus radiata*).

Human impacts on the study area have been significant and have played a large part in the change in the evolution of Long and Nutgrove Beaches over the past 50 years. The construction of the Long Beach seawall, in addition to development on the Nutgrove Beach foreshore have resulted in substantial changes to the shoreline.

The following chapter will provide an overview of the dynamics of Long Beach and surrounding areas, and the influence of the various coastal processes on sediment transfer within the system.

CHAPTER 3

FORM AND PROCESS

Chapter Three analyses and discusses literature related to the formation and dynamics of estuarine beach systems. This chapter concentrates on the evolution of Long Beach and Nutgrove Beach in the 50 years since 1947 and also discusses the processes operating within the lower Derwent estuary. Sediment transfer and cycling within the study area will also be mentioned. The aim of this chapter is to gain an understanding of the coastal processes operating within coastal estuarine beach systems, and to associate these processes with the movement of sediment and the formation of landforms. The major themes are then discussed in the context of the Long Beach, Nutgrove Beach system.

Section 3.1 provides an introduction to the problems associated with the coastal environment in the global context, with an emphasis on coastal erosion in estuarine beach systems. Section 3.2 also provides an overview of the development and evolution of estuarine beach systems and outlines the processes acting, and their effects, on sediment movement within the study area. Section 3.3 discusses the significance of several meteorological variables on sediment transport, and comments on the effects of wind direction on accretion and erosion patterns on Long Beach. Section 3.4 focuses on the influence of wave action on a sandy beach system, and makes reference to the types of waves and their effects on Long Beach. Section 3.5 provides an overview of the various types of currents acting in an estuarine beach system and the influence that they would have on the movement of sediment; in this section the currents operating within Little Sandy Bay and Sandy Bay will be discussed. Section 3.6 will summarise the chapter.

3.1 INTRODUCTION

About 20 % of the world's coast is sandy and backed by beach ridges, dunes, or other sandy deposits. Of this, more than 70 % has shown net erosion over the past few decades (Bird, 1985a in Viles and Spencer, 1995). In addition to this, 50 % of the population in the industrialised world lives within one kilometre of a coast. This population will grow at about 1.5 % per year during the next decade (Goldberg, 1994 in Viles and Spencer, 1995).

As coastal populations grow, problems affecting the coastal environment are becoming more prevalent throughout the world's beaches. The problems affecting coastal areas are diverse and vary with location around the world. However, a common problem affecting sandy coastlines is coastline retreat. The reasons for shoreline erosion can be classified into those that result from changes in the relationship between sea level rise and sediment supply, human-induced pressures on the coastal zone, and the initial signs of human-induced climate change (Viles and Spencer, 1995). Throughout the world human activity is a major influence on the coastal zone. Human influences on the coastal zone may be direct or indirect, and include: dredging operations, extraction of sand and gravel, building of dams to reduce fluvial sediment inputs, reduction in sediment supply from eroding cliffs due to basal protection, and interference with longshore sediment transport from the construction of piers, jetties and breakwaters (Viles and Spencer, 1995).

Natural processes are also largely responsible for changes to the shoreline. The influence of several coastal processes leads to the development and erosion of coastal landforms. The effects of wind, waves and currents on sandy beaches are discussed later in section 3.3.

Owing to increased population, and development of the coastal zone, sandy beaches are no longer able to change and react in response to changing sea conditions. Beaches are being stabilised and infrastructure being built to prevent sand loss and retain the value of land in the coastal zone.

In Tasmania there have been several documented cases of shoreline erosion. In south-eastern Tasmania, Dobson and Williams (1977) investigated the problem of coastal erosion at Dodges Ferry. They identified a number of factors that contributed to the erosion of the shoreline at Dodges Ferry and suggested a number of recommendations to halt the retreat of the shoreline. The erosion on Okines Beach, Dodges Ferry was linked to several factors which included: a lack of beach-building swell in the region; an impervious layer below the surface that prevents the percolation of water; and fine sediment that prevents the formation of a protecting beach slope. However, in recent years the rate of erosion has been accelerated. The reasons for this increase in erosion have been linked to the following: trampling of the bank by cattle and humans; acccess tracks allowing material to be blown off the beach and bank; and a rise in groundwater levels due to loss of vegetation resulting in a damp and weakened beach bank (Dobson and Williams, 1977).

Dobson and Williams (1977) made several recommendations to help control the erosion at Dodges Ferry. The recommendations were based on two stages of action, the first being initial work and construction to reduce erosion. This initial stage involved the stabilisation of the eroding bank, the repair of blow-outs caused by access tracks, the creation of steps and walkways and the general maintenance of the area. The second phase of the recommendation was the implementation of an on-going management programme including, environmental information programmes, monitoring programmes and the creation of a town plan.

The problem of shoreline retreat on Long Beach is an ideal example of the relationship between form and process acting on many ocean and estuarine beach systems in Tasmania and the world. The influence of coastal processes including waves, currents and wind, in addition to the human induced changes such as coastal defence structures, has greatly altered the morphology of the Long Beach shoreline over the past 50 years.

The subsequent sections of this chapter will discuss the formation of estuarine beaches and the influence of several coastal processes on sandy beaches, with an emphasis on shoreline erosion. The effect that these processes have on Long Beach, and the surrounding study area, will be discussed. Literature relating to the relationship between coastal erosion and coastal processes will be discussed in order to fully understand the problems present on Long Beach.

3.2 FORMATION AND EROSION OF ESTUARINE BEACHES

Estuaries are defined as semi-enclosed inlets where saltwater and river water mix (Viles and Spencer, 1995). Estuaries are found world wide; but are usually more developed in the mid-latitudes with wide continental shelves and locally rising sea level (Viles and Spencer, 1995).

There are a number of variables that influence the formation of all beach types. First is the sediment budget and sediment type; second is wave type and wind regime; and finally, biota and water temperature all play an important part in the formation of a sandy beach (Short, 1999). For a beach to form there must be an adequate supply of sediment. Sediment within a beach system is moved by waves and deposited in an accumulation area. For a beach to remain stable the sediment budget must be balanced or positive, whilst a negative budget will result in the loss of sand from a beach (Short, 1999). Sediment budgets fluctuate greatly with time and can vary in response to storm events and season.

Sediment type can influence the type and characteristics of a beach that may be formed, and varies greatly with geographical location. Beaches in the mid to low latitudes are commonly composed of fine to medium sands, but beaches can be composed of gravel and boulders in the higher latitudes. Sediment type greatly influences the beach slope and overall morphology of a beach (Short, 1999). Regional and

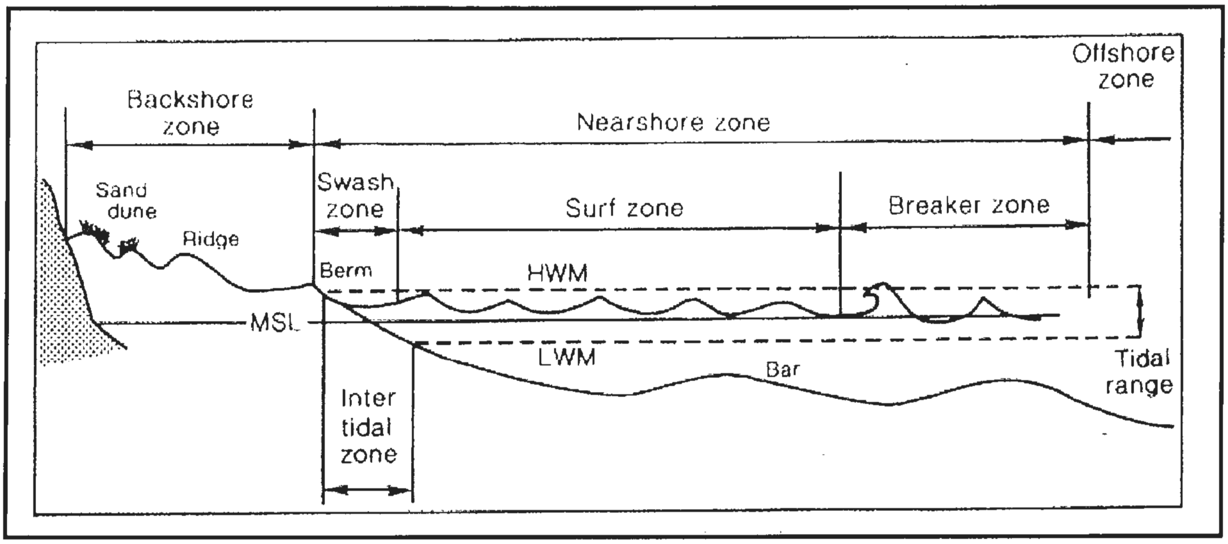

Figure 3.1 The definition of the shore zone regions (Viles and Spencer, 1995).

local variation in sediment type is governed largely by climate, source rocks, substrate and biota (Short, 1999).

Wind speed and direction can also contribute greatly to the formation and erosion of beach systems. Longshore winds can contribute to longshore currents and, as a result, sediment movement. Strong onshore and offshore winds can contribute to sub-aqueous sediment transport through downwelling and upwelling currents (Short, 1999). Onshore winds also contribute to aeolian sediment transport, which will be discussed in greater detail later in section 3.5.

Two primary environmental factors influence the formation of estuarine beaches and often lead to the narrow, low beach profile characteristic of many estuarine beaches. First, the low wave energies experienced within estuarine and bay areas severely limit the horizontal and vertical change in the beach profile (Davies, 1980). Second, the depositional phase of the beach change cycle is suppressed and the dominance of erosion conditions limits the amount of sediment available to the beach (Nordstrom, 1989).

The narrow beaches of estuarine and bay systems have limited sand supplies and as a result dunes are slow to form. Dunes that are established are often destroyed through overwashing during small storms or spring tides (Nordstrom, 1989). Estuarine sediments are derived from a range of sources including the drainage basin, the continental shelf and coastal waters, the atmosphere, erosion and biological activity (Viles and Spencer, 1995) (Figure 3.2). In the majority of estuarine systems around the world the marine environment is the dominant source of sediment.

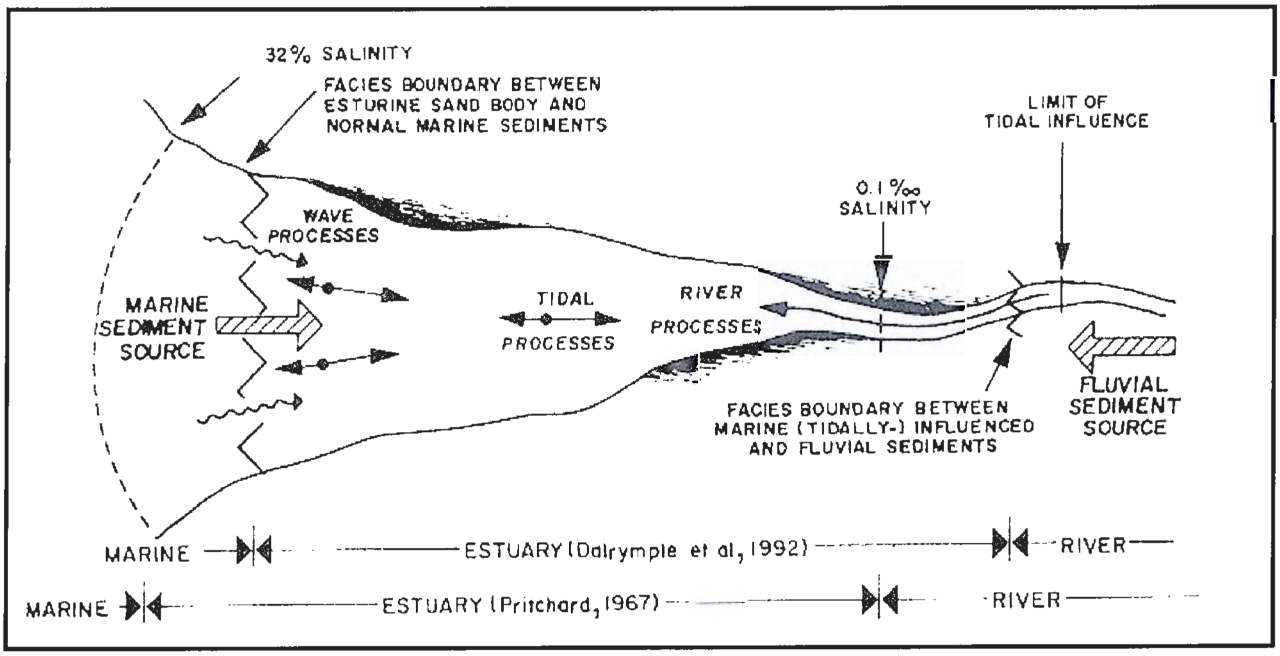

Figure 3.2 Sediment supply within the marine/estuary environment (Perillo, 1995).

3.3 THE EFFECT OF WAVES ON THE DYNAMICS OF BEACH SYSTEMS

Beaches vary considerably in plan, profile and dynamic behaviour - the wave climate in a given region is the most influential factor when considering beach morphology (Davies, 1980). From the initial conception of an ocean swell kilometres offshore, through to the impacting on the beach, several changes take place in the characteristics of the wave. Davies (1980) describes these changes through the defining of three zones - the deep water zone, the intermediate water zone and the shallow water zone.

In the open ocean waves travel at high velocities, with both high potential and kinetic energy. Wave movement is in closed circular orbits that have minimal forward movement and transport. The orbital diameter is equal to the amplitude of the wave and decreases exponentially with depth (Davies, 1980). At a depth equal to half the wavelength, forward motion ceases - this depth is defined as the wave base (Bird, 1964). This theory is illustrated in Figure 3.3.

As the wave train moves into shallow water the orbital motion touches the ocean bottom, wave velocity decreases and, as a result, wave length also decreases. Variations in the bottom contour can lead to unequal deceleration in the wave resulting in refraction (Davies, 1980). Refraction of swell waves can in turn result in the realignment of beaches. The dominant wave refraction pattern will erode and deposit sediment from a beach until the beach is in equilibrium and consistent with the wave pattern.

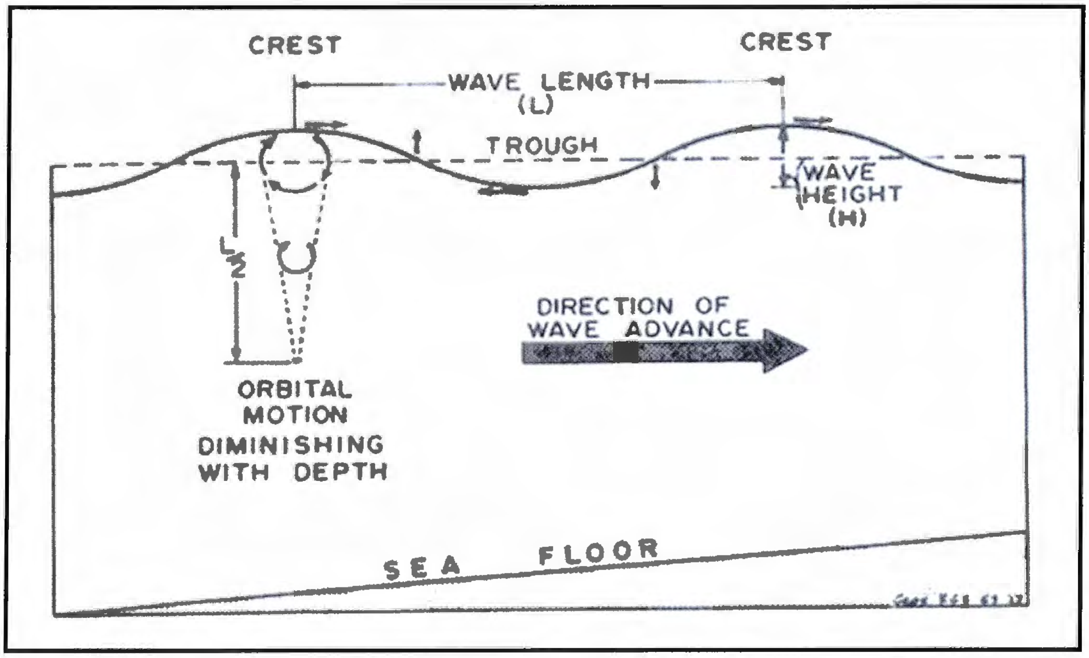

Figure 3.3 Diagram of wave terminology and dynamics (Bird, 1964).

On-site field work by Ingle (1966) showed that the most reliable indicator of erosion and accretion on natural beaches is the average breaker height. Increasing deep-water wave steepness has been shown to be linked with increased seaward sand movement. As a result it can be concluded that wave height and wave steepness are directly related to the degree of sand movement.

Plate 3.1 Swell wave breaking on Long Beach, June 2000.

3.3.1 Swell waves

The transfer of energy from wind to the sea surface results in the formation of various sea conditions and currents. The fetch, or distance over which wind blows continuously, determines the intensity and type of swell (Davies, 1980). Swell waves are formed as a result of consistent winds blowing over a long fetch and often result from distant storms (Davies, 1980). Swell waves are formed when they leave the area of wave generation (Short, 1999).

Swell waves are characterised by a long wave length, a long period between waves, and a low wave frequency (Davies, 1980). Once swell leaves the area of generation it transforms to allow great distances to be travelled with minimal energy loss (Short, 1999). Swell waves decrease in height, increase in length and become more uniform as they leave the area of generation (Davies, 1980). Swell waves travel in wave groups, sets of higher and lower waves, that contribute greatly to the energy of the surfzone (Short, 1999).

Swell waves are often associated with the accretion or fill of the beach system. Figure 3.4 illustrates the position of both the onshore and offshore sand accumulation areas, and indicates cross section profiles during periods of accretion and erosion. The low frequency of inbound waves allows sufficient time for wave run up to percolate down into the beach surface, depositing suspended sediment in the swash zone (see Figure 3.1). However, the effect that swell waves have on a coastal region is largely dependent on the location and orientation of the beach and the intensity of the swell waves (Davies, 1980).

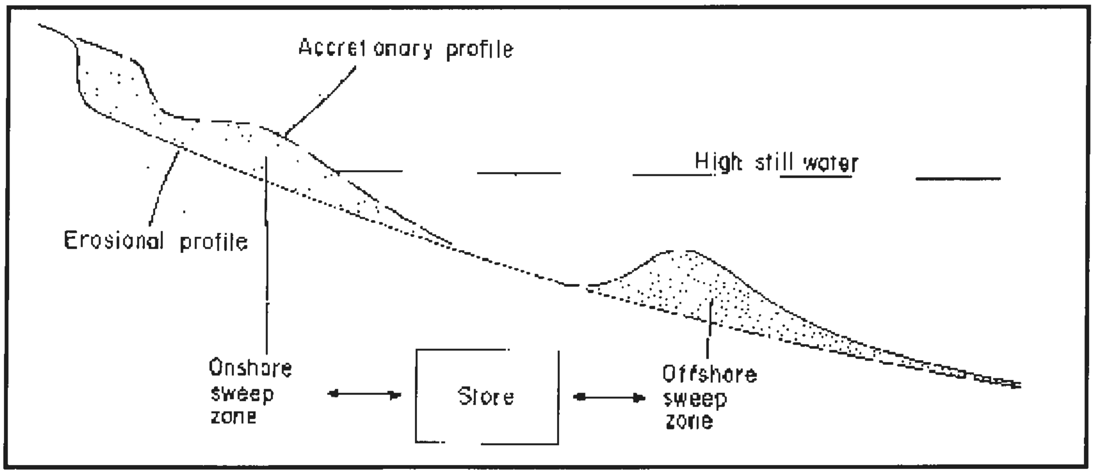

Figure 3.4 Onshore and offshore sweep zones depicting 'cut and fill' profiles (Davies, 1980).

Swell waves approaching at an oblique angle to the coast result in the longshore movement and deposition of sediment as a result of littoral drift, this process will be discussed in detail later in section 3.4.

The influence of swell waves on an estuarine beach system is dependent largely on the distance of the beach from the point of refraction and the orientation of the beach. Swell waves lose a large percentage of their energy, and as a result their ability to move sediment, when refracting around headlands or other areas of shallow water (Nordstrom, 1992).

Figure3.5 shows refraction patterns for southerly swell waves in Frederick Henry Bay, Tasmania. It can be seen that the original south west swell has been refracted and impinges on Seven Mile Beach as a south east swell. This high degree of refraction would result in a large loss of wave energy. A similar situation exists in bays and inlets around Tasmania, including the Derwent Estuary where swell waves refract around Blinking Billy Point and impact on Long Beach.

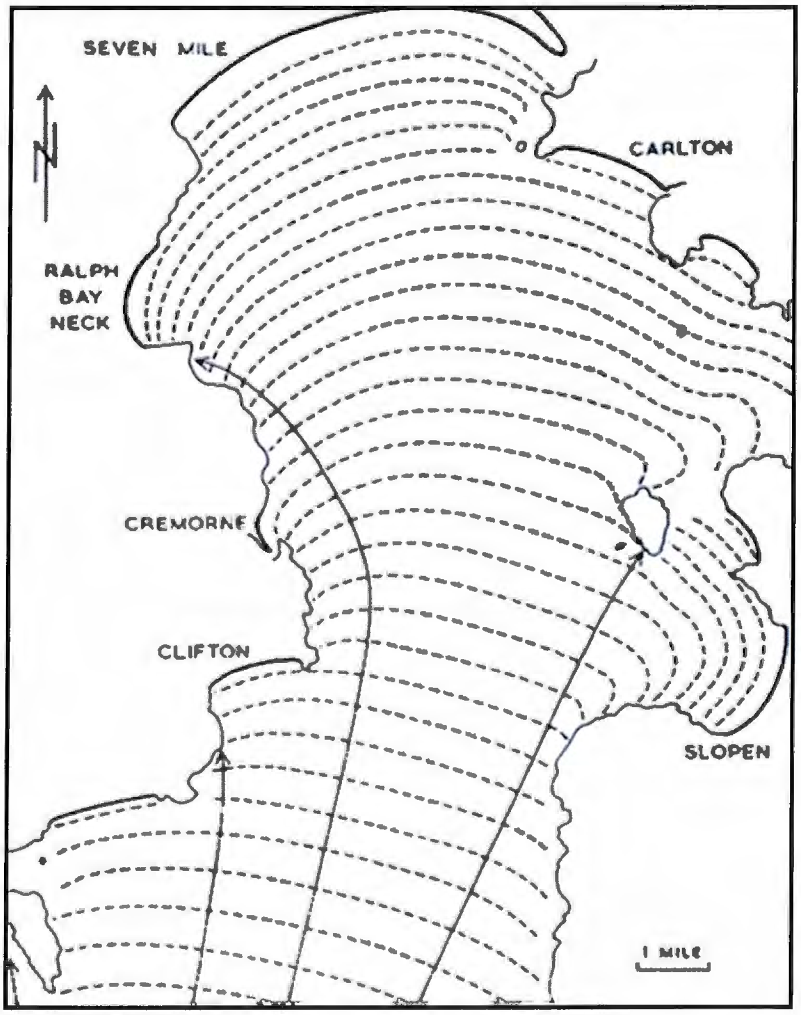

Figure 3.5 Wave Refraction processes in the upper Derwent River (Davies, 1958)

3.3.2 The effect of Southern Ocean Swell Waves on the Study Area

The swell waves that influence Long Beach are produced by strong westerly winds in the Southern Ocean, with unlimited fetch and storm duration (Patterson and Britton, 1998). The 'Roaring Forties' formed by deep low pressure systems produce these swell waves. On leaving the generation area the swell waves are deflected by the Coriolis Force causing them to travel as south west swell (Short, 1999). The south west swell averages 1.5 to 2 metres in height and has an average period of 12 seconds (Patterson and Britton, 1998).

Swell waves travel up the Derwent River and are refracted around Blinking Billy Point onto Long Beach (Carpenter, 1984). The association of swell waves with low pressure systems can result in unusually high water levels, resulting in a higher wave run up height and over-topping of the seawall, which exacerbates beach damage. Although swell waves are often associated with accretion and the regeneration of beaches, this is not the case at Long Beach. Swells refracting around Blinking Billy Point and breaking onto Long Beach produce plunging waves of up to 1.5 metres with high erosion potential (Carpenter, 1984).

There are only limited long term records for swell waves in the study area. Wave parameters such as wave height, period and wave direction are limited, making it difficult to gain an overall perspective on the wave climate. However, CSIRO collected one year of wave data in 1993 near Wedge Island in Storm Bay. This information suggests a high proportion of waves with low wave height and mid-range period and is presented in greater detail in section 2.3.1.

The influence of swell waves on sediment movement on Long Beach is discussed further in Chapter Five.

3.3.3 Wind waves

Wind waves are often associated with inconsistent winds blowing over relatively short fetches. Wind waves are characterised by short wavelengths and period, by a steep wave crest and low rates of longshore sediment transport (Davies, 1980). The maximum height which these waves will reach is largely governed by fetch, wind duration, wind direction, wind velocity and water depth (Nordstrom, 1989).

Wind waves are often associated with the erosion or cut of beach systems. The short wavelength and high frequency of wind waves results in the saturation of the swash zone due to the insufficient time for the water to percolate into the surface (Cooke and Doornkamp, 1990). The subsequent saturation of the swash zone allows for particles to be easily removed from the area.

Wind waves are less effective in the transportation of sediment when compared to swell waves. However, the inability of short period wind waves to refract in shallow water and conform to the shoreline orientation results in waves approaching the beach at an oblique angle. This causes significant longshore currents and contributes to the erosion and transport of sediment (Nordstrom, 1989).

A significant characteristic of estuary wind waves is the proximity with which they break to the shoreline. Waves breaking on the upper beach pose considerable risk to human structures and as a result must be addressed in coastal management strategies.

3.3.4 The Effect of Estuary Wind Waves within the Study Area

The primary cause of erosion on the Long Beach foreshore is waves generated by local winds. The geography of the study area exposes the sandy beaches to several significant fetches. Due to the presence of Blinking Billy Point, Long Beach is sheltered from a south-west fetch, however, to the north-west there is a 3 kilometre fetch; to the north an 8 kilometre fetch while a 15 kilometre fetch extends to the south-east. The southerly fetch is essentially unlimited.

In relation to the accretion of Long Beach, the effect of the relatively short-fetched north-west wind waves on Nutgrove Beach are considered to be most significant. Waves approaching Nutgrove Beach from the north-west have been recorded at heights up to 0.3 metres with periods of 2-3 seconds (Carpenter, 1984). The waves approaching Nutgrove Beach from this direction are predominantly wind generated waves with short wavelengths and low periods. The short period waves are unable to refract and conform to the shoreline when entering shallow water and as a result break on a sharp angle to the beach (Nordstrom, 1989). This oblique angle produces a rapid longshore drift that is able to move up to 2000 m^3 of sediment in a 24 hour period (Carpenter, 1984). The sediment is transported in slugs onto Long Point and then onto Long Beach.

Wind blowing from southerly directions over large distances can produce low energy wind waves that deposit sand onto Nutgrove Beach (Kinhill, 1994). Sand is sourced from offshore bars formed during periods of erosion. Wind waves generated over the southerly fetch are able to refract around the John Garrow Light, due to their longer periods and the shallow water, and break onto Long Beach. Wind waves generated over the southerly fetch have varying degrees of energy and usually break before impacting on the seawall. Although reflection from the seawall and the subsequent scouring does not occur, significant erosion still results due to the low period between waves.

The severity of the erosion problem on Long Beach can be related to the long time interval between post-storm deposition which is insufficient to replenish loss after periods of erosion. Except for deposition related to the southerly swell waves, minimal sediment is deposited on Long Beach during calm periods between storms because of low wave energy. Offshore sand is unlikely to be entrained due to the binding effect of fine-grained sediments or bottom vegetation (Nordstrom, 1989).

3.4 THE EFFECT OF CURRENTS ON THE DYNAMICS OF BEACH SYSTEMS

Currents operating in the coastal zone can be categorised in two ways: those currents that run parallel to the shore (long-shore currents), and currents that act at an angle normal to shore (shore-normal currents) (Pethick, 1992). Although these currents have been defined separately they do interact to a large degree in the coastal environment.

3.4.1 Long-shore currents

Longshore currents are continuous shore-parallel flows within the surf zone (Thom, 1984). Longshore currents are capable of transporting large quantities of sediment and are often associated with long-term beach erosion. Both swell waves and wind waves approaching the coast at an oblique angle will result in the formation of long-shore currents. The angled up rush of waves and the resulting perpendicular down rush can result in large amounts of sediment being transported along the coast.

Longshore currents are not only dependent on incident waves but also on wind and tides. At high tides the velocity of longshore currents may increase due to the height of local waves. Tides have the added effect of modulating the longshore current (Short, 1999).

Due to wave refraction in shallow water the angle at which a wave approaches the coastline will not be large and rarely exceeds 10 degrees (Davies, 1980). The source of energy for any current is the wave-energy arriving in the near-shore zone. The incoming waves result in two forms of sediment movement, namely oscillatory movement and mass transport. Oscillatory movement occurs as a result of the circular wave orbit (Figure 3.3) and is often associated with swell waves. Sediment is moved onshore when the wave base interacts with the seafloor, resulting in the transport of sediment (King, 1972).

Although wave approach and tides are largely responsible for the formation of longshore currents, wind is also significant in governing the strength of currents. Studies by Nummedal and Finley (1978) and also Whitford and Thornton (1993) have shown that during periods of strong winds blowing alongshore, wind forcing may influence current velocities – particularly on gently sloping beaches.

The processes involved in the formation of longshore currents are illustrated in Figure 3.6.

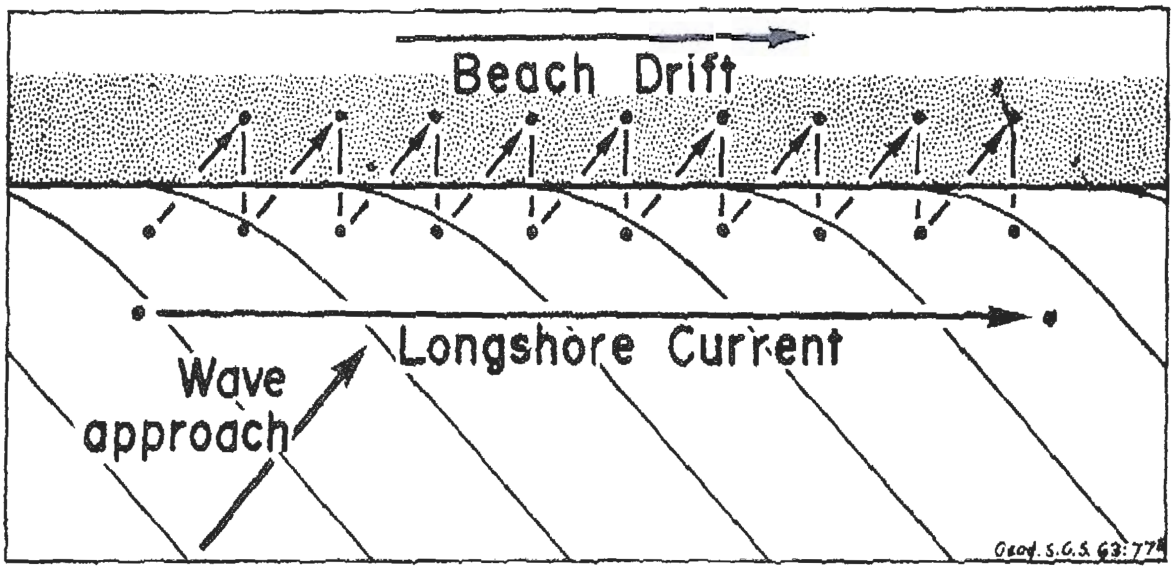

Figure 3.6 Processes involved in Longshore Current formation (Bird, 1964).

3.4.2 Shore-normal currents

Shore-normal currents can be further sub-divided into three forms: bed return currents; tidal currents; and wind currents. Each of these will be discussed briefly in the following sections.

3.4.2.1 Bed Return Currents

As an incoming wave moves from deeper water into the near-shore zone, wave energy is transformed from a circular orbit within the wave to onshore-offshore movement. The exact point at which this change occurs is defined as the break-point (Pethick, 1992). This change results in the formation of shore-normal currents and the movement of sediment between the beach and off-shore region. The circular orbit of waves in deep water has very little significance in terms of geomorphic change. However, as the water depth decreases the circular orbit becomes more elliptical and an alternating current forms (Pethick, 1992). The forward and backward movement of water over short distances does move sediment but would have little impact on the larger scale coastal geomorphology. As the wave moves into shallow water the water movement onshore increases in velocity but decreases in duration, while offshore velocities decrease but duration increases (Pethick, 1992).

The circular orbit associated with waves is not a completely closed system but does contain a small degree of forward movement. This uni-directional movement creates mass transport - an important shore-normal current (Pethick, 1992). The velocity of mass transport increases as water depth decreases, therefore maintaining constant onshore deposition in relation to the minimizing surface area. The onshore deposition previously explained is negated by rip-currents that transport sediment into the off-shore zone (Pethick, 1992). Rip-currents are formed as a result of water and run off, that has been forced into shallow water by wave action, moving offshore through openings between sandbars. High current velocities are formed as a result of large amounts of water moving through small openings (Davies, 1980).

3.4.2.2 Tidal Currents

Although being somewhat predictable, currents resulting from tidal flow can result in the transport of considerable amounts of particulates, and are an important process when considering the erosion, accretion and transport of sediment within a beach system. Tidal currents are at a maximum where beaches are located near tidal channels, at projecting headlands, or at constrictions in the bay (Nordstrom, 1989). Tidal currents have a maximum effect when operating in conjuction with waves, in such circumstances current velocity may be equivalent to currents observed on high energy days on ocean beaches (Nordstrom, 1977a).

Tidal currents usually operate at considerable water depths seaward of the surfzone (Short, 1999). As the tidal range increases, nearshore processes are able to act on the intertidal zone and tidal currents become more influential in the shaping of a beach. The presence of residual currents, or permanent currents, can have a large effect on rates of longshore sediment movement. Residual currents are a result of tidal movement and nearshore topographic effects (Short, 1999). Residual currents are usually of small velocities.

3.4.2.3 Wind Currents

Surface friction between wind and the water surface can result in current speeds of up to 3 % of the wind speed (Kinhill, 1994). Wind and other currents, such as density currents, have been shown to be effective in the transport of sediment only if water movement is greater than 0.2 metres per second (Kinhill, 1994).

3.4.1 The Effect of Currents within the Study Area

Prior to the Kinhill report in 1994, there was no available data on currents in the study region. The report conducted measurements of currents at both spring and neap tides. It was anticipated that currents would be relatively small in magnitude and variable. It was also expected that currents would differ greatly with depth. Owing to these expectations, the measurements were undertaken using drogues and tethered buoys. The information gathered by the field investigations included in the Kinhill report (1994) resulted in a number of conclusions. The first was that current velocities were consistently low, and rarely exceeded 2 metres/second. Second, there was no significant difference in maximum current velocity measured between the neap and spring tides (Kinhill, 1994). It was also discerned, from current measurements along the shoreline of Little Sandy Bay, that there is a dominant clockwise current. This current is formed by the breaking of swell waves and is likely to be able to move sand to the north.

There are three main types of currents operating within the study area: tidal water variations; wind induced currents; and river flow. The significance of each of these can be analysed separately. Tidal currents operating within the Sandy Bay area are predictable and rarely exceed strengths of 0.2 metres/second (Patterson and Britton, 1998). Wind driven currents usually move at velocities of around 3 % of the wind speed. Wind speeds of 6 metres/second are common over the Derwent River, occurring more than 25 % of the time (Cruise, 1978). This wind speed also provides a wind driven current speed of 0.2 metres/second. River flow in the Derwent River is governed largely by water release from the hydro-electric schemes up river. Water is released in response to demand, thus resulting in a variable discharge pattern; the Patterson and Britton (1998) study was able to discern a current of 0.2 metres/second off Sandy Bay.

It can be concluded that current patterns within Sandy Bay and Little Sandy Bay are not predictable nor clearly defined. Current strengths do not exceed the threshhold of 0.2 metres/second in the near shore zone and, as a result, have little effect on the net or long term sediment movement of the beach systems. Only four days were spent in the field measuring current speeds in the Derwent River, however, due to the accurate methods used (drogues in combination with GPS) it can be concluded that current speeds of 0.2 metres/second are accurate but are only representative of the season in which they were measured, and the locations in which they were measured.

3.5 AEOLIAN SEDIMENT TRANSPORT

The movement of sand by the wind is a highly complex process and is a good example of process-form geomorphology. Much of the earlier study into aeolian sediment transport was carried out by Bagnold (1941), while later theory was developed by Pethick (1992), Short (1999) and others.

The interaction between air movement and the sand surface can be described in terms of frictional drag. Air flowing at a minimal height above the surface is subject to the 'effective surface roughness' which acts to decrease wind velocity. This decrease in wind velocity at low levels is transmitted up the vertical velocity profile (Pethick, 1992). The shear created by wind moving over sand particles will begin to move sand particles when the particle size is below the threshold for that velocity (Short, 1999). Aeolian sediment transport occurs via three main processes; saltation, surface creep and suspension, each of these will be discussed.

Aeolian sand transport on sandy beaches does vary greatly from those theories mentioned. Due to the interaction of several variables aeolian sediment transport on sandy beaches is unique. Wind coming off the surfzone and onto the beach is highly turbulent and as a result several internal boundary layers may develop (Short, 1999). Beach surfaces are rarely flat and undulate in both across-shore and alongshore directions. Beach sand varies greatly in size and often contains a high degree of organic matter, while the moisture content of beach sand varies from completely dry to saturated. For these reasons it has proven difficult to formulate set theory for calculating sand transport rates (Short, 1999).

A sand grain is 2000 times heavier than air of the same volume, as a result the sand grain becomes very bouncy (Pethick, 1992). Due to the large disparities in density, the impact between moving and stationary sand grains on the beach surface flicks the mobile particles into the air. As the particles move higher in the vertical wind profile they are affected by greater wind velocities. The sand particles are then transported at the same velocity as the wind at this height, and follow a parabolic trajectory to the surface. The impact of the sand particle on the surface disturbs further particles that follow the same process (Pethick, 1992). This process is referred to as saltation.

Surface creep is another process by which sand is moved under the influence of wind. A suspended sand particle when returning to the surface may impact on a particle too heavy to be flicked into the air, as a result the sand grain will roll forwards. Sand grains up to six times the diameter of the incident grain will be moved through this process (Pethick, 1992). Although an infrequent process, only 25 % of sand movement occurs through surface creep, it is highly significant as it results in the sorting of sand grains. Finer, saltating grains move quicker and further downwind than the larger surface creep grains (Pethick, 1992).

Suspension is the final process by which sand is transported. Small sand gains, usually less than 0.2 mm, have fall velocities that are less than the velocity of upward turbulent eddies (Short, 1999). These finer sand grains are suspended in the air and are transported away from the dune or beach. These fine grained particles lie below the zone of zero wind velocity and as a result are not moved by any wind velocity, however, disturbance results in the fine particles becoming suspended (Pethick, 1992).

3.5.1 Aeolian Sediment Transport in the Study Area

The effect of wind and the movement of sand through aeolian transport is an important factor affecting the sediment budget and beach characteristics of the Sandy Bay beaches. As previously mentioned, the dominant wind directions acting in the Sandy Bay area are from the north west and the south west, and also the south east summer sea breeze. The northerly winds blow over a large fetch and are able to move large amounts of sand. Carpenter (1984) analysed wind frequency data and demonstrated that winds from the north west which are capable of moving fine grained sediments occur 65 % of the time, winds capable of moving coarser particles occur 11 % of the time, while winds capable of generating a long shore current occur only 0.8 % of the time.

On Nutgrove Beach aeolian transport plays a significant role in the movement of sediment. The median grain size on Nutgrove Beach is less than 0.2 mm, which means that the strong winds blowing across the area are capable of moving large quantities of sand (Kinhill, 1994). Aeolian sediment movement on Nutgrove Beach is of such a magnitude that it is of greater significance than the low energy waves impacting on Nutgrove Beach (Cruise, 1978). Prior to the construction on Nutgrove Beach in 1932, sand was transported by aeolian processes from the Nutgrove foreshore onto Long Beach to replenish the beach after periods of erosion. However, the construction of housing lead to problems with the wind blown sand and, as a result, fences were constructed to stabilise the sand and vegetation planted to stabilise the dune. The effectiveness of the fences in trapping sand has possibly resulted in the loss of sand from the beach system.

The trapping of sand on Nutgrove Beach due to the installation of fencing has resulted in the formation of a dune system, and the sand stored in this dune system is available to act as a buffer against further erosion events. The dune system does not act as a barrier to erosion but provides sand for erosion during storm events.

3.6 HUMAN IMPACTS ON BEACH MORPHOLOGY

Human impacts on beach morphology vary considerably and range from the mining of beaches for mineral deposits, and the construction of coastal defence structures through to deforestation and the burning of dune-stabilising vegetation (Cooke and Doornkamp, 1990). In the majority of cases human activity in the coastal zone has a negative impact on beach development and results in the loss of sediment and erosion of the coastline.

For example, on the southern Namibian coast, extensive diamond mining on the beaches has required the construction of seawalls 350 metres seaward of the highwater mark, 12 metres below sea level (Viles and Spencer, 1995). As a result the seawall must be continuously maintained against wave and wind attack.

It can be seen that human activities often affect longshore transport and, as a result, alter sediment supply, causing net erosion. In response to beach erosion, coastal defence structures are installed to protect land from further encroachment, minimise wave energy or to retain sediment. Coastal defence structures include seawalls, groynes, breakwaters and jetties all aim to reudce sediment loss by reducing wave energy or trapping sediment. Coastal defence structures can create further problems through edge effects and downdrift erosion, as a result further construction is required resulting in a circle of construction. This has been demonstrated at Point Lonsdale in Victoria where seawall construction began in the 1900s and continued through to the 1970s as a result of downdrift erosion (Cooke and Doornkamp, 1990).

Human impacts in the coastal zone vary considerably but in the majority of cases results in disruption to sediment transport patterns and erosion of the beach. The construction of groynes, breakwaters and jetties results in problems of downdrift erosion, while the construction of sea-walls and off-shore breakwaters leads to problems of wave reflection, accelerated sediment movement and a reduction in littoral drift. The purpose of sea-walls is to prevent the attack of the backshore by large waves and to stabilize the shoreline position (Cooke and Doornkamp, 1990). However, sea-walls do not favour beach development but in many cases accelerate erosion, both in front of the seawall and at other unprotected regions of the coast. Groynes are often used to act as a barrier to the movement of sand alongshore by attempting to reduce the rate of longshore transport. Groynes produce a wide beach on the updrift side of the structure but starve the downdrift side of sediment which results in downdrift erosion (Cooke and Doornkamp, 1990).

Attempts to restrict sediment loss, minimise incident wave energy and halt sea encroachment leads to the construction of further structures which in turn create further problems. This is illustrated below in Figure 3.7 where a seawall has been installed to minimise sand loss from a beach. However, wave energy is reflected from the hard seawall structure, and this energy is then used to scour sand from the beach surface. Over a period of time, the beach surface is lowered relative to the original level.

Due to several investigations there has been a growing recognition, amongst the public and wider community, of the impacts of coastal defence structures on sandy beaches. As a result of this growing concern there has been a shift towards the use of 'soft' engineering structures to maintain sediment levels and beach morphology. The recognition of the beach and other coastal regions as dynamic entities has resulted in the use of artificial and nourished dune systems to act as natural buffers to protect against storm processes. A greater understanding of coastal processes has recognised that beaches are in fact dynamic systems and levels of erosion and accretion must be considered during development of the coastal zone.

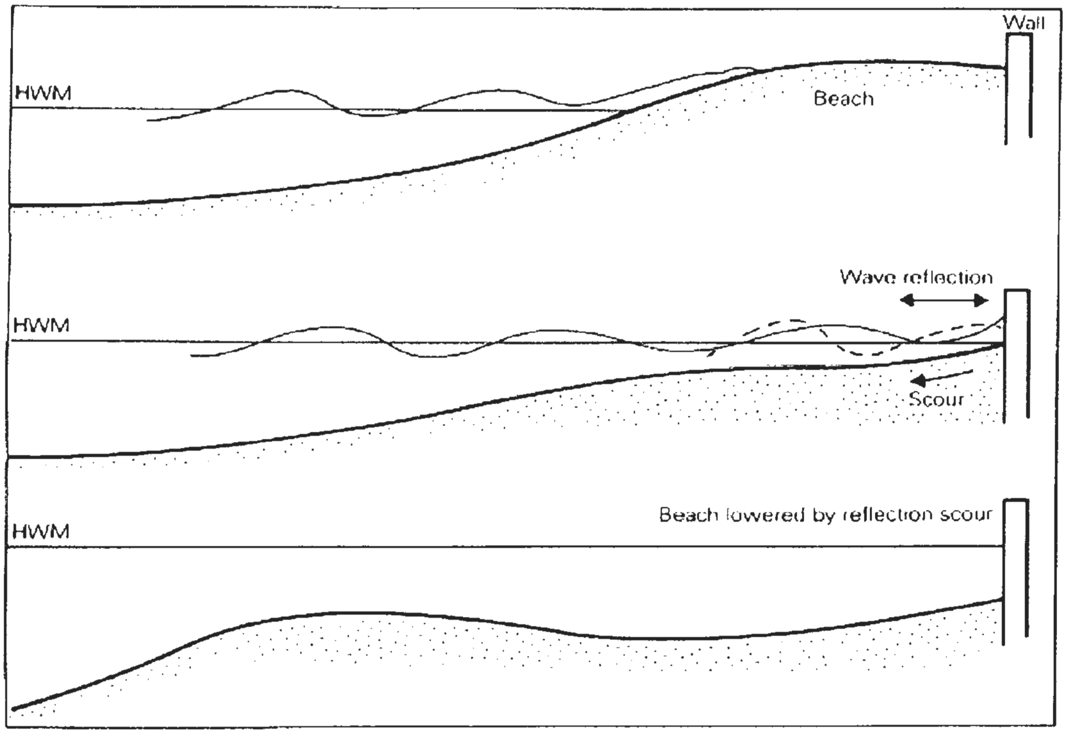

Figure 3.7 Wave interaction with sea-walls illustrating the processes of wave reflection and scour (Cooke and Doornkamp, 1990).

3.7 CHAPTER SUMMARY

Long Beach is subject to a range of coastal processes that have acted to shape and alter the shoreline position. The dominant influence on the formation, and the constant fluctuation, of the shoreline position of Long Beach is the local wave regime. Both swell waves generated in the Southern Ocean, and storm waves developed over the relatively short northerly fetch, greatly influence sediment movement both on and off Long Beach and the surrounding foreshore.

Long-shore currents and shore-normal currents produced by oblique wave approach, tidal movements, and surface friction due to wind, play an important part in the transport of sediment in coastal environments. The currents operating in the Long Beach area have been outlined and their influence on the morphology of the shoreline discussed.

Aeolian sediment transport is also an influencing process on the cycling and supply of sediment to various regions of the coastal foreshore. The dominant wind regimes have been outlined in this chapter and have been related to sediment transfer within the study area. The many human impacts on the closed system including Long Beach and Nutgrove Beach have been outlined. The impact that these human induced changes have had on aeolian sediment transfer have also been discussed.

The following chapter will present the methods used to study the changes in the shoreline position of Long Beach from 1947 to 1997, and will outline possible errors in the data and the method of study.

CHAPTER 4

THE RESULTS AND METHODS USED TO ANALYSE CHANGES IN SHORELINE POSITION AND MORPHOLOGY OF LONG BEACH SINCE 1947

4.1 INTRODUCTION

The aim of this chapter is to analyse and discuss the methods used to assess changes in the shoreline position of Long Beach during the 53 years since 1947. The main procedures involved in the analysis of the data will be outlined and possible sources of error or data inaccuracy will be discussed. In addition the results of the study will be presented.

Included in this chapter will be an overview of the methods and systems that were used to monitor the changes in shoreline since 1947 (section 4.2). Section 4.3 contains a discussion of possible error sources and the accuracy of spatial and attribute data. Section 4.4 and 4.5 presents the results of the study. Section 4.6 provides a summary of the chapter.

The primary objective of the study is addressed in this chapter, that is, to effectively utilise aerial photography and Geographic Information Systems to monitor the changes in shoreline position of Long Beach for the years 1947, 1967, 1973, 1981, 1988 and 1998.

4.2 METHODS

Several previous studies have been carried out which have incorporated remotely sensed data - such as aerial photography - with GIS analysis. For example Rongxing et al. (1996) developed a GIS for the monitoring and management of shoreline erosion in Malaysia; Watt (1999) effectively incorporated GIS analysis of aerial photographs with field work to monitor the morphology and sediment transport dynamics of the Seven Mile beach spit; while Hesselmans (1997) produced a report into the possibilities of remote sensing technologies in coastal studies. In addition, Klemas and Srna (1973) used satellite imagery to investigate coastal processes as did Maktav and Kapdash (1994).

4.2.1 Creating spatial data sets from aerial photographs

Aerial photographs representing six intervals between 1947 and 1998 were used to analyse the changes in shoreline position of Long Beach, Blinking Billy Point and Long Point in Lower Sandy Bay. The spread of fifty years was deemed sufficient to establish fluctuations in shoreline position. Attempts were made to obtain an aerial photograph for each decade from the 1940s to the 1990s, however due to photograph availability this proved impossible. As a result the interval between photographs varies. Photographs ranged in scale from 1: 2,500 to 1: 15,000. Aerial photograph information is included in Table 4.1.

Table 4.1 Aerial photograph information

Year	Scale	Elevation (feet)	Date	Photo type	Sea Level (mm)
1947	unknown	unknown	1947	B and W	unknown
1967	1:2,500	650	1967	B and W	unknown
1973	1:12,500	2700	24.3.73	B and W	1100 (low water neap)
1981	1:15,000	16,200	27.1.81	B and W	unknown
1988	1:12,500	6,500	22.12.88	B and W	1130 (low water neap)
1998	1:12,500	13,000	25.2.98	Colour	1170 (low water neap)

4.2.1.1 Inputting spatial data

A number of methods were used to input the aerial photographs into a Geographic Information System and produce spatial data sets. The initial requirement was to input the aerial photographs into the computer system, this was carried out by scanning the photos at a high resolution, 1200 dpi (dots per square inch). During the scanning of the six images, digital enhancement was carried out to increase the clarity of the images when viewed at high resolution. Noise removal and image sharpening were the two main processes used to improve the images. These processes of image enhancement are commonly used applications that greatly increase the quality of the final image.

Once the images were cleaned to an acceptable level, they were imported into an Arc/Info GIS environment.

4.2.1.2 Rectification

Before further analysis of the images could proceed, rectification of the images had to be completed to ensure they were geographically correct, contained grid coordinates, and were correctly orientated. Rectification involves the conversion of spatial data into vector point coverages and the establishment of true coordinates and correct orientation of the image.

To rectify the data, registration of the images must be completed. The capture of ground control points provides the GIS with a framework of known, real word grid coordinates on which to manipulate and stretch the image. Ground control points, or known grid locations, were located at seven distinct locations within the study area, and the coordinates recorded using a differential Global Positioning System (GPS). A GPS is a satellite-based device that records x,y,z coordinates and other data, calculated by signals from satellites orbiting the Earth (ESRI, 1996). For the purpose of this study, high positional accuracy was required. For this reason a Garmen Differential GPS was used. The Differential GPS ensures positional accuracy to within 2 metres (ESRI, 1996).

Seven ground control points were recorded between Long Point and Blinking Billy Point. The points were entered into Arc/Info so as to register each photo, and the resulting RMS (root mean square) error was noted. The RMS error represents the difference between the orginal control points collected in the field and the new control points calculated by the transformation process (ESRI, 1996). The RMS errors obtained during this study will be discussed in more detail in section 4.3.1. The images were then rectified to enable conversion into vector point coverages.

4.2.1.3 Digitising aerial photographs

Digitising of shoreline position was carried out in Arc/Info using on-screen digitising. Images were displayed in the ArcEdit environment and the shoreline position digitised using the mouse as the input device. A series of line arcs were produced representing the high water mark of the six images, while two fixed buildings acted as control points to help identify shoreline changes. The arcs for each image were then edited to correct errors made during the digitising process.

4.2.1.4 Creation of a Digital Elevation Model

A Digital Elevation Model (DEM) was constructed of the sea floor off Long Beach, Long Point and Blinking Billy Point in an attempt to gain an idea of the location of offshore sand bars and troughs, and their influence on incident waves. A Triangulated Irregular Network (TIN) was used in preference to a lattice or grid because it was believed that this method would give the best graphical representation of the study area.

The DEM was created by digitizing bathymetric charts that contained a series of spot height data, ranging from north of Long Point through to the south of Blinking Billy Point. The process was similar to that carried out for the aerial photographs. One hundred and fifteen separate spot heights were entered using the digitizer; the depth data was later added. The shoreline of Long Beach was digitized and built for line topology. The spot height data was then digitized and built for point topology, and the depth data added in the Table environment of ArcView. By building line and point topology the GIS is able to recognise and analysis those spatial features. The two data sets were then joined and imported into the ArcInfo GIS. Using the create TIN command, the two data sets were combined to create a 3-dimensional model of the Long Beach sea floor. A Triangulated Irregular Network is formed through the networking of a series of triangles, the apex of the triangles represent peaks in the terrain, while the face and edges represent aspect, slope and ridge lines (ESRI, 1996).

The image was then manipulated and rotated in the Spatial Analyst extension of ArcView to obtain the best 3-dimensional perspective.

Owing to the limitations of the software, the 3-dimensional image could only be exported as a separate image. The map presented in section 4.6 contains the 2-dimensional model that was created.

4.2.1.5 Analysis of data

Shoreline analysis was conducted by overlaying the images for each year, and comparing the changes in shoreline position over the 50 year period. A two metre buffer was created on the shoreline position to account for variations in tide level. By analysing the overlayed images, areas of accretion and erosion on Long Beach could be identified during the 50 year period.

4.3 DATA ACCURACY

4.3.1 Spatial data

Inaccuracies in the spatial data were caused as a result of differing levels of accuracy during the registration process. Possible errors were generated due to variation in resolution or cell size of the images and also by the RMS error. Watt (1999) experienced similar problems during her study of Seven Mile Beach. The RMS error represents the difference between the original control points and the new control point locations calculated by the transformation process (ESRI, 1996). The RMS error varied for different coverages but ranged from 0.4 m to 4.684 m. It can be seen that a lower RMS error results in greater accuracy of the final image. The RMS errors obtained are considered to be more than adequate for the purposes of this study.

During construction of the Digital Elevation Model problems were encountered during the transformation of the preset control points to the real world coordinates obtained from the bathymetric charts. A large RMS error of 6 metres was obtained; the bathymetric chart was at a scale of 1:1250 which meant RMS error should have been no greater than 1 metre. The reasons for this inaccuracy are unclear but may be related to digitising inaccuracy. The second problem encountered was the accuracy of the Digital Elevation Model. The model works by analysing the known spot depths and creating the remainder of the model by interpolating values between each of the known depths. As a result of this there is a large degree of data uncertainty. The presence of features that may be interpreted as sandbars (particularly at the top of the image) may be areas extended from the last known depth. However, the model does give a good representation of the bathymetry of the study area.

4.3.2 Attribute Data

A major factor that contributed to possible inaccuracies in the data was generated when digitizing the shorelines of the images. The problem of accurately identifying and digitizing the high water mark created uncertainties in the data and inconsistencies between coverages. Some aerial photographs obtained were taken at high flight altitudes (up to 16 200 feet) and as a result had small scales (1:15,000). Owing to the problems associated with the aerial photographs, difficulties were encountered identifying the high water mark (the boundary between wet and dry sand). This problem was partly solved by zooming in to the required area when digitsing, however this generated new problems, such as image clarity and recognition of features. This problem was minimized to a certain degree by knowing the tide level at the time the photograph was taken. Tidal information was obtained from the National Tide Centre (2000) and compared to mean water levels included in the report by Patterson, Britton and Partners (1998). Tidal data is included in Table 4.1. It can be seen that for the years data was obtained, tides were at approximately the same level and were classified as the mean low water neap tide.

The maximum resolution of the scanned images was not adequate to allow for images to be viewed at high zoom levels. As a result there was a considerable loss of clarity and high levels of fuzziness when the zoom tool was used. This problem could have been solved through the use of better hardware during the initial scanning process to increase the resolution of the images. Another problem generated by the use of the zoom was inconsistencies between coverages. The GIS program used did not display what level of zoom was being used and as a result the shoreline was being digitized at differing zoom levels and, as a result, differing levels of accuracy for each coverage. This created slight inconsistencies between the data sets.

A second problem encountered during the digitising of the high water position was that of objects obstructing the shoreline. In several cases large trees obstructed the shoreline, making it impossible to digitise the high water mark. This problem was solved by estimating a trend line through the obstruction. In most cases the obstructions were small and this method proved to be effective.

The most common problem encountered during the digitising of the shoreline was human error. The inability to digitise the shoreline position of each coverage to the same level of accuracy lead to inaccuracies in the data and inconsistencies between coverages. Although digitsing was carried out at high zoom levels the high water mark was not always digitized exactly, as a result of human error. This also created differing levels of accuracy between coverages.

Further problems were encountered during the rectification of the 1947 image. For the images taken between 1967 and 1998 easily identifiable objects could be used as ground control points. Objects such as buildings or road junctions could be used as a reference point to record grid coordinates for rectification. The problem encountered was that the majority of possible ground control points selected in the photographs after 1967 were not available in the 1947 photograph.

As a result only four control points could be selected that were common in both the 1947 photo and what is present on Long Beach today.

4.4 RESULTS

The results of the shoreline analysis are included in Figures 4.1 – 4.6. Shoreline changes were identified by overlaying consecutive images and visually comparing the changes. Rates of change were calculated for each change map.

4.4.1 1947 – 1967

In Figure 4.1 it can be seen that there has been extensive shoreline retreat between 1947 and 1967. Shoreline retreat is evident throughout the entirety of Long Beach, with the maximum erosion occurring on the mid to southern stretch of the beach. Accretion has occurred on the north facing shoreline of Blinking Billy Point. The extension of the headland is considerable and would have significant impacts on wave refraction and sand bypassing onto Long Beach. The extension of Blinking Billy Point is probably not a result of coastal processes but more likely due to engineering activity, including land reclamation that took place at Blinking Billy Point for the extension of the sewage pipe.

Over the twenty year period from 1947 – 1967 the mid-section of Long Beach retreated by approximately 40 metres, an average of 2 metres/year. Long Point also showed severe erosion over this period, starting a trend that carries through the entire time series.

4.4.2 1967 – 1973

During this time interval there was very little shoreline movement on Long Beach. The majority of the beach remained stable, however there was some minor movement as can be seen in Figure 4.2. The southern section of Long Point has eroded, as has the far southern section of Long Beach. In comparison the central section of Long Beach has shown a small amount of accretion. In addition, Long Point has retreated noticeably, particularly in the southern parts.

4.4.3 1973 – 1981

It may be observed in Figure 4.3, that during this period the most active region of the study area was the northern stretch of Long Beach. Shoreline retreat began on the southern section of Long Point and continued through to the southern end of Long Beach. From the image it is evident that the northern stretch of Long Beach had the greatest shoreline retreat over the eight year period. The northern stretch of Long Beach retreated by 7 metres between 1973 and 1981, an average of approximately 80 cm/year. The majority of Long Point has also shown signs of erosion between 1973 and 1981.

4.4.4 1981 – 1988

During the 7 years between 1981 and 1988 there has been little shoreline movement on Long Beach except for the southern section. In Figure 4.4 it can be seen that there has been considerable accretion in the far south of Long Beach. From calculations made in ArcView it was established that this section of Long Beach has accreted 7 metres over the 7 years, an average rate of 1 metre/year. In addition there has been shoreline retreat on the southern facing shoreline of Long Point.

4.4.5 1988 – 1998

Between 1988 and 1998 there has been considerable movement in the south of Long Beach and minor movement on Long Point. Following the trend of the last forty years, Long Point has shown small but significant erosion over this time frame. The erosion on Long Point is isolated to the southern region, as is demonstrated in Figure 4.5.

4.4.6 1947 – 1998

From Figure 4.6, it can be seen that there has been considerable erosion of Long Point and all sections of Long Beach. The extent of erosion is equally spread over the entirety of the beach. However, it can be seen that the southern corner of Long Beach has not retreated to the same degree as the remainder of the beach. Blinking Billy Point has shown extensive accretion as a result of human influence, a topic that will be discussed further in section 5.2.1.

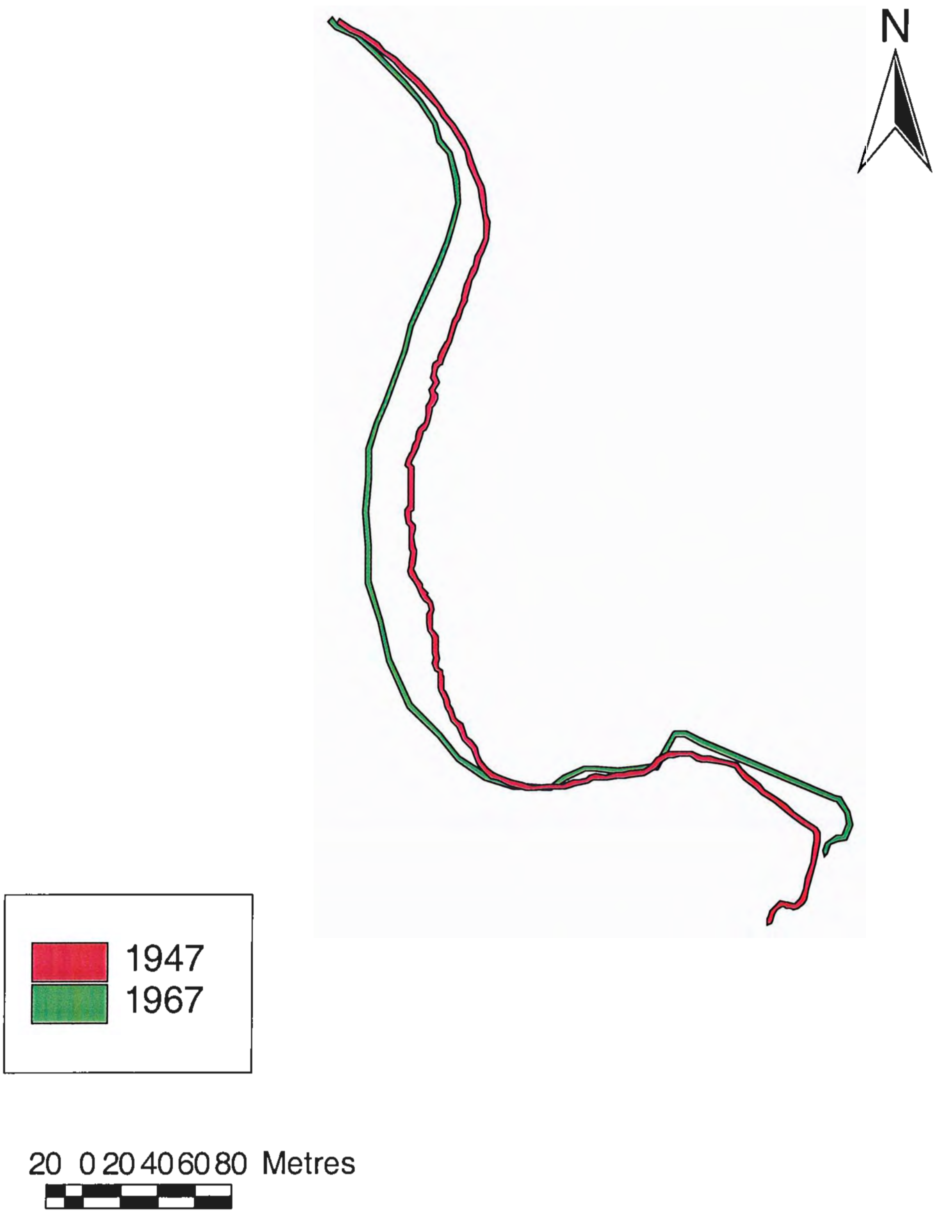

Figure 4.1 Shoreline comparison for Long Beach, 1947-1967

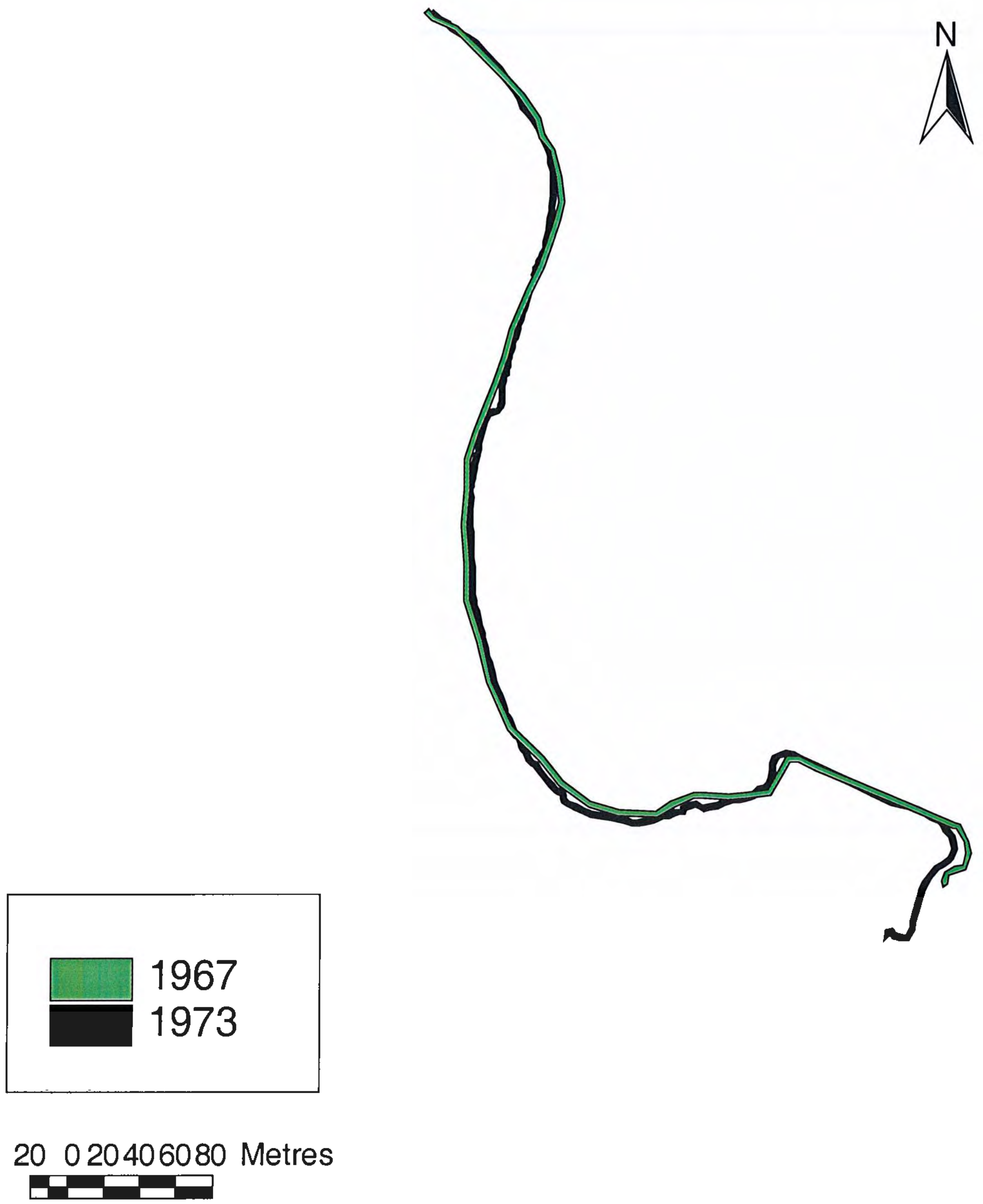

Figure 4.2 Shoreline comparison for Long Beach, 1967-1973

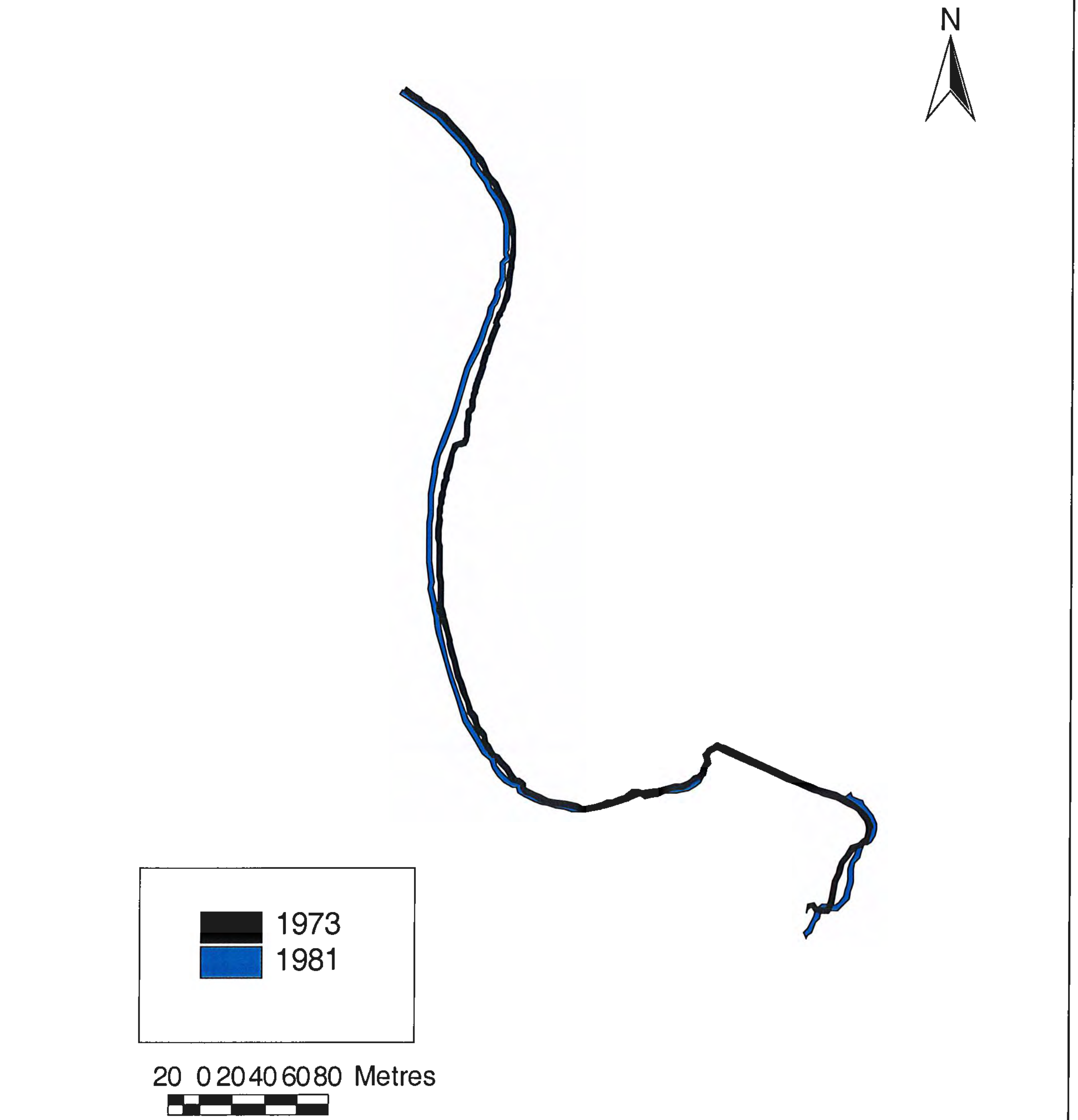

Figure 4.3 Shoreline comparison for Long Beach, 1973-1981

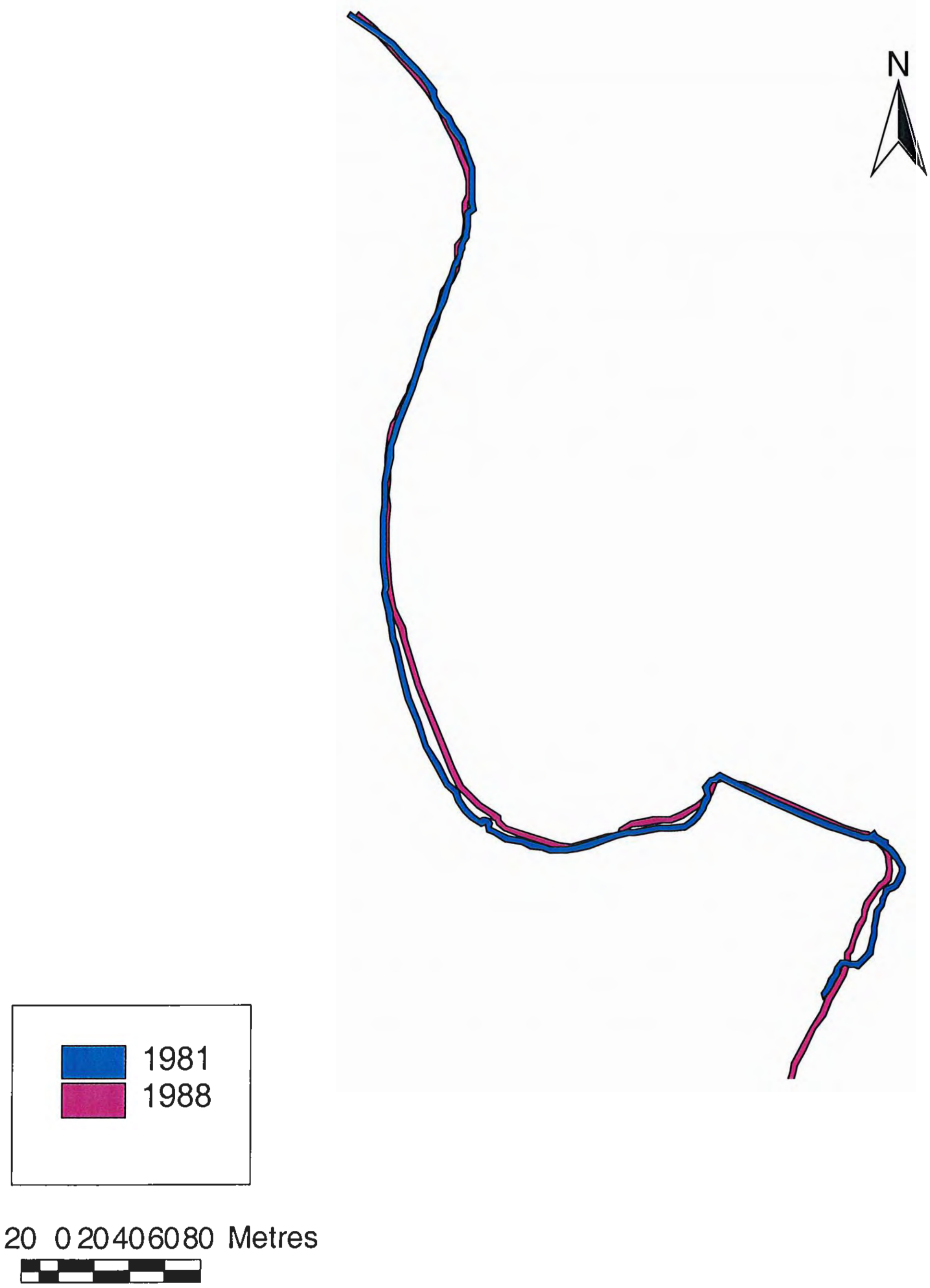

Figure 4.4 Shoreline comparison for Long Beach, 1981-1988

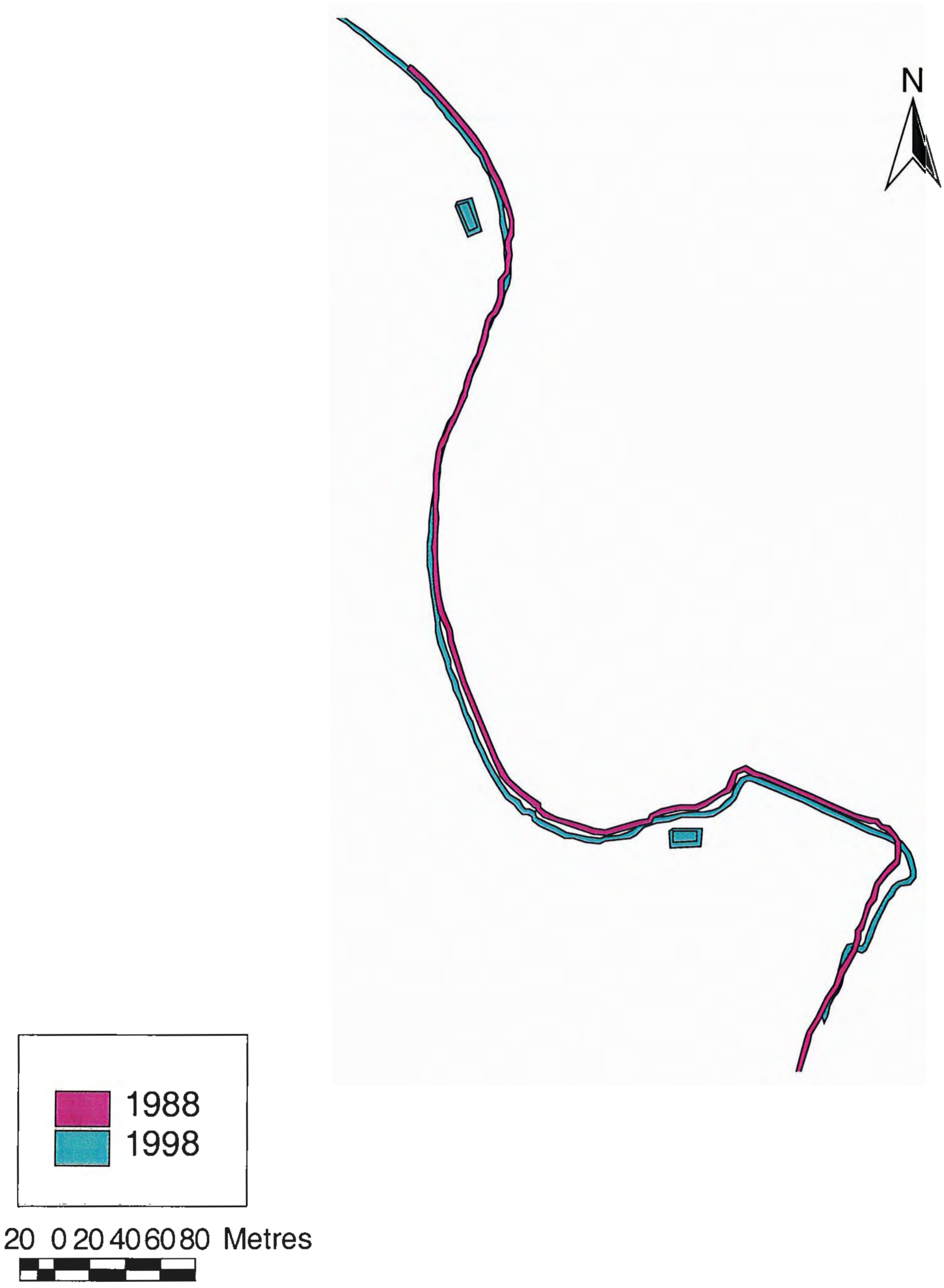

Figure 4.5 Shoreline comparison for Long Beach, 1988-1998

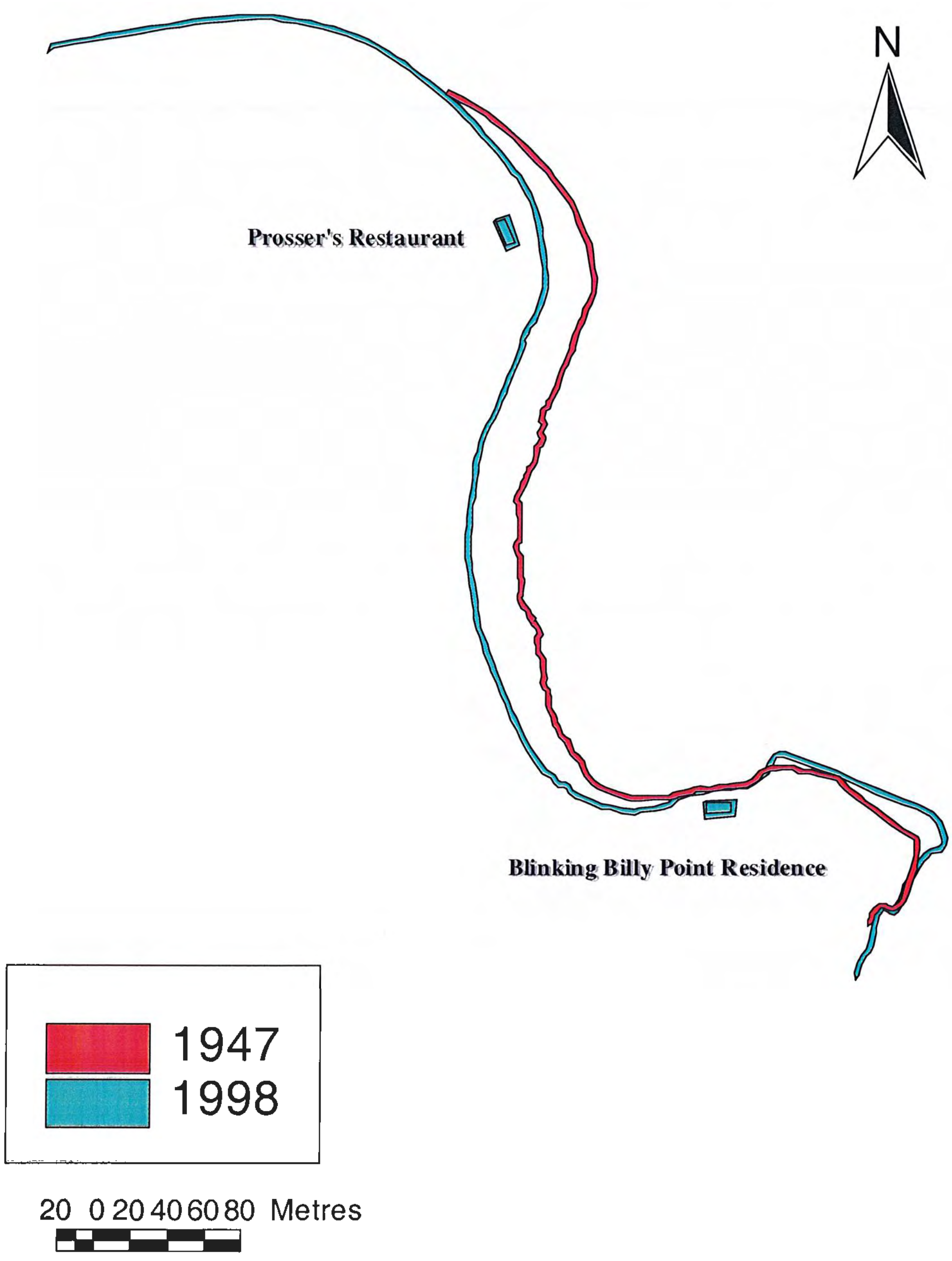

Figure 4.6 Shoreline comparison for Long Beach, 1947-1998

4.5 DIGITAL ELEVATION MODEL

The DEM shows the gradient of the submarine regions offshore from Long Beach, Blinking Billy Point and, to a lesser extent, Long Point.

The model presents a graphical representation of the offshore bathymetry and gives a basic idea of sediment storage zones, particularly in the north of the study area around Long Point.

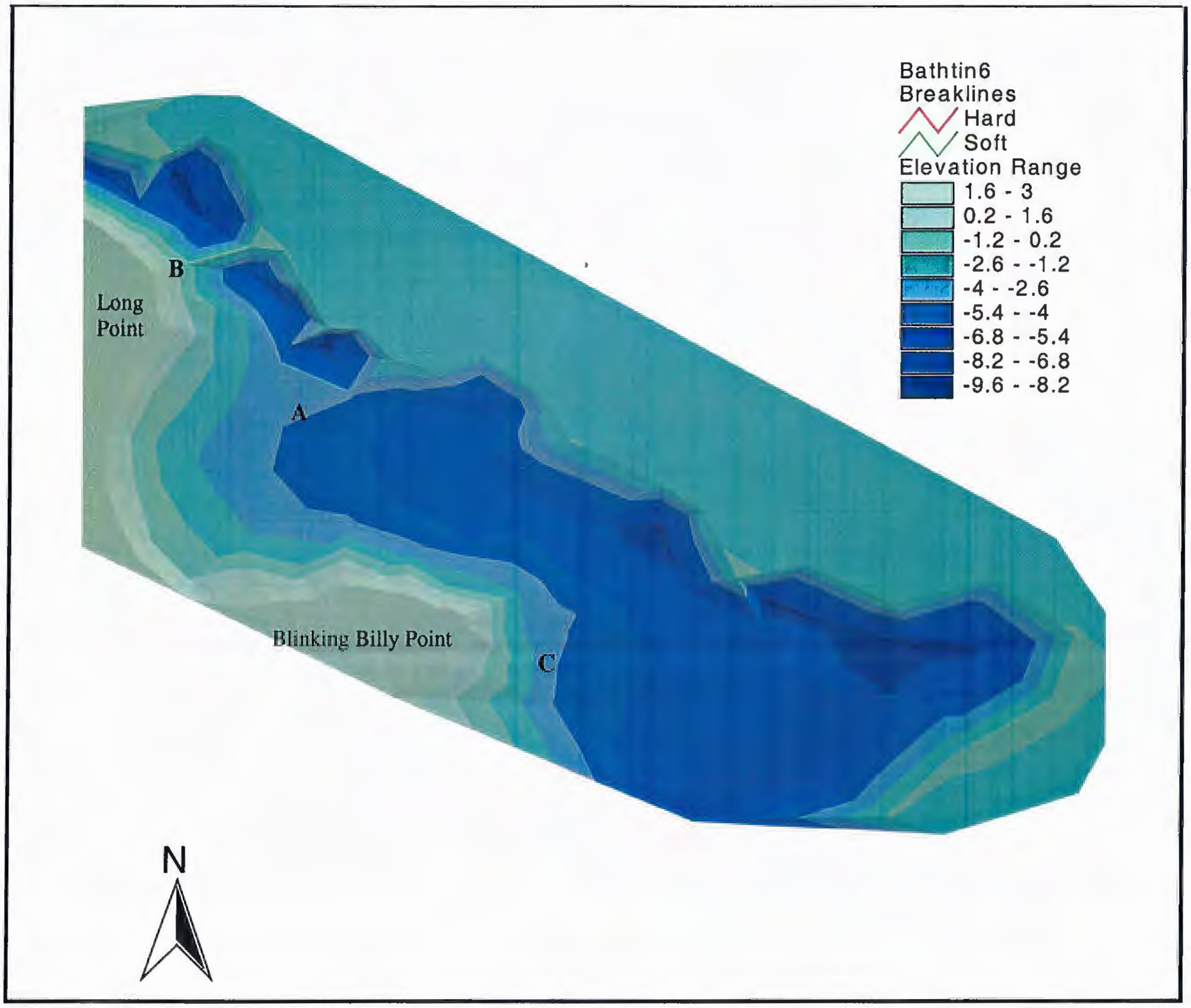

Figure 4.7 Top down Digital Elevation Model showing bathymetric data for the study area. Image border is on the right of the image – represented by the uniform aqua surface.

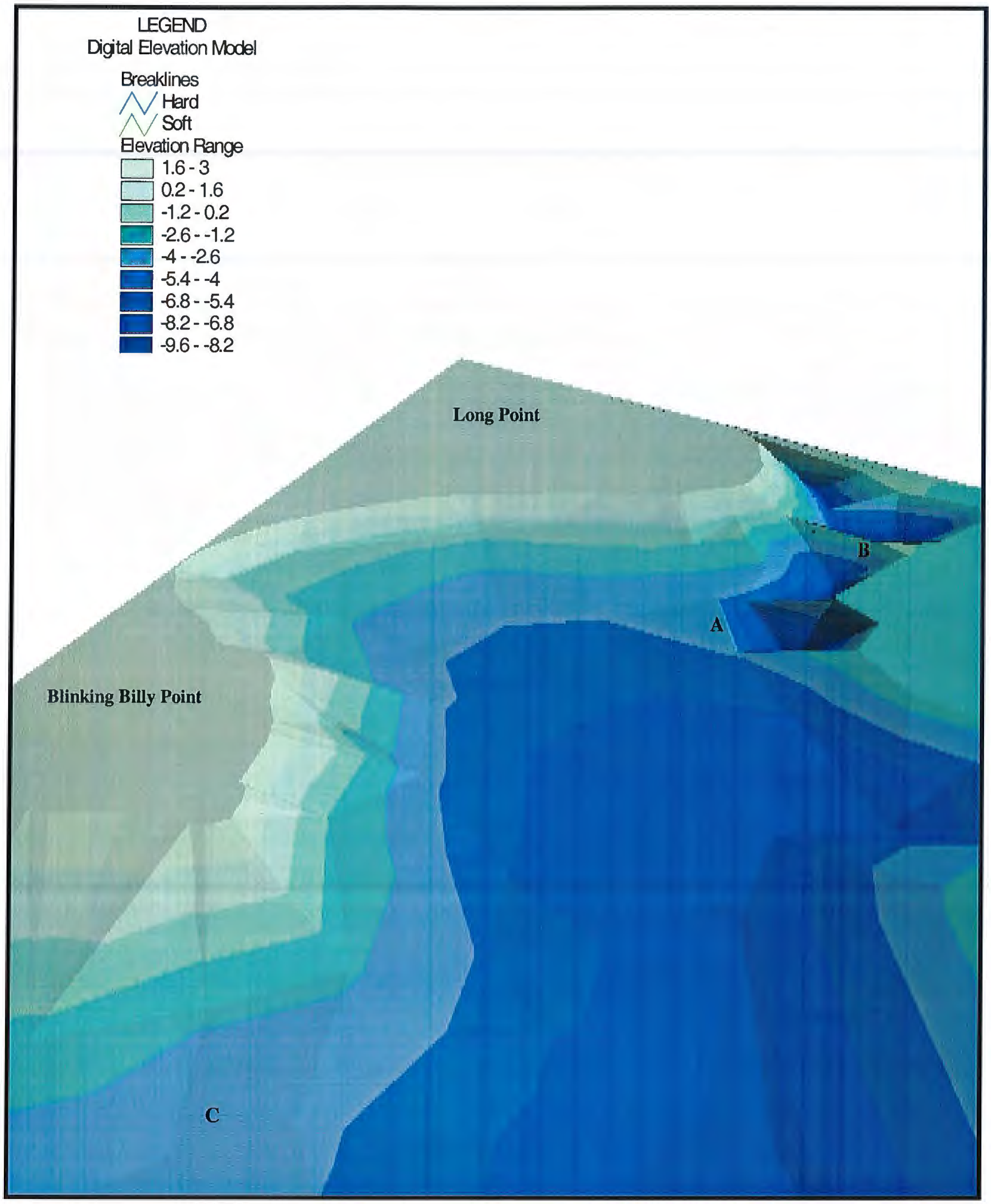

Figure 4.8 3-Dimensional Digital Elevation Model of the study area, looking from south-east of Blinking Billy Point to Long Point (depths are in metres below sea level).

The model presents a graphical representation of the offshore bathymetry and gives a basic idea of sediment storage zones, particularly in the north of the study area around Long Point.

It can be seen clearly in Figure 4.7 and 4.8 that there is a gradual underwater gradient from Long Beach out into the Derwent River, this represents a large amount of sediment in the regions directly off Long Beach. A similar situation exists to the south of Blinking Billy Point. The gradient of the offshore profile is low, indicating sediment is being stored to the south of the headland (area C in Figures 4.7 and 4.8). To the north of the study area it can be seen that there is a sharp drop off from Long Point into the deep water channel of the Derwent River, this is compliant with the report published by Cruise (1978).

The Digital Elevation Model also shows the presence of a large amount of sand off the south-east corner of Long Point and also to the east of Long Point. The sand store extending from Long Point to the east (B) is excessively steep, straight and unnatural – for these reasons this feature is deemed to be a computer error and will not be discussed. The shallow region to the south-east of Long Point (A) is feasible and can be explained by several natural processes. The results identified in the Digital Elevation Model will be discussed in section 5.2.2.

4.6 CHAPTER SUMMARY

The changes in shoreline position between 1947 and 1998 were analysed using a combination of aerial photography and Geographic Information Systems. Six aerial photographs, taken in 1947, 1967, 1973, 1981, 1988 and 1998 were scanned and then imported into the ArcInfo GIS. The images were rectified using ground control points collected in the field using Global Positioning Systems, and were then digitized to create a visual representation of the shoreline position. Change maps were created from the images using the ArcView GIS, and compared to assess shoreline change for the relevant period.

Problems related to spatial data accuracy and attribute accuracy were encountered during the shoreline analysis. The main source or spatial data error was related to the RMS error. Errors in attribute accuracy were primarily a result of digitizing errors related to the scale and resolution of aerial photographs. Other problems were encountered when applying the ground control points to each of the aerial photographs.

Chapter Five will contain a discussion of the results of the study.

CHAPTER 5

CHANGES IN THE SHORELINE POSITION OF LONG BEACH SINCE 1947

5.1 INTRODUCTION

The objectives of this chapter are to discuss the results of the study and provide an assessment of the morphology and changes in shoreline position of Long Beach in the 50 year period since 1947.

Chapter 5 will discuss the results of the study and the possible effects of coastal engineering structures and coastal processes operating on the shoreline of Long Beach. A discussion of the results and the influence of local coastal processes and coastal engineering structures is included in section 5.2, while the chapter summary is presented in section 5.3.

5.2 DISCUSSION

5.2.1 Shoreline Changes

The results from the study show extensive shoreline retreat between 1947 and 1967, however after this period of erosion there is significant stabilisation through the rest of the time series. Localised erosion periods can be seen in the 1973 – 1981 map where there has been considerable shoreline retreat on the northern region of Long Beach; and also in the 1988 – 1998 image where the southern region of Long Beach has retreated considerably. Generally, the images show shoreline retreat is most prevalent throughout the northern and southern regions of Long Beach while Long Point remains stable. The southern section of Long Beach appears to be less affected by erosion processes compared to the northern section of Long Beach, and this can be related to the wind ratios and swell characteristics of the region (discussed in detail in section 5.3.3).

During erosion events on Long Beach southerly swell waves will refract around Blinking Billy Point and impact on Long Beach. Due to the refraction process, the extreme south of Long Beach is in the 'shadow' of the headland and as a result does not receive the same wave energy as the northern and mid regions of Long Beach. This variation in exposure to swell waves along the length of Long Beach may account for the disparity in shoreline retreat between the north and south of Long Beach. To support this argument, it can be seen in the 1981 – 1988 image (Figure 4.4) that there has been considerable accretion of Long Beach in the southern region. This can be attributed to the sheltering effect of Blinking Billy Point; the lower wave energy has allowed sediment to be deposited in this area to gradually develop the shoreline.

To some extent the loss of material from the northern region of Long Beach can be attributed to local wind waves. Meteorological records show that from the 1950s there was a large scale shift in wind direction, with southerly winds becoming the dominant process. As a result of this, the northern most region of Long Beach would be exposed to the greatest wind fetch and orientated to receive the maximum wave energy.

In general it can be seen that there is a clear link between the coastal processes operating in the Long Beach area and the changes in morphology of the Long Beach coastline during the 50 years since 1947. Southern Ocean swell waves and local wind waves are responsible for removing sediment from Long Beach and depositing it on offshore slugs (Patterson and Britton, 1998). The influence of the waves in transporting sand offshore is greatly amplified when they impact on the seawall, as will be discussed in section 5.3. Sediment that is suspended by wave impact or scouring, or that is deposited on offshore slugs, is moved to the north by tidal currents or longshore currents.

The higher frequency of southern winds since the 1950s may have resulted in an imbalance in the sediment budget. Long Beach has eroded considerably to supply sediment to Nutgrove Beach and to the dune system on Nutgrove Beach. The northerly winds, that transport sediment from the north to Long Beach, are no longer as frequent as the pre 1950s and thus Long Beach has become sediment depleted.

The report by Kinhill (1994) includes detailed current measurements in the waters off Long Beach. The report suggests low longshore current velocities in most areas. As a result it could be said that tidal currents, and not longshore currents, are responsible for moving sediment in this system.

The only previous study that includes information on past shoreline position and rates of migration is the report by Cruise (1978). The results obtained throughout this study strongly correlate with the chronological history of the study area provided by Cruise (1978). In his report Cruise gave a description of the study area at consecutive time frames beginning in the mid-19th century and continuing through to 1978. He suggested a change in the balance of north to south winds could be responsible for the sudden erosion of Long Beach during the 1950s and the subsequent accretion and development of Nutgrove Beach, this idea is discussed further in section 5.3.3.

The results obtained in this study also support the observation made by Cruise (1978) relating to noticeable erosion beginning in the 1950s. The 1947 - 1967 comparison demonstrates that Long Point and Long Beach have eroded considerably during this time. In his report, Cruise (1978) makes reference to large quantities of sand deposited on Long Beach between 1908 and 1950, the source of this sand remains unknown. This deposition of sand most probably accounts for the wide beach present in the 1947 image. Although pictures of Long Beach taken prior to the 1940s show a wide, well developed beach.

The rates of erosion identified in Chapter Four are similar to those recorded during previous studies. No data on rates of shoreline migration were included in the report by Cruise (1978), however results obtained in this study can be compared to shoreline studies of the Seven Mile Beach Spit, also located in south east Tasmania, by Dobson and Williams (1977), Culver (1979) and Watt (1999). The report by Dobson and Williams (1977) included rates of migration of 1-2 metres/year for the Seven Mile Beach Spit. This is comparable to the Long Beach study for the years 1947 – 1998. As mentioned in Chapter Four migration rates for Long Beach ranged from 80cm/year for the years 1973 –1981 to 2 metres/year for the years 1947- 1967. In her report Watt (1999) stated a maximum displacement of 58 metres on the Seven Mile Spit between 1948 and 1966, and a displacement of 43 metres between 1980 and 1997. The maximum diplacement of the Long Beach shoreline was 40 metres between 1947 and 1967.

On a global scale, Basco and Bellomo (1997) in his study of shoreline movement at Sandbridge, Virginia (USA) identified historic recession rates of 2 metres/year. Morton (1988) conducted a study into seawall effects on three locations in Texas (USA) using aerial photography and subaerial profiles. He identified recession rates of 2.0 metres/year at the Galveston Seawall and recession rates of 2.7 metres/year at the control location. These rates of coastline change are clearly consistent with those obtained during the present study.

5.2.2 Coastal Bathymetry

The results obtained from the Digital Elevation Model presented in section 4.5 can be related to the coastal processes and landform changes that have been discussed previously in chapter 3.

The most noticeable characteristic of the bathymetric model is the extended accumulation of sediment to the south of both Blinking Billy Point and Long Point (area A and C in Figure 4.7 and 4.8). These areas of sand accumulation may be 'sand slugs' described by Cruise (1978). Sand eroded from Long Beach and areas south of Blinking Billy Point are deposited on offshore sand bars. These sand bars or sand slugs are then transported to the north under the influence of southerly swell waves during storm events and currents.

The sand accumulation to the south of Blinking Billy Point may be a result of sand trapping associated with the outfall pipe, however this is unlikely as the positioning and width of the sand store do not correlate with the position of the pipe.

In summary it can be seen that there is a gradual gradient from Long Beach into the Derwent River, this gradient may be associated with the deposition of sediment eroded from the beach during major storm events. A similar situation exists off Blinking Billy Point, while Long Point has a sharp drop over into the Derwent River channel. The location of two major sand storage areas can be seen to the south of Blinking Billy Point and south-east of Long Point. These may be sand bars or sand slugs formed through the mass deposition of eroded sand material. As is expected, water depth increases with distance from the shoreline.

5.2.3 Influence of Coastal Engineering Structures

A range of coastal engineering structures exist along the length of Long Beach. These structures may have influenced the sediment transport processes in operation.

5.2.3.1 Influence of Outfall Pipe

The presence of the old Outfall Pipe on Long Beach may retard sediment movement along Long Beach to both the north and south. As can be seen in Plate 5.1, sand is considerably higher on the southern side of the pipeline suggesting that northerly sediment movement is being impeded by the disused pipe and mound. If the pipeline was acting as a groyne and reducing sediment movement, the actual amounts of sediment being trapped would be negligible in the wider context of the sediment budget. The height and length of the outfall pipe would result in only small amounts of sediment being trapped before overtopping of the pipe occurred.

Plate 5.1 The outfall pipe on Long Beach. Sand accretion on the far side of the pipe may be evident of sand trapping.

5.2.3.2 Influence of Seawall

Several studies have been conducted into the effects of seawalls on rates of erosion on sandy beaches. Basco and Bellomo (1997) conducted a study into the influence of seawalls on subaerial beach volumes with receding shorelines. The purpose of this investigation was to determine if seawalls are responsible for altering the 'natural'erosional trend of the shoreline at Sandbridge, Virginia. Historic recession rates of 2 metres/year were identified in the 120 years before seawall construction began. It was determined that volume erosion rates are not higher infront of seawalls, however there was a high degree of seasonal variability. During the winter months sand is removed to the offshore zone from infront of the seawall, whereas during the summer sand is piled up against the seawall during rebuilding (Basco and Bellomo, 1997).

Nersesian et al. (1992) investigated the effects of structures on landforms and sediment availability. The main findings outlined in this report were based on the seawall scouring and edge effects associated with 'hard' coastal engineering structures. Rakha and Kamphuis (1996) produced a model for an eroding beach backed by a seawall. It was found that beach erosion in the vicinity of a seawall could be successfully predicted through the use of a morphology model. Factored into the model was the effect of wave reflection. Results from this study have showed that reflected waves have a small effect on the beach profile and only remove sand close to the seawall. Studies by Kraus and McDougal (1997) into the effect of seawalls on sandy beaches concluded that there were no adverse impacts of a seawall on the adjacent beach, given a constant sediment supply.

A study by Morton (1988) incorporated aerial photographs and subaerial profiles to investigate wall effects in Texas. Results showed that rates of erosion doubled from 0.9 metres/year to 2.0 metres/year following the extension of the Galveston seawall. Griggs et al. (1994) conducted a seven year study on the shoreline of Monterey Bay, California. It was concluded that there were no significant long-term effects of the seawalls on the adjacent beaches. It was found that summer rebuilding was not influenced by the seawall, and there was no difference in summer and winter profiles at walled and non-walled beaches. Moody and Madsen (1995) conducted a series of laboratory experiments into the effect of normally incident waves on a beach backed by a seawall. Results showed that beaches infront of seawalls behave identically to unprotected beaches, except in the case of severe storms.

It can be seen from the above studies that the effects of seawalls on sandy beaches varies greatly with location, season and wave climate along with a number of other factors such as beach slope and sediment size. Initial observations, including the report by Moody and Madsen (1995), show that beaches backed by seawalls are not adversely affected except during storm periods. These results are comparable to the current situation at Long Beach, sand loss is greatly accelerated during storm periods when large swell waves impact on the wall causing accelerated sand loss.

The first seawall was constructed from timber on Long Beach in March 1908 in an attempt to halt the erosion of the foreshore. Following the undermining of the seawall during storm events, a concrete wall was constructed in 1938 to 1940, so as to protect the southern end of the beach up to the sand dunes on Long Point. Further storm events caused extensive damage to the seawall requiring frequent repairs; in 1962 200 feet of the wall was replaced and the seawall extended to protect the Regatta Pavilion in the north. Further damage has focussed on the section of the seawall between the gabion mattress wall and the concrete step wall, and also the wall north of the boatramp (Patterson and Britton, 1998). The current seawall on Long Beach can be seen in Plates 5.2 and 5.4. Heavy seas continue to damage the seawall with the latest damage being repaired in June 2000. Damage that results from storm events is illustrated in Plate 5.3.

During the 1960s, following the continual loss of sand from Long Beach due to the reduction in northerly winds and increased storm events, waves began impacting on the concrete seawall causing an acceleration in erosion. The results from this study clearly show an acceleration in beach retreat beginning in the period from 1947 to 1967. The actual morphologic response of a beach to a seawall depends largely on the position of the wall on the beach profile relative to breaking waves and swash Nersesian et al. (1992). Studies have shown that during high energy events seawalls result in higher backwash velocities and duration, and greater turbulence (Nersesian et al., 1992). The increased turbulence results in scouring and removal of the sand infront of the wall, and a subsequent reduction in beach width. These processes of wave reflection and scouring are demonstrated in Plates 5.4 and 5.5. Increased turbulence also results in greater amounts of suspended sediment that can be transported along the coast. Long Beach has a beach slope recorded at 5°, which is significantly steeper than should occur on a beach with similar sand grain size (Patterson and Britton, 1998). Nutgrove Beach has the same grain size as Long Beach but has a slope of 3° (Patterson and Britton, 1998).

The effect of seawalls on offshore bathymetry is not well understood. Studies by Short (1999) suggest that sand bars may form in front of shore-parallel structures that lack an intertidal beach, indicating geomorphic effects do not extend far seaward of seawalls. The results obtained from the Digital Elevation Model show that there is a constant gradient from the area directly of Long Beach into the Derwent River (Figure 4.8).

Seawalls have also been shown to have an adverse impact on aeolian transport within the beach system and on dune formation. The size, shape and positioning of seawalls can affect dune formation and the beach profile that is developed. Nersesian et al. (1992) noted that the vertical height of the seawall governs how far the structure rises into the boundary layer, and subsequently acts as a barrier against aeolian processes and migration of sediments. Due to the height of the Long Beach seawall and the dominant wind directions, the size of the seawall is not considered to be significant on aeolian transport. Low seawalls, such as that on Long Beach, may be buried by wind blown or wave deposited sand. Sand is able to pass over seawalls by forming a ramp in front

Plate 5.2 The seawall on Long Beach, August 2000.

Plate 5.3 Damage on the Long Beach seawall as a result of overtopping during the June 2000 storm.

Plate 5.4 Wave impact and reflection off the Long Beach seawall.

Plate 5.5 Wave reflection and scouring on the seawall.

of the structure from aeolian deposition, the ramp is then used as a transport surface for the movement of sand inland. Sediment ramps are also formed after major storms as a result of wave action. Plate 5.5 shows sediment ramps in the early stages of development following the June 2000 storm. Plate 5.6 shows sediment present on the path behind the seawall, a possible result of wave action.

The alignment of the seawall does not follow the natural curvature of Long Beach as depicted by the water line. As a result, small pockets of sandy beach are formed above the high water mark. The alignment of the seawall creates increased interaction with incident waves and as a result large quantities of sand are removed from the beach. The reclamation of land around the Regatta Pavilion resulting from the 1960 extensions to the seawall has created an artificial shore alignment that will be constantly eroded by prevailing winds.

Plate 5.5 Wave reflection and scouring on the seawall.

Plate 5.6 Sand present on the path behind the Long Beach seawall as a result of wave action.

5.2.3.3 Influence of Foreshore development

Sub-division and construction on the foreshore along Nutgrove Beach commenced in 1932. To alleviate problems of wind blown sand, sand trapping fences and cut-off walls were constructed within the naturally active beach zone. As a result the sand retaining structures in the Nutgrove Beach area effectively became sediment sinks. Sediment being eroded from Long Beach and Long Point was deposited on Nutgrove Beach, however the natural recycling of sand back to the Long Beach area through aeolian transport was no longer able to occurr.

Sand trapping fences may also have had an adverse impact on the width of Nutgrove Beach. Sand trapped in the fences may result in the loss of sand from Nutgrove Beach, this is not a severe problem as sand that is accreted is stored in the dune and is available to act as a natural buffer during storm events.

5.2.3.4 Influence of other factors

The significant changes in shoreline position of the Sandy Bay Beaches, in particular the erosion of Long Beach and the accretion of Nutgrove Beach, has been related to several previous factors. The removal of the floating pontoon bridge upstream of the study area has been suggested as one possible cause of changes to the morphology of the Sandy Bay Beaches. The floating bridge, and also the Tasman bridge, would reduce the effective wind fetch to the north acting on Nutgrove Beach. As a result the energy of waves acting on Nutgrove would be considerably reduced. It has been stated in previous reports (Cruise, 1978) that high energy waves from the north remove sediment from Nutgrove Beach while low energy northerly waves deposit sediment. It can be seen that the presence of the floating bridge and Tasman bridge would be beneficial to Nutgrove Beach but would have an adverse impact on Long Beach by starving it of sediment, transported by the stronger northerly winds. The report by Kinhill (1994) rejected these ideas stating that the effective fetch would have been reduced by only 1 kilometre, from 5 kilometres to 4 kilometres. The Kinhill report also outlined that northerly waves impact perpendicularly on Nutgrove Beach and as a result do not generate a significant longshore drift. Cruise (1978) also stated that the sediment movement from Nutgrove Beach to Long Beach is controlled to a large extent by the natural cementing effect of the fine river silt.

Research has shown that dams on rivers can restrict sand supplies reaching the lower river estuaries (Cruise, 1978; Morton, 1979; Walker and Mossa, 1986). Morton (1988) conducted research into the effect of dams on sediment flow in Texas rivers. It was found that sediment flow on the Brazos River now delivers 860 000 m^3 per year of sediment to the beaches of the Gulf of Mexico. This represents 30 % of the original volume before dams were constructed on the river. In Italy beaches account for 3250 kilometres of a 7500 kilometre coastline, due to river damming and other factors 35 % of beaches are eroding (Viles and Spencer, 1995).

There have been several dams built on the upper Derwent for both water supply and hydro-electric schemes, the majority of them being built since the late 1950s. This coincides with the period in which considerable sand loss became noticeable on Long Beach. Hydrographic data included in the Cruise report (1978) shows that in the period 1901-1962, 1.25 million cubic metres of sediment were deposited in the study area. The 1960 flood, which recorded water movements of 3400 cubic metres per second, would have contributed significantly to this figure (Cruise, 1978). In the period 1962-1977 143 000 cubic metres per year of sediment were lost from the system (Cruise, 1978).

The relationship between dam construction and sediment supply to the lower reaches of the Derwent River is unproven and lacks sufficient supporting data. The Kinhill report (1994) stated that all sand sediments would have been deposited upstream of Sandy Bay and would not have reached Sandy Bay since human habitation.

Table 5.1 Dams and construction dates for the Derwent River (Cruise, 1978).

Dam Name	Date Built
Tarraleah	1938
Butler's Gorge	1951
Wayatinah	1957
Catagunya	1962
Meadow Bank	1967
Cluny	1968
Repulse	1968

The construction of a new pumping station and the extension of the sewerage outfall pipe in 1960 caused considerable seaward protrusion of land on Blinking Billy Point. The land extension may have had a minor effect on the refraction of swell waves around the headland, resulting in increased protection of the southern portion of Long Beach and increased exposure of the mid-sections of Long Beach.

5.2.4 Influence of Coastal Processes

5.2.4.1 Influence of Swell and Wind

The transport of sediment by both storm waves and swell waves is perhaps the single most important coastal process when discussing the shoreline change of Long Beach. The report by Kinhill (1984) states that wind waves have the ability to generate longhsore currents with the ability to move significant quantities of sediment. The net longshore movement at Nutgrove Beach was calculated to be of the order of 10 000 cubic metres per year, of which 5000 cubic metres per year is moved towards Long Point (Cruise, 1978). On Long Beach a longshore current generated by southerly sector wind waves has the capacity to transport 10 000 to 20 000 cubic metres per year. The net northerly portion of this quantity would be 10 000 cubic metres per year (Patterson and Britton, 1998). This data was calculated using annual sea wave climate information and refers to the ability of storm waves to transport sediment but does not give actual data on sediment movements.

Sediment transport by southerly swell waves is an important factor when considering the sediment dynamics of the study area. Swell waves originating in the Southern Ocean travel up the Derwent River, refract around Blinking Billy Point and impact on Long Beach at an oblique angle. As discussed in Chapter 3, oblique wave approach initiates longshore sediment transport and the ability of swell waves to initiate sediment movement. The swell waves acting on Long Beach would result in the movement of sediment northwards, along Long Beach towards Long Point. The onshore and offshore currents produced by swell waves can also have a significant impact on the beach profile and the transport of sediment. During periods of low swell when waves do not impact on the seawall and there is an onshore movement of sediment, during large swells when the seawall initiates refraction and scouring sediment is lost from the beach.

The report by Patterson and Britton (1998) provides data on rates of swell wave-initiated sediment transport. Sand supply along the coastline is in a south to north direction towards Long Point, and also in an east to west direction along Nutgrove Beach at 250 cubic metres per year. Sediment is transported both onshore and offshore under the influence of swell waves and is deposited on Long Point, the eastern end of Nutgrove Beach or on offshore bars. Sediment movement in the nearshore areas of Long Point and Nutgrove Beach is in the form of sand slugs or large banks of deposited material that are moved during high energy swell events (Patterson and Britton, 1998). The deposition of one slug on Nutgrove Beach may account for several years of net transport.

The report by Cruise (1978) provided a seasonal analysis of the sediment movement occurring in the study area. During the summer months sand moves from Long Beach to Nutgrove Beach as a result of a combination of wave erosion and outgoing tides. From the wind rose data included in Figure 2.4 it can be seen that during the summer months the dominant wind direction is from the north and north west. From this data it can be concluded that the southern swell waves are responsible for instigating the northerly sediment movement. During the autumn months a combination of afternoon south easterly winds and incoming tides are responsible for the erosion of sand from the north of Long Beach and the south and central regions of Long Point. During the incoming tide, due to a decrease in strength of the longshore current, there is accretion on the north of Long Point and also on the south of Long Beach. From the months June to August there is deposition of material on Nutgrove Beach and on the southern region of Long Beach, sediment is lost on the south of Long Point. This can be explained by sediment being removed from the central part of Long Beach by tides to nourish Long Point. Due to a combination of strong north west winds and prevailing outgoing tides during spring mornings there is a net movement of sediment from west to east along Nutgrove Beach. During the afternoon offshore deposition occurrs off Long Beach.

5.2.4.2 Influence of Currents

Both longshore currents produced as a result of oblique wave approach and shore-normal currents may have influenced the morphology of the Long Beach-Long Point-Nutgrove Beach shoreline in the 50 years since 1947. There are three possible factors that are responsible for the formation of currents in the study area, these include: tidal water level variations, wind and wave induced currents, and river flow.

Tide levels and wind must also be taken into account when considering currents and sediment transport. Ignoring the effect of tides, the maximum longshore current occurs when the angle of wave approach is 45° (Davies, 1980). When considering the sediment movement to the south, driven by north west wind waves the direction of the tide influences the strength of the longshore current. On an incoming tide the effect of the longshore current is reduced, whereas on an outgoing tide the longshore current is increased. This can be explained by the direction of water movement and the subsequent ability of sediment to be entrained by the current. Data recorded in previous studies show a net northerly movement of sediment along Long Beach as a result of tidal current flow (Patterson and Britton, 1998).

5.3 CHAPTER SUMMARY

The shoreline of Long Beach and Long Point has eroded considerably in the 50 years between 1947 and 1998. The results of the study show a wide, highly developed beach with considerable dune development present in 1947. Between 1947 and 1967 considerable erosion has taken place and has continued, to a lesser degree, through to the present day. Records show that in 1946 Long Beach was 45 feet wide at high tide and 120 feet wide at low tide. In the year 2000 Long Beach is virtually non existent at high tide. The reasons for the large scale loss of material from Long Beach to Nutgrove Beach and the sudden change in equilibrium between the two beaches can be explained by a number of possible factors.

- A number of human induced influences may be responsible for the changes in shoreline position of Long Beach. The development of the Nutgrove Beach foreshore in 1932 may have altered the sediment cycling of the study area, causing large quantities of sand to be trapped in the fences on Nutgrove Beach. Sediment trapped in the Nutgrove Beach region is unable to be recycled and is unable to nourish Long Beach, as was the case before 1932.

- The presence of the seawall on Long Beach has accentuated sand loss through scouring and wave refraction and has contributed to the large shift in sediment from Long Beach to Nutgrove Beach. Recent observations of the Long Beach seawall show the initial stages of sand ramping which may lead to sediment being deposited inland of the seawall.

- The impact of the old outfall pipe on Long Beach, along with the construction of dams on the Derwent River and also the presence of the floating pontoon bridge may have influenced the geomorphology of the region my restricting sediment movement or influencing wind fetch. However, there is little evidence or data records to substantiate these claims.

The changes in the shoreline position of Long Beach and surrounding areas can be attributed to the coastal processes operating in the region and the variations in direction and intensity of these processes over the 50 year period. Southern Ocean swells and locally derived wind waves are the primary process of sediment movement. Although longshore currents have been shown to be low in velocity, the erosion of sediment from Long Beach and the deposition of sand in slugs offshore is a major factor in the sediment cycling of the region. Swell waves refracting around Blinking Billy Point usually impact on the Long Beach seawall, resulting in accelerated sand loss.

Both northerly sector and southerly sector wind waves play a dominant part in the evolution of the shoreline. Prior to the 1950s a balance between northerly and southerly winds existed. During southerly wind events, waves would transport sediment from the Long Beach area onto Nutgrove Beach. During northerly wind events, sediment would be eroded from Nutgrove Beach and subsequently nourish Long Beach. This system of sediment cycling remained in equilibrium with both beaches sustaining wide berms. However, during the 1950s, this balance was greatly altered and the ratio of north to south winds decreased. The increase in frequency of southerly winds lead to the continual loss of sand from Long Beach until the natural buffer was eroded and waves began impacting on the seawall, accelerating erosion. The loss of sand continues today and will not cease until there is another large-scale shift in the wind regime or humans intervene to alter the natural processes occurring in the area.

CHAPTER 6

CONCLUSION

The primary aim of this thesis was to analyse the changes in shoreline position of Long Beach, Sandy Bay during the 50 years between 1947 and 1998. A secondary aim of the thesis was to study the offshore profile of the study area using bathymetric data. Analysis and interpretation of six aerial photographs taken between 1947 and 1998 has enabled documentation of shoreline changes and an understanding of the interaction between landform dynamics and the coastal processes operating on Long Beach, Sandy Bay. By analysing the coastal processes operating in the study area, an understanding of the sediment dynamics was gained. Within the study, three main aims were achieved and will be discussed individually.

6.1 ADDRESSING THE AIMS OF THE THESIS

Aim 1 Assess the shoreline changes of Long Beach between 1947 and 1998.

The aim of shoreline analysis was achieved through a combination of aerial photograph analysis and GIS interpretation. This methodology proved effective in recording the long term variation in shoreline retreat and shoreline accretion over the 50 year period. However, the accuracy and detail of the study could have been increased through the analysis of more aerial photographs and through the use of photos prior to 1947.

Aim 2 Assess the rate of change in shoreline position by analysing sediment movement within the Long Beach – Nutgrove Beach system.

The results of the study show that there have been significant changes in shoreline position during the 50 year period. The most considerable changes occurred between 1947 and 1967, over which time the shoreline retreated approximately 40 metres. Shoreline changes continued to a lesser degree over the remainder of the time frame. Periods of accretion and erosion occurred on all sections of the beach, with rates of migration ranging between 0.8 metres/year and 2 metres/year. Over the 50 year period the shoreline of Long Beach and Long Point has retreated considerably, with the majority of the erosion occurring between 1947 and 1967. The rates of migration and maximum shoreline measurements were comparable to previous shoreline studies, including those conducted on the Seven Mile Beach Spit by Dobson and Williams (1977) and Watt (1999).

Aim 3 Investigate the effect of the seawall, and human impacts, on rates of erosion on Long Beach.

The extensive erosion of Long Beach has been associated with a number of coastal processes and the presence or construction of engineering structures. The large scale loss of sand from Long Beach coincides with the extensive accretion and development of Nutgrove Beach and its dune system. This pattern of sediment transport suggests that wave and tide generated currents are responsible for the erosion of sand from Long Beach and the deposition on Nutgrove Beach. An alteration to the balance of northerly and southerly winds occurred in the 1950s and may be responsible for the net northerly movement of sediment and the large scale erosion occurring on Long Beach. Sand is eroded from Long Beach as a result of local wind waves and swell waves during large scale storm events, and is deposited on offshore sand bars. The offshore bars are then transported to the north under the influence of longshore currents and tidal currents.

The reduction in the width of Long Beach has resulted in the seawall being directly exposed to waves. Waves impacting on the seawall amplify the erosion potential through processes such as scouring and wave reflection. The presence of the outfall pipe on Long Beach and the extension of Blinking Billy Point may have altered the sediment supply to Long Beach, causing a gradual decline in beach width. Sediment supply from the south of the study area is dependent on the local wave climate and is a possible area for further research.

The extension of Blinking Billy Point may have hindered the movement of sediment from the south, onto Long Beach. The change in shape of Blinking Billy Point may also have caused a change in the refraction and subsequent approach angle of swell waves impacting on Long Beach. These factors may have resulted in a realignment of Long Beach with considerable accretion in the south of the beach.

The sub-division on the Nutgrove Beach foreshore may have caused wind blown sand to be trapped in the fences bordering the beach, restricting the recycling of sediment back to Long Beach. The trapping of sand on Nutgrove Beach was clearly responsible for the development of the dune system present on Nutgrove Beach today and the erosion of Long Beach.

The presence of the Tasman Bridge and the floating pontoon bridge may have caused a reduction in wind fetch onto Nutgrove Beach. The subsequent drop in wave energy may have caused a reduction in the amount of sediment being removed from Nutgrove Beach and deposited on Long Beach. As a result the primary source of sediment for Long Beach has been minimized and Long Beach has eroded as a result.

The dams present on the upper Derwent River system may be restricting sediment supply to Long Beach. However the amount of sediment that would be supplied through the Derwent River would be negligible.

6.2 CONCLUSION

It can be seen that the primary sources of sediment for Long Beach - from the south (past Blinking Billy Point), from the north (Nutgrove Beach) and from the Derwent River - have been severely limited through human influence and coastal engineering. In addition the sand currently present on Long Beach is being eroded through wind waves and southerly swell waves, and transported to the north by longshore and tidal currents. Wave erosion is greatly amplified when interaction occurs with the Long Beach seawall. Processes such as scouring and wave reflection increase sediment mobilisation as waves impact on the seawall. The frequency of waves impacting on the seawall increases as the width of Long Beach decreases. The loss of the natural buffer of Long Beach has resulted in the seawall receiving the full impact of incident waves, which has resulted in frequent damage occurring.

Shoreline retreat along Long Beach was first noted in 1866. In the 1950s a combination of human influence and change in natural processes accelerated the erosion and deposition patterns along Long Beach. As a result, Long Beach has been transformed from a wide, natural beach to a depleted stretch of sand bordered by a concrete seawall. A lack of foresight and understanding of coastal processes lead to Long Beach deteriorating to its current condition.

However options do exist for Long Beach to be converted back to a stable, independent beach system. The Hobart City Council, through the commissioning of a number of reports, has investigated a number of options for the rehabilitation of Long Beach. Options that have been investigated include the construction of several structures that will minimise the wave energy impacting on Long Beach, resulting in reduced sand loss during storm events. Options that have been investigated include the construction of a groyne, beakwater or offshore reef to restrict sand flow and minimise wave energy. Other projects focus on the widening of the beach through the movement and reshaping of the seawall, in order to reduce wave reflection and processes associated with wave alignment and beach curvature. Beach nourishment options have also been suggested to help initiate dune formation and to maintain a natural beach buffer.

The latest option being investigated is the installation of geofabric sand socks off the Long Beach shoreline. The presence of these sand socks would help reduce the energy of incoming waves, in addition the sand socks would restrict sand loss from the beach to the offshore zone. An added benefit of the geofabric bars is the possibility for weed and marine plants to establish and grow, possibly resulting in a return of marine species to the area.

The construction of further coastal structures to repair the damage caused by previous structures is a costly exercise, that does not guarantee complete rehabilitation of Long Beach. Perhaps the most feasible and natural option for the rehabilitation of Long Beach is the movement and reshaping of the seawall and the nourishment of the beach from external sources. By increasing the width of the natural beach, a buffer will exist between incoming waves and the foreshore.

By correctly analysing the coastal processes influencing sandy beaches, the coastal zone can be effectively managed without the use of 'hard' coastal engineering structures such as seawalls.

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