COASTAL EROSION MANAGEMENT OPTIONS

FOR

PIGEON BAY RECREATION RESERVE

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Presented in partial fulfilment of the

requirements for the degree of

Master of Science

in the

University of Canterbury

by

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January 1982

Joint Centre for Environmental Sciences

University of Canterbury and Lincoln College

ABSTRACT

Pigeon Bay Recreation Reserve is a small beach ridge system at the head of Pigeon Bay, Banks Peninsula. The reserve is 1.14 hectares near the head of the bay. It protrudes into the bay with a boulder beach, a spit and a sheltered sandy bay as its main coastal features.

The reserve is administered by the Pigeon Bay Recreation Reserve Board and is used for camping, fishing, tennis and barbecues. Since management of the area became the responsibility of the local residents in 1930, concern has been expressed for erosion occurring on the seaward face.

The reserve was found to have existed as a boulder bank in its natural state and to have been modified for ship building purposes in the 1850's. The level of the reserve was subsequently raised considerably by material deposited on it by a slip from the hill-side above and behind it.

Comparison of surveys carried out in 1929 and 1981 indicates that the seaward face of the reserve is retreating at 0.1 m yr^{-1}, that the spit is advancing at about 0.6 m yr^{-1} and that the sand beach is advancing at about 0.6 m yr^{-1}. Average annual rates such as these disguise the fact that the changes tend to take place episodically, usually as a result of storm conditions. The reserve as a whole is increasing in area.

Movement of beach material, and hence changes in the shape and area of the reserve, is caused by littoral drift. The amount of

material moved is not large and the movement is in a single direction, towards the bay head.

The board has three principal options to choose from. It may do nothing and accept the consequences of continued accretion and erosion. Alternatively the board may choose to build one of a number of structures to protect areas of the reserve subject to erosion. The third choice the board has is to feed the area of loss with appropriate beach material. These options are examined in detail and the likely consequences discussed.

The option selected by the board will reflect the long term management strategy that it adopts for Pigeon Bay Recreation Reserve.

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CHAPTER I

INTRODUCTION

This project presents the results of an investigation into coastal erosion at Pigeon Bay Recreation Reserve, on the east side of Pigeon Bay, Banks Peninsula. The reserve is presently administered under the Reserves Act 1977, by a board of members appointed by the Minister of Lands. In implementing the provisions of the Reserves Act, the board has recently prepared a draft management plan. Section 3.6 of this plan expresses the board's concern regarding the erosion of the coastline of the reserve, and accords remedial action a high priority.

The management plan for the reserve states that the policy of the board is, "to investigate and implement if possible means of halting erosion by the sea on the western side of the reserve, and at the head of the lagoon to the south". It is proposed to implement this policy by seeking qualified comment, and investigating possible engineering solutions and their respective costs for the western coastline. For the head of the lagoon the board intends to seek advice on the processes occurring in this area and on a course of action that it has devised. The board intends to seek this advice through the University of Canterbury.

1.1 THE AREA

Figure 1.1 shows Pigeon Bay Recreation Reserve located on the eastern side of Pigeon Bay, the largest bay of Banks Peninsula

after Akaroa and Lyttelton Harbours. It is approximately 80 kilometres by road from Christchurch. The bay runs inland south by west and narrows from 1600 metres wide at the mouth to about 800 metres wide at the head and is seven kilometres long (Figure 1.2). The reserve lies almost at the head of Pigeon Bay, occupies 1,138 hectares and forms a protuberance into the sea with a spit from its southern end oriented toward the head of the bay. This spit forms a shallow and sheltered area of water as is shown in Figure 1.3. The shape and formation of the reserve is unusual and interesting. While such features are not common, it is not a unique or special phenomenon. Similar land-forms do exist, usually on a larger scale and in higher wave energy environments. It is therefore possible to analyse the processes occurring in Pigeon Bay by reference to principles and methods that are internationally accepted.

1.2 THE PROBLEM

Over the 50 years that the reserve has been managed for recreation purposes it has been known locally that the foreshore is eroding. Opinions have varied as to the distance that the seaward face has retreated, from "a couple of chains" to "two or three rows of trees", but of the existence of eroding forces there has been no doubt. There is clear evidence of parts of the seaward berm collapsing into the sea and of some of the macrocarpa trees close to this having died of salt burn. The northern section of the reserve is used for camping, and some campers have built retaining walls

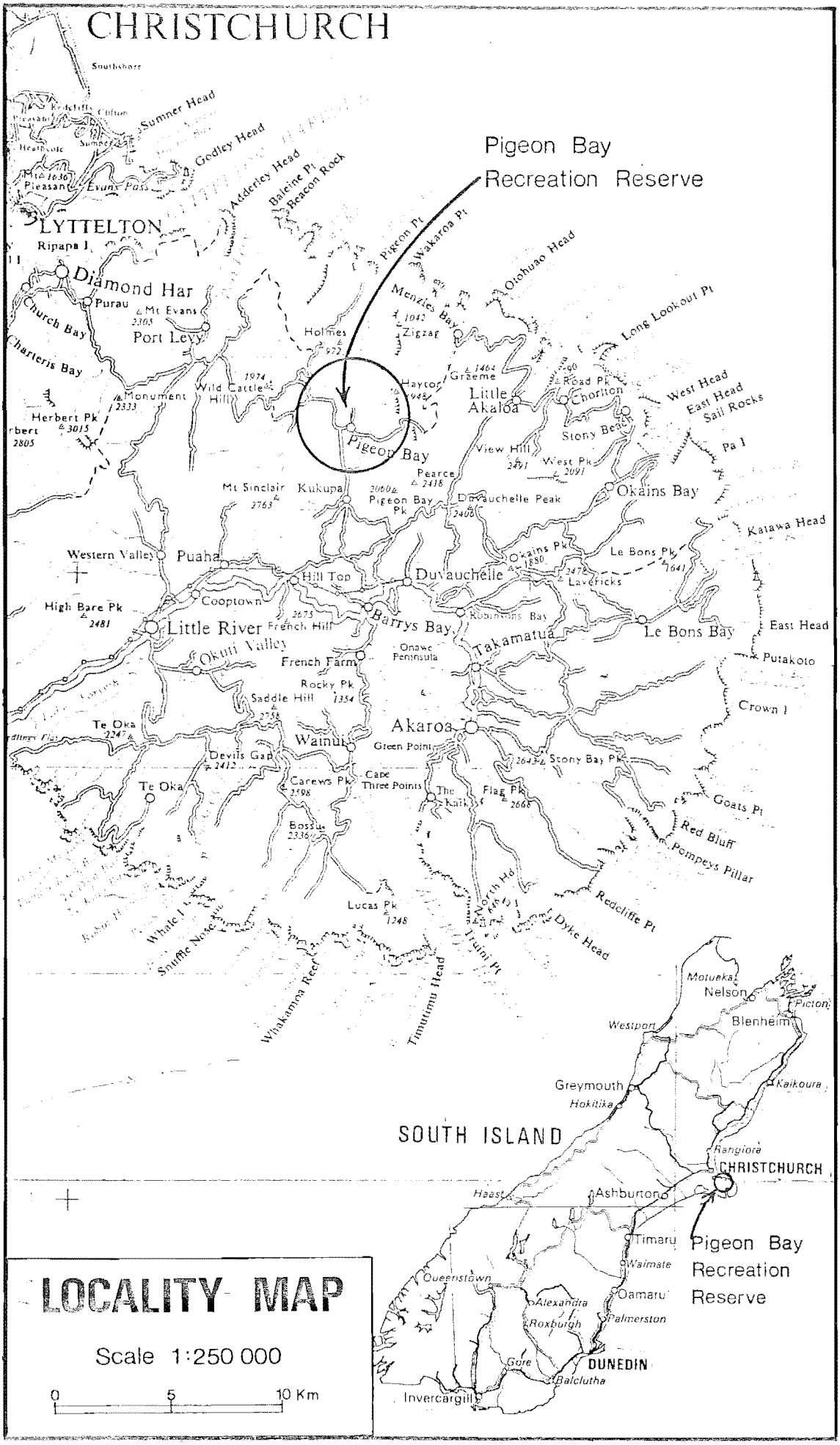
CHRISTCHURCH
Pigeon Bay
Recreation Reserve
LYTTELTON
Ripapa I
Diamond Har
Purau
Mt Evans
Port Levy
Church Bay
Charteris Bay
Monument
Herbert Pk
Wild Cattle Hill
Holmes
Zigzag
Haytor
Graeme
Little Akaloa
Chorlton
Road Pk
Stony Bay
West Head
East Head
Sail Rocks
Pa I
View Hill
West Pk
Pigeon Bay
Pearce
Mt Sinclair
Kukupa
Pigeon Bay Pk
Duvauchelle Peak
Okains Bay
Western Valley
Puaha
Hill Top
Duvauchelle
Okains Pk
Le Bons Pk
Lavericks
Katawa Head
High Bare Pk
Cooptown
Little River
French Hill
Barrys Bay
Robinsons Bay
Takamatua
Le Bons Bay
East Head
Okuti Valley
French Farm
Onawe Peninsula
Putakoto
Rocky Pk
Saddle Hill
Crown I
Te Oka
Akaroa
Wainui
Green Point
Devils Gap
Carews Pk
Cape Three Points
The Kaik
Flag Pk
Stony Bay Pk
Goats Pt
Red Bluff
Pompeys Pillar
Te Oka
Bossu
Lucas Pk
Redcliffe Pt
Dyke Head
Whale I
Snuffle Nose Hill
Whakamoa Reef
Timutimu Head
Motueka
Nelson
Picton
Westport
Blenheim
Greymouth
Hokitika
Kaikoura
SOUTH ISLAND
Rangiora
CHRISTCHURCH
Haast
Ashburton
Timaru
Pigeon Bay
Recreation
Reserve
Waimate
Queenstown
Alexandra
Oamaru
Roxburgh
Palmerston
Gore
DUNEDIN
Balclutha
Invercargill
LOCALITY MAP
Scale 1:250 000
0
5
10 Km

FIGURE 1·1

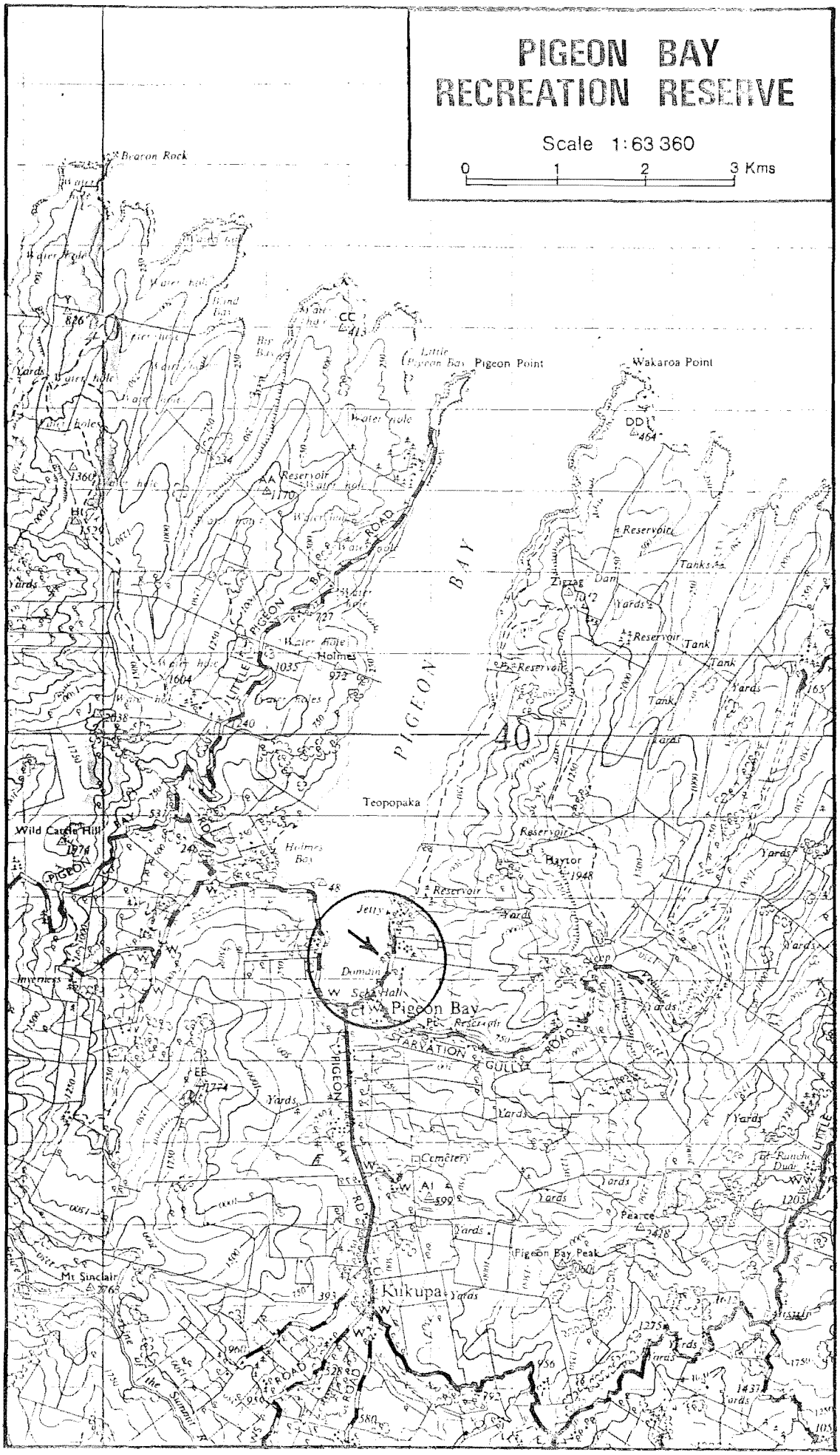
PIGEON BAY
RECREATION RESERVE
Scale 1:63 360
0 1 2 3 Kms
Beacon Rock
Pigeon Point
Wakaroa Point
Little Pigeon Bay
PIGEON BAY
Teopopaka
Wild Cattle Hill
Pigeon Bay
Kukupa
Mt Sinclair
Haytor
Pearce
Pigeon Bay Peak
Holmes
Reservoir
Tanks
Tank
Cemetery
Jetty
Domain
Inverness
STARVATION GULLY ROAD
PIGEON BAY RD
LITTLE PIGEON BAY ROAD
ROAD
Yards

FIGURE 1·2

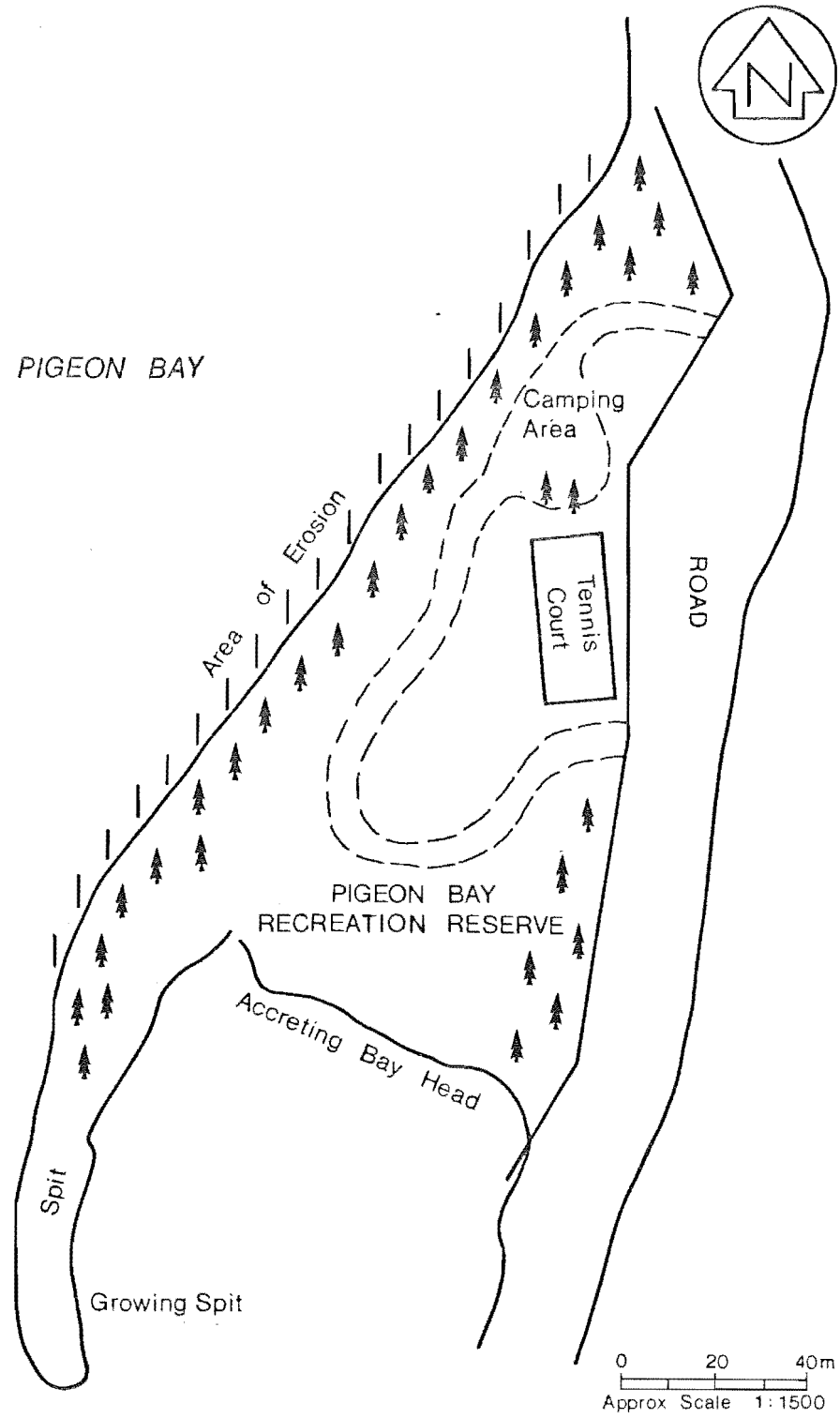

FIGURE 1·3

PIGEON BAY RECREATION RESERVE

to safeguard their sites. While affording some protection, this activity has tended to increase the problem by accelerating erosion adjacent to the structures.

1.3 THE PURPOSE OF THIS STUDY

The purpose of this report is to achieve an understanding of the recent coastal changes that have taken place at Pigeon Bay Recreation Reserve in order that management options can be prepared and their respective consequences can be predicted. It will remain for the Board to assess these options with respect to the long term goals it hopes to achieve and to adopt such policies as may best accomplish the selected option.

To make a rational statement about the possible consequences of erosion control methods, it is first necessary to understand the active natural coastal processes causing the problem, and secondly to be able to predict the likely outcome of any remedial action taken, including any undesired side-effects. It is also necessary that some knowledge be available about the land itself, such as its geomorphology. It is therefore essential that before examining options for coastal management, sufficient information about the land-form be gathered and interpreted. It is important to understand the origins of the present shape and structure of the reserve. This begins with an explanation of how the formation came into existence and its structure before and after human intervention. In addition some effort must be made to explain the dynamics bringing about change in the land, and the types

of changes which have taken place. From the combination of these facts, it should be possible to predict what future changes may be expected. It should also be possible to accurately foresee the results that may follow adoption of any one of the available management options. To endeavour to make responsible management decisions without a full understanding of the patterns of change, the processes and their interactions would be at least precipitate.

It is not the intention of this report to recommend to the Reserve Board which course of action it should choose. The management responsibility remains with that body. It is hoped that having decided the long term future of the site, the board will then be sufficiently informed about the wider implications of the alternative operational techniques to make a sound judgement about future management that will achieve its desired end.

1.4 THE STRUCTURE OF THE REPORT

As a prelude to the understanding and interpretation of the physical data gathered, Chapter II of this report will briefly detail the administrative and cultural history of Pigeon Bay Recreation Reserve. Information for this section was gained mostly from files of the Christchurch Office of the Department of Lands and Survey, supplemented by local and general knowledge.

Chapter III contains a summary and conclusions from the

physical information gathered in the course of the study. This includes historical data from public survey records, new survey work carried out by the author, aerial photographs and auger sampling of the sub-strate.

Chapter IV explains the natural forces that are acting upon the land mass and how these have brought the reserve to its present state. Some reference is also made to other similar features referred to in international literature.

The options available to the board are examined in Chapter V. These cover the full range of alternatives available to coastal managers at all levels and the likely consequences for the reserve and its environs, both direct and indirect.

The concluding chapter summarises the findings of Chapters III and V and makes some general comments about coastal land management.

CHAPTER II

PIGEON BAY RECREATION RESERVE

2.1 INTRODUCTION

The reserve has caused its administrators some concern through most of its cultural history as a result of the erosion of its western coastline. Recently erosion in the small bay formed by the spit has also been detected. The reserve is used for few local activities but attracts the shore activities of a substantial group of yachtsmen. Regattas are run at least twice a year in Pigeon Bay since it is reputed to have some of the best sailing conditions in Canterbury. Many camp on the reserve for lengthy periods during the sailing season from October to March.

A tennis court is presently on the reserve but with the decline of local interest in the area, this has fallen into general disrepair and is little used. There are still a few local activities carried out on the reserve including picnics, barbecues, swimming and fishing. It is because of these activities, and the fact that there are few other recreation reserves within the wider area, that the Reserve Board is particularly concerned about the loss of land by sea action on its western boundary and the inundation of the low lying silted bay.

2.2 ADMINISTRATIVE HISTORY

The Pigeon Bay Recreation Reserve was first reserved for

ship building purposes in 1858 but little is known about its administration until 1914 when the then Crown Lands Department acknowledged responsibility for it. Seemingly until this time only the Pigeon Bay Road Board had taken any interest in it. About 1914 trees were planted on slip material in order to stabilise and beautify the area. In 1929 local interest was keen and the lack of a public recreation area was felt. On the 3rd of April 1930 control was placed in the hands of the newly formed Pigeon Bay Domain Board under the Public Reserves, Domains and National Parks Act 1928, and the status of the reserve changed to recreation purposes. Despite the keenness of the local population, the financing of minor capital works such as fencing, levelling, draining and the building of facilities lacked sufficient support. Little more than two years after gaining control of the domain, the board was approaching the Department of Lands and Survey with a view to the Road Board resuming control, in the hope that the Government might make finance available for protection and improvement. In 1937 when the board was due for reappointment (under the Act boards were appointed for 7 year periods) local interest was at such a low ebb that it was barely possible to convene meetings that would accurately reflect the local opinion. In June of 1939 the Pigeon Bay Road Board was appointed to be the Pigeon Bay Domain Board.

Interest in the domain appears to have been lacking until 1944. In the intervening period the Akaroa County Council, by powers it had under Section 30 of the Counties Act 1920,

merged the County with the Road District and abolished the Pigeon Bay Road Board. However, by 1944 the County Council had no wish to administer the domain, and it approached the local residents, through the then active tennis club, to assume control. On the 7th of March 1945 the 1939 Gazette Notice appointing the Road Board as the Domain Board was revoked, and a Domain Board of local residents was appointed. The domain became subject to the Reserves and Domains Act 1953 when this replaced the previous legislation. Administration continued under this Act until it also was superseded. The Reserves Act 1977 became the controlling legislation and on the 6th of September 1979, Reserve 140 situated in Block X of the Pigeon Bay Survey District was classified as a reserve for recreation purposes. The reserve is administered by a Reserve Board under the general control of the Department of Lands and Survey.

The Reserves Act 1977 provides that within 5 years of classification a management plan shall be prepared and published for the reserve. The Reserve Board has accepted this responsibility and with data collection assistance from students of the Parks and Recreation Course at Lincoln College, the first steps towards producing such a plan have been taken. It is expected that in the near future the board will publish its first management plan.

2.3 HISTORY OF EROSION

The site first became a reserve in 1858 but the first detected

dealings with the reserve by the Department of Lands and Survey were in 1929. A request was received from the local residents to use the land as a recreation ground (establishing a tennis court, basketball court and children's playground) and to beautify it. The area was estimated at one acre (4047 square metres). At this time the population of Pigeon Bay was estimated to be about 200. It is in this letter of application that first mention is made of a slip from the adjacent hillside forming part of the reserve "about twenty odd years ago".

Erosion is first referred to in a letter from the Minister of Lands to his Under Secretary (Permanent Head). The reference comes from the Pigeon Bay Road Board which had planted trees at some earlier date and wished to have the reserve placed under its control in order to legally invest some of its funds in protection work for the road.

The reserve was then surveyed and found to be 2 acres 3 roods and 10 perches (1.138 hectares). As ship building had discontinued after the clearing of the native bush from the surrounding hills, and with the agreement of the Road Board, the reserve was "constituted as a public domain and placed under the control of a local domain board". (L & S file 8/3/131 folio 19), though it is recorded in the Lyttelton Times on the 22nd August 1929 that the Road Board had spent £50 on planting trees and fencing the area and "was loth to lose possession of same".

It followed that on 3rd February 1930, the purpose of the reserve was changed from ship building to recreation.

Reference to camping first appears in the Department's records about 1940, when the claim was made that the reserve was widely used for such purposes as tennis and sea-bathing. For the latter purpose both ladies and gents dressing sheds were provided, though it is not clear by whom. Erosion of the seaward side of the reserve featured regularly in all correspondence from 1930, and by 1952 it was believed that three rows of gum trees had been washed away. The last row of trees was now at the water's edge. Some fears were held for the safety of the road. Nothing was done at this time and the erosion problem was not raised again until 1959. A report by a Departmental officer suggested that the tip of the spit had once been an island, with the sea covering a low lying area between it and the main land. At this time the Ministry of Works was invited to inspect and report on the erosion problem being experienced. The report advised the "dumping of rock random fashion along the existing face to a height slightly above the general level of the banks", at a cost of about £500. Because of the high cost and the lack of available finance, it was suggested that it could be possible to "preserve with protection work by felling and securing more trees along this face. If carried out sufficiently this should slow the active erosion taking place, but would not completely arrest it", though "it would be unwise to fell any more trees from the domain frontage as

the root system of the existing trees is assisting to hold the bank". It is not recorded if this cost saving method was carried out, though the contradictory nature of the advice probably nullified it.

The random rock dumping was not proceeded with and erosion is not mentioned again until the 1967 annual report of the board where construction of a sea groyne is suggested, "in an endeavour to halt erosion of the sea frontage due to wave action". It was not until 1969 that action was initiated and new reports called for. In 1970 it was estimated that it would require $3,000 to protect about 220 metres of shore with material transported from a rock quarry on the opposite side of Pigeon Bay. At this time it was first suggested that the Soil Conservation and Rivers Control Council would provide a subsidy for such work if a local contribution was made. After considerable negotiations among the Domain Board, the Department of Lands and Survey, the Akaroa County Council and the Ministry of Works and Development, the necessary finance was forthcoming. As a result, in February 1972, 2,000 cubic yards (1530 cubic metres) of material was placed on the sea frontage of the domain by the County Council.

In October of 1972 a Departmental officer advised that the rock fill used contained too much soft material (reddish volcanic rock was used) and that heavy winter seas had washed most of it away leaving a four foot exposed bank, resulting in severe erosion. A further $200 was granted by

the Department to the Akaroa County Council for transporting more appropriate material ("igneous granite") to the site, with the hope that the Soil Conservation and Rivers Control Council would make a further grant. Since this time there is no record of any further action or advice regarding erosion to the sea frontage of the Pigeon Bay Reserve.

In 1952 reference was made by a Lands and Survey officer to accretion occurring at the south-west tip of the spit. The reference was vague and without further support. In searching through all available records, no other references to the possibility of accretion occurring to the reserve were found.

CHAPTER III

MORPHOLOGY AND STRUCTURE

3.1 INTRODUCTION

To understand the land-forms and the way in which they have changed over time, information was gathered from four principal sources.

In order to provide confirmation of the deductions made about the changes of the land-form and to establish its internal structure, a series of auger holes were drilled over the area.

An examination of the aerial photograph library at the Department of Lands and Survey also provided information about the reserve, though the photographs proved to be less useful than was first expected.

The survey records of the Christchurch Office at the Department of Lands and Survey contain field notes and original plans of the earliest surveying done in Canterbury, including Pigeon Bay. A search of these records revealed plans of the area under study from as early as 1851. In support of this technical data, file 8/3/131 concerning the Pigeon Bay Domain, beginning in 1929, was examined. Further general historical information that served to round out the technical and administrative facts, was found in a book about the place names of Banks Peninsula (Andersen, 1927).

To complete the information gained from the survey records, a survey of mean high water mark was carried out by the author in January 1981. This yielded a comparison with similar work done in 1929.

The aggregation of the past and present physical data, in conjunction with the historical and administrative information gives a complete picture of the nature of the landforms being dealt with, their present structure, and the manner in which they are developing.

3.2 AUGER SAMPLING

From survey work past and present, it has been possible to establish a probable history of the changing shape of the Pigeon Bay Reserve and to infer the way in which the landforms have changed over the one hundred and thirty years in the public record. To add to this knowledge a series of core samples were taken from the site by the author in January 1981. The location of these is shown in Figure 3.1. A two metre hand auger with a three centimetre wide, twenty centimetre long bit was used to remove samples from the ground and analysis was made in the field. As a detailed structural analysis was not required, the data obtained from this exercise were classified by only three deposit types;

(i) terrestrial material (predominantly silts) which appeared in two forms

  (a) yellow-brown loess, free draining and above the water table most of the time

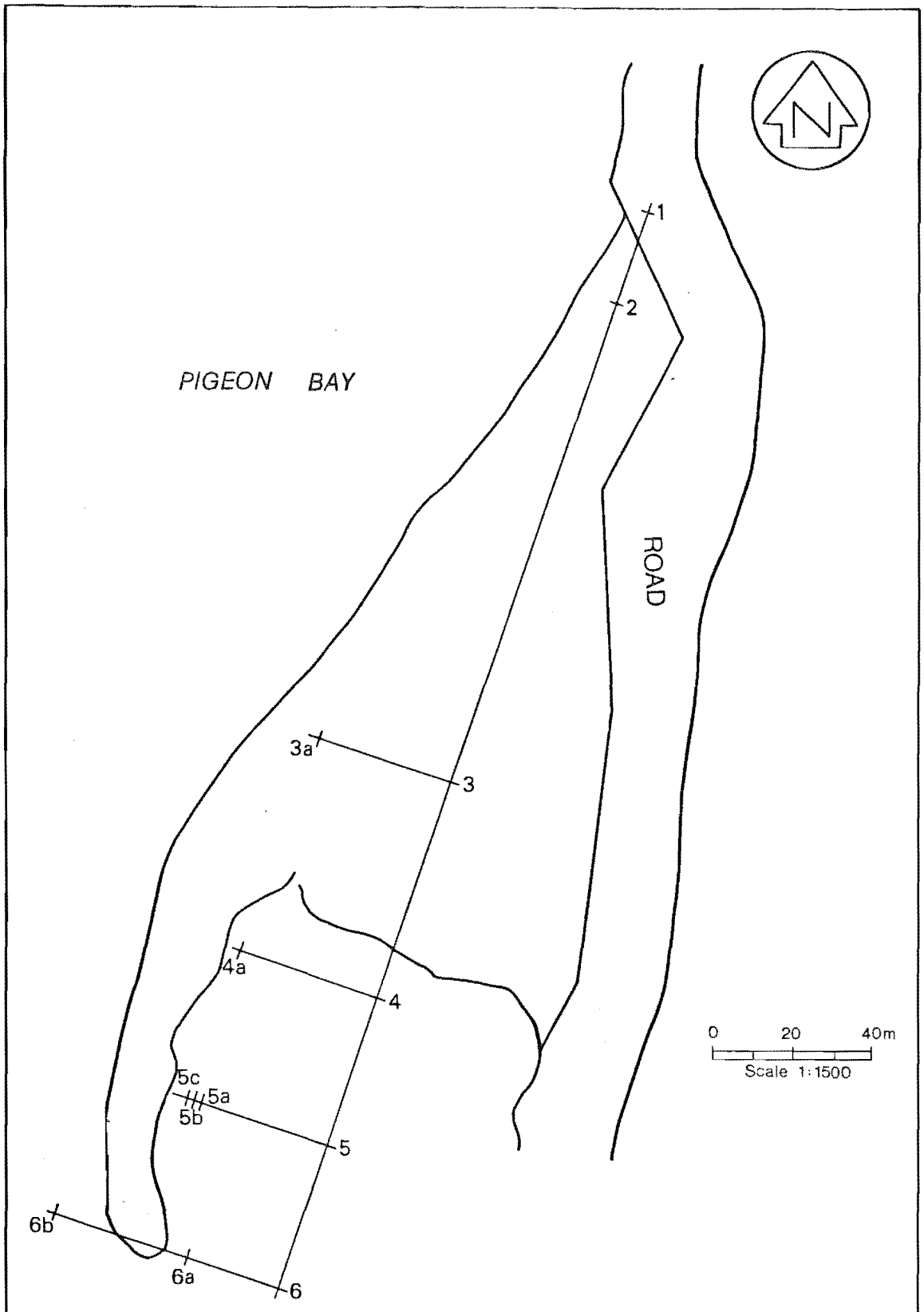

FIGURE 3·1

AUGER SAMPLING SITES

but which is grey towards the surface where it is subject to the soil formation process. This material is considered to have been a combination of fill material brought to the site at some time, and hillside slip material deposited by the land slip in the early days of this century (the scar of which remains above the reserve). It is likely that this terrestrial material was distributed over the area at some later date.

(b) darker coloured matter, indicating the presence of organic material and anaerobic conditions below the water table, such as in a swamp,

(ii) fine marine sediments formed in quiet water areas where marine conditions existed for a considerable time. The sediments are characteristically blue because of anaerobic conditions. They contain much shell and granules,

(iii) coarse beach material being gravel and boulders, as is found forming the active beach on the seaward side of the reserve.

The first series of samples was taken on a line through the centre of the reserve in holes numbered from 1 to 6. The

results from these when plotted have provided a long section of the structure of the reserve as is shown in Figure 3.2. Interpolations have been made between sample holes in order to approximate the internal structure of the land mass. To further explain the formation of the reserve, more samples were taken to the east of the long section, and these are indicated by numbers with superscripts a, b and c. From the information accumulated from all the samples, cross-sections have been sketched through the six original points as shown in Figure 3.3.

The cross-sections show clearly that the structure of the reserve is relatively simple and conforms with the information gathered from survey data and administrative sources. The boulder bank was found to exist under the fill material and can be seen at low tide from the beach. While this berm is quite rounded at its crest, and is clearly visible at the spit end the reserve, on the landward side it falls away quite steeply, as is demonstrated by the holes 5a, 5b and 5c. It appears from holes 5b and 5c that the slope angle of the berm would be in the region of 50°.

The fill material indicates that at some time a considerable quantity has been placed on the site but the timing of this is in doubt. It is likely that the filling took place in two stages. It is suggested that the area north of the tennis courts, now used as a camping ground, was filled in the 1850's in order to create an adequate working site for

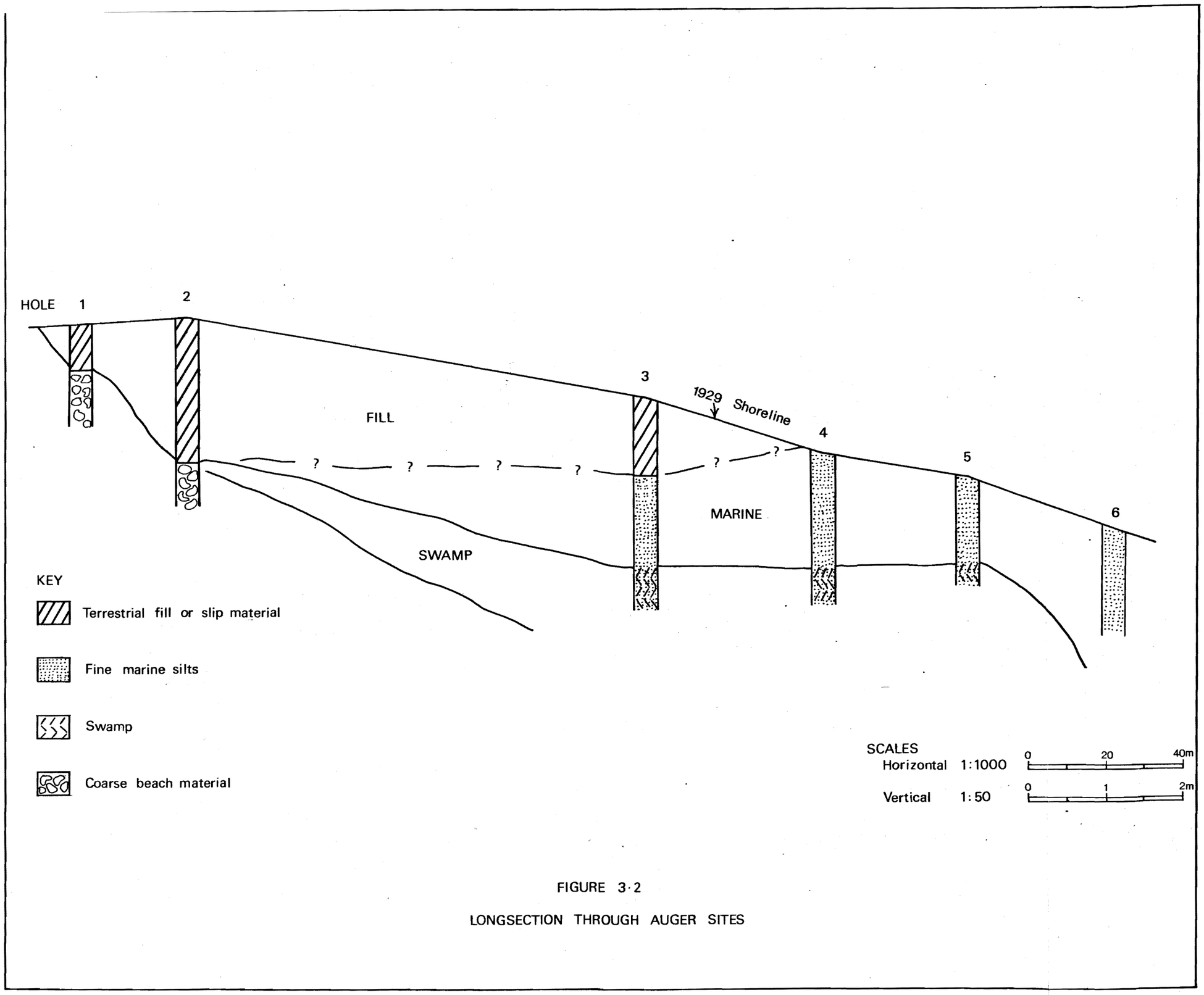

FIGURE 3·2

LONGSECTION THROUGH AUGER SITES

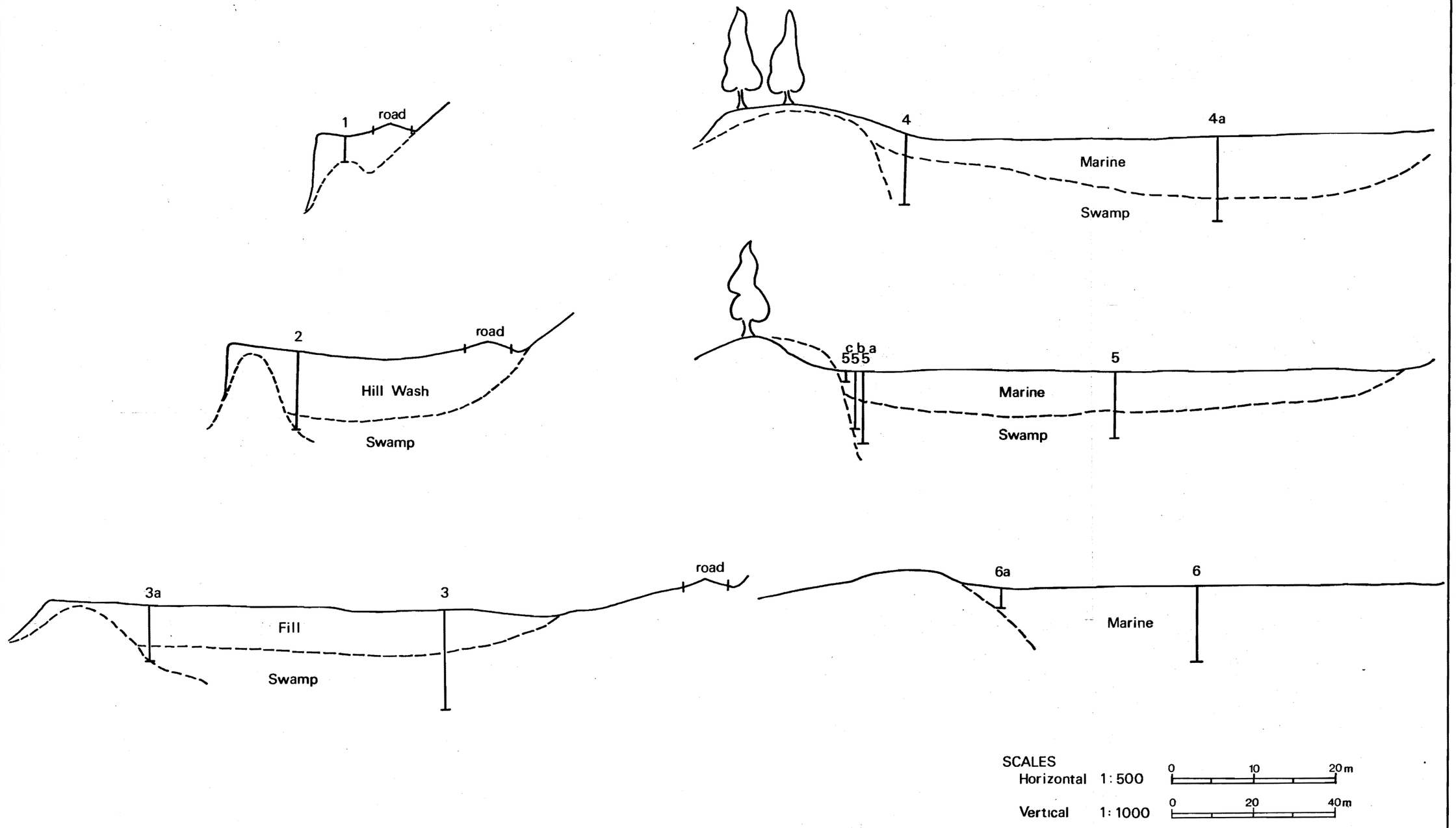

FIGURE 3·3

CROSS - SECTIONS THROUGH AUGER SITES

the sawmilling and ship buildings activities. The second stage of filling was accidental since it resulted from the landslip soon after the turn of the century and covered the area between the trees of the northern part of the reserve and the present high water line. Prior to these intervals of natural and man-made hard fill, there is evidence to suggest that a swamp existed between the boulder bank and the land.

3.3 AERIAL PHOTOGRAPHS

A full search of aerial photograph records held in the Christchurch Office of the Department of Lands and Survey was made for further information. The most useful found were Survey Number 165 run 136 photograph 28 taken on 17 January 1941 and Survey Number 2860 run M photograph 43 taken on 17 September 1975. These photos were enlarged to a scale of approximately 1:2000 in the hope of comparing the shape of the beach at those times with the survey evidence of 1929 and 1981. Because of scale distortions in the photos this proved to be unsuccessful. The distortions were due to excessive enlargement necessary to achieve a satisfactory working scale, and to inability to find photographs with the reserve near to the image centre. Distortion is present towards the edge of aerial photographs because of lens aberrations. Enlargement of the photographs magnifies these distortions. However the 1975 photograph has proved useful in the preparation of the refraction diagram to be presented in Chapter IV. Though not sufficient to supply empirical data for comparisons

over the period between them, the photographs were useful for confirmation of conclusions made from other sources about the general trends in shape and position of the reserve.

3.4 LANDS AND SURVEY RECORDS

The earliest survey record of a feature protruding into Pigeon Bay at this site has been found on Black Map 227. It was prepared from surveys by Assistant Surveyor S. Hewlings of the Canterbury Association in 1851, and is supported by original field notes in Field Book 90 (old series). The map is drawn at a small scale and was not of great assistance in defining the detail of the boulder beach, though it is described as a "boulder bank", and is shown with what appears to be a small sandy beach behind it. The field book from which the map was drawn however, shows the complex in slightly greater detail on page 51. Figure 3.4 shows the field notes plotted at 1:1500. The feature appears as a spit about 90 metres long, some 22 metres wide at its greatest expanse and with a stream flowing to landward and parallel to it.

According to Andersen (1927) the first European Settlement in Pigeon Bay occurred in 1843 with the arrival of the Hay and Sinclair families, though whalers had visited the bay earlier. It is known that boat building was undertaken by Captain Sinclair and that the Hay family owned vessels. In the Canterbury Provincial Gazette, on 22nd December 1858 the notice was given making "the following reserves for

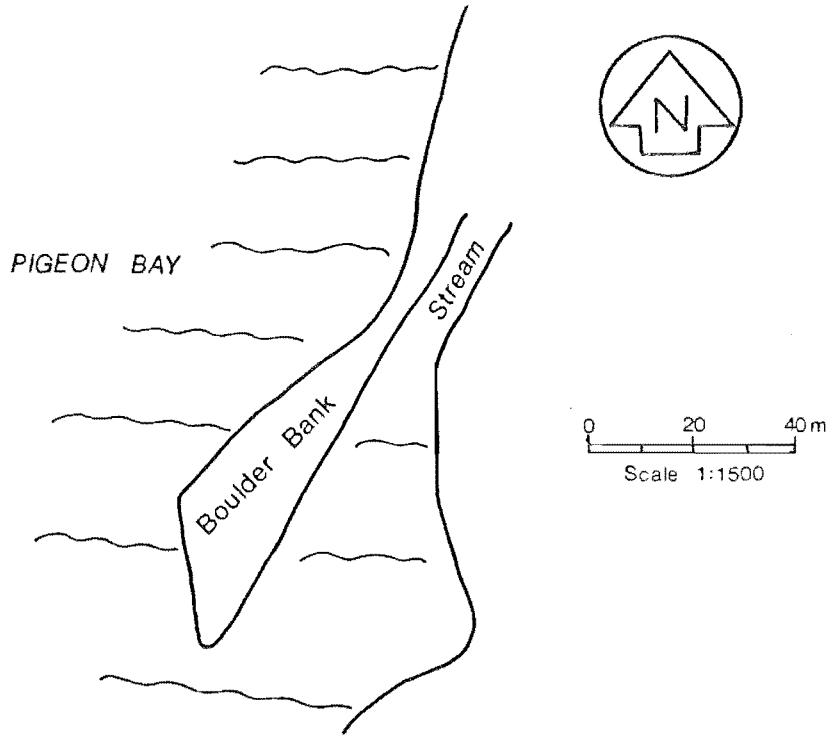

FIGURE 3·4

BOULDER BANK 1851
(prepared from Field Notes of Black Map 227)

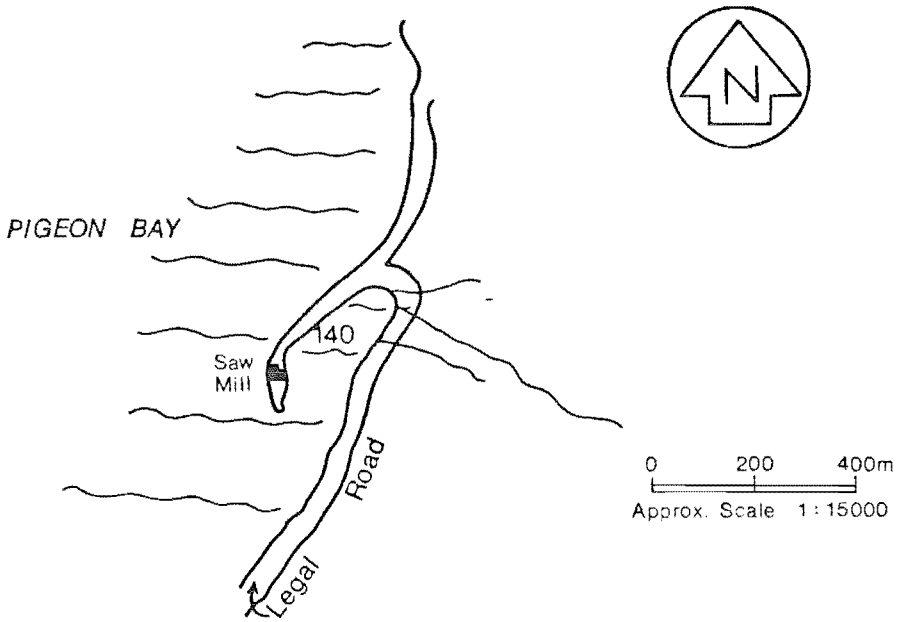

FIGURE 3·5

RESERVE 140. 1861
(as shown on Black Map 117(2))

the undermentioned purposes, viz.: ...

> One rood, more or less, being a spit or tongue of land running out into the sea, opposite Rural Section 207, in Pigeon Bay, and numbered 140 in red on the map in the Land Office, Christchurch, for ship building purposes."

From the above information it is not positive that the survey of 1851 shows the beach complex in its "natural" or undisturbed form, since ship building had been undertaken for 8 years in the bay, though not necessarily at this site. It is however, highly probable that field book representation of the "spit boulders" is one of a generally unmodified natural feature. Other evidence tends to support this conclusion. It is suggested that the boulder bank was formed by the deposition of material removed from the hillside behind the reserve and carried to this point by the stream shown in Hewling's field notes.

Black Map 117 also shows the area. Prepared in 1861, this map outlines a spit of considerably larger proportions, and with a sawmill towards the southernmost tip. As part of the clearing of Banks Peninsula of timber for the development of farm land, there are believed to have been a number of sawmills in Pigeon Bay. It is likely that in this case, the mill may have been associated with the ship building enterprise for which the reserve was created. It has not

been possible to locate the field notes from which this map was drawn so further information is not available. The spit, estimated from the map, appears to have been about 300 metres long at this time, with a distinct hook at the southern end, and about 10 metres wide. The area behind the spit appears to have been a small bay which was fed by three small streams running off the hills behind. Figure 3.5 shows the configuration of the reserve as depicted on Black Map 117.

No further historical evidence has been located until the survey of H.R. Mottram in 1929. Records of correspondence dealing with the reserve begin in the Lands and Survey in 1929. Residents of the area were concerned about the untidiness of the site and wished to beautify it and use it as a recreation area. In the first approach to the Department by residents seeking control of the reserve, first mention is made of a slip occurring on the hillside behind and above the reserve, and of the subsiding material filling in the sheltered bay behind the spit. The slip is estimated to have occurred "about twenty odd years ago", that is sometime between 1900 and 1909. By the time of this approach the Pigeon Bay Road Board had planted trees, believed to be macrocarpas and blue gums, on the reserve and seem to have assumed control and responsibility for it.

In response to this request from the residents, Surveyor Mottram was instructed to carry out a survey of the land when next in the area. This was done in July 1929 and the

record of this is found on Survey Office plan 6324. The reserve by this time had grown to 1.138 hectares (2 acres 3 roods 10 perches), and was about 280 metres in length. The spit was only about 100 metres long, the balance having been infilled and shown on the map as dry land. The seaward boundary was the line of high water mark. As a result of the enquiries made the purpose of the reservation was changed on 6 February 1930 from ship building to recreation.

The administrative history from 1930 through to about 1960 is quite confused with a number of bodies having been involved, but it is not intended to explore that issue in this paper.

In 1929 the first suggestion was made that erosion was occurring on the seaward side of the reserve, but it was not until 1968 that any work was done to modify the erosion trend. About 1967 a proposal was made to construct a sea groyne, and the Akaroa County was going to assist. However, in 1968 there was dumping of material obtained from a quarry on the west side of Pigeon Bay. This enjoyed the financial assistance of the Soil Conservation and Rivers Control Council, and the advice and equipment of the Akaroa County. About 1530 cubic metres of rock (2000 cubic yards) was placed at the sea frontage of the reserve. No further erosion control works have been instituted for the reserve since then. Concern for the erosion has been shown by the management body for the reserve since the time of its inception, but has tended to be cyclic, apparently dependent

on the enthusiasm and energy of the individual board members. The board has recently completed the draft of a management plan for the reserve and is currently seeking advice on the management of its perceived erosion problem.

3.5 SURVEY 1981

In January 1981 a survey was carried out to ascertain the present position of the high water mark for comparison with that specified by Mottram. In so doing three old survey marks were located, two placed by Mottram during the 1929 survey (I.S.IV and I.S.VI, S.O. 6324) and one placed earlier and used by him (O.I.P. XIV D.P. 7799). Two other old survey marks were found and confirmed the position of O.I.P. XIV (O.I.P. XVII and O.I.P. XIX, D.P. 7799). Locating these ground marks, one 270 metres north of the site and two beside it, gave good survey control for the comparison of data between the 1929 and the 1981 coast lines.

In addition to these old marks, five new positions were established and marked with iron tubes. From these control positions on the reserve itself, offsets were taken to the edge of the beach scarp on the seaward side and to the edge of the vegetation in other places. These positions were considered to represent the approximate horizontal location of high water mark at January 1981. The data so gained were plotted at a scale of 1:1500. S.O. 6324 was reduced in scale so that it too showed the outline of the reserve at a scale of 1:1500, and the two super-imposed with the legal boundary between the road and the reserve

added. This is shown on Figure 3.6.

There are several conclusions that may be drawn from this comparison. The magnitude of the erosion problem is not as great as was first expected. The maximum distance that the foreshore has retreated is 12 metres and the average movement is of the order of 6 metres over the length of the seaward face. However, the most significant observation that may be made is that the spit itself, and the shore of the sandy beach behind the spit, have moved southwards a distance of 30 to 35 metres. The net change in the size of the reserve is positive, that is it has become larger rather than smaller. The complex has apparently moved southward along the shore of Pigeon Bay. Planimetered areas from Figure 3.6 indicate that there has been a gain in area at the spit and the sheltered bay of approximately 2700 square metres. Along the front of the reserve there has been a loss of about 1400 square metres. This represents a net gain in the area of the reserve of more than 10 per cent. Along a distance of 260 metres, the retreat at the sea frontage has been in the order of 5.4 metres in the 52 years from 1929 to 1981. On an annual basis, this represents an average erosion rate of the scale of 0.1 metres per annum. The final notable characteristic evident from the comparison of the two surveys is that the spit has developed from a straight-shored and sharp pointed feature in 1929 to a distinctly hook shaped one with a bulbous rather than pointed southern extremity in 1981. The validity of any conclusion which might be made from this is

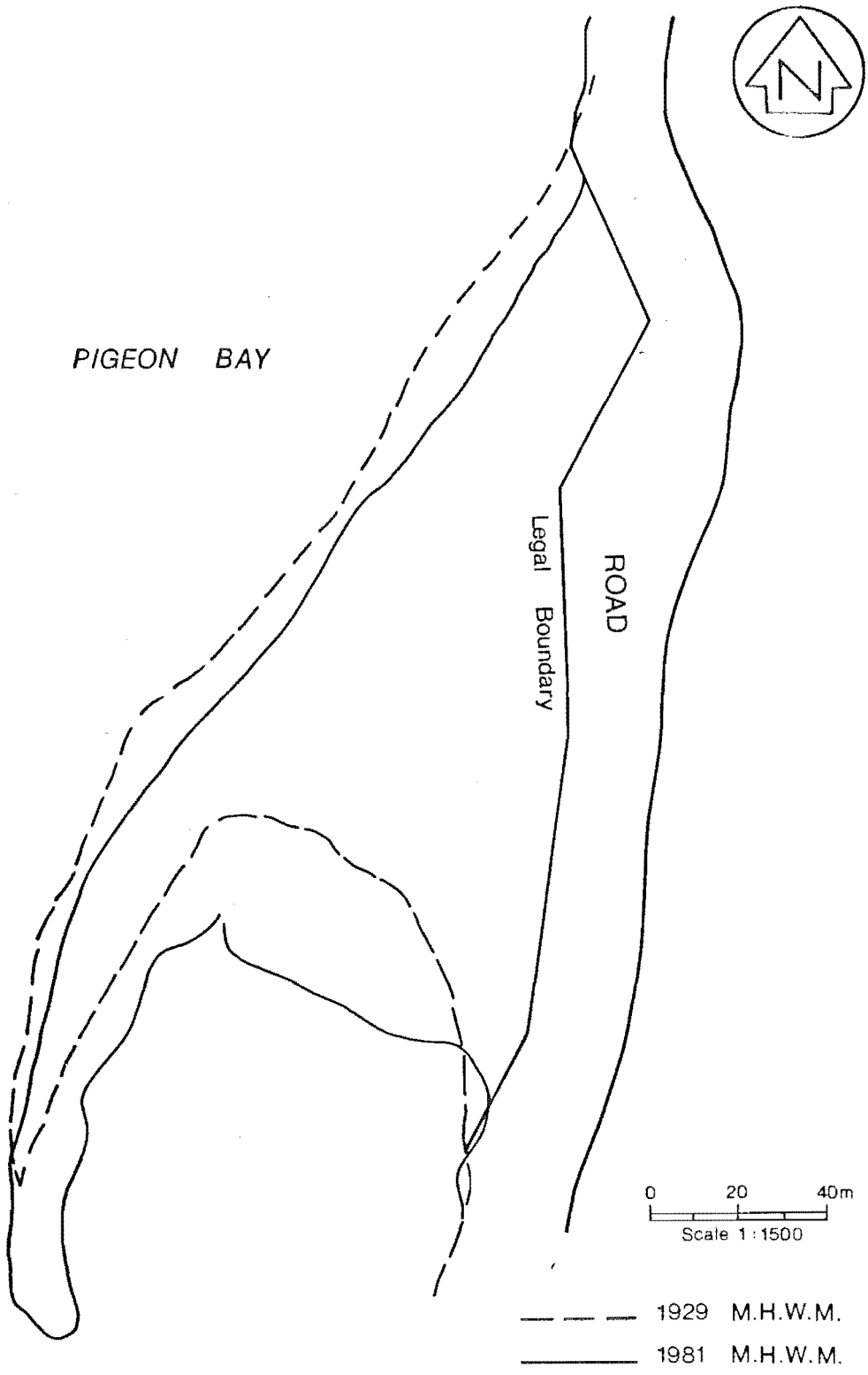

FIGURE 3·6

MEAN HIGH WATER MARK

1929 AND 1981

dubious as it is not clear what Surveyor Mottram used as the high water mark indicator. The plan does show that the feature had a more rounded shape below mean high water mark and the map of 1861 showed both the rounded head and the hooked shape that exist today. Without the assistance of the original field data further conclusions are merely speculative.

3.6 CONCLUSIONS

Before the interference of European man, there was a boulder bank protruding into Pigeon Bay, landward of which was a stream. This stream was the source of the boulders, carrying them down from the hillside above and depositing them in the bay. A small long shore drift component of the low energy wave action that is present in Pigeon Bay shaped this deposit into a long narrow beach, the direction of growth of which resulted from the combined effect of the stream on one side and the wave action on the other.

The arrival of the early settlers in Pigeon Bay resulted in a considerable change in less than 20 years. The spit became three times as long and twice as wide, and was used to support a sawmill. The fact that there was a ship builder among the earliest arrivals does not appear to be insignificant in this development. Such extensive growth by natural processes is unlikely. It must therefore be accounted for by human activities. At some time between 1843 and 1861 the spit was considerably lengthened and widened, a sawmill built, and ship building carried out. At this time there

was also probably some infilling of the area behind the spit. Early in the present century, further material was added from the hillside when a slip occurred. How this deposit was treated is not recorded, but it seems likely that the material was spread or levelled at some stage to make the area of dry land larger.

In 1929 the reserve became a recreation area, and the responsibility of the local residents for management purposes. Since that time, the seaward face has undergone a slow but steady erosion, retreating on average about 0.1 metres per year. Concurrently with this, the spit has advanced approximately 35 metres and the sandy beach behind the barrier has infilled about 30 metres. Overall, there has been a net gain in the size of the reserve over the fifty year period.

While it may be fairly stated that the amount of erosion to date has not been great, the future rate may not be a continuation of the past. At the northern end of the reserve, the boulder bank is being continually worked on and material is transported southward from here to the distal end of the spit. It must be assumed that at some time the erosion will breach the berm because the supply of new material to it was cut off some time ago. When breaching of the boulder bank does occur, subsequent erosion must be expected at a greatly increased rate. Once there is direct wave action on the fill material (predominantly silt with sand and clay) it must be expected that rapid alteration will take place.

Without further investigation it is not possible to state how much of the original boulder bank remains. It appears that it may have been about 10 metres wide, and it can be confidently stated that at least 6 metres have been removed in the last 50 years. It is therefore likely that in the northern area, there no longer exists a substantial barrier to wave action. If ameliorative works are not instituted before this bank is breached, it is unlikely that inundation by the sea could be prevented. It is not possible to predict at this time, when such an occurrence might take place. Prudent management would act in the immediate future to safeguard the existence of the remainder of the original bank, as protection from the loss of the whole area.

CHAPTER IV

LITTORAL DRIFT

4.1 THE PATTERN

In the fifty-two years since the survey of Mottram, there has been a sustained pattern of erosion affecting the Pigeon Bay Recreation Reserve. This pattern is characterised by three distinct facets which occur in three different areas of the reserve and which are manifestations of the natural process regime.

The most concerning aspect of the pattern is that boulders at the seaward face of the beach are being removed, causing the small cliff face behind it to fall away. The roots of trees on the land are then subject to salt inundation, usually resulting in the death of the tree. The tree dies, falls and takes with it further quantities of the bank. According to local sources this pattern of land loss has been observed over a considerable period, and is confirmed by evidence gathered in this study.

The second aspect of the process regime is that the spit is growing. Gravel is accumulating on the southern end of the spit causing it to lengthen, to increase in breadth and to take on the appearance of a hook. Although this growth has been significant, and is consistent with the erosion of the seafront, there has not been the same awareness of it. This is probably explained by the fact that such growth is imperceptible while the erosion tends to be episodic and

conspicuous when it occurs.

In conjunction with the growth of the spit there has been a third type of change. The sandy beach landward of the spit has advanced. Over a lengthy period there has been process of infilling in this area so that the sandy beach has prograded at a rate similar to the elongation rate of the spit. The spit has therefore remained about the same length with the tip and the beach advancing by approximately the same amount. The spit has consequently maintained the same general form while moving in a southerly direction.

The common cause of these effects on the reserve is long-shore drift. The movement of material along the shore is one of the most important processes at work on the coast (King, 1972) and is responsible for a large number of shore features such as spits. It is an important cause of many instances of coastal erosion.

4.2 LITTORAL DRIFT

Longshore transport of material may take place above or below the water level. When it happens in the foreshore area (that part of the beach between high and low water), it is known as littoral drift. The erosion and accretion of the Pigeon Bay Reserve is an example of the littoral drift of gravel and sand.

The reserve is situated about seven kilometres from the mouth of Pigeon Bay and the open sea. The length of the

bay causes the predominant wave action at the head to be approximately perpendicular to the bay shore. The waves may be generated by wind conditions combined with rising or falling tide. In southerly and easterly conditions the bay is comparatively sheltered while during times of northerly conditions it is likely that the wave action will be at its greatest. During swells or storms the greatest damage is done to the shore of the reserve.

Although along the centre line of the bay the waves travel inland at right angles to the coast the pattern at the shore tends to be different. As the waves strike obstacles such as small headlands protruding into the bay, they are refracted. The inshore part of the wave is travelling in shallower water and travels more slowly because of increased drag. The result is that the wave front tends to become parallel to the shore. This effect is clearly shown in Figure 4.1 which was prepared from an aerial photograph taken in 1975 in which the wave crests were particularly visible. In addition, headlands tend to create sheltered areas of quiet water in their lee that become depositional areas because the water does not have sufficient energy to carry particulate matter.

The effect of waves approaching the shore is to carry material, in this case boulders from the original ridge, up the foreshore and along the coast (Figure 4.2). As waves run up the beach they have greater energy than during their

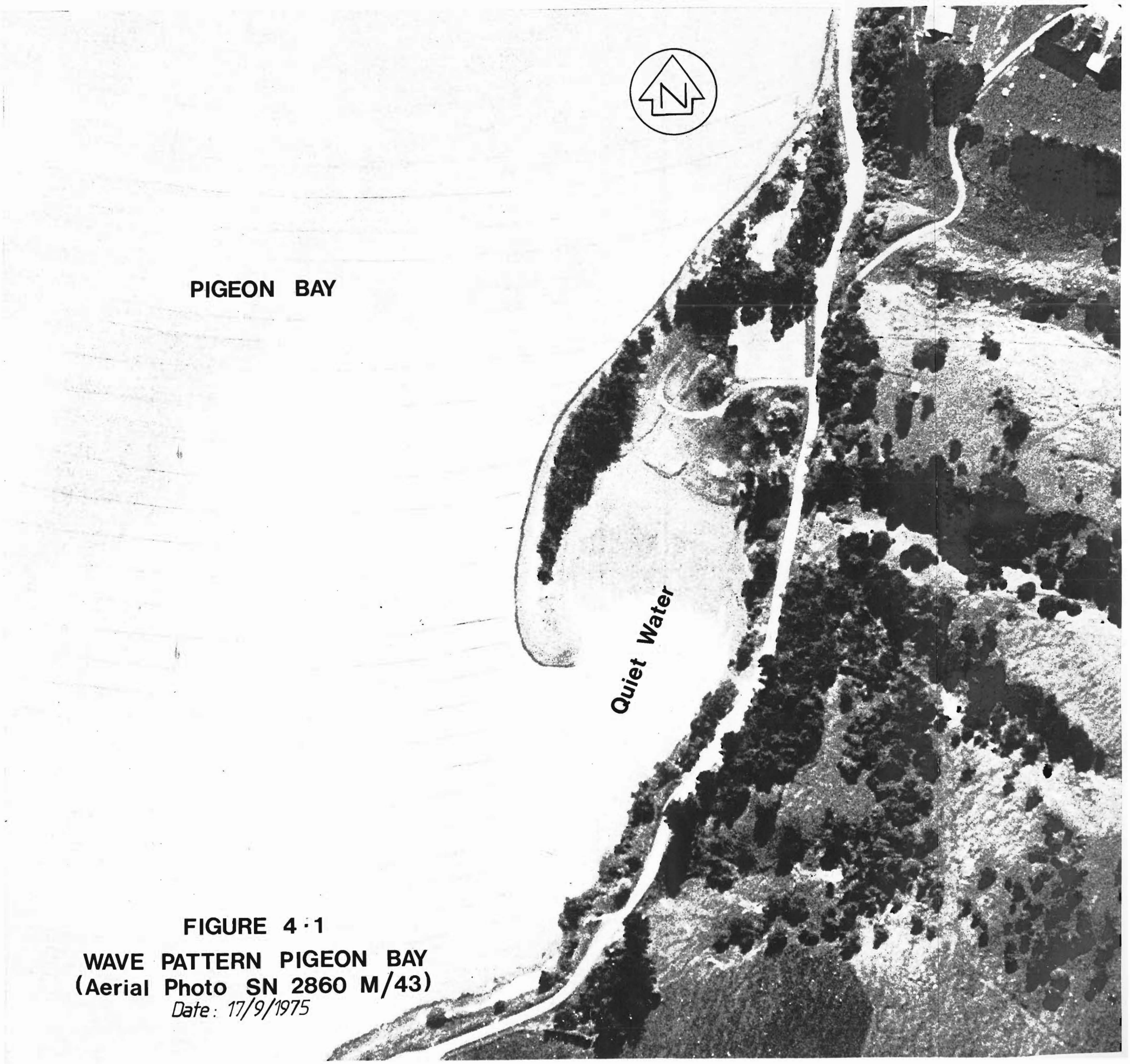

FIGURE 4·1

WAVE PATTERN PIGEON BAY
(Aerial Photo SN 2860 M/43)
Date: 17/9/1975

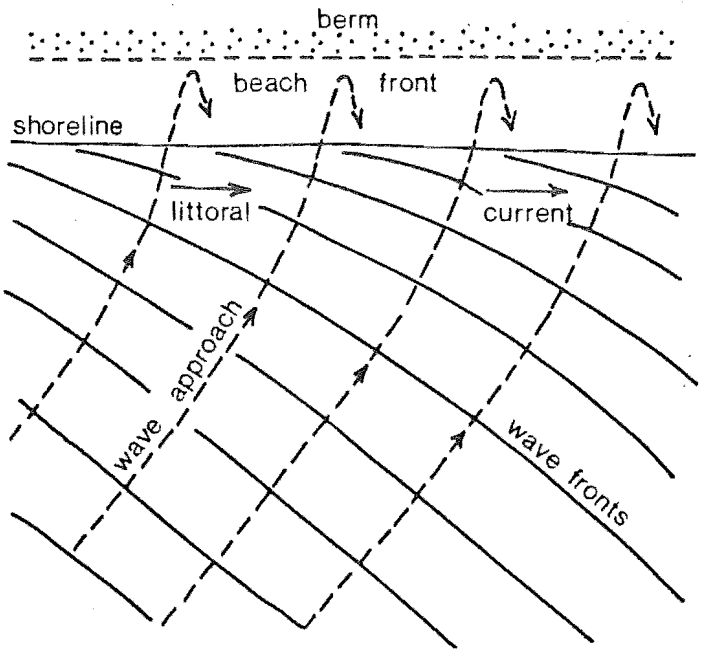

FIGURE 4·2

LITTORAL CURRENT
from Bascom, 1964

backwash phase, enabling them to carry greater loads on to the beach than away from it. This allows the heavier sediments to be moved higher up the beach, but prohibits their removal. In times of higher wave energy this material is moved beyond the reach of waves present during normal conditions. The tendency for the Pigeon Bay Reserve therefore, is that boulders are moved in strong northerly conditions, from the north end of the reserve towards the south. The supply of such boulders to the north end of the reserve has been minimised since the stream from the hills behind was deviated to allow the road to be constructed, causing the gradual but continuous depletion of movable material.

About 190 metres south along the coast from where the reserve begins the shoreline changes direction towards the land, making the area of water in the lee of the reserve sheltered and generally quiet. When the tide is rising the movement of water in this area tends to be into the bay, that is east of north, and this carries finer sediments (all the rising tide has enough energy to move) into the bay, accounting for the general accretion in this area.

This pattern is confirmed by the structure of the spit beyond the change of direction of the shore. South of this point the beach is characterised by accumulations of gravel and boulders, becoming generally smaller toward the spit tip and by the absence of undermined and unstable parts of the berm. The

berm and the beach also become less distinct.

The angle at which wave fronts approach the coast is of some importance in relation to their ability to carry sediment loads, but opinions differ as to the most effective angle. According to King (1972) the rate of transport will be a maximum when the angle of approach is 30° while Bird (1976) maintains that optimum conditions for longshore drift will occur when wave crests approach the shore at 45°. Theoretical differences are not the concern of this study, but it is necessary to note that on the day the aerial photograph used for Figure 4.1 was taken the wave crests were approaching the northern end of the reserve at between thirty and forty degrees. That is, in the situation of higher energy wave conditions, the angle of approach indicates that there will be efficient longshore movement of beach material.

It is generally agreed in the literature that movement of sand and gravel along coastlines is responsible for most coastal erosion problems and there are many sites throughout the world that illustrate this. Examples of longshore movement tend to be found in areas where the wave energy of the system is much greater and more consistent than at Pigeon Bay, but both seafront erosion and spit accumulation are the common results.

4.3 OTHER SITES

Longshore transport systems have been studied in a number of

areas in the United State of America including California, Florida and New Jersey. Though most of these studies have considered sand transport rather than gravel, the principles involved are the same. They have generally looked at areas of erosion that have man-made structures as their prime cause and for this reason are of interest if structural methods as solutions to erosional problems are being considered. It is not proposed to discuss these studies here but they may be pursued in King (1972). Much of this literature has explored in some depth the theoretical calculations of the amounts of material being moved in longshore transport systems.

Some studies have been carried out on longshore drift in Australia, such as at the recurved spit in Carrickfergus Bay, Tasmania (Davies, 1959) and Cape Bowling Green on the northern Queensland coast. These Australian studies also tend to concentrate on the finer sand beaches that are common in that country.

The English experience with longshore currents is wider and covers more sites and a greater variety of conditions. In some cases data can be obtained covering centuries of activity on the erosion and accumulation of spits. The history of Spurn Point in Yorkshire (De Boer, 1964) has been traced since the 14th century and maps from 1530 suggest that the spit at Orford Ness in East Anglia has grown about 4 miles in that period and has deflected the mouth of the River Adle by about 11 miles. Orford Ness and Dungeness, also in East

Anglia, are formed by large gravel ridges that have been built by storm waves. The material forming the ridges is brought to the site by longshore movement of gravel under the influence of constructive waves approaching the shore obliquely. The storm waves build the ridges to a height well above the normal high water. The Dungeness feature is up to 7.6 metres deep and in places stretches 3.2 kilometres inland from the present shore (King, 1972). Salt marshes are known to develop on the sheltered landward side of spits, particularly between recurves and good examples of these exist at Blakeney Point and Scolt Head Island in Norfolk.

According to Bird (1968) some of the best examples of spits are found on the shores of landlocked seas, lakes and coastal lagoons, where sand and gravel carried along the shoreline are deposited as spits where the orientation of the shoreline changes, in forms related to the prevailing wave conditions.

4.4 CONCLUSION

Pigeon Bay Recreation Reserve, as a spit feature, exhibits characteristics of spit behaviour that may be found at many other sites around the world, under different conditions and with different basic materials. Though the English examples are illustrations of much larger features, and though they represent coastal systems of a much greater magnitude, their patterns of development have similarities to Pigeon Bay. American and Australian studies, although centred on sand movements, show that despite differences in the size of the materials in motion, the effects of longshore

drift follow the same pattern.

The Pigeon Bay spit has been growing because of systematic littoral drift with the greatest alteration taking place during storm conditions. The change of direction of the coastline (caused by the body of the reserve) serves to magnify the refraction of the waves and increase the drag. This is also the prime cause of the erosion on the foreshore of the reserve. The reserve differs from other sites in the nature of man induced interference in the natural system.

CHAPTER V

MANAGEMENT OPTIONS

5.1 INTRODUCTION

Management options for coastal erosion problems divide naturally into three broad categories. These categories are:

(i) Do nothing

(ii) Install structures - the "hard" option

(iii) Beach renourishment - the "soft" option

The deliberate choice to do nothing having recognised a coastal erosion problem is a valid consideration, but not one that is often chosen. In the present case, where investment in capital assets has not been great, life is not endangered and the rate of erosion is not large, the alternative of taking no action must be seriously considered. However, before selecting a do nothing option, the likely consequences must be fully understood.

In New Zealand, the most common reaction to a perception of coastal erosion is to build a coastal protection structure. Over 85 such structures have been built in this country in the 25 years from 1953 to 1978 (Kirk, pers. comm.). "Hard" structures are of a variety of shapes, forms and functions, the most common being groynes, sea walls, jetties, revetments and breakwaters. These are commonly an unnecessary and unwise response to the physical problem particularly

where capital investment in shoreline developments is low. There are few bodies, either public or private, that have an adequate understanding of the natural coastal processes active in beach systems together with a thorough knowledge of the engineering design and construction of marine and sub-marine structures. This is often compounded by inadequate funding of protection programmes. Coastal protection structures should thus be considered only as a remedy in the last resort, and even then only when the value of the assets can justify the cost.

The objective of beach renourishment is to supply the eroding area with material that is less erodable than the original material in an attempt to stabilise the beach. Some attention must be paid to the coastal processes and data gathered on the site of the renourishment. The sources, sizes and feed rates of feed-stock sediments must be a carefully considered. Renourishment is not usually achieved in a single action. Rather it must be a continuing programme of maintenance and topping up. Beach renourishment is the only control technique that seeks to directly remedy the cause of erosion, that is sediment deficiency.

Because the existence of beaches is inconsistent with the presence of many types of hard structures the choice between renourishment or a structure may be the choice between the retention or enhancement of the beach environment and the protection of capital assets. Renourishment experience in New Zealand is not substantial, only three schemes being

currently active. This fact, however, should not daunt managers of the coastal environment, if certain criteria are met before embarking on such a course of action. Providing there is a reasonable understanding of the processes causing the demand for sediment, there is some understanding of the characteristics of the site, and that adequate attention is paid to the selection of appropriate feed material, renourishment is a viable option. Whether successful or not, with reasonable care, in the worst event a renourishment programme is likely to be less harmful than the more traditional hard options.

All the above methods are capable of being applied to the Pigeon Bay Recreation Reserve erosion problem and must be considered in greater detail with respect to the knowledge that has now been gained about it.

5.2 THE DO NOTHING OPTION

It is important to note that consideration of this course of action is a positive decision not to interfere with the current natural regime rather than a method of management by default, so that the reserve board must be fully aware of the likely consequences of such a decision.

The short term result of non-interference will be that erosion will continue along the western, seaward facing boundary of the reserve, and there is no evidence to suggest that the rate of such erosion will be significantly different from that of the last 50 years, (in the order of 10 cm per

annum). The spit will also continue to lengthen as material that has been eroded from the sea front, and transported southwards along the face of the reserve, accumulates at the end of the feature. In addition there will be a continuation of the accumulation of fine sediment landward of the spit, with the resulting advancement of the shoreline of the sheltered beach. That is, the pattern of development that has been described in Chapter II will continue, the reserve will appear to be migrating southward, along the eastern shore of Pigeon Bay. It must be emphasised at this point that this continuation is in the short term, and with the knowledge available presently, it cannot be predicted how long or how short that term may be.

The limiting factor on the continuance of the present situation will be the severity of erosion at the northern end of the reserve. The original boulder bank has been subject to small but consistent erosion for 50 years of recorded history, and it must be assumed that this has been going on for a much longer period. This erosion regime has probably been active since the supply of material from the hillside behind was interrupted and this is most likely to have occurred in the 1850's when the reserve was first developed for ship building purposes. Without knowing the magnitude of the original boulder bank, it is not practical to estimate how much of it may remain. What can be confidently predicted, however, is what may happen to the reserve when the erosion finally breaches this natural barrier at the northern end.

In Figure 3.4 the natural spit is shown to be wedge shaped, with the narrow end of the formation to the north. As the erosion is acting approximately parallel to the line of the front of the reserve, it is clear that the northern end is the one which will be breached first. There is no doubt that such a breaching will take place; only the timing of it is in doubt. When the ridge is exhausted, erosion of the remaining fill material will accelerate. As the fill is mostly silts, sand and clay, without the protection of the heavy material it will be easily removed even by quite low energy activity. It is clear that the reserve would then be subject to continuing erosion along the seaward margin as previously, while the body of the reserve would be attacked from the north, at a much greater rate.

The do nothing option for management has some advantages that, though obvious, require stating. There are no unwanted or unplanned side effects that often appear as a result of other solutions and that may have ruled them out if considered initially. This is particularly true for the environmental considerations, which are often very difficult to predict even with the assistance of specialist advice. Taking no action to arrest coastal erosion is clearly the cheapest of all solutions. Managers are not involved with professional fees for the design and construction of structures nor are they involved with the cost of purchase, transporting and placing material for either structural solutions or for a renourishment programme.

The financial aspect of coastal management is particularly important to areas such as a recreation reserve, since funding is not readily available for such projects and its income would not be adequate to promote protection unaided.

Doing nothing to alter the present coastal process regime must be a serious alternative for the management of Pigeon Bay Recreation Reserve. It would follow that development would be restricted to the southern end of the land-form if such a course were selected, and it may be fortuitous that the board's improvements are currently devoted to this area. In the long term the reserve would be lost.

5.3 MOVING THE ASSETS

A conventional response to coastal attack is quite often to remove the assets that are endangered. In this case the main asset involved is the land itself. The improvements made over the last 50 years, the toilet block, tennis courts and water supply are probably not significant in value in relation to the worth of the site itself.

The significance of this option in the case of the Pigeon Bay Reserve then, would be for the board to seek an alternative site in which its main activities could be carried out. It is not likely to prove difficult to find another area that would be suitable for a caravan and camping area in the locality, though it may be more difficult to find suitable

flat land for the replacement of the tennis court. Since the local tennis club no longer exists this may be a lesser consideration. It is not likely that another site could be found that would supply the enclosed swimming area and boat landing irrespective of the tide as well as providing fishing sites.

If it were possible to find another location that satisfied enough of the above activities to make it a viable alternative, the question must remain as to whether the board could afford to purchase it. Finance may be more readily available from the Soil Conservation and Rivers Control Council for structural or renourishment programmes of erosion control than from other sources for the purchase of alternative sites. It is possible, however, that the purchase price of an equivalent area of suitable land would be less than the finance required to build and maintain the structural alternatives discussed in the next section.

This option could be considered in conjunction with the alternative to do nothing.

5.4 STRUCTURAL OPTIONS

There are three structural options available for coastal protection, each of which would be selected to achieve a particular goal. The effect of each of these options would be to modify a different part of the present system, with an ultimate view of achieving some level of stability in a

form different from the present one.

5.4.1 Modify the Natural Process

The present erosion state of the reserve is as a result of a small longshore current in the presence of a fixed supply of material available for transport. The supply of material has been fixed since the interrruption of the stream shown to have been present in 1851, probably as a result of the construction of a road along the edge of Pigeon Bay that passes between the reserve and the hillside. The present location of this stream is not known.

Modifying the natural process in this context would be achieved by the construction of an off-shore breakwater. A breakwater is "a structure designed to protect an area from wave action,.. (and)... may serve as... a trap for littoral drift" (U.S. Army C.E.R.C.). It would consist of a wall built on the sea floor that would break the surface of the water. Waves would then dissipate their energy against this structure and would not reach the shore. An off-shore breakwater could be placed to shelter the Pigeon Bay Reserve in this way.

The effect of a breakwater would be twofold. Firstly, and probably most importantly, the wave energy at the beach would be reduced. As a consequence of this, the waves reaching the beach would not be capable of moving such large material. Only the smaller material would be trans-

ported along the frontage to the spit. Depending on the size and location of the breakwater, variable amounts of energy could be removed from the waves, altering the size of material transportable. The less energy retained by the waves, the smaller the beach gravel they can move. Secondly, a breakwater can be used to alter the direction of the waves. Positioned carefully, the wave action travelling up Pigeon Bay could be redirected so that it is deflected from the reserve altogether. The effect would be somewhat similar to that already caused by the spit. South and east of the spit there is an area of quiet water as can be seen in Figure 4.1, where there is little wave action, and consequently an area of sediment deposition. It is this deposited material that is moved into the small bay area landward of the spit by tidal action, and accounts for the advance of this beach head. A breakwater therefore would not only reduce the wave energy at the shore but could be used to alter the direction from which the waves approach the seaward face of the reserve.

As with all major interventions in natural processes, breakwaters have drawbacks. They are particularly expensive to construct and require professional engineering design and supervision. Since breakwaters are not a common occurrence in New Zealand, experience in this field is also very rare. Under the Harbours Act 1950, all physical works in tidal or navigable waters require approval, normally considered by the Ministry of Transport. The Ministry is required to consider the public interest as well

as the navigational and engineering aspects of any proposal. It may also be necessary to obtain a licence to occupy the area of foreshore or seabed covered by such a structure. As control of the waters and foreshore of Pigeon Bay is vested in the Akaroa County Council, this body would be involved in the necessary approvals and licences.

Less obvious perhaps are the likely environmental consequences of a breakwater on the inner area of Pigeon Bay. Clearly the presence of a partially submerged structure in the calm and popular sailing area will reduce its desirability as well as creating a potential hazard to boats. In mitigation of this, however, breakwaters have a reputation for creating excellent habitats for marine life, particularly fish, and so there would be an improvement in the area for local fishermen, while the yachting fraternity would suffer a loss of amenity. It is quite likely that there would be further environmental impacts on the harbour area but it is not possible to speculate on their nature in the absence of a particular design proposal. It is likely that if such a stage were reached further specialist advice on the marine environment may be desirable.

A breakwater to protect the reserve would bring with it other advantages as well as disadvantages, if the cost could be met and the design expertise found.

5.4.2 Modify the Effect of the Process

It would be possible to modify the longshore drift causing

the erosion of the reserve by means of a series of groynes. The groyne is the classical coastal structure being constructed usually of rock (though not necessarily) and built seaward from the shore at right angles. It must be realised that it does not cure the erosion problem, but merely modifies the effect of the longshore drift. The purpose is to trap the material being transported by the longshore drift process and accumulate it on the updrift side. Characteristically, an area of scour remains on the downdrift side of the groyne though with the selection of an appropriate spacing of them, this can be reduced to a minimum. As a general rule the groyne will create an accumulation area for a distance of two to three times its own length upstream, and a scour area for about the same distance downstream. The erosion problem is therefore broken down into a series of smaller areas, while the mobile material is prevented from accumulating at the one place, in this case at the end of the spit. It should be pointed out that the areas of scour are less predictable than the areas of accumulation.

If such an option were to be selected for this reserve it is estimated that between six and eight groynes would be required to control the situation, each structure being 10 to 12 metres long. Shorter groynes would necessitate more of them. With judicious placement of the first structure, it would be possible to protect the more sensitive northern area adequately. The groyne is most effective as an

erosion control aid if there is a large movement of material by longshore drift, and the net movement is in the one direction. In this case while the movement is definitely in the one direction, the quantities involved are not great.

As for the breakwater option, the design construction and maintenance of groynes would be expensive, and professional advice would be necessary on these aspects. Since structures are again involved on the foreshore and the seabed, approvals and licences would be required under the Harbours Act 1950, necessitating the involvement of the Akaroa County Council and the Ministry of Transport. As groynes are specifically suited to erosion problems caused by longshore movement, they would have no appreciable effect on any on-shore/off-shore component contributing to the erosion of the reserve. It is not expected that this is a significant factor in the present problem, but it may be disguised by the much larger longshore drift component.

The construction of a number of rock structures along the shore of the reserve would have considerable visual impact on the area. While many may not find them unattractive, some may even approve of the site, the addition of six or eight stone structures would disturb the natural appearance of the present reserve to a degree that could not be disguised. As the present use of the reserve to a large extent is in the nature of passive recreation, such modification of the apparently natural area may be unaccept-

able to both the reserve board and the users of the area.

5.4.3 Protection of the Land-form

The third approach to structural control of the erosion of the reserve would be to protect the seaward berm directly by the construction of a sea wall or bulkhead. The function of a sea wall would be to directly protect the remaining land mass rather than to interfere with the processes presently acting upon it. This would involve the construction of a vertical face from rock, concrete or steel in order to retain material landward of it. The use of sea walls is more appropriate for the control of material in the on-shore direction, but could be successful in this low energy longshore problem.

In this instance, a bulkhead could be established using a plastic filter sheeting material placed directly on the present berm and with imported heavy rock (heavier than that forming the present beach) placed on top, with the space between the boulders such that finer material under-neath could not be washed out. As sea walls are a relatively common response to frontal attack, there is a reasonable body of literature about them, and their characteristics are well known. Such a wall must be high enough to ensure that during higher energy conditions (storms, when most damage is done) it would not be over-topped by wave action. Failure at the base of sea walls is the most common fault and it would therefore be essential to bury the toe of the wall in the present beach to avoid

such an event, taking into account the material that the wall would stand on. Care must also be taken at the places where the wall ends. If flanking construction is not carried out properly at both ends of a wall, increased erosion can be experienced, not only damaging the area adjacent to that being protected, but the wall itself may be attacked from behind. The spit would cause a problem in this respect, being a "free end". The bulkhead structure therefore becomes a much larger structure than it appears.

The effect of a sea wall is to fix the coastline at the line of the structure. As a rule, the existence of beaches is inconsistent with the presence of a bulkhead. Turbulence is increased at the foot of the structure by the reflection of the wave motion from it causing the removal of the beach. In this case, the present beach would leak away at an accelerating rate until all the present material was deposited in the spit vicinity, or moved off-shore. As for the other structures already described, the expense of the professional design and construction is likely to prove a limiting factor in the consideration of a sea wall as a solution to the present problem. Such a structure would not require consultation with local or central government. Not only would there be financial expense, but the environmental character of the area would be dramatically and permanently affected. The present land mass would remain more or less unaltered, but the natural

rocky foreshore, and with it the foot access to the sea itself, would be lost.

5.4.4 Summary

While there are other structures used in the management of coastal erosion (jetties, revetments, gabions) it is not considered that they would be appropriate in the context of the Pigeon Bay Recreation Reserve. While structural solutions are the most frequent reaction to coastal problems, they generally tend to be inadequate. They tend to be prohibitively expensive to construct and maintain and require the expertise of the engineering profession for design. They also need to be carefully constructed to ensure that they achieve their purpose.

Before selecting a structural option as a solution to any coastal erosion problem, it is essential that full consideration should be given to the likely environmental consequences involved. In most cases, some of these effects are simple to recognise, while others remain in the domain of speculation. Critical to the consideration of a structural solution is that without the input of a wide range of expertise at the decision stage, during the design process and while the erection is taking place, unexpected consequences may result. Even with all the appropriate information, previously unconsidered problems may arise as a result of the interruption of natural processes.

5.5 BEACH RENOURISHMENT

The objective of beach renourishment is to either reinstate a beach that has been removed, or to stabilize one that is undergoing removal. This is done by feeding appropriate material to it, either by placing it directly on the affected site or by dumping it at such a location that it will be transported to the erosion area by the same natural processes which are the cause of the problem. For example, if material is being removed from the site by longshore drift, and if the renourishment substance is dumped upstream of the site, then the natural process will carry it to the appropriate place. Similarly, if the cause of the erosion is an on-shore/off-shore movement, then dumping material in the off-shore area may feed the beach. In the case of the Pigeon Bay Reserve, renourishment would best be carried out by the dumping of suitable feeding material at the north end of the beach. This would have the effect of simulating the original system that created the feature.

The selection of material for dumping would be a critical aspect of such an option. If boulders of the same size and morphology as those presently being removed are used, then it is obvious that this process will continue, with the perpetuation of the deposition of the spit end of the reserve. If additional material was selected that had the same morphology as the original but was slightly larger and heavier than present, then the transport would be slowed at least, if not arrested. The amount of the

reduction would depend on how much larger the new material was than that arriving by the original depositional regime. Since the process responsible for the erosion is not being altered some maintenance of such a programme would be required, to replace material which continued to leak away.

As the erosion rate at Pigeon Bay is quite slow, to feed it would not require a large supply of additional material, even using that of the same size as the beach is presently constituted. It is fortunate that there already exists a quarry on the west side of Pigeon Bay where rock could be extracted. This source has already been used for supplying the reserve with additional beach. The rock from this site is basically the same as the original beach and is therefore compatible both morphologically and visually. The general character of the beach would not be altered by the addition of rock from this source. Further, depositing material that is of the same structure and size as the existing beach at the north end of the reserve, would benefit the entire length of eroding face, because the material would be free to move along the length of the beach. The principal advantage of this option over those already discussed, is that the boulder beach of the reserve would remain substantially unaltered, except for some improvement where the fill material of the land-form has slipped into the sea.

Such a solution has the advantage that engineering input would be minimal and probably only in respect of selecting

suitable material and the placement. With the co-operation of local residents and the Akaroa County Council an ongoing programme of renourishment could be developed so that additions were carried out as equipment, time and finance permitted. It is unlikely that machinery in excess of that already locally owned would be required for the successful implementation of an adequate renourishment programme. Since the placement of material would necessarily be below mean high water mark, it is probable that approval would be required under the Harbours Act 1950, obtained either through the delegated authority of the Akaroa County Council or from the Ministry of Transport.

There is one further serious aspect to dealing with the present erosion in this manner. As material would continue to be transported along the reserve frontage, it must be expected that the size of the land mass would increase. That is, there would be a net increase in the area of the reserve, proportional to the amount of new material added to the system. It is for the reserve board to consider the implications of such an occurrence.

Beach renourishment as a solution to coastal erosion problems has not been widely used in New Zealand, but this should not deter experimentation. The principal advantages over other control methods are that it tends by its nature, to be environmentally sympathetic to natural systems. Should it prove not to be successful, it does not preclude managers from resorting to other more traditional responses.

Beach renourishment is the only solution that seeks to remedy the cause of erosion. Other solutions attempt to reduce the effect of natural processes.

5.6 DISCUSSION

The Pigeon Bay Recreation Reserve Board has several alternatives available to it in the treatment of its coastal erosion problem. The board will be guided in its selection of the appropriate response by consideration of what it hopes to achieve by gaining control of the erosion. Each of the options discussed, while giving varying degrees of control over the problems, has associated side effects that make each alternative quite different in total outcome for the reserve.

The board may choose to take no action, and accept the consequences of the present natural process. In doing so, it will face the prospect of continuing its present form of management for an indefinite time, until the original boulder ridge is breached. It is not easy to predict how the new stable structure will appear in this event. The possibility exists that the reserve will be completely lost, or that at least it will exist in a form no longer useful for recreation purposes. As a consequence of this the board may wish to seek another site in the vicinity of the present one on which it could continue its present activities.

If stabilization of the present land-form is the desired

state then the board may opt for a structural solution. If this is the case, the effect will be to freeze the available land in its present state, but there may be considerable consequences for the foreshore and the adjacent seabed. The choice of which structure to adopt will be dictated by the shoreline form that is acceptable: a breakwater would leave the beach in its present form; groynes would result in a scalloped effect of areas of scour and areas of accumulation; a sea wall would become the usable edge of the reserve and would result in the removal of the present beach. Any structural options would involve considerable expense in construction and maintenance as well as involving professional engineering services for the design and supervision of the erection. The approval (and possibly licensing) of the Akaroa County Council, after consultation with the Ministry of Transport, would be required. The likely impact of such structures on the environment, in particular the marine habitats existing in Pigeon Bay, and the visual intrusion into an otherwise natural landscape cannot be overstated.

The option that will leave the reserve as near as possible in its present state is the renourishment one. A supply of appropriate feed material is locally available, and this option requires the minimum of further expert advice. With the exception of doing nothing, renourishment is quite definitely the cheapest alternative in financial terms. By renourishment the reserve would be subject to

a gradual growth at the southern spit end, at a rate related to the amount and frequency of new material supplied. Environmental effects of this option could be expected to be minimal. It is also fortuitous that the part of the reserve where the problem is most severe has the easiest access for renourishment dumpings.

CHAPTER VI

CONCLUSION

The Pigeon Bay Recreation Reserve Board has recognised that erosion is active on the land it has the responsibility for administering. The board has been aware that the natural forces have been acting on the feature for some considerable time, but had no details on the amount of land lost or the rate at which the coastline was receding. In discussion with local residents and users of the reserve, it became apparent that opinions on the amount of erosion that had taken place in living memory varied considerably. Some believed that the reserve had once extended about forty metres further into the sea than it does presently, while others felt that about three rows of trees, probably about 10 metres, had been lost from the reserve. This highlights a problem with all erosion or accretion sites. Local opinion tends to diverge considerably on the magnitude of the problem, with a bias toward enlarging it. It is not satisfactory to base management decisions on such subjective data.

In recognising the problem, the board has indicated in its draft management plan that it desires to make an appropriate response to it. It states that before doing so it wishes to seek informed advice on the processes occurring locally and the likelihood for controlling the problem. It has proposed that on the receipt of this advice, it will further investigate engineering possibilities and costs with a view to implementation. It is the aim of this report to supply the board with

adequate information on which to make a sound judgment on the response it will make to its problem.

The feature that is now known as the Pigeon Bay Recreation Reserve has undergone considerable modification by both Man and Nature. At some early date, when it consisted of a single boulder bank, the supply of boulders was cut off when a road was constructed along the shore of the bay. A stream carrying weathered hillside rock was diverted and the supply of its bed load material ceased. This material had been carried down to the sea shore by the stream, and then moved by the longshore current of the sea to form a wedge shaped boulder bank as indicated in the earliest maps of the area. During the 1850's the feature was modified, probably for ship building purposes, and became longer, narrower and of constant width with a sheltered bay landward of it, probably with a sandy beach where it joined the mainland. Early in the 20th century a slip of some magnitude occurred on the hillside above and behind the reserve and a large quantity of fill, a mixture of soil, vegetation and weathered small rock, was deposited in the sheltered bay between the spit and the shore. Soil samples indicate that this area had been a swamp before this event. At some time subsequent to the slip the area must have been levelled, and in 1914 the Pigeon Bay Road Board planted the area with blue gums and macrocarpas. To some extent this may have stabilized the land. From 1930 onwards, when the reserve was placed under the day to day management of a group of local residents,

there exists written evidence that the side of the reserve facing into Pigeon Bay has been the subject of erosion by the sea, and this has been of concern to both residents and users.

This study has shown that while the reserve is definitely subject to erosion from the sea, the system is neither as active nor as simple as was generally thought. In fact, in the period of 52 years since 1929 the total area of land increased as a result of the natural processes rather than decreased, although material is being removed from the seaward face of the land. The heavier boulder type sediments are deposited around the distal end of the spit while the sand and silt that has accumulated over the original boulder bank is deposited in the sheltered bay landward of the spit. In all, there has been a net growth of over 10% in the area of the reserve over that time. The average retreat of the seaward face is about 10 centimetres per year, and the advance of the spit and the beach at the south end is greater than 60 centimetres per year. It should be understood that while these values represent averages over 52 years, erosion takes place in episodes during storms. In any one year or during a single storm greater quantities than these may be moved. The most serious aspect of this erosion, is that the original boulder bank is being gradually removed, particularly at the northern end where the 1851 evidence indicates that the bank was at its narrowest. Without further examination it is not possible to estimate how much

of this now remains. It can be stated however, that when the original bank is breached, the rate of erosion of the rest of the reserve will increase dramatically. After more than a hundred years it is not likely that much remains of the boulder ridge.

This study also shows that concern for minor erosion of the beach in the sheltered bay is unfounded. Over the last 52 years this has advanced about 35 metres so that with no alteration to the natural processes this will tend to continue. Should the sediment supply be arrested by the construction of control structures the advance would be stopped. It is not likely that erosion could be induced in this area by such actions.

The reserve board is now faced with a number of responses to its problem. These responses are quite different in their nature, and vary considerably in their total effect. It is important that in its deliberations over the selection of one of the options the board gives full recognition to the impacts supplementary to the prime objective. The board must first decide on the values it considers most important for its reserve and choose the erosion management technique that will not only control the problem, but which will also safeguard or enhance the other attractions of the area.

The board may choose to do nothing and allow nature to take its course. In doing so, it will be recognised that in the

long term, the reserve will undergo considerable change, and that it will be unlikely to be suitable for camping and picnicking or as a base for yachtsmen, though it may retain some value as a fishing area. In this case the board would foresee the termination of its own activities, or it may wish to pursue some other site at which to conduct its activities. It is unlikely that such a site could be located in Pigeon Bay if all the present functions were to continue. It is more likely that if only land oriented facilities were to be considered, such as camping, picnics and barbecues, and tennis courts then a site may be found that would be suitable, if a local land owner were to be amenable to a sale. It is not proposed in this report to pursue the likelihood of finance being made available by either central or local government for the purchase of a new area for a reserve, other than to recognise that such a matter would require much negotiation.

The board may choose to make a more typical coastal management response and build some sort of protecting or retaining structure. Such responses are the most common reaction to coastal erosion problems, both within New Zealand and overseas. While structures do often prove adequate for the needs of erosion sites, it is not uncommon for further problems to occur as a result of the structure either at the original site or at an adjacent one. In some cases, such as at Omaha Beach in New Zealand, the coastal structure may prove to be totally inadequate. The structures discussed in this report are those that could adequately and effectively control erosion at Pigeon Bay, and from the narrow point of view of the loss

of land at the foreshore would be satisfactory. They do however have certain drawbacks. All structures built in such a dynamic area would require professional engineering advice on their design, construction and maintenance. Sufficient expertise in this area is not easily found. The cost of any structure, particularly the construction and maintenance, is likely to be considerable.

As the resources of the reserve board itself are relatively modest, financial assistance would have to be sought, either with the local authority, or central government through the Department of Lands and Survey or the Ministry of Works and Development and the Soil Conservation and Rivers Control Council. This latter body has already assisted with protection work and may consider doing so again. The availability of such finance is not known. However, while finance may be available for the building of structures, the Soil Conservation and Rivers Control Council does not assist in the maintenance of them. This aspect would be the sole responsibility of the board. The greatest concern in selecting a structural feature to solve the problem of coastal erosion, is the environmental side effects. In almost all cases, structures tend to remove any sense of a natural environment by their visual impact, but may also create other problems for marine life habitats and yachtsmen, and cause erosion in other areas. It is also necessary if there is involvement below mean high water mark, that approvals and licences are sought from the Ministry of Transport or such body as it has delegated authority to under the Harbour Act 1950.

If it is the overriding desire of the board to retain the reserve as near to its present character as possible and it also wishes to exert some control over the erosion of the seaward berm, then beach renourishment will best achieve this. It could be carried out relatively simply and the financial cost of such an exercise is not likely to be beyond the resources of the board, though it is probable that support would be required from central government. Renourishment would involve the dumping and placement of Banks Peninsula boulders of a similar size to those already making up the beach, at the northern end of the present reserve. This area is important for two reasons. Boulders dumped here would be free to be moved by the longshore drift, along the entire length of the sea front thereby benefiting the whole reserve. More importantly however, the period of time over which the erosion regime has been active and the width of the original boulder ridge at the northern end, would indicate that its present width is not great. It may therefore be a matter of some immediacy that restorative action be taken, or at the very least some protection of the remaining feature. Should this underlying structure be breached at any time, the effects on the reserve would be considerable and it would be unlikely that the present state could be retrieved. The relative inexperience in New Zealand of beach renourishment programmes should not deter the board from this course of action if for other reasons it is the most preferred.

In the light of the present accumulated information, the board must now make a decision on how it will treat its

erosion problem. It must be guided in this exercise by the form that it wishes the reserve to take in the long term, and by the amount of impact that is acceptable on the other aspects of Pigeon Bay. It is expected that this decision will also be constrained by the availability of finance and by the influence of other regulatory bodies.

ACKNOWLEDGEMENTS

I would like to thank the following people who have assisted with the preparation of this study.

Dr R.M. Kirk - for the inspiration to select a coastal topic, for assistance in field data gathering, for guidance in the presentation of the work and for rekindling enthusiasm when required.

Department of Lands and Survey - the Chief Surveyor for supplying the aerial photographs, vehicle and surveying equipment. The Planning Section of General Draughting for preparing the figures. The Typists for efficient and speedy typing.

Dr J.A. Hayward and Mr K.A. Ackley - for constructive criticism of this report in its draft form.

Mrs R.C. Coutts - for assisting in data gathering and the editing of the study.

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