COASTAL DYNAMICS AND SEDIMENTATION AT POINT ELIZABETH, WEST COAST, SOUTH ISLAND, NEW ZEALAND.

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CHAPTER THREE

PATTERNS OF HISTORICAL COASTLINE CHANGE

Introduction

An important facet of this investigation is to identify whether the position of the shoreline has in the past and/or is presently undergoing erosion and/or accumulation of sediment. This is necessary in that it not only allows calculations to be made of the volume of change, but enables predictions of future change as well. The identification of sources and depositional zones for sediment allows further inferences to be made on the direction(s) of sediment transport. It is therefore possible to begin constructing a sediment budget for the area, identifying the sources, transport paths and volumes of sediment under transport.

Research Undertaken

To measure historical fluctuations in the position of the shoreline, a study was made of all relevant Deposited Plans and Survey Office Plans at the Lands and Survey Department in Hokitika. Additional information was obtained from maps and plans belonging to the Greymouth Harbour Board in Greymouth. Aerial photographs were obtained from New Zealand Aerial Mapping Limited in Hastings. A list of the sources used in this investigation is given in Appendix V.

Where shown, the position of the Mean High Water Mark (MHWM) was scaled from the original sources onto one of three basemaps for interpretation. Cadastral maps were used for this purpose because road and property boundaries provided reference points to which accurate measurements could be made. The cadastral maps used on Blaketown and Rapahoe beaches were at a scale of 1:2000. The map used at Cobden Beach was at a scale of 1:10,000. The subsequent calculations made with respect to the volume and rate of historical coastline change may therefore be in error by approximately (±) 1 to 2% on Blaketown and Rapahoe beaches. On Cobden Beach the error could be as large as (±) 5%.

The Crown Grants Act (1908) provides a precise definition of the legal seaward boundary of the land around the New Zealand coast. This boundary is the Mean High Water Mark (MHWM). When a building section, road or any other facility is surveyed adjacent to the coast, the position of the MHWM must be shown on the survey plan in accordance with the Act.

In practice, considerable difficulty has been experienced in implementing the precise legal definition provided by the Crown Grants Act (1908). Gibb (1978) has shown that up to seven practical procedures that purport to define the Mean High Water Mark, each with its own line on the ground, are in current use. Because of these differences in the positioning of the MHWM there are errors involved in the calculation of coastal erosion and accretion, which are of an unknown magnitude. However, it has been assumed that these errors are small, relative to the extent of coastal change.

After the MHWM positions were transferred onto the basemaps, the area present between successive positions was calculated in square metres. This figure was then multiplied by the average depth of sediment which has eroded (or accumulated) above MHWM, in order to determine the volume of coastal erosion or accretion.

Good historical data were available only for Blaketown, Cobden and Rapahoe beaches. These areas have had regular surveys for roads and houses adjacent to the coast. The cliffed coastline has had little work carried out on it for which the position of the MHWM has been marked.

As previously noted, the Kaiata Mudstone is the only cliff-forming lithology which is rapidly eroded by the sea. The remaining hardrock cliffs erode at a rate which aerial photographs do not reveal. The reason for this is the short time span these photographs cover. Rates of cliff retreat along this section of coast are discussed by Gibb (1978) and are referred to later in this chapter.

This chapter now turns to deal with the beaches of Blaketown, Cobden and Rapahoe, for which good historical data were available.

Blaketown Beach

The five kilometres of beach south of the Grey River has the longest and most detailed record of historical change in the study area. Here, maps and plans show successive positions of MHWM back to 1874.

Prior to construction of the Grey River port in 1884 the position of the river mouth varied considerably from north to south. Like many other river mouths on the West

Coast, the passage of storms and high river flows regularly changed the position of the entrance to the river. Several maps and plans held at the Greymouth Harbour Board offices in Greymouth show these fluctuations. For example; map numbers 136-1, 134, 251, 252 and 253.

However with the construction of the breakwaters either side of the river mouth being completed in 1884, the position of the river mouth became permanently fixed. Sediment began accumulating against the southern breakwater from this time, a process which continues today. Successive surveys along this beach have recorded the gradual seaward movement of the position of the MHWM. The surveys indicate that the construction of the breakwaters has caused sediment to accumulate for the full five kilometres of beach which this study addresses. The volume and rate of accumulation is greatest adjacent the breakwater and decreases toward the south. Figures 17 and 18 show the positions of the MHWM's which were adopted off old maps and plans. Many more positions of MHWM could have been shown on Figure 17, but those shown are representative of sediment accumulation on the beach for the years 1874 to 1981. Not all the beach has been subject to surveys from which the volume and rate of sediment accumulation can be measured. That part of Blaketown Beach around the Greymouth aerodrome is particularly lacking in this respect (Figure 19). The only two areas for which measurements are possible are shown in Figures 17 and 18.

The plotting of these MHWM positions yields data relating only to the area of accumulated sediment. To calculate volumetric change the depth of sediment which has

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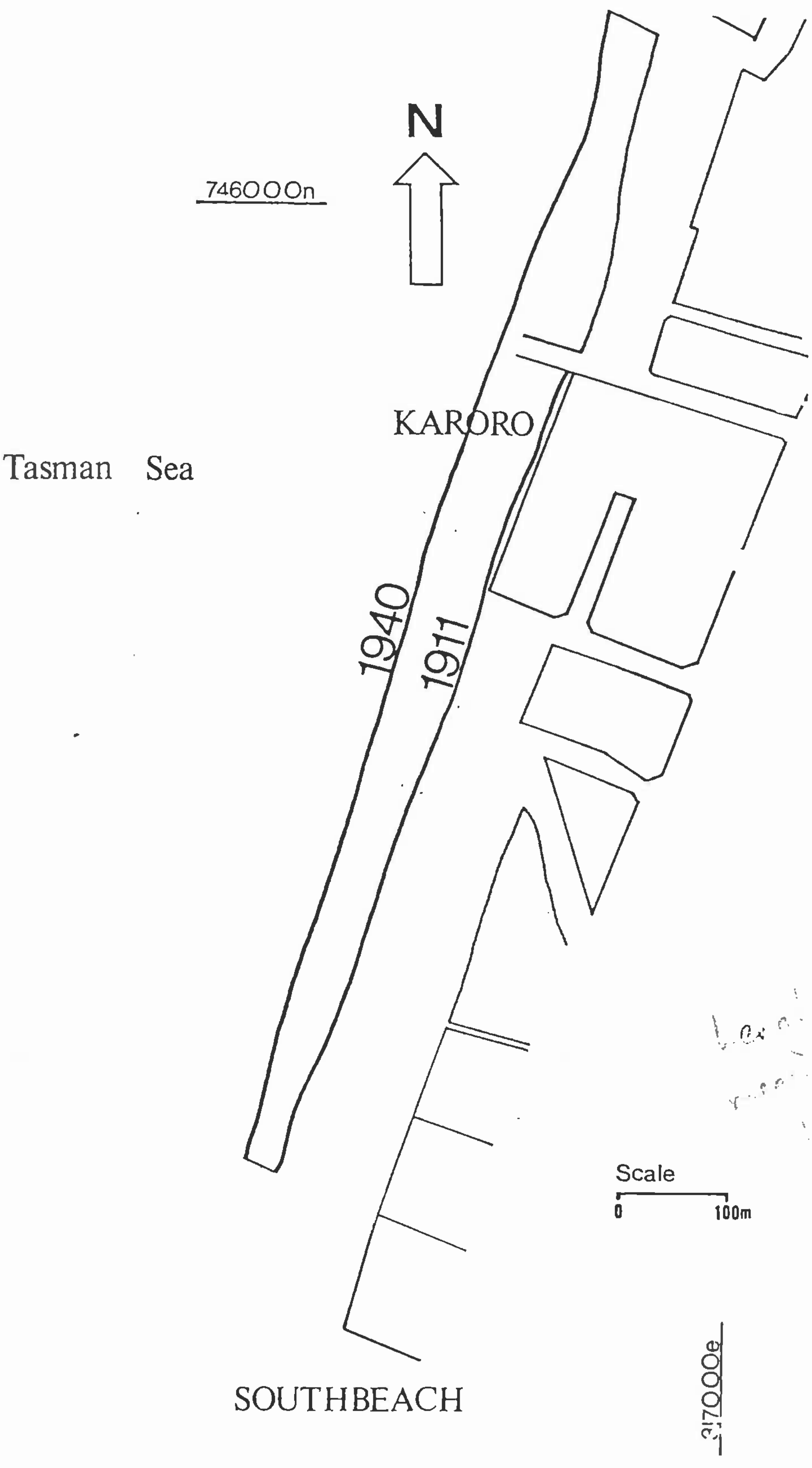

Figure 18

Positions of Mean High Water Mark, 1911 and 1940

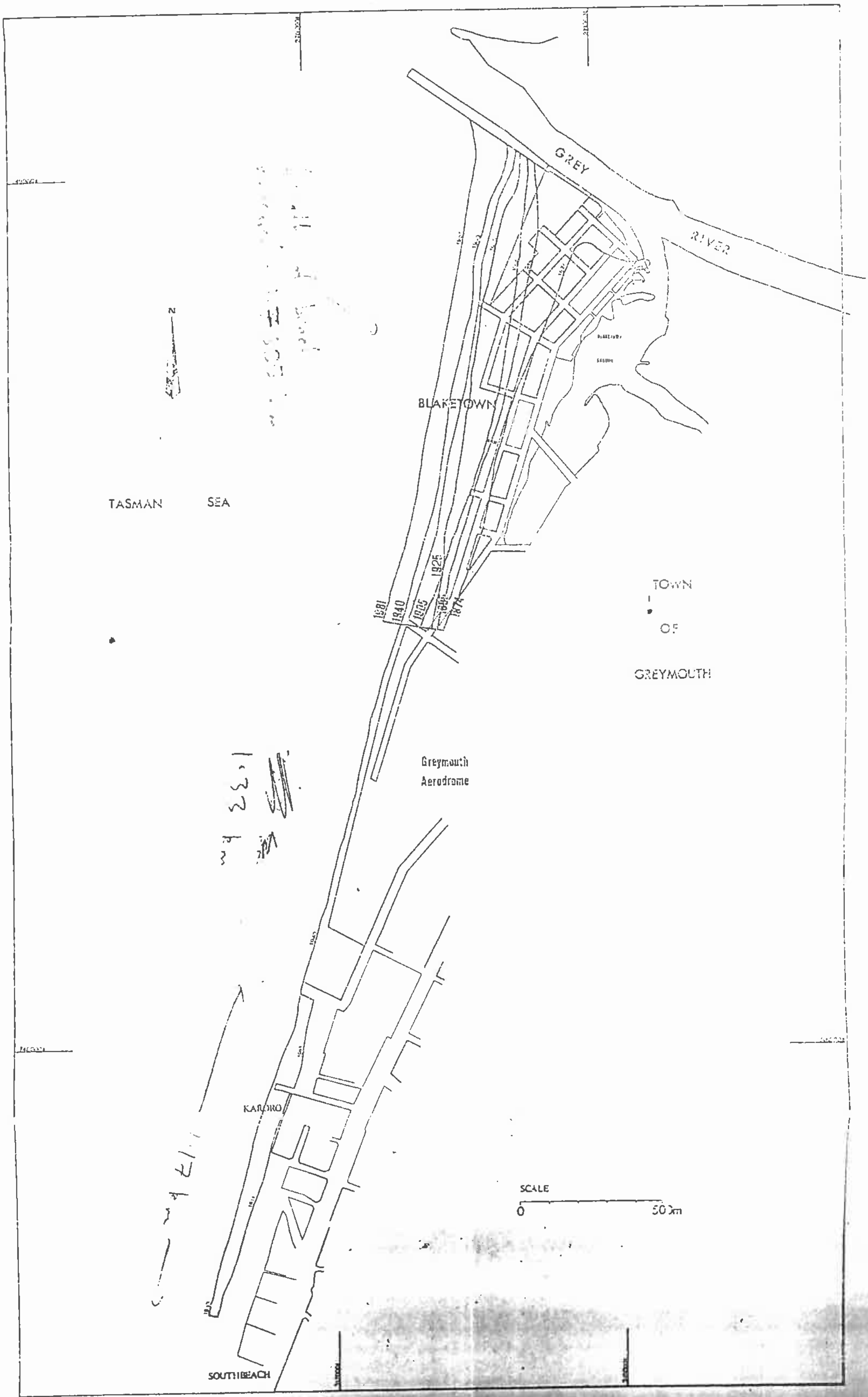

Figure 19

Successive positions of the Mean High Water Mark on Blaketown and Karoro Beaches.

accumulated above MHWM must be measured. On Blaketown Beach this depth averages 2.83 metres. This figure was obtained from ten sets of beach profiles constructed along this beach between 1923 and 1944. They show that the depth of accumulation is relatively homogeneous for the whole beach. Since there is no evidence that the angle of the beach face has been changing along the beach, the figure of 2.83 metres has been adopted for the whole beach from 1874 to 1981.

Table 4 shows the volume and rate of sediment accumulation between the successive positions of MHWM for the years 1874 to 1981. The data in Table 4 refers to Figure 17. The area to the south of Figure 17 around Karoro (Figure 18) has accumulated 178,813 cubic metres at an average rate of 6165 cubic metres a year ($m^3.yr^{-1}$), for the years 1911 to 1940. If allowance is made for the fact that sediment accumulation decreases south along the beach, then an average rate of coastal progradation for the full five kilometres of + 2.87 $m.yr^{-1}$ seems reasonable. This applies to the years 1874 to 1981. Of course the rate of accumulation adjacent to the breakwater itself has been much higher. Gibb (1978) has estimated that adjacent the southern breakwater of the Grey River the rate of progradation for the years 1930 to 1944 was + 6.29 $m.yr^{-1}$. However, the present study shows that for the longer time span of 1874 to 1981 the rate was approximately + 4.75 $m.yr^{-1}$ at the same site. Further south at Karoro the rate of progradation for the years 1911 to 1940 was + 1.53 $m.yr^{-1}$.

Gravel extraction plants have operated on this beach for many years. Discussion with the operators of these

Table 4: Volume and rate of sediment accumulation on Blaketown Beach for the five survey periods between 1874 and 1980.

Dates	Years	Volume change (Cubic metres)	Mean rate of accumulation ($m^3.yr^{-1}$)
1874-1895	21	+396720	18891
1895-1905	10	+135840	13584
1905-1925	20	+286848	14342
1925-1940	15	+301740	20116
1940-1980	40	+325693	8142
Total		+1446841	Average: 15061

plants suggests that less than 15,000 m^3 in total has been removed. Therefore the valid conclusion, based on the evidence available, is that between 1874 and 1981 not less than 1,610,654 m^3 have accumulated on Blaketown Beach. Obviously much more than this has accumulated because there are large areas for which data are unavailable. However it is not known how much more.

In addition to discussing the rate and volume of sediment deposition, there is a considerable quantity of information available concerning the origins, and modes of sediment transport on Blaketown Beach.

The most straightforward proposal to explain the accumulation of sediment is to invoke a simple net northward transport up this coast which construction of the breakwater interrupted. This would account for accumulation on Blaketown Beach and erosion due to sediment starving on Cobden Beach. The sources of sediment under such a scenario are probably contributions by rivers and coastal erosion to the south of the study area.

However, analysis of sediments, wave and current processes, and changes in the rate of sediment accumulation on Blaketown Beach, reveals that this explanation is overly simplistic. Furthermore, it will be shown that to accept such a simple pattern of sediment transport is to mask other patterns of sediment transport which are also occurring.

Although analysis of sediments will be covered in detail in Chapters Five, Six and Seven, some of the points discussed in those chapters are worthy of mention here. Analysis shows that sediment in the size range from fine sand to pebbles is being moved from the Grey River onto the adjacent Blaketown and Cobden beaches. The analysis also shows that most of the fines discharged from the Grey River are winnowed offshore into deeper, quieter water. Since only fine sand was found around the Grey River mouth, the gravel which is presumably deposited there during floods must be out of hydraulic equilibrium. Because Blaketown and Cobden beaches contain grain sizes as coarse as those found in the Grey River, and since gravel is not accumulating on the seafloor around the river mouth, transport of this coarse sediment onto the beaches must occur. The question arises - does this coarse material move onto both Blaketown and Cobden beaches? The historical accumulation of material on Blaketown Beach suggests that the highest proportion accumulates there. Evidence presented shortly however, indicates sediment bypassing from Blaketown to Cobden Beach is becoming increasingly important through ti

The Grey River was shown in Chapter Two to yield between 140 and 322 kt of bedload to the coast each year. As a general guide, volumes in cubic metres equates to tonnes multiplied by 1.8. Therefore, between 252,000 and 579,000 $m^3.yr^{-1}$ are discharged as bedload by the Grey River each year. If this is so, there is no difficulty in accounting for the 15,000 $m^3.yr^{-1}$ accumulating on Blaketown Beach as originating from the Grey River. In fact the volume being supplied far exceeds that which has historically accumulated. This means that either the calculations of bedload are incorrect; or that the majority of bedload is the fine sand being deposited on the shelf; or that vast volumes of material are reaching the beaches, being broken down, and then winnowed offshore.

For sediment to accumulate on Blaketown Beach having been derived from the Grey River, it must be transported south and onshore by waves from the northwest with an associated southerly longshore current. It is uncertain whether the river sediment is deposited in decreasing quantities south of the breakwater; or carried south in the surfzone before being moved onshore, and later north along the beach to be stopped by the breakwater.

Sunamura and Horikawa (1972) have shown that by analysing the sediment coefficients of mean size and sorting, detection of their transport directions on beaches, especially away from known sources, is possible. On Blaketown Beach the coefficients of both mean size and of sorting decrease toward the south. This is seen to indicate transport of sediment away from the Grey River mouth (the source) south down Blaketown Beach. This supports the view that sediment derived from the Grey River is deposited directly onto Blaketown Beach adjacent to the breakwater. Subsequently this material is transported south down the beach. This appears to be the most logical explanation for the origin of the sediment found there. There are no good reasons to expect that material is transported south in the surfzone before being moved onshore. Furthermore, under a northwest angle of wave approach the beach immediately south of the breakwater is relatively protected from northwest waves, favouring sediment deposition. Therefore, based solely on sediment analysis it can be shown that a simplistic northward transport of sediment is not occurring.

The second approach which was used to determine sedimentation patterns on Blaketown Beach was analysis of wave refraction diagrams. Figures 20 and 21 show waves approaching the study area from the west-southwest and northwest respectively. Under a northwest angle of wave approach there are no significant longshore energy gradients or wave height differences on Blaketown Beach. Under these conditions the angle of wave approach with the shore determines the direction of the longshore currents and resulting sediment transport. Under a southwest angle of wave approach a longshore energy gradient decreasing to the north is set up along Blaketown Beach. The difference in wave height south to north is - 0.25 metres. This is sufficient to substantially augment any longshore current which may be present due to the angle of wave approach with the shore. Together, or individually, these currents are probably capable of transporting sediment north against the breakwater. Under these southwesterly conditions it seems likely that if sediment is available to be moved north along this beach from south of the study area, then the longshore currents generated under a southwest angle of wave approach are there to do so. In addition, sediment deposited on this beach from the Grey River is almost certainly redistributed by these currents.

In fact both situations described above probably occur. That is, bedload from the Grey River is deposited on the beach and transported south by longshore currents. Under southwest angles of wave approach, both this sedime plus some unknown quantity from south of the study area, is moved back to the north. The evidence presented by th

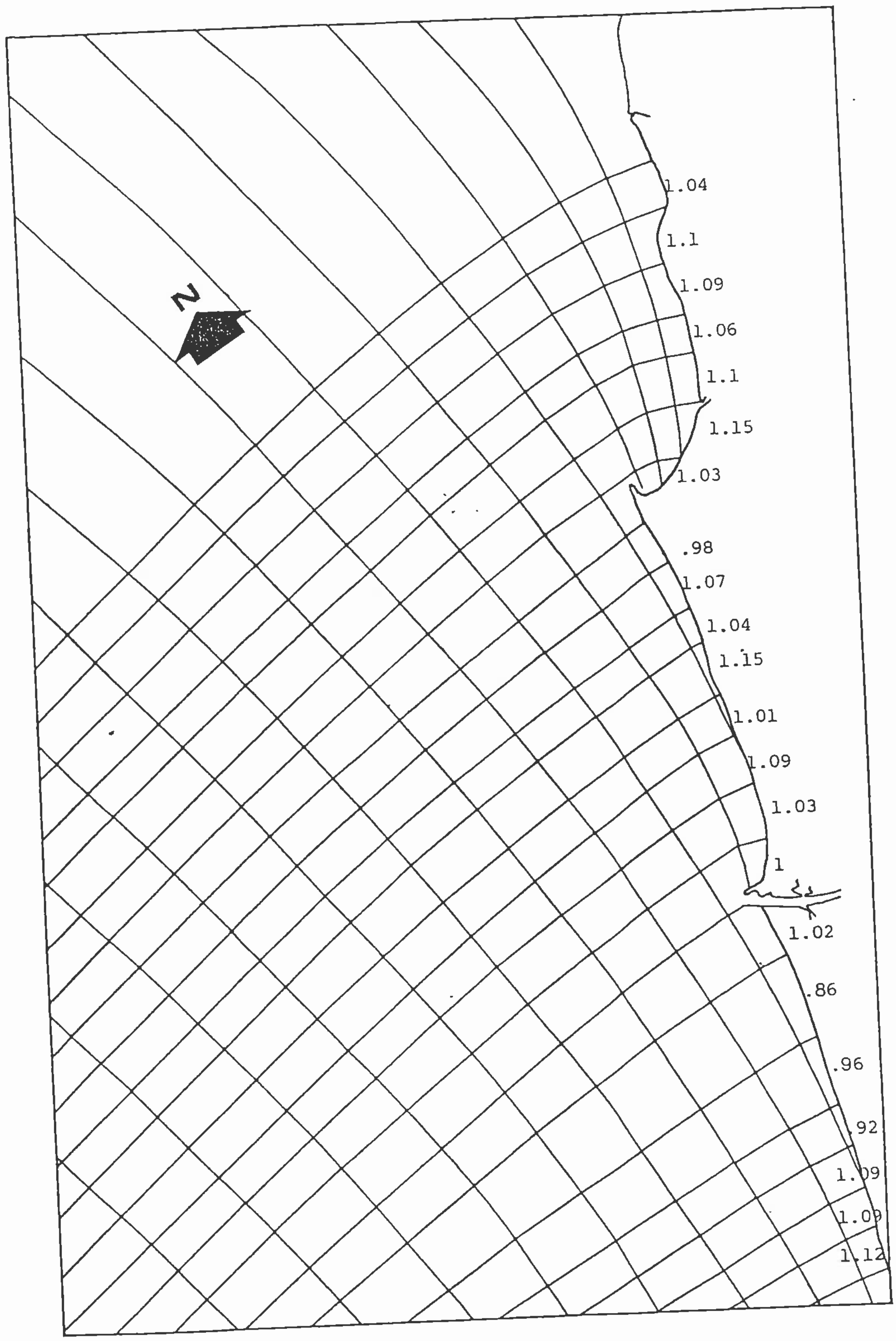

Figure 20

Wave refraction, wave crests approaching from the west-southwest. T = 10 seconds. Every 8th wave crest is shown. Numbers refer to wave height in metres at the shore.

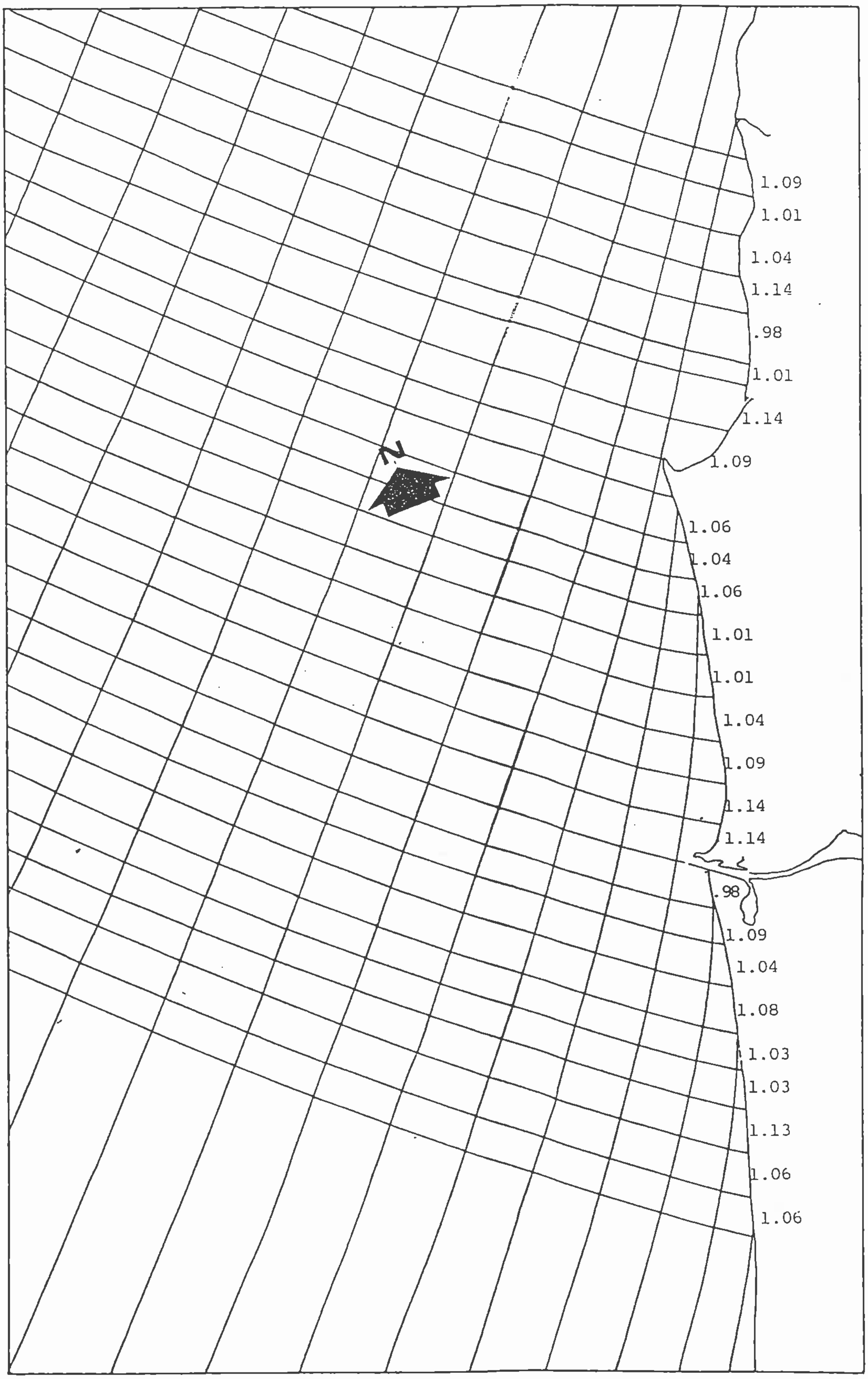

Figure 21

Wave refraction, wave crests approaching from the northwest. T = 10.2 seconds. Every 10th wave crest is shown. Numbers refer to wave height in metres at the shore.

wave, current and sediment analyses indicates that this sediment is largely trapped by the breakwater, thereby preventing its transport onto Cobden Beach. However, analysis of long term changes in the rate of sediment accumulation on Blaketown Beach indicates that this may not always be the case. To see whether long term changes in the rate of sediment accumulation have taken place on Blaketown Beach, the rate of accumulation in $m^3.yr^{-1}$ was plotted against time. This was done for each of the five survey periods listed in Table 4. A regression trend line was plotted through these points. Figure 22 is the resulting correlation diagram. Note that there is a weak negative correlation of - 0.57 which appears to indicate a decrease in the rate of sediment accumulation through time. Although mean annual rates of accumulation vary considerably about this trend line, the average decrease in the rate with which sediment is being trapped is - 95.25 $m^3.yr^{-1}$. The accumulation indicated by this correlation is a minimum estimate of both longshore transport from south of the study area; and onshore transport from the Grey River, since the breakwater probably does not trap everything supplied to it.

The important feature about this correlation is that it shows the minimum net longshore drift on Blaketown Beach is in the range between 8000 and 19,000 $m^3.yr^{-1}$. That is, a magnitude of 10^4 $m^3.yr^{-1}$. This is in direct contrast to the conclusion reached by Furkert (1947), who maintained that littoral drift from south of Cape Foulwind was of the order of 10^6 $m^3.yr^{-1}$, a higher rate by two orders of magnitude. The results from the present study are of a

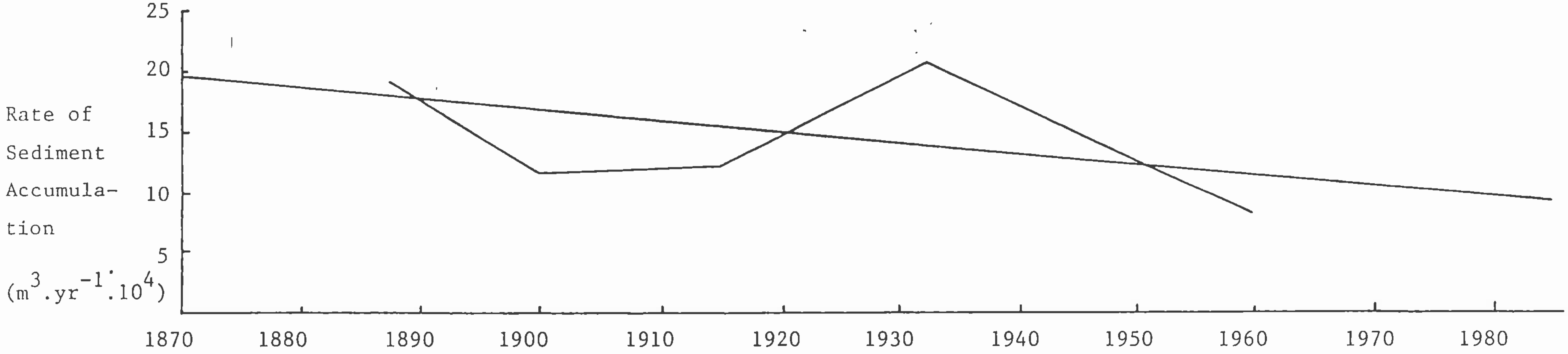

Figure 22

Regression showing changes in the rate of sediment accumulation through time on Blaketown Beach.
($a = 19,776\ m^3$; $b = -95.25\ m^3.yr^{-1}$; $r = -0.57$; $r^2 = 0.324$)

similar magnitude to the drift presently accumulating against the southern breakwater of Timaru harbour. There, Tierney (1977) has shown that 60,000 $m^3.yr^{-1}$ are being trapped. Because accumulation on Blaketown Beach includes both longshore transport from south of the study area, and onshore transport from the Grey River, the net long-shore transport must be less than that which has accumulated annually on Blaketown Beach. How much less is unknown because it is impossible to determine the volume supplied by each source.

This fall in the rate of accumulation (- 95.25 $m^3.yr^{-1}$) requires an explanation. It is proposed that this fall (or apparent fall given that only five data points exist) is caused by an increase in the bypassing of sediment past the river mouth. When the breakwaters were initially constructed, the quantity of material which accumulated on Blaketown Beach each year was high because the area available for it to accumulate in was large. As time has passed the rate of accumulation has fallen because there is less space for it to accumulate in.

Referring to Figure 22, if it is argued that the regression line value for the year 1884 is the best estimate of the proportion of the longshore drift able to be trapped by the breakwater at that time, then 18,085 m^3 would have accumulated in 1884. That is;

$$\frac{Q\ (\text{gross})}{Q\ (\text{trapped})} = 18{,}085\ m^3.yr^{-1}$$

where Q equals quantity of sediment. Therefore Q (net) equals 18,085 m^3 for the year 1884. If this was the case for 1884 then the regression line indicates that the rate of accumulation for 1984 is down to 8,804 $m^3.yr^{-1}$. This is 48.6% of the initial rate of accumulation for 1884. This means that either the rate of sediment supplied to Blaketown Beach has declined, or that the rate at which sediment is bypassing the Grey River mouth onto Cobden Beach is 51.4% greater than in 1884. There is no evidence that the rate of sediment supply has decreased. If anything, land clearing due to increased farming in the Grey River valley should have increased the rate of sediment supply since 1884.

This argument suggests that half of the original volume which accumulated on Blaketown Beach in 1884 now bypasses onto Cobden Beach. This represents approximately 8000 to 9000 $m^3.yr^{-1}$. If the annual decrease in the rate of accumulation continues at the rate of - 95.25 $m^3.yr^{-1}$, then Blaketown Beach should cease to accumulate sediment in approximately 2067 A.D. Until that time the breakwater will act like a groin, preventing much of the northward transport of littoral sediment. However, its effectiveness in that role will continue to diminish through time as more and more sediment accumulates. When Blaketown Beach ceases to act as a trap for sediment, all sediment derived from south of the study area and the Grey River will presumably bypass Blaketown Beach and be deposited on Cobden Beach.

Cobden Beach

North of the Grey River the evidence available indicates that the beach has been undergoing erosion in historical times. Unlike Blaketown Beach there are less data available to work with, covering a much shorter time span. Although some data are available for short lengths of coast for the years 1874, 1958, 1971 and 1976; the only adequate data for the whole beach are for the years 1910 and 1984. An unbroken record of MHWM for these two years runs from the beach adjacent to Bright Street in Cobden, north to the end of the road at Cobden Beach (Figure 23). Based on two sets of transverse beach profiles made on this beach during 1983 and 1984, the average depth of sediment eroded off this beach above MHWM is approximately 4.72 metres. Since the alluvial surface into which the beach is cut is essentially horizontal, this figure has been adopted as the average depth of sediment eroded off this beach. Based on these measurements this represents a total loss of sediment from this beach of 1,598,970 cubic metres between the years 1910 and 1984. The beach has retreated, on average, 100 metres in these 74 years, at an average rate of $- 1.35\ m.yr^{-1}$. Gibb (1978) has also calculated erosion rates at three sites on this beach. Averaged, they represent a net rate of erosion of $- 0.69\ m.yr^{-1}$. Such differences could be due to variations in the rate of erosion along Cobden Beach. However, different data sources may have been used to calculate the rates of retreat, which may account for the observed differences.

Such differences do not invalidate the conclusion that Cobden Beach has been eroding since 1910. Unfortunately no data exists for the period prior to port construction being completed in 1884 that would allow an assessment of coastal change for "natural" pre-construction conditions. Are there then any explanations to account for this

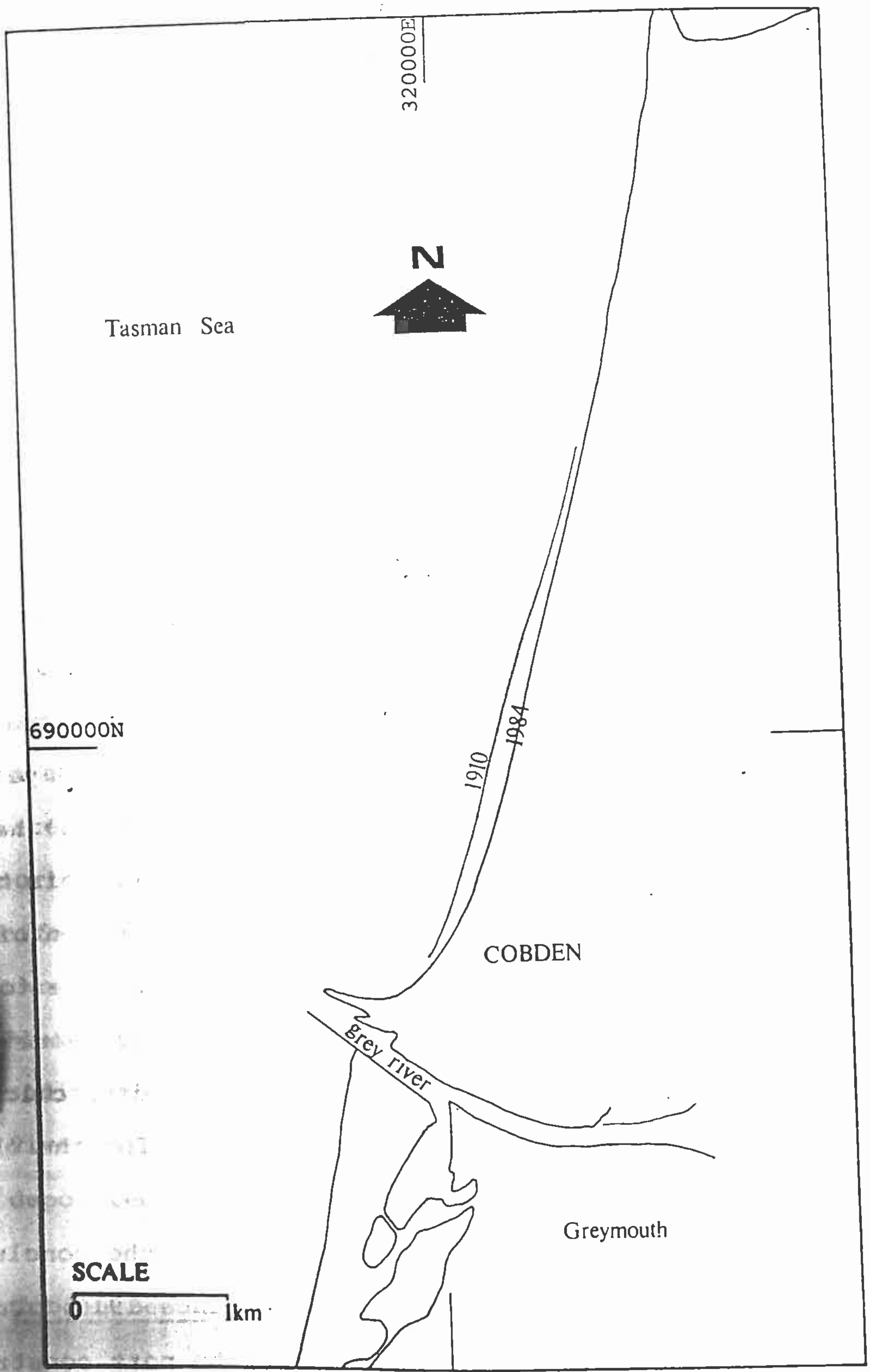

Figure 23

Map showing the historical positions of Mean High **Water** Mark on Cobden Beach for the years 1910-1984.

historical erosion? The obvious explanation lies in the construction of the breakwaters. Presumably material which is now accumulating on Blaketown Beach was moved onto Cobden Beach prior to port construction.

It is interesting to note that the average storage on Blaketown Beach approximates the average loss from Cobden Beach; approximately 15,000 $m^3.yr^{-1}$ versus approximately 22,000 $m^3.yr^{-1}$. Note that the length of beach and the time spans over which these calculations were made are different, possibly accounting for the observed differences. This does suggest that the harbour works are the cause of the erosion. It also suggests that the range of around 8000 to 19,000 $m^3.yr^{-1}$, which was suggested as the minimum net longshore drift level, is in fact close to the actual value of the net northward transport which the harbour works are trapping.

With increased bypassing of sediment onto Cobden Beach one would expect the rate of coastal erosion on Cobden Beach to be decreasing. Although 8000 to 9000 $m^3.yr^{-1}$ is apparently being deposited on Cobden Beach, the ultimate source of which is the Grey River and possibly the coast south of the study area, the quantity is small in relation to the total volume of Cobden Beach. The effect in ameliorating the erosion is therefore small.

The second feature which would support the notion of sediment bypassing the river mouth onto Cobden Beach is the relatively coarse nature of the sediment on the beach immediately north of the river. Further analysis of the origin of sediment on this beach is made in later chapters.

tectonically uplifted marine terrace of the Awatuna Formation is experiencing erosion as the mudstone cliff retreats. In Chapter Six modal analysis indicates that this is a possible source of fine and very fine sand to the floor of Rapahoe Bay. Pebbles derived from this terrace probably also contribute very small quantities to the bay floor. However, these pebbles could also be derived from Rapahoe Beach or Seven Mile Creek, transported south under the net southerly longshore current present in the bay. The sand and/or pebbles derived from the terrace are probably minor sources in relation to the others which exist in the vicinity.

Conclusion

In conclusion, it is possible to see that several important features with respect to historical coastline change have been identified. Apart from Blaketown Beach, the balance of the coastline is undergoing erosion, the rate dependent upon the lithology in question. Most eroding sediment probably gets transported offshore, although the morphological evidence suggests considerable longshore transport to both north and south also occurs. The cause of the erosion appears to be the low level of coarse sediment nourishment to beaches, combined with a high level of wave energy which the coast is unable to withstand.

Blaketown Beach is the only zone in which historical deposition has been recorded. It appears to be receiving the bulk of its sediment from the Grey River, although an unknown contribution from south of the study area also seems likely.