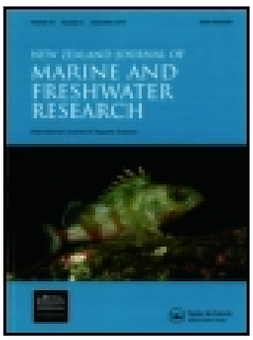

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Poverty Bay, New Zealand: a case of coastal accretion 1886–1975

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Abstract Survey and aerial photograph measurements reveal that increased sediment yield has resulted in the deposition of 3 970 000 m^3 of material around the bay and up to 500 m of progradation in the south-west of Poverty Bay, New Zealand, since the 1880s. Initially, port development enhanced sedimentation on the north-eastern side of the Bay, but later sand mining and river diversion caused the newly accreted deposit to be eroded. The eastern end of the beach now appears to be in a state of quasi-equilibrium. Stopbanking the Waipaoa River has increased sedimentation in the south-west where the rate of fluvial supply exceeds the capacity of marine transport processes. Increased sediment yield associated with land clearance has caused a 25% increase in the volume of material annually deposited on Waikanae and Muriwai beaches.

Keywords Poverty Bay; beach surveys; bush clearance; coastline development

INTRODUCTION

Land clearance associated with the conversion of native forest to exotic pastures during European settlement has been shown to cause river regime changes (Strahler 1958; Leopold et al. 1964) and an increase in peak flows and sediment yields (Sopper & Lynch 1970; Williams 1980). In New Zealand, catchment erosion studies have mainly concentrated on the effects of higher sediment yields within the catchments (Hamilton & Kellman 1952; National Water and Soil Conservation Organisation 1970); little attention has been given to the effects of increased sedimentation rates on the coast. Indeed, Bird (1973) has cited human activities as promoting coastal erosion through dam construction, for hydro electricity, irrigation, or flood control schemes, preventing new sediment reaching the coast. In contrast to Bird's experience, land development in Poverty Bay has caused an increase in the volume of sediment being deposited on the beaches. Jones & Howie (1970) estimated that about half of the sediment eroded from the headwaters of the Waipaoa River, was deposited in the lower reaches of the basin, the remainder being discharged into the sea in Poverty Bay (Fig. 1). Of the material being discharged by the river, Smith (1977b) estimated that less than 1% was being deposited on the beaches, the remaining fines being lost offshore.

Gisborne Harbour Board reports indicate that port development, including construction of a river training wall at the mouth of the Turanganui River, initially caused accumulation of sediment on Waikanae Beach and prevented gravel drifting west of the river mouth. Since the Turanganui River was diverted to the west of its original course and out of the harbour in 1927, it has removed much of the material which had been deposited in the lee of the training wall.

The effects of the river mouth changes, and the altered flow and sediment regime of the rivers accompanying land clearance, have been recorded on the coast by a series of surveys (1886, 1910, 1926, and 1942) and, since 1938, by aerial photographs. This paper examines these changes and describes the effect of European settlement on coastline development in Poverty Bay.

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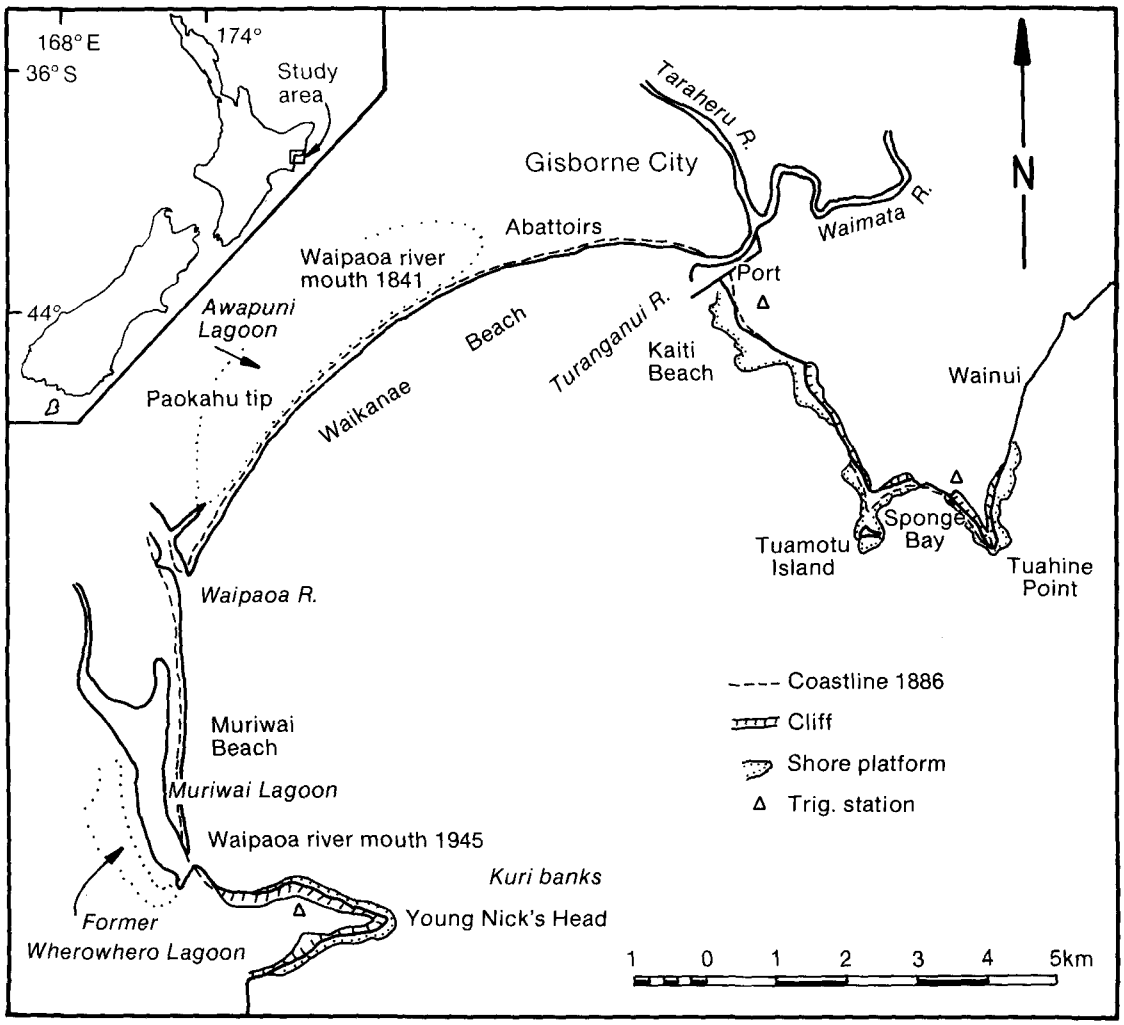

Fig. 1 Location map of Poverty Bay, New Zealand.

PHYSICAL SETTING

Poverty Bay lies on the east coast of the North Island, New Zealand. It is exposed to the south-east, but is protected from the north and south by the headlands of Tuahine Point and Young Nick's Head (Fig. 1). The bay entrance is 8.5 km wide from headland to headland. However, an area of shallow water (Kuri Banks) north-east of Young Nick's Head, and extensive shore platforms around Tuahine Point and Tuamotu Island reduce the effective width of the deep-water entrance.

Within Poverty Bay the coast opens out onto 13.4 km of mainly sandy beaches which are interrupted by the mouths of Muriwai Lagoon and the Waipaoa River. The northern end of the sandy coast is terminated by the mouth of the Turanganui River adjacent to the harbour training wall. Beaches to the east of the port and Muriwai Lagoon mouth consist of mainly gravel deposits with some sand.

The Waipaoa and Turanganui rivers drain Tertiary sandstone and mudstone hill-country catchments of 2200 km^2 and 220 km^2 respectively. The strata are faulted and highly erodible. Before European settlement, the Waipaoa River meandered freely over the Poverty Bay flats and distributed material along the coast. The presence of lagoons, numerous old channels, and varying depths of deposition across the flats (Pullar & Penhale 1970), all demonstrate the importance of the Waipaoa River as a mechanism for sediment dispersion and coastal progradation around the bay.

Wave observations made from 1973 to 1977 (Ministry of Works unpubl. data) show the predominant waves are from the south and south-east, have 9–10 s periods, and are about 0.8–0.9 m high. The variability of wave conditions within any month is as great as between months and no seasonal pattern is distinguishable (author's unpubl. data).

EUROPEAN SETTLEMENT AND COASTLINE CHANGE

Settlement and land clearance of the Waipaoa basin and Gisborne Plains can be considered to have taken place in three stages. Initially, under missionary guidance and together with examples set by European settlers, the scrub and bracken was cleared from the plains. The second stage, the clearing of the lightly bush-clad hills was largely completed by the mid 1870s. The final stage, from 1880s to 1910, was the clearing of the densely clad headwaters hill country which was mainly comprised of beech forest. Whereas bush clearance was practically completed by 1910, sporadic clearing continued to the 1920s (Allsop 1973). The geologists Adams (1910) and Henderson & Ongley (1920) observed increased hillslope instability and river channel sedimentation associated with land clearance and advocated reafforesting some of the more unsuitable areas.

The coastline of Poverty Bay is the seaward extremity of a roughly triangular fluvial plain. Pullar & Penhale (1970) mapped the deposition sequences and some former positions of the Waipaoa River channels over the last 3400 years and showed that sediments were widely distributed across the plains as a result of channel migration.

Since European settlement, the river has continued to change its course, particularly near the coast. Before 1841 the mouth was located immediately to the east of the present abattoirs and drained through what is now Awapuni Lagoon (Fig. 1; Williams 1899). After a flood in 1841 the river mouth was roughly at its present position, but in about 1925 it commenced a southerly migration, eroding the dunes in front of Wherowhero Lagoon and depositing the material seawards to form a sand spit. By 1945 the river mouth had reached the base of Young Nick's Head. In 1946 the river was diverted by a groyne to its present location as part of a flood control scheme. The old river channel, between the diversion groyne and Young Nick's Head, is now known as Muriwai Lagoon. Aerial photographs taken in 1938 show the remains of Wherowhero, and an earlier lagoon on the landward side of Muriwai Lagoon.

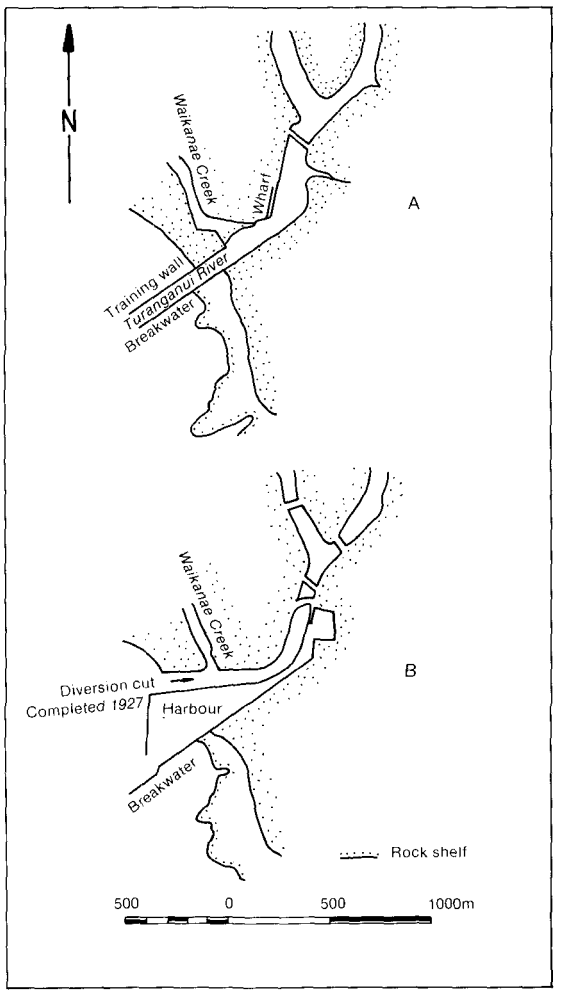

Fig. 2 Gisborne Harbour development: A, 1902; B, 1975.

The Turanganui River mouth and estuary have also undergone changes since the start of European settlement. Originally the port of Gisborne was located within the estuary. To overcome problems caused by the entrance bar and sedimentation within the estuary, a breakwater and a river training wall were constructed in 1902 (Fig. 2A). The added shelter provided by the training wall caused deposition along the eastern extremity of Waikanae Beach (Cadastral Plan held by Lands and Survey Department, DP 2956). Sedimentation problems within the harbour and at the entrance in 1914, 1916, 1917, and 1918 (unpublished Gisborne Harbour Board annual reports), led to the adoption of a plan to divert the river west onto Waikanae Beach. The diversion was completed by 1927 and the river mouth has remained in this

position ever since (Fig. 2B). Erosion of the eastern end of Waikanae Beach was reported in 1927, 1935, 1957, and 1958 (unpublished Gisborne Harbour Board Annual Reports 1927 to 1961), and as a result a limestone boulder protection wall was installed in 1959 to prevent further erosion.

COASTAL PROGRADATION AND EROSION

Historical positions of the coast line were established from transverse surveys, and examination of aerial photographs. Survey information consisted of field books and plans drawn by the original surveyors which were based on the local meridonal circuit. These surveys were converted to metric, coordinated and plotted on a common base map. Comparisons discussed here were made from this new metric map. The earliest survey, made in 1877, was omitted from this study because it was a compass traverse and could not be satisfactorily correlated with later surveys. An 1886 survey was found to be reliable and since it could be related to later surveys, it was used as a baseline map for coastline positions. The earlier traverses of the coast were relocated and the coastline resurveyed in 1974 (eastern end of Waikanae Beach) and in 1975. Because of the absence of a local datum, the high-water mark depicted on early plans was usually the edge of the dune vegetation or, less frequently, the storm flotsam line (Surveyors field notes, Department of Lands and Survey). Only in the 1926 survey (Department of Lands and Survey, DP 2956), in the vicinity of Gisborne City, was the high-water mark defined in terms of a level. When considering historical data, one should bear in mind that there may be volume changes without coastline position movement and also the reverse can be true. For example, early plans have little, or more commonly, no elevation data and hence estimates of dune growth cannot be made. Quite significant volumes of material may accumulate in the dunes without causing a change in shoreline position. By contrast, the migration of the Waipaoa river between 1925 and 1945 reworked existing beach sand moving to coastline c. 200 m seawards, but there was no evidence of a change in the rate of supply of new sediment at this time.

Twenty-seven sites were selected to measure the changing shoreline position on the Poverty Bay coastline (Fig. 3). Figure 4 explains the terms used in the text for linear and volume changes on the sandy beaches of Poverty Bay. Progradation and retrogradation refer to linear changes while accretion and erosion describe volume changes. Volumes have been estimated by assuming the beach cross section to represent the beach for half of the distance to the adjacent cross sections. The area of

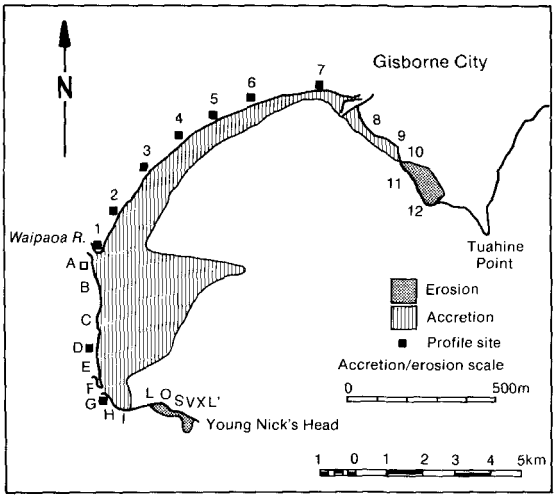

Fig. 3 Progradation and erosion around Poverty Bay, 1886–1975. Sedimentation has been mainly in the southwest of the bay. The profile sites are the positions where historical changes and modern beach fluctuations have been monitored. The other sites are where historical positions of the coast only have been compared.

the cross section was multiplied by the associated length of coastline to get volume. The area of the cross section referred to is the beach deposit above mean sea level (0.0 m elevation) and thus represents the minimum volume of material deposited in the bay since the 1880s. When discussing cliff erosion or accretion the erosion refers to the whole cliff face whereas accretion refers to a small deposit which may form at the base of the cliff preventing direct wave action on the cliff face. Comparison of Fig. 1 and 3 demonstrates that while the beach has prograded, the cliffs have tended to retreat. The cliffs facing south have retreated at a faster rate than those facing north, demonstrating the superior erosive effect of the dominant south and southeasterly wave climate.

For the sandy beaches, total progradation has been greatest in the southern part of the bay where extensive progradation of up to 500 m has taken place along Muriwai Beach. This extreme progradation has been caused by an influx of new fluvial material and the seaward redistribution of existing beach material as the Waipaoa River moved south in the lee of Young Nick's Head. On both the Waikanae and Muriwai beaches progradation increases towards the Waipaoa River mouth.

The surveys of the mean high-water mark in 1910, 1926, 1942, and 1975 show that the rate of progradation on Waikanae Beach has not been constant (Table 1). Before 1910 the highest rate (2.8 m/year) was near the Waipaoa river mouth,

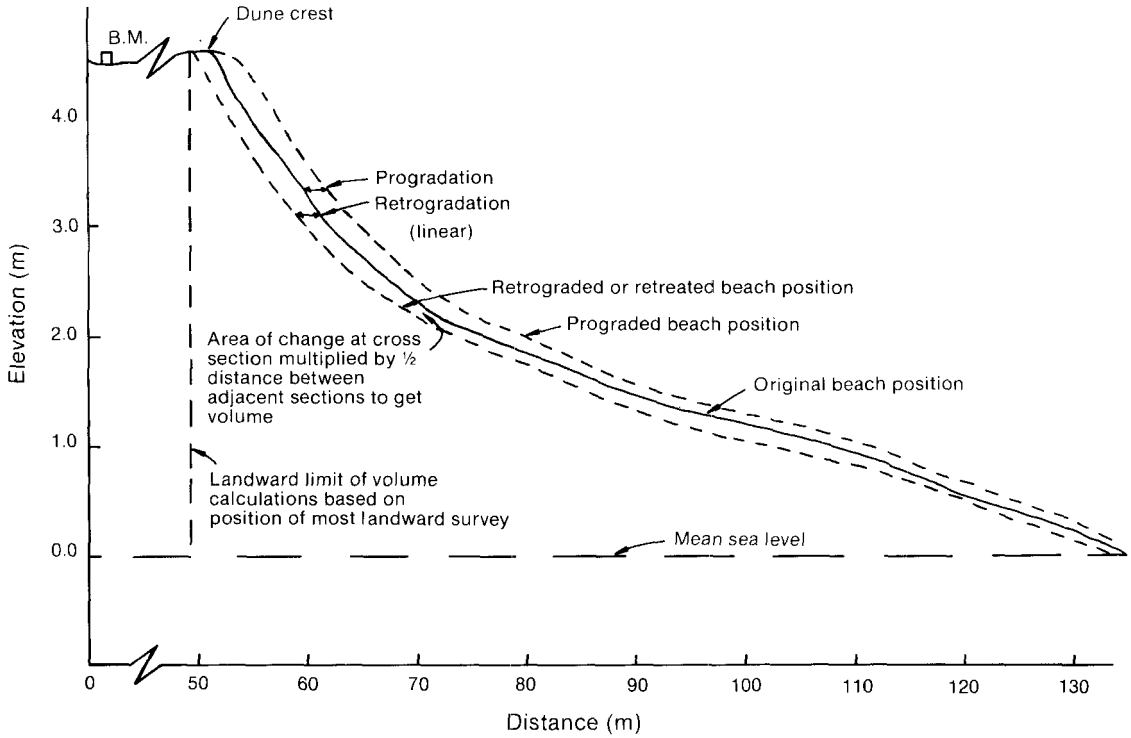

Fig. 4 Definition of linear and volumetric terms of beach change at a profile site as used in this study.

with Sites 2–6 having rates varying between 0.9 and 0.5 m/year. At Site 7 the rate was 1.2 m/year resulting from shelter given by the river training wall installed as part of the port development. From 1910 to 1942 Sites 1–3 maintained progradation rates in excess of 1 m/year whereas in the central bay, at Sites 4 and 5, rates declined to less than 0.5 m/year. At Site 6 the previous rate of progradation was maintained. The reduction in progradation in the central bay appears to be caused by the southward migration of the Waipaoa River mouth. From 1942 to 1975 the progradation pattern changed, with progradation rates of 0.6 m/year near the river mouth and greater than 1 m/year at Sites 3–5. Site 6 remained constant at 0.7 m/year. The rate of change at Site 7 was negligible, 0.1 m/year for the period 1926–74, and appears to be a result of the Turanganui River diversion. East of Site 7, erosion rather than progradation predominated; the average erosion rate was 0.4 m/year and adjacent to the river mouth erosion reached a rate of 1.1 m/year for the period 1926–74. Assuming that the limestone boulder protection constructed in 1959 on the beach backshore (immediately west of the diverted river mouth) prevented further erosion, the rates of retreat at Site 7 for the period 1926–59 becomes 0.5 m/year and 1.6 m/year at the river mouth, or considering the beach above mean sea level, an average loss of about 1000 m^3/year.

The volume of accretion on Waikanae Beach was determined at each of the profile sites and the total volume calculated by multiplying these volumes by the distance between sites. For Waikanae Beach, the volume of accretion from 1886 to 1910, and from 1942 to 1975, was 35 000 m^3/year — whereas for the same length of beach (the Waipaoa drifted South after 1925), between 1910 to 1942, the accreted volume was 30 000 m^3/year.

There are no data on the size of the developing sand spit caused by the Waipaoa River migrating south from about 1925. Material deposited south of Site 1 during this period is included in the estimates of deposition for Muriwai Beach. For the period 1886–1910, survey data show that Sites 1 and 7 were severely affected by fluctuating positions of the Waipaoa River mouth and the construction of a harbour training wall. If the localised changes at these sites are ignored, and cross section data from Sites 2–6 used to estimate the volume of deposition, the average annual volume of material being deposited on Waikanae Beach during early European settlement (1880s) was approximately 27 000 m^3/year. This volume is about 25% lower than the estimated sedimentation rate for the

period 1942–75 for the same length of beach. The total volume of sediment deposited on Waikanae beach from 1886–1975 is c. 2 730 000 m³.

There are insufficient surveys covering the length of Muriwai Beach to ascertain the rates of accretion for different periods. Part of the sediment source for Muriwai Beach has been sand from the eroding cliffs of Young Nick's Head to the south (Fig. 1). Smith (1975) estimated sediment from this source to be about 2000 m³/year. A comparison of the 1945 aerial photograph and the 1975 survey, together with profiles across the spit, established that the annual volume of deposition was c. 14 000 m³ (12 000 m³ being supplied by the Waipaoa River). The probable total volume of material deposited on Muriwai Beach between 1886 and 1975 is c. 1 240 000 m³.

The total volume of material deposited around the bay from 1886 to 1975 has been estimated at 3 970 000 m³, giving an average progradation rate of 0.8 m/year. Assuming that the effects of bush clearance had not become apparent on the coastline by 1910, and that the deposition rates on Muriwai Beach were about 25% lower than the 1945–75 rate, the rate of deposition at the start of the European era was about 38 000 m³/year which gives an average pre-European progradation rate of 0.6 m/year. This agrees closely with Pullar & Penhale's (1970) estimate of 0.57 m/year for the period 131 A.D. to 1953.

Table 2 summarises the sources of sediment supplied to the Poverty Bay foreshore for pre-European and present times. The estimate of sediment from the cliffs east of Kaiti is open to question. Whereas the rate of erosion is higher for these cliffs than Young Nick's Head, the proportion of sand sizes in the material is lower. Also part of this sand deposit is intercepted before it can get to the beach by harbour dredging. Thus 2000 m³ annually is probably a reasonable estimate. Before harbour development the volume from this source may have been considerably more since pebbles were drifted into Waikanae Beach from Kaiti continuously (MacKay 1949).

Table 1 Beach progradation and cliff retreat around Poverty Bay 1886–1975. Values in m/year; minus values refer to erosion.

Site	1886–1910	1910–42	1942–75	1886–1975
L'				0.0
X				−0.4
V				−0.1
S				−0.2
O				−0.3
L				0
I				0
H				0.8
G				0.9
F				1.7
E				2.7
D				2.8
C				3.3
B				3.7
A				5.6
	1886–1910	1910–42	1942–75	
1	2.8	1.4	0.6	1.5
2	0.8	1.4	0.6	1.3
3	0.9	1.2	1.2	1.1
4	0.8	0.5	1.4	0.9
5	0.5	0.4	1.0	0.7
6	0.7	0.7	0.7	0.7
	1886–1926		1926–75	
7	1.2		0.1	0.6
8	0.9		0.2	0.5
9	1.3		-0.1	0.5
10	0		0	0
11	-		-	−0.7
12	-		-	−0.7

DISCUSSION OF FACTORS CAUSING COASTLINE CHANGE

Since European settlement, the survey data described confirms the major role of the Waipaoa River in the supply and distribution of sediment. The Waipaoa flood control scheme has confined the river mouth to its present position so that sediment dispersal along the coast is now reliant upon wave-induced longshore transport, rather than a shifting river mouth.

Miller (1981) sampled the beaches and produced mineralogical evidence which indicated both northerly and southerly drift directions. The higher volume of deposition on Waikanae Beach, relative to Muriwai Beach, indicates a dominant northward drift. Similarly, the greater erosion rates on the south compared to the north-facing headlands confirms the dominance of a wave climate which would

Table 2 Sources and estimated volumes of sediment supplied to the Poverty Bay beaches, pre- and post-European settlement, m³/year.

Source	Present	Pre-European
Cliffs east of Kaiti	2 000	2 000?
Turanganui River	4 000	3 000
Waipaoa River	47 000	35 000
Cliffs of Young Nick's Head	2 000	2 000
Total	55 000	42 000

induce a northward drift. However, the localisation of coastal progradation to the vicinity of the Waipaoa River mouth indicates that the rate of sediment supply is greater than the rate of sediment dispersal in the long-term. Both the 1886–1910 and 1910–42 survey comparisons show a tendency for the highest rates of deposition to be near the river mouth. The Waipaoa River mouth position, stabilised by the flood protection scheme, has confined the supply of new sediment to the south-western side of the bay. Sedimentation rates will remain highest in the south-west until the coast has prograded sufficiently for the river to be free of the effects of the stop bank, and until it can commence migrating parallel to the beach through the sand deposit as it did in pre-European times.

Modifications to the entrance of the Turanganui River, before 1927, caused rapid progradation on the eastern end of Waikanae Beach. The probable source of this sediment was the Turanganui River and material from Kaiti Beach (MacKay 1949). The diversion of the Turanganui River in 1927 caused scouring of the beach deposit at an average rate of about 1000 m^3/year. Although the protective works installed in 1959 appear to have prevented further erosion adjacent to the river mouth, the beach at Site 7 has shown no signs of accretion since 1927. The beach between the mouth of the Turanganui River and Site 6 had been used as a source of building sand and road material for many years (MacKay 1949) and in the early 1960s the Gisborne Harbour Board closed the beach in front of the urban area to mining because of erosion (unpublished Gisborne Harbour Board Annual Reports), and opened a new area just east of Site 6. The volume of material removed annually from the beach between 1971 and 1974 averaged 12 000 m^3, which is greater than the natural long-term accretion rate indicated by the surveys so that this will eventually lead to erosion at this site if the extraction rate is maintained.

The estimated sediment yield of the Turanganui River is 4000 m^3/year which is based on the specific yield of 18 m^3/km^2 of sand-size sediment from the Waipaoa basin (Smith 1977a). Material from the Turanganui River, together with an estimated 2000 m^3 from east of Kaiti, is the probable volume of new material being deposited annually on the eastern end of Waikanae Beach. The estimated 6000 m^3 of new material is about half the average annual rate of extraction for the years 1971–74. If the rate of extraction is continued, erosion of the beach deposit can be expected to occur west of Site 7. East of Site 7, the loss of beach material appears to be primarily related to scour associated with the Turanganui River diversion. If this is so, the beach will naturally find an equilibrium position provided there is no sand mining in the area.

CONCLUSIONS

Before the construction of the flood control scheme for the Waipaoa River in the 1940s, periodic migration of the Waipaoa River mouth dispersed sediments along the Poverty Bay foreshore. Since that time land clearance associated with European settlement has increased the natural sediment supply from the rivers by about 25%. Coastal accretion has been localised on the south-western side of Poverty Bay because longshore transport processes are unable to disperse the large fluvial input.

In eastern Poverty Bay, construction of a breakwater and river training wall at the Turanganui River mouth port initially caused beach accretion. Subsequent diversion of the Turanganui River and beach sand extraction have caused erosion at the eastern end of Waikanae Beach. Since mining activities have moved further west, the eastern end of Waikanae Beach appears to be in a state of quasi-equilibrium.

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