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THE PROBLEM OF COASTAL EROSION ALONG THE 'GOLDEN COAST' WESTERN WELLINGTON, NEW ZEALAND

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THE PROBLEM OF COASTAL EROSION ALONG THE 'GOLDEN COAST' WESTERN WELLINGTON, NEW ZEALAND

by

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ABSTRACT

The history and processes responsible for the development of the 'Golden Coast' have been investigated in the field and from a study of cadastral plans and aerial photographs. From c. 4000 B.C. to A.D. 150 the 'Golden Coast' advanced as a result of an abundant supply of littoral drift from northern sources. The present trend of erosion at Paekakariki and Raumati commenced between A.D. 150 and 1874 with severe erosion occurring episodically and not periodically. From 1874 to 1975, 25% of the coastline has shown net retreat resulting in 18–60 m loss of foredune at Paekakariki and 23–37 m at Raumati. By contrast the shoreline has shown net advance of 171–195 m at Paraparaumu and 49–171 m at Waikanae. During this period advance and retreat have alternated erratically with maxima of 50 m retreat recorded at Paekakariki and Raumati, and 40 m at Waikanae.

Natural causes of erosion include the growing cuspate foreland at Paraparaumu, and attack by severe episodic storms from the northwest quadrant. Man-induced causes include construction of State Highway 1 south of Paekakariki in the late 1930's and a seawall at Paekakariki and Raumati in 1955–59 and 1976–78. Coastal erosion along the 'Golden Coast' is a natural process. It became a problem when the foredune was first subdivided in 1906.

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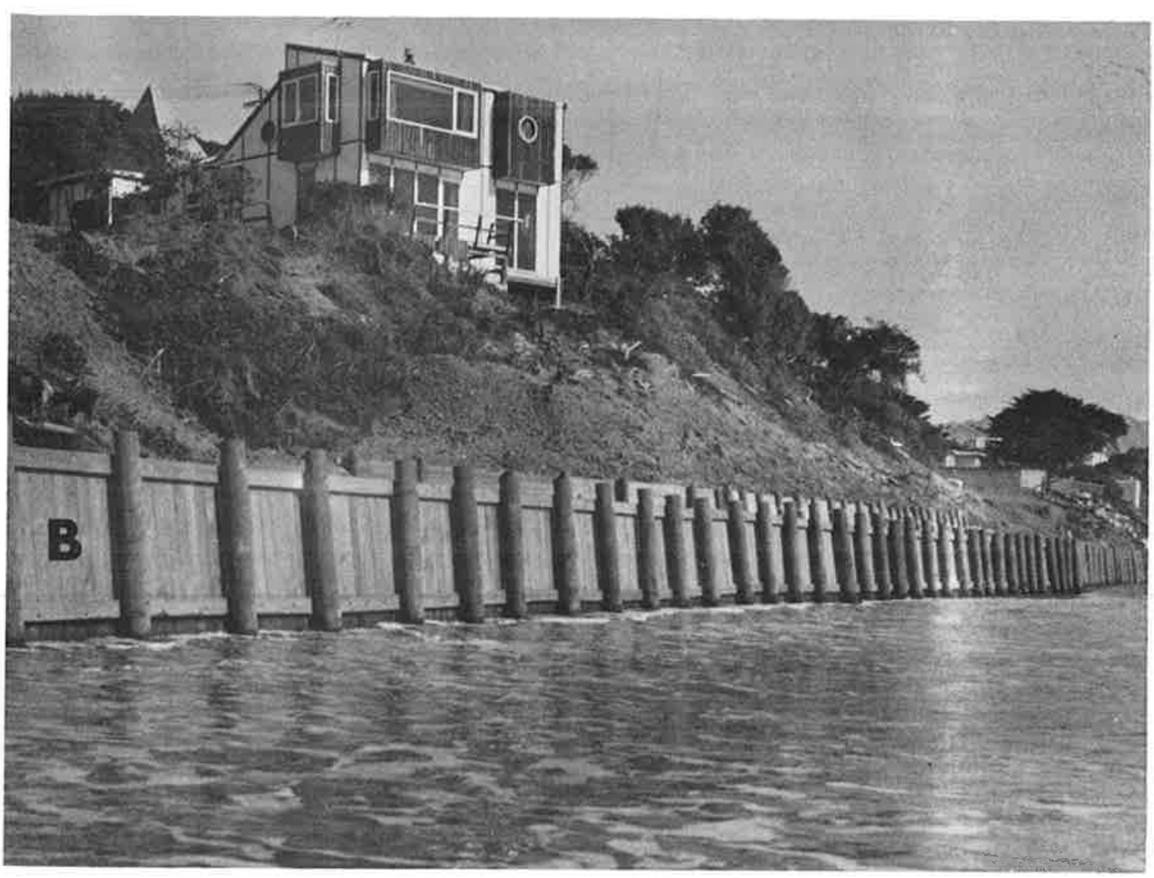
FIG. 1 Coastal erosion and protection at Raumati Beach, 'Golden Coast'.

A – September 1976. Extensive damage from the 11–13 September 1976 storm surge. Before this event the foredune extended to the steel posts awash in the foreground. The rails are the remains of protection work constructed in 1955.

B – November 1977. The same house protected by a timber seawall back-filled with beach sand and quarried weathered greywacke. The base of the seawall is awash at mid-tide during calm sea conditions. *Photo* J.G.G.



INTRODUCTION

Between 1906 and 1923 coastal subdivisions of public land were made between Paekakariki and Waikanae (fig. 3) along the 'Golden Coast' (fig. 2). Property boundaries and dwellings were allowed to encroach onto the foredune at Paekakariki and Raumati regardless of a previous record of erosion and accretion (Appendix 1). By contrast the first subdivisions at Paraparaumu and Waikanae allowed a buffer-zone between the seaward property boundaries and the beach. In recent years, however, development has been allowed to extend onto the fragile foredune at both Paraparaumu and Waikanae. As a consequence of developing the foredune the natural process of coastal erosion is now a very real threat to property owners along the 'Golden Coast'. Protection of property and assets has become a paramount issue.

The first protection works were constructed between 1955 and 1959 under the supervision of Mr L S Donnelley, engineer to the Hutt County Council. A total length of 1,700 m (84 chains) of rail and brush longitudinal protection work was constructed along the toe of the foredune at Paekakariki and Raumati. Stimulus for this work was provided by erosion of 2–3 m of foredune during a severe storm on 10–11 July 1954, and by further erosion during another storm on 12–13 October 1957 (Donnelley 1959). Since 1955, the foredune immediately south of the protection work at Raumati has continued to retreat. The beach in front of the protection work has progressively narrowed so that by 1976 MHWM was at the base of the seawall.

On 11–13 September 1976 a storm surge generated by a slow moving deep depression (970 mb) centred about 5–700 nautical miles west of Cape Egmont destroyed most of the protection work. Unprotected parts of the 'Golden Coast' lost up to 6 m of foredune. At Raumati, however, lower beach levels allowed the full force of the seas to ramp into the seawall and foredune, eroding up to 15 m. One house was destroyed and 30 others threatened (fig. 1A). In response the Kapiti Borough Council has constructed a continuous treated-timber seawall at Raumati and Paekakariki (fig. 1B). It is back-filled with weathered greywacke and is constructed a few metres seaward of the 1955–59 protection works. Depending on beach levels vertical posts extend about 2.5 m into the sand and planks about 1 m. The wall is anchored back onto existing steel posts.

This paper describes shoreline movements and related coastal processes along the 'Golden Coast' over the past 6000 y. In the light of the facts presented here future trends are discussed together with long-term alternative lines of action. In this context long-term covers the next 50–100 y, the expected life of dwellings along the present foredune.

GEOLOGY

The 'Golden Coast' borders a coastal plain 2–4 km wide (fig. 8) of Holocene age comprising belts of dunes separated by peaty lowlands. The coastal plain lies at the foot of a post-glacial sea-cliff cut in greywacke (Adkin 1951; Te Punga 1962). It has been constructed over the past 6000–6500 y from longshore drift materials derived from sediment sources as far north as Cape Egmont (Fleming 1965, 1972). Sea-level has been within 1 m of present day level since post-glacial sea-level rise stabilised about 6500 years ago (J.G. Gibb, in prep.). Over the past 5000 years the coast at Paekakariki has been uplifted approximately 2 m, evidenced by a raised beach of gravel exposed in the eroding foredune.

The developing cuspate foreland at Paraparaumu is forming in the 'wave-shadow' created by Kapiti Island which acts as a giant offshore breakwater reducing wave energy from the prevailing northwest waves (Coddington 1972). Wave generated longshore currents lose velocity as a consequence of this effect and deposit most of their load to form the cusp. The development of this feature is causing adjustments in the position of the shoreline and steadily constricting tidal flow in Rauoterangi channel.

Shoreline Changes

Changes in the position of the coast during the formation of the sand plain have been investigated both in the field and from a study of cadastral plans and vertical aerial photographs. Findings are summarised on figs. 3 and 5 and in Appendix 1.

Holocene Shoreline Changes

Beach deposits exposed by coastal erosion near the post-glacial sea-cliff 200 m south of the Centennial Inn, Paekakariki, have a radiocarbon age of 5140±90 years B.P. (NZ 519A) (Fleming 1965). At Waikanae, woody peats between the post-glacial sea-cliff and the oldest dunes yielded dates some hundreds of years earlier (Fleming 1972). The oldest shoreline therefore, is the post-glacial sea-cliff which generally follows the eastern boundary of State Highway 1 (fig. 3). Based on radiocarbon dates Fleming (1972) suggests that the Waikanae coast was already accreting before the coast started building out at Paekakariki. The inferred age of the sea-cliff behind the 'Golden Coast' therefore, is 6000–6500 y (c. 4000 B.C.).

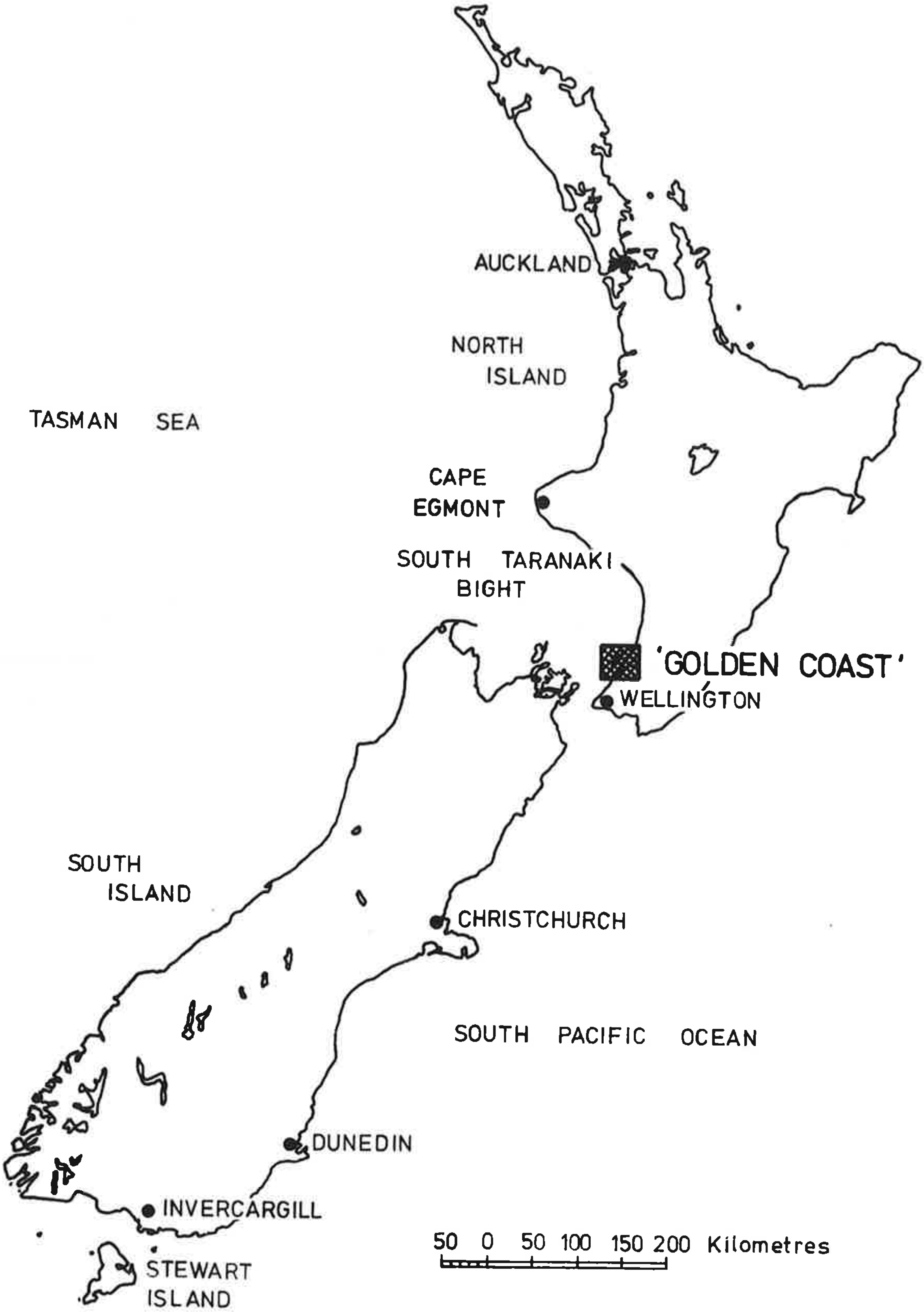


FIG. 2 Location of the 'Golden Coast'.

A ridge of sea-rafted Taupo pumice between the ancient sea-cliff and present day shoreline is the next oldest shoreline (A.D. 150). This ridge has been mapped in the field by the writer and Sir Charles Fleming (fig. 3). Its geographic position relative to the post-glacial sea-cliff indicates a trend of maximum accretion northwards from Paraparaumu between 4000 B.C. and A.D. 150 compared with less accretion along the coast to the south. This trend commenced after the sea cut the post-glacial cliff.

Shells representing a third shoreline 700 m inland from the present day coast at Waikanae, (N156/575742), have been radiocarbon dated. Sample R26/76 collected by the author gave an age of 1130±50 years B.P. (NZ 4228A). It was not possible to map this shoreline (A.D. 800) further along the 'Golden Coast'.

Historic Shoreline Changes

Shoreline displacements over the past century were measured from cadastral plans dating from 1874 to 1968 and aerial photographs dating from 1943 to 1977 held at the Department of Lands and Survey district office and Head Office, Wellington, respectively. On cadastral plans, measurements were made from plan to plan with proportional dividers, using trig stations and property boundaries as fixed points and for scale control. Measurements from air photos were made according to techniques described by Gibb (in prep. 1978b). Rates and amounts of erosion and accretion over the past century have been tabulated for each item (fig. 3) in Appendix 1.

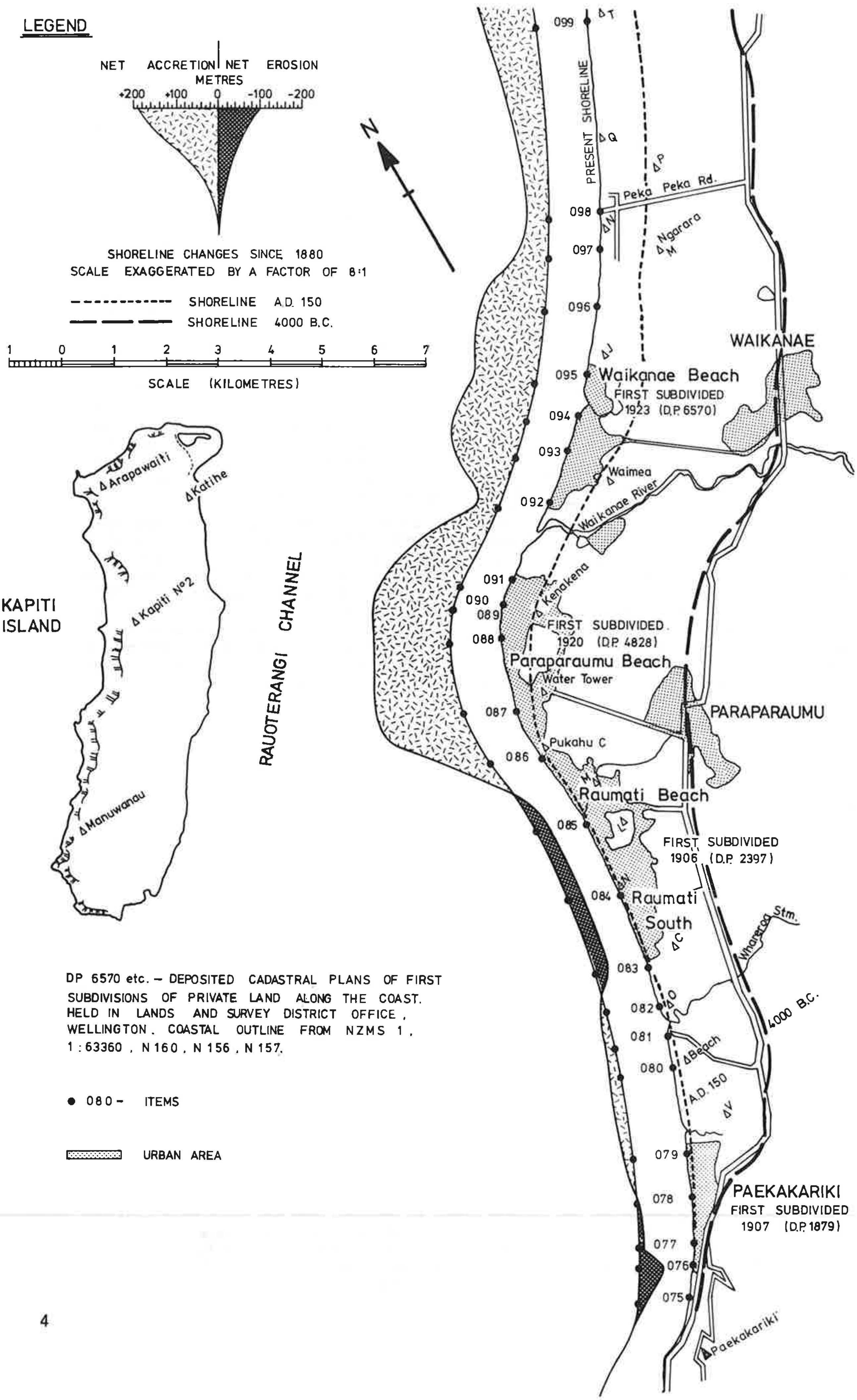
For all measurements, the seaward limit of land vegetation was used as the reference 'shoreline'. Rates of erosion and accretion therefore, refer to loss and gain of the foredune.

At Paekakariki, coastal erosion has resulted in a loss of 18–60 m of foredune between 1894 and 1977 (Items 075–076, Appendix 1) and at Raumati, 24–37 m between 1874 and 1977 (Items 083–085, Appendix 1). From 1880 to 1977 accretion has resulted in a foredune advance of 171–195 m and 49–171 m at Paraparaumu (Items 087–091, Appendix 1) and Waikanae (Items 092–095 Appendix 1) respectively.

These changes (fig. 3) indicate a trend of net accretion over the past century for the coastline between Paraparaumu and Peka Peka, whereas net erosion has occurred at Raumati and Paekakariki. As expected accretion has been greatest at Paraparaumu at the apex of the cuspate foreland.

Shoreline changes since 1974 have been determined directly from measurements made in the field by the writer and from MWD surveys. Present trends are compared with the pattern over the past century (fig. 5). Since 1975, there has been a dramatic reversal from net accretion to erosion along the coastline north of Paraparaumu. This reversal is recorded by comparative photographs along the undeveloped foreshore at Peka Peka (fig. 4).

FIG. 3 Shoreline changes along the 'Golden Coast' in geologic time and since early European colonization of the area. Shorelines dated at 4000 B.C. and A.D. 150 are shown. Net erosion and accretion trends recorded over the past century are offset from the present shoreline. These changes are exaggerated in scale. Data are from Appendix 1. Dates and plans of first subdivisions are given for each coastal settlement. →


LEGEND
NET ACCRETION NET EROSION
METRES
+200 +100 0 -100 -200
SHORELINE CHANGES SINCE 1880
SCALE EXAGGERATED BY A FACTOR OF 8:1
SHORELINE A.D. 150
SHORELINE 4000 B.C.
1 0 1 2 3 4 5 6 7
SCALE (KILOMETRES)
N
KAPITI ISLAND
Arapawaiti
Katihe
Kapiti No 2
Manuwanau
RAUOTERANGI CHANNEL
PRESENT SHORELINE
Peka Peka Rd.
Ngarara
WAIKANAE
Waikanae Beach
FIRST SUBDIVIDED 1923 (D.P. 6570)
Waimea
Waikanae River
Kenakena
FIRST SUBDIVIDED 1920 (D.P. 4828)
Paraparaumu Beach
Water Tower
PARAPARAUMU
Pukahu C
Raumati Beach
FIRST SUBDIVIDED 1906 (D.P. 2397)
Raumati South
Wharemoa Stm.
4000 B.C.
Beach
A.D. 150
PAEKAKARIKI
FIRST SUBDIVIDED 1907 (D.P. 1879)
Paekakariki
099 098 097 096 095 094 093 092 091 090 089 088 087 086 085 084 083 082 081 080 079 078 077 076 075
DP 6570 etc. – DEPOSITED CADASTRAL PLANS OF FIRST SUBDIVISIONS OF PRIVATE LAND ALONG THE COAST. HELD IN LANDS AND SURVEY DISTRICT OFFICE, WELLINGTON. COASTAL OUTLINE FROM NZMS 1, 1:63360, N 160, N 156, N 157.
080 – ITEMS
URBAN AREA

A

FIG. 4 Peka Peka looking south towards Waikanae.

A – June 1975. Accreting foredune stabilised naturally by marram grass. *Photo* J.G.G.

B – November 1977. Eroding foredune at approximately the same site. About 8 m of erosion has occurred along 10 km of this coast since 1975. *Photo* J.G.G.

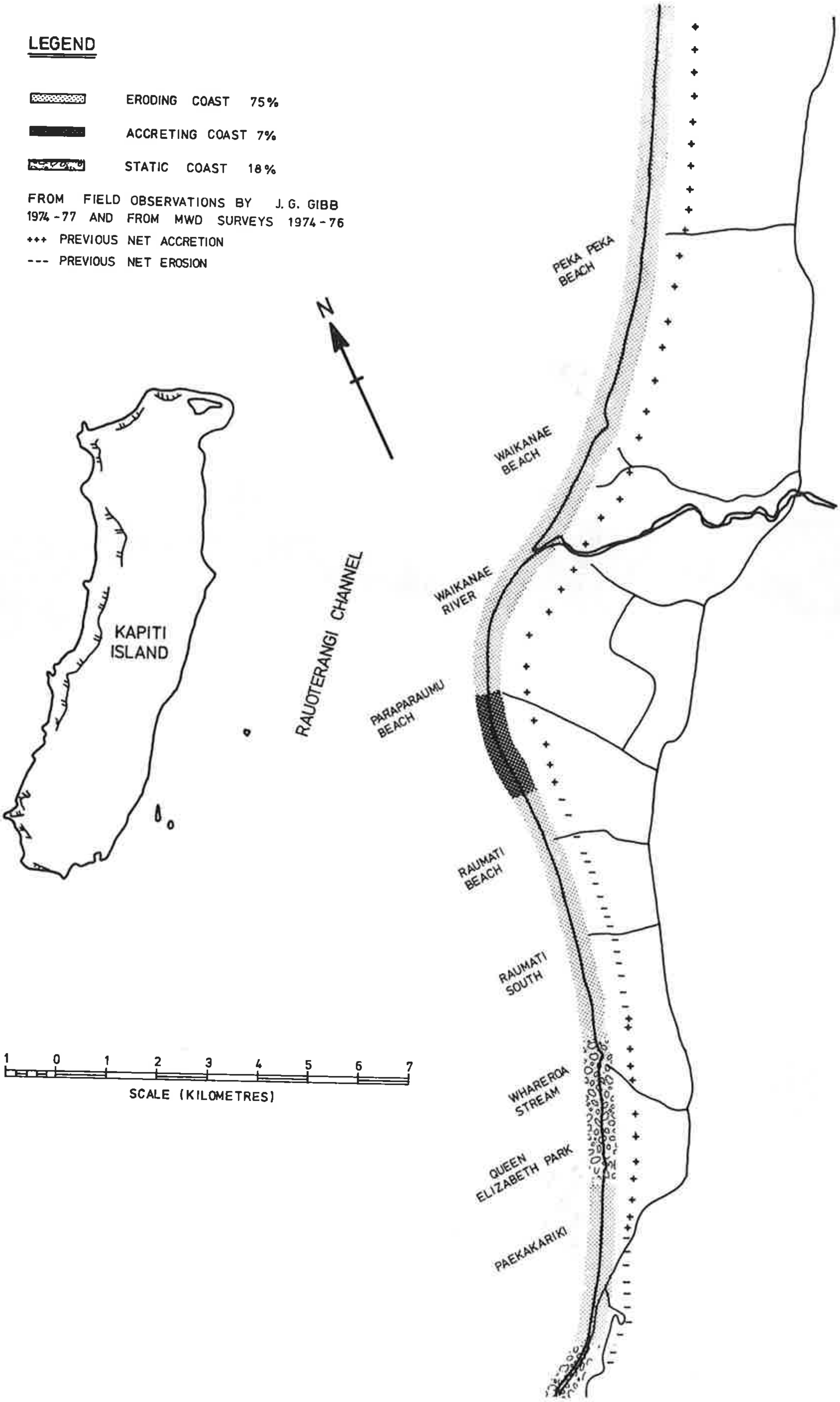


FIG. 5 A comparison of shoreline trends along the 'Golden Coast' since about 1975, with historic trends (fig. 3). Note the dramatic reversal from a general trend of accretion to one of erosion along the coast north of Paraparaumu.

In summary, changes in the position of the shoreline since about 4000 B.C. over the 27km length of 'Golden Coast' between Paekakariki and Peka Peka, fall naturally into three significant time periods. Between c. 4000 B.C. and A.D. 150, 100% of the shoreline advanced. From 1874 to 1975, 75% advanced and 25% retreated. From 1975 to 1977, 7% advanced, 75% retreated and 18% remained static. The trend of greatest accretion that has occurred along the coast north of Paraparaumu, has persisted over the past 6000–6500 years. The trend of accretion south of Paraparaumu reversed to net erosion between A.D. 150 and 1874. This long-term reversal is substantiated at Raumati by the occurrence of peat under the beach and at Paekakariki, by the present-day shoreline having retreated back to the approximate position of the shoreline 5000 years ago (Fleming 1965). Dunes must have existed well seaward of the present-day shoreline between A.D. 150 and 1874 at both localities.

Trends of Coastal Erosion and Accretion

Over the past century erosion and accretion have followed an erratic cycle along most of the 'Golden Coast'. These long-term trends are shown graphically (fig. 6A). Fluctuations in rates of erosion and accretion of the foredune with reversals in trends are evident. The maximum amount of erosion recorded at Paekakariki (Item 076, Appendix 1) and Raumati (Item 084, Appendix 1) is 50 m and at Waikanae 40 m (Item 092, Appendix 1). By contrast, most of Paraparaumu has no record of past erosion up to 1975 (Items 087–091, Appendix 1).

The natural cycle of erosion and accretion along the 'Golden Coast' is therefore episodic and not periodic. This factor makes it difficult to predict future trends. All that is known at this stage is that the most recent trend (1975–77) is resulting in about 75% of the 'Golden Coast' undergoing erosion.

Short-term Beach Movements

Figure 6B illustrates short-term oscillations of the beach over an 18 month period. Data were selected from Pinfold (1977) and are an analysis of surveys carried out by MWD between April 1974 and September 1976. During this survey, 16 profile sites were established between Paekakariki and Peka Peka and were tied into the national trig network. Both beach and offshore profiles were surveyed at monthly and 3 monthly intervals respectively. Datum at each site is geodetic MSL (Wellington Datum 1953).

Vertical and horizontal displacements at the intersection of the beach with geodetic MSL and MHWM, are given in Table 1 for the range of material sizes (fig. 7) along the 'Golden Coast'.

TABLE 1 – Monthly and seasonal vertical and horizontal displacements for the range of mean grain size of beach sediments along the 'Golden Coast'. Data are from MWD surveys April 1974 to September 1975 and Gibb (1977). (phi, Ø = $-\log_2$ diameter in mm).

		Fine Sand (2Ø to 3Ø)	Medium Sand (1Ø to 2Ø)	V. Coarse Sand (0Ø to –1Ø)	Granules & Pebbles (–1Ø to –6Ø)
Average Shore Gradient at MSL		1: 65	1:30	1:15	1:10
Range of Vertical Displacements (m)	at MSL	0.4–1.1	0.8–1.0	0.7–0.9	0.5–0.7
	Profile Maximum (MLWM)	2.4	1.4	1.2	1.2
Range of Horizontal Displacements (m)	MHWM	10–38	4–15	9–10	5–10
	MSL	24–95	30–33	22–23	6–12

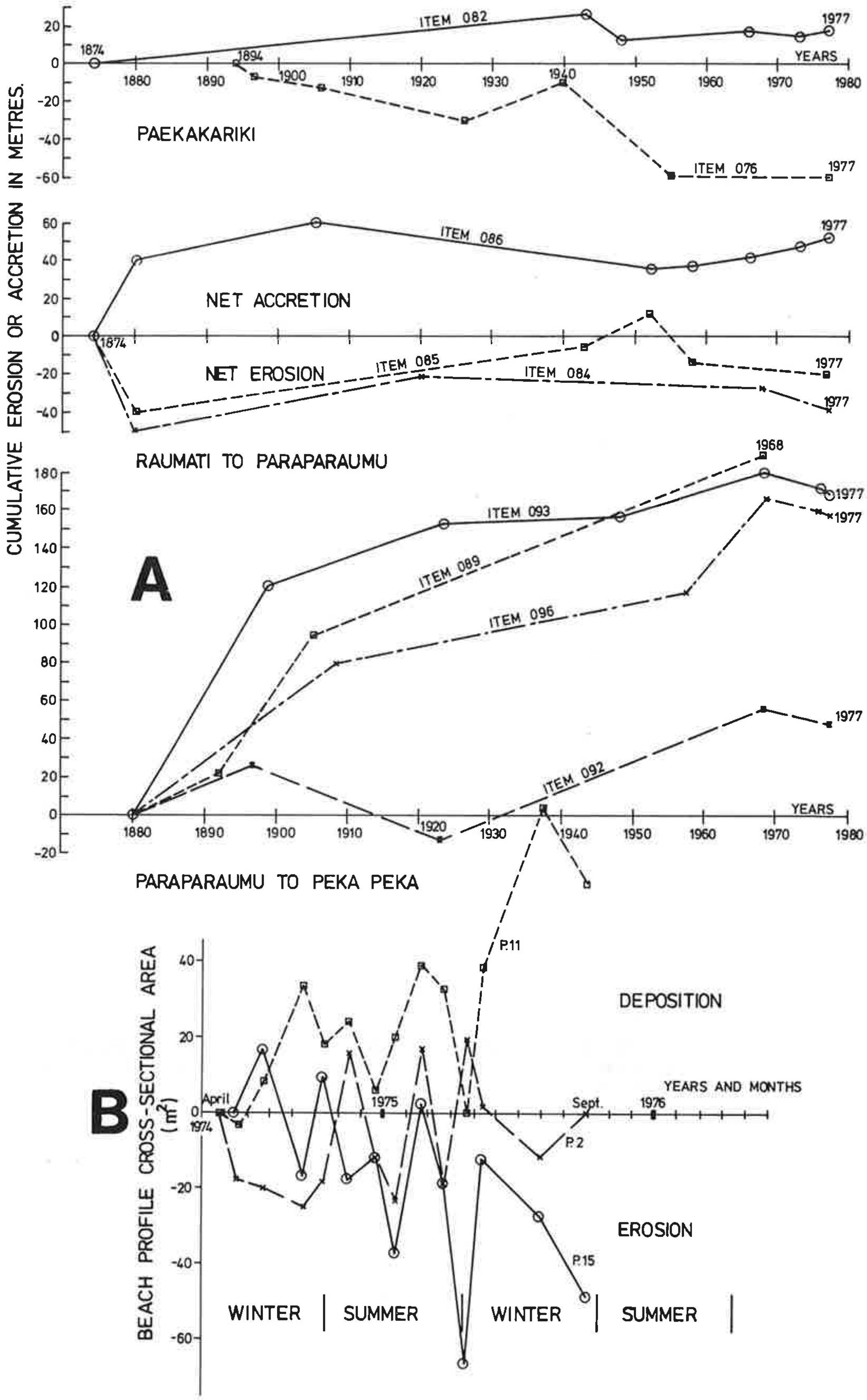


FIG. 6 Graphs of shoreline movements along the 'Golden Coast'.

A. – Cumulative erosion and accretion over the past century. Data from column G, Appendix 1. For location of items see fig. 3.

B – Monthly beach profile changes at Paekakariki (P. 2, item 077) Paraparaumu (P. 11, item 091) and Peka Peka (P. 15, item 096) recorded by MWD surveys (Pinfold 1977). Map locations of profiles are given in column C, Appendix 1. Profile areas are calculated from the benchmark to MLWM (–0.9 m). Changes in area between successive surveys are relative to the April 1974 profile cross-sectional area at each site.

Profile gradients at MSL increase southwards towards Paekakariki as material size increases along the 'Golden Coast' beaches. Results in Table 1 show that both vertical and horizontal displacements of the beach increase with decreasing mean grain size. Furthermore, displacements in all cases increase down the beach towards MLWM. Erosion and deposition of the beach fluctuate from site to site with some profiles building up while others erode (see fig. 6B). During periods when beaches are eroding the foredune becomes susceptible to wave attack. Between December 1977 and February 1978 persistant summer anticyclones moving eastward across New Zealand have resulted in deposition taking place along the 'Golden Coast' beaches. Fine sand (2–3Ø) has migrated onshore from longshore bars.

Observations of beach behaviour during the 11–13 September 1976 storm surge and after other severe storms disclosed that beaches of material greater than 2Ø (0.25 mm) tend to steepen in gradient. By contrast, material less than 2Ø is removed from the beach and transported offshore. This process of selective sorting by heavy seas results in beaches south of Raumati Beach comprising only coarse material and dead shells after storms.

Sediment Source

Beach and offshore sediments were sampled and analysed according to techniques described by Gibb (1977). Both textural and petrographic analyses were performed on samples with the objectives of determining sources of sediment and net longshore transport directions. Data relevant to Wellington's west coast including sediment analyses from rivers discharging onto the coast are given in Gibb (1977, 1978 a). Textural characteristics are given for 'Golden Coast' beaches in fig. 7.

Several sources are recognised for 'Golden Coast' sediment from petrographic data. Sand is from two volcanic sources (Egmont and Ruapehu), a mixed source (Wanganui Basin) and a greywacke source (Tararua and Ruahine ranges). Gravel forming the beach at Paekakariki is from the greywacke hills immediately south of the sand plain (fig. 8).

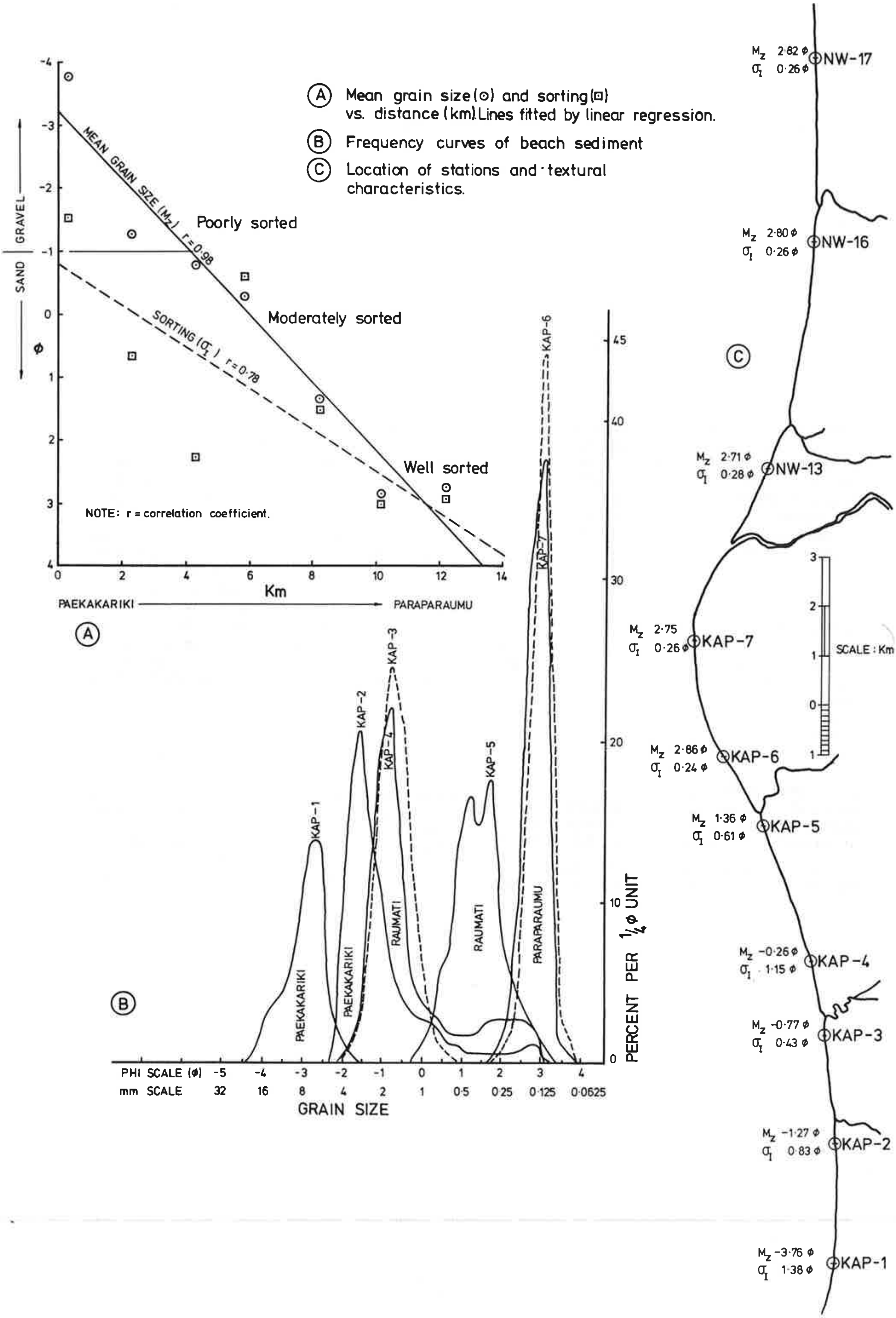
Sand is being supplied to the coastal system from actively eroding sea cliffs between Wanganui and Cape Egmont and via rivers discharging onto the coast between Waikanae and Cape Egmont. Gravel, however, is no longer being supplied to the coast from the cliffs south of Paekakariki.

Sediment Transport

Sediment supplied to Wellington's west coast from the above sources is transported to the 'Golden Coast' mainly by a net southward flowing long shore current. Several lines of evidence support a net southward longshore drift as far as Paraparaumu. Firstly, small, round, black hypersthene andesite pebbles are deposited at high tide mark as far south as Paraparaumu (source – Ruapehu via Whangaehu River). Secondly, beach sand contains 2–10% of minerals such as hornblende, augite, hypersthene, magnetite and mica (source – Egmont and Taupo volcanic zones). Thirdly, the Waikanae River mouth always migrates southwards. Under low flow conditions a spit grows across the mouth from north to south diverting the flow along the coast. This spit is constructed from longshore drift material.

Between Paekakariki and Paraparaumu the net longshore drift is northwards. The main evidence for this is the trend of decreasing mean grain size and improvement in sorting northwards of material derived from the cliffs south of the Centennial Inn, Paekakariki (fig. 7A). Material coarser than 2Ø (0.25 mm) is derived from this source and is found in beach sand up to Raumati Beach (see fig. 7B).

FIG. 7 Textural characteristics of beach sediment along the 'Golden Coast'. Mean grain size (M_z) decreases and sorting (σ_I) improves along the coast between Paekakariki and Paraparaumu (A & B). Negligible changes in textural characteristics occur northwards (C). Frequency curves for KAP–6 and KAP–7 are typical for beaches up to Peka Peka and for sediment comprising the nearshore seabed along the 'Golden Coast' (adapted from Gibb 1977). →


A Mean grain size (⊙) and sorting (⊡) vs. distance (km). Lines fitted by linear regression.
B Frequency curves of beach sediment
C Location of stations and textural characteristics.
GRAVEL
SAND
ϕ
MEAN GRAIN SIZE (M_z) r = 0.98
SORTING (σ_I) r = 0.78
Poorly sorted
Moderately sorted
Well sorted
NOTE: r = correlation coefficient.
Km
PAEKAKARIKI
PARAPARAUMU
KAP-1
KAP-2
KAP-3
KAP-4
KAP-5
KAP-6
KAP-7
PAEKAKARIKI
PAEKAKARIKI
RAUMATI
RAUMATI
PARAPARAUMU
PHI SCALE (ϕ) -5 -4 -3 -2 -1 0 1 2 3 4
mm SCALE 32 16 8 4 2 1 0·5 0·25 0·125 0·0625
GRAIN SIZE
PERCENT PER 1/4 ϕ UNIT
M_z 2·82 ϕ σ_I 0·26 ϕ NW-17
M_z 2·80 ϕ σ_I 0·26 ϕ NW-16
M_z 2·71 ϕ σ_I 0·28 ϕ NW-13
M_z 2·75 σ_I 0·26 ϕ KAP-7
M_z 2·86 ϕ σ_I 0·24 ϕ KAP-6
M_z 1·36 ϕ σ_I 0·61 ϕ KAP-5
M_z -0·26 ϕ σ_I 1·15 ϕ KAP-4
M_z -0·77 ϕ σ_I 0·43 ϕ KAP-3
M_z -1·27 ϕ σ_I 0·83 ϕ KAP-2
M_z -3·76 ϕ σ_I 1·38 ϕ KAP-1
SCALE : Km

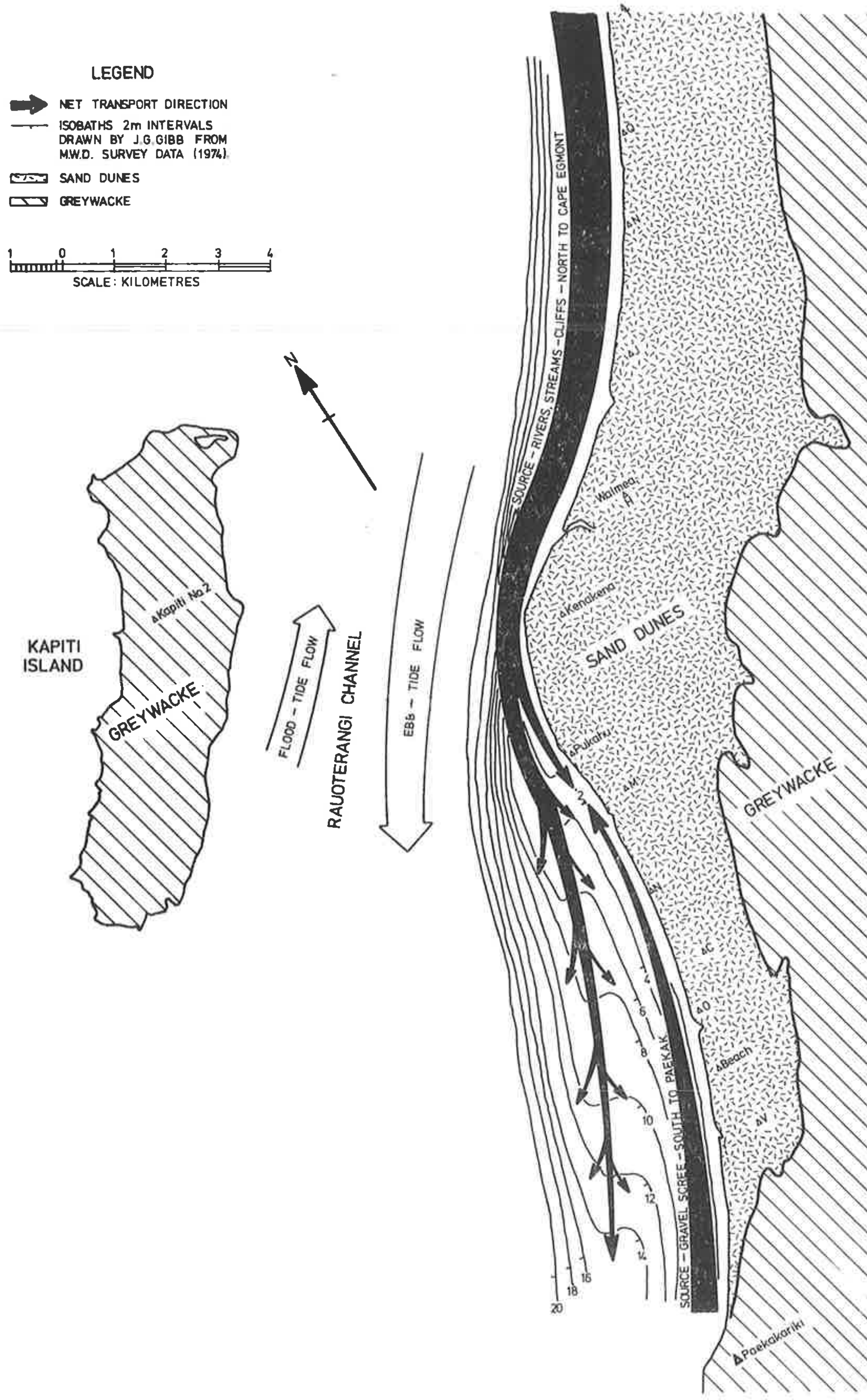


FIG. 8 Inferred net sediment transport directions along the 'Golden Coast'. Solid arrows paralleling the shoreline represent littoral material transported by wave-induced longshore currents. The divergent solid arrows passing southwards offshore from Raumati and Paekakariki represent nearshore transport by ebb-tidal flow. Decreasing width of solid arrows indicates a progressive loss of material with distance away from source. Net directions of ebb and flood tidal flow in Rauoterangi channel are shown. These may reverse at times or flow in the same direction for some days depending on meteorologic conditions in Cook Strait.

Direct measurements of longshore current velocity and direction were made daily between April 1974 and June 1975 by 8 volunteer observers along the 'Golden Coast'. Measurements were made by casting a semi-submersible float into the surf and timing its drift alongshore. Selected results from four observers are given for the 'Golden Coast' in Table 2. Daily observations were recorded on a form designed by the author. An example of observations made by an observer at Raumati together with observation methods is given in Appendix 2.

The observers' results show that during the 14 month observation period an oscillatory longshore drift was recorded at each site. Mean velocities of 0.1 – 0.3 $m.sec^{-1}$ were typical, with maximum velocities of 0.6 – 0.9 $m.sec^{-1}$ both north and south being recorded by each observer. During calm sea conditions velocities up to 0.2 $m.sec^{-1}$ were often recorded south of Paraparaumu indicating the influence of tidal currents along the beach. At all sites the majority of observations recorded wave direction as parallel to the beach. Seas from the southwest quadrant generated northward flowing longshore currents and seas from the northwest quadrant, a current in the opposite direction. During the 11–13 September 1976 event debris from the 'protection works' at Raumati was spread along the beach as far south as Paekakariki (see fig. 10d). Seas were from the northwest quadrant at the time.

A sand bank made up of sediment with the same properties as the beach sands between Paraparaumu and Peka Peka lies offshore between the cuspate foreland and Paekakariki (fig. 8). The location and sediment properties of this bank infer construction by a southwest flowing current. As Kapiti Island reduces longshore current velocities in the vicinity of the cuspate foreland, sediment is probably transported southward by tidal currents. Observations during this study show that dominant ebb-tidal currents flow southwards, while subordinate flood-tidal currents flow northwards. The bank is formed as a result of ebb-tidal currents picking up a portion of the net southward longshore drift material.

EROSION PROCESSES

Several factors operating within two different time scales are responsible for coastal erosion along the 'Golden Coast'. These may be broadly grouped into first and second order categories. The first category is of the order of centuries and the second, of years.

First Order

The lack of sand of the same textural properties as that of beaches from Paraparaumu northwards indicates that the beach between Raumati and Paekakariki is being starved of the natural supply of longshore drift material.

TABLE 2 — Longshore current velocity and direction. Columns list number of observations of drift north (N) and south (S) along the beach. Measurements were made daily at each site by observers between April 1974 and June 1975.

	Localities and Drift Direction							
	Paekakariki (Galletly)		Raumati (Liddicoat)		Paraparaumu (Hardy & Coddington)		Waikanae (Young)	
Velocity $m.sec^{-1}$	N	S	N	S	N	S	N	S
0	14		15		59		89	
0.1	92	83	54	59	64	71	63	80
0.2	46	49	47	59	44	83	56	48
0.3	39	22	14	19	34	31	26	23
0.4	11	10	18	14	14	5	4	3
0.5	8	9	14	4	9	1	8	3
0.6	6	2	1	–	1	2	3	1
0.7	2	2	1	–	–	–	–	1
0.8	2	–	–	–	–	–	1	1
0.9	–	–	1	1	–	–	–	–
1.0	–	–	–	–	–	–	–	–
Total Observations	206	177	150	156	166	193	161	160

The main cause of this is the growing cuspate foreland. Over the past centuries rapid accretion at this point has resulted in the foreland becoming an effective groyne trapping longshore drift along the updrift (northern) coast thereby starving the downdrift (southern) coast. Quantities of sand that do pass southwards are being deflected offshore by the protruding cuspate foreland to form an offshore bank (fig. 8). This sand is not being transported from this bank to the shore between Raumati and Paekakariki.

The second factor is the termination of the supply of gravel from the greywacke hills to the south to the beach at Paekakariki. At the turn of the century this supply was partially reduced with the construction of the 'Manawatu' Railway and completely terminated in the late 1930's with the construction of State Highway 1 along the coast between Pukerua Bay and Paekakariki.

Second Order

At Raumati and to a lesser extent along the Marine Parade, Paekakariki, the situation is being aggravated by a seawall on the active beach. At high tide the newly constructed timber seawall at Raumati is awash along most of its length (see fig. 1B). It is constructed some metres seaward of the 1955–59 protection works (fig. 1A). The type and positioning of the structure reflects waves and in so doing suspends fine sand, interfering with the natural depositional part of the beach cycle. Material less than 2Ø (0.25 mm) diameter does not settle permanently on the beach. Only material coarser than 2Ø remains (see fig. 7B, C) and the supply of this material was terminated in the late 1930's. These factors result in a steady loss of beach material in front of the seawall (fig. 9).

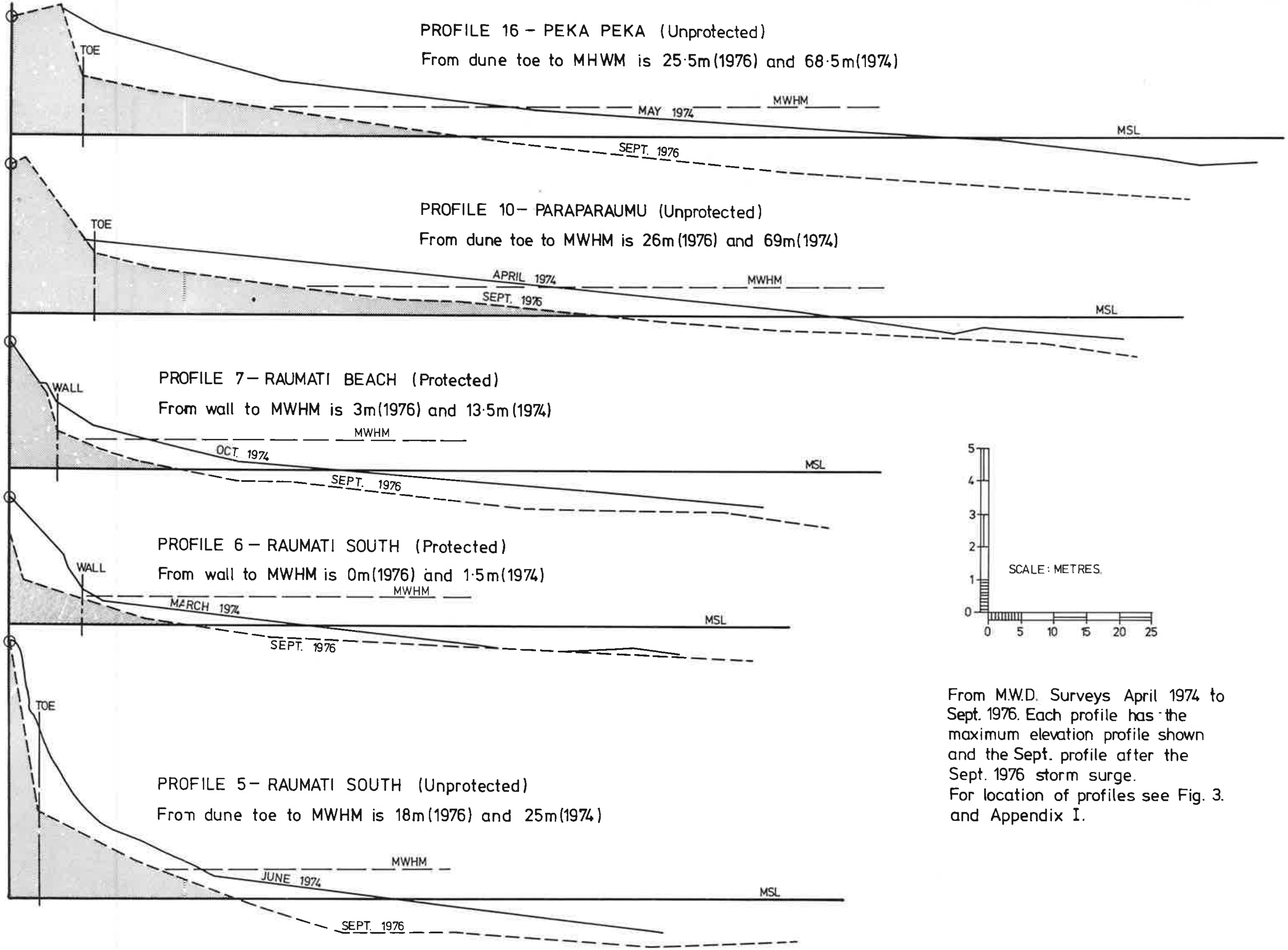
A wide beach is critical for protecting the foredune from attack by the sea. When the beach is narrowed it is a natural process for seas to erode sand 'stored' in the foredune and re-establish an equilibrium beach profile. The permanent loss of the natural beach by coastal 'protection' means that the full force of storm waves will be greatest along the 'protected' coast. This was amplified during the 11–13 September 1976 storm surge when up to 15 m of foredune were eroded at Raumati compared with negligible erosion at Queen Elizabeth Park, 2 km south (fig. 10).

Along the unprotected coast at Paekakariki the foredune is most susceptible to erosion after prolonged southerlies. During these conditions the gravel beach by Centennial Inn is narrowed as gravel is transported northwards by southerly swells. If southerly conditions are followed by storms from the northwest quadrant, seas ramp across the narrowed beach and erode the unprotected dune. If storms are accompanied by spring high tides erosion is severe. During the September 1976 storm surge a wide gravel beach existed and negligible erosion occurred (Items 075–079, Appendix 1).

Finally, the present cycle of erosion affecting 75% of the 'Golden Coast' is still continuing. This cycle is characterised by episodic storms of the nature of the September 1976 event. Similar storm events in the 1950's are recorded by Donnelley (1959). Slow moving deep depressions centred west of Cape Egmont provide the energy for erosion. Very high seas (9–14 m) are generated by storm force winds from the northwest quadrant which push water into the South Taranaki Bight. The only escape route for this massive increase in volume is the narrow throat of Cook Strait. The result is a storm surge.

During the 1976 event, the normal driftwood line along the beach was raised an average of 2.6 m along Wellington's west coast to be deposited on the crest of the eroding foredune. Fifteen kilometres south of Paekakariki at Pauatahanui Inlet, the storm surge raised HWM an average of 0.72 m above normal. Ships in the South Taranaki Bight recorded 11–13 m swells and NW winds of 50 knots.

FIG. 9 Beach profile changes along the 'Golden Coast'. Note the distance of MHWM from the seawall. Prior to construction of a seawall in 1955 beach profiles at Raumati were similar to those shown in Profiles 5 and 10. The reflective action of the seawall is resulting in a narrowing of the beach along the protected area. →



From M.W.D. Surveys April 1974 to Sept. 1976. Each profile has the maximum elevation profile shown and the Sept. profile after the Sept. 1976 storm surge.
For location of profiles see Fig. 3. and Appendix I.

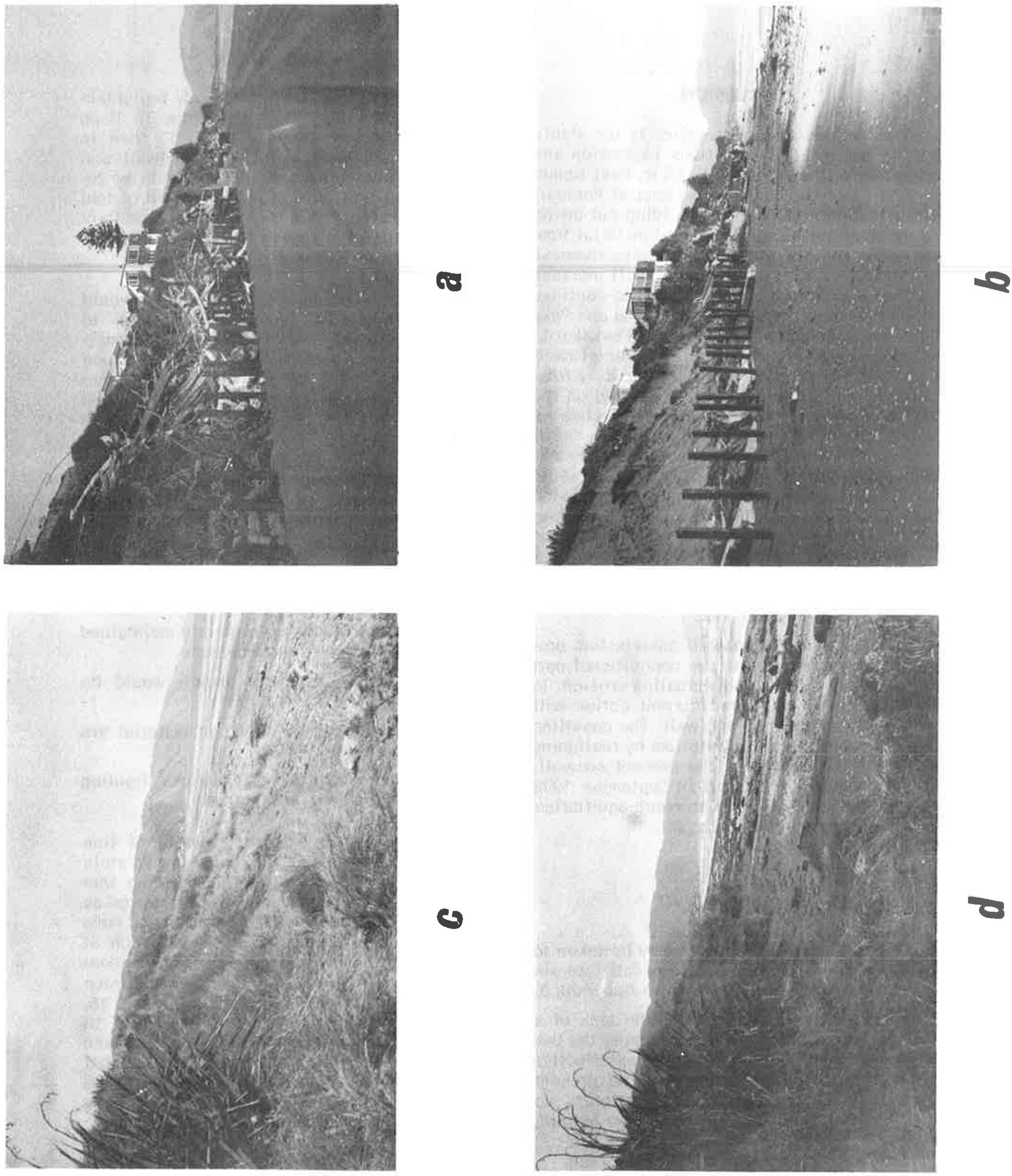


FIG. 10 The negative effect of seawall protection highlighted by the 11–13 September 1976 storm surge compared with the response of the natural beach and foredune. *Photos* J.G.G.

a – March 1976. Raumati Beach looking south at low tide. High tide reaches the rail and log protection work owing to unnaturally lowered beach levels.

b – September 1976. Storm damage from the September storm surge resulting in 5–15 m of erosion following removal of logs by high seas.

c – March 1976. The unprotected shoreline at Queen Elizabeth II park, MHWM varies between 25 and 70 m from the foredune.

d – September 1976. Aftermath of the September storm surge. The natural beach has absorbed the force of the storm and the foredune has remained intact. Logs on the beach are from the 'protection' works at Raumati.

DISCUSSION

The 'Golden Coast' shoreline is not stable and is subject to fluctuations in erosion and accretion of the order of 40–50 m. Past trends suggest that the cuspate foreland at Paraparaumu is likely to continue building out owing to an abundant supply of littoral material from the north. As this continues, the effectiveness of this feature as a giant 'groyne' will increase so that accretion can be expected to continue along the coast between Paraparaumu and Peka Peka while the coast southwards to Paekakariki is effectively starved of natural replenishment. Quantities of sand carried southwards by tidal currents will continue to be deposited on the sea bed and not on the southern beaches as the cuspate foreland grows towards Kapiti Island. The existing gravel beach at Paekakariki is being steadily destroyed by abrasion so that its present effectiveness in slowing erosion will be reduced. The seawall at Paekakariki and Raumati has been constructed on unconsolidated sand. At both localities long-term retreat of the foredune is outflanking the fixed structures making them subject to increasing attack by the sea.

The fact that the seawall assists this process by interfering with the depositional part of the beach cycle is accentuating erosion. In time, scour by wave and current action will undermine and destroy the wall. The coastline will attempt to reach equilibrium by realigning some 20 m landward of the present seawall. Severe erosion at Raumati in September 1976 was an attempt by the sea to reach equilibrium along this section of the coast.

Future Alternatives

Future lines of action that may be taken to combat coastal erosion problems fall into six categories which are described in Appendix 3.

At Paekakariki and Raumati the lack of a natural supply of littoral drift negates the use of groynes or offshore breakwaters as effective alternative long-term measures. The present seawall must be regarded as temporary so that future alternatives are either 'no action', 'relocate development' or 'beach replenishment' (Options 1, 2, 6 – Appendix 3). If no further action is taken (Option 1) then in time the sea will destroy the seawall and houses fronting the beach. The costs of relocating several million dollars worth of real estate (Option 2) are probably exorbitant which narrows the choice to either 'no action' or 'beach replenishment'.

Artificial beach replenishment would restore the natural supply of material to the beaches at Paekakariki and Raumati and have no harmful side effects along the coast. If this was carried out then net erosion of 0.2 – 0.4 $m.y^{-1}$ at Raumati and 0.2 – 0.7 $m.y^{-1}$ at Paekakariki (Appendix 2) would necessitate that the initial quantity placed on the beach, be added to annually to compensate for long-term losses. Incentives for investigating the long-term feasibility of artificial beach replenishment at Paekakariki and Raumati are:

(1) Foredune would be protected by restoring a wide beach to absorb wave energy.

(2) Seawall would be permanently maintained and act as last line of defence.

(3) Recreational asset of beach would be restored.

(4) Supply sources of abundant material are nearby (see fig. 11).

(5) If successful, property values fronting the coast would be restored.

At Raumati, an abundant supply of fine sand is available in the bank immediately offshore (fig. 11). Sediment comprising this bank has the same textural characteristics as the beach sand between Paraparaumu and Peka Peka (fig. 7). If pumped onto the beach at Raumati, this sand can be expected to adopt similar profiles as the beaches between Paraparaumu and Peka Peka (see P. 10 & P. 16, fig. 9). Based on the gradient of Profile 16 (fig. 9) volumes of sand required to replenish the beach along a 4 km stretch at Raumati have been calculated such that geodetic MHWM will be displaced seaward between 10 m and 80 m. Values are tabulated below:

Displacement seaward of MHWM in metres	10	20	30	40	50	60	70	80
Sand volume required $m^3 \times 10^6$	0.16	0.24	0.39	0.6	0.82	1.14	1.52	1.92

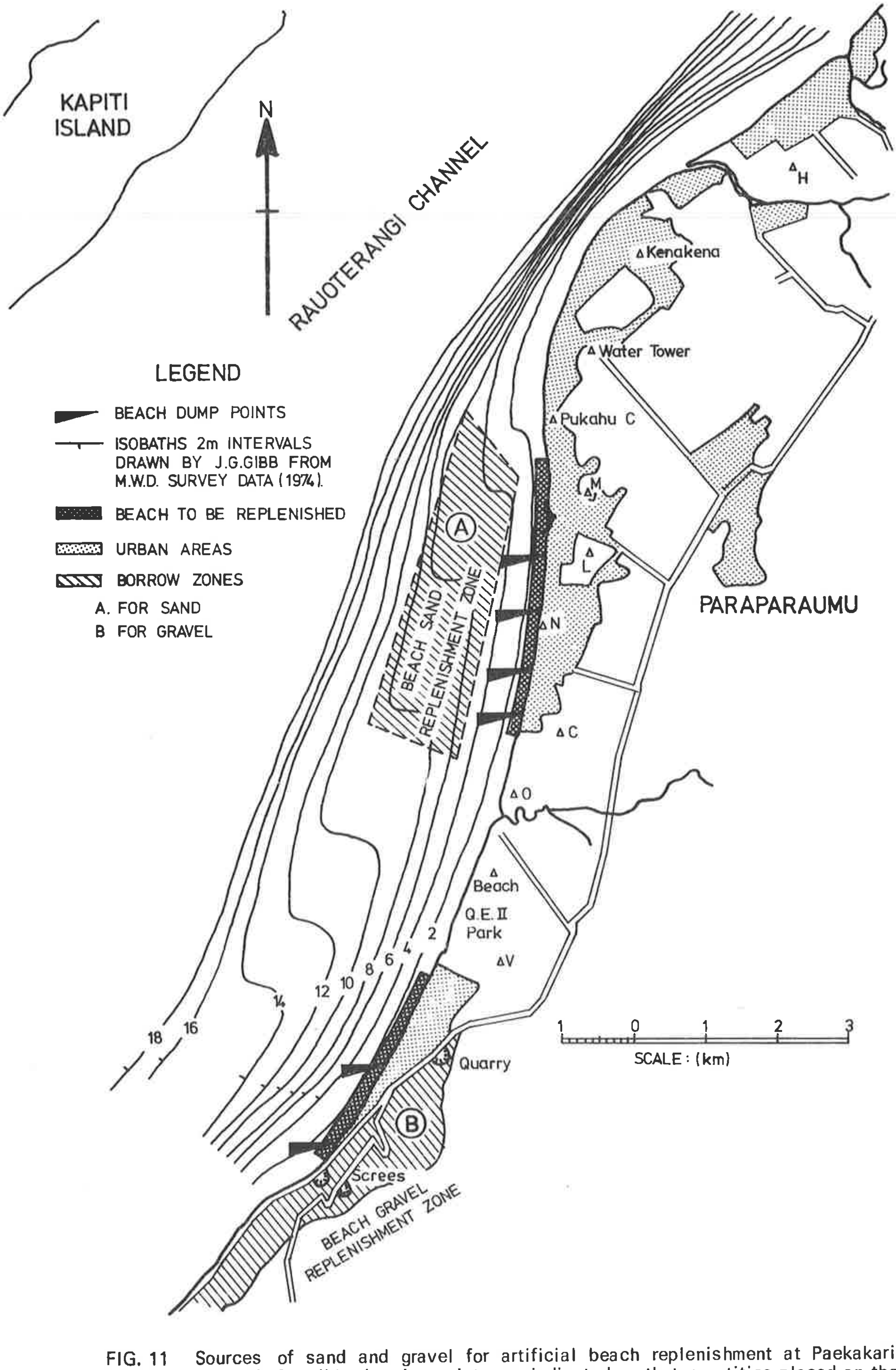


FIG. 11 Sources of sand and gravel for artificial beach replenishment at Paekakariki and Raumati. Possible dumping points are indicated so that quantities placed on the beach can be distributed alongshore by longshore currents.

Based on a maximum seasonal displacement of 38 m of MHWM for a fine sandy beach along the 'Golden Coast' (Table 1) the minimum established beach-width should be no less than 50 m. This would require an initial volume of 820,000 m^3 of fine sand. Less volume would be required if a nearby source of coarser material could be found. Surveys have shown that seasonal horizontal displacements of MHWM decrease with increasing mean grain size of sediment along the 'Golden Coast' (see Table 1). Also material coarser than 2Ø (0.25 mm) diameter tends to remain on the beach during storm attack whereas material less than 2Ø is transported offshore. If sand was placed at the points indicated at Raumati (fig. 11) then oscillatory longshore currents (see 'Liddicoat', Table 2) would spread the volume along the 4 km stretch of coast.

At Paekakariki unweathered greywacke outcrops close to the coast. A disused quarry by Paekakariki railway station and active screes above the railway line (see fig. 11) are ready sources of good beach material. Unweathered gravels would survive constant abrasion for a greater period than weathered material being quarried at Paraparaumu for back-filling the present protection work. If gravels from Paekakariki were trucked and dumped onto the beach by Centennial Inn and the Marine Parade (fig. 11), longshore currents and wave action would round gravels and distribute the volume northwards along the beach (see 'Galletly', Table 2). Calculations based on MWD beach surveys at Paekakariki (Pinfold 1977) indicate that over a 3 km length of coast from Centennial Inn northwards, 100,000 – 150,000 m^3 of gravel would be sufficient to advance MHWM up to 20 m seawards. This would adequately cope with seasonal displacements up to 10 m (Table 1) of MHWM.

Since 1975 the past trend of accretion between Paraparaumu and Peka Peka has reversed to rapid erosion of 2 $m.y^{-1}$ (Appendix 1). Whether this continues is largely dependent on the frequency of episodic storms of the severity of the 11–13 September 1976 event. Two or three events of this magnitude would result in complete loss of the foredune and possibly secondary dune. The Meteorological Office, Kelburn, advises that depressions similar to the September 1976 event can form at any time and follow no predictable cyclic pattern. Along the 'Golden Coast', this factor must emphasise the necessity in long-term planning to always leave a sufficient buffer-zone free of development between properties and the beach. Although past trends are dominantly accreting they have been accompanied by severe erosional phases resulting in up to 50 m retreat of the foredune.

CONCLUSIONS

1. The problem of coastal erosion along the 'Golden Coast' commenced in 1906 with development being allowed to extend onto the foredune. This practice is still continuing today.

2. Severe erosion is episodic and not periodic along the 'Golden Coast' and results from frequent attack by storms from the northwest quadrant.

3. The present phase of coastal erosion commenced at Paekakariki and Raumati between A.D. 150 and 1874 and continues today with maximum erosion of 50 m at Raumati and Paekakariki and 40 m at Waikanae being recorded since 1874.

4. The main cause of long-term erosion at Paekakariki and Raumati is the growth of the cuspate foreland at Paraparaumu in the wave-shadow of Kapiti Island. This feature prevents fine sand from naturally replenishing these beaches by trapping material along the updrift (northern) coast and deflecting the rest offshore south of Paraparaumu.

5. Man has contributed to erosion at Paekakariki and Raumati by terminating the supply of gravel to the beach at Paekakariki by construction of State Highway 1 along the coast south of Paekakariki and by preventing deposition of fine sand on the beach by construction of reflective seawalls.

6. Maximum erosion of 15 m at Raumati during the 11–13 September 1976 storm surge compared with 6 m along unprotected parts of the 'Golden Coast' was directly due to the effect of the seawall narrowing the beach at Raumati.

7. Coastal erosion since 1975 along the accreting coast north of Paraparaumu is the result of attack by a number of severe episodic storms from the northwest quadrant.

8. The frequency of occurrence of these storms is unpredictable which means no part of the 'Golden Coast' can be regarded as permanently stable. Two or three events in succession are likely to cause up to 50 m of erosion along the 'Golden Coast'.

9. Seawalls at Paekakariki and Raumati will not last and will eventually be destroyed by the combination of long-term net erosion and destruction of the natural beach.

10. Long-term (50–100 y) alternative lines of action for combatting coastal erosion at Raumati and Paekakariki are either 'no action' or 'beach replenishment'. Further development along the 'Golden Coast' should allow a buffer-zone of at least 50 m between properties and the beach to allow for shoreline movements.

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APPENDICES

APPENDIX 1. Rates of coastal erosion and accretion for the 'Golden Coast'. (Source – Gibb, in prep.1978 b).

APPENDIX 2. 'Golden Coast' study. Surf Observation Programme (S.O.P.) recording form and instructions for filling out form.

APPENDIX 3. Alternative means of combatting beach erosion. (Source – Beach Protection Authority of Queensland 1977: Beach Conservation Newsletter No. 29. Box 2195 GPO Brisbane, Australia).
Published by permission of the Secretary, Beach Protection Authority of Queensland.
NOTE: Rock revetment is equivalent to timber seawall.

APPENDIX 1 — Rates of coastal erosion and accretion are tabulated for the 'Golden Coast'. Data are from Gibb (in prep.) and are extracted from data covering the New Zealand coastline. Each locality is numbered consecutively from Item 075 to Item 099 in column (A). Columns (B) and (C) list locality and grid reference of each item and have been taken from the latest set of NZMS 1, 1:63360 topographic maps of New Zealand. Column (D) lists landforms, their age of formation and the lithology of the material forming the coast at each locality. Along the 'Golden Coast', H3d refers to recent sanddunes. Texture of beach sediment based on mechanical analysis is given in column (E). Sand is S, and gravel, G.

Survey years are listed in column (F) including relevant information regarding significant erosion events and establishment of coastal subdivisions. The amount of land gained from accretion (+) or lost from erosion (—) is tabulated as a horizontal distance for each locality in column (G). Rates of coastal erosion or accretion for each survey interval are given in column (H) and the net rate for the entire survey period at each locality in column (I).

Numbers listed in column (J) refer to information sources listed below.

12 Donnelley, L.S. 1959: *N.Z. Engineering 14 (2)*: 48–52

18 Measurements by the author from vertical aerial photographs held by Department of Lands and Survey, Head Office, Wellington.

19 Field measurements by the author.

70 Measurements by the author from cadastral plans held by Department of Lands and Survey, district office, Wellington, and by Wellington Regional Water Board.

(A) ITEM	(B) LOCALITY	(C) N.Z.M.S.1 GRID REF.	(D) LITHOLOGY AND AGE	(E) BEACH	(F) SURVEY INTERVAL (y)	(G) ACCRETION(+) OR EROSION(-)(m)	(H) RATES ($m \cdot y^{-1}$)	(I) NET RATE ($m \cdot y^{-1}$)	(J) DATA SOURCE
075	CENTENNIAL INN - PAEKAKARIKI	N160/485570	H_3d	G	1894–1940	-12	-0.26		70
					1940–1977	-6	-0.16	-0.22	19
			(STORM SURGE SEPTEMBER 11-13, 1976			-1)			19
076	PAEKAKARIKI	N160/489576	H_3d	G	1894–1897	-7	-2.3		70
					1897–1906	-6	-0.67		70
					1906–1926	-18	-0.9		70
					1926–1940	+21	+1.5		70
					1940–1958	-50	-2.78		70
					1958–1977	0	0	-0.72	19
077	PAEKAKARIKI	N160/491579	H_3d	G	1926–1941	-9	-0.6		70
					1941–1963	0	0		70
					1963–1977	0	0	-0.18	19
					1907 FIRST SUBDIVISION OF PAEKAKARIKI COAST				70
078	PAEKAKARIKI PARADE	N160/495587	ROAD FILL	-	1907–1976	0	0		70
					1976–1977	-2	-2	-0.03	19
079	PROFILE 3	N160/500596	H_3d	S/G	1874–1968	+48	+0.51		70
					1968–1977	-1	-0.14	+0.46	19
			(STORM SURGE SEPTEMBER 11-13, 1976			-1)			19
080	TRIG BEACH	N156/506613	H_3d	G/S	1874–1968	+32	+0.34	+0.34	70
081	TRIG O	N156/512624	H_3d	G/S	1874–1968	+17	+0.18	+0.18	70
082	PROFILE 4	N156/508618	H_3d	G/S	1874–1943	+26	+0.38		70
					1943–1948	-13.8	-2.76		18
					1948–1952	+1.2	+0.3		18
					1952–1966	+4.4	+0.31		18
					1966–1973	-2.9	-0.41		18
					1973–1977	+3.0	+0.75	+0.17	18
			(STORM SURGE SEPTEMBER 11-13, 1976			0)			19
083	PROFILE 5	N156/513633	H_3d	S	1874–1943	-5	-0.07		70
					1943–1948	-9.7	-1.94		18
					1948–1952	+3.9	+0.98		18
					1952–1966	-4.4	-0.31		18
					1966–1973	-10.2	-1.46		18
					1973–1977	-3.0	-0.75	-0.28	18
			(STORM SURGE SEPTEMBER 11-13, 1976			-2.5)			19
					1906 FIRST SUBDIVISION OF RAUMATI COAST				70

(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)
084	PROFILE 6	N156/516649	H_3d	S	1874-1880	-50	-8.33		70
					1880-1920	+29	+0.73		70
					1920-1968	-5	-0.10		70
					1968-1977	-11	-1.22	-0.36	19
			(STORM SURGE SEPTEMBER 11-13, 1976			-11)			19
085	PROFILE 7	N156/518666	H_3d	S	1874-1880	-40	-6.67		70
					1880-1943	+35	+0.56		70
					1943-1952	+12.4	+1.38		18
					1952-1958	-25	-4.17		18
					1958-1977	-6	-0.32	-0.23	18
			(STORM SURGE SEPTEMBER 11-13, 1976			-6)			19
086	PROFILE 8	N156/518682	H_3d	S	1874-1880	+40	+6.67		70
					1880-1905	+20	+0.8		70
					1905-1952	-24	-0.51		70
					1952-1958	+2.2	+0.37		18
					1958-1966	+4.4	+0.55		18
					1966-1973	+5.2	+0.74		18
					1973-1977	+5.3	+1.33	+0.52	18
			(STORM SURGE SEPTEMBER 11-13, 1976			-4)			19
087	PROFILE 9	N156/519694	H_3d	S	1880-1905	+143	+5.72		70
					1905-1968	+52	+0.83	+2.22	70
			(STORM SURGE SEPTEMBER 11-13, 1976			-4)			19
088	PROFILE 10	N156/523708	H_3d	S	1880-1905	+119	+4.76		70
					1905-1968	+52	+0.83	+1.94	70
			(STORM SURGE SEPTEMBER 11-13, 1976			-1)			19
					1920 FIRST SUBDIVISION OF PARAPARAUMU COAST				70
089	KENAKENA TRIG	N156/527714	H_3d	S	1880-1892	+22	+1.83		70
					1892-1905	+73	+5.62		70
					1905-1968	+96	+1.51	+2.16	70
090	KENAKENA POINT	N156/527714	H_3d	S	1877-1892	+60	+4.0		12
					1892-1914	+60	+2.73		12
					1914-1940	+40	+1.54	+2.54	12
091	PROFILE 11	N156/532717	H_3d	S	1880-1968	+171	+1.94	+1.94	70
			(STORM SURGE SEPTEMBER 11-13, 1976			-1)			19
092	PROFILE 12	N156/548727	H_3d	S	1860-1898	+26	+1.44		70
					1898-1923	-40	-1.6		70
					1923-1968	+71	+1.58		70
					1968-1977	-8	-0.89	+0.51	19
			(STORM SURGE SEPTEMBER 11-13, 1976			-2)			19
093	PROFILE 13	N157/556733	H_3d	S	1880-1898	+121	+6.72		70
					1890-1923	+32	+1.28		70
					1923-1948	+4	+0.16		70
					1943-1968	+24	+1.2		70
					1968-1976	-8	-1.0		19
					1976-1977	-2	-2.0	+1.76	19
			(STORM SURGE SEPTEMBER 11-13, 1976			-3)			19
					1923-1924 FIRST SUBDIVISION OF WAIKANAE COAST				70
094	WAIKANAE	N157/563739	H_3d	S	1880-1924	+116	+2.64		70
					1924-1948	+13	+0.54		70
					1948-1968	+45	+2.25		70
					1968-1977	-8	-0.89	+1.71	19
095	PROFILE 14	N157/569745	H_3d	S	1880-1898	+120	+6.67		70
					1898-1957	+18	+0.31		70
					1957-1968	+18	+1.64		70
					1968-1977	-8	-0.89	+1.53	19
			(STORM SURGE SEPTEMBER 11-13, 1976			-4)			19
096	PROFILE 15	N157/578757	H_3d	S	1880-1908	+80	+2.85		70
					1908-1957	+38	+0.77		70
					1957-1968	+51	+4.64		70
					1968-1976	-6	-0.75		19
					1976-1977	-2	-2.0	+1.66	19
			(STORM SURGE SEPTEMBER 11-13, 1976			-6)			19

(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)
097	TRIG M	N157/584765	H_3d	S	1880-1908	+14	+0.5		70
					1908-1964	+34	+0.61		70
					1964-1968	+33	+8.25		70
					1968-1977	-8	-0.89	+0.75	19
098	PROFILE 16	N157/589772	H_3d	S	1914-1964	+17	+0.34		70
					1964-1968	+17	+4.25		70
					1968-1976	-6	-0.75		19
					1976-1977	-2	-2.0	+0.41	19
			(STORM SURGE SEPTEMBER 11-13, 1976			-6)			19
099	TRIG T	N157/608808	H_3d	S	1879-1918	+19	+0.66		70
					1918-1968	+100	+2.0	+1.34	70

"GOLDEN COAST" STUDY

SURF OBSERVATION PROGRAMME

(S.O.P.)

INSTRUCTIONS FOR FILLING OUT S.O.P. RECORDING FORM

SITE NUMBER

Each observation point along the coast has been assigned an alphanumeric code (1A, 1B, 2A, etc.) consisting of one digit and a letter of the alphabet. One (1), represents the most southern observation station, with the numbers increasing progressively with each station northwards. Where there is more than one observer at each station, a letter of the alphabet will be given to denote the particular observer. The digit is recorded in the left box and the letter of the alphabet in the right.

DATE

Record the day, month and year in the boxes provided on the recording sheet.

TIME

Record the time to the nearest quarter-hour at which the observation is made. The 24-hour clock system of recording time is used to avoid any confusion between a.m. and p.m. (e.g. 9.00 a.m. is 0900, 1.00 p.m. is 1300, and 3.15 p.m. is 1515).

Daily observations should be made as close as possible to 0900 hours. Observations should be made at the *same* time every day.

WAVE OBSERVATIONS

(These observations are to be made once daily).

(1) **Wave Period:** Record the time in seconds for eleven wave "crests" to pass a stationary point. Eleven "crests" will include ten complete waves (crests and trough). Crest 1 is zero-time, crest 11 is cut time.

(2) **Wave Height:** This observation is based solely on the judgement of the observer. The observer's best estimate will be sufficient. Record the breaking wave height to the nearest one-tenth metre. If wave height is less than one-tenth metre (0.1), the wave height is "0". If no waves exist at all, mark "0" for *both* WAVE HEIGHT and WAVE PERIOD.

(3) **Wave Direction:** Using the Wave Direction Code on the back of the recording form, enter the number in the box, that best describes the direction of the approaching waves. If no waves exist at all, write the direction as "0".

(4) **Type of Breaking Wave:** If no waves exist, enter "0" in the box, otherwise choose only *ONE* of the following four types of waves:

Spilling - Spilling occurs when the wave crest becomes unstable and the crest flows down the front face of the wave, producing an irregular, foamy water surface. This wave is sometimes referred to as a "roller". Mark "1" for spilling.

Plunging - Plunging occurs when the wave crest curls over the front face of the wave and falls into the base of the wave, producing a high splash and much foam. This wave is sometimes referred to as a "dumper". Mark "2" for plunging.

Plunging/Spilling - This occurs when there is a combination of spilling and plunging waves. Mark "4" for plunging/spilling.

Surging - Surging occurs when the wave crest remains unbroken while the base of the front of the wave advances up the beach. Mark "3" for surging.

(5) **Surf Zone Width:** This observation is based on the judgement of the observer. The observer's best estimate is sufficient. Record the distance, to the nearest whole metre, from the water line at the time of observation to the line of the most seaward row of breakers, at the time of observation. If no waves exist at all, mark "0". If two or more breaker zones exist, record the distance to the most seaward row of breakers of the most seaward breaker zone.

(6) **Offshore Bar:** Record whether or not a significant offshore bar exists. This may be determined as "yes" if there is a distinct channel between the initial breaking waves and the beach, allowing the wave to reform; and "no" if the wave continues in a broken state from the initial breakpoint to the beach. If an offshore bar exists enter "1" in the box, and if not enter "0".

STATE OF TIDE

(This observation is to be made once daily).

Indicate the relative state of tide by marking one of the ranges: low tide "0", quarter tide "1", half tide "2", three-quarter tide "3", full tide "4", and mark whether the tide is rising "R", falling "F", or stationary "S", at the time of observation.

LITTORAL CURRENT OBSERVATIONS

(These observations are to be made once daily).

(1) **Current Velocity:** This can be measured by throwing a partly submerged float as near as possible to the midpoint of the surf zone. The observer will note the position of the float at entry to the breaker zone and the position of the float after an elapsed time of one minute. The distance between these two positions is entered in the boxes provided on the form. If there is no long shore movement after one minute, record "0" in the box.

(2) **Current Direction:** Indicate whether the float moves downcoast or upcoast. In general, current that flows to the north or to the observer's right is considered upcoast, and that which flows to the south or the observer's left, is considered downcoast. Enter "L" in the box if the current flows downcoast and "R" if the current flows upcoast. If no current is evident, enter "0" in the box.

COMMENTS

Note any remarks or sketches or unusual events (e.g. erosion scarps, storm damage, unusual tides, etc.) in the comments section of the recording form.

Remember: To mark *all* recording sheets with your site number, and time and date.

Remember: Systematic observations are imperative to understand your coastline.

Issued by

Planning and Technical Services

WATER AND SOIL DIVISION, HEAD OFFICE

Ministry of Works and Development
Aitken Street, Wellington

(Box 12-041, Wellington North)

SURF OBSERVATION PROGRAMME

RECORD ALL DATA CAREFULLY AND LEGIBLY **SOP**

SITE NUMBER	DAY	MONTH	YEAR	TIME
2 8	2 1	0 7	7 4	1 1 0 0

WAVE PERIOD

Record the time in seconds for eleven (11) wave crests to pass a stationary point. If calm record 0

0 8 5

WAVE HEIGHT

Record the best estimate of the average wave height to the nearest tenth of a metre.

0 . 7

WAVE ANGLE AT BREAKER

Record the direction the waves are coming from using the code on the reverse side

3

WAVE TYPE

0 — calm
1 — spilling
2 — plunging
3 — surging
4 — spill / plunge

4

SURF ZONE WIDTH

Estimate in metres the distance from shore to breakers. If calm record 0

3 0 0

OFFSHORE BAR

Is an off-shore bar present?

I — yes 0 — no

1

STATE OF TIDE

0 — low
1 — 1/4
2 — half
3 — 3/4
4 — high

4

1027 Hrs

Is the tide?

R — rising F — falling S — stationary

S

LITTORAL CURRENT SPEED

Measure in metres the distance the dye patch or float is observed to move during a one (1) minute period: If no long shore movement record 0

0 0 4

CURRENT DIRECTION

When the observer faces the sea

0 — no long shore movement
L — dye or float moves to the left
R — dye or float moves to the right

L

PLEASE PRINT

Please check the form for completeness

SITE NAME: Raumati South

OBSERVER: V Liddicoat

REMARKS: Unusual high tides forecast still with us. Fairly big breakers over the sea protection wall. Difficult to accurately assess the littoral current speed as tide taking markers and tossing them on beach. Assessment using heavy log floating off shore. Wind light. Lee of Kapiti further up beach Different tide/surf, seas/ breakers quite different from Raumati South.

Make any additional remarks, computations or sketches on the reverse side of this form.

ALTERNATIVE MEANS OF COMBATTING BEACH EROSION

Reprinted from "Beach Conservation", the newsletter of the Beach Protection Authority of Queensland, Australia.

by Engineer Les Ford

BEACH EROSION is a natural part of beach behaviour and becomes a problem only when it threatens property and improvements. The essence of the problem is not that beaches erode but that development has occurred within the zone of these natural beach movements.

Combatting any particular beach erosion problem is usually a very expensive business which, in the case of future development, can be completely avoided simply by the provision of an adequate buffer zone between the development and the beach.

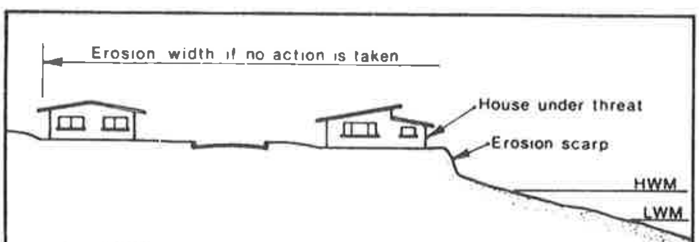
However, where existing development is experiencing erosion problems, remedial action can be taken by implementing one or more of the measures outlined below.

ALTERNATIVE EROSION CONTROL MEASURES

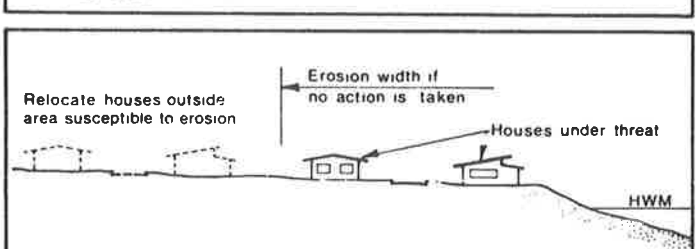
The selection of the most appropriate method of combatting an erosion problem is by no means simple and will be influenced by the type of beach, the erosion mechanisms at work and the availability of funds for the project.

There are six basic ways of dealing with beach erosion problems which can be implemented individually or in various combinations. These are:

1. No Action — allowing nature to take its course and accepting the resulting property losses.
2. Relocate Development — removing the problem by relocating development outside the threatened zone.
3. Rock Revetment — providing a physical barrier to further erosion.
4. Groynes — to trap sand in the eroding areas.
5. Offshore Breakwaters — to reduce wave energy behind the breakwater and to trap sand in the eroding areas.
6. Beach Nourishment — rebuilding eroding beaches by direct placement of sand onto the beach.



1 - NO ACTION



2 - RELOCATE DEVELOPMENT

1. NO ACTION (See Fig. 1)

A decision to take no action and allow erosion to continue is the best course of action when the threatened development has little value. Such a course of action requires no expenditure on protective measures and involves minimal interference with existing beach behaviour.

However, residents will naturally take action to protect their homes and government agencies will also wish to protect their assets and amenities, making this method often impractical.

Before this course of action is rejected as unacceptable, it is desirable that the costs of the protective measures and the value of the assets to be protected be compared objectively. This has not always been done in the past.

2. RELOCATE DEVELOPMENT (See Fig. 2)

In cases where the development can be re-established elsewhere at reasonable cost, buffer zones can be provided where they previously did not exist. Such provision may necessitate moving amenities, roads and even domestic houses with payment of compensation to the people involved.

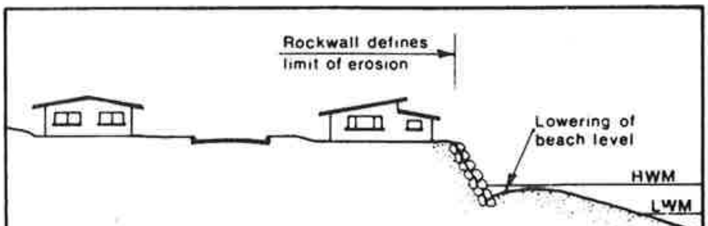
The financial and social costs involved in resumption and compensation payments are usually high especially in densely populated areas and public reaction against this general approach is understandably strong. In spite of its apparent drawbacks, in some areas relocation may well be cheaper in the long run than expensive protection works.

3. ROCK REVETMENT (See Fig. 3)

Rock revetment is probably the most commonly adopted method of combatting erosion problems in Queensland. Rock walls are surprisingly expensive, but can be provided at short notice and, for this reason, are commonly used for erosion control during cyclones and severe storms. They also give property owners a feeling of security by their solid appearance but this will be an illusion unless the wall has been properly designed and constructed to resist severe wave attack.

Once provided, rock walls constitute a lasting artificial impediment to natural beach behaviour and generally result in an appreciable drop in the level of the beach. Erosion can still continue at each end of the rock wall and may even be accentuated at these locations.

Rock revetment offers protection against further erosion but only at the expense of the beach which may need beach nourishment to restore its value as a recreational asset.



3. ROCK REVETMENT

4. GROYNES (See Fig. 4)

Groynes are a common but sometimes misunderstood method of combatting erosion. Groynes function by trapping sand moving along the coast on the updrift side of the groyne but starve the beach of sand supply on the downdrift side. Groynes can only function if there is a significant drift of sand along the coast in a predominant direction.

The main problem with groynes is they do not solve an erosion problem but merely transfer it along the beach. Often this leads to the construction of a series of groynes (a groyne field) with the result that the erosion problem becomes concentrated on the downdrift side of the last groyne.

During severe wave attack, groynes do not prevent erosion because they have no effect in reducing the movement of sand in the offshore direction (i.e. at right angles to the beach). However, by trapping sand on the updrift side they do help to provide a wider beach to accommodate erosion. At the same time, the depleted beach on the downdrift side of the groyne will be more susceptible to erosion than before.

The erosion problems associated with groynes can be compensated for to a large extent by beach nourishment. As a general rule a combined approach is preferable to using groyne construction by itself unless the concentration of erosion on the downdrift side is acceptable.

5. OFFSHORE BREAKWATERS (See Fig. 5)

Offshore breakwaters constructed parallel to the beach alter the height and direction of waves reaching the beach. They create a sheltered zone behind them into which sand may be moved by longshore transport processes but out of which longshore transport will be greatly reduced because of the altered wave climate. In addition, short term storm erosion will be reduced as much smaller waves will reach the beach.

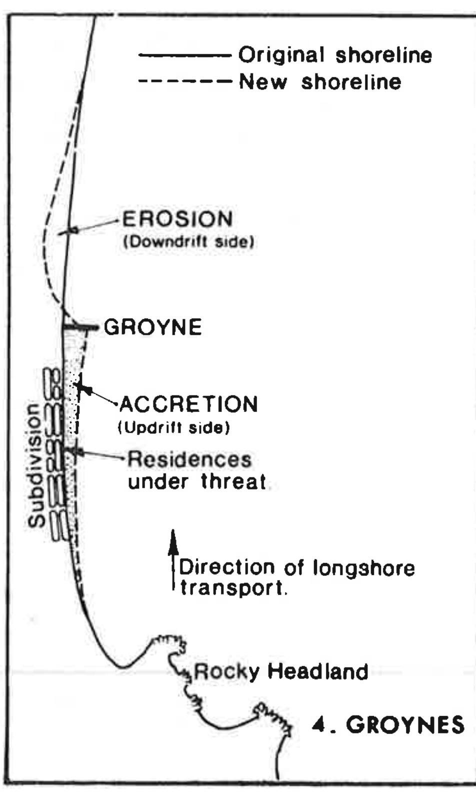
Offshore breakwaters, like groynes, cause erosion on the downdrift side of the structure and usually will need to be complemented by using beach nourishment.

The construction of offshore breakwaters is difficult and expensive and the cost is generally prohibitive unless other benefits such as a small craft harbour are involved.

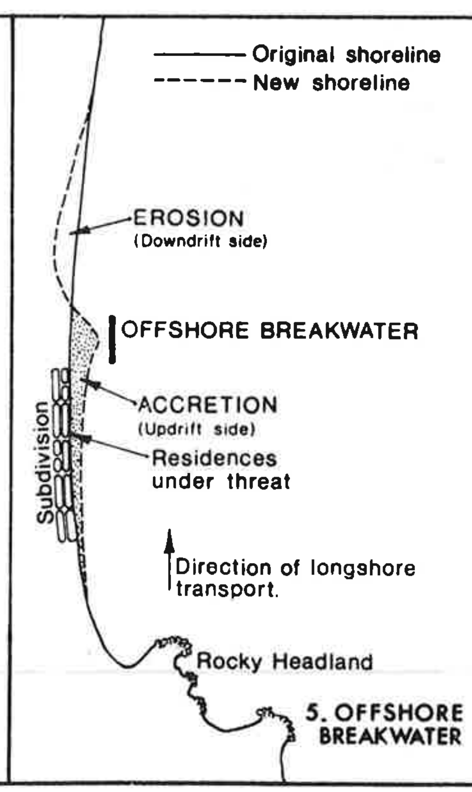
6. BEACH NOURISHMENT (See Fig. 6)

Beach nourishment refers to the deposition of sand onto beaches by pumping or other means with a view to restoring an adequate buffer zone in front of the threatened property. Suitable sources of the sand for beach nourishment are usually nearby estuaries or offshore areas but they must not be part of the active beach system.

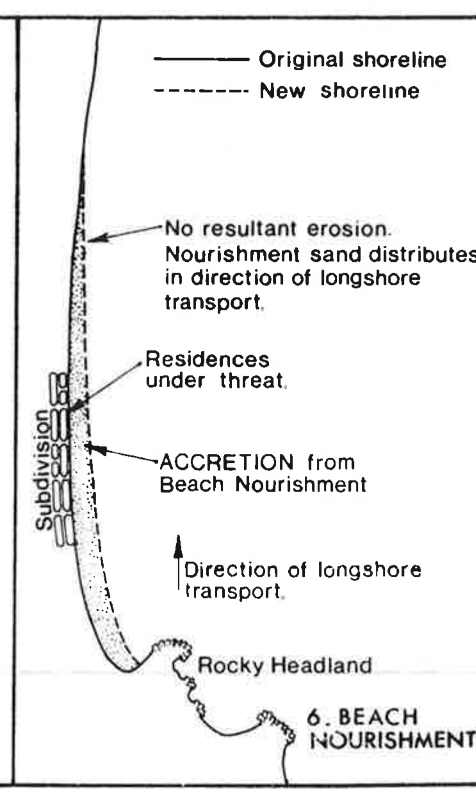
The attraction of beach nourishment as a method of erosion control is that it improves the beaches while providing protection to previously threatened property. The approach has no adverse effects on adjacent beaches and is currently recognised as the best solution to erosion problems in areas where a suitable sand source is available nearby.



4. GROYNES



5. OFFSHORE BREAKWATER



6. BEACH NOURISHMENT

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