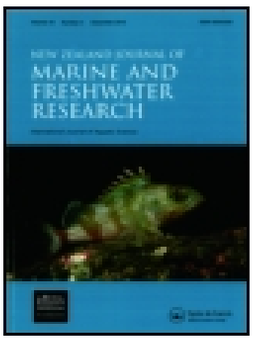

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Littoral sediment transport at Mangatawhiri Spit, New Zealand

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Abstract Beach sand characteristics were used to determine littoral drift along Mangatawhiri Spit, New Zealand. These show there is a bi-directional movement of sediment away from the approximate centre of the spit; that spit orientation is not a reliable indicator of littoral drift direction along Mangatawhiri Spit; and that present remedial works for erosion control at Mangatawhiri Spit will only be partially effective during an erosion phase.

Keywords Mangatawhiri Spit; littoral drift; spit orientation; sorting coefficient; bi-directional drift; beach nourishment; sediment transport

INTRODUCTION

The orientation of a sandspit is commonly used as an indicator of the direction of net littoral drift along the spit. However, spit orientation is determined by a combination of factors, including inlet channel geometry, wave refraction, and tidal flow. Consequently, spit orientation may sometimes be contrary to dominant littoral drift (Hayes et al. 1970; Hubbard 1976; Lynch-Blosse & Kumor 1976).

This study investigates the relationship between spit orientation and littoral drift at Mangatawhiri Spit. Mangatawhiri Spit lies 60 km north of Auckland (Fig. 1A). Its orientation is south to north, sitting between the rocky headlands of Ti Point and Karamuroa Point. The Whangateau Harbour entrance separates the tip of the spit from the northern headland (Ti Point).

From 1871 to 1953 the spit was stable, it then entered a phase of erosion. By 1976 the spit tip had retreated some 300 m from its 1953 position (Beca et al. 1976). During the early 1970s the central part of the spit was developed as a residential subdivision. This development involved the levelling of foredunes and the removal of 25 000 m^3 of sand. However, by 1976 continuing erosion resulted in a ban on house construction on many beach front sections (Beca et al. 1980).

In an effort to stabilise the beach and to prevent further loss of property, dredging and reclamation works commenced in 1979. This work involved the construction of a series of groynes at the northern end of the spit (Fig. 1B) and the spreading of 400 000 m^3 of sand over the beach face extending along the spit to south of the subdivision (Beca et al. 1980). The groynes were supposed to recreate the tidal currents which existed before the erosion and contain the artificially placed sediment and sediment drift (Beca et al. 1980). However, these construction works were based on the premise of a northward littoral drift (Beca et al. 1976). On simple morphological grounds a northward drift is indicated by the orientation of the spit.

The purposes of this study were twofold: the first was to determine the net direction of littoral drift along Mangatawhiri Spit using a method described by Sunamura and Horikawa (1973). The second purpose was to compare the results with the usual inference made from spit orientation.

METHODS

Sunamura and Horikawa (1973) concluded the direction of littoral sediment transport can be determined from spatial variation of both grain size and sorting, each of which should be sensitive to particular depositional environments. Earlier they had established that mean grain diameter and standard deviation of grain size were suitable measures of size and sorting respectively (Sunamura & Horikawa 1972).

Sediment samples were collected at intervals along the length of Mangatawhiri Spit during May 1984 (Fig. 1B). Samples were taken from that part of the beach face subject to wave action at mid-tide level. This 'reference point' on a shore was described by Bascom (1951) as permitting satisfactory comparison of beach characteristics. The sediment samples were scraped from the top few centimetres of the surface. The sediments were

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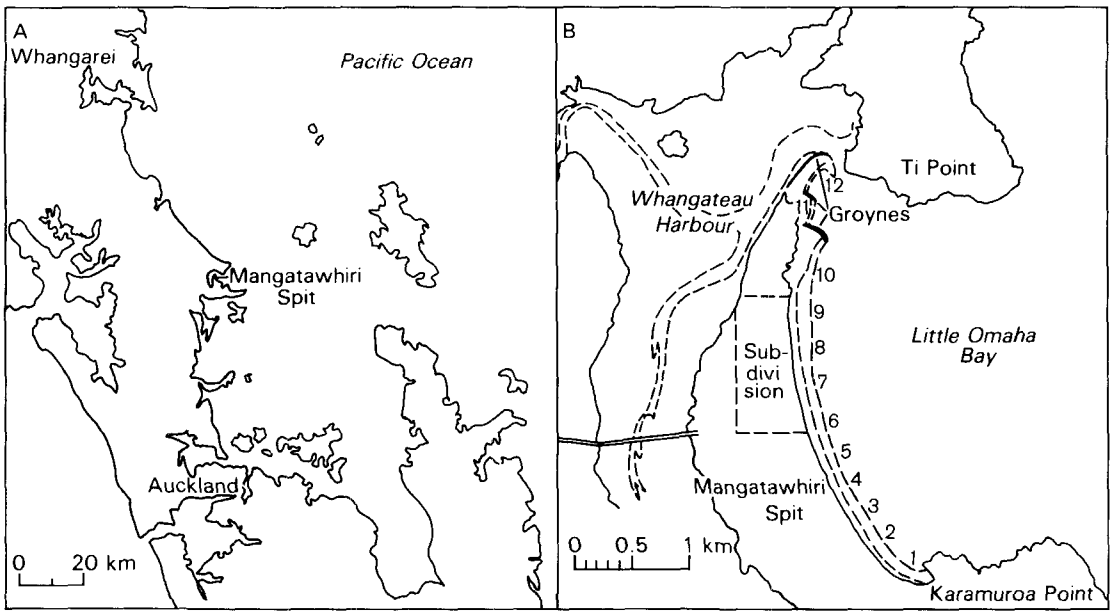

Fig. 1 Mangatawhiri Spit. **A,** Location of spit on the north-east coast of North Island, New Zealand. **B,** Map of Mangatawhiri spit showing location of sediment sample sites (1–12) and the position of the groynes at the northern tip of the spit.

washed, dried, and then sieved to quarter phi (ϕ) intervals. Mean grain diameter and standard deviation of grain size were determined as described by Folk and Ward (1957). These measurements produce results which closely parallel those derived from the moments method (Fox et al. 1966), which Sunamura and Horikawa (1973) used in their study.

A single set of samples might be said to represent littoral drift during only a short period of antecedent conditions. However, in common with Sunamura and Horikawa (1972: 61) and others, it is considered that a variation series of grain size properties can indicate a longer term transport direction when considered in relation to known sources and sinks of sand.

RESULTS

For the present study, no records were available for beach state prior to sampling. However, the foreshore showed no evidence of recent storm erosion and had depositional berms at some sites. These were taken as indications that the beach was in an accretional phase.

Spatial variation of mean size (M_ϕ) and standard deviation (σ_ϕ) for each station were plotted (Fig. 2). The inference criteria of Sunamura and Horikawa (1972) (Fig. 3) were then applied to evaluate the direction of sediment movement.

Mean grain diameter and the standard deviation of grain size decrease both to the north and south of Site 6 (Fig. 2). By using the criteria of Fig. 3d these data indicate a bi-directional littoral drift from an area near to Site 6 in this study.

DISCUSSION

Two interpretations of the bi-directional drift at Mangatawhiri Spit are possible. First, the results might be an artefact of construction arising from the placement of coarse material adjacent to the subdivision. If this were so, it would be expected that mean grain size from Sites 6–12 would be of a more random nature; with little or no distinct trends in either grain size or sorting. A second and the more likely interpretation, is that the central part of the spit is a source area for sediments, from which there is movement to both the distal and proximal ends.

The littoral drift pattern identified in this study is in agreement with two previous studies at Mangatawhiri Spit. Schofield (1967, 1975) proposed a north and south sediment drift from the central part of the spit during periods of deposition. However, during periods of erosion he identified a southerly drift along the entire length of the spit. He based these drift directions on evidence derived from minerological, grain size, and zoological investi-

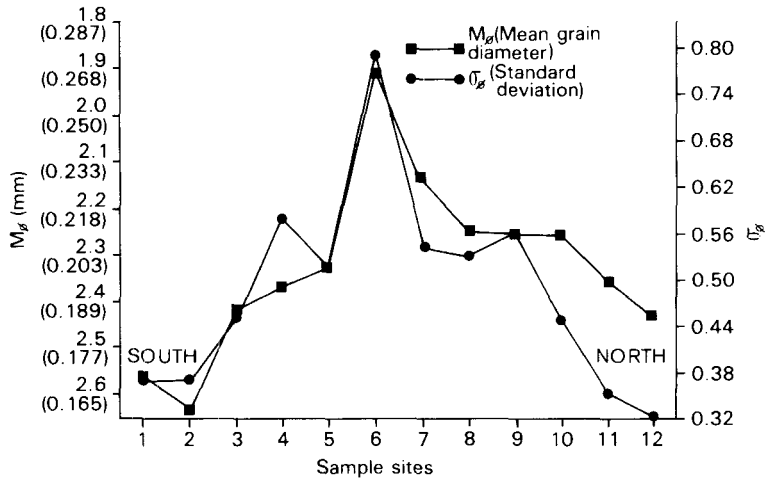

Fig. 2 Spatial variation series of mean grain size (M_ϕ) and standard deviation (σ_ϕ) of sediment samples.

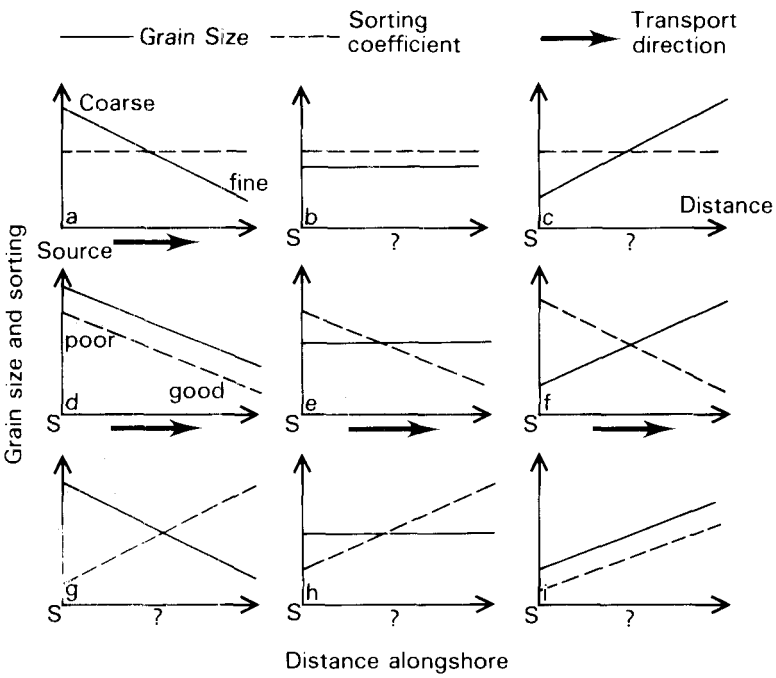

Fig. 3 Criterion for the inference of transport direction. (Published with permission from Sunamura & Horikawa 1972.)

gations within Little Omaha Bay. Beca et al. (1976) also illustrated a littoral drift pattern similar to that proposed using the results of wave refraction analysis for the bay.

The importance of the bi-directional littoral drift at Mangatawhiri Spit is twofold. First, it confirms that the decision to build the groynes at the northern end of the spit to intercept northward sand transport was a correct one. Thus, the groynes help stabilise the tip of the spit. Second, and more important, is the response of the beach to this bi-directional drift of sand during a period of erosion. The design of the remedial works assumed a northerly sand transport along the length of the spit, so its effectiveness is limited under the proposed bi-directional drift. This limitation arises because the groynes trap and contain only part of the overall drift. The southern drift results in a net loss of sand which will cause beach nourishment to dissipate over time.

Mangatawhiri Spit is believed to be part of an essentially closed sand system; the 'Ocean Beach-Mangatawhiri Sand System' as described by Schofield (1975). In Schofield's opinion, sand which is eroded from the beach is deposited offshore until conditions are suitable for its deposition back onshore. Schofield (1975) suggests that this can occur at two timescales; a short term storm/post-storm scale and a long term scale related to sea-level. A rise in sea-level favours erosion and a fall in sea-level favours progradation, other factors being constant. Schofield (1967) states Little Omaha Bay must be the immediate source of the sand being deposited on the spit — locally derived sand from the erosion of nearby rock is of much less importance. Thus, the rate of sediment movement to either end of the spit would be controlled by three factors: (1) the rate of supply of 'new' Omaha Bay sediment to the beach; (2) sea-level change; and (3) the amount of sediment drift from the central part of the beach. If there were not a sufficient supply of new sediment to the beach from factors (1) and (2) then the central area would experience a net loss of sediment. Loss would continue until the geometry of the beach reached a stable equilibrium condition or until such time that further artificial beach renourishment was required to prevent erosion of sections within the subdivision.

This study confirms the possibilities raised in the Introduction. Inferring the direction of littoral drift from spit orientation may result in oversimplification of the situation or in error of the drift direction. The data here show a different and more complex pattern to that suggested by the orientation of the spit. Agreement between these results and those of Schofield (1967, 1975) suggests that the method of Sunamura and Horikawa (1973) is a reliable and effective method for determining the direction of littoral drift. The value of this method lies in its ready application, provided care is taken in sampling. Finally, an underlying factor that emerges from this study is the importance of not relying on only one method in identifying drift direction along spits. By confirming the results of one method with those from another a more reliable and precise understanding can be obtained of the processes involved.

SUMMARY

A method proposed by Sunamura and Horikawa (1973) was used to determine a net littoral drift direction along Mangatawhiri Spit and to see if these results supported those obtained from a simple morphological interpretation of spit orientation. The former method uses spatial variation of both mean grain size and standard deviation as parameters.

The results obtained show there is a bi-directional movement of sediment along the spit from near the centre (north and southwards). The importance of this bi-directional drift is twofold. First, it confirms that the decision to build the groynes to trap and contain a northerly sediment drift was correct. The second, and more important, factor is the likely effects of erosion on the central and southern part of the beach. As the groynes trap only part of the overall drift, and with sea-level rising, over time there will be a net loss of sand from the beach. The result will be either a new equilibrium profile for the beach, or the need for further beach renourishment to prevent erosion at the southern end of the beach and of sections within the subdivision.

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