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Presaging Beach Renourishment from a Nearshore Dredge Dump Mound, Mt. Maunganui Beach, New Zealand

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ABSTRACT

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A study was undertaken to ascertain whether material to be dredged from the shipping channel through a large ebb tidal delta at the entrance to Tauranga Harbor, New Zealand, could be dumped in shallow water (5–8 m below Mean Sea Level) off the downdrift Mt. Maunganui Beach and induce beach nourishment. Investigations included comparison of sedimentological texture of the material to be dredged, the dump site on the beach; a fluorescent sediment tracing experiment; application of standard Shore Protection Manual "fill" and "renourishment" factors; and application of the new techniques of KRAUS *et al.* (1991), and HANDS and ALLISON (1991).

Results illustrated textural similarity between the sediments to be dredged and the natural beach and dump zone, while the sediment tracing experiment indicated predominantly onshore movement. Application of the S.P.M. techniques along with the new techniques of KRAUS *et al.* (1991) and HANDS and ALLISON (1991) gave consistent, plausible indications that beach nourishment would succeed from the nearshore dumping. This was confirmed by sequential beach and bathymetric surveys subsequent to dumping.

ADDITIONAL INDEX WORDS: *Ebb delta beach, erosion, accretion, sediment tracing, beach profiles.*

INTRODUCTION

Mt. Maunganui Beach is a 700 m long beach located immediately downdrift to an ebb tidal delta on the northeastern coast of New Zealand (FOSTER, 1991). The beach is bordered to the west by Mt. Maunganui tombolo and to the southeast by Moturiki Island, and is also adjacent to Tauranga Harbour and the major port facility there (Figures 1 and 2).

The beach is characterised by a low foredune, and typically exhibits a well-formed berm and offshore bar. Historically, the beach experienced erosion between 1943 and 1974, with as much as 20 m of dune retreat occurring (HEALY *et al.*, 1977). Since 1974, the beach appears to have stabilised, evidently as a result of shoreward migration of dredged material from dumping on the inner shelf adjacent to the Tauranga Harbour (HEALY *et al.*, 1991).

Recognition that Mt. Maunganui Beach has suffered historical erosion, as well as concern for the erosive potential of long term sea level rise (HEALY, 1990; HEALY and McCABE, 1990), led to a proposal to dump material dredged from the shipping channel (known as the "Entrance Channel" or "Number One Reach") through the ebb tidal delta directly offshore from Mt. Maunganui Beach. Environmentally, such an option is desirable in that Mt. Maunganui Beach is the southeast extension of the ebb tidal delta and thus is composed of sediments from the same morphodynamic environment. Accordingly, in December 1990, some 80,000 m^3 of maintenance dredging from the Entrance Channel were dumped in a strip 200 m by 600 m (Figures 2 and 3) in approximately 4–7 m water depth below chart datum (chart datum is defined as Mean Low Water Spring, approximately 1 m below Mean Sea Level).

The purpose of this paper is to present the results of investigations initiated to (1) determine the suitability of the material to be dumped compared with the dump site from comparison of physical and textural characteristics; (2) make predictions about the stability of the dumped material and the likely directions of sediment movement from the dump site; and (3) monitor the movement of the dumped material.

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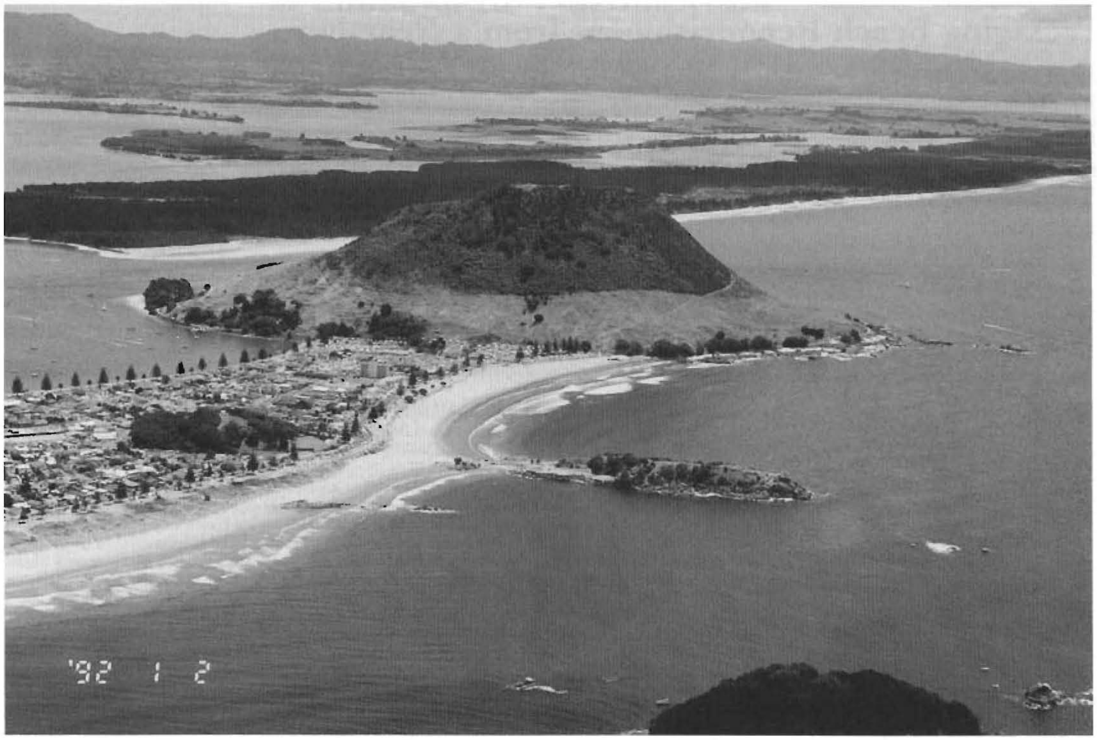

Figure 1. Oblique aerial view of Mt. Maunganui Beach and tombolo with Matakana barrier island and the tidal inlet entrance to Tauranga Harbour in the background. The dump zone was to the right of Moturiki Island, which is attached by a lee cusp deposit to the main Mt. Maunganui beach.

METHODS AND RESULTS

In order to assess the suitability of the sediment to be dumped, surficial samples were collected from the proposed dump ground (Figure 3), and shallow 1 m long cores were collected from the area to be dredged in the Entrance Channel (Figure 4). Composite samples were analysed for sediment textural characteristics using the Rapid Sediment Analyser (R.S.A.) at the University of Waikato.

Both geochemical and microbiological tests of the sediments were undertaken to assess compatibility prior to dumping (HEALY and McCABE, 1990), and their results showed no apparent differences between the dredged sediments and those already present on the proposed dump ground.

The movement of sediment on the dump ground was assessed by a sediment tracing experiment conducted in July 1990, prior to dumping, using ultra-violet fluorescent dyed sand.

Methods given in the Shore Protection Manual (SPM) (1984) for determining "renourishment" and "fill" factors and sediment compatibility were applied. Subsequently, the behaviour of the dump mound after dumping was predicted using the methods developed by KRAUS *et al.* (1991) to assess whether the beach would be accreted by across shore sediment transport, and by HANDS and ALLISON (1991) to predict whether the dump material would be "active" (*i.e.*, moved ashore) or "stable" (*i.e.*, remain in place offshore).

Confirmation of the predicted behaviour of the dump mound, and whether the beach had been accreted by the shorewards movement of dredged sand, was determined by the analysis of seven shore normal beach and bathymetric profiles established over the dump ground and adjacent beach, as detailed in FOSTER (1991).

THE SEDIMENT TRACING EXPERIMENT

Sediment tracing experiments using ultra-violet fluorescent sand have been regarded as relatively inexpensive and easy, although rather labour intensive, methods of determining the direction of sediment movement either along shore or across shore under a variety of conditions (*e.g.* KOMAR and INMAN, 1970; MILLER and KOMAR, 1979; FIELDS and WEISHAR, 1987; and others).

A sediment tracing experiment was conducted over the period of 17–19 July 1990 to determine the main patterns of sediment movement from the 6 m bathymetric contour adjacent to Mt. Maunganui beach in the location of the renourishment dump site. Some 510 kg of beach sand from Mt. Maunganui Beach were collected, dried, then treated with fluorescent dye after the method developed by ROY (1970, 1972). Following treatment, tracer adherence was tested under ultra-violet light after a variety of shaking tests to simulate field conditions. Adherence was found to be > 80% for all grains tested.

The tracer sand was then deployed at two sites (S29 and S60; Figure 2) on the 6 m contour located approximately at the centre of the proposed dump site. Prior to deployment, a radial collection grid was set up by SCUBA divers on each site with 8 stakes deployed within a 20 m radius from a central marker stake.

Wave and wind conditions were recorded at the time of deployment and over the period of the experiment. No current measurements could be taken over the dump ground due to the unavailability of current recorders at the time of the experiment. Wave data (wave height and period) were collected by the Port of Tauranga, Ltd., from a wave recorder located adjacent to the experiment site (known as 'A' beacon in the main Entrance Channel to Tauranga Harbour). Significant wave height (H_s) increased from $H_s = 0.11$ m at the time of deployment to $H_s = 0.42$ m after 48 hours when final samples were collected. Over the same time span, the significant period decreased from T = 9.41 sec to T = 7.95 sec.

Surficial sand samples (approximately 0.2 kg) were collected by a SCUBA diver using a hand held scoop and plastic bags. A total of 32 samples were collected at distances of 3, 5, 10, and 20 m from each of the central stakes after 24 and 48 hours which allowed for maximum movement over the period of the experiment. Sampling was hampered by the weather with southerly onshore winds rising from calm to 15 knots and gusting up to 32 knots over the period of collection, and by water turbidity due to increased wave agitation.

For laboratory analysis, the bulk surface samples were dried and a 10 g sub-sample split from each and analysed under UV light across a vibrating tray. The luminophores present in each sample were hand-counted, and the results used to create tracer dispersion maps.

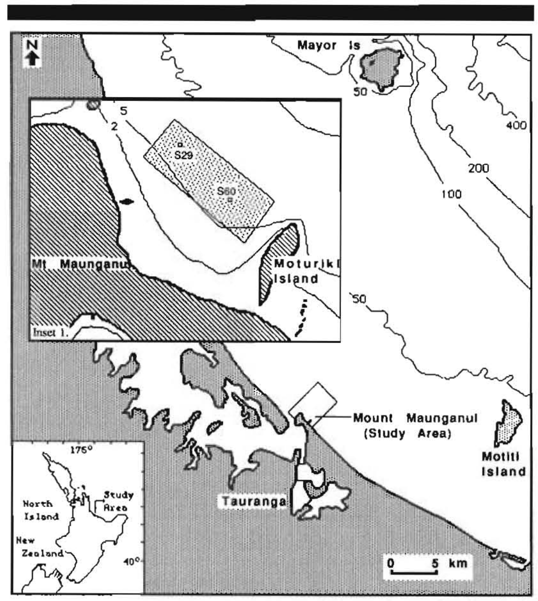

Figure 2. Location map of the study area, including the sites of the sediment tracing experiment.

Sediment Tracing Results

The results for each site were plotted as the number of luminophores per kg along with the main direction of wave approach. Results for Site 29, 24 hours after tracer dumping, show that dispersion of luminophores was confined to an area within 10 m of dumping. The main direction of movement appears to be southwards and shorewards (Figure 4A) apparently as a result of wave motion. Results for the same site 48 hours after dumping show a greater dispersion of luminophores exceeding 20 m from the dump point in a south-westerly (shorewards) direction, following the direction of main wave approach (Figure 4B).

Results for Site 60, 24 hours after tracer dumping, show a wide dispersion of luminophores from the dump site. Grain dispersion occurred more than 20 m in a south-southwest, shorewards, direction following wave crest approach (Figure 4C). Dispersion was further than the previous site. Results 48 hours after dumping (Figure 4D) were more diverse, with predominant movement to the

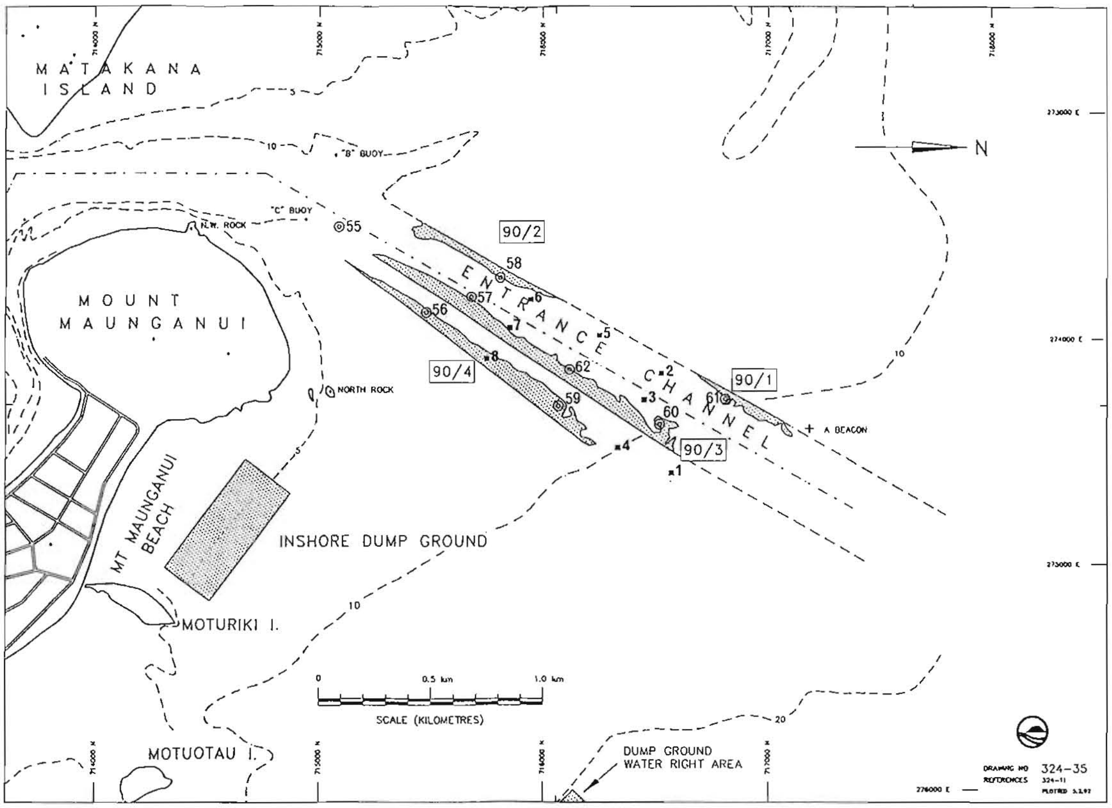

Figure 3. Location map of the shallow cores used for determining the textural characteristics of the material to be dredged. Cores 1–8 are from FOSTER (1991) and cores 55–62 from HEALY and MCCABE (1990). The stippled area alongside the Entrance Channel indicates the source of the dredged material.

south-west (normal to the wave crests), but with dispersion also occurring along a north-south direction both shorewards and seawards.

This last result may reflect the action of tidal or rip currents although these have not been fully investigated (due to lack of available equipment) but have been noted from aerial photographs of the area. The tracer dumps were in close proximity to the main entrance channel to Tauranga Harbour and are affected by the influence of an eddy circulation system set up by ebb tidal currents. This phenomenon was observed during field sampling throughout 1990 and compares favourably with the circulation vector diagrams predicted by a hydrodynamic model during the Tauranga Harbour Study (BARNETT, 1984) and the field observations made by DAVIES-COLLEY and HEALY (1978).

A further set of samples from each site closer to shore were collected one week after the initial experiment, but no tracers were detected during analysis.

Natural Tracers

Two other lines of evidence of the shorewards migration of material from the inner shelf off Tauranga on to Mt. Maunganui Beach came from (1) the presence of the bivalve clam species *Paphies australe,* the common New Zealand pipi, on the beach (FOSTER, 1991; HEALY *et al.*, 1991), and (2) the results of previous dredge dumping programs.

The common pipi is an estuarine dweller generally found only within the confines of Tauranga Harbour and is normally not mobile. Dredgings removed from within the harbour channels include this shell species and have been dumped on the inner shelf at approximately −15 to −20 m

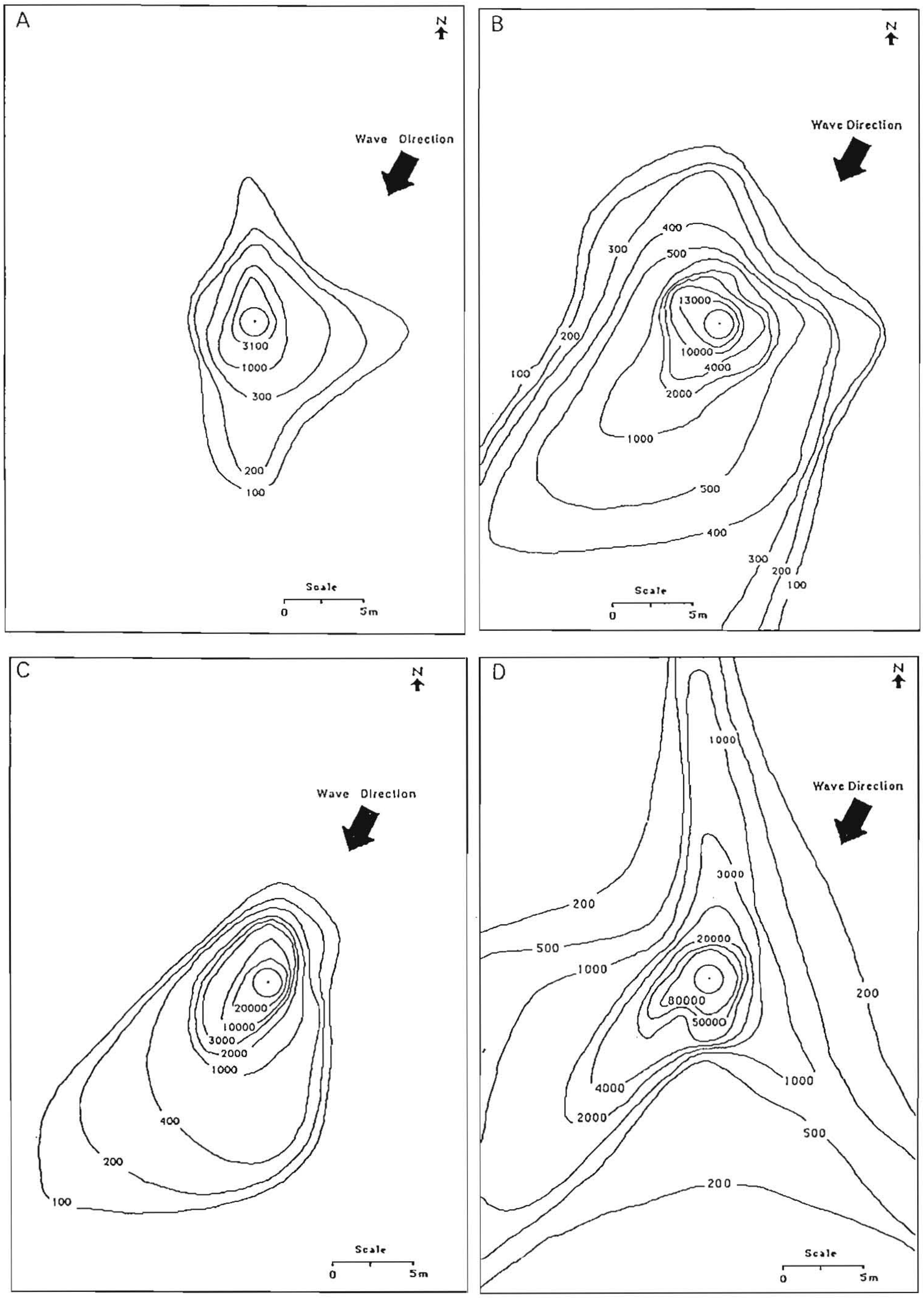

Figure 4. Tracer dispersion maps for (A) Site S29 after 24 hours, (B) Site S29 after 48 hours, (C) Site S60 after 24 hours, and (D) Site S60 after 48 hours. The shoreline is approximately 400 m southsouthwest from the dump site.

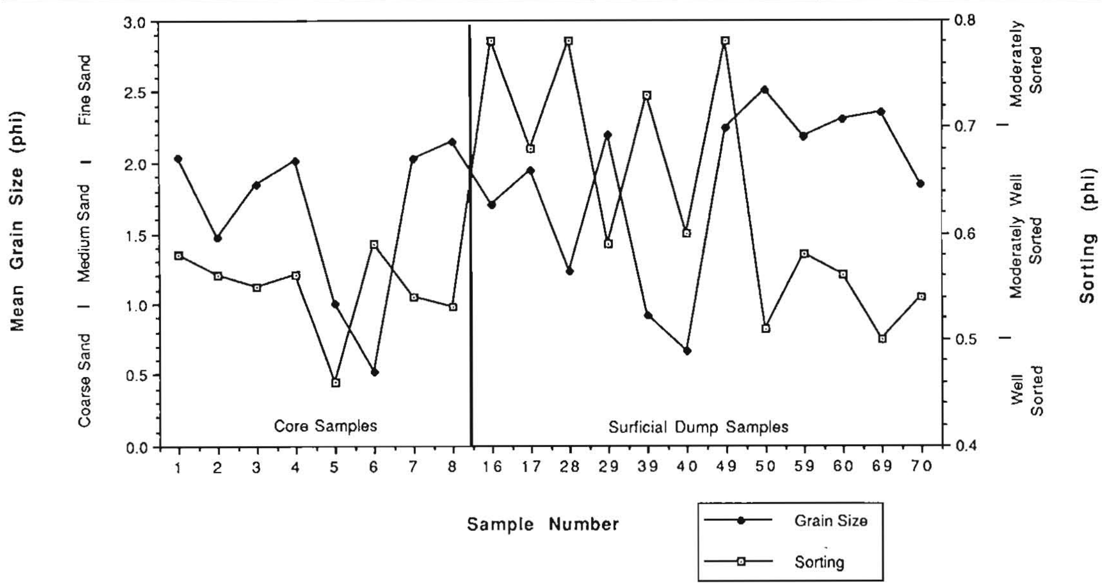

Figure 5. Comparison of mean grain size and sorting characteristics of the dump site with the material to be dredged. Sites numbers 16–70 along the bottom axis are situated within the inshore dump ground in Figure 3.

chart datum (HARMS, 1989; FOSTER, 1992). For these shells (which also exhibit signs of bio-erosion and abrasion) to be present on the beach is clear evidence that migration of material from the inner shelf shorewards must occur.

During dredge dumping programmes, pumice granules or shards (DE LANGE *et al.*, 1991) are likewise found widespread along Mt. Maunganui Beach. Because of its relatively fragile structure, this material is not a large component of naturally occurring beach sediments, but its light hydraulic equivalence allows it to migrate onshore extremely rapidly from the dump ground.

RENOURISHMENT AND FILL FACTORS

Selection of fill or renourishment material plays an important part in any beach nourishment project. The most commonly used reference for this type of consideration is the SPM (1984) which outlines procedures for determining the compatibility of borrow materials with the naturally occurring sediments to which they will be added. Recent discussion of these types of calculations and factors (*e.g.*, STAUBLE *et al.*, 1984; LEONARD *et al.*, 1990, *et seq.*; HOUSTON, 1990, 1991, *et seq.*) has led to a re-evaluation of the suitability of these factors. For the purposes of this study, these factors were applied, but greater emphasis was accorded to the overall geochemical and biological characteristics of the borrow sediments than just these factors.

For the purposes of their investigations into the sediment geochemical and microbiological characteristics HEALY and MCCABE (1990) collected twelve shallow, hammer driven, cores from the Entrance Channel to Tauranga Harbour. A further eight cores were then collected for this study to supplement the sediment textural information already gained by HEALY and MCCABE. Figure 3 shows the core locations within the Entrance Channel.

Sediment textural analysis revealed that silt content ranged from 0 to 0.6% by weight for the eight supplementary cores (FOSTER, 1991), while the cores of HEALY and MCCABE (1990) had on average about 1.16% silt content by weight. These results were similar to the results obtained from samples collected from the dump ground prior to dumping which had 0 to 2.36% silt content (FOSTER, 1991). Similarity of textural and geochemical characteristics permitted the dumping to proceed under the statutory water right conditions set by the consent granting regional authority.

The mean grain size and sorting characteristics of the cores were also found to be similar for both the borrow site sediments and dump ground sediments (Figure 5). Mean grain sizes from the cores obtained by HEALY and MCCABE (1990) ranged from 0.27 to 2.24 ϕ; mean grain sizes for the supplementary core sediments ranged from 0.52 ϕ to 2.14 ϕ (average = 1.63 ϕ); and the mean grain sizes on the proposed dump ground ranged from 0.66 ϕ to 2.50 ϕ (average = 1.64 ϕ). Sorting values for the core sediments ranged from 0.46 ϕ to 0.59 ϕ (average = 0.55 ϕ); whereas for the dump ground, the sorting characteristics ranged from 0.50 ϕ to 0.78 ϕ (average = 0.58 ϕ). These average values were then applied to the formulae given by the SPM for calculation of fill (R_A) and renourishment (R_J) factors.

Suitability of Material for Dumping from the SPM (1984) Methods

Using the equations outlined by the SPM (1984, Volume II) the fill factor, R_A, was determined as 1.052 m^3 of material required to produce 1 m^3 of beach material in a condition compatible with the natural beach.

A value of 1.14 was obtained for the renourishment factor, R_J, suggesting that the sediments to be dumped are closely compatible with the native dump site sediments, and that renourishment will not need to be repeated soon after emplacement.

These results indicate that the material to be dredged and dumped would be compatible in terms of grain size and sorting characteristics with those sediments present in the proposed dump site.

The aim of the project was to add dredged material to the nearshore zone rather than direct emplacement onshore for which the SPM factors were primarily developed, but R_A and R_J, nevertheless, act as indicators of sediment texture suitability and provide support to the pre-dredging investigations of HEALY and MCCABE (1990) which was the basis upon which dumping was permitted to proceed.

DUMP MOUND EROSION OR ACCRETION? THE KRAUS *et al.* (1991) CRITERION

KRAUS *et al.* (1991) conducted an evaluation of the capability of simple criteria to predict whether a beach will erode or accrete by wave-induced cross-shore sand transport and the criteria evaluated were found to correctly predict most erosion and accretion events. The criterion used by KRAUS *et al.* (1991), derived from both laboratory and field observations, involved combinations of dimensionless parameters composed of wave height, wavelength, wave period, grain size, sand fall speed, beach slope, sand specific weight, and other properties of waves and beach.

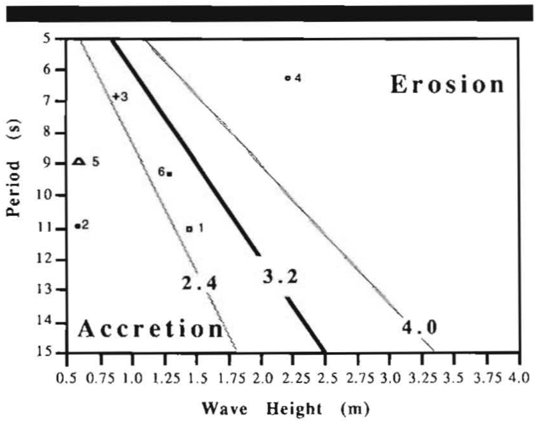

Figure 6. Values of the Dean number, N_0, in nomogram form developed by FOSTER (1991) using the KRAUS *et al.* (1991) relationship. The boundary condition of $N_0 = 3.2$ separates erosion from accretion for the Mt. Maunganui wave climate. The plotted values 1–6 are derived from Table 1.

The criterion used to predict sediment erosion and accretion for this study involved the use of a dimensionless parameter, N_0, known as the "Dean Number", similar to that used by KRAUS *et al.* (1991):

$$N_0 = \frac{H_0}{wT} \tag{1}$$

where H_0 = deep water wave height (m), w = sediment fall velocity (ms^{-1}), and T = wave period (sec). The "Dean Number" was first suggested by DEAN (1973) who found that N_0 was related to the time a particle is suspended in the water column and exposed to onshore or offshore wave orbital motions. KRAUS *et al.* (1991) pointed out that N_0 was both a measure of the wave steepness (as H_0/T instead of H_0/T^2) and a sediment-related descriptor that may be used to characterise beach change. They further noted that the significant wave height (H_S) was the most commonly used wave criteria in engineering applications and developed their relationships accordingly. This condition was used for the predictions in this study and where only mean wave height (H_m) was available (*e.g.*, DAVIES-COLLEY and HEALY, 1978; HARRAY and HEALY, 1978), it was converted to H_S by assuming a Rayleigh wave height distribution, so that:

$$H_S = 1.596H_m \tag{2}$$

Table 1. *Wave data, sediment size, and the Hallermeier Limits generated by the Hallermeier Program for the Hands and Allison (1991) relationships (where HIL = Hallermeier's Inner Limit and HOL = Hallermeier's Outer Limit). The wave data was also used for determining the Kraus* et al. *(1991) relationship. The plot numbers relate to the data plotted in Figures 6 and 7. The wave data collected during the tracer experiment are contained within the de Lange (1991) results.*

Data Source	Plot Number	Wave Height (m)	Period (s)	Sediment Size (mm)	HIL (m)	HOL (m)
Davies-Colley and Healy (1978)	1	1.5	11	—	—	—
Harray and Healy (1978)	2	0.6	11	0.40	5.76	9.41
Pickrill and Mitchell (1979)	3	0.5	7	0.29	4.49	7.21
Hilton (1990)	4	2.23	6.55	—	—	—
de Lange (1990)	5	0.658	8.9	0.25	6.05	13.41
de Lange (1991)	6	1.26	9.3	0.62	10.74	17.54

KRAUS *et al.* (1991) found that the data yielded by their study could be separated into conditions of highly probable and probable accretion, and conditions of probable and highly probable erosion, for the following conditions:

If $N_0 < 2.4$, then ACCRETION is highly probable.
If $N_0 < 3.2$, then ACCRETION is probable.
If $N_0 \geq 3.2$, then EROSION is probable.
If $N_0 > 4.0$, then EROSION is highly probable.

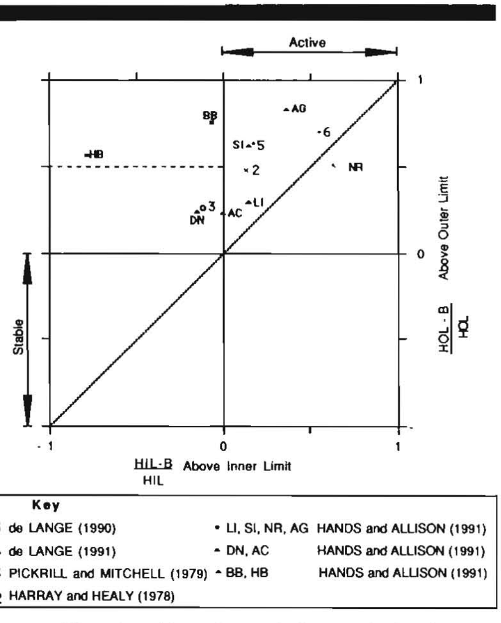

Figure 7. Elevation of berm base relative to calculated profile zonation based on the Hallermeier's Limits (after HANDS and ALLISON, 1991) including the results of FOSTER (1991). B signifies the water depth of the berm base. The plotted values 2, 3, 5 and 6 are derived from Table 1, the remainder from HANDS and ALLISON (1991).

Applying these conditions to this study, a nomogram (Figure 6) was developed for $w = 0.0375$ ms^{-1}, the fall velocity for the corresponding mean grain size of $1.65\,\phi$ of the average dredged material (DE LANGE, 1988). Isolines of N_0 were defined using Equation 1 and then a series of published New Zealand East Coast wave data (Table 1) were plotted to find the conditions under which material was likely to erode from the dump mound and move shorewards. Because of the limited wave data collected at Tauranga (DE LANGE, 1991), the available data does not cover a yearly period. These data are probably conservative in that they do not contain many storm events and tend to under-predict mean H_S and possibly over-predict mean T_S since storm wave period is less than background swell period.

Figure 6 illustrates the results of the KRAUS *et al.* analysis and supports the perception that the dumped material would be eroded from the dump ground under the predominant wave conditions and be moved ashore. These predictions are consistent with the sediment tracing experiment which suggested that sediment would move shorewards from the dump ground.

A STABLE OR UNSTABLE DUMP MOUND? THE HANDS AND ALLISON (1991) CRITERION

HANDS and ALLISON (1991) proposed a new method for estimating the depth for either dispersion or retention of dumped dredgings. Berms—otherwise known as mounds or bars built of dredged material—can be categorised as "active" or "stable". "Stable" berms are those that tend to retain most of their original volume and may remain at the disposal site for years, while "active" berms show significant dispersal of their material within a few months.

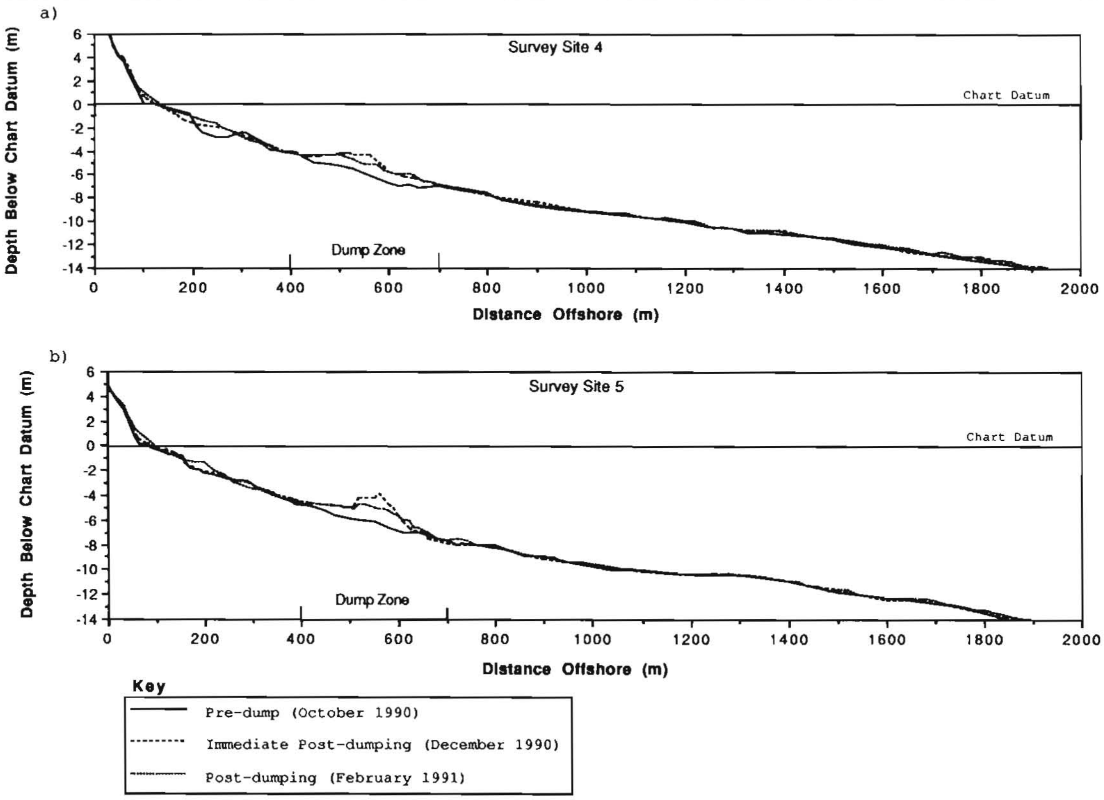

Figure 8. Representative combined beach and bathymetric profile through (a) survey Site 4 and (b) survey Site 5 (FOSTER, 1991) illustrating pre-dumping (October 1990), immediate post-dumping (December 1990), and post-dumping (February 1991).

The criterion developed by HANDS and ALLISON (1991) was based on the use of Hallermeier's limits of profile zonation (HALLERMEIER, 1981) and defined as Hallermeier's Inner Limit (HIL) and Hallermeier's Outer Limit (HOL). These zones bound a "shoal or buffer" zone in which "surface waves have neither strong or negligible effects on the sand bottom during a typical year" (HALLERMEIER, 1981). Suitable material for nourishment of the nearshore profile must generally be placed landward of the HIL to "ensure its inclusion in the annually active littoral zone". HOL is the maximum water depth of sediment motion initiation by annual median wave conditions—and corresponds to the "seaward limit to the usual wave constructed shoreface" (HALLERMEIER, 1981).

To determine the Hallermeier Limits, a computer program called "Hallermeier" was developed by DE LANGE (*in preparation*) for the Macintosh®, based on the formulae of HALLERMEIER (1981), and which uses the median grain-size, D_{50}, and measured annual wave data, as used above, to determine the limits. The limits generated for HIL and HOL are also listed in Table 1 along with the local grain size data required for, and used in, the Hallermeier program. Where the program required grain-size values for depths where no information was available, HIL and HOL were not calculated.

The generated Hallermeier Limits were then applied to the HANDS and ALLISON (1991) method to determine the stability of the proposed dump mound in 4–7 m water depth relative to chart datum (Figure 7; for detailed explanation of application refer to HANDS and ALLISON (1991)). For this analysis, an estimated berm base (B in Figure 7) of −5 m chart datum was used since this was the approximate depth of the middle of the dump ground where dumping predominantly occurred.

Figure 7 illustrates that the proposed dump mound lies in the "Active" zone of the Hands and Allison diagram. This has been interpreted to mean that the dump mound will become rapidly dispersed, probably shorewards as implied by the sediment tracing experiment.

Our results are in contrast to those of HANDS and ALLISON (1991)—also plotted on Figure 7—in that for their study the failure of a project to meet its design requirements resulted in an "active" berm. For this study, an "active" berm was required to permit shorewards sediment transport and, hence, the renourishment of Mt. Maunganui Beach.

BEACH AND BATHYMETRIC PROFILES

Seven shore-normal combined beach and bathymetric profiles were established across Mt. Maunganui beach and over the proposed dump ground for the purpose of monitoring the dumped material. Beach profiles were measured using standard staff and level techniques by registered surveyor and as close as possible to low tide for lateral maximum coverage and with a known accuracy of ±0.05 m (GABLE and WANETICK, 1984). These were tied onto bathymetric sounding lines positioned using Racal Microfix position fixing and measured using an Atlas Deso-20, 33 kHz, echo sounder aboard the Port of Tauranga Ltd. survey vessel, "Kairuri IV".

Profile surveys, discussed in detail by FOSTER (1991), illustrated that immediately after dumping in December 1990, a substantial dump mound was noticeably present. By February 1991 and later in May 1991 (FOSTER and HEALY, in preparation), the dump mound had been significantly reduced, with predominant movement of material towards the beach, with appreciable accretion measured in the lower beach face and swash zone along the beach (Figure 8a and b). The results of the beach profiles confirmed the predictions made using the schemes of KRAUS *et al.* (1991), HANDS and ALLISON (1991), and those of the sediment tracing experiment.

SUMMARY AND CONCLUSIONS

(1) Initial consideration of the morphodynamics of the proposed dump ground by HEALY *et al.* (1991) suggested a likely interaction between the nearshore dump zone, in water depths of 4 to 7 m below chart datum, and the beach.

(2) Comparison of sediment samples from the dredge zone, dump zone and beach showed texturally compatible sediments. The sand tracing experiment conducted within the proposed dump zone indicated that onshore movement of sediment was likely, but that some offshore movement was possible.

(3) Application of the standard SPM techniques for Fill and Renourishment factors indicated that material to be dumped was compatible with that on the dump zone and would be suitable for beach renourishment purposes.

(4) The new techniques of KRAUS *et al.* (1991) based on the Dean Number, and the new HANDS and ALLISON (1991) criterion based on calculated Hallermeier Limits, suggested that the dump mound would be mobile, from which it was inferred that the material would move onshore.

(5) Beach and offshore bathymetric profiles show clearly that the dump mound was dispersed mainly towards, and onto, Mt. Maunganui Beach.

(6) The combination of different techniques applied to this study gave plausible indications that beach nourishment would be successful. The new techniques of KRAUS *et al.* (1991) and HANDS and ALLISON (1991) provided consistent prediction of beach nourishment from the dumping of dredged material in the nearshore zone, which was subsequently confirmed by comparison of beach and bathymetric profiles.

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