GOLD COAST CITY COUNCIL

BEACH REPLENISHMENT PROGRAM

REPORT NO. 6

SAND RESOURCES – KIRRA BEACH REPLENISHMENT

SUMMARY

This report sets out the investigations carried out in the Tweed River and offshore in the Kirra area to determine the amounts of sand available for replenishment purposes together with an assessment of the suitability of both resource materials for beach nourishment.

1. INTRODUCTION

The second contract to be let in Council's Beach Replenishment programme is expected to be ready for pumping sand either from the Tweed River or offshore at Kirra to artificially nourish the beach between the Kirra Pavilion and approximately to the North Kirra surf Lifesaving Clubhouse. Originally Kirra was assigned the highest priority of all the replenishment beach areas and a specific contract to pump sand from the tweed river was prepared but later this work was amalgamated with the other Beach Nourishment areas into a single overall contract. However the King Tides of October, 1973 caused accelerated erosion at Kirra Beach so separate contract documents were re-drafted to call tenders for this replenishment on an urgent basis. At the time Council's beach replenishment section was fully extended wit its programme of sampling the active zone of the gold Coast beaches to determine the actual sand properties of the existing beaches for comparison with both the Broadwater and offshore available sand resources. This programme was approximately half completed but the hydrographic party was immediately switched to Kirra and the sampling work there was completed during a very fortunate calm sea period during the last week of October and the first week of November, 1973. Fig 1 show the proposed replenishment and both the alternative and resource area.

2. TWEED RIVER SURVEYS

With the approval of the Maritime Services Board of NSW the initial surveys of the Tweed River sand resource area were made by the survey forces of the department of Harbours and Marine in October, 1971. Some 52 cross sections were taken in the sand bar area and the thickness of the deposit was measured by 75 jet probes of which only six found a hard bottom within 18 feet of the sand surface which indicated that the agreed figure of 500,000 cu.yds. could be removed from the river without dredging lower than R.L. –20 feet below State datum. Although much of the original sand-bank now has up to a 2 metre thickness more sand over the 1971 survey profiles this Harbours and Marine Department survey remains as the definitive sand resource volume assessment to this day.

3. OFFSHORE SURVEYS

The area offshore from Coolangatta and Kirra Beaches was selected in the Delft Report (Ref. 1) as being a suitable source for replenishment sand particularly because the sea-bed profiles here are flatter than the remainder of the coast. It was thought therefore that a significant sandbank existed in this area and that this might perhaps be safely used as an offshore source. As such this offshore area was surveyed early in the offshore sand resource programme in mid 1972 and repetitive surveys were made on several later occasions in an attempt to detect sea-bed variations developed during and subsequent to the construction of the experimental groyne at Kirra Point by Department of Harbours and Marine. Finally when the contract documents for the replenishment of Kirra beach were being drafted in November, 1983 the offshore profiles were re-surveyed by Council's Hydrographic party.

4. OFFSHORE DRILLING

also as part of the offshore sand resources programme six bores were drilled within the sea-bed area suggested by Delft with the DUKW amphibious drilling rig of "Offshore Drillers P/L" of Southport. Since it was expected that and dredging offshore would be to depths below the seabed in the range of 3 to 4 metres most of the bores were limited to a depth of 5 metres below seabed but one bore was taken to a greater depth as a research exercise. In the event the bore had to be terminated at a depth of only 7 metres below seabed when 0.6 metres of peat were penetrated at which depth the vibrating core airlift drill was unable to obtain any further progress. While this bore indicated that the flatter sea-bed off Kirra was not in fact an immense sandbank the drilling did prove however that the offshore source would be capable of providing at least 900,000 cubic metres of sand without dredging a cut exceeding 3 metres in depth.

5. TWEED RIVER DRILLING

As part of the data examined in the Delft Report the Co-ordinator General's Department had recovered sand samples from the sand=bank in the Tweed River for comparison with the natural sand beaches but these were generally restricted to surface samples. Since Council had developed its SLIM sampler in August, 1983 (Ref. 2) additional sampling of the tweed sand-bank with this equipment to recover samples to a depth of 3 metres below river-bed level was carried out in October, 1983. Some twelve bores were sunk recovering 85 individual sand samples.

6. NATURAL BEACH DRILLING

(a) Although the offshore and Tweed River sand resource areas had both been sampled the final requirement was to sample the active zone of the beach existing naturally at Kirra so that both resource sand properties could be compared with the actual beach sand. This work was carried out by the Hydrographic Survey party in the first week of November, 1983 using the SLIM sampler from the top of the natural beach through the surf zone to a water depth of 10 metres. At the same time the beach profiles were re-surveyed to determine the post 1983 erosion shape. Time was available to survey and sample three standard lines only before inclement weather intervened but a total of 174 individual sand samples were recovered.

(b) It was known that a significant rock reef existed towards the South end of Kirra bay but the sea-bed drilling disclosed a somewhat unexpected result, the whole of Kirra bay out to a water depth of 6 metres is underlain by an apparently continuous deposit of rock, clay and peat and the maximum thickness of sand existing in the area is only 2.7 metres and the average is only about 2 metres. The line of the Southern part of Kirra beach is at an unusually acute angle with the predominant wave fronts entering the whole Kirra, Bilinga and Tugun area and for some time it had been regarded as a minor mystery as to why Kirra beach had not eroded back to lie more parallel with these wave fronts. This drilling finally resolved the matter, there is not enough sand in Kirra Bay to erode back to the natural angle before bedrock and original country are found, these materials naturally being practically un-erodable.

7. SEISMIC SURVEY

In July 1973 Mr Alistair Haydock of Queensland University Geology Department under the auspices of Professor Sargent, carried out a seismic survey of much of the Gold Coast seabed offshore which fortunately included the Kirra offshore sand resource area. Since peat had been found in offshore drilling in this area the seismic work was commenced off Kirra where this sea-bed discontinuity had already been discovered. The seismic work is reported in Mr Haydock's thesis (Ref. 3) and the calculated thicknesses of sand overlaying the first subsurface layer in the proposed offshore resource area is shown in Fig. 2. The data from the seismic survey provided a valuable check on the volume of resource sand offshore and provides an upper limit to the amount of sand that may ever be available.

8. LABORATORY TESTING

All sand samples were sieved in Council's Soils Laboratory using a standard train of B.S. sieves following normal soil mechanics procedures. Material smaller than No. 200 sieve (0.075mm) is reported as silt and material larger than No. 25 sieve (0.60 mm) is reported as grit. Because of shortage of time and laboratory capacity all samples were oven dried and sieved warm without being washed to remove salt. While the salt coatings on the soil particles must generate a variation or bias compared to clean washed sand at least all the samples were treated exactly the same and thus the sieve results are on the same basis when comparisons are made between the two alternative sand resources available and the natural beach.

9. ASSESSMENT OF NATIVE BEACH

(a) There appears to be no accepted definition of exactly what the native beach consists of. In the past apparently most of the sand sampling carried out on beaches has been only from the surface or near surface of the sand. From this type of sampling many conclusions have been drawn as to the distribution of sand particle sizes on the beach, particularly the concentration of the coarsest particles in the surf zone where wave energy is a maximum. Typical examples are reported in Refs. 4 and 5. However the results of this type of sampling provide an indication of the manner of sorting of the surface sand only under the wave climate existing at the time of sampling but the profiles, behaviour and sorting of the sand on any beach tens to vary not only with each tide as the waves migrate up and down the beach but also with the type of wave itself. On the Gold Coast short northerly waves usually build up the beach and the long south easterly waves erode the beach. Even the variation in tide heights causes similar effects.

(b) In addition and as the dominant natural process that affects the beaches are the occurrence of tropical cyclones and intense depressions. During a typical cyclonic sea with a significant deep water wave height of 4 to 5 metres a thickness of at least two metres of sand can be expected to be eroded from Gold Coast beaches, and under worse sea conditions even more. It seems essential therefore that any assessment of what the "natural" beach consists of should take in the properties of all the sand on the beach to a depth of at least three and possibly four metres below the sand surface existing under "normal" non cyclonic conditions. This has been emphasised by Council's drilling the beaches with the SLIM gear where multiple erosion scarps consisting of concentrated coarse particles have been located beneath the beach profiles existing as of late 1973. Two of these scarps have already been tentatively assigned to the 1972 and 1967 erosion levels and are thought to represent the mini-armour left on the cyclone beach profile by high energy wave sorting. At the moment Council's SLIM sampling gear has a standard reach capacity of 3 metres and since this encompasses at least three erosion scarps this depth has been adopted as representing a reasonable thickness of the active zone beaches to give a reasonable average of the variable properties and sorting of the sand particles vertically on the beach.

(c) The distance offshore from the beach that limits the active zone is much better documented and the outer limit is usually taken as the outer edge of the outer bar that is formed during cyclonic conditions, this representing approximately the outer limit of the on-shore off-shore movement of the sea-bed which is much wider than the usual limits of the active littoral drift zone for normal weather. The preliminary results of other investigational work suggests that the outer limit of the active zone extends into 11 metres below State Datum and perhaps reaches 12 metres. For this assessment of the active zone materials the beaches were sampled from the toe of the natural first dune or the boulder wall where either existed out to a water depth of 10 metres below State Datum. It has thus been assumed that the <u>average</u> sand parameters within this volume of beach represents a material overall that is capable of resisting both normal littoral drift and cyclonic erosion and that if any similar material were placed on the beach it would be capable (within slope limits) of remaining within the same active zone and respond to all normal beach processes in the same way. It would further be assumed that the replenishment material would respond dynamically in the same way as the natural beach and thus ultimately be sorted and distributed within the active zone also in the same way as the natural material regardless of the manner or the rate or the position where it might initially be deposited.

<u>10. SAND PROPERTIES</u>

(a) The sand samples from the offshore area were recovered by an air-lift vibrating core sampler that discharged the sample semi-continuously into a container. A suitable series of containers were used such that the total sample column was broken into segments each nearly 2' 6" long. The SLIM sampler recovers a continuous stem of sand 3 metres long and after extension this was broken into segments generally 0.3 metres long. Each segment from either sampler was then treated as an individual sample for sieve analysis.

(b) each sample was sieved individually using Nos. 25, 36, 52, 75, 100 and 200 mesh B.S. Imperial Sieves. A sieve grading curve for each sample was then drawn and an amalgamated grading curve drawn by adding and averaging the percentages passing on each individual curve for each separate sand population. All the samples from the Tweed River were amalgamated into one population as were the samples from the offshore drilling. However for the natural beach three cross sections had been sampled Lines K4, K9 and K12 and initially each of these was treated as a separate population. These were examined at this stage when the K4 amalgamated material was found to vary considerably from the amalgamated curves for Lines K9 and K12. Each population i.e. Tweed, Offshore, K4, K9 and K12 therefore was then converted into normal percentage grain size population plots for comparative purposes. These diagrams are shown in Figs. 3 and 4 with K9 and K12 amalgamated.

(c) As can be seeen from the shape of the population diagram for the K4 line there is a very much larger proportion of coarse material in the active zone than any of the other curves but this might be expected from the beach profiles shown in Fig. 5 since the beach zone of Line K4 is in the lee of a marked offshore reef. As such the inshore material contains not only a large proportion of shell debris derived from life on the reef itself but also there is a permanent wave set-up over the reef inducing locally higher wave energy around the reef and thus concentrating higher energy resistant coarse particles there. The

Line K4 data was therefore regarded as atypical and for the comparison of sand suitability the K4 data was discarded and all comparisons made with the more typical data from Lines K9 and K12.

(d) The whole of the sieve analyses and graphical amalgamation procedures naturally must generate reading errors, plotting errors and other ordinary unavoidable variations. For example the sand has all been sieved without washing and smoothed curves have been drawn on graphs through individually calculated points. It is not known whether these variations might be random or cumulative and to date there has not been enough time to analyse the variables in any way. The only approach adopted to reasonably attempt to reduce the probable effects of unknown variables has been:-

(i) to treat all samples and data in exactly the same way so that comparisons should be reasonably valid in spite of any absolute variation in the procedures used.

(ii) To process a large number of samples in the simplest possible manner so that a statistically large population is examined and individual sample variations should tend to be damped out.

In general, any sample population of less than thirty has been taken to be unreliable. In this way it is hoped that the data will certainly indicate overall trends and probably records reasonably accurate average properties. The basic sand properties are set out in Table I.

11. SAND SUITABILITY

(a) The amount of research work carried out to make a firm assessment of sand suitability is comparatively small and the definitive work carried out to date is that by Krumbein and James for the US Army Coastal Engineering research Centre (Ref. 6). This work apparently remains the data to be used in the current revision of Tech. Memo No. 4 Krumbein classified the relationships between the sand-resource (borrow material) with the existing (native) beach under 4 categories.

Case I	Borrow material is finer than native.	Borrow material is more poorly sorted than native.
Case II	Borrow material is coarser than native.	Borrow material is more poorly sorted than native.
Case III	Borrow material is coarser than native.	Borrow material is better sorted than native.
Case IV	Borrow material is finer than native.	Borrow material is better sorted than native.

He then calculated the critical ration i.e. the number of units of borrow sand that would be needed to provide one unit of sand that would remain on the beach after natural sorting. However to calculate the critical ratio it was necessary to assume that the sand grading was log normal and the equations are quoted as applicable in any case to Cases I and II only. However when the Tweed and Offshore resource sand parameters compared to the natural sand represented by Lines K9 and K12 were calculated it was found that the Tweed sand fell into Case III and the Offshore sand into Case IV. For Case III the response to sorting action is given as “The distributions cannot be matched but the fill material should all be stable” and for Case IV “The distributions cannot be matched. Fill losses cannot be predicted…” The major mathematical problem here may well lie in the form of the amalgamated grading and population curves shown in Fig. 4. the sand populations are not close to a log-normal distribution and in fact all three sand populations are tri-model and thus strictly not applicable to the bases of Krumbein’s hypotheses. It seems therefore that the C.E.R.C. work is unable to assist greatly in this case.

(b) Another approach to assessing resource sand suitability is to consider the log probability of the D50 population diagram as shown in fig. 6. the Tweed d50 line is above the native beach population so no extra river material would be required and indeed in this (somewhat arbitrary perhaps) size zone the tweed material would be better than the native material under natural sorting. The Offshore D50 line however is finer and an offset of 30% in the probability plots would be required to make the 50% D50 points coincide. It is possible therefore that up to an extra 155 of Offshore material cold be required to result in a given volume of offshore as naturally on the beach.

(c) A further check of suitability would be the normal soil mechanics grading curve as shown in Fig. 4. From this curve the 50% passing diameter for offshore sand is slightly finer than the Natural Beach and the offshore grading curve would have to be displaced some 5% to coincide with the natural beach, or approximately 5% more offshore material would be required. The Tweed material however is coarser and should behave better than the natural sand on the beach.

(d) The third approach is to consider the normal-normal population diagrams for the three amalgamated sand materials shown in fig. 4. Although this diagram has been drawn with smoothed curves the similarities are most striking and all three modes occur at almost exactly the same grain sizes. The dominent modes all coincide at about 0.15mm and in each case the tweed and Offshore source materials are richer in this size of material than the natural beach so any critical ratio based on this property would be less than one! However a simple visual inspection of the graph would suggest strongly that either borrow material should be perfectly satisfactory on the natural beach. The Tweed River source has less fines and more coarse material and should behave better than the natural beach whilst the offshore source has the same fines and is only deficient in the very coarse material in the 0.35mm size range so this material should be nearly as stable as the natural beach, the maximum excess required would then be approximately 5% taken as the offset in the grading curve at the 0.35mm grain size.

(c) The variations in the fine silt and grit and shell percentages set out in Table I do not appear significant. Whilst the offshore source has more fines than the Tweed source sand the coarse grit proportion is likewise larger and these should more than balance out. However the smaller grit contents of both the Tweed and Offshore materials compared to the natural beach might cause some concern as to the replenished beaches' behaviour during cyclonic erosion but no data is yet available to even suggest what the quantitative significance of the coarse shell grit might be. It does seem certain however that grit is accumulated as mini-armour on the beach during heavy wave attack so the performance of the replenishment material under such attack may be worse than the natural beach but at least once the original existing natural is exposed the same natural proportion of coarse material will become available once more.

12. CONCLUSION

(a) The natural sand in the existing natural beach inshore of Kirra reef (Line K4) is extremely coarse and this material is very different to the remainder of the natural beach exemplified by lines K9 and K12. Neither of the potential resource sand from Tweed and Offshore can be expected to be compatible with the existing sea-bed. However this area of beach already forms a semi tombolo and the effect of this phenomenon may not be deleterious to the proposed beach replenishment.

(b) For the remainder of Kirra beach both the Tweed and Offshore resource sand should be satisfactory, perhaps a little less Tweed sand would suffice and between 5% and a maximum 10% more offshore sand may be necessary for stability under extreme conditions.

(c) The significance of high shell and grit contents in the natural Kirra beach sands is unknown but is though to represent natural sorting under very heavy wave attach and the development of miniature erosion scarps.

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REFERENCES

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(2) Gold Coast City Council – Beach Replenishment Program Report No. 4 – The Surf Zone Sand Sampler. 6/10/73.

(3) A.W. Haydock – The Marine Geology of the Gold Coast. University of Queensland Honorary Thesis 1973.

(4) G.S. Visher – Grain Size Distributions and Depositional Processes. Journal of Sedimentary Petrology Vol. 39 No. 3 September, 1969.

(5) U.S. Army Coastal Engineering Research Centre – Shore Protection Planning and Design Tech. Report No. 4 3rd Ed. 1966 (Fig. 204).

(6) W.C. Krumbein & W.R. James – "A Lognormal Size distribution Model for Estimating Stability of Beach Fill Material". Tech. Memo No. 16 C.E.R.C. November, 1965

TABLE I – SAND POPULATION PROPERTIES

	NATURAL BEACH (k9 + k12)	TWEED RIVER	OFFSHORE KIRRA
SILT CONTENT	0.35%	0.21%	0.44$
GRIT CONTENT	8.2%	1.86%	2.74%
D50 SIZE	0.20mm	0.21mm	0.18mm
SKEWNESS 0	0.164	0.40	0.16
KURTOSIS 0	0.84	1.36	0.88
STD. DEVIATION 0	0.40	0.40	0.50