CHAPTER 108

Analysis of a Beach Quality Problem

Gordon K. Prestedge*, M.ASCE and
Christopher A. Fleming**

A study was recently undertaken to investigate sediment transport on a section of coastline where recreational beaches have experienced periodic erosion. Alongshore, onshore/offshore and aeolian sediment transport processes were investigated and quantitative transports predicted with the aid of calibration using surveys and aerial photographs. This paper describes the study and the recommendations proposed for beach quality improvements.

Introduction

Recreational Beaches at Port Elizabeth, South Africa, consist of small sandy areas on an otherwise rocky section of the Algoa Bay coastline (Figures 1 and 2). The natural beaches, Pollok, Hobie and Humewood (shown on Figure 2) have been plagued by loss of sand and exposure of cobbles and rock sub-strata at times. Poor quality of the beaches particular during peak summer periods has become a matter of considerable public concern. A study was initiated to investigate the macro sediment regime on this coastline, understand the root cause of the problem and put forward proposals for beach improvement measures. The possibility that stabilisation of the headland bypass dunefield in 1968 at Cape Recife has aggravated the problem as well as the impact that a proposed boat launching facility would have on the adjacent beaches was also considered.

Nearshore Wave Data

To be able to determine the wave conditions at the nearshore sites of interest it was first of all necessary to select appropriate offshore wave data. Offshore wave data was obtained from measurements at the site of oil exploration platforms that had been operating for several years in an area south-west of Algoa Bay. Significant wave heights and peak energy wave periods obtained from the Waverider records were combined with concurrent visual observations of wave direction taken from the rig. The deep sea wave rose is shown in Figure 1. The data set of wave height, period and direction for the deep ocean conditions obtained in this way provided an excellent definition of deep ocean wave conditions which were refracted on a record-by-record basis to thirteen nearshore calculation positions along the study coastline. Wave refraction was undertaken using wave ray back-tracking and three-dimensional spectral transfer techniques (Abernethy et al, 1975).

* Associate, Watermeyer, Legge, Piêsold & Uhlmann, Cape Town, Republic of South Africa
** Director, Sir William Halcrow & Partners, Swindon, United Kingdom.

In view of the shape of Algoa Bay and the fact that the majority of energy in the deep ocean was contained in the south-west quadrant, it was important to ensure that a pure refraction model would correctly represent the nearshore wave conditions on the study coastline. An investigation using a combined refraction/diffraction model (Southgate, 1981) as well as pure diffraction (Sommerfeld, 1896) was investigated. It was found that pure diffracted energy would be small in the area of interest for waves with deep ocean directions from the south-west quadrant and for predominant wave periods. Owing to the gently shelving nature of the seabed at Cape Recife, the majority of wave energy would reach the area of interest during south-westerly conditions by refraction alone.

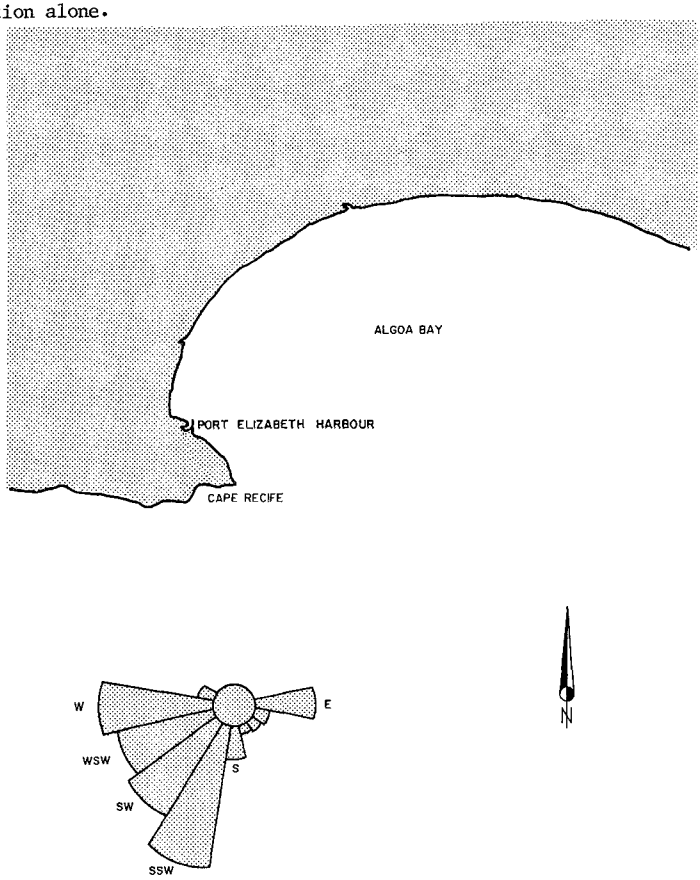

Figure 1. Locality Map and Deep Ocen Wave Energy Rose

Figure 2. Aerial Photograph of Study Coastline

The study coastline is exposed to locally generated wind waves from the easterly sector. A check was therefore carried out using a parametric wind wave hindcasting model to ensure that the locally generated wind wave components were adequately represented in the deep ocean wave data.

Nearshore wave energy roses on the study coastline are shown on Figure 3.

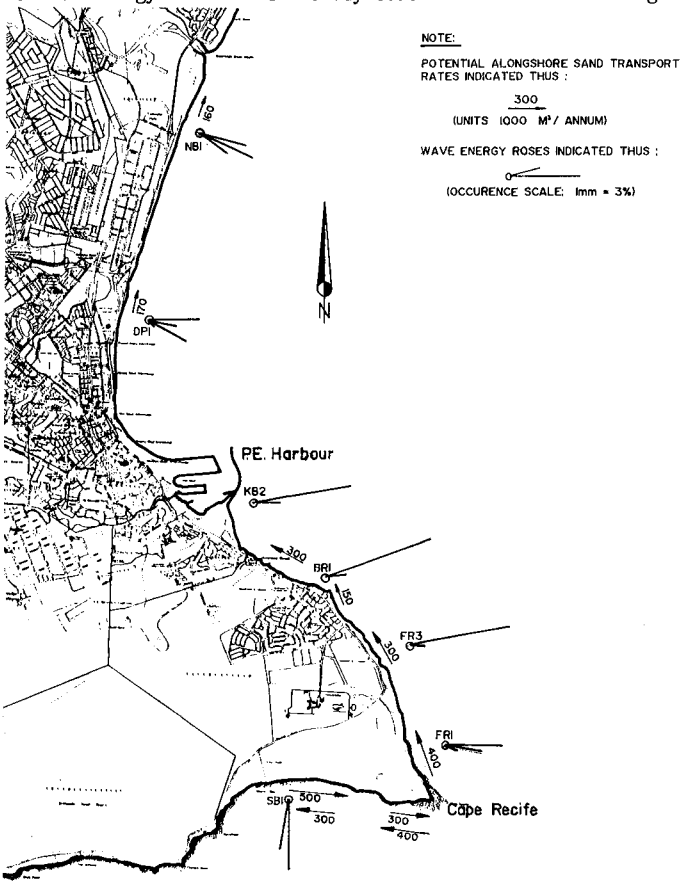

Figure 3. Nearshore Wave Energy Roses and Potential Alongshore Transport Rates

Alongshore Sediment Transport

Alongshore sediment transport was evaluated using three alongshore sediment transport theories after thirteen theories, both bulk and detail predictors had been investigated. The three detailed predictor theories used were as follows:

- Engelund and Hansen as adapted by Swart
- Neilsen
- Swart and Lenhoff (Swart, 1980)

The wave data was arranged in statistical groups of 15° directional increments, 0,5m wave increments and period increments ranging from 1 to 3 seconds. The wave data used represented an average year based on all available deep ocean data. For the detailed predictor type transport models each profile was divided into a number of sand transport zones. From each transport zone local wave conditions were determined from the nearshore wave statistics at the nearshore calculation positions and from refraction and shoaling between the calculation positions and the transport zones. The location of the breaker line was determined by considering refraction and shoaling in relation to input data.

Transport rates obtained from the theories were compared with historical information on the rate of accretion at Kings Beach, the location of which is shown in Figure 2. Port Elizabeth harbour was constructed in 1931 and has formed a total barrier to alongshore transport in this area. Various surveys of the area have been carried out over the years and this has permitted the volume of sand trapped south of the harbour to be quantified. The results are shown in Figure 4. From this information and harbour records (which indicated that a certain amount of sand has permeated the breakwater and has been removed by dredging from the harbour side of the breakwater), a best estimate of the average alongshore sand transport rate at King's Beach of 180 000 cubic metres per annum was established.

The headland bypass dunefield at Cape Recife was stabilised in 1968. It had been suggested that that may have been the cause of beach erosion problems. However dune stabilisation does not appear to have signficantly affected the rate of accretion of sand at King's Beach in recent years. An aeolian transport analysis (Swart, 1985) of the rate at which sand was likely to have been transported across the headland bypass dunefield to the study coastline prior to stabilisation, was undertaken. It was found that the rate of supply of sand from such sources was likely to have been of the order of about 30 000 cubic metres per annum.

It appears therefore that approximately 150 000 cubic metres of sand is at present still being fed to the study coastline from the area west of Cape Recife by wave-induced transport around the gently shelving seabed area in the vicinity of the Cape.

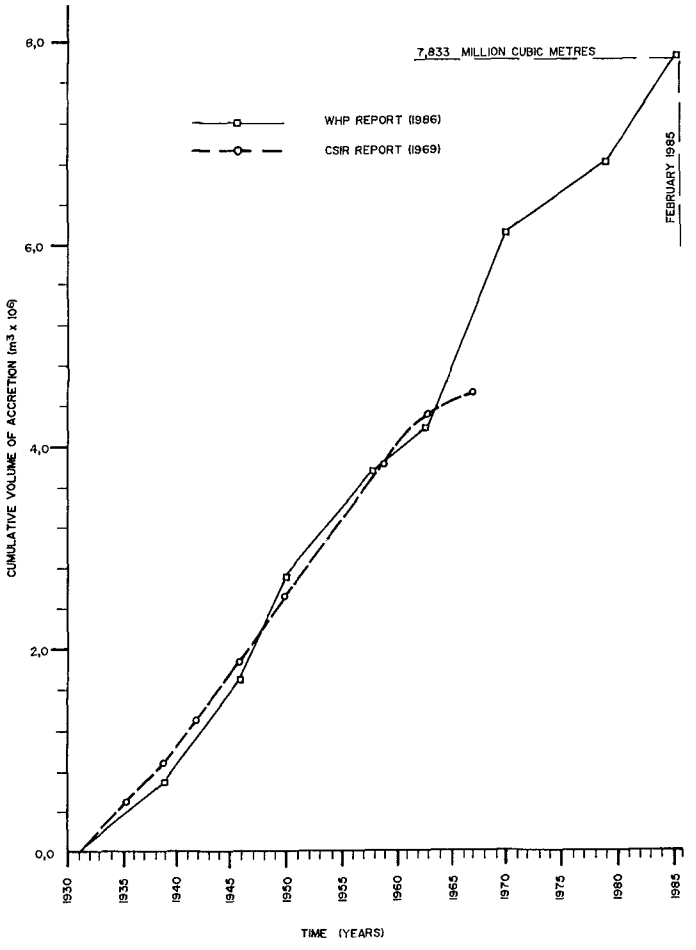

Figure 4. Cumulative volume of Accretion at King's Beach

Theoretically predicted transport rates were calibrated with the aid of data obtained from accretion at King's Beach and it was found that in order to match measured alongshore transport rates, consideration had to be given to saturated wave spectra effects in shallow water after Bouws et al 1985 who developed the TMA spectrum by applying the Kitaigorodskii et al 1975 depth dependant term to the Jonswap spectrum. In this case a nominal nearshore water depth of 6m was used. Considerations of similar analyses for all the shoreline sections led to the derivation of a sand budget based on the variation in alongshore transport obtained from the model. Alongshore sand transport rates are shown in Figure 3.

A large portion of the study coastline is rocky so that it is important to distinguish between the "potential" alongshore sand transport rate and the actual alongshore sand transprot rate. Sand can only be transported at the calculated potential transport rate if sufficient sand exists on the coastline. If insufficient sand exists such as on a rocky coastline, then the actual transport rate would be less than the potential rate and limited to the rate of supply of sand to the coastline from further updrift. The rate of supply is currently estimated to be 150 000 cubic metres per annum despite the stabilisation of the headland bypass dunefield at Cape Recife. Potential transport rates of up to 450 000 cubic metres per annum were calculated.

The apparent net transport rate from east to west in the area immediately west of Cape Recife, is hypothetical since during conditions that produce transport to the east, sand is carried past the headland and northwards along the study coastline and that sand is not available to be moved westwards under westerly transporting conditions.

It was found that for all conditions alongshore transport was northwards on the study coastline between Cape Recife and the harbour.

Onshore/Offshore Sediment Transport

Onshore/offshore sediment transport (Swart, 1985) was used in a qualitative application to examine the response of the beach to storm waves. Calibration required in order to obtain quantitative results was not possible in this case in view of the presence of cobbles and bedrock close to the beach surface which at present prevents full development of the equilibrium profiles. Observations of the beaches after recent major storms were however useful for comparison with theoretical predictions and for evaluating the depth of sand cover required to accommodate beach profile fluctuations without exposing rocky and sub-strata cobble layers.

The beach quality problem accordingly appeared to be the result of a lack of retention of sand on the beaches and not the result of a lack of supply of sand to the coastline.

Beach Processes

It is concluded that the only reason why Pollok Beach, Hobie Beach and Humewood Beach exist is that each is formed by a rocky headland behind which sand is trapped (pocket beaches). If these headlands did not exist there would be no beaches. The rocky headlands are not large enough to trap sufficient sand to ensure sandy beaches under all normal weather conditions. During locally generated wind waves from the east and south-east, the steep storm waves move sand offshore and expose the bedrock and cobbles frequently.

The object of the proposed recommendations are therefore to extend the natural rocky headlands responsible for the creation of the beaches and thereby trap a larger reservoir of sand and in turn enable the beaches to respond to the cyclic onshore/offshore movement of sand under normal storm conditions. This solution would be one of emulating the natural processes and simply trapping larger volumes of sand on the beaches and reducing the occurrence of stony beaches to rare occasions after very stormy seas.

Proposals had also been made previously for the construction of a small boat harbour on this section of coastline and these proposals were investigated in relation to the observed nearshore beach processes. It was advised that a large harbour should not be constructed as this would tend to cut off the alongshore sand transport to beaches downdrift. Furthermore all beach structures should be of minimal length and care should be taken that structures did not divert sand offshore particularly in areas where the seabed dips steeply seawards.

Proposed beach improvements at Pollok Beach, Hobie Beach and Humewood Beach are shown in Figures 5, 6 and 7 respectively. Improvements proposed at Hobie Beach were augmented with an offshore breakwater to improve the launching of small sailing boats from that beach.

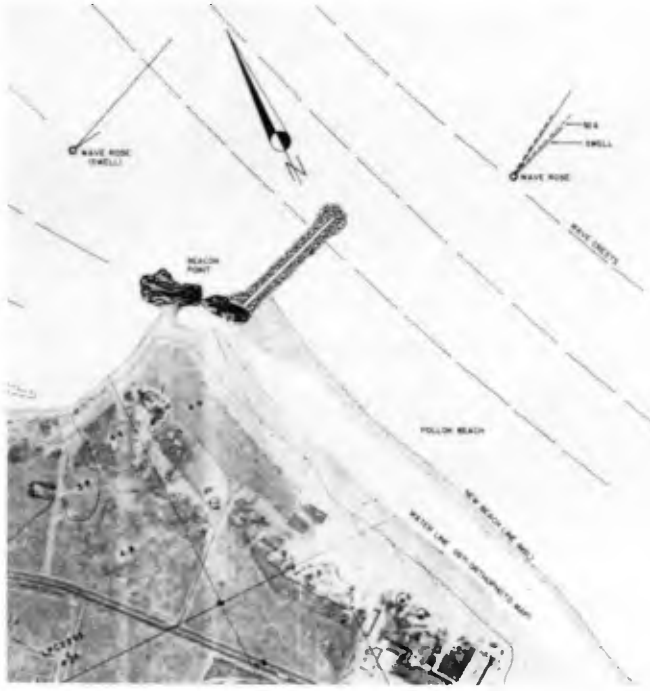

Figure 5. Proposed Headland Extension at Pollok Beach

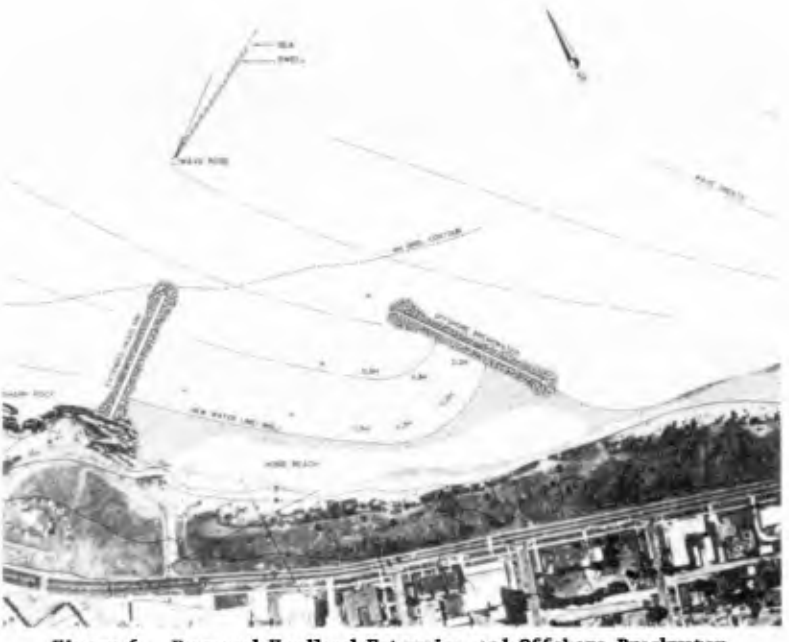

Figure 6. Proposed Headland Extension and Offshore Breakwater at Hobie Beach

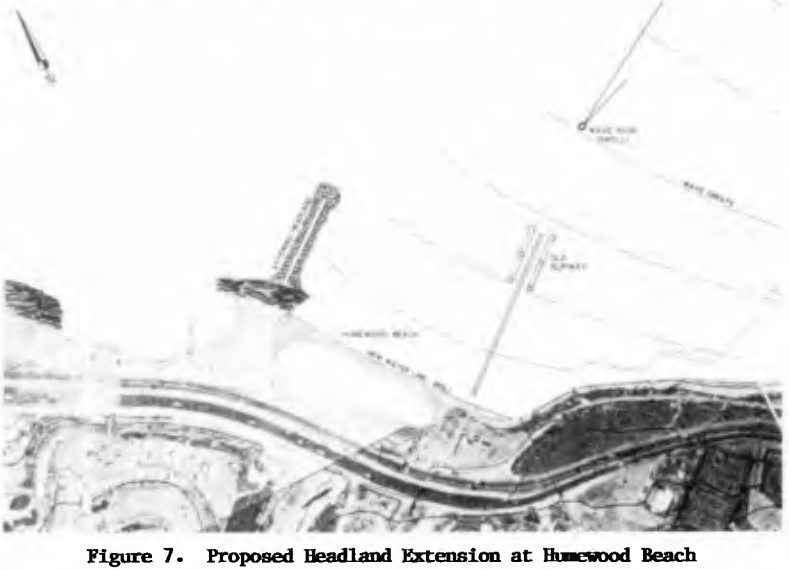

Figure 7. Proposed Headland Extension at Homewood Beach

Conclusions

Beach erosion problems on the southern beaches of Port Elizabeth were found to be caused by an inadequate reservoir of sand on the beaches. The existing reservoir was found to be unable to accommodate the natural beach changes which occur in response to variations in the wave climate. Extensions of the rocky headlands at these beaches would result in more sand being held on the beaches. It was found that an adequate supply of sand is supplied to the study coastline and transported along the coast by wave action to fill and maintain the beaches after the headland structures are built.

Acknowledgements

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