CHAPTER ONE HUNDRED THREE

BEACH RESPONSE TO COASTAL WORKS

GOLD COAST, AUSTRALIA

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ABSTRACT

The paper outlines the results of comprehensive beach surveys carried out over more than 20 years showing the effects of seawalls, groynes and beach nourishment on the beaches of the beach resort city of Gold Coast, Australia. Beach profile changes and, in particular, quantification of the overall extent of accretion and erosion resulting from groynes which interrupt the longshore movement of sand are outlined. The paper confirms the already known principles of behaviour of these coastal works and documents clearly the full detrimental impact that inappropriate structures can have on a natural sand beach system.

1.0 INTRODUCTION

The city of Gold Coast, one of Australia's richest and most popular tourist centres, extends in a relatively narrow strip along 30 kilometres of predominantly sandy coastline immediately north from Queensland's state border (Figure 1). The city is an amalgamation of several townships originally settled early this century as resorts where the climate, beaches and surf conditions were all highly suited to public recreation. Today the city's economy still depends on tourism, which in turn depends on the existence of adequate beaches.

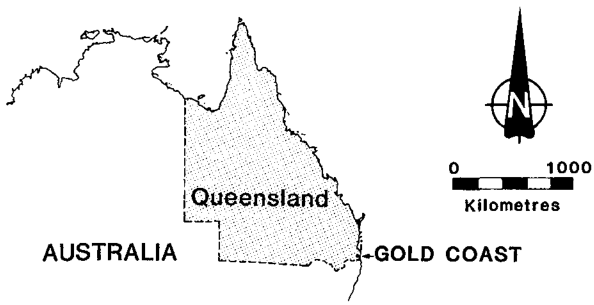

Figure 1(a). General Locality Plan

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Figure 1(b). Gold Coast City

1.1 Erosion Problems and Coastal Works

Over the years, residential development located close to the beach has increased substantially in extent and value. The threat of damage to this property from beach erosion caused by the effects of cyclones which regularly affect the area has led to the construction of protective rock seawalls along most of the city's foreshore. Initially the problems were the result only of locating the development too close to the sea within the zone of natural beach movements. However, over the past 20 years, these problems have been exacerbated in some areas by groyne structures constructed at various locations along this coastline which experiences a relatively strong longshore sand transport. Some beach replenishment has been carried out in several badly eroded or more popular recreational areas. A summary of the major coastal engineering works carried out in the area is shown in Figure 2.

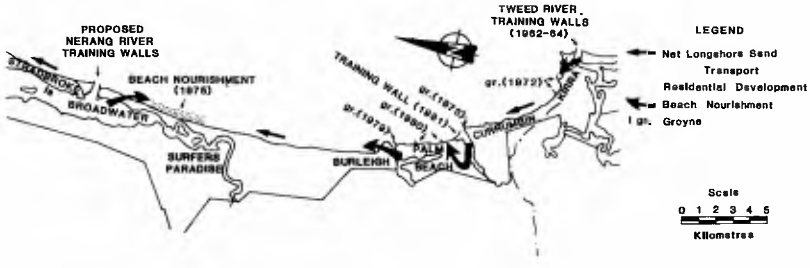

Figure 2. Summary of Coastal Works, Gold Coast.

1.2 Coastal Management

The principal components of investigation and planning for management of Gold Coast beaches are listed below.

(a) Commencing in 1964, the Queensland State Government collected field data relating to beach processes and in 1968 commissioned the Delft Hydraulics Laboratory, Netherlands to evaluate the data and report on the erosion problems. In 1970 the laboratory presented its report containing detailed recommendations for beach restoration by sand nourishment and other accompanying works.

(b) In 1968 the Queensland Government passed its Beach Protection Act and established the Beach Protection Authority to investigate and provide advice to local governments on beach erosion problems. In Queensland, financial responsibility for implementing beach restoration works rests essentially with the various local governments including the Gold Coast City Council.

(c) The Authority and the State Government adopted the Laboratory's recommendations and the Gold Coast City Council was advised accordingly through extensive discussion and through the provisions of the legislation.

(d) The Authority has continued its programme of wave recording, beach surveys, aerial photography and daily beach readings (COPE) in the Gold Coast area with particular emphasis being given to those areas affected by works carried out from time to time. Recently, the Authority's engineers reassessed the rates of sand transport along the coast based on the extended wave data record. As well, the survey data was used to identify changes to the beach system since 1962 including the effects of coastal works carried out during that time. This information is passed to the Gold Coast City Council to assist in planning and implementation of appropriate beach protection works in accordance with the approved scheme.

1.3 Aims and Objectives

The aim of the paper is to document the coastal protection measures used at Gold Coast in terms of their effects on beaches and on property as well as a comparison of the benefits which accrue in the immediate vicinity of the works with the effects on the coastline as a whole. The ultimate objective is that the decisions on works to be implemented at Gold Coast and other beach areas be based on a full and clear understanding of the impact that some works can and have had on the beach system as a whole.

2.0 GOLD COAST BEACH PROCESSES

Analyses of the results of beach surveys together with calculations based on the measured wave climate for the area have been used to provide a good understanding of the natural beach processes along the Gold Coast. In the broader view, the Gold Coast beaches form part of an extensive system of longshore moving sand having its origins up to 150 kilometres to the south. The entire supply of sand to the beaches comes from this longshore movement of sand.

2.1 Delft Hydraulics Laboratory Report (Reference 2)

The fundamental conclusions of the 1970 report by the Delft Hydraulics Laboratory were -

(a) onshore/offshore transfers of up to about 400 cubic metres per metre can be expected during and subsequent to severe cyclone erosion events. However there is no net loss of sand from the beach system during this process.

(b) because development has been located over the former natural dune system, the beaches contain insufficient sand reserves seaward of the development to accommodate severe cyclone erosion events and require restoration by nourishment of 10 - 15 million cubic metres of sand.

(c) there is a differential in the longshore transport rates along the Gold Coast, leading to a persistent long term erosion of the beaches of 0.3 million cubic metres of sand per year. The Laboratory's assessed longshore transport rates were -

(i)	Letitia Spit	: approx 0.5 million m^3/year
(ii)	Kirra area	: approx 0.2 million m^3/year
(iii)	Nerang River area	: approx 0.5 million m^3/year

It can be seen that there is an assessed corresponding "loss" to deep water of 0.3 million cubic metres per year between Letitia Spit and Kirra. There is no evidence available to support an accumulation of such an amount of sand offshore in this area.

(d) construction in 1962-64 of training walls at the Tweed River mouth would trap about 4 million cubic metres of sand on Letitia Spit. Because not all of this effect would have passed to the Gold Coast, this groyne effect would result in a loss of 1.7 million cubic metres of sand from the beaches at the southern end of the Gold Coast.

2.2 Beach Protection Authority Report (References 1 and 4)

The recent study of longshore transport rates carried out by the Beach Protection Authority of Queensland concluded that -

(a) there is little or no longshore transport differential along the Gold Coast and, correspondingly, there would be little or no loss of sand to deep water between Letitia Spit and Kirra. The net longshore rate is uniform at approximately 500,000 m^3/year.

(b) any significant changes to the beaches over the past 20 years have been the direct result of coastal works. Specifically, essentially all of the sand trapped on Letitia Spit by the Tweed River training walls would have moved northward to the Gold Coast beaches and therefore represents a loss of sand from those beaches.

3.0 BEACH RESPONSE TO COASTAL WORKS

Each beach section of the Gold Coast has a different history of coastal management and therefore has responded uniquely to the coastal works affecting it. It is convenient to consider the coast in three broad units based on both geographic and management considerations. These units are-

(i) Southern Region - Letitia Spit to Currumbin, affected predominantly by the Tweed River training walls and seawalls.

(ii) Central Region - Currumbin to Burleigh, affected predominantly by groynes and seawalls.

(iii) Northern Region - Burleigh to Nerang River, with extensive development protected by seawalls and limited beach nourishment.

Each of these three coastal units are discussed separately below.

3.1 Southern Region (incorporating Tweed River Training Walls).

The groyne works undertaken in this region are shown in Figure 3 and include the Tweed River training walls (aimed at improving navigation to the river) and groynes at Kirra (aimed at offsetting erosion caused by the training walls). The river mouth was trained originally around 1900, however the strong longshore transport subsequently re-established the entrance bar. The training walls were extended a further 400 metres during 1962-1964 by the New South Wales Government.

The beaches both updrift and downdrift of the river training works have been monitored in detail since 1962, providing a good understanding of the effects of these works. The beach monitoring has included -

(i) regular aerial photography including low level work used for photogrammetric contouring during 1962 and 1963.

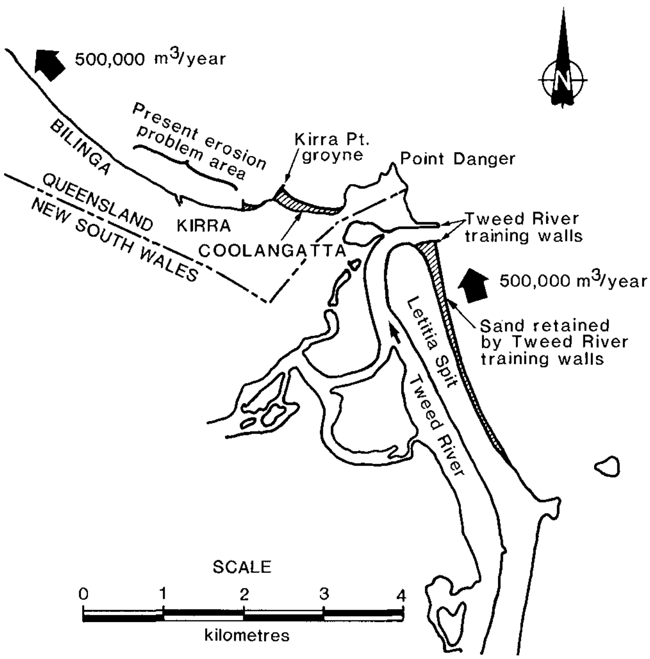

Figure 3. Groyne Works – Southern Gold Coast Region

(ii) beach and hydrographic surveys by the New South Wales Government (available for 1962 to 1965), the Gold Coast City Council (1984) and the Beach Protection Authority over the period 1964 to 1984.

(iii) an Authority's COPE station established at Coolangatta in 1982.

Accretion updrift of Tweed River Training Walls

To 1983, the coastline immediately south (updrift) of the training walls had accreted by a distance of 250 to 300 metres since wall construction in 1962, with changes to the near-shore profile extending to the 18 metre depth contour (Figure 4). The quantity of accretion varies from a maximum of 4000 m^3/m near the walls to essentially nil at Fingal about 3 kilometres to the south, totalling 4.8 million cubic metres south of the walls (Figure 5). As well, a new bar has formed across the river entrance, involving the accretion of an additional 1.6 million cubic metres to date.

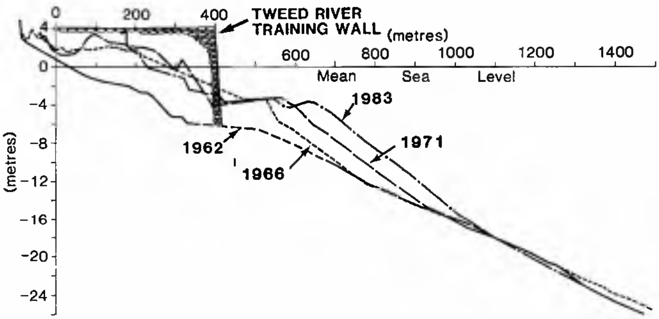

Figure 4. Accretion Adjacent to Tweed River Training Walls.

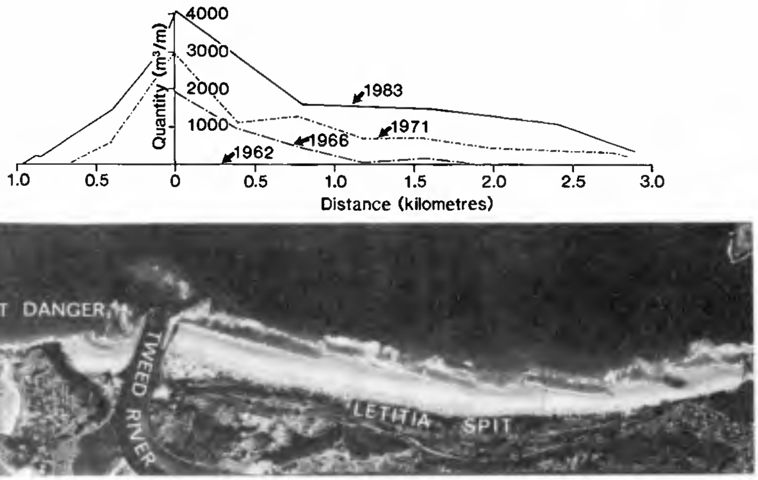

Figure 5. Distribution of Accretion Along Letitia Spit.

The time history of total accretion, including that along Letitia Spit and in the new entrance bar, is shown in Figure 6, reaching a total of 6.4 million cubic metres in 1983. The accretion trend indicates that further sand accumulation in this area can be expected, although the rate of such accumulation should decrease as the rate of natural sand bypassing to the Gold Coast beaches increases.

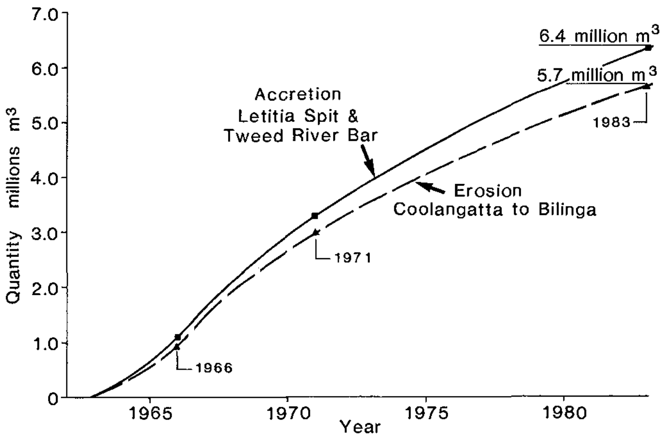

Figure 6. Time History of Updrift Accretion and Downdrift Erosion Resulting From Tweed River Training Walls.

Erosion Downdrift of Tweed River Training Walls

The downdrift erosion measured to 1983 extends along about 4.5 kilometres of coastline from Point Danger to Bilinga (Figure 7). The erosion trend indicates that this loss is propogating further downdrift with time. The time history of erosion (Figure 6) indicates a trend similar to that of the updrift accretion, although somewhat (about 10%) less. While this difference may be the result of a minor reduction in the longshore transport capacities between Letitia Spit and the southern Gold Coast beaches, it is considered more likely to be attributable to the limitations of the survey procedures. The measured total downdrift erosion had reached 5.7 million cubic metres by 1983. It should be noted that this quantity, based on the surveyed changes at 21 profile locations, exceeds but is more reliable than the preliminary estimate of 3.5 million cubic metres of erosion outlined in Reference 4 based on only 4 profile locations. This emphasises the need for comprehensive surveys for such analyses.

The measured downdrift erosion has occurred across some 1200 metres width of the nearshore profile, out to depths of about 15 metres (Figures 8 & 9). Sand levels have dropped by up to 5 metres near the beach in the worst eroded area with general erosion by 1 to 2 metres over a broad offshore area in water depths formerly of the order of 5 to 9 metres.

Rock seawalls were constructed at Coolangatta and Kirra to limit the beachline recession there. In 1972 a groyne was constructed at Kirra Point in order to restore Coolangatta's recreational surfing beach (Figure 3).

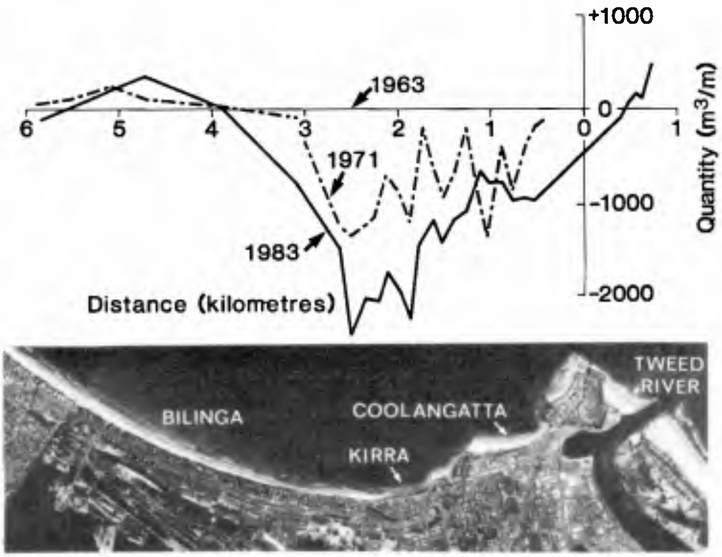

Figure 7. Distribution of Downdrift Erosion – Point Danger to Bilinga.

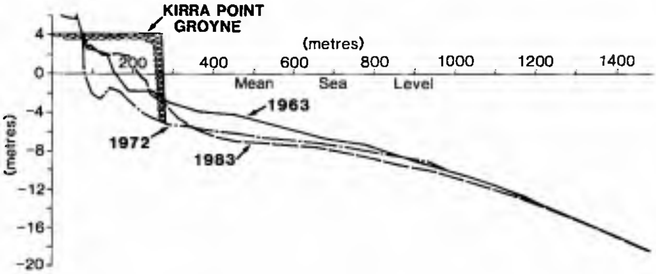

Figure 8. Sequence of Surveyed Profiles Updrift of Kirra Point Groyne.

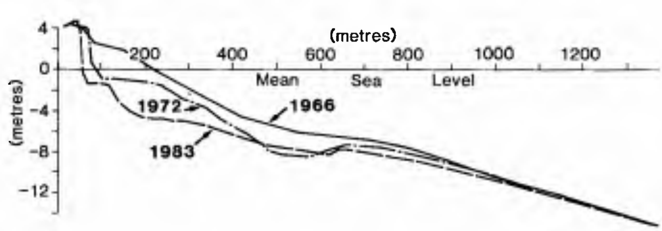

Figure 9. Sequence of Surveyed Profiles Downdrift of Kirra Point Groyne.

Effects of Kirra Point Groyne

Details of the design and effects of the Kirra Point groyne are outlined in Reference 5 (Robinson & Patterson 1975). The influence of the Kirra Point groyne in accumulating sand extends seawards to about the 6 metre depth contour. Some 300,000 cubic metres of sand have been accumulated on Coolangatta beach above that level. In the deeper parts of the offshore profile unaffected by the groyne, erosion caused by the Tweed River training walls continued progressively (Figure 8) such that there remains an overall net erosion of these profiles (Figure 7).

The trapping of sand by the Kirra Point groyne exacerbated the erosion effects of the Tweed River training walls at Kirra, immediately downdrift, where massive erosion of the beach and dune occurred during storms in 1974. As a result, a rock seawall was destroyed and a camping park area was eroded away as the coastline receded by up to 80 metres. A new seawall was constructed along the new eroded dune alignment to protect roads and facilities.

A second groyne was constructed at Kirra during 1974 (the Miles Street groyne - Figure 3) in an attempt to retain a usable beach in front of the Kirra Surf Lifesavers' Clubhouse. Approximately 1 million cubic metres of sand were pumped from the Tweed River to Kirra Beach to offset the erosion. However, the benefits of this nourishment were temporary because -

(a) the rate of longshore supply of sand to the nourished area downdrift of the various groyne structures was, at the time, substantially less than the longshore transport capacity which distributed the nourished sand along the coast towards the north.

(b) the quantity pumped was small in relation to the total quantity eroded in the Kirra area.

The Tweed River training walls have trapped on Letitia Spit 6.4 million cubic metres of sand that would otherwise have moved northward to the Gold Coast beaches. The construction of groynes at Kirra in an attempt to overcome the resulting beach erosion problem has further interrupted the flow of sand, and has moved the problem area further north.

(c) the sand was taken from the zone of beach sand transport within the river which subsequently has progressively infilled with sand from the beaches (Reference 3). Hence the long term benefit to the beaches would be small.

The downdrift beach at North Kirra has never recovered from the combined erosion effects of the training walls and groynes. The sand loss is presently concentrated in this area where erosion of the beach profile by about 2500 m^3/m to 1983 has been surveyed. A rock seawall there is prventing further erosion of roads and property, but at the same time is also preventing the re-establishment of a beach.

3.2 Central Region (Currumbin/Palm Beach/Burleigh)

The Currumbin/Palm Beach area is characterised by residential development and associated roadways located close to the beach. At Currumbin, the esplanade road was constructed along the foredune. This road was eroded repeatedly until a rock seawall was constructed to protect it in the 1950's. The frequent lack of a usable beach led to groyne construction connecting Currumbin Rock to the mainland in 1973 (Figure 10).

Palm Beach has experienced long-standing erosion problems largely as a result of residential development being located too close to the beach. Some freehold allotments were originally established on bare areas of dune sand. As a result of periodic dune erosion, rock seawalls have been constructed over the years to protect what remains of the properties. Worsening erosion and the threat of damage to properties led to construction of three groynes over the period 1977 to 1980. A training wall was constructed at Currumbin Creek in 1981 to control the natural cyclical migration of the entrance.

Burleigh Beach extends 2 kilometres between two rocky headlands. A 250 metre long seawall was constructed in 1956 to protect car park and surf lifesaving facilities in the southernmost section. The remaining 1.75 kilometres of esplanade land was left undeveloped, although the natural dunes was levelled after mining for heavy minerals, mown and recreational park facilities installed.

From time to time, sand has been dredged from the creek estuaries at Currumbin and Tallebudgera to the beaches, including some 0.3 million m^3 to Palm Beach in 1980 to accompany groyne construction. These estuaries form part of the active beach sand transport system.

Monitoring of the beaches and estuaries in this region has been carried out through regular aerial photography and beach and hydrographic surveys by the Beach Protection Authority over the period 1966 to 1983, with intense coverage since 1980. An Authority COPE station has operated at Burleigh since 1980.

Currumbin Rock Groyne (1973)

This groyne connected Currumbin Rock to the mainland, thereby preventing the longshore transport of sand through the intermediate area. As a result, about 0.79 million cubic metres of sand accreted on Currumbin Beach (Figure 10) and the entire longshore transport now passes around the seaward side of Currumbin Rock.

Immediately downdrift, within about a kilometre of Currumbin Rock, while the beach line receded, the nearshore profile accreted to carry the longshore transport. Works have been carried out effectively removing sand from the creek estuary and moving the beach line seawards in this area. These combined effects are shown on Figure 10 as a net gain

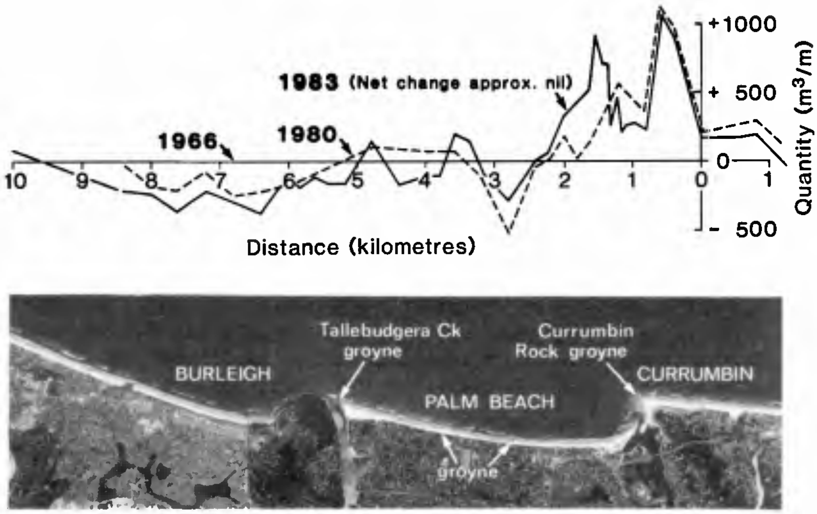

Figure 10. Distribution of Accretion / Erosion — Currumbin to Burleigh.

of sand to the beach system amounting to about 0.5 million cubic metres to 1983. Of this, a net quantity of about 0.2 million has come from the estuary which will tend to infill again with sand from the beaches unless repeated dredging is undertaken to keep the sand on the beaches.

Further downdrift, erosion has occurred along some 5 kilometres of coast at both Palm Beach and Burleigh. At Palm Beach where beaches were already in poor condition in front of seawalls protecting property, sand levels dropped still further, in some areas, to below the low tide level. A nearshore gutter some 200 metres wide and 2 to 3 metres deep, often carrying strong longshore currents, developed adjacent to the seawalls and persisted through to 1980 (Figure 11).

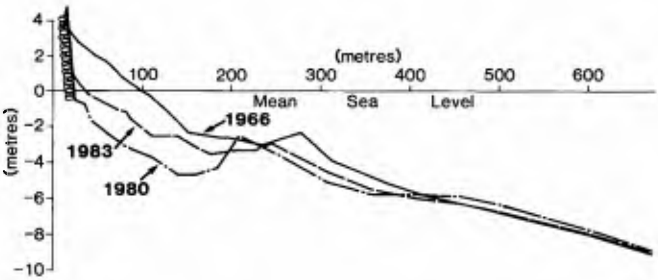

Figure 11. Effect of Seawall on Beach Profile, Palm Beach.

Palm Beach in 1980 with residential development protected by rock seawall and no usable beach.

The Tallebudgera Creek groyne, built in stages between 1977 and 1979, stabilised the northern section of Palm Beach against progressive erosion and is expected to have had the effect of transferring sand losses further downdrift to Burleigh. The groynes built on Palm Beach in 1980 are relatively short in relation to the width of the zone of longshore transport. They have held small quantities of the nourished sand in their immediate vicinity.

Overall, there was a surveyed net erosion of some 1.1 million cubic metres of sand along the downdrift areas of Palm Beach and Burleigh between 1966 and 1983. This is comparable with the total net gain to the beaches of 1.29 million cubic metres adjacent to the Currumbin Rock groyne, of which some 0.2 million has been obtained from the Currumbin Creek estuary. Hence, there is a balance in the overall quantities, with a redistribution leading to accretion in some areas and erosion in others as a result of groyne construction.

The losses of sand along Burleigh Beach occurred first in the offshore parts of the beach profiles, and manifested as significant beachline recession only during and after storms which served to re-establish the normal profile shape but at a more landward location. The net erosion at Burleigh since 1966 had reached typically 300 m^3/m by 1983 with recession of the duneline of up to 20 metres. Despite this, where erosion into the dune has occurred unobstructed by seawalls, the beach itself remains in good condition as a recreational amenity.

3.3 Northern Region (Burleigh to Nerang River)

This section of the Gold Coast is characterised by an almost continuous strip of residential development located on the main dune. Properties along most of this coastal section have periodically been subjected to erosion during cyclones. As a result, a seawall extends along almost the entire 14 kilometre length of beach.

The Nerang River entrance is located at the northern end of the Spit. The entrance has migrated progressively northwards for at least 4.4 kilometres over the past 80 years accompanied by growth of the Spit and erosion of Stradbroke Island. In the process, sand transported into the river entrance has been left deposited in the Broadwater and alienated from the active beach system. As well, the groyne effect of the entrance bar has moved progressively northwards with the entrance.

Beach Nourishment

In 1974, some 1.4 million cubic metres of sand were dredged from the sand reserves in the Broadwater to Surfers Paradise beach to improve its recreational amenity. The sand was placed on a limited beach length of about 3.5 kilometres at an average rate of 400 m^3/m creating a new dune and berm in front of the seawall. It would be expected that the effect of this nourishment would distribute progressively in both directions along the coast while the benefit in the central nourishment area would reduce over time.

Figure 12 shows a plot of the time history of the distance to the mean monthly edge of berm from the seawall line over the period 1974 to 1984. This data was obtained from the COPE station at Surfers Paradise. Despite the expected redistribution of the nourished sand, these works have clearly provided a substantial benefit in terms of the usable beach width over this entire period. Recent storms in 1983 and 1984 have eroded the beach significantly as shown in Figure 12 and the profiles of Figure 13, however the erosion has been accommodated within the dune system and a usable recreational beach continues to exist. No detrimental effects resulting from the beach nourishment works have been noted either within the beach system or at the sand source area.

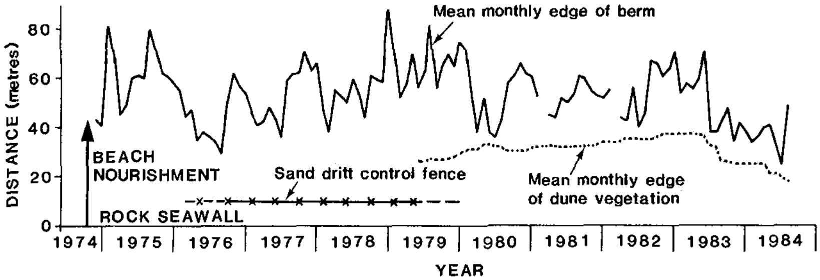

Figure 12. Time History of Berm Width at Surfers Paradise Following Beach Nourishment in 1974.

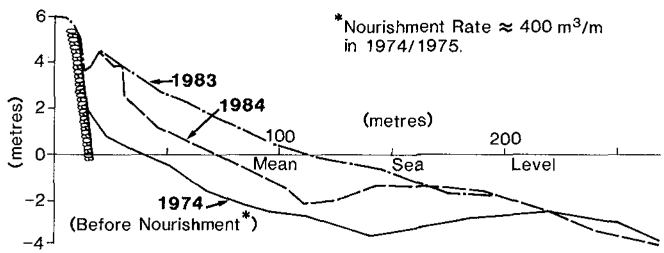

Figure 13. Behaviour of Beach Nourishment, Surfers Paradise.

All of the Gold Coast beaches were substantially eroded by cyclones in 1967. Severe problems were experienced where development was located close to the beaches, such as in the Surfers Paradise area (pictured).

Beach nourishment to Surfers Paradise in 1974 has established a new beach and dune system in front of the seawall. The photo shows the beach in 1983 in good condition.

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Beach nourishment to Surfers Paradise in 1974 has established a new beach and dune system in front of the seawall. The photo shows the beach in 1983 in good condition.

4.0 CONCLUSIONS

The variety and magnitude of works carried out along the Gold Coast and the comprehensive monitoring of the effects of these works over some 20 years have allowed a good understanding of their effects on the coastal system to be obtained. In general, the effects of these works on the beaches of the Gold Coast conform with the already known principles of behaviour. These are summarised below.

Groyne Structures

Groynes interrupting the net longshore sand transport have trapped sand on the updrift side and caused an equivalent quantity of erosion on the downdrift side. The extent and time scale of these effects depends on the effective length of the groyne and the total longshore transport intercepted by the groyne. It is apparent that the effective groyne length of river training walls is greater than for equal length groynes on a continuous beach, presumably because of the additional effects of the river flow. Entrance bar development may add significantly to the total quantity accumulated by such training walls, as appears the case at the Tweed River. The quantity of sand accumulated by these walls now exceeds 6 million cubic metres.

The approximate equality of the surveyed quantities of accretion adjacent to the Tweed River training walls and of erosion along the southern Gold Coast beaches supports the conclusions of the recent longshore transport study for the area. That is, that essentially all of the longshore transport along Letitia Spit would normally have passed to the Gold Coast beaches had the training walls not been constructed. Theoretical groyne accretion calculations together with the trends in the surveyed results indicate that the training walls may ultimately trap of the order of 7 million cubic metres of sand and that the majority of the longshore transport is currently bypassing the walls naturally to the beaches to the north. It is expected that this natural bypassing will be restored to at least 90% of its original rate by 1990.

Other groynes along the coast have affected the beaches to varying degrees, depending on their effective lengths and the proportion of the total longshore transport intercepted. Of these, the Kirra Point groyne which intercepted about 70% of the transport, trapping some 0.3 million cubic metres, and the Currumbin Rock groyne which has accumulated about 1.1 million cubic metres, have had the most impact on the beaches.

Seawalls

Seawalls serve to restrict the horizontal recession of the beachline resulting from erosion occurring either during storm events or as a persistent trend such as at beaches downdrift of groynes. Their impact on the beaches is largely dependent on their location on the beach profile. The further seaward they are constructed, the greater their influence and the less likely will a usable beach be maintained in front.

On the persistently eroding beaches at North Kirra and Palm Beach, the receding beachline has effectively placed the seawall progressively further and further seaward on the beach profile until no beach exists at all in front of the wall. Clearly, the establishment of fixed seawall alignments on persistently eroding sections of beach will lead eventually to loss of the beach as a useful recreational amenity.

It has been noted at Coolangatta, Kirra and Palm Beach that, once the waves impinge on the seawalls for a significant proportion of the time, wave reflections and accelerated longshore currents can lead to increased scour adjacent to the walls.

Beach Nourishment

Beach nourishment to Surfers Paradise beach using the native sand derived from a source remote from the active beach system has been highly effective. Despite the fact that the nourishment was limited in its extent and would be expected to distribute along the coast over time, the benefit of these works has persisted for over 10 years and storm erosion continues to be accommodated within the nourished dune system in most areas.

Sand pumping to the beaches from areas such as estuaries within the zone of natural movements of beach sand will provide no lasting benefit to the beaches unless repeatedly carried out.

Restoration of the beaches in the Kirra area and re-establishment of the normal flow of sand along the coast could be achieved by beach nourishment, but would require nourishment to the eroded beaches by a quantity of sand equal to that trapped by the training walls, the source of such sand being remote from the active beach system.

Beach Management

The Gold Coast erosion problems, namely the threat of property damage and the loss of the adjacent beaches, are the result of inappropriately located development (leading to the construction of seawalls) exacerbated by works (groynes) intended to overcome these problems together with the construction of the Tweed River training walls aimed at improving navigation to the river.

The future beach management policy at Gold Coast will be influenced by the needs of the tourist industry. The variety of works undertaken to date, their obvious effects and those reported from survey results provide the decision-makers with positive evidence of their impact on the coast and allow future works to be undertaken with a clear understanding of these impacts.

The present state of the Gold Coast beaches as a whole is such that the fundamental recommendation of the Delft Hydraulics Laboratory in 1970, namely restoration of the beaches by extensive sand nourishment, is still appropriate despite the expenditure of millions of dollars on coastal works in the area.

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