CAPRICORN COAST BEACHES

D.C. Patterson and L.R. Ford
Engineers, Beach Protection Branch, Department of Harbours & Marine, Queensland, Australia

1.0 INTRODUCTION

The Beach Protection Authority of Queensland published in December 1979 a report outlining the results of its investigation into all the factors which determine the coastal behaviour of the 90 km strip of Central Queensland's coastline known as the Capricorn Coast (Fig. 1). The purpose of the investigation was to provide a detailed explanation of beach behaviour in this area including all the data necessary for the preparation of a comprehensive program of works and management strategies for improving beach conditions and minimising present and future erosion problems. This paper represents a brief summary of the contents of the published report.

2.0 OBJECTIVES

No previous studies have been made into the nature and behaviour of the Capricorn Coast beaches. It was clear from the location and wave exposure of this stretch of Queensland's coast that the behaviour of the beaches is unique and not easily related to other previously studied areas. Hence it was necessary to initiate a full scale investigation into all aspects affecting the beaches of this coastal region. The investigation into coastal behaviour along the Capricorn Coast was commenced in 1975 and carried out in compliance with the Beach Protection Authority's stated functions which include:-

(a) The carrying out of investigations with respect to erosion or encroachment by the sea of or upon lands of the coast;
(b) The investigation and planning of preventative and remedial measures in respect of erosion or encroachment by the sea of or upon lands of the coast;
(c) The recording and evaluating of the results of such investigations and plans.

The primary objective of the study was to provide a firm basis for the preparation of an overall scheme of works and management for the beaches and dunes. The Beach Protection Authority's approach involves determining the extent of foreshore which is likely to be vulnerable to erosion in the future and attempting to restore or carefully manage this land so that it remains available as a buffer zone between the ocean and nearby development. The extent of buffer zone depends on -

- The rate of long term coastal erosion (R metres per year)
- The extent of the design cyclone erosion (C metres)

BUFFER ZONE WIDTH = $[(N \times R) + C] + F$ (metres)
where N = Planning period (years)
F = Factor of safety (metres).

Hence the investigation was directed toward quantifying the values R and C for each beach in the study area. The Beach Protection Authority has adopted a planning period of 50 years and a factor of safety of 40 metres for the Capricorn Coast area.

2.1 Data Collection

Data collection was carried out over the three years 1975 to 1977 inclusive. During that time repetitive surveys, wave recording, dune vegetation studies, geological investigations and current measurements were carried out.

This program of data collection provided data on -

1. the geological history of the region;
2. beach sediment properties;
3. beach profile forms and measured modifications under varying wave attack;
4. meteorological conditions;
5. incident wave conditions;
6. dune vegetation;
7. nearshore currents;
8. sea level fluctuations resulting from tides and storm surges;
9. beach and dune conditions;
10. the nature of the coast and the erosion problems.

2.2 Data Assessment

The task of assessing all of the available data was carried out by engineers and scientists of the Beach Protection Branch of the Department of Harbours and Marine. Assistance was also provided in respect of -

(a) the geology of the area by geologists from the Geological Survey of Queensland and

(b) dune vegetation by botanists from the Department of Primary Industries.

The principle aim of this data assessment was to provide an understanding of the active beach processes in the Capricorn Coast area with particular regard to -

- sediment supply and distribution along the coast
- erosion/accretion behaviour of the beaches in both the short and long term
- the role of dune vegetation in beach and dune stability
- buffer zone widths within which future dune erosion is likely to occur.

3.0 LOCATION AND TOPOGRAPHY

The Capricorn Coast is uniquely placed along Queensland's coastline (Fig. 1). Its location in relation to the Great Barrier Reef, the continental shelf and the shape of the adjacent coastline exposes it to wave, current and tidal forces different from those experienced elsewhere on our coast.

The physical appearance of this 90 kilometre stretch of coast is one of great contrasts. Prominent rocky headlands separate numerous sandy pocket beaches in the central sections while to the north and south long stretches of uninterrupted beach have developed (photo 1). The beaches of the Capricorn Coast are gently sloping, consisting of relatively fine sand containing a significant proportion of muds. The 4 metre ocean tidy typically rises and falls across a beach width exceeding 150 to 200 metres.

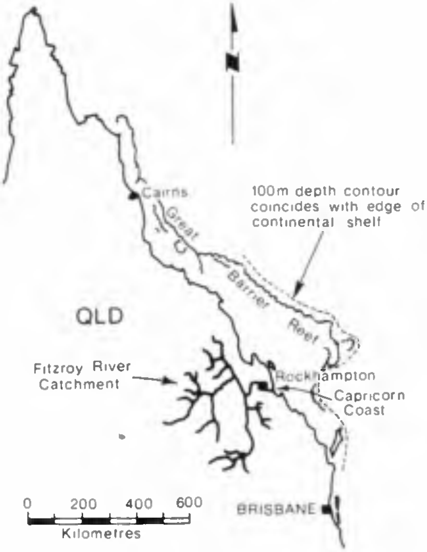


Fig. 1a Locality Plan

Fig. 1b The Study Area

Photo 1. The Yeppoon region of the study area.

The most common coastal landform along the beaches of the area is extensive sand dune development in various forms including recent foredunes, older parallel beach ridges, and both mobile and stabilised transgressive dune formations.

The Fitzroy River is by far the largest of the streams in this coastal region. This river has a comparatively large catchment area of about 14 million hectares. However the major part of the Fitzroy s catchment receives only 600-700 mm of rainfall per year on average, and significant fresh water flows in the river are typically associated only with cyclonic activity in the region.

4.0 GEOLOGICAL HISTORY

The present day topography of the Capricorn Coast and the beach processes taking place there are more readily understood when the past behaviour of the region is known. The beaches and dunes as we see them today have formed during the last 6000 years. The reason for this relates to the rise in sea level which ended at that time. Fluctuations of the sea level reaching about one metre above and below the present level have occurred since then. During the sea level rise, the position of the coastline moved landward from its former alignment resulting in large scale submergence of the former coastal plain to form the present day Keppel Bay. In the process many former mainland hills became headlands of the present shoreline or islands such as Great Keppel Island. The present day seabed topography of Keppel Bay is shown on Figure 2a. The present coastline has developed in response to the last 6000 years of wave and current influence and the input and output of sediment from offshore, alongshore and river sources.

4.1 Fitzroy River Sediments

The Fitzroy River carries with it vast quantities of sand and silt which are discharged to the sea and settle to the bed of Keppel Bay. These sediments have been eroded from the up-stream catchment areas and exhibit characteristics which identify them as less mature than the pre-existing coastal sands of Keppel Bay. For example, the Fitzroy River sediments are finer grained and contain a significant proportion of muds. They also contain relatively large amounts of certain minerals such as feldspar which can be visually identified under microscopic examination and which break down in the coastal environment with time so that they are not present in mature sands. As well, sediment deposited from the river during floods has not been sorted (a winnowing process) by wave and current action and can be differentiated from the better sorted mature sands by grain size distribution analysis.

During the investigation nearly 700 samples of sand were collected from the seabed of Keppel Bay and from the beaches and dunes for analysis to identify these characteristics. This enabled the zone of deposition and transport of sediments supplied from the Fitzroy River during the last 6000 years to be delineated. This zone is shown on Figure 2 and is unusual in that it forms a well defined nearshore belt along the entire Capricorn Coast rather than extending directly seaward from the river mouth. Seismic profiling provided information on the total depth of the nearshore sands and the thickness of the Fitzroy River derived sediments. Using this information together with data on flow in the Fitzroy River during floods, it was estimated that an average quantity of 350,000 cubic metres of sand is supplied by the river each year.

The beaches and seabed in the vicinity of the Fitzroy River exhibit a very strong trend of accretion which diminishes with distance away from the river. This indicates that the rate of distribution of the input sediment is not as great as the rate at which the river supplies it. This has resulted in the flat shallow offshore profiles which characterise the southern Keppel Bay regions and which contrast with the steeper profiles further north.

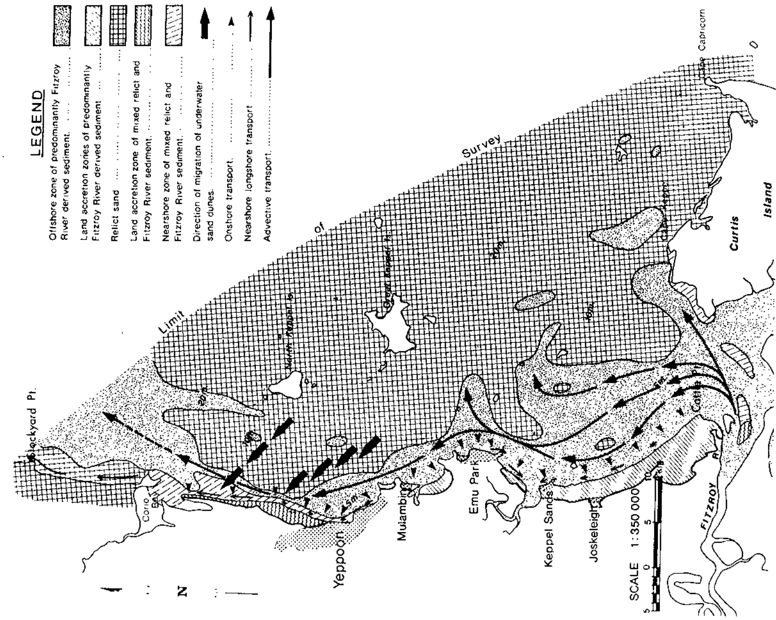


Fig. 2b Sediment Movements in Keppel Bay

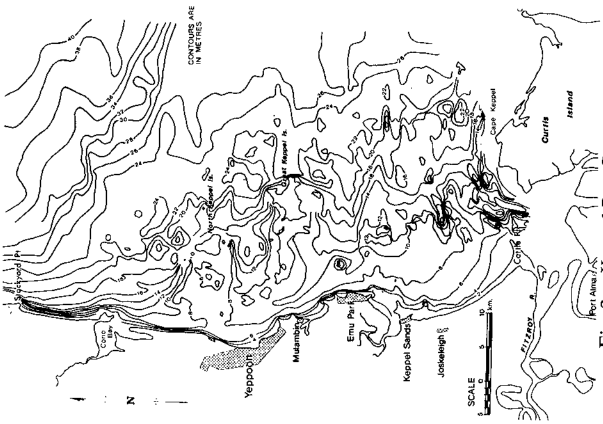


Fig. 2a Keppel Bay Contours

4.2 Offshore Sediment Distribution

The seabed sediments of Keppel Bay are being gradually distributed northwards away from the Fitzroy River (Fig. 2b). The sediment in motion includes both the relatively new Fitzroy River derived muddy sands and the older mature relict sands drowned by the sea transgression prior to 6000 years B.P. The mechanisms involved in this movement of sediment are not clearly understood but are thought to result from the combined action of waves and a northerly current induced by the predominant south easterly winds producing advective transport.

There are no established techniques readily available for calculating these advective transport rates using the available wave and current data. However an estimate has been made from the quantities of Fitzroy River derived sand which has been transported northwards past various locations over the last 6000 years (Table 1).

TABLE 1
NET NORTHWARD ADVECTIVE TRANSPORT IN KEPPEL BAY

Location	Total Holocene Sedimentation North of Location (cubic metres)	Net Northward Advective Transport (m^3/yr)
Cattle Point	2160×10^6	360,000
Keppel Sands	1146×10^6	191,000
Tanby Point	990×10^6	165,000
Double Head	900×10^6	150,000
Farnborough	726×10^6	121,000
Water Park Point	588×10^6	98,000

These rates of transport are large compared with the nearshore longshore transport rates particularly in the southern and central regions. Clearly advective transport represents the primary mechanism for the northward supply of sediment along the coast from the Fitzroy River.

4.3 Holocene Coastal Accretion

At the Capricorn Coast extensive accretion has occurred during the last 6000 years as a result of a persistent onshore movement of sand from the nearshore area of Keppel Bay. Most of this sand has come from the zone of Fitzroy River sediment delineated on Figure 2, and average rates of up to 2000 cubic metres per kilometre of beach per year have been assessed.

The land developed by this Holocene accretion (the "outer barrier") often has the form of a series of dune ridges and swales that correspond to erosion/accretion cycles probably associated with major cyclone events and are clearly evident from the air (Fig. 3 and photo 2). This dune ridge system is superimposed on a broader sequence of accretion features associated with six significant fluctuations in sea level which have occurred during the last 6000 years. During phases of high sea level the accretion sequence is truncated by sustained periods of erosion. Despite this however, the general landward movement of sediment from nearshore continues so that phases of falling sea level are accompanied by accelerated accretion.

As Fig. 2b shows, the beach areas strongly exhibiting this trend of long term accretion are -

(a) the southern region between the Fitzroy River and Emu Park, including Keppel Sands (photo 2).
(b) the deeply embayed shoreline of Mulambin and Kinka Beach.
(c) the Farnborough area north of Yeppoon. In this area an additional input of the older mature sand from both nearshore and alongshore can be identified in the accreted dune sands.

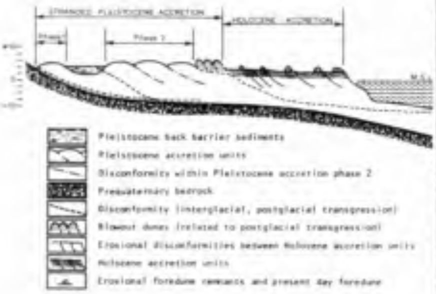


Fig. 3 Section of Holocene Accretion

Photo 2. Holocene accretion
Cattle Point to Keppel Sands

4.4 Persistently Eroding Beaches

In contrast to the strong accretion discussed above, those beaches where nearshore profiles are steep or where the onshore sand supply is moved away along the coast show little accretion and in some locations, general erosion.

Nine Mile Beach and the northern section of Farnborough Beach near Corio Bay show evidence of persistent erosion. This part of the Capricorn Coast is more exposed to the ocean wave conditions than the southern beaches which lie in the lee of the nearshore islands. Erosion by the rising sea level, longshore movement of sand and cyclones has led to persistently unstable foredunes and wind erosion on a large scale. Dune blows and extensive transgressive dune formations are thus the main landforms there (photo 3) and have allowed considerable vertical growth of the dunes reaching to over 150 metres above mean sea level inland of Nine Mile Beach.

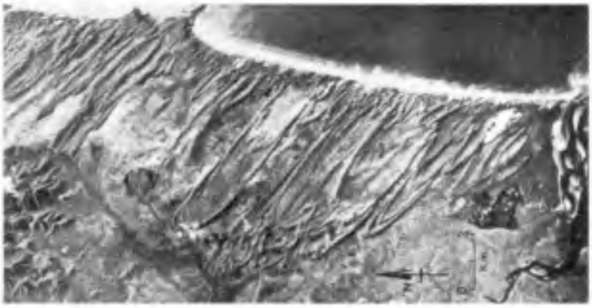


Photo 3. Transgressive dunes - Nine Mile Beach

5.0 NATURAL FACTORS INFLUENCING BEACH PROCESSES

5.1 The present day behaviour of the beaches varies from year to year, seasonally and from day to day depending on the occurrence of cyclones, climatic changes throughout the year and daily weather variations. Longshore transport and onshore/offshore transfer of sand were assessed on the basis of surveyed beach properties and measured forces such as the wind, waves and currents. The growth of dune vegetation which controls the stability of the dunes against wind erosion is determined largely by the climate and the nature of the dune soils.

Some of the natural factors influencing beach processes are outlined briefly below.

5.2 Meteorological Influences

Wind strengths at the coast are consistently moderate to fresh with velocities exceeding 20 km/hr about 50% of the time and essentially no calm days. Strong winds in excess of 50 km/hr occur less than 2% of the time. South east winds predominate and persist longer than all other winds.

There is considerable variation in annual rainfall along the Capricorn Coast with a predominant trend for average rainfall to increase from south to north (Table 2). This trend coincides with a general increase in relief in the coastal topography from south to north with minimum rainfall occurring in the low coastal plains at Cattle Point and maximum rainfall occurring in the coastal ranges inland from Stockyard Point.

TABLE 2
MONTHLY & ANNUAL RAINFALL DATA YEPPOON & EMU PARK

Recording Station	Recording Period	Average Rainfall (mm)												
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Yeppoon	1891-1975	259	240	183	104	77	77	47	30	36	66	76	149	1344
Emu Park	1886-1976	203	201	145	78	59	60	43	24	30	46	71	123	1083

The incidence of tropical cyclones is a significant feature of the study area's climatology. On the average, the Capricorn Coast suffers the effects of tropical cyclones once every two years, although the occurrence of widespread cyclonic destruction in the study area is a much rarer occurrence.

TABLE 3

CYCLONE CENTRAL PRESSURE VS PROBABILITY OF OCCURRENCE

Pressure Range	Representative Pressure	Probability
> 985	990	0.5
975-985	980	0.1
968-975	970	0.08
963-967	965	0.01
958-962	960	0.005
953-958	955	0.003
948-952	950	0.001
943-947	945	0.001
935-942	940	0.0002
< 935	920	0.00002

5.3 Dune Vegetation

Coastal processes would not approach or attain the dynamic equilibrium status common along many coasts without plants that tolerate salt spray, resist strong winds, trap and hold windblown sand and add organic soil components. The establishment, maintenance, and protection of vegetation within those zones affected by coastal processes, are important aspects of coastal management.

The type and distribution of coastal dune vegetation along the Capricorn Coast is highly variable and is determined by geology, landform/topography, climate and land use.

A field survey of vegetation in the Capricorn Coast study area was undertaken as a joint project by the Authority's Dune Conservation Section and the Botany Branch, Queensland Department of Primary Industries.

The survey was carried out to produce a vegetation map and report on the existing vegetation communities of the study area with special reference to beach and dunal areas.

The aggregation of plants in a coastal beach/dune system form, in general, three types of vegetative cover:-

1. a pioneer type composed mostly of herbaceous plants;
2. a heath/scrub type of woody shrubs, vines and small trees with a few associated herbs;
3. a woodland or forest type dominated by trees.

Nearly all the plants of the first two types are tolerant to salt spray, strong onshore winds and various degrees of soil salinity. The pioneer herbaceous vegetation occurs on foredunes nearest the beach. The scrub vegetation is found on the partly to fully stabilised older foredunes landward of the pioneer zone. The forest vegetation usually occurs towards the interior on the oldest and most stable dune/beach ridge systems.

Pioneer vegetation is the chief dune-forming agent. These herbaceous plants grow in a manner that enables them to help develop dunes in conjunction with wind action. Plants growing on the upper part of the beach trap windblown sand and initiate formation of a low frontal dune. Most of the pioneer plants occur on the seaward slope, crest and landward slope of the frontal dune.

Pioneer plants are the initial vegetation of the coastal succession or sequence of vegetation that finally develops into a climax community be it grassland, shrubland, heath, scrub, woodland, forest, or wetland. They increase the rate and height of dune formation and determine the pattern of vegetation development of the coastal dune system. They prepare the soil and other habitat conditions for the development of other vegetation communities (e.g. scrub) in the normal course of coastal succession.

Beach spinifex grass (Fig. 4a) is the most important pioneer sand stabilising plant occurring naturally on the frontal dune and foredunes and is usually the dominant species colonising the seaward slope of the frontal dune in exposed situations. It is tolerant to air borne salts, strong onshore winds, and has the ability to grow through accumulations of windblown sand.

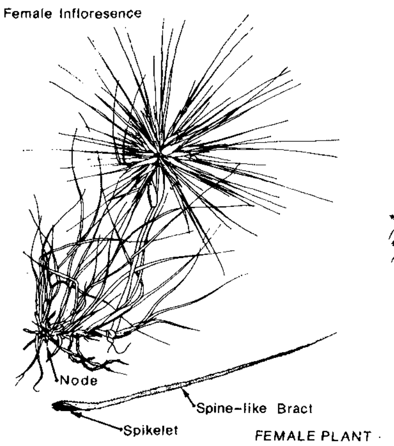


Fig. 4a Beach Spinifex Grass

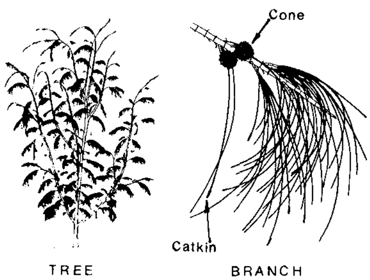
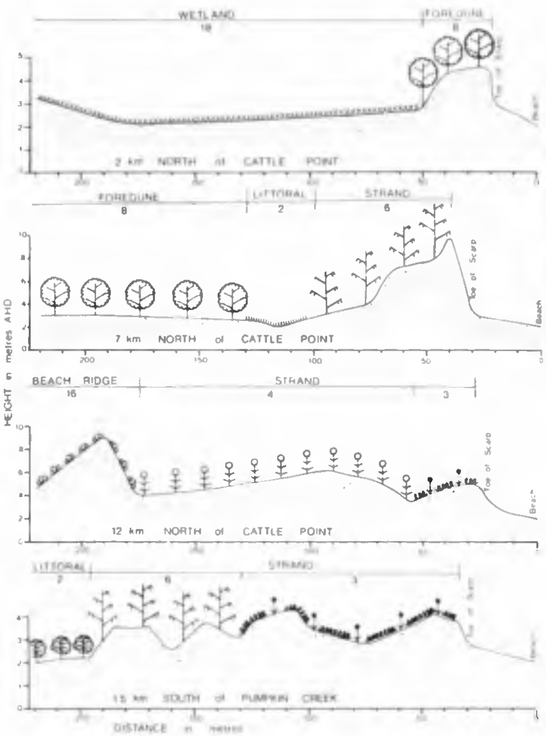


Fig. 4b Coastal She-Oak

Coastal she-oak (Fig. 4b) belongs to the genus: *Casuarina* which is the only non-legume genus native to Australia that can "fix" atmospheric nitrogen. Micro-organisms in the root nodules convert nitrogen from the air into a form which is more readily used by the plant. This process improves the nitrogen content of the sand/soil enable more nutrient demanding plants to establish.



Symbol	Plant	Map Unit	Community Description	Vegetation Zone
		1		Disturbed
	Mangroves Mudflats	2	Mangroves, mudflats	Littoral
	Spinifex Ipomoea Sunflower	3 4	*Spinifex* — *Ipomoea* herbland *Helianthus argophyllus* herbland	Strand
	Grasses Casuarina	5 6	Mixed grassland *Casuarina equisetifolia* var. *incana* low open-forest to low open-woodland	
	Heath Scrub	7 8	Foredune closed-heath/scrub and open-heath/scrub Foredune closed-scrub and open scrub	Foredune
	Lantana	16	*Lantana camara* low shrubland and open-heath	Beach Ridge
xxx	Sedges	18	Swampy mixed grassland	Wetland
		23 24	Rocky shore closed-heath and open-heath Mixed *Eucalyptus* low open-forest, low woodland and woodland	Rocky Shore
	Heath Scrub	28 29	Coastal open-heath and closed-heath *Casuarina littoralis* mixed open-scrub	Parabolic Dune

Fig. 5 Typical Vegetation on Dune Profiles

5.4 Sea Level Variations

Variations in sea level substantially influence beach behaviour through their effect on various wave phenomena such as refraction, shoaling and breaking, and the level at which the waves attack the beach. A significant change in sea level will upset a pre-existing equilibrium and result in changes to the original shoreline profile or plan form. Major sea level variations in the geological time scale are important in understanding contemporary coastal behaviour especially in relation to sediment distribution. During the Holocene period (last 10,000 years), the sea level as risen 20 metres. This rise occurred prior to 6,000 years ago and since then fluctuations in sea level of magnitude about ± 1 metre and period of almost 1,000 years have occurred.

Adopted values for the various tidal planes at the Capricorn Coast are as follows -

TABLE 4
TIDAL PLANES CAPRICORN COAST

Tidal Plane	Low Water Datum	Australian Height Datum
Mean High Water Springs:	4.0m	1.7m
Mean High Water Neaps:	3.1m	0.8m
Mean Low Water Neaps:	1.5m	-0.8m
Mean Low Water Springs:	0.6m	-1.7m

Three separate studies concerning storm surge statistics along the Capricorn Coast have been prepared over recent years. The most recent of these was carried out by the James Cook University, Townsville, for the Beach Protection Authority. It involved the numerical simulation of various cyclones in the Capricorn Coast region in terms of the cyclone intensity and direction of approach. Results from that study are outlined in Table 5.

TABLE 5
MAXIMUM SURGE AT VARIOUS LOCATIONS AS PREDICTED BY NUMERICAL MODEL

LOCATION	CYCLONE RETURN PERIOD		
	1 in 50yrs	1 in 100yrs	1 in 500yrs
Stockyard pt.	1.52	1.66	2.00
Water Park Pt.	1.67	1.83	2.19
Yeppoon	2.03	2.21	2.62
Emu Park	2.54	2.75	3.22
Fitzroy River	2.12	2.29	2.66
Cape Capricorn	1.11	1.21	1.41

5.5 Wave Climate

Waves affecting the Capricorn Coast may be generated locally within 100-500 kilometres of the study area or may arrive as decaying swell generated outside the vicinity of the region. The possible directions from which waves can arrive are confined to the seaward sector between north (O°) and south (180°), being the general alignment of the coast. Swell waves are further restricted by the shape of the coast and offshore reefs to directions between 60° and 120°, being intercepted by the Great Barrier Reef to the north-east and Fraser Island to the south-east. Recording of waves using the Dutch Waverider wave recording system was carried out at one location over the period November 1974 to April 1978. The recorder location was 33 km east of Yeppoon in 28 metres of water, being seaward of North and Great Keppel Islands and away from the sheltering effects of Cape Capricorn.

WAVEHEIGHT EXCEEDANCE

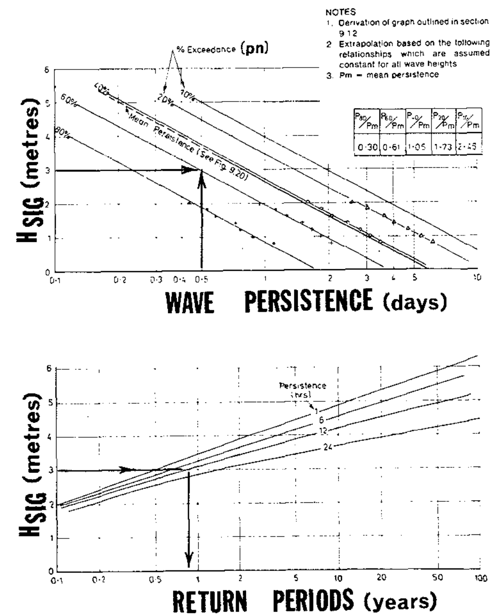
AVE No HOURS PER YEAR $= \frac{(pe)}{100} \times 8760$

AVE No EVENTS PER YEAR $= \frac{(pe)}{Pm} \times 87 \cdot 6$

For a particular persistence ___

AVE No EVENTS PER YEAR $= \frac{(pe)}{Pm} \times 87 \cdot 6 \times \frac{(pn)}{100}$

AVE RECURRENCE INTERVAL $= \frac{Pm}{0 \cdot 876\ (pe \cdot pn)}$



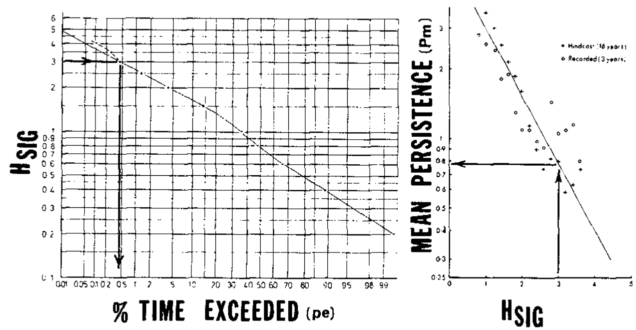


Fig. 6 Wave Climate - Capricorn Coast

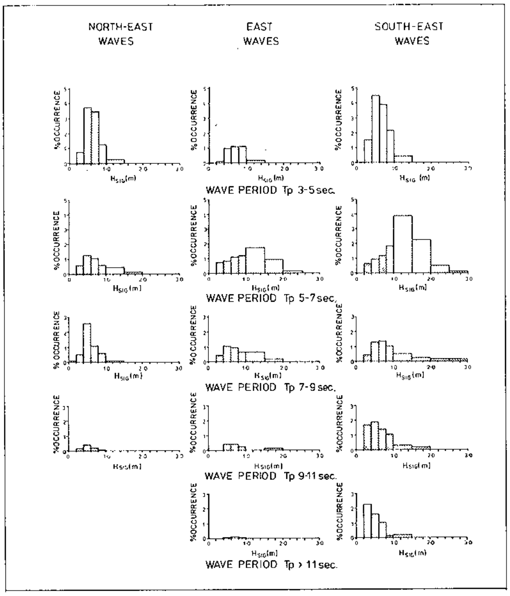


Fig. 7 Wave Height/Period/Direction Occurrence

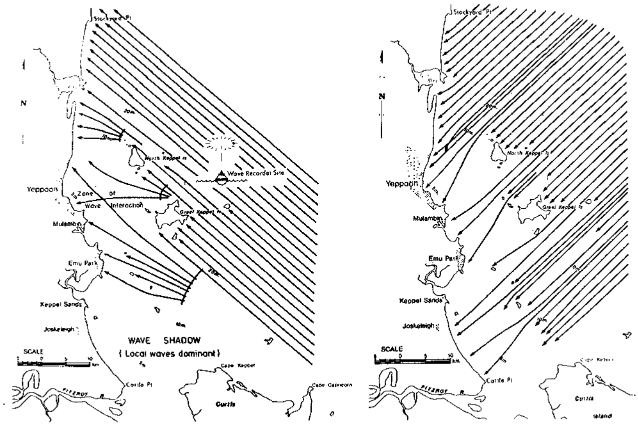


Fig. 8 Typical Wave Refraction

A wide range of basic wave parameters were analysed for each 20 minute wave record. However, the parameters considered most useful for determining beach processes were the significant wave height (H_{sig}) and the period corresponding to the peak of the energy spectrum (T_p). Hindcasting was also performed using twice daily wind data recorded at Cape Capricorn Lighthouse over a 17 year period. This involved the use of the revised S.M.B. empirical relationship for the non-deep water situation.

The reasons for hindcasting wave height data were -

(a) to compare the results with recorded data to confirm a wave hindcasting/forecasting procedure for use in estimating wave heights during particular storm events either in the future or for past cyclones for which wind data is available.

(b) to extend the time base of available wave data from the 3 years of recording to the period of available wind data namely 16 years in this region. This provides a better basis for statistical analysis of the less frequent high wave occurrences.

The calibrated hindcasting model provided wave height data showing good agreement with the recorded data over the three year period of recordings. Wave directions were assessed on a daily basis from synoptic charts and from wind data used in the hindcasting procedure.

Representative wave data for the Capricorn Coast determined from the wave study are outlined in Figures 6 and 7. The largest significant wave height recorded during the investigation was 4.26 metres associated with cyclone "David" in January, 1976.

Wave refraction procedures based on first order wave theory using peak energy wave periods were used to transfer the offshore wave data to the various locations along the coast (Fig. 8).

5.6 Nearshore Currents

Current measurements were undertaken both within the surf zone and nearshore outside the surf zone. Four types of currents were considered -

- Ocean Currents
- Nearshore Tidal Currents
- Nearshore Wind Drift Currents
- Wave Induced Currents

Measurement techniques involved the use of current meters outside the surf zone to provide the vertical velocity and direction profiles and float and dye tracking within the surf zone. It was found that both the wind and the tide contributed significantly with wave induced forces to the generation of longshore currents.

The data obtained was used to confirm or determine analytical expressions from the longshore current necessary as input to the calculation of the longshore transport of sand.

6.0 CYCLONE EROSION

Erosion of the beaches and dunes often accompanies the occurrence of major storms and cyclones in the region. Abnormally big waves attack the dunes during the high tides and accompanying storm surges and move sand in the offshore direction.

6.1 Measured Cyclone Erosion

The extent of erosion caused by Cyclone "David" in 1976 was monitored by surveys in terms of the quantity of sand eroded and the typical horizontal recession of the toe of the frontal dune. This is shown in Table 6 (terms defined on Fig. 9).

TABLE 6
EROSION DURING CYCLONE DAVID

Location	Quantity Eroded (m^3/m)	Horizontal Recession (m)	Transition Level (m) (related to M.S.L.)	Offshore Limit of Deposition (m)	
				Related to M.S.L.	Below peak storm tide
Cattle Pt. to Keppel Sands	35	15	+1.0	-1.0	4.2
Keppel Sands	15	4	+1.5	0.0	3.2
Emu Park	30	13	+0.8	-3.0	6.2
Emu Pt. to Ritamada Headland	30	15	+1.0	-2.0	5.2
Kinka Beach	25	10	+1.5	0.0	3.2
Mulambin	10	5	+2.0	+0.5	2.7
Kemp Beach	20	7	+1.0	-1.5	4.7
Lammermoor	45	12	+1.0	-2.3	5.5
Yeppoon	30	N/A	+0.5	-3.0	6.2
Yeppoon to Bangalee	70	15	+0.5	-4.5	7.7
Nine Mile Beach	65	9	-1.0	-4.5	7.7

6.2 Erosion by the "Design" Cyclone

The method of Edelman for estimation of dune erosion during storms is based on the principle that a characteristic beach profile is developed by the cyclonic waves with sand eroded from the dune (Fig. 9).

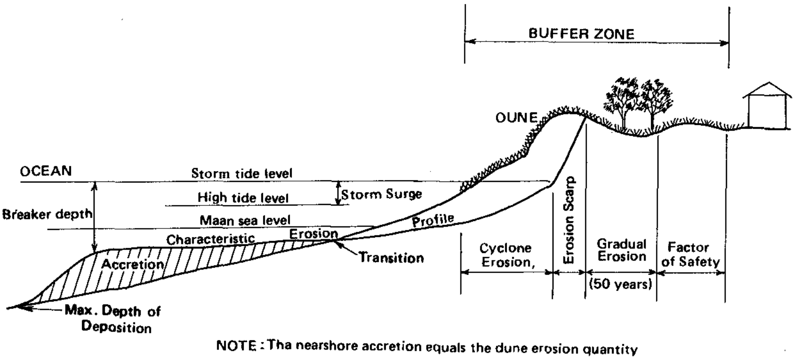


Fig. 9 Dune Erosion - Buffer Zone

Beach surveys immediately after cyclone David indicated that the Edelman profile closely approximated this characteristic profile for the Capricorn Coast beaches and could reasonably be used in the absence of more reliable information. Clearly sand grain size strongly influences the shape of this profile. For the estimation of erosion resulting from the adopted "design" cyclone conditions, the profiles actually developed during cyclone David were used for each individual beach along the study area.

The extent of cyclonic dune erosion depends also on the storm tide level and the wave height. Design wave heights were based on the recorded data as outlined in Section 5 with appropriate modification to allow for refraction. Design storm tide and wave heights for various beaches along the coast are shown in Table 7 along with the assessed dune erosion results.

TABLE 7
"DESIGN" CYCLONE DUNE EROSION

Location	Design Wave Height (m)	Design Storm Tide Level (m)	Erosion Quantity (cu m/m)	Erosion Distance (m)
Nine Mile Beach				
- High Foredune	5.9	3.40	50	20
- Low Foredune	5.9	3.50	140	35
Farnborough	5.3	3.60	175	35
Bangalee	3.0	3.75	75	25
Yeppoon	3.5	3.90	80*	40*
Lammermoor	3.5	3.90	130	50
Kemp Beach	3.5	4.00	50	35
Mulambin	3.8	4.00	115	50
Kinka Beach	3.8	4.20	65	50
Tanby/Ritamada	4.0	4.20	100	60
Emu Park/Zilzie	4.5	4.45	80	50
Keppel Sands	2.7	4.20	60*	20*
Cattle Point	2.2	4.00	50	50-150+

*Sections of beach protected by seawalls
+Large horizontal erosion where overtopping of foredune occurs.

7.0 LONGSHORE TRANSPORT

At the Capricorn Coast where the offshore profiles are relatively flat and wind and tide induced currents are frequently large compared with wave induced currents, the transition from the offshore advective transport to the nearshore longshore transport is not a clear one.

Several methods were used to estimate the gross and net longshore transport rates for the various beaches (refer Fig. 1b). These were -

(a) the "CERC Method which is based on the assumption that all transport is caused by wave forces alone
(b) the Bijker method which allows the input of the appropriate longshore current velocity together with wave, sediment and profile parameters
(c) a method developed by the Authority for estimating longshore transport using observed daily wave and longshore current information from the COPE stations.

The results are summarised in Tables 8 and 9. Greater reliability is expected of the COPE data results as they incorporate longshore current directions and velocities obtained by direct measurement and include the influence of the tide and wind.

8.0 GRADUAL EROSION

Persistent gradual erosion may result from a differential in the longshore transport along a beach, the effects of a rising sea level or wind erosion. Historical information given by the geological study and successive surveys or aerial photography is available, together with the assessed longshore transport data, to quantify the gradual erosion for each beach. Rates in the range 0-4 metres per year have been obtained.

TABLE 8
SEDIMENT TRANSPORT CALCULATED FROM WAVE DATA

Site	SEDIMENT TRANSPORT						
	Refracted Offshore Waves		Wave Generated Within Keppel Bay		Total Sediment Transport		
	Upcoast	Downcoast	Upcoast	Downcoast	Upcoast	Downcoast	Net
Nine Mile Beach	368,000	64,000			368,000	64,000	+ 304,000
Sandy Spit	138,000	86,000	43,000		181,000	86,000	+ 95,000
Farnborough		86,000	43,000		43,000	86,000	- 43,000
Barwell Ck.	29,000	60,000			29,000	60,000	- 31,000
Yeppoon	55,000	63,000			55,000	63,000	- 8,000
Lammermoor	69,000	50,000			69,000	50,000	+ 19,000
Mulambin	83,000	80,000			83,000	80,000	+ 3,000
Ritamada	67,000	57,000			67,000	57,000	+ 10,000
Emu Park	34,000	38,000			34,000	38,000	+ 4,000
Keppel Sands	11,000		7,000	2,000	18,000	2,000	+ 16,000
Cattle Point - Keppel Sands			46,000	2,000	46,000	2,000	+ 44,000

*Keppel Sands Transport rates apply only at the beach, above the tidal flats.

NOTE: (+) Upcoast
(-) Downcoast

TABLE 9
LONGSHORE SEDIMENT TRANSPORT CALCULATED FROM COPE DATA
MONTHLY AND ANNUAL NET RATES

	SITE		
	Barwell Creek	Yeppoon (Main Beach)	Lammermoor
January	1,700	-10,000	0
February	800	- 2,700	7,000
March	500	- 4,000	4,400
April	+ 700	- 3,300	6,300
May	1,300	- 1,200	4,200
June	700	- 600	2,300
July	600	0	4,800
August	0	0	1,200
September	0	0	600
October	-1,000	- 3,000	300
November	-2,800	- 1,500	-2,700
December	- 6,000	- 1,500	3,800
Net Annual Transport	- 4,500	-27,800	32,200

9.0 BUFFER ZONES AND BEACH PROTECTION SCHEMES

Using the assessed rates of gradual erosion over the adopted 50 year planning period and the extent of the design cyclone erosion for each beach, the buffer zones have been calculated as outlined in Section 2.0. Typical results are outlined in Table 10.

Existing and potential erosion problems have been identified and recommendations for protection (including restoration where necessary) of the beaches are outlined in the published Beach Protection Authority report. While several beaches require works such as beach nourishment, groynes or seawalls, most of the beaches can be protected by careful dune management and control over adjacent residential development.

Photo 4. Natural Dune Vegetation

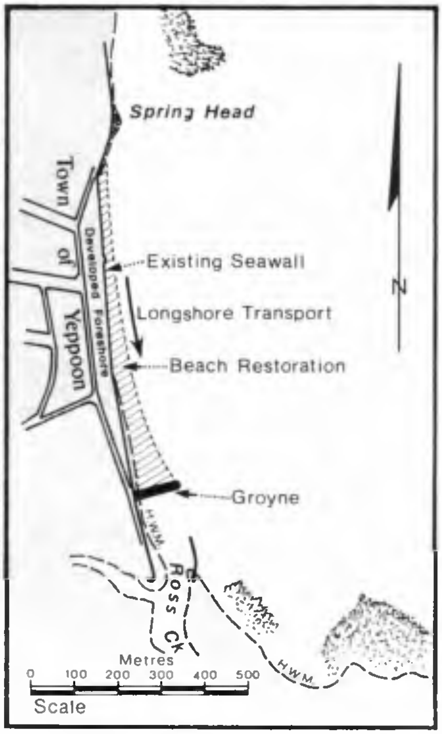


Photo 5.
The residences and access road at Keppel Sands is perilously close to the eroding beach.

Fig. 10 Recommended Beach Restoration at Yeppoon

TABLE 10
BUFFER ZONE WIDTHS

Location	Gradual Erosion (m)	Cyclone Erosion (m)	Dune Scarp Component (m)	Factor of Safety (m)	Buffer Zone Width (m)
Nine Mile Beach					
- High Foredune	50	20	30	40	140
- Low Foredune	50	35	10	40	135
Farnborough	40	35	10	40	125
Bangalee	25	25	10	40	100
Yeppoon	0*	40	10	40	90
Lammermoor	15	50	10	40	115
Kemp Beach	10	35	10	40	95
Mulambin	10	50	10	40	110
Kinka Beach	0-75	50	10	40	100-175
Tanby/Ritamada	10	60	10	40	120
Emu Park/Zilzie	10	50	10	40	110
Keppel Sands	50	20	10	40	120
Cattle Point to Keppel Sands	0-200	50	10	40	100-300

*Protected by seawall.

10.0 CONCLUSION

The provision of adequate buffer zones between development and the sea and the protection of the dunes contained within them by careful dune management is clearly the best way of protecting both the beaches and the nearby development. Every effort should be made in future town planning schemes to make such provisions. However some beaches are already experiencing erosion problems where development has been permitted too close to the sea in the past and has come under threat of erosion by cyclonic wave action. Determination of the most appropriate remedial action is not simple and depends on the individual beach behaviour. The consequences of incorrect decisions in beach protection matters can be financially severe and physically disastrous for the beach itself. To date the financial resources available for beach protection measures has been limited. It is important that available funds are directed towards the most appropriate solutions which do not create other problems. It is therefore necessary for beach protection proposals to be based on a thorough knowledge of local behaviour.

The Capricorn Coast Beaches investigation has provided an explanation of beach behaviour in that area in quantitative terms based on actual field data with the additional testing and use of empirical and theoretical predictions.

The Beach Protection Authority is convinced that such detailed investigations are necessary to determine the optimal use of the limited money resources available for the improvement of existing beach conditions and the minimising of future erosion problems.

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