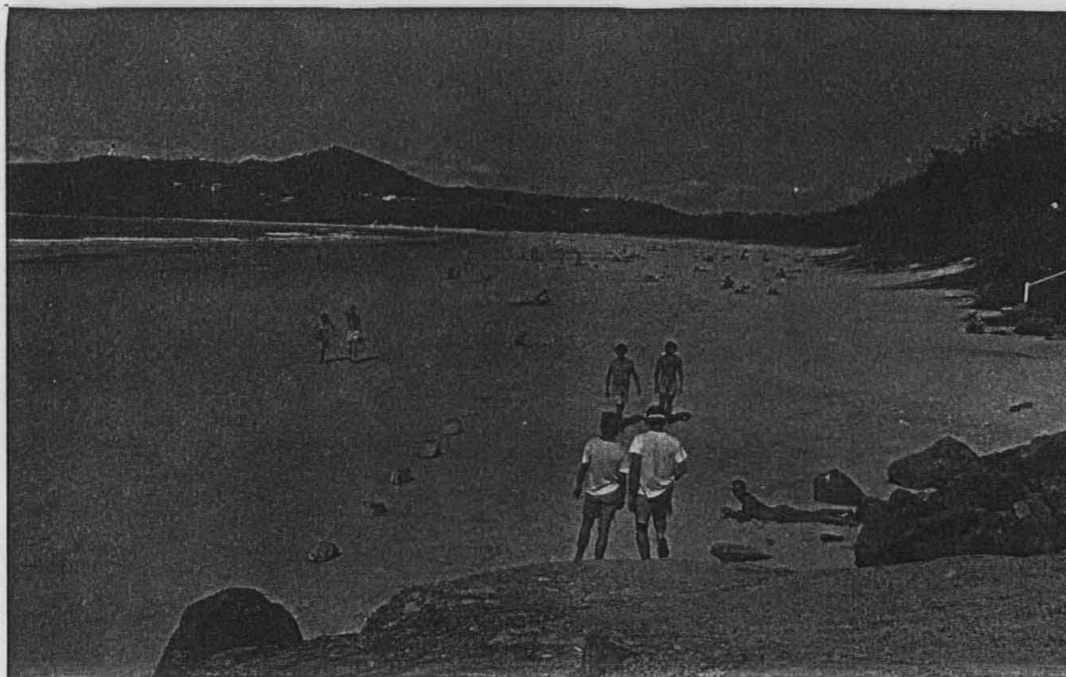


# VOLUME 1

## BEACH BEHAVIOUR IN RESPONSE TO CHANGES IN WIND, WAVE, AND TIDAL CHARACTERISTICS AT BYRON BAY, NEW SOUTH WALES

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Integrated Coastal Project for the  
Bachelor of Applied Science (Coastal Management)

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## ABSTRACT

A serious coastal erosion problem exists at Byron Bay, in northern New South Wales. A long-term erosion trend has been identified in the area, which is associated with a continuing loss of sand from the beach zone. The retreating coastline is threatening private homes, public facilities and the commercial district, thereby jeopardising the economy of the town. Very little research has been conducted in recent years to investigate this problem.

This study examines beach behaviour at Byron Bay over long, intermediate, and short-term time scales. A review of the literature was carried out to assess the pattern of erosion and accretion from 1883 to 1976. For the years 1976 to 1990, aerial photographs were analysed, as was the wave climate record. Intermediate and short-term beach behaviour over the Summer and Autumn months of 1990/1991 was monitored by repetitive surveys of the active beach zone. The observed changes in the profiles were then correlated with changes in wind, wave and tidal characteristics.

Results of this study indicate that the beaches of Byron Bay are surprisingly "dynamic". An accretionary trend on the majority of the beaches was identified, although this was found to be an atypical Summer/Autumn pattern caused by an increase in the sediment supply and an abnormally calm, winter-like, south-easterly wave climate. Wategos Beach and the corner of Clarks Beach suffered significant erosion over the study period due to sediment being temporarily trapped elsewhere, while short period waves superimposed on extreme high tides caused an erosion scarp at Clarks Beach to recede dramatically.

Historical records show that coastal erosion at Byron Bay is most common between the months of December and May. Strong, moisture-laden winds from the north-eastern quadrant generate large, short period waves that have a destructive effect on the exposed coastline. Large south-easterly swells, most prevalent in the late Autumn and Winter, have little effect on Byron Bay due to the protection provided by the Cape. These waves actually facilitate accretion by causing longshore drifting from the south and transporting sand around Cape Byron and into the embayment. The offshore Winter south-westerlies also cause accretion by flattening the sea surface and setting up an onshore current at depth. Therefore, in a 'normal' year at Byron Bay, a build-up of material in the Winter is offset by a process of erosion during the Summer and Autumn.

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## 1.0 INTRODUCTION

### 1.1 Introduction to the study

#### 1.1.1 Significance, relevance, and aims

A 1978 study undertaken by the New South Wales Public Works Department (N.S.W. P.W.D.) found the Byron Bay-Hastings Point region (Fig. 1) to contain the most pressing coastal erosion problems faced in the northern part of the state (Gordon, *et al* ., 1978). The investigation clearly established the existence of a serious long-term erosion trend in the area, with an estimated \$14 million worth of public and private assets at risk over the next 50 years. The problem is not only one for the individuals whose homes are in danger. The erosion is also posing a threat to tourist camping areas, recreation facilities, and the commercial district of Byron Bay. The economic stability of the district could therefore be substantially undermined.

This project aims to investigate the coastal erosion problem at Byron Bay by examining the behaviour of the active beach zone over long, intermediate, and short-term time scales. This is part of a long-term monitoring project by final year Coastal Management students at the University of New England - Northern Rivers to evaluate the behaviour of all beaches from South Ballina to Hastings Point, N.S.W.

There have only been two major studies conducted in the Byron Bay region (Hopley, 1967, and Gordon, *et al* ., 1978). The main conclusions of these studies have never been tested and the data obtained are considerably outdated. Thus, new data are desperately needed - this project is the first attempt to correlate wave direction, height and period with beach behaviour, and the only attempt since Hopley (1967) to correlate wind patterns in the area with erosion/accretion events.

The success (or failure) of an early Summer beach skimming programme conducted on Clarks and Main Beach, Byron Bay will be evaluated. The likely impact on the beach system of the proposed Byron Bay jetty will also be assessed.

### 1.1.2 Location of study area

The township of Byron Bay is located on the far north coast of New South Wales, approximately 173 kilometres south of Brisbane and 823 kilometres north of Sydney (inset, Fig. 1). Cape Byron is the most easterly point of Australia and forms the southern anchor point for a beach nearly 30 kilometres in length. The coastline of the embayment trends west and curves toward the north-northeast until it reaches Cudgera Headland at its most northerly point (Hopley, 1967).

As shown in Figure 1, the section of coastline under examination in this study is the active beach area between Wategos Gap (known locally as "The Pass") and the Main Beach parking lot which is adjacent to the Memorial Swimming Pool.

### 1.1.3 Data availability

Byron Bay was chosen as the subject of this study for a number of reasons. The Bay's close proximity to Lismore minimised travelling time and costs, and it was an area where a recognised coastal erosion problem existed. The main factor behind the site selection, however, was the availability of data. A comprehensive catalogue of maps, charts, plans and photographs of Byron Bay is obtainable from a wide variety of sources; including the N.S.W. P.W.D., the N.S.W. Lands Department, and Byron Shire Council.

Since the aim of this study is to correlate long, intermediate and short-term beach behaviour with wind, wave and tidal characteristics, it was vital that ready access to these data be obtained. As explained in the Methodology section of this report, Byron Bay wave height and period data are available since the start of records in 1976, whilst wind and state of sea and swell data have been recorded at Cape Byron since 1949.

## 1.2 Project objectives

The objectives of this project are:

- 1) To establish permanent beach profiles and supply baseline data for beach behaviour at Byron Bay.
- 2) To collate and interpret wind, wave, and tide data for Byron Bay.
- 3) To gain a better understanding of the coastal processes operating in the area.
- 4) To evaluate the success (or failure) of the beach skimming programme.

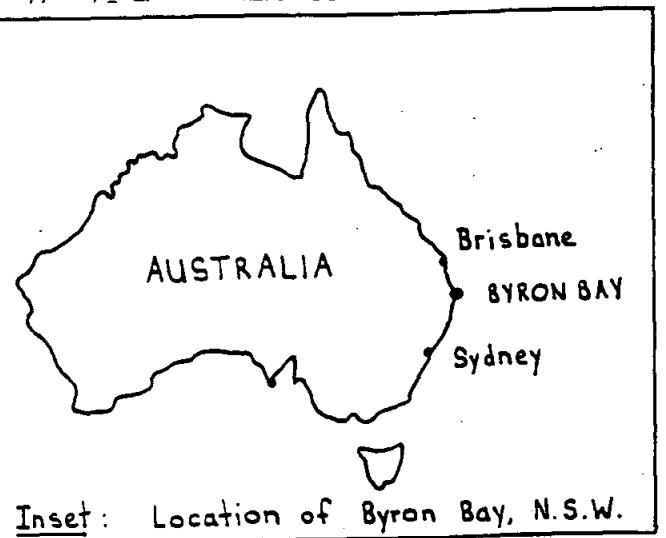
Hastings Point  
(30 km)

### ACCOMMODATION

Adventure Lodges GH, 29 Shirley St  
Aldermans SCA, 2 Palm Valley Dr  
Arts Factory Lodge YH, Skinners Shoot Rd  
Backpackers Holiday Village Hostel YH, 116 Jonson St  
Baymist Motel M, 12 Bay St  
Bayview Lodge SA, 22 Bay St  
Beachfront Holiday Apartments SCA, 39-41 Lawson St  
Beacon Motel M, 6 Bay St  
Belongil Beach House GH, Childe St  
Belongil by the Sea HC, Childe St  
Byron Bay Beach Resort R/SCA, Bayshore Dr  
Byron Bay Holiday Inn M, 45 Lawson St  
Byron Bay Palms Hostel YH, 78 Bangalow Rd  
Byron Beach Motel M, 12 Lawson St  
Byron Hibiscus Court Motel M, 33 Lawson St  
Byron Links Holiday Village M/HC, Broken Hd Rd (Map 2) Q21

L7 Byron Motor Lodge M, car Butler & Lawson Sts  
V5 Cape Byron Resort Motel M, 16 Lawson St  
L10 Cape Byron Van Village CP/CG, Ewingsdale Rd  
O10 Clarkes Beach Caravan Park CP/CG, Massinger St  
O7 Crosby's Caravan Court CP/CG, Broken Head Rd (Map 2)  
O7 First Sun Caravan Park CP/CG, Lawson St  
O8 Glen Villa Mobile Home Park CP/CG, Butler St  
O7 Great Northern Hotel H, Jonson St  
G5 Lord Byron Motel R/M, Jonson St  
G5 Pacific Holiday Apartments SCA, 62 Lawson St  
B2 Shoreline Holiday Apartments SCA, 18-20 Bay St  
Q8 Sunaway Motel M, 42 Alcorn St  
Q15 Sunseeker Motel & Cabins M/HC, Bangalow Rd  
Q8 Suffolk Park Caravan Park CP/CG, Alcorn St (Map 2)  
Q8 Suriside Hotel/Motel H/M, 1 Jonson St  
Q8 Tallow Beach Resort R/HC, Alcorn St (Map 2)  
Q21 Taylors (outside map area) GH, McGettigans Ln Ewingsdale  
T16 The Oasis R/SCA, 28 Scott St  
R23 The Wheel Resort HC, Broken Head Rd (Map 2)

CODE:  
CG Camping Ground  
CP Caravan Park  
GH Guest House  
H Hotel (Licensed)  
HC Holiday Cabins  
M Motel  
R Resort  
SA Serviced Apartment  
SCA Self Contained Apartment  
YH Youth Hostel



# BYRON BAY MAP 1

Scale 1: 13 750

## Map 1 Streets

Acacia St	B7	Carlisle St	P10	Kendall St	K8	Sandpiper Ct	T13
Bangalow Rd	R16	Cavvanbah St	K7	Kingsley St	P10	Seastar Ct	T14
Banksia Dr	A7	Cemetery Rd	O16	Lawson St	O8	Seaview St	Q12
Bay St	O7	Childe St	G5	Lighthouse Rd	T7	Scott St	R15
Bayshore Dr	A8	Cooper St	R14	Mackay St	R15	Shelley Dr	S13
Beachcomber Dr	S15	Coral Crt	T15	Mahogany Dr	R17	Shirley St	K8
Belongil Cres	B5	Cowper St	R11	Manfred St	F5	Short St	S10
Border St	J6	Cumbebin Pk	Q14	Marine Pde	W4	Skinners Shoot Rd	K10
Boronia Pl	B7	Driftwood Ave	T15	Marvell St (E)	P9	Somerset St	N9
Brook Dr	U5	Dryden St	L8	Marvell St (W)	R9	South Pacific Ct	S14
Brownell Dr	W4	Evans St	T10	Massinger St	S11	Sunrise Blvd	A6
Browning St (E)	P12	Ewingsdale Rd	C8	Middleton St (N)	P8	Tallow Wood Cr	R17
Browning St (W)	R12	Fern Pl	C7	Middleton St (S)	P10	Tennyson St	P11
Burns St	M9	Fletcher St	O9	Milton St (N)	M8	Ti-Tree Pl	C7
Butler St	N10	Giaour St	G6	Milton St (S)	L10	The Esplanade	G5
Byron St (E)	K8	Gordon St	M10	Mott St	R13	Walker St	S13
Byron St (W)	O8	Grevillea St	A8	Osprey Cres	T14	Wentworth St	L10
Cape Crt	B6	Ironbark Ave	R17	Pacific Vista Dr	S14	Wollumbin St	Q12
		Jonson St	P11	Palm Valley Dr	V4	Wordsworth St (N)	N8
		Julian Rocks Rd	B5	Patterson St	S11	Wordsworth St (S)	M10
		Keats St	Q13	Ruskin St	P11	Wright St	R15

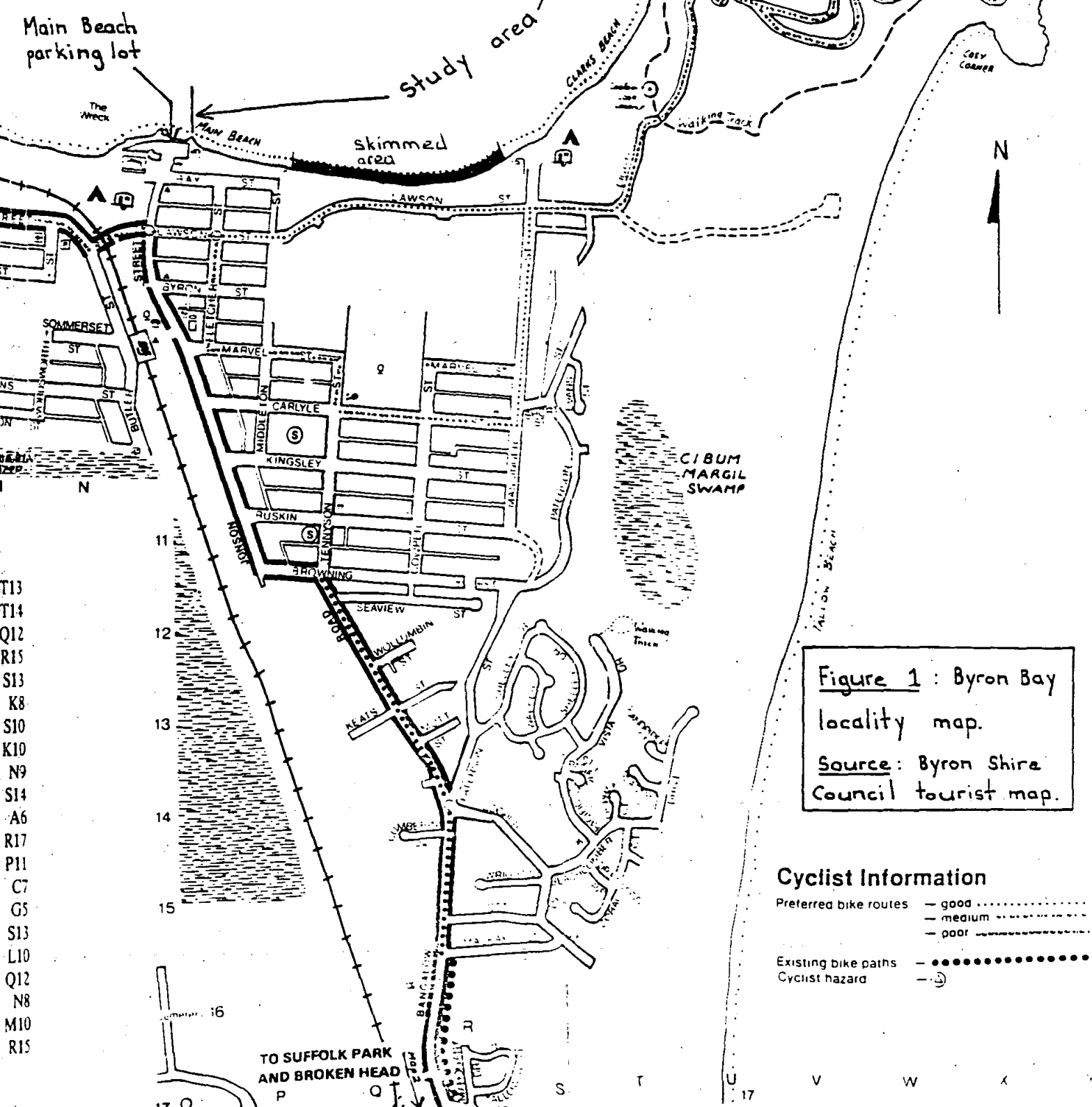


Figure 1: Byron Bay  
locality map.  
Source: Byron Shire  
Council tourist map.

### Cyclist Information

Preferred bike routes — good — medium — poor  
Existing bike paths —  
Cyclist hazard —

## 2.0 BACKGROUND

### 2.1 History of settlement at Byron Bay

Ryan (1984) states that Cape Byron was first sighted on Tuesday 15th May 1770 by Captain James Cook. Cook named it after his friend, Captain John Byron, father of George Gordon (Lord) Byron, the poet.

The area was known by the Bundjalung Aborigines as "Cavanba" or "meeting place". The sheltered bay north of the Cape was charted by William Johns in August 1828 and became known as Byron Bay.

In the 1850's cedar cutters were operating around the Bay, and according to Gordon, *et al.* (1978), by 1857 squatters had moved into the area with 150,000 head of cattle. Legally-entitled farmers came to the district in 1881 and started to grow wheat, cotton, bananas, sugar cane and corn.

Palm Valley was the site of the first settlement in the Bay area in 1883, and the town's first jetty was opened in 1888 (more on this later). In 1894 the rail link with Lismore was completed, and in 1895 the Norco factory commenced operation. The development of the Bay then shifted from Palm Valley to the present commercial centre around the railway and jetty (Ryan, 1984).

### 2.2 History of shipwrecks in Byron Bay

As early as 1849, shipwrecks had been reported along the Byron Bay coast. This led to the area's first jetty being constructed in 1888. It was 402 metres long, eight metres wide and set on 66 rows of turpentine piles, some of which can be seen in front of the present day swimming pool (Anon., 1888; Gordon, *et al.*, 1978; Ryan, 1984). As Gordon, *et al.* (1978) states, the construction and opening of the Byron Bay jetty marked the beginning of Byron Bay's most prosperous period, and by 1914 the North Coast Steam Navigation Company was operating 28 steamers. Evidence that the bay was dangerous to shipping became obvious as the number of shipwrecks increased. In 1896 there was the wreckage of no less than five ships on the beaches of Byron Bay.

In 1921 the "Wollongbar" was destroyed and it is seen by many as the most disastrous loss to the North Coast shipping industry. The wreck occurred when the ship was pulled away from the jetty by gale force winds and pounded upon the shore by rough seas. The jetty was also severely damaged by that and subsequent storms, and had to be replaced in 1928 by a longer and wider jetty. A successful fishermen's co-operative was opened in 1945, but a series of heavy seas over a period of six years caused serious damage to the fishing fleet. In 1948, six launches tied to the jetty were destroyed by heavy seas, while 15 were destroyed in 1952. In February 1954, a tropical cyclone in the South Coral Sea generated disastrous storms along the southern Queensland and northern N.S.W. coasts and 26 fishing boats were destroyed. This marked the end of Byron Bay as a major fishing port and the P.W.D. decided on Brunswick Heads as the most suitable site for a fishing harbour (Gordon, *et al.*, 1978; Little, 1989).

### 2.3 Erosion history of the Byron Bay area

Reports of coastal erosion can be found in official reports and surveys of the Byron Bay area dating back to the late 1800's. Reports were made of rapid changes to the beachface occurring due to the movement of sand and the varying position of the high water mark. In 1883, Staff Commander Frederick Howard reported on the "ever shifting nature of the low water line" and that a beach may be flat one day but become after "a few day's rough weather, quite steep" (Hopley, 1967).

A study carried out by Hopley (1967) in Byron Bay used the intersection of extended street lines and the foot of the leading dune as observation points to gauge the amount of erosion or sand build-up (Fig. 2). At the eastern end of the beach only moderate movements of sand occurred between 1883 and 1958. The shoreline receded 7.6 metres in front of Massinger Street and 6.1 metres in front of Cowper Street between 1883 and 1915, but it was rebuilt by steady aggradation up to the mid-1940's. Rapid erosion occurred between 1959 and 1965 which caused the beach to retreat 61 metres in front of Massinger Street and 36.6 metres in front of Cowper Street.

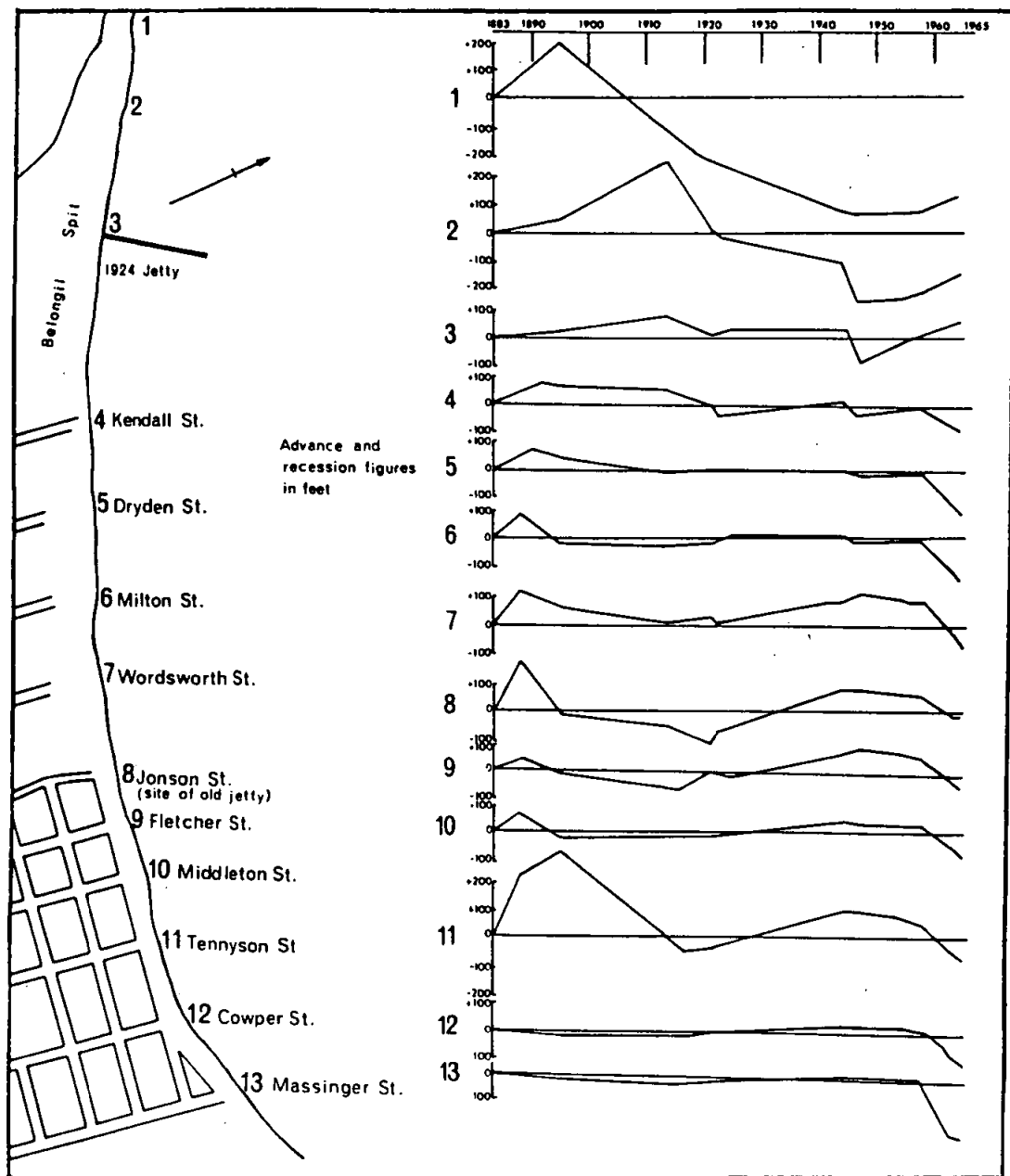


Figure 2: Aggradation and recession of the beachfront at Byron Bay, 1883 - 1965.

Source: Hopley (1967).

Hopley (1967) associates the rapid sand build-up in the area between Cowper and Dryden Streets during the late 1880's with the building of the first jetty, inferring the structure acted as a groyne. A pattern was established with greater deposition occurring in the lee of the jetty than to the east. Between Tennyson and Middleton Streets, a very dramatic advance occurred extending into the 1890's, and was accompanied by a rapid migration of sand dunes inland for about 400 metres.

This period of coastal advancement was counter-acted whenever "unfavourable conditions" were experienced. Storm events resulted in rapid cutting back to the extent that the amount of erosion was equal to the previous amount of accretion. A series of low dunes were built out during the 1920's, 1930's, and 1940's as the coastline remained relatively stable. Despite this, rapid erosion between 1959 and 1964 saw the coast recede 59.5 metres in front of Wordsworth Street. With the exception of the area of the beach in front of Jonson Street, where a wall was constructed to protect the Surf Life Saving Club and the pool, the coast in all places receded over 30 metres.

In the area extending west of Dryden Street to Belongil Creek the aggradation of the 1880's continued for a longer period. During the 1920's, 1930's, and 1940's the area was stable at the eastern end but rapidly eroding at the mouth of the creek. Since the late 1940's the spit was rebuilt and extending out. This pattern of erosion can not be attributed only to storm events, or short-term erosion, as process studies have shown that littoral drift rates in the embayment increase towards the north (Chapman, *et al.*, 1982; Little, 1989).

As stated by Gordon, *et al.* (1978), many people in the local community believe that a state of dynamic equilibrium exists in the embayment with the beach receding in large steps during severe storms and cyclones, but recovering during calmer periods. These short-term seasonal fluctuations have acted to mask a long-term erosion trend associated with a continuing loss of sand from the beach zone. People's false sense of security was shattered in the late 1960's and early 1970's when a series of severe storms and heavy seas occurred, and the underlying erosion trend destroyed the remaining area in front of many houses.

Between 1967 and 1974 there was significant erosion along the coast with widespread property damage and some beaches being cut by up to 33 metres. According to Caton (1975), Cyclone 'Pam' formed in the Coral Sea in February 1974 and with a central pressure of 940 millibars, came within 450 kilometres of Byron Bay. By the 6th February, strong winds and heavy seas combined with an exceptional spring tide and storm surge to cause beach and property damage to the southern Queensland and northern N.S.W. coasts.

Figure 3 depicts the average erosion rates for the period 1947 to 1977 as obtained from an analysis of aerial photographs (Gordon, *et al.*, 1978). The broken line indicates the impact of disturbances which occurred during the period of analysis. On Main Beach, the rate of recession is believed to be in the order of 0.6 metres per year, while in fact it was accreting at a rate of 6.5 metres per year from 1947 to 1958, then eroding at a rate of 3.7 metres per year from 1958 to 1977. The beach at Wategos Gap is believed to be in a state of equilibrium with only a slight variation in the location of the vegetation line prior to 1960 and 1970. Clarks Beach is also eroding at a rate calculated as 0.14 metres per year. The vegetation line receded dramatically in 1971 but recovered in the following years to remain relatively stable.

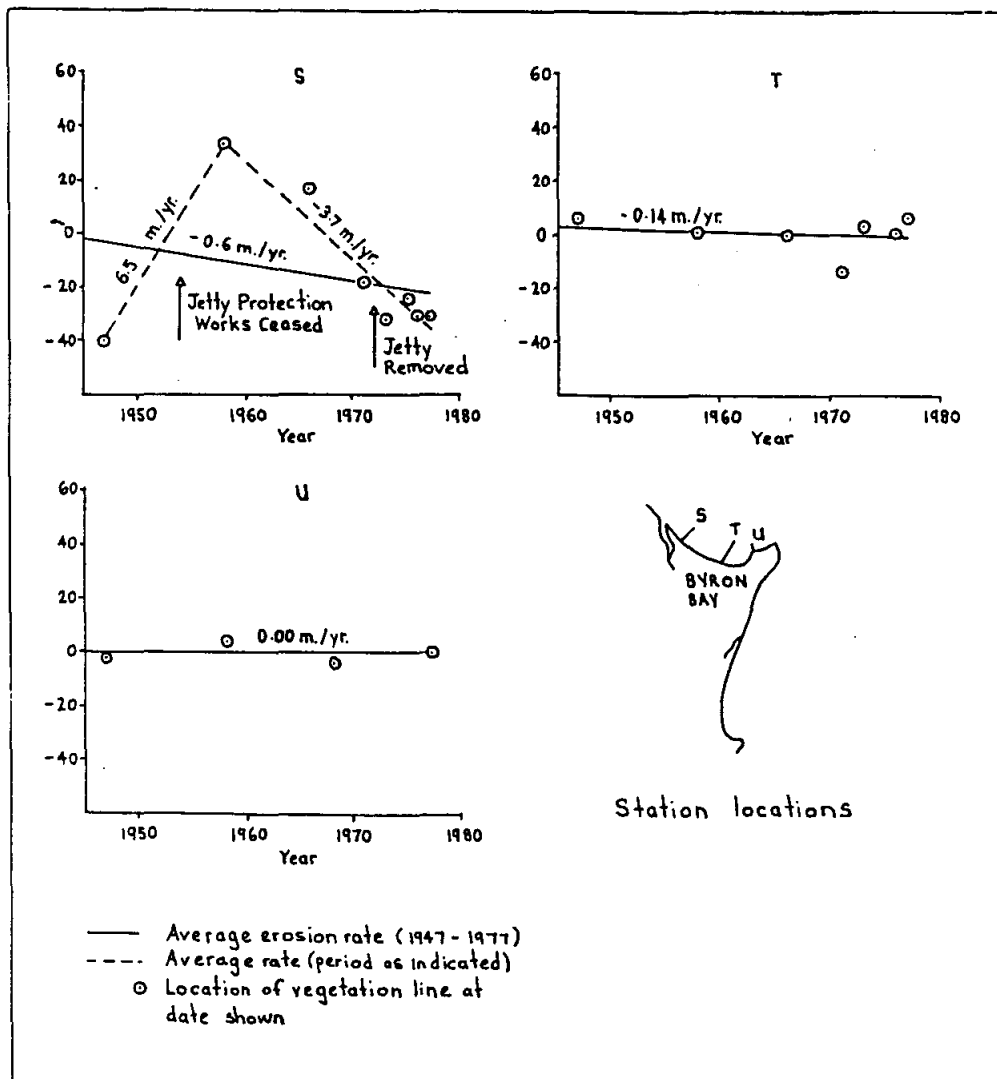


Figure 3: Analysis of beach recession rates at Byron Bay, 1947 - 1977.

Source: Gordon, *et al.* (1978).

The weather since 1974 has been relatively quiescent except for 1976 when Cyclones 'David' and 'Colin' occurred, causing minor beach erosion but no property damage.



## 2.4 Sand mining

In 1878, gold was first found in payable quantities in the black sands along the coast between Ballina and Cudgen Head. In the Bay area, the miners were at work along Tallow Beach and Byron Bay beaches by 1882. These miners were amongst the earlier residents of the Bay, but like most miners they were probably itinerants chasing the elusive metal where and whenever a new find was reported (Gordon, *et al.*, 1978; Ryan, 1984).

Parker (1988) states that the mining of zircon and rutile commenced in 1933 and extensive mining was carried out by the Cudgen R.Z. Mining Company between Byron Bay and Hastings Point during the mid to late 1960's. The area between the surf club and the Beach Café was mined and rehabilitated in the late 60's and early 70's.

## 2.5 Present situation

A number of developments within the study area are under direct threat from erosion. The Surf Life Saving Clubhouse, the beachfront carpark, and the Memorial Swimming Pool have been under attack for a number of years. Further north along the embayment, the beachface boundary of the First Sun Caravan Park is steadily eroding, while the Main North Coast Railway Line is within 80 metres of the scarp. The old meatworks complex is within 50 metres of the erosion line, 12 houses are within 20 metres, eight houses within ten metres, and two houses are within two metres (Fig. 4) (N.S.W. P.W.D., 1978; Little, 1989).

As the N.S.W. P.W.D. (1978) and Little (1989) explain, Byron Shire Council and residents in the area have employed a number of measures in attempts to combat erosion and protect structures against wave attack. These measures include placing rock fill, old car bodies and rubber tyres along the beachfront, and building rock walls. The Water Research Laboratory (1983) found that the existing rock protection in front of the town centre was inadequate and that the rock protection was not acting as a groyne to stabilise the Clarks Beach area. Further, it was predicted that as the erosion continued the existing wall would be outflanked and fail.

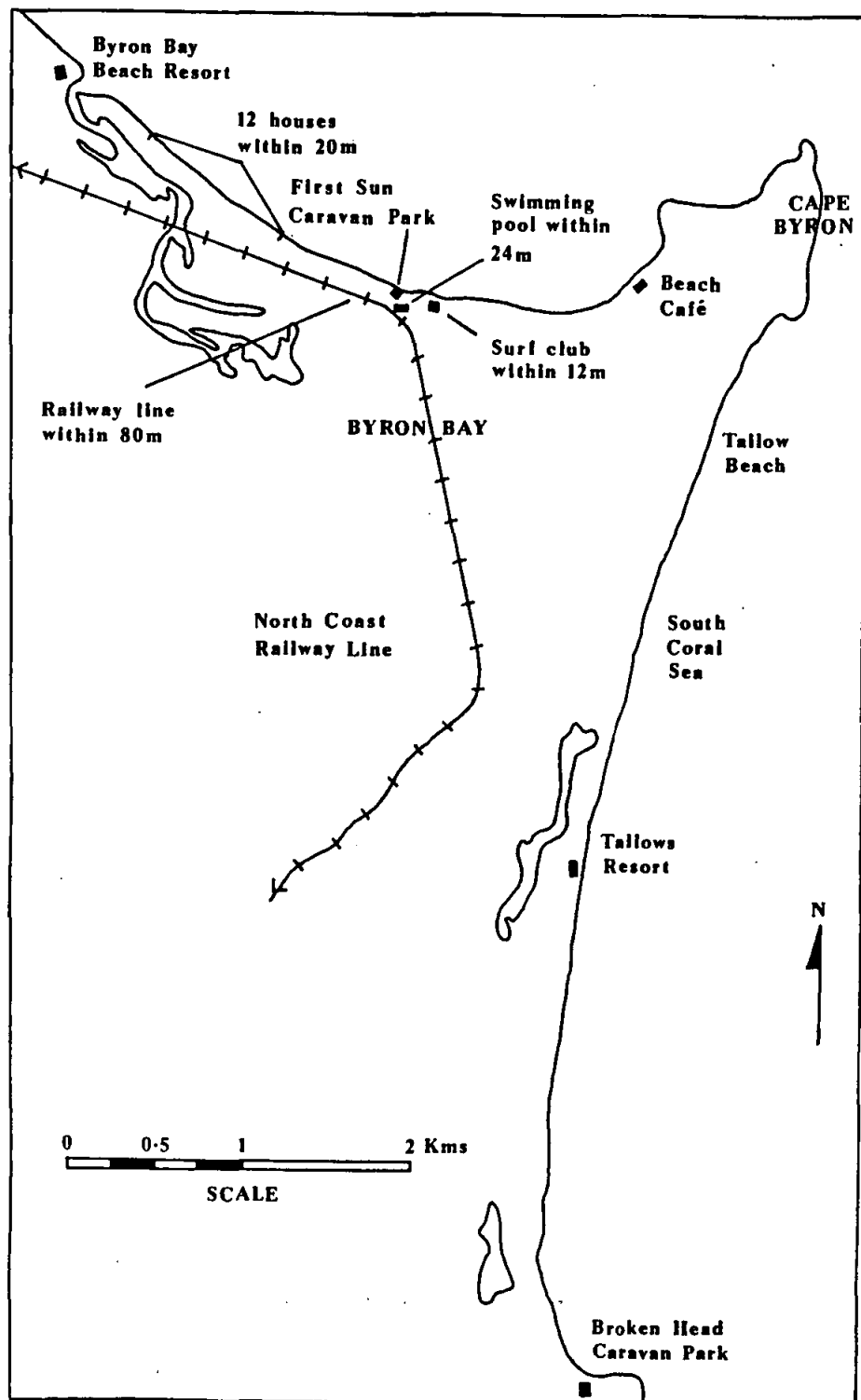


Figure 4: Location of developments in the Byron Bay region under threat from erosion.

Source: N.S.W. P.W.D. (1978) and Little (1989).

## 2.6 Beach skimming

In the November 28, 1990 edition of *The Northern Star* newspaper (p. 5), a Byron Bay resident complained that a stagnant lagoon formed near a stormwater outlet at Clarks Beach was a "health hazard and an eyesore". He said the lagoon had not been drained for over 12 months because of a build-up of sand between it and the sea. There was also a danger that the dunes behind the lagoon could be eroded during a heavy storm.

Consequently, Byron Shire Council workers began shifting sand that same day to allow the lagoon to drain. On the 30th November 1990, a council engineer commenced a beach skimming programme on Clarks and Main Beach. Over a four day period (ending 6/12/90), earthmoving equipment was used to push sand from the ocean side of the lagoon back towards the frontal dune to help further protect the beach. The skimmed area (shown on Fig. 1) extended from just west of the Beach Café to immediately in front of the amenity block near the corner of Bay and Middleton Streets.

Approximately the same area of beach was reskimmed by Byron Shire Council between the 17th and 22nd May 1991, as the stormwater drain was again causing problems.

### 3.0 METHODOLOGY

The long-term purpose of this project is to establish a beach surveying network and up-to-date database upon which future studies may be based.

It is envisaged that the behaviour of all beaches on the N.S.W. far north coast will eventually be closely monitored to determine just how "dynamic" they really are. Therefore, it must be emphasised that the beach profiling techniques used in this study are capable of monitoring quite subtle changes, rather than just the effects of cyclonic events which are easy to document.

#### 3.1 Monitoring beach behaviour

##### 3.1.1 Benchmark construction and location

The permanent benchmarks are situated about 5-50 metres behind the active beach zone. This is to allow for a significant amount of storm erosion without losing any benchmark to the ocean. It is hoped that these marks will last for many years and be available for future studies.

As shown in Figure 5, the permanent benchmark at Wategos Gap (WG 1) is the north-western corner of the concrete slab beneath the picnic table nearest to the amenity block.

The permanent benchmark at the eastern end of Clarks Beach (CB 1) is a pre-existing structure. At Mr. and Mrs. G. Partridge's home in Lighthouse Road, a notch has been carved into the concrete at the base of a drain pipe on the house's western side (Figure 6).

Figures 7 and 8 show the construction and location details of the five permanent benchmarks built to monitor the success/failure of the beach skimming programme (SK 1 to 5). These marks were constructed by spray-painting a yellow triangle onto the seaward side of a wooden fence post. A large nail or clout was then hammered into the centre of this triangle until about one centimetre remained exposed. This is to place the staff upon.

The permanent benchmark at the western end of the study area (MB 1) is also a pre-existing structure. A nail has been hammered into the top of the kerb in front of the 'Bayview Lodge' apartments at 22 Bay Street (Figure 8).

The locality maps of the eight benchmarks used in this study (Figures 5, 6, 7 and 8) were drafted by measuring the distance and bearing to permanent objects in close proximity to the benchmark. The distance to the object was measured using a 100 metre measuring tape. The bearing to the object was read in relation to magnetic north using a Suunto sighting compass.

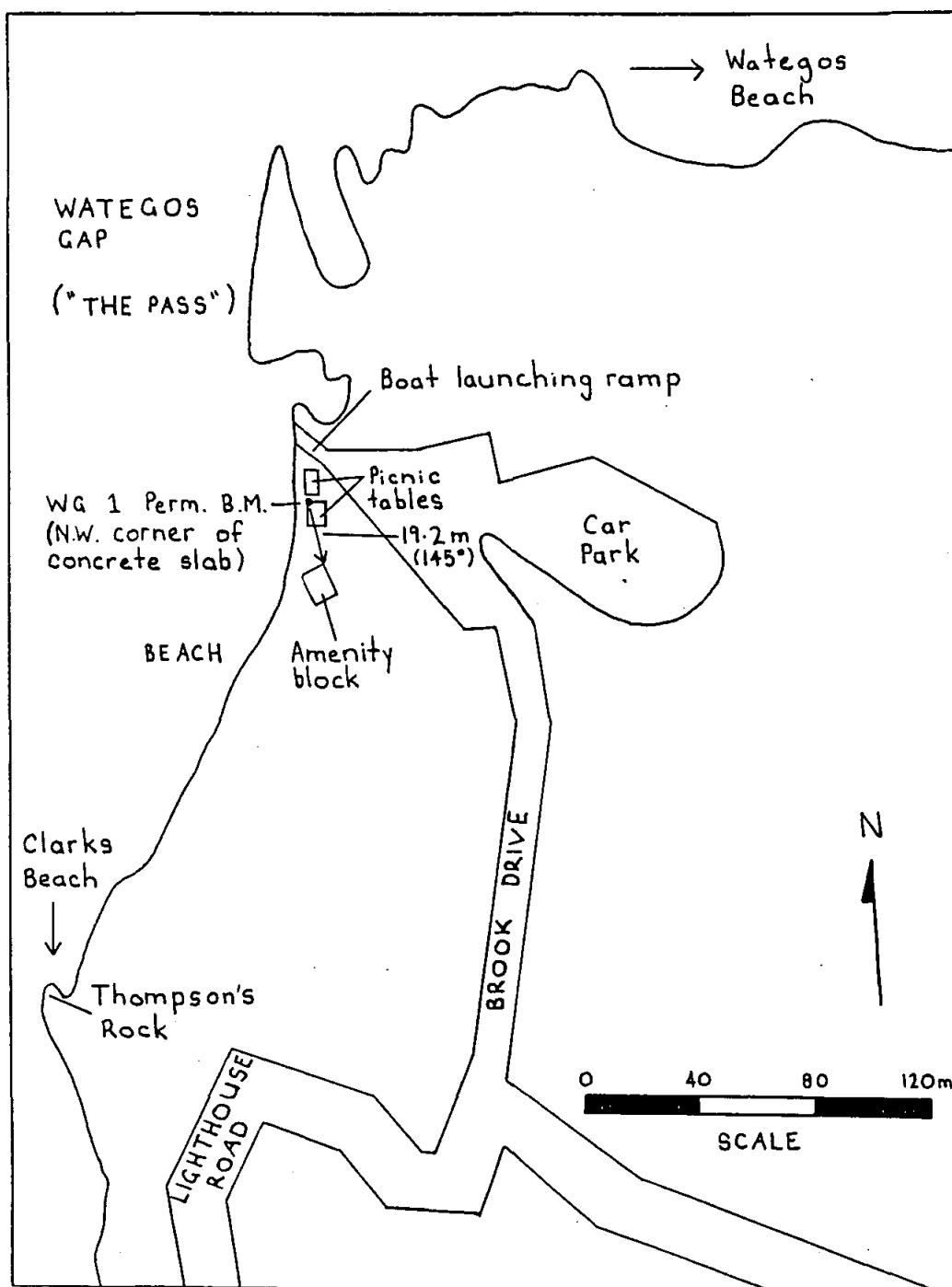


Figure 5: Locality map of WG 1 permanent benchmark.

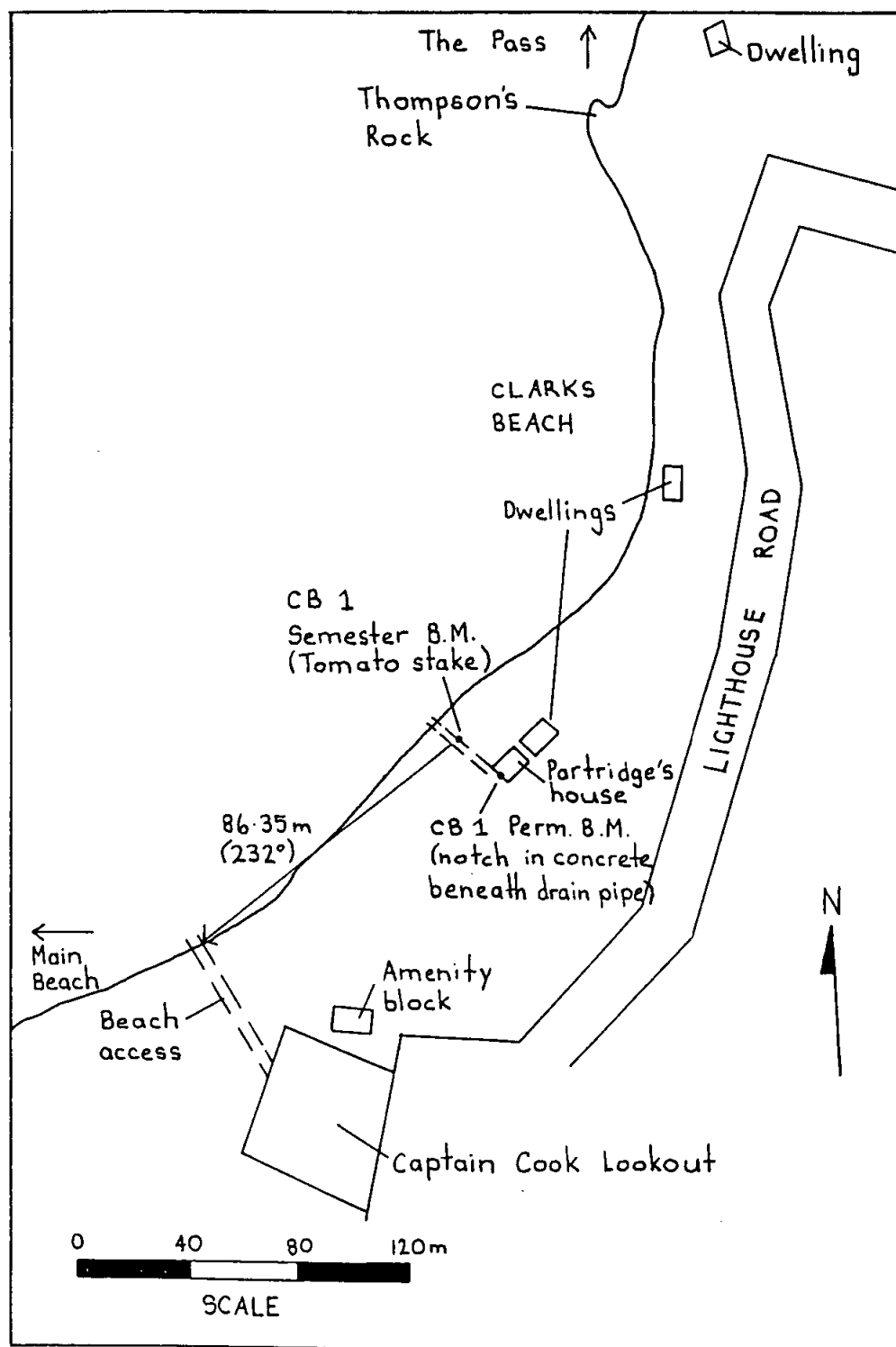


Figure 6: Locality map of CB 1 permanent and semester benchmarks.

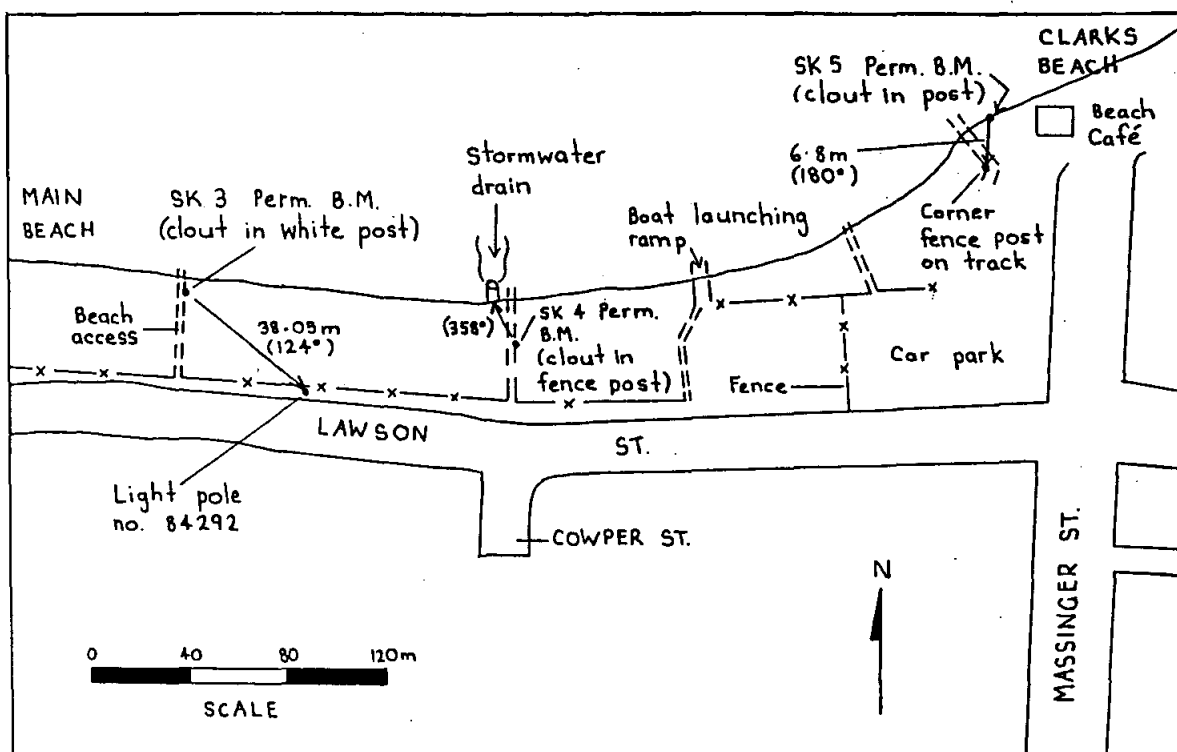


Figure 7: Locality map of SK 5, SK 4, and SK 3 permanent benchmarks.

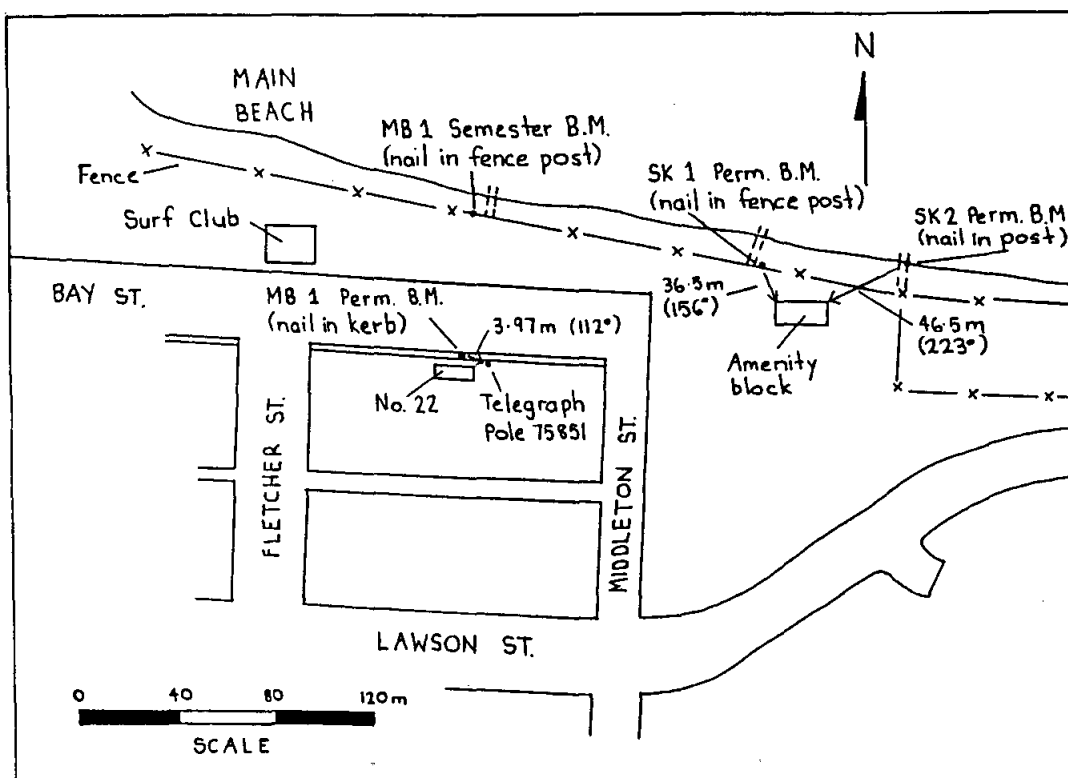


Figure 8: Locality map of SK 2, SK 1, and MB 1 permanent benchmarks, and MB 1 semester benchmark.

### 3.1.2 Elevations of benchmarks

The elevations of the eight permanent benchmarks used in this study were determined in relation to Australian Height Datum (A.H.D.). This was achieved by locating the nearest N.S.W. Lands Department State Survey Marks (S.S.M.'s) from location maps provided by a Byron Shire Council surveyor. Surveys were then conducted from the S.S.M.'s to the newly constructed and pre-existing benchmarks to establish their approximate elevations in relation to A.H.D.

### 3.1.3 Beach profiling

#### a) *Surveying techniques*

From the permanent benchmarks, a line was surveyed as straight and as perpendicular to the shoreline as possible. The bearing of the profile line, in relation to magnetic north, was read using a Suunto sighting compass. Surveying was carried out using either a Survey Chief TD - 20T theodolite or a Wild Heerbrugg NA 20 level, tripod, and a Myzog five metre extendible staff.

Using the 'rise and fall' levelling technique, a line was surveyed from the permanent benchmarks across the active beach zone and as far into the water as possible. A 100 metre measuring tape was used to measure horizontal distances to sites below the water line (the stadia method is inaccurate here because the staff sinks too much resulting in large horizontal errors). The sites of the profile lines (Fig. 9) were coded for ease of recording, such as WG 1 (WG = Wategos Gap, and 1 represents the specific site).

At lines SK 1-5, an additional survey was conducted landward from the permanent benchmarks to show the morphology of the backdune area. Semester marks were placed along lines CB 1 and MB 1 (Figures 6 and 8). These marks allowed the active beach zone to be surveyed without repeatedly surveying back to the permanent benchmark.

The profile lines were "closed" by surveying back to the permanent or semester benchmarks, thus allowing any discrepancies in the data to be identified. Profiling of the active beach zone was undertaken at low tide which allowed a longer line to be surveyed.



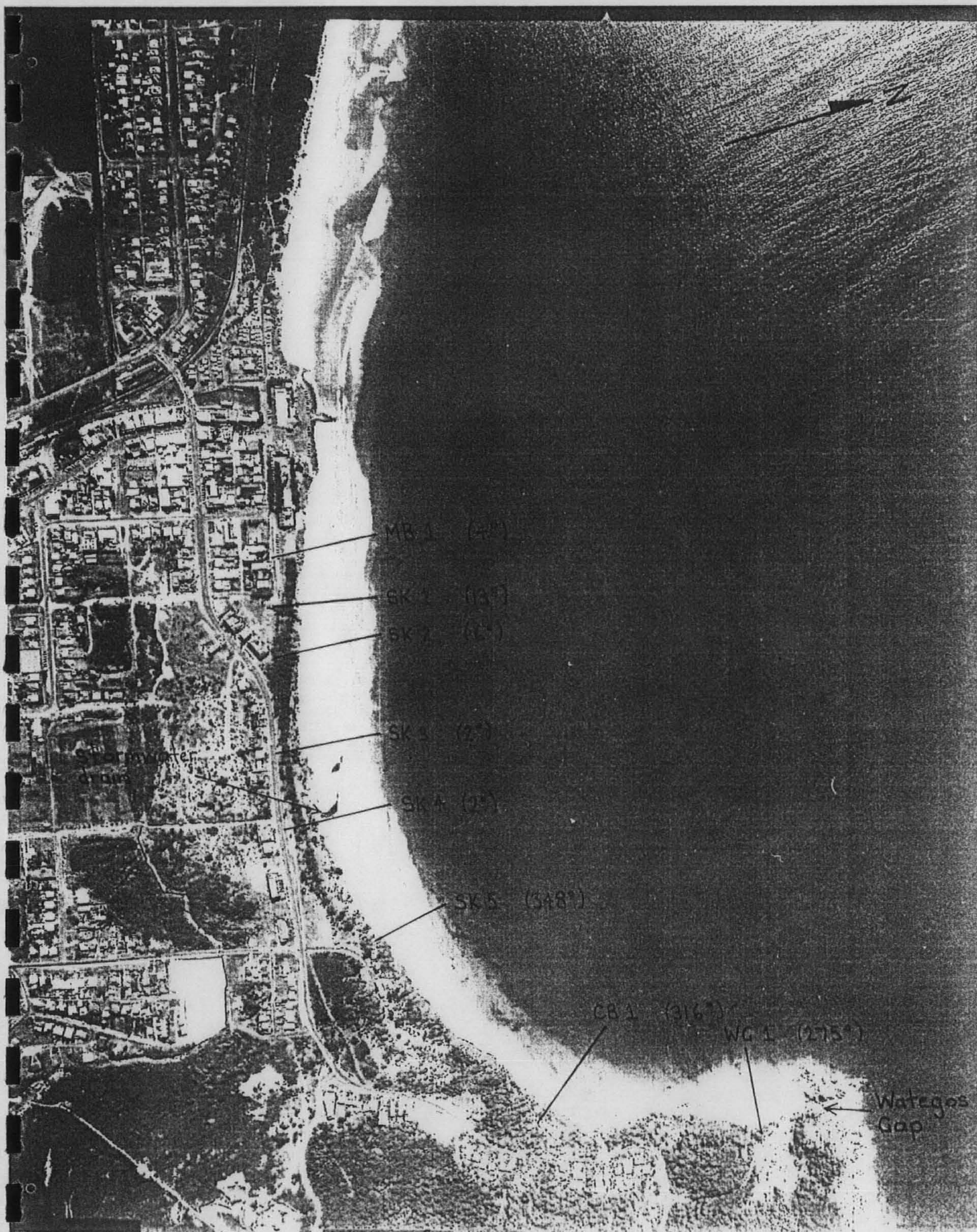


Figure 9 : Location of beach profiles.

Source : Byron Bay 1:10 000 Colour Aerial Photograph.  
 N.S.W. 3404 . Run 3B, 31/8/84. (C.M.A.).

### *b) Comparison of different surveying techniques*

The theodolite was found to be a more accurate surveying instrument for beach profiling than the automatic level, in that smaller "miscloses" were generally achieved. However, the theodolite required far greater technical expertise and experience to operate, and calculations in the field took much longer to complete. It was for these reasons that the change to the level was made after the initial surveys in December 1990.

### *c) Accuracy/sources of error*

The degree of accuracy in levelling required for this study was determined by the N.S.W. P.W.D. On the advice of surveyors in this department, it was decided that the vertical misclose should not exceed **five** centimetres. That is, when the survey lines were "closed", the difference between the elevation of the starting point determined on the forward and return runs was not to differ by more than five centimetres.

The horizontal misclose was not to exceed **50** centimetres. That is, the sum of the total horizontal distance was not to differ by more than 50 centimetres on the forward and return runs.

As Bannister and Raymond (1979) explain, the main errors affecting accuracy in levelling are:

- 1) Errors due to the bubble not being central.
- 2) Errors due to the instrument not being in adjustment.
- 3) Errors due to differential settlement of the tripod.
- 4) Errors due to tilting and settlement of the staff.
- 5) Errors in reading the staff.

These errors were avoided as much as possible during the study.

### 3.1.4 Offshore diving

An investigation of offshore sediment movement was carried out in Autumn 1991 by Greg Daley, a fellow student from the University of New England - Northern Rivers. Daley, a qualified scuba diver, regularly measured the distance from the top of the old jetty pylons to the sea bed. Thus, by recording the amount of sand accretion/erosion around each of these pylons he was able to document the onshore/offshore sediment transport. The orientation of sand ripples in the area were also regularly observed to record changes in sediment transport direction. For a more detailed description of this method, refer to Daley (1991).

It was hoped that the results of this survey could be used to interpret changes in the beach profiles.

### 3.2 Wind data collection techniques

Wind direction and wind speed data were obtained directly from Cape Byron Headland Reserve where a meteorological station is established.

A combination wind vane/cup anemometer located on the roof of the lighthouse keeper's cottage is electronically linked to a display unit in the cottage's 'weather room' (Fig. 10).

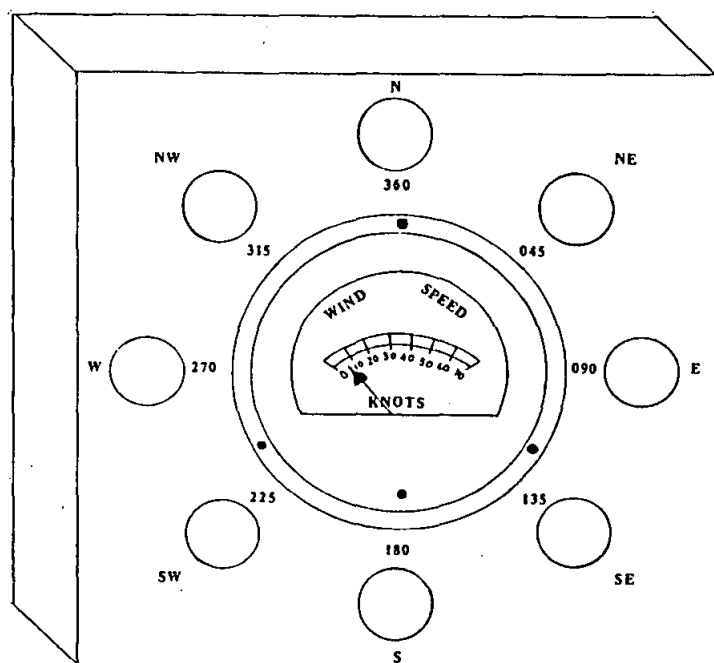


Figure 10: Diagram of Cape Byron wind direction/speed indicator.

The wind vane measures wind direction which, as Figure 10 illustrates, is shown by the illuminated direction indicator lights on the display unit. At precisely three hourly intervals (except at midnight), the direction of the wind is read from the direction indicator to the nearest one of the 16 points of the compass. When two indicator lights are illuminated simultaneously (for example, north and north-east), the intermediate direction of the two lights is reported (north-northeast in this case). If two or more lights are flashing on and off, the intermediate direction of the two extreme flashing lights observed over a period of one minute is reported. If a power failure occurs, the wind direction is read manually from the wind vane.

The observed wind direction is allocated a computer code which is then entered into the 'Bureau of Meteorology, Department of Administrative Services Field Book of Meteorological Observations' along with numerous other recorded meteorological data. This field book is sent to the Bureau's N.S.W. Regional Office in Sydney after the end of each month for data storage and analysis.

The cup anemometer measures wind speed in knots which, as Figure 10 also illustrates, is shown by the position of the pointer on the dial. Wind speed, like wind direction, continually fluctuates and generally the higher the wind speed the greater the fluctuations. The *mean* wind speed is therefore required and is recorded every three hours in the following way:

- 1) The fluctuations of the pointer are observed over a period of one minute. A visual estimation of the mean value of the lulls and the mean value of the gusts is made.
- 2) The mean of the two values is obtained; this is the mean wind speed (Rigby, pers. comm., 1991; Bureau of Meteorology, 1984).

### **3.3 Wave data collection techniques**

#### **3.3.1 Collection and distribution**

Byron Bay wave data have been collected by the N.S.W. P.W.D.'s Manly Hydraulics Laboratory since the 14th October 1976 (Fig. 11).

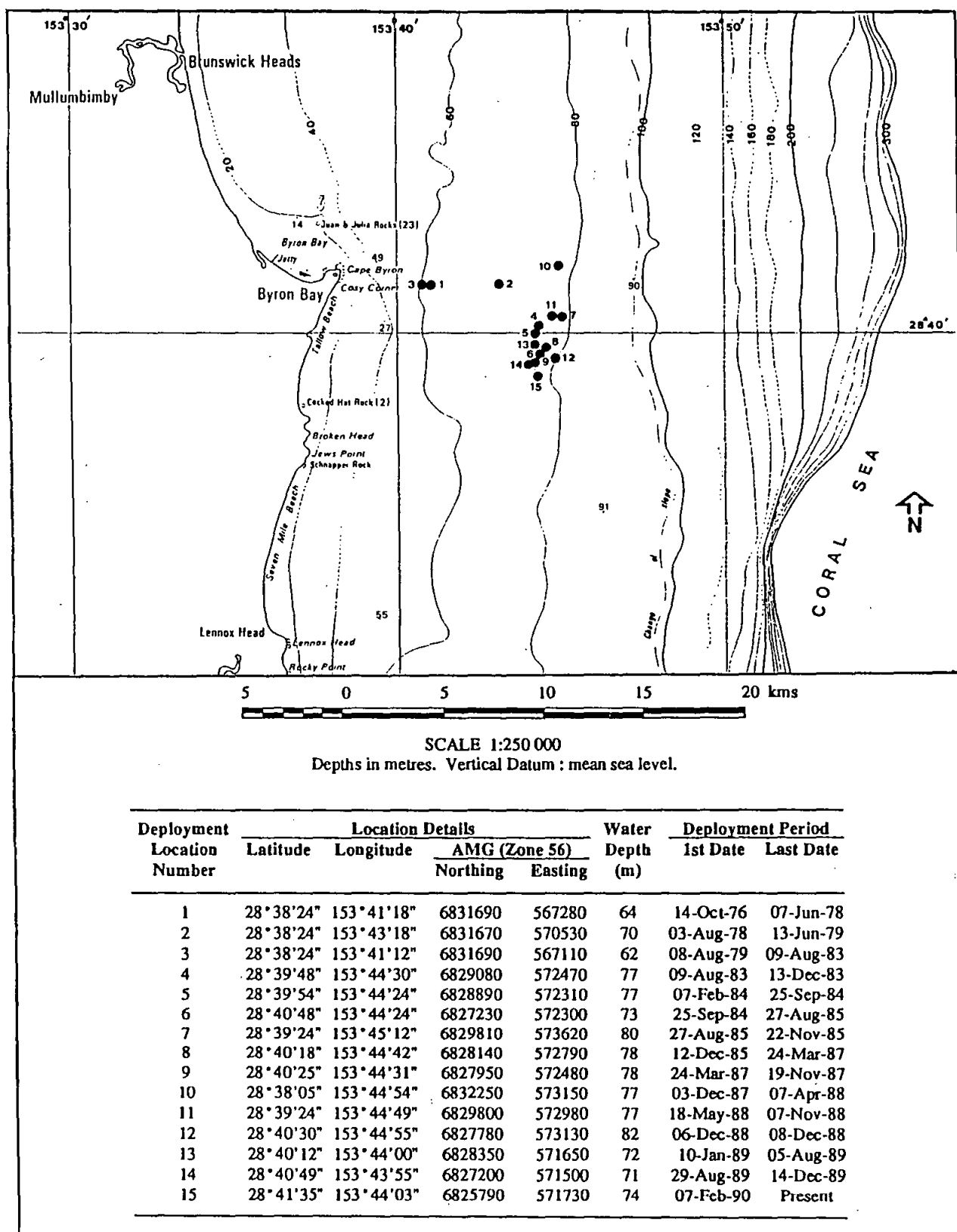


Figure 11: Byron Bay offshore waverider buoy locations.

Source: N.S.W. P.W.D. (1990).

The onshore recording station at Cape Byron Lighthouse is based on the **Datawell Waverider** system which uses an accelerometer mounted in a loose tethered buoy to measure the vertical accelerations of the buoy as it moves with the water surface. The accelerations are integrated twice within the buoy and the displacement signal so obtained is then transmitted to the shore station. The data are held in the memory of the on-site data loggers and down loaded to Manly Hydraulics Laboratory's VAX computer by telephone link (N.S.W. P.W.D., 1990).

Figure 12 presents a flowchart of the wave data collection and distribution system operated by Manly Hydraulics Laboratory.

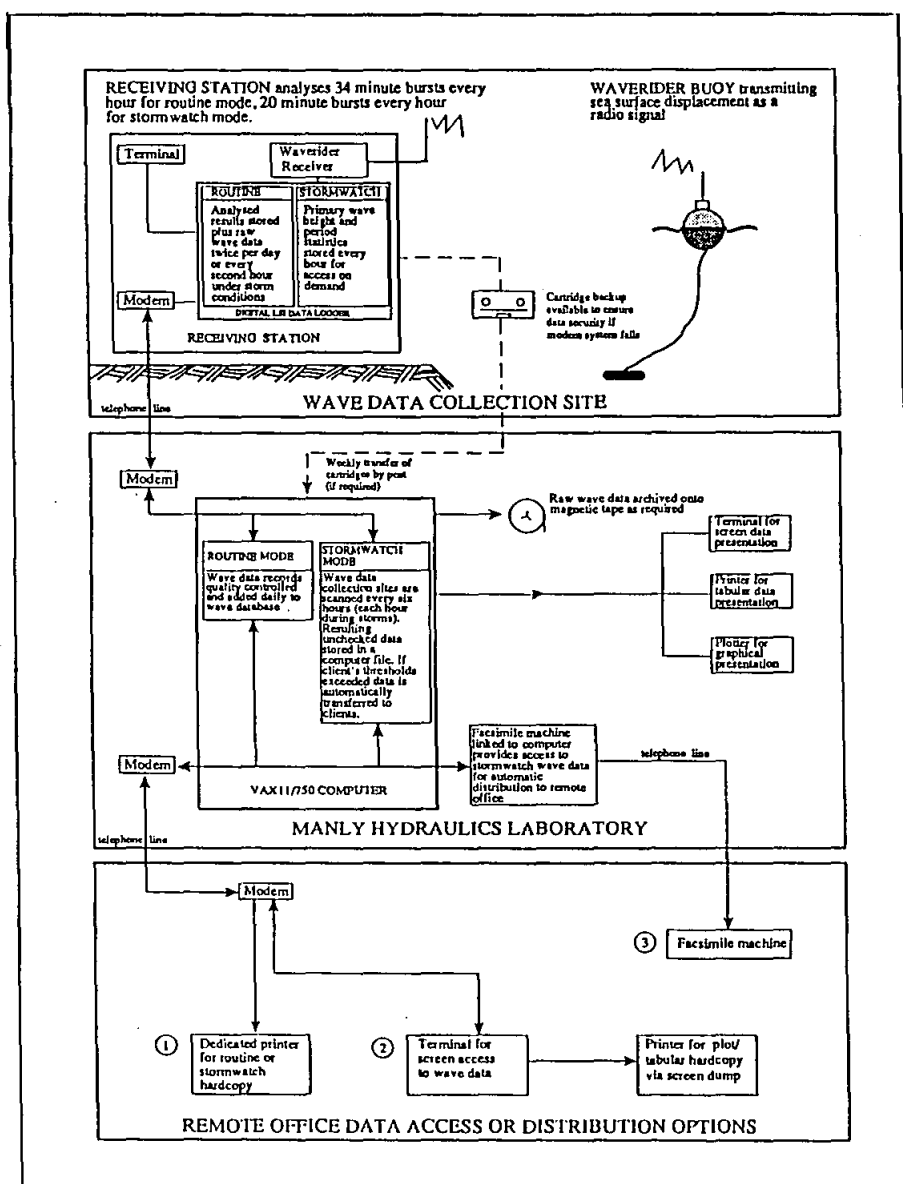


Figure 12: Byron Bay wave data collection and distribution system.

Source: N.S.W. P.W.D. (1990).

### 3.3.2 Zero crossing analysis

As illustrated in Figure 12, the position of the sea surface is recorded against time for a period of approximately 34 minutes once every hour, thus yielding a 34 minute trace for each hour of the day. The Manly Hydraulics Laboratory uses the widely accepted zero crossing method to extract representative statistics from these wave traces. For this method, a 'wave' is defined by the N.S.W. P.W.D. (1990) as the portion of record between two successive zero upcrossings. The waves are ranked (with their corresponding periods), and the following statistics computed:

- $H_{sig}$  : significant wave height = average height of the waves which comprise the top 33%.
- $H_{10}$  : average height of the waves which comprise the top 10%.
- $H_{max}$  : maximum wave height in a record.
- $H_{rms}$  : root mean square wave height.
- $H_{mean}$  : mean wave height.
- $T_z$  : zero crossing period = mean period.
- $T_{sig}$  : significant period = average period of the waves used to define  $H_{sig}$ .
- $T_c$  : crest period = average time between successive crests (this involves a different definition of wave).

A basic explanation of the method is provided in Figure 13.

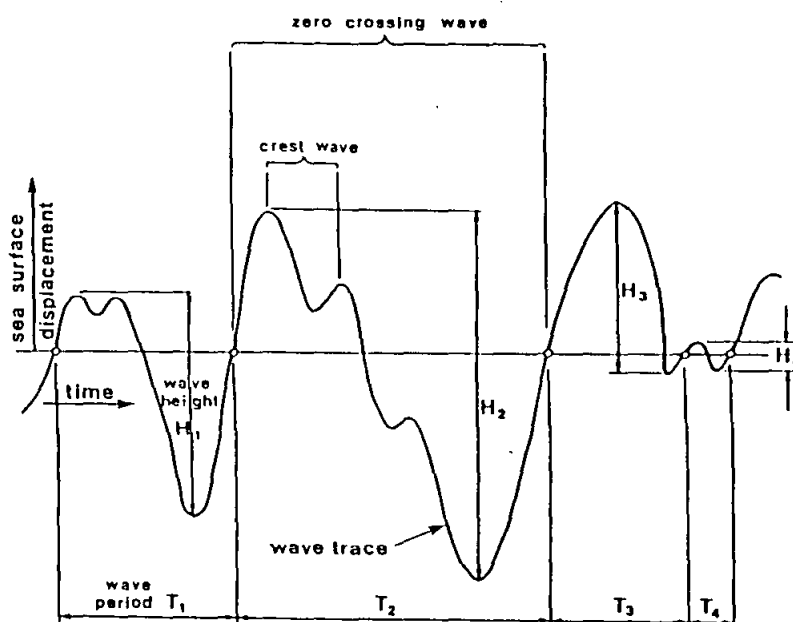


Figure 13: Zero crossing wave analysis.

Source: N.S.W. P.W.D. (1990).

### 3.4 State of sea and swell data collection techniques

#### 3.4.1 Sea state and state of swell

These observations are made by the Cape Byron Headland Reserve Managers, and involve distinguishing between sea and swell waves, visually estimating the height of the sea waves, and the length, height and direction of movement of swell waves (see subsection 3.4.2). The observations are made every three hours, except at midnight (nobody is on duty) or during periods of low visibility when it is considered there is insufficient light to make satisfactory observations. Unlike many coastal stations, observations are possible most nights due to the illumination of the sea by the powerful Cape Byron Lighthouse beam.

The sea and swell waves are observed at a point where they are not deformed by shallow water, and are not deflected or reflected by rocks, and are defined according to criteria set down by the Bureau of Meteorology (1984).

To estimate the **height** of a wave system, only the well-developed waves in the centre of the groups are averaged. The flat and badly formed waves between the groups are excluded. The reported average height of the waves is therefore less than the height of the largest waves seen. To measure the **period** of the swell, the Reserve Managers time the passage of two successive wave crests past a fixed point. This is done for 4-5 well-developed waves and the results are averaged (Rigby, pers. comm., 1991; Bureau of Meteorology, 1984).

The appearance of the sea and the height of the sea waves classify the 'state of sea' as shown in the State of sea table (Table D.1a in Appendix D.1). The period and height of swell waves classify the 'state of swell' as shown in the State of swell table (Table D.1b in Appendix D.1).

#### 3.4.2 Swell direction

As defined by the Bureau of Meteorology (1984), sea waves are generated locally and move in the same direction as surface wind. Swell waves have been generated elsewhere and have travelled out of the generating area. Swell waves travel in regular succession and in a well-defined direction, with generally long and rounded crests. At Cape Byron, the direction from which the swell is coming is estimated to the nearest eight points of the compass (Rigby, pers. comm., 1991).



## 4.0 RESULTS

### 4.1 Intermediate-term beach behaviour (1st December 1990 - 31st May 1991)

Presented in this section are the results of the beach profile surveys conducted over the Autumn Semester. The surveying recording sheets are contained in Appendix A. The results indicate a general accretionary trend on the beach at Byron Bay.

#### 4.1.1 WG 1 profile changes

The changes in the beach profile at the Pass are shown in Figure 14, and may be summarised as follows:

##### 1/4/91 - 30/4/91:

A small beach berm developed near the high water line and the profile was steepened slightly offshore.

##### 30/4/91 - 27/5/91:

Some deposition of sand occurred near the toe of the embankment, and the berm moved closer to the shoreline. A small sand bar developed offshore.

##### Overall:

WG 1 showed moderate deposition on the visible beach over the period of the study.

#### 4.1.2 CB 1 profile changes

The changes in the beach profile in the Clarks Beach "hook" have been divided into two diagrams (Fig. 15 and 16) for ease of interpretation. Some very interesting results were obtained:

##### 7/10/90 - 1/4/91:

The vegetated foredune increased slightly in height, and a small erosion scarp developed at its base (although this is hard to distinguish). Some erosion occurred offshore.

1/4/91 - 30/4/91:

Erosion scarp receded 0.5 metres. Some sand deposition and sand bar development offshore.

30/4/91 - 15/5/91:

Scarp receded a massive 8.8 metres, cutting further into the foredune. Some deposition near shoreline but offshore bar removed.

15/5/91 - 17/5/91:

1.99 metre spring tide caused scarp to recede a further three metres in two days. Slight deposition near low tide level and minor erosion offshore.

Overall:

CB 1 showed very significant erosion with the scarp receding a total of 12.3 metres in just seven weeks. The foredune has virtually disappeared.

#### 4.1.3 SK 5 profile changes

The changes in the beach profile near the Beach Café are shown in Figure 17. This line was immediately east of the skimmed area.

8/12/90 - 25/1/91:

A large berm developed in the intertidal zone. Deposition also occurred offshore.

25/1/91 - 16/3/91:

Further deposition both onshore and offshore.

Overall:

SK 5 showed significant accretion over the study period.

#### 4.1.4 SK 4 profile changes

The changes in the beach profile nearest to the Clarks Beach stormwater outlet are shown in Figure 18. This line was within the skimmed area.

9-10/12/90 - 31/1/91:

The mound of sand left by the bulldozer near the toe of the foredune was levelled off. A large berm developed near the high tide level, with some deposition occurring offshore.

31/1/91 - 16/3/91:

241 millimetres of rain was received at Cape Byron over the 12th - 13th March, 1991, causing minor flooding in the area. The stormwater drain overflowed to the extent that the discharge cut right through a section of the line. The beach berm grew even larger.

Overall:

SK 4 showed significant accretion despite some scouring by stormwater discharge.

#### 4.1.5 SK 3 profile changes

The changes in the beach profile in the middle of the skimmed area are shown in Figure 19, and may be summarised as follows:

9-10/12/90 - 25/1/91:

A large berm developed near the high tide level.

25/1/91 - 23/3/91:

Berm increased in size and deposition occurred offshore.

28/5/91:

This is the reskimmed beach profile. Note that the sand was not pushed as close to the frontal dune this time. The bulldozer completely removed the berm thereby steepening the profile. Minor erosion occurred offshore.

Overall:

SK 3 showed significant accretion before being altered by beach skimming.

#### 4.1.6 SK 2 profile changes

The changes in the beach profile toward the western end of the skimmed area are shown in Figure 20, and may be summarised as follows:

9/12/90 - 31/1/91:

A large beach berm developed near the high tide level. There was also considerable deposition offshore.

31/1/91 - 23/3/91:

The berm increased in size but there was erosion offshore.

Overall:

SK 2 showed accretion over the study period.

## 4.1.7 SK 1 profile changes

The changes in the beach profile immediately west of the skimmed area are shown in Figure 21, and are summarised below:

7/12/90 - 25/1/91:

Deposition of sand in the intertidal zone, and minor accretion offshore.

25/1/91 - 23/3/91:

Greater development of the beach berm but minor erosion offshore.

Overall:

SK 1 showed accretion over the period of the study.

## 4.1.8 MB 1 profile changes

The changes in the westernmost beach profile are shown in Figure 22, and may be summarised as follows:

10/4/91 - 1/5/91:

A medium-sized berm developed, but the profile was steepened offshore.

1/5/91 - 25/5/91:

The entire berm was eroded away and some sand deposition occurred offshore.

Overall:

MB 1 was accreting up to the end of April, but suffered minor erosion during the wet period in May.

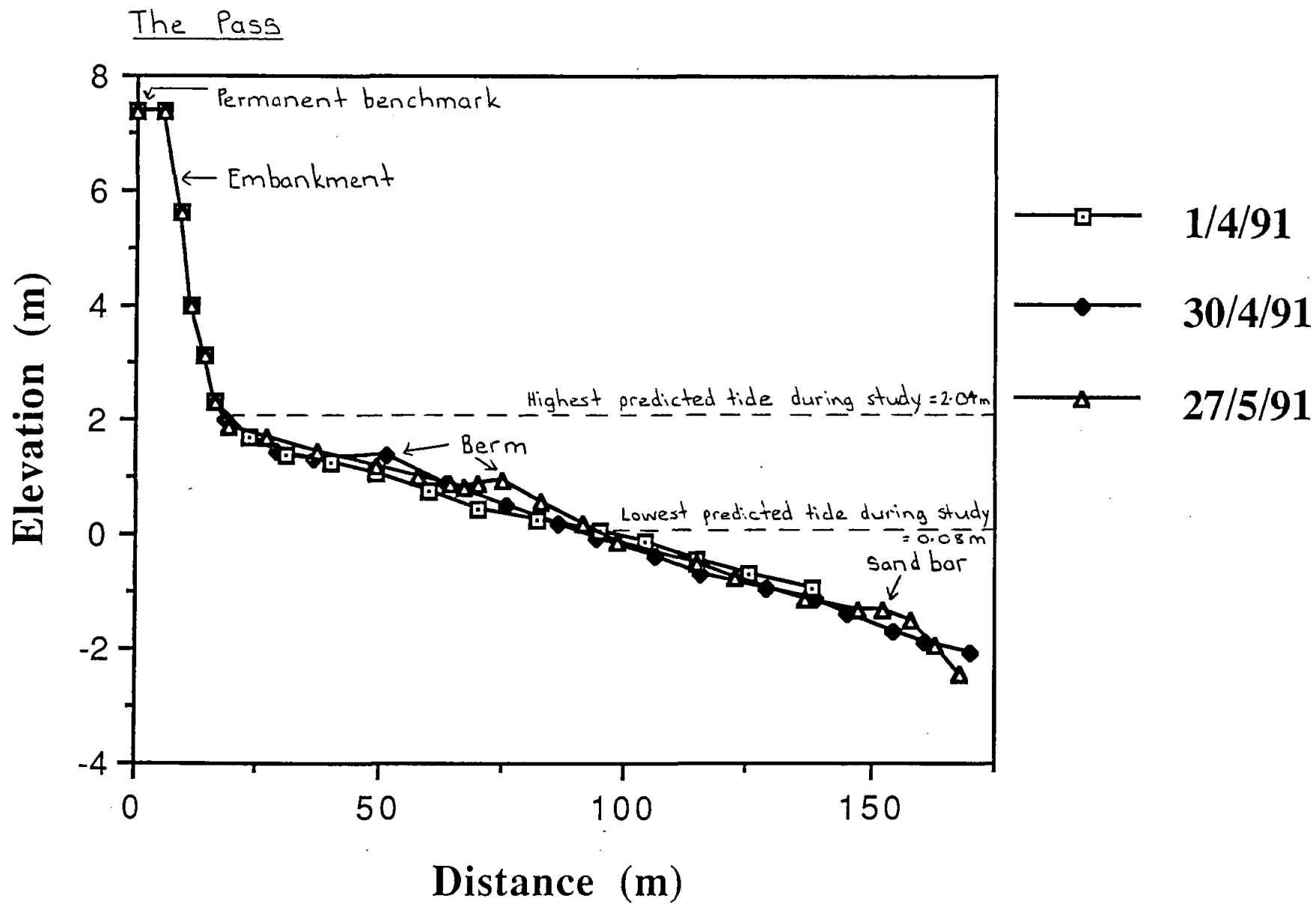


Figure 14 : WG 1 profile changes.

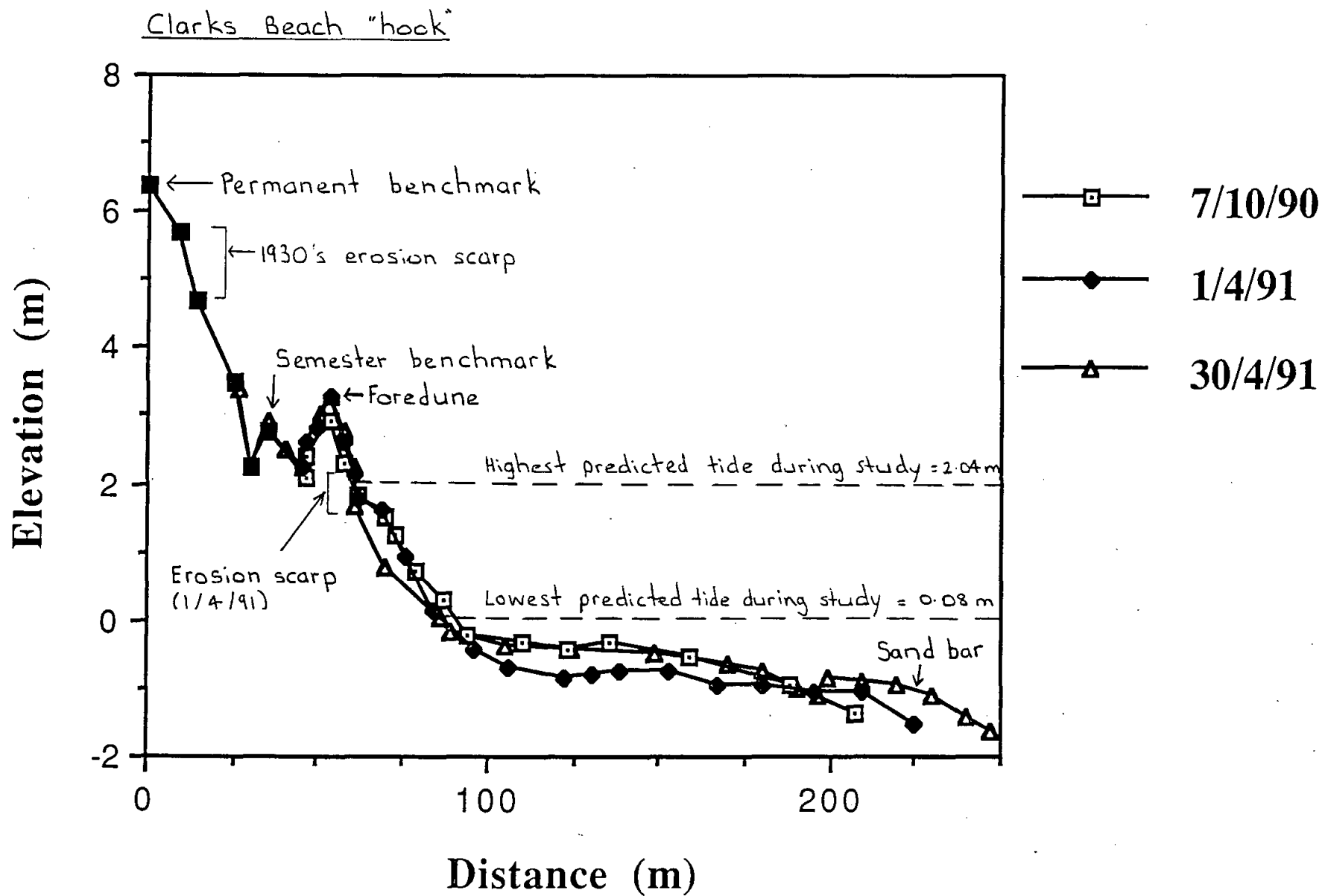


Figure 15: CB 1 profile changes.

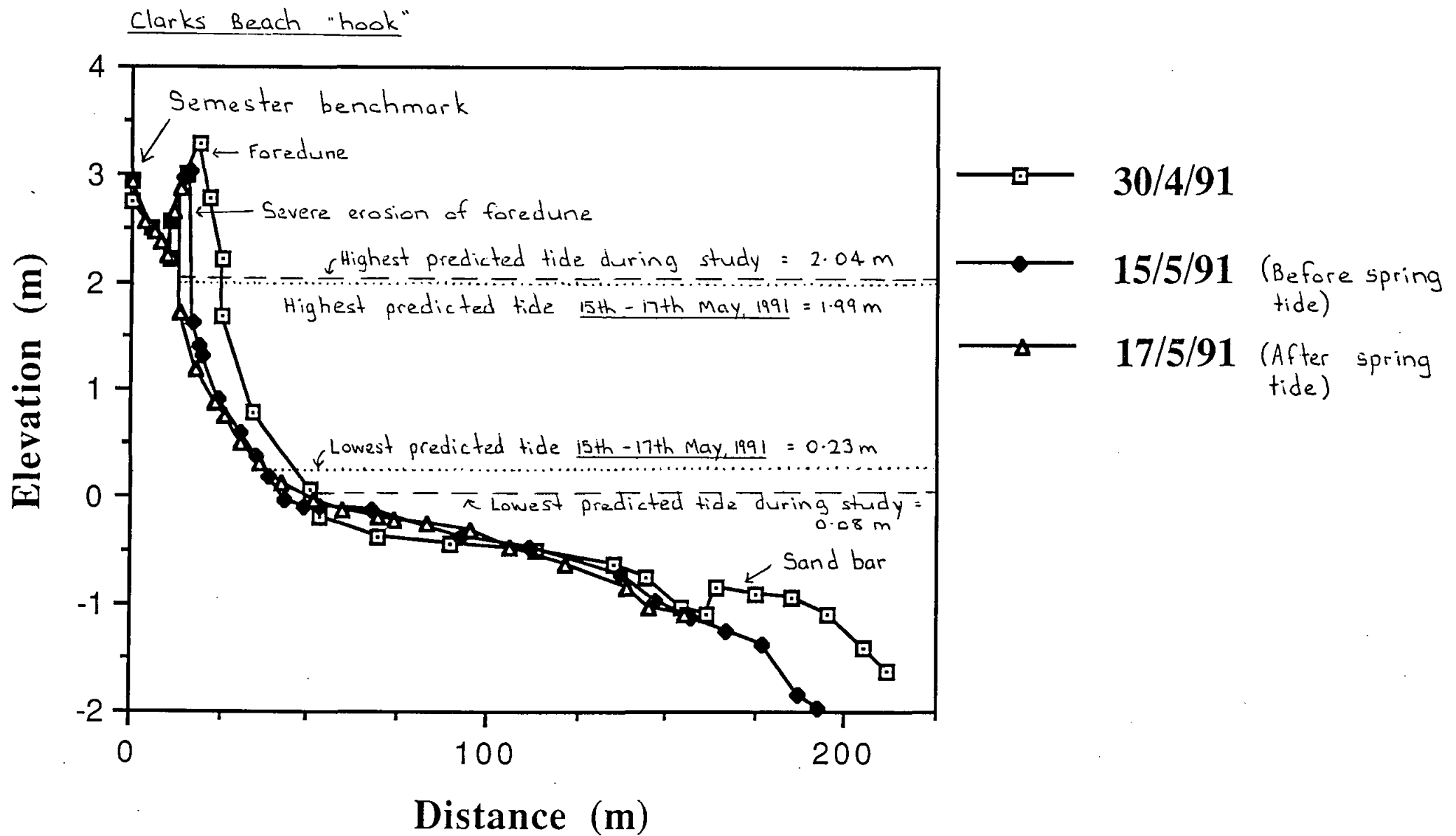


Figure 16: CB 1 - effect of extreme high tide event (1.99 m).

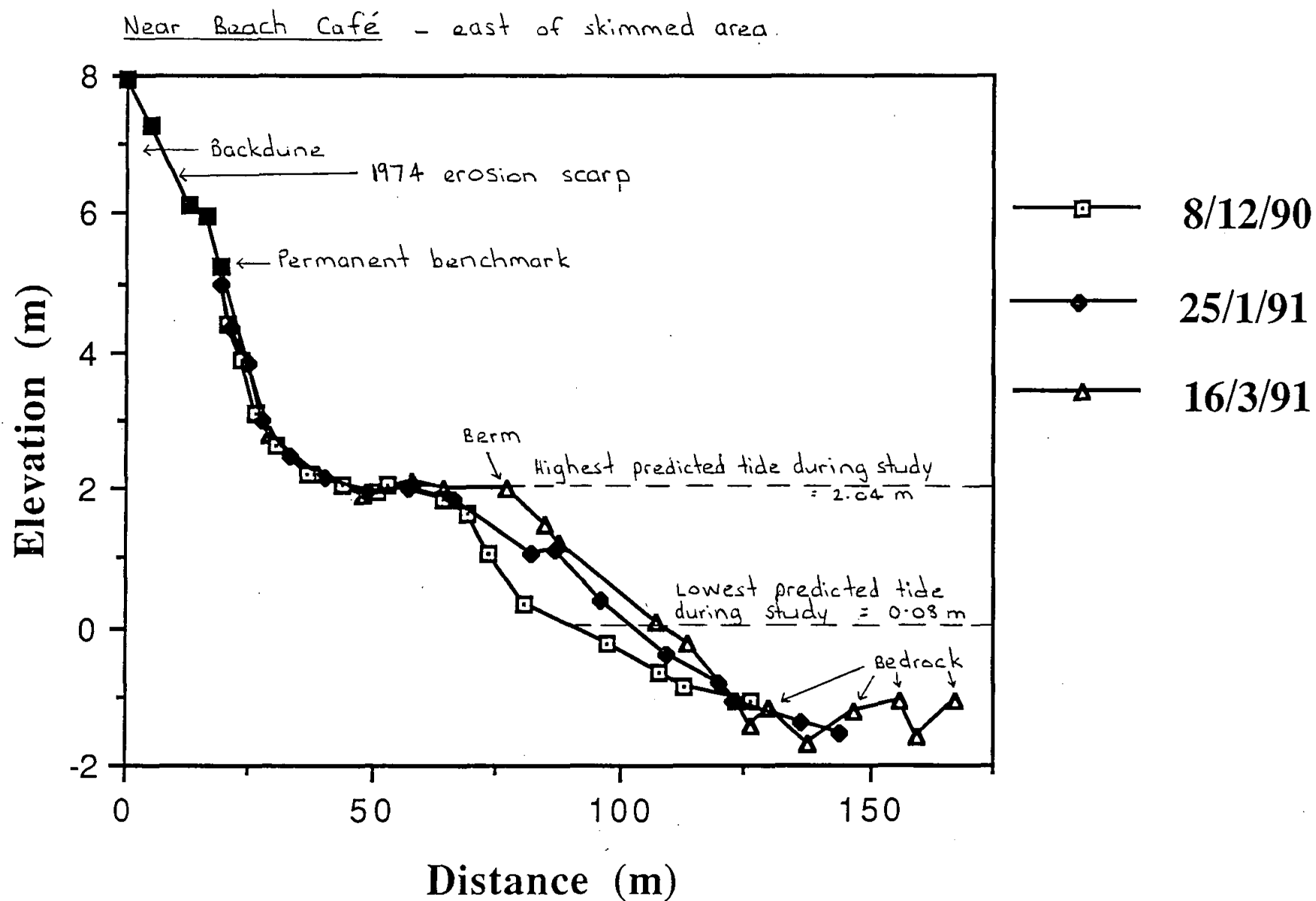


Figure 17: SK 5 profile changes.



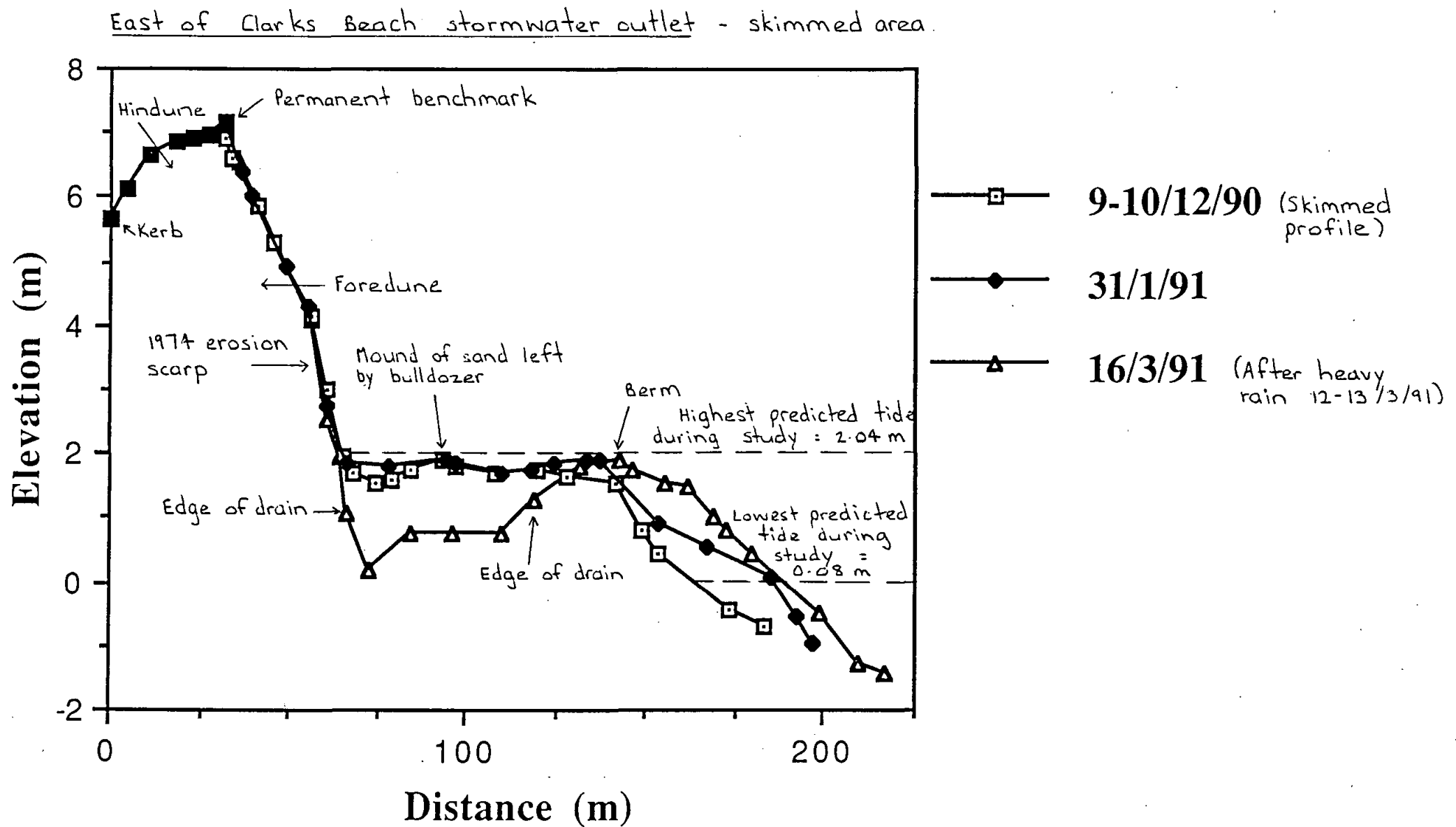


Figure 18: SK 4 profile changes.

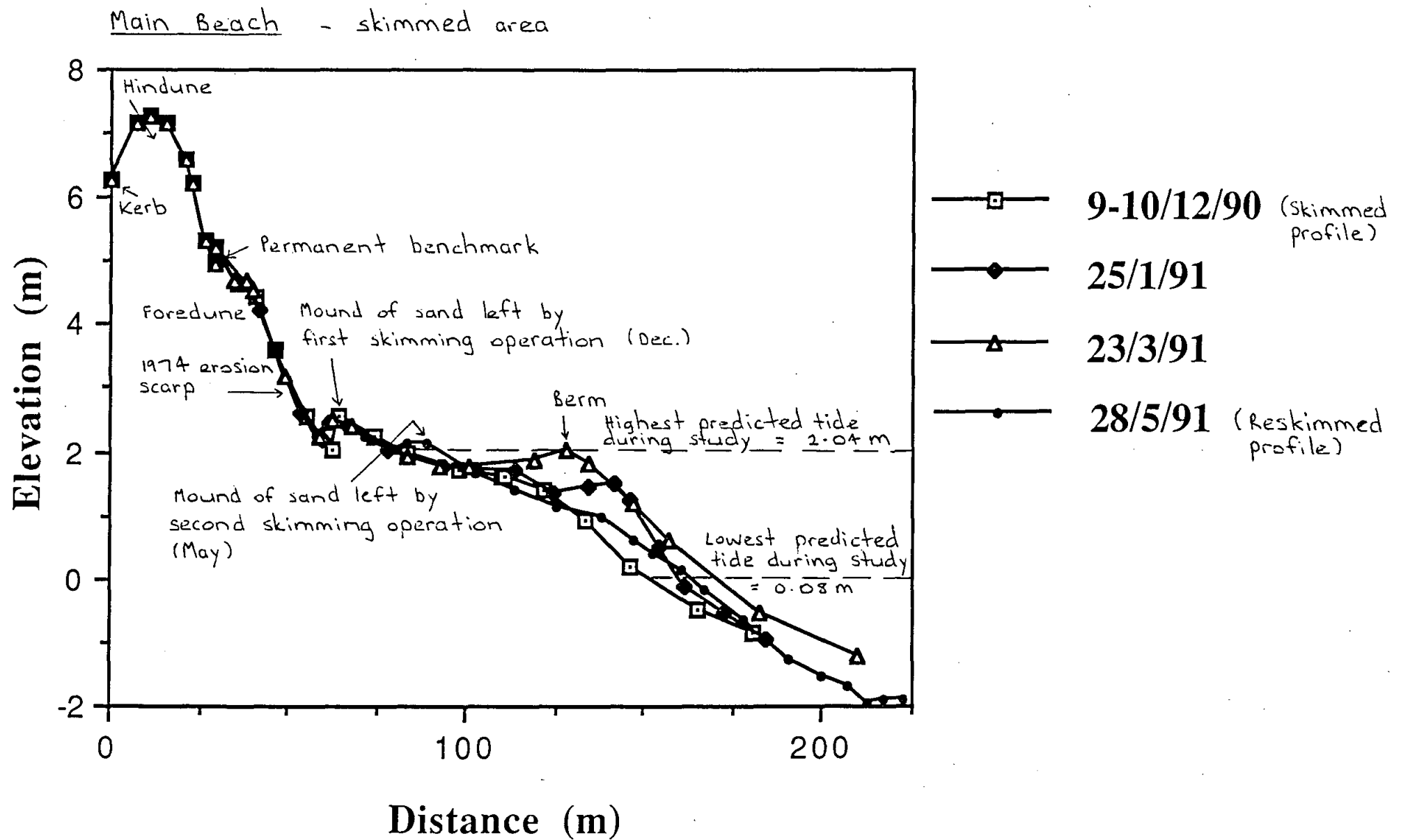


Figure 19: SK 3 profile changes.

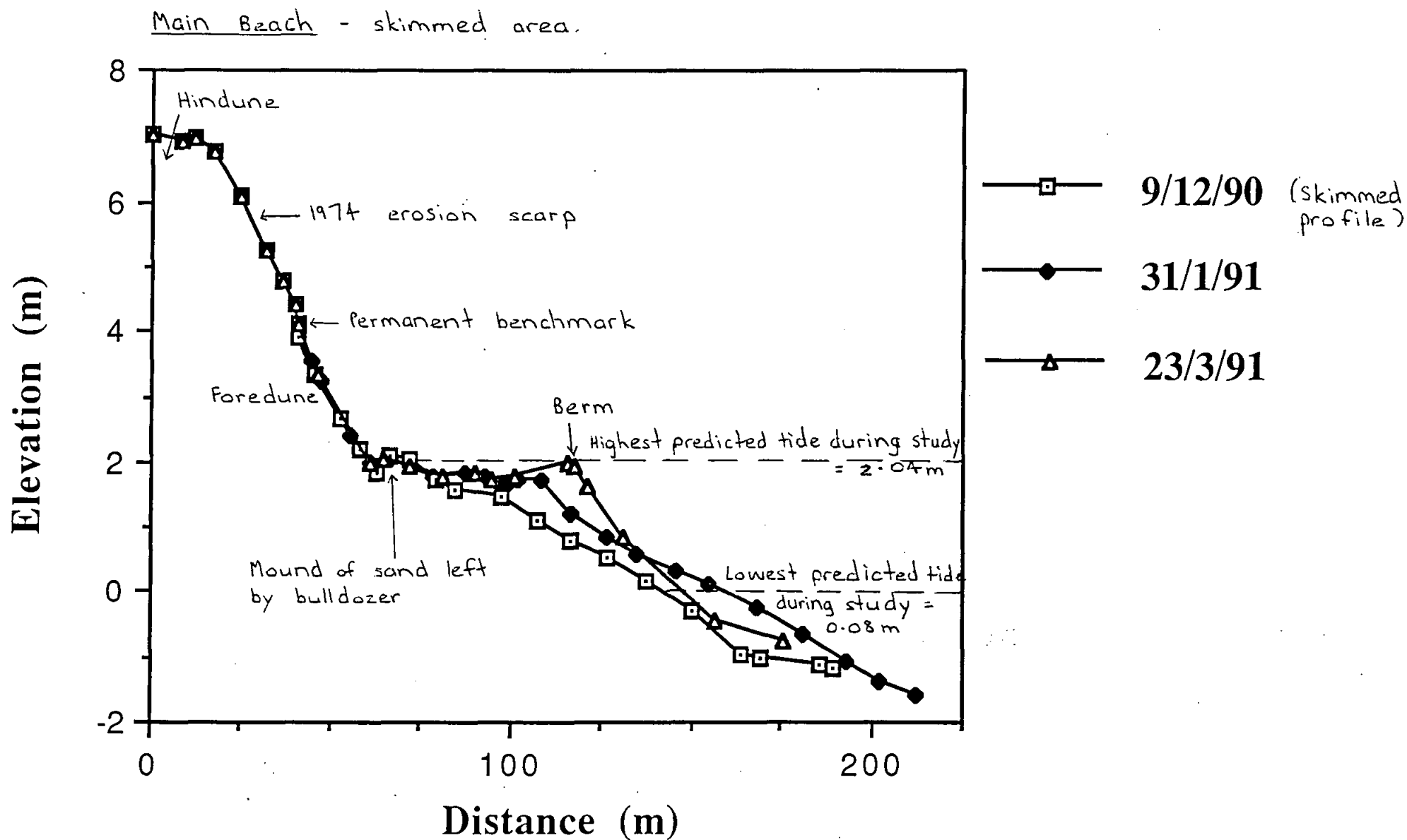


Figure 20: SK 2 profile changes.

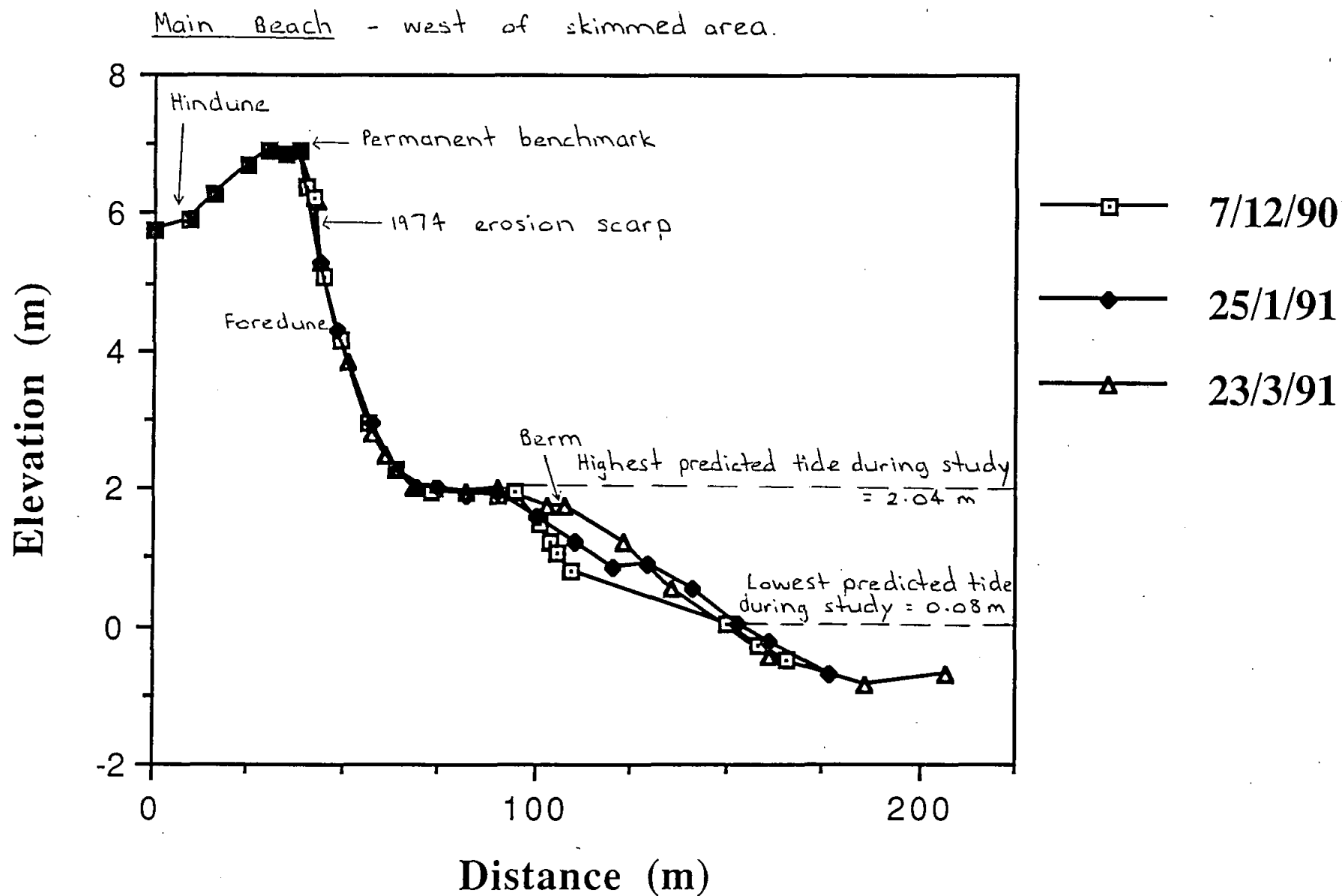


Figure 21: SK 1 profile changes.

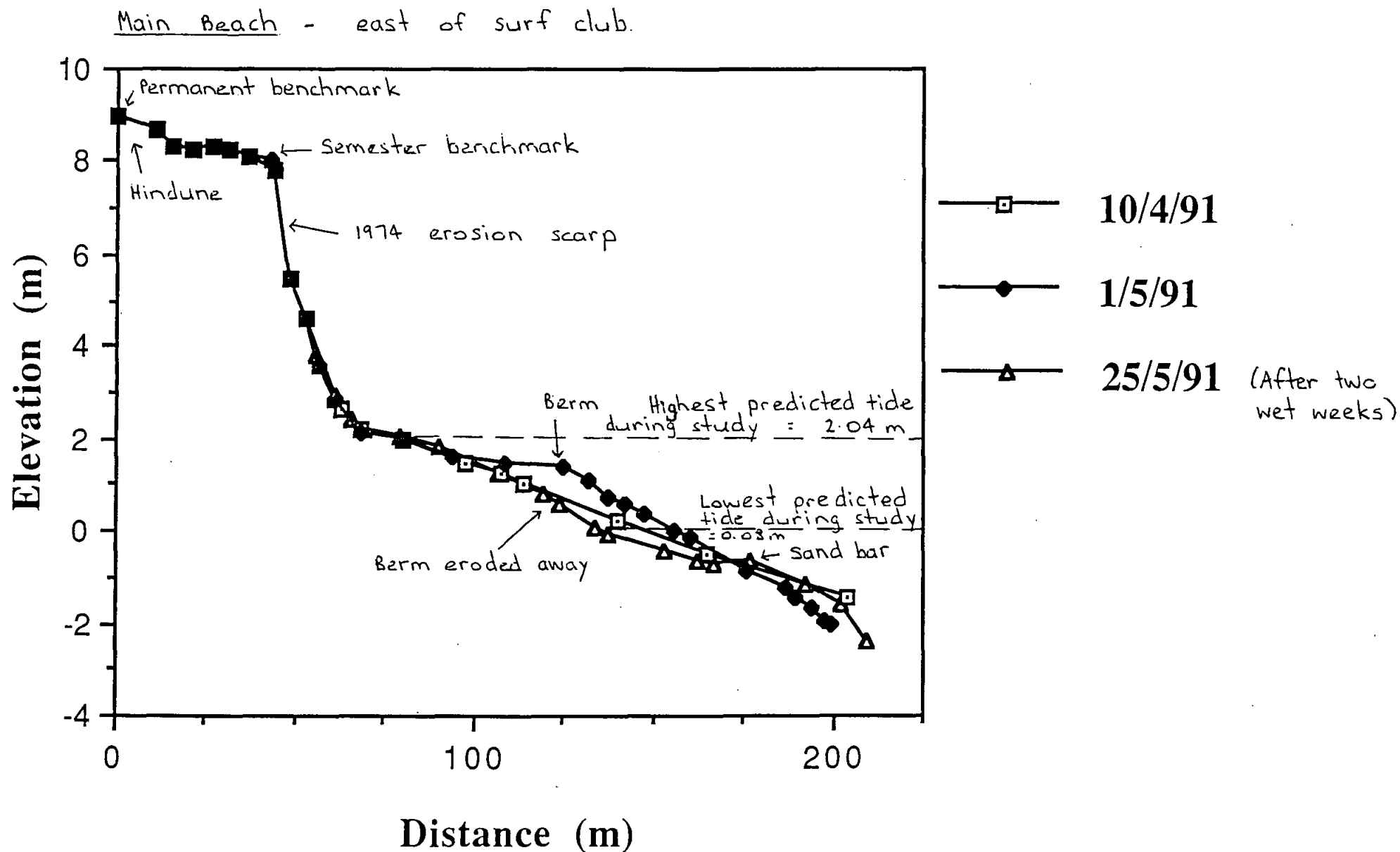


Figure 22: MB 1 profile changes.

#### 4.2 Summary of intermediate-term beach behaviour

The results of this surveying exercise, and that carried out by Daley (1991) on nearby Wategos and Little Wategos Beach, show that the beaches of Byron Bay are surprisingly "dynamic". Even during a semester of relatively complacent weather, some big changes in the profiles were observed.

Despite some short-term fluctuations in the profiles, general areas of erosion and sediment deposition over the study period can be identified, and these have been summarised in Figure 23. The following trends have emerged:

- 1) Possibly unprecedented deposition at Little Wategos Beach. Discussions with local residents and the lighthouse keepers suggest there is more sand in Little Wategos than has been seen in years.
- 2) Significant erosion at Wategos (at least of the visible beach, anyway).
- 3) Possibly unprecedented deposition at the Pass.
- 4) Very significant and unusual erosion in the Clarks Beach hook.
- 5) Significant deposition on the majority of Byron Bay beaches.

Thus, the overall pattern is one of significant accretion with the exception of Wategos and the Clarks Beach hook.

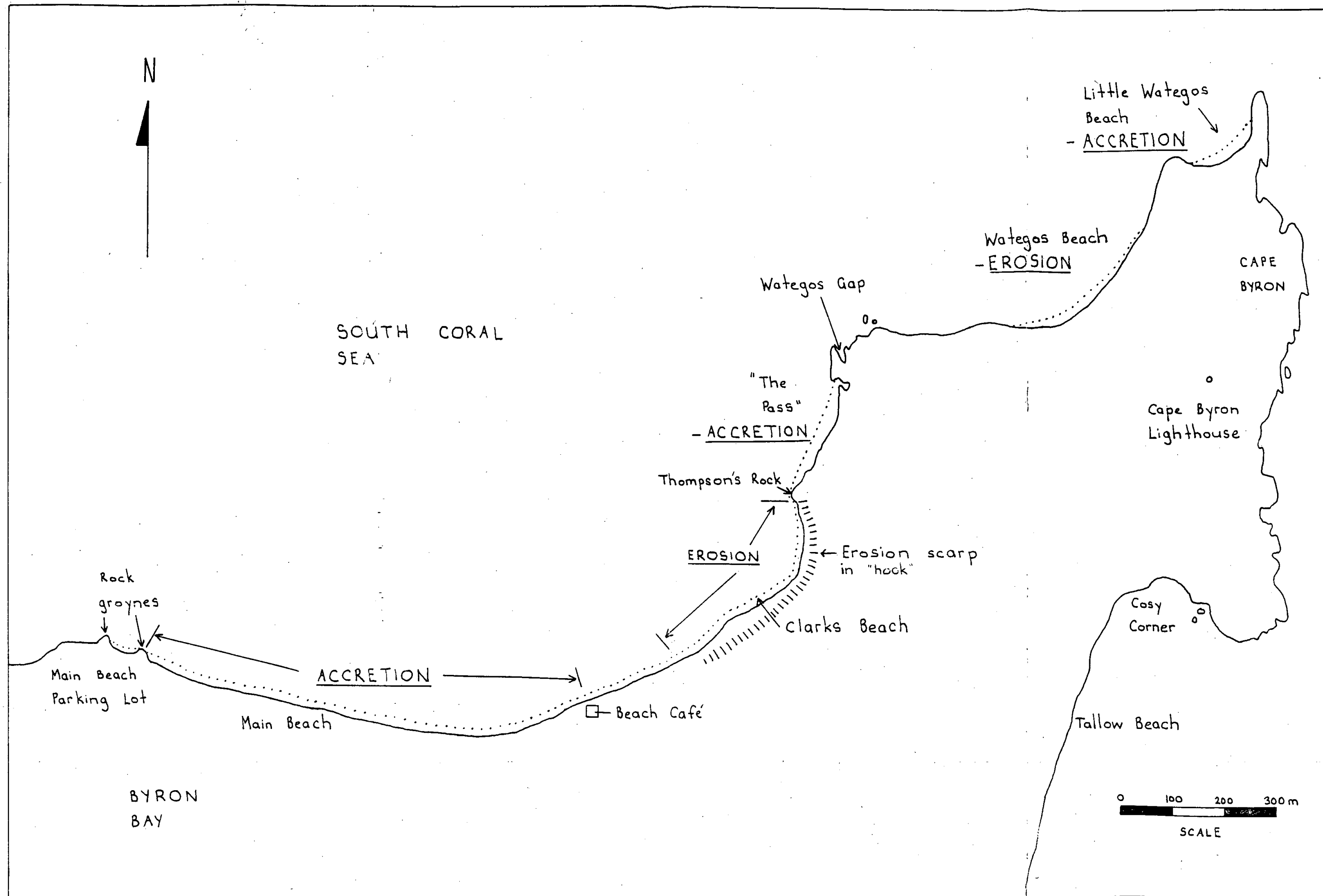


Figure 23: Map showing areas of deposition and erosion at Byron Bay, December 1990 - May 1991.

### 4.3 Cape Byron wind data

#### 4.3.1 Wind direction, 1/12/90 - 31/5/91

Plots of the wind direction at Cape Byron over the study period are contained in Appendix B.1. These data have been summarised in Table 1.

Table 1 shows that the prevailing winds at Cape Byron during the early Summer months were from the north-eastern sector, while the majority of winds from late Summer to Autumn were from the south-eastern sector. A Winter wind pattern was becoming established in May, with a relative decline in the south-easterlies and north-easterlies in favour of the offshore south-westerlies.

#### 4.3.2 Wind speed, 1/12/90 - 31/5/91

Plots of the wind speed (in knots) at Cape Byron over the study period are contained in Appendix B.2. These data have been summarised in Table 2.

Table 2 shows that the strongest winds at Cape Byron over all the Summer and Autumn months were from the south-eastern quadrant. Winds from this sector generally blew at speeds of between 15 and 20 knots. There was a gradual decline in velocity of winds from the north-eastern sector over the six-month period, while the north-westerlies showed a marked decrease in speed over the Summer months.

The calmest winds were generally from the west to south-west during Summer, and from the north-western quadrant over Autumn.

By comparing Table 2 with Table 1, some interesting patterns emerge. While the north-easterlies were the prevailing Summer winds, they were also fairly strong. During Autumn, an increase in the prevalence of the south-easterly winds coincided with an increase in velocity of winds from this direction. With the onset of Winter weather in May, the strength of the prevailing south and south-southwesterlies also increased.



**Table 1:** Monthly percentage of winds from stated directions at Cape Byron, New South Wales, 1/12/90 - 31/5/91.

Mnth.	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	CALM
Dec.	14.0	<u>16.8</u>	7.0	8.0	2.3	2.8	5.2	1.4	3.7	2.3	0	3.3	0.9	2.8	15.0	13.1	1.4
Jan.	9.7	6.9	<u>26.9</u>	0	1.4	0	16.2	5.6	2.3	6.5	2.3	2.3	1.4	2.8	10.6	4.6	0.5
Feb.	3.6	4.6	16.4	0.5	0.5	0	<u>32.3</u>	13.3	3.1	8.7	2.1	3.6	0.5	1.0	3.1	4.1	2.6
Mar.	4.2	5.6	5.1	9.7	9.7	<u>13.9</u>	7.4	6.9	1.8	10.6	4.6	5.1	1.4	2.8	6.1	2.3	2.8
April	3.4	2.4	4.4	6.3	3.9	<u>17.5</u>	1.0	8.7	4.9	11.7	9.2	9.2	2.4	5.3	6.8	1.9	1.0
May	3.3	1.4	2.3	10.8	2.3	6.5	0.9	12.6	7.9	<u>23.4</u>	5.2	6.1	4.7	1.9	3.7	0.9	6.1

**Table 2:** Monthly average wind speed (in knots) at Cape Byron, New South Wales, 1/12/90 - 31/5/91.

Mnth.	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
Dec.	10.9	14.8	12.5	12.8	9.6	15.3	<u>15.4</u>	14.7	10.0	9.8	-	7.9	11.0	9.2	9.6	13.9
Jan.	13.4	14.2	12.5	-	9.0	-	<u>15.4</u>	10.7	6.8	8.8	6.8	4.6	2.7	7.7	8.6	12.9
Feb.	8.8	14.2	12.5	10.0	2.0	-	15.2	<u>18.5</u>	16.5	14.5	3.4	4.9	4.0	3.0	3.0	12.0
Mar.	13.4	10.9	10.5	12.6	12.8	16.5	17.8	<u>19.8</u>	7.8	11.2	7.3	6.0	4.2	6.0	7.1	11.2
April	10.9	11.0	9.6	8.5	14.1	<u>17.9</u>	15.0	15.4	11.8	12.3	9.4	10.6	8.0	8.3	7.6	5.0
May	5.3	10.0	4.3	9.7	3.4	<u>18.6</u>	14.0	15.3	15.2	14.3	7.6	8.4	4.0	4.2	5.0	3.3

#### 4.4 Byron Bay offshore waverider buoy data

##### 4.4.1 Long-term wave height, 14th October 1976 - 31st December 1990

Plots of the height of the waves offshore from Cape Byron from the start of records in 1976 to the end of 1990 were obtained from the N.S.W. P.W.D.'s Hydraulics Laboratory at Manly Vale. These plots are presented in Appendix C.1.

For the years 1976 to 1988, the monthly and annual rainfall figures (in millimetres) at Lismore have been drafted onto the respective wave graphs. Also shown are the approximate times when Lismore experienced a major flood event. This information was extracted from an article in the May 3, 1989 edition of *The Northern Star* (p. 14).

These graphs show that there are distinct differences in the wave climate between years and between seasons.

##### Yearly differences:

An examination of the annual rainfall figures and flood history of nearby Lismore show that certain years can be identified as being relatively complacent weather-wise, while other years are rather energetic. For example, the late 1970's - early 1980's were fairly dry years on the N.S.W. far north coast, and this is accurately reflected in the Byron Bay wave climate. During these years, a significant percentage of the waves were less than one metre in height, with very few waves over three metres occurring at all.

In contrast, 1987 to 1989 were very wet years in this region, and the Byron Bay wave climate was vastly different. A much higher percentage of waves were over three metres in height, with several large 'peaks' occurring particularly during flood-causing weather.

##### Seasonal differences:

The rainfall figures and flood records also show that certain seasons are more energetic than others. The months from **December** to **May** can be identified as the "high energy window" time of year in this area, when the storms which cause floods are most common.

The Summer/Autumn wave climate is noticeably different (for example, compare January - May, 1989, with June - November, 1989). The waves tend to be of much higher amplitude and presumably shorter period.

#### 4.4.2 Intermediate-term wave height and period, 1st December 1990 - 31st May 1991

Plots of the height and period of the waves offshore from Cape Byron over the study period are presented in Appendix C.2. Other information such as swell direction (see subsection 4.5.2), survey dates, and rainfall figures have been marked on these graphs for interpretive purposes.

Computer sheets of the raw waverider data used to plot these graphs were also obtained from the Hydraulics Laboratory (these are not contained in the Appendices). This statistical information was used to compile Tables 3 and 4.

##### Wave height:

Appendix C.2 and Table 3 show that the predominant significant wave height ( $H_{sig}$ ) over the entire study period was only 1-1.99 metres. Fairly calm conditions were experienced in the early Summer months, with the wave height tending to increase over time. The largest percentage of waves over three metres were recorded in April.

**Table 3:** Monthly percentage occurrence for  $H_{sig}$  at Byron Bay, New South Wales, 1/12/90 - 31/5/91.

Month	0 - 0.99 m	1 - 1.99 m	2 - 2.99 m	3 - 3.99 m
December	20.3	<u>72.4</u>	6.9	0.4
January	8.5	<u>76.5</u>	13.3	1.7
February	3.7	<u>66.7</u>	28.4	1.2
March	3.4	<u>64.4</u>	29.5	2.7
April	10.8	<u>62.8</u>	23.5	2.9
May *	24.5	<u>73.9</u>	1.6	0

\* To 11 p.m. May 8th only (waverider buoy went adrift).

##### Wave period:

Appendix C.2 and Table 4 show that the mean wave period ( $T_z$ ) was very short during December, and, like the wave height, increased steadily over time. Fairly long period swells were experienced throughout March, but these shortened considerably in late April - early May.

**Table 4:** Monthly percentage occurrence for  $T_z$  at Byron Bay, New South Wales, 1/12/90 - 31/5/91.

Month	1 - 1.99 sec.	2 - 3.99 sec.	4 - 5.99 sec.	6 - 7.99 sec.	8 - 9.99 sec.	10-11.99 sec.	12-13.99 sec.
Déc.	0	5.7	<b>63.2</b>	27.6	3.5	0	0
Jan.	0	0	43.2	<b>51.0</b>	5.5	0.3	0
Feb.	0	0	42.7	<b>51.7</b>	5.3	0.3	0
March	0	0	3.7	<b>70.1</b>	25.6	0.6	0
April	0	0	20.9	<b>67.5</b>	11.6	0	0
May *	0	1.5	<b>69.3</b>	29.2	0	0	0

\* To 11 p.m. May 8th only (waverider buoy went adrift).

The wave climate over the six-month period may be summarised as follows:

- \* Generally small waves with a long period, thus the wave period/wave height ratio was large. Wave climate can therefore be described as "winter-like".
- \* The north-easterly swells, most prevalent in early Summer, had a short period and low amplitude.
- \* Swells from the south-east had a longer period and higher amplitude.
- \* Easterly swells were somewhere in the middle - with a medium wave period and medium amplitude.
- \* Wave height and period generally increased over time.

#### **4.5 Cape Byron state of sea and swell data**

##### **4.5.1 Sea state and state of swell, 1/12/90 - 31/5/91**

Observations of the state of the sea and swell off Cape Byron over the study period are listed in Table D.1c in Appendix D.1. These data have been summarised in Tables 5 and 6.

##### *a) State of sea*

Table 5 shows that the sea waves during the first two months of Summer were predominantly 'slight' to 'moderate' and only about 0.5-2.5 metres in height. As explained in section 4.3, these waves were generated by local north-east winds of moderate strength.

As Autumn progressed, and the much stronger south-easterly winds became well-established, the sea waves turned increasingly 'moderate' to 'rough', with a mean maximum height of between 1.5 and 4 metres. In May, the prevailing offshore south-westerly winds would have acted to flatten the sea surface, which may account for the sudden drop in the percentage of 'rough' seas.

It must be noted that there were no 'seas' during the study period classed any higher than 'rough'. This reflects the relative complacency of the weather conditions experienced during this time.

**Table 5:** Monthly percentage occurrence for 'state of sea' classifications at Cape Byron, New South Wales, 1/12/90 - 31/5/91.

Mnth.	* 0	1	2	3	4	5	6	7	8	9
Dec.	0	0	0	<u>72.4</u>	27.6	0	0	0	0	0
Jan.	0	0.9	1.4	<u>47.7</u>	46.3	3.7	0	0	0	0
Feb.	0	0	0	23.1	<u>65.1</u>	11.8	0	0	0	0
Mar.	0	0	0	16.7	<u>71.6</u>	11.6	0	0	0	0
April	0	0	0	38.2	<u>49.5</u>	12.2	0	0	0	0
May	0	0	0	34.7	<u>64.8</u>	0.5	0	0	0	0

\* For key to classification codes, refer to Table D.1a in Appendix D.1.

#### b) *State of swell*

The period and height of swell waves off Cape Byron over the study period were accurately measured by the waverider buoy, therefore the results have already been presented in subsection 4.4.2. However, the visual observations of the state of swell have been included in this report mainly to cover those periods of time when the buoy was 'out-of-action' (January and May).

As expected, the 'state of swell' data summarised in Table 6 correlate very well with the waverider data presented in Tables 3 and 4. No further trends are apparent.

**Table 6:** Monthly percentage occurrence for 'state of swell' classifications at Cape Byron, New South Wales, 1/12/90 - 31/5/91.

Mnth.	* 0	1	2	3	4	5	6	7	8	9
Dec.	0	<u>59.3</u>	17.8	10.8	10.3	1.9	0	0	0	0
Jan.	0	<u>42.1</u>	13.0	20.4	21.3	3.2	0	0	0	0
Feb.	0	12.3	12.8	24.1	<u>46.2</u>	4.6	0	0	0	0
Mar.	0	5.1	14.0	<u>33.0</u>	20.5	21.9	0	3.7	1.9	0
April	0	<u>30.4</u>	15.7	12.3	21.1	9.3	6.4	0.5	4.4	0
May	0	28.6	10.3	<u>36.2</u>	23.9	0	0.9	0	0	0

\* For key to classification codes, refer to Table D.1b in Appendix D.1.

#### 4.5.2 Swell direction, 1/12/90 - 31/5/91.

Plots of the direction of movement of swell in the open sea off Cape Byron over the study period are contained in Appendix D.2. These data have been summarised in Table 7.

**Table 7:** Monthly percentage of swell waves from stated directions at Cape Byron, New South Wales, 1/12/90 - 31/5/91.

Month	N	NE	E	SE	S
December	0	<u>71.0</u>	0.9	28.1	0
January	0	<u>41.7</u>	31.9	26.4	0
February	0	<u>41.0</u>	20.5	38.5	0
March	0	11.2	<u>54.9</u>	33.9	0
April	0	5.4	19.1	<u>75.5</u>	0
May	0	10.8	<u>55.2</u>	34.0	0

Table 7 shows that the majority of swell waves arriving at Cape Byron during the Summer months were from the north-eastern quadrant. With the onset of Autumn, the north-east swells declined significantly, with the dominant wave direction swinging to the east, and eventually to the south-east during April. In May, the swell was constantly alternating from the easterly and south-easterly directions.

#### 4.6 Byron Bay tidal movements, 1/12/90 - 31/5/91

The tidal movements at Byron Bay over the study period have been plotted relative to Australian Height Datum (Appendix E).

As these graphs illustrate, Byron Bay experiences semi-diurnal tides. That is, each tidal cycle takes an average of 12 hours 25 minutes, so that two tidal cycles occur for each transit of the moon (every 24 hours 50 minutes). As Pugh (1987) explains, semi-diurnal tides have a range which typically increases and decreases cyclically over a 14-day period. The maximum ranges, called **spring tides**, occur a few days after both new and full moons (syzygy, when the moon, earth, and sun are in line), whereas the minimum ranges, called **neap tides**, occur shortly after the times of the first and last quarters (lunar quadrature). The relationship between tidal ranges and the phase of the moon is due to the additional tide-raising attraction of the sun, which reinforces the moon's tides at syzygy, but reduces them at quadrature. When the moon is at its maximum distance from the earth, known as lunar apogee, semi-diurnal tidal ranges are less than when the moon is at its nearest approach, known as lunar perigee. This cycle in the moon's motion is repeated every 27.55 solar days. Maximum semi-diurnal ranges (such as those experienced on December 3-4, 1990) occur when spring tides (syzygy) coincide with lunar perigee, whereas minimum semi-diurnal ranges (such as those experienced on February 8, 1991) occur when neap tides (quadrature) coincide with lunar apogee.

The Department of Defence (1990) lists the following tidal levels for Byron Bay:

M.H.W.S. (Mean High Water Springs)\* = 1.4 m.

M.H.W.N. (Mean High Water Neaps)\* = 1.3 m.

M.S.L. (Mean Sea-level)\* = 0.9 m.

M.L.W.N. (Mean Low Water Neaps)\* = 0.6 m.

M.L.W.S. (Mean Low Water Springs)\* = 0.4 m.

\* See Department of Defence (1990) for explanation of these terms.

The H.A.T. (Highest Astronomical Tide) and L.A.T. (Lowest Astronomical Tide) have not been calculated for Byron Bay, but the highest predicted tidal level during the study period was 2.04 metres (December 4), while the lowest level was 0.08 metres (January 1-2).

## 5.0 DISCUSSION

### 5.1 Long-term beach behaviour (1976 - 1990)

An examination of available aerial photographs of the Byron Bay region for the years 1976 to 1990 found there was a distinct correlation between beach behaviour and wet and dry years.

The years from 1977 to 1982 have already been identified as being relatively complacent weather-wise, with a generally calm wave climate being experienced. The aerial photographs of this period show that the beaches were in a highly accreted state. Of particular significance is an enormous build-up of sand at the Pass and along Clarks Beach, visible in the 1977, 1979, 1980, and 1982 photographs.

In contrast, 1984 may be described as being more energetic in terms of both weather and wave climate. As Appendix C.1 shows, Lismore experienced a major flood event in April. Although the waverider buoy was inactive at this time, it can safely be assumed that Byron Bay was subjected to a prolonged, wind-driven, easterly air flow which caused large, short period waves. Subsequently, the August 1984 aerial photograph shows the beaches in a moderately eroded condition, with very little sand at the Pass, and almost nothing in the hook of Clarks Beach. Main Beach seemed to escape relatively unscathed.

The years from 1987 to 1989 have also been identified as being very energetic, in that several major flood events occurred (mainly in the Summer and Autumn months), and the wave climate was generally rough. Although no photographs were available for these years, personal observations and discussions with local residents have shown that the beaches were in a severely eroded state. After some of the worst flooding in Lismore's history in April 1989, the shoreline receded almost to the toe of the foredune along most of the Byron Bay embayment (Gagan, pers. comm., 1991).

As Appendix C.1 shows, most of 1990 was fairly quiet weather-wise, with some heavy rain in March but no flood events occurring. Particularly in the latter half of the year, the beaches were observed to be steadily accreting.



Thus, the results of this study suggest that erosion in Byron Bay reflects the predominance of Summer/Autumn style storms. Not distant cyclones (long period waves, energy expended offshore) but the storms which cause floods (wind-driven, easterly air flows which cause large, short period waves).

## 5.2 Intermediate-term beach behaviour (1st December 1990 - 31st May 1991)

### 5.2.1 Explanation of general depositional trend

The results of this study and that conducted by Daley (1991), show that there was significant deposition on the beaches of Byron Bay over the Summer and Autumn months, with the exception of Wategos and the Clarks Beach hook. One possible explanation for this unusual Summer/Autumn beach behaviour is an increase in the volume of sand transported into Byron Bay. This change may be examined in two ways; in terms of sediment supply and wave style.

#### a) *Sediment supply*

Investigations by Gordon, *et al.*, (1978) have found the average annual nett northerly drift along Tallow Beach to be 65,000 m<sup>3</sup>. Of this, 50,000 m<sup>3</sup> per year is swept away by the **East Australian Current** to be deposited offshore, while 15,000 m<sup>3</sup> per year passes around the Cape entering the littoral system of the embayment.

However, due to the variability of both wave climate and offshore currents, the quantity of sand bypassing Cape Byron in any particular year may vary from 0 m<sup>3</sup> per year to a figure in excess of 65,000 m<sup>3</sup> per year. Observations by the author, as well as by local residents and the lighthouse keepers over the past 12 months suggest that a lot of sand is being transported around Cape Byron, more than has been seen in years. In fact, even local professional fishermen have noticed a change in their catch from pelagic (open ocean) fish to more nearshore species (Rigby, pers. comm., 1991), indicating possible shoaling of the embayment.

This increase in the sediment supply may have initiated in late August 1990, when large south-easterly swell waves were observed transporting significant volumes of sand around the Cape (Gagan, pers. comm., 1991).

Furthermore, the results of the diving exercise on the old jetty pylons (see Daley, 1991) also show that sediment is being moved shoreward. For example, the main line of marine growth on the pylons is well above the present sand surface at the 0-5 metre deep sites - suggesting that the sand has been transported to the visible beach.

#### b) *Wave climate*

The results indicate that the wave climate this Summer/Autumn has been unusually calm and can be described as winter-like. Generally small, long period waves were experienced, therefore the wave period/wave height ratio was large. As Bird (1984) explains, this style of wave forms 'spilling' breakers with a constructive swash which moves sand onto the beach, building up a berm parallel to the shoreline. In rougher weather normally experienced at this time of year, higher and steeper waves form 'plunging' breakers, with collapsing crests which produce less swash, and a more destructive backwash which scours sediment away from the beach.

#### 5.2.2 Little Wategos Beach deposition

The possibly unprecedented deposition at Little Wategos must be a reflection of the abundant sand moving around Cape Byron and the winter-like, south-easterly wave climate. This beach faces north-northeast and is well protected from the large south-easterly swells, so the abundant sand transported in front of the Cape could "round the corner" and be easily deposited there, in the protected lee of the headland.

#### 5.2.3 Wategos Beach erosion

Wategos has been in an eroded condition since October 1990, which Raymond (1990) concluded was caused by Spring/Summer northerly seas superimposed on high tides. This beach is still being starved of sediment for two possible reasons:

- 1) because it faces north and is protected from the prevailing south-easterly swell, the waves cannot move sand shoreward as effectively; or
- 2) because sand is being temporarily trapped at Little Wategos and is therefore not available offshore. Gordon, *et al.* (1978) and Skene (1986) explain that as slugs of sand move around the Cape under southerly and south-easterly wave action, Little Wategos Beach becomes full of sand while at the same time, Wategos Beach is depleted and bedrock is exposed along the entire shoreface. When Little Wategos reaches a state of equilibrium, the excess sand will then be bypassed to Wategos.

#### 5.2.4 Pass accretion

The significant deposition at the Pass over the period of the study (Fig. 24) may be a reflection of three processes; including an abundance of sand eroded from Wategos, sand transported from offshore, and an unusual sand corridor at Wategos Gap. It is possible that what sand is available off Wategos is not being transported shoreward (for reasons discussed in subsection 5.2.3), but rather is moving directly to the Pass area. Highly refracted fair-weather waves would allow an abundance of sediment to accumulate in the protected area behind the rocks here.

An unusual situation existing over the past few months is that the channel between these rocks, known as Wategos Gap, has been choked with sand and may in fact be acting as a sand corridor to the Pass. That is, much of the sand might not even be transported around the point between Wategos Beach and the Pass, it may be passing straight through it. The area of deposition has been slowly but surely expanding and working its way west along the beach.

#### 5.2.5 Clarks Beach "hook" erosion

The extent of erosion in the "hook" of Clarks Beach over the study period has been very significant, if not 'unusual'. This is a rather strange situation, and it is possible that this area represents a sediment supply and wave style transition point between the Pass and Main Beach.

##### *a) Sand supply transition*

Abundant sand is available to the Pass from Wategos Beach for reasons already discussed.

The hook of Clarks Beach is not getting its share because sand is being temporarily trapped at the Pass. This is analogous to the Little Wategos/Wategos Beach situation.

Main Beach is receiving sand from the eroded area at Clarks Beach.

### b) *Wave style transition*

Waves at the Pass are highly refracted, allowing sand to deposit in the lee behind the rocks.

The waves in the hook of Clarks Beach are too refracted to push sand shoreward, but are just the right size to pass over the shallow bottom at high tides to expend their energy on the visible beach and erode it (Figure 25 and 26). This is discussed more fully in subsection 5.3.1.

Main Beach waves are not as highly refracted so are more effective in transporting sand shoreward. Any high tide erosion is simultaneously replaced by sand and "masked" by sand from Clarks Beach and offshore.

#### 5.2.6 Main Beach accretion

The deposition on Main Beach over most of the study period is largely a result of the winter style waves transporting sand onshore. Some sand is being received from the eroded area at Clarks Beach, while some might be derived from the Clarks Beach stormwater drain (Fig. 27 and 28). However, the volume of sand accreted is too great to have come from these two sources alone, so onshore movement is easy to imply.

Main Beach did suffer minor 'short-term' erosion during the wet period in May. The reasons for this are discussed in subsection 5.3.2.

### 5.3 Short-term beach behaviour

#### 5.3.1 Extreme high tide event

The most dramatic erosion occurred at profile line CB 1, where two 1.99 metre spring tides over the 15th - 16th May 1991 (Appendix E) caused the scarp to recede three metres in just two days.

As Figure 16 shows, the line was surveyed at low tide on the afternoon of May 15 - about six hours before the first 1.99 metre high tide. A repeat survey of the line was conducted on the afternoon of May 17 - about 18 hours after the second 1.99 metre high tide.

The important result shown by this experiment is that even small waves can cause significant erosion during high tides. In the hook of Clarks Beach, on a spring high tide, short period waves can break right at the base of the erosion scarp causing it to be undermined and recede.

### 5.3.2 Storm event

A minor storm event occurred during the study during a two week period from May 9 - May 23, 1991, when over 274 millimetres of rain was recorded at Cape Byron.

By the 25th May, the entire beach berm at profile line MB 1 (Figure 22) had been eroded away. Storm waves moved a moderate quantity of sand from the beach and transported it offshore to form a small storm bar. The following meteorological and wave conditions were being experienced at the time:

A large, very slow moving high pressure system centred off Victoria and a low pressure system situated in the North Coral Sea directed a strong, moist, south-east to easterly air flow onto the coast. The results show that a short to average period swell of moderate height from the east was combined with locally moderate to rough seas. Two 1.99 metre spring tides were experienced over the 15th - 16th May. These factors all combined to cause the erosion at MB 1.

## 5.4 Critique of Hopley (1967)

In this section, the findings of Hopley (1967) will be critically analysed and compared with the results of this study.

Hopley (1967) used the 'student t-test' method to correlate the pattern of erosion at Byron Bay with changes in wind patterns observed between 1949 and 1964. He concluded that **south-westerly** winds during the Autumn and Winter months were most responsible for erosion at Byron Bay.

Hopley provides no real "mechanism" for this, but merely states the Winter south-westerlies produce a scouring of the beach. Thus, a build-up of material during the Summer months is offset by a process of erosion during the Winter. This is contradictory with the findings of this study.

The results of this study show that it is winds from the north-eastern quadrant which facilitate erosion at Byron Bay. Historical records show that these strong, moist, onshore winds which are most prevalent in the Summer and early Autumn months, generate large, short period waves which have a destructive influence on the beach profile.

Furthermore, Komar (1976) explains that onshore winds cause a landward movement of surface waters which must be compensated by a seaward current at depth which also tends to cut back the beach. In late Autumn and Winter, the prevailing offshore south-westerlies at Byron Bay tend to reduce the height of the advancing waves, so that the waves reaching the shore are of lower steepness. A near-bottom, onshore wind-induced current is set up which, combined with the reduced wave steepness, has a constructive effect on the beach.

Therefore, regardless of Hopley's statistical correlations, his conclusions must be considered invalid. The coastline at Byron Bay is well-exposed to the north and east, and it is the wind-generated waves from these directions that are most responsible for beach erosion.

### 5.5 Evaluation of beach skimming programme

The early Summer beach skimming programme conducted by Byron Shire Council on Clarks and Main Beach, Byron Bay may be considered a partial success for the following reasons:

- 1) The beach profiles (Figures 14-22) show that, for reasons unclear to the author, berm development is greater in the skimmed area than in the unskimmed area.
- 2) As Figure 29 illustrates, there is now a greater volume of sand available near the base of the foredunes to act as a reservoir for resupplying sand to the beach during future storm events.

However, the Council may not have been so lucky. Skimming the beach in the early Summer was very risky, as the removal of the protective berm and steepening of the profile rendered the beach and dunal areas susceptible to damage from wave attack. It was only through 'good-luck' that abnormally calm sea conditions were experienced over the Summer and Autumn months.

The beach skimming has failed in one respect, in that no control over the stormwater drain has been achieved. This continues to be a problem and is considered an "eyesore" by locals and tourists alike. Furthermore, the extra sand trapped near the dune by bulldozing is no longer available to the longshore drift and may eventually cause erosion further west.



Figure 24: Sand build-up at the Pass, Byron Bay (20/4/91).



Figure 25: Erosion in the "hook" of Clarks Beach, Byron Bay (1/5/91).



Figure 26: Clarks Beach erosion scarp (1/5/91).



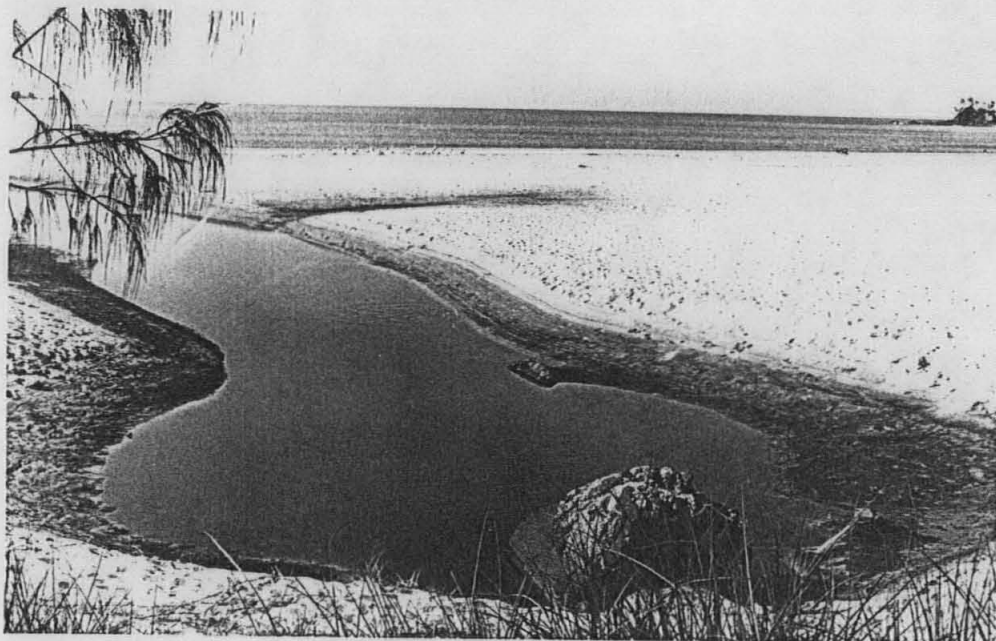


Figure 27: Stormwater drain on Clarks Beach, Byron Bay (19/4/91).



Figure 28: Severe scouring by Clarks Beach stormwater drain (19/4/91).



Figure 29: Sand reservoir along Main Beach, Byron Bay - created by beach skimming operation. Photograph taken 19/4/91.

## 6.0 MANAGEMENT IMPLICATIONS

### 6.1 Beach skimming/stormwater drain problem

Bruun (1983) reviews the effects of beach skimming on beach stability and concludes that if undertaken in a practical and modest manner, skimming will protect dunes on a short-term basis.

As the beach skimming programme conducted on Clarks and Main Beach, Byron Bay appears to have been effective in preventing erosion, it is recommended that the programme be continued, but with the following alterations:

- 1) Byron Shire Council should only skim the beach in the Winter or Spring months, when the beach is in an accreted state and is likely to stay that way for some time.
- 2) The material scraped from the swash zone should be placed further above the influence of wave action on the dune face - not quarter of the way down the beach.
- 3) Beach skimming should be undertaken on a neap tide. Steepening the profile on a spring tide only increases the potential of storm waves to travel up the artificially created ramp and attack the beach and dunal areas.
- 4) Down-drift areas should be monitored to see if erosion is hastened.

The stormwater outlet on Clarks Beach collects urban runoff water from several sources east of the town centre (Parker, 1988). As this runoff water passes through humic peats and coastal 'wallum' swamps it is discoloured by tannins. During periods of high rainfall, this water discharges across the beach causing a discoloration to and loss of beach sands.

The short-term solution to this problem is for Byron Shire Council to continue keeping the drain open to the sea, thereby preventing unsightly lagoons from forming, as happened in 1990.

The long-term solution, of course, is to remove the outlet altogether. One suggestion put forward is to divert the water into the town's main drainage system. In the November 30, 1990 edition of *The Northern Star* (p. 2), Mr. Greg Alderson, the Byron Shire Council's works and services director, said to do this would require extensive works. Because of the expense involved, this would not be done until the nearby Sandhills Estate was developed.

## 6.2 Current and future development

Considering the long-term erosion trend which exists in the embayment, nearly all developments located near the shoreline may be classified as being 'at risk'. A number of management options have been examined and evaluated, and these are discussed fully by Gordon, *et al.* (1978).

The problem of siting future developments has been addressed by Byron Shire Council in its Local Environment Plan (L.E.P.) which was formally gazetted in 1988. Parker (1988) explains that the L.E.P. has a two-fold approach to the coastal hazard:

- 1) it excludes all significant developments from the area in which they can be considered to be immediately at risk during a severe storm or series of storms. Thus a buffer zone is created which accommodates coastal erosion, and the foreshore can be maintained free of developments which require protective works; and
- 2) as the shoreline retreats, the buffer zone will be relocated landward and the development consent originally approved for this land will lapse.

Current development in the Clarks Beach hook area is under immediate threat if the present erosional trend continues. For example, the Partridge's house was within about 48 metres of the scarp as of the 17th May 1991. In the 1930's, the erosion scarp receded to within ten metres of this dwelling (Partridge, pers. comm., 1991), so there is no reason to suggest this could not happen again.

Development at Wategos Beach is not considered under any threat from present erosion. As stated by Gordon, *et al.* (1978), the shoreline here will not recede to any great degree as it is virtually fixed by bedrock outcrops.

### 6.3 Proposed new jetty

A group of Byron Bay businessmen have recently revived interest in the much debated Byron Bay jetty proposal. Three public meetings have been called, the first in November 1990 resulted in the attendance of over 200 people (Clark, pers. comm., 1991).

A letter to a Byron Bay resident by a Gold Coast Civil Engineer (Smith, 1985) claimed that a new jetty in Byron Bay would represent an added tourist attraction to the area. He said the most obvious site for the structure would be opposite Jonson Street, in almost the same location as the 1888 jetty. Nearly all tourists visit this locality when they stay or pause in Byron Bay, and it is close to ample public car parking. The seabed here is also suitable for the driving of piles - the 1978 P.W.D. report having indicated a gap between indurated sandrock deposits. A provisional cost estimate for the jetty is \$800 per square metre.

The jetty's likely impact on the natural beach system depends largely upon its design. Smith (1985) recommends a jetty length of between 200 and 250 metres minimum, terminating in a water depth of between 2.5 and 3 metres at least at low tide. The jetty should be 3-4 metres wide and 6-10 metres at the seaward terminous. Two lessons have been learnt from the previous jetties:

- 1) there should maximum deck spans for a minimum number of foundation piles to facilitate longshore sediment transport; and
- 2) that the height of the jetty should progressively increase from the shorewards end, and always exceed the ambient cyclone, plus surge breaking wave height.

Smith (1985) explains that every structure built on a natural beach generates either direct effects or side effects. Piled jetties are no exception, but with their now very much open construction, jetties are usually the least dangerous of coastal structures. In this, we have reliable data from the Corps. of Engineers pier at Duck, North Carolina (U.S.A.) to act as a guide. At Duck, the pier's piles changed the seabed contours in an obvious fashion, but the overall effect upon the visible beach has been almost minimal. At Byron Bay, a very similar result is expected; a change in the deeper mid-jetty contours, but little change inshore. It is expected that a new jetty would have less effect on the natural beach, than has the highly reflective rubble wall already existing in front of the swimming pool carpark.

## 7.0 PROJECT LIMITATIONS / RECOMMENDATIONS FOR FUTURE WORK

### Project limitations:

The main aim of this project was to document the behaviour of the beach at Byron Bay over various time scales, and to identify what styles of waves, winds, and tides cause beach erosion and accretion. The methods used were found to be quite satisfactory, with even subtle changes in the profiles being easily detected.

However, to better document beach behaviour, the following improvements to the beach profiling technique are suggested:

- 1) The lines should ideally be closer together, say 100-150 metres apart. In this way, large sections of beach will not be left unmonitored.
- 2) Allow a shorter time interval between surveys. Short-term changes, such as those resulting from minor storm events, are more likely to be detected.
- 3) Combine surveying with regular photography of the lines. Photographs often record the three-dimensional shape of features that surveying does not.

More offshore work should have been conducted in this project, but this was not possible due to severe time and funding constraints. Methods such as setting up star-picket lines adjacent to the profiles, and coring offshore to document the erosion stratigraphy would have improved interpretations of the beach profile changes by providing additional information on onshore/offshore sediment movement. Documenting the longshore drift (which beach profiling cannot do) is a difficult task as the turbulent water of the surf zone plays havoc with equipment such as current meters. However, it may have been possible to set up sediment traps to measure the littoral transport of sand. Dye experiments could also have been conducted during various wave styles to measure current velocities and hence differences in the rate of longshore drift.

### Recommendations for future work:

Obviously, much more work needs to be done at Byron Bay before we can fully understand the past, present, and possible future behaviour of the beaches, and thus be able to implement the most effective management plan. Some recommendations for future work are listed below:

1) Learn more about ancient beach behaviour, which is especially important to understand man-induced effects.

Examine the magnitude of ancient storms and the resultant beach behaviour by conducting onshore and offshore drilling. Onshore, it may soon be possible to use the thermoluminescence method to accurately date layers containing heavy minerals which signify previous storm events. In the offshore zone, big events may be shown in graded beds preserved beneath normal sedimentation. Palaeoclimate studies of the last 1000 years are needed to understand storm recurrence intervals.

2) More historical information is required:

- \* As yet, nobody has investigated the connection between the construction of the Richmond River training walls and coastal erosion at Byron Bay. Thus, we need to examine the behaviour of the coast from the Richmond River northward - to document the northward movement of the erosion shadow.
- \* Examine the impact of sand mining - the alteration of vegetation, and the disturbance to the natural geomorphology and physical properties of the beach. Has this contributed to the coastal erosion problem?
- \* Further studies of storm events known to have caused erosion at Byron Bay are required. Examine the meteorology, wave patterns, and tidal characteristics. This knowledge may allow scientists in the near future to predict major erosional events before they occur. In this way, the public can be given advanced warning so that necessary precautions to save property may be taken.

3) More offshore studies are needed, such as examining the connection between sedimentation on the continental shelf and beach behaviour.

4) Examine the possible connection between groundwater movement and beach erosion. For example, areas of Clarks Beach are always wet, and groundwater has often been observed seeping from the dunes in the vicinity of the caravan park. Does this increase the erodibility of the sand? How does the clearing of vegetation affect groundwater flux through the backdune to the beach?



## 8.0 CONCLUSION

Whilst a long-term erosional trend is believed to exist in the Byron Bay embayment, the majority of the beaches have been steadily accreting over the Summer and Autumn months of 1990/1991.

This pattern of beach behaviour is **atypical**, as historical records show that erosion is most common between the months of December and May. During this "high energy window" time of year, the coastline at Byron Bay is often subjected to wind-driven, easterly air flows which generate large, short period waves that have a destructive influence on the beach profile.

The unusual Summer/Autumn beach behaviour can be attributed to the following factors:

- 1) an increase in the sediment supply, initiated in late August 1990 when large south-easterly waves transported significant volumes of sand around Cape Byron; and
- 2) the winter-like, south-easterly wave climate. Generally small, long period waves were experienced and these have a constructive effect on the beach.

The only areas to have suffered significant erosion over the study period have been Wategos Beach and the eastern end of Clarks Beach. Both these areas have been starved of sediment because it is being temporarily trapped elsewhere. Erosion in the hook of Clarks Beach was further accelerated in May by shorter period waves superimposed on extreme high tides.

Therefore, the main conclusions to be gained from this study are as follows:

- 1) The beaches of Byron Bay are very "dynamic". Even during a semester of relatively complacent weather, some big changes in the profiles were observed.
- 2) Erosion at Byron Bay is caused by large, short period waves generated by strong, local winds from the north-eastern quadrant. These winds are most prevalent in the Summer and early Autumn.
- 3) Even small waves can cause significant erosion during spring high tides.
- 4) Large south-easterly swells have little effect on Byron Bay because of the protection provided by the Cape. In fact, large south-easterly waves cause longshore drifting from the south and transport sand around the Cape and into the embayment. This produces accretion.

- 5) Accretion at Byron Bay is also caused by the Winter south-westerlies which flatten the sea surface and set up an onshore, sand-bearing current at depth.
- 6) Therefore, a build-up of material during the Winter months is offset by a process of erosion during the Summer and Autumn. This is contradictory with the findings of Hopley (1967).

These factors should be taken into consideration if an effective management plan is ever to be implemented for the beaches of Byron Bay. More long-term studies of beach behaviour are needed to test these conclusions and to gain a better understanding of the coastal processes operating in the area.

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