BARRON RIVER DELTA INVESTIGATION

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1.0 INTRODUCTION

The Barron River flows to sea through a 50 km^2 alluvial Delta on the narrow coastal plain near Cairns, Queensland in north eastern Australia. The Delta is in the tropics at 17 degrees south latitude. Most of the 2175 km^2 catchment lies above 450 m above sea level. The coastal portion of the catchment has an average annual rainfall in excess of 2000 mm. River flows are highly variable with peak flood flows of over 4000 $m^3 s^{-1}$, and dry season flows of less than 15 $m^3 s^{-1}$. The Delta is tidal with ocean tides having a range of 1.8 m at Spring Tides. There are three water storages on the catchment, one on the upper catchment having an ungated spillway and a capacity of 407 x 10^6 m^3 for irrigation purposes and the other two just upstream of the Delta, are a small weir of 1.7 x 10^6 m^3 capacity to regulate water supply to the Barron Gorge Hydro-electric Power Station, and Copperlode Falls Dam on Freshwater Creek, a 45 x 10^6 m^3 ungated storage to provide water to Cairns City and the nearby Mulgrave Shire.

The Delta consists of alluvial soils which support 3600 hectares of sugar cane farm land. The beaches in the Delta are being developed as resort towns and dormitory suburbs.

Sand and gravel is reularly dredged from the lower reaches of the main river in the Delta at the rate of 50,000-80,000 m^3 per year. Increasing scarcity of sand sources, and the concern that dredging and dam construction is threatening beach sand sources have raised conflicting pressures on the Authority which licences the extraction of sand and gravel from the river.

This, coupled with regular flooding of the Delta and the cutting of major highways, and the continuing erosion of cane farm land has initiated a major data collection programme as a prerequisite to formulating solutions for the flooding and erosion problems.

2.0 IDENTIFICATION OF THE PROBLEM

A Steering Committee consisting of representatives of the local administering bodies and relevant State Government Departments was formed to supervise the data collection programme.

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Five major problems relating to the physical processes of the Delta were identified.

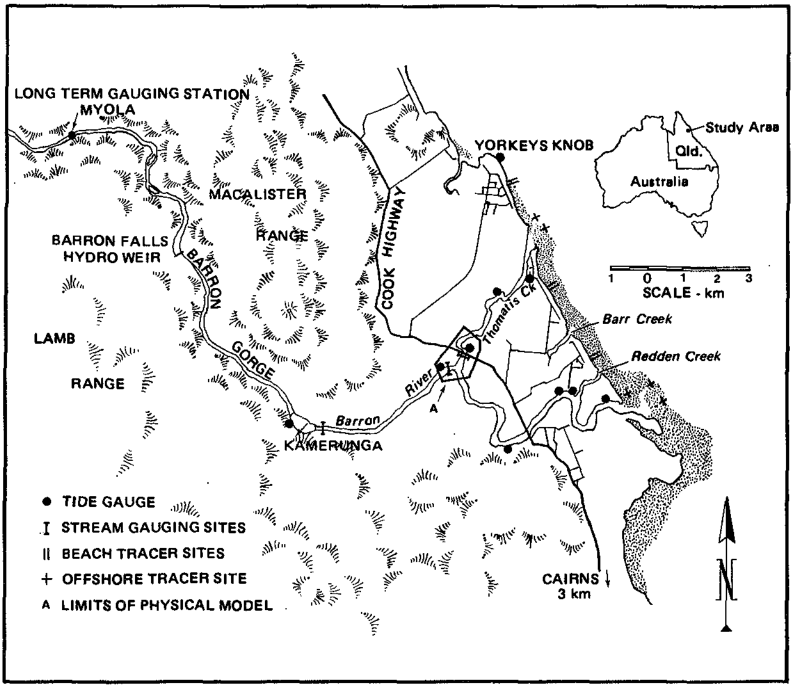
(a) The increasing urban settlement and the increasing value of the sugar crop has brought pressures to mitigate floods in the delta.

(b) Erosion of the river banks, particularly in Thomatis Creek is resulting in the loss of farm lands.

(c) Erosion of the ocean beaches is threatening beachfront facilities and degrading the recreational value of the beaches.

(d) The maximum quantity of sand and gravel, which can be removed from the river without damage to the river banks and adjacent beaches needs to be determined.

(e) The percentage of flow down each of the two main river channels in the delta needs to be determined, with regard to the conflicting requirements of bank stability, sediment discharge capacity and flood levels for each stream.



LOCALITY PLAN

Figure 1

A three year data collection programme (1975-1979) was initiated to provide the basis for solution of these problems. Thc data collection and collation was co-ordinated and largely undertaken by the Queensland State Government Department of Harbours and Marine. This paper is a summary of the much larger investigation report prepared by the Department of Harbours and Marine for the Steering Committee. (Reference 1).

3.0 DATA COLLECTION

A large component of this investigation was the data collection programme. This programme, spread over a 3 year period included the following:-

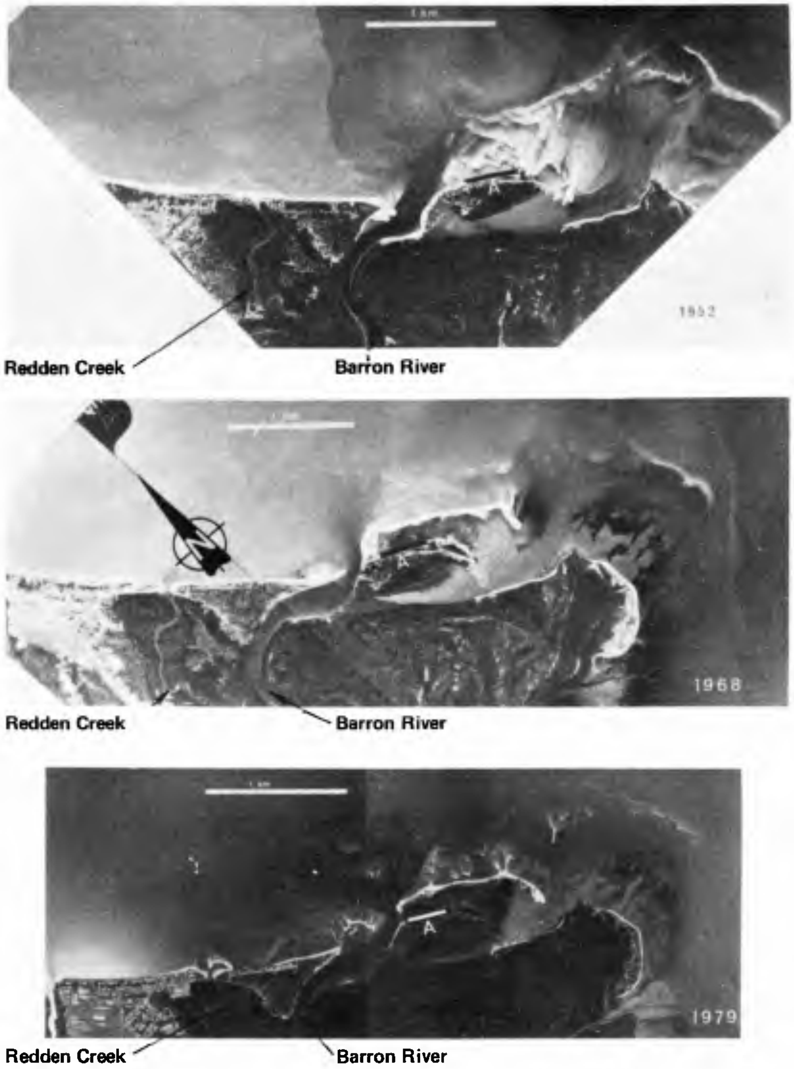
(a) orthophoto mapping of the Delta at scale 1:2500
(b) cross-section survey of river and creek channels at 250 m intervals
(c) water level recording (tide and flood) at 7 locations in the Delta
(d) bed material sampling for particle size determination in river channels and on the beaches
(e) stream flow measurement at 5 locations during flood conditions
(f) tidal flow measurements in the river and creek channels and offshore
(g) repetitive beach surveys
(h) wave recording
(i) radio active tracer studies at the junction of Barron River and Thomatis Creek and on the beaches
(j) siltation survey of the Tinaroo Falls Dam; and
(k) geological and geophysical studies of the Delta and immediate offshore area
(l) historical searches of cadastral surveys and aerial photographs.

During the study period, two of the three largest floods experienced in the Delta since the commencement of streamflow measurement on a systematic basis in 1915, occurred, presenting a remarkable opportunity for stream flow measurement and suspended sediment sampling.

In relation to the specific objectives listed in section 2.0 of this paper, the data collection programme is obviously very extensive. However a second, but equally important aim of the study was to provide a comprehensive data base for the understanding of Delta behaviour and the assessment of management proposals for the area. As a result of the success of this data collection programme, the study report will fulfil this second objective, providing a comprehensive and detailed description of the Delta which will be of immense value in the future.

4.0 RIVER PROCESSES

The Barron River, in creating a delta where it reaches the sea, has created some of the most valuable agricultural land in northern Australia, and, if left undisturbed, would continue to expand the Delta land mass. It would also however, continually change the plan geometry of the river channels and the importance of each of the distributaries would also change from time to time. These processes can be seen at work in the Delta today. Channel meandering has threatened valuable farmland by bank erosion and many examples of this can be found in the Delta. It is however, the question of distributary dominance that is of more interest to this paper, affecting as it does the overall stability of the river/beach system by controlling the distribution of sedimentary materials.



Position of line 'A' common to all photographs.

DEVELOPMENT OF THE BARRON RIVER BAR 1952-1979

Figure 2

The Barron River has three tidally connected outlets to the sea - the main channel, Thomatis Creek and Redden Creek. The relative importance of these three channels has changed over the past fifty years. Until 1932, the Thomatis channel carried Barron River water only in major floods, but surveys dating from about 1900 show clearly the development of Thomatis Creek, until, in the major 1932 flood, the River broke through and Thomatis Creek began to develop as a permanent mouth. There is a gradient advantage along this channel to the sea. The flow path is 6 km compared to 9 km via the Barron and it is reasonable to assume that unless man intervenes, the main Barron Channel will become less important and Thomatis Creek will become the major mouth.

The proportion of flow carried by each channel at high flood is difficult to estimate because of the large overland flows which occur at such times. However, at the bankfull stage, which many authors suggest is most closely associated with the channel forming process, the flow split is about 65% main channel to 35% Thomatis Creek. Hardin (Reference 2) in studies of the distributaries of Mississippi Delta suggested that when the emerging distributary has grown to the size where it can carry 40% of the flow the process is very difficult to reverse.

Whilst there is no reason to suggest that an identical figure will apply to the Barron River, it is clear that Thomatis Creek is increasing in size and that siltation is occurring in the Barron River downstream of the junction, and that the longer an attempt to reverse the process is delayed, the more difficult it will be to effect. To investigate ways of controlling the flow split at the junction, a 100:1 undistorted physical model was constructed at the Queensland Governnment Hydraulics Laboratory (Reference 3) to examine a variety of control works and to estimate their effect elsewhere in the system. The limits of the model are shown on Figure 1.

An important factor to be considered is the effect of works at the junction on distribution of sediments to the beaches. Suspended sediment measurements and tracer experiments show that the sand size and smaller sediments in the Barron River, in all but the smallest floods, are carried in suspension. At the bankfull condition, it is estimated that only 12% of sediments are carried to the sea via Thomatis Creek, so total closure of that mouth (to bank full level) would have only a very small effect of supply to the beaches, as the great bulk of transport takes place in floods larger than bank full. These would be affected to a much smaller extent.

So even if the junction is closed off to the maximum practicable level, (about bankfull), the study has shown that only a few percent of the sediments carried by Thomatis Creek will be diverted. Closing off the junction will also have only a very minor effect on the tidal flows in the Delta channels. Field measurements have shown that there is only a very small net tidal circulation through the junction which is what one would expect when the history of development of Thomatis Creek, first as a tidal creek and then later as a distributary, is considered.

Redden Creek, whilst only a very minor distributary, has quite an interesting history nonetheless. Prior to 1939, the main Barron River channel entered the sea about 1.5 km further south than at present, and Redden Creek was then considerably more important than at present. Since the new entrance developed, it is not only less favoured hydraulically but its mouth is dominated by the sands of the Barron River bar and is closed for most of the year. Figure 2 illustrates the changes that have taken place over the last 27 years. In the last fifty years the Thomatis Creek mouth has also moved 1.2 km to the North.

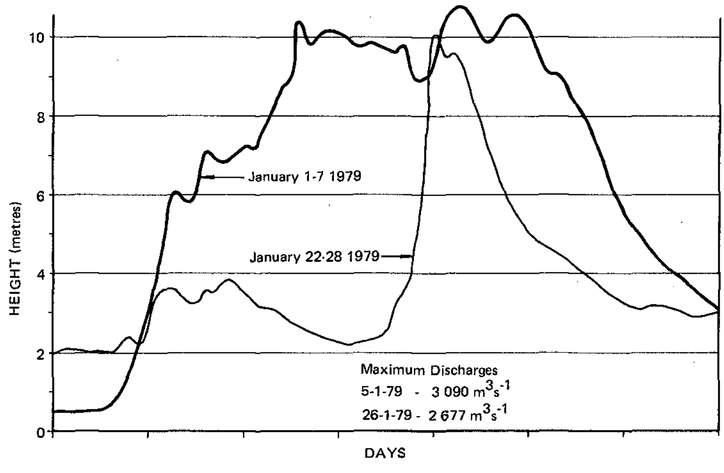
Although these changes are very important to property owners with river and creek frontages, they are far less significant when compared to changes that have taken place over the much longer geological time scale. Geophysical evidence suggests that in the period before the last major sea level change (6000 years ago) the main Barron River channel flowed to the sea close to the modern Thomatis/Richters Creek channel alignment.

5.0 FLOODS

During the summer monsoon period, November to April, tropical cyclones or hurricanes can occur. While rainfall in the Delta is reliable flood rains in the 2175 km^2 catchment can be quite variable. River flows can range from less than 15 m^3s^{-1} in the dry season to annual peak flows which have been recorded to vary from 80 m^3s^{-1} to 4500 m^3s^{-1} in 63 complete years of record.

Figure 4(a) shows the variation of the annual maximum instantaneous discharges. The major floods are all associated with tropical cyclones crossing the catchment.

During major floods agricultural land on the Delta is inundated to depths of between 1 and 3 metres. In the 1979 flood over 100 houses had to be evacuated. The duration of floods can be quite variable. In 1979 two floods with almost equal peak flows occurred. While the peak discharges are similar Figure 3 shows that the total discharge and hence total sediment discharge will be markedly different.



NOTE: Flood levels shown for Myola Water Level Recorder Station for two 1979 floods.

COMPARISON OF TWO FLOODS

Figure 3

Following the major 1979 floods, flood inundation maps for the Delta have been prepared. The 1979 flood, the second largest on record had a peak discharge of 4600 $m^3 s^{-1}$ on the Delta. The inundation maps reveal that virtually all of the Delta is subject to river flooding. The only areas free from flooding are the coastal sand ridges occupied by residential development. These coastal ridges are only 2 metres above the ocean high water level and are vulnerable to inundation by storm surges associated with tropical cyclones.

Further development of the Delta for residential purposes will require careful planning to ensure adequate escape routes are available in the event of major floods or storm surge inundation.

6.0 RIVER SEDIMENT TRANSPORT

Sediment in the river consists of fine to medium sands up to gravels of 300 mm diameter at the head of the Delta, to medium to fine sands and muds in the lower reaches. River bed samples were collected during the dry season. 268 suspended sediment samples were collected during floods and 240 samples collected during the dry season when river flows in the Delta were tide generated.

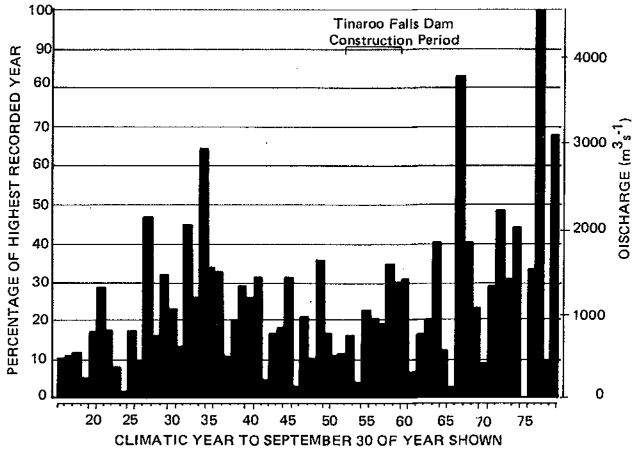
Several approaches for estimating sediment transport in the river were used including estimates from -

* recent geological evidence
* regional catchment predictors which use catchment characteristic parameters such as slope area, soil type etc.
* direct measurements of suspended sediment load
* sediment transport predictor formulae.

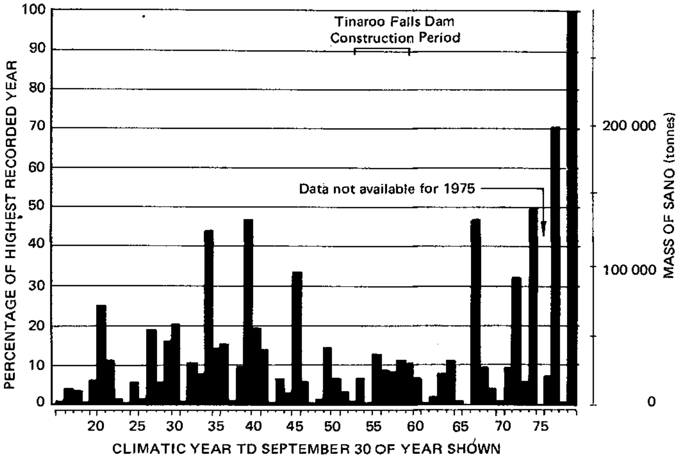
Considering only sand size particles, estimates of sediment transport were made using several theoretical methods, notably those of Engelund and Hansen (Reference 4) and White-Ackers (Reference 5) calibrated against the measured suspended sediment (Figure 5). At high flows sand sized particles are all carried in suspension. Observations during flood conditions confirm this. In sections of the river that could be accessed during major floods the channel bed was found to be composed of gravel or stiff clay indicating that the rivers capacity for transporting sand exceeded the actual transport. During the falling stages of the flood sand was deposited over the river bed.

Several difficulties were encountered in estimating sediment transport using total load predictors. Selection of a suitable gauging site required a compromise between sites at the head of the Delta where multiple channels exist but little overbank flow occurs and downstream sites where well defined channels occur but overbank flow is significant though difficult to quantify.

Based on 63 years of river flows transport of sand was estimated to be of the order of 23,000 m^3 per year. The annual sediment transport rate estimate is shown in Figure 4(b).



a. Annual Maximum Discharge

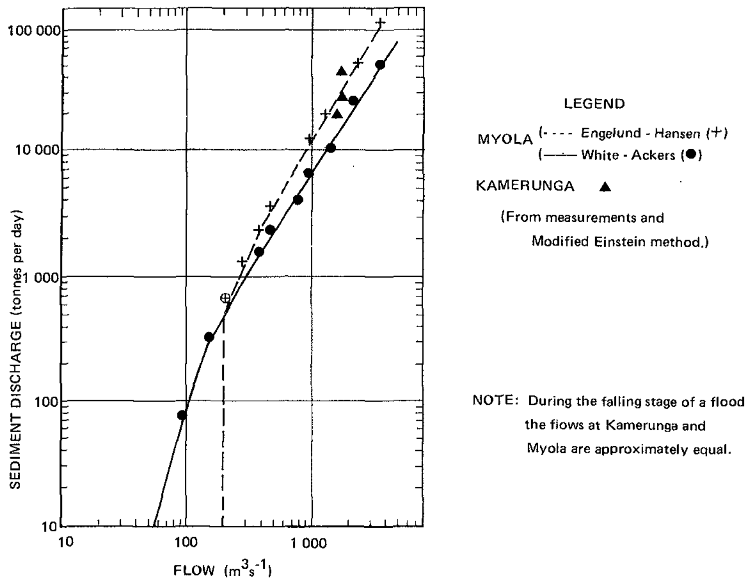


b. Sediment Discharge

NOTES: Plots for discharge past Myola Water Level Recorder each Climatic Year.
Calculation of Sediment Discharge used the Engelund and Hansen Method.

DISCHARGES AT MYOLA 1916 to 1979

Figure 4



SAND TRANSPORT CAPACITY VS FLOW AT KAMERUNGA AND MYOLA GAUGING STATIONS

Figure 5

The estimates of sand transport gave sediment transport rates ranging from 3500 m^3/year based on beach ridge accumulation through 11,000 m^3/year from regional catchment characteristics and 23,000 m^3/year from sediment transport formulae to 35,000-50,000 m^3/year from recent geological evidence. For sand resource management a figure of 23,000 m^3/year has been adopted.

7.0 COASTAL PROCESSES

Geological evidence shows that the most of the Delta has formed during the last 6000 years following the last major change in the world's sea level. From geological evidence the Barron River is supplying about 300,000 m^3/year of sediment of which 60,000 m^3/year is sand and gravel. Written history of the Delta only exists from the 1870s with firm evidence restricted to this century. During the last 50 years the Delta's beaches north of the Barron River have eroded at rates of the order of 30 m in 50 years.

The Beach Protection Authority is currently undertaking a study of beach processes in the Cairns area. The study includes the 8 km of beaches of the Barron Delta. Preliminary results from the Authority's study have been used. The Authority's beach study is similar in approach to a study of the Capricorn Coast Beaches reported elsewhere in these proceedings.

The Delta's beaches are protected from ocean swells by the coral reefs of the Great Barrier Reef, which restricts fetches to 50 km. The beaches of the Barron River Delta exhibit the typical North Queensland beach profile which consists of a steep beach down to Mean Sea Level and extensive, nearly horizontal sand and mud flats extending 1000 m or more offshore. Waves recorded in 18 m of water offshore from the Delta over a three year period, using a Datawell "Waverider" recorder show how sheltered the beaches are under normal weather conditions (Reference 6). A significant wave height (H_s) of 0.5 m was exceeded 50% of this time, while only 3% of the time did H_s exceed 1.0 m. No waves over 2.0 m were recorded over the 3 year period. Using 9 years of available wind data, a hindcast wave climate (wave height, period and direction) was also determined (Table 1).

TABLE 1

WAVE CLIMATE
BARRON RIVER BEACHES

WAVE HEIGHT	PERCENTAGE OF TIME WAVE HEIGHT EXCEEDED		
	OFFSHORE		BREAKING WAVES – MACHANS BEACH
m	RECORDED	HINDCAST	(observed)
0.2	95.	99.6	54.
0.4	63.	67.	18.
0.6	37.	42.	6.
0.8	17.	2.8	1.5
1.0	3.0	0.7	0.15
2.0	–	0.02	–

The Delta region is subject to tropical cyclones (hurricanes). Historically the Delta has not experienced a major cyclone in the last 50 years. Statistically however, it is estimated that 7 cyclones pass within 100 km of the Delta every 66 years. A cyclone of 50 year return period within 200 km radius of the Delta is estimated to have a central pressure of 963 mb.

Beach profiles were measured from the dune crest extending out to 3000 metres offshore along the 8 km of the Delta's beaches. Sixteen profile lines were repeatedly surveyed to assess seasonal variations and to measure any changes in beach shape directly attributable to floods. Surface sediment samples were collected and an explanatory geophysical survey was undertaken of the nearshore marine sediments.

The beaches exhibit a wide range of sediment sizes reflecting the river source of the material and the poor sorting by the low energy wave climate. The beaches between low water mark and the dunes are fine to medium silica sands (0.2 to 0.5 mm median size) while offshore silt and mud fractions become significant as water depth increases.

A radioactive tracer study was undertaken to measure sediment movement on the beaches, and on the bars at the mouths of the Barron River and Thomatis Creek. Active gold - 198 labelled sand was used offshore while an inactive tracer (Indium Nitrate) was used to label the beach sands.

Estimates of longshore transport were made using the method in the Shore Protection Manual, and methods of Bijker, Komar and the Authority's own procedure using observed daily longshore currents and breaking wave data (Reference 1). Annual nett longshore transport capacity was predicted to be in the range of 10,000-30,000 m^3/year to the north.

It was the longer term beach changes with 5 to 50 year cycles, and changes related to major flood events which were of interest to this study rather than seasonal onshore-offshore or short term fluctuations.

The Barron River supplies 23,000 m^3/year of sand sized sediments. Currently most of these sediments reach the coast via the main Barron River mouth, with minor amounts debouching from the other distributaries. The supply rate is very irregular as can be seen in Fig. 4(b). This contrasts with the longshore transport which tends to be of the same order from year to year.

The Barron River mouth moved 1.5 km with the connection of a meander to the sea 40 years ago. The old mouth closed and a new mouth and bar formed. The growth of the new bar and some reduction in size of the old bar can be seen in Fig. 2 as well as evidence of the strong onshore transport which has produced a new beach ridge south of the present mouth - the only coastal accretion recorded in the last 50 years on the Delta's beaches.

Geologically the coastline has accreted over the last 6000 years, at an "average" rate of 30 metres per 100 years. Historically the coastline has eroded in the order of 30 m in the last 50 years. A possible explanation for this paradox was found in the growth of the new Barron River bar. Empirical relationships between the volume of sand in the bar and the tidal prism of the river estuary (Reference 7), suggest that 500,000 m^3 of sand sized sediments are required to form the new bar. The main source of these sediments can only be from the river. Until the bar reaches an equilibrium state then excess sediment will not be readily available for transport away from the river mouth to the northern beaches. Thus until the new bar is fully developed erosion of the adjacent beaches is expected as longshore transport is removing sand from these beaches while little sand is being supplied from the river mouth.

8.0 CONCLUSION

The Barron River Delta Investigation had two clear objectives -

(a) to compile a data base to assist those Authorities with responsibility for management of the waterways and sedimentary resources of the Delta in the formulation of a management plan for the Delta; and

(b) to interpret the data as it relates to several important areas of concern at the Delta - the Barron River/Thomatis Creek junction, the Barron River beaches, sand and gravel dredging, and flooding of urban areas, and to suggest ways alleviating problems in these locations.

The first of these objectives has clearly been met, climatic events having provided an unequalled opportunity for data collection. Whether the second objective has been fully met will not be known until a considerable period of time has elapsed and the effects of any remedial works that are undertaken can be assessed.

9.0 ACKNOWLEDGEMENTS

The permission of Mr J. Leech, the Director of the Department of Harbours and Marine, Queensland State Government, and Mr A.H. Britton, the Chairman of the Barron River Delta Investigation Steering Committee, to present this paper is gratefully acknowledged. It is desired to especially thank those members of the several organisations who assisted in the data collection and collation for the study.

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