CHAPTER 101

RESULTS OF RIVER MOUTH TRAINING ON THE CLARENCE BAR, NEW SOUTH WALES, AUSTRALIA

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ABSTRACT

A case study is given of river training works at the mouth of the Clarence River. The study spans a period of ninety years. Extensive hydrographic data from the later part of this period is presented and examined in detail.

Prior to 1903 internal training walls had been constructed to stabilise the internal channel and stabilise the bar location at the mouth of the Clarence River. In 1956 construction started on entrance jetties with the aim of deepening the bar. The work was carried out over a period of 16 years. The slow rate of construction has allowed changes in bar depth to be compared with depths estimated by an empirical formula which relates bar depth to tidal flow and channel width. Results have shown that the empirical formula gives a reasonable estimate of bar depths and that bar depth is independent of jetty length.

Results have shown that the behaviour of the bar is strongly affected by floods. Some details of bar volume and movement are presented.

1. GENERAL

The Clarence River is the largest river reaching the coast of New South Wales. It is situated in the north of the state of New South Wales and the entrance lies on the southern fringe of the Australian cyclone area - see fig. 1. The Clarence has a catchment area of 8463 square miles (2190 km^2).

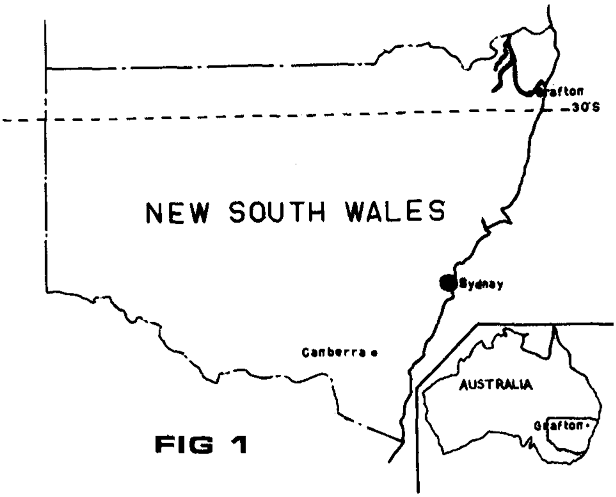


FIG 1

Flow from the catchment is extremely variable. At times the flow can be zero for long periods and in flood, flows of up to 600,000 cubic feet per second (16800 cubic metres per second) have been recorded at Grafton which is 40 miles (64 Km.) from the ocean. Normal fresh water flow is about 4000 cubic feet per second (113 m^3/sec.).

Below Grafton a flood plain of about 127,000 acres (51,000 ha.) acts as storage for flood flows so that the maximum flow at the entrance is much reduced and prolonged. Flood flows at the entrance exceeding the normal tidal flow at extreme spring tides are rare.

The river is tidal for a distance of about 60 miles (96 Km.) from the ocean and the area of the tidal reaches is 34,000 acres (13,750 ha.). Tidal range in the ocean is 4.42 feet (1.34m.) for mean spring tides and extreme range is 6.58 feet (1.99m.).

Maximum tidal flow through the entrance for a mean spring tide (4.42 ft. ocean range) is 88,000 cubic feet per second (2.5 x 10^3 m^3 per second) ebb tide and the total volume of flow is about 8 x 10^8 cubic feet/ (2.26 x 10^7 m^3). The maximum flow occurs at low water with a tide level of about 1 foot above I.S.L.W.

The entrance and lower reaches are in tidal regime. Prevailing swell is from the south east and net annual littoral drift, from south to north, is considered to be of the order of 100,000 cubic yards.

2. HISTORICAL

The mouth of the river was first surveyed in 1845 but details other than the position of mean high water mark are not now available. A report several years later states that the mouth which was 6,800 feet (2060m.) wide consisted of a series of shallow tortuous channels which were not navigable. See fig. 2

In 1860 the entrance had narrowed to 750 feet (228m.) and at this time plans were prepared to construct training walls and jetties to stabilise the location of the channel and the bar crossing. Details of this proposal are shown in figure 3.

Following a series of floods in the years 1860 to 1880 the scheme was modified to that shown in figure 3 (Moriarty's proposals) but the work was abandoned in 1889 when a new scheme was approved as shown in figure 3. At that stage works constructed under the original proposal were as indicated in the same figure.

The internal training walls of the 1889 scheme were constructed but the entrance jetties were not. The work stopped in 1903 and apart from some additions and alterations to the internal walls no further work was carried out until 1956.

Although no effective work was carried out on the entrance jetties other than a short length on the southern one the internal walls resulted in a stable location and a bar which with frequent dredging served reasonably well for coastal shipping until this declined during the war years 1939/45.

3. WORK SINCE 1956

Following on from a Parliamentary decision to establish a port at the mouth of the river, plans were prepared for the construction of jetties to improve bar depths. It is not possible to ascertain with any certainty what bar depth it was hoped to obtain but it seems that a channel depth of 20 feet (6.1m.) below I.S.L.W. was the aim, with apparently a similar bar depth.

The works proposed are shown in figure 3 and consisted of two jetties of unequal length, the northern being the longer. The original plan was not adhered to and during construction the width between the jetties was reduced and the southern jetty lengthened.

Construction started in 1956 and continued until July, 1971 when work ceased. During this period the entrance channel, bar and nearby areas were surveyed at frequent intervals (usually every

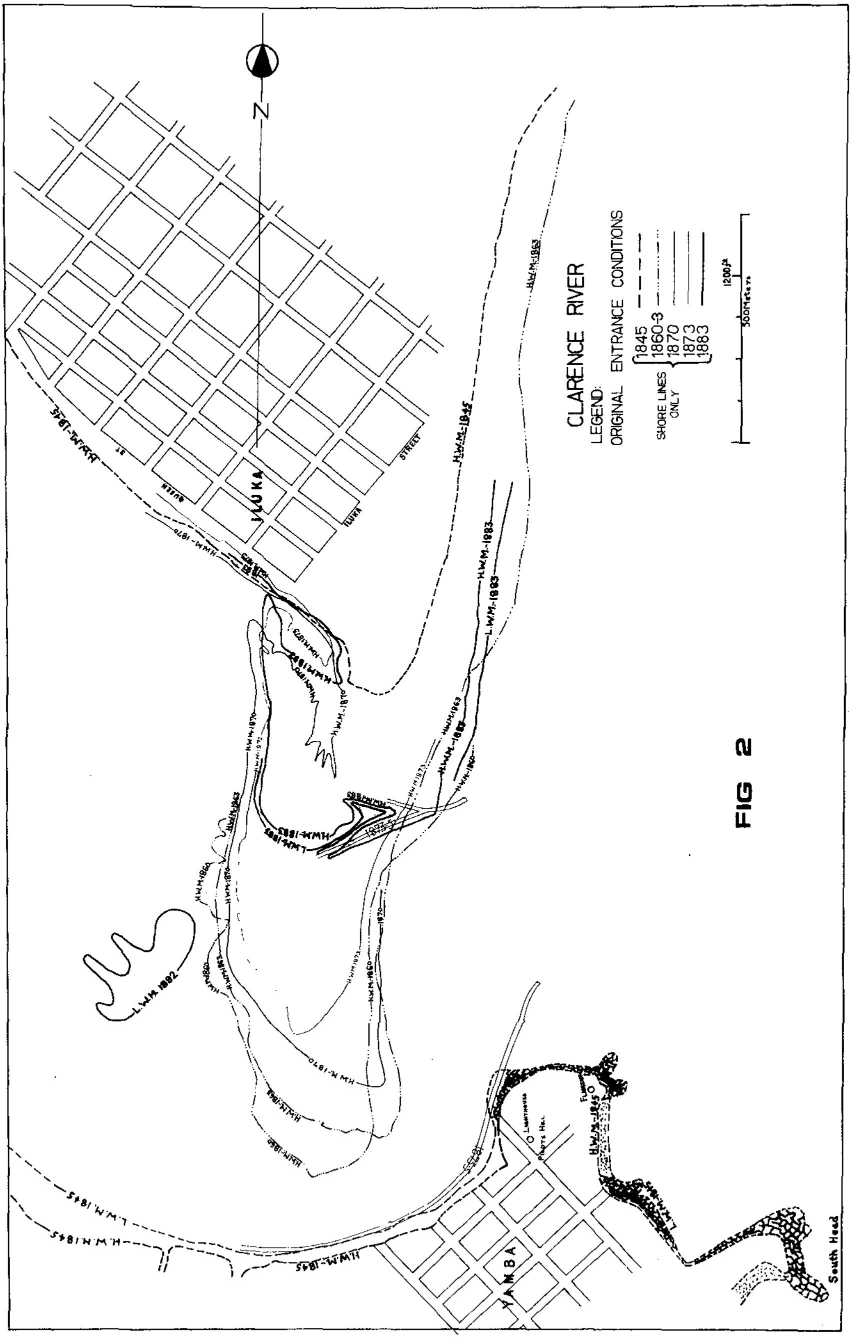

CLARENCE RIVER
LEGEND:
ORIGINAL ENTRANCE CONDITIONS 1845
SHORE LINES ONLY 1860-3
1870
1873
1883
1200 ft
500 Meters
N
ILUKA
YAMBA
South Head
Lighthouse
H.W.M.-1845
L.W.M.-1845
H.W.M.-1883
L.W.M.-1883
H.W.M.-1870
H.W.M.-1873
H.W.M.-1863
H.W.M.-1860
L.W.M. 1882
STREET

FIG 2

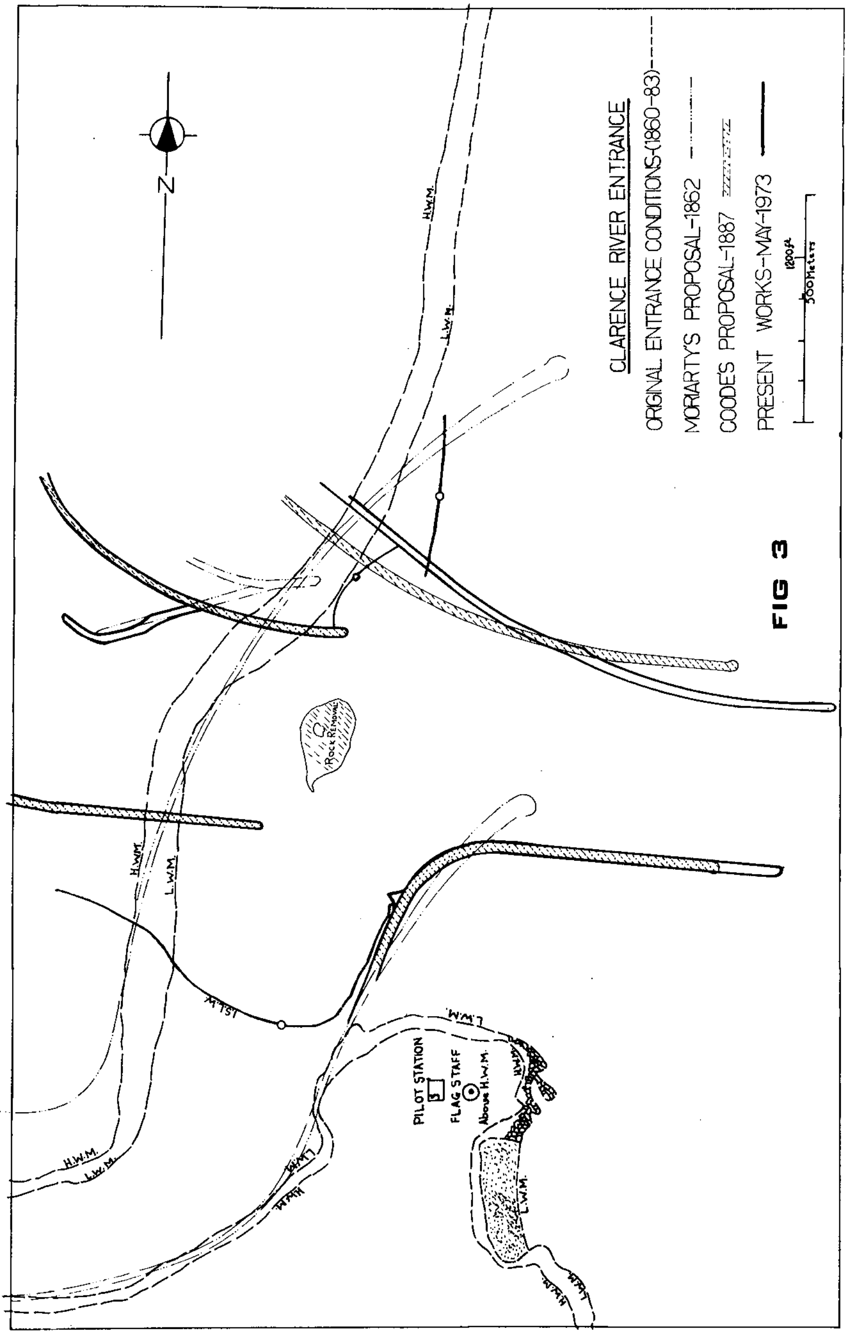

CLARENCE RIVER ENTRANCE
ORGINAL ENTRANCE CONDITIONS-(1860-83)
MORIARTY'S PROPOSAL-1862
COODE'S PROPOSAL-1887
PRESENT WORKS-MAY-1973
1200ft
500 Meters
N
H.W.M.
L.W.M.
ROCK REMOVAL
PILOT STATION
FLAG STAFF
Above H.W.M.

FIG 3

three to six months and quite often monthly).

A rock reef with depths varying from about 23 feet on the south to 8 feet on the north lies between the ends of the old internal training walls. This reef is irregular and causes considerable turbulence at flood and ebb tides as well as during floods. Removal to a depth of about 23 feet below I.S.L.W. over a width of about 500 feet was included in the authorised works but has not been done.

Construction started on the northern jetty and when it reached a distance of 2,150 feet seaward of the end of the old southern training wall (for convenience and also as an approximate indication of effective change in entrance geometry the end of the old southern training wall has been used as a reference point in this paper) work then transferred to the southern jetty which was constructed to an effective length of 2,750 by July, 1964. As this stage work again transferred to the northern jetty and it was extended to its final length of 3,950 feet seaward of the reference point by November, 1968. The final stage was the extension of the southern jetty to an effective length of 3,800 feet by July, 1971.

The old internal training walls had been constructed with centre lines 1450 feet apart at their seaward ends. The new jetties commenced in 1956 were to be 1450 feet apart.

In 1964 an assessment of tidal flow was first made. This indicated that the jetty spacing as authorised would not result in a channel depth of 20 feet below I.S.L.W. if tidal flow was distributed evenly between the jetties. A spacing of 1,200 feet centre to centre was then adopted as a compromise between navigation and flood needs.

4. RESULTS OF WORKS

(a) Bar Formation

Early surveys from 1860 to 1883 show bar depths of from 12 feet to 15 feet below a low water datum (exact definition not known). The alignment of the entrance was due north as shown in fig. 4. Internal channels had ruling depths of about 14 feet.

The original scheme did not progress sufficiently to draw any conclusions on its effects.

The works carried out under the 1889 proposal improved the internal channel depths and alignment and resulted in a stable mouth which was now aligned almost due east. A Symmetrical bar formed with a natural depth of 12 feet below I.S.L.W. see fig. 5. Flow patterns through the entrance were irregular, a result of the reef between the ends of the walls and of the alignment of the internal channels.

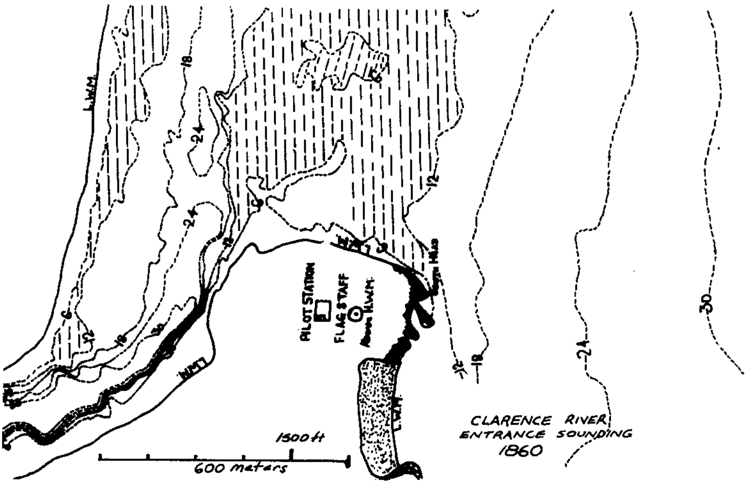

PILOT STATION
FLAG STAFF
CLARENCE RIVER
ENTRANCE SOUNDING
1860
1500 ft
600 meters

FIG 4

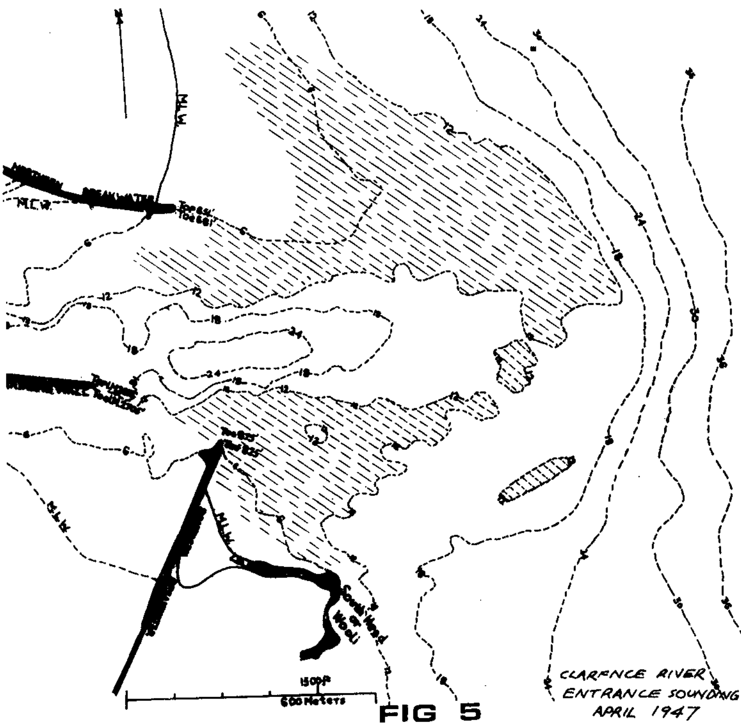

CLARENCE RIVER
ENTRANCE SOUNDING
APRIL 1947
1500 ft
600 Meters

FIG 5

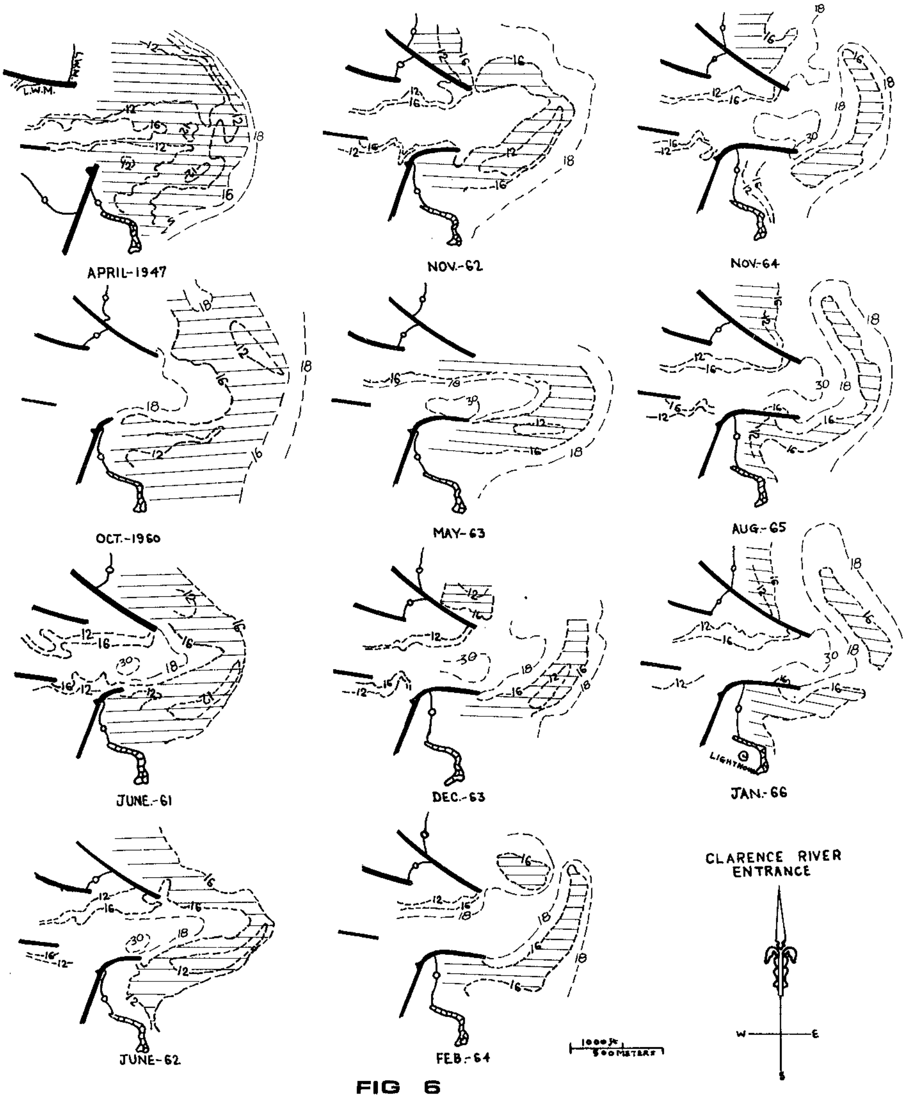

APRIL-1947
NOV.-62
NOV.-64
OCT.-1960
MAY-63
AUG.-65
JUNE.-61
DEC.-63
JAN.-66
JUNE-62
FEB.-64
CLARENCE RIVER ENTRANCE
L.W.M.
LIGHTHOUSE
1000 ft
500 METERS
W
E
S

FIG 6

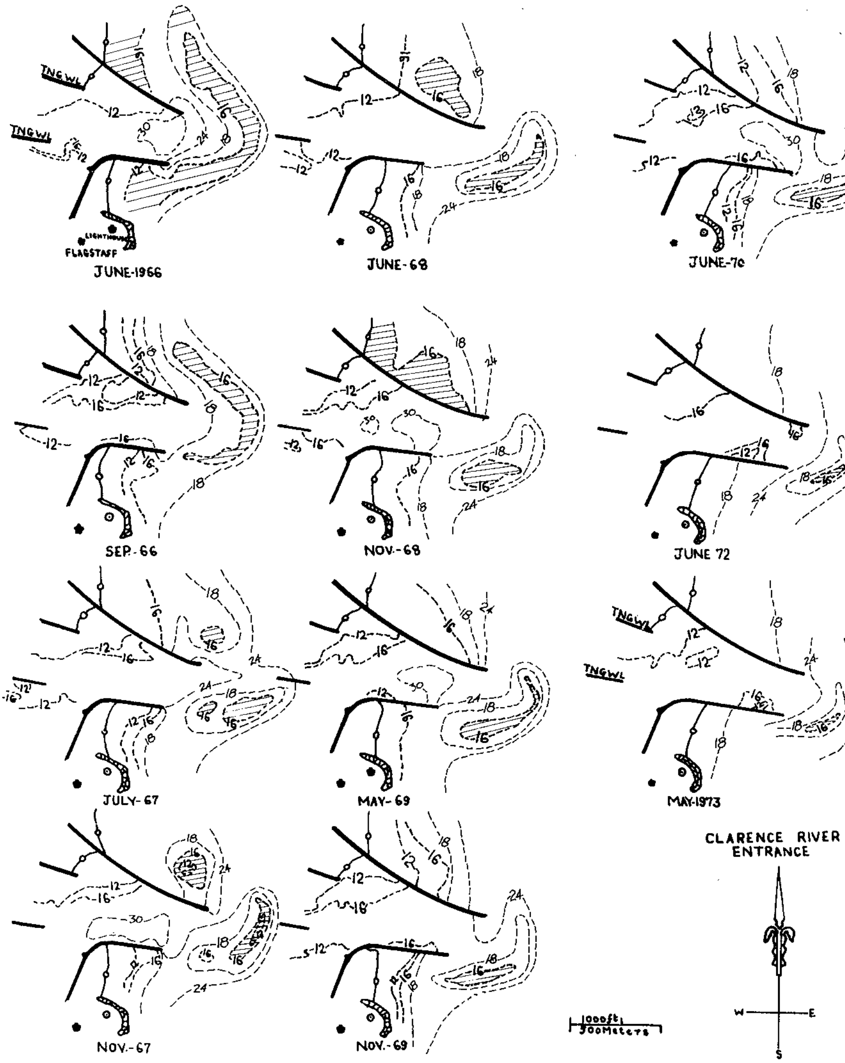

TNGWL
LIGHTHOUSE
FLAGSTAFF
JUNE-1966
JUNE-68
JUNE-70
SEP.-66
NOV.-68
JUNE 72
JULY-67
MAY-69
MAY-1973
NOV.-67
NOV.-69
CLARENCE RIVER
ENTRANCE
1000ft
300Meters
W
E
S

FIG 7

In the period 1956-1959 the northern jetty was built to a point of 2,150 feet seaward of the reference line referred to earlier. At this stage the bar depth was unchanged but the bar was in the form of an isolated shoal with deeper water between the shore and its two ends. The bed of the small bay between the entrance and Wooli Head had deepened by about 10 feet - see fig. 6.

From 1960 to 1965 the northern jetty length was unaltered and the southern one was constructed to 2,750 feet from base. The alignment of the inshore section of the south wall is such that it did not affect ebb flow through the entrance until mid-1961 when its effective length changed from nil to 1,400 feet in a few months. Shortly afterwards the bar became asymmetrical and could almost be considered a half bar (figure 6). This condition continued until mid-1964 when the two jetties projected equal distances and the bar again became symmetrical. The bar was again in the form of a crescent shoal with deeper water shoreward of each end.

With further extension of the northern jetty the bar remained symmetrical until the northern jetty was about 1,200 feet beyond the southern. The bar then again became asymmetrical. Further lengthening of the southern jetty did not alter this and the work ceased in 1970 with the northern jetty 3,950 feet and the southern jetty 3,800 feet seaward of the base line. The last survey in 1973 showed no marked change - see fig. 7.

(b) Bar Movement

Bar movement seems to have been strongly related to at least two factors :-

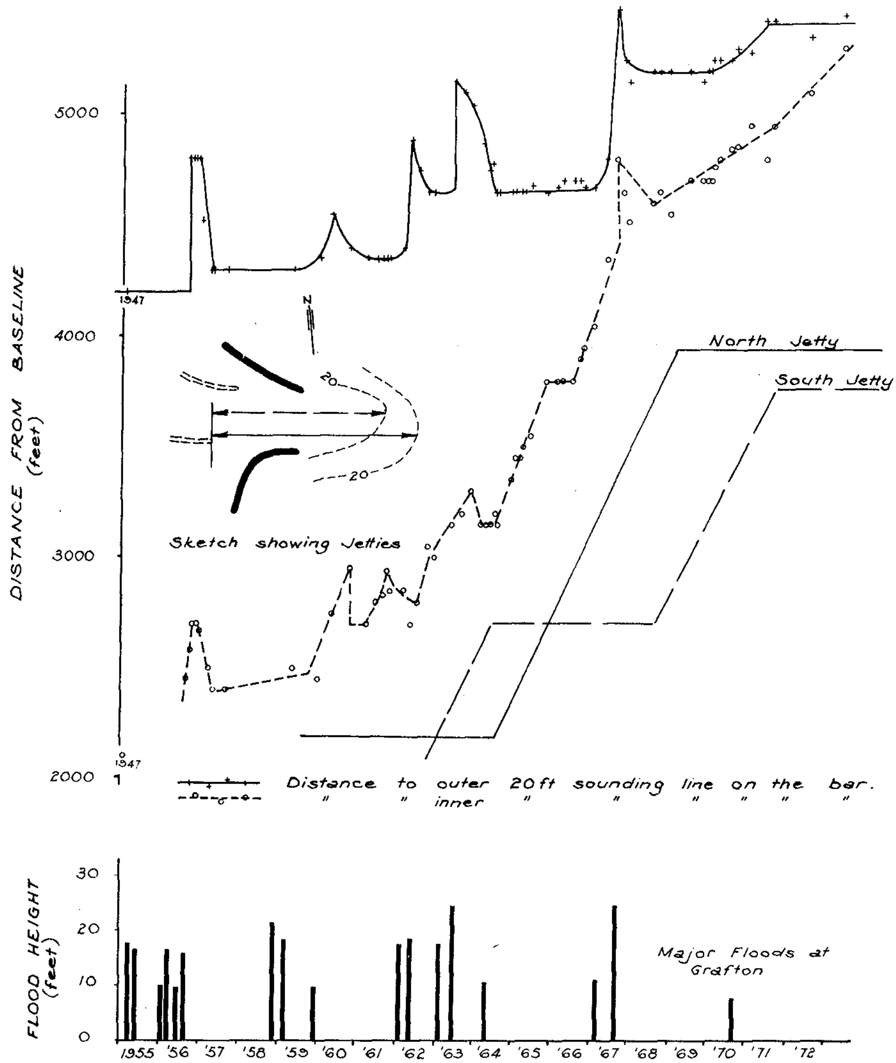
1. The seaward advance of the jetties

2. The occurrence of floods

Referring to fig. 8, the solid line is a plot of the distance from the end of the southern internal training wall to the seaward extremity of the outer 20 ft. contour of the bar. The broken line is a similar plot for the inner 20 ft. contour. The progress in construction of the entrance jetties is also shown from the same baseline.

On the whole it can be seen that the construction of the entrance jetties to a length of approx. 3900 ft. has caused the outer face of the bar to advance seawards by 1000 ft. and the inner face to advance seawards by 2600 ft. The result has been a progressive decrease in width across the bar.

The abrupt peaks on the graph correspond to the occurrence of



5000
4000
3000
2000
1947
1947
DISTANCE FROM BASELINE (feet)
North Jetty
South Jetty
Sketch showing Jetties
20
20
Distance to outer 20 ft sounding line on the bar.
" " inner " " " " " "
30
20
10
0
FLOOD HEIGHT (feet)
Major Floods at Grafton
1955 '56 '57 '58 '59 '60 '61 '62 '63 '64 '65 '66 '67 '68 '69 '70 '71 '72
YEAR

FIG 8

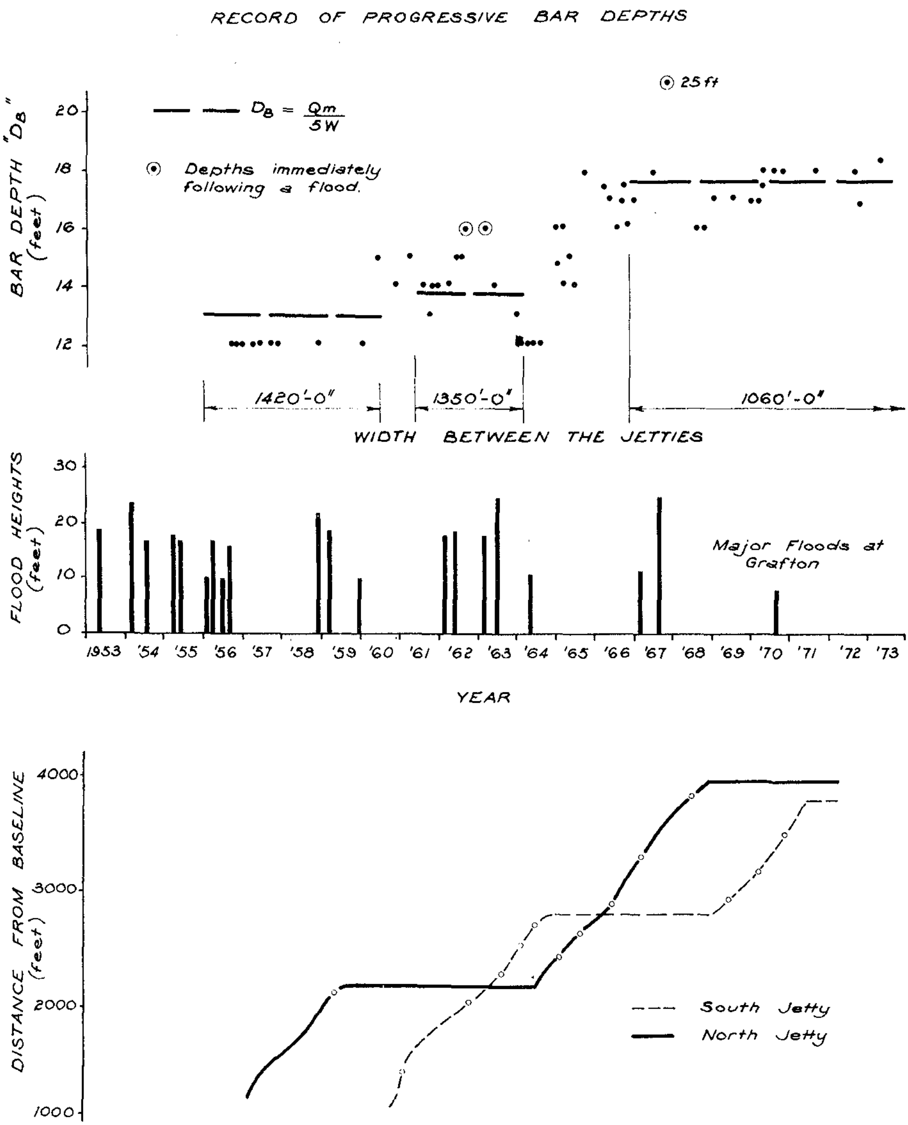

RECORD OF PROGRESSIVE BAR DEPTHS
BAR DEPTH "D_B" (feet)
$D_B = \frac{Qm}{5W}$
Depths immediately following a flood.
25 ft
1420'-0"
1350'-0"
1060'-0"
WIDTH BETWEEN THE JETTIES
FLOOD HEIGHTS (feet)
Major Floods at Grafton
1953 '54 '55 '56 '57 '58 '59 '60 '61 '62 '63 '64 '65 '66 '67 '68 '69 '70 '71 '72 '73
YEAR
DISTANCE FROM BASELINE (feet)
South Jetty
North Jetty

FIG 9

a major flood in the river. During each flood sand in quantities up to 0.6 million cubic yds. (N.B. volumes are discussed under (d)), were deposited on the seaward face of the bar thereby causing it to advance seawards as much as 700 ft. Scouring of the inner face of the bar occurred but the advance was seldom more than half that of the outer face.

During the 12 months immediately after each flood, the outer face of the bar retreated to a new equilibrium position compatible with the position of the advancing jetties. After this 12 month period of adjustment the outer face was very stable and showed very little tendency to move.

(c) Bar Depth

In a paper presented at the 1968 Coastal Engineering Conference (ref. 1) an empirical relationship for prediction of bar depths was derived from results of other river training works.

This was in the form :

$$D_B = \frac{Qm}{5W}$$

where D_B = depth over bar saddle measured below the surface when maximum ebb flow occurs for a tide of mean spring range.

Qm = Maximum ebb flow for that tide channel.

W = Surface width when Qm occurs (all measurements in feet).

In figure 9, D_B is compared with measured bar depths (depths measured below water level for maximum flow during a tide of mean spring range, i.e. 1 foot above I.S.L.W.).

With a full semi-circular bar the depth is taken as the best depth over the bar saddle. With a "half" bar the depth is taken on the centre line of the ebb flow as indicated by bottom contours.

The correlation between bar depth and channel depth found on other entrances could not be checked here because of the turbulence resulting from the reef formation near the ends of internal walls. The bottom contours at all times were very irregular between the jetties.

During the first stage of construction whilst the northern jetty was being built to 2,150 feet the bar was consistently at a depth of 12 feet or 1 foot less than calculated D_B. In the second stage whilst the southern jetty was being constructed to 2,750 feet bar depths fluctuated between 16 feet and 13 feet. It returned to a depth of 12 feet for a short period as further lengthening of the northern jetty was started. Calculated D_B was 13.75 feet at this time.

With further extension of the northern and southern jetties to their final length bar depths were generally between 0.6 and 1.6 feet less than the calculated value of D_B.

Since the work stopped bar depths have been consistently 0.4 feet deeper than calculated D_B.

The period when bar depths are less than predicted D_B are when the northern jetty projects beyond the southern.

Depths appreciably greater than predicted occur from the time the works first reduced the entrance width until the final width was established.

Such consistent increases in bar depths as occurred followed reductions in the effective width of the channel.

The comparatively small variation in bar depths from the predicted ($\pm$ 1 3/4 ft. neglecting short term increases in depth due to local guttering by floods) is probably due to the slow rate of construction and the long pauses whilst jetties were brought up to equal lengths. Usually bar depths of as much as twice the predicted can be expected during construction.

(d) Sand Volume

Within the limitations of early surveys, it appears that the volume of sand in the bays to the south of the river mouth, the bar, and the adjacent beaches and dunes has not significantly altered between 1860 and 1960. That is to say the early training works simply re-distributed the entrance bar and shoal with very little change in overall sand volumes.

The results of detailed volume calculations for the period 1962-1972 are shown in fig. 10. The volumes were calculated within a control area bounded by a line joining the ends of the internal training walls, the 42ft. sounding line, 1600 ft. of Iluka Beach to the north and 800 ft. of Yamba Beach to the south.

It can be seen that floods have supplied sediment in quantities up to 0.6 million cubic yards during any one year of floods. The total supply of sediment during 62/72 period was 1.5 million cubic yards.

VOLUME CHANGES ON THE
CLARENCE RIVER BAR

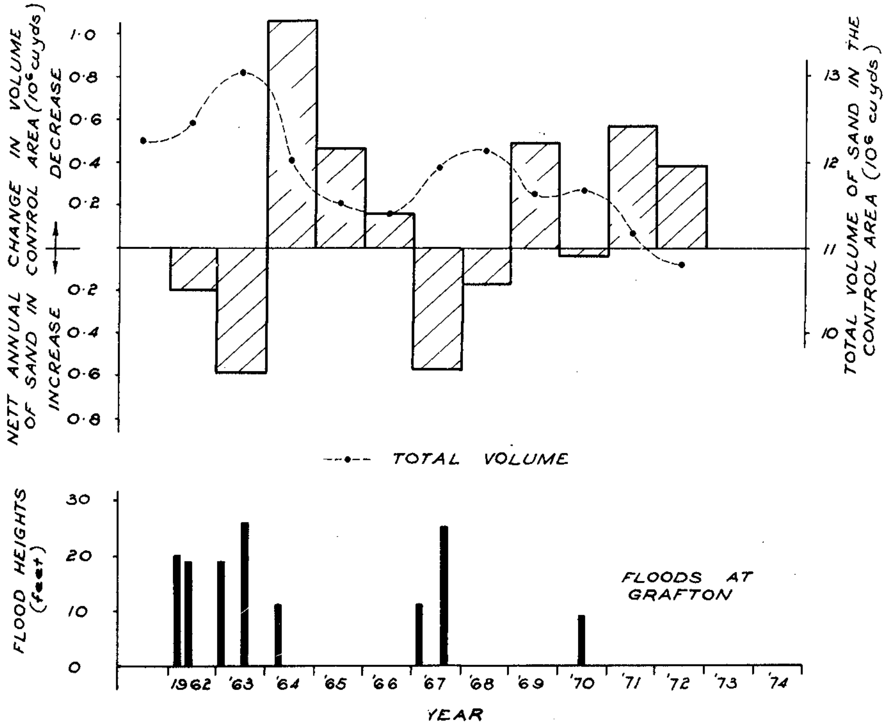


FIG 10

The rate of removal of sediment from the bar system by littoral agencies was greatest immediately following periods of deposition. The maximum loss occurred in 1964 when approx. one million cubic yards was removed from the control area. The gross removal of sediment during the 62/72 period was 3.0 million cubic yards.

There has been some accumulation of sand on Yamba Beach and on the new beach between Wooli Head and the southern jetty. This, however, has been accompanied by a compensatory deepening immediately seaward.

It appears, therefore, that the small littoral drift from the south is deflected by Yamba Head and either enters the bar exchange system to eventually pass to the north or even passes around the bar.

Volume calculations have not been sufficiently extensive to trace the path of the sediment removed from the bar. It is strongly suspected that the majority has moved northwards up the coast.

5. CONCLUSIONS

The results of entrance jetty constructions over a period of sixteen years on this river confirm that bar depth can be related to tidal flow and channel width and is independant of jetty length. It follows that entrance jetties should not be any longer than is necessary to move the bar outside the beach system so that it may be reasonably stable.

In this case jetties just long enough to transition smoothly to the required width would have produced the same bar depth. Possibly because of the sheltered position it might have been possible to obtain a satisfactory result with modification to the existing training walls.

Floods have been an important factor in the behaviour of the Clarence River bar. While the inner face of the bar responded to construction of the entrance jetties by progressively moving seawards, it was found that floods were the necessary catalyst to bring about movement of the seaward face. There is an inference here that if construction of the jetties had been carried out at a considerably greater rate, the bar would have been eliminated for a time until re-established by flood and littoral deposits.

The decrease in sand volume around the entrance would lead to the expectation that with a return of a period of more regular floods, the bar formation will cease to be that of a "half bar" and again assume a semi-circular shape.

TABLE 1

DATE MONTH	YEAR	EFFECTIVE JETTY LENGTH IN FEET* SOUTH	NORTH	DISTANCE TO 20' CONTOUR INNER	OUTER	EFFECTIVE CHANNEL WIDTH IN FEET AT EBB FLOW MAX.	BAR DEPTH IN FEET AT MAX. EBB FLOW MEAN SPRING RANGE
	1947	-	-	2100	4200	1420	12
Aug.	1956	-	-	2450	4800	-	12
Sept.	do	-	2150	2580	4800	-	12
Oct.	do	-	-	2700	4800	-	12
Nov.	do	-	-	2700	4800	-	12
Dec.	do	-	-	2670	4530	-	12
Mar.	1957	-	-	2500	4300	-	12
April	do	-	-	2400	4300	-	12
Aug.	do	-	-	2400	4300	-	12
April	1959	-	-	2500	4300	-	12
Dec.	do	-	-	2450	4350	-	12
April	1960	-	2200	2750	4550	1420	15
Oct.	do	-	2200	2950	4400	-	14
Mar.	1961	1400	2200	2700	4350	1350	15
June	do	1500	2200	2800	4350	-	14
Aug.	do	-	-	2880	4350	-	13
Sept.	do	-	-	2940	4350	-	14
Oct.	do	-	-	2850	4350	-	14
Feb.	1962	1900	2200	2850	4400	-	14
April	do	-	-	2700	4890	-	15
June	do	-	-	2800	4750	-	15
Sept.	do	-	-	3050	4650	-	15
Nov.	do	2100	2200	3000	4650	-	16
May	1963	-	-	3150	5150	-	16
Aug.	do	2250	2200	3200	5100	-	14
Dec.	do	-	-	3300	5040	-	13
Feb.	1964	2550	2200	3150	4875	1350	12
April	do	-	-	3150	4750	-	12
May	do	-	-	3150	4785	-	12
June	do	2700	2200	3200	4650	-	12
July	do	2700	2200	3150	4650	-	12
Nov.	do	-	-	3350	4650	-	16
Dec.	do	-	-	3450	4650	-	16
Feb.	1965	2750	2450	3450	4650	-	14
Mar.	do	-	-	3500	4650	-	15
May	do	-	-	3550	4680	-	14
Oct.	do	2750	2650	3800	4650	-	18
Jan.	1966	2750	2750	3800	4670	1100	17½
Mar.	do	-	-	3800	4700	-	16
June	do	-	2850	3800	4700	-	16
Aug.	do	-	-	3900	4700	-	17
Sept.	do	-	-	3950	4650	-	16
Dec.	do	-	3150	4050	4650	1060	17
April	1967	-	-	4350	4800	-	18
July	do	-	3550	4800	5480	-	25
Sept.	do	-	-	4650	5250	-	-
Nov.	do	-	-	4520	5150	-	-

TABLE 1 (cont.)

DATE		EFFECTIVE JETTY LENGTH IN FEET*		DISTANCE TO 20' CONTOUR		EFFECTIVE CHANNEL WIDTH IN FEET AT	BAR DEPTH IN FEET AT MAX. EBB FLOW MEAN
MONTH	YEAR	SOUTH	NORTH	INNER	OUTER	EBB FLOW MAX.	SPRING RANGE
June	1968	-	3850	4580	5200	-	16
Aug.	do	-	-	4650	5200	-	16
Nov.	do	2800	3950	4680	5200	-	17
May	1969	2950	-	4700	5200	-	17
Sept.	do	-	-	4700	5150	-	16
Nov.	do	3150	-	4700	5200	-	17
Dec.	do	-	-	4700	5200	-	17
Jan.	1970	-	-	4770	5250	-	
Mar.	do	-	-	4800	5250	-	18
June	do	3350	-	4850	5250	-	18
Aug.	do	-	-	4860	5300	-	18
Dec.	do	-	-	4950	5280	-	18
May	1971	-	-	4800	5430	1060	18
July	do	3800	3950	4950	5430	-	18
June	1972	-	-	5100	5350	-	18
May	1973	-	-	5200	5450	-	18½

NOTE : * from baseline through end of south training wall.

6. ACKNOWLEDGEMENTS

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The junior author would like to acknowledge the contribution to and inspiration for this paper by the late C.D. Floyd.

7. REFERENCES

1. "RIVER MOUTH TRAINING IN NEW SOUTH WALES" C.D. FLOYD, 1968 CONFERENCE COASTAL ENGINEERING.