CHAPTER 73

STUDY OF TOPOLOBAMPO'S BAY, MEXICO, ENTRANCE

by

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SUMMARY

Brief examination of the geomorphological background of the Topolobampo's bay inlet is made

A theoretical study of the inlet and spits, based on field data such as wind, waves, tides, currents, bathimetric charts from 1875 to 1965, was developed in order to determinate the most convenient position of an experimental channel dregged on 1963.

Radioactive tracer studies, photographic and periodical surveys of the inlet and the channel gave the information for the design of the definitive channel, which at present is behaving in accordance with the predicted way in the theoretical study

INTRODUCTION

The economical needs of the northwest of Mexico have led to the conclusion that a port is required at Topolobampo Bay.

1 Consulting Engineers

The main problem to establish the port has been the existence of a bar at the entrance of the bay The study of such problem started in 1952 and several solutions have been given, most of them, considering the use of jetties, but these being so long, the solution have always been an economic obstacle for the port

With hat thought in mind, this study has been carried out, with the purpose of finding a solution based on a dredged channel across the bar, which has to be hept by small works or maintenance dredging

I GEOMORPHOLOGICAL BACKGROUND

Topolobampo Bay is located at the northwest of Mexico (fig 1), it has an approximate area of 48 85 km^2 and also has several shallow zones and secondary inlets It is communicated with the Gulf of California through an inlet with a width of 4 5 km which is limited at its ends by two sandy spits called "Punta Copas" and "Punta Santa María" Tnere are two perfectly defined channels, the main one that covers the whole bay with NE-SW direction up to "Punta Copas" where it changes to an E-W direction, up to Santa María where the second channel, called Lechuguillas, joins it This letter channel is communicated with San Esteban Bay located in the northern zone From there the inlet channel is formed with a S-SW direction

Topolobampo Bay is communicated with Ohuira Bay by a narrow and deep pass (30 m) The letter bay with an extension of 148 00 km^2 is a very important factor in the bar's dynamics due to the great tidal prism generated by it

The present shape is due to an evolution of the "Rio Fuerte" delta, whose first mouth combined with volcanic action, remolded a great part of Topolobampo and Ohuira bays (1)

Latest processes determined an emigration of the mouth towards the North, and its old delta continued as the main source for the litoral barriers that limit San Esteban, Topolobampo and San Ignacio bays At the present time the "Rio Fuerte" continues as the main source of beach material

Due to the wave characteristics acting in the zone as well as the induced currents produced by flood and ebb of the tide, a sandy bar has been formed at the bay's entrance, with a length of 12 Km , a width of 2 Km and a depth of 2 3 m in a shape of a horse shoe, that joins "Punta Santa María" and "Punta Copas"

2 WINDS, WAVES, TIDES AND CURRENTS

2 1 Winds.

The prevailing and strongest winds come from the WNW, their main influence is the formation of seas which act from October to May, and from June to September there are others that produce swells from the SE The effect of both of them on the wind transport is of a secondary importance (2)

2 2 Waves.

Table 1

Type	Direction	$H_{1/3}$ (m)	T (sec)	Acting Time hr/year
Sea	WNW	1.25	5	3720
Swell	S30W	0 9	12	480
Swell	SSE	0.9	12	840

2.3 Tides

They are of the mixed type with a mean range of 0 826 m. and a spring tidal range of 1 80 m They were recorded simultaneously at four points in order to relate them with the observed currents (fig 1)

2 4 Currents

The tidal currents are significant at the main chamel (3) being the mean maximum velocity of 1 2 m/sec

From the field measurements it was obtained the following descharges distribution in everyone of the section indicated in fig. 2 and table 2 (4).

Table 2

1 Phase	2 Amplitude m	3 Section I	4 Section II	5 Section I+II	6 100 5/o-
Flood	1 25	66%	33 8%	99 8%	0 2%
Ebb	1.31	44%	31.6%	75 6%	24 4%
Flood	1.128	62%	28.7%	90 8%	9 3%
Ebb	1 037	51%	38 2%	89 2%	10.8%

Discharge in Section III = 100%

Column 3 shows that at Lechuguilla Inlet $Q_{flood} = Q_{Ebb}$

Column 4 shows that the shallow zones have a considerable regulation effect.

Column 6 gives us an idea of the regulation capacity of the shallow zones.

3. LITTORAL DRIFT

The studies of grain sizes carried out in the bay as well as in the bar showed the presence of fine sand with a mean diameter ranging from 0.25 mm to 0.125 mm with a very good distribution

On the bar there are two defined types of sediment transport

3.1. Shoreward transport.

Produced by the swells that with their incidence almost normal to the shoreline and the bar itself as well as their length and period induce a transport towards the bar

3 2 Littoral transport

Due mainly to waves with a short period which effect is located at both littoral barriers.

The analysis of these data lead to the computation (4), (5), that the littoral drift along the bar, in the zone in which it was gaing to be dredged, the channel was of the order of 360,000 m^3/year. Larras, Pychkine and Manohar criteria were used (fig 3 and 4)

3.3 Suspended transport

Suspended transport measurements were made at the different velocity control sections, and it was found that the amount of suspended transport varies from 0 mg/lt up to 15 5 mg/lt, depending on the current velocity and the sections of study, being the maximum recorded values taken at the channel zone, finding out that at 6 m. depth and a velocity of 0 60 m/sec, the transport was 10 mg/lt, on the other hand, at 1 m depth in the same zone, it was recorded 5 mg/lt, which leads to the conclusion that its effect is of secondary importance.

4 BAR EVOLUTION FROM 1875 TO 1962

The analysis (4) was made considering the variations of the centroidal axis of the bar in order to study its movements in a plan view as well as in elevation (Fig 5)

It was observed that

a Between 5° and 45° the bar tended to grow seaward, due probably to the channel effect of Punta Copas which dissipates the wave action from the SW. The maximum variation was 1300 metres for 1967

b Between 45° and 75° exists a transition zone, because the bar showed movements towards WNW as well as to the bay, the reason for this behaviour could be the gradual disappearance of high ebb currents, that could appose to the SW waves.

c Between 75° and 120° the bar tendency was to grow towards the bay, due to the wave action in that zone in which there does not exist any definite active of tidal currents. Nevertheless, due to the sand transport diffusion and the channels that limit the zone, the movements are, as an average, 4 times smaller than the ones occuring between 5° and 45°

d. From 127° up to 180° the bar tendency is growing towards the sea in a similar way to the first zone considered above, being the maximum movements between 150° and 165°, which are of the order of 1455 m. for 1962. This is due to the fact that some small bars appeared as a result of the littoral drift from the WNW and the veryefficient hydraulic groin formed by the main outlet channel.

Depth variations.

Generally speaking, the vertical movements of the bar are not excesive, being up wards as well as downwards, these variations being noticible at radiations 5°, 15°, 75°, 90° and 105° whose maximum relative values are 1.5 m., 1.55 m , 0 70 m., 1 35 m and 1.30 m respectively.

The rest of the zones tend to keep the same depth that in 1875, having small movements upwards as well as down wards The most stable zones are the 45°, 60°, 127°, 130°, 150° and 180°

The mean depth in the bar varies from 3 m. to 4 m , the 3.90 m being the most stable depth which is located between 105° and 120°, the smallest depths are between 15° and 75° with a value of 3 m.

3. EXPERIMENTAL CHANNEL

In 1962, from theoretical results showed in the above pragraphs, the existing zone between 75° and 120° was chosen as the proper place for the dredging of the experimental channel as this had demostrated the maximum stability.

The alignment of the channel was made following the tendency of the natural channel.

The design dimensions were

Bottom width	75 m
Slopes	5 1
Mean depth	7 m

The experimental channel had as a main function the precise evaluation of the littoral drift and hence its maintenance cost In addition the channel would permit the access of small ships to the port.

From the date of its construction, periodical soundings were made, and during a four months period, in 1964, the channel dredging was suspended in order to be able to know if its natural tendency would be its accreation, maintanance or erosion Simultaneously, a radioactive tracer study, was carried out (Fig 6)

The results of the experimental channel can be divided into two groups

Channel behaviour
Effects on the bar.

5.1 Channel behaviour

The amount of littoral drift that reached the channel, recorded in its initial phase, when its efficiency and discharge were still low, was of the order of 320,000 m^3/year (360,000 m^3/year computed) (fig 7) At that time, the mean currents velocities in the channel was 0 4 m/sec. From 1965 in which dredging was practicaly suspended, a tendency to increase the section has been observed In table 3, the results of control soundings are shown, pointing out that in 1966, the channel velocities, for similar tide conditions were of 0 8 m/sec

Table 3

Date		Minimum depth	Maximum depth	Channel mean width at 6 m depth
July	1966	6 15	8 40	50
Aug	1966	6 90	8 65	60
Oct	1956	6 55	8 65	70
Nov.	1966	7 05	8.80	90
Dic	1966	7 10	8.70	75
Feb.	1967	6.95	9 00	100
Mar.	1967	6 80	8 75	115
Apr.	1967	7 35	9.15	130
Jun	1967	7.20	9 20	120
Sept.	1968	8.50	9 85	150

5 2 Effects on the bar

Inmediately after dredging the experimental channel, a big shallow zone started its formation on the NW side of the bar, which was modified by the changes in wave action, but that in general, showned the tendency to increase in size in such away that at present its distance from Punta Santa María is of only 150 m Initially that distance was 1200 m (fig 8)

6 RADIOACTIVE TRACERS INVESTIGATION

During a period of four months in 1964 a radioactive tracers investigation was programmed using a synthetic glass sample with $Ta_2 O_5$ to obtain T_a 182 with a 250 milicurie of activity The tendencies showed by the tracers checked notably with the results of the soundings in the same period of time (fig 7) The accretion tendency observed at that time disappeared when the hydraulic efficiency of the channel was improved

7 RESULTS ANALYSIS AND CHANNEL DESIGN

The analysis of the experimental channel behaviour shows a definite tendency to the increase of tidal currents velocities and hence an increase of the shear stress which represents a channel erosion This effect is favoured by the shallow zones formed, so it can be assumed that the channel tends to an equilibrium state, due to the increase of its hydraulic efficiency when the tidal prism diffusion decreases due to the shallow zone and its concentration into the channel This tendency can be natural or be increased in an artificial way by means of dredging in the channel so that it can acquire a stable section

It is convenient to point out that in the analysed period there was a season (January to March 1967) in which the channel showed a tendency to accretion This tendency corresponded to the forecast made by the computations and radioactive tracer studies, nevertheless, spring tides in April eliminated the accretion (7) continuing in such a way the self dredging of the channel From that date up to now all the dredging work has been abandoned

Providing that for navigation requirements the channel must have a minimum width of 150 m , 11 m depth and construction slopes 5 1 (fig 6), at present a dredging volume of 1,300,000 m^3 is still required

Considering that the mean diameter of the sandy material that constitutes the bar in the channel zone is 0 125 mm , it is required a = 0 36 Kg/m^2 and a velocity of 25 cm/sec (8) in order that the bottom particles start their movements and taking irto accourt that at present, mean maximum velocities have been measured with a value of 0.8 m/sec it is expectable that for spring tides the mean maximum velocity reaches similar values to that existing in the present main channel with a value of 1 m/sec (3)

Therefore, using the mean velocity of 0 8 m/sec. the following results in relation to the self dredging capacity of the channel are obtained

$$\tau = \frac{640}{2020} = 0.315 \ Kg/m^2$$

In accordance with Kalinke's Formula

$$q_s = \frac{10 \ D \ \tau^{5/2}}{\rho^{1/2} D^2 \ \gamma^2 \ (S_s - 1)^2} = \frac{10 \times 0.56}{11 \ 0 \times 125 \times 10^{-3} (1000)^2 (1 \ 6)^2} =$$

$$= \frac{0 \ 56}{3 \ 5 \times 10^3} = 1 \ 6 \times 10^{-4} \ m^2/seg/m.$$

$$Q_s = 1 \ 6 \times 10^{-4} \times 195 = 314 \times 10^{-4} \ m^3/sec$$

$$M_s = 495{,}000 \ m^3/year$$

$$\frac{Ms}{Me} = \frac{495{,}000}{300{,}000} = 1.66 > 1$$

So the section will tend to increase (9) diminishing the shear stress, until the equilibrium between the channel capacity for washing out the accretion and the material transported from the bar is reached.

With the increased values of the velocities observed in the channel zone, it is very feasible that it could reach the value of 1 m/sec, and hence, the required shear stress required for the equilibrium is attained with a much bigger area than the one necessary for navigation purposes.

In other words, the channel in the way it has been designed, will not have any maintenance problems as depth concerns.

CONCLUSION

From the above study the following conclusions are obtained

i The applied theoretical and experimental methods have been checked with nature results.

ii The access channel has a definite tendency to be stable

iii This stable status will be completely attained when, by navigation requirements, the channel gets at least 150 m. of bottom width and 11 m. depth

iv The maintanance dredgings during certain seasons in the year will be small and very well located.

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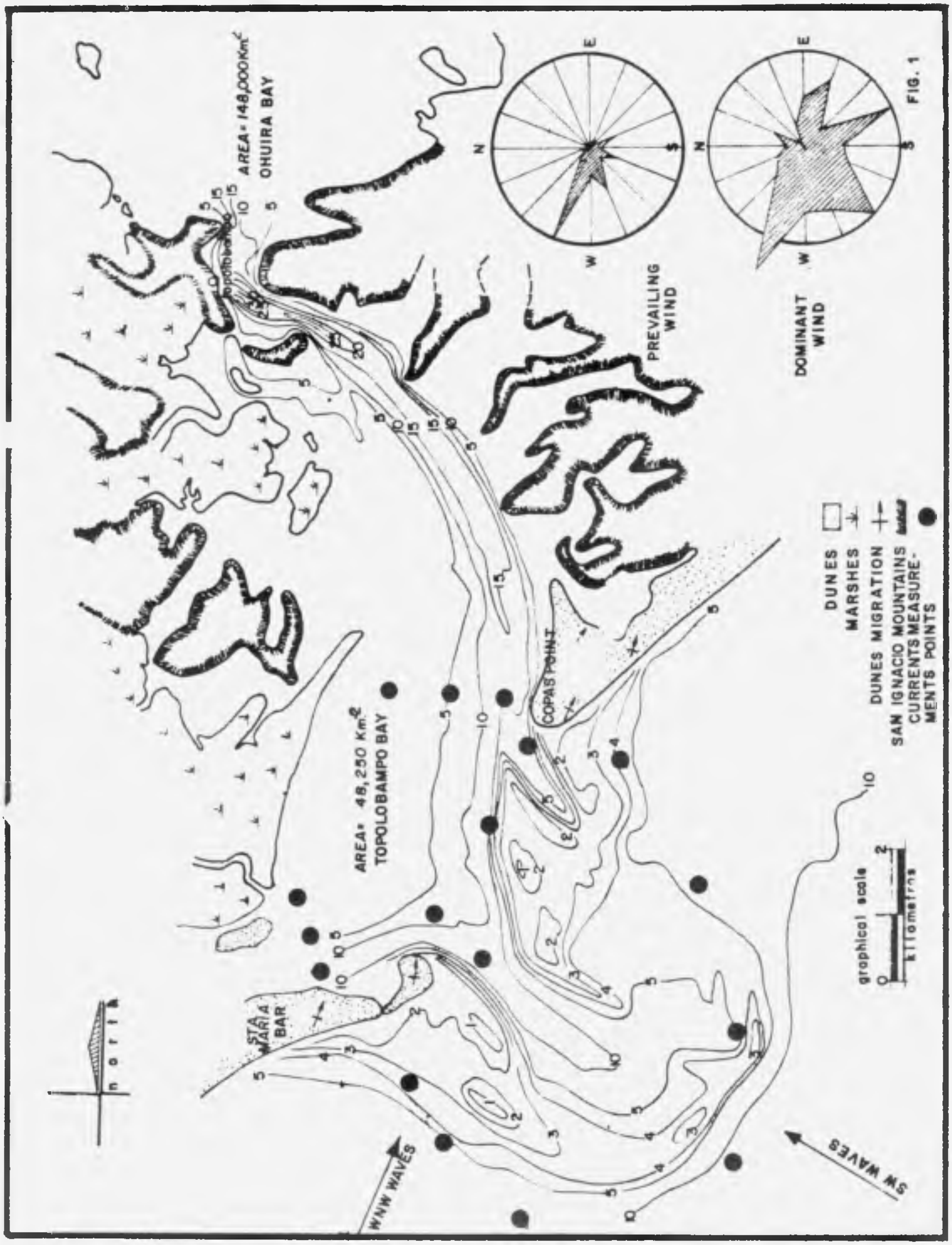
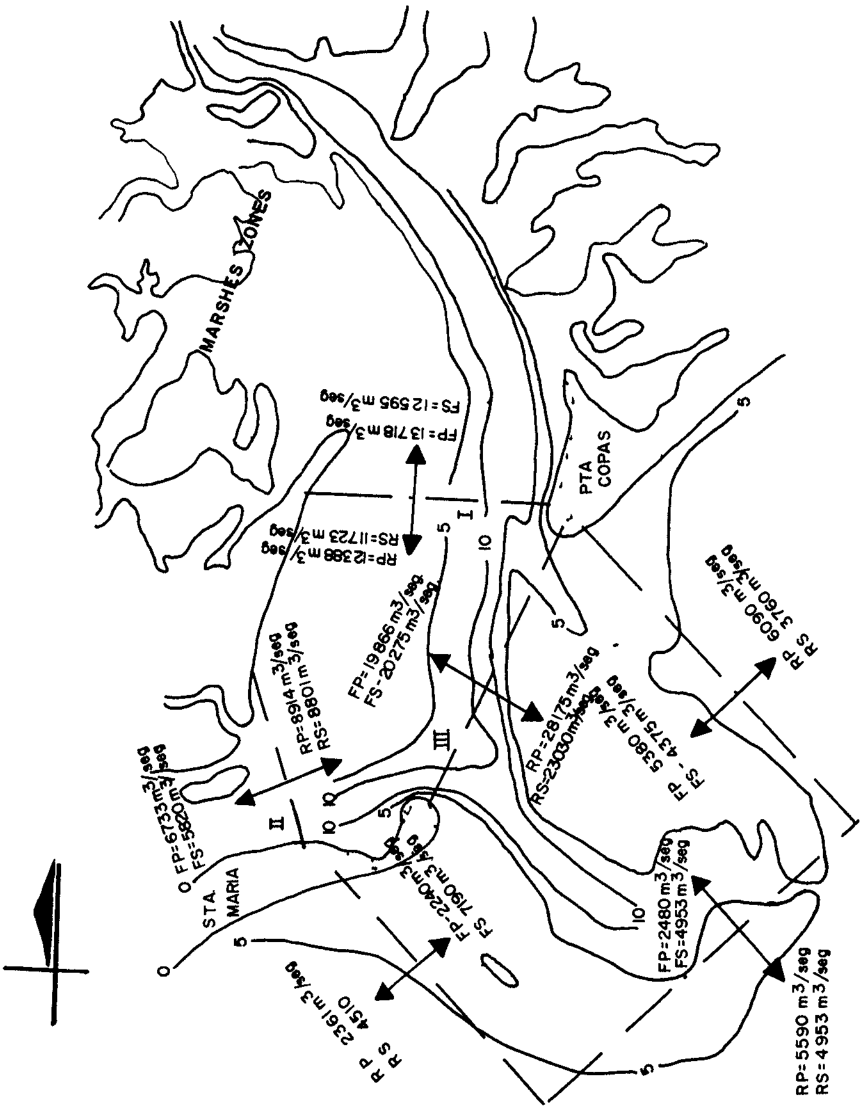

AREA = 148,000 Km²
OHUIRA BAY
AREA = 48,250 Km²
TOPOLOBAMPO BAY
PREVAILING WIND
DOMINANT WIND
COPAS POINT
STA MARIA BAR
WNW WAVES
SW WAVES
DUNES
MARSHES
DUNES MIGRATION
SAN IGNACIO MOUNTAINS
CURRENTS MEASUREMENTS POINTS
graphical scale
kilometres
north

FIG. 1



GENERAL TATTERN OF TIDAL CURRENTS

Fig Nº 2

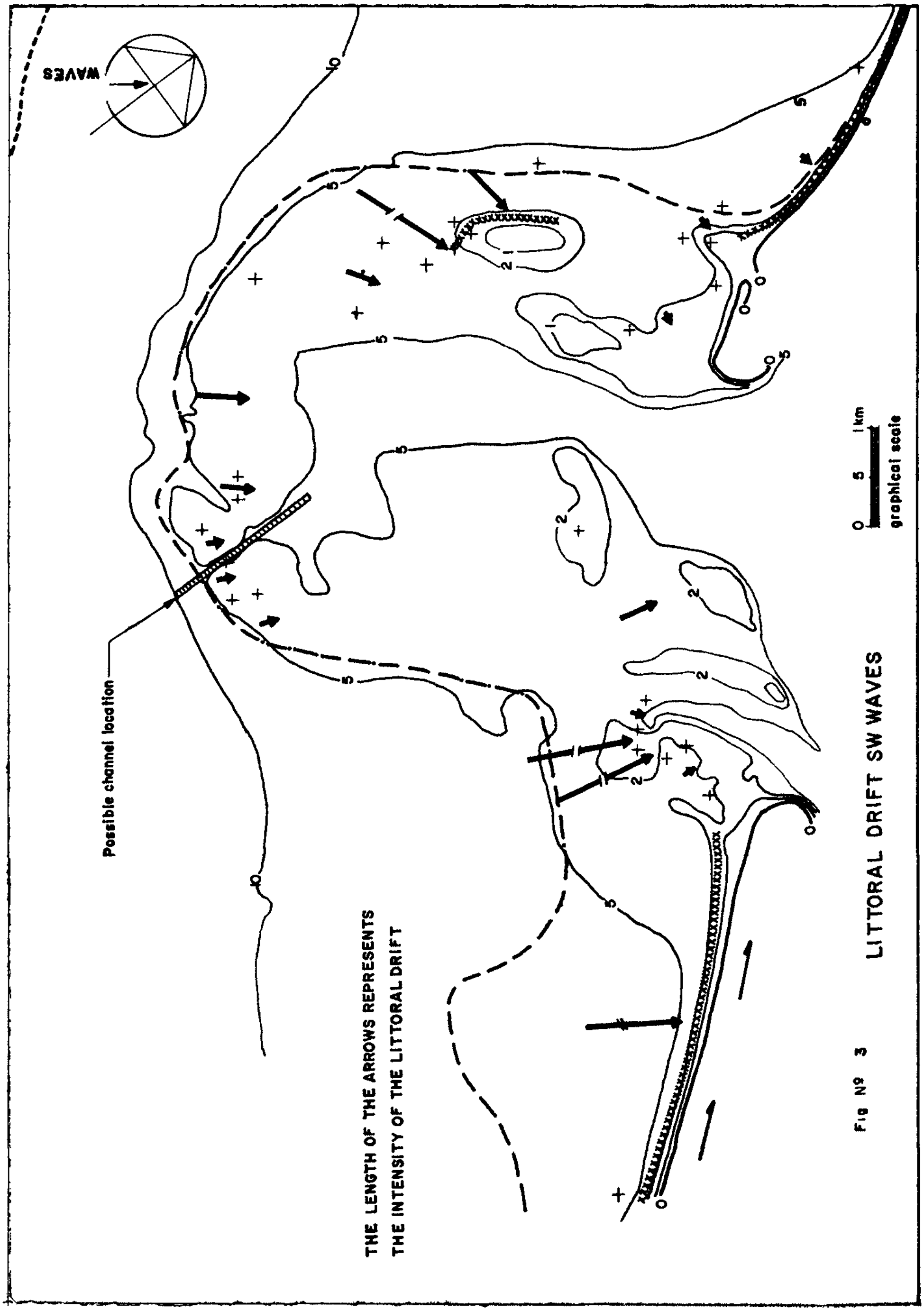
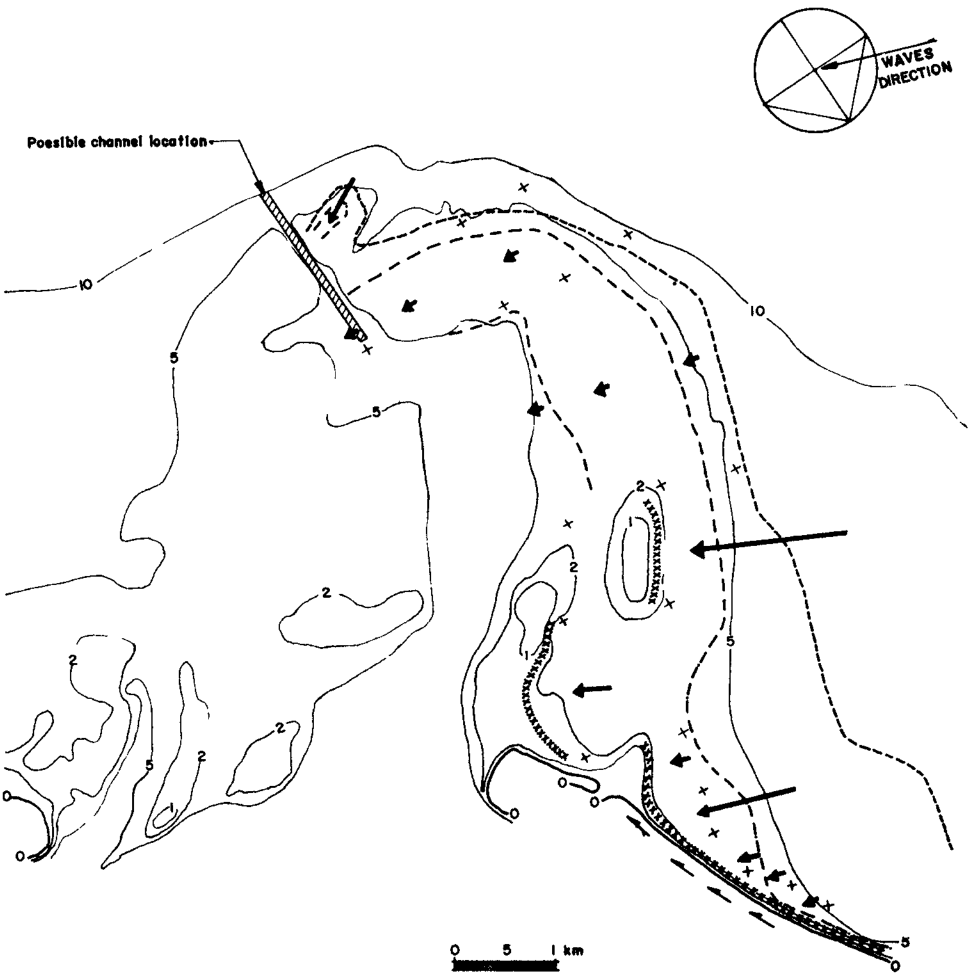
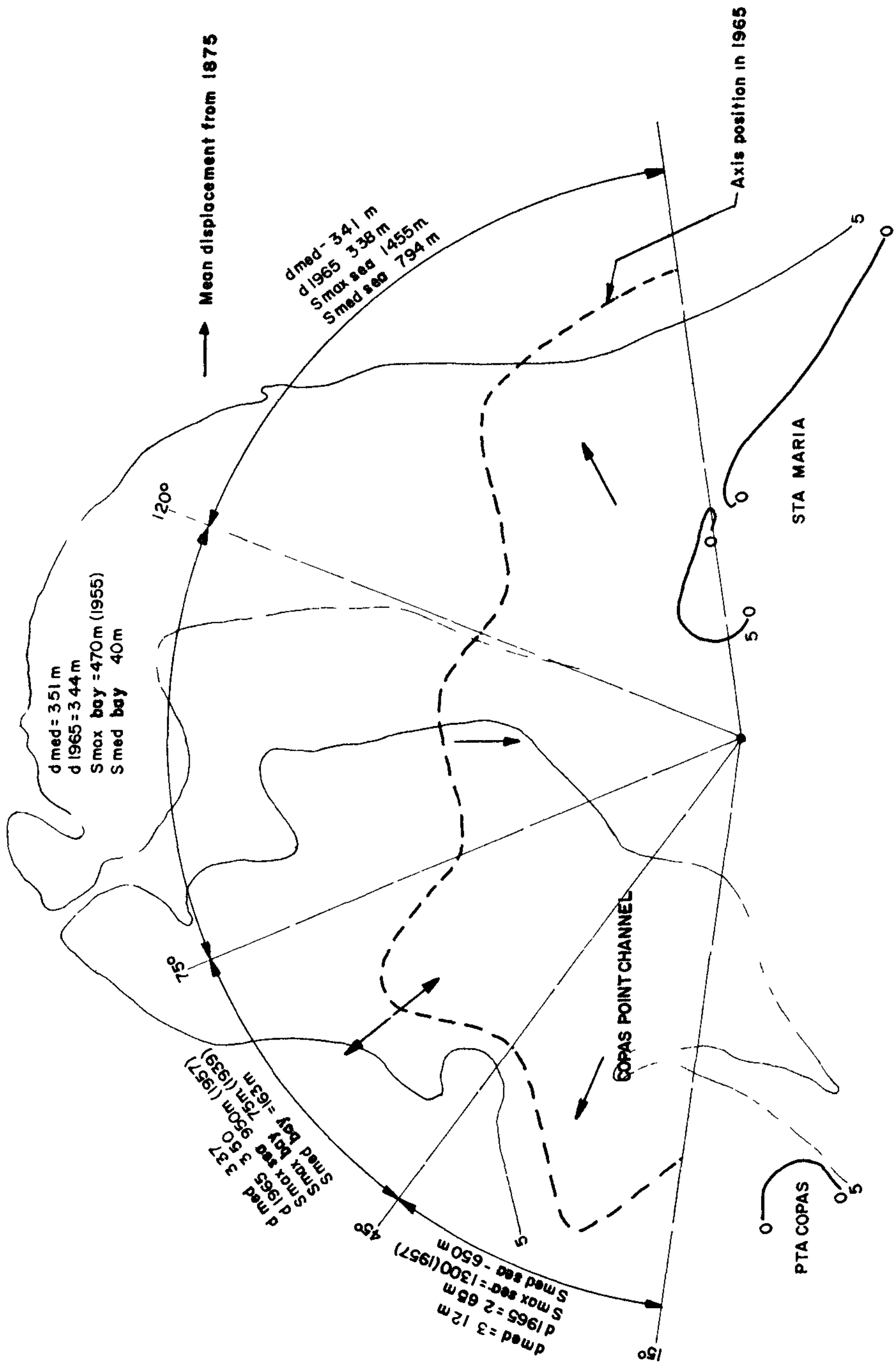


Fig Nº 3 LITTORAL DRIFT SW WAVES



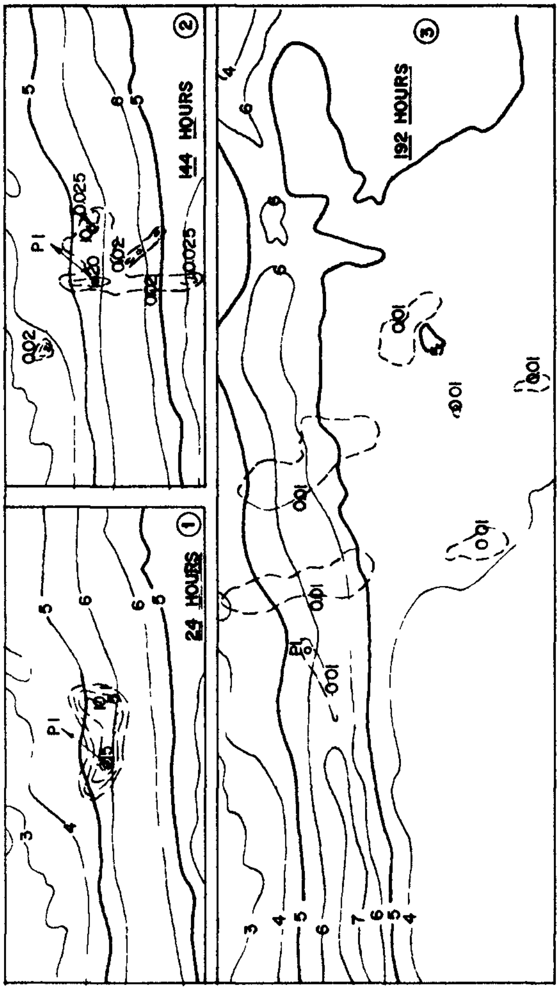
LITTORAL DRIFT WNW WAVES

Fig No 4



CENTROIDAL BAR AXIS VARIATIONS

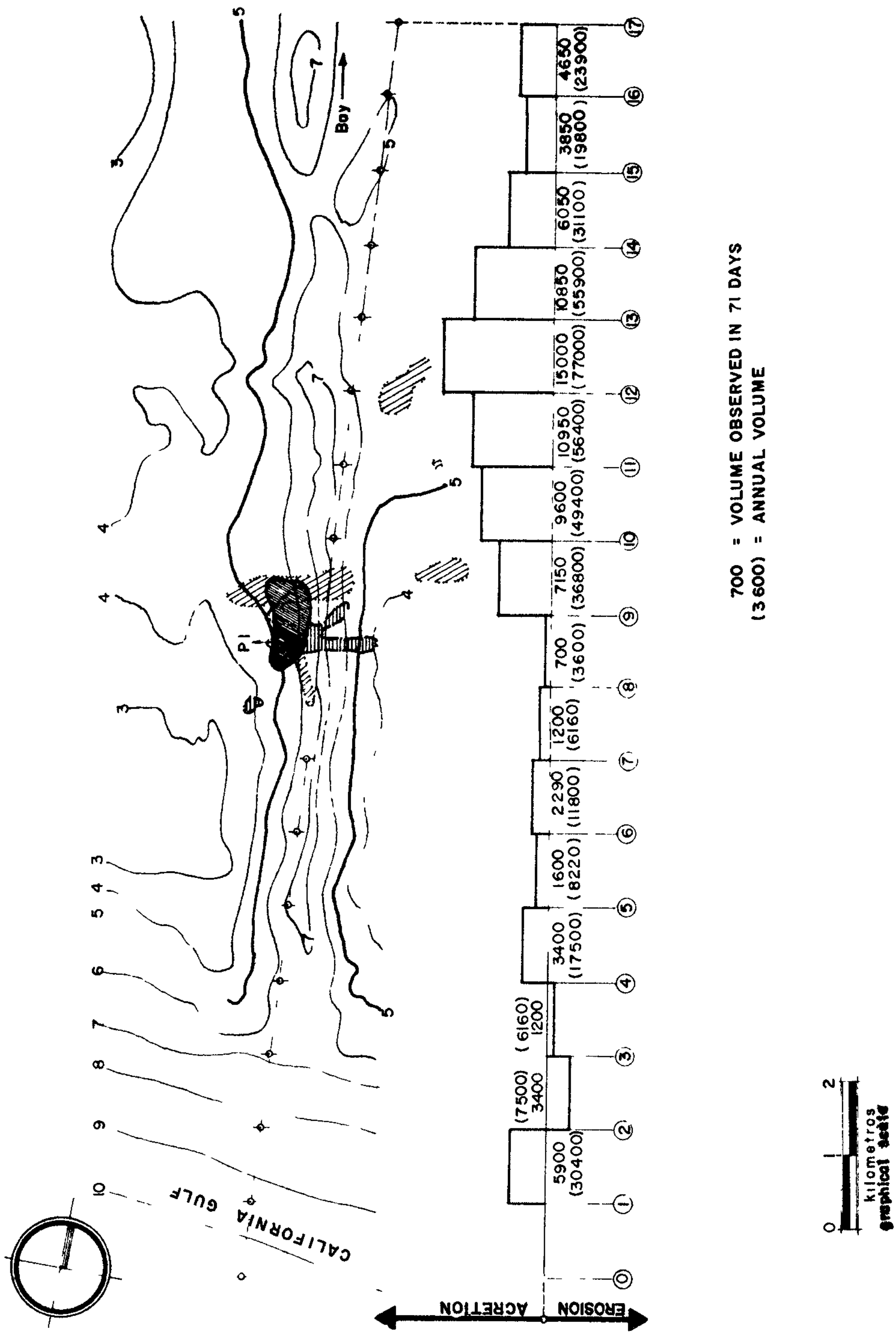
Fig Nº 5



RADIOACTIVE TRACERS STUDY
IN THE EXPERIMENTAL CHANNEL

ACTIVITIES IN MILICURIES
PI = INMERSION POINT

FIG 6



EXPERIMENTAL CHANNEL BEHAVIOUR

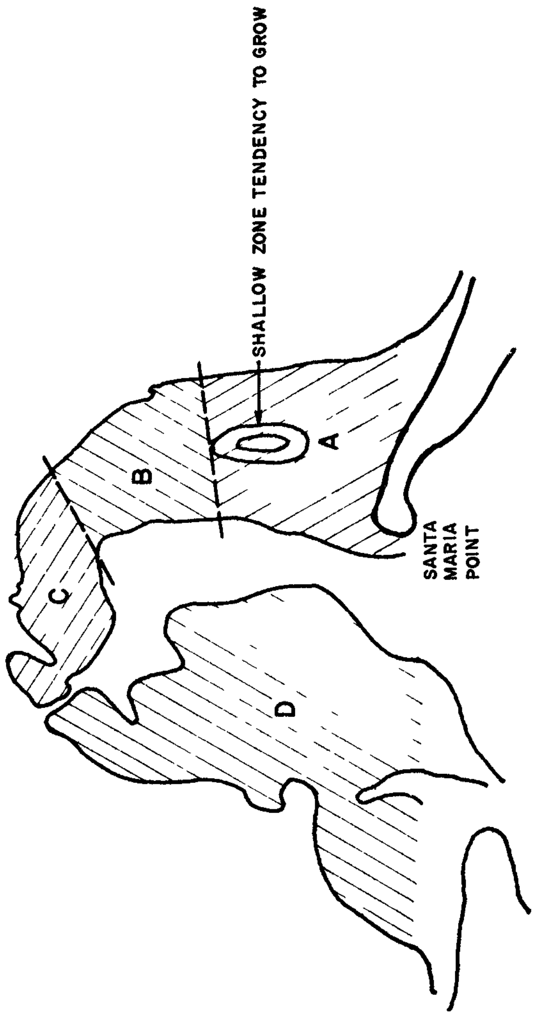


FIG. 8