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PORT MUHAMMAD-BIN-QASIM PROJECT

DETAILED DESIGN REPORT

NAVIGATION CHANNEL DREDGING

DECEMBER 1975

JAPAN INTERNATIONAL COOPERATION AGENCY

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CHAPTER I   SITE CONDITIONS

I-1 LOCATION AND TOPOGRAPHY

The port area of Port Qasim in Pipri site lies approximately 34 km east southeast of Port Karachi, located in Gharo Creek, 26 km inland from the sea coast through Phitti Creek and the upper Kadiro Creek.

Phitti Creek cuts inland from the open sea in the N.NE direction, curves to the N direction around Buddo Island, and further bends to the NE direction 5 km further upstream in the shape of the letter S. Further upstream from Buddo Island to the Kadiro swamps, the distance is approximately 16 km.

In the area in front of the shoreline towards the sea, estuary sand bars are found at depths of about -6 m (-20') along the coast to a distance of about 11 km offshore. (Refer to Dwg.-1).

1. Approach Channel

The water depth at the entrance of the channel in the open sea section is -13.5 m. In the outer Approach Channel extending from 2.0 km ~ 8.0 km from the entrance, the water depth is approximately -6 m. In the inner Approach Channel, 8.0 km ~ 14.7 km from the entrance, the water depth increases to 13.5 m ~ -21.0 m. forming a gut of the Phitti Creek with widths of 700 ~ 800 m.

2. Phitti Creek

The water depth of the channel is -12 m ~ -16.5 m with a maximum of -18 m. The width is around 200 m. In the upper streams there is a wide water area with widths of 300 ~ 350 m.

On the west and north side of the creek, the islands of Buddo, Bundal and Khiprianwala form sand dunes and swamps mostly submerged at times of H.W.L. The ground levels of the majority of the islands are approximately 0 m - +3.0 m. On the south and east sides of the creek, the Muchak Island, lower than the islands on the north, appears as a wide swamp 1.6 km wide at times of L.W.L.

3. Kadiro Creek

The creek extends for approximately 6.4 km, smaller in width and depth than the Phitti Creek. The width is about 200 m and the maximum depth is -16.5 m.

4. Gharo Creek

The inner section of the creek system in front of Pipri site, extending for approximately 2.7 km with favorable width and water depths is a calm basin secluded from the open sea by a distance of 16 km from the entrance of Phitti Creek and curves in the creek system. The east section has the greatest water depth of approximately -15m.

Of the above four narrow channels, the sand bar area in the vicinity of the entrance in the open sea is the most shallow section, with a water depth of -6 m. A section with a width of approximately 150 m in Phitti Creek is the most narrow section. The present conditions of the channel will allow the navigation of vessels of 5,000 D.W.T. to the inland port site.

I-2 SOIL CONDITIONS

From 1972 to 1974, the Port Qasim Authority carried out a series of boring tests at principle points in the vicinity of the port area, the channel and basin to investigate the soil conditions. Though boring tests have not been repeated a sufficient number of times in the channel and basin, the results of the investigation are as shown in Dwg.-2. The soil conditions of the respective areas are as follows.

1. Open Sea Area (S-1. S-2. S-3) (Dwg. 3-1)

Boring tests have been carried out to depths of -60' at three locations, S-1, S-2, and S-3, in the middle section of the Approach Channel in the open sea. According to boring logs, generally, a homogeneous layer of dark gray fine micaceous sand exists below the present ground level (-20' ~ 25') to a depth of -60'. The N-value increases with the depth from the surface layer, with compact sand layers of N=20 in depths of -35' ~ -40', and N=25 ~ 30 in a depth of -60'. The surface sand layer may be easily dredged by ordinary suction dredgers or trailer suction dredgers.

2. Lower Stream of Phitti Creek (CR-6) (Dwg. 3-2)

The bore hole was located in roughly the middle of the creek east of Bundal Island. The depth of the present ground level is -35'. A surface layer of soft mud about 2' in thickness overlies a dark gray clay deposit containing silt to a depth of -50', with N-value in the range of 10 ~ 15. Similar deposits of slightly hard clay with some silt and sand with N-values in the range of 30 ~ 35 exist to depths of -60'.

3. Upper Stream of Phitti Creek (CR-7) (Dwg. 3-2)

The boring hole is located in approximately the middle of Phitti Creek, on the southeast of Khiprianwala Island. Similarly as site CR-6, a soft mud layer of 3' in thickness covers the present ground level in a depth of -33', under which a plastic clay deposit with silt and shell pieces extends to a depth of -70'. A thin layer (4' in thickness) of clay with occasional gravel and silt is encountered around depths of -60'.

The mud layer is rather compact with the N-value in the range of N=10 in the upper layer (-40'), and N=30 in the lower layer (-60'). Judging from the soil conditions in the upper and lower streams of Phitti Creek, the surface layers in both areas may be easily dredged by suction dredgers.

4. Gharo Creek (Dwg. 3-3)

The proposed site of the wharf extending for 600 m was investigated through drilling of 9 bore holes (No. 101~115), and the results are shown in Dwg. 3-3. The boring logs reveal the following soil characteristics.

1) In the major part of the lower stream area, (No. 101~108), with a depth of -50' as the boundary, the upper layers to the surface of the sea bed (-50' ~ -30') consist of rather soft gray silty clay or clayey silt of N values below N=10, with occasional layers of fine sand with N values in the range of N=20. It will be possible to dredge the soil with a regular cutter suction dredger. In depths beyond -50', the material is very hard mudstone (hard silty clay or clayey silt) of N value over 50. The bearing power of ground will be sufficient as the foundation of wharf structures.

2) Area near the upper stream end (No. 110~115)

The subsoil in the area show different features. Underlying a surface layer of loose clay, a deposit of sand layers 25' ~ 20' in thickness is encountered. The depth of the layer decreases from the lower stream to the upper stream, appearing at depths of -30' at the upper stream end. The sand layer is compact with N values in the range of 30 ~ 50. It may be difficult to dredge the material with a regular trailer suction dredger. It is therefore judged that grab bucket dredgers or other dredgers may be necessary.

Hard mudstone with N-values over 50 underlie the sand deposit in depths of -70' ~ -50'. The material may be judged to possess sufficient bearing power of ground as the foundation to support wharf structures.

I-3 METEOROLOGICAL CONDITIONS

Port Qasim is located on the north coast of the Arabian Sea, characterized by the monsoon both in summer and winter. From May to October, the S.W. monsoon prevails with high temperature and humidity. From November to April, the N.E. monsoon prevails with moderate temperature.

1. Temperature

The range of temperature according to the seasons is relatively small throughout the year. The lowest temperature of 82°F ~ 51°F is recorded in January, and the highest temperature of 96°F is recorded in May.

2. Rainfall

The rainfall is generally extremely small along the seacoast. The average annual rainfall in Karachi is about 8", and the number of rainy days in a year is less than 10 days. Months with rainfall more than once a month are January, February, July and August.

3. Visibility

Visibility depends on weather conditions such as dust storms, fogs, cloud, rainfall and haze. The weather in Karachi is generally fine, and the visibility is only affected by the amount of haze.

4. Winds

The S.W. monsoon from May to September, and the N.E. monsoon from November to March are two distinct seasons which characterize wind conditions in the area, with slightly variable winds in October and April. From May to September the predominant wind direction is from W to WSW, and in the remaining months, the direction is from NE.

Table - 1

MEAN MONTHLY WIND SPEED (KNOTS) - KARACHI

Station & Time Hours	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
0500												
Manora	5.8	3.7	4.5	5.1	7.0	8.4	9.1	8.2	8.2	6.2	2.4	5.0
Airport	2.5	1.8	2.4	2.6	4.6	7.8	8.0	7.4	5.1	1.3	1.2	3.7
0800												
Manora	5.8	4.0	4.5	5.7	7.5	9.8	9.3	9.4	6.7	3.3	3.7	5.5
Airport	2.7	2.2	2.4	4.5	8.1	9.0	9.6	8.8	6.9	2.1	1.2	1.9
1700												
Manora	8.8	8.8	10.4	11.7	12.4	13.2	12.3	11.6	10.5	8.8	8.1	7.5
Airport	7.4	8.4	8.8	10.4	12.0	13.5	13.5	12.3	11.5	9.4	7.3	6.2

Table-1 gives the mean monthly wind velocity recorded at 8:00 A.M. in the morning and 5:00 P.M. in the evening. Generally, the wind velocity is higher in the evening than in the morning. The mean maximum wind velocity is 13.5 knots, occurring in the evening, and centered around June. From May to September, the mean wind velocity is 5 ~ 10 knots in the mornings and 10 ~ 16 knots in the evenings, while from October to March, the velocity is 1 ~ 6 knots in the mornings and 7 ~ 16 knots in the evenings. The maximum wind velocity of 81 mph (36 m/s) was recorded at 6:00 P.M. on June 29, 1936. In general, even during the S.W. monsoon, the wind velocity seldom exceeds 20 knots (10 m/s), and strong winds over 40 knots (20 m/s) are extremely rare.

According to the record of storms in the Arabian Sea for the 69 years from 1881 ~ 1949, cyclone storms occur predominantly in the months of April, May, June, October, November, and December. Storms are recorded 87 times making the average frequency of occurrence less than 2 per year.

I-4 HYDROGRAPHIC CONDITIONS

1. Tides

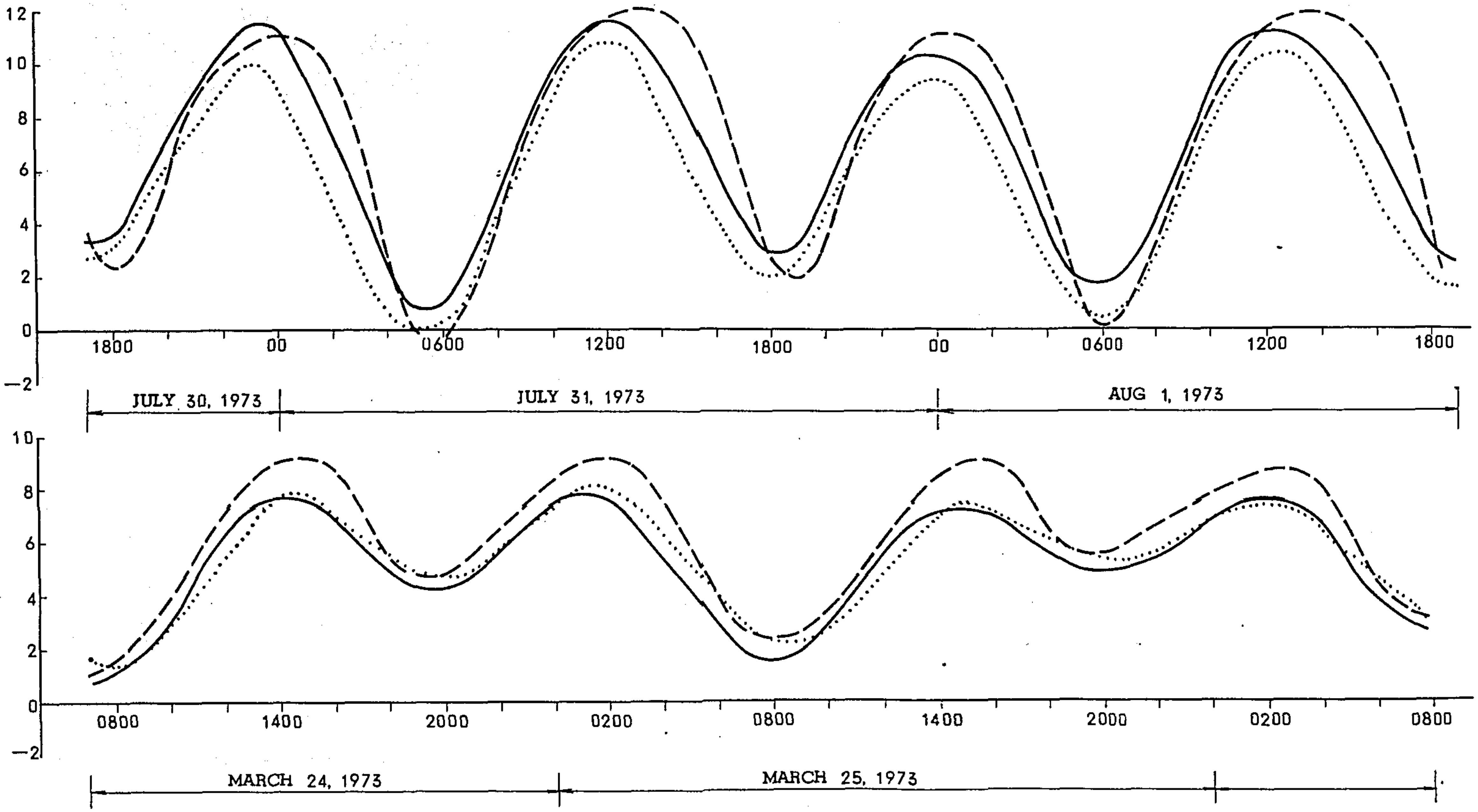
In Phitti Creek, semi-diurnal and diurnal tides are observed, similar to tides in the Karachi Port.

Tidal levels in Karachi Port, Phitti Creek, and Pipri Point are as shown in Table-2. The tidal levels at Phitti Creek were recorded for 3 months in 1970. Tides at Phitti and Pipri sites have been recorded continuously since October, 1972.

In Karachi Port, the tidal range is 10.1' at times of high tide in spring and autumn, and the mean monthly highest water level is 8.8' above the datum level.

As may be seen from Fig.1-1, the tidal level at Phitti Creek is about 6 % higher than the level at Karachi, and the level at Pipri is about 25 % higher, while the high water at Phitti and Pipri tend to lag about 12 minutes and 55 minutes respectively behind high water in Karachi Port.

Fig— 1



TYPICAL TIDAL GRAPHS
KARACHI-PHITTI-PIPRI

LEGEND

KARACHI	....
PHITTI	———
PIPRI	— — — —

NOTE

THE TIDAL GRAPHS ARE BASED ON RECORDS SUPPLIED BY P.Q.A.

Fig 1-2 Tidal Currents

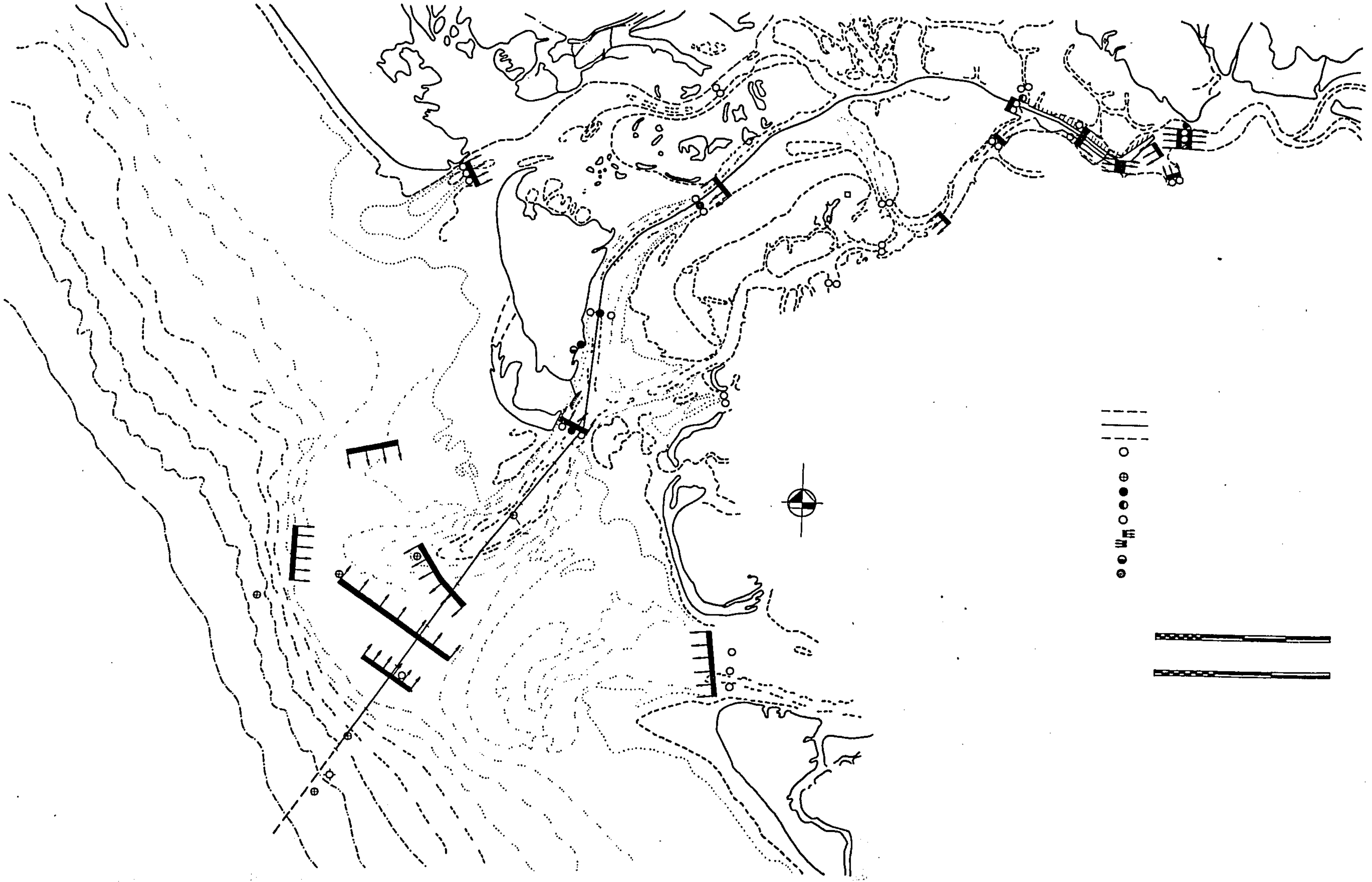


Table - 2

COMPARISON OF TIDE ELEVATIONS

KARACHI–PHITTI–PIPRI

	Karachi	Phitti	Pipri
Extreme recorded high water	+14.3 (June 1902)	+12.7	+13.00
Highest astronomic tide (HAT)	+10.5	+11.3	+13.00
Mean higher high water (MHHW)	+ 8.8	+ 9.55	+11.16
Mean lower high water (MLHW)	+ 8.0	+ 7.42	+ 8.76
Mean sea level (MSL)	+ 5.4	+ 5.68	+ 6.73
Mean higher low water (MHLW)	+ 3.5	+ 3.93	+ 4.69
Mean lower low water (MLLW)	+ 1.4	+ 1.80	+ 2.30
Chart datum	0.0	0.0	0.0
Lowest astronomic tide (LAT)	- 1.4	- 1.9	- 2.0
Extreme recorded low water	- 2.0	- 2.7	- 2.7

NOTE

(1) Chart datum at Phitti and Pipri is below survey of Pakistan datum by 5.68 and 6.73 feet respectively, K.P.T datum is 5.40 feet below survey of Pakistan datum.

(2) Values of MHHW, MLHW, MHLW, and MLLW for Phitti and Pipri have been computed by P.Q.A. from tide observations between 11.10.72 and 31.12.73.

(3) Values of HAT, LAT, extreme highest and lowest water levels are observed values.

Elevation 0 at Phitti Creek is 5.68' below the Survey of Pakistan (mean sea level) datum.

Storm surges are relatively small, occurring during the cyclones which seldom occur in this area. In Karachi, the maximum storm surge recorded was 3.9', and during such a storm, a similar rise in tidal levels may be expected to occur at Phitti and Pipri sites.

2. Tidal Currents

According to the Admiralty Pilot, offshore currents in the Arabian Sea generally occur in the westerly direction during the N.E. monsoon season, and the easterly direction during the S.W. monsoon season. The maximum current velocities are approximately 1 ~ 2 knots during the two monsoon seasons.

A program of current measurement for the entire Phitti Creek system was carried out by both float tracking and measurement of current profiles at fixed stations. The locations at which measurements were taken are shown in Fig.1-2. The maximum and average velocities recorded at the respective creeks are as given in Table-3.

Table - 3

CURRENT VELOCITIES IN KNOTS

	Flood		Ebb	
Location	Maximum	Average	Maximum	Average
Approach Channel	2.0	1.1	2.5	1.0
Buddo Island	2.9	2.2	2.2	1.2
Phitti Creek	2.2	1.3	2.8	1.1
Kadiro Creek	1.2	0.8	1.9	1.0
Gharo Creek	2.4	1.0	3.6	1.6

According to the above table, maximum current velocities occur in the vicinity of the proposed port construction site in Gharo Creek, with a velocity of 3.6 knots recorded at ebb tide.

In Gharo and Kadiro Creeks, the velocities are greater at ebb tide.

In the approach channel, the maximum velocity is 2 ~ 2.5 knots and the average is 1.0 knot, without much difference in flood and ebb tides.

At the entrance of the Approach Channel, the flood current direction is at an angle of about 45° to the alignment of the proposed navigation channel, but the velocity is less than 1 knot.

At ebb tide the current is roughly in line with the alignment of the navigation channel.

3. Waves

On the coast of Pakistan, generally, waves like winds are dominated by monsoons. Waves hardly occur during the N.E. monsoon season, while high waves occur and continue during the S.W. monsoon season.

1) Wave Height

Measurement of waves in the open sea was carried out offshore the entrance of the channel to Port Qasim using a Waverider Buoy in November, 1972. Maximum wave heights recorded were in the range of 3 m ~ 4 m from June to August, and 1 m ~ 2 m from November to May. The significant wave height was 3.0 m. During times of peak monsoon wave action, the wave period was in the range of 8 to 9 seconds.

Significant wave height and significant wave period exceedance percentage curves are shown in Fig. 1-3 and Fig. 1-4.

According to mariners, waves in the order of H_0=6.0 m have been observed off Karachi Port during storms. However, such occurrences are very rare, and in general, do not greatly affect the operation of vessels in port.

In the Phitti Creek water area, the entrance is narrow, and the channel is curved, so that the wave height is moderate, giving no difficulty in navigation and operation of vessels.

2) Wave Direction

Wave directions have been measured off Karachi by the Pakistan Navy. The mean wave direction was 237° with 90 % of the waves having a direction between 225° ~ 255°. The prevailing wave direction will be considered in determining the direction of the channel at the entrance. If the direction of the channel is to be 208°, the wave direction will be at an angle of 360°.

4. Littoral Drift

On the coasts of Pakistan, littoral drift depends on the S.W. monsoon wave action, and in waters west of Karachi Port, generally, littoral drift is predominantly in the easterly direction. However, littoral drift from Karachi to Phitti Creeks is complicated due to the peculiar topography of the area.

According to the report of the British Hydraulic Research Station Ex.557 (1971), northward offshore the middle of Bundal Island, littoral drift in the northerly direction prevails, while on the south side towards the navigation channel, littoral drift in the southerly direction prevails. Further south, the direction of littoral drift turns northward. Littoral drift moves in either the north or south direction according to the wave direction. The amount of littoral drift to be deposited in the dredged channel will be the total of sand shifted in the two directions. From 1973 to 1974, a program of trial dredging was carried out in the Approach Channel to predict the amount of infilling. According to the Report of H.R.S. Ex.698, the amount was assumed to be approximately 1,700,000 m^3 per year.

Fig — 3

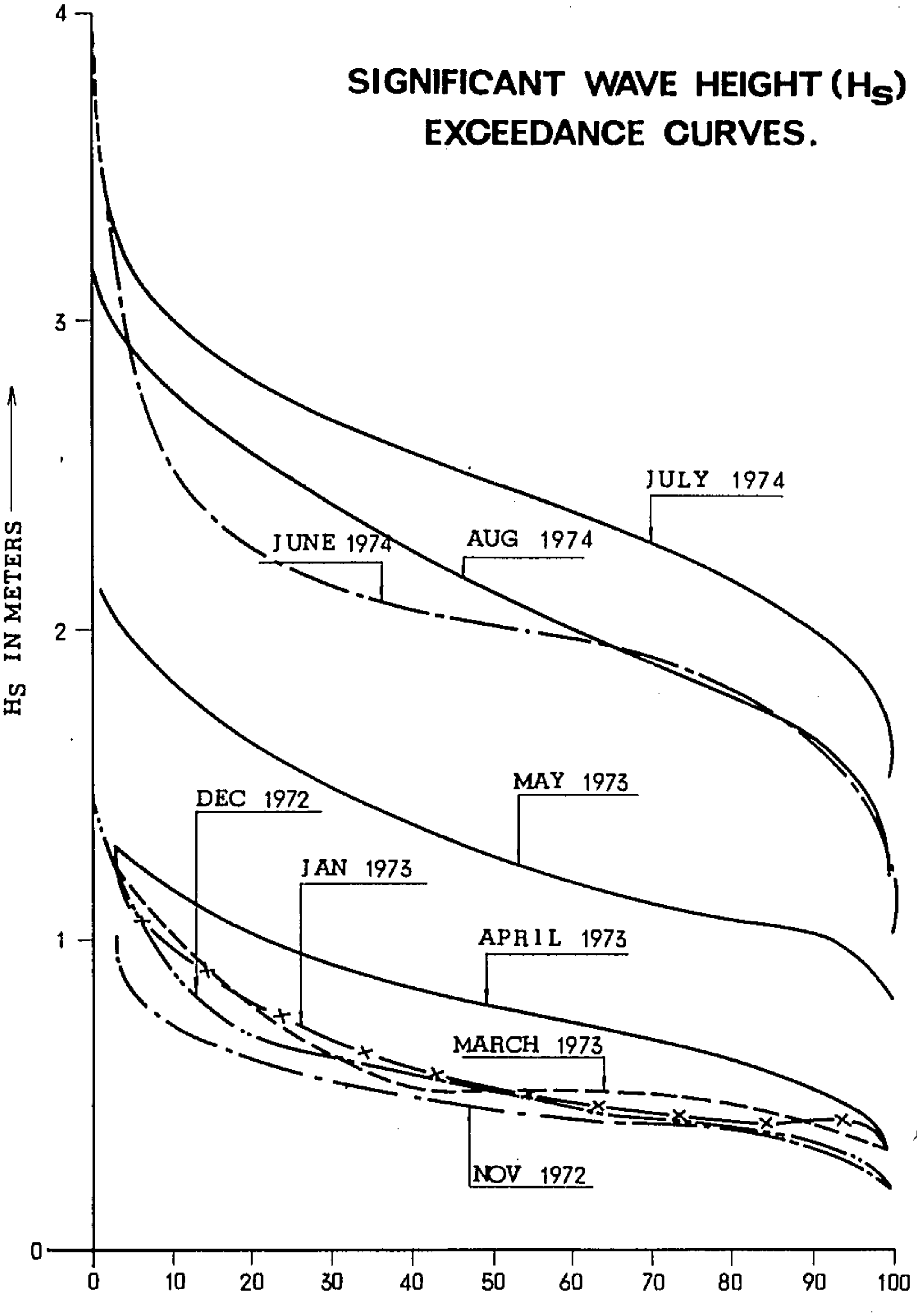
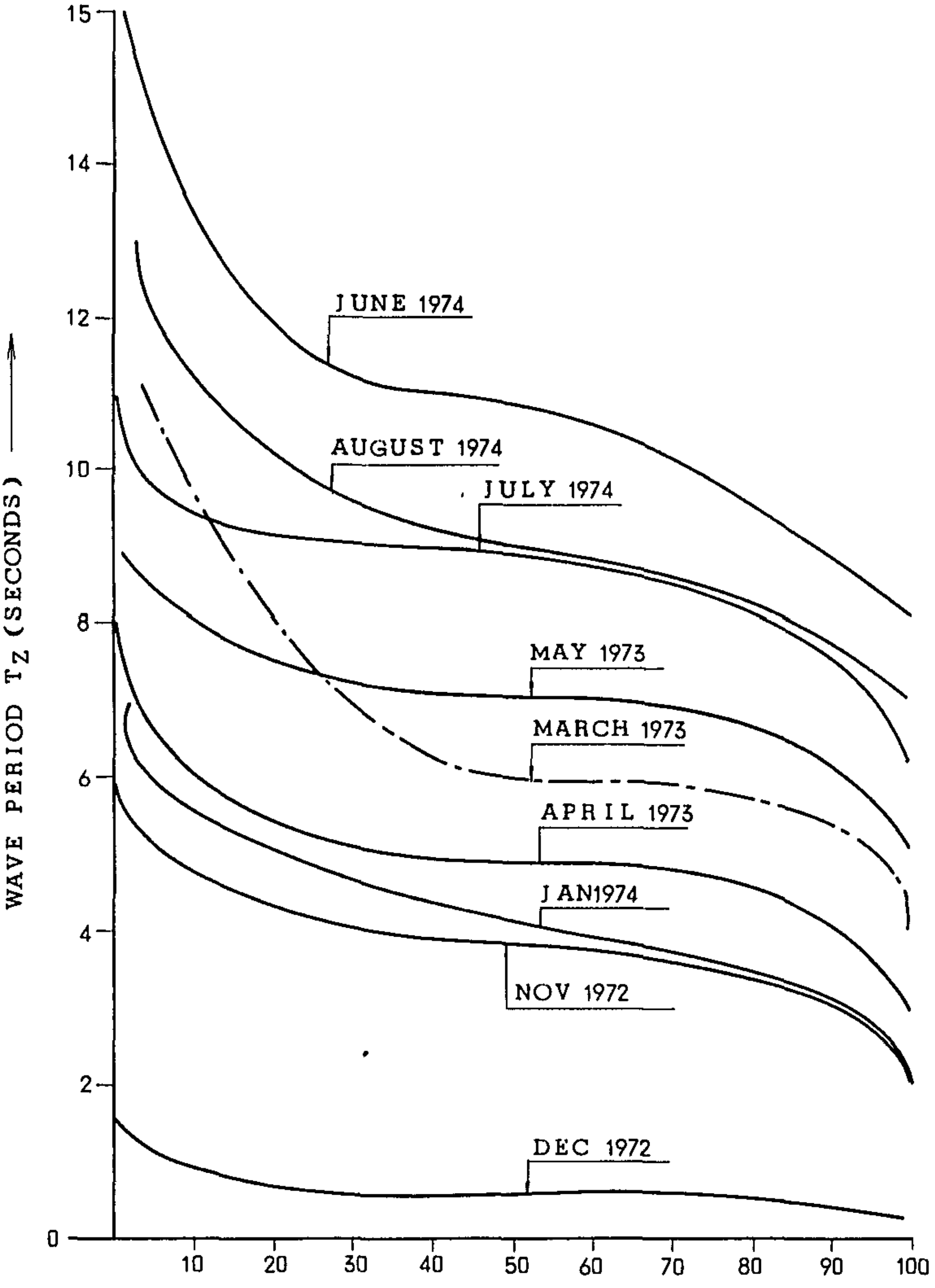

SIGNIFICANT WAVE HEIGHT (H_S)
EXCEEDANCE CURVES.
JULY 1974
JUNE 1974
AUG 1974
MAY 1973
DEC 1972
JAN 1973
APRIL 1973
MARCH 1973
NOV 1972
H_S IN METERS
4
3
2
1
0
0
10
20
30
40
50
60
70
80
90
100
PERCENT EXCEEDANCE

Fig — 4

WAVE PERIOD (Tz) EXCEEDANCE CURVES



PERCENT EXCEEDANCE

CHAPTER II NAVIGATION CHANNEL

II-1 CHANNEL ALIGNMENT (Refer to Dwg.-1, Dwg. 4-1-14, and Fig.2-5.)

1. General

The design of the navigation channel will depend on the size of vessels to enter Port Qasim. The port construction program will be planned to accommodate 25,000DWT ore carriers in the first phase, and 50,000 DWT ore carriers in the second phase. The dimensions of vessels will be assumed to be as follows, based on statistics compiled in National Ports Council (U.K.) Research and Technical Bulletin No.5, 1969.

Table 2-1

Design Ship Dimensions

DWT	Length Overall	Beam	Draft Loaded
25,000	183 m	23.2 m	10.1 m
50,000	223	31.1	11.9

Generally, the alignment of the navigation channel is determined so that vessels will not be subject to unfavorable effects of winds, waves and tidal currents in maneuvering, keeping the number of curves to a minimum. Criteria for establishing the alignment are as follows.

1) The channel should be located to take advantage of the natural water depth as far as possible, reducing the dredging quantity to a minimum.

2) The number of bends or curves should be as small as possible, and the deflection angle should be smaller than 30° from the point of manoeuvering of vessels.

3) Between the channel axis and the direction of strong winds, waves, and tidal currents, a minimum angle should be maintained.

The alignment of the navigation channel will be determined on the basis of the above criteria.

2. Approach Channel

The alignment will be determined considering the water depths based on the local sounding charts, weather and sea conditions, and the location of navigation aids (leading lights) to be installed.

1) Weather and sea conditions

Strong winds occur most frequently during the summer S.W. monsoon, followed by the winter N.E. monsoon. The prevailing wave direction is between 225° and 255°, mostly SW. The current direction is predominantly SW at ebb tide, and E - ESE at flood tide. Cross currents of approximately 0.5 m/s (1.0 knot) occur at flood tide.

2) Location of leading lights

For the benefit of vessels entering the channel from the outer sea, it will be necessary to instal leading lights on the extension of the center line of the channel. It will be desirable to install the light in locations near the entrance of the channel with clear visibility, preferably on land so that the lights will not obstruct the passage of vessels.

The southern end of the Buddo Island, and a shoal 1,800m south of the Island will be favorable sites for the location of leading lights. The alignment of the two sites will be in N 28° 30' E, roughly in the same direction as the above mentioned winds, waves and tidal currents, and the angle will be small. From the above standpoint, the direction of the approach channel will be N 28° 30' E as shown in Fig. 2-5. The section from the open sea through the shallow sand bar area extending for approximately 9.5 Km will be the outer Approach Channel.

The inner Approach Channel from the end of the outer Approach Channel to Phitti Creek extending over a distance of approximately 5.2 Km takes advantage of the natural deep water area with a width of 500m - 800m. With some dredging, the section will serve as a passing zone and a relief turning basin in cases of emergency.

Entering the inner Approach Channel from the outer Approach Channel the alignment curves from the NNE direction to a slightly NE direction to take advantage of the natural water depth, but the angle of curve will be extremely small.

3. Phitti Reach

Entering Phitti Creek from the Approach Channel the alignment of the channel is restricted by the Bundal Island on the west side, and small islands and sand bars scattered on the east side. The width becomes narrow, but the natural water depth is deep. At the entrance of Phitti Creek, the channel alignment bends nearly

30° in roughly the N direction. The section extends for about 5.3km and will be called the lower Phitti Creek.

Further upstream in the upper Phitti Creek, the alignment curves in the NE direction due to the topography of the area. A wide area (over 300 m) with natural deep water extends for about 3.0 km, providing a relief zone for small vessels. This zone covers a distance of approximately 11.0 km to the upper Kadiro reach with bends and curves. As the angle of curves are less than 30°, it is considered that there will not be any particular maneuvering problems.

4. Kadiro Reach

Entering Kadiro Reach, the channel alignment bends roughly in the ENE - E - ESE directions into the proposed Ore-Coal Berth site of Gharo Basin. This zone is the most difficult section of the entire channel with bends with deflection angles over 30°, including a reverse bend, and the largest deflection angle is 42°. Straight sections are short, and the width is restricted by topographic features. Speed of vessels passing the channel will be reduced, and tugs will be necessary for the safe maneuvering of vessels.

To accommodate vessels of larger dimensions in the future, it will be necessary to improve the bend with an angle of 42° to a bend with an angle of 30° or less, involving dredging work of large scale to increase the width of the channel.

5. Gharo Reach

The alignment of the Ore-Coal berth in the Gharo reach will be planned to fall in line with the current direction of the area. The line will be in agreement with the direction of the alignment of bore holes for soil investegation along the originally proposed face line of the berth as well as the line proposed by the Hydraulic Research Station (HRS), Wallingford, England.

II-2 CHANNEL WIDTH (Dwg.-1 Fig. 2-5)

1. Traffic Requirement

In general, the channel width is determined considering the size of vessels, traffic, topographic features, weather and sea conditions, one way or two way traffic, and the service of tugboats.

The channel will be designed for one way traffic on the following grounds.

- The traffic estimate for vessels in the next 10 years will be merely 3 vessels per day.
- Traffic control facilities will be established enabling the control of navigating vessels.
- A two way traffic will require greater dredging quantities, increasing the cost of construction.

In case two large vessels desire to enter port at the same time, the situation may be solved by adjusting the time of entry.

To meet the demand for overtaking, vessels may be controlled to take advantage of the two wide zones with natural deep water.

One way traffic will be desirable from the point of traffic requirements and construction costs. Therefore, the channel will be designed for one way traffic.

2. Channel Width

Nespak proposes to use the design criteria specified in the I.O.T.C. report for various dimensions of the navigation channel in Port Qasim. The dimensions to be adopted will be determined on the basis of the above criteria and design criteria accepted in Japan.

1) Design criteria

i. In Japan, the width of the channel is determined on the basis of the length of vessels according to the following criteria.

Two way traffic channel : 1.0 - 1.5 times the vessel length

One way traffic channel : (in case of a calm channel with currents in line with the channel)
0.5 times the vessel length

ii. Channel width proposed by Nespak

Nespak proposes to calculate the channel width for one way traffic on the basis of the width of navigating vessels with allowance for the following factors. Vessels to be accommodated will be of the 25,000 DWT and 50,000 DWT classes.

a. Effect of Winds and currents

- Tidal currents ..... In Phitti and Kadiro reaches, as the current flow is in line with the channel alignment, no allowance for increased width is required. In the Approach Channel, at the worst, during the S.W. monsoon, at flood tide, cross currents of about 1 knot occur, and an allowance of approx. 100' (30.0 m) will be required for the course correction of vessels.

- Winds .... During the S.W. monsoon of maximum wind velocities, the mean maximum wind speed is 13.5 knots (7 m/s) with no sustained velocity of 30 knots (15 m/s). No allowance for lateral drift caused by winds will be required.

b. Accuracy of aids to navigation

The standard deviation for the location of channel buoys and beacons to be used throughout the channel suggested in the PIANC final report is of 20m - 50m accuracy. This accuracy decreases as the distance from the shore is increased. Therefore, an allowance of 35 m in the Approach Channel, 30 m in Phitti Creek, and 25 m in Kadiro Creek will be calculated.

c. Bank suction effect

This is the hydrodynamic effect of water movement past the vessel against the banks of the channel, and the effect increases in closed channels. It is suggested that a figure of 2 X design beam (B) be used for bank clearance in the Approach Channel, a figure of 2 X design beam (B) in the Kadiro reach where the bank suction effect is great as the channel is closed in this section, and a figure of 1.7 X design beam (B) in Phitti reach where the channel configuration is open.

d. Ship maneuvering lane

This is the width allowance necessary for vessels to make adjustments of course to maintain a position at or near the center line of the channel. An allowance of 2 X design beam will be used as a minimum for vessels up to 25,000 DWT. Considering the required allowance for the above factors, for 25,000 DWT vessels, channel widths of 181 m, 139 m and 141 m have been proposed for the Approach Channel, Phitti Creek, and Kadiro Creek and the basin, respectively in the Nespak report. Comparing the figures with the channel width based on vessel length according to the Japanese criteria, the width proposed for the Approach Channel is equivalent to the vessel length, and the width proposed for the Phitti and Kadiro Creeks are 80% of the vessel length.

As both figures are quite reasonable, the channel width will be determined as follows.

Table 2-2

CHANNEL WIDTH

Ship Size	Approach Channel	Phitti Creek	Kadiro Creek Basin
25,000 DWG	185 m	145 m	145 m =
50,000 DWT	225 m	180 m	180 m

3. <u>Channel Entrance Width</u>

In major ports of the world, as facilities to lead vessels safely into a long straight channel, generally, lighted buoys are installed to indicate the sides of the channel, and leading lights are established to indicate the center line of the channel. Lighted buoys and leading lights possess their respective functions.

Buoys are subject to the effect of tidal currents and winds, and in times of storms, the chain may be severed, and the buoy may be lost. Buoys merely indicate the approximate location of the sides of the navigation channel, and cannot be considered to indicate the direction of the course of vessels.

Leading lights indicate the direction of the course of vessels, and the deviation from the course when the vessels turn off the center line of the channel to either side.

Lighted buoys and leading lights cannot be replaced by each other due to the respective functions.

In Port Qasim, the Approach Channel to be dredged will extend in a straight line over a distance of approximately 8 km.

Lighted buoys and leading lights will both be required as navigation aids for the channel. Leading lights are composed of the front light and rear light. The rear light will be established on Buddo Island, and the front light will be established on a shoal at a distance of 1,800 km in front of the rear light. The distance from the channel entrance to the front light will be 12,000 km, and the leading lights will not be clearly visible at the entrance. Vessels entering port will find difficulty in fixing the course.

The following navigation aid systems may be considered for accurate position fixing of vessels in the Approach Channel.

1) Line determined by floating buoys

Two or three buoys will be installed offshore the channel at intervals of approximately 1 km as shown below. Vessels will enter the channel with the line determined by the buoys in the rear.

In the location of buoys, the water depths are 30 m - 50 m. In order to secure the buoys safely in position, the length of the chain to connect the buoy and the sinker at the sea bottom must be three times the water depth. The sinker will not be moved by winds and tidal currents, but the buoys on the sea surface will be shifted to a maximum distance of half the length of the chain. Moreover, as the locations of buoys are considerably separated, the buoys will be affected by the winds and currents at the respective site, and the movement of the buoys will not be identical.

Even in calm sea conditions, slight winds and currents will occur, and the buoys will not remain in the fixed location. A line determined by the buoys cannot be expected to indicate accurately the center line of the channel. The plan will not be a practical solution to lead vessels safely into the Approach Channel.

2) Wireless Course Beacon

Mainly for small vessels which are not equipped with a radar system, a wireless course beacon is used to indicate the channel. Vessels entering and leaving port may recognize the channel for safe navigation by a simple receiver, even in the dark of nights and days of fog, without other navigation aids.

A course beacon station will be established on the shore along the center line of the channel, and coded signals of radio waves

Fig 2-1 LINE DETERMINED BY FLOATING BUOYS

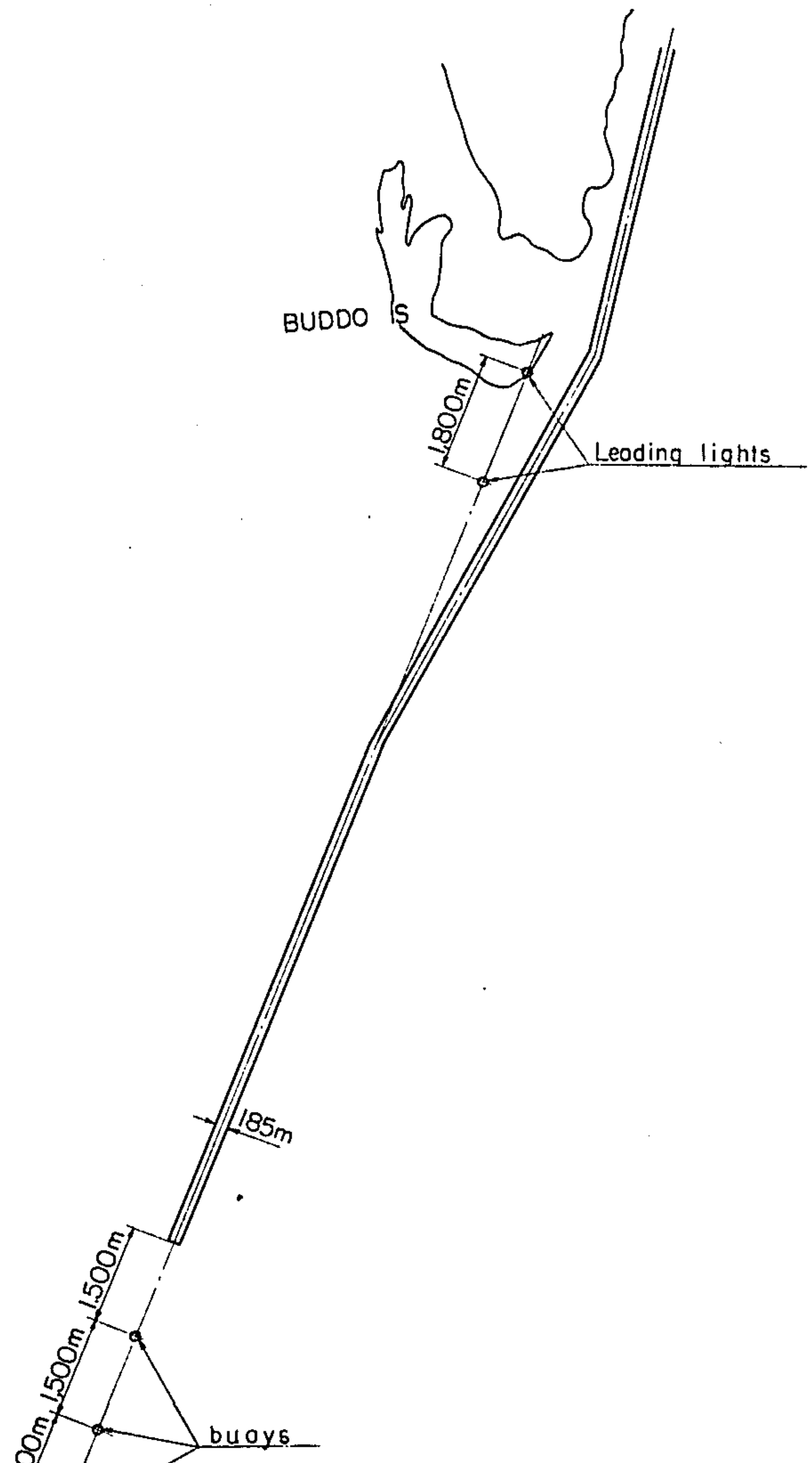
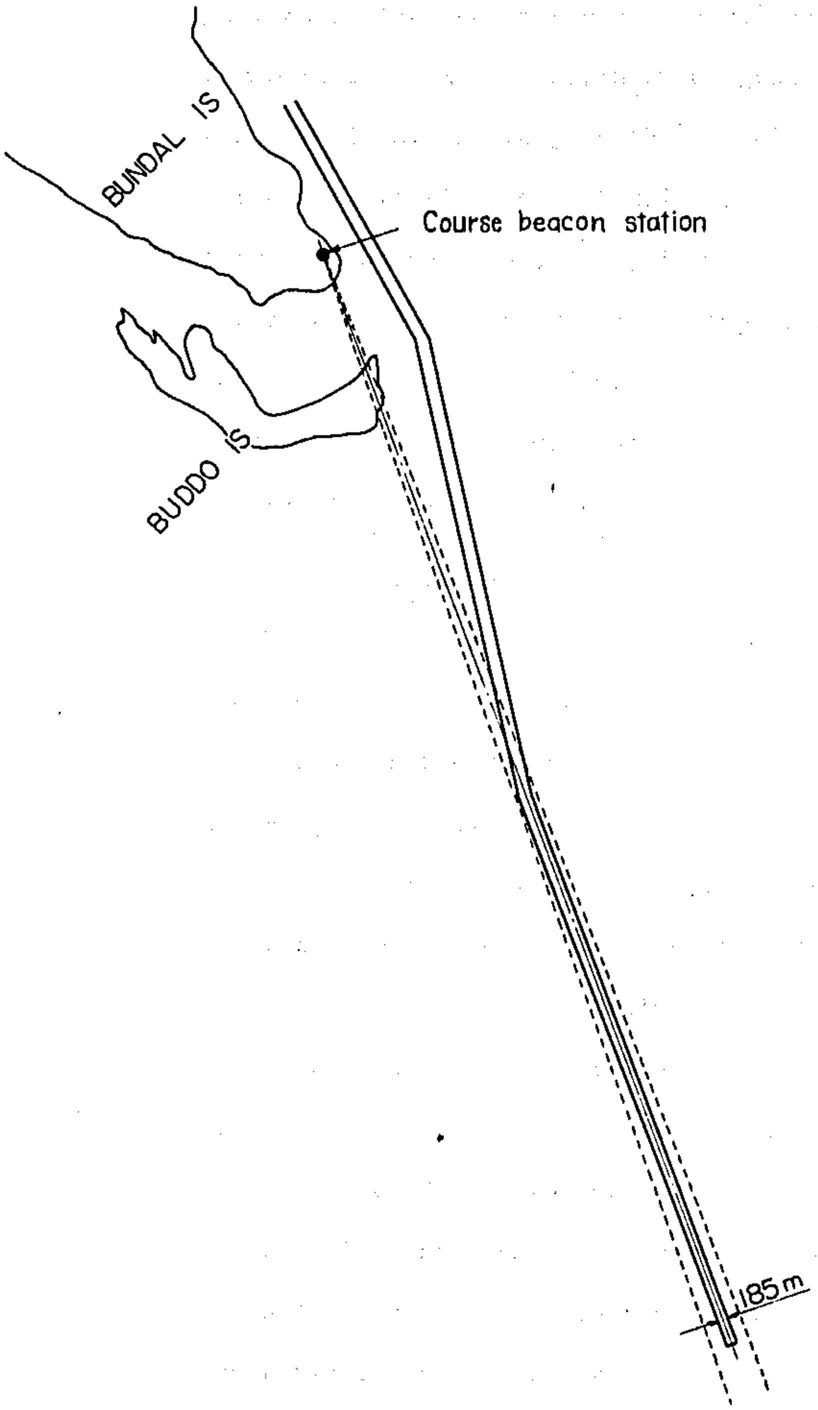


Fig 2-2 DIFFUSION OF RADIO WAVES OF WIRELESS COURSE BEACON



will be emitted.

However, when radio waves to indicate the channel are emitted from the station, the waves are diffused at an angle of 1°. If the station is located on Buddo Island, the width of diffusion will be 260 m at the channel entrance, of greater width than the entire channel width. As long as the vessel is within the width of diffusion, it will be difficult to recognize the degree of deviation from the course. Therefore, it will be extremely dangerous for large vessels with slow maneuvering performance to proceed into the channel with the aid of a wireless course beacon, even if the channel width is 260 m. The system will not be a practical solution to prevent vessels from turning aside from the Approach Channel.

3) Decca Navigator System

The Decca system may be divided into the Decca survey system and the Decca navigator system. The system in use in Port Qasim at present is the Decca survey system, and is not generally used as navigation aids.

The Decca navigator system is established for the safe coastal navigation of vessels. In case of Port Qasim, along the coasts of Port Karachi and Port Qasim, one master station and two slave stations may be established. The Decca chain of the three stations will serve as navigation aids.

In case three decca stations are established, the master station and one slave station may be used as aids for vessels in the Approach Channel of Port Qasim, besides serving as aids for coastal navigation. The system has been adopted in the approach channel of the Europort in the Netherlands with great success.

The master station and one slave station will be located so that the center line of the Approach Channel will fall along the bisector of the distance between the two stations, and a receiving apparatus will be attached to a regular Decca receiver. Radio waves emitted from the two stations will indicate the course of the channel.

Vessels entering port may obtain information on the position of the center line of the channel, and in case the ship turns off the channel, the distance of deviation will be indicated on the receiver. Unlike the course beacon the diffusion angle of waves of the Decca system is extremely small.

With a high degree of accuracy, vessels may proceed into the channel safely, regardless of the weather conditions.

The Decca navigator system will be a very favorable system as navigation aids in Port Qasim both for safe navigation along the coasts and in the Approach Channel. However, various difficulties will be encountered in applying the system in Port Qasim.

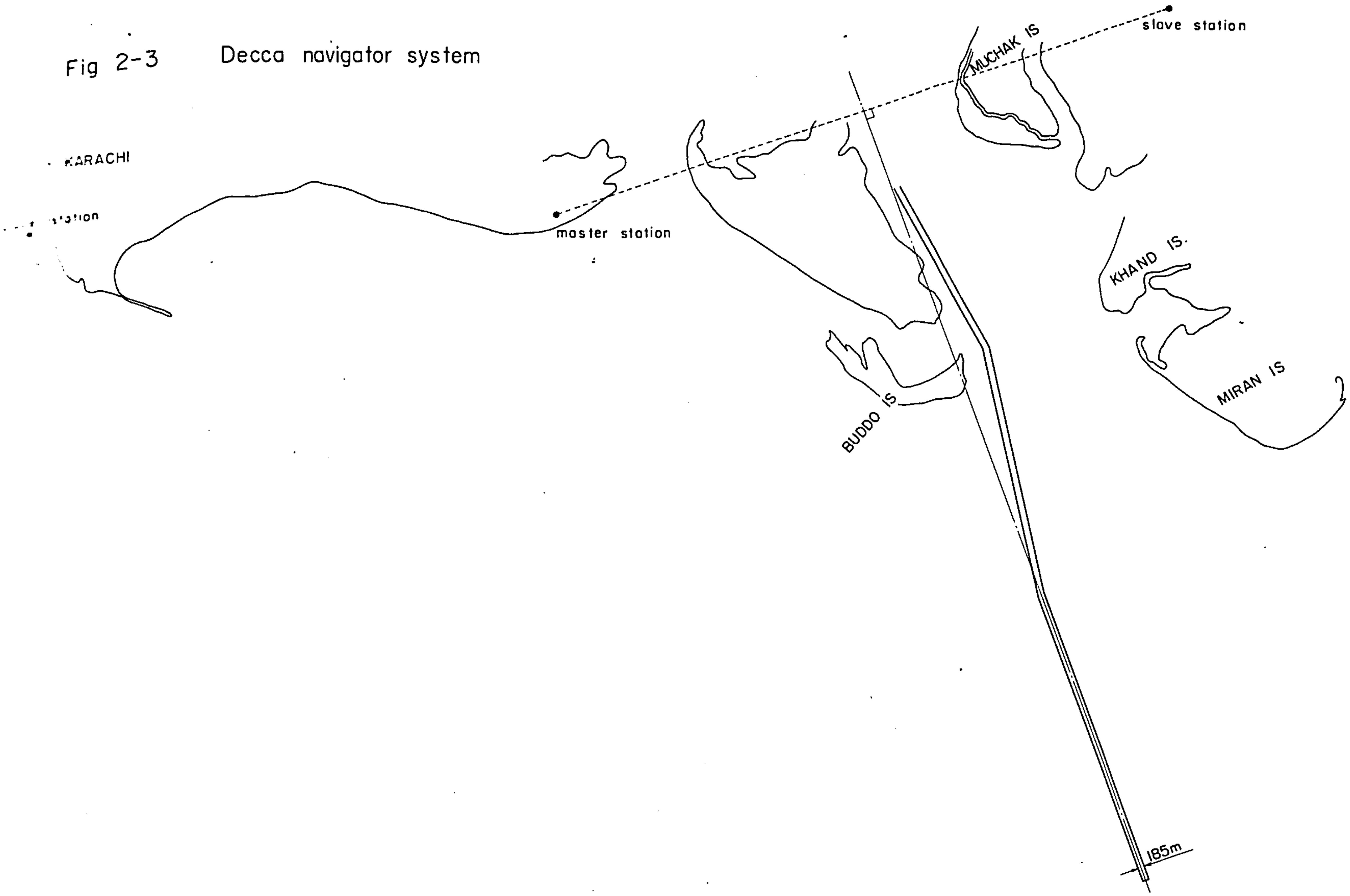
The system equipment and cost of construction will amount to more than $6,000,000, and the yearly maintenance cost will be about $300,000.

The construction cost will be several times the cost of dredging the channel entrance to the required width for safe approach.

Generally, as vessels will not be equipped with the particular receiver, the equipment must be installed on board vessels in the outer port. In Europort, the equipment is carried with the pilot on a helicopter to vessels entering port.

As the Decca navigator system will also be used as aids for coastal

Fig 2-3 Decca navigator system



navigation, the coverage area will include Port Karachi. It will be necessary to discuss the problem with the Port Karachi Authority. With a high degree of accuracy in position fixing, the Decca navigator system will be a very favorable system as aids for vessels navigating in a narrow channel. However, the high cost of construction, maintenance expenses, and administrative procedures are problems to be solved. It is recommended that the establishment of the system be studied in the Second Stage Construction Program of Port Qasim.

4) Widening of Channel Entrance

As navigation aids in the Approach Channel, lighted buoys will be installed on both sides of the channel, and leading lights will be installed to indicate the center line of the channel.

The buoys will move around in a circle with a diameter of approximately 20 m on the sea surface, affected by winds, tidal currents, and waves.

Incoming vessels will rely on leading lights for navigation in the Approach Channel. The distance from the channel entrance to the front light will be 12,000 m. With a long distance between the front and rear lights, the senstivity of the two lights in separation will be decreased. The front and rear lights may be identified in separation when the vessel deviates approximately 90 m to one side from the center line of the channel. (Refer to Navigation Aids II-3 Side Sensibility of Leading Lights).

In case of navigation depending on leading lights, the required width of the channel on one side will be at least 90 m with an additional width of twice the vessel width equivalent to 50 m *in case of 25,000 DWT vessels, or a total of 140 m.*

An entrance width of 280 m in the first phase dredging program for 25,000 DWT vessels, and 300 m in the second phase for 50,000 DWT vessels, will be required to enable vessels to identify the leading lights at the entrance and proceed safely into the Approach Channel. The width may be gradually reduced to the regular width of the channel over a distance of 4,000 m. The cost of extra dredging to increase the width at the entrance of the channel in funnel shape will amount to several million dollars. However, in comparison to the above three navigation aid systems, it may be concluded that the widening of the channel entrance for navigation depending on leading lights will be the most reliable and cost saving system to meet the navigational requirements in the Approach Channel.

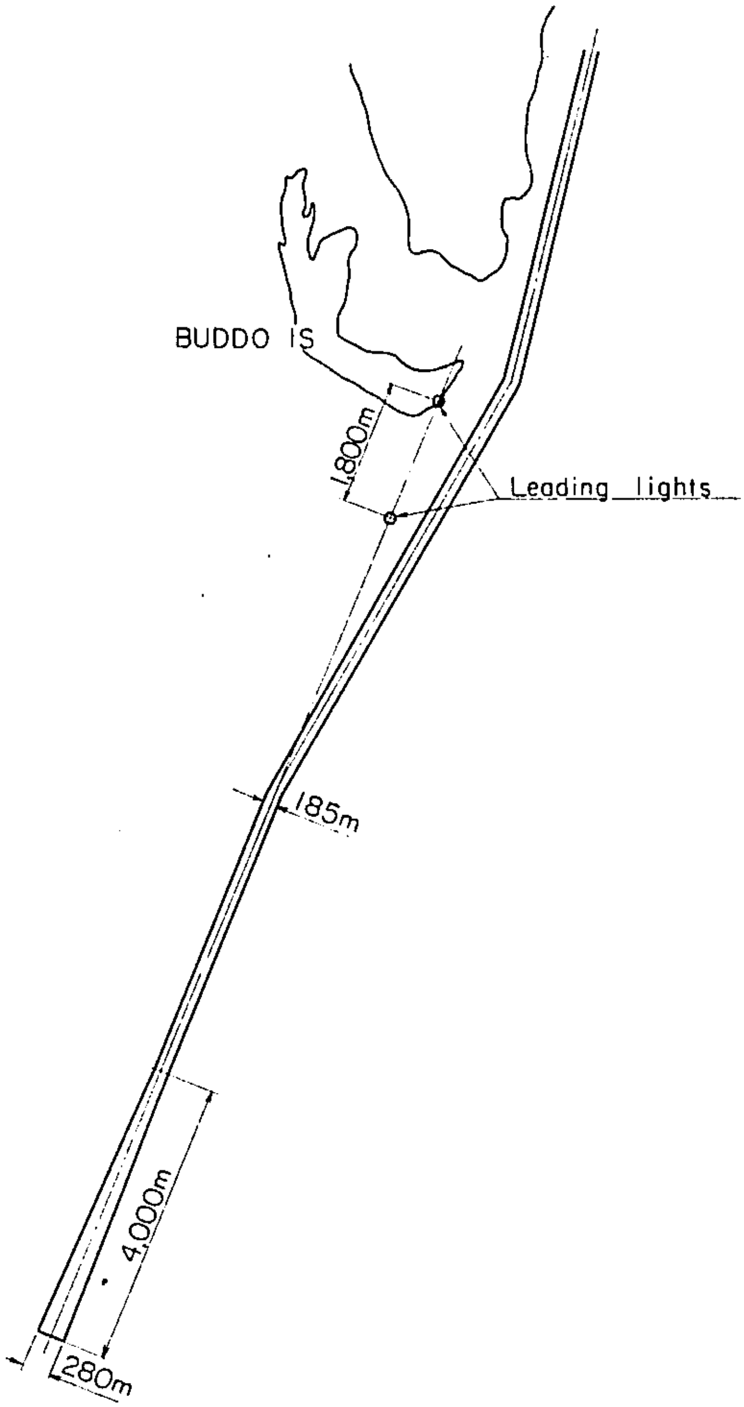
5) Hydraulic Study

As it may be feared that the effect of flushing of the channel with the rise and fall of tides will be reduced, the effect of widening the entrance of the Approach Channel will be analyzed briefly from the point of hydraulics.

a. As the channel entrance is located at a long distance of approximately 20 km from the shore, though the channel may be dredged from depths of -6.0 m to -12.0 m, the flow of tidal currents will not be concentrated at the entrance.

b. The flow of currents from the inner channel has a tendency to be dispersed into the wide water area on both sides at the river mouth.

Fig 2-4   APPROACH CHANNEL ENTRANCE WIDTH



c. With the effect of currents from the Chhawaddo Creek and the Khuddi Creek on the east side of the channel, currents in the vicinity of the Approach Channel possess a tendency to turn towards the west at ebb tide.

On the above grounds, the effect of flushing due to the rise and fall of tides may hardly be expected in the Approach Channel. It may be said that the widening of the channel entrance will not cause unfavorable effects from the hydraulic point of view.

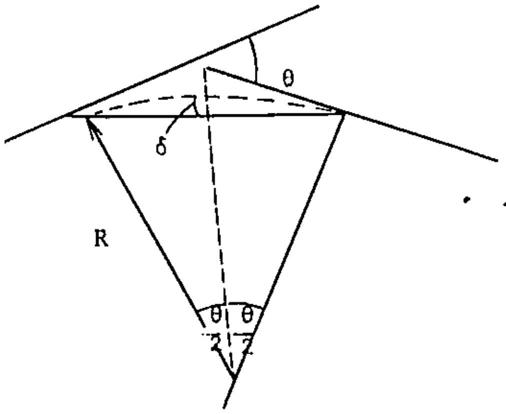
4. Channel Bends

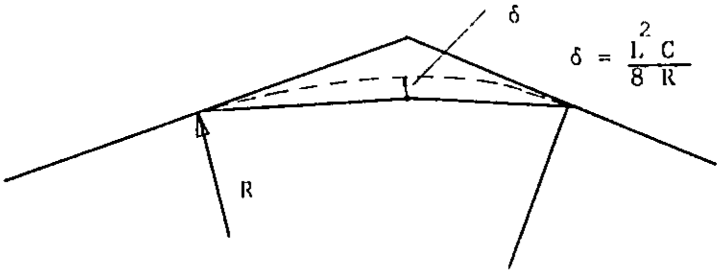
1) According to the Japanese criteria, it is recommended that the maximum deflection angle does not exceed 30°, and in case the angle exceeds 30°, the corner will be cut off. In this case, the radius of the cut-off curve will be more than,

$$R = 4 \times \text{vessel length } (L)$$

However, the corner need not be cut off in case the channel is of sufficient width.

$$\delta = R\left(1 - \mathrm{Cos}\,\frac{\theta}{2}\right)$$





$$\delta = \frac{L^{2}C}{8R}$$

2) Nespak plan

According to the PIANC Final Report, the allowance for extra width at channel bends is calculated as follows, with δ as the extra width.

Extra width $\delta = \frac{L^2C}{8\ R}$

L : vessel length R: curve radius

C : maneuvering coefficient

Will vary with the controllability of vessels and difficulty of bends.

Good : 1 Moderate : 2

Poor : 3 Very poor: 4

The curve radius will vary with the deflection angle θ.

Where the deflection angle θ is,

less than 25°	R = 5 X L
25° - 35	R = 6 X L
35° - 45	R = 7 X L

Applying the two methods of calculation to the bend with the maximum deflection angle $\theta = 42°$ in Kadiro Creek in case of vessels of 50,000 DWT (L = 223 m),

Japanese criteria ..... $R = 4L = 892\text{m}$, $\delta = R(1-\text{Cos}\ \frac{\theta}{2}) = 59$ m

Nespak plan .... $R = 7L = 1{,}561\text{m}$, $\delta = \frac{L^2C}{8R} = \frac{223^2\text{x}4}{8\text{x}1{,}561} = 16$ m

From the above results, in the Nespak plan, the allowance for extra width at the bend δ = 16 m is smaller than the Japanese criteria. However, as the curve radius R is larger, the maneuvering of vessels will be easier, and the dredging quantity will be less. Therefore, widths at channel bends will be determined according to the Nespak plan.

5. Turning Basin and Berth Setback

In general, a circle with 3 X vessel length (L) as the diameter is suggested as the dimension of the turning basin. However, when tugs are available for turning and maneuvering, the minimum diameter may be 2 X vessel length (L). As both the Japanese criteria and the Nespak plan recommend the above figures, the diameter of the turning basin will be 2L.

The setback of berths from the navigation channel or turning basin will be 80 m.

6. Passing Zones

The channel will be designed primarily for one way traffic except in two zones where the channel is deep and wide.

In the inner Approach Channel 10.0 km - 14.0 km from the channel entrance, vessels will be allowed to pass or moor for relief, and the section in Phitti Creek 20 km - 23 km from the channel entrance will be considered as the mooring basin for small vessels. In the two sections, excluding the navigation channel, the depth will be designed for 25,000 DWT vessels. In case of passing of two vessels of 50,000 DWT, the incoming full-loaded vessel will navigate the channel, and the outgoing vessel with light draft will be able to wait in the mooring basin.

II-3 CHANNEL DEPTH

The channel depth is determined by adding extra depth allowance to the full load draft of vessels to enable vessels to navigate safely at an economic speed. According to the Japanese design criteria, the depth of the channel is determined by the depth of berths to accommodate the navigating vessels.

However, in approach channels where vessels navigate at regular speed, channels subject to strong effects of waves, winds, and tidal currents, channels with a large tidal range, and channels for extremely large vessels, it is recommended that, (1) vessel motion due to wave action (extra depth allowance will be $\frac{2}{3}$ the wave height for small boats and $\frac{1}{2}$ the wave height for large vessels), and (2) trim and squat due to the navigation of vessels be considered. However, in case of low navigating speed, the sinking of the hull due to trim and squat is not considered.

The Nespak plan has taken into consideration waves at ordinary times and during monsoons, and has made a detailed analysis of particular conditions of the area such as tidal assistance. As there is not much difference between the two criteria, the Nespak plan will be adopted.

a. Design Vessel Draft

DWT	Draft loaded
25,000	10.1 m (33')
50,000	11.9 m (39')

b. Vessel motion due to wave action

An allowance of $\frac{1}{2}$ the wave height will be considered for vessel motion due to wave action for all vessels.

In the Approach Channel the wave height is,

- During monsoons, the significant wave height is H = 3.0 m
- At other times, the wave height is H = 0.6 m - 0.9 m

The Phitti and Kadiro reaches are closed channels with bends, and vessels will not be moved by wave action.

Therefore, vessel motion due to wave action will be as follows.

	Approach Channel	Phitti and Kadiro Reaches
During monsoons	$= \frac{1}{2} \cdot H = 1.5$ m	0 m
Ordinary times	0.6 m	0 m

c. Squat

In water areas of shallow depths or small channel sections, the hull of vessels squat. Squat for various vessel sizes and channel configuration is in the range of 12.5 cm - 20 cm (5" - 8"). Therefore, an allowance of 15 cm (0.5') will be used for all vessels.

d. Net underkeel clearance

To provide a margin for safety against contact with the sea bottom, an allowance of 0.45 m (1.5') will be made.

e. Survey accuracy

An allowance of 0.3 m (1') will be made in consideration of the degree of accuracy of sounding surveys.

f. Sediment deposition

An allowance of 0.90 m (3') will be made for sediment deposition in the Approach Channel during the S.W. monsoon.

In the Phitti and Kadiro reaches, an allowance of 0.15 m (0.5') will be sufficient to provide against suspended particles due to turbulence by passing vessels.

g. Tidal assistance

It would not be economically jusified to dredge the channel for vessels of maximum size to navigate the channel at all stages of tides in view of the small number of large vessels to enter port and the relatively high cost of dredging. Therefore it is recommended that vessels wait for suitable tides to enter port. The cost of dredging, the cost of ship delays, and the time required for waiting and transit have been studied and analyzed. The time required for transit from the channel entrance to berthing at Pipri is assumed to be 6 hours. It is recommended that the port commence operation on the basis of a tide elevation criteria of + 1.8 m (+ 6').

h. Berth depth

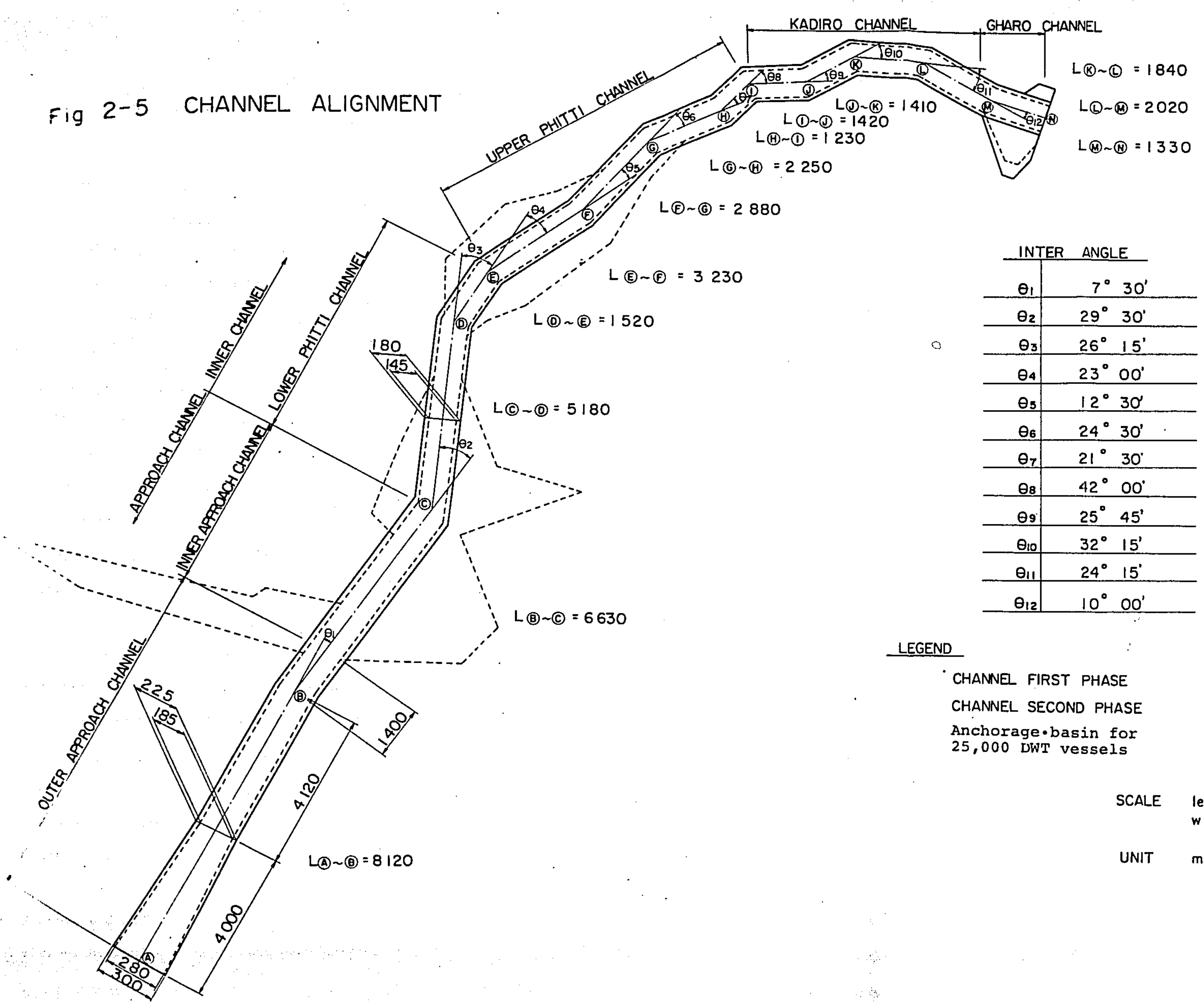
The Nespak plan considers an allowance of 0.9 m (underkeel 0.6 m and sediment deposit 0.3 m) for the berth depth.
In the Japanese criteria, the allowance is 0.5 m - 1.5 m.
The figures are roughly of the same value, and the Nespak plan will be adopted.
Channel depths calculated on the basis of the above criteria are shown in the following Table-5.

Table 2-3

CHANNEL DEPTHS

	Approach Channel				Phitti and Kadiro Channel		Berth and Turning Basin	
	25,000 DWT		50,000 DWT		25,000 DWT	50,000 DWT	25,000 DWT	50,000 DWT
	Normal	Monsoon	Normal	Monsoon				
Maximum draft	10.1^{m}	10.1^{m}	11.9^{m}	11.9^{m}	10.9^{m}	11.9^{m}	10.9^{m}	11.9^{m}
Depth allowance								
Wave action	0.6	1.5	0.6	1.5	-	-	-	-
Squat	0.15	0.15	0.15	0.15	0.15	0.15	-	-
Underkeel clearance	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Survey accuracy	0.3	0.3	0.3	0.3	0.3	0.3	-	-
Sediment deposition	-	0.9	-	0.9	0.15	0.15	0.3	0.3
Total	11.75	13.55	13.55	15.35	11.30	13.10	11.0	12.8
Available depth								
Tides	(-)1.8	(-)1.8	(-)1.8	(-)1.8	(-)1.8	(-)1.8	-	-
Total	9.95	11.75	11.75	13.55	9.5	11.30		
Channel depth	11.8 m		13.6 m		9.5 m	11.3 m	11.0 m	12.8 m

Fig 2-5 CHANNEL ALIGNMENT



INTER	ANGLE
θ1	7° 30'
θ2	29° 30'
θ3	26° 15'
θ4	23° 00'
θ5	12° 30'
θ6	24° 30'
θ7	21° 30'
θ8	42° 00'
θ9	25° 45'
θ10	32° 15'
θ11	24° 15'
θ12	10° 00'

LEGEND

CHANNEL FIRST PHASE - - - - - - - - - -

CHANNEL SECOND PHASE ————————

Anchorage•basin for 25,000 DWT vessels - - - - - - - - - -

SCALE length 1: 100 000
width 1: 20 000

UNIT meter

CHAPTER III CHANNEL SEDIMENTATION

III-1 NAVIGATION CHANNEL

The principle port facilities of Port Qasim consist of the inner port channel of Phitti Creek and the Approach Channel to be dredged from the creek to the open sea. The Inner Channel is a natural deep water area, and it will not be difficult to improve the channel and construct wharves along the banks.

However, the proposed site for the Approach Channel is a relatively shallow Phitti Creek bar extending for 8 km with water depths of 6 m. For the navigation of large vessels, the channel must be dredged across the bar, and constant dredging will be necessary to maintain the depth and width of the channel.

In the area including the sand bars, from May to September, the S.W. monsoon prevails, and the wave height rises to 3m - 4m. In crossing the bars, the waves will carry sand and silt into the channel. The sediment deposits must be dredged to restore the channel during the remainder of the year. The sedimentation and maintenance dredging will be repeated every year, an extremely unfavorable problem for Port Qasim.

The cost of maintenance dredging must be kept within the balance of port finances, an important key to the sucessful development of Port Qasim as an up-to-date port with facilities on a high and operating level and efficient services.

III-2 HYDRAULIC STUDIES

A number of hydraulic studies have been carried out in the Phitti Creek sand bar zone prior to the decision of the Government of Pakistan to develop Port Qasim as the second port of Pakistan.

From 1969 to 1974, detailed hydraulic studies were carried out by the Hydraulic Research Station of England. Later, the Japanese Investigation Team studied the problem seriously in the pre-feasibility study. From these various studies, it was concluded that the yearly sedimentation in the channel would be in the range of 1,000,000 tons, and the cost of maintenance dredging would be within the balance of port finances, indicating the feasibility of developing a port complex.

The H.R.S. study recommended that a trial dredging program will be carried out to provide for a more accurate rate of infill and annual maintenance dredging.

From November 1973 to April 1974, P.Q.A. carried out dredging with two large trailing suction hopper dredges. The trial cut consisted of a 600 feet wide channel over a distance of 4,000 feet and an average depth of 4 feet. The following results were revealed by the trial dredging.

a. Infilling will occur through the entire approach channel across the bar.

b. Throughout the entire 8 km of the channel a large amount of infill will accumulate in the middle sections, gradually decreasing at both ends.

c. From the sections of the channel, the side slopes on the north-west end have been flattened, and the amount of infilling in the channel is predominant, while on the southeast end, the side slopes are only slightly flattened.

d. Judging from the trial dredging, the amount of infilling in the entire proposed channel may be assumed to be 1,700,000 m^3 per year.

e. The calculated rates of siltation based on trial dredging is approximately 2 - 3 times the amount predicted by H.R.S. The study merely indicates the order of the figures, and siltation of 2 - 3 times the figure may well be dredged with expenses within the annual budget of Port Quasim.

III-3 SEDIMENTATION DURING DREDGING PERIOD

The dredging of the channel for vessels of 50,000 DWT will require about three years, passing through the monsoon season three times. Dredging works will be commenced when each monsoon season is over. Sedimentation during the monsoon will be removed, and the next capital dredging will be commenced.

In the report of H.R.S. on the trial dredging, the amount of sedimentation during the monsoon season is predicted to be 1,700,000 m^3. However, in the proposed Approach Channel dredging program, the side slopes will be in the grade of 1 : 20. The volume of infill may be assumed to be reduced to 82% of the above predicted amount. The volume of infill to be removed will be 1,400,000 m^3.

As the source of infill is considered to be the erosion of the channel slopes, the quantity is expected to be reduced each year. However, as the exact trend is not clear at present, during the three monsoon seasons of the dredging period, it will be assumed that the same volume of infill must be removed.

The total dreding quantity to remove the infill throughout the course of dreding will be 4,200,000 m^3. Removal of infill during the course of dredging should not be considred as maintenance dredging. Maintenance dredging applies to dredging works to maintain the necessary depth of the channel after the port has commenced operation. The above restoration works are works to be repeated in the course of dredging, and should be included in the capital dredging. The trial dredging report of H.R.S. has predicted the rate of sedimentation from actual figures. Nevertheless, as it is merely an assumption, it cannot be said to be an accurate prediction of the actual rate of sedimentation following the completion of the navigation channel.

Repeating the dredging of the channel and removal of infill after each monsoon, useful information and experience may be gained for the planning of maintenance dredging in Port Qasim in the future. It is recommended that the state of infill and the effect of removing the infill be closely studied during the course of dredging.

When the monsoon season is over, the infill must be completely removed before capital dredging is commenced. If part of the infill should be left unremoved when the next monsoon comes, it will be difficult to observe the accurate state of sedimentation of the year.

It is recommended that an efficient system of conducting sounding surveys be established within the P.Q.A.

III-4 MAINTENANCE DREDGING OF APPROACH CHANNEL

After the first stage of construction works has been completed and the port has commenced operation, it will be necessary to carry out the dredging of infill in the channel every year. The dreding will be referred to as maintenance dredging. Maintenance dredging may be planned on the basis of the trend of infill studied during the course of capital dredging.

Considering the sedimentation during the monsoon season, capital dredging will be planned to include a depth allowance of 0.9 m for the infill. Studying the trend of infilling, it will be possible to increase the rate of over-dredging at sections with heavy sedimentation in the course of maintenance dredging.

With appropriate measures to provide against sedimentation, vessels may navigate without difficulty during the monsoon season.

For at least 3 years from the opening of Port Qasim for general use, it is recommended that maintenance dredging be carried out on a contract basis.

As the erosion of channel slopes is the source of sedimentation, it is considered that the quantity of sediment will be gradually reduced each year. Monsoon waves are not of the same force each year, and it will be difficult to make an accurate prediction of future sedimentation from the experience of one or two years. Therefore, the required capacity of the dredger for maintenance dredging will be uncertain, and it will be a large risk for P.Q.A. to purchase a dredger at an early date.

Conducting maintenance dredging on a contract basis for the first 3 years, after the trend of infill has been studied, and the capacity of the dredger has been determined, P.Q.A. may purchase a dredger and carry out the maintenance dredging directly.

However, the following difficulties will be encountered in case P.Q.A. owns and operates a dredger for maintenance dredging.

1) The ship-building price of a dredger will probably be more than U.S.$15,000,000.

2) A crew of 25 men will be required for the operation of the dredger. To work on 3 shifts, a total of 75 men will be necessary, and one third must be experienced foreign crew. For four or five months during the monsoon, the dredger and crew will be idle.

3) A management system with a staff of about 30 personnel will be necessary for the operation, maintenance and support of dredging operations.

4) An efficient operation of a trailer suction dredger cannot be easily assured. With complicated mechanism, the skill and knowledge of experienced crew are necessary for efficient dredging operations.

Therefore, it is recommended that maintenance dredging be carried out completely by contract rather than by a port-owned dredger.

In case of an open bid for contract dredging, it cannot be assured that a dredger suited for Port Qasim will be available every year.

In years of international shortage of dredging capacity, a dredger may not be available. Therefore, it is recommended that P.Q.A. select a foreign contractor well experienced in dredging operations, and enter into a long term contract for maintenance dredging.

The contractor will build a dredger suited for Port Qasim. P.Q.A. will assure the depreciation of the shipbuilding cost by entrusting the maintenance dredging of the channel to the contractor every year, and take advantage of the engineering skill and experience of the contractor.

In case maintenance dredging is to be carried out by P.Q.A. with a port-owned dredger, the following system may be recommended.

In concluding the above long term contract for maintenance dredging, it may be specified that, after a fixed period, first, the crew and then, the management system will be gradually turned over to P.Q.A. Finally, P.Q.A. will purchase the dredger of the contractor, which has been largely depreciated, and conduct maintenance dredging directly.

Engineering technique will be transfered smoothly, and the dredger may be procured at a low cost.

III-5 DREDGING OF INNER CHANNEL

1. Capital Dredging

The natural water depth of Phitti Creek is quite sufficient for the navigation of vessels of 3,000 - 5,000 DWT, but the channel must be dredged for large vessels to enter port.

According to the dredging program, for the navigation of vessels of 25,000 DWT and 50,000 DWT, the dredging quantity is less than 1,000,000 m^3 and 5,000,000 m^3 respectively. Locations to be dredged are scattered, and the dredging quantity in each location is small.

Therefore, it is recommended that this capital dredging be entrusted to a contractor with a high professional level and long experience.

2. Maintenance Dredging

In the course of capital dredging to increase the width of the channel, the banks will be dredged to sharp slopes. With swift tidal currents in the channel, sedimentation may occur from the erosion of slopes, but the quantity will be small as the creek is free of floods and waves.

An extra depth allowance of 0.15m for infill is included in the design water depth for the inner channel dredging program. It will not be necessary to remove a slight infill at once.

It is recommended that an accurate sounding survey be carried out every year, and maintenance dredging works commenced when necessary.

As the dredging will be an occasional operation, contract dredging will be recommended.

CHAPTER IV NAVIGATION CHANNEL DREDGING PROGRAM

IV-1 OUTLINE OF PROGRAM

1. General

The development of Port Qasim may be divided into the construction of a port complex in the inner reaches of the Phitti Creek system and the dredging of a navigation channel of approximately 40 km from the open sea to the port complex.

The dredging of the navigation channel will occupy a large portion of the entire construction cost of Port Qasim, and dredging works will involve difficult hydraulic problems. Successful dredging of the navigation channel will be an important key to the development of Port Qasim as an up-to-date port.

From the configuration, the entire navigation channel may be divided into two sections. The inner channel of 24 km within the creek system is a natural deep water area, protected from winds and waves from the open sea. Middle size vessels navigate the channel at present.

In the Approach Channel section, a wide sand bar with depths less than -6 m, known as the Phitti Creek bar must be dredged. Dredging operations will encounter difficulties from winds and waves, and sedimentation deposits will occur from S.W. monsoons.

Therefore, as channel dredging in the two sections will be of quite different nature, technical discussions will be carried on for each section of the channel.

From the construction schedule of Port Qasim, the navigation channel must be available in time for the commencement of operation of the Steel Mill to be established near the Port complex. As the first phase of construction works, by the end of 1977, both the Inner Channel and Approach Channel must be dredged to accommodate vessels of 25,000 DWT, and as the second phase, by the end of 1979, the channel must be dredged for vessels of 50,000 DWT.

2. Approach Channel

The Approach Channel extends from the entrance of the channel to the second bend past a deep water area approximately 9.5 km from the entrance. In the Approach Channel, the section with the minimum water depth is around a shoal of El - 6.1 m (-20'), and the sea bottom is of a very gradual natural slope. The average water depth of deep water areas is around -15 m (-50') with a maximum water depth at El. -20m (-70').

By dredging shallow areas scattered in five locations, the deep water area will be available as the anchorage for 25,000 DWT vessels. In the second phase, the depth of the anchorage will not be increased, though the navigation channel will be deepened for 50,000 DWT vessels. Refer to DWG. 4-1 - 4-3, and 4-8 - 4-10.

In the first phase dredging program, the dredging quantity inclusive of the navigation channel, anchorage and side slopes will be 12,731,000 m^3. In the second phase, the dredging quantity inclusive of the navigation channel and side slopes will be 9,261,000 m^3. Refer to DWG. 4-1 - 4-3.

3. Inner Channel

The lower Phitti Creek section of the navigation channel is generally of sufficient natural water depth. In the first phase, minor areas in three locations will require dredging of very small quantities. Refer to DWG. 4-4 - 4-5.

In the second phase, four locations will require dredging, and the dredging quantity will be 499,000 m^3. Refer to DWG. 4-11 - 4-12.

The upper Phitti Creek section of the navigation channel is also favored with natural water depth. In the first phase, a small quantity of dredging will be required in one location. Refer to DWG. 4-6.

In the second phase, small areas in 8 locations require to be slightly dredged, with a dredging quantity of 216,000 m^3. Refer to Dwg. 4-13.

In the Kadiro Creek section, the width of the channel becomes narrower. Dredging areas increase with the deepening and widening of the channel and cutting of the side slopes on both sides of the channel. In the first phase, areas in 9 locations will be dredged with a dredging quantity of 460,000 m^3. Refer to Dwg. 4-6 - 4-7. In the second phase, areas in 19 locations will be dredged with a total dredging quantity of 2,019,000 m^3. Refer to Dwg. 4-13 - 4-14.

In the Gharo Creek section, the water area is wide with natural water depth. However, in times of strong winds, the area will serve as a place of refuge for vessels loading and unloading cargo at the berth. Considerable dredging will be required to secure the design water depth of -12.8 m of the berth.

In the first phase, dredging will be carried out in five locations with a dredging quantity of approximately 16,000 m^3. In the second phase, approximately 307,000 m^3 will be dredged in 4 locations.

Refer to Dwg. 4-7, 4-14.

In the berth and anchorage area, after the berth has been constructed, it will be difficult to increase the water depth to the design water depth for the second phase dredging. Therefore, in the first phase, the area will be dredged to the design water depth of -12.8 m for the second phase. In regard to the construction of the berth structure, as the width of the water area in the rear of the berth is narrow, a water area of 40 m in width and -3 m in depth will be dredged to secure sufficient space for the entry of working crafts, casting of anchors, and execution of works. The entire dredging quantity will be approximately 360,000 m^3. Refer to Dwg. 4-7.

Excavation for removal of the existing foundation for the construction of the terminal for related facilities of the Iron Ore and Coal Berth will be carried out by the dredger for the above operation both from the point of dredging schedule and cost. The estimated dredging quantity will be approximately 180,000 m^3. Refer to Dwg. 4-7.

Similarily as the channel in front of the berth, the turning basin will also serve as a place of refuge in times of strong winds. Dredging will extend over nearly the entire area. In the first phase approximately 93,000 m^3 will be dredged in two locations. In the second phase, the natural water depth will not be sufficient, and the majority of the area will be dredged with an estimated dredging quantity of approximately 815,000 m^3. Refer to Dwg. 4-4 - 4-7. 4-11 - 4-14.

4. Dredging Criteria

1) Datum level and design water depth

The natural water depth, depths on sounding charts, and the design water depth are of values below the chart datum.

2) Side slopes

i. Approach channel

From the sedimentation in the trial cut dredged during the trial dredging program carried out by P.Q.A. in 1974, and the natural slope of the sea bottom in the vicinity of Buddo Island, the side slopes of the Approach Channel and mooring basin may be assumed to be in a gradual grade of 1:20.

If the slopes are to be flatter, the dredging quantity will be greatly increased. Therefore, the side slopes of the Approach Channel and basin will be designed as slopes of 1:20.

ii. Inner channel

The side slopes and the natural slope of the sea bottom of the creek system may be assumed to be roughly 1:5 - 1:6. Therefore, the side slopes of the Inner Channel, including the berth basin and turning basin will be designed as 1:6.

3) Over-dredging

An over-dredging allowance of 0.6 m will be added to the design water depth in the Approach Channel and anchorage. From the performance of a trailing suction dredger, it will be difficult to dredge the channel to the design water depth with an over-dredging of merely 0.3 m. In the inner channel, with dredging areas of small quantities in numerous locations, from the performance of a cutter suction dredger, it will be difficult to carry out dredging operations with an over-dredging of 0.3 m.

IV-2 DREDGING PLANT

1. Dredging Plant for Approach Channel

The subsoil of the Approach Channel and basin consists mainly of fine sand which may be easily dredged. The dumping site must be selected so that the dredged material will not return into the channel or basin.

For this purpose, a water area 9.5 km offshore the channel entrance will be selected as the dumping site, and the type of dredging plant to be used will be quite restricted. A trailing suction dredger and a cutter suction dredger with a barge line will be studied to determine the most desirable type of dredging plant to be used.

1) Trailing suction dredger

The plant dredges as it trails, and the dredged material is pumped into the hopper of the dredger. When the hopper is filled to capacity, the dredger stops dredging operations, proceeds to the dumping site by self-propelling, dumps the dredged material, and returns to continue dredging operations. The dredger is capable of both dredging and carrying sand. A dredger with a hopper capacity of 4,000 m^3 is the standard size of the plant.

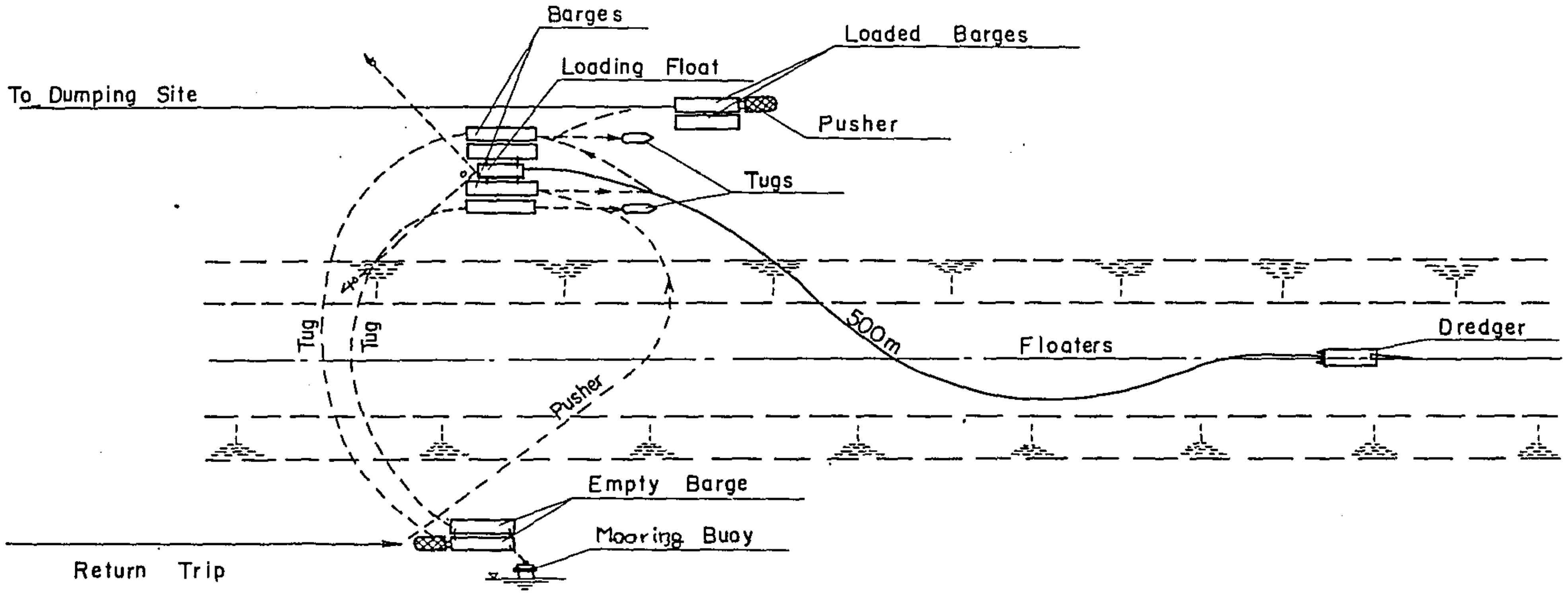
2) Cutter suction dredger and barge line

The material dredged by a cutter suction dredger will be

FIG 4-1

(INDIRECT LOADING SYSTEM)

PUMP CUTTER SUCTION DREDGER AND BARGE LINE



conveyed to a loading float through pipelines on floaters over a distance of 500 m. The material will then be loaded into a large barge. Two barges will be pushed at the same time by a pusher to the dumping site. The operation is shown in Fig. 4-1.

The dredging capacity of the cutter suction dredger and the sand carrying capacity of the barge line must be well balanced to form a dredging fleet for efficient operation as shown in Table 4-1.

Table 4-1

CUTTER SUCTION DREDGER AND BARGE LINE

Item	Horse Power of main engine and others	No.
Cutter suction dredger	D-4,000 PS	1
Floaters		500 m
Anchor barge	15 ton anchor lift	1
Loading float	Capable of loading on both sides	1
Barge	1,200 m^3 loading capacity	6
Tug	D-250 PS	1
Pusher	D-3,000 PS	2
Tug	D-450 PS	1
Supervising launch	D-250 PS	1

3) Comparison of capacity and cost

A comparison of the sand carrying capacity and the cost per cubic meter for a trailing suction dredger and a cutter suction dredger with a barge line is shown in Table 4-2.

Table 4-2

SAND CARRYING CAPACITY AND COST PER m^3

Dredging plant	Sand carrying capacity	Cost per m^3
Trailing suction dredger	100%	100%
Cutter suction dredger and barge line	70%	170%

4) Dredging plant to be used

From the above comparison of the two types of dredging plants, as the trailing suction dredger is superior to the cutter suction dredger with a barge line, a trailing suction dredger will be used to dredge the Approach Channel and basin.

2. Dredging Plant for Inner Channel

The subsoil of the Inner Channel, anchorage and turning basin consists generally of clay with silt or clay with silt and fine sand. The soil may be easily dredged, but the dredged material must be dumped in a site so that the spoil will not be carried back into the channel or anchorage.

A grab-bucket dredger with a barge line and a pump cutter suction dredger may be considered as dredging plants for Inner Channel dredging.

1) Grab-bucket dredger and a barge line

Dredging Fleet

i) Grab-bucket dredger 16 m^3 or more 2 dredgers

ii) Pusher boat	2,000 PS or more	2 boats
iii) Barge	1,200 m^3 capacity	8 barges
iv) Anchor barge		2 barges
v) Supervising launch	250 PS	1 launch

In case of dredging by a grab-bucket dredger, barges of a hopper capacity of 1,200 m^3 will be required to meet the large capacity of the grab-bucket. The full-load draft of a barge with a loading capacity of 1,200 m^3 will be 3.6 m. If the spoil is to be dumped to a thickness of 2.0 m, the required water depth will be 5.6 m. Adding a depth allowance of 0.4 m, the dumping site must be selected in areas with water depths of -6.0 m or deeper.

Sites for dumping with water depths deeper than -6.0 m on the starboard side may be found in the Chara Creek, Rakahal Creek, and Chanwadoo Creek systems. However, as the lower reaches of the creek systems run into the Approach Channel, the spoil dumped in the creek systems may be expected to be carried back into the channel. Therefore, the sites will be ruled out as dumping sites for dredged spoil.

As alternate sites, in the Korangi Creek, a separate creek system from the navigation channel, in the northwest of the Khiprianwalu Islands, dumping sites with sufficient water depths may be found. However, a fishery port exists in the creek system, and the distance of carrying sand will be 17 km from the dredging areas. The dredging cost will be far greater than the case of dredging by a cutter suction dredger.

Moreover, two dredging fleets will be required for the smooth operation of dredging works. Therefore, dredging by a grab-bucket dredger will be ruled out for dredging operations in the Inner Channel.

2) Pump Cutter Suction Dredger

Dredging Fleet

i)	Cutter Suction Dredger	D-4000 PS class	1 dredger
ii)	Anchor barge	15 ton anchor lift	1 barge
iii)	Tug	D-450 PS	1 tug
iv)	Supervising launch	D-250 PS	1 launch
v)	Conveyance barge	150 ton capacity	1 barge

The material dredged by a cutter suction dredger may be disposed in the creek sites exposed at ebb tide around the respective dredging areas, or discharged to distant dumping sites in the mangrove swamps of elevation in the range of 0 m. It is recommended that the Inner Channel dredging be planned with a pump cutter suction dredger.

CHAPTER V APPROACH CHANNEL DREDGING

V-1 DREDGING QUANTITIES

1. Calculation of Dredging Quantities

On sounding charts, Dwg. 4-1 - 4-3, on a scale of one to ten thousand, the channel and basin were plotted in large divisions with numbers for each division. For each numbered division, sites with depths less than the design depth were marked. When several marked sites formed an independent area in one division, sub-numbers were given, and, the area to be dredged was calculated for each sub-number. The average ground level was calculated by dividing the total of values smaller than the design depth by the total number of the smaller values.

The dredging thickness was calculated by subtracting the average ground level from the design water depth. The dredging quantity may be obtained by multiplying the area to be dredged by the dredging thickness.

The calculation may be indicated as follows.

(i) Area of sites to be dredged ---------------------------- A

(ii) $\frac{\text{Total of values less than the design depth}}{\text{No. of values less than the design depth}}$ = average

ground level -- D

(iii) Design water depth ------------------------------------ H

(iv) H-D = average dredging thickness ---------------------- d

(v) A x d = Channel dredging quantity

(vi) A x 0.6 = Over-dredging allowance

(vii) Calculation of the channel slopes

The channel will be divided into the starboard and portside, and sections will be made for each side according to the topography of the area.

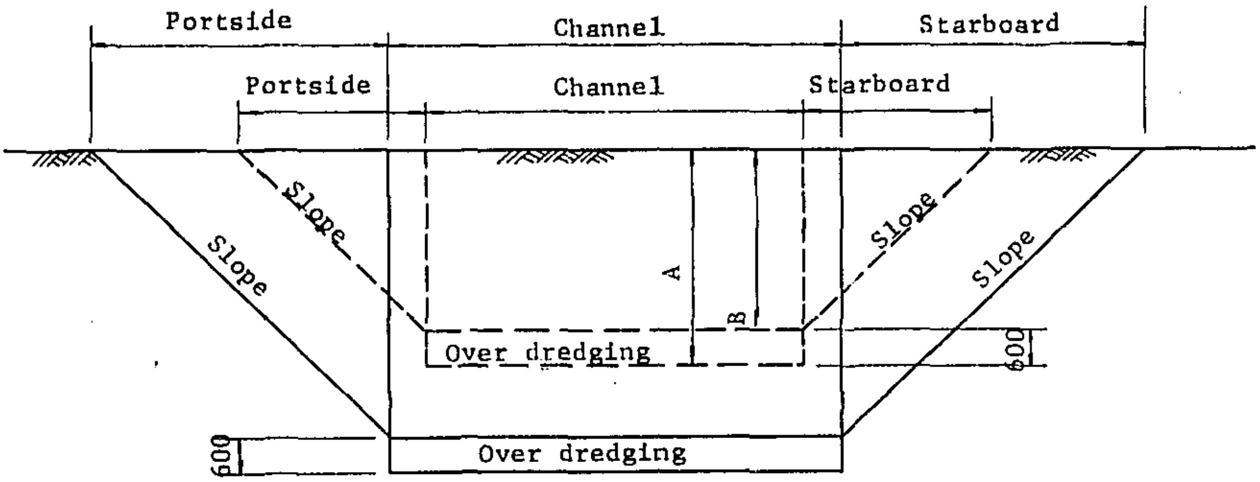
The dredging quantity may be obtained by multiplying the average section area by the extension length.

The dredging quantity may be calculated for each division, and the sum of the respective dredging quantities will be the total dredging quantity for the first phase.

In calculating the dredging quantity for the second phase, the first phase dredging will be disregarded. The dredging quantity will be calculated by the method applied in the case of the first phase dredging. From the calculated dredging quantity, the quantity to be dredged in the first phase will be subtracted. The second phase dredging quantity will be obtained as shown in Fig. 5-1.

Calculation of the over-dredging quantities will not be overlapped.

FIG 5 - 1



A - - - - - - - First phase dredging quantity

B ———————— Total dredging quantity

B - A = Second phase dredging quantity

2. Estimated Dredging Quantities

Dredging quantities calculated according to the above methods will be as given in Tables 5-1 and 5-2.

i) First Phase

Table 5-1

DREDGING QUANTITIES FOR APPROACH CHANNEL

Channel basin	Over-dredging	Side slopes		Total
		Portside	Starboard	
7,710	1,097	1,798	2,126	12,731
60.6%	8.6%	14.1%	16.7%	100%

Unit: 1,000 m^3

ii) Second Phase

Table 5-2

DREDGING QUANTITIES FOR APPROACH CHANNEL

Channel basin	Over-dredging	Side slopes		Total
		Portside	Starboard	
4,477	1,541	1,559	1,685	9,262
48.4%	16.6%	16.8%	18.2%	100%

Unit: 1,000 m^3

Dredging of sedimentation during the dredging period is not included in the above dredging quantities.

Refer to Tables 5-3 - 5-4 for a detailed breakdown of the dredging quantities.

3. Sedimentation during Dredging Period

As described in Chapter III, the amount of sedimentation in the course of dredging works will be assumed to be 1,400,000 m^3 for one monsoon.

The monsoon will be experienced once during the first phase dredging, and twice during the second phase dredging. The amount of sedimentation will be added to the dredging quantities given in Tables 5-3 and 5-4 to obtain the total dredging quantities.

i) First Phase

12,731 thousand m^3 + 1,400 thousand m^3 = 14,131 thousand m^3

ii) Second Phase

9,262 thousand m^3 + 2,800 thousand m^3 = 12,062 thousand m^3

Table 5-3

DREDGING QUANTITIES FOR APPROACH CHANNEL (FIRST PHASE)

Zone	Division No.		Channel · Basin					Side Slopes		Total
			Design Depth	Dredging Area (A)	Dredging Thickness	Dredging Quantities	Over-Dredging (A 0.6)	Portside	Starboard	
Approach Channel	1		-11.8	763,425 m^2	3.94 m	3,006,559 m^3	458,055 m^3	627,885 m^3	704,895 m^3	4,797,394 m^3
	2		-11.8	762,663	5.29	4,032,277	457,598	1,098,540	1,199,625	6,788,040
	3		-11.8	204,500	2.93	599,185	122,700	67,728	174,263	963,876
	4		-11.8	0	0	0	0	0	0	0
	4'	1.Right	-11.8	6,500	0.58	3,770	3,900	0	2,240	9,910
		2.Right	-11.8	25,175	1.65	41,539	15,105	0	30,670	87,314
		Sub-Total		31,675		45,309	19,005	0	32,910	97,224
	5		-11.8	17,200	0.21	3,612	10,320	4,653	0	18,585
	6'	1. Right	-11.8	47,000	0.43	20,210	28,200	0	6,648	55,058
		2. Right	-11.8	1,625	1.74	2,828	975	0	7,475	11,270
		Sub-Total		48,625		23,038	29,175	0	14,123	66,336
	6		-11.8	0	0	0	0	0	0	0
Total				1,828,088		7,709,980	1,096,853	1,789,806	2,125,816	12,731,455

DREDGING QUANTITIES FOR APPROACH CHANNEL (SECOND PHASE)

Zone	Division No.		Channel · Basin					Side Slopes		Total
			Design Depth	Dredging Area (A)	Dredging Thickness	Dredging Quantities	Over-Dredging (A 0.6)	Portside	Starboard	
Approach Channel	1		-13.6	1,050,000m^3	1.56^m	1,636,886m^3	630,000m^3	537,718m^3	562,118m^3	3,366,722m^3
	2		-13.6	927,563	2.25	2,088,173	556,538	839,740	894,568	4,379,019
	3	(1)	-13.6	262,000	1.75	459,735	157,200	79,032	223,215	919,182
		(2)	-13.6	71,500	1.07	76,505	42,900	19,068	0	138,473
		Sub-Total		333,500		536,240	200,000	98,100	223,215	1,057,655
	4	(1)	-13.6	64,500	0.88	56,760	38,700	3,350	0	98,810
		(2)	-13.6	113,000	0.73	82,490	67,800	1,775	3,900	155,965
		(3)	-13.6	9,250	0.40	3,700	5,550	0	100	9,350
		Sub-Total		186,750		142,950	111,050	5,125	4,000	264,125
	5	(1)	-13.6	9,000	0.49	4,410	5,400	0	563	10,373
		(2)	-13.6	62,500	1.09	67,943	37,500	78,153	78	183,674
		Sub-Total		71,500		72,353	42,900	78,153	641	194,047
	6		-13.6	0		0	0	0	0	0
Total				2,569,313		4,476,602	1,541,588	1,558,836	1,684,542	9,261,568

V-2 DREDGING AND DUMPING

1. Dredging Material

Boring holes, S_1, S_2, S_3 have been drilled in three locations as shown in Dwg. 2-1, 3-1 to investigate the subsoil of the outer Approach Channel area. Data on samples collected during the trial dredging in 1974 have also been available. Though the elevation of the site from which the samples were collected is unknown, from the sample data and boring logs of S_1, S_2 and S_3, the soil may be assumed to consist of silty sand of very fine grained sand and micaceous pieces.

In the vicinities of E ℓ.- 11.74 m(-38.5') ~ -13.57 m (-44.5') the N-values are 5-25.

Though boring tests have not been carried out to investigate soil conditions in the inner Approach Channel, from the configuration, soil conditions may be considered as an extension of the outer Approach Channel. And it is assumed that silty clay will be encountered as the channel approaches Phitti Creek. As the average dredging thickness is small, the average N-value of the soil has been assumed to be in the range of 10.

2. Dumping Site

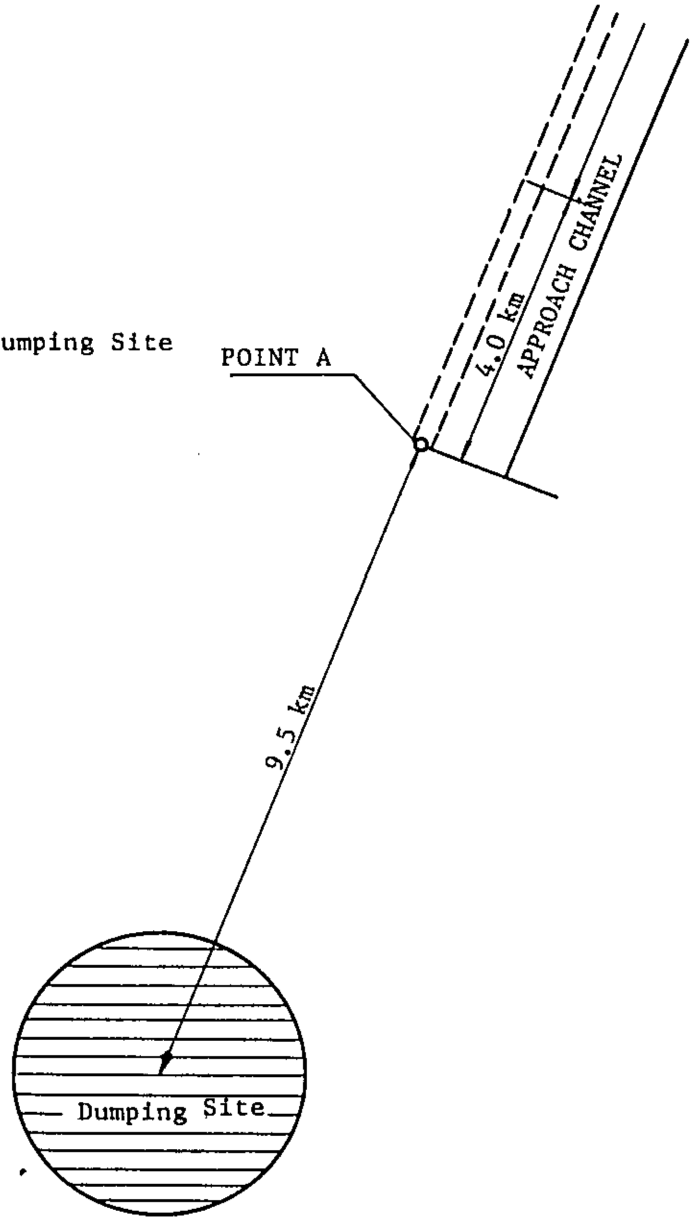
1) Location of dumping site

The dumping site will be located on the extension of the center line of the channel at a distance 9.5 km offshore from the channel entrance A, with water depths of -22m - -24m.

Refer to Fig. 5-2 and Dwg. 1.

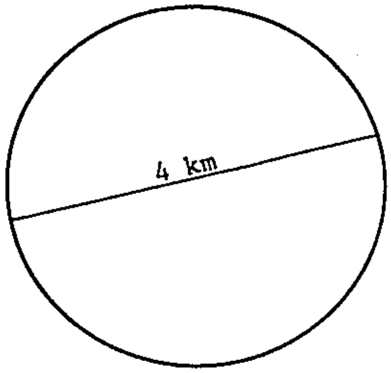
FIG 5 - 2

Proposed Dumping Site



2) Area of dumping site and thickness of spoil

i) Area of dumping site



Area A = 12,566 thousand m^3

ii) Average water depth of dumping site - 23 m

iii) Crown height of spoil - 20 m

iv) Estimated capacity,

A x thickness of spoil = 12,566,000 m^2 x 3 m^2 = 37,700,000 m^2

v) Thickness of spoil

26,193,000 $m^3 \div$ 12,566,000 $m^2 \fallingdotseq$ 2.1 m

3) Advantage of Proposed Site

Spoil dumped in the proposed site will not be carried back into the navigation channel. Waves and tidal currents may be considered as factors to cause movements of sand.

The wave height of maximum waves during the monsoon is 3 m, but it is proved theoretically by hydraulics that there is hardly any effect of waves at a sea bottom of -20 m. It may be assumed that sand at the sea bottom will hardly move throughout the year.

As described in Chapter I-4-2, the current velocity at the channel entrance is 2.0 knot at the maximum and 1.0 knot on the average. Contrary to waves, tidal currents move from the surface to the bottom simultaneously, but the current velocity at the sea bottom is $\frac{1}{2} - \frac{1}{3}$ of the velocity at the surface. Therefore, if the velocity is 1.0 knot at the surface, the velocity at the bottom will be 0.3 - 0.5 knot. A velocity of 1 knot/hr is required to move sand in the vicinity of a dumping site. It may be assumed that the sand will not be carried back into the channel by waves or tidal currents.

3. Monthly Dredge Production

Conditions

Soil: Fine sand with silt
Average N value 10 - 20

Dumping site: Shown in Dwg. 1
In location with depths over -20 m at a distance of 9.5 km offshore from the channel entrance

Dredging plant: Trailing suction dredger

Pumping capacity Q: 2 pumps with pumping capacity of $8{,}000\ m^3$ per hour
$Q = 8{,}000\ m^3 \times 2 = 16{,}000\ m^3/hr$

Density δ: 15%

Hopper capacity V: $4000\ m^3$

Hopper efficiency α: 80%

Swelling rate β: 20%
Volume of dredged material will swell 20% in the hopper

Dredging quantity A for 1 cycle of dredging operations:

$$A = V \times \alpha \div (1 + \beta) = 4{,}000\ m^3 \times 0.8 \div 1.20 = 2{,}670\ m^3$$

Dredging Time T_1: $T_1 = \frac{V \cdot \alpha}{Q \cdot \gamma \ (1+\rho)} = \frac{4,000 \ m^3 \times 0.6}{16,000 \ m^3 \times 0.15 \times 1.20}$

$= 1.1$ hr

Travelling time T_2:

Travelling distance L: Average distance from center of dredging area to dumping site is 15 Km

Travelling speed v: Travelling speed of dredger from dredging area to dumping site and back

$v = 8$ knot x $1.852 = 14.8$ km/hr

$T_2 = \frac{2 \cdot L}{v} = \frac{2 \times 15}{14.8} = 2.0$ hr

Dumping time T_3: Time from the arrival at dumping site, opening of hopper for dumping, dumping of spoil, to turning of ship's bow to begin the return trip.

$T_3 = 0.25$ hr.

Time required for 1 cycle of dredging operation:

$T = T_1 + T_2 + T_3 = 1.1 + 2.0 + 0.25 \doteq 3.35$ hr

Working hours per day: 24 hr.

Net working hours per day: 23 hr.

No. of working cycles per day: 23 hr ÷ 3.35 hr = 6.9 cycles

The figure will be taken as an average of 7 cycles per day.

Dredging quantity per day: A x 7.0 = 2,670 m^3 x 7.0 = 18,700 m^3

No. of working days will be 23 days per month

Monthly production: 18,700 m^3 x 23 days = 430,000 m^3/month

The above monthly production for dredging and sand carrying will be applied to both the first phase and second phase dredging.

4. Progress Schedule

The following schedule will be considered prior to planning the progress schedule for the Approach Channel dredging program. The period of commencing the dreding works will be determined from the following schedule.

1) Progress schedule prior to commencement of dredging works

a)	Invitation of bids and conclusion of contracts	July, 1976
b)	Preparation of dredging fleet	July, 1976
c)	Navigation of dredging fleet to site	Aug. 1976
d)	Commencement of dredging works	Sept. 1976

2) Progress schedule of dredging works

A fleet of two trailing suction dredgers with a hopper capacity of 4,000 m^3 will be used for the first phase and second phase dredging from the point of dredging cost.

The progress schedule will be slightly tight in the first phase, but in the second phase, dredging works will be completed on schedule.

Progress Schedule

i) First phase for 25,000 DWT vessels

Dredging quantity: 14,131,000 m^3

Monthly production: 430 thousand m^3 x 2 dredgers

No. of months required: 16.4 months

ii) Second phase for 50,000 DWT vessels

Dredging quantity: 12,062 thousand m^3

Monthly production: 430 thousand m^3 x 2 dredgers

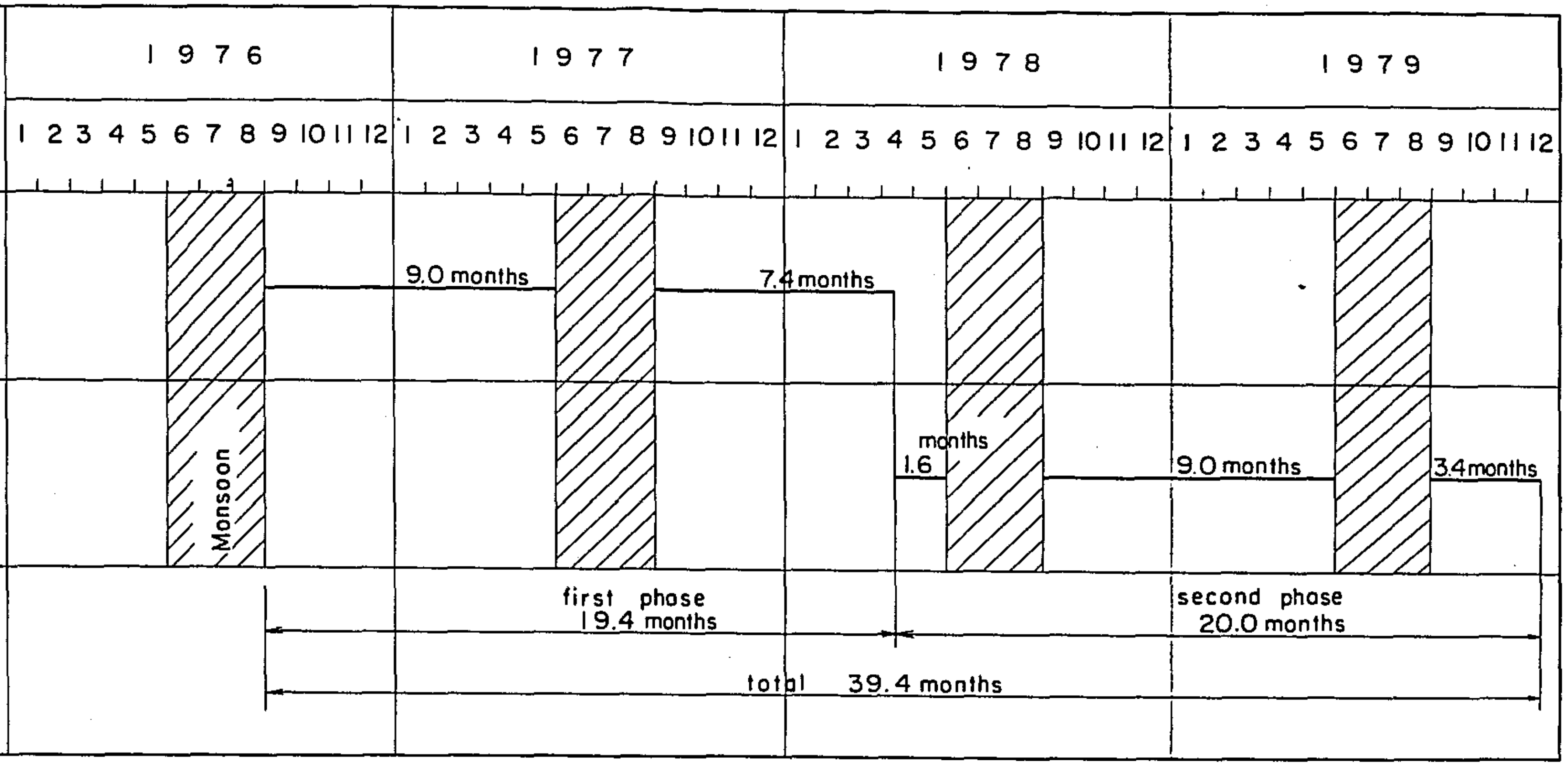
No. of months required: 14.0 months

Total dredging quantity: 26,193 thousand m^3

No. of months required: 30.4 months

Table 5-5 Progress Schedule for Approach Channel Dredging (First phase and second phase)

Vessel	Main Engine	Dredging site	Estimated Dredging Quantities (1 000m³)	Monthty Dredge Production (1000m³)	Working Months (month)
Trailing Suction Dredger	Diesel 9.400ps Hopper Capacity 4.000m³	First Phase	14,131	430x2 = 860	16.4
		Second Phase	12,062	430x2 =860	14.0
Total			26.193		30.4



V-3 COST OF DREDGING AND DUMPING

1. Wages of Crew

In estimating the cost of the dredging program, wages of the crew have been calculated as follows.

Officers will all be foreign hire. One half of the ordinary crew requirement will be foreign, and the remaining half will be local hire. As local crew will not be experienced in dredging operations, the minimum requirement will be twice the regular number. The crew will work on 3 shifts, and extra allowances will not be paid for overtime and late hours.

1) Monthly wage per crew

i) Officers (foreign hire)

Basic pay, including overseas allowance	$65/day

Monthly pay $65/day x 30 days = $1,950/month

ii) Ordinary crew (foreign hire)

Basic pay, including overseas allowance	$55/day

Monthly pay $55/day x 30 days = $1,650/month

iii) Ordinary crew (local hire)

Pay, including miscellaneous cost	30 Rs ($3.00)/day

Monthly pay 30Rs ($3.00)/day x 30 days = 900 Rs ($90)

Table 5-6

CREW REQUIREMENT OF DREDGER

Dredging Plant	Class	Crew Requirement	
		Regular	Present Project
Trailing Suction Dredger (4,000 m^3 hopper capacity)	Officers (foreign hire)	18	18
	Ordinary crew (foreign hire)	54	27
	Ordinary crew (local hire)	0	54
	Total	72	99

2) Cost of crew per dredger for 1 working month

Table 5-7

Class	No.	Monthly Cost per Crew		Total Monthly Cost		
		Foreign Currency	Local Currency	Foreign Currency	Local Currency	Total
Officers (foreign hire)	18 men	1,267 $	680 $	22,860 $	12,240 $	35,100 $
Ordinary Crew (foreign hire)	27	1,070	580	28,890	15,660	44,550
Ordinary Crew (local hire)	54	0	90	0	4,860	4,860
Total	99				32,700	84,510

3) Cost of crew per dredger for 1 non-working month

(in monsoon season)

Table 5-8

Class	No.	Monthly Cost per Crew		Total Monthly Cost		
Officers (foreign hire)	18 men	1,660 $	290 $	29,880 $	5,220 $	35,100 $
Ordinary crew (foreign hire)	27	1,440	250	37,800	6,750	44,550
Ordinary crew (local hire)	0	0	0	0	0	0
Total	45			67,680	11,970	79,650

4) Monthly cost of crew during navigation

Table 5-9

Class	No.	Monthly Cost per crew		Total Monthly Cost		
		Foreign Currency	Local Currency	Foreign Currency	Loccal Currency	Total
Officers (foreign hire)	18	1,950 $	0 $	35,100 $	$	35,100 $
Ordinary Crew (foreign hire)	54	1,650	0	89,100	0	89,100
Total	72			124,200		124,200

2. Cost of Supervising Launch

One launch will be chartered for supervision and transit purposes. Monthly charter cost $4,000/month (local currency)

3. Depreciation of Dredger

In calculating the depreciation cost of the dredger, the shipbuilding price will be estimated to be $15,000,000, and the life span of working days will be 2,700 days. During the life span of working days, the dredger will undergo repairs once every year. The total cost of repairs will be estimated to be equivalent to the shipbuilding price, and a sum of $15,000,000 will be added for maintenance and repairs.

Shipbuilding cost:	$15,000,000 per dredger
Maintenance and repairs:	$15,000,000 per dredger
Working days in life span:	2700 days
Monthly depreciation rate:	30 days/2700 days = 0.0111
Monthly depreciation cost:	$30,000,000 x 0.0111 ≒ $333,000 (foreign currency)

4. Monthly Cost of Trailing Suction Dredger

The number of working months of the trailing suction dredger throughout the year will be calculated as 9 months. During the three monsoon months of June, July, and August, the dredger will be moored for maintenance and repairs of the ship and engine.

1) Monthly cost for 1 working month

	Foreign Currency	Local Currency	Total
Depreciation of dredger	333,000 $	0 $	333,000 $
Fuel	0	24,200	24,200
Wages of crew	67,680	16,830	84,510
Insurance	11,200	0	11,200
Supervising launch	0	4,000	4,000
Miscellaneous	5,120	1,970	7,090
Total	417,000	47,000	464,000

2) Monthly cost for 1 non-working month

	Foreign Currency	Local Currency	Total
Fuel	0 $	5,000 $	5,000 $
Wages of crew	67,680	11,970	79,650
Insurance	11,200	0	11,200
Miscellaneous	120	2,030	2,150
Total	79,000	19,000	98,000

5. Cost of Navigation

Navigation cost of trailing suction dredger

Assuming that the dredger will be navigated from Europe or the Far East, the average distance will be approximately 6,400 miles.

i) Distance of navigation 6,400 miles (one way)

ii) Number of days required for navigation

Navigating days 6,400 miles ÷ (10 miles/hr x 24 hr) = 27 days

Preparation for navigation = 3 days

Total 30 days

iii) Cost of navigation

	Foreign Currency	Local Currency	Total
Depreciation of dredger	333,000 $	0 $	333,000 $
Fuel	24,200	0	242,000
Wages of crew	124,200	0	124,200
Insurance	11,200	0	11,200
Miscellaneous	5,400	0	5,400
Total	498,000	0	498,000

(one way trip)

V-5 COST ESTIMATES

Cost estimates for first phase dredging of the Approach Channel and basin are given in Table 5-10.

Cost estimates for second phase dredging of the Approach Channel and basin are given in Table 5-11.

The navigation cost of the dredger to the site will be calculated in the first phase dredging, and the cost of the return trip will be calculated in the second phase dredging. The dredgers will be off work for 3 months during the monsoon season.

1. FIRST PHASE DREDGING COST Table 5-10

Item	Dredging Plant	Unit	No.	Unit Foreign Currency \$ Local Currency \$	Dredging Cost		Total (\$)
					Foreign Currency \$	Local Currency \$	
Operating Cost	Trailing Suction Dredger	Month	16.4 x 2 = 32.8	417,000 47,000	13,677,600	1,541,600	15,219,200
Off Work Cost	"	"	3 x 2 = 6	79,000 19,000	474,000	114,000	588,000
Navigation Cost	"	Dredger	2	498,000 0	996,000	0	996,000
Contingency		%	8		1,209,800	135,000	1,344,800
Total					16,357,400	1,790,600	18,148,000

Cost per 1 m^3 18,148,000\$ ÷ 14,131,000 m^3 = \$1.28/m^3

2. Second Phase Dredging Cost

Table 5-11

Item	Dredging Plant	Unit	No.	Unit Foreign Currency $	Dredging Cost		Total($)
				Local Currency $	Foreign Currency $	Local Currency $	
Operating Cost	Trailing Suction Dredger	Month	14.0 x 2 = 28.0	417,000	11,676,000	1,316,000	12,992,000
				47,000			
Off-Work Cost	"	"	6.0 x 2 = 12.0	79,000	948,000	228,000	1,176,000
				19,000			
Navigation Cost	"	Dredger	2	473,800	947,600	48,400	996,000
				24,200			
Contingency		%	8		1,091,700	121,300	1,213,000
Total					14,663,300	1,713,700	16,377,000

Cost per 1 m^3 16,377,000$ ÷ 12,062,000 m^3 =$1.36/$m^3$

Average cost per 1m^3 for first and second phase dredging
(18,148,000$ + 16,377,000$) ÷ (14,131,000 m^3 + 12,062,000 m^3) =$1.32/$m^3$

The cost of removing and relocating buoys in the channel is included in the above cost.

CHAPTER VI

INNER CHANNEL DREDGING

VI-1 DREDGING QUANTITIES

1. Calculation of Dredging Quantities

Dredging quantities will be calculated according to the method applied to the calculation of dredging quantities in the Approach Channel.

2. Estimated Dredging Quantities

Dredging quantities calculated according to the above method will be as given in Tables 6-1 - 6-2.

i) First Phase Dredging

Table 6-1

DREDGING QUANTITIES FOR INNER CHANNEL

Channel Basin	Over-dredging	Side Slopes		Total
		Portside	Starboard	
492 44.2%	100 9.0%	436 39.1%	86 7.7%	1,114 100%

Unit: 1,000 m^3

Refer to Tables 6-3-1 - 6-3-2 for a detailed breakdown of the dredging quantities.

ii) Second Phase Dredging

Table 5-2

DREDGING QUANTITIES FOR INNER CHANNEL

Channel • Basin	Over-Dredging	Side Slopes		Total
		Portside	Starboard	
1,940 50.3%	726 18.8%	481 12.5%	711 18.4%	3,858 100%

Unit: 1,000 m^3

Refer to Tables 6-4-1 - 6-4-2 for a detailed breakdown of the dredging quantities.

3. Sedimentation during Dredging Period

In regard to sedimentation during the dredging period described in Chapter III, as the Inner Channel is not affected by the monsoon, it will be assumed that hardly any sedimentation will occur during the dredging period.

Table 6-3-1

DREDGING QUANTITIES FOR INNER CHANNEL (FIRST PHASE)

Zone	Division No.		Channel • Basin					Side Slopes		Total
			Design Depth	Dredging Area (A)	Dredging Thickness	Dredging Quantities	Over-Dredging (A 0.6)	Portside	Starboard	
Lower Phitti Creek Channel	7		-9.5^{m}	0^{m^2}	0^{m}	0^{m^3}	0^{m^3}	0^{m^3}	0^{m^3}	0^{m^3}
	8		-9.5	1,575	0.21	331	945	0	0	1,276
	9		-9.5	1,170	0.52	608	702	0	0	1,310
	10		-9.5	0	0	0	0	0	0	0
	11		-9.5	0	0	0	0	0	0	0
	Total			2,745		939	1,647	0	0	2,586
Upper Phitti Creek Channel	12		-9.5	0	0	0	0	0	0	0
	13		-9,5	0	0	0	0	0	0	0
	14		-9.5	0	0	0	0	0	0	0
	15		-9.5	0	0	0	0	0	0	0
	16		-9.5	0	0	0	0	0	0	0
	17		-9.5	0	0	0	0	0	0	0
	18		-9.5	1,900	0.21	399	1,140	0	0	1,539
	Total			1,900		399	1,140	0	0	1,539
Kadiro Creek Chanel	19	(1)	-9.5	10,800	3.81	41,148	6,480	125,105	0	172,733
		(2)	-9.5	1,500	1.49	2,235	900	4,600	0	7,735
		Sub-Total		12,300		43,383	7,380	129,705	0	180,468
	20		-9.5	9,500	1.68	15,960	5,700	0	27,115	48,775
	20	(1)	-9.5	4,000	1.86	7,440	2,400	0	40,595	50,435
		(2)	-9.5	3,000	1.68	5,040	1,800	21,660	0	28,500
		Sub-Total		7,000		12,480	4,200	21,660	40,595	78,935
	21	(1)	-9.5	413	2.18	904	248	4,710	0	5,862
		(2)	-9.5	2,475	2.80	6,930	1,485	8,145	0	16,560
		Sub-Total		2,888		7,834	1,733	12,855	0	22,422

Table 6-3-2

DREDGING QUANTITIES FOR INNER CHANNEL (FIRST PHASE)

Zone	Division No.		Design Depth	Channel · Basin				Side Slopes		Total
				Dredging Area (A)	Dredging Thickness	Dredging Quantities	Over-Dredging (A 0.6)	Portside	Starboard	
Kadiro Creek Channel	23	(1)	-9.5	11,500$^{m^2}$	4.16^m	47,669$^{m^3}$	6,900$^{m^3}$	39,895$^{m^3}$	0$^{m^3}$	94,464$^{m^3}$
		(2)	-9.5	900	0.98	882	540	4,275	0	5,697
		(3)	-9.5	310	1.71	530	186	0	2,460	3,176
		Sub-Total		12,710		49,081	7,626	44,170	2,460	103,337
	24		-9.5	0	0	0	0	0	0	0
	25		-9.5	1,339	2.16	2,892	803	0	8,365	12,060
	26	(1)	-9.5	5,400	0.76	4,104	3,240	0	2,625	9.969
		(2)	-9.5	240	1.28	307	144	3,440	0	3,891
		Sub-Total		5,640		4,411	3,384	3,440	2,625	13,860
	Total			51,377		136,041	30,826	211,830	81,160	459,857
Gharo Creek Channel	27	1	-9.5	750	0.46	345	450	705	0	1,500
		2	-9.5	1,400	0.27	378	840	0	2	1,220
		Sub-Total		2,150		723	1,290	705	2	2,720
	28	1	-9.5	2,500	1.20	3,000	1,500	4,026	0	8,526
		2	-9.5	1,700	0.40	680	1,020	24	0	1,724
		3	-11.0	2,000	0.60	1,200	1,200	0	0	2,400
		4	-11.0	750	0.30	225	450	0	165	840
		Sub-Total		6,950		5,105	4,170	4,050	165	13,490
	Total			9,100		5,828	5,460	4,755	167	16,210
Turning Basin	29	1	-9.5	5,000	0.80	4,000	3,000	0	685	7,685
		2	-9.5	3,500	0.40	1,400	2,100	0	77	3,577
		3	-11.0	52,000	0.90	46,800	31,200	0	3,509	81,509
		Sub-Total		60,500		52,200	36,300	0	4,271	92,771
Berth	30		-11.0	41,500	2.80	116,200	24,900	219,574	0	360,674
Land Reclamation Area			-5.0			180,493				180,493
Total- First Phase				167,122		492,100	100,273	436,159	85,598	1,114,130

Table 6-4-1

DREDGING QUANTITIES FOR INNER CHANNEL (SECOND PHASE)

Zone	Division No.		Design Depth	Channel • Basin				Side Slopes		Total
				Dredging Area (A)	Dredging Thickness	Dredging Quantities	Over-Dredging (A 0.6)	Portside	Starboard	
Lower Phitti Creek Channel	7		-11.3^{m}	$13,560^{m^2}$	0.10^{m}	$1,356^{m^3}$	$8,136^{m^3}$	0^{m^3}	0^{m^3}	$9,492^{m^3}$
	8		-11.3	285,350	0.67	189,909	171,210	2,295	19,950	383,364
	9		-11.3	6,000	0.47	31,030	39,600	9,190	1,155	80,975
	10		-11.3	28,000	0.27	7,560	16,800	0	1,350	25,710
	11			0	0	0	0	0	0	0
	Total			392,910		229,855	235,746	11,485	22,455	499,541
Upper Phitti Channel	12			0	0	0	0	0	0	0
	13			0	0	0	0	0	0	0
	14	(1)	-11.3	1,800	0.64	1,152	1,080	1,010	0	3,742
		(2)	-11.3	10,000	0.18	1,800	6,000	0	0	7,800
		Sub-Total		11,800		2,952	7,080	1,010	0	11,042
	15		-11.3	9,000	1.16	10,440	5,400	12,950	0	28,790
	16		-11.3	19,740	0.67	13,226	11,844	1,080	6,205	32,355
	17		-11.3	6,213	1.19	7,393	3,728	0	5,805	16,926
	18		-11.3	62,750	1.05	65,604	37,650	14,645	9,460	127,359
	Total			109,503		99,615	65,702	29,685	21,470	216,472
Kadiro Creek Channel	19	(1)	-11.3	140,000	3.60	503,637	84,000	0	114,800	702,437
		(2)	-11.3	1,200	0.03	36	720	8,785	0	9,541
		Sub-Total		141,200		503,673	84,720	8,785	114,800	711,978
	20		-11.3	18,500	2.18	40,315	11,100	64,880	0	116,295
	21	(1)	-11.3	16,500	3.79	62,595	9,900	85,845	0	158,340
		(2)	-11.3	11,750	2.77	32,523	7,050	0	33,895	73,468
		Sub-Total		28,250		95,118	16,950	85,845	33,895	231,808
	22	(1)	-11.3	7,500	2.23	16,698	4,500	3,050	31,650	55,898
		(2)	-11.3	5,000	2.77	13,835	3,000	0	18,175	35,010
		Sub-Total		12,500		30,533	7,500	3,050	49,825	90,908
	23	(1)	-11.3	35,500	3.78	134,289	21,300	0	175,470	331,059
		(2)	-11.3	4,330	2.05	8,897	2,598	26,510	0	38,005
		Sub-Total		39,830		143,186	23,898	26,510	175,470	369,064
	24	(1)	-11.3	24,500	1.01	24,745	14,700	0	22,155	61,600
		(2)	-11.3	2,800	0.85	2,380	1,680	27,430	0	31,490
		Sub-Total		27,300		27,125	16,380	27,430	22,155	93,090

Table 6-4-2

Dredging Quantities for Inner Channel (Second Phase)

Zone	Division No.		Channel • Basin					Side Slopes		Total
			Design Depth	Dredging Area (A)	Dredging Thickness	Dredging Quantities	Over-Dredging (A 0.6)	Portside	Starboard	
Kadiro Creek Channel	25		-11.3^m	4,475m^2	1.55^m	6,955m^3	2,685m^3	35,945m^3	0m^3	45,585m^3
	26	1	-11.3	45,000	1.46	65,554	27,000	161,930	0	254,484
		2	-11.3	21,000	0.86	14,249	12,600	0	79,630	106,479
		Sub-Total		66,000		79,803	39,600	161,930	79,630	360,963
	Total			338,055		926,708	202,833	414,375	475,775	2,019,691
Gharo Creek Channel	27	1	-11.3	8,000	1.24	9,925	4,800	6,358	0	21,083
		2	-11.3	9,500	1.82	17,307	5,700	0	4,993	28,000
		Sub-Total		17,500		27,232	10,500	6,358	4,993	49,083
	28	1	-11.3	58,500	1.26	73,945	35,100	19,215	0	128,260
		2	-12.8	4,500	1.30	5,835	2,700	0	0	8,535
		3	-12.8	76,000	0.97	73,805	45,600	0	2,085	121,490
		Sub-Total		139,000		153,585	83,400	19,215	2,085	258,285
	Total			156,500		180,817	93,900	25,573	7,078	307,368
Turning Basin	29	1	-11.3	13,500	1.67	22,565	8,100	0	975	31,640
		2	-11.3	32,000	1.23	39,380	19,200	0	5,471	64,051
		3	-12.8	168,500	2.62	440,980	101,100	0	177,536	719,616
		Sub-Total		214,000		502,925	128,400	0	183,982	815,307
Berth	30			0		0	0	0	0	0
Total Second Phase				1,210,968		1,939,920	726,581	481,118	710,760	3,858,379

VI-2 DREDGING AND DUMPING

1. Dredging Material

As may be observed from Dwg. 2-1·3-1, the material to be dredged in the Inner Channel, anchorage, and turning basin consists of clay with silt or clay with silt and fine sand with N-values in the range of 5 in the first phase, and in the range of 8 in the second phase dredging.

2. Location of Dumping Sites

As shown in Dwg. 4-4 - 4-7·4-11 - 4-14, dumping sites for the dredged material will be located in the mangrove swamp areas submerged at flood tides, approximately 500m from the shores of the respective creeks.

1) Selection of dumping sites

In case the spoil is dumped through floaters of the dredger and pipelines, the natural slope of the accumulated spoil may be assumed to be roughly 1/30 - 1/40. The width of side slopes formed by the accumulation of spoil may be assumed to be roughly 90 m - 120 m. If the spoil is dumped in a location 500 m from the shore of the creek, a width of 500m - 120m = 380m will be preserved in the natural state.

Soils will not run back into the channel except for material in suspension. Material carried back in suspension will be distributed over a very wide area by tidal currents. Therefore, it has been judged that it will not be necessary to build dykes using in situ clay.

2) Dumping sites in respective channels

Dumping sites for spoil in the respective channels are located in sites 500m from the shores of the creeks in the vicinities of the dredging areas as indicated in the drawings. In case of danger of spoil running back into the channel due to tidal currents and the topography of the area, the dumping site will be changed to a safer zone. It is recommended that the location of dumping sites be determined according to the conditions of the site in the course of actual dumping to prevent unfavorable effects on tidal currents.

3. Dumping of Spoil

As shown in Dwg. 6-1·6-2 for dredging and dumping of dredged material, the end of floating pipelines of the dredger extending for 1,000 m will be fixed by anchor at the beginning point of dumping in the mangrove swamp area, 500m from the side slope of the channel or the shore of the creek. Then the dredger will commence dredging and discharge of dredged material.

When the spoil discharged from the end of the pipeline accumulates to a height above the high water level, one or two discharge pipes will be connected. The process will be repeated, extending the length of spoil accumulation.

When the extension of the spoil reaches a length of 1,000 m, a delivery manifold will be attached, and the spoil will be dumped along the first line. The operation will be repeated during the course of dredging and dumping.

In case the final course of dumping should end within the extension of 1,000 m for the first phase of dredging works, the second phase will be continued from the end of dumping of the first phase.

The purpose of the above method of dumping is to prevent the scattering of spoil in small quantities, and to dump the spoil in one location evenly for future use.

4. Monthly Dredge Production

1) First Phase

(a) Dredging conditions

Soil and average N value: Clay with silt or clay with silt and fine sand

N value in the range of 5

Average discharge distance to dumping site: 2,000 m

Dredger: Pump cutter suction dredger

Main engine: Diesel 4,000 P.S.

Yearly operating hours: 4,000 hours

Monthly operating hours: 4,000 hr/yr ÷ 10 operating month/yr. = 400 hr.

Daily operating hours: 400 hr/month ÷ 23 operating days/month = 17.4 hr.

Daily dredging hours: 17.4 hr. x 0.9 = 15.7 hr.

(b) Monthly dredge production

Dredging quantity per hour of a pump cutter suction dredger (Diesel 4000 P.S.) Q will be,

$Q = q \cdot \alpha \beta$

$q = 740\ m^3/hr$ dredging quantity per hour

α : 0.85 site working efficiency

The value of α, site working efficiency will not be greatly affected by tidal currents and waves. However, dredging sites of small area of 310 m - 11,500 m are scattered in 19 locations out of a total of 22 locations to be dredged.

The dredging quantity in 19 locations of the total 22 locations including the side slopes is less than 1,200 m^3 - 100,000 m^3. Refer to Tables 6-2-1 - 2.

In many locations, dredging must be started from a dredging thickness of 0 m. Dredging of the side slopes of the channel will also greatly reduce the efficiency of operation.

β : 0.90 actual operating rate

As discussed above, with small dredging areas scattered in many locations, due to shifting of dredgers, the operating rate will be considerably reduced.

$Q = 740\ m^3/hr \times 0.85 \times 0.9 = 570\ m^3/hr$

Daily production will be,

$570\ m^3/hr \times 15.7\ hr/day = 8,900\ m^3/day$

Monthly production will be,

$8,900\ m^3/hr \times 23\ days/month = 205,000\ m^3$

2) Second phase

(a) Dredging conditions

Soil and average N value:	Clay with silt, clay with silt and fine sand, N value around 8
Average discharge distance:	2,000 m
Dredger:	Pump cutter suction dredger
Main engine:	Diesel - 4,000 P.S.
Yearly operating hours:	4,000 hrs.
Monthly operating hours:	4,000 hrs ÷ 10 operating month/yr. = 400 hours.
Daily operating hours:	16.4 hr/day

Standard daily operating hours will be,

400 hr/month ÷ 23 operating days/month = 17.4 hr.

FIG 6-1 DREDGING AND DUMPING - PLAN S=2000/1

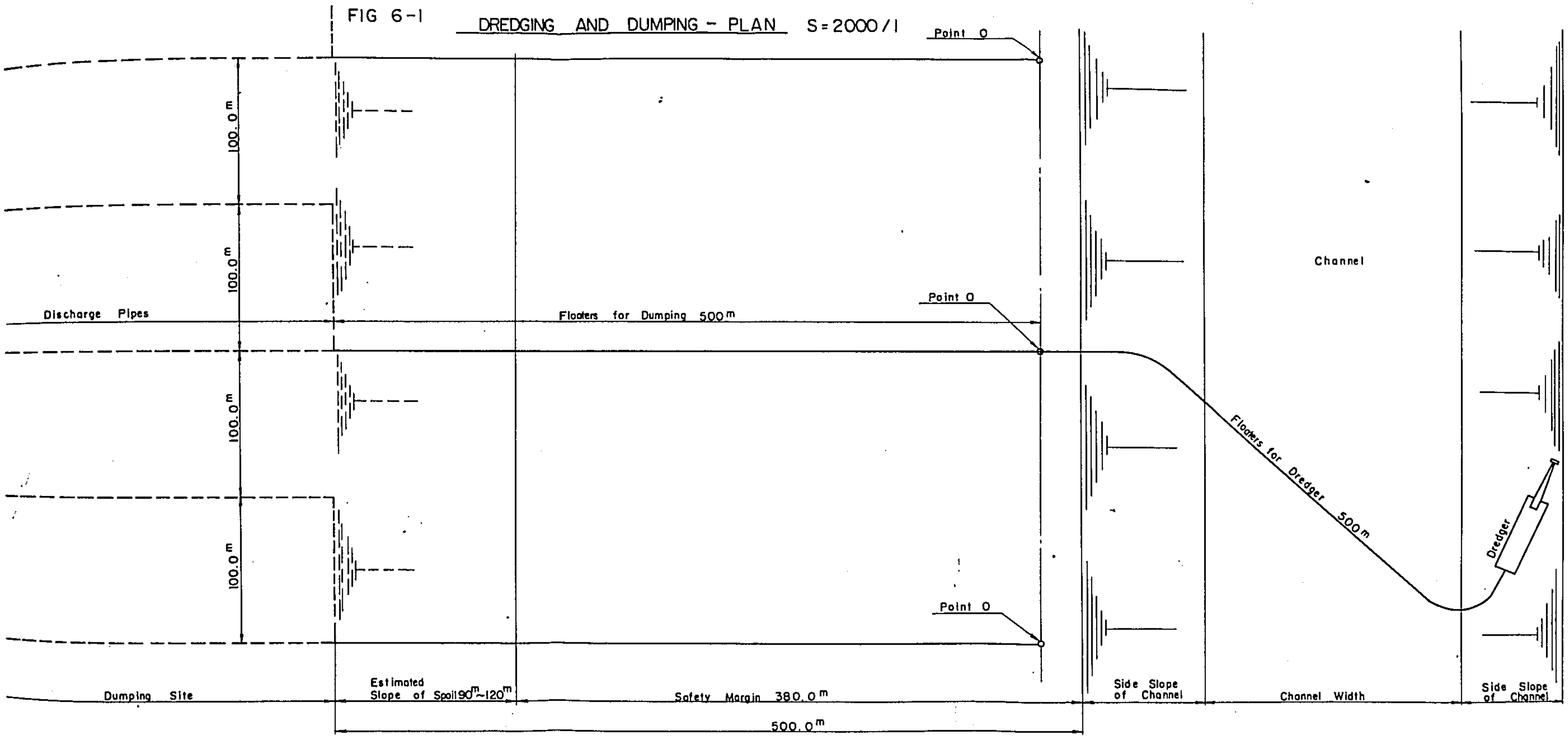


FIG 6-2 DREDGING AND DUMPING - PROFILE

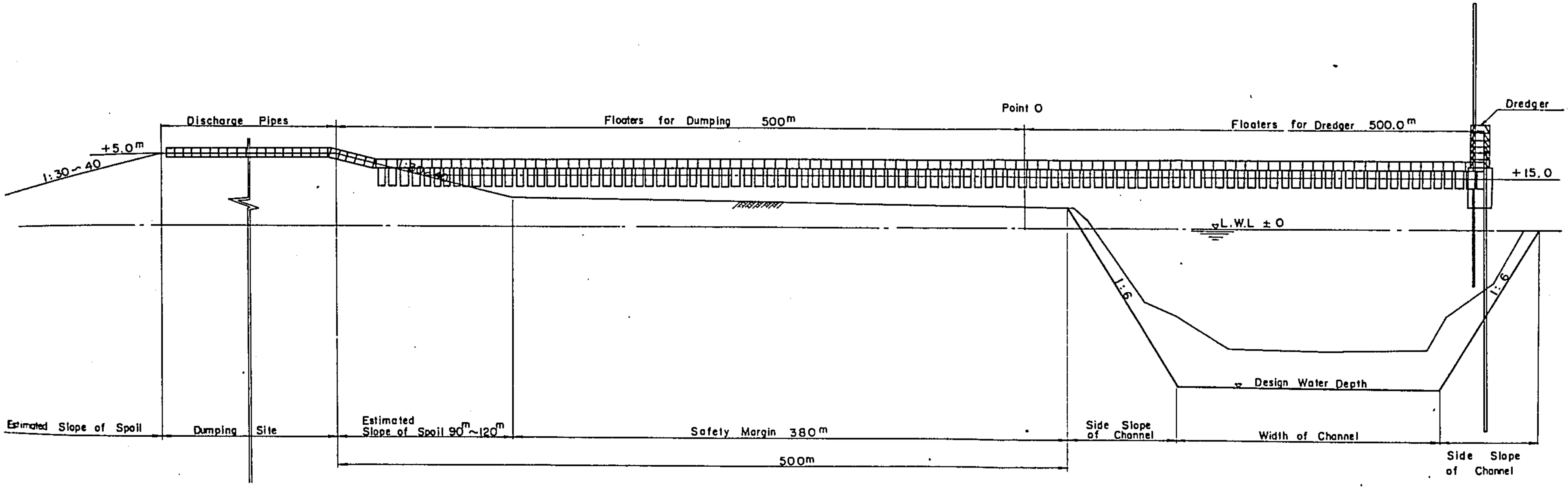
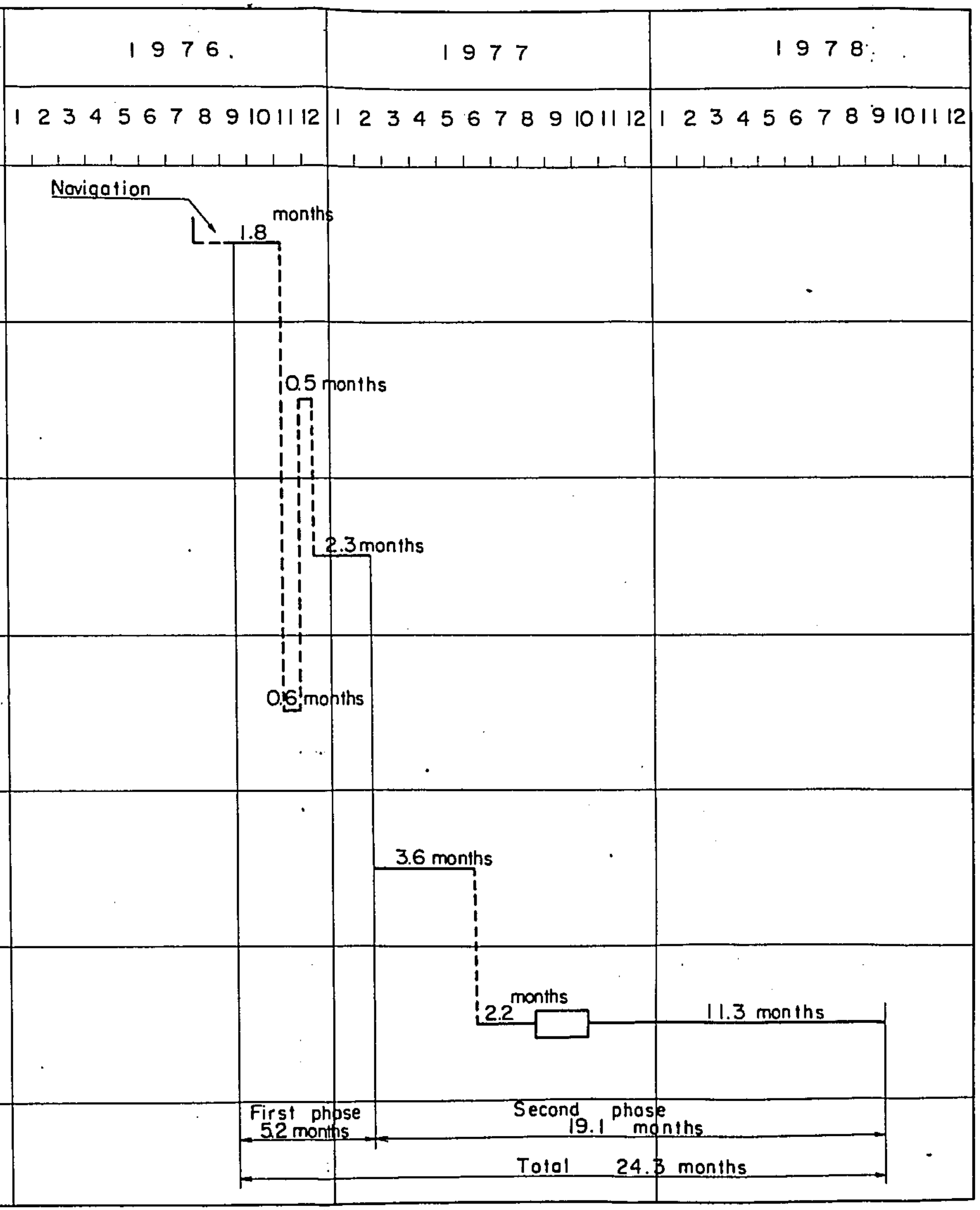


Table 6-5 Progress Schedule for Inner Channel Dredging (First phase and second phase)

Vessel	Main Engine		Dredging Site	Estimated Dredging Quantities (1000m³)	Monthty Dredge Production (1 000m³)	Working Months (month)
Pump cutter suction dredger	Diesel 4,000ps	First phase	Berth (first· second phase) L=600m	361	205x1	1.8
			Turning basin	93	205x1	0.5
			Channel	480	205x1	2.3
			Land reclamation area	180	297x1	0.6
		Second phase	Turning basin	815	225x1	3.6
			Channel	3,043	225x1	13.5
Total				4,972		22.3



It is assumed that cargo vessels of a maximum of 25,000 DWT will enter port at an average of once a day. The dredger will be compelled to suspend operation, and the dredger and floaters must be evacuated. The evacuation and returning to position will take at least one hour for a passing of one cargo vessel. Therefore, with 1 times x 1 hr. = 1 hr. the actual daily operating hours will be,

17.4 hr. - 1 hr. = 16.4 hrs.

Daily dredging hours: 16.4 hrs/day x 0.9 = 14.8 hrs.

(b) Monthly dredge production

Dredging quantity per hour of a pump cutter suction dredger (Diesel 4000 PS) Q will be,

$Q = q \cdot \alpha \cdot \beta$

q : 740 m^3/hr dredging quantity per hour

α : 0.9 site working efficiency

In regard to the value of α , conditions do not greatly differ from the first phase channel dredging. Though the effect of tidal currents and waves are slight, the site working efficiency will be reduced as dredging sites of small areas are scattered in many locations. In 30 locations out of the total 37 locations to be dredged, the dredging areas are of 1,200 m^2 - 30,000 m^2. In 27 locations out of the entire 37 locations, including dredging of the side slopes, the dredging quantities are of 3,242 m^3 - 100,000 m^3.

In many locations, dredging must be started from a dredging thickness of 0 m, and the dredging of the side slopes of the channel will also greatly reduce the working efficiency.

B : 1.0 actual operating rate

$Q = 740\ m^3/hr \times 0.9 \times 1.0 = 660\ m^3/hr$

Daily production will be,

$660\ m^3/hr \times 14.8\ hr/day = 9,77?\ m^3/day$

Monthly production will be,

$9,770\ m^3/day \times 23\ days/mon. = 225,000\ m^3/month.$

5. Progress Schedule

One pump cutter suction dredger of D-4,000 PS will be sufficient for the second phase dredging of the Inner Channel.

1) In the berth area, it will be impossible to dredge the sea bottom to the design water depth for 30,000 DWT vessels after piles have been driven in for the Iron Ore and Coal Berth.

The area will be dredged in the first phase prior to the commencement of pile driving.

An excavation of 180 thousand m^3 for the removal of the existing foundation in the land reclamation area will be carried out by the dredger for inner channel dredging as related works of the navigation channel dredging. Excavation will be commenced in September 1976, and completed in 1977.

2) As it will be advisable to commence the second phase dredging in succession to the first phase dredging, the progress schedule will be planned accordingly.

Progress Schedule

1) First Phase Dredging

(a) Berth area only

	Dredging quantity	361 thousand m^3
	Monthly production	205 thousand m^3 x 1 dredger
	Months required	1.8 months
(b)	Turning basin	
	Dredging quantity	93 thousand m^3
	Monthly production	205 thousand m^3 x 1 dredger
	Months required	0.5 month
(c)	Channel	
	Dredging quantity	480 thousand m^3
	Monthly production	205 thousand m^3
	Months required	2.3 months
(d)	Land reclamation area	
	Dredging quantity	180 thousand m^3
	Monthly production	297 thousand m^3 x 1 dredger
	Months required	0.6 months
	Total dredging quantity	1,114 thousand m^3
	Months required	0.6 months
ii)	Second Phase Dredging	
(a)	Turning basin	
	Dredging quantity	815 thousand m^3
	Monthly production	225 thousand m^3 x 1 dredger
	Months required	3.6 months
(b)	Channel	
	Dredging quantity	3,043 thousand m^3
	Monthly production	225 thousand m^3 x 1 dredger
	Months required	13.5 months

Total dredging quantity	3,858 thousand m^3
Months required	17.1 months
Total dredging quantity for first and second phase	4,972 thousand m^3
Months required	22.3 months

VI-3 COST OF DREDGING

1. Dredging Fleet

i. Dredging plant

Pump cutter suction dredger D-4000 PS		1 dredger
Floaters for dredger		1,000 m
Anchor barge for dredger		1 barge

ii. Auxiliary crafts

(a)	Tug	450 PS	1 tug
(b)	Supervising launch	250 PS	1 launch
(c)	Pontoon	150 ton capacity	1 pontoon

2. Wages of Crew

Wages and working conditions of officers and crew of the pump cutter suction dredger and the anchor barge will be similar to wages and conditions of the officers and crew of the trailing suction dredger, working on three shifts.

1) Crew requirement of pump cutter suction dredger

Table 6-6

Dredging Plant	Class	Number	
		Regular	Present Project
Pump cutter suction dredger D-4,000 P.S.	Officers (foreign)	7	7
	Crew (foreign)	30	16
	Crew (local)	0	28
	Total	37	51

2) Crew requirement of anchor barge

Table 6-7

Dredging Plant	Class	Number	
		Regular	Present Project
Anchor barge	Officers (foreign)	3	3
15 ton anchor lift capacity	Crew (foreign)	3	0
	Crew (local)	0	6
	Total	6	9

3) Wages of crew of dredger and anchor barge per one working month.

Table 6-8

Vessel	Class	No.	Unit cost per person per month		Total Monthly Cost		
			Foreign Currency	Local Currency	Foreign Currency	Local Currency	Total
Pump Cutter Suction Dredger	Officers (foreign)	men 7	$ 1,660	$ 290	$ 11,620	$ 2,030	$ 13,650
	Crew (foreign)	16	1,400	250	22,400	4,000	26,400
	Crew (local)	28	0	90	0	2,520	2,520
Anchor Barge	Officers (foreign)	3	1,660	290	4,980	870	5,850
	Crew (local)	6	0	90	0	540	540
	Total	60			39,000	9,960	48,960

3. Cost of Auxiliary Crafts

Auxiliary crafts will be acquired locally or transported from abroad.

i.	Tug	1	$7,000
ii.	Supervising and transport launch	1	$4,000
iii.	Pontoon	1	$1,000
	Total		$12,000 (local currency)

4. Depreciation of Dredger, Floaters, and Anchor Barge

1) Monthly depreciation of pump cutter suction dredger

In calculating the depreciation of the dredger, the shipbuilding price will be estimated to be $5,000,000, and the life span of working days to be 1,900 days. During the life span of working days, the dredger will undergo repairs once a year. The total cost of repairs will be assumed to be equivalent to the shipbuilding price, and a sum of $5,000,000 will be added for maintenance and repairs.

Depreciation per working month

Shipbuilding price	$5,000,000/1 dredger
Maintenance and repairs	$5,000,000/1 dredger
Life span of working days	1,900 days
Monthly depreciation rate	30 days/1,900 days = 0.0157
Monthly depreciation	$10,000,000 x 0.0157 ≑ $160,000 (foreign currency)

2) Monthly depreciation of floaters

Discharge pipes and rubber sleeves will be included in the set of floaters. The floater requirement will be, the extension of 1,000 m ÷ 7.5 m/floater = 134 floaters.

Depreciation per working month

Prices

Floaters	$2,500/floater x 134 =	$335,000
Discharge pipes	$500/floater x 134 =	$67,000
Rubber sleeves	$1,400/floater x 134 =	$188,000
	Sub-total	$590,000

Maintenance and repairs	$590,000 x 22% ≑ $130,000
Life span	300 days
Monthly depreciation rate	30 days/800 days = 0.04
Monthly depreciation	$720,000 x 0.04 ≑ $29,000

3) Depreciation of anchor barge

In calculating the depreciation of the anchor barge, the shipbuilding price will be assumed to be $270,000, and the life span of working days will be 1,900 days. As regular yearly repairs will be required during the period, assuming that the cost of repairs will be equivalent to the shipbuilding cost, the sum will be added as maintenance and repairs cost.

Depreciation per working month

Shipbuilding price	$270,000
Maintenance and repairs	$270,000
Life span of working days	1,900 days
Monthly depreciation rate	30 days/1,900 days = 0.0157
Monthly depreciation	$540,000 x 0.0157 ≑ $8,000

5. Monthly Cost of Dredger

Though the Inner Channel dredging will hardly be affected by the monsoon, the dredger will be moored for a period of 1 - 1.5 months through the year for regular maintenance and repairs of the ship and engine.

Table 6-9

OPERATING COST PER WORKING MONTH

Item	Dredging Fleet	Foreign Currency	Local Currency	Total
Depreciation	Dredger	160,000$	0$	160,000$
	Floaters	29,000	0	29,000
	Anchor barge	8,000	0	8,000
	Sub-total	197,000	0	197,000
Fuel	Dredger	0	28,000	28,000
	Anchor barge	0	540	540
	Sub-total	0	28,540	28,540
Wages of Crew	Dredger	34,020	8,550	42,570
	Anchor barge	4,980	1,410	6,390
	Sub-total	39,000	9,960	48,960
Insurance		6,250	0	6,250
Auxiliary Crafts		0	12,000	12,000
Miscellaneous		2,750	1,500	4,250
Total		245,000	52,000	297,000

6. Cost of Transport

1) Dredger and equipment

(a) Pump cutter suction dredger

(b) Floaters

(c) Anchor barge

(d) Pumps and supplies

Assuming that the dredging fleet will be transported from Europe or the Far East, the average distance will be roughly 6,400 miles.

2) Cost of transport of dredger and equipment

i) Period required (Tug D-3,000 PS)

6,400 miles + (7 miles/hr x 24 hr) =	38 days
Return trip of tug 6,400 miles + (10 miles/hr x 24 hr) =	27 days
Preparation and delivery	5 days
Total	70 days

ii) Cost of transport

Handling in homeland	$17,000
Preparation for trip (reinforcement of hull, fitting, and preparation)	$100,000
Customs clearance	$1,000
Insurance for trip $5,000,000 x 4% =	$200,000
Cost of towing and return trip of tug $3,300/day x 70 days =	$231,000
Depreciation of ship $\$160,000 \times \frac{1}{2} \times (43 \text{ days} + 30 \text{ days}) =$	$115,000
Miscellaneous	$6,000
Total	$670,000

3) Transport cost of floaters, anchor barge and supplies.

Floaters, anchor barge, and parts will be transported to site by cargo vessels.

Transport cost (one way)

Handling in homeland

4,200 tons x $7 = $29,400

Packing of parts 150 ton x \$5 = \$ 750

Customs clearance 4,200 x \$10 = \$42,000

Freight charges 4,200 ton x \$70 ≒\$294,000

Insurance for transport
\$1,000,000 x 120% x 0.3% = \$36,000

Total 402,150 ≒\$400,000

7. Cost of Dumping Spoil

(i) Depreciation

The total extension of the discharge pipeline to be used in the first phase and second phase dredging will be 2,600 m.

The dredging quantity for depreciation will be 5,000,000 m^3.

Depreciation

2,600 m ÷ 6 m/discharge pipe ≒ 440 pipes x \$550 = \$242,000

including cost of repairs (foreign currency)

(ii) Cost of transport ≒ \$192,000

(iii) Erection and removal of framework, placing and removal of pipeline \$143,000
(local currency)

Total \$577,000 {foreign currency \$434,000
local currency \$143,000

(1) Cost of dumping per 1 m^3 of spoil

\$577,000 ÷ 4,972,000 m^3 = \$0.116

(2) Cost of dumping spoil in the first phase

\$0.116 x 1,114,000 m^3 ≒ \$129,000 {foreign currency \$97,000
local currency \$32,000

(3) Cost of dumping spoil in the second phase

\$0.116 x 3,858,000 m^3 ≒ \$448,000 {foreign currency \$336,000
local currency \$112,000

Total \$577,000

VI-4 COST ESTIMATES

Cost estimates for the first phase dredging of the Inner Channel and basin are given in Table 6-10, and cost estimates for the second phase are given in Table 6-11.

The cost of bringing the dredger and equipment to the site will be included in the cost for first phase dredging, and the cost for the return trip will be included in the cost for second phase dredging.

Cost estimates for the entire dredging program are given in Table 6-12, and the unit costs of dredging are given in Table 6-13.

1. First Phase Dredging Cost

Table 6-10

Item		Unit	No.	Unit		Dredging Cost		Total ($)
				Foreign Currency ($)	Local Currency ($)	Foreign Currency ($)	Local Currency ($)	
Operating Cost		Month	5.2	245,000	52,000	1,274,000	270,400	1,544,400
Transport Cost	Dredger	set	1	670,000	0	670,000	0	670,000
	Floater anchor barge parts	"		400,000	0	400,000	0	400,000
Dumping of spoil		"	1	97,000	32,000	97,000	32,000	129,000
Miscellaneous		%	18			444,200	49,400	493,600
Total						2,885,200	351,800	3,237,000

Cost per $1m^3$ = 3,237,000\$ ÷ $1,114,000m^3$ = $\$2.91/m^3$

2. Second Phase Dredging Cost

Table 6-11

Item		Unit	No.	Unit Foreign Currency ($)	Dredging Cost		Total ($)
				Local Currency ($)	Foreign Currency ($)	Local Currency ($)	
Operating Cost		Month	17.1	245,000	4,189,500	889,200	5,078,700
				52,000			
Transport Cost	Dredger	set	1	603,000	603,000	67,000	670,000
				67,000			
	Floater anchor barge parts			360,000	360,000	40,000	400,000
				40,000			
Dumping of spoil		"	1	336,000	336,000	112,000	448,000
				112,000			
Miscellaneous		%	18	Including removal and relocation of navigation aids	1,068,300	119,000	1,187,300
Total					6,556,800	1,227,200	7,784,000

Cost per 1 m^3 7,784,000\$ ÷ 3,858,000 m^3 = \$2.02/ m^3

Average cost for first and second phase dredging

(3,237,000\$ + 7,784,000\$) ÷ (1,114,000 m^3 + 3,858,000 m^3) = \$2.22/m^3

Table 6-12

COST ESTIMATES FOR ENTIRE CHANNEL DREDGING PROGRAM

	Total Cost	Foreign Currency	Local Currency
	($)	($)	($)
First phase Appraoch Channel Dredging	18,148,000	16,357,400	1,790,600
Second phase Approach Channel Dredging	16,377,000	14,663,300	1,713,700
Sub-Total	34,525,000	31,020,700	3,504,300
First phase Inner Channel Dredging	3,237,000	2,885,200	351,800
Second phase Inner Channel Dredging	7,784,000	6,556,800	1,227,200
Sub-Total	11,021,000	9,442,000	1,579,000
		88.8%	11.2%
Total	45,546,000	40,462,700	5,083,300

Table 6-13

UNIT COST OF DREDGING

First phase Approach Channel Dredging			First phase Inner Channel Dredging			Total	
Dredging Cost $	Q'ty (1000 m^3)	Unit Cost (m^3)$	Dredging Cost $	Q'ty (1000 m^3)	Unit Cost (m^3)	Dredging Cost $	Q'ty (1000 m^3)
18,148,000	14,131	1.28	3,237,000	1,114	2.91	21,385,000	15,245
Second phase Approach Channel Dredging			Second phase Inner Channel Dredging			Total	
Dredging Cost $	Q'ty (1000 m^3)	Unit Cost (m^3)$	Dredging Cost $	Q'ty (1000 m^3)	Unit Cost (m^3)$	Dredging Cost $	Q'ty (1000 m^3)
16.377,000	12,062	1.36	7,784,000	3,858	2.02	24,161,000	15,920
Total 34,525,000	26,193	1.32	11,021,000	4,972	2.22	45,546,000	31,165

CHAPTER VII PROBLEMS RELATED TO EXECUTION OF WORKS

VII-1 DREDGING CONTRACT

1. Dredging Quantities and Contract Price

It is recommended that the Approach Channel dredging and Inner Channel Dredging for the first phase and second phase programs be tendered for contractors to bid on the entire project at the same time. The depreciation cost of dredgers which occupies a larger part of the dredging cost is determined by the shipbuilding cost of the dredger at the time of concluding the contract. As prices may be expected to continue to rise in the future, by inviting tenders separately for each phase, the dredging cost will be higher in the later contracts. Though dredging plants to be used in the Approach Channel and Inner Channel will not be of the same type, they will have related problems, and it will be of advantage, both to the employer and the contractor, to have the dredging works tendered as a single project.

A unit price contract will be preferable to a lump sum contract. Drawings for the contract documents are not quite accurate, and the total dredging quantities cannot be properly estimated. It is recommended that an accurate survey be conducted in the appendix, and the exact quantities to be dredged must be computed from drawings based on accurate survey of the dredging area.

Sedimentation in the Approach Channel during the monsoon season has been estimated to be 1,400,000 m^3 in Chapter III. However the quantity will depend on the character of the monsoon, and the figure will not represent the exact quantity. As the contractor must be informed of a rough estimate of the dredging quantities, the figure used as the basis for the cost estimation will be given as the estimated quantities.

The contract sum will be computed on the basis of an estimated sedimentation of 1,400,000 m^3 for one monsoon season. In case the actual sedimentation is less than the estimated quantity, extra dredging may be carried out in parts where heavy sedimentation may be expected from the following monsoon with the surplus contract sum. In case the sedimentation exceeds the estimated quantity, the sedimentation must be dredged at additional cost. Particularly, in the second phase of the dredging program, Port Qasim will be open for public use. It will not be a desirable situation should the sedimentation in the Approach Channel prevent vessels from entering port. If possible, it will be advisable to carry out extra dredging in the channel to provide for sedimentation expected in the following year with surplus funds in the contract sum.

2. Measurement and Survey

Though the Approach Channel dredging and Inner Channel dredging will be undertaken as a single project, dredging operations will be carried out in several areas. In each dredging area, the supervising engineer and the contractor will make surveys of accurate soundings prior to the commencement of works and on completion of the works. The results will indicate the quantities of materials dredged which will form the basis of computing the sum to be paid to the contractor.

To carry out surveys efficiently in a short period, the contractor shall use a highly-efficient survey equipment consisting of an echo-sounder (Kelvin or Atlas) and a Sea-Fix receiver (Type 80402A).

Prior to the commencement of works, P.Q.A. will install staff gauges in Phitti Creek and the channel entrance, and indicate the level of dredging to the contractor. Coordinates of the channel alignment must also be installed and supplied to the contractor.

Dredgers will carry on dredging operations depending on position fixing by the Sea-Fix system. As the Approach Channel is a long but harrow channel, dredging operations will be apt to extend beyond the specified width. It will be desirable to instal leading lights in the early stage of the dredging program to enable dredging operators to identify the center line of the channel visually in additon to the Sea-Fix system. P.Q.A. shall provide for the adequate operation of the Sea-Fix survey system to prevent any failure in transmitting radio waves.

3. Working Period

Dredging operations will be carried on 24 hours per day with 2 or 3 shifts of the crew. For the sake of calculation, the number of working days will be assumed to be 23 days per month, allowing for shifting and repairs. The actual number of working days may be determined by the contractor.

In cost estimation, the three months of the monsoon season, June, July and August have been excluded from the actual working months, allowing for the docking, repairs, and mooring of dredgers.
The contractor is free to carry on dredging operations on calm

days during the monsoon at his own responsibility.

In the Approach Channel, during the monsoon, infill will be deposited on stormy days, and dredged on the following calm days, and the process will be repeated. The dredging production cannot be measured by sounding survey of the channel.

The quantity may be measured from the amount of dredged material in the hopper of the dredger. The daily production may be calculated by adding the dredged material in the hopper on each trip of the dredger. The volume of material in the hopper may be considered to be 20 - 25% greater than the volume in situ. The volumes in the hopper and in situ may be measured to obtain the accurate ratio, but in the contract, it may be specified that the in situ volume is equivalent to 80% of the volume measured in the hopper.

4. Method of Working

The recommended types of dredging plants to be used in the Approach Channel and the Inner Channel have been given in Chapter IV, but no particular restrictions will be made in regard to the dredging plants to be used in the contract documents. However, the dredging plants to be used must be approved by the engineer.

The first phase dredging program and the second phase dredging program will be undertaken separately. Both in the Approach Channel and Inner Channel, the first phase dredging program must be completed before the second phase dredging program is commenced. In the first phase dredging program, of the water area in front of the proposed berth in the Inner Channel, the portion required for the berth construction shall be dredged prior to the dredging of the

Inner Channel.

In the second phase dredging program, for the navigation of 25,000 DWT ore carriers, after the monsoon season, the sedimentation in the channel must be dredged prior to regular dredging operations in the Approach Channel. In case large vessels enter or leave port, the dredgers must suspend dredging operations and evacuate to the side of the channel.

The above basic requirements will be instructed to the contractor, but details of the program and methods of working may be planned by the contractor from his knowledge and experience in order that the dredging of the specified channel will be completed in the specified period.

5. Navigation Cost of Dredgers

As the distance to Port Qasim from Europe or the Far East is approximately the same, the navigation cost of the dredging plant computed for cost estimation may be applied to either case.
The cost of trip to Port Qasim will be included in the first phase dredging costs, and the cost of the return trip will be included in the second phase dredging costs.

6. Dumping of Spoil in the Channel

In the anchorage of the Inner Approach Channel there are a number of dredging areas of small quantities along the sides of the channel, involving difficulty for dredging by a trailing suction dredger.
As an alternate method of dredging, the areas may be dredged by a pump suction dredger, and the spoil may be deposited in the channel temporarily. The spoil may then be dredged by a trailing suction

dredger and carried to a dumping site offshore the channel. The contractor will be free to choose the alternate method, but will be held responsible to remove all dredged material temporarily deposited in the channel.

VII-2 DREDGING OPERATION BASE

1. Location of Base

The port of Karachi will not be considered as the base for navigation channel dredging.

The traffic in the port is over-crowded, and during the monsoon season, it will be difficult to maintain contact between the base and Port Qasim by small launches.

Besides Port Karachi, two alternate sites may be considered, the sea and land area at the south end of the Steel Mill, in the upper stream area of the proposed marginal wharf, and the area round the fishery port in the Korangi Creek, between Port Karachi and Phitti Creek.

The former site will be used as the construction base for the Iron Ore and Coal Berth and related facilities. In case the construction of the marginal wharf is to be commenced at the same time, the construction base will also be established at the site. The site is within close reach of the construction site, with advantages for the transport of construction material. Sufficient area of land may be secured for the base, and water and electric power will be supplied from Karachi. However, it will be quite confusing to have construction bases for different projects in one location.

For dredging operations, as transport of material from the base need not be considered, the area around the Korangi fishery port will be a preferable site for the base, within close reach of both the Approach Channel and Inner Channel dredging areas. The fishery port will be an advantage for the mooring of supervising launches and auxiliary crafts, embarking and disembarking of the crew, and loading and unloading of materials.

During the monsoon season, the Inner Channel dredging areas may be reached through calm waters between the Bundal and Buddo Islands. In the Approach Channel, on days of high waves, the trailing suction dredgers will be moored in the anchorage of the Approach Channel with natural deep waters protected from the waves of the open sea.

Launches will be able to maintain contact between the dredgers and the base.

With a fishery village on land, water and electric power may be supplied, with convenience for accommodation and daily necessities of the crew. The location is at a short distance from Karachi.

Prefabricated houses may be built for the office and residence, or private houses may be rented for the purpose.

2. Local Workers

In general, around Karachi, labor force is readily available, and the workers are eager to work, and abide by labor regulations. However, skilled laborers are scarce, and the workers must be trained for hire in construction works. Particularly for marine works, good workers must be recruited. With the base near a fishery port, it will not be difficult to recruit crew for the dredgers from workers with experience on the sea.

Dredging operations on dredgers in the Approach Channel and Inner Channel, and auxiliary crafts consist largely of simple labour work. It will be advisable to hire local labourers to reduce the cost of operation, and to follow the labor employment policy of the Pakistani Government.

3. Local Environment

In the vicinity of Karachi, peace and order is well maintained with satisfactory sanitary facilities, a great advantage for foreign contractors proposing to undertake the dredging project.

The city of Karachi has prospered as an international port for 100 years. With western style hotels and houses in the city, daily foodstuffs available at low cost, and up-to-date hospitals and medical facilities, foreign crew will not encounter difficulties in daily life both on board and on shore.

4. Supplies and Services

With the base for dredging works at Korangi, the shifting of crew, and the boarding and disembarking of crew of dredgers for Approach Channel dredging and Inner Channel dredging may be conducted by small launches.

Materials to be supplied to the dredgers will not be of large quantity, and may be easily transported by launches.

In case the Approach Channel dredging is to be carried out by trailing suction dredgers, the dredgers may be supplied with fuel and water by navigating to the facilities in the port of Karachi. In case the berth is occupied, the dredgers may be served by oil bunkering and water boats in Karachi. For the non-propelling dredger for Inner Channel dredging, fuel will be supplied from the oil refinery in Karachi by an oil bunkering boat, and fresh water may be supplied by a water boat from the port of Karachi. In case it is impossible to depend on the water boat, it will be necessary to supply water by a launch.

In the base of Korangi, electric power for domestic use will be available, but electric power for welding of the cutter of the pump cutter suction dredger may not be available, in which case it will be necessary to provide an independent power plant.

In Karachi, there is a large up-to-date shipbuilding yard, where vessels of 10,000 DWT may enter dock for repairs and supply of equipment. The dockyard will be available for the repairs of the dredgers and equipment.

APPENDIX

RECOMMENDATION FOR AREIAL SURVEY

1. Demand for Accurate Survey

Port Qasim occupies a vast area with the navigation channel extending for 40 km. The Approach Channel extends over a distance of approximately 15 km without particular landmarks. The channel dredging program involves estimated dredging quantities of 30,000,000 m^3 at a cost of U.S.$45,000,000. A slight error in positioning dredging works will result in a costly loss of several million dollars.

For the purpose of dredging operations, a Sea-Fix chain has been installed in Port Qasim, and a Decca lattice chart has been prepared. However, accurate and detailed charts indicating the exact location of Sea-Fix stations and survey points of the channel will be required for the execution of the channel dredging program.

It is strongly recommended that control survey, aerial triangulation, and hydrographic survey be carried out to obtain accurate data as the basis for the dredging program.

The development of Port Qasim as an up-to-date port depends on the maintenance of the Approach Channel and dredging in the Inner Channel. Accurate survey will be required to continue close observation of sedimentation in the Approach Channel and hydraulic problems in the Inner Channel. Aerial survey will be the most reliable method to obtain accurate data in a short period of time at a low cost. Together with the Sea-Fix chain, the construction of the port and maintenance works may be carried out with accuracy and efficiency.

2. Purpose of Survey

Prior to the commencement of dredging works in the navigation channel, it is recommended that topographic survey and hydrographic survey be carried out immediately for the following purposes.

1) The navigation channel dredging program has been designed on the basis of available sounding charts which are not quite accurate. In order to invite tenders for the dredging works, the program must be revised according to accurate sounding charts.

2) In carrying out the dredging works, the contractor must be informed of the accurate dredging sites and quantities.

3) The contractor must be able to position the dredgers in the accurate dredging sites.

4) At the beginning and end of each dredging operation, accurate dredging quantities must be obtained through survey, as the basis of payment of dredging costs.

5) Survey will be required for the maintenance and management of the navigation channel after capital dredging has been completed.

6) After Port Qasim has commenced operation, it will be necessary to control incoming and outgoing vessels and berthing of vessels, to assure the safe navigation of vessels in the channel.

3. Topographic Survey

Aerial survey is recommended to complete topographic survey of the entire Port Qasim area in a short period of time. A brief outline of the aerial survey will be as follows.

1) Ground Control Survey

Location of the existing Sea-Fix stations will be adjusted, and locations of new stations for the second Sea-Fix chain will be determined.

Control points will be established at intervals of 5 km along the coasts of the Inner Channel, and at intervals of 8 km in other areas.

A control network will be formed to connect the control points and Sea-Fix stations of the existing chain and new chain to be established.

2) Photography

Aerial photographs will be taken of the entire Port Qasim area with an aerial camera properly calibrated within the last year, in accordance with recommendations of the International Society for Photogrammetry.

The film will be analyzed by aerial triangulation, using a Stereo Comparator.

3) Mapping

The analyzed film will be mapped by a stereoplotter.

The map will be plotted with the following contour intervals.

Entire Port Qasim area	1/2,500 - 1/5,000 scale 5 m contour intervals
Port Complex	1/1,000 scale 1 m contour intervals

Universal Transverse Mercator Coordinates will be used for projection on the map.

4. Hydrographic Survey

With maps prepared by aerial survey and 2 chains of Sea-Fix lanes, the navigation channel depths and location will be surveyed efficiently as follows:

1) Sea Fix-Chain

At points determined by aerial survey, Sea-Fix stations will be established. In case the new Sea-Fix equipment cannot be delivered in time, a spare equipment may be rented.

2) Decca Lattice Chart

A Decca lattice chart of the two Sea-Fix chains will be plotted on the map prepared by aerial survey.

3) Harmonic Analysis of Tides

Tidal harmonic constants will be computed by harmonic analysis to be correlated with tidal harmonic constants surveyed by the Pakistan Navy.

4) Sounding Survey

Positions of sounding will be fixed by the radio-wave positioning system, and sounding will be carried out by an echo sounder.

5) Mapping

Water depths obtained by sounding survey will be plotted on the chart prepared by aerial survey.

Outer Channel area	scale 1/5,000	50 m intervals
Inner Channel area	scale 1/2,500	25 m intervals

5. Cost and Period of Survey

Though it is desirable that aerial survey will be completed prior to the commencement of the dredging program, from the point of securing funds, the contract for survey may be concluded about the same time as the contract for dredging. In case the topographic survey and hydrographic survey are carried out by separate contracts, a period of approximately one year will be required. Therefore, it is recommended that the two survey projects be carried out under a single contract.

The cost and period for survey will be as follows.

Cost of survey	$1,200,000
Aerial survey	$ 700,000
Hydrographic survey	$ 500,000
Working period	Report on the survey will be submited within 6 months from the date of contract.

VI Survey Team

After charts have been drawn from the results of aerial and hydrographic surveys, it will be necessary for P.Q.A. to carry out survey for the following purposes.

(i) To plan future port development

(ii) To give instructions for dredging to the contractor.

(iii) To plan the capital dredging and maintenance dredging programs of the navigation channel, and to carry out the dredging programs as planned.

(iv) To ascertain and provide for any change of tidal currents in the navigation channel.

If the aerial survey is carried out once, it will not be necessary to repeat the survey, but the aerial map must be revised in parts with the development of port facilities. With the progress of the dredging program, it will be necessary to carry out hydrographic survey for the revision of the hydrographic map every year.

In order to carry out hydrographic survey efficiently in a short period in the long navigation channel and wide water area of port Qasim, it is recommended that a powerful survey team be established as an organization of the P.Q.A.