2.6.4 Geology

At the New Mangalore Port a number of borings, including the ones executed in the pre-construction stage, have been conducted.

In 1975 deepening of the navigational channel and basin was planned in order to enable larger size vessels to call at the port. The sonic prospecting and probings for the purpose of clarifying the bed rock stratum were executed. The table below shows the number and area of existing borings and probings.

Area	Boring	Probings
a. Lagoon	76 points	526 points
b. Outlet of lagoon area	12 points	----
c. Cargo berth area	17 points	----

However some discrepancy was found between borings and sonic prospecting. Consequently the purpose of the geological investigation to be executed in this study are:

a. To confirm the distribution of the bedrock stratum.
b. To clarify the characteristic of the bedrock material.
c. To determine subsoil property necessary for the improvement design of the iron ore berth and oil jetty.

Figure-2.6.24 shows location of the geological investigation executed in this study.

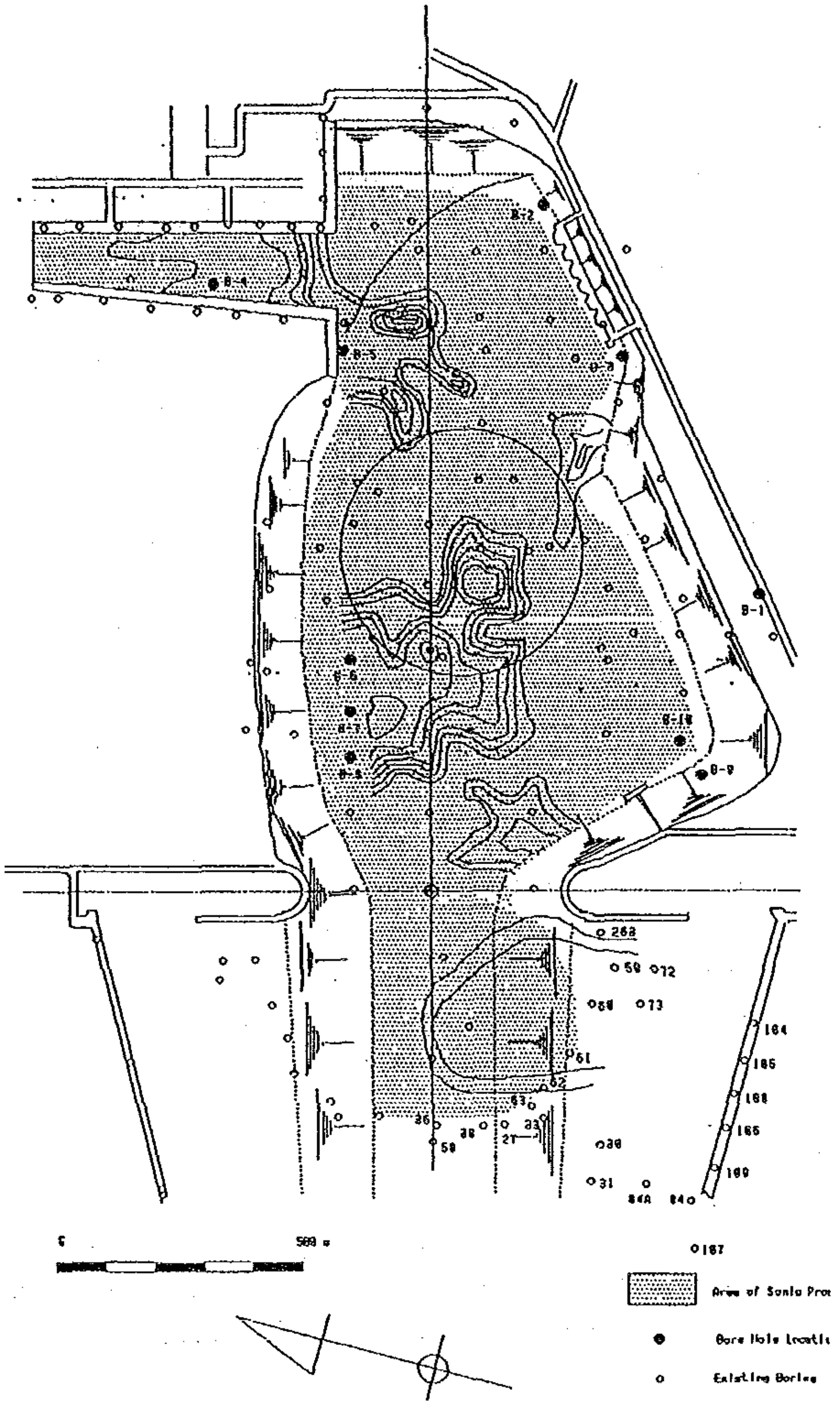


Figure-2.6.24 Location of the Geological Investigation

(1) Method of geological investigation

1) Sonic prospecting

The distribution of the bed-rock stratum is one of the important factor for the execution of the improvement project for the New Mangalore port. The sonic prospecting was executed to define the bed-rock distribution in the lagoon area, outlet of lagoon area and cargo berth area using sub-bottom profiler Model SP-3 which has the following specifications:

Signal frequencies	3 to 8 KHZ
Segregation accuracy	30 cm
Max. profiling depth	approx. 50m

The sonic survey lines were established at approximately 50 meter interval. The important part in the lagoon area which was decided by the existing study/survey data, the sonic survey lines were established at approximately 25 meters intervals. To obtain the reliable results, the tracing speed was kept at 2-3 knots per hours (slower than usual speed) on the sonic survey lines.

The position of the survey boat was determined by means of two onboarded sextants with the cooperation of the staff of Marine Survey Section of New Mangalore Port Trust. The position of the survey boat was confirmed at approximately one minute intervals and marked on the 1:1,000 scale charts which are used for sounding surveys.

2) Borings

Borings were executed using a hand feed type rotary boring machine mounted on a steel pontoon. Standard penetration tests (SPT) were conducted at 1.5 m intervals of the soil strata and the samples obtained by SPT were tested for the physical properties of the soil.

3) Seismic survey

To clarify the property of the bedrock such as hardness or rippability, a seismic survey has been executed using a borehole method. Seismic wave sensors(bore hole pick)were installed inside boreholes verticallly at intervals of 1 meter. The seismic wave was generated by knocking and hammer wave velocity was measured at every 1 meter.

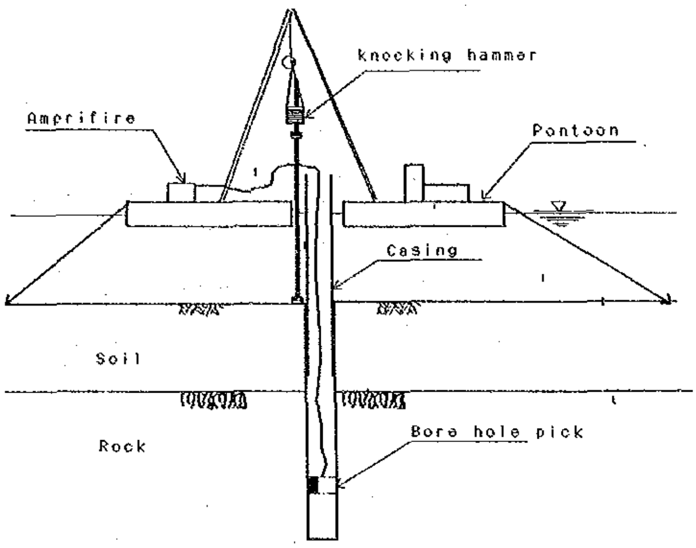


Figure-2.6.25 Method of Seismic Survey

(2) Brief description of the geological condition

Figure-2.6.26 shows the rough sketch of geological strata around the New Mangalore Port and the navigational channel. From the top, the geological strata consists of a sandy soil layer, clayey soil layer and bed rock. Each soil layer is not homogeneous and includes alternative layers of sand and clay.

Stiffness and density of soil layers fluctuate in a wide range, however the strata consist of relatively hard soil in general. Underneath the soil layer, the bedrock strata composed of hard granite rock varies from a depth of 14 m to 25 m from the datum level. Around the breakwater, the subsoil consists of soft to medium-stiff marine clay. The N value of this layer ranges from 3 to 5.

Alluvial soft marine clay seems to extend seaward 1.5 km or further from the shore line , however the soil properties of the layer are not clear.

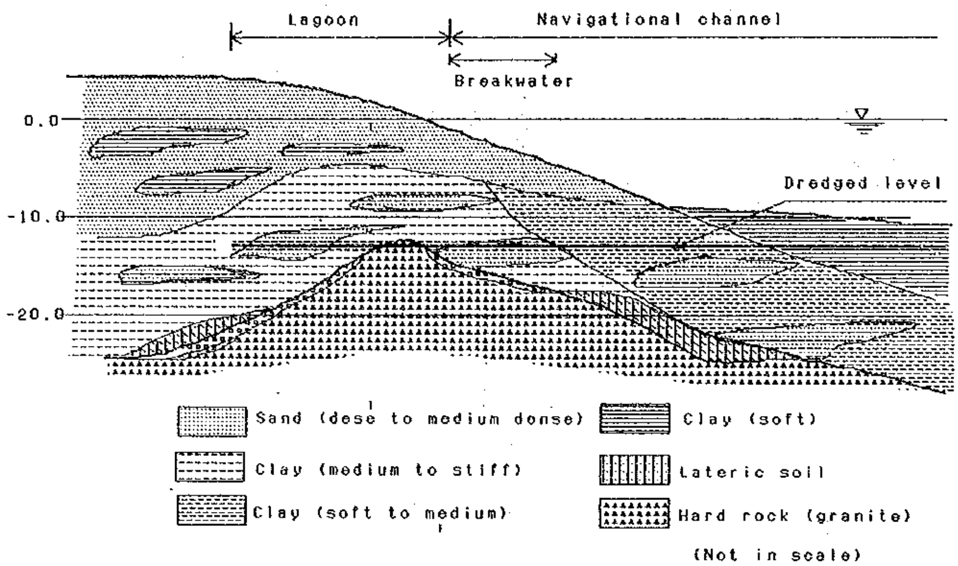


Figure-2.6.26 Rough Sketch of the Geological Strata

(3) Distribution of the bedrock stratum

Sonic survey data was analyzed and 1:2,000 scale sea-bed rock contour map was prepared at the project site.

After the boring work was finished, sea bedrock contour map was prepared taking into consideration the boring results.

According to the results of sonic survey, the areas where the sea-bed rock (weathered rock) appear shallower than 20 meters from chart datum are as follws;

a) All area of cargo berth

The depth of sea-bed rock is approximately 20 to 15 meters at the outlet of the cargo berth area, approximately 15 meters to 11 meters at the cargo berth area.

But, at the berth No.3 and the additional berth area, the rock outcrops at -9.8m and -7.0m were found respectively by the existing data.

b) 900 meters to 1,150meters on the centerline in the Lagoon area

The depth of sea-bed rock is approximetly -13 meters to -20 meters and the slope of the sea-bed rock is steep.

BED ROCK CONTOUR MAP

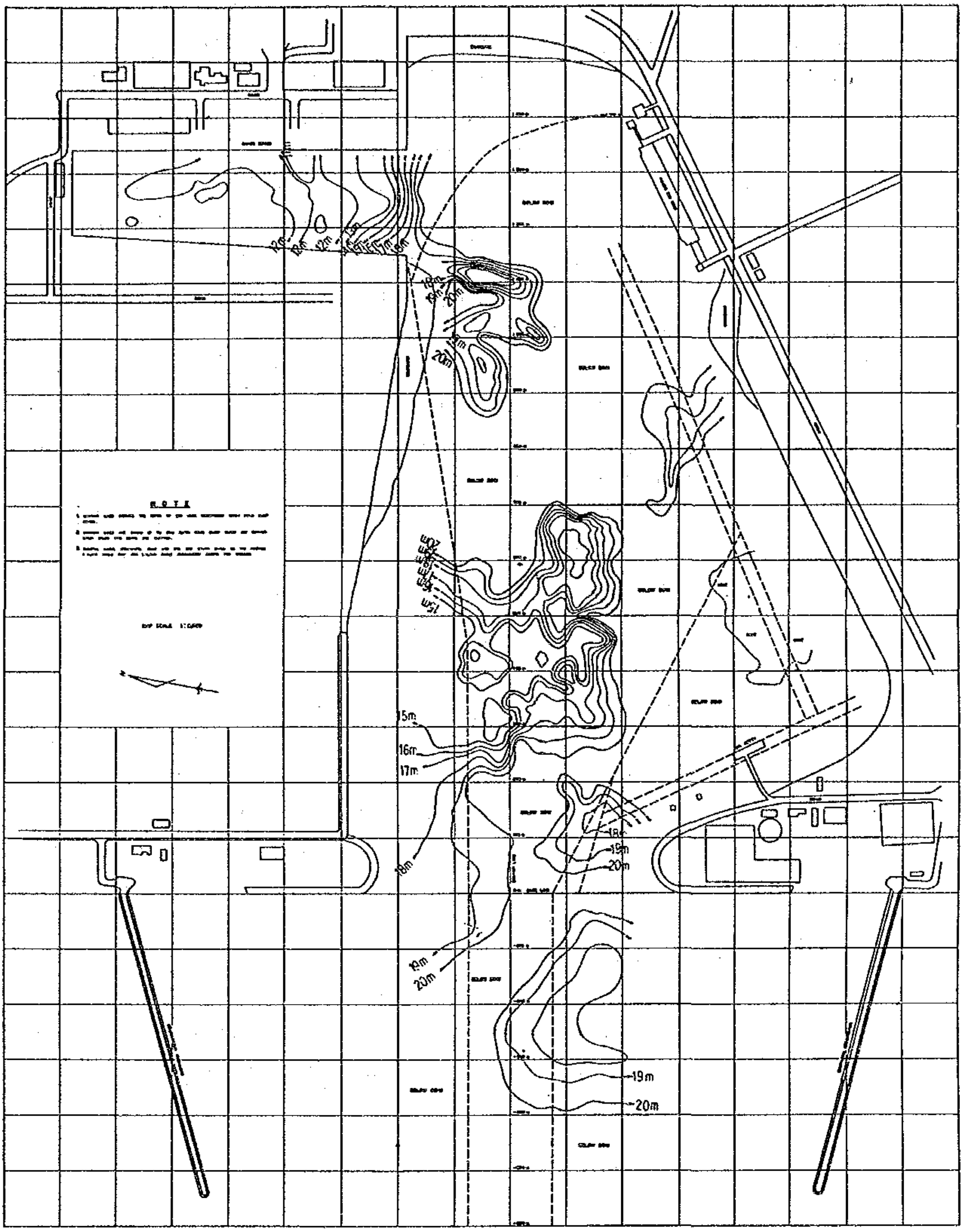


Figure-2.6.27 Distribution of the Bed Rock Stratum

c) 200 meters to 700 meters on the centerline in the Lagoon area

The depth of sea-bed rock is approximately -14 meters to -20 meters. According to "Report of case study of capital dredging at New Mangalore port by M. M. kamath",

sea-bed rock in this area was dredged in the stage of capital dredging up to -13.5 meters from chart datum. However, present condition of top of the sea-bed rock after dredging is very zigzag between the depth -14 meters and -15.5 meters. The reason of this zigzag shape of sea-bed rock is considered as follows.

However, it is difficult to judge the reason based on the sonic survey data only.

i) The dredging of sea-bed rock was executed by blasting, the shape of sea-bed rock after blast is usually zigzag. Therefore, it is considered that levelling the top of sea-bed rock after balsting is not executed.

ii) It is considered that many huge pieces of blasted sea-bed rock are remain on the top of the sea-bed rock after dredging.

d) Appoximately 300 meters west from Iron Ore Berth

The depth of sea-bed rock is approximately -19 meters to -20 meters.

e) Outlet of Lagoon Area

The depth of sea-bed rock is approximaty -18 meter to -20 meters. Especially, judging from the data available, (ref. boring location executed as shown in Figure-2.6.10) the depth of sea-bed rock at the outer port area (inside area of the southern breakwater) is considered deeper than -20m.

(4) Result of Seismic Survey

Figure-2.6.28 shows the results of the seismic survey.

The velocity of Primary wave (Vp) transmitting through rock was measured as 4,500 to 5,000 m/sec, and it means that the rock stratum is composed of very hard rock.

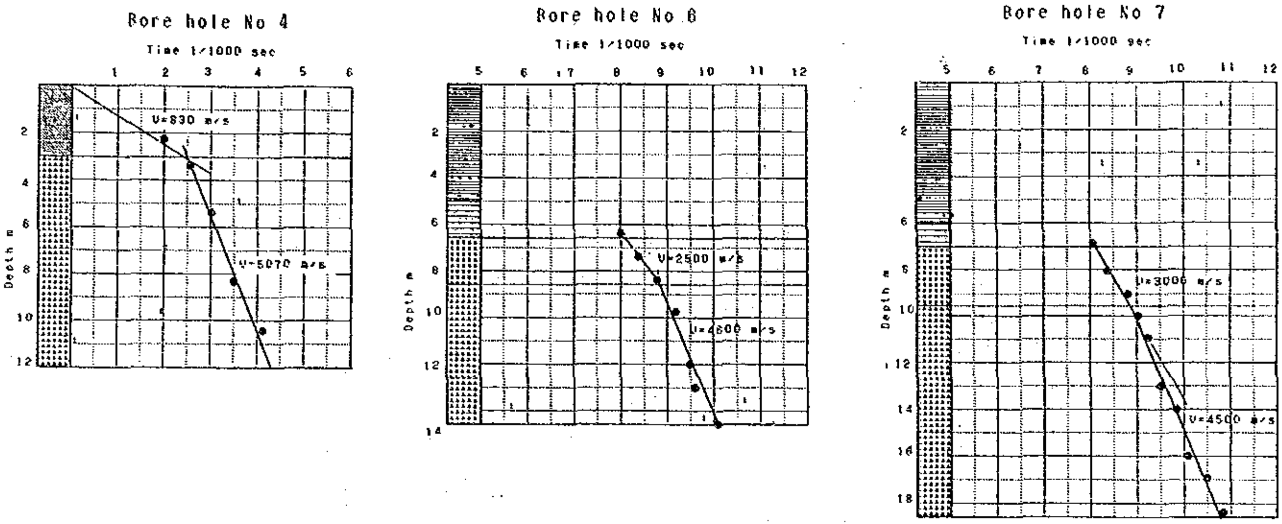


Figure-2.6.28 Results of the Seismic Survey

(5) Soil profile

1) Iron ore berth and oil jetty

Figure-2.6.29 shows the soil profile of the iron ore berth and oil jetty. The subsoil is composed respectively from the top of a sandy soil layer, clayey soil layer, sandy soil layer and bedrock. The N value of the soil layers range 10 to more than 50 and the soils consist of stiff to medium stiff clay or dense to very dense sand. The bed rock is located at a depth of 25 m around iron ore berth and at 18 to 25 m around oil jetty.

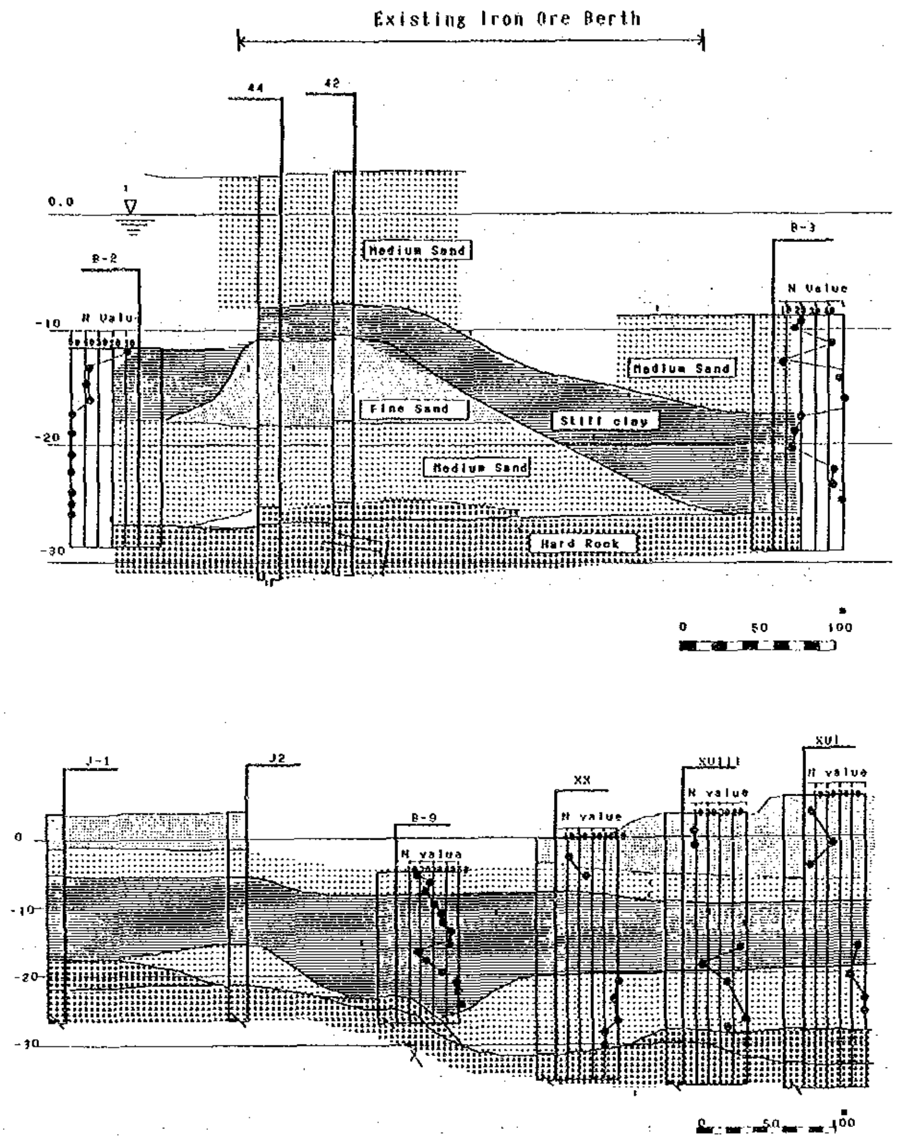


Figure-2.6.29 Soil Profile of Iron Ore Berth and Oli Jetty

2) 200 m to 700 m on the centerline in lagoon

Figure-2.6.30 show the soil profile at 200 m to 700 m on the centerline in the lagoon where the bedrock appears in shallow portion. Since upper part of this area has already been dredged, the soil is composed of a clayey layer and bedrock. The N value of clayey layer ranges from 2 to 15 and the layer consist of soft to medium stiff clay. About 15 m below datum level, a bed rock stratum consisting of hard granite rock is encountered.

The upper part of the bed-rock stratum consists of a layer of 2 to 3 meters Weatherd rock however, the boundary of weatherd rock and fresh rock is not clear.

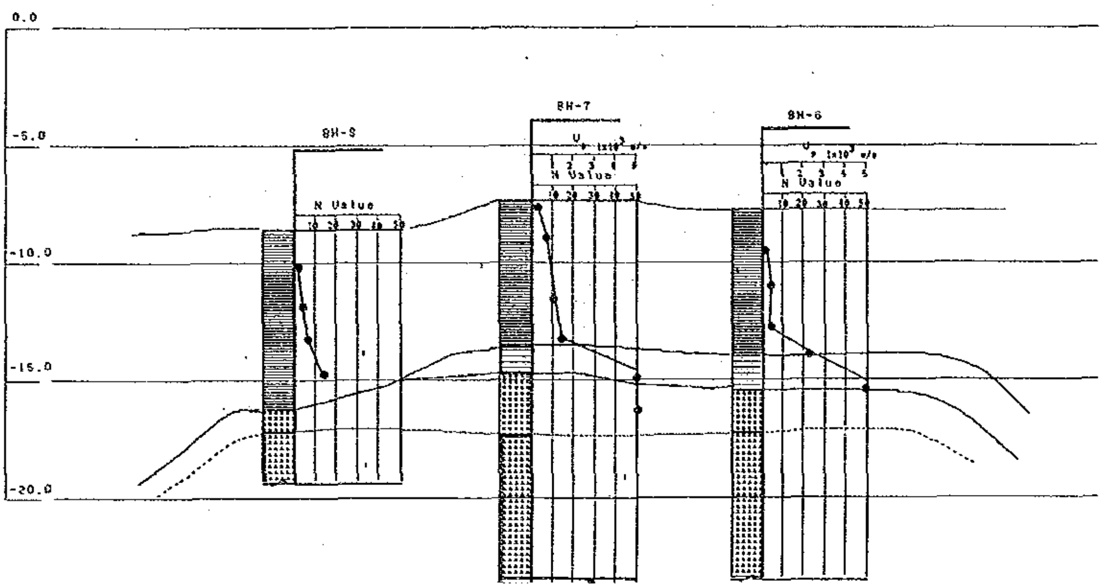


Figure-2.6.30 Soil Profile of 200 m to 700 m in Lagoon

3) Break water

Figure-2.6.31 shows soil profile and Figure-2.6.32 shows soil properties of break water area. The subsoil consists of a sandy soil layer, clayey soil layer, laterite soil (silty sand) and bed-rock. Sandy soil layer has N value of 20 to 30, and a relative density of dense to medium dense. Underneath the sandy soil layer, an alluvial marine clay layer has been deposited. This layer has a relatively high natural moisture content of 60 to 80 %. The N value ranges from 3 to 5, and the layer has a consistency of soft to medium stiff. The cohesion measured by triaxial compression test (UU) ranges from 0.1 to 0.4 kg/cm2 corresponding to the distribution rate of normal consolidated clay. However, this cohesion seem to be smaller compared to that inferred from the N valne.

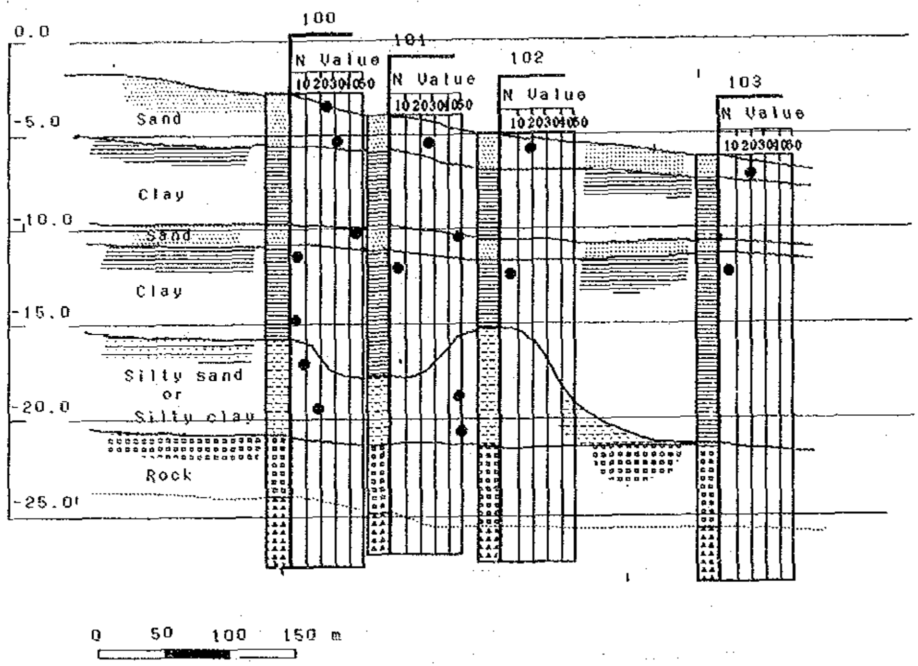


Figure-2.6.31 Soil Profile of the Breakwater

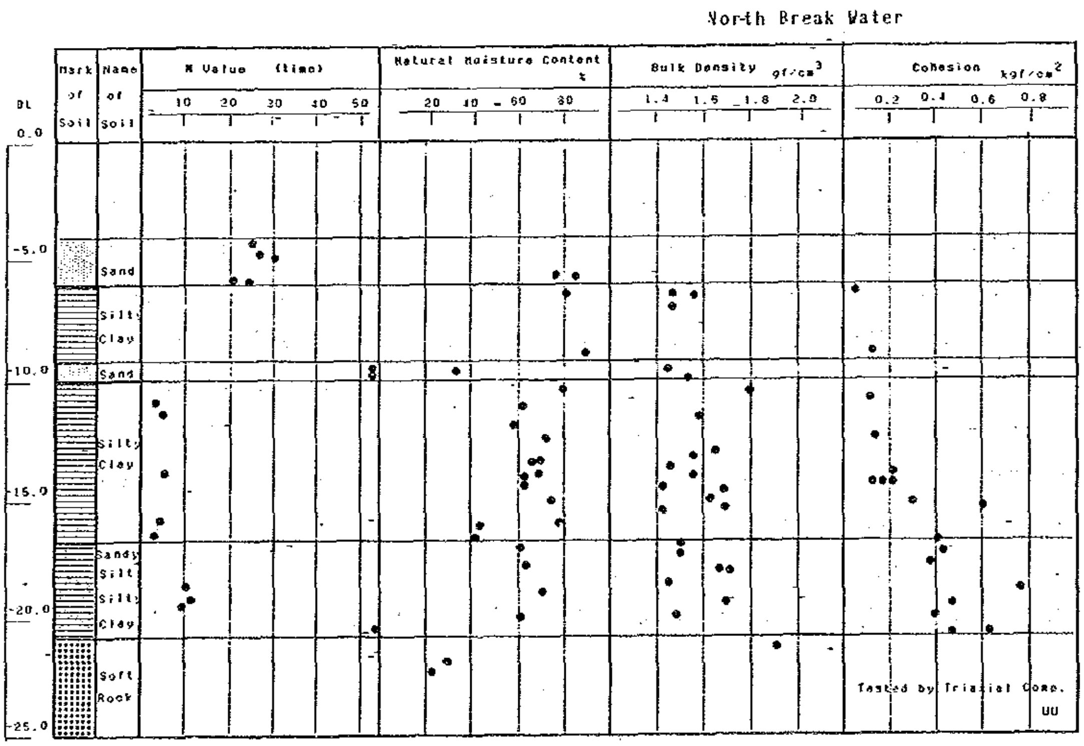


Figure-2.6.32 Soil Properties of Breakwater

4) Navigational channel

Figure-2.6.33 shows the soil profile around the navigational channel.

At the outlet of the lagoon area, the soil composition corresponds to that of the with break water area, however in the logs of borehole No 68 and 69 the clay layer was described as stiff clay even though N value of this layer was measured as 2 to 5 in the boring data executed around the break water area. In consideration of safety for construction of the break-water, this layer is assumed as soft clay in the study of circulars failure analysis described in chapter 5.2.

Alluvial soft marine clay seems to extend seaward 1.5 km or further from the shore line, however the soil properties of the layer are not clear.

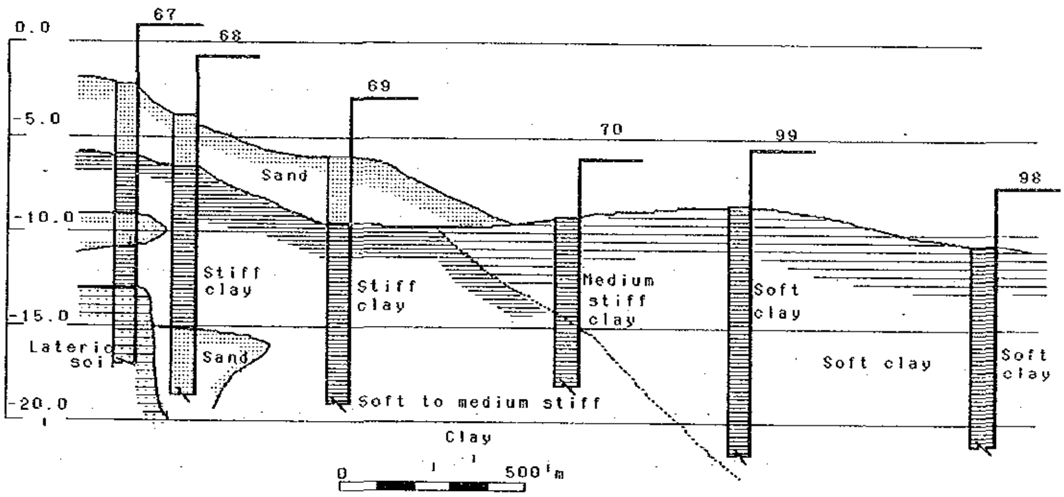


Figure-2.6.33 Soil Profile of Navigational Channel

2.7 Siltation in the Channel and the Lagoon

2.7.1 Characteristics of siltation

New Mangalore Port is located between Goa and Cochin on the west coast of India. Siltation in the outer approach channel and the lagoon is a serious problem in New Mangalore Port, just as in another major ports on the west coast of India. The yearly volume (1982-1987)of maintenance dredging in the outer approach channel and the lagoon is presented in Table-2.7.1. The average volume of dredging per year for the six years is 2.50 million cubic meters, of which 1.57 million cubic meters is taken from the outer approach channel, and 0.93 million cubic meters from the lagoon. From Table-2.7.1, it appears that the maintenance dredging volume varies from year to year and shows a high value every alternate year. The main reasons for the variation of dredged volume in various years are as follows:

1) The siltation volume to be dredged is roughly of the order of 3 million cubic meters and hence the maintenance dredging volume over 3 million cubic meters can be considered normal.
2) The maintenance dredging volume less than 2 million cubic meters is small compared with the siltation volume to be dredged. This situation occurs from the following reasons.
   (a) Financial constraints
   (b) Dredgers are sometimes deployed in a hard patch area, hence the dredging in the channel can not be carried out to the required depth and width.
   (c) Non-availability of dredgers due to the deployment of dredgers at another ports.

Table-2.7.1 The yearly volume of the maintenance dredging

(Kamath*) unit:cubic meters

year	channel(a)	lagoon(b)	(a)+(b)
1982	1,242,600	444,300	1,686,900
1983	1,934,350	1,178,760	3,113,110
1984	1,026,450	824,750	1,851,200
1985	2,062,490	1,234,400	3,296,890
1986	1,088,928	871,964	1,960,901
1987	2,039,688	1,053,306	3,092,994
mean	1,565,751	934,580	2,500,311

* M.M. Kamath, Dredging for Port Development, Case Study, Maintenance Dredging Practice at New Mangalore Port

From examination of sounding maps which have been produced annually on the basis of surveys made by the New Mangalore Port Trust (NMPT), the characteristics of siltation in the outer approach channel and the lagoon is summarized as follows.

(1) Although the outer approach channel in the original plan is 5,340 m long, 245 m wide and -13.5 m deep, the maintenance dredging in the outer approach channel is being carried out for a limited width of 152 m and also a limited depth of -12.5 m due to certain financial constraints. The maintenance dredging in the lagoon is also limited to a specified depth which is less than that of the original plan.

(2) According to the master plan report for New Mangalore Port, nearly 60 to 70 % of annual siltation takes place during May to September (the southwest monsoon period). Kamath* also reported that about 80 % of annual siltation occurs during the monsoon months from June to September, with the balance of 20% occuring during the rest of the year.

(3) To investigate the actual situations of siltation, sounding maps for the latest five years prepared by the NMPT were analyzed. From these analysis the total siltation volume during a monsoon season of every year is shown in Table-2.7.2. This table was made by the comparison of sounding maps surveyed at pre-monsoon and post monsoon periods. The surveys at pre-monsoon were carried out in April or May, and the surveys at post-monsoon in September or October.

Table-2.7.2 The siltation volume during one monsoon season

unit:cubic meters

year	channel(a)	lagoon(b)	(a)+(b)	dredging volume per year
1984	2,195,450	-	-	1,851,200
1985	1,911,000	1,152,000	3,063,000	3,296,890
1986	1,700,000*	812,500	2,512,500	1,960,892
1987	2,826,625	968,500	3,795,125	3,092,994
1988	2,971,750	861,900	3,833,650	-
1989	-	691,100	-	-

* The siltation volume in the channel in 1986 calculated by the above method was 0.63 million cubic meters. However, in the year a dredging operation was partially carried out in the channel before the post monsoon soundings. Therefore, the siltation volume in the channel in 1986 was taken from the value calculated by the NMPT using another method.

(4) According to Table-2.7.2 the siltation volume in the outer approach channel amounts to about two million cubic meters or more. There are some years when the volume approaches nearly three million cubic meters.

(5) The siltation volume in the lagoon is about 0.95 million cubic meters on the average of four years except 1989. In 1989, some dredgings were carried out before the post monsoon soundings.

(6) As for distribution of the siltation volume, the depth of siltation is maximum in the area on both side of the base line in the outer approach channel and the lagoon. The depth of siltation decreases with the distance from the area of maximum siltation .

(7) However, as can be detected by a detailed examination of depth surveyed just after monsoon (abbreviated to POM depth, hereafter), the area where the POM depth is the shallowest is often located 0.5 km to 1.5 km west (offshore) of the base line rather than in the vicinity of the base line. To see this in more detail, Figure-2.7.1 shows the depth in the channel, for 1987 and 1988. In these years the siltation volumes in the channel were very large. In the figure, both the PRM (depth surveyed at pre-monsoon) and POM depths on the center line are plotted in addition to the POM depth on the line 400 m north of the center line. From this figure it is noticed that the POM depth on the center line is the shallowest in the area 1.0 km to 1.5 km west of the base line.

However, the soundings taken during November, 1988 indicate the shallowest depth at the base line and a deeper sounding at 0.5kms. to 1.5kms. offshore. At 1.2kms. offshore the difference of depth from October to November, 1988 is about 0.8m (deeper on November). But depths at the base line are almost the same between these two months. This change of offshore depth may be due to settlement and/or outflowing of deposited material. The smaller change of depth at the base line suggests that deposited materials near the base line contain smaller amount of water than offshore, so the materials near the base line have characteristics of smaller settlement and smaller fluidity.

(8) In addition, a conspicuous feature in the figure is that the POM depth on the center line is very similar to the depth on the line 400 m north of the center line in the offshore area which is more than 2 km to 2.5 km from the base line. This indicates that the channel lying more than 2 km to 2.5 km offshore from the base line is completely filled up with sediments during a southwest monsoon season.

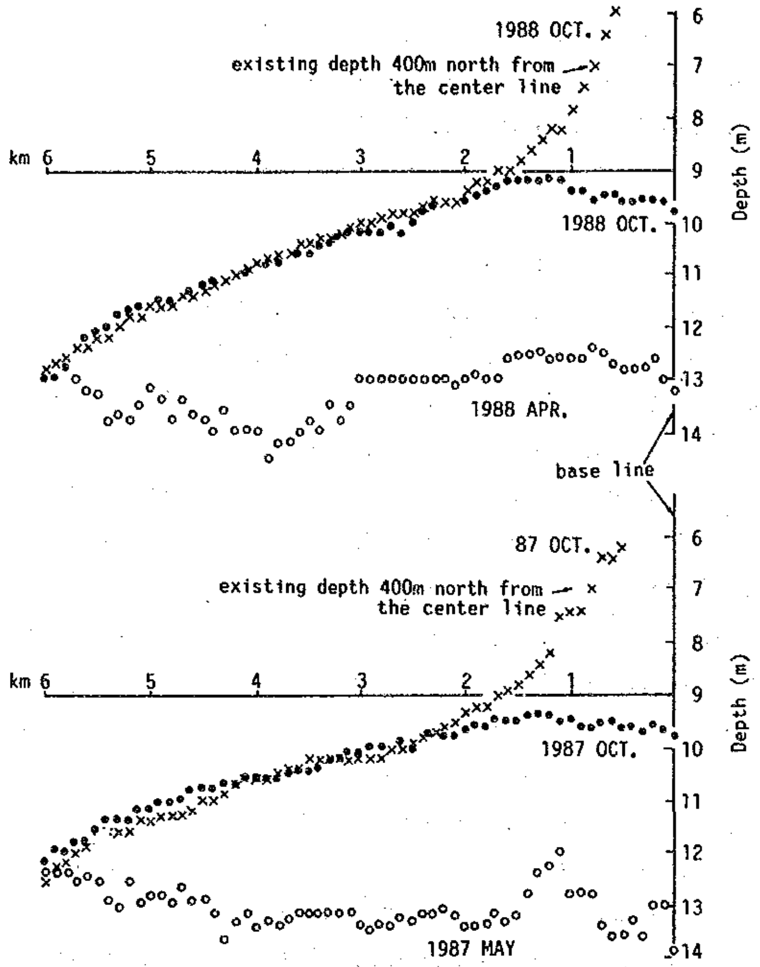


Figure-2.7.1 Distribution of the depth along the center line (A comparison between the pre-monsoon and the post monsoon surveys 1987, 1988)

(9) Distributions of POM depths in the direction across the channel are quite uniform in the offshore area which is more than about 2 km apart from the base line. This again indicates that the POM depths in the channel at distances beyond 2 km offshore from the base line, are similar to the depths on any onshore-offshore line of non-dredged or original sea bed.

The distribution of siltation volume across the channel shows that the siltation volume on the north side in the channel is often larger than on the south side. However, it is impossible to judge whether this situation means the predominant direction of sediment movement being from north to south or not. It may simply be a reflection of the fact that the north side of the channel is often deeper than the south side in the pre-monsoon period because of some bias in dredging operation.

(10) In the onshore area, within 2 km from the base line, it can also be noted that the POM depths at the center line and at lines 75 m north and south from the center line are almost the same. On the other hand in the pre-monsoon period, depths at the center line are often about 1 m deeper than depths at the lines located 75 m north and south of the center line. This may be due to dredging operations.

(11) In the distribution of depths in the lagoon it is found that the POM depth in the dredged area is very uniform. For example, the difference of the POM depths on the center line between the location of the base line and the head of the lagoon is only about 0.7 m to 0.8 m each year. Thus the slope of the sea bed over a distance of about 1300 m from the base line to the head is about 1/2000.

(12) A study of the distribution of depths of siltation in the lagoon reveals that the volume of siltation in the area (west side) near the entrance up to a distance of 1000 m from the base line is large, within a width of 100 m in the area south of the center line. On the eastern side (inner lagoon) from the line 1000 m east of the base line, an area of large volume of siltation is located to the south rather than in the western area (entrance region). Thus the volume of siltation in front of the iron ore berth is large, reflecting the fact that this area is deeply dredged originally and that the depths in the post monsoon period are fairly uniform.

(13) Up to this point, discussion has centered on PRM, POM depths and the volume of siltation deduced from the difference of the depths, since the siltation volume is large in the southwest monsoon season. The discussion will now center on the depth differences between the post monsoon and the pre-dredging times and also between the post dredging and the pre-monsoon times. Comparing depths between the post monsoon and the pre-dredging times, it is found that changes of depths during this period are very small in both the channel and the lagoon.

(14) A comparison of depths between the post dredging and the pre-monsoon times shows that depth changes during this period are also small as in the case mentioned in (13). In the lagoon there is a tendency for depths to increase slightly in the period from the post dredging to the pre-monsoon.

2.7.2 Characteristics of sediment

The New Mangalore Port Trust (NMPT) has conducted soil sampling and analysis every year since 1984. The silt and clay content in these soil samples are presented in Figure-2.7.2.

The soil sampling is conducted along three lines; the center line and the lines 700 m north and south of the center line. A summary of the soil survey in 1986, when two sampling operations were conducted in the pre-monsoon (May) and the post monsoon (September) periods, is presented in Table-2.7.3. Data within a distance of 250 m from the shore line on the northern and southern lines are excluded from the figure and table.

According to the figure and the table, the silt and clay content in the post monsoon period is generally greater than 80 % and the overall average of silt and clay content is about 85 % or more on all three lines. However along the lines 700 m north and south of the center line there is no silt and clay but only fine sand from the base line to 250 m offshore.

This implies that the materials responsible for siltation in the channel and the lagoon are the sediments widely distributed in the area beyond 250 m offshore from the shore line with depth greater than about 5 m. The fact that there is no silt and clay in the onshore area, which is shallower than about 5 m, suggests that these shallow areas are zones of breaking waves where silt and clay can not remain on the bottom since they are always suspended in water by the breaking waves and flow towards offshore.

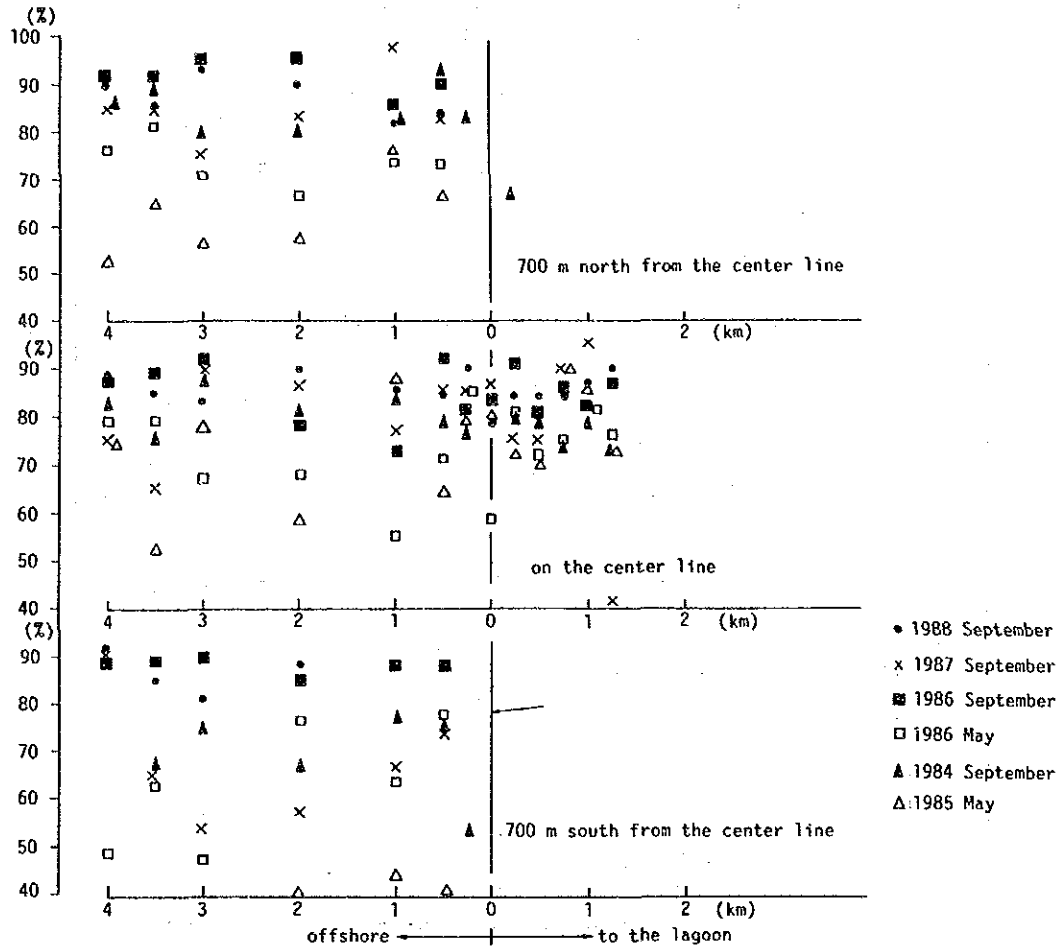


Figure-2.7.2 Silt and clay content in soil samples

Table-2.7.3 The summary of soil surveys conducted by the NMPT in 1986: Contents of silt and clay, %.

Location		May	September
center line	mean	70	84
	range	55 to 85	73 to 91
	standard deviation	10	6
lagoon	mean	74	85
	range	63 to 81	79 to 91
	standard deviation	6	4
700 m north from c/l	mean	74	91
	range	67 to 81	85 to 95
	standard deviation	4	3
700 m south from c/l	mean	63	88
	range	48 to 78	85 to 90
	standard deviation	12	1

Note: For the two lines 700m north and south of the center line silt and clay content of the samples in the onshore area from the base line to 250m offshore are zero and they are excluded in calculations of the mean etc.

According to Figure-2.7.2 and Table-2.7.3, the differences in silt and clay contents between the pre-monsoon and the post monsoon periods are large in both the dredged and undredged areas; i.e., the silt and clay contents at the pre-monsoon period is relatively small compared with those at the post monsoon period.

It is relatively easy to understand this phenomenon in the dredged area, namely in the channel and the lagoon; in these areas sediments obtained at the pre-monsoon survey are the remains of the dredging operation, although at the time of the post monsoon survey, the channel and the lagoon are filled with very fine sediments containing much silt and clay. However it is hard to understand the same phenomenon in undredged areas; namely, on the two lines 700 m north and south of the center line.

It is thought that at the time of post monsoon survey, immediately after the monsoon disturbances, the water content within the bed material is large and the bulk density of bed material is small. At the time of pre-monsoon survey the reverse is expected to occur because of sediment settling. However it is still hard to understand why the change in silt and clay content takes place from the post monsoon to the pre-monsoon surveys. There seems to exist some mechanism of sediment sorting in these season.

2.8 Littoral Sand Drift

There are long beaches consisting of fine sand both to the north of the north breakwater and to the south of the south breakwater of the Port. It is thought that these beaches had been affected by the construction of breakwaters. As regards littoral sand drift at Mangalore, the Central Water and Power Research Station (CWPRS, Pune) reported as follows:

(1) The net littoral drift at Mångalore is about 200,000 tons per annum according to Per Brunn, though the basis for this estimation is not known.

(2) There is a tendency for accretion to take place on the north side of the north breakwater and erosion on the south side of the south breakwater. This situation indicates the direction of the drift being dominant from north to south.

To see the real changes of the beach, depth contours of 0 m and -5 m for six years from 1980 to 1985 were examined based on sounding maps prepared by the NMPT. Figure-2.8.1 shows the depth contour lines of 0 m and -5 m every year from 1980 to 1985. According to this figure, both the contour lines of 0 m and -5 m on the north side of the north breakwater are situated further offshore than those on the south side of the south breakwater with respect to the base line.

This implies the north shore line of the port being in accretion and the south shore line in erosion. It is said that the amount of littoral sand drift on the west coast of India is smaller than that on the east coast, and the direction of the littoral sand drift on the west coast of India in the southwest monsoon season is dominantly from north to south.

The situation of depth contours seen in Figure-2.8.1 indicates that the direction of littoral sand drift in the relevant shore area is predominantly from north to south coinciding with the direction in other coastal areas on the west coast of India.

Although the locations of the same depth contours varied each year from 1980 to 1986, no long term trend can be observed. For example, both the depth contours of 0 m and -5 m in the south side of the south breakwater moved considerably offshore from 1981 to 1982, but they returned almost to the previous locations in 1983. Thus the following conclusion can be drawn: After the construction of breakwaters a degree of accretion took place on the north side of the north breakwater and a degree of erosion on the south side of the south breakwater due to the interruption of the southward littoral sand drift. However, at present, the shore line in the vicinity of the Port seems to be almost stable in the long term, in spite of the fact that yearly movements of the shore line in the off and on-shore directions take place through yearly differences in oceanographical conditions.

In July 1989, when a cyclone was attacking northern area of the west coast of India, littoral sand drift took place through the top of the breakwaters and filled some part of the channel in the portion of 600 to 1600 m from the base line with compact sand. This required immediate dredging to clear the way for navigation. Though these events are unusual and have no fatal effects under normal weather conditions, they are a non-negligible factor for the maintenance of the navigational channel.

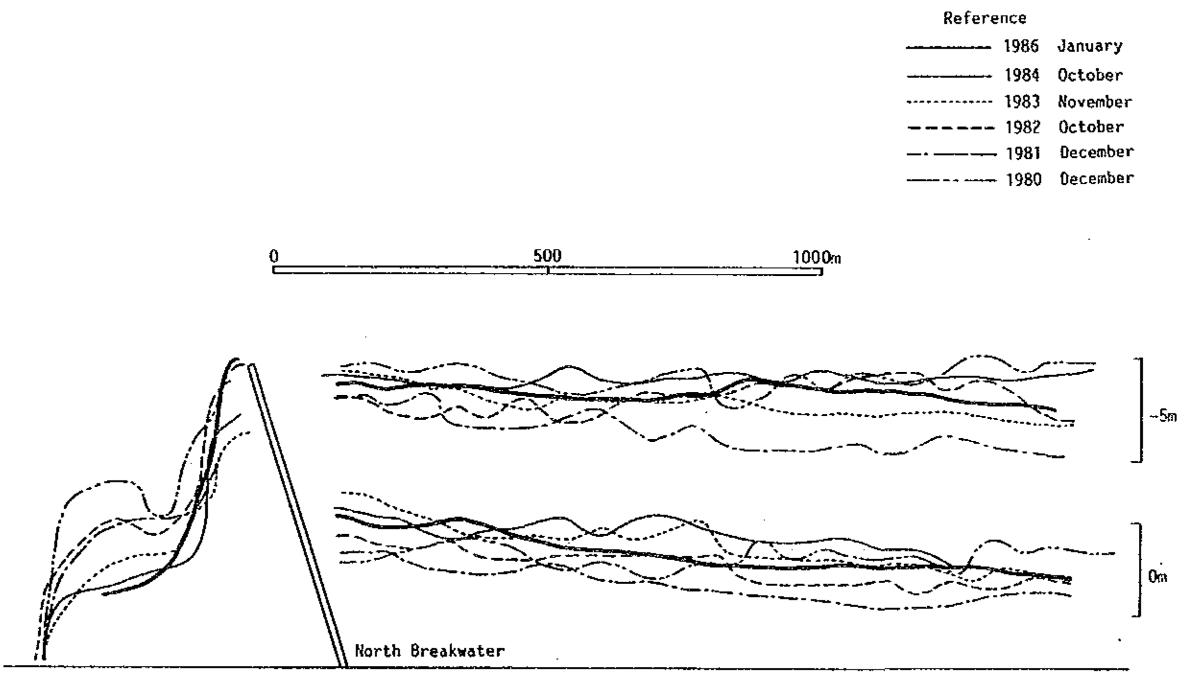


Figure-2.8.1(1) Yearly change of depth contours of 0 m and -5m from 1980 to 1985 (north side)

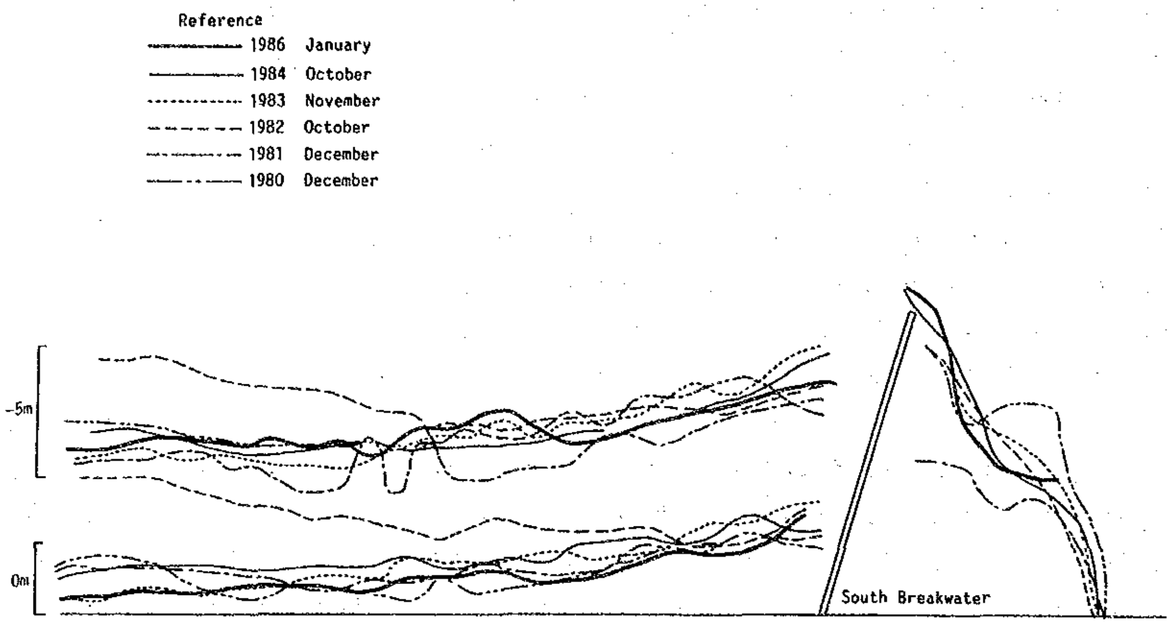


Figure-2.8.1(2) Yearly change of depth contours of 0 m and -5m from 1980 to 1985 (south side)

3. PRESENT SHIPPING AND CARGO TRAFFIC

3.1 Present Shipping Traffic

3.1.1 No. of vessels calling at the port

Table-3.1.1 shows the number of vessels calling at the port from the 1980-81 period to the 1987-88 period. This table shows that more and more vessels are calling at the port and that the number of vessels has incresed by 1.88 times between 1980-81 and 1987-88. Moreover, 74% to 86% of this total are foreign trade vessels. The increase in the number of vessels handled was mainly due to an increase in calls by iron ore carriers.

Table-3.1.1 No. of Vessels Calling at New Mangalore Port

Period	1980-81	81-82	82-83	83-84	84-85	85-86	86-87	87-88
Foreign Trade	167	200	215	255	293	234	319	344
Domestic Trade	60	54	40	44	49	65	86	82
TOTAL	227	254	255	299	342	309	405	426

3.1.2 Vessel types and sizes

Table-3.1.2 explains the number of vessels by type, that is, bulk carrier, general cargo carrier and tanker, handled at the port between the 1980-81 period and the 1987-88 period and shows that both tankers and bulk carriers increased drastically in number between 1985-86 and 1986-87 while the number of general cargo carrier rose moderately. The increse in bulk carriers was caused by an increse in tonnage of iron ore handled. Also, the number of vessels by commodity and their movements from 1983-84 to 1987-88 are available in Appendix-1.

Table-3.1.2 No. of Vessels Calling at New Mangalore Port by Type

Period	1980-81	81-82	82-83	83-84	84-85	85-86	86-87	87-88
Bulk Carriers	26	40	43	69	82	68	116	120
General Cargo	163	159	152	172	189	173	182	201
Tankers	38	55	60	53	71	68	107	105
TOTAL	227	254	255	294	342	309	405	426

Bulk Carriers: Fertilizer, Iron Ore, Other One, Steel Scrap, Coal
General Cargo: Cement, Timber, Other Cargo
Tankers : P.O.L., Liquid Ammonia, Phosphoric Acid, Edible Oil

Table-3.1.3 shows the total and average G.R.T of vessels which called at the port during the past eight years and shows that the vessel size has gradually increased. Additionally, the number of vessels handled at the iron ore berth and the oil jetty in 1988-89 by DWT class is shown in Table-3.1.4 and 3.1.5.

Table-3.1.3 Average G.R.T of Vessels Calling at New Mangalore Port

Period	1980-81	81-82	82-83	83-84	84-85	85-86	86-87	87-88
G.R.T (million T)	1.89	2.75	2.90	3.40	4.08	3.90	5.55	5.42
No.of Vessels	227	254	255	299	342	309	405	426
Average G.R.T (thousand T)	8.3	10.8	11.4	11.4	11.9	12.6	13.7	12.7

Table-3.1.4 DWT of Vessels which moored at the Iron One Berth (1988/89)

Vessel Size (DWT)	No. of Vessel
0 - 9,999	0
10,000 - 19,999	7
20,000 - 29,999	39
30,000 - 39,999	21
40,000 - 49,999	31
50,000 - 59,999	10
60,000 - 69,999	19
70,000 - 79,999	8
80,000 -	0
TOTAL	135

Table-3.1.5 DWT of Vessels which moored at the Oil Jetty (1988/89)

Vessel Size (DWT)	No. of Vessel
0 - 4,999	1
5,000 - 9,999	8
10,000 - 14,999	0
15,000 - 19,999	24
20,000 - 24,999	20
25,000 - 29,999	20
30,000 - 34,999	2
35,000 -	0
TOTAL	75

3.2 Present Cargo Traffic

3.2.1 Cargo traffic volume

Table-3.2.1 show export and import cargo traffic at the port from 1980-81 to 1988-89 and indicates that about seven times the cargo volume handled in 1980-81 was handled in 1988-89. Similarly, Export and import cargoes increased by 17 and 2.5 times, respectively. The drastic increase in export cargo volume is mainly due to the increase in iron ore exports by Kudremukh Iron Ore Company Limited (K.I.O.C.L.).

Table-3.2.1 Cargo Traffic Through New Mangalore Port

('000 t)

Period	1980-81	81-82	82-83	83-84	84-85	85-86	86-87	87-88	88-89
Export	323	830	1431	1595	2387	2690	4243	4803	5517
Import	639	822	851	1242	995	996	1197	1305	1567
TOTAL	962	1652	2282	2837	3382	3686	5431	6108	7084

3.2.2 Cargo traffic by commodity

(Exports)

The predominant export cargo is iron ore, which has been handled on a large scale since 1981-82 and accounted for 90.8% of the port's total export cargo as expressed in tonnage in 1988-89. The other main export commodities are granite stone, coffee, manganese ore and chrome ore. Granite stone exports have doubled in tonnage in the past eight years, but the volume of other commodities handled has not changed on the whole. The volume of each commodity handled at the port in the last decade is shown in Figure-3.2.2. Detailed statistics are furnished in Appendix-2.

Table-3.2.2 Cargo Traffic by Commodity Through New Mangalore Port(Exports)

('000 t)

Period	1980-81	81-82	82-83	83-84	84-85	85-86	86-87	87-88	88-89
Iron Ore	3	547	1122	1231	1727	2260	3873	4357	5011
Other Ore	43	66	70	47	94	80	37	47	33
Granite Stone	174	118	147	168	273	215	244	314	386
Coffee	63	45	47	39	32	43	49	46	43
Others	40	54	45	110	261	92	31	39	44
TOTAL	323	830	1431	1595	2387	2690	4243	4803	5517

(Imports)

The main commodities handled at the port changed in the last decade. About ten years ago, cement, fertilizers and P.O.L were the main cargoes, but at present, the main commodities are P.O.L, timber, fertilizer materials and steel scrap. This change was due to the establishment of local industries and the governmental regulation (a ban placed on cutting trees). P.O.L started increasing in 1984-85 and grew by 1.9 times from 1980-81 to 1988-89. Timber is the most rapidly increasing import commodity at the port. It has been handled since 1985-86 and has increased about 6 times in the last three years. It is imported from Southeast Asian countries. Fertilizer materials, liquid ammonia and phosphoric acid are used for production of "urea," "DAP," "ABC" by Mangalore Chemicals & Fertilizers Ltd. located just behind the port. This company was established by the state government and is expanding its production capacity. The volume of each commodity handled at the port in the past decade is shown in Figure-3.2.3. Detailed statistics are furnished in Appendix-3.

Table-3.2.3 Cargo Traffic by Commodity Through New Mangalore Port(Imports)

('000 t)

Period	1980-81	81-82	82-83	83-84	84-85	85-86	86-87	87-88	88-89
Cement	87	86	278	359	36	41	14	1	1
Fertilizer	207	180	153	211	247	219	165	93	46
Steel Scrap	21	37	42	39	59	81	120	90	117
Timber	0	0	0	0	0	65	204	342	375
P.O.L.	310	364	351	348	437	412	533	461	571
Lq. Ammonia /Phos. Acid	0	0	0	0	16	17	57	79	141
Edible Oil	0	0	0	0	27	47	57	116	42
Food Grains	4	152	22	141	83	0	0	2	62
Others	10	3	5	144	90	111	47	121	212
TOTAL	639	822	851	1242	995	996	1197	1305	1567

(Container Cargo)

The number of containers in TEU, loaded and empty, handled at the port in the past five years is shown in Table-3.2.4. The containerized cargo tonnage is depicted in Figure-3.2.5. These figures show that the number of TEUs handled at the port has increased steadily, and on the other hand, containerized cargo volume has grown rapidly within the last couple of years (the increase in 1983-84 can be neglected because it was caused by temporary import of a considerable amount of cargo in containers for the erection of the pipe coating and offshore platform plants of Mazagon Dock Ltd). This means that number of loaded containers has increased rapidly. Commodities loaded in containers are coffee, cashew kernels. In 1986 baggage of tourists from Gulf contries joined this list. The volumes of coffee and cashew kernels handled at the port were 32, 43, 50 and 47 thousand tonnes in 1984-85, 85-86, 86-87 and 87-88, respectively, and it can be estimated that about 20-30% of them were transported in containers.

Table-3.2.4 Containers Handled at New Mangalore Port

units in TEU

Period	Shipped		Landed		TOTAL
	Empty	Loaded	Empty	Loaded	
1984-85	182	472	380	213	1247
1985-86	403	515	528	367	1813
1986-87	164	1369	1198	329	3060
1987-88	865	752	597	817	3031
1988-89	635	488	383	720	2226

Table-3.2.5 Tonnage Handled in Containers through New Mangalore Port

Period	Tonnes
1984-85	8303
1985-86	8828
1986-87	24054
1987-88	21130
1988-89	20461

Commodity:

Export Coffee
Granite aggregate
Other
Import Personal Belongings
(with passengers from the Gulf, 7,000 to 8,000 t)
Machinery
Other

3.2.3 Cargo handling berths

As mentioned in previous chapter, New Mangalore Port has currently four general cargo berths (more two general cargo berths are under construction), one shallow berth, one iron ore berth and one oil jetty. Figure-3.2.1 illustrates which commodities are handled at which berth or jetty.

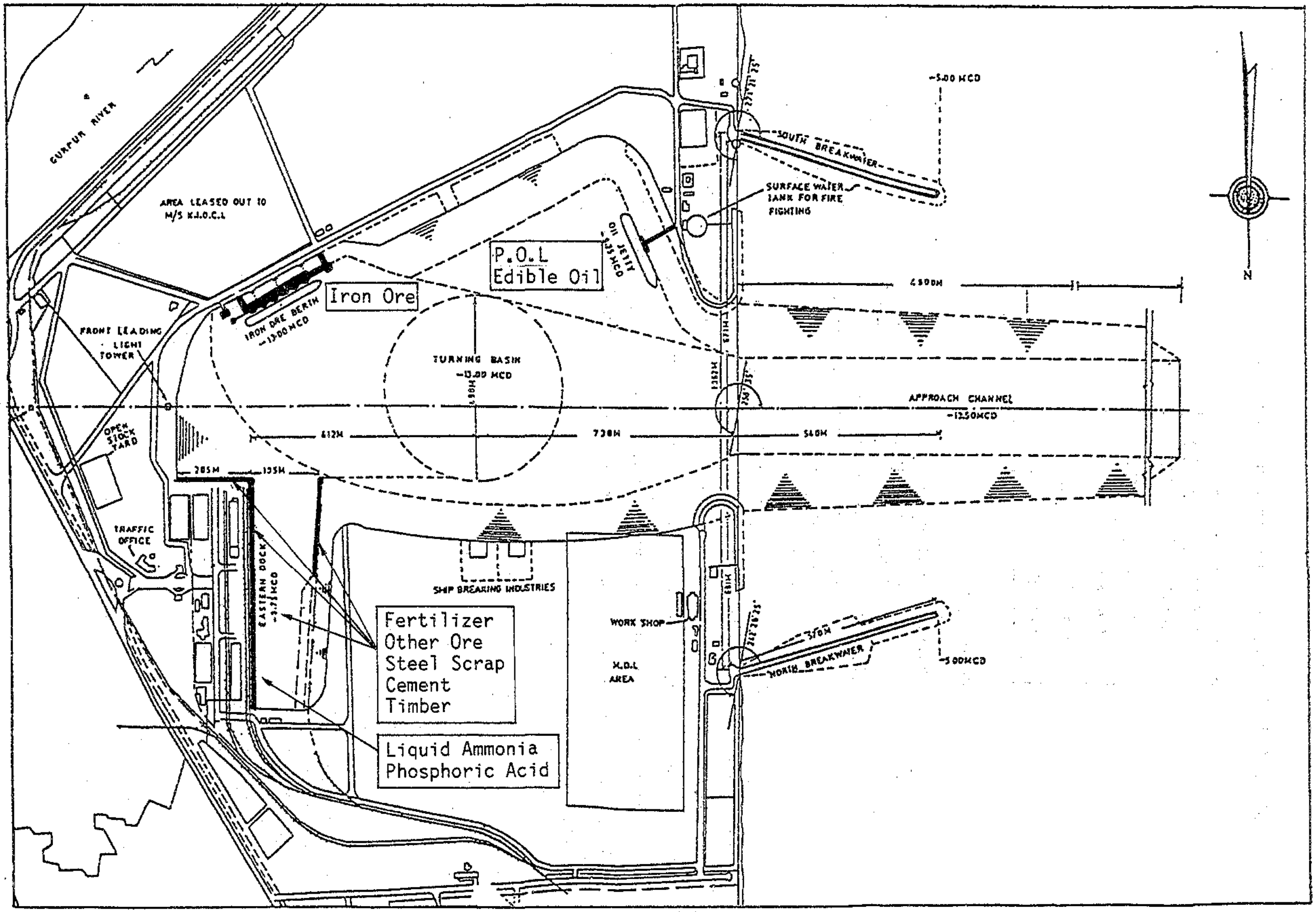


Figure-3.2.1 Commodity Handled at Each Berth of New mangalore Port

4. PORT MANAGEMENT AND OPERATION

4.1 Present Situation of Ship Performance

Performance of ships by ship type between 1984/85 and 1987/88 at N.M.P are as follows:

Types of vessels handled at N.M.P. are listed below:

Table-4.1.1 Type of Vessels

Years	Break bulk ships	Dry bulk ships	Liquid bulk ships	Total
1984/85	184	82	76	342
1985/86	149	79	81	309
1986/87	182	116	107	405
1987/88	201	120	88	409

* Break bulk: Cement, Sugar, Timber, Other Gen. Cargo
Dry bulk : Food grain, Fertilizer, Coal, Iron ore, Other ore, Steel scrap
Liquid bulk: P.O.L., Edible oil, Liquid Ammonia

4.1.1 Break bulk ships

Ship performance of break bulk ships at New Mangalore Port is listed below:

Table-4.1.2 Ship Performance of Break Bulk Ships

Description	84/85	85/86	86/87	87/88
1. No. of ships	182	149	182	201
2. Total cargo handled ('000 Tonnes)	448	506	589	796
3. Avg. output per ship day (Tonnes)	587	438	500	488
4. Avg. pre-berthing time	1.38	1.74	1.10	1.23
5. Avg. stay at berth	4.20	7.74	6.47	8.11
6. Avg. working time	1.82	3.63	3.19	3.53
7. Avg. non-working time	2.38	4.11	3.28	4.58
8. Working/stay time ratio	0.43	0.47	0.49	0.43
9. Avg. output handled per effective hour (Tonnes)	56.5	39.0	42.2	46.7

Table-4.1.3 Ship Performance (Cement)

Type of vessels category wise	84/85	85/86	86/87	87/88
(Cement)				
1 Total No. of vessels left	8	6	1	1
2 Total No. of vessels waiting at anchorage	4	2	1	1
3 Pre-berthing waiting hrs.				
(1) For want of berth	904	359	34	40
(2) Other reasons				
4 Average pre-berthing wait	113	60	34	40
5 Total tonnage handled in tonnes	36,358	44,093	14,189	1,430
6 Average tonnage per ship	4,545	7,349	14,189	1,430
7 Pilotage inward and outward (in hours)	19	12	3	2
8 Berth hours				
(1) Working hours of vessels left	928	914	304	26
(2) Idling hours at berth	1,093	892	364	33
(3) Total No. of berth hours spent by ships	2,021	1,806	668	59
9 Average output per berth hours	18	24	21	24
10 Average output per working hours by vessels	39	48	47	55
11 Average time taken to handle 1,000 tonnes of cargo	56	41	47	41

Table-4.1.4 Ship Performance (Sugar)

Type of vessels category wise	84/85	85/86	86/87	87/88
(Sugar)				
1 Total No. of vessels left	2	7	1	
2 Total No. of vessels waiting at anchorage	2	4	-	
3 Pre-berthing waiting hrs.				
(1) For want of berth	303	854	-	
(2) Other reasons				
4 Average pre-berthing wait	152	122	-	
5 Total tonnage handled in tonnes	24,125	91,599	14,300	
6 Average tonnage per ship	12,062	13,086	14,300	
7 Pilotage inward and outward (in hours)	6	14	3	
8 Berth hours				
(1) Working hours of vessels left	525	1,678	206	
(2) Idling hours at berth	1,223	2,685	143	
(3) Total No. of berth hours spent by ships	1,748	4,363	349	
9 Average output per berth hours	14	21	41	
10 Average output per working hours by vessels	46	55	69	
11 Average time taken to handle 1,000 tonnes of cargo	72	48	24	

Table-4.1.5 Ship Performance (Timber)

Type of vessels category wise	84/85	85/86	86/87	87/88
(Timber)				
1 Total No. of vessels left		15	38	52
2 Total No. of vessels waiting at anchorage		11	18	41
3 Pre-berthing waiting hrs.				
(1) For want of berth		709	829	2,698
(2) Other reasons				
4 Average pre-berthing wait		47	22	52
5 Total tonnage handled in tonnes		65,413	204,273	336,395
6 Average tonnage per ship		4,361	5,376	6,469
7 Pilotage inward and outward (in hours)		33	3	100
8 Berth hours				
(1) Working hours of vessels left		2,207	5,343	8,690
(2) Idling hours at berth		2,513	5,358	11,581
(3) Total No. of berth hours spent by ships		4,720	10,071	20,271
9 Average output per berth hours		14	19	17
10 Average output per working hours by vessels		30	38	39
11 Average time taken to handle 1,000 tonnes of cargo		72	52	60

Table-4.1.6 Ship Performance (Other Gen.Cargo)

Type of vessels category wise	84/85	85/86	86/87	87/88
(Other Gen. Cargo)				
1 Total No. of vessels left	172	121	142	148
2 Total No. of vessels waiting at anchorage	90	64	53	63
3 Pre-berthing waiting hrs.				
(1) For want of berth	4,819	4,318	3,964	3,179
(2) Other reasons				
4 Average pre-berthing wait	28	36	28	21
5 Total tonnage handled in tonnes	387,894	305,003	355,889	458,156
6 Average tonnage per ship	2,255	3,042	2,506	3,096
7 Pilotage inward and outward (in hours)	400	245	220	283
8 Berth hours				
(1) Working hours of vessels left	6,480	8,166	8,095	8,320
(2) Idling hours at berth	8,095	8,632	8,443	10,466
(3) Total No. of berth hours spent by ships	14,575	21,208	16,538	18,786
9 Average output per berth hours	27	18	22	24
10 Average output per working hours by vessels	60	37	42	44
11 Average time taken to handle 1,000 tonnes of cargo	37	55	46	41

4.1.2 Dry bulk ships

The ship performance of dry bulk ships is shown in the following table:

Table-4.1.7 Ship Performance of Dry Bulk Ships

Description	84/85	85/86	86/87	87/88
1. No. of ships	77	79	116	120
2. Total cargo handled ('000 Tonnes)	2,209	2,625	4,195	4,602
3. Avg. output per ship day (Tonnes)	1,644	3,273	4,732	7,215
4. Avg. pre-berthing time	0.3	4.97	5.4	5.16
5. Avg. stay at berth	17.5	10.15	7.6	5.3
6. Avg. working time	6.0	5.02	3.6	2.8
7. Avg. non-working time	11.5	5.13	4.0	2.5
8. Working/stay time ratio	0.34	0.49	0.47	0.53
9. Avg. output handled per effective hour (Tonnes)	200	275	413	570

Ship performance by each commodity is shown in the following table:

Table-4.1.8 Ship Performance (Iron Ore)

Type of vessels category wise	84/85	85/86	86/87	87/88
(Iron ore)				
1 Total No. of vessels left	42	54	97	107
2 Total No. of vessels waiting at anchorage	16	34	69	83
3 Pre-berthing waiting hrs.				
(1) For want of berth	322	8,610	14,356	348
(2) Other reasons				13,572
4. Average pre-berthing wait	8	159	148	130
5 Total tonnage handled in tonnes	1,726,620	2,260,139	3,873,289	4,327,359
6 Average tonnage per ship	41,110	41,854	39,931	40,443
7 Pilotage inward and outward (in hours)	121	116	325	210
8 Berth hours				
(1) Working hours of vessels left	1,005	1,873	3,300	3,622
(2) Idling hours at berth	708	632	2,530	2,401
(3) Total No. of berth hours spent by ships	1,713	2,505	5,830	6,023
9 Average output per berth hours	1,008	902	664	718
10 Average output per working hours by vessels	1,718	1,207	1,174	1,195
11 Average time taken to handle 1,000 tonnes of cargo	1	1	2	1.4

Table-4.1.9 Ship Performance (Other Ores)

Type of vessels category wise	84/85	85/86	86/87	87/88
(Other ores)				
1 Total No. of vessels left	10	6	3	3
2 Total No. of vessels waiting at anchorage	5	4	2	3
3 Pre-berthing waiting hrs.				
(1) For want of berth	173	164	92	119
(2) Other reasons				
4 Average pre-berthing wait	18	27	31	40
5 Total tonnage handled in tonnes	94,400	79,865	36,750	46,350
6 Average tonnage per ship	9,440	13,311	12,150	15,450
7 Pilotage inward and outward (in hours)	32	10	10	6
8 Berth hours				
(1) Working hours of vessels left	954	1,182	402	449
(2) Idling hours at berth	825	857	338	388
(3) Total No. of berth hours spent by ships	1,779	2,039	740	837
9 Average output per berth hours	53	89	50	55
10 Average output per working hours by vessels	99	36	91	103
11 Average time taken to handle 1,000 tonnes of cargo	10	26	20	18

Table-4.1.10 Ship Performance (Coal)

Type of vessels category wise	84/85	85/86	86/87	87/88
(Coal)				
1 Total No. of vessels left				2
2 Total No. of vessels waiting at anchorage				1
3 Pre-berthing waiting hrs.				
(1) For want of berth				23
(2) Other reasons				
4 Average pre-berthing wait				12
5 Total tonnage handled in tonnes				65,072
6 Average tonnage per ship				32,536
7 Pilotage inward and outward (in hours)				4
8 Berth hours				
(1) Working hours of vessels left				408
(2) Idling hours at berth				301
(3) Total No. of berth hours spent by ships				709
9 Average output per berth hours				92
10 Average output per working hours by vessels				159
11 Average time taken to handle 1,000 tonnes of cargo				11

Table-4.1.11 Ship Performance (Fertilizers)

Type of vessels category wise	84/85	85/86	86/87	87/88
(Fertilizers)				
1 Total No. of vessels left	17	14	11	3
2 Total No. of vessels waiting at anchorage	13	13	7	3
3 Pre-berthing waiting hrs.				
(1) For want of berth	4,488	6,633	426	167
(2) Other reasons				
4 Average pre-berthing wait	262	473	39	56
5 Total tonnage handled in tonnes	246,772	219,235	164,628	73,610
6 Average tonnage per ship	14,516	15,660	14,966	24,536
7 Pilotage inward and outward (in hours)	60	35	35	6
8 Berth hours				
(1) Working hours of vessels left	6,642	7,184	3,923	1,401
(2) Idling hours at berth	14,864	8,628	5,160	1,537
(3) Total No. of berth hours spent by ships	21,506	15,812	9,083	2,938
9 Average output per berth hours	12	14	18	25
10 Average output per working hours by vessels	37	31	42	52
11 Average time taken to handle 1,000 tonnes of cargo	87	72	55	40

Table-4.1.12 Ship Performance (Food grains)

Type of vessels category wise	84/85	85/86	86/87	87/88
(Food grains)				
1 Total No. of vessels left	9			
2 Total No. of vessels waiting at anchorage	4			
3 Pre-berthing waiting hrs.				
(1) For want of berth	1,534			
(2) Other reasons				
4 Average pre-berthing wait	170			
5 Total tonnage handled in tonnes	82,828			
6 Average tonnage per ship	9,203			
7 Pilotage inward and outward (in hours)	16			
8 Berth hours				
(1) Working hours of vessels left	1,053			
(2) Idling hours at berth	2,869			
(3) Total No. of berth hours spent by ships	3,922			
9 Average output per berth hours	21			
10 Average output per working hours by vessels	79			
11 Average time taken to handle 1,000 tonnes of cargo	47			

Table-4.1.13 Ship Performance (Steel scrap)

Type of vessels category wise	84/85	85/86	86/87	87/88
(Steel scrap)				
1 Total No. of vessels left	4	5	5	5
2 Total No. of vessels waiting at anchorage	4	4	3	4
3 Pre-berthing waiting hrs.				
(1) For want of berth	512	684	216	625
(2) Other reasons				
4 Average pre-berthing wait	128	137	43	125
5 Total tonnage handled in tonnes	58,642	80,899	120,278	90,075
6 Average tonnage per ship	14,660	16,180	24,056	18,015
7 Pilotage inward and outward (in hours)	18	10	15	9
8 Berth hours				
(1) Working hours of vessels left	1,403	2,088	2,541	2,184
(2) Idling hours at berth	1,922	3,444	3,080	2,617
(3) Total No. of berth hours spent by ships	3,325	5,532	5,621	4,801
9 Average output per berth hours	18	15	21	19
10 Average output per working hours by vessels	42	39	47	41
11 Average time taken to handle 1,000 tonnes of cargo	57	68	47	53

4.1.3 Liquid bulk ships

The ship performance of dry bulk ships is shown in the following table.

Table-4.1.14 Ship Performance of Liquid Bulk Ships

Description	84/85	85/86	86/87	87/88
1. No. of ships	76	81	107	105
2. Total cargo handled ('000 Tonnes)	480	476	647	650
3. Avg. output per ship day (Tonnes)	5,596	5,409	6,072	6,000
4. Avg. pre-berthing time	0.23	0.10	0.38	0.45
5. Avg. stay at berth	1.12	1.08	1.00	1.03
6. Avg. working time	0.70	0.72	0.63	0.67
7. Avg. non-working time	0.42	0.36	0.37	0.36
8. Working/stay time ratio	0.63	0.67	0.63	0.65
9. Avg. output handled per effective hour (Tonnes)	373	336	399	385

Ship performance by each commodity is listed below:

Table-4.1.15 Ship Performance (Liquid ammonia & Phosphoric Acid)

Type of vessels category wise	84/85	85/86	86/87	87/88
(Liquid ammonia & Phosphoric Acid)				
1 Total No. of vessels left	2	4	15	12
2 Total No. of vessels waiting at anchorage	-	-	1	4
3 Pre-berthing waiting hrs.	-	-	15	27
(1) For want of berth				
(2) Other reasons				
4 Average pre-berthing wait	-	-	1	2
5 Total tonnage handled in tonnes	16,378	17,204	57,018	79,420
6 Average tonnage per ship	5,784	4,301	3,801	1,023
7 Pilotage inward and outward (in hours)	10	7	50	20
8 Berth hours				
(1) Working hours of vessels left	133	43	119	121
(2) Idling hours at berth	62	39	116	114
(3) Total No. of berth hours spent by ships	195	82	235	235
9 Average output per berth hours	59	210	243	337
10 Average output per working hours by vessels	87	400	479	696
11 Average time taken to handle 1,000 tonnes of cargo	17	5	4	3

Table-4.1.16 Ship Performance (P.O.L.)

Type of vessels by category	84/85	85/86	86/87	87/88
(P.O.L.)				
1 Total No. of vessels left	71	68	84	76
2 Total No. of vessels waiting at anchorage	20	10	14	19
3 Pre-berthing waiting hrs.				
(1) For want of berth	416	137	957	331
(2) Other reasons				309
4 Average pre-berthing wait	6	2	11	8
5 Total tonnage handled in tonnes	436,637	411,772	533,435	455,025
6 Average tonnage per ship	6,150	6,055	6,350	5,987
7 Pilotage inward and outward (in hours)	214	154	300	130
8 Berth hours				
(1) Working hours of vessels left	985	1,104	1,271	1,072
(2) Idling hours at berth	626	570	765	665
(3) Total No. of berth hours spent by ships	1,611	1,674	2,036	1,737
9 Average output per berth hours	271	246	262	262
10 Average output per working hours by vessels	443	372	420	424
11 Average time taken to handle 1,000 tonnes of cargo	4	4	4	4

Table-4.1.17 Ship Performance (Edible Oil)

Type of vessels category wise	84/85	85/86	86/87	87/88
(Edible oil)				
1 Total No. of vessels left	3	9	8	17
2 Total No. of vessels waiting at anchorage	1	2	1	8
3 Pre-berthing waiting hrs.				
(1) For want of berth	15	28	9	139
(2) Other reasons				323
4 Average pre-berthing wait	5	3	1	27
5 Total tonnage handled in tonnes	27,205	47,218	56,545	115,612
6 Average tonnage per ship	9,068	5,246	7,068	6,800
7 Pilotage inward and outward (in hours)	22	20	20	30
8 Berth hours				
(1) Working hours of vessels left	166	270	230	492
(2) Idling hours at berth	87	87	56	128
(3) Total No. of berth hours spent by ships	253	357	286	620
9 Average output per berth hours	108	132	198	186
10 Average output per working hours by vessels	164	175	246	235
11 Average time taken to handle 1,000 tonnes of cargo	9	8	5	5

4.2 Comparison of Performance of Ships Among Major Ports

The performance of ships by ship type among major ports in 1986/87 is compared based on the following three indicators:

A. Average output per effective working hour
This indicator shows the cargo handling efficiency at the ship face during net working hours per ship. The non-working time at the berth, which reduces the output, is excluded.

B. Average non-working time at berth
This indicator shows the importance of factors limiting cargo-handling operations at ship face, taking into account that some portion of this time is unavoidable from the viewpoint of ship maneuvering. This indicator is not influenced by ship size or parcel size.

C. Average pre-berthing waiting time
This indicates the importance of factors such as the non-availability of suitable berths in the port.

4.2.1 Break bulk ships

The table below shows the performance of break bulk ships in ports:

Table-4.2.1 Comparison of Ship Performance (Break bulk)

Port	Indicator A	Indicator B	Indicator C
New Mangalore	46 tonnes	3.58	1.36
Calcutta	24	4.64	0.73
Haldia	39	3.87	2.85
Bombay	38	2.90	0.27
Madras	56	2.28	0.47
Cochin	34	2.43	0.83
Visag	50	2.17	0.67
Mormugao	30	3.07	2.28
Paradip	25	1.96	1.45
Tuticorin	42	2.00	0.17

4.2.2 Dry bulk ships (Mechanized operation)

The table below shows the performance of dry bulk ships operated mechanically:

Table-4.2.2 Comparison of Ship Performance (Dry-bulk Mechanized)

Port	Indicator A	Indicator B	Indicator
New Mangalore	1,243 tonnes	0.87	5.16
Haldia	610	3.03	1.33
Madras	3,480	1.24	0.98
Visag	1,694	3.13	1.81
Mormugao	821	0.86	3.75
Paradip	1,447	2.20	4.82
Tuticorin	433	0.43	0.71

4.2.3 Dry bulk ships (Conventional operation)

The table below shows the performance of dry bulk ships operated conventionally.

Table-4.2.3 Comparison of Ship Performance (Dry bulk Conventional)

Port	Indicator A	Indicator B	Indicator C
New Mangalore	49 tonnes	18.5	3.94
Calcutta	32	5.04	0.97
Haldia	113	1.98	2.76
Bombay	63	3.47	2.30
Madras	89	5.26	1.31
Cochin	51	13.58	3.47
Visag	56	3.67	1.69
Mormugao	93	4.46	0.54
Paradip	131	1.74	2.01
Tuticorin	81	1.30	0.20

4.2.4 **Liquid bulk ships**

The table below shows the performance of liquid bulk ships:

Table-4.2.4 Comparion of Ship Performance (Liquid Bulk)

Port	Indicator A	Indicator B	Indicator C
New Mangalore	375 tonnes	0.37	0.26
Calcutta	150	1.11	0.56
Haldia	913	0.55	1.10
Bombay	789	0.87	0.82
Madras	1,065	0.50	1.47
Cochin	919	0.50	0.69
Visag	750	0.55	1.03
Mormugao	310	0.55	1.28
Paradip	410	N.A	0.44
Tuticorin	358	0.48	0.29

4.3 Accounts of the port

4.3.1 Receipts

The total operating income of the Trust in 1987-88 was Rs. 1964.38 lakhs. Financial and miscellaneous income was Rs. 119.04 lakhs.

A table showing the position of operating income for 1983-84, 1984-85, 1985-86, 1986-87 and 1987-88 is given below:

Table-4.3.1 Income of NMPT

(lanks)

	1983-84	1984-85	1985-86	1986-87	1987-88
Operating income	837.68	1,067.2	1,313.78	1,790.41	1,964.38
Financial and Miscellaneous	97.46	222.48	272.09	670.38	645.40
Total					

Tables listed below shows the breakdown of operating income.

Table-4.3.2 Operating Income

('000 Rs)

	83/84	84/85	85/86	86/87	87/88
Operating Income (Total)	83,768	106,720	131,378	179,041	196,438
1. Cargo handling & Storage charges	53,219	66,034	78,393	110,644	121,138
(1) Handling and storage charges on General cargo	19,292	21,747	18,218	21,080	25,202
(2) Handling and storage receipt on Ore					
(3) Storage of goods in Warehouses and open area	22,550	28,978	42,177	-	-
(4) Cranage	2,451	1,962	1,450	1,192	1,484
(5) Petroleum oil and Lubricants handling charges	8,167	12,116	14,427	18,602	15,577
(6) Demurrage on Gen. cargo	141	367	965	541	803
(7) Miscellaneous Income	618	864	1,156	1,118	1,234
2. Port & Dock charges (Including Pilotage fees)	17,215	24,784	35,026	44,813	48,669
(1) Towage and Mooring fees	3,494	4,786	5,729	7,364	8,172
(2) Dock dues and Berth hire	5,393	7,787	10,839	11,357	12,968
(3) Pilotage	4,227	7,210	11,730	16,952	18,255
(4) Port dues	2,807	3,462	5,148	7,173	7,871
(5) Water supply to shipping	1,245	1,492	1,538	1,861	1,387
(6) Salvage and Divers fees	1	-	2	-	-
(7) Miscellaneous income	48	47	40	106	16
3. Railway earnings		289	236	384	287
(1) Railway earnings	170	289	236	384	287
(2) Wharfage and Demurrage					
(3) Miscellaneous income					
4. Estate Rentals	13,165	15,613	17,723	23,200	26,344
(1) Rent from Buildings etc.	13,112	15,563	17,073	22,646	25,063
(2) Miscellaneous	53	50	650	554	1,281

4.3.2 Expenditure

The operating expenditure in 1987-88 was Rs. 1318.98 lakhs against Rs. 1120.03 lakhs during 1986-87. The financial and miscellaneous expenditure has increased to Rs. 476.18 lakhs as against Rs 470.87 lakhs during 1986-87. This is mainly due to increased interest on loans from Government of India and Bombay Port Trust.

A table showing the operating expenditure for 1983-84,1984-85,1985-86,1986-87 and 1987-88 is given below:

Table-4.3.3 Expenditure of N.M.P.T

(lakhs)

	1983-84	1984-85	1985-86	1986-87	1987-88
Operating income	678.70	844.72	1,041.69	1,120.03	1,318.98
Financial and Miscellaneous	129.04	178.57	275.24	470.87	476.18
Total	807.74	1,023.29	1,316.93	1,590.90	1,795.16

Tables described below shows breakdown of type of expenditure.

Table-4.3.4(1) Operating Expenditure

(1000 Rs)

	83/84	84/85	85/86	86/87	87/88
Operating Expenditure (Total)	67,870	84,472	104,167	112,003	131,899
1. Cargo handling and Storage	9,131	10,868	13,398	14,268	15,638
(1) Handling and storage of Gen. cargo at Sheds and Wharves	2,421	2,935	3,328	3,267	3,201
(2) Ore berth and stacking yards	38	32	26	19	43
(3) Warehousing	0	-	1		4
(4) Operation and maintenance of Wharf cranes and Crane vessels	964	1,273	1,487	1,544	1,951
(5) Handling of Petroleum Oil and Lubricants	27	65	31	38	18
(6) Expenditure on general facilities at docks	99	96	41	39	68
(7) Administration and general expenses	2,220	2,794	3,280	3,418	4,413
(8) New Minor Works	-		1	1	1
(9) Depreciation	3,362	3,673	5,203	5,942	5,939
2. Port and Dock facilities	37,672	45,268	59,416	65,094	73,984
(1) Towing, Berthing and Mooring	12,157	14,035	19,232	18,761	19,816
(2) Pilotage	432	263	1,199	1,313	1,610
(3) Drydocking expenses	0	53	-	-	-
(4) Water supply to shipping	281	289	627	501	711
(5) Firefighting	1,441	1,969	4,342	2,377	3,505
(6) Dredging and Marine survey	19,583	19,951	25,931	33,171	39,552
(7) Harbour Patrol	-	-		-	-
(8) Operation and maintenance of navigational aids	255	346	494	1,058	701
(9) Salvage and underwater repairs					
(10) Maintenance of dock and harbour walls, marine structures, etc.	1	-	4	2	1
(11) Administration and General Expenses	1,149	1,293	419	410	496
(12) New Minor Works	-	1	0		
(13) Depreciation	2,319	6,985	7,141	7,413	7,460

Table-4.3.4(2) Operating Expenditure

(1000 Rs)

	83/84	84/85	85/86	86/87	87/88
3. Railway operation	151	291	517	773	992
(1) Operation and maintenance of locomotives, wagons, etc.	-	-	-	-	-
(2) Maintenance of Permanent Way Signals and Inter-locking	-	-	-	-	-
(3) Operation, Maintenance, Administration expenses of station yards and siding	35	216	443	699	917
(4) Administration and general expenses		-	-	-	
(5) New Minor Works		1	-	-	
(6) Depreciation	116	74	74	74	74
4. Rentable lands and buildings	2,087	2,221	3,739	3,321	3,663
(1) Estate Maintenance	1,239	1,608	1,954	1,439	1,645
(2) New Minor Works	0	26	30	-	6
(3) Depreciation	848	587	1,755	1,882	2,012
5. Management and General Administration	18,829	25,824	27,097	28,547	37,622
(1) Management and Secretarial expenses	3,245	3,446	4,129	3,395	3,843
(2) Port Security	1,657	3,457	2,978	3,616	4,811
(3) Labour and Welfare expenses	61	337	605	554	820
(4) Medical Expenses	1,591	1,614	1,920	2,242	2,964
(5) Storekeeping	206	325	406	486	577
(6) Accounting & Auditing	1,731	1,872	2,383	2,547	3,327
(7) Expenditure on head office building, telephones, etc.	909	839	984	809	1,797
(8) New Minor Works	-	-	-	-	-
(9) Depreciation	326	1,253	344	346	346
(10) Engineering and Workshop	9,073	12,636	13,232	14,490	19,096
(11) Administration & Overheads	-				
(12) Sundry expenses	31	45	116	62	41

4.3.3 Working results

The net revenue surplus in 1987-88 was Rs. 288.26 lakhs. After contributing to the Employees Welfare Fund of the Port Trust and Rs. 75.75 lakhs towards repayment of government loans, the net working result of the Port stood at Rs. 212.21 lakhs, which was set aside as a replacement reserve.

4.3.4 Capital expenditure

The capital expenditure during 1987-88 on Plan works was Rs. 402.65 lakhs and Rs. 38.38 lakhs on nonplan works. The entire expenditure was met out of the capital assets replacement reserve fund and by a withdrawal from the depreciation fund.

4.3.5 Profits and losses

The table below shows the Profits and Losses of N.M.P.T:

Table-4.3.5 Profit & Loss (1983/84 - 1987/88)

	83/84	84/85	85/86	87/88	88/89
Operating Income	83,768	106,720	131,378	179,041	196,438
Operating Expenditure	67,870	84,472	104,169	112,003	131,898
Operating Surplus(+) Deficit(-)	15,898	22,248	27,209	67,038	64,540
(+) Financial & Misc. Income	9,746	13,381	9,728	12,494	11,904
Balance	25,644	35,629	36,937	79,532	76,544
(-) Financial & Misc. Expenditure	12,904	17,857	27,524	47,087	47,618
Balance	12,740	17,772	9,413	32,445	28,826
(+) Amount withdrawn from Reserves	-	-	-	-	-
Balance	12,740	17,772	9,413	32,445	28,826
(+) Transfer to Funds Debt charges etc.	125	125	125	2,520	7,605
Net Surplus (+) Deficit (-)	12,615	17,647	9,288	29,925	21,221

5. PRODUCTION AND EXPORT OF IRON ORE AT KUDREMUKH

5.1 Present Situation of the Facilities

Kudremukh Iron Ore Company Limited (KIOCL) has mining, pelletizing and loading facilities in and near New Mangalore Port to export iron ore to Japan, Yugoslavia, Hungary, Bahrain, etc.

5.1.1 Mining

The Kudremukh iron ore deposits are located 110km east of Mangalore, in Chickmagalur district, Karnataka. The deposits occur as banded magnetite quartzite with an average thickness of iron formation extending up to 100 meters. The ore now mined has an average iron content of 38%. The mine has production potential of 22.6 million tonnes of crude ore per year. The deposits currently mined can possibly continue to supply iron ore for twenty years. After the present deposits run out, next deposits will be available with a marginal cost.

5.1.2 Production Process

The mined crude ore is crushed and ground. Then, the ore is transported to the magnetic and spiral separator to be concentrated to 67% iron. The concentrate is reground in ball mills, and pumped through a 67km long slurry pipeline to New Mangalore Port where the slurry is filtered to produce filter cake with about 8% moisture. Then the concentrate is conveyed to the stockyard.

5.1.3 Shiploading

From the stockyard, concentrate is picked up by reclaimers and loaded and transported on conveyer directly to the shiploader installed at the berth for export, or to the pelletization plant and conveyed as pellets to shiploader, then loaded onto a ship. The shiploader and the berth can accommodate iron ore carriers up to 60,000 DWT.

Details of loading facilities are depicted in Figure-5.1.1 and also explained in 2.3 and 2.4.

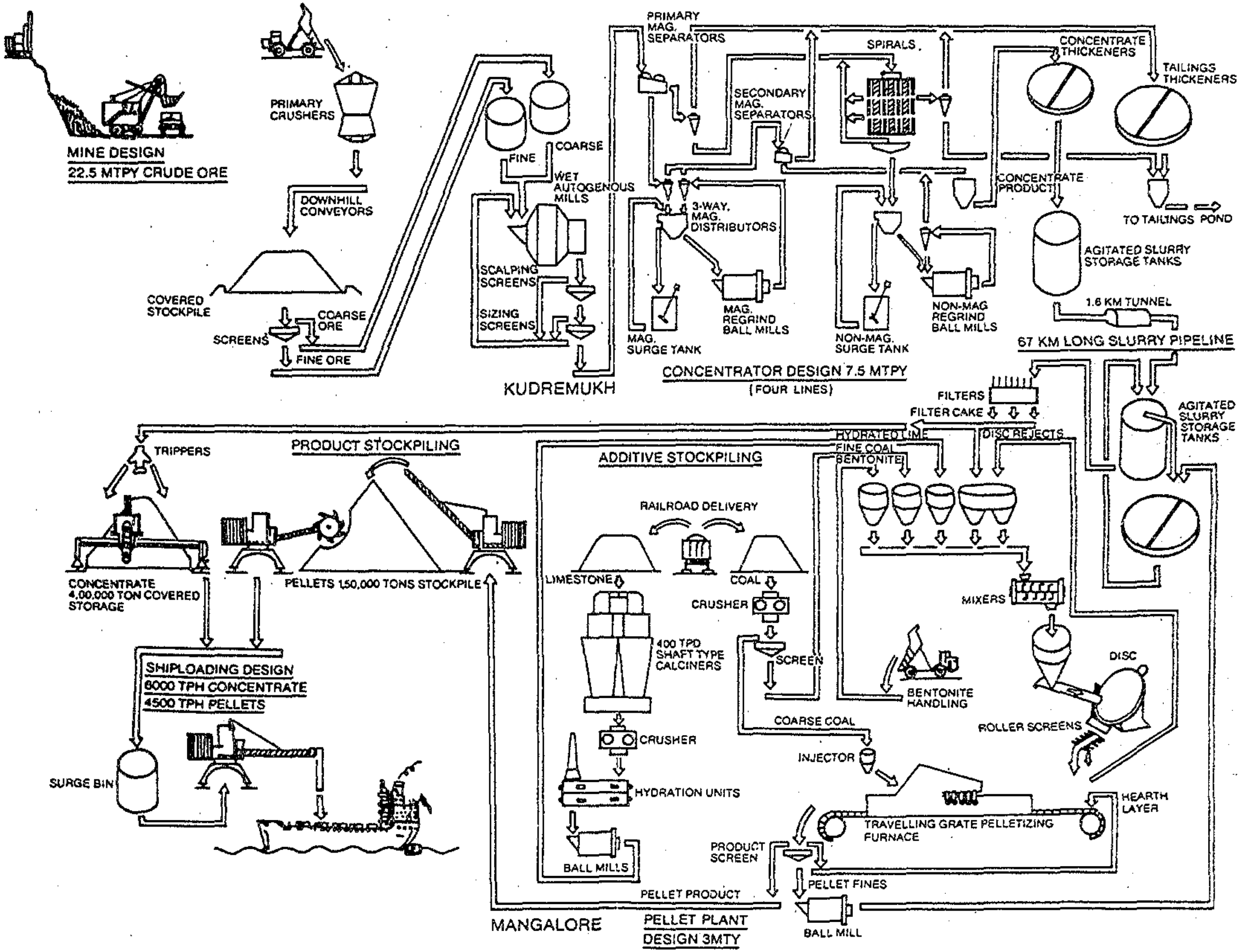


Figure-5.1.1 Iron Ore Production and Shipping at Kudremukh

5.2 Present and Future Production of Iron Ore

The existing mine has an iron ore production capacity of 7.5 million tonnes per annum. In 1988-89, 5 million tonnes of iron ore was produced and exported by KIOCL and the annual throughput of iron ore has increased year by year. According to KIOCL, the actual annual production level will reach 7.5 million tonnes commencing form 1991/92 onwards and will then reach 10 million tonnes from 1994 onwards. Moreover, KIOCL plans to increase pellet production to 3.0 million tonnes per annum commencing from 1991/92 onwards and then increase to 6.0 million tonnes per annum after expansion when their annual iron ore production reaches to 10 million tonnes.

6. MAJOR PROJECTS LIKELY TO AFFECT TRAFFIC AT NEW MANGALORE PORT

6.1 Oil Refinery Plant Project

Mangalore Refinery and Petrochemicals Ltd. has proposed a oil refinery plant near New Mangalore Port. Following is an outline of the plant and seaborne traffic generated by the plant.

6.1.1 Outline of the Project

(1) Location

The project site is located 20 km north of Mangalore City and 10 km north of New Mangalore Port. National highway NH-17 can be reached in 5 km and water is available from the Netravathi River (Figure-6.1.1).

(2) Area

The project area occupies approximately 1,700 acres (690ha).

(3) Facilities

The plant complex will consist of oil refinery and petrochemical plants. Pipelines will be connected with New Mangalore Port for crude oil and P.O.L. products and with the seashore for effluent disposal (Figure-6.1.2).

(4) Capacity

3 million and 6 million tonnes of crude oil will be processed in stage-I and stage-II, respectively.

(5) Products

The following will be produced as finished products:

- Petroleum Fuel Products
  LPG, Motor Spirit (MS), Kero/ATF, High Speed Diesel (HSD), Furnace Oil (FO), and Bitumen
- Petrochemical Products
  Ethylene, Propylene and Butadiene

Moreover, naptha, an intermediate product, will be supplied to Mangalore Chemicals and Fertilizers Limited as material for fertilizer.

The quantity of each product will be as follows:

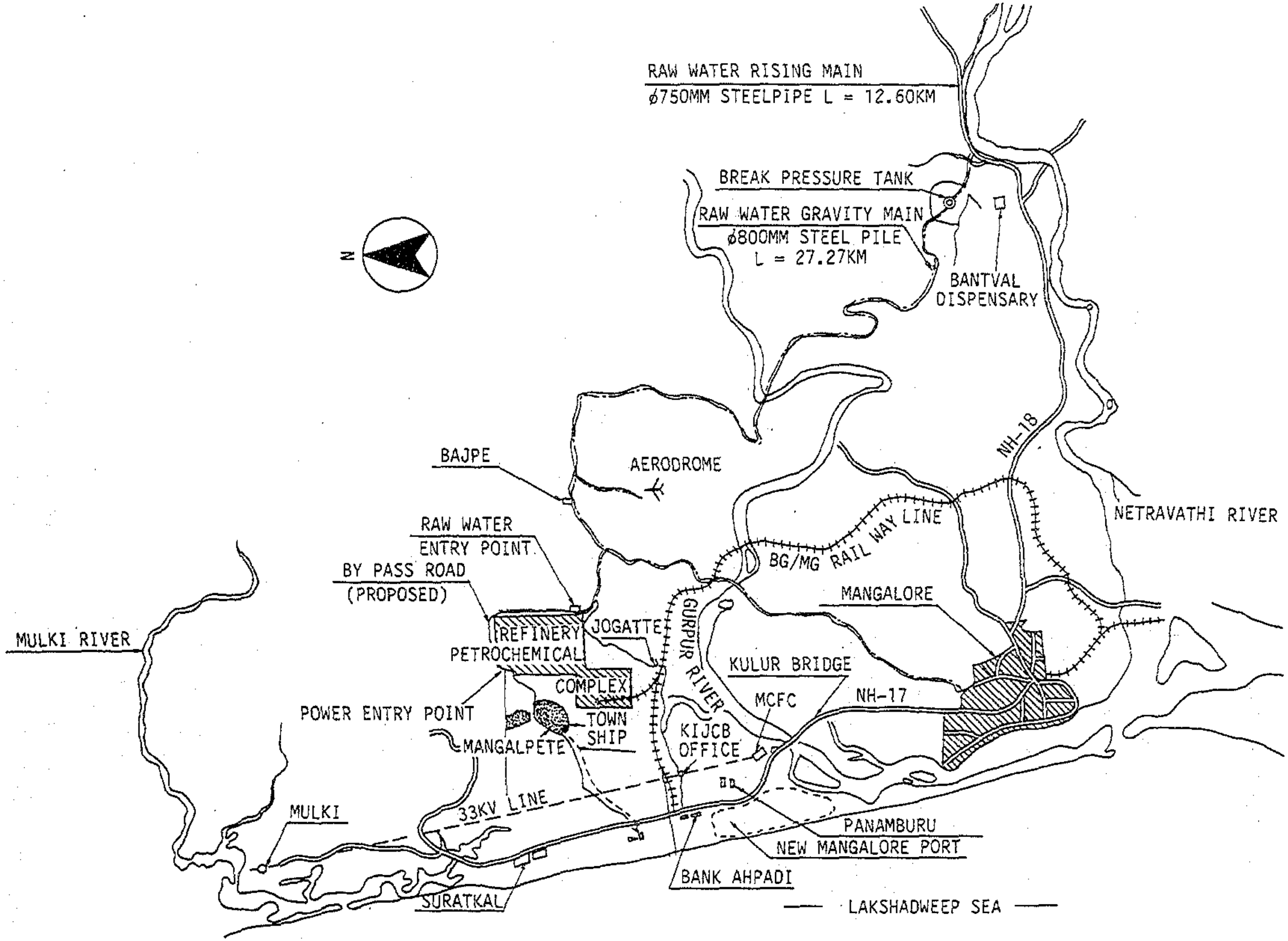


Figure-6.1.1 Location of Proposed Oil Refinery

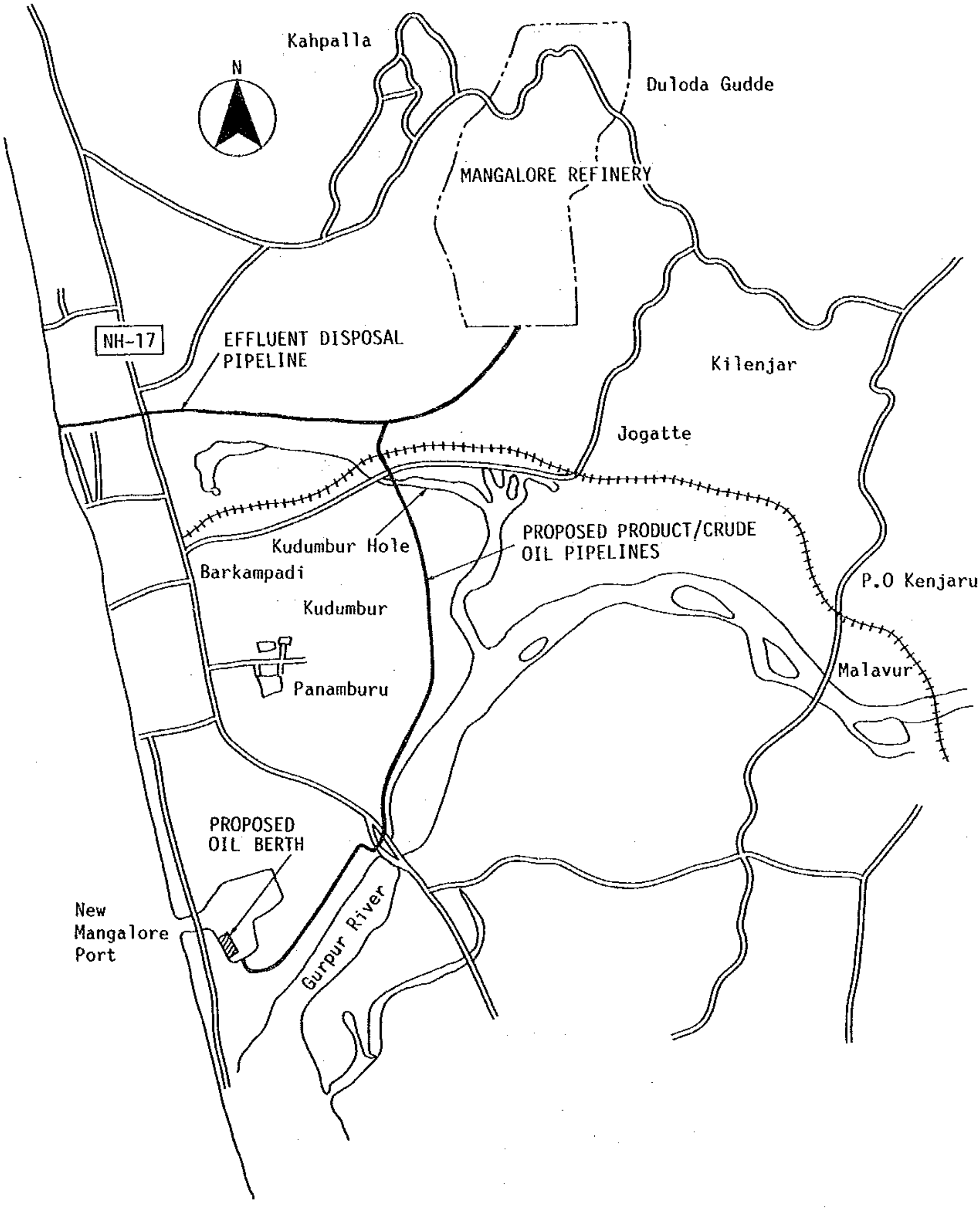


Figure-6.1.2 Pipelines of the Oil Refinery

Table-6.1.1 Products from the Oil Refinery

	Stage-I 1994-1995	Stage-II 1999-2000
INPUT crude oil	3,000	6,000
OUTPUT		
MS	278	668
Kero/ATF	1,008	1,585
HSD	890	1,925
FO	192	355
LPG	NA	NA
Bitumen	NA	NA
Ethylene	NA	NA
Propylene	NA	NA
Butadiene	NA	NA
Naptha	NA	NA

6.1.2 Seaborne traffic

Several products, such as MS, Kero/ATF, HSD and FO, will be exported through New Mangalore Port as follows. They will also be supplied to Mangalore Chemicals & Fertilizers Ltd (160,000t naptha), to the Indian Oil Corporation and for local distribution.

Table-6.1.2 Export of P.O.L. through New Mangalore Port

Year	1994-95	1999-2000
MS	179	505
Kero/ATF	843	1,348
HSD	457	1,075
FO	87	232
TOTAL	1,566	3,160

As mentioned before, crude oil will be imported from Bomby High and Gulf countries. Therefore, the plant will generate the following seaborne traffic through New Mangalore Port.

Table-6.1.3 Seaborne Traffic from/to the Oil Refinery

Year	1994-1995	1999-2000
EXPORT P.O.L.	1,566	3,160
IMPORT Crude Oil	3,000	6,000
TOTAL	4,566	9,160

6.2 Coal Thermal Power Plant Project

National Thermal Power Corporation Ltd. (NTPC) has proposed a coal thermal power plant project named the Super Thermal Power Plant Project Outline and seaborne traffic generated are as follows:

6.2.1 Outline of the Project

(1) Location

The proposed site is bound by Nadsal, Phabimar, Nandikur and Hejmady villages of Udupi Taluk in Kanada district and is located on the north bank of Mulki River, about 35km north of New Mangalore Port(Figure-6.2.1). National highway NH-17 runs along the western side of the plant area at a distance of about 1 km. Nandikur is located 35 km from Mangalore Railway Station.

(2) Land Requirement

The project area is 2452.8 acres (990ha).

(3) Capacity

The generator with capacity of 2,420 MW will be installed in the ultimate stage.

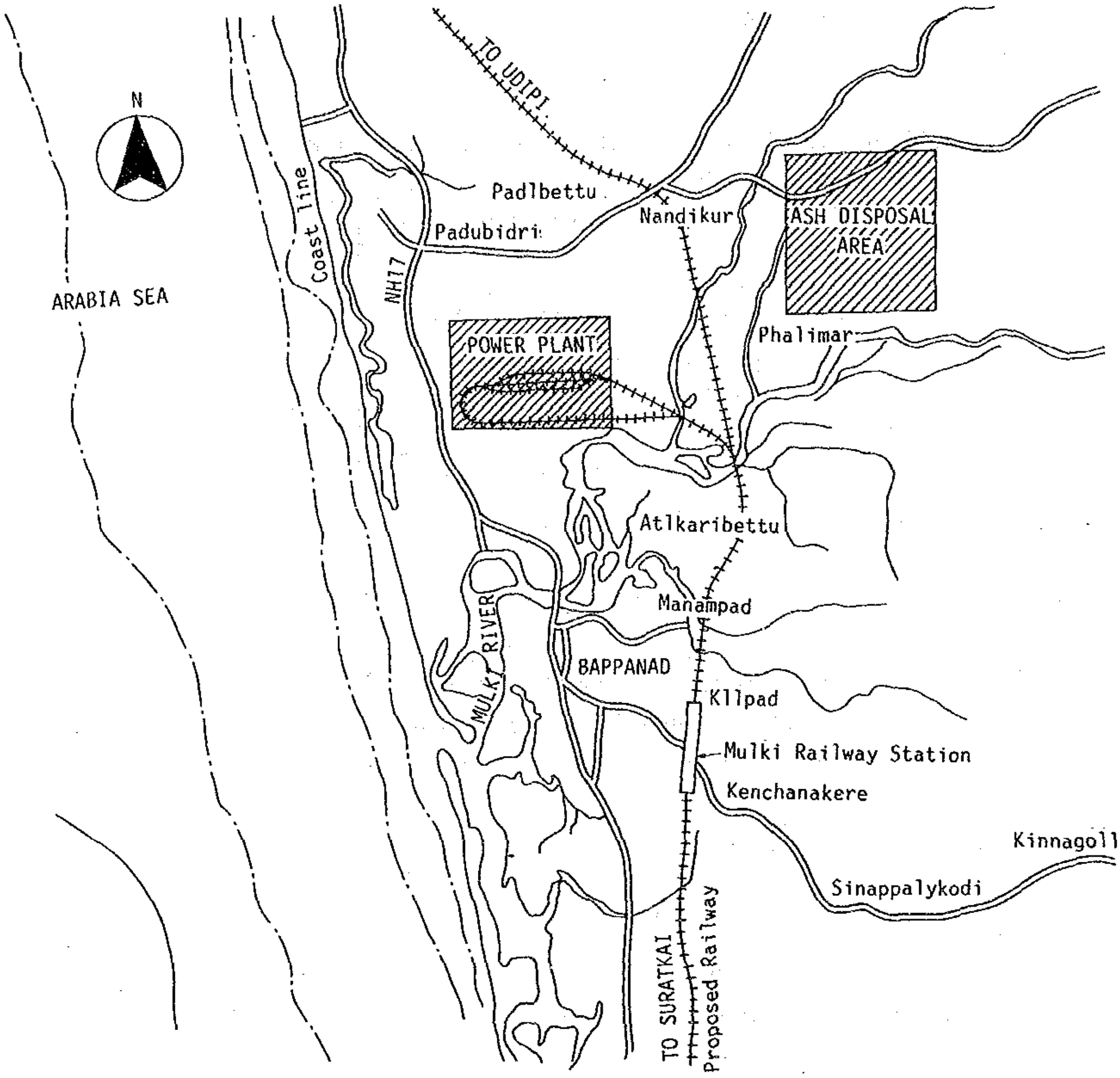


Figure-6.2.1 Location of Proposed Coal Thermal Power Plant

(4) Fuel

The plants will be operated using coal as the main fuel, and oil and gas as supplementary fuels.

Coal requirements at the ultimate stage will be 12.12 million ton per annum.

(5) Coal Movement

It is proposed that the coal be transported from Talcher Coal Field to Paradip Port by railway. The coal will then be transported by coastal shipping from Paradip port to New Mangalore Port. From New Mangalore Port, it is proposed that the coal be transported to the site by the proposed Mangalore-Udupi Railway Line.

6.2.2 Seaborne traffic

All coal to be consumed for the plant could be transported through New Mangalore Port and the proposed railway from New Mangalore Port to Udupi.

As shown in Chapter 7, three coal berths could be located in the western dock which will constructed next to the existing eastern dock. So, seaborne traffic through New Mangalore Port can be estimated as shown in Table-6.2.1.

Table 6.2.1 Seaborne Traffic to the Coal Thermal Power Plant

'000 ton

	1994-95	1999-2000	2004-05
IMPORT			
Coal	450	6,240	12,120

7. REVIEW OF THE MASTER PLAN

7.1 Demand Forecast

Target Year of existing Master Plan is 2000. Here, the master plan was reviewed with a long-term perspective for the period up to the year 2005. The review includes "Demand Forecast" and "Review of Facilities Layout Plan".

7.1.1 Delineation of hinterland

The economic hinterland of New Mangalore Port defined by the government of Karnataka covers the districts of Dakshina Kanara, Kodagu, Hassan, Chikmagalur, Shimoga on the Western Ghats and portions of Uthara kanara in Karnataka state as its primary hinterland.

The secondary hinterland covers the districts of Tumkur, Bangalore, Mandya and Mysore of Karnataka state, Connanore district, especially Casargode taluk in Kerala. A part of the state of Andra Pradesh between the Bellary and Bangalore districts falls under the secondary hinterland category.

7.1.2 Origin and destination of principal commodities

New Mangalore Port is basically a bulk commodity port. The main bulk export commodity shipped through the port is iron ore. The share of iron ore cargo handled to total cargo handled in New Mangalore was about 90% in 1987/88 and 71% in 1988/89. Thus it can be said that cargo handling activities at New Mangalore Port are concentrated on iron ore.

(1) Origin of Iron Ore

There are vast resources on iron ore distributed throughout the state, which makes the state number four in the country in terms of the value of iron ore production (1985). Iron ore deposits occur in the Bellary-Hospete belt, Kudremukh hills, Kodochadri and Kemmonugudi in the western ghats, in Vajra, Kuderekaneve-Kavak and Lakkihalli in Chitradurga district. Bellary-Hospet iron ore is one of the richest in the world, with an average iron content of more than 65%. About 6 million tonnes of magnetic ore in Kudremukh are being mined and processed annually, and the Kudremukh iron ore project has a capacity of 7.5 million tonnes of iron ore concentrates per annum.

(2) Destination of Iron Ore

Exports of iron ore in 1988/89 are shown as follows:

Table-7.1.1 Destination of iron ore (1988/89)

(Unit: '000 tonnes)

Countries	Pellet	Concentrate	Total	Share
Japan	-	2,430	2,430	51.3
Hungary	594	-	594	12.5
Turkey	357	-	357	7.5
Yugoslavia	68	241	309	6.5
Australia	72	183	255	5.4
West Germany	176	-	176	3.7
Czechoslovakia	90	59	149	3.2
Bahrain	-	128	128	2.7
U.S.A.	109	-	109	2.3
Other	210	22	232	4.9
Total	1,676	3,063	4,739	100.0

7.1.3 Demand forecast

(1) Main Cargoes to be Forecasted

Iron ore is the main cargo handled at New Mangalore Port and has a high share of the total amount of cargo handled at New Mangalore Port as mentioned above. There are few cargoes to be forecasted independently, though granite stones, coffee (export cargo) and wood logs, P.O.L. (products) (import cargo) are important cargoes. Therefore we treat these cargoes as other cargoes when we estimate future cargo volume, except for P.O.L. (products).

P.O.L. products are imported at present but are expected to be exported in the future because there is a plan to set up an oil refinery near Mangalore. Therefore we independently estimated the demand forecast of crude oil (import cargo) and P.O.L. (products: export cargo) taking into consideration the information obtained in our interview with Mangalore

Refinery and Petrochemicals Ltd. There is also a plan by Hindustan Petroleum Corporation Limited to develop L.P.G. import and storage facilities at Mangalore. Therefore, we also independently estimated the demand forecast of L.P.G. imports.

Coal is not handled at New Mangalore Port at present. But there is a plan to install a coal based super thermal power plant near Mangalore. Karnataka state is suffering from power scarcity. In order to deal with this, the state imports power from the neighboring states. Thus coal is expected to be a major cargo of New Mangalore Port in the near future. Therefore we estimated the demand forecast of coal independently.

(2) Summary of Demand Forecast

Table-7.1.2 and Figure-7.1.1 show projected cargo volumes through New Mangalore Port for the years 1994/95 and 2004/05. High, medium and low projection levels have been set, and the medium projection has been used in formulating to make the plan of New Mangalore Port based on the related materials in the following section.

Table-7.1.2 Summary of Demand Forecast

(Unit: Thousand Tonnes)

		1988/89 (Actual)	1994/95	2004/05
Export	Iron Ore	5,011	7,500	10,000
	POL(Products)	–	1,570	3,160
	Granite Stone	386	386	386
	Other Cargoes	120	184	274
	Sub Total	5,517	9,640	13,820
Import	Crude Oil	–	3,000	6,000
	POL(Products)	571	–	–
	L.P.G	–	200	500
	Coal	–	450	12,120
	Other Cargoes	996	1,320	2,530
	Sub Total	1,567	4,970	21,150
Total		7,084	14,610	34,970

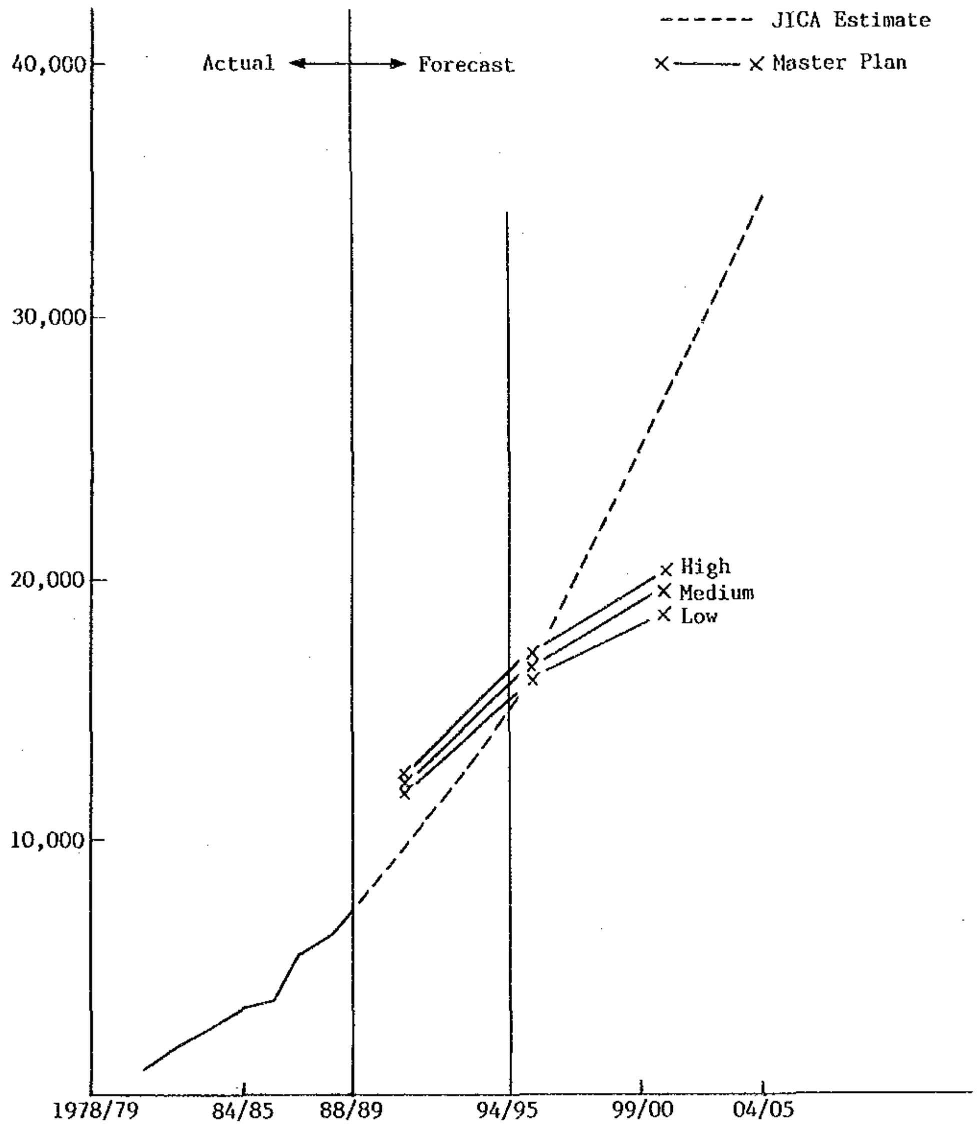


Figure-7.1.1 Demand Forecast

(3) Method of Forecast

i) Export

① Iron Ore

(Medium Case)

It is assumed that the utilization rate of the present iron ore cargo handling system will reach to almost 100% in 1994/95 from 70% in 1988/89. We estimate 7,500 thousand tonnes of iron ore cargo will be handled in 1994/95.

Due to improvement of the production system of iron ore, the cargo will be handled at a level of 10,000 thousand tonnes after 1995. Thus we assume that the cargo volume of iron ore will level off up to 2004/05: 10,000 thousand tonnes.

② P.O.L.(Products)

There is a plan to set up an oil refinery near Mangalore by 1994/95, with an installed processing capacity of 3 million tonnes of crude oil in Stage I and 6 million tonnes of crude oil in Stage II. The refinery produces P.O.L. products in which several products will be exported through New Mangalore Port. According to information from Mangalore Refinery and Petrochemicals Ltd., the export volume of P.O.L. products will be 1,570 thousand tonnes in 1994/95 and 3,160 thousand tonnes in 1999/2000. Therefore we have adopted an estimate of 1,570 thousand tonnes in 1994/95 and we assume that the export of P.O.L. products in 2004/05 will be on the same level as that in 1999/2000, that is, 3,160 thousand tonnes.

ii) Import

① Curde Oil

As mentioned above, the planned oil refinery will need imports of crude oil from Bombay High and Gulf Countries. Mangalore Refinery and Petrochemicals Ltd. estimates the import volumes of crude oil at 3 million tonnes in 1994/95 and 6 million tonnes in 1999/2000. Thus, we have adopted an estimate of 3 million tonnes in 1994/95 and we assume that imports of crude oil in 2004/05 will be on the same level as that in 1999/2000, that is, 6 million tonnes.

② P.O.L (Products:LPG)

Hindustan Petroleum Corporation Limited (HPCL), one of the public sector undertakings of the Government of India, has proposed to develop L.P.G. import and storage facilities at Mangalore in order to meet the projected L.P.G. short fall in the country.

L.P.G. is handled at the oil jetty of New Mangalore Port and transferred to storage tanks by a pipeline about 8km long. The proposed facilities are desinged to handle L.P.G. imports of about 200,000 tonnes/year and go up to 500,000 tonnes/year in the ultimate stage. Therefore, we have adopted an estimate of 200 thousand tonnes in 1994/95 and 500 thousand tonnes in 2004/05.

③ Coal

There is a plan to install a coal-based super thermal power plant whose capacity is 210MW x 2 for Stage I and 500MW x 4 for Stage II. According to the National Thermal Power Corporation Ltd. (a government of India enterprise), Stage I shall be commissioned by 1994/95 through New Mangalore Port, but it is not clear when stage II of the project will be commissioned. Recently the Ministry of Energy has informed us of the requirement of coal as finalised for the proposed Thermal Power Station at Mangalore as follows:

1994/95	0.45	million	tonnes
1999/2000	6.24	"	"
2004/05	12.12	"	"

We adopt the above requirement of coal as the estimate of New Mangalore Port cargo handling of coal.

④ Other Cargo

The total amount of other cargo was first estimated through correlation between the Gross National Product (GDP) and cargo volume. Records show that the annual growth rate in the hinterland of New Mangalore Port is approximately 95% of India's national GDP. According to an information, the annual growth rate of the Eighth Five Year Plan for 1990-1995 is set around 6%. Thus the annual growth rate of GDP in the hinterland will be 5.7%. We assume that the annual growth rate in the GDP will continue at the same pace up to 2004/05. Then the cargo volume of other cargo are as follows:

Table-7.1.3 Total Other Cargo Projection

Year	Total Other Cargo (thousand tonnes)
1994/95	2,100
2004/05	3,660

Then, we forecast other export cargo from the time series correlation using a 5-year moving average. The cargo volumes of other export cargoes are as follows:

Table-7.1.4 Other Cargo Projection (Export)

Year	Other Cargo (Export, thousand tonnes)
1994/95	780
2004/05	1,130

According to NMPT information, the amount of granite stone at present being exported may not increase in the future due to the Indian Government's policy and the development of Karwar Port on the west coast. Therefore, we assumed that the export of granite stone through NMP would be the same level with 1988/89 cargo handling volume. Thus exports of granite stone are 386 thousand tonnes in both 1994/95 and 2004/05. The volume of other cargo, excluding granite stone is estimated through the share of other cargo excluding granite stone are same with the share in 1988/89, that is 23.7% in 1994/95 and 2004/05.

The level of other import cargoes was estimated from total other cargo minus other export cargo (Table-7.1.4). The cargo volume of other import cargoes are as follows:

Table-7.1.5 Other Cargo Projection (Import)

Year	Other Cargo (Import, thousand tonnes)
1994/95	1,320
2004/05	2,530

⑤ LNG

According to information from the New Mangalore Port Trust, the Gas Authority of India Limited (GAIL) is examining the possibility of importing Liquified Natural Gas (LNG) and is in the process of preparing a techno-economic feasibility report.

In the information, demand for LNG is predicted as 2.9 million metric tons per year (MMTPA) in 1995 and 4.1 MMTPA in 2000. However we haven't included the LNG prediction in our demand forecast, because the above proposal for importin LNG depends on the results of the techno-economic feasibility report. However we forecast that there is a possibility of handling LNG at New Mangalore Port after 2005 in the very long term.

7.2 Review of Facility Layout

Due to an expected increase in the volume of iron ore handled and a trend toward use of larger ships, improvement of the existing berth or construction of a new iron ore berth is needed. Moreover, enlargement of the basin, the channel and the width of the channel as well as improvement of the berth itself must be carried out.

7.2.1 Iron ore berth

(1) Present Situation of the Existing Iron Ore Terminal

Approximately 4.3 and 5 million tonnes of iron ore were handled in 1987-88 and 1988-89, respectively, at the berth. This resulted in high occupancy rates at the berth of 76% and 89%, respectively, and long preberthing waiting times of 130.1 and 203.6 hours per ship in 1987-88 and 1988-89, respectively (Table-7.2.1).

Table-7.2.1 Performance of the Iron Ore Berth

Period	No. of Ships	Average Ship Size ('000DWT)	Tonnes Handled	Preberthing Waiting Hrs		Berth hrs		Berth Occup. Rate (%)	Average Handling Hours per 1000 t
				Total	per ship	Total	per ship		
1986-87	97	40	3,873	14,356	148.0	5,830	60.1	71	1.51
87-88	107	40	4,327	13,920	130.1	6,023	56.3	76	1.39
88-89	128	39	5,011	26,060	203.6	6,454	50.4	89	1.30

(2) Capacity of the Iron Ore Handling Facility

These records show that the volumes handled have almost exceeded the capacity of the berth even though the berth is used exclusively for one commodity. As mentioned above, it is proposed that the annual throughput of iron ore reach 7.5 million tonnes by 1993 and 10 million tonnes in 1999-2000. According to the export plan of Kudremukh Iron Ore Company Limited, between 3 million and 6 million tonnes of the total will be exported as pellets, which are handled at a slower loading rate than concentrate. Moreover, according to "Port Development, A Handbook for Planners in Developing Countries, " UNCTAD, recommends that the berth occupancy rate for handling break bulk cargo at one berth be 0.4 in order to minimize expensive ship time at port, and adds that it is necessary to ensure a relatively low berth occupancy for dry bulk carriers to avoid the risk of ships, having to wait for a berth. Although the current berth occupancy rate of the iron ore berth is around 0.9, 0.6 is applicable to this berth at most.

On the other hand, the loading equipment installed in the terminal behind the berth could be upgraded to have higher shiploading capacities. K.I.O.C.L. has also an upgrading plan for the equipment. Here, minor and major upgrading plans and existing and after-upgrading handling capacities can be set as follows.

Table-7.2.2 Loading Capacity of the Handling System

	Capacity of the System (t/h)	Modification
Present	6,000 / 3,500	-None
Minor Modification	7,000 / 3,500	Capacity Upgrading of Out-going Conveyor Cross Conveyor Wharf Conveyor
Major Modification	8,100 / 4,100	Additional Reclaimer for concentrate capacity upgrading of Reclaimer for pallets Out-going Conveyor Cross Conveyor Wharf Conveyor

Concentrate / Pellets

The details of the modifications are provided in Appendix-7.1.

Under conditions related to iron-ore handling at the berth shown as follows, berth occupancy rate and handling capacity can be expressed as below:

Average Ship Size : M (DWT)
Loading Factor of Ship : r
Handling Volume (Capacity) at the Berth : V (ton)

Loading Capacity of Concentrate	: L_c (t/h)
Loading Capacity of Pellets	: L_p (t/h)
Loading Efficiency	: e
Concentrate Ratio of Iron Ore	: I_c
Pellets Ratio of Iron Ore	: I_p
Docking Time of Ship	: T_d (hour)
Undocking Time of Ship	: T_{ud} (hour)
Non-operating Time while Berthign	: T_{no} (hour)
Working Days per Year	: D (day/year)
Working Hours per Day	: H (hour/day)
Berth Occupancy Rate	: b

Then, average operation time per ship, no. of calling ship, berth occupancy and berth-handling capacity can be calculated as follows:

Average Operation Time:

Concentrate Ship:

$$T_c = M * r / (L_c * e) + T_d + T_{ud} + T_{no}$$

Pellets Ship:

$$T_p = M * r / (L_p * e) + T_d + T_{ud} + T_{no}$$

No. of Calling Ship:

Concentrate Ship:

$$N_c = V * I_c / (M * r)$$

Pellets Ship:

$$N_p = V * I_p / (M * r)$$

Berth Occupancy Rate:

$$b = (T_c * N_c + T_p * N_p)/(D * H)$$

Handling Capacity:

$$V = M * r * D * H * b / (I_c * T_c + I_p * T_p)$$

Accordingly, handling capacity at the berth according to both existing and after-modification loading equipments capacities can be calculated (Table-7.2.4).

Here, conditions of calculation other than the loading equipment capacities shown in Table-7.2.3 are applied.

Table-7.2.3 Calculation Conditions for the Handling Capacity of the Iron Ore Berth

Average Ship Size	: 40,000 DWT (60,000DWT Berth), 65,000 DWT (100,000DWT Berth), 73,000 DWT (130,000DWT Berth), 88,000 DWT (150,000DWT Berth), 95,000 DWT (170,000DWT Berth)
Loading Factor of Ship	: 0.9
Loading Efficiency	: 0.7
Concentrate (Pellets) Ratio of Iron ORe	: 0.6(0.4), 0.4(0.6)
Docking Time of Ship	: 2 hours
Undoking Time of Ship	: 2 hours
Non-operating Time while Berthing	: 6 hours
Working Days per Year*	: 270 days (present), 290 days (future)
Working Hours per Day	: 20 hours
Berth Occupancy Rate	: 0.6

* Appendix-7.2

Table-7.2.4 Berth Handling Capacities

Unit: Million Ton

Max. Ship Size (Ave. Ship Size) (D W T)	Existing	Minor Modification		Major Modification
	D=270	D=270	D=290	D=290
60,000 (40,000)	5.55 5.24	5.75 5.36	6.18 5.76	6.64 6.23
100,000 (65,000)	6.79 6.34	7.10 6.51	7.62 7.00	8.34 7.71
130,000 (73,000)	7.07 6.58	7.40 6.77	7.95 7.27	8.73 8.04
150,000 (88,000)	7.49 6.95	7.86 7.16	8.45 7.69	9.34 8.56
170,000 (95,000)	7.66 7.09	8.05 7.31	8.64 7.85	9.57 8.76

D : Working Days per year

	Ratio	
	concent.	pellets
Upper	0.6	0.4
Lower	0.4	0.6

Conversely, Table-7.2.5 shows the berth occupancy rate when the berth handles iron ore of 7.5 (concentrate : 60%) or 10.0 (concentrate : 40%) M tons.

Table-7.2.5 Berth Occupancy Rate

Annual Throughput of Iron Ore	Max. Ship Size (Ave. Ship Size)	Modification			
		None D=270	Minor D=270	Minor D=290	Major D=290
7.5 million	60,000 DWT (40,000)	0.81	0.78	0.73	0.68
concentrate = 4.5 (60%)	100,000 (65,000)	0.66	0.63	0.59	0.54
pellets = 3.0 (40%)	130,000 (73,000)	0.64	0.61	0.57	0.52
	150,000 (88,000)	0.60	0.57	0.53	0.48
	170,000 (95,000)	0.59	0.56	0.52	0.47
10.0 million	60,000 (40,000)	1.14	1.12	1.04	0.96
concentrate = 4.0 (40%)	100,000 (65,000)	0.95	0.92	0.86	0.78
pellets = 6.0 (60%)	130,000 (73,000)	0.91	0.89	0.83	0.75
	150,000 (88,000)	0.86	0.84	0.78	0.70
	170,000 (95,000)	0.85	0.82	0.76	0.69

It can be concluded that:

1) without berth improvement, the berth could handle
   a. 5.2 to 5.6 M tons without modification of the equipment, (this is the maximum handling capacity of the berth under the present conditions)
   b. 5.4 to 5.8 M tons with minor modifications at present and 5.8 to 6.2 M tons with minor modifications and additional working days which could be achieved in the future,
   c. 6.2 to 6.6 M tons with major modifications and additional working days,

2) and if the berth were upgraded up to 100,000 DWT, it could handle

   a. 7.0 to 7.6 M tons with minor modifications and additional working days which could be achieved in the future,

   b. 7.7 to 8.3 M tons with major modification and additional working days (moreover, under the same conditions, except that the berth occupancy rate is relaxed to 0.7, 9.0 M tons could be handled even if the pellets ratio is 0.6),

3) in order to handle 7.5 M tons (pellets ratio = 0.4), the berth should be upgraded up to at least 100,000 DWT, and additional working days and at least minor modifications of the equipment will be needed,

4) even if the berth is upgraded up to 170,000 DWT, major modifications of the equipment is done and annual working days is extended to 290 days, the berth can handle 8.8 M tons per annum (pellets ratio = 0.6) at most,

5) in order to handle 10.0 M tons, an additional iron ore berth will be required.

(3) Transshipment System

Usually, a berth has enough water depth to accept ships with full draught. This system sometimes requires great expenditure for dredging great amount of soil.

A transshipment system loading at a berth followed by loading from transshipper anchored offshore. Transshipper, a special offshore loading ship has an advantage in cases where the berth does not have enough water depth.

In a transshipment loading system,

-first, iron ore carriers are loaded at the berth as much as the water depth allows and leave the berth to head out to anchor offshore,

-second, the transshiper receives iron ore from the berth and goes out and moors alongside the anchoring carriers to fill iron ore up to the carrier's full capacity.

The vessel size of transshipers is usually between 20,000 and 30,000 DWT. The ship of 20,000 DWT (second-hand) with handling equipment costs about 2,500 million Yen (around 28 Crore Rs). The details are shown in Appendix-7.3.

Here, assuming that a 20,000 DWT transshiper is used and that maximum size of iron ore carriers calling at the berth is 170,000 DWT, berth occupancy would be 0.55 and 0.80 in case of annual throughputs of 7.5 M and 10.0 M, respectively, on condition that the berth is not deepened at all but extended to accommodate 170,000 DWT iron ore carriers. The details are shown in Appendix-7.4.

This results show that the transshiper system can handle 7.5 millon tons per annum but cannot handle 10.0 millon tons per annum.

Costs of the transshiper system consist of :

Procurement of transshiper with handling gears	:	28 crore Rs.,
Extension of the existing berth	:	8 crore Rs.,
Installation of shiploader at the berth for 170,000 DWT class vessel	:	16 crore Rs.,
T O T A L		52 crore Rs.,

also, crew, fuel and maintenance cost are needed.

Another point to be resolved is setting aside an anchoring area for the transshiper in the basin while the iron ore berth is occupied. If the area should be newly prepared, more money will be needed.

Consequently, this system should not be applied because of the high berth occupancy in the case of an annual throughput of 10.0 million tonnes and because the system is not economically feasibile.

(4) Enlargement Scale of the Berth

Therefore, it would seem difficult to handle 7.5 million tonnes of iron ore at the present berth, which can accommodate 60,000 DWT vessels at most. Moreover, other Indian ports handling iron ore have terminals which can accommodate 100,000 DWT or larger vessels.

Therefore, the berth must be enlarged to accept at least 100,000 DWT vessels, and improvement of the handling equipment must be carried out in order to handle 7,500,000 tonnes per year without congestion and to maintain an appropriate occupancy rate. Moreover, Table-7.2.5 show that 10,000,000 tonnes cannot be loaded at one berth even if a 100,000 DWT or larger carrier is acceptable.

(5) Vessel Sizes

(Present Stock in the World)

Figure-7.2.1 shows the percentage of iron ore carriers by DWT class. This shows that about 70% and 36% of iron ore carriers currently operating are large size ships of 100,000 DWT or more and 150,000 DWT or more, respectively. This distribution depends on the area in the world where carriers are operated. Table-7.2.6 shows the percentage of iron ore carriers by area as well as by vessels size. It can be said that more than 50% of carriers operated in Japan, on the Pacific coast of South America and in Other Africa are vessels of 150,000 DWT or more and that in West Africa, Asia, Other Europe, USA and other areas, more than 50% of carriers have less than 100,000 DWT.

Figure-7.2.2 depicts the year of launch for ore carriers in the world by DWT class and shows that many new (built after 1981) vessels can be found in the 40,000 - 60,000 DWT class and the 60,000 - 80,000 DWT class.

(Size of Ships calling at New Mangalore Port)

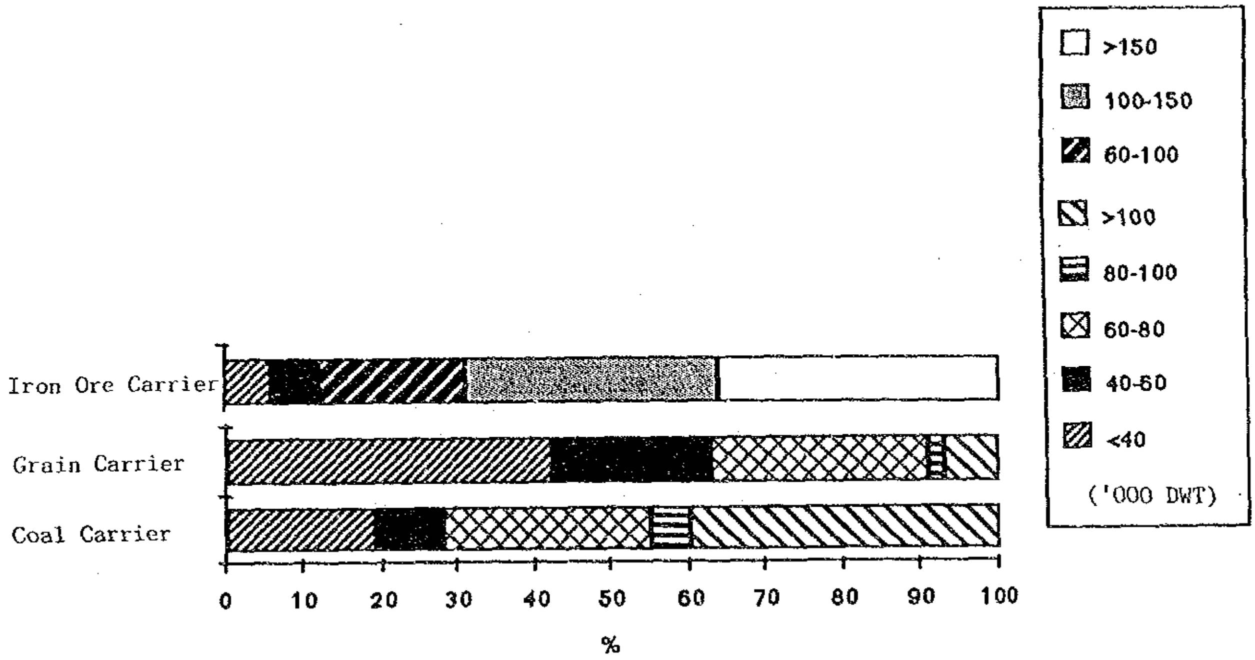
In 1988-89, the sizes of ore carriers which called at the iron ore berth of New Mangalore Port are listed by destination in Table-7.2.7. According to this figure, almost all vessels of 60,000 DWT or more carry iron ore concentrate to Japan, and vessels that carried pellets are relatively small.

(Japanese Ore Carries)

According to the record of ships that docked at the iron ore terminal of New Mangalore, almost all large carriers of iron ore concentrate were Japanese. Figure-7.2.3 shows the number of Japanese vessels by DWT class and indicates that the predominant classes are 140,000-150,000DWT, 170,000-180,000DWT and those over 200,000DWT.

(Iron Ore Loading Ports)

The capacities of the world's main iron ore loading ports are shown in Table-7.2.8, and it can be said that most of them have capacities above 100,000 DWT. Details of the loading ports in India are shown in Table-7.2.9, showing that almost all these ports have or plan to have capacities above 100,000 DWT.



(Fearnleys [World Bulk Trades])

Figure-7.2.1 Ship Size Distribution of Dry Bulk Carrier

Table-7.2.6 Ship Size Distribution by Area

1987.

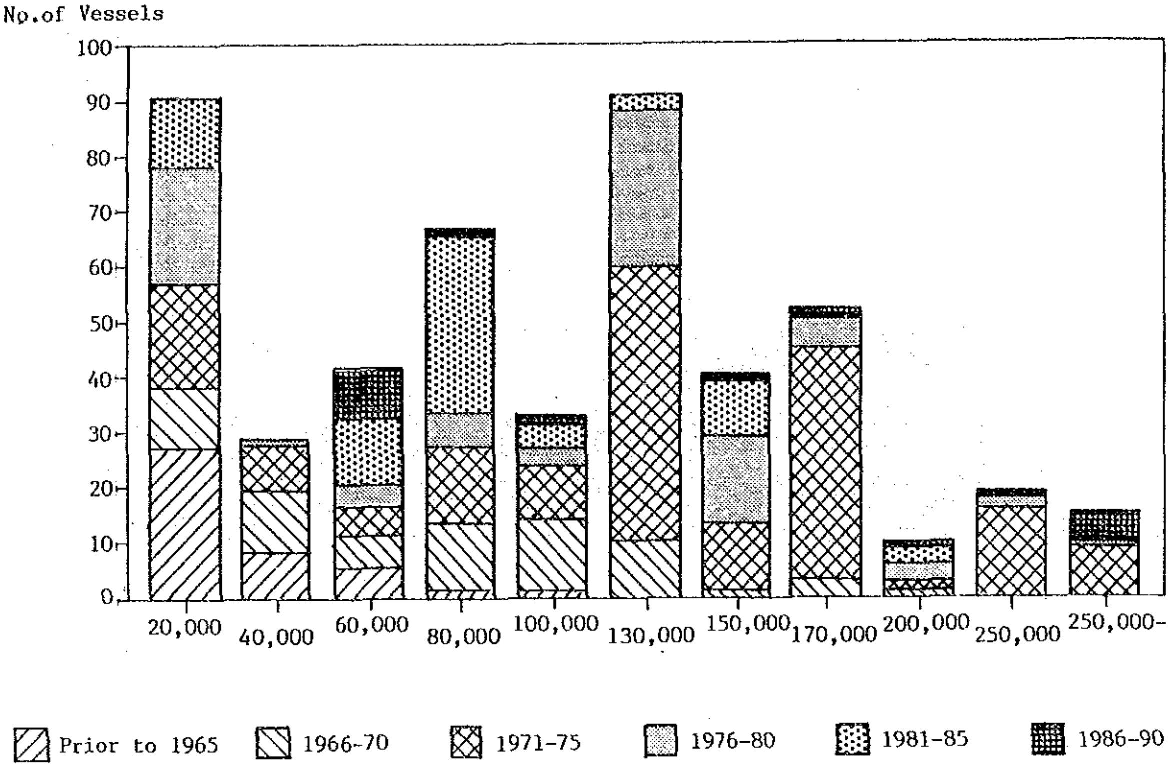
Figures in % of total seaborne trade of each area.

Size groups of vessels in '000 dwt

	-40	40-60	60-100	100-150	150+	Total
Exporting areas						
Scandinavia	11	1	26	51	11	100
West Africa	6	3	53	34	4	100
Other Africa	4	4	9	17	66	100
North America	3	5	26	48	18	100
S. America Atl.	4	8	18	25	45	100
S. America Pac.	9	2	7	19	63	100
Asia	24	15	16	32	13	100
Australia	2	2	9	39	48	100
Importing areas						
UK/Continent	4	1	26	37	32	100
Mediterranean	3	4	27	18	48	100
Other Europe	23	20	30	24	3	100
USA	12	7	50	28	3	100
Japan	6	3	5	34	52	100
Other Far East	3	6	18	36	37	100
Others	15	31	18	23	13	100
Total 1987	6	6	19	33	36	100
Total 1986	8	7	22	33	30	100

Note: Percentages for vessels below 40 000 dwt are residuals, calculated as the difference between total quantity of iron ore movements and shipments by vessels over 40 000 dwt.

(Fearnleys [World Bulk Trades])



(analysed by Port & Harbour Research Institute, Japan based on "Lloyd's Register of Ship")

Figure-7.2.2 Year of Launch of Ore Carriers in the World by DWT Class

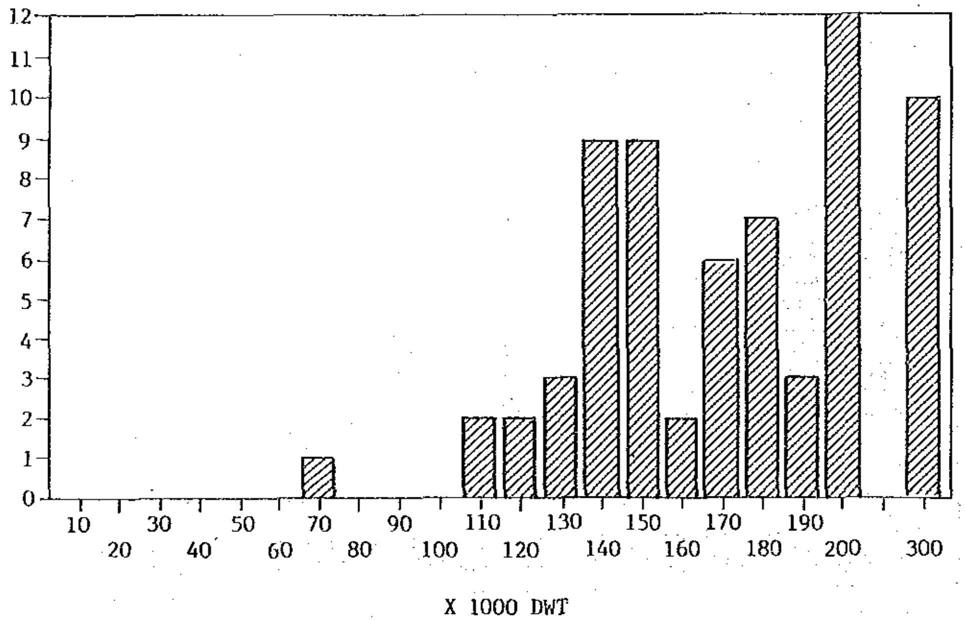


Figure-7.2.3 No.of Japanese Ore Carrier by DWT Class

Table-7.2.7 Ship Size Distribution of Iron Ore Carreier at New Mangalore Port by DWT

	SHIP SIZE	UK-CONT	MED.	OTHER E.	USA	JAPAN	OTHER F/E	OTHER	TOTAL
TOTAL	0 — 9999	0	0	0	0	0	0	0	0
	10000 — 19999	0	0	3	0	1	1	2	7
	20000 — 29999	0	0	33	0	4	1	1	39
	30000 — 39999	0	0	8	0	8	1	4	21
	40000 — 49999	0	0	4	0	25	0	2	31
	50000 — 59999	0	0	2	0	4	0	4	10
	60000 — 69999	2	0	0	2	13	0	2	19
	70000 — 79999	0	0	2	0	5	1	0	8
	TOTAL	2	0	52	2	60	4	15	135
CONCENT	0 — 9999	0	0	0	0	0	0	0	0
	10000 — 19999	0	0	1	0	1	0	0	2
	20000 — 29999	0	0	5	0	4	0	0	9
	30000 — 39999	0	0	1	0	7	1	3	12
	40000 — 49999	0	0	3	0	25	0	0	28
	50000 — 59999	0	0	0	0	4	0	4	8
	60000 — 69999	0	0	0	0	12	0	2	14
	70000 — 79999	0	0	0	0	5	0	0	5
	TOTAL	0	0	10	0	58	1	9	78

	SHIP SIZE	UK-CONT	MED.	OTHER E.	USA	JAPAN	OTHER F/E	OTHER	TOTAL
PELLET	0 — 9999	0	0	0	0	0	0	0	0
	10000 — 19999	0	0	2	0	0	1	2	5
	20000 — 29999	0	0	28	0	0	1	1	30
	30000 — 39999	0	0	7	0	1	0	1	9
	40000 — 49999	0	0	1	0	0	0	2	3
	50000 — 59999	0	0	2	0	0	0	0	2
	60000 — 69999	2	0	0	2	1	0	0	5
	70000 — 79999	0	0	2	0	0	1	0	3
	TOTAL	2	0	42	2	2	3	6	57

UK-CONT : UK/Continent
MED : Mediterranean
OTHER E. : Other Europe (Eastern Europe)
OTHER F/E : Other Far East

Table-7.2.8(1) Capacity of Main Iron Ore Loading Ports

Area	Ore Brand	Loading Port	PORT CAPACITY: Water Depth: Channel (A)	Berth Front	Average Tide (B)	Keel Clearance (C)	Width of Channel	Length of Berth	Loader (nominal T/H)	Loading Rate (T/D)	Stock-pile Capacity (10,000 tons)	MAXIMUM ACCOMMODATION: Draft (A+B-C)	L.O.A.	Beam	D.W.T
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
India	Basic Grade	Madras Outer Harbour (A) 1st Phase	15.8 m	14.6 m	3' (0.9 m)		244 m at straight reach and 305 m at southern end of channel	730' (222 m) Dolphin to Dolphin 357.58 m	4000 x 2	40,000	80	46' (14 m)			88,000
		(B) 2nd Phase (completion undecided)	17.6 m	15.55 m											100,000
		Paradeep	39' (11.89 m)	39' (11.89 m)	3' (0.9 m)		558' (170 m)	508' (155 m)	2500 x 1	12,000	40	38' (11.58 m)	700' (213.36 m)	105' (32.2 m)	45,000
	Bailadila	Vizagapatnam Outer Harbour (VOH)	54'1" (16.50 m)	54'1" (16.50 m)			656'2" (200 m)	1233'7" (376 m)	8000 x 1	40,000	90	50'2" (15.30 m)	885'10" (270 m)	137'10" (42 m)	120,000
	Goa: All Brands	Marmugao Berth No.9	45' (13.7 m)	43' (13.1 m)	4' (1.2 m)	3' (0.9 m)	820' (250 m)	984' (300 m)	4000 x 2	60,000	100	43' (13.1 m) 15.0 m Future	660' (201 m)	104' (31.7 m)	60,000 100,000 (Future)
		Marmugao No.6 Berth	30' (9.1 m)	28' (8.5 m)	4' (1.2 m)	3' (0.9 m)		722' (220 m)	1000 x 1	7,000	22	29' (8.8 m)	561' (170.4 m)	75' (22.86 m)	20,000
	Goa: Chowgule	Offshore Loading {addl. loading by Maratha Transhipper}							900 x 1	6,000		42' (12.80 m)	725' (220.5 m)	104' (31.7 m)	100,000
	Goa: Salgaocar	Marmugao (Transfer Vessel)							1050 x 1	12,000		51'6" (15.7 m)	856' (261 m)	132' (40.23 m)	160,000
	Goa: Dempo	Marmugao "PRIYADARSHINI" Loading Station		47'7" (14.5 m)		7'4" (2.25 m)		352'8" (107.50m)	1250 x 2 (Capacity 250 x 3)	12,000		40'02" (12.2 m)	738' (225 m)	105' (32.0 m)	Not available
	KUDREMUKH	New Mangalore Port	13.5 m	13.0 m	1.585 m	0.9 m	245 m	288 m	6000 x 1		50 (conc.) 15 (pellets)	12.5 m	245 m		60,000

SOURCE : 1981-82 IRON ORE MANUAL PUBLISHED BY - THE TEX REPORT CO. LTD.
(Revised with available information on Indian Ports)

Table-7.2.8(2) Capacity of Main Iron Ore Loading Ports

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Australia	Mt. Goldsworthy	Port Hedland	42' (12.8m)	42' (12.8 m)	12'7" (3.9 m)	6'7" (2.0 m)	600' (182.9 m)		4500 x 1	60,000	80	48' (14.6 m)	1000' (304.8 m)	138' (42.1 m)	160,000
	Hamersley	Port Dampier (1) Parker Point	52' (15.85 m)	53' (16.15 m)	7'5" (2.29 m)	3' (0.91 m)	500' (152.40 m)	882' (268.90m)	6000 x 1 (ORE) 4500 x 2 (PELLET)	100,000 80,000	170	1463 m	260.6 m	42.67 m	130,000
		(2) East Intercourse Island	52' (15.85 m)	61' (18.59 m)	7'5" (2.29 m)	5' (1.52 m)	549'11" (167.60 m)	1380' (421 m)	7600 x 1	100,000 L/T	300	56' (17.07 m)	1030' (313.93 m)	156' (47.55m)	160,000
	Mt. Newman	Port Hedland	11.8 m	No.1 16.0 m No.2 16.0 m	4.8 m	2.1 m	183 m	A 306 m B 352 m	No. 1 8000 x 1 No. 2 10000 x 1	110,000	350	48' (14.63 m)	1000' (303 m)		160,000
	Robe River	Port Walcott	12.8 m	Southern Berth 17.3 m Northern Berth 19.2 m	3.96 m	2.1 m		366 m	6000 x 1	100,000	200	48' (14.63 m) (Max. Recept. Record) 16.70 m	335.64 m	53.64 m	160,000 260,412 (short loaded)
	Savage River (Pellet)	Port Latta	50' (15.24 m)						2750 x 2	48,000	103	42' (12.8 m)	820' (250 m)	121' (37 m)	100,000
	Yampi Sound	Koolan Island		45' (13.71 m)	30' (9.1 m)	4' (1.2 m)		790' (240.79m	3000 x 1	38,000	6	47' (14.3 m)	780' (237.74 m)	118' (35.97m)	100,000
		Cockatoo Island		42' (12.80 m)	30' (9.1 m)	4' (1.2 m)		780' (237.67m)	800 1000	24,000		43'8⅜" (13.4m)	735' (224.03 m)	104' (31.70 m)	
South America (AtlanticCoast)	Rio Doce	Tubarao No. 1	70'6" (21.5 m)	70'6" (21.5 m)	4'11" (1.5 m)	4'11" (1.5 m)	918'8" (280 m)	1722'6" (525 m)	8000 x 1 6000 x 1	80,000 L/T	450	65'7" (20 m)	1148'4" (350 m)	183'9" (56 m)	250,000
		No. 2	73'82" (22.5 m)						16000 x 2				1279'53" (390 m)	200'13" (61 m)	350,000
	M B R	Sepetiba	73'10" (22.5 m)	Outer 78'9" (24 m) Inner 62'4" (19 m)		8'2" (2.5 m)	Outer 918'8" (280 m) Inner 1082'8" (330 m)	1295'11" (395 m)	7000 x 1	50,000 L/T		Outer 65'7" (20 m) Inner 54'2" (16.50 m)	1148'6" (350 m) 1148'6" (350 m)	183'9" (56 m) 183'9" (56 m)	300,000 300,000

Table-7.2.8(3) Capacity of Main Iron Ore Loading Ports

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Chile	Algarrobo	Huasco (Guacolda Pier)	50'10" (15.5 m)	50'10" (15.5 m)	2'7" (0.8 m)	9'2" (2.8 m)	-	600' (183 m)	2500 x 1	25,000	35	44'4" (13.5 m)	853' (260 m)	128' (39 m)	80,000
		Huasco (New Pier)	85'4" (26 m)	85'4" (26 m)	2'7" (0.8 m)	6'7" (2 m)	-	990' (302 m)	6000 x 1	100,000 (assumed)	100	59' (18 m)	1030' (314 m)	156' (47.5 m)	160,000
	Romeral	Guayacan	55' (16.76 m)	55' (16.76 m)	2'7" (0.8 m)	5'7" (1.71 m)	-	705'5" (215 m)	3000 x 1	35,000	100	52' (15.85 m)	919' (280 m)	135' (41 m)	about 110,000
	Santa Barbara	Caldera	-	42'8" (13 m)					2000 x 1	about 25,000	35	42' (12.8 m)	853' (260 m)	131' (40 m)	80,000
		Huasco (Las Losas Pier)		52'6" (16 m)					2500 x 1	about 32,000	40	48'11" (14.9 m)	951' (290 m)	144' (44 m)	80,000
	Santa Fe	Chanaral	-	41' (12.50 m)					2000 x 1	about 15,000	35	40' (12.2 m)	794' (242 m)	118' (36 m)	80,000
Peru	Marcona	San Nicolas	-	62' (18.9 m)				1000' (305 m)	4500 x 1	50,000	211	59' (18 m)	958' (292 m)	146' (44.5 m)	160,000
Canada	Tasu	Tasu Harbour		44'3" (13.5 m)				500' (152.4 m)	2800 x 1	about 35,000 L/T (Performance base)	21	44'11" (13.4 m)	795'7" (243 m)	105'10" (32 m)	68,500
	Carol Lake	Seven Islands	no limit	60' (18.3 m)	10'6" (3.2 m)	3' (0.9 m)	no limit	985' (282 m)	7500 x 2	about 100,000 L/T	550	60' (18.3 m)	1600' (488 m)	184' (56.1m)	260,000
Africa	Iscor	Port Elizabeth	38' (11.6 m)	40' (12.2 m)	3'2" (1.0 m)	2'5" - 4' (0.8 m - 1.2 m)	1286' (392 m)	840' (256 m)	760 x 2	20,000 L/T	46	38' (11.6 M)	825' (251 m)		55,000
		Saldanha Bay	77' (23.5 m)	76' (23.25 m)	-	9' (2.75 m)	1230' (375 m)	2073' (632 m)	10000 x 2	160,000 L/T	250	67' (20.5 m)	1148' (350 m)	184' (56.1 m)	250,000
	Swaziland	Maputo		40' (12.19 m)	(2 - 4 M)		328'1" (100 m)	667' (208 m)	2700 x 2	20,000 L/T	58	36' (11 m)	820' (250 m)	Outreach 70' (21.33m)	
	Lamco	Buchanan	48' (14.6 m)	42' (12.8 m)	3' (0.9 m)	3' (0.9 m)	Over 754'6" (over 230m)	843' (257 m)	6000 x 1	40,000 L/T	210	39' (11.89 m)	850' (259 m)	131' (40 m)	100,000
	Mauritania	Nouadhibou	54' (16.5 m)		3'2" (1.0 m)	5'4" (1.65 m)	1300' (396 m)		5000 x 1	80,000 L/T	156	52' (15.85 m)	1000' (305 m)	144' (44 m)	135,000

Table-7.2.8(4) Capacity of Main Iron Ore Loading Ports

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
USSR	Krivoyrog	Ilijichevsk	39'4" (12m)		7.87" (20 cm)		328' (100 m)	2296' (700 m)		15,000 L/T	25	38' (11.58 m)	820' (250 m)	118' (36 m)	69,833
		Grigorevsky	56'(17 m) 1st phase 18 - 20 m 2nd phase					No.1-400m No.2-360m No.3-360m	8000 x 3			56' (17.0 m)	(305 m)	(42 m)	100,000 170,000

(Proposed Oil Handling Facility)

As mentioned in Chapter 6, the proposed oil refinery plant would export and import oil products and crude oil, respectively, through the port. The sizes of tankers likely to call at the proposed jetties are described in 7.2.2. So the scope of the iron ore berth improvement should be decided giving consideration to tanker size.

(Vessel Size Alternatives)

The following vessel sizes can be set as first-stage alternative, based on the ore carriers currently operating in the world, the iron ore handling facilities of other Indian ports and the construction plan for oil jetties at New Mangalore Port.

1) 100,000 DWT

The capacity which is required to handle 7.5 million tonnes of iron ore annually, as well as the size which other Indian ports can currently accommodate and New Mangalore Port should catch up with. And th size whose full draught is similar to that of a crude Oil tanker of 100,000 DWT class, one of the alternative sizes for th oil handling plan. Moreover, the maximum size which the present terminal can accept with minor changes in the existing shiploader.

2) 130,000 DWT

The size whose full draught is similar to that of a crude oil tanker of 120,000 DWT class, one of the alternative sizes for the oil handling plan.

3) 150,000 DWT

The size whose full draught is similar to that of a crude oil tanker of 150,000 DWT class, one of the alternative sizes for the oil handling plant. And one of predominant vessel sizes of Japanese iron ore carriers.

4) 170,000 DWT

One of the common sizes that Japanese steel makers request.

The dimensions of each alternative carrier can be decided on the basis of 95% envelope of the existing ore carriers' dimensions based on Lloyd's Register (Figure-7.2.4 - 7.2.7). Table-7.2.9 shows the dimensions set for various vessels.

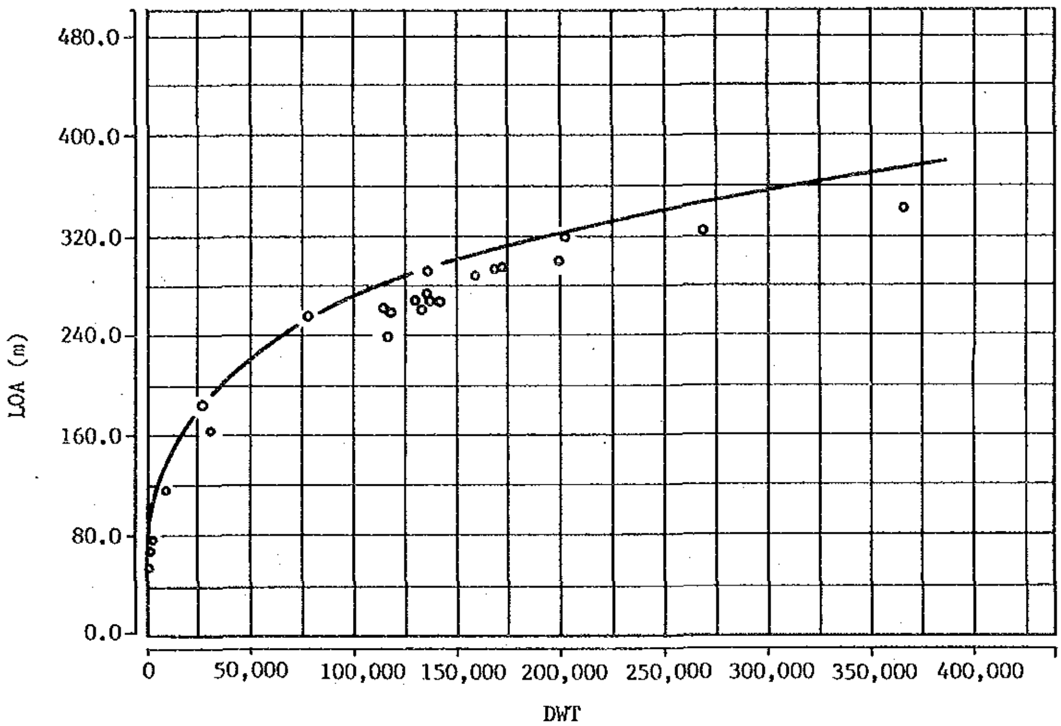


Figure-7.2.4 Relationship between DWT and LOA of Iron Ore Carriers

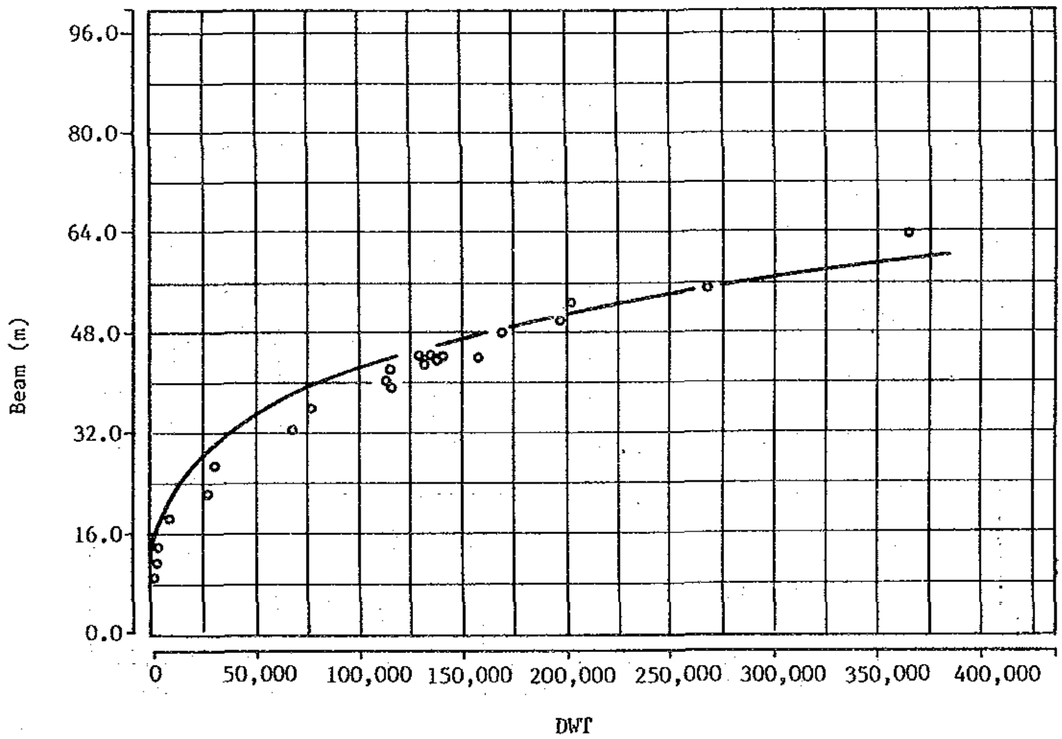


Figure-7.2.5 Relationship between DWT and Beam of Iron Ore Carriers

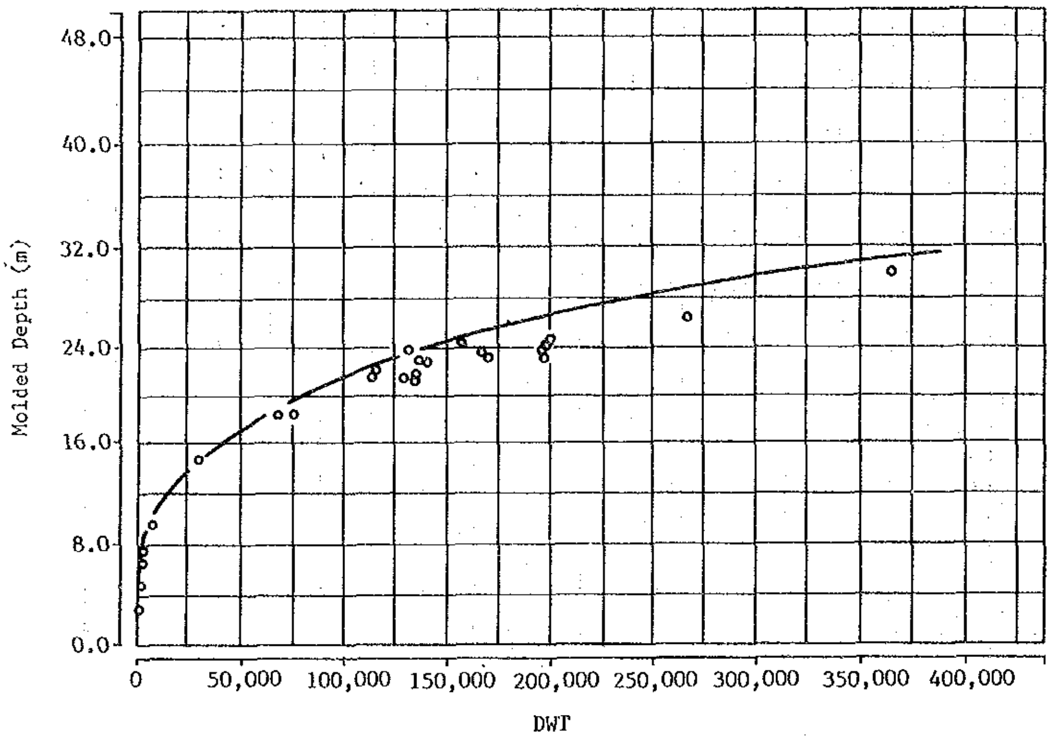


Figure-7.2.6 Relationship between DWT and Molded Depth of Ore Carriers

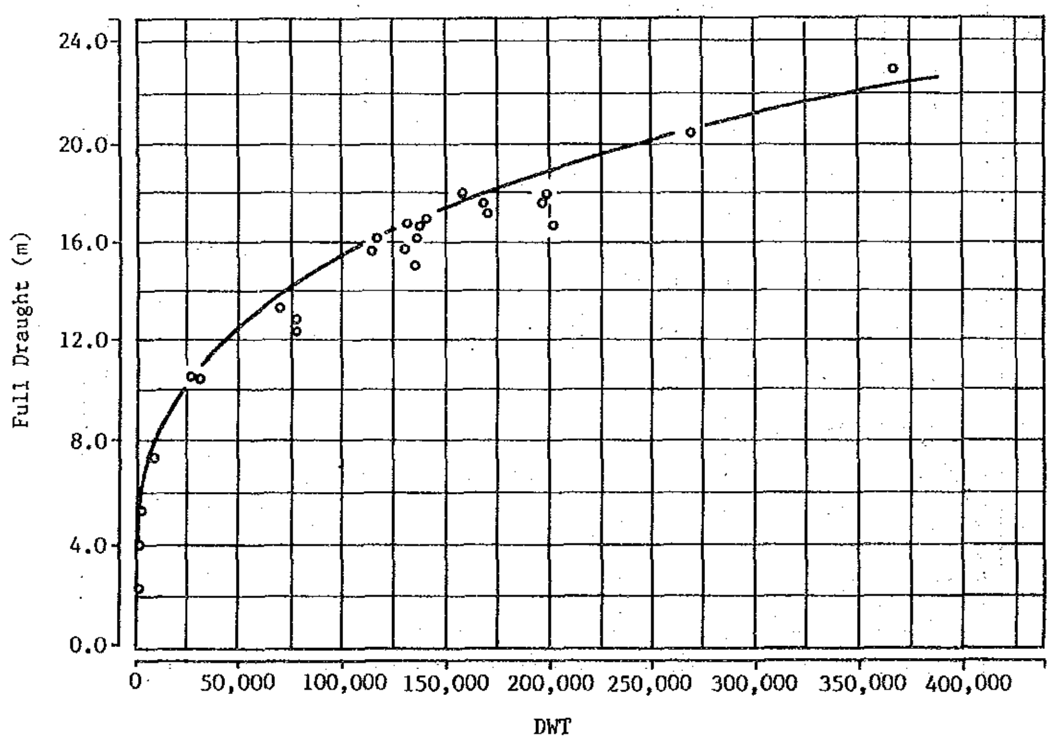


Figure-7.2.7 Relationship between DWT and Full Draught of Ore Carriers

Table-7.2.9 Dimensions of Iron Ore Carriers

Vessel Size (DWT)	LOA (M)	Full Draught (M)	Beam (M)	Molded Depth (M)
100,000	270	15.5	42	22
130,000	290	17.0	45	24
150,000	300	17.5	47	25
170,000	310	18.0	48	26

There is a jump of full draught from 100,000 DWT to 130,000 DWT and the difference in dredging cost between these two alternatives will be enormous. Moreover, only a few Japanese iron ore carriers can call at a 130,000 DWT class berth.

150,000 DWT is the vessel size whose full draught is almost the same as that of an oil tanker of 150,000 DWT, which is the largest alternative for the oil handing plan. So, the surcharge required for depending and widening the channel and basin for 170,000 DWT class iron our carriers should be paid only by parties involved in iron ore exports. This is clearly uneconomical.

Therefore, 130,000 DWT and 170,000 DWT can be removed from the vessel size alternatives.

(5) Improvement Scenario

As mentioned above, the existing iron ore berth can handle 7.5 million tonnes if it is upgraded to accept 100,000 DWT class vessels and also if its handling equipment and productivity are improved to increase their handling capacity. In order to handle iron ore of 10 million tonnes, one more iron ore berth will be needed. Therefore, improvement of the berth to 100,000 DWT class at least and upgrading handling equipment capacities to the proper level not later than 1994/95 followed by construction of another iron ore berth of 100,000 DWT class at least are included in the first scenario (scenario-1).

In order to improve the existing berth to enable it to accept large vessels, the whole basin area should be dredged because the berth is located at the end of the basin. So, another scenario can be set. The second scenario (scenario-2) is to keep the existing iron berth and its equipment unchanged and to construct a new iron ore berth with relevant handle equipment (shiploader and conveyers system etc.) not later than 1994/95.

The location of the new berth in both scenario-1 and scenario-2 is limited to the southern side of the port because of the convenience of the conveyer connections as follows.

i) Area next to the existing terminal

As this area is next to the existing iron ore terminal, the need for additional conveyer lines would be minimal, and high efficiency in handling could be obtained because of flexible usage of continuous berths. Therefore, this area is an appropriate site for an additional iron ore berth.

ii) Area where the existing oil products jetty is located

If a new terminal were constructed in this area, the existing oil jetty would have to be removed, however, the dredging area in the basin would be minimal.

iii) Southern shore area next to the channel (inside of the south breakwater)

The geological conditions of this area are relatively good. Seabed rock stratum seems not to appear up to -18.0m. A terminal on the southern shore would have a jetty with a heavy loader and roofed long conveyer line connecting the stockyard located behind the existing terminal and the structure of the jetty should be firm, which would result in enormous expendenture. Therefore, this area is not appropriate for the terminal.

iv) Offshore Area

An offshore terminal would not require dredging to be carried out, but basically, the terminal would be far from the shore and directly exposed to waves, so cargo handling operating would often be interrupted. During the SW-monsoon season, continuous high waves would stop the terminal operation. On the other hand, providing handling equipment at an offshore terminal for liquid bulk cargo such as crude oil and POL products would be simple and less costly. However, for iron ore concentrate not only handling machines and conveyers but also a huge structure connecting the terminal with the onshore site supporting the machine, conveyer and so on would be required. Moreover, as the iron ore concentrate must be sheltered from rain in order to ensure quality control, the conveyer system would be very costly. Therefore, this area is not appropriate as a terminal site.

Accordingly, the area next to the existing iron ore terminal and area where the existing oil product jetty is located are possible sites for construction of new iron ore terminal.

Consequently, improvement of the port's iron ore handling capability will be achieved, according to one of the two following scenarios:

-- Scenario 1

a) Not later than 1994-95, the existing iron ore berth will be upgraded for 100,000 DWT or larger vessels, and

b) the handling equipment will be upgraded with minor modifications, then.

c) not later than 1999-2000, an additional iron ore berth will be constructed at one of the possible sites and proper handling equipment will be installed at the same time.

--Scenario 2

a) Not later than 1994-95, an additional iron ore berth will be constructed at one of the possible sites and proper handling equipment will be installed at the same time.

(Meanwhile, the existing berth and equipment are left unchanged.)

7.2.2 Oil berth

(General)

The crude oil handling and product berths will have to handle raw material and the finished products of the proposed refinery plant. The existing feasibility study report, "Detailed project Report for Port Facilities for Handling Crude & POL Products" prepared for the New Mangalore Port Trust by Consulting Engineering Service, Dec. 1985, (Oil F/S Report), recommends that design sizes of crude oil tankers and product tankers be 100,000/120,000/150,000 DWT and 35,000 DWT (actually, 85,000 DWT for use of crude tanker in case of breakdown of the crude oil jetty), respectively, with the following dimensions shown in Table-7.2.10, and that jetties be constructed by improving the existing jetty now used for imported oil products and by excavating and dredging the south bank of the lagoon.

Table-7.2.10 Dimensions of Oil Tankers

Vessel Size (DWT)	LOA (M)	Full Draught (M)	Beam (M)	Remarks
35,000	195	10.5	30	Products
65,000	230	13.6	32	Crude
85,000	240	14.0	38	Crude
100,000	275	16.4	43	Crude
120,000	285	17.1	43	Crude
150,000	300	17.8	45	Crude

The Oil F/S Report proposes that the existing jetty be reconstructed to make an 85,000 DWT class crude oil/product jetty and that a 120,000 DWT class crude oil jetty be located in the area behind the 85,000 DWT class jetty where a more than 5m-high bank exists.

(Berth Scale)

The scale of the crude oil jetty is decided in accordance with the water depth decided by the scale of the iron ore berth.

Following alternatives for oil jetties are set in accordance with the alternatives for the iron ore berth.

And although the oil products jetty will have to accept 35,000 DWT class tankers, if the additional dredging volume to change the 35,000 class jetty (-11.5m - deep) to a 85,000 class jetty (-15.5m - deep) is slight, the jetty can be constructed to accommodate 85,000 DWT class crude tankers.

Table-7.2.11 Oil Berth Alternatives

Iron Ore Berth Alternative (DWT)	Oil Berth Alternative	
	Crude Oil Jetty (DWT)	Product Jetty (DWT)
100,000	100,000	35,000*
150,000	150,000	35,000*

* 85,000 is possible.

(Number of Berth)

In 1994/95, crude oil of 3.0 million tonnes and oil products of 1.6 million tonnes as well as 0.2 million tonnes of LPG will be handled, according to the demand forecast. The required number of jetties can be decided under the following handling conditions:

Crude Oil	- Average Tanker Size	83,000 DWT
	- Loading Factor of Tankers	0.9
	- Pumping Rate	3,500 t/hr
	- Docking, Undocking and non-Working Time	15 hours
	- Working Hours per Annum	6,000 hrs(300 day x 20hr/y)
	- Berth Occupancy Rate	0.6
Oil Products	- Average Tanker Size	28,000 DWT
	- Loading Factor of Tankers	0.9
	- Pumping Rate	1,000 t/hrs
	- Docking, Undocking and non-Working Time	15 hours
	- Working Hours per Annum	6,000 hrs
	- Berth Occupancy Rate	0.6

Average Service Time

Crude Oil	83,000 x 0.9 / 3,500 + 15 = 36.3 hrs
Oil Products	28,000 x 0.9 / 1,000 + 15 = 40.2 hrs

No. of Tankers Calling

Crude Oil	3,000,000 / (83,000 x 0.9) = 40
Oil Products	1,766,000 / (28,000 x 0.9) = 70

Berth Occupancy Rate by a Single Jetty

Crude Oil	36.3 x 40 / 6,000 = 0.24
Oil Products	40.2 x 70 / 6,000 = 0.47

Therefore, a single crude jetty and a single products jetty will be required to meet the demand of 1994/95.

Secondly, in 2004/05, the demand for crude oil, oil products and LPG will be 6.0 million tonnes, 3.16 million tonnes and 0.5 million tonnes, respectively. Similarly, the same conditions are applied to calculate the required number of jetties.

No. of Tankers Calling

Crude Oil	6,000,000 / (83,000 x 0.9) = 80
Oil Products	3,660,000 / (28,000 x 0.9) = 145

Berth Occupancy Rate by a Single Jetty

Crude Oil	36.3 x 80 / 6,000 = 0.48
Oil Products	40.2 x 145 / 6,000 = 0.97

Therefore, a single crude jetty and a two products jetties will be needed in 2004/05.

(Location)

- Crude Oil Jetty

Besides being located in the basin (inner port area), location in outer port area is possible because, unlike an iron ore jetty, only light gear (pipeline, loading arms etc.) are needed. That is, structure dose not have to be as firm as that for an iron ore berth. Therefore, possible locations of the crude oil jetty are:

1) on the south dike of the lagoon (renovation of the existing oil product jetty and,

2) in the outer port area.

- Oil Products Jetty

Possible locations of the oil products jetty are:

1) on the south shore of the lagoon and,

2) in the outer port area.

7.2.3 Coal berth

According to the demand forecast, coal handling volume will jump up to 6,240,000 tonnes in 1999/2000 and 12,120,000 tonnes in 2004/05 from 450,000 tonnes in 1994/95 (This amount can be handled at general cargo berth).

Therefore, not later than 1999/2000, a coal terminal should be constructed .

The ship size of coal carriers is assumed to be 50,000 DWT, the same size as that used in the existing master plan. Then, three berths and three unloaders will be required to receive 6,240,000 tonnes per annum and an additional three unloaders will be needed to handle 12,120,000 tonnes per annum.

To select the location of a coal terminal is out of scope of this Study. So, the Indian side determined the location; the west side of the proposed second dock (Figure-7.2.8). Though at present, this area is leased to M/S M.D.L., a half of the leased area and an area along the waterfront line facing the proposed dock will be returned to the New Mangalore Port Trust and can be used for the coal terminal including handling facilities and a stockyard according to the Indian side.

Therefore, the coal terminal with three berths, a stock yard and a loading system of coal on railway can be planned as shown in Figure-7.2.9.

Coal will be conveyed from the yard to the railway loading point and transported to the thermal power plant at Nardikur. Moreover, the handling capacity and the stockyard are studied in Appendix-7.5.

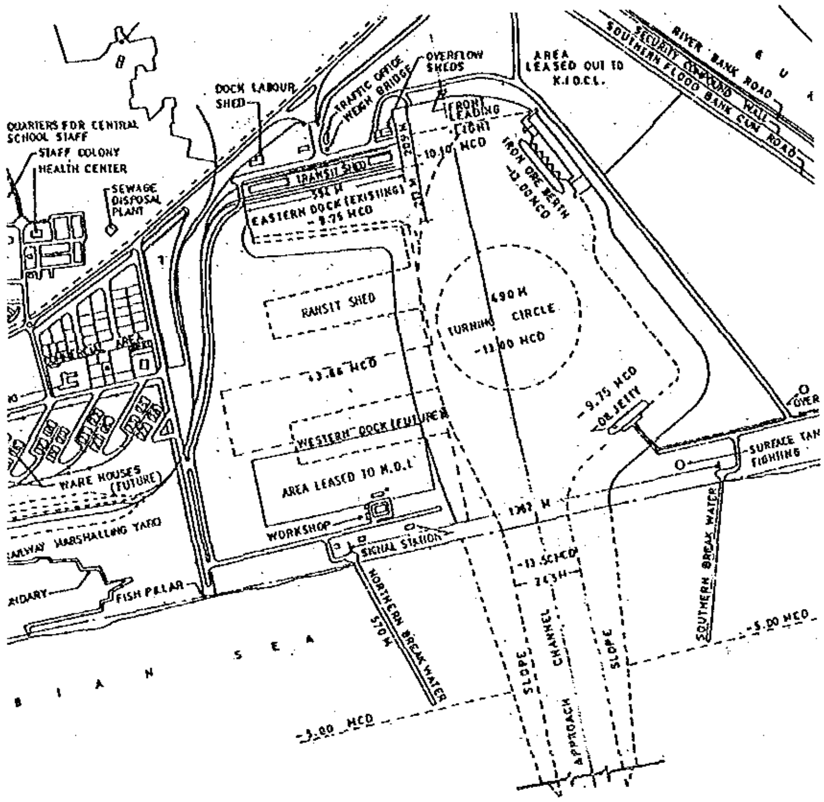


Figure-7.2.8 Area for the Coal Terminal

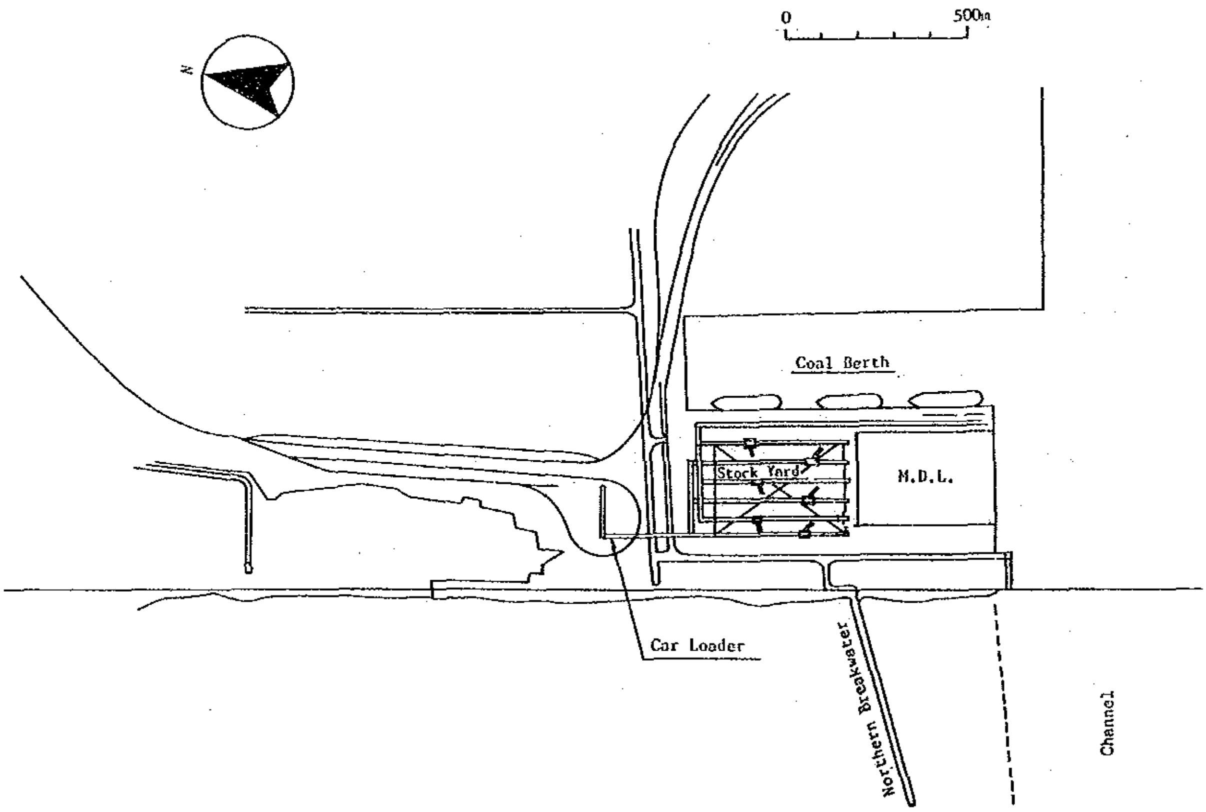


Figure-7.2.9 Coal Handling Facility Plan for 12 Million Tons per Year
New Mangalore Port

7.2.4 Other berths

(General Cargo)

Plan for general cargo berths, remain unchanged, from the following reasons.

The projected volumes of both exported and imported other cargo (general cargo) are 2,340,000 (coal included) and 3,190,000 tonnes in 1994/95 and 2004/05, respectively. The present annual handling rate per berth is around 330,000 t/berth (1,502,000 t/4.5 berths; a shallow berth = 0.5 berth). On the other hand, if all berths are completed (2 berths will be completed soon and 4 more berths are proposed in the proposed west dock) to handle 3,190,000 tonnes, the annual handling rate will be reduced to about 304,000 t/berth.

(LNG)

LNG is expected to be handled at New Mangalore Port in the future. The Gas Authority of India Limited has proposed (not been authorized) a LNG terminal at New Mangalore Port. According to the proposal 1) 4.1 Million MT would be accepted per annum, 2) land of 20 - 30 hectares would be required for the terminal, and 3) the possible location of the terminal is the south side of the India Oil storage tank or on the south side of the port limits. Since LNG is exprosive material, LNG handling should be carried out in a calm area, that is, an area protected by a breakwater. And since a cryogenic unloading line is needed between the jetty and the terminal, the terminal should be located as near the jetty as possible. Moreover, the jetty and the terminal should be apart from other facilities to prevent accidents. Therefore, the southern shore of the south breakwater should be reclaimed as land for the terminal, and the jetty should be constructed inside the breakwater. Figure-7.2.10 shows possible sites for the terminal and jetty.

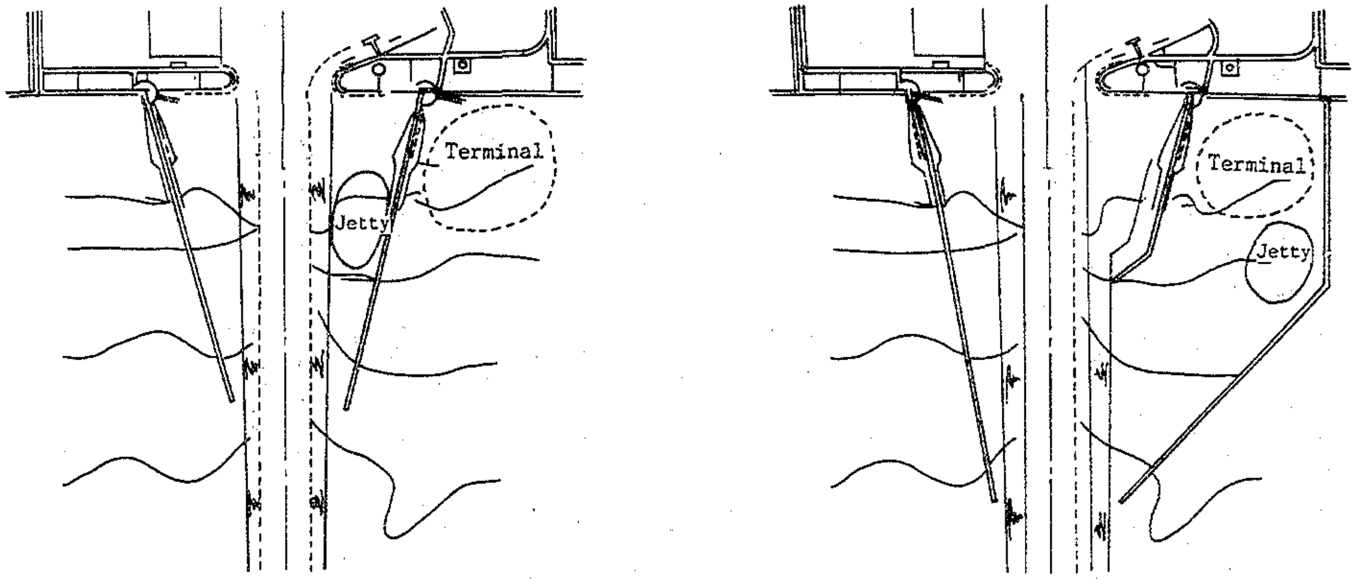


Figure-7.2.10 Possible Sites for LNG Jetty and Terminal

7.2.5 Channel and basin

(1) Ship Maneuvering Manner

Maneuvering manner of the main ships arriving at New Mangalore Port are as follows:

-- Iron Ore Carriers
to enter with no cargo, stop/turn at turning basin, be pulled and moor with the aid of tugboats at the iron ore berth in an outgoing position,

-- Crude Oil Tanker of Coal Carriers
to enter with full load, stop/turn at turning basin, and moor with aid of tugboats at the crude oil jetty or coal berth in an incoming position,

-- POL Product Tanker
to enter with no or full cargo, stop/turn at turning basin, be pulled and moor with aid of tugboats at the product jetty in an outgoing position.

A ship can come to a full stop in a space four times its length, and the normal stopping distance in five lengths for safety reasons. If there is further water area with the same depth as the turning basin behind it, the stopping distance from the entrance to the turning basin can be reduced to 4 times the length of the ship.

(2) Depth

The squat and trim of ships should be considered when deciding on depth requirements. According to the Oil F/S Report, an additional 0.3m for squat and an additional 0.9 m for trim of a 300m-long vessel during the monsoon season in unprotected water areas should be taken into account. Also, 0.6m net under-keel clearance is needed, as PIANC recommends. Moreover, in the case of a hard rock seabed, further clearance is needed for safety.

Consequently, the under-keel clearance allowances for the basin and channel are as shown in Table-7.2.12.

Table-7.2.12 Under-keel Clearance Allowances

(m)

	Unprotected Area (Channel)	Protected Area (Basin)
Tidal Allowance*	- 0.3	- 0.3
Squat	0.3	0.3
Trim	0.9	-
Net Under-keel Clearance	0.6	0.6
For safety against Hard Rock Seabed	-	0.4
Total	1.5	1.0

* MLWL : 0.26m above CD

(2) Other Dimensions

(Width of Channel)

The width of the channel should be one length of biggest vessels under single lane traffic control. On the other hand, according to "UNCTAD Handbook", a maneuvering lane needs twice the beam of the biggest vessels as well as 1.5 times the beam for bank clearance. So, the width of a channel composed of a maneuvering lane and bank clearance for both sides is 5 times the beam.

(Stopping Distance)

A straight protected water area of a relevant depth and five times the length of a ship approaching a berth at the port is normally required to ensure the safe maneuvering of the ship. Actually, a ship entering a port at a speed of 5 - 6 knots can come to a full stop after going about four times the length of the ship (generally, a loaded ship needs a longer distance to stop than an empty ship) with astern propulsion and the aid of tugboats. One ship length is added for safety.

(Turning Circle)

It is generally accepted that the diameter of the turning circle for vessels aided by tugboats is twice the length of the biggest vessels.

(3) Required Dimensions of Basin and Channel

Table-7.2.13 shows the required dimensions of the basin and channel discussed above for each size of iron ore carrier.

Table-7.2.13 Requirement of Demensions for the Basin and Channel

Iron Ore Carrier Size (DWT)	Length (m)	Beam (m)	Full Draught (m)	Depth		Width of Channel (m)	Diameter for Turning Circle (m)
				Basin (m)	Channel (m)		
100,000	270	42	15.5	-16.5	-17.0	275*	550*
150,000	300	47	17.5	-18.5	-19.0	300	600

* In the case of a 100,000 DWT iron ore carrier, crude oil tanker of 100,000 DWT can enter at high tide. The width and diameter are decided by the length of the tanker.

(4) Layout of the Channel and Basin

As mentioned in 2.7.4, bedrock strata are found in a wide area inside the basin. In order to accept larger ships, the basin and channel must be widened and dredged and it is requested that these facilities be shifted to the south as much as possible so that the volume of expensive rock dredging can be reduced. On the other hand, to ensure safety during the ships' maneuvering, channel and basin must keep a necessary distance from structures and mooring ships. Moreover, a turning circle with a diameter twice the length of the biggest ship is required.

Iron ore carriers and Crude Oil tankers are large vessels which determine dimensions of the channel and basin.

In the case where the crude oil jetty is located in the outer port area, a deep turning circle could be located outer port area because iron ore carriers which come into the basin in ballast condition does not need a deep turning circle. In this case, deep dredging can be limited to only an area for out-going fully-loaded iron ore carriers so that rock dredging can be reduced. This applies to the Master Plan Alternative.

7.2.6 Breakwaters

Extension of the breakwaters is one of the possible countermeasures against the siltation and littoral sand drift that takes place in areas with a depth of up to -7 m and accumulates compact sand in the channel. Other elements which determine the length and layout of breakwaters are stopping distance and tranquility at the berth.

The optimum breakwater length is decided in Chapter 10. Here only concepts for deciding of the optimum breakwater length are explained.

(1) Siltation

It is clear that a narrower entrance and a longer breakwater would reduce siltation volume. Thus the optimum breakwater length, that is in terms of the lowest total cost for maintenance dredging and construction, should be determined. On the other hand, the width of the entrance must be as narrow as possible and wide enough for the stability of the breakwater.

(2) Littoral Sand Drift

This phenomenon does not usually take place, but it would be fatal for the port. Considering that littoral sand drift has occurred at depths up to -7m, the breakwater should be extended up to -7m at least.

(3) Stopping Distance

Normally, five times the length of the biggest vessel is to be guaranteed for stopping distance within a protected water area. Breakwaters are required to protect this water area.

(4) Tranquility

In the monsoon season, water in front of the existing oil jetty is sometimes disturbed by wave action. The existing breakwaters must be extended in order to sufficiently protect the channel and basin. For mooring ships, the wave height must be below 0.7m to 1.5m (depending on the ship size and mooring system and whether the service boats are used or not), and for the basin and channel, the wave height must be low enough for tugboats.

7.2.7 Layout plan alternative

Based on examinations above, the following alternative facility layout plans are drawn (Figure-7.2.11 - 7.2.14).

Case-1 is planned under scenario-1 and other cases are planned under scenario-2.

The layout of the breakwater of case-1 and 2 is different from that of cases-3 and 4 because a future LNG jetty is planned outside of the existing souther breakwater in the latter 2 cases.

The turning circles of cases-3, and 4 are located in the outer port area, whereas those of case-1 and 2 are located in the lagoon. Moreover, cases-3 and 4 have deep dredging plans of limited area in the lagoon for outgoing iron ore carriers of 150,000 DWT.

Plans of mooring facilities for each case are as follows:

(1) Case-1

-- Improvement of the Existing Iron Ore Berth to 100,000 DWT Class (short-term)

Under scenario-1, the existing berth will be improved first. The maximum iron ore carrier size to be accepted with only minor modification of the shiploader currently installed and 33m extension of the berth length is 100,000 DWT. It would cost much more to accept 150,000 DWT because the apron would have to be widened and because a 66m extension of the length and installation of a new shiploader suitable for 150,000 DWT class carriers would be needed.

-- Reconstruction of the Existing Oil Products Jetty to Crude Jetty of 100,000 DWT Class (short-term)

The existing oil products jetty can be reconstructed by adding a couple of mooring and breasting dolphins. So, both crude oil and oil products tankers can use this jetty before the new oil product jetty is constructed and/or while handling volume of crude oil and oil products is small in the first stage of the oil refinery project.

-- Oil Products Jetty of 85,000 DWT Class (short-term)

Although the size of oil products tankers is not expected to exceed 35,000 DWT, an 85,000 DWT class products jetty is planned in the lagoon to accept crude tankers when the crude jetty cannot be used for whatever reasons. the difference in costs could be marginal. And the jetty will be constructed on the shore of the lagoon without excavation of the land. The second oil products jetty could be constructed inside the southern breakwater (in the outer port area) if needed.

-- Additional Iron Ore Berth and Oil Products Jetty

If a single iron ore berth and two jetties cannot meet the demand for iron ore and oil products, an additional berth and jetty will be constructed next to the existing berth and in the outer port area, respectively.

-- Construction of Three Coal Berths (long-term)

Three coal berths of 50,000 DWT class are planned in the proposed west dock.

-- LNG jetty (future)

In the future, LNG is expected to be handled at New Mangalore Port. LNG is so inflammable and dangerous that the jetty should be located as far from other facilities as possible. Therefore, it is planned for the outer port area; inside of the southern breakwater. Although a second oil product jetty is also planned there, only four LNG carriers a month could call at it, and the jetty would not accommodate many tankers because the crude oil and oil products jetties located in the lagoon could handled large volumes. So, there would be no problem in this regard.

-- Reclamation of Southern Shore for LNG Terminal (future)

Since it would be better if the cryogenic unloading lines were short, the LNG processing facilities should be located as near the unloading jetty as possible. Moreover, as stated above, facilities related to LNG should be located as far from other facilities as possible. Therefore, the southern shore area could be reclaimed for the LNG terminal.

(2) Case-2

-- Construction of a New Iron Ore Berth of 100,000 DWT Class (Short-term)

Under scenario-2, a new iron ore berth is planned next to the existing berth without improvment of the existing one. This location has advantage in that two contiuous iron ore berths would have high handling efficiency. And vessel size of 100,000 DWT is selected for this case because the dredging area in the lagoon would be huge.

-- Crude Jetty, Oil Products Jetty (short-term), Coal Berths and Additional Oil Products Jetty (long-term) and Facilities Related to LNG (future)

Same as case-1.

(3) Case-3

-- Construction of New Iron Ore Berth of 150,000 DWT Class (long-term)

In order to reduce the deep dredging area in the lagoon, another iron ore berth is planned to be located nearer to the entrance than in cases-1 or 2 and only a limited area for outgoing iron ore carriers of 150,000 DWT is planned to be dredged.

-- Construction of Crude Oil Jetty of 150,000 DWT Class in the Outer Port Area (short-term)

A crude oil jetty would be better located in the outer port area because crude tankers that come with full loads would need a deep turning basin in the lagoon if the crude oil jetty were located in the lagoon. Instead, a deep turning circle is planned in the outer port area, where hard rock strata are not likely to be found in shallow areas.

-- Additional Oil Products Jetty (long-term)

An additional oil products jetty will be prepared in response to the demand in the outer port area.

-- Coal Berths (long-term) and Facilities Related to LNG (future)

Same as Case-1.

(4) Case-4

--Construction of New Iron Ore Berth of 150,000 DWT Class (short-term)

As with Case-3, in order to reduce the deep dredging area in the lagoon, a new iron ore berth is planned to be located at the site where the oil product jetty is currently located and a further limited area for outgoing iron ore carriers of 150,000 DWT is planned to be dredged.

-- Oil Products Jetty (short-term and long-term)

On the shore of the lagoon, two oil products jetties of 35,000 DWT each are planned, one of which is for the short-term and another for the long-term.

-- Crude Oil (short-term), Coal Berths (long-term) and Facilities Related to LNG (future)

Same as Case-3.

7.2.8 Selection of the optimum layout plan

(1) Methodology

Of the four alternatives shown in the previous section, the optimum layout plan is selected based upon the following point of view:

Costs
Benefit
Flexibility
Future Development (LNG Jetty)

(2) Costs

Costs can be divided into capital costs and maintenance costs, etc. as follows:

. Capital Costs --------------- Iron Ore Berth,
Crude Oil Jetty,
Oil Products Jetty,
Dredging of Basin and Channel,
Breakwater,
Iron Ore Handling Equipment,
Tugboats, and Navigation Aids

. Maintenance Costs ----------- Maintenance Dredging

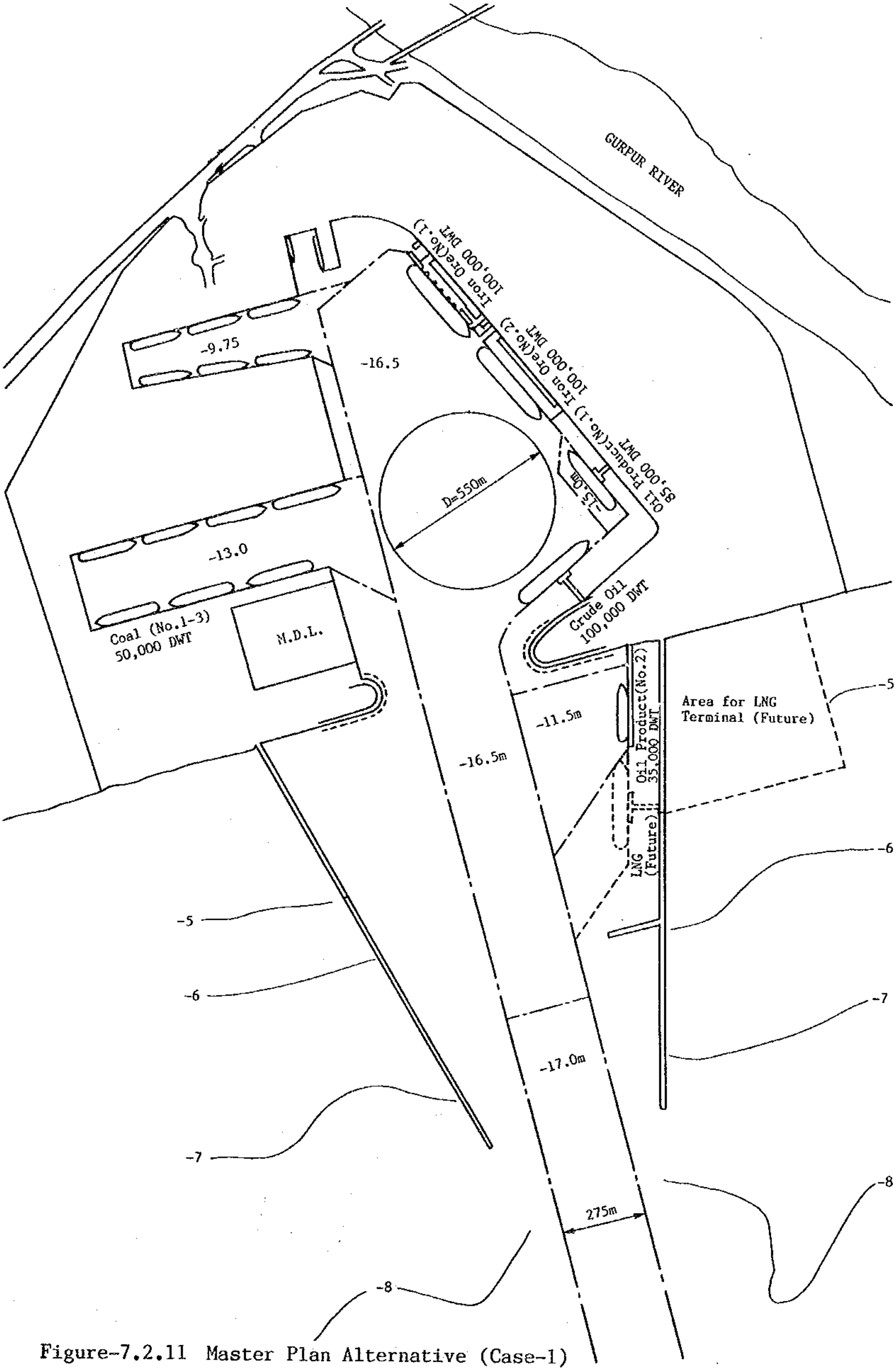


Figure-7.2.11 Master Plan Alternative (Case-1)

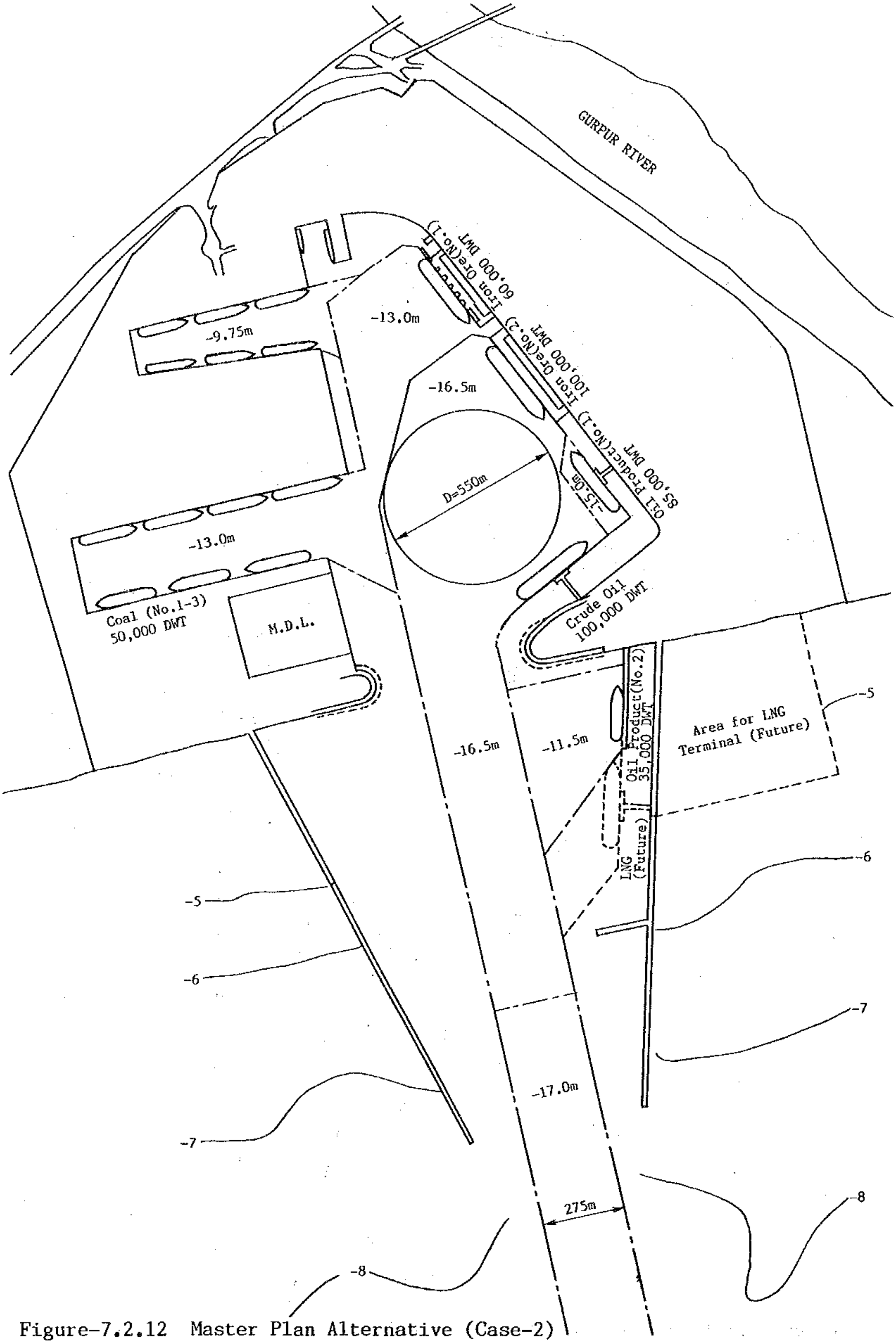


Figure-7.2.12 Master Plan Alternative (Case-2)

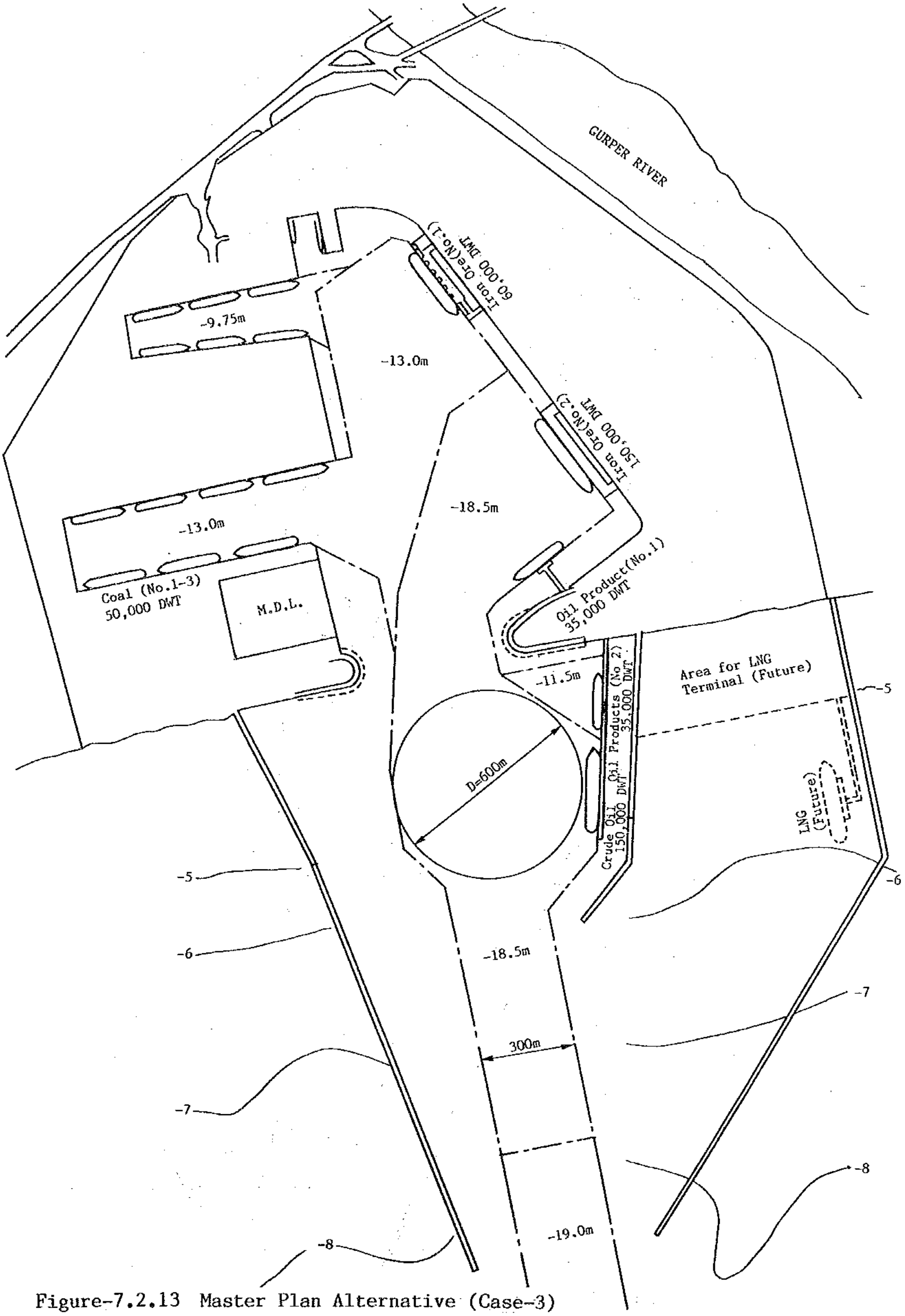


Figure-7.2.13 Master Plan Alternative (Case-3)

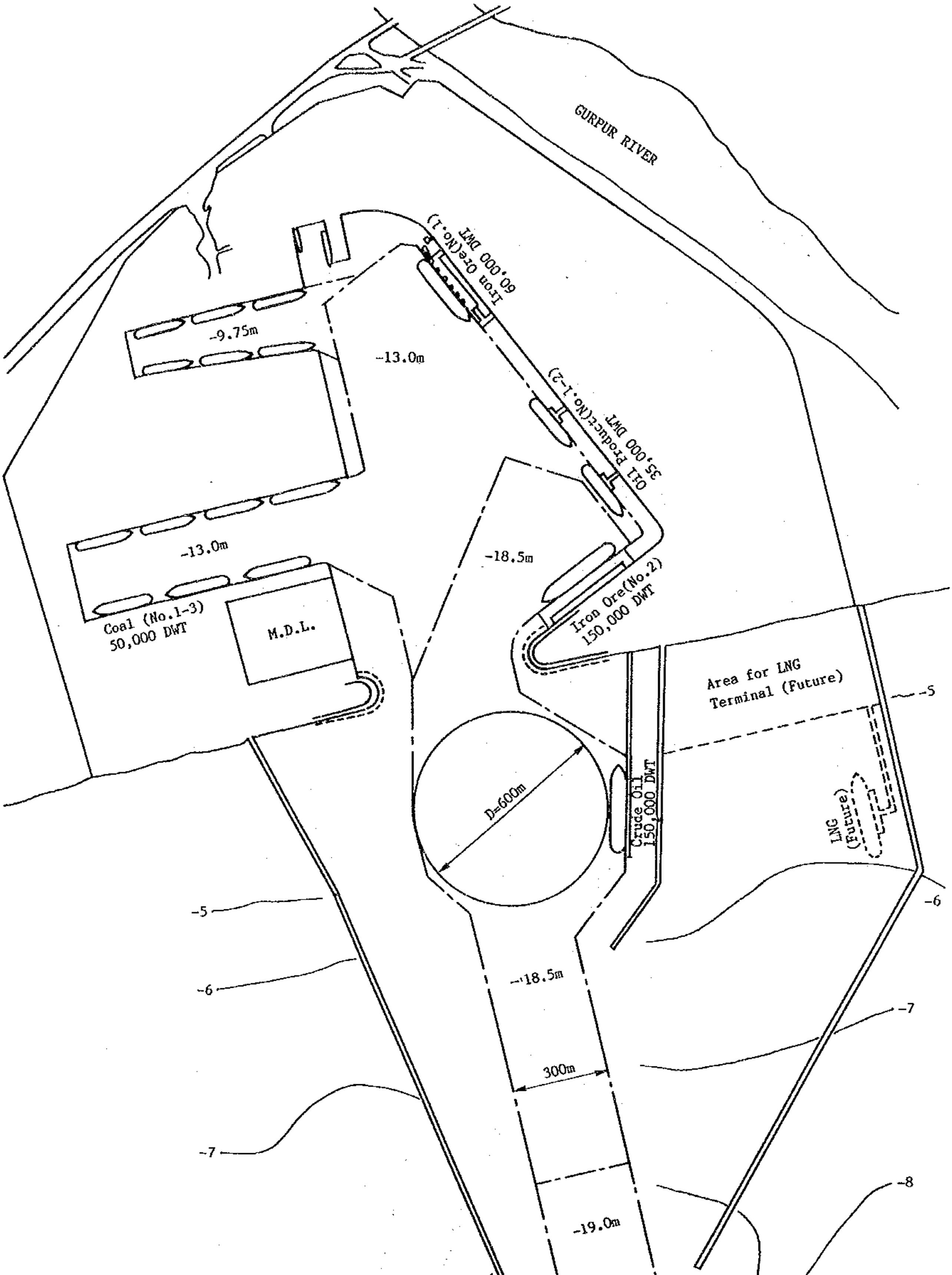


Figure-7.2.14 Master Plan Alternative (Case-4)

- Administration Costs related to the above facilities
- Operation Costs related to the above facilities

The cost of other facilities, such as general cargo berths, can be discounted, because these other facilities could be constructed separately from the project discussed in this report.

Table-7.2.14 and 7.2.15 shows the cost of the various alternatives.

Table-7.2.14 Rough Capital Costs

(unit: Crore Rs.)

Case	1	2	3	4
Iron Ore Berth ('000 DWT) (long-term) / (short-term)	100+100 (100)	60+100 (60+100)	60+150 (60+150)	60+150 (60+150)
Iron Ore Berth				
Improvement	3.5	–	–	–
Construction	9.7	9.7	13.7	13.7
Crude Oil Jetty	3.7	3.7	10.9	10.9
POL Jetty	9.3	9.3	4.3	8.9
Dredging	66.2	63.9	94.3	73.2
Breakwater	22.0	22.0	45.4	45.4
Total (for short-term plan only)	114.4 (99.6)	108.6 (103.5)	168.6 (164.3)	152.1 (148.9)
Equipment (for short-term plan only)	80.7 (21.6)	78.5 (78.5)	85.2 (85.2)	98.8 (98.8)
Other (for short-term plan only)	7.3 (7.3)	7.3 (7.3)	7.5 (7.5)	7.5 (7.5)
Grand Total (for short-term plan only)	202.4 (128.5)	194.4 (189.3)	261.3 (257.0)	258.4 (255.2)

(contingency not included)

Table-7.2.15 Increase in Annual Maintenance Dredging Cost

Case	1	2	3	4
Siltation Volume (Mm3)	6.1	6.1	5.1	5.1
Increase in Maintenance Volume (Mm3) *	1.3	1.3	0.6	0.6
Increase in Dredging Cost (Cr. Rs.)	2.0	2.0	0.9	0.9

* Present maintenance dredging volume ≒ 3 Mm^3
Maintenance dredging volume = 0.7 x siltation volume

1) Minimum development costs are required for the short-term plan (1994/95) in case-1.
2) Minimum development costs are required for the long-term plan (2004/05) in case-2.
3) Maximum development costs are required for the short-term plan (1994/95) in case-3.
4) Maximum development costs are required for the long-term plan (2004/05) in case-3.
5) Only case-1 does not need much expenditure for handling equipment in the short-term plan.
6) The cost of breakwater in cases-3 and 4 is twice that in cases-1 and 2, but the reduction of maintenance dredging costs can make up for this.

(3) Benefits

Here, benefits are calculated as the sum of savings in operating time, savings in waiting time and savings in freight cost. These savings can be increased as the size and number of the berths grow. Table-7.2.16 and 7.2.17 show the discounted costs and benefits of each alternative development plan. For long-term development, the benefit/cost ratio of each case is shown in Table-7.2.18, which shows that there are no significant differences between the alternatives.

(4) Flexibility

Besides case-1, alternative plans include a great expenditure before 1994/95, when 7.5 million tonnes of iron ore will be exported, which would enable the port to handle over 10 million tonnes of iron ore. Although the projection shows that the volume of iron ore exports will increase to 10 million tonnes, there is some uncertainty regarding this and when such a volume will be reached. Therefore, cases-2, 3 and 4 present the possibility of excess investment. Conversely, case-1 has flexibility regarding demand because in that case the existing iron ore berth would first be upgraded to handle 7.5 million tonnes and the decision to build an additional iron ore berth can be made by considering the demand trend.

Table-7.2.16 Cost of Each Long-term Development Alternatives

(Unit: Crore Rs.)

Discount Rate	0.05	0.07	0.1	0.12	0.15	0.2
Case-1	173	154	132	122	107	91
Case-2	167	152	134	125	113	99
Case-3	208	192	174	164	152	135
Case-4	205	189	171	161	149	133

Table-7.2.17 Benefit of Each Long-term Development Alternatives

(Unit: Crore Rs.)

Discount Rate	0.05	0.07	0.1	0.12	0.15	0.2
Case-1	267	206	146	119	90	60
Case-2	271	210	150	123	94	64
Case-3	346	268	191	156	120	82
Case-4	346	268	191	156	120	82

Table-7.2.18 Benefit/Cost of Each Long-term Development Alternatives

Discount Rate	0.05	0.07	0.1	0.12	0.15	0.2
Case-1	1.54	1.34	1.11	0.98	0.84	0.66
Case-2	1.62	1.38	1.12	0.98	0.83	0.65
Case-3	1.66	1.40	1.10	0.95	0.79	0.61
Case-4	1.69	1.42	1.12	0.97	0.81	0.62

(5) LNG Terminal

An LNG terminal is likely to be required at New Mangalore Port in the future. It could be located on the southern side of the southern breakwater. Since in cases-1 and 2 an LNG jetty is located in the inside area of the southern breakwater, where the second oil products jetty is also planned, the oil products jetty cannot be used while the LNG jetty is being used. However, because only four LNG ships a month are expected to call at the jetty and other oil products jetty located in the inner basin will have an annual handling capacity of 1.8 - 2.0 million tonnes, there will be no problem in operations at the second oil product jetty.

In cases-3 and 4, an LNG jetty is planned inside the area of the new southern breakwater, because the area inside the existing southern breakwater will be occupied by a crude oil jetty. This requires construction of a long breakwater.

(6) Conclusion

Based on the examination as stated above, case-1 is considered to be the best solution, as shown in Table-7.2.19.

Table-7.2.19 Evaluation of the Alternatives

Case	1	2	3	4
Cost				
Short-term	A	B	C	C
Long-term	B	A	C	C
Benefit	A	A	A	A
Flexibility	A	C	C	C
LNG Terminal	B	B	B	B
Overall Evaluation	A	B	C	C

Note: The Master Plan alternatives proposed above have been studied under the precondition agreed by the Indian side that it would be possible to take over a part of the land area that is now leased out for 20 years to M/S Mazagen Dock Limited (MDL) to use as coal berths in future for the National Thermal Power Corporation.

However, the Indian side informed the team in their comments on the Draft Final Report that it is unlikely that MDL will part with the land area, and that there is the likelihood of strong objection from MDL to the idea of handling coal adjacent to their yard. The Indian side asked the team to study an additional Master Plan alternative in which the coal berths would be shifted to the opposite side adjacent to the KIOCL iron ore berth.

In complying with this unexpected request, which was received at the very end of the study period, the team decided to conduct an additional study on another Master Plan alternative on the basis of a new arrangement of the coal berths but the study result would be rather rough and is presented separately as the "Subsidiary Paper of the Final Report for the Feasibility Study of New Mangalore Port."

8. SILTATION

8.1 Mechanism of Siltation at New Mangalore Port

The present situation of siltation at this port has been described in section 2.7. In this chapter, mathematical models have been employed to estimate the effect of breakwater extension on the mitigation of siltation. At first, siltation mechanisms are discussed in order to establish appropriate mathematical models in this harbour.

The siltation mechanisms in the Port suggested from the analysis of sounding maps, together with bed material data and oceanographical data from various literatures are summarized as follows.

8.1.1 The role of waves

1) It is clear that siltation in the channel and the lagoon takes place during a southwest monsoon season. Therefore, the rough wave conditions widely observed on the west coast of India during the southwest monsoon season are considered to be the main agency causing siltation.

2) Table-8.1.1 presents the wave climate offshore from Mangalore, compiled from Ship Reports. From this table, it can be seen that the exceedance probability of significant wave height over 2 m is about 5 % in all seasons except in the southwest monsoon period when the probability is up to 30 %. Similarly the exceedance probability of significant wave height over 3 m is about 0.5 % in all seasons except in the southwest monsoon period when the probability is 7 % or more.

Table-8.1.1 Wave Data of Mangalore (% of occurrence)

(Ship reports 1961-1966)

Season	Wave Height in Meters	Direction in Degrees From North: 0	30	60	90	120	150	180	210	240	270	300	330	Subtotal
December January to March	0.75	9.60	7.20	4.30	2.50	1.20	1.03	1.10	0.70	1.71	3.40	7.70	12.30	52.74
	1-1.5	8.70	5.20	3.00	2.30	1.10	1.00	0.85	0.30	0.67	1.90	5.20	13.20	43.42
	2-2.5	0.45	0.35	0.28	0.28	0.24	0.09	0.06	0.03	-	0.03	0.12	0.70	[illegible]
	3-3.5	0.03	0.03	-	0.03	0.03	-	-	-	-	-	-	0.03	[illegible]
	4-5.5	-	-	-	-	-	-	0.03	-	-	-	0.03	-	[illegible]
	6-7.5	-	-	-	-	-	-	-	-	-	-	-	-	-
	8-9.5	-	-	-	-	-	-	-	-	-	-	-	-	-
April to May	0.75	4.40	0.90	0.85	0.40	0.44	0.50	1.70	2.00	3.70	7.30	14.00	15.10	51.29
	1-1.5	3.30	0.20	0.16	-	0.28	1.00	2.30	4.00	5.00	7.80	10.10	3.00	37.14
	2-2.5	-	-	-	-	0.05	0.05	0.40	0.40	1.10	1.74	0.90	0.80	5.44
	3-3.5	-	-	-	-	-	-	0.05	0.05	0.16	0.16	0.05	0.05	0.52
	4-5.5	-	-	-	-	-	0.05	-	0.05	-	-	-	-	0.10
	6-7.5	-	-	-	-	-	-	-	-	-	-	-	-	-
	8-9.5	-	-	-	-	-	-	-	-	-	-	-	-	-
June to September	0.75	0.70	0.37	0.12	0.14	0.06	0.45	0.32	0.95	3.60	5.80	5.60	3.00	21.11
	1-1.5	0.60	0.14	-	0.14	0.14	0.37	0.50	1.85	11.40	19.00	12.00	4.20	50.34
	2-2.5	0.08	-	-	-	0.04	0.06	0.14	0.80	7.20	10.30	2.80	0.45	21.87
	3-3.5	0.02	-	0.02	0.02	-	-	0.02	0.22	1.60	2.50	0.40	0.06	4.86
	4-5.5	-	-	-	-	-	-	-	0.18	0.60	0.50	0.18	0.02	1.38
	6-7.5	-	-	-	-	-	-	-	-	-	0.16	0.06	-	0.22
	8-9.5	-	-	-	-	-	-	-	-	-	0.04	0.04	-	0.08
October to November	0.75	6.60	5.20	3.45	1.82	1.20	3.00	2.42	1.92	3.44	5.00	7.40	9.00	50.65
	1-1.5	3.60	2.80	1.90	1.30	1.50	3.30	3.50	3.60	2.90	5.20	6.50	7.00	43.10
	2-2.5	0.21	0.16	0.10	0.10	0.32	0.16	0.90	0.22	0.50	0.80	0.50	0.27	4.24
	3-3.5	0.05	-	-	-	-	0.05	-	-	0.27	0.11	0.05	0.05	0.53
	4-5.5	-	-	-	-	-	-	-	0.05	-	-	-	-	0.05
	6-7.5	-	-	-	-	-	-	-	-	-	-	-	-	-
	8-9.5	-	-	-	-	-	-	-	-	-	-	-	-	-

Season	Period Seconds	0	30	60	90	120	150	180	210	240	270	300	330	Subtotal
December, January to March	<5	14.20	10.60	6.40	3.70	1.60	1.48	1.23	0.75	2.04	4.70	11.00	19.40	77.10
	6-7	3.50	1.83	0.80	0.70	0.40	0.50	0.45	0.09	0.15	0.57	1.83	5.00	15.82
	8-9	0.60	0.47	0.23	0.12	0.18	0.03	0.18	0.06	0.06	-	0.36	1.35	3.64
	10-19	0.21	0.06	-	-	0.18	0.06	0.12	0.09	-	-	0.09	0.24	1.05
	≥20	0.37	0.42	0.24	0.18	0.03	-	-	-	0.03	0.12	0.09	0.52	2.00
April to May	<5	5.90	1.00	0.70	0.45	0.50	0.50	1.95	2.65	4.30	9.80	23.80	20.90	72.45
	6-7	1.60	0.10	0.05	-	0.05	0.40	0.75	1.15	2.10	3.30	4.20	4.80	18.50
	8-9	0.15	0.05	-	-	0.05	0.25	1.10	0.65	1.20	1.40	1.00	1.00	6.85
	10-19	0.20	-	-	-	-	0.15	0.65	0.35	0.40	0.50	0.25	0.35	2.85
	≥20	0.20	0.05	-	0.05	0.10	0.15	0.05	0.20	0.25	0.25	0.60	0.65	2.55
June to September	<5	1.05	0.42	0.21	0.25	0.23	0.70	0.60	2.00	8.70	15.20	11.80	6.00	47.16
	6-7	0.30	0.04	-	0.02	-	0.08	0.08	0.80	7.50	11.80	5.80	1.34	27.76
	8-9	0.02	-	-	0.02	0.04	0.14	0.20	0.75	4.00	7.00	2.10	0.40	14.67
	10-19	0.08	-	0.02	0.02	0.02	-	0.14	0.30	3.30	4.30	1.30	0.06	9.54
	≥20	0.04	-	0.02	-	-	-	-	0.10	0.10	0.19	0.19	0.08	0.72
October to November	<5	11.00	8.80	5.00	3.20	2.00	2.80	3.00	2.30	3.90	6.00	11.40	18.00	77.40
	6-7	1.10	0.80	0.50	0.40	0.40	1.10	1.00	1.10	1.30	2.50	2.00	1.53	13.73
	8-9	0.50	0.18	0.22	0.13	0.13	0.36	0.80	0.40	0.34	0.72	0.40	0.50	4.68
	10-19	0.13	0.04	0.04	0.09	0.09	0.31	0.45	0.40	0.22	0.40	-	-	2.17
	≥20	0.22	0.18	0.09	0.04	0.09	0.09	0.04	0.04	0.04	0.09	0.13	0.22	[illegible]

3) The above mentioned wave data from the ship-reports were from the region within 9 degree N to 15 degree N and bounded by the coastline on the east and by longitudes of 71 degree E in the north and 73 degree E in the south. Thus, these wave data represent deep water waves in the large region. Since the bed slope in the relevant sea area is very gentle, from 1/500 to 1/1000, it is expected that waves are attenuated considerably during the propagation from deep to shallow water. During this propagation, sediments are suspended in a water column by large bottom shear stresses due to waves, and these suspended sediments eventually cause siltation. In fact, the wave

heights which were actually measured in the past by using a wave rider buoy, etc. seem to be somewhat smaller than those of ship reports. These data were obtained offshore from Mangalore at a depth less than 30 m.

4) There are two primary roles that waves play on siltation or sediment transport. One is the role in the breaker zone and the other in the area outside of the breaker zone.

5) Breaking waves are remarkable phenomena by which energy transported by waves is dramatically transformed. Before the wave breaking the energy propagates as wave action through the orbital motion of water particles. Through wave breaking, however, the energy is transformed to both translational motion of water and turbulence. Bed materials are suspended by vigorous turbulence and transported by currents generated by wave breaking. Therefore, in general, the sediment transport in the breaker zone is large.

6) The fact that there are no silt and clay and only fine sand exists in the undredged area from the shore line to about 250 m offshore (with the depth of about 5 m) indicates that this area is a breaker zone, where silt and clay are always suspended in water by the disturbances in breaking waves and eventually flow offshore.

7) The role of waves offshore, beyond the breaker zone is to disturb the sea bed by orbital motions of water waves. In deep water, which is defined to be deeper than one half the wave length, both the orbital velocity of a wave immediately above the sea bed and the mass transport velocity are negligible. In general, ocean currents of long periods are too weak to set bed materials into motion. In these circumstances, bed materials consisting of cohesive substances, such as those in the relevant sea area, may be in a compact state. However, in shallow water there is a significant wave orbital velocity immediately above the sea bed. This velocity increases as the water depth becomes shallower and/or the wave height larger and the wave period longer. The wave particle velocity is much larger than ocean currents and sufficient to force bed materials into initial

motion and into suspension. After suspension, even weak ocean currents are able to transport the materials in the direction of the current vector. When the water containing high concentration of sediment flows from shallow to a deeper area namely artificially dredged channel, the sediments fall gravitationally due to the decrease of silt carrying capacity of water. This capacity depends on the strength of shear stresses and turbulence in water. These are the fundamental mechanisms of siltation.

8) The fact that the material silting up the dredged area consists of silt and clay, which are found widely in the surrounding sea bed (deeper than 5 m) suggests that, of the two roles as described above, the latter is more important for siltation mechanisms in this sea area.

8.1.2 The Roles of currents

A second factor affecting siltation is ocean currents, which play a fundamental role in the transport of sediments suspended in water by wave disturbances. Ocean currents are generally weaker than orbital velocity of waves in shallow water in this area, so that they rarely contribute to the initial movement of the bed materials or in forcing bed materials into suspension.

Ocean currents on the open sea coast under consideration may consist of various types, including the general circulation of the ocean, tidal currents, wind driven currents, density currents and wave induced currents. Therefore the ocean currents in this area may be very complex, and it is hard to separate each component of the currents. In fact, actual ocean currents measured using current meters can not be separated into each component. Therefore, to establish a representative current pattern in the relevant area, it is advantageous to use the joint distribution of actually measured current speed and direction. The joint distribution will be shown later.

8.1.3 Characteristics of sediment

A third factor affecting siltation is the characteristics of the bed materials. As described in 2.7.2, silt and clay are widely distributed in the offshore area with a depth greater than about 5 m. These materials clearly cause siltation in the dredged area since the materials filling the channel and the lagoon are silt and clay.

The type of bed materials, whether cohesive or non-cohesive, is an important aspect to be considered while examining sediment transport and the siltation mechanism. The transport of non-cohesive materials such as sand has been studied by many investigators and a large number of sediment transport relationships have been proposed. On the other hand, the mechanism of transportation of cohesive materials is quite complex and is not yet fully understood.

The bed materials consisting of silt and clay in the sea area under consideration may be cohesive and in a compact state during calm seasons. After the onset of the southwest monsoon season a rough wave condition prevails, and bed materials are shaken to loose gradually by wave agitation. Thus, the compacted body absorbs water and loses cohesive force, and finally the bed materials are suspended in the water column. This is the qualitative mechanism of suspension of cohesive materials. Therefore, it is expected that the water content of sediment on the sea bed is high and the bulk density is low during and immediately after the monsoon season. In connection with this, Kamath* reported that during a monsoon season bed materials are in a fluid state and do not have sufficient density for economical dredging.

As described in 2.7.1, the depth in the channel and the lagoon measured in the post monsoon season was fairly uniform both along and across the center line. This situation might arise from the fluid-like flow of bed materials during and immediately after the monsoon season. In this period, the materials contain a lot of water and therefore are able to flow as a density current. This property of bed materials should be taken into account in the estimation of siltation volume.

8.1.4 Source of sediment

The material which silts up the channel and the lagoon probably comes from the surrounding sea bed. Every year the material is dredged and dumped about 10 km offshore from the shore line. It remains to examine the changes occuring in the sea bed around the channel. To clarify this the

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* M.M. Kamath, Dredging for Port Development, Case Study, Maintenance Dredging Practice at New Mangalore Port.

changes of depths at several locations were examined for 8 years based on the sounding maps prepared by the NMPT. These sounding maps cover an area about 5 km alongshore and about 7 km offshore. The results are presented in Figure-8.1.1. From this figure, it can be seen that the depths became shallower year by year at most locations for the 7 years from 1980 to 1987. However, the depths increase slightly from 1987 to 1988.

On the alongshore points 2400 m offshore of the shore line, the changes of depth are not so large and the trend of decreasing depth with time is not so clear compared with that at more offshore points. On the offshore points with distances of 4000 m or more from the shore line, the trend of shoaling year by year can be clearly seen except for the two figures on the line 2000 m north and 4000 m, 5600 m offshore. This phenomenon may mean that this sea area with gentle slope is going to be more gentle year by year.

For a rough estimation of the change of volume of the sea bed, the average change of depths in the area of sounding maps was calculated from 1981 to 1987. There are 36 points at which the depth was taken from sounding maps. These points are on four lines at a pitch of 800 m, situated 2000 m and 400 m north and 400 m and 2000 m south respectively of the center line.

The average value of depth differences from 1981 to 1987 is 0.89 m, and by multiplying by the area of 5 km x 7 km, the change of total volume in the area is about 30 million cubic meters. Therefore, the average siltation volume per year is about 5 million cubic meters in this relatively limited area of 5 km x 7 km. If there exists the same tendency in the surrounding sounding area, the total siltation volume could be surprisingly large.

The channel is almost completely filled with sediment, and a volume of about 3 million cubic meters is dredged and dumped every year in the area outside of the sounding area. This means that about 3 million cubic meters of sediment is removed from the area in question every year. In addition to this removed volume, it is suspected that sediments with volume of about 5 million cubic meters or more of sediment move into the relevant area to make the depth shallower in this area. A question arises as to the source of this large amount of sediments.

There are three possible sources to be speculated. One of them is the worrying possibility that materials dredged and dumped offshore return to

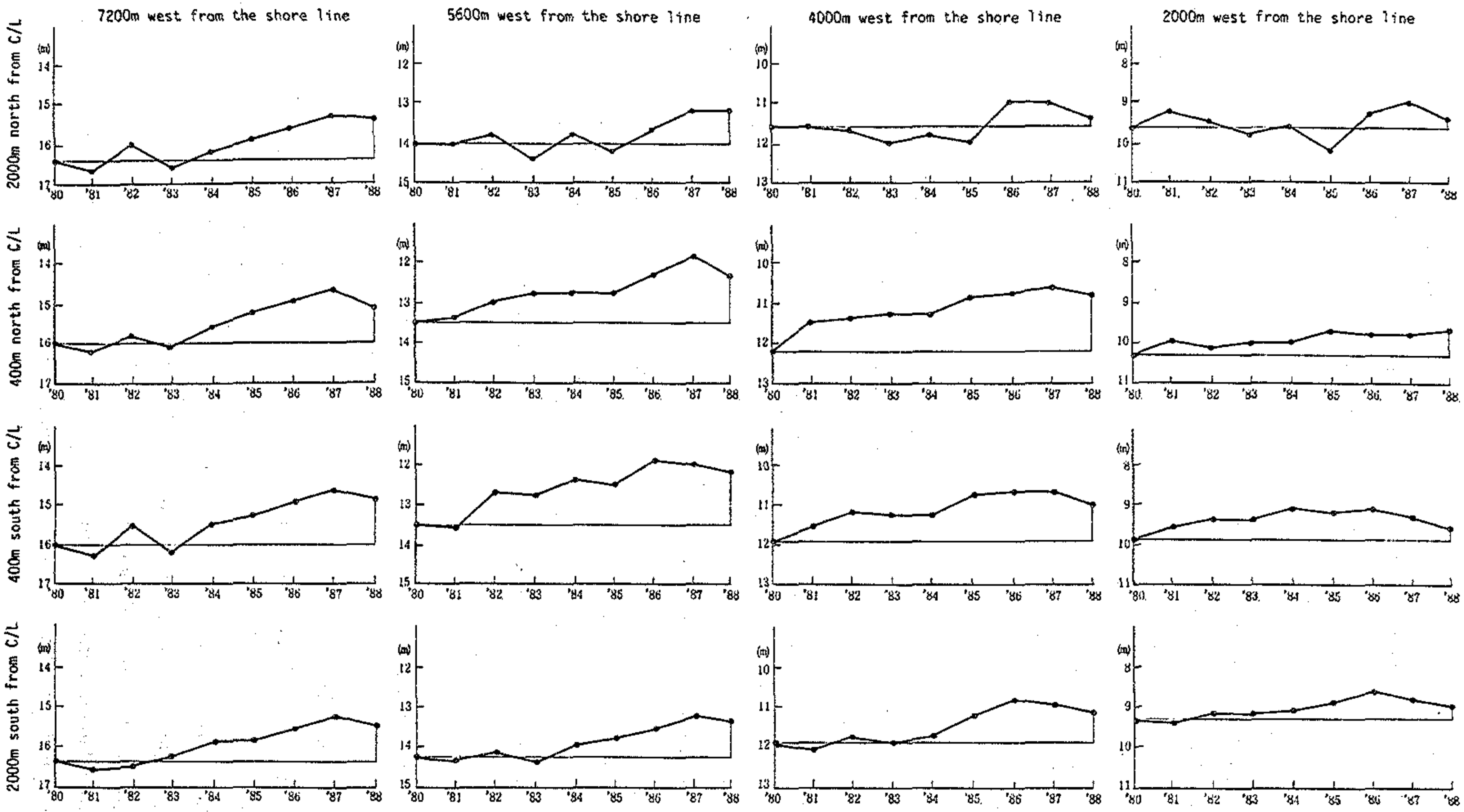

Figure-8.1.1 Yearly Change of Depth around the Channel for 8 Years the relevant area. Although a tracer study to examine this possibility has been planned by an Indian agency, for the 1989 southwest monsoon season, the study has not yet been conducted. Howrver, according to studies using radio active and fluorescent tracers carried out earlier, it is unlikely that the dumped material finds its way back to the channel and the lagoon. Therefore, the dumped material is likely not to be the main source of siltation.

The second possibility is that the large amount of sediments are brought by rivers, namely the Gurpur and the Netravati, whose mouths lie about 10 km south of the New Port. The annual average discharge of the two rivers is about 250 cubic meters per second and the annual maximum discharge in a rainy season is up to about 9000 cubic meters per second. The amount of sediments carried by the two rivers is unknown. In the master plan report of New Mangalore Port, it is clearly stated that the materials deposited near the harbour are from these two rivers. However, the previous tracer studies indicate that the direction of the sediment transport in this area is predominantly southwards. This suggests that sediments carried by the two rivers could not be the main source of siltation around the harbour.

The last possibility is that the yearly change of depths in the relevant sea area is due to a movement of mudbanks. Moni* reported the existence and behavior of mudbanks mainly along the Kerala coast. These mudbanks have scales of the order of 10 kilometers and move on a time scale of the order of decades. It is reported that they definitely influence shore processes and effectively disturb the equilibrium conditions of the southwest coast of India. However, the existence of mudbank at Mangalore has not been reported and hence the contribution of mudbanks to siltation can not be confirmed in the absence of collaborative data.

As mentioned above, there are not enough data to identify the source of siltation. Since the identification of the source of sediments is very important in the siltation problem, it is recommended that surveys to examine the origin of sediments should be conducted in the future.

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* N.S. Moni, Study of Mudbanks Along the Southwest Coast of India

8.2 The Countermeasures

8.2.1 Breakwater

The siltation mechanisms in this port suggested by various data have been discussed in 8.1. It is thought that the primary mechanism of siltation is deposition of fine materials widely distributed on the bed around the channel. These fine materials consisting of silt and clay are suspended in water column by vigorous wave agitation during the southwest monsoon season. After the suspended materials move into the channel and lagoon, they settle gravitationally due to the decrease of silt carrying capacity of water.

Therefore a primary concept in countermeasures against siltation is to prevent inflow of water containing a lot of sediments into the channel and lagoon. One of the most direct measures to mitigate this inflow is the extension of breakwaters.

It is said that littoral sand drift sometimes takes place in a area of depth up to -7m and compact sand accumulates in the channel. This compact sand requires immediate dredging to clear the navigation channel. The extension of breakwaters is also expected to be effective in mitigation of the inflow of sand drift into the channel.

A long extension of breakwaters would be expensive. The construction of breakwaters for the entire channel may be impossible due to financial constraints.

The amount of sediment transported into the channel from the surrounding area is considered to be the largest in the breaker zone and decrease gradually offshore. Therefore, the role of the breakwater extension on the mitigation of siltation is most effective at the initial stage of the extension and gradually decreases its effectiveness as the breakwater is extended offshore. On the other hand the construction cost per unit length of breakwater extension is smaller in the initial stage and increases gradually as the breakwater is extended into deeper water. From this reason, the sum of the construction cost of breakwater and the cost of maintenance dredging (not the cost per year but the total cost of dredging for several ten years of project life) is expected to be a function of the length of the breakwater extension with the minimum at a certain length of the extension.

8.2.2 Submerged-type breakwater

The inflow of suspended sediments may be prevented by a submerged-type breakwater. The concept for this structure is based on the fact that, in general, sediment concentration in water is high near the bottom rather than near the surface, so that sediment transport near the bottom accounts for most of the total sediment load in the entire water column.

The effect of submerged-type breakwater as a countermeasure against siltation has been tested in Kumamoto Port, Japan. The sediments on the bed around Kumamoto Port consist of silt and clay. The water content of the bed material is about 200% by weight. This is somewhat similar with that in New Mangalore Port. In Kumamoto Port, two areas, each of 50m x 50m with depth of about 4m, were dredged to a depth of 6m in order to examine the effect of this submerged type structure on siltation. A submerged structure with a height of 1m above the bed was made to surround one of the dredged areas. The other test area had no surrounding structure. The annual siltation depth was observed to be greater than 1m in the area without the submerged structure. However, in the area with the submerged structure the annual siltation depth was about 0.2m.

According to the result of this small scale test dredging, a submerged-type breakwater seems to be effective for the mitigation of siltation at least under similar environmental conditions like Kumamoto Port in Japan. However, this conclusion is based only on a result of a small scale test dredging and not yet verified in a prototype channel. Therefore, a submerged breakwater is not considered in the present report as a countermeasure against siltation. In view of the possibility that a submerged breakwater works effectively to mitigate siltation, it may be, however, worthy to test the effect of a submerged breakwater on siltation at the time of improvement of New Mangalore Port, by constructing a part of the breakwater as a submerged type.