8.3 Estimation of the Effect of the Breakwater Extension on Siltation

8.3.1 Model

(1) Concept of Modelling

According to a result of sounding survey carried out in the post-monsoon period, the channel depth in the area more than 2km offshore from the base line is almost the same as the original depth in the surrounding area. This means that the channel is almost completely filled by siltation. On the other hand, in the harbour area, the thickness of siltation decreases from the base line to the head of the harbour with the bottom slope of about 1/2000. This small bottom slope, together with the fact that the large siltation thickness is found in the area in front of the Iron Ore Berth, which is dredged deeply every year, indicates that the mobility of inflowing sediment is very large.

From these evidences, the siltation of the part of the channel surrounded by the breakwaters and in the harbour area is considered to be a result of the movement of very fine sediment as a density current along the channel. The original source of this sediment may be a longshore drift of bottom materials transported into the channel where no breakwater exists. Of course, there may be a part of siltation which is a result of sedimentation of solid materials suspended by wave actions in the monsoon period and then transported into the harbour by advective-diffusive mechanisms.

However, according to a result of a numerical simulation using an advective-diffusive model, it was not possible to reproduce the very flat and small slope of the water bottom. Thus, it may be concluded that the influx of solid materials into the harbour was mainly caused by the movement of the sediment as a density current. The material was originally transported into the channel by a longshore drift.

Taking these factors into account, the siltation is estimated by two models. The first is the Swanby model, by which the inflow of solid material into the channel is estimated. The Swanby model was used in the past by CWPRS for the estimation of siltation in New Mangalore Port and another major ports in India.

The second is a sediment transport model, by which the slow movement of solid material along the channel is formulated as a density current. Although there is no literature documenting the application of the latter model to a realistic situation, we believe that this modelling is adequate and necessary from an engineering and practical point of view, taking into account the actual situation of siltation in New Mangalore Port.

(2) The Swanby Model

CWPRS has used the Swanby approach to estimate total sediment load and consequently estimate the siltation volume of artificially dredged channels in open sea coasts. The Swanby approach has been also applied to estimate the siltation volume of the channel of New Mangalore Port. It has been stated that the Swanby approach is conceived mainly to calculate the sediment transport in coastal zones where both waves and currents are important. It can be used in the breaker zone and in the offshore zone. This approach is widely used at present, and it is thought that the model is applicable to the estimation of siltation volume of the channel outside the breakwater.

The formula for this approach has been summarized, according to CWPRS, as follows:

The total sediment load in the sea near the coastal region consists of suspended load and bed load. As it is difficult to separate the suspended load and bed load transport in coastal areas, the formula giving the total sediment transport has been selected for computation in coastal areas. One such formula for total sediment transport is that given by Ackers and White. This formula deals with the total sediment transport in a field where only currents exist. To extend the applicability of the formula into a field where both currents and waves exist, the shear velocity due to only current is replaced by the shear velocity due to both wave and current. In this manner the following formula for total sediment transport under the action of waves and currents has been derived:

$$Qs = \frac{B}{(1-e)} D35\ V \left(\frac{Ch}{g1/2}\right) Iwc^{1-n} \frac{Cdgr}{A^{m}} (Fwc-A)^{m} \quad \ldots\ldots\ldots\ldots (1)$$

where, Qs : total sediment transport

e : porosity of the material

V : mean current velocity

D35 : particle diameter

Ch : Chezy coefficient

g : gravity acceleration

Iwc : square root of the shear stress ratio ($\tau wc/ \tau c$)

$Cdgr = \exp [2.86 \ln (Dgr) - 0.4343 [\ln (Dgr)]^2 - 8.128]$

: dimensionless parameter

$$Dgr = D_{35}\left(\frac{g \Delta s}{\nu^2}\right)^{1/3}$$

: dimensionless grain size parameter

$\Delta s = (\rho s - \rho w)/\rho w$

: relative specific gravity

ρs : density of sediment

ρw : density of water

ν : kinematic viscosity of water

$A = 0.23\ Dgr^{-1/2} + 0.14$

: a critical value with respect to the beginning of sediment movement

$Fwc = V I^n_{wc}\ C_D^{n-1}\ Ch^{-n}\ (\Delta S\ D_{35})^{-1/2}$

: sediment mobility number

$n = 1 - 0.2432 \ln (Dgr)$

$m = 9.66\ Dgr^{-1} + 1.34$

B = empirical coefficient which is determined by a calibration process

Chezy coefficient, Ch is expressed as follows:

$$Ch = 18\log_{10}\left(\frac{12h}{Rh}\right)$$

where h is local water depth and Rh ripple height. The shear stress ratio ($\tau wc/ \tau c$) is expressed as follows:

$$\tau wc/ \tau c = 1+0.5\left(\xi \frac{u_o}{v}\right)^2$$

where τwc is the shear stress due to waves and currents, τc is the shear stress due to the current given by $\tau c = \rho wg\ V^2\ Ch^{-2}$, u_o is the orbital velocity at the bottom due to waves and V the mean velocity. ξ is the Bijker's parameter, expressed as follows,

$$\xi = Ch \left(\frac{fw}{2g} \right)^{1/2}$$

where, fw is the friction coefficient and expressed as follows:

$$fw = \exp\left[-5.97 + 5.213/(a_0/Rh)^{0.194}\right]$$

where a_0 is the diameter of orbital motion due to waves.

Only when the sediment mobility number, Fwc is larger than A in the formula (1), sediment transport takes place.

When this formula is applied to estimate siltation volume of an artificially dredged channel, the relevant parameters namely local water depth, mean velocity etc., are changed due to the difference of water depth between the general depth and the artificially deepened channel.

The input parameters required for the computation are as follows.

(i) Sediment data - D_{35}, D_{50}, Gs, P

D_{35} and D_{50} are the percentage of sediment finer than D_{35} and D_{50} values in mm

Gs = Specific gravity of sediment, normally taken as 2650 kg/m^3

P = Porosity of sediment, taken as 0.75 from soil density

(ii) Current and wave data - wave heights in respective durations, wave period in sec (T), existing velocity in m/s (VE)

(iii) Bed and channel data - Ripple height in mm (RH), ρ_w (density of water), ν, dredged depth in m (DEP), existing depth in m (HE) with corresponding lengths in m (ℓ)

ν = Kinematic viscosity of sea water, taken as 1×10^{-6} m^2/s.

To evaluate the sediment volume transported into the channel by means of the Swanby formula, the channel is segmented into every 500m in length. And in each segment, the local conditions such as the existing depth and the wave condition are specified. The wave condition is specified on the basis of the wave climate for the monsoon period in the past. The local wave height in each segment of 500m in length is determined by the wave-height ratio for each location calculated by a simulation model of the shallow water wave deformation. The water current condition is set on the basis of past observations in the period of south-west monsoon.

Another parameters except porosity are set to the same values as used in the computation of siltation volume in the channel of New Mangalore Port by CWPRS.

(3) A Model of Sediment Transport in the Channel and Lagoon

Let us consider the amount of sediment transport along the channel per unit width and unit time. If we assume that the sediment is able to flow as a density current, the phenomena can be described by the following equation in its main aspects;

$$\frac{\partial Q}{\partial t} = - g' h_* \frac{\partial h}{\partial x} - \tau \quad \cdots\cdots (2)$$

where,
- Q : amount of sediment transport along the channel per unit width and unit time,
- g' : $(\Delta\rho/\rho)g$, $\Delta\rho$: difference of sediment and water density, g: acceleration due to gravity, g' is called reduced gravity,
- h_* : thickness of sediment transport,
- h : deposition height of sediment from a reference height,
- τ : shear stress,
- t : time,
- x : length along the channel from a reference point.

The first term on the right handside of eq. (2) represents the inflowing sediment which is assumed to behave as a density current.

A recent conceptual model of cohesive sediment transport has been proposed as shown in Figure-8.3.1.

This figure shows that there is a layer of mobile fluid mud with high sediment concentration between water column including suspended sediment and cohesive bed. The sediments deposited in the channel during and just after the monsoon season are thought to have considerable fluidity and to correspond to the layer of mobile fluid mud in Figure-8.3.1. The water depth detected by echo-sounder corresponds to the depth of lutocline in the figure, and so called nautical depth is thought to be in the layer of stationary mud in the figure.

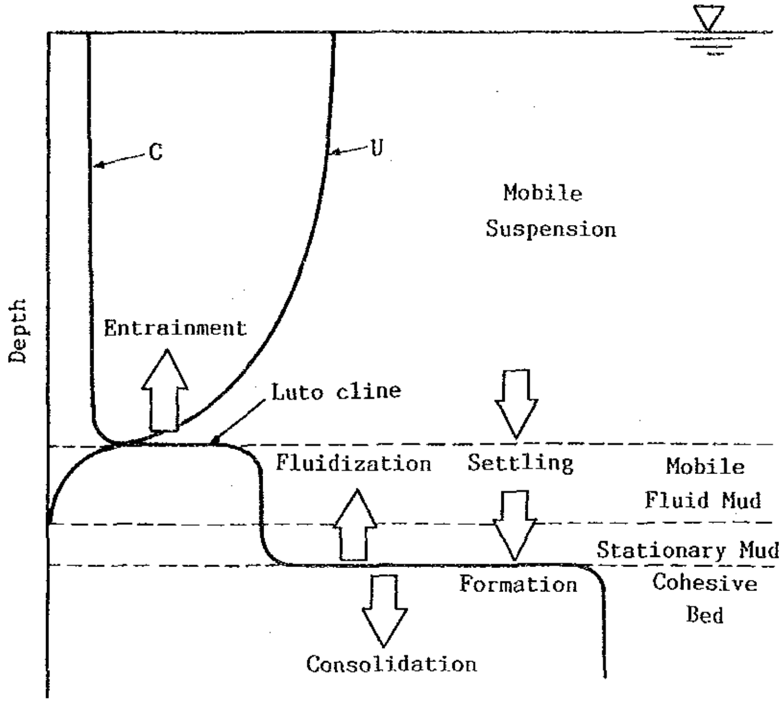


Figure-8.3.1 Idealized Profiles of Instantaneous Vertical Concentration and Velocity

(A.J. Mehta, On estuarine cohesive sediment suspension behavior, JGR, Vol.94 No. C10, 14303-14314, 1989)

Although the thickness of sediment transport, h_* in eq. (2) is considered to correspond to the thickness of mobile fluid mud in the figure, the value can not be known definitely. Though about 10cm as a value of h_* has been obtained based on a laboratory experiment, it is not clear whether this value is applicable to prototype or not.

Next, the shear stress, τ in eq. (2) can be expressed as follows;

$$\tau = \nu \frac{\partial u}{\partial z}$$

where, τ : shear stress,

ν : kinematic viscosity of fluid mud,

$u = u(z)$: vertical distribution of horizontal velocity of fluid mud along the channel,

z : vertical coordinate.

If we assume that the vertical velocity distribution in the fluid mud is linear like a laminar flow, τ may be put as follows;

$$\tau = \nu \frac{2u_*}{h_*}$$

where u_* is average velocity in the fluid mud. From the definition, $Q = h_* u_*$, τ is rewritten as

$$\tau = \nu \frac{2Q}{h_*^2} \quad .$$

Substituting the above equation into eq.(2), and neglecting the acceleration term, $\partial Q/\partial t = 0$, because of the very slow change of a phenomenon of mud flow, it follows that the solution for Q becomes,

$$Q = -\frac{g' h_*^3}{2\nu} \frac{\partial h}{\partial x} \quad \cdots\cdots\cdots(3)$$

This is rewritten as

$$Q = -\alpha \frac{\partial h}{\partial x} \quad \cdots\cdots\cdots(4)$$

where,

$$\alpha = g' h_*^3 / 2\nu$$

On the other hand, the variation of the bottom surface due to the mud flow Q is given by a continuity equation,

$$\frac{\partial h}{\partial t} = -\frac{\partial Q}{\partial X.} \quad \cdots\cdots\cdots(5)$$

Equations (4) and (5) are a set of differential equations representing the processes of sediment movement along the channel. The coefficient α in equation (4) is not clear what value takes in the case of mud flow. Thus, the value of α is assumed in such a way that the actual situation is most faithfully reproduced.

The values of h in each 500m segment of the channel are obtained by evaluating the influx of sediment into the channel by means of the Swanby formula. Taking these values as an initial condition, the movement of sediment inside the channel takes place following equations (4), (5) and finally the siltation is produced in the channel surrounded by the breakwaters and in the lagoon. The movement of sediment in the channel is not restricted in the direction of the inner channel and lagoon but occurs in the offshore direction also from the location near the breaker zone where the sediment influx from outside is the largest. Therefore, it is possible that, in some offshore segments of the channel, the siltation volume becomes larger than the volume of sediment directly transported from the surrounding area into these segments.

The computation of the influx of sediment by the Swanby formula, and the computation of the redistribution of sediment inside the channel and lagoon by equations (4) and (5) are performed alternately, every 0.3 days.

(4) Wave Condition

From the analysis of the sounding maps, it is clear that the rough wave condition during the southwest monsoon season is mainly responsible for siltation. Therefore wave climate during the monsoon season should be established.

At the time of preparing the designs for New Mangalore Harbor Project, a wave observation was performed from 1968-1969 for a period of about 18 months (Jade Dattatri, Waves off Mangalore Harbour - west coast of India, Journal of the Waterways, Harbours and Coastal Engineering Division, Proceeding of the American Society of Civil Engineers, Vol. 99, No. WW1, Feb. 1973). A wave recorder was installed at a location about 1.5km west of the harbour, in a water depth of about 10m.

1) Wave height distribution

Figure-8.3.2 shows the cumulative distribution of the significant wave height and the height of the highest wave in the recording interval. From this, for example, it can be seen that the significant wave height exceeds 1m for 26% of the time, and 2m for 10% of the time.

The variation in wave hights between the southwest monsoon season and the other season is sufficiently large. Figure-8.3.3 shows the distribution of occurrence of the highest waves during the southwest monsoon season and the fair-weather season. During the fair-weather season, for more than 90% of the time, the wave heights are less than 0.8m. During the monsoon season, the wave heights exceed 3.2m for about 20% of the time.

In order to set the wave condition for every month during the monsoon season, the same data set has been used. Table-8.3.1 shows the cumulative distribution of the significant wave height from June to September. The distribution of the significant wave height in Table-8.3.1 has been used as the wave condition in the Swanby model computation.

Table-8.3.1 Cumulative Distribution of the Significant Wave Height from June to September (1968)

month	percentage of time, significant wave height exceeded					
	0.5m	1.0	1.5	2.0	2.5	3.0
June	100	97	55	25	8	1
July	100	73	31	17	3	1
August	100	94	25	3	0	0
September	100	18	0	0	0	0

IMOBCO International Inc., Report of wave & current studies pertinent to an offshore terminal site at Mangalore.

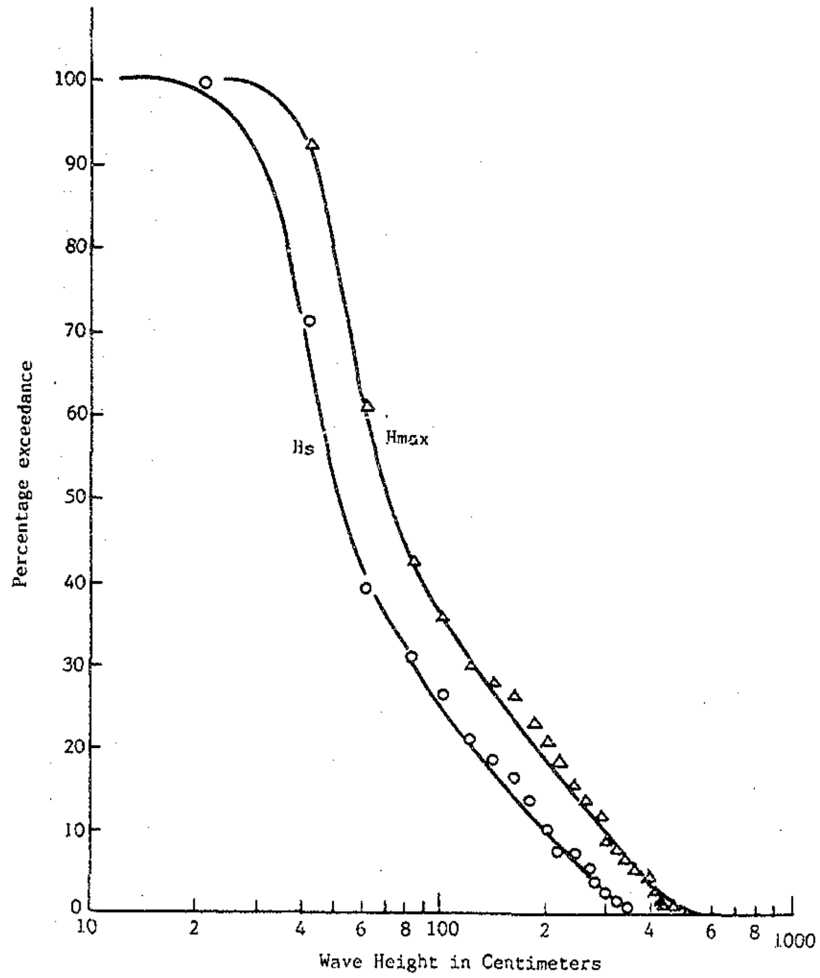


Figure-8.3.2 Cumulative Distribution of Significant Wave Height and Maximum Wave Height

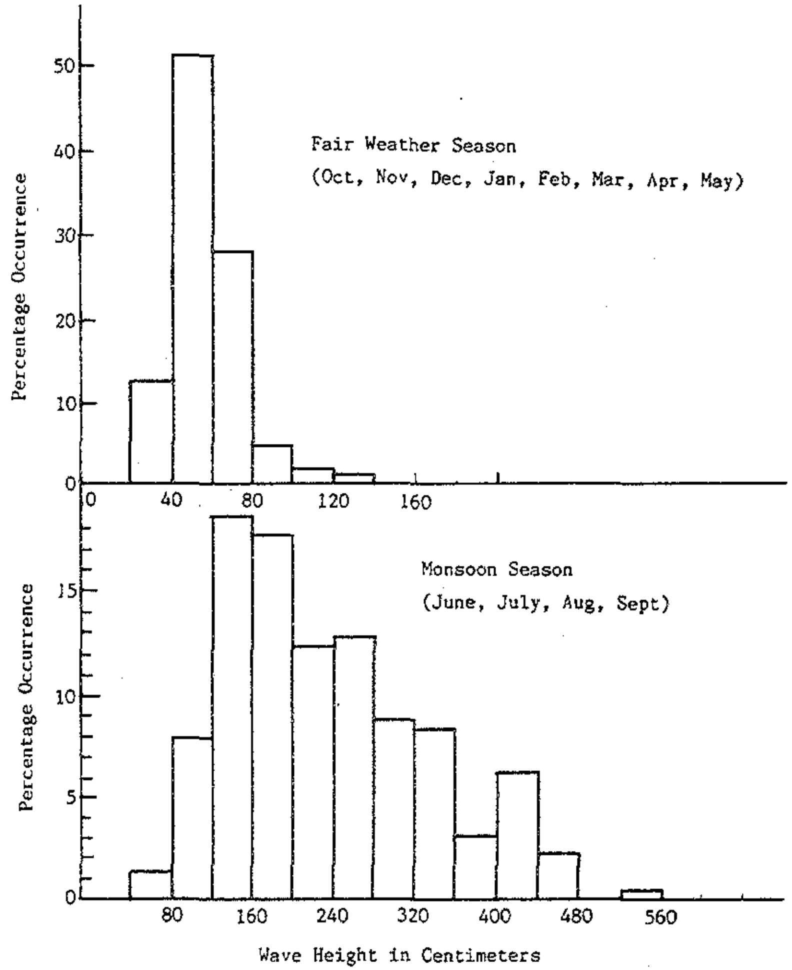


Figure-8.3.3 Frequency Distribution of Maximum Wave Height

2) Wave period

Figure-8.3.4 shows the distribution of zero-crossing period during the two seasons. Nearly 95% of the observations fall within the range of 8 and 11 sec during the monsoon period. The predominant period is approximately 10 sec. Therefore the representative wave period has been taken as 10 sec.

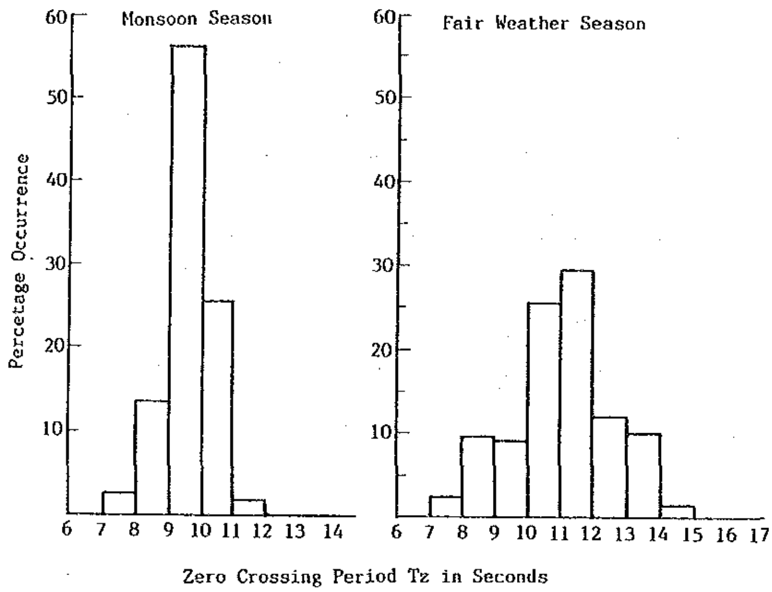


Figure-8.3.4 Distribution of Zero-Crossing Period

3) Local wave height

In order to estimate the siltation volume for every 500m segment of the channel, it is necessary to determine wave conditions in-and outside of the channel corresponding to every segment. To do this, the spacial distribution of the wave height ratio has been used, which has been produced by a numerical model of wave transformation in shallow water. This simulation method is presented in Appendix-10.1.

(5) Current Condition

Ocean currents play a primary role in the transport of suspended sediment for siltation. Ocean currents on an open sea coast are complicated, and it is advantageous to establish a representative ocean current pattern based on a actually measured current data during the southwest monsoon season for the estimation of siltation volume.

Actually measured ocean currents, during the southwest monsoon season, are presented in Table-8.3.2 and Table-8.3.3 which show joint distributions of ocean current speed and direction. Figure-8.3.5 and Figure-8.3.6 show the frequency of occurrence of ocean current direction and speed produced from the same data source in Table-8.3.2 and Table-8.3.3 respectively.

As can be seen in Figure-8.3.5, the direction of current in 1972 was predominantly towards south-southwest to south during both of two observation periods. In these periods periodic tidal currents were weak and ocean currents of subtidal periods prevailed, according to raw current data. The current speed was predominantly 15 cm/s to 25 cm/s.

By contrast, as can be seen in Figure-8.3.6, the direction of current in 1973 was bimodal and the dominant speed range was 5 to 15 cm/s. During this period periodic variations of the currents with tidal cycle were observed in raw data.

Thus, current conditions varied for each observation. Here, the representative current speed is taken to be 15cm/s from the above two observations.

Table-8.3.2 Joint distribution of ocean current speed and direction 8 km offshore from the shore line at Mangalore. The total water depth at the measured point is about 20 m and the measurement was performed 2m above the bed. The time interval of measurement is 10 minutes.

(a) Observation period: August 11 to August 29, 1972
upper (times of occurrence), lower (%)

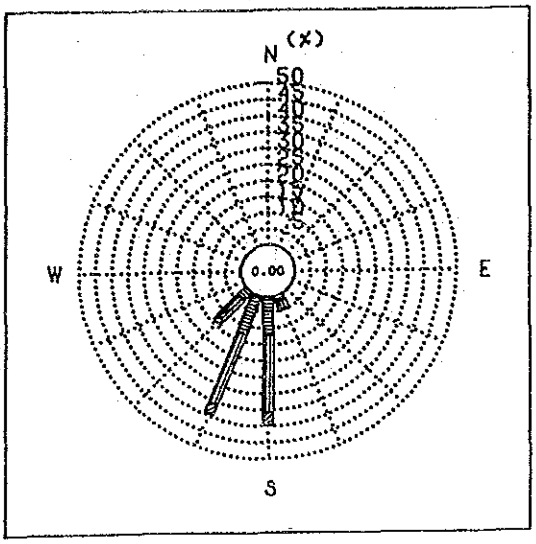
speed \ direction	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	N	①
v≤ 0.0																	0 0.0
0.0 <v< 5.0																	0 0.0
5.0 ≤v< 10.0																	0 0.0
10.0 ≤v< 15.0							2 0.1	14 0.5	32 1.2	4 0.2							52 2.0
15.0 ≤v< 20.0							48 1.8	305 11.7	297 11.4	83 3.2							733 28.1
20.0 ≤v< 25.0				1 0.0			44 1.7	414 15.9	398 15.2	151 5.8		2 0.1					1010 38.7
25.0 ≤v< 30.0							28 1.1	203 7.8	213 8.2	87 3.3	1 0.0	5 0.2	2 0.1				539 20.7
30.0 ≤v< 35.0							7 0.3	77 3.0	71 2.7	39 1.5	2 0.1	9 0.3	7 0.3	3 0.1		1 0.0	218 8.3
35.0 ≤v< 40.0				2 0.1			7 0.3	25 1.0	20 0.8	4 0.2		1 0.0					59 2.3
40.0 ≤v< 45.0										1 0.0							1 0.0
45.0 ≤v< 50.0																	0 0.0
50.0 ≤v																	0 0.0
sub-total	0 0.0	0 0.0	0 0.0	3 0.1	0 0.0	0 0.0	136 5.2	1038 39.8	1031 39.5	369 14.1	3 0.1	17 0.7	9 0.3	3 0.1	0 0.0	1 0.0	2610 100.0
mean speed				32.5			22.7	22.9	22.8	23.5	31.4	30.2	30.8	31.1		33.8	23.0

(① Sub-total Unit of speed is cm/s.

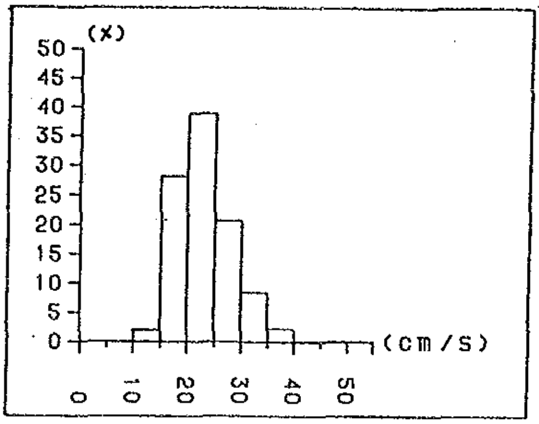
(b) Observation period: August 29 to September 15, 1972
upper (times of occurrence), lower (%)

speed \ direction	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	N	①
v≤ 0.0																	0 0.0
0.0 <v< 5.0																	0 0.0
5.0 ≤v< 10.0																	0 0.0
10.0 ≤v< 15.0							29 1.2	250 10.2	266 10.9	57 2.3							602 24.6
15.0 ≤v< 20.0				1 0.0			93 3.8	603 24.6	560 22.9	123 5.0							1380 56.3
20.0 ≤v< 25.0							14 0.6	137 5.6	161 6.6	33 1.3		1 0.0	1 0.0	2 0.1			349 14.3
25.0 ≤v< 30.0							2 0.1	52 2.1	39 1.6	6 0.2							99 4.0
30.0 ≤v< 35.0								12 0.5	6 0.2	1 0.0							19 0.8
35.0 ≤v< 40.0																	0 0.0
40.0 ≤v< 45.0																	0 0.0
45.0 ≤v< 50.0																	0 0.0
50.0 ≤v																	0 0.0
sub-total	0 0.0	0 0.0	0 0.0	1 0.0	0 0.0	0 0.0	138 5.6	1054 43.0	1032 42.1	220 9.0	0 0.0	1 0.0	1 0.0	2 0.1	0 0.0	0 0.0	2449 100.0
mean speed				19.9			17.0	17.4	17.4	17.3		22.8	21.5	21.5			17.4

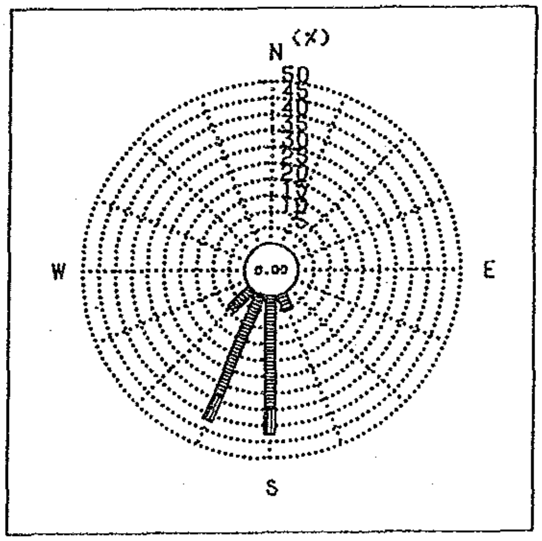
(① Sub-total Unit of speed is cm/s.



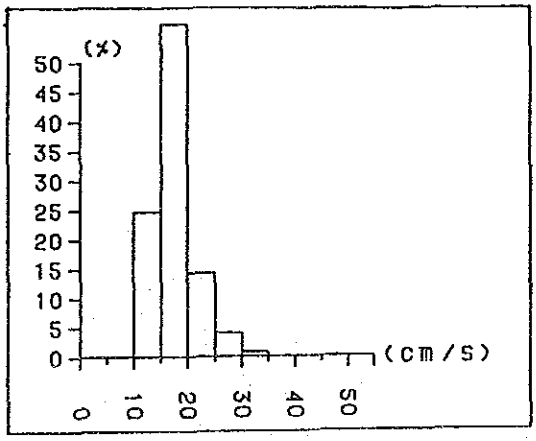
(a) Frequency of direction



(b) Frequency of speed



(c) Frequency of direction



(d) Frequency of speed

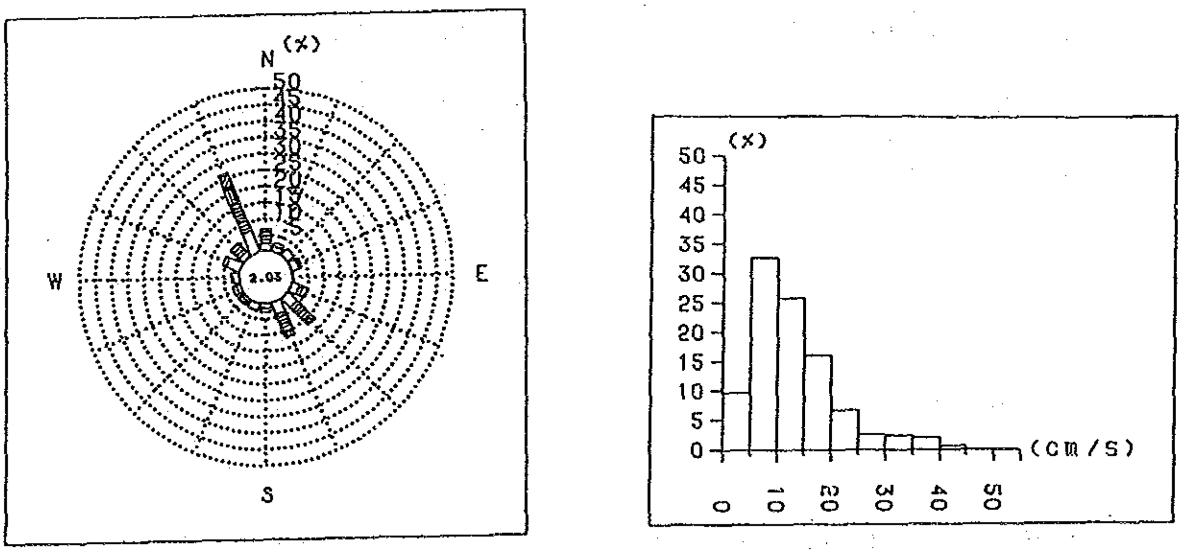
Figure-8.3.5 Frequency of occurrence of ocean current direction and speed(I). The data source is the same as in Table-8.3.2. (a)(b) From August 11 to August 29, 1972, (c)(d) From August 29 to September 15, 1972.

Table-8.3.3 Joint distribution of ocean current speed and direction offshore from Mangalore at a depth of 18.6m. Measurement was performed 3m above the bed between May 25 to June 8, 1973. The time interval of measurement is 60 minutes.

Upper (times of occurrence), lower (%)

speed \ direction	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	N	①
V≤ 0.0																	7 2.0
0.0 <V< 5.0	1 0.3	1 0.3	3 0.9	1 0.3	3 0.9	4 1.2	3 0.9	2 0.6	4 1.2	1 0.3		2 0.6	1 0.3	2 0.6	3 0.9	2 0.6	33 9.6
5.0 ≤V< 10.0	5 1.5	8 2.3	6 1.7	1 0.3	6 1.7	10 2.9	11 3.2	4 1.2	4 1.2	3 0.9	1 0.3	5 1.5	15 4.4	5 1.5	22 6.4	6 1.7	112 32.6
10.0 ≤V< 15.0	2 0.6	1 0.3	3 0.9		10 2.9	10 2.9	7 2.0	4 1.2	1 0.3	2 0.6	3 0.9	2 0.6	4 1.2	11 3.2	21 6.1	7 2.0	88 25.6
15.0 ≤V< 20.0	2 0.6					12 3.5	14 4.1	1 0.3		2 0.6	5 1.5			2 0.6	11 3.2	6 1.7	55 16.0
20.0 ≤V< 25.0						4 1.2	5 1.5								11 3.2	3 0.9	23 6.7
25.0 ≤V< 30.0						1 0.3	1 0.3								7 2.0		9 2.6
30.0 ≤V< 35.0															8 2.3		8 2.3
35.0 ≤V< 40.0															7 2.0		7 2.0
40.0 ≤V< 45.0															2 0.6		2 0.6
45.0 ≤V< 50.0																	0 0.0
50.0 ≤V																	0 0.0
sub-total	10 2.9	10 2.9	12 3.5	2 0.6	19 5.5	41 11.9	41 11.9	11 3.2	9 2.6	8 2.3	9 2.6	9 2.6	20 5.8	20 5.8	92 26.7	24 7.0	344 100.0
mean speed	8.9	6.7	6.6	4.5	8.7	12.1	12.9	8.7	5.2	10.9	13.2	7.0	7.8	10.3	17.7	12.7	12.3

① Sub-total Unit of speed is cm/s.



(a) Frequency of direction (b) Frequency of speed

Figure-8.3.6 Frequency of occurrence of ocean current direction and speed(II), The data source is the same as in Table-8.3.3.

8.3.2 Estimation of the siltation volume

(1) Calibration of the Model

Model parameters have been calibrated so that the model described in the previous sub-section faithfully reproduce the present situation of siltation. The model parameters which should be calibrated are B in eq.(1) and α in eq.(4) in 8.3.1. A result in the case of B = 4.5 and $\alpha = 0.5 m^2/s$ is shown in Table-8.3.4 in which the actual siltation volume is shown for comparison. It can be seen that the model output almost coincides with the actual siltation volume. In this case, the total sediment load inflowing to the channel outside the breakwater has been simulated to be 10.1 million m^3 during 4 months of the monsoon season, and total sediment load outflowing from the channel has been calculated to be 5.4 million m^3 during the same period. Therefore the net inflow volume to the channel is 10.1 - 5.4 = 4.7 million m^3. This value does not coincide with the value 3.3 million m^3 of the simulated siltation volume. This means that the balance 4.7 - 3.3 = 1.4 million m^3 flow offshore along the channel. A large sediment load amounting to 5.4 million m^3 is outflowing from the channel and this outflow arises from the situation that the channel is completely filled up at sometime during the computation. From these simulation results, it appears that the potential power of siltation is very large.

Table-8.3.4 Comparison of Siltation Volume between Model Output and the Actual Siltation

(million m^3)

	Channel (a)	Lagoon (b)	(a) + (b)
Model output	2.26	1.02	3.28
Actual Siltation	2.48	0.95	3.43

(2) Estimation of Siltation Volume for Various Lengths of Breakwater

In order to decide the optimum length of the breakwater, calculation of siltation volume has been performed for cases with various lengths of the breakwater from 500m (corresponds to the present situation) to 2,500m with a pitch of 500m. The results are shown in Table-8.3.5.

In these cases, the outer approach channel has been planned to be -17m deep, 270m wide with a side slope of 1/5, and 7,500m long. This length of the channel is about 2,500m longer than the present channel length. The water volume of the channel outside the breakwaters with a length of 500m is about 12 million cubic meters in the plan, while the value in the present situation is 2.9 million cubic meters.

From Table-8.3.5, we can see that the siltation volume in the case with a length of 500m is 9.3 million m^3 and the siltation volume decreases as the length of the breakwater becomes longer. The amounts of the decrease in siltation volume are 2.2 million m^3 for the first extension of 500m and 1.0 million m^3 for each extension of 500m after that. Thus, the breakwater extension appears to be very effective for the mitigation of siltation.

Table-8.3.5 Estimation of Siltation Volume for Cases with Various Lengths of the Breakwater

(million m^3)

length of the breakwater	Channel outside the breakwater	Channel inside the B.W. and Lagoon	Total
500 m	7.3	2.0	9.3
1,000 m	5.6	1.5	7.1
1,500 m	4.6	1.5	6.1
2,000 m	3.7	1.4	5.1
2,500 m	2.9	1.2	4.1

9. DREDGING

9.1 Dredging History at New Mangalore Port

9.1.1 First-stage development

New Mangalore Port is located midway between Mormugao and Cochin on the west coast of India. The port was declared Indian ninth major port in May 1974 and was commissioned in May 1975 to cater to requirements of vessels drawing a draught of -9.15 m and the following depths were provided in the various zones:

Outer approach channel----	- 10.7 m from Chart Datum (CD)
Lagoon ----	- 10.1 m from CD
Alongside berths ----	- 9.75 m from CD

The total area of the lagoon is 704,900 m^2 and the channel's width and length are 152 m and 3,210 m, respectively. The diameter of the turning circle is 366 m.

New Mangalore Port is an artificial lagoon harbour. Initially, in 1970, the dredging was carried out by the deployment of a locally fabricated cutter suction dredger. This work was continued by the addition of two (2) more cutter suction dredgers owned by the Ministry of Shipping and Transport (called the Ministry of Surface Transport: MOST, now) and operated by the Shipping Corporation of India (SCI) by 1972. Also, the contract dredging was awarded to M/S Dredging Consortium India B.V., a consortium of four (4) Dutch firms, in 1973. The entire dredging work was completed in 1975 except that specified below.

During the dredging operations, certain hard patches were encountered inside the lagoon. These were subsequently cleared by underwater drilling and blasting during the dredging in connection with the Kudremukh Development Scheme as the cutter suction dredgers were not able to clear the patches.

9.1.2 Kudremukh development scheme

At the end of 1976, the Government of India approved a scheme for the development of New mangalore Port, which was needed to facilitate the export of 7,500,000 tons of Kudremukh Iron Ore Co. concentrates to Iran.

The port was deepened to provide for vessels drawing a draught of 12.5 m. The following depths were provided in the various zones:

Outer approach channel	--- - 13.5 m from CD
Lagoon	--- - 13.0 m from CD
Iron Ore berth	--- - 13.0 m from CD

The channel's width and length are 245 m and 5,340 m, respectively. The diameter of the turning circle is 490 m.

Trailer suction hopper dredgers were mainly employed for this dredging. However, in shallow areas up to a depth of about - 8 m, cutter suction dredgers were used, since trailer suction draggers were not able to navigate in these areas. They were also used for the hard compact sand that was encountered in the outer approach channel. One (1) trailer suction hopper dredger was owned by the Mormugao Port Trust. Other dredgers were owned by Dredging Corporation of India (DCI), whose dredgers were transfered from MOST.

As mentioned above, certain hard patches were encountered in the lagoon during the final part of the first stage of development. Sonic prospecting followed by jet probing and rock drilling confirmed these hard patches to be rock pinnacles with very steep side slopes. The rock mainly consisted of hard granite overlaid with soft weathered rock. The unconfined compression strength of the hard rock was in the region of 1,000 kg/cm^2. The rock was cleared by underwater drilling and blasting using a jack-up platform (drill rig) in most of the areas. In a few isolated patches, shaped charges were also used. The rock dredging contract was awarded to M/S Essar Construction Ltd. (India) in collaboration with M/S Ingenoir F. Selmar (Norway).

9.1.3 Present conditions and the proposed development scheme

A large amount of siltation occurs at New Mangalore Port during the monsoon period from June to September. The average depths of siltation in the outer approach channel and the lagoon is about 1.8 m and 1.6 m, respectively. Therefore, maintenance dredging is necessary to keep the depth required for ships to Navigate. However, in view of financial constraints, maintenance dredging in the lagoon and the outer approach channel is being carried out on the basis of restricted width and limited depth.

Future development scheme of New Mangalore Port is designed to enable it to cater to the requirements of larger ships, that is, these of 100,000 DWT or more. The principal requirements are as follows.

Table-9.1.1 The Requirements of Future Development Scheme

(Unit: m)

	100,000DWT	130,000DWT	150,000DWT	170,000DWT
The depth of the channel	-17.0	-18.5	-19.0	-19.5
The length of the channel	7,900	8,860	9,180	9,500
The width of the channel	275	290	300	310
The depth of the lagoon	-16.5	-18.0	-18.5	-19.0
The turning circle's diameter	550	580	600	620

9.2 Dredging Fleet

9.2.1 General

There are many kinds of dredgers. They vary according to factors such as soil characteristics, topographic conditions, etc. The characteristics of the dredgers deployed at New Mangalore port are briefly described as below.

(1) Cutter Suction Dredger

A cutter suction dredger can carry out dredging and reclamation work at the same time and has a wide applicability for various soils. This type of dredger is mostly non-propelled and has a pontoon-type hull in which a powerful dredging pump is installed. A cutter suction dredger consists of ladder, suction pipe, cutter, main pump and engine, spud frame and spud and so on. Two (2) spuds are used in the swinging and stepping-forward movement of the dredger. During dredging, the delivery pipeline, consisting of a floating line and a shoreline, is connected with the dredger. The bottom materials are excavated by a cutter and sucked up by a dredging pump and then transported to the delivery site through pipelines.

(2) Trailer Suction Hopper Dredger

A trailer suction hopper dredger sucks up bottom materials while in motion. It has two (2) dredge pumps, two (2) ladders and two (2) pipes on the port and starboard sides and one (1) large hopper which is stocked with dredged materials. A trailer suction hopper dredger transports materials to the delivery site itself. It is equipped with a high-pressure water jet device which is used for the excavation and agitation of bottom materials, instead of a cutter.

(3) Grab Dredger

A grab dredger is vessel on which one (1) or two (2) grab cranes are mounted. Dredging work is performed by swinging the crane and excavating the bottom materials with the grab-bucket. There are two (2) types of grab dredger: with and without hopper. The former is self-propelled and can carry dredged materials by itself, while the latter carries out dredging work only and dredged materials are carried by a hopper barge.

9.2.2 First-stage development

(1) Midget Dredger

This dredger is a cutter suction dredger with a total installed horsepower of 350. It was fabricated on land and launched into a pond created nearby. The dredger, which was originally designed to dredge up to a 4 m depth, was modified to dredge up to a 6 m and was finally capable of dredging up to a 11 m depth, by extending a ladder. Its average dredging rate was 33 m^3/Hr, and the unit cost was Rs. 2.78/m^3.

(2) MOT Dredge II

This dredger is a self-propelled cutter suction dredger with a total installed horsepower of 2,300. It was mainly used for making a pilot channel. The minimum and maximum outputs of the dredger were 45 and 350 m^3/Hr, respectively. Its average dredging rate was 100 m^3/Hr, and the unit cost was Rs. 21.39/m^3

(3) MOT Dredge IV

This dredger is a cutter suction dredger with a total installed horsepower of 8,000. It was towed into the lagoon through the channel dredged by MOT Dredge II and commenced dredging operations inside the lagoon. Its total output was somewhat less than potential ability suggested because it often encountered technical problems. The minimum and maximum outputs of the dredger were 310 and 880 m^3/Hr, respectively. Its average dredging rate was 560 m^3/Hr, and the unit cost was Rs. 15.15/m^3.

(4) HAM 208

This dredger is a cutter suction dredger with a total installed horsepower of 6,000. It was owned by the Dutch contractor.

(5) A.D. Geopotes I

This dredger is a trailing suction hopper dredger with a hopper capacity of 3,200 m^3. It was owned by the Dutch contractor.

9.2.3 Kudremukh development scheme

(1) MOT Dredge I, II, VII

These dredgers are cutter suction dredgers. They have two (2) different total installed horsepowers of two (2) 2,300 and 8,500, respectively. They were mainly used in shallow areas ranging from -3.0 m to -8.0 m, specially from about the - 8.0 m contour towards the shore up to the base line, and also on the side sloped on the northern and southern sides of the lagoon.

In addition, dredging by cutter suction draggers had to be carried out from the existing ground level to the full designed depth in front of the iron ore berth because the iron ore berth was constructed on dry land.

(2) MOT Dredge III, VI, VIII, and Mandovi-II

These dredgers are trailer suction hopper dredgers. They have hopper capacities of 3,400, 3,700, 6,500 and 2,500 m^3, respectively. they were used only below - 8.0 m because of their full draught. However, rehandling of dredged materials by cutter suction dredgers had to be carried out by trailer suction hopper dredgers in order to transport these materials to the dumping area.

9.2.4 Maintenance dredging

(1) MOT Dredge III, IV, VIII, IX and DCI Drege XI

These dredgers are trailer suction hopper dredgers. MOT Dredge IX has a hopper capacity of 4,500 m^3, and DCI Drege is the same type. Almost all maintenance dredging was carried out by these dredgers, which are suitable for dredging long channels.

(2) MOT Dredge VII

This dredger is a cutter suction dredger and was used near structures such as piers. When hard materials were encountered, it was often used because of its dredging efficiency.

9.2.5 Specification of dredgers

The specifications of each of the dredgers deployed at New Manglore Port are shown in Tables 9.2.1 and 9.2.2.

Table-9.2.1 Specifications of Dredging Fleet Deployed at New Mangalore Port

Cutter Suction Dredgers

No.	Name of Ship	Year Built	Over all Length (m)	Moulded Breadth (m)	Moulded Depth (m)	Loaded Draught (m)	Propelled	Dredging Capacity (m3/Hr)	Cutter Motor (HP)	Output of Propulsion (HP)	Dredging Pumps (HP)	Total Installed (HP)
1	Midget D.	1967					Non-self					350
2	MOT-II	1967	63.5	12.0	3.0	2.1	self	500	150	2 x 540	850	2,700
3	MOT-IV	1972	75.5	13.5	3.6	2.25	Non-self	1,000	600		2 x 2,300	8,000
4	HAM 208						Non-self	1,000				6,000
5	MOT -VII	1976	86.0	14.5	4.0	2.5	Non-self	1,000	1,000		2 x 2,300	8,500
6	MOT-I	1966	63.5	12.0	3.0	2.1	self	500	150	2 x 540	850	2,700

Diameter of Pipe (mm)	Dredging Depth (m)	Distance (m)	Owned by	Price (Mil.Rs.)	Remarks
300	11.0	400	NMPT		Stage I Capi. & Dredging Only
550	13.7	600	DCI		Stage I & II Capital Dredging
800	22.0	2,000	DCI		ditto
700			Ducth PC		ditto
800	22.0	3,000	DCI		Stage II Capi. & Maintenance
550	13.7	600	DCI		Stage II Capi. Dredging only

PC: Private Company

DCI: Dredging Corporation of India

NMPT: New Mangalore Port Trust

Table-9.2.2 Specifications of dredging Fleet Deployed at New Mangalore Port

Trailing Suction Hopper Dredgers

No.	Name of Ship	Year Built	Over all Length (m)	Moulded Breadth (m)	Moulded Depth (m)	Loaded Draught (m)	Loaded Speed (knots)	Hopper Capacity (m3)	Output of Propulsion (HP)	Dredging Pumps (HP)	Jet Pump (HP)	Total Installed (HP)	Diameter of Pipe (mm)	Dredging Capacity (m3/Hr.)	Dredging Depth (m)	Owned by	Price (Mil.Rs.)	Remarks
1	Geoprtes I							3,170				7,700				DUTCH PC		Stage I Capi. Dredging only
2	MOT-III	1971	99	15.5	8.4	6.32	11	3,400	2 x 1,600	2 x 1,200	2,120	9,000	2 x 850	517	22.0	DCI	500	Stage II Capi. & Maintenance
3	MOT-VI	1975	104	15.5	8.4	6.90	11	3,700	2 x 1,600	2 x 1,200	2,300	9,200	2 x 850	565	22.0	DCI	820	ditto
4	MOT-VIII	1977	124.3	19.5	11.5	8.50	13	6,500	4 x 1,670	2 x 1,200	1,960	15,000	2 x 1,000	975	25.0	DCI	1,000	ditto
5	Mandovi-II	1973	92	15.5	8.4	5.64	11	2,500	2 x 1,700	2 x 1,200		7,000	850	375	22.0	MPT		Stage II Capi. dredging only
6	MOT-IX	1984	102.2	18.2	8.9	7.50	13.8	4,500	2 x 5,250	2 x 1,460	2 x 612	10,500	2 x 800	653	25.0	DCI		Maintenance dredging only
7	DCI-XI	1986	102.7	18.2	8.9	7.50	13.8	4,500	2 x 5,250	2 x 1,460	2 x 612	10,500	2 x 800	653	25.0	DCI		ditto

PC: Private Company
DCI: Dredging Corporation of India
MPT: Mormugao Port Trust

9.3 Dredging Activities

9.3.1 Organization

The organization chart of New Mangalore Port Trust (NMPT) is as follows:

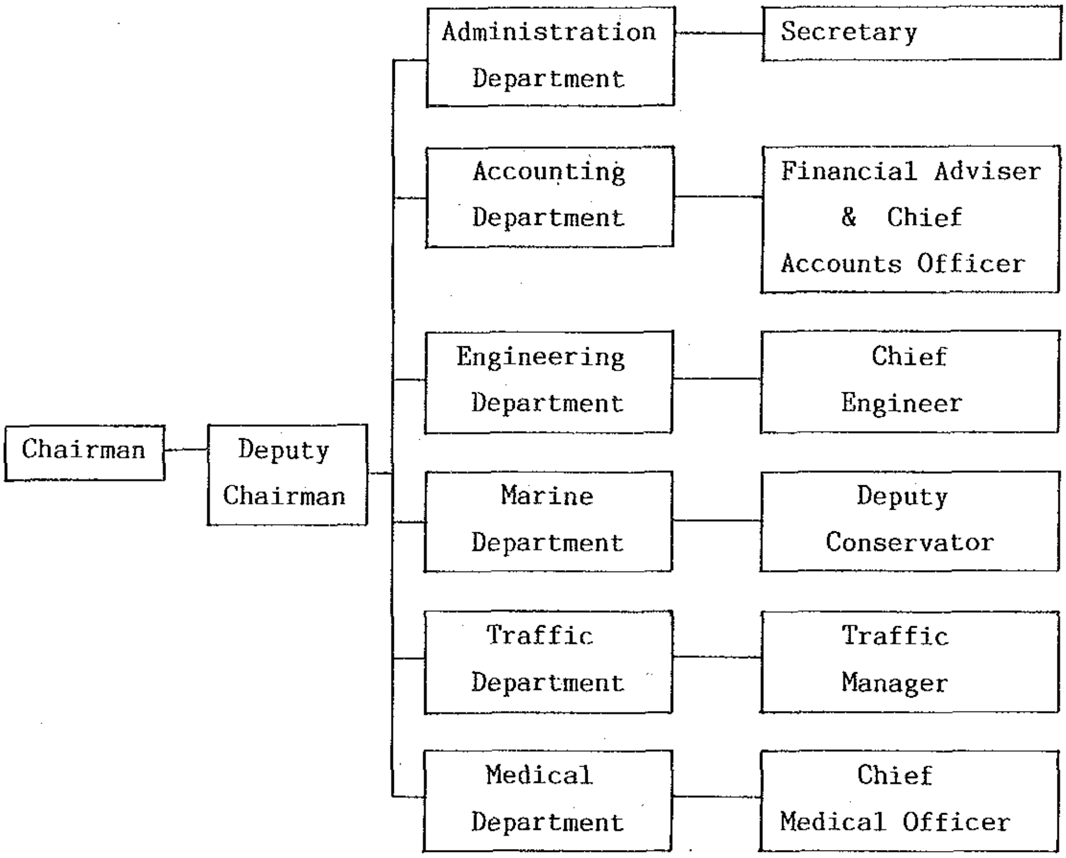


Figure-9.3.1 The Organization Chart of NMPT

The Engineering Department is in charge of dredging work at New Mangalore Port. Payment to the Dredging Corporation of India (DCI) and/or contractors is made by the Accounting Department. Technical advice is sometimes given by the Marine Department.

9.3.2 Planning

The following studies should be carried out for dredging planning:

1) understanding the dredging requirements.
2) deciding on the disposal area
3) selection of the most suitable dredgers
4) accurate estimation of the dredging capacity of the selected dredgers
5) taking appropriate measures to have its full capacity rated

Selecting dredgers that can carry out dredging economically and efficiently is the most important point here, and the following factors should be taken into consideration:

1) disposal method of dredged materials
2) soil coditions
3) meteorological and marine conditions
4) completion time
5) extent of offshore working area
6) location of shelter and anchorage for dredging fleet
7) water depth before dredging and dredging depth
8) environmental/conservation restrictions

Most ports on the west coast of India suffer from heavy siltation. At these ports, the annual dredging requirements are around three (3) million cubic meters. The dredging fleet currently consists of the Kutch Vallabh, owned by Kandla Port; the Mandovi II, owned by Marmugao Port; and the dredgers owned by the Dredging Corporation of India (DCI). All dredgers including the Kutch Vallabh and the Mandovi II, are deployed and operated by DCI on Indian coast. All of these dredgers are used for annual maintenance dredging.

9.3.3 Execution

(1) Results of Execution

a) First-Stage Development

The dredging work for the First-Stage Development was executed by cutter suction dredgers and trailer suction hopper dredgers 1970 to 1975. The total volume dredged was 13,891,000 m^3, and the total cost was Rs. 149,280,000. The principal statistical data for each dredger is shown in Table-9.3.1:

Table-9.3.1 Execution Data for the First-Stage Development

Dredger	Dredged Volume (m^3)	Working Hours	Dredging Rate (m^3/Hr)	Cost (Rs)	Unit Cost (Rs./m^3)
Midget Dredger	835,000	25,650	32.6	2,330,000	2.79
MOT Dredge II	970,000	9,770	99.3	20,750,000	21.39
MOT Dredge IV	1,462,000	2,625	557.0	22,200,000	15.18
HAM 208	5,840,000	10,752	543.2	104,000,000	9.79
A.D.Geopotes I	4,784,000	10,080	474.6		
Total	13,891,000	58,877		149,280,000	

b) Kudremukh Development Scheme

The dredging work for the Kudremukh Development Scheme was executed by cutter suction dredgers and trailer suction hopper dredgers from Sept. 1977 to April 1982. The principal statistical data is shown in Table-9.3. 2:

Table-9.3.2 Execution Data for the Kudremukh Development Scheme

	Dredged Volume (m^3)	Working Hours	Cost (Rs)
MOT Dredge I		16,752	
MOT Dredge II		3,168	
MOT Dredge VII		12,816	
MOT Dredge III		4,848	
MOT Dredge VI		7,008	
MOT Dredge VIII		19,728	
Mandovi-II		240	
Total	9,361,000	64,560	283,460,000
Lagoon	4,067,000		
Channel	5,294,000		

The underwater blasting and dredging of overburden was carried out by a jack-up type drill rig and other types of equipment from Sept. 1976 to Sept. 1979. The relevant statistical data is shown below:

Volume of overburden dredged	:	237,800 m^3
Volume of rock dredged	:	31,200 m^3
No. of holes drilled	:	12,150
Total length of drill holes	:	19,900 m
Quantity of explosives	:	85.58 t
Actual time spent for drilling of 226 settings	:	160 day
Total idle time	:	200 day
Total working/idle time	:	360 day

c) Maintenance Dredging

The principal statistical data concerning maintenance dredging from 1975 to 1988 is shown in Table-9.3.3 attached to the following notes:

Notes

- The volume of the material dredged in the lagoon in 1978, 1979 and 1980 is not available, since the capital dredging work was in progress.
- The volume of the material dredged in the channel in 1981 also includes the part of the volume dredged in 1980.
- The volume of the material dredged in 1984 is reduced. The dredger was deployed in the hard patch area of the channel without much success in addition to the financial difficulty.
  Hence, the dredging in the channel could not be carried out to the required depth and width.
- The volume of the material dredged in 1986 is reduced. The dredger was deployed in the hard patch area of the channel without much success with a consequent non-availability of the dredger for deepening the other areas.
- The volume of the material in the channel in 1988 is reduced. the reduction is due to non-availability of the dredger as the dredger was withdrawn by DCI for deployment at other ports.
- The increase in the cost in 1978 is due to the single tube operation of the dredger.
- The increase in the cost in 1981 is due to inclusion of The mob./demobilization charge
- In addition to MOT Dredge VIII, MOT Dredge VII was deployed for dredging alongside berths, etc. in double-handling operations in 1983 and 1987. This expenditure was included in the total amount.
- The increase in the cost in 1984 and 1986 are due to dredging of the hard patch in the channel by the trailer suction hopper dredgers. A total of 21 days was needed for the MOT Dredger IX to carry out dredging in the hard patch area in the channel.
- During 1982 to 1988, the dredging in the channel was carried out for a width of 152 m and depth of -12.50 m CD (approx.). Similarly, the dredging was carried out only in the manoeuvring area in the lagoon for a depth of -12.00 m CD (approx).

Table-9.3.3 Execution Data for Maintenance Dredging

		1			2	3	4	5	6	7	8	9	10
Year	Ship Name	Quantity Dredged	Channel	Lagoon	No. of Working Days	No. of Non-Working Days	2 + 3	1 / 2	1 / 4	Total Cost	No. of Trips	Unit Cost	Dredger Hire Charge
		M3	M3	M3				M3/Day	M3/Day	Rs		Rs/M3	Rs/Day
1975	MOT VI	3,507,120	2,353,800	1,153,320	70	N.A.	N.A.	50,102	N.A.	6,755,000	N.A.	1.93	93,000
1976	MOT III	1,690,200	573,390	1,116,810	52	N.A.	N.A.	32,504	N.A.	5,264,000	N.A.	3.11	87,000
1977	MOT VIII	1,636,150	1,183,300	452,850	40	N.A.	N.A.	40,904	N.A.	9,914,000	536	6.06	220,000
1978	MOT VIII	1,137,480	1,107,420	30,060	34	N.A.	N.A.	33,455	N.A.	9,128,000	496	8.02	220,000
1979	MOT VIII	1,765,600	1,765,600	0	38	N.A.	N.A.	46,463	N.A.	10,110,000	441	5.73	220,000
1980	MOT VIII	540,000	540,000	0	13	N.A.	N.A.	41,538	N.A.	3,337,000	137	6.18	220,000
1981	MOT VIII	4,549,800	3,808,890	740,910	104	N.A.	N.A.	39,911	N.A.	34,830,000	1,390	7.65	220,000
	MOT III	-	-	-	10	N.A.	N.A.	-	N.A.	-	N.A.	-	106,500
1982	MOT VIII	1,686,900	1,242,600	444,300	40	N.A.	N.A.	42,173	N.A.	13,463,000	N.A.	7.98	308,000
1983	MOT VIII	3,113,110	1,934,350	1,178,760	64	N.A.	N.A.	48,642	N.A.	23,152,000	N.A.	7.44	308,000
1984	MOT VIII	1,851,200	1,026,450	824,750	66	N.A.	N.A.	28,048	N.A.	24,661,000	N.A.	13.32	352,500
1985	MOT VIII	3,296,890	2,062,490	1,234,400	60	N.A.	N.A.	41,211	N.A.	30,270,000	N.A.	9.18	361,400
	MOT IX	-	-	-	20	N.A.	N.A.	-	N.A.	-	N.A.	-	330,600
1986	MOT IX	1,904,348	1,032,384	871,964	70.0	14.0	84.0	23,984	19,432	30,801,300	882	16.17	330,600
	MOT VIII	-	-	-	9.4	4.6	14.0	-	-	-	109	-	361,400
	MOT IX	56,544	56,544	0	21.0	N.A.	N.A.	2,693	N.A.	7,490,200	N.A.	132.47	330,600
1987	MOT VIII	3,092,994	2,039,688	1,053,306	73.5	15.5	89.0	42,082	34,753	35,700,000	1,013	11.55	388,000
1988	MOT VIII	2,400,000	1,437,396	962,604	46.5	N.A.	N.A.	36,364	N.A.	27,871,000	N.A.	11.61	388,000
	MOT IX	-	-	-	19.9	N.A.	N.A.	-	-	-	-	-	354,000

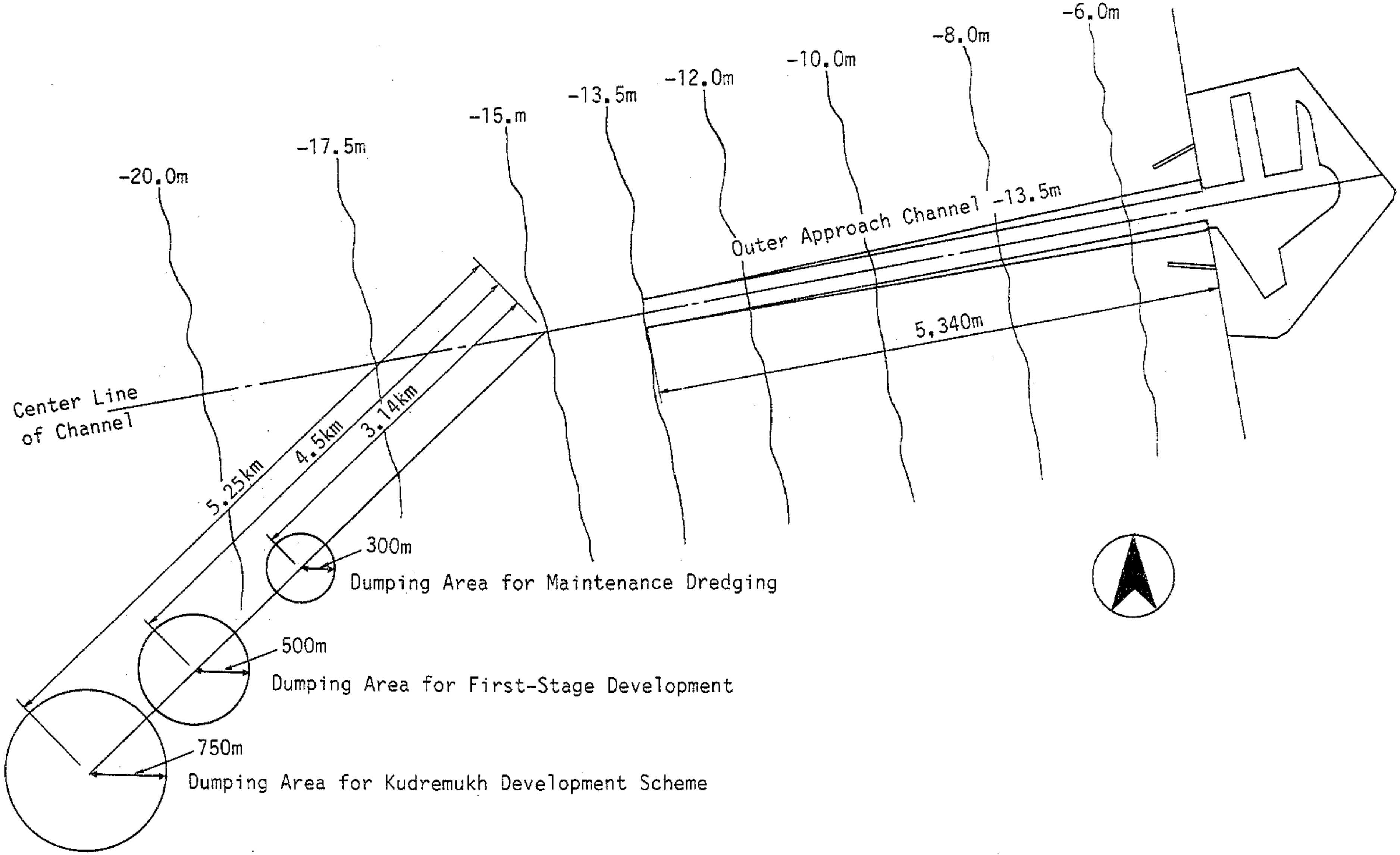


Figure-9.3.2 Location of Dumping Areas

d) Dumping Area

The offshore dumping areas for the First-Stage Development were located 4.5 km southwest of the intersection of the center line of the outer approach channel with the -15 m contour. The areas for the Kudremukh Development Scheme were located 5.25 km southwest of the same point and the areas for maintenance dredging have been located 3.14 km southwest of the same point. They are shown in Figure-9.3.2.

9.3.4 Control

Like other construction projects, dredging operations are controlled in terms of quality, progress, safety and cost.

(1) Quality Control

The quality of dredging work is usually checked by a series of sounding surveys: including pre-dredging, in-progress and post-dredging surveys. Pre-dredging and post-dredging surveys are carried out by the New Mangalore Port Trust (NMPT) at New Mangalore Port. Location is measured with two (2) sextants and water depth is measured with an echo-sounder. An in-progress survey is carried out by the body carrying out the dredging in order to verify the depth that has been dredged. During the First-Stage Development, the location of the dredger was measured with the 'Toran Electronic Positioning Fixing System' by the contractor. The 'Toran' was basically a hyperbolic system based on the measurement of the phase of three (3) audio-frequency transmitting stations.

(2) In-progress Control

As for the in-progress control of the dredging, daily progress reports are used. Concerning trailing suction hopper dredgers, control of cycle time is necessary because there is a lot of unproductive time, that is, the time needed for the dredgers to go to and from the dumping site. The results of the analysis on the daily progress reports of maintenance dredging from 1986 to 1988 are shown in Table-9.3.4. And the summary of the daily progress reports are shown in Appendix-9.1

The volume dredged is the most important factor in dredging work. The following formula is used in calculating the volume dredged by trailer suction hopper dredgers.

Table-9.3.4 Analysis of Daily Reports of Maintenance Dredging

Year		1986-87		1987-88	1988-89		
Dredger		MOT VIII	MOT IX	MOT VIII	MOT VIII	MOT IX	MOT VIII
	Unit						
Total Nos. of Cycle		109	882	1,013	564	268	110
Av. Dredging Time	(min.)	21.6	25.8	27.8	34.4	35.7	81.2
Av. Sailing Time (Going)	(min.)	43.9	35.3	37.1	37.0	29.0	29.3
Av. Dumping Time	(min.)	5.0	10.0	5.0	5.0	10.0	5.0
Av. Sailing Time (Returning)	(min.)	53.6	43.1	34.6	41.5	31.6	30.4
Working Time per Cycle	(min.)	124.1	114.2	104.5	117.8	106.3	145.8
Total Working Time	(hrs.)	225.4	1,679.1	1,764.0	1,107.7	474.9	267.3
Total Working Days		9.4	70.0	73.5	46.2	19.8	11.1
Mechanical Trouble	(hrs.)	18.6	9.3	18.2	74.8	4.1	13.3
Fresh Water Supply	(hrs.)	0.0	4.0	8.0	6.0	0.0	0.0
Routine Maintenance	(hrs.)	72.0	288.9	311.0	145.2	71.4	90.3
Major Repairs	(hrs.)	0.0	0.0	0.0	131.0	0.0	0.0
Bad Weather	(hrs.)	0.0	1.9	6.0	0.0	1.0	1.8
Mob./Demobilization	(hrs.)	0.0	8.8	10.8	13.5	0.0	154.5
Others	(hrs.)	20.0	24.0	18.0	9.8	24.6	0.8
Total Intermission Time	(hrs.)	110.6	336.9	372.0	380.3	101.1	260.7
Total Intermission Days		4.6	14.0	15.5	15.8	4.2	10.9
Dredger Staying Days		14	84	89	62	24	22
Dredging Volume at Lagoon	(m^3)	223,290	691,045	1,658,368	1,001,325	626,072	54,883
Dredging Volume at Channel	(m^3)	227,425	2,553,275	2,549,916	1,575,396	357,783	392,890
Total Dredging Volume	(m^3)	450,715	3,244,320	4,208,284	2,576,721	983,855	447,773

$$V = (W - \gamma w * Vh) / (\gamma s - \gamma w) \quad (m3)$$

where,

V : The in-situ volume of dredged material (m^3)

W : The weight of dredged material (t)

Vh : The volume of the hopper (m^3)

γw : Density of sea water (t/m^3)

γs : The in-situ wet bulk density of dredged material (t/m^3)

In principle, the actual dredging volume is calculated based on the differences between the results of the pre-dredging and post-dredging surveys. The volumes obtained based on theses surveys and calculated using the above-mentioned formula are usually slightly different.

(3) Safety Control

Safety control is very important. Once the dredger starts dredging, it continues to dredge for 24 hours a day until it completes dredging save for a routine maintenance period. Therefore, the crew lives in the dredger. There are many moving parts and dangerous areas inside dredgers. The main task of project managers and captains is to train site people to be aware of the safety factor. And they should observe the crew's mental state.

(4) Cost Control

Cost control cannot be considered apart from quality control, in-progress control and safety control. The management staff should keep in mind that cost is affected by these three (3) controls. Also, regular adjustment of the electrical and mechanical equipment is of course important, as trouble with this equipment has a great effect upon the dredging effeciency.

9.4 Proposed Dredging Plan

In this clause, the dredging plan for capital/maintenance dredging is to be studied based on the "Short-term Plan" in Chapter 10. This plan is the partial plan of "Layout Plan Alternative CASE-1" in Chapter 7.

The proposed dredging will be carried out to cater to the requirements of 100,000 DWT class iron ore carriers and oil tankers.

9.4.1 Geological characteristics of soil

(1) Channel

A sand surface layer exists in the area adjacent to the lagoon and the existing alluvial soft-to-medium clay layer seems to extend seaward 1.5km or further. This clay layer seems to cover almost all of the channel area as described in "Clause 2.6". And the sediment in the channel is very soft, silty material with a silt/clay content of 85% as described in "Clause 2.7".

(2) Lagoon

The surface strata in the lagoon consist of a sandy soil layer which is dense to medium dense and clayey soil layer with medium to stiff density. Hard granite rock is exposed in some places because rock blasting was carried out during the Kudremukh Development Scheme. Almost all of the rock below the sea bottom is covered with a weathered rock layer. Lens-type-shape grit exists in some parts of the lagoon.

9.4.2 Estimation of volume dredged

(1) Hard Rock

The study team for the Feasibility Study on the Improvement Plan of New Mangalore Port (hereinafter referred to as the Team) carried out a sonic prospecting survey in order to verify the distribution of rock in the lagoon and the channel near the entrance of the lagoon. The Team made a rock distribution map based on the results of this survey. previous probing and boring data obtained from the New Mangalore Port Trust (NMPT) were also taken into consideration. (see Figure-9.4.1)

The rock volume to be dredged for the Short-term Plan to cater to the requirements of 100,000 DWT class iron ore carriers and oil tankers is 136,100m^3. Hard rock volume is what is left after the weathered rock volume is subtracted from the above volume. All rock volumes are sliced up and calculated as the sum of truncated cones. The following formula is used in the calculation:

V = [A]*h+(Al-Au)*SQRT(Au)*h/{SQRT(Al)-SQRT(Au)}/3+Vu

where,

V : Volume between upper and lower faces (m^3)

Al: Area of lower face (m^2)

h : Distance between upper and lower faces (m)

Au: Area of upper face (m^2)

Vu: Volume above upper face (m^3)

The results of detailed calculations of rock distribution area and rock volumes are shown in Table-9.4.1 and 9.4.2 together with the following notes:

Notes

* Requirements of the dredged area of rock is based on the "Layout Plan Alternatives" in Chapter 7.
* The rock distribution areas are divided into areas A to K for the sake of simplifying the calculation.
* Areas were calculated based on the drawing "BEDROCK CONTOUR MAP scale 1:2,000" made by the Team except as noted below.
* The area "At -18.5m" was calculated in the middle value of areas "At -18.0m" and "At -19.0m". The following formula was used in the calculation:

  A = [{SQRT(Au) + SQRT(Al)}/2]**2

  where,

  A : Area "At -18.5m"

  Au : Area "At -18.0m"

  Al : Area "At -19.0m"

* Extra depth blasted is assumed as 50cm.

The results of detailed calculations of rock distribution area and rock volumes for the Short-term Plan of CASE-2, 3 and 4 are also shown in

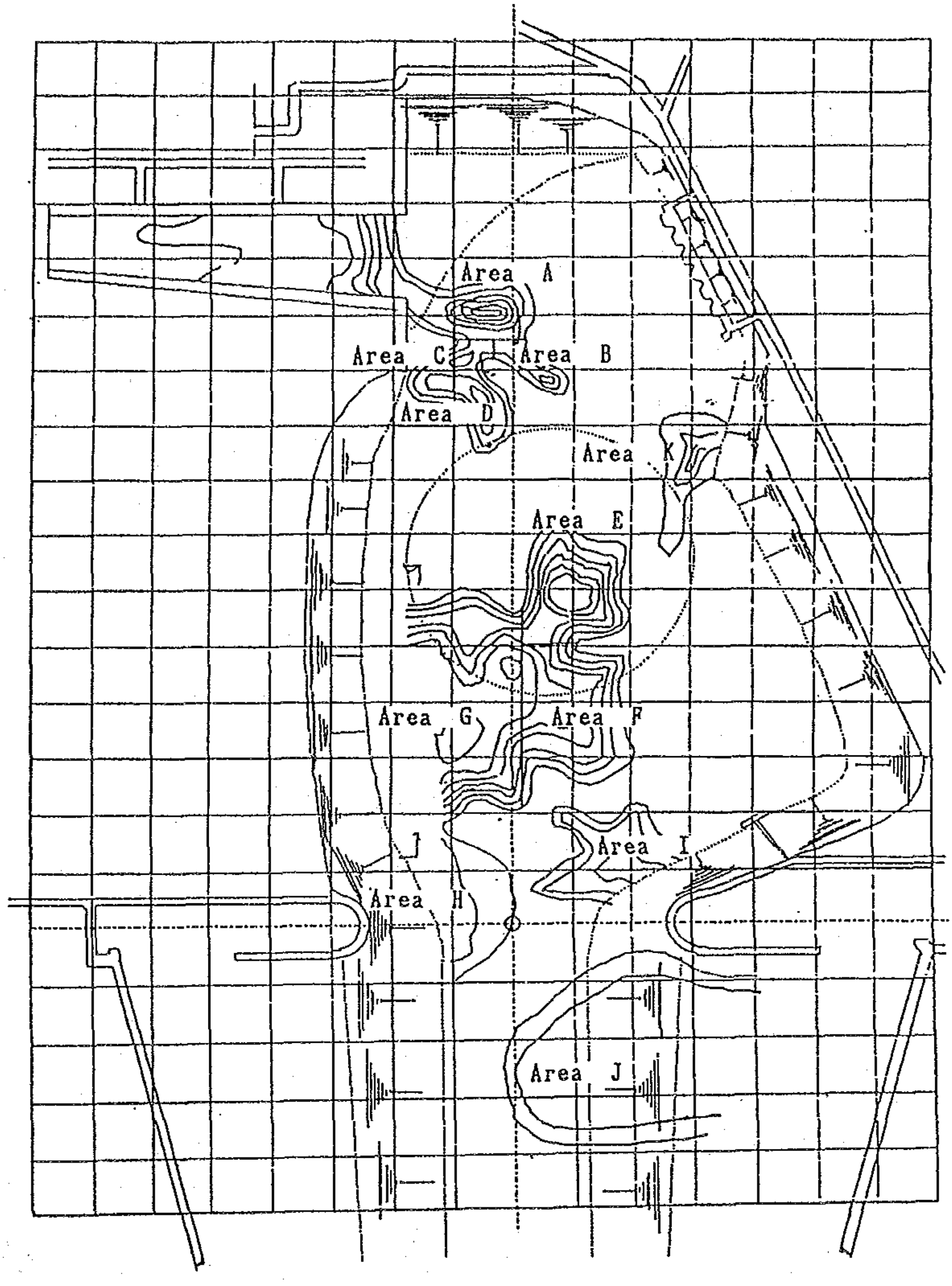


Figure-9.4.1 Rock Distribution Area

Table-9.4.1 Calculation of Rock Distribution Area for the Proposed Development Scheme

			At -14.5 m (m2)	At -17.0 m (m2)	At -18.0 m (m2)	At -18.5 m (m2)	At -19.0 m (m2)
Area A	100,000DWT	CASE-1	1,580	4,342			
	100,000DWT	CASE-2	0	0			
	150,000DWT	CASE-3	0	0	0	0	0
	150,000DWT	CASE-4	0	0	0	0	0
Area B	100,000DWT	CASE-1	0	244			
	100,000DWT	CASE-2	0	0			
	150,000DWT	CASE-3	0	0	0	0	0
	150,000DWT	CASE-4	0	0	0	0	0
Area C	100,000DWT	CASE-1	0	0			
	100,000DWT	CASE-2	0	0			
	150,000DWT	CASE-3	0	0	0	0	0
	150,000DWT	CASE-4	0	0	0	0	0
Area D	100,000DWT	CASE-1	0	241			
	100,000DWT	CASE-2	0	0			
	150,000DWT	CASE-3	0	0	0	0	0
	150,000DWT	CASE-4	0	0	0	0	0
Area E	100,000DWT	CASE-1	2,690	13,598			
	100,000DWT	CASE-2	2,690	13,598			
	150,000DWT	CASE-3	2,237	10,698	14,248	15,816	17,466
	150,000DWT	CASE-4	0	14	476	815	1,244
Area F	100,000DWT	CASE-1	6,892	16,562			
	100,000DWT	CASE-2	6,892	16,562			
	150,000DWT	CASE-3	6,892	16,562	23,262	26,524	30,000
	150,000DWT	CASE-4	4,698	13,496	19,395	22,296	25,400
Area G	100,000DWT	CASE-1	24,876	40,983			
	100,000DWT	CASE-2	24,876	40,983			
	150,000DWT	CASE-3	10,543	16,174	18,294	19,427	20,594
	150,000DWT	CASE-4	3,042	6,709	8,568	9,673	10,844
Area H	100,000DWT	CASE-1	0	0			
	100,000DWT	CASE-2	0	0			
	150,000DWT	CASE-3	0	0	0	2,906	11,529
	150,000DWT	CASE-4	0	0	0	2,906	11,529
Area I	100,000DWT	CASE-1	0	0			
	100,000DWT	CASE-2	0	0			
	150,000DWT	CASE-3	0	0	1,781	4,552	8,599
	150,000DWT	CASE-4	0	0	1,781	4,552	8,599
Area J	100,000DWT	CASE-1	0	0			
	100,000DWT	CASE-2	0	0			
	150,000DWT	CASE-3	0	0	17,821	32,082	50,506
	150,000DWT	CASE-4	0	0	17,821	32,082	50,506
Area K	100,000DWT	CASE-1	0	0			
	100,000DWT	CASE-2	0	0			
	150,000DWT	CASE-3	0	0	0	1,324	5,231
	150,000DWT	CASE-4	0	0	0	0	0
Total	100,000DWT	CASE-1	36,038	75,971			
	100,000DWT	CASE-2	34,458	71,144			
	150,000DWT	CASE-3	19,672	43,435	75,407	102,632	143,926
	150,000DWT	CASE-4	7,740	20,220	48,042	72,325	108,124

Table-9.4.2 Calculation of Rock Volumes for the Proposed Development Scheme

			-14m～-15m (m3)	Above -17m (m3) 100,000DWT	Above -18m (m3)	Above -18.5m (m3) 130,000DWT	Above -19m (m3) 150,000DWT
Area A	100,000DWT	CASE-1		7,118			
	100,000DWT	CASE-2		0			
	150,000DWT	CASE-3		0	0	0	0
	150,000DWT	CASE-4		0	0	0	0
Area B	100,000DWT	CASE-1		203			
	100,000DWT	CASE-2		0			
	150,000DWT	CASE-3		0	0	0	0
	150,000DWT	CASE-4		0	0	0	0
Area C	100,000DWT	CASE-1		0			
	100,000DWT	CASE-2		0			
	150,000DWT	CASE-3		0	0	0	0
	150,000DWT	CASE-4		0	0	0	0
Area D	100,000DWT	CASE-1		201			
	100,000DWT	CASE-2		0			
	150,000DWT	CASE-3		0	0	0	0
	150,000DWT	CASE-4		0	0	0	0
Area E	100,000DWT	CASE-1		18,613			
	100,000DWT	CASE-2		18,613			
	150,000DWT	CASE-3		14,856	27,286	34,799	43,116
	150,000DWT	CASE-4		12	202	521	1,032
Area F	100,000DWT	CASE-1		28,448			
	100,000DWT	CASE-2		28,448			
	150,000DWT	CASE-3		28,448	48,266	60,703	74,825
	150,000DWT	CASE-4		21,797	38,154	48,568	60,484
Area G	100,000DWT	CASE-1		81,490			
	100,000DWT	CASE-2		81,490			
	150,000DWT	CASE-3		33,146	50,369	59,798	69,802
	150,000DWT	CASE-4		11,891	19,510	24,067	29,194
Area H	100,000DWT	CASE-1		0			
	100,000DWT	CASE-2		0			
	150,000DWT	CASE-3		0	0	489	3,859
	150,000DWT	CASE-4		0	0	489	3,859
Area I	100,000DWT	CASE-1		0			
	100,000DWT	CASE-2		0			
	150,000DWT	CASE-3		0	598	2,128	5,363
	150,000DWT	CASE-4		0	598	2,128	5,363
Area J	100,000DWT	CASE-1		0			
	100,000DWT	CASE-2		0			
	150,000DWT	CASE-3		0	5,955	18,257	38,731
	150,000DWT	CASE-4		0	5,955	18,257	38,731
Area K	100,000DWT	CASE-1		0			
	100,000DWT	CASE-2		0			
	150,000DWT	CASE-3		0	0	223	1,755
	150,000DWT	CASE-4		0	0	0	0
Total	100,000DWT	CASE-1		136,074			
	100,000DWT	CASE-2		128,553			
	150,000DWT	CASE-3		76,451	132,475	176,176	237,022
	150,000DWT	CASE-4		33,700	64,420	94,032	138,664

Table-9.4.1 and 9.4.2 for reference.

(2) Weathered Rock and Grit

According to the present boring survey, hard rock is often covered with weathered rock in the area that has not been blasted. The thickness of weathered rock is around 1.5m. However, because the part that can be dredged without blasting is only that near the surface, the weathered rock is assumed to be 0.5m thick in the calculation of the volume.

Grit is distributed on the west-south part of the lagoon and is found in a lens-type shape. Grit can also be dredged without blasting. The area is obtained from the drawing "BEDROCK CONTOUR MAP scale 1:2,000" and the thickness is estimated at around 1.5m.

The volumes of weathered rock and grit are estimated 20,000m^3 and 47,600m^3, respectively.

(3) Soil for capital dredging

The volume to be dredged in the lagoon is estimated based on the "Layout Plan Alternatives" in Chapter 7. The side slopes in the lagoon are to be basically 1:3, except for the slope at the rear of the existing oil berth area, which will be 1:5. The extra depth to be dredged is assumed to be 50cm.

The volume to be dredged in the outer approach channel is estimated based on the chart for the area off the coast of Mangalore. The side slopes in the channel area to be 1:5 in consideration of the characteristics of the soil as well as the influence of the slopes upon the tranquillity of the lagoon.

The volumes of soil in the lagoon and the channel are estimated at 3,910,000m^3 and 9,330,000M^3, respectively.

The extra depth to be dredged is assumed to be 50cm.

(4) Soil for maintenance dredging

The volume to be dredged for annual maintenance should be equal to the annual siltation volume after the completion of this project, which is estimated in Chapter 8. However, in deepening the channel the siltation volume increases heavily. Therefore, the volume to be dredged in the first year after the completion of this project is estimated based on the following assumption in consideration of financial constraint (see Figure-9.4.2). The volume is 4,200,000m^3.

* The dredging is to be carried out with the channel width of five (5) times of the beam length of the biggest vessel, that is, 215m.
* The dredging is to be carried out with the bottom level of the channel of 0.5m above from the planned depth. In this case, the biggest vessels with full loads have to wait off the coast when tide level is lower than +0.5m. The probability of waiting is about 20%, and average waiting time is about two (2) hours. This would seem not to interfere with port activity so much given the number of 100,000 DWT class vessels.

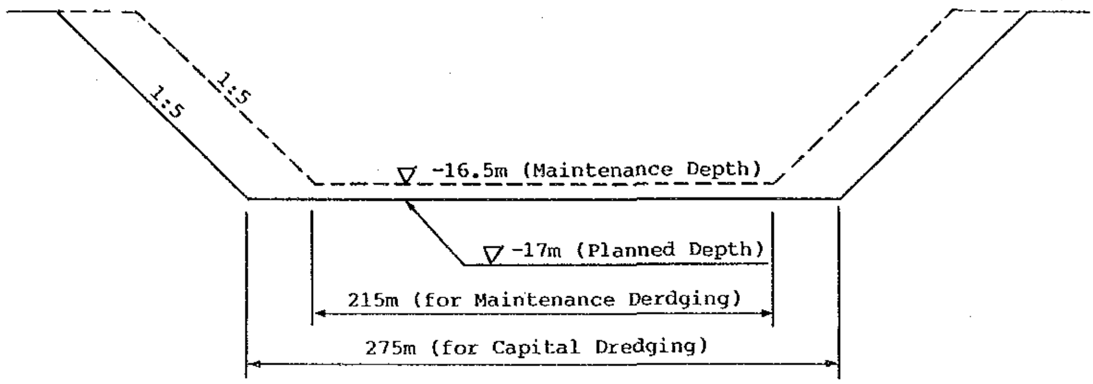


Figure-9.4.2 Section Dredged for Maintenance Dredging

The volume to be dredged from the second year after completion of this project is equal to the annual siltation volume estimated against the restricted capacity of the channel. The volume is estimated at 5,270,000m^3.

The extra depth to be dredged is assumed to be 50cm.

(5) Summary of Volumes Dredged

A summary of the volumes dredged for the Short-term Plan is shown in Table-9.4.3. Case-2 to 4 are also shown in Table-9.4.3 for only reference.

Table-9.4.3 Volumes Dredged for the Proposed Development Scheme

(Unit: m3)

		Case-1 100,000DWT (-17.0m)	Case-2 100,000DWT (-17.0m)	Case-3 150,000DWT (-19.0m)	Case-4 150,000DWT (-19.0m)
Hard Rock	Area (m2)	76,000	71,100	143,900	108,100
	Volume (m3)	116,100	110,300	174,900	88,500
Soft Rock	Weathered Rock	20,000	18,300	62,100	50,200
	Grit	47,600	47,600	47,600	47,600
	(Sum)	67,600	65,900	109,700	97,800
Soil (Lagoon)		3,910,000	5,010,000	2,910,000	2,000,000
Soil (Channel)		9,300,000	9,330,000	18,440,000	18,650,000

9.4.3 Dredging method

(1) Capital Dredging

a) Channel

The main items of dredging work in the outer approach channel involved in the Short-term Plan are:

* Widening the channel from the existing width of 245m to 275m.
* Deepening the channel with the length of 1,000m from the base line from -13.5m from CD to -16.5m from CD and the rest of the area from -13.5m from CD to -17.0m from CD.
* Extending the length of the channel from 5,340m to 7,580m.

A trailer suction hopper dredger with a hopper capacity of 4,500m^3 may be used in the channel. In the case of slope dredging above the level of -8.0m, a cutter suction dredger with a total installed horsepower of 8,000 is to be used, because a fully loaded trailer suction hopper dredger cannot navigate in this area. A "Double Handling" system will be adopted as a transportation method. This system involves initial dredging with the cutter suction dredger up to the level of about -8.0m and then dumping the dredged materials with a short floating pipeline in the deeper waters to be rehandled with the trailer suction hopper dredger (see Figure-9.4.3). All the dredged materials are transported and dumped at the designated offshore

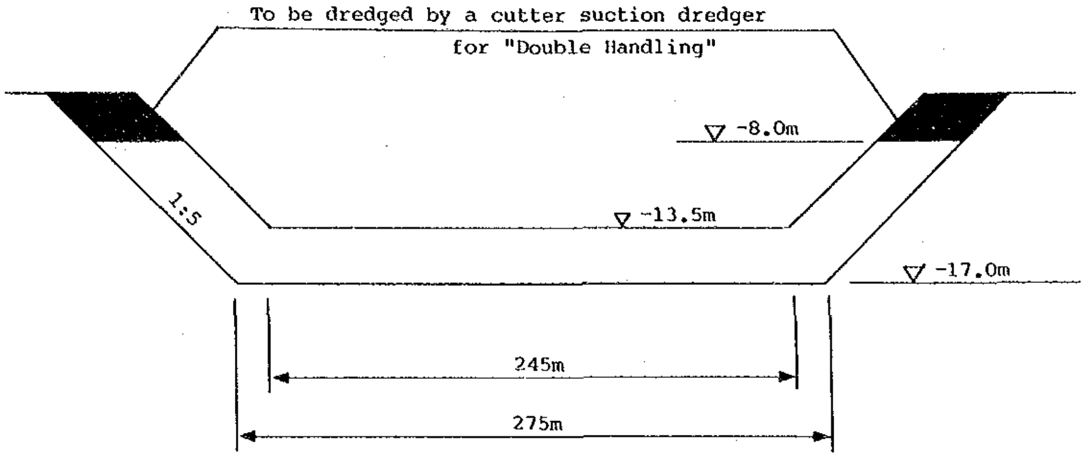


Figure-9.4.3 Double Handling Method

disposal area.

The volumes to be dredged at the slope above the level of -8.0m and in the remaining areas are estimated at 340,000m^3 and 8,990,000m^3, respectively. The total volume is 9,330,000m^3.

b) Lagoon

The main items of dredging work in the lagoon involved in the Short-term Plan are:

* Widening the turning circle from the existing diameter of 490m to 550m and deepening it from -13.0m from CD to -16.5m from CD.
* Deepening the area of the existing iron ore berth from -13.0m from CD to -16.5m from CD.
* Deepening the area of the existing oil berth from -9.75m from CD to -16.5m from CD.
* Deepening the area of the future iron ore berth from -13.0m from CD to -15.0m from CD.
* Deepening the area of the new oil products berth from -9.75m from CD to -15.0m from CD.

A cutter suction dredger with a total installed horsepower of 15,000 is to be used in the south-west part of the lagoon. This includes the slope of the area of the future iron ore berth and the new oil products berth. The volume to be dredged in these ares is estimated at 2,000,000m^3 and the materials are assumed to be composed of sandy materials of 1,000,000m^3 and silty materials of 1,000,000m^3. Sandy materials sucked up by a dredging pump are transported to the seashore area located south of the southern breakwater through floating/shore pipelines. Erosion caused by sand littoral drift occurs to some extent in this area. Silty materials sucked up by the dredging pump are dumped at the designated deeper area near the dredger through a short floating pipeline to be rehandled with the trailer suction hopper dredger. Pipelines are to be changed properly according to the soil characteristics.

A grab dredger with a grab capacity of $1.91m^3$ is to be used in the area in front of the existing iron ore berth in order to avoid any damage to structure. The area has a width of 20m or more and a length of about 340m. The volume to be dredged in this area is estimated at $30,000m^3$. Dredged materials are transported and dumped at the designated offshore disposal area by this dredger.

The trailer suction hopper dredger is used in other areas. The volume to be dredged is estimated at $1,710,000m^3$. Dredged materials are trasported and dumped at the designated offshore disposal area.

The total volume dredged in the lagoon is $3,910,000m^3$.

(2) Maintenance Dredging

Basically, a trailer suction hopper dredger is to be used in the channel and the lagoon because it is suitable for long-distance dredging and the dredged materials are usually very soft sediment. However, if a dredger encounters some hard compact materials, the plan should consider using a water jet device or a different type of dredger such as a cutter suction dredger. A grab dredger with a grab capacity of $1.91m^3$ owned by NMPT is to be used in the areas adjacent to the existing/new structures.

The volumes to be dredged in the first year after completion of this project in the lagoon and the channel are estimated at $420,000m^3$ and 3,780,000m3, respectively. And the volumes from the second year are estimated at $430,000m^3$ and $4,840,000m^3$, respectively (see Table-9.4.4). Dredged materials are transported and dumped at the designated offshore disposal area.

9.4.4 Rock dredging and blasting

(1) Removal of Over-burden Lying over the Rock

Before hard rock blasting, the over-burden is to be removed to the extent that is possible by the cutter suction dredger with a total installed horsepower of 15,000. Materials sucked up by the dredging pump are dumped at the designed deeper area near the dredger through a short floating pipeline to be rehandled with the trailer suction hopper dredger.

Table-9.4.4 Volume Dreged for Annual Maintenance

	Unit	Lagoon	B/Line to 0.5km	0.5km to 1.0km	1.0km to 1.5km	1.5km to 2.0km	2.0km to 2.5km	2.5km to 3.0km	3.0km to 3.5km	3.5km to 4.0km	4.0km to 4.5km	4.5km to 5.0km	5.0km to 5.5km	5.5km to 6.0km	6.0km to 6.5km	6.5km to 7.0km	7.0km to 7.5km	Total
Existing Depth	(m)	-	2.25	5.90	7.00	7.78	8.56	9.34	10.11	10.89	11.67	12.44	13.22	14.05	14.91	15.70	16.48	
Siltation Thickness (1)	(m)	0.600	2.055	2.549	2.943	3.253	3.429	3.494	3.458	3.337	3.145	2.895	2.594	2.249	1.867	1.450	1.000	
Siltation Volume (1)	(m3)	423,103	293,120	366,731	426,316	473,743	500,883	510,945	505,369	486,676	457,165	419,015	373,497	321,883	265,427	204,631	140,000	6,170,000
Maintenance Dredging Volume (1)	(m)	423,103	231,470	290,261	277,543	314,895	336,315	344,265	339,859	325,099	301,828	271,803	236,067	195,665	151,624	104,381	54,375	4,200,000
Siltation Thickness (2)	(m3)	0.610	2.415	2.972	3.385	3.691	3.845	3.871	3.784	3.602	3.340	3.009	2.616	2.166	1.664	1.109	0.500	
Siltation Volume (2)	(m3)	430,437	274,193	341,572	392,533	430,841	450,298	453,594	442,577	419,651	386,939	346,103	298,329	244,574	185,802	122,292	54,375	5,270,000
Maintenance Dredging Volume (2)	(m3)	430,437	274,193	341,572	392,533	430,841	450,298	453,594	442,577	419,651	386,939	346,103	298,329	244,574	185,802	122,292	54,375	5,270,000

(1) : The first year after completion of this project.
(2) : From the second year after completion of this project.

Volume is at estimated 170,000m^3.

Besides the over-burden, in view of economical considerations, overlaying weathered rock is to be removed by the cutter suction dredger. However, as it is difficult to distinguish clearly between hard rock and weathered rock, attention should always be paid to the wear on the cutter's blades and the efficiency of dredging. Materials sucked up by the dredging pump are discharged into the hopper barges alongside the dredger through a short pipeline and dumped at the extended alignment of the breakwaters. These barges are towed by a tugboat with a horsepower of 1,000.

A grab dredger with a grab capacity of 20m^3 can be used instead of the cutter suction dredger for the removal of the over-burden and the weathered rock.

(2) Underwater Drilling

After the removal of the over-burden and weathered rock, rock drilling is to be carried out. A special floating pontoon or a self elevated platform with drilling rigs is to be used for drilling. As it is impossible to remove the over-burden completely, the over-burden drilling technique developed in Sweden or similar techniques is to be adopted as the method of drilling.

The over-burden drilling technique is the method whereby a steel drill pipe (a casing tube) is driven through the over-burden into the bedrock to be blasted. A drill rod inside the casing driven by a top hammer, hammers and rotates the drill bit to make the disired hole in the bedrock. And this drill rod is withdrawn after the hole depth is completed. The casing prevents the over-burden falling into the completed hole.

The holes are to be drilled at intervals of two (2) meters both longitudinally and transversely. And to ensure rock blasting up to -17.0m from CD, the holes are to be drilled up to the following levels:

Rock surface level not deeper than -16.0m from CD : -19.0m from CD
Rock surface level deeper than -16.0m from CD : -18.5m from CD

(3) Underwater Blasting

Explosives are to be placed into the borehole via the casing tube. For detonating the charges, several systems are used, including detonating cord, electrical detonation and non-electrical detonation (pyrotechnical). When the prescribed number of holes have been charged with explosives, the pontoon or platform is moved 200m or more away from the blasting area. After final preparations of the blast and checking of safety measures, a round of explosive charges is fired. The average fragmentation of the rock after blasting is to be around 20cm.

Appropriate explosives for underwater blasting such as gluey dynamite are to be used. The total quantity of explosives to be used for blasting is about 250t.

(4) Removal of Blasted Rock

A grab dredger with a grab capacity of $20m^3$ is to be used. The volume to be dredged is estimated at $193,500m^3$ in consideration of the swelling of the rock after blasting. Dredged materials are transported and dumped at the extended alignment of the breakwaters using hopper barges with a capacity of $800m^3$. These barges are towed by a tugboat with a horsepower of 1,000.

(5) Dredging of Grit

Grit is to be dredged by a cutter suction dredger with a total installed horsepower of 15,000. Materials sucked up by a dredging pump are transported to the seashore area south of the southern breakwater through floating/shore pipelines.

(6) Consideration

Regarding rock drilling and blasting, the values such as a interval of holes, depth of holes, quantity of explosives and so on as mentioned above are only standard values. And the effect of blasting is affected by a various site conditions. Therefore, pilot drilling and blasting should be carried out before the execution of the project. Then, these values should be finally decided upon.

Necessary steps for safety should be taken to prevent accidents and to carry out the blasting smoothly because the blasting is to be carried out for two (2) years in area congested with vessels.

9.4.5 Location of offshore disposal area

The offshore disposal area for the capital dredging is to be located 5.0km southwest of the intersection of the center line of the outer approach channel with the -20m contour. The location of the disposal area is selected based on the silt movement pattern observed during the "Radioactive and Fluorescent Tracer Studies" carried out in the monsoon season of 1964 and the fair weather season of 1967-68. However, it is recommended that a further tracer study be carried out in the proposed disposal area to verify the silt movement pattern again.

The offshore disposal area for maintenance dredging is to be located 3.0km southwest of the same point for reasons of economy (see Figure-9.4.4).

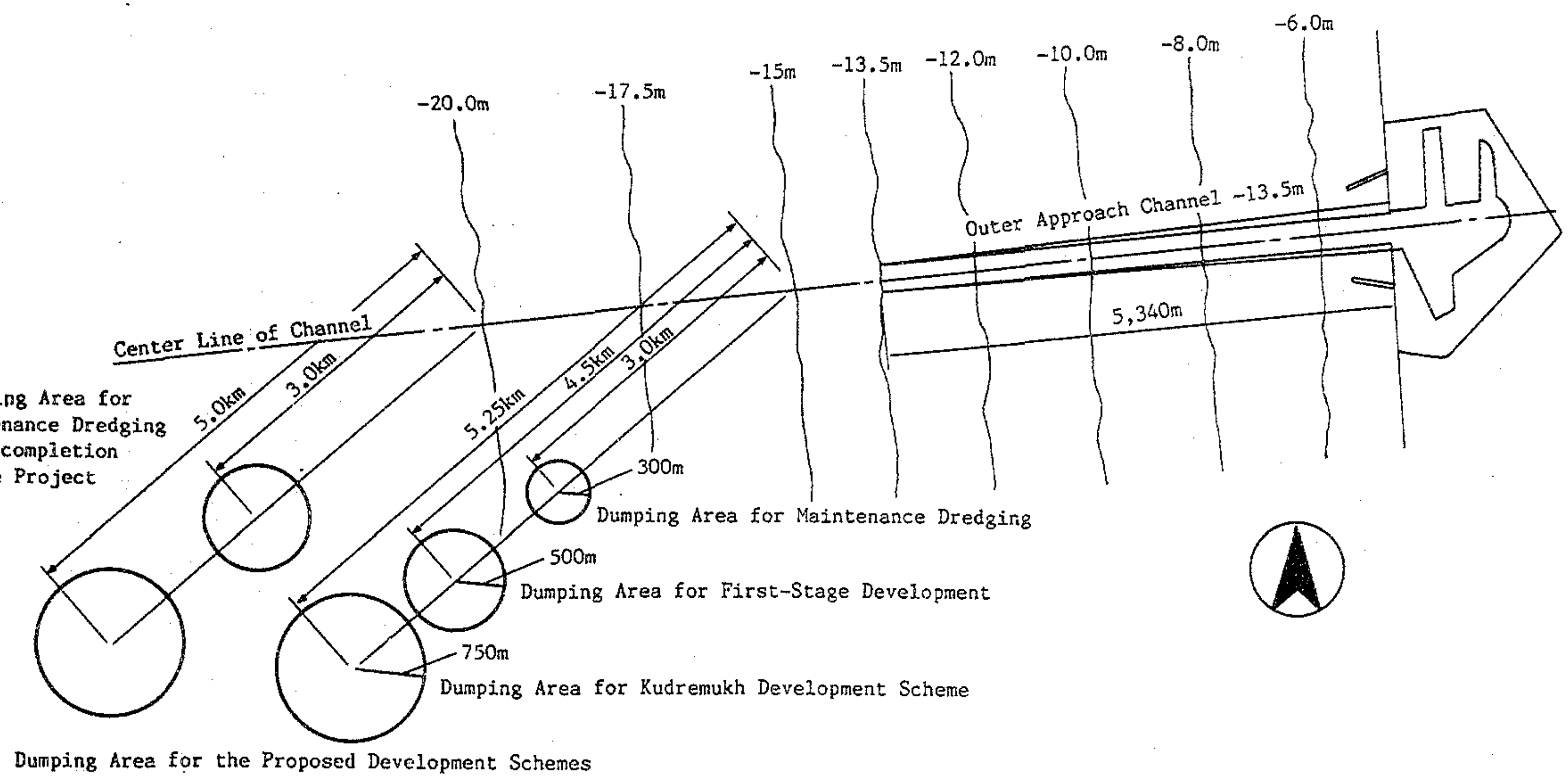


Figure-9.4.4 Location of Proposed Dumping Areas

10. FORMULATION OF SHORT-TERM PLAN (1995)

10.1 Improvement Plan for the Iron Ore Handling Facilities

10.1.1 Vessels size

As mentioned in Chapter 7, the maximum vessel size is 100,000 DWT. Sizes of ships calling at the berth will be distributed according to the maximum acceptable size at the berth.

As the size distribution depends on the destinations of the ships as shown in Table-7.2.7, the size distribution of ships calling at the berth can be projected by the destination as follows.

The iron ore has been exported mainly to Japan, Eastern European countries and other destinations. Assuming that the shares of iron ore exports from New Mangalore Port to each of these destinations do not change, iron ore export volume in 1994/95 can be calculated as shown in Table-10.1.1.

Table-10.1.1 Iron Ore Export Volume by Destination (1994/95)

Unit: 1,000ton

Destination	Total	Concentrate	Pellets
Japan	3,400	3,400	0
Eastern Europe	2,600	500	2,000
Others	1,500	600	1,000
Total	7,500	4,500	3,000

(Japan)

As mentioned above, iron ore carriers of 100,000 DWT or more are predominant in exports of ore to Japan and only 9% of the carriers are of 60,000 DWT or less. Moreover, although the berth was designed for 60,000 DWT class vessels, 27 vessels of 60,000 to 80,000 DWT called in 1988/89. Therefore, if the berth can accommodate vessels of 100,000 DWT or more, the Japanese will use larger ships.

The following assumptions are made in forecasting future ship distribution:

i) 100% of the cargo currently carried by ships of less than 40,000 DWT will be carried by ships of 80,000 to 100,000 DWT

ii) 50% of the cargo currently carried by ships of 40,000 to 60,000 DWT will be carried by ships of 80,000 to 100,000 DWT

iii) incremental cargo will be carried by ships of 80,000 to 100,000 DWT

(Eastern Europe)

Table-7.2.3 shows that almost all the ships transporting iron ore to Eastern European countries are less than 150,000 DWT and are almost evenly distributed among the vessel size categories below 150,000 DWT. Future ship distribution is forecast by assuming that the breakdown of cargo distribution by ship size is the same as relative rates among groups with sizes below 100,000 DWT.

Present Sharing Rate of Ships exporting ore to Eastern European Countries (ref. Table-7.2.3) is as follows.

0 - 40,000 DWT	23%
40,000 - 60,000	20
60,000 - 100,000	30
100,000 - 150,000	24
150,000 -	3

Improvement of the existing berth is planned up to 100,000 DWT class, so ships of the first three DWT categories are expected to call at the improved berth.

Therefore, future sharing rates after improvement of 100,000 DWT berth are as follows:

0 - 40,000 DWT	32%	(23 / (23+20+30))
40,000 - 60,000	27	(20 / (23+20+30))
60,000 - 100,000	41	(30 / (23+20+30))

(Others)

The same method as that for Eastern European countries is used.

Table-10.1.2 shows the distribution of ships for exporting 7,500,000 tonnes of iron ore. The figure for 60,000 DWT (existing) was calculated by using the same percentage as the present distribution.

Table-10.1.2 Ship Size Distribution for Short-term Plan

(No. of ships)

Ship Size (DWT)	Berth Capacity (DWT)	
	60,000 (existing)	100,000 (Improved)
0 - 20,000	10	3
20,000 - 40,000	86	19
40,000 - 60,000	59	44
60,000 - 80,000	39	34
80,000 - 100,000	0	35
100,000 - 130,000	0	0
130,000 - 150,000	0	0
150,000 - 170,000	0	0
AVERAGE SHIP SIZE (DWT)	43,000	65,000

10.1.2 Berth requirement

As mentioned in Chapter 7, improvement of the existing iron ore berth up to 100,000 DWT capacity will be enough for handling iron ore of 7.5 million tonnes.

So, no other iron ore berth will be required.

In the improvement, to accommodate 100,000 DWT carriers, depth, the position of bitts (position of mooring dolphins) and width and length of the apron, as well as the strength of port structures must be examined.

(Depth)

As mentioned in Chapter 7, the following depths are required for vessels of 100,000 DWT:

Table-10.1.3 Required Depth of Iron Ore Berth

Vessel Size (DWT)	Full Draught (M)	Depth (M)
100,000	15.5	-16.5

(Position of Bitts)

Mooring ropes must be stretched at an angle of 45 degrees or less to the berth head line. So, mooring bitts must be located at distances appropriate for the length of the vessel. In the case of improvement of the existing berth, the mooring dolphins should be shifted in accordance with ship size.

(Length/Width of Apron)

A shiploader is installed on the iron ore berth. The shiploader must move in a straight line from one end of the ship's hold to the other to load iron ore evenly on the ship. The shiploader moves on double rails and the distance between the two rails must be determined such as to ensure the stability of the shiploader. In the case of improvement of the existing berth for handling vessels of 100,000 DWT, the apron should be extended by 33m. However, the apron should not be widened because the existing shiploader can be used for 100,000 DWT vessels with minor modifications.

10.2 Plan for the Oil Handling Facilities

10.2.1 Vessel size

Crude oil would come from the Persian Gulf or Bombay High. According to Oil F/S Report, tankers of 65,000/85,000 and 150,000 DWT would be suitable for crude oil exports from Bombay High and the Persian Gulf, respectively.

Moreover, the report adds that 100,000/120,000 DWT would be used for crude oil exports.

Therefore, we assume the sizes of tankers operating for crude oil export to New Mangalore Port will be as follows:

Table-10.2.1 Tanker Size for Crude Oil Jetty (DWT)

Crude Oil Jetty	From Bombay	From Persian Gulf
100,000 DWT	65,000(1/4), 85,000(1/4)	100,000(1/2)

( ): Portion carried by each tanker size

The existing product jetty currently accommodates tankers of up to 35,000 DWT, as shown in Table-3.1.5. Therefore, we assume that the distribution rates will be the same as at present.

Table-10.2.2 Crude Oil Tanker Size Distribution

Crude Tanker Size (DWT)	No. of Ship
65,000 DWT	13
85,000	10
100,000	17
120,000	0
150,000	0
Total	40
Av. Size	83,000 DWT

loading factor = 0.9

Table-10.2.3 Oil Product Tanker Size Distribution

Product Tanker Size (DWT)	Product Jetty 35,000 DWT
0 - 5,000	0
5,000 - 10,000	0
10,000 - 15,000	0
15,000 - 20,000	23
20,000 - 25,000	19
25,000 - 30,000	19
30,000 - 35,000	2
Total	63
Av. Size	28,000 DWT

10.2.2 Berth requirement

As mentioned in Chapter 7, one oil products jetty as well as one crude oil jetty is required to meet the demand of oil products and crude oil transport.

Therefore, the oil products jetty planned in the outer port area will be set aside for long-term demand.

Required depths of oil jetties are as follows:

Table-10.2.4 Required Depths for the Oil Jetties

Jetty	Vessels	Full Draught(m)	Depth (m)
Crude Jetty	Crude Tanker (100,000DWT)	16.4m	-16.5m*
Oil Product Jetty	Oil Product Tanker (35,000DWT) Crude Tanker (85,000 DWT)	10.5m 14.0m	-15.0m

* 100,000 DWT tankers can call with 90% of full load.

Moreover, both crude tankers and product tankers could tentatively be accepted at the improved existing jetty before construction of the product jetty if the construction schedule of the oil refinery is delayed.

10.3 Plan for the Other Facilities

10.3.1 General cargo berth

The general cargo berths will handle granite stone (export:386,000t), coal (import:450,000t) and other cargoes (export:184,000t, import: 1,320,000t), totaling 2,340,000t in 1994/95. There are seven existing or under-construction berths (including one shallow berth). Each berth should handle 360,000t per annum (shallow berth is regarded as 0.5 berth in calculation) in 1994/95. Since the present average annual handling volume of each general cargo berth is 330,000t, as mentioned in Chapter 7, no additional general cargo berth should be constructed before 1994/95.

10.3.2 Channel

The channel should be widened and deepened as follows to accept iron ore carriers and crude oil tankers of 100,000 DWT.

Width : 275M
Depth : -16.5M (inside the breakwaters)
-17.0M (outside the breakwaters)

The channel has one-tenth slopes on the both sides.

10.3.3 Basin

The basin should be also widened and deepened as follows:

Diameter of Turning Circle : 550 M
Depth : -16.5M

10.3.4 Breakwater

Both breakwaters should be extended in almost the same alignment as that of the existing ones. The length of the breakwater is decided from the point of view of siltation, littoral sand drift, tranquility and stopping distance.

(1) Siltation

It is clear that the siltation volume in the channel and inflow of silt into the basin can be reduced as the breakwaters are extended farther and the mouth of the breakwater is narrowed.

The mouth cannot be narrowed so much because it has to be wider than width of the channel and the slopes. Moreover, the breakwaters need appropriate distances from the shoulder of the channel to avoid collapse of the shoulder.

There must be a balancing point between the extension and siltation because breakwater extension requires much expenditure in exchange for reduction of siltation, that is, reduction of maintenance dredging costs. Therefore, the optimum extension length should be decided by total costs of the extension and maintenance dredging.

Table-10.3.1 shows the estimation of the siltation volume and maintenance dredging cost for thirty years as present net value (discount rate = 7%) of each extension alternative. As mentioned in Chapter 9, only 70% of the siltation volume will be dredged. Table-10.3.2 shows the cost estimation of breakwater extension for each alternative, and Table-10.2.3, showing the total of the two costs, gives the solution: 1,500M (total length).

Table-10.3.1 Estimation of Siltation Volume and Maintenance Dredging Cost

Unit: m(Length), Million m3(Volume), Crore Rs. (Cost)

Length of Breakwater	500	1000	1500	2000	2500
Siltation Volume	9.3	7.1	6.1	5.1	4.1
Maint. Dredging Volume	6.5	5.0	4.3	3.6	2.9
Maint. Dredging Cost*	129.5	98.9	85.0	71.0	57.1

* present net value of 30-year cost

Table-10.3.2 Cost Estimation of Breakwater Extension

Length of Breakwater (m)	500	1000	1500	2000	2500
Extension Cost (Crore Rs.)	0	8.1	19.9	34.4	51.3

Table-10.3.3 Total Cost of the B/W Extention and Maint. Dredging

Length of Breakwater (m)	500	1000	1500	2000	2500
Total Cost (crore Rs.)	129.5	107.0	104.8	105.5	108.5

(2) Littoral Sand Drift

Littoral sand drift takes place in area of depth up to -7m and fills the channel with compact sand in the case of a strong storm. Therefore, breakwater with lengths of at least 1,300m, whose points would reach depth of -7m, will be needed.

(3) Tranquillity

Table-10.3.4 shows the annual effective rate of each berth in case of a 1,500m breakwater length. Tranquillity at each berth was calculated by using a numerical simulation model (details in Appndix-10.1) based on the distribution of wave direction and height at the point with a depth of -8.5m. As well, 0.7m and 0.5m are applied as allowable wave heights for cargo handling at the crude jetty and other berths, respectively. This calculation results that extension up to 1,500m satisfies necessary tranquility levels.

Table-10.3.4 Annual Effective Rates of Berths

Berth	Effective Rate (%)
Iron Ore Berth	93 (78)
Crude Oil Jetty	100 (100)
Oil Products Jetty	100 (100)
East Dock	99 (98)

( ) : effective rate during S/W monsoon (June to September)

(4) Stopping Distance

A protected and strait water area five times the length of the largest vessel and deep enough for the vessel is normally needed for stopping distance. As the largest vessel is 100,000 DWT crude oil tanker with 275m length, a stopping distance of more than 1,375m should be prepared. Figure-10.3.1 shows that the necessary length will be protected by the extension of the breakwater.

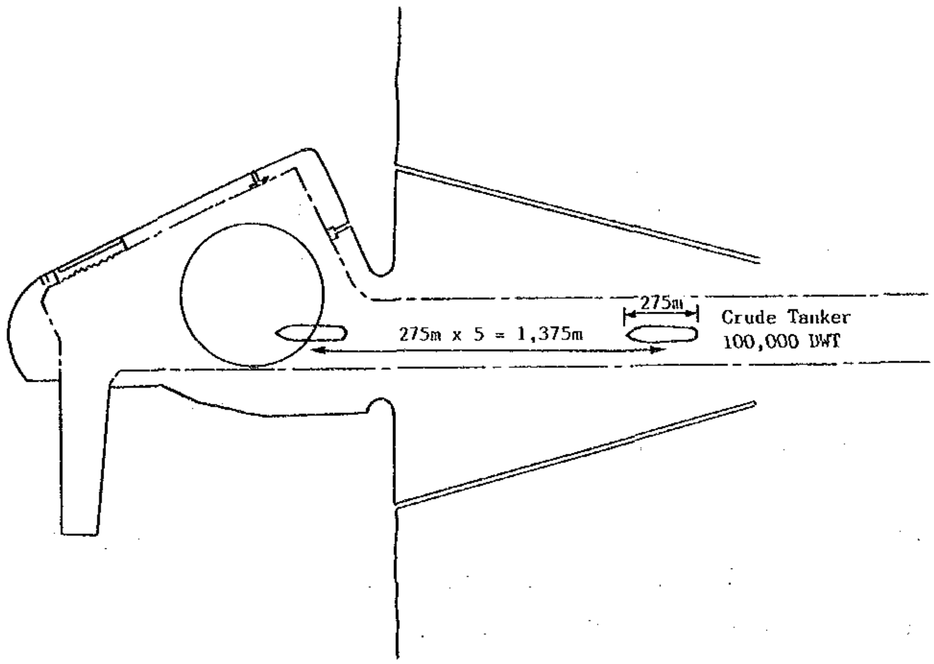


Figure-10.3.1 Stopping Distance

(5) Conclusion

Consequently, the optimum length of each breakwater should be 1,500m.

10.3.5 Improvement plan for aids to navigation

As the channel will be extended to around 8km to accommodate 100,000 DWT vessels, navigation aids will be required for safety maneuvering in the long waterway.

Preliminary coverage and effective range were estimated to geographically allocate the sites by visual and electronic aids to navigation. The site allocation was also examined by interpolation and/or parallel establishment of the systems. Table-10.3.1 shows equipment required for navigation aids (see Appendix-10.3, 10.4 in ditail).

Table-10.3.5 Equipment for Navigational Aids

Type of Aids	No.of Units
1) Rader Beacon (Transponder)	2 (spare 1)
2) Loading Light	2 (spare 1)
3) Day Mark	2
4) Light Buoy	15
a) Lateral Marks	14
- Port hand marks	7
- Starboard hand marks	7
b) Safe Water Marks	1
5) Light Beacon	8
a) Breakwater	2
b) Dolphin	6 (3 X 2)
6) Synchronized Flashing	1

Lighting character, buoy color, top mark and radar reflector are fitted as specified according to the "IALA A" system. Location of aids to navigation is illustrated in Figure-10.3.1.

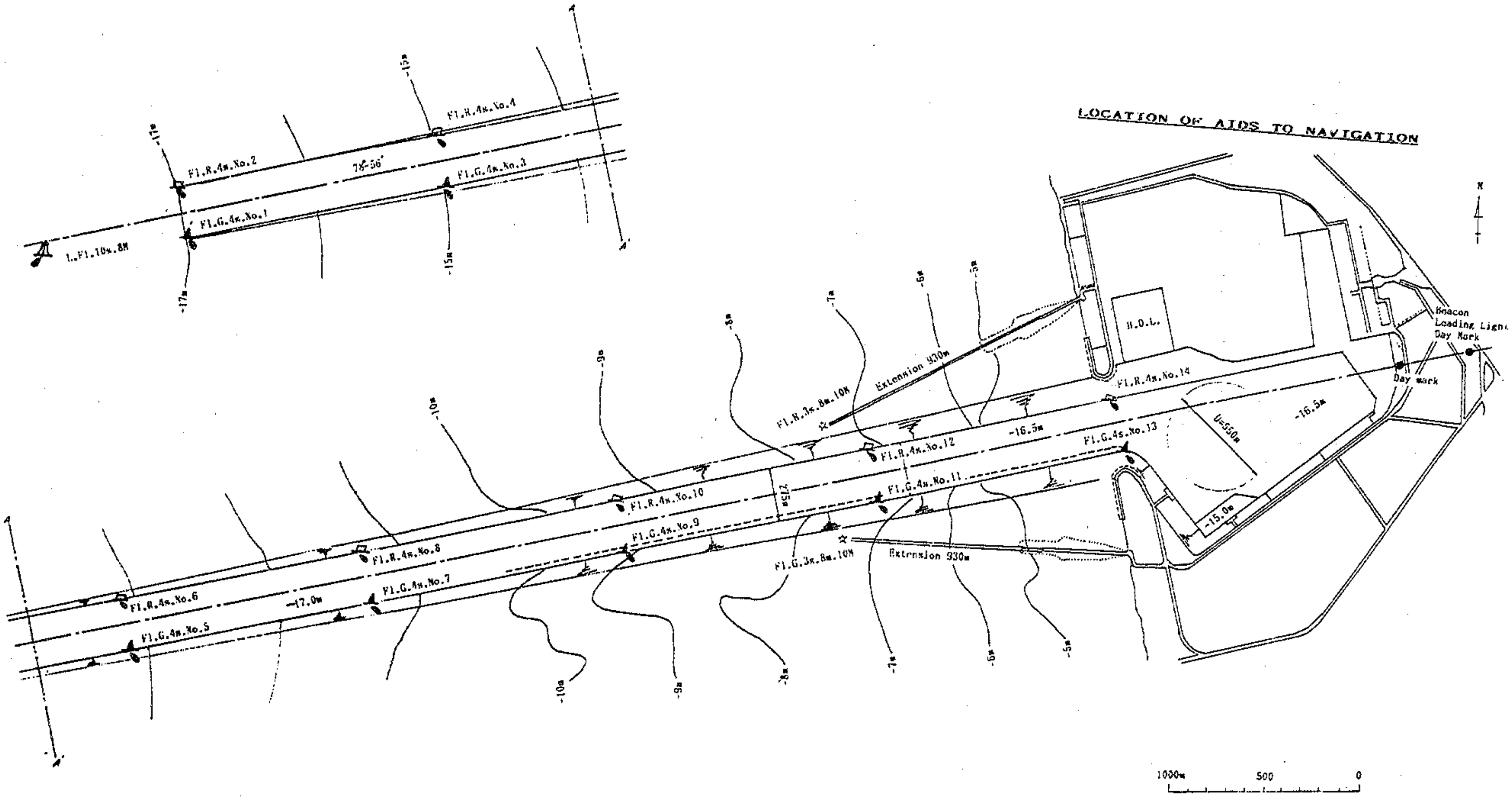


Figure-10.3.2 Location of Aids to Navigation

10.4 Short-term Plan

The following facilities are included in the Short-term Plan:

- Improvement of the Existing Iron Ore Berth to 100,000 DWT Class
- Reconstruction of the Existing Oil Product Jetty to a Crude Oil Jetty of 100,000 DWT Class
- Construction of an Oil Products Jetty of 85,000 DWT Class
- Deepening and widening of the Channel

  Depth : -16.5m (protected area)

  -17.0m (un-protected area)

  Width : 275m
- Deepening and Widening of the Basin

  Depth : -16.5m

  Turning Basin : Diameter 550m
- Extension of the Southern and Northern Breakwaters up to 1,500m

Figure-10.4.1 depicts the Layout of the Short-term Plan.

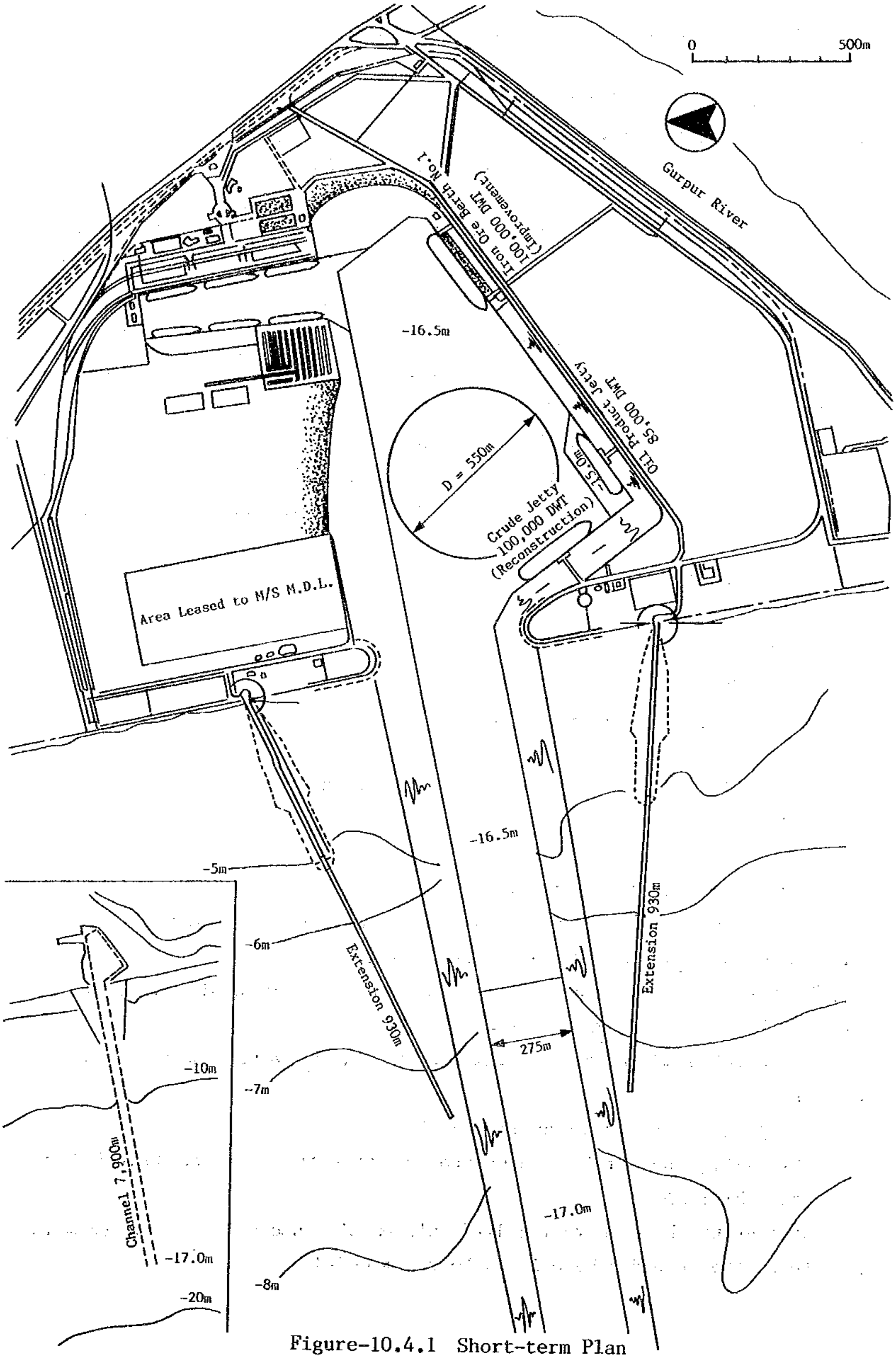


Figure-10.4.1 Short-term Plan

11. PRELIMINARY DESIGN FOR EACH ALTERNATIVE SHORT-PLAN

11.1 The Iron Ore Handling Facility

11.1.1 Improvement plan of existing iron ore berth

1) Augmenting the Berth up to 100,000/110,000 DWT Ships (in case 1)

a) Ship Characteristics

The iron ore berth with its associated handling system was designed for 60,000 DWT ships to load iron ore concentrate. In order to study the feasibility of extending the existing iron ore berth and the associated handling system from the existing capacity to receive ore carriers up to 100,000/110,000 DWT, these ships' characteristics shall first be defined.

Matching the existing systems and minimum modifications it is observed that full laden vessels of 110,000 DWT can be accommodated. The maximum design dimensions have been selected such that 75% of the vessels have leading dimensions less than or equal to the following dimensions:

Length overall	:	270 m
Extreme	:	42 m
Maximum draught	:	15.5 m
Moulded depth	:	22 m
Maximum length of holds	:	188 m

The selected dimensions match those of various iron ore handling ports of similar size.

b) Technical Points for Augmentation

The present handling system shall be improved in order to receive 100,000 DWT class ships at the existing berth.

The modification methods of the handling system shall be minor as described in the following chapter.

For dealing with ships bigger than 60,000 DWT, two schemes are considered.

- Warping of the vessel during loading,
- Extending the berth to accommodate the extra distance traveled by the shiploader.

Considering the maneuvering difficulties of vessels for a long term in the future, the second scheme is to be recommended.

c) Countermeasures to be Taken for Augmentation

Reinforcement of existing breasting dolphin

The breasting dolphin will receive greater horizontal force from berthing ships which will be almost twice the size of previous ones, so some counter measures to increase the strength of pilings should be under taken.

Because the seabed level, which is -13.0m CDL, must be deepened to -16.5m CDL, a kind of retaining wall protecting the soil level below the berth and the stability of the pilings will be needed.

New breasting dolphin

To accommodate the extra distance traveled by the shiploader in dealing with bigger ships a new breasting dolphin 33m in length shall be constructed. The new dolphin shall be installed where the driving house and its platform are located. The approach jetty located at the west side shall remain as it is.

New mooring dolphins

Two mooring dolphins would satisfy the requirements of good mooring practice. Without these dolphins, the vertical inclination of mooring lines will be critical and arranging breasting lines will be difficult.

New drive house for conveyer

To make the conveyer line longer the existing drive house shall be moved to the western part of the approach jetty. Therefore, new drive house foundation shall be constructed.

d) Summary of Augmentation Plan

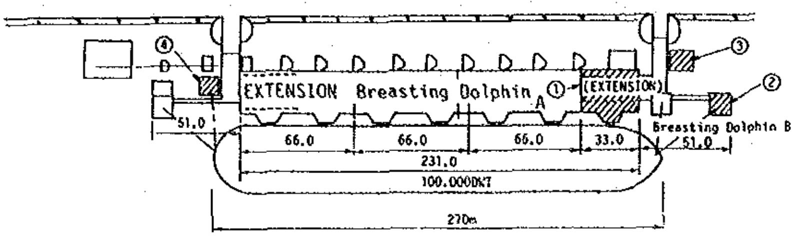


Figure-11.1.1 Augmentation Plan of the Iron Ore Berth

Figure-11.1.1 shows the sketch of the augmentation plan. The scheme mainly consists of the following.

1 Constructing a new breasting dolphin 33m in length
2 Constructing 2 mooring dolphins.
3 Constructing a new drive house for the conveyer
4 Protecting the existing soil level below the berth

1.1.2 Design of iron ore berth augmentation

a) General

The main facilities to be considered are as follows:

(1) Strengthening/extending of the existing dolphins
(2) Constructing a new dolphin
(3) Constructing New mooring dolphins
(4) Constructing a drive house and an approach jetty
(5) Constructing a sheet pile protection

The structural type of the facilities to be extended shall be determined considering various factors including natural conditions, construction period and availability of the construction material.

The conditions to be considered include the following:

- Marinal condition
- Meteorological condition
- Soil condition
- Earthquake
- Construction period

b) Design condition

(1) Tidal level

M.H.HWL	+ 1.48M
M.L.HWL	+ 1.26M
M.W.L.	+ 0.95M
M.H.LWL	+ 0.77M
M.L.LWL	+ 0.26M
L.L.WL	+ 0.03M

(2) Soil condition

Soil layers at the face line of the berth are shown in Figure-11.1.2. A hard rock surface located at the level of -26 ~ -23m C.D.L is covered with medium sand layers including stiff clay.

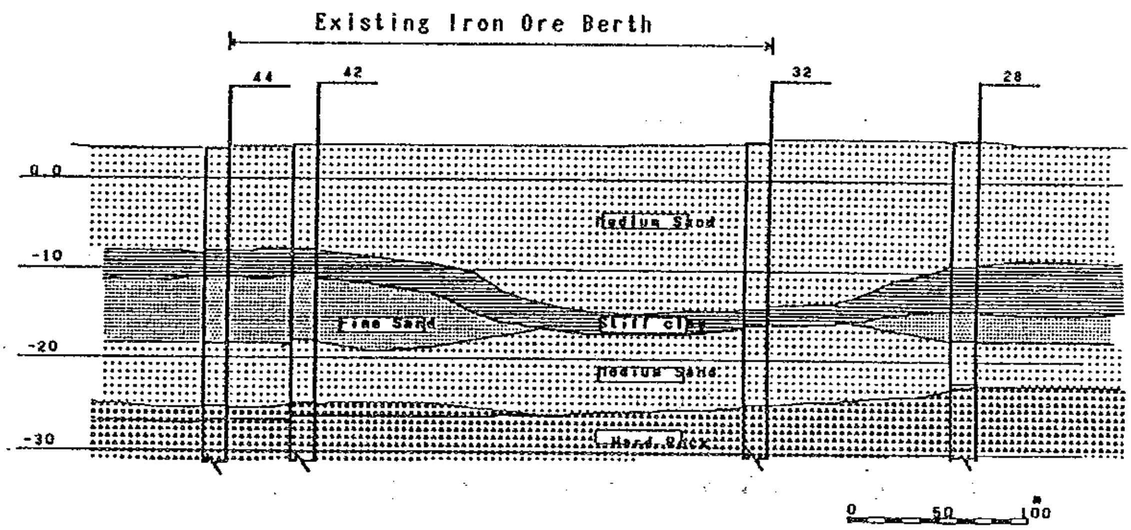


Figure-11.1.2 Soil Strata

(3) Wave condition

Ship impact at breasting is colossal compared with wave action. The latter therefore, can be neglected.

(4) Seismic coefficient

Horizontal	Kh = 0.04
Vertical	Kv = 0

(5) Kinetic energy of vessels

The energy shall be calculated as follows:

- Dead weight tonnage : 110,000 170,000 DWT
- Actual weight : log f = 0.294 + 0.956 log DWT
- Additional weight : $Wa = \frac{\pi}{4} D^2 LWo$
- Approach velocity : V = 0.15 m/s
- Kinetic energy : $E = \frac{1}{4g} WV^2$

where : f = Total weight of full cargo and ship itself

Wa = Weight of water being incidental to the mooring ship

D = Draft of ships

L = Total length of a ship

Wo = Unit weight of sea water

g = Gravity acceleration 9.8m/s/s

Each kinetic energy acting on one dolphin becomes as follows:

E 110,000 = 104 tm

E 170,000 = 203 tm

(6) Impact force of vessels

Kinetic energy of vessels are converted into reaction force through a rubber fender.

E_1 = 104 tm ⟶ 120 ton (suc-2000H-R_1)

⟶ or, 170 ton (suc-1700H-RH)

E_2 = 203 tm ⟶ 215 ton (suc-2000H-RH)

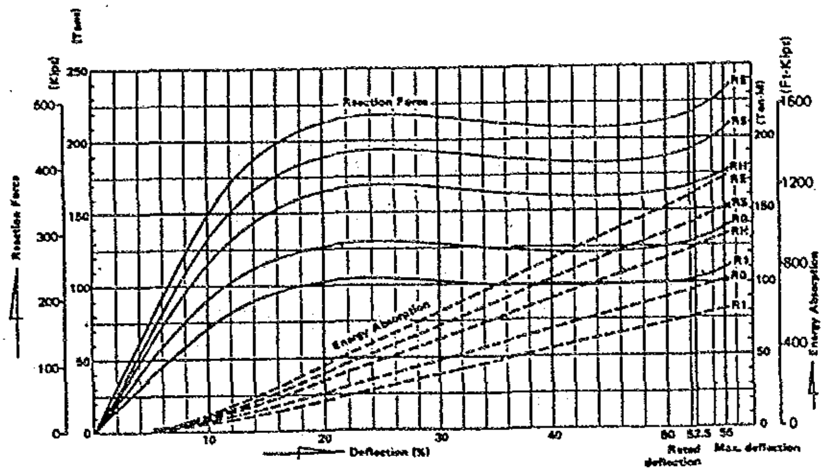


Figure-11.1.3 Suc 1700H Performance Cruve

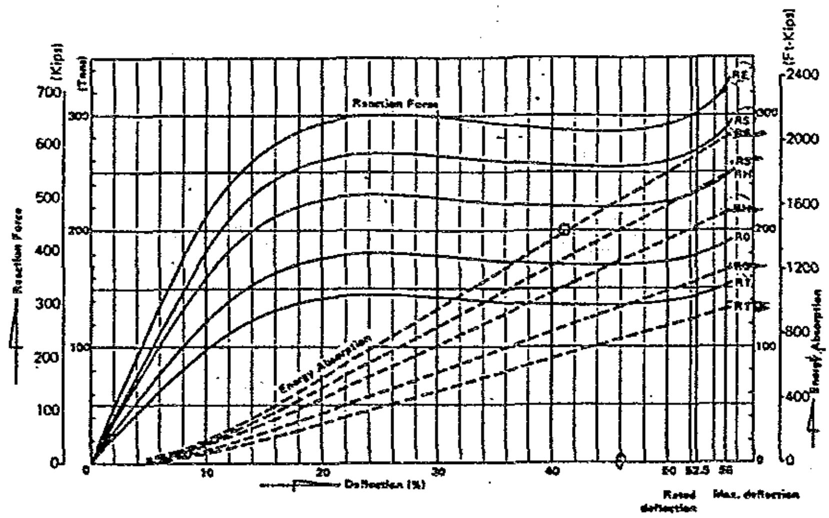


Figure-11.1.4 Suc 2000H Performance Curve

(7) Allowable stress

Concrete (structure)	:	70kg/cm^2
Concrete (pile)	:	90kg/cm^2
Iron bars (SR-24)	:	1,400kg/cm^2
Iron bars (SD-30)	:	1,800kg/cm^2
Steel Sheet pile	:	1,800kg/cm^2
Steel Pipe	:	1,400kg/cm^2

Allowable stress shall be increased by 50% for unusual loads.

(8) Load

- Wheel load

Table-11.1.1 Shiploader Wheel Load (in ton)

	Horizontal Boom				Boom up			
	transvers section wind V=80km/h		parallel section wind V=80km/h		transvers section wind V=80km/h		Parallel section wind V=80km/h	
	Land side	Sea side	Land side	Sea side	Land side	Sea side	Land side	Sea side
Vertical load for one wheel	22	31	22	33	29	18	30	19
Horizontal L. for one wheel	2.2	0.1	2.2	-	2.9	0.1	3	-

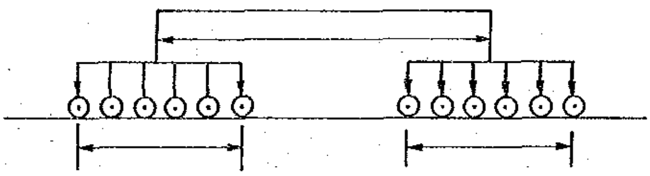


Figure-11.1.5 Load of Shiploader

- Uniform load

  Floor level : 2.0 t/m^2

c) Structural design

(1) New Dolphin

A new dolphin shall be constructed at the western end of the existing dolphin as shown in Figure-11.1.6 for a 100,000 DWT ship.

The dolphins are founded on reinforced concrete piles of 1,220MM dia with concrete slabs cast in situ as per the existing ones.

(2) Reinforcement of existing dolphin

For the 100,000 DWT berth, the existing dolphin shall be strengthened with steel beams, and sheet pile retaining wall is provided so as to protect the present sea bed slope which will be necessary for the stability of the piles as shown in Figure-11.1.8.

(3) Mooring dolphins

Mooring dolphins are installed as shown in Figure-11.1.6 and 11.1.8. These are necessary for good ship maneuvering practice. Type and size are decided as per existing ones.

(4) Miscellaneous Items

Other miscellaneous items are shown in Figure-11.1.7 and Table-11.1.2.

S=1/2,000

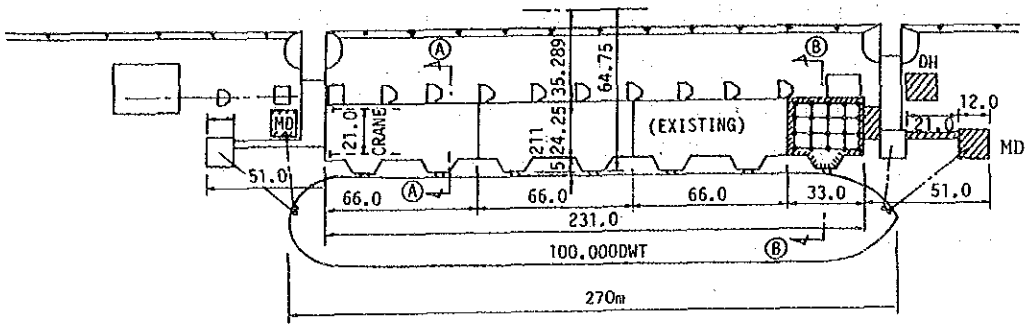


Figure-11.1.6 Lay-out Plan of 100,000 DWT Iron Ore Berth

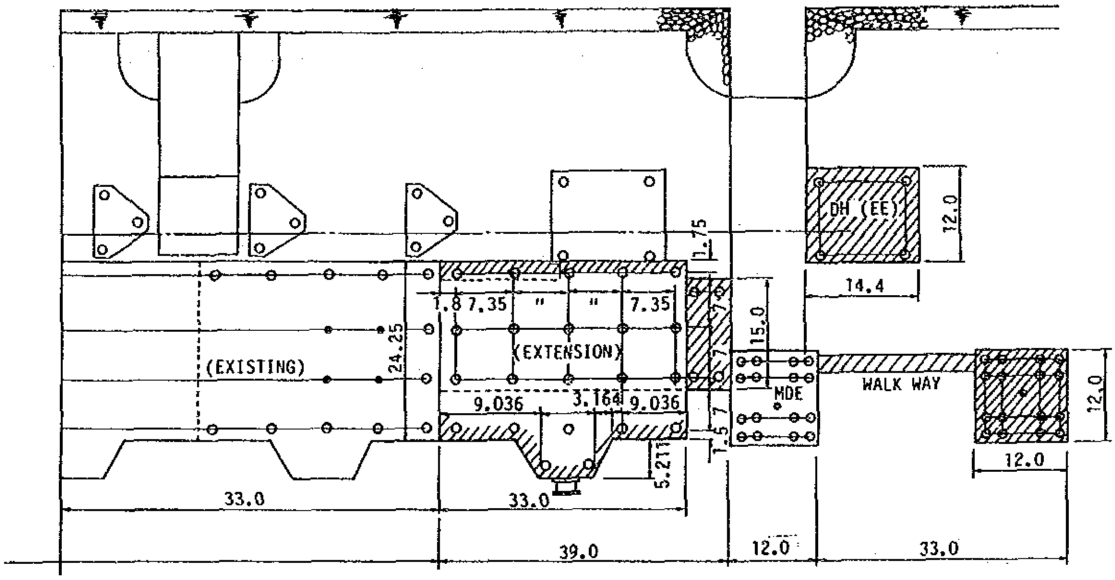


Figure-11.1.7 Detailed Plan of 100,000 DWT Iron Ore Berth

S=1/400

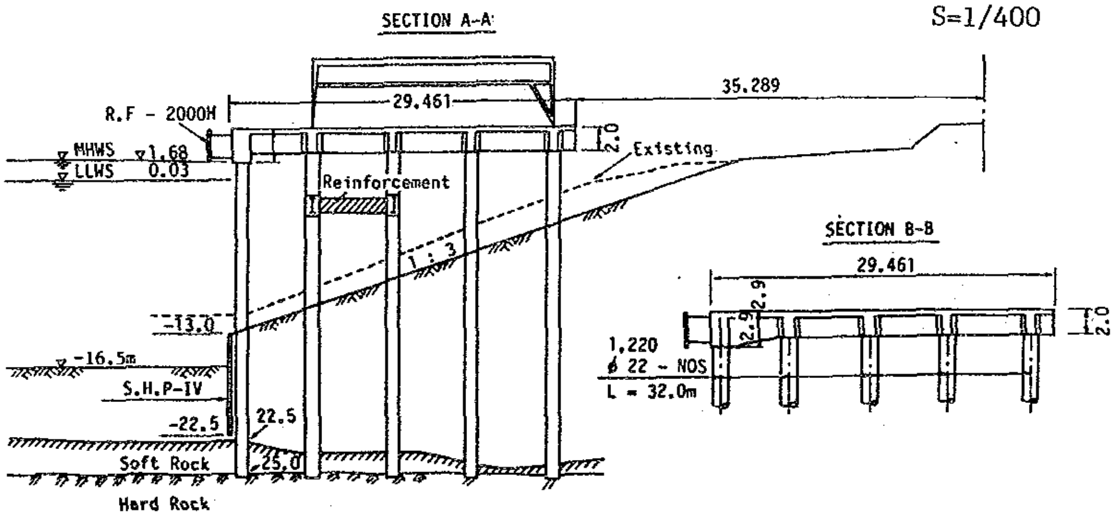


Figure-11.1.8 Typical Section of 100,000 DWT Berth

Table-11.1.2 Item to be Augmented for 100,000 DWT

Item	Nos	Piles	Slab	Note
1. Two Mooring Dolphins 2. Breasting Dolphin 3. Drive House 4. Walk Way	2 1 1 1	ϕ 1,220 x 32 ϕ 1,220 x 26 ϕ 1,000 x 4 ϕ 910 x 8	As per DWG As per DWG 1.0m " 0.6 "	. All pile length shall be L = 28.0 meters
5. Sheet Pile	1-Lot	Type IV. = 10m		
6. Rubber Fender	7	suc-2000H		

11.2 The Product and Crude Oil Jetties

11.2.1 Crude berth

1) Up grading the berth up to handle 100,000 DWT ships (in case 1)

a) General

As described in the previous clause, the existing oil jetty can be used by 30,000 DWT class vessels.

However, considering that oil tankers are becoming bigger, up grading of the existing oil jetty is inevitable. For example, it is said that M/S Shipping Corporation of India (S.C.I) has procured several 65,000 DWT tankers which it plans to deploy on the Mangalore route. The S.C.I. has also proposed orders with a local shipyard limited for a few tankers of 85,000 DWT size.

Considering these circumstances, the improvement of the oil jetty shall be determined on the basis of 65,000/85,000 DWT tanker as the design vessels.

Moreover, the shipping Corporation of India is considering proposals to replace their present fleet with tankers in the 87,000 to 100,000 DWT class.

On the other hand, oil berths at Bombay and Cochin are being planned for vessels of 125,000 DWT and 115,000 DWT, respectively. To keep the facilities at Mangalore on a par with these, crude oil berth for vessels of 100,000 DWT should be constructed.

The crude oil berth will be created by extending/strengthening the existing oil jetty.

The maximum extent of improvement of the berth shall be designed to cater for vessels of 100,000 DWT, which is incidentally much higher than the oil tankers of 35,000 DWT which mainly use the jetty . This will enable the berth also to receive product vessels whenever the main product berth is either over burdened or out of commission. A plan illustrating this proposal is shown in Figure-11.2.1, 11.2.2.

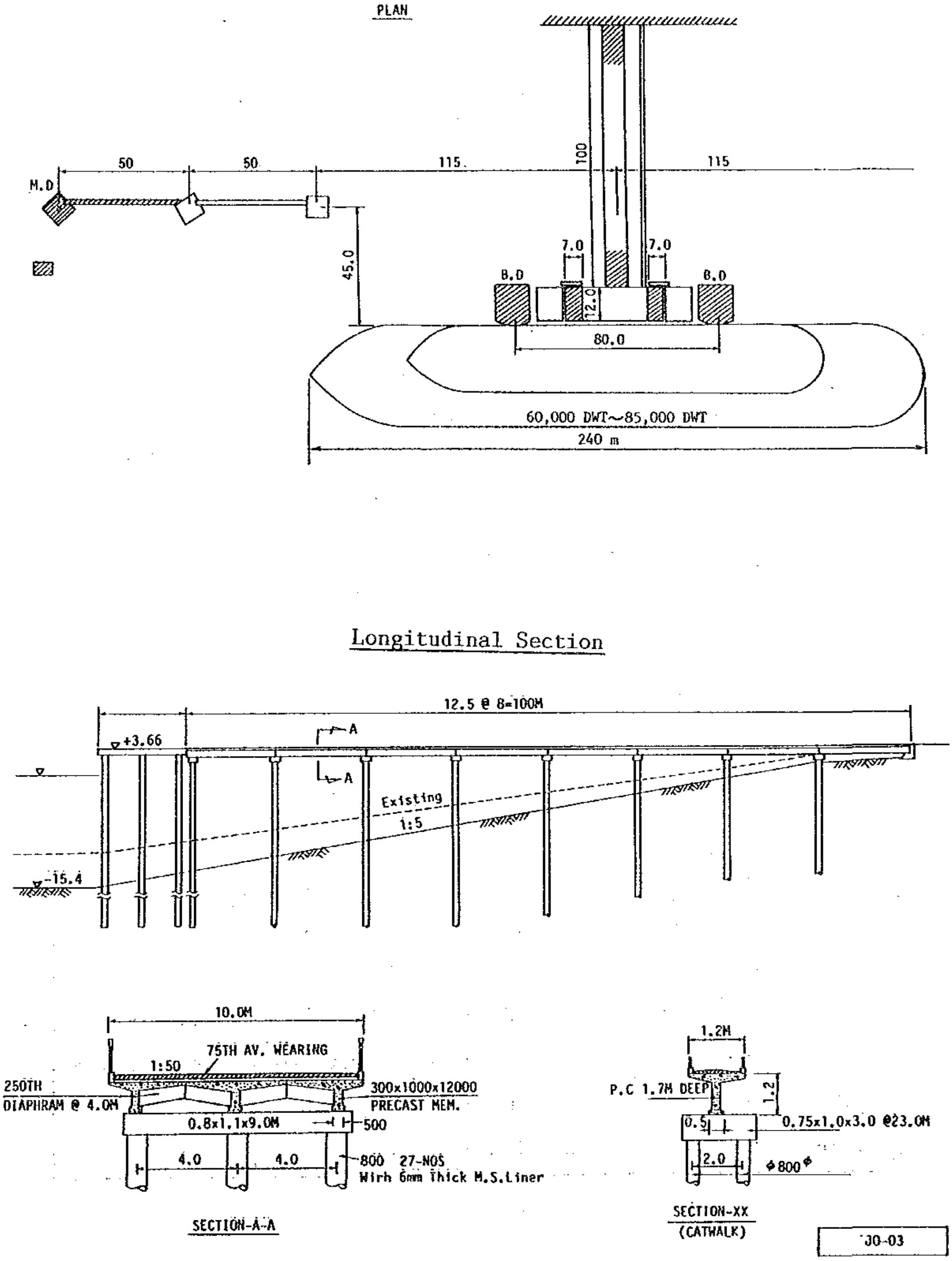


Figure-11.2.1 Upgrading the Existing Oil Berth up to 100,000 DWT Ships

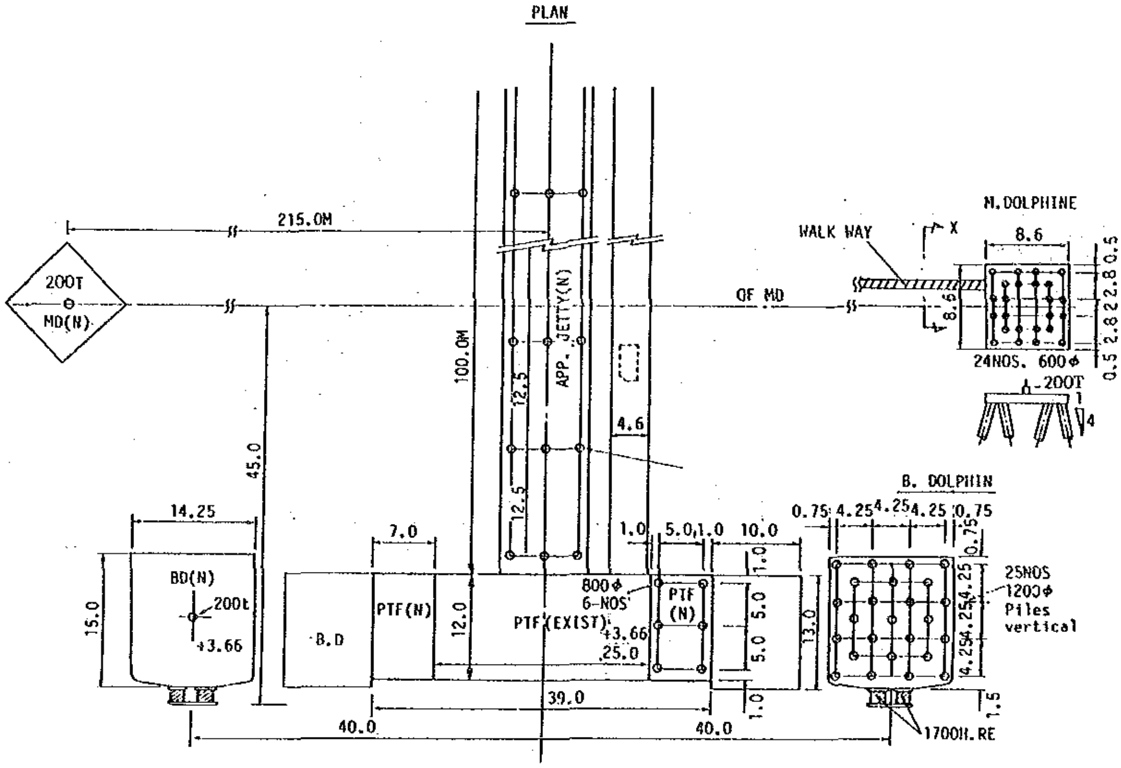


Figure-11.2.2 Detail of Structures (Crude Berth)

Table-11.2.1 List of the Structures (Crude Berth)

Item	Piles	Slab	Note
1. Two B. Dolphins	ϕ 1,200 x 50	1.5m thick	
2. One Platform	ϕ 800 x 12	0.6m "	
3. Two M. Dolphins	ϕ 600 x 48	1.0m "	Pile length
4. One Approach Jetty	ϕ 800 x 27	As Per DWG	to be 33.0m
5. Walk Way	ϕ 800 x 24	" "	
6. Rub. Fenders.	ϕ 1,700 x 4	– "	

11.2.2 Product berth

1) New 85,000 DWT

New 85,000 DWT Oil Product Jetty was planned at the southern part of the basin.

The layout of the berth is also shown in the general layout. Facilities enabling them to meet present-day and future requirements of crude/product handling shall be provided.

They include marine loading/unloading arms, firefighting facilities, pollution control facilities, navigational facilities and electrical facilities.

Besides 2 tractor tugs of 30 - 35 BP each, one pilot/survey launch and two mooring boats are to be procured. A rough sketch of the berth structure is shown in Figure-11.2.3. The facilities are listed in Table-11.2.2.

Table-11.2.2 List of the Structures (Oil Product Berth)

Item	Piles	Slab	Note
1. Two B. Dolphins	ϕ 1,200 x 50	1.5m thick	
2. Six M. Dolphins	ϕ 600 x 144	1.0m "	
3. One Platform	ϕ 800 x 27	0.6m "	
4. One Approach Jetty	ϕ 800 x 27	As Per DWG	
5. Walk Way	ϕ 800 x 32	"	
6. Rub. Fenders.	ϕ 1,300 x 4	– "	

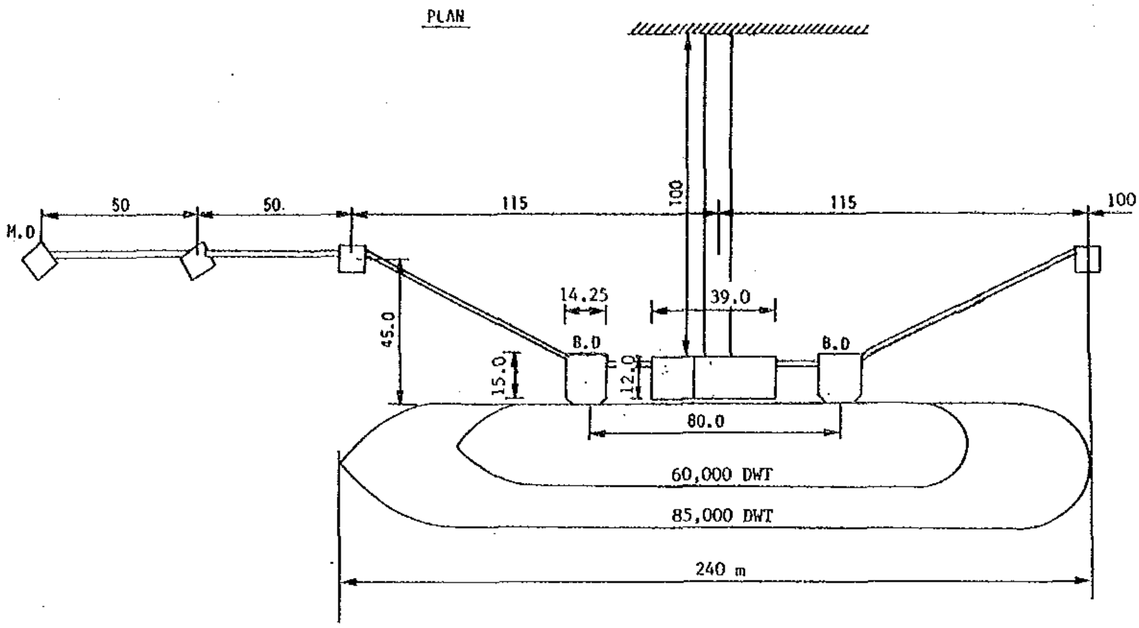


Figure-11.2.3 New 85,000 DWT Oil Product Jetty

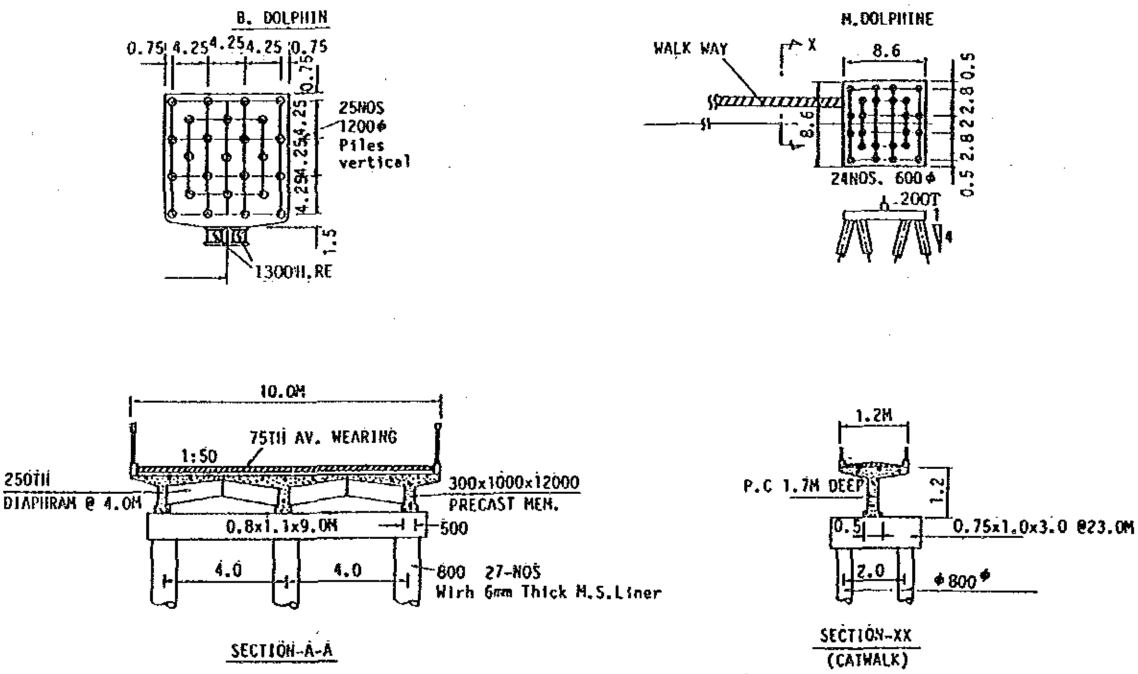


Figure-11.2.4 New Oil Product Jetty Detail

11.3 The Breakwater

11.3.1 General

According to the Master Plan, several layout plans are suggested but they are forcussed in a plan for the breakwater arrangement.

Figure-11.3.1 shows the breakwater arrangement of the inner port type. Both north and south breakwaters are extended 930m in length and at their extremity the water depth becomes -7.0m.

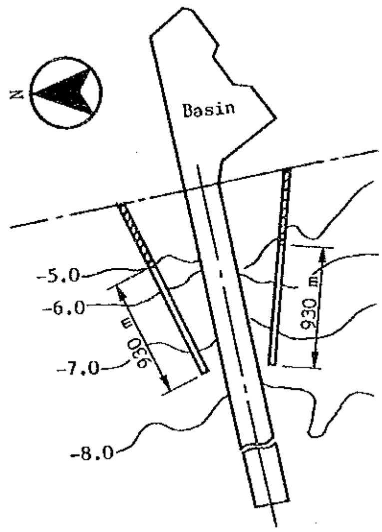


Figure-11.3.1 Breakwater Arrangement

11.3.2 Design condition

1) Crown level of breakwater

$$C.L = HWL + 0.6\ H_{1/3} = 1.48 + 0.6 \times 3.6 = 3.5m$$

2) Dimensions of breakwater

The Dimensions of the breakwaters shall be decided considering the stability of circular failure owing to the soil condition on which the breakwaters are arranged.

3) Size of rubble stone

The sizes of armor stone shall be calculated from Hudson's formula and decided taking into consideration stone sizes which have been actually used in construition.

$$W = \frac{H^3}{K_D\ (Sr - 1)^3\ \cot\alpha}$$

Where, W = Minimum weight of a rubble stone

γr = 2.65 t/m^3

H = Significant wave height = 3.6m

K_D = Coefficient decided by material and damage ratio. 4.0 - 2.3

Sr = Specific gravity of stone to sea water 2.57 t/m^3

4) Soil data

Soil characteristics used in the analysis is applied from the latest data which was carried out at the first and second construction stage of the existing breakwater.

Main soil characteristics are as follows,

C	; Initial cohesion of clay	(1.0, 2.0 t/m^2)
γt	; Bulk density saturated	(0.6 t/m^3, 1.0 t/m^3)
ϕ	; Friction angle of sand.	(30°, 35°)
Cu/p	; Increment ratio of cohesion	(0.35)
Cv	; Coefficient of consolidation	(500 cm^2/day)
D	; Thickness of consolidation layer	(10.0 m)

The soil profile is shown in Chapter 2.6.4 Geological Investigation.

11.3.3 Stability of breakwaters

1) Study Cases

The calculation of the circular failure are examined for the following three cases.

a) Breakwater section at -5.5m contour

b) Breakwater section at -8.0m contour

c) Existing south breakwater area where dredging works are expected at the level of -19.0m for outer port plan.

2) Stability of the breakwater at -5.5m

Safety factors against a circular failure are calculated in consideration of the increasing of the cohesion by consolidation phenomena which will be caused during the gradual execution of rubble stone banking work.

Figure-11.3.2 shows a critical circular failure section calculated with soil characteristics mentioned above.

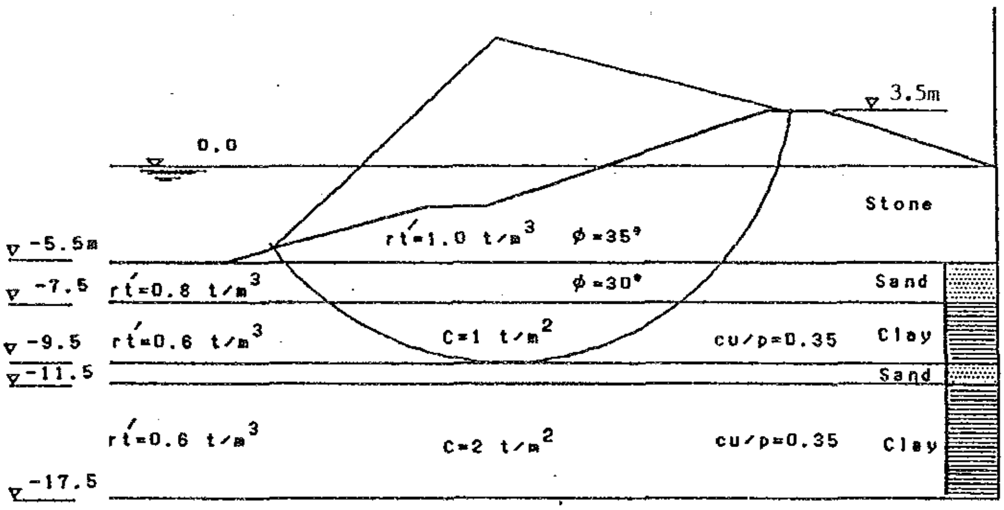


Figure-11.3.2 Circular Failure Analysis

The circular failure calculation was repeated considering the increasing soil consolidation degree until the safety factor becomes satisfactory. Figure-11.3.3 shows the relation between the safety factor and degree of consolidation. From this graph, when degree of the consolidation becomes greater than sixty (60) percent, the safety factor of breakwater stability becomes more than 1.2.

In order to achieve a satisfactory safety factor of 1.2, the breakwater works should be executed gradually layer by layer to achieve a stable condition spending about a one year in construction period.

Figure-11.3.4 shows the relation between construction period and consolidation degree.

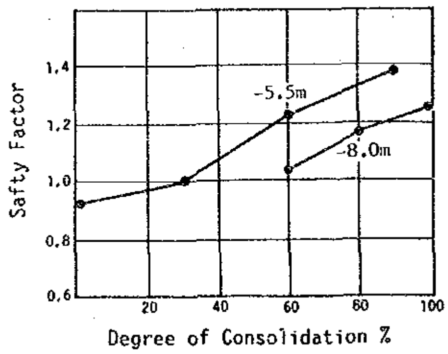


Figure-11.3.3 Safty factor - Consolidation

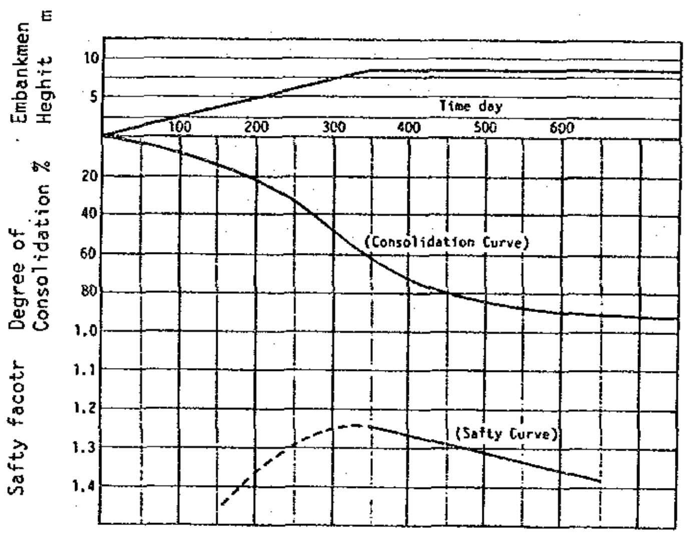


Figure-11.3.4 Construction Period - Consolidation Degree

3) Stability of breakwater at -8.0m

There are few boring data in this area, so the soil strata were assumed as shown in Figure-11.3.5.

Compared with -5.5m contour area, weak clay layer is thick at this point, the condition for breakwater stability becomes very serve.

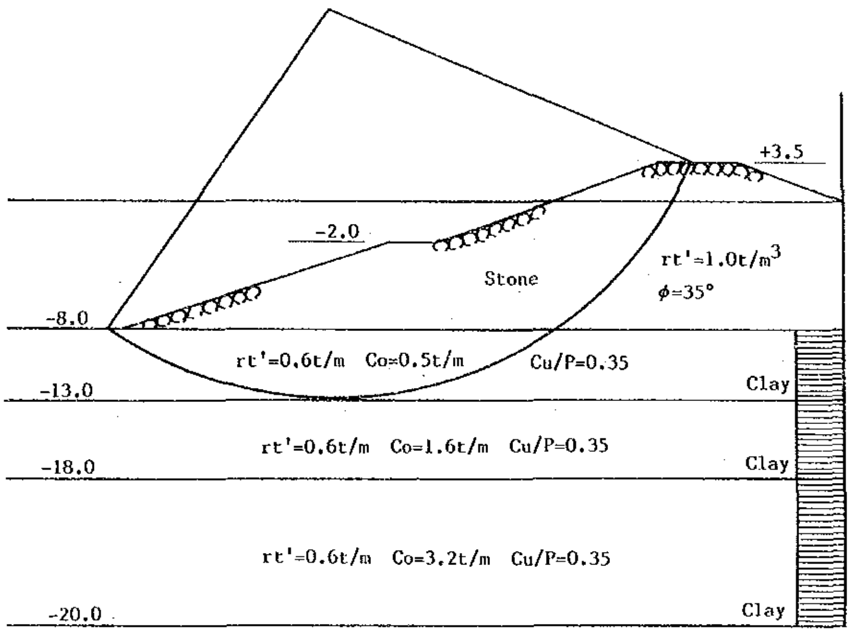


Figure-11.3.5 Circular Failure Analysis at -0.8m

Stability of this breakwater shall be obtained when the degree of consolidation has become more than 80%.

The time necessary to obtain this consolidation of 80%, is unpredictable because of the lack of detailed soil data. In the case of no special soil improvement of the bed strata, the breakwater stability could be obtained by the slow construction method.

The precise construction period shall be decided after soil investigation results in the future, but it might be estimated that at least a 3 year construction period would be required.

4) Stability of existing breakwater area

The circular failure analysis was performed in the case of outer port plan. According to the plan, the front of the existing south breakwater area is planned dredging to the level of -19.0m for the future crude berth.

The dredging slope was assumed to be 1 to 5 and soil properties were assumed as shown in the Figure-11.3.6. The stability of the existing break water was confirmed as safe.

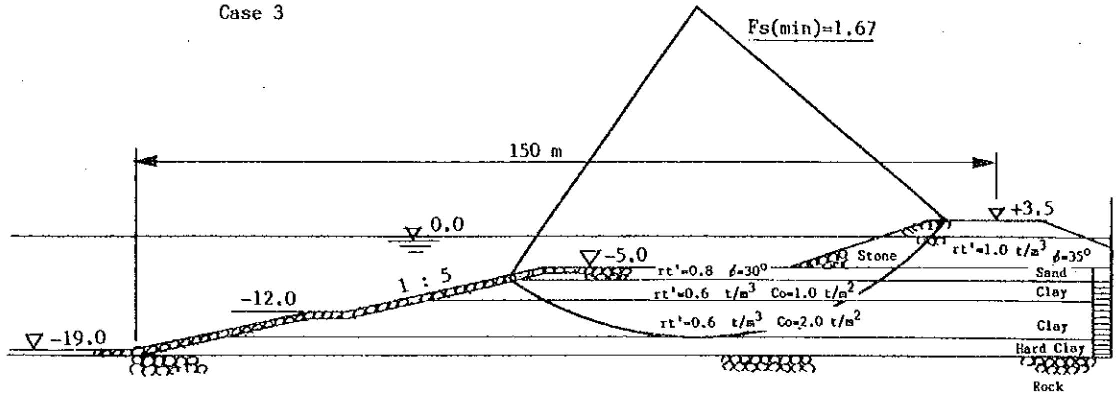


Fig-11.3.6 Circular Failure Analysis at existing breakwater area

11.3.4 Standard sections of breakwaters

Standard Sections of Breakwater are shown in Fig-11.3.7

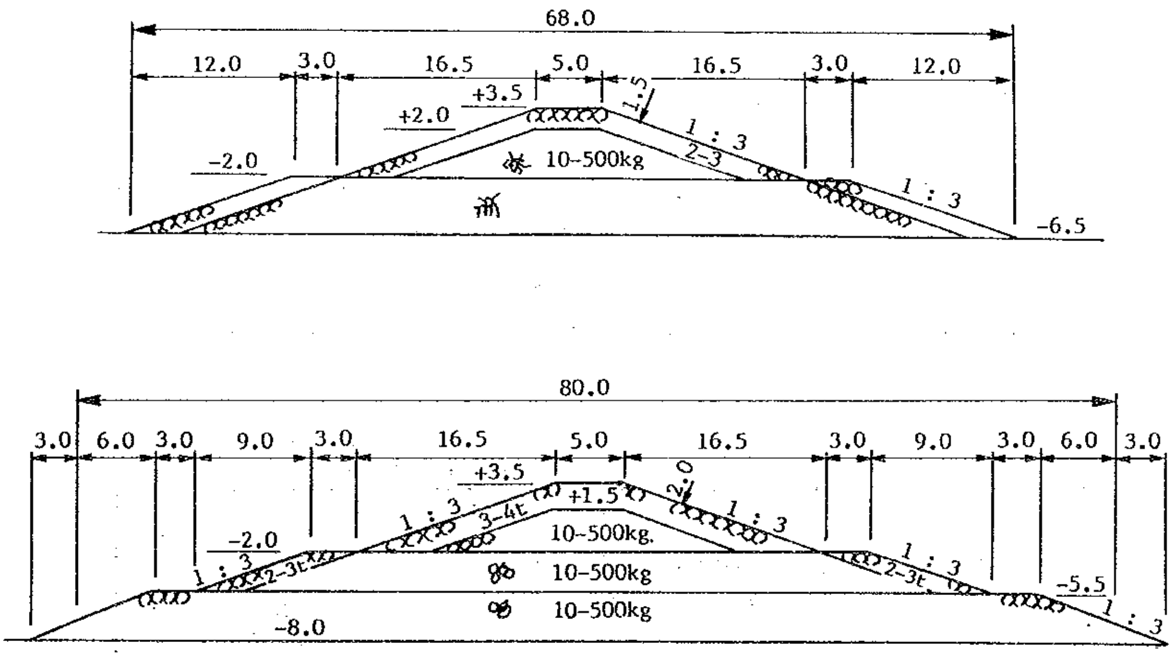


Fig-11.3.7 Standard Section of Breakwater

11.4 The Iron Ore Handling Equipments

11.4.1 Introduction

The handling equipment for the iron ore handling facility to be designed in this report are the shiploader, conveyer, stockpile for concentrate and pellet, shed for concentrate stockpile and reclaimers for concentrate and pellet. Design conditions for each piece of equipment are as follows:

Shiploader
- Loading rate
- Ship size
  - Out reach of chute
  - Travelling range on the berth
  - Boom clearance

Conveyor
- Handling capacity

Stockpile
- Annual throughput

Reclaimer
- Reclaiming capacity

11.4.2 Shiploader

(1) Loading rate

It was concluded in Chapter 7 that capacity upgrading of conveyors and berth upgrading to at least 100,000 DWT is required to handle annual throughput of 7.5 million tons (pellet ratio = 0.4). Therefore, as mentioned in Table-7.2.2, Chapter 7, the ore shiploading capacity will be examined as follows:

Table-11.4.1 Shiploading Capacity

System Capacity t/h		Modification
Present	6,000/3,500*	
Future (7.5 Million t)	7,000/3,500	Capacity Upgrading of Outgoing Conveyor Cross Conveyor Wharf Conveyor

* The shiploading capacity of each Concentrate/Pellet.

The nominal shiploading capacity of the existing shiploader is 6800 t/h, as described in Chapter 2.5.2. However, the boom conveyor on the shiploader is designed to be upgraded easily by changing the conveyor speed to the capacity of 8000 t/h for concentrate and 4100 t/h for pellet. Thus, it is easy to upgrade the shiploader capacity to 7,000 t/h

(2) Outreach of chute, travelling range and boom clearance

An alternative improvement plan of the existing iron ore berth is made for 100,000 DWT class vessels. The existing iron ore berth and the shiploader were built based on the maximum size of vessels being 60,000 DWT. Therefore, it is necessary to examine the outreach of the shiploader chute, the travelling range of the shiploader and the horizontal boom clearance with reference to bigger ships.

a) Outreach of chute

Figure-11.4.1 and Table-11.4.2 show that the existing shiploader will be able to be used for 100,000 DWT size ships after some minor modifications to the chute, as shown in figure-11.4.2.

Table-11.4.2 Outreach of the Shiploader

Ship Size DWT	B m	bm	R3/4 m
60,000	34.5	14.8	29.95
100,000	40.3	18.8	33.85

b) Travelling range

The travelling range of the shiploader shall be extended in accordance with the hatch length of the biggest ships. So, for ships up to 100,000 DWT, the travelling rail shall be extended by 20 meters.

c) Boom clearance

As shown in Figure-11.4.2, the horizontal boom level of the existing shiploader will interfere slightly with the hatch coaming of a vacant vessel of 100,000 DWT. However, this interference can be avoided by ballast adjustment when approaching the berth.

(3) Conclusion

Consequently, the following modifications or additions will be required for the existing shiploader to be able to handle 100,000 DWT class ships:

a) Boom chute modification

b) Extension of travelling rail

c) Replacement of cables for travelling

d) Replacement of cable drums, etc.

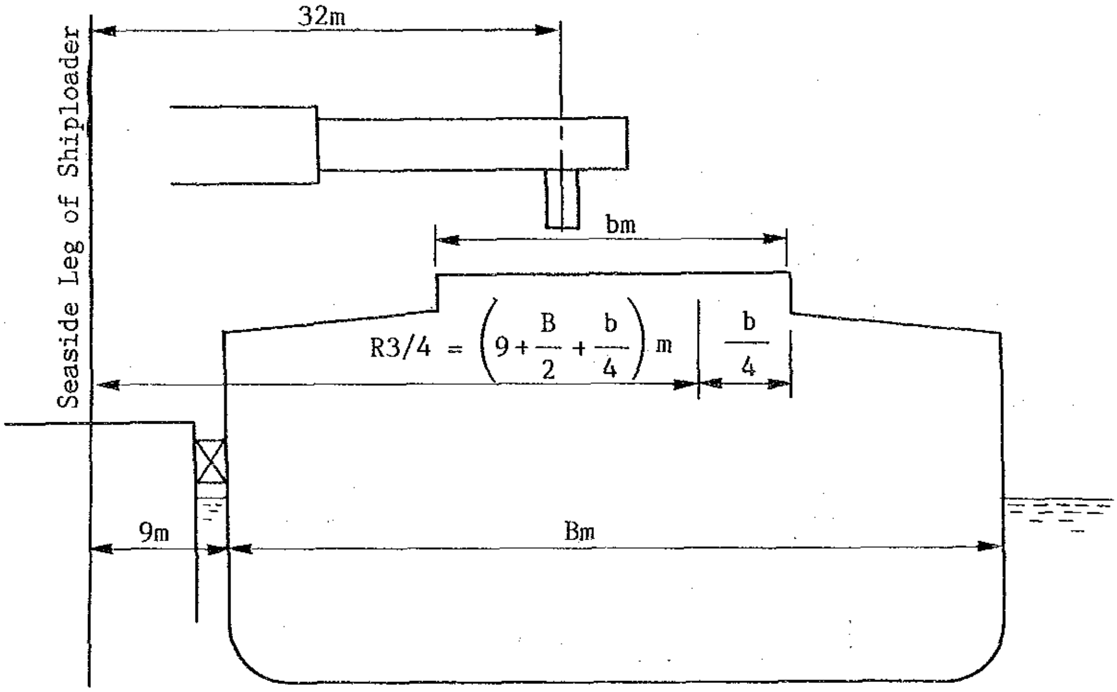


Figure-11.4.1 Outreach of Chute

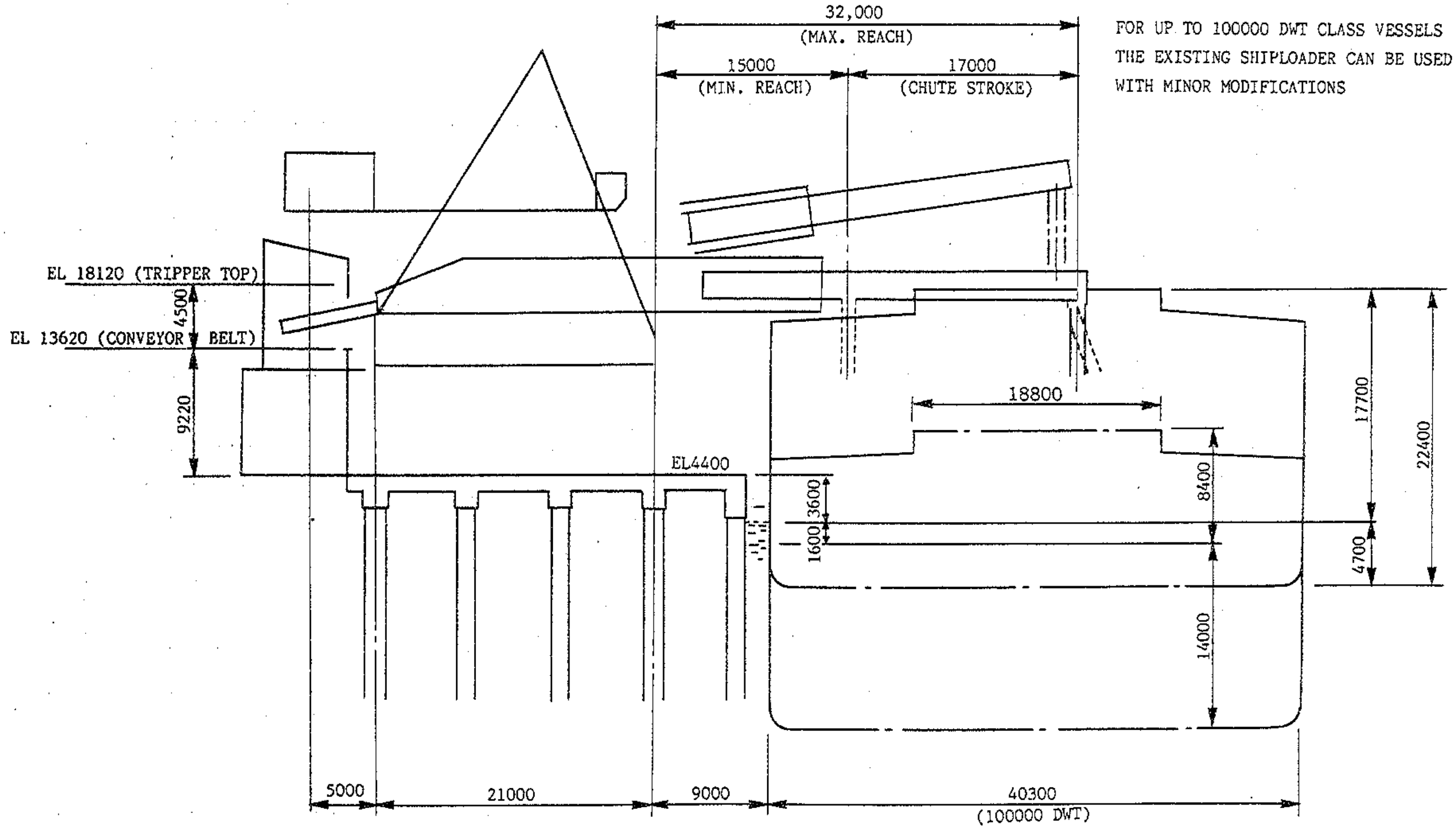


Figure-11.4.2 Shiploader Layout for 100000 DWT Carriers

11.4.3 Conveyor system

The existing conveyor of the iron ore shiploading facility consists of four conveyor lines;

1) Outgoing conveyor:receiving material from the reclaimer placed in the stockyard and discharging to the cross conveyor,
2) Cross conveyor:receiving material from the outgoing conveyor and discharging into the surging hopper,
3) Wharf conveyor:receiving material from the apron feeder under the surging hopper and discharging through the travelling tripper to the boom conveyor on shiploader,
4) Boom conveyor:receiving material from the wharf conveyor and discharging into the hatch of vessel by boom chute.

The flow diagram is shown in Figure-11.4.3. The flow of existing conveyor lines and rough specifications are shown on Table-11.4.3.

In order to stock the material, incoming conveyor lines are also provided. For concentrate, CB 81 and CB 82 are located above the concentrate stockyard shed, discharging material by the travelling tripper, and for pellets, CB 432 and CB 433 are located beside pellet stockyard, discharging material by means of the travelling stacker.

Table-11.4.3 Existing Conveyor Line

Shiploading Conveyor Lines			Cap.t/h	Belt Width mm	Belt Speed m/min
1) Outgoing conveyor	concentrate	CB 85 CB 86	3000	1000	150
	pellet	CB434	6600	1800	190
2) Cross conveyor	concentrate	CB 89	6800	1400	170
	pellet		3500		
3) Wharf conveyor	concentrate	CB 92	6800	1400	170
	pellet		3500		
4) Boom conveyor	concentrate	on ship-loader	6800	1400	170
	pellet		3500		

Note: Trough angle	35°	
Material Handled	Concentrate	Pellet
Specific gravity	2.88 t/cub.m	1.91 t/cub.m
Angel of surcharge	20°	5°
Angle of repose	40°	28°
Load cross section area	0.2324 squ.m	0.1796 squ.m

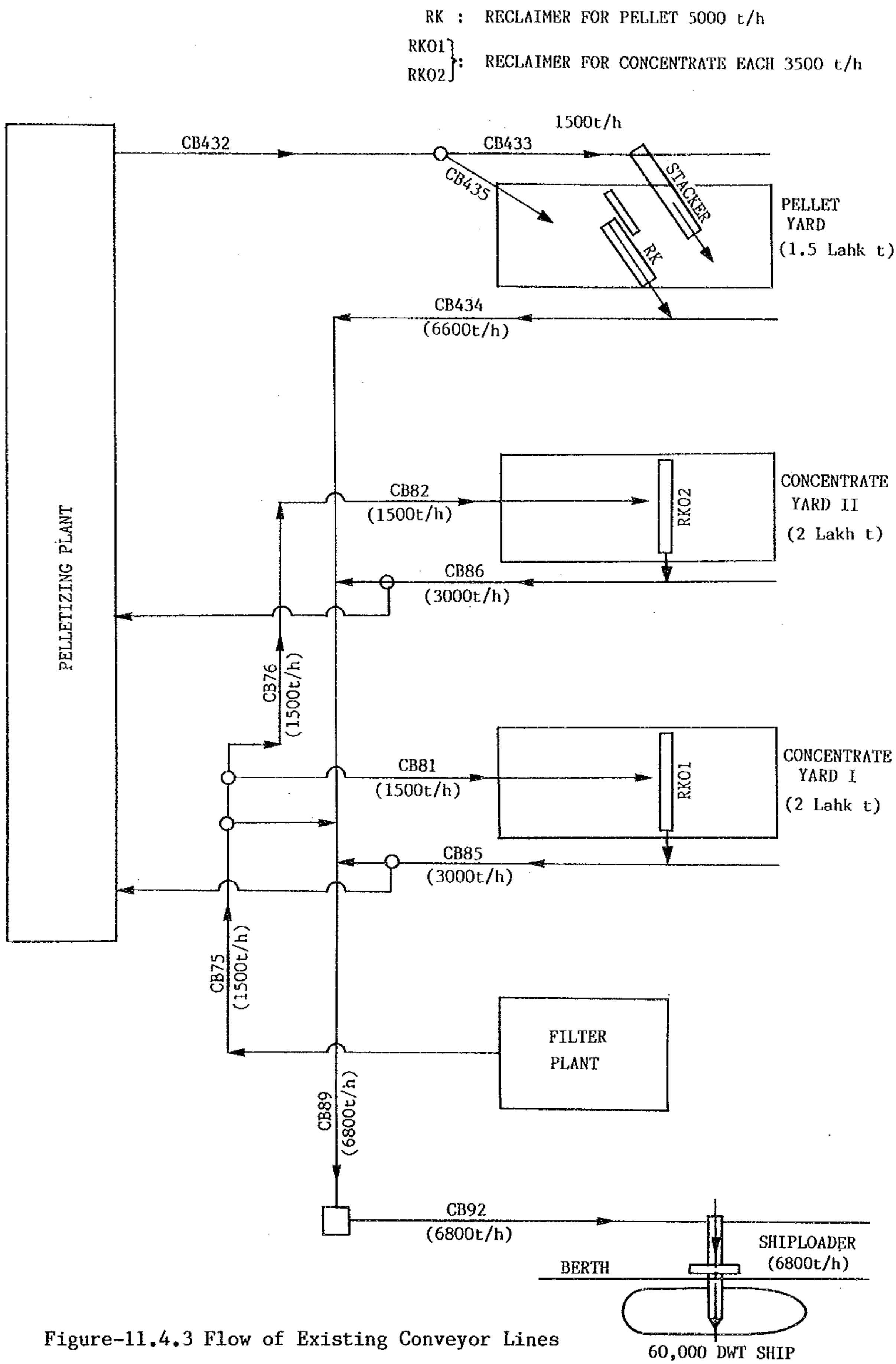


Figure-11.4.3 Flow of Existing Conveyor Lines

As shown in Figure-11.4.3, the outgoing conveyors CB 85 and CB 86 branch off to the pellet plant to feed the concentrate as raw material. Assuming the required concentrate flow capacity for the pellet plant is 1500 t/h and 2000 t/h for annual pellet throughput of 3 million tons and 6 million tons, respectively, the capacities of the outgoing conveyor for concentrate should be 1500 t/h and 2000 t/h, respectively, more than the figures calculated from the required shiploading capacity. As also, shown in Figure-11.4.3, a direct shiploading line whose capacity is 1500 t/h from the filter plant is provided, so that the capacity of outgoing conveyor for concentrate can be decreased by 1500 t/h for the two lines, as shown in Appendix-11.1. The location of the driving unit tower for the wharf conveyor shall be shifted to match the longer hatch length of bigger ships.

Incoming and outgoing conveyors shall be extended to meet the stockyard extension, as described in Chapter 11.4.5, Stockpile.

The conveyor capacity must exceed the required shiploading capacity, as shown in Table-11.4.1. Therefore, the required in capacity and conveyor length extension are shown in Table-11.4.4.

Table-11.4.4 Modification list of Conveyors

Conv.No.	Location		Existing	Minor Modifications	
CB 81 82	Incoming Concent.	Q t/h L m B mm V m/m	1500 370 800 130	1500 555 800 130	Extension Length
85 86	Outgoing Concent.	Q L B V	3000 370 1000 150	3500 555 1000 180	Capacity Gradeup Extension Length
89	Cross	Q L B V	6800 330 1400 170	7000 330 1400 170	Capacity Gradeup (Neglegible)
92	Wharf	Q L B V	6800 308 1400 170	7000 343 1400 170	Capacity Gradeup (Neglegible) Extension Length
433	Incoming Pellet	Q L B V	1500 370 1000 150	1500 490 1000 150	Extension Length
434	Outgoing Pellet	Q L B V	6600 370 1800 190	6600 490 1800 190	Extension Length
Boom Conveyor	on Shiploa- der	Q L B V	6800 60 1400 170	8000 60 1400 200	Gear Change (Negligible)

Note, Q: Conveyor Capacity t/h
L: Conveyor Length m
B: Breadth of Conveyor Belt mm
V: speed of Belt Conveyor m/m

The capacity of each conveyor incoming, outgoing, cross and wharf conveyor could be increased by changing the belt speed, changing the trough angle of carrier rollers or widening the belt width. A comparative list of load cross section areas is provided in Table-11.4.5.

Table 11.4.5 Conveyor Capacity Comparative List

(Load Cross Section Area : squ.m)

Trough Angle		35°		40°		45°	
Surcharge Angle		5°	20°	5°	20°	5°	20°
(mm)	1400	0.1796	0.2324	1.937	0.2426	0.2047	0.2496
Belt Width		(1.0)	(1.0)	(1.078)	(1.043)	(1.139)	(1.074)
	1600	0.2373	0.3069	0.2558	0.3204	0.2704	0.3295
		(1.321)	(1.320)	(1.424)	(1.378)	(1.505)	(1.417)
	1800	0.3031	0.3917	0.3267	0.4089	0.3452	0.4206
		(1.678)	(1.685)	(1.189)	(1.799)	(1.922)	(1.809)

( ): Load Cross Section Rate as 1.0 for 1400mm width and 35 Trough Angle
Surcharge angle: 20° for Concentrate, 5° for Pellet

11.4.4 Reclaimer

(1) Reclaimer for concentrate

Two bridge girder type bucket-wheel reclaimers (RK01,RK02), each with a nominal reclaiming capacity of 3500 t/h, are presently installed in each concentrate stockyard.

(2) Reclaimer for pellets

One boom rotating type bucket-wheel reclaimer, with a nominal reclaiming capacity of 5,000 t/h, is presently installed at the pellet stockyard.

(3) Requirement of Reclaiming Capacity for concentrate

The required shiploading capacity for concentrate is 7000 t/h. Direct loading capacity from the filter plant is 1500 t/h and the concentrate supply to the palletizing plant is 1500 t/h. Therefore, the required reclaiming capacity for concentrate is:

7000 + 1500 - 1500 = 7000 t/h for two reclaimers.

Thus, the existing reclaimer capacity of 3500 t/h per one reclaimer is just enough.

(4) Requirement of Reclaiming capacity for pellets.

The required shiploading capacity for pellets is 3500 t/h. The existing nominal reclaimer capacity is 5000 t/h, but the reclaiming efficiency of this type of reclaimer is estimated at 0.7. So, the real capacity shall be 5000 x 0.7 = 3500 t/h.

(5) Conclusion

New reclaimers are not required for either the concentrate or pellet stockyards.

11.4.5 Stockpile

(1) Stockyard capacity for concentrate

The existing stockyard capacity is calculated as follows:

$$C = \frac{B \times H \times L}{2} \times \gamma \quad \text{(per one line)}$$

Here, C = stockyard capacity : tons

B = breadth of pile : 30 m

H = height of pile

= (B / 2) x tan α, α: angle of repose = 40°

= 12.6 m

L = length of pile : 370 m

γ = specific gravity of concentrate : 2.88 t/cub.m

therefore,

$$C = \frac{30 \times 12.6 \times 370}{2} \times 2.88 = 200{,}000 \text{ tons}$$

As two piles of this size can be accommodated in this stockyard, the total capacity will be twice this.

The mean number of staying days of ore in the stockyard is calculated as follows:

m = C x N / A

here, m = mean staying days

C = stockyard capacity: tons

N = annual working days

A = annual throughput : tons

for 1989-90, A = 5.0 million tons

Ac = 3.3 million tons

Ap = 1.7 million tons

N = 270 days(assuming)

Nc = 150 days

Np = 120 days

then, m = 20 x 2 x 270 / 500 = 21.6 days

(2) Stockyard capacity for Pellet

Similarly, the existing stockyard capacity for pellet is calculated as follows:

$$C = \frac{B \times H \times L}{2} \times \gamma$$

here, C = stockyard capacity : tons

B = 40 m

H = (B/2) x tan α , α = 28°

= 10.6 m

L = 370 m

γ = 1.91 t/cub.m

therefore,

$$C = \frac{40 \times 10.6 \times 370}{2} \times 1.91 = 150{,}000 \text{ tons}$$

The number of staying days for 1989-90 can be calculated in the same way: m = C x Np/Ap = 15 x 120/170 = 10.6 days

(3) Required Capacity

It is recommended that the mean number of staying days shall be more than 30 days for this type of exclusive yard. From this viewpoint the existing stockyard would appear not to have enough space for both concentrate and pellets. In particular, the number of mean staying days are decreasing in accordance with the increase in annual throughput.

Therefore, it is recommended that the present mean number of staying days remain at least those the same as those shown in Table-11.4.6.

Table-11.4.6 Required Stockyard Capacity

unit:10,000tons

Stockyard \ Annual Throughput		1989-90	1994-95
		500	750
Concentrate	Yard Capacity	2 x 20	2 x 30
	Yard Length (m)	370	555
Pellet	Yard Capacity	15	20
	Yard Length (m)	370	490

Note: The required stockyard capacities are calculated as follows:
for concentrate stockyard
C = m x A / N = 21.6 x 750 / 270 = 60 x 10,000 t(1994-95)
for pellet stockyard
C = 10 x 325/155 = 20.96 → 20 x 10,000t(1994-95)

11.4.6 Modification layout

For 100,000 DWT class ship, each piece of shiploading equipment shall be modified as listed in Table-11.4.7, and the layout is shown on Figure-11.4.4.

Table-11.4.7 Modification List of the Shiploading System

Equipment		Modification
Shiploader		Chute modification Cable Drum modification Cable for travelling replacement Extension of travelling rail Boom conveyor speed up
Conveyors	Incoming concent.	Extension Length
	Outgoing concent.	Extension Length and Capacity up
	Cross	Capacity up
	Wharf	Capacity up and Extension Length
	Drive Unit Tower	Shift
	Incoming Pellet	Extension length
	Out going Pellet	Extension Length
Stockyard	Concentrate	Extension Yard and Shed
	Pellet	Extension Yard

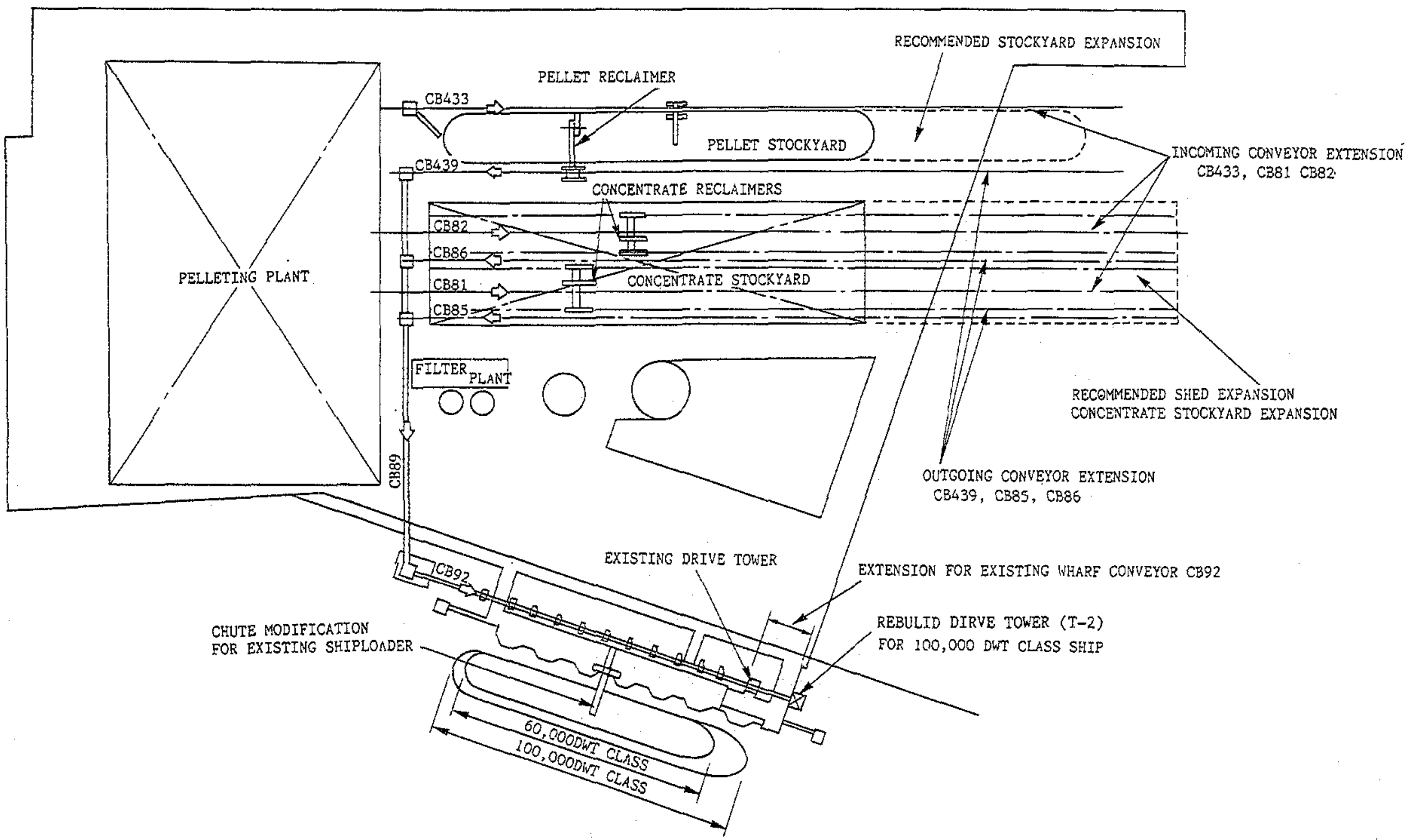


Figure-11.4.4 Modification Plan for Shiploading System

12. IMPLEMENTATION PROGRAMME FOR THE SHORT-TERM PLAN

12.1 Working principles

The following must be taken into account for the implementation programme:

a. The current port operations, including ship maneuvering, cargo handling, etc., should not be interfered with.

b. Capital dreding procedure should be taken in order to delay the time when an annual siltation volume is increased.

c. Efficient and economical method to dredge hard rock.

In order to meet the above demand it is necessary to make appropriate plans for both in the planning phase and design phases.

12.2 Major facilities and construction works

Major facilities and construction works are listed below:

Iron Ore Berth	Breasting dolphin A	33.0m x 29.5m x 1span
for 100,000DWT	Breasting Dolphin B	33.0m x 29.5m x 6span
(Improvement)		(reinforcement)
	Mooring Dolphin	12.0m x 12.0m x 2units
	Driving House	12.0m x 14.4m(base)
Crude Oil Jetty	Breasting Dolphin	15.0m x 14.25mx 2units
for 100,000DWT	Mooring Dolphin	8.6m x 8.6m x 2units
	Platform	70.0m x 12.0m x 2units
	Approach Jetty	100m x 10m x 1units
Oil Products Jetty	Breasting Dolphin	15.0m x 14.25mx 2units
for 85,000DWT	Mooring Dolphin	8.6m x 8.6m x 6units
	Platform	39m x 12m x 1units
	Approach Jetty	100m x 10m x 1units
Breakwaters	South-breakwaters	930m
	North-breakwaters	930m

12.3 Construction Materials

In Mangalore district, there is plentiful supply of stones and gravel that can be used as construction materials. They can be transported from a distance of about 20 ~ 30km from four quarries to New Mangalore Port. Most of these stones are granite, which is comparatively hard and thus suited for constructing the basement or rubble mound of breakwaters.

Sand is also collected in the upstream areas of the Gurpur and the Netravati rivers. It is assumed that there will be no shortage in the supply of stones and sand. Cement, reinforcement-bars and wood are available locally. It is assumed that large-sized steel pipe piles, sheet piles and large rubber fenders must be imported.

12.4 Outline of Construction Method

(1) Iron Ore and Oil Berth

1) General

In India, the diaphragm wall and cast-in-situ concrete pile methods are popularly used for constructing quay walls. But in improving the iron ore berth, the crude and oil products berths should be carried out offshore. Therefore, instead of the above method, steel liner pipes for cast-in-situ concrete piles should be adopted.

At first, steel liner pipes are driven into the sea-bottom layer using a pile driver vessel or a self-elevated platform equipped with a pile driver. Material inside the pipes is then excavated and removed. Fresh concrete is poured into the pipes through tremie pipes after reinforcing bars are installed.

As mentioned in 12.1, working principles, careful attention should be paid not to disturb cargo handling. However, when cargo handling must be suspended the time lost must be minimized, even if the total construction work time is longthened. It is recommended that use be made of this idle time or night time and that each structure is completed one by one.

2) In the Case of Augmentation of the Existing Iron Ore Berth

In the case of the augmentation of the existing iron ore berth to cater to the requirements of 100,000 DWT class vessels, as shown in Figure-12.4.1, the augmentation works should be carried out independently of the existing berth operation. But some pile-driving works will interrupt normal loading operations.

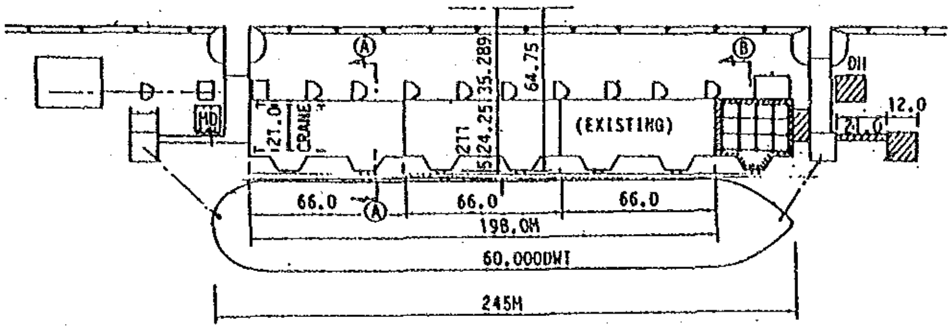


Figure-12.4.1 Augmentation Plan

During the augmentation works, the maximum size berthing vessel is expected to be 60,000 DWT class with a length of 230m ~ 245m. The Figure shows the relation between augmentation facilities and a berthing ship 245m in length. For the augmentation works, attention should be paid to minimize the length of time normal ship-loading operations are suspended. Therefore, the following two points should be noted:

a. Construction method and selection of construction equipment for civil works
b. Construction method of loading system extension for mechanical works

3) Civil Works

for the new Breasting Dolphin, concrete work should be executed on a temporary stage made of steel H-shaped piles or concrete piles. (some existing concrete piles may be available at the platform.) The concrete slabs and beams of the new dolphin might be precast, but cast-in-situ concrete is considered better because of construction equipment.

The two (2) new mooring dolphins and the driving house of the conveyer line are supported by new piles driven by the pile driver vessel.

In order to protect the slope under the Iron ore berth, retaining walls consisting of steel sheet piles are to be constructed. The steel sheet piles just in front of the berth are driven on the platform of the berth and the piles at the both ends are driven by the pile driver vessel.

The reinforcement work of the existing piles of the Breasting dolphins are carried out using chain-blocks and small boats.

4) Mechanical works

The construction of a new conveyor driving house and the extension of the belt conveyor should be carried out so as to minimize the period in which normal ship-loading operations are suspended. This period should be included in the interrupting time caused by the augmentation of the Iron ore berth.

5) Interrupting period of loading operations

The total length of time in which loading operations will be suspended will be about three (3) weeks or so, by adjusting the civil construction and the mechanical erection works.

(2) Breakwaters

Breakwaters are supposed to be the stone-filled type, considering materials' availability, cost, and ease of construction. At first, part of the existing breakwaters is to be raised in dry work to pass the road to the site of breakwaters for extension. The main construction equipment will be bulldozers, crawler cranes and dump trucks. We assume the section of the breakwaters above -2.0m shall be constructed in dry work. For construction of the part under -2.0m level, we shall use stone carrier vessels, tug-boats, diver-boats, etc. Careful attention must be paid so that circular slides do not occur in the soft sea bed section.

(3) Navigation channel and basin

The methods of dredging and rock blasting is described in "Clause 9.4".

12.5 Construction Schedule

To meet the demand for iron ore in 1994/95, improvement of the iron ore berth is to be started in 1990/91. Principal construction works are to be carried out based on the following schedule:

Table-12.5.1 Construction Schedule

Item		1990/91	1991/92	1992/93	1993/94	1994/95
Survey/Consultant Work		———	———	———		
Iron Ore Berth	100,000 DWT				———	
Product Oil Berth	85,000 DWT			———		
Crude Oil Berth	100,000 DWT				———	
Southern Breakwater	930 m		———	———	———	
Northern Breakwater	930 m		———	———	———	
Dredging	Channel			———	———	
	Lagoon		———			
Rock Blasting			———	———		
Handling Equipment	Shiploader				———	
	Conveyor				———	
	Stock Shed			———	———	

13. ROUGH COST ESTIMATION FOR THE SHORT-TERM PLAN

13.1 General

In this chapter the approximate construction cost is estimated for the short-term Plan suggested in Chapter 10. The estimates have been prepared based on current market prices and the cost of similar works carried out in recent years at New Mangalore Port and its vicinity. The estimates include a local sales tax, but they don't include an import tax and other taxes related to the project. The adopted or referenced major unit prices for wages, materials, and construction are shown in Table-13.1.1.

In India, almost all civil construction materials can be supplied by their own resources or manufactured products, so they are purchased with domestic currency. However, large steel pipe piles more than 1.0m in diameter and large rubber fenders cannot be manufactured locally, so they are to be accounted as foreign currency expenditures.

13.2 The Iron Ore Handling Facility

According to the Figures in "Chapter 11" the quantity of each facility is roughly calculated, and using unit prices and costs, the cost of the construction work is determined. The result of the Iron Ore Berth for 100,000 DWT vessels is shown in Table-13.2.1.

The foreign currency portion is 54.8% for 100,000 DWT Berth.

Table-13.2.2 shows detailed costs for labour and material/equipment.

Table-13.1.1 Unit Prices and Costs

Description	Unit	Price in Rupees	Remarks
Wages			
Foreman	Rs./month	3,500	
Common worker	"	900	
Skilled worker	"	1,500	
Steel worker	"	1,200	
Welder	"	1,800	
Bar bender	"	1,500	
Carpenter	"	1,800	
Skilled Operator	"	3,000	
Crew for work vessels	"	1,500-3,000	
Material			
Light oil	liter	3.65	
Gasoline	"	9.68	
Re-bars	ton	9,000	D8-D32
Deformed bar	"	9,500	"
Steel angle	"	10,000	
Channel	"	10,000	
plate	"	12,000	thick
sheet pile	"	10,000	II-IV
Cement	"	1,550	Ordinary portland
Cement	"	2,500-3,000	Sulphate resistance
Sand for concrete	cu'm	50	
for construction	"	50	
Gravel 20-40m/m	"	50	
Stone 10-500kg	"	120	
Armour stone			
1000-2000kg		250	
2000-3000		300	
3000-4000		350	
Flat wood t=12m/m	sq'm	200	
Asphalt straight	ton	4,000-5,000	
hot mix	"	3,000	
Rubber fender			
500H x 1.0m(V Type)	nos	17,000	
1000H x 1.0m(V Type)	"	34,000	
1700H (Cell Type)	"	10,520,000	with protection
2000H (Cell Type)	"	11,400,000	with protection
Construction work			
Concrete	cu'm	1,095	M 250
	"	590	M 100
Re-bar	ton	9,000	
Form work	sq'm	450	wood
Excavation	cu'm	20	
Back filling	cu'm	20	
Asphalt pavement including base	sq'm	200	
Road 2 lanes		1,500	simple asphalt
4 lanes		3,000	
Building			
office/house		2,500	
transit shed (incl. foundation)	sq'm "	2,000	

Table-13.2.1 Iron Ore Berth for 100,000 DWT Carrier

Description	Q'ty	Unit	Unit cost (Rupees)	Amount (Lakhs)	For. C (Lakhs)	Note
Breasting Dolphin A	6	nos	1,293,500	77.61	72.55	reinforcement only
sheet pile (IV)	833	sheets	8,157	67.95	63.77	
brace(Ibeam)	30	nos	32,200	9.66	8.78	
Breasting Dolphin B	779	sq'm	12,512	97.47	28.58	1nos
pile (1220 ϕ)	26	nos	221,780	57.66	17.18	
deck	779	sq'm	3,570	27.81	-	
rubber fender (2000H)	1	nos	1,200,000	12.00	11.40	
Mooring Dolphin	288	sq'm	29,479	84.9	21.14	2nos
pile (1220 ϕ)	32	nos	224,063	71.70	21.14	
deck	288	sq'm	3,540	10.20	-	
bollard(200t)	2	nos	150,000	3.00	-	
Driving House	162.4	sq'm	10,603	17.22	2.16	1nos
pile (1000 ϕ)	4	nos	174,000	6.96	2.16	
deck	172.8	sq'm	3,540	6.12	-	
house building	162.4	sq'm	2,550	4.14	-	
Walk Way	42	sq'm	12,905	5.42	1.48	21m length x 2m wide
pile (910 ϕ)	3	nos	159,330	4.78	1.48	
deck	42	sq'm	1,520	0.64	-	
Rubber Fender(2000H) replace	6	nos	1,200,000	72.00	68.4	replace
T o t a l				354.62	194.31	

Table-13.2.2 Iron Ore Berth for 100,000 DWT Carrier

(Unit:Lakhs)

	Total			Detail							
	Local	Foreign	Total	Labour Fee				Material/Equipment			Miscel-laneous
				Unskilled	Skilled	Foreign	Subtotal	Imported	Local	Subtotal	
Breasting Dolphin A	5.06	72.55	77.61	0.56	0.4	-	0.96	72.55	3.04	75.59	1.06
Breasting Dolphin B	68.89	28.58	97.47	7.58	5.51	-	13.09	28.58	41.33	69.91	14.47
Mooring Dolphin	63.76	21.14	84.90	7.02	5.1	-	12.12	21.14	38.26	59.40	13.38
Driving House	15.06	2.16	17.22	1.65	1.20	-	2.85	2.16	9.04	11.26	3.17
Walkway	3.94	1.48	5.42	0.43	0.31	-	0.74	1.48	2.36	3.84	0.84
Rubber Fender	3.60	68.40	72.00	0.36	0.36	-	0.72	68.4	-	68.4	2.88
T o t a l	160.31	194.31	354.62	17.6	12.88	-	30.48	194.31	94.03	288.34	35.8

13.3 Oil Handling Facilities

To meet the demand for oil handling cargo volume, one (1) crude oil berth for 100,000 DWT tankers and one (1) oil products berth for 85,000 DWT tankers are to be constructed. According to the Figures in "Chapter 11", the cost can be estimated in the same way as in "Clause 13.1".

The results are shown in Table-13.3.1 for the oil products berth and in Table-13.3.2 for the crude oil berth. The foreign currency portions for the oil products berth and the crude oil berth are 25.3% and 27.1%, respectively. These costs do not include navigation/berthing aids, fire-fighting facilities, anti-pollution facilities and loading/unloading equipment. Table-13.3.3 and 13.3.4 show detailed costs for labour and materials/equipment.

Table-13.3.1 Oil Products Berth for 85,000 DWT Tankers

Description	Q'ty	Unit	Unit cost (Rupees)	Amount (Lakhs)	For. C (Lakhs)	Note
Breasting Dolphin	426	sq'm	37,700	160.6	55.1	2nos
pile (1200 ø)	50	nos	197,600	98.8	16.3	
deck	426	sq'm	3,582	15.3		
bollard(150t)	2	nos	125,000	2.5		
rubber fender (1300H)	4	nos	1,020,000	40.8	38.8	
miscellaneous	2%			3.2		
Mooring Dolphin	444	sq'm	59,410	263.8	57.6	6nos
pile (600 ø)	144	nos	162,080	233.4	57.6	
deck	444	sq'm	3,650	16.2		
bollard(200t)	6	nos	150,000	9.0		
miscellaneous	2%			5.2		
Platform	468	sq'm	9,145	42.8	9.7	1nos
pile (800 ø)	27	nos	118,340	32.0	9.7	39.0mx12.0m
deck	468	sq'm	2,140	10.0		
miscelaneous	2%			0.8		
Approach Jetty	1,000	sq'm	5,450	54.5	9.8	100m length
pile (800 ø)	27	nos	118,340	32.0	9.8	
deck	1,000	sq'm	2,140	21.4		
miscellaneous	2%			1.1		
Walk Way	437	sq'm	10,660	46.6	11.6	364m length
pile (800 ø)	32	nos	118,340	37.9	11.6	
deck	437	sq'm	1,780	7.8		
miscellaneous	2%			0.9		
Total				568.3	143.8	

Table-13.3.2 Crude Oil Berth for 100,000 DWT Tankers

Description	Q'ty	Unit	Unit cost (Rupees)	Amount (Lakhs)	For. C (Lakhs)	Note
Breasting Dolphin	426	sq'm	41,033	174.8	58.4	2nos
pile (1200 ϕ)	50	nos	197,600	98.8	16.3	
deck	426	sq'm	3,582	15.3		
bollard(200t)	2	nos	150,000	3.0		
rubber fender (1700H)	4	nos	1,170,000	44.3	42.1	
dismantling work	1			10.0		
miscellaneous	2%			3.4		
Mooring Dolphin	148	sq'm	59,390	87.9	19.2	2nos
pile (600 ϕ)	48	nos	162,080	77.8	19.2	
deck	148	sq'm	3,650	5.4		
bollard(200t)	2	nos	150,000	3.0		
miscellaneous	2%			1.7		
Platform	168	sq'm	10,830	18.2	4.3	1nos
pile (800 ϕ)	12	nos	118,340	14.2	4.3	
deck	168	sq'm	2,140	3.6		
miscellaneous	2%			0.4		
Approach Jetty	1,000	sq'm	5,450	54.5	9.8	100m length
pile (800 ϕ)	27	nos	118,340	32.0	9.8	
deck	1,000	sq'm	2,140	21.4		
miscellaneous	2%			1.1		
Walk Way	312	sq'm	4,936	34.7	8.7	260m length
pile (800 ϕ)	24	nos	118,340	28.4	8.7	
deck	312	sq'm	1,780	5.6		
miscellaneous	2%			0.7		
Total				370.1	100.4	

Table-13.3.3 Oil Products Berth for 85,000 DWT Tanker

(Unit:Lakhs)

	Total			Detail							
	Local	Foreign	Total	Labour Fee				Material/Equipment			Miscel-laneous
				Unskilled	Skilled	Foreign	Subtotal	Imported	Local	Subtotal	
Breasting Dolphin	105.50	55.10	160.60	11.61	8.44	-	20.05	55.10	63.30	118.40	22.15
Mooring Dolphin	206.30	57.50	263.80	22.69	16.50	-	39.19	57.50	123.78	181.28	43.33
Platform	33.10	9.70	42.80	3.64	2.65	-	6.29	9.70	19.86	29.56	6.95
Approach Jetty	44.70	9.80	54.50	4.92	3.58	-	8.50	9.80	26.82	36.62	9.38
Walkway	35.00	11.60	46.60	3.85	2.80	-	6.65	11.60	21.0	32.60	7.35
T o t a l	424.60	143.70	568.30	46.71	33.97	-	80.68	143.70	254.76	398.46	89.16

Table-13.3.4 Crude Oil Berth for 100,000 DWT Tanker

(Unit:Lakhs)

	Total			Detail							
	Local	Foreign	Total	Labour Fee				Material/Equipment			Miscel-laneous
				Unskilled	Skilled	Foreign	Subtotal	Imported	Local	Subtotal	
Breasting Dolphin	116.40	58.40	174.80	12.80	9.31	-	22.11	58.40	69.84	128.24	24.45
Mooring Dolphin	68.70	19.20	87.90	7.56	5.50	-	13.06	19.20	41.22	60.42	14.42
Platform	13.90	4.30	18.20	1.53	1.11	-	2.64	4.30	8.34	12.64	2.92
Approach Jetty	44.70	9.80	54.50	4.92	3.58	-	8.50	9.80	26.82	36.62	9.38
Walkway	26.00	8.70	34.70	2.86	2.08	-	4.94	8.70	15.60	24.30	5.46
T o t a l	269.70	100.40	370.10	29.67	21.58	-	51.25	100.40	161.82	262.22	56.63

13.4 Breakwaters

The cost of the Breakwaters is estimated based on the amount of materials and their prices. Unit costs are decided by totaling the prices of materials indicated in Table-13.1.1 and the cost of leveling and forming the stone mound.

The results are shown in Table-13.4.1.

Moreover, Table-13.4.2 shows detailed costs for labour and materials/equipment.

Table-13.4.1 Breakwater

Description	Q'ty	Unit	Unit cost (Rupees)	Amount (Lakhs)	For.C (Lakhs)	Note
Raising Existing Breakwater	840	m	9,720	81.6		crown height+3.5
South-Breakwater	930	m	104,600	972.8		"
North-Breakwater	930	m	107,690	1,001.5		"
Total				2,055.9		

Table-13.4.2 Breakwater

(Unit:Lakhs)

	Total			Detail							
	Local	Foreign	Total	Labour Fee				Material/Equipment			Miscel-laneous
				Unskilled	Skilled	Foreign	Subtotal	Imported	Local	Subtotal	
Raising											
Existing	81.60		81.60	1.63	1.63	-	3.26	-	48.96	48.96	29.38
Breakwater											
South-Breakwater	972.80		972.80	24.32	24.32	-	48.64	-	632.32	632.32	291.84
North-Breakwater	1,001.50		1,001.50	25.04	25.04	-	50.08	-	650.98	650.98	300.45
T o t a l	2,055.90		2,055.90	50.99	50.99	-	101.98	-	1,332.26	1,332.26	621.67

13.5 The Navigation channel and the Basin

Unit costs are estimated as follows:

Capital dredging		
Hard rock	:	1,570 (Rs./m3)
Soft rock	:	525 (Rs./m3)
Soil in the Lagoon	:	60 (Rs./m3)
Soil in the channel	:	22 (Rs./m3)
Maintenance dredging		
At present	:	15 (Rs./m3)
In future	:	14 (Rs./m3)

Each unit cost of the combination of various types of dredgers and equipment is shown in Table-13.5.1. Please refer to "9.4.3 and 9.4.4 in Chapter 9" for the number of soils divided in the Table.

Total cost and the breakdown of capital dredging are shown in Table-13.5.2 with the following notes attached:

Unit costs of dredging by trailer section hopper dredgers are estimated based on the past records of dredging by this type of dredgers at New Mangalore port (refer to Table-9.3.4 and Appendix-13.1).

Notes

- .The blasting and the dredging of hard and soft rock are to be carried out by foreign contractors.
- .The dredging of soil in the lagoon is to be carried out by both foreign contractors and domestic contractors.
- .The dredging of soil in the channel is to be carried out by domestic contractors.

The total cost and the breakdown of maintenance dredging are shown in Table-13.5.3.

Table-13.5.1 Unit Cost of Capital/Maintenance Dredging

		Quantity (m3)	Unit Cost (Rs)					
			Drilling/ Blasting	Dredging by			Transpor- tation	Total
				Trailer	Cutter	Grab		
Capital Dredging	Soil (C)	340,000	----	16.4	39.8	----	----	56
	Soil (C)	8,990,000	----	21.2	----	----	----	21
	Soil (L)	1,000,000	----	----	64.1	----	13.2	77
	Soil (L)	1,170,000	----	19.5	64.1	----	----	84
	Soil (L)	30,000	----	----	----	112	56.4	168
	Soil (L)	1,710,000	----	31.8	----	----	----	32
	Rock	116,100	1,210	----	----	302	62.9	1,575
	Rock (W)	20,000	----	----	507	----	28.8	536
	Grit	47,600	----	----	507	----	13.2	520
Maintenance Dredging(P)	Soil (C)	2,000,000	----	13.9	----	----	----	14
	Soil (L)	1,000,000	----	17.2	----	----	----	17
Maintenance Dredging(B)	Soil (C)	540,000	----	13.9	21.5	----	----	35
	Soil (C)	4,790,000	----	13.9	----	----	----	14
	Soil (L)	1,500,000	----	17.2	----	----	----	17
Maintenance Dredging(A1)	Soil (C)	3,780,000	----	13.4	----	----	----	13
	Soil (L)	420,000	----	17.7	----	----	----	18
Maintenance Dredging(A2)	Soil (C)	4,840,000	----	13.4	----	----	----	13
	Soil (L)	430,000	----	17.7	----	----	----	18

P : At present
B : The year before the capital dredging
A1 : The first year after the completion of the proposed project
A2 : From the second year after the completion of the proposed project
C : Channel L : Lagoon W : Weathered

Table-13.5.2 Cost of Capital Dredging

	Quantity (m3)	Unit Cost (Rs./m3)	Total Cost (Rs.)	Foreign Currency (Rs.)	Local Currency		
					Materials/ Equipment (Rs.)	Skilled Labor (Rs.)	Unskilled Labor (Rs.)
Soil (C)	340,000	56	19,100,000	5,973,474	7,139,526	5,987,000	0
Soil (C)	8,990,000	21	190,600,000	57,180,000	76,240,000	57,180,000	0
Sub Total	9,330,000		209,700,000				
Soil (L)	1,000,000	77	77,300,000	59,339,300	16,612,600	1,070,900	277,200
Soil (L)	1,170,000	84	97,800,000	30,689,780	36,345,451	30,764,768	0
Soil (L)	30,000	168	5,100,000	831,300	1,147,500	3,121,200	0
Soil (L)	1,710,000	32	54,400,000	16,320,000	21,760,000	16,320,000	0
Sub Total	3,910,000		234,600,000				
Rock	116,100	1,570	182,300,000	158,820,874	20,746,073	2,733,053	0
Rock (W)	20,000	540	10,800,000	8,905,344	1,755,998	138,658	0
Grit	47,600	520	24,800,000	20,152,245	4,308,993	325,546	13,215
Total			662,200,000	358,212,317	186,056,141	117,641,127	290,415

Table-13.5.3 Cost of Maintenance Dredging

	Quantity (m3)	Unit Cost (Rs./m3)	Total Cost (Rs.)	Foreign Currency (Rs.)	Local Currency		
					Materials/ Equipment (Rs.)	Skilled Labor (Rs.)	Unskilled Labor (Rs.)
			(Maintenance Dredging (P))				
Soil (C)	2,000,000	14	27,800,000	8,340,000	11,120,000	8,340,000	0
Soil (L)	1,000,000	17	17,200,000	5,160,000	6,880,000	5,160,000	0
Total			45,000,000	13,500,000	18,000,000	13,500,000	0
			(Maintenance Dredging (B))				
Soil (C)	540,000	35	19,100,000	5,996,806	7,222,390	5,880,804	0
Soil (C)	4,790,000	14	66,600,000	19,980,000	26,640,000	19,980,000	0
Soil (L)	1,500,000	17	25,800,000	7,740,000	10,320,000	7,740,000	0
Total			111,500,000	33,716,806	44,182,390	33,600,804	0
			(Maintenance Dredging (A1))				
Soil (C)	3,780,000	13	50,700,000	15,210,000	20,280,000	15,210,000	0
Soil (L)	420,000	18	7,400,000	2,220,000	2,960,000	2,220,000	0
Total			58,100,000	17,430,000	23,240,000	17,430,000	0
			(Maintenance Dredging (A2))				
Soil (C)	4,840,000	13	64,900,000	19,470,000	25,960,000	19,470,000	0
Soil (L)	430,000	18	7,600,000	2,280,000	3,040,000	2,280,000	0
Total			72,500,000	21,750,000	29,000,000	21,750,000	0

13.6 Iron Ore Handling Equipment

The cost of improvements to handling equipment are presented in Table-13.6.1. Detailed costs regarding each piece of equipment are explained below.

Table-13.6.1 Improvement of Handling Equipment

crone.

Shiploader Modification	29
Conveyor	865
Stockpile Shed	985
Total Japanese Yen (Crore Rs.)	1987(21.62)

(1) Cost of Modifying Existing Shiploader

Table-13.6.2 Modification Costs of Existing Shiploader

	Weight t	Cost ¥1,000,000
Chute Modification	8	8
Cable Drum Modification	3	4
Cable for Travelling (Power and Control 200 meters each)	-	3
Extension of Travelling Rail	4	1
Others		13
T o t a l	15	29

(0.33 Crore Rs.)

(2) Modification of Conveyors

The specifications regarding minor modifications to conveyors are listed in Table-11.4.4, and the layout of the modified conveyer lines is shown in Figure-11.4.4.

Table-13.6.3 Modification Costs of Conveyors

		Cost ¥1,000,000	Remark
Conveyor CB	81,82	2x55	
	85,86	2x80	
	92	100	
	433	55	
	439	175	
	T-2	70	
Subtotal of Conveyors		670	
Transportation		45	
Erection and Test Operation		150	
Total cost		865(9.95 Crore)	
Total Weight t		1,500	

Note: T-2 is the construction cost of the drive unit tower for the wharf conveyor.

(3) Construction Cost of Stockyard Shed for Concentrate

Table-13.6.4 Expansion Costs of Concentrate Shed

Unit: ¥1,000,000

Steel Structure	675
Transportation Members	60
Erection	250
Total Cost	985(11.33 Crore)
Total Weight t	2500

13.7 Summary

Total capital costs for the Short-term Plan are shown in Table-13.7.1 and the annual investment schedule is shown in Table-13.7.2.

Table-13.7.1 Total Construction Cost

Item		Total Cost (Rs.)	Foreign Currency (Rs.)	Local Currency		
				Materials/ Equipment (Rs.)	Skilled Labor (Rs.)	Unskilled Labor (Rs.)
Survey/Consultant		7,380,000	7,380,000	0	0	0
Iron Ore Berth		35,462,000	19,431,000	12,983,000	1,288,000	1,760,000
Product Oil Berth		56,830,000	14,370,000	34,392,000	3,397,000	4,671,000
Crude Oil Berth		37,010,000	10,040,000	21,845,000	2,158,000	2,967,000
Breakwaters	Southern	101,360,000	0	96,333,000	2,513,500	2,513,500
	Northern	104,231,000	0	99,060,000	2,585,500	2,585,500
Dredging	Channel	209,700,000	63,153,500	83,379,500	63,167,000	0
	Lagoon	234,600,000	107,180,400	75,865,500	51,276,900	277,200
	Soft Rock	35,600,000	29,057,600	6,065,000	464,200	13,200
	Hard Rock	182,300,000	158,820,900	20,746,100	2,733,000	0
Contingency	5 %	50,224,000				
T o t a l (A)		1,054,697,000	409,433,400	450,669,100	129,583,100	14,787,400
Handling Equipment	Shiploader	3,338,000	1,266,000	921,000	1,151,000	0
	Conveyor	99,540,000	42,578,000	35,098,000	11,507,000	10,357,000
	Stock Shed	113,348,000	0	73,072,000	16,110,000	24,166,000
Contingency	5 %	10,811,000				
T o t a l (B)		1,281,734,000	453,277,400	559,760,100	158,351,100	49,310,400

Table-13.7.2 Annual Investment Schedule

(Unit: Million Rs.)

Item		1990 / 91		1991 / 92		1992 /93		1993 / 94	
		Foreign	Local	Foreign	Local	Foreign	Local	Foreign	Local
Survey/Consultant		2.06		1.7		3.62			
Iron Ore Berth								19.43	16.03
Product Oil Berth						14.37	42.46		
Crude Oil Berth								10.04	26.97
Breakwaters	Southern				28.40		48.64		24.32
	Northern				29.12		50.08		25.04
Dredging	Channel					21.05	48.85	42.10	97.70
	Lagoon			107.18	127.42				
	Soft Rock			29.06	6.54				
	Hard Rock			52.94	7.83	105.88	15.65		
Navigation Aids								31.80	
Tug Boats								41.43	
Contingency	5 %	0.10		9.54	9.97	7.25	10.28	7.24	9.50
T o t a l (A)		2.16		200.42	209.27	152.17	215.96	152.04	199.56
Handling Equipment	Shiploader							1.27	2.07
	Conveyor							42.58	56.96
	Stock Shed						56.67	0.00	56.67
Contingency	5 %					0.00	2.83	2.19	5.79
T o t a l (B)						152.17	275.47	198.08	321.05

Total (B): Including Handling Equipment