MORMUGAO PORT TRUST

Deepening of Approach Channel for Capesize Vessels

Feasibility Report

August 2014

Section – 1
Introduction

1.1 Background

Mormugao Port Trust (MPT) is strategically located to cater to the needs of the coal requirement of steel and power plants of its hinterland in Karnataka. The main user for MPT is currently JSW steel. JSW steel imports about 7 million tons of coal and exports about 1 million ton of finished steel products through MPT. However their coal requirement is in excess of 15 million tons and they have to depend on ports on the Eastern Coast like Krishnapatnam for coal imports despite the fact that MPT is closer to their steel plant situated at Toranagallu. Coal imports for JSW at MPT is carried out at Berth No.6 which is operated by South West Port Ltd. Another Coal Berth No.7 has recently been made operational by Adani Port Terminal Ltd. which serves a number of users. Coal Importers stand to gain significantly in terms of freight benefit if imports are done through Capesize vessels. MPT, taking into account the growing competition from private ports and other Major Ports in the vicinity has decided to deepen the Approach Channel for Capesize vessels. The outer Channel which is presently dredged to -14.40 m is to be deepened to -19.80 m and the inner Channel from -14.10 m to -19.50 m. This will facilitate navigation of Capesize Vessels at any state of tide.

Goa has large deposits of iron ore and at its peak in 2010-11, MPT exported about 40 million tons of iron ore with Panjim also exporting about 15 million tons during the same period. The iron ore exports came to a grinding halt after the ban on exports imposed by the Supreme Court in October 2012. The ban has now been relaxed. However, iron ore exports are yet to gain steam. Worldwide, iron ore prices have slumped. Since the iron ore markets continue to be depressed and also taking into account that iron ore exports are unlikely to achieve the former glory, exports of ore through Capesize vessels has not been considered in this report. Another aspect is that, Berth No.9 which is the dedicated iron ore berth cannot be deepened for Capesize vessels unless some kind of strengthening work is undertaken. Hence at this stage the port is not contemplating to make any investment for strengthening of Berth No.9. Capesize vessels can be topped up at stream after partial loading at berth, a procedure which was earlier adopted.

MPT expects that substantial growth in coal traffic can be achieved if larger vessels can be serviced. However, a very big factor for MPT's growth is the doubling of the South Western Railway network which is presently choked. The SWR has already awarded doubling for a part of this rail network.

Doubling of the rail network coupled with MPT's expansion plan will open up a lot of exciting opportunities for investments in the hinterland particularly for the steel sector and power sector.

1.2 Objective of the study

The objective of this study is to evaluate the Techno –Economic Feasibility of Deepening the Approach Channel at Mormugao Port

1.3 Scope of Work

The scope of work includes;

i) Assessment of cargo volumes which can be generated due to the deepening project. Identification of sizes of ships expected to call.

ii) Study of site data including oceanographic, meteorological and sea bed conditions in the area of interest with a view to plan deepening of channel.

iii) Design of Channel and maneuvering areas on the basis of standards as specified by Bureau of Indian Standards and PIANC.

iv) Estimation of dredging quantities on the basis of present available depths and designed depths.

v) Estimation of costs and project viability evaluation.

1.4 Methodology

The relevant data has been collected from survey investigation reports. The data has been analysed with regard to specific requirements of the present project.

The assessment of cargo potential directly attributable to the deepening of harbour has been done to assess the viability of the project. Presently only 3 berths namely berth 5,6 and 7 can be deepened for Capesize vessels. Hence the revenue for the project will have to come out of coal handling only. Based on the above, the cargo volumes which can be directly attributable to harbour deepening and likely ship sizes have been forecasted.

Useful information as to the nature of material to be dredged has been obtained from various borehole data, sub bottom profile studies and previous capital dredging work undertaken by the port during 2003-04.

The capital cost has been estimated based on proposed components of developments and current market rates. The recurring cost has been taken as the incremental costs directly attributable to the deepening project. The income from the project is the incremental income based on cargo volumes directly attributable to the project. Incremental income will be realized only from Capesize Vessels calling at the port and there will not be any tariff increase for the existing class of vessels served by the port. The project viability is done based on IRR by drawing cash flow for a period of 15 years.

Section – 2

Traffic Potential

2.1 General

MPT has 7 cargo handling berths and 6 Mooring Dolphins. Berth-wise cargo and vessel details at Mormugao Port during the year 2013-14 are detailed in Table 2.1

Table 2.1

Berth	Cargo	Capacity (MTPA)	No. of Vessels	Tonnage handled 2013-14	Average Parcel size 2013-14	Owned & Operated
Berth No.5	HR Coil, Steel slabs, steel plates	7.5	57	1083468	19008	SWPL
Berth No.6	Coking coal, R.P.Coke		106	7492222	70681	SWPL
Berth No.7	R.P.Coke	4.61	2	15992	7996	Adani Port
Berth No.8	Ammonia, C.Soda, Liquids	1.50	78	552917	7089	MPT
Berth No.9	Granite, HR Coil	11.50	11	84996	7727	MPT
Berth No.10	Bauxite,Container,Coils, granite, woodchips, fertilizers etc	2.65	84	752201	8955	MPT
Berth No.11	Bauxite ,Container, Coils, granite, woodchips, fertilizers		80	985249	12316	MPT
Mooring Dolphins	Coal, pig iron	10.00	17	679326	39960	MPT

Cargo handled during the past 3 years through MPT is given in Table 2.2;

Table 2.2

	Commodity	2011-12	2012-13	2013-14
	Exports			
1	Iron ore & pellets	29208319	7491518	196923
2	Bauxite	0	70397	153400
3	Containers	86569	110369	122062
4	C.P.Coke	20659	10185	0
5	Granite	53471	194160	364367
6	H.R.Coils	381255	787369	1204153
7	Iron & Steel	119270	12831	59746
8	Maize	0	27500	0
9	Pig Iron	0	0	271936
10	Sugar	0	0	60988
11	Wheat	0	31500	43713
12	POL	0	0	4623
9	Misc. Gen. Cargo	23582	2319	4811
	Total Export	**29893125**	**8667751**	**2333322**
	Imports			
10	Liquid Bulk	1363459	1032792	859889
11	Fertilisers	93495	77950	179478
12	Pet. Coke	163188	176943	347968
13	Met. Coke	192296	87325	0
14	C.P.Coke	0	152371	0
15	Coking Coal	5668863	6605889	7517587
16	Thermal Coal	1163116	767785	0
17	Containers	144230	147571	113567
18	Edible Oil	4970	5001	0

19	Wood Chips	0	0	386344
20	Misc. Gen. cargo	314721	16766	615
	Total Imports	**9108338**	**9070393**	**9405448**
	Total Traffic	**39001463**	**17738144**	**11738770**

From the above Tables it is evident that Coal and Coke consist of the main contributor to cargo for MPT. It can also be seen that cargo volumes have reduced only on account of depletion in iron ore traffic. Coal imports show an increasing trend. SWPL has commissioned Rapid in Motion Silo facility in July 2014. Also Coal Berth No.7 operated by Adani Ports has become operational in June 2014. Adani Ports have also installed Rapid in Motion Wagon handling facility. Hence the coal traffic is set to further rise.

2.2 Shipping Trends

The maximum ship sizes to be considered for planning of facilities for various commodities are given at Table 2.3.

Table 2.3 Recommended maximum ship sizes

	Cargo	Maximum ship size (in DWT)
1.	Break bulk cargo	50,000
2.	Containers (a) Main Line (b)Feeder	 8,000 TEUs 1500 TEUs
3	Iron Ore (a) Coastal traffic (b)International traffic	 65,000 150,000
4	Thermal coal (a) Coastal traffic (b)International traffic	 65,000 185,000
5	Coking coal	1,85,000
6	Crude Petroleum oil (a) Handled at SBMs (b) Sheltered terminals	 300,000 150,000
7	Petroleum products	60,000
8	LNG	67,500
9	LPG	40,000
10	Fertilisers and raw materials, other dry and liquid bulk and break bulk cargo	50,000

From the maximum sizes as given in Table 2.3, it can be seen that, as far as Mormugao port is concerned, the only commodity that will immediately be benefited from deepening of the port is coal.

2.3 Assessment of traffic potential attributable to deepening of harbour

Coking coal is mainly imported by steel plants located in the hinterland of the port . The traffic volume in respect of this cargo is dependant upon the capacity of steel plants, their production program and policy with regard to using imported coal. At Mormugao Port, during the last 5 years, there has been a sharp increase in coal imports as can be seen from the Table 2.4.

Table 2.4 Coal Imported through Mormugao Port

Year	Qty in M.T.
2009-10	4.71
2010-11	6.56
2011-12	6.83
2012-13	7.38
2013-14	7.52

The main importer of coal through Mormugao Port is JSW Steel at Toranangallu. There are other smaller players also for which coal is imported through Mormugao Port. Most of these steel companies are poised for major expansion and the demand for coal is set to go up in the near future.

In addition to steel plants, coal imports through Mormugao Port can also serve power plants which will come up in the hinterlands.

At present Coal meant for JSW are brought in gearless vessels of about 75,000 DWT. Coal importers stand to gain substantial freight advantage by deploying Capesize vessels. The deepening of the navigational channel will not only provide impetus for existing steel companies to increase their capacities, but also encourage new steel plants to come up. The Capesize ships will be in the region of 185,000 DWT.

One aspect that needs to be specially mentioned is the congestion in the South Western Railway Network. The SWR has taken up the doubling work. Once this is completed it will open up a whole lot of opportunities for the steel and power sector as coal transportation will become hassle free. However even at this stage, the SWR has not made any timelines for completing the doubling work. Hence, realistically, assuming that SWR takes up operational issues and minor modification works to augment the capacity of the lines, about 12 million tons of coal traffic would be possible within the next few years. This can gradually go upto 14 million tons. For the purpose of this project, the following coal traffic projections have been made as shown in Table 2.5;

Table 2.5 Coal Traffic Projections

2015	2016	2017-18	2019-20	2021-23	2024-2026	2027-2029
9.00	**10.00**	**12.00**	**12.00**	**12.00**	**13.00**	**14.00**

Section -3

Site Conditions

3.1 Geographical Location

The port of Mormugao, one among the twelve major ports in India, is situated in the State of Goa, on the west coast of India, between the Major ports of Mumbai and New Mangalore. It is located at the mouth of the river Zuari at latitude 15 25' North and longitude 73 47' East. Mormugao is an open type natural harbour and has a natural promontory known as Mormugao Headland. The harbour is protected by a breakwater of 550 m long and a mole of 270 m long. The approach channel is 6 km long.

The State of Goa is connected with the rest of the country through two National Highways, the NH-17 running from Mumbai to Cochin through Goa and the NH-4A connecting Panjim to Belgaum. The NH-4A eventually joins NH-4 which connects Mumbai and Bangalore. The NH-17A, approximately 17 kms. connects Mormugao to NH –17 at Cortalim. Another Highway NH-17B is under construction which will connect the port with the NH-17 at Verna Jn. Goa is connected to the National railway network through the South Western and Konkan Railways. Apart from this Goa has a grid of all weather navigable rivers. The rivers Zuari and Mandovi are extensively used for transportation of iron ore to the port.

3.2 Topography

The existing port stretches from the breakwater area to berth no. 11 close to the Vasco city. The back up area consist of a strip of land sandwiched between the Mormugao Headland and the water area.

3.3 Tidal Information

The mean tidal variation at Mormugao Port is the order of 1.6 meters at spring tides and around 0.7 meters at neap tides. The maximum height of tides is 2.5 mts. The following tides level refers to the chart datum which is 4.84 mts. below the principle bench mark. The bench mark is 3.60 mts. above the IMSL (Indian Mean Sea Level).

Table 3.1 Tidal Levels

Lower low water springs near solstices	0.00 mts
Mean lower low water	+0.37 mts.
Mean higher low water	+1.05 mts
Mean sea level	+1.30 mts
Mean lower high water	+1.78 mts
Mean higher high water	+2.06 mts
Higher high water springs near solstices	+2.30 mts

The above is based on Hydrographic chart No. 2020. The observations were recorded in 1969-70.

3.4 Prevailing winds

The mean sea wind varies from 2 on the Beaufort scale in November to 4 in July, the annual mean sea wind speed being 13.6 Kmph. In an average year, there are 316 days with wind varying between 0 to 3 on the Beaufort scale and 48 days with winds varying between 4 to 7 on the Beaufort scale.

The predominant wind direction changes with the time of the year. During the period June – September, wind blows from the west and south- west. During the remaining period, the wind direction is from NE, ESE during the evening. The highest speed is 105 kms recorded in June 1994. Winds of force more than 10 on the Beaufort scale are not expected.

3.5 Sea swell and currents

In fair season on the open sea, wave heights are almost always under 2 m. Very rarely are they in the range of 2m to 3m, direction of waves being from the west, north-west and north. In the monsoon season, the waves are mainly from the west and south-west. About 25% of the observations indicate waves of between 2 to 3m. Currents in the area are generally less than one knot.

3.6 Temperature and relative humidity

There is little variation in temperature and the humidity is high. The Maximum temperature varies 28 degrees Celsius in January to 36 degrees Celsius in May. The minimum temperature varies between 21 degrees Celsius in January to 28 degrees Celsius in May. The mean percentage relative humidity is about 83% for the year.

3.7 Visibility

Except to some extent in the monsoon season, the visibility conditions are excellent. There may be 3 to 4 days in a year with visibility less than 4 kms.

3.8 Cyclones

Mormugao is not situated in the a pronounced cyclonic zone. The number of occasions it was visited by cyclones during the past 75 years is less than a dozen.

3.9 Monsoon period

The south-west monsoon is the main rainy season. 80% of the rainfall is during the months of June, July and August. The average rainfall is about 2500 mm per year.

3.10 Geotechnical Data

A number of boreholes have been sunk in the entrance channel to assess the composition and properties of soil layers. The borelogs are enclosed alongwith this report. Isolated patches of hard strata could be encountered during the capital dredging work.

3.11 Berth Statistics

The physical features of the present berth facilities are summarised Table 3.2.

Table 3.2 **Present Facilities**

Berth No.	Length (mts)	Dredge Depth (mts)	Year of Construction	Type of cargo	Capacity Mn. Tons
Cruise Berth	450	9.50	2012	Cruise vessels	-
Mole Berth	250	9.50	2012	Non cargo vessels	-
1,2,3	-	9.00	1995	Ship repair facility	-
4	194	8.00	2012	Port crafts	-
5	200	14.10	2004	General Cargo	7.50
6	250	14.10	2004	Coal	
7	300	14.50	2014	Coal	-
8	298	13.10	1976	Liquid bulk	1.50
9	357	14.10	1978	Iron ore	11.50
10	250	13.10	1985	General cargo	2.65
11	270	13.10	1994		
Mooring Dolphins	6 nos	14.10	2003-2011	Bulk Cargo	10.00

Section -4

Design of Channel and Maneuvering Areas

4.1 General

In this section the required dimensions of navigation channel are determined based on the accepted norms for the design vessel. The approach channel will be designed for vessels 1,85,000 DWT. The environmental data as available MPT and the PIANC Guidelines and BSI codes have been considered to arrive at the recommended channel dimensions. The local navigator's views pertaining to constraints in navigation have been also considered.

4.2 Existing Harbour

The Features of the existing channel as follows :
Approach channel (from open sea to the tip of breakwater)

Length	- 6200 m
Width	- 250 m
Depth	- -14.40 m CD

Basin Area

Length	- 2500 m
Width	- 220 m to 400 m
Depth	- -14.10 m CD

Turning circle No.1&2 of diameter 480 m and depth of – 14.10m and 13.10 CD respectively

4.3 Theoretically Desirable Channel Dimensions

4.3.1 Factors involved in Channel Design,

Basically the factors can be divided into three groups. The first group covers the inherent design characteristics of the ships. The other two groups consist of factors resulting from the effect of constrained water flowing past the hull form, causing certain behavioral characteristics, which will vary with the ship's design,

Those in Group A, being chosen at the design stage of the ship, and therefore are constant. Those in Group B will change during the ship's operation and so are termed as variable. While those in Group C, are beyond the ability of the ship to alter and therefore called external.

Group A – Fixed (related to Design Ships

- Fullness of the hull i.e. block co-efficient,
- Length to breadth ratio
- Breadth to maximum draught ratio
- Longitudinal radius of gyration
- Position of the rudder(s) relative to the propeller(s)
- Type and area of the rudder(s)
- Position of the longitudinal centre of buoyancy

Group B – Variable (related to operation of ship)

- Speed and propeller revolutions.
- Rudder activity
- Loaded state
- Trim

Group C – External (related to environment)

- Currents and tides.
- Wind
- Waves and swell
- Navigational aids
- Bank of the channel
- Water depth
- Level of cargo hazard
- Bottom surface of channel
- Human response

The understanding of likely ship behavior in the navigation channel is essential to plan and design a navigation channel. To appreciate and predict ship behavior it is necessary to understand ship motions which have six degrees of freedom i.e. pitch, heave, roll, sway, surge and yaw. Horizontal and vertical ship motion governs the channel design.

4.3.2 Horizontal Motions

Much of the research to date deals with the individual factors and most factors connected with ship maneuvers were found to cause ship motion in the horizontal plane. Few research findings have resulted in quantified information suitable for application in the ports and much of it being of a qualitative nature.

Within the few research findings with objective recommendations considerable disparity existed probably due to the research methods employed and the non consideration of scale effect in model tests. Also, in the past much of the work has been based on assumption that the ship behaves as if it were moving through an infinite sea, thus not reflecting the water flow phenomena of a restricted port approach channel.

The work to date may be assessed in terms of hydrodynamic and environmental factors, relating to the water flow effects imposed upon a ship within a restricted waterway.

The factors may be grouped under three broad headings, i.e. hydrodynamic, environmental and operational**.**

4.3.2.1 Hydrodynamic Factors

These may be described briefly as follows :

- Ship lane or directional stability which is the width required to allow for the oscillating track produced by the ship maintaining its course.

- Bank suction, which is the clearance to allow between the hull and channel banks for the turning moment caused by the asymmetrical flow of water around the ship, attracting the stern of the ship towards the bank.

- Channel bend allowance, which is the additional width to accommodate the “sweep” of the ship’s track, as it experiences a moment and sideways force while negotiating the bend.

- Ship to ship interaction causing yaw and course deviation to occur, thus requiring a minimum safe clearance between ships passing either in the opposite, or same direction.

- Stopping and turning distances which vary with reduced underkeel clearances. In the case of turning distances, it is known that decreasing underkeel clearances will increase a ship’s turning circle diameter dramatically.

4.3.2.2 **Marine Environmental Factors**

These environmental factors, however,, lend themselves more readily to quantification when their forces are constant. The effect of cross-current for example, causes a ship to “crab” along its chosen path and thus requires a width of track in excess of its beam. This is a well known effect, and can be simply calculated as a relationship between ship and water current speeds.

The effect on ship depends on such factors as:

- The ratio of wind speed to ship speed

- The direction of wind relative to ship’s heading.

- Whether the ship is light or laden.

The resultant forces on a ship will thus have two main effects. Firstly, these will cause a turning moment requiring the ship to apply helm to counteract the drift, including a further “crabbing” effect similar to that for cross-currents.

A conventional ship with a single rudder normally has a maximum helm angle of 35” When considering the effect of wind or the maximum relative wind speed that can be tolerated in any given transit, thought must be given to the amount of helm angle that can be dedicated to counteracting wind. The amount needs to be balanced against the helm required by the ship handler for normal navigational control and course-keeping and for collision avoidance during a port transit. However, it should be noted that not only a suitably safe equilibrium helm angle must be considered, but also the response of the helmsman and steering system of the ship must be taken into account

4.3.2.3 **Summation of Factors**

If the relevant individual factors can be defined and quantified, it would then seem reasonable to combine them into what may be termed a “Total Beam Factor”. Summation of all these factors showed err but on the side of safe provision. From this conclusion can be drawn regarding the required channel width for a given ship or conversely, the largest size of ship acceptable in a given channel. The Total Beam Factor will be greatest when the cross-current and wind are in the same direction, making their effects additive.

4.3.2.4 Vertical Motions

Any ship, if it is to stay afloat must be allowed a depth of water in excess of its static draught to cater for vertical motions, and this allowance for underkeel clearance for the large ships falls in the range of 9% to 15% of its static draught at most ports. However, it is a fact that at most of the ports accepting the large ships, although the individual factors may have been recognized and considered but these have not been objectively related to vertical motion.

The factors relevant for underkeel requirement are as follows :

- Any ship speed and size, causing changes in trim and squat.
- The nature of channel e.g. the extent to which it is exposed to swell
- Changes in water density or salinity
- Extent of siltation.
- The accuracy and frequency of dredging and hydrographic surveys.
- Operational factors such as inaccuracy of tidal height readings or unpredicted cuts in tidal height during the port transit.
- Nature of sea bed.

The above factors need to be considered while dredging the depth in channel and maneuvering areas.

4.4 Channel Design

4.4.1 Methodology

The methodology adopted involves :

- Establishment of the design criteria with respect to vessel size and environmental conditions
- Assessment of the horizontal dimensions of navigation channel and maneuvering areas.
- Assessment of the vertical dimensions of the navigational channel and maneuvering areas.

Generally the navigational studies are carried out in two phases which are :

- Phase 1 – Concept design, based on desk study.
- Phase 2 – Detailed design based on a more elaborate evaluation which may utilize physical, mathematical and real time ship maneuvering simulator studies.

In this report, only studies covered under Phase 1 have been carried out based on published data and technical literature (such as PIANC, BIS codes etc.) This phase-1 study gives fair estimate of channel width and depth and also the alignment for the channel.

The second phase of study when done will further optimize these parameters and add to the confidence of navigators which can be taken up at a later stage.

4.4.2 Design Vessel

The channel has been designed for 185,000 DWT bulk carrier. The typical dimensions of design vessels area as follows :

Vessel size (DWT)	Length (m)	Beam (m)	Draft (m)
1,85,000 (bulk carrier)	300	45.0	18.5

4.4.3 Channel Width

Navigation channel has been designed based on the two approaches

(1) Theoretical, considering design vessel and oceanographic conditions and

(2) On the basis of operational constrains of vessel and oceanographic conditions.

The channel width is calculated on the basis of these two approaches and the larger value of channel width is adopted for the channel.

4.4.4 Width on the Basis of Theoretical Approach

A typical one way channel width would comprise of a basic maneuvering lane, additional widths (to allow for the effects of wind, current, *etc.)* and bank clearance.

The factors considered in channel width design are:

- Ship maneuverability
- Vessel speed
- Environmental factors like cross wind, current, waves etc.
- Aids to navigation
- Type of cargo (hazardous or otherwise)
- Depth of channel
- Type of bottom surface
- Bank clearance

There are no rational formulae, which explicitly include all the above parameters to arrive at appropriate widths. The width of channel is expressed in multiple of beam of the design ship. The channel width is designed for one way traffic taking into account the characteristics of the design vessel. The navigational width is estimated using the PIANC 'Guidelines for Design of Approach Channels. Width provisions for various factors are calculated separately which are described hereunder :

A. *Width of Basic Maneuvering Lane*

Moderate ship maneuverability, experienced pilots with ability of quick response in interpreting the visual cues indicating position and that of the ship in reacting to the rudder have been assumed

Basic width of maneuvering lane equal to 1.5 times the beam of vessel (B) is considered.

B. Additional widths for straight channel sections due to effects of Environmental

Factors

The factors and considered additional width for shore facilities are as follows:

a. *Vessel speed*

Vessel speed of 11 knots has been considered in approach channel and thus no additional width is proposed.

b. Cross winds .

The prevailing cross wind is of the order of 25 knots, which is considered moderate and hence additional width of 04B for- approach channel is considered.

c. Cross and longitudinal currents

As per the recorded data, the maximum current is in the order of 1.00 knots. Hence an additional width of 1.0 B is considered.

d. Wave Height

Wave height in the approach channel is about 2 m. Hence an additional width of 1.0B has been considered.

e. Bottom surface of channel

An additional width of 0.1 B has been considered since the sea bed is considered smooth and soft.

f) Depth of waterway

An allowance of 0.4B has been considered assuming depth to draft ratio as less than 1.15.

g) Additional width for bank clearance

An allowance of 0.5B has been considered on either side of the channel . The width allowances for the design vessel as discussed under them above are summarized in Table 4.2 and the required channel widths in Table 4.3.

Table No.4.2 Width allowances for channel

	Factors	Allowances
1	Maneuverability	1.5B
2	Speed	0
3	Cross wind	0.4B
4	Cross current	1.0B
5	Waves	1.0B
6	Bottom surface	0.1B
7	Depth	0.4B
8	Bank clearance	0.5B
	Total width	**4.9B**

Table 4.3 Theoretical channel width

Design Vessel Size	Approach channel width
185,000 DWT	206m

At present the approach channel has a width of 250m which is adequate.

4.4.5 Depth of Channel

For the determination of the required depths in the navigation channel and the maneuvering areas, the methodology as described earlier is used and various parameters are superimposed to arrive at the design depths.

4.4.5.1 Vertical ship motions due to waves

Waves cause a ship to pitch, roll and heave. Wave climate in the region is generally mild except during cyclones. The limiting wave height is taken as 2.5 m in outer channel. The half wave height has been considered for fixing channel depths.

4.4.5.2 Net under keel clearance

There is no hard and fast rule to calculate the UKC. As per BIS recommendation (IS 4651 Part V) an allowance of 0.60 to 0.75 m is given when the channel bed is soft. and 1.0 m when the channel bottom is hard.

4.4.5.3Squat

Squat is estimated by using CORELS equation as under :
Squat (m) = 2.4
Where, V = Volume of displacement in m^3
= C_B $L_{pp.}$ B x Df
F = Froude Depth Number
V = Speed of vessel in metre/ second
h = Water depth in metres
g = acceleration due to gravity = 9.81 m/Sec2
L_{pp}= Length of ship between perpendiculars
B = Beam of ship
Df= Draft of ship
C_B= Block coefficient

4.4.5.4 Tidal Variation

Tidal variation is of the order of 1 m. If this' advantage is taken the vessel navigation will not be throughout the tidal cycle. Therefore considering vessel, navigation throughout the tidal cycle tidal variation advantage has not been taken.

4.4.5.5 Trim

As per the conservative practice, the trim at the stern is taken as 15 mm for every 10 m length of vessel.

4.4.5.6 Dredging Tolerance

In addition to the advance maintenance dredging an additional 0.2m below the selected dredging depth is generally provided as a dredging pay item because of the inability to dredge at uniform depth with a fluctuating water surface.

4.4.5.7 Proposed Depth

The proposed depth of the channel has been arrived at as follows.

Draft for 185,000 DWT vessels	- 18.50 mts
Under keel clearance	- 1.30 mts
Total depth required	- 19.80 mts.

Hence the depth for the approach channel will be -19.80 m CD. The inner channel and turning circle no.1 will be dredged to -19.50 m CD.

Section – 5
Dredging Plan and Estimates of Quantity

5.1 General

In this section a dredging plan has been prepared considering the various available equipment and site conditions. The dredging quantities for deepening the approach and entrance channel and maneuvering areas have been estimated on the basis of recommended dimension of channel. The maintenance dredging requirement is also discussed.

5.2 Dredging Plan

5.2.1 Dredgers

There are various types of dredging equipment available for executing capital dredging works. These include the following;

- ☐ Trailer Suction Hopper Dredger (TSHD)
- ☐ Cutter Suction Dredger (CSD)
- ☐ Bucket Dredger
- ☐ Grab / Clamshell Dredger
- ☐ Backhoe Dredger

The most common type of dredgers used for large scale works are TSHD and CSD. It is proposed to deploy these equipments at Mormugao Port to carry out the dredging work. The features of these dredgers are discussed hereunder;

5.2.1.1 Trailer Suction Hopper Dredger (TSHD)

The TSHD is a sea-going self propelled vessel which is equipped with suction pipes provided on the sides of the vessel. The suction pipes terminate at the lower end in a drag head which is provided to draw the maximum amount of sea bed material and discharge it into a hopper in the vessel. The TSHD is a very versatile dredging unit. These equipments are most suitable for deployment in busy navigational channels. It can dredge material varying from sand, silt gravel and soft to medium clay. It can work in exposed conditions with wave heights upto 3 m. The material dredged can be used for reclamation either by pumping through pipelines or rainbowing technique.

5.2.1.2 Cutter Suction Dredger (CSD)

The CSD comprises a rotating cutter head mounted at the end of a suction pipe and connected to a dredging pump in the main body of the dredger. The dredger pivots around a spud located at the rear of the dredger by using a system of anchor wires and winches. The cutter head cuts the material on seabed and then the material is sucked up through the suction pipe by the dredger pump and discharged through a pipeline. The CSD can dredge a variety of different type of soils, including clay, silt, sand and weak rocks. It is sensitive to wave conditions and can operate for significant wave conditions upto 1 m. Hence deployment of CSD at Mormugao Port should be during fair weather seasons when the sea is relatively calm.

5.2.2 Choice of dredger for Mormugao Port

Major part of the dredging work can be accomplished by deployment of the TSHD. However, there could be some stiff clay and rock patches for which a CSD will have to be deployed. Hence for the dredging project, a CSD and TSHD will be deployed.

5.3 Estimation of Capital Dredging

The existing depth of inner channel is -14.10 m CD and outer channel -14.40m CD. The proposal is for deepening outer channel to -19.80m CD and inner channel to -19.50m CD. The quantity of dredging to be carried out is estimated to be 12.75 million cubic meters. The quantity calculation was carried out using 'hypack', a software used for this purpose. Details of quantity are as follows;

Location	Area in sq.m	Design Depth	Quantity (Mn.Cum)
Outer Channel	2234280	19.80	9.40
Inner Channel	6582445	19.50	3.35
		Total	**12.75**

5.4 Disposal of dredged spoil

The dredge spoil could be used for reclamation of the area west of the breakwater where MPT is proposing for its future development. However, a retaining bund will have to be constructed for this purpose. If this does not materialize, the dredge spoil will have to be dumped at a suitable location. The existing spoil ground may not be suitable for this purpose. MPT will need to carry out necessary studies at CWPRS to find out a new dumping ground.

5.5 Maintenance Dredging

Estimation of rate of siltation is a complex phenomena. A fairly good estimation of maintenance dredging can be assessed by taking past dredging records. MPT has consulted CWPRS Pune was to assess the maintenance dredging quantity. Preliminary assessments suggest that the maintenance dredging could be in the region of 2 to 3 million cubic meters. The viability for the project has been calculated based on incremental maintenance dredging quantity of 3 million cum.

5.6 Studies to be conducted

The following studies needs to be carried out prior to taking up the dredging work;

i) Assessment of incremental maintenance dredging
ii) Location of new dumping ground for dredged material
iii) Wave tranquility studies within the harbor area

MPT has already approached CWPRS, Pune for carrying out these studies.