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JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)
MINISTRY OF SURFACE TRANSPORT (MOST)
MUMBAI PORT TRUST (MBPT)

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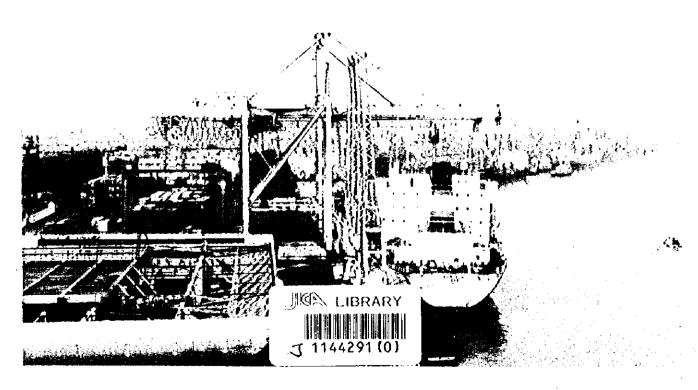
# FINAL REPORT

# THE STUDY ON DEVIALORMANT OF THE PORT OF MUMBALIN INDA

# (VOLUME II)

PART 2 MASTER PLAN

PART 3 SHORT-TERM PLAN

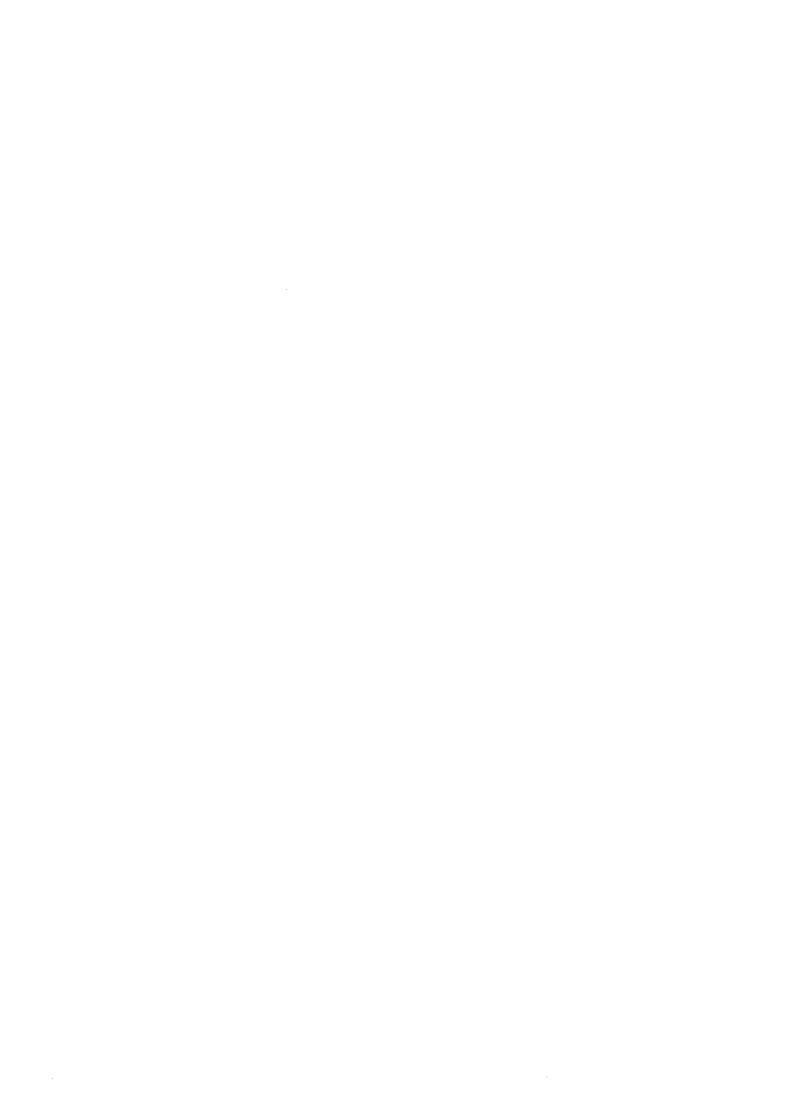


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### ABBREVIATIONS

ACR Annual Confidential Report

A/N Arrival Notice

1A 20 Foot Container

BARC Bhabha Atomic Research Center

B/C Benefit/Cost

BI Butcher Island

BIS Bureau of Indian Standard

B/L Bill of Lading

BOD Biochemical Oxygen Demand

BOQ Bill of Quantity

BOT Build-Operate-Transfer

B&P Bertlin and Partners

BPCL Bharat Petroleum Corporation Limited

BPS Ballard Pier Station, Ballard Pier South

BPX Ballard Pier Extension

CARMINS Cargo Management and Information System

CD Chart Datum

CDW Cotton Depot West

CFS Container Freight Station

CIF Cost, Insurance and Freight

CLP Container Load Plan

COD Cotton Depot, Chemical Oxygen Demand

CONCOR Container Corporation of India

CPA Closest Position of Approach

CPCB Central Pollution Control Board

CRS Central Railway Stores

CRZ Coastal Regulation Zone

CTCS Container Traffic and Control System

CUM Cubic Metre

CWC Central Warehousing Corporation

CWPC Central Water and Power Commission

CWPRS Central Water & Power Research Station

1C 40 Foot Container

dB Decibel

DCI Dredging Corporation of India

DD Designed Depth

DF Dual Frequency

DGPS Differential Global Positioning System

Dk Dock

DO Dissolved Oxygen

D/O Delivery Order

DRCM Direct Reading Current Meter

DWT Dead Weight Tonnage

E East

EIA Environmental Impact Assessment

EIR Equipment Interchange Receipt

EIRR Economic Internal Rate of Return

EIS Executive Information System, Environmental Impact Statement

EL Entrance Lock

EMPA Europe Maritime Pilot Association

E/P Export Permission

ETA Estimated Time of Arrival

ETD Estimated Time of Departure

ETP Efficient Treatment Plant

FA & CAO Financial Adviser & Chief Accounting Officer

FB Frere Basin

FCL Full Container Load

FMS Financial Management System

FOB Free on Board

FW New Ferry Wharf

G Green

GAP Ganga Action Plan

GDP Growth Domestic Products

GLD General Landing Date

Gp.Fl. Group Flashing

GPS Global Positioning System

GRT Gross Registered Tonnage

HC Harbor Channel

HJ Haji Bunder

HP Horse Power

HPCL Hindustan Petroleum Corporation Limited

HTL High Tide Line

HY Hay Bunder

Hz Hertz

IALA The International Association of Lighthouse Authority

ICD Inland Container Depot

ID Indira Dock

IDB Indira Dock Berth

IDH Indira Dock Harbor Wall

ID-HW Indira Dock Harbor Wall

IEE Initial Environmental Examination

IGM Import General Manifest

ILAC Ilac Limited

IMD Indian Meteorological Department

IMO International Maritime Organization

IS Indian Standard

ISO International Standardization Organization

JD Jawahar Dweep

J/E Jetty End

JICA Japan International Cooperation Agency

JNP Jawaharlal Nehru Port

JNPT Jawaharlal Nehru Port Trust

JVC Joint Venture Companies

KPT Kandla Port Trust

kt Knot

L Length

LCL Less than Container Load

LOA Length Overall

LPG Liquid Petroleum Gas

LTL Low Tide Line

M Mile, Million

m metre

MBP Mumbai Port

MBPT Mumbai Port Trust

MCGB Municipal Corporation of Greater Bombay

MD Maintained Depth, Manganese Depot

MHWN Mean High Water Neap

MHWS Mean High Water Spring

MLD Million Litre per Day

MLWN Mean Low Water Neap

MLWS Mean Low Water Spring

MMRDA Mumbai Metropolitan Region Development Authority.

MOD Manganese Ore Depot

MOEF Ministry of Environment and Forest

MOST Ministry of Surface Transport

MOT Marine Oil Terminal

M/P Master Plan

MPCB Maharashtra Pollution Control Board

MPN Most Probable Number

MSR Mazagaon Sewri Reclamation

M/R Mate's Receipt

MT Motor Tanker, Metric Ton

MV Motor Vessel

MWL Maintained Water Level

N North

ND Not Detected

NE Northeast

NGO Non Governmental Organization

NIO National Institute of Oceanography

NM Nautical Mile

NNE North Northeast

NOI Net Operating Income

N.O.S. Not Otherwise Specified

NRT Net Registered Tonnage

NW Northwest

NWDB National Wasteland Development Board

Occ Occulting

OIL Oil India Limited

ONGC Oil and National Gas Corporation Limited, Oil&Natural Gas Commission

ORZ Ocean Regulation Zone

PC Slab Prestressed Concrete Slab

PD Prince's Dock

pH Potential Hydrogen

POL Petroleum, Oil and Lubricant

PP Pir Pau Oil Terminal

PPT Parts per Trillion

PS Horse Power

Q Quick

QGC Quay side Gantry Crane

R Red

RCD Railway Container Depot

RCF Rashtriya Chemical & Fetilizers

RS Reach Stacker

Rs. Rupee

RTG Rubber Tired Gantry Crane

S South

S/A Shipping Application

SE Southeast

S/O Shipping Order

SPCB State Pollution Control Board

SPM Suspended Particulate Matter

SSW South Southwest

SW Southwest

T&L Tug & Launch

TC Turning Circle

TEU Twenty Foot Equivalent Unit

TP Timber Pond Depot

TPM Total Particulate Matter

TPS Timber Pond South

TV Television

UKC Under Keel Clearance

UNCTAD United Nations Conference on Trade and Development

UNDP United Nations Development Program

VD Victoria Dock

VHF Very High Frequency

VTMS Vessel Traffic Management System

VTS Vessel Traffic Service

W West, White

WA Wadala Area Depot

WHO World Health Organization

YAP Yamuna Action Plan

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# Part II MASTER PLAN

# **Chapter IX Demand Forecast**

# 9.1 Socio-Economic Framework for the Target year

# 9.1.1 Population

The forecast is carried out under the following conditions.

- 1) The Population of India is 916.0 million in 1995 based on the mid-year estimation of "Statistical outline of India 1996-97".
- 2) The average annual growth rate from 1995 to 2007 is set at 1.7% which is expressed in the Ninth Five Year Plan by the Indian government, and that from 2007 to 2017 is forecast at 1.3% according to report of the Asia Development Bank and World Bank.

The resulting figures in target years are shown in Table 9.1.1 The population will reach 1.121 billion in 2007 and 1.276 billion in 2017.

Table 9.1.1 Projected Population

(Unit: million)

	1995	2007	2017
Population	916.0	1,121.4	1,276.0
Annual Growth Rate	<del></del>	1.7%	1.3%

#### 9.1.2 Economic Framework

#### (1) Gross Domestic Products (GDP)

According to the "Ninth Five Year Plan 1997 - 2002 (Government of India Planning Commission)", the average growth rate of GDP during 1997 - 2002 is estimated as 6.2 % in the period from 1997 - 2002 and 6.5% in the Post Plan. Referring to above figures, the average growth rate of GDP is assumed as 6.2 % in the period from 1995 - 2007 and as 6.5 % in the period from 2007 - 2017 in this study. The sectoral GDP of agriculture is estimated as 4.5% in the "Ninth Five Year Plan 1997 - 2002 (Government of India Planning Commission)", and

this figure is used up to 2017 in this study.

The resulting GDP in the target years is shown in Table 9.1.2.

Table 9.1.2 Projected GDP

(Unit: Rs million)

	1994	2007	2017
GDP	2,560,950	5,597,831 6.2%	10,507,898
Annual Growth Rate GDP(Agriculture) Annual Growth Rate	785,900	1,392,769	2,162,928 4.5%

Note: Figures at 1980-81 constant price

# 9.2 Methodology of Demand Forecast

There are two different methods of forecasting future port traffic in the target year. One is the so-called macro forecast method which estimates the cargo volume as a group including entire commodities regardless of the volume of each commodity. The other is the so-called micro forecast method which estimates the cargo volume of each commodity individually.

In the former method, the total cargo volume in the target year is forecast by relating the past records of the total cargo volume to socio-economic indices such as GDP(Gross Domestic Products) and/or population and using future estimates of these indices.

In the latter one, the cargo volumes of major commodities in the target year are forecast individually based on the correlation analyses between cargo volumes and the corresponding indices of the historical records.

In the first step of the port traffic projection, the total volumes through the ports of Mumbai and Jawaharlal-Nehru are forecast taking account of the overlap of their hinterlands to a great extent. Next, cargo volume is allocated to the two ports according to the basic concept of the functional allocation between the two ports (see Table 9.2.1).

Table 9.2.1 Cargo volume by mains commodities

(Unit: '000sons) (Import) 1986-87 1987-88 1988-89 1989-90 1990-91 1991-92 1992-93 1993-94 1994-95 1995-96 Commodity Containcrizable Cargo 193 298 100 144 143 100 100 Agricultural, Fishery & Forest Products 473 425 751 769 899 340 516 Paper and Paper Product 348 1,869 1,888 2,341 3,373 3,550 2,390 1,760 1,850 1,617 2,096 Light Industry Products 4,335 4,747 3,235 2,492 2,134 2,601 2,544 2,820 2,200 2,367 Containerizable Cargo Sub-total Statistically mixed cargo in containerization 405 938 2,483 1,181 1,360 717 918 1,156 Agricultural, Fishery & Forest Products 1,338 1,510 224 151 170 Wood Pulp 130 110 208 101 141 1,777 1.660 2,733 Fertilizers and their Raw Materials 1,130 1,410 1,424 2,034 1,936 960 1,000 1,951 1,871 973 1,380 1,200 1,152 858 1,062 1,250 fron and Steet Material 1,028 481 831 385 182 17. 871 750 760 820 Scrap and Dross 227 261 85 Motor Vehicles and Miscellaneous sub total 287 226 270 310 Statistically mixed cargo in containerization 4,008 5,111 4,659 5,782 6,177 Sub Total 5,370 4,271 5,627 4,894 4,790 260 280 270 250 220 164 24 89 185 Non-Containerizable Cargo 3,980 4.706 5,463 5,531 7,278 8,891 4,554 3 559 4,728 POL(couse) 1,532 2,982 4,815 1,628 2,089 1,661 1,749 POL(products) 1,176 965 2,157 7,192 8,906 10,980 7,900 9,369 5,729 6,863 6,995 4,735 5,693 Petroleum Sub-total 18,049 20,382 15,364 13,554 16,785 18,898 13,579 13,771 Tetal (Source: Administration report of MBFT and INPT)

Non-Containerizable	 								
Chemical products (liquid)	 60	45	21	44	27	52	58	92	94
Non-Containerizable Sub Total	 60	45	21	44	27	52	58	92	94

(Source: Traffic Department of MBP)

(Export)

(issport)									(Unit: '000:	lons)
Ye	ar 1986-87	1987-88	1988-89	1989-90	1920-91	1991-92	1992-93	1993-94	1994-95	1995-96
Commodity										
Containerizable Cargo										
Agricultural, Fishery & Forest Products	427	290	310	597	1,345	871	556		528	1,69
Light Industry Products	915	1,340	1,370	1,414	1,434	1,482	1,519	2,335	3,412	3,06
Containerizable cargo Sub total	1,372	1,630	1,680	2,011	2,779	2,353	2,074	2,981	3,940	4,755
Statistically reliced cargo in containerization	n i					•				
Agricultural Products	671	480	600	510	440	594	525	1,026	839	
Metal and Metal Products	104	180	160	194	152	199	213	285	172	
Mixture Sub-total	775	660	768	704	592	793	738	1,311	1,011	1,67
Petroleum										
POL(crude)	8,437	9,629	10,442	8,703	9,917	9,981	8,161	6,940		
POL(products)	3,143	4,061	2,892	3,103	2,756	2,339				
Petroleum Sub-total	11,580	13,690	13,334	11,806	12,673	12,320	11,701	9,670		
Total	13,727	15,980	15,774	14,521	16,044	15,466	14,513	13,962	15,881	18,41

(Source: Administration report of MBPT)

Non-Containerizable cargo										
Chemical products (liquid)	1	0.4	0.2	0.3	2	0.2	- 1	4	7	5
Non-Containerizable cargo Sub Total		0.4	0.2	0.3	2	0.2	1	4	7	5

(Source: Traffic Deportment of MBPT)

#### 9.3 Macro forecast

GDP is used as an index in the correlation analysis of the macro forecast in this study.

# (1) Import

The correlation between the total volume of import cargo through MBP and JNP and GDP from 1986 to 1995 is expressed as the following equation.

$$Y = 0.004232 \times GDP + 2,418.9 \times D + 5,589.3$$
(3.04) (2.51)

where,

: Total import cargo volume

GDP: GDP (1980's constant prices, million Rs) in India at target year

D : Dummy Variable (0 for 1986-1991, 1 for 1992-1995)

 $r^2$  : 0.927

( ): t-value

The resulting figures of the estimation using the above equation are shown in Table 9.3.1 and Figure 9.3.1.

Table 9.3.1 Import Volume of Cargo by Macro Forecast

(Unit: thousand tons)

	1995	2007	2017
Import Cargo Volume	20,382	31,698	52,477

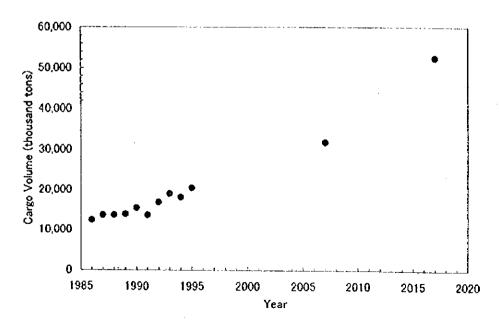


Figure 9.3.1 Import Cargo Volume of Macro Forecast

# (2) Export

The total volume of export cargo in the last decade handled at Mumbai Port and Jawaharlal - Nehru Port has fluctuated greatly year by year showing no obvious correlation with socio economic indices. The total export volumes in the target years are estimated by the past growth rate of cargo from 1986 - 1995.

$$Y = Y_0 \times (1 + G_1 \times E_L)^{(t - 1995)}$$

where,

Y: Total export cargo volume

Y<sub>o</sub>: Existing volume in 1995 (= 18,416 thousand tons)

G<sub>1</sub>: Annual growth rate of GDP in India

at target year 6.2%(2007),6.5%(2017)

 $E_L$ : Elasticity (= 0.318)

t : Target year

The export cargo volume is estimated in Table 9.3.2.

Table 9.3.2 Export Volume of Cargo by Macro Forecast

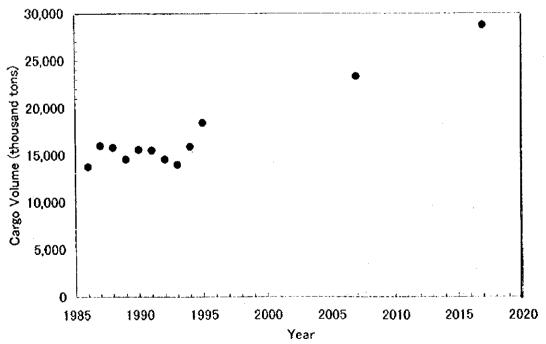


Figure 9.3.2 Export Cargo volume of Macro Forecast

# (3) Result of Macro Forecast

The result of the macro forecast in target years is shown in Table 9.3.3.

Table 9.3.3 The Result of Macro Forecast

(Unit: thousand tons)

	1995	2007	2017
Import Cargo Volume	20382	31,698	52,478
Export Cargo Volume	18,416	23,356	28,751
Total	38,798	55,054	81,229

#### 9.4 Micro Forecast

# 9.4.1 Classification of the Major Commodity Groups

The cargo handled at the two ports MBP and JNP is classified into the following major commodity groups for the micro forecast.

# (Import)

- 1) Containerizable Cargo
  - Agricultural, fishery and forest products
  - Paper and paper products
  - Light industry products
- 2) Statistically Mixed Cargo in Containerization
  - Agricultural, fishery and forest products
  - Wood pulp
  - Fertilizer and their raw materials
  - Iron and steel
  - Scrap and dross
  - Motor vehicles and miscellaneous
- 3) Non-Containerizable Cargo
  - Non-Containerizable Cargo
- 4) Petroleum (POL)

- Crude oil
- Refined petroleum products
- 5) Chemical Products (liquid)
  - Chemical Products

# (Export)

- 1) Containerizable Cargo
  - Agricultural, fishery and forest products
  - Light industry products
- 2) Statistically Mixed Cargo in Containerization
  - Agricultural products
  - Wood pulp
  - Metal and metal products
- 3) Petroleum (POL)
  - Crude oil
  - Refined petroleum products
- 4) Chemical Products (liquid)
  - Chemical products

# 9.4.2 Result of Micro Forecast

The results of the micro forecast, showing import and export cargo volume by major commodity groups of MBP and JNP are shown in Table 9.4.1 and Table 9.4.2. The detailed process is described in Appendix 9.

Table 9.4.1 Summary of Forecast Volume of MBP and JNP (Import)

			· · · · · · · · · · · · · · · · · · ·		(Unit: the	usand tons)	
Year	1995	-95	2007	-08	2017	-18	
	MBP	JNP	MBP	JNP	MBP	JNP	
1						761	
						3,451	
						5,291	
	3,061	1,686	7,554	4,161	17,254	9,503	
<b>l</b> .	4.7	<b>17</b>	11,7	715	26,7	57	
				·			
		0		0		0	
1.		0				0	
$\perp$	838	1,895			2,471	4,728	
		0				0	
	173	0	178	0	178	0	
	49	0	310	0	310	0	
	4,282	1,895	6,905	3,044	9,740	4,728	
L	6,1	77	9,9	49	14,468		
	89	0		0		0	
	89	G	280	0	280	0	
	- 8		2:	30	280		
	4,554	0	8,891	0	8,891	0	
	4,815	0	7,375	0	15,192	0	
	9,369	6	16,266	. 0	24,083	0	
	9,3	69	16.	266	24,0	83	
	16,801	3,581	31,005	7,205	51,357	14,231	
	20,	382	38,	210	65,5	88	
	Year	MBP  192 580 2,289 3,061 4,7  1,181 170 838 1,871 173 49 4,282 6,1 89 89 89 89 89 4,554 4,815 9,369 9,369	MBP   JNP   192   106   580   319   2,289   1,261   3,061   1,686   4,747     1,181   0   170   0   633   1,895   1,871   0   173   0   49   0   4,282   1,895   6,177   899   0   899   0   89   0   89   0   89   0   89   0   89   0   1,554   0   4,815   0   9,369   0   0   9,369   0   0   0   0   0   0   0   0   0	MBP   JNP   MBP	MBP   JNP   MBP   JNP	Teal   1995-96   2007-08   2017   MBP   JNP   JNP	

(Source: Administration report of MBPTand JNPT)

	1995-96		2007-	)8	2017-18	
•	MBP	JNP	MBP	JNP	MBP	JNP
Non-containerizable						
Chemical products (liquid)	94	0	200	- 0	386	(
Non-containerizable Sub-total	94	0	200	0	386	C
Non-containerizable Total	9.5		200		386	

Source) Traffic Department of MBP)

Remark) \*: Forecast volume of MBP and JNP at 2007-08 and 2017-18 are divided from the total volume by refering the volume of MBP and JNP at 1995-96.

Table 9.4.2 Summary of Forecast Volume of MBP and JNP (Export)

(Export)		•		. ` •	(Unit: thou	sand tons)
Year	1995	-96	2007-0	08	2017-	18
Commodity	MBP	JNP	MBP	JNP	MBP	JNP
Containerizable cargo						
Agricultural, Fishery & Forest Products *	845	849	1.177	1,183	1,612	1,621
Light Industry Products *	1,526	1,535	7,354	7,394	19,073	19,178
Containerizable cargo Sub Total	2,371	2,384	8,531	8,577	20,685	20,799
Containerizable cargo Total	4,7	55	17,10	8	41,48	4
Statistically Mixed Cargo in Containerization						
Agricultural Products	1,394	0	1,942	0	2,661	0
Metal and Metal Products:	276	O	285	0	285	0
Mixture Cargo Sub-total	1,670	0	2,227	0	2,946	0
Mixture Cargo Total	1,6	70	2,22	7	2,94	6
Petroleum (POL)					**	
Crude oil	9,994	0	10,000	0	10,000	C
Refined petroleum products	1,607	0	2,413	0	2,413	0
Petroleum Sub-total	11,601	0	12,413	0	12,413	0
Petroleum Total	11,0	501	12,41	3	12,41	3
Total	15,642	2,384	23,171	8,577	36,044	20,799
Grand Total	18,	926	31,74	18	56,8-	13

(Source: Administration report of MBPT)

	Year 1	ır 1995-96		2007-	08	2017-18		
Commodity	MBP	JNP	•	MBP	JNP	MBP	JNP	
Non-containerizable Sub-total								
Chemical products (liquid)		5	0	7	0	7		
Non-containerizable Sub-total		5	-0	7	0	7		
		5		7		7		

(Source: Traffic Department of MBP)

Remark) \*: Forecast volume of MBP and JNP at 2007-08 and 2017-18 are divided from the total volume by referring the volume of MBP and JNP at 1995-96.

#### 9.4.3 Cross Check with the Result of Macro Forecast

Table 9.4.3 shows a comparison of cargo volumes obtained by the macro and micro forecast methods described in section 9.3 and section 9.4.2

The result of the micro forecast is larger than that of the macro forecast. Herein, the cargo volume handled at Mumbai Port for the target years will be forecasted by the micro forecast method.

Table 9.4.3 Forecast of Total Cargo Volume in Target Years

(Unit: thousand tons)

	Forecast method	1995-96	2007-08	2017-18
Import	Macro method	20.202	31,698	52,477
-	Micro method	20,382	38,210	65,627
Export	Macro method	10.416	23,356	28,751
•	Micro method	18,416	31,748	56,843
Total	Macro method	20 700	55,054	81,228
	Micro method	38,798	69,958	122,470

# 9.5 Forecast of Cargo Volume (Container, Conventional, Dry Bulk and Liquid Bulk)

# 9.5.1 Forecast of Container Cargo Volume

#### (1) Historical Trend of Containerization

The percentage of containerization is computed by using the volume of containerized cargo as numerator and the volume of containerizable cargo as denominator which is already containerized or has the potential to be containerized in the future. Containerizable cargo items are selected and are checked by the actual percentage of containerization using the past traffic records. Cargo which is not selected as containerizable cargo is classified as non-containerizable cargo. Thus, non-containerizable cargo naturally includes bulky, long and heavy cargoes which can not be stuffed into container boxes physically and non-valuable cargo which can not burden costly container transport freight.

Actual port cargo statistics, however, have some cargo items containing both containerizable and non-containerizable cargoes. In this study, port cargo statistics are compiled according to the three categories, viz. containerizable cargo, non-containerizable

cargo and statistically mixed cargo in containerization and cargo forecast is conducted according to these categories. The resulting classification of containerizable cargo and non-containerizable cargo is shown in Table 5.2.5 (a) and (b) in Chapter V. The historical trend of the percentage of containerization is shown in Table 9.5.1.

Table 9.5.1 Historical Trend of Containerization

(Unit: %)

	1991	1992	1993	1994	1995
Import (loaded)					
Containerizable Cargoes	77.6	74.8	85.2	80.8	86.7
Statistically Mixed Cargo in Containerization					
1. Agricultural, Fishery and Forest Products	21.1	22.9	46.5	15.4	36.5
2.Oil and Fats	15.2	14.8	38.4	6.2	12.5
3.Fertilizer and its Raw Material	6.0	14.8	18.9	0.5	10.8
4.Wood pulp	17.8	14.2	53.1	11.9	41.8
5 Iron and Steel Products	17.1	17.7	42.0	33.8	29.9
6.Scrap	28.5	32.5	53.8	5.5	43.9
Export (unloaded)					
Containerizable Cargoes	66.2	63.0	84.5	96.1	93.3
Statistically Mixed Cargo in Containerization					
1.Agricultural Products	15.3	5.6	38.3	72.7	47.8
2.Fodder	20.5	10.2	36.6	56.1	48.0
3.Oil and Fats	30.8	6.7	28.2	78.0	53.9
4.Fertilizer	41.7	27.3	4.7	90.9	93.3
5.Metal and Metal Products	41.8	19.6	48.9	85.7	59.2

(2) Estimation of Volume of Container Cargoes belonging to the Group of Containerizable Cargoes

The percentage of containerization for the target year is forecast by using the logistic curve expressed as the following formula.

$$P = 1/\{1 + C^{(1+10)}\}$$

where; P: The percentage of containerization in t year (%)

C: Parameter prescribing curvature

t : Year

t<sub>a</sub>: Year in which the percentage of containerization reached 50%

Table 9.5.2 shows the future volume of containerized cargo and percentage of containerization which is calculated by above method.

Table 9.5.2 Forecast Volume of Container cargoes

(Unit: thousand tons)

		2007-08	2017-18		
	Containerize d cargo	Percentage of Containerization	Containerized cargo	Percentage of containerization	
Import(loaded)	11,287	96.3	26,434	99.7	
Export(unloaded)	16,543	96.7	41,028	98.9	
Total	27,830		67,461		

# (3) Estimation of Volume of Container Cargoes belonging to the Group of Statistically Mixed Cargo in Containerization

The percentage of containerization of statistically mixed cargo in containerization is assumed considering the past trend of the percentage of containerization and the feature of each commodity. Table 9.5.3 shows the volume of container and the percentage of containerization in the target years.

Table 9.5.3 The Volume of Containerized Cargo and the Percentage of Containerization of Statistically Mixed Cargo in Containerization.

(Unit: thousand tons)

	2007-08		201	7-18
Import (unloaded)	thousand	%	thousand	%
Statistically Mixed Cargo in Containerization	tons	70	tons	70
1. Agricultural, Fishery and Forest Products	514	50.0	798	50.0
2.Oil and Fats	170	17.4	264	17.4
3.Fertilizer and its Raw Material	474	10.2	735	10.2
4.Wood pulp	108	50.0	176	70.0
5.Iron and Steel Products	732	28.1	961	28.1
6.Scrap	58	32.8	58	32.8
Import Sub Total	2,056		2,992	
Export (loaded)				
Statistically Mixed Cargo in Containerization				
1.Agricultural Products	589	50.0	831	50.0
2.Fodder	319	80.0	417	50.0
3.Oil and Fats	42	39.5	55_	39.5
4.Fertilizer	11	51.6	14	51.6
5.Metal and Metal Products	101	51.0	101	51.0
Export Sub Total	1,062		1,418	
Total	3,118	<u> </u>	4,410	<u></u>

#### (4) Estimation of Number of Containers

Considering that the volume of exports exceeds that of imports in container transport through Mumbai Port and Jawaharlal-Nehru Port, and assuming imported and exported container boxes will be balanced as is generally the case in world wide container ports, the number of containers is estimated as followed:

$$N = Vexp/W \times (1/(1-Ep)) \times 2$$

where; N: Number of containers (TEUs / year)

Vexp: Container export volume (tons / year)

W: Average cargo weight per TEU in laden container.

Ep: Ratio of empty container

The average weight of container cargo is assumed to be 12.95 tons / TEU referring to 1995 data. Empty container ratio is set as 10% in 2007 and 5% in 2017 referring to the actual data. The resulting number of containers in the target years is as follows.

Table 9.5.4 Number of Containers in the Target Year

(Unit: thousand TEUs)

	1995-96	2007-08	2017-18
Mumbai Port and			
Jawaharlal-Nehru Port	860	3,021	6,900

# (5) Possible Diversion of Containers from MBP and JNP to New Port in Guiarat

The hinterland of MBP includes not only the Mumbai Metropolis consisting of Greater Mumbai and New Mumbai and the remaining Maharashtra State but also west India including Gujarat State and the north India including the States of Delhi, Haryana and Punjab. MBP's share of hinterland is assumed using manifest data. Gujarat State's share of the container cargoes through MBP and JNP is shown in Figure 9.5.1.

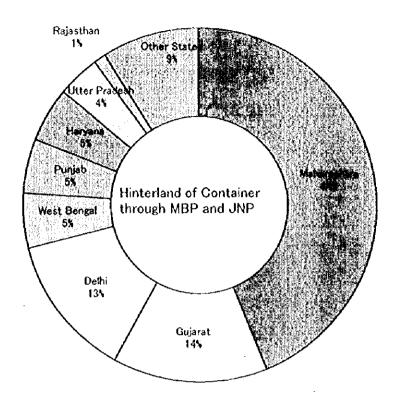


Figure 9.5.1 Hinterland of Container Cargoes through MBP

The volume of container cargo to be diverted from MBP to a new port in Gujarat State for the target year is estimated in accordance with the present Gujarat State's share of hinterland. Gujarat State accounts for 14% of container volume handled at MBP and JNP, therefore, 423,000TEUs in 2007 and 966,000TEUs in 2017 will be diverted from MBP and JNP to the new port in Gujarat State. The volume of containers to be diverted is shown in Table 9.5.5.

Table 9.5.5 Diverted Volume of Container from MBP and JNP to Gujarat State

(Unit: thousand TEUs)

	2007-08			2017-18		
	Gujarat	MBP+JNP	Total	Gujarat	MBP+JNP	Total
Container	423	2,598	3,021	966	5,934	6,900
Share	14%	86%	100%	14%	86%	100%

#### 9.5.2 Forecast of Conventional Cargo Volume

The forecast volume of conventional cargo for the target year is computed by deducting containerized cargo volume from the total cargo volume. Whole of Conventional cargo will be handled in MBP. The resulting figures are shown in Table 9.5.6.

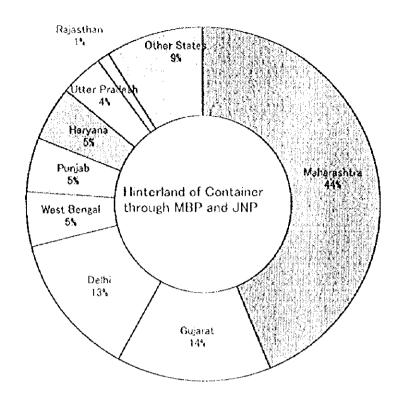


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(Unit: thousand TEUs)

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Container	423	2,598	3,021	966	5,934	6,900
Share	14%	86%	100%	14%	86%	100%

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Table 9.5.6 Conventional Cargo in the Target Year

(Unit: thousand tons)

	2007-08	2017-18
Import		
Non-Container in Containerizable cargo and		
Non-Containerizable Cargo	708	642
Agricultural, Fishery and Forest Products	514	798
Oil and Fats	805	1,251
Wood pulp	108	76
Iron and Steel Products	1,875	2,458
Vehicles	25	25
Miscellaneous	285	285
Import Sub Total	4,320	5,535
Export		
Non-Container in Containerizable cargo	565	456
Agricultural Products	589	831
Fodder	319	417
Oil and Fats	64	84
Metal and Metal Products	97	97
Miscellaneous	88	88
Export Sub Total	1,732	1,973
Total (Import + Export)	6,052	7,508

(2) Possible Diversion of Conventional Cargoes from MBP to New Port in Gujarat Gujarat State's share of conventional cargoes through MBP is shown in Figure 9.5.2. Gujarat State accounts for 8.2%. Gujarat State's share of each cargoes ie; paper products and miscellaneous of 7%, iron and steel of 0.5% and scrap of 0.7% are shown in Table 9.5.7.

Table 9.5.7 Gujarat State's Share of Conventional Cargoes from MBP

State Name	Commodity	Distribution of commodity (%)
Gujarat	I. Conventional Cargo	8.2
	i) Paper products and miscellaneous	7.0
	ii) Iron and steel	0.5
	iii) Scrap	0.7

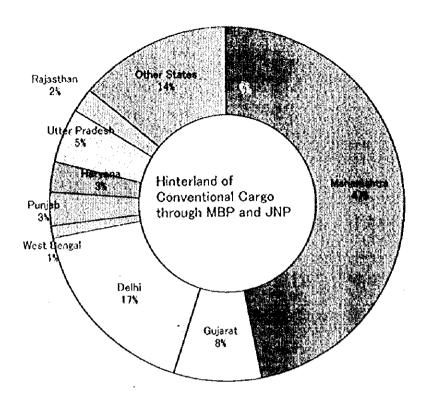


Figure 9.5.2 Hinterland of Conventional Cargoes through MBP

Diversion of conventional cargoes from MBP to Gujarat State is shown in Table 9.5.8.

Table 9.5.8 Diverted Volume of Conventional Cargoes from MBP to Gujarat State

(Unit: tons)

		2007-08			2017-18		
	Gujarat	MBP	Total	Gujarat	MBP	Total	
[Import]		:					
Paper products	27,998	371,976	399,974	34,114	453,230	487,344	
Share	7.0%	93.0%	100%	7.0%	93.0%	100%	
Iron and Steel	9,376	1,865,776	1,875,152	12,291	2,445,970	2,458,261	
Share	0.5%	99.5%	100%	0.5%	99.5%	100%	
Miscellaneous	54,798	728,033	782,831	51,055	678,301	729,355	
Share	7.0%	93.0%	100%	7.0%	93.0%	100%	
[Export]							
Iron and Steel	4,828	89,804	96,563	4,828	89,804	96,563	
Share	0.5%	99.5%	100%	0.5%	99.5%	100%	
Miscellaneous	47,711	633,880	681,591	51,055	678,305	581,197	
Share	7.0%	93.0%	100%	7.0%	93.0%	100%	

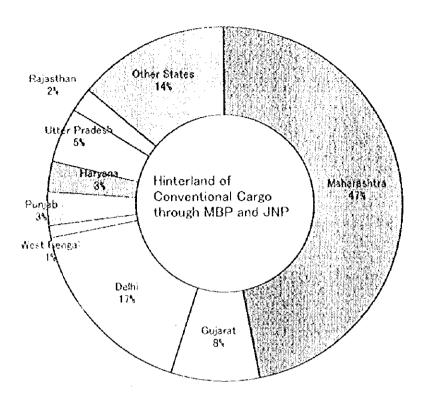


Figure 9.5.2 Hinterland of Conventional Cargoes through MBP

Diversion of conventional cargoes from MBP to Gujarat State is shown in Table 9.5.8.

Table 9.5.8 Diverted Volume of Conventional Cargoes from MBP to Gujarat State

(Unit: tons)

		2007-08			2017-18			
	Gujarat	MBP	Total	Gujarat	MBP	Total		
[Import]								
Paper products	27,998	371,976	399,974	34,114	453,230	487,344		
Share	7.0%	93.0%	100%	7.0%	93.0%	100%		
Iron and Steel	9,376	1,865,776	1,875,152	12,291	2,445,970	2,458,261		
Share	0.5%	99.5%	100%	0.5%	99.5%	100%		
Miscellaneous	54,798	728,033	782,831	51,055	678,301	729,355		
Share	7.0%	93.0%	100%	7.0%	93.0%	100%		
[Export]		.,						
Iron and Steel	4,828	89,804	96,563	4,828	89,804	96,563		
Share	0.5%	99.5%	100%	0.5%	99.5%	100%		
Miscellaneous	47,711	633,880	681,591	51,055	678,305	581,197		
Share	7.0%	93.0%	100%	7.0%	93.0%	100%		

# 9.5.3 Forecast of Cargo Volume of Dry Bulk

The forecast volume of Dry Bulk cargo for the target year is computed by deducting container cargo volume from the total volume. In case of Fertilizer, it set to be handled in JNP and the other cargoes are handled in MBP. The results are shown in Table 9.5.9.

Table 9.5.9 Volume of Dry Bulk Cargo.

(Unit: thousand tons)

	2007-08	2017-18
Import		
Fertilizer (JNP)	3,044	4,727
Phosphate	551	856
Sulphur	567	880
Scrap	120	120
Import Sub Total	4,282	6,583
Export		
Fertilizer	10	14
Export Sub Total	10	14
Total	4,292	6,597

Gujarat State share of scrap is 0.7% and diversion of volumes of scrap is shown in Table 9.5.10. However, Fertilizer, Phosphate and Sulphur isn't diverted to Gujarat State.

Table 9.5.10 Diverted Volume of Dry Bulk Cargo

(Unit: tons)

	2007-08			2017-18		
	Gujarat	MBP+JNP	Total	Gujarat	MBP+JNP	Total
Import					1.1	
Scrap	839	118,706	119,545	839	118,706	119,545
Share	0.7%	99.3%	100%	0.7%	99.3%	100%

# 9.5.4 Forecast of Cargo Volume of Liquid Bulk

Liquid bulk cargo handled at the marine oil terminals consists of crud oil, refined petroleum products and chemical products. The forecast volume of liquid bulk cargo to be handled for the target year is shown in Table 9.5.11.

Result of the forecast volume of POL is 9.8 million tons in 2007and 17.6 million tons in

2017, which are 1.52 times and 2.74times of the volume in 1995 respectively. No additional space for POL storage facility is reserved on landed estate under MBPT's control. However, petroleum companies will be able to expand their storage facility on their premises as demand increases in future. Thus, it is assumed that their is no storage capacity limitation of POL in the study. Since POL is a low price product which can not offer high land transportation cost, POL is a usually transported within a limited hinterland. Therefore, no diversion of POL is assumed to the new port in Gujarat State.

Table 9.5.11 Forecast Volume of Liquid Bulk.

(Unit: thousand tons)

	2007-08	2017-18
Import		
Crude oil	8,891	8,891
Refined petroleum products	7,375	15,192
Chemical products	200	386
Import Sub Total	16,466	24,469
Export		
Crude oil	10,000	10,000
Refined petroleum products	2,413	2,413
Chemical products	7	7
Export Sub Total	12,420	12,420
Import + Export		
Crude oil	18,891	18,891
Refined petroleum products	9,788	17,605
Chemical products	207	393
Total	28,886	36,889

# 9.5.5 Summary of Forecast Cargoes by Packing Type

Cargo volume by packing type is shown in Table 9.5.12. The forecast volume is converted into the volume of packing type by referring to the present share.

Table 9.5.12 Forecast Volume by Package Type of MBP and JNP

	Packing Type	2007-0		2017-	.18
		MBP	JNP	MBP	JNP
Container					sand TEUs)
[Import]	Container	500	799	500	2,468
[Export]	Container	500	799	500	2,468
Container total		1,000	1,598	1,000	4,936
Conventional ca	rgo				(Unit: tons)
[ Import ]	3. <b>2</b>				
3.33.4. ***	Pulses (Bag)	378,200	0	587,355	0
	Sugar (Bag)	38,159	0	59,262	0
	Paper products	371,976	0	453,230	0
	Iron and steel	1,865,776	0	2,445,970	0
	Miscellaneous	728,033	0	678,301	0
Impo	rt total	3,382,144	0	4,224,118	0
[Export]					
	Pulses (Bag)	81,497	0	163,422	0
	Rice (Bag)	449,279	0	569,768	0
	Sugar (Bag)	28,559	0	36,218	0
	Oil cakes (Bag)	319,023	0	437,137	0
	Iron and steel	89,804	0	89,804	0
	Miscellaneous	633,880	0	540,514	0
Expo	rt total	1,602,042	0	1,836,863	0
Conventional ca	irgo Total	4,984,186	0	6,060,981	0
Dry Bulk Cargo	)				(Unit: tons)
[ Import ]					
	Salt	40,703	0	0	0
	Fertilizer (JNP)	0	3,043,885	0	4,727,238
	Phosphate rock	551,219	0	856,058	0_
	Sulphur	566,446	0	879,706	0
	Scrap	118,706	0	118,706	0
Dry Bulk Cargo			3,043,885	1,854,470	4,727,238
Dry Bulk Cargo	Total	4,320	,959	6,581	
Liquid Bulk		<del></del>			(Unit: tons)
[Import]					
	Edible oil	805,303	0	1,250,658	0
	Crude oil	8,891,000	0	8,891,000	11.11 0
	POL	7,375,000	0	15,192,000	0
	Chemical liquid	200,000	0	386,000	0
<u> </u>	ort total	17,271,303	0	25,719,658	0
[Export]		;" 		· · · · · · · · · · · · · · · · · · ·	
	Edible oil	64,034	0	87,742	0
	Crude oil	10,000,000	0	10,000,000	0
	POL	2,413,000	0	2,413,000	0
	ort total	12,477,034	0	12,500,742	0
Liquid Bulk tot	al	29,748,337	0	38,220,400	0

# 9.6 Forecast of Passenger Volumes

As to the inter-harbor passenger traffic, there are six service routes between Mumbai and the opposite-side port in Mumbai Bay; Rewas, Mora, Mandowa, Elephant island, JNP and Vashi.

The number of passengers for the target years is estimated using the annual growth rate of population of the destination region of each route and elasticity of passenger growth to opportunity growth for the route between Munbai and Mora which has been most stable in the past.

The forecast can be conducted by the following equation.

$$N_P = N_O \times (1 + E_L \times G_T)^{(\tau-1936)}$$

where, N<sub>P</sub>: Number of passenger

No. Number of Passenger in 1996-97 and 2000-01

E<sub>L</sub>: Elasticity (0.6726) (Annual growth rate of passenger/Annual growth rate of population)

 $G_T$ . Annul Growth Rate of Population of destination region of each route towards target year

t :Target year

Elasticity of 0.6726 for the route between MBP and Mora is adopted for the other route, because the growth trend of passenger between MBP and Mora has been the most stable. Annual growth rate of population of the destination region and the number of passenger for each route in 1996-97 are shown in Table 9.6.1.

Table 9.6.1 Calculation Items

Rout	Mora	Rewas	Mondwa	Elephanta	JNP	Vashi
Item						. <u></u>
N <sub>o</sub> :	1,089.8	860.4	253.3	746.1	657.0	117.9
1996	1,137.7	867.9	255.5	779.0	685.9	151.3
2000						
(thousand)						
$\dot{E}_{L}$	0.6726	0.6726	0.6726	0.6726	0.6726	0.6726
$G_{r}$	1.61	0.32	0.32	1.61	1.61	9.86
2000	2.27	4.94	4.9	2.27	2.27	5.12
(%) 2010					_,	
t 2017	2017	2017	2017	2017	2017	2017

# Based on the above equation, the number of passenger by route is shown in Table 9.6.2. Table 9.6.2 Number of Passenger by Route

(Unit: thousand)

Rout Target year	Mora	Rewas	Mondwa	Elephanta	JNP	Vashi
2017	1,472.3	1,506.0	443.4	1,007.8	887.6	268.9

# Chapter X Potential and Constraints of the Future Development

#### 10.1 Future Development Potential of MBP and JNP

The total container traffic through MBP and JNP, whose hinterlands overlap each other, has shown high growth since the opening of JNP. The annual growth rate has been 14.7% on average, reaching 984,000 TEUs in 1996-97. Along with the economic growth and further progress of containerization in India and its trade partners towards the next century, a huge capacity for handling containers will be required for the two ports towards the foreseeable future. The two ports, MBP and JNP, are expected to share the future capacity requirement in an optimum manner from the standpoint of the national economy of India.

MBP which handled 583,000 TEUs with an average berth occupancy rate of 82.5% at dedicated container berths in 1996-97 seems to be almost saturated in container handling so long as the present operational way remains without any physical and institutional improvement. On the other hand, a total annual container handling capacity of JNP is said to be one million TEUs including the P&O terminals to be constructed adjacent to the existing terminal operated by JNPT. Considering the conditions of MBP and JNP mentioned above, it is necessary to increase container handling capacity with additional investmen.

Given its spacious reserved areas, JNP has great potential as the site for future additional container terminals and hence is expected to share a major portion of the incremental capacity requirement for container handling in the future. On the other hand, MBP is also expected to share some portion of the incremental capacity requirement by making the most of its existing port facilities through redevelopment and modernization. This option at MBP is attractive because it could increase capacity while minimizing investment costs. On the other hand, full-scale development of JNP could be beneficial to the national economy.

In this option, concerning the limited space inside the docks at MBP, it is necessary to clarify the possibility of land acquisition for additional container depots outside the docks within the land under MBPT's control to back up container operations inside the docks. According to a detailed survey by the Study Team, leased land under MBPT's control was categorized with the degree of possibility of eviction and conversion as additional container depots. It was revealed that an area of about 13.5 hectares could become usable for additional container depots through the survey.

# 10.2 Preliminary Estimation of Dredging Volume in case of Deepening Channels

# 10.2.1 Capital Dredging Volume in Channels and Basin

The Master Plan has studied a possibility of construction of offshore jetty type container berths with the water depth of -12.0 to -13.0 meters. In order to construct such open-sea berths and ensure the safety navigation channels for 27,000 DWT Class container ships (or 35,000 DWT Class, depending on an option), Main Channel of Bombay Harbour and Approach Channel to Indira Dock, including Approach Channel to Marine Oil Terminal and that to JNPT, need to be deepened and locally widened. The channel dimensions (proposed width is 500 meters through the entire channel) and estimated capital dredging volumes of each channel section are given in Tables 10.2.1 to 10.2.3, each of which shows only a relationship between the dredging depth and the capital dredging volume.

The capital dredging volume includes the dredging volume to the required depth of water, the extra dredging volume at the channel bed (extra dredging depth was assumed to be 0.5 meter deep), and that of both sides of channel bank, of which slope was assumed to be formed into a ratio of 1/30.

On the other hand, the capital dredging volumes to construct the proposed offshore container berths and accompanying basin are estimated as given in Table 10.2.4.

Table 10.2.1 Channel Dimensions and Estimated Capital Dredging Volume in Main Channel

	Present Channel				Dredged to -12.0 m			Dredged to -13.0 m		
Channel	Length	Wid	th	Depth	Length	Width	Dredging	Length	Width	Dredging
Section		West	East				Volume	- 1 · 1		Volume
	(m)	(m)	(m)	(m)	(m)	(m)	( <sup>6</sup> m 000')	(m)	(m)	('000 m <sup>3</sup> )
1	4,500	500	440	11.5	4,500	500	1,772	5,500	500	3,788
2	2,700	440	440	11.2	2,700	500	1,819	2,700	500	3,453
3	3,631	440	325	11.0	3,631	500	2,968	3,631	500	5,219
4A	2,500	325	400	10.8	2,500	500	2,193	2,500	500	3,758
4B	2,360	400	420	10.8	2,360	500	2,070	2,360	500	3,547
4C	2,920	420	500	11.0	2,920	500	2,387	2,920	500	4,198
51	2,440	500	500	11.0	2,440	500	2,086	2,440	500	3,660
511	2,136	500	550	11.5	2,136	550	1,282	2,136	550	2,702
JWD	2,150	550	700	11.3	2,150	600	N.A.	2,150	600	N.A.
Total	25,337	-		-	25,337	_	16,577	26,337		30,325

Table 10.2.2 Channel Dimensions and Estimated Capital Dredging Volume in JNP Channel

Present Channel			Dredged to -12.0 m		Dredged to -13.0 m					
Channel	Length	Widt	h	Depth	Length	Width	Dredging	Leagth	Width	Dredging
Section		West	East				volume			volumo
	(m)	(m)	(m)	(m)	(m)	(m)	('000 m <sup>3</sup> )	(m)	(m)	('000 m <sup>3</sup> )
!	2,900	230	330	11.5	2,900	500		2,900	500	
2	2,300	430	500	11.5	2,300	500		2,300	500	
3	600	500	500	11.5	600	500	<b>.</b>	600	500	
Total	5,800				5,800	-	3,118	5,800	-	6,540

Note: Schematic drawing of Main Channel of Bombay Harbour

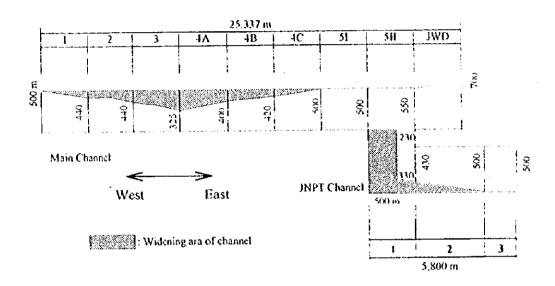


Table 10.2.3 Channel Dimensions and Estimated Capital Dredging Volume in 1D Channel

Prese	nt Chann	Dredged to -13.0 m				
Length	Width	Depth	Dredging Volume	Dredging Volume	Dredging Volume	Dredging Volume
(m)	(m)	(m)	('000 m³)	('000 m <sup>3</sup> )	('000 m <sup>3</sup> )	('000 m <sup>3</sup> )
2,400	360	7.8	1,520	2,280	3,720	4,960

Table 10.2.4 Estimated Capital Dredging Volume at Berth and Basin

Location	Dredged to	Dredging Volume ('000 m³)	Dredged to (m)	Dredging Volume ('000 m³)
Basin A & B	Berth = -12.0 Basin = -9.5	4,410	Berth = -13.5 Basin = -11.0	6,185

# 10.2.2 Maintenance Dredging Volume in Channels and Basin

Annual maintenance dredging is a requirement for most of the navigable areas in Mumbai Harbour. Except for the main channel which needs to be dredged once every three years so far, the remaining areas normally need to be dredged once a year, just after the south west monsoon period is over.

As previous studies of the siltation problems have been mentioned in Chapter II Clause 2.3 of this report, in this chapter, firstly temporal bathymetric records have been analyzed to get a hint helpful for estimating the maintenance dredging volume involved in case of deepening the channels, secondly a rate of siltation was approximately predicted by assuming a simple mathematical model for deepened channels, and thirdly the maintenance dredging volume was roughly estimated by using this assumed rate of siltation.

#### (1) Analysis of bathymetric records

MBPT has been carrying out the bathymetric survey in the main harbour channel, approach channels to Indira Dock, Prince's and Victoria Docks, each Dock basin, and all other port waters periodically, i.e. yearly, quarterly, half yearly, monthly and as required. This periodicity of sounding will be dependent on a rate of siltation in each area.

Bathymetric charts for the latest five years, or during the 1992-1997 period, including HAM's records, were collected and analyzed from a viewpoint of siltation.

In order to examine a temporal change of water depth, an average water depth on the lines across the main harbour channel at a right angle was analyzed, taking a measurement interval of each line at every 500 meters along the channel. In addition, an average water depth on the center line of the channel was also analyzed to check the values obtained at the cross sections and investigate an effect of flow of bottom materials near the side slopes of the channel banks.

Figures 10.2.1 and 10.2.2 show one of the typical temporal changes of the average depth of water in the access channels. It is impossible to draw a definite conclusion about a complicated siltation phenomenon over the harbour only from this analysis of sounding data, but these figures may suggest that the siltation rate seems to be large for short periods after the completion of dredging and will decrease gradually with the lapse of time and approach to an equilibrium profile at each site. Although there appear some local depositions near the foot of

slopes of the channel banks, there were no remarkable differences between rates of siltation examined by two methods.

Fig. 10.2.3 shows a temporal change of water depth at Prince's & Victoria Docks Approach Channel, Indira Dock Harbour Wall Berth and Ballard Pier Extension Berth, respectively. This figure may suggest that the characteristics of siltation are not always uniform over the channel and berthing areas, because the soft bottom sediment flow from the shallow side slopes into the dredged areas causes a large amount of deposition.

Table 10.2.5 summarizes the result of analysis of sounding data in each section of Main Channel and gives an estimated average annual rate of siltation in meter per year. This may give us a hint about possible rate of siltation in Main Channel. Although considerable dispersion is recognized in siltation rates, that may result from various factors including the strength and direction of the current, effects of winds and waves, profile of the surrounding seabed, etc. It is known that sediment discharge is increased by greater tidal activity and by increased wave action or wind disturbance. Average silt contents were therefore generally much greater during the monsoon than during fair weather. Sediment discharge is, however, reduced by low tidal activity and calm weather. Furthermore, such dispersion of data may be influenced by limitation of sounding accuracy.

Table 10.2.5 Estimated Rate of Siltation in Main Channel

(Unit: meter/year) Main On the center line of the channel Annual Rate of On the line across the channel Channel at right angle Siltation Estimated Section Mean Range Mean (Present study) Range N.A N.A N.A N.A N.A N.AN.A 2 N.A N.A N.A 0.25 0.06 to 0.43 0.14 to 0.49 0.27 3 0.22 0.09 to 0.59 0 to 0.45 0.26 4A 0.28 **4B** 0.04 to 0.71 0.30 0.11 to 0.74 0.34 0.26 4C 0 to 0.51 0.16 0 to 0.70 0.24 51 0.07 to 0.28 0.10 0 to 0.19 0.11 0.10 0 to 0.25 0.04 to 0.10 0.07 **511** 0.11

Note: 1) Estimated by an analysis of the following administrative sounding data obtained by MBPT. (Drawing No./Year)

Channel Section 3 (165/92, 55/94, 62/95, 269.83, 270.83)

Channel Section 4A (129/92, 62/93, 106/93, 14/94, 63/95, 11/96, 267-8.S4A)

Channel Section 4B (79/92, 140/92, 53/94, 61/95, 10/96, 266-7.S)

Channel Section 4C (53/92, 141/92, 54/94, 60/95, 4/96, 264.S1, 265.S)

Channel Section 51 (81/92, 104/92, 114/92, 142/92, 92/94, 46/95, 48/96, 263-4.S) Channel Section 511 (81/92, 114/92, 142/92, 115/94, 53/95, 55/96, 262.S)

2) Annual rate of siltation (Present study) in the above Table represents an average of each group of mean values.

Table 10.2.6 summarizes the result of analysis of sounding data in the major port areas and gives an estimated average annual rate of siltation in meter per year. It describes the corresponding annual rate of siltation currently adapted by MBPT. Siltation is more significant in these areas.

Table 10.2.6 Estimated Rate of Siltation in Port Areas

		(Ui	nit : meter/year)
Location and area	Annual Rate of Silt (Present	Annual Rate of Siltation	
	Range	Mean	(MBPT Criteria)
Indira Dock Approach Channel	0.32 to 0.77	0.46	0.50
Indira Dock Entrance Channel	0.56 to 1.70	0.82	1.50
Ballard Pier South Face	1.39 to 1.84	1.61	0.30
Ballard Pier Extension	1.27 to 1.96	1.61	3.00
East Mole	0.19 to 0.40	0.30	2,50
Indira Dock Harbour Wall Channel	0.88 to 1.88	1.31	1.80
ID Harbour Wall Berths Nos.18 to 21	2.21 to 2.84	2.60	3.00
Tug Berth, etc.	0.24 to 1.28	0.59	1.50
PD & VD Approach Channel	1.45 to 2.17	1.84	2.00

Note: 1) Estimated by an analysis of the following administrative sounding data obtained by MBPT.

(Drawing No./Year)

I.D. Approach Channel (43/92, 59/92, 35/93, 58/93, 94/94, 133/94, 6/95, 137/95, 2/96)
I.D. Entrance Channel (44/92, 58/92, 25/93, 34/93, 93/94, 132/94, 5/95, 17/95, 12/96, 26/96)

B.P. South Face, Extension and East Mole

PD & VD Approach Channel (2/92, 107/93, 128/93, 85/94, 101/94, 4/95, 147/95, 8/96)

2) As for argual rate of siltation (MBPT Criteria), refer to Chapter 7.4.

<sup>(210/91, 1/92, 149/92, 1/93, 81/94, 134/94, 2/95, 143/95, 25/96)
1.</sup>D. Harbour Wall Berth (33/92, 49/92, 96/93, 110/93, 98/94, 121/94, 8/95, 19/95, 1/96, 15/96)

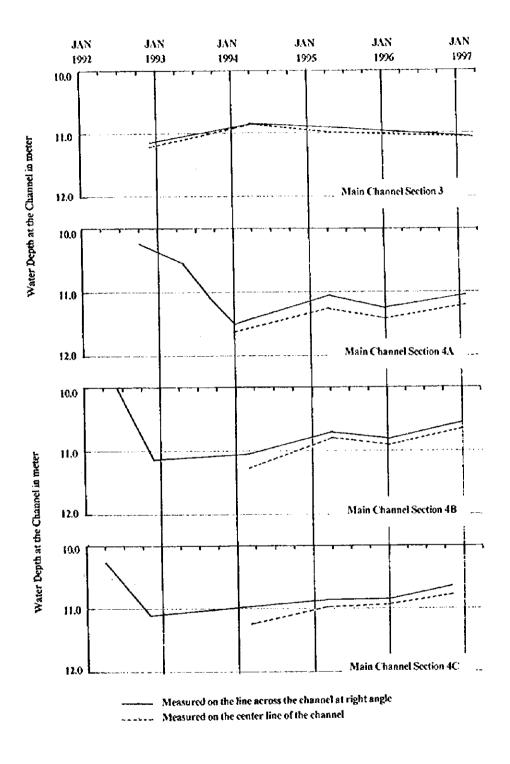


Figure 10.2.1 Temporal Change of Water Depth in the Channels (1)

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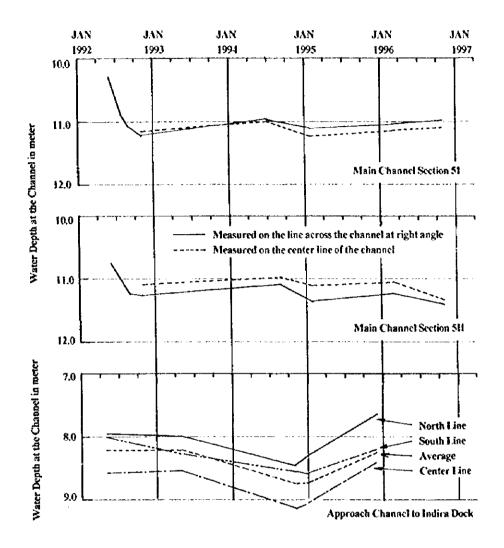
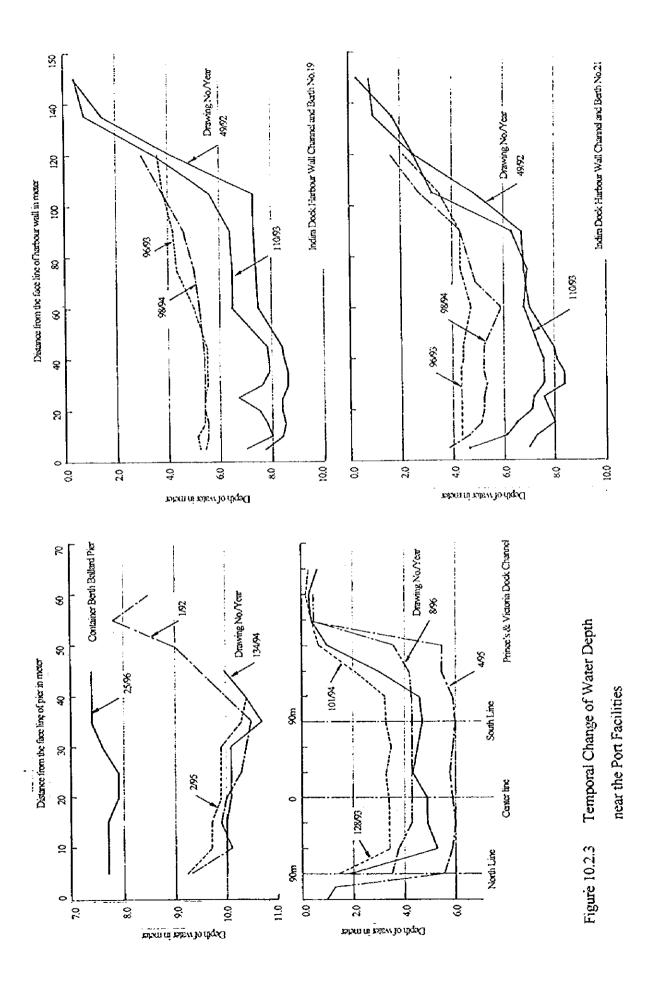


Figure 10.2.2 Temporal Change of Water Depth in the Channels (2)



# (2) Approximate Estimation of Rate of Siltation in case of Deepening Channels

Those navigation channels excavated in the muddy seabed areas must keep their water depth by the periodic maintenance dredging. As the volume of siltation may be directly influenced by differences in the water depth between the channel bed and the surrounding seabed, deepening the channel will result in increasing the extra volume of maintenance dredging.

The rate of siltation in any particular area depends upon various factors including the strength and direction of the current, effects of winds and waves, profiles of surrounding seabed, etc. Consequently, no precise calculation with respect to siltation is possible in the present state of knowledge. However, it was required to assess its future magnitude approximately for the purpose of evaluation of port development plans, particularly for the sake of estimating the cost of maintenance dredging.

In this study, an approximate estimation of rate of siltation was attempted on the assumption that the Bijker's theory could be applicable.

Analysis of this kind is intended for guidance only, since its accuracy is limited by the comparatively small amount of data upon which it is based and by the assumptions that have to be made in simplifying a very complex problem.

#### 1) A method applied to estimation of an approximate rate of siltation

When the current crosses the channel, the actual sedimentation, or vertical transport, is described approximately by the following formula, which is derived from Bijker's theory. The theoretical model of Bijker's equation is given in Figure 10.2.4. In this study a diffusion coefficient for the suspended material was assumed to be constant at any places in the vertical direction.

$$S_v = w \cdot C_b (1 - h_1/h_2)$$

in which  $S_v$ = vertical transport expressed in  $m^2/s$  per unit of bed surface, w = fall velocity of the sediment in still water,  $C_b$ = concentration at the bed,  $h_1$ = water depth at the surrounding seabed, and  $h_2$ = water depth at the channel.

The concentration at the bed will be described by:

$$C_b = S_b \, C_h / 6.34 \, V \, r \, \sqrt{g}$$
 
$$S_b = (B \, d_{50} \, V \, \sqrt{g} \, / C_h) \, \exp \left[ -0.27 \, \Delta \, d_{50} \, C_h^2 / \mu \, V^2 \, \left\{ \, 1 \pm (1/2) (\xi \, U_w / V)^2 \, \right\} \, \right]$$
 and

$$\xi = C_b \sqrt{f_w/(2g)}$$

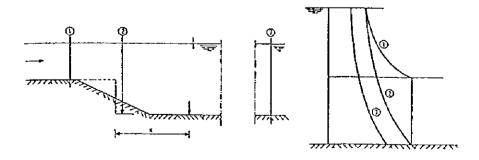
in which  $C_h$ = Chezy's resistance coefficient, V = mean value of the uniform flow, r = apparent bed roughness, B = coefficient,  $d_{50}$ = grain size of the bed material, g = acceleration of the earth gravity,  $\mu$  = ripple coefficient,  $\Delta$ = relative density of the bed material,  $U_n$ = amplitude of the horizontal orbital velocity at the bed, and  $f_n$ = friction coefficient as derived by Jonsson.

Assuming that all this vertical transport would produce sediment deposition within the channel area, an average volume of sediments  $\Delta$  h deposited during one unit of time  $\Delta$  t will be described by:

$$\Delta h = S_v \Delta t/B_o$$

with  $B_c =$ width of the channel.

As the water depth at the channel bed will increase due to the sediments deposited during one unit time, the calculation for the following unit time will be carried out for the adjusted water depth. In this manner, computation was carried out repeatedly for a significant period of time as  $\Delta t = 1$  hour. The strength and direction of the current necessary for the above computation were predicted by the harmonic analysis of the current data obtained through the field current observation carried out during the study and the local currents at the given sections were estimated by an interpolating method with the aid of current ellipse observed at each observation point. As an initial condition at time of this calculation, the annual rates of siltation analyzed in this study and given in Tables 10.2.5 and 10.2.6 were adopted.



- a. Mechanism of sedimentation
- b. Concentration verticals

Figure 10.2.4 Theoretical Model of Bijker's Equation

# 2) Approximate estimation of annual rate of siltation

Approximate estimation of annual rate of siltation was carried out for the following three representative sections of the channel as shown in Figure 10.2.5.

Section A: Main channel Section 4B

Section B : Main channel Section 51

Section C: Approach channel to Indira Dock

The channel is aligned across the flow of direction at Section C, but at Sections A and B the channels are aligned nearly parallel to the flow. In these sections, the flow component across the channel were adopted when computing the siltation. Table 10.2.7 gives an estimated annual rate of siltation in case of deepening the channels. On the same assumption, annual rates of siltation at the berth and basin in front of the proposed offshore container berths were estimated, of which result is given in Table 10.2.8.

In the present study, a volume of sediment was estimated on the assumption that all the vertical transport would produce sediment deposition within the channel area. This assumption may overestimate the calculated result much more than the actual deposition phenomenon, and then it may give a maximum value of deposition.

Rates of siltation estimated on this assumption are only for approximation and further basic study is necessary to discuss this problem

Table 10.2.7 Estimated Rates of Siltation in case of Deepening Channels

(Unit: meter/year) Channel Present rate Estimated average annual rate of siltation Section of siltation Dredged to -14.0 m Dredged to -12.0 m Dredged to -13.0 m ٨ 0.26 0.44 0.63 0.82 В 0.10 0.14 0.17 0.20 Dredged to -9.5 m Dredged to -10.5 m Dredged to -12.0 m C 0.46 1.00 1,27 1.62

Note: This estimation was made on an assumption that all the vertical transport would produce sediment deposition within the channel.

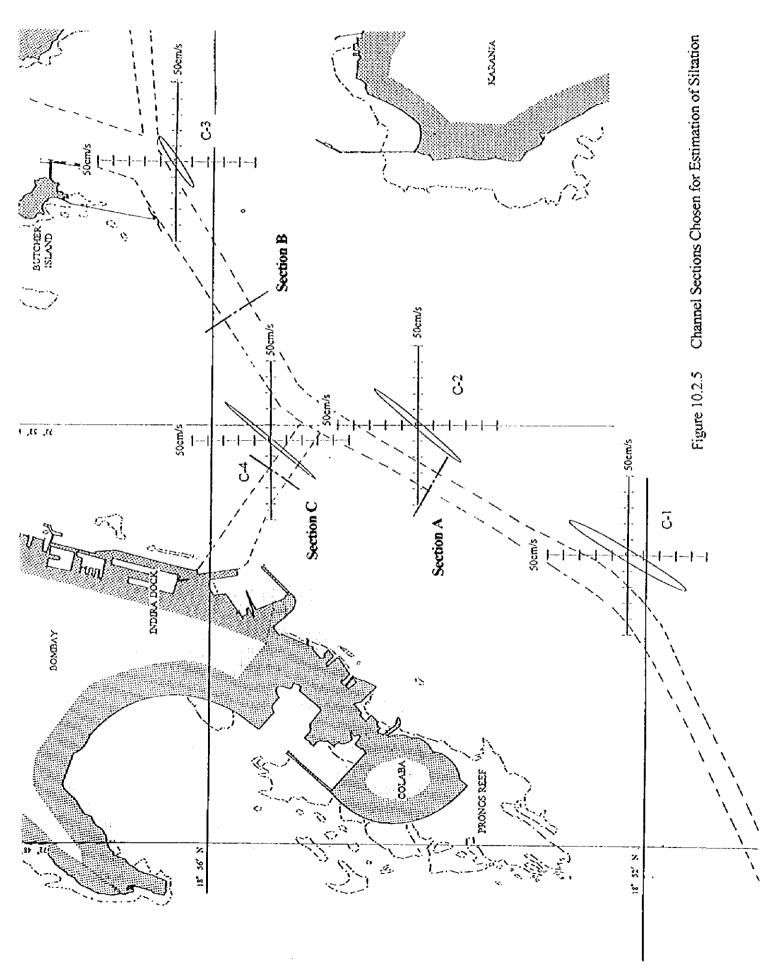


Table 10.2.8 Estimated Rate of Siltation at Berth and Basin

**	<del></del>		(Ui	nit: meter/year)			
Location	Dredged to						
	-9.5 m	-10.5 m	-12,0 m	-13,0 m			
Berth	•	-	0.75	0.84			
Basin	0.38	0.47	0.60	0.68			

Note: This estimation was carried out on the assumption that Bijker's Theory could be applicable even in this case.

# 3) Preliminary estimation of maintenance dredging volume

Using these estimated annual rates of siltation, an preliminary estimation of maintenance dredging volume was carried out for several cases of deepening the channel and the berthing area/basin. The result of calculation is given in Table 10.2.9 for Main Channel and Approach Channel to Indira Dock, and in Table 10.2.10 for the proposed offshore container berths and basin.

The amount of dredging volume estimated here is only for approximation.

Table 10.2.9 Preliminary Estimation of Maintenance Dredging Volume in Main Channel and Approach Channel to Indira Dock

	Dredging depth					
	-11.0 m	-12.0 m	-12.5 m			
Channel Section	Quantity	Quantity	Quantity			
	('000 m <sup>3</sup> /year)	('000 m³/year)	('000 m <sup>3</sup> /year)			
Main Harbour Channel	1,947	6,132	7,391			
Approach Channel to JNP	305	459	522			
		Dredging depth				
	-9.5 m	-11.0 m	-12.0m			
Channel Section	Quantity ('000 m <sup>3</sup> /year)	Quantity ('000 m³/year)	Quantity ('000 m <sup>3</sup> /year)			
Approach Channel to ID	1,143	1,542	1,819			

Note: 1) Main Harbour Channel includes the channels from Channel S-I to JWD.

- 2) The above dredging volume includes the extra dredging volumes both at the channel bed and the side slope of channel bank.
- 3) The side slope of channel bank is assumed to be formed to 1/30.

Table 10.2.10 Preliminary Estimation of Maintenance Dredging Volume at Proposed Offshore Berths and Basin

Location	Dredging Depth	Quantity	Dredging Depth	Quantity
	(m)	('000 m3/year)	(m)	('000 m3/year)
Basin	Berth = -12.0 m	370	Berth = -13.5m	500
A & B	Basin = -9.5 m		Basin = -11.0m	

Note: The above mentioned maintenance dredging volume includes the extra dredging volumes both at the channel bed and the site slope of channel bank.

# 10.2.3 Dredging Implementation

In planning dredging work, it is most important to select a suitable type of dredger by carefully investigating the kind of soil at the site to be dredged, because an optimum dredging method could reduce the construction period and every expense. The present study had carried out three numbers of boring test at the proposed project site. The following description on dredging implementation is a proposal based on the result of present soil exploration with the aid of present dredging programme being carried out by MBPT.

#### (1)Selection of Dredger

The following subjects must be discussed at the time of selecting the most proper dredger.

- Kind of soil.
- Volume of soil to be dredged and construction period.
- Meteorological, oceanographical and topographical conditions.
- Dredging depth and thickness of the soil to be dredged.
- Soil disposal area and method.
- Disturbance of bottom sediments.
- Kind of dredger and auxiliary work vessels.
- Possibility of employment of desired dredger.

Volume of soil to be dredged and construction period are very important factors to determine the size and capacity of dredger, and at time of discussion on this subject an economical evaluation with respect to the fleet of dredger becomes a governing factor. While,

meteorological, oceanographical and topographical conditions shall include the following items to be examined.

- Wave, wind, current, tide, etc.
- Workable days and hours.
- Dredging volume and maximum dredging depth.
- Working area, mooring place, and volume of traffic.
- Place of refuge for dredgers and other vessels, repairing facility, etc.
- Power equipment, water supply, bankering facility, etc.
- Anchoring forces.
- Accommodation of dredger and miscellaneous crafts.

Discussion about kind of dredger and auxiliary work vessels is necessary for selecting a suitable combination of size and capacity of each work vessel, and proper number of reserve hopper barges in order to minimize time lost due to waiting hopper barge operation.

Taking into considerations the above mentioned factors, both capital and maintenance dredging methods at the proposed project site were examined.

# 1) Capital Dredging

Channels: Judging from the seabed soil characteristics, a drag suction dredger is most suitable for deepening and widening of the navigation channels without disturbing other sailing ships. As far as local widening of the channel is concerned, a grab dredger with a large-sized grab bucket capacity is applicable.

Berth and Basin: Judging from the seabed soil characteristics at the proposed project site, which were investigated by the present study, dredging by a cutter suction dredger seems to be the most efficient method, but there exist no proper dredged material dumping grounds near the dredging area. (Dredged material dumping grounds are legally determined at the entrance of Bombay Harbour.) Then, a barge loading type pump dredger may be applicable, if she is available. Employment of a large-sized grab dredger will be a reasonable and practical method, because she is available for a wide range of seabed soils from soft to hard by changing the type of grab bucket from light to heavy.

#### 2) Maintenance Dredging

Channels: A drag suction dredger is the most suitable dredger for maintenance dredging in the navigation channels. She will be able to carry out the maintenance dredging with the same dredging efficiency as the present maintenance dredger does.

Beith and Basin: A drag suction dredger may be applied to the maintenance dredging at the area of berth and basin in front of and near the proposed offshore container berths, though very skilled operation of the dredger is required. It seems to be desirable to adopt a barge loading type pump dredger in this case, if available. Unfortunately, however, there exist few of this type of dredger available. Then, it will be reasonable and practical to select a hydraulic or grab dredging method for maintenance dredging at the area just in front of the jetty, while a drag suction dredging method for at the basin area.

# (2) Dredging Capacity

Generally, the dredging capacity in a given working period is described as follows.

$$V = Q \times p_1 \times e_1 \times p_2 \times e_2$$

where, V: Dredging volume in a given working period (m<sup>3</sup>)

Q: Dredging capacity per unit working hour (m<sup>3</sup>/hr)

p<sub>1</sub>: Daily working hours (hr/day)

e<sub>1</sub>: Working hours coefficient (=Net working hours/Daily working hours)

p<sub>2</sub>: Working days in a given period (day)

e<sub>2</sub>: Working days coefficient

(=Net working days in a working period/Total days in a working period)

As actual dredging works in the field are affected by various factors, a field operational coefficient(E) is usually considered, which is expressed as a ratio of the actual dredging capacity per actual working hours against the ideal dredging capacity per actual working hours.

Speaking of maintenance dredging at the area just in front of the proposed container berths, its dredging efficiency will affect the berth occupancy directly. The following is an estimation of days necessary for maintenance dredging at the area in case of adopting a grab dredge for this work.

The dredging capacity per unit hour may be described by the following equation.

$$Q = (60 \times 60 \times q \times K \times f/C_m) \times E \times \eta$$

where, Q: Dredging capacity per unit hour (m³/hr),

q: Grab bucket nominal capacity (m<sup>3</sup>),

K: Grab bucket excavation efficiency,

C<sub>w</sub>: Cycle time (sec),

f : Dredged material conversion rate,

E: Field operational coefficient, and

 $\eta$ : Actual working hours coefficient.

Assuming that  $q=16\text{m}^3$ , K=0.9, f=0.9,  $C_m=180\text{sec.}$ , E=0.9, and  $\eta=0.85$ , Q will be estimated at 198 m<sup>3</sup>/hr. Taking 17.5hrs/day for  $p_ie_i$ , the dredging capacity per unit day will be estimated at 3,470 m<sup>3</sup>/day.

Assuming that the estimated maintenance dredging volume at the berthing area may be 10 % of the total volume estimated in Table 10.2.10, or 50,000m<sup>3</sup> for berth depth of -13.5m, the net days necessary for dredging this volume will be calculated at about 15 days.

# (3) Environmental Countermeasures During Dredging

Drag suction dredger: Generally, a drag suction dredger performs overflow dredging, that is, muddy water overflows through the weir of her hopper during dredging in order to increase loading of dredged soils in the hopper. This overflow of muddy mixture, however, causes diffusion of turbidity over the dredging area widely. The most simple and reliable method to prevent such disadvantage is to stop loading of the dredged mixture in the hopper at the overflow level of the hopper. The more active preventive method for this purpose is to improve the mechanism of overflow trough and separate air bubbles from the overflow mixture. This system is called "Anti-Turbidity Overflow System" and employed in Japanese drag suction dredgers.

Grab dredger: It is difficult to prevent turbidity during grab dredging. But these days in order to answer the social requirements for environmental preservation, in some work sites, a flexible curtain type turbidity diffusion protector is provided around the excavation area, particularly in front of the bow of the grab dredger. Such kind of protector installed from the water surface level to near the seabed may be effective for reduction of diffusion of turbidity.

At the time of designing the protector, tidal current at the site, maintenance of the protector and anchoring system, and additional time required for shifting the protector in accordance with movement of dredging area shall be considered.

(4) Environmental Countermeasures at the time of Land Reclamation of Victoria Dock

Soil quantity required for land reclamation of Victoria Dock is estimated approx. 1.3 million cu. meters. In case of reclamation with soft bottom materials dredged by pump, the reasonable spillage treatment method suitable for the effluent and environmental conditions must be adopted. It may be one of the effective ways to promote settling of suspended solids by providing baffle walls in the reclamation pond. Land reclamation at Victoria Dock, however, such hydraulic transportation of the filling-in materials is not desirable and economical from a viewpoint of spillage treatment.

At the first stage of the land reclamation works, the filling-in soils will be carried by hopper barges and dumped directly into the Dock basin, as the barges can enter the Dock through the existing Dock gate. After construction of closing structure at the place of existing Dock gate, filling-in materials will be unloaded through the Victoria Dock Harbour Walls and conveyed by bulldozers. The following countermeasures shall be considered when designing the reclamation method.

- a) During the period of dumping soils by hopper barges, a line of movable flexible curtain type turbidity diffusion protector shall be installed around the entrance of the Dock gate.
- b) At the final stage of dumping soils, hopper barges with shallow water depth shall be selected to promote reclamation works.
- e) When the water depth becomes too shallow to dump the soil directly, the existing dock gate shall be closed with a suitable structure. After construction of the walls there, one waste way shall be provided at a seaside corner of the Dock.
- d) Lower the water level in the Dock as low as possible in order to reduce the volume of spillage to be treated.
- e) To reclaim the Dock basin from seaside toward land side in order to secure enough distance to an outlet gate.
- f) To provide a flexible curtain type turbidity diffusion protector around the outlet gate.