社会開発調査部報告書

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

NO. 52

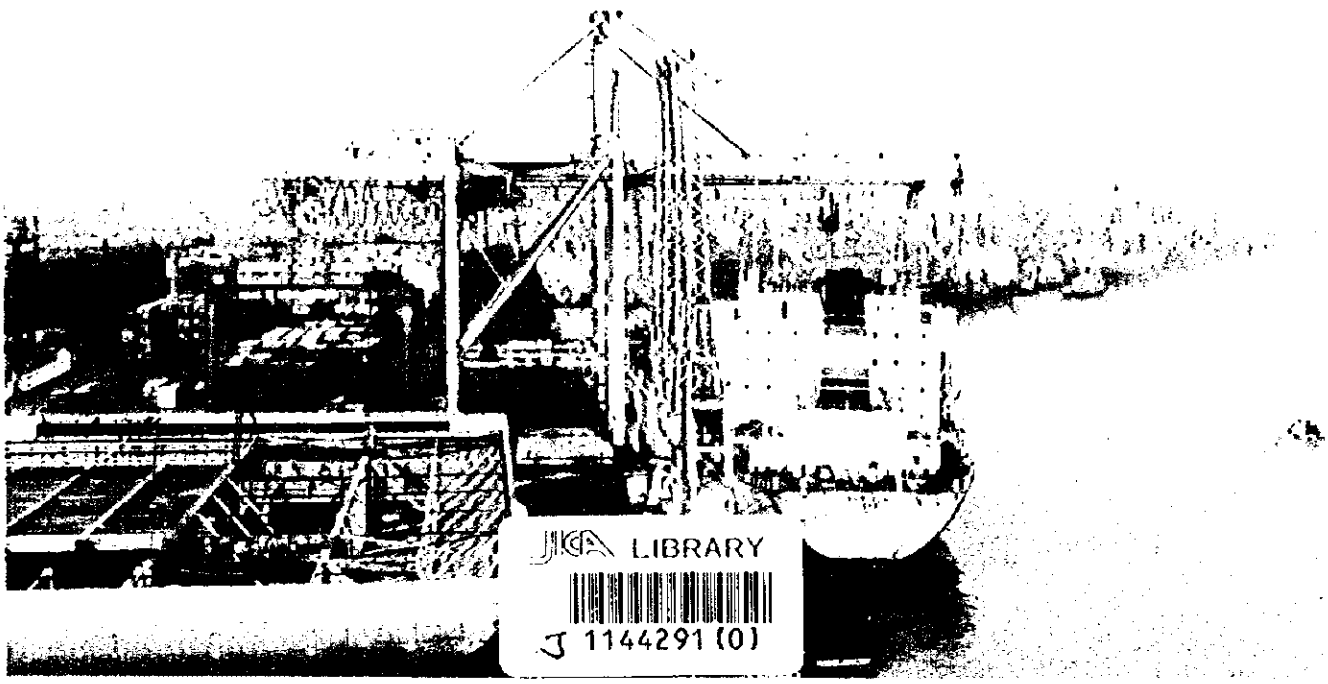
FINAL REPORT

THE STUDY ON DEVELOPMENT OF THE PORT OF MUMBAI IN INDIA

(VOLUME II)

PART 2 MASTER PLAN

PART 3 SHORT-TERM PLAN



MARCH 1998

THE OVERSEAS COASTAL AREA DEVELOPMENT INSTITUTE OF JAPAN (OCDI)

JAPAN PORT CONSULTANTS, LTD. (JPC)

The following foreign exchange rates are applied in this study:
US$ 1.00 = Indian Rs. 35.10 = ¥113.8 (as of May, 1997)

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

FINAL REPORT

THE STUDY ON DEVELOPMENT OF THE PORT OF MUMBAI IN INDIA

(VOLUME II)

PART 2 MASTER PLAN

PART 3 SHORT-TERM PLAN

MARCH 1998

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

CONTENTS OF THE DRAFT FINAL REPORT (Volume 2)

ABBREVIATIONS

Part 2 MASTER PLAN

Chapter IX Demand Forecast

Chapter X Potential and Constraints of the Future Development

Chapter XI Functional Allotment of MBP and JNP

Chapter XII Master Plan for MBP

Chapter XIII Design and Cost Estimation

Chapter XIV Preliminary Economic Analysis

Chapter XX Economic Analysis

Chapter XXI Financial Analysis

Chapter XXII Improvement Plan of Management and Operation System for the Short-term Plan

List of Tables (Volume 2)

Chapter IX

Chapter X

Chapter XI

Chapter XIII

Chapter XVII

Chapter XVIII

Chapter XIX

Chapter XX

Chapter XXI

List of Figures (Volume 2)

Chapter IX

Chapter X

Chapter XI

Chapter XII

Chapter XV

Chapter XVII

Chapter XVIII

Chapter XX

Chapter XXI

Chapter XXIII

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	—	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 Annual Growth Rate	2,560,950	5,597,831 6.2%	10,507,898 6.5%
GDP(Agriculture) Annual Growth Rate	785,900	1,392,769 4.5%	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

(Import)

(Unit: '000tons)

Commodity	1986-87	1987-88	1988-89	1989-90	1990-91	1991-92	1992-93	1993-94	1994-95	1995-96
Containerizable Cargo										
Agricultural, Fishery & Forest Products	100	100	100	44	103	92	144	143	193	298
Paper and Paper Product	348	330	340	473	516	425	573	751	769	899
Light Industry Products	2,096	2,390	1,760	1,850	1,869	1,617	1,888	2,341	3,373	3,550
Containerizable Cargo Sub-total	**2,544**	**2,820**	**2,200**	**2,367**	**2,492**	**2,134**	**2,604**	**3,235**	**4,335**	**4,747**
Statistically mixed cargo in containerization										
Agricultural, Fishery & Forest Products	1,338	1,510	1,360	717	918	405	1,156	938	2,483	1,181
Wood Pulp	158	130	150	110	208	101	141	224	151	170
Fertilizers and their Raw Materials	1,328	1,130	1,410	1,424	2,034	1,936	1,660	1,777	960	2,733
Iron and Steel Material	973	1,000	1,380	1,200	1,152	858	1,062	1,250	1,951	1,871
Scrap and Dross	871	750	760	820	1,028	481	831	385	182	173
Motor Vehicles and Miscellaneous sub total	226	270	310	0	287	227	261	85	55	49
Statistically mixed cargo in containerization Sub Total	**4,894**	**4,790**	**5,370**	**4,271**	**5,627**	**4,008**	**5,111**	**4,659**	**5,782**	**6,177**
Non-Containerizable Cargo	**185**	**260**	**280**	**270**	**250**	**220**	**164**	**24**	**32**	**89**
Petroleum										
POL(crude)	3,559	4,728	3,980	4,706	5,463	5,531	7,278	8,891	4,918	4,554
POL(products)	1,176	965	1,749	2,157	1,532	1,661	1,628	2,089	2,982	4,815
Petroleum Sub-total	**4,735**	**5,693**	**5,729**	**6,863**	**6,995**	**7,192**	**8,906**	**10,980**	**7,900**	**9,369**
Total	**12,358**	**13,563**	**13,579**	**13,771**	**15,364**	**13,554**	**16,785**	**18,898**	**18,049**	**20,382**

(Source: Administration report of MBPT and JNPT)

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)

(Unit: '000tons)

Year / Commodity	1986-87	1987-88	1988-89	1989-90	1990-91	1991-92	1992-93	1993-94	1994-95	1995-96
Containerizable Cargo										
Agricultural, Fishery & Forest Products	427	290	310	597	1,345	871	556	646	528	1,694
Light Industry Products	945	1,340	1,370	1,414	1,434	1,482	1,519	2,335	3,412	3,061
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 mixed cargo in containerization										
Agricultural Products	671	480	600	510	440	594	525	1,026	839	1,394
Metal and Metal Products	104	180	160	194	152	199	213	285	172	276
Mixture Sub-total	**775**	**660**	**760**	**704**	**592**	**793**	**738**	**1,311**	**1,011**	**1,670**
Petroleum										
POL(crude)	8,437	9,629	10,442	8,703	9,917	9,981	8,161	6,940	8,975	9,994
POL(products)	3,143	4,061	2,892	3,103	2,756	2,339	3,540	2,730	1,955	1,997
Petroleum Sub-total	**11,580**	**13,690**	**13,334**	**11,806**	**12,673**	**12,320**	**11,701**	**9,670**	**10,930**	**11,991**
Total	**13,727**	**15,980**	**15,774**	**14,521**	**16,044**	**15,466**	**14,513**	**13,962**	**15,881**	**18,416**

(Source: Administration report of MBPT)

Non-Containerizable cargo										
Chemical products (liquid)		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,

Y	:	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

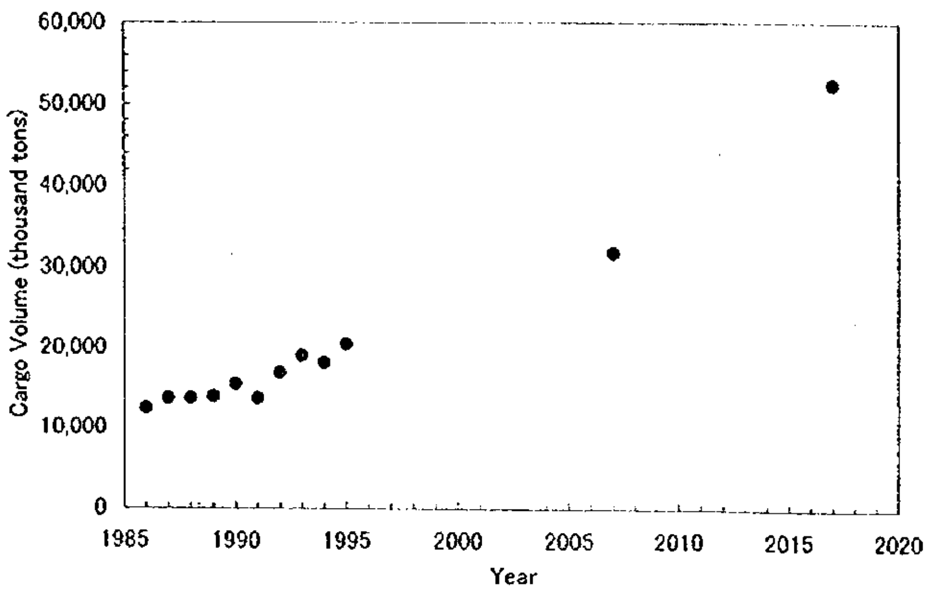


Figure 9.3.1 Import Cargo Volume of Macro Forecast

(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.

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

where, Y : Total export cargo volume

Y_0 : Existing volume in 1995 (= 18,416 thousand tons)

G_r : 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

(Unit : thousand tons)

	1995	2007	2017
Export Cargo Volume	18,416	23,356	28,751

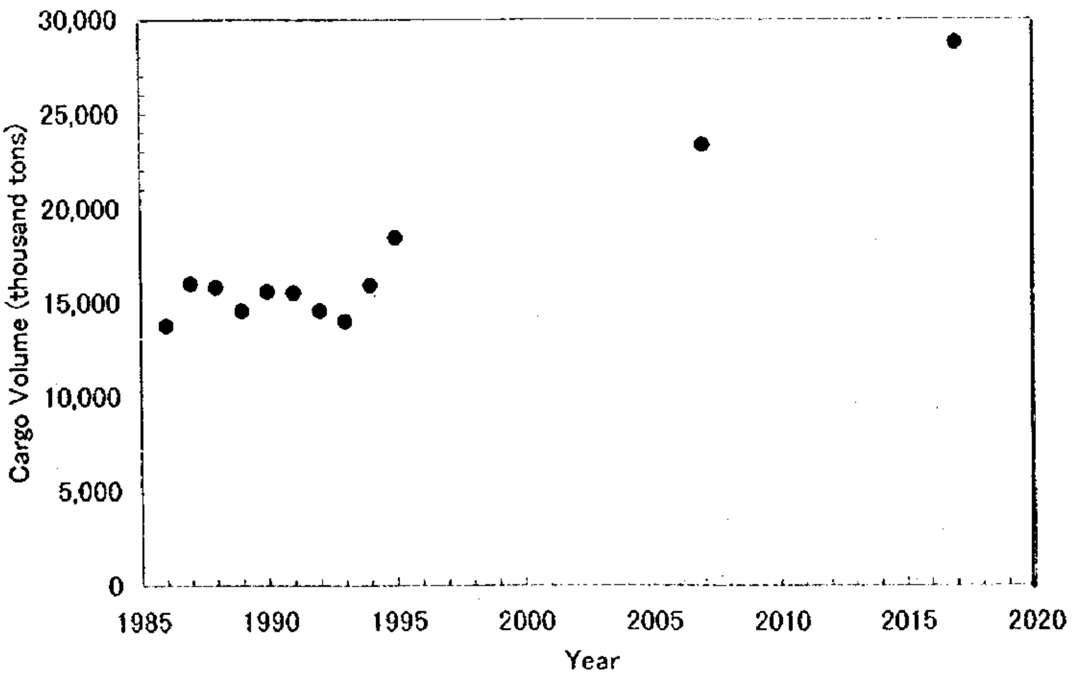


Figure 9.3.2 Export Cargo volume of Macro Forecast

(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)

(Import) (Unit: thousand tons)

Commodity \ Year	1995-96 MBP	1995-96 JNP	2007-08 MBP	2007-08 JNP	2017-18 MBP	2017-18 JNP
Containerizable Cargo						
Agricultural,Fishery & Forest Products *	192	106	553	304	1,382	761
Paper and Paper Product *	580	319	2,072	1,142	6,266	3,451
Light Industry Products *	2,289	1,261	4,929	2,715	9,606	5,291
Containerizable Subtotal	3,061	1,686	7,554	4,161	17,254	9,503
Containerizable Total	4,747		11,715		26,757	
Statistically Mixed cargo in Containerization						
Agricultural,Fishery & Forest Products	1,181	0	2,003	0	3,110	0
Wood Pulp	170	0	215	0	252	0
Fertilizers and its row material *	838	1,895	1,591	3,044	2,471	4,728
Iron and Steel Material	1,871	0	2,608	0	3,419	0
Scrap and Dross	173	0	178	0	178	0
Motor Vehicles and Miscellaneous	49	0	310	0	310	0
Mixture Cargo Sub-total	4,282	1,895	6,905	3,044	9,740	4,728
Mixture Cargo Total	6,177		9,949		14,468	
Non-containerizable Cargo	89	0	280	0	280	0
Non-containerizable Cargo Sub-total	89	0	280	0	280	0
Non-containerizable Cargo Total	89		280		280	
Petroleum (POL)						
Crude oil	4,554	0	8,891	0	8,891	0
Refined petroleum products	4,815	0	7,375	0	15,192	0
Petroleum Sub-total	9,369	0	16,266	0	24,083	0
Petroleum Total	9,369		16,266		24,083	
Total	16,801	3,581	31,005	7,205	51,357	14,231
Grand Total	20,382		38,210		65,588	

(Source: Administration report of MBPTand JNPT)

	1995-96 MBP	1995-96 JNP	2007-08 MBP	2007-08 JNP	2017-18 MBP	2017-18 JNP
Non-containerizable						
Chemical products (liquid)	94	0	200	0	386	0
Non-containerizable Sub-total	94	0	200	0	386	0
Non-containerizable Total	94		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: thousand tons)

Commodity \ Year	1995-96 MBP	1995-96 JNP	2007-08 MBP	2007-08 JNP	2017-18 MBP	2017-18 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	4,755		17,108		41,484	
Statistically Mixed Cargo in Containerization						
Agricultural Products	1,394	0	1,942	0	2,661	0
Metal and Metal Products	276	0	285	0	285	0
Mixture Cargo Sub-total	1,670	0	2,227	0	2,946	0
Mixture Cargo Total	1,670		2,227		2,946	
Petroleum (POL)						
Crude oil	9,994	0	10,000	0	10,000	0
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	11,601		12,413		12,413	
Total	15,642	2,384	23,171	8,577	36,044	20,799
Grand Total	18,026		31,748		56,843	

(Source: Administration report of MBPT)

Commodity \ Year	1995-96 MBP	1995-96 JNP	2007-08 MBP	2007-08 JNP	2017-18 MBP	2017-18 JNP
Non-containerizable Sub-total						
Chemical products (liquid)	5	0	7	0	7	0
Non-containerizable Sub-total	5	0	7	0	7	0
	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 refering 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 Micro method	20,382	31,698 38,210	52,477 65,627
Export	Macro method Micro method	18,416	23,356 31,748	28,751 56,843
Total	Macro method Micro method	38,798	55,054 69,958	81,228 122,470

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.

$$\mathbf{P = 1 / \{ 1 + C^{(t-t0)} \}}$$

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

C : Parameter prescribing curvature

t : Year

t_0 : 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	
	Containerized 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		2017-18	
Import (unloaded) Statistically Mixed Cargo in Containerization	thousand tons	%	thousand tons	%
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**		**4,410**	

(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 Gujarat

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.

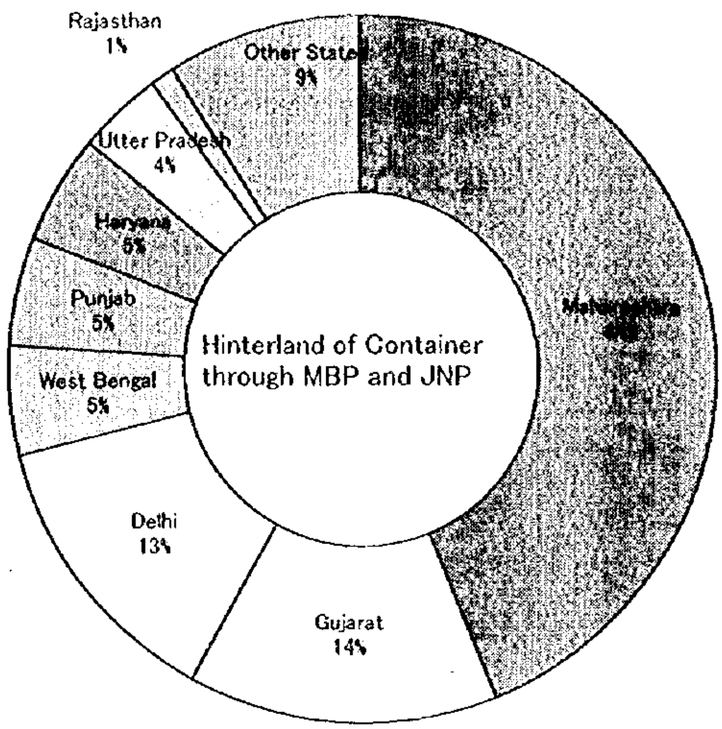


Figure 9.5.1 Hinterland of Container Cargoes through MBP

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.

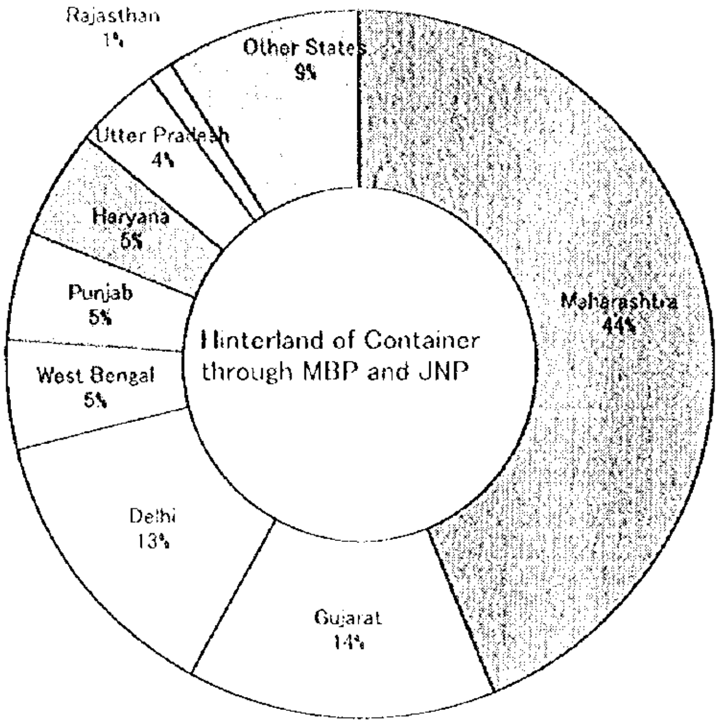


Figure 9.5.1 Hinterland of Container Cargoes through MBP

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.

handled in MBP. The resulting figures are shown in Table 9.5.6.

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

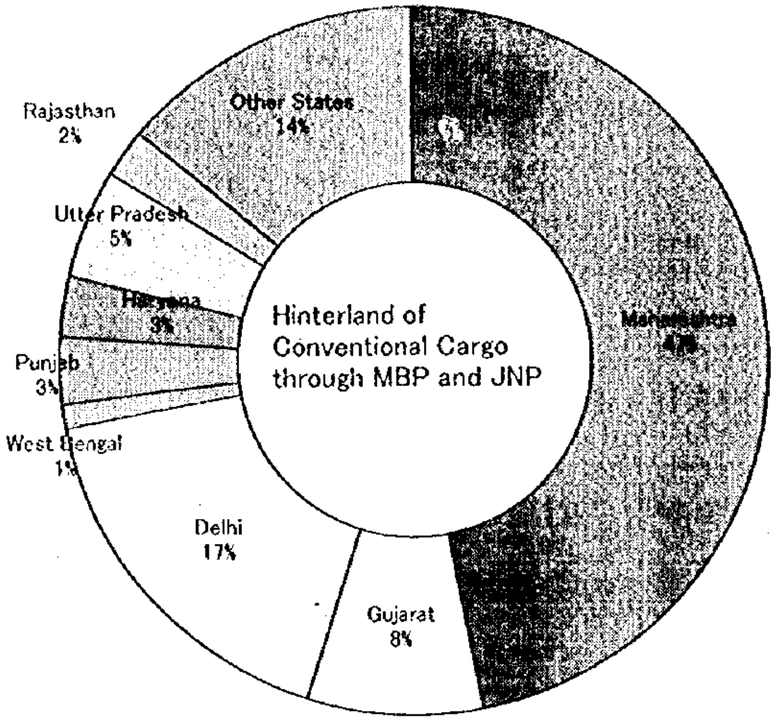


Figure 9.5.2 Hinterland of Conventional Cargoes through MBP

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%

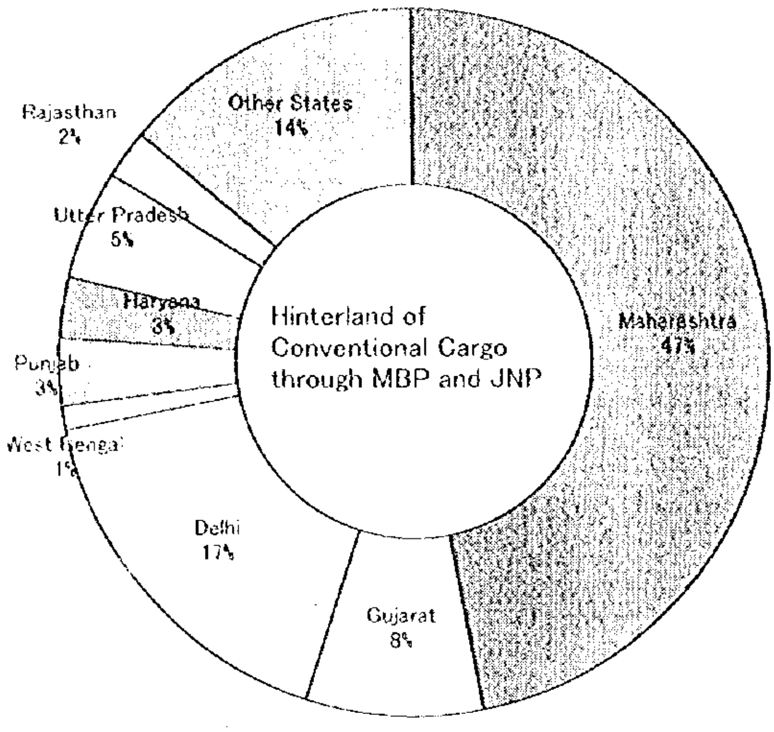


Figure 9.5.2 Hinterland of Conventional Cargoes through MBP

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						
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 refering to the present share.

Table 9.5.12 Forecast Volume by Package Type of MBP and JNP

Packing Type		2007-08		2017-18	
		MBP	JNP	MBP	JNP
Container					(Unit: thousand 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 cargo					(Unit: tons)
[Import]					
	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
Import 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
Export total		1,602,042	0	1,836,863	0
Conventional cargo 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 Sub-total		**1,277,074**	**3,043,885**	**1,854,470**	**4,727,238**
Dry Bulk Cargo Total		**4,320,959**		**6,581,708**	
Liquid Bulk					(Unit: tons)
[Import]					
	Edible oil	805,303	0	1,250,658	0
	Crude oil	8,891,000	0	8,891,000	0
	POL	7,375,000	0	15,192,000	0
	Chemical liquid	200,000	0	386,000	0
Import 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
Export total		12,477,034	0	12,500,742	0
Liquid Bulk total		**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.

$$N_P = N_O \times (1 + E_L \times G_T)^{(t-1996)}$$

where, N_P : Number of passenger

N_O: Number of Passenger in 1996-97and 2000-01

E_L : 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 / Item	Mora	Rewas	Mondwa	Elephanta	JNP	Vashi
N_O : 1996 2000 (thousand)	1,089.8 1,137.7	860.4 867.9	253.3 255.5	746.1 779.0	657.0 685.9	117.9 151.3
E_L	0.6726	0.6726	0.6726	0.6726	0.6726	0.6726
G_r 2000 (%) 2010	1.61 2.27	0.32 4.94	0.32 4.9	1.61 2.27	1.61 2.27	9.86 5.12
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

Channel Section	Present Channel				Dredged to -12.0 m			Dredged to -13.0 m		
	Length	Width		Depth	Length	Width	Dredging Volume	Length	Width	Dredging Volume
		West	East							
	(m)	(m)	(m)	(m)	(m)	(m)	('000 m³)	(m)	(m)	('000 m³)
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
5I	2,440	500	500	11.0	2,440	500	2,086	2,440	500	3,660
5II	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

Channel Section	Present Channel				Dredged to -12.0 m			Dredged to -13.0 m		
	Length	Width		Depth	Length	Width	Dredging volume	Length	Width	Dredging volume
		West	East							
	(m)	(m)	(m)	(m)	(m)	(m)	('000 m^3)	(m)	(m)	('000 m^3)
1	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		600	500	
Total	5,800	-	-	-	5,800	-	3,118	5,800	-	6,540

Note: Schematic drawing of Main Channel of Bombay Harbour

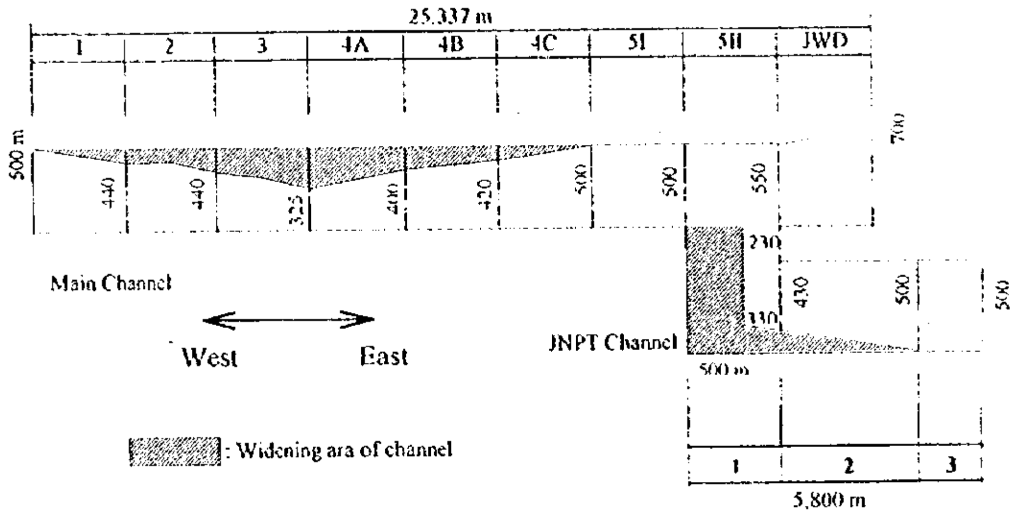


Table 10.2.3 Channel Dimensions and Estimated Capital Dredging Volume in ID Channel

Present Channel			Dredged to -9.5 m	Dredged to -10.5 m	Dredged to -12.0 m	Dredged to -13.0 m
Length (m)	Width (m)	Depth (m)	Dredging Volume ('000 m^3)	Dredging Volume ('000 m^3)	Dredging Volume ('000 m^3)	Dredging Volume ('000 m^3)
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 (m)	Dredging Volume ('000 m^3)	Dredged to (m)	Dredging Volume ('000 m^3)
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 Channel Section	On the line across the channel at right angle		On the center line of the channel		Annual Rate of Siltation Estimated (Present study)
	Range	Mean	Range	Mean	
1	N.A	N.A	N.A	N.A	N.A
2	N.A	N.A	N.A	N.A	N.A
3	0.06 to 0.43	0.22	0.14 to 0.49	0.27	0.25
4A	0.09 to 0.59	0.28	0 to 0.45	0.26	
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	
5I	0.07 to 0.28	0.10	0 to 0.19	0.11	0.10
5II	0 to 0.25	0.11	0.04 to 0.10	0.07	

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.S3, 270.S3)
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 5I (81/92, 104/92, 114/92, 142/92, 92/94, 46/95, 48/96, 263-4.S)
Channel Section 5II (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

(Unit : meter/year)

Location and area	Annual Rate of Siltation Estimated (Present Study)		Annual Rate of Siltation (MBPT Criteria)
	Range	Mean	
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
(210/91, 1/92, 149/92, 1/93, 81/94, 134/94, 2/95, 143/95, 25/96)
I.D. Harbour Wall Berth (33/92, 49/92, 96/93, 110/93, 98/94, 121/94, 8/95, 19/95, 1/96, 15/96)
PD & VD Approach Channel (2/92, 107/93, 128/93, 85/94, 101/94, 4/95, 147/95, 8/96)
2) As for annual rate of siltation (MBPT Criteria), refer to Chapter 7.4.

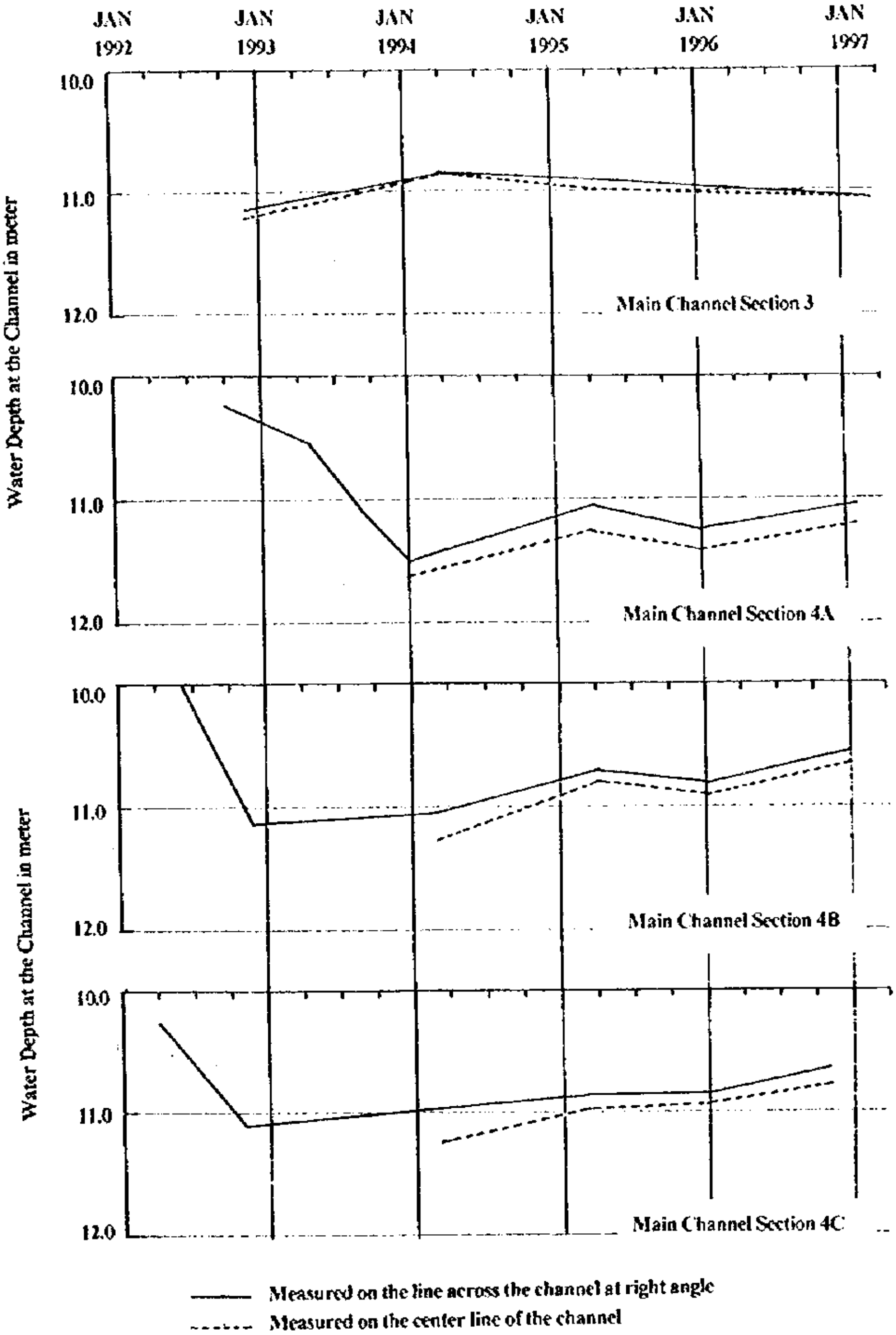


Figure 10.2.1 Temporal Change of Water Depth in the Channels (1)

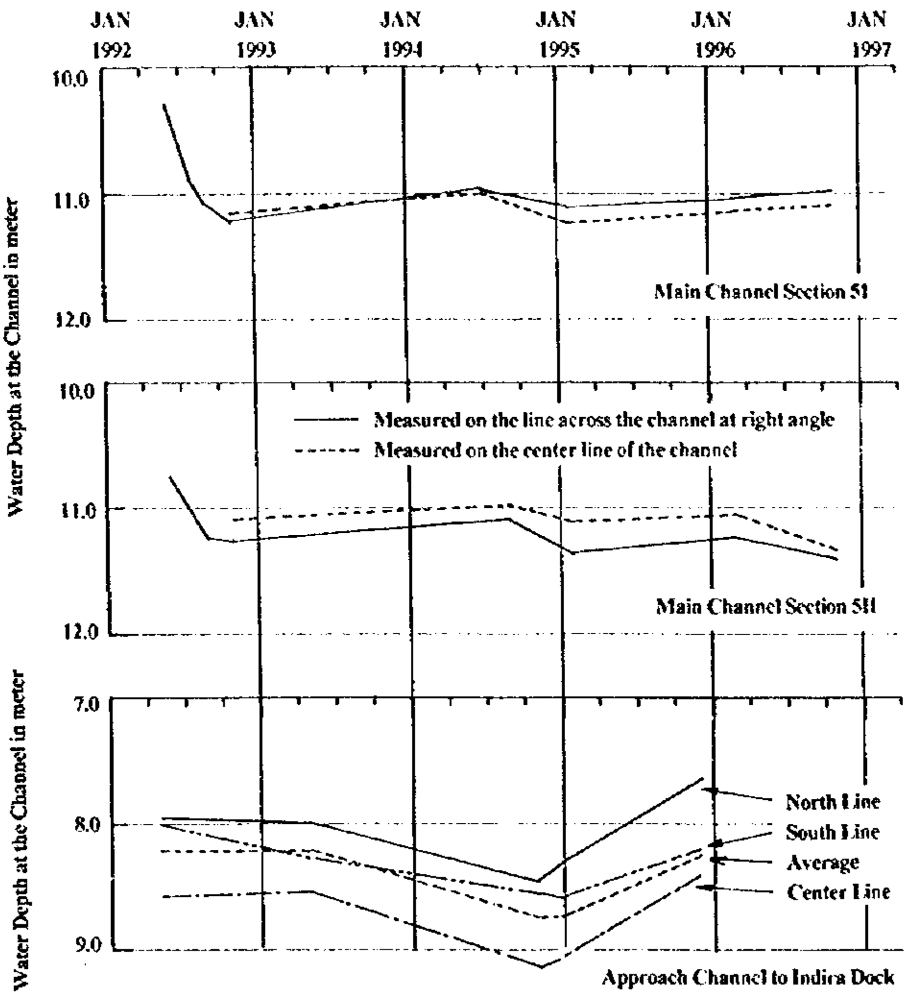
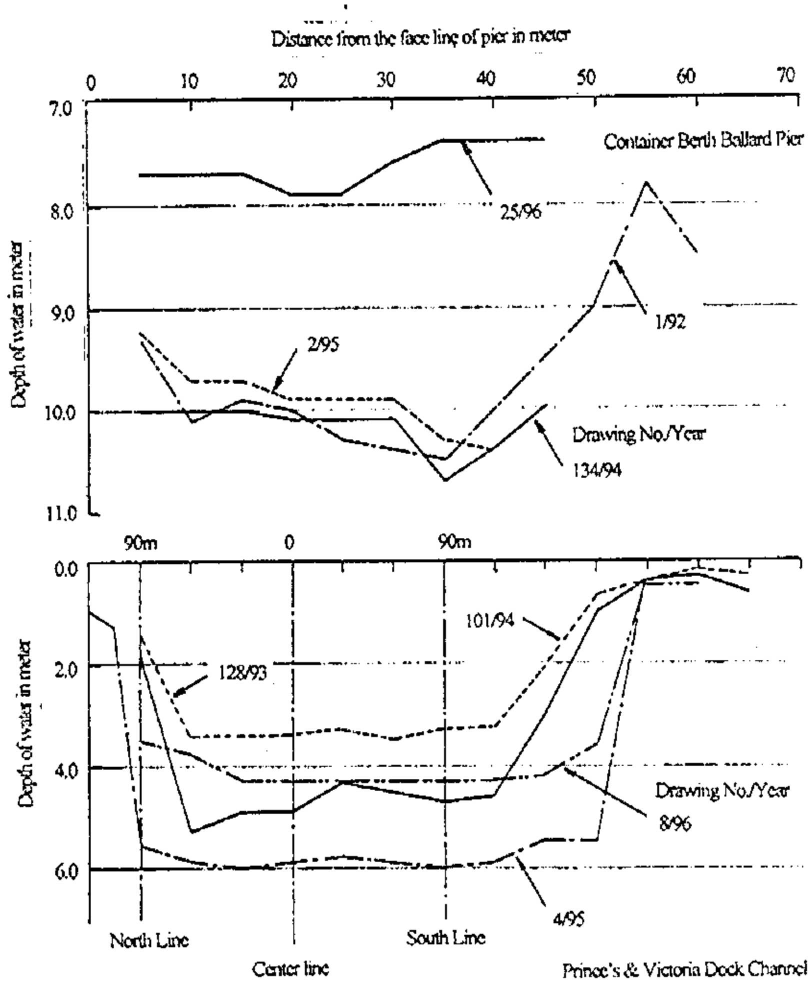


Figure 10.2.2 Temporal Change of Water Depth in the Channels (2)



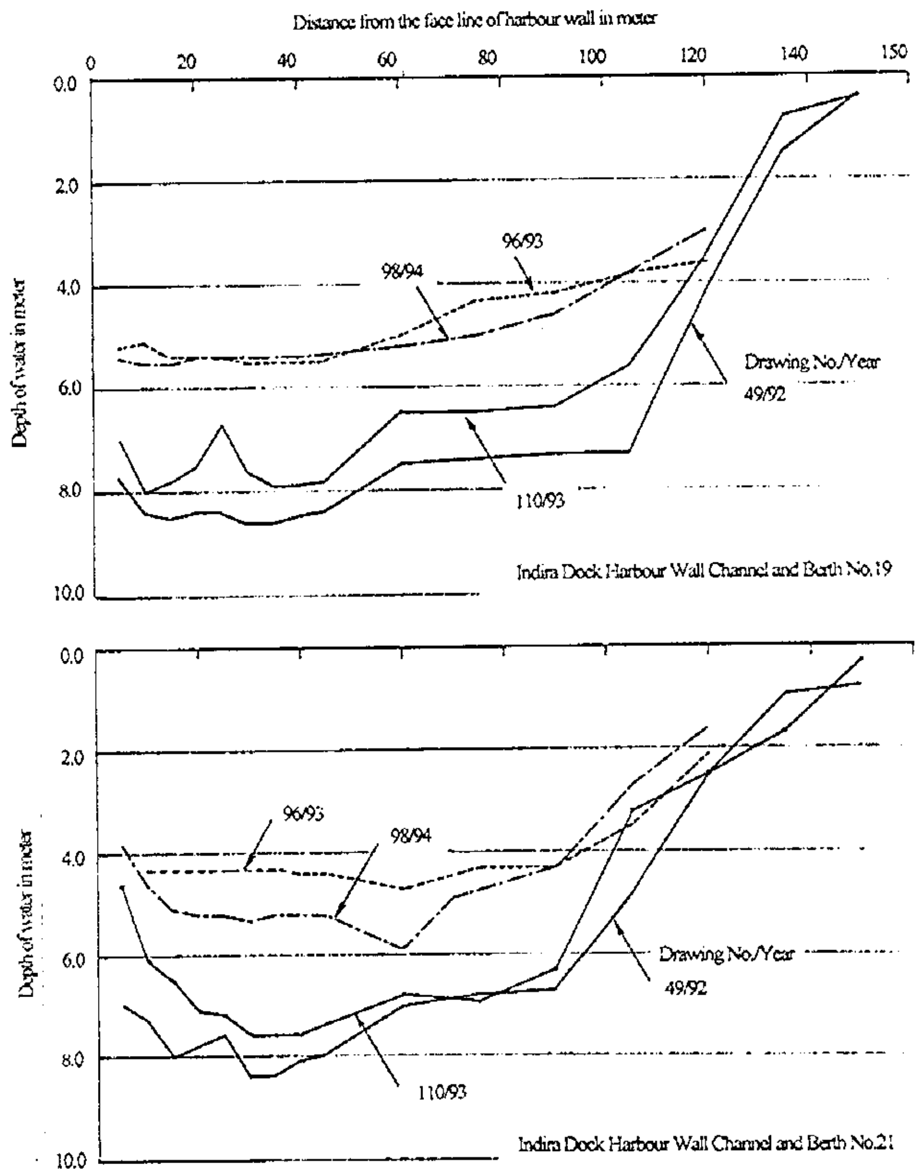


Figure 10.2.3 Temporal Change of Water Depth near the Port Facilities

(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:

$$C_b = S_b C_h / 6.34 V r \sqrt{g}$$

$$S_b = (B d_{50} V \sqrt{g} / C_h) \exp [-0.27 \Delta d_{50} C_h^2 / \mu V^2 \{ 1 + (1/2)(\xi U_w / V)^2 \}]$$

and

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

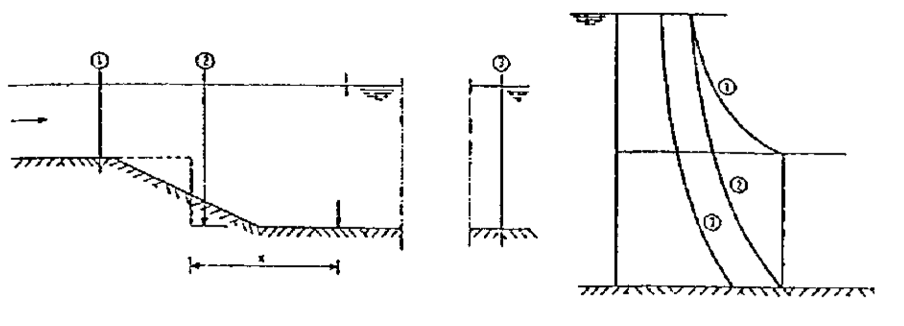
in which C_h= Chezy's resistance coefficient, V = mean value of the uniform flow, r = apparent bed roughness, B = coefficient, d_{50}= grain size of the bed material, g = acceleration of the earth gravity, μ = ripple coefficient, Δ= relative density of the bed material, U_w= amplitude of the horizontal orbital velocity at the bed, and f_w= 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 Δh deposited during one unit of time Δt will be described by :

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

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 Δt = 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 5I

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 Section	Present rate of siltation	Estimated average annual rate of siltation		
		Dredged to -12.0 m	Dredged to -13.0 m	Dredged to -14.0 m
A	0.26	0.44	0.63	0.82
B	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.

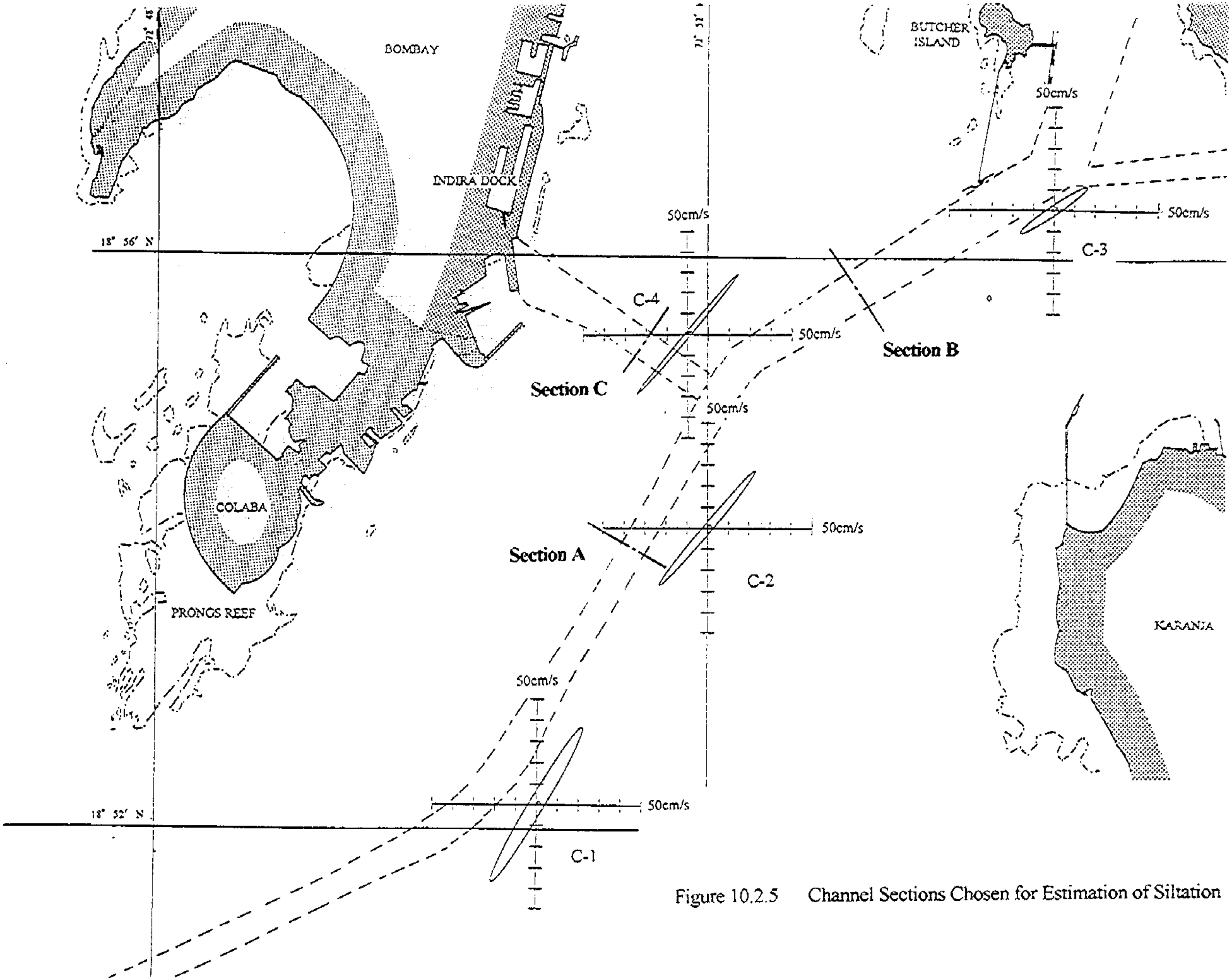


Figure 10.2.5 Channel Sections Chosen for Estimation of Siltation

Table 10.2.8 Estimated Rate of Siltation at Berth and Basin

(Unit : 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

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

Note : 1) Main Harbour Channel includes the channles from Channel S-1 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 (m)	Quantity ('000 m3/year)	Dredging Depth (m)	Quantity ('000 m3/year)
Basin A & B	Berth = -12.0 m Basin = -9.5 m	370	Berth = -13.5m Basin = -11.0m	500

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.

Berth 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^3)

Q : Dredging capacity per unit working hour (m^3/hr)

p_1 : Daily working hours (hr/day)

e_1 : Working hours coefficient (=Net working hours/Daily working hours)

p_2 : Working days in a given period (day)

e_2 : 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 (m^3/hr),

q : Grab bucket nominal capacity (m^3),

K : Grab bucket excavation efficiency,

C_m: Cycle time (sec),

f : Dredged material conversion rate,

E : Field operational coefficient, and

η : Actual working hours coefficient.

Assuming that $q=16m^3$, $K=0.9$, $f=0.9$, $C_m=180sec.$, $E=0.9$, and $\eta=0.85$, Q will be estimated at 198 m^3/hr. Taking 17.5hrs/day for p_1e_1, the dredging capacity per unit day will be estimated at 3,470 m^3/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^3 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.

c) 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.