REPORT

Development of Greenfield Vadhavan Port

Detailed Project Report

Client: Jawaharlal Nehru Port Authority

Reference: DI1452-DP-XX-RP-PM-0001

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Glossary

ADCP	Acoustic Doppler Current Profiler
AIS	Automatic Identification System
APFC	Automatic Power Factor Correction
AtoN	Aids to Navigation
BMCT	Bharat Mumbai Container Terminal
BOQ	Bill of Quantities
BS	British Standards
CAGR	Compound Annual Growth Rate
CAPEX	Capital Expenditure
CBM	Cement Bound Material
CBP	Concrete Block Paving
CBR	California Bearing Ratio
CCTV	Closed Circuit Television
CD	Chart Datum
CESS	Centre for Earth Science Studies
CFO	Chief Financial Officer
CFS	Container Freight Station
CIRIA	Construction Industry Research and Information Association
CLC	Construction Logistic Centre
CLI	Concrete Layer Innovation
CMFRI	Central Marine Fisheries Research Institute
CPHEEO	Central Public Health and Environment Engineering Organization
CPCB	Central Pollution Control Board
CRZ	Coastal Regulation Zone
CSD	Cutter Suction Dredger
CSIR	Council of Scientific and Industrial Research
CSS	Compact Substation
CT	Container Terminal
CWPRS	Central Water and Power Research Station
CY	Container Yard
DFC	Dedicated Freight Corridor
DFCC	Dedicated Freight Container Corridor
DMIC	Delhi Mumbai Industrial Corridor
DPR	Detail Project Report
DSS	Distribution Substation
DWT	Deadweight Tonnage
EAC	Environmental Appraisal Committee
EC	Environmental Clearance
ECDIS	Electronic Chart Display and Information System
ECH	Empty Containers Handlers

EDI	Electronic Data Interchange
EIA	Environmental Impact Assessment
EMC	Environmental Monitoring Cell
EMP	Environmental Management Plan
EOL	Engine on Load
EPC	Engineering Procurement Construction
eRMG	Electric Rail Mounted Gantry
eRTG	Electric Rubber Tired Gantry
EXIM	Export Import
FB	Fairway buoy
FGDS	Fire and Gas Detection System
FO	Fibre Optic
FRM	Fertilizer Raw Material
FSRU	Floating Storage Regasification Unit
FY	Fiscal Year
GDP	Gross Domestic Product
GIS	Gas Insulated Substation
GoM	Government of Maharashtra
GOS	Gate Operating System
GSB	Granular Subbase
GSI	Geological Survey of India
GST	Goods and Service Tax
GTA	General Terminal Area
HED	Harbour Engineering Department
HFO	Heavy Fuel Oil
HHWS	Highest High-Water Spring
Hs	Wave Height Significant
HV	High Voltage
HWL	High Water Line
HYSD	High Yield Strength Deformed
IALA	International Association of Marine Aids to Navigation and Lighthouse Authorities
IAPH	International Association for Ports and Harbours
IBC	Inter Box Connector
ICD	Inland Container Depot
IDC	Interest During Construction
IEC	International Electrotechnical Commission
IIT	Indian Institute of Technology
IMD	Indian Meteorological Department
IMZ	Inter Modal Zone
INR	Indian National Rupees
IRC	Indian Road Congress

IS	Indian Standards
ISC	Indian Sub-Continent
ISPS	International Ship and Port Facility Security
IT	Informational Technologies
ITV	Internal Transfer Vehicles
IVT	Intra Terminal Vehicle
JNPA	Jawaharlal Nehru Port Authority
KLD	Kilo Litres per Day
KSEB	Kerala State Electricity Board
KVA	Kilo Volt Ampere
kW	Kilo Watts
LCL	Less than Container Load
LLWS	Lowest Low Water Spring
LOA	Length Overall
LTR	L&T Ramboll Consulting Engineers Limited
LV	Low Voltage
MARPOL	Marine Pollution, the International Convention for the Prevention of Pollution from Ships
MbPA	Mumbai Port Authority
MHHW	Mean Highest High Water
MHLW	Mean Highest Low Water
MIDC	Maharashtra Industrial Development Corporation
MLD	Million Litres per Day
MLHW	Mean Lowest High Water
MLLW	Mean Lowest Low Water
MMB	Maharashtra Maritime Board
MoEF	Ministry of Environment & Forests
MSL	Mean Sea Level
MRSS	Main receiving Substation
MSS	Main Substation
MT	Million Tonnes
MTPA	Million Tons per Annum
MVA	Mega Volt Ampere
NBC	National Building Code
NCR	National Capital Region
NE	North East
NFPA	The National Fire Protection Association
NH	National Highway
NHO	National Hydrographic Office
NIO	National Institute of Oceanography
NW	North West
NOx	Nitrogen Oxide

O&C	Opportunities and Constraints
OPEX	Operational Estimates
PAGA	Public Address and General Alarm
PBX	Private Branch Exchange
PCC	Portland Cement Concrete
PCU	Passenger Car Equivalent
PIANC	Permanent International Association for Navigation and Congress
PM	Particulate Matter
POV	Personally Owned Vehicles
PPP	Public Private Partnership
PRECAP	Preliminary Capacity
PWD	Public Works Department
QC	Quay Crane
R&D	Receipt & Dispatch
R&R	Relocation & Rehabilitation
RCC	Reinforced Cement Concrete
RDT	Radio Data Transfer
REFCON	Reefer Control System
RFID	Radio Frequency Identification
RHDHV	Royal HaskoningDHV
RMGC	Rail Mounted Gantry Cranes
RMQC	Rail Mounted Quay Cranes
RPM	Radiation Portal Monitor
RS	Reach Stacker
RSS	Reefer Substations
CBSS	Building & Services Substation
RTG	Rubber Tired Gantry
SCADA	Supervisory Control and Data Acquisition
SEZ	Special Economic Zone
SF	Safety Factor
SOx	Sulphur Oxide
SPT	Standard Penetration Test
SPV	Special Purpose Vehicle
SS	Substation
SSC	Suspended Solids Concentration
SSW	South-South West
STP	Sewage Treatment Plant
SW	South West
TAPS	Tarapur Atomic Power Station
TEU	Twenty-foot Equivalent Unit
TGS	Twenty-foot Ground Slot
TOB	Terminal Operation Building

TOS	Terminal Operating System
TSHD	Trailing Suction Hopper Dredge
UHF	Ultra High Frequency
UPS	Uninterruptible Power Supply
USACE	United States Army Corps Engineers
USD	United States Dollar
USS	Utility Substation
UTM	Universal Transverse Mercator
VDU	Video Display Unit
VPPL	Vadhavan Port Projects Limited
VTMIS	Vessel Traffic Management Information System
VTMS	Vessel Traffic Management System
WCIP	West Coast India Pilot
WGS	World Geodetic System
XLPE	Cross-Linked Polyethylene

Executive Summary

Vadhavan Port

Executive Summary

1. Background

India has an approximately 7,500 km long peninsular coastline and is located close to major shipping routes linking East Asia, Europe and the Middle East. Presently, there are 12 Major Ports and 200 Non-Major ports in India. The 12 major ports carry about 54% of the total port traffic of the country. The share of non-major ports in cargo traffic has increased from 7% in 1990 to the current levels of 46%.

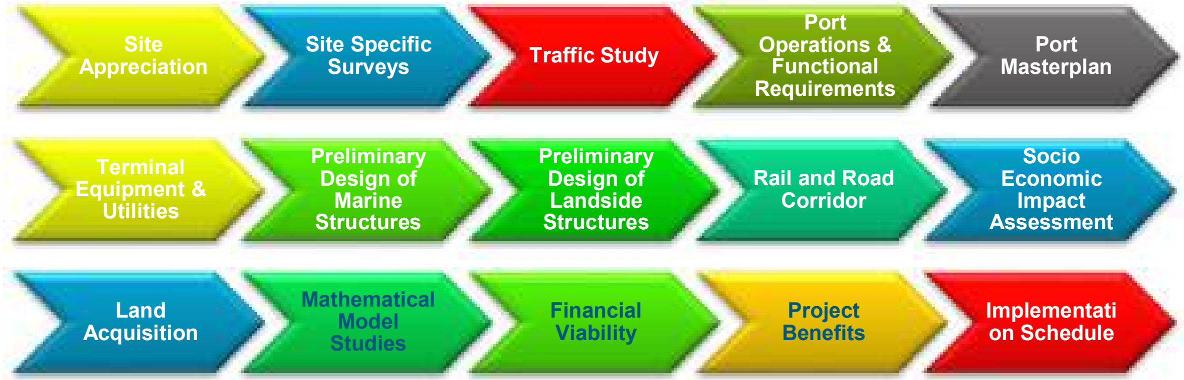
Maharashtra with a coastline of 720 km stretching along the Arabian sea has two major ports. Mumbai and JNPA which cater to the hinterland of Maharashtra, North Karnataka, Telangana, Gujarat and secondary hinterland of NCR, Punjab, Rajasthan and Uttar Pradesh. JNPA was developed as a satellite port of Mumbai port and has coped well in becoming the largest container port of the country. The development of Phase 2 of 4th container terminal is underway and after its full development there is little space for further expansion. Apart from that due to the presence of bed rock at or very close the existing bed level, JNPA cannot be deepened further economically to handle the future generation of mega container ships drawing draft of 16 m or more. There is a need for a deep draft port that will cater to the spill over traffic from JNPA port once its expanded capacity of 10.4 million TEUs is fully utilized.

As the projected demand for containers to go up, it is necessary to locate a new mega port site which can cater to increased requirement of capacity and could be developed to handle the future deep draft ships. Considering the above it has been decided to develop Vadhavan port as a satellite port for JNPA and for this purpose the present report has been prepared to assess its technical suitability and cost economics.

1.1. Project Vision

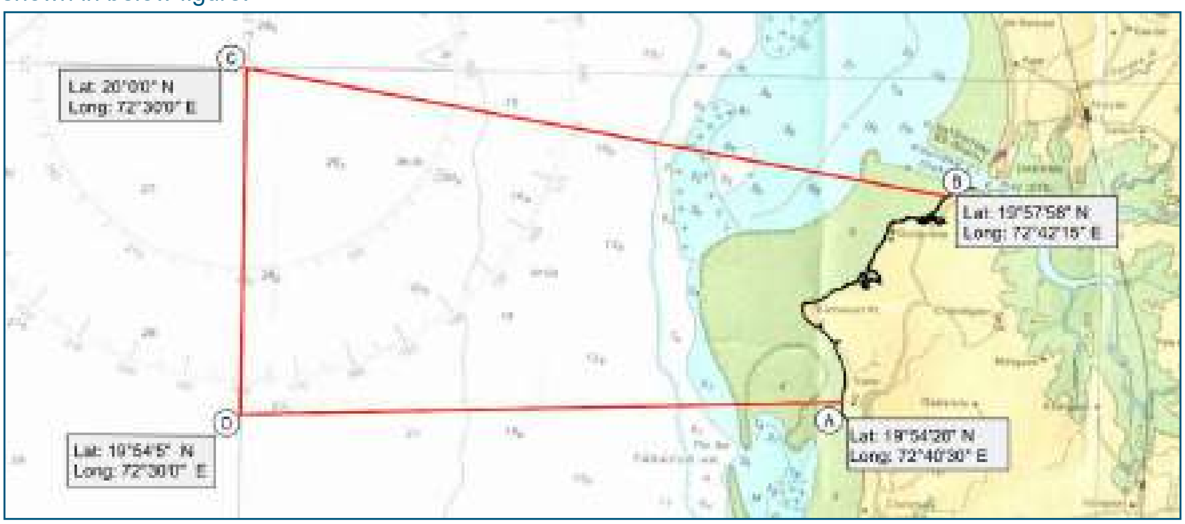
The vision of JNPA is to develop a state-of-art Port which shall be in lines with the International Port Terminal The port will be developed in two phases. The proposed port is to be developed on landlord model. In this model, basic infrastructure of the port necessitating upfront investment such as, breakwater, rail and road linkages, power, water lines and common infrastructure and services will be developed by the port/ SPV whereas all cargo handling infrastructure will be developed and operated by the agencies which are awarded the concessions.

Project related



2. Site Appreciation

Vadhavan Port is planned to be developed by Jawaharlal Nehru Port Authority (JNPA) and Maharashtra Maritime Board (MMB) to handle the additional traffic. Vadhavan is a Greenfield site located along the west coast of India, at the North tip of Maharashtra which is about 150 km north of JN Port. The port limits is as shown in below figure.



A natural water depth of around 20.0 m below CD is available at 10 km from Vadhavan point and 15 m contour is available at a distance of 6 km which will allow safe voyage and mooring for the new generation vessels. As deep-water depth is available from 6 to 10 km, new generation vessels calling for deep draft can be planned with minimal cost on dredging.

2.1. Metrological & Oceanographic Information

The metrological data has been extracted from previous/ historical studies for the project as well as from the West Coast of India Pilot (WCIP) climatological table applicable for the area and the project site. The average annual rainfall is 1163 mm with the total number of rainy days of 51 per year. The mean daily maximum temperature is 31°C and with 34°C the highest occurring in April. Mean daily minimum temperature is 24°C and with 18°C the lowest occurring in December.

Relative humidity is generally high and rises to about 85% during the monsoons in the month of August. Visibility is good throughout the year as the region has zero fog days. However, during rains and squalls, the visibility deteriorates. In general, the cyclones in the Arabian Sea from 1877 to 2012 that only 10 storms endangering the Mumbai coast have occurred in the above said period i.e., at a frequency of once in 12 years.

2.2. Oceanographic Information

This information has been extracted from previous/ historical studies for the project area and the project site.

Based on the ship observed offshore wind data from India Meteorological Department (IMD) wind speed is less than 10 m/s for 88% of the time. A maximum wind speed of 22.7 m/s has been reported, under normal conditions.

The ship observed wave data were collected from the India Meteorological Department (IMD). The waves are less than 1 m, 2 m and 3 m in height for 77%, 94% and 98% of the time respectively. Based on UKMO data, Wave heights were found to be less than 3 m for about 93% of the time.

Tide levels in the Vadhavan Port region as per the NHO Chart No. 210 Umargam to Satpati are summarised below.

Table 1 Tide levels in Vadhavan (NHO Chart No. 210)

Description	Tide Levels (m CD)
Mean High Water Spring	+4.7
Mean High Water Neap	+3.7
Mean Sea Level	+2.8
Mean Low Water Neap	+2.0
Mean Low Water Level Spring	+1.2

The currents in the region are mainly of monsoon origin and sets in south-westerly and north-easterly direction with a strength of about 2.5 knots (1.25 m/s). Vadhavan Port site is in Zone III of Indian Map of Seismic zones (IS-1893 Part-1 2002) which is a moderate risk seismic intensity zone. However, considering the Palghar earthquake sequence, whose largest magnitude was 4.5 till now and considering the project of national importance and vital installations, it was advised by CSIR - National Geophysical Research Institute to consider the seismic zone IV in design parameters.

2.3. Transport Linkages and External Infrastructure

Vadhavan is 12 km away from Vangaon Railway Station along Mumbai-Surat Western Rail Link. The port location is 33.4 km away from NH 8 and 22 Km away from Vadodara Expressway from Port.

2.4. Power & Water Supply

Two locations of the nearest 220 kV source from PGCIL/ Tarapur Borivalli station. The PGCIL/ Tarapur Borivalli power grid located at 14 km away from Vadhavan site. The water source identified for the port operations from Surya River about 22 km (approx.) from the proposed Vadhavan Port.

3. Site Specific Survey

Oceanographic data has been compiled previously in DPR prepared by Progen-Pentacle. Sea Geo Surveys Pvt. Ltd, Navi-Mumbai carried out the surveys and investigations. The outcome of the surveys has been summarised below. The surveys and investigations were carried out at Dahanu for the period from Jan. 2017 – Feb. 2017.

3.1. Oceanographic investigations

The wind speeds measured during this period varies from 0.2 knots to 4.0 knots with most of the wind blows from 0-45° N.

Wave climate in the area is dominated during SW monsoon period (June to September). The maximum significant wave height observed in the entire period is 1.19 m and the minimum of 0.14 m. Currents are significant in the project area.

The current speeds in general are observed within the range of 0.00 knots to 2.60 knots with the dominant speeds observed in the range of 0.20 knots to 1.60 knots.

Site specific tide measurements were carried out for the proposed development. The observed tidal range was about 3.5 m during spring tide and 1.7 m during neap tide.

3.2. Bathymetry Survey

Bathy 500 dual frequency single beam echo sounder was deployed for the collection of bathymetry data. The bathymetric survey covered the proposed port limit with an area of 169 sq.km extending 18.4 km from the shore into the sea and about 7 km along the shore. Water depths within survey area range between a minimum of 0.0 m recorded in the Eastern end and maximum of 25.3 m at North West corner of the survey area. Rock outcrops appear in some places as high as 3 to 4 m above the adjoining seabed levels in the area. The '0' m contour is about 2.1 km from the shoreline at the NE corner, curving outwards for up to 4.9 km and then inwards. 5 m contour lies at about 3.5 km west of Vadhavan point.10 m contour starts on the north side from about 4.5 km west of Vadhavan point and runs towards south. At its nearest point, the 15 m contour lies 1.5 km west of 10 m contour on the northern side, running in the S-SE direction. 20 m contour lies at about 10 km from Vadhavan point.

3.3. Geophysical Survey

Shallow seismic survey was carried out and the water depths are overlaid on the isopach contours to understand the minimum navigable depth that can be achieved by dredging in the study region. The shallow geological successions within the window examined by the digital data within the surveyed area are described as Silty clay/sand and Weathered bedrock. Silty clay/sand is recorded as the surficial layer in survey corridor in depths of more than 15 m and is interpreted as comprising silty clay/sand. The survey reveals predominant rocky seabed with buried channel comprising of soft clay over sand/gravel or highly weathered rock.

Side Scan Sonar Survey classifies the seabed into following categories such as Soft silty clay, Highly weathered rock /sand /gravel and Basalt rock. The seafloor appeared to be clear of any debris other objects which are likely to be hazardous or otherwise obstruct anchoring and operations in the port.

3.4. Geotechnical Survey

The geotechnical investigation was carried out by M/s Zed Geotechnics & Cons and reports for geotechnical investigation were submitted by Progen in May-June 2017 to assess and confirm the sub soil data. Geotechnical investigation for marine areas was carried out through 61 boreholes. Additionally, 70 boreholes were carried out for proposed rail and road connectivity areas. Specific borehole data has been utilized to prepare soil profiles to study the distribution of the sub strata and assess the geotechnical conditions of the component. Since the port facilities are proposed to be located on the reclaimed land, the topographic investigations were carried out for the external rail and road connectivity to the port along the proposed corridor.

4. Traffic Study

The summary of the traffic projection for the proposed Vadhavan port is as below:

Table 2 Traffic Projection for Vadhavan Port (mn T)

Commodities	FY21	FY25	FY30	FY35	FY40	FY45	FY50
Container Cargo (mn TEUs)	0.0	0.9	6.5	14.1	23.2	31.3	39.4
	0.0	1.2	78	169.2	278.4	375.6	472.8
Edible Oil	0.0	0.4	1.0	1.1	1.2	1.3	1.4
Chemical	0.0	0.6	0.9	1.0	1.1	1.2	1.3
Bulk Liquid	0.0	2.7	3.1	3.8	4.2	4.7	5.2
Fertilizer	0.0	0.9	1.0	1.2	1.2	1.3	1.4
General cargo	0.0	1.5	2.4	3.5	4.6	5.9	7.2
Coastal Cargo	0.0	1.0	1.7	2.4	3.2	4.1	5.0
Other Liquid	0.0	0.0	2.3	4.5	4.5	4.5	4.5
Total	**0.0**	**18.26**	**90.52**	**186.7**	**298.6**	**414.2**	**498.5**
Ro-Ro ('000 Vehicles)	0.0	20.9	49.5	76.8	169.0	195.9	227.1

5. Port Operation & Functional Requirement

One of the main factors that influence the layout and sizing of the port facilities and therefore the costs is the size of ships for different commodities, dimensions and the design of berth, the basin, the approach channel. This, in turn will influence the layout and alignment of the breakwaters, required at a particular port. Based on the outcome of ship size analysis for container traffic, the design ship sizes considered, and berth required for development of Vadhavan port have been presented below.

Table 3 Summary of Design Vessels for Phase 1 Development

S. No	Commodity	Average parcel size	Design Ship Size		Overall Length	Beam	Loaded Draft
		TEU (DWT)	TEU (DWT)		(m)	(m)	(m)
1.	Containers	4,500 (56,250)	Min	6,000 (82,000)	300	40.0	14.0
			Max	24,000 (233,000)	400	61.0	16.5
2.	Multipurpose Cargo vessels	(30,000)	Min.	(20,000)	166	24.8	10.0
			Max.	(40,000)	209	30	10.5
3.	Ro-Ro	1,200 units	Min.	1,000 (7,200)	153	23.4	7.4
			Max.	8,000 (30,386)	221	32	11.3
4.	Liquid Tanker	6,000/ 18,000	Min.	(5,000)	105	16	6.3
			Max.	(30,000)	175	29	9.5
5.	Bulk Liquid Tankers	32,000	Min.	(20,000)	145	24	9.5
			Max.	(45,000)	180	30	10.5
6.	Other Liquid(m^3)	239,000	Min.	145,000	283	43.4	11.4
			Max.	266,000	345	53.8	12.0

Table 4 Berths at Vadhavan Port

S. No.	Commodity	Total berth length/ no.		Total
		Phase-1	*Phase-2*	
1.	Containerised Cargo (m)	4000	5000	9000
2.	Breakbulk (Fertiliser, General, coastal Cargo) (m)	750	250	1000
3.	Liquid Cargo (Chemical, Edible oil) (no.)	3	1	4
4.	RO-RO (m)	300	0	300

5.1. Container Storage and Gate Capacity

Container yard capacity is defined as the potential maximum throughput of containers handled inside the container yard. The container storage yard capacity requirement for Phase 1 and Master plan is 9,781,483 TEU/year and 2,20,08,735 TEU/year.

Gate capacity analysis is essential feature to get essence of seamless inward and outward traffic movement including major share of trucks having containers. The number of exit lanes required for Phase 1 is 6 lanes and in Master plan 26 lanes.

5.2. Other Cargo Capacity

The berth capacity for other cargoes have been assessed taking into consideration the proposed facility and handling arrangement. The Overall berth capacity of Phase-1 and Phase 2 is 19.83 MTPA

5.3. Approach Trestle Capacity & Port Crafts Berth

The road truck movements to/from the marine and rail terminals on the offshore reclamation has been evaluated to establish the requirements for the road connection to the offshore reclamation. Based on calculations the approach trestle capacity in Phase 1 shall be 34,215 PCU/day and in Masterplan 1,12,825 PCU/day is expected.

Based on the Level of Services (LOS) grade as per the HCM, it is proposed to provide the approach trestle with 4 lanes each way for the approach trestle to cater the truck movements in and out of the Vadhavan port.

For the initial stage development, the port would require 6 tugs (4 operational + 2 standby) with a capacity of 65 T and 100 T bollard pull, 1 pilot cum survey launches and 2 mooring launches. Berth of 200 m is proposed for berthing of port crafts.

5.4. Other Cargo Storage Requirements

The area requirement for storage of other cargo is provided in below table.

Table 5 Storage Areas – Master Plan horizon

S. No.	Commodity	Requirement of Storage Area (m²)	
		Phase 1	*Phase 2*
1.	RO-RO Vehicles	21,699	74,082
2.	Edible Oil	9,543	10,603
3.	Bulk Liquid	42,765	57,020
4.	Chemicals	14,844	16,965
5.	Other Liquid	0	0
6.	Fertiliser	31,983	38,379
7.	General Cargo	59,178	113,425
8.	Coastal Cargo	20,959	39,452
Total Storage Area Required (m²)		**203,001**	**351,966**
Total Storage Area Required (Ha)		**20**	**35**

5.5. Buildings

The terminal administration building will be required to house the terminal operator’s management, security, admin, and customer service personnel. Typical users/uses of the administration building shall include Terminal Administration, Customer Service, Gate Equipment Control, IT/Server, Gate Control Clerks, Offices, Shipping Lines Offices, and Terminal Security and Communications Hub.

5.6. Pre-gate building and Customs Clearance

This facility is provided for the administrative functions of the remote pre-gate facility. The Pre-gate Building is required to provide facility for functions such as Customs clearance, Demurrage payment, Customer service, Trouble transactions, Truck driver canteen, Toilets and washrooms, Public phone, fax, and internet.

Maintenance and Repair Building shall provide maintenance, repair, and related activities for RTGs, yard tractors, top-picks, side-picks, truck chassis, and other container terminal operating equipment. It also supports other service areas such as tire changing, and equipment steam cleaning activities.

A separate JNPA Administration building, and land area will be required to provide for functioning of JNPA in managing the port operations. This will include but not limited to office building for the JNPA management and administration staff, office for government officials, security staff and customs and border protection officers. This will also include the facilities for port maintenance and engineering staff.

A centralized fire station with special firefighting equipment such as foam and gas extinguishers will also be provided for chemical and electrical fires. Fire detection, monitoring and control system will be provided in all vulnerable area of the port. In addition to it a separate building will be required to provide for functioning of rail operations within the terminal. This building will house the rail master and associated staff managing the rail operations within the port. This building will also house a small workshop for minor maintenance functions.

5.7. Cargo Receipt and Evacuation

At Vadhavan Port, the cargo receipt and evacuation will be primarily through road and rail. The estimated proportions for different commodities to be brought in/ taken out through rail and road are presented in below table. The modal split for container is currently being rationalised.

Table 6 Estimated Proportions for Different Commodities

S. No.	Commodity	Truck Capacity	Rail Capacity	Phase-1			Phase-2		
				Road Share	Pipeline	Rail Share	Road Share	Pipeline	Rail Share
		T	T	%	%	%	%	%	%
1.	Containers (EXIM)								
	– Indian Railway	1.5	90	68%	-	2.3%	64%	-	2.3%
	– DFCC	1.5	360		-	29.8%		-	33.3%
2.	RO-RO Vehicles '000	5.0	180	100%	-	0%	100%	-	0%
3.	Edible Oil	18	2,500	85%	-	15%	85%	-	15%
4.	Bulk Liquid	18	2,500	15%	5%	80%	15%	5%	80%
5.	Chemicals	10	2,650	100%	-	0%	100%	-	0%
6.	Other Liquid	8	2,200	0%	100%	0%	0%	100%	0%
7.	Fertiliser	12	3,600	0%	-	70%	30%	-	70%
8.	General Cargo	10	2,200	100%	-	0%	100%	-	0%
9.	Coastal Cargo	10	2,200	100%	-	0%	100%	-	0%

Based on the above, almost 13,441 trucks (71,661 PCUs) are expected in the year 2030, increasing to about 34,284 truck (186,348 PCUs) movements in 2040. It is proposed to provide an 8-lane road with a capacity of 173,000 PCU.

The number of rail movement is summarised as below

S. No.	Commodity	Rake Movements per day	
		Phase 1	*Phase 2*
Total Outgoing rakes per Day for other cargoes		**4**	**9**
Containers (EXIM)			
	DFCC Rakes	27	186
	Indian railway rakes	6	47

S. No.	Commodity	Rake Movements per day	
		Phase 1	*Phase 2*
Total Incoming/ Outgoing rakes per Day		**33**	**232**
Total Rake Movements (in and out of port)		**73**	**482**

5.8. Water and Power Requirements

The total water demand within the port is broadly classified into categories such as Potable water for consumption of port personnel, Ship supply, Township use and Firefighting, other uses like gardening etc. For the master plan development, it is expected that the water demand at the port shall be 6.18 MLD and 9.05 MLD for the port township.

The port will be supplied through a 220 KV Main Receiving Substation. Based on the requirements of berths over the master plan horizon, it is expected that the power demand at the port shall increase from 50 MVA in the Phase 1 development to about 80 MVA over the master plan horizon.

6. Port Master Plan

The recommended masterplan layout is mentioned below.

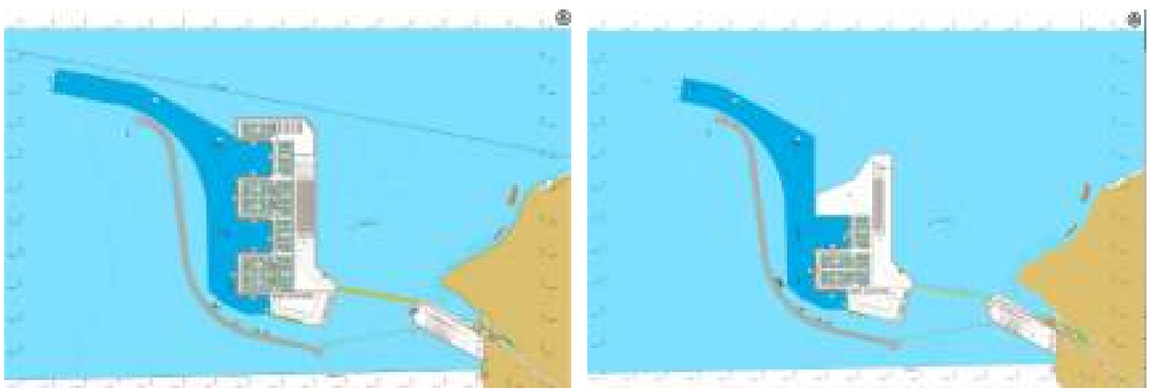
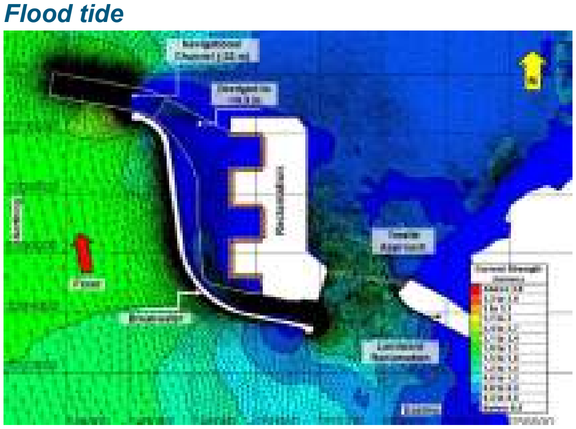


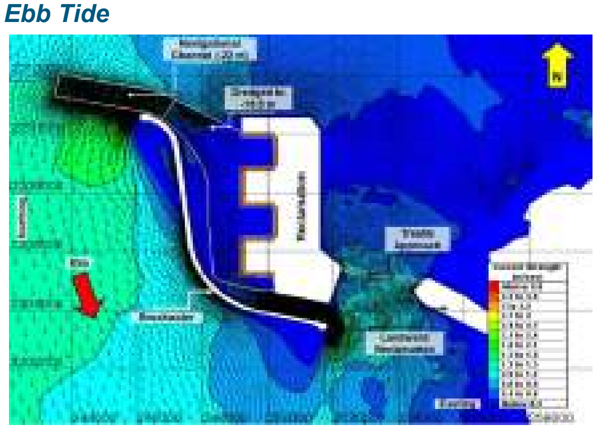
Figure 1 Recommended Masterplan and Phase 1 Layout for Vadhavan

The model studies were carried out for the proposed master plan and Phase 1 layout to ascertain the flow conditions within the harbour.

Flood tide



Ebb Tide



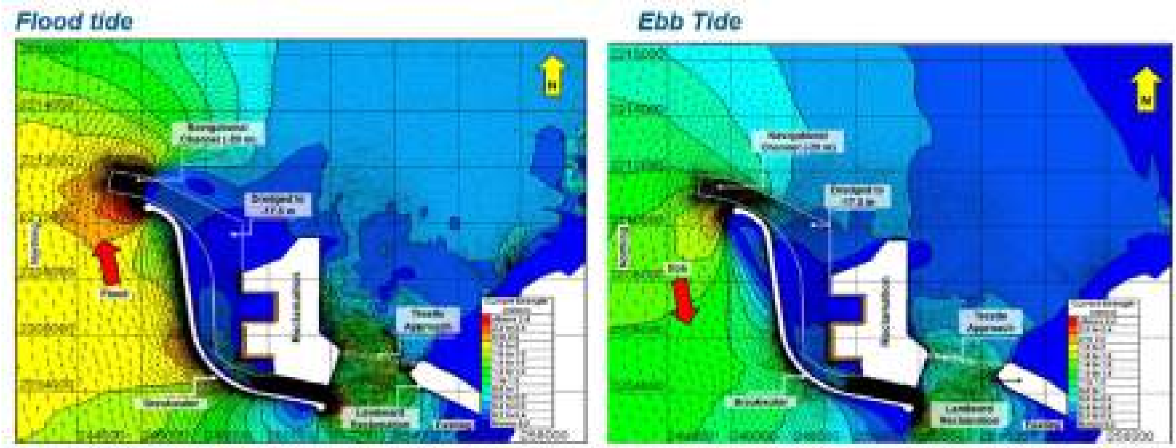


Figure 2 Recommended Vadhavan Port Phase-1 Layout

Based on mathematical model studies maximum velocities at harbour entrance, stopping distance and turning circle are 2.6 m/s, 1.2 m/s and 0.3 m/s respectively. The maximum current strength at berths is about 0.05 m/s. The annual siltation in the dredged areas will be about 6.45 M cum during Phase 1 and 8.65 M cum for Master Plan development.

The estimated berths and the total quay length for the various phases of development is provided below.

Table 7 Vadhavan Port berths & terminal requirements established from the market study

Berths/terminals	Berth/ Quay length (m)	Ship max. draught (m)	Phase 1	Phase 2	Total
Container quay (1,000 m each)	1,000	16.5	4	5	9
Multi-purpose berths (250 m each)	250	10.5	3	1	4
Liquid bulk berths	200	9.5	2	0	2
Bulk Liquid berth	280	10.5	1	0	1
Other liquid berth	400	12.0	1	0	1
Ro-Ro berth	250	11.3	1	0	1
Coastguard berth			1	0	1

A water depth of - 22.0 m CD is required in the approach channel and -19.5 m CD in the basins and at the container berths. The development will essentially be a large deep-water container port for the largest deep-draught container ships.

6.1. Navigational Requirements

The port approach channel consists of the two parts outer and inner approach channel. The dimensions for outer and inner approach channel are provided in table below.

Table 8 Navigational Channel for Design Ships

Design Ship Size	Beam (m)	Outer Channel Width (m)		Inner Channel width (m)	
		One-way Channel	*Two-way Channel*	*One-way Channel*	*Two-way Channel*
24,000 - TEUs Container Carrier	61	290	620	230	490

The depth of the approach channel is a very important parameter in approach channel design. Water depth in the channel is around 17 to 18 m depth below CD. +2.0 m tidal advantage has been considered as the

MSL is about +2.8 m CD. The dredged depths with tidal advantage at different parts of the harbour for the design ships are provided below.

Table 9 Dredged Levels at Port for the Design Ships - With Tidal Advantage

Ship Category	Ship Size	Draft (m)	Tidal Advantage (m)	Approach channel outside breakwater (m CD)	Inner channel and manoeuvring area (m CD)	At Berths (m CD)
Containers	24,000 TEUs	16.5	2	20.0	17.5	19.5
Other Liquid	2,67,000 m^3	12	2	14.1	12.3	14.3
Bulk Liquid	45,000 DWT	12.5	2	14.8	12.9	14.9
Multipurpose	40,000 DWT	10.5	2	12.2	10.6	12.6
Liquid bulk	20,000 DWT	9.5	2	10.9	9.4	11.4
RORO	8000 units	11.3	2	13.2	11.5	13.5

The diameter of the sheltered turning circle with tug assistance is 700 m.

The main emphasis while developing the port layout is given to balance the cost of dredging and reclamation land area developed. It is estimated that approximately 200 million cum of reclamation material would be required for the proposed port development.

7. Terminal Equipment and Utilities

7.1. Equipment

Based on the Phase-1 and Master plan development certain equipment's will be required to effectively support the turnaround time of the vessel.

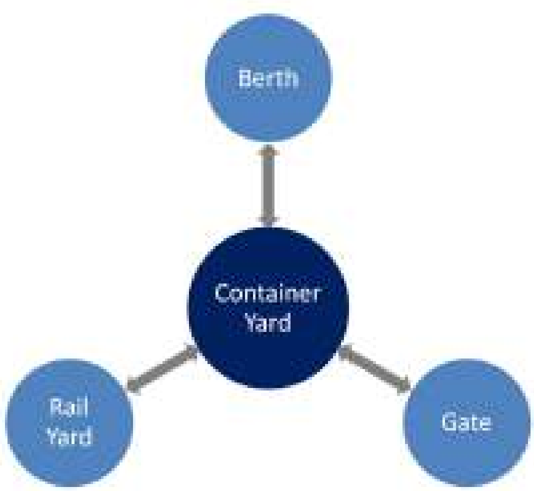


Figure 3 Schematic Container Flow Diagram

Phase 1 development will have 4 container terminals each can cater minimum of 3 container ships at any time. It is proposed to provide 12 Rail Mounted Quay Cranes (RMQCs) on each of these terminals. 36 electric Rubber Tyred Gantry Cranes (e-RTGCs) are provided for each container yard. Similarly, 5 Rail Mounted Gantry Cranes (RMGCs) are provided to handle containers being moved by rails. ITV's are provided for movement of containers between quay, container yard and rail yard. The flow diagram for the container handling system for import and export containers are as presented below.

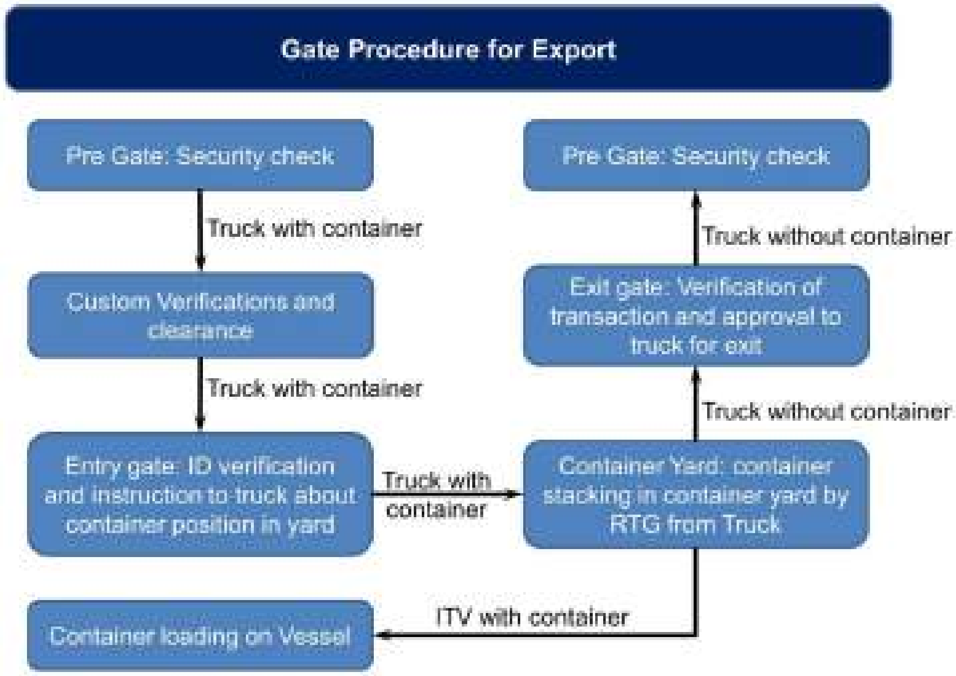


Figure 4 Container Terminal Operation Strategy - Export container

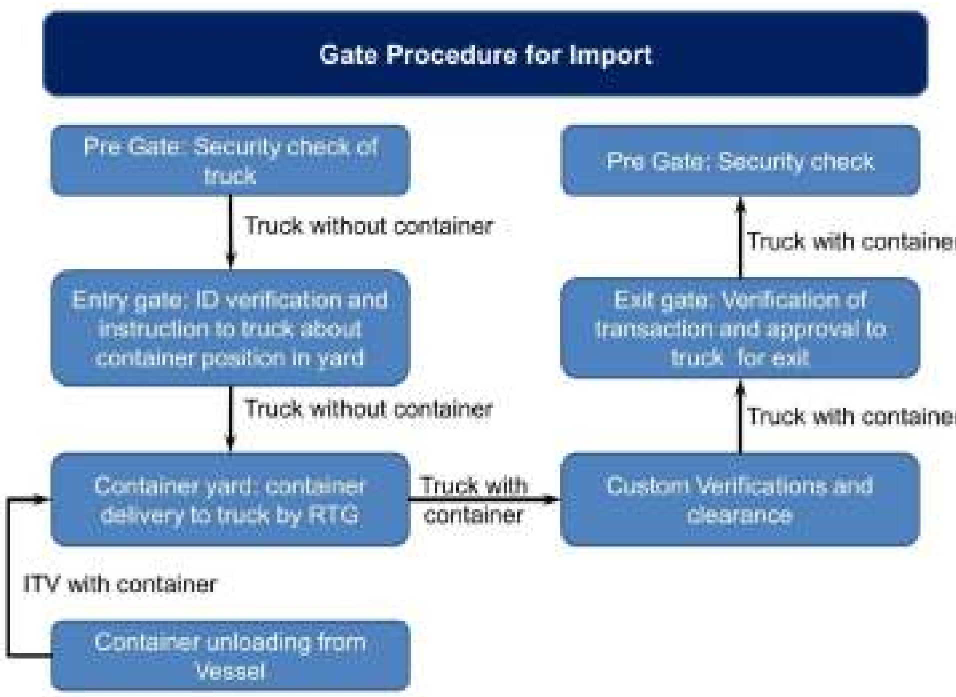


Figure 5 Container Terminal Operation Strategy - Import container

Similarly, the equipment's required for other bulk cargo are Mobile harbour cranes etc. Liquid terminal is planned to handle Chemicals & Edible oil and Bulk Liquid. The liquid bulk, received in tanker will be unloaded at berth using the marine unloading arms and transferred to the tank farms by means of pipeline. The cargo is pumped directly from the vessel's pump later based on requirements, the cargo will be dispatched to the destinations by loading into trucks or through pipelines.

7.2. Utilities

MSEDCL has assured that 80 MVA will be available from PGCIL/ Tarapur-Borivali station through a tapping from double circuit line. The required electrical system for the project will consist of incoming electrical supply at 220 kV level, 220/33 kV substations, switchboards, control equipment, etc. to supply the electrical power to various parts of the site at the required voltage levels of 11kV or 6.6 kV & 0.415 kV, Control and Monitoring systems, 11 or 6.6 kV underground cabling system for medium voltage supply like for quay cranes, Fibre optic communications from the substation to the quay cranes. 0.415 kV cabling system from the 11 or 6.6 /0.415 kV substations to the reefer area. The cables should be run in cable trenches, Provision of underground power cabling to the buildings and gate complex shall be provided, Provision of underground power cabling to terminal light towers. In addition, consideration of future electrical requirements of the terminal all necessary provisions shall be made in the design and installation of the electrical system, to take account of future requirements. This applies to switchboards, transformers, underground cabling system etc.

The water requirement for the port shall be fulfilled from Surya River 22 km away from the port location.

Drainage systems are also planned for the port. A drainage system will be provided below the stacking area, with buried perforated drain lines. It is proposed to lay the RCC trench drain parallel to the proposed internal road. The storm water from the berths, administrative offices, all terminal operator facility buildings, transit sheds and all other buildings from the different areas of the terminals will also be connected to the storm water drain. The wastewater collected from the workshop will be treated in an oil skimmer before disposing off to the storm water drain.

The sewerage system is provided for the buildings such as office buildings, canteens, and other operational buildings. For isolated buildings and berths portable sanitary cabins are proposed. As per MARPOL convention, the ships are now required to have STP on board. Sewage and sullage generated from various buildings with-in a terminal shall be disposed to a Sewage treatment plant (STP) proposed near each terminal operator facility building / administration building. A separate sewage treatment plant is required to be provided for township and the type of treatment will be as per the population and township conditions.

7.3. Harbour Crafts & Navigational Aids

As per the results of the 3D ship navigation simulation studies carried out by DHI through Force, July 2018 and 2021, for berthing / de-berthing of the design container vessels a minimum of two ASD tugs of 65T and two ASD tug of 100T bollard pull capacity are required along with 2 tugs on standby or instant use during vessel's outbound departure channel transit. Two mooring launches will be required at the port for vessel mooring activities. Two all-weather Pilot launch with LOA of 15-20 m and speed range of 15-20 knots. The pilot launches will be equipped with hydrographic survey equipment's.

Navigation aids for the port are required to ensure safe and efficient navigation of ships entering and leaving the port through the approach channel as well as berthing / un-berthing requirements inside the harbour. The navigational aids shall include Buoys - a total of 11 buoys, which include 4 channel buoys i.e., 2 port side buoys (3m dia.) & 2 starboard buoys (3 m dia.), BEACONS and Vessel traffic management information system (VTMIS) would be required for the navigational purpose.

8. Preliminary Design of Marine Structures

Preliminary engineering analysis for various civil infrastructures for Phase 1 development has been carried out in this section.

8.1. Offshore Breakwater and Revetments

The harbour and land reclamation area will be protected by an offshore breakwater and revetments. The design criteria is discussed consisting its functional requirements of breakwater and revetments. Design life of new offshore breakwater and revetment shall be as a minimum of 50 years. Armour stability has been thoroughly verified wile proposing Accropode II™ as concrete armour layer. Overtopping requirements were verified for 1 year and 100 year of extreme conditions of breakwater and revetment. Permissible overtopping for breakwater is less than 0.4 litres/s/m for 1 in 1 year operational and less than 50 litres/s/m 1 in 100-year extreme condition. Whereas the overtopping at revetment is limited to less than 10 litres/s/m for 1 in 100-year extreme condition. Toe stability is also designed with an accuracy where the acceptable damage number N_{od} for stability of toe berm along the revetment and breakwater 0.5 under 100-years of extreme conditions is considered. The crown wall stability criteria is also evaluated which is at the crest of breakwater.

Design conditions consist of tide levels, 2 m high storm sure for 100-year return period, 0.2 m od sea level rise in next 50-years, maximum and minimum design water levels with 100-year extreme are +6.9 m CD and +0.00 m CD. Design wave conditions at breakwater for 1 in 1 year design wave: i.e., Significant wave height (H_s) is 3.0m and wave period (T_p) of 10s

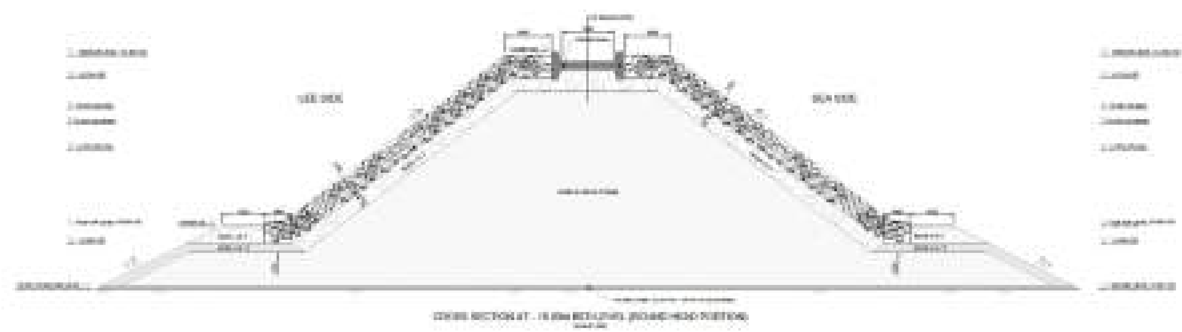


Figure 6 Typical cross section at -19 m CD bed level.

The details type and size of armour units in various layers are provided in below tables.

Table 10 Proposed Primary Armour Layers on seaside slope of the Offshore Breakwater

Seaside	Breakwater Roundhead	Breakwater Trunk	Breakwater Roundhead	Breakwater Trunk
Seabed level (m CD)	-19.0	-10 to -19.0	-6.4	-8.0
Armour Type	Accropode II™	Accropode II™	Accropode II™	Accropode II™
Slope (V:H)	3:4	3:4	3:4	3:4
Recommended Armour Size	13 m^3	11 m^3	13 m^3	11 m^3
Underlayer Rock	2,000-4,000 kg	2000-4,000 kg	2,000-4,000 kg	2000-4,000 kg

Table 5 Proposed Primary Armour Layers on leeside slope

Leeside	Main Breakwater Trunk
Slope (V:H)	2:3
Recommended Armour Size	2,000 - 4,000 kg
Underlayer Rock	Quarry run

Table 6 Crest details for original design

Description	Roundhead	Trunk
Crest Berm Width (m)	≥ 6.56	≥ 6.22
Crest Berm Level (m CD)	≥ +16.0	≥ +16.0
Crown Wall Crest Level (m CD)	≥ +16.0	≥ +16.0
Crown Wall – Roadway (width) (m)	10m	10m
Crown Wall – Roadway (level) (m CD)	+15.0 m CD	+15.0m CD

Table 13 Toe Armour on seaside slope

Seaside	Breakwater Roundhead (-19m CD)	Breakwater Trunk	Breakwater Trunk	Breakwater Roundhead (-6.4m CD)
Critical Condition	100 year at LAT	100 year at LAT	100 year at LAT	100 year at LAT
Founding Level (m CD)	-19.0	-15 to -19	-8.0 to -10	-6.4
Toe Level (m CD)	-10.0	-6.0 to -10.0	-3.0 to -5.0	-2.35
Recommended Toe Armour Size	4,000-6,000 kg	4,000-6,000 kg	3,000-6,000 kg	3000-6000 kg
Underlayer Rock	300-1,000 kg	300-1,000 kg	300-1,000 kg	300-1000 kg

The revetments protecting the land reclamation can be built as a series of small rock bunds to form a compact core which minimise the volume of quarry run rock required. This approach is sometimes referred to as the "Christmas tree" concept.

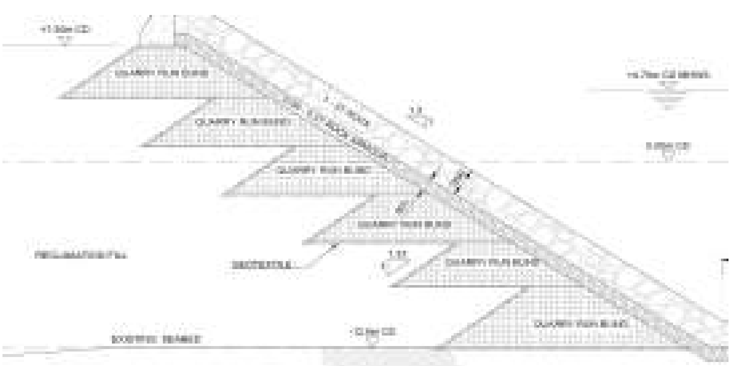


Figure 7 "Christmas tree" concept to form the core of the revetment

Design cross sections have been developed for the trunk and roundhead locations along the offshore breakwater and revetments.

The development of port facilities at Vadhavan would require huge quantity of rock and aggregates for construction of various port structures. About 73.55 MT of rock quarry is required which shall suffice the requirements for Breakwater, shore protection, murrum and aggregates for construction of various facilities including rail and road. The required quarry shall be procured from various quarry site such as Gargaon, Khanivade, Nanivali, Borsheti, Kirat, Nagzari, Girnoli and Mahagaon.

8.2. Berthing Facilities

The deck top level of berths at Vadhavan port shall be 7.6 m CD. The structural design of the berths shall be carried out for the design dredged level in the ultimate stage based on the design vessel sizes to be handled at these berths.

Geotechnical design of piles shall be done with the factor of safety of 2.5 for end bearing and skin friction on compression piles, 3.0 skin friction on tension piles and 2.0 for lateral load. Termination criteria shall correspond to PPR of 100 $Tm/m^2/cm$ corresponding to safe end bearing resistance of 500 T/m^2. The loads such as dead load, live load, vehicle & crane load, seismic load, wind loads, current load, wave load, mooring loads, berthing loads shall be considered based on structural requirements.

Berth details are based on functional requirements geotechnical conditions construction methodology and structural arrangements for container berth, multipurpose berth, Ro-Ro, Bulk liquid jetty and other liquid jetty has been provided.

8.3. Capital and Maintenance Dredging

Dredging and reclamation is one of the major costing parameters for any port project. The dredged volume of 6.9 M cum comprising of soil and rock is required to be dredged. The rocks that might encounter while dredging is envisaged that the rock strength shall vary from 6 to 51 MPa with an average of 19 MPa.

Based on the mathematical model studies on siltation, the estimate the likely rate of annual siltation for Phase 1 reveal that, the average rate of siltation in the dredged areas will be about 6.45 million cum. The siltation rates are not uniform over the area under consideration and seems to vary based on the prevailing hydrodynamic conditions. The dredged material in channel and harbour basin would be disposed at the designated dumping site offshore.

The location of the disposal site which is in deep water (beyond 25 m contour). The disposal site is spread over an area of about 20 sq. km and the depth of dumping will be restricted to only 0.5 m.

8.4. Reclamation

Emphasis was given to balance the cost of dredging and reclamation land while developing the port layout. Based on the stakeholder consultation, the capital investment required for Private entity and mitigate the risk of basic development cost, the reclamation of 1,227 Ha +5.0 m CD by VPPL while upto the FFL shall be carried out by the concessionaire, is planned in the offshore of the coast on a seabed ranging from -6.00 m to -15.00 m below the CD and an area of 221 ha nearshore on the seabed from 0 m CD to -1 m CD. About 227 million cum of reclamation material would be required for the proposed port development.

9. Preliminary Design of Landside Structures

The finished levels of onshore areas and reclamation areas will be kept at around +7.6 m CD. The fill for reclamation will be obtained from dredged areas. The suitable dredged materials will be discharged by the CSD into one of the reclamation areas. The reclamation areas to be filled in maximum six layers to final fill level (+5.0 m CD). Ground improvements and foundations shall be required for strengthening of the ground. This shall be done by Vibro-Compaction. Once the ground improvement is done to the desired strength this will aid in development of container yard/open storage for various cargo terminal.

Internal roads shall be developed for improved internal connectivity. 204 ha. of area to be developed for Container yard storage in Phase 1. The stack areas shall be developed using concrete block paving. Considering the various terminals to be developed by various operators and the number of truck movements within the port, it is required to provide a centralised truck parking space close to the respective terminals. 49 ha. of parking space shall be required over the master plan.

Two step entry/exit gate complex has been planned. Initially in Phase-1 there shall be 6 lanes increasing to 26 lanes in Master plan. The gate complex shall consist of controls access to and from the container handling and storage areas and facilitates the transfer of responsibility for the cargo from one party to another.

9.1. Port Buildings and Other Civil Structures

The port buildings consist of administration buildings, port operations buildings, port user buildings, Gate House Building, Maintenance Workshop, Fertilizer Shed, and Utility Buildings.

Table 14 List of building envisaged for the for concessionaire in Master plan

List of Buildings	Operating Terminal Buildings											
	Container Terminals									Multi-purpose Terminal	Ro-Ro Terminal	Liquid Terminal
	CT1	CT2	CT3	CT4	CT5	CT6	CT7	CT8	CT9			
Admin Building	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Customs Building	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Gate House	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Maintenance Workshop	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Storage Shed	-	-	-	-	-	-	-	-	-	✓	-	-
Electric Substation	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Fire Pump House	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Tank Farms	-	-	-	-	-	-	-	-	-	-	-	✓

The administration building is planned for offices of key personnel engaged in managerial and departmental activities. The building will have provision to accommodate custom office building, CISF office and police station. Port operation building to be developed for providing space for engineering department, terminal operations, marine operations, and vessel traffic control room. Port user building to provide working space for general store, dispensary, restaurants, canteen, recreational area such as theatre and shops. Maintenance workshops for foremen, mechanics, electricians, technicians and the storekeepers and rooms for off duty operational personnel and maintenance labour. Substation building for transformer and other electrical equipment.

10. Rail and Road Corridor

The nearest railway stations to Vadhavan port along Western Dedicated Freight Corridor (WDFC) will be the proposed New Palghar crossing station of WDFC which runs parallel to Mumbai – Delhi western railway main line. Connectivity from Vadhavan in port rail yard to WDFC at proposed New Palghar station is only 'feasible' by crossing proposed WDFC main lines, existing WR main lines and the proposed MRVC lines by a 'Rail Fly Over (RFO)/ Rail-Over-Rail (ROR)' and then connect to WDFC network. The route length is 28 km., total track length is 151 km, 20 No. of major bridges/road bridges, 18 no. of minor bridges, 10 weigh bridges of 100 m each on each side. Four 'Conceptual' Options for direct connectivity to WDFC have been identified as part of rail connectivity DPR for this port and accordingly, the recommended option is indicated as below.

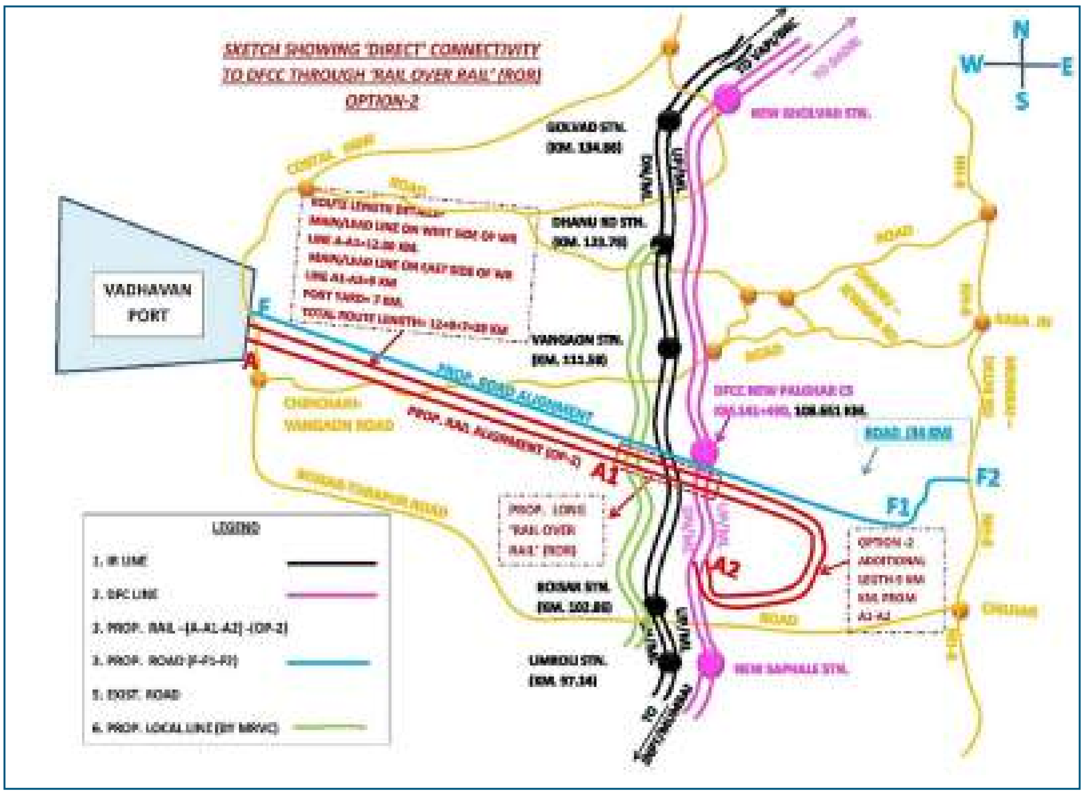


Figure 8 Sketch of 'Direct Connectivity to WDFC through 'ROR

It is proposed to have a road connecting Vadhavan port with NH-48 and Mumbai-Vadodara expressway. The entire 34 km. of road is split in to three sections i.e., first 12 km. is from Vadhavan to Western railway line, next section is from Western railway line at 12 km. upto Surya river 21 km. and third section starting from Surya river at 21 km. upto NH-48 junction at 34 km. All roads will be merging with the road connecting port to the NH-48 and Mumbai Vadodara expressway. Road from custom gate to container terminals will be of 8 lane wide road and the other roads from gate complex to JNPA Port Administration Building will be of two-lane wide road. The 4-lane road from the gate complex bifurcate to the multipurpose/ liquid/terminal.

11. Socio Economic Impact Assessment

There is no land acquisition involved for the port estate onshore facilities, as the land requirement is mostly accommodated on reclaimed land of approximately 1448 Hectares in the inter-tidal area adjacent to the coast. Vadhavan port is located at 12 km distance from the main rail link and upcoming dedicated freight corridor for rail connectivity and is 35 km from the Mumbai - Delhi NH 8. Accordingly, land acquisition is required for the rail and road connectivity, with a corridor width of 160 m over a length of 12 km where both the road and the rail tracks are required, and a corridor width of 120 m over the remaining length of approximately 22 km where only road connectivity is required. The Socio-Economic Assessment (SEIA) was conducted as part of the DPR for the people whose agricultural land / partial agriculture land needs to be acquired by the Government for the public interest and to study the impact of the development of the port on 21 affected villages.

Various mitigation measures are adopted to reduce the effect of socio-economic impact assessment. The project affected people and families may be encouraged to participate in the development of the port and to have a positive view towards port development. The project affected people shall be clearly informed regarding the development of the port and benefit to the society and same to be conveyed through personal meeting printed literature, audio visual presentation and videos. JNPAA may arrange meetings and discussions with project affected people and apprehensions to be cleared. Focused group interactions shall be required to be carried out. Statutory meetings of Gram panchayat to be participated and brief on project and its overall benefits to be discussed. The misconception of the people should be removed through public meetings with locals in association of Gram panchayat, NGOs and promoting authorities of governments.

12. Land Acquisition

Based on the land requirement assessment for the proposed rail and road corridor, the land acquisition details were worked out. This includes the private land, agricultural land, forest land. The land acquisition has been worked out for the rail and road separately. Total land acquisition for rail and road development shall be 571 ha. Additional area of 100 ha. will be taken on lease from CIDCO, a GoM undertaking for construction of residential accommodation and related utilities for the officers and staffs working under VPPL. The total cost for land acquisition shall be about INR 884.68 crore.

Table 15 Land acquisition area

S. No.	Type of Land	Area (in Ha.)
1.	Govt. Land	25.69
2.	Forest Land	127.19
3.	Private Land	418.18
4.	Land lease from CIDCO for township	100
	Total	571.06 (Acquisition) 100.00 (Long Term Lease)

Table 16 Total Land acquisition for Road and Rail

S. No.	Taluka	Total Land Acquisition (in Ha.)		
		For Road	For Rail	Total
1.	Palghar/ Dahanu	395.49	74.87	470.36
2.	Railway Yard	-	33.99	33.99
3.	Tawa Road Junction	34.70	-	34.70
4.	Extra Land at Road/Rail Junctions	32.00	-	32.00
5.	Leased Land from CIDCO, GoM for Township			100.00
Grand Total		**462.19**	**108.86**	**571.05 (Aq) 100.00 (L)**

13. Mathematical Model Studies

Mathematical Model Studies is an eminent study that needs to be carried out to determine the optimum layout of the master plan development.

13.1. Model Studies carried out by CWPRS

Hydrodynamic and siltation studies have been completed by CWPRS to finalise the layout of the breakwater and assess the rate of siltation in the port. The influence of the breakwater and reclamation bund on tidal flows have been assessed, this led to the introduction of a Current Deflecting Wall (CDW) inside the southern end of the main breakwater to trap and stop the propagation of the southern eddy into the port during the flood tide.

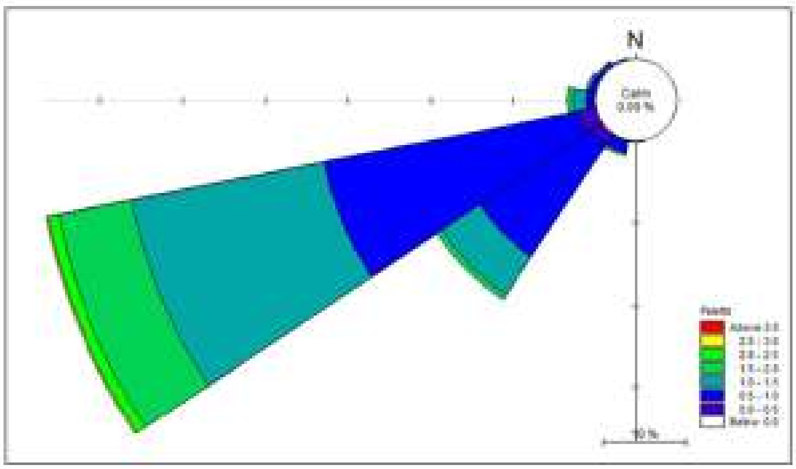


Figure 9 Wave Rose offshore of Vadhavan (-60m water depth)

The wave modelling software MIKE21 SW was used to transform the offshore wave conditions nearshore to a point at depth -24 m CD outside the port. The results from the modelling are reproduced below.

Table 17 Annual Wave Frequency Offshore outside Vadhavan Port (-24m water depth)

Wave Height (m)	0.5-1.0	1.0-1.5	1.5-2.0	2.0-2.5	2.5-3.0	3.0-3.5	3.5-4.0	4.0-4.5	Total
Direction (°)									Calm 54.49%
180 (S)	0.35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.35**
202.5 (SSW)	1.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**1.11**
225 (SW)	5.28	0.21	0.63	0.35	0.00	0.00	0.00	0.00	**6.47**
247.5 (WSW)	2.13	7.61	13.27	5.35	0.35	0.00	0.00	0.00	**28.71**
270 (W)	3.27	1.9	0.49	0.00	0.00	0.00	0.00	0.00	**5.66**
292.5 WNW)	3.07	0.07	0.00	0.00	0.00	0.00	0.00	0.00	**3.14**
315 (NW)	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.0.7**
Total	**40.92**	**26.53**	**9.61**	**3.01**	**0.97**	**0.38**	**0.14**	**0.06**	**100**

The wave modelling software MIKE21 BW has been used to assess the shelter provided by the breakwater and conditions within the port. The model has been used to assess a range of layouts which were rejected in favour of the final layout. The final layout provides good protection to all berths from waves from SW, WSW, and W with conditions within the limits set earlier. At the container berths waves conditions are also less than 0.5 m for these directions. The berths are less well protected for waves from the NW with the limiting criteria of 0.8 m exceeded at the coal berth which is now replaced by additional container terminals. Wave conditions at the container berths are less than the limit of 0.8 m but exceed 0.5 m. It is expected that the proposed breakwater layout will provide adequate protection to the port with low downtime at the berths as the assessment has been completed using 1-year storm conditions.

13.2. Sedimentation studies

Siltation model was established using Telemac-2D. Hydrodynamics model described in the previous section was used to drive the sedimentation model. From the analysis of the seabed samples, it was concluded that the typical D50 size of the seabed soil is around 0.011 mm. As this size of the bed material was found to be in the same order as that of the suspended material whose D50 is around 0.008 mm, it was concluded that the deposited seabed material is due to settlement of material in suspension. Based on the studies total quantum of likely siltation in the dredged areas will be about 3.1 million cum for non-monsoon season only.

13.3. Assessment of Thermal dispersion from TAPS

This study was conducted to assess the impact of proposed Vadhavan port on dispersion of outfall at Tarapur atomic power station (TAPS). Initially the existing conditions along with the intake and outfall discharge volumes of for the power plant are introduced in the model and current were extracted at different observation points i.e., around the intake and outfall structures from the model. Comparison between the current strengths and water depths at the observation locations were compared for both the scenarios i.e., with and without proposed Vadhavan port were compared to understand the impact of Vadhavan port on the flow around intake and outfall structures of TAPS.

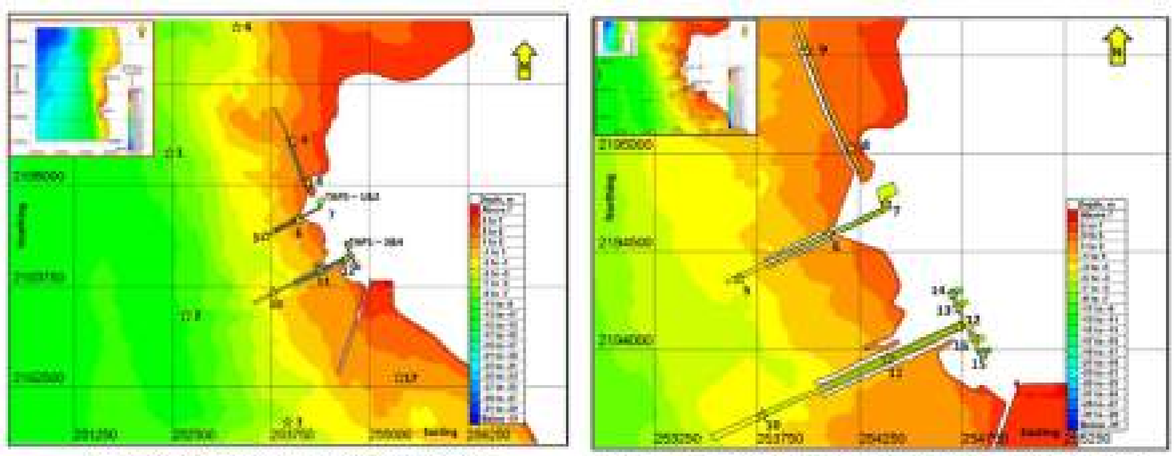


FIG. 16 (A): Locations of Current Data near TAPS Area

FIG. 16(B): Locations of Current Data in Forebays / Pumpbays of TAPS

Figure 10 Location of Current Observations near TAPS area

Results show that due to the development of proposed port the current strength on the seaward side of the intake channels at TAPS reduce by 9%. At the outfall channel, the change in current magnitude is around 11% on the north side and by 2% on the south side of the outfall channel. In the guided portion of the intake and outfalls, the impact on the current is negligible i.e., less than 2%. As per the model study, difference between water depth before and after construction of Vadhavan port at all the observation locations in and around TAPS were found to be negligible.

13.4. Study on Shoreline changes

This study was conducted to assess the impact of the port on the 20 km long shoreline between Dahanu and Tarapur. The study was done in two stages. In the first stage, littoral drift was assessed for existing using LITDRIFT module of the LITPACK module. In the second stage LITLINE module was used to assess the evolution of the coastline due to construction of port.

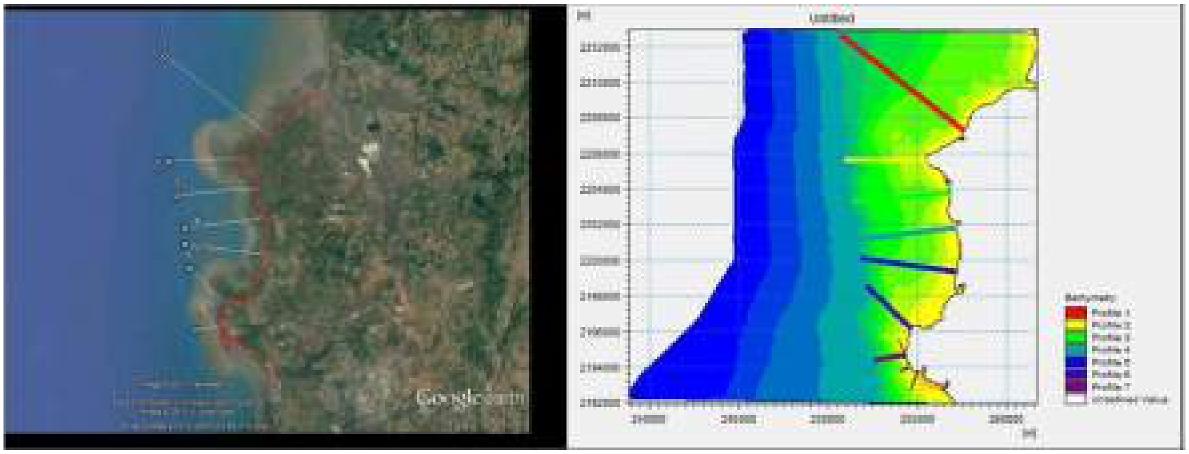


Figure 11 Cross shore profile locations

For estimation of change in the coastline, the breakwater is introduced into the LITLINE model and comparison is made with the existing scenario to estimate the changes in the coastline. The construction of port for a period of 1,2,4 and 6 years after the construction of breakwater and the results show that the change in the shoreline due to the construction of Vadhavan is negligible. Model output for shoreline evolution after construction of breakwater is shown in below figure.

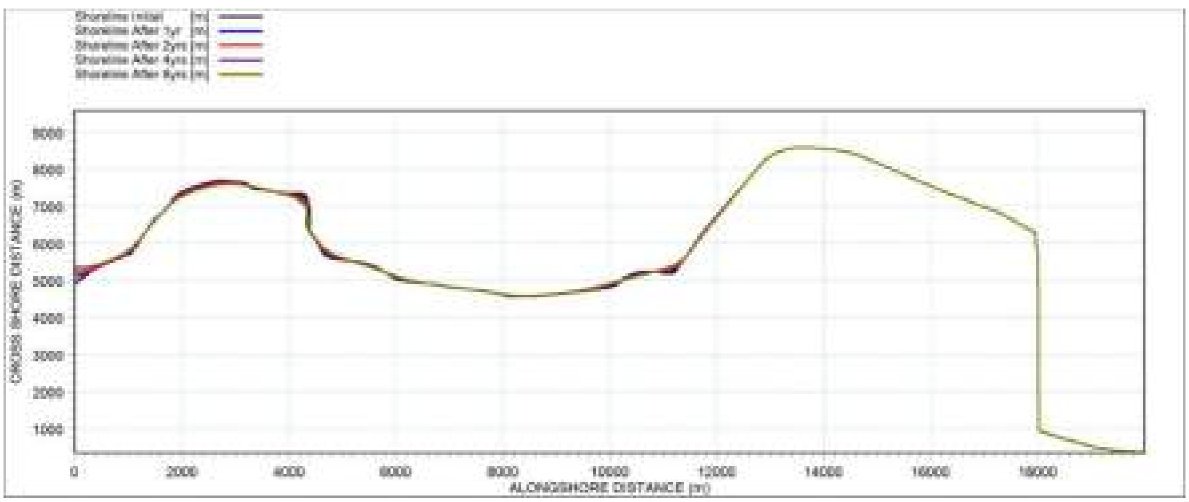


Figure 12 Model output for shoreline evolution

Studies for simulation of shoreline changes indicated that the construction of proposed offshore breakwater of 10.1 km length will result in negligible deposition of sand behind the breakwater and will have negligible impact on the adjacent shoreline as well.

13.5. Ship Simulation Studies

The study area covers from the entrance of approach channel buoy no.1 in the North to the proposed berth CT-2 in the South as shown above. The distance between these points are about 4.3 nautical miles. From the study it was concluded that CT-2 is optimally and favourably aligned with the tidal current, no significant concern with the berthing and unberthing of the largest designed vessel at the proposed jetty/berth, optimum speed for the vessel before a swing manoeuvre was found to be below 20 knots. A higher speed may compromise safety in case of loss of tug power and control, Four ASD tugs of 65 tons bollard pull were marginally adequate in handling the largest designed vessel to berth and un-berth at the proposed berth

CT-2, Manoeuvring near and at the approach channel during maximum flood and ebb with wind speed of 20 knots was on the high side.

13.6. Sedimentation Studies

CWPRS carried out the sedimentation studies to estimate the likely siltation in various dredged areas i.e., berths pockets, approach channel, basin etc. of the harbour area. The total siltation in the dredged areas over the plan master plan will be about 8.45 M cum per annum and 6.45 M cum per annum for Phase 1.

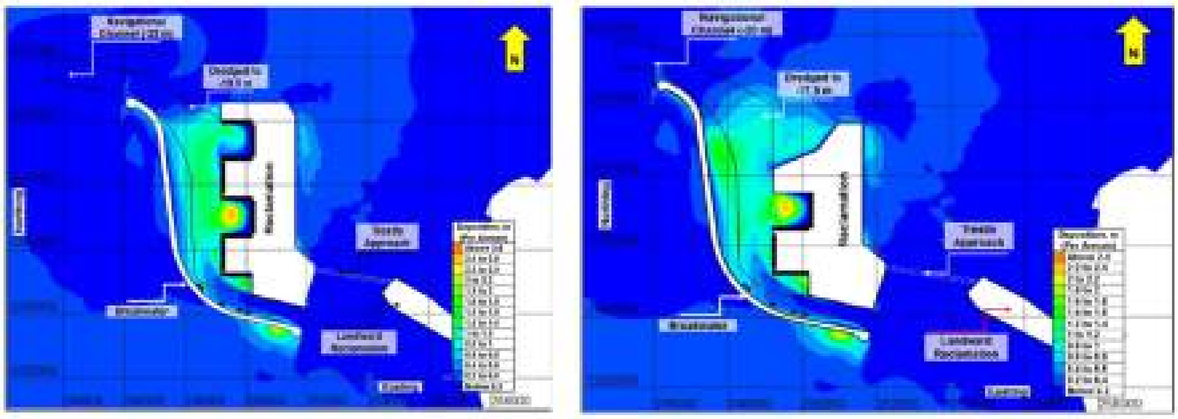


Figure 13 Annual siltation pattern for the recommended Master plan and Phase 1 layout

14. Financial Viability

14.1. Cost Estimates

The port is proposed to be developed as on landlord model with the port terminals to be developed on PPP basis. The basic infrastructure of the port necessitating upfront investment such as, breakwater, reclamation rail and road linkages, power, water lines, harbour crafts and common infrastructure and services will be developed by the port/ SPV whereas the cargo terminal facilities would be leased out to the various operators who shall be responsible for its construction, operations and maintenance. A Detailed CAPEX (Capital Expenditure) estimate has been prepared for the Phase 1 and Phase-2 development as provided below.

Table 18 Vadhavan Port Block Cost Estimate Summary

S. No.	Item		JNPA (INR in Crores)		PPP (INR in Crores)		Total (JNPA)	Total (PPP)	Total cost (INR in crores)
			Phase -1	Phase -2	Phase-1	Phase-2			
1	Project Preliminaries and Site Development		60	60	-	-	120	-	120
2	Dredging		936	2,016	-	-	2,952	-	2,952
3	Reclamation		9,321	2,586	-	-	11,907	-	11,907
4	Shore Protection Works		2,381	1,111	-	-	3,492	-	3,492
5	Breakwater		5,361		-	-	5,361	-	5,361
6	Berths/ Terminals								
	6.1	Container Terminal 1 (CT1)	-	-	2,689	-	-	2,689	2,689
	6.2	Container Terminal 2 (CT2)	-	-	2,693	-	-	2,693	2,693
	6.3	Container Terminal 3 (CT3)	-	-	2,688	-	-	2,688	2,688
	6.4	Container Terminal 4 (CT4)	-	-	2,699	-	-	2,699	2,699
	6.5	Container Terminal 5 (CT5)	-	-	-	2,703	-	2,703	2,703
	6.6	Container Terminal 6 (CT6)	-		-	2,704	-	2,704	2,704

S. No.	Item		JNPA (INR in Crores)		PPP (INR in Crores)		Total (JNPA)	Total (PPP)	Total cost (INR in crores)
			Phase -1	Phase -2	Phase-1	Phase-2			
	6.7	Container Terminal 7 (CT7)	-	-	-	2,684	-	2,684	2,684
	6.8	Container Terminal 8 (CT8)	-	-	-	2,708	-	2,708	2,708
	6.9	Container Terminal 9 (CT9)	-	-		2,717	-	2,717	2,717
	6.1	Multipurpose Terminal – 4 No.	-	-	861	161	-	1,021	1,021
	6.11	RO-RO Terminal	-	-	204		-	204	204
	6.12	Bulk Liquid Terminal	-	-	239	-	-	239	239
	6.13	Liquid Terminal Edible and Chemical -2 No	-	-	299	-	-	299	299
7	Common Port Infrastructure								
	7.1	Reclamation	181	90	-	-	271		271
	7.2	Approach Trestle	1,777	0	-	-	1,777		1,777
	7.3	Port Buildings	248	15	-	-	263		263
	7.4	Tug Berth	71	0	-	-	71		71
	7.5	Internal Roads, ROB, Underpass	1,073	362	-	-	1,435		1,435
	7.6	Utilities and fencing	383	12	-	-	394		394
8	Roads and Railways				-				
	8.1	External Road Connectivity	-	-		-	-	-	-
	8.2	External Rail Connectivity (up to port gate and in-Port tracks)	-	-	-	-	-	-	-
	8.3	In-Port Rail Yard	-	-	1,478	883		2,361	2,361
9	External Utilities, Township and Others		339	43	-	-	382		382
10	Port Crafts and Navigational Aids		34	1	-	-	35		35
11	Gates Complex		40	57	-	-	97		97
12	Landscaping		90	-	-	-	90		90
(A) Total (1+2+3+4+5+6+7+8+9+10+11+12)			**22,296**	**6,353**	**13,849**	**14,560**	**28,648**	**28,410**	**57,058**
(B) GST (@18%) on infra Cost			4,013	1,143	2,493	2,621	5,157	5,114	10,270
(C) Total Infra Cost (including GST) (A+B)			26,309	7,496	16,342	17,181	33,805	33,523	67,328
(D) Contingency at 1%			263	75	163	172	338	335	673
Total EPC Cost (C+D)			26,572	7,571	16,506	17,353	34,143	33,859	68,002
(E) Preliminary & Preoperative Cost			60	0			60	3,386	3,446
(F) Financial Cost for Debt syndication			125	25	1,651	1,735	150	-	150
(G) PMC charges			150	25			175	-	175
(G) Interest During Construction Period (IDC Cost of Borrowing)			2,503	500			3,003	-	3,003
Land acquisition			885	-	-	-	885	-	885
Compensation to fishermen and fee to TAPS			560	-	-	-	560	-	560
Total (INR in crores)			**30,855**	**8,121**	**18,156**	**19,088**	**38,976**	**37,244**	**76,220**

Table 19 Summary of Operations & Maintenance Cost Estimates

S. No.	Item	Annual Costs (Rs. in Crores) Phase 1	Phase 2
Terminal Operator			
1.	Container Terminal CT1	224.6	-
2.	Container Terminal CT2	224.6	-
3.	Container Terminal CT3	224.6	-
4.	Container Terminal CT4	224.6	-
5.	Container Terminal CT5	-	224.6
6.	Container Terminal CT6	-	224.6
7.	Container Terminal CT7	-	224.6
8.	Container Terminal CT8	-	224.6
9.	Container Terminal CT9	-	224.6
10.	Multipurpose Terminal	46.0	12.8
12.	RO-RO Terminal	7.6	-
14.	Bulk Liquid	15.0	-
15.	Liquid Jetty - Edible and Chemical – 2 No.	35.8	-
16.	In-port rail yard	57.4	109.2
JNPA			
1.	Landlord component	577.8	557.7

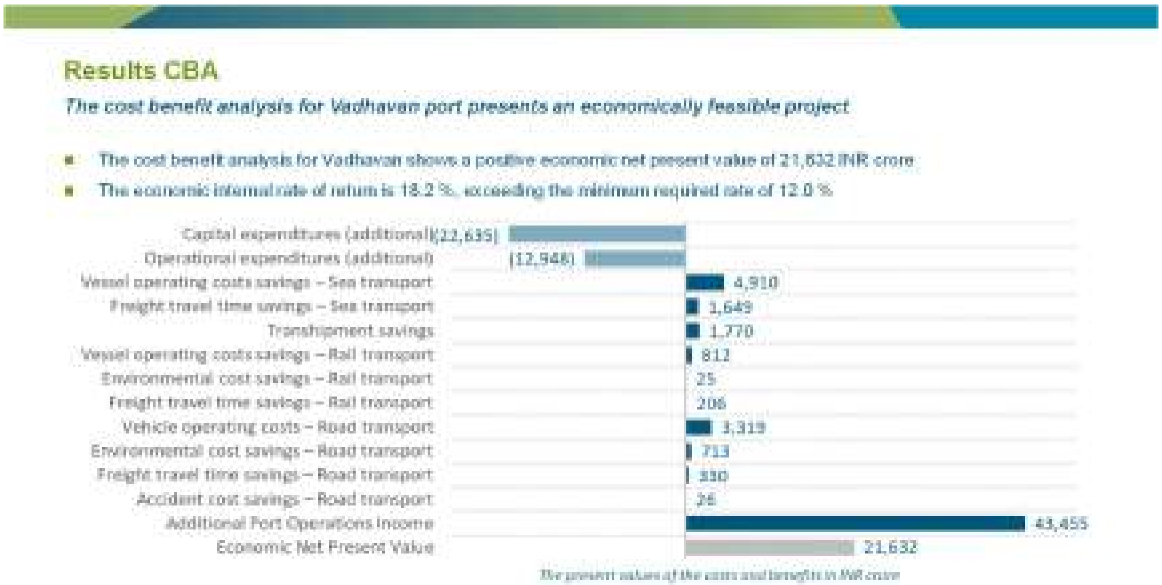
14.2. Financial Analysis

Results all Business Units

Key financial metrics unlevered free cash flow analysis

Business Unit	FIRR	FNPV INR cr.	FPBT years	FDPBT years	Phase 1 only FIRR	Phase 1 only FNPV INR cr.	Phase 1 only FPBT years	Phase 1 only FDPBT years	F. Hurdle Rate
JNPT (Port Authority)	11%	6,729	10	25	9%	(1,222)	18	N/A	10%
Container Terminal 1	21%	4,570	7	8	22%	4,530	7	9	16%
Container Terminal 2	21%	4,567	7	8	22%	4,567	7	9	16%
Container Terminal 3	20%	3,646	7	10	20%	3,648	7	10	16%
Container Terminal 4	20%	3,690	8	10	20%	3,690	8	10	16%
Container Terminal 5	19%	2,772	8	10	N/A	-	N/A	N/A	16%
Container Terminal 6	19%	2,771	8	10	N/A	-	N/A	N/A	16%
Container Terminal 7	19%	2,331	8	10	N/A	-	N/A	N/A	16%
Container Terminal 8	19%	2,319	8	10	N/A	-	N/A	N/A	16%
Container Terminal 9	18%	1,828	8	10	N/A	-	N/A	N/A	16%
Multipurpose Terminal	41%	5,026	4	5	41%	5,136	4	5	16%
Ro-Ro Terminal	17%	283	10	14	17%	283	10	14	16%
Liquids Terminal	25%	822	6	7	25%	612	6	7	16%
LPG Terminal	23%	442	7	8	23%	442	7	8	16%
LNG Terminal	N/A	-	N/A	N/A	N/A	-	N/A	N/A	16%
Rail Yard Terminal	15%	1,348	13	17	12%	588	13	19	16%
Rail DFC	9%	40	18	N/A	5%	(415)	19	N/A	10%
Toll Road	10%	326	14	25	5%	(845)	18	N/A	10%

14.3. Economic Analysis



15. Project Implementation Schedule

The project will be implemented in 52 months' time frame.

1 Introduction

1.1 Project Background

India has an approximately 5,423 km long peninsular coastline and is located close to major shipping routes linking East Asia, Europe and the Middle East. India therefore has the potential to significantly grow its maritime trade with other countries and as its economy grows, necessity of developing ports for international trade will also grow. Presently, there are 12 Major Ports and 187 Non-Major ports in India. The Major Ports are all Government owned and handled around 54% of India's maritime trade in 2019-20. The cumulative traffic handled by Indian Ports in 2019-20 were about 1,310 MT of which Major Ports contributed 704.9 MT and Non-Major Ports (minor and intermediate ports) handled 604.8 MT. Major Ports are ports developed by act of Parliament with Ministry of Ports, Shipping & Waterways, Government of India ownership. Non-major ports include ports owned by State Government, Private Ports, Captive Ports setup for specific cargo by large industries, etc. Though there are 187 non-major ports, the number of functional ports with more than 2 MT of annual traffic are 26 only.

The country's ports sector has witnessed strong growth over the past decade with total traffic handled by it increasing from 360 MT in FY01 to 1,310 MT in FY20. The traffic-handling capacity of major ports increased at a CAGR of 7.3% during 2012–2017 to reach 945 MT. During the same year, traffic handled at non-major ports grew at 8.6% year on year, largely due to the 12.4% year on year growth of Gujarat Maritime Board (GMB) ports.

The 12 major ports carry about 54% of the total port traffic of the country. The share of non-major ports in cargo traffic has increased from 7% in 1990 to the current levels of 46%. Large cities have grown around Major ports restricting its expansion, limiting cargo evacuation to hinterland. There exist inefficiencies at major ports. The non-major ports (especially private ports) are developed away from cities with modern infrastructure. The operational efficiencies of these non-major ports have gradually taken away incremental cargo of Major ports and with development of minor ports by the respective states. The Government of India initiated the ambitious SAGARMALA project which aimed at capacity enhancement of all major ports by means of increasing the productivity and efficiency through mechanisation of berths, stackyard and effective evacuation of cargo. Development of Vadhavan Port as satellite port of Jawaharlal Nehru Port Authority (JNPA) is one such initiative of Government of India. This would facilitate larger contribution of Major Ports in sea borne trade of India.

There has been an impressive growth of about 9% per annum in container traffic during the five years ending 2015-20. The container trade went up to 17.3 million twenty-foot equivalent units (TEU) by 2020 from 11.5 million TEU in 2015, 8.0 million TEU in 2010, 4.5 million TEU in 2005 and 2.1 million TEU in 2000. India's container traffic has grown by 8 times in last 20 years. There is certainly a need for new and state-of-the-art container port to sustain high trade growth. Vadhavan would provide good alternative for same.

Maharashtra with a coastline of 720 km stretching along the Arabian sea has two major ports. Mumbai and JNPA which cater to the hinterland of Maharashtra, North Karnataka, Telengana, Gujarat and secondary hinterland of NCR, Punjab, Rajasthan, and Uttar Pradesh. JNPA was developed as a satellite port of Mumbai port and has coped well in becoming the largest container port of the country. The development of Phase 2 of 4th container terminal is underway and after its full development there is little space for further expansion. Apart from that due to the presence of bed rock at or very close the existing bed level, JNPA cannot be deepened further economically to handle the future generation of mega container ships drawing draft of 16 m or more. There is a need for a deep draft port that will cater to the spill over traffic from JNPA port once its expanded capacity of 10 million TEUs is fully utilized.

With the projected demand for containers to go up, it is necessary to locate a new mega port site which can cater to increased requirement of capacity and could be developed to handle the future deep draft ships. Considering the above it has been decided to develop Vadhavan port as a satellite port for JNPA and for this purpose the present report has been prepared to assess its technical suitability and cost economics.

1.2 Salient Features of Phase 1 Development

Vadhavan Port is planned to be developed by JNPA (Jawaharlal Nehru Port Authority) and MMB (Maharashtra Maritime Board) as Joint Venture Project with equity share of 74% & 26% respectively. The port will be developed in two phases. The proposed port is to be developed on landlord model with the port terminals to be developed on PPP basis. In this model, basic infrastructure of the port necessitating upfront investment such as, breakwater, rail and road linkages, power, water lines and common infrastructure and services will be developed by the port/ SPV whereas all cargo handling infrastructure will be developed and operated by the agencies which are awarded concessions through global tender in an open and transparent manner by the port.

The Phase 1 development of port is envisioned to have the following components:

JNPA (Landlord)

Inside Port

- Breakwater of total length 10.14 km main breakwater
- Dredging 6.98 M cum (soil dredging – 3.97 M cum, Rock dredging – 3.01 M cum)
- Port craft/ Tug berth of 200 m (1 berth with berthing face of 100m on each side).
- Total Reclamation area inside the port 1448 ha. of 257 M cum with 1162 ha. in Phase 1
- Road inside the port 32 km
- DFC rail yard 227.5 ha.
- Buildings with area of 23,500 m^2
- Pavement inside port.

Outside Port

- Land acquisition 571 ha.
- External road connectivity of 33.4 km
- Rail linkage area length 12 km 40 m wide corridor
- Water pipeline from Kwadas reservoir
- Power line from Boisar power station 20 km from port

Concessionaire (Operator)

- Container terminals including yard storage, equipment, internal terminal pavements, drainage, utilities networks etc., with berth length of 4000 m (4 terminbals each of 1000 m length) capable of handling upto 24,000 TEU vessel with 24,000 TEU design container vessels.
- Multipurpose berths of 1000 m (4 berths each of 250 m) including equipment, storage yard/ shed
- 1 Ro Ro berth of 250 m including storage and onshore facilities
- 2 Liquid berths of 200 m including pipelines and tankfarm
- 1 Bulk Liquid berth of 280 m including pipelines and tankfarm
- 1 Other Liquid berth of 400 m including FSRU and pipelines (provisional)

The port is designed primarily to cater container business. Other berths are being developed to utilise the waterfront facility given the Greenfield development.

1.3 Setting of Port Location

The proposed port at Vadhavan (Lat 19º55.8’N Long 72º39.6’E) is located along the west coast of India in the state of Maharashtra, which is about 150 km north of JN Port. The location of the port is as shown in Figure 1-1.

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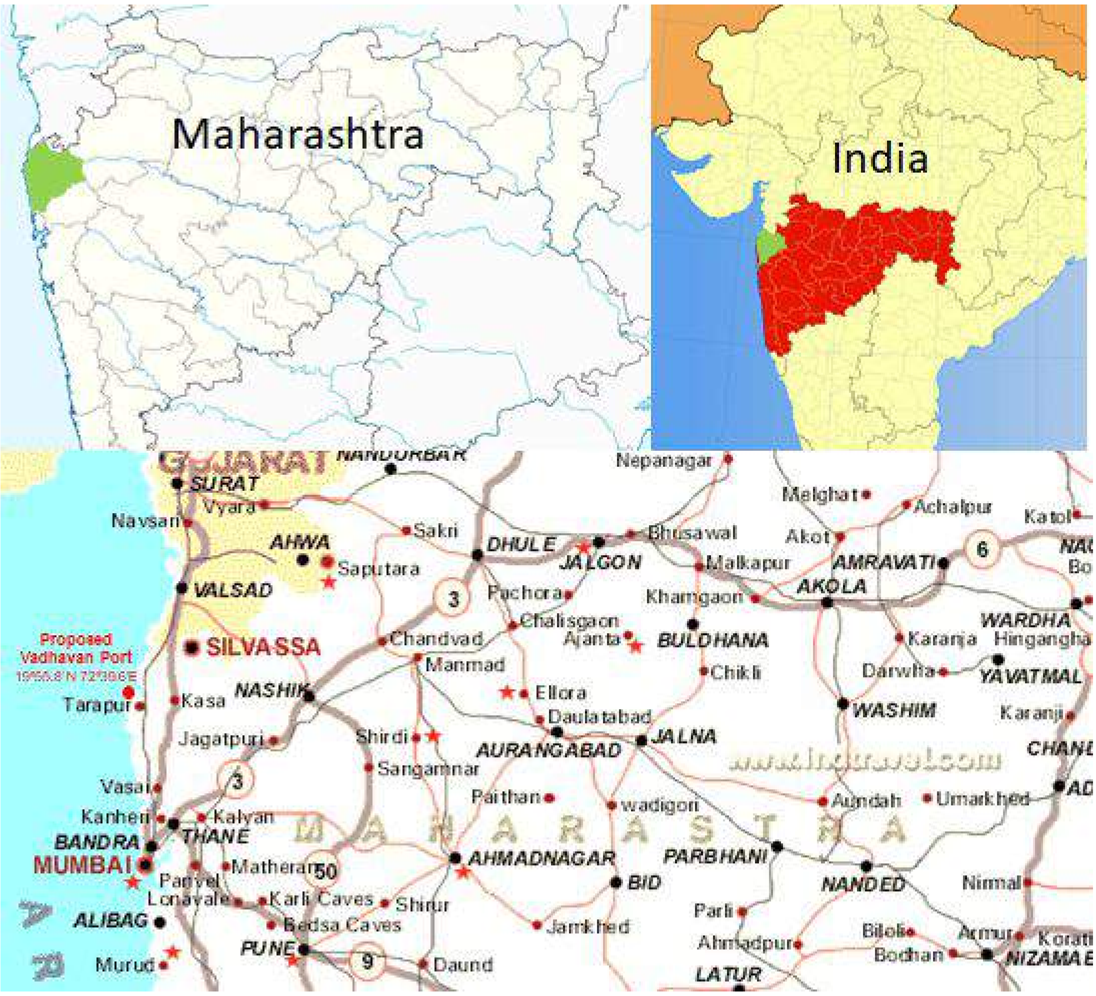


Figure 1-1 Location of Port

With the projected increase in container traffic growth in India and the Maritime India vision of doubling the container volume in next 10 years and aggressive economic growth in manufacturing activities, there is a requirement mega gateway port alternate to JNPA and other container ports along the west coast. Vadhavan is well placed for the development of mega port to handle bigger size container vessels. The natural water depth available at proposed Vadhavan port is more than any competing Indian port and more than or equal to competing international ports. It will be able to capture the increasing trend of larger container vessels which none of the existing Indian ports can service, due to which majority of containers destined or generated from India are being transhipped or double-handled from competing international ports, resulting in higher import/export cost. Vadhavan port will further enhance India’s ability to handle containerised cargo while establishing a strong supply chain network in Maharashtra.

Apart from catering to the needs of hinterland cargo, Vadhavan Port will facilitate entire country’s maritime trade and boost the development of a Special Economic Zones (SEZ) in the region due to opening of new supply-chain networks.

1.4 Detailed Project Report by PROGEN

JNPA through M/s. Progen-Pentacle appointed Ernst & Young (E&Y) to study the traffic potential at the proposed Vadhavan port. E&Y submitted their final report in March 2017. M/s. Progen-Pentacle prepared the Detailed Project Report for the proposed Greenfield port in October 2018. The Vadhavan Port is to be developed as a deep draft all weather multipurpose port with state-of-the-art facilities to ensure least turnaround time to the vessels. The port is planned to be developed in phases as and when the traffic builds up. The port master plan prepared by M/s. Progen-Pentacle is shown in Figure 1-2 envisaging 6,000 m container berth to handle the capacity up to 24 M TEUs in 2050, 1,000 m multipurpose berth, RORO, Other Liquid, Bulk Liquid, bulk liquid berths and coal berths.

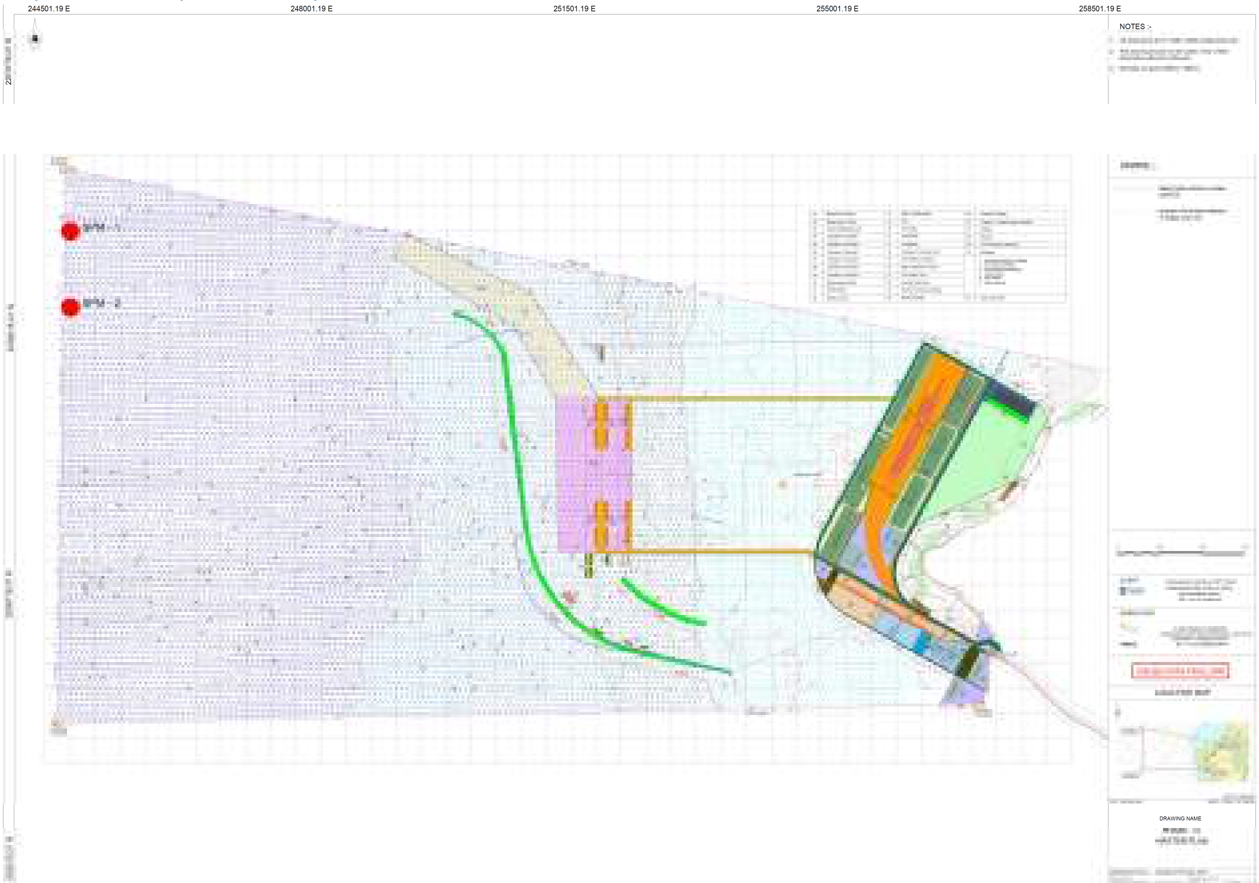
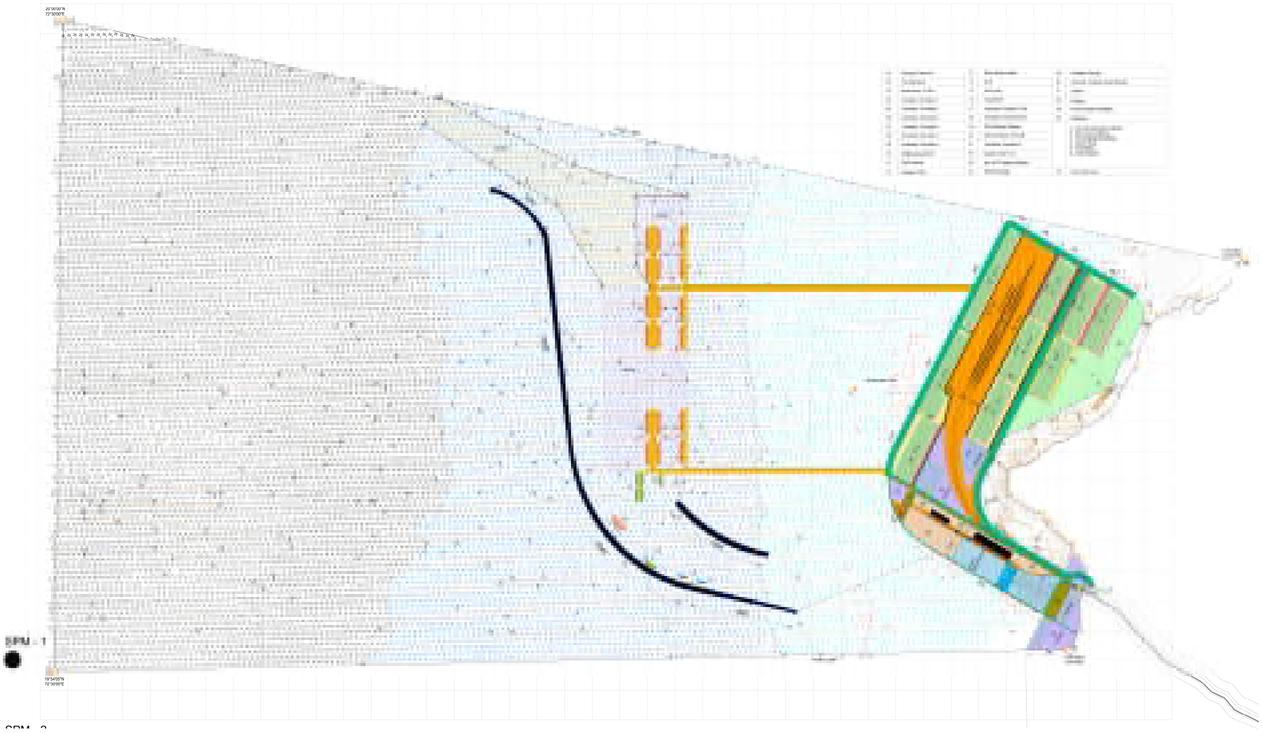


Figure 1-2 Port Master Plan Layout

[Source: Progen-Pentacle Detailed Project Report, October 2018]

Subsequently, JNPA approached the Ministry of Ports, Shipping & Waterways, Government of India for the approval of the proposed port. Considering the Greenfield development, the Ministry advised the changes in the proposed port development considering the futuristic requirement and state-of- the-art development. The Ministry accorded in-principal approval for the port development and the modified port master plan layout is as shown below.



[Source: Ministry of Shipping Cabinet Note]

JNPA appointed RHDHV to prepare and update the Detailed Project Report (DPR) including Detailed Design and engineering of various components of port structures for both JNPA and the Concessionaire for the project after its need was identified in July 2020 for Environmental Impact Assessment (EIA) completion. JNPA has appointed M/s. Fine Envirotech Engineers for carrying out the EIA studies. The model studies for Ship Simulation were undertaken by DHI through Force Technology, Singapore, on a real time ship simulator in July 2018 for validating the alignment and dimensions of the approach channel of the planned port. The model studies for the hydrodynamic condition, wave transformation, sedimentation and wave tranquillity studies, wave flume studies for breakwater stability have been undertaken by Central Water & Power Research Station (CWPRS), Pune.

1.5 Objective and Outline of DPR

RHDHV was entrusted on 30th September 2020 to prepare a Detailed Project Report for Phase 1 Development of Greenfield port at Vadhavan to cater to the forecasted traffic which would be met by providing the harbour, berthing, storage and evacuation facilities at the port – a step forward based on the previous studies.

To realize this objective, the data and various studies already carried out for the proposed project were compiled and reviewed. This study was a step forward in terms of reassessing the port layout based on the prevailing site condition and model studies to cater to sixth generation container vessels forecasted to call at the port.

The outcome of the studies is presented in the current report to assist JNPA in EIA clearance process for the proposed Greenfield port.

1.6 Field Investigations and Studies Organised by JNPA

JNPA have carried out the necessary technical studies, which have become the basis of this report. Additional studies were also carried out as part of updating the DPR through various other agencies Table 1-1 mentions reports related to Vadhavan port project and work carried out by previous consultants that have been sourced and referenced in preparation of the DPR:

Table 1-1 Past Studies carried out for Vadhavan Port

Reports	Volumes
Detailed Project Report, 2018 (M/s. Progen Pentacle)	• Volume 1 – Executive summary • Volume 2 – Traffic Study and Demand Assessment Report • Volume 3 – Surveys and Investigations - Land & Marine geotechnical investigation, oceanographic, quarry, resource • Volume 4 – Rail & Road Connectivity, Port complex building • Volume 5 - Port Master Plan & Preliminary Engineering Report, Report on Rail Operations • Volume 6 - Report on Socio-Economical Impact Assessment • Volume 7 - Report on Land Acquisition • Volume 8 - Mathematical Model (CWPRS) & Real Time Simulation (DHI) • Volume 9 - Report on Financial Viability • Socio-Economic Impact Assessment, 2017
Mathematical Model and Wave flume Study Report (CWPRS)	• Shoreline Changes Report (Jan. 2018) • Wave Tranquillity Report (Jan. 2018) • Desk Studies for Prediction of Extreme Wave Conditions (Mar. 2018) • Mathematical Model Studies for hydrodynamic & Siltation studies (Mar. 2018) • Desk & Wave Flume Studies for Breakwater Design (Nov. 2018) • Mathematical model studies for assessment of thermal dispersion from TAPS due to proposed port at Vadhavan (Dec. 2018) • Model Studies on Impact of proposed port on Tarapur Atomic Power Station (Jan. 2019). • Desk and 2-D Wave Flume Studies for the Design of Revised Breakwater Cross-section for the Development of Port at Vadhavan (Sept. 2021) • Model studies for Tidal hydrodynamics and Siltation for revised layout of Phase 1 and Master Plan for Port at Vadhavan (Nov. 2021) • Model Studies for Assessment of Wave Tranquillity for modified final layout of proposed Vadhavan port (Nov. 2021) • Model studies to assess the impact of proposed capital dredging on tidal hydrodynamics of nearby area of proposed Vadhavan port (Nov. 2021)
Other Reports	• Vadhavan Port Navigation Study Draft, DHI - Force Technology, July 2018 • AutoCAD for Master plan, JNPA 2019 • CLI Report, May 2018 • Suspended particle analysis • Draft EIA Study Report, Global Management and Engg. Consultant, Sept. 2018 • Hazard Analysis Study Report

Reports	Volumes
	• Key Plan of Proposed road connecting Vadhavan to NH-8 at Village Charoti • Key Plan of Proposed rail yard at Village Newale • Key Plan of Proposed rail connecting to village Varor to W.R., at Village Newale • Key Plan of Proposed road connecting Vadhavan to NH-8 at Village Tawa • Shoreline change map by National Centre for Sustainable Coastal Management, 2016 • Ecology & Biodiversity Study, 2021 • Demarcation of High Tide Line and Low Tide Line by Institute of Remote sensing, Anna University, Chennai in 2021 • Impact Study on Proposed Vadhavan Port on Coastal Fisheries, 2021, CMFRI • Traffic Analysis in the Vicinity of Proposed Port at Vadhavan, May 2021, IIT Mumbai.

1.7 Project Status

RHDHV submitted the Detailed Project Report for the Development of Vadhavan Port in Feb. 2021. The proposed port master plan and Phase 1 layout as per the DPR is as indicated below.

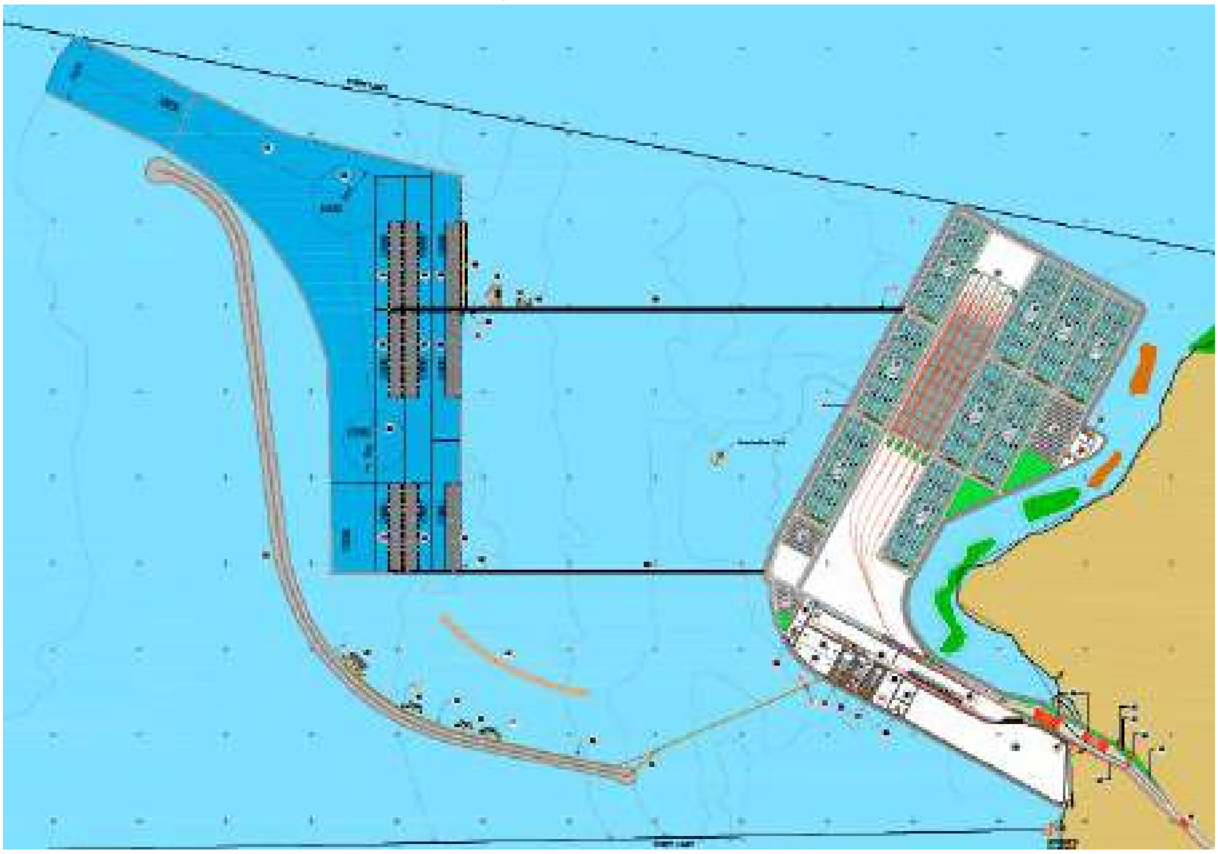


Figure 1-4 Proposed Master Plan Layout for Vadhavan Port as per DPR Feb. 2021

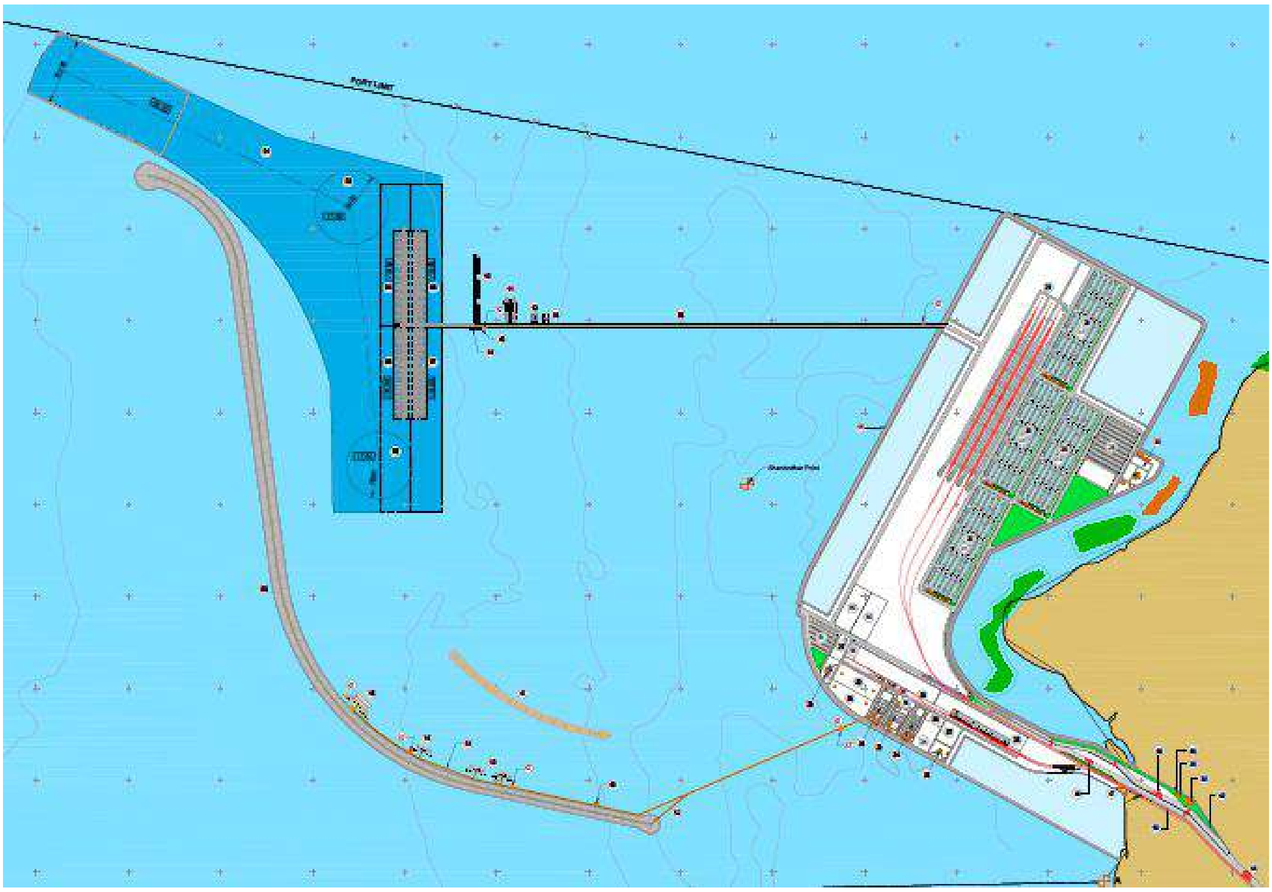


Figure 1-5 Proposed Phase 1 Layout for Vadhavan Port as per DPR Feb. 2021

The salient features of this layout are as below:

- Breakwater of total length 12,040 (main breakwater of 10,140 m and current deflecting wall of 1,900 m).
- Deep draft container berths located at 15 m depth contour connected to the shore with south and north approach trestles of 6-7 km long.
- Container yard and other port infrastructure located on the reclaimed land towards the shore.

Most of the container terminals across the globe prefer to have the yard area just behind the berth making it more efficient from operations perspective. Accordingly, it was decided to relook into the port master plan layout taking into consideration the capital investment required for the project and operation efficiency. The high operating costs associated with the long access trestles connecting the offshore berths to the onshore back-up storage facilities meant that the project was not attractive to potential terminal operators interested in investing in the project. Based on various level of discussions on the proposed port master plan with various stakeholders especially the various port operators/ developers, it was decided that the port master plan need to relook from the operational efficiency once the port is fully developed.

In view of the above, RHDHV prepared various alternative layouts to arrive at the most optimum one which would be a mixture of balance in the capital as well as the operational cost which is covered in this report.

1.8 Organisation of Detailed Project Report

The Detailed Project Report has been finalized after modification in the proposed port layout including the updated results of mathematical model studies carried out on the new port layout and taking into considerations the views of JNPA and the entrusted technical committee appointed by JNPA on the DPR.

The Detailed Project Report presented is organized in the following sections:

- Section 2 – Site Appreciation
- Section 3 – Site Specific Survey
- Section 4 – Traffic Study
- Section 5 – Port Operations & Functional Requirements
- Section 6 – Port Master Plan
- Section 7 – Terminal Equipment and Utilities
- Section 8 – Preliminary Design of Marine Structures
- Section 9 – Preliminary Design of Landside Structures
- Section 10 – Rail and Road Corridor
- Section 11 – Socio Economic Impact Assessment
- Section 12 – Land Acquisition
- Section 13 – Mathematical Model Studies
- Section 14 – Financial Viability
- Section15 – Project Benefits
- Section 16 – Implementation Schedule

2 Site Appreciation

2.1 General

The distinctive features of the location identified are as below:

- A natural water depth of around 20.0 m below CD is available at 10 km from Vadhavan point and 15 m contour is available at a distance of 6 km which will allow safe voyage and mooring for the new generation vessels.
- Land required for port is about 1443 ha. and is planned to be developed through reclamation. Offshore marine area between 5.0 and 15.0 m contours is proposed to be reclaimed for backyard area development which is ideal and eliminates the scope of land acquisition and rehabilitation. Thus, avoiding the R&R issues.
- As deep-water depth is available from 6 to 10 km, new generation vessels calling for deep draft can be planned with minimal cost on dredging.
- Connectivity to national highway NH-8 (Mumbai-Delhi), upcoming Vadodara-Mumbai Expressway, existing Indian railways link and upcoming DFC (Dedicated Freight Corridor) is available at short distances for providing connectivity to cargo destinations centre in the hinterland.
- The Road and Rail Connectivity can be availed through uninhabited areas which do not call for rehabilitation and resettlement.

2.2 Site features

The land close to Vadhavan site is flat and having undulations close to hilly area. The rocky outcrop close to shoreline of Vadhavan can be seen and indicate rock patches in the inter-tidal area.

The inter tidal zone is wide and extends up to 1.7 km into the sea. The beach is sandy. The general terrain of the site area is largely flat with a mild slope. The following gives a general picture of the site terrain:

Figure 2-1 Site Terrain in Vadhavan Port area

[Source: Progen-Pentacle Detailed Project Report, October 2018]

2.3 Port Location

The location plan of proposed Vadhavan Port with respect to JNPA and Mumbai Port is shown in Figure 2-2.

Figure 2-2 Vadhavan Location with reference to JNPA & Mumbai Port

The port limits for the proposed Vadhavan port is as shown in Figure 2-3.

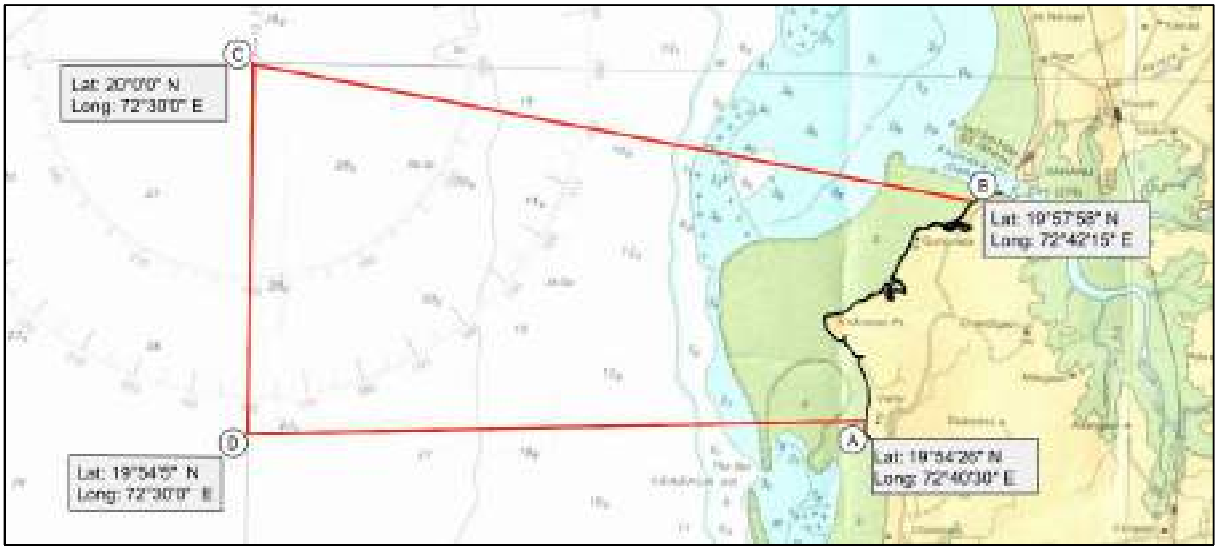


Figure 2-3 Vadhavan Port Limits

[Source: Progen-Pentacle Detailed Project Report, October 2018]

2.4 Meteorological and Oceanographic Information

2.4.1 Meteorological Information

This information has been extracted from previous/ historical studies for the project as well as from the West Coast of India Pilot (WCIP) climatological table applicable for the area and the project site.

2.4.1.1 Rainfall

The average annual rainfall is 1163 mm with the total number of rainy days of 51 per year. June to August is the wettest months of the year with an average rainfall in excess of 274 mm per month, with a maximum of 451 mm in July during the southwest monsoon period. February and March are dry months with average rainfall below 1 mm per month.

2.4.1.2 Temperature

The mean daily maximum temperature is 31°C and with 34°C the highest occurring in April. Mean daily minimum temperature is 24°C and with 18°C the lowest occurring in December.

2.4.1.3 Relative Humidity

Relative humidity is generally high and rises to about 85% during the monsoons in the month of August.

2.4.1.4 Visibility

Visibility is good throughout the year as the region has zero fog days. However, during rains and squalls, the visibility deteriorates.

2.4.1.5 Cyclone

In general, the west coast of India is less prone to cyclonic storms compared to the east coast. From the information reported by India Meteorological Department (IMD) it is observed from the tracks of the cyclones in the Arabian Sea from 1877 to 2012 that only 10 storms endangering the Mumbai coast have occurred in the above said period i.e., at a frequency of once in 12 years.

2.4.2 Oceanographic Information

This information has been extracted from previous/ historical studies for the project area and the project site.

2.4.2.1 Wind

Based on the ship observed offshore wind data from India Meteorological Department (IMD) for a period of 30 years from 1976 to 2005 for the grid covering Lat. 18° – 20° N and Long 71° – 73° E, it may be seen that west is the predominant wind direction and that the wind speed is less than 10 m/s for 88% of the time. The distribution of wind speed and direction is presented in Figure 2-4. The observations represent measurements taken at sea level for every 3 minutes.

The results are also presented in the form of monthly wind roses. It may be seen that the predominant wind is NE-N-NW in January. It gradually shifts towards west and by May it becomes NW to SW. During the months of June, July and August, the wind blows from W to SW. From September the wind direction starts changing and by December, again the predominant sector becomes NE-N-NW.

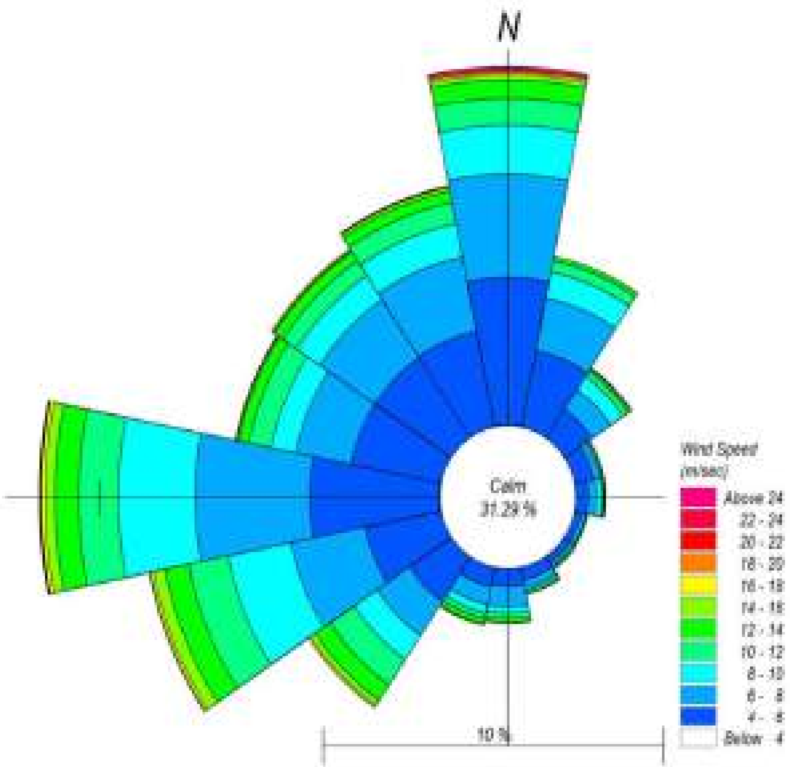


Figure 2-4 Wind rose diagram IMD, 1976 – 2005

[Source: Report 3: Oceanographic & Bathymetry Survey Report]

It may be observed that during the fair-weather season viz. October to May, the wind speed is less than 6 m/s for about 91% of the time. However, during the monsoon season (June to September), the wind speed is less than 8 m/s knots for only 62% of the time. It may also be seen that during the peak monsoon period (July and August), wind speed of 6 to 13 m/s occurs for about 29% of the time. Wind speed of 13 m/s is seldom exceeded. However, a maximum wind speed of 22.7 m/s has been reported, under normal conditions.

For this study, wind and wave data were also compared with the UK Met Office data. The data comprises of wind and wave parameters (wind speed and direction, wave height, wave period and wave direction for all resultant, sea and swell wave). The data covered a 12-year period between May 1999 and April 2012 and the point is located at 19.17°N 72.08°E at 46 m depth.

The wind speed at the offshore location was recorded more than 14 m/s from WSW direction (15%), which is also the most prominent wind direction and encountered during SW monsoon (Figure 2-5). About 85% of the time wind is less than 8 m/s.

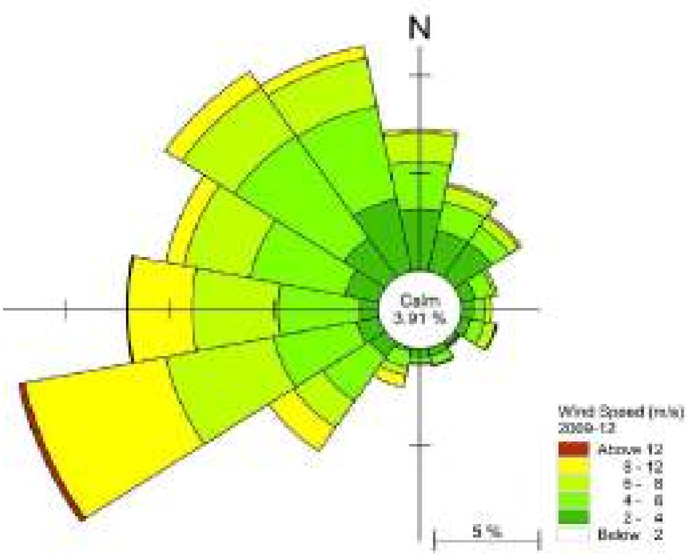


Figure 2-5 Wind Rose (UKMO: 1999-2012)

[Source: Report 3: Oceanographic & Bathymetry Survey Report]

2.4.2.2 Waves

The ship observed wave data were collected from the India Meteorological Department (IMD) for the quadrant bounded by Latitudes 18° to 20° N and Longitudes 71° to 73° E, between 1976 and 2005. The annual distribution of wave heights and wave period is given in the form of wave rose diagrams in Figure 2-6. It may be seen that the predominant directions of waves in the deep sea are from SW to NW. It can also be seen that waves are less than 1 m, 2 m and 3 m in height for 77%, 94% and 98% of the time respectively.

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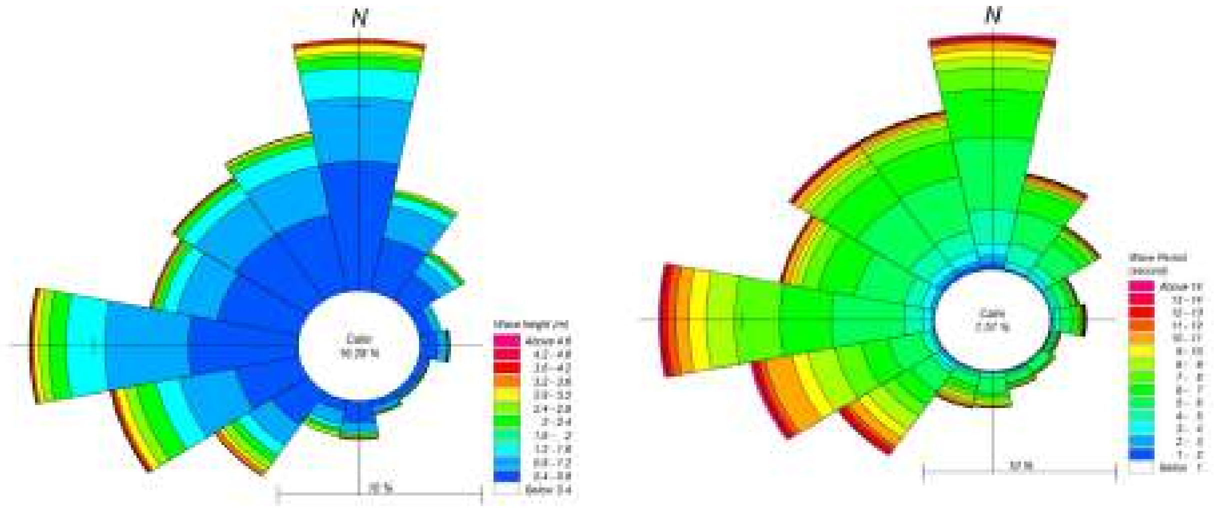


Figure 2-6 Wave rose diagram and Wave period IMD, 1976 – 2005

[Source: Report 3: Oceanographic & Bathymetry Survey Report]

During the pre-monsoon period (January to May) over 92.93% of waves are less than 3 m in height. During the monsoon period (June to September) wave heights are less than 2 m for 85% and less than 3 m for 97% of the time. During the post monsoon period (October to December) wave heights are more than 3 m for 0.9% of the time. The predominant wave directions are in the NW quadrant for pre-monsoon period, from W to SW during the southwest monsoon and from NE to NW in the post-monsoon period. These wave heights applicable for the offshore conditions and waves are completely attenuated as they enter the well-protected creek.

Based on UKMO data, the most prominent resultant wave direction is W (54.2%) followed by SW (23.8 %). Wave heights were found to be less than 3 m for about 93% of the time (Figure 2-7) Waves higher than 4 m were recorded for only 1 % of the time from the W and WSW directions. The resultant wave period varied between 2 s to 12 s for most of the time.

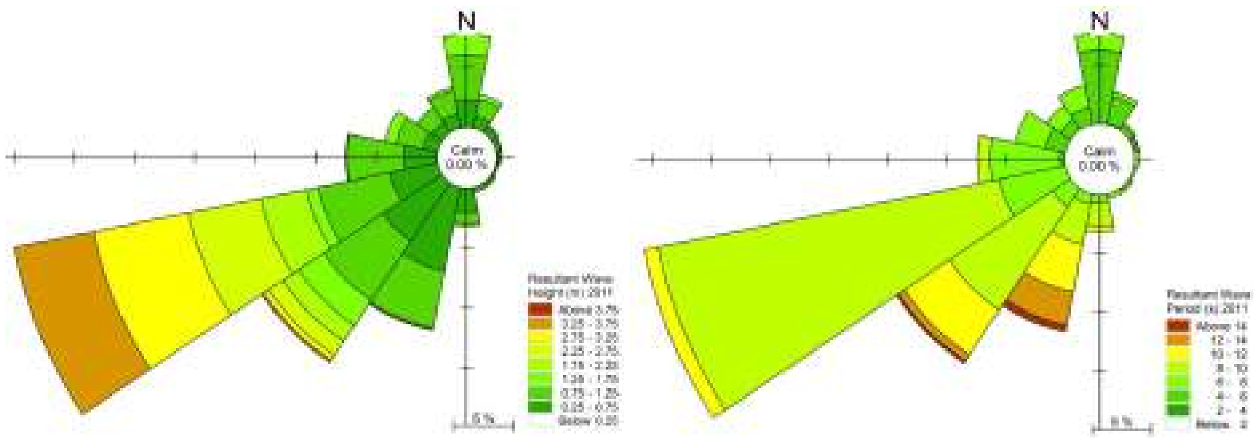


Figure 2-7 Resultant Wave height and period (UKMO: 2011)

[Source: Progen-Pentacle Detailed Project Report, October 2018]

2.4.2.3 Tides

The tides in the region are of the semi-diurnal type i.e., characterized by occurrence of two High and two Low Waters every day. Duration of each tidal cycle is between 5 to 7 hours (theoretically 6 hours and 12 minutes). There is a marked inequality in the levels of the two low waters in a day. Tide levels in the Vadhavan Port region as per the NHO Chart No. 210 Umargam to Satpati are summarised below.

Table 2-1 Tide levels in Vadhavan (NHO Chart No. 210)

Description	Tide Levels (m CD)
Mean High Water Spring	+4.7
Mean High Water Neap	+3.7
Mean Sea Level	+2.8
Mean Low Water Neap	+2.0
Mean Low Water Level Spring	+1.2

2.4.2.4 Current

The currents in the region are mainly of monsoon origin and sets in south-westerly and north-easterly direction with a strength of about 2.5 knots (1.25 m/s).

2.4.2.5 Seismicity

Vadhavan Port site is in Zone III of Indian Map of Seismic zones (IS-1893 Part-1 2002) which is a moderate risk seismic intensity zone. The zoning map as per Geological Survey of India is as shown in Figure 2-8.

However, considering the Palghar earthquake sequence, whose largest magnitude was 4.5 till now and considering the project of national importance and vital installations, it was advised by CSIR - National Geophysical Research Institute to consider the seismic zone IV in design parameters.

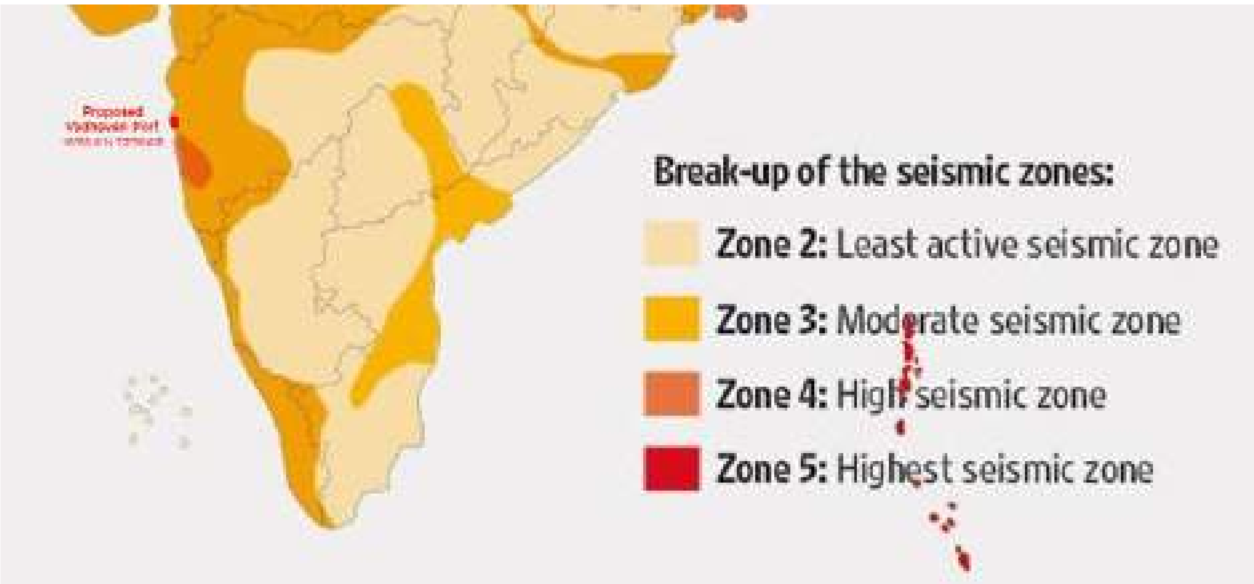


Figure 2-8 Seismic Zoning Map as per Geological Survey of India (GSI)

[Source: Geological Survey of India]

2.5 Transport Linkages and External Infrastructure

The site is150 km north of JNPA and 150 km west of Nashik and 180 km south of Surat.

2.5.1 Rail Connectivity

Vadhavan is 12 km away from Vangaon Railway Station along Mumbai-Surat Western Rail Link. Further Dedicated Freight Corridor (DFC) is planned to connect Mumbai -Delhi is also 12 km from proposed port location with provision of Rail yard near Vangaon.

2.5.2 Road Connectivity

The port location is 33.4 km away from NH 8 i.e., Mumbai-Delhi 6-lane National Highway and connected with State highway at Tawa Junction. Further Mumbai-Vadodara Expressway is also coming up at a distance 22 Km from Port location near Ravate.

Figure 2-9 Rail and Road Connectivity

[Source: Progen-Pentacle Detailed Project Report, 2018]

2.5.3 Power Supply

Two locations of the nearest 220 kV source from Assangaon-Boisar and Dahanu were identified.

The Assangaon-Boisar power grid located at 20 km away from Vadhavan site by overhead 220 KVA HT Line to Vadhavan port site.

Figure 2-10 Location of Boisar Substation

[Source: Sagarmala Report, 2016]

2.5.4 Water Supply

The water source identified for the port operations is Kawadas Weir near Dhamni Dam at the East of NH-8 about 40 km (approx.) away from the proposed Vadhavan Port.

Figure 2-11 Location of water source

[Source: Google maps]

JNPA has decided to have the water pipeline alignment running parallel to the state highway from Kawdas Pickup Weir till NH-8, running parallel to NH-8 till connectivity point of NH-8 to proposed port road and then finally running on the utility corridor provided with water line facility parallel to the proposed port road. Maharashtra Jeevan Pradhikaran (Government of Maharashtra) will be facilitating the required water supply to Vadhavan Port.

2.5.5 Construction Material

Development of an all-weather deep draft port would require a large quantity of stones/ rocks of various sizes for construction of breakwaters, murrum material for reclamation. From the available information it is understood that a total of seven hillocks are identified and proposed as prospective mining locations for murrum and stone/ rock to be used in reclamation of port, embankment of road and railway and breakwater. Identified hillocks are situated in villages of Palghar Taluka. Hillocks located in villages of Dahanu Taluka are purposefully avoided since 'Dahanu Taluka' is environmentally protected zone.

The geological conditions in the study area are dominated by basalt. Successive eruptions of basalt have formed the Deccan plateau region of South West India. Hillocks of height varying from 120 m from MSL to 400 m from MSL can be located around port location.

Quality of rock in identified nearest locations is of basaltic origin with weathered soft strata (murrum) carpet of 1 m to 8 m thickness. Fractured and jointed amygdaloidal basalt is found below soft strata. Large size boulders predominantly are encountered in soft strata carpet. Visual observation of rock suggests good quality for breakwater construction purpose. Geotechnical properties can be further evaluated and confirmed before excavation. The quarry details are as indicated below:

Table 2-2 Quarry locations

S. No.	Quarry location (Hillock)	Distance from Port (km)	Ownership
	Gargaon (A)	17	Government/ Forest land
	Gargaon (B)	17	Government / Forest land
	Khanivade (C)	19	Government/ Forest land
	Khanivade (D)	19	Government/ Forest land
	Mahagaon (E)	20	Government/ Forest land
	Mahagaon (F)	20	Government/ Forest land
	Nanivali (G)	25	Government/ Forest land

[Source: Progen-Pentacle Detailed Project Report, 2018]

Additionally, JNPA identified additional prospective private quarry sites for rock sourcing. The quarry details are as indicated below:

Table 2-3 Additional private quarry locations

S. No.	Quarry location (Hillock)	Distance from Port (km)	Ownership
1.	Borsheti	24	Private
2.	Kirat	25	Private
3.	Nagzari	26	Private
4.	Girnoli	28	Private

3 Site Specific Survey

3.1 General

Oceanographic data has been compiled previously in DPR prepared by Progen-Pentacle. Sea Geo Surveys Pvt. Ltd, Navi-Mumbai carried out the surveys and investigations. The surveys and investigations were carried out at Dahanu for the period from Jan. 2017 – Feb. 2017.

3.2 Sea Parameters

3.2.1 Sea Water Temperature

The average seawater temperature during the period of the investigation was 23.5°C.

3.2.2 Seawater density

The average sea water density observed was 1024 kg/cum.

3.2.3 Salinity

The salinity in the proposed project region is 35.5 PSU.

3.3 Oceanographic investigations

3.3.1 Wind

The wind speeds measured during this period varies from 0.2 knots to 4.0 knots with most of the wind blows from 0-45° N.

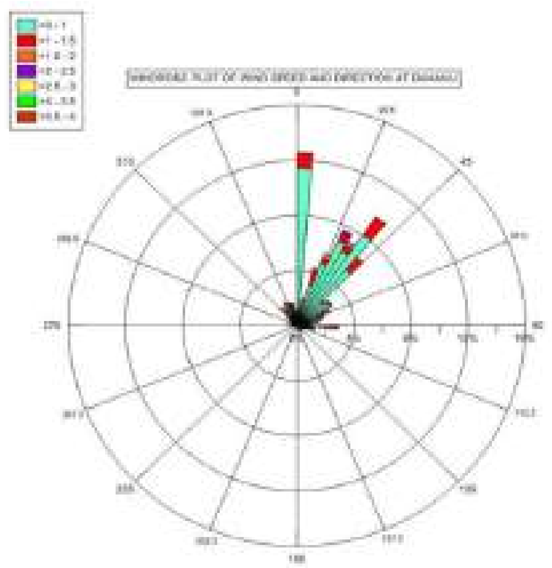


Figure 3-1 Measured Wind Rose at Dahanu

[Source: CWPRS Report, Technical Report No.: 5583, March 2018]

3.3.2 Waves

Wave climate in the area is dominated during SW monsoon period (June to September). High waves with comparatively shorter periods occur during the monsoon period and the sea appears to be calm in non-monsoon period except for the cyclonic events.

Site specific wave data collection was carried out by Progen-Pentacle through M/s. Seageo Surveys Pvt. Ltd. Acoustic Doppler Current Profiler (ADCP) for measuring waves and currents was deployed at 11.5 km off Dahanu, in the Arabian Sea for period of one month i.e., from 10th Jan. 2017 to 10th Feb. 2017 covering one full cycle of neap and spring tides. ACDP of RDI Sentinel Workhorse 600KHZ with accessories and mooring frames was used for the collection. The location of ADCP is as shown in Figure 3-2.

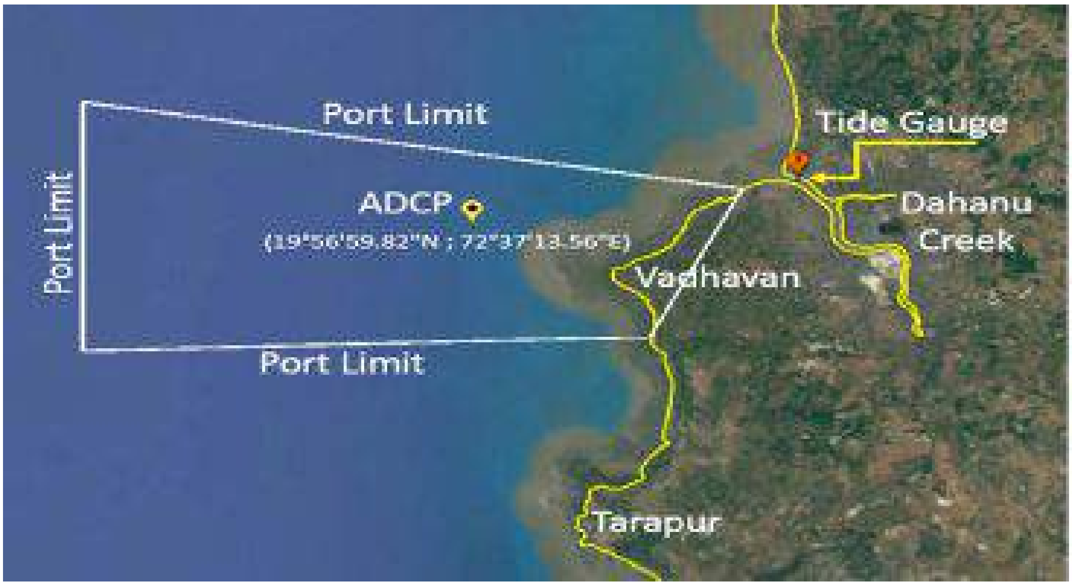


Figure 3-2 Location of Acoustic Doppler Current Profiler (ADCP) deployed

[Source: CWRPS Technical Report - 5583, March 2018]

The wave parameters that were recorded during the measurements included - Significant wave height (H_s), Peak Wave Period (T_p), Peak Wave Direction (D_p), Water Depth (WL), $H_{1/10}$, Mean Wave Period (T_{mean}) and Mean Wave Direction (D_{mean}).

The maximum significant wave height observed in the entire period is 1.19 m and the minimum of 0.14 m. In general, the amplitude of the wave height shows considerable variation changing from highs to lows with changing spring and neap tides. The variation of peak wave period is between a minimum of 2.0 sec to 16.90 sec and is dominant at around 4.0 sec. During spring tide, the peak wave period surges to highs of 17 sec and then consequently settling down to around 14 sec during transition from spring to neap. The wave direction is dominant in between directions 247.5° (West) and 360.0° (North - waves from Arabian Sea) during the observed period which is generally the post monsoon period. The peak wave direction perfectly matches with the location of observation i.e., with the coastline of Dahanu. The magnitude of significant wave is observed to be less from WSW and W when compared to NW and N.

The maximum and minimum significant wave height with the corresponding peak wave period and the occurrence time is given here below:

Table 3-1 Significant wave height details

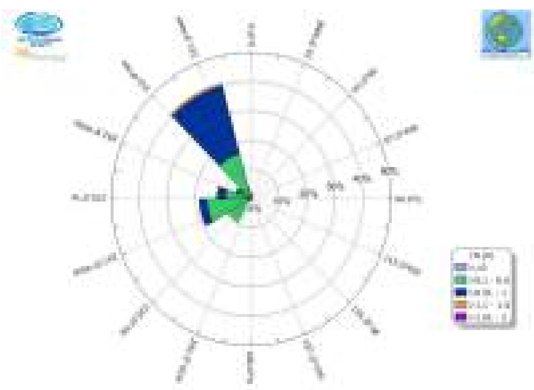
Wave Height (H_s)	Wave Period (T_p)	Wave direction
1.19	5.40	351°
0.14	14.90	244°

The Percentage of Occurrence of Significant Wave Height (Hs) and Peak Direction (Dp) is as indicated below:

Table 3-2 Occurrence Significant Wave Height (Hs) and Direction (Dp)

H_s (m)	Wave Direction from True North							
	N	NE	E	SE	S	SW	W	NW
0.0 – 0.2	1	0	0	0	1	8	15	2
0.2 – 0.4	11	0	0	1	0	34	73	37
0.4 – 0.6	10	0	0	0	0	0	18	53
0.6 – 0.8	12	0	0	0	0	0	7	38
0.8 – 1.0	7	0	0	0	0	0	6	8
1.0 – 1.2	5	0	0	0	0	0	3	0
Percentage Occurrence	**7.29%**	**0**	**0**	**0.16%**	**0.16%**	**6.66%**	**19.33%**	**21.87%**

Wave rose diagram indicating the significant wave height, wave direction and peak wave period during the investigation is as shown in Figure 3-3. The dominant direction is between 315.0° and 337.5° with wave height up to 1.51 m.



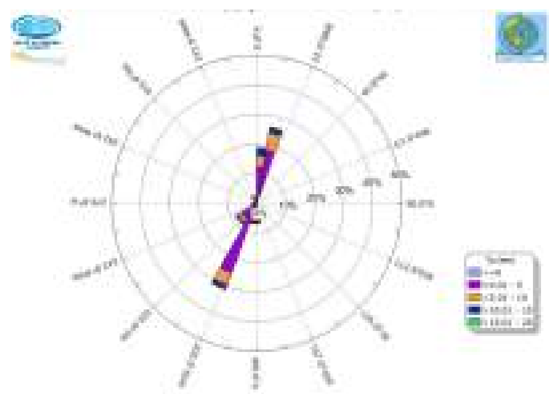


Figure 3-3 Wave rose plot of significant wave height, direction and peak wave period

[Source: Progen-Pentacle Detailed Project Report, 2018]

The above wave rose is only for one-month period of investigation, whereas the historical data represents pre-monsoon, monsoon and post-monsoon periods over an entire year. Therefore, the historical study can be considered more reliable and hence these results are considered for further analysis.

3.3.3 Current

The primary driving force behind ocean currents is constant winds. Wind creates currents as it blows over the water surface, producing a stress on the surface water particles and starting the movement of the water particles in the direction in which the wind is blowing that give rise to a surface current. Thus, a surface current is created.

When the surface current reaches a carrier, such as the coast, water tends to pile up against the land. Of all currents, those that flow near coasts have substantial effect on coastal landforms. The most important type of current in the coastal zone is a long shore current. Longshore current ("along the shore") is a current that flows in shallow water, parallel to the shoreline, generally downwind. Longshore currents transport sediments along the coasts, sometimes they are powerful enough to erode sea bottom. Surface currents in this region are driven mainly by tides, except during a short spell, when surface currents are influenced by the monsoon winds.

Currents are significant in the project area and primarily forced by tide and wind components. The vertical variation of currents measurements was carried out at the location (Figure 3-2) using ADCP instrument. ADCP data for currents were collected in the project area for the period of 27 days. The current speeds in general are observed within the range of 0.00 knots to 2.60 knots with the dominant speeds observed in the range of 0.20 knots to 1.60 knots. The current directions in general are observed in the entire range from 000.0° to 360° degrees with the dominant directions observed in the range of 348.75° to 033.75° during flooding and 191.26° to 236.25° during ebbing. The roll and pitch of the ADCP during the observation period remains relatively stable. The observations at different depths are summarised as below:

Table 3-3 Summary of Current Measurements

Location	Level of current above seabed (m)	Current Speed during flooding (Knots)		Current Speed during ebbing (Knots)	
		Min.	Max.	Min.	Max.
Surface	13.61	0.066	2.268	0.049	1.594
Near surface	12.61	0.075	2.550	0.037	1.816
Mid	8.11	0.008	2.439	0.023	1.757
Seabed	2.61	0.031	2.043	0.008	1.456

[Source: Progen-Pentacle Detailed Project Report, 2018]

The observed current data indicates that the flood and ebb flows do not follow a reversal in direction. The general flooding direction is between 000.00° to 022.50° (N-NNE), whereas the general ebbing direction is between 202.50° to 225.00° (SSW-SW). It is observed that the land abutting south of Dahanu bay juts out, obstructing the path of ebbing flow of currents straight along. Hence, the ebbing currents take an unobstructed direction towards SSW-SW.

3.3.4 Tides

Site specific tide measurements were carried out for the proposed development. The tidal observations were carried out using the Auto Tide Gauges (Figure 3-2). The recording of the data was carried out for a period of one month covering one full cycle of the neap and spring tides. The period of observation started from near spring tide covering near neap tide from 10th January to 10th February 2017. Tide gauge was set up and levelled to the Survey of India benchmark at Dahanu lighthouse, which is 7.81 m above chart datum, using RTK survey heights of tide were recorded continuously at this location, and used to reduce observed depths to Chart Datum. The observed tidal range was about 3.5 m during spring tide and 1.7 m during neap tide.

3.3.5 Bathymetry Survey

Bathy 500 dual frequency single beam echo sounder was deployed for the collection of bathymetry data. The seabed engineering surveys were carried out during Jan. – Feb. 2017. The survey maps were prepared in UTM co-ordinates (Universal Transverse Mercator) and supplemented by geographical co-ordinates (latitudes and longitudes in degrees, minutes and seconds), on WGS 84 datum. The depths are indicated with respect to chart datum. The bathymetric survey covered the proposed port limit with an area of 169 sq.km extending 18.4 km from the shore into the sea and about 7 km along the shore.

In general, the seabed is smooth on regional scale with a light gradient towards west. The contours have a general trend in NE-SW direction. Water depths within survey area range between a minimum of 0.0 m recorded in the Eastern end and maximum of 25.3 m at North West corner of the survey area. Rock outcrops appear in some places as high as 3 to 4 m above the adjoining seabed levels in the area.

The ‘0’ m contour is about 2.1 km from the shoreline at the NE corner, curving outwards for up to 4.9 km and then inwards. This contour tends to follow the general trend of the coast. The inter-tidal zone is thus observed to be about 2 km wide, between the shoreline and 0 m contour. 2 m contour starts about 2.5 km towards offshore from NE corner of the survey area and follows the general trend of the coast.

5 m contour lies at about 3.5 km west of Vadhavan point.10 m contour starts on the north side from about 4.5 km west of Vadhavan point and runs towards south. At its nearest point, the 15 m contour lies 1.5 km west of 10 m contour on the northern side, running in the S-SE direction. 20 m contour lies at about 10 km from Vadhavan point.

3.3.6 Geophysical Survey

3.3.6.1 Shallow Seismic Survey

Seismic survey was carried out to study the compactness of the seabed sediment. The extent of the survey area was similar to that of bathymetric survey.

The compactness of the sediment derived from the seismic records, is presented in the form of isopach map (or acoustic basement map). Water depths are overlaid on the isopach contours to understand the minimum navigable depth that can be achieved by dredging in the study region.

The sedimentary properties defined here are based on assessment of the recorded acoustic characteristics of the material along with interpreted sedimentary structures. In general, weathered bedrock is recorded all along the route below the surficial layer. The shallow geological successions within the window examined by the digital data within the surveyed area are described as follows:

- Unit A: Silty clay/sand
- Unit B: Weathered bedrock

Most of the rocks in and around comprise of basic volcanic rock of basaltic composition. Unit A is recorded as the surficial layer in survey corridor in depths of more than 15 m and is interpreted as comprising silty clay/sand. Maximum thickness of Unit-A surficial layer recorded up to 10.0 m below the seabed overlying the bedrock. Unit B is recorded all along the survey route within the survey corridor and is interpreted as comprising weathered bedrock.

This layer is seen to be present all along the survey area near to coast and seen as outcrops at certain places. This layer is seen to be sloping from 1 m at the eastern side of the area to about 13 m at the end of the survey area on the West as the depths increase.

The survey reveals predominant rocky seabed with buried channel comprising of soft clay over sand/gravel or highly weathered rock.

The bathymetry and isopach map of the project area is as shown in Figure 3-4.

3.3.6.2 Side Scan Sonar Survey

This survey reveals the seabed features and any obstruction to the navigational operations. Based on the acoustic reflectivity, it is observed on the side scan sonar records, the seabed sediments can be broadly classified into following categories.

- Unit A: Soft silty clay
- Unit B: Highly weathered rock /sand /gravel
- Unit C: Basalt rock

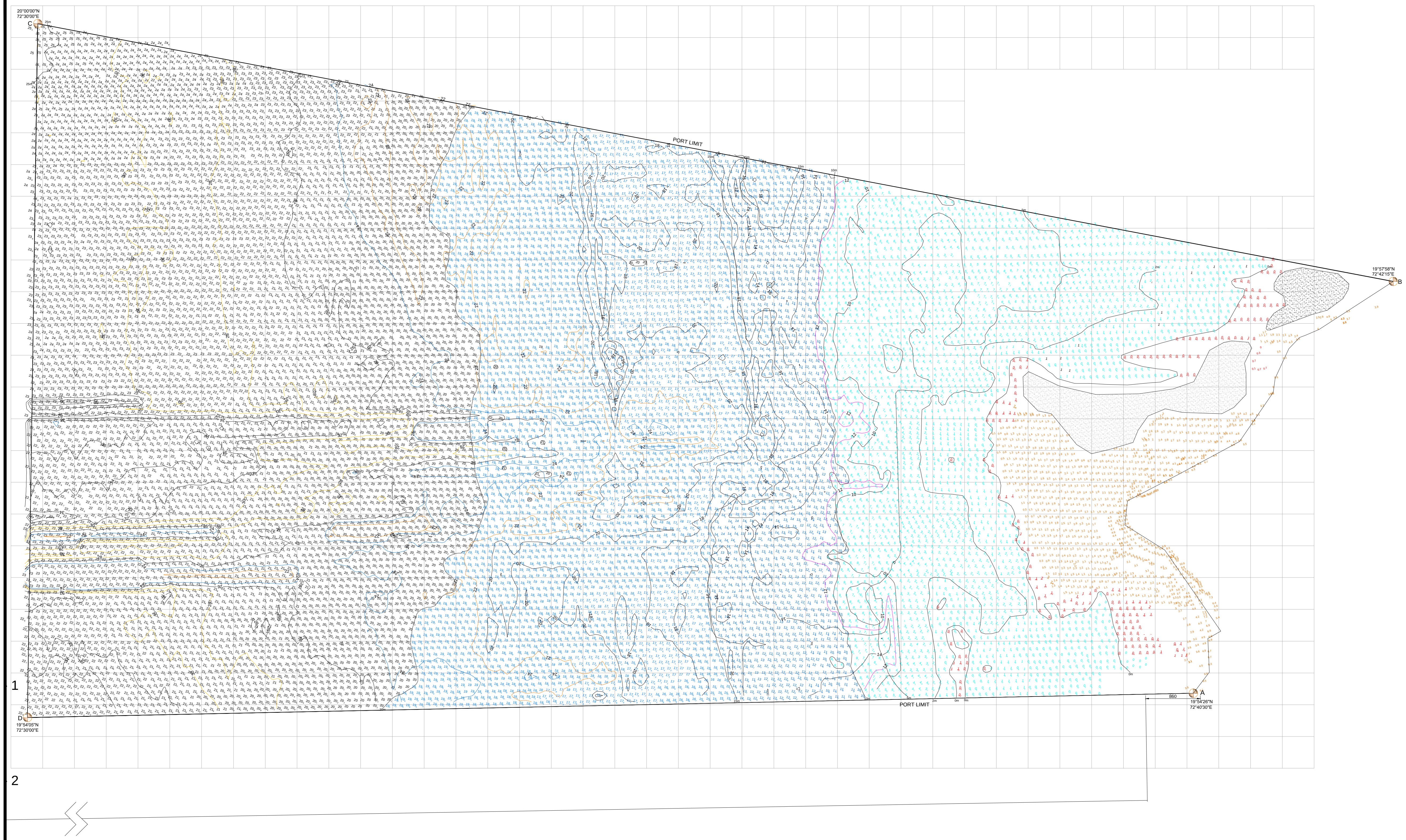
Unit A sediments are unconsolidated soft silt clay which are overlying the weathered rock. These sediments mostly occur in the top layer along a linear stretch on western side of the port near entrance of the harbour, and in some portion near the southern breakwater towards the berths.

Unit B sediments are identified as highly weathered rock /sand /gravel which is found beneath the top layer of Unit A type of sediments. Layers of Unit A and Unit B sediments are observed in intermittent patches on top of Unit C.

Unit C is the basalt rock, which is present all along the seabed in the entire harbour area. The basalt rock is exposed to open towards the eastern side of the harbour near the backup area.

No evidence of any cables and other submarine facilities were recorded in the survey area. The seafloor appeared to be clear of any debris other objects which are likely to be hazardous or otherwise obstruct anchoring and operations in the port.

DO NOT SCALE



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TITLE	PROJECT	CLIENT	CONSULTANT
BATHYMETRY AND ISOPACH SURVEY	Consultancy services for Design and Detailed Engineering for Greenfield Vadhavan port project	JAWAHARLAL NEHRU PORT TRUST	Royal HaskoningDHV Enhancing Society Together

Job No.	DI1452	DATE	24.12. 2020	SCALE	NTS
ACAD Ref.	-	CHECKED	ASM	PASSED	ASM
DRAWN	SNJ	FIGURE No.	FIGURE 3.4	REV	A

3.4 Water and Seabed Samples

3.4.1 Water Samples

Water samples were collected at 3 locations covering the spring and the neap tide. The samples were collected at three depths i.e., at surface, mid-depth and bottom for each location. Total of 108 samples were collected during the period of investigation to assess various properties such as the suspended solid concentration, salinity and pH.

Based on the outcome of the collected samples it was found that the average sediment concentration during spring tide is 0.23% and during neap it is 0.18%. However, it may be noted that the sediment concentration was presented in terms of % concentration as against mg/l. Also, the turbidity parameter was not assessed which would have been more useful for the sedimentation assessment.

Also, CWPRS during their study, in order to assess the siltation in the harbour area the information of suspended sediment concentration (non-monsoon season only) was provided by JNPA. The SSC data was collected at location (Figure 3-5) for 24 hr. in Jan. 2018 at mid depth for one hour interval during which the tidal range was of the order of 2.5 m.

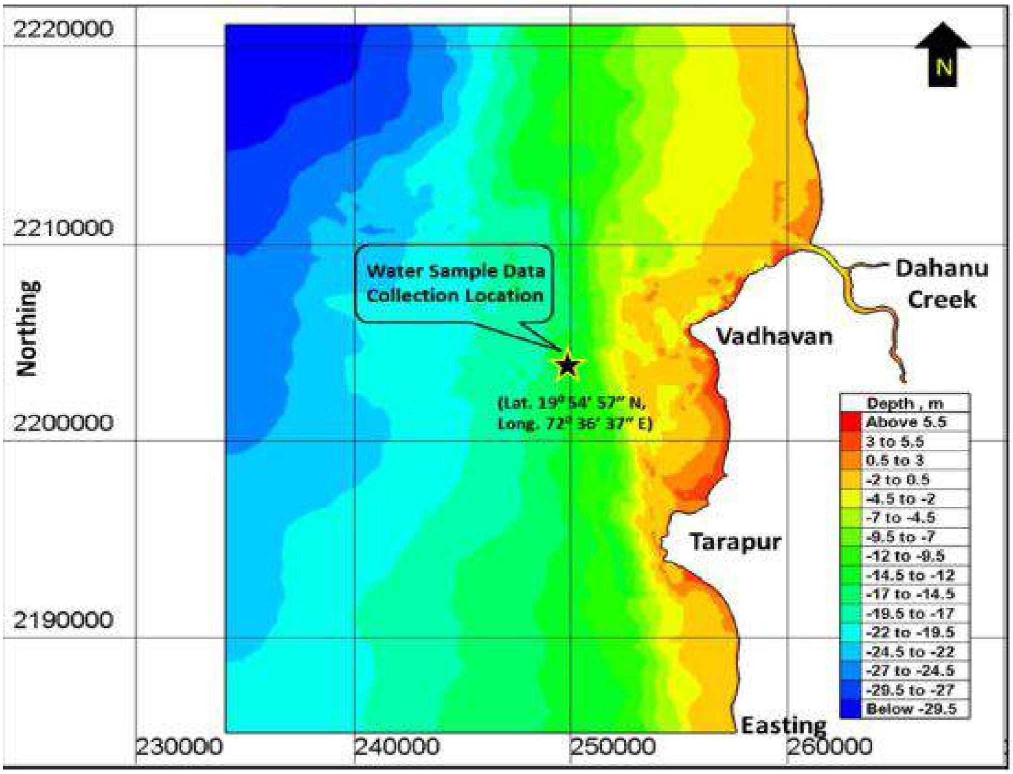


Figure 3-5 Location of water samples

[Source: CWPRS Report, Technical Report No.: 5583, March 2018]

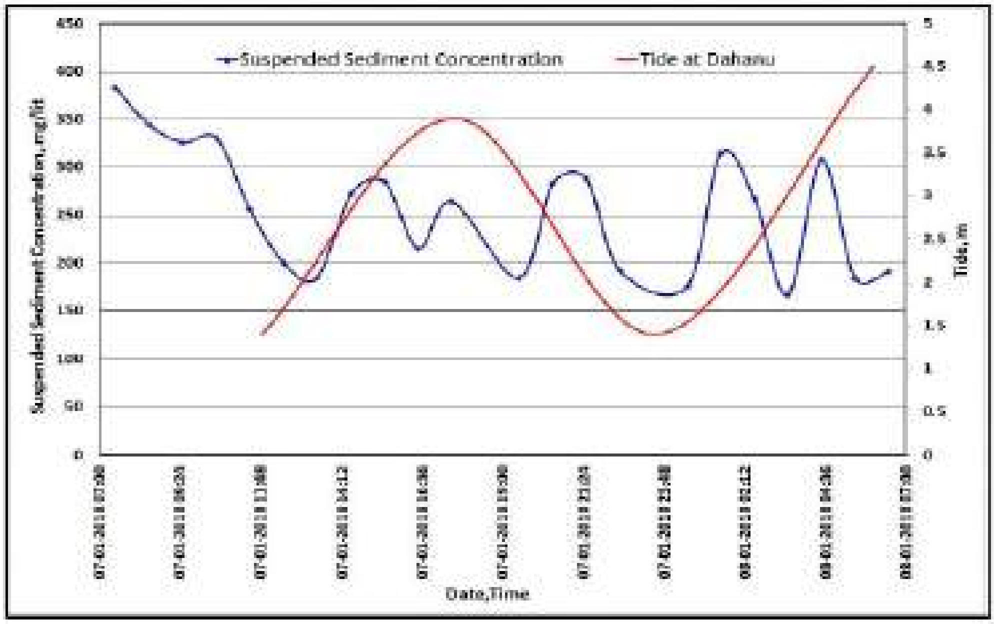


Figure 3-6 Suspended Solids Concentration plots

[Source: CWPRS Report, Technical Report No.: 5583, March 2018]

Based on the SSC plot, it may be noted that the SSC varies from 380 mg/lit to 170 mg/lit for non-monsoon season while the SCC was varying between 473 mg/lit to 105 mg/ lit during monsoon season. The SSC concentration is higher during the mid-tide level, while it reduces as the flow reaches the high water during the flood tide and low waters during the ebb tide. The grain size analysis of the suspended sediments reveal that the suspended sediments contain 68% of silt and 26% of clay and as such the sediment is classified as clayey silt.

3.4.2 Sediment Samples

Similarly, CWPRS through JNPA in Jan. 2018, collected the seabed sediment samples at 8 locations in the vicinity of proposed port area. The samples were analyzed in the laboratory for size distribution using sieve analysis.

The sample test results indicate that the seabed predominantly comprises of clayey silt with the Median sediment sizes (D_{50}) extracted from the grain size distribution varies between 0.005 to 0.015 mm. This indicates that the material in suspension and that at the bed is having similar characteristics with material of cohesive nature.

3.5 Geotechnical Survey

The geotechnical investigation was carried out by M/s Zed Geotechnics & Cons and reports for geotechnical investigation were submitted by Progen in May-June 2017 to assess and confirm the sub soil data. The broad objectives of the investigation were as follows:

- To acquire detailed geotechnical information on the sub seabed
- To assess the engineering properties and classification of soil / rock samples
- To provide geotechnical parameters and interpretation of the lithology across the site

Geotechnical investigation for marine areas was carried out through 61 boreholes. Additionally, 70 boreholes were carried out for proposed rail and road connectivity areas.

This section evaluates the geotechnical information available from 61 marine boreholes. These boreholes were explored between seabed varying from -0.31 m CD to -18.8 m CD combined with SPT/Disturbed sample followed by rotary coring, where the penetration refused. The marine borehole locations are as shown in **Figure 3-7** [Source: Progen-Pentacle DPR, 2018].

The investigation carried out for port area included drilling marine boreholes up to maximum depth of 20 m and drilling landside boreholes upto maximum 15 m depth, in-situ testing and laboratory test of selected samples.

The in-situ and laboratory tests performed on the soil and rock samples is summarised as below:

- In-situ Field Tests
  - In-situ Standard Penetration Tests (SPT)

- Geotechnical Laboratory tests
  - Atterberg Limits Tests
  - Density and moisture content of soil samples
  - Particle Size Distribution Tests
  - Uniaxial Compressive Strength of rock samples.
  - Density, porosity, moisture content of rock samples.
  - Chemical Analysis of the soil and water samples.

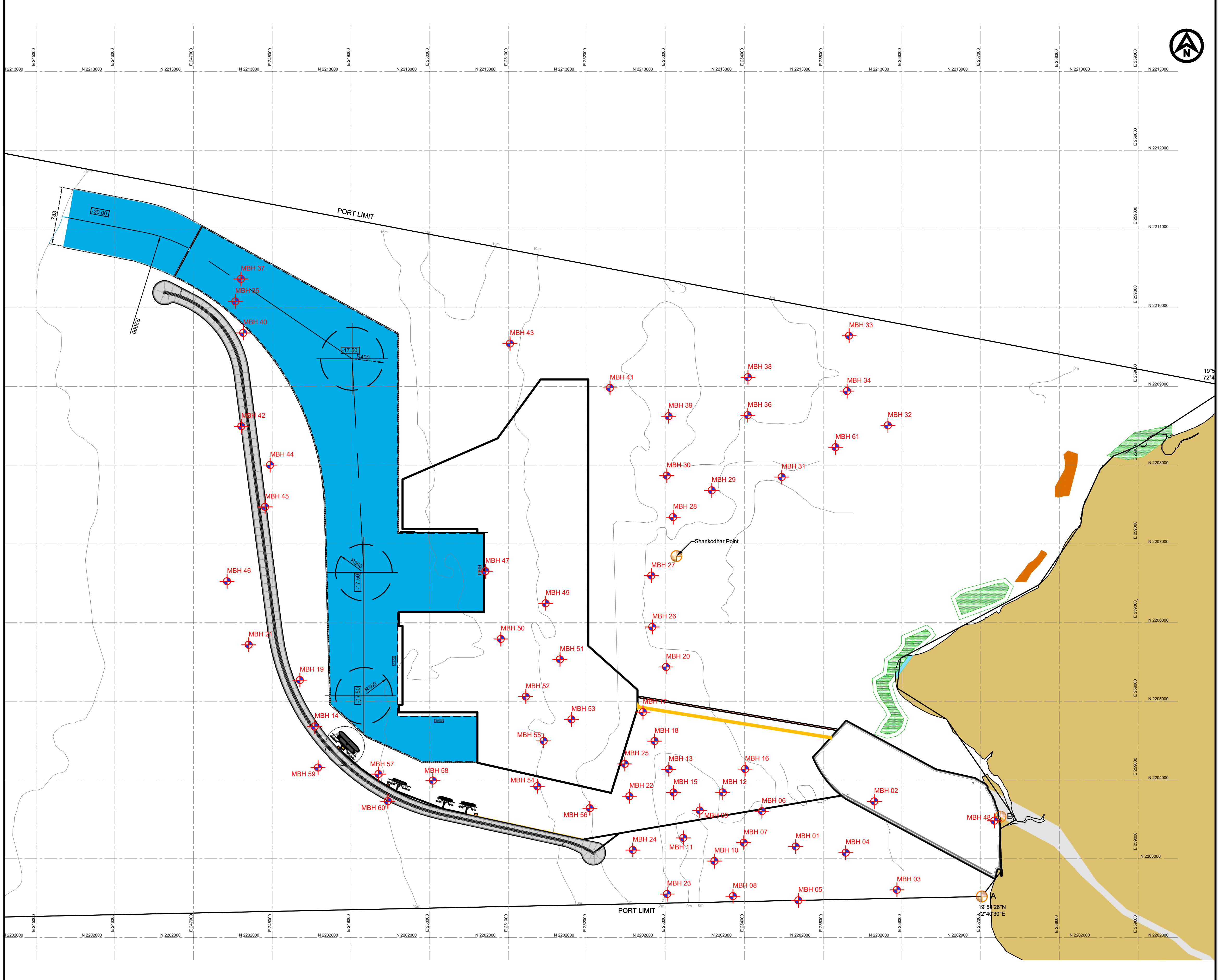
The in-situ testing and the laboratory testing were carried out in accordance with the relevant Indian standards.

3.5.1 Summary of Marine Geotechnical Investigation

Based on the layout developed by Progen - Pentacle, marine geotechnical investigations were undertaken by M/s Zed Geotechnics & Cons as part of the investigation study. The location plan of marine boreholes conducted at site is presented in Figure 3-7.

Specific borehole data has been utilized to prepare soil profiles to study the distribution of the sub strata and assess the geotechnical conditions of the particular component.

DO NOT SCALE



NOTES

1. ALL DIMENSIONS AND LEVELS ARE IN METERS, UNLESS NOTED OTHERWISE.
2. DRAWINGS ARE NOT TO BE SCALED, ONLY WRITTEN DIMENSIONS ARE TO BE FOLLOWED.

BOREHOLE CO-ORDINATES

BORE NO.	EASTING	NORTHING
MBH 1	254235.00 m E	2203532.00 m N
MBH 2	255232.89 m E	2204105.73 m N
MBH 3	255520.30 m E	2202982.84 m N
MBH 4	254870.50 m E	2203454.00 m N
MBH 5	254269.57 m E	2202848.96 m N
MBH 6	253805.32 m E	2203981.00 m N
MBH 7	253574.41 m E	2203581.14 m N
MBH 8	253437.21 m E	2202902.43 m N
MBH 9	253015.46 m E	2203989.00 m N
MBH 10	253203.23 m E	2203348.24 m N
MBH 11	252807.21 m E	2203643.05 m N
MBH 12	253308.19 m E	2204219.60 m N
MBH 13	252621.93 m E	2204515.27 m N
MBH 14	248124. 00 m E	2205058.00 m N
MBH 15	252683.62 m E	2204218.76 m N
MBH 16	253591.86 m E	2204516.05 m N
MBH 17	252294.65 m E	2205239.96 m N
MBH 18	252442.44 m E	2204872.95 m N
MBH 19	247936.00 m E	2205647.00 m N
MBH 20	252588.04 m E	2205814.55 m N
MBH 21	247286.00 m E	2206096.00 m N
MBH 22	252122.00 m E	2204172.61 m N
MBH 23	252602.00 m E	2202929.00 m N
MBH 24	252166.20 m E	2203488.66 m N
MBH 25	252063.00 m E	2204581.81 m N
MBH 26	252412.15 m E	2206322.42 m N
MBH 27	252400.66 m E	2206974.60 m N
MBH 28	252677.65 m E	2207716.87 m N
MBH 29	253168.00 m E	2208058.00 m N
MBH 30	252597.00 m E	2208243.00 m N
MBH 31	254057.00 m E	2208226.00 m N
MBH 32	255406.55 m E	2208882.02 m N
MBH 33	254913.42 m E	2210021.42 m N
MBH 34	254886.27 m E	2209317.85 m N
MBH 35	247117.00 m E	2210458.00 m N
MBH 36	253626.76 m E	2209012.55 m N
MBH 37	247186.00 m E	2210743.00 m N
MBH 38	253628.00 m E	2209494.00 m N
MBH 39	252619.34 m E	2208999.98 m N
MBH 40	247216.00 m E	2210058.00 m N
MBH 41	251875.57 m E	2209359.85 m N
MBH 42	247193.00 m E	2208872.00 m N
MBH 43	250604.27 m E	2209922.03 m N
MBH 44	247558.00 m E	2208379.00 m N
MBH 45	247494.00 m E	2207847.00 m N
MBH 46	247011.00 m E	2206901.00 m N
MBH 47	250294.00 m E	2207030.00 m N
MBH 48	256758.00 m E	2203860.00 m N
MBH 49	251058.92 m E	2206623.24 m N
MBH 50	250487.91 m E	2206169.51 m N
MBH 51	251239.90 m E	2205909.40 m N
MBH 52	250806.00 m E	2205438.00 m N
MBH 53	251387.00 m E	2205148.00 m N
MBH 54	250952.00 m E	2204299.00 m N
MBH 55	251033.67 m E	2204875.25 m N
MBH 56	251619.64 m E	2204020.39 m N
MBH 57	248936.00 m E	2204454.00 m N
MBH 58	249626.00 m E	2204371.00 m N
MBH 59	248166.00 m E	2204536.00 m N
MBH 60	249053.00 m E	2204108.00 m N
MBH 61	254742.00 m E	2208605.00 m N

TITLE: VADHAVAN PORT EXISTING BOREHOLE LAYOUT	PROJECT: Consultancy services for Design and Detailed Engineering for Greenfield Vadhavan port project	CLIENT: JAWAHARLAL NEHRU PORT TRUST	CONSULTANT: Royal HaskoningDHV Enhancing Society Together	
Job No. DI1452	DATE SEP. 2021	SCALE 1:50		
ACAD Ref. -	CHECKED NN	PASSED ASM		
DRAWN SNJ	DRG No. FIGURE 3-7	REV B		

The table below shows the relevant boreholes in the proximity of the structures in the Phase 1 development.

Table 3-4 Borehole details with respect to proposed port structures

S. No.	Proposed Structure/Area	Seabed level as per Bathymetry	Relevant Boreholes
1.	Port craft/ Tug berth of 200 m (2 berths of 100 m each).	-3.9 m CD to -5.3 m CD	MBH-56, Profile between MBH-22 to MBH-54
2.	Total Reclamation area inside the port 1447 ha. with 1162 ha. in Phase 1	-3.2m CD to -17.9 m CD	MBH-17, MBH-25, MBH-47, MBH-49, MBH-50, MBH-51, MBH-52, MBH-53, MBH-54, MBH-55
3.	In port rail yard / IRC railway area	-4.6 m CD to -10 m CD	Profile between MBH-41, MBH-49
4.	Utility area, Port operation building, Bulk Liquid tank farm, Chemical tank form, Edible oil tank farm, Other Liquid terminal, Main substation, Admin building	-0.4 m CD to +4.8 m CD	MBH-02, MBH-48
5.	Container terminals (each of 1,000 m length) capable of handling upto current largest 24,000 TEU container vessels. (CT1, CT2, CT3, CT4)	-11.6 m CD to -17.9 m CD	Profile between MBH-43, MBH-47, MBH-50, & MBH-52 considered.
6.	Multipurpose berths	-8.3 m CD to -12.7 m CD	MBH-54
7.	Bulk liquid jetties	-12.5mCD to -13.4mCD	MBH 58, profile between MBH-60 & MBH-56 considered.
8.	1 Bulk Liquid jetty	-12.9mCD to -13.6	MBH 57 and MBH-60
9.	Other Liquid jetty	-17.6mCD to -18.7mCD	No immediate nearby borehole (Profile between MBH-14 and MBH-57 can be considered)
10.	Approach trestle for liquid terminals and breakwater	-0.4 m CD to -7.6 m CD	Profile between MBH-24, MBH-11, MBH-09, MBH-06 and MBH-02 can be referred
11.	Road and Rail approach trestle to offshore terminal	-0.3 m CD to -3.2 m CD	MBH-17 at leeward side, No immediate borehole along remaining length of the trestle
12.	Offshore Breakwater	-12.4mCD to 18.8mCD	MBH-40, MBH-42, MBH-44, MBH-45, MBH-46, MBH-21, MBH-19, MBH-14, MBH-59, MBH-57, MBH-60, MBH-58, MBH-24

The following sequences of deposits/ solid geology were encountered during the ground investigation as shown on the borehole logs.

Unit	Soil / Rock Description	Thickness (m)
Soil Unit 1	Silty Sand	1.6 to 11.27
Soil Unit 2	Silty Clay	1.6 to 9.0
Rock Unit 1 and Rock Unit 2	Weathered sandstone	8.0 to 17.6

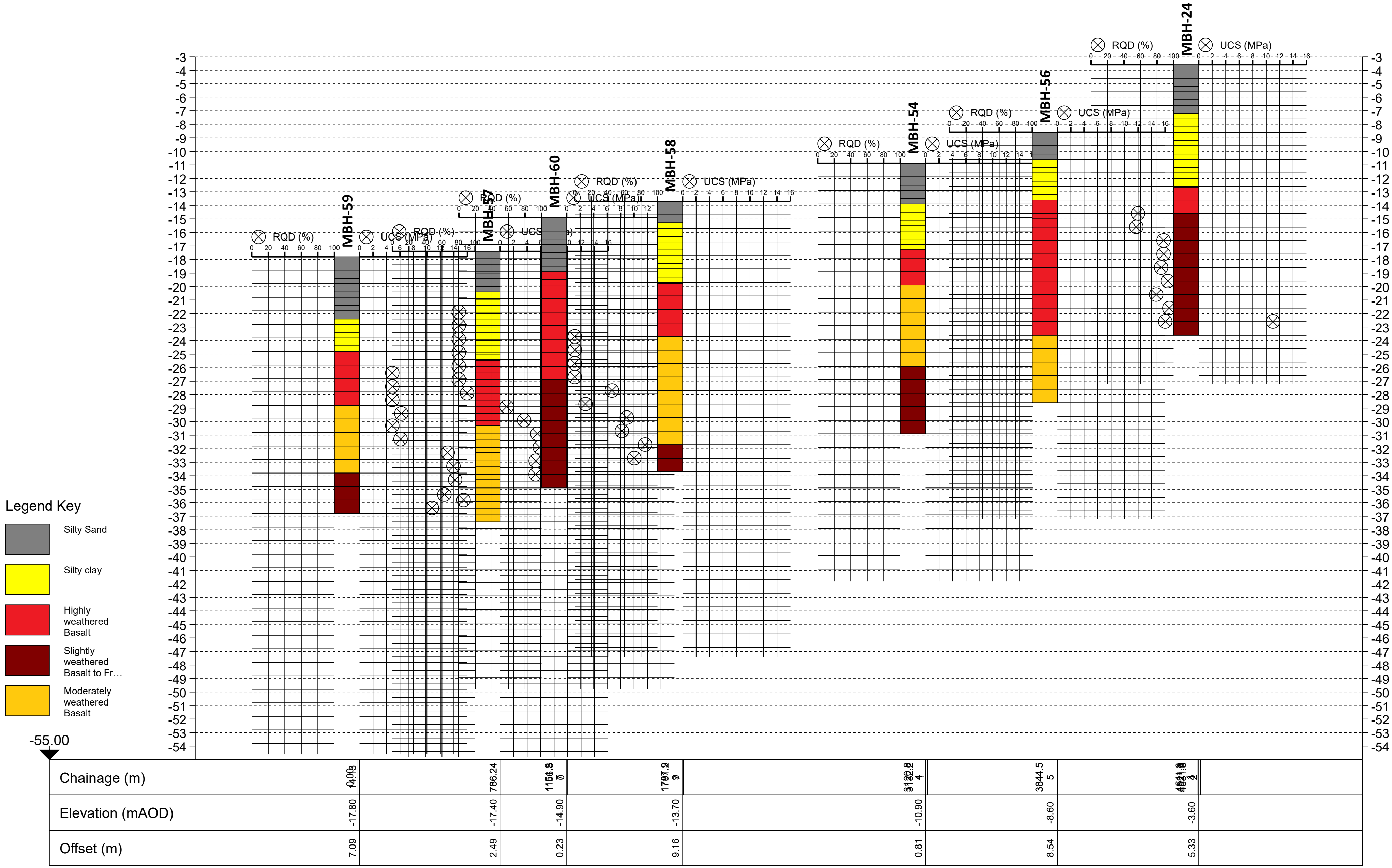
The rock level is found to vary with the deepest level of -26 m CD seen near MBH-21. Shallowest rock level of -13 m CD can be observed near MBH-24 at the southern side of the main breakwater.

The various soil profiles along the important components of the port are as shown in Figure 3-8 to Figure 3-13. Detailed description of soil layers encountered at the above locations are discussed in Section 8.

3.6 Topographic Information

Since the port facilities are proposed to be located on the reclaimed land, the topographic investigations were carried out for the external rail and road connectivity to the port along the proposed corridor.

Figure No.:	3-8	Horizontal Scale:	1:28301	Vertical Scale:	1:381



Project Title:	Figure Title:			Notes:
Development of Greenfield Vadhavan Port	**Borehole profile MBH-59, MBH-57, MBH-60, MBH-58, MBH-54, MBH-56, MBH-24**	**Date:**	04/12/2020	1. All Levels are in metres relative to chart datum unless otherwise noted.
		Revision:	Revision 0	2. For Locations of Sections refer to Drawing Number DDI1452-RHD-DP-ZZ-DR-Z-1002
		Drawn By:	Nikita Naik	
		Checked By:	Sandip Kundu	

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Figure No.:	3-9	Horizontal Scale:	1:23494	Vertical Scale:	1:298

Project Title:	Drawing Title:		
Development of Greenfield Vadhavan Port	**Borehole profile MBH-43, MBH-47, MBH-50, MBH-52**	**Date:**	30/09/2021
		Revision:	Revision A
		Drawn By:	Nikita Naik
		Checked By:	Sandip Kundu

Notes:

1. All Levels are in metres relative to chart datum unless otherwise noted.
2. For Locations of Sections refer to Drawing Number DI1452-RHD-DP-ZZ-DR-Z-1002

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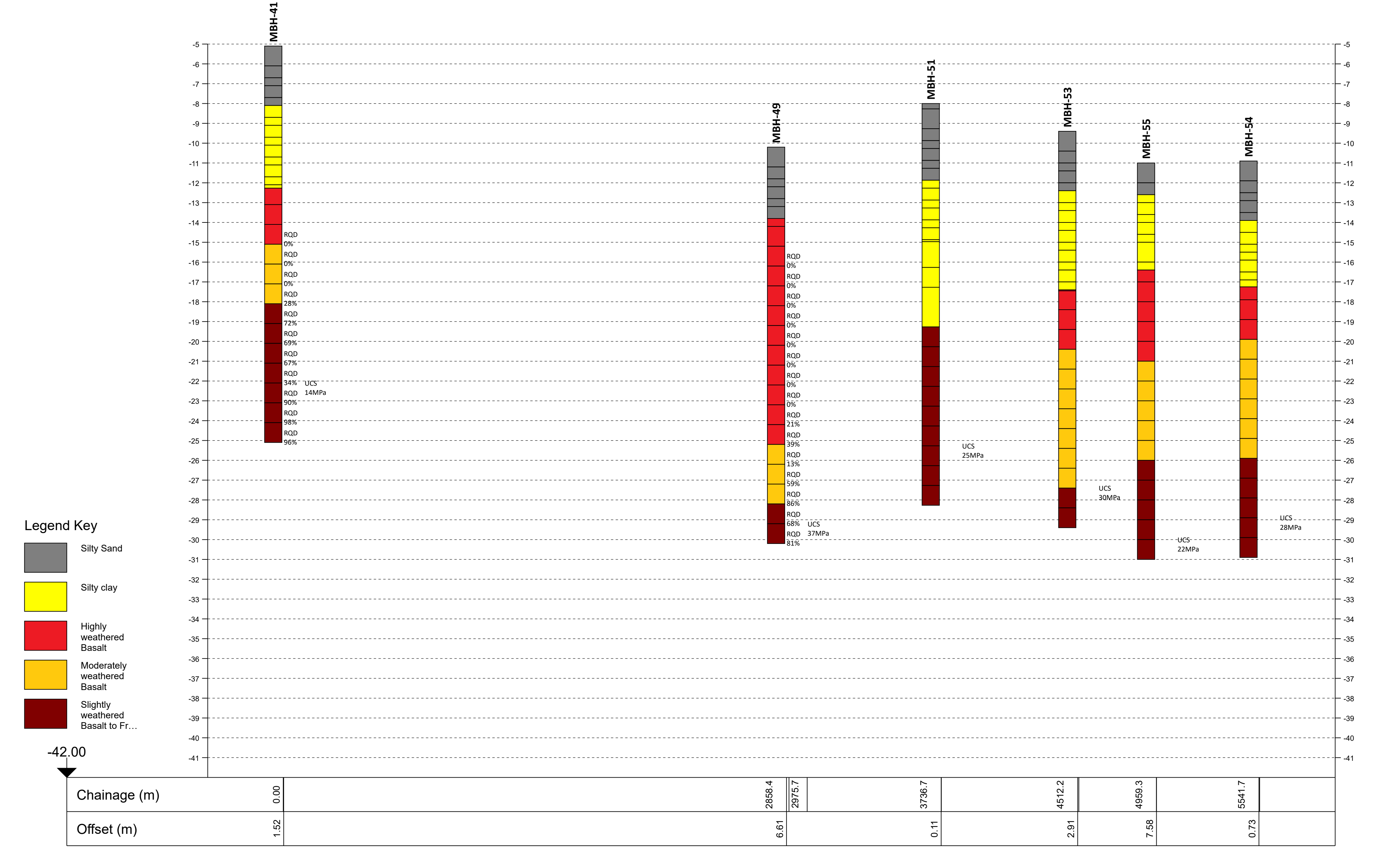
Figure No.:	3-10	Horizontal Scale:	1:28284	Vertical Scale:	1:251



Project Title:	Drawing Title:			Notes:
Development of Greenfield Vadhavan Port	**Borehole profile MBH-41, MBH-49, MBH-51, MBH-53, MBH-55**	**Date:**	30/09/2021	1. All Levels are in metres relative to chart datum unless otherwise noted.
		Revision:	Revision 0	2. For Locations of Sections refer to Drawing Number DI1452-RHD-DP-ZZ-DR-Z-1002
		Drawn By:	Nikita Naik	
		Checked By:	Sandip Kundu	

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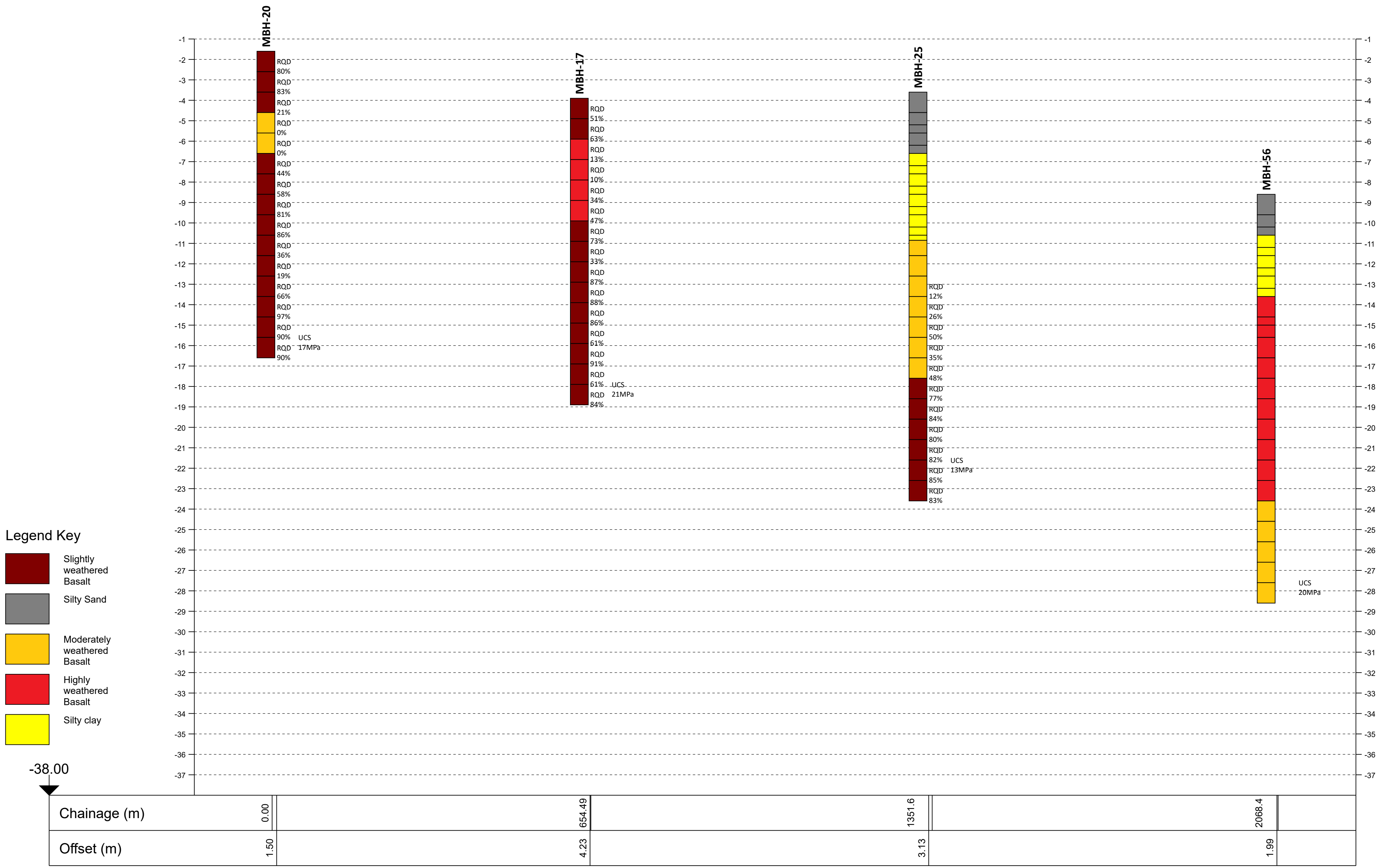
Figure No.:	3-11	Horizontal Scale:	1:10562	Vertical Scale:	1:251



Project Title:	Drawing Title:			Notes:
Development of Greenfield Vadhavan Port	**Borehole profile MBH-20, MBH-17, MBH-25, MBH-56**	**Date:**	30/09/2021	1. All Levels are in metres relative to chart datum unless otherwise noted.
		Revision:	Revision 0	2. For Locations of Sections refer to Drawing Number DDI1452-RHD-DP-ZZ-DR-Z-1002
		Drawn By:	Nikita Naik	
		Checked By:	Sandip Kundu	

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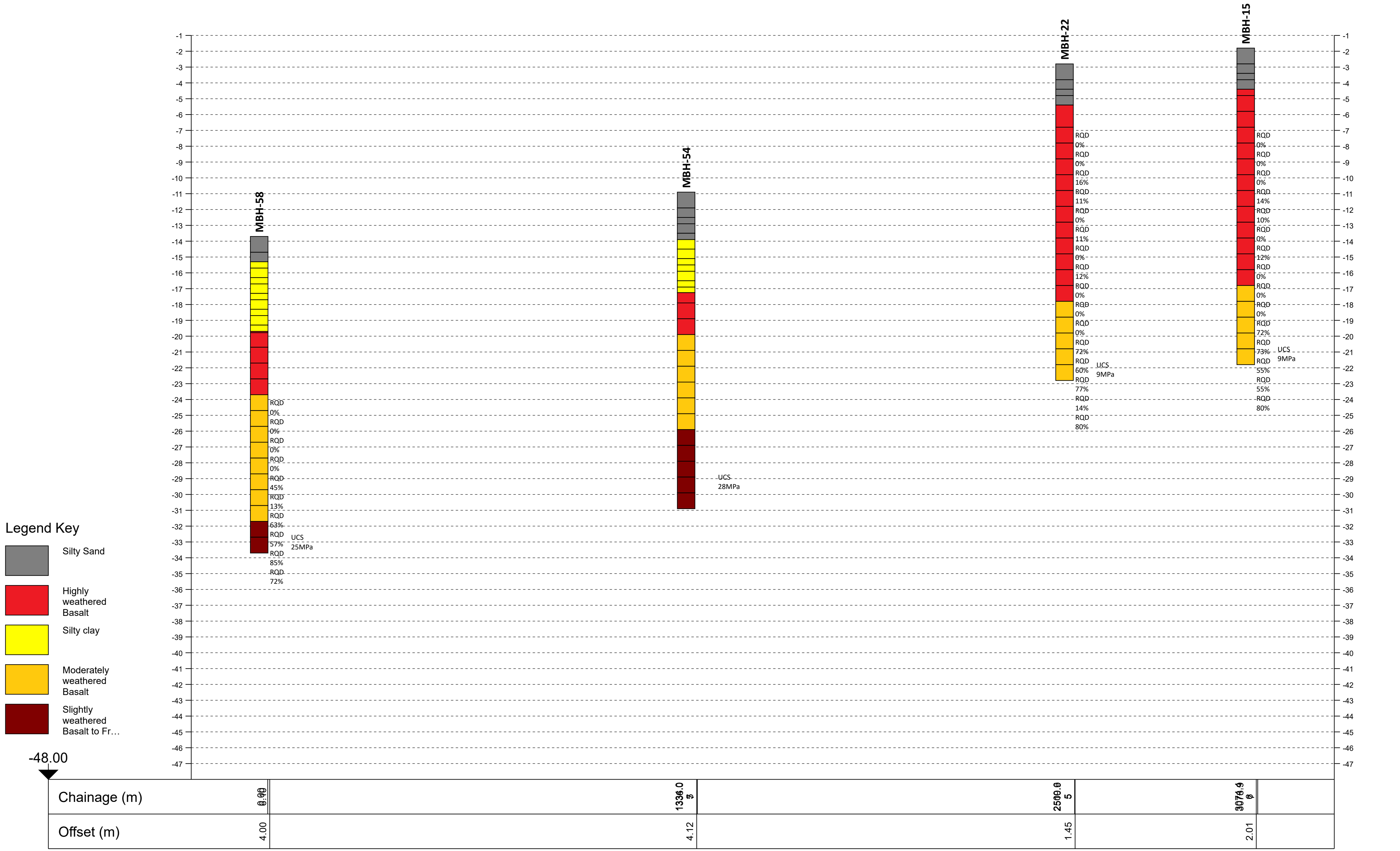
Figure No.:	3-12	Horizontal Scale:	1:15703	Vertical Scale:	1:319



Project Title:	Drawing Title:		
Development of Greenfield Vadhavan Port	**Borehole profile MBH-58, MBH-54, MBH-22, MBH-15**	**Date:**	30/09/2021
		Revision:	Revision 0
		Drawn By:	Nikita Naik
		Checked By:	Sandip Kundu

Notes:

1. All Levels are in metres relative to chart datum unless otherwise noted.
2. For Locations of Sections refer to Drawing Number DDI1452-RHD-DP-ZZ-DR-Z-1002

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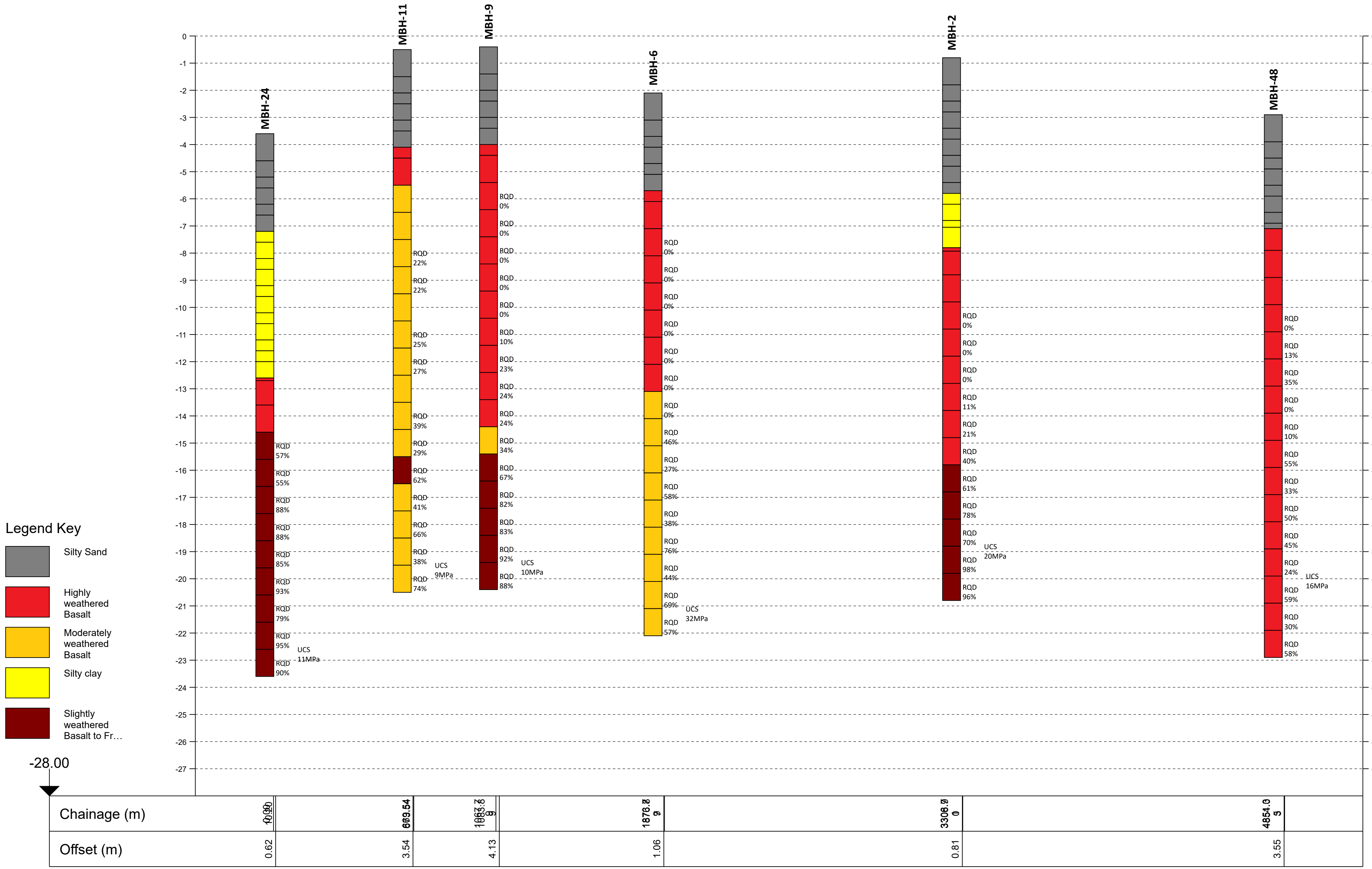
Figure No.:	3-13	Horizontal Scale:	1:24756	Vertical Scale:	1:190



Project Title:	Drawing Title:		Notes:
Development of Greenfield Vadhavan Port	**Borehole profile MBH-24, MBH-11, MBH-9, MBH-6, MBH-2, MBH-48**	**Date:** 30/09/2021 **Revision:** Revision 0 **Drawn By:** Nikita Naik **Checked By:** Sandip Kundu	1. All Levels are in metres relative to chart datum unless otherwise noted. 2. For Locations of Sections refer to Drawing Number DI1452-RHD-DP-ZZ-DR-Z-1002

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4 Traffic Study

Vadhavan port has been conceptualised as gateway port to handle clean cargo. The previous detailed project report prepared by consultants namely Ernst & Young and Progen-Pentacle Consultants had found substantial potential for container cargo at Vadhavan Port. Containers constituted more than 84% of the trade volume by 2050 in the DPR. The other commodities like Crude Oil, Coal, Fertiliser, Chemicals and other General & coastal cargo constituted around 16% of the 2050 traffic share. Dirty cargo namely coal has been permanently discarded and Crude Oil temporarily discarded based on JNPA and Governments vision of developing Vadhavan port as clean cargo port.

As part of the DPR updation, RHDHV carried out the traffic potential at Vadhavan Port after assessing and analysing the impact of various macro and micro factors influencing the maritime trade globally. All the analysis undertaken in this chapter for the Vadhavan port has larger analytical perspective to evaluate and quantify opportunities for container trade. The detailed analysis of other commodities has also been carried out. The section has undertaken a holistic analysis of all the trade happening in the ports of Gujarat and Maharashtra to identify promising cargo other than containers likely to be attracted at proposed Vadhavan port. The cargo volume projections for Vadhavan Port were forecast under three different scenarios viz. Optimistic, Realistic and Pessimistic scenarios.

The section summarises the findings of Traffic Study. The detailed traffic assessment is enclosed in Appendix 3.

4.1 Hinterland & Connectivity Analysis

Vadhavan Port's hinterland comprises of Maharashtra as primary, Gujarat as secondary and other northern states and Madhya Pradesh as tertiary hinterland. Proposed Vadhavan Port is in north Maharashtra, it would cater to the North West region of India. All the analysis and economic prospect of Vadhavan Port has been linked to the economic and trade growth in North-West region of India.

Population residing in the tertiary hinterland prefer North-West (Gujarat-Maharashtra) ports due to better connectivity and cost-effective evacuation. Their significance further increased in containerised segment due to shipping lines preference. Hence, North-West ports handle around 67% of India's container trade.

Vadhavan port is located next to NH-8 that is connects to Nashik. Nashik further connects to the northern states of India. Connectivity to northern states via Nashik facilitates seamless cargo movement. This can also take up the cargo that would produce along the DMIC in future. MIDC Golden Quadrilateral project is under pipeline, once it gets operational it is going to enhance the connectivity with prominent centres even more. Further, one more road connectivity project is under implementation i.e., Nagpur-Mumbai Super-Communication. This connectivity is going to free up the congestion from existing route. Vangaon is the nearest station to Vadhavan Port, it is around 16.2 km from the proposed location. Vangaon railway station is a part of Mumbai Central (BCT) division falling on western line between Umaroli and Dahanu. Western railway line runs parallel to the proposed location at approximately at 15 km. Kalyan is the nearest junction for connecting Vangaon to Nashik and Aurangabad and further to Madhya Pradesh. Connectivity with northern states is via Surat and Ahmedabad rail line and with southern states is by using Mumbai and Pune rail line.

4.2 Competition Analysis

Container trade of India has shown growth of around 8% CAGR in last decade. Cumulative container port traffic of India has grown by 2 times in the last 10 years and 8 times in last 20 years. North-West region of India has grown in similar proposition like all India container trade. In FY20, ports catering to north-west region contributed 67% share to the total India's container trade. Market share of North-West region has remained consistent in last 2 decades. All ports of Maharashtra and Gujarat falls under secondary and tertiary hinterland of Vadhavan Port. Gujarat and Maharashtra have several smaller, lighterage, seasonal and captive ports, these ports have different commodities and market segment. Vadhavan would not compete with these ports as focus of such ports is to cater local cargo. Major competitors of Vadhavan will be the large ports with direct berthing, round the year operational facilities and large traffic volume. JNPA, MbPA, Hazira, Pipavav, Adani Dahej and Mundra Port would have large competitive influence over market segment of Vadhavan Port. Prominent competitor for container segment is JNPA, Mundra, Hazira, Pipavav and Kandla, While JNPA, MbPA, Kandla, Mundra, Hazira, Pipavav and Adani Dahej in other commodities segment.

4.3 Need and Advantages of Vadhavan Port

Existing ports have strong customer base, infrastructure, connectivity and logistics services along with long years of experiences. However, over the period of time, some of the ports have reached their capacity and due to expansion constraint, the congestion at port has caused serious concern especially ports like JNPA and MbPA. Competitors are facing following 5 major restrictions for capacity expansion.

- Unavailability of waterfront to create new Jetties/Terminals (JNPA, AHPPL-partially)
- Located further away from the route considered unproductive for shipping lines to divert (Kandla, Dahej)
- Heavy siltation/tidal issues rendering expansion of infrastructure extremely high (Hazira, Dahej)
- Legal & Regulatory issues embedded in the 30 years' concession agreement restricting expansion of private ports till the time they are sure of extension of Concession Agreement (Mundra and Pipavav)
- Limited availability of waterfront suitable for construction of Container port on the Coast of Maharashtra and Gujarat (discussed in detail in section Need for Vadhavan).

Because of capacity constrains the cargo of these ports is routed to other ports available in immediate hinterland. Vadhavan is nearest to MbPA and JNPA as compared to ports of Gujarat. Vadhavan have huge advantage due to its proximity to JNPA and MbPA making it easier to attract spill over traffic. Vadhavan would have competitive edge over these major ports also due to the ability to berth large ships and closeness to northern hinterland. The logistics cost savings due to infrastructure and connectivity advantage to Vadhavan is likely to provide higher traffic gains for Vadhavan compared to competitors. Vadhavan would be able to attract incremental increase in traffic over the years is then distributed as per the facilities and capacity constraints at different ports. Vadhavan having the highest potential with modern facilities, deep draft and no capacity constraints in the initial years is expected to gain a larger share in the traffic. Also, there is no other container port planned in near future in the hinterland by respective state government. Possibility of any new port in competitive location is very limited. It has been assumed that Vadhavan will be the new large container port in Maharashtra catering to NCR region.

4.4 Development Modalities

The port would be developed based on Public-Private Partnership (PPP) model devised by Government of India. The authority would invite private developers for further development of infrastructure. The responsibilities of private developers would include

- Development of respective Jetties.
- Installation of all material handling equipment.
- Creation of respective backup and other storage facilities.
- Other infrastructure exclusively for use of PPP developer.

The container terminal of Vadhavan is likely to attract global container terminal operators. A combination of transparency due to government initiation and deep draft would increase attractiveness of Vadhavan port for developers compared to other ports in the region. Larger shipping lines intend to own and operate container ports and container terminals. Several such instances are available in India. Hence, forging a partnership with the shipping line by the port developer is likely to increase commercial attractiveness of the port.

Following are some of the key drivers for success of Container Terminals of Vadhavan Port.

- Futuristic Container Terminals with deep draft to cater largest container vessels available even on the design board.
- Proximity to hinterland clusters including upcoming Dedicated Freight Corridor (DFC) and DMIC corridor resulting in lower inland evacuation cost to the hinterland.
- The port is developed at a location of deep draft that would provide channel availability without recurring dredging. This would reduce maintenance cost of port, impacting favourable tariffs for container handling.

4.5 Projections

Vadhavan is envisaged to be a container and clean cargo port. Container traffic is likely to dominate ports business. The infrastructure and equipment for container handling are specialised and can rarely be used for handling other commodities. Multiple methods of traffic analysis and projection for Vadhavan has been undertaken. Following are broad methods used in traffic projections of Vadhavan.

- Commodity wise detailed projection of containerised cargo of North and West India region
- Country comparison
- Extrapolation of historic trade
- Co-relation with GDP growth

The container projection arrived using above methods for India is distributed in the region. Market share for Vadhavan is arrived based on the capacity constraints at existing ports in North and West India region (Gujarat and Maharashtra).

Table 4-1 Vadhavan Port's Container Traffic Projections (mn TEUs)

India Traffic	2020	2025	2030	2035	2040	2045	2050
Pessimistic	0.0	0.7	4.0	7.7	12.2	14.8	19.3
Realistic	0.0	0.9	6.5	14.1	23.2	31.3	39.4
Optimistic	0.0	1.0	7.4	16.5	29.4	43.0	57.5

Table 4-2 Other Principal Commodities Traffic Projection for Vadhavan Port (mn T)

Commodities	FY21	FY25	FY30	FY35	FY40	FY45	FY50
Edible Oil	0.0	0.4	1.0	1.1	1.2	1.3	1.4
Chemical	0.0	0.6	0.9	1.0	1.1	1.2	1.3
Bulk Liquid	0.0	2.7	3.1	3.8	4.2	4.7	5.2
Fertilizer	0.0	0.9	1.0	1.2	1.2	1.3	1.4
General cargo	0.0	1.5	2.4	3.5	4.6	5.9	7.2
Coastal Cargo	0.0	1.0	1.7	2.4	3.2	4.1	5.0
Other Liquid *	0.0	0.0	2.3	4.5	4.5	4.5	4.5
Total	**0.0**	**7.1**	**12.3**	**17.5**	**20.1**	**23.1**	**26.1**
Ro-Ro ('000 Vehicles)	0.0	20.9	49.5	76.8	169.0	195.9	227.1

* For Other Liquid, it may be noted that the cargo will be evacuated through pipeline by connecting it to the national grid. Given the Other Liquid facilities developed along the west coast, there are 7 terminals in operations (Cochin, Dabhol, Jaigad, Dahej, Hazira, Mundra, Chhara – under construction) which connects to the national supply grid. The capacity of the grid would be the constraint for evacuation from Vadhavan Port. It is therefore proposed that provision for Other Liquid development will be provided within the port which can be developed by the PPP operator once the need for the capacity addition/ market demand is reckoned.

4.6 Cargo Evacuation

Cargo evaluation for Vadhavan Port is based on Traffic Projections, Evacuation pattern at competing ports, Availability of first/last mile connectivity and Development in transportation sector (Rail, Road, Pipeline). Seamless evacuation of container and cargo to the hinterland is essential for success of Vadhavan Port. The capacity of port is minimum of the capacity of berth, capacity of storage and capacity of cargo evacuation to the hinterland. Hence, inland evacuation capacity has to be augmented in line with the capacity of port. Any gap in the inland evacuation capacity is likely to force shift of cargo projected to be handled at Vadhavan Port to other competing port. Commissioning of Western Dedicated Freight Corridor (W-DFC) is likely to benefit Vadhavan. It would help reduce logistics cost of evacuating containers from existing mode namely Indian Railways and Roadways. It would also help enhance otherwise restricted capacity of containers on Indian Railway and road.

The container movement distribution has been categorised in 3 geographical regions

- NCR and Other Northern Stages (presence of DFC)
- Gujarat (Mostly South Gujarat, Central Gujarat, etc.)
- Immediate Hinterland of Maharashtra, MP and Central India

Following table summarises total container movement in the hinterland using various modes of transportation. It is estimated that about 13.5 million TEU containers will moving using road, 4.8 million TEU using Indian Railways and 6 million TEU using DFC in Fy-40. The share will increase to about 22.4 million TEU containers will moving using road, 5.3 million TEU using Indian Railways and 13.5 million TEU using DFC in Fy-50.

Table 4-3 Container volumes distribution to various OD pairs (mn TEUs)

Mode	Fy-21	Fy-25	Fy-30	Fy-35	Fy-40	Fy-45	Fy-50
Cumulative Annual Traffic from Vadhavan using Various Modes							
Total	**0.0**	**0.9**	**6.5**	**14.1**	**23.2**	**31.3**	**39.4**
Road	0.0	0.7	4.4	9.3	15.3	20.2	25.4
Rail (IR)	0.0	0.3	0.1	0.3	0.5	0.7	0.9
Rail (DFC)	0.0	0.0	1.9	4.4	7.4	10.4	13.1

The preferred modes of transportation for evacuating different commodities from Vadhavan port is presented in the table below. Eight commodities are considered in the table while 3 modes of transportation are implemented. Some commodities would be evacuated via only a single mode of transportation while other commodities would have access to all three modes of transportation. In FY50, the total volume by roads would be 16 million tonnes, by rails would be 5.3 million tonnes and by pipeline would be 4.8 million tonnes. Ro-Ro vehicles are excluded from the total as they are tallied based on the number of units. In 2050, 227,100 vehicles would be evacuated by road from Vadhavan.

Table 4-4 Selected MoT wise Traffic Spilt for Evacuation (mn T)

Commodities	MoT (% Share)	FY21	FY25	FY30	FY35	FY40	FY45	FY50
Edible Oil	Road	0.0	0.4	0.8	0.9	1.0	1.1	1.2
	Rail	0.0	0.1	0.1	0.2	0.2	0.2	0.2
Chemical	Road	0.0	0.6	0.9	1.0	1.1	1.2	1.3
Bulk Liquid	Pipeline	0.0	0.1	0.2	0.2	0.2	0.2	0.3
	Road	0.0	0.4	0.5	0.6	0.6	0.7	0.8
	Rail	0.0	2.1	2.5	3.1	3.4	3.7	4.1
Fertilizer	Road	0.0	0.3	0.3	0.4	0.3	0.4	0.4
	Rail	0.0	0.6	0.7	0.8	0.8	0.9	1.0
General Cargo	Road	0.0	1.5	2.4	3.5	4.6	5.9	7.2
	Rail	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Coastal Cargo	Road	0.0	1.0	1.7	2.4	3.2	4.1	5.0
	Rail	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Other Liquid	Pipeline	0.0	0.0	2.3	4.5	4.5	4.5	4.5
Total	Road	**0.0**	**4.1**	**6.5**	**8.7**	**10.9**	**13.4**	**16.0**
	Rail	**0.0**	**2.8**	**3.3**	**4.1**	**4.4**	**4.8**	**5.3**
	Pipeline	**0.0**	**0.1**	**2.5**	**4.7**	**4.8**	**4.8**	**4.8**
Ro-Ro ('000 Vehicles)	Road	0.0	20.9	49.5	76.8	169.0	195.9	227.1

[Note: Total excludes Ro-Ro Traffic]

4.7 Vessel Calls

Vessel calls signify the number of vessels docking at the port to load or unload their cargo. The statistics for the next 25 years in terms of parcel size of the vessels and the number of weekly vessel calls is mentioned below. These values are given for proposed container and other principal commodities volume proposed for Vadhavan Port.

Table 4-5 Container Vessel Capacity and Parcel Size Assumptions

Design Capacity of Vessels (TEU)	Carrying Capacity @ 14 T	Parcel Sizes (TEU)
1,500	1,050	683
2,000	1,400	910
5,000	3,500	2,275
8,000	5,600	3,640
12,000	8,400	3,360
14,000	9,800	3,920
16,000	11,200	4,480
18,000	12,600	5,040
20,000	13,000	4,800
24,000	15,000	6,000

- Local Trade of Middle East & Asia in Ships less than 8,000 TEU
- Parcel Assumed 60% of Carrying Capacity
- Long Distance trade to East & West in Ships more than 12,000 TEU
- Parcel Assumed 30% of Carrying Capacity

Table 4-6 Weekly Vessel Calls for Container Volume

Mode	Fy-21	Fy-25	Fy-30	Fy-35	Fy-40	Fy-45	Fy-50
Cumulative Weekly Calls							
1,500	0	1	2	4	0	0	0
2,000	0	1	3	6	5	0	0
5,000	0	1	5	10	18	24	31
8,000	0	1	4	7	13	19	23
12,000	0	2	4	4	6	8	10
14,000	0	2	4	6	8	8	8
16,000	0	2	6	10	16	22	28
18,000	0	2	6	10	16	22	28
20,000	0	2	6	12	20	26	32
24,000	0	2	4	8	12	20	24
Total	**0**	**16**	**44**	**77**	**114**	**149**	**184**

Table 4-7 Commodity wise Vessel Parcel Size

Parcel Size	FY21 – FY30 (T)	FY31 – FY40 (T)	FY41 – FY50 (T)
Edible Oil	9,000	16,200	27,000
Chemical	4,500	9,000	9,000
Bulk Liquid	22,500	31,500	54,000
Fertilizer	16,200	31,500	54,000
Ro-Ro	1,800	3,600	5,580
General cargo	18,750	30,000	41,250
Coastal Cargo	13,500	18,750	30,000
Other Liquid	70,000	125,000	125,000

The table below describes weekly vessel calls for different commodities. The vessel calls depend on the parcel size of the vessel and traffic projected.

Table 4-8 Commodity wise Weekly Vessel Calls

Weekly Vessel Calls	FY21	FY25	FY30	FY35	FY40	FY45	FY50
Edible Oil	0	1	3	2	2	1	2
Chemical	0	3	4	3	3	3	3
Bulk Liquid	0	3	3	3	3	2	2
Fertilizer	0	2	2	1	1	1	1
Ro-Ro	0	1	1	1	1	1	1
General cargo	0	2	3	3	3	3	4
Coastal Cargo	0	2	3	3	4	3	4
Other Liquid	0	0	2	3	3	3	3
Total	0	**14**	**21**	**19**	**20**	**17**	**20**

4.8 Tariff Structure

4.8.1 Tariff Structure for Other Principal Commodities

Overall logistics cost is influenced by the tariff charged by ports / terminals for each commodity. Tariff structure of each port is divided into two sections i.e., Vessel Related Charges and Terminal Handling Charges. The tariff rates are linked to the type of cargo (liquid, bulk, break-bulk) and commodities, vessel size and type, operational hours of terminal, assistance and service taken from terminal management, storage facilities, etc. The table below shows the tariff structure comparison between competing ports of Vadhavan i.e., Kandla, Mundra, Pipavav, Hazira and MbPA for each principal commodity.

Table 4-9 Edible Oil Handling Charges at Competing Ports (US$)

Components	Kandla	Mundra	Hazira	Pipavav
Anchorage	**0.001** GRT/Hr.	**0.001** GRT/Hr.	**0.001** GRT/Hr.	**0.02** GRT/6 Hrs
Berth Hire	**0.01** GRT/Hr.	**0.01** GRT/Hr.	**0.05** GRT/8 hour (15,001 to 30,000)	**0.02** GRT/Hr.
	N/A	N/A	**0.07** GRT/8 hour (15,001 to 30,000)	N/A
	N/A	N/A	**0.08** GRT/8 hour	N/A

Components	Kandla	Mundra	Hazira	Pipavav
			(above 30,000)	
Mooring	**0.002** GRT/Hr.	**0.03** GRT/VCN	**0.02** per GRT	N/A
Port Dues	**0.48** GRT/Vessel	**0.05** GRT/Vessel	**0.05** per GRT	**0.31** GRT/Vessel
Pilotage	**0.97** per GRT <30,000	**0.70** per GRT (<10,000)	**1.01** per Tanker (<15,000 GRT)	**0.61** per GRT (<60,000)
	29,085 for 1st 30,000 GRT + **0.77** per GRT (30,001 to 60,000)	**0.83** per GRT (>10,000)	**1.01** per Tanker (15,001 to 25,000 GRT)	N/A
	52,322.68 for 1st 60,000 GRT + **0.68** per GRT (>60,000)	N/A	**1.07** per Tanker (>25,000 GRT)	N/A
Warping	N/A	50% of applicable pilotage charges		N/A
Tug / Boat hire	N/A	**1,755** per trip	N/A	N/A
Wharfage	**0.75** per Ton	**0.88** per Ton	**1.20** per Ton	**1.07** per Ton
Stevedoring	N/A	N/A	N/A	N/A
Pipeline /Cargo Throughput	N/A	**0.04** per Ton	**0.03** per Ton	**0.17** per Ton

Table 4-10 Fertilizer Handling Charges at Competing Ports (US$)

Components	Kandla	Mundra	Hazira	Pipavav
Anchorage	**0.001** GRT/Hr.	**0.001** GRT/Hr.	**0.001** GRT/Hr.	**0.02** GRT/6 Hrs.
Berth Hire	**0.01** GRT/Hr.	**0.01** GRT/Hr.	**0.07** GRT/8 Hrs.	**0.01** GRT/Hr.
Mooring	**0.002** GRT/Hr.	**0.03** GRT/Hr.	**0.02** per GRT	N/A
Port Dues	**0.48** GRT/Vessel	**0.05** GRT/Vessel	**0.05** per GRT	**0.19** GRT/Vessel
Pilotage	**0.97** per GRT <30,000	**0.70** per GRT <10,000	**1.01** per GRT <3,000	**0.55** per GRT <60,000
	29,085 for 1st 30,000 GRT + **0.77** per GRT (30,001 to 60,000)	**0.83** per GRT >=10,000	**1.01** per GRT (3,001 to 15,000)	**0.60** per GRT >60,000
	52,322.7 for 1st 60,000 GRT + **0.68** per GRT (>60,000)	N/A	**1.01** per GRT (15,001 to 60,000)	N/A
Warping	N/A	50% of applicable pilotage charges		N/A
Tug / Boat hire	N/A	**1,755** per trip	N/A	N/A
Wharfage	**0.83** per Ton	**0.87** per Ton	**0.93** per Ton	**0.73** per Ton

Table 4-11 Chemical Handling Charges at Competing Ports (US$)

Components	Kandla	Mundra	Hazira	Pipavav
Anchorage	**0.001** GRT/Hr.	**0.001** GRT/Hr.	**0.001** GRT/Hr.	**0.02** GRT/6 Hrs.
Berth Hire	**0.01** GRT/Hr.	**0.01** GRT/Hr.	**0.05** GRT/8 Hrs.	**0.02** GRT/Hr.
Mooring	**0.002** GRT/Hr.	**0.03** GRT/VCN	**0.02** per GRT	N/A
Port Dues	**0.48** GRT/Vessel	**0.05** GRT/Vessel	**0.05** per GRT	**0.31** GRT/Vessel
Pilotage	**0.97** per GRT <30,000	**0.70** per GRT <10,000	**1.01** per Tanker (<15,000 GRT)	**0.61** per GRT <60,000
	29,085 for 1st 30,000 GRT + **0.77** per GRT (30,001 to 60,000)	**0.83** per GRT >=10,000	**1.01** per Tanker (15,001 to 25,000 GRT)	N/A

Components	Kandla	Mundra	Hazira	Pipavav
	52,322.7 for 1st 60,000 GRT + **0.68** per GRT (>60,000)	N/A	**1.07** per Tanker (>25,000 GRT)	N/A
Warping	N/A	50% of applicable pilotage charges		N/A
Tug / Boat hire	N/A	**1,755** per trip	N/A	N/A
Wharfage	**0.75** per Ton	**1.107** per Ton	**1.33** per Ton	**1.20** per Ton
Pipeline/Cargo Throughput	N/A	**0.04** per Ton	**0.03** per Ton	**0.17** per Ton

Table 4-12 Bulk Liquid Handling Charges at Competing Ports (US$)

Components	Kandla	Mundra	Hazira	Pipavav
Anchorage	**0.001** GRT/Hr.	**0.001** GRT/Hr.	**0.001** GRT/Hr.	**0.02** GRT/6 Hrs.
Berth Hire	**0.01** GRT/Hr.	**0.01** GRT/Hr.	**0.08** GRT/8 Hrs.	**0.02** GRT/Hr.
Mooring	**0.002** GRT/Hr.	**0.03** GRT/VCN	**0.02** per GRT	N/A
Port Dues	**0.48** GRT/Vessel	**0.05** GRT/Vessel	**0.35** per GRT	**0.30** GRT/Vessel
Pilotage	**0.97** per GRT <30,000	**0.70** per GRT <10,000	**1.01** per Tanker (<15,000 GRT)	**0.55** per GRT <60,000
	29,085 for 1st 30,000 GRT + **0.77** per GRT (30,001 to 60,000)	**0.83** per GRT >=10,000	**1.01** per Tanker (15,001 to 25,000 GRT)	N/A
	52,322.7 for 1st 60,000 GRT + **0.68** per GRT (>60,000)	N/A	**1.07** per Tanker (>25,000 GRT)	N/A
Warping	N/A	50% of applicable pilotage charges		N/A
Tug / Boat hire	N/A	**1,755** per trip	N/A	N/A
Wharfage	**1.87** Cu.m	**4.67** per Ton	N/A	**3.33** per Ton
Pipeline/Cargo Throughput	N/A	**0.04** per Ton	**0.03** per Ton	**0.17** per Ton

Table 4-13 Other Liquid Handling Charges at Competing Ports (US$)

Components	Mundra	Hazira	Pipavav
Anchorage	**0.03** GRT/Hr.	**0.001** GRT/Hr.	**0.02** GRT/6 Hrs.
Berth Hire	**0.21** GRT/Hr.	**0.08** GRT/8 Hrs.	**0.02** GRT/Hr.
Mooring	-	**0.02** per GRT	N/A
Port Dues	**0.05** GRT/Vessel	**0.35** per GRT	**0.30** GRT/Vessel
Pilotage	**1.05** GRT/Vessel	**0.60** per GRT	**0.55** per GRT <60,000
Warping	50% of applicable pilotage charges		N/A
Tug / Boat hire	**1,755** per trip	N/A	N/A
Wharfage	**2.39** per Ton	N/A	**3.67** per Ton
Pipeline/Cargo Throughput	**0.04** per Ton	**0.03** per Ton	**0.17** per Ton

Table 4-14 Ro-Ro Tariff Charges at Competing Ports (US$)

Components	Mumbai	Mundra	Pipavav
Anchorage	**0.06** GRT/Hr.	**0.001** GRT/Hr.	**0.02** GRT/6 Hrs.
Berth Hire	**0.01** GRT/Hr.	**0.01** GRT/Hr.	**0.01** GRT/Hr.
Mooring	N/A	**0.03** GRT/VCN	N/A

Components	Mumbai	Mundra	Pipavav
Port Dues	**0.03** per GRT >30,000	**0.05** GRT/Vessel	**0.20** GRT/Vessel
Pilotage	**0.49 per** GRT =<30,000	**0.70** GRT <10,000	**0.55** per GRT
	14,844 for 1st 30,000 GRT + **0.40** per GRT (30,001 to 60,000)	**0.83** per GRT =>10,000	N/A
	26,718 for 1st 60,000 GRT + **0.35** per GRT (>60,000)	N/A	N/A
Warping	N/A	50% of applicable pilotage charges	N/A
Tug / Boat hire	N/A	**1,755** per trip	N/A
Wharfage	N/A	N/A	N/A

4.8.2 Containers

Vadhavan port container terminal has been found to be commercially competitive using container tariff of JNPA's BMCT container terminal. Hence, it is concluded that Vadhavan could adopt existing tariffs of BMCT terminal for THC, CY and other charges. It could follow JNPA vessel related charges. Following table summarises proposed tariffs for Vadhavan Port.

Table 4-15 Proposed Tariff Structure for Vadhavan Container Terminal

S. No.	Components	Foreign (US$)	Coastal (Rs.)
1.	**Port Dues**		
a.	Bulk Carriers	**0.22** GRT/Vessel	**5.87** GRT/Vessel
b.	Container vessel	**0.17** GRT/Vessel	**4.51** GRT/Vessel
c.	Car Carrier Vessels (RoRo)	**0.11** GRT/Vessel	**2.92** GRT/Vessel
2.	**Professional Pilot cum towage Fees**		
a.	=<30,000 GRT	**0.38** per GRT	**10.05** per GRT
b.	30,001- 60,000 GRT	**11,505** for first 30,000 GRT + **0.3073** for every additional GRT	**3,01,392** for first 30,000 GRT + **8.0347** for every additional GRT
c.	>60,000 GRT	**20,724** for first 60,000 GRT + **0.2689** for every additional GRT	**5,42,433** for first 60,000 GRT + **7.0349** for every additional GRT
3.	**Berth Hire Charges**		
a.	For occupying JNPA Berth All Berths including Landing Jetty	**0.006** GRT/Hr.	**0.145** GRT/Hr.
b.	For occupying Anchorage Berth	**0.0029** GRT/Hr.	**0.0644** GRT/Hr.

Table 4-16 Terminal Handling Charges (THC) for Vadhavan Container Terminal

S. No.	Components	20 Ft. Container (Per TEU/Rs.)			
		Foreign		Coastal	
		Loaded	Empty	Loaded	Empty
1.	**Normal Containers**				
a.	Terminal Handling Cost	4,270.68	3,449.4	2,562.4	2,069.65
b.	Inland Evacuation – Rail	2,135.34	2,135.34	2,135.34	2,135.34
c.	Inland Evacuation – Road	657.04	657.04	657.04	657.04
2	**Reefer Containers**				
a	Terminal Handling Cost	4,270.68	3,449.4	2,562.4	2,069.65
b	Inland Evacuation - Rail	2,135.34	2,135.34	2,135.34	2,135.34
c	Inland Evacuation - Road	657.04	657.04	657.04	657.04
3	**Hazardous Containers**				
a	Terminal Handling Cost	5,339.33	0.0	3,203.99	0.0
b	Inland Evacuation - Rail	2,668.71	0.0	2,668.71	0.0
c	Inland Evacuation - Road	821.29	0.0	821.29	0.0
4	**Transhipment Containers**				
a	1 – 3000 TEUs	4,944.0	4,284.8	2,966.4	2,570.9
b	3001 – 6000 TEUs	4,614.4	3,955.2	2,768.6	2,373.1
c	6001 – 9000 TEUs	4,284.8	3,625.6	2,570.9	2,175.4
d	Thereafter.	3,955.2	3,296.0	2,373.1	1,977.6
5	**Over Dimensional Cargo Containers**				
a	Terminal Handling Cost	8541.39	6,898.81	5,124.83	4,139.28
b	Inland Evacuation - Rail	4270.68	4270.68	4270.68	4270.68
c	Inland Evacuation - Road	1,314.05	1,314.05	1,314.05	1,314.05

5 Port Operation & Functional Requirements

5.1 General

One of the main factors that influence the layout and sizing of the port facilities and therefore the costs is the size of ships for different commodities. The design ship is the largest ship for a particular commodity that is likely to be handled at the port and based on which the dimensions and the design of berth, the basin, the approach channel will have to be finalised. This, in turn will influence the layout and alignment of the breakwaters, required at a particular port.

When selecting the design ship size for a particular commodity, it is essential to consider the development trends in the international maritime trade driven by the scale of economics in freight. The size of ships calling at the port will also have a bearing on the facilities available at the ports of origin/destination.

The size of ships that would call at Vadhavan Port will be governed by the following aspects:

- The trading route and distance between Vadhavan Port and origin/ destination ports;
- The facilities available at the loading/unloading port including the draft;
- Availability of a suitable ship in the market;
- Future availability of vessel on the market including ‘trickle down’ effects from mainline routes to secondary routes;
- Volume of annual traffic to be handled and the likely parcel size;
- Balance between capital costs for Vadhavan port development and freight transport costs.

The traffic study has projected the following main cargo commodities for Vadhavan Port:

- Containers
- Multipurpose Cargo
- Ro-Ro
- Other Liquid
- Liquid Bulk – Edible Oil, Chemicals, Bulk Liquid

Since ocean freight is a major component of the overall logistic costs for any consignee, the operator always looks for a modern port with large draft for handling big parcels and with modern handling equipment which ensures faster and loss-free turnaround of ships.

5.2 Design Ships

5.2.1 Container Ships

5.2.1.1 General

The success of the container ship story is unparalleled in the history of shipping. Ever since its start in the early sixties, the idea of shipping cargo in locked containers has been widely accepted, resulting in uninterrupted growth, continuing even into the beginning of this century. Consequently, the world container fleet has the fastest growth rate than any other ship type. Economy of scale effects in container shipping have led to a rapid increase in size for all types of vessels, from feeders to the large inter-continental carriers. The trend towards larger ships has accelerated in recent years and can be observed in the increasing size of the line haul as well as feeder vessels.

5.2.1.2 Container Vessels – World Fleet

Since its start in the early sixties, container trade has grown exponentially worldwide, resulting in significant increase in vessel numbers and sizes.

The distribution of world fleet container vessel sizes is shown in Table 5-1.

Table 5-1 World Fleet of Container Ships and Order Books

Container Ship	**Year end ('000' TEU)**				**2020**		**Order Book & Delivery Schedule**					
Fleet (TEUs)	**2017**	**2018**	**2019**	**No**	**'000' TEU**	**No**	**'000' TEU**	**% Fleet**	**2020**	**2021**	**2022**	**2023**
100 - 999	841	863	887	890	550	5	2	1%	2	3	0	0
1,000 - 1,999	1,129	1,161	1,222	1,263	1,942	17	125	1%	17	0	0	0
2,000 - 2,999	615	659	678	703	2,004	72	174	10%	17	40	15	0
3,000 - 7,999	1,307	1,317	1,325	1,329	6,573	9	30	1%	2	7	0	0
8,000 - 10,000	467	-	-	467	4,123	0	0	0%	0	0	0	0
10,000 - 15,000	347	387	407	415	5,760	43	**549**	10%	10	20	13	0
15,000+	101	131	161	186	4,492	41	**798**	23%	1	27	8	5
Total Fleet	**4,706**	**4,387**	**4,519**	**5,248**	**25,443**	**187**	**1,678**	**4%**	**49**	**97**	**36**	**5**

[Source: IHS Seaweb]

Figure 5-1 depicts the distribution of world fleet container vessel sizes.

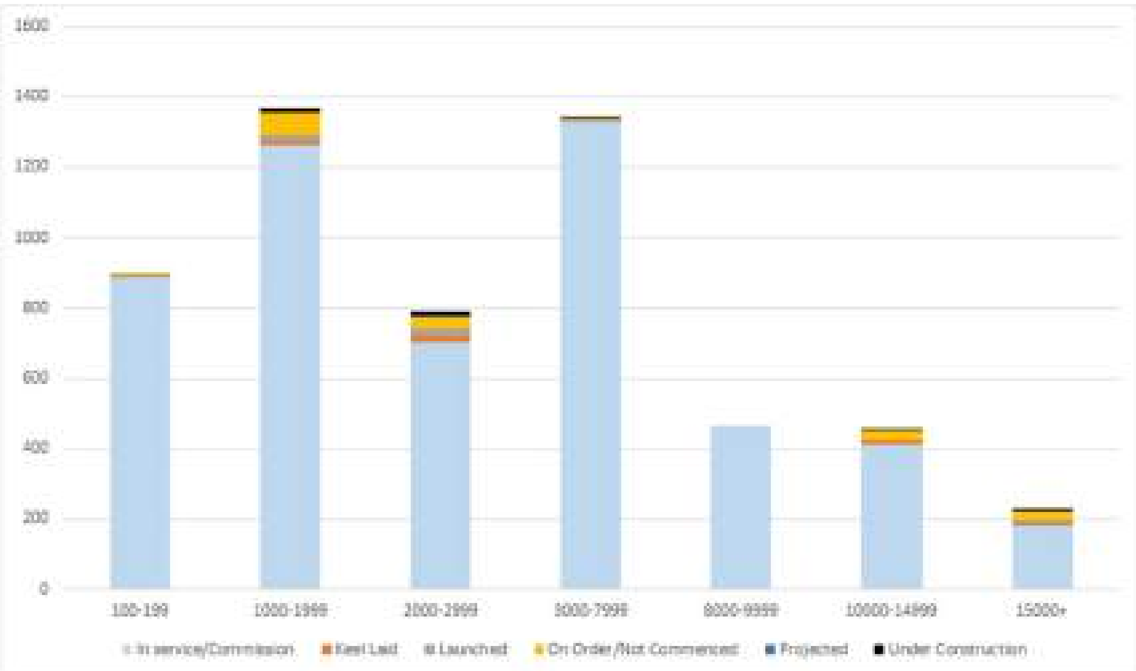


Figure 5-1 Distribution of Container Vessels by TEU

[Source: IHS Seaweb]

There is a continuing trend towards larger container vessels and several vessels at the top end of the size range are already on order as of November 2020:

- 34 no. 23,000+ TEU minimum ships ordered for delivery between 2020 and 2023.
- 5 no. 23,656 TEU ships ordered by one of the largest shipping line Mediterranean Shipping Company (MSC) on Daewoo Shipbuilding & Marine Engineering. Expected delivery in 2021.
- A series of 23,000+ TEU ships have been ordered from Samsung Heavy Industries, Hudong-Zhonghua Shipbuilding, Jiangnan Shipyard by Evergreen marine Corporation.
- Orient Overseas Container Line (OOCL) have ordered 12 new 23,000 TEU ships from Nantong COSCO KHI Ship Engineering and Dalian COSCO KHI Ship Engineering. Expected delivery in 2023.
- Other shipping lines like CMA CGM have also ordered 9 no. of 23,000 TEU ships with expected delivery in 2020.

Historically, as the mainline vessel sizes have increased, larger vessels operating in primary routes have 'trickled down' to the second-tier routes. It is expected that vessels in the range of 10,000 TEU will 'trickle down' to serve secondary or feeder routes in the future.

In order to establish Vadhavan port's position as a Major Container port, it will need to be able to handle ships normally in the range of 12,000 to 24,000 TEU.

5.2.1.3 Container Ships Dimension

Container ships are classified into seven broad categories viz. Feeder, Feeder Max, Handy, Sub-Panamax, Panamax, Post-Panamax and Ultra Large Container Carriers. The following table, which has been compiled through data from the IHS Seaweb database, gives a broad outline of the principal dimensions of the ships under the different categories. The Table 5-2 gives the dimensions of the smallest and the largest ship in each category. This will help in planning the layout of the container terminal and the other facilities.

Table 5-2 Dimensions of the Smallest and Largest Ship

Category	Capacity	Dimensions (m)		
	(TEUs)	LOA	Beam	Loaded Draft
Feeder	1,000	175	27	10.0
Feeder Max	2,000	210	32	12.0
Handy to Sub-Panamax	6,000	285	40	14.5
>Panamax	8,000	335	42	14.5
Post-Panamax	12,500	397	56	16.0
Super Post-Panamax	21,000	400	59	16.0
ULCC	24,000	400	61	16.5

[Source: IHS Seaweb]

5.2.1.4 Selection of Container Design Ship Size

Figure 5-2 below, shows all active container ships as of Q3 2020 and compares laden draft with Length Over All (LOA). The largest ULCCs in service today will require a berth depth of 18.0 m.

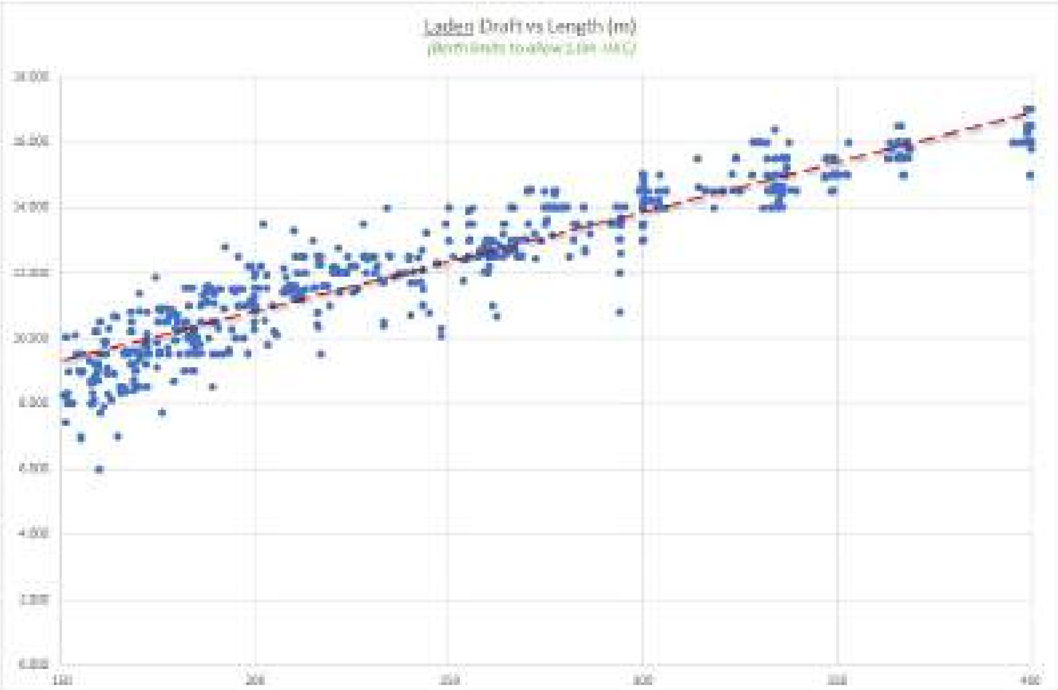


Figure 5-2 Container Vessel Draft vs LOA (150m – 400m)

[Source: IHS Seaweb]

Figure 5-3 shows how the ship length increases with capacity. Both figures are based on the current global container ship fleet.

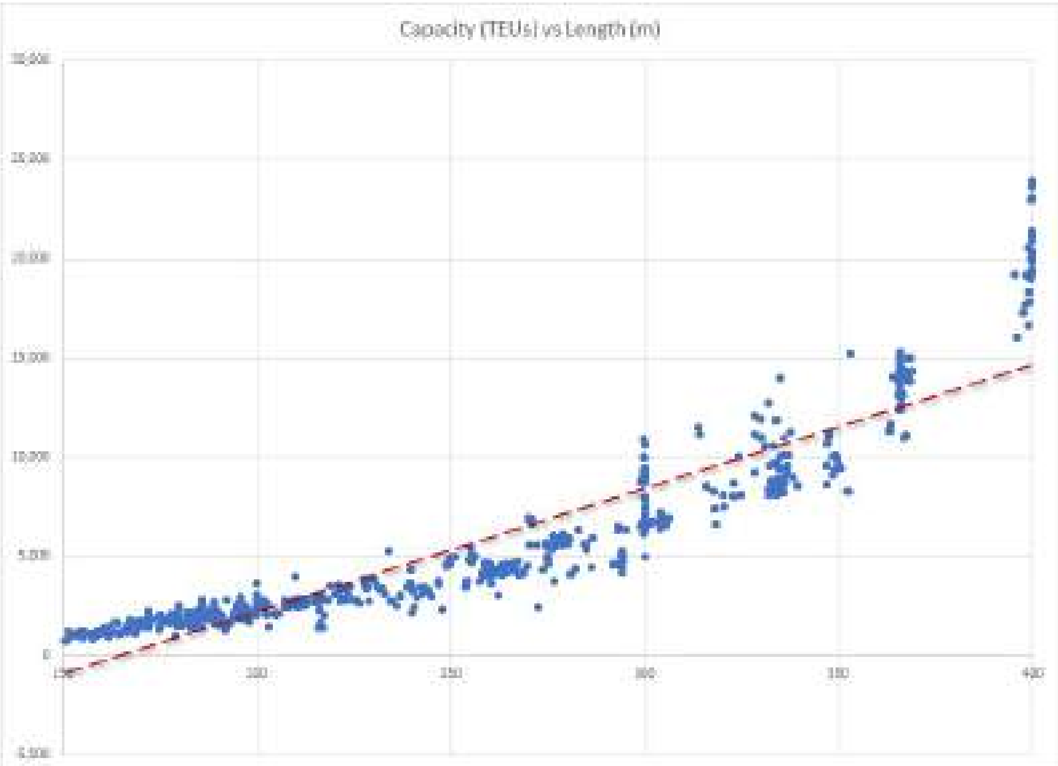


Figure 5-3: Container Vessel Capacity vs LOA (150m – 400m)

[Source: IHS Seaweb]

A Seaweb analysis of actual ship calls at JNPA over the three months to mid-November 2020 shows that the largest ships are of about 14,000 TEUs capacity with the main ‘workhorses’ being of the 4,500 TEU to 10,000 TEU capacity range representing 55% of all port calls.

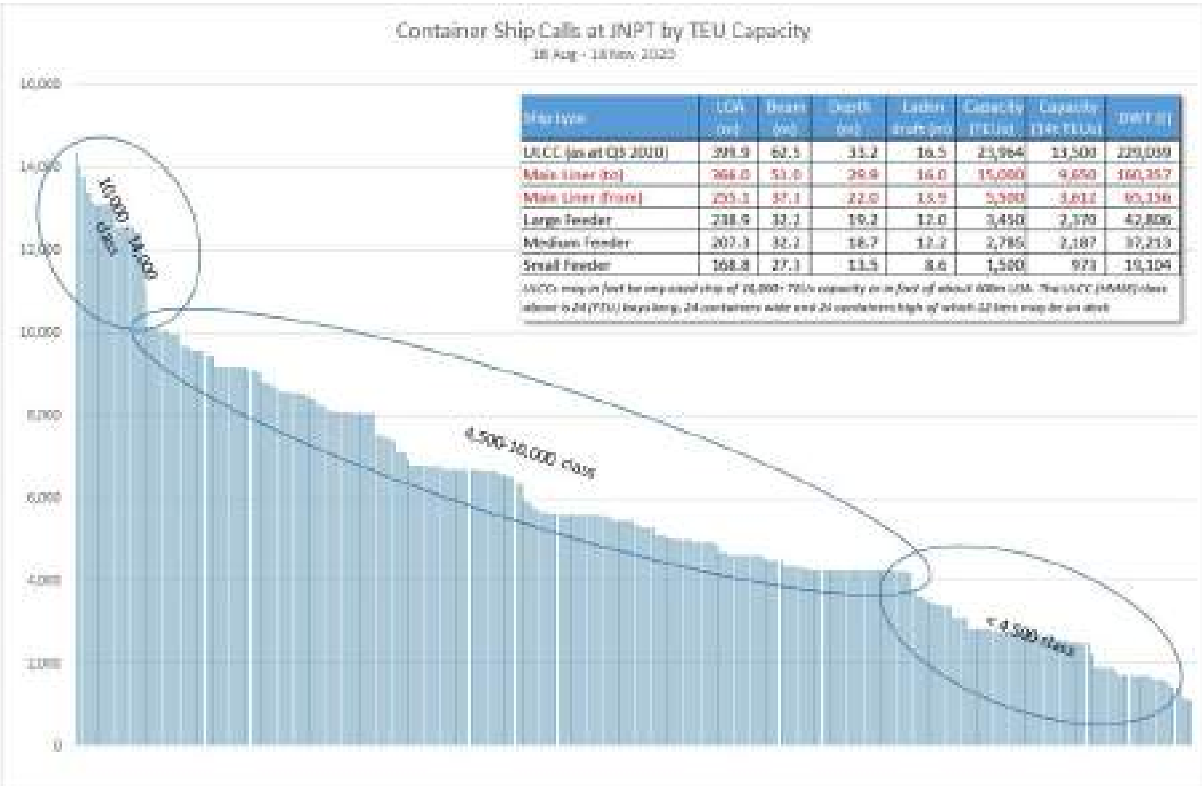


Figure 5-4 Ships Calls at JNPA, Aug-Nov ‘20

[Source: IHS Seaweb]

5.2.1.5 Import/ Export Container Vessels

The projected import / export trade through the port hinterland is the primary cargo for Vadhavan Port right from the Phase 1 development. Based on the projections, the maximum vessel size at the port is likely to be driven by the import/ export traffic. For Phase 1, the design vessel considered is 24,000 TEU which is currently the largest container vessel.

5.2.1.6 Summary of Container Design Vessels

Based on the outcome of ship size analysis for container traffic carried out in the preceding paragraphs, the design ship sizes considered for development of Vadhavan port have been presented in Table 5-3.

Table 5-3 Design Container Vessels over Master Plan Horizon

S. No	Commodity	Average Parcel Size in moves	Design Ship Capacity		Overall Length	Beam	Loaded Draft
		Moves	*TEU*		*(m)*	*(m)*	*(m)*
1.	Containers	4,500	Min.	6,000	300	40	14.0
			Max.	24,000	400	61	16.5

[Source: IHS Seaweb]

5.2.2 Multipurpose Cargo Ships

The breakbulk commodities are likely to be imported / exported in ships, which range from 10,000 DWT to 40,000 DWT. For planning purposes 40,000 DWT is recommended as the maximum design size of general cargo ships.

Fertiliser and its raw materials are imported primarily from the Middle East, USA, Israel, Western African countries, and sometimes Western European countries. Generally, the ships deployed for transportation of fertilisers are dry bulk cargo ships available on charter basis. The Handymax size is the preferred size worldwide because of economics of transportation. The maximum ship size calling at the major ports in the Middle East exporting fertiliser is around 60,000 DWT.

In Indian ports, even though in some ports the facilities have been designed for handling larger ships upto 60,000 DWT, the average parcel sizes have been less than 25,000 T. Considering all these aspects, it is recommended to adopt the design ship size for fertilisers and raw products as 40,000 DWT, however the multipurpose berths are designed to cater 60,000 DWT capacity.

5.2.3 Coastal Cargo Ships

For Coastal vessels, the size ranges from 10,000 DWT to 20,000 DWT. For planning purpose, 20,000 DWT vessel is considered as the design ship.

5.2.4 Ro-Ro Carriers

The Ro-Ro carriers generally which range from 10,000 DWT (2,500 car units) to 30,000 DWT (8,000 car units). For port planning purposes 30,000 DWT is recommended as the maximum design size of Ro-Ro ships.

5.2.5 Liquid tankers

The edible oil and chemicals are generally handled in small ships of sizes varying from 5,000 DWT to 10,000 DWT.

Currently, JNPA handles liquid bulk vessels of upto 30,000 DWT for edible oil. The parcel size of chemical is less because handling of volatile chemical is difficult, and these products have a limited shelf life. As a result, the consigners prefer to import or export optimal volume only.

Considering the above, it is proposed that design ship size of 30,000 DWT is considered for liquid tankers for planning and design purpose.

5.2.6 Bulk Liquid tankers

An in-house data bank on the present composition of the World Product Tanker Fleet was reviewed to establish the overall numbers and sizes of product tankers available in the world.

Table 5-4 indicates size-wise distribution of the product tankers together with their percentage share of the total fleet.

Table 5-4 Ship size distribution of Tankers

Tanker Size ('000 DWT)	No. of Tankers	Fraction
Below 20	8,578	57%
20 to 30	355	2%
30 to 45	855	6%
45 to 70	1843	12%
Above 70	3,343	22%
Total	**14,974**	**100%**

[Source: IHS Seaweb]

It could be seen from the table that more than 65% of the total tanker fleet falls under 45,000 DWT size. Considering the projected traffic of products being moved in small to medium size tankers, it is suggested that the structure of the berth could be designed for the maximum tanker size i.e., 60,000 DWT.

However, this being mainly a product handling facility, the berth may be required to handle smaller tankers on exigencies. Hence, for laying out jetty the ship size range to be considered could be from 20,000 DWT to 45,000 DWT.

5.2.7 Other Liquid carriers

The Other Liquid berth is planned to be able to cater to a range of Other Liquid carriers ranging from 75,000 m^3 to 266,000 m^3 Q-max carrier. As Floating Storage and Regasification Units (FSRU's) is treated as the latest and most appreciated system of handling Other Liquid nowadays, FSRU system is considered for the storage, regasification and handling of Other Liquid.

The configuration of FSRU vessel permanently moored to the Other Liquid berth is considered for the proposed project, and the Other Liquid carrier will unload the Other Liquid to FSRU vessel by a ship-to-ship transfer system.

5.2.7.1 Floating Storage and Regasification Unit

FSRU's are different in design than onshore Other Liquid terminal. Typically, existing Other Liquid ships are converted to FSRU by making necessary changes to accommodate unloading arms, regasification system and utilizing the storage tank on the ship as storage media or as a newly build FSRU custom designed. These FSRU can be either moored in the mid sea with turret mooring with seabed or can be permanently moored with the shore using single mooring or can be berthed at jetty on the shore permanently. Criticality of the FSRU lies in the logistic management of FSRU, and it typically works on fast turnaround time for Other Liquid ship.

Several mooring and offloading systems for breakwater protected Other Liquid transfer are under development by different companies. There are three main different mooring arrangements: Across the jetty, tandem and side-side offloading.

- *Side-by-side mooring arrangement:* The mooring arrangement is like that used at jetties, i.e., with many mooring lines to minimise the relative motions between both vessels. Side-by-side offloading *is suitable only for relatively benign environmental conditions.*
- *Tandem mooring arrangement:* The mooring is executed either via a mooring hawser, or via a flexible structural mooring system. Tandem offloading allows harsher weather conditions during which offloading can commence or be continued.
- *Across the jetty:* In this offloading concept, FSRU is permanently berthed on one side of the jetty and an Other Liquid carrier is brought on to the FSRU or on the other side of the jetty.

The third configuration of FSRU moored permanently on the jetty is proposed for Vadhavan port and the Other Liquid vessels will be berthed along the moored FSRU. Typical scheme of FSRU process is shown in the below figure.

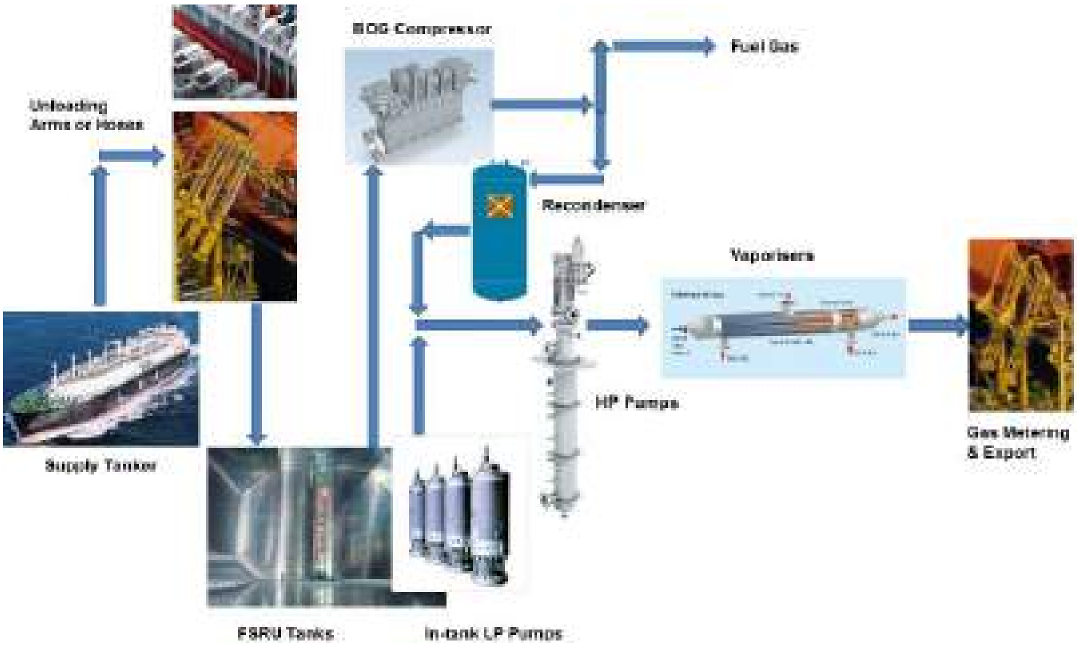


Figure 5-5 Typical Scheme of FSRU Process

[Source: The outlook for FSRUs, Brian Songhurst]

5.2.7.2 Advantages of FSRU

The benefits of FSRU technology are based on the various advantages as follows:

- Competitive cost in number of areas
- Strong environmental lobby amongst local communities against onshore facilities.
- No environmental impact on shoreline.
- Security and safety.
- Minimal land requirement as Other Liquid storage tanks is located on the ship.
- Remote from inhabitants, hence consequences of accidents are limited.
- Contain or lower risk arising out of terrorist threat.
- Planning/permitting may be reduced for offshore facilities.

5.2.7.3 Principal dimensions of FSRU considered for the design

The principal dimensions of FSRU are as follows:

Table 5-5 Dimensions of FSRU

Characteristics	Values
Dead Weight	Approx. 90,000 metric tons
Length O.A.	Approx. 295 m
Length B.P.	284 m
Breadth moulded	46.5 m
Depth moulded	26.5 m
Design draught moulded	11.5 m
Scantling draught moulded	12.5 m
Capacity	1,73,000 m^3

For the projected traffic, the configurations of FSRU and Other Liquid vessels of 173,000 m^3 as FSRU and Q max vessel of 266,000 m^3 capacity is considered for planning purpose.

The location of the Other Liquid grid from Vadhavan port is as shown in figure below.

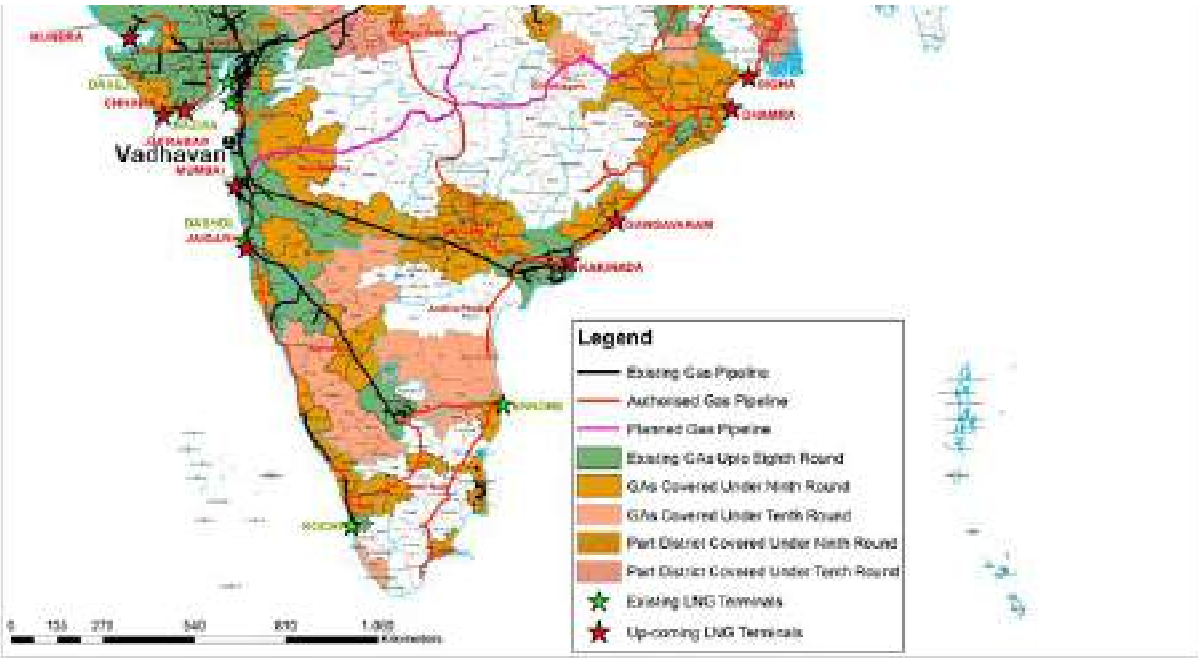


Figure 5-6 Other Liquid Grid – Gas Infrastructure Map of India

5.3 Governing Parameters of Design Ships

5.3.1 Range of Ship Sizes

Based on the outcome of ship size analysis for major commodities carried out in the preceding paragraphs, the design ship sizes considered for Phase 1 development of Vadhavan port is presented in Table 5-6.

Table 5-6 Summary of Design Vessels for Phase 1 Development

S. No	Commodity	Average parcel size	Design Ship Size		Overall Length	Beam	Loaded Draft
		TEU (DWT)	TEU (DWT)		(m)	(m)	(m)
1.	Containers	4,500 (56,250)	Min	6,000 (82,000)	300	40.0	14.0
			Max	24,000 (233,000)	400	61.0	16.5
2.	Multipurpose Cargo vessels	(30,000)	Min.	(20,000)	166	24.8	10.0
			Max.	(40,000)	209	30	10.5
3.	Ro-Ro	1,200 units	Min.	1,000 (7,200)	153	23.4	7.4
			Max.	8,000 (30,386)	221	32	11.3
4.	Liquid Tanker	6,000/ 18,000	Min.	(5,000)	105	16	6.3
			Max.	(30,000)	175	29	9.5
5.	Bulk Liquid Tankers	32,000	Min.	(20,000)	145	24	9.5
			Max.	(45,000)	180	30	10.5
6.	Other Liquid (m^3)	239,000	Min.	145,000	283	43.4	11.4
			Max.	266,000	345	53.8	12.0

[Source: IHS Seaweb]

5.3.2 Governing Parameters of Design Ships

Parameters of design ship considered for estimating the navigational requirements (dredged depths, channel widths, safe stopping distance etc.) of the channel and harbour basin for Phase 1 and Master Plan layout development of Vadhavan port, is presented in Table 5-7.

Table 5-7 Governing Parameters of Design Ship

S. No	Commodity	Average parcel size	Design Ship Size	Overall Length	Beam	Loaded Draft
		TEU (DWT)	TEU/DWT	(m)	(m)	(m)
1.	Containers	4,500 (56,250)	24,000 (233,000)	400	61.0	16.5

5.4 Functional Requirements

The Vadhavan port development plan has been prepared to guide the Phase 1 development of the port and identify the facility requirements in terms of number and length of berths, navigational requirements, terminal equipment, terminal storage area, road and rail access for the receipt and evacuation of cargo and other utilities and service facilities. The focus of the Phase 1 development is primarily on container cargo (93% of total traffic), other cargo terminals and port requirements. This section deals with the assessment of port facilities for the projected traffic at Vadhavan Port for Phase 1 development and over the master plan horizon.

5.4.1 Berth Requirements

5.4.1.1 General

The berth length needs to be sufficient to accommodate the length of the vessel plus an allowance at either ends for mooring and clearances between vessels. The amount of clearance required at either end of the vessel depends upon the vessel size. Minimum single berth length for the design vessels is shown in Table 5-8.

Table 5-8 Minimum Berth Lengths

S. No.	Berth Type	Unit	Average Design Ship Size	Phase 1 (m)	Phase 2 (Master Plan) (m)
1.	Container Berths	TEU	13,500 TEU	360 – 430	360 – 430
2.	Multipurpose Berth	DWT	30,000	190 - 240	190 - 240
3.	Ro-Ro berth	DWT	1200 units	180 - 250	180 - 250
4.	Bulk Liquid berth*	DWT	27,000	-	-
5.	Other Liquid berth*	DWT	205,000	-	-

* unloading platform, mooring and breasting dolphin arrangement

RHDHV used capacity analysis model to determine Vadhavan port's container terminal throughput capacity, which is defined as the amount of cargo a terminal can handle under given operating parameters. For containerized cargo, the capacity is calculated in either lifts or TEU per year.

The total amount of cargo a terminal can handle annually depends on the capacity of four main components: ship operations, yard operations, gate operations, and rail operations. RHDHV evaluated each of these terminal-operation components independently to identify elements limiting the overall throughput capacity of Port facilities. If one component of the facility has a much lower throughput capacity than the others, then the entire facility must operate at the capacity of that lower-functioning component.

5.4.1.2 Container Terminal Capacity Analysis

RHDHV conducted the Vadhavan Port container terminal capacity analysis using the Preliminary Capacity analysis model.

The following table summarizes the key inputs to Preliminary Capacity for each terminal element.

Figure 5-7 Key inputs to Preliminary Capacity

Berth	Container Yard	Rail	Gate
– Cargo moved per vessel call – Cranes used per vessel – Crane productivity – Working hours – Non-working time at berth – Seasonal peaking factors – Maximum allowable berth utilization	– Mix of cargo types – Dwell time – Static storage capacity – Inventory peaking factors	– Number of rail cranes in use – Rail crane productivity – Working hours – Switching delay – Static working track capacity	– Gate to vessel move ratio – Hourly arrival pattern – Number of gate stages – Fraction of trucks that visit each stage – Truck processing time at each stage

Berth capacity is defined as the volume of cargo that can be handled across the berth, without concern for any backup-land constraints. As with all elements of capacity, berth capacity is not a single fixed number, but a range of plausible values. Higher berth capacity means higher cost (more equipment and more labour cost) and lower levels of service because some vessels may have to queue for berth space. The potential maximum number of containers handled over the berth (measured in twenty-foot equivalent units or TEU), is primarily dependent on following factors:

Design Vessel Size: Size of vessels is increasing day by day to accommodate a greater number of TEU per vessel call. Considering the order-book of vessels and the vessels under construction, the typical average maximum size of the vessel for direct call at Vadhavan port in Phase 1 is considered as 24,000 TEU (for capacity analysis).

Available Berth Length: The berth length should be optimized to be able to cater to the largest design vessel along with mix of average vessels.

Dock Cranes Assigned per Vessel: Number of dock cranes deployed per vessel call varies based on the vessel size and number of containers to be handled per vessel call. For the vessel of size 24,000 TEU, up to six dock cranes are being used and for smaller feeder vessels two to three dock cranes will be deployed. On average, four dock cranes per average vessel call are considered for the capacity analysis.

Productivity per Dock Crane: As per prevailing practice in India, an average productivity of 30 moves per hour is used for initial development of the Vadhavan port. Once the operation stabilizes and core traffic achieved at the proposed port, the productivity is assumed to be reaching 32.5 moves per hour.

Maximum Practical Berth Utilization: It is a key subjective variable in a Berth Capacity Analysis. No berth can effectively run at 100% full. Shipping lines expect a certain level of customer service when calling a terminal; they do not want to queue out at sea for too long waiting for a berth to become available. Conversely, shipping lines work on fairly rigid vessel schedules around the world and filling a berth on a given day of the week may prove difficult to accomplish by changing sailing patterns. Due to the variable nature of vessel arrivals (delays at berth, storms, etc.), and the market-driven need to service vessels in a timely manner, the maximum practical berth utilization should be limited to avoid vessel queuing. In some locations, especially in Asia where feeder vessels will in fact queue for berth space, terminals can operate at berth occupancy up to 80%. Longer contiguous berths allow for greater occupancy than shorter berths. Vessels start queuing on a two-berth facility when average berth utilization goes over 65% on a gateway terminal, whereas for a single berth, it happens at around 50% to 60%. At port of Vadhavan, the initial Phase 1 development will comprise of 1000 m contiguous berth for each terminal and hence a value of 75% has been used for capacity calculations, however upto 80% berth utilization will be feasible for the operator in longer run.

Operational Time: Being an all-weather port, it is assumed that Vadhavan Port will work seven days a week for 350 days, allowing for 15 non-operational days due to weather. Further, it is assumed that the port will operate round the clock i.e., three shifts of eight hours each with allowance for one-hour break between each shift. This result in an effective working of 21 hours a day used in the capacity analysis.

Unproductive Time at Berth: It accounts for ship tie-up and untie time, which represents time where the berth is physically occupied by a vessel (i.e., no other vessel can be in that berth position) but there is no crane activity, excluding breaks which are captured by the work hours per day input. This activity includes mooring, line fastening, unlashing prior to first container move, administrative clearance, etc. These activities are assumed to take, on an average, 3 hours per vessel call.

Peak/mean Week Seasonal Demand: It is assumed that a peak week demand of berth will be 20% higher than the average week demand to account for changes in seasonal demand and adjust peak week berth capacity down to an average week berth capacity for calculation of the annual berth capacity.

Table 5-9 describes step-by-step assessment of annual berth capacity for the Port of Vadhavan Container Terminal. The right most column provides the variable's description.

Table 5-9 Container Berth Capacity Analysis for Vadhavan Port

2030	2040	BERTH CAPACITY
24,000	24,000	Typical Max Vessel Class Size TEUs
2,800	4,372	Container moves (Lifts) per vessel call
4.5	5.0	Dock cranes assigned per vessel
30.0	32.5	Productivity per dock crane (moves/hr)

2030	2040	BERTH CAPACITY
135.0	162.5	Vessel productivity (moves/hr)
20.7	26.9	Work hours per vessel call
3	3	Unproductive time at berth (hrs)
23.7	29.9	Total vessel time at berth (hrs)
21	21	Work hours per day
1.14	1.14	Calendar hrs/ work hour
27.1	34.2	Total vessel hrs at berth
168	168	Calendar hrs per week
6.19	4.92	Vessel calls per week at 100% berth utilization
75%	75%	Maximum practical peak week berth utilization
4.64	3.69	Maximum practical vessel calls per week
13,003	16,118	Peak week berth capacity (moves)
1.2	1.2	Peak/mean week seasonal demand factor
10,836	13,432	Mean week throughput capacity (moves)
563,000	698,000	**Annual unit berth capacity (moves)**
1.3	1.3	TEU per container
730,000	910,000	**Annual unit berth capacity (TEU)**
12	27	Number of berths (100'-gauge crane)
8,760,000	24,570,000	**Annual total berth capacity (TEU)**
730,000	910,000	**Capacity Per Berth (TEU)**
125,111	139,600	Annual lifts per dock crane
3,960	8,910	Total berth length (m)
4,000	9,000	Proposed Berth length (m)
2,210	2,760	Annual berth capacity per unit berth length (TEU/m)

It may be noted that for Phase 1 there is a requirement of 4,000 m long container quay for 2030 increasing to 9,000 m quay length in 2040 based on the above assessment.

Sensitivity Analysis for Berth Capacity

However, based on the deliberations with the client and the perspective that the port would be developed as a landlord port, sensitivity analysis on the berth capacity was carried out with the change in the following parameters.

- Unproductive time at berths
- Work hours per day

Table 5-10 Case 1 – Sensitivity Analysis for Container Berth Capacity

2030	2040	BERTH CAPACITY
1.5	1.5	Unproductive time at berths (hr)
22	22	Work hours per day (hr)
7,380,000	**24,000,000**	**Annual total berth capacity (TEU)**
2,970	7,920	Total berth length (m)
3,000	8,000	Proposed Berth length (m)
2,480	3,030	Annual berth capacity per unit berth length (TEU/m)

Table 5-11 Case 2 – Sensitivity Analysis for Container Berth Capacity

2030	2040	BERTH CAPACITY
1.5	1.5	Unproductive time at berths (hr)
24	24	Work hours per day (hr)
8,010,000	**23,980,000**	**Annual total berth capacity (TEU)**
2,640	7,260	Total berth length (m)
3,000	7,500	Proposed Berth length (m)
2,700	3,300	Annual berth capacity per unit berth length (TEU/m)

It may be noted that with the 22 work hours per day, the annual berth capacity is 7.38 MTEU and 24 MTEU in 2030 and 2040 respectively (Case 1). Similarly, it is 8 MTEU and 23.98 MTEU (Case 2) with 24 work hour per day

With this arrangement, the number of container terminal requirement would be 3 and 8 for Case 1 while it is 3 and 7.5 for Case 2 providing additional capacity for expansion beyond 2040.

5.4.2 Storage Requirements

5.4.2.1 Container Yard Capacity

Container yard capacity is defined as the potential maximum throughput of containers handled inside the container yard (measured in twenty-foot equivalent units or TEU), is primarily dependent on following factors:

Mean Dwell Time: The number of days a container sits inside the container terminal (dwell), which significantly varies for transhipment (usually 2 to 3 days) vs. the gateway traffic (varies from 3 to 7 days). For the gateway traffic, it varies by import vs. export vs. empty container. For the capacity calculation, an average of 4 days is used.

TGS Capacity: Represents the static storage capacity in terms of total number of twenty feet ground slots (TGS) or net acres available to store those containers inside the container yard.

Mean Storage Height: A mean storage height is calculated which takes into account the peak stacking height of the machine and various utilization factors than can be applied. It represents the maximum overall desired height for grounded operations. Most operators feel that 70-80% of the peak theoretical capacity is a reasonable level for planning purposes in order to account for sufficient empty slots for reshuffling and yard marshalling moves. Mean storage height used for this case is 3.5 high for capacity calculations.

Direct port Delivery: 50% of the import loaded containers are assumed to be part of direct port delivery where the import containers are delivered to the importer directly from the terminal instead of routing it through CFS a push by Government of India with an objective to reduce overall logistic costs.

Seasonal Peaking Factor: It is assumed that a peak week demand of container yard will be 10% higher than the average week demand to account for changes in seasonal demand and adjust peak week container yard capacity down to an average week yard capacity for calculation of the annual container yard capacity.

Weekly Inventory Peaking Factor: During a week, when a vessel arrives or departs, there is a sudden surge of inventory of containers that needs to be handled in the container yard, based on the size of the vessel and number of containers handled per vessel call. The factor applied to account for this surge is 10%.

Table 5-12 describes calculation of container yard capacity and formulas used to derive it.

Table 5-12 Container Yard Capacity Analysis for Vadhavan Port

2030	2040	CY CAPACITY
1000	1000	Nominal TGS capacity available
3.5	3.5	Mean storage height (containers)
3,500	3,500	TEU static capacity
4.0	4.0	Mean dwell time (days)
73.00	73.00	Turnovers per year per TEU static capacity
196,538	196,538	Box capacity without peaking
1.10	1.10	Seasonal throughput peak factor
1.10	1.10	Weekly inventory peak factor
65%	65%	Yard Utilisation
110,000	110,000	Nominal Annual CY Capacity in TGS
6,438,600	18,058,950	Capacity excluding DPD containers
49,528	**138,915**	**Required TGS to meet berth capacity**
55,303	**124,434**	**Available TGS**
9,781,483	**22,008,735**	**Container Yard Capacity TEU/year**

Sensitivity analysis of Container yard

The assessment of the yard requirements is simplified as all the container throughput is considered as domestic trade, i.e., without any transhipments which result in two quay moves for each yard call.

In the 2040 case with a throughput of 23.2 million TEUs, an average dwell time of 4 days across all container types, a yard stack height of 3.5 containers, a utilisation of 65% utilisation (as a TEU yard slot is not instantly filled as soon as emptied) and a peak of 15%, the number of TEU Ground Slots (TGS) required will be almost 100,262. However, sensitivities were developed with different dwell time over the range of containers and the peak factor in Table 5-13 and Table 5-14.

Table 5-13 Case 1 - Sensitivity analysis for TGS over Master plan horizon

Volume	TEUs	23,217,137	Stack height	Dwell	Utilisation	Peak	TGS required
DFD Imp (F)	21.3%	4,933,642	4.5	2.0	65%	15%	10,629
Imp (F)	21.3%	4,933,642	4.5	5.0	65%	15%	26,572
Imp (E)	0.0%	-	7.0	5.0	65%	15%	-
Exp (f)	41.0%	9,519,026	5.0	5.0	65%	15%	46,141
Exp (E)	6.0%	1,393,028	7.0	5.0	65%	15%	4,823
Imp (RFR)	7.0%	1,625,200	4.0	4.0	65%	15%	7,878
Imp (DG)	3.0%	696,514	4.0	3.0	65%	15%	2,532
Imp (OOG)	0.5%	116,086	1.0	3.0	65%	15%	1,688
Total							**100,262**

Table 5-14 Case 2 - Sensitivity analysis for TGS over Master plan horizon

Volume	TEUs	23,217,137	Stack height	Dwell	Utilisation	Peak	TGS required
DPD Imp (F)	21.3%	4,933,642	4.5	2.0	80%	10%	8,260
Imp (F)	21.3%	4,933,642	4.5	3.0	80%	10%	12,390
Imp (E)	0.0%	-	7.0	3.0	80%	10%	-
Exp (f)	41.0%	9,519,026	5.0	3.0	80%	10%	21,516
Exp (E)	6.0%	1,393,028	7.0	3.0	80%	10%	2,249
Imp (RFR)	7.0%	1,625,200	4.0	3.0	80%	10%	4,592
Imp (DG)	3.0%	696,514	4.0	3.0	80%	10%	1,968
Imp (OOG)	0.5%	116,086	1.0	3.0	80%	10%	1,312
Total							**52,287**

With the change in the dwell time, the yard utilisation and peaking factor, it can be noted that the total ground slot requirement reduces to 52,287. This case would project a highly optimistic case. However, from planning perspective, it is proposed to provide the total ground slots of 55,303 for Phase 1 and 124,434 for Phase 2. The total ground slot for each terminal required is 13,826 to cater the berth capacity.

5.4.3 Receipt and Evacuation of Cargo

5.4.3.1 Rail Throughput Capacity

This section describes the methodology that is used to determine the rail throughput capacity which is expressed as number of rail tracks required to handle the forecasted gateway container traffic that can be handled from the port.

For capacity calculations, RHDHV has considered the following container cargo split for rail and road connectivity based on the traffic assessment.

Table 5-15 Railroad split for Container Cargo

Cargo	Phase 1 (2030)			Phase 2 (2040)			Phase 3 (2050)		
	Rail (%)		Road (%)	Rail (%)		Road (%)	Rail (%)		Road (%)
	DFCC	IR		DFCC	IR		DFCC	IR	
Containers	28.8	2.3	68	31.5	2.3	66	33.3	2.3	65

Following factors impact rail throughput capacity:

Track Length: Track length is taken as 1500 m clear length for each track as per the length of container train operated by DFCC.

Maximum possible number of cranes working to load/discharge containers from railcars: Based on the track length available at the proposed rail yard, it is assumed that two RMGC can be deployed to work simultaneously on the rail track during Phase 1 development.

Amount of railcar double cycling: It is assumed that for 90% of arriving railcars that bring in a container in the port will leave with a container while departing.

Crane Productivity: RMGC are assumed for loading/unloading of train racks over a single or double rail track respectively. As per prevailing practice in India, an average productivity of 18 moves per hour is used for initial development of the Vadhavan port. Once the operation stabilizes and core traffic achieved at the proposed port, the productivity is assumed to be reaching 22 moves per hour.

Allowable loading/ unloading, switching hours: Based on the discussions with the railway authority, with the Engine of Load (EOL) operating concept the overall allowable working time for railways for loading/ unloading of container rakes including the switching time is 5 hours.

Work hours per day: 20 hours per day is assumed for Phase 1 development. In future, with increased demand, the work hours can be increased per day for rail yard operation.

Peaking factors: It is assumed that the peak month will be 20% higher than the average month and peak day throughput will be 20% higher than the average day throughput.

Switching time: It is defined as time between the first set of railcars getting ready to depart from the port rail yard and going to the mainline and a second set of railcars arriving in the port rail yard through the single rail track. For the capacity analysis purpose, the switching time of trains is considered to be 2 hours. This will account for all the delays incurred in bringing the set of rail cars from the mainline to the port.

Table 5-16 describes calculations to determine the number of working tracks to handle the forecasted demand.

Table 5-16 Rail Yard Capacity Analysis for Vadhavan Port

2030	2040	2050	RAIL CAPACITY
32%	**34%**	**35.6%**	% of Total Container Traffic via Rail
2,807,580	**8,390,655**	**14,234,220**	Total Rail Throughput Goal (TEU)
1	1	1	Nominal Number of Working Tracks
1,500	1,500	1,500	Average Length of Each Track (m) for 90 railcars
13.8	13.8	13.8	m per one flat railcar (BLC wagon)
360	360	360	Full Static capacity with double stack loading (TEU)
30%	22%	17%	Single Stack loading share
90	180	180	Single Stack capacity [TEU]
279	320	329	Average Static TEU Capacity
95%	95%	95%	Rail working track utilization factor
90%	90%	90%	Railcar utilization factor
1.30	1.30	1.30	Box factor
367	421	433	Discharge + load moves possible w/o switching
5	8	10	Max Rail Yard Cranes in use
18	22	22	Moves per hour per RMG
4.08	2.39	1.97	Train work time (workhours)
5	5	5	Total allowable working hours by railways with EOL
20	20	20	Work hours per day
1.2	1.2	1.2	Calendar hrs per work hour
4.9	2.9	2.4	Train work time (hours)
2.0	2.0	2.0	Switch time to replenish working tracks (hours)
20%	20%	20%	Allowance for bunching of rakes
2.8	3.9	4.4	Max turnovers per day
1,022	1,660	1,907	Max container moves/day
110%	110%	110%	Peak/mean week throughput
110%	110%	110%	Peak/mean day within week for rail
845	1,372	1,576	Mean rail capacity per day (moves)
350	350	350	Number of working days per year
300,000	490,000	560,000	Annual rail capacity per module year (moves)
390,000	637,000	728,000	Annual on-terminal rail capacity per module (TEU)

2030	2040	2050	RAIL CAPACITY
10,798	19,758	29,329	Total working track length required to meet vessel capacity (m)
8	14	20	Number of Working Tracks Required (each track of 1500 m. length)
18	18	24	**Number of Working Tracks Provided**
7,020,000	**11,466,000**	**17,472,000**	**Annual Rail Capacity Provided TEU/year**

5.4.3.2 Gate Capacity

Gate capacity analysis is essential feature to get essence of seamless inward and outward traffic movement including major share of trucks having containers. Following factors impact gate throughput capacity:

Throughput share handled by trucks: Share of throughput which is forecasted to be handled by truck is key factor for gate capacity planning. Amount of TEU handled by truck will determine the daily truck traffic at port and the movements at gate complex. For capacity analysis, the container cargo split is as per Table 5-15.

Peak Ratio: For weekly mean moves 20% peak factor is considered. For daily traffic movement 30% peak in daily traffic is considered. For hourly traffic, 30% peak is considered for mean hourly traffic.

Working Hours: Working hours of gate directly impacts the gate capacity. For Phase 1 development three shifts each of 8-hour per gate shift is assumed.

Moves per Truck visit: Moves per truck visit reflect the container handling movement per truck. It reflects the number of trucks which come with a container and leave port with a container. The amount of such truck traffic is assumed 50% of total daily truck traffic.

RPM Capacity: Radiation Portal Monitors (RPM) are passive radiation detection devices used for the screening of vehicles and cargo for detection of illicit sources at port gates. Number of trucks that can be screened by this device per hour determines its capacity, which is being considered as 120 trucks per hour for capacity calculation. This number can increase with reduction in screening time.

Table 5-17 describes calculations to determine phase wise the fraction of capacity required for seamless container truck traffic movement through the gate.

Table 5-17 Gate Capacity Analysis for Vadhavan Port

2030	2040	2050	GATE CAPACITY
6,738,462	18,900,000	30,800,000	Vessel moves/year
68%	66%	64%	% of Total Container Traffic via Truck
4,578,785	12,445,650	19,850,600	Total throughput moved through Gate
88,054	239,339	381,742	Moves per mean week
1.2	1.2	1.2	Peak/mean week ratio
105,664	287,207	458,091	Peak week moves
7	7	7	Days per week operation

2030	2040	2050	GATE CAPACITY
15,095	41,030	65,442	Mean day moves
1.3	1.3	1.3	Peak/mean day ratio
19,623	53,339	85,074	Peak day moves
24	24	24	Hours worked per day
818	2,222	3,545	Moves per mean hour on a peak day
1.3	1.3	1.3	Peak/mean hour factor
1,063	2,889	4,608	Peak hour on a peak day moves
1.5	1.5	1.5	Moves per truck visit
709	1,926	3,072	Peak hour truck entries
100%	100%	100%	Fraction of entries that have a container
709	1,926	3,072	Trucks per hour at RPM
30	30	30	RPM process incl. truck replacement (sec)]
120	120	120	RPM capacity per hour
6.0	**17.0**	**26.0**	**RPM lanes required**
30	30	30	Entry pedestal process time (sec)
120	120	120	Gate capacity per hour
6.0	**17.0**	**26.0**	**Gate entry lanes required**
30	30	30	Exit process time (sec)
120	120	120	Exit capacity per lane
6.0	**17.0**	**26.0**	**Exit lanes required**

5.4.4 Other Cargo Requirements

5.4.4.1 Cargo Handling System

Fertiliser

The fertiliser commodity can be handled at the multipurpose berth using the mobile harbour cranes. The handling rate for fertilizers would be 9,000 TPD during the initial phase increasing to 12,000 TPD. Accordingly, for estimating berth requirements the average handling rates for the fertiliser is 9,000 TPD.

No mechanised handling for fertiliser is envisaged in Phase 1 considering the projected traffic. However, provision for mechanisation has been considered in the overall terminal planning to commensurate with the traffic in future.

General/ Coastal Cargo

For the General/ Coastal cargo at Vadhavan Port, it is proposed to provide two mobile harbour cranes at each berth to achieve higher handling rates. Support dumpers/ trailers shall be provided to match the handling rates at berth. At storage areas adequate number of front-end loaders, mobiles cranes would be provided.

An average handling rate of 12,000 TPD and 10,000 TPD has been considered for general and coastal cargo respectively.

Liquid Cargo – Bulk Liquid, Edible Oil and Chemicals

The Bulk Liquid is unloaded from the tankers by means of marine unloading arms and transferred to the tank farms through the pipelines. The unloading rates mainly depend upon the capacity of the onboard ships provided the matching capacity of unloading arms and pipelines provided. The transfer system of chemicals, which come in much smaller parcel sizes, is also similar.

The average handling rates achieved at berth for Bulk Liquid and edible oil/ chemicals are 24,000 TPD and 6,000 TPD respectively.

Ro-Ro

The auto cars will be loaded to the Ro-Ro carrier at an exclusive berth. The average loading achieved is 1,200 cars per day per berth.

Other Liquid

The Other Liquid Jetty is unloaded from the carrier by means of FSRU and connected to the Other Liquid grid which run close to the proposed Vadhavan port site through pipelines. The average unloading rate for Other Liquid is considered to be 38,000 TPD.

5.4.4.2 Cargo Handling Rates

The following cargo handling rates have been assumed over the master plan horizon as mentioned in Table 5-18.

Table 5-18 Cargo Handling Rates for Other Cargoes

S. No.	Commodity	Average Handling Rate (tonnes per day per berth)	
		2030	*2040*
1.	Fertiliser	9,000	12,000
2.	RO-RO	1,200	1,320
3.	Other Liquid	38,000	38,000
4.	Bulk Liquid	28,000	30,000
5.	Chemicals, Edible Oil	6,000	6,000
6.	General Cargo	12,000	15,000
7.	Coastal Cargo	10,000	12,000

5.4.4.3 Operational Time

Considering that the port is planned as all-weather port, the effective number of working days is taken as 350 days per year, allowing for 15 non-operational days due to weather. Further, it is assumed that the port will operate round the clock i.e., three shifts of eight hours each. This results in an effective working of 20 hours a day.

5.4.4.4 Time required for Peripheral Activities

Apart from the time involved in loading / unloading of cargo, additional time is required for peripheral activities such as berthing and de-berthing of the vessels, customs clearance, cargo surveys, positioning and hook up of equipment, waiting for clearance to sail, etc. An average of 4 hours per vessel call has been assumed for these activities.

5.4.4.5 Allowable Levels of Berth Occupancy

Berth occupancy is expressed as the ratio of the total number of days per year that a berth is occupied by a vessel (including the time spent in peripheral activities) to the number of port operational days in a year. High levels of berth occupancy will result in bunching of ships resulting in undesirable pre-berthing detention. In order to be competitive, it is important that the ships calling at the port should have minimal pre-berthing detention. At the same time the investment at the port infrastructure has to be kept at optimal level. Keeping these in consideration it is proposed to limit berth occupancy of 60% for 1 berth and that 65% for 2 berths for similar commodity. This shall reduce the pre-berthing detention of ships and offer reduced logistics cost to the shippers.

5.4.4.6 Berths Requirements for the Master Plan

Based on the above criteria, the berth requirements for different cargo have been worked out. A summary of the estimated berths over master plan horizon is presented in Table 5-19 below:

Table 5-19 Estimated Berths for Other Cargoes at the Vadhavan Port

S. No.	Commodity	Phase-wise Berths		Total
		2030	*2040*	
1.	Breakbulk (Fertiliser, General, coastal Cargo)	3	1	4
2.	Liquid Cargo (Chemical, Edible oil)	2	0	2
3.	RO-RO	1	0	1
4.	Bulk Liquid	1	0	1
5.	Other Liquid	1	0	1

5.4.5 Berth Capacity - Other Cargoes

The berth capacity for other cargoes have been assessed taking into consideration the proposed facility and handling arrangement. The basic data pertaining to traffic, design ship sizes, handling rates and berth occupancy, for the Phase 1 development of the Vadhavan port is presented in attached Table 5-20.

Table 5-20 2030 - Berth Capacity for Other Cargoes

Commodities	Import (I) / Export (E)	Handling Rate TPD	Average Parcel Size T	Year 2030						Allowable Berth Occupancy	Berth Capacity (MTPA)
				Annual Throughput MTPA	Ship Calls Annum	Berth Days Required	Total Berth Occupancy	Berths Provided	Combined Berth Occupancy		
LNG		38,000	239,400	2.30	10	63	18%	1	18%		6.31
LPG	I	26,000	31,632	3.10	98	127	36%	1	36%	65%	5.55
Edible Oil		7,500	12,226	1.00	82	147	42%	2	46%		1.33
Chemicals		6,000	5,625	0.90	160	177	51%				
Fertiliser	I	9,000	25,080	1.00	40	118					
General Cargo	I/E	10,000	27,731	2.40	87	214	156%	3	52%	65%	6.37
Coastal Cargo	I/E	12,000	18,665	1.70	185	214					
Ro - Ro	E	1,200	3,302	49,500	15	44	12%	1	12%	65%	257,400

Table 5-21 2040 - Berth Capacity for Other Cargoes

Berth Type	Commodities	Import (I) / Export (E)	Handling Rate TPD	Average Parcel Size T	Year 2040						Allowable Berth Occupancy	Berth Capacity (MTPA)
					Annual Throughput MTPA	Ship Calls Annum	Berth Days Required	Total Berth Occupancy	Berths Provided	Combined Berth Occupancy		
Liquid Bulk	LNG	I	38,000	239,400	4.50	19	123	35%	1	35%	65%	4.50
	LPG		30,000	31,632	4.20	133	162	46%	1	46%		3.19
	Edible Oil		7,500	12,226	1.20	98	177	50%	2	51%		1.59
	Chemicals		7,500	5,625	1.10	196	180	51%				
Multipurpose Berth	Fertiliser	I	12,000	25,080	1.20	48	108					
	General Cargo	I/E	12,000	27,731	4.60	166	334	222%	4	55%	65%	10.55
	Coastal Cargo	I/E	16,000	18,665	3.20	295	334					
RO-RO	Ro - Ro	E	1,320	3,302	169,000	51	137	39%	1	39%	65%	281,541
Containers	EXIM	I/E	3,600	5,684	23.22	4085	7704	2201%	31	71%	75%	24.53
GRAND TOTAL					**20.00**	**954**			**8**			**19.83**

Table 5-21 presents the similar details for the next phase of development i.e., year 2040. The port capacity would need minor increase in the facility to handle the projected traffic of next phase. It may however be noted that with the expensive common infrastructure such as breakwaters and dredged depths in place, the port capacity can be easily increased with the addition of required berths along with associated material handling system and onshore infrastructure.

5.4.6 Approach Trestle Capacity

Following are the parameters considered to arrive at the width and capacity requirement for the approach trestle. The road truck movements to/from the marine and rail terminals on the offshore reclamation has been evaluated to establish the requirements for the road connection to the offshore reclamation.

Table 5-22 Calculation of PCUs inside port and leaving port

Parameters	Assumptions	2030	2040	Quantities
Containers		**6,510,000**	**23,220,000**	**TEUs/year**
Road cargo		**5,100,000**	**9,000,000**	**TPA/year**

Parameters	Assumptions	2030	2040	Quantities
RO-RO		**49,500**	**169,000**	**PCU/year**
Transhipment	0%	-	-	TEUs/year
TEU - Working days/year	350	18,600	66,343	TEUs/day
TPA - Working days/year	350	14,571	25,714	TPAs/day
Rail (for TEU traffic leaving port)	33%	6,045	21,561	TEUs/day
TEU/truck (40 feet)	1.95	6,438	22,965	TEUs/day
TPA/truck	10	1,457	2,571	TPAs/day
RO-RO (PCU CT-PID)	**350**	141	483	**PCU/day**
PCU of Truck (TEU CT-CY, in-port)	**4.5**	28,973	103,342	**PCU/day**
PCU of Truck (TPA T-Y, in-port)	**3.5**	5,100	9,000	**PCU/day**
Approach Trestle (CT1-9), MPBs, RORO		**34,215**	**112,825**	**PCU/day**

Based on the calculations above, there is a maximum of 112,825 PCU (26,019 trucks) movements in the port when the port is in full operation in 2040.

Table 5-23 Capacities of Urban roads (Highway Capacity Manual 2010)

Capacity of Roads (HCM2010)	PCU/hr	PCU/day	Remarks
1 lane	2200	52,800	1 direction, continuous flow
2 lanes	4400	105,600	1 direction, continuous flow
3 lanes	6600	158,400	1 direction, continuous flow
4 lanes	8800	211,200	1 direction, continuous flow

With 52,800 PCU/day/lane according to the Highway Capacity Manual 2010,

- For Approach Trestle 3 lanes per direction is sufficient to serve all CTs, multipurpose terminal, RO-RO terminal and port craft berths, Coast guard.

The above assessment has been validated through the Level of Services (LOS) grade as per the HCM. Below are the levels of service grades.

Grade	Type of Flow	Headway
A	Free flow	distance between vehicles 167 m or 27 car lengths (or 9 container trailer lengths)
B	Reasonably free flow	distance between two vehicles is 100 m or 16 car lengths (or 5 container trailer lengths)
C	Stable flow	distance between two vehicles is 67 meters or 11 car lengths (4 container lengths)
D	Approaching unstable flow	distance between two vehicles is 50 m or 8 car lengths (2.5 container lengths)

Grade	Type of Flow	Headway
E	Unstable flow	distance between two vehicles is 37 m or 6 car lengths (2 container lengths)
F	Breakdown flow	

The following assumptions have been made to arrive at the trestle capacity and lane requirements.

- Level of service - Grade C has been considered distance between two vehicles is 67 meters or 11 car lengths (4 container lengths)
- Average length of the vehicle by Phase 2 - 17.26 m
- Average speed of the vehicle by Phase 2 - 20.3 km/h

Based on the above, the Trestle capacity have been arrived at based on the above assumptions

Table 5-24 Calculation of number of trucks inside port and leaving port

Value	Parameters
20.3	Average Speed of Vehicle V in kmph (a)
C	Level of Services (b)
67	Headway S in m ©
303	Trestle Capacity rc = 1000V/S vehicles/lane/hour (d)
24	hours of operation hr (e)
26,019	# of TT/ trucks at Approach trestle (f)
1,084	# of TT per hr. on Approach Trestle (g)
10%	Peaking factor (h)
1,193	Peak hour number of vehicles per hr. on North Trestle (i)
3.94	Number of lanes at Approach Trestle (j)
4	**Proposed # of lanes for Approach Trestle (k)**

Considering the above, it is proposed to provide the approach trestle with 4 lanes each way for the approach trestle to cater the truck movements in and out of the Vadhavan port.

5.4.7 Port Crafts Berth

For the initial stage development, the port would require 6 tugs (4 operational + 2 standby) with a capacity of 65 T and 100 T bollard pull, 1 pilot cum survey launches and 2 mooring launches.

Berth of 200 m is proposed for berthing of port crafts.

5.4.8 Provision for Coast Guard

The need for effective coastal security in the present security scenario was highlighted by Coast Guard to JNPA. The same was indicated by JNPA, where Coast Guard had put requirement for development of a station at Vadhavan.

The Coast Guard requested a dedicated berthing space at Port of Vadhavan to enable operation of its ships. The present docking facility available within the existing Mumbai harbour is insufficient to cater to the increased needs in the region. The Coast Guard is planning to have station at Port of Vadhavan for effective coastal security and monitoring of Sea Lanes of Communication which is located around 70 nautical miles off the north coast of Mumbai. It will also help in providing enhanced training to the Marine Police.

The Coast Guard at Vadhavan requested for a dedicated berth having a minimum berthing space of 100 m, alongside depth of 8 m. A land parcel for onshore Coast Guard facilities is proposed at the Port of Vadhavan. JNPA agreed to the above requirement on a cost sharing basis, considering the coastal security needs of the region.

5.4.9 Other Liquid Bunkering

In order to make the proposed port more attractive location for shipping lines traversing through the East-West/ Middle east shipping channel, a provision for bunkering facility can be also provided at the proposed Vadhavan port. In order to provide for the latest state-of-the art bunkering facilities, following key elements will be required at the port:

- Bunker fuel loading hydrant system along all container berths
- Bunker fuel storage tanks
- Bunker fuel unloading berth

Currently, most of the ports are thrusting on reducing the carbon footprints and moving to efficient/ clean fuel. Other Liquid is being used by most of the shipping lines and one of the clean fuels as an alternate to diesel. For the proposed Greenfield port at Vadhavan, it is prudent to provide the provision of Other Liquid bunkering facility considering the number of ships calls at the port. With a capacity of forecasted annual demand of approximately 3.5 MT to be handled from the proposed port, it equates to approximately 350,000 T of static storage capacity and one dedicated berth for unloading of the Other Liquid cargo.

5.5 Storage Requirements

As per the international practice the storage capacity at port for a particular commodity should at least cater to the higher of the following:

- 5% to 10% of the annual cargo throughput i.e., dwell time at port; or
- 1.5 times the maximum parcel size.

For some cargo, the annual throughput is relatively small as compared to the parcel sizes and hence the frequency of vessel calls will be low to moderate. This will, most likely, allow for the clearance of the stored cargo prior to the arrival of the next shipment. Further, during cargo handling operations at the multi-purpose berths, part of the cargo is likely to be directly evacuated without passing through the storage area. Under these circumstances, the storage areas could be optimised at least for the initial stages of development.

Other factors to be taken into account in determining the size of the storage areas are stacked densities, angle of repose, maximum and average stacking height, aisle space, reserve capacity factor, peaking factor, etc.

The norms adopted for calculating the storage areas in port for various commodities are given in Table 5-25 below:

Table 5-25 Norms adopted for calculating storage area at port

S. No.	Commodity	Average Parcel Size (T)	Maximum Parcel Size (T)	Criteria for Providing Storage Area		Stacking Assumption
				Days at Port	*% of Annual Throughput*	
1.	Fertiliser	25,000	54,000	30	8%	6 m high
2.	General Cargo	27,700	41,250	30	8%	
3.	Coastal Cargo	18,700	30,000	15	4%	
4.	Liquid Cargo (Chemical, Edible oil)	9,000	9,000	30	8%	18 m dia and 16 m high tanks
5.	RO-RO	7,600	12,834	10	2.7%	16 Sqm/ Car
6.	Bulk Liquid	31,600	54,000	30	8%	55 m dia and 32 m high tanks
7.	Other Liquid	239,000	266,000	15	4%	FSRU

Based on the above criteria the storage areas have been worked out for various cargos over the master plan horizon.

Table 5-26 Storage Areas – Master Plan horizon

S. No.	Commodity	Requirement of Storage Area (m²)	
		2030	*2040*
1.	RO-RO Vehicles	21,699	74,082
2.	Edible Oil	9,543	10,603
3.	Bulk Liquid	42,765	57,020
4.	Chemicals	14,844	16,965
5.	Other Liquid	0	0
6.	Fertiliser	31,983	38,379
7.	General Cargo	59,178	113,425
8.	Coastal Cargo	20,959	39,452
Total Storage Area Required (m²)		**203,001**	**351,966**
Total Storage Area Required (Ha)		**20**	**35**

5.6 Buildings

5.6.1 Terminal Admin Building

The terminal administration building will be required to house the terminal operator's management, security, admin, and customer service personnel.

The building is located on the site plan to allow visual access to the terminal gate complex from the Customer Service Department and Control Room. Office areas will have visual access to the container yard, container ship wharf, rail yard, and all gate areas. The building location has been planned in such a way that additional annex can be added in the same location for future phases if needed.

Typical users/uses of the administration building include:

- Terminal Administration
- Customer Service
- Gate Equipment Control
- IT/Server
- Gate Control Clerks
- Offices
- Shipping Lines Offices
- Terminal Security and Communications Hub

The Administration Building generally equips the following systems:

- TOS Computer System
- Container Yard Lighting Controls
- Annunciation and Alarm Systems
- Gate Control and Systems (voice, data, scale, sign bridge etc.)
- Public Address System
- Telecommunications System

5.6.2 Entry Exit Gate Inspection Canopy

The Entry Gate Inspection Canopy is used to process container traffic into the terminal and the Exit Gate Inspection Canopy is used to process container traffic out of the terminal.

Gate canopies provide weather protection for the gate activities and provide a mounting structure for gate cameras and infrastructure. Any statutory scanning of import as well as export cargo will also take place here.

The Entry/Exit Gate Canopy equipment shall include, but not be limited to the following:

- TOS and Gate Computer Systems
- Gate Camera Controllers
- Cameras with automatic vibration correction
- Sign Bridge Controllers
- Scales and Scale Interface Controls
- Communication antennae and associated hardware

5.6.3 Security Guard Booth

Security guard booth provides security surveillance at the main gate truck access and exit lanes. The guard booth serving the main gate should be elevated and provided with sliding windows so that communications with drivers within the truck cabs can be facilitated.

The Guard Booth equipment shall include, but not be limited to the following:

- Central Security Monitoring and ‘Annunciation Panels. Panels shall accurately depict the site plan of the terminal.
- CCTV monitors and controls with split screen and view selection capability.

5.6.4 Pre-gate building and Customs Clearance

This facility is provided for the administrative functions of the remote pre-gate facility. The Pre-gate Building houses the Customs and Customer Service Department. The Customer Service Buildings and Kiosks provide facilities for truck drivers to resolve problems they may have with their paperwork, as well as convenience facilities.

The Pre-gate Building is required to provide facility for following functions:

- Customs clearance
- Demurrage payment
- Customer service
- Trouble transactions
- Truck driver canteen
- Toilets and washrooms
- Public phone, fax, and internet

5.6.5 Maintenance and Repair Building

This facility houses maintenance, repair, and related activities for RTGs, yard tractors, top-picks, side-picks, truck chassis, and other container terminal operating equipment. It also supports other service areas such as tire changing, and equipment steam cleaning activities.

Typical users/uses for this building include:

- Maintenance Supervisors
- Power and Chassis Repair Mechanics
- Parts Storage and Control
- Mechanics' Lockers
- Genset Repair
- Offices
- Vendors

Parking for service vehicles and bad order equipment needs to be adjacent to the building. Adequate circulation is required to move vehicles to and from the service bays. Roll-up overhead doors are required in the parts room and service bays. Building location shall allow for the ease of vendor access through the perimeter fence.

5.6.6 Quay Crane and Marine Operations Building

This facility houses ship loading/unloading operations and planning functions as well as break facilities for the ship operations. The building should be multi-levelled.

Typical users/uses of this building include:
- Marine Operations Supervisors
- Labour Breakroom and Restroom Facilities
- Crane Repair Mechanics (Spreaders, Ropes)
- Parts Storage and Control
- Mechanics' Lockers

The building equipment shall include, but not be limited to the following:
- TOS Computer System
- TV Supervisory System

5.6.7 JNPA Port Administration Building

A separate building and land area will be required to provide for functioning of JNPA in managing the port operations. This will include but not limited to office building for the JNPA management and administration staff, office for government officials, security staff and customs and border protection officers. This will also include the facilities for port maintenance and engineering staff.

5.6.8 Port Fire Station

A centralized fire station will also be provided for attending to all calls. This station will house mobile fire tenders. Further special firefighting equipment such as foam and gas extinguishers will also be provided for chemical and electrical fires. Fire detection, monitoring and control system will be provided in all vulnerable area of the port.

5.6.9 Rail Master Building

A separate building will be required to provide for functioning of rail operations within the terminal. This building will house the rail master and associated staff managing the rail operations within the port. This building will also house a small workshop for minor maintenance functions.

5.7 Cargo Receipt and Evacuation

For the efficient functioning of a port, the essential pre-requisite is the connectivity to the hinterland for the effective movement of cargo in and out of the port. This connectivity includes conventional road and rail linkage. Planning for any port should consider the types of cargo and the modes that would be required to transport the cargo in and out of the port.

At Vadhavan Port, the cargo receipt and evacuation will be primarily through road and rail. Based on RHDHV's assessment, the estimated proportions for different commodities to be brought in/ taken out through rail and road are presented in Table 5-27. The modal split for container is currently being rationalised.

Table 5-27 Estimated Proportions for Different Commodities

S. No.	Commodity	Truck Capacity	Rail Capacity	2030			2040/ 2050		
				Road Share	Pipeline	Rail Share	Road Share	Pipeline	Rail Share
		T	T	%	%	%	%	%	%
1.	Containers (EXIM)								
	– Indian Railway	1.5	90	68%	-	2.3%	64%	-	2.3%
	– DFCC	1.5	360		-	29.8%		-	33.3%
2.	RO-RO Vehicles '000	5.0	180	100%	-	0%	100%	-	0%
3.	Edible Oil	18	2,500	85%	-	15%	85%	-	15%
4.	Bulk Liquid	18	2,500	15%	5%	80%	15%	5%	80%
5.	Chemicals	10	2,650	100%	-	0%	100%	-	0%
6.	Other Liquid	8	2,200	0%	100%	0%	0%	100%	0%
7.	Fertiliser	12	3,600	0%	-	70%	30%	-	70%
8.	General Cargo	10	2,200	100%	-	0%	100%	-	0%
9.	Coastal Cargo	10	2,200	100%	-	0%	100%	-	0%

5.7.1 Port Access Road

Table 5-28 presents the assessment on the truck movements for Phase 1 and master plan horizon. These calculations have been performed assuming 350 effective working days for the trucks handling. Further, a peaking factor of 25% has been considered. The average payload / capacity of each truck is based on the type of cargo handled.

Table 5-28 Assessment of the Truck Movements

S. No.	Commodity	Truck Movements per day		
		2030	*2040*	*2050*
Outgoing				
1.	Fertiliser	86	86	100
2.	Edible Oil	135	162	189
3.	Bulk Liquid	74	100	124
4.	Chemicals	143	175	206

S. No.	Commodity	Truck Movements per day		
		2030	2040	2050
Total Outgoing Trucks per Day		**437**	**522**	**619**
Incoming				
5.	RORO	28	97	130
Total Incoming Trucks per Day		**28**	**97**	**130**
Incoming /Outgoing				
6.	General Cargo	686	1,314	2,057
7.	Coastal Cargo	486	914	1,429
8.	Containers (EXIM)	11,338	30,818	49,154
Total Incoming/ Outgoing Trucks per Day		**12,509**	**33,046**	**52,640**
Total Trucks to be Handled per Day (incoming and Outgoing)		**13,441**	**34,284**	**54,137**
Total PCUs to be Handled per Day including a peaking factor of 25%		**71,661**	**186,348**	**295,178**

It could be seen that almost 13,441 trucks are expected in the year 2030, increasing to about 54,137 truck movements over 2050.

It may be noted that for four lane roads the design service volume is of the order of 86,000 PCUs, 130,000 PCUs for six lane and 173,000 for eight lane road with a peak hour flow of 6%. The above table represents that the proposed major road bridge at the Surya River will need to have the capacity to meet the projected traffic for 2050. Further, it should be noted that nearby port area there will be additional vehicular traffic on account movement of port personnel and users, vendors etc. which is not included in the above assessment and therefore there is a need to provide additional /wider access to the -port than arrived at above.

5.7.2 Railway System

Table 5-29 presents the assessment of rail movement in the port during different stages of the project period.

Table 5-29 Assessment of the Rail Movements

S. No.	Commodity	Rake Movements per day		
		2030	2040	2050
Outgoing				
1.	Fertiliser	1	1	1

S. No.	Commodity	Rake Movements per day		
		2030	*2040*	*2050*
2.	Edible Oil	0	0	0
3.	Bulk Liquid	3	3	4
4.	Chemicals	0	0	0
Total Outgoing rakes per Day		**4**	**4**	**5**
Incoming				
5.	RO-RO	0	0	0
Total Incoming rakes per Day		**0**	**0**	**0**
Incoming /Outgoing				
6.	General Cargo	0	0	0
7.	Coastal Cargo	0	0	0
8.	Containers (EXIM)			
	– DFCC Rakes	27	70	116
	– Indian railway rakes	6	18	29
Total Incoming/ Outgoing rakes per Day		**33**	**88**	**144**
Total Rake Movements (in and out of port)		**73**	**184**	**298**

Adequate rail sidings will be provided within the port area and located close to the various terminals. It may be noted that the capacity of a double line with automatic signalling is of the order of 140 rakes per day. Therefore, the current proposed linkage (with two lines) provided to the hinterland should be adequate to cater the Phase 2 and beyond.

5.8 Residential Requirement for Staff and Social Infrastructure

A residential colony is proposed for the administrative and operational personnel of Vadhavan Port. The housing accommodation would depend upon the deployment of staff at the port and would need to be augmented over the master plan horizon. In addition to the residential colony other social infrastructure such as primary school, hospital, convenient shopping centres, playgrounds, open spaces etc. need to be provided as per URDPFI (Urban and Regional Development Plans Formulation & Implementation, 2014) as well as NBC 2016 guidelines. The physical infrastructure comprising of a sewage treatment plant, water distribution system, roads, power, and water supply would also need to be provided. Based on the assessment of the port personnel over the master plan horizon, it is assessed that an area of 41 ha. would be required in the Phase 1 increasing to about 89 ha. over the master plan horizon for the port housing and social infrastructure. The detailed estimation of the residential requirements is as shown in the table below.

Royal HaskoningDHV

JNPA

Table 5-30 Residential Requirements for Staff and Social Infrastructure

Category of Housing Units					Estimated Port Personnel (Number of Housing Units) Over Master Plan Horizon	
S. No.	Category of Housing Units	Plinth Area (m^2)	Floors	Unit	Phase 1	Phase 2
1.	Type - I	48.75	Ground + 1		3,413	7,351
2.	Type - II	52.95	Ground + 1		1,659	3,573
3.	Type - III	72.4	Ground + 1		359	773
4.	Type - IV	101.1	Ground + 1		17	36
5.	Type -V	196.3	Duplex unit with Garage and Servant quarters		3	7
	Total Population Considered	4	persons/family	No.	21,806	46,965

Type of Structures:

Housing					Built-up Area for Houses	
S. No.	Category of Housing Units	Plinth Area (m^2)	Floors		G+	3
1	Type - I	48.75	Ground + n		41,597.78	89,590.61
2	Type - II	52.95	Ground + n		21,963.27	47,303.08
3	Type - III	72.4	Ground + n		6,496.50	13,991.74
4	Type - IV	101.1	Ground + n		855.83	1,843.23
5	Type -V	196.3	Duplex unit with Garage and Servant quarters		332.34	715.78
Total Built-up Area of Houses				m^2	71,245.72	153,444.43
				1 Children per Dwelling units		10

Primary School (nursery to 5th)	Note		Built-up Area for School	
	1 Children per 10 Dwelling units	No.	2,180.62	4,696.49
Primary school	0.4 Ha for 500 students	m^2	17,445.00	37,571.90

Pre-Primary school	0.08 Ha for 2500 population	m^2	6,978.00	15,028.76
Total School Area =		**m^2**	**24,422.99**	**52,600.66**

Shopping Centre	Note	Built up Area of Shopping Centres (sqm)		
Convenience Shopping	1500 sqm for every 5000 population	m^2	**6,541.87**	**14,089.46**
Local Shopping Centre	4600 sqm for every 5000 population	m^2	**6,687.25**	**14,402.56**
Total Shopping Area		**m^2**	**13,229.12**	**28,492.03**

Hospital	Note		Built up Area of Hospital (sqm)	
Intermediate Hospital Category A 200 beds	for 1 to 1,00,000 population	m^2	3.7	Ha. including residential area
Total Hospital Area		**m^2**	**12,333.33**	**24,666.67**

Petrol filling Station	Petrol filling Station with service Bay (37 × 31 m)	No.	1	1
		m^2	**1,147**	**1,147**

Total Built up Space =		**122,378.17**	**260,350.79**
Township area after considering open space, roads and Parking. i.e., 10 sqm/person open space and 15% area for roads and parking	**m^2**	218,062.44	469,648.78
	Ha	12,237.82	26,035.08
	Grand Total (m^2)	**352,678.43**	**756,034.65**
	Ha.	**35.27**	**75.60**

Additional area required as per town planning guidelines but was not included in previous DPR						
1.	Senior secondary School		1.80	Ha	52,334.99	112,715.71
2.	Family Welfare centre		1 for 50,000 population			800.00
3.	Diagnostics centre		1 for 50,000 population			800.00
4.	Community Hall	2,000.00	1/15000 population		2,907.50	6,261.98
5.	Religious facilities	400.00	1/5000 population		1,744.50	3,757.19
6.	Bulk Liquid Gas Godown	520.00	40,000 to 50,000			520.00
7.	Police post	0.16	40,000 to 50,000			1,600.00

8.	Sub Fire station					6,000.00
					56,986.98	132,454.88
Total area considering additional facilities					**409,665.41**	**888,489.53**
				Total	**40.97**	**88.85**

This colony should be located close to the port but outside the port limits.

5.9 Water and Power Requirements

5.9.1 Water Requirements

Total water demand within the port is broadly classified in the following categories:

- Potable water for consumption of port personnel.
- Ship supply
- Township use
- Firefighting, other uses like gardening etc.

Table 5-31 Water demand for Port and Township

Total water requirement	2030 (kL/day)	2040 (kL/day)
Port		
1. Daily water demand	3,019	5,642
2. Static storage for fire fighting	1,192	2,769
Total (A)	**4,211**	**8,410**
Township		
1. Daily water demand	3,807	7,678
2. Static storage for fire fighting	2,147	4,387
Total (B)	**5,711**	**11,516**
Total Daily Demand	**6,826**	**13,319**

Based on the requirements of berths over the master plan horizon, it is expected that the water demand at the port shall increase from 3.0 million litres per day in the Phase 1 development to about 5.6 million litres per day over the master plan horizon. A static storage of 1.2 million litres increasing to 2.8 million litres for master plan is required for firefighting. The exact water demand shall be governed by the actual usage of the terminal area.

Based on this, suitable size of underground and overhead storage tanks will be provided at appropriate places. The water supply system within the port will be designed for optimum services to all the port areas such container area, other cargo areas, housing areas etc.

5.9.2 Power Requirement

The power is required at the port for the following activities:

- Mechanized cargo handling equipment – RMQC, eRTG, MHCr, eRMGC.

- Lighting of the port area;
- Offices and transit sheds;
- Miscellaneous.

The required electrical system for the project will consist of:

- A substation containing transformers, switchboards, control equipment, etc. to allow the distribution of electrical supply to the various parts of the site at the required voltage levels;
- Monitoring and control systems;
- Power cabling and fibre optic communications from the substation to the quay cranes at 66kV;
- Power cabling from the substation to the reefer area. The cables should be run at medium tension with step-down transformers installed beneath reefer platforms in the reefer areas;
- Provision of power cabling to the buildings and gate complex;
- Provision of power cabling to terminal light towers.

The port will be supplied through a 220 KV Main Receiving Substation located near the main entry exit gate through dedicated HV lines. The proposed new container terminal development will contain all the features of a modern first-class terminal, and as such will require a reliable power supply system. Consideration of future electrical requirements of the terminal shall also be taken into account, and all necessary provisions shall be made in the design and installation of the electrical system, to take account of future requirements. This applies to switchboards, transformers, underground conduits etc.

Based on the requirements of berths over the master plan horizon, it is expected that the power demand at the port shall increase from 75 MVA in the Phase 1 development to about 150 MVA over the master plan horizon. The exact requirement will have to be governed by the facilities proposed mainly in terms of handling system. The suitable electrical distribution system in the port area will have to be accordingly planned.

6 Port Master Plan

6.1 Planning Framework

6.1.1 Physical Environment

The following aspects of the physical environment that will influence the port layout:

- **Winds:** During the peak monsoon season winds are from W to SW but seldom exceed 13 m/s. The wind veers to NE-N-NW over December-January.
- **Water levels:** Mean Sea Level is 2.8 m CD indicating a maximum tidal range of about 5.6 m.
- **Waves:** The predominant wave direction is from W to SW during the monsoon season and NE-NW pre- and post-monsoon. Wave heights are generally less than 3.0 m.
- **Currents:** The tidal streams are generally in a SW-NE direction with the flood tide setting in a northerly direction and the ebb tide in a southerly direction. The typical maximum current speed is reported to be about 1.25 m/s.
- **Sediment transport:** Sediment transport from north. The suspended sediment concentration at mid-depth is 170-380mg/l [CWPRS March 2018].
- **Geotechnical:** The seabed comprises a superficial layer of silty clay/sand overlying weathered bedrock. The cost of dredging rock and using in reclamation was estimated to be about Rs/m^3 3,100. This is roughly three times higher than the estimated cost of dredging soft clay and reclaiming using imported fill (Rs/m^3 1,150). In this case, it is more economical to reclaim using imported fill than to dredge in rock.
- **Mangroves:** Areas of mangrove are encountered along the shoreline. Any reclamation needs to avoid these areas.

6.1.2 Limiting wave and current conditions for port operations

For carrying out cargo handling operations at the berths, it must be ensured that there are no excessive movements of the ships due to wave action that will hamper the ship-shore handling operations. This limit varies with the handling system for the different types of cargoes. Hence, the breakwater configuration and the overall port layout should ensure adequate tranquillity at the berths so that cargo handling may continue even when the offshore wave climate exceeds the limit for ships' movement in and out of the harbour.

The maximum acceptable wave conditions for cargo handling operations at the berth are dependent on ship size, the type and method of cargo handling and the direction of the wave attack. Beam waves cause the vessel to roll and affect the cargo handling operations more than head waves.

Guidelines published by PIANC[1] [2014] give the recommended limiting current and wave conditions for ship navigation at the harbour entrance and stopping area, turning, berthing, and loading/unloading ships (Table 6-1 and Table 6-2). Individually these limits may be regarded as conservative since they assume that the limiting wind, current and wave conditions are in combination.

[1] *Permanent International Association for Navigation Congresses; an international body establishing design guidelines for maritime*

Table 6-1 Limiting Conditions of Wave Heights for Cargo Handling

Type of Ship	Limiting Wave Height (H_s)	
	Head or Stern (0°)	*Quadrant (45°- 90°)*
Break-bulk Ships	1.0 m	0.8 m
Liquid Carriers	1.5 m	1.0 m
Containers	0.5 m	0.4 m
Other Liquid – With unloading arms – With flexible hoses	 1.5 m 2.0 m	 1.0 m 1.5 m
RO-RO	0.6 m	0.6 m

Table 6-2 Limiting conditions of wind, wave and currents within the harbour

Location/operation	Transverse			Longitudinal		
	Wind (m/s)	Currents (m/s)	Waves (m)	Wind (m/s)	Currents (m/s)	Waves (m)
Harbour entrance	15	1.00	3.0	-	-	-
Stopping areas	10	1.00	2.0	-	-	-
Turning area (tug assistance)	10	0.10	1.5-2.0	-	-	-
Berthing	10	0.10	1.5	17	1.0	2.0
(Un)loading (containers & Ro-Ro)	22	0.50	0.3	22	1.5	0.5

Source: PIANC

6.1.3 Breakwater

A breakwater is required to protect the berths and other facilities within the port from the predominant south west to north-west waves which approach the Vadhavan site. These conditions are illustrated in the nearshore wave rose taken from the wave modelling by CWPRS[2].

CPWRS advised that the main breakwater location and alignment as shown in the original master plan should be retained since:

- Extensive numerical modelling was carried out previously to optimise the location, length and alignment of the breakwater in order to minimise wave penetration, currents and sedimentation in the harbour.
- Part of the breakwater is located on a shallower area offshore in order to limit the CAPEX.

[2] Central Water and Power Research Station, Pune, India

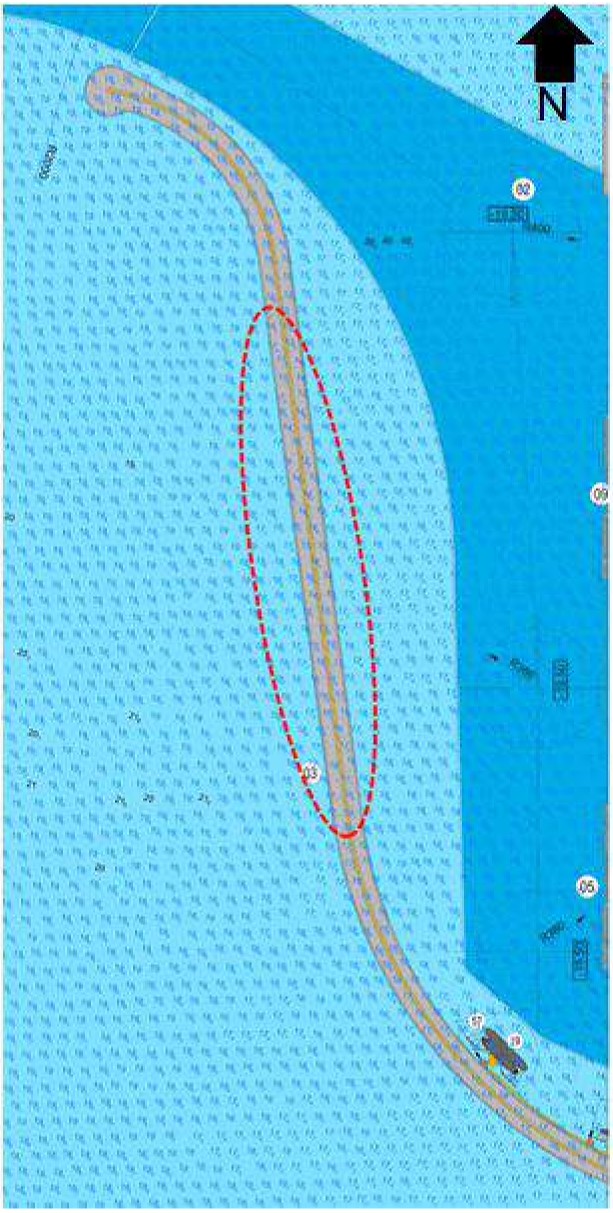


Figure 6-1 Shallow patch along breakwater alignment

- Tarapur Atomic Power Station (TAPS) is located some 11 km to the south of the proposed port site and numerical modelling studies had been carried out by CWPRS to assess the impact of the original port development master plan on the power station intake/outfall. Any changes to the breakwater location and alignment would need to be acceptable to the Atomic Energy Authority.

6.1.3.1 Layout of Breakwater and Revetments

The final layout of the breakwater and revetment/ reclamation bund has been arrived at through the wave tranquillity and hydrodynamic modelling studies completed by CWPRS. These studies are reported in the following documents:

- Model Studies for hydrodynamics and siltation for development of port at Vadhavan, Technical Report No 5583 (March 2018)

- Model studies for hydrodynamics and siltation for development of port at Vadhavan, Technical Report No 5968 (Nov. 2021)
- Model studies for wave tranquillity studies for modified final layout of Vadhavan port, Technical Report No 5971 (Nov. 2021)

The reports are discussed in detail in Section 13 of this report. Discussion and a review of the findings are provided in this section.

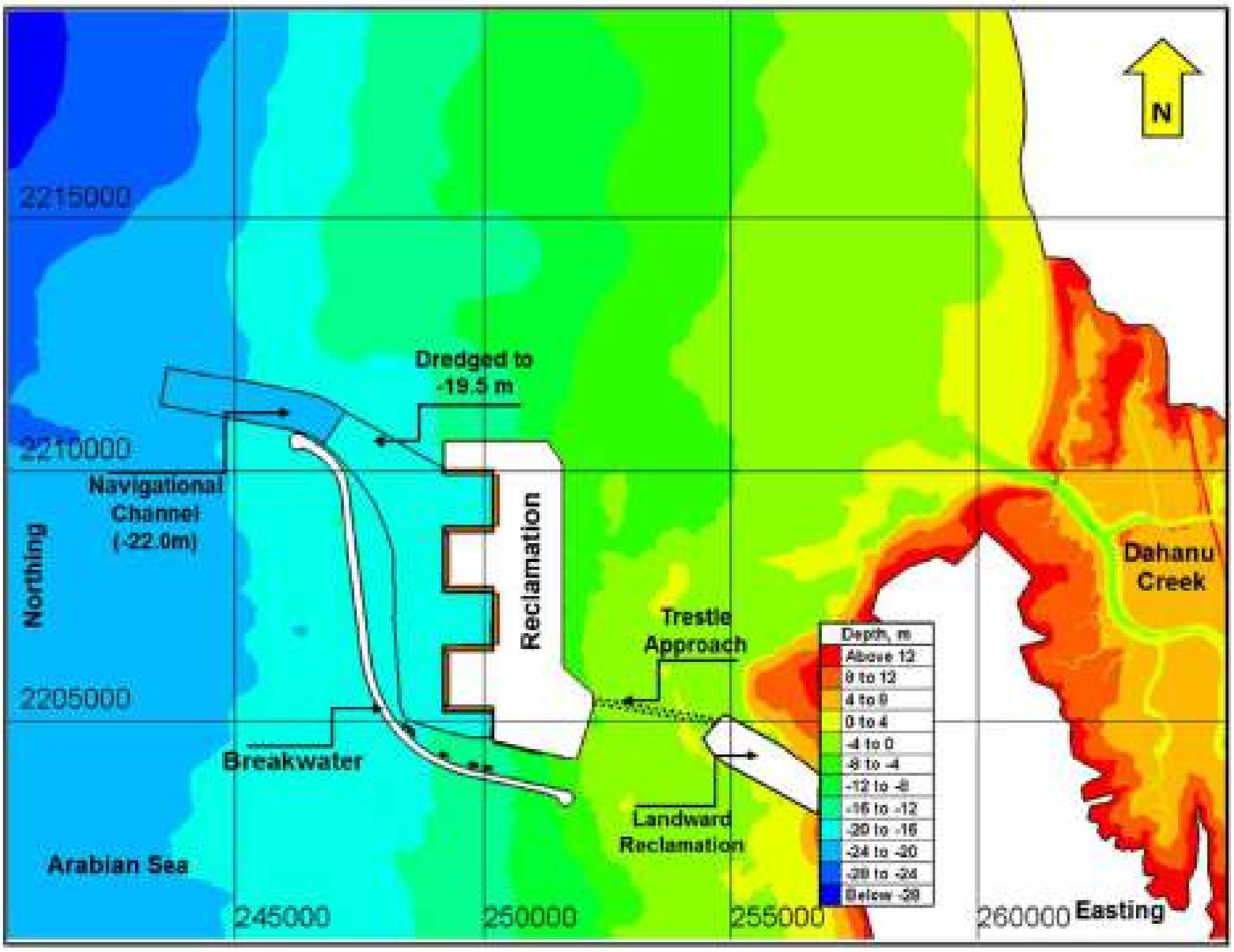


Figure 6-2 Breakwater alignment for Vadhavan Port

6.1.4 Berths

The estimated berths and the total quay length for the various phases of development have been worked out and are presented in Table 5-19. It may be noted that the table only indicates the number of berths needed as per the traffic projections. The actual number of berths provided in different phases would be governed by the physical and financial constraints of the proposed port site. Further, it may be noted that for containers, it is the total quay length rather than the number of berths is important for handling operations. Table 6-3 provides the terminal requirements.

Table 6-3 Vadhavan Port berths & terminal requirements established from the market study

Berths/terminals	Berth/ Quay length (m)	Ship max. draught (m)	Phase 1	Phase 2	Total
Container quay (1,000 m each)	1,000	16.5	4	5	9
Multi-purpose berths (250 m each)	250	10.5	3	1	4
Liquid bulk berths	200	9.5	2	0	2
Bulk Liquid berth	280	10.5	1	0	1
Other Liquid FSRU berth	400	12.0	1	0	1
Ro-Ro berth	250	11.3	1	0	1
Coastguard berth			1	0	1

A water depth of - 22.0 m CD is required in the approach channel and -19.5 m CD in the basins and at the container berths.

The development will essentially be a large deep-water container port for the largest deep-draught container ships.

6.1.5 Navigational Requirements

6.1.5.1 Approach Channel width

The port approach channel consists of the two parts:

- The outer approach channel which is the section of the channel outside the breakwater area; and
- The inner approach channel, which is the section of the channel from the head of the breakwater area to the vessel turning area.

The outer approach channel would be unprotected with vessels in transit along this section sailing under their own power without tug assistance. The inner entrance channel would be protected and should be fairly sheltered from wave attacks. Tugs will be able to meet and fasten to the vessel before it enters the turning area and starts to manoeuvre towards the allocated berth.

The vessels will start slowing down after tugs are attached in the inner approach channel. As per PIANC (1997) guidelines, sheltered inner approach channel should have around 4-5 times length of the design ship. However, considering the capital cost of longer breakwater, it is expected that breakwater will provide an effective length of 3-4 times the design vessel length overall for Phase 1 operations which is deemed adequate.

The channel width has been calculated from the latest PIANC Guidelines "Harbour Approach Channels – Design Guidelines: Report No. 121 – 2014". The detailed calculations are shown in below table.

Table 6.4 Assessment of Channel Width based on PIANC Recommendations

	PIANC Recommendations				Channel	
	Basic Lane Width W_{bm} (multiple of ship beam B)	Vessel Speed	Outer Channel Exposed to Open Water	Inner Channel Protected Water	outer	inner
	vessel manoeuvrability					
	- good	all	1.3	1.3	1.3	1.3
	- moderate	all	1.5	1.5		
	- poor	all	1.8	1.8		
				TOTAL BASIC MANOEUVRING LANE W_{bm}	**1.3**	**1.3**
	PIANC table 5.2 - Additional Width for Straight Channel Sections (multiple of ship beam B)					
(a)	**vessel Speed (knots)**					
	- fast >12		0.1	0.1		
	- moderate >8 - 12		0.0	0.0	0.0	0.0
	- slow 5 - 8		0.0	0.0		
(b)	**Prevailing cross wind (knots)**					
	- mild ≤ 15 (≤ Beaufort 4)	all	0.0	0.0		
	- moderate > 15 - 33	fast	0.3	-		
	(> Beaufort 4 - Beaufort 7)	mod	0.4	0.4	0.4	0.4
		slow	0.5	0.5		
	- severe >33 - 48	fast	0.6	-		
	(> Beaufort 7 - Beaufort 9)	mod	0.8	0.8		
		slow	1.0	1.0		
(c)	**Prevailing cross current (knots)**					
	- negligible < 0.2	all	0.0	0.0		
	- low 0.2 - 0.5	fast	0.1	-		
		mod	0.2	0.1		
		slow	0.3	0.2		
	- moderate >0.5 - 1.5	fast	0.5	-		
		mod	0.7	0.5	0.7	0.5
		slow	1.0	0.8		
	- strong > 1.5 - 2.0	fast	0.7	-		
		mod	1.0	-		
		slow	1.3	-		
(d)	**Prevailing longitudinal current (knots)**					
	- low ≤ 1.5	all	0.0	0.0	0.0	0.0
	- moderate > 1.5 - 3	fast	0.0	-		
		mod	0.1	0.1		
		slow	0.2	0.2		
	- strong > 3	fast	0.1	-		
		mod	0.2	0.2		
		slow	0.4	0.4		
(e)	**Significant wave height H_s and length l (m)**					
	- Hs ≥ 1 and l ≥ L	all	0.0			0.0
	- 3> H_s > 1 and l = L	fast	2.0			
		mod	1.0	1.0	1.0	
		slow	0.5			
	- H_s > 3 and l > L	fast	3.0			
		mod	2.2			
		slow	1.5			
(f)	**Aids to Navigation**					
	- excellent with shore traffic control		0.0	0.0	0.0	0.0
	- good		0.2	0.1		
	- moderate with infrequent poor visibility		0.5	0.2		
	- moderate with frequent poor visibility		0.5	0.5		
(g)	**Bottom Surface**					
	- if depth ≥ 1.5T		0.0	0.0		
	- if depth < 1.5T then					
	- smooth and soft		0.1	0.1		
	- smooth or sloping and hard		0.1	0.1		
	- rough and hard		0.2	0.2	0.2	0.2
(h)	**Depth of Waterway**					
	- ≥ 1.5T (inner and outer waterway)		0.0	0.0		
	- 1.5T - 1.25T (outer waterway)		0.1			
	- < 1.25T (outer waterway)		0.2		0.2	
	- < 1.5T - 1.15T (outer waterway)			0.2		
	- < 1.15T (inner waterway)			0.4		0.4
(i)	**Cargo Hazard Level**					
	- low		0.0	0.0	0.0	0.0
	- medium		0.5	0.4		
	- high		1.0	0.8		

PIANC Recommendations				Channel	
Basic Lane Width W_{bm} (multiple of ship beam B)	Vessel Speed	Outer Channel Exposed to Open Water	Inner Channel Protected Water	outer	inner
TOTAL ADDITIONAL MANOEUVRING WIDTH FACTOR W_i				**2.5**	**1.5**
PIANC Table 5.4 - Additional Width for Bank Clearance					
- sloping channel edges and shoals	fast	-			
	mod	0.5		0.5	0.5
	slow	0.3			
- steep and hard embankments and structures	fast	-			
	mod	1.0			
	slow	0.5			
TOTAL BANK CLEARANCE FACTOR W_{br} or W_{bg}				**0.5**	**0.5**
PIANC Table 5.3 - Additional Width for Passing Distance for Two-Way Traffic					
additional width for traffic speed	fast	2.0	-		
	mod	1.6	1.4	1.6	1.4
	slow	1.2	1.0		
additional width for traffic encounter density					
- light	all	0.0	0.0	0.0	0.0
- moderate	all	0.2	0.2		
- heavy	all	0.5	0.4		
TOTAL EXTRA FOR STRAIGHT CHANNEL TWO-WAY TRAFFIC W_p				**1.6**	**1.4**
Curved Channel Width Factor W_c - PIANC Figure 5.9					
assume rudder angle 20 deg, W/D ratio 1.1, therefore Ws/B = 1.18	all	0.18	0.18	**0.18**	**0.18**

Required channel width

ship beam (m)	
Container 18000 TEU	59
Container 24000 TEU	61

	Channel Width	
	outer	Inner
one way straight channel		
Container 18000 TEU	**283**	**224**
Container 24000 TEU	**293**	**232**
one way curved channel		
Container 18000 TEU	**294**	**235**
Container 24000 TEU	**304**	**243**
two way straight channel		
Container 18000 TEU+Container 24000 TEU	**614**	**481**
two Container 24000 TEU	**622**	**488**
two way curved channel		
Container 18000 TEU+Container 24000 TEU	**635**	**503**
two Container 24000 TEU	**644**	**510**

The calculated channel width for the proposed design ship size is summarised below.

Table 6-5 Particulars of Navigational Channel for Design Ships

Design Ship Size	Beam (m)	Outer Channel Width (m)		Inner Channel width (m)	
		One-way Channel	*Two-way Channel*	*One-way Channel*	*Two-way Channel*
24,000 - TEUs Container Carrier	61	290	620	230	490

The approach channel can be a one-way or a two-way channel. Based on the above assessment, for a busy port like Vadhavan which handle very large throughput and have many vessel calls, it is recommended to have a two-way approach channel.

6.1.5.2 Dredged Depth at Port

The depth of the approach channel is a very important parameter in approach channel design. The Vadhavan port location has a very favourable bathymetry and natural depth. Water depth in the channel region is around 17 to 18 m depth below CD. This will minimize the initial capital dredging cost involved.

The depth in the channel is determined by the vessel's loaded draught; trim or tilt due to loads within the holds; ship's motion due to waves, such as pitch, roll and heave; character of the sea-bottom, soft or hard; wind; influence of water level and tidal variations; the increase in draft of the vessel due to squat or bottom suction. In this particular case the bed level comprises of rock and hence additional underkeel clearance of 0.5 m is considered.

The dredged depths at the port entrance channel and manoeuvring areas will be governed by the fully loaded draft of the design ship. Based on PIANC guidelines, the dredged depths have been arrived at different parts of the harbour as per below.

Approach channel outside breakwater (m CD)	Loaded draft +30%+Under keel-tide
Inner channel and manoeuvring area (m CD)	Loaded drat+15%+Under keel-tide
At berths	Loaded drat+15%+Under keel

The following dredged depths (after rounding off) at different parts of the harbour for the design ships have been worked out for two scenarios i.e., with tidal advantage and without tidal advantage. The calculated values are given in below table:

Table 6-6 Dredged Levels at Port for the Design Ships - With Tidal Advantage

Ship Category	Ship Size	Draft (m)	Tidal Advantage (m)	Approach channel outside breakwater (m CD)	Inner channel and manoeuvring area (m CD)	At Berths (m CD)
Containers	24,000 TEUs	16.5	2	20.0	17.5	19.5
Other Liquid	2,67,000 m^3	12	2	14.1	12.3	14.3
Bulk Liquid	45,000 DWT	12.5	2	14.8	12.9	14.9
Multipurpose	40,000 DWT	10.5	2	12.2	10.6	12.6

Ship Category	Ship Size	Draft (m)	Tidal Advantage (m)	Approach channel outside breakwater (m CD)	Inner channel and manoeuvring area (m CD)	At Berths (m CD)
Liquid bulk	20,000 DWT	9.5	2	10.9	9.4	11.4
RORO	8000 units	11.3	2	13.2	11.5	13.5

As the mean sea level is about +2.8 m CD and the channel is short, it is possible to take the tidal advantage of minimum +2.0 m during the traversing of the design ship through the channel and manoeuvring area, at least during the initial phase of the port development. This is unlikely to result in any significant waiting time. Taking advantage of tide while entering and leaving the port is a normal practice in major ports around the world. Even the largest ports namely the ports of Dampier and New Castle rely on tides. Having said all this, containerships rarely sail at maximum draft since they are unlikely to be fully loaded in terms of TEU capacity and also will carry empty containers.

However, in case it is desired that there should not be any waiting time for the ships on account of tide levels the minimum dredged levels to be provided at the port are given below:

Table 6-7 Dredged Levels at Port for the Design Ships - Without Tidal Advantage

Ship Category	Ship Size	Draft (m)	Tidal Advantage (m)	Approach channel outside breakwater (m CD)	Inner channel and manoeuvring area (m CD)	At Berths (m CD)
Containers	24,000 TEUs	16.5	0	22.0	19.5	19.5
Other Liquid	2,67,000 m^3	12	0	16.1	14.3	14.3
Bulk Liquid	45,000 DWT	12.5	0	16.8	14.9	14.9
Multipurpose	40,000 DWT	10.5	0	14.2	12.6	12.6
Liquid bulk	20,000 DWT	9.5	0	12.9	11.4	11.4
RORO	8000 units	11.3	0	15.2	13.5	13.5

6.1.5.3 Turning Circle

As per the PIANC guidelines, diameter of the sheltered turning circle with tug assistance should be 1.75 times length of the design ship. The design ship length is taken as 400 m so the turning circle diameter required would be 1.75 times 400 m which is 700 m. The vessel navigation study has further confirmed the adequacy of the turning circle diameter and location.

6.1.6 Rail Terminal

The minimum length of the land plot required for the rail terminal unloading/loading sidings will be determined by the maximum operating length of the container trains (1500 m). Straight container unloading/loading sidings are required which are at least the length of the longest train together with additional allowance at either end for the turnouts required for each set of sidings under the container (un)loading equipment together with locomotive run-round loop.

In addition, train reception and despatch sidings will be required for inspection and checks on arriving and departing trains including the removal of any crippled wagons.

Independent/ different tracks were proposed to cater for the Indian Railways rakes and DFCC rakes, which will lead to inefficient utilisation of the rail sidings. Also, the arrangement shown in the rail yard will not suffice the rake loading arrangements as it is required to have the buffer storage in the rail yard to cater the number of DFCC/ IR rakes through RMGC. The optimised/modified rail yard arrangement is as shown below.

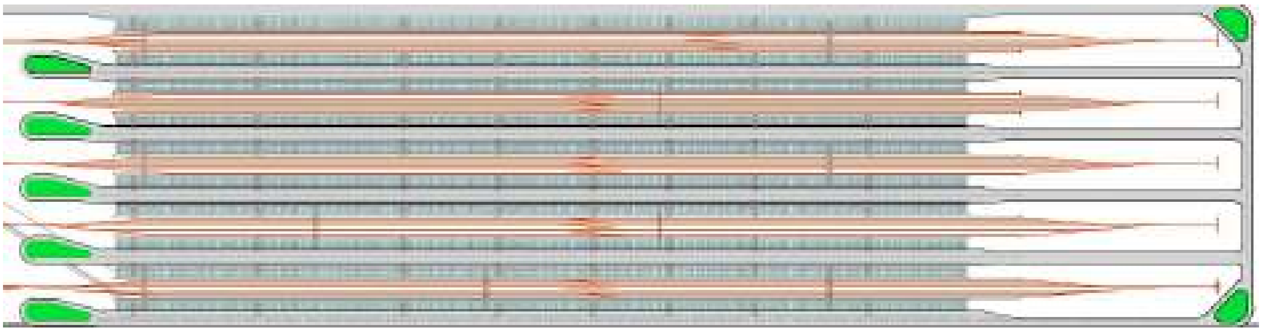


Figure 6-3 Buffer storage at rail yard

6.1.7 Reclamation Requirement

The layout of the port at Vadhavan has been developed keeping in view the planning framework as mentioned in section 6.1, for the forecast traffic till year 2040. The design ship size for the Phase 1 and master plan development is taken as the Container carrier of 24,000 TEU.

The main emphasis while developing the port layout is given to balance the cost of dredging and reclamation land area developed. It is estimated that approximately 200 million cum of reclamation material would be required for the proposed port development. On the contrary in case of the harbour located closer to the shore additional dredging of the harbour would be needed which include substantial amount of rock. Therefore, the harbour area should be located so as to minimize the capital cost by optimizing the dredging and reclamation quantities. In view of huge quantity of reclamation material requirement, it is proposed that the material to be sourced from marine pit from the nearby location. The cost for reclamation based on the distancing of the marine source pit is as given below:

Table 6-8 Cost of reclamation per cum based on distancing source

Sourcing distance (km)	Cost of reclamation material (INR/ cum)
15	250
25	350
40	490
50	590

Based on the secondary information, suitable reclamation material is available to the north of the proposed port which can be dredged, transported, and reclaimed. From the above table, it may be noted that the cost of reclamation through marine pit will increase with the distance of the source from port.

It may not be possible to source the required quantity within the distance of 15 km from the port site given the constraints from the locals. From costing perspective, a consolidated rate of INR 450/ cum is considered for the estimation of reclamation cost of this project.

6.2 Master Plan Overview

The Port Master Plan development process initiated with the initial inputs taken from JNPA/ Progen Pentacle Report (Detailed Project Report 2018). Progen-Pentacle considered different layouts of breakwater alignment and berthing arrangements. In all the layouts the channel was oriented in North west direction which is evident to protect the harbour from the South-West monsoon. Based on these layouts, Progen-Pentacle proposed the port master plan layout as shown in Figure 1-2, which is used as the base plan for the further development and refinement of the Port Master Plan.

RHDHV prepared an updated DPR based on this port master plan. The draft DPR was submitted to JNPA in February 2021 [RHDHV, 18 February 2021]. Figure 1-4 shows the port master plan as submitted in the draft DPR.

The port will be developed on a Public Private Partnership (PPP) basis with concessions awarded to terminal operators. In principle, for the container operations

The preferred concept for the container terminals is to have the yard area just behind the berth making it more efficient from operations perspective. Based on the discussion on the submission of the draft DPR, it was decided to relook into the port master plan layout taking into consideration the following:

- The capital investment required for the project needed to be reduced.
- The high operating costs associated with the long access trestles connecting the offshore berths to the onshore back-up storage facilities meant that the project was not attractive to potential terminal operators interested in investing in the project.
- Operation efficiency

There was a requirement to review the port master plan with a view to reducing both the capital and operating costs (CAPEX & OPEX) and improving the operability of the container terminals.

The main factors influencing the high CAPEX are the breakwater, current deflection wall, reclamation, and shore protection bunds. The long access trestles are the main factor influencing the OPEX and also the operational efficiency of the port.

6.2.1 Approach

The general approach taken to developing a new layout for the port was as follows:

- The main breakwater location and alignment as shown in the original port master plan was retained
- Marginal quays to be provided for container terminals where possible
- Consideration given to limiting both CAPEX and OPEX.

The cost of a rubble mound breakwater is roughly proportional to the square of the water depth. The main breakwater is located in deep water and although the location was to be retained, the possibility of reclamation and terminal development behind the breakwater was considered as a way of reducing the cost of the armour protection along the inner edge of the breakwater. However, it was determined that any potential savings in armour protection would be offset by the increased cost of reclamation in the deeper water adjacent to the inner edge of the breakwater.

The following parameters were also taken into consideration for developing the layouts

- *Balance in reclamation and dredging*
  In order to develop a modular container terminal, there is a requirement of creating the reclaimed land in deep waters. The main emphasis while developing the port layout is given to balance the cost of dredging and reclamation for the land area developed.
- *Material for Reclamation*
  The nearshore reclamation was proposed in the master plan shown Figure 1-4 owing to high quantity of reclamation when carried out in deep water. The reclamation is also dependent on the source i.e., marine / burrow earth in which the latter one would be expensive affair and is also dependent on the availability of the required material. For marine source the reclamation is sensitive to the distance of source from the port location.
- *Marine Terminal Requirements*
  The preferred arrangement for a container terminal is a straight marginal quay with container storage yard directly behind. The straight quay allows for flexibility of ship berthing and movement of rail-mounted quayside cranes. A container storage yard directly behind the quay apron provides for efficient transfer of containers between quayside and storage as well as limiting the operating costs.

  Refrigerated pipelines should be as short as possible in order to limit the CAPEX.

  Other Liquid/FRSU safety distance requirements – A safe exclusive zone of 250 m is required for Other Liquid terminal
- *Rail yard at the proximity to container yard*
  For efficient functioning and evacuation of the container terminal, the rail yard need to the provided close to the container storage yard. Locating the rail terminal away from the container handling facility would result in inefficiency in handling and high OPEX cost.
- *Trestle connecting offshore reclamation*
  Trestle connecting the nearshore with the offshore reclamation to be such that there is ample space for the current flow without having any adverse impact on the port facilities.
- *Sedimentation within the harbour*
  The phenomenon of littoral drift of sediments along the west coast of India is low. The drift of sediments along the coast is caused by the action of waves impinging on the coastline at an angle, and this slowly drives the material in the direction of the waves. The littoral drift at the project site predominantly driven by the currents along the coastline. This is predominantly from north to south along the west coast of India, along with some reverse drift.

The port layout has been modified to improve the operability of the container terminals. A layout for Phase 1 of the port development has also been prepared.

In order to finalise and confirm these layouts, it is recommended that the following work is carried out:

- Submission of the results of sediment transport modelling carried out by CWPRS on the port master plan layout and estimation of annual quantity of maintenance dredging required to remove accretion from suspended sediments

- Numerical hydrodynamic and sediment transport modelling on the proposed Phase 1 development port layout in order to confirm that current speeds are within acceptable limits (particularly at the harbour entrance) and estimate the annual quantity of maintenance dredging required.
  Wave tranquillity studies for Phase 1 and master plan layout.

6.2.2 Master Plan Development Options

Various master plan layouts were developed for Vadhavan port keeping in view of the planning framework as mentioned in section 6.2, for the forecast traffic till year 2040. The design ship size for the master plan development is taken as the container carrier of 24,000 TEU. Also, the port layout has to be developed to fit within the port limit allocated for port purposes.

6.2.2.1 Master Plan Alternative 1

In this option (Figure 6-4) an offshore island is created to cater for all the 9 container terminals. An offshore box shape arrangement is proposed with 4 terminals located at the west and 4 terminals on the rear side of the box (at the east) and one terminal at the north. The container terminal at the north is completely exposed to the waves from WNW and would pose operation constraints warranting for the requirement of additional protection from the north. The multipurpose, Ro-Ro and port craft terminals are proposed at the south of the offshore reclaimed land.

The rail yard is proposed nearshore which is similar to the original proposed layout (Figure 1-4). Functionally, this layout provides better and equal interface between the berth and yard for all the terminals. However, pose inefficiency from rail handling perspective which is located away from the terminals.

This option would involve high rock dredging along the container terminals for the approach which is located towards the east where rock levels are at shallow depths and at some stretches at the seabed surface.

6.2.2.2 Master Plan Alternative 2

(Figure 6-5) Nine container terminals are planned with a total length of 9,000 m. The container quay arrangement is provided such that the backup area of about 500 m width is available to accommodate the storage for the containers, approach corridors and terminal infrastructure. Finger piers are proposed multipurpose, Ro-Ro and other port terminal. All the liquid terminals are located on the leeside of breakwater as originally proposed.

The scheme comprises a large area of confined water with the long offshore breakwater arrangement. IN order tom streamline the current flow and provide better tranquillity from the waves in WNW direction an additional breakwater at the north is proposed, to cater to the master plan (Phase 2) requirements. The harbour is aligned such that container terminals are provided east west which is connected to the common rail yard adjacent to these terminals. The nearshore reclamation is proposed for the bulk and multipurpose storage.

The gap between the offshore and the nearshore area is very lean and would have an adverse impact within the harbour. However, this option would involve considerable amount of rock dredging for safe manoeuvring of ships and substantial land fill to provide the required yard and other port facilities. This kind of arrangement would result in high CAPEX making the port development financial unviable and also impact the flexibility of terminal development.

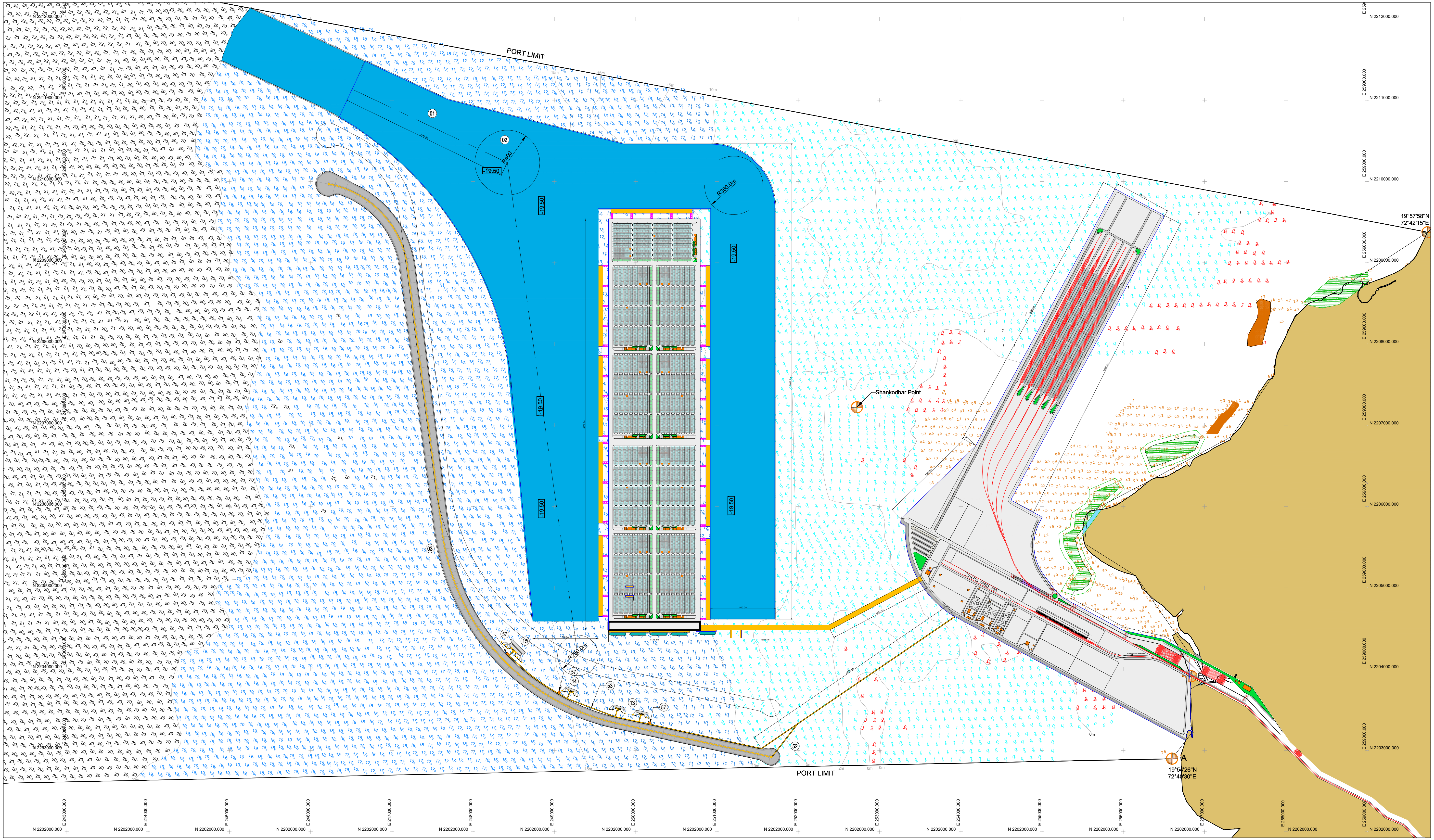
6.2.2.3 Master Plan Alternative 3

This option was developed addressing the constraints and limitations in the above two layouts. Six finger piers are proposed in the east west direction and 3 marginal quays with the yard behind these quays. The rail yard is located at the rear side of the container yards connecting the onshore reclamation area. This option provides a balance in the dredging and reclamation fill which impacts the overall project cost.

DO NOT SCALE

NOTES

1. ALL DIMENSIONS AND LEVELS ARE IN METERS, UNLESS NOTED OTHERWISE.
2. DRAWINGS ARE NOT TO BE SCALED, ONLY WRITTEN DIMENSIONS ARE TO BE FOLLOWED.



TITLE VADHAVAN PORT MASTER PLAN ALTERNATIVE 1	PROJECT Consultancy services for Design and Detailed Engineering for Greenfield Vadhavan port project	CLIENT JAWAHARLAL NEHRU PORT TRUST	CONSULTANT Royal HaskoningDHV Enhancing Society Together

Job No.	DI1452	DATE	OCT. 2021	SCALE	N.T.S.
ACAD Ref.	-	CHECKED	MS	PASSED	ASM
DRAWN	ZR	DRG No.	FIGURE 6-4	REV	A

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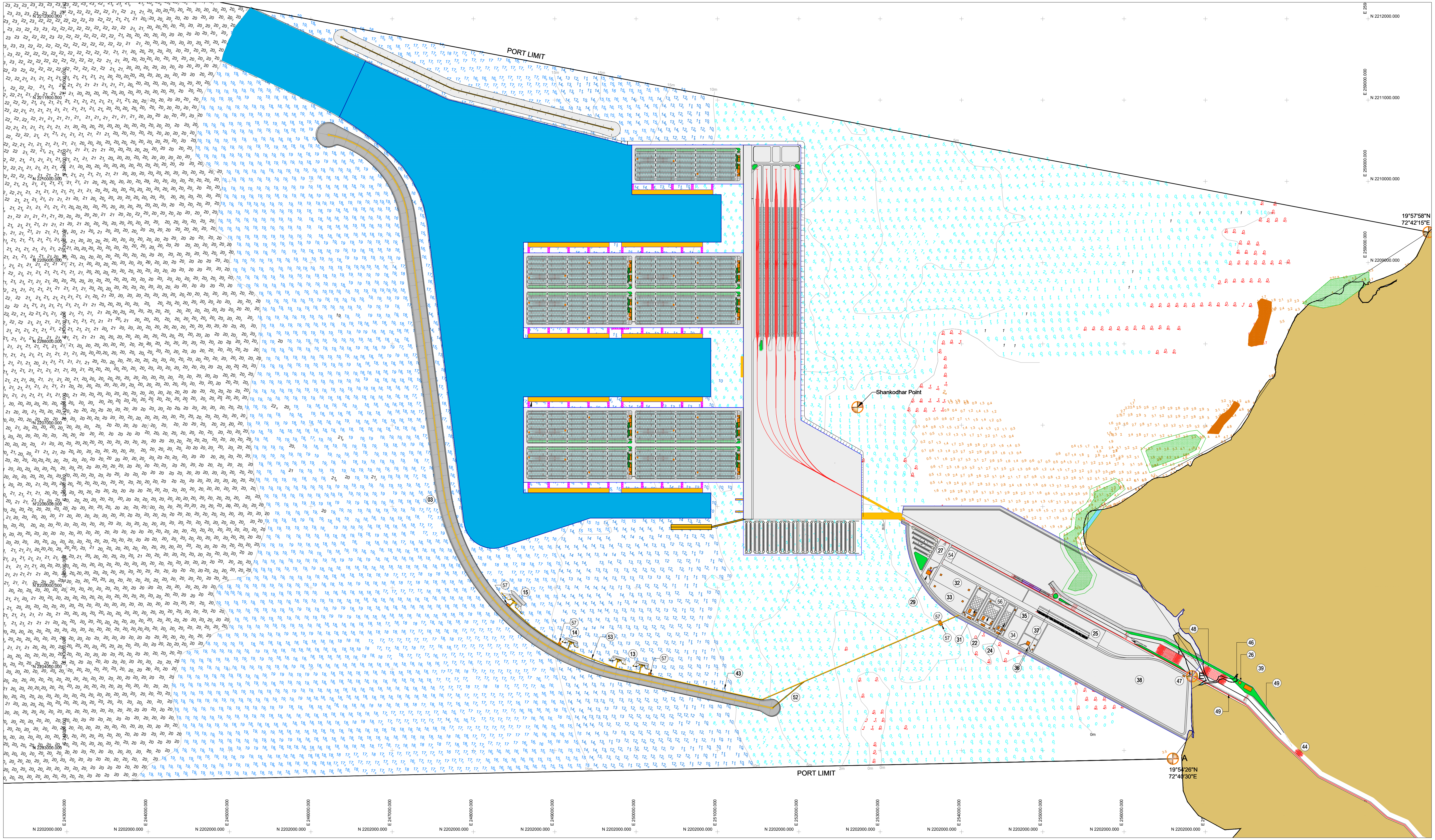

TITLE	PROJECT	CLIENT	CONSULTANT	Job No.	DI1452	DATE	OCT. 2021	SCALE	N.T.S.
VADHAVAN PORT MASTER PLAN ALTERNATIVE 2	Consultancy services for Design and Detailed Engineering for Greenfield Vadhavan port project	JAWAHARLAL NEHRU PORT TRUST	Royal HaskoningDHV Enhancing Society Together	ACAD Ref.	-	CHECKED	MS	PASSED	ASM
				DRAWN	ZR	DRG No.	FIGURE 6-5	REV	A

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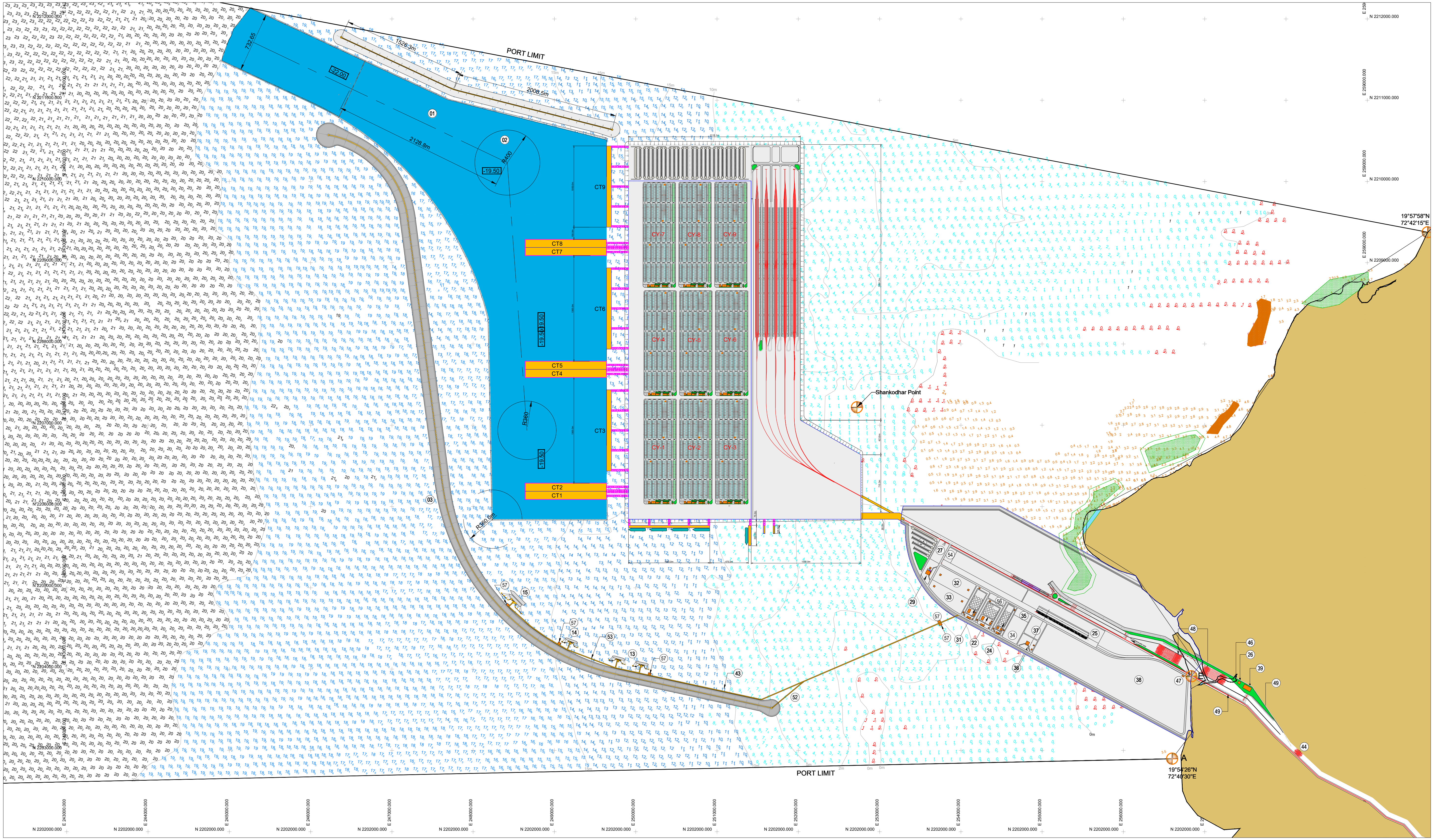


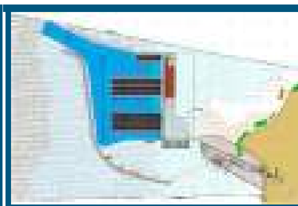
TITLE	PROJECT	CLIENT	CONSULTANT		
VADHAVAN PORT MASTER PLAN ALTERNATIVE 3	Consultancy services for Design and Detailed Engineering for Greenfield Vadhavan port project	JAWAHARLAL NEHRU PORT TRUST	Royal HaskoningDHV Enhancing Society Together		

Job No.	DI1452	DATE	OCT. 2021	SCALE	N.T.S.
ACAD Ref.	-	CHECKED	MS	PASSED	ASM
DRAWN	ZR	DRG No.	FIGURE 6-6	REV	A

6.2.2.4 Evaluation of Master Plan Options

The above alternative master plan options were evaluated using Multi-criteria-analysis as presented in Table 6-9. While comparing the capital cost of the development it may be noted that for all the options the cost of breakwater, berth structure, equipment is comparable except with the reclamation, infrastructure facilities in terms of rail alignment and smooth terminal operations.

Table 6-9 Multi Criteria Evaluation of Alternative Master Plan Layouts

S. No.	Criteria	 Alternative 1	 Alternative 2	 Alternative 3
1.	Space to accommodate types of berths required in master plan horizon	Substantial rock dredging is required to be carried to accommodate the berths	Less rock dredging compared to Alternative 1	Less rock dredging compared to Alternative 1 and 2
2.	Flexibility in implementing as staged development	The layout is very much suitable for staged expansion	The layout is very much suitable for staged expansion	The layout is very much suitable for staged expansion
3.	Rail Connectivity	Rail connectivity, away from the terminals leading to operational inefficiency and challenges	Good and efficient Rail connectivity	Same as Alternative 2
4.	Operational Flexibility	This layout provides good operational flexibility with the container terminal being contiguous and inefficient in terms of rail operations	Same as Alternative 1	This layout does not provide operational flexibility as the container terminal is not contiguous
5.	Capital Cost of Development	Moderate	High	Low
6.	Operation and Maintenance Costs of Phased Expansion	Moderate	Moderate	High

Of the above layouts, Alternative 3 was taken forward for assessment of its suitability through mathematical model studies. Model studies were carried out with the option of with and without the north breakwater.

6.2.2.5 Outcome of Model Studies

Numerical hydrodynamic and sediment transport modelling studies were carried out on the layout shown in Figure 6-6.

The results (Figure 6-7) indicated that:

- Maximum cross current at the harbour entrance of 2.5 m/s reducing to 0.3m/s at the expected ship stopping point
- Maximum current speed at the turning areas 0.3 m/s in a S-N direction
- Maximum current speed in the dredged basins between the finger piers in the range 0.15-0.30m/s. These currents are transverse to the berths since open-piled finger pier structures were modelled.
- Annual accretion rate in a limited number of areas of the harbour basin of over 2m. It was estimated that the annual siltation within the harbour would amount to some 11 million m^3.

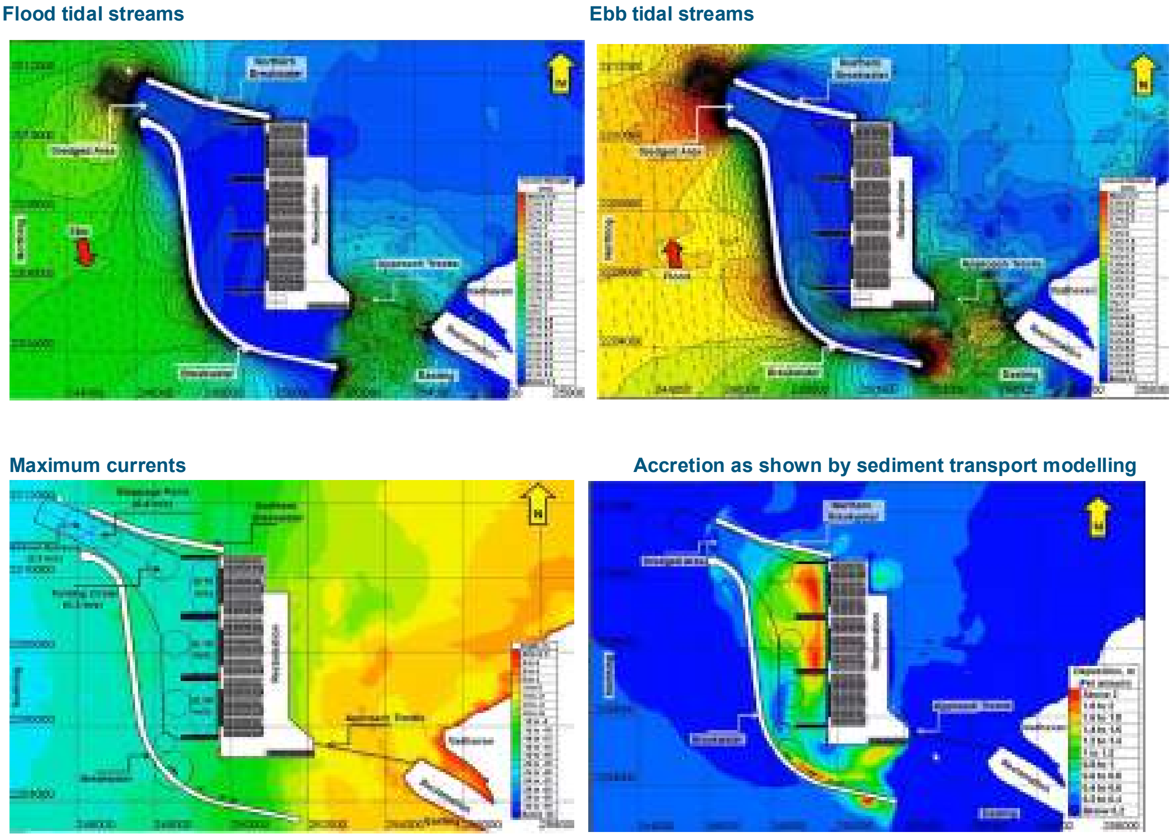


Figure 6-7 Alternative 3 layout (with north breakwater)- results of numerical hydrodynamic & sediment transport modelling

Source: CWPRS

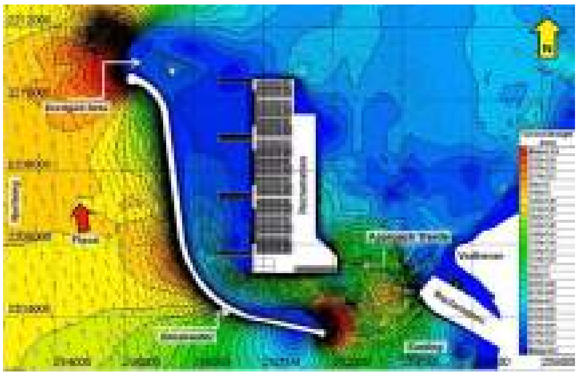
The same layout was also modelled without the north breakwater. The results (Figure 6-8) indicated that:

- Maximum cross current at the harbour entrance of 2.7m/s reducing to 1.2m/s at the expected ship stopping point
- Maximum current speed at the turning areas 0.5m/s in a S-N direction

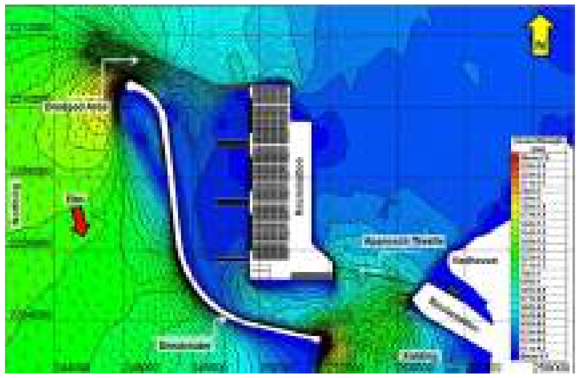
- Maximum current speed in the dredged basins between the finger piers in the range 0.27-0.4m/s. However, these currents are transverse to the berths since open-piled finger pier structures were modelled.

The Spring flood tide currents perpendicular to the berths are too high in either the “with” (0.15-0.30m/s) or “without” (0.27-0.45m/s) north breakwater scenarios. As a result, berthing/unberthing will be difficult, if not impossible, and excessive loads will be imposed on the mooring lines when ships are berthed alongside.

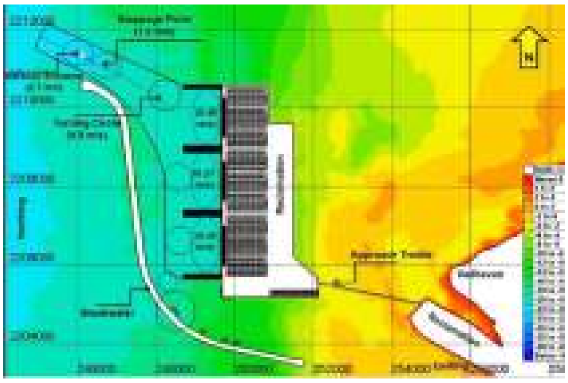
Flood tidal streams



Ebb tidal streams



Maximum currents



Accretion as shown by sediment transport modelling

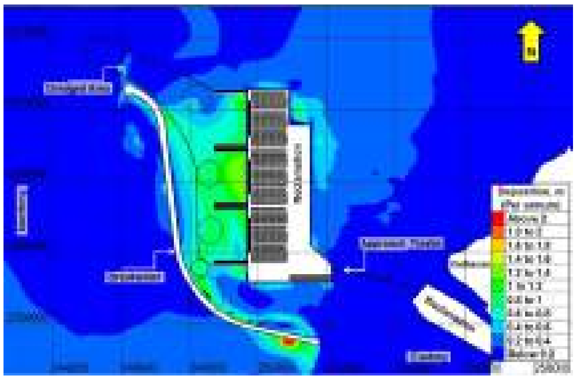


Figure 6-8 Alternative 3 Layout (without north breakwater)- results of numerical hydrodynamic & sediment transport modelling

Source: CWPRS

Comparison of the maximum current profile at the entrance to the harbour for the “with” and “without” north breakwater scenarios indicated that, “without” the north breakwater, although the current speeds are slightly higher, the current gradient along the centreline of the entrance channel is less than “with” the breakwater (Figure 6-9). Ship navigation of the transition open sea-harbour entrance and slowing/stopping should therefore be easier in the “without” north breakwater scenario.

A layout without a north breakwater was therefore adopted.

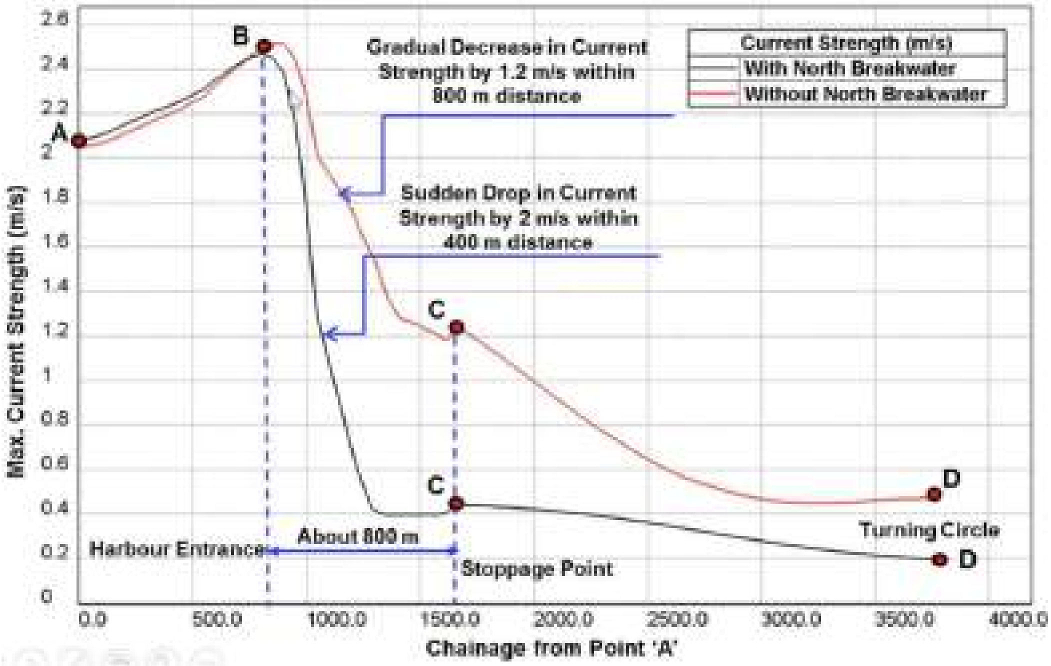


Figure 6-9 Alternative 3 layout - Maximum currents along entrance channel/harbour centreline (with & without north breakwater)

Source: CWPRS

Nevertheless, the transverse currents at the berths were too high and therefore an alternative layout with solid reclaimed fingers was proposed.

6.2.3 Proposed Master Plan layout

In the recommended scheme the adoption of solid narrow finger piers will avoid currents perpendicular to the berths. However, container berths on either side of narrow finger piers with the container storage yards located some distance from the berths are undesirable from an operational point of view.

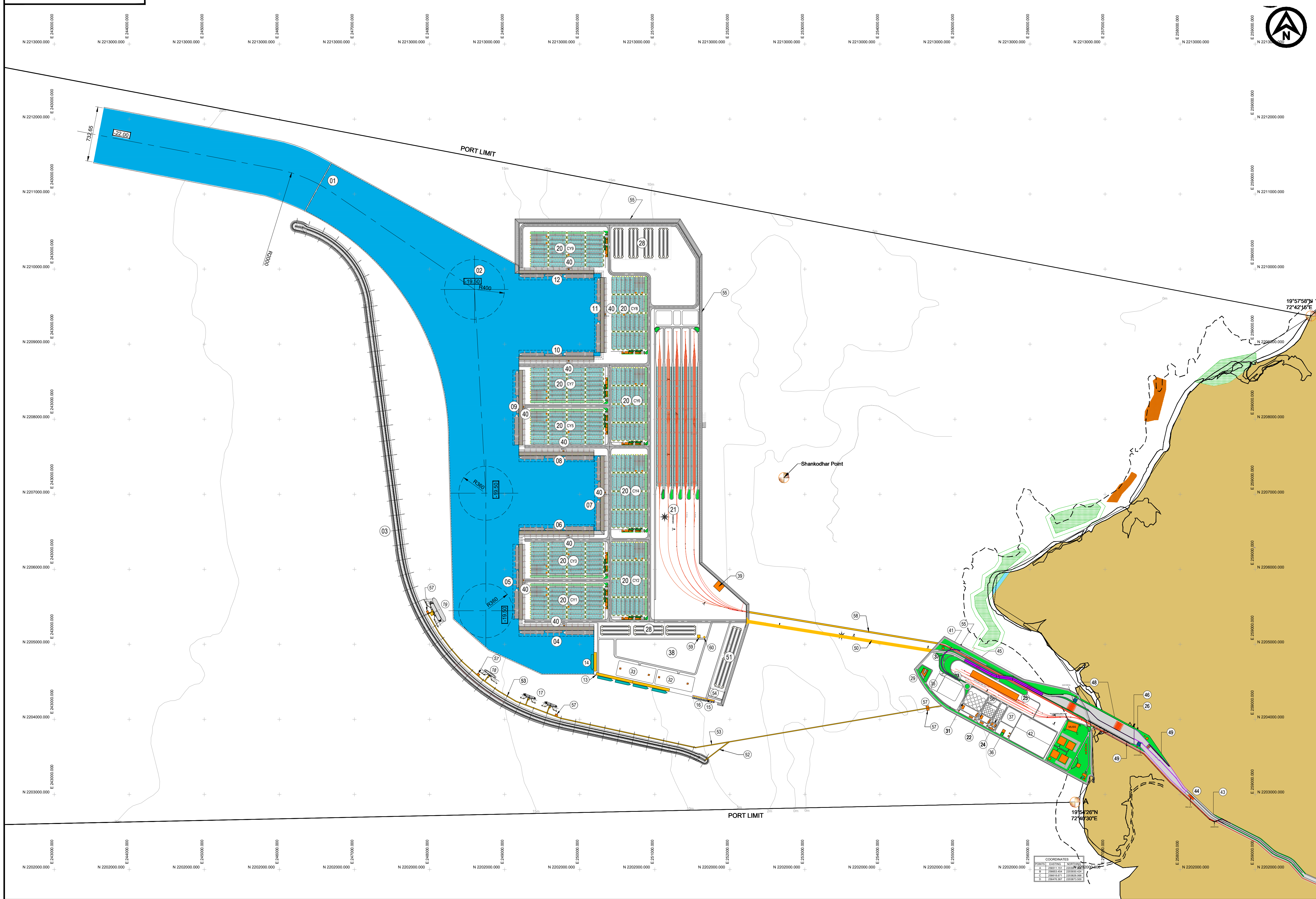
As a consequence, wide reclamation fingers were proposed with marginal container quays and container storage yards directly behind the quay apron.

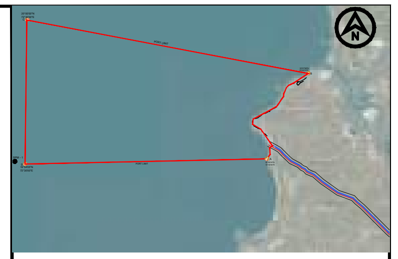
However, with solid narrow or wide reclamation fingers some increase in siltation may be expected in the basin area between the fingers.

The Proposed master plan layout is shown in Figure 6-10.

DRG No.
DI1452-RHD-DP-MA-DR-CM-XXX

DO NOT SCALE





KEY PLAN

NOTES

1. ALL DIMENSIONS AND LEVELS ARE IN METERS, UNLESS NOTED OTHERWISE.
2. DRAWINGS ARE NOT TO BE SCALED, WRITTEN DIMENSIONS SHOULD BE FOLLOWED AND VERIFIED WITH THE DETAILS.
3. ANY DISCREPANCIES FOUND IN DRAWINGS ARE TO BE REPORTED TO THE ENGINEER.

LEGEND

- LAND
- SEA
- MANGROVES
- ROCKY OUTCROP
- ROAD
- FLYOVER BRIDGE
- PEDESTRIAN AREA
- LANDSCAPING
- BUILDINGS
- GATE COMPLEX
- EMPTY CONTAINER SLOTS
- LOADED CONTAINER SLOTS
- RAIL TRACK

KEYNOTES

1. ENTRANCE CHANNEL
2. TURNING BASIN
3. BREAKWATER
4. CONTAINER TERMINAL 1
5. CONTAINER TERMINAL 2
6. CONTAINER TERMINAL 3
7. CONTAINER TERMINAL 4
8. CONTAINER TERMINAL 5
9. CONTAINER TERMINAL 6
10. CONTAINER TERMINAL 7
11. CONTAINER TERMINAL 8
12. CONTAINER TERMINAL 9
13. MULTIPURPOSE BERTHS
14. RO-RO BERTH
15. COAST GUARD BERTH
16. TUG/PORT CRAFT BERTH
17. BULK LIQUID JETTY
18. BUILK LIQUID JETTY
19. OTHER LIQUID JETTY
20. CONTAINER YARD (CY 1 TO CY 9)
21. IN PORT RAIL YARD
22. CHEMICAL TANK FARM
23. RAIL YARD FOR OTHER CARGOES
24. EDIBLE OIL TANK FARM
25. COVERED STORAGE SHED
26. UNDERGROUND WATER STORAGE TANK WITH PUMP ROOM
27. UTILITY AREA
28. TRAILER PARKING FOR CONTAINER TERMINAL (CY 1 TO CY 4)
29. PORT OPERATIONS BUILDING
30. JNPT ADMIN BUILDING
31. BULK LIQUID TANK FARM
32. GENERAL CARGO STORAGE
33. COASTAL CARGO STORAGE
34. RO RO STORAGE AREA
35. PDI FACILITY FOR CARS
36. OTHER LIQUID TERMINAL
37. UTILITY AREA
38. AREA FOR FUTURE DEVLOPMENT
39. MAIN RECEIVING SUBSTATION (MRSS)
40. BERTH SUBSTATION (BSS-1 to BSS-9)
41. UTILITY SUBSTATION (USS)
42. COMMON PORT INFRASTRUCTURE
43. ROAD TO PORT
44. PRE ENTRY / EXIT GATE
45. FLYOVER
46. OVERHEAD TANK
47. MAIN SUBSTATION (MSS)
48. MAIN GATE COMPLEX
49. TRAILER PARKING AT ENTRY & EXIT
50. APPROACH TRESTLE FOR ROAD MOVEMENT
51. TRAILER PARKING FOR MULTIPURPOSE BERTH
52. APPROACH TRESTLE TO BREAKWATER
53. COMMON APPROACH TRESTLE TO LIQUID TERMINAL
54. COAST GUARD AREA
55. RECLAMATION BUND
56. PARKING FOR CHEMICAL & EDIBLE OIL TANKERS
57. SEA WATER PUMP HOUSE
58. APPROACH TRESTLE FOR RAIL
59. PORT USER BUILDING
60. INCINERATION AREA
61. CUSTOM BUILDING

REV	DATE	DESCRIPTION	BY	CHK	APP

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PROJECT
Consultancy services for Design and Detailed Engineering for Greenfield Vadhavan port project

TITLE
VADHAVAN PORT MASTER PLAN

DRAWN SNJ	CHECKED MS	APPROVED ASM
DATE AUG' 2023	SCALE @A1 1:1000	REF.

DRAWING No.	SUITABILITY	REVISION
DI1452-RHD-DP-MA-DR-CM-xxx	S4	P01

CWPRS carried out hydrodynamic modelling of this layout. The results (Figure 6-11) indicate the following:

- Maximum cross current at the harbour entrance of 2.55m/s reducing to 1.3m/s at the expected ship stopping point
- Maximum currents at the turning areas less than 0.4m/s in a S-N direction
- Currents in the dredged basins between reclamation fingers less than 0.05m/s
- Currents longitudinal to the berths at the ends of the reclamation fingers less than 0.2-0.4m/s
- The total quantum of siltation in the dredged areas will be about 9.20 M cum.

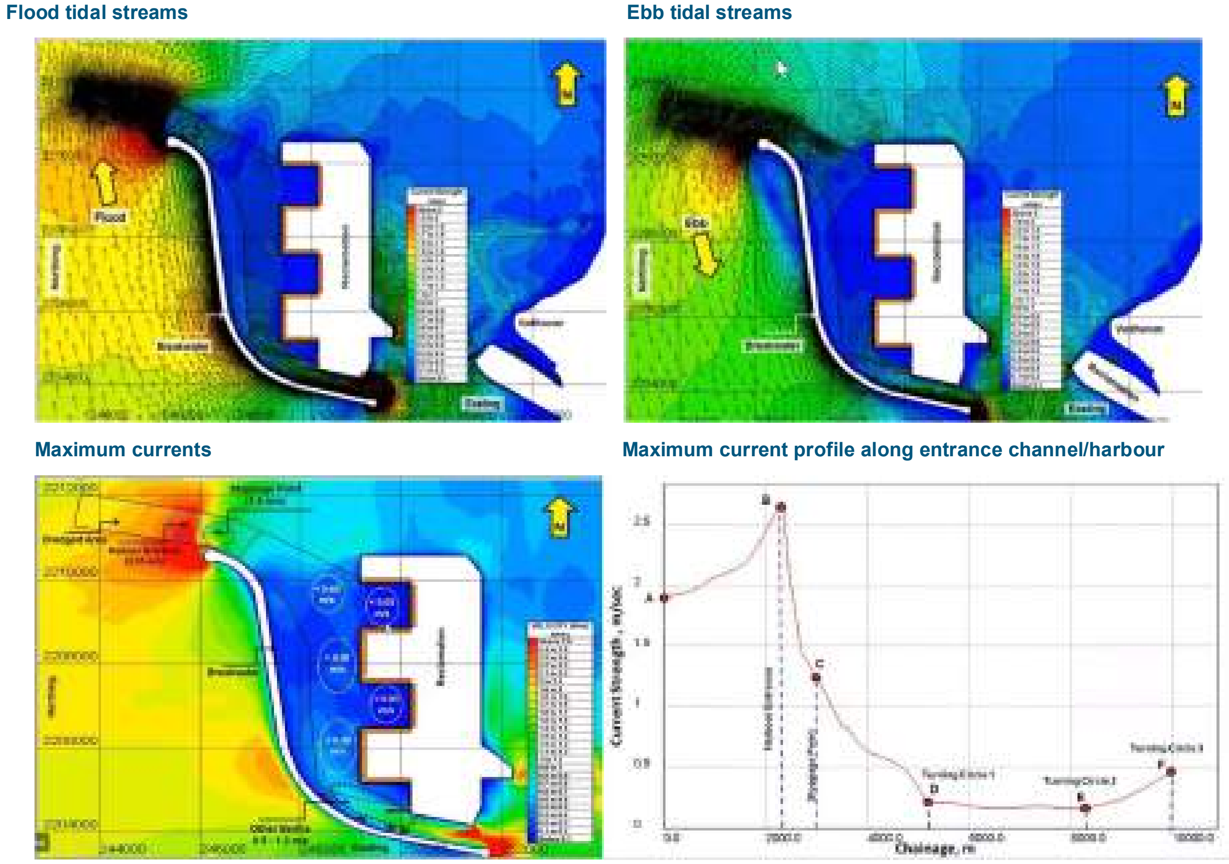


Figure 6-11 Recommended Vadhavan Port Master Plan Layout - results of hydrodynamic modelling

Source: CWPRS

Based on the flow fields, it was observed that the tidal flow conditions are suitable at all container berths as well as in the manoeuvring area. However, the results of the numerical hydrodynamic modelling indicated that on Spring flood tides the maximum current speed between the southern end of the offshore reclamation and the southern end of the breakwater could exceed 2.5m/sec. In addition, there was indication of eddy formation at the south breakwater head (Figure 6-12).

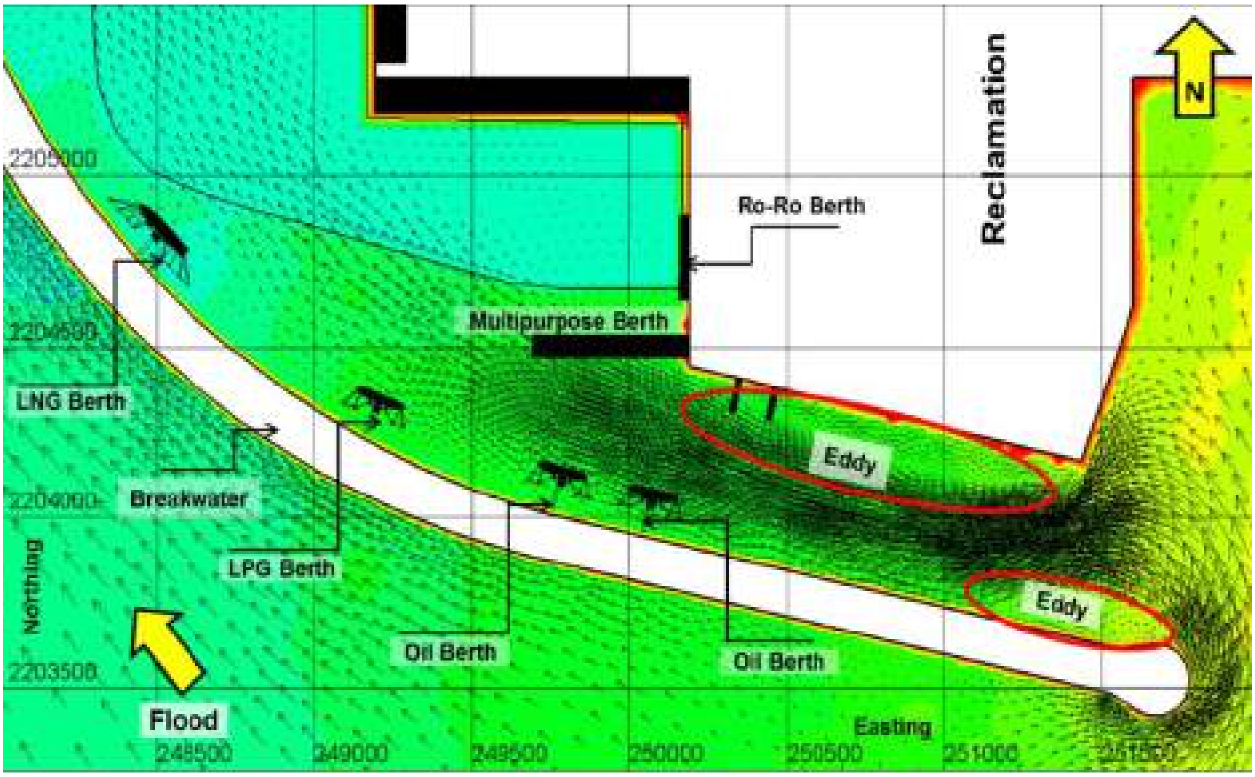
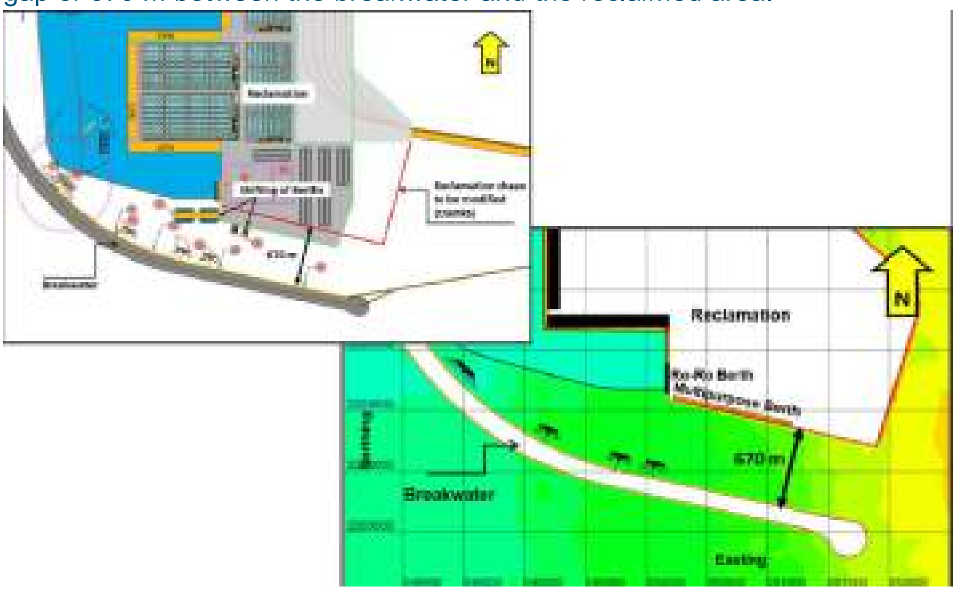


Figure 6-12 Maximum Spring flood tide current speeds at southern end of the reclamation

Source: CWPRS

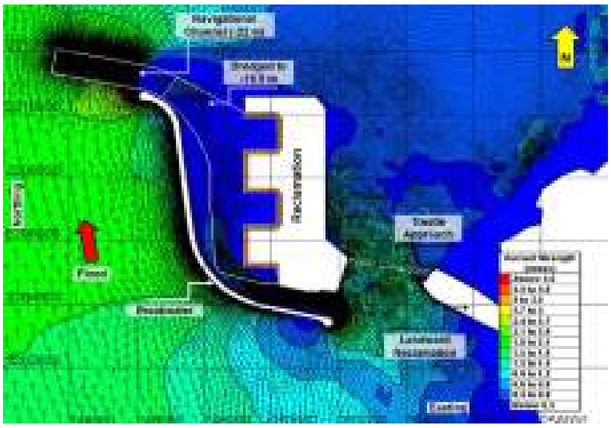
Modifications were therefore made by CWPRS to the layout in order to reduce/improve the flood tide current flows at the southern end of the harbour basin. The final port layout is shown in Figure 6-13.

- Modification in the area at along the southern end of reclamation footprint and maintaining a gap of 670 m between the breakwater and the reclaimed area.

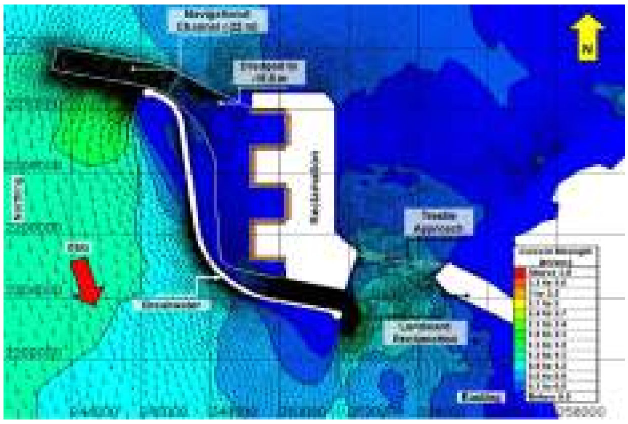


- The revised reclamation arrangement facilitated the flow to align along the reclamation face during the flood as well as the ebb tide providing favourable condition for multipurpose berth along the southern end of reclamation.

Flood tide



Ebb Tide



- Shifting of the liquid terminals 500 m along the breakwater towards north to achieve favourable flow conditions.
- The quantum of likely siltation will be about 8.45 M cum per annum with the reduction of 0.75 M cum in annual siltation due to favourable tidal hydrodynamic conditions.

The final master plan layout incorporates the following:

- 9 container terminals each with a straight 1,000m long marginal quay. 7 terminals have the container storage yard located directly behind the quay apron whilst for two of the terminals the container yard is located about 1km behind the quay.
- A total of four multi-purpose berths each 250 m long at the southern end of the reclamation
- Two liquid bulk berths located on the inner edge of the breakwater at the southern end
- An Bulk Liquid berth located on the inner edge of the breakwater just north of the liquid berths
- An Other Liquid FSRU berth located on the inner edge of the breakwater north of the Bulk Liquid berth
- A Ro-Ro berth at the south-west end of the offshore reclamation with adjacent vehicle parking
- Small craft (pilot boats and tugs) and coastguard berths at the southern end of the reclamation. Additional berths for small craft may also be provided at the northern end of the reclamation if required.
- Rail terminal located along the eastern side of the offshore reclamation
- Onshore reclamation for liquid bulks storage and administrative facilities.

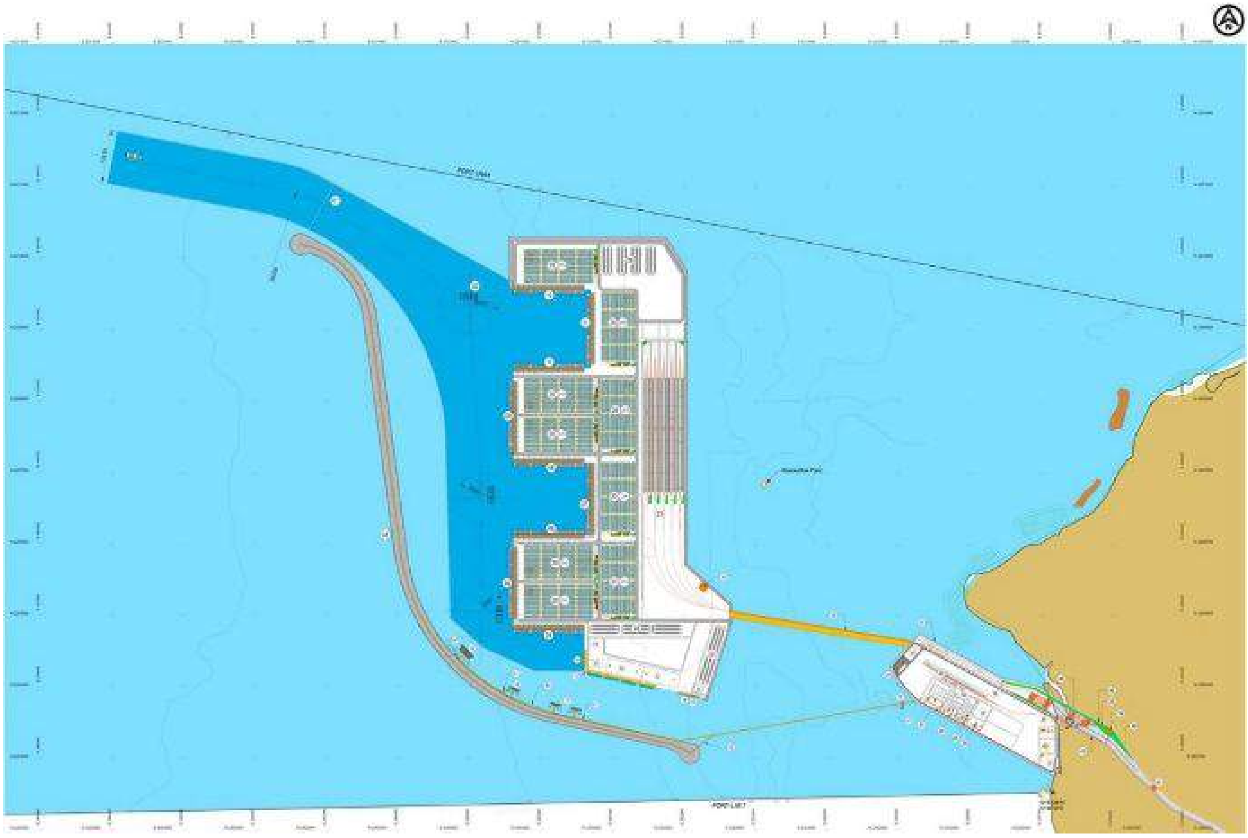
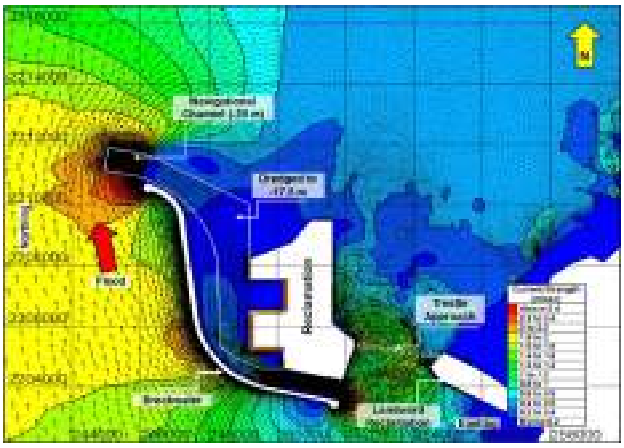


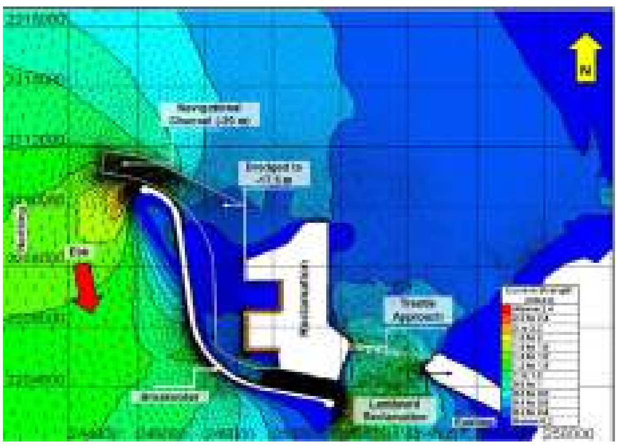
Figure 6-13 Final Vadhavan Port Master Plan Layout

The port is proposed to be developed in phases and accordingly, the model studies were carried out for the proposed Phase 1 layout to ascertain the flow conditions within the harbour. The results of the model studies are as below:

Flood tide



Ebb Tide



The maximum velocities at harbour entrance, stopping distance and turning circle are 2.6 m/s, 1.2 m/s and 0.3 m/s respectively. The maximum current strength at berths is about 0.05 m/s.

The annual siltation in the dredged areas will be about 6.45 M cum.

6.2.4 Wave tranquillity

As noted earlier a breakwater is required to protect the berths and port facilities for south-west to north-west waves. To achieve this a north-south alignment was selected for the breakwater and number of potential layouts tested before arriving at the final layout.

Input conditions for the wave tranquillity modelling were derived from data held within the CWPRS database and transformed onshore using a wave transformation model. This resulted in wave conditions immediately offshore of the port (in 24 m of water) as shown in Table 6-10. It is not entirely clear from the CWPRS report, but it is assumed that these are annual conditions i.e., 1-year storm conditions.

Table 6-10 Annual Wave Conditions outside Vadhavan Port

Wave Direction (deg. N)	Wave Height (m)
270 (W)	2.5
292.5 (WNW)	1.5
315 (NW)	1.5
Peak wave period T_p 10 sec	

Based on the results of the model studies, it may be noted that the most critical incident wave direction is from west, WNW and NW direction during monsoon and non-monsoon season. Higher significant wave height of 1 m is observed at CT 07 during non-monsoon season. The downtime would not exceed 10 -12 days in a year.

Also, the wave propagation within the harbour is in the range of 0.2 m to 1.0 m for the wave incident from west, WNW, and NW direction for the master plan layout. For the Phase 1 layout, all the jetties have significant wave height less than 0.35 m during non-monsoon and monsoon season. No downtime was observed for Phase 1 layout.

6.3 Recommended Master Plan

6.3.1 Master Plan Key Components

The final Master Plan (also referred to as Phase 2 development) results from identifying the infrastructure needed to achieve the projected market demand over the 2040 planning horizon for the Vadhavan Port's three core commodities: containerized cargo, multipurpose and liquid. This is based on the revised traffic projections and considering the utilizable shore length of 9.5 km at Vadhavan. This infrastructure will include:

- Ability to berth fully laden two 24,000 20-foot equivalent container units (TEU) vessels in Phase 1 itself.
- Ability to handle Q_{max} Other Liquid ships, liquid bulk carriers for chemicals and edible oil.
- Multipurpose vessels
- Container Yard on reclaimed land.
- Rail line to port and the railway yard.
- Berthing facilities for Coast Guard and Port crafts.
- Other support and ancillary facilities.

RHDHV team applied the site-specific physical constraints, based on the infrastructure assessment, to identify the master plan while keeping JNPA's objectives in mind. These constraints include no interference with local community, independent approaches to the port, proximity to an existing fishing harbour and fishermen settlements in the north; Shankodhar point in the middle of the sea; mangroves and rocky outcrop near the coast.

In summary the Master Plan addresses four main factors:

- *Market:* The master plan is based on the traffic analysis performed by RHDHV and is planned to accommodate the 2040 realistic scenario. In addition, expansion potential of the master plan will allow to port to expand beyond 2040. The master plan is flexible enough to accommodate various types of cargoes depending on the market situation (liquid, Other Liquid, multipurpose, RORO cargo). Based on the market forecast, it is recommended that Port of Vadhavan be developed in two phases with Phase 2 bringing it up to the final master plan development.
- *Technical:* The master plan presents the most technically sound option after taking into due consideration the physical constraints at the site and providing a futuristic world class efficient facility with green design concepts.
- *Environmental:* The master plan takes into account various environmental aspects such as:
  - Provides a minimum of 300 m clearance between the shoreline and the bund to avoid disturbing the flow to the mangroves due to the proposed port.
  - Locating the terminal and onshore facilities on the reclaimed land.
  - Provides flexibility to incorporate green initiatives.
- *Social:* The Master Plan has been carefully arrived at to minimize impact on the adjoining population, some of the factors considered are:
  - Fishing community near the proposed port site.
  - Rail and road access have been planned for minimal impact on the adjoining village.
  - Facilities for Coast Guard to improve security of the country.
  - Master plan preserves the existing Shankodhar Point and provides for unimpeded access to it.
- *Cost Benefits:* Cost benefit analysis was carried out for the Old DPR layout (Figure 1-4) and the revised layout shown in Figure 6-13. It may be noted that the NPV of T/T operations for the entire project over the period of 30 years of concession for Old DPR layout is INR 62,383.5 crores and INR 50,868.5 crores for the revised layout respectively.

The Master Plan layout is as shown in drawing **DI1452-RHD-DP-MA-DR-CM-1001**.

6.4 Phasing of Terminal Development

The phasing of the facility to be such that spare capacity is available to commensurate the traffic forecast. Also, care should be taken that spare capacity is available to capture the traffic during the implementation of the respective phase so as to avoid traffic congestion and bunching of ships.

Nine Container terminals each of 1,000 m length by 2040 be expected to perform at 2,670 TEUs/m/yr. It is likely that some of these terminals will be common-user facilities where this KPI is considered high.

In only projecting demand to 23.2 MTEUs in 2040, a linear growth is now evident, albeit at a CAGR of 7.3%. If it is accepted that the terminals will perform at such a high KPI, then two terminals (2,000 m of quay) will provide 5.46 MTEUs of capacity. If we assume that capacity is developed at a rate to ensure – for as long as possible - that demand does not exceed 65% of available capacity, then supply vs demand will be as shown in Figure 6-14.

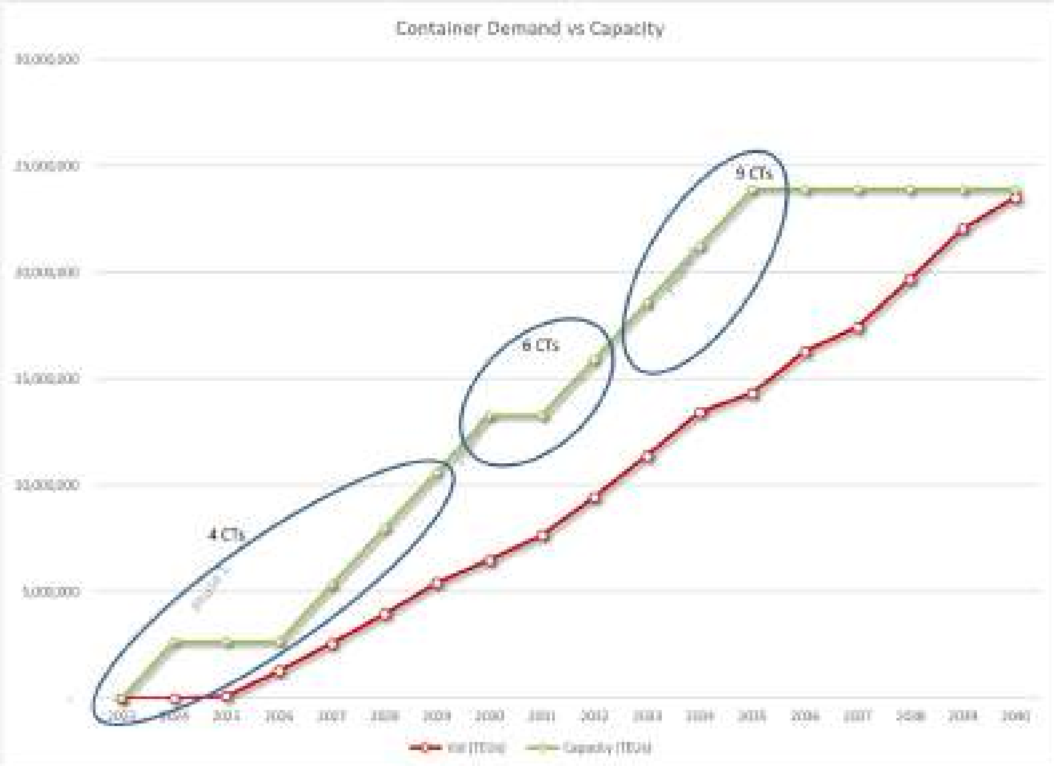


Figure 6-14 Revised Case Container Capacity Supply vs Demand

However, once CT9 is developed, the utilisation commences to exceed 65% year on year and by the planning horizon will reach 100%. In using a system to trigger capacity development at a certain value, phasing can be problematic as can be seen in Figure 6-14.
In any capacity development process, additional capacity is ideally brought online before utilisation of the available capacity becomes too high. A trigger of 65% to 75% is typical. However, we cannot assume that in using a performance of 2,670 TEUs/m/yr. and which x 9 CTs and x 1,000 m per CT yields 24.0 MTEUs overall means that in reality we need 36.9 million MTEUs of capacity so that the 65% threshold is not exceeded. Afterall, if a terminal achieves 2,000 TEU/m/yr. it does actually handle 2,000 TEUs/m/yr., i.e., 100%. Therefore, in respect of capacity planning a 65% trigger is acceptable subject to the timing of further consents and contractor mobilisation, but in respect of absolute values, then 100% is acceptable.

It is probable that international contractors will undertake the marine works such as dredging, reclamation, berth platform, trestle and breakwater construction and therefore given mobilisation timing and cost the phasing is best managed in larger phases rather than piecemeal projects. Figure 6-15 below considers three distinct phases but triggered at a higher 75% capacity utilisation.

Figure 6-15 Revised Case Container Capacity Supply vs Demand – Phased Case

Notwithstanding the above, the quay performance KPI is considered ambitious, but the obligation to achieve it will rest with the concession holders and any cost of mitigating its shortfall, e.g., funding additional early capacity, may also be an obligation of the concessions.

The Phase 1 development is planned in such a manner that container berths can be expanded and additional berths for multipurpose can be added at the port. This would involve additional reclamation for creation of back-up land area. The requirements presented in Section 5 are met based on the expected traffic forecast. The recommended layout of the Phase 1 for Vadhavan port (2030) is shown in Drawing **DI1452-RHD-DP-MA-DR-CM-1002**.

6.5 Land Use Plan

Large backup area has always been a prime requirement for major port development anywhere in the world. Therefore, especially in the case of a completely new port it will be prudent if a large area is specifically reserved for the long-term development of the port, so that the port facilities which are so vital to the growth of the nation can be developed easily to cater to its growing needs.

The minimum land area required for the purpose of cargo handling, storage, port operations, rail and road connectivity, greenery etc. has been worked out as shown in Table 6-11 below:

Table 6-11 Minimum Land Area Requirement for Vadhavan Port

S. No.	Commodity	Land Allocation over Master Plan Horizon (sqm)	
		2030	*2040*
1.	Storage Space for various Cargoes	4,614,560	7,892,833
2.	Internal Roads and Circulation Space in Storage areas @ 25%	1,153,640	1,973,208
3.	Rail and Road Corridor (internal)	1,224,000	1,964,000
4.	Rail and Road Corridor (external)	4,968,000	4,968,000
5.	Port Building Complexes including parking	14,843	30,311
6.	Landscaping, Green belt and other for Expansion	450,000	975,000
	Total Land Area (Sqm)	**12,425,042**	**17,803,352**
	Total Land Area (Acres)	**3,070**	**4,399**
	Total Land Area (Hectares)	**1,242**	**1,780**

Drawing **DI1452-RHD-DP-MA-DR-CM-1003** shows the overall development for the project along with different land uses area planned.

7 Terminal Equipment and Utilities

7.1 Terminal Handling Equipment

7.1.1 Container handling System

7.1.1.1 General

It is important to note that all container moves either begin or end in the container yard. No containers go directly from vessel to rail or from gate to vessel for example. Figure 7-1 shows a schematic of each container flow at Vadhavan Port.

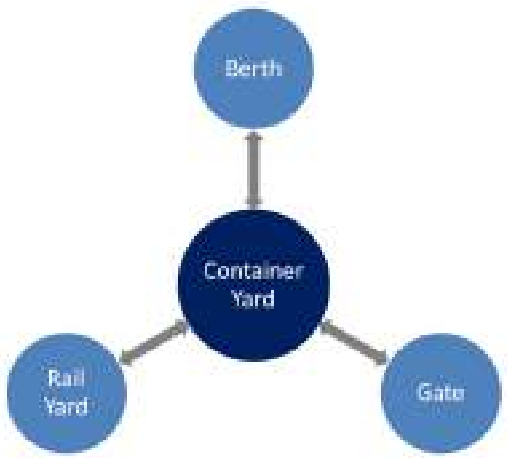


Figure 7-1 Schematic Container Flow Diagram

7.1.1.2 Container Terminal Operation Strategy

The Phase 1 development will have 4 container terminals with a total quay length of 4,000 m with each terminal of 1,000 m, which can cater minimum of 3 container ships at any time. It is proposed to provide 48 (12 at each terminal) Rail Mounted Quay Cranes (RMQCs) on these terminals. There would be flexibility of moving the quay cranes to the adjacent berths so that 2 to 5 cranes can be deployed on a ship, depending upon its size. For handling in the Container Yard 36 electric Rubber Tyred Gantry Cranes (e-RTGCs) are provided for each CY. Similarly, 5 Rail Mounted Gantry Cranes (RMGCs) are provided to handle containers being moved by rails. For movement of containers between quay, container yard and rail yard Internal Transport Vehicles (ITVs) are provided.

It is to be noted that the actual operation strategy is to be decided by the selected operator who would be operating the terminal. However, the number of equipment is arrived based on the terminal capacity to cater the projected forecast.

The flow diagram for the container handling system for import and export containers are as presented below.

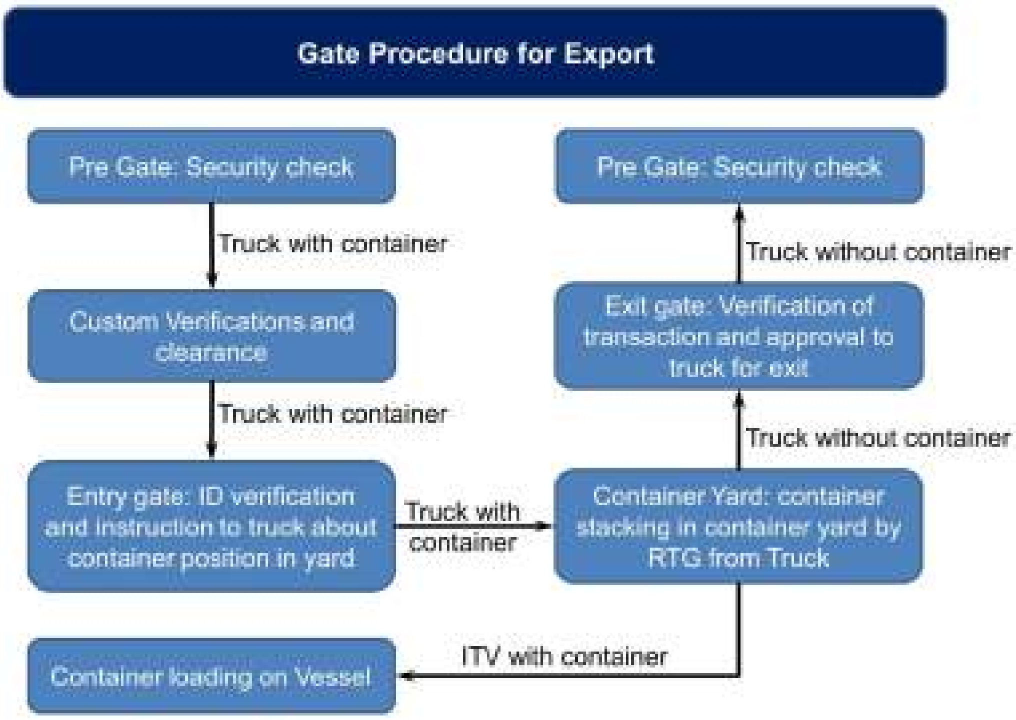


Figure 7-2 Container Terminal Operation Strategy - Export container

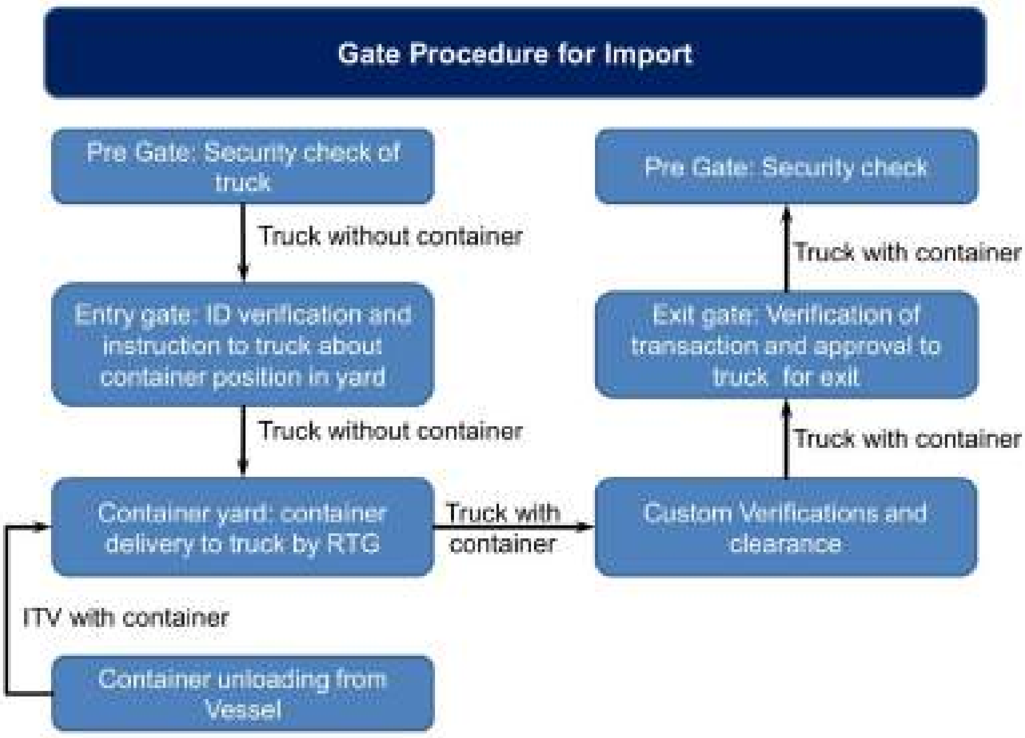


Figure 7-3 Container Terminal Operation Strategy - Import container

7.1.1.3 Storage and Evacuation Strategies for Container Terminal

The container yard is planned based on the import - export container forecast, expected dwell time at yard and the storage height of the containers. During the initial years to promote the traffic, more free time for storage of import and export containers will be provided. Non-ICD Import and Export containers can be given a free time of 3 days while ICD containers can be given a free time of 15 days as per the general trend. Separate blocks for Reefer Containers, Long Standing Containers shall be provided in the yard.

The container shall be stored upto 5 high. Empty containers will be stored separately and will have to be cleared initially within a free period of 3 days, which subsequently will be reduced to 24 hours since the yard space is very costly and should be used for only laden containers.

7.1.1.4 Container Yard Operation Strategy

Vadhavan Port is being developed with a vision of green initiative, it is planned to operate the container yard with (eRTG's) i.e., RTG's run on electric power supply rather than diesel electric power, which are eco-friendly. E-RTGCs can be operated in the yard to handle the containers up to 1+5 high and it can be moved from one block to another block. ITVs would be utilised for transfer of containers between yard and the berths.

Separate blocks shall be designated for long standing containers, i.e., containers which are not lifted beyond 60 days should be moved away from the yard for subsequent auction and disposal of the cargo. If necessary, these containers can be moved out to another custom bound area where the CFS operations will be undertaken. This will minimize the unproductive moves in the yard.

7.1.1.5 Container Terminal Equipment Planning

System Requirements

The container traffic will consist of both import and export traffic of almost equal proportions. The incoming containers will comprise of:

- Transhipped from mainline mother vessels to feeder line vessels.
- Going to ICDs by rail.
- Going to nearby ICDs or customers' premises by road.
- Going to CFS where they will be de-stuffed, and the goods transported by road to consignees' premises.

Similarly, outgoing containers will also comprise of units as under:

- Coming from ICDs by rail.
- Coming from nearby ICDs or customers' premises by road.
- Stuffed at the CFS after bringing goods from consignees' premises.
- transhipped from feeder line vessels.

The system should be capable of handling all the above types of traffic, including storage and retrieval from storage.

7.1.1.6 Container Terminal Equipment

Ship-to-Shore handling facility (Rail Mounted Quay Cranes - RMQCs)

These are rail mounted travelling cranes on quay provided as a ship-to-shore handling facility. They will have a front outreach of up to 72 m for handling upto 24,000 TEUs vessels. It is not envisaged to stack any containers on the quay except in emergency situations. The cranes will be provided with telescopic twin lift spreaders. Typical details of RMQCs are shown in Figure 7-4.

Figure 7-4 Typical RMQCs Operating at Berth

RTGs (Rubber Tired Gantry Cranes)

RTG cranes have long been the most common mode of operating worldwide in a container yard. As the name implies, these machines operate on rubber tires and can roam anywhere in the container yard. They typically run on reinforced concrete runways to minimize the rutting that can take place along the RTG travel paths.

Although, RTGs have traditionally been diesel powered, there is a major trend in the container handling industry to shift to electrically powered RTGs. RTGs can be powered from a cable reel but the most common electrical solution is an above ground bus bar power system.

Taking due care of the green nature of the proposed port, spatial provisions are provided in the planned development for E-RTGs (Electric RTGs) for container yard handling. It will run with zero emission compared to a diesel-powered RTG, a greenhouse gas emission free container yard operation and saving in energy costs on long run. Local NOX, PM, CO emissions can be reduced at greater level with use of E-RTGs. Figure 7-5 shows an E-RTG in operation.

Figure 7-5 Typical E-RTG for Yard Operation with Electric Buss Bar Arrangement for E-RTG

RMGCs (Rail mounted gantry Cranes)

Loading / Unloading of containers on rakes will be done by Rail Mounted Gantry Cranes (RMGCs). They move on a straight rail track slightly longer than the length of the rake. This equipment has cantilevers at both end through which the containers are lifted from trailers and then loaded to wagons and vice versa.

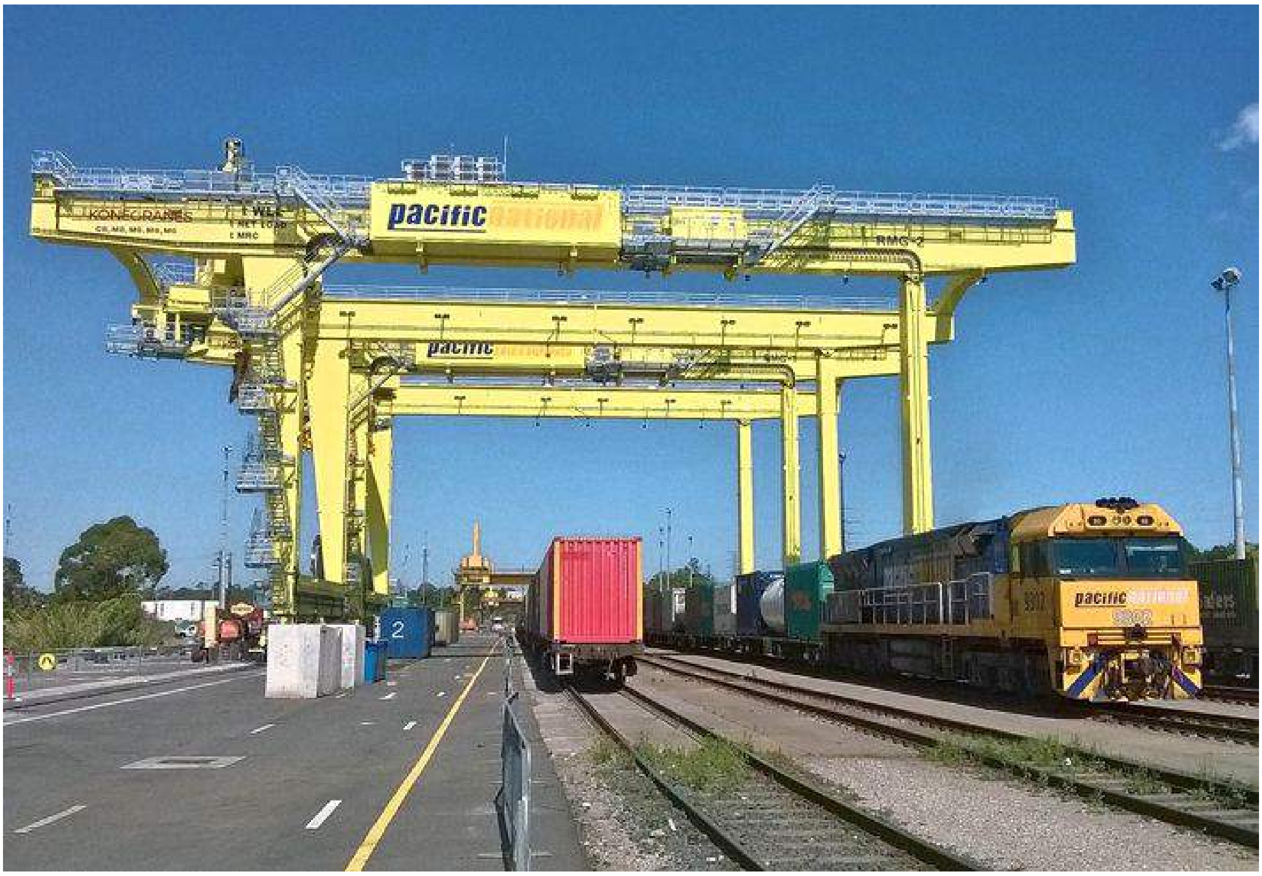


Figure 7-6 Typical Details of Rail Mounted gantry Cranes (RMGCs)

The requirement of 5 RMGCs is calculated for Phase 1 based on the time required to clear a rake within the specified time. However, based on the operational requirement, a greater number of ITVs maybe deployed.

Reefer load container storage

Refrigerated loaded containers (reefers) are envisioned to be stored at the west end of the middle RTG stack row. The reefers will be stored for access via multi-level reefer racks, stacked to a maximum of five containers high. The racks will provide power and maintenance access. Reefers will be delivered and retrieved by ITVs.

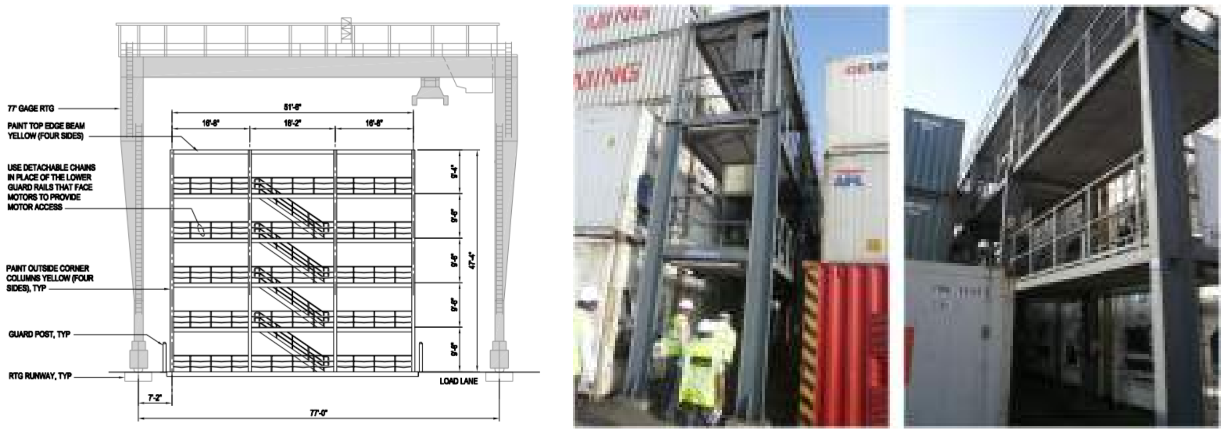


Figure 7-7 Typical Arrangement Details of Reefer Stacks

Figure 7-8 Typical Details of Reefer Stacks Operation

Reefer racks provide grounded storage for reefers. Multi-level reefer racks are provided to allow mechanics access to plug and unplug units, to check reefer machinery status, and to perform low level maintenance and repair. Refrigerated loads are plugged into power receptacles, located on the reefer racks, to maintain temperature while stored in the container yard.

Empty reefer containers can be stored in designated areas of the empty storage area and/or the RTG container storage rows.

Empty reefers are plugged in and tested (pre-tripped) to confirm their operating condition. Pre-tripping can be done in the grounded reefer stacks.

Empty container handlers

Empty containers will be block-stowed in grounded rows with containers stacked up to eleven-wide by six to seven high. Empty Container Handlers (ECHs) will service these rows.

ECHs may include, at the discretion of the concessionaire:

- Medium-duty forklift trucks.
- Side-pick cranes.
- Top pick cranes.
- Reach-stacker cranes.

Side-Pick empty container handlers are recommended as the primary equipment for ECH operations (See image below). Should the concessionaire elect to do twin-picking of twenty-foot boxes, a twin-pick reach-stacker can be used in the proposed layout.

Figure 7-9 Snapshot of Typical Side-pick Handling

The dedicated empty storage area is provided at the rear of the individual container terminal yard area.

ECHs may transport empty containers over short distances to or from the container repair shop or reefer washout area. Containers will be transported between the quay and the empty storage areas by ITVs. Traffic through the ECH storage rows can be either unidirectional or bidirectional based on the preference of the operator.

Reach Stacker is the equipment used for handling containers within container yard and intermodal operation of the containers. It can transport containers for short distances and stack them in various rows depending on its access. In small to mid-size ports reach stackers are also used in the yard operation for stacking containers. Reach stacker has gained ground in container handling in rail yard because of its flexibility and ability to stack across rail tracks.

Figure 7-10 Snapshot of Typical Reach Stacker Handling

Internal transfer vehicles (ITVs)

These are the vehicles used for cargo movement within the terminal area from berth to storage area and storage area to rail yard or vice-versa. Generally, trucks with a forty feet long trailer are used for container handling and dumper trucks are used for dry/ break bulk cargo. The battery-operated ITVs are also in practice in place of diesel-based ITVs in upcoming terminals developing on green and eco-friendly mechanisms.

Figure 7-11 Typical ITV for Handling Containers

ITVs requirement for container handling has been identified as 1317 no. for Phase 1 development of Vadhavan Port. The actual requirement and classification of the ITV procurement will be decided by the awarded terminal operator.

7.1.1.7 Yard Service and Support

Reefer Wash Facility

A reefer wash facility is used to clean and sanitize the interiors and clean the exteriors of refrigerated containers using manually operated high-pressure hot spray washing machines.

The number of reefer wash slots required will depend on the operator's requirement. However, from the land use plan, the Reefer Wash Facility should be located adjacent to the Maintenance and Repair Building. All the buildings are provided to the shorter length of the individual terminals.

This area shall be graded, and berm be made so that water and wash materials will be contained and flow to a sump equipped with an appropriate water separator and shut-off valves. Grading of the surrounding areas shall cause rainwater to drain away from the area.

Yard Equipment Parking

Yard equipment parking area is provided to allow for consolidated storage of inactive terminal equipment. This area is provided adjacent to workshop areas with easy access from the entry/exit gate so as not to interfere with terminal operations.

As shown in the terminal plan, this area is provided at the end of the terminal adjacent to the Maintenance and Repair Facility. Additional yard equipment parking is provided along the landside edge of the terminal adjacent to the terminal POV parking area.

Most powered vehicles will be fuelled at the Fuel Station in the parking area. Therefore, the pavement in these areas shall be graded so that spills are contained and flow to special drains and/or sumps provided with oil-water separators and drain shut-off valves.

POV Parking Areas

Parking spaces for management employees, visitors, and other personally owned vehicles (POVs) is provided on the gate entry/exit area of individual terminal. It is assumed that the yard personnel will arrive by port-operated bus service or personal vehicles. Additional POV parking is not provided for the yard personnel. Vehicle parking is provided inside the POV parking area.

The adequacy of these values should be verified, in concert with refined building planning, during the final design process. Each POV parking stall shall be 2.7 m wide by 6.1 m long. An aisle of at least 7.6 m in width shall serve the parking stalls. On-terminal bus stops will be required adjacent to each of the terminal buildings and yard equipment parking areas. On-terminal buses are to be used to transport employees to their places of work on the terminal.

7.1.2 Break bulk handling system

7.1.2.1 General/ Coastal cargo

The general cargo shall be loaded/ unloaded to the ships using two Mobile Harbour cranes on each berth. The transfer of material between the berth and storage area shall be by means of dumpers, which shall be loaded/unloaded by pay loaders/ front end loaders at the storage yard.

7.1.2.2 Fertiliser

The fertilizer unloading from ship to shore is can be carried out by a variety of arrangements like Gantry type grab unloaders, Mobile harbour cranes and screw type unloaders etc. The typical systems are described below:

Grab Unloaders

This equipment could be Gantry type grab unloader/ Electric level luffing (ELL) cranes or Mobile Harbour cranes (MHCr). The equipment shall unload the material from the ship using grabs and transfer it to connected hopper (a separate mobile hopper is required in case of ELL cranes and MHCr). From hopper the material is transferred to the conveyor located underneath and the conveyor finally takes the material to the bulk storage shed. Typical arrangement is shown in Figure 7-12.

Figure 7-12 Typical Arrangement of ELL / Mobile Harbour Cranes with Mobile Hopper

Screw Type Unloader for Ship to Shore Unloading

A typical screw type unloader consists of a vertical screw conveyor arm, which after lifting the dry bulk fertilizer transfer it to the horizontal arm that contains a closed conveyor which finally transfers through the central column on to the dock side conveyor.

Figure 7-13 Screw Type Unloader

The vertical screw can dig through the material as it is positioned and the screw ensures a high degree of filling of material, thus ensuring uninterrupted flow. As the cargo leaves the vertical conveyor, it is transferred through a completely sealed box to a horizontal screw conveyor.

The horizontal screw that runs to the complete length of horizontal arm transfers the fertilizer into the vertical gravity chute in the slewing tower. Here the material is directed onto the receiving jetty conveyor which is covered on three sides with only the front side open to facilitate transfer of material as the unloader moves along the length of jetty.

Proposed Arrangement

Both the ship unloading systems discussed above have their own merits and demerits. While the grab unloaders are the conventional machines suitable to handle variety of cargoes, the screw type unloaders are sophisticated machines requiring careful operation and maintenance while dealing with different product types. The screw unloaders allow uniform and higher handling rate as compared to the equivalent grab unloader.

It is however proposed to use the Mobile Harbour Crane with grab and integrated hoppers due to the following reasons:

- Flexibility to handle different grades of material and variety of cargoes unlike their compatibility issues with the screw unloaders
- Combination of MHCr and mobile hopper arrangement for loading trucks is proposed in Phase 1. Once sufficient traffic is realised the terminal can be converted for mechanised handling of the cargo.
- The cost of two grab type cranes may be equivalent to cost of one screw type unloader, however they would unload vessel more uniformly as compared to the single screw unloader.

7.1.2.3 Bulk Shed

The proposed bulk shed shall be mainly built using structural steel. Portals are kept at a distance of 12 m and to support the sheeting, extra portal is kept at 6 m transferring its load to main portal via tie girder. Toe wall and grade slab are provided for maintaining the finished floor level at +8.5 m CD so as to give a clear height of 1,500 mm above road level. A small retaining wall shall be provided towards the stack so as to provide required profile to the floor to enable reclaiming by scrapper reclaimer. On top of the retaining wall, along the entire length, a small rail shall be provided to support one end of the mobile hopper, the other end of which shall be supported on the rails of scrapper reclaimer.

For foundations, longitudinal beams supported on piles are provided for rail track of scrapper reclaimer, whereas portals are resting on pile cap provided at every 12 m c/c. Foundations of both the structures are integrated with the foundations of the shed structure to achieve overall economy.

7.1.2.4 Bagging and Evacuation Requirements

The bulk material stored in the bulk shed will need to be transferred to the bagging shed for bagging and stitching. For this purpose, it is proposed to deploy a portal type scraper reclaimer at the bulk shed. This machine shall reclaim the material from the relevant stockpile and transfer it to the connected conveyor system. From conveyor the material shall be taken to the top of the bagging shed, where a series of hoppers shall be provided along its length. The material shall be dropped to the main hopper one by one using the plough feeders.

There shall be an intermediate floor in the bagging shed for the bagging and stitching of the fertilizers from where the bags shall be transferred to the platform level through chute. A total of 8 bagging machine shall be provided in the shed along its length. The bagging machines are proposed to be semiautomatic type with design capacity of 700 bags per hour each. With this system, it would take about 4 hours to bag the material for loading to one rake.

The bagging plant will typically consist of two units. The first unit comprises one tower of height 22 m, at each location of bagging cum stitching unit for its support. The second unit will be about 9 m high provided for storage of bagged fertilizers from where the bags are led to covered loading railway platform for despatch through rail wagons. At platform level the bags are stored prior to loading to wagons.

Considering the maximum rake length of 680 m, the length of bagging shed shall also be around 700 m. The overall width of the shed is taken as about 23 m so as to provide cover to the wagons positioned for loading along the shed which has loading platforms between the rake and the shed. The platform will have a width of 2 m.

Considering the predominant manual operations in bagging, only 16 working hours are assumed in a day. The proposed bagging system would provide annual capacity of about 1.2 MTPA. For arriving at the size of platform the suitable space for storage of cargo for two complete rakes has been considered.

To match with the peak bagging rate, it is proposed to provide the scraper reclaimer at the bulk shed with design capacity of 800 TPH. This duly allows for lower reclaiming rate achieved for the bottom cargo of the stockpile. However, the conveyor system for transfer of material from bulk shed to the bagging machines in the bagging shed shall have the design capacity of 1,600 TPH to allow for taking feed from one more scraper reclaimer.

As the reclaiming conveyor would be provided towards one side only, the other side shall be available for entry of the front-end loaders/dumpers to provide operational flexibility of reclaiming the material by semi-mechanized method of front-end loaders and dumpers.

Bagging Plant and Wagon Loading Shed

A separate bagging plant cum wagon loading shed is proposed along the length of the southern boundary of the port. The overall width of the shed is taken as 23 m so as to provide cover to the wagons positioned for loading beside the shed platform. The overall length of shed is 700 m.

There shall be an intermediate floor in the bagging shed for the bagging and stitching of the fertilizers from where the bags shall be transferred to the platform level through chute.

Bagging plant structure will also be a pre-engineered steel structure but will be designed without side and gable walls. It shall be designed as framed structure with bracing system and steel beams to serve as support to Bagging Plant unit. Adequate steel doors /rolling shutter and windows for natural lighting / ventilation shall be provided.

Bagging plant consists of two units. The first unit comprises one tower of height 22 m, at each location of bagging cum stitching unit for its support. The secondly unit is about 10 m high provided for storage of bagged fertilizers.

It is proposed to carry out the fertiliser handling through conventional means though the combination of MHCr, dumpers and manual handling during the initial stage of the development and mechanisation of the terminal can be taken up to commensurate the traffic.

7.1.3 Liquid Bulk, Bulk Liquid Handling System

7.1.3.1 General

Liquid terminal is planned to handle Chemicals & Edible oil and Bulk Liquid. The liquid bulk, Bulk Liquid received in tanker will be unloaded at berth using the marine unloading arms and transferred to the tank farms by means of pipeline. The cargo is pumped directly from the vessel's pump. From the tank farms, the cargo will be dispatched to the destinations by loading into trucks or through pipelines.

7.1.3.2 Marine Unloading Arms

For transfer of products from the tankers to shore, marine unloading arms will be provided. There will be two arms each for Chemicals, Edible Oil and Bulk Liquid with two arms as standby exclusively for Bulk Liquid. These arms are not interchangeable and hence the connections from these are made to the respective pipelines of the users. The marine arms will be designed to withstand a pressure of 16.0 Kg/cm^2 while the normal operating pressure will be about 12.5 Kg/cm^2 under ambient temperature. However, the arms will be tested to withstand a maximum pressure of 24 Kg/cm^2. The capacity of these arms shall be a maximum discharge rate of 1,500 cum/hr.

7.1.3.3 Operating Envelope

The marine unloading arms are required to move in sync with the tankers' movement due to tidal variation, wave motion, drift due to currents and wind and variation in tanker's deck elevation during product discharge. The arm should also accommodate the change in position of the tanker due to sway and surge. The other factors are the physical characteristics of the tanker manifold, the fender stand-off at the berth, the set-off of the arm from the face of the service platform, etc.

The proposed marine loading arms are therefore designed for an operating envelope based on the following conditions:

- the highest position of the tanker manifold considering the largest tanker at near empty condition during high tide.
- the lowest position of the tanker manifold considering the smallest tanker fully loaded during the lowest tide.

7.1.4 LNG Handling System

The LNG through marine unloading arms will be unloaded in FSRU where the regasification process would take place and then transferred to the main grid through pipelines. The main component of the unloading system is as indicated in the below subsections.

7.1.4.1 Ship Manifold Considerations

LNG manifolds are built in compliance with SIGTTO guidelines and standardized according to the LNG Ship category (A, B or C) as shown in table below.

Table 7-1 SIGTTO LNG Standardized Flange Size and Reducers

Ship Volume	Liquid line		Vapour line	
	Presentation flange size	*Reducer size*	*Presentation flange size*	*Reducer size*
Category A	12”	12”/16”	12”	12”/16”
		12”/10”		12”/10”
Category B	16”	16”/12”	16”	16”/12”
		16”/20”		16”/20”
Category C	20”	20”/16”	20”	20”/16”

Where “category” depends on the LNG storage capacity as follows:

- Category A: less than 59,999 m^3;
- Category B: from 60,000 to 149,999 m^3;
- Category C: more than 150,000 m^3.

7.1.4.2 STS Transfer using articulated arms

This technology comprises:

- Articulated LNG arms.
- Quick Connect / Disconnect Coupler.
- Emergency release system (PERC).
- Hydraulic unit.

Also, there are several components which are not part of the STS system, but are required for a safe and effective transfer, including:

- Mooring equipment.
- Floating fenders.
- Drip tray.
- Water curtain.

Articulated LNG arms

LNG Unloading Arms are today's standard technology for the LNG Terminals worldwide and also there are being adopted for offshore facilities located in unprotected places with calm to mild weather as LNG and some FSRUs.

Unloading arms are rigid structures supporting rigid stainless-steel piping with several swivels allowing the arm to extend, rotate and follow ship movements. The arm is flanged to the ship and provided with emergency disconnection systems (PERC) for rapid disconnection and isolation in case of emergency. Unloading arms are equipped with hydraulic units and control systems to be operated. Furthermore, at least two unloading arms must be installed in the FSRU: a liquid one for LNG and one for BOG. In addition is widespread practice to provide a hybrid spare arm to be used for LNG or BOG in case of a malfunction in one of the main ones.

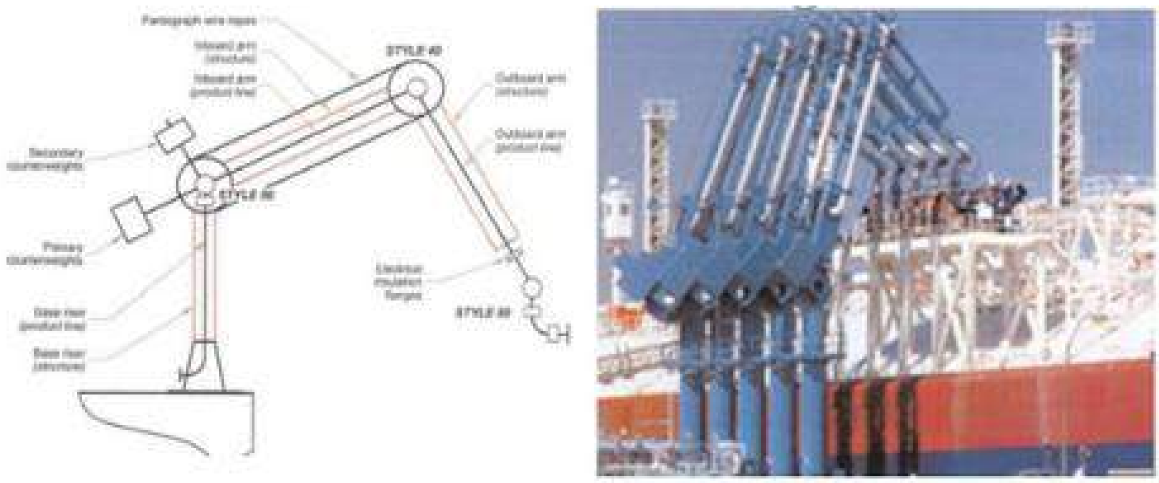


Figure 7-14 LNG unloading Arms mounted on LNG terminal

Figure 7.15 LNG unloading Arms (OLFA) designed for offshore applications as LNG

Unloading arms are built in compliance with SIGTTO guidelines and standardize according to the LNG ship category (A, B or C) as shown in the table below:

Table 7-2 SIGTTO LNG Standardized Flange Size and Reducers

Ship Volume	Liquid line		Vapour line	
	Presentation flange size	*Reducer size*	*Presentation flange size*	*Reducer size*
Category A	12”	12”/16” 12”/10”	12”	12”/16” 12”/10”
Category B	16”	16”/12” 16”/20”	16”	16”/12” 16”/20”
Category C	20”	20”/16”	20”	20”/16”

Where “category” depends on the LNG vessel storage capacity as follows:

- Category A: less than 59,999 m^3;
- Category B: from 60,000 to 149,999 m^3;
- Category C: more than 150,000 m^3.

For this case, considering a 173,000 m^3 FSRU, Category C with a recommended flange size of 20” will be applicable, but there are cases in which this recommendation is not strictly followed (i.e., vessels of 150,000 m^3 using flange size of 16”) and there is a possibility for the FSRU to have flanges of 16” instead of 20”.

To meet the constant movement of the LNG carriers and to warrant an adequate level of safety, LNG Unloading Arms must include the possibility of being automatically and manually controlled during connection/disconnection and when in operation as they must meet:

- The constant movement of the vessel when connecting or disconnecting.
- The constant movement of the vessel once the arm has been connected to the ship.
- The need to limit spillage of LNG in case of an emergency disconnection.

Quick Connect / Disconnect Coupler (QC/DC)

LNG articulated unloading arms include specially designed couplers for facilitating the connection with the manifold’s flanges without the need of bolted flanges thus making the connection/disconnection task safer and less time consuming than in the case of using flexible hoses. This optimizes the turnaround time for loading and unloading operations. The QC/DC shall be hydraulically operated and shall be designed to function reliably for the expected relative motions between ships. An example of QC/DC coupler is included in figure below.

Figure 7-15 QCDC System

Powered emergency release coupling system (PERC)

LNG articulated unloading arms must incorporate a PERC as a safety device for disengaging the arm in case:

- Emergency disconnection is required.
- Operational envelope of the loading arms is exceeded.
- Ship drifting away from the FSRU.

PERC consists of a double arrangement of full-bore ball valves, an Emergency Release Coupler (ERC) and a hydraulic actuator. In case the emergency release system is activated, the double valve arrangement closes and the connection between them is released in order to release the loading arm without having LNG spill. The system must be regulated to ensure that no pressure surges shall occur in the loading arms. An example of PERC is included in the figure below.

Figure 7-16 PERC System

Hydraulic Power Unit

Hydraulic Power Unit (HPU) is used for enabling the unloading arms movements, as well as operating the QC/QD system and PERC. Some requirements for this unit are:

- Hydraulic units shall be a stand-alone unit, bolted to the FSU's deck
- Must include a secondary hydraulic power unit or independent hydraulic accumulators in each arm for backup in case of failure of the main unit.
- Hydraulic connections should be done by either hoses or hard piped with the FSU.
- Hydraulic units must be specified for "zone 2" gas hazardous area.

7.2 Power Supply and Distribution

7.2.1 General

The required electrical system for the project will consist of:

- The incoming electrical supply at 220 kV level.
- 220/33 kV substations containing transformers, switchboards, control equipment, etc. to supply the electrical power to various parts of the site at the required voltage levels of 11kV or 6.6 kV & 0.415 kV.
- Control and Monitoring systems.
- 11 or 6.6 kV underground cabling system for medium voltage supply like for quay cranes etc.
- Fibre optic communications from the substation to the quay cranes.
- 0.415 kV cabling system from the 11 or 6.6 /0.415 kV substations to the reefer area. The cables should be run in cable trenches.
- Provision of underground power cabling to the buildings and gate complex shall be provided.
- Provision of underground power cabling to terminal light towers.

In addition, consideration of future electrical requirements of the terminal shall also be taken into account, and all necessary provisions shall be made in the design and installation of the electrical system, to take account of future requirements. This applies to switchboards, transformers, underground cabling system etc.

Details of the electrical load and demand requirements are as discussed in the sections below.

7.2.2 Electrical Load and Demand

The handling systems for containers are power intensive. Hence require considerable high-tension electrical power for their operation. The terminal development will contain all the features of a modern first-class terminal, and as such will require a reliable power supply system. The following energy requirements have been considered when defining the electrical supply requirements.

7.2.2.1 High Voltage Supply

It is understood that the power to the site will be supplied at 220 kV through overhead double circuit transmission line which would be stepped down at 33 kV level through 4 numbers of 220/33 kV 50 MVA transformers.

It is envisaged that Medium Voltage (MV) supply at 6.6 kV or 11kV depending upon operators' requirement will be provided for the MV power requirements of container yard and terminal support facilities like:

- Power Supply to Quay cranes.
- Provision for Power Supply to ERTGs for yard operations

7.2.2.2 Low Voltage Supply

It is envisaged that Low Voltage (LV) supply at 415 V will be provided to each installation. LV requirements for the wharf and access include lighting, the operation of the fire pump house and miscellaneous LV power services.

The LV power requirements for the container yard and terminal support facilities include:
- Reefer Points,
- Yard Lighting,
- Miscellaneous LV power Requirements, and
- Power Supply to the Gate Complex and Terminal Buildings.

7.2.2.3 Electrical Demand

The electrical demand for the Phase 1 development for Vadhavan Port is estimated in Table 7-3. The overall electrical demand will vary with the use of eRTGS with adequate provision for the electrical infrastructure at the terminal. Similarly, the need for "Cold Ironing" will change the electrical demand and shall be accounted for during the detailed design of the project.

Table 7-3 Peak Demand for Vadhavan Port

S. No.	Area / Description of Load	Quantity / Area	Load / Unit in kW	Total Connected Load in kW	Diversity Factor	Total Max. Demand in kW	Power Factor (cos Ø)	Total Max. Demand in kVA
Power Demand for each Container Terminal								
1.	RMQC	12	2,000.00	24,000.00	0.20	4,800.00	0.90	5,333.33
2.	ERTGC	36	500.00	18,000.00	0.20	3,600.00	0.90	4,000.00
3.	Reefer Points	500	6.00	3,000.00	0.33	990.00	0.85	1,164.71
4.	High mast Lighting	60	12.00	720.00	0.80	576.00	0.95	606.32
5.	Street Lighting	167	0.25	41.67	0.80	33.33	0.95	35.09
6.	Terminal Operation Buildings / Services	5,220	0.20	1,044.00	0.70	730.80	0.90	812.00
	Total			**46,805.67**		**10,730.13**		**11,951.44**
Power Demand for each Multi-purpose Berth								
1.	MHC	1	750.00	750.00	0.40	300.00	0.85	352.94
2.	Lighting Towers	5	10.00	50.00	0.80	40.00	0.95	42.11
3.	Storage Shed	35,000	0.02	700.00	0.70	490.00	0.90	544.44
4.	Fire Fighting System	1	400.00	400.00	0.00	0.00	0.95	0.00
	Total			**1,500.00**		**830.00**		**939.49**
Power Demand for Liquid Berth Edible Oil								
1.	Unloading ARM- edible oil (300tph)	2	200.00	400.00	0.50	200.00	0.85	235.29
2.	Tank Farms	1	100.00	100.00	0.50	50.00	0.90	55.56
3.	Loading bays for tankers	1	100.00	100.00	0.50	50.00	0.85	58.82
4.	Services	1	50.00	50.00	0.80	40.00	0.90	44.44
5.	Fire Fighting System	1	400.00	400.00	0.00	0.00	0.95	0.00
	Total			**1050.00**		**340.00**		**421.05**

S. No.	Area / Description of Load	Quantity / Area	Load / Unit in kW	Total Connected Load in kW	Diversity Factor	Total Max. Demand in kW	Power Factor (cos Ø)	Total Max. Demand in kVA
Power Demand for Liquid Berth Chemicals								
1.	Unloading ARM- Chemicals (1500tph)	1	200.00	200.00	0.50	100.00	0.85	117.65
2.	Tank Farms	1	100.00	100.00	0.50	50.00	0.90	55.56
3.	Loading bays for tankers	1	100.00	100.00	0.50	50.00	0.85	58.82
4.	Services	1	50.00	50.00	0.80	40.00	0.90	44.44
5.	Fire Fighting System	1	400.00	400.00	0.00	0.00	0.95	0.00
	Total			**850.00**		**240.00**		**421.05**
Power Demand for Bulk Liquid Jetty								
1.	Unloading ARM - (1500tph)	4	200.00	800.00	0.50	400.00	0.85	470.59
2.	Rake handling facility	1	100.00	100.00	0.50	50.00	0.90	55.56
3.	Loading bays for tankers	1	100.00	100.00	0.50	50.00	0.85	58.82
4.	Services	1	50.00	50.00	0.80	40.00	0.90	44.44
5.	Fire Fighting System	1	400.00	400.00	0.00	0.00	0.95	0.00
	Total			**1450.00**		**540.00**		**629.41**
Power Demand for Other Liquid Jetty								
1.	Unloading ARM - (1500tph)	2	200.00	400.00	0.50	200.00	0.85	235.29
2.	Services	1	50.00	50.00	0.80	40.00	0.90	44.44
3.	Fire Fighting System	1	400.00	400.00	0.00	0.00	0.95	0.00
	Total			**850.00**		**240.00**		**421.05**
Power Demand for Ro-Ro								
1.	Lighting Towers	1	100.00	100.00	0.80	80.00	0.90	88.89
2.	Services	1	50.00	50.00	0.80	40.00	0.90	44.44
3.	PED	1	500.00	500.00	0.70	350.00	0.90	388.89
4.	Fire Fighting System	2	150.00	300.00	0.00	0.00	0.95	0.00
	Total			**950.00**		**470.00**		**522.22**
Power Demand for Common POB								
1.	Administrative Building	3,000	0.20	600.00	0.70	420.00	0.90	466.67
2.	Customs Building	500	0.15	75.00	0.70	52.50	0.90	58.33
3.	CISF Building	300	0.10	30.00	0.70	21.00	0.90	23.33
4.	Port Operations Building	500	0.20	100.00	0.70	70.00	0.90	77.78
5.	Canteen Building	600	0.10	60.00	0.70	42.00	0.90	46.67

S. No.	Area / Description of Load	Quantity / Area	Load / Unit in kW	Total Connected Load in kW	Diversity Factor	Total Max. Demand in kW	Power Factor (cos Ø)	Total Max. Demand in kVA
6.	Gate House	120	0.20	24.00	0.70	16.80	0.90	18.67
7.	Maintenance Building	1000	0.10	100.00	0.70	70.00	0.90	77.78
8.	MRSS	500	0.10	50.00	0.70	35.00	0.90	38.89
9.	Fire station	100	0.30	30.00	0.70	21.00	0.90	23.33
10.	Port User Building	1000	0.20	200.00	0.70	140.00	0.90	155.56
11.	Guest House	500	0.15	75.00	0.70	52.50	0.90	58.33
12.	General Store	1000	0.10	100.00	0.70	70.00	0.90	77.78
13.	Warehouse	1000	0.12	120.00	0.70	84.00	0.90	93.33
14.	Dispensary Building	1000	0.20	200.00	0.70	140.00	0.90	155.56
15.	Restaurant	200	0.10	20.00	0.70	14.00	0.90	15.56
16.	Police Station	3000	0.10	300.00	0.70	210.00	0.90	233.33
17.	Miscellaneous	500	1.00	500.00	0.70	350.00	0.90	388.89
18.	Recreational Building	2000	0.30	600.00	0.70	420.00	0.90	466.67
	Total			**3184.00**		**2228.80**		**2476.44**
Power Demand for Rail Yard								
1.	Miscellaneous	1	100.00	100.00	0.70	70.00	0.90	77.78
2.	ERTGC	16	500.00	8,000.00	0.33	2,640.00	0.90	2,933.33
3.	RMGC	5	500.00	2,500.00	0.33	825.00	0.90	916.67
4.	Street Lighting	333	0.25	83.33	0.80	66.67	0.95	70.18
	Total			**10,683.33**		**3,601.67**		**3,997.95**

S. No.	Area / Description of Load	Quantity / Area	Load / Unit in MVA	Total Demand Load in MVA	Diversity Factor	Total Max. Demand in MVA
Power Demand for Phase 1						
1.	Power Demand for each Container Terminal	4	11.95	47.81	0.80	38.24
2.	Power Demand for each Multi-purpose Berth	3	0.94	2.82	0.80	2.25
3.	Power Demand for Liquid Berth Edible Oil	1	0.42	0.42	0.80	0.34
4.	Power Demand for Liquid Berth Chemicals	1	0.42	0.42	0.80	0.34
5.	Power Demand for Bulk Liquid Jetty	1	0.63	0.63	0.80	0.50

S. No.	Area / Description of Load	Quantity / Area	Load / Unit in MVA	Total Demand Load in MVA	Diversity Factor	Total Max. Demand in MVA
6.	Power Demand for Other Liquid Jetty	1	0.42	0.42	0.80	0.34
7.	Power Demand for Ro-Ro	1	0.52	0.52	0.80	0.42
8.	Power Demand for Common POB	1	2.48	2.48	0.80	1.98
9.	Power Demand for Rail Yard	1	2.48	2.48	0.80	1.99
	Total			**55.52**		**46.40**
Power Demand for Masterplan						
1.	Power Demand for each Container Terminal	9	11.95	107.56	0.80	86.05
2.	Power Demand for each Multi-purpose Berth	4	0.94	3.76	0.80	3.01
3.	Power Demand for Liquid Berth Edible Oil	1	0.42	0.42	0.80	0.34
4.	Power Demand for Liquid Berth Chemicals	1	0.42	0.42	0.80	0.34
5.	Power Demand for Bulk Liquid Jetty	1	0.63	0.63	0.80	0.50
6.	Power Demand for Other Liquid Jetty	1	0.42	0.42	0.80	0.34
7.	Power Demand for Ro-Ro	1	0.52	0.52	0.80	0.42
8.	Power Demand for Common POB	2	2.48	4.95	0.80	3.96
9.	Power Demand for Rail Yard	1	5.70	5.70	0.80	4.56
	Total			**118.69**		**99.51**
Considering all peak loads will not occur at same time, 0.8 d.f is considered; Maximum Demand will be 100 x 0.8 = 80 MVA						

S. No.	Phase	Load (MVA)	Total Load (MVA)
Power Demand for Vadhavan Phase 1			
1.	Year 2026	7.5	7.5
2.	Year 2027	7.5	15
3.	Year 2028	7.5	22.5
4.	Year 2029	7.5	30
5.	Year 2030	7.5	37.5
	Total	**37.5**	**37.5**
Power Demand for Vadhavan Phase 2			
1.	Year 2031	7.5	45

S. No.	Phase	Load (MVA)	Total Load (MVA)
2.	Year 2032	5	50
3.	Year 2033	5	55
4.	Year 2034	5	60
5.	Year 2035	5	65
6.	Year 2036	5	70
7.	Year 2037	2.5	72.5
8.	Year 2038	2.5	75
9.	Year 2039	2.5	77.5
10.	Year 2040	2.5	80
	Total	**42.5**	**80**

7.2.3 Source of Power Supply

Two locations of the nearest 220 kV source from Assangaon-Boisar and Dahanu were identified.

Regarding tapping from Dahanu, it was discussed that 220 KV GIS bays would be available in near future however the generating station is already loaded and MSETCL will have to check availability of 150 MVA by 2023.
MSETCL has assured that 150 MVA will be available from Assangaon through a tapping from double circuit line, hence even if capacity is unavailable at Dahanu, reliable power supply at Vadhavan is ensured.

New 220 KV bays are required to be created by MSETCL at 220 KV switch yard in order to provide connectivity for 150 MVA Power at 220 KV through new power transmission line to the port from existing power lines.

Power supply to Vadhavan port can be brought through overhead transmission lines through a suitably selected route. The route to the port is one of the complex activities which involve the constraints to the alignments, obstructions, site level and geotechnical conditions. The feasibility study of the alignment needs to be taken up by MSETCL or relevant approved agency.

It is required to run a new receiving line to the port main receiving substation to draw the power load requirement for the port development activities and some critical loads such as emergency lighting, headed equipment of ELV systems etc.

7.2.4 System Arrangement

The power will be made available from the selected source to Vadhavan by constructing a new 220/33 kV Main Receiving Switching Station (MRSS) along with dedicated GIS, outside the proposed Vadhavan port premises.

As per MSETCL, an area of 120m x 120m space is required for MRSS at Vadhavan port.

220 kV Transmission line shall be double circuit to have better reliability, each circuit shall be distributed using outdoor busbar distribution system to 2 feeders each for 1 no. of 30 MVA Transformer. Four transformers shall step down voltage to 33 kV for further distribution.

MRSS switchyard shall consist of metering, switching and protection devices to distribution company standards. From MRSS, power shall be distributed inside the port premises to Main Substation (MSS) using single core cables. MSS Switchboards shall be so arranged that substations (SB-1, SB-2, SB-3) each of 30 MVA capacity feeders with all redundant feeders connected to SB-4 which is spare / standby in case of failure of any of the transformer or the cable, for maximum reliability of power availability in case of equipment or cable failures. The single line diagram of the system arrangement is as shown in **Drawing DI1452-RHD-DR-US-DR-EE-1101**.

From MSS, power distribution will be to various substations, located at different terminals in ring formation in order to have higher reliability and minimize the probability of failure. For Phase 1 redundant feeders shall be used from SB-1, SB-2, and SB-4 and for Masterplan Phase, redundant feeders from SB-3 and SB-4 to have maximum utilisation thus providing reliability from both circuits.

7.2.4.1 Power Distribution for Container Terminal

Each container terminal will have Distribution Substation (DSS). The DSS will receive power from MSS at 33 kV using redundant ring feeders. Load demand for each container terminal is 9.6 MVA. Hence 2 no. 10 MVA Transformers shall be considered.

At the DSS, voltage will be stepped down to 11 kV or 6.6 kV (depending on operator) from 33 kV,11kV or 6.6 kV is considered ideal as RMQCs, eRTGs and RMGCs will operate on 11 kV or 6.6 kV. RMQCs and berth services will be supplied by 11 kV or 6.6 kV using redundant feeders through Berth Substations (BSS) with MV switchboards and 1 Packaged or Compact Substation (PSS) at berths.

eRTG and RMGC shall be fed at 6.6 kV from several distinct Substations (SS), depending upon location and number of RMGCs and eRTGs. SS will receive power from DSS at 6.6 kV.

Reefers shall have dedicated Reefer Substations (RSS), RSS will be Packaged Compact Substation consisting of RMU. RSS will step down to 0.415 kV from 6.6 kV for power distribution to Reefer Sockets. RSS shall vary depending upon number of Reefers.

Each Container terminal will have 1 no. Building & Services Substation (CBSS) for External Illumination, building services and utilities. CBSS will step down to 0.415 kV from 6.6 kV received from DSS. Each CBSS shall have APFC to achieve P.F of 0.95 at 415 V.

These requirements will vary from operator to operator, only infrastructure will be provided by the JNPA.

7.2.4.2 Power Distribution for Multi-purpose Berths and STS Cranes

For berth side equipment there will be Berth Substation (BSS). The BSS will receive power from DSS at 11 kV or 6.6 kV using redundant ring feeders.

For STS cranes 11 kV or 6.6 kV feeders shall be used, Multipurpose berths 6.6 kV shall be used for Crane and further stepped down to 433 V for LV Loads. For Illumination and pumping loads 6.6 kV from shall be stepped down to 433V from BSS.

These requirements will vary from operator to operator, only infrastructure will be provided by the JNPA.

7.2.4.3 Power Distribution for Terminal Operation Services and Buildings

For overall terminal operations services and Bulk Liquid, Other Liquid and Liquid Berths, there shall 1 no. strategically located Utility Substation (USS) consisting of 33 kV / 11 kV 10 MVA Transformers for services distribution, as follows:

11 kV feeders from USS shall be further distributed to Buildings, Utilities and Services. Depending upon location, some of these substations can be part of USS itself or if remotely located, a small Compact Substations (CSS) can be considered.

USS shall have dedicated DG sets for Emergency Loads for Terminal Operation Admin Building and some essential services of 1250 kVA.

These requirements will vary from operator to operator, only infrastructure will be provided by the JNPA.

7.2.4.4 Power Distribution for Bulk Liquid, Other Liquid, and Liquid Berths

USS will draw power at 33 kV from DSS. Bulk Liquid, Other Liquid, and Liquid berths shall have dedicated substations (SS) connected in ring to the Berth Substation BSS-4 depending upon lowest loaded substation. SS shall receive power from BSS-4 at 11 kV, this is further stepped down to 0.415 kV for berth services.

Each Berth shall have 1 dedicated D.G Set of 100% capacity for emergency use.

7.2.5 Voltage Levels

The voltage of the different systems required is as under.

Table 7-4 Voltage levels requirement

Description	Voltage Level (kV)
Main Incoming from Distribution Company	220
MRSS	220 / 34.5
MRSS to MSS, MSS to DSS / BSS / USS	33
DSS / BSS / USS	33 / 6.9
DSS to CBSS, RSS, SS, RMQC, RMGC, ERTG	6.6
BSS to STS, MHC	6.6
DSS D.G Sets	6.6
Sub USS / RSS / CBSS / BSS	6.6 / 0.433
Final Power Loads	415V / 230V, 3 Ph / 1 Ph
CBSS D.G Set, USS D.G Set/s	0.415

7.2.6 Emergency Power Requirements

The diesel generator in the substation as well as installed at different locations shall have sufficient capacity to provide power for the following functions in the event of an interruption to power from the supply authority:

- The security, firefighting, and communication system.
- 25% of lighting in the Administration Building.
- 25% of lighting in the Workshop Offices.
- Computers of key staff as nominated by the Client.
- Computer system main server and back-up server UPS.
- All gates function.
- All Operations Team functions.
- The slow operation of 1 or 2 cranes acting simultaneously, for the purpose of installing back the vessel hatch covers.
- 25% of terminal flood lighting.
- Compact Substations (CSS) of Reefer Plug Points.

In addition, appropriate electrical connections shall be provided at the reefer area to allow the RTGs, acting as electrical generators, to supply power to reefers stacked at the terminal when needed.

DSS shall house 4 no. of 6.6 kV DGs each of about 1 MVA for Emergency power, for CBSS and Crane Emergency, DGs shall operate in Parallel. This will support closing operation of vessel during power failure as well as backup to Reefers and power functional requirements.

Each BSS shall have 1 dedicated D.G for Critical Loads. Sizing of the same will be detailed later.

DSS shall have Power Factor improvement at 6.6 kV itself, as all the loads are located at 6.6 kV and RSS being compact will not have APFCs. APFC shall be designed to achieve P.F of 0.95.

7.2.7 Power Distribution Infrastructure

All power cables will be of XLPE type to IS: 7098 and as per voltage level requirements for their respective applications. 33 kV cables from MRSS to MSS shall be single core UE type to meet the load requirements of stated MVA, in optimum numbers. 33 kV cables from MSS to DSS and BSS shall be multicore cables designed to carry demand load. Power cables for 415 V system shall be 1.1 kV. Other cables including 6.6 kV, or 11 kV and 1.1 kV shall be multicore power distribution cables.

Cables will be installed underground at minimum depth of 1 m. Cables shall be laid in PVC ducts of minimum 150 mm inside dia. for each 11 kV or 6.6 kV and 33 kV cables. At places, where cables have to cross the roads and areas where heavy equipment is likely to exert pressure during their working, RCC pipes or box culverts will be provided. The cable routes will be provided with route markers.

There will be no overhead cables and all cables inside the port either HT or LT will be UG cables of optimum designed size, capacity, and type. All wiring inside the buildings will be concealed PVC / steel conduit types using copper conductors insulated to 1,100 V. As far as practically possible ring paths for 33 kV cables shall be so planned that they offer physical redundancy, like running parallelly along different sides of the road. Where it is not possible, it will be ensured that they are laid in RCC pipes or construction to have minimum physical damage. Manholes will be considered at regular intervals for cable pulling. Power Cable Infrastructure will be designed to cater for ultimate phase.

7.2.8 Earthing System

Earthing system for MRSS will be in line with power supply company standards and in accordance with IEEE: 80 latest version to ensure step and touch potentials are in limits. MRSS grid earthing shall also ensure that earth resistance is less than 1 ohm. All equipment in control room for MRSS is proposed to be provided with dedicated mat type electronic earthing and earth pits and shall ensure resistivity is less than 10 ohms.

Earthing system for MSS, CSS and BSS shall be of grid type in line with IEEE: 80 latest version, to ensure step and touch potential are in limits. Grid earthing shall also ensure that earth resistance is less than 1 ohm without effect of equi-potential bonding. Each neutral shall be connected with separate dedicated earth pits, each equipment shall be body earthed at minimum 2 points and connected to Earth bus. Earthing systems for all other substations to be in line with IS:3048 and shall ensure that earth resistance is less than 1 ohm without effect of equi-potential bonding.

Earthing distribution system for each substation shall consist of Earth bus located at the least in the 4 corners of the substation, in case of larger substations and / or with multiple transformations, they shall have multiple Earth busbars. Busbars shall be inter-connected to form Earth Ring inside the substation, Earth busbars shall have 2 main end distribution points connected to Earth pits and the below ground Earth grid.

Earthing for berth substations shall be through suitably sized cables to carry fault current. This is brought to the nearest ground and forms an earth grid to ensure 1-ohm resistance. All other services and fixed equipment of Buildings and Utility services shall earth and connected to the earth grid. All earthing system can be interconnected to ensure equi-potential bonding.

For high-masts, light poles, and outside feeder pillars, one dedicated earth pit per circuit and one connection to earth grid per circuit shall be provided. Separate dedicated earthing shall be provided for each substation and facility mat type electronic earthing and earth pits shall ensure resistivity is less than 10 ohms.

All metal equipment not used for electrical purposes shall also be connected to earthing system.

7.2.9 Lightning Protection System

Lightening Protection System shall be considered in line with IS / IEC: 62305. Lightening risk assessment is required for the complete terminal and shall be designed in accordance with the results of the assessment. The design consisting of a roof conductor grid, down conductors, below ground earth grid and earth pits. Earthing system for lightening shall be dedicated and designed to achieve a resistance of less than 10 ohms.

All substations shall be provided with lightening protection irrespective of whether they are covered by nearest tall structure or not. Suitable surge arrester to be provided within the power distribution system.

7.2.10 Illumination

Lighting for various external areas of the port shall be through high-masts and lighting poles. Inside buildings lighting shall be through surface or recess lights depending on ceiling profile. LED lighting is proposed for the entire port area.

The general lighting of various spaces will be planned to provide the following illumination levels.

Table 7-5 Illumination level for various port space

Area / Space	Illumination level (Lux)
Substation/Control Room	200 – 300 – 500
Reefer Platforms	100
Wharf/Jetty, Yard Area, Gates Area, Workshop Perimeter, High Mast	150-200-300
Car Parking/ Road	20 – 30
Buildings (based on functionality)	100 – 500 – 750

In the lighting calculations, an allowance shall be made for 20% deterioration in the performance of each luminaire over time. This shall be taken into account when final illumination measurements are taken, with Lux levels on site to be 20% higher than the design levels nominated above.

Each Terminal Yard light tower shall have separate circuits – a Main Lighting Circuit and an Emergency Lighting Circuit.

Each light tower shall have a lightning rod at its top and have a separate lightning conductor connected to an earth pocket.

7.2.11 Switching arrangement

Switching arrangements at various locations will be planned keeping in view the ease with which isolation can be achieved and also the level of fault protection desired at the particular current rating.

In the panel, switching on incoming circuits will consist of air circuit breakers (ACBs), whereas switching on outgoing circuits up to 1000 amps will be using moulded case circuit breakers (MCCBs) and for current ratings above 1000 amps it will again be ACBs. Main distribution panels and sub- distribution panels will incorporate MCCBs. Final distribution panels will incorporate miniature circuit breakers and earth leakage circuit breakers.

7.3 Water Supply and Distribution

7.3.1 Water Demand

The water demand for Vadhavan Port over the Master plan horizon has been worked out in the Table 7-6 below:

Table 7-6 Estimated Water Demand over Master Plan Horizon

	Consumer	Demand (kL /day)	
		Phase 1	Master Plan (incremental)
A.	**Raw Water**		
	Greenery and Landscape	900	1,950
	Reefer Wash and Misc.	292	819
	Total Raw Water (A)	**1,192**	**2,769**
B.	**Potable Water**		
	Port Personnel, Users & Misc.	1,173	1,978
	Township	3,807	7,678
	Ship Supply	654	895
	Total Potable Water (B)	5,634	10,551
	Total (A + B)	**6,826**	**13,319**

The water demand for Vadhavan Port over the Master plan horizon has been worked out in the Table 7-6 above. It /can be seen from the table that daily water demand for the Phase 1 development is estimated to be around 6.8 MLD (million litres per day) and for the master plan phase, the anticipated demand is at 13.3 MLD. Out of this the potable water demand for port usage is 1.8 MLD in Phase 1 and 2.8 MLD in master plan phase, with the balance being the demand for raw water and supply to port township. A static storage of raw water of 1 day storage is provided for the port while half a day storage is provided for the township.

The proposed freshwater mains will mainly serve the purpose of potable water supply to the usage points. Since the raw water quality is a crucial parameter while deciding any treatment process, it is recommended to get the quantity and quality of available water analysed. The water treatment plant must ensure that it produces water of acceptable quality as per the provisions of IS 10500: 1991.

The schematic diagram showing the proposed water storage and supply arrangement in the port area is presented in **Drawing DI1452-RHD-DP-US-DR-M-1102**.

7.3.1.1 Raw Water

The water supply for the port is combined with the requirement to provision water to the port township located outside the port boundary. The water required for the port is stored in various underground water tanks for Potable and firefighting purposes. The total underground water storage is designed to hold upto 2 days of port's cumulative water requirement. The untreated raw water is directly supplied to various firewater tanks to meet the requirements for various Terminals / Buildings.

Additionally, raw water is used to supply the sanitary flushing system, reefer wash and various miscellaneous uses including the supply for storage and utilities, workshops, and operational areas. Requirement for landscaping and green areas is primarily met by reuse of treated water from the sewage system.

7.3.1.2 Firewater

Separate firefighting facilities will be provided for all the port areas and facilities, viz, for

- Container terminals
- Chemical / edible oil terminal
- Bulk Liquid terminal
- Other Liquid terminal
- Ro-Ro terminal
- General & coastal cargo terminal
- Common user buildings and utilities

The system involves the distribution of firewater that comprises a seawater-based pumping and hydrant system for the jetty and approach trestles and freshwater based sprinkling and onshore hydrant system. Separate raw-water fire pump houses and storage is provided for the closed loop hydrant systems for terminals, storage and yard areas with single/multiple heads located in such a manner that hose lines can effectively reach any part of the area.

7.3.1.3 Potable Water

Based on an assessment of the input supply of fresh water, a suitable water treatment plant will be selected before the water is pumped to an overhead tank for potable supply distribution. An underground reservoir in the port utility area stores the portable water required to accommodate the requirement of the port for 2 days of potable water supply. The capacity of the same is estimated to be approx. 550 m^3 as per Phase 1 requirements. Consideration of future potable water requirements of the terminal shall also be taken into account and all necessary provisions shall be made in the design and installation of the distribution system.

A pump house next to the main underground reservoir will supply water to one or more overhead tanks in order to have min. head of 30m at the foot of the tank and the cumulative storage capacity of the same will be one day's requirement of potable water demand for the buildings in their respective areas.

Gravity supply to the port users will be augmented with the use of booster pumps to supply potable water to the remote locations of the port.

7.3.2 Storage of Water Supply

RCC underground storage tanks will be used for designated storage of potable water, firewater and raw/ recycled water for landscaping / miscellaneous uses. Overhead water tank is for gravity supply of potable water distribution system. Wherever overhead tanks on top of buildings are intended, prefabricated plastic tanks of appropriate capacity will be used.

7.3.3 Distribution System

The distribution of the water shall be using the pressurised pumping system or the gravity system. System components and material of piping shall be compatible with the marine environment of the location. The pipes shall be cement lined where the sea water is used as conveying fluid. Proper wrapping and coating shall be provided on all underground pipes. The pipes routed underground shall be routed at sufficient depth to protect from heavy loads and this shall be as per codal requirements. The road crossings of buried shall be within RCC Hume pipes. All above ground pipe shall be supported suitably as the per the specifications.

7.4 Drainage and Sewerage System

7.4.1 Stormwater Drainage System

The stormwater drainage system needs to be designed to minimize the potential pollution in the port basin. The rainy season persists during the Southwest monsoon. June to August is the wettest months of the year with an average rainfall in excess of 274 mm per month, with a maximum of 451 mm in July. The average annual rainfall is around 1163 mm. The average number of rainy days per year is 51 days. The maximum rainfall intensity assumed for the storm water drain assessment is 75 mm / hr.

It is proposed to lay the RCC trench drain parallel to the proposed internal road. All the drains will be via trenches and buried pipelines, which will be discharged out into the sea through various outfall points. These drains are connected through various cross drains bringing the water from the different areas of the terminals covering the port operational buildings.

A drainage system will be provided below the stacking area, with buried perforated drain lines. An impervious layer will be placed in the ground below these transverse drain lines. The storm water runoff from the yard area and adjacent roads will be collected, via trenches and buried pipelines. Figure 7-17 shows a typical arrangement for drainage system over gravel bed container pavement.

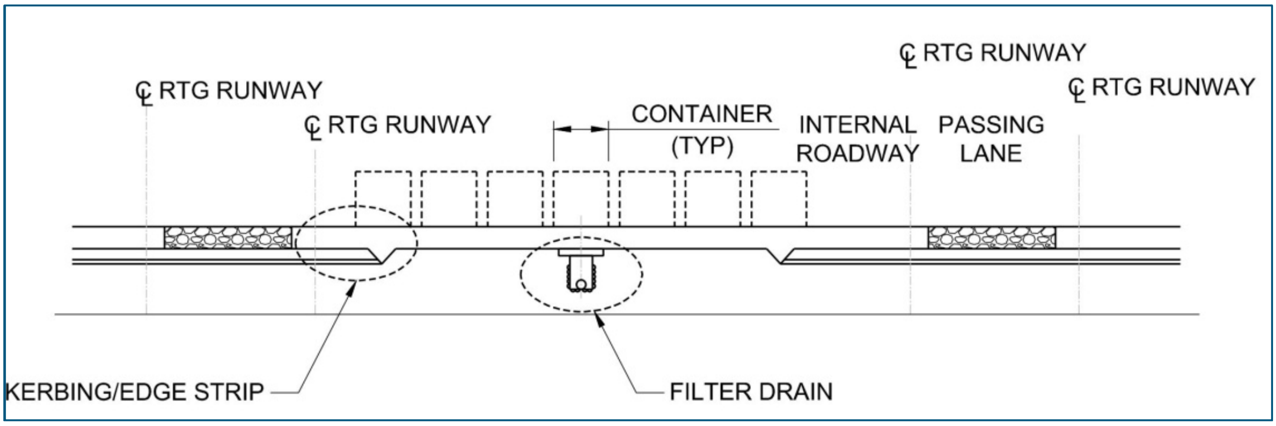


Figure 7-17 Typical Representation of Drainage in Container Yard

The storm water from the administrative offices, all terminal operator facility buildings, transit sheds and all other buildings from the different areas of the terminals will also be connected to the storm water drain. The wastewater collected from the workshop will be treated in an oil skimmer before disposing off to the storm water drain.

7.4.2 Sewerage System

The sewerage system is limited to the areas wherever office buildings, canteens, and other operational buildings are constructed. For the isolated buildings where the quantity is negligible, it is proposed to construct septic tanks and connect the septic tank outlets to soak pits for disposal. The treated sewage shall be discharged to the main drainage network. During monsoon months, the sludge will be stored separately in a storage structure with adequate capacity. The treated water will be discharged into the main drainage system of the port. The sludge from the treatment plant will be processed and converted into Biomass used as manure.

There will be very little sewage water generated at the berths and hence separate treatment proposals are not contemplated. Portable sanitary cabins are proposed to be provided on the berths. Sewage from cabin-toilets shall be disposed to a septic tank and further treated by vacuum suction sewage trucks and handling equipment on a regular basis.

Two pipe sewage systems with vent facility shall be provided for buildings in various terminals as per ASPE standard & NBC standard. The soil and waste will be carried down in separate independently vented pipes. The sanitary, waste & vent system will be watertight, and gas tight designed to prevent escape of foul gases and odour from various fixtures.

The ships will not be allowed to discharge their sewage in the port complex. As per MARPOL convention, the ships are now required to have STP on board. Sewage and sullage generated from various buildings with-in a terminal shall be disposed to a Sewage treatment plant (STP) proposed near each terminal operator facility building / administration building. Treated water received from outlet of Sewage treatment plant shall be reused for flushing and landscaping / gardening.

A separate sewage treatment plant is required to be provided for township and the type of treatment will be as per the population and township conditions. Sewage is collected from various buildings and disposed through collection chambers, manholes and lifting station or through gravity as per the population and available site conditions.

The following parameters/ site conditions will be considered when designing the sewage system:

- natural slope of the area.
- layout of different facilities in the complex.
- sub-soil water table.
- soil conditions.
- provision of sewage lifting station.
- provision of venting arrangement for manholes.
- construction of manholes and laying of pipes considering ground conditions.
- termination of vent cowl at terrace level.
- provision of adequate slope for horizontal header in the under slung pipes especially for toilets

The system will be designed as per design criteria stipulated in the “Manual for Sewerage & Treatment” published by the CPHEEO (Central Public Health and Environment Engineering Organization), Ministry of Urban Development, Govt. of India, IS-SP/35 (S&T)-1987 and National and International practices on the subject. The treated water properties shall meet the CPCB norms and the requirements of re-use.

Following material for piping is proposed to be used in the sanitary system.

- CPVC pipes in chases and in shafts
- HDPE/UPVC material for sewage & drainage pipes within the core of the building
- HDPE/ DI for external sewage disposal (manhole to manhole connection)

7.4.3 Solid Waste Management

The solid waste generation will be basically from 2 sources – cargo handling and the garbage/ human waste. The cargo envisaged at the port is primarily container cargo. The garbage and human waste generation will be minimal and is proposed to be disposed off using the normal measures. The garbage will be carried through covered trucks and disposed at the designated dumping grounds in the locality. One Incinerator will be required in Vadhavan Port to dispose the solid waste.

Drawing DI1452-RHD-DP-US-DR-M-1103 shows the various utility arrangements within the Phase 1 terminal development area.

7.5 Terminal Support Systems

7.5.1 Harbour Crafts

7.5.1.1 Tugs

The main activity of harbour tug is providing assistance to vessels entering / leaving the harbour, turning of the vessel in the harbour and the berthing / de-berthing operations.

Phase 1 development of Vadhavan Port envisages a creation of approximately 6.7 km long inner channel within breakwater dredged to -17.5 m CD depth and outer channel of 1.6 km dredged to -20 m CD with four container terminals for handling large size container vessels, 3 berths for handling multipurpose cargo, 1 berth each for Bulk Liquid and Other Liquid and 2 berths for liquid bulk. The maximum size of the ships to call at this port during initial development is fully loaded 24,000 TEU container vessels. As per the results of the 3D ship navigation simulation studies carried out by DHI through Force, July 2018, for berthing / de-berthing of the design container vessels a minimum of two ASD tugs of 65T and two ASD tug of 100T bollard pull capacity are required along with 2 tugs on standby or instant use during vessel's outbound departure channel transit.

7.5.1.2 Mooring Launches

The main activities with these small boats are the transfer of mooring ropes between vessel and quay and transfer of mooring crew.

The mooring launches with good manoeuvrability will be about 10 m long with open deck and single screw. The propulsion power shall be delivered by an electrically starting diesel engine of approximate 75-100 kW, driving the propeller shaft via a reverse reduction gearbox. Two mooring launches will be provided at the port.

7.5.1.3 Pilot cum Survey Vessels

Pilot boats transfer pilots to and from the incoming / outgoing vessels.

It is proposed to provide two all-weather type pilot launch. The pilot launch should be a twin screw with 15 to 20 m overall length and of steel construction. The speed range shall be 15-20 knots. The pilot launches will be provided with survey equipment and it can be used for hydrographic surveys and for buoy lights maintenance.

The summary of the requirements of Harbour Crafts envisaged for the Phase 1 development of Vadhavan Port development are given in Table 7-7 below based on the Ship Navigation Studies.

Table 7-7 Harbour Craft Requirements for Phase 1 Development

S. No.	Harbour Craft	Phase 1 (No.)
1.	Tugs	
	− 65 T bollard pull	2
	− 100 T bollard pull	2
	− Standby tugs	2
2.	Mooring Launch	2
3.	Pilot cum Survey Vessels	2

[Source: 3D Simulation Navigation Study, DHI Force, July 2018]

Also, based on the simulation studies, it is also suggested that all the large and deep draft vessel berthing to Vadhavan port should have an operational ECDIS (Electronic Chart Display and Information System) and a Doppler side log mandatorily.

7.5.2 Navigational Aids

Navigation aids for the port are required to ensure safe and efficient navigation of ships entering and leaving the port through the approach channel as well as berthing / un-berthing requirements inside the harbour. It is envisaged that navigation will be carried out throughout the year, by day and night, except during cyclonic weather. These aids will assist the captains and pilots in determining the position of vessel while transiting the navigational channel and manoeuvring inside the port.

The approach channel stretching from the breakwaters head to 20.0 m contour has a width of 732 m. The channel has a total length of about 4 km.

These aids as listed below are proposed to be installed on land or in water for guidance to all vessels for safe and regulated navigation in channels, basin, berths, and docks.

- Buoys
  - Fairway buoys
  - Port and Starboard buoys
- BEACONS and
- Vessel Traffic Management Information System (VTMIS)

VTMIS will have the requisite communication, Radar system integrated into it.

Drawing DI1452-RHD-DP-OS-DR-CM-1104 indicates the proposed layout of navigational aids at Vadhavan Port.

7.5.2.1 Fair Buoys, Port and Starboard Buoys

Fairway buoy (FB) marks the entry to the approach channel and indicates the location of the pilot boarding area. Hence the vessels calling at port should be able to detect the fairway buoy while approaching the port. As per PIANC guidelines the maximum spacing of paired navigation buoys is 1 nautical mile. However, as per IALA guidelines the ideal spacing of paired buoys should be 3 times the width of the channel in the straight portion and 2.8 times the channel width in the curved portion of the channel. IALA[3] maritime buoyage system as per Region A in which Vadhavan port falls will be followed. The lateral marks will be red and green colours to denote the port and starboard sides of channel.

A total of 11 buoys, which include 4 channel buoys i.e., 2 port side buoys (3m dia.) & 2 starboard buoys (3 m dia.) would be required for the navigational purpose.

7.5.2.2 BEACONS/ Breakwater Lights

Roundhead of the main breakwater will be provided with Beacon. It will also be provided with RACON. The structure would consist of 200mm CHS with an access ladder on mass concrete block foundation to reach light position.

7.6 Controls and Networked System

7.6.1 Fibre Optic (FO) backbone network

Following types of Fibre optic backbone networks are envisaged for this project:

- FO backbone network for SCADA System
- FO backbone network for LAN system
- FO backbone network for FGDS, PAGA system
- FO backbone network for CCTV, Access control system
- FO backbone network for Container terminal equipment

All FO cables for FO backbone networks shall be armoured, single mode, OS1, loose tube, jelly filled type confirming to ITU-T recommendation G.652.D.

FO backbone network for SCADA system shall consist of redundant ring formation connecting all substations, applicable BMS Buildings, Pumping and Machineries Control systems.

FO backbone network for LAN system with minimum 24 cores starting from the control room in Terminal Office Building control room will be connected in dual star configuration to Main/Administration buildings control room, additionally smaller buildings and utilities with LAN will be connected in redundant ring formation.

Common FO backbone network shall be used for FGDS and PAGA systems. Minimum 24 core cables shall be used for these systems. Main FACP will be located at control room in fire station and shall be connected in a redundant ring formation to various other buildings/structures. Main PAGA panel shall be located at control room in TOB and shall be connected in redundant ring formation to various other buildings/structure.

[3] *International Association of Marine Aids to Navigation and Lighthouse Authorities*

Common FO backbone network for CCTV and Access control system of minimum 24 cores started from control/security room in Admin building will be connected in redundant ring formation and downwards in tree / star formation to various CCTV cameras, Access control endpoint access switches.

FO backbone network for Crane control and container terminal equipment shall be in dual star formation connected to main controllers in Main/Administration buildings control room.

Other system like Reefer System, TOB IT & Terminal Operating System, ISPS, VTMS, Other Liquid, Bulk Liquid, Liquid berth control and monitoring station, etc. shall use same FO backbone network depending on systems usability aspect like Fire safety, Security, data connectivity, access systems.

7.6.2 SCADA

Supervisory Control and Data Acquisition (SCADA) system shall consist of Main PLC panels located at both MRSS (external) Control Room and MSS (inside) Control Room with both SCADA system integrated with each other. Other substations like DSS, SS, USS shall consist of RIO (Remote I/O Panels) and shall be connected in ring or star configuration to PLC SCADA panel at MSS. The SCADA system will monitor and control power system aspects using meter and relays connected to RIO Panels. Any building with BMS can be connected to SCADA for status monitoring.

7.6.3 LAN System

The LAN network shall be designed to allow data transfer between Ethernet access switches, at speeds of up to 10 Gbps between Core/distribution and access switches, and 01 Gbps between access switches and endpoints.

Main Core / distribution switches in Terminal Operations Admin. building, control room shall be of layer 3 VLAN type. All other Ethernet access switches in other building/ structures shall be layer 2 VLAN type.

LAN cabinets shall typically consist of fibre optic patch panels (FOPP), Ethernet access switches, FO patch cords, CAT 6A patch panels, CAT 6A Patch cords.

7.6.4 FGDS System

The Fire and Gas Detection System (FGDS) shall be considered with following standards:

- IS: 2189 Selection, Installation and Maintenance of Automatic Fire Detection and Alarm System (Edition 2008)
- NFPA 72 The National Fire Protection Association 72,
- NBC National Building Code (Edition 2005)

The fire alarm system shall be addressable type, consisting of main fire alarm control panel (FACP), located in control room of Main Fire Station with sub FACP located in other buildings and structures connected to each other connected in Ring formation with maximum 8 Panels per loop.

The addressable detectors, (smoke, heat, Gas, IR,), Control module, monitor module, repeater panel, Manual Call Points, Hooters, and linear heat detecting cables shall be considered for buildings/structures.

Addressable hydrogen gas detectors shall be considered for battery rooms in substation buildings.

Fire resistant cable which has low smoke properties and confirming to NFPA 72 shall be used (min 2.5 sq.mm Cu). The cable shall provide circuit integrity according to NFPA 72 and shall be fire resistant to IEC 60331.

7.6.5 PAGA System

Public Address and General Alarm (PAGA) system shall confirm to NFPA 72. The PAGA system shall be designed for public annunciation and emergency evacuation. PAGA system shall consist of all the essential functionalities – such as system supervision, power amplifiers and switching, loudspeaker and line surveillance, digital message management.

PAGA system shall be capable of delivering a sound pressure level of 85 dB at the listening level for general areas and 100 dB at areas with higher noise levels, e.g., plant rooms, machine rooms and material handling areas.

Fire resistant cable which has low smoke properties shall be confirming to NFPA 72 shall be used (min 2.5 sq.mm. Cu.). The cable shall provide circuit integrity according to NFPA 72 and shall be fire resistant to IEC 60331.

7.7 Information and Technology Systems

7.7.1 General

State-of-the-art information technology is essential if the productivity levels and container handling efficiency of the port are to be maximized. The IT Management System will be designed to encompass port planning, operations, administration, and accounts, in addition to internal and external communications. The following minimum functions should be available:

- Ship-to-shore loading and discharge control.
- Yard planning, gate delivery and receipt control.
- Ship planning and dispatch including a vessel stowage planning module.
- Electronic Data Interchange (EDI) abilities.
- Radio Data Transfer (RDT) abilities.
- Payment status and service billing.
- Management information reports and statistics.
- Linking to shipping lines/agents.

The IT infrastructure will encompass a wide range of port functions, including planning operations and financial processing. This will allow the Licensee to optimize the management functions, respond in a timely manner to events, and readily provide shipping lines with information requested. In addition, these systems will enable the service of electronic data exchange and stowage planning to be offered to the shipping lines. The Personal Computing (PC) network will include PC workstations for all relevant port employees, communication devices such as RDT, internet links and adequate servers, storage capacity for the operational database, and network management. Provision for data security and uninterrupted power supply will be included in the hardware, network, and communications systems.

A Vessel Traffic Management System (VTMS) will be installed at the new port with the system being built up from a family of advanced maritime information applications and sensors. It will be based on a well proven, concept of software modules and components that will make the system highly flexible and able to be augmented in both functionality and scalability.

The VTMS provided will allow it to be used as an Aid to Navigation (AtoN), ship reporting, Automatic Identification System (AIS) and voyage management. It will have features such as message and voice communications, multi-media logging and replay. It is intended that the system software will use a programming language that enables the software to be executed on virtually any kind of computer platform to reduce costs and ensuring a maximum system life-length.

A VTMS control centre will be designed and built to suite operational requirements. The console display units for VTS operators' workstations will provide state-of-the-art presentation and control systems. The software to be installed will permit several functions to be combined in a single workstation such as radar, AIS, AtoN management, seamless handling of voyage management information, CCTV, weather information, air situation picture, multi-fuel chart and GIS presentation etc. as applicable.

7.7.2 IT & Terminal Operating System

7.7.2.1 General

This section describes the proposed IT and Terminal Operating System architecture to be utilized for managing and operating the terminal.

A typical IT system Cloud is as shown in Figure 7-18 depicting the complete process and modules involved in the system.

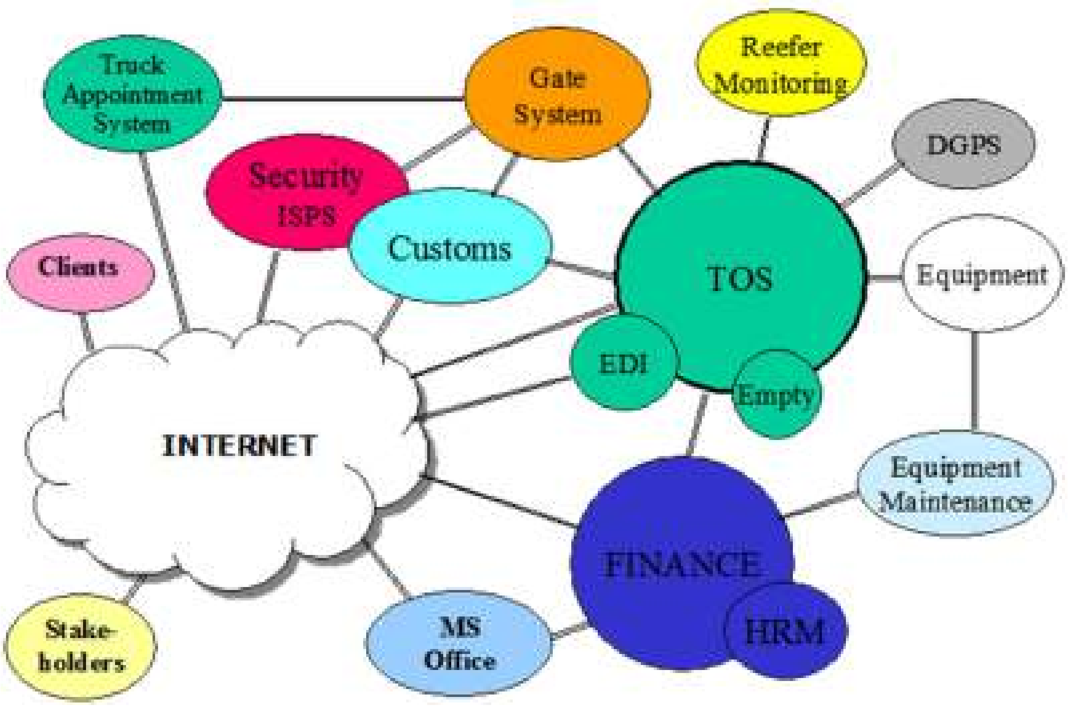


Figure 7-18 Typical Terminal IT System Cloud

7.7.2.2 IT Systems and Logistics

The efficiency of a port container terminal is synonymous with the information systems that practically drive and track the movement of containers as well as acting as an interface between the user, the vessel, and the terminal. The container terminal with a huge amount of data being generated would naturally require sophisticated IT infrastructure with connectivity to its users. The system provided is likely to have database servers, a large number of PCs, printers, Uninterruptible Power Supply (UPS), terminal operation/ planning software (supplied by NAVIS, Cosmos or Total Softbank) etc. In particular, the Terminal Operating System should have ship planning, Electronic Data Interchange (EDI), BAPLIE, external tracking and billing modules.

The cargo terminal is an intermodal link in the logistics chain. And since a chain is as strong as its weakest link the cargo terminal must be equipped with modern systems to fully function (cargo tracking and handling, safety, security) in the logistics chain.

A computer system for port operation takes the form of a central computer processor with hard disc storage on which information files are stored and updated. It is linked to a variety of terminals where operators can access, update, or supplement this information at any time.

The operator terminals may have visual display units comprising screens and keyboards, printers for obtaining ‘hard’ copy or gaining access to printed information, card, or tape readers, etc. depending on the specific system requirements.

A system whereby the central computer connected with computers with Pentium or equivalent processors through local area network (LAN) is required. The computers would be able to work independently as well as ‘in linked’ mode with the container terminal’s central computer. The capital cost of this would also include developing specialised software, computerization of all operations including the management information system etc.

Typical systems just range between 5% and 7% of the total capital investment in cargo terminals. These systems are crucial for productivity, serviceability, and cost control, and represent the higher risk in the implementation of any terminal development project.

7.7.2.3 Container Terminal Software Modules

A container terminal can be best managed when management and the supporting departments can use an integrated set of software systems.

The operational process is automated by a software system such as the Terminal Operating System (TOS) and its related modules. All of these systems are inter-related and can transfer data between each other. The systems receive data via the Internet and EDI. The systems provide information to the external stakeholders via the Internet.

The software selection process involves the selection of modules in the TOS and the Gate Operating System (GOS) if needed.

Brief descriptions additional subsystems that can be interfaced with the TOS and GOS are provided below.

7.7.2.4 The Finance and Human Resource Management System

These systems cover financial management, terminal labour management, management reporting and control. The systems are connected with the TOS for management reporting, invoicing, and labour planning purposes. The equipment maintenance system is linked with the finance system for cost control, management reporting and purchasing. The finance system is linked with the external stakeholders and bank's authorities and clients, via secured Internet.

Office System

This covers the standard Microsoft Office® software suite. The office systems have access, via well-defined protocols, to the TOS and the Finance System for data access (read-only).

Database System

The terminal operator will need to have a data base license agreement for a system such as Oracle, SAP, or other database, including maintenance and support.

Equipment Maintenance System

All equipment in use at the terminal requires preventive and corrective maintenance. Cost control, spare part management, resource management, quality control and equipment failure analyses are covered by this system. The system reads data from the equipment for error analyses and feeds the finance system for financial control.

Customs

The Customs system in this overview is not a terminal system. Rather, it is the system to be developed and implemented by Customs at their cost. This system will be linked with the TOS and the GOS. The Custom officers should have special authorized access to the TOS container data base.

Security ISPS

This system needs to be developed in collaboration with agencies (Coast Guard etc.) responsible for national security. The Gate Operating System (GOS) and the Terminal Operating System (TOS) include certain interfaces to security and access to the terminal. When such a system is implemented, the interface between the TOS, the GOS and the Port Security System should be evaluated and implemented as needed to support the security procedures developed by the port operator.

The terminal gate confirms authorized access to the terminal based on information obtained from the Port Security System. Access to Vadhavan port facilities is controlled for drivers, suppliers, maintenance companies, employees, visitors, and the authorities.

The terminal access system checks the card database for access control and can be used as well for the registration of working hours of the employees; a step that requires integration with the terminal's Human Resource Management and Payroll system. A more advanced option could involve integration with Shift Planning Systems.

7.7.2.5 Terminal Operating System

The TOS is the nucleus of the terminal. EDI and empty handling are basic modules of a TOS. It is important to define the integration of all systems in detail. Data dictionary, database design and data management are of utmost importance.

Typically, there are dedicated systems for power supplies, uninterrupted power units, power distribution, lights and light monitoring, harbour control system, radar systems and camera surveillance systems. These are separate from the above-described architecture.

7.7.2.6 TOS Satellite Systems

The TOS will be surrounded by satellite systems, including the following:

Gate Systems
A basic gate system is embedded in the TOS. This application can manage the truck visits to the terminal in the Phase 1 development stage of the terminal. A (semi) automated gate system based on OCR technology and equipped with X-ray, gamma ray and RPM scanners and RFID technology can be installed for efficient turnaround time. This type of system is very modular, and the detailed configuration is highly dependent on local security rules defined by Port Police and Customs. This advanced functionality is not available in standard TOSs. An automated gate system, hardware and software, is only obtainable from specialized gate suppliers. The GOS is linked with the TOS, the Truck Appointment System, the Port Security Systems, and the Customs System.

Truck Appointment System
Trucks usually arrive at the container terminal as they please. This leads to traffic peaks, congestions, and pollution. To manage and control the truck visits to the terminal an Internet-based truck appointment system can also be implemented. The trucker makes an appointment via the Internet to visit the terminal. The system maximizes terminal visits by allowing a maximum number of truck visits per hour. The GOS manages the terminal visits by checking the Truck Appointment System and the Customs Systems.

Equipment
Driven equipment can also be equipped with screens to give the drivers the ability to query into and receive information from the TOS. The TOS can send instructions to the drivers. The TOS can detect equipment running idle or not running at all. The TOS can measure the equipment performances to monitor the terminal performance and if needed, can reschedule equipment for optimized vessel handling. The screens and communication systems should be part of the equipment specifications and built-in by the equipment suppliers as an integrated part of the equipment controls.

7.7.3 Communications

7.7.3.1 General

An efficient and effective operation of a port terminal requires the provision of reliable and adequate communication facilities. Communication is usually required between the outside world and the port, between and within the terminals as well as other locations where port staff, customs officials etc. are located. To meet these requirements, a communication system comprising telephones, fax machines, wireless sets, computers, etc. and a public address system will have to be provided. These are broadly described below.

7.7.3.2 Radio Communications

The efficiency of port terminal operations depends on a speedy flow of information between the key personnel who are directly involved in the handling of cargo.

A radio communications system will need to be developed in order to handle the flow of information which passes between the personnel engaged in the following operations:

- Ship working duties.
- Quay crane and mobile equipment operations.
- Shore side duties.
- Control office.
- Terminal engineering services.
- Operations management.
- Supervision; and
- Port Security.

In order to ensure an effective radio communication network, the port operations have been divided into the following four organizational segments each of which requires a dedicated radio channel(s):

- Ship work.
- Quay and Storage work.
- Control (base station); and
- Port Security/Customs

The system will need to reflect the importance of establishing and maintaining contact between the following areas of operation:

- Ship and crane
- Ship and quay/stacking yard/storage area(s)
- Ship and base station.
- Base station and engineers.
- Engineers and supervisors.
- Supervisors and all foremen, ship, and quay/stacking yard/storage area(s).
- Base station and supervisors.
- Management and supervisors; and
- Port security staff and customs officials.

For planning of the radio communication system, it is essential that the installations provided in Phase-1 can be readily expanded in response to the future growth of the port.

7.7.3.3 Public Address System

The public address system will supplement the above two systems. The central control for the system will be kept with the control room.

The public address system would provide a comprehensive paging system for oral communication and announcement by loudspeakers covering all working areas of the port terminal. The loudspeakers would be mounted on purpose-built supports provided on permanent structures. The exterior speakers would be weather-proof.

7.7.4 CCTV and Access Control System

CCTV and Access control system shall consist of Layer-2 Access switches located at Admin. building and connected to various buildings with access switches by FO backbone network. CCTV and Access control monitors shall be located at gatehouse and Terminal Operations Admin building.

The CCTV system shall be designed to cover all the external areas of the project with IP-66 weatherproof PTZ / fixed cameras strategically located on high mast or dedicated CCTV poles as per requirement.

IP-66 Fixed type cameras shall be considered for strategic locations like Entry / Exit gates, security gates and entrances of buildings / structures etc. to monitor vehicular movement and personnel entry/exits.

Indoor type PTZ/Fixed type cameras shall be considered for internal areas of building/structures as per operational requirement of the project and critical aspects of the room.

The gates and turnstile shall be considered with smart card reader. This Access control system shall enable only authorised personnel to enter/exit through the main gates.

Access control system shall be designed to secure the following areas with suitably sized access controllers in ACS panels to control the following.

- Inbound and Outbound gates with arm gates for each lane if any.
- Swing Gates
- Access gates for Container yard if any
- Car Park
- Staff Entrance
- Substations, offices etc.

CCTV & ACS unitized racks shall be located across various buildings and/or at CCTV masts consisting of suitable size FO patch panels, Ethernet switches, Power supply units (PSU) and Patch cords as required.

Final distribution to cameras shall be through CAT-6A Cables.

7.7.5 Telephone system

The system and equipment shall comply with relevant BIS (Bureau of Indian Standards) and other Indian/ International standards, as applicable. Telephone System shall establish communication between intercoms, to connect outside the telephone exchange.

EPABX (Electronic Private Automatic Branch Exchange) based conventional telephone system shall be considered for communication between the various buildings/structures

Main distribution frame (MDF) sized for multiple pairs as per the total requirement of the site with 20% design factor connected with EPABX shall be considered to be located in communications room inside Terminal Operations Admin building.

MDF shall further distribute to Intermediate distribution frame (IDF), which shall be further distributed to final RJ 11 telephone sockets.

MDF and IDF shall be multiple paired as per the requirement made up of disconnection type 10 pair KRONE modules.

Telephone cables considered shall be minimum 0.5 sq.mm for internal use & 0.64 sq.mm for external use. For internal distribution points cable shall be confirm to CW1308 & for external distribution points cables shall be jelly filled armoured telephone cable confirming CW1128/1198.

7.7.6 Container Terminal Control System

Container Terminal Control system shall function primarily through a wireless transmitter and receiver system, located at each crane control room and Rx/Tx module located in vicinity of crane / equipment connected to Container Terminal Control Panel located at Terminal Operations Admin. Building by fibre optic network.

Container Terminal Control Panel shall be located at Container Terminal Admin building control Room.

7.7.7 Reefer Monitoring System

Reefer monitoring system shall be LAN based either using FO LAN Network or FO SCADA network to connect to RMS Control Panel depending upon location. RMS will consist of Main Control module and submodules with LAN connectivity modules communicating with Power Analysers located in Panels in Reefer gantries.

Reefer Monitoring shall be independent system with dedicated Software and Workstation, handheld devices for exchange of power usage data and metering tariffs.

7.7.8 Mooring and Berthing Control System

Bulk Liquid, Other Liquid, and Liquid berths will have following system for each berth connected to Central Computer System (CCS) of each berth:

- The mooring load monitoring system shall consist of number of load measuring pins (LMP), installed into the quick release mooring hooks, (QRH), which convert the tension forces in the mooring lines to electrical signals that are directly proportional to the loads. The load cells shall be connected to I/O modules, which are connected with the CCS via Profibus/Modbus network and PLCs for post-processing sensor data.

- Berthing Aid system consisting of Lasers, Display Boards, and the transceivers to be capable of reliably transmitting and receiving a laser signal to and from the hull of a berthing carrier under all weather conditions. Will perform following task:
    - Compute berthing and display angle with 0.1-degree accuracy
    - Compute distance and velocity with 0.5% accuracy, for the bow and stern of the berthing tanker
    - Indicate distance (0-199 m) and velocity (0 to plus or minus 99 cm/sec.) of the bow and stern sections of the berthing tanker. The information shall be related to the outer breasting dolphin.
    - Print the bow and stern distance, berthing angle, and velocity with the time at intervals adjustable between 1 and 120 seconds.

- The EMS shall comply with the local environment regulations, and shall consist of:
    - 1 (one) weather station
    - 2 (two) current stations
    - 2 (two) wave and tide sensors

- Ship Shore communication & Safety Link system, the primary purpose of the SSL is to carry the signals needed for Emergency Shut Down (ESD). In addition, the SSL will also carry telephone signals as well as data from the mooring load monitoring system. Emergency shut-down shall be fail-safe and transmitted by an electric or fibre-optic SSL. An independent back-up system, which may be electric, fibre-optic, or pneumatic, shall be provided so that a common failure mode is reduced as far as is reasonably practicable. SSL will not be connected to CCS but interfaced only.

- VHF marine communication system consisting of Antenna's connected to CCS through Co-axial cables, Handheld devices, Carryon board Laptop, with predefined communication frequencies.

- CCS can be interfaced to Terminal operations building through fire FO network

7.7.9 Bulk Liquid, Other Liquid, and Liquid berth Fire Control System

Bulk Liquid, Other Liquid, and Liquid berths will each have PLC based control system for firefighting system for Pumps, Valves, Fire Pumps, Foam Pumps, Tower monitors, valves, measurements, and indications.

These systems shall be connected to Main Fire Alarm Panel located at Main Fire station through common Fire FO network.

7.7.10 Fire Fighting System

The firefighting system is to be designed to be capable of both controlling and extinguishing fires. There will be two types of system i.e.

- Sea Water and
- Fresh Water

The sea water system would broadly consist of a fire water intake to draw water from the sea, pump house with pumps, ground water monitors for all POL products, nozzles for water curtains along the front side of operating platform, hydrants, and distribution networks. The container and car carrier berths will also be covered under the sea water system.

A centralized fire station will be provided for attending to all calls which will house 5 mobile fire tenders. One fire tender will be provided with snorkel attachment.

Fire Alarm Bells will be located on permanent structures at strategic locations that can be heard by the terminal operators. Buildings where the hazard of fire and the occupancy are high will be provided with alarm bells (e.g., the workshop, administration building etc.). The fire alarm system will be activated by push buttons located at strategic places within the terminal areas and around the port's perimeter.

7.7.10.1 Container / Multi-purpose / Ro-Ro Terminal

Being a deep-water port extending seawards from the mainland, seawater will be the primary mode of fire fighting for container, RO-RO, and general cargo berths. The onshore buildings, storage sheds will have separate freshwater based firefighting system. Each concessionaire will develop separate fire-water networks to independently operate and maintain the fire-fighting systems of their respective concession areas.

System Requirement

The fire hydrant system is the principal means of the terminal fire protection system for major fire incidents. In this system, a solid jet of water is directed around the seat of fire. The extinguishing is affected by smothering and quenching the fire. The design of the system conforms to the guidelines of Fire Protection Manual and Rules for Water hydrants, Portable Fire Extinguishers etc., published by Tariff Advisory Committee (TAC). Wherever TAC does not address any issue, NFPA guidelines are to be followed.

The system is designed in such a way that it can supply water under all conditions for firefighting purposes at the fire hose / hydrants points. For supply of fire water under all conditions of power supply, electric motor driven pump and diesel engine driven back-up pump are provided to ensure firewater availability under blackout conditions.

The hydrant system will have piped network supplying independent ring mains in the container terminal. The hydrant network with intermediate loops/ sub networks are provided with isolating valves so that water can be diverted from any damaged section to the point of use to maintain the continuous availability of fire water supply at all remote locations along with the optimum water pressure at the seat of fire.

Fire water pumps are to be optimally located within the concession areas to have independent sea-water intake and tap into the raw water network for storage and pumping systems.

As per TAC norms, considering ordinary hazard category, the pumping capacity selected should cater to a minimum of 3.5 kg/cm^2 pressure at the remotest location.

All common duty pumps are fed from the fire water reservoir through a common suction header. The discharge is connected to a delivery header from where the hydrant mains are tapped off. Every yard hydrant point has a hose box along with accessories (02 x 15m long rubber lined firehoses, 01 branch pipe with nozzles for various fire applications) to be pedestal mounted alongside the jetties, trestles, and onshore hydrant locations.

Different types of portable fire extinguishers – DCP, AFFF, CO_2 based on the nature of the fire hazard are provided at significant locations like security cabin, admin building, sub stations, parking, and other areas.

Operation of hydrant system

Pipelines of the hydrant system will be charged with pressurized water up to the hydrant valves. Minor system leakages will be made up by replenishment of firewater, from jockey pumps. The jockey pumps will be stopped automatically through system interlocks in the pump control panel, on operation of Main fire pumps.

In the event of fire taking place or during routine fire drills, when the hydrant valves are opened, the water pressure in the system will fall rapidly. Water will be supplied by the jockey pump to make up this water loss but would be inadequate to meet the demand. As a result of this, water pressure in the main line will further fall and a signal from a pressure switch will start the motor driven main fire pump through the auto starting panel. If this pump is not adequate to meet the demand or if it does not start due to any fault, the pressure will further drop and the signal from another pressure switch will start the standby diesel engine driven pump. Based on the size of the terminal and usage, adequate back up to meet all eventualities of power supply and equipment availability will be catered for.

7.7.10.2 Liquid Terminal

Sea water will be used for firefighting for the liquid terminal approach trestle and berths. The onshore buildings areas shall have separate fresh water based firefighting system.

The liquid terminal will be provided with fixed fire-fighting facilities according to the requirements of the following design codes and standards.

- TAC - Tariff Advisory Committee
- OISD - Oil Industries Safety Directorate
- NFPA - National Fire Protection Association
- TAC Fire Protection Manual - Latest Addition.
- OISD -116
- OISD -117

The hydrant system will be designed as per OSID/TAC for the Liquid Terminal considering it to be as “Highly Hazardous – Type A” risk.

The facilities include firewater pump house equipment, fire water distribution network and monitoring system, automatic (Mechanical) MVW Spray System with QBD Detection, fixed foam / water monitor with appropriate supply of bulk concentrate and portable / wheeled fire extinguishers.

System Requirement

The system design is adherent to OISD/TAC norms. As in ports with many terminals or in congested industrial locations, the local authority or port authority may provide the back-up fire-fighting capability. The type and quantity of fire-fighting equipment will be related to the terminal size and location, the frequency of terminal use, and the additional factors identified below.

In addition to statutory regulatory requirements, capability should be based on the general guidance of the local authorities and the outputs of a formal risk assessment. The risk assessment would consider the following criteria for each berth:

- The sizes of tankers that can be accommodated on the berth.
- Location of the terminal and the berth.
- Nature of the cargoes handled.
- Potential impact of oil spillage.
- Areas to be protected.
- Regional fire response capability.
- Level of training and experience of local emergency response organizations.

Distribution system

Where the firewater supply is obtained from a static storage, such as a tank or reservoir, then the reserve for firefighting purposes will be equivalent to at least 4 hours of continuous use at the maximum design capacity of the fire-fighting system. The reserve for firefighting, would normally be additional to that required by any other user taking water from the same static storage. The piping arrangements at such storage facilities should be arranged to prevent use of the firefighting reserve for other purposes and the integrity of the makeup water supply will be assured through the raw water network, with backup connection to the sea-water network wherever necessary.

Fire water flow rates and pressures will be sufficient to cover both extinguishing and cooling water requirements for a fire that might realistically occur.

Permanent fire water mains and / or foam-water solution mains shall be installed in terminals and along the approach routes to berths. Mains will extend as near to the head of the terminal as possible and be provided with a number of accessible waters take-off (hydrant) points. The hydrant points will generally consist of headers with individually valve outlets fitted with a fire hose connection suitable for the particular type of fire hose coupling in use locally.

Isolating valves will be fitted to prevent the loss of all firefighting systems due to a single fracture or blockage of the fire-main network. The isolating valves shall be positioned so that, in the event of fire-main failure in the berth area, there will still be a supply at the berth approach. Where the berth fire-main is extended from a shore installation, an isolating valve(s) shall be provided at the shore side end of the jetty. Additional fire hydrants will be provided upstream of an isolating valve.

Fire-main construction materials should be compatible with the water supply. The minimum capacities and pressures for fire water mains are dependent upon whether the system is to be used for cooling or for the production of foam, and upon the length of jet required.

Fixed Foam system

The system will be designed for the foam concentrate to be properly proportioned and mixed with water downstream of fire water pumps and upstream of foam making equipment and application nozzles. Fixed pipelines for expanded (aerated) foam are not recommended because the fully developed foam cannot be projected effectively due to loss of kinetic energy and high frictional losses through such systems.

The type of foam concentrates selected, i.e., protein, fluoro-protein, Aqueous Film Forming Foam (AFFF), or alcohol/polar solvent resistant type concentrate (hydrocarbon surfactant type concentrate), will depend upon the fuel type and formulation, whether aspirating or non-aspirating equipment is installed and ease of re-supply. There are several systems that can be adopted for feeding foam concentrate into foam making equipment at the berths. Fixed water-cum-foam monitors (ground and tower mounted) are to be placed as per requirements to optimize bulk liquid terminal capability.

All monitors will be located at a min. 15 m away from the relevant equipment / structure under consideration.

Fixed Water Sprinkling System (MVWS / Deluge)

Use of fire detection equipment that is designed to activate fixed fire-fighting equipment automatically is advisable where a terminal extends away from shore in such a way that manual firefighting is difficult, dangerous, or ineffective. The medium velocity fixed water sprinkling (MVWS) and Deluge spraying system for liquid bulk jetties and storage is automatically operated using Quartzoid Bulb Detectors (QBD), to activate the system.

The design of the medium velocity water / deluge sprinkling will be generally in accordance with the relevant OISD. The alarm system would have the capability to raise local audible and visual alarms and possibly a general alarm if the terminal is manned and depending upon local regulations. It will indicate an alarm at a continuously attended central fire control panel showing the location of the activated detection and fire extinguishing system activated.

The isolating valves to the fixed water system are to be manually operated with a status indicator to the fire control panel. Upon actuation of a detector, the detection system should sound a local alarm and send a signal to a continuously attended control panel. If conditions warrant, the fire protection system may be manually activated by an operator, the fire brigade, or by personnel who monitor the alarm. The electrical control and actuation system are designed with back-up electrical supply, to function under all eventualities. System design flow rates and pressure limit range for the nozzle will be as per OISD.

Fire Extinguishers

Portable and wheeled fire extinguishers will be provided at all liquid bulk terminal berths and storage facilities on a scale relative to the size, location, and frequency of use of the facility. Portable fire extinguishers should be located so that a fire extinguisher can be reached without travelling more than 15m. Wheeled extinguishers will normally be located in accessible positions at each end of loading arm gantries or at the berth approach access point.

Fire extinguisher locations will be permanent and conspicuously identified by luminous background paint or suitably coloured protective boxes or cabinets. The top or lifting handle of a fire extinguisher is normally not at a height of more than one meter.

Dry chemical extinguishers are recognized as the most appropriate type of extinguisher for the quick knock-down of small hydrocarbon fires. Carbon dioxide extinguishers have little value at berths or on jetties, except at points where minor electrical fires could occur. However, enclosed electrical sub-stations or switch rooms located within terminals should be equipped with an adequate number of carbon dioxide extinguishers or should have a fixed carbon dioxide system installed.

Foam extinguishers with a capacity in the order of 100 litres of pre-mix foam solution are suitable for use at berths. They are capable of producing approximately 1,000 litres of foam and provide a typical jet length of about 12m.

Fire Protection Summary

The design and planning of Fire Protection System will be done keeping in view the following criteria:

- National Building Code Sept 2005: Part IV for Fire Protection
- Local Byelaws
- Relevant BIS codes: Specifically, IS: 3044, IS: 5290 and IS: 5312, IS: 908 and IS: 2190, IS: 3844, IS: 15105
- TAC Manual
- Compliance to local Chief Fire Officer norms

The specific fire protection systems provided at each area are as follows.

Table 7-8 Facility and type of Fire Protection

S. No	Area	Fire Protection type
1.	Container & general cargo terminals	i. Hydrant system ii. Fire extinguishers
2.	Other Liquid, Bulk Liquid, Chemical terminals	i. Hydrant system ii. Medium velocity water spray system iii. Fire extinguishers

		iv.	Jumbo curtain, Fire / Foam monitors, Deluge sprinkling systems
3.	Port Fire Station	i.	Water Tender
		ii.	Foam Tender
		iii.	FF gear and extinguishers

7.8 Heating Ventilation and Air Conditioning System (HVAC)

All HVAC units shall be suitable for operation with 415 V + 10%, 50 Hz + 3%, 3 Phase supply for outdoor units & 220 V + 10%, 50 Hz + 3%, 1 Phase supply for indoor units.
The VRF system shall be air-cooled, direct expansion type central air conditioning system consisting of one or more Variable Refrigerant Flow Condensing unit (Outdoor Unit) and connected to one or more Evaporator (indoor) units, air distribution system-duct with grilles/diffusers/VCD, control panel, wiring, control wiring and adequate earthing. Eco friendly refrigerant shall be used R134a or R410a for VRF system.

DX system shall be direct expansion type central air conditioning system consisting of Air handling unit which supply cooled air to various premises through ducting arrangement (air distribution system - grills/nozzles), outdoor unit, control panel, wiring, control wiring and adequate earthing. Eco friendly refrigerant shall be used R134a or R410a for DX system.

The spilt unit system shall provide stable, trouble free & safe operation, with flexibility of operating desired indoor units. The outdoor units must be capable of delivering exact capacity proportional to the number of indoor units switched on & the heat load in the air-conditioned area. The split AC units shall be provided with control wiring and earthing. Eco friendly refrigerant shall be used R134a or R410a for this system. The units shall have BEE Energy Efficiency rating of 5 star.

The ventilation /exhaust system shall be provided with fans of appropriate capacity, Sound attenuators along with weatherproof arrangement i.e., with bird screen, canopy, and louvers.

Ventilation/Exhaust system for all areas which are mentioned below in Table-1 HVAC SYSTEM CATAGORIES, shall be designed as per NBC code & ISHRAE STANDARDs (like ACH, occupancy etc). The inside temperature for arriving at the air quantity shall be not be more than ambient temperature + 5ºC during peak summer.

Substations & Electrical rooms shall be provided with positive pressurized ventilation system to avoid the ingress of dust & dirt.

Air conditioning and Ventilation ducting shall be provided in accordance with SMACNA standard. Manufacturer should submit complete cooling load calculations and other design calculations for the approval of the client/consultant.

The steel framework, fans, attenuators, and exposed ductwork shall be provided with suitable protection required to suit the saline and corrosive external environment. Contractor shall propose suitable painting and coating /insulation for further protection of all system equipment.

7.9 Security System

Security system of the port is required to provide sufficient protection against:

- Sabotage.
- Pilferage and thefts.
- Encroachments by unauthorized persons.
- Trespassers and antisocial elements.

The security system must comply with the requirements of ISPS Code. Keeping in view the importance of various areas in the port, the following proposals are made:

- Port boundary provided with a rubble masonry wall 2.4 m high with barbed wire fencing of 1 m high.
- Perimeter Fence CCTV System - comprising high sensitivity colour cameras
- A security office and check post at the entrance to the terminal.
- Provision of watch towers at suitable intervals for manual monitoring.
- Adequate Container scanners are provided to scan percentage of boxes as per security plan.
- Radiation Portal Monitors (RPM) for the screening of vehicles and cargo for detection of illicit sources.
- Adequate isolated area would be allocated for storage of dangerous goods.
- The lighting in the port area shall be to the acceptable standards.

For Phase 1 development, it is proposed that the boundary wall be constructed only around the reclaimed land area to avoid any trespassing of the locals and port safety point of view.

The security arrangements proposed would have to be to the approval of the Director General of shipping who is the designated authority under the ISPS code.

7.10 Pollution Control

One of the essential regulatory functions of a Port Authority is to ensure that the Port waters are free from pollution. To this end, pollution control assumes a significant role in any port operations. The main sources of pollution in the port are:

- Discharge of oil by ships / crafts.
- Discharge of bilge by ships / crafts.
- Discharge of dirty / contaminated ballast by ships.
- Discharge of cargo overboard.
- Spillage of cargo during unloading / loading operations.
- Discharge of garbage, sweepings, sewage, etc.
- Discharge of industrial effluents.
- Municipal sewage and drainage.
- Dust from cargo.
- Smoke from ships, vehicles.
- Noise from vehicles, machinery.

Containers being low hazardous cargo, no specific pollution control facilities are required for a container terminal. The following steps will be taken for pollution control at the port:

- For containment and cleaning of oil spillage from fuel stations, a special drainage system will be installed for the area which can separate oils from drain water. The reefer wash down area will also be provided with an oil-sediment separator unit as part of the drainage system.
- For containment and cleaning of oil spillage from vessels, a portable inflatable type oil spill containment booms and oil skimmer is proposed.
- High mast lights with shielding arrangements will be used at the terminal to minimize light pollution.

The port is envisaged as a green port and usage of eRTGs, and hybrid ITVs is proposed amongst other measures to reduce the environmental impact of the port. In addition, the port is planned as a world-class facility with efficient systems that minimize processing times which reduce fuel consumption and air pollution, thus positively impacting the environment.

7.11 Green Port Initiatives

Sustainable development is a broad-reaching concept that seeks to provide a good quality of life for today's population while preserving the ability for future generations to maintain their quality of life. At the highest level, it incorporates environmental, social, and economic aspects which can be further defined into human, social, manufactured, natural and financial capitals that must be sustained and enhanced.

In the context of development within the built environment, the imperatives of sustainability require schemes that address sustainability concerns and enhance opportunities to improve the quality of life of occupants and the surrounding community. Assessing the extent to which aspirations are achieved can be performed using sustainability appraisal techniques through the duration of the development, or by incorporating sustainability statements against defined criteria as part of the planning process.

The proposed port at Vadhavan aims to provide long-term commitment, strong policy push, innovation, and alignment of interests and business philosophies along with serious investment in technologies, systems, and manpower in order to achieve this objective set out in developing the vision of the port by JNPA. These sustainable solutions will range from analysis of climate change risk and resiliency at the planning stage to incorporation of renewable and alternative energy sources, where feasible, to minimize the site carbon footprints and energy costs during the operations phase.

Factors considered and mitigated as appropriate in designing and constructing waterfront structures commonly include, but are not limited to:

- *Site selection, design, and configuration*
  The potential for material reuse, access to rail and multi-modal transportation networks, vulnerability to flooding and sea level rise, storm-water best management practices, impact to marine environment and native species, and impacts on the surrounding community including light and noise pollution.

- *Material selection*
  Focus on durability in addition to reuse of dredged materials, use of recycled, re-used, sustainably harvested, or locally sourced content where possible, and avoidance of toxic or hazardous materials.

- *Emissions reduction strategies*
  On-terminal or near terminal electric generation (solar, wind), waterborne delivery of construction materials, terminal configuration, equipment selection, and transportation technologies to efficiently handle cargo and reduce emissions and air quality impacts from terminal handling equipment and

truck traffic. The proposed port will involve a wide range of mechanized equipment and vehicles used in the loading, unloading, handling, storage, and transportation of cargoes.

Under a ‘green port’ initiative, the Shipping Ministry had directed all the major ports to install grid-connected and roof-top solar and wind power projects to facilitate day-to-day operations including supplying shore-power to visiting ships in an eco-friendly manner. Using renewable energy also helps ports cut power bills - a key operating cost - which in turn translates into lower vessel- and cargo-related charges.

The Clean Power Opportunities in Ports are as below:

- Solar canopies over all auto parking
- Solar canopies over wheeled reefers (US terminals)
- Solar panels on roofs of terminal buildings
- Solar panels along port roadways/ right-of-way
- Wind turbines on port land or offshore near port areas
    - Coastal areas tend to be relatively windy
    - Offshore construction (via barge) is most efficient technique for wind turbines
    - Port areas already have large container cranes on the horizon so large wind turbines are less objectionable.

Clean Power Advantages

- Zero emissions
- Predictable long-term fuel cost, and overall system cost
- Short transmission distance
- Solar and wind systems typically generate peak power in times of peak demand (mid-day)
- Positive PR can help offset negative public view of port development
- Government subsidies may apply in some cases

For Vadhavan port, the installation of windmills along the approach trestle can be explored and a feasibility of exploring this option of energy can be assessed separately.

Thrust to be given for the use of more electric vehicles within the port for port operational personnel. For e.g., canopies w/ solar panels could be attached to electric powered machines – like this golf cart but at a larger scale.

Some of the specific solutions amongst others include the following:

- *Electric RTGs*

  It is proposed to utilize fully electrified RTGs at the port in future phases. These RTGs provide significant reduction in fuel consumptions as well as emissions (both air and noise). Several Asian, European, and North American ports including the JN Port in India have already converted from diesel RTGs to electric RTGs.

- *Intra-Terminal Vehicles (ITV)*

The ITV fleet will comprise of a mix of Other Liquid based and efficient low sulphur diesel vehicles. The ITVs comprise most of the vehicle movement within a container terminal and the proposed port fleet will provide a considerable reduction in emissions compared to a typical diesel engine fleet. In the future, the fleet can also include hybrid and electric vehicles. The hybrid and electric technology are expected to eliminate emissions during idling, which can represent more than half of a yard hustler's duty cycle. Successful projects including this technology have been considered at ports including Port of Los Angeles and Long Beach in California, USA. Several European ports are exploring use of biofuels and bio-mass gases as alternate ways to power these vehicles.

- *Electric Quay Cranes*
  All the quay cranes for the container as well as the future multi-cargo terminals will be fully electrified. The electric quay cranes have been successfully adopted by most of the new port developments and result in significant reduction in emissions compared to their diesel counterparts in addition to providing higher productivity.

- *Gate Technology*
  Street Trucks Emit a Large Fraction of Port Pollution. Appointments and Gate Technology can Reduce Street Truck Time on Terminal.
  - Ports and operators have little control over emissions per hour from street trucks
  - Terminals can be operated to minimize the time spent on terminal
  - Appointments to smooth congestion and to re-handle in advance
  - Automated data capture at entry and exit gate to reduce gate time

- *Bigger Vessels*
  The proposed port can handle the world's biggest container vessels of 24,000 TEU. These bigger vessels have fewer emissions compared to smaller vessels (up to 14,000 TEUs currently used in Indian ports) proportionate to their cargo.

- *Cold Ironing*
  The proposed port can utilize the practice of cold ironing at the berths. This concept avoids the use of ship's engines which burn heavy fuel oil and replaces it with alternative sources of power for a berthed ship. Electrical plug-ins will be provided along the berths for ships while they are berthed.

  It has been observed that this technology has shown an average reduction of 90 percent in nitrogen oxide (NOx), sulphur oxide (SOx), and particulate matter (PM) per vessel call in ports where it is implemented.

- *Automated mooring systems*

  Vessels generate a large fraction of total port pollution. Techniques to reduce vessel emissions are as below.
  - Electric shore power for hoteling of vessels (AMP)
  - Use of alternate fuels on vessel when in port
  - Reduce the amount of time vessels spend in port via automated mooring devices
  - Voluntary or mandatory speed reduction near the port

  Automatic Mooring Systems Reduce Ship Idle Time During Manual Line Handling.

- *Modern Efficient Operations reduce Emissions & Fuel consumption*

  A modern operation at the port utilizing the state-of-the-art IT technologies will avoid bottlenecks and reduce queuing, idling, and dwelling of port equipment resulting in significant reduction in emissions and result in energy saving. A performance evaluation system may also be established as part of maintenance system at the port which will observe and evaluate various port equipment on fuel economy, emissions, and operator baseline performance.

- *Green Buildings*

  Green building (also known as green construction or sustainable building) refers to both a structure and the application of processes that are environmentally responsible and resource-efficient throughout a building's life cycle. The sustainability measures should aim to achieve IGBC rating equivalent to LEEDS Gold. Overall goal for sustainability to ensure:
  - Use minimum (a) energy in its functioning by its shape and form.
  - Generate its own energy as much as possible.

- *Smart Street Control System*

  The issue of large energy consumption is a concern not only at a local level. The constantly increasing number has made lighting responsible for a staggering 19% of global electricity usage and is contributing towards the already exceeding levels of CO2 emissions. Functions such as on/off/dimming are the basics of any connected lighting system. Autonomous operation, adaptive lighting and maintenance optimization can further support the cause of smart street lighting. In the process of modernizing the public lighting system, municipalities can opt for diverse smart street lighting control systems, streetlight remote control software solutions or communication technologies to build connected street lighting infrastructures.

- *Storm Water Treatment system*

  The proposed port is planned to have its own storm water runoff collection system by providing renewable system to collect and treat the storm water. It will treat oil contaminated rainwater (run-off) from impervious areas, e.g., roads, yard areas and will be spread throughout the port area.

- *Waste Management system*

  In order to avoid and minimize the potential effects of generated wastes, the port will develop and implement a port waste management plan to provide adequate reception facilities for oil, chemical and garbage wastes, and remove, as far as is practicable, any disincentives to landing waste in the port. As part of this process the port will encourage responsible management of waste, including minimization and recycling, at the point of generation on ships, reception in ports, transportation, and disposal, and ensure that port employees and users dispose of garbage and other wastes responsibly in facilities provided and report any spills or large pieces of floating garbage to the port authority.

- *Construction Stage*

  During construction stage, various sustainable solutions are envisaged for the port. Green additives will be added to our concrete mixtures for almost all specifications. Additives such as fly ash, blast furnace slag, and silica fume are by-products in the combustion of various materials. The use of these materials offers tremendous potential to alleviate their placement in landfills. In addition, because the carbon emissions generated by fly ash are significantly less than that generated by an equal weight of cement, "greenhouse gas" production is reduced. Moreover, these additives enhance the properties of concrete, including its durability, performance, and resistance to corrosion caused by sulphates and chlorides. Steel buildings are considered green structures because 100% of the material can be recycled once its life cycle has been reached. The Port would also incorporate the use of recycled steel, or steel with recycled content, into construction projects whenever possible.

  The proposed port will require dredging activities and this dredge material will be utilized to the full extent possible for reclaiming the port area and low-lying areas within the port. This will avoid the need for transporting material from far flung areas.

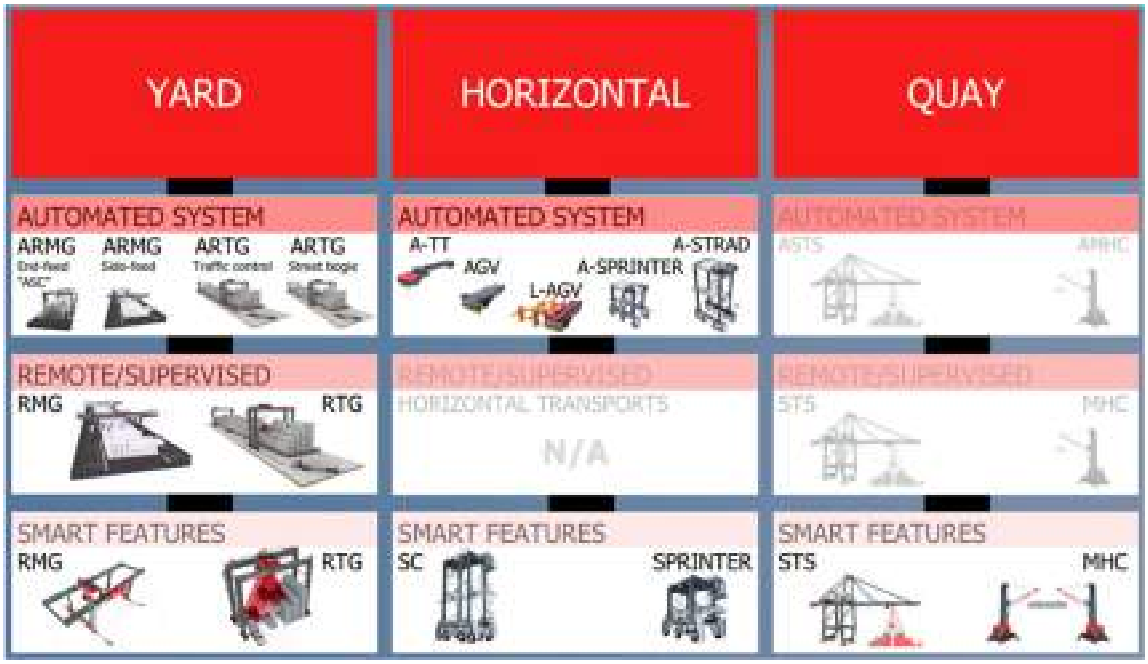
- *Port Automation*

The port automation can be categorized into two levels of automation in container terminals.

- Fully automated and
- semi-automated.

When the stacking yard and horizontal transfers between the quay and the yard are all automated, the container terminal is fully automated. Automation that has begun in the stacking yard but has not reached the quay all in one process is semi-automatic.

The process is automation is categorized in the following areas.



For the terminal automation, one of the challenges is that of increased ship sizes- mega ships as they are called. Port infrastructure is being forced to develop and improve in order to meet these new demands required for receiving mega ships. Automation would help avoid port congestion, decrease port storage charges, and reduce demurrage & detention. Although the initial investment to automate terminals is extremely expensive, it is speculated that the investment is worth the future cost reductions it will bring.

The objective of automation is to minimize error, increase efficiency and reduce costs, removing the possibility of human error and reducing the size of the workforce, helps achieve these targets. The elimination of human labour reduces operational costs not only in terms of wages but also increased efficiency, thereby reducing the carbon footprints. In view of the proposed the terminal developments and activities, it would be efficient to automate the yard operations with Automated RTG in future which can further be the TOS.

8 Preliminary Design of Marine Structures

8.1 General

Preliminary engineering analysis for various civil infrastructures for Phase 1 development has been carried out in this section. These analyses are based on model studies described in this report. RHDHV is making recommendations based on the information that has been made available to them from these studies; such recommendations are subject to many factors that are beyond the control of RHDHV; and RHDHV thus make no representations or warranties with respect to such recommendations and disclaim any responsibility for the accuracy of estimates and recommendations.

The preliminary engineering makes certain assumptions as to the structure types for various port components whereas the contractor may make modifications based on adopted final design, construction methodology and equipment availability without compromising the stability and functional requirement of the structure.

8.2 Offshore Breakwater and Revetments

8.2.1 Source of Documents for Preliminary Design

A full list of documents was provided in Section 1.6. The reports associated to the design of breakwater are summarised below.

REF.	Report title	Author	Date
1.	Technical Report No. 5558 – Mathematical model studies for assessment of wave tranquillity	CWPRS	January 2018
2.	Technical Report No. 5581 – Desk Studies for Prediction of Extreme Wave Conditions		March 2018
3.	Technical Report No. 5583 – Mathematical model studies for Hydrodynamics & Siltation		March 2018
4.	Technical Report No. 5648 – Desk and wave flume studies for the design of breakwater		November 2018
5.	Technical Report – Desk and 2D Wave flume studies for the design of revised breakwater cross-section		September 2021
6.	Technical Assessment Report for Placement of Model Units in Laboratory	CLI	May 2018

8.2.2 Design Criteria

8.2.2.1 General

The harbour and land reclamation area will be protected by an offshore breakwater and revetments. Full details of the design criteria and conditions adopted for the preliminary design of the breakwaters and revetment are discussed in the following sub-sections.

8.2.2.2 Functional Requirements

The breakwater and revetment structures are required to absorb wave energy and provide acceptable wave conditions for safe navigation and berthing within the harbour.

The revetments are required to contain land reclamation and fill, maintain the design levels, and protect the reclamation fill from wave loading, currents, propeller wash, wind, and flooding. The revetment is designed to withstand the prevailing environmental and marine conditions.

Road access is required on the offshore breakwater for maintenance and access to the navigation aids on the roundhead; the road needs to be suitable for slow driving light vehicles and occasional light trucks or excavators for maintenance of the structures.

8.2.2.3 Design Life and Standard

The design life for the new offshore breakwater and revetments shall be, as a minimum, 50 years, with an associated design standard of 100 years. By definition, a 100-year extreme storm event has a 39% probability of occurring or being exceeded during the 50-year life.

8.2.2.4 Armour Stability Requirements

Rock Armour

RHDHV recommends reducing the regular maintenance required for the breakwater and revetment structures over their 50 years design life and these structures will be designed to an “initial damage” level during the design extreme 100-year event. The initial damage level means that between 0% and 5% of the primary rock armour layer on average are displaced during the design event. This means that with rock armour slope of 1V:1.5H to 1V:3H the Damage Parameter, S=2 (using Van der Meer formula) is used for extreme 100-year design conditions.

Concrete Armour Layer

Accropode II™ units were chosen as the preferred single layer concrete armour units. The sizing of Accropode II™ units is based on the guidance given in the Rock Manual and guidance from the unit developer.

The stability of Accropode II™ units on the structure can be described by a damage number N_{od} (number of displaced units within a strip of width D_n). Therefore, a relation between this parameter N_{od} and the accepted damage level is required to design such concrete armour units. Taking into account the adopted damage level, the design damage parameter N_{od} for Accropode II™ units will therefore be taken as $N_{od} = 0$ under extreme 100 years design conditions. The sizing of the Accropode II™ unit will be based on the guidance from Concrete Layer Innovation (CLI) as shown in Figure 8-1. The preliminary sizing has been confirmed using physical modelling.

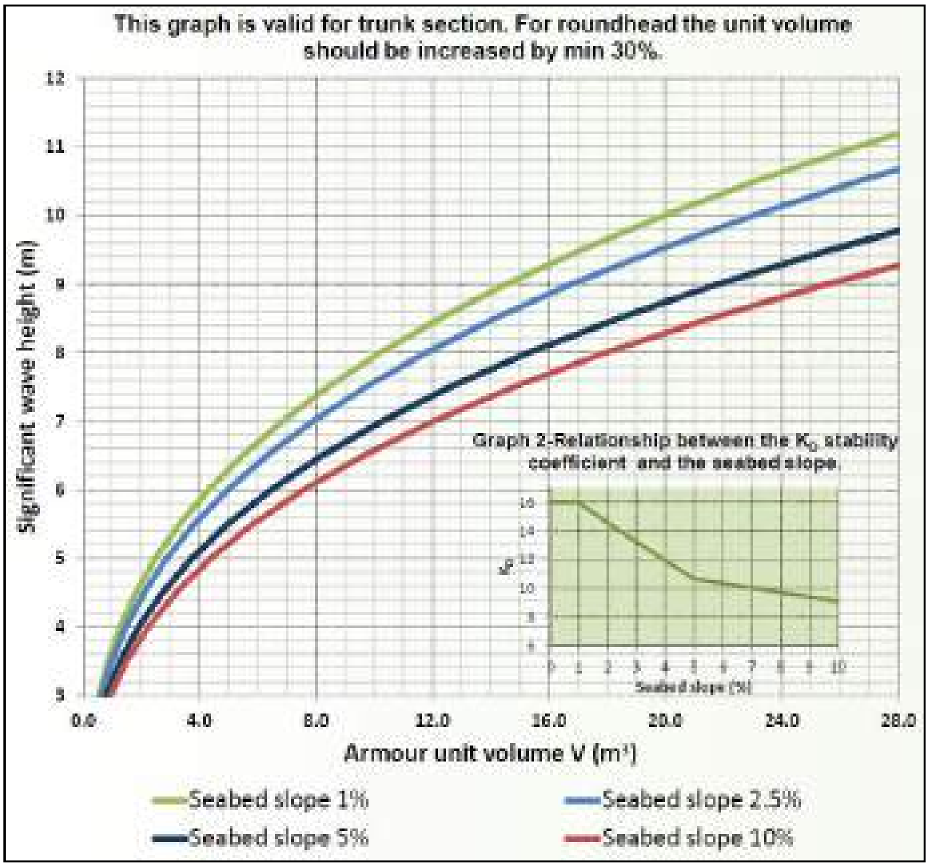


Figure 8-1 Relationship between the design wave height as a function of the Accropode II size.

The roundhead and bend of a breakwater are generally the most vulnerable parts of the structure. This is because of the more complex wave attack and generally greater depths.

Current best practice is that the concrete armour units on the roundhead and bend sections are generally increased by around 30% in volume, to protect these sections of the breakwater.

Underlayer Rock

The weight of the underlayer rock will be determined according to the filter rules set up for armour layers in The Rock Manual and from the guidance provided by the developers of the concrete armour units.

For sections where the primary armour layer is of rock material, the underlayer and its interface stability are determined based on the guidance in the Rock Manual – chapter 5.2.2.10.

Filter rules have been applied to check the suitability of rock sub-layers against internal stability, interface stability, permeability, and segregation. The criteria are taken from the guidance in the Rock Manual – chapter 5.4.3.6.

8.2.2.5 Overtopping Criteria

The overtopping requirements during both the 1-year operational condition and 100-year extreme condition for breakwaters and revetments are summarised in Table 8-1.

Table 8-1 Overtopping Limits

Structures	Design Condition	Permissible Overtopping (litres/s/m)
Breakwater, Revetment	1 in 1 year Operational	"No overtopping discharge" < 0.4
Breakwater	1 in 100-year Extreme	<50 at the crown wall
Revetment	1 in 100-year Extreme	<10 at the crown wall

8.2.2.6 Toe Stability Criteria

The toe armour design will be undertaken following the guidance provided in CIRIA C683 The Rock Manual and will use the LAT +0 m CD as design extreme low water level.

The acceptable damage number N_{od} for the stability of the toe berm along the breakwater and revetments is 0.5 under 100 years extreme condition. N_{od} is defined as the actual number of displaced primary armour stones within a strip of width D_{n50} across the structure [CIRIA C683 the Rock Manual]. For standard toe construction dimensions (3-5 stones wide and 2-3 stones thick), a N_{od} of 0.5 means start of damage or minor movement in the toe.

8.2.2.7 Crown Wall Stability Criteria

The crown wall on the crest of the breakwater is incorporated into the roadway. The design of the crown wall will be undertaken in the next design phase following the guidance provided in The Rock Manual and other literature papers. In particular, the Pedersen method (and other methods) will be used to determine the wave pressures acting on the wall and the results will be compared to determine the most appropriate forces to be used in the design. The design of the crown wall will need to achieve a minimum safety factor against sliding and overturning of 1.5.

Design guidance on the value for the friction coefficient (μ) beneath the crown wall is provided in the following documents:

- BS6349-7: It is suggested that the coefficients of friction between the flat concrete base of a structure and a coarse granular material should not be assumed to be greater than 0.6. With corrugated caisson base higher values can be appropriate.
- CIRIA C683 The Rock Manual: The value of the friction coefficient is generally assumed to be around 0.5. Where the crown wall incorporates a substantial key into the underlayer, higher values may be assumed.
- CEM Part VI: Tables VI-5-62, VI-5-63 and VI-5-64 suggest the values of (0.5 – 0.7) for the flat bottom structures.

Considering the above guidance, the following friction coefficient will be adopted for the design of crown wall:

- For the flat bottom crown wall (L shape without down stand key), the friction coefficient $\mu = 0.5$
- For the crown wall with down stand key, the friction coefficient $\mu = 0.6$
- The friction coefficient between the vertical stem unit and the horizontal base unit (concrete on concrete surfaces) with shear key into the base unit will be $\mu = 1.0$. A lower value should be adopted if the horizontal shear key is not provided.

8.2.3 Design Conditions

8.2.3.1 Tide Levels

The tide levels at the project site are stated in earlier Section 2.4.2.3 and 3.3.4.

8.2.3.2 Storm Surge

The storm surge was assessed during the Desk Studies for Prediction of Extreme Wave Conditions [REF 2] by CWPRS to be 2 m high under 100-year return period. This is adopted in determining the design extreme high-water level.

8.2.3.3 Sea Level Rise (SLR)

The sea level rise for 50 years design life is calculated to be 0.2 m, and this is based on the sea level rise predictions of Intergovernmental Panel on Climate Change (IPCC): 2001 for the design life of the structures. The mean sea level rise estimates to 2013 is around 0.05 m and to 2065 is around 0.25 m resulting in a change of around 0.2 m. Therefore, 0.2 m was used for sea level rise over the 50 years design life of structures. This value will be reviewed at detailed design against recent (2021) guidance issued by IPCC.

8.2.3.4 Design water levels

The design high water level is a function of the maximum tidal level in combination with the storm surge and sea level rise. The following values were used in the design:

High Water

- 100 Year extreme: +6.9 m CD (MHWS 4.7 m CD + Surge 2 m + 50-year SLR 0.2 m)
- 1 Year operational: +4.9 m CD (MHWS 4.7 m CD + 50-year SLR 0.2 m)

Low Water

- 100 Year extreme: +0.00 m CD
- 1 Year operational: +1.2 m CD

RHDHV does not recommend combining HAT with 100-year storm surge and SLR because the HAT occurs once every 18 years for a few hours and that it is a very rare chance for HAT occurring within 5 to 10 hours storm of 100-year event. Therefore, it is considered conservative to use HAT level in determining the 100-year return period high water level.

Based on the discussions with CWPRS and JNPA on 23rd March 2021 it was concluded that the 1-year design condition should be a combination of the 1-year wave and 1 year water level and that the 100-year design condition is a combination of the 100-year wave and 100-year water level.

8.2.3.5 Design wave conditions

The design extreme wave conditions at the project site are summarised in Table 8-2 based on the DPR and CWPRS reports. RHDHV observed the wave conditions given in CWPRS report are much higher than the wave conditions stated in the DPR. The wave conditions derived by CWPRS were based on their desk studies for prediction of extreme wave conditions [REF 5] which considered past cyclone events. Whereas the wave conditions in DPR were analysed based on non-cyclonic events in the modelling analysis.

Table 8-2 Extreme Wave Condition at Project Site for 1 in 100-year Return Period

Structure (seabed level in m CD)	DPR [1]		CWPRS [2]	
	H_s (m)	T_p (s)	H_s (m)	T_p (s)
Offshore main Breakwater – Head and trunk (-20 m)	5.9	12	7.5	12
Offshore main Breakwater – Head and trunk (-6 m)	4.0	12	6.8	12
Offshore main Breakwater – trunk (-15 m)	5.9	12	7.5	12
Offshore main Breakwater – trunk (-10 m)	4.6	12	7.1	12
Revetment (+0 to -4 m)	3.0	12	NA	NA
Revetment (> +2 m)	2.4	12	NA	NA

NA denotes Not Available

(1) Source: DPR reports [REF 1, 2]

(2) Source: CWPRS Report [REF 5, 7]

It should be noted that the studies by CWPRS were carried out a high tide level with storm surge of 2 m (water levels in the range from 6.2 m to 7.4 m were tested in the CWPRS modelling studies). The extreme wave conditions from CWPRS were used in the 2D & 3D physical modelling studies.

There is limited information in the previous studies on 1 year wave conditions (required to assess operational wave overtopping). CWPRS Technical Report 5558 [REF 1] presents nearshore wave data used in the assessment of wave tranquillity within the port. Although no return period has been provided for these conditions, it is assumed that they are between 1 and 5 years and these have been adopted as the 1-year condition for the design of the breakwater. The 1-year conditions at the breakwater are:

- **1 in 1 year design wave: H_s = 3.0m, T_p = 10s**

8.2.3.6 Material Density

The densities of material which were used in the DPR design are listed in Table 8-3.

Table 8-3 Density of Material

Material	Density (kg/m^3)
Sea water	1,025
Rock	2,650
Mass Concrete Armour Unit	2,400
Mass Concrete for Crown Wall	2,400

8.2.4 Preliminary Design

The design of the offshore breakwater based on the requirements and conditions set out in the previous section is described below.

8.2.4.1 Verification with Physical Modelling

The original design for the offshore breakwater was completed by CWPRS who also undertook 2D & 3D physical modelling studies in 2018 at their facilities in Pune. The cross section developed by CWPRS is shown in Figure 8-2 and has the following key attributes:
/

- Crest Level = +16 m CD
- Primary Armour = 11cum Accropode II units

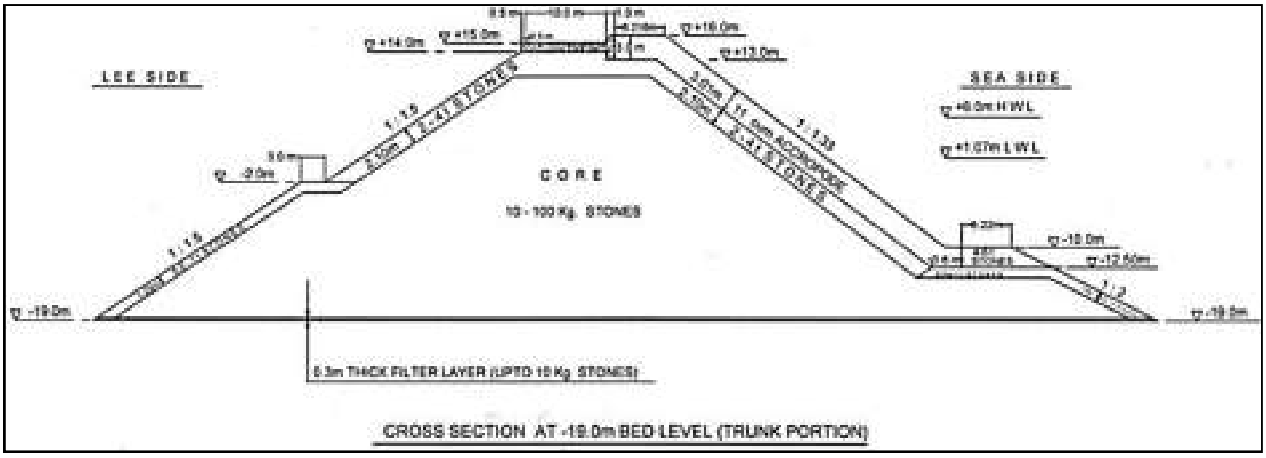


Figure 8-2 Tested breakwater cross section in deeper water at -19 m CD bed level.

This cross section has been further developed and optimised by RHDHV and the final section presented was tested in a 2D flume at CWPRS in September 2021 (see Section 0).

8.2.4.2 Sizing Primary Armour and Underlayer

The wave conditions at the offshore breakwater location require the use of Accropode II units, rather than large rock, as the main primary armour. This is because the required rock size for the main armour is found to be very large (i.e., significantly greater than 6t) and cannot be supplied from quarries.

Seaside

The proposed primary armour layer and rock underlayer for the offshore breakwater are summarised in Table 8-4. These are extracted from the available design reports given in Section 8.2.1.

Table 8-4 Proposed Primary Armour Layers on seaside slope of the Offshore Breakwater

Seaside	Breakwater Roundhead	Breakwater Trunk	Breakwater Roundhead	Breakwater Trunk
Seabed level (m CD)	-19.0	-10 to -19.0	-6.4	-8.0
Armour Type	Accropode II™	Accropode II™	Accropode II™	Accropode II™
Slope (V:H)	3:4	3:4	3:4	3:4
Recommended Armour Size	13 m^3	11 m^3	13 m^3	11 m^3
Underlayer Rock	2,000-4,000 kg	2000-4,000 kg	2,000-4,000 kg	2000-4,000 kg

It is proposed that the armour layer for the offshore breakwater is formed of a single layer concrete unit Accropode II™. The Accropode II™ slopes are designed with a maximum of 20 rows to avoid the lower units being crushed. The main concrete armour unit slope has a gradient of 3:4.

The size was confirmed in the 2018 physical model tests at CWPRS.

Leeside

A summary of the proposed armour layer and rock underlayer at the leeside of the breakwater is provided in below table.

Table 8-5 Proposed Primary Armour Layers on leeside slope

Leeside	Main Breakwater Trunk
Slope (V:H)	2:3
Recommended Armour Size	2,000 - 4,000 kg
Underlayer Rock	Quarry run

The 2021 CWPRS physical model results show that the leeside 2,000 - 4,000 kg rock armour was stable under wave overtopping and leeside wave conditions. The slope of the primary rock armour is constant along the whole breakwater at 1:1.5 and the main rock armour is terminated with a berm at -2.0 m CD to allow a change to a smaller armour size. The armour size on the lower part of the slope will be two rock layers of 300 - 1,000 kg as this size is adequate given the reduced wave energy in the lower part of the water column.

Core Material

RHDHV proposes the use of quarry run material for the core to the offshore breakwater with a size range from 1 to 500kg and a coefficient of uniformity (D_{60} divided by D_{10}) of no less than 3.0.

8.2.4.3 Crest Berm Details

During the original design studies, the crest level of the breakwater was determined from overtopping calculations. The level was set to ensure that the overtopping limits set out in Section 8.2.2.5 are not exceeded. However, no overtopping assessment was carried out for operational conditions.

The crest elevations of the offshore breakwater were tested in the 2018 physical modelling studies by CWPRS. It should be noted that no overtopping measurement was undertaken during the 2D & 3D model studies and that the overtopping performance was visually observed. It is, therefore, difficult to verify the overtopping performance from the model studies with the empirical calculations.

Table 8-6 summarises the proposed crest height and width for the selected for the original design for the breakwater.

Table 8-6 Crest details for original design

Description	Roundhead	Trunk
Crest Berm Width (m)	≥ 6.56	≥ 6.22
Crest Berm Level (m CD)	≥ +16.0	≥ +16.0
Crown Wall Crest Level (m CD)	≥ +16.0	≥ +16.0
Crown Wall – Roadway (width) (m)	10m	10m
Crown Wall – Roadway (level) (m CD)	+15.0 m CD	+15.0m CD

RHDHV completed further design studies to optimise the crest level and widths against the overtopping criteria set out in Section 8.2.2.5 and proposed the following modification to the original design:

- **Reduction in crest level** – A reduction in the crest level of the breakwater would have a significant influence on the volume of quarry run and hence costs. A reassessment of the overtopping rates indicates that the crest level of the breakwater could be reduced by 1 m to +15 m CD and still meet the overtopping limits (see the results of calculations below in Table 8-7). As part of this optimisation the roadway level has been lowered to +13 m CD and reduced in width to 7.5 m. The lowering of the crest requires a heavier wave wall and roadway due to the increase in the wave loading.

Table 8-7 Mean overtopping rates based on reduction in crest level

Wave Wall & Berm Crest Levels (m CD)	Mean Overtopping Rates (EurOtop 2018) (l/s/m)
+15	51
+14.5	74
+14.0	107
+13.5	155

The overtopping calculations indicate that a relaxation in the 100-year overtopping limits would be required if the crest is to be lowered below +15 m CD. The limit of 50 l/s/m under these conditions is to protect the leeside armour from damage under overtopping waves. Higher overtopping rates would require heavier rock armour or an alternative type of armour (e.g., pattern placed concrete cubes) to protect the upper part of the leeside slope. This was later confirmed using physical modelling as discussed in Section 0 was rejected.

The need for a roadway on the crest of the breakwater was discussed with JNPA. RHDHV questioned whether a roadway was required as heavy maintenance equipment would not have access as the breakwater is not connected to the shore. JNPA advised that a roadway was required but the width could be reduced to 7.5m.

8.2.4.4 Toe Berm Details

The design of the toe armour for the offshore breakwater, based on the method described in Section 8.2.2.6, are indicated in Table 8-8.

Table 8-8 Toe Armour on seaside slope

Seaside	Breakwater Roundhead (-19m CD)	Breakwater Trunk	Breakwater Trunk	Breakwater Roundhead (-6.4m CD)
Critical Condition	100 year at LAT	100 year at LAT	100 year at LAT	100 year at LAT
Founding Level (m CD)	-19.0	-15 to -19	-8.0 to -10	-6.4
Toe Level (m CD)	-10.0	-6.0 to -10.0	-3.0 to -5.0	-2.35
Recommended Toe Armour Size	4,000-6,000 kg	4,000-6,000 kg	3,000-6,000 kg	3000-6000 kg
Underlayer Rock	300-1,000 kg	300-1,000 kg	300-1,000 kg	300-1000 kg

During the 2018 2D physical modelling test, a low water level of +1.07 m CD was tested to assess the stability of toe armour for the breakwater sections. No damage was observed during the tests.

A further check on toe stability with an extreme low water level at LAT +0 m CD was undertaken during the 2021 2D model tests to ensure the proposed toe armour is stable against the criteria set out in Section 8.2.2.6. The model results are discussed in Section 0.

The scour apron under the breakwater especially at the roundheads is to protect the toe berm against scouring due to strong flow currents. Where sections are founded on mobile sediments additional scour protection and filters may be required.

The toe and scour design will be finalised in the next design phase.

8.2.4.5 Crown Wall

The stability of the crown wall was visually observed during the 2018 physical modelling studies but there was no measurement (i.e., movement, wave pressure measurement) taken during the model studies to verify its stability against empirical methods.

The crown wall incorporates a roadway, and this is adequate for the type of traffic required for inspection and maintenance. The roadway will be drained by applying a slope of 1:50 so that water runs off to the port side.

The design of the crown wall will be finalised in the next design phase against the stability criteria set out in Section 8.2.2.7. The crown wall will be designed as cast in-situ in two pieces, the stem, and the base. The wall structure will be of unreinforced mass concrete with synthetic macro fibres. The crown wall will be founded on a blinding layer which will serve to cover the voids of the quarry run and to provide a suitable working surface for the structural concrete.

8.2.5 Optimisation with Further 2D Physical Modelling

As noted previously, further 2D physical model studies were undertaken by CWPRS in August 2021 [REF 5] to test the revised breakwater trunk crest details (wave wall and berm crest levels and roadway width). The optimisation of crest level was assessed against the volume of wave overtopping and the stability of the rear slope armour from the 2D model test the following was concluded:

- The armour berm level of the breakwater can be reduced to +14.5 m CD with a 0.5 m upstand crown wall (i.e., +15 m CD level). This satisfied the overtopping limit of 50litres/s/m under 100-year condition.
- The 2-4T leeside rock armour is found to be stable with limited 1% damage the crest configuration above and a reduced roadway width of 7 m.
- The 4-6T rock toe berm at -10m CD is found to be stable under LAT water level during extreme 100-year design condition.

8.2.6 Design of Revetments

The design of the revetments protecting the offshore and shore reclamations based on the requirements and conditions set out in the previous section is described below.

8.2.6.1 Design Background

The revetments protecting the land reclamation can be built as a series of small rock bunds to form a compact core which minimise the volume of quarry run rock required. This approach is sometimes referred to as the “Christmas tree” concept, as shown in Figure 8-3. The plan is to construct a small rock bund with an outer slope of 1(v):1.5(h) and an inner slope of 1(v):1.33(h). The rock bunds will be constructed out of quarry run material and will have a height of around 3 m above the foundation level and a crest width of 3 m. Once both the seaward and landward side bunds are built, the area between will be infilled with dredged material, which will be placed in a domed shape to natural slopes. Given the grading of the quarry run and nature of the dredged material, it will be necessary to provide a geotextile membrane filter between the interface on the quarry run and dredged material.

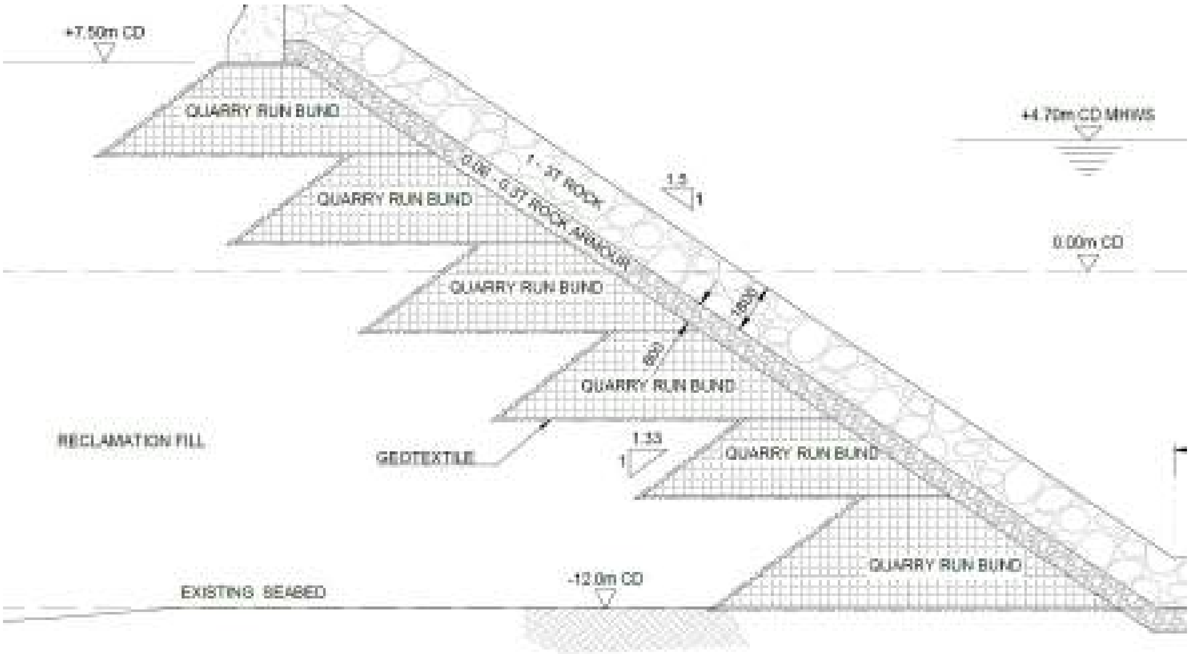


Figure 8-3 "Christmas tree" concept to form the core of the revetment

Having created the first raised section, this whole process is repeated several times until the inner core is constructed up to a level of around +5 m CD using marine equipment. At this point all further construction will be land based to reach the final crest elevation (i.e., top of reclamation) of +7.5mCD. The whole structure is protected with a rock underlayer and armour layer which are placed at a slope of 1(v):1.5(h) on all sides.

8.2.6.2 Sizing Primary Armour and Underlayer

The revetements are partly protected by the offshore breakwater so wave conditions allow the use of rock as the main primary armour with the exception of the Northern Revetment. This revetment is exposed to a higher wave conditions and requires Accropode II units. Details are provided below.

Seaside

The proposed primary armour layer and rock underlayer for the revetment are summarised in Table 8-9.

Table 8-9 Proposed Primary Armour Layers on the revetment

Seaside	Northern (Final Layout)	Northern (Phase 1)	Berth sides	Southern side	Eastern side	Shore	Shore
Seabed or dredged level (m CD)	-12.0	-12.0	-19.5	-12.0	-8.0	0 to -4	>+2.0
Armour Type	Accropode II	Rock	Rock	Rock	Rock	Rock	Rock
Slope (V:H)	1:1.5	1:1.5	1:1.5	1:1.5	1:1.5	1:1.5	1:1.5
Recommended Armour Size	2 m^3 (5T)	1-3T	60-300kg 300 – 1000kg	0.3-1T	60-300kg	3-6T	1-3T
Underlayer Rock	300-1,000 kg	60-300kg	Quarry run	60-300kg	Quarry run	60-300kg	60-300kg

At the berth revetments the 60-300 kg is designed to protect the upper slope above -10 m CD whereas the lower slope below -10 m CD is armoured with a larger rock grading 300-1000 kg to support the upper slope and function as a scour protection against propeller wash. The 300-1000 kg also extends across the berth pocket.

Core Material

It is proposed that the quarry run selected for the rock bund is a well graded rock varying in weight from 1 kg to 100 kg. It has a coefficient of uniformity (D_{60} divided by D_{10}) of no less than 3.0.

8.2.6.3 Crest Berm Details

During the design, the crest levels of the structures were determined from overtopping calculations. The level is set to ensure that the overtopping limits set out in Section 8.2.2.5 are not exceeded.

Table 8-10 summarises the proposed crest height and width for the structures.

Table 8-10 Crest details

	Northern (Final Layout)	Northern (Phase 1)	Berth sides	Southern side	Eastern side	Shore (-4 to 0m CD)	Shore (>+2m CD)
Crest Berm Width (m)	≥ 1.4	≥ 1.4	≥ 1.0	≥ 1.0	≥ 1.0	≥ 4.7	≥ 3.6
Crest Berm Level (m CD)	≥ +10.0	≥ +10.0	≥ +4.7	≥ +8.5	≥ +8.5	≥ +10	≥ +9
Crown Wall Crest Level (m CD)	≥ +10.0	≥ +10.0	≥ +7.0	≥ +8.5	≥ +8.5	Not Applicable	Not Applicable
Reclamation Level (m CD)	+7.0	+7.0	+7.0	+7.0	+7.0	+6.7	+6.7

8.2.6.4 Toe Berm Details

The design of the toe armour for the revetment structures, based on the method described in Section 8.2.2.6, are indicated in Table 8-11. The critical condition for the toe stability is at LAT water level under 100-year wave condition. To simplify construction, the toe berm is formed the same armour as required on the slope.

Table 8-11 Toe Armour on revetment slope

Seaside	Northern (Final Layout)	Northern (Phase 1)	Berth sides	Southern side	Eastern side	Shore	Shore
Founding Level (m CD)	-12	-13 trench	Below -19.5 in trench	Below -12.0 in trench	-8.0	-4.0 to +0	>+2.0
Toe Level (m CD)	-9.8	-10.2	-19.5	-12.0	-6.2	Varies	Varies
Recommended Toe Armour Rock Size	0.3-1T	1-3T	0.3-1T	0.3-1T	60-300kg	3-6T	1-3T
Underlayer Rock	1-500kg quarry run	60-300 kg	1-500kg quarry run	1-500kg quarry run	1-500kg quarry run	Filter layer	Filter layer

8.2.6.5 Crown Wall

Small crown walls are required at the crest of the revetments to support the armour and to control the flow over overtopping water onto the reclamation. A preliminary assessment of the size of the revetment walls has been completed following guidance in the Rock Manual. The design of the crown walls will be finalised in the next design phase against the criteria set out in Section 8.2.2.7

The crown wall will be designed as cast in-situ in one piece. The wall structure will be of unreinforced mass concrete with synthetic macro fibres. The crown wall will be founded on a blinding layer which will serve to cover the voids of the quarry run and to provide a suitable working surface for the structural concrete.

8.2.7 Summary & Cross Sections

8.2.7.1 Summary

Design cross sections have been developed for the trunk and roundhead locations along the offshore breakwater and revetments. Reference can be made to the following drawings for cross sections of the offshore breakwater and revetment.

- DI1452-RHD-DP-MA-DR-CM-1201-SH1 of SH3 – Breakwater sections at -6.4 m & -8 m bed level
- DI1452-RHD-DP-MA-DR-CM-1201-SH2 of SH3 – Breakwater sections at -10 m & -15 m bed level
- DI1452-RHD-DP-MA-DR-CM-1201-SH3 of SH3 – Breakwater sections at -19 m bed level
- DI1452-RHD-DP-MA-DR-CM-1202-SH1 of SH 2 - Revetment section for Phase 1 and Master plan
- DI1452-RHD-DP-MA-DR-CM-1202-SH2 of SH2 – Revetment for Phase 1 and Master Plan

8.2.8 Geotechnical Assessment of Breakwater

The geotechnical design of the breakwater slope is carried out to meet the following requirements:

- Factor of safety for non-seismic conditions: 1.3
- Factor of safety for seismic conditions: 1.0
- Factor of safety for construction stage conditions: 1.0

Based on the Extreme Wave Condition assessment carried out for the Project Site for 1 in 100-year return period in Section 8.2.3.5, Hs for offshore main breakwater is 7.5 m. This indicates a wave height of approximately 3.75 m (Hs/2). Further, based on section 8.2.3.4, storm surge condition of 2.0 m has been proposed. Accordingly, water level difference of 5.75 m has been considered between leeside and seaside. The same shall be re-visited during the detailed design stage.

For the main offshore breakwater, longitudinal geotechnical profiles along MBH-40, MBH-42, MBH-44, MBH-45, MBH-46, MBH-21, MBH-19, MBH-14, MBH-59, MBH-57, MBH-60, MBH-58, MBH-54, MBH-56, and MBH-24 can be referred from Section 3.5.1. The seabed level in these boreholes varies from -12.4 m CD to -18.8 m CD.

The boreholes located towards leeside of the proposed breakwater (MBH-44, MBH-45, MBH-19, MBH-14) indicate presence of silty sand layer underlain by weathered basalt at mid-stretch of the proposed breakwater. Thickness of silty sand layer in these boreholes is approximately 3.6 m. These boreholes were explored upto a depth of 20 m.

All other boreholes (MBH-40, MBH-42, MBH-21, MBH-59, MBH57), except MBH-46, indicate presence of silty sand layer followed by silty clay which is underlain by weathered Basalt. Thickness of the silty sand and silty clay layer in these boreholes varies from 1.6 m to 4.6 m and 3.4 m to 4.4 m respectively.

All these boreholes were drilled upto a depth of 20 m. No boreholes were available towards the Northern roundhead of the proposed breakwater.

Geotechnical information obtained from these boreholes have been used for preliminary stability assessment at various sections of the proposed main breakwater.

8.2.8.1 Seismic Design criteria: Calculation of Design Horizontal coefficient

IS:1893 provides criteria for earthquake resistant design of structures which can be used as general consideration for all type of structures. According to IS1893:1984, Mumbai falls into seismic zone III. However, as advised by JNPA, Zone IV has been considered for the analysis since the project is of national importance.

Horizontal and vertical seismic coefficients have been arrived at considering the seismic conditions of the project area as indicated in section 2.4.2.4 and accordingly the horizontal coefficient of 0.075 and vertical coefficient of 0.0375 has been adopted for the calculations.

8.2.8.2 Summary of stability analysis

Settlement calculation is carried out to estimate the anticipated post-construction settlement. In absence of sufficient laboratory test results, total settlement of 350 mm is estimated to occur in the first 5 years. The initial crest height shall be set taking into account the calculated settlement for the first five years. Liquefaction assessment will be carried out for the loose silty sand layer in the detailed design stage.

D-Geo stability software has been used for the stability analyses. This software package is developed by Deltares specifically for slope stability analyses. The calculations are based on Bishop's method for slope stability with circular slip planes. For non-circular slip failure Spencer method of slope stability shall considered for the most critical case. The slip circle stability assessment for the offshore breakwater was carried out for static and seismic conditions as indicated below.

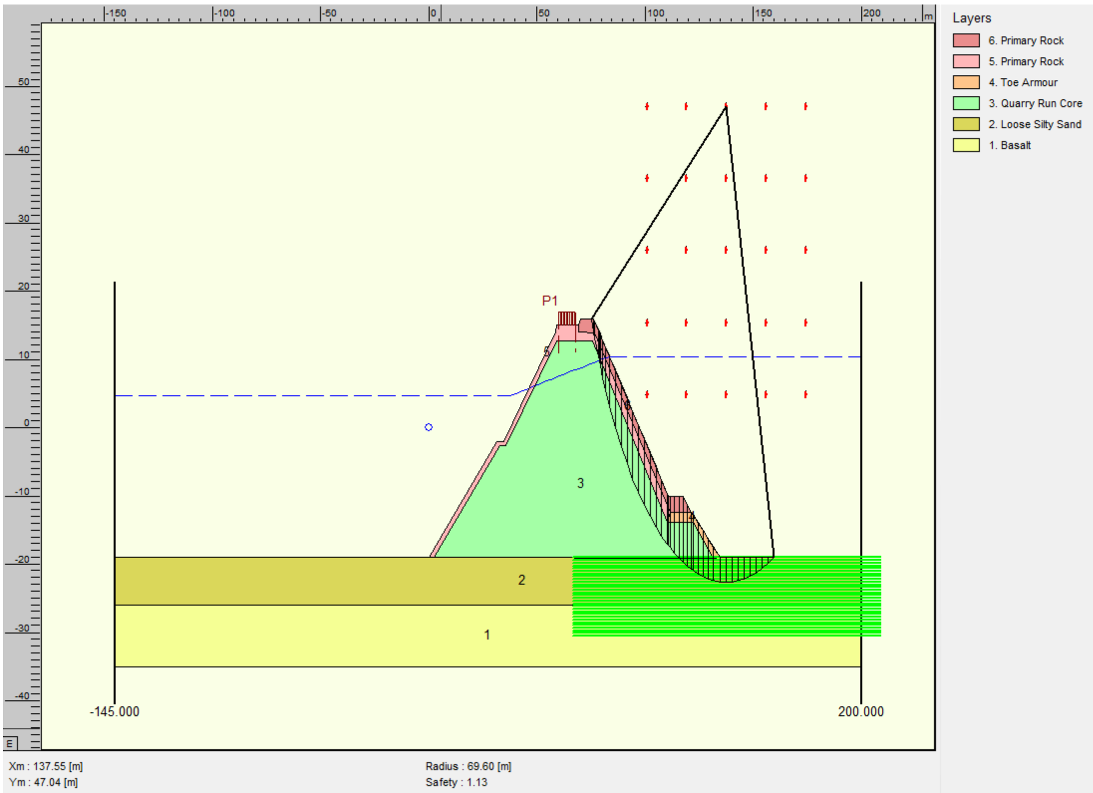


Figure 8-4 Stability assessment for seaside under seismic condition for FOS>1.0

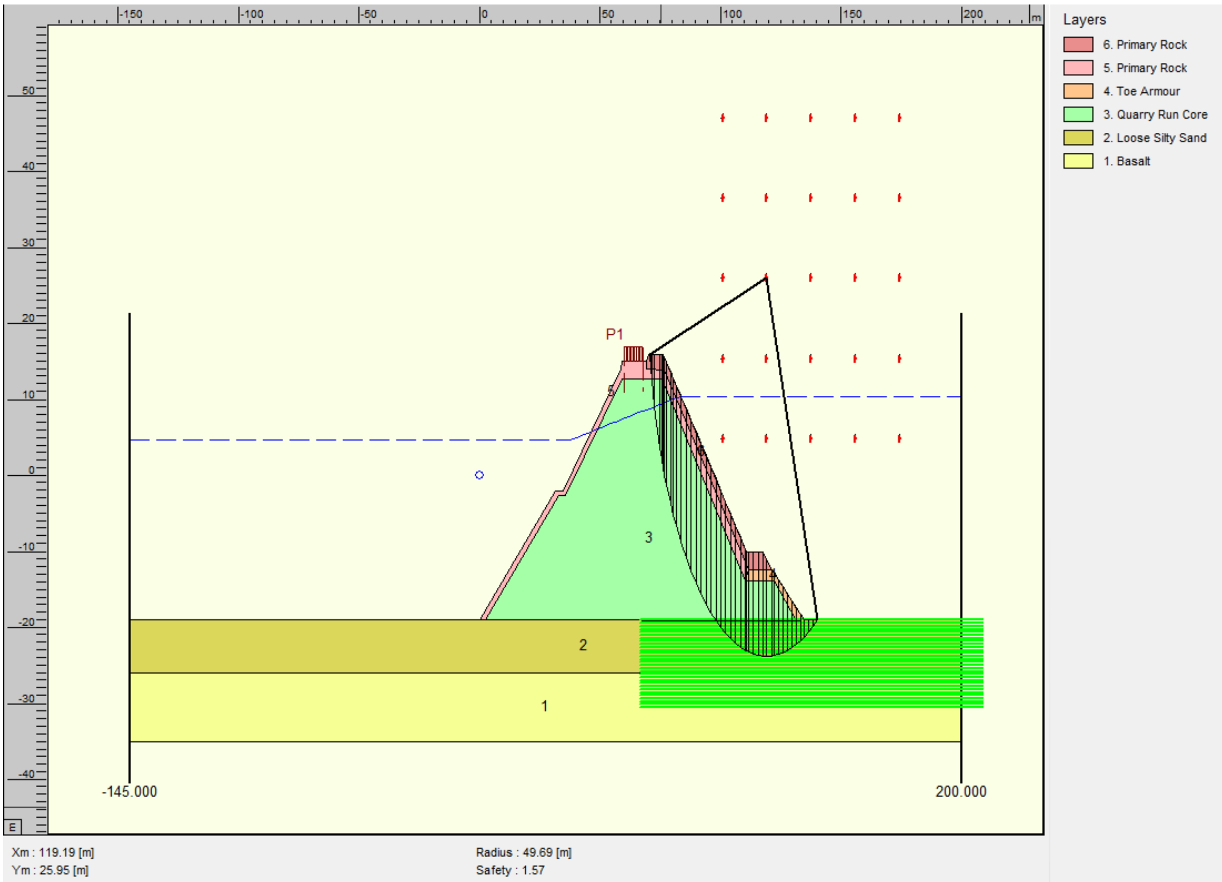


Figure 8-5 Stability assessment for seaside static condition for FOS>1.30

Based on our preliminary assessment, the breakwater is found to have adequate factor of safety against slope failure under both static and seismic conditions. No ground improvement including replacement seems necessary. Detailed slope stability analysis of the breakwater sections will be carried out at the detail design stage.

8.2.9 Geotechnical Assessment of Reclamation Bund

Stability check of the proposed reclamation bund is carried out to meet the following requirements:

- Factor of safety for non-seismic conditions: 1.3
- Factor of safety for seismic conditions: 1.0
- Factor of safety for construction stage conditions: 1.2

The sections for the shore protection bund may be referred from drawing **DI1452-RHD-DP-MA-DR-CM-1202**. Two different sections have been assessed, section A-A along container terminal (CT-04) and section C-C along the multipurpose berth. Geotechnical profile along MBH-47, MBH-50, MBH-52, MBH-55, and MBH-54 is considered relevant for the present analysis. The same may be referred from Section 3.5. The seabed level in these boreholes varies from -10.9 m CD to -13.3 m CD.

Water level and wave height as mentioned in section 13.2.4 are considered in the analysis.

Borehole MBH-47 located near the container terminal (CT-07) indicate presence of silty sand layer underlain by weathered basalt. Thickness of silty sand layer in these boreholes is approximately found to be 3.6 m. MBH-54, located near the multipurpose berth, indicate presence of silty sand layer underlain by silty clay layer, followed by weathered basalt. Thickness of silty sand layer and silty clay layer are approximately 3m and 3.35 m respectively. These boreholes were explored upto a depth of 30 m.

Geotechnical information obtained from these boreholes have been used for preliminary stability assessment at various sections of the proposed cross-section.

Uniform loading of 5 kN/m^2 has been considered on the top of quarry run bund for construction stage as well as operational stage.

8.2.9.1 Seismic Design criteria: Calculation of Design Horizontal coefficient

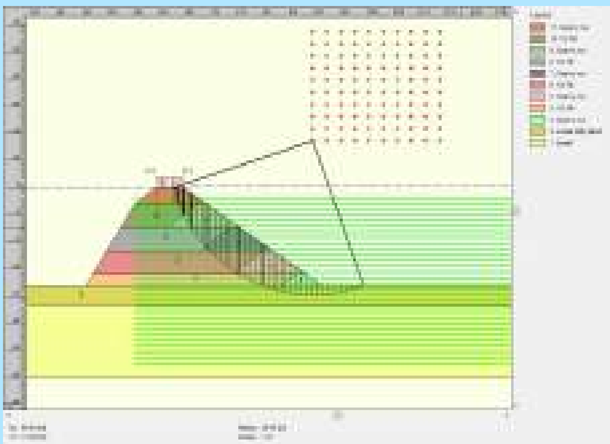
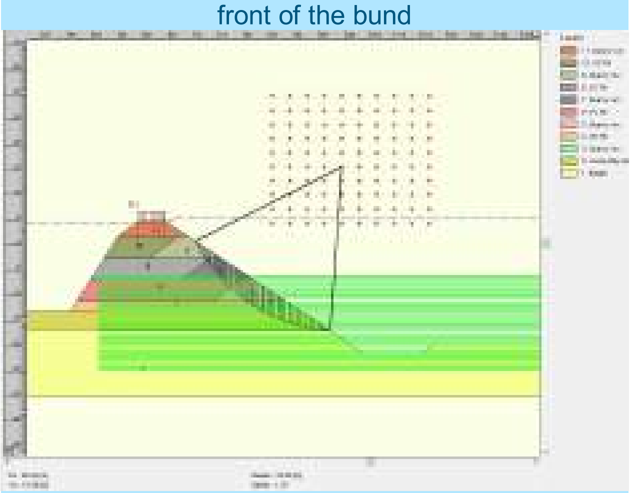
IS:1893 provides criteria for earthquake resistant design of structures which can be used as general consideration for all type of structures. According to IS1893:1984, Mumbai falls into seismic zone III. However, as advised by JNPA, Zone IV has been considered for the analysis since the project is of national importance.

Horizontal and vertical seismic coefficients have been arrived at considering the seismic conditions of the project area as indicated in section 2.4.2.4 and accordingly the horizontal coefficient of 0.075 and vertical coefficient of 0.0375 has been adopted for the calculations.

8.2.9.2 Summary of Stability Analysis

D-Geo stability software has been used for the stability analyses. This software package is developed by Deltares specifically for slope stability analyses. The calculations are based on Bishop's method for slope stability with circular slip planes.

Stability assessment for the proposed reclamation bund was carried out for static and seismic conditions at both sections (Sec A-A and Sec B-B) as described below.

Section A-A: Stage 1- Placing of fill material on existing seabed (-13.5 m CD)	Section A-A - Stage 2- Dredging upto -19.5 m CD in front of the bund
	
Stability assessment for seaside under static condition for FOS>1.2	Stability assessment for seaside under static condition for FOS>1.2

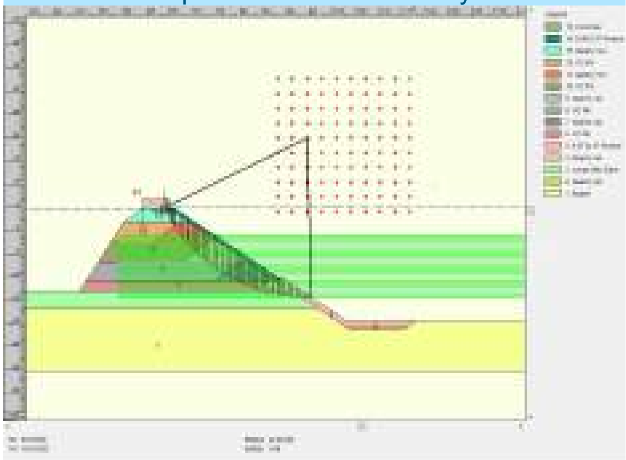
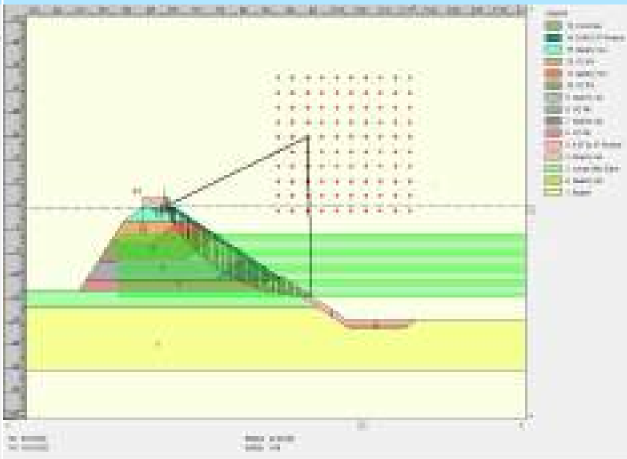
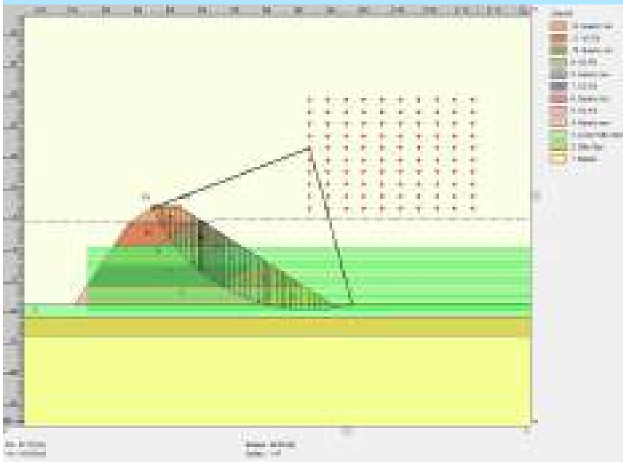
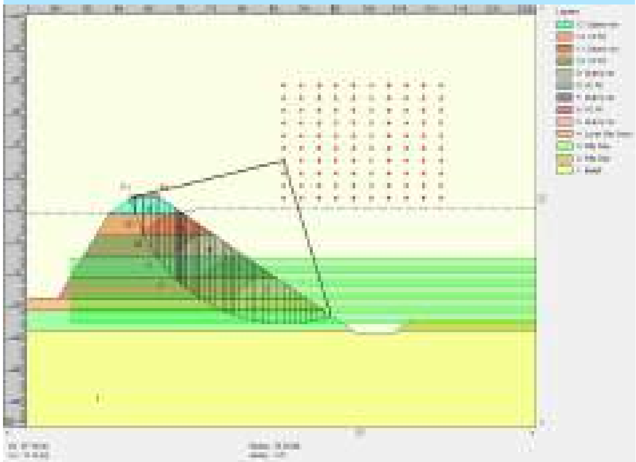
Section A-A: Stage 3- Placing the scour protection and Armor layer	Section A-A: Stage 4- Seismic check
	
Stability assessment for seaside under static condition for FOS>1.3	Stability assessment for seaside under seismic condition for FOS>1.0

Figure 8-6 Section A-A Stability assessment for seaside under Static and seismic condition at various stage of construction

Section B-B: Stage 1- Placing the fill material on existing seabed (-13.5 m CD)	**Section B-B: Stage 2- Dredging up to -19.5 m CD**
	
Stability assessment for seaside under static condition for FOS>1.2	**Stability assessment for seaside under static condition for FOS>1.2**

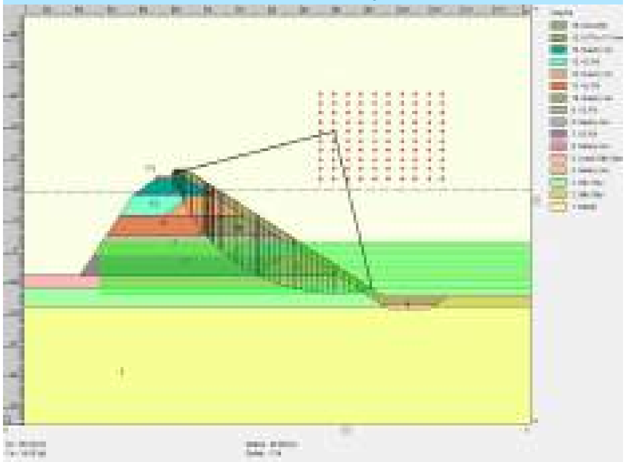
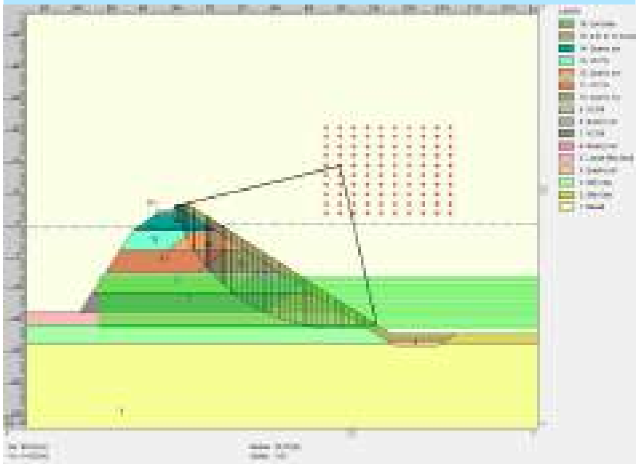
Section B-B: Stage 3- Placing the scour protection and Armor layer	Section B-B: Stage - Seismic check
	
Stability assessment for seaside under static condition for FOS>1.3	Stability assessment for seaside under seismic condition for FOS>1.0

Figure 8-7 Section B-B Stability assessment for seaside under Static and seismic condition at various stage of construction

Based on our preliminary assessment, both the reclamation bund sections are found to have adequate factor of safety against slope failure under static and seismic conditions respectively. Stage-wise assessment of the various construction stages and the final operational stage indicate acceptable factor of safety against slope failure.

8.2.10 Evaluation of the geotechnical Information

The evaluation presented in this section relates to the soil and rock layers encountered at the proposed site. For the purpose of this report, the soil/ rock deposits encountered have been grouped into different soil/ rock units.

8.2.10.1 Soil Unit 1 – Silty sand

The thickness of this layer varies from 1.6 m to 11.27 m in the marine boreholes. This unit is underlain by soil unit 2 (Silty clay) or rock unit 1 (weathered basalt). SPT-N varies from 8 to 50 for this soil unit. The variation of SPT-N with depth is shown in figure below.

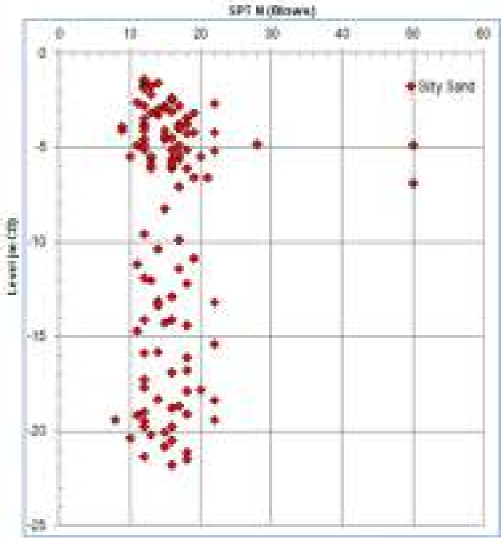


Figure 8-8 SPT-N for Silty Sand layer

The density of the silty sand layer is observed from 22 samples and varies between 14.10 kN/m^3 to 18.90 kN/m^3. An average of 17.08 kN/m^3 is observed.

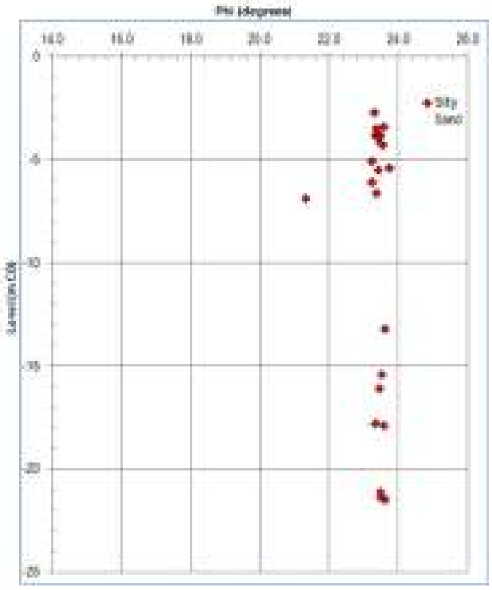


Figure 8-9 phi-value for Silty Sand layer

Following moderately conservative parameters for Soil Unit 1 have been assessed:

- $\gamma_{bulk;k}$ = 17.5 kN/m^3.
- φ = 23 deg
- E-modulus = 12,500 kPa

8.2.11 Soil Unit 2-Silty clay

The thickness varies from 1.6 to 9m in the marine boreholes. This unit is underlain by rock unit 1 (weathered basalt). SPT-N varies from 10 to 75 for this soil unit. The variation of SPT-N with depth is shown in below figure.

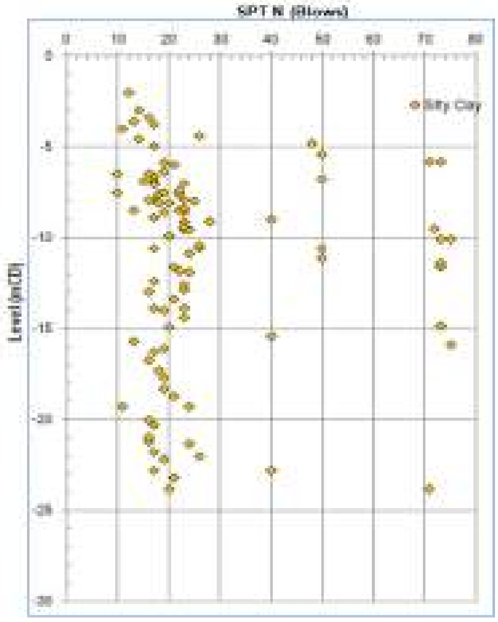


Figure 8-10 SPT-N for Silty clay layer

The undrained shear strength of the clay layer is shown in below figure.

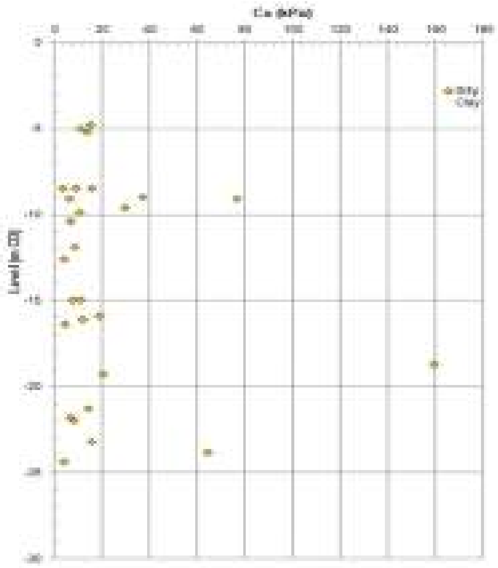


Figure 8-11 Cu with depth for silty Clay layer

Following moderately conservative characteristic parameters for Soil Unit have been assessed:

- $\gamma_{bulk;k}$ = 17.5 kN/m^3.
- E-modulus= 5,000 kPa

8.2.12 Rock Unit 1 - Highly weathered to slightly weathered Basalt

The unit weight for Rock Unit 1 was determined from 60 core samples as part of uniaxial compressive strength on the material. It is observed that in most of the boreholes the weathered rock commences from around 9.00 m to 21.00 m depth below seabed. At few borehole locations, rock is encountered at shallower depths. In MBH-08, MBH-10, MBH-13, MBH-17, MBH-20, MBH-27, MBH-28 which are located near the shoreline, rock unit-1 is observed to start at the seabed level (-0.31 to -3.9 m CD). The boreholes which are located nearby proposed breakwater, container terminals and jetties etc. indicate start of rock unit-1 between -16 m CD to -25.8 m CD.

Rock strength has been determined in the laboratory by means of UCS testing. The results are presented in figure below.

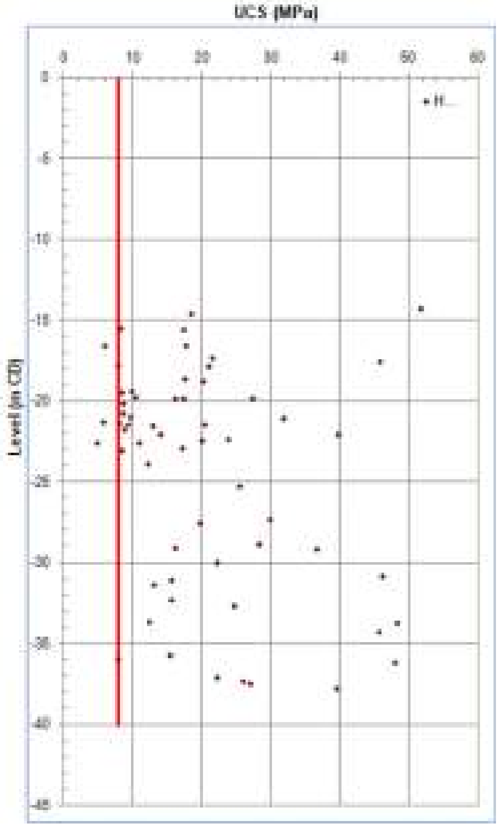


Figure 8-12 Rock Strength

The strength of the rock of Unit 1 varies between 4.95 and 51.7 MPa with an average of 20.5 MPa. The lowest value measured in the different boreholes is 4.95 MPa, recorded in MBH-30 at -20 m CD. Based on the above, rock strength of 8 MPa is found to be consistent for the weathered basalt.

It is important to note that, the uniaxial test results indicate that higher UCS values than the design profile recommended above can occur. As Rock Unit 1 is likely to be present at the proposed pile toe level, the higher strengths will influence the methods used for boring of the rock during construction. Contractor should consider the possibility for stronger zones of rock in Rock Units 1, with UCS values in excess of 8 MPa.

The unit weights obtained from the samples tested for UCS agree well with what would be anticipated for partially weathered Basalt. Unit weight in the range of 22 to 27.50 kN/m^3 with an average of 24.91 kN/m^3 is observed. The lowest values of 12.08 kN/m^3 and 13 kN/m^3 are observed in MBH-8 and MBH-4 at 4.83m and 21.9 m depth from the seabed.

Despite the above, the design pile design is likely to be dictated by the mass properties of Rock Unit 1 due to the low RQD results. Rock was recovered as mainly Basalt with RQD varying from 7% to 68% up to -10m CD and varies from 0 to 98%.

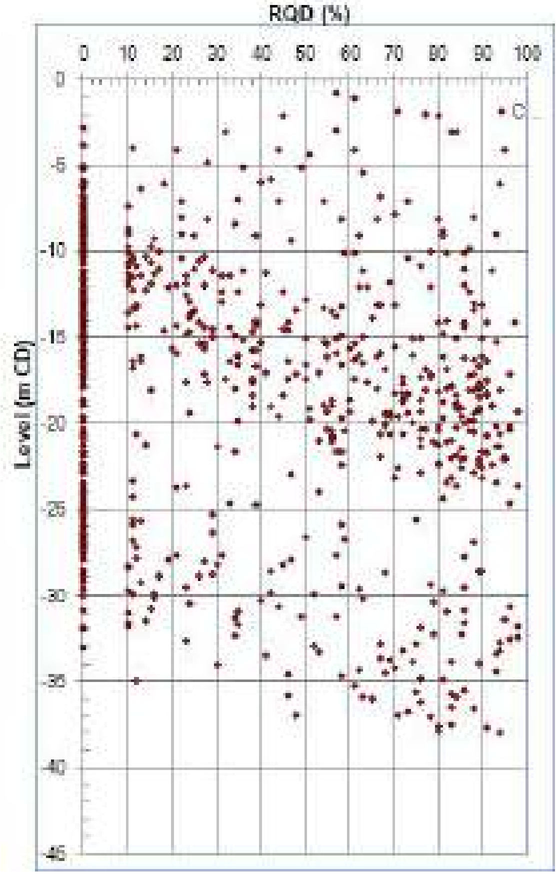


Figure 8-13 RQD of Unit 1

Solid core recovery is seen to vary from 16% to 100% as shown in figure below.

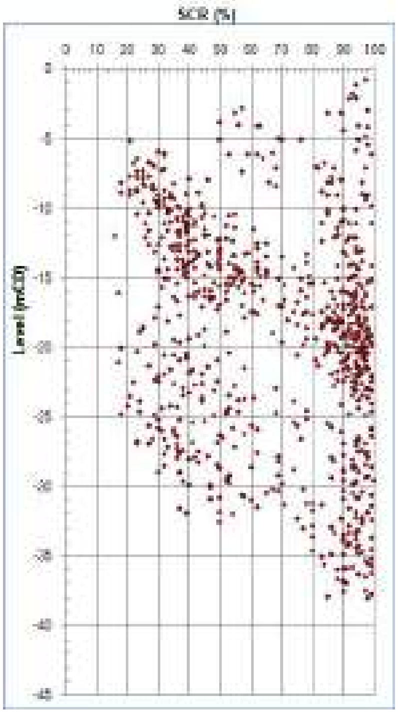


Figure 8-14 TCR of Unit 1

In summary, the following moderately conservative characteristic rock parameters for Rock Unit 1 have been assessed as:

- $\gamma_{dry;k}$ = 22.50 kN/m^3.
- $\omega_{n,k}$ = 1.25-15.62%.
- UCS = 8 MPa

The above results were used for the assessment of geotechnical stability of breakwater.

8.2.13 Rock Quarrying and Transportation

The development of port facilities at Vadhavan would require huge quantity of rock and aggregates for construction of various port structures. The details of the requirements are as indicated below.

Table 8-12 Rock and stone quantity requirement

S. No.	Component	Quantity (Million T)
1.	Breakwater	32.10
2.	Shore protection bund	16.40
3.	Murrum	8.05
4.	Aggregates for the construction of various harbour facilities including rail and road	17.0
	Total	**73.55**

The required quantity of stones can be sourced from quarries locations indicted in section 2.5.5.

The viable option for rock quarrying and transportation of rocks to the site through dumpers. The potential quarry areas which have been zeroed in are as indicated in section 2.5.5. The location of potential quarry sites is shown in Figure 8-15 below:

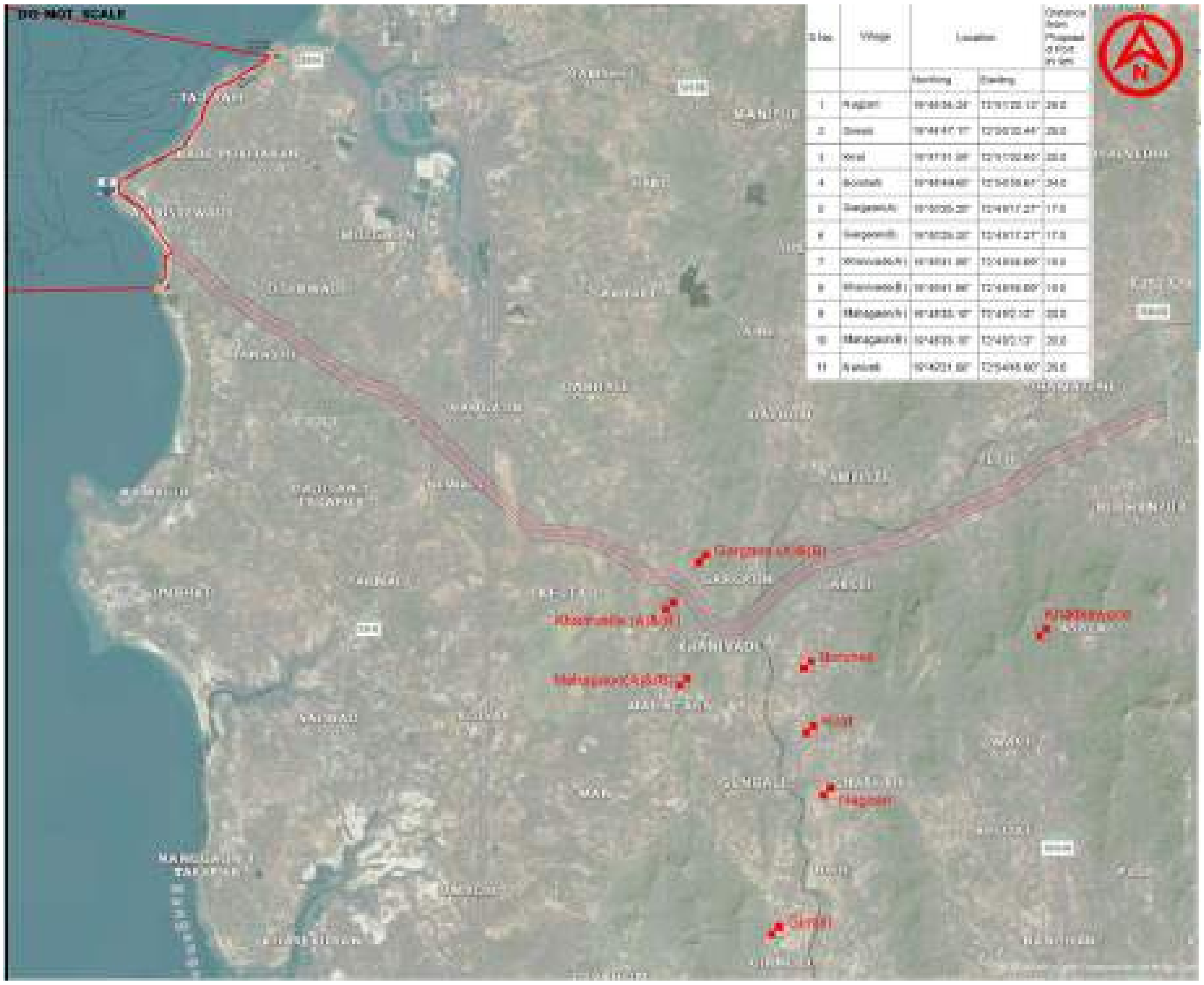


Figure 8-15 Location of Quarry Sites

The nearest road connectivity to these sites is through Shigaon road. These quarry sites need to be connected to the proposed port through road network. The approach to the port site is via Boisar through Boisar road then Boisar-Tarapur road. This road passes through the dense habitation in Boisar. Other two options to reach Vadhavan are Kasa junction on NH-8 then - Dahanu-Jewhar road and Kasa Junction then – Chinchani-Vangaon road via Chinchani.

It is estimated that at least 67 million tonnes of rocks/ stones need to be moved to the site per day. Assuming carrying capacity of each truck to be 24 T, this would mean about average of 4,000 truck movements per day between port and quarry and vice versa for a period of about 3 years.

The quarry survey was carried out by Progen-Pentacle and by JNPA for the sourcing the rock and transportation to the project site. The details of the various quarries' information collected at the site are given below. However, assessment on the extraction of stones of bigger size and hard murrum from this quarry is required to be carried out prior construction. It is also required to carry out necessary investigations from the availability of stone quality point of view.

Quarry Site at Gargaon (A) & (B)

Quarry sites are available at Gargaon in Palghar taluka. Two quarry sites are available at this place. The quarry located at Gargaon is a hillock with an elevation of 140 – 200 m above mean sea level. The projected quantity available in terms of area for the two quarries is 2,548 ha. (6,296 acre) and 4,576 ha. (11,308 acre). The quarry site can be approached through Vanai- Shigaon road and also through Shigaon road. The total lead distance from the quarry to the port site is 17 km. It is anticipated that the quarry comprises of hard murrum as overburden over the basalt rock.

Figure 8-16 Gargaon Quarry Location

Quarry Site at Khanivade (A) & (B)

The quarry sites at Khanivade are located beside Gargaon quarry hillock. Two quarry sites are available at this place. The quarry located at Khanivade is a virgin hillock with an elevation of 100 – 140 m above mean sea level. The projected quantity available in terms of area for the two quarries is 3,938 ha. (9,730 acre) and 3,740 ha. (9,242 acre).

The quarry site is located in Palghar taluka and is at a distance of 19 km from the project site.

Figure 8-17 Khanivade Quarry Location

The quarries at Gargaon and Khanivade together are as indicated below.

Figure 8-18 Gargaon and Khanivade Quarry Location

Quarry Site at Mahagaon (A) & (B)

The quarry sites at Mahagaon are located in Palghar taluka and is at a distance of 20 km from the proposed port site. Two quarry sites are available at this place. The projected quantity available in terms of area for the two quarries is 4,230 ha. (10,453 acre) and 1,450 ha. (3,583 acre).

Figure 8-19 Mahagaon Quarry Location

Quarry Site at Nanivali

The quarry site at Nanivali is located in Palghar taluka and is at a distance of 25 km from the proposed port site. This is a huge quarry with the projected quantity available in terms of area is 84,526 ha. (208,868 acre).

Quarry Site at Borsheti, Kirat, Nagzari and Girnoli

These are the private quarries and are being mainly used for the supply of stones for road and building construction. The projected quantity area of these quarries is as indicated below.

Quarry Site	Quantity area (acre)
Borshetti	8
Kirat	6.5
Nagzari	30
Girnoli	15

Figure 8-20 Borsheti Quarry Location

Figure 8-21 Kirat Quarry Location

Figure 8-22 Kirat Quarry Location

Currently, there is no road connectivity to the quarries from the nearby roads. New road connectivity from the near road as well as some localized road improvement measures will need to be undertaken near the quarries and near the project site to enable moving of the large quantity of stones by road using truck.

The transportation operation will involve development of roads from quarry to the project site. The proposed external railroad corridor passes close to the proposed quarry location. It is proposed that JNPA should initially implement the proposed external road connectivity to the port to facilitate the movement of trucks carrying construction material. Also, based on the quality of stones and material available, quarries at Gargaon and Khanivade followed by other quarry can be selected for implementation at that JNPA which is located close to the proposed road connecting the port.

The selected contractor needs to construct the road connecting the quarries to the nearby road for the efficient movement of rock dumpers to the port site. Figure 8-23 describes the transportation process assumed for rock required for breakwater and shore protection construction.

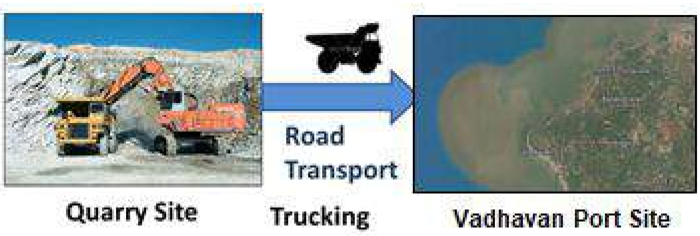


Figure 8-23 Transportation from Quarry Site

8.3 Berthing Facilities

8.3.1 Location and Orientation of Berths

The Phase 1 development of Vadhavan port has been planned with major development of 4,000 m of container berths with 1000 m for each terminal, an Bulk Liquid berth, 2 Liquid bulk berths, an Other Liquid berth, 3 Multipurpose berth, RO-RO berth and TUG/ port craft and coast guard berth. Container berths have been planned in North-South as well as East-West direction forming a U-shaped dock.

The container berths are located approximately at the depth of 15 to17 m considering the navigational depth requirement and existing rock levels.

Similarly, multipurpose berths are provided on the southern side of the harbour along a straight berthing line oriented at an angle of 283° N and RO-RO berth is provided at 15 m depth in North-South direction considering the navigation requirement. The port crafts and coast guard berth are provided in line with the multipurpose berth on the southern side of the harbour.

8.3.2 Deck Elevation

The maximum wave height expected at the berths under design conditions have been taken from the CWPRS design wave height report. The deck of the berths should be high enough to prevent the wave slamming underneath during extreme weather conditions. This deck level will also ensure adequate clearance to the deck during operational wave conditions. Sea level is currently rising and is expected to continue rising during 21st century. This would mean about 0.2 m increase in sea levels over life of the structures (50 years).

The maximum significant wave height expected at the location of container berths is about 1.0 m as per CWPRS model studies, under the normal weather conditions (wave height of 3.0 m outside port basin at -24 m depth).

It has been proposed by JNPA to adopt a deck level for the berths and marine structures by considering the operational conditions and to bench mark the same with existing facility at JNPA. Hence for assessing the deck top levels of berths, the following levels are considered during operating conditions.

Mean High-Water Springs (HHWS)	4.7	m CD
Add for Wave Crest Height (0.7 *Design wave)	0.7	m
Clearance for Sea level rise (50 Yr.)	0.2	m
Clear freeboard allowance	0.5	m
Add for Deck Thickness	1.5	m
Total	**7.6**	**m CD**

The existing deck elevation at JNPA is +7.1 m CD, which is comparable with the proposed deck elevation. Hence a deck elevation of +7.6 m CD will be considered for all berths at Vadhavan port. The deck level will be revisited during the detailed design stage.

Approach trestle deck levels will be kept same as to match the deck levels of the Berth/Jetty Head.

8.3.3 Design Criteria

8.3.3.1 Design Ship & Dredged Level

The structural design of the berths shall be carried out for the design dredged level in the ultimate stage based on the design vessel sizes to be handled at these berths:

Table 8-13 Design Ships and Dredged Levels at Various Berths

S. No.	Cargo	Design Vessel Size (DWT)	Design Vessel Dimensions (m)			Minimum Designed Dredged Level at Berth (m w.r.t. CD)
			LOA	Beam	Loaded Draft	
1.	Container/ Car	24,000 TEU	400.0	61.0	16.5	-19.5
2.	General Cargo	50,000 DWT	210.0	32.3	10.5	-12.6
3.	Liquid bulk	20,000 DWT	174.0	24.5	9.8	-11.4
4.	Bulk Liquid	45,000 DWT	180.0	30	10.5	-14.90
5.	Other Liquid	2,67,000 m^3	345.0	53.8	12.65	-14.30
6.	RO - RO	8,000 CEU	221.0	32.0	11.3	-13.5
7.	Port Crafts	100 T Tugs	32.7	10.7	4.7	-6.0
8.	Coastguard	2000 T	90.0	18	3.5	-4.3

8.3.3.2 Geotechnical Criteria

The brief description of the existing geotechnical information at site has been provided in Section 3.5 of this report. Preliminary design of the berths has been carried out considering relevant subsoil profiles at the location of berths.

The following safety factors are used to establish the safe geotechnical working load capacities of the piles.

Table 8-14 Adopted Values for Factor of Safety for Piles

Pile loading	Factor of Safety
End Bearing	SF = 2.5
Skin Friction on compression piles	SF = 2.5
Skin Friction on tension piles	SF = 3.0
Lateral Load	SF = 2.0

For the ground conditions found at the site, the contribution to the pile capacity of the materials overlying the rock will be insignificant and will be ignored. The pile capacity will be calculated based only on the rock layer.

The geotechnical design of the piles will consider the following:

- The axial compression capacity will be assessed using an overall factor of safety of FS=2.5. In this case, the relative contributions of the shaft and base resistance will be considered based on the ratio of the pile embedment length in the rock and the pile diameter (i.e., L_s/D_s, L_s=Length of pile embedded in the rock and D_s=Diameter of the pile shaft).
- The design for pull-out (tension) will be carried out based on side shear resistance and cone-pull-out resistance. Then, the required pile length will be estimated based on whichever governs.
- For the piles subjected to lateral load and bending moment, design for lateral load and bending moment capacities will be carried out using factor of safety of 2.5.
- For the structural modelling of piles, approximate pile depth of fixity will be estimated based on the rock mass modulus, E_m. In this case, the sensitivity ranges of the rock mass modulus will also be assessed. In this case the contribution of the overburden materials may be considered.

8.3.3.3 Termination Criteria

To ensure that the bearing stratum is not weaker than considered in design for pile termination, one of the following criteria shall be followed during execution:

- Chiselling energy criteria
- SPT test criteria
- Extraction of Cores at termination depth

Geological identification of the rock samples collected from the pile bore shall be done at site. Specified socket lengths in highly weathered to slightly weathered basalt shall be measured after identification of the respective strata as above. The decision of the Engineer regarding identification of rock strata and depth of penetration into the rock strata shall be final and binding on the Contractor. The following may be considered as a guideline for identifying the start of rock and termination level.

- Start of rock shall correspond to PPR value of 50 T-m/m^2/cm corresponding to safe resistance of 10 T/m^2.
- Termination shall correspond to PPR of 100 Tm/m^2/cm corresponding to safe end bearing resistance of 500 T/m^2.

8.3.3.4 Design Loads

The principal loads that will be considered for the design of berths and approach trestles are as follows:

Dead Load

It comprises the self-weight of the structure plus superimposed loads of permanent nature are considered as per IS: 875 (Part-I) 1987 and other codes as appropriate. The self-weight of the element will be based on the density of the material.

The following unit weight of materials will be considered for calculating the dead weight of members:

Table 8-15 Unit Weights of Materials

Material	Unit Weight (kN/m^3)
Concrete (reinforced)	25
Steel	78.5
Concrete (plain)	24
Seawater	10.25
Marine growth	14
Wearing Coat	25

The berth and approach trestle design will consider superimposed dead loads due to the following appropriately:

- Any kind of substructure, superstructure and permanent installations like equipment, services, foundations, and structures for services etc.
- Weight of loading and unloading cranes, any other material handling equipment.
- Unloading arms and associated topside facilities for Liquid/ Bulk Liquid/ Other Liquid terminals.
- Piping, piping manifolds and valves, cable trays, crossovers etc.
- Conveyor systems and associated structures.
- Fire monitor towers, retractable gangways, and any other operational facilities.
- Fenders, quick release mooring hooks, constant tension winches or bollards
- Roadway and associated traffic structures, kerbs, traffic barriers etc.

Live Loads

Following minimum live loads will be considered in the design of berths:

Table 8-16 Live Loads for different berths

Live Loads	Container Berth	Multipurpose/ RO-RO Berth	Tug/Port Craft/ Coast Guard Berth	Approach Trestle to various berths
Deck UDL	50 kN/m^2	30 kN/m^2	20kN/m^2	50 kN/m^2 for Container 30 kN/m^2 for MPB

Vehicle and Crane Loads

The following loads are considered on various berths:

Table 8-17 Vehicle and Crane Loads for different berths

Live Loads	Container Berth	Multipurpose/ RO-RO Berth	Tug/Port Craft/ Coast Guard Berth	Approach Trestle
Vehicular Loading	IRC class A/ AA/ 70R (Wheeled or tracked)	IRC class A/ AA/ 70R (Wheeled or tracked)	IRC class A/ AA/ 70R (Wheeled or tracked)	**For Trailers:** IRC class A/ AA/ 70R (Wheeled or tracked) **For Rail:** 32.5 tonne axle load with 12 T/m trailing load
Construction Load	2.5 kN/ m²	2.5 kN/ m²	2.5 kN/ m²	2.5 kN/ m²
Equipment Loads	– -Rail mounted quay cranes for handling containers. – -Reach Stacker	These loads are only for Multipurpose berths and are as follows – -Loads from ship loaders/ unloaders/ mobile harbour cranes. – - Loads from conveyor system.		**For Trailers:** Loads from conveyor system, pipelines, etc. **For Rail:** Locomotive – 9000 HP- 12000 HP Wagon – 25 tonne Axle loads Diesel Traction: for internal Port yard movement

Notes:

1. *For the approach trestles of the island jetties, UDL of 10 Kpa, IRC loads, 50 T mobile crane, any loads from the pipeline services and construction load of 2.5 Kpa are considered.*
2. *The live load of 5 Kpa is considered for all the dolphins and catwalks.*
3. *For the unloading platform, UDL of 10 Kpa, IRC loads, any loads from the pipeline services and construction load of 2.5 Kpa are considered. Apart from this, suitable loads are applied to account for the elevated platforms that would be casted on the unloading platform.*

The number, type and capacity of cranes and equipment proposed to be used on each berth will be considered during detailed engineering. Equipment and their combinations will be such that, this will produce the critical maximum stresses. Appropriate dynamic factors will be considered for the mobile equipment.

Seismic Loads

Earthquake loads will be adopted as applicable for the site as per IS 1893 – 2016. Vadhavan falls under Zone III, as per the seismic map of India shown in IS 1893-2016. However, considering the importance of structures, Zone IV has been considered in design parameters with the following factors.

- Zone Factor Z : 0.24 (for Zone IV)
- Importance factor, I : 1.5
- Response Reduction Factor, R : 3 (For Ordinary RC moment resisting frame)
- Avg. response acceleration coeff. (S_a/g) : Depends on time period of structure
- Damping percentage : 5%, for RCC and 2% for Steel structures

Wind Loads

As per IS Code 875 – Part 3: Code of Practice for Design Load (Other Than Earthquake) for Buildings and Structures for calculating the wind loads on the structures for a basic design wind speed of 44 m/s has been used as per the Indian standards. However, during the operational conditions, the wind speed has been limited to 20 m/s only.

However, during design studies the wind pressure shall be determined from the design wind speed in accordance with BS 6399 Part 2:1997.

During extreme wind conditions, 50% of the live load will be considered.

Current Loads

Current forces are determined as per IS 4651 (Part III) – 1974 and pressure due to current will be applied to the submerged area of the structure. Hydrodynamic study report from CWPRS (Report No. 5583) shows a maximum current of 0.35 m/s at the project location. However, conservatively for the structural design purpose a current velocity of 1.0 m/s shall be considered on the submerged parts for the marine structures.

Wave loads

Wave force are calculated using Morrison's equation and an appropriate theory. Based on this, a design wave height of 1 m and 2 m will be considered for the operational and extreme conditions respectively with wave period of 12 s. These are the maximum wave heights that could be expected at the berths and approach trestle locations.

Temperature, Shrinkage and Creep

Design temperatures rise and fall of ± 20°C will be considered for the analysis of structures. In addition to temperature fall of 20°C, equivalent temperature fall of 13°C will be considered towards shrinkage.

The co-efficient of thermal expansion for concrete shall be considered as 12 × 10-6/°C.

Creep coefficient of 1.1 will be used for calculating long term effects.

Mooring Loads

The mooring requirements for each berth will be as per the recommendations of IS 4651 Part-III. The following bollard pulls will be considered for the design of the structure.

Table 8-18 Bollard Pulls on Various Berths

Parameter	Multipurpose Berths	Container berths	Liquid Berths/ Bulk Liquid	Other Liquid berth	RO-RO Berth	Port Craft / Coastguard Berth
Bollard Pull (T)	100	200	100 (QRMH)	150 (QRMH)	100	10

In the design stage, the capacity of bollards shall be determined in accordance with BS: 6349 from the mooring loads generated by the design maximum vessel when in ballast and at full displacement under the combined action of the maximum current flow, the operational wave conditions at the berth and the design wind conditions.

For Other Liquid, Bulk Liquid and Liquid jetties, mooring requirements will be as per the relevant OCIMF guidelines.

Berthing Loads

Berthing Energy

The berthing force will be calculated in accordance with IS 4651 Part-III. Based on the design ships to be handled at various berths, the approach velocity perpendicular to the berths has been assumed based on the design vessel size under difficult berthing conditions. The approach angle of 10° has been considered for the vessels lesser than 50,000 DWT and likewise 6° for vessels larger than 50,000 DWT. Based on this, the design berthing energy for various design ships has been worked out.

The friction force of 20% will be considered in both horizontal and vertical direction.

Berthing contact will be assumed to occur on two adjacent fenders simultaneously. Berthing loads will be considered in combination with out-of-service (stowed) cranes only.

Fendering System

Considering the tidal range at the site and also the variation in the sizes of vessels to be handled at the jetty, the fendering system is designed such that sufficient contact area between the hull of the ship and the fender face is ensured at all tidal levels.

It is required to provide a suitable fender system, not only to absorb the design berthing energy of the vessel but also to keep the vessel's hull pressure below the limit of 20 T/m^2. PIANC suggests abnormal impact safety factors be applied to the design (normal) energy. Accordingly, it is recommended to design for 150% - 200% of the normal berthing energy to prevent the damage to the fenders and the ship's hull, depending upon type of the vessel. Based on these criteria the suitable fendering system has been proposed at the different berths.

Fender Reaction (berthing force)

The berthing energy and fender requirement have been arrived at for range of vessels, design ship size and other design parameters. The design ship has been arrived based on comparison with largest available vessel details in the market and its berthing criticality.

Corresponding to the energy to be absorbed and the fender selected, the design reaction force has been worked out based on the standard fender design catalogues.

The berthing energy, fender selection and the berthing force applied at various berths is given in the following table:

Table 8-19 Berthing Energy, Fender Type and Reaction at various berths

Component	Multipurpose Berths	Container berths	Liquid Berths	Bulk Liquid Berth	Other Liquid berth	RO-RO Berth	Port Craft/ Coastguard Berth
Berthing Energy (kN m)	1,971	2,970	925	2,268	2,423	2,736	61
Fender	SCN-1600 F 1.8 or equivalent cone fender	SCN-2000 F 1.0 or equivalent cone fender	SCN 1300 F.1.2 or equivalent cone fender	SCN-1800 F 1.0 or equivalent cone fender	SCN-1800 F 1.2 or equivalent cone fender	SCN 1800 F.1.7 or equivalent cone fender	AN-500 E 1.5 or equivalent arch fender
Berthing Reaction (kN)	2,385	2,950	1,348	2,406	2,536	2,920	372

In addition, a horizontal and vertical force component equal to 20% of the above transverse berthing force is also applied simultaneously on the fender point to account for the friction between the ship's hull and the fender. The parameters of the fender need to be confirmed after getting the exact details from the supplier during the detailed engineering stage.

Load Combination

The above loads with appropriate load combinations, as per IS 4651 (Part 4): 2014 and IS 1893 (Part 1): 2016 have been applied on the different components of the berths.

Material and Material Grades

Concrete Strength

All reinforced and unreinforced concrete structures will be in accordance with the requirement of IS: 456 and will be of minimum strength as mentioned in below table.

Table 8-20 Concrete Strength

Design Element	Minimum Strength Class	Minimum Cement Content (kg/cum)	Maximum Water Cement Ratio
Reinforced Concrete	M40	400	0.4
Plain Cement Concrete	M25	310	0.4

Steel Strength

The Reinforcement steel will be of grade Fe 500D (corrosion resistant) and comply with the requirements of IS: 1786.

The structural steel work of rolled sections, plates, bars, hollow sections, nuts, bolts, and washers for structural connections will comply with the requirements of IS: 2062, IS: 1161 and IS: 4923. The minimum yield stress requirement for various structural members is presented in below table.

Table 8-21 Material Grades

Item	Minimum Yield Stress (Mpa)
Primary Members	345
Secondary Members	250
Misc. items like plates, gratings, handrails, chequered plates etc	250
Hollow Sections	240

Partial safety factor

The following partial safety factors are considered for the material strength

- Concrete 1.5
- Reinforcement 1.15

The equations and tables for limit state design incorporates γ_m values given in IS 456:2000.

Concrete Cover

Nominal Cover of reinforcement in all structural elements will be as per Table 16 of IS 456-2000. For maintaining proper cover, concrete cover blocks are proposed to be used.

Clear cover to the outermost reinforcement (for precast or cast in-situ RC) members will be as follows:

- Beams and pile muffs 50mm
- Concrete piles, fender block 75mm

Increase in Permissible Stresses

Increase in permissible stresses will be allowed as per the recommendations of IS 4651 Part IV – Table 2.

Serviceability Criteria

Crack Control

The crack width checks will be carried out for two scenarios.

- The structural elements will be checked for crack width for load combinations of limit state of serviceability, in accordance with provisions of IS: 456-2000. Crack width for final section with final loading will be calculated and will not exceed 0.2mm.
- For sustained condition: Under DL + 50% LL + operation wave and current, crack width will not exceed 0.1 mm

Deflection Limits

Deflection will be co-related with the material handling system and equipment installed above the deck. Deflection limit will be mutually agreed and acceptable to MHS contractor and top side facility contractor during detailed engineering stage.

Horizontal deflection limit: The maximum horizontal displacement of the berth will be limited to:

- For operating condition : L/350
- For extreme condition : L/250

Horizontal deflection limit for Bulk Liquid, and Liquid Jetties:

- For operating condition : L/350 (UP, AT)
- For extreme condition : L/350 (UP, AT)

Where,
"L" is the distance between deck centre lines to the point of fixity of the pile.
"UP" and "AT" are unloading platform and approach trestle respectively.

Structural Design and Analysis

- Unless otherwise tated, berth structure & other concrete structures are designed in respect to defined load combination cases under ultimate limit state to confirm the section dimensions, quantity of reinforcement in accordance with IS 456.
- Three-dimensional structural analysis of the structure will be conducted under all specified load combinations in STAAD Pro.
- P-delta analysis will be considered.
- Reinforced concrete members will be designed and detailed as per IS 13920:1993 for ductility conditions, if required.

8.3.4 Alternatives for Berth Structure

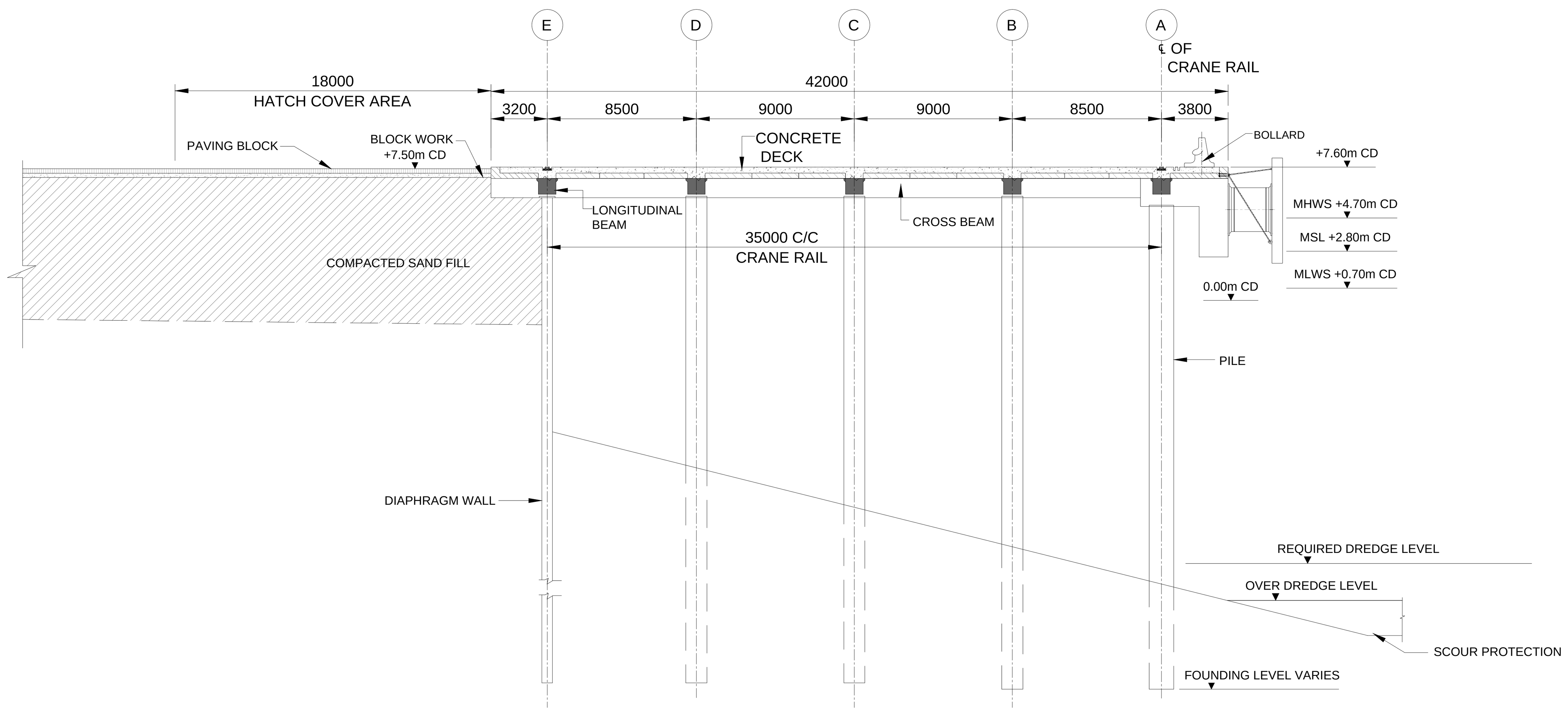
Various alternative structures were considered for evaluation of suitable berthing facility at Vadhavan. The structures include block work, caisson, counterfort, cantilever, sheet piles/ diaphragm wall.

The port facilities are proposed on reclamation area. Considering this aspect and also the requirements of keeping the berth structure contiguous to the shore, following alternative structures were considered shown in as shown in

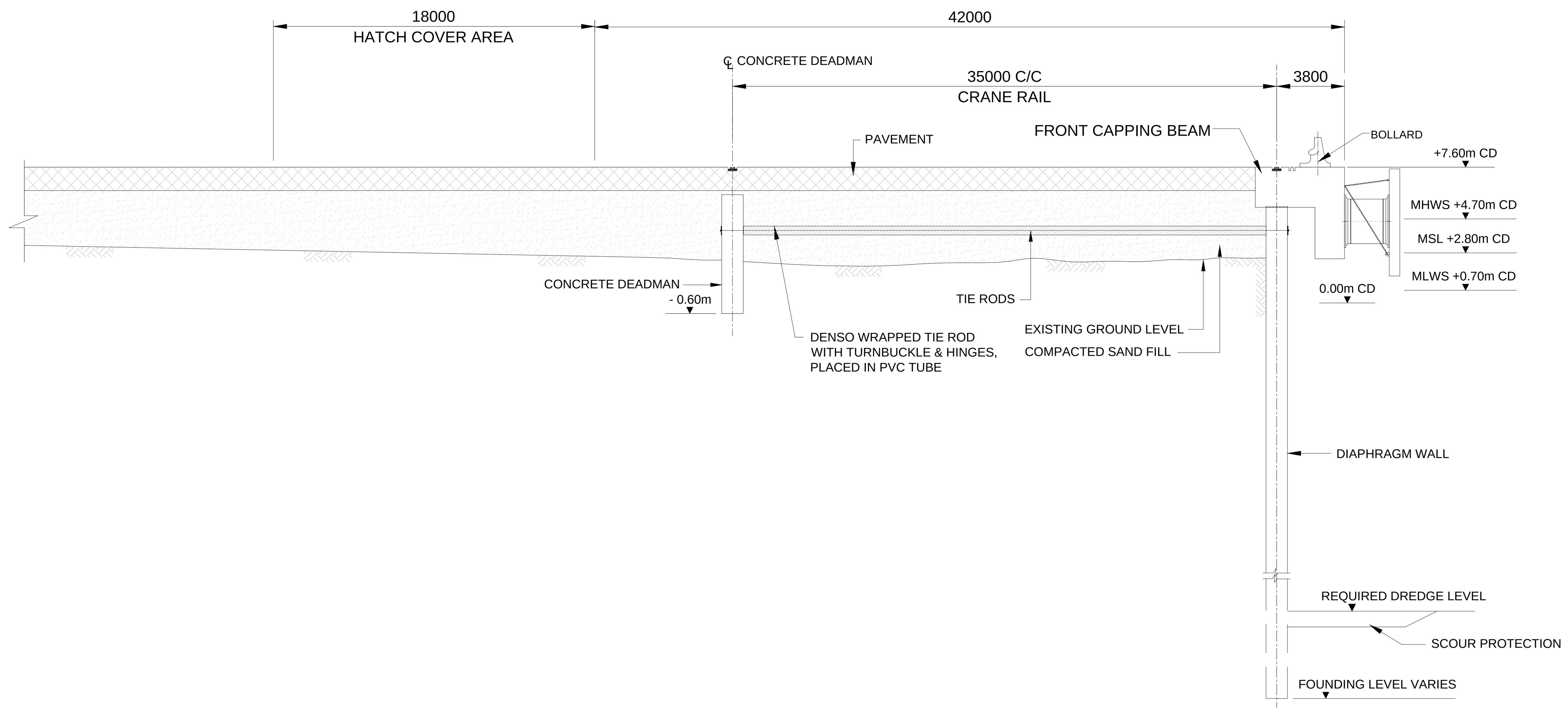
DO NOT SCALE

NOTES

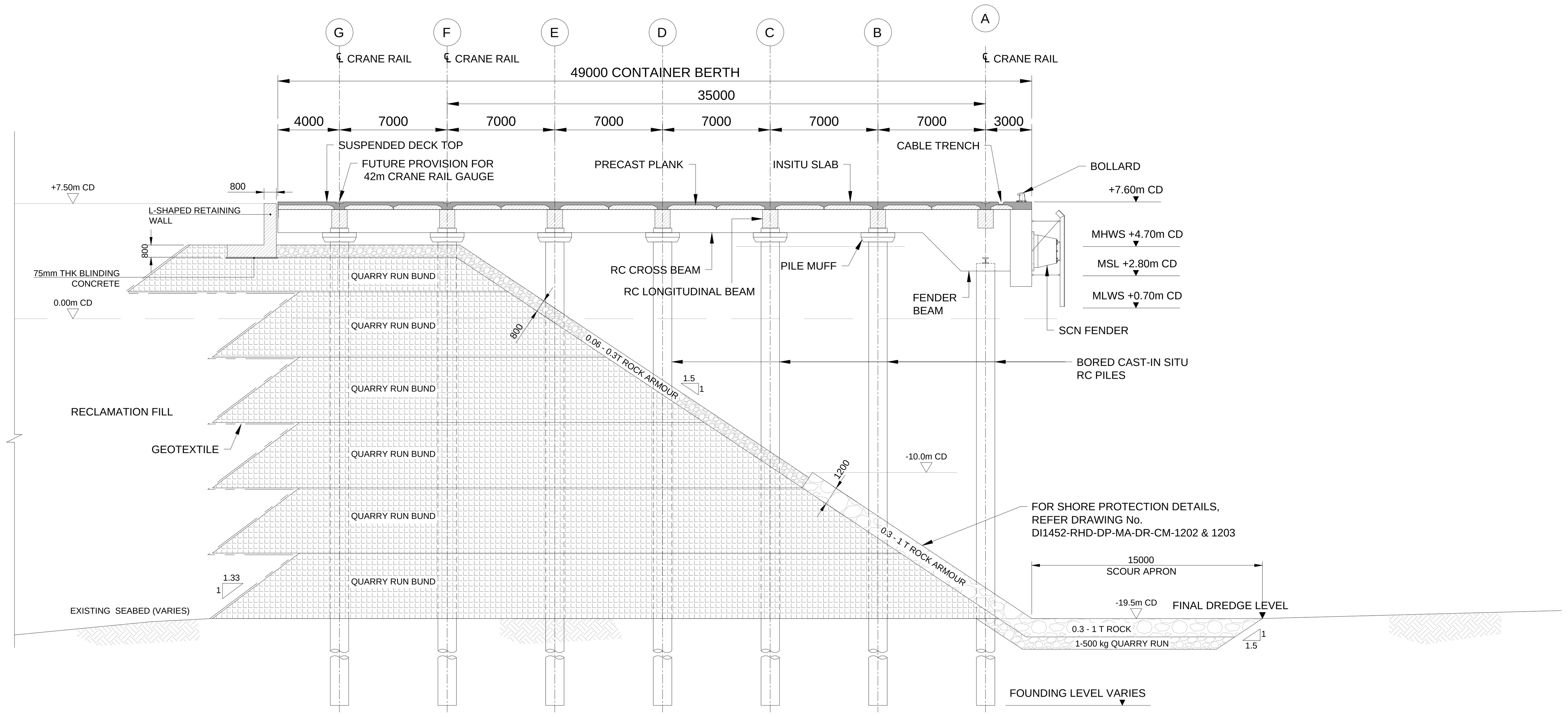
1. ALL DIMENSIONS AND LEVELS ARE IN METERS, UNLESS NOTED OTHERWISE.
2. DRAWINGS ARE NOT TO BE SCALED, ONLY WRITTEN DIMENSIONS ARE TO BE FOLLOWED.



ALTERNATIVE-1 : BERTH SUPPORTED ON PILES WITH DIAPHRAGM WALL AT REAR



ALTERNATIVE-2 : BERTH SUPPORTED ON DIAPHRAGM WALL WITH RELIEVING PLATFORM



ALTERNATIVE-3 : BERTH SUPPORTED ON PILES WITH RETAINING WALL AT REAR

TITLE: VADHAVAN PORT ALTERNATIVE BERTH STRUCTURE OPTIONS	PROJECT: Consultancy services for Design and Detailed Engineering for Greenfield Vadhavan port project	CLIENT: JAWAHARLAL NEHRU PORT TRUST	CONSULTANT: Royal HaskoningDHV Enhancing Society Together	Job No. DI1452	DATE NOV. 2021
				ACAD Ref. -	CHECKED MS
				DRAWN ZR	DRG No. FIGURE 8.24
				SCALE 1:500	PASSED ASM
				REV B	

502-505, 5th Floor, Platinum Techno Park, Plot 17 & 18, Sector 30A, Vashi, Navi Mumbai - 400 703, INDIA
Tel +91 (0) 22 41615000
Email mail@haskoningindia.co.in
Website www.royalhaskoningdhv.com

8.3.4.1 Alternative I: Berth supported on piles with diaphragm wall at the rear

Considering the difficulties likely to be encountered in creating a stable slope through the hard rock in the layers below the design dredged level another alternative has been proposed where a diaphragm wall is provided in the rear of the berth and the slope underneath the deck is left as a natural slope. The diaphragm wall is integrated with the piled structure, which would be designed to carry the lateral loads on the diaphragm wall. A natural bed slope of 1 V: 4 H from the berth face has been assumed on a conservative side for design of the diaphragm wall.

8.3.4.2 Alternative II: Berth Supported on Diaphragm Wall

In this type of structure, the face of the berth will be a continuous diaphragm wall. The quay apron comprises a hard stand pavement. The diaphragm wall is tied back to a concrete dead man. The dredging is carried out once the diaphragm wall is built and anchored to the dead man. Alternatively, in the container berth area (where rock is relatively shallow) rock anchors could be used to tie back diaphragm wall, but these are not preferred due to varying rock levels along the container berths.

In the zones where the soil conditions above rock level are poor it would be required to anchor the wall into the rock strata and therefore concrete diaphragm wall would be favourable over sheet pile walls, which cannot be driven to the rock for the necessary anchorage.

8.3.4.3 Alternative III: Berth supported on piles with a protected slope underneath

In this alternative, it is considered to provide the deck structure on the piled foundation. A stable slope of 1.5 H: 1 V from the design dredged level at the berth face to the rear end is provided. The width of the apron in this case is considered as 42 m. A retaining wall of suitable height would be provided in the rear end to make the structure contiguous. It is proposed to provide bored cast-in-situ piles for reasons of economy. The berth face is dredged only after the piles are tied by grid beams but before the construction of the deck, the opening for which is utilized for trimming of the slope underneath. Once the design slope and slope protection are formed, the deck is cast.

The comparison of the above options is as indicated below.

Table 8-22 Comparison of the Alternatives for berth Structures

Description	Alternative 1/ Alternative 2	Alternative 3
Features	Alternative I and II involves excavation of a trench with vertical sides, using a bentonite slurry to prevent the sides collapsing. A reinforcement cage is lowered through the slurry and tremie concrete is poured into the trench displacing the slurry. The strength of the wall can be matched to the required strength by arranging the excavated sections in the shape of a 'T' (or similar). Designs for this project have been considered with the web of the T facing in either direction (seaward or landward).	The ground investigations show that the rock layer is not far below the dredged level. Piles will be bored to the depth where the rock layer can be found.
Advantages	• Reasonably low cost. • Design can be adapted to provide good durability.	• Reasonably durable, particularly if concrete piles are used. • Costs are not heavily influenced by variations in soil properties. • Use of local materials.

Description	Alternative 1/ Alternative 2	Alternative 3
		• Rigid deck between crane rails, which avoids any future problems with differential settlement. • The piles will be socketed in hard rock, available at shallow depth below the dredge level. • No deep-seated failure of the under-deck revetment likely since the rock is at shallow depth. • Relatively steeper slope of the revetment is possible, minimizing the deck width, thereby reducing cost.
Disadvantages	• Not suited to the geotechnical conditions at the site: difficult to excavate the trenches in hard rock. • Specialist technique – requiring input from international experts. • Durability dependent on good workmanship and inspection.	• Relatively high cost. • Possible increase in construction time in case hard rock is encountered. • Sourcing of revetment core material
Conclusion	Alternative I and II are rejected, as it would be difficult to excavate the trenches in hard rock.	Avoidance of construction work that must be carried out underwater is an important goal in modern berth design. Emphasis is placed on the application of construction method that allow as much work as possible to be carried out from a position above water, thus keeping the amount of diving at a minimum. Pile structures are ideal in this respect. Consequently, alternative III is considered appropriate for preliminary design.

8.3.5 Container Berths

8.3.5.1 Functional Requirements

In Phase 1 of the port development, four container terminals each of 1,000 m with a total length of 4,000 m is proposed for the development. I In view of the ship to shore transfer system of container handling, these berths will be contiguous to the reclaimed land so that the operational area is not restricted. The reclaimed land area for the container terminals is connected through approach trestles to the shore.

8.3.5.2 Geotechnical Conditions for Container Berths

Container Terminals CT1, CT2, CT3 and CT4

Geotechnical investigation data for the entire area of proposed container terminals is not available since inadequate boreholes were explored in this area. However, geotechnical profiles along MBH-43, MBH-47, MBH-50 and MBH-52is referred which is in the vicinity of the proposed terminals. The Borehole profile is included in section 3.5.1. The seabed level in these boreholes varies from -3.5 m CD in MBH-50 to -13.3 m CD in MBH 52. From the bathymetry survey data, it can be observed that seabed level in the proposed container terminal area varies from -12.5 m CD to -16.4 m CD.

The borehole profile along MBH-43, MBH-47, MBH-50 and MBH-52indicate presence of silty sand layer of approximately 3 m to 3.6 m thick followed by silty clay layer of about 2m to 4.25m thick. The silty clay layer in MBH- 43, MBH-50, MBH-52, and silty sand layer in MBH-47 is underlain by weathered basalt. From the available isopach, rock level at these locations varies from -18 m CD to -20 m CD. All these boreholes were terminated at 20 m below the seabed.

Geotechnical information obtained from the above-mentioned boreholes will be used for detailed design of piles.

8.3.5.3 Construction Methodology

The ground level at the proposed location of the container berths is about -13 m to -16 m CD. The soil profiles at the container berths reveal the presence of silty sand layer from level of approximately -13.1 m CD to -16.7 m CD. This layer has got good shear strength and any dredging carried out at front of the deck, after construction, might not impact on the stability of the structure. The construction sequence duly takes this factor into account. The rock level varies from -16.5 m on the southern end to -17.1 m at the northern end of container berth.

It is proposed to first reclaim the site using the suitable dredged spoil up to a level of +6.0 m CD. The reclamation of dredged spoil is to be carried out in stages forming the small bunds which is protected by the quarry run material to avoid slipping of dredged spoil due to current flow and also optimise the quantity of quarry bund.

The bored cast in-situ piles supporting the quay deck are then constructed using the land-based equipment. The erection of pile muff longitudinal and transverse beams connecting the berth piles are also constructed using land-based construction. After the integration of beam with pile is established, the dredging operation in the berth area can presume, until the design dredged level of -19.5 m CD. The soil behind the berth is strengthened using vibro compaction along with the hydraulic fill.

It is expected that the soil mass within the piles would form a natural slope through hydraulic filling after the dredging in front of berths is carried out. A stone pitching is then placed below the deck from the ultimate dredged level to the quay wall at a slope of 1 in 1.5. The retaining wall is constructed behind the berth to retain the reclaimed fill. Once the retaining wall is placed reclamation material is filled and thoroughly compacted with the help of vibro compaction.

The concrete deck for the berth and the fixtures is placed thereafter.

Drawing DI1452-RHD-DP-MA-DR-CM-1204 presents the construction sequence of container berth.

8.3.5.4 Structural arrangement of Container berth

Basic engineering of the proposed scheme was carried out based on the design criteria established above. The width of the proposed berths is considered as 49 m with ship to shore (STS) container handling cranes mounted on rails spaced at 35 m with the provision of increasing the rail gauge to 42 m to cater futuristic vessels and the remaining area for hatch cover and other functional requirement. The berths are proposed as open piled structures.

Each berth is a concrete deck structure resting on vertical concrete pile foundation extending up to the rock stratum. The proposed scheme consists of seven rows of bored cast-in-situ piles, spaced at 6.5 m c/c in the longitudinal direction. The berth will comprise a deck supported on beams running in longitudinal and transverse directions, which are supported at grids by concrete piles. Crane rails are running on crane beams and are supported by piles at suitable intervals. Cantilever portion of RC fender beam and fascia block are provided for supporting fender installations and bollards. Bollards and rubber fenders will be provided at 19.5 m c/c along the berthing face. A service trench will be provided on the berthing side to accommodate cables/utilities.

The RMQC will move over rails crane rails (CR 120) provided on the berth. The rails will be fixed on the berth with base plate and bolts, the gap in between the base plate and deck will be grouted with non-shrink compound. Edge angles and bituminous concrete will be provided for enabling movement of trucks and trailers over the rails.

Drawing DI1452-RHD-DP-MA-DR-CM-1205 presents the general arrangement and cross section of container berth.

8.3.6 Multipurpose Berth

8.3.6.1 Functional Requirement

Three number of multipurpose terminals are proposed with a total length of 750 m. Since the multipurpose berths have to handle vessels of different size ranges and different cargo, pneumatic mobile harbour cranes are proposed at the berth. The wheel spacing of the mobile harbour cranes is considered as 10 m leading to a total width of berth of 24 m.

In addition to this, the approach trestle connecting the nearshore reclamation will have a provision for conveyor corridor, which will be used for handling fertilizers. The conveyor corridor will be planned as steel structures fixed on the main girders of the approach trestle. The backup area required for the storage of the cargo handled is provided on the offshore reclaimed land at the rear side of the berth.

8.3.6.2 Geotechnical conditions for Multipurpose berth

Geotechnical investigation data at the location of proposed multipurpose berth is referred from borehole MBH-54. Also, geotechnical profile along MBH-58 to MBH-54 is referred which is in the vicinity of the proposed multipurpose berth. Geotechnical profile considering the boreholes to the vicinity of multipurpose is included in this report. The seabed level in these boreholes varies from -10.9 m CD to -13.7 m CD. From the bathymetry survey data, it can be observed that seabed level along the multipurpose berth varies from -9.6 m CD to -12.7 m CD. The same is in line with seabed observed in the reference boreholes.

Borehole MBH-54 shows presence of silty sand layer of 3 m, which is followed by silty clay layer of about 3.35 m thick and which is underlain by weathered basalt.

These boreholes were drilled upto a depth of 20 m. Geotechnical information obtained from the above-mentioned boreholes will be used for design of piles.

8.3.6.3 Construction Sequence

The construction sequence for multipurpose berth is similar to the container berths with the dimensions to suit the functional requirements.

8.3.6.4 Structural arrangement of Multipurpose berth

The proposed scheme consists of four rows of bored cast-in-situ piles, spaced at 6.5 m c/c in the longitudinal direction. The berth will comprise a deck supported on beams running in longitudinal and transverse directions, which are supported at grids by concrete piles. Cantilever portion of RC fender beam and fascia block are provided for supporting fender installations and bollards. Bollards and rubber fenders will be provided at 19.5m c/c along the berthing face. A service trench will be provided on the berthing side to accommodate cables/utilities.

The berths are proposed to be constructed as an open piled structure.

Drawing DI1452-RHD-DP-MA-DR-CM-1206 presents the general arrangement and cross section of Multipurpose berth and approach trestle.

8.3.7 Ro-Ro Berths

8.3.7.1 Functional Requirement

One Ro-Ro berth of length 250 m to handle vessels of 8,000 ceu (car equivalent unit) is proposed. No separate provisions have been made for the roll on and roll off operations of the cargo on the berth such as ro-ro ramp. It is considered that the operations will be handled by the inbuilt ramp of the Ro-Ro or car carrier ships. Backup area required for the storage of cars and other cargo is provided on the reclaimed land at the rear of the berth.

8.3.7.2 Geotechnical conditions for Ro-Ro Berths

Geotechnical investigation data at the location of proposed Ro-Ro berth is not available since no boreholes were explored in this area. However, geotechnical profile along MBH-58to MBH-55 is referred which is in the vicinity of the berths. The profile of the seabed strata for Ro-Ro berth was developed considering the boreholes in the vicinity of the proposed structure. The seabed level in these boreholes varies from -11 m CD to -13.7 m CD. From the bathymetry survey data, it is observed that seabed level in the proposed Ro-Ro berth varies from -12.9 m CD to -13.4 m CD. The same can also be verified from the borehole profile.

Boreholes MBH-58 & MBH-55 indicate presence of silty sand layer followed by silty clay which is underlain by weathered basalt. Thickness of the silty sand and silty clay layer in these boreholes are 1.6 m and to 4.4 m respectively. All these boreholes were drilled upto a depth of 20 m below seabed.

8.3.7.3 Structural Arrangement of RO-RO Berth

The Ro-Ro berth is proposed as a conventional piled berth. The structural arrangement is similar to that of multipurpose berth.

Drawing DI1452-RHD-DP-MA-DR-CM-1207 presents the general arrangement and cross section of RO-RO berth.

8.3.8 Tug/Port Craft and Coast Guard Berths

8.3.8.1 Functional requirements

One berth of 200 m length for port crafts and 100 m length for coastguard is proposed for Phase 1 development to cater the berthing facilities.

8.3.8.2 Geotechnical conditions for Tugs/ Port Craft berth and Coastguard Berth

Geotechnical investigation data at the location of proposed Tugs/ Port Craft berth and Coast guard berth is referred from MBH-56 which is in the vicinity of the berths. Additionally, profile along MBH-54 and MBH-22 can also be referred. The profile of the seabed strata port craft and coastguard berth was developed considering the boreholes in the vicinity of the proposed structure. The seabed level in these boreholes varies from -8.6 m CD to -13.3 m CD. From the bathymetry survey data, it is observed that seabed level at the proposed port craft and coastguard berth varies from -3.9 m CD to -5.1 m CD. The same can also be verified from the borehole profile.

Borehole MBH-56 indicate presence of silty sand layer followed by silty clay which is underlain by weathered basalt. Thickness of the silty sand and silty clay layer in the borehole is 2 m and to 3 m respectively. The borehole was drilled upto a depth of 20 m below seabed.

8.3.8.3 Structural arrangement of Tug/ Port craft berth and Coastguard berth

The tug/ port craft and coastguard berth are proposed as a conventional piled berth. A vehicle access lane of width 5 m is provided on top of the deck and access stairs to access the tugs and port crafts during various water levels are also provided.

Arch rubber fenders and bollards will be provided along the berthing face for the proposed berthing arrangement. A service trench will be provided on the berthing side to accommodate cables/utilities.

Drawing **DI1452-RHD-DP-MA-DR-CM-1208** presents the general arrangement and cross section of Port Craft berth.

8.3.9 Approach Trestle for Road and Rail Movement

Two approach are proposed one to cater for road movement of trailers and another for rail movement. The geotechnical aspects for both the trestles will be same differing only with the functional requirements as discussed below.

8.3.9.1 Functional Requirements

The proposed container terminals, multipurpose terminals, RORO, port craft and coastguard berths are catered with a common approach trestle. An offshore area is reclaimed to facilitate the storage and yard operation for these terminals. The trestle will facilitate the movement of trailers.

A separate trestle is proposed for the rail movement connecting the nearshore and offshore reclamation area where the rail yard is located for container evacuation.

8.3.9.2 Geotechnical aspects

Geotechnical investigation data for the entire length of proposed Approach Trestle is not available since no boreholes were explored in this area. Only MBH-17 can be referred which is located at the rear of the reclaimed land at the vicinity of the proposed trestle. Geotechnical profile considering the boreholes in the vicinity to the approach trestle is included in this report. The seabed level in MBH-17 is -3.9 m CD. From the bathymetry survey data, it can be observed that seabed level along the approach trestle varies from -0.3 m CD m towards landside end to -3.2 m CD into the sea which is in line with seabed levels observed in the reference boreholes.

The borehole MBH-17 indicate presence of weathered basalt at the seabed level. This borehole was drilled upto a depth of 15 m. Geotechnical information obtained from the above-mentioned borehole will be used for detailed design of piles.

8.3.9.3 Structural Arrangement

One common approach trestle (4-lane each way) is proposed, of 40 m wide, connecting the nearshore and offshore reclamation area. The approach trestles are planned as 4-lane each way road bridges. The length of the approach trestle is 2,600 km.

The proposed scheme consists of seven rows of bored cast-in-situ piles, spaced at 13 m c/c in the longitudinal direction. In the transverse direction, main beams are provided supported over the piles, which in turn support beams in the longitudinal direction. A 500 mm thick deck slab will be provided supported over the intermittent longitudinal beams. A 75 mm thick wearing coat will be provided over the RCC deck slab.

Drawing DI1452-RHD-DP-MA-DR-CM-1209 and **Drawing DI1452-RHD-DP-MA-DR-CM-1210** presents cross sectional arrangement of approach trestle for road movement of trailers and rail connecting the nearshore and offshore reclamation area to cater the container terminals, Multipurpose berth, RO-RO berth and Tug/Port craft and coast guard berth for Phase 1 as well as the master plan development respectively.

8.3.10 Other Liquid Berth

8.3.10.1 Functional Requirement

One Other Liquid berth with FSRU arrangement has been proposed to cater Other Liquid carriers. With this arrangement, it is proposed that the Other Liquid cargo is directly connected the supply grid running close to the Vadhavan port. The design philosophy for the initial assessment of the mooring and berthing layout is based on the relevant guidelines published by the Oil Companies International Marine Forum (OCIMF guidelines – 2nd edition 1997 & MEG4 edition 2018) and relevant BS Codes. The design guidelines considered are as follows:

Dolphin Spacing

- Breasting (fender) dolphin spacing: 25% to 40% of LOA, to locate on parallel body side. It should be noted that for Other Liquid ships, consideration will be given to spacing the exterior breasting structures no more than 35% of the ship LOA as their parallel mid-body lengths are generally smaller compared to other ship types.
- Inner mooring dolphin spacing: 80% LOA
- Outer mooring dolphin spacing: 135% LOA.

Mooring Dolphin Set-Back

As a standard recommendation, 35 – 50 m setback will be used. However, more rigorous and detail computational analyses for mooring, berthing / de-berthing, navigation, etc. should be undertaken during the detailed design stage to optimise the set-back value.

Quick Release Hooks

Minimum 1.5 m above highest water level will be ensured.

Mooring Line Angle Criteria

The below table presents mooring line angle criteria.

Table 8-23 Mooring Line Characteristics

Mooring Lines	Characteristics
Head / stern lines	Head and stern lines are inefficient in providing restraint capacity. However, a mooring point which provides a good breast line lead for a larger ship, becomes a head or stern line mooring point for a smaller ship. Thus, where a wide range of vessels to be handled will require head and stern dolphins for first line ashore.
Breasting lines	Breast mooring lines to be at an angle of 15 degrees to the perpendicular axis of the ship.
Spring lines	A horizontal angle of 10 degrees to the side of the ship will be considered for spring mooring lines.
Vertical angles	Maximum vertical angles of 25 degrees will be assumed for the lightest ballasted condition. Vessels with highly eccentric manifold positions may require special arrangements.

Deck Top Elevation

All structure top levels such as breasting dolphins, mooring dolphins and unloading platforms are considered at +7.5 m CD. Elevated platforms may be provided at the unloading platforms to support the export/ unloading arms. This will be decided and done by the topside design consultant during the detailed engineering.

The final elevation of deck, structures, quick release hooks etc. will be established based on a more rigorous vertical envelope study with the entire range of vessels to meet the above mooring line criterion and recommended set back distances.

8.3.10.2 Ground conditions for Other Liquid Berth

MBH-14 is the nearest borehole for the proposed Other Liquid berth. The seabed level at this borehole location is observed as -18.1 m CD. This borehole was drilled upto a depth of 20 m below seabed. From the bathymetry survey data, it was observed that seabed level in the proposed Other Liquid Berth area varies from -17.4 m CD to -18.3 m CD, which is in line with the seabed level observed in MBH-14.

Borehole MBH-14 indicate presence of silty sand layer of 3.6 m thick underlain by weathered basalt.

8.3.10.3 Structural Arrangement of Other Liquid Berth

The proposed layout of the Other Liquid jetty and the associated components are described below: The main components include:

- Unloading platform
- Approach trestle
- Breasting dolphins

- Mooring dolphins
- Catwalks

The Other Liquid terminal has been proposed to have one unloading platform, three breasting dolphins and eight mooring dolphins to facilitate the mooring and berthing of FSRU and Other Liquid carriers.

Unloading Platform

The unloading platform generally consists equipment that form the basis for the geometry, structural configuration, and design of the platform. Modern FSRU's uses same technology as onshore terminals and are fitted with all necessary equipment.

A 50m x 50m platform is proposed as a preliminary to accommodate the gas export arms or regasification systems and gas send out pipelines, fire monitor tower and other equipment. This requirement may vary according to the scheme adopted and top side requirements.

Unloading platform will be made of structural members such as bored cast in situ RC piles, precast and cast in-situ combined superstructure. Any other supports on the superstructure to account for equipment's or other operational aspects will also be provided. However, this is will be investigated in detail engineering stage.

The regasification units are integrated to the FSRU vessel and required gas export arms at the platform to send out the gas-to-gas grids. Another scheme for FSRU is that the jetty or unloading platform will have the regasification units installed and the Other Liquid vessel is used as a floating storage unit (FSUs). FSUs provide an alternative to onshore Other Liquid storage tanks. This system needs Other Liquid unloading arms and vapour return arms to be installed. Unloading platform will also need to be equipped with regasification units and boiled off gas (BOG) management system.

A single fender provision is considered to provide berthing requirement for the FSRU in the (UN)loading platform also.

Breasting Dolphins

Three breasting dolphins will be required for absorbing the berthing energy of FSRU and Other Liquid carriers. These breasting dolphins and the other structures such as unloading platform, mooring dolphins will be interconnected to each other by steel walkways known as Catwalks (bridges) made of tubular steel construction.

The equipment that forms the basis for the geometry, structural configuration and design of the platform are gangway, fenders, Quick-release mooring hooks with a mooring capstan, with load cells and load monitoring instrumentation. A Docking Aid System (DAS) is also envisaged to monitor vessels that will be located on the breasting dolphins or unloading platform as required.

Berthing Dolphins will be made of structural members such as bored cast in situ RC piles, precast and cast in-situ combined superstructure. Any other supports on the superstructure to account for equipment's or other operational aspects will also be provided. However, this is will be investigated in detail engineering stage.

Mooring Dolphins

Eight nos. mooring dolphins are proposed for mooring the FSRU and Other Liquid carriers for a side-by-side berthing and ship to ship (STS) transfer. The optimized locations and arrangement of mooring dolphins will be established based on detailed layout assessment and mooring analysis studies.

These mooring dolphins and the other structures such as unloading platform, breasting dolphins will be interconnected to each other by steel walkways. The equipment that forms the basis for the geometry, structural configuration and design of the platform are Quick-release mooring hooks with a mooring capstan, with load cells and load monitoring instrumentation.

Mooring Dolphins will be made of structural members such as bored cast in situ RC piles, precast and cast in-situ combined superstructure. Any other supports on the superstructure to account for equipment's or other operational aspects will also be provided. However, this is will be investigated in detail engineering stage.

In addition to the above-mentioned equipment and structural components, the unloading platform and the dolphins will also include miscellaneous items such as handrails, anti-climb barriers all around the loading platform, safety marine ladders, service ducts, adequate drainage fall to collect storm and splash water and channel it into the sea, utilities, and other services (pipe supports, electrical pits etc).

Approach Trestle

Approach trestle connects pipelines and utility services from an unloading platform to the pipeline service trestle. The pipeline service trestle further connects it to the reclaimed land or the onshore facilities and thereby to the supply grid. The vaporised Other Liquid evacuated from the ship will be transported via pipelines directly to the gas grid. The approach trestle will support the pipe rack which carries Other Liquid pipelines, cable trays, utility lines and roadway.

Approach trestle will be made of structural members such as bored cast in situ RC piles, precast or cast in-situ RC pile muff, girders and beams, slabs etc. Support for pipe rack and cable tray, passing bay platforms, expansion loop platforms and support for roadway as well as lighting poles etc. will be provided.

An approach trestle of 10m wide is assumed to accommodate one lane roadway and the pipeline supporting structures as shown in the figure below. The pipelines and supporting structures will be designed by the top side engineer. Approximate width of 6 m is considered to accommodate all the pipelines and associated services, another 4m width is considered for approach roadway for the maintenance and access to the berth.

Drawing **DI1452-RHD-DP-MA-DR-CM-1211** presents the general arrangement and cross section of Other Liquid berth.

8.3.11 Bulk Liquid Berth

8.3.11.1 Functional Requirement

The functional requirement of Bulk Liquid berth is similar to the Liquid bulk berth to handle Bulk Liquid cargo vessels.

The berth will be designed to accommodate a vessel of capacity 60,000 DWT with a berth pocket depth of -15.5m CD. The length of the berth extending between the mooring dolphins is approximately 280m. Two unloading arms each with handling rate of 24,000 TPD together with two unloading arms as standby are proposed on the unloading platform.

Approach trestle connects pipelines and utility services from an unloading platform to the pipeline service trestle. The pipeline service trestle further connects to the tankfarm located onshore. The approach trestle will support the pipe rack which carries Bulk Liquid pipelines, cable trays, utility lines and roadway.

8.3.11.2 Ground conditions for Bulk Liquid Berth

MBH-57 and MBH-60 are the nearest borehole to the proposed Other Liquid berth. The seabed level at this borehole is observed as -17.4 m CD and -14.9 m CD respectively. These boreholes were drilled upto a depth of 20 m below seabed. From the bathymetry survey data, it was observed that seabed level at the proposed Bulk Liquid berth area varies from -12.9 m CD to -14.9 m CD, which is in line with the seabed level observed in the reference boreholes.

Borehole MBH-57 indicate presence of silty sand layer followed by silty clay layer underlain by weathered basalt. Thickness of the silty sand layer and silty clay layer in these boreholes is 3 to 4 m and 5 m respectively.

8.3.11.3 Structural Arrangement of Bulk Liquid Jetty

Suitable size and number of mooring and breasting dolphins are proposed similar to the liquid bulk jetty. Unloading platform will be made of structural members such as bored cast in situ RC piles, precast and cast in-situ RC pile muff, beams, slabs etc. Support for unloading arms, support for fire monitor (if provided), supports for the above-mentioned equipment and supports for catwalks are also provided.

Two breasting dolphins are provided, and these are connected to the other structures such as unloading platform, mooring dolphins through steel walkways. The equipment that forms the basis for the geometry, structural configuration and design of the platform are fenders, Quick-release mooring hooks with a mooring capstan etc. A Docking Aid System (DAS) is also envisaged to monitor vessels will be located on the breasting dolphins or unloading platform as required.

Breasting dolphins will be supported in bored cast in situ RC piles, precast RC pile muff, precast plus cast in situ RC longitudinal beam, precast plus cast in situ RC cross beams, precast slab planks plus cast in situ slabs, support for fenders, Quick-release mooring hooks and supports for catwalks.

Six mooring dolphins are proposed for mooring the Bulk Liquid carriers. These are made of structural members such as bored cast in situ RC piles, precast RC pile muff, precast plus cast in situ RC longitudinal beam, precast plus cast in situ RC cross beams, precast slab planks plus cast in situ slabs, supports for Quick release hooks and constant Tension Mooring Winches and supports for catwalk.

An approach trestle of 10 m wide is assumed to accommodate one lane roadway and the pipeline supporting structures. The pipelines and supporting structures will be designed by the top side engineer. Approximate width of 6 m is considered to accommodate all the pipelines and associated services, along with that another 4m width is considered for approach roadway for the maintenance and access to the berth.

Catwalks are used for connecting the dolphins (Both berthing and mooring) to the unloading platform. These are made up of steel tubular members.

Drawing **DI1452-RHD-DP-MA-DR-CM-1212** presents the general arrangement and cross section of Bulk Liquid berth.

8.3.12 Liquid Bulk berth

8.3.12.1 Functional requirement

Two liquid berths are proposed for handling of liquid cargo, i.e., for chemicals and for edible oil. The depth required at the berth is -11 m CD to handle a maximum vessel size of 20,000 DWT. The proposed berth includes 1 no. of unloading platform, 2 no. of breasting dolphins and 4 no. of mooring dolphins. The unloading platform will house the unloading arms for unloading cargo and pipe rack to support the pipes carrying cargo from the platform to storage tanks. The pipelines and supporting structures will be designed by the top side engineer.

Approach trestle connects pipelines and utility services from the unloading platform to the pipeline service trestle. The pipeline service trestle further connects to the onshore facilities via pipelines. The approach trestle will support the pipe rack which carries pipelines, cable trays, utility lines and roadway. Approximate width of 6 m is considered to accommodate all the pipelines and associated services, along with that another 4 m width is considered for approach roadway for the maintenance and access to the berth.

8.3.12.2 Geotechnical conditions at Liquid bulk berth

MBH-58 is the nearest borehole for the proposed Liquid Bulk berth. The seabed level at this borehole is observed as -13.7 m CD. This borehole was drilled upto a depth of 20 m below seabed. From the bathymetry survey data, it can be observed that seabed level at the proposed liquid bulk berth area varies from -11.7 m CD to -14.1 m CD, which is in line with the seabed level observed in MBH-58.

Borehole MBH-58 indicate presence of silty sand layer followed by silty clay which is underlain by weathered basalt. thickness of the silty sand and silty clay layer in these boreholes are 1.6m and to 4.4m respectively.

8.3.12.3 Structural arrangement of Liquid bulk berth

The overall structural arrangement consists of an unloading platform, 2nos berthing dolphin and 4nos mooring dolphins interconnected with catwalks.

Unloading platform will be made of structural members such as bored cast in situ RC piles, precast and cast in-situ RC pile muff, beams, slabs etc. Support for unloading arms, support for fire monitor (if provided), supports for the above-mentioned equipment and supports for catwalks are also provided.

Two breasting dolphins are provided, and these are connected to the other structures such as unloading platform, mooring dolphins through steel walkways. The equipment that form the basis for the geometry, structural configuration and design of the platform are feners, Quick-release mooring hooks with a mooring capstan etc. A Docking Aid System (DAS) is also envisaged to monitor vessels will be located on the breasting dolphins or unloading platform as required.

Breasting dolphins will be made of structural members such as bored cast in situ RC piles, precast RC pile muff, precast plus cast in situ RC longitudinal beam, precast plus cast in situ RC cross beams, precast slab planks plus cast in situ slabs, support for fenders, Quick-release mooring hooks and supports for catwalks.

Four mooring dolphins are proposed for mooring the Liquid bulk carriers. These are made of structural members such as bored cast in situ RC piles, precast RC pile muff, precast plus cast in situ RC longitudinal beam, precast plus cast in situ RC cross beams, precast slab planks plus cast in situ slabs, supports for Quick release hooks and constant Tension Mooring Winches and supports for catwalk.

An approach trestle of 10 m wide is assumed to accommodate one lane roadway and the pipeline supporting structures. The pipelines and supporting structures will be designed by the top side engineer. Approximate width of 6m is considered to accommodate all the pipelines and associated services, along with that another 4m width is considered for approach roadway for the maintenance and access to the berth.

Catwalks are used for connecting the dolphins (Both berthing and mooring) to the unloading platform. These are made up of steel tubular members.

Drawing **DI1452-RHD-DP-MA-DR-CM-1213** presents the general arrangement and cross section of Liquid bulk berths.

The ship to shore transfer system for the Other Liquid, Bulk Liquid and liquid cargo does not warrant continuous berth structure and contiguity with the land. Therefore, these berths will be built as piled jetty on the leeside of main breakwater. Depending upon the timing of the backup area development, the approach to the berth may be built using the end on construction method, whereas the berthing jetty could be built using the marine rig.

8.3.13 Service Trestles for Bulk Liquid, and Liquid Berths

Other Liquid, Liquid and Bulk Liquid berths are proposed to be developed under different concessions. However, an approach and pipeline trestle has been considered based on a shared operation for Liquid bulk and Bulk Liquid pipelines routed through a common trestle. A dedicated service trestle is proposed for the Other Liquid facility. These two service trestles comprise of 4 m single lane road and 6 m wide pipeline corridor connecting the onshore facilities through approach trestles of the respective island jetties. There will be an access trestle to the breakwater from the Other Liquid service trestle.

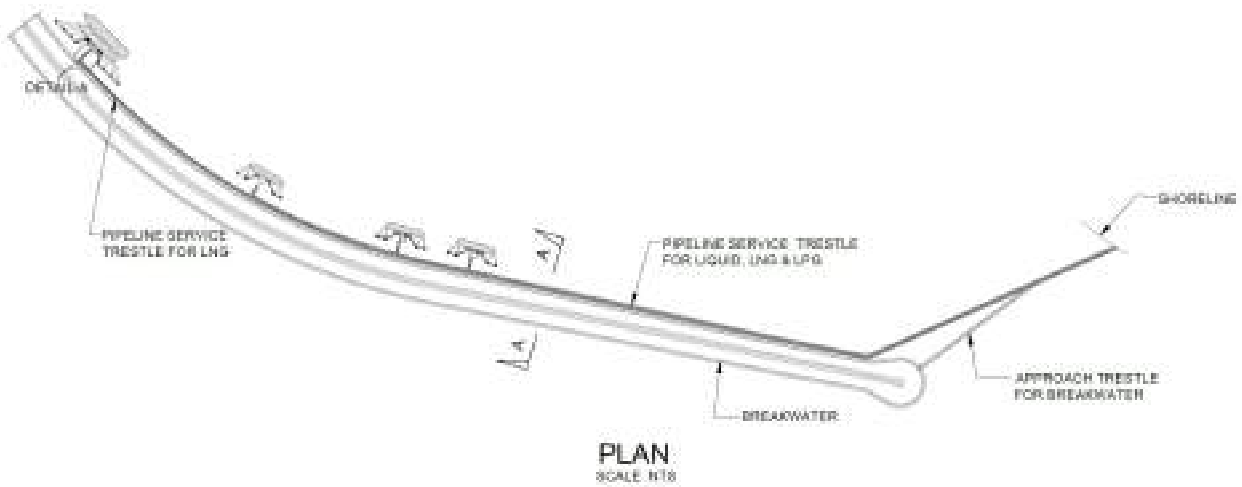


Figure 8-25 Layout Plan of Pipeline Service Trestle

Drawing **DI1452-RHD-DP-MA-DR-CM-1214** presents the arrangement plan and cross sections of the pipeline service trestles.

8.4 Dredging and Reclamation

8.4.1 Capital Dredging

Dredging and reclamation is one of the major costing parameters for any port project. The proposed port site is characterized by available depths with 20 m contour located at 11,500 m from the shore. This substantially reduces the dredging cost and hence enabling the port to provide berthing ability for the largest container vessels (up to 24,000 TEU). The port intends to utilize reclaimed land for the port backup facilities. The volumes have been calculated based on the bathymetry information of the site.

Table 8-24 Volume of Dredging in various Areas for the Vadhavan Port

S. No.	Dredge Area	Dredged Depths (m CD)	Dredge Volume (m^3)	
			Soil	*Rock*
1.	Approach Channel	-20	717,648	-
2.	Turning Circle and Manoeuvring area	-17.5	2,261,410	2,263,990
3.	Berths pockets			
	– CT 1	-19.5	446,684	26,620
	– CT 2	-19.5	300,294	18182.2
	– CT 3	-19.5	143,853	161,395
	– CT 4	-19.5	102,246	537,364
	Total (cum)		**3,972,136**	**3007,552**
	TOTAL (Soil +Rock) (cum)		**6,979,688**	

Based on the information from geophysical and geotechnical surveys, it is estimated that the volume also consists of rock dredging. The overburden from the approach channel and harbour basin shall be dredged using the cutter suction dredger of suitable power to dredge rock up to compressive strength of 20 MPa. The rock dredged using cutter suction dredger shall be mostly in the pulverised form and could be pumped ashore for the purpose of reclamation.

8.4.2 Characteristics of Dredged Material

Based on the available data from geotechnical investigation carried out in this area, the primary characteristics of materials to be dredged as per the laboratory test results and dredging effort required is discussed below.

- The dredge levels vary from -20.0 m CD at the entrance channel to -17.5 m CD in the basin area with -19.5 m CD at the container berth terminals.
- In absence of sufficient boreholes at the berth location and channel, MBH-35, MBH-37, MBH-40, MBH-42, MBH-43, MBH-44, MBH-45, and MBH-47 have been considered for the present study. Out of these boreholes, MBH-43, MBH-45, and MBH-47 show the presence of weathered rock above dredge level. Weathered rock is encountered at -16 m CD in MBH-45, -16.7 m CD in MBH-47 and -17.1 m CD in MBH-43. Hard rock is encountered below -27.1 m CD in MBH-43 hence dredging in hard rock is not anticipated.
- Core recovery values in weathered rock generally varies from 24 to 34% above dredge level and corresponding RQD values varies from Nil to 12%.

- Although values of rock strength are not available in above mentioned boreholes at shallower depths, based on our understanding of general geology in the area, weathered basalt is envisaged with rock strength varying from 6 to 51 MPa with an average of 19 MPa.

The dredged material is considered suitable for reclamation.

8.4.3 Utilisation of Dredged Material

The geotechnical investigation borehole data at the site reveals that the subsurface generally consists of marine deposited silty sand followed by rock for the full depth of exploration in the approach channel area while layers of silty sand and rock were encountered in the terminal area.

The borehole data within the proposed channel area was analysed to understand the properties of dredged material. Profile across the boreholes MBH-37, MBH-35, and MBH-40 at the outer approach channel reveal presence of silty sand of 3 m thick. The weathered rock is encountered below -20 CD, therefore certain amount of rock dredging is also anticipated in the outer channel.

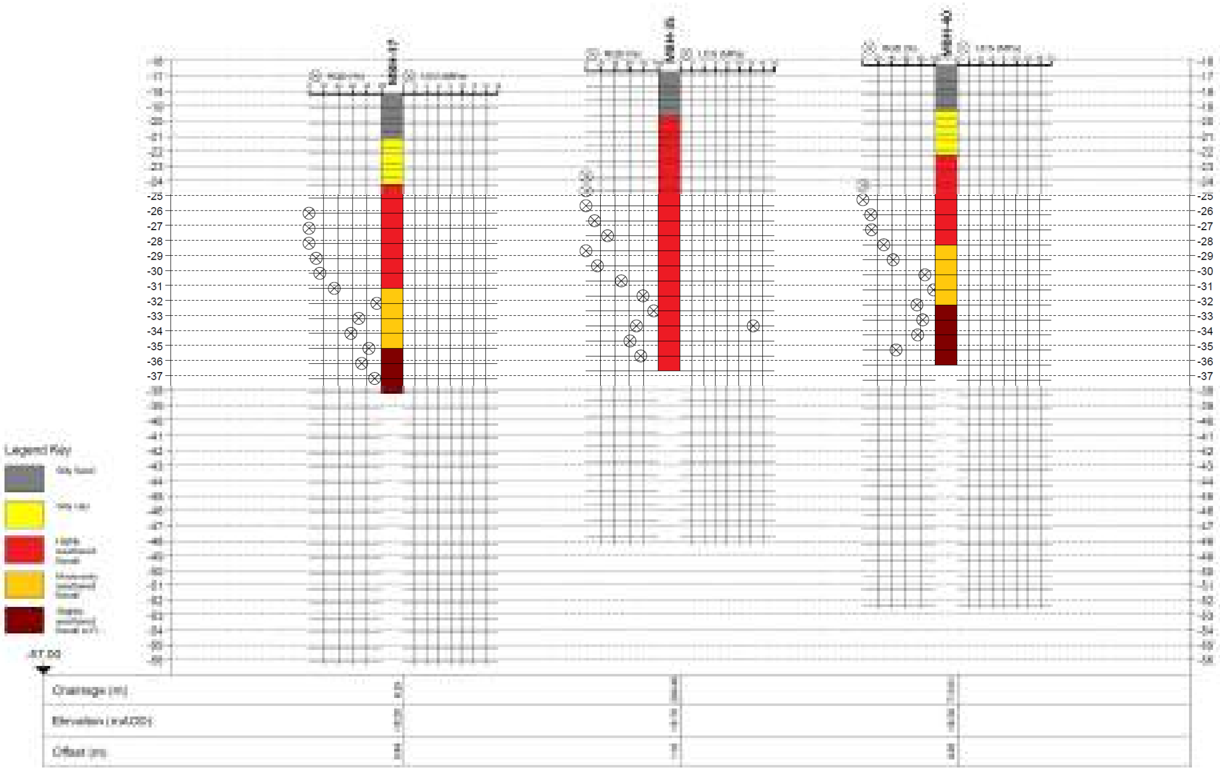


Figure 8-26 Borehole profile along the outer approach channel

Along the inner channel, two boreholes MBH-19 and MBH-47 available at the southern edge of the breakwater and profile across three boreholes MBH-46, MBH-45, and MBH-43 at the northern edge of the breakwater reveals the 4 m of silty sand overlying the weathered basalt. these boreholes show sand content in excess of 70% for the silty sand layer. The weathered rock is encountered at -17 to -22 m CD, therefore certain amount of rock dredging is also anticipated.

However, geophysical survey shows that rock layer is encountered beyond depth of -17 m CD in the outer approach channel. It is also observed that rock can be expected along the container berth face at around – 16 m CD to -20 m CD. In other areas, weathered to hard rocks are expected to be found at depths at or below -15 m CD. The dredge depths proposed for the port are deeper than rock levels and hence it is expected to encounter hard material.

The borehole profiles show that the dredge spoils (except the initial surface material up to the depth of approximately 0.5 – 1 m below the existing seabed) comprise of good quality silty sand and is suitable for reclamation for the development of the onshore facilities. The unsuitable material, such as silty clay, will be dredged and discharged to the designated offshore disposal area.

Based on these boreholes, it was deduced that the volume of sand is estimated to be in the order of 3.1 million m^3. The volume of the weathered rock is estimated to be in the order of 3.0 million m^3.

8.4.4 Tolerance Limits

Tolerance limits to be followed for the dredging works are given below:

Table 8-25 Tolerance Limits

Type of Soil	Tolerance Limits		
	Horizontal	Vertical	Side Slope
Soft clay, silt, fine dense and with silt, gravels etc.	– +100 cm total for the width of the channel	– Nothing above	1: 6 in Sand and 1: 8 in Clay
	– 0.50 m on either side	– Not more than 30 cm below	As per PIANC Guidelines
Rock without Blasting	– +100 cm total for the width of the channel	a) Nothing above	1: 1 Rock

8.4.5 Dredging Methodology

This method statement is prepared based on the information available at this stage the aim of not to freeze the methodology but to consider possible alternatives and feasibility of the dredging and shall be modified /revised by the specialised dredging contractor to be appointed through EPC tendering process. The final approach has to be developed by the contractors who are experienced and innovative in the field of marine dredging operations.

8.4.5.1 Work Method

The prevailing site conditions and equipment properties dominate the selection of the equipment and work method. The materials to be dredged consist of layers varying from coarse sand to silty clay at the top. The suitable silty sand material will be placed in the reclamation area for container yard construction. The unsuitable material, such as silty clay, will be dredged and discharged to the designated offshore disposal area. Considering the variety of soil/ rock in combination with pumping distance between the dredging and reclamation areas, the work method utilizes a large Cutter Suction Dredger (CSD).

A large Cutter Suction Dredger will be deployed to dredge the materials and hydraulically transport these to the required reclamation areas. The dredged suitable materials will be pumped ashore by means of a system of onboard dredging pumps in combination with floating, submerged and land lines.

The suitable and unsuitable soil layers will be placed in a soil model which will be loaded into the onboard dredge computer. The dredging will take place in several cuts. Based on this plan the dredge master can determine his dredging strategy and synchronize this with the reclamation crew.

8.4.5.2 Dredging by Cutter Suction Dredger (CSD)

The CSD is deployed for dredging and pumping materials directly into the reclamation area. The pipeline may consist of a combination of floating, submerged and shorelines. In this particular situation, the CSD is connected directly to a shore connection point by means of a floating pipeline where required in combination with a submerged line and there off to the reclamation area, by means of a shore pipeline. As the reclamation progresses, the shoreline will be extended. Two different pipeline configurations are schematized in the figure below.

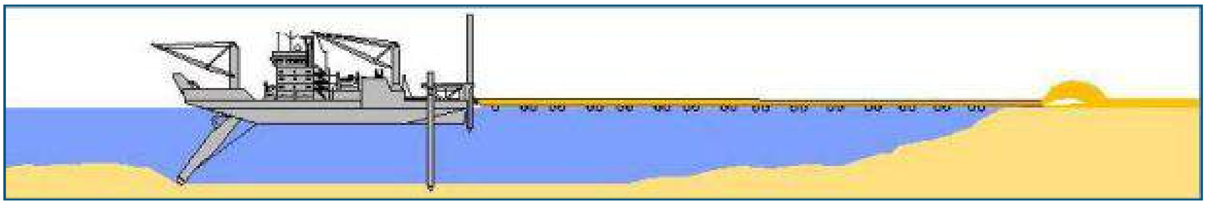


Figure 8-27 CSD Discharging Onshore through Floating Pipe

Figure 8-28 CSD Discharging Onshore through Submerged Pipe

Depending on the layer thickness to be dredged and the characteristic of the materials, the CSD will cut and dredge the material in one and more layers. On an average 0.5 m vertical over depth will be dredged by the CSD. The dredging will be carried out by using the box-cut method and slopes will be allowed to fall to natural angle of repose. The example of box-cut cross section is as shown below.

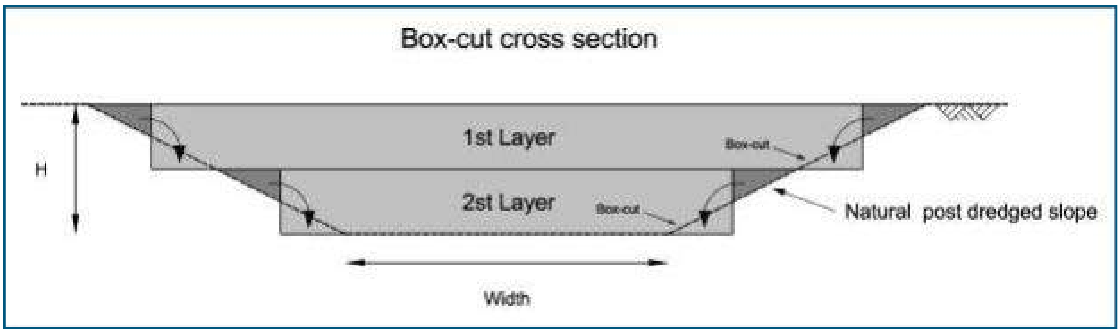


Figure 8-29 Principal of Box Cut Method

8.4.6 Maintenance Dredging

Based on the mathematical model studies on siltation, the estimate the likely rate of annual siltation for Phase 1 reveal that, the average rate of siltation in the dredged areas will be about 6.45 million cum. The siltation rates are not uniform over the area under consideration and seems to vary based on the prevailing hydrodynamic conditions. The dredged material in channel and harbour basin would be disposed at the designated dumping site offshore.

The location of the disposal site which is in deep water (beyond 25 m contour). The disposal site is spread over an area of about 20 sq. km and the depth of dumping will be restricted to only 0.5 m.

9 Preliminary Design of Landside Structures

9.1 Working Level of Backup area

Considering the level of mean high-water springs as +4.7 m CD and allowing for the operational wave height of 1.0 m, the finished levels of onshore areas will be kept at around +7.6 m CD. This level is considered adequate to avoid any flooding of site under the storm conditions and enable better planning of drainage system at site. However, during the detailed design stage, the level of the backup area will be relooked for the onshore facilities.

9.2 Reclamation

Reclamation would be needed for the access corridor from mainland and stacking areas for containers and breakbulk cargo. The reclamation level is proposed to be +7.6 m CD.

Reclamation must be carried out by allowing long passage for the material to settle down and reduce the spillage to bare minimum. Even then, it is expected that about 10% material out of the suitable fill placed would escape (i.e., escape of fines).

9.2.1 Reclamation Strategy

The development will need to include a strategy for reclamation of land behind the container berths to create container yard and other terminal facilities.

Sourcing of fill for reclamations has always been a major issue, not only for the proposed port of Vadhavan but for the other port developments throughout Maharashtra. It is unlikely that enough fill material for full development would be available from dredging within Vadhavan Port with the location being blessed with natural depths and the seabed strata encountered. Therefore, alternate sources of fill have been investigated. A brief summary of potential sources is:

- Sourcing the sand from the marine borrow area.
- Major dredging projects within the region.
- There are potential quarry sites to be utilized. The available volumes may suffice the construction requirements; however, this would lead to high transportation costs of the material resulting in the high project cost.
- Major civil and road works projects in the Vadhavan and Palghar Region.

It is expected that the reclamation strategy would include either of the above options or a combination of them.

In addition, suitable rock material needs to be sourced for reclamation protection, bunds, and breakwaters. These might comprise:

- Rock from the identified quarry sites in section 2.5.5.
- Alternate man-made protection systems such as concrete armour units (ACCROPODE, CORELOC etc.) may be required instead of rock of large size (which is usually difficult to produce).

9.2.2 Source of Reclamation

The fill for reclamation work may be obtained from dredged areas and from external marine source suitable for reclamation. The dredged material will be controlled in order to avoid build-up of fine material and the potential for the formation areas of compressible fill within the reclamation. For underwater filling the fine content in fill material will be restricted to maximum 10%.

9.2.3 Reclamation Methodology

It is estimated that around 177 million m^3 of material will be required for reclamation in Phase 1. The dredged material suitable for reclamation is around 7 million m^3. The additional material of around 170 million m^3 over the required dredging quantity may be obtained by sourcing the fill material from external source/ marine borrow pit.

The reclamation process comprises of creating bunds in the reclamation areas of suitable heights to receive the dredged material. Considering that most of the fill will be placed under water, the bunds will need to be formed of Rock/ boulders. Thereafter the reclamation levels within the bunds are raised in suitable stages, to prevent overloading of the underlying subsoil. Placement of the reclamation fill will be mostly sub-aqueous i.e., in the water body, considering that the tidal levels in the area vary between +0.0 to +4.7 m CD. Between the elevations +4.7 to +6.0 m, the placement will be sub-aerial, i.e., in the air. The reclamation sequence should be such that there is no accumulation of silt/clay at one place. The western, northern, eastern, and southern retention bunds will be constructed by rock and boulders.

As the reclamation quantity is much higher, most of the fill for reclamation works will be obtained from external source. The reclamation fill material will be placed in layers with height of each layer is suitably limited to 1.5 to 2 m underwater. The sub aerial filling will be in suitable layers of thickness 200 mm to 300 mm to achieve the required compaction as mentioned the design requirements. Enough resting period will be provided for the subsoil to gain strength after each stage of filling.

The reclamation through dredged material is proposed to be carried out upto a level of +5.0 CD. Murrum fill/ burrowed earth is proposed to be used for fill upto +7.0 followed by the pavement layers as per the design requirement.

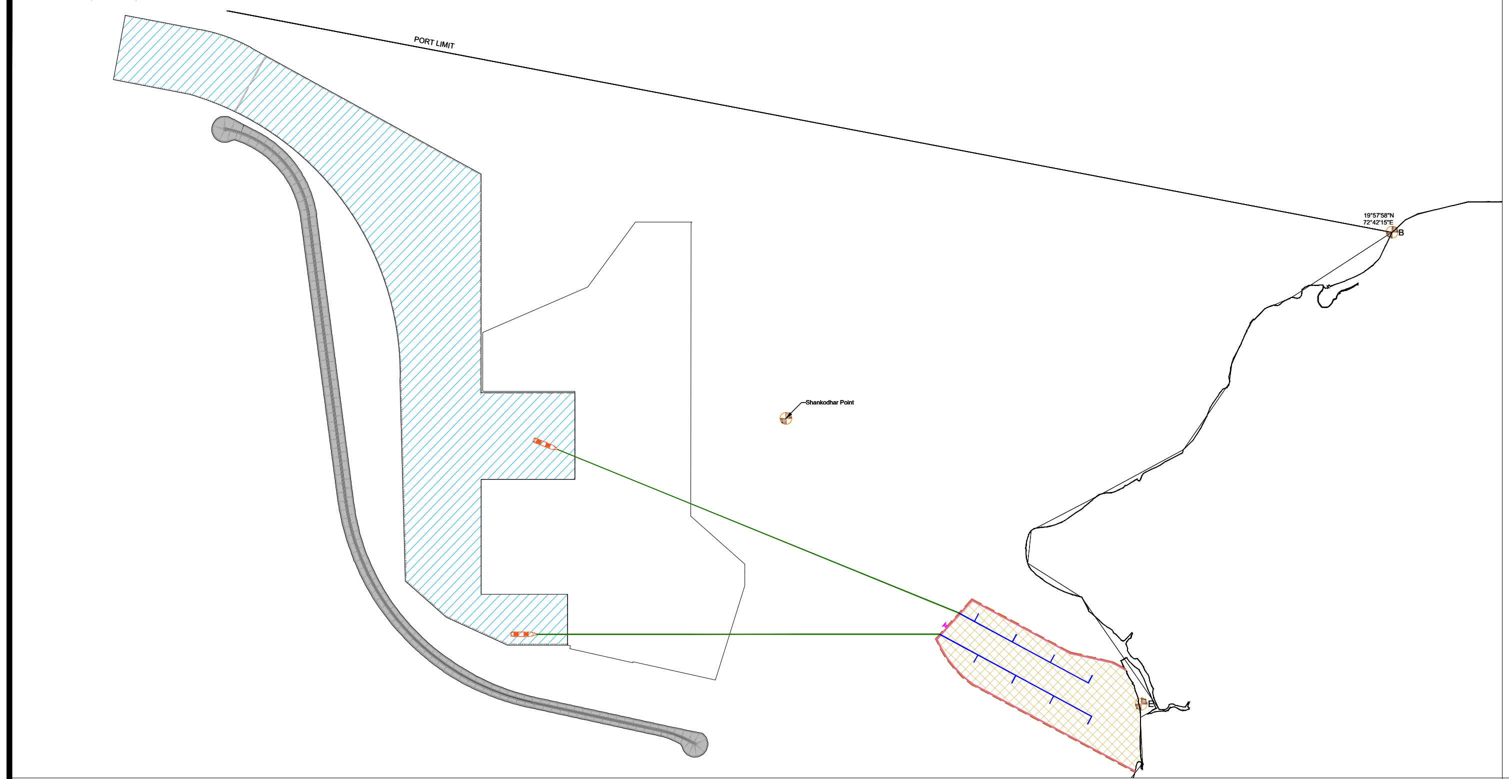
9.2.3.1 Reclamation through Dredged Material

The suitable dredged materials will be discharged by the CSD into one of the reclamation areas. Prior to commencement of the dredging and reclamation works, land-based equipment will be used to install weir boxes in between the sea and reclamation bunds (where deemed necessary). Bunds will be constructed around each of the reclamation areas prior to start filling.

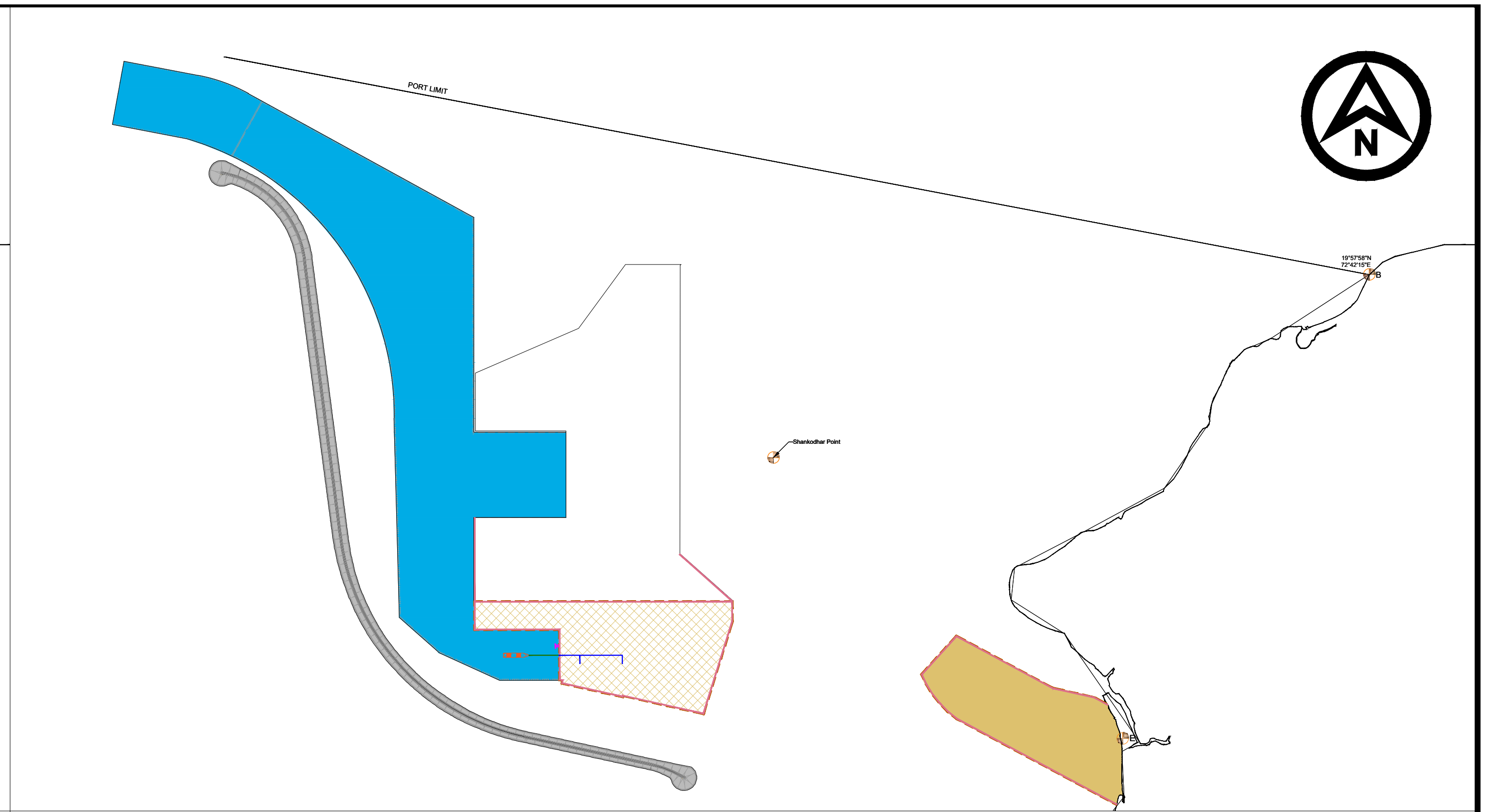
Permanent bund will be constructed partly by dredged materials and armour stones. The borders/edges (temporary bunds) of the various reclamation areas are pumped in by using hydraulic filling methods (Figure 9-1). As a result, the reclamation slopes will become natural angle of repose and will be in the order of approximately 1:7 in steepness.

After preparation of the reclamation area, the CSD will be connected to the shore connection point by means of a floating pipeline where required in combination with a submerged line. The shore connection point is installed as close as possible to the reclamation area. From this point, shore pipelines will transport the soil/water mixture to the reclamation area. The layout of the total pipeline trajectory will depend on the location of the shore connection, the local circumstances, the number of earth moving equipment available.

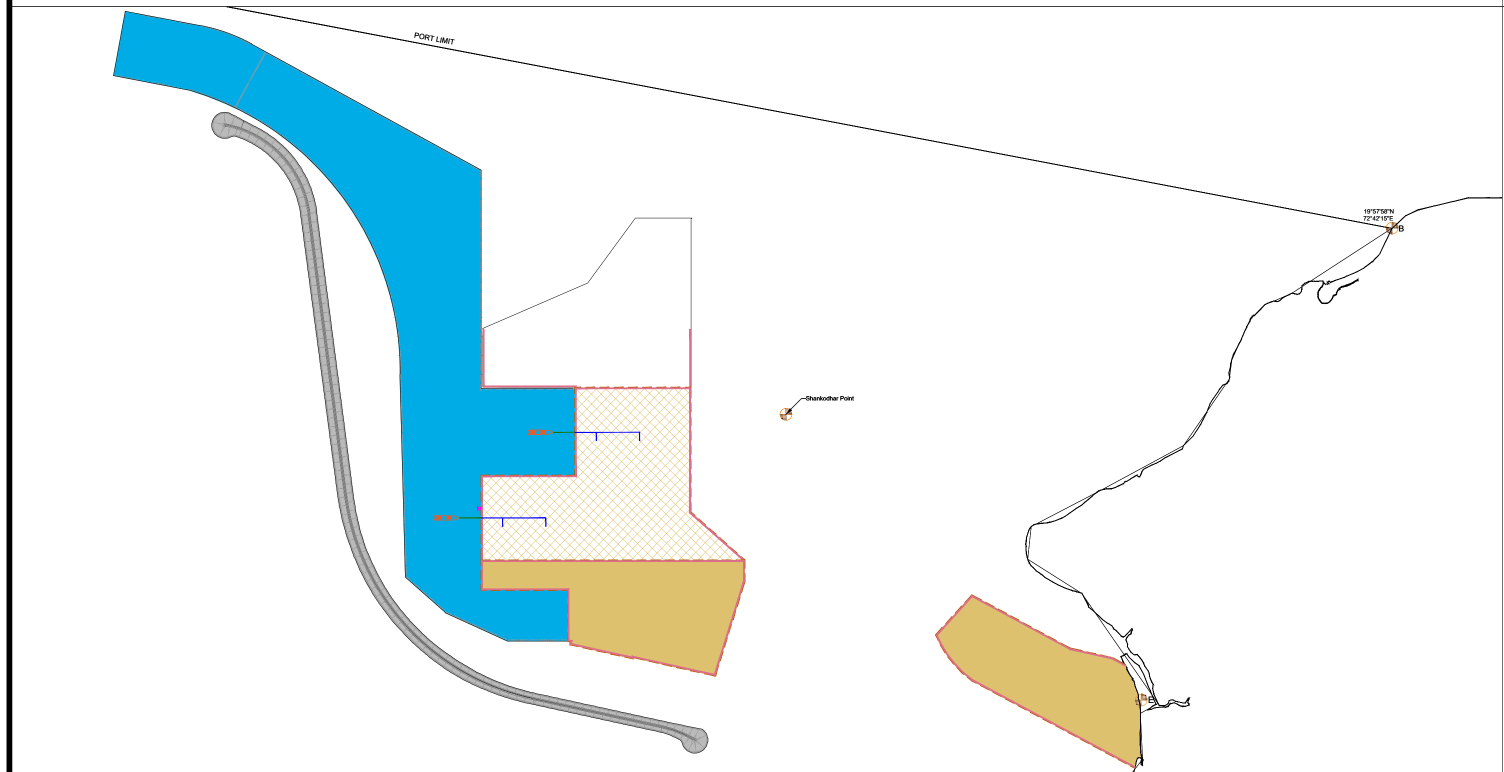
DO NOT SCALE



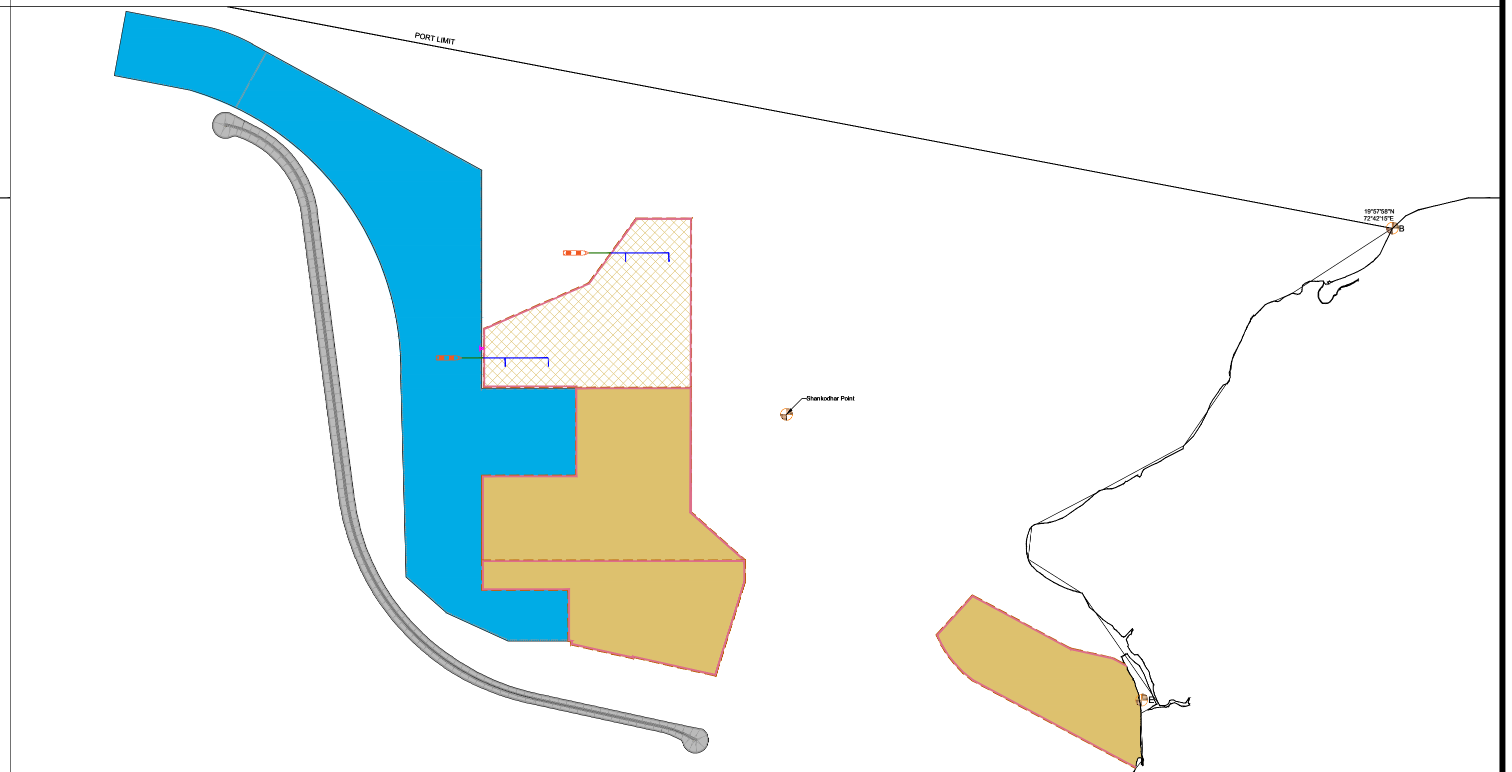
STAGE - 1
CHANNEL DREDGING AND RECLAMATION



STAGE - 2
RECLAMATION OF OFFSHORE AREA



STAGE - 3
RECLAMATION OF OFFSHORE AREA



STAGE - 4
RECLAMATION OF OFFSHORE AREA

LEGEND

- ONSHORE PIPELINE
- MARINE PIPELINE
- TEMPORARY BUND
- BUND
- WIRE BOX
- DREDGER
- DREDGING AREA
- RECLAMATION AREA
- DREDGED AREA
- RECLAMED AREA

NOTES

1. ALL DIMENSIONS AND LEVELS ARE IN METERS, UNLESS NOTED OTHERWISE.
2. DRAWINGS ARE NOT TO BE SCALED, ONLY WRITTEN DIMENSIONS ARE TO BE FOLLOWED.

TITLE	VADHAVAN PORT PHASE 1 WORK SEQUENCES FOR DREDGING AND RECLAMATION
PROJECT	Consultancy services for Design and Detailed Engineering for Greenfield Vadhavan port project
CLIENT	JAWAHARLAL NEHRU PORT TRUST
CONSULTANT	Royal HaskoningDHV Enhancing Society Together
Job No.	DI1452
DATE	OCT. 2021
SCALE	N.T.S.
ACAD Ref.	-
CHECKED	MS
PASSED	ASM
DRAWN	ZR
DRG No.	FIGURE 9.1
REV	A

The reclamation areas to be filled in maximum six layers to final fill level (+5.0 m CD). Considering vast area of the reclamation, the uniform level is maintained with appropriate slope within the yard to maintain the gravity flow. Suitable sub-grade and pavement will be used on top of the fill level for a depth of around 0.80 m. Land-based equipment will be used to spread and level the delivered materials. During the progress of the reclamation works the shore pipeline will be extended as the reclamation area is being filled with material and bunds will be raised. A cross-section for the raising of bunds is given below.

Figure 9-2 Typical Cross section of Raising of the Bunds by using Bulldozers/ Excavator

On reaching the design fill level of +6.70 m CD, vibrating roller compaction is applied before placing of the surcharge loads (if required). This is in order to reach the required 95 % MDD (Maximum Dry Density) for the top 1.5 m of the fill. After a fill area is completed, parts of the shore pipeline can be disconnected and used at the next fill area.

In order to ensure continuity of dredging and reclamation process, the reclamation area is generally laid out in such a way that there are always different discharge points available. The pipeline trajectory is arranged in such a way that switching from the suitable to unsuitable reclamation area can be made quickly using valves system. This will create certain flexibility and provide the ability to respond to external factors.

Figure 9-3 Splitting of shore pipeline to different areas

Figure 9-4 Extension of pipeline at reclamation area

The transport water will be guided through the reclamation area and in order to control the outflow of transport water from the reclamation area, Weir Box (or water boxes) is installed. With Weir boxes, the water level inside the reclamation areas can be controlled by means of changing the elevation of the weir box boards (refer Figure 9-5). By adjusting the weir level, the outflow of fines into the sea can be controlled. As a result, significantly more fines can be retained. A cross section of a weir box is shown below. This will also control the turbidity level of the sea water.

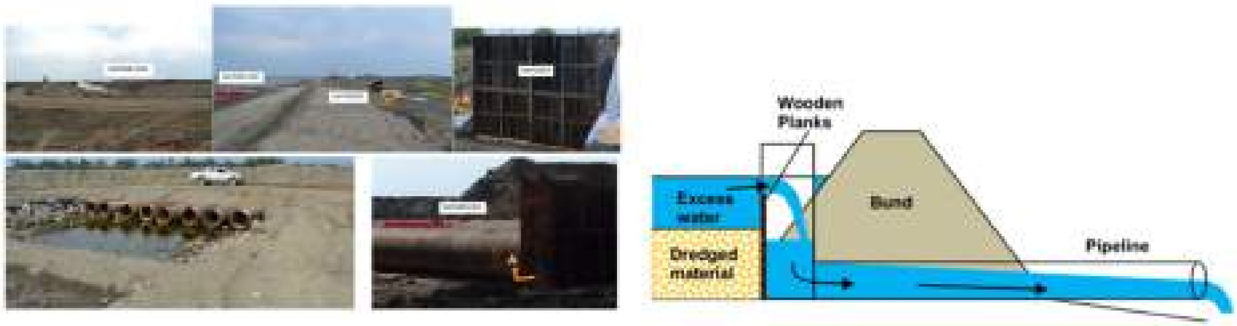


Figure 9-5 Water box and cross section of Water box

9.2.3.2 Burrow Material for Reclamation

Reclamation will be carried out by filling the area required using suitable material derived from land sources as well. For the proposed development mainly, it is planned to use the sourced good quality granular earth materials available in the nearby identified quarry (refer section 2.5.5). Since the quantity of reclamation is much greater than the dredging quantity which in turn is dependent on the suitability of dredged material for reclamation, it is considered that additional reclamation will be carried out by sourced earth.

The sourced materials for reclamation will be as per MORTH guidelines. Where filling or backfilling is to be placed under water, acceptable granular material or rock will be used. Acceptable granular material will consist of well graded, hard durable particles with maximum particle size not exceeding 75 mm. The material should be non-plastic having uniformity coefficient of not less than 10. The material placed in open water will be deposited by end tipping without compaction. The fine contents in the underwater filling will be controlled and should not exceed 10%. If hydraulic filling to be used, then this will be carried out as per BS-6349 Part-5.

9.3 Ground Improvements and Foundations

9.3.1 Overview of the Options

9.3.1.1 Soil Improvement by Band Drains & Preloading

Improvement of the subsoil properties by installation of band drains, also known as Prefabricated Vertical Drains, which are, vertical drainage channels serving to expedite release of pore pressures developed in the subsoil on account of loading. They are normally installed in a square or triangular grid at a spacing of 1 to 2 m, depending upon the permeability of the subsoil and the time period that can be allowed for strength gain in the subsoil.

Building up a preload can cause consolidation of the subsoil, hence causing gain in strength of the subsoil. The strength gain is a function of the intensity of preload intensity. Usually, this process is employed where the primary requirement is to eliminate potential settlements. The cost of building and removal of preloading is an added cost.

Generally, preloading requires to be done in stages so that the subsoil strength is built up gradually and failure due to rapid loading is avoided. This time needs to be factored into the schedule.

9.3.1.2 Soil Improvement by Stone Columns

Stone Columns are columns formed in the ground using stone aggregates, 75mm & down. Special equipment is required to ensure proper construction. The process is also known as “Vibro Replacement”. While in sandy strata stone columns serve to increase the φ value, in Clays, they impart a “φ” values to the strata on an overall basis, owing to their granular composition.

The ratio of the area of one stone column to its command area is known as “replacement ratio”. The closer the spacing, the higher the replacement ratio and consequently higher improved soil parameters are achieved. Based on the replacement ratio, the improved parameters “C” and “φ” are computed.

Stone columns are installed in a square or a triangular grid. For the same grid spacing, the triangular grid gives a higher replacement ratio.

9.3.1.3 Soil Improvement by Vibro-Compaction

In this method the soil particles are rearranged into a denser configuration using powerful depth vibrators. By vibro compaction there will be reduction in settlement. This method is more applicable in the strata comprising of silty sand. The reclamation at the port is estimated to be dredge material and will consist of silty sand. Thus, Vibro-Compaction will be the preferred method for soil improvement.

9.3.1.4 Shallow Foundations and Piled Foundations

In the event of concentrated loads being applied, it is preferable to use the shallow foundations to evenly distribute these loads to the soil strata underneath. However, if the bearing capacity of the strata below is inadequate piled foundations would need to be provided.

9.3.2 Container yard/ open storage for Various Cargo terminals

The Container yard/ open storage and the onshore facilities would be developed, by reclaiming the suitable dredged material comprising of silty sand. In order to consolidate the area, surcharge fill would be required. The surcharge is placed in various section of the reclaimed area for consolidation to avoid any liquefaction in conjunction with vibro-compaction. Apart from this no ground improvement would be required for the yard development.

9.3.3 Port Buildings and Covered Storages

Most of the port buildings are low rise buildings and it is expected that these can be safely founded on shallow foundation comprising of a combination of strip and isolated footing. However, the storage sheds, port operations and administration building would be supported on the piled foundation.

9.4 Internal Roads

Internal connectivity of the terminal will be developed by the terminal operator selected by JNPA authority. The approach roads to the Container terminal and other cargo terminal area are designed taking into consideration the density of traffic and the wheel pressure of the tractor trailers, tankers, dumpers/trucks etc. All roads are designed to IRC Class AA standards.

The proposed internal roads for traffic flow within the port are shown in Phase 1 layout Drawing **DI1452-RHD-DP-MA-DR-CM-1002**. Most of the terminal roads will have two-way traffic. The truck lanes under the RTG as well as under the quay crane will have one-way traffic. The quay apron - yard movement will be anti-clockwise or clockwise based on the location of the berth, whereas the yard – gate/ rail yard movement will be clockwise.

9.4.1 Traffic Circulation Plan at the Container Terminals

Maintaining a proper circulation within the port from berth to the yard is of prime importance for the seamless operation of the port. Careful planning of circulation of ITVs within the port is required to avoid any choking of the traffic movement. Accordingly, the width of the road needs to be fixed and aligned such that there is no criss-crossing of TT. Based on the requirement of the no. of ITVs for cargo evacuation and the lane capacity the following width of the roads are proposed.

9.4.1.1 Movement of ITVs along Berths

All the container berths are contiguous to the reclaimed land. The berths are proposed with 35.0 m rail gauge STS (ship to shore) cranes. Additionally, it is likely that the larger ships will have 5 STS cranes deployed to them during operations although it is accepted that on occasions this may be more – or less.

It is standard practice within the industry that container doors should always face aft when loaded aboard a ship. The exception being for reefer containers when the motors should face aft. This ensures some weather protection when at sea. This standard practice defines traffic routing within terminals and so is led by the preferred side alongside which a port tends to berth its ships. In turn this is driven by weather, i.e., wind, tide and current, navigability such as ease and safety of turning, availability of tugs, pilot preference and the notion that a ship's master prefers to lie with the ship's bow to sea for an easy 'escape'.

For Vadhavan port, it is seemingly preferred to berth ships heading west such that at CTs 1, 2, 5, 6 and 9, ships would be starboard side quay (SSQ) and at berths 3, 4, 7 and 8 they would lie portside quay (PSQ). The trailers travel along the quayside, under a series of working STS cranes as indicated below.

Figure 9-6 Trailer movement below the Quay Cranes

When the cranes are closely placed along the length of a ship, the ITV travel the full length of the ship before pulling out of the 'tunnel' in the gap between one ship and another, but of course ITVs serving the other ship will be pulling into the tunnel at the same place. If STS cranes are quite some distance apart, then there may be an opportunity for ITVs to pull out of the tunnel part way along the ship if safe to do so. All ITVs must travel in the same direction. All traffic flows must be established by the ship and quay supervisors based on Standard Operating Procedures (SOPs) and Safe Systems of Work (SSOW). Traffic must be managed during the operation. Objects will be approaching the ITV drivers from the front, back, side and overhead.

In between the designated ITV service lanes, there will be hatched areas where the twist lock bins are placed, and stevedores/ operators will handle the twist locks at each side of the lane. If twin-lifting is taking place, there may be two stevedores at each side of each lane. Each lane is designated to a particular crane. Tandem lifting will create a different issue which must be safely managed by the quayside supervisors.

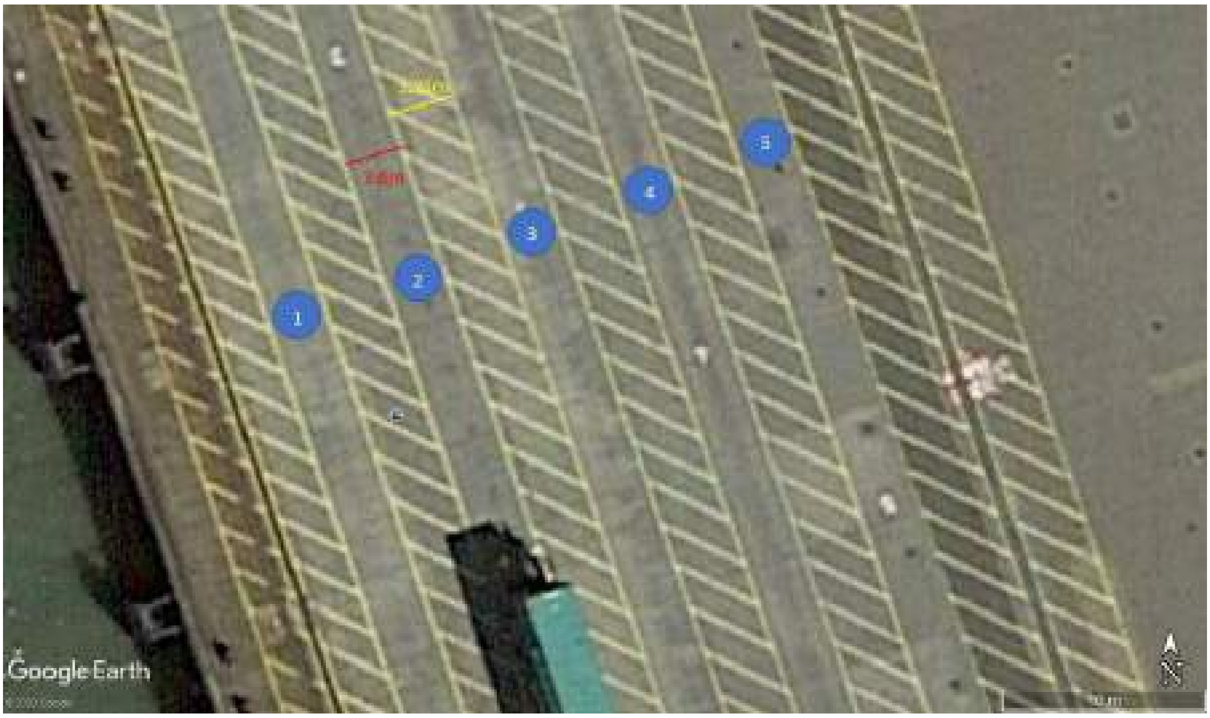


Figure 9-7 Typical Lane marking on Container Berth

Reefers which require their doors to face forward cannot of course use these lanes under the STS cranes without conflicting the traffic flow and it is common for reefers to be handled behind the STS crane in a dedicated ‘container the wrong way’ lane.

The largest ships will have 3 hatch lids per 40’ bay of 19 m width, each of which can weigh about 35 T. If stacked one on top of another the load on the quay will be over 100 T although the point load will be shared over at least 4 sledge type landing pads. Not every ship will be of the largest dimensions and it is likely that the workhorses calling at Vadhavan Port will be of about 24,000 TEU size.

In case of Vadhavan port, the STS rail gauge is 35 m wide, and this will enable 5 ITV lanes to fit within the rail gauge. With the container yard located at the rear side of the berth, 5 or more STS cranes deployed to a ship, then the crane programme must try to ensure that a gap is available within the ‘tunnel’ to allow ITVs to enter and leave the ‘system’ thereby, effectively working a ship in two halves. Twist lock handling may sometimes be handled at the end of a ship or the end of a quay if space allows rather than under every STS crane, but this does usually require each ITV to pass along the full length of the tunnel to reach the remote tipstock station. However, twist lock handling is not required for containers being discharged from or loaded to underdeck positions.

For the movement of the ITVs on berths the designated path will be as shown in the Figure 9-8.

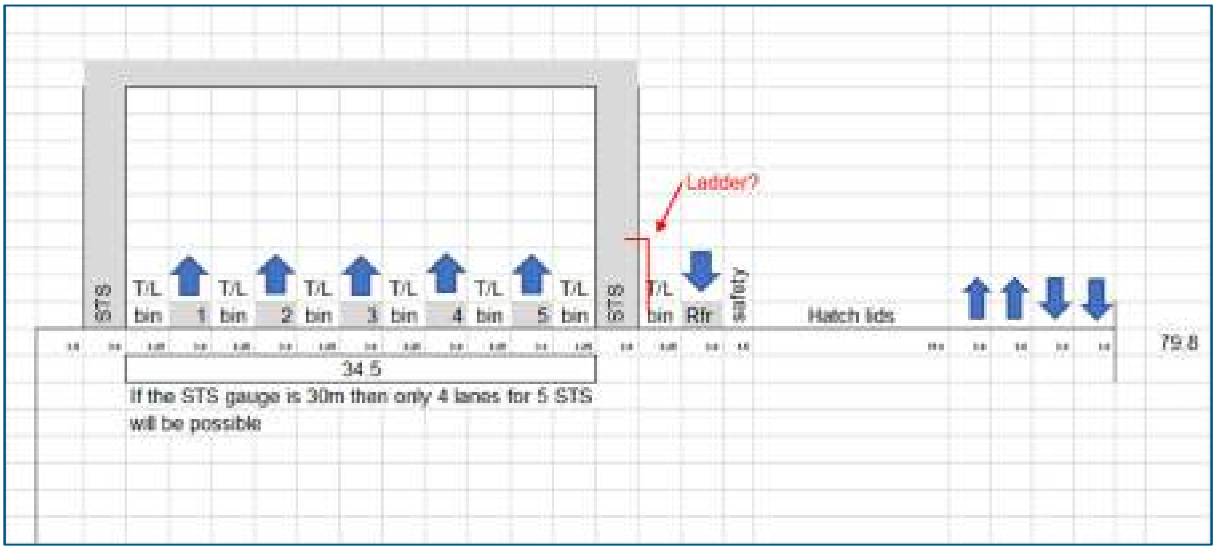


Figure 9-8 Proposed lane requirement on Container terminals

9.4.1.2 Movement of ITVs and External TTs in Container Yard

The movement of trailer within the terminals will be as described above. The typical circulation plan of the trailer movement within the terminal is as shown in Figure 9-9.

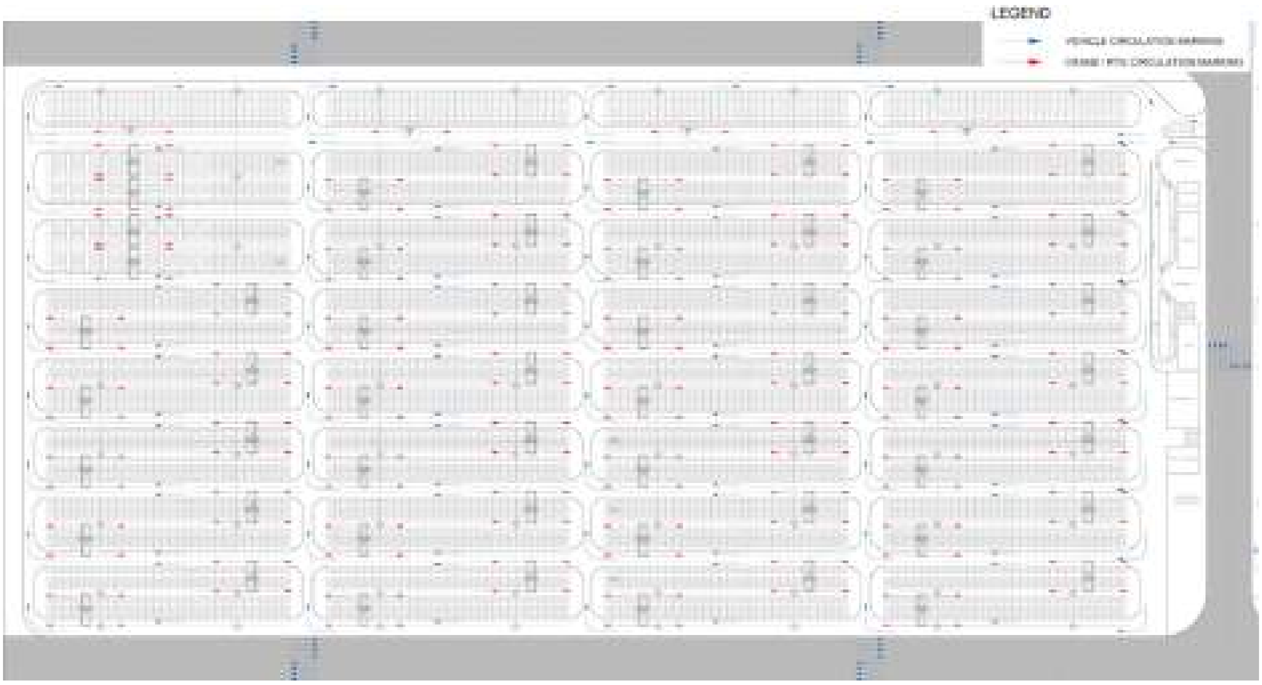


Figure 9-9 Traffic Circulation Plan for Container Terminals and Container Yard

9.4.1.3 Movement of ITVs in the In-port Common Rail Yard

The movement of the ITVs from the proposed container terminals to common rail yard shall be as per the designated path/ route. One way circulation movement is proposed for the ITVs in the in-port common rail yard as shown in the Figure 9-10.

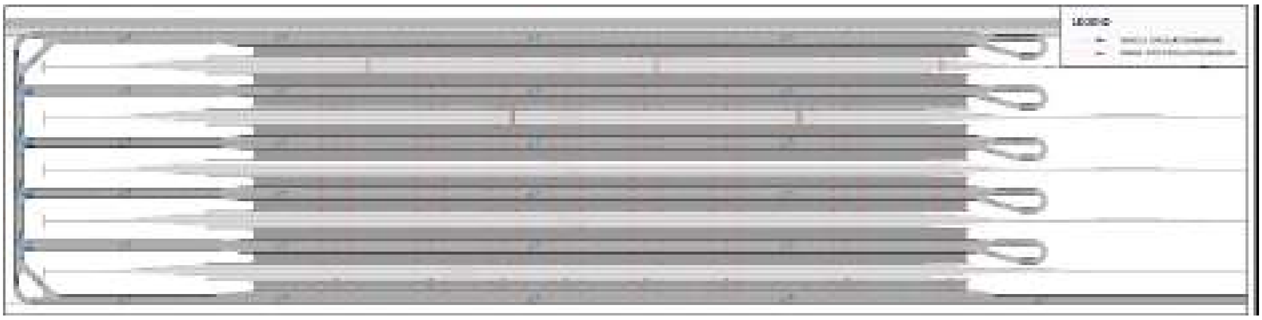


Figure 9-10 Traffic Circulation Plan for the In-port Common Rail Yard

9.4.1.4 Flyover for Trailer Movement

The main entry to the port will be through the gate complex located towards the east of the port. It may be noted that the proposed rail line entering the port is on the left side of proposed road corridor which require to cross the road inside the port to enter into the in-port rail yard. For the entry of external TTs to container terminals a flyover is proposed. This flyover allows the external trucks to enter and exit the container terminals without any criss-crossing the rail line and thereby maintain the seamless operations without any bottlenecks.

9.5 Container Terminal Infrastructure

9.5.1 Container Yard

9.5.1.1 Container Stack Area

For Phase 1, yard area of approximately 204 ha. for container stack will be designed for stacking 5.5 T/sqm (for upto 5 full container high stacks) for four container terminals. After consolidation of reclaimed dredge material, the yard area will be levelled, and fill material will be spread and compacted for base layer.

Alternative solutions for the paving in the stacks are discussed in this section. The stack area options are discussed below.

Concrete Block Paving (CBP) in Stack Areas

If hard surfacing is to be adopted for the stack area, it is recommended that this would be formed using Concrete Block Paving (CBP). CBP is well known in the marine terminal world where ground conditions are good (and limited settlement is expected). The periods between major maintenance are relatively long and hence annual maintenance costs are relatively low. If large settlements are expected, however, maintenance costs can be higher and involve more frequent lifting and re-laying of blocks. This is a time-consuming operation and significant coordination of yard activities is required to avoid reduction of yard capacity during maintenance periods.

CBP in direct contact with corner castings can show local deterioration. However, experience has shown this is not usually of operational significance. Capital costs for CBP are relatively high in comparison with other options.

Gravel Stacking Beds

Gravel beds can offer a cost-effective solution where RTGs are used to handle boxes to and from the stacks. This option involves supporting the container stacks directly on to gravel beds, without the use of concrete pads. Construction of beams for the RTGs will still be required.

Plain gravel beds have been successfully used elsewhere for four high stacking. Gravel beds have been used satisfactorily in several container terminals world-wide, including Ashdod, Limassol, Rotterdam, Dusseldorf, Penang, Haifa, JNPA, Vallarapadam, Thames's port and ECT[4]. Singapore also uses gravel but only combined with corner pads. However, five high (or higher) stacks on plain gravel beds are not common.

The use of plain gravel beds requires the use of high-quality gravels to accommodate the loads without crushing of the gravel. Sourcing suitable gravel to Vadhavan could be a significant construction risk.

Use of gravel beds is operationally relatively inflexible because the locations of the stacks cannot be easily moved. However, boxes can be readily moved within the stack area. The gravel beds cannot accommodate frequent access by forklifts or reach stackers. The capital costs for a gravel bed solution are lower than that for a hard pavement solution.

Properly graded crushed rock is free draining. Water can be drained from under the stacking areas and adjacent roads by the provision of porous pipes within the gravel layer, minimizing, avoiding, or delaying installation of expensive slot drains. In areas of high rainfall, the gravel beds can also be used to temporarily 'store' peaks in surface water runoff volumes, allowing the drainage system for the yard to be optimized for peak rainfall conditions. One perceived drawback of gravel beds is that there is less opportunity to intercept spillage. However, several standard technologies exist that retain or detain runoff for testing or clean up prior to release.

Maintenance of gravel beds is required more often, particularly during the first few years of operation. It is relatively simple, comprising of re-levelling and refilling of the gravel as and when necessary. For sites with good ground conditions, where only limited settlements are expected, maintenance is generally more expensive than for a hard pavement. Where large ground settlements are expected, however, then gravel beds can offer reduced maintenance costs over a hard pavement option such as CBP.

If necessary, plain gravel beds can be readily upgraded to gravel beds with beams and there can be some advantages in doing this after the initial settlements at the site have occurred. However, that the new stacks will be fully utilized relatively soon after construction. It is therefore likely that the stack will be operated as five high stacking from early on, and that the disruption associated with a subsequent 'upgrade' would be operationally unacceptable.

While gravel beds can be cost effective, the limitation on stack heights, the need to source very high-quality gravel, and the need for the stack to be fully utilized early on mean that this option appears less advantageous than other stack options.

One possible advantage for the use of gravel beds is in situations where significant subsidence of surface profiles is expected. The surface can be re-levelled simply by the addition of gravel on a periodic basis.

Gravel Beds with Concrete Bearing Beams / Pads for Corner Castings

This involves supporting the corner castings of the containers on concrete beams or pads that are set into the gravel bed. The areas between the beams/ pads are filled with gravel. Five high stacks are well within the scope of this concept. In one configuration pads/ beams are generally set out to suit 40' boxes, with special provision being made to accommodate 20' boxes within certain areas of the stack. This method imposes certain constraints on yard operations about container distribution within the yard. Pads or beams can be installed to accommodate 20' containers throughout the yard but the configuration is significantly more expensive.

[4] *Europe Container Terminal*

Gravel beds with pads/ beams are operationally inflexible and do not allow movement of the stack or relocation of the box positions within the stack area. Capital costs for beams and pads are likely to be similar - although beams require a greater volume of concrete; this is likely to be an offset by the reduced work required during forming. Capital costs mostly fall between the costs of plain gravel beds and hard surfacing.

Maintenance is required less frequently than for plain gravel beds but more frequently than for a hard-paved solution. Maintenance involves lifting the pads/ beams and re-packing the gravel. This is simpler for pads than for beams. Beams are likely to require less frequent maintenance than pads albeit, that each maintenance will be more expensive given the size of the beams. Beams will offer a marginally more flexible solution as they will allow movement of boxes sideways within the stack and are more stable than pads.

9.5.1.2 Proposed Yard Pavement

It is noted that no ground improvement is envisaged for the container and storage yard. It is therefore proposed that CBP solution be adopted for efficient handling and minimise the maintenance cost.

Pavement area of 204 ha. will be designed for stacking 5.5 T/sqm. After consolidation and removal of preload material, the yard area will be levelled, followed by fill material (CBR> 10), and compacted for the base layer. For area other than RTGC beam and cross over, the pavement consists of a Granular sub-base GSB layer 300 mm thick, GB layer of 300 mm, followed with 150 mm CBM layer of crushed rock and base course of 575 and 600 mm thick based on the loading conditions and functional requirements. Sand of 30 mm thick is laid over the base course layer. The top layer of the stacking area will be paved with M50 cement concrete CC blocks of 100 mm thick. The precast concrete block paving is based on the guidelines of BPA Interpave manual for 5 stack high containers.

In the container yard, electrical conduits and pits are to be provided for cranes, HT electrical, general lighting, communications, and reefer arrangements. Also, miscellaneous works like kerbs, foundations for lighting, RTGC tie down are to be provided.

For the area covered around buildings (Light traffic areas) Asphalt roads have been proposed. The Asphalt topping is laid on the CBM3 base course.

Drawing DI1452-RHD-DP-OS-DR-CM-1302 presents the cross section of pavement.

9.5.1.3 RTG Runways

For the movement of RTGCs, reinforced concrete beams of 500 mm thick are provided with sub-base layer of CBM3 (200 mm thick) material and crushed rock material. For RTGCs, turning pads with structural plates and inserts will be provided. A well compacted granular fill of 1.5 m deep with 1V:2H side slope, is provided below each RTG/RMC track, upto 2 m width, for underpinning the sub strata.

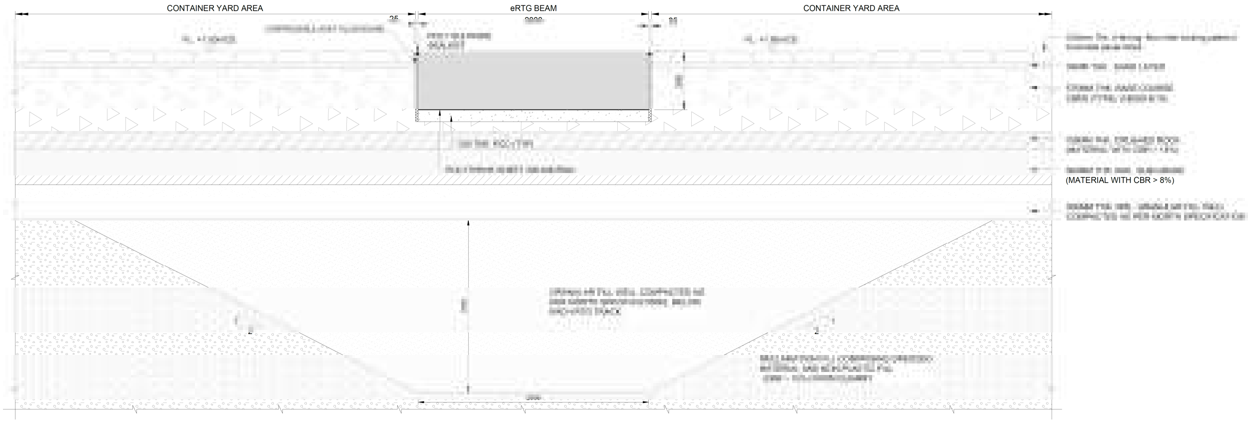


Figure 9-11 Typical section of RCC beam for RTG runway

9.5.2 Reefer Gantries

Reefer containers are planned to be stacked up to 4 high. Plug in and plug out the power supply and monitoring the reefer container parameters are the operations carried out in each reefer boxes. To carry out these operations of reefer boxes which are stacked above ground level, an operation platform is required. Hence a galvanized iron gantry structure is planned in each slot to accommodate the power plugs as well as carry out operations. Under these platforms the compact substation and the reefer power distribution panels will be installed. From the reefer distribution panel along the platform structure the power cable will be laid for each reefer power plugs.

470 TGS will hold on an average 1180 TEUs. Each Reefer Block will have 28 plug points (7 containers * 4 stack heights) for 42 TEUs. Hence 28 Reefer Blocks are required for supporting 907 (1180/TEU Factor 1.3) Reefer Points for each terminal.

9.5.3 In-port Rail Yard

It is proposed to provide a common rail yard for the proposed container terminals at Vadhavan port. Additional rail line/ terminal is proposed for handling the cargoes other than containers. It is proposed by JNPA that a Special Purpose Vehicle (SPV) will be appointed for the operation in the rail yard.

The basic purpose of this yard is to:

- Aggregate the containers from different terminals at one location to ensure faster turnaround time of rakes.
- To allow handling of DFCC rakes which are double the length of current rakes.

The common rail terminal will have the following components:

- In rail yard there shall be sidings for receipt/dispatch of DFCC rakes, assumed to be of 1400 m length.
- Roads for movement of ITVs from the CY area and rail yard
- Stacking space for containers adjacent to rail yard
- RTGs at the rail yards area
- RMGCs at rail yard for loading and unloading of rakes
- ITVs, other equipment, and utilities.

9.6 Internal Rail Links

Vadhavan port envisage handling of Bulk Liquid, Fertilizer & Container traffic through rail as well as road within the port. Two separate yards are proposed to handle Bulk Liquid/Fertilizer & Container cargo. The main/Lead line from RFO/ROR connects WDFC to Vadhavan Port railway yard. The lead line bifurcates into two (2) separate yards viz Container & Bulk Liquid/Fertilizer yards after crossing Vadhavan Port gate.

Train coming to the port will be having locomotive with EOL (Engine on load) scheme of Indian Railways and the entire rail operation within port will be carried out by the same locomotive; no separate provision for dedicated locomotive/ shunting loco has been considered for rail yard in port.

9.6.1 In-port rail yard for Containers

In-port rail yard for Container is proposed to be developed in 3 phases commensurate with the projected traffic for the years 2030, 2040 and 2050 respectively.

- Phase 1 (2030)
  - In Phase 1, rail yard is proposed to comprise of two groups (clusters) of railway tracks viz Group A & B. Each group comprises of 6 lines for loading/unloading of container rakes and one line as sick line.
  - Total No. of lines in Phase 1: 12 container lines with CSR-1500 each and 2 sick lines with CSR-140 each.
- Phase 2 (2040)
  - In Phase 2, rail yard will have additional one group viz Group C comprising of 6 lines for loading/unloading of containers and 1 line as sick line.
  - Total additional no. of lines in Phase 2: 6 Container lines with CSR-1500 each & 1 sick line with CSR-140.
  - Hence total combined lines in Phase 1 (2030) and Phase 2 (2040) - 18 container lines with CSR-1500 each and 3 sick lines with CSR -140 each.
- Phase 3 (2050)
  - In Phase 3, rail yard is proposed to add two more groups (clusters) viz Group D & E. Each group comprises of 6 lines for loading/unloading of container rakes and 1 line as sick line.
  - Total No. of new lines in Phase 3 (2050): 12 lines with CSR-1500 each and 2 lines with CSR-140 each.
  - After Phase 3, total no. of lines in rail yard will be 30 for container loading/unloading and 6 lines as sick line.

Provision of a sick line of 140 m long for each 'group' (cluster) has been made to take care of exigency of placement of sick wagons during day-to-day railway operations.

The schematic key plan of the proposed rail yard within the port is as indicated below.

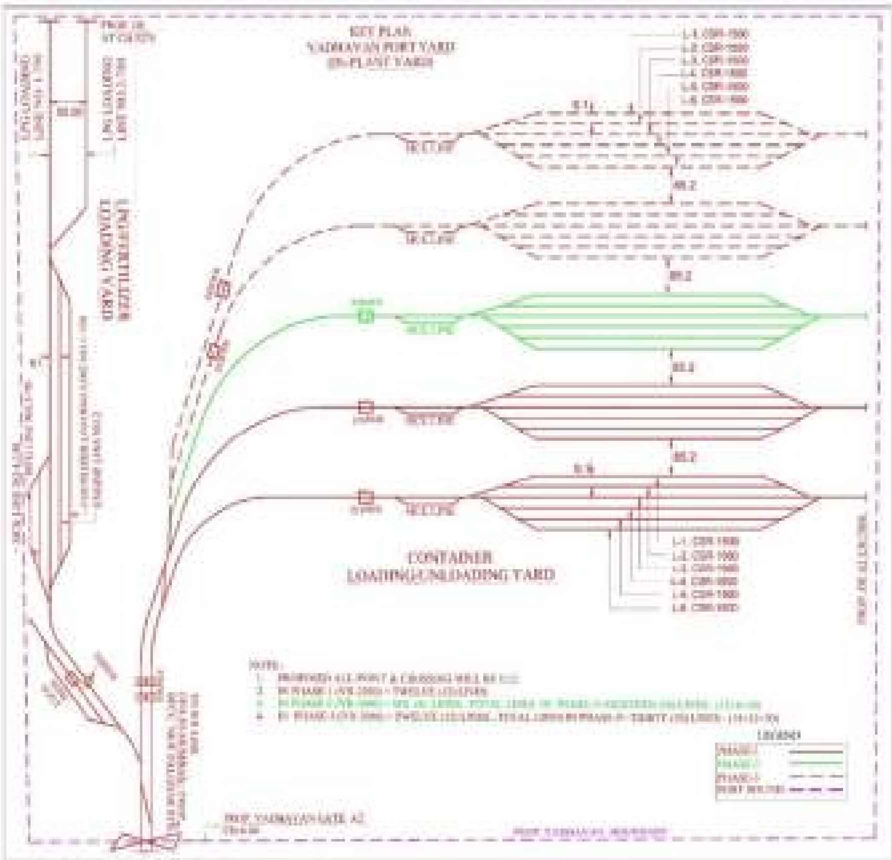


Figure 9-12 Schematic Key Plan of Vadhavan in port rail yard

In view of the seamless port operations, it is proposed that for Phase 1, 18 rail lines is recommended to be developed which would cater the Phase 1 and Phase 2 capacity.

9.6.1.1 Container Storage at in-port rail yard

For arriving at the facility requirements at the rail terminal following assumptions have been made:

- Maximum 5 high container stacking is assumed
- Dwell time of containers in the yard is taken as 1 day
- Total time for loading and unloading of each DFCC rake is limited to 5 hours including the switching time

The facility requirements for the common rail terminal are worked out in Table 9-1.

Table 9-1 Facility Requirement for Common Rail Terminal

S. No.	Parameter	2030	2040	2050
1.	Total Rail throughput	2,807,580	8,010,237	11,718,680
2.	Boxes to be moved	2,159,677	6,161,721	9,014,369

S. No.	Parameter	2030	2040	2050
3.	Average Dwell Time at Container Yard (days)	1.0	1.0	1.0
4.	Maximum Stack Height	5	5	5
5.	Yard Utilization Factor	0.7	0.7	0.7
6.	Average Stack Height	3.5	3.5	3.5
7.	Peaking Factor	25%	25%	25%
8.	Number of Ground Slots Required at Container Yard	**2,204**	**6,287**	**9,198**

It may be noted that the ground slot requirements for the common yard could be reduced by lowering the dwell time meaning the containers are transferred from this yard to the respective yards immediately on receipt or vice versa the containers are brought to this common yard just before their despatch by rakes.

9.6.1.2 Proposed Railyard Layout for Container Evacuation

The common rail yard shall be located in between the Container yards. The overall yard length is kept as 4750 m and width as 605 m. This would enable handling of DFCC Compliant rakes at this yard. The main line to the port segregates to the container terminal and liquid & multipurpose terminal.

The stacking areas are proposed adjacent to rail sidings with nested RMGCs and RTGs. The storage area in this yard shall be utilised for aggregation and separation of ICD traffic. In the proposed arrangement about 2,804 ground slots are available for stacking in Phase 1 increasing to 16,114 in 2050. The Phase 1 layout of common rail yard for container terminal is shown in Figure 9-13.

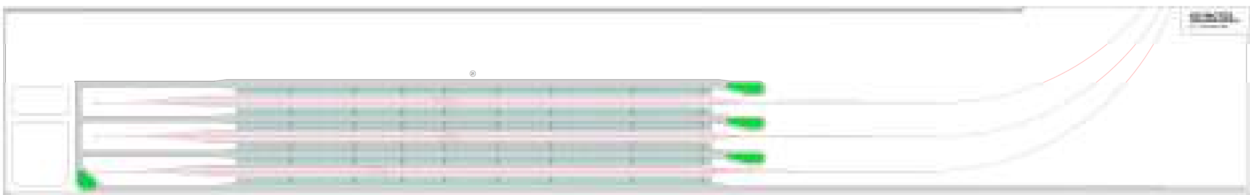


Figure 9-13 Phase 1 Layout of in-port Common Rail Yard for Container Terminals

9.6.2 Bulk Liquid/Fertilizer Yard

- Bulk Liquid yard has 2 line for loading of Bulk Liquid rakes.
- Loco shed line is provided on Bulk Liquid/Fertilizer lead line near port gate.
- Fertilizer yard has 4 lines for loading, engine reversal, brake van and sick lines.

The rail yard arrangement for other cargoes is as indicated below.

Figure 9-14 Rail yard arrangement for other cargoes

9.6.3 System Operation at Vadhavan Port Yard

Vadhavan Port yard consists of two separate yards viz Container & Bulk Liquid/Fertilizer yards for handling Container and Bulk Liquid/ Fertilizer.

The container rakes of Vadhavan port will arrive at port yard from proposed New Palghar station of WDFC. The rakes will require reversal of engine inside Port yard for return movement from Port yard to New Palghar station. To avoid engine reversal of rakes in port yard, DFCCIL has proposed that Vadhavan Port rakes from WDFC will be placed at port yard with Electric locomotive at either end. The leading loco will be in ‘operation’ & the rear loco will be in ‘dead condition’.

The container rail yard, loading of containers on ‘BLC’ wagons require operation from top by Rail Mounted Gantry Crane (RMGC). Hence, the yards earmarked for loading of containers cannot be ‘Fully Electrified’. Only ‘Top Wiring’ will be provided i.e. electrification will be limited to the point which will not infringe use of RMGC and is safe from all other angles. On container handling line, rake can be placed only by ‘Backing’. After reaching edge of container loading/unloading line, the leading electric loco will be switched off/dead and rear electric loco will be brought in operation. The rear loco will push the rake to container loading/unloading line through ‘Top Wiring’ provided at Vadhavan Port gate side of container loading/unloading line. After loading/unloading, the rake will require to be moved to New Palghar station. Now for movement of the rake, the original leading electric loco in dead condition will be at rear position and original rear electric loco will be in leading position for movement to New Palghar station.

For loading of Bulk Liquid tanker rakes which is carried out from top. Therefore, proposed rail yard for handling Bulk Liquid cannot be ‘Fully Electrified’. Only ‘Top Wiring’ will be provided till the ‘Cut Off’ location. Since fertilizer yard is proposed before Bulk Liquid yard, the cut off location would be before the fertilizer yard.

9.6.4 Rail Yard Infrastructure

9.6.4.1 Pavement in Container Rail Yard

The rail yard area is planned with a total outer dimension of 4780 m length and 605 m width. This area will also be on reclaimed land. After consolidation of the reclaimed dredged material / burrowed fill, the yard area will be levelled, and fill material (CBR 20) will be spread and compacted for base layer. For the track portion the sub-base will be CBM, and infill concrete will be provided in between sleepers and rails.

The pavement in the rail yard will be same as that of container yard.

9.6.4.2 RMGC Runway in rail yard

For the movement of RMGCs in the rail yard, reinforced concrete beams of 500 mm thick are provided with sub-base layer of CBM3 material of 600 mm, followed by a layer of lean concrete of 100 mm thick with 300 mm thick subgrade (material with CBR> 8%) and 300 mm crushed rock material as subgrade as per MORTH specification. A well compacted granular fill of 1.5 m deep with 1V:2H side slope, is provided below each RMC track, for underpinning the sub strata.

The typical cross section of RMGC beam is as indicated below.

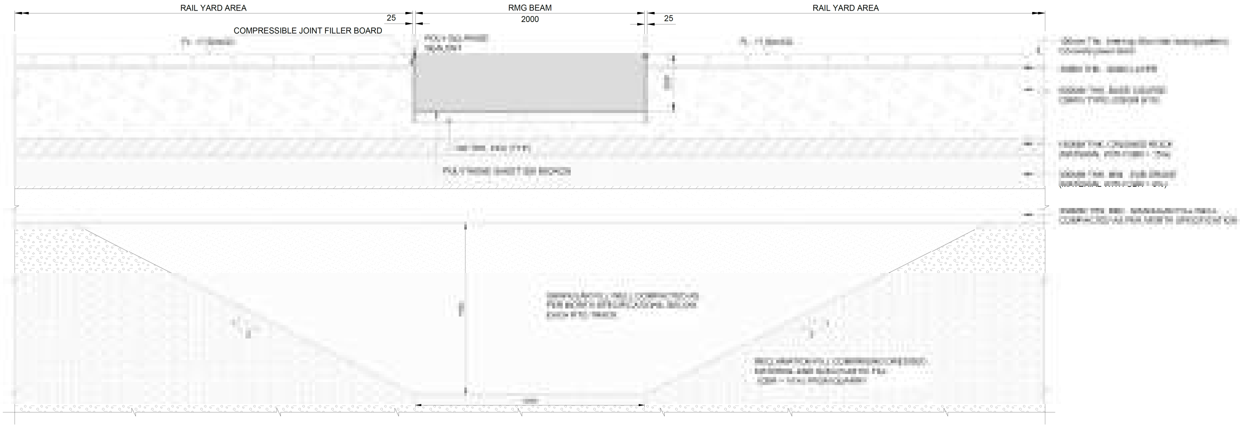


Figure 9-15 Typical section of RCC beam for RMC runway at in-port Rail yard

9.7 Centralised Truck Parking Area

Considering the various terminals to be developed by various operators and the number of truck movements within the port, it is required to provide a centralised truck parking space close to the respective terminals. It may be noted that the number of ITVs required in Phase 1 is about 1307 (say (1300) increasing to 3542 (say 3600) in Phase 2. Considering the high number of ITV requirements, it is prudent to provide a centralised parking area.

It is proposed to provide parking facility of 400 TT for each terminal. The following parameters are considered for the planning of the parking area:

- Parking for 40 ft container trailer is considered.
- Area required for a 40 ft container trailer is 70 m^2.
- Circulation space required is 100% i.e., per truck 70 m^2.
- Box factor of 1.3.
- Total parking space required per truck including circulation space is 105 m^2.

Based on the above, the parking area required for the Phase 1 and Master plan (Phase 2) of the port development is as below

Table 9-2 Centralised Parking area for Phase 1 and Master plan (Phase 2)

Project Phase	Area (ha.)
Phase 1	18
Master Plan (Phase 2)	49

[Source: Neufert Architects' Data]

9.8 Entry/Exit Gate Complex

The entry/exit gate has been planned as a two-step gate. A pre-gate will be constructed on the main terminal road which will have parking and facilities for truckers. Only drivers will be allowed to leave the pre-gate area and enter the main terminal gate. The main terminal gate has been provided at the east end of the port. It will consist of a gate canopy with six entry and six exit lanes with two bypass lane in each side for other cargo terminals and ODC in Phase 1 increasing to 26 entry and 26 exit gates over master plan horizon. The gate operations are planned to consist of three shifts of operations from Phase 1 itself considering the traffic movement. The proposed port is essentially to cater the gateway container terminal. The split of gateway traffic coming through road trucks is 68 % in Phase 1 and 64 % over the master plan horizon and 2050. The gate lanes have been sized to accommodate this traffic. Adequate queuing space has been planned for in the gate complex. Space has been provided for customs and other regulatory processes near the gate complex. Container scanning can be accommodated within the gate complex itself. Users other than the container trucks such as multipurpose, liquid, port staff etc. has been provided a dedicated lane in the gate complex. Figure 9-16 shows a detailed view of the proposed gate complex.

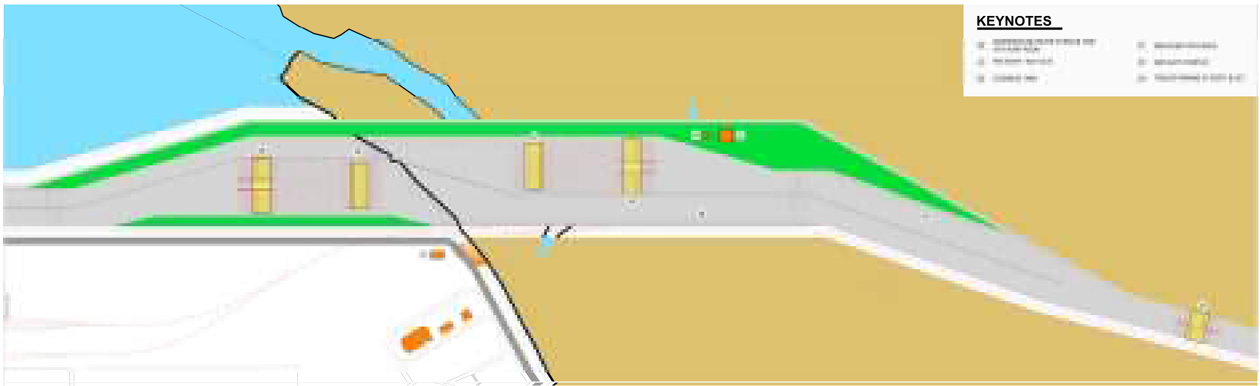


Figure 9-16 Gate Complex for Port of Vadhavan

As discussed earlier in Section 5, master plan has been kept flexible for the eventuality of multiple private terminal operators for different phases of container terminal development. The gate complex shown above can be used for upto nine terminal operators by demarcating three entry and three exit lanes for each operator. For other cargo operators, it is suggested that an additional gate complex be created in the future expansion area at the port entrance located at the east of the port.

Each container gate lane will be equipped with a weigh bridge that is used to measure and assess truck axle weights for enforcement of axle load highway rules.

9.8.1 Gate Complex

Controls access to and from the container handling and storage areas, and facilitates the transfer of responsibility for the cargo from one party to another and allows for:

- Exchange of information between truck drivers and the container terminal operator’s gate clerks
- Verification of container transaction records
- Verification of customs information
- Physical inspection of containers as they enter and exit the terminal
- Inspection of container seals

Adjacency and Access
An entry trouble parking area consistent with the size is provided adjacent to the gate and trucker service area. See the Gate Plans for layout of the trouble parking areas. The exit queues shall be situated so that they will not interfere with other container terminal operations.

Canopy
The inbound and outbound truck processing booths shall be shielded by an overhead canopy to keep the truck operators and gate clerks out of the weather and provide protected mounting locations and consistent lighting levels for any future camera systems. Fixed signage will be used to visually direct trucks to the proper lanes within the gate complex.

Trouble Kiosks
Two or more of these shall be provided at the entry trouble area. Each will include payphones, in-yard phones for calling the Customer Service office, a receive-only fax, and toilets for the truckers.

Trucker Service Area
The pre-check building shall be equipped with truckers' service area to handle problem transactions at a service counter. A striped pedestrian walkway will connect the trouble parking with this area.

Impact Protection
All above-grade structures within the gate complex shall be suitably protected from being struck by moving and manoeuvring trucks through concrete-filled steel pipe bollards. Concrete-filled steel pipes embedded in concrete footings shall protect the clerk booths. The use of curbs shall be avoided, especially at gate islands.

Scales
Entry scales provided at each entry inspection station, pit type, suitable for trailers carrying 45-foot containers plus typical truck/ dumpers and shall be in accordance with all government and local regulations for scale accuracy. Load capacity shall be 100 T. Scale data shall be electronically uploaded to the terminal operating system for each transaction and capable of being printed in booth.

Technology
Conduit should be installed to allow for the future installation of advanced technologies such as Automatic Equipment Identification (AEI), and Optical Character Recognition (OCR). Installed conduit shall be at most 50% full at the start of container terminal operations.

9.8.2 Gate House

The area can accommodate parking for 175 trucks. Provision for additional parking area would be provided on the southern side of the gate complex. The pavement for the gate house area will be provided with a layer of GSB under CBM. 6 no. in-gates lanes and 6 no. out-gates lanes are to be provided for the container gate house area. **Drawing DI1452-RHD-DP-OS-DR-CM-1401** shows details of the proposed gate complex. The area of Gate house is 14,600 m^2 as given below:

Table 9-3 Area of Container Gatehouse

S. No.	Component	Area (m^2)
1.	Garden	2,000
2.	Gate staff (Administration) and Custom Building	3,600
3.	Gate Pavement Area	9,000
	Total Gate House Area	**14,600**

9.9 Terminal Fencing

Container terminal fencing will be provided as per ISPS requirements. The fencing is planned along the periphery of the individual terminals.

9.10 Port Buildings and Other Civil Structures

In the proposed development plan, there will basic common user buildings which shall be operated and occupied by port owners. Further there shall be other set buildings which will be developed for port operators, since the terminals will be given on concessions to other parties for the development and operation. Suitable number of buildings as per the functional requirements shall be developed in the port. The following buildings are envisaged in the port for the Phase 1 and Masterplan development.

The list of common user buildings is mentioned below.

- Administrative Building
  - Customs Building
  - CISF Building
  - Police Station
- Port Operations Building
  - VTMS
  - Harbour master
  - Pilot and survey team
- Port user Building
  - General Store
  - Dispensary
  - Restaurants
  - Canteen
  - Recreational Area like Theatre and shops
- Gate House Building
- Maintenance Workshop
- Fertilizer Shed
- Utility Buildings
  - Main Substation Building
  - Fire Station Building
  - Pump House
  - Overhead and underground tanks
  - Communication and security
  - STP

Details of port users (i.e., Concessionaire) buildings are given below. Since the terminals are operated by other parties there will separate port operations building for each concessionaire. Following set of buildings envisaged for the Phase 1 and Masterplan development.

The table below presents the building list for Phase 1 development plan.

Table 9-4 List of building envisaged for Concessionaire in Phase-1 development plan

List of Buildings	Operating Terminals Buildings								
	Container Terminals				Multipurpose Terminal	Ro-Ro Terminal	Bulk Liquid Terminal	Bulk Liquid Terminal	Other Liquid Terminal
	CT1	CT2	CT3	CT4					
Administrative Building	✓	✓	✓	✓	✓	✓	✓	✓	✓
Customs Building	✓	✓	✓	✓	✓	✓	✓	✓	-
Gate House	✓	✓	✓	✓	✓	✓	✓	✓	✓
Maintenance Workshop	✓	✓	✓	✓	✓	✓	✓	✓	✓
Storage Shed	-	-	-	-	✓	-	-	-	-
Electric Substation	✓	✓	✓	✓	✓	✓	✓	✓	✓
Fire Pump House building	✓	✓	✓	✓	✓	✓	✓	✓	✓
Tank Forms	-	-	-	-	-	-	✓	✓	-

The table below presents the overall building list during Master plan.

Table 9-5 List of building envisaged for the for concessionaire in Master plan

List of Buildings	Operating Terminal Buildings													
	Container Terminals									Multipurpose Terminal	Ro-Ro Terminal	Bulk Liquid Terminal	Bulk Liquid Terminal	Other Liquid Terminal
	CT1	CT2	CT3	CT4	CT5	CT6	CT7	CT8	CT9					
Admin Building	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Customs Building	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Gate House	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Maintenance Workshop	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Storage Shed	-	-	-	-	-	-	-	-	-	✓	-	-	-	-
Electric Substation	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Fire Pump House	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Tank Farms	-	-	-	-	-	-	-	-	-	-	-	✓	✓	✓

The subsections describe a brief description on the functional requirements of the above-mentioned buildings.

9.10.1 Administrative Building

Administrative building for offices of key personnel engaged in managerial and departmental activities related to terminal operations and management and their support staff. This building can also accommodate Customs office building, CISF office building and Police station.

Separate access is proposed to the administrative building complex for smooth/ seamless flow of cargo and ease of movement of stakeholders/ employees etc. to administrative complex for business.

9.10.2 Port Operation Building

Port operations building to provide space for the operating staff in all the shifts. It would have engineering department, terminal operations department, marine operations department, and a vessel traffic control room.

9.10.3 Port User Building

Port user building to provide space for the offices of the port operators. Since the terminals will be given on concessions to other parties for the development and operation. This building can also accommodate general store, dispensary, restaurants, canteen, recreational area such as theatre and shops.

9.10.4 Maintenance Workshops

Maintenance workshops comprising of a workshop plus storeroom, and an annex building to provide space for offices of the workshop foremen, mechanics, electricians, technicians and the storekeepers and rooms for off duty operational personnel and maintenance labour.

9.10.5 Fertilizer Shed

The fertilizer shall be consisting of fertilizer stocking area, baggage plant and baggage stacking areas.

9.10.6 Substation Buildings

Substation buildings to house the transformers and other electrical equipment. This is to provide the load requirements in the different parts of the terminal area.

9.10.7 Miscellaneous Utility Buildings

Other miscellaneous utility buildings such as fire station building, pump house, water tank, communication, and security and STP etc. shall be planned to meet the demand.

10 Rail and Road Corridor

10.1 External Rail Connectivity

The nearest railway stations to Vadhavan port along Western Dedicated Freight Corridor (WDFC) will be the proposed New Palghar crossing station of WDFC which runs parallel to Mumbai – Delhi western railway main line. WDFC is passing parallel to the existing western railway main line on east side in the same corridor. Vadhavan Port is located on west side of existing Mumbai – Delhi Railway line as well as the proposed Western DFC i.e., on the opposite/other side of Western DFC.

During the initial stage of the study, Progen-Pentacle suggested the rail through surface connectivity to Western Railway and Western Dedicated Freight Corridor (WDFC) from a Marshalling/ R&D yard located to the west of these lines. The existing WR Main line is already ‘oversaturated’ with line capacity of more than 150%. Hence, surface connectivity by ‘puncturing’ the WR Main line is not feasible. This was confirmed by Divisional Railway Manager (DRM), Mumbai Central, Western Railway, during the course of project meeting with WR.

Connectivity from Vadhavan in port rail yard to WDFC at proposed New Palghar station is only ‘feasible’ by crossing proposed WDFC main lines, existing WR main lines and the proposed MRVC lines by a ‘Rail Fly Over (RFO)/ Rail-Over-Rail (ROR)’ and then connect to WDFC network. WDFC is creating facilities at New Palghar station to accommodate ‘Long haul container rake’. Vadhavan Port traffic arriving at New Palghar station will have direct connectivity to port yard through RFO/ROR. Further, the overwhelming majority of traffic from the Vadhavan port is ‘Container’ traffic which will be transported by ‘Double Stacking’ in ‘Long Haul’ trains. Dedicated Freight Corridors (DFC) in India are being developed specifically to fulfil the requirements of this type of transportation needs.

The railway alignment design of Vadhavan Port siding has considered “Design Criteria’ compatible with DFC standards as well as those of Indian Railway. The cross section and other dimensional stipulations are in compliance with “Standard Schedule of Dimensions (BG) for Western Dedicated Freight Corridor of Indian Railways -2013”.

Based on numerous meetings and discussions with various stakeholders, and the Consultant’s own assessment as described above, the ‘surface connectivity’ by puncturing of main lines of WR and then connecting to Western DFC seems highly ‘improbable’. Four ‘Conceptual’ Options for direct connectivity to WDFC have been identified as part of rail connectivity DPR for this port and accordingly, the recommended option is indicated as below.

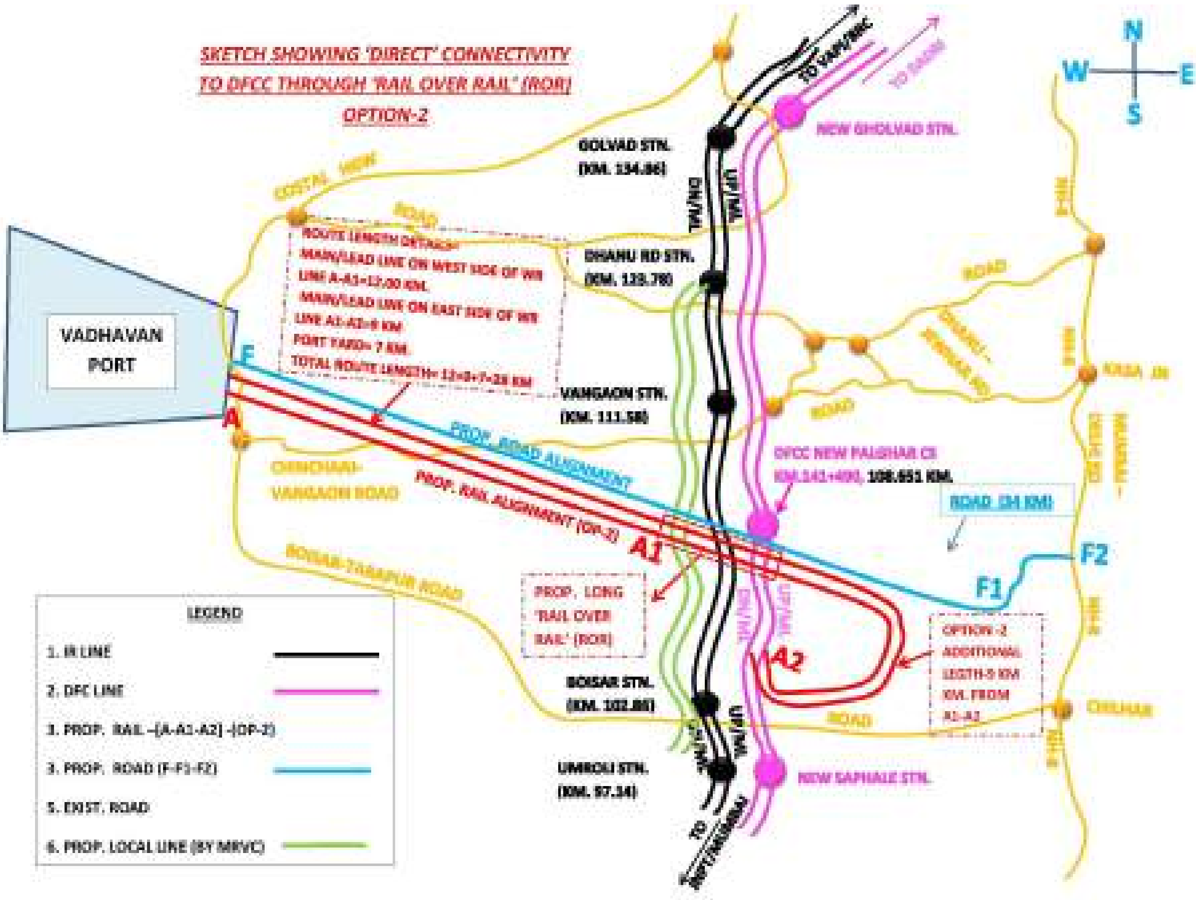


Figure 10-1 Sketch of 'Direct Connectivity to WDFC through 'ROR

The concept layout of the new Palghar Station along with the ROR crossing the DFCC, MVRC and WR line is as shown below.

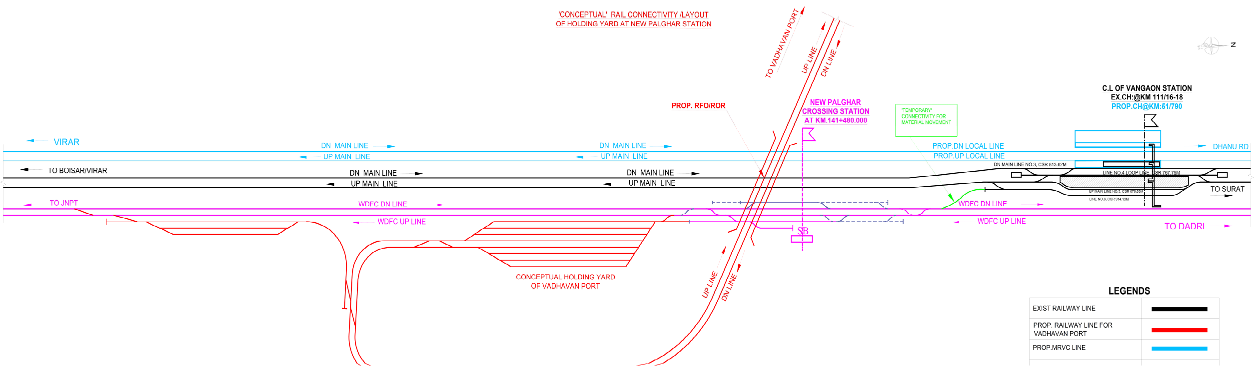


Figure 10-2 Concept Layout of ROR and New Palghar station arrangement

The rail link to Vadhavan Port will be a double line with automatic signalling to ensure that the trains can be moved efficiently.

It is estimated that around 42 trains per day would be calling into the port for the forecasted hinterland traffic for Phase 1 development.

10.1.1 Salient Features

Salient Features of Vadhavan port's siding including lead line, RFO/ROR & inside Port yard (In-plant yard) are as follows:

- Route Length: 28.00 km including Port yard (In-Plant Yard)
- Total Track Length: 151 km (including port yard)
- No. of Curvatures on lead line: 13 No. (Max. 2 degree)
- No. of Major Bridges/Road Bridges: 20 No. (Including RFO/ROR)
- No. of Minor Bridges: 18 No.
- Ten (10) weigh bridges are proposed inside the port yard by keeping level and straight lengths, 100 m each on each side.
- Provision of Yard Masters Office, Signalling Room, Crew Rest Room, FOIS Room etc. will be provided for in Yard Operations building.

10.1.2 System of Operation

Vadhavan Port yard will be required to handle traffic from Western Dedicated Freight Corridor (WDFC). The railway siding to Vadhavan port and Port yard will be 'electrified' since serving station (New Palghar station) of WDFC is 'electrified'. WDFC, designed to handle 'Double Stack Containers', has proposed 'electrification (OHE)' with 2x25 KV & High rise OHE with contact wire height of 7.45 m. 2x25 KV OHE has following advantages over 25 KV OHE:

- Feed voltage doubles up to 50 KV, reducing OHE current by 50%, thereby saving energy.
- Permits increase in distance between Traction Supply Stations (TSS) to 60-80 km apart.
- Improved voltage regulation and power supply.
- Permitting higher haulage at higher speed

Vadhavan Port rakes will arrive at proposed New Palghar station of WDFC. Rakes from New Palghar station will moves towards Port yard through main/lead line & proposed Rail Fly Over (RFO) / Rail Over Rail (ROR). The main/lead line & RFO/ROR will be 'Fully Electrified'.

10.2 External Road Connectivity

It is proposed to have a road connecting Vadhavan port to NH-08 and Mumbai-Vadodara expressway. For ease of study and design, the road alignment has been split into Three sections as under:

- From Varor (Vadhavan port) to Western Railway line - Ch. 0.00 to 12.00 km
- From Western Railway line to Surya River - Ch. 12.00 to 21.00 km
- From Surya River to NH-08 junction - Ch. 21.00 to 34.00 km.

10.2.1 From Varor (Vadhavan port) to Western Railway line - Ch. 0.00 to 12.00 Km

- The proposed road starts from Varor (Vadhavan port).
- It crosses two (2) village roads near Varor and moves toward southeast.
- Again, it crosses five (5) village roads and crosses Chinchani - Vangaon road at CH: 8663.
- It crosses Suburban lines of WR (under construction by MRVC); Western Railway Mumbai – Delhi Main line, & Western Dedicated Freight Corridor Lines under construction at CH: 11310. ROB with approach roads will be provide at this location.

- The route length of proposed road for this section is 12.00 km.
- The Vangaon Western railway station is 2.50 km from proposed road.
- The proposed road is. about 0.50 km away from DFCC-New Palghar crossing station.

Figure 10-3 Varor (Vadhavan port) to Western Railway line- Ch. 0.00 to 12.00 Km

10.2.2 From Western Railway line to Surya River- Ch. 12.00 to 21.00 km

- After crossing the Railway lines, alignment moves southeast.
- Certain stretches of the terrain in this portion are hilly. Hence, the road alignment has been designed avoiding hilly areas (as shown in figure below).
- It crosses three (3) village roads near Hanuman Nagar.
- It crosses Vanai - Shigaon road at CH: 17420 and turns toward south.
- It crosses Shigaon road at CH: 19450 and moves toward east.
- It crosses Surya River of approx. 210 m with 400 m approach width at CH: 19510
- The route length of the road for this section is 9.00 km.

Figure 10-4 Western Railway line to Surya River- Ch. 12.00 to 21.00 Km

10.2.3 From Surya River to NH-08 (Tawa junction)- Ch. 21.00 to 34.00 km

- After crossing Surya River alignment moves toward North.
- It crosses Mumbai-Vadodara expressway at CH: 22080 which is 8 lane Greenfield Project.
- It crosses stream of Surya river at CH:30220 & CH: 33520 of approx. width of 40 m & 25 m respectively.
- The proposed road alignment ends at NH-08 junction near Tawa.
- The route length of the road for this section is 14.00 km.
- The total length of the road/ expressway is about 34.00 km.

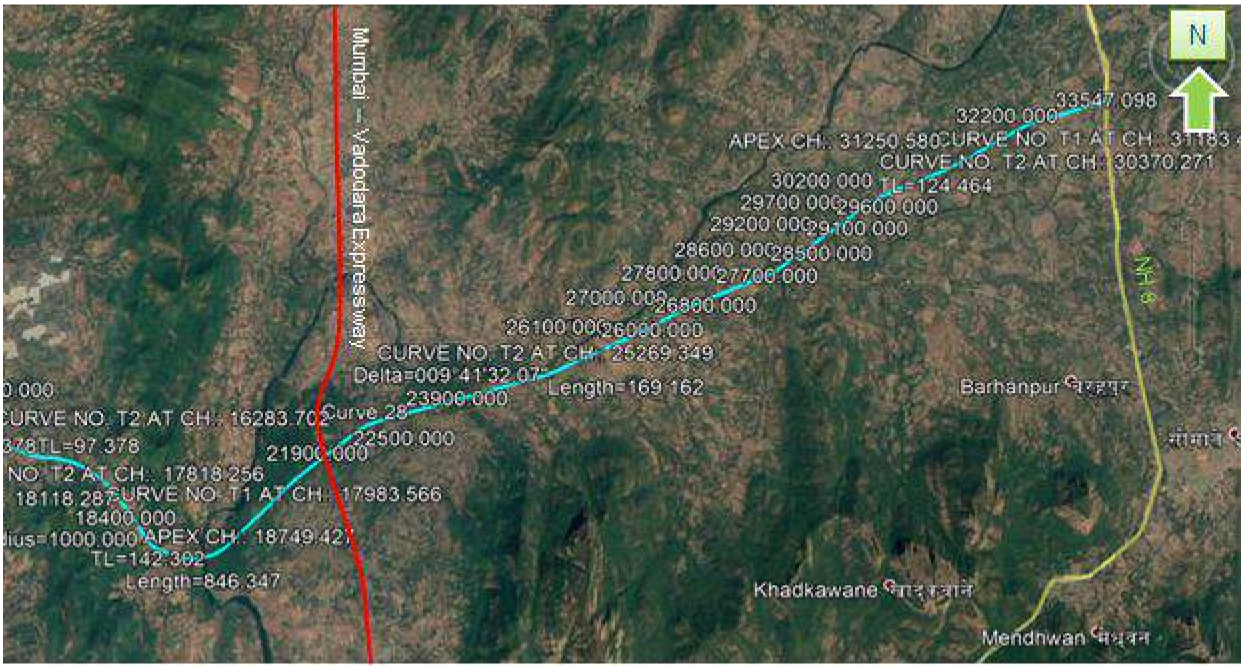


Figure 10-5 *Surya River to NH-08 junction- Ch. 21.00 to 34.00 km*

10.2.4 Intersection and Junction

The road is planned as an entry restricted road connecting with Mumbai Vadodara Expressway and NH-08. The recommended connectivity is designed as per MORTH Guidelines for traffic transfer shown in the figure below.

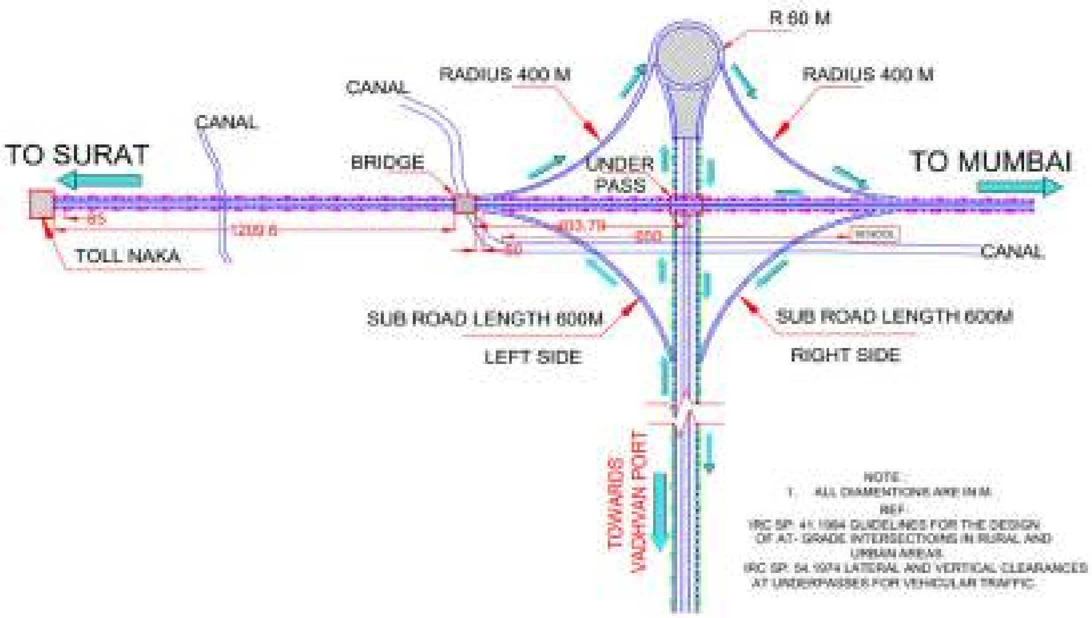


Figure 10-6 *Recommended Connectivity to NH-08*

The connectivity to Mumbai Vadodara expressway is as shown in the below figure.

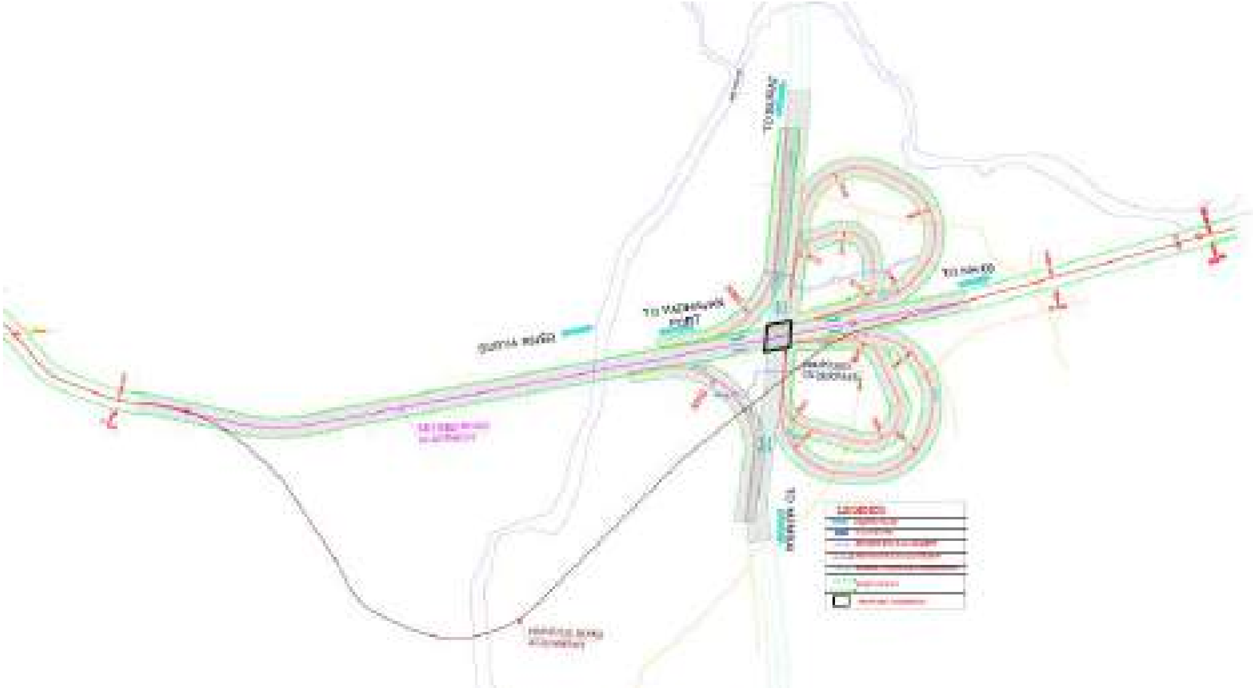


Figure 10-7 Recommended Connectivity to Mumbai-Vadodara Expressway

10.2.4.1 Recommendation for Junction Connectivity

Based on above junction drawing options following is recommended:

Connectivity to Mumbai-Vadodara expressway & NH-08

As the traffic towards Mumbai is going to be less compared to northward traffic, the above recommended option to NH-08 and to Mumbai- Vadodara connectivity is suggested.

Recommended connectivity of Port Road with NH-08, the port road crosses NH-08 via underpass.

- The proposed port formation level at the point of crossing is 39.340 m, ground level is 44.658 m.
- The existing level of NH-08 is 47.00 m at chainage 33.547 Km

Recommended connectivity of port road with Mumbai-Vadodara Expressway, the port road crosses expressway (Mumbai-Vadodara) via underpass.

- The proposed port formation level at the point of crossing is 25.407 m; Average ground level is 25.159 m.
- The proposed level of Mumbai-Vadodara Expressway is 28.89m at chainage 65.900 km, which has to be revised to Average 30.907 m by raising the expressway by 2.01 m for attaining the height of underpass for port road.

10.2.4.2 Connectivity to Port

The connectivity of the port can be further divided in three portions.

- Road towards gate and container terminal,
- Road connecting JNPA Port Administration Building and
- Road connecting Multipurpose terminal, liquid terminal, and RORO terminal.

All roads will be merging with the road connecting port to the NH-08 and Mumbai Vadodara expressway. Road from custom gate to container terminals will be of 8 lane wide road and the other roads from gate complex to JNPA Port Administration Building will be of two-lane wide road. The 4-lane road from the gate complex bifurcate to the multipurpose/ liquid/terminal.

11 Socio Economic Impact Assessment

11.1 General

The Socio-Economic Assessment (SEIA) was conducted as part of the DPR prepared by M/s. Progen Pentacle in 2018 for the people whose agricultural land / partial agriculture land needs to be acquired by the Government for the public interest and to study the impact of the development of the port on 21 (8 villages in Dahanu taluka and 13 villages in Palghar taluka) affected villages.

Additional study was carried out for the villages falling under 10 km radius numbering 25 villages (20 villages in Dahanu taluka and 5 villages in Palghar taluka) as it is felt that residents of these villages being in close proximity of the project will probably face disturbance in their present lives by movement of workers and project equipment and would also expect benefits from the project by way of livelihood support and improvement in their present living conditions.

Five villages are common in the above two studies as they are falling within a radius of 10 kms from the Port as well as on the rail or road corridors to the port. These five villages are within Dahanu taluka namely, Varor, Chinchani, Bavade, Tanashi and Kolavali. Thus, the number of villages in the above two studies is 41 considering the 5 villages which are common in the two lists only once.

This chapter is an abridged version of the Socio-Economic Assessment (SEIA) carried out and presented in the original DPR.

There is no land acquisition involved for the port estate onshore facilities, as the land requirement is mostly accommodated on reclaimed land of approximately 1,447 Hectares in the inter-tidal zone (221 ha.) adjacent to the coast and offshore area (1226 ha.).

Vadhavan port is located at 12 km distance from the main rail link and upcoming dedicated freight corridor for rail connectivity and is 35 km from the Mumbai - Delhi NH 8. Accordingly, land acquisition is required for the rail and road connectivity, with a corridor width of 160 m over a length of 12 km where both the road and the rail tracks are required, and a corridor width of 120 m over the remaining length of approximately 22 km where only road connectivity is required.

In accordance with extant policies and guidelines, a SEIA was carried out by Progen-Pentacle to determine the socio-economic consequences of industrial projects. For the Vadhavan Port development, this is particularly relevant for planning the acquisition of land required for the rail and road corridor.

The key objectives of subject studies were:

- To provide an accurate representation of the social, cultural, and economic conditions of the population of the village along which proposed road and rail alignment connecting Vadhavan port within 10 km radius of Vadhavan port.
- To identity the potential socio, socio-economic positive and negative impacts on the people living in the villages where road and rail line will pass.
- To develop attainable mitigation measures to enhance positive impacts and reduce or avoid negative impacts amongst the population of the villages along the proposed road and rail corridor.

11.2 SEIA Study Details

The SEIA was to carry out a qualitative assessment through a household survey, verification of government records, census data and a review of existing documents and records. The surveyed data was compiled and analysed for various parameters envisaged as under for Socio- Economic Assessment and mitigation measures:

- Population of villages through which road and rail alignment shall pass
- Educational background
- Gender and Age profile
- Caste based categorization
- Economic profile, occupation, and Social fabric
- Cattle population
- Number of automotive and type
- Welfare measures, Schools and colleges, Medical centre/Hospitals, and social gathering centre (Dharamshala /Library /Panchayat Hall/Samaj mandir)
- Water and power supply
- Road and rail access

For the purpose of the SEIA, the local study area is limited to the villages through which road and rail alignment is passing. The same is indicated in figure 11-1.

Figure 11-1 Schematic representation of proposed Road-Rail corridor of Vadhavan Port

11.2.1 Review of Literature

Reference has been made to the following documents and reports for the SEIA studies carried out in the previous DPR for obtaining information:

- Censes data of Palghar district (Previously Thane district), 2011
- NLGM project EIA: Socio-economic assessment report by Golder Associates 2012
- SEIA study for Ahmedabad metro rail project (Phase 1), 2014
- Techno-Economic Feasibility Report for Development of Port at Vadhavan - Draft
- Final by AECOM India Private Limited 2016
- Vadhavan port project, Public Opinion Survey Report by Goldmine Advertising Ltd., 2016.
- Household survey

11.2.2 Field Work

A preliminary site visit to the project area was conducted in December 2016. Primary data collection was subsequently undertaken during January 2017. This included the data collection of based line of demographic, family, social, educational, economic, cultural, housing, health, and project related information.

Qualitative research was undertaken to compliment the qualitative data collection and gain contextual understanding of social environment through observation of daily life. This was in the form of few focus group discussions of male/female and mixed sex discussions in villages and key informal interviews

The land holders falling under the proposed road and rail corridor for Vadhavan port were listed out from these holders, 10% were selected for sampling in order to prepare and firm up the SEIA report. The details have been presented in the table below:

Table 11-1 Overall population and sample size of the area

Description	Total Influenced land holders	Selected sample size
Proposed road and rail line are passing through 21 villages	1,237	125

Table 11-2 Sample selections of respondents from land holders falling under the influence zone of proposed road- rail corridor

S. No.	Village Name	Total Influenced Land Holders	Selected Sample Size
1.	Aakegavhan	34	3
2.	Aakoli	15	2
3.	Ambhede	31	3
4.	Bavade	151	15
5.	Chinchani	48	5
6.	Dhamatne	28	3
7.	Chinchare	Nil*	Nil*
8.	Ghol	Nil*	Nil*

S. No.	Village Name	Total Influenced Land Holders	Selected Sample Size
9.	Hanuman Nagar	Nil*	Nil*
10.	Kolavali	17	2
11.	Kolhan	7	1
12.	Naniwali	40	4
13.	Newale	229	23
14.	Ravte	21	2
15.	Shigaon	117	12
16.	Khaniwade	28	3
17.	Tawa	Nil*	Nil*
18.	Tanashi	93	9
19.	Varor	282	28
20.	Vangaon	77	8
21.	Sumadi	19	2
	Total	**1,237**	**125**

*Note: Since proposed road & rail corridor in these four villages passes through Government owned land only, none of the private land holders are affected from these villages.

The total population of these 25 villages as per 2011 census is 56,181 persons living in 12,652 households of which 8,830 persons are tribal.

11.3 Summary

The summary of the major findings of the survey is presented below.

11.3.1 Demographic characteristics

The total population of these 25 villages within 10 km radius as per 2011 census is 56,181 persons living in 12,652 households of which 8,830 persons are tribal. Total population of these 21 villages along rail road corridor as per 2011 census is 39,890 people out of which 26,044 persons are tribal showing tribals constitute above 65% of the population in these villages.

There is a substantial population of tribes in the 41 target villages and in many villages, they form a majority population. Their total population in the target 41 villages is 34,874 which comes to 38% % of the population (this excludes the 3 fishing villages situated outside 10 kms radius).

- The 88% of respondent have male as family head.
- Nearly two third of respondents are adults and middle age group.
- Majority of the respondents are following Hindu religion.
- The majority of population converses in Marathi.
- One third of the respondents are illiterate, while more than one half have completed only secondary education.

11.3.2 Family Characteristics

- The majority of respondents follow Hindu family values and culture.
- The respondent's family members have healthy interfamily relations.
- Many members of the families are gradually entering into the public life.

11.3.3 Social Characteristics

- Majority of the respondents settle their inter community dispute through mutual settlement.
- The two third of adults are still ignorant of traditional services like post office and modern services such as Bank.

11.3.4 Economic Characteristics

The study has brought out that main occupation of the people in targeted villages is agriculture which provides seasonal employment. Total extent of the agricultural land in these 41 target villages (excluding 3 fishing villages located outside 10 km radius of Vadhavan Port) is about 7,337 ha. which is about 50% of the total geographical area in these villages (14,489 ha.). Big and rich landholders and orchard owners whose number is less than 5-6% of population in the target villages have irrigated or partly irrigated land are better off and may not be residing in the village most of the time. About 64% of the agriculturists cultivate less than one hectare of land which does not make a sustainable holding given the fact that most of the land is dry one crop land and about 10% of population is landless. Thus, 74% of population in target villages is the prime focus for improvement in their lot. Further, about 37% of the people in the target villages are in the age group of 21-40 years which should be the prime focus for training them to make them employable. 34% of population appears to be in the age group of 50 years and above indicating that dependence of ageing population on the working age population is likely to increase in future. Hence there is a great need to teach or train and provide employment to the working age people in the target villages so that the port project brings about long term prosperity in the area and become an ideal example of a project related uplifting of the local people to a bright or at least a better future.

- The majority of the respondents are involved in farming followed by fishing and dye making.
- The majority of the respondents have ancestral agricultural land holding.
- Nearly one half of the respondents have size of agriculture land less than one hectares.
- Rice is the predominant crop in this region.
- Majority of the respondents are at the border of poverty line.
- Most of the respondents use farm production for family (self) consumption.

11.3.5 Educational information

Primary education is well spread and accessible to the target villages and secondary education is available at a short distance to these villages. There are 5 colleges and 4 vocational/ technical education institutes like ITI in the area covered by the target villages. There are 15 private as well as government run Ashramshalas (boarding schools for education of tribal children) in the area for tribal students.

- Lack facilities of computer education, potable drinking water, sports and toilet facilities.

11.3.6 Housing Information

- Majority of the farmers are living in traditional huts and semi pukka houses.
- Most of the tribal have scattered housing location in Padas.
- Tribal communities are lacking provision of safe portable drinking water.
- Traditional fuel such as solid wood, grass and dunk cake is used by majority respondents.

11.3.7 Health Information

Primary health infrastructure is also well provided in the targeted villages and there are private clinics as well. All these villages are very accessible and are connected by all-weather roads. Vangaon railway station in the midst of target villages provides local train access to Palghar, Dahanu and Mumbai.

- Malnutrition seems to be major health problem of women.
- Children have various Vitamin deficiencies.
- Hygiene and sanitation in these villages needs improvement

11.3.8 Project Related Information

- Majority of the respondents are unaware of proposed project.
- While most of the respondents have neutral view about the project.
- Some of the respondents felt there will be disturbance in current way of living of fishermen, farmers, and artisans
- Few percent of people are anxious about minimal returns against property and loss of natural resources.
- Some of the respondents are worried about less employment opportunities, loss of land, danger to marine environment.
- While little less than one half of respondents were perceived that they will be forcefully displaced to Jawhar and Mokhada taluka.

11.4 Socio-Economic Impact Prediction and Evaluation

The aim of this section is to identify the potential socio-economic impacts that are likely to arise as a result of the proposed project.

11.4.1 Impact Assessment Methodology

The impact assessment was done according to the following methodology:

- Direction of an impact may be positive, neutral, or negative with respect to the particular impact (e.g., a habitat gain for a key species would be classed as positive, whereas a habitat loss would be considered negative).
- Magnitude is a measure of the degree of change in a measurement; it is classified as none/ negligible, low, moderate, or high. The categorization of the impact magnitude may be based on a set of criteria (e.g., health risk levels, ecological concepts and/or professional judgment) pertinent to each of the discipline areas and key questions analysed. The specialist study must attempt to quantify the magnitude and outline the rationale used. Appropriate, widely- recognized standards are used as a measure of the level of impact.

- Duration refers to the length of time over which an impact/ influence may occur i.e., transient (less than 1 year), short-term (0 to 5 years), medium term (5 to 15 years), long term (greater than 15 years with impact ceasing after closure of the project) or permanent.
- Scale/ Geographic extent refers to the area that could be affected/ influenced by the impact and is classified as site, local, regional, State, National or International.
- Probability of occurrence is a description of the probability of the impact/ influence actually occurring as improbable (less than 5% chance), low probability (5% to 40% chance), medium probability (40% to 60% chance), highly probable (most likely, 60% to 90% chance) or definite (impact will definitely occur).
- Impact significance was rated by the specialists using the scoring system shown in the box below.

Table 11-3 Impact significance scale

Magnitude	Duration	Scale	Probability
10, Very high/ don't know	5, Permanent	5, International/ National	5, Definite/ don't know
8, High	4, Long term (impact ceases after closure of activity)	4, State	4, Very Highly Probable
6, Moderate	3, Medium term (5 to 15 years)	3, Regional	3, Highly Probable
4, Low	2, Short term (0 to 5 years)	2, Local	2, Medium Probable
2, Minor	1, Transient	1, Site only	1, Low Probable
1, None			0, None

- Maximum SP (significance points) is 100 points
- SP >75, High significance
- SP = 25 to 50, Moderate significance
- SP< 25, Low significance

After ranking these factors for each impact, the significance of the two aspects, occurrence, and severity, was assessed using the following formula:

SP = (magnitude + duration + scale) x probability

The maximum value is 100 significance points (SP). The potential impacts were then rated as of High (SP >75), Moderate (SP 25-50) or Low (SP<25) significance, both with and without mitigation measures on the following basis:

Table 11-4 Impact significance scale basis

Significance Point	Probability	Description
SP >75	Indicates High significance	Where it would influence the decision regardless of any possible mitigation. An impact which could influence the decision about whether or not to proceed with the project.
SP 25 to 50	Indicates Moderate significance	Where it could have an influence on the decision unless it is mitigated. An impact or benefit which is sufficiently important to require management of moderate significance - could influence the decisions about the project if left unmanaged.

Significance Point	Probability	Description
SP< 25	Indicates Low significance	Where it will not have an influence on the decision Impacts with little real effect and which should not have an influence on or require modification of the project design or alternative mitigation
+	Positive Impact	An impact that is likely to result in positive consequences / effects.

11.4.2 Identification of direct impacted people and vulnerable group

The assessment has determined that farmers might be most affected by the proposed road and rail line traversing through villages.

Table 11-5 Identification of direct impacted people and vulnerable group

S. No.	Development of Infrastructure	Direct Impacted People	Vulnerable groups
1.	Proposed road and rail line will pass through 25 villages	Farmers	Tribal

11.4.3 Identification of loss caused to people who are directly impacted and vulnerable

The SP value assessment shows that the impact on farmers will be low due to their relatively sound economic status, whilst the impact on tribal groups will be moderate.

Table 11-6 Identification of loss caused to people who are directly impacted and vulnerable group

Group of People	Impact	M	D	S	P	Total	SP
Farmers	Partial loss of Agriculture land	2	5	2	1	9	L
Tribal	Partial loss of Agriculture land	4	5	2	3	33	M

11.4.4 Social Impact Assessment of Farmers

The SP value assessment shows that the impact on cash crop farmers will be low due to their relatively sound economic status. The impact on marginal and small farmers will also be low but the impact on tribal farmers will be moderate. Most of tribal are middle aged person, who cannot easily change their occupational pattern. Hence, it is necessary to offer them handsome benefit against land acquisition.

Table 11-7 Social Impact assessment matrix of farmer

Farmer Groups	Impact	M	D	S	P	Total	SP
Cash Croppers	Partial loss of agriculture land	4	5	1	1	10	L
Small and Marginal farmers	Partial loss of agriculture land	4	5	1	2	20	L
Tribal farmers	Partial loss of agricultural land	4	5	1	3	30	M

11.4.5 Social Impact Assessment of Vulnerable Tribal Groups

The table below shows moderate impact on tribal population due to the partial loss of agricultural land. Tribal are customary land users engaged in crop cultivation and they will experience loss of income. Similarly, the backwardness of tribal may result in exploitation by non-tribal and hence tribal rights shall be protected to avoid negative impact on their life.

Table 11-8 Social impact assessment matrix of vulnerable tribal group

S. No.	Impact on Vulnerable Tribal Groups	M	D	S	P	Total	SP
1.	Partial loss of agriculture land	4	5	1	4	30	M
2.	Exploitation due to backwardness	6	4	3	4	39	M

11.4.6 Social Impact Assessment of Community Resources

From the table below it is seen that there will a low impact on people from issues related to community resources such as water, road, electricity, industrialization, urbanization.

Table 11-9 Social impact assessment matrix of community resources

Community resources	Potential Impact	M	D	S	P	Total	SP
Water Resources	Loss of easy access	2	4	2	1	8	L
Road	Traffic, road safety issues	4	3	2	2	18	L
Electricity	Load on power	4	3	2	2	18	L
Industrialization	Change in occupation	4	3	2	2	18	L
Urbanization	Inflation, Crime	2	4	2	1	8	L

11.5 Recommendations

11.5.1 General Recommendations

- The involvement of NGOs may be taken to reduce deprivation of people with the use of community interaction methods.
- The social service benefit and facilities may be introduced among education, health, and government institutions to create positive impact and gather consensus about the project.
- The farmers should be given appropriate compensation to acquire the land. Compared to the general category, the tribal community is most vulnerable, so special care and protection may be developed to them in order to avoid any exploitation. Tribal farmers shall be given agricultural land in nearby places on priority.

11.5.2 Project Communication Recommendations

- The project affected people and families may be encouraged to participate in the development of the port and in order to have a positive view towards port development by following methods.
  - The project affected people should be clearly informed regarding the development of the port and benefit to the society and same to be conveyed through personal meeting printed literature, audio visual presentation and videos.

  - JNPA may arrange meetings and discussions with project affected people and apprehensions to be cleared.
  - Focused group interactions are required to be carried out.
  - Statutory meetings of Gram panchayat to be participated and brief on project and its overall benefits to be discussed.
- The misconception of the people should be removed through public meetings with locals in association of Gram panchayat, NGOs and promoting authorities of governments.

11.5.3 Health Provision Recommendations

- Port authorities may arrange health check-up camps and ambulance services in the village areas.

11.5.4 Education and Training Recommendations

- The project proponent should ensure skilled development and life improvement by training and provision of agricultural programmes.
- Since all the villages have educational institutions, the educational institutions shall be supported by port authorities to start various schemes for development of infrastructure for sport facility at school. The children of project affected families may be helped through.
  - Various Scholarships.
  - Distribution of bicycles or transport facilities
  - Supply of cultural equipment's
  - Supply of sport equipment's and other facilities.
- Students may be helped by the Educational or Career counsellor to solve their issues related to education; similarly, he may act as mentor for as mentor for personality, leadership, and soft skills development of students.

The following tables suggest the village-wise recommendations.

11.5.5 Village-Wise Recommendations

11.5.5.1 Education Sector Development Recommendations

Table 11-10 Village wise recommendations for educational improvements

Development of Infrastructure for Sport facility at schools	Supply of personal sports equipment sets and cultural equipment sets	Supply of Bicycles for commuting	Career/ Educational Counselling services and training centres	Learning infrastructure enhancement
1. Playground *2. Net court*	*1. Football* *2. Basketball* *3. Cricket* *4. Volleyball* *5. Dhol* *6. Lezim*	*1. Bicycles*		*1.Computer* *2.Projector* *3. Screen*
Chinchani, Dhamatne, Chinchare,	Chinchani, Dhamatne, Chinchare,	Chinchani, Dhamatne, Chinchare,	Chinchani, Dhamatne, Chinchare, Naniwali, Varor, Vangaon	Aakegavhan, Aakoli, Ambhede, Bavade, Hanuman Nagar,

Development of Infrastructure for Sport facility at schools	Supply of personal sports equipment sets and cultural equipment sets	Supply of Bicycles for commuting	Career/ Educational Counselling services and training centres	Learning infrastructure enhancement
1. Playground *2. Net court*	*1. Football* *2. Basketball* *3. Cricket* *4. Volleyball* *5. Dhol* *6. Lezim*	*1. Bicycles*		*1.Computer* *2.Projector* *3. Screen*
Naniwali, Varor, Vangaon	Naniwali, Varor, Vangaon	Naniwali, Varor, Vangaon		Kolavali, Kolhan, Newale, Ravte, Shigaon, Khaniwade, Tanashi

11.5.5.2 Health Sector Related Recommendations

The health problem of people may be addressed by medical social worker services through health counselling. Malnutrition control program for tribal may be undertaken to improve the health standers of tribal. The basic health facilities like ambulance services and donations for medical emergency problems may be very useful for these people.

Table 11-11 Village wise recommendations for health care-sector

Medical Social Worker Services/ Health Counselling	Ambulance services and Mobile clinic	Malnutrition Control Program for tribal	Improvements of Health Infrastructure and Services	Financial aid for Medical Emergency problems
Aakegavhan, Aakoli, Ambhede, Bavade, Chinchani, Dhamatne, Chinchare, Ghol, Hanuman Nagar, Kolavali, Kolhan, Naniwali, Newale, Ravte, Shigaon, Khaniwade, Tawa, Tanashi, Varor, Vangaon, Sumadi	Aakegavhan, Aakoli, Ambhede, Bavade, Chinchani, Dhamatne, Chinchare, Ghol, Hanuman Nagar, Kolavali, Kolhan, Naniwali, Newale, Ravte, Shigaon, Khaniwade, Tawa, Tanashi, Varor, Vangaon, Sumadi	Aakegavhan, Aakoli, Bavade, Dhamatne, Kolhan, Naniwali, Newale, Ravte, Shigaon, Khaniwade, Tanashi, Varor, Vangaon, Sumadi	Bavade, Chinchani, Hanuman Nagar, Naniwali, Shigaon, Tawa, Varor, Vangaon	Aakegavhan, Aakoli, Ambhede, Bavade, Chinchani, Dhamatne, Chinchare, Ghol, Hanuman Nagar, Kolavali, Kolhan, Naniwali, Newale, Ravte, Shigaon, Khaniwade, Tawa, Tanashi, Varor, Vangaon, Sumadi

11.5.6 Employment related Recommendations

11.5.6.1 For Adults of Project Affected Families

The employment opportunities of project affected family members may be encouraged by giving them skill development training on areas like driving skills, vehicle mechanical works etc. and business opportunities in areas like agriculture allied business industry like dairy, poultry, goat farming, Hotel industries and horticulture and its maintenance etc. Similarly, the project affected family members may be offered jobs in port.

Table 11-12 Village wise recommendations for employment opportunities

Employment Through Skill Development	Business Opportunities	Job Opportunities at port
1. Driving LMV/HMV *2. Vehicle mechanic*	*1. Agriculture allied business* *(a) Dairy* *(b) Poultry* *(c) Goat farming* *2. Hotel Management* *3.Horticulture*	
All Villages	All Villages	All Villages

11.5.6.2 For Youth of Project Affected Families.

During discussions with youths for socio-economic impact assessment, it was noted that majority of the youths could complete the education up to the secondary schools. Hence considering the educational background of the youth following possible skill-based trainings are suggested for the employment opportunities.

- Employment opportunity may be developed through training of unskilled/ semi-skilled workers at ITIs.
- Employment opportunities may be developed under National Skill Development Corporation by running training courses among the youths through partnerships with local Industrial Training Institutes (ITIs) for creating employment in all the villages in service and business field. Special training courses can be offered like A.C. installation and repairing work, hardware shop keeping, horticulture and its maintenance, mechanical works, electrical works, auto electrician works, driving skills, plumbing, mason works, carpentry and business in each village to create entrepreneurs.
- Employability of people may be encouraged through promotion of agriculture allied business like dairy, poultry, goat farming etc.
- The women empowerment may be achieved through formation of Self-Help Group (SHG) and there by developing women entrepreneurs.

Table 11-13 Village wise recommendations for employment opportunities

Training of unskilled /semi-skilled workers at ITIs	Employment through skill development	Business opportunities	For women entrepreneurs
1.Mechanic **2.Electrician** **3.AutoMobile**	**1. Driving (LMV/HMV)** **2. Plumbing** **3. Masonry** **4. Carpentry**	**1. A.C Installation/ repairing** **2. Hardware** **3. Agriculture allied business such as Dairy, Poultry, Goat farming etc.**	**Self-Help Group (SHG)**

Training of unskilled /semi-skilled workers at ITIs	Employment through skill development	Business opportunities	For women entrepreneurs
Aakegavhan, Aakoli, Dhamatne, Kolhan, Naniwali, Newale, Ravte, Shigaon, Khaniwade, Varor, Vangaon, Sumadi	Aakegavhan, Aakoli, Ambhede, Bavade, Chinchani, Dhamatne, Chinchare, Ghol, Hanuman Nagar, Kolavali, Kolhan, Naniwali, Newale, Ravte, Shigaon, Khaniwade, Tawa, Tanashi, Varor, Vangaon, Sumadi	Aakegavhan, Aakoli, Ambhede, Bavade, Chinchani, Dhamatne, Chinchare, Ghol, Hanuman Nagar, Kolavali, Kolhan, Naniwali, Newale, Ravte, Shigaon, Khaniwade, Tawa, Tanashi, Varor, Vangaon, Sumadi	Aakegavhan, Aakoli, Ambhede, Bavade, Chinchani, Dhamatne, Chinchare, Ghol, Hanuman Nagar, Kolavali, Kolhan, Naniwali, Newale, Ravte, Shigaon, Khaniwade, Tawa, Tanashi, Varor, Vangaon, Sumadi

Table 11-14 Village wise recommendations for employment opportunities in different sectors – For Males

Automotive Repairs	Electricals	Construction Works	Security Jobs	Hospitality and Food Industry
Aakegavhan, Aakoli, Chinchani, Dhamatne, Ghol, Hanuman Nagar, Kolhan, Naniwali, Newale, Ravte, Shigaon, Khaniwade, Tawa, Varor	Chinchani, Dhamatne, Chinchare, Ghol, Hanuman Nagar, Kolavali, Kolhan, Naniwali, Newale, Ravte, Shigaon, Khaniwade, Tawa, Tanashi, Varor	Aakegavhan, Aakoli, Ambhede, Kolavali, Kolhan, Naniwali, Newale, Ravte, Shigaon, Khaniwade, Tanashi, Sumadi	Aakegavhan, Aakoli, Ambhede, Bavade, Kolavali, Kolhan, Naniwali, Newale, Shigaon, Tanashi, Varor, Vangaon, Sumadi	Chinchani, Kolhan, Naniwali, Newale, Ravte, Tanashi, Varor, Vangaon, Sumadi

A focused group discussion with female members during the base line survey identified their interest related to work and it is classified in terms of suitable and possible employment opportunities for different villages.

Accordingly, suitable trainings are suggested for females in the following table.

Table 11-15 Village wise recommendations for employment opportunities in different sectors – For Females

Soft Toys Making	Beauty culture and Fair Dressing	Construction Works	Tailoring and Dress Making	Food processing and Preservation
Chinchani, Ghol, Hanuman Nagar, Kolavali, Shigaon, Khaniwade, Varor, Vangaon	Chinchani, Ghol, Hanuman Nagar, Kolavali, Shigaon, Khaniwade, Varor, Vangaon	Aakoli, Ambhede, Chinchani, Dhamatne, Kolhan, Naniwali, Newale, Ravte, Tawa, Tanashi, Sumadi	Aakegavhan, Bavade, Chinchare, Ghol, Hanuman Nagar, Kolavali, Shigaon, Khaniwade, Varor, Vangaon	Aakegavhan, Chinchani, Dhamatne, Chinchare, Kolhan, Naniwali, Newale, Ravte, Tawa, Tanashi, Sumadi

12 Land Acquisition

Based on the land requirement assessment for the proposed rail and road corridor, the land acquisition details were worked out. This includes the private land, agricultural land, forest land. The land acquisition has been worked out for the rail and road separately as indicated in the below table.

Table 12-1 Category-wise Land Acquisition details for Road Connectivity

S. No	Villages	Aadivasi Land		Private Land		Forest Land		Govt Land		Total	
		Total Area (m^2)	Area under Acquisition (m^2)	Total Area (m^2)	Area under Acquisition (m^2)	Total Area (m^2)	Area under Acquisition (m^2)	Total Area (m^2)	Area under Acquisition (m^2)	Total Area (m^2)	Total Area under Acquisition (m^2)
1	Varor	-	-	42.20	20.49	-	-	0.17	0.13	42.37	20.62
2	Chinchani	-	-	31.91	9.84	-	-	0.06	0.00	31.97	9.85
3	Tanashi	-	-	94.35	29.34	-	-	4.05	0.07	98.40	29.41
4	Bavade	1.68	0.28	139.12	44.38	-	-	11.56	0.44	152.36	44.99
5	Vangaon	-	-	93.94	9.36	-	-	-	-	93.94	9.36
6	Kolavali	-	-	128.84	22.30	-	-	2.81	0.20	131.54	22.54
7	Newale	6.02	1.35	11.95	24.01	-	-	-	-	18.07	25.36
8	Hanuman Nagar	-	-	[illegible]	[illegible]	8.42	10.96	-	-	8.42	10.96
9	Shigaon	18.52	13.29	13.60	6.61	[illegible]	[illegible]	1.60	0.79	34.12	20.69
10	Sumdi	0.01	5.85	4.19	8.58	-	7.26	0.20	0.07	14.31	18.79
11	Gargaon	19.62	2.20	0.98	7.96	246.53	11.18	-	-	267.12	21.33
12	Ravate	47.01	4.67	22.29	1.47	-	-	-	-	69.79	6.14
13	Chinchare	6.67	1.41	20.93	2.68	50.20	12.63	-	-	77.00	16.81
14	Aakoli	11.88	1.88	22.10	3.67	-	-	-	-	33.98	5.52
15	Aakegavhan	55.45	18.75	-	-	0.54	2.52	-	-	55.99	19.27
16	Nanivali	6.16	4.64	20.84	36.54	-	-	-	-	32.00	41.18
17	Ambiste	-	-	18.70	9.67	-	-	37.48	0.62	56.18	13.89
18	Dhamatane	51.34	17.98	-	-	65.44	5.00	-	-	116.78	22.98
19	Kolhan	5.63	2.72	0.51	0.27	27.21	14.10	-	-	33.35	17.09
20	Ghol	13.43	4.17	-	-	99.89	16.44	-	-	113.32	20.61
21	Tawa	5.63	1.96	-	-	251.37	6.01	-	-	257.00	7.97
	Total Area	260.16		641.23		741.59		57.88		1,700.86	
	Total Area under Acquisition		79.24		236.48		86.01		0.73		485.46

Table 12-2 Category-wise Land Acquisition for Rail Connectivity

S. No	Villages	Aadivasi Land		Private Land		Forest Land		Govt Land		Total	
		Total Area (ha)	Area under Acquisition (ha)	Total Area (ha)	Area under Acquisition (ha)	Total Area (ha)	Area under Acquisition (ha)	Total Area (ha)	Area under Acquisition (ha)	Total Area (ha)	Total Area under Acquisition (ha)
1	Varor	-	-	17.63	10.03	13.65	-	0.05	0.03	31.34	10.06
2	Chinchani	-	-	23.59	5.40	-	-	-	-	23.59	5.40
3	Tanashi	0.84	0.14	44.68	14.20	-	-	0.01	0.04	45.52	14.38
4	Bavade	-	-	116.63	20.37	-	-	6.06	0.75	122.69	21.12
5	Vangaon	-	-	29.61	5.19	-	-	4.91	-	34.52	5.19
6	Kolavali	-	-	119.48	10.80	-	-	3.00	0.10	122.48	10.89
7	Newale	-	-	35.63	1.97	-	-	26.02	-	61.65	1.97
	Total Area	0.84		387.24		13.66		40.05		441.79	
	Total Area under Acquistion		0.14		67.95		-		0.92		69.01

Table 12-3 Total Land Acquisition for Road and Rail Connectivity

			For Road (in Ha.)	**For Rail (in Ha.)**	**Total (in Ha.)**
1.	Dahanu	Varor	20.62	10.06	30.68
2.	Dahanu	Chinchani	9.65	5.40	15.04
3.	Dahanu	Tanashi	29.41	14.38	43.79
4.	Dahanu	Bavade	44.09	21.12	65.21
5.	Dahanu	Vangaon	9.35	5.19	14.53
6.	Dahanu	Kolavali	22.54	10.89	33.43
7.	Palghar	Newale	25.36	1.97	27.33
8.	Palghar	Hanuman Nagar	10.96	-	10.96
9.	Palghar	Shigaon	20.89	-	20.89
10.	Palghar	Sumadi	19.79	-	19.79
11.	Palghar	Gargaon	21.33	-	21.33
12.	Palghar	Ravate	6.14	-	6.14
13.	Palghar	Chichare	16.83	-	16.83
14.	Palghar	Akoli	5.52	-	5.52
15.	Palghar	Akhegavaon	19.27	-	19.27
16.	Palghar	Nanivali	41.18	-	41.18
17.	Palghar	Ambhedhe	13.89	-	13.89
18.	Palghar	Dhamatane	22.98	-	22.98
19.	Palghar	Kolhan	17.10	-	17.10
20.	Palghar	Ghol	20.61	-	20.61
21.	Palghar	Tawa	7.97	-	7.97
22.	Total		405.46	69.01	474.47
23.		Land from MMB (Reclamation)	-	-	1,473.00
	Grand Total		**405.46**	**69.01**	**1,947.47**

Table 12-4 Total Land Acquisition Cost for Road and Rail Connectivity

S. No.	Taluka	Village	Private Land				Adivasi Land				Govt Land				Forest Land				Total Cost
			Area		Amount		Area		Amount		Area		Amount						
			For Road (in Ha.)	For Rail (in Ha.)	For Road (in Cr.)	For Rail (in Cr.)	For Road (in Ha.)	For Rail (in Ha.)	For Road (in Cr.)	For Rail (in Cr.)	For Road (in Ha.)	For Rail (in Ha.)	For Road (in Cr.)	For Rail (in Cr.)	For Road (in Ha.)	For Rail (in Ha.)	For Road (in Cr.)	For Rail (in Cr.)	
1	Dahanu	Varor	20.49	10.63	4.07	1.89	-	-	-	-	0.13	0.03	0.03	0.01	-	-	-	-	24.25
2	Dahanu	Chinchani	9.64	5.40	10.73	5.99	-	-	-	-	0.09	-	0.01	-	-	-	-	-	66.75
3	Dahanu	Tanashi	29.34	14.20	4.52	2.38	-	0.14	-	0.02	0.07	0.04	0.01	0.01	-	-	-	-	29.23
4	Dahanu	Bavade	40.38	20.17	18.22	9.70	3.28	-	0.14	-	3.44	0.75	1.84	0.98	-	-	-	-	117.69
5	Dahanu	Vangaon	9.35	5.19	5.89	3.27	-	-	-	-	-	-	-	-	-	-	-	-	36.62
6	Dahanu	Kolavali	22.35	10.80	4.43	2.14	-	-	-	-	0.20	0.10	0.04	0.02	-	-	-	-	28.28
7	Palghar	Navali	24.01	1.87	6.70	0.55	1.35	-	0.38	-	-	-	-	-	-	-	-	-	29.03
8	Palghar	Hanuman Nagar	-	-	-	-	-	-	-	-	-	-	-	-	10.90	-	1.34	-	1.34
9	Palghar	Biligaon	6.81	-	0.83	-	13.29	-	1.63	-	0.78	-	0.13	-	-	-	-	-	3.40
10	Palghar	Saravali	6.00	-	0.80	-	5.85	-	0.73	-	0.07	-	0.01	-	7.28	-	0.89	-	4.08
11	Palghar	Dungaon	7.98	-	0.58	-	2.20	-	0.27	-	-	-	-	-	11.16	-	1.37	-	5.27
12	Palghar	Ravate	1.47	-	0.18	-	4.67	-	0.57	-	-	-	-	-	-	-	-	-	0.72
13	Palghar	Chichare	2.00	-	0.41	-	1.41	-	0.20	-	-	-	-	-	12.53	-	1.80	-	3.48
14	Palghar	Akoli	3.07	-	2.45	-	1.85	-	0.23	-	-	-	-	-	-	-	-	-	1.80
15	Palghar	Akhegavhan	-	-	-	-	16.75	-	2.05	-	-	-	-	-	2.52	-	0.31	-	0.31
16	Palghar	Navali	36.54	-	3.53	-	4.64	-	0.48	-	-	-	-	-	-	-	-	-	14.38
17	Palghar	Ambavade	6.97	-	0.87	-	-	-	-	-	3.02	-	0.49	-	-	-	-	-	3.98
18	Palghar	Chanatane	-	-	-	-	17.30	-	3.02	-	-	-	-	-	5.00	-	0.84	-	0.84
19	Palghar	Kolwal	0.27	-	0.05	-	2.73	-	0.48	-	-	-	-	-	14.10	-	2.37	-	2.35
20	Palghar	Shil	-	-	-	-	4.17	-	1.01	-	-	-	-	-	19.44	-	4.03	-	4.03
21	Palghar	Tave	-	-	-	-	1.90	-	0.48	-	-	-	-	-	0.01	-	1.40	-	1.40
22	Total		230.49	67.95	64.09	26.02	79.24	0.14	11.61	0.02	6.73	0.62	2.32	0.38	86.01	-	14.38	-	377.56
23		Land from [illegible] (Reclamation)	-	-	-	-							-	-			-	-	292.30
		Grand Total	230.49	67.95	64.09	26.02	79.24	0.14	11.63	0.02	6.73	0.62	2.32	0.39	86.01	-	14.38	-	669.86

Description		
Private and Adhivashi Land Cost	75.71	26.05
कलम 26 प्रमाणे पोट कलम (2) अन्वये बाजार मुल्य व त्याचे कलम 26(1) प्रमाणे लावलेल्या किंमतीला गावांचे फॅक्टरद्वारे गुणले जाईल. महाराष्ट्र शासन अधिसुचना दि. 26/05/2015 प्रमाणे प्रस्तुत गावांचा गुणांक घटक 2.00 आहे.	151.42	52.10
कलम 26 व 27 प्रमाणे आदीवासी भुधारक व नविन अविभाज्य शर्त व भोगवटा वर्ग. 2,कु. का.32 ग चे जमीनीची नजराना व अनर्जीत रक्कम बाजार मुल्याचे 50% ऐवजी 10% रक्कम आकारणी करणेचे शासनाचे 15/06/2010 चे आदेशा प्रमाणे या प्रकरणी 10% (अंदाजे) रक्कम अनर्जीत म्हणून गृहीत धरली आहे व बिगर आदीवासी संदर्भात 50% अनर्जीत रक्कम शासन जमा करणेची आहे.	15.14	5.21
वरील नजराना/अनर्जीत रक्कम वरील मोबदला मधून कमी केली.	136.28	46.89
भूसंपादन अधिनियम 2013 चे कलम 27 प्रमाणे संपादीत जमीनीवरील झाड/झाडोरा बांधकाम/विहीरी/बोअरवेल यांचे मुल्यावान हे जोडावे. (संयुक्त मोजणी अती संपादीत जमीनीत अंतर्गत असणारे) (सध्या- निरंक)	-	-
कलम 28 प्रमाणे एकूण एकंदर रक्कम मोबदला	136.28	46.89

Description		
भूसंपादन अधिनियम 2013 चे कलम 28,29,30 प्रमाणे मुल्यांकन दिलासा रक्कम – अंतिम निवाडयात एकूण देय नुकसान भरपाई रक्कमेमध्ये रकमेच्या स: विभाजन (solitium) 100% रक्कम देण्याची तरतुद करणेत आली आहे.	272.55	93.77
12% अतिरिक्त वाढ कलम 30 प्रमाणे महाराष्ट्र शासनाचे महसूल व वन विभाग कडील परिपत्रक क्र. संकिर्ण/ 03/2016/ स.क्र. 270/ अ.2 दि. 28/10/2016अन्वये वरील रक्कमेवर 12% अतिरिक्त वाढ देण्याची तरतुद केली आहे.	32.71	11.25
एकूण एकंदर देय रक्कम	305.26	105.02
यामध्ये वरील प्रमाणे सरकार जमा करणेची अनर्जीत व नजराना रक्कम जोडावी	15.14	5.21
जमीनी बाबत अंतिम निवाडयात जमीनीची नुकसान भरपाई देय राहील.	320.40	110.23
आस्थापना खर्च व सोयी सुविधासाठी तरतुद भूसंपादन अधिकारी या भुसंपादनाचे कामा करीता 3% आस्थापना खर्च व 3% महाराष्ट्र शासनाचे महसूल व वन विभागाकडील अधिसुचना क्र. LAQ/12/2013/CR-190/A2 दि. 19/03/2014 नुसार आकारणी करेल ती रक्कम खालील प्रमाणे 3% आस्थापना खर्च 13.31 3% खर्च सोयी सुविधा 13.31	9.61	3.31
	9.61	3.31
वरील प्रमाणे येणारी रक्कम एकूण रक्कमेत जोडावी.	**339.63**	**116.85**
Govt. Land (शासकिय जमीन)	2.32	0.39
Forest Land (वन जमीन)	14.38	-
Land from MMB (Reclamation)		
Grand Total	**356.32**	**117.24**

13 Mathematical Model Studies

13.1 General

Various model and technical studies have been performed to ascertain various oceanographic and coastal impacts of the proposed port development and to determine the optimum layout of the master plan development. These studies are listed in Section 1.6. Other site-specific model studies conducted by JNPA are listed below. The CWPRS studies have evolved during the study period and have been used to arrive at the final proposed layout. The studies were carried out for the old layout as shown in Figure 1-2.

- **Wave Modelling Study by CWPRS**
  - Near shore wave transformation for normal and extreme wave conditions
  - Hydrodynamics and siltation
  - Wave penetration inside the proposed port for extreme conditions.
  - Shoreline changes and littoral drift
  - Design of breakwaters – Wave flume studies
- **Ship Navigation Simulation Studies, DHI/ Force**

Additional studies were conducted by CWPRS in view of change/ optimisation of the port master plan layout. Following are the additional studies conducted:

- **Desk flume studies for breakwater optimisation**
- **Hydrodynamic flow conditions**
- **Sedimentation studies**
- **Impact of dredging on tidal hydrodynamics**
- **Wave tranquillity studies**

The studies are relevant for the modified layout (Figure 6-13) and additional studies as mentioned above were carried to ascertain the adequacy and any impact to the proposed layout. The summary of the findings of the model study are presented in following paragraphs. The report on the additional studies is yet to be received from CWPRS. On the receipt of the same the summary of the studies will be included in this section.

13.2 Model Studies carried out by CWPRS

13.2.1 Hydrodynamic Model Studies

Hydrodynamic and siltation studies have been completed by CWPRS to finalise the layout of the breakwater and assess the rate of siltation in the port. The work is reported in the following document:

- Mathematical Model Studies for Hydrodynamics & Siltation for the Development of Proposed Port at Vadhavan for JNPA, Technical Report No. 5583 (March 2018)

13.2.1.1 Hydrodynamic Modelling

The influence of the breakwater and reclamation bund on tidal flows have been assessed through hydrodynamic modelling studies completed by CWPRS. The 2D finite element software TELEMAC-2D was used by CWPRS to simulate tidal flows in the vicinity of the port.

As discussed in Section 6.2, a number of initial layouts were tested in the hydrodynamic model which all suffered from the development of large eddies around the southern and northern ends of the breakwaters.

This led to the introduction of a Current Deflecting Wall (CDW) inside the southern end of the main breakwater to trap and stop the propagation of the southern eddy into the port during the flood tide. Additionally, a more streamlined shape was adopted for the alignment of the revetment protecting the shore reclamation. At the northern end, it was not possible to control the eddy which formed on the flood tide and affected the navigation channel. It was, however, found that the additional length of curved breakwater at the northern end moved the eddy to the west and away from the bend in the navigation channel. It is proposed to modify the reclamation shape to curvilinear to improve flow field during the flood phase of tide. The berth orientation to be changed to north-south direction.

Though no model study was carried out for Phase 1 layout but based on the outcome of the results for the master plan it may be noted that any change in the length of breakwater would require more streamlined shape at the northern end similar to the above. Hence, there is a requirement of entire breakwater length at the initial stage of project development.

13.2.2 Wave Transformation Studies

Wave transformation and penetration studies have been completed by CWPRS to finalise the layout of the breakwater and ensure wave conditions within the port are acceptable. The work is reported in the following document:

- Mathematical Model Studies for Assessment of Wave Tranquillity for the Development of Proposed Port at Vadhavan, Maharashtra, Technical Report No. 5558 (January 2018)

13.2.2.1 Offshore Data

The offshore wave conditions have been derived from the CWPRS data bank for the period from May 1999 and April 2012. This data was analysed to provide annual offshore conditions. The source of this data is not clear, but a 13-year record is adequate for the prediction of annual conditions and assessment of operational conditions within the port.

The offshore wave climate derived by CWPRS are shown in Table 13-1 and Figure 13-1 and appears correct with conditions dominated by waves from the south west through to the north-west. The largest waves in the record are up to 4.5m and are from 247.5° N. Waves from 315° N are smaller and up to 1.5 m.

Table 13-1 Annual Wave Frequency Offshore of Vadhavan (-60m water depth)

Wave Height (m) Direction (°)	0-0.5	0.5-1.0	1.0-1.5	1.5-2.0	2.0-2.5	2.5-3.0	3.0-3.5	3.5-4.0	4.0-4.5	Total
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
22.5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
45	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
67.5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
112.5	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.02**
135	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
157.5	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.02**

Wave Height (m) Direction (°)	0-0.5	0.5-1.0	1.0-1.5	1.5-2.0	2.0-2.5	2.5-3.0	3.0-3.5	3.5-4.0	4.0-4.5	Total
180	1.76	0.53	0.03	0.00	0.00	0.00	0.00	0.00	0.00	**2.32**
202.5	7.20	3.44	0.24	0.02	0.00	0.00	0.00	0.00	0.00	**10.89**
225	4.38	12.60	5.99	1.02	0.15	0.08	0.07	0.02	0.00	**24.30**
247.5	3.11	21.55	18.57	7.93	2.76	0.87	0.32	0.13	0.06	**55.30**
270	0.14	1.09	1.44	0.63	0.09	0.02	0.00	0.00	0.00	**3.40**
292.5	1.17	1.39	0.19	0.01	0.01	0.00	0.00	0.00	0.00	**2.77**
315	0.33	0.20	0.07	0.00	0.01	0.00	0.00	0.00	0.00	**0.61**
337.5	0.17	0.06	0.01	0.00	0.00	0.00	0.00	0.00	0.00	**0.24**
360	0.08	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.15**
Total	**18.37**	**40.92**	**26.53**	**9.61**	**3.01**	**0.97**	**0.38**	**0.14**	**0.06**	**100**

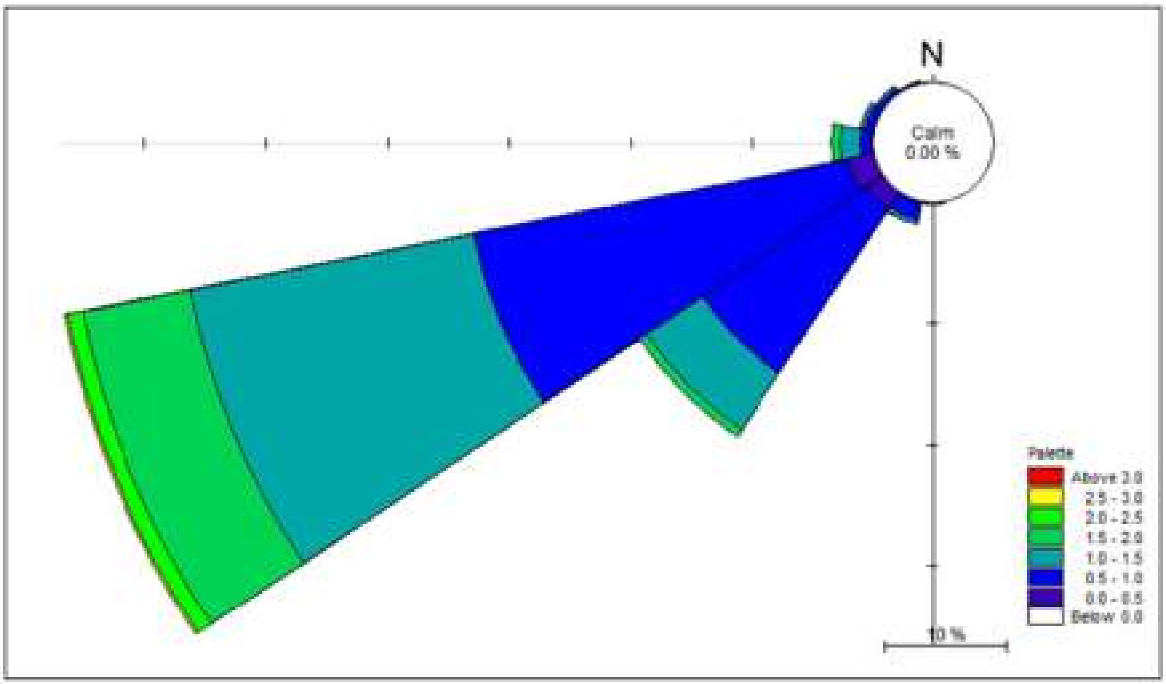


Figure 13-1 Wave Rose offshore of Vadhavan (-60m water depth)

13.2.2.2 Nearshore Wave Transformation

The wave modelling software MIKE21 SW was used to transform the offshore wave conditions nearshore to a point at depth -24 m CD outside the port. Very limited information is provided in the CWPRS report on the set up of the model and no discussion on calibration or validation is provided.

The modelling software selected by CWPRS is widely recognised within the industry and capable of providing accurate nearshore wave conditions. The results from the modelling are reproduced below in Table 13-2 and Figure 13-2 and appear reasonable.

Table 13-2 Annual Wave Frequency Offshore outside Vadhavan Port (-24m water depth)

Wave Height (m)	0.5-1.0	1.0-1.5	1.5-2.0	2.0-2.5	2.5-3.0	3.0-3.5	3.5-4.0	4.0-4.5	Total
Direction (°)									Calm 54.49%
180 (S)	0.35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.35**
202.5 (SSW)	1.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**1.11**
225 (SW)	5.28	0.21	0.63	0.35	0.00	0.00	0.00	0.00	**6.47**
247.5 (WSW)	2.13	7.61	13.27	5.35	0.35	0.00	0.00	0.00	**28.71**
270 (W)	3.27	1.9	0.49	0.00	0.00	0.00	0.00	0.00	**5.66**
292.5 WNW)	3.07	0.07	0.00	0.00	0.00	0.00	0.00	0.00	**3.14**
315 (NW)	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.0.7**
Total	**40.92**	**26.53**	**9.61**	**3.01**	**0.97**	**0.38**	**0.14**	**0.06**	**100**

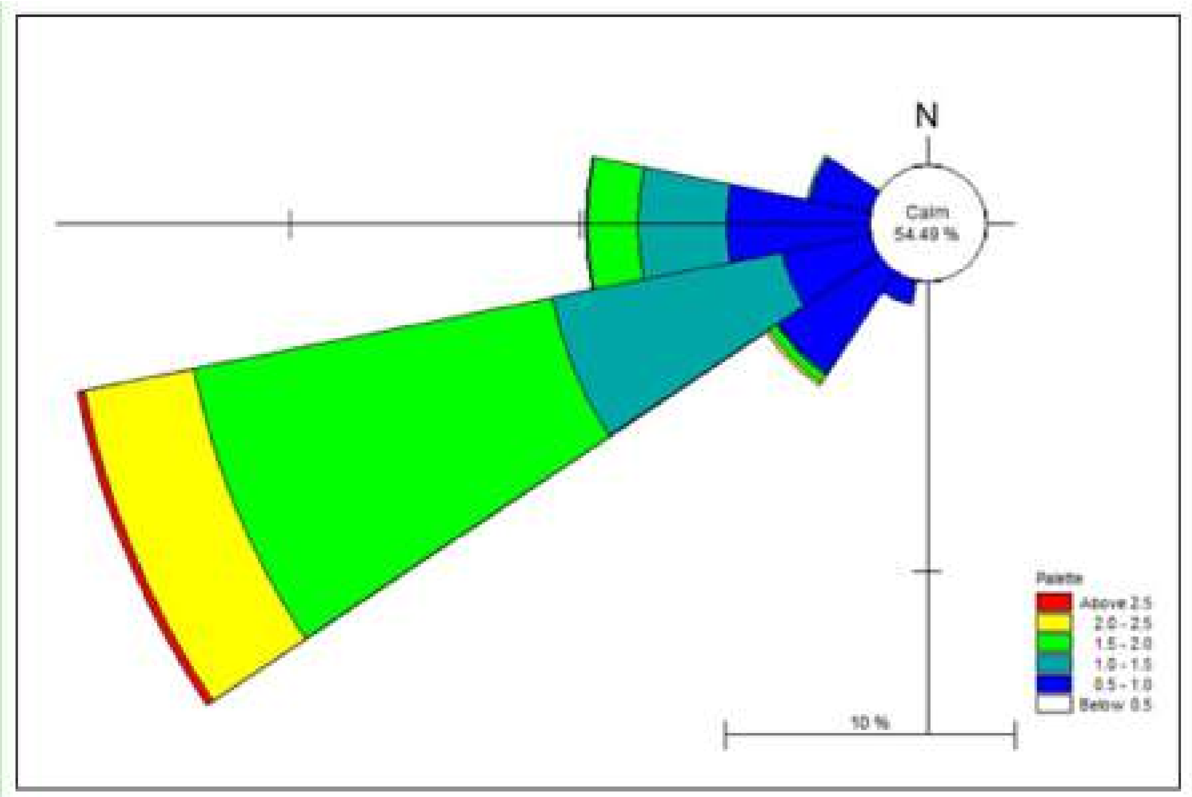


Figure 13-2 Wave Rose outside Vadhavan Port (-24m water depth)

13.2.3 Extreme Wave Conditions

Studies have been completed by CWPRS to establish extreme nearshore wave conditions and storm surges for the design of the breakwater. The work is reported in the following document:

- Desk Studies for the Prediction of Extreme Wave Conditions for the Proposed Development of Port at Vadhavan for JNPA, Technical Report no 5581 (March 2018)

13.2.3.1 Wave Modelling

The study correctly recognises that tropical storms and cyclone events will determine the design conditions for the breakwaters and that such events are not adequately captured in long term wave databases. For this reason, CWPRS collected data from the Indian Meteorological Office (IMD) on 95 storms between 1946 and 2015 that have had an impact on the Vadhavan coast.

The methods used to determine the offshore waves generated during these storms is not entirely clear, but it would appear that empirical methods were adopted rather than using a 2D wave model. The resulting wave conditions were then extrapolated to give extreme offshore design conditions. Finally, these offshore conditions were transformed nearshore using the 2D wave model Tomawac which gave the 100-year design conditions along the breakwater shown in Figure 13-3.

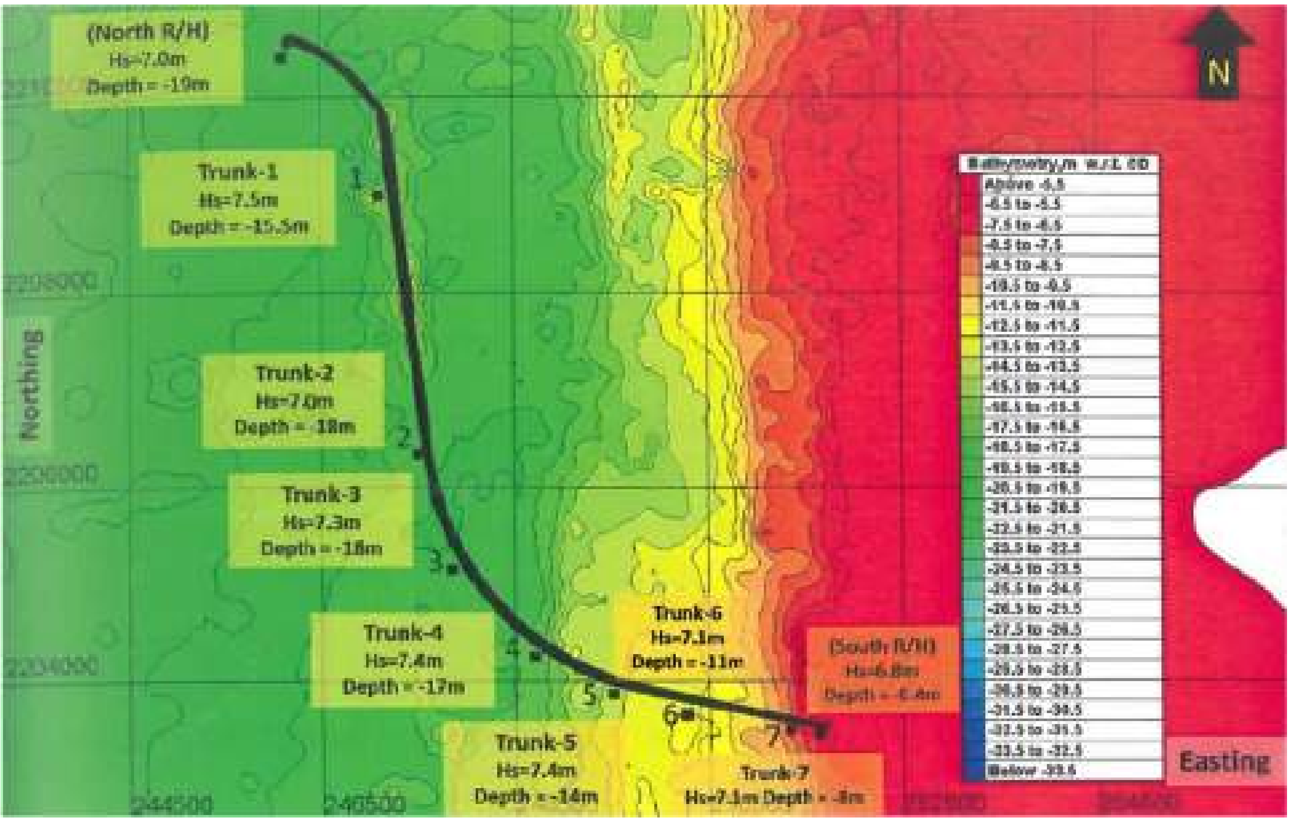


Figure 13-3 100-Year Significant Wave Heights along Vadhavan Breakwater

The approach used to derive offshore extreme wave conditions have used empirical methods rather than more accurate 2D wave models. These models are able simulate the track and wind fields associated with the storm events and hindcast wave conditions at Vadhavan. It would be worthwhile modelling a number of more critical cyclone events to affect Vadhavan to provide some validation of the results presented in the report.

The extreme values presented in Figure 13-3 appear reasonable based on RHDHV experience in the region. It is noted that these wave conditions are significantly higher than the values adopted for the preliminary breakwater design presented in the DPR but agree with the conditions used by CWPRS to develop the breakwater cross sections tested in the physical model. This is discussed in more detail in Sections 8 and 13 of this report.

13.2.3.2 Storm Surges

Tropical storms and cyclones are associated with high winds, torrential rain, high waves, and elevated water levels, known as storm surges. The rise in water levels is caused by low atmospheric pressure and wind effects acting on the water surface.

CWPRS have used empirical relationships to derive storm surge associated with the storms discussed above and extrapolated the results to give the extreme values presented in Table 13-3 below.

Table 13-3 Extreme Storm Surge at Vadhavan

Return Period R_p	Storm Surge (S_s)
in years	*in m*
10	1.50
25	1.72
50	1.90
100	2.05

The approach used to derive extreme surges at Vadhavan has used empirical methods rather than more accurate 2D models. Nevertheless, the values presented in the table above appear reasonable based on RHDHV's experience in the region.

13.2.4 Wave Tranquillity

13.2.4.1 Wave Penetration Modelling

The wave modelling software MIKE21 BW has been used to assess the shelter provided by the breakwater and conditions within the port. Very limited information is provided in the CWPRS report on the set up of the model. It is generally not possible to calibrate this type of modelling.

The modelling software selected by CWPRS for wave tranquillity studies is widely recognised within the industry and capable of accurately predicting the wave conditions within the port as it is able to reproduce diffraction around the ends of the breakwaters and also reflections from internal structures etc.

The model has been used to assess a range of layouts which were rejected in favour of the final layout which is shown in Figure 13-4.

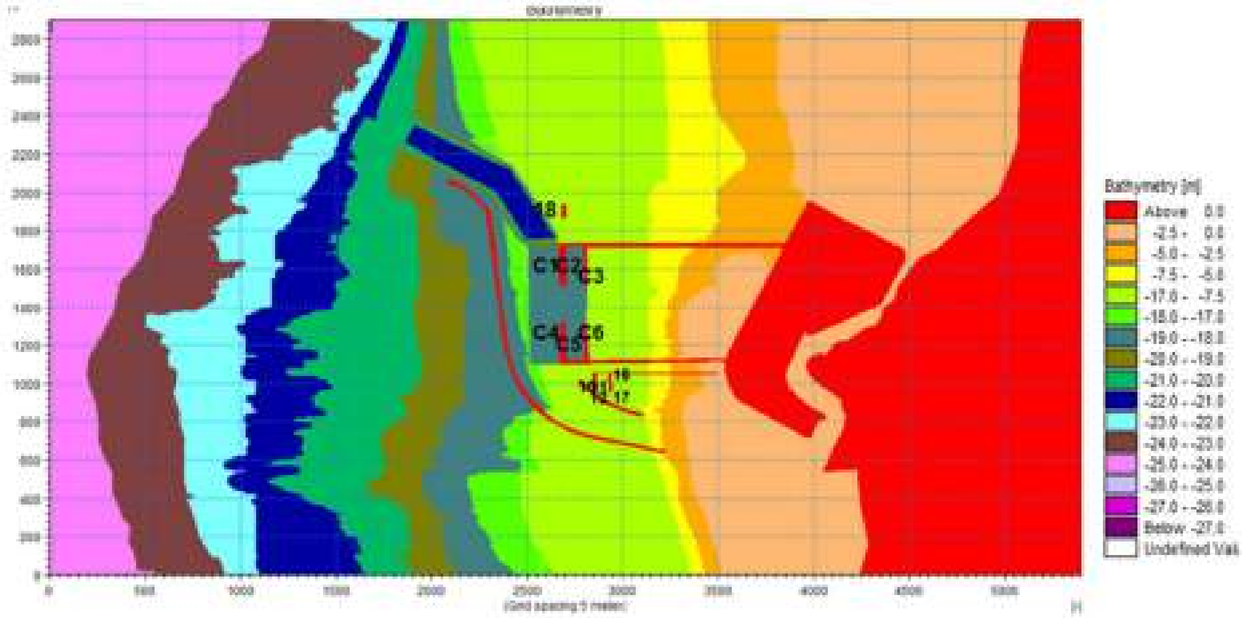


Figure 13-4 Final Layout tested in Wave Tranquillity Model

As discussed in Section 6.3, the final layout provides good protection to all berths from waves from SW, WSW, and W with conditions within the limits set earlier in Section 6. At the container berths waves conditions are also less than 0.5 m for these directions. The berths are less well protected for waves from the NW with the limiting criteria of 0.8 m exceeded at the coal berth which is now replaced by additional container terminals. Wave conditions at the container berths are less than the limit of 0.8 m but exceed 0.5 m. The results for NW waves are provided in Figure 13-5.

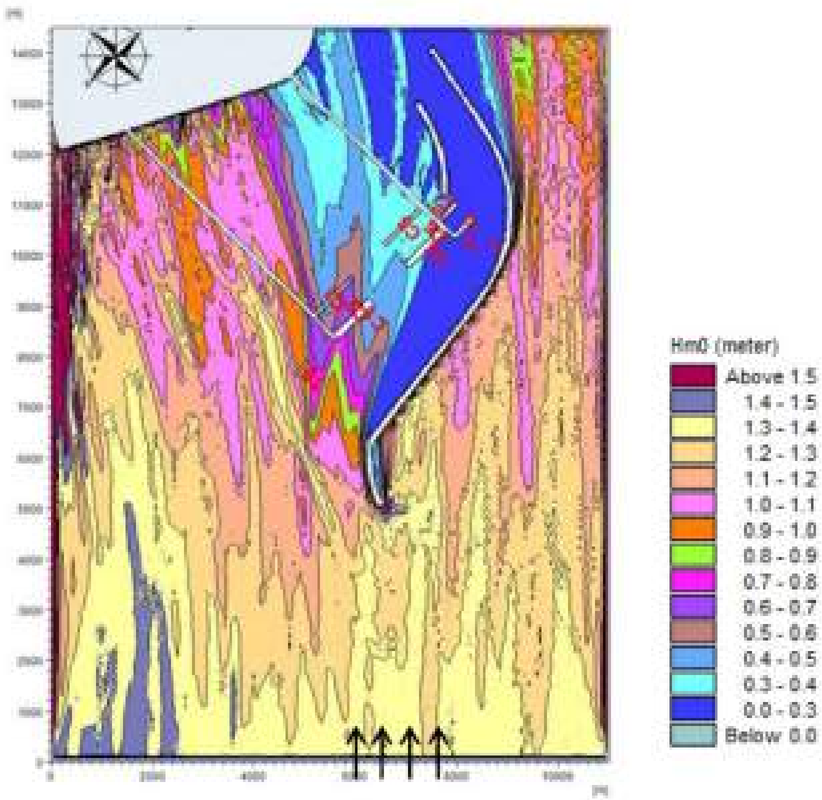


Figure 13-5 Final Layout with Waves from North-West

It is expected that the proposed breakwater layout will provide adequate protection to the port with low downtime at the berths as the assessment has been completed using 1-year storm conditions

13.2.5 Sedimentation studies

Siltation model was established using Telemac-2D. Hydrodynamics model described in the previous section was used to drive the sedimentation model. seabed soil samples collected at 8 locations and suspended sedimentation concentrations observed at one location near the project site were used to setup the model to replicate the existing conditions.

From the analysis of the seabed samples, it was concluded that the typical D50 size of the seabed soil is around 0.011 mm. As this size of the bed material was found to be in the same order as that of the suspended material whose D50 is around 0.008 mm, it was concluded that the deposited seabed material is due to settlement of material in suspension. As the suspended material is found to be cohesive, the erosional and depositional behaviour of the sediment is modelled using Krone and Parthenaides formulation.

The model was calibrated for existing conditions derived from suspended sediment concentrations observed at site i.e., 400 mg/l for spring tide and 300 mg/l for neap tide. Various parameters which impact the sediment deposition and erosion were adjusted to obtain the calibration of the sedimentation model.

The calibrated sedimentation model was then introduced with the proposed layout and the model was run to estimate the siltation in the approach channel and port basin. The resultant sedimentation from the run given in the report is reproduced in the figure below.

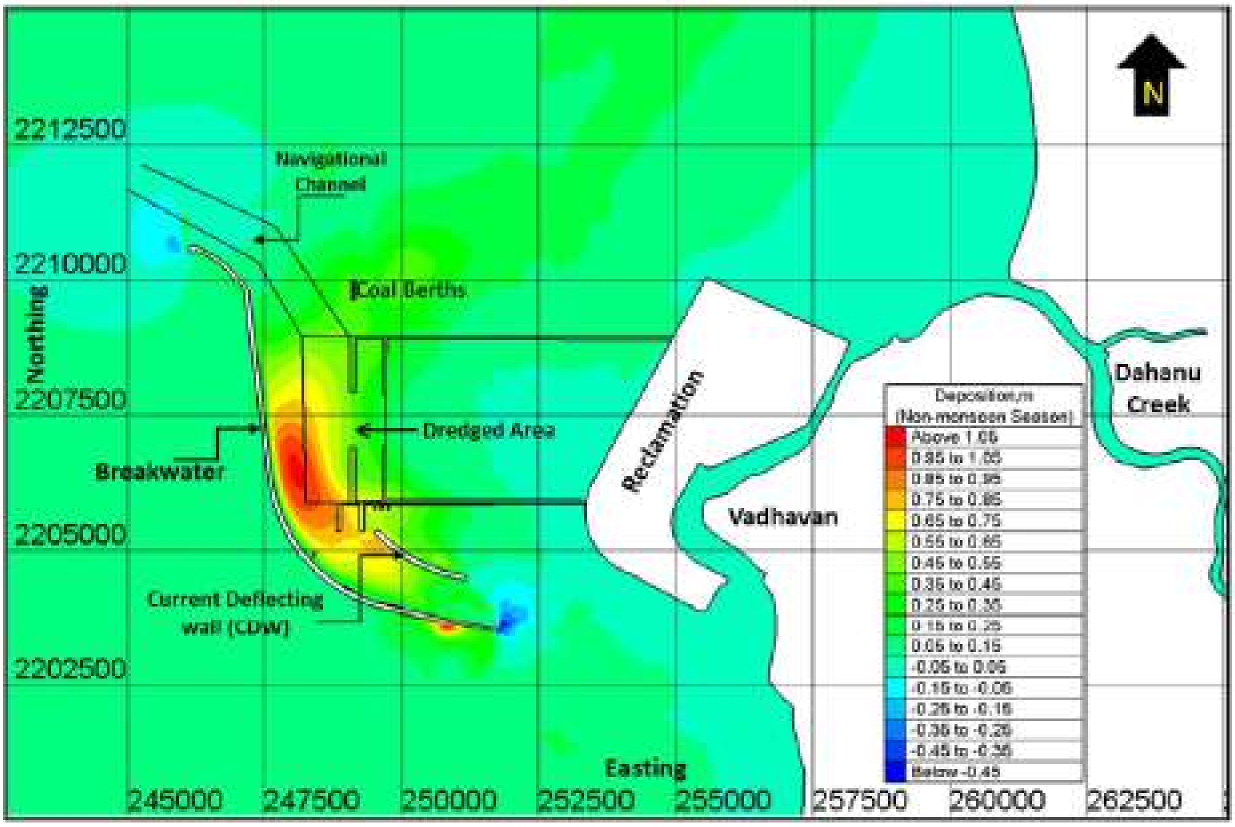


Figure 13-6 Siltation in the proposed harbour basin during non-monsoon season

The study gave result only for non-monsoon season. The studies to estimate the likely rate of siltation during non-monsoon season reveal that, the average rate of siltation in the navigational channel is about 0.11 m, while it is about 0.5 m in dredged area. Thus, total quantum of likely siltation in the dredged areas will be about 3.1 million cum for non-monsoon season only. The siltation rates are not uniform over the area under consideration and seems to vary based on the prevailing hydrodynamic conditions.

13.2.6 Desk and Wave Flume Studies

Design studies and 2D physical model tests have been undertaken CWPRS and the work is reported in the following document:

- Desk and Wave Flume Studies for the Design of Breakwater for the Development of Port at Vadhavan, Maharashtra, Technical Report No 5648 (November 2018)

13.2.6.1 Desk Study

The desk study has revised the design cross-sections presented in the DPR to take into consideration the updated wave conditions derived in the Desk Studies for the prediction of Extreme Wave Conditions (Technical Report no 5581). A comparison of primary armour on the breakwater from the two studies is shown in Table 13-4 below.

Table 13-4 Comparison of Accropode II Units

Cross-section	Accropode II unit from DPR (cum)	Accropode II unit from CWPRS (cum)
Roundhead @ -6m CD	4	13
Trunk -8 to -15m CD	4 to 6	11
Trunk -15 to -19m CD	6	11
Roundhead @ -19m CD	6	13

As shown in the table this has resulted in a significant increase in the size of primary armour required on the breakwater. There is also an increase in the crest level from +10 m CD in the DPR design to +16.0 m CD in the CWPRS design.

The design of the breakwater is discussed further in Section 8.2.

13.2.6.2 Flume Tests

Physical model tests of the breakwater have been undertaken of the CWPRS cross sections at scales of 1:56 for the trunk and 1:60 for the roundhead.

The model studies confirmed the overall stability of the trunk and roundheads. Heavy wave overtopping resulting in some damage was reported to the lee side armour under extreme conditions. Consequently, further tests with the crest of the wave wall raised by 1.5 m.

The physical model tests have shown that the cross sections developed by CWPRS are stable and should be adopted in preference to the sections presented in the DPR. Based on the tests, it is concluded that the lighter cross sections from the DPR will not be stable.

13.2.7 Assessment of Thermal dispersion from TAPS

This study was conducted to assess the impact of proposed Vadhavan port on dispersion of outfall at Tarapur atomic power station (TAPS). As part of the study, the calibrated hydrodynamic model established for the area of interest which is discussed about in the previous section was used to assess the flow field in and around TAPS. Initially the existing conditions along with the intake and outfall discharge volumes of for the power plant are introduced in the model and current were extracted at different observation points i.e., around the intake and outfall structures from the model.

Later the proposed Vadhavan layout was introduced in the model and current strengths were extracted at the same observation points. Comparison between the current strengths and water depths at the observation locations were compared for both the scenarios i.e., with and without proposed Vadhavan port were compared to understand the impact of Vadhavan port on the flow around intake and outfall structures of TAPS. The observation points are given in Figure 13-7 below. The comparison of current magnitudes at the observation points for scenario existing scenario and Vardhan port scenario is given in Table 13-6 below. Results show that due to the development of proposed port the current strength on the seaward side of the intake channels at TAPS reduce by 9%. At the outfall channel, the change in current magnitude is around 11% on the north side and by 2% on the south side of the outfall channel. In the guided portion of the intake and outfalls, the impact on the current is negligible i.e., less than 2%. As per the model study, difference between water depth before and after construction of Vadhavan port at all the observation locations in and around TAPS were found to be negligible.

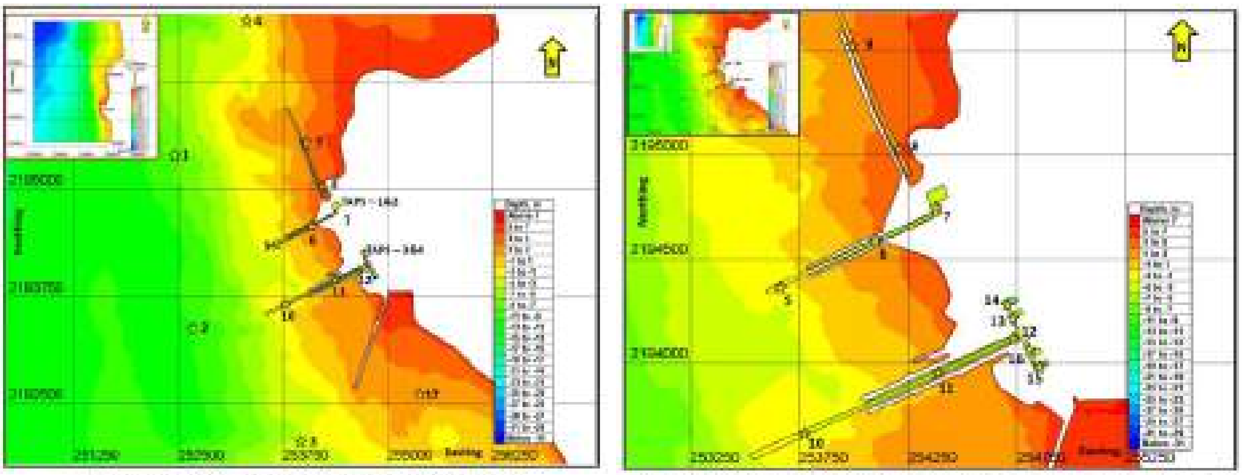


FIG. 16 (A): Locations of Current Data near TAPS Area

FIG. 16(B): Locations of Current Data in Forebays / Pumpbays of TAPS

Figure 13-7 Location of Current Observations near TAPS area

Siltation study was conducted to estimate the likely quantum of silt deposit in the intake channel upto travelling screen ins of TAPS 1 & 2 and pump bays of TAPS 3 & 4. The siltation model was calibrated using the information of the de-siltation operations carried out at the following locations as given in Table 13-5.

Table 13-5 Rate of deposition observed at site used for siltation model calibration

Area	Duration (Years)	Deposition of silt (cum)
Intake channel up to travelling screen of TAPS 1 & 2	1 year	362
Pump bays of TAPS 3 & 4 (Each Unit)	2 years	1100

The study reported a siltation quantity of 340 m^3 and 1040 m^3 for a period of one year and period of two years for the TAPS-1 & 2 and TAPS 3 & 4 respectively. The comparison of siltation at different locations for both the cases with and without Vadhavan port is given in the Table 13-6 below.

Table 13-6 Comparison of estimated Quantum of silt deposition obtained from model for existing a final layout condition

Area Considered	Quantum of silt deposition in cum	
	Existing Condition	*Final port layout condition*
Intake channel upto pump bay of TAPS 1 & 2	366 / yr.	350 / yr.
Pump bays of TAPS 3 & 4 for each unit	1060 / 2 yr.	1040 / 2 yr.
Northern outfall channel of TAPS 1 & 2 (Guided portion)	2.0 / yr.	2.0 / yr.
Outfall of TAPS 3 & 4 (Down flow side of weir)	175 / yr.	55 / yr.

The results above reveal that there will not be increase in siltation in intake/outfall and pump bays of TAPS 1 & 2 and 3 & 4 due to development of proposed port at Vadhavan. The values in the above table indicate practically no siltation over an area of TAPS 1 & 2 northern outfall channel and down-flow side of TAPS 3 & 4 outfall (upto 4 m contour w.r.t. CD) i.e., over area of about 20 ha. Thus, at the outfall weir of TAPS 3 & 4, average depth of deposition per year is practically insignificant. The results obtained from model studies for intake channel, forebays and branch channel of TAPS 3 & 4 also shows a similar trend of reduction in quantum of siltation as that of prescribed areas considered for calibration of silt model. Hence, the report concludes that there is no adverse impact on the siltation at intake and outfall channels, forebays and pump bays at TAPS due to proposed Vadhavan port.

13.2.8 Study on Shoreline changes

This study was conducted to assess the impact of the port on the 20 km long shoreline between Dahanu and Tarapur. The study was done using LITPACK model which is 1-D model which is used to simulate transport of non-cohesive sediment under the influence of waves, currents.

The study was done in two stages. In the first stage, littoral drift was assessed for existing using LITDRIFT module of the LITPACK module. In the second stage LITLINE module was used to assess the evolution of the coastline due to construction of port.

For estimation of the littoral drift, eight different profiles normal to the coastlines were established and sediment transport across each of the profile was calculated. The results were approximated based on the comparison between google earth images of the coastline between different years. The results show a predominantly northward drift at each cross profile. The southward drift is many orders or negligible when compared to Northward drift. The average net transport is towards North and is in the order of 0.07 million cum.

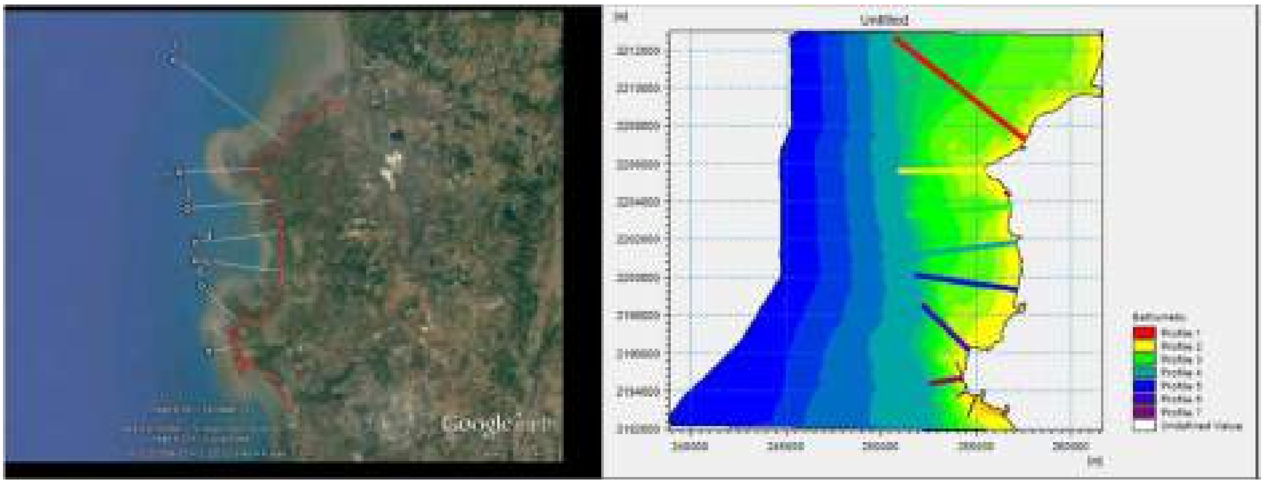


Figure 13-8 Cross shore profile locations

Table 13-7 Littoral Transport Rates (m^3) at the cross profiles

Profile No.	Northward	Southward	Net	Gross	Drift Direction
P1	102,950	50	102,900	103,000	North
P2	70,630	1,410	69,220	72,040	North
P3	104,750	3,450	101,300	108,200	North
P4	79,610	3,440	76,170	83,050	North
P5	130,850	1,350	129,500	132,200	North
P6	46,450	0	46,450	46,450	North
P7	32,625	1,815	30,810	34,440	North
P8	32,805	25	32,780	32,830	North

'-ve' Southward, '+ve' Northward for Net Drift

For estimation of change in the coastline, the breakwater is introduced into the LITLINE model and comparison is made with the existing scenario to estimate the changes in the coastline due to the construction of port for a period of 1,2,4 and 6 years after the construction of breakwater and the results show that the change in the shoreline due to the construction of Vadhavan is negligible. Model output for shoreline evolution after construction of breakwater is shown in Figure 13-9. Studies for simulation of shoreline changes indicated that the construction of proposed offshore breakwater of 10.1 km length will result in negligible deposition of sand behind the breakwater and will have negligible impact on the adjacent shoreline as well.

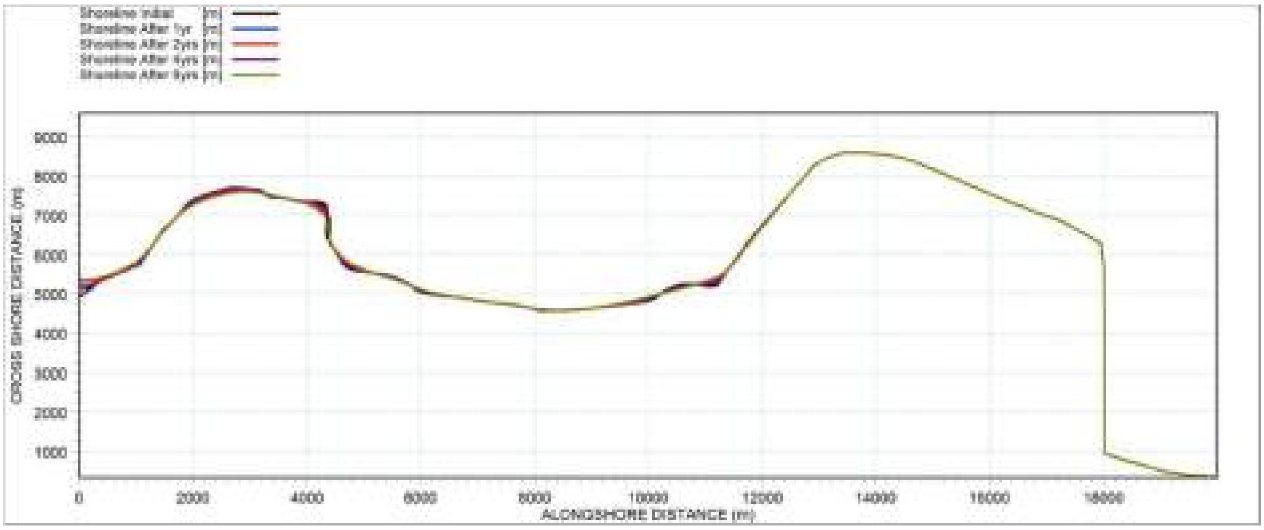


Figure 13-9 Model output for shoreline evolution

It should be noted that the LITPACK model is used for predominantly non cohesive type soils. As per the sedimentation study report, the site seabed is characterised as clayey type basis the Geotech investigation report. Hence using LITPACK might underestimate the annual littoral drift quantity. High resolution satellite pictures would have been better suited to estimate the historical change in the shoreline instead of google earth images. It is also not clear from the report, whether the proposed reclamation area for Vadhavan port is included in the assessment of the littoral drift transport and shoreline changes.

13.3 Studies carried out by DHI/Force Technology

13.3.1 Ship Simulation Studies

DPR prepared by M/s Pentacle Consultants has carried out a 3D simulation navigational study for tug movement inside the harbour along with M/s DHI. Objective of this assignment is to conduct a 3D simulation navigation study to assess the channel navigability, the berthing and unberthing of the largest designed vessel at the proposed berth CT-2 and for identification of requirements for navigation aids.

The study area covers from the entrance of approach channel buoy no.1 in the North to the proposed berth CT-2 in the South as shown above. The distance between these points are about 4.3 nautical miles.

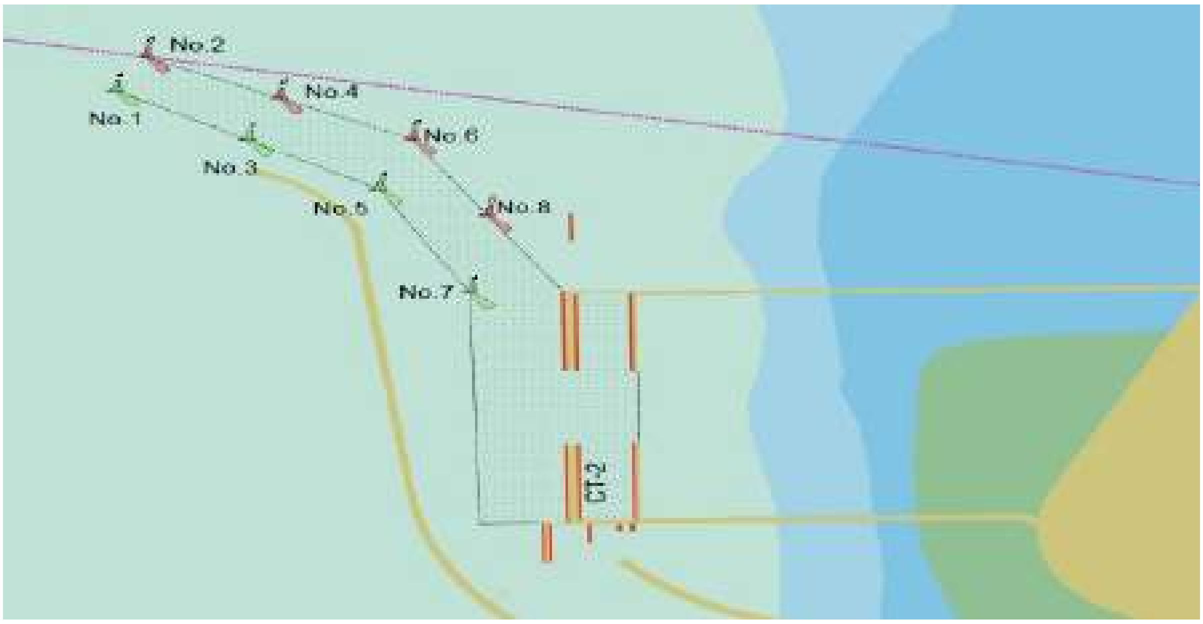


Figure 13-10 Study Location

For this simulation study, following data has been considered

1. Tidal Current
   Two tidal timestamps for the maximum flood and maximum ebb currents were considered. The tidal current during flood flows in the northerly direction with speed ranging from 3.2 knots at entrance to 0.5 knots at berth. The tidal current during ebb flows in the southerly direction with speed ranging from 2.4 knots at entrance to 0.2 knots at berth.

2. Tidal Height
   Tidal height used for the study were given in the below table.

Tidal Current Phase	Tide Height (w.r.t CD)
Maximum Flood	4.6 m
Maximum Ebb	1.0 m

3. Prevailing Wind
   The prevailing wind blows predominantly from the north to northeast and from the west to southwest, which corresponds to the Northeast and Southwest Monsoon seasons.

Type	Wind Direction	Wind Speed
North East Monsoon	045 degrees	15 knots
South West Monsoon	245 degrees	20 knots

   In the simulator, the wind speed is given in "meteorological wind speed" which corresponds to a 10-minute mean wind at 10-metre height.

4. Waves
   Basis the study made by Central Water and Power Research Station (CWPRS) on significant wave height in the study area, the following wave characteristics were used during the simulation study.

Area	Height	Period	Direction
Outer Channel @24m water depth	3.1 m	10.0 sec	225 degrees

Inner Channel @18m water depth 1.2 m 10.0 sec 315 degrees

5. Simulation Model Vessel Specification

Model	Vessel	LOA (m)	Beam (m)	Draft (m)	Displacement (m^3)	Propeller	Rudder	Thruster
3749	20,000 TEU Container	400.0	60.0	16.0	300,040	1F	1	2xFwd 2xAft

6. Tugs
During simulation runs Vector Tugs were used to simulate 65 ton and 100-ton bollard pull ASD tugs of 30m LOA. The vector tugs were controlled by the simulator operator and can push or pull in each direction and/or with a given force as requested by the pilot/captain.

The following runs were made as part of the study.

A total of twelve (12) simulation runs were undertaken by Force Technology Master Mariner/Pilot on the SIMFLEX Full-Mission simulator

Run Ref	Route	Side Alongside	Current	Wind	Height of Tide
01	Arrive	Starboard	Flood	045° x 15kts	4.6
02	Depart	Starboard	Flood	045° x 15kts	4.6
03	Arrive	Starboard	Flood	245° x 20kts	4.6
04	Depart	Starboard	Flood	245° x 20kts	4.6
05	Arrive	Port	Ebb	045° x 15kts	1.0
06	Depart	Port	Ebb	045° x 15kts	1.0
07	Arrive	Port	Ebb	245° x 20kts	1.0
08	Depart	Starboard	Ebb	245° x 20kts	1.0
Emergency Run Scenario					
09	Arrive	Port	Ebb	045° x 15kts	1.0
10	Arrive	Port	Ebb	045° x 15kts	1.0
11	Arrive	Port	Ebb	245° x 20kts	1.0
12	Depart	Starboard	Flood	045° x 15kts	4.6

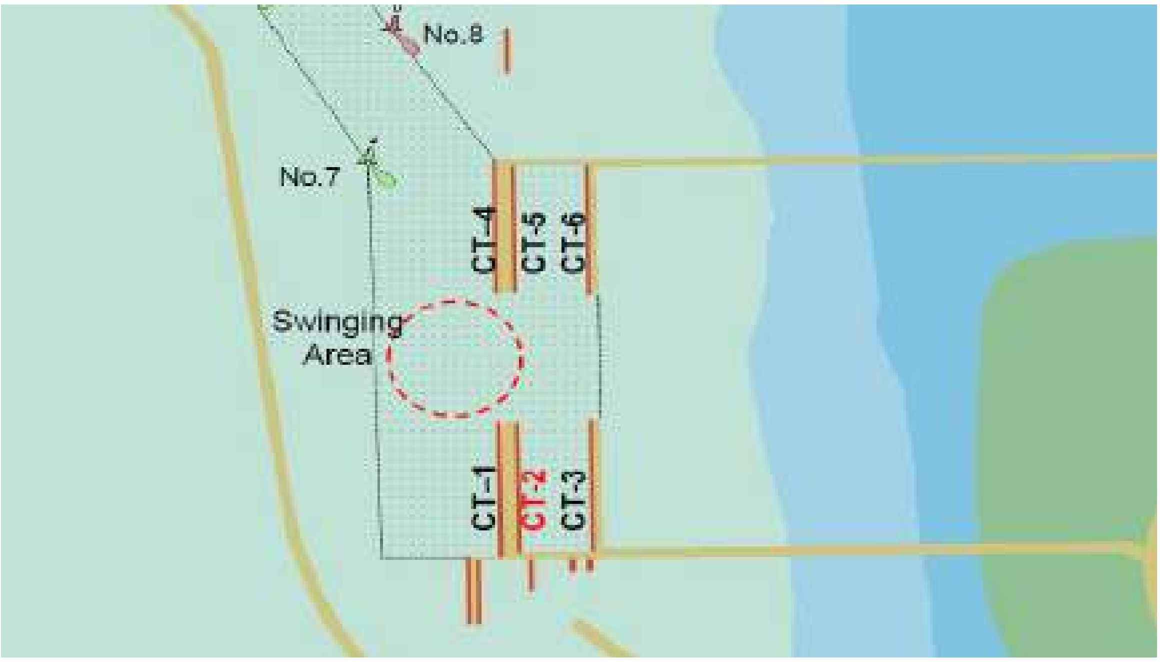
The following assumptions were made as part of the study.

- No traffic situation impeding the vessel during her berthing and unberthing manoeuvres.
- No other traffic movement during the vessel channel transit.
- Tugs were made fast inside the breakwater between buoys no.5 and no.7
- Clear visibility

From the study, it was concluded that,

1. The proposed berth CT-2 is optimally and favourably aligned with the tidal current making it easy for vessel to berth and un-berth at the jetty
2. There was no significant concern with the berthing and unberthing of the largest designed vessel at the proposed jetty/berth.
3. All normal operation scenario runs were successfully undertaken in a controllable manner within acceptable level of safety

4. The swinging area/turning space between jetty/berth CT-4 and CT-1 for vessel to execute a swing during the berthing / un-berthing manoeuvre was found to be adequate for the largest designed vessel and provides sufficient clearance and distance for possibility to correct minor manoeuvring mistakes without compromising safety.
5. The optimum speed for the vessel before a swing manoeuvre was found to be below 20 knots. A higher speed may compromise safety in case of loss of tug power and control.



6. Four ASD tugs of 65 tons bollard pull were marginally adequate in handling the largest designed vessel to berth and un-berth at the proposed berth CT-2.
7. Maximum tug power used was between 75% with occasional 100% for most of the normal scenario simulation runs. A higher capacity tugs will make manoeuvring more efficient and increase the safety margin for the handling of large vessel.
8. Manoeuvring near and at the approach channel during maximum flood and ebb with wind speed of 20 knots was on the high side
9. Vigilance must be exercised in controlling the vessel's bow during manoeuvring near the entrance of approach channel due to strong cross tidal current of between 2.5 to 3.2 knots during maximum flood and ebb. Vessel set/drift had to be closely monitored.
10. Simulation runs number 01, 02, 07, 10 and 11 were graded as "Marginal". The runs were graded as "Marginal" because although the manoeuvre was completed successfully, maximum full tug power had to be used during the manoeuvre, hence no or little possibility of correction error or misjudgement was reserved should something else happen.

The following recommendations were made as part of the study.

1. The vessel approach speed to the berth should be consistent with existing pilotage practice.
2. A channel transit speed of between 9 to 10 knots at the entrance of the approach channel proofs to be sufficient to keep vessel's heading with manageable angle of drift.
3. During vessel's arrival, it is recommended that all tugs to be made fast soonest possible and not later than buoy no.8.
4. Consider using at least two 65ton bollard pull ASD tugs and two 100ton bollard pull ASD tugs capacity during the berthing and un-berthing of large vessel.
5. Consider having two tugs to follow vessel on stand-by for instant use during vessel's outbound departure channel transit.

6. Consider suspending berthing and un-berthing operations when wind speed exceeds 20 knots or when the risk is deemed to be high.
7. It is recommended to limit the operable wind speed and tidal current to low initially during the handling of large vessel with deep draft and large windage area. This restriction can possibly be relaxed when routine and experience has been acquired.
8. Consider imposing all large and deep draft vessel berthing to Vadhavan port have an operational ECDIS (Electronic Chart Display and Information System) and a Doppler side log.

As part of the navigation study, the assumption no other vessel except for the target vessel is using the channel and this assumption renders the channel suitable for one-way traffic. Hence, the channel needs to be checked for two ships using the channel at the same time i.e., for two-way operations.

13.4 Additional Model Studies for Revised Port Layout

As discussed in section 13.2, it was required to carry out additional model studies to test adequacy of the proposed layout (Figure 6-13) and accordingly the said studies were carried out and summarised as below.

13.4.1 Desk flume studies for breakwater

2D physical model tests were undertaken by CWPRS and the work is reported in the following document:

- Desk and 2-D Wave Flume Studies for the Design of revised Breakwater cross section for the Development of Port at Vadhavan, Maharashtra, Technical Report No 5952 (September 2021)

As no overtopping measurements were carried by CWPRS during the earlier wave flume studies (2018) to arrive at the crest height of the breakwater. The following optimisation was suggested in the revised cross section.

- Top of the crest slab is at el.+12.5 m level with a parapet top at el.+15.0 m.
- A clear carriage way of 7.5 m width is provided on the crest slab.

The stability test was conducted for various wave height and water level conditions. Mean over toppings rates were arrived at as indicated below.

Table 13-8 Mean overtopping rates

Crest Level (m CD)	Mean overtopping rates (EurOtop 2018) (l/s/m)	Mean overtopping rates (EurOtop 2008) (l/s/m)
+15.0	51	40
+14.5	74	57
+14.0	107	80
+13.0	155	115

The wave flume studies conducted to confirm the wave overtopping discharges, leeward side, and toe-berm stability of breakwater for different test conditions. All other parameters and design conditions were same as in the previous studies.

The hydraulic stability and overtopping discharge at different test conditions of revised breakwater cross-section with 11 cum Accropode-II ™ units in the armour at -19 m CD bed level have been confirmed through 2D wave flume studies. These revised breakwater sections are hydraulically stable under the design wave conditions.

The hydraulic stability of toe-berm of breakwater at various bed levels also confirmed through wave flume studies by generating design wave height at low water. Under the extreme climatic conditions, some damage was noticed on the lee side of the breakwater trunk portion.

There is a very rare possibility of overtopping of waves in extreme climate conditions. However, about 5% damage may be occurred on the lee side of the breakwater under the extreme climatic conditions of HHWL including storm surge and significant wave height of 7.5 m. As such, maintenance on the lee side of the breakwater with 2 to 4 t stones are very much essential when damage occurs during extreme events. Further, reduction of crest elevation is not suggested.

13.4.2 Hydrodynamic Model Studies for Revised Layout

CWPRS carried out hydrodynamic modelling on the revised port layout. The results have been discussed in detail in section 6.2.2.5 indicate the following:

- Maximum cross current at the harbour entrance of 2.55m/s reducing to 1.3m/s at the expected ship stopping point
- Maximum currents at the turning areas less than 0.4m/s in a S-N direction
- Currents in the dredged basins between reclamation fingers less than 0.05m/s
- Currents longitudinal to the berths at the ends of the reclamation fingers less than 0.2-0.4m/s

However, the results of the numerical hydrodynamic modelling indicated that on Spring flood tides the maximum current speed between the southern end of the offshore reclamation and the southern end of the breakwater could exceed 2.5m/sec. In addition, there was indication of eddy formation at the south breakwater head.

Modifications were therefore made by CWPRS to the layout in order to reduce/improve the flood tide current flows at the southern end of the harbour basin.

13.4.3 Sedimentation Studies

CWPRS carried out the sedimentation studies to estimate the likely siltation in various dredged areas i.e., berths pockets, approach channel, basin etc. of the harbour area. The sediment in suspension was cohesive in nature, the erosion and deposition behaviour of sediment was estimated based on Krone and Parthenaides formulation. The factors influencing the siltation process are grain size, suspended sediments, its concentration, settling velocity, salinity, temperature, current strength etc. Siltation studies were carried out with the hydrodynamic conditions coupled with the sedimentation module for monsoon and non-monsoon season.

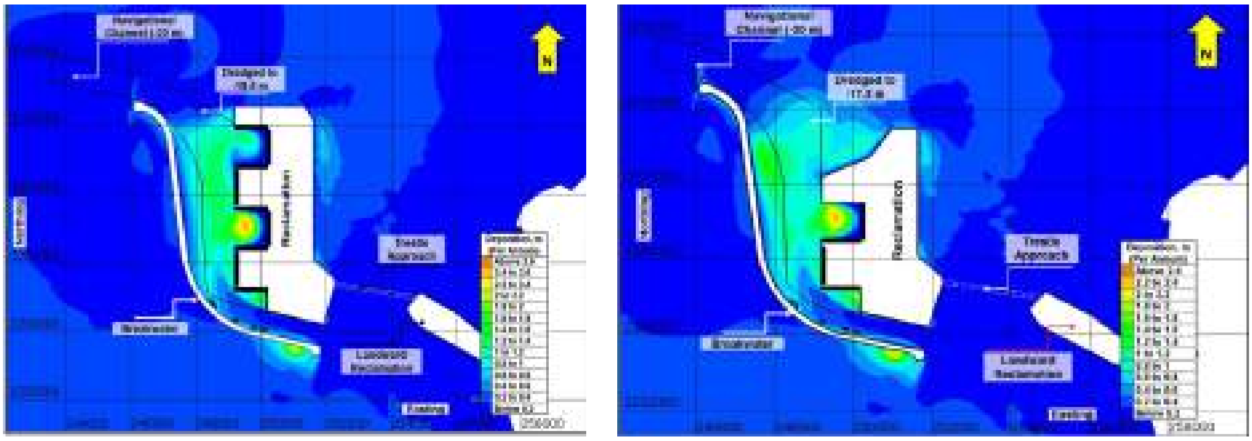


Figure 13-11 Annual siltation pattern for the recommended Master plan and Phase 1 layout

The total siltation in the dredged areas over the plan master plan will be about 8.45 M cum per annum and 6.45 M cum per annum for Phase 1.

13.4.4 Wave Tranquillity Studies

CWPRS through Mike 21 BW model carried out the wave tranquillity studies for the revised port layout. Through this, the wave tranquillity model for the final layout was developed and results for the critical NW waves are shown in Figure 13-12.

Waves from West ***Waves from WNW*** ***Waves from NW***

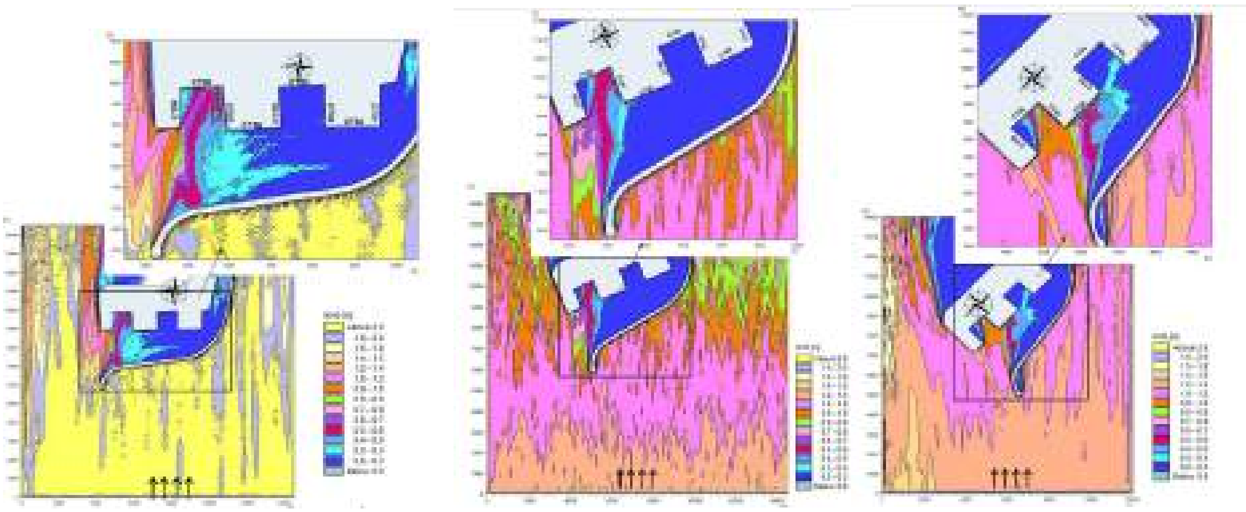


Figure 13-12 Wave tranquillity results for Master Plan Layout with Waves from West, West-North-West and North-West

Wave direction/ Wave height	Average Significant Wave Height (m) at Terminals								
	CT 1	*CT 2*	*CT3*	*CT4*	*CT5*	*CT 6*	*CT 7*	*CT 8*	*CT 9*
270° West / 2.5 m	0.25	0.25	0.25	0.28	0.30	0.35	0.63	0.60	0.40
292.5° (WNW)/ 1.5 m	0.20	0.30	0.30	0.25	0.25	0.45	0.65	0.70	0.40
315° (NW)/ 1.5 m	0.20	0.30	0.30	0.25	0.25	0.65	0.95	0.50	0.30

Based on the above critical wave direction significant wave height of 1.0 m is observed at CT 7during non monsoon season. The downtime will not exceed 10 -12 days in a year.

Waves from West ***Waves from WNW*** ***Waves from NW***

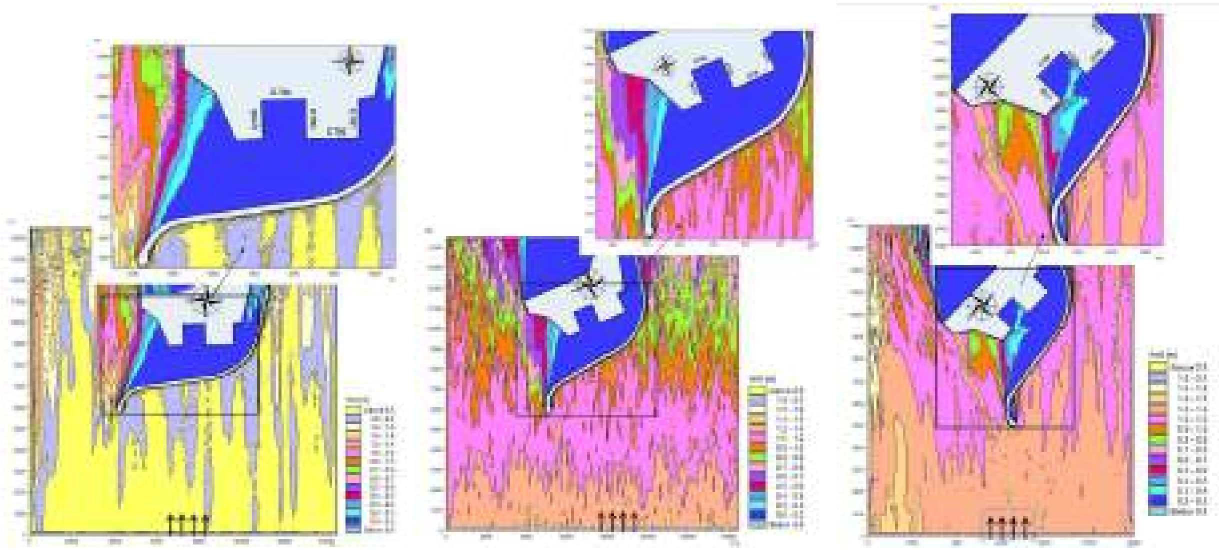


Figure 13-13 Wave tranquillity results for Phase 1 layout with Waves from West, West-North-West and North-West

Wave direction/ Wave height	Average Significant Wave Height (m) at Terminals				
	CT 1	*CT 2*	*CT3*	*CT4*	*CT5*
270° West / 2.5 m	0.25	0.25	0.25	0.28	0.30
292.5° (WNW)/ 1.5 m	0.20	0.30	0.30	0.25	0.25
315° (NW)/ 1.5 m	0.20	0.30	0.40	0.35	0.36

Based on the above, the significant wave height of about 0.4 m is observed at CT 3 and all terminals in Phase 1 have significant wave height of less than 0.35 m during monsoon and non-monsoon season and no downtime was observed at these terminals.

13.4.5 Impact of Capital Dredging on Tidal Hydrodynamics

Mathematical model study was carried out to assess the impact of proposed capital dredging on tidal hydrodynamics in the harbour and nearby area of proposed Vadhavan port. The hydrodynamic parameters like currents, water levels were extracted from the model at 15 locations along the shoreline and inside Dahanu creek.

Royal HaskoningDHV

JNPA

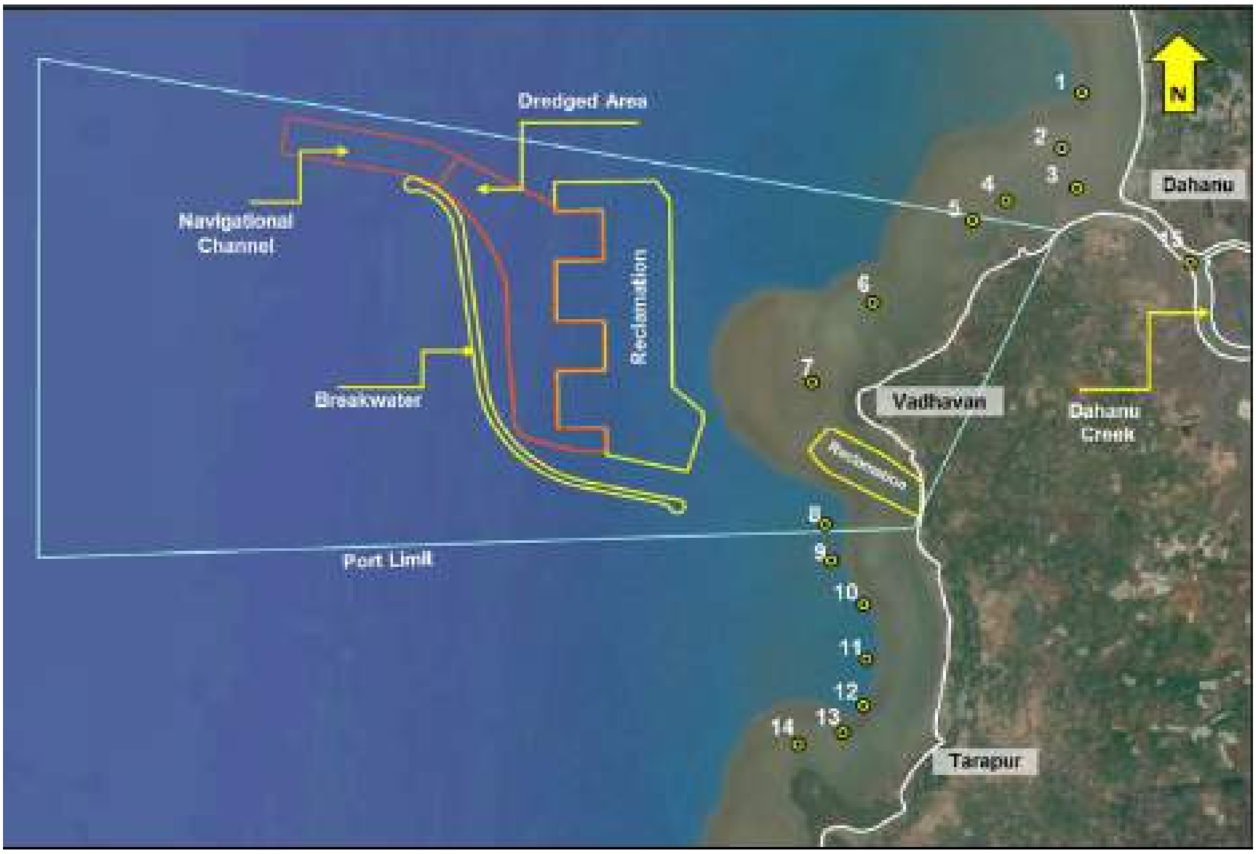
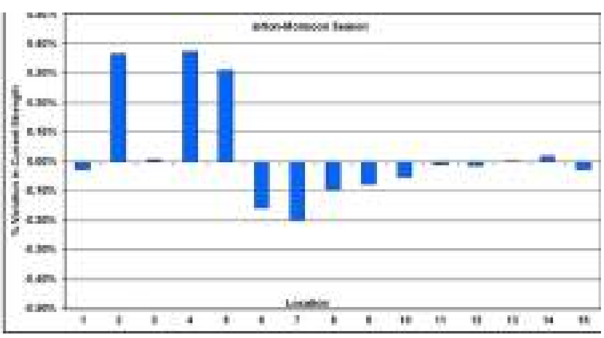


Figure 13-14 Data extraction locations

The percentage variation in current strength at the above locations for monsoon and non-monsoon season is as indicated below.

% Variation of current during non-monsoon



% Variation of current during monsoon

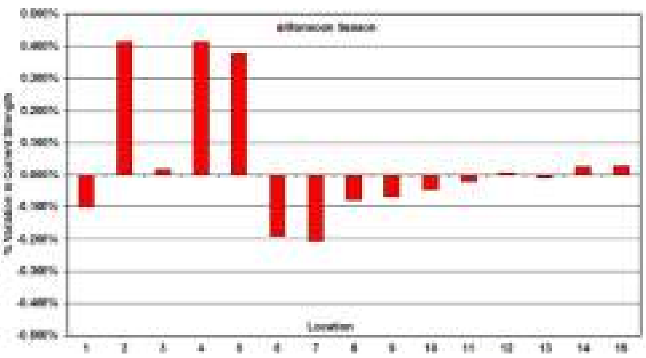


Figure 13-15 Percentage variation of current during non-monsoon and monsoon season due to Master plan dredging

The variation in current strength is less than 0.4% during non-monsoon season while during monsoon it is less than 0.45% i.e., there is insignificant variation in the current strength due to the proposed development to the nearby areas.

14 Financial Viability

14.1 Project Development

The port is proposed to be developed as on landlord model with the port terminals to be developed on PPP basis. The basic infrastructure of the port necessitating upfront investment such as, breakwater, reclamation rail and road linkages, power, water lines, harbour crafts and common infrastructure and services will be developed by the port/ SPV whereas the cargo terminal facilities would be leased out to the various operators who shall be responsible for its construction, operations, and maintenance.

The work limits for landlord (JNPA) and the PPP operators are as detailed out in Fig 14.1

14.2 Cost Estimates

14.2.1 Introduction

A detailed CAPEX (**Cap**ital **Ex**penditure) estimate has been prepared for the Phase 1 and Phase 2 development. The detailed development budget estimates are provided for reference only, and represent a professional opinion based on "macro" cost level and available site information. Actual costs may vary significantly from the provided cost estimates, depending on the construction timeline, changed market conditions, availability of materials, change of policy and other unlisted factors. Therefore, these budget cost estimates are not guaranteed figures for financing or carrying out any transactions.

The cost is divided into major components such as Project Preliminaries & Site Development, Dredging & Reclamation, Breakwaters, Berthing Structures, Buildings, Container Yard, Equipment, Utilities, Port Crafts & Aids to Navigation and Gate Complex etc. For each major component, based on its functional requirements, cost has been estimated as per the proposed development. For berthing structures, dredging & reclamation, breakwaters the cost estimation has been done by considering the preliminary engineering as per the Vadhavan Port site and environmental conditions. The unit rates have been taken based on the past projects carried out by RHDHV in India and current market rates obtained from ongoing projects and vendors.

The calculations used to create the estimates reflect current construction costs (2020 base year), as well as estimated allocation of funds for construction contingencies and planning/design costs. Refer to Annexure 2 for the detailed estimates for the master plan development. Refer to Section 8 and 9 for various details of the proposed port components which have been used to develop the cost estimates.

The following assumptions were used during the development of these estimates:

- The capital cost estimates are based on the project descriptions and drawings which were prepared after carrying out basic engineering of various components of the project. These will need to be developed, revised, and refined during the detailed design phase, and, therefore, some quantities shown in the cost estimates may undergo revision.
- All cost estimates are represented in INR for FY 2020.
- All mobilization costs are included in respective entities.
- A construction methodology has been assumed based on experience of similar structures and utilized for costing provided in this section.

DO NOT SCALE

LEGEND

- MANGROVES
- ROCKY OUTCROP

JNPT WORK LIMIT

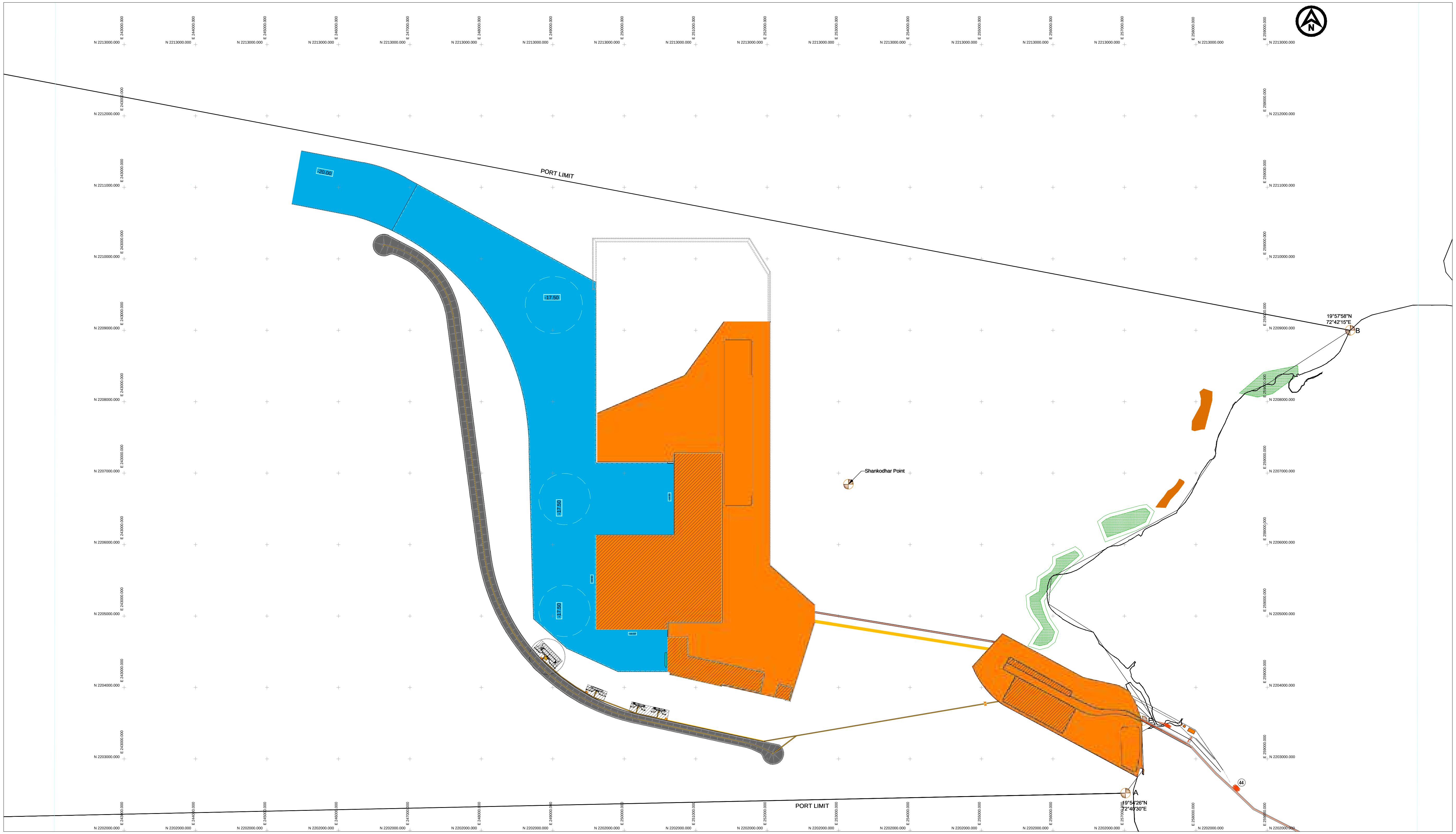
- DREDGING AREA
- RECLAMATION AREA, BUND & RAILYARD, AND JNPT ADMIN BUILDING

CONCESSIONAIRE WORK LIMIT

- CONTAINER BERTHS, YARD, STORAGE SHED , MPB, RORO, LIQUID, LPG, LNG

NOTES

1. ALL DIMENSIONS AND LEVELS ARE IN METERS, UNLESS NOTED OTHERWISE.
2. DRAWINGS ARE NOT TO BE SCALED, ONLY WRITTEN DIMENSIONS ARE TO BE FOLLOWED.



TITLE	PROJECT	CLIENT	CONSULTANT
VADHAVAN PORT PHASE 1 WORK LIMIT LAYOUT	Consultancy services for Design and Detailed Engineering for Greenfield Vadhavan port project	JAWAHARLAL NEHRU PORT TRUST	Royal HaskoningDHV Enhancing Society Together

Job No.	DI1452	DATE	OCT. 2021	SCALE	N.T.S.
ACAD Ref.	-	CHECKED	MS	PASSED	ASM
DRAWN	ZR	DRG No.	FIGURE 14.1	REV	A

The costs for components of the port outside the secured boundary that include components that are responsibility of JNPA such as JNPA Building, Rail Yard and External connectivity etc. have been assessed based on the IR/ DFCC and NHAI requirements.

14.2.2 Exclusions from CAPEX

The following exclusions were used during the development of these estimates:

- Cost towards tank farm, pipelines, FSRU, topside facility is excluded from the cost
- Costs for environmental studies and potential mitigation have to be estimated by Environmental consultant as part of the EIA studies.
- General administrative supplies are not included.

14.2.3 Assumptions towards Estimates

The overall Project cost also include costs towards contingencies, professional charges for PMC and escalation during construction and IDC. The contingencies considered in the Project Cost as per the Project Appraisal Committee in the past for various projects were at 10%, escalation was at 5% per annum. Accordingly, the total centage charges will be in the order of 20 to 25%. This would escalate the Overall Project Cost and the realistic project cost cannot be arrived at. Therefore, it was suggested that the realistic costing to be considered towards these costs i.e., the escalation between the period of conceptualisation and first award of work, contingency for entire civil portion of work and pre-operating expenses and financial charges etc. The centage charges should be in the range of 10 to 15%. Based on various documentary evidence/ guidelines, it was found that the latest circulation issued by NHAI on 10th Aug 2016 as well as in April 2018, NHAI considers the centage charges for both EPC and HAM type of projects at the rate of 11 to 15% of Project Cost. This will enable us to appraise the Project Cost and deduce the financial returns as well as the project financial plan based on these factors. In view of this, it is proposed to adopt NHAI policy which will be based on the committee which has gone into details for centage charges for NHAI projects.

There are circulars related to other sectors like power sector, rail sector where in the contingencies considered are different based on the firming of the estimates. However, in view of the large-scale projects taken up by NHAI, it is proposed to adopt NHAI standards of arriving at the centage charges based on the circular dated 10th Aug. 2016.

14.2.4 Project CAPEX

14.2.4.1 Project Preliminaries and Site Development

This includes the cost involved in site preparation & development for construction activities, pre-operative expenses, initial surveys & project studies.

14.2.4.2 Dredging & Reclamation

Dredging and reclamation is one of the major cost parameters for any port project. Based on the bathymetry contours provided by JNPA and as per the proposed phase wise development plan, the dredging and reclamation quantities have been estimated.

It is estimated that reclamation quantity required for Phase 1 development will be met by burrow material from marine source and some amount by dredging in the harbour as explained in Section 8.4.5. The initial reclamation bund and shore protection revetment costs have also been included. The ground improvement costs are estimated over the complete gross reclaimed area of the port.

14.2.4.3 Breakwater

As per the site-specific nearshore wave climate studies and wave flume studies carried out by CWPRS, cross sections were proposed for the breakwaters considering the recommended design wave height. The breakwater is considered to have a single layer concrete armour (ACCROPODE) unit and crest elevations designed as per Section 8.2.4.3. The cost estimation has been done for the breakwater based on estimated Bill of Quantities (BOQ) of armour units, crown wall, rubble requirements for secondary layer, bedding, and toe protection. The Schedule of rates (2020) from Govt. of Maharashtra has been used to arrive at average cost of quarry material based on the options identified in Section 8.2.13.

14.2.4.4 Berthing Structures

Cost estimated for the berthing structures includes container terminal berths, multipurpose berths, liquid berths, Other Liquid, Bulk Liquid, Coast Guard and Port craft berths. The cost estimates are done considering the basic design of an open pile berthing structure. These include costs for piles, crane rails where applicable, fenders, bollards, in-situ, and pre-cast concrete works.

14.2.4.5 Container and Storage Yard

Major items included in the cost estimate for container yard development are site grading, pavement and RTG beams.

14.2.4.6 Equipment

Costs for required equipment as discussed in Section 7 have been considered for Phase 1 development. Major equipment is Rail Mounted Quay Cranes (RMQC), Electric Rubber Tire Gantry (eRTG for container yard), Rail Mounted Gantry Cranes (RMGC) and Empty Handlers.

14.2.4.7 Utilities

The following within the terminal utilities have been included in the cost estimate:

- Electric supply & distribution including high mast lighting for container yard.
- Firefighting.
- Lighting & Earthing.
- Water supply.
- Drainage & Sewerage.
- Communication & IT (including Terminal Operating System).
- Compound wall for land side port area.
- Workshop equipment.
- Security infrastructure.

14.2.4.8 Port Crafts and Aids to Navigation

The terminal will need tugboats for berthing, stopping & turning manoeuvres for the container and other vessels. The other port crafts include mooring launch and pilot cum survey launch. Aids to Navigation requirements have been assessed as per the IALA guidelines with details provided in Section 7.5.

14.2.4.9 Gate Complex and Terminal Roads

The gate complex, customs processing area and main terminal road (4 lane road along the container yard) costs have been included.

14.2.5 Basic Project Block Cost Estimates Summary

Based on the "Landlord" port model, **Table 14-1** lists out the estimated capital cost split between JNPA and private terminal operator(s) on the basis of discussions with JNPA and RHDHV's understanding of the market. It is assumed that JNPA will provide all civil costs associated with the project including breakwaters, dredging and reclamation, external rail and road connectivity, port crafts, Landscaping, Gate complex and navigation aids. Some buildings such as JNPA Admin, security guard booth, will be provided by JNPA. Private operator will provide all container terminal, In-Port rail yard development costs as well as equipment costs. It is also assumed that JNPA will provide utilities to an agreed upon "hand-shake" point and the private terminal operator will be providing the utilities for the rest of the container terminal.

Table 14-1 Overall cost estimate of JNPA and PPP operators

S. No.	Item		JNPA (INR in Crores)		PPP (INR in Crores)		Total (JNPA)	Total (PPP)	Total cost (INR in crores)
			Phase -1	Phase -2	Phase-1	Phase-2			
1	Project Preliminaries and Site Development		60	60	-	-	120	-	120
2	Dredging		936	2,016	-	-	2,952	-	2,952
3	Reclamation		9,321	2,586	-	-	11,907	-	11,907
4	Shore Protection Works		2,381	1,111	-	-	3,492	-	3,492
5	Breakwater		5,361		-	-	5,361	-	5,361
6	Berths/ Terminals								
	6.1	Container Terminal 1 (CT1)	-	-	2,689	-	-	2,689	2,689
	6.2	Container Terminal 2 (CT2)	-	-	2,693	-	-	2,693	2,693
	6.3	Container Terminal 3 (CT3)	-	-	2,688	-	-	2,688	2,688
	6.4	Container Terminal 4 (CT4)	-	-	2,699	-	-	2,699	2,699
	6.5	Container Terminal 5 (CT5)	-	-	-	2,703	-	2,703	2,703
	6.6	Container Terminal 6 (CT6)	-		-	2,704	-	2,704	2,704
	6.7	Container Terminal 7 (CT7)	-	-	-	2,684	-	2,684	2,684
	6.8	Container Terminal 8 (CT8)	-	-	-	2,708	-	2,708	2,708
	6.9	Container Terminal 9 (CT9)	-	-		2,717	-	2,717	2,717
	6.1	Multipurpose Terminal - 4 No.	-	-	861	161	-	1,021	1,021
	6.11	RO-RO Terminal	-	-	204		-	204	204
	6.12	Bulk Liquid Terminal	-	-	239	-	-	239	239
	6.13	Liquid Terminal Edible and Chemical -2 No	-	-	299	-	-	299	299
7	Common Port Infrastructure								
	7.1	Reclamation	181	90	-	-	271		271
	7.2	Approach Trestle	1,777	0	-	-	1,777		1,777

S. No.	Item		JNPA (INR in Crores)		PPP (INR in Crores)		Total (JNPA)	Total (PPP)	Total cost (INR in crores)
			Phase -1	Phase -2	Phase-1	Phase-2			
	7.3	Port Buildings	248	15	-	-	263		263
	7.4	Tug Berth	71	0	-	-	71		71
	7.5	Internal Roads, ROB, Underpass	1,073	362	-	-	1,435		1,435
	7.6	Utilities and fencing	383	12	-	-	394		394
8	Roads and Railways				-				
	8.1	External Road Connectivity	-	-		-	-	-	-
	8.2	External Rail Connectivity (upto port gate and inport tracks)	-	-	-	-	-	-	-
	8.3	In-Port Rail Yard	-	-	1,478	883		2,361	2,361
9	External Utilities, Township and Others		339	43	-	-	382		382
10	Port Crafts and Navigational Aids		34	1	-	-	35		35
11	Gates Complex		40	57	-	-	97		97
12	Landscaping		90	-	-	-	90		90
Total (1+2+3+4+5+6+7+8+9+10+11+12)			**22,296**	**6,353**	**13,849**	**14,560**	**28,648**	**28,410**	**57,058**
(A) Total (1+2+3+4+5+6+7+8+9+10+11+12)			22,296	6,353	13,849	14,560	28,648	28,410	57,058
(B) GST (@18%) on infra Cost			4,013	1,143	2,493	2,621	5,157	5,114	10,270
(C) Total Infra Cost (including GST) (A+B)			26,309	7,496	16,342	17,181	33,805	33,523	67,328
(D) Contingency at 1%			263	75	163	172	338	335	673
Total EPC Cost (C+D)			26,572	7,571	16,506	17,353	34,143	33,859	68,002
(E) Preliminary & Preoperative Cost			60	0	1,651	1,735	60	3,386	3,446
(F) Financial Cost for Debt syndication			125	25	-	-	150	-	150
(G) PMC charges			150	25	-	-	175	-	175
(G) Interest During Construction Period (IDC Cost of Borrowing)			2,503	500	-	-	3,003	-	3,003
Land acquisition			885	-	-	-	885	-	885
Compensation to fishermen and fee to TAPS			560	-	-	-	560	-	560
Total (INR in crores)			30,855	8,121	18,156	19,088	38,976	37,244	76,220

14.3 Operation and Maintenance Costs

14.3.1 General

Operation and Maintenance costs have been calculated under various heads as described in the subsequent paras. These costs do not include the following items:

- Lease rent to the state government
- Maintenance of Infrastructure outside the port boundary

14.3.2 Repair and Maintenance Costs

The following norms have been used for estimating the annual maintenance and repair costs:

- 1% of Civil Works
- 3% of Quay Cranes and Gantries
- 5% of Diesel driven equipment
- 5% of other Mechanical equipment and Electrical Works
- 3% of Utilities and Other Works

For dredging, the actual cost based on the maintenance dredging volume estimated from model studies is considered.

14.3.3 Manpower Costs

The estimated number of personnel required for the Phase 1 port administration as well as operation and maintenance shall be as below:

- Landlord/ Admin Staff 64 No.
- Operation & Maintenance Staff for various terminals

I.	For Multipurpose Terminal	329	No.
II.	Container Terminal	1,024	No.
III.	RO RO Terminal	50	No.
IV.	Liquid Bulk and Bulk Liquid terminals	114	No.
V.	Other Liquid terminals	53	No.
VI.	Manning Requirement of Common Systems / Utilities	204	No.
VII,	In-port Rail yard	202	No.
	Total O&M Personnel at Port	**1,976**	No.

14.3.4 Operation Costs

The operation costs include the fuel, water, and power costs. These have been considered as below:

Power	-	Rs. 9.2 per unit plus Rs. 432 per MVA of demand rate per month
Water Charges	-	Rs. 150 per kilolitre
Diesel	-	Rs. 100 per litre

The operation costs for the equipment run by electrical power have been calculated based on the maximum throughput and utilisation of the equipment. Similarly, the operation cost of equipment run by diesel like ITVs has been worked out based on the utilisation level for the annual throughput. Further the operation costs of the following items have been estimated as a percentage of their capital cost, as given below:

Diesel Driven Equipment (minor) and Marine Crafts	-	5% per annum
Other Works such as Firefighting & Pollution Control	-	3% per annum

14.3.5 Annual Operation and Maintenance Costs

Based on the various criteria discussed above, the annual operation and maintenance cost for Phase 1 of Vadhavan Port are provided in table below, (refer Appendix 2 for detailed breakup of the OPEX estimates).

Table 14-2 Summary of Operations & Maintenance Cost Estimates

S. No.	Item	Annual Costs (Rs. in Crores)		
			Phase 1	Phase 2
		Terminal Operator		
1.		Container Terminal CT1	224.6	-
2.		Container Terminal CT2	224.6	-
3.		Container Terminal CT3	224.6	-
4.		Container Terminal CT4	224.6	-
5.		Container Terminal CT5	-	224.6
6.		Container Terminal CT6	-	224.6
7.		Container Terminal CT7	-	224.6
8.		Container Terminal CT8	-	224.6
9.		Container Terminal CT9	-	224.6
10.		Multipurpose Terminal	46.0	12.8
12.		RO-RO Terminal	7.6	-
14.		Bulk Liquid Jetty	15.0	-
15.		Liquid Jetty - Edible and Chemical – 2 No.	35.8	-
16.		In-port rail yard	57.4	109.2
		JNPA		
1.		Landlord component	577.8	557.7

14.4 Financial Analysis

Vadhavan Port

Financial & Economic Analysis Results

December 2022

Confidential

CONTENT

Financial Analysis

Set-up

Financial analysis

Financial analysis set-up

Assessment of financial feasibility of both the port authority business case and the underlying operator's business cases

- The analysis assumes a landlord port model, in which JNPT acts as port authority and concessions out port operations to private sector operators
- JNPT provides the private operators the basic port infrastructure and the (reclaimed) land to develop terminals for port activities.
- The operators will pay a fee to the port authority (JNPT SPV) for the right to use the general port facilities and the land.
- The port authority and the operators are assumed as stand-alone business units, attracting their own required funding and financing.

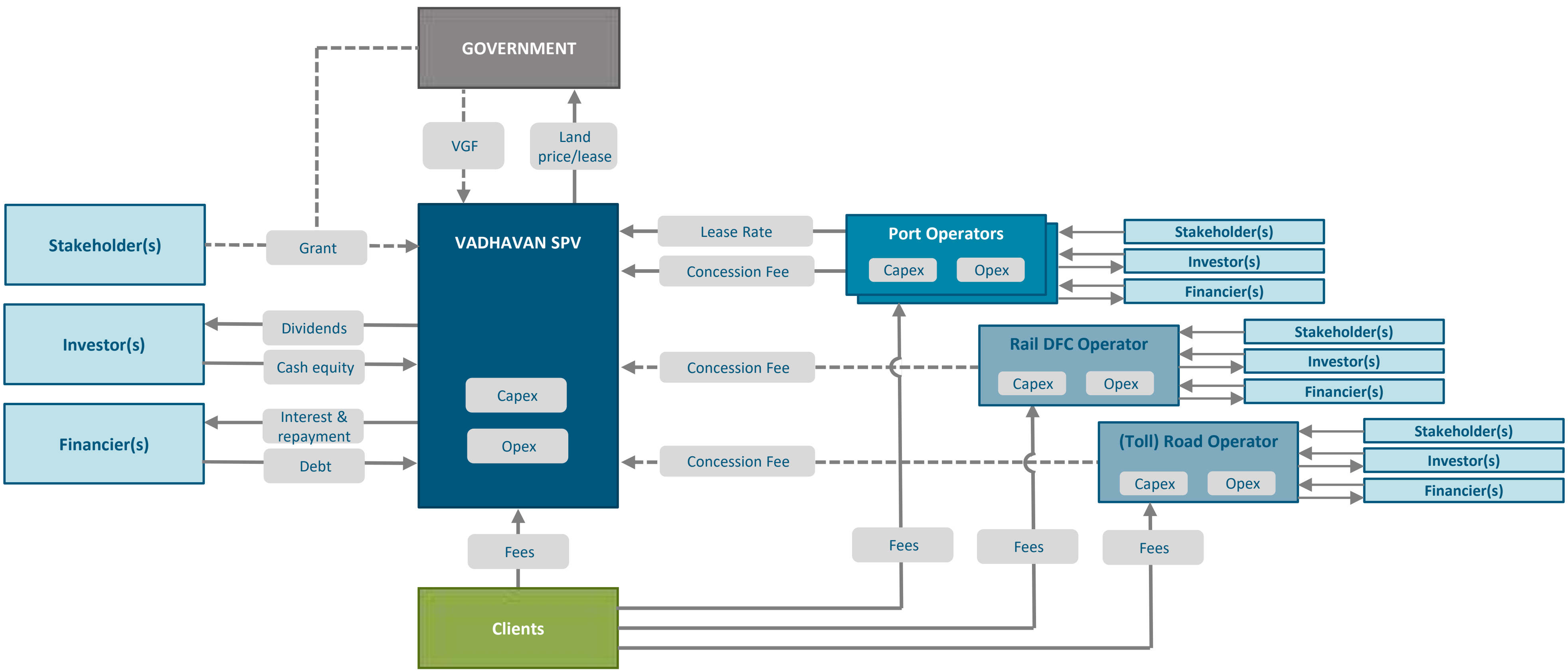
Business Units included

Landlord Port Model with JNPT as Port Authority and private sector Operators

Business Unit	Included	Concession Fee(s)		Key income sources
JNPT (Port Authority)	✓	Receivable from operators		Port dues, Pilotage, Concession Fees, Lease Fees
Container Terminal 1	✓	Payable to JNPT	30% of revenues	Bert hire, Handling, Storage
Container Terminal 2	✓	Payable to JNPT	30% of revenues	Bert hire, Handling, Storage
Container Terminal 3	✓	Payable to JNPT	30% of revenues	Bert hire, Handling, Storage
Container Terminal 4	✓	Payable to JNPT	30% of revenues	Bert hire, Handling, Storage
Container Terminal 5	✓	Payable to JNPT	30% of revenues	Bert hire, Handling, Storage
Container Terminal 6	✓	Payable to JNPT	30% of revenues	Bert hire, Handling, Storage
Container Terminal 7	✓	Payable to JNPT	30% of revenues	Bert hire, Handling, Storage
Container Terminal 8	✓	Payable to JNPT	30% of revenues	Bert hire, Handling, Storage
Container Terminal 9	✓	Payable to JNPT	30% of revenues	Bert hire, Handling, Storage
Multipurpose Terminal	✓	Payable to JNPT	30% of revenues	Bert hire, Handling, Storage
Ro-Ro Terminal	✓	Payable to JNPT	30% of revenues	Bert hire, Handling
Liquids Terminal	✓	Payable to JNPT	30% of revenues	Bert hire, Handling, Storage
LPG Terminal	✓	Payable to JNPT	30% of revenues	Bert hire, Handling, Storage
LNG Terminal	✗	N/A	N/A	Bert hire, Handling, Storage
Rail Yard Terminal	✓	Payable to JNPT	30% of revenues	Handling
Rail DFC	✓	None	N/A	Haulage charges
Toll Road	✓	None	N/A	Toll charges

Business Units

Cash flows for financial assessment of Port Authority business case and Operator business cases



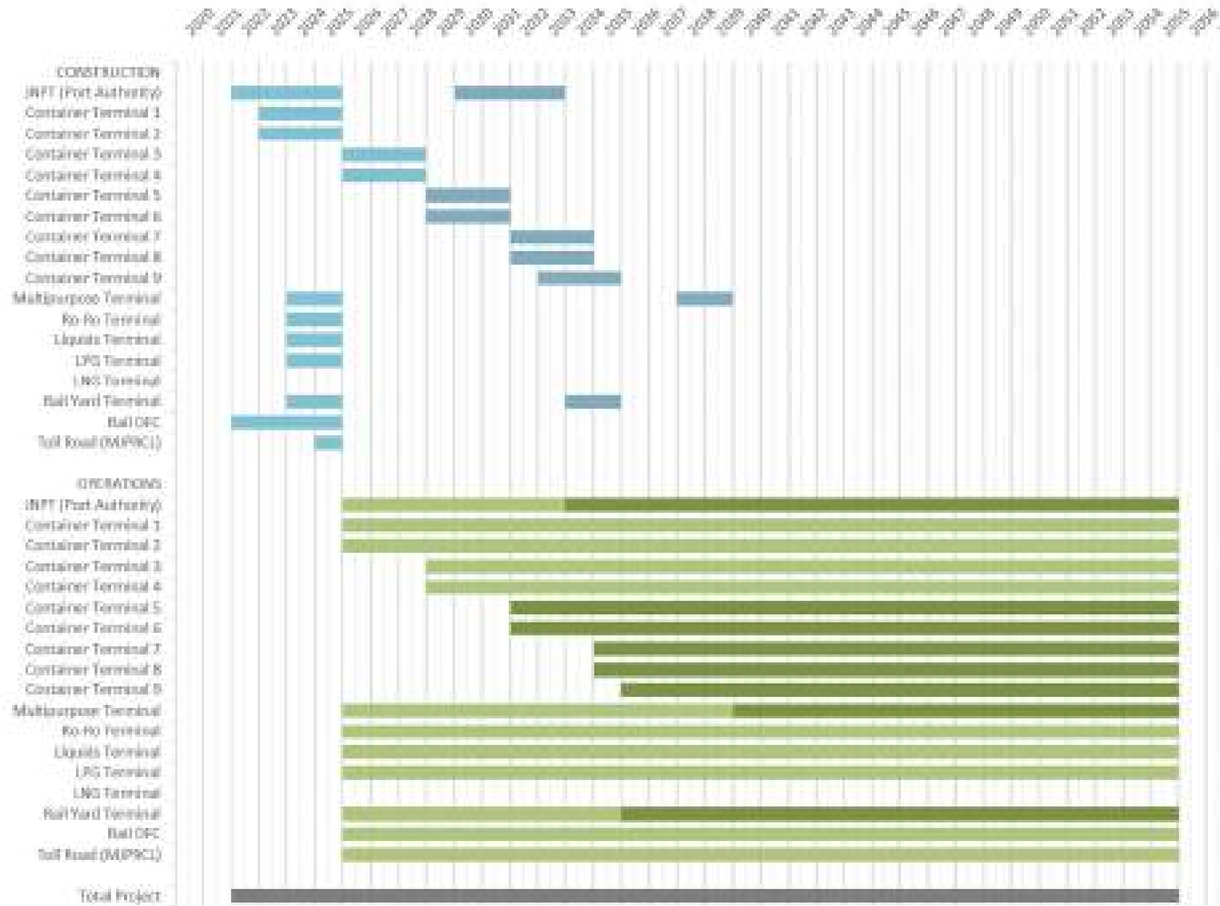
Assumptions

Financial Analysis

Planning

Phased development of port and business units.

- A phased development approach is assumed, with two distinctive phases (phase 1 and 2)
- End year of operations for all business units is set to 2055 for financial analysis purposes. In practice concessions will continue after that.

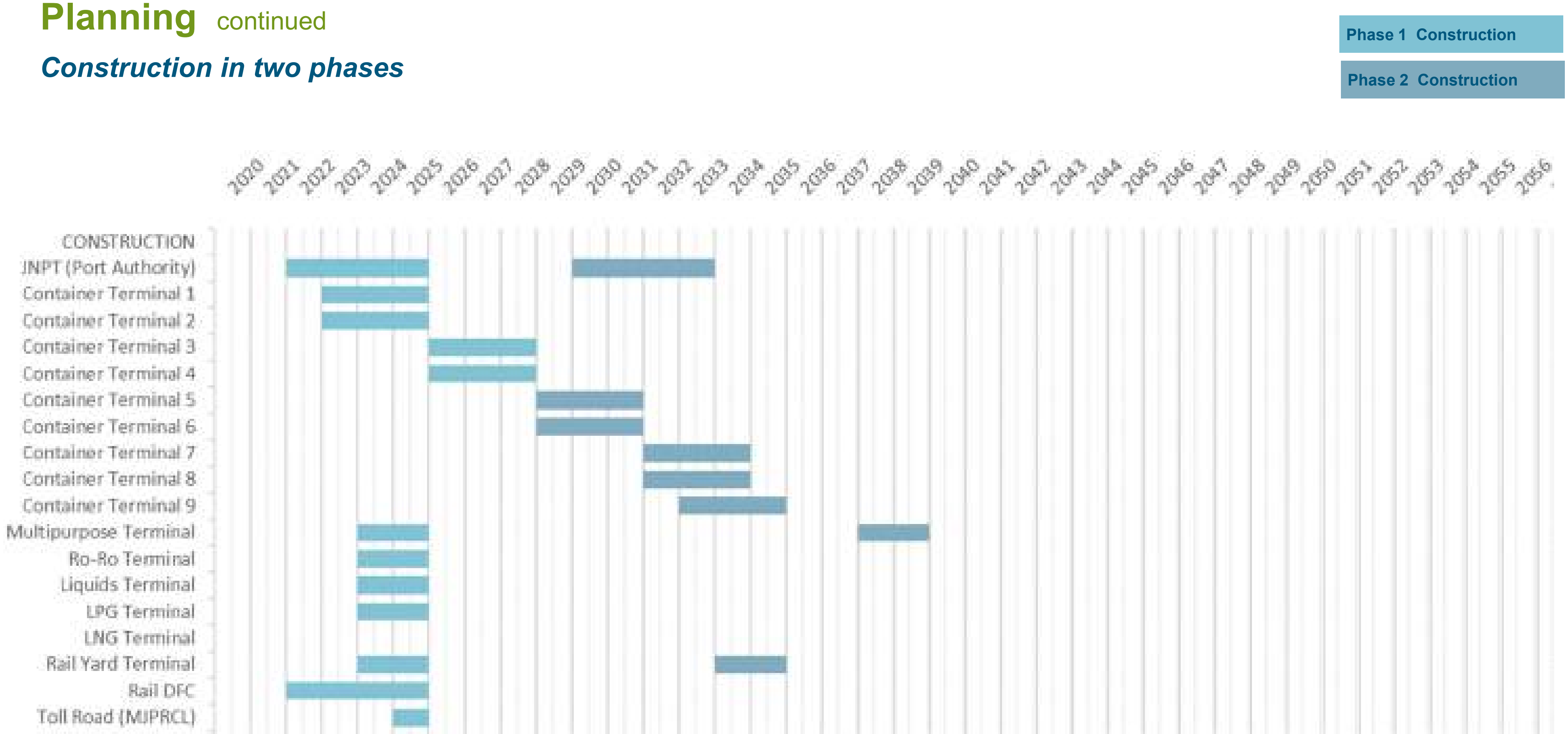


Phase 1 Construction
Phase 2 Construction
Phase 1 Operations
Phase 2 Operations

December 2022

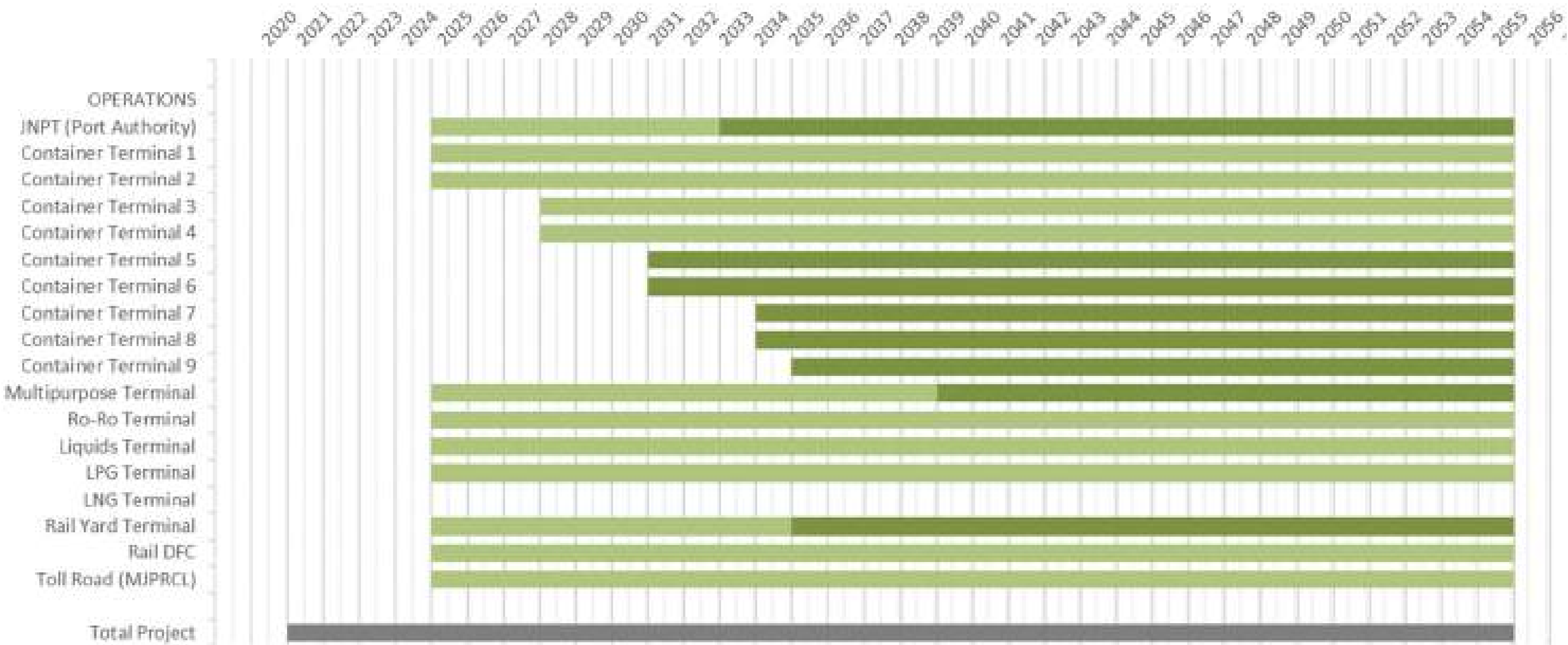
Planning continued

Construction in two phases



Planning continued

Operations with a fixed end year for financial analysis purposes



Indexation, Exchange and Financing assumptions

All cash flows are assumed in nominal amounts by including projected indexation. The WACC is applied in the unlevered free cash flow analysis to determine NPV.

Cash flow	Indexation rate
Devex	4.00%
Capex	4.00%
Opex	4.00%
Tariffs General	2.50%
Tariffs Toll Road	2.50%
Lease rates	2.00%

Country	Inflation rate
India	4.00%
USD inflation rate	2.25%

Exchange	Rate
USD -> INR exchange rate (fixed)	75.17
INR -> USD exchange rate (fixed)	0.0133

WACC	Rate
Project - Equity rate	16.00%
Project - Debt rate	8.00%
Project - Leverage (Debt to Capital) D/(D+E)	70.00%
Project - Tax rate	30.00%
Project - WACC	**8.72%**

Tariffs

Charged by PORT AUTHORITY

Port Dues		
Port Dues - Container	0.145	USD / GRT
Port Dues - Liquid, LPG, LNG	0.188	USD / GRT
Port Dues - General Cargo	0.188	USD / GRT
Port Dues - Coastal Cargo	7.316	INR / GRT

Miscellaneous		
Miscellaneous income - Signanes / Advertisements	500,000	INR / year / concessionaire
Miscellaneous income - Royalty Fees	1.00	INR cr. / year
Miscellaneous income - Utilities	1.00	INR cr. / year
Miscellaneous income - Bunker Supply	1.00	INR cr. / year
Miscellaneous income - Solar Power Harvesting	1.20	INR cr. / year
Miscellaneous income - Rent on Mobile Communication	0.06	INR cr. / year
Miscellaneous income - Royalty Fees	1.00	INR cr. / year

Tariffs

Charged by PORT AUTHORITY

Pilotage – Foreign vessels		
Pilotage - Base Slab Rates - Foreign Vessels - 0 to 30,000	0.32	USD / vessel
Pilotage - Base Slab Rates - Foreign Vessels - 30,001 to 60,000	9,666	USD / vessel
Pilotage - Base Slab Rates - Foreign Vessels - 60,001 to max	17,412	USD / vessel
	-	
Pilotage - Incremental Rates - Foreign Vessels - 0 to 30,000	0.3222	USD / vessel / GRT
Pilotage - Incremental Rates - Foreign Vessels - 30,001 to 60,000	0.2582	USD / vessel / GRT
Pilotage - Incremental Rates - Foreign Vessels - 60,001 to max	0.2259	USD / vessel / GRT

Pilotage – Coastal vessels		
Pilotage - Base Slab Rates - Foreign Vessels - 0 to 30,000	8.44	USD / vessel
Pilotage - Base Slab Rates - Foreign Vessels - 30,001 to 60,000	253,323	USD / vessel
Pilotage - Base Slab Rates - Foreign Vessels - 60,001 to max	455,901	USD / vessel
	-	
Pilotage - Incremental Rates - Foreign Vessels - 0 to 30,000	8.40	USD / vessel / GRT
Pilotage - Incremental Rates - Foreign Vessels - 30,001 to 60,000	6.75	USD / vessel / GRT
Pilotage - Incremental Rates - Foreign Vessels - 60,001 to max	5.91	USD / vessel / GRT

Tariffs

Charged by PORT AUTHORITY (to operators)

Business Unit	Concession Fee(s)	Concession Lease
JNPT (Port Authority)		
Container Terminal 1	30% of revenues	1 INR / m2
Container Terminal 2	30% of revenues	1 INR / m2
Container Terminal 3	30% of revenues	1 INR / m2
Container Terminal 4	30% of revenues	1 INR / m2
Container Terminal 5	30% of revenues	1 INR / m2
Container Terminal 6	30% of revenues	1 INR / m2
Container Terminal 7	30% of revenues	1 INR / m2
Container Terminal 8	30% of revenues	1 INR / m2
Container Terminal 9	30% of revenues	1 INR / m2
Multipurpose Terminal	30% of revenues	1 INR / m2
Ro-Ro Terminal	30% of revenues	1 INR / m2
Liquids Terminal	30% of revenues	1 INR / m2
LPG Terminal	30% of revenues	1 INR / m2
LNG Terminal	N/A	N/A
Rail Yard Terminal	30% of revenues	1 INR / m2
Rail DFC	N/A	N/A
Toll Road	N/A	N/A

Tariffs

Charged by CONTAINER TERMINALS

Bert Hire		
Berth Hire - Container Terminal - Rate	0.005	USD / GRT hour

Handling - Ship to CT Yard - Normal		
Container handling - Ship to CT Yard - Normal - 20 ft - Foreign - Loaded	4,271	INR / TEU
Container handling - Ship to CT Yard - Normal - 20 ft - Foreign - Empty	3,449	INR / TEU
Container handling - Ship to CT Yard - Normal - 20 ft - Coastal - Loaded	2,562	INR / TEU
Container handling - Ship to CT Yard - Normal - 20 ft - Coastal - Empty	2,070	INR / TEU
	-	
Container handling - Ship to CT Yard - Normal - 40 ft - Foreign - Loaded	6,406	INR / TEU
Container handling - Ship to CT Yard - Normal - 40 ft - Foreign - Empty	5,174	INR / TEU
Container handling - Ship to CT Yard - Normal - 40 ft - Coastal - Loaded	3,844	INR / TEU
Container handling - Ship to CT Yard - Normal - 40 ft - Coastal - Empty	3,104	INR / TEU

Tariffs

Charged by CONTAINER TERMINALS

Handling - Ship to CT Yard - Reefer		
Container handling - Ship to CT Yard - Reefer - 20 ft - Foreign - Loaded	4,271	INR / TEU
Container handling - Ship to CT Yard - Reefer - 20 ft - Foreign - Empty	3,449	INR / TEU
Container handling - Ship to CT Yard - Reefer - 20 ft - Coastal - Loaded	2,562	INR / TEU
Container handling - Ship to CT Yard - Reefer - 20 ft - Coastal - Empty	2,070	INR / TEU
	-	
Container handling - Ship to CT Yard - Reefer - 40 ft - Foreign - Loaded	6,406	INR / TEU
Container handling - Ship to CT Yard - Reefer - 40 ft - Foreign - Empty	5,174	INR / TEU
Container handling - Ship to CT Yard - Reefer - 40 ft - Coastal - Loaded	3,844	INR / TEU
Container handling - Ship to CT Yard - Reefer - 40 ft - Coastal - Empty	3,104	INR / TEU

Handling - Ship to CT Yard - Hazardous		
Container handling - Ship to CT Yard - Hazardous - 20 ft - Foreign - Loaded	5,339	INR / TEU
Container handling - Ship to CT Yard - Hazardous - 20 ft - Foreign - Empty	-	INR / TEU
Container handling - Ship to CT Yard - Hazardous - 20 ft - Coastal - Loaded	3,204	INR / TEU
Container handling - Ship to CT Yard - Hazardous - 20 ft - Coastal - Empty	-	INR / TEU
	-	
Container handling - Ship to CT Yard - Hazardous - 40 ft - Foreign - Loaded	8,009	INR / TEU
Container handling - Ship to CT Yard - Hazardous - 40 ft - Foreign - Empty	-	INR / TEU
Container handling - Ship to CT Yard - Hazardous - 40 ft - Coastal - Loaded	4,806	INR / TEU
Container handling - Ship to CT Yard - Hazardous - 40 ft - Coastal - Empty	-	INR / TEU

Tariffs

Charged by CONTAINER TERMINALS

Ship to CT Yard - OverDimensional		
Container handling - Ship to CT Yard - OverDimensional - 20 ft - Foreign - Loaded	8,541	INR / TEU
Container handling - Ship to CT Yard - OverDimensional - 20 ft - Foreign - Empty	6,899	INR / TEU
Container handling - Ship to CT Yard - OverDimensional - 20 ft - Coastal - Loaded	5,125	INR / TEU
Container handling - Ship to CT Yard - OverDimensional - 20 ft - Coastal - Empty	4,139	INR / TEU

CT Yard to Rail Yard - Normal		
Container handling - CT Yard to Rail Yard - Normal - 20 ft - Foreign - Loaded	657	INR / TEU
Container handling - CT Yard to Rail Yard - Normal - 20 ft - Foreign - Empty	657	INR / TEU
Container handling - CT Yard to Rail Yard - Normal - 20 ft - Coastal - Loaded	657	INR / TEU
Container handling - CT Yard to Rail Yard - Normal - 20 ft - Coastal - Empty	657	INR / TEU
	-	
Container handling - CT Yard to Rail Yard - Normal - 40 ft - Foreign - Loaded	986	INR / TEU
Container handling - CT Yard to Rail Yard - Normal - 40 ft - Foreign - Empty	986	INR / TEU
Container handling - CT Yard to Rail Yard - Normal - 40 ft - Coastal - Loaded	986	INR / TEU
Container handling - CT Yard to Rail Yard - Normal - 40 ft - Coastal - Empty	986	INR / TEU

Tariffs

Charged by CONTAINER TERMINALS

Handling - CT Yard to Rail Yard - Reefer		
Container handling - CT Yard to Rail Yard - Reefer - 20 ft - Foreign - Loaded	657	INR / TEU
Container handling - CT Yard to Rail Yard - Reefer - 20 ft - Foreign - Empty	657	INR / TEU
Container handling - CT Yard to Rail Yard - Reefer - 20 ft - Coastal - Loaded	657	INR / TEU
Container handling - CT Yard to Rail Yard - Reefer - 20 ft - Coastal - Empty	657	INR / TEU
	-	
Container handling - CT Yard to Rail Yard - Reefer - 40 ft - Foreign - Loaded	986	INR / TEU
Container handling - CT Yard to Rail Yard - Reefer - 40 ft - Foreign - Empty	986	INR / TEU
Container handling - CT Yard to Rail Yard - Reefer - 40 ft - Coastal - Loaded	986	INR / TEU
Container handling - CT Yard to Rail Yard - Reefer - 40 ft - Coastal - Empty	986	INR / TEU

Handling - CT Yard to Rail Yard - Hazardous		
Container handling - CT Yard to Rail Yard - Hazardous - 20 ft - Foreign - Loaded	821	INR / TEU
Container handling - CT Yard to Rail Yard - Hazardous - 20 ft - Foreign - Empty	-	INR / TEU
Container handling - CT Yard to Rail Yard - Hazardous - 20 ft - Coastal - Loaded	821	INR / TEU
Container handling - CT Yard to Rail Yard - Hazardous - 20 ft - Coastal - Empty	-	INR / TEU
	-	
Container handling - CT Yard to Rail Yard - Hazardous - 40 ft - Foreign - Loaded	1,232	INR / TEU
Container handling - CT Yard to Rail Yard - Hazardous - 40 ft - Foreign - Empty	-	INR / TEU
Container handling - CT Yard to Rail Yard - Hazardous - 40 ft - Coastal - Loaded	1,232	INR / TEU
Container handling - CT Yard to Rail Yard - Hazardous - 40 ft - Coastal - Empty	-	INR / TEU

Tariffs

Charged by CONTAINER TERMINALS

Handling - CT Yard to Rail Yard - OverDimensional		
Container handling - CT Yard to Rail Yard - OverDimensional - 20 ft - Foreign - Loaded	1,314	INR / TEU
Container handling - CT Yard to Rail Yard - OverDimensional - 20 ft - Foreign - Empty	1,314	INR / TEU
Container handling - CT Yard to Rail Yard - OverDimensional - 20 ft - Coastal - Loaded	1,314	INR / TEU
Container handling - CT Yard to Rail Yard - OverDimensional - 20 ft - Coastal - Empty	1,314	INR / TEU

Handling - CT Yard to Truck - Normal		
Container handling - CT Yard to Truck - Normal - 20 ft - Foreign - Loaded	657	INR / TEU
Container handling - CT Yard to Truck - Normal - 20 ft - Foreign - Empty	657	INR / TEU
Container handling - CT Yard to Truck - Normal - 20 ft - Coastal - Loaded	657	INR / TEU
Container handling - CT Yard to Truck - Normal - 20 ft - Coastal - Empty	657	INR / TEU
	-	
Container handling - CT Yard to Truck - Normal - 40 ft - Foreign - Loaded	986	INR / TEU
Container handling - CT Yard to Truck - Normal - 40 ft - Foreign - Empty	986	INR / TEU
Container handling - CT Yard to Truck - Normal - 40 ft - Coastal - Loaded	986	INR / TEU
Container handling - CT Yard to Truck - Normal - 40 ft - Coastal - Empty	986	INR / TEU

Tariffs

Charged by CONTAINER TERMINALS

Handling - CT Yard to Truck - Reefer		
Container handling - CT Yard to Truck - Reefer - 20 ft - Foreign - Loaded	657	INR / TEU
Container handling - CT Yard to Truck - Reefer - 20 ft - Foreign - Empty	657	INR / TEU
Container handling - CT Yard to Truck - Reefer - 20 ft - Coastal - Loaded	657	INR / TEU
Container handling - CT Yard to Truck - Reefer - 20 ft - Coastal - Empty	657	INR / TEU
	-	
Container handling - CT Yard to Truck - Reefer - 40 ft - Foreign - Loaded	986	INR / TEU
Container handling - CT Yard to Truck - Reefer - 40 ft - Foreign - Empty	986	INR / TEU
Container handling - CT Yard to Truck - Reefer - 40 ft - Coastal - Loaded	986	INR / TEU
Container handling - CT Yard to Truck - Reefer - 40 ft - Coastal - Empty	986	INR / TEU

Handling - CT Yard to Truck - Hazerdous		
Container handling - CT Yard to Truck - Hazerdous - 20 ft - Foreign - Loaded	821	INR / TEU
Container handling - CT Yard to Truck - Hazerdous - 20 ft - Foreign - Empty	-	INR / TEU
Container handling - CT Yard to Truck - Hazerdous - 20 ft - Coastal - Loaded	821	INR / TEU
Container handling - CT Yard to Truck - Hazerdous - 20 ft - Coastal - Empty	-	INR / TEU
	-	
Container handling - CT Yard to Truck - Hazerdous - 40 ft - Foreign - Loaded	1,232	INR / TEU
Container handling - CT Yard to Truck - Hazerdous - 40 ft - Foreign - Empty	-	INR / TEU
Container handling - CT Yard to Truck - Hazerdous - 40 ft - Coastal - Loaded	1,232	INR / TEU
Container handling - CT Yard to Truck - Hazerdous - 40 ft - Coastal - Empty	-	INR / TEU

Tariffs

Charged by CONTAINER TERMINALS

Handling - CT Yard to Truck - OverDimensional		
Container handling - CT Yard to Truck - OverDimensional - 20 ft - Foreign - Loaded	1,314	INR / TEU
Container handling - CT Yard to Truck - OverDimensional - 20 ft - Foreign - Empty	1,314	INR / TEU
Container handling - CT Yard to Truck - OverDimensional - 20 ft - Coastal - Loaded	1,314	INR / TEU
Container handling - CT Yard to Truck - OverDimensional - 20 ft - Coastal - Empty	1,314	INR / TEU

Storage		
Storage - Container Terminal - Rate - period 0 (--> NO CHARGE !)	-	INR / TEU / day
Storage - Container Terminal - Rate - period 1	522.25	INR / TEU / day
Storage - Container Terminal - Rate - period 2	621.24	INR / TEU / day
Storage - Container Terminal - Rate - period 3	1,283.41	INR / TEU / day

Tariffs

Charged by MULTI PURPOSE TERMINAL

Berth Hire		
Berth hire - Multi Purpose Terminal - Foreign Vessels - Rate	0.009	USD / GRT hour
Berth hire - Multi Purpose Terminal - Coastal Vessels - Rate	0.230	INR / GRT hour

Handling		
Handling - Multi Purpose Terminal - Wharfage & Crane Handling	151	INR / ton
Handling - Multi Purpose Terminal - Conveyor Charges	27	INR / ton
Handling - Multi Purpose Terminal - Bagging Charges	1,600	INR / ton
Handling - Multi Purpose Terminal - Loading Charges - Rail loading	30	INR / ton
Handling - Multi Purpose Terminal - Loading Charges - Truck loading	10	INR / ton
	-	
Handling - Multi Purpose Terminal - Tariffs Coastal Cargo as % of Tariffs Foreign Cargo	60%	%

Tariffs

Charged by MULTI PURPOSE TERMINAL

Storage		
Storage - Multi Purpose Terminal (Fertilizer & FRM) - Rate - period 0	279.00	INR / m2 / day
Storage - Multi Purpose Terminal (Fertilizer & FRM) - Rate - period 1	558.00	INR / m2 / day
Storage - Multi Purpose Terminal (Fertilizer & FRM) - Rate - period 2	697.50	INR / m2 / day
Storage - Multi Purpose Terminal (Fertilizer & FRM) - Rate - period 3	837.00	INR / m2 / day
	-	
Storage - Multi Purpose Terminal (General & Coastal Cargo) - Rate - period 0	144.00	INR / m2 / day
Storage - Multi Purpose Terminal (General & Coastal Cargo) - Rate - period 1	288.00	INR / m2 / day
Storage - Multi Purpose Terminal (General & Coastal Cargo) - Rate - period 2	360.00	INR / m2 / day
Storage - Multi Purpose Terminal (General & Coastal Cargo) - Rate - period 3	432.00	INR / m2 / day

Tariffs

Charged by LIQUIDS TERMINAL

Berth Hire		
Berth Hire - Liquids Terminal - Rate	0.006	USD / GRT hour

Handling		
Handling - Liquids Terminal - Wharfage - Edible Oil - rate	82.38	INR / MT
Handling - Liquids Terminal - Wharfage - Special Chemical - rate	192.21	INR / MT
Handling - Liquids Terminal - Wharfage - Other Chemical - rate	155.59	INR / MT
Handling - Liquids Terminal - Pipeline Charges - rate	59.66	INR / MT
Handling - Liquids Terminal - Pigging Charges - rate	20,000.00	INR / Vessel
Handling - Liquids Terminal - Terminal Handling Charges - rate	200.00	INR / MT
Handling - Liquids Terminal - Wharfage - Edible Oil - rate	82.38	INR / MT
Handling - Liquids Terminal - Wharfage - Special Chemical - rate	192.21	INR / MT

Storage		
Storage - Liquids Terminal - Rate - period 0 (--> NO CHARGE !)	-	INR / TEU / day
Storage - Liquids Terminal - Rate - period 1	40.00	INR / TEU / day
Storage - Liquids Terminal - Rate - period 2	50.00	INR / TEU / day
Storage - Liquids Terminal - Rate - period 3	-	INR / TEU / day

Tariffs

Charged by LPG TERMINAL

Berth Hire		
Berth Hire - LPG Terminal - Rate	0.006	USD / GRT hour

Handling		
Handling - LPG Terminal - Wharfage	168.160	INR / MT
Handling - LPG Terminal - Pipeline Charges - rate	59.660	INR / MT
Handling - LPG Terminal - Pigging Charges - rate	20,000.000	INR / Vessel
Handling - LPG Terminal - Terminal Handling Charges - rate	100.000	INR / MT

Storage		
Storage - LPG Terminal - Rate - period 0 (--> NO CHARGE !)	-	INR / TEU / day
Storage - LPG Terminal - Rate - period 1	40.00	INR / TEU / day
Storage - LPG Terminal - Rate - period 2	50.00	INR / TEU / day
Storage - LPG Terminal - Rate - period 3	-	INR / TEU / day

Tariffs

Charged by RAIL YARD TERMINAL

Handling - Rail Yard to Train Rig - Normal		
Rail Yard handling (containers) - Rail Yard to Train Rig - Normal - 20 ft - Foreign - Loaded	1,478.30	INR / TEU
Rail Yard handling (containers) - Rail Yard to Train Rig - Normal - 20 ft - Foreign - Empty	1,478.30	INR / TEU
Rail Yard handling (containers) - Rail Yard to Train Rig - Normal - 20 ft - Coastal - Loaded	1,478.30	INR / TEU
Rail Yard handling (containers) - Rail Yard to Train Rig - Normal - 20 ft - Coastal - Empty	1,478.30	INR / TEU
	-	
Rail Yard handling (containers) - Rail Yard to Train Rig - Normal - 40 ft - Foreign - Loaded	2,217.45	INR / TEU
Rail Yard handling (containers) - Rail Yard to Train Rig - Normal - 40 ft - Foreign - Empty	2,217.45	INR / TEU
Rail Yard handling (containers) - Rail Yard to Train Rig - Normal - 40 ft - Coastal - Loaded	2,217.45	INR / TEU
Rail Yard handling (containers) - Rail Yard to Train Rig - Normal - 40 ft - Coastal - Empty	2,217.45	INR / TEU

Handling - Rail Yard to Train Rig - Reefer		
Rail Yard handling (containers) - Rail Yard to Train Rig - Reefer - 20 ft - Foreign - Loaded	1,478.30	INR / TEU
Rail Yard handling (containers) - Rail Yard to Train Rig - Reefer - 20 ft - Foreign - Empty	1,478.30	INR / TEU
Rail Yard handling (containers) - Rail Yard to Train Rig - Reefer - 20 ft - Coastal - Loaded	1,478.30	INR / TEU
Rail Yard handling (containers) - Rail Yard to Train Rig - Reefer - 20 ft - Coastal - Empty	1,478.30	INR / TEU
	-	
Rail Yard handling (containers) - Rail Yard to Train Rig - Reefer - 40 ft - Foreign - Loaded	2,217.45	INR / TEU
Rail Yard handling (containers) - Rail Yard to Train Rig - Reefer - 40 ft - Foreign - Empty	2,217.45	INR / TEU
Rail Yard handling (containers) - Rail Yard to Train Rig - Reefer - 40 ft - Coastal - Loaded	2,217.45	INR / TEU
Rail Yard handling (containers) - Rail Yard to Train Rig - Reefer - 40 ft - Coastal - Empty	2,217.45	INR / TEU

Tariffs

Charged by RAIL YARD TERMINAL

Handling - Rail Yard to Train Rig - Hazerdous		
Rail Yard handling (containers) - Rail Yard to Train Rig - Hazerdous - 20 ft - Foreign - Loaded	1,847.42	INR / TEU
Rail Yard handling (containers) - Rail Yard to Train Rig - Hazerdous - 20 ft - Foreign - Empty	-	INR / TEU
Rail Yard handling (containers) - Rail Yard to Train Rig - Hazerdous - 20 ft - Coastal - Loaded	1,847.42	INR / TEU
Rail Yard handling (containers) - Rail Yard to Train Rig - Hazerdous - 20 ft - Coastal - Empty	-	INR / TEU
	-	
Rail Yard handling (containers) - Rail Yard to Train Rig - Hazerdous - 40 ft - Foreign - Loaded	2,771.13	INR / TEU
Rail Yard handling (containers) - Rail Yard to Train Rig - Hazerdous - 40 ft - Foreign - Empty	-	INR / TEU
Rail Yard handling (containers) - Rail Yard to Train Rig - Hazerdous - 40 ft - Coastal - Loaded	2,771.13	INR / TEU
Rail Yard handling (containers) - Rail Yard to Train Rig - Hazerdous - 40 ft - Coastal - Empty	-	INR / TEU

Handling - Rail Yard to Train Rig - OverDimensional		
Rail Yard handling (containers) - Rail Yard to Train Rig - OverDimensional - 20 ft - Foreign – Loaded	2,956.63	INR / TEU
Rail Yard handling (containers) - Rail Yard to Train Rig - OverDimensional - 20 ft - Foreign – Empty	2,956.63	INR / TEU
Rail Yard handling (containers) - Rail Yard to Train Rig - OverDimensional - 20 ft - Coastal – Loaded	2,956.63	INR / TEU
Rail Yard handling (containers) - Rail Yard to Train Rig - OverDimensional - 20 ft - Coastal - Empty	2,956.63	INR / TEU

Access		
Rail Yard Terminal - Train Access Fee	-	INR / rake

Tariffs

Charged by RO-RO TERMINAL

Berth Hire		
Berth Hire - RoRo Terminal – Rate	0.005	USD / GRT hour

Handling		
Handling - RoRo Terminal - Wharfage - Rate	8,400.00	INR / CEU

Charged by RAIL DFC (outside the terminal)

Haulage		
Rail DFC - Cargo Haulage Charge	349	INR / TEU

Charged by TOLL ROAD

Tolling		
Toll Road - Charge (24h pass) - Trucks	615	INR / vehicle
Toll Road - Charge (24h pass) - Passenger cars	150	INR / vehicle

Results

Financial Analysis

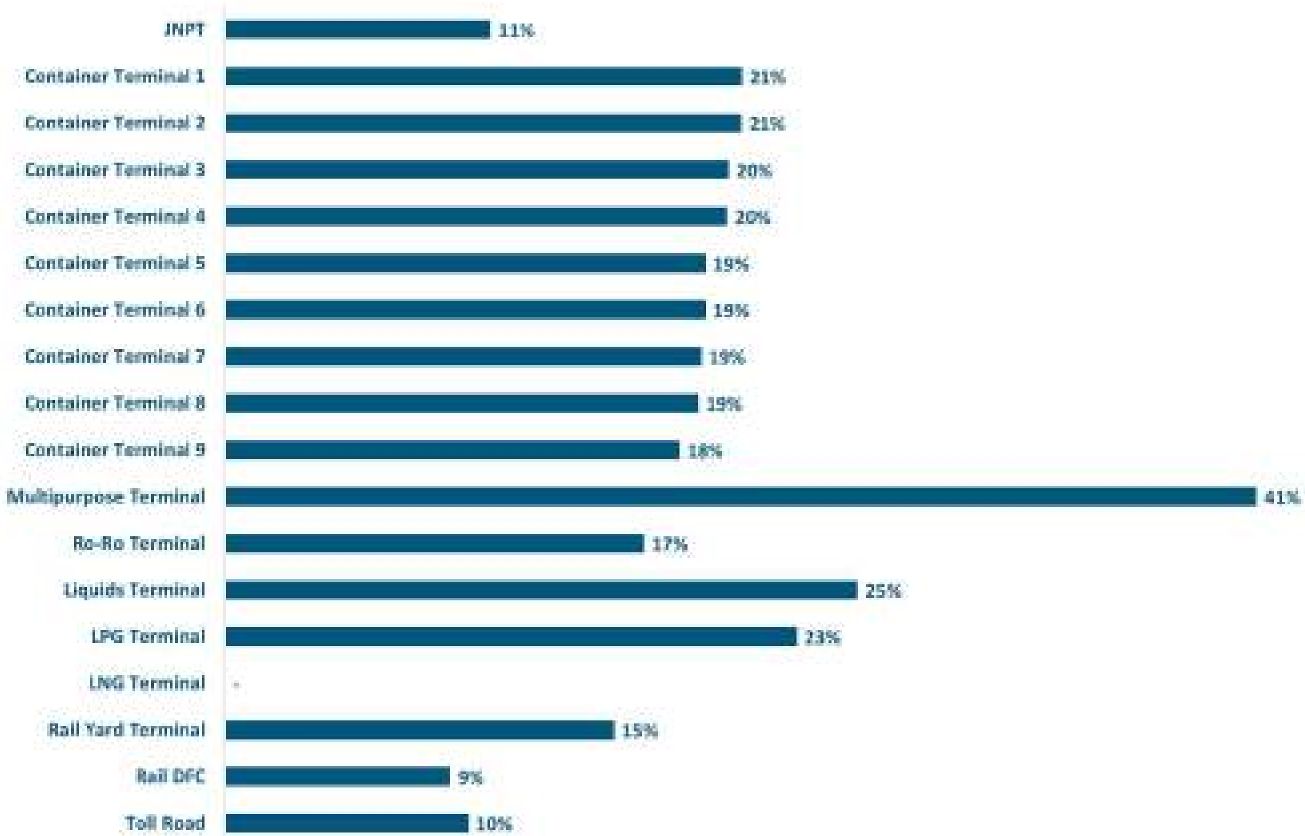
Results all Business Units

Key financial metrics unlevered free cash flow analysis

Business Unit	FIRR	FNPV INR cr.	FPBT years	FDPBT years	Phase 1 only FIRR	Phase 1 only FNPV INR cr.	Phase 1 only FPBT years	Phase 1 only FDPBT years	*F. Hurdle Rate*
JNPT (Port Authority)	11%	6,729	16	25	8%	(1,222)	16	N/A	*10%*
Container Terminal 1	21%	4,570	7	9	21%	4,570	7	9	*16%*
Container Terminal 2	21%	4,567	7	9	21%	4,567	7	9	*16%*
Container Terminal 3	20%	3,638	7	10	20%	3,638	7	10	*16%*
Container Terminal 4	20%	3,630	8	10	20%	3,630	8	10	*16%*
Container Terminal 5	19%	2,772	8	10	N/A	-	N/A	N/A	*16%*
Container Terminal 6	19%	2,771	8	10	N/A	-	N/A	N/A	*16%*
Container Terminal 7	19%	2,131	8	10	N/A	-	N/A	N/A	*16%*
Container Terminal 8	19%	2,119	8	10	N/A	-	N/A	N/A	*16%*
Container Terminal 9	18%	1,828	8	10	N/A	-	N/A	N/A	*16%*
Multipurpose Terminal	41%	5,028	4	5	41%	5,136	4	5	*16%*
Ro-Ro Terminal	17%	283	10	14	17%	283	10	14	*16%*
Liquids Terminal	25%	622	6	7	25%	622	6	7	*16%*
LPG Terminal	23%	442	7	8	23%	442	7	8	*16%*
LNG Terminal	N/A	-	N/A	N/A	N/A	-	N/A	N/A	*16%*
Rail Yard Terminal	15%	1,748	13	17	12%	588	12	19	*16%*
Rail DFC	9%	40	16	N/A	5%	(415)	19	N/A	*10%*
Toll Road	10%	326	14	25	5%	(845)	18	N/A	*10%*

Results all Business Units

Financial internal rates of return

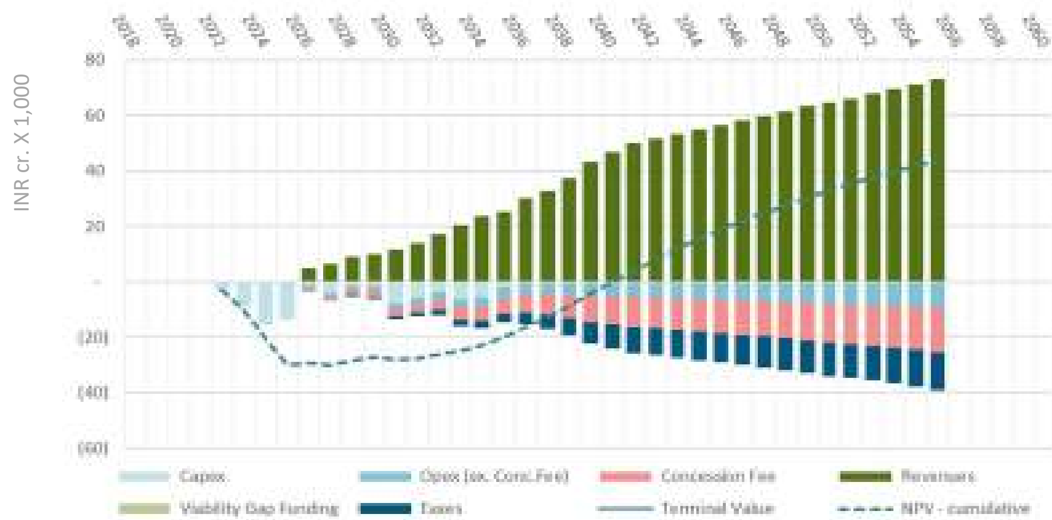


Results ALL Business Units (incl. JNPT)

Amounts in INR cr.

	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2040	2045	2050	2055
Revenues	-	-	-	-	4,678	6,721	8,998	10,086	11,756	13,862	16,981	20,482	23,499	25,498	46,940	56,348	64,900	73,106
VGF	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Devex	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Opex	-	-	-	-	1,318	1,373	1,430	1,947	2,026	2,109	2,713	2,826	3,189	3,900	5,285	6,437	7,831	9,528
Concession fee	-	-	-	-	982	1,415	1,900	2,140	2,497	2,968	3,643	4,399	5,053	5,492	10,116	12,163	14,012	15,782
Tax	-	-	-	-	300	753	1,232	1,316	1,671	2,058	2,550	3,302	3,839	4,038	8,645	10,508	12,101	13,801
Capex	3,408	9,064	15,368	13,477	1,350	4,212	1,460	1,525	7,867	6,001	3,799	6,330	5,545	1,904	-	-	-	-
Unlevered FCF	(3,408)	(9,064)	(15,368)	(13,477)	728	(1,032)	2,977	3,158	(2,305)	726	4,275	3,626	5,874	10,165	22,894	27,241	30,956	33,995

Project IRR	14.4%	%
Project NPV	43.4	INR cr. x 1.000
Project Payback Time	14	years
Project Discounted Payback Time	19	years



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Results JNPT (Port Authority)

Amounts in INR cr.

	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2040	2045	2050	2055
Revenues	-	-	-	-	1,277	1,810	2,395	2,647	3,069	3,536	4,300	5,164	5,899	6,368	11,674	13,957	16,072	18,108
VGF	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Devex	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Opex	-	-	-	-	552	574	597	621	646	672	699	727	1,003	1,043	1,269	1,544	1,879	2,286
Concession fee	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tax	-	-	-	-	-	103	272	340	460	561	738	968	1,105	1,234	2,758	3,360	3,894	4,587
Capex	3,009	7,311	10,096	6,311	-	-	-	-	3,110	4,352	2,089	98	-	-	-	-	-	-
Unlevered FCF	(3,009)	(7,311)	(10,096)	(6,311)	724	1,132	1,526	1,685	(1,147)	(2,049)	774	3,371	3,791	4,091	7,647	9,053	10,299	11,235

Project IRR	10.6%	%
Project NPV	6.7	INR cr. x 1.000
Project Payback Time	16	years
Project Discounted Payback Time	25	years

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Results JNPT (Port Authority)

Revenues and opex specified

Amounts in INR cr.

	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2040	2045	2050	2055
Port Dues	-	-	-	-	83	107	129	109	119	101	107	114	120	121	170	182	218	244
Pilotage	-	-	-	-	202	283	360	392	446	461	544	645	720	749	1,379	1,603	1,832	2,070
Concession Fee	-	-	-	-	982	1,415	1,900	2,139	2,497	2,968	3,642	4,398	5,052	5,491	10,115	12,162	14,010	15,781
Concession Lease	-	-	-	-	0	0	0	0	0	0	1	1	1	1	1	1	1	1
Miscellaneous	-	-	-	-	9	6	6	6	6	6	7	7	7	7	8	9	10	12
Revenues	-	-	-	-	1,277	1,810	2,395	2,647	3,069	3,536	4,300	5,164	5,899	6,368	11,674	13,957	16,072	18,108

Specifications of Capex and Opex of all business units is included section 14.2 and 14.3 of the DPR Report

Results Container Terminal 1

	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2040	2045	2050	2055
Revenues	-	-	-	-	951	1,575	2,278	1,483	1,668	1,889	2,047	2,168	2,250	2,197	3,121	3,695	4,181	4,730
VGF	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Devex	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Opex	-	-	-	-	204	212	221	230	239	248	258	268	279	290	353	430	523	636
Concession fee	-	-	-	-	285	473	683	445	500	567	614	650	675	659	936	1,109	1,254	1,419
Tax	-	-	-	-	107	236	381	211	247	291	321	343	358	343	518	616	690	796
Capex	-	599	1,869	648	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Unlevered FCF	-	(599)	(1,869)	(648)	354	655	993	597	681	783	854	905	938	905	1,313	1,541	1,714	1,879

Project IRR	20.5%	%
Project NPV	4.6	INR cr. x 1.000
Project Payback Time	7	years
Project Discounted Payback Time	9	years

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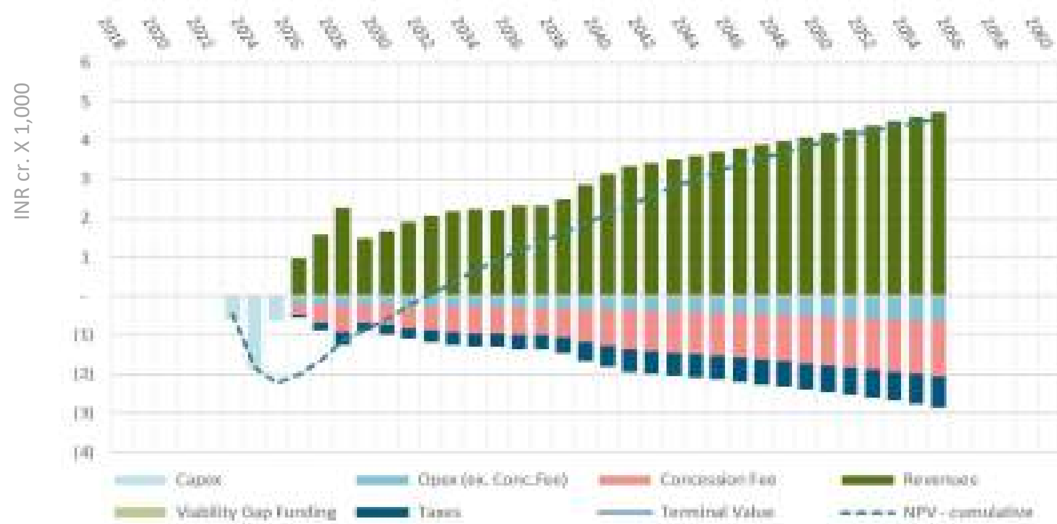
Results Container Terminal 2

Amounts in INR cr.

	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2040	2045	2050	2055
Revenues	-	-	-	-	951	1,575	2,278	1,483	1,668	1,889	2,047	2,168	2,250	2,197	3,121	3,695	4,181	4,730
VGF	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Devex	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Opex	-	-	-	-	204	212	221	230	239	248	258	268	279	290	353	430	523	636
Concession fee	-	-	-	-	285	473	683	445	500	567	614	650	675	659	936	1,109	1,254	1,419
Tax	-	-	-	-	107	236	381	211	247	291	321	343	358	343	518	616	690	796
Capex	-	600	1,872	649	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Unlevered FCF	-	(600)	(1,872)	(649)	354	655	993	597	681	783	854	905	938	905	1,313	1,541	1,714	1,879

Project IRR	20.5%	%
Project NPV	4.6	INR cr. x 1.000
Project Payback Time	7	years
Project Discounted Payback Time	9	years



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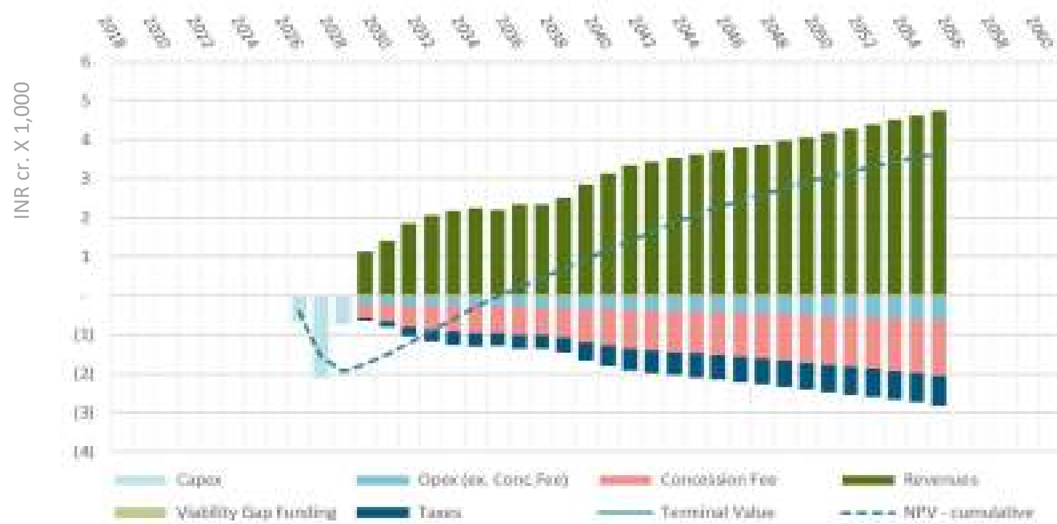
Results Container Terminal 3

Amounts in INR cr.

	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2040	2045	2050	2055
Revenues	-	-	-	-	-	-	-	1,112	1,422	1,848	2,047	2,168	2,250	2,197	3,121	3,695	4,181	4,730
VGF	-	-	-	-	-	-	-	-	-	-	-	-	-		-	-	-	-
Devex	-	-	-	-	-	-	-											
Opex	-	-	-	-	-	-	-	230	239	248	258	268	279	290	353	430	523	636
Concession fee	-	-	-	-	-	-	-	334	427	554	614	650	675	659	936	1,109	1,254	1,419
Tax	-	-	-	-	-	-	-	130	192	279	317	340	354	339	514	612	686	767
Capex	-	-	-	-	674	2,102	729	-	-	-	-	-	-		-	-	-	-
Unlevered FCF	-	-	-	-	(674)	(2,102)	(729)	419	565	767	857	909	942	908	1,317	1,545	1,717	1,907

Project IRR	20.0%	%
Project NPV	3.6	INR cr. x 1.000
Project Payback Time	7	years
Project Discounted Payback Time	10	years



Results Container Terminal 4

Amounts in INR cr.

	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2040	2045	2050	2055
Revenues	-	-	-	-	-	-	-	1,112	1,422	1,848	2,047	2,168	2,250	2,197	3,121	3,695	4,181	4,730
VGF	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Devex	-	-	-	-	-	-	-											
Opex	-	-	-	-	-	-	-	230	239	248	258	268	279	290	353	430	523	636
Concession fee	-	-	-	-	-	-	-	334	427	554	614	650	675	659	936	1,109	1,254	1,419
Tax	-	-	-	-	-	-	-	130	192	278	317	339	354	339	514	612	686	767
Capex	-	-	-	-	676	2,111	732	-	-	-	-	-	-	-	-	-	-	-
Unlevered FCF	-	-	-	-	(676)	(2,111)	(732)	420	565	767	858	909	942	909	1,317	1,545	1,718	1,908

Project IRR	20.0%	%
Project NPV	3.6	INR cr. x 1.000
Project Payback Time	8	years
Project Discounted Payback Time	10	years

Royal HaskoningDHV

Results Container Terminal 5

Amounts in INR cr.

	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2040	2045	2050	2055
Revenues	-	-	-	-	-	-	-	-	-	-	622	1,481	2,250	2,197	3,121	3,695	4,181	4,730
VGF	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Devex	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Opex	-	-	-	-	-	-	-	-	-	-	258	268	279	290	353	430	523	636
Concession fee	-	-	-	-	-	-	-	-	-	-	187	444	675	659	936	1,109	1,254	1,419
Tax	-	-	-	-	-	-	-	-	-	-	14	191	349	335	510	607	681	763
Capex	-	-	-	-	-	-	-	762	2,378	824	-	-	-	-	-	-	-	-
Unlevered FCF	-	-	-	-	-	-	-	(762)	(2,378)	(824)	164	577	947	913	1,321	1,549	1,722	1,912

Project IRR	19.1%	%
Project NPV	2.8	INR cr. x 1.000
Project Payback Time	8	years
Project Discounted Payback Time	10	years

Results Container Terminal 6

Amounts in INR cr.

	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2040	2045	2050	2055
Revenues	-	-	-	-	-	-	-	-	-	-	622	1,481	2,250	2,197	3,121	3,695	4,181	4,730
VGF	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Devex	-	-	-	-	-	-	-	-	-	-	-	-	-					
Opex	-	-	-	-	-	-	-	-	-	-	258	268	279	290	353	430	523	636
Concession fee	-	-	-	-	-	-	-	-	-	-	187	444	675	659	936	1,109	1,254	1,419
Tax	-	-	-	-	-	-	-	-	-	-	14	191	349	335	510	607	681	763
Capex	-	-	-	-	-	-	-	762	2,379	825	-	-	-	-	-	-	-	-
Unlevered FCF	-	-	-	-	-	-	-	(762)	(2,379)	(825)	164	577	947	913	1,322	1,549	1,722	1,912

Project IRR	19.1%	%
Project NPV	2.8	INR cr. x 1.000
Project Payback Time	8	years
Project Discounted Payback Time	10	years

Royal HaskoningDHV

Results Container Terminal 7

Amounts in INR cr.

	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2040	2045	2050	2055
Revenues	-	-	-	-	-	-	-	-	-	-	-	-	-	754	3,121	3,695	4,181	4,730
VGF	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Devex	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Opex	-	-	-	-	-	-	-	-	-	-	-	-	-	290	353	430	523	636
Concession fee	-	-	-	-	-	-	-	-	-	-	-	-	-	226	936	1,109	1,254	1,419
Tax	-	-	-	-	-	-	-	-	-	-	-	-	-	27	505	603	677	758
Capex	-	-	-	-	-	-	-	-	-	-	851	2,656	921	-	-	-	-	-
Unlevered FCF	-	-	-	-	-	-	-	-	-	-	(851)	(2,656)	(921)	210	1,326	1,554	1,727	1,917

Project IRR	18.9%	%
Project NPV	2.1	INR cr. x 1.000
Project Payback Time	8	years
Project Discounted Payback Time	10	years

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Results Container Terminal 8

Amounts in INR cr.

	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2040	2045	2050	2055
Revenues	-	-	-	-	-	-	-	-	-	-	-	-	-	754	3,121	3,695	4,181	4,730
VGF	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Devex	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Opex	-	-	-	-	-	-	-	-	-	-	-	-	-	290	353	430	523	636
Concession fee	-	-	-	-	-	-	-	-	-	-	-	-	-	226	936	1,109	1,254	1,419
Tax	-	-	-	-	-	-	-	-	-	-	-	-	-	26	505	602	676	758
Capex	-	-	-	-	-	-	-	-	-	-	859	2,680	929	-	-	-	-	-
Unlevered FCF	-	-	-	-	-	-	-	-	-	-	(859)	(2,680)	(929)	211	1,327	1,554	1,727	1,917

Project IRR	18.8%	%
Project NPV	2.1	INR cr. x 1.000
Project Payback Time	8	years
Project Discounted Payback Time	10	years

Royal HaskoningDHV

Results Container Terminal 9

Amounts in INR cr.

	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2040	2045	2050	2055
Revenues	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3,121	3,695	4,181	4,730
VGF	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Devex	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Opex	-	-	-	-	-	-	-	-	-	-	-	-	-	-	353	430	523	636
Concession fee	-	-	-	-	-	-	-	-	-	-	-	-	-	-	936	1,109	1,254	1,419
Tax	-	-	-	-	-	-	-	-	-	-	-	-	-	-	503	600	674	756
Capex	-	-	-	-	-	-	-	-	-	-	-	896	2,797	970	-	-	-	-
Unlevered FCF	-	-	-	-	-	-	-	-	-	-	-	(896)	(2,797)	(970)	1,328	1,556	1,729	1,919

Project IRR	18.1%	%
Project NPV	1.8	INR cr. x 1.000
Project Payback Time	8	years
Project Discounted Payback Time	10	years

Royal HaskoningDHV

Results Multi Purpose Terminal

Amounts in INR cr.

	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2040	2045	2050	2055
Revenues	-	-	-	-	806	878	957	1,045	1,142	1,256	1,356	1,466	1,586	1,717	2,334	3,200	4,290	4,644
VGF	-	-	-	-	-	-	-	-	-	-	-	-	-		-	-	-	-
Devex	-	-	-	-	-	-	-	-	-	-	-	-	-		-	-	-	-
Opex	-	-	-	-	49	51	54	56	58	60	63	65	68	70	114	139	169	206
Concession fee	-	-	-	-	242	263	287	313	343	377	407	440	476	515	700	960	1,287	1,393
Tax	-	-	-	-	144	159	175	192	212	235	256	278	302	329	442	617	837	903
Capex	-	-	299	726	-	-	-	-	-	-	-	-	-		-	-	-	-
Unlevered FCF	-	-	(299)	(726)	371	404	442	483	529	583	631	683	740	802	1,077	1,484	1,997	2,142

Project IRR	41.0%	%
Project NPV	5.0	INR cr. x 1.000
Project Payback Time	4	years
Project Discounted Payback Time	5	years

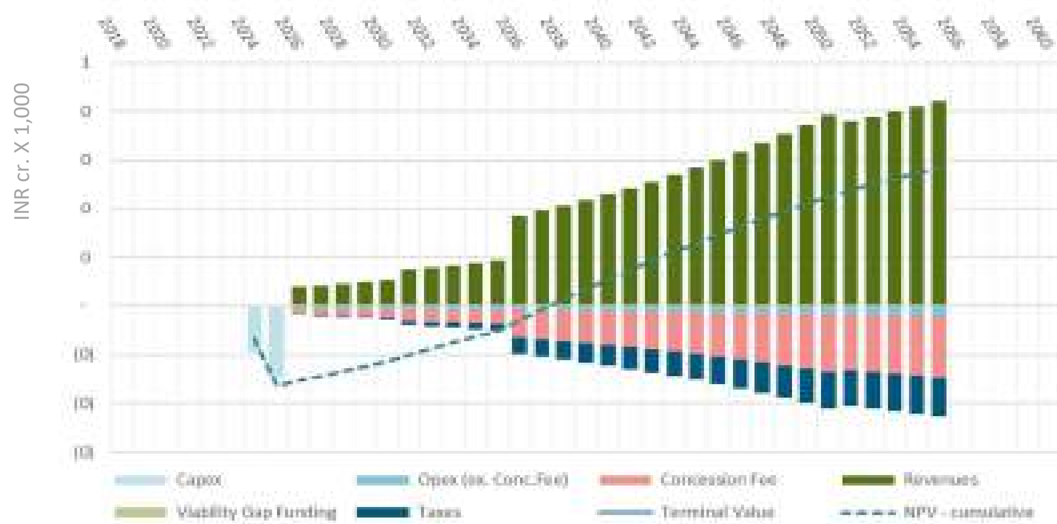
Royal HaskoningDHV

Results RoRo Terminal

Amounts in INR cr.

	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2040	2045	2050	2055
Revenues	-	-	-	-	40	43	46	49	53	74	78	83	87	92	230	300	394	420
VGF	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Devex	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Opex	-	-	-	-	7	7	7	8	8	8	9	9	9	10	12	14	17	21
Concession fee	-	-	-	-	12	13	14	15	16	22	24	25	26	28	69	90	118	126
Tax	-	-	-	-	4	4	5	6	6	11	11	12	13	14	42	56	75	80
Capex	-	-	95	147	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Unlevered FCF	-	-	(95)	(147)	17	18	20	21	23	33	35	37	39	41	107	139	183	193

Project IRR	16.7%	%
Project NPV	0.3	INR cr. x 1.000
Project Payback Time	10	years
Project Discounted Payback Time	14	years

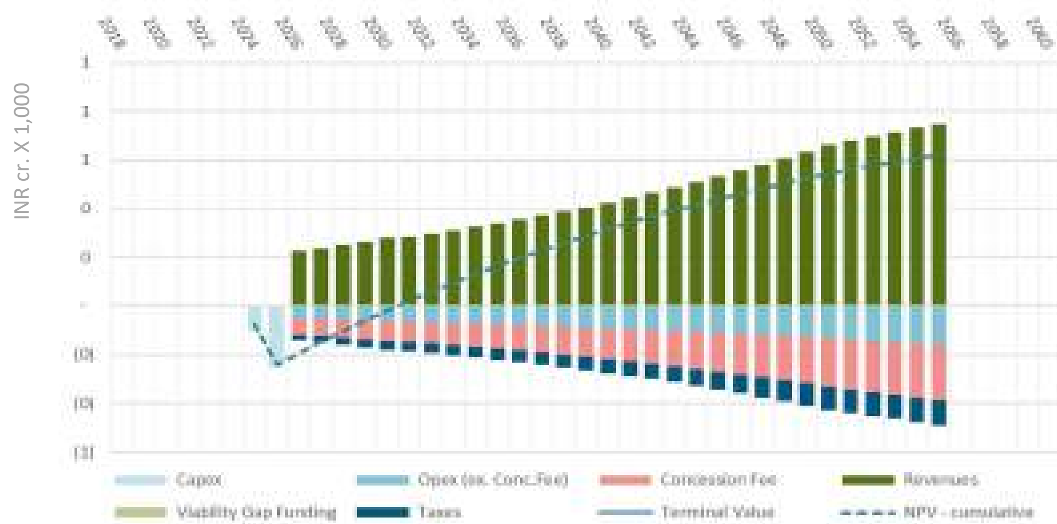


Results Liquids Terminal

Amounts in INR cr.

	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2040	2045	2050	2055
Revenues	-	-	-	-	225	238	251	264	280	284	298	311	325	340	425	531	663	750
VGF	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Devex	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Opex	-	-	-	-	52	54	57	59	61	64	66	69	71	74	90	110	134	163
Concession fee	-	-	-	-	67	72	75	79	84	85	89	93	98	102	128	159	199	225
Tax	-	-	-	-	28	30	32	34	37	37	39	41	43	46	59	75	95	106
Capex	-	-	104	252	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Unlevered FCF	-	-	(104)	(252)	77	82	87	92	98	98	103	108	113	118	148	187	235	256

Project IRR	25.2 %	%
Project NPV	0.6	INR cr. x 1.000
Project Payback Time	6	years
Project Discounted Payback Time	7	years



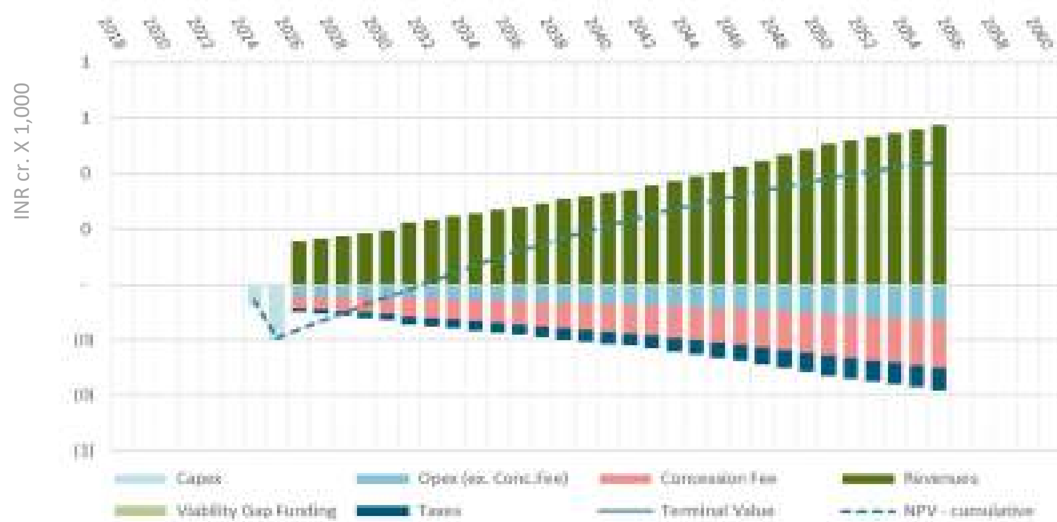
Royal HaskoningDHV

Results LPG Terminal

Amounts in INR cr.

	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2040	2045	2050	2055
Revenues	-	-	-	-	156	164	174	183	193	223	233	243	255	266	333	406	507	574
VGF	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Devex	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Opex	-	-	-	-	42	43	45	47	49	51	53	55	57	59	72	88	107	130
Concession fee	-	-	-	-	47	49	52	55	58	67	70	73	76	80	100	122	152	172
Tax	-	-	-	-	17	19	20	22	23	29	30	32	34	35	45	56	72	80
Capex	-	-	83	202	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Unlevered FCF	-	-	(83)	(202)	50	53	56	60	64	77	80	84	88	92	115	140	177	192

Project IRR	22.7%	%
Project NPV	0.4	INR cr. x 1.000
Project Payback Time	7	years
Project Discounted Payback Time	8	years



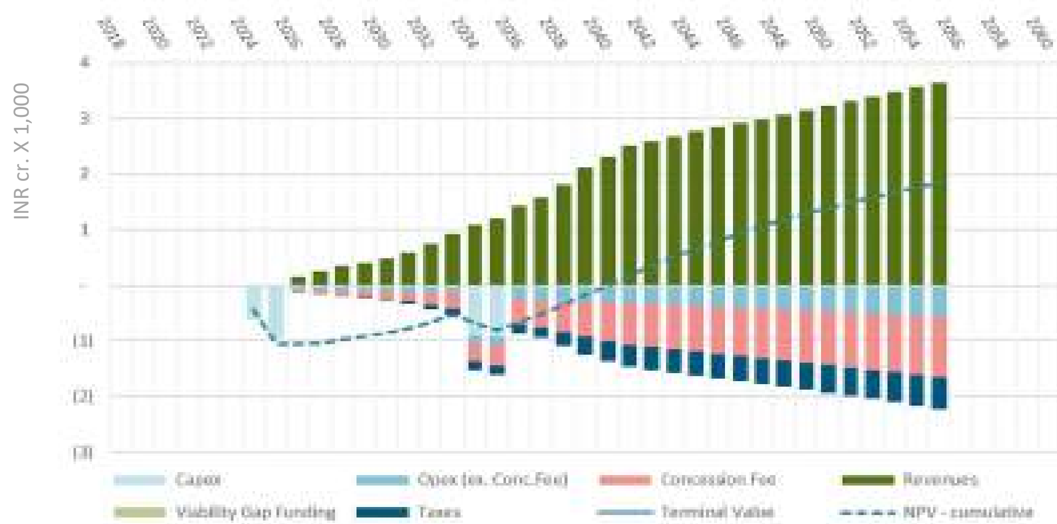
Royal HaskoningDHV

Results Rail Yard Terminal

Amounts in INR cr.

	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2040	2045	2050	2055
Revenues	-	-	-	-	145	241	349	398	474	581	742	925	1,086	1,195	2,308	2,846	3,219	3,642
VGF	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Devex	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Opex	-	-	-	-	106	110	114	119	124	129	134	139	145	150	317	385	469	571
Concession fee	-	-	-	-	44	72	105	119	142	174	223	277	326	359	693	854	966	1,093
Tax	-	-	-	-	-	2	23	32	47	68	100	137	169	181	356	448	501	566
Capex	-	-	614	957	-	-	-	-	-	-	-	-	899	935	-	-	-	-
Unlevered FCF	-	-	(662)	(1,033)	(4)	58	108	129	163	212	287	373	(451)	(428)	945	1,160	1,285	1,414

Project IRR	15.5%	%
Project NPV	1.8	INR cr. x 1.000
Project Payback Time	13	years
Project Discounted Payback Time	17	years



Royal HaskoningDHV

Results Rail DFC

Amounts in INR cr.

	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2040	2045	2050	2055
Revenues	-	-	-	-	28	46	67	76	91	111	142	177	208	229	442	545	616	697
VGF	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Devex	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Opex	-	-	-	-	3	5	8	9	11	13	17	22	26	29	60	79	97	118
Concession fee	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tax	-	-	-	-	-	-	4	6	10	16	24	33	41	46	101	126	142	172
Capex	399	553	288	150	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Unlevered FCF	(399)	(553)	(288)	(150)	25	41	55	61	70	82	101	123	141	154	281	340	378	407

Project IRR	8.9%	%
Project NPV	0.0	INR cr. x 1.000
Project Payback Time	16	years
Project Discounted Payback Time	N/A	years

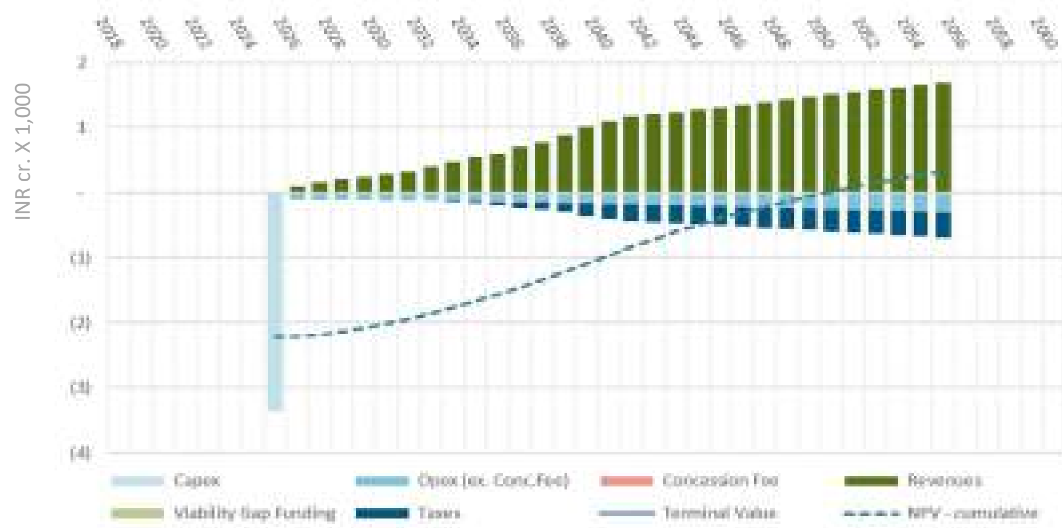
Royal HaskoningDHV

Results Toll Road

Amounts in INR cr.

	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2040	2045	2050	2055
Revenues	-	-	-	-	101	150	205	232	273	324	398	481	552	598	1,107	1,307	1,510	1,697
VGF	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Devex	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Opex	-	-	-	-	99	103	107	111	115	120	125	130	135	140	171	208	253	307
Concession fee	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tax	-	-	-	-	-	-	-	3	14	28	48	72	92	104	247	296	344	383
Capex	-	-	-	3,360	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Unlevered FCF	-	-	-	(3,360)	2	47	98	118	144	176	225	280	326	354	689	803	914	1,007

Project IRR	9.7%	%
Project NPV	0.3	INR cr. x 1.000
Project Payback Time	14	years
Project Discounted Payback Time	25	years



Royal HaskoningDHV

Sensitivity analysis

Financial Analysis

Royal HaskoningDHV
Enhancing Society Together

Sensitivity results

Internal Rate of Return

Business Unit	IRR	Capex +20% IRR	Opex +20% IRR	Volumes -10% IRR	Volumes +10% IRR	Capex +20% Volumes -10% IRR
JNPT (Port Authority)	11%	9%	10%	10%	11%	9%
Container Terminal 1	21%	18%	20%	19%	22%	17%
Container Terminal 2	21%	18%	20%	19%	22%	17%
Container Terminal 3	20%	18%	19%	19%	21%	17%
Container Terminal 4	20%	18%	19%	19%	21%	16%
Container Terminal 5	19%	17%	18%	18%	20%	16%
Container Terminal 6	19%	17%	18%	18%	20%	16%
Container Terminal 7	19%	17%	18%	18%	20%	16%
Container Terminal 8	19%	17%	18%	18%	20%	16%
Container Terminal 9	18%	16%	17%	17%	19%	15%
Multipurpose Terminal	41%	36%	41%	38%	44%	33%
Ro-Ro Terminal	17%	15%	16%	16%	18%	14%
Liquids Terminal	25%	22%	23%	22%	28%	19%
LPG Terminal	23%	20%	21%	20%	25%	18%
LNG Terminal	N/A	N/A	N/A	N/A	N/A	N/A
Rail Yard Terminal	15%	14%	15%	15%	16%	13%
Rail DFC	9%	8%	9%	9%	9%	8%
Toll Road	10%	8%	9%	9%	10%	8%

Sensitivity results

Port Authority results with increased capex (+20%) and low volumes (-10%)

Amounts in INR cr.

	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2040	2045	2050	2055
Revenues	-	-	-	-	1,150	1,630	2,156	2,383	2,763	3,182	3,871	4,647	5,310	5,732	10,507	13,798	15,866	17,882
VGF	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Devex	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Opex	-	-	-	-	552	574	597	621	646	672	699	727	1,003	1,043	1,269	1,544	1,879	2,286
Tax	-	-	-	-	-	-	147	208	314	395	541	741	856	970	2,335	3,240	3,760	4,487
Capex	3,611	8,774	12,115	7,573	-	-	-	-	3,732	5,223	2,507	117	-	-	-	-	-	-
Unlevered FCF	(3,611)	(8,774)	(12,115)	(7,573)	597	1,055	1,412	1,554	(1,930)	(3,107)	123	3,063	3,451	3,719	6,903	9,015	10,227	11,109

Project IRR	8.8%	%
Project NPV	0.4	INR cr. x 1.000
Project Payback Time	18	years
Project Discounted Payback Time	N/A	years

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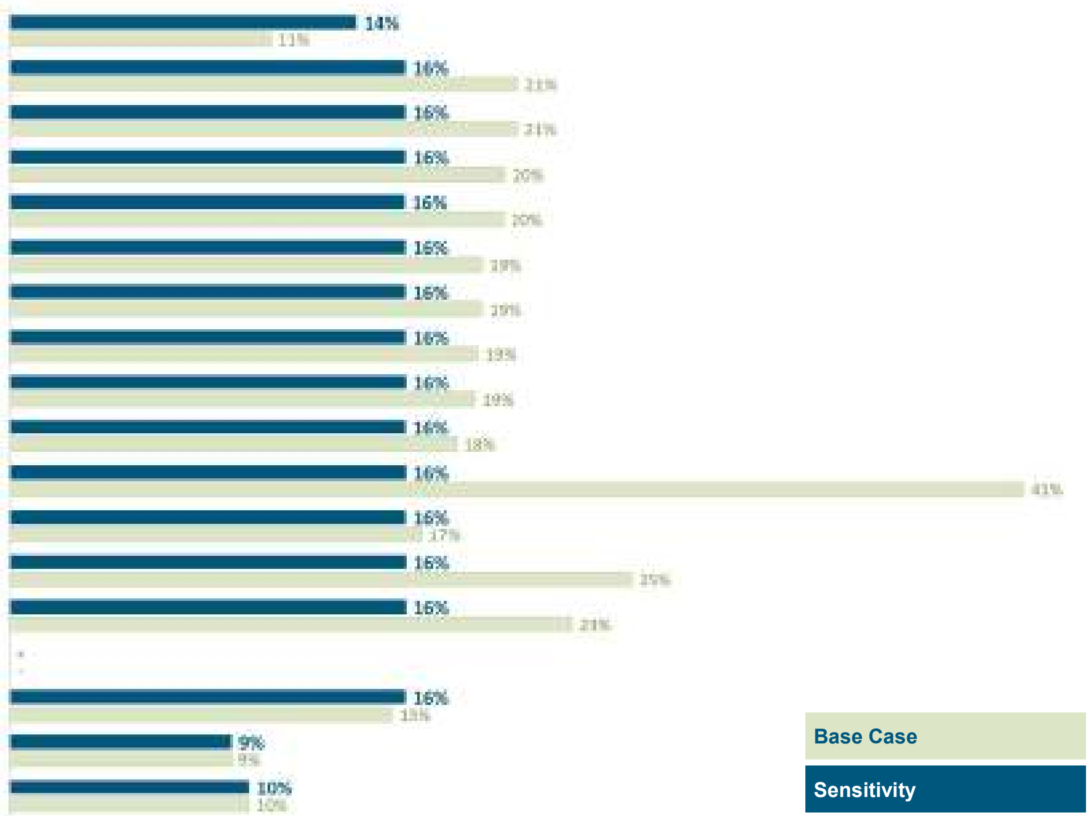
Sensitivity results

Increasing concession fees to match hurdle rates

Business Unit	IRR	Concession fee	IRR
JNPT (Port Authority)	11%	N/A	14%
Container Terminal 1	21%	30% → 48%	16%
Container Terminal 2	21%	30% → 48%	16%
Container Terminal 3	20%	30% → 46%	16%
Container Terminal 4	20%	30% → 46%	16%
Container Terminal 5	19%	30% → 43%	16%
Container Terminal 6	19%	30% → 43%	16%
Container Terminal 7	19%	30% → 42%	16%
Container Terminal 8	19%	30% → 41%	16%
Container Terminal 9	18%	30% → 39%	16%
Multipurpose Terminal	41%	30% → 78%	16%
Ro-Ro Terminal	17%	30% → 34%	16%
Liquids Terminal	25%	30% → 52%	16%
LPG Terminal	23%	30% → 48%	16%
LNG Terminal	N/A	N/A	N/A
Rail Yard Terminal	15%	30% → 27%	16%
Rail DFC	9%	N/A	9%
Toll Road	10%	N/A	10%



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15 Project Benefits

Vadhavan Port

Financial & Economic Analysis Results

December 2022

Confidential

CONTENT

INDIA'S NO.1 CONTAINER PORT

Economic Analysis

Set-up

Economic Analysis

Economic analysis set-up

Assessment of economic feasibility of the port project and its contribution to the welfare of India

- Starting point for the economic analysis is the financial analysis in which:
  - the analysis assumes a landlord port model, in which JNPT acts as port authority and concessions out port operations to private sector operators.
  - JNPT provides the private operators the basic port infrastructure and the (reclaimed) land to develop terminals for port activities.
- For the economic analysis the port is considered as one integrated project
- Financial costs are converted to economic costs
- Economic benefits were determined by looking at logistic cost reductions and volumes driving changes in consumer surplus and producer surplus.

Economic analysis set-up

Benefits are related to cost savings generated through the availability of the new port facilities.

- The CBA includes the following costs and benefits:

Costs		***Key driver***
Capital expenditures (additional)	Capex	*Construction costs*
Operational expenditures (additional)	Opex	*Operational costs*
Benefits		***Key driver***
Vessel operating costs savings – Sea transport	VOC Sea	*Decrease in vessel kilometres*
Freight travel time savings – Sea transport	FTT Sea	*Decrease in travel time*
Transhipment savings	Tranship	*Increase in direct calls (less transhipment)*
Vessel operating costs savings – Rail transport	VOC Rail	*Decrease in cargo kilometres*
Environmental cost savings – Rail transport	Env. Rail	*Decrease in cargo kilometres*
Freight travel time savings – Rail transport	FTT Rail	*Decrease in travel time*
Vehicle operating costs – Road transport	VOC Road	*Decrease in cargo kilometres*
Environmental cost savings – Road transport	Env. Road	*Decrease in cargo kilometres*
Freight travel time savings – Road transport	FTT Road	*Decrease in travel time*
Accident cost savings – Road transport	Acc. Road	*Decrease in cargo kilometres*
Additional operations income	Add. Inc.	*Generated (container) traffic*

Assumptions

Economic Analysis

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Economic analysis assumptions

Theoretical approach and formulas

- The economic net present value (ENPV) of the port investment can be expressed as:

$$ENPV = \sum_{t=1}^{T} \left(-I_t + (\Delta CS_t + \Delta PS_t) \right) \cdot (1+i)^{-t}$$

$$\Delta CS_t = (gc_{t,wo} - gc_{t,w}) \cdot q_{t,wo} + \frac{1}{2} \cdot (gc_{t,wo} - gc_{t,w}) \cdot (q_{t,w} - q_{t,wo})$$

$$gc_{t,wo} = p_{t,wo} + \tau_{t,wo}$$

$$gc_{t,w} = p_{t,w} + \tau_{t,w}$$

$$\Delta PS_t = p_{t,w} \cdot q_{t,w} - p_{t,wo} \cdot q_{t,wo} + C_{t,wo}(q_{t,wo}) - C_{t,w}(q_{t,w})$$

T : *project life (planning horizon) in years*
t : *year*

I_t : *economic costs of investment in year t*
ΔCS_t : *change in consumer surplus in year t*
ΔPS_t : *change in producer surplus in year t*
i : *economic discount rate*

$gc_{t,wo}$: *generalised costs in year t without project*
$gc_{t,w}$: *generalised costs in year t with project*
$q_{t,wo}$: *quantity in year t without project*
$q_{t,w}$: *quantity in year t with project*
$p_{t,wo}$: *price per trip (incl. port charges) in year t without project*
$p_{t,w}$: *price per trip (incl. port charges) in year t with project*
$p_{t,wo}$: *price per trip (incl. port charges) in year t without project*
$p_{t,w}$: *price per trip (incl. port charges) in year t with project*

$C_{t,wo}(q_{t,wo})$: *total variable costs without project*
$C_{t,w}(q_{t,w})$: *total variable costs with project*

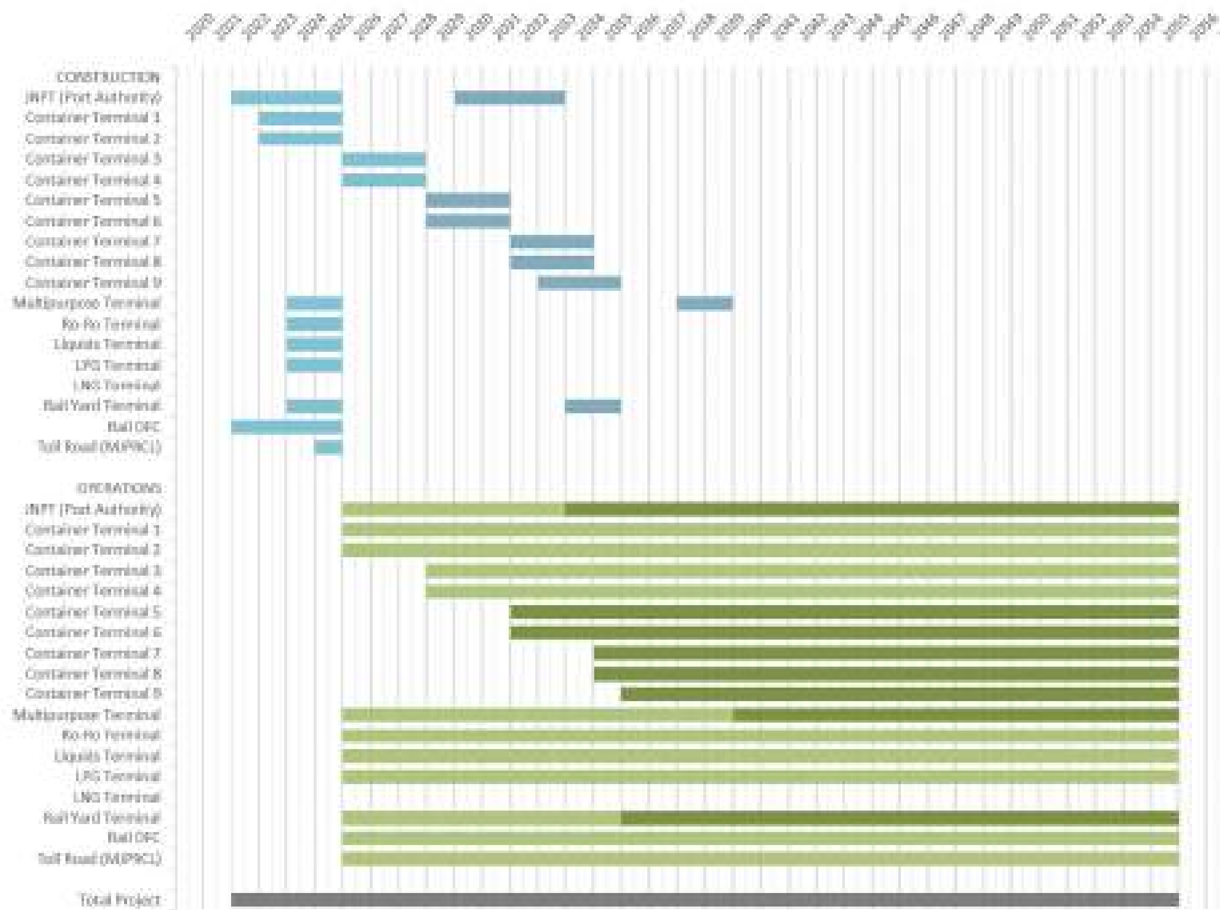
Economic analysis assumptions

Economic cashflows follow a phased port development and are included in real prices and local currency

- A phased development approach is assumed, with two distinctive phases (phase 1 and 2)
- The CBA planning horizon is set to 2055. In practice the project will continue to operate after that.
- No residual value is included in the CBA. This is a conservative assumption, as economic value at the end of the set horizon is positive.
- General CBA assumptions:

Assumption	Value	Unit
CBA price level	2021	year
India long term inflation (*)	4.00 %	% p.a.
Exchange Rate USD	75.17	INR / USD

(*) Assumption is in line with financial analysis. The indexes applied for price level corrections are based on CPI data from Oxford Economics



Economic analysis assumptions

Volumes at Vadhavan are assumed to be partly avoided diversion and partly generated

Avoided diversion and generated

- Volumes going through Vadhavan in the ‘with-project’ case are assumed to be split in two categories; avoided diversion and generated volumes.
- **Avoided diversion volumes** account for the traffic that in the ‘without-project’ case would be facilitated by other ports in the region. Based on estimates of available capacity this is assumed to be 47% of total traffic to be handled by Vadhavan in the ‘with-project’ case.
- **Generated volumes** account for the traffic that is assumed not to be facilitated in the ‘without-project’ case. This is a theoretical assumption to value the economic benefits, as in practice these volumes would likely be facilitated by different not yet planned new port investments in case Vadhavan would not be realised. Generated volumes are assumed to be 53% (100% - 47%) of total traffic to be handled by Vadhavan in the ‘with-project’ case.

‘Rule-of-half’

- In monetising the benefits in the CBA, the ‘rule-of-half’ is applied to all benefits related to generated volumes. This rule is commonly applied in CBA; it states that the average change in consumer surplus of generated traffic can be estimated as half of the difference in the generalised costs of transport with and without the project.

Import & Export

- As a conservative assumption the CBA assumes that the benefits based on an increase in consumer surplus are only accounted for imported volumes. It assumes that benefits from cost reductions in the transportation of exported volumes will fall with consumers outside of India.

Volumes	Percentage
Import	53%
Export	47%

Economic analysis assumptions

Capital and operational costs in the CBA are excluding of taxes and in real amounts

General

- Cost cash flows in the financial analysis are in nominal amounts. These were adjusted to exclude any projections of inflation or indexation.

Conversion

- To convert financial costs to economic costs the CBA applied conversion factors, based on national standards conversion factors
- Applied conversion factors are included on the next page

Taxes

- The cash flows in the CBA are excluding any taxes
- The financial analysis was already performed based on cash flows excluding GST. No correction was needed.

Economic analysis assumptions

Capital and operational expenditures from the financial analysis are corrected for inclusion in the CBA

Capex

- Land reclamation
  - The capex from the financial analysis was corrected for costs for land reclamation under the assumption that the economic costs of reclaiming the land will be offset by the net economic value created by the newly available land.
  - The economic value of new port area created, netted from the economic costs of loosing seabed area, based on construction costs is considered a conservative assumption as actual economic value is deemed to be higher (but hard to value).
- Contingencies
  - Physical Contingencies are included in both the financial and economic analysis.
  - Price Contingencies are excluded from the economic analyses and only considered in the financial analysis.

Opex

- Fixed and variable operational costs
  - The CBA only accounts for the additional operational expenditures of the 'with-project' case; the extra costs that come with the implementation of Vadhavan project.
  - The opex from the financial analysis was corrected for costs that are assumed to be variable operational costs linked to diverted traffic.
- Fuel costs
  - The part of the operational expenditures that relates to fuel costs was converted using a specific conversion factor to express financial costs into economic costs.

Economic analysis assumptions

Financial costs are converted into economic costs based on conversion factors

- To convert financial costs to economic costs the CBA applied conversion factors, based on international standards for cost-benefit analysis.
- The conversion factor ensures the prices used in the CBA reflect the values of goods, services, and other project effects on the national economy.
- General costs conversion factors used, based on previous research.

Conversion	Factor
Conversion Factor - Devex	0.88
Conversion Factor - Capex	0.88
Conversion Factor - Opex	0.88

- This value is in line with a study by the ADB*. A high-level calculation based on more recent macro-economic indicates the current conversion factor may be higher (up to 0.98). A sensitivity scenario is included to assess the impact of a higher conversion factor.

* *Shadow Exchange Rates for Project Economic Analysis: Toward Improving Practice at the Asian Development Bank*, Anneli Lagman-Martin, ADB Economics and Research Department, ERD Technical Note Series, No.11, Febnruary 2004.

- Fuel costs conversion factor

	Particulars	Unit	Value
a	FOB price @ Arab Gulf	USD / bbl	82.20
b	Trade premium	USD / bbl	2.36
c	Derived quality premium	USD / bbl	0.20
d	Ocean freight from Arab Gulf to Indian ports	USD / bbl	2.10
e	Cost and Freight (C&F) price (a + b + c + d)	USD / bbl	86.86
f	Litres/barrel	Litres / bbl	158.91
g	INR per USD	INR / USD	75.07
h	Economic price (e / f * g)	INR / litre	41.03

m	Market price in Cost Estimates	INR / litre	95.00
n	Conversion factor (l / m)	Factor	0.43

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Economic analysis assumptions

Freight Travel Time cost savings are relevant for sea transportation and inland transportation by road and rail

Value of Freight Travel Time

- The CBA accounts for benefits relating to the total time needed for freight arriving at its destination. This related to travel time at sea, travel time for inland transportation and travel time due to transhipment.
- The benefits of freight travel time cost savings are assumed based on the average value of containerized cargo and financing costs.
- For non-containerized volume the value of freight travel time is assumed to be zero. A conservative assumption, but the actual value is deemed to be low.

Component	Unit	Value
Value of consignment	INR	4,000,000
Interest rate	% p.a.	12.00%
Days per year	Days	365
Hours per day	Hours	24
Value of Freight Time (containerized traffic)	INR / TEU hour	55.00

Economic analysis assumptions

Volumes handled through the new Vadhavan port will result in less sea travel distances and travel time

Sea travel distance and time

- The realisation of Vadhavan port facilities will lead to a decrease in sea travel times and distances, due to the relative distances to alternative ports in the region.
- The benefits of less travel distance and travel time are accounted for using estimations for vessel operating costs and value of freight time.
- For sea transport the origin or destination of volumes for Vadhavan is assumed to be split in three major area's: (1) East bound Traffic, (2) West Bound Traffic and (3) Asian Traffic)

Origin (destination) sea volumes	% of volume
East bound	40%
West bound	40%
Asin trade	20%

Vessel Operating Costs

- The differences in vessel operating costs are estimated based on discounts offered by shipping line vessels comparing lowest quotes for FCL 20 Ft. between Indian and Foreign Ports (US$)

	Vessel operating costs savings in USD/TEU
East Bound	83.00
West Bound	55.00
Asian Trade	50.00

- Savings from less travel distance and less travel time of non-containerised volumes are excluded from the analysis resulting in a conservative approach to the benefits included in the CBA.

Economic analysis assumptions

Volumes handled through the new Vadhavan port will result in less inland travel distances and travel time

Inland travel distance and time

- The realisation of Vadhavan port facilities will lead to a decrease in inland travel times and distances, due to the relative distances from alternative ports in the region to Vadhavan hinterland locations.
- The benefits of less travel distance and travel time are accounted for using estimations for vessel operating costs for road and rail and value of freight time.

Vehicle Operating Costs (VOC)

- Vehicle operating cost savings for road transport are based on a breakdown of costs of transportation and assumed at 4.1 INR per ton kilometre.
- Vehicle operating cost savings for rail transport are based on a benchmark by Ministry of Shipping, Road Transport and Highways and assumed at 2.1 INR per ton kilometre.

Road VOC	Unit	2014	2021
Fuel Price	INR/litre	57	94
Milage	km/litre	4.0	4.0
Truck Load 20 footer	ton	18	18
Daily average truck runs	km	400	400
Fuel costs	INR	5,700	9,413
General R&M, Tyre, consumable replacement	INR	3,600	5,400
Truck Finance costs	INR	1,500	1,850
Driver/Crew	INR	1,000	1,500
Profit + Other costs	INR	5,000	9,300
Toll Charges	INR	1,000	1,500
Total costs	INR	17,800	28,963
Per Ton/km costs Road	INR/ton km	2.5	**4.1**

Rail VOC	Unit	2018	2021
Per Ton/km costs Rail	INR/ton km	1.8	**2.1**

Economic analysis assumptions

More direct calls at Vadhavan port decreases transshipment and generated traffic generates additional income

Transhipment

- Development of state of the art port facilities at Vadhavan port with a deep draft will increase direct ship calls. A percentage of containers that are presently using intermediary transhipment terminals will shift to direct calls.
- Only transhipment benefits for containers are included in the CBA. Transhipment reduction benefits related to non-containerised volumes are assumed to be zero.
- The CBA assumes 30% of container volumes, using vessels over 14,000 TEU, are transhipped in the 'without project' case. In the 'with project' case the transhipment is halved to 15%.
- An increase in direct calls and decline in transhipment will also result in both freight travel time savings as well as vessel operating cost saving. The latter is hard to quantify based on available information and excluded from the CBA.

Additional income

- The CBA assumes that a large percentage of total volumes that will be facilitated by Vadhavan in the 'with-project' case are generated volumes.
- These additional (generated) volumes result in additional income that can be included as benefits from an increase in producer surplus.

Economic analysis assumptions

Less travel kilometres for inland transportation leads to less accidents and environmental costs

Accidents

- Less travel kilometres for inland transportation by road will lead to less accidents.
- Benefits are based on benchmark figures by Ministry of Shipping, Road Transport and Highways for number of accidents per distance travelled and the economic costs of accidents.

Accidents Road per 100 million vkm	Number of accidents
Fatal accident	3
Serious accident	30
Major Accident	0 (no data)
Minor accident	0 (no data)

Economic costs	unit	2009	2021
Fatal accident	INR	864,350	1,823,779
Serious accident	INR	391,800	826,698
Major Accident	INR	172,650	364,292
Minor accident	INR	30,450	64,250

Environmental costs

- Less travel kilometres for inland transportation by both rail and road will lead to less strain on the environment.
- Benefits are based on benchmark figures by Ministry of Shipping, Road Transport and Highways expressed in INR per ton kilometre.

Environmental costs	unit	2008	2021
Rail	INR / ton km	0.015	0.035
Road	INR / ton km	0.202	0.467

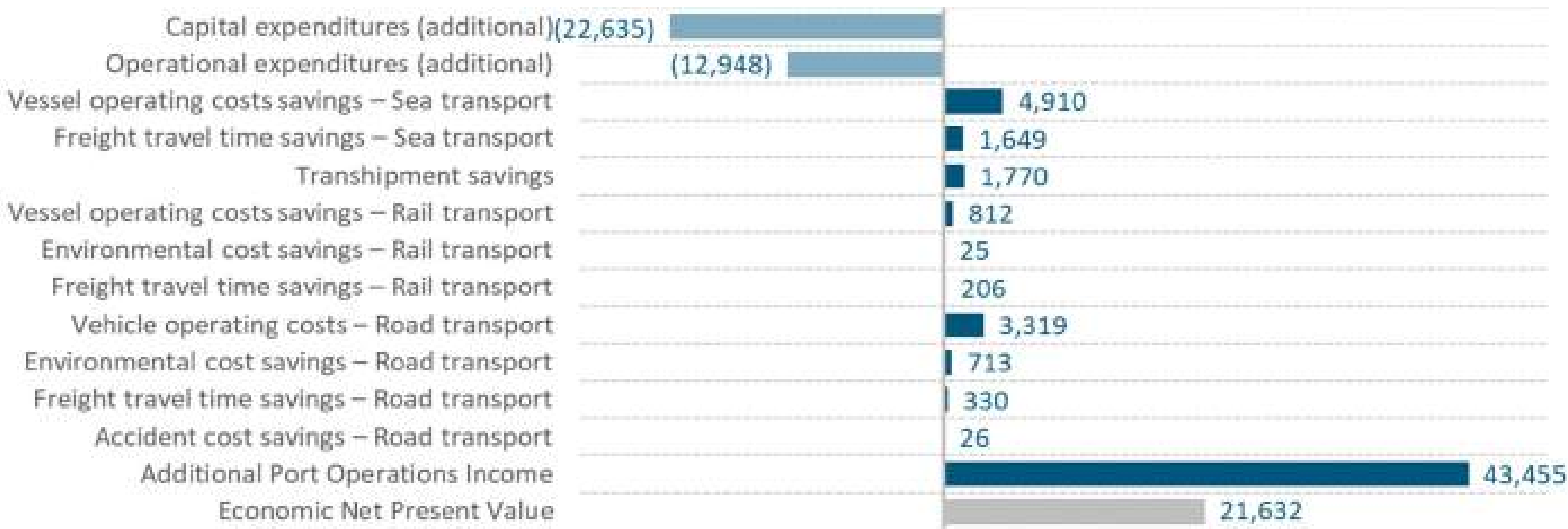
Results

Economic Analysis

Results CBA

The cost benefit analysis for Vadhavan port presents an economically feasible project

- The cost benefit analysis for Vadhavan shows a positive economic net present value of 21,632 INR crore
- The economic internal rate of return is 18.2 %, exceeding the minimum required rate of 12.0 %

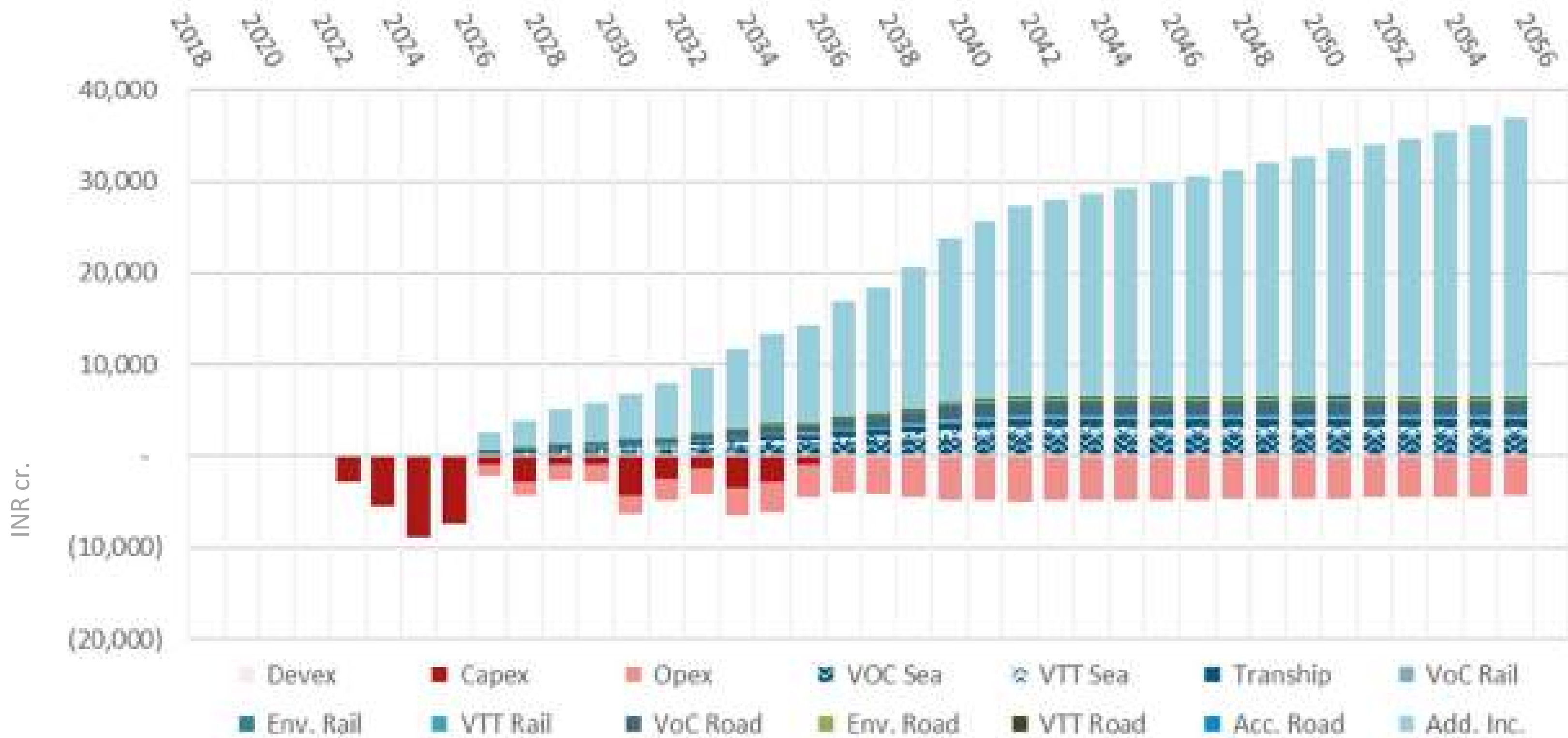


The present values of the costs and benefits in INR crore

Results CBA

The costs and benefits are phased in time corresponding with the construction and operations phasing assumed for the different terminals in the port

- Economic cash flows – real amounts in INR cr.



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Results CBA

Amounts real in INR cr.

	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2040	2045	2050	2055
Capex	(2,867)	(5,453)	(8,910)	(7,393)	(971)	(2,912)	(971)	(974)	(4,266)	(2,522)	(1,476)	(3,458)	(2,913)	(962)	-	-	-	-
Opex	-	-	-	-	(1,250)	(1,456)	(1,673)	(1,974)	(2,101)	(2,267)	(2,729)	(2,983)	(3,272)	(3,585)	(4,832)	(4,797)	(4,630)	(4,409)
VOC Sea	-	-	-	-	212	343	484	539	627	740	913	1,099	1,245	1,323	2,236	2,340	2,340	2,340
VTT Sea	-	-	-	-	71	115	163	181	211	249	307	369	418	444	751	786	786	786
Tranship	-	-	-	-	76	124	175	194	226	267	329	396	449	477	806	843	843	843
VOC Rail	-	-	-	-	36	56	78	86	100	119	147	178	203	218	369	402	402	402
Env. Rail	-	-	-	-	1	2	2	3	3	4	5	6	6	7	12	13	13	13
VTT Rail	-	-	-	-	9	14	20	23	26	31	38	46	52	56	94	98	98	98
VOC Road	-	-	-	-	171	257	350	388	447	521	630	747	839	887	1,464	1,516	1,535	1,529
Env. Road	-	-	-	-	37	55	75	83	96	112	135	160	180	190	314	326	330	328
VTT Road	-	-	-	-	14	23	33	36	42	50	61	74	84	89	150	157	157	157
Acc. Road	-	-	-	-	1	2	3	3	4	4	5	6	7	7	11	12	12	12
Port Income	-	-	-	-	1,959	2,812	3,762	4,211	4,907	5,774	7,069	8,524	9,777	10,603	19,517	23,418	26,971	30,382
Economic CF	(2,867)	(5,453)	(8,910)	(7,393)	367	(565)	2,502	2,800	322	3,081	5,434	5,164	7,074	9,754	20,891	25,114	28,856	32,481

Metric	value	unit
Economic IRR	**18.2**	%
Economic NPV	**21,632**	INR cr.
Economic Payback Time	12	years
Economic Discounted Payback Time	17	years

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Results – Employment

The project leads to a substantial number of new jobs for O&M.

- As a prudent approach and in line with international standards, this benefit is presented separately alongside the CBA results.

Project component	O&M personnel
Multipurpose terminal	185
Container and Ro-Ro terminal	4,296
Import Rail Yard	202
Liquid Bulk and LPG terminals	114
LNG terminals	53
Manning requirement of common systems and utilities	204
Total	**5,054**

- During construction, the direct employment will be approximately 7,000 – 8,000 jobs.

Sensitivity Analysis

Economic Analysis

Sensitivity CBA results

Economic Internal Rate of Return under changes assumptions

- Sensitivities on the economic internal rate of return (EIRR) show double digit returns in all cases. In none of the cases does the EIRR drop under the hurdle rate of 12.0%.
- Increased opex has a limited effect on EIRR as the CBA takes only additional opex (‘with project’ versus ‘without project’) into account
- Percentage import has an effect on EIRR as the CBA assumes that benefits due to logistics costs decreases in export related cargo will benefit consumers outside India only

	Sensitivity	EIRR
0.	*Base case*	*18.2 %*
1.	Capex @ 120 %	16.4 %
2.	Opex @ 120 %	17.9 %
3.	Volumes @ 90 %	17.2 %
4.	Volumes @ 110 %	19.1 %
5.	Vessel and Vehicle Operating Costs @ 90 %	18.0 %
6.	Vessel and Vehicle Operating Costs @ 110 %	18.4 %
7.	Value of Freight Travel Time @ 90 %	18.1 %
8.	Value of Freight Travel Time @ 110 %	18.3 %
9.	Inland transport kilometer savings @ 90%	18.1 %
10.	Inland transport kilometer savings @ 110%	18.3 %
11.	Percentage Diverted/Generated : 47%/53% to 60%/40%	15.4 %
12.	Percentage Diverted/Generated : 47%/53% to 40%/60%	19.5 %
13.	Percentage import/export : 53%/47% to 50%/50%	18.2 %
14.	Planning horizon + 10 years	18.5 %
1.|3.	Capex @ 120 % | Volumes @ 90 %	15.5 %
5.|7.|9.	VOC @ 90 % | VFTT @ 90 % | IT km savings @ 90 %	17.7 %
15.	Conversion Factor increased from 0.88 to 0.98	16.8 %

APPENDICES

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Abbreviations

FCL	Full Container Load
LCL	Less Container Load
MT	Empty
TEU	Twenty-foot Equivalent Unit
MTEU	Million TEU
FEU	Forty-foot Equivalent Unit
CEU	Car Equivalent Units
GRT	Gross Register Tonnage
DWT	Deadweight Tonnage
MTPA	Metric Ton
MTPA	Metric Tonnes Per Annum
NM	Nautical Mile
BCF or BSCF	Billions (1,000,000,000) of standard cubic feet of gas
LNG	Liquified Natural Gas
PLNG	Pressurized Liquified Natural Gas
THC	Terminal Handling Charges
CT	Container Terminal
JNPT	Jawaharlal Nehru Port Trust

Abbreviations cont.

GST	Goods and Services Tax
DFC	Dedicated Freight Corridor
ILC	Integrated Logistics Cost
FNPV	Financial Net Present Value
FIRR	Financial Internal Rate of Return
FPBT	Financial Pay Back Time
FDPBT	Financial Discounted Payback Time
ENPV	Economic Net Present Value
EIRR	Economic Internal Rate of Return
EPBT	Economic Pay Back Time
EDPBT	Economic Discounted Payback Time
FCF	Free Cash Flow
CAPEX	Capital Expenditures
OPEX	Operational Expenditures
INR	Indian Rupee
cr.	Crore
P1	Phase 1
P2	Phase 2

Abbreviations cont.

VOC	Vehicle Operating Costs
VFTT	Value of Freight Travel Time
FTT	Freight Travel Time
vkm	Vehicle Kilometres

Rail Yard Terminal Rates

Source

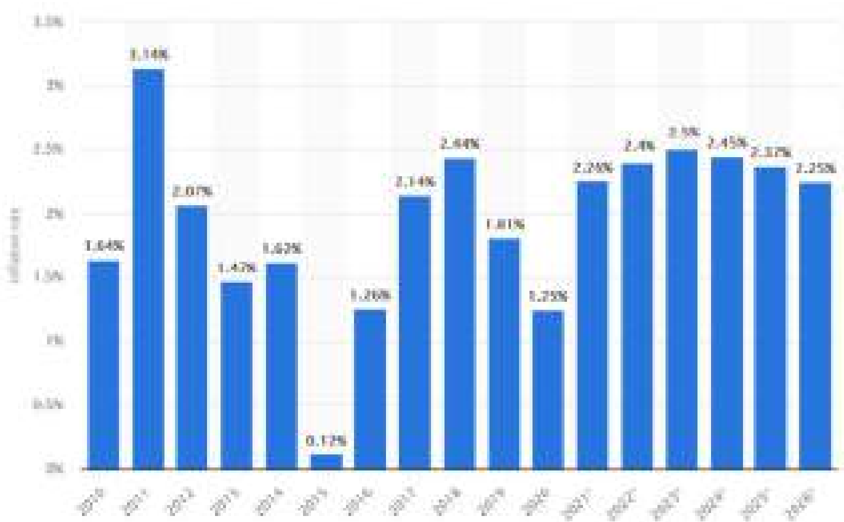
- Distinction between 'Container Yard' (CT Yard) and 'Rail Yard'
- CT Yard for storage of containers coming from or going to the berth (responsibility of CT Operator).
- Rail Yard for temporarily storage of containers to and from train rigs.
- Rates Rail Yard Handling based on old rates for container handling:
  - 'CT Yard to Rail'
  - 'CT Yard to Truck'
- Rate for 'CT Yard to Rail Yard' assumed equal to rate for 'CT Yard to Truck'
- Rate for Rail Yard to Train Rig assumed to be (old) rate for 'CT Yard to Rail' minus rate for 'CT Yard to Truck'.
- Summed the overall charge remains the same (no double counting)

		(A) CT Yard to Rail *(old rate)*	(B) CT Yard to Truck	(=B) CT Yard to Rail Yard	(= A - B) Rail Yard to Train Rig
Normal					
Container handling - Normal - 20 ft - Foreign - Loaded	INR / TEU	2,135.34	657.04	657.04	1,478.30
Container handling - Normal - 20 ft - Foreign - Empty	INR / TEU	2,135.34	657.04	657.04	1,478.30
Container handling - Normal - 20 ft - Coastal - Loaded	INR / TEU	2,135.34	657.04	657.04	1,478.30
Container handling - Normal - 20 ft - Coastal - Empty	INR / TEU	2,135.34	657.04	657.04	1,478.30
Container handling - Normal - 40 ft - Foreign - Loaded	INR / TEU	3,203.01	985.56	985.56	2,217.45
Container handling - Normal - 40 ft - Foreign - Empty	INR / TEU	3,203.01	985.56	985.56	2,217.45
Container handling - Normal - 40 ft - Coastal - Loaded	INR / TEU	3,203.01	985.56	985.56	2,217.45
Container handling - Normal - 40 ft - Coastal - Empty	INR / TEU	3,203.01	985.56	985.56	2,217.45
Reefer					
Container handling - Reefer - 20 ft - Foreign - Loaded	INR / TEU	2,135.34	657.04	657.04	1,478.30
Container handling - Reefer - 20 ft - Foreign - Empty	INR / TEU	2,135.34	657.04	657.04	1,478.30
Container handling - Reefer - 20 ft - Coastal - Loaded	INR / TEU	2,135.34	657.04	657.04	1,478.30
Container handling - Reefer - 20 ft - Coastal - Empty	INR / TEU	2,135.34	657.04	657.04	1,478.30
Container handling - Reefer - 40 ft - Foreign - Loaded	INR / TEU	3,203.01	985.56	985.56	2,217.45
Container handling - Reefer - 40 ft - Foreign - Empty	INR / TEU	3,203.01	985.56	985.56	2,217.45
Container handling - Reefer - 40 ft - Coastal - Loaded	INR / TEU	3,203.01	985.56	985.56	2,217.45
Container handling - Reefer - 40 ft - Coastal - Empty	INR / TEU	3,203.01	985.56	985.56	2,217.45
Hazerdous					
Container handling - Hazerdous - 20 ft - Foreign - Loaded	INR / TEU	2,668.71	821.29	821.29	1,847.42
Container handling - Hazerdous - 20 ft - Foreign - Empty	INR / TEU	-	-	-	-
Container handling - Hazerdous - 20 ft - Coastal - Loaded	INR / TEU	2,668.71	821.29	821.29	1,847.42
Container handling - Hazerdous - 20 ft - Coastal - Empty	INR / TEU	-	-	-	-
Container handling - Hazerdous - 40 ft - Foreign - Loaded	INR / TEU	4,003.07	1,231.94	1,231.94	2,771.13
Container handling - Hazerdous - 40 ft - Foreign - Empty	INR / TEU	-	-	-	-
Container handling - Hazerdous - 40 ft - Coastal - Loaded	INR / TEU	4,003.07	1,231.94	1,231.94	2,771.13
Container handling - Hazerdous - 40 ft - Coastal - Empty	INR / TEU	-	-	-	-
OverDimensional					
Container handling - OverDimensional - 20 ft - Foreign - Loaded	INR / TEU	4,270.68	1,314.05	1,314.05	2,956.63
Container handling - OverDimensional - 20 ft - Foreign - Empty	INR / TEU	4,270.68	1,314.05	1,314.05	2,956.63
Container handling - OverDimensional - 20 ft - Coastal - Loaded	INR / TEU	4,270.68	1,314.05	1,314.05	2,956.63
Container handling - OverDimensional - 20 ft - Coastal - Empty	INR / TEU	4,270.68	1,314.05	1,314.05	2,956.63

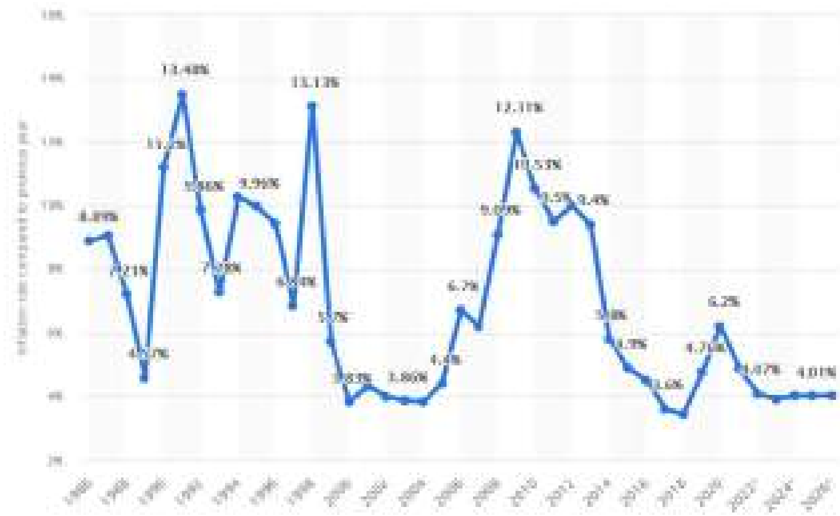
Assumptions

Long term inflation forecasts for USD and India

US



India



Source : https://www.statista.com/statistics/271322/inflation-rate-in-india/

Traffic Flow Assumptions

Calculation inland transportation kilometer savings

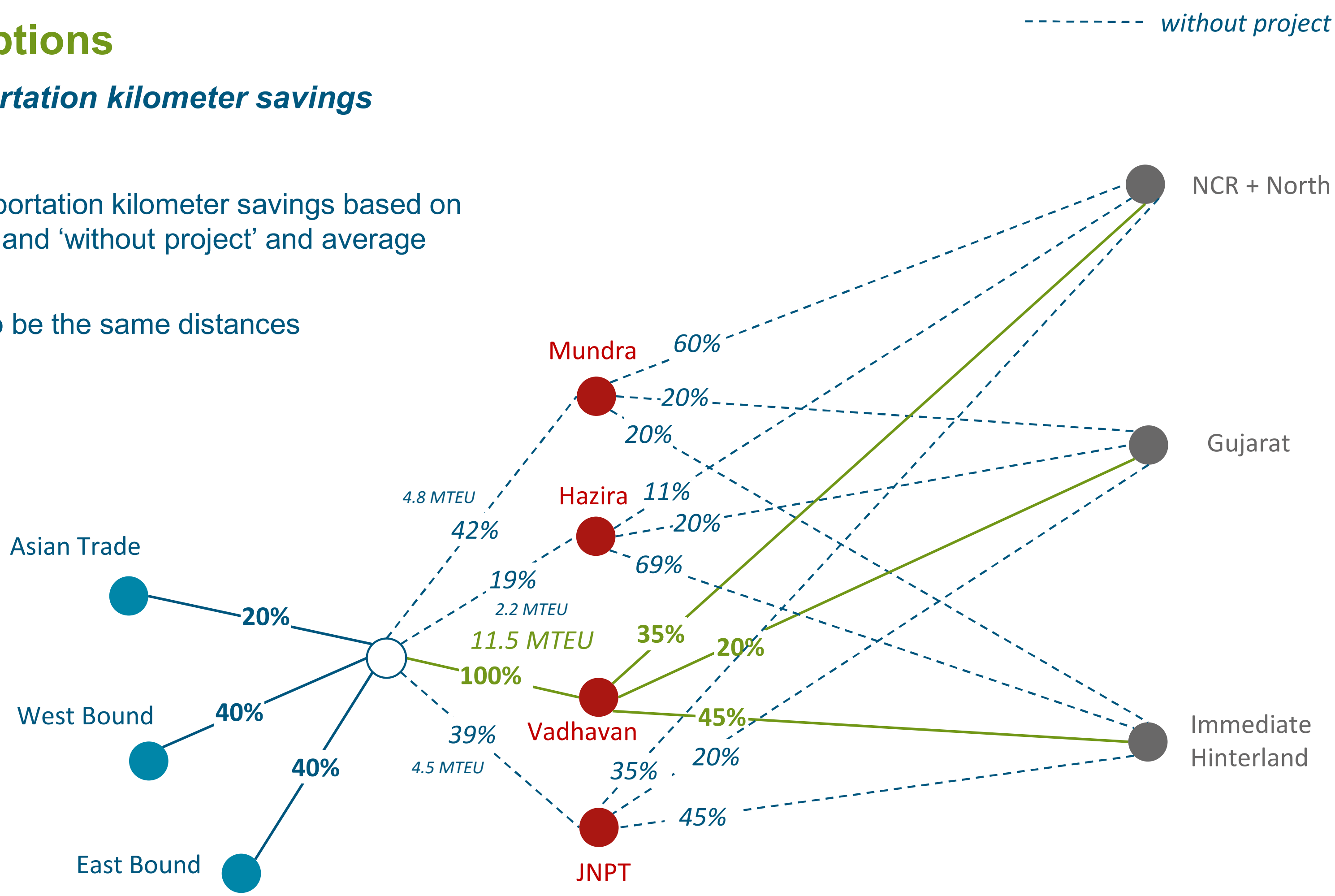
- Calculation of inland transportation kilometer savings based on traffic split in 'with project' and 'without project' and average distances.
- Train and road assumed to be the same distances

MUNDRA + Near ports
Capacity : 10 + 1 MTEU
Used : 5.7 + 0.5 MTEU
Available : 4.3 + 0.5 MTEU
→ 4.8 / (4.8+2,2+4,5) = 42%

HASIRA + Near ports
Capacity : 3 MTEU
Used : 0.8 MTEU
Available : 2.2 MTEU
→ 2.2 / (4.8+2,2+4,5) = 19%

JNPT
Capacity : 10 MTEU
Used : 5.5 MTEU
Available : 4.5 MTEU
→ 4.5 / (4.8+2,2+4,5) = 39%

GENERATED / DIVERTED
Vadhavan volume : 24,3 MTEU
Avoided diversion : 4.8 + 2.2 + 4.5 = 11.5 MTEU
Avoided diversion : 11.5 / 24,3 = 47%
Generated : 24.3 – 11.5 = 12.8 MTEU
Generated : 100% - 47% = 53%



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Hinterland West Coast Ports India

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16 Project Implementation Schedule

16.1 Implementation Strategy

The port is proposed to be developed as Landlord port, the EPC contract for the implementation of landlord component can be carried out into the following tentative contracting packages. The exact packages and modality of implementation will be arrived at based on discussion with JNPA.

- Package 1 – Marine Civil Works – Breakwater and approach trestle for trailer road movement
- Package 2 – Dredging, Reclamation and Shore protection works
- Package 3 – Onshore Civil Works and Utilities – Buildings, Pavements and Utilities
- Package 4 – Road Connectivity to Port - NHAI
- Package 5 – Rail connectivity to Port - DFCC

The Works towards supply of water and power from the respective sources will be carried out by the respective state government authorities.

16.2 Organisation Structure

Vadhavan port will be developed as an all-weather port for handling primarily the containers including other cargoes such as multipurpose, Ro-Ro, Bulk Liquid, liquid bulk. Various terminals would be developed to cater these respective cargoes. The marine facilities such as breakwaters, approach channel, port craft, navigational aids will be common to all these terminals.

As the port is proposed to be developed on PPP basis, the management of port proposed is as below:

1. Management and operations by M/s. Vadhavan Port Project Limited (VPPL – a SPV for the implementation of Vadhavan port) directly by employing suitable personnel.
2. Operations by leasing out the terminals to Terminal Operators (TO) with expertise in handling these operations.

However, the M/s. VPPL will still be directly responsible for:

- Appointing a Harbour - Master and conservator of the port.
- Navigation in the port by having qualified and licensed pilots to pilot ships with aids like tugs etc., attending to berthing and de-berthing of ships calling at the port.
- Providing and maintaining the basic infrastructure like road, rail, water & power supply etc.
- Payment to the State Government as may be contained in the agreement.
- Furnishing management information to the appropriate authority on port operations including cargo-handling activities at the various marine terminals, whether operated directed by it or by subleased to others.
- Co-ordinating with the Collectorate of customs within whose jurisdiction the port falls, for proper accounting of ships entering the port and cargo unloaded or loaded into them.
- Administering subleases for the various marine terminals leased to users, terminal operators as applicable.
- Co-ordinating all port activities, monitoring port performance by individual terminal operators and ensuring optimal performance and collecting necessary management information and furnishing the same to the Government authorities as required.
- Safety and security, pollution control and environmental protection, water supply, power supply.

The levels of management have been designed as three levels - top, middle and operational (shop floor level). The operational or shop floor levels consist of Asst. Manager/Shift In charge, and their subordinate supervisors and staff/operatives. The organization chart is provided below in Figure 16-1.

Figure 16-1 Overall Management Structure

16.3 Project Implementation

The following sections describe significant construction elements in the development of port at Vadhavan. Construction timeframes are described further based on BOQs and construction schedule for Phase 1 development is provided in this section.

It should be noted that the timeframes have been estimated based on an assumed construction methodology. The EPC contractor may choose a different construction methodology depending on their capability and understanding and this may change the calculations presented below.

It should also be noted that delays in project implementation due to environmental or other statutory approvals, financial closure, construction delays etc., that are beyond RHDHV's control and cannot be estimated, have not been factored in the implementation schedule.

16.4 Breakwater

The breakwater construction is proposed to be the foremost activity as it is needed to provide shelter for other activities such as reclamation and berth construction to commence. It is intended to construct the rubble mound breakwater using plant based on land and at sea. Due to the size of the offshore Breakwater and a tight completion timeframe for Phase 1 development, it is believed it would be economical to incorporate both methods and work on two fronts or more. The typical sequence of construction is as follows:

- Bed preparation
- Core placing
- Toe construction
- Under-layer
- Armour- seaward and leeward sides and
- Crest structure.

It is estimated that about 32.1 million tons of rock/ stone is required for the construction of breakwaters. The stones from the quarry sites would be brought and stacked at site in the plots earmarked for the different size of stones. The rock quarries are located at a distance of 20 km from site. There would need to construct the proposed approach to the port connecting NH 48 along with some improvements in the approach road to the quarries to enable free movement of dumpers carrying rock to the project site.

It is proposed that core of the breakwater be formed up to say -3.0 m CD by using the marine equipment viz. self-propelled side dumping and/or bottom opening barges.

It is envisaged that using the floating equipment, about 10,000 T stones can be placed per day per plant. A total of 3 plants would be required for the breakwater construction. The placement rates would also depend upon the adequate supply of stone to site from the quarry sites. The breakwater profile will be constructed by barge dumping. The building of breakwaters section shall be progressed by barge dumping. Upon completion of the Accropode armour / stone armour to full length, the mass concrete capping shall be commenced from the root.

Marine plant will be used for placement of under-layer and armour layers. It is expected that breakwater construction through marine plant will be halted for around 4 months during the monsoon season whereas construction through land plant will experience considerable downtimes. It is also acknowledged that some rock will be lost in the monsoon.

An allowance has been made in the development of the preliminary schedule covering the construction phase for downtime due to adverse weather. There will be a need to perform a detailed assessment of the potential for downtime during construction planning in order to derive the optimum solution in terms of working fronts, equipment selection and so on for the likely conditions at the site. It is expected that breakwater construction will be very crucial for completion of the project in time. This will involve careful analysis of the logistics chain. Table 16-1 shows a calculation to assess breakwater construction schedule. The contractor may optimize this construction schedule based on equipment availability, adopted final design and construction methodology.

Table 16-1 Breakwater Construction Timeframe

Construction	Unit	Values
Offshore Breakwater		
– Length	m	10,140

Construction	Unit	Values
– Core	T	27,038,474
– Stone	T	5,072,298
– -Accropode II	No.	670,795
Supply		
– Rock/Core	T	32,110,773
– Accropode (Total)	No.	670,795
Rock/Core		
– Production rate expected	T/month	751,069
– Transport by road	T/day	27,540
– Truck capacity	T	24
– Trucks per day	No.	1148
– Hours per day for rock delivery	Hr.	20
– Number of Trucks	No.	57
For 7-day week, expected duration	Months	**36**
Accropode II		
– Placing rate	Mins each	5
– No. placed per day	Per 9-hour day	864
– Days placing time	Days, incl. 5% for peaks	815
For 7-day week, expected duration	**Months**	**28**

16.5 Dredging

The dredging methodology has been explained in Section 8.4.5. As discussed earlier in Section 8, it is recommended to deploy CSD for undertaking capital dredging works for the harbour. If the contractor wishes to operate in rougher weather conditions than permissible with CSD dredges, TSHD can also be deployed in the outer approach channel. It is recommended that CSD be used for dredging within the basin including the turning circle and berth pockets.

Soft silty sand and weathered rock can be dredged by a powerful CSD and the dredged material will be disposed to designated reclamation ground. Sound rock needs to be pre-treated before being dredged by a CSD. The production rate is expressed in the pumped slurry density and efficiency factors like net operational hours (including bunkering, scheduled maintenance). The workability is limited by the downtime of dredging vessel (due to weather conditions, expressed as workability). Dredging operations are normally suspended during monsoon season (13 weeks i.e., from June to Aug.) and hence the number of weeks the dredging operations can be carried out annually is about 39 weeks. An optimum time frame recommended for carrying out the capital dredging operations is 9 months (36 weeks). The exact positioning of this activity will be dependent on the timing of the project implementation relative to the monsoon period. The dredging methodology described above has been considered to meet the required time frame.

Table 16-2 shows calculation for calculating dredging completion time for Phase 1 capital dredging. The dredging work is estimated to take 9 months. The contractor may optimize this construction schedule based on equipment availability, adopted final design and construction methodology.

Table 16-2 Weekly and Daily Production Rates of CSD

Description	Quantity (cum)
	CSD
Soil Dredging	3,574,922
Rock Dredging	3,007,552
Total dredging quantity (cum)	**6,582,474**
No of weeks	36
Weekly production rate (cum)	182,847
Daily production rate (cum)	26,121

The quantity of weathered rock to be dredged in the channel has been estimated as 3,007,000 m^3. With modern cutter suction dredgers, it is possible to directly dredge weathered rock having an unconfined compressive strength of upto 50 MPa, without any pre-treatment of the rock. The achievable average weekly output of a CSD proposed for dredging this material is taken as 40,000 m^3.

16.6 Reclamation Bund and Shore Protection

The reclaimed ground will be protected by providing rubble mound bund on all sides supported by sand fill from dredge spoils and burrowed earth. This reclamation bund will be designed for a design life of 50 years. The methodology provided in the Construction Industry Research and Information Association (CIRIA) manual (manual on use of rock in coastal and shoreline engineering) has been followed.

It is estimated that about 16 million tons of rock/ stone is required for the construction of reclamation/ shore protection bund. The reclamation bund will comprise of quarried rock / stones and core fill from quarry sites. It will include a geotextile membrane on the rear face to enhance its fill retention properties. The outer face will be protected against wave action with suitable protection. The stones required for the construction of bund will be supplied by local quarry through barges and road trucks similar to breakwater construction.

The rock bund and revetment capital works are proposed to be performed in advance of the reclamation work in order to provide the containment necessary for the reclamation material. Assuming similar supply and placement rates as for the breakwater construction, it is estimated that reclamation bund be in parallel with initial dredging works and precede the reclamation works. It is approximated that reclamation bund and shore protection work will last for approximately 24 months. The contractor may optimize this construction schedule based on equipment availability, adopted final design and construction methodology.

Table 16-3 Shore Protection Bund Construction Timeframe

Construction	Unit	Values
Reclamation Bund and Shore Protection Bund		
– Length	m	23,900

Construction	Unit	Values
– Core	T	6,879,403
– Stone	T	2,840,932
– Accropode II	No.	0
Supply		
– Rock/Core	T	9,720,336
– Accropode (Total)	No.	0
Rock/Core		
– Production rate expected	T/month	405,014
– Transport by road	T/day	14,850.51
– Truck capacity	T	24
– Trucks per day	No.	618.77
– Hours per day for rock delivery	Hr.	0
– Number of Trucks	No.	30.94
For 7-day week, expected duration	Months	**24**

16.7 Reclamation

During Phase 1 the fill is needed from a depth varying between -8 m and -15 m up to +7.5m CD. It is estimated that all fill material for reclamation for Phase 1 development will come from marine burrow pit. It is assumed that reclamation can start after one-month delay from construction of reclamation bund and continues for the duration of dredging and breakwater construction activities. The reclamation activity is assessed to be completed in 27 months.

16.8 Berths

All the proposed terminal berths viz., Container terminal, Multipurpose terminals, RORO, Liquid bulk, Bulk Liquid, and Other Liquid terminals along with the approach trestles and harbour craft berths will be formed from concrete piles socketed into rock beneath the seabed supporting a suspended concrete slab for the quay apron.

To provide adequate protection from waves during monsoons the piling activity will have to be synchronized with the construction of breakwater. It is proposed to first reclaim the site using the suitable dredged spoil and burrowed earth upto a level of +7.5 m CD. The bored piles supporting the quay deck are then constructed using the land based as well as marine equipment. The longitudinal and transverse beams connecting the berth piles are also constructed using land based as well as marine construction.

Table 14.3 provides a calculation for estimating timeframe of completion for Phase-1 berth construction. It is estimated that container berths will be completed within 20 months, cruise/ multipurpose berth can be built in about 13 months and the fishery berths will take around 12 months for construction. The construction activity for the coast guard and navy would be around 14 months. It is assumed that construction activity will be impacted during monsoon and 50% of the time will be lost. It is important to note that breakwater will provide significant sheltering for the marine works. The contractor may optimize this construction schedule based on equipment availability, adopted final design and construction methodology.

Table 16-4 Marine Works Construction Timeframe Calculation

Description		Container Berth	MP berth	Coastguard berth	Port Craft Berth	Approach trestle to Offshore land	Approach trestle for liquid berths	Liquid berths	LPG berth
Total Length	m	1,000	250	100	100	2,600	6,150	228	106
Spacing of piles	m	6.5	6.5	6.5	6	13	10	6	6
Bends/Piles per Week		1.5	3	2	2	2	2	3	3
Number of Working Weeks		103	13	8	8	100	308	13	6
No. of Simultaneous Operation		2	2	1	1	3	4	1	1
Efficiency of Operation		0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
Effective Schedule with 80% Efficiency	Weeks	64	8	10	10	42	96	16	7
Pre-Cast Works	Weeks	10	10	6	6	12	12	8	8
In-Situ Works	Weeks	10	8	6	6	12	12	12	12
Monsoon Delay	Months	2	1	1	1	2	2	2	2
Total Work Completion	**Months**	**24**	**8**	**7**	**7**	**19**	**33**	**11**	**9**
No. of terminals	**Months**	**4**	**3**	**1**	**1**	**1**	**1**	**2**	**1**
Total Work Completion	**Months**	**96**	**24**	**7**	**7**	**19**	**33**	**22**	**9**

The time frame for the construction of single terminal is 24 months and the construction schedule can be staggered or can be simultaneous based on the award to the concessionaire.

16.9 Equipment and Onshore Developments

The container terminal operating equipment and other equipment will need to be procured in such a manner that they are ready for commissioning in time of finish of construction. Due consideration should be given to longer lead time equipment such as quay cranes and items such as terminal operating system requiring significant training times.

Open spaces/storage areas will be paved with a variety of surfacing as follows:

- Container terminal areas: block paving.
- Access roads: asphalt paving.
- Gate complex and parking areas: asphalt concrete; and
- Truck parking: block paving.

These works can be carried out to suit the commissioning of the facilities by the selected operator. However, construction of the access road by mean of approach trestle to tip of breakwater will need to be taken up on priority basis.

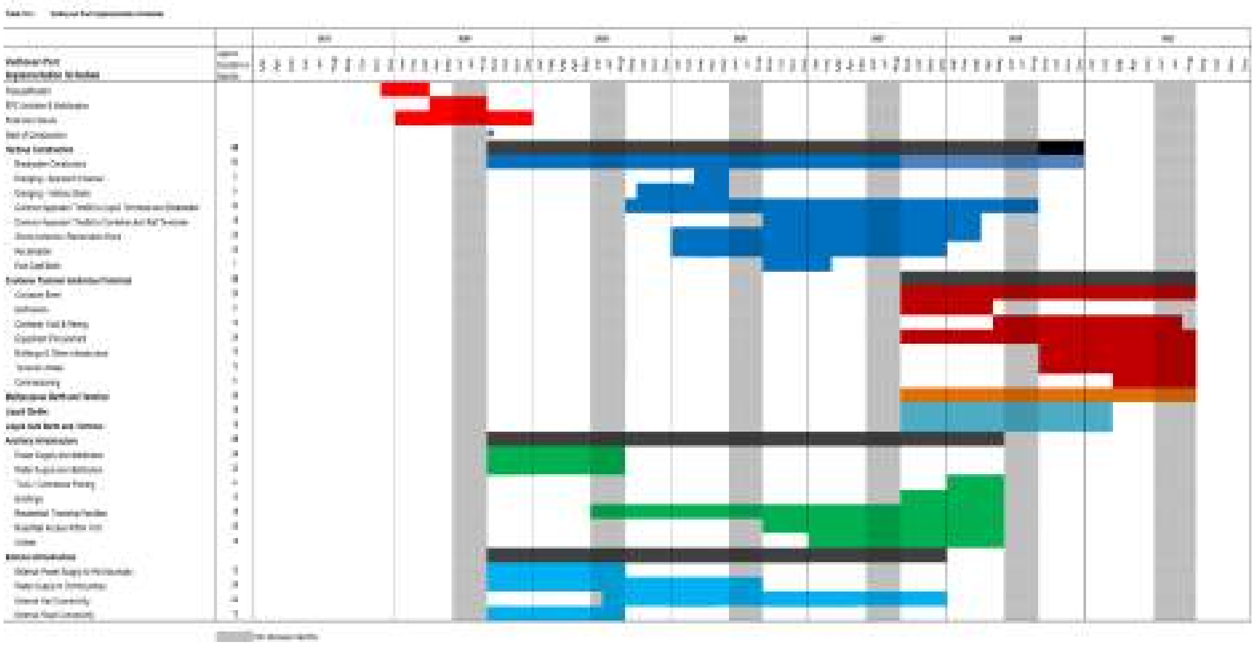
It is planned for the pavements of open/storage areas to commence after soil stabilization within reclamation areas has been completed. Provisions of required utilities such as electric, power, potable water, water main and communication etc. will also commence after the soil stabilization works.

All the buildings shall have RCC framed structure. Heavy structures on the reclaimed land shall be provided with pile foundations or shallow foundations depending on expected settlements. All other structures can be founded on isolated footings. The buildings will start construction after the reclamation areas are stabilized. It is expected that works on pavement, utilities and buildings will be done concurrently with the berth and other site works.

16.10 Summary

Table 16-5 shows the implementation schedule and timeframes for various construction elements for Phase-1.

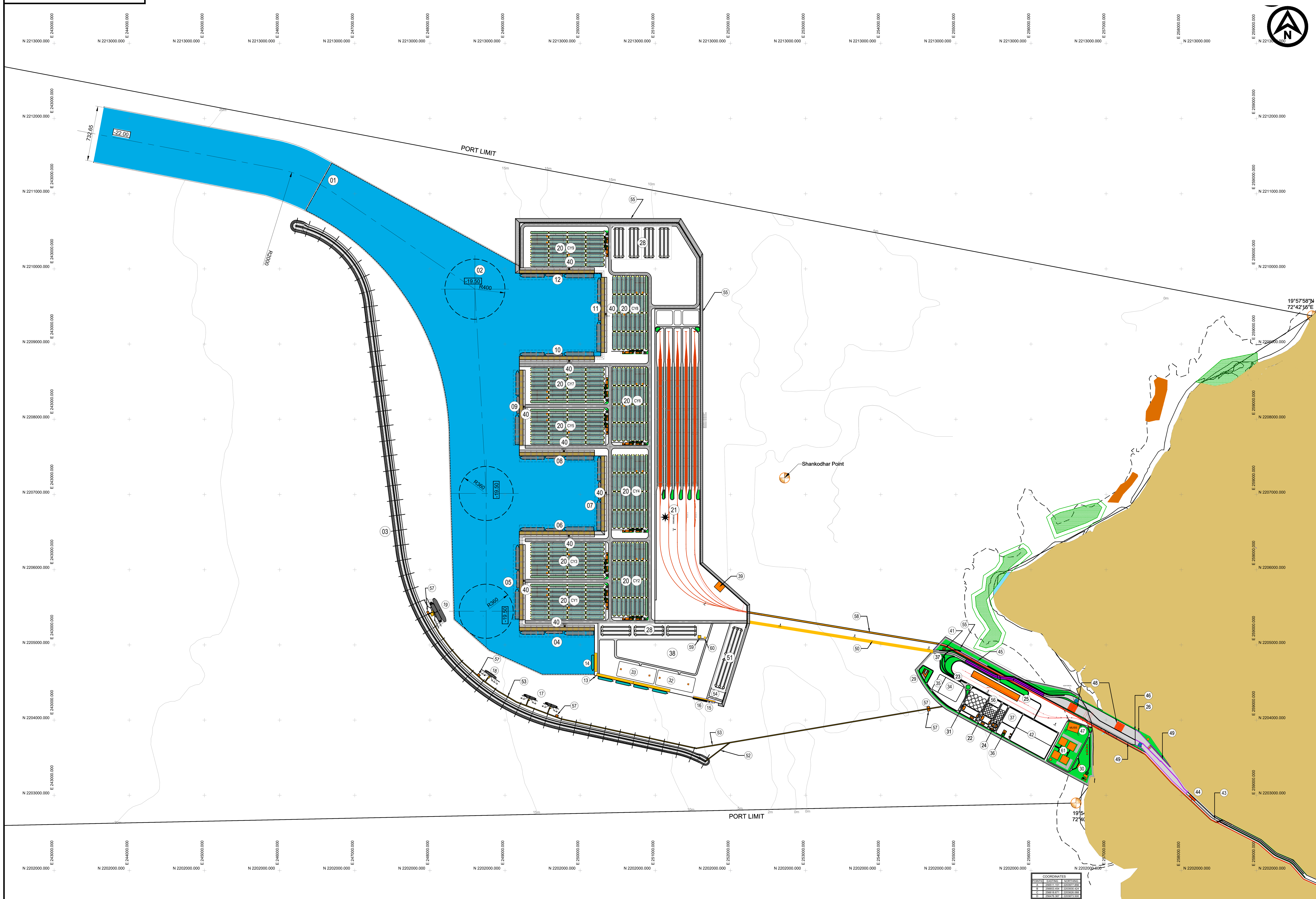
Table 16-5 Vadhavan Port Implementation Schedule

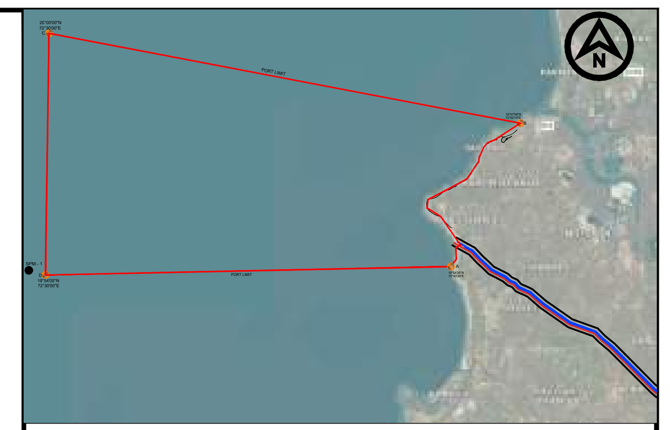


APPENDIX 1 – DRAWINGS

DRG No. DI1452-RHD-DP-MA-DR-CM-1001

DO NOT SCALE





KEY PLAN

NOTES

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2. DRAWINGS ARE NOT TO BE SCALED, WRITTEN DIMENSIONS SHOULD BE FOLLOWED AND VERIFIED WITH THE DETAILS.
3. ANY DISCREPANCIES FOUND IN DRAWINGS ARE TO BE REPORTED TO THE ENGINEER.

LEGEND

- LAND
- SEA
- MANGROVES
- ROCKY OUTCROP
- ROAD
- FLYOVER BRIDGE
- PEDESTRIAN AREA
- LANDSCAPING
- BUILDINGS
- GATE COMPLEX
- EMPTY CONTAINER SLOTS
- LOADED CONTAINER SLOTS
- RAIL TRACK

ISSUED FOR DPR

REV	DATE	DESCRIPTION	BY	CHK	APP
P08	15/09/2021	ISSUED FOR DPR	SNJ	PK	ASM
P07	24/12/2021	ISSUED FOR DPR	SNJ	MS	ASM
P06	18/11/2021	ISSUED FOR DPR	TSM	MS	ASM
P05	12/11/2021	ISSUED FOR DPR	SNJ	MS	ASM
P04	08/10/2021	ISSUED FOR DPR	SNJ	MS	ASM
P03	14/04/2021	ISSUED FOR DPR	ZR	GPS	ASM
P02	15/03/2021	ISSUED FOR DPR	ZR	GPS	ASM
P01	16/02/2021	ISSUED FOR DPR	TSM	GPS	ASM

REVISIONS

CLIENT
JAWAHARLAL NEHRU PORT TRUST

CONSULTANT
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www.royalhaskoningdhv.com

PROJECT
Consultancy services for Design and Detailed Engineering for Greenfield Vadhavan port project

TITLE
VADHAVAN PORT MASTER PLAN

DRAWN SNJ	CHECKED MS	APPROVED ASM
DATE AUG' 2023	SCALE @A1 1:1000	REF.

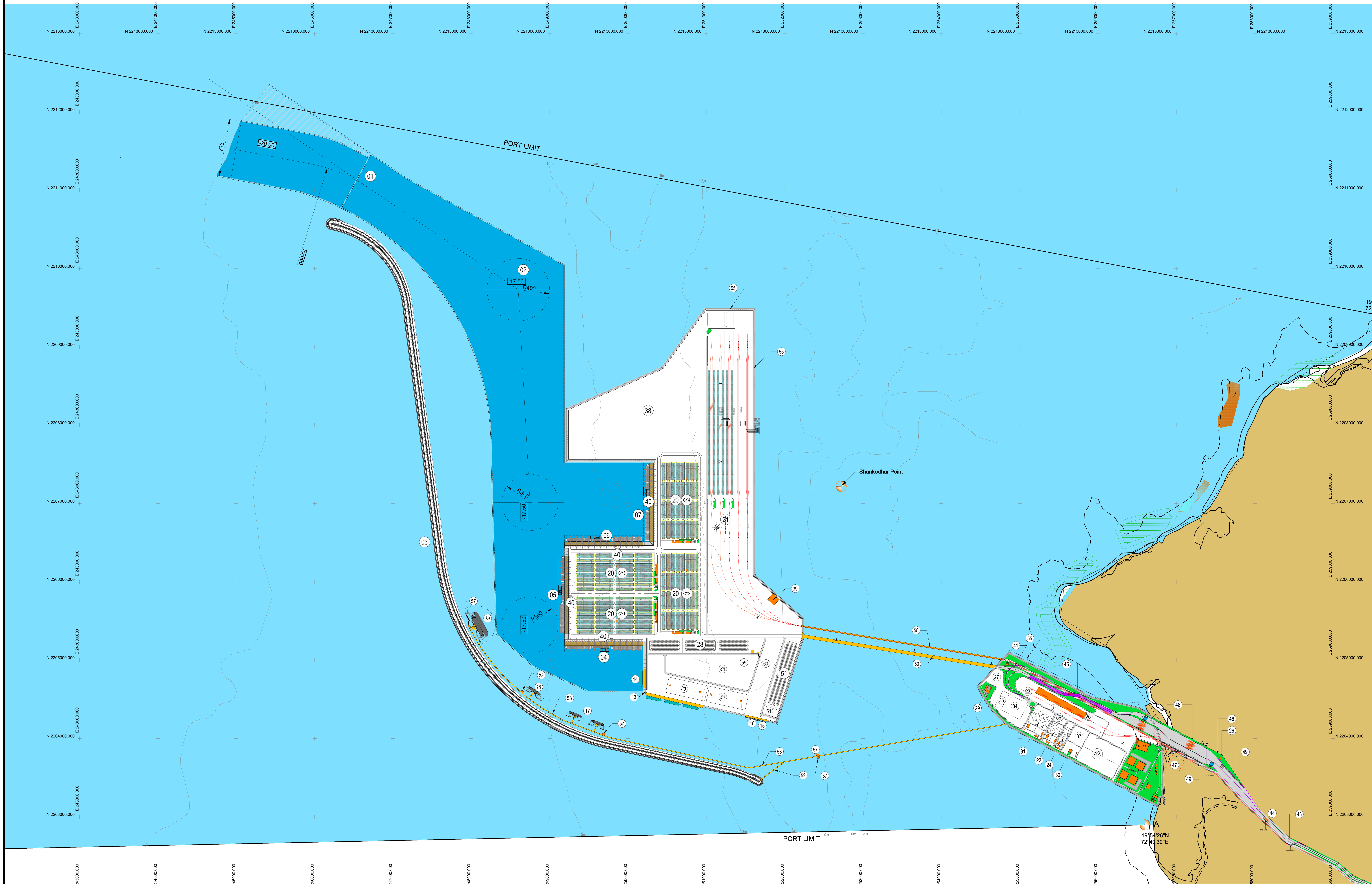
DRAWING No.	SUITABILITY	REVISION
DI1452-RHD-DP-MA-DR-CM-1001	S4	P08

KEYNOTES

1. ENTRANCE CHANNEL
2. TURNING BASIN
3. BREAKWATER
4. CONTAINER TERMINAL 1
5. CONTAINER TERMINAL 2
6. CONTAINER TERMINAL 3
7. CONTAINER TERMINAL 4
8. CONTAINER TERMINAL 5
9. CONTAINER TERMINAL 6
10. CONTAINER TERMINAL 7
11. CONTAINER TERMINAL 8
12. CONTAINER TERMINAL 9
13. MULTIPURPOSE BERTHS
14. RO-RO BERTH
15. COAST GUARD BERTH
16. TUG/PORT CRAFT BERTH
17. BULK LIQUID JETTY
18. BUILK LIQUID JETTY
19. OTHER LIQUID JETTY
20. CONTAINER YARD (CY 1 TO CY 9)
21. IN PORT RAIL YARD
22. CHEMICAL TANK FARM
23. RAIL YARD FOR OTHER CARGOES
24. EDIBLE OIL TANK FARM
25. COVERED STORAGE SHED
26. UNDERGROUND WATER STORAGE TANK WITH PUMP ROOM
27. UTILITY AREA
28. TRAILER PARKING FOR CONTAINER TERMINAL (CY 1 TO CY 4)
29. PORT OPERATIONS BUILDING
30. JNPT ADMIN BUILDING
31. BULK LIQUID TANK FARM
32. GENERAL CARGO STORAGE
33. COASTAL CARGO STORAGE
34. RO RO STORAGE AREA
35. PDI FACILITY FOR CARS
36. OTHER LIQUID TERMINAL
37. UTILITY AREA
38. AREA FOR FUTURE DEVLOPMENT
39. MAIN RECEIVING SUBSTATION (MRSS)
40. BERTH SUBSTATION (BSS-1 to BSS-9)
41. UTILITY SUBSTATION (USS)
42. COMMON PORT INFRASTRUCTURE
43. ROAD TO PORT
44. PRE ENTRY / EXIT GATE
45. FLYOVER
46. OVERHEAD TANK
47. MAIN SUBSTATION (MSS)
48. MAIN GATE COMPLEX
49. TRAILER PARKING AT ENTRY & EXIT
50. APPROACH TRESTLE FOR ROAD MOVEMENT
51. TRAILER PARKING FOR MULTIPURPOSE BERTH
52. APPROACH TRESTLE TO BREAKWATER
53. COMMON APPROACH TRESTLE TO LIQUID TERMINAL
54. COAST GUARD AREA
55. RECLAMATION BUND
56. PARKING FOR CHEMICAL & EDIBLE OIL TANKERS
57. SEA WATER PUMP HOUSE
58. APPROACH TRESTLE FOR RAIL
59. PORT USER BUILDING
60. INCINERATION AREA
61. CUSTOM BUILDING

DRG No.
DI1452-RHD-DP-MA-DR-CM-1002

DO NOT SCALE



KEY PLAN

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- RAIL TRACK

ISSUED FOR DPR

REV	DATE	DESCRIPTION	BY	CHK	APP
P03	15/09/2023	ISSUED FOR APPROVAL	SNJ	PK	SD
P02	28/03/2022	ISSUED FOR APPROVAL	SNJ	MS	SD
P01	14/01/2022	ISSUED FOR APPROVAL	SNJ	MS	SD

REVISIONS

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PROJECT
Consultancy services for Design and Detailed Engineering for Greenfield Vadhavan port project

TITLE
PHASE 1 LAYOUT FOR VADHAVAN PORT

DRAWN	CHECKED	APPROVED
SNJ	MS	ASM

DATE	SCALE @A1	REF.
JAN ' 2022	1:25000	

DRAWING No.	SUITABILITY	REVISION
DI1452-RHD-DP-MA-DR-CM-1002	S4	P02

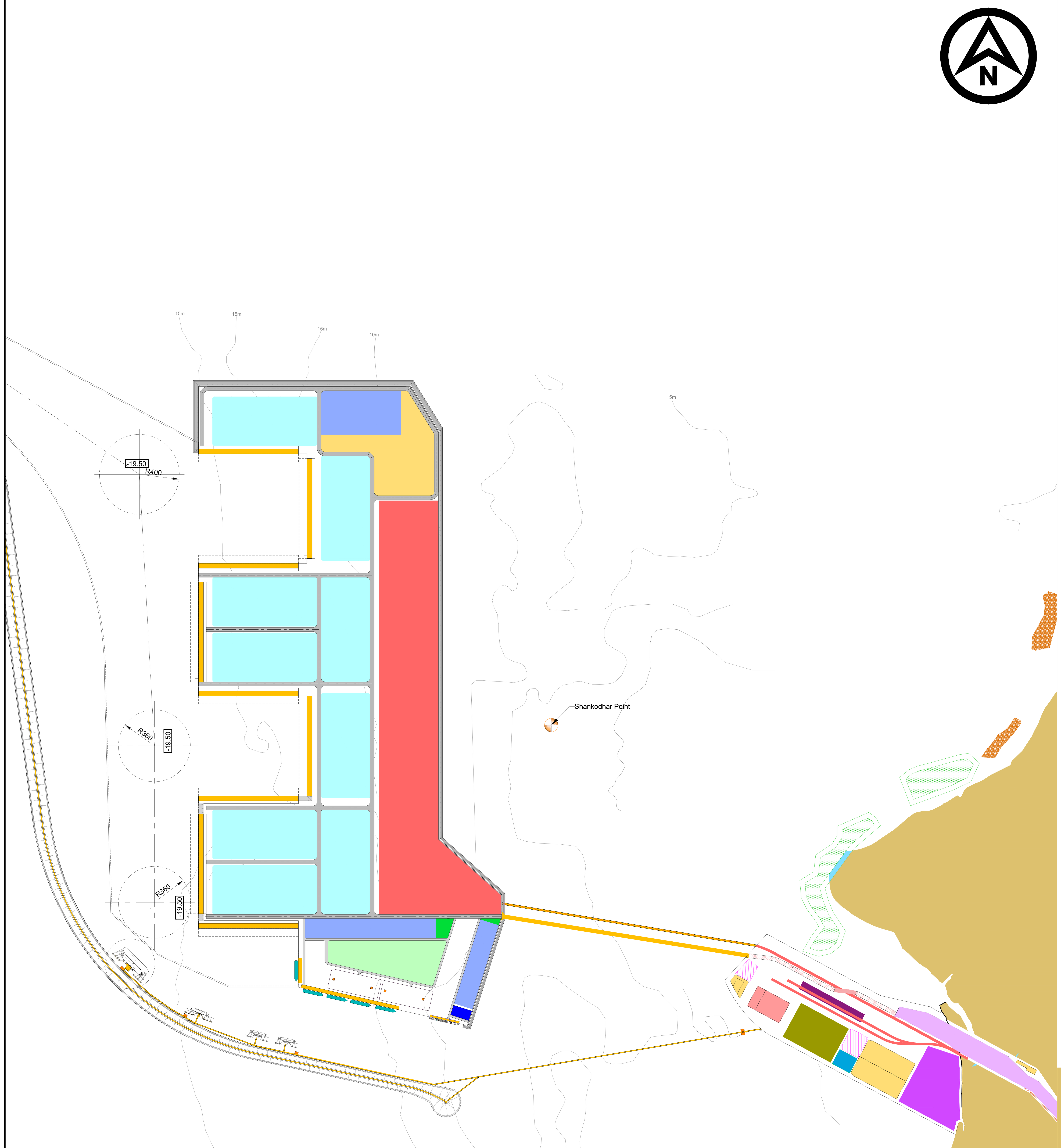
KEYNOTES

1. ENTRANCE CHANNEL
2. TURNING BASIN
3. BREAKWATER
4. CONTAINER TERMINAL 1
5. CONTAINER TERMINAL 2
6. CONTAINER TERMINAL 3
7. CONTAINER TERMINAL 4
8. -
9. -
10. -
11. -
12. -
13. MULTIPURPOSE BERTHS
14. RO-RO BERTH
15. COAST GUARD BERTH
16. TUG/PORT CRAFT BERTH
17. BULK LIQUID JETTY
18. BULK LIQUID JETTY
19. OTHER LIQUID JETTY
20. CONTAINER YARD (CY 1 TO CY 9)
21. IN PORT RAIL YARD
22. CHEMICAL TANK FARM
23. RAIL YARD FOR OTHER CARGOES
24. EDIBLE OIL TANK FARM
25. COVERED STORAGE SHED
26. UNDERGROUND WATER STORAGE TANK WITH PUMP ROOM
27. UTILITY AREA
28. TRAILER PARKING FOR CONTAINER TERMINAL (CY 1 TO CY 4)
29. PORT OPERATIONS BUILDING
30. JNPT ADMIN BUILDING
31. BULK LIQUID TANK FARM
32. GENERAL CARGO STORAGE
33. COASTAL CARGO STORAGE
34. RO RO STORAGE AREA
35. PDI FACILITY FOR CARS
36. OTHER LIQUID TERMINAL
37. UTILITY AREA
38. AREA FOR FUTURE DEVLOPMENT
39. MAIN RECEIVING SUBSTATION (MRSS)
40. BERTH SUBSTATION (BSS-1 to BSS-9)
41. UTILITY SUBSTATION (USS)
42. COMMON PORT INFRASTRUCTURE
43. ROAD TO PORT
44. PRE ENTRY / EXIT GATE
45. FLYOVER
46. OVERHEAD TANK
47. MAIN SUBSTATION (MSS)
48. MAIN GATE COMPLEX
49. TRAILER PARKING AT ENTRY & EXIT
50. APPROACH TRESTLE FOR ROAD MOVEMENT
51. TRAILER PARKING FOR MULTIPURPOSE BERTH
52. APPROACH TRESTLE TO BREAKWATER
53. COMMON APPROACH TRESTLE TO LIQUID TERMINAL
54. COAST GUARD AREA
55. RECLAMATION BUND
56. PARKING FOR CHEMICAL & EDIBLE OIL TANKERS
57. SEA WATER PUMP HOUSE
58. APPROACH TRESTLE FOR RAIL
59. PORT USER BUILDING
60. INCINERATION AREA
61. CUSTOM BUILDING

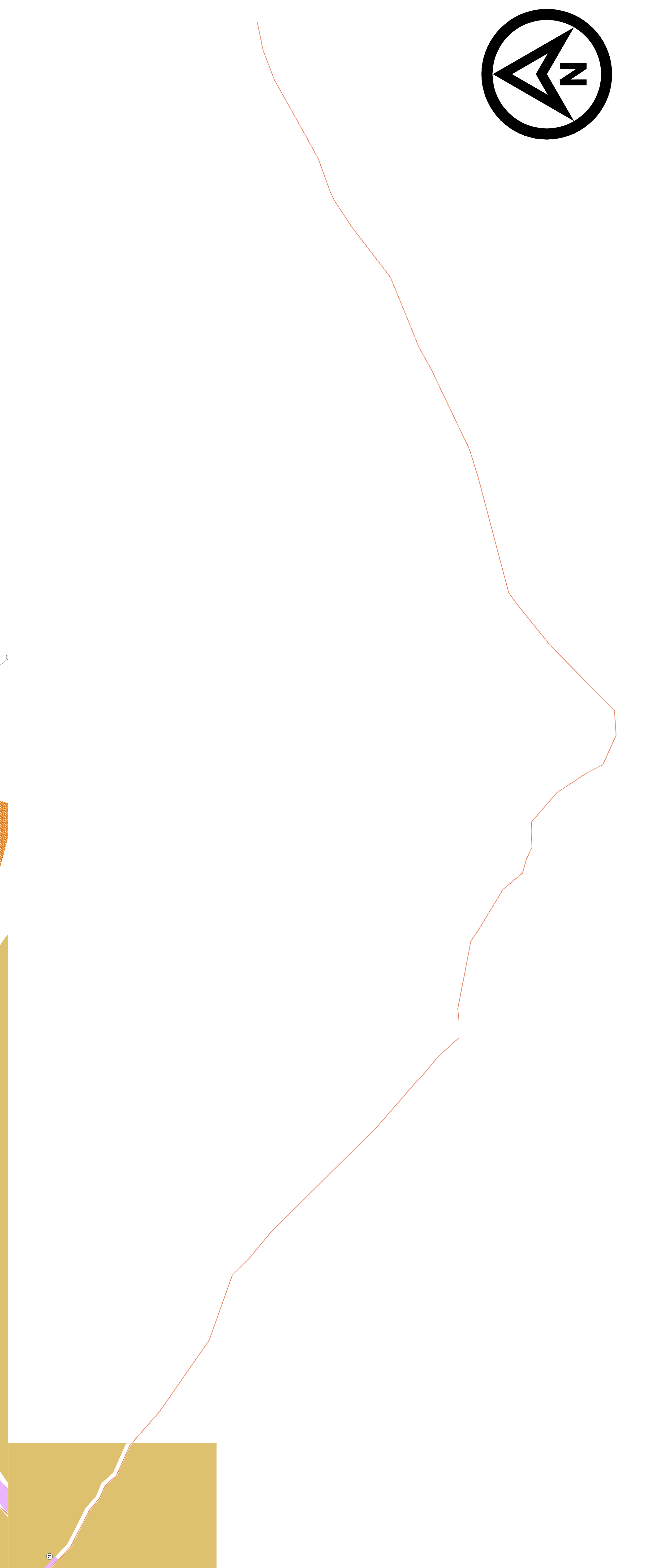
FILE INFO: C:\Users\231149\Desktop\New folder\DI1452-RHD-P1-XX-DR-CM-0002-S4P02\DI1452-RHD-P1-XX-DR-CM-1002-S4P03.dwg 18-Sep-23

DRG No.
DI1452-RHD-DP-MA-DR-CM-1003

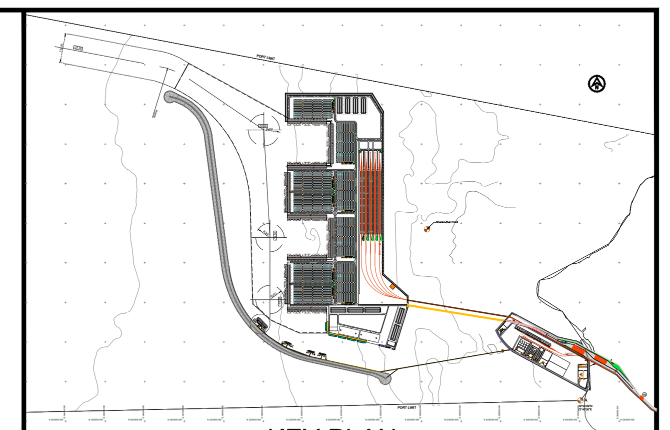
DO NOT SCALE



PART PLAN
SCALE 1:150



PART PLAN
SCALE N.T.S.



KEY PLAN

NOTES

1. ALL DIMENSIONS AND LEVELS ARE IN METERS, UNLESS NOTED OTHERWISE.
2. DRAWINGS ARE NOT TO BE SCALED, WRITTEN DIMENSIONS SHOULD BE FOLLOWED AND VERIFIED WITH THE DETAILS.
3. ANY DISCREPANCIES FOUND IN DRAWINGS ARE TO BE REPORTED TO THE ENGINEER.

LEGEND

- CONTAINER YARD
- COMMON PORT INFRASTRUCTURE
- FUTURE DEVELOPMENT AREA
- JNPT AREA
- RORO AREA
- MULTIPURPOSE AREA
- RAIL YARD
- LANDSCAPING
- GATE COMPLEX
- ROAD
- MANGROVES
- ROCKY OUTCROP
- EXISTING LAND
- BULK LIQUID TERMINAL
- LIQUID BULK TERMINAL
- OTHER LIQUID TERMINAL
- COAST GUARD AREA
- PARKING AREA
- UTILITY AREA

ISSUED FOR DPR

REV	DATE	DESCRIPTION	BY	CHK	APP
P04	15/09/2023	FOR DETAILED PROJECT REPORT	SNJ	PK	ASM
P03	12/11/2021	FOR DETAILED PROJECT REPORT	SNJ	MS	ASM
P02	12/10/2021	FOR DETAILED PROJECT REPORT	SNJ	MS	ASM
P01	17/02/2021	FOR DETAILED PROJECT REPORT	TSM	GPS	ASM

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PROJECT
Consultancy services for Design and Detailed Engineering for Greenfield Vadhavan port project

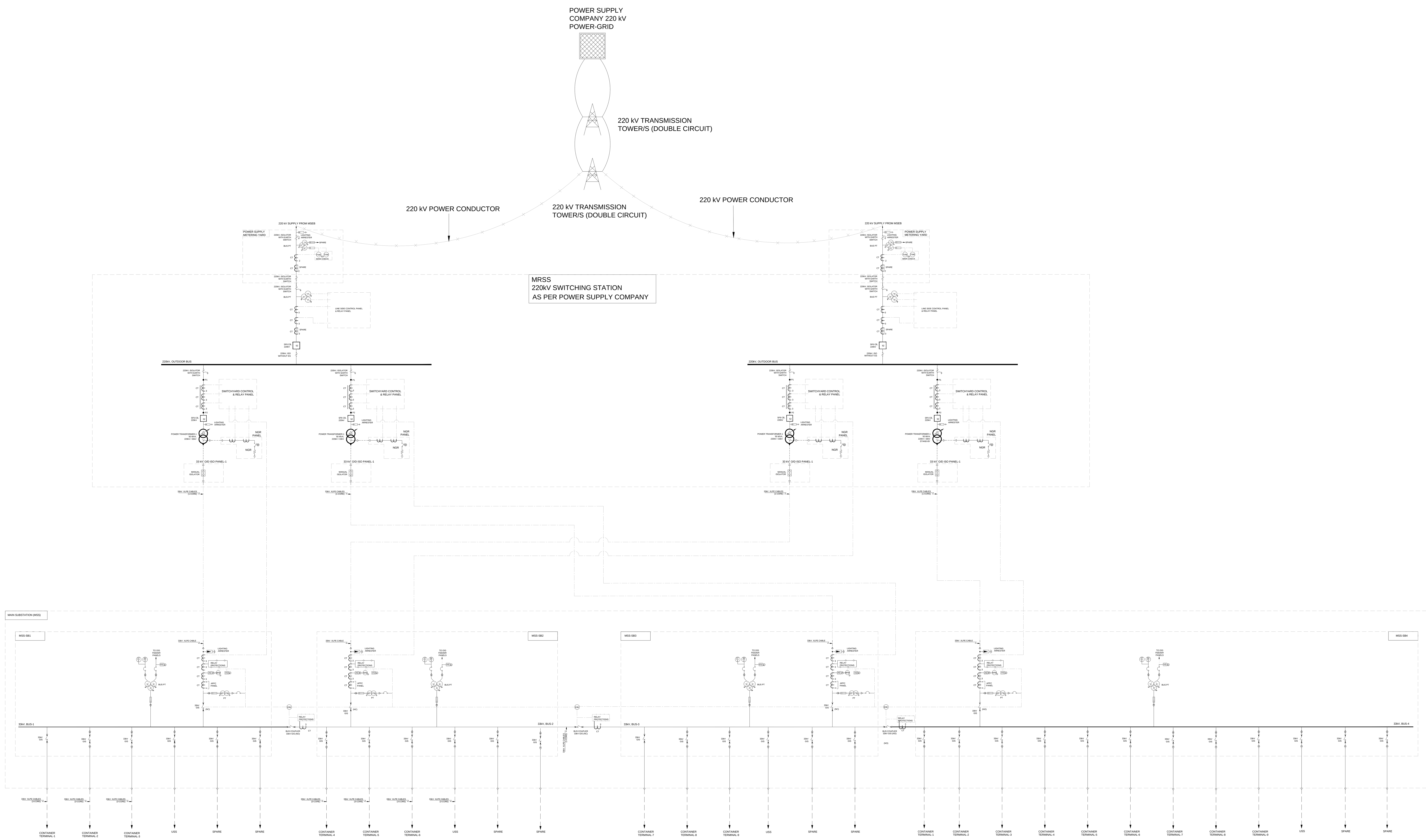
TITLE
LAND USE PLAN
FOR VADHAVAN PORT

DRAWN	CHECKED	APPROVED
SNJ	GPS	ASM
DATE FEB ' 2021	SCALE @A1 AS SHOWN	REF.

DRAWING No.	SUITABILITY	REVISION
DI1452-RHD-DP-MA-DR-CM-1003	S4	P04

DRG No.
DI1452-RHD-DP-US-DR-EE-1101

DO NOT SCALE



LEGEND DETAILS

	HRC FUSE	A_n	AMMETER n - No.OFF
	CURRENT TRANSFORMER n-NUMBER OF CTs X-X/1A-ADOPTED CT RATION	V_n	VOLTMETER n - No.OFF
	SURGE CAPACITOR	KW_D	KILO-WATT METER D - DIGITAL
	POTENTIAL TRANSFORMER	KVA	KILO-VOLTAMPERE METER
	FUSE SWITCH UNIT	PF_D	POWER FACTOR METER D - DIGITAL
52C	CIRCUIT BREAKER	KVAR D	KILO-VAR METER D - DIGITAL
	SF6 CB		
NGR	NEUTRAL GROUNDING RESISTER	VS	VOLTMETER SELECTOR SWITCH
	ISOLATOR WITH EARTH SWITCH	F_D	DIGITAL FREQUENCY METER
	LIGHTNING ARRESTOR	CBCT	CORE BALANCED CURRENT TRANSFORMER
MFM	MULTI FUNCTION METER	Y—Z	MULTIFUNCTIONAL RELAY COMPRISING OF VARIOUS PROTECTIONS (Y....Z PROTECTION COVERED)

ISSUED FOR DPR

REV	DATE	DESCRIPTION	BY	CHK	APP
P02	08/10/2021	ISSUED FOR DPR	SH	RC	RJK
P01	05/02/2021	ISSUED FOR DPR	SH	RC	RJK

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CONSULTANT
Royal HaskoningDHV
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PROJECT
Consultancy services for Design and Detailed Engineering for Greenfield Vadhavan port project

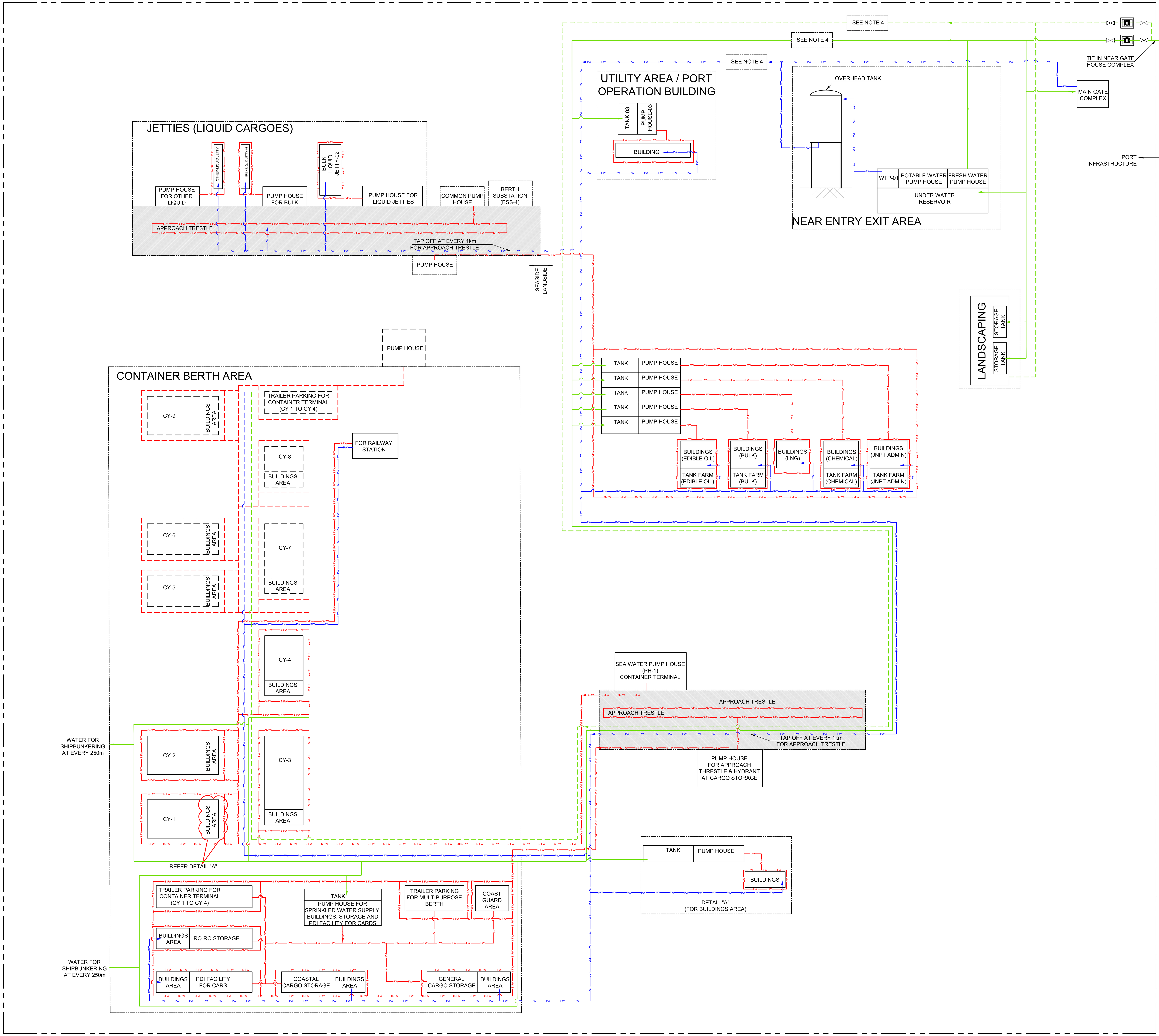
TITLE
SINGLE LINE DIAGRAM FOR ELECTRICAL DISTRIBUTION

DRAWN	CHECKED	APPROVED
SH	RC	RJK
DATE FEB'2021	SCALE @A1 NTS	REF. -

DRAWING No.	SUITABILITY	REVISION
DI1452-RHD-DP-US-DR-EE-1101	S4	P02

DRG No.
DI1452-RHD-DP-US-DR-M-1102

DO NOT SCALE



NOTES:

1. THIS DRAWING REPRESENTS THE CONCEPTUAL REQUIREMENTS.
2. THE DRAWING IS INDICATIVE AND USED AS GUIDELINE ONLY.
3. THE PUMP HOUSE QUANTITY ARE INDICATIVE ONLY, EXACT NUMBERS SHALL BE ARRIVED BASED ON HYDRAULIC CALCULATIONS USING SOFTWARE LIKE PIPE NET, AFT.
4. SUFFICIENT NUMBERS OF BOOSTER PUMP SHALL BE INSTALLED BASED ON THE DEMAND FOR ALL WATER SERVICES.
5. ALL THE EXTERNAL HYDRANTS AND MONITORS SHALL BE SEA WATER BASED SYSTEM.
6. ALL THE INTERNAL HYDRANT AND SPRINKLER SYSTEM FOR THE BUILDINGS SHALL BE FRESH WATER BASED SYSTEM.

LEGEND:

- VALVE
- FIRE WATER LINE
- SEA - FIRE WATER LINE (PH-1)
- POTABLE / FLUSHING WATER LINE (PH-1)
- WATER LINE (PH-1)
- FLOW METER
- PHASE 2 FACILITIES
- SEA - FIRE WATER LINE (PH-2)
- POTABLE / FLUSHING WATER LINE (PH-2)
- WATER LINE (PH-2)
- PH - PHASE

ISSUED FOR DPR

REV	DATE	DESCRIPTION	BY	CHK	APP
P03	15/09/2023	ISSUED FOR DPR	SNJ	PK	ASM
P02	08.10.21	ISSUED FOR DPR	PC	HHA	JRS
P01	05.02.21	ISSUED FOR DPR	PC	HHA	JRS

REVISIONS

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PROJECT
Consultancy services for Design and Detailed Engineering for Greenfield Vadhavan port project

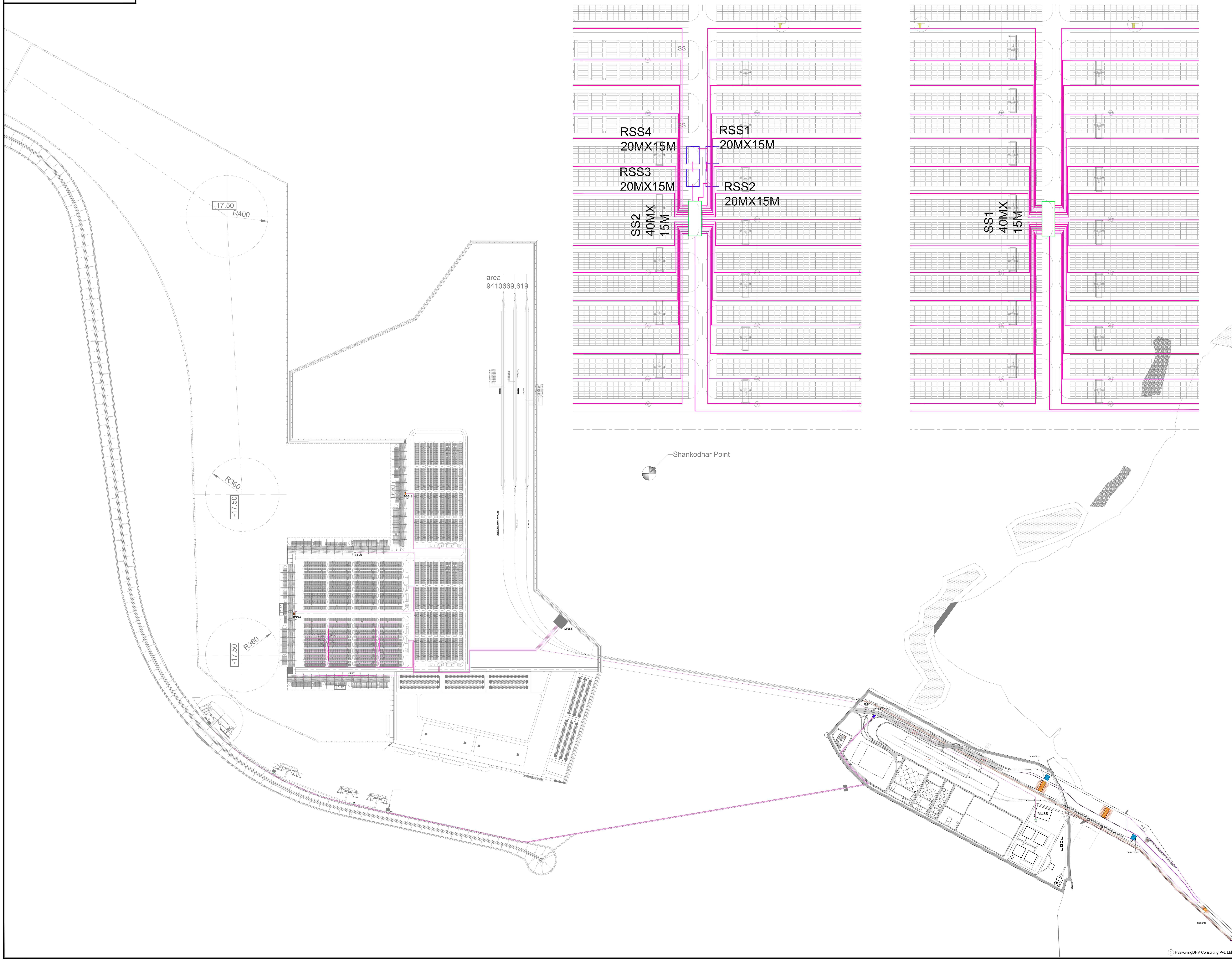
TITLE
SCHEMATIC DIAGRAM FOR RAW WATER, POTABLE WATER AND FIRE WATER SYSTEMS

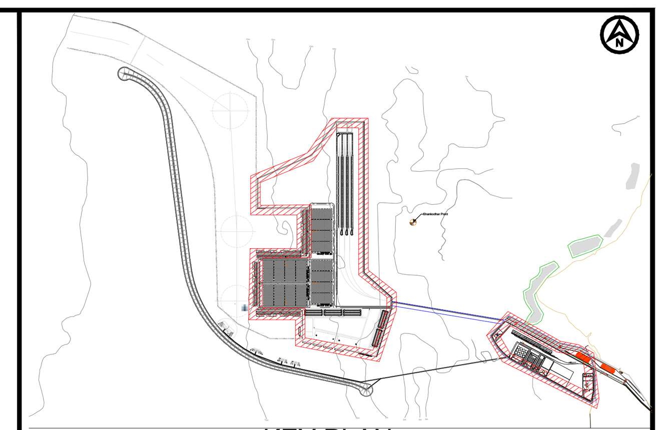
DRAWN PC	CHECKED HHA	APPROVED JRS
DATE FEB.'2021	SCALE @A1 -	REF.

DRAWING No.	SUITABILITY	REVISION
DI1452-RHD-DP-US-DR-M-1102	S4	P03

DRG No.
DI1452-RHD-DP-US-DR-M-1103

DO NOT SCALE





NOTES

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3. ANY DISCREPANCIES FOUND IN DRAWINGS ARE TO BE REPORTED TO THE ENGINEER.

LEGEND

- CABLE ROUTING
- SUBSTATION
- REEFER SUBSTATION
- BERTH SUBSTATION (BSS)
- MAIN RECEIVING SUBSTATION (MRSS)
- UTILITY SUBSTATION (USS)

ISSUED FOR DPR

REV	DATE	DESCRIPTION	BY	CHK	APP
P04	15/08/2023	ISSUED FOR DPR	SNJ	RC	RJK
P03	12/11/2021	ISSUED FOR DPR	SNJ	RC	RJK
P02	08/10/2021	ISSUED FOR DPR	SH	RC	RJK
P01	09/02/2021	ISSUED FOR DPR	SH	RC	RJK

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www.royalhaskoningdhv.com

PROJECT
Consultancy services for Design and Detailed Engineering for Greenfield Vadhavan port project

TITLE
CONCEPT UTILITY ARRANGEMENT WITH PORT AREA (SH 1 OF 3)

DRAWN SH	CHECKED RC	APPROVED RJK
DATE FEB ' 2021	SCALE @A1 1:1000	REF.

DRAWING No.	SUITABILITY	REVISION
DI1452-RHD-DP-US-DR-M-1103- SH1	S4	P04

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DRG No.
DI1452-RHD-DP-US-DR-M-1103-SH2

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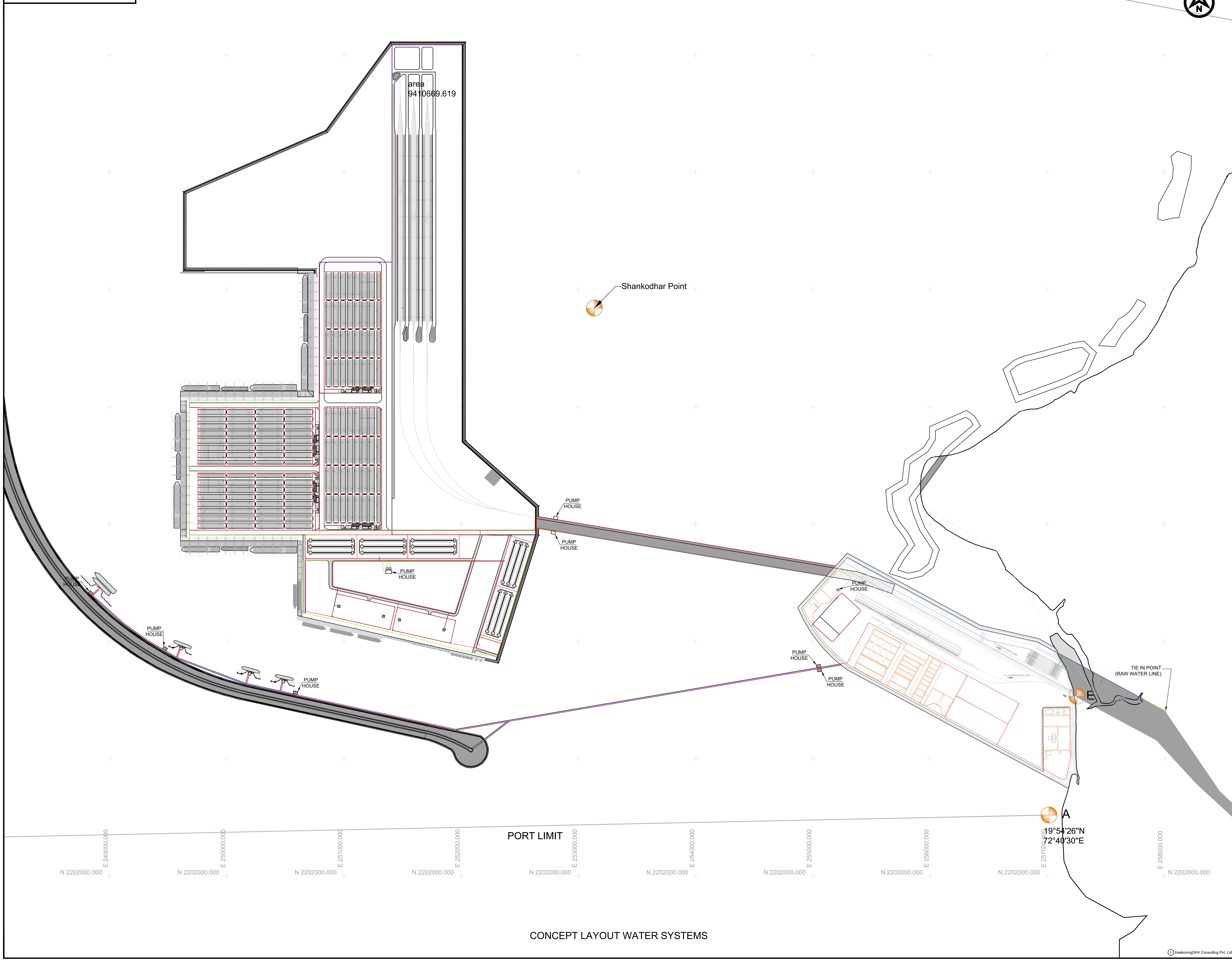
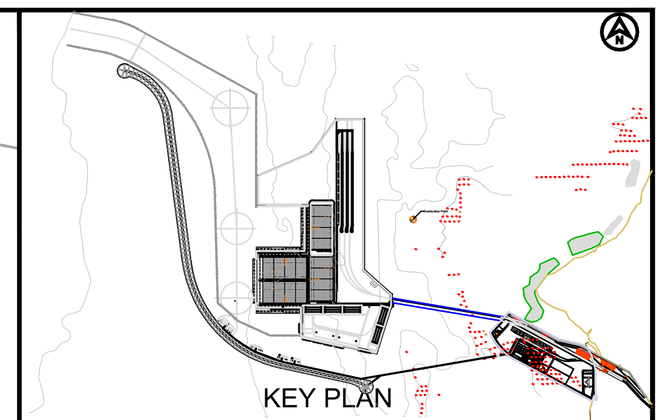


CONCEPT LAYOUT WATER SYSTEMS



NOTES

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3. ANY DISCREPANCIES FOUND IN DRAWINGS ARE TO BE REPORTED TO THE ENGINEER.
4. THE PUMP HOUSE LOCATION & QUANTITY ARE INDICATIVE ONLY, EXACT NUMBERS SHALL BE ARRIVED BASED ON HYDRAULIC CALCULATIONS USING SOFTWARE LIKE PIPE NET, AFT.
5. SUFFICIENT NUMBERS OF BOOSTER PUMP SHALL BE INSTALLED BASED ON THE DEMAND FOR ALL WATER SERVICES.

LEGEND

- FIRE WATER LINE (SEA WATER)
- FIRE WATER LINE (RAW WATER)
- POTABLE WATER LINE
- RAW WATER LINE

ISSUED FOR DPR

REV	DATE	DESCRIPTION	BY	CHK	APP
P04	15/09/2023	ISSUED FOR DPR	SNJ	HHA	JRS
P03	12/11/2021	ISSUED FOR DPR	PC	HHA	JRS
P02	08/10/2021	ISSUED FOR DPR	PC	HHA	JRS
P01	17/02/2021	ISSUED FOR DPR	PC	HHA	JRS

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PROJECT
Consultancy services for Design and Detailed Engineering for Greenfield Vadhavan port project

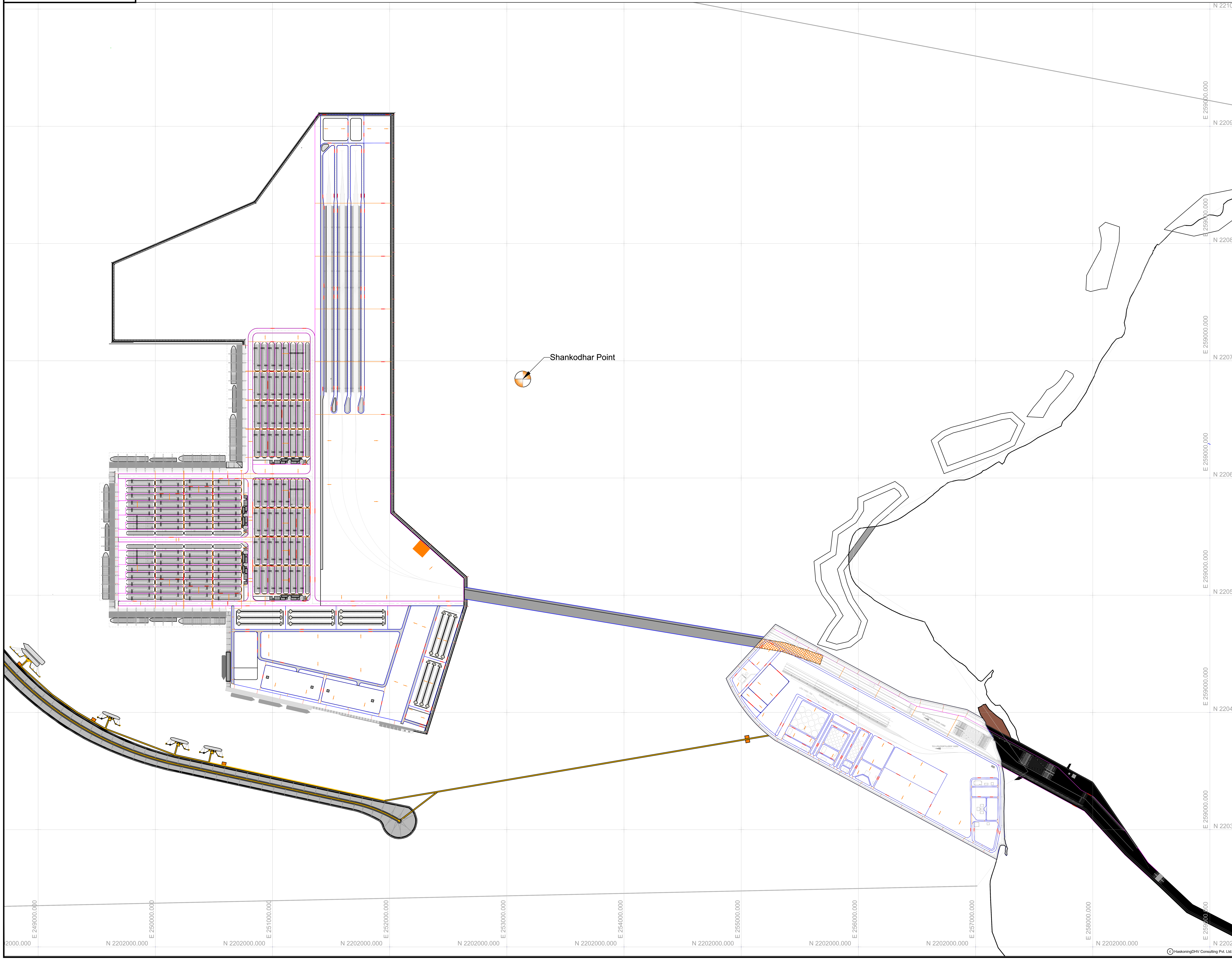
TITLE
CONCEPT UTILITY ARRANGEMENT FOR RAW WATER, POTABLE WATER AND FIREFIGHTING SYSTEM (SHEET 2 OF 3)

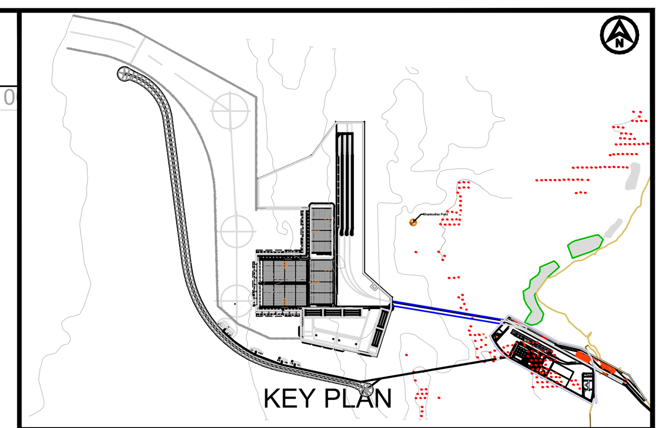
DRAWN PC	CHECKED HHA	APPROVED JRS
DATE FEB ' 2021	SCALE @A1 1:15000	REF.

DRAWING No.	SUITABILITY	REVISION
DI1452-RHD-DP-US-DR-M-1103-SH2	S4	P03

DRG No.
DI1452-RHD-DP-US-DR-M-1103-SH3

DO NOT SCALE





NOTES

1. ALL DIMENSIONS AND LEVELS ARE IN METERS, UNLESS NOTED OTHERWISE.
2. THE OUTFALL PIPES SHALL BE PROVIDED WITH A SCREEN AND FLAP VALVE.
3. DRAWINGS ARE NOT TO BE SCALED, WRITTEN DIMENSIONS SHOULD BE FOLLOWED AND VERIFIED WITH THE DETAILS.
4. DRAINS FROM OILY AREAS SHALL PASS THROUGH OIL WATER SEPARATOR BEFORE CONNECTED TO MAIN STORM DRAIN NETWORK.
5. AS PER THE FINAL INVERT LEVELS ACHIEVED IN THE PERIPHERAL ROAD DRAIN PUMPS SHALL BE INSTALLED IF REQUIRED.
6. HEAVY DUTY INSPECTION CHAMBERS SHALL BE PROVIDED AT REGULAR INTERVALS.

LEGEND

- INTERNAL ROAD STORM WATER DRAIN
- RCC PIPE / CULVERT
- PERIPHERAL MAIN ROAD & CONTAINER YARD STORM DRAIN TRENCH
- COLLECTION CHAMBER WITH OUTFALL PIPE

ISSUED FOR DPR

REV	DATE	DESCRIPTION	BY	CHK	APP
P04	15/09/2023	ISSUED FOR DPR	SNJ	SG	JRS
P03	12/11/2021	ISSUED FOR DPR	SNJ	SG	JRS
P02	07/10/2021	ISSUED FOR DPR	AK	SG	JRS
P01	17/02/2021	ISSUED FOR DPR	AK	SG	JRS

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www.royalhaskoningdhv.com

PROJECT
Consultancy services for Design and Detailed Engineering for Greenfield Vadhavan port project

TITLE
CONCEPT UTILITY ARRANGEMENT STORM WATER NETWORK (SHEET 3 OF 3)

DRAWN AK	CHECKED SG	APPROVED JRS
DATE FEB 2021	SCALE @A1 N.T.S.	REF.

DRAWING No.	SUITABILITY	REVISION
DI1452-RHD-DP-US-DR-M-1103-SH3	S4	P04

DRG No. DI1452-RHD-DP-OS-DR-CM-1104

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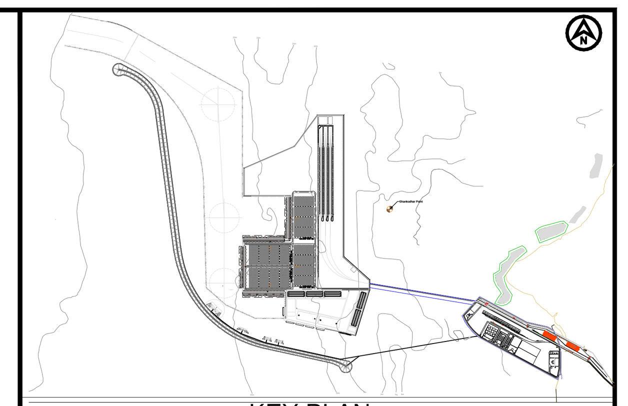

KEY PLAN

NOTES

1. ALL DIMENSIONS AND LEVELS ARE IN METERS, UNLESS NOTED OTHERWISE.
2. DRAWINGS ARE NOT TO BE SCALED, WRITTEN DIMENSIONS SHOULD BE FOLLOWED AND VERIFIED WITH THE DETAILS.
3. ANY DISCREPANCIES FOUND IN DRAWINGS ARE TO BE REPORTED TO THE ENGINEER.

LEGEND:

- PORT SIDE BUOYS
- STARBOARD BUOYS
- BEACON

KEY NOTES:

B1 - CHANNEL MARKING BUOY
FB - FAIRWAY BUOY
BN - BEACON

ISSUED FOR DPR

REV	DATE	DESCRIPTION	BY	CHK	APP
P03	12/11/2021	ISSUED FOR DPR	SNJ	MS	ASM
P02	08/10/2021	ISSUED FOR DPR	SNJ	MS	ASM
P01	05/02/2021	ISSUED FOR DPR	SNJ	ASM	ASM

REVISIONS

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PROJECT
Consultancy services for Design and Detailed Engineering for Greenfield Vadhavan port project

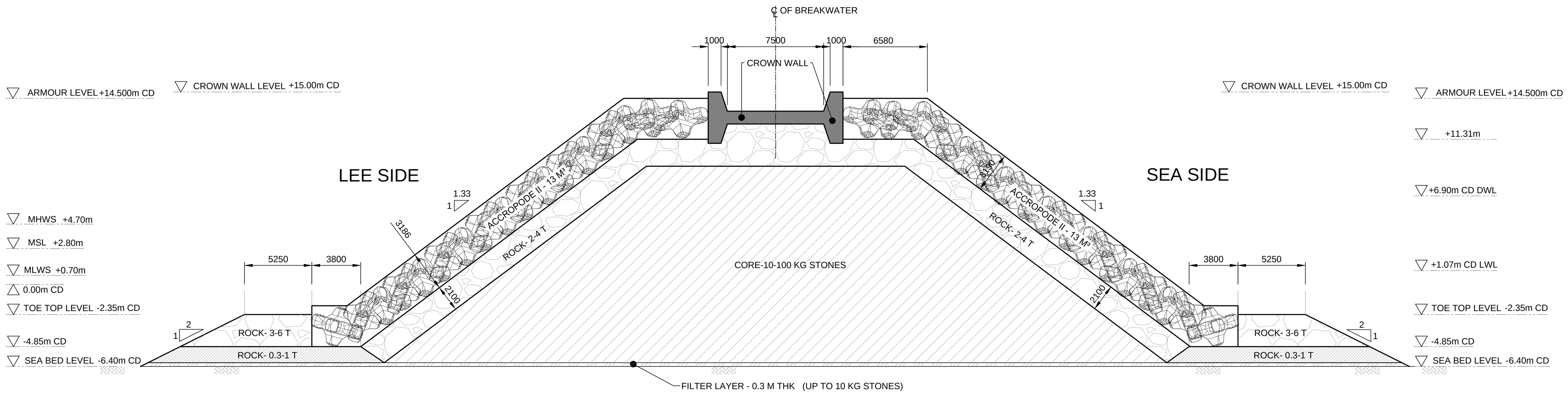
TITLE
AIDS TO NAVIGATION

DRAWN SNJ	CHECKED MS	APPROVED ASM
DATE FEB ' 2021	SCALE @A1 1:1000	REF.

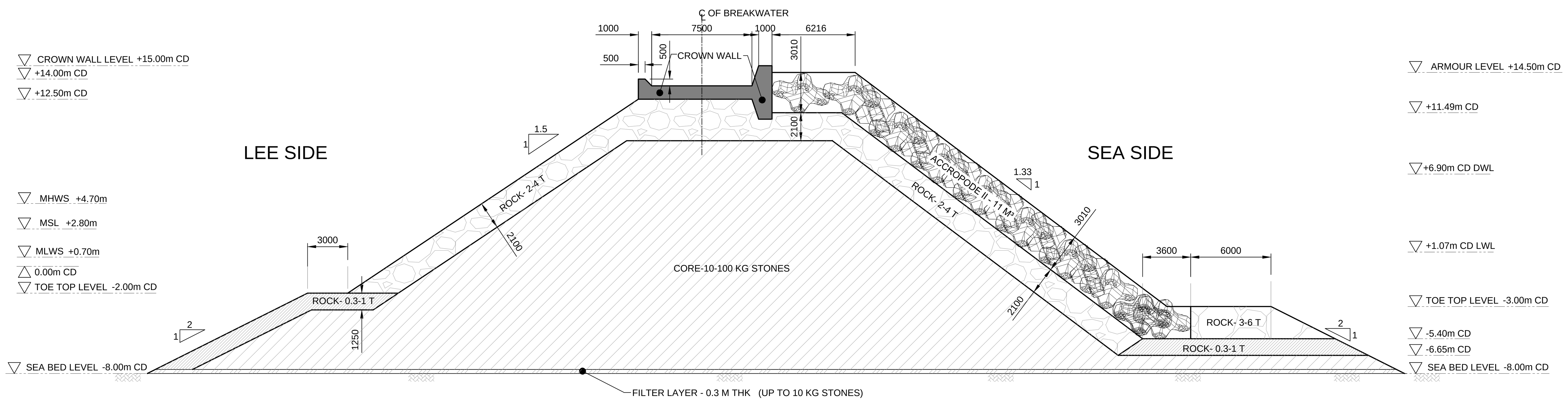
DRAWING No.	SUITABILITY	REVISION
DI1452-RHD-DP-OS-DR-CM-1104	S4	P03

DRG No.
DI1452-RHD-DP-MA-DR-CM-1201-SH1

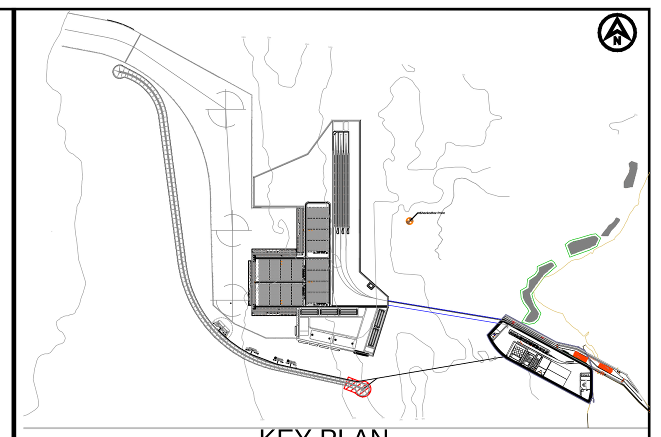
DO NOT SCALE



CROSS SECTION AT - 6.40m BED LEVEL (ROUND HEAD PORTION)
(SCALE 1:200)



CROSS SECTION AT - 8.00m BED LEVEL (TRUNK PORTION)
(SCALE 1:250)



KEY PLAN

NOTES:

1. ALL DIMENSIONS ARE IN MM AND ALL LEVELS ARE IN METRE UNLESS NOTED OTHERWISE.
2. ALL LEVELS ARE IN METRES ABOVE CHART DATUM (MARKED ±0.00m CD).
3. THIS DRAWING SHOULD NOT BE SCALED. ONLY WRITTEN DIMENSIONS SHALL BE FOLLOWED.

ISSUED FOR DPR

REV	DATE	DESCRIPTION	BY	CHK	APP
P02	08/10/2021	ISSUED FOR DPR	SNJ	MS	SD
P01	05/02/2021	ISSUED FOR DPR	SNJ	MS	SD

REVISIONS

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PROJECT
Consultancy services for Design and Detailed Engineering for Greenfield Vadhavan port project

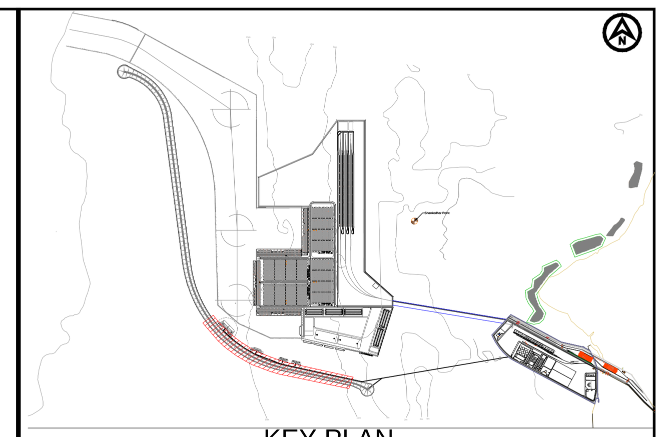
TITLE
BREAKWATER CROSS SECTIONS AT-6.40m BED LEVEL (ROUND HEAD PORTION) AND -8.00m BED LEVEL (TRUNK PORTION) (SHEET 01 OF 03)

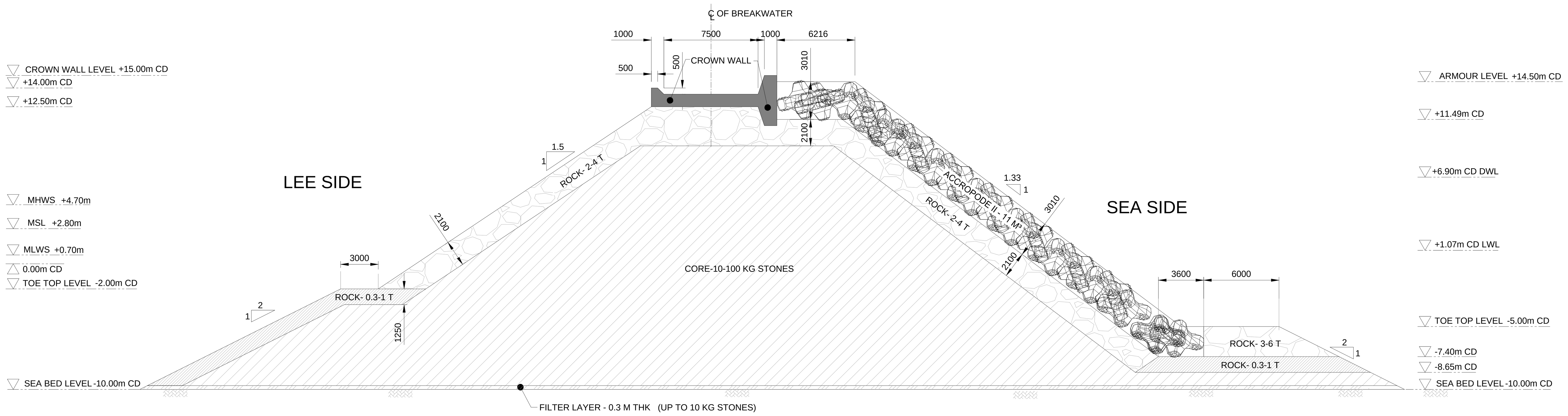
DRAWN SNJ	CHECKED MS	APPROVED SD
DATE FEB 2021	SCALE @A1 AS SHOWN	REF.

DRAWING No.	SUITABILITY	REVISION
DI1452-RHD-DP-MA-DR-CM-1201-SH1	S4	P02

DRG No.
DI1452-RHD-DP-MA-DR-CM-1201-SH2

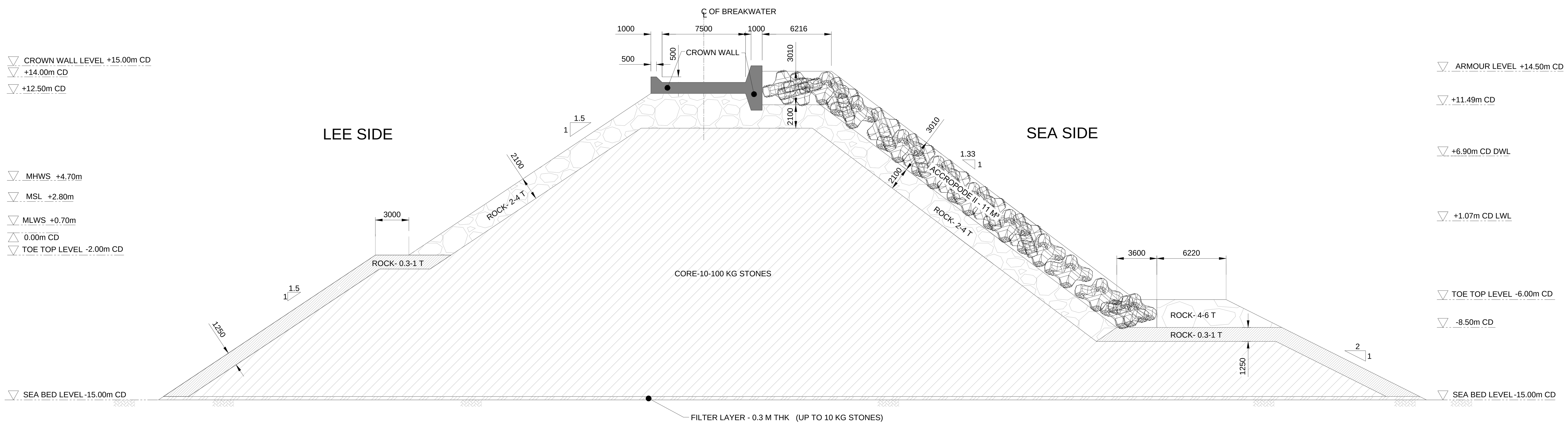
DO NOT SCALE





CROSS SECTION AT - 10.00m BED LEVEL (TRUNK PORTION)

(SCALE 1:250)



CROSS SECTION AT - 15.00m BED LEVEL (TRUNK PORTION)

(SCALE 1:250)

NOTES:

1. ALL DIMENSIONS ARE IN MM AND ALL LEVELS ARE IN METRE UNLESS NOTED OTHERWISE.
2. ALL LEVELS ARE IN METRES ABOVE CHART DATUM (MARKED ±0.00m CD).
3. THIS DRAWING SHOULD NOT BE SCALED. ONLY WRITTEN DIMENSIONS SHALL BE FOLLOWED.

ISSUED FOR DPR

REV	DATE	DESCRIPTION	BY	CHK	APP
P02	08/10/21	ISSUED FOR DPR	SNJ	MS	SD
P01	05/02/21	ISSUED FOR DPR	SNJ	MS	SD

REVISIONS

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JAWAHARLAL NEHRU PORT TRUST

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PROJECT
Consultancy services for Design and Detailed Engineering for Greenfield Vadhavan port project

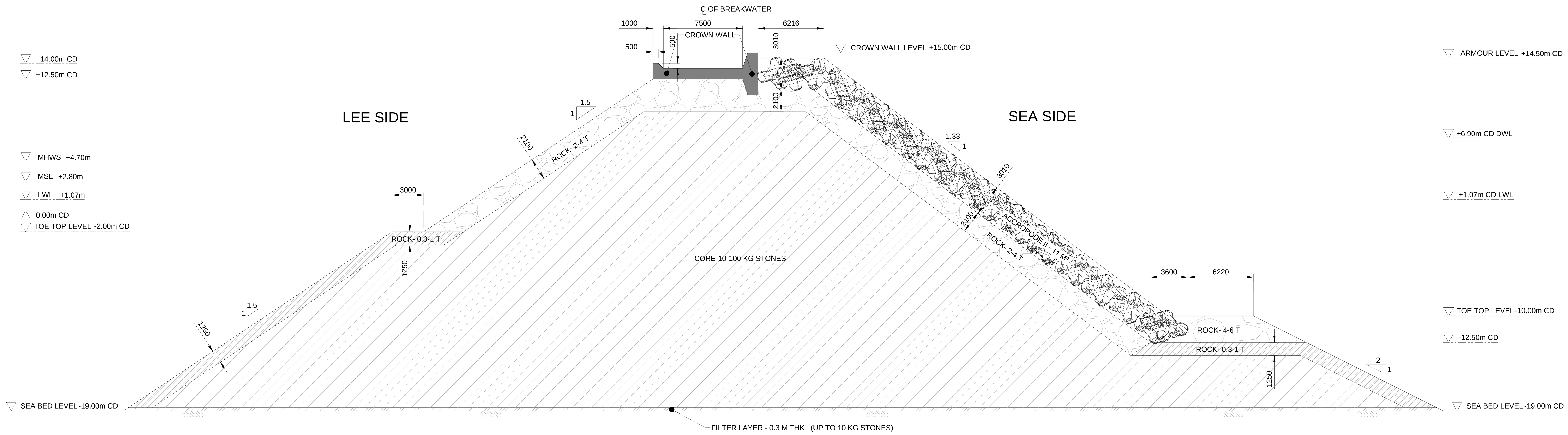
TITLE
BREAKWATER CROSS SECTIONS AT-10.00m BED LEVEL (TRUNK PORTION) AND -15.00m BED LEVEL (TRUNK PORTION) (SHEET 02 OF 03)

DRAWN	CHECKED	APPROVED
SNJ	MS	SD
DATE FEB 2021	SCALE @A1 AS SHOWN	REF.

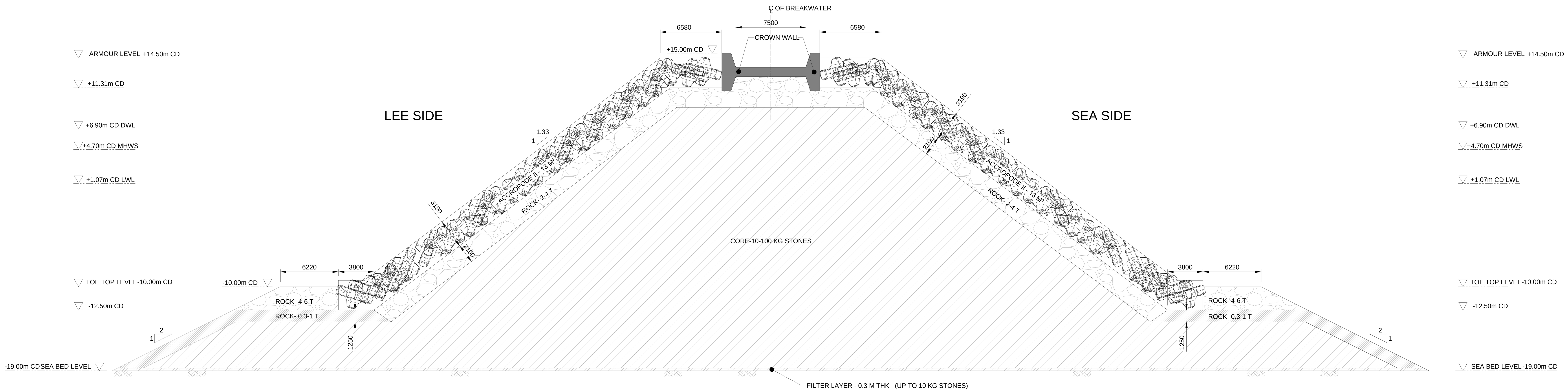
DRAWING No.	SUITABILITY	REVISION
DI1452-RHD-DP-MA-DR-CM-1201-SH2	S4	P02

DRG No.
DI1452-RHD-DP-MA-DR-CM-1201-SH3

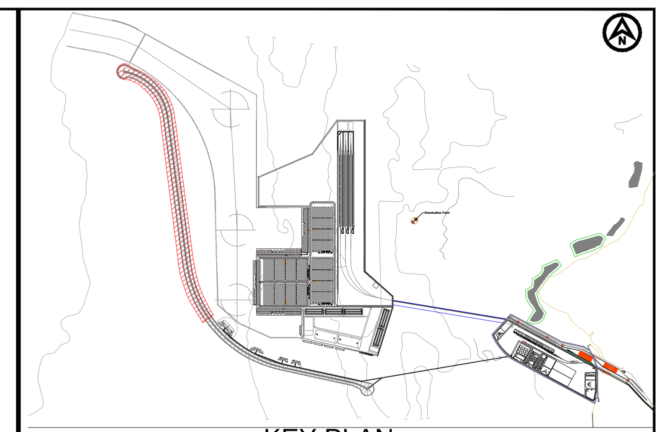
DO NOT SCALE



CROSS SECTION AT - 19.00m BED LEVEL (TRUNK PORTION)
(SCALE 1:250)



CROSS SECTION AT - 19.00m BED LEVEL (ROUND HEAD PORTION)
(SCALE 1:250)



KEY PLAN

NOTES:

1. ALL DIMENSIONS ARE IN MM AND ALL LEVELS ARE IN METRE UNLESS NOTED OTHERWISE.
2. ALL LEVELS ARE IN METRES ABOVE CHART DATUM (MARKED ±0.00m CD).
3. THIS DRAWING SHOULD NOT BE SCALED. ONLY WRITTEN DIMENSIONS SHALL BE FOLLOWED.

ISSUED FOR DPR

REV	DATE	DESCRIPTION	BY	CHK	APP
P02	08/10/21	ISSUED FOR DPR	SNJ	MS	SD
P01	05/02/21	ISSUED FOR DPR	SNJ	MS	SD

REVISIONS

CLIENT
JAWAHARLAL NEHRU PORT TRUST

CONSULTANT
Royal HaskoningDHV
Enhancing Society Together

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Tel +91 (0) 22 61395000
Email info.india@rhdhv.com
www.royalhaskoningdhv.com

PROJECT
Consultancy services for Design and Detailed Engineering for Greenfield Vadhavan port project

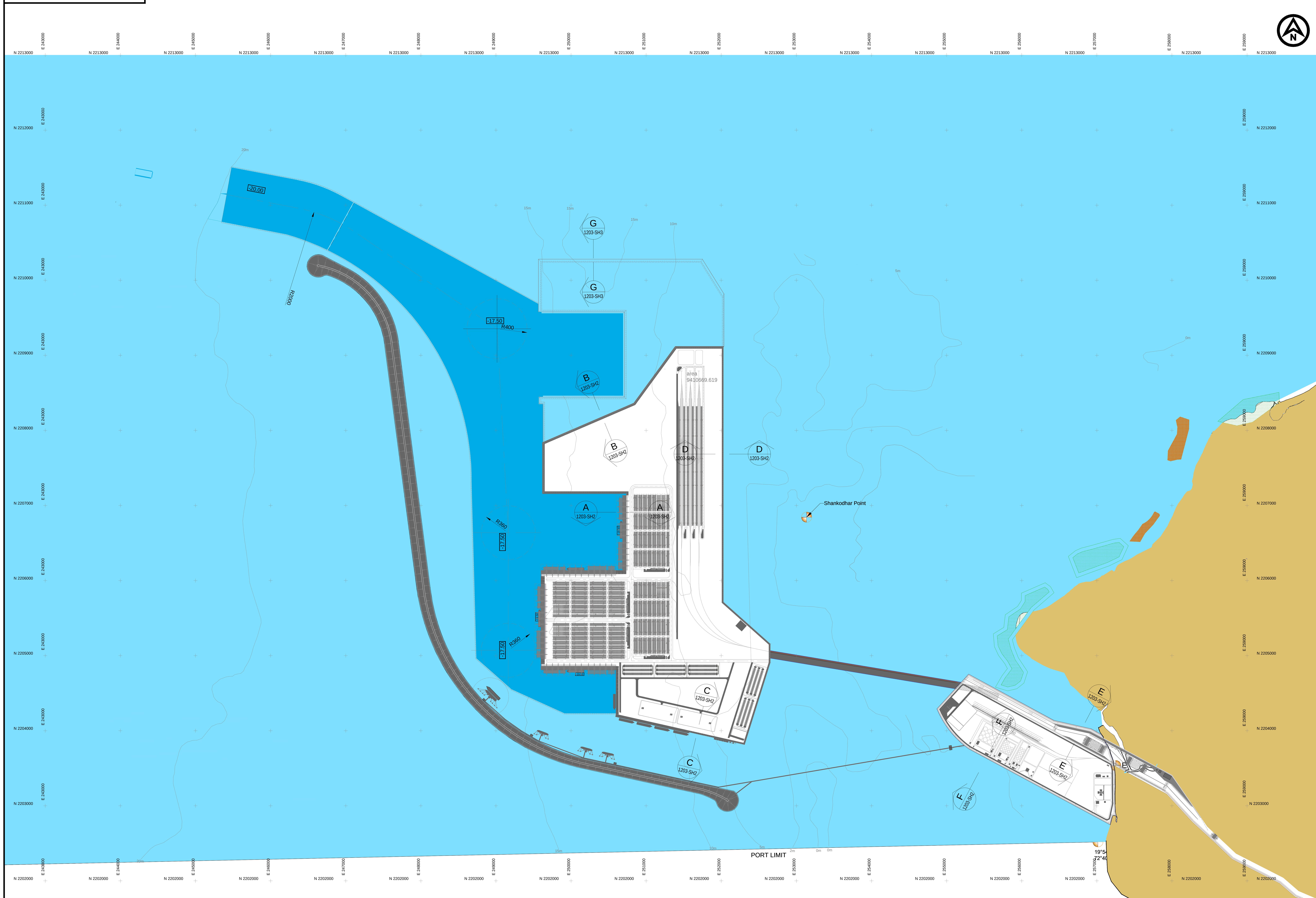
TITLE
BREAKWATER CROSS SECTIONS AT -19.00m BED LEVEL (TRUNK PORTION) AND -19.00m BED LEVEL (ROUND - HEAD PORTION) (SHEET 03 OF 03)

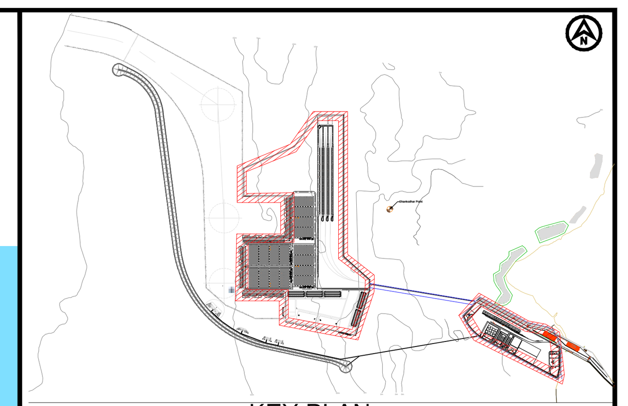
DRAWN	CHECKED	APPROVED
SNJ	MS	SD
DATE FEB 2021	SCALE @A1 AS SHOWN	REF. -

DRAWING No.	SUITABILITY	REVISION
DI1452-RHD-DP-MA-DR-CM-1201-SH3	S4	P02

DRG No.
DI1452-RHD-DP-MA-DR-CM-1202

DO NOT SCALE





KEY PLAN

NOTES

1. ALL DIMENSIONS AND LEVELS ARE IN METERS, UNLESS NOTED OTHERWISE.
2. DRAWINGS ARE NOT TO BE SCALED, WRITTEN DIMENSIONS SHOULD BE FOLLOWED AND VERIFIED WITH THE DETAILS.
3. ANY DISCREPANCIES FOUND IN DRAWINGS ARE TO BE REPORTED TO THE ENGINEER.

ISSUED FOR DPR

REV	DATE	DESCRIPTION	BY	CHK	APP
P04	12/11/2021	ISSUED FOR DPR	TSM	MS	SD
P03	29/10/2021	ISSUED FOR DPR	TSM	MS	SD
P02	28/10/2021	ISSUED FOR DPR	TSM	MS	SD
P01	29/01/2021	ISSUED FOR DPR	SNJ	MS	SD

REVISIONS

CLIENT

JAWAHARLAL NEHRU PORT TRUST

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PROJECT

Consultancy services for Design and Detailed Engineering for Greenfield Vadhavan port project

TITLE

VADHAVAN PORT PHASE 1 LAYOUT FOR SHORE PROTECTION CROSS SECTION MARKS (SHEET 1 OF 2)

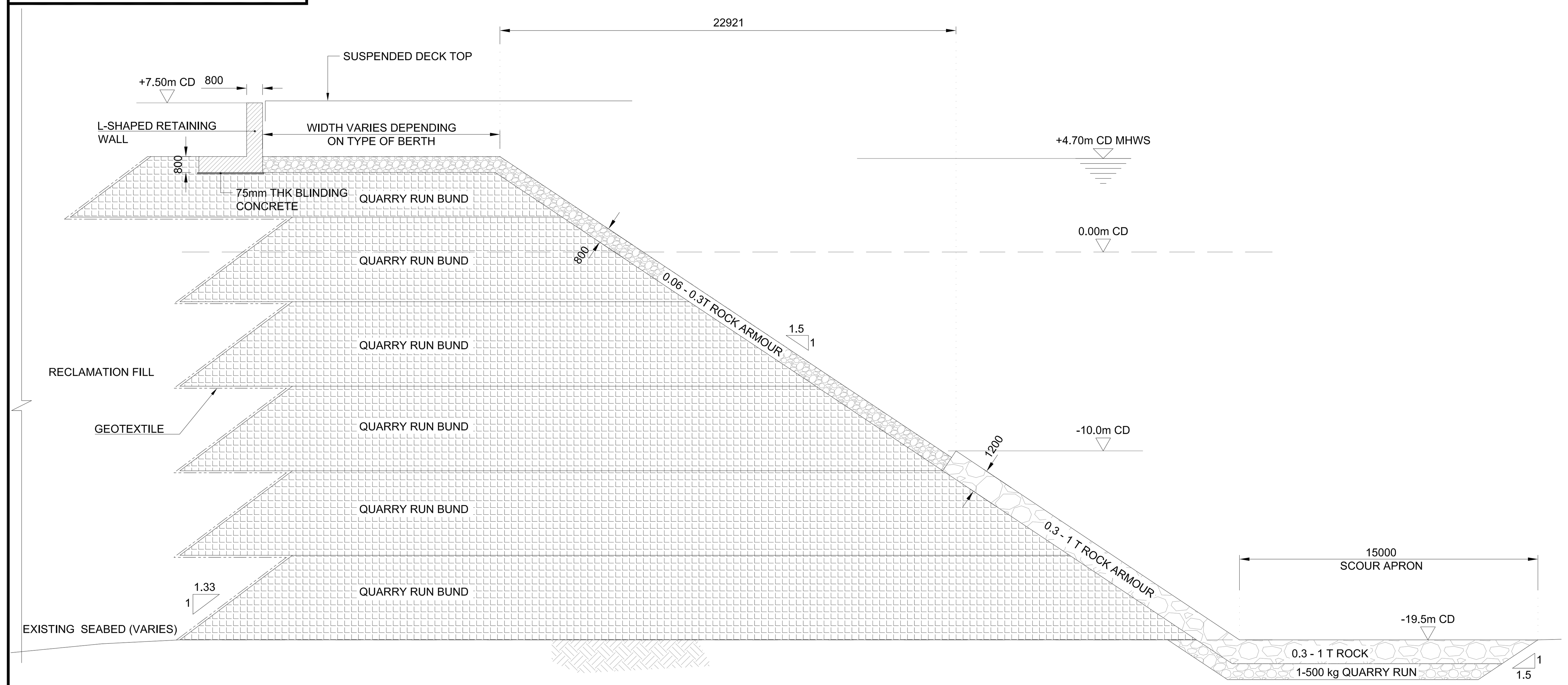
DRAWN SNJ	CHECKED MS	APPROVED ASM
DATE SEP ' 2021	SCALE @A1 1:1000	REF.

DRAWING No.	SUITABILITY	REVISION
DI1452-RHD-DP-MA-DR-CM-1202	S4	P04

FILE INFO C:\Users\231401\Box\DI1452 Vadhavan Port\Master File Folder\20211029_Final Drawing\20211112_Drawings\DI1452-RHD-DP-MA-DR-CM-1202-S4-P04\DI1452-RHD-DP-MA-DR-CM-1202-S4P04.dwg 12-Nov-21

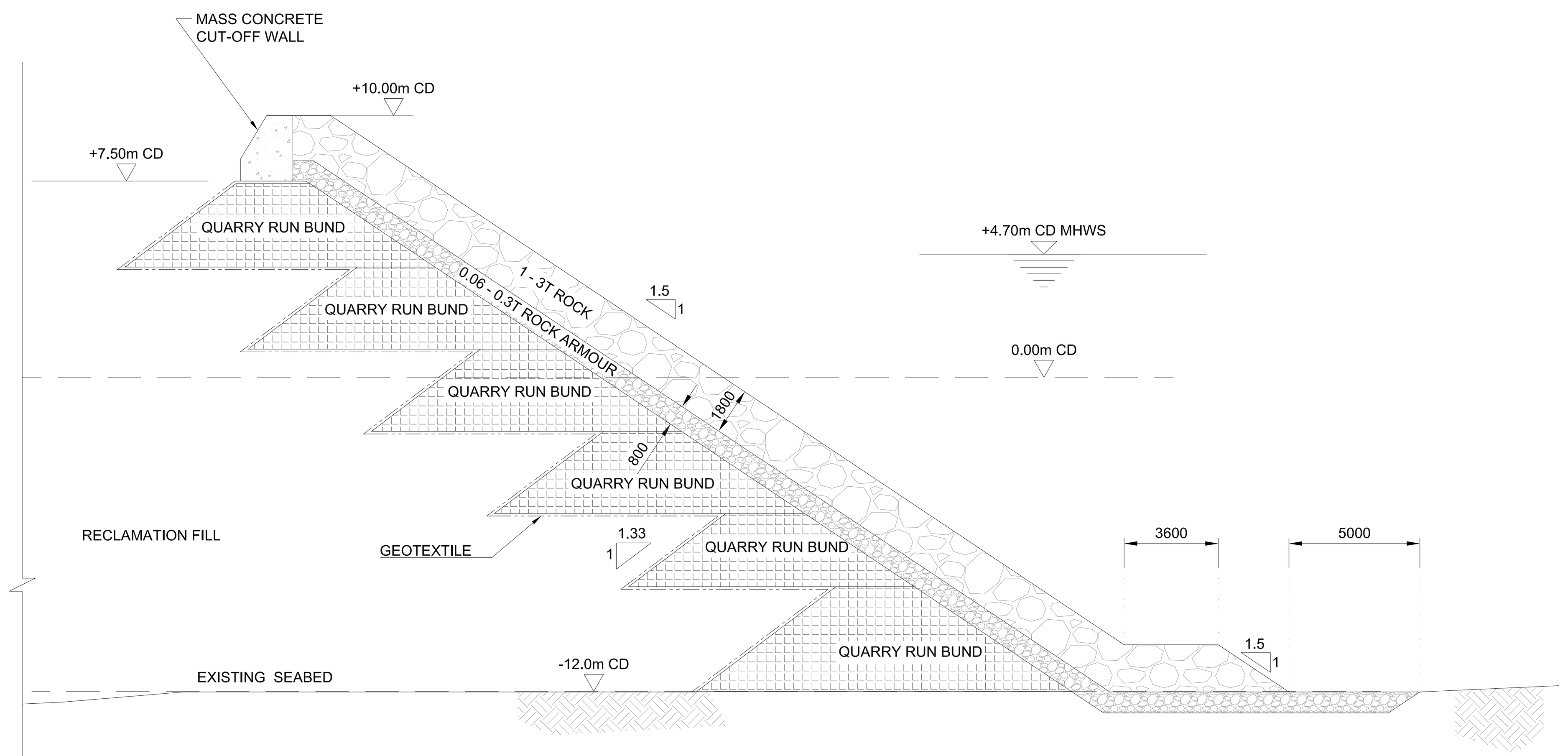
DRG No.
DI1452-RHD-DP-MA-DR-CM-1203

DO NOT SCALE



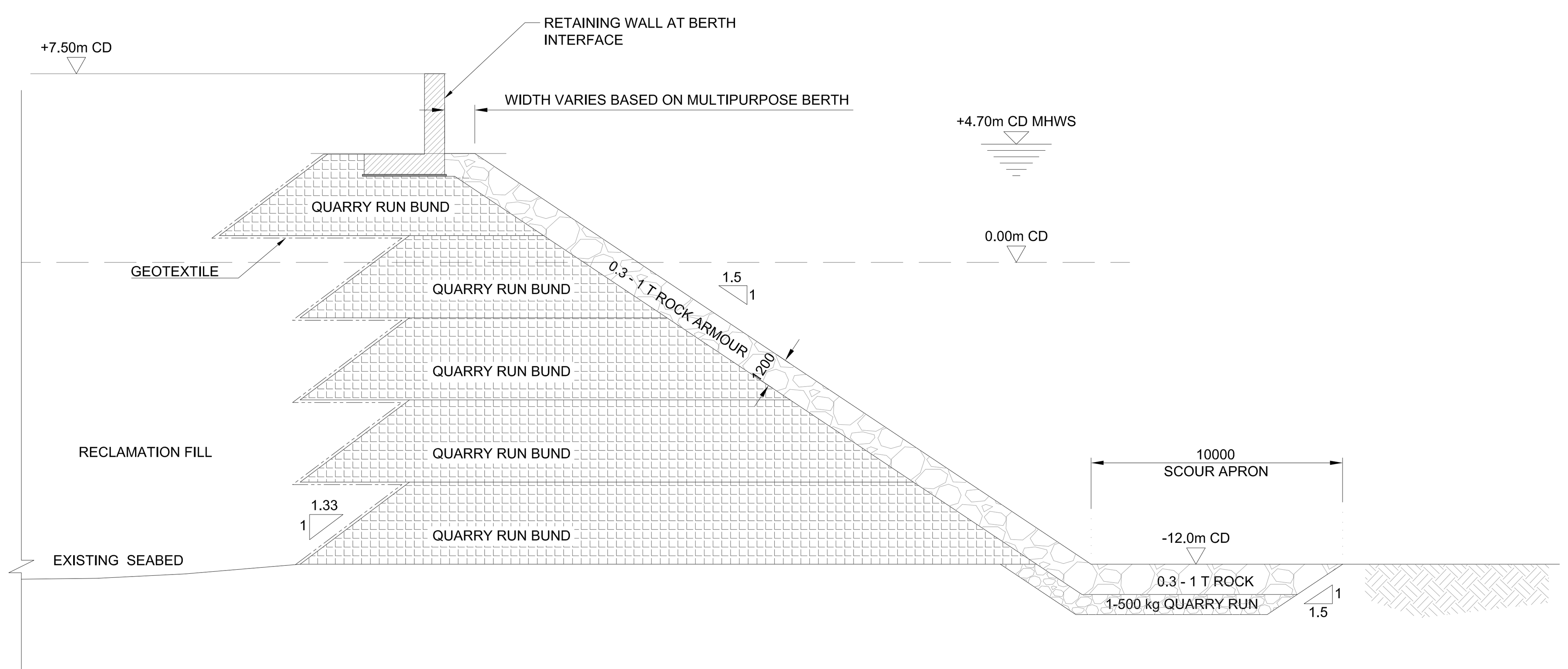
BERTH REVETMENT SECTION A-A

(SCALE 1:200)



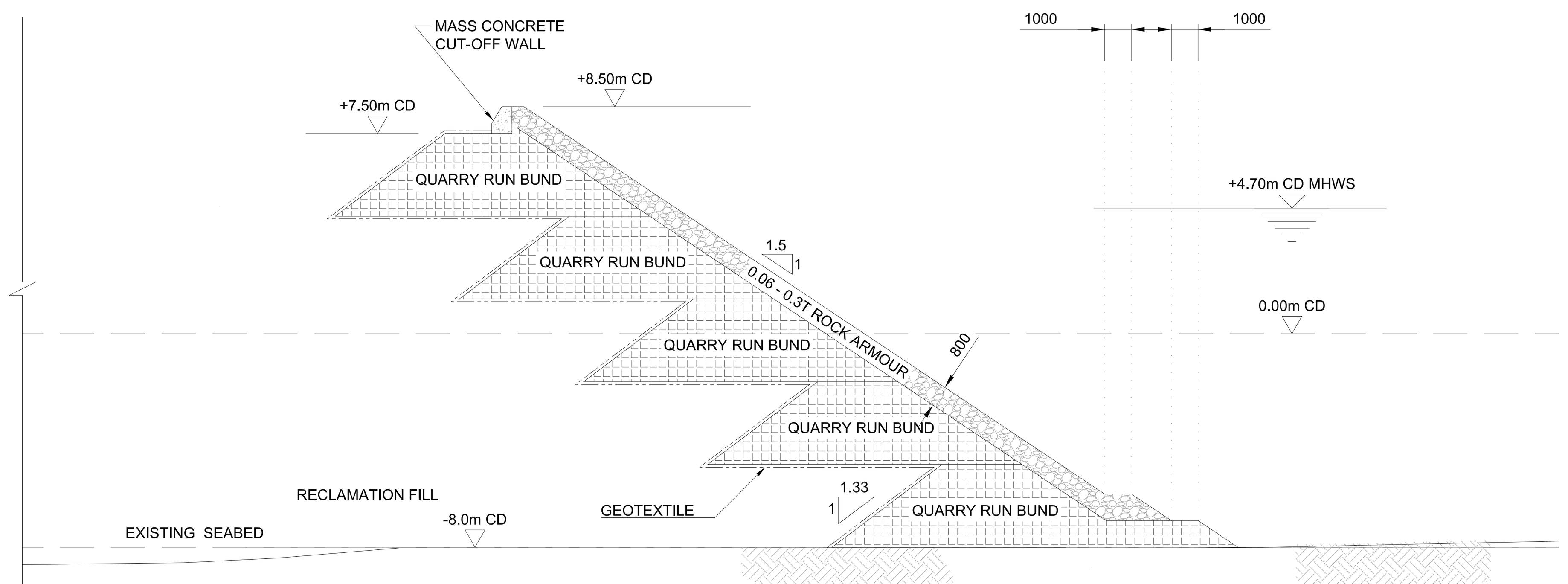
NORTHERN REVETMENT SECTION B-B

(SCALE 1:200)



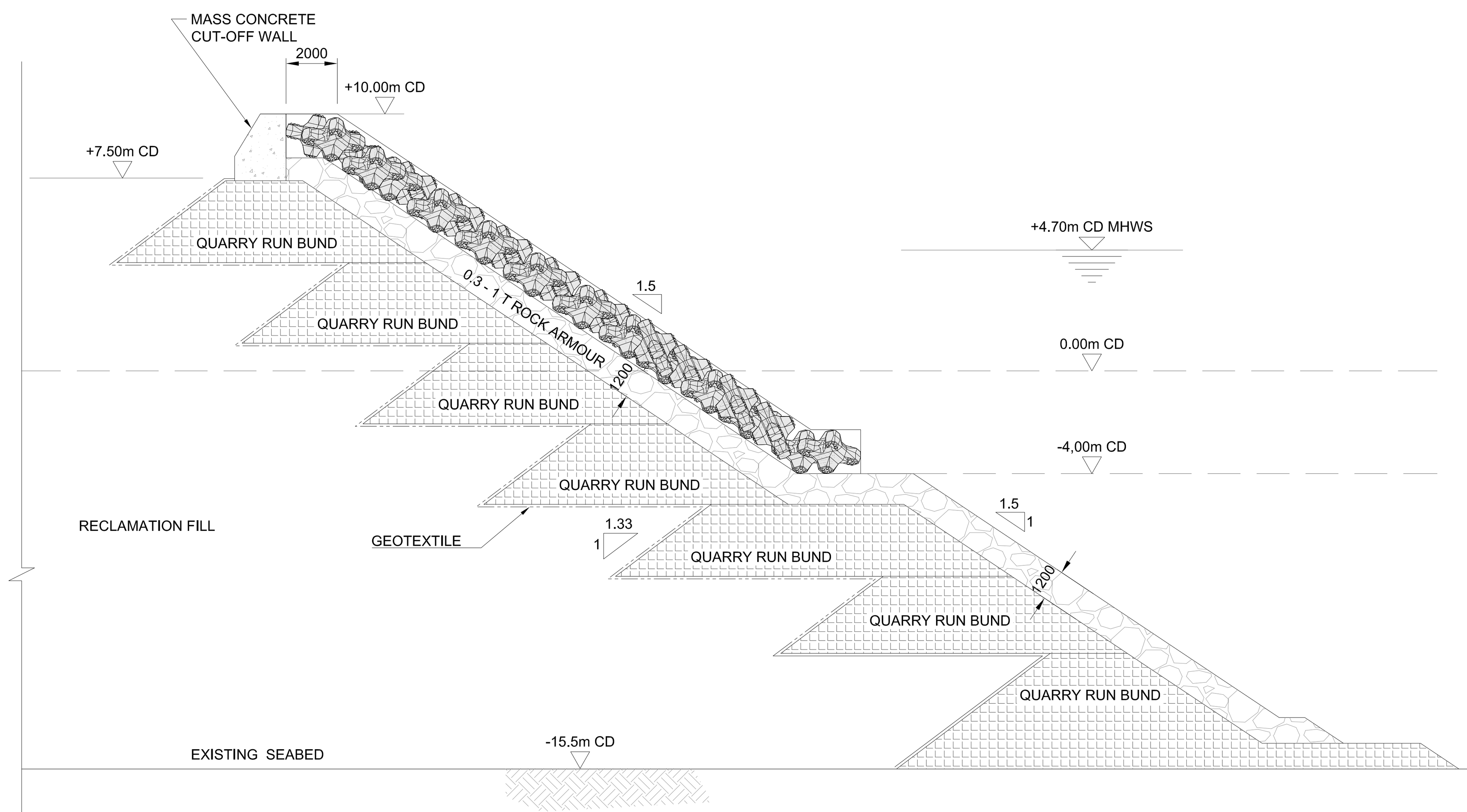
SOUTHERN REVETMENT SECTION C-C

(SCALE 1:200)



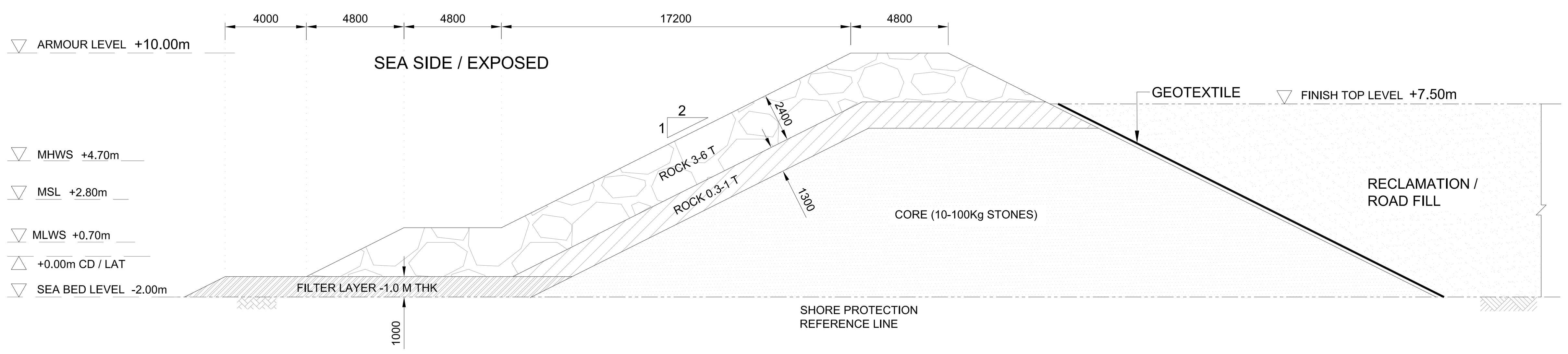
EASTERN REVETMENT SECTION D-D

(SCALE 1:200)



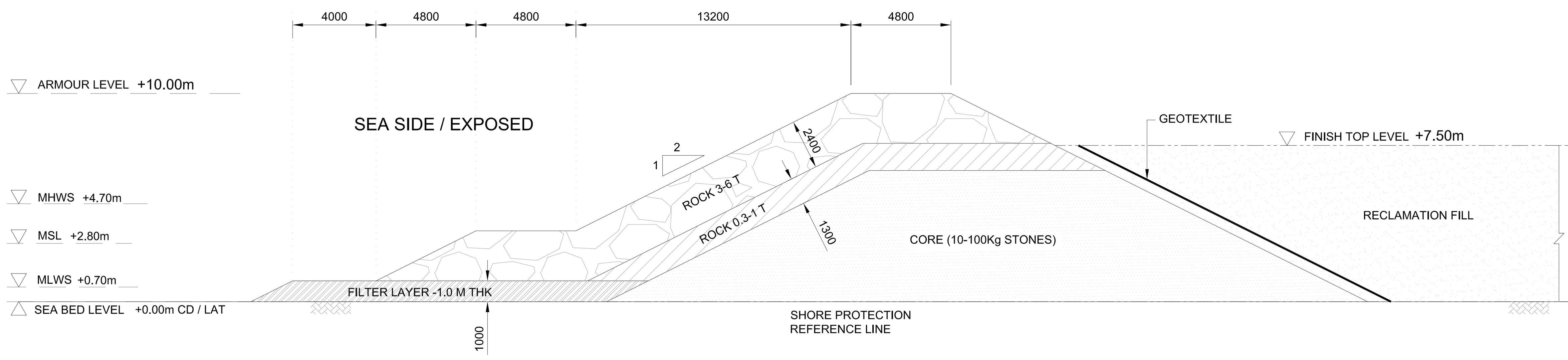
PHASE - 2 SECTIONS - BERTH REVETMENT SECTION G-G

(SCALE 1:200)



NEAR SHORE REVETMENT SECTION E-E

(SCALE 1:200)



NEAR SHORE REVETMENT SECTION F-F

(SCALE 1:200)

NOTES:

1. ALL DIMENSIONS ARE IN MILLIMETERS UNLESS NOTED OTHERWISE.
2. ALL LEVELS IN METERS RELATIVE TO CHART DATUM.
3. DRAWING SHALL NOT BE SCALED. ONLY WRITTEN DIMENSIONS ARE TO BE FOLLOWED.
4. ANY DISCREPANCIES FOUND IN DRAWINGS ARE TO BE REPORTED TO THE ENGINEER.

ISSUED FOR DPR

REV	DATE	DESCRIPTION	BY	CHK	APP
P03	29/10/2021	ISSUED FOR DPR	YSK	MS	SD
P02	06/10/2021	ISSUED FOR DPR	YSK	MS	SD
P01	29/01/2021	ISSUED FOR DPR	SNJ	MS	SD

REVISIONS

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Enhancing Society Together

PROJECT
Consultancy services for Design and Detailed Engineering for Greenfield Vadhavan port project

TITLE
SHORE PROTECTION WORKS -CROSS SECTION FOR PHASE 1 DEVELOPMENT (SHEET 2 OF 2)

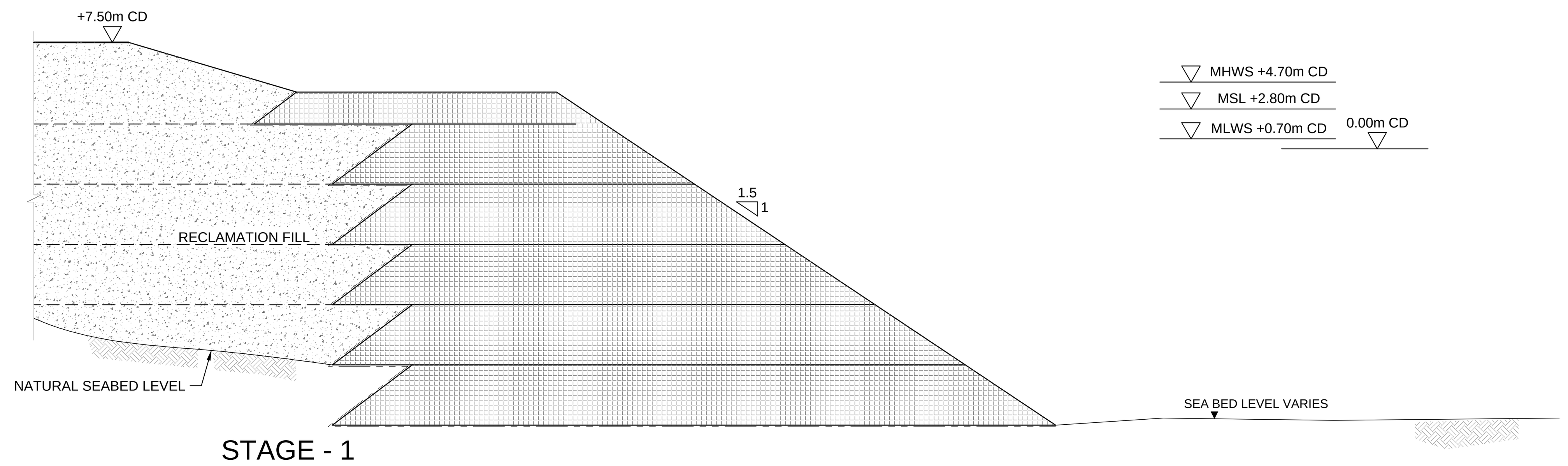
DRAWN SNJ	CHECKED MS	APPROVED SD
DATE SEP' 2021	SCALE @A1 1:200	REF. -

DRAWING No.	SUITABILITY	REVISION
DI1452-RHD-DP-MA-DR-CM-1203	S4	P03

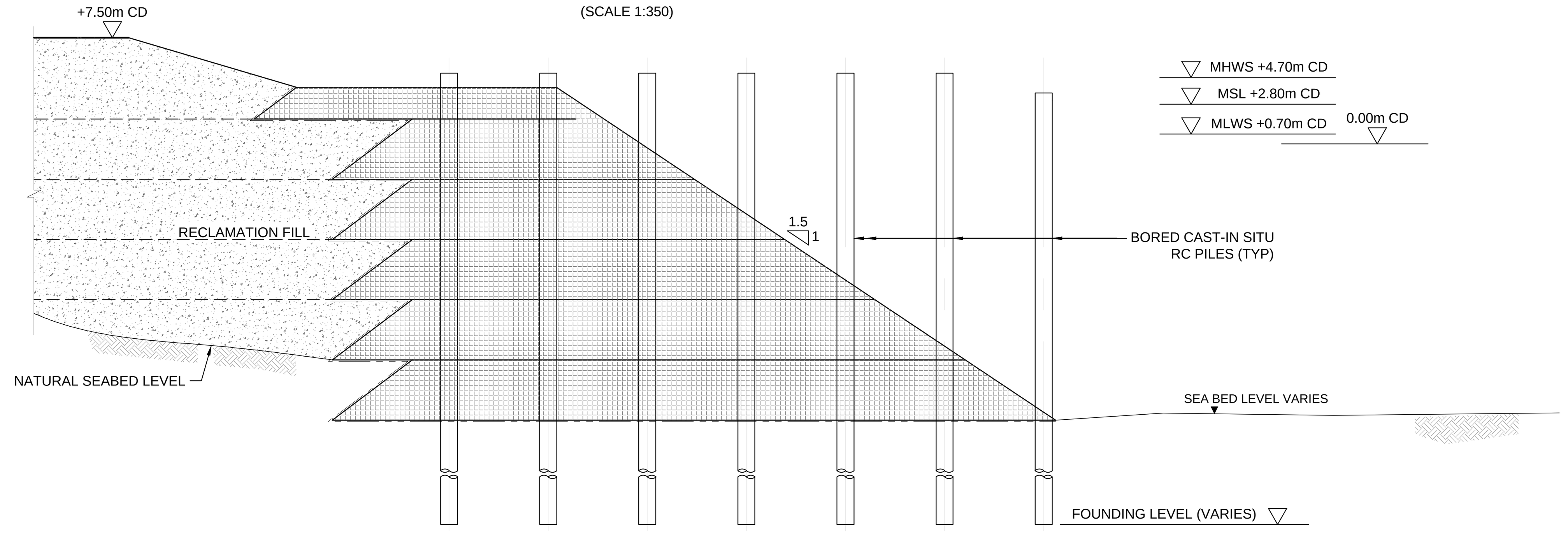
FILE INFO C:\Users\231401\Box\DI1452 Vadhavan Port\00 Drawings\September Drg Set\DI1452-RHD-DP-MA-DR-CM-1203-S4P03.dwg 28-Oct-21

DRG No.
DI1452-RHD-DP-MA-DR-CM-1204

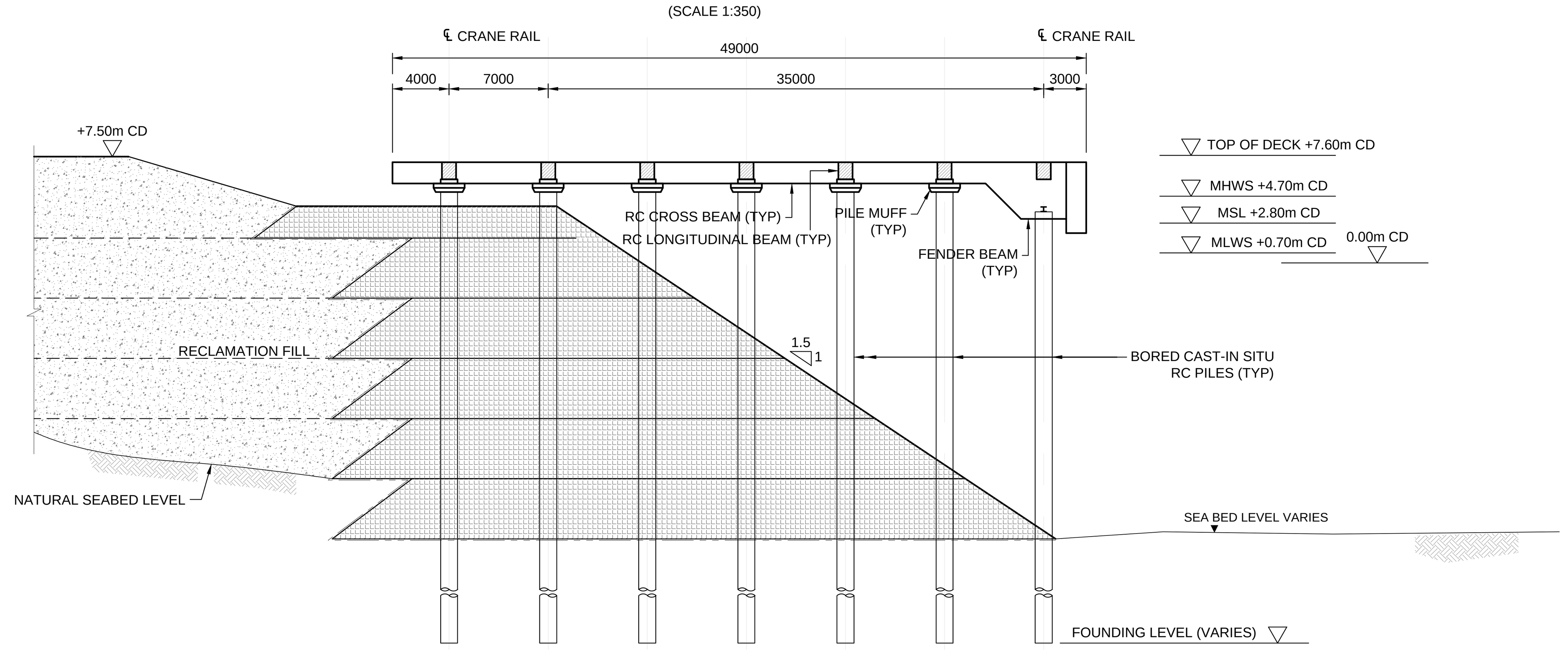
DO NOT SCALE



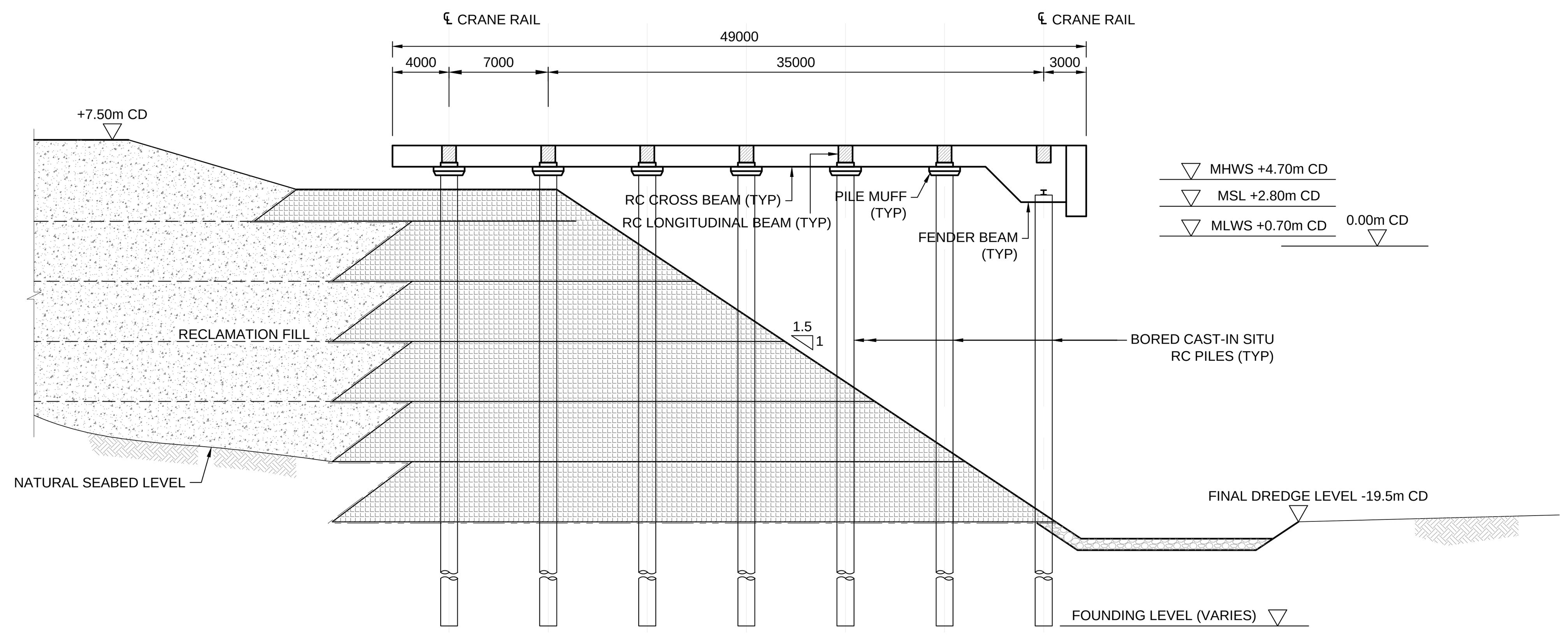
STAGE - 1
RECLAMATION OF BACKUP AREA, PLACING OF GEOTEXTILE FABRIC & QUARRY STONE
(SCALE 1:350)



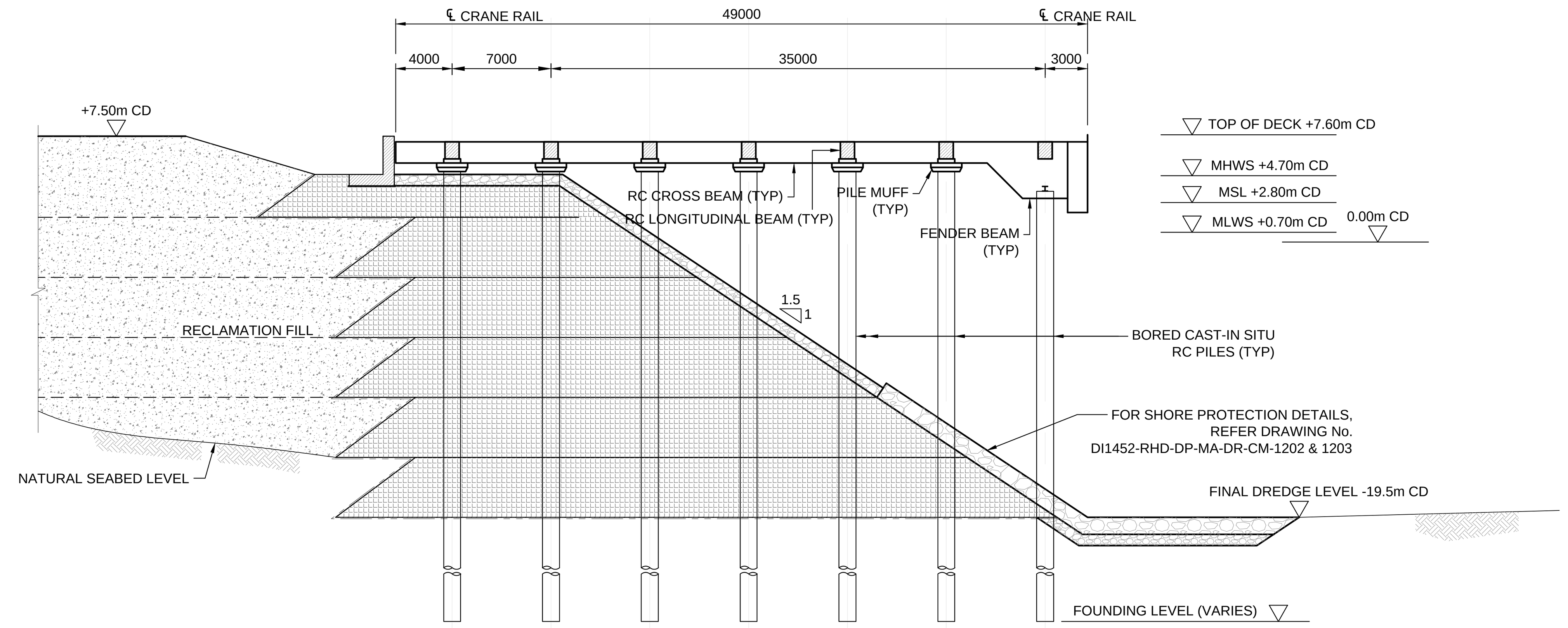
STAGE - 2
CONSTRUCT BORED CAST IN-SITU CONCRETE PILE
(SCALE 1:350)



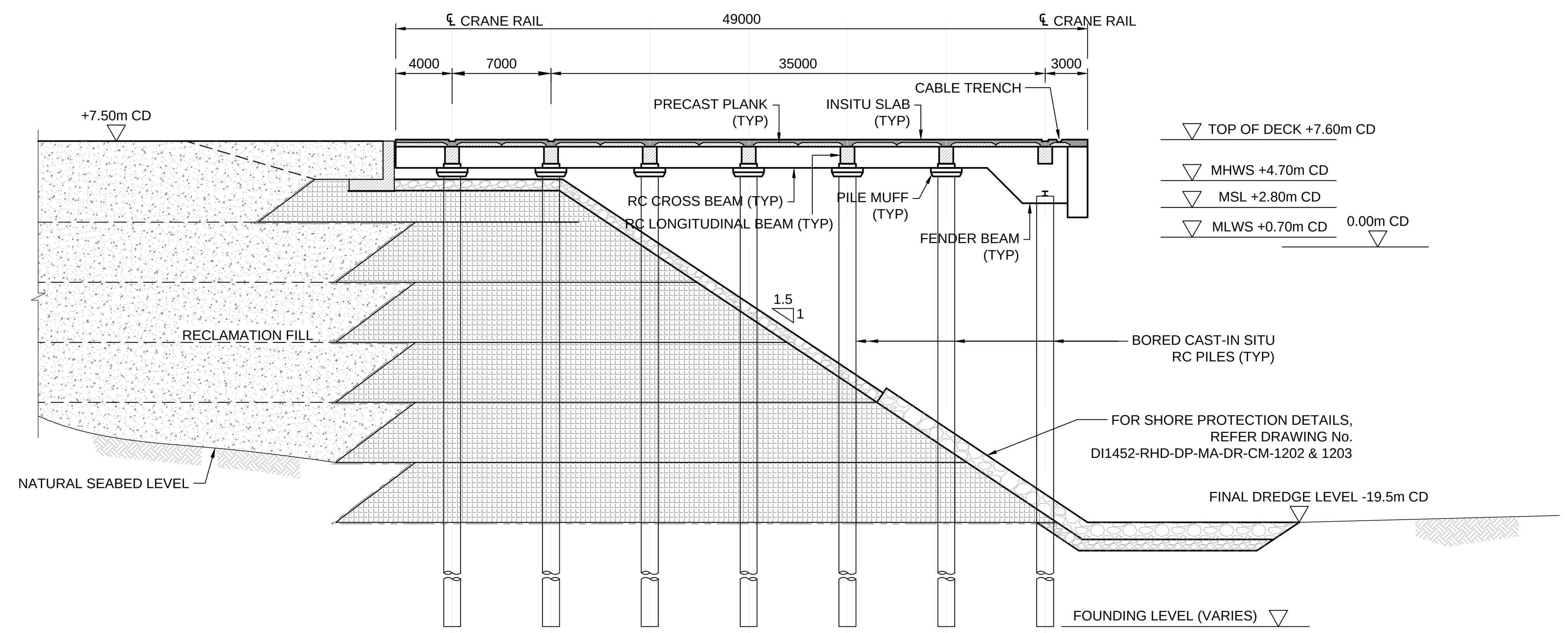
STAGE - 3
ERECTION OF LONGITUDINAL & TRANSVERSE BEAM
(SCALE 1:350)



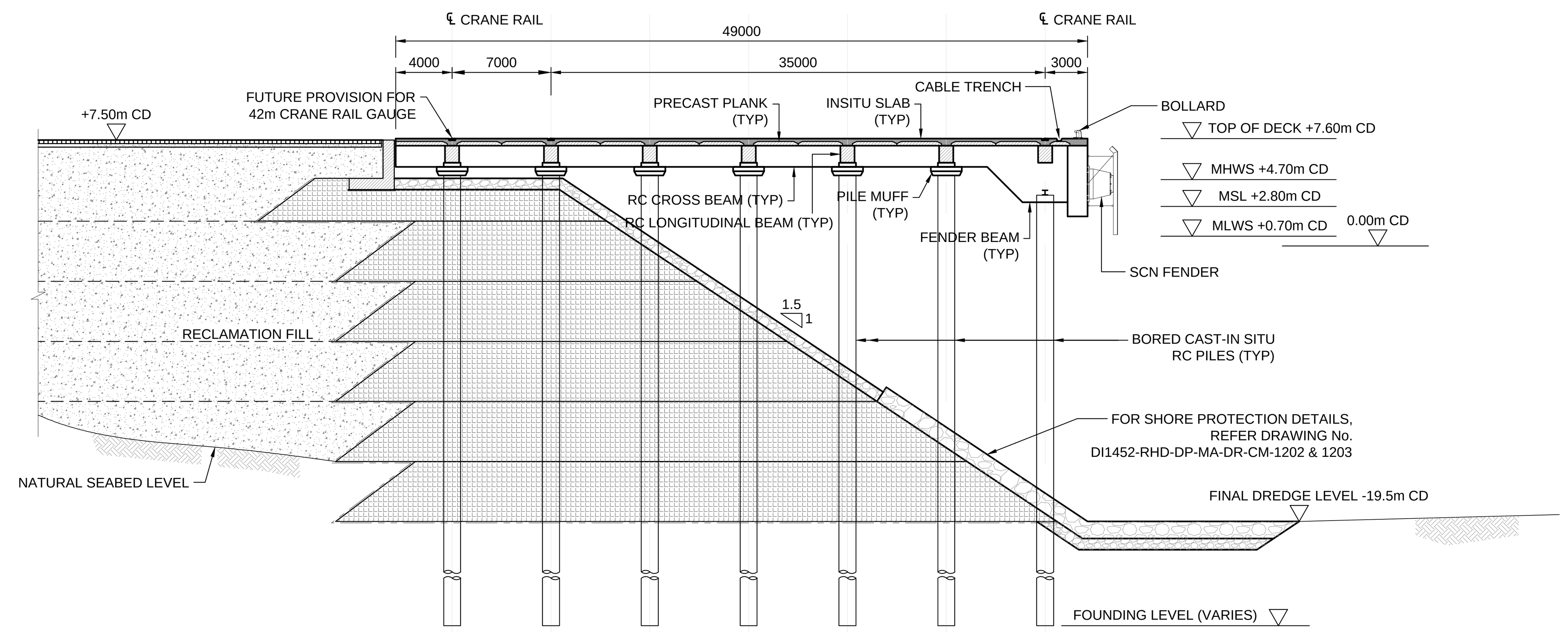
STAGE - 4
DREDGING IN FRONT OF BERTH TO ULTIMATE DREDGE LEVEL
(SCALE 1:350)



STAGE - 5
PLACE STONE PITCHING UNDERNEATH THE DECK & TOE PROTECTION & CONSTRUCT RETAINING WALL
(SCALE 1:350)



STAGE - 6
CONSTRUCT DECK & FILL RECLAMATION BEHIND BERTH
(SCALE 1:350)



STAGE - 7
BERTH FIXTURES & YARD PAVEMENT
(SCALE 1:350)

NOTES:

1. ALL DIMENSIONS ARE IN MILLIMETERS, UNLESS OTHERWISE NOTED.
2. ALL LEVELS ARE IN METERS WITH RESPECT TO CHART DATUM.

ISSUED FOR DPR

REV	DATE	DESCRIPTION	BY	CHK	APP
P03	19/10/21	ISSUED FOR DPR	YSK	MS	ASM
P02	08/10/21	ISSUED FOR DPR	YSK	MS	ASM
P01	21/09/21	ISSUED FOR DPR	TSM	MS	SD

REVISIONS

CLIENT
JAWAHARLAL NEHRU PORT TRUST

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Tel +91 (0) 22 61395000
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www.royalhaskoningdhv.com

PROJECT
Consultancy services for Design and Detailed Engineering for Greenfield Vadhavan port project

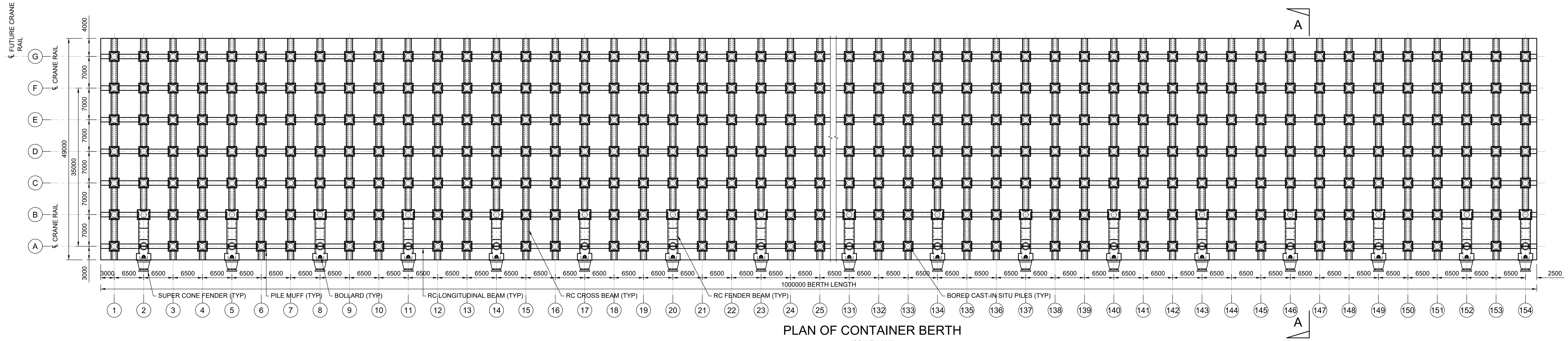
TITLE
GENERAL CONSTRUCTION SEQUENCE FOR RECLAIMED LAND AND BERTH

DRAWN SNJ	CHECKED MS	APPROVED ASM
DATE FEB 2021	SCALE @A1 AS SHOWN	REF. -

DRAWING No.	SUITABILITY	REVISION
DI1452-RHD-DP-MA-DR-CM-1204	S4	P03

DRG No.
DI1452-RHD-DP-MA-DR-CM-1205

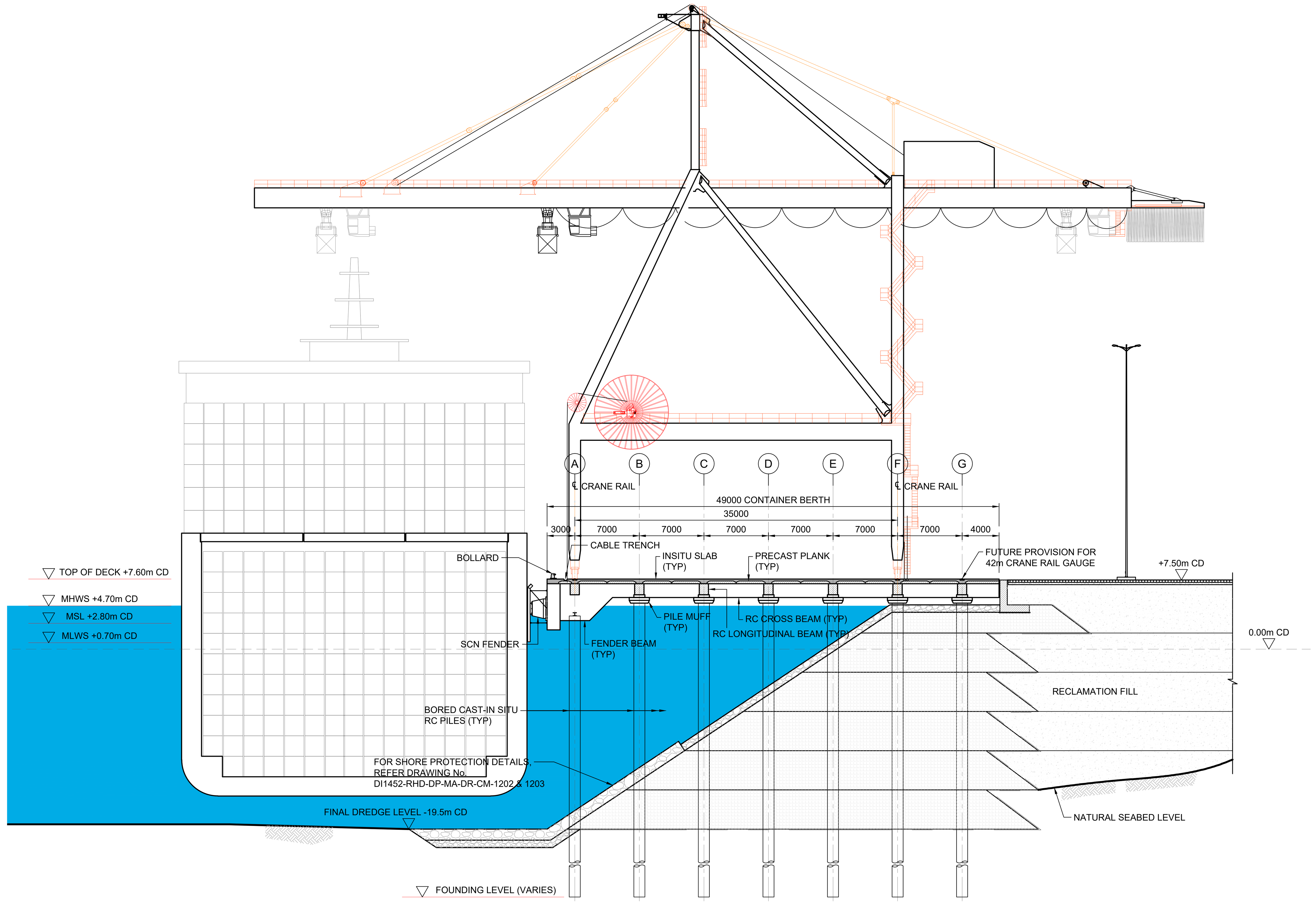
DO NOT SCALE



PLAN OF CONTAINER BERTH

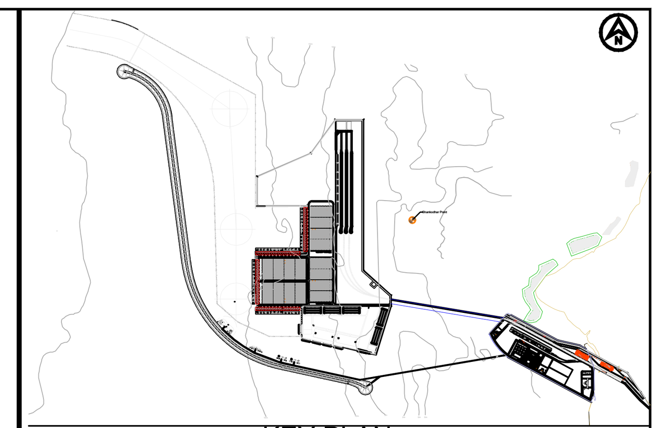
(SCALE 1:500)

(NOTE : SHORE PROTECTION WORKS AND REAR SIDE OF THE BERTH ARE NOT SHOWN FOR CLARITY)



SECTION A-A

(SCALE 1:350)



KEY PLAN

NOTES:

1. ALL DIMENSIONS ARE IN MILLIMETRES, UNLESS NOTED OTHERWISE.
2. ALL LEVELS ARE IN METRES ABOVE CHART DATUM (MARKED ±0.00m CD).
3. THIS DRAWING SHOULD NOT BE SCALED. ONLY WRITTEN DIMENSIONS SHALL BE FOLLOWED.
4. PROPOSED FENDER AND BOLLARD SHALL BE CONFIRMED BY DETAILED DESK STUDY CONSIDERING 18500 TEU TO 24000 TEU VESSEL BERTHING.
5. ALL THE CONTAINER TERMINALS WILL BE OF SAME GEOMETRY AND STRUCTURAL ARRANGEMENT.

SERVICE LEGEND:

SUPER CONE FENDER SCN2000-F1.0

BOLLARD- 200 T

LEGEND:

MHWS - MEAN HIGH WATER SPRING
MLWS - MEAN LOW WATER SPRING
MSL - MEAN SEA LEVEL
FGL - FINISH GROUND LEVEL

ISSUED FOR DPR

REV	DATE	DESCRIPTION	BY	CHK	APP
P03	19/10/21	ISSUED FOR DPR	AAB	MS	SD
P02	08/10/21	ISSUED FOR DPR	AAB	MS	SD
P01	05/02/21	ISSUED FOR DPR	SNJ	MS	SD

REVISIONS

CLIENT
JAWAHARLAL NEHRU PORT TRUST

CONSULTANT
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www.royalhaskoningdhv.com

PROJECT
Consultancy services for Design and Detailed Engineering for Greenfield Vadhavan port project

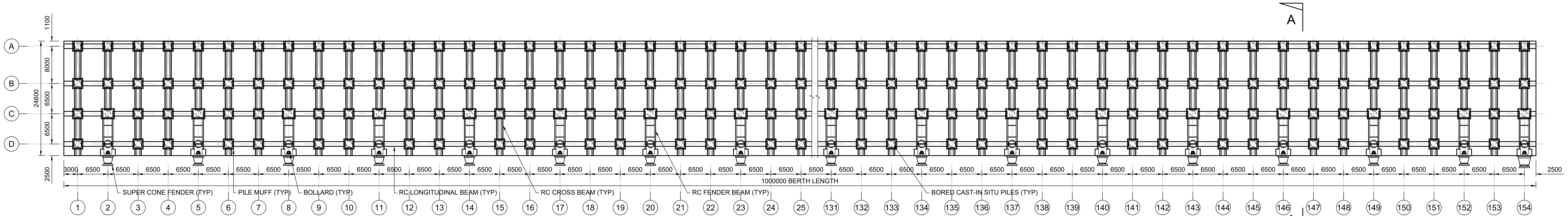
TITLE
CONTAINER BERTH - GENERAL ARRANGEMENT PLAN AND CROSS SECTION

DRAWN SNJ	CHECKED MS	APPROVED SD
DATE FEB 2021	SCALE @A1 AS SHOWN	REF. -

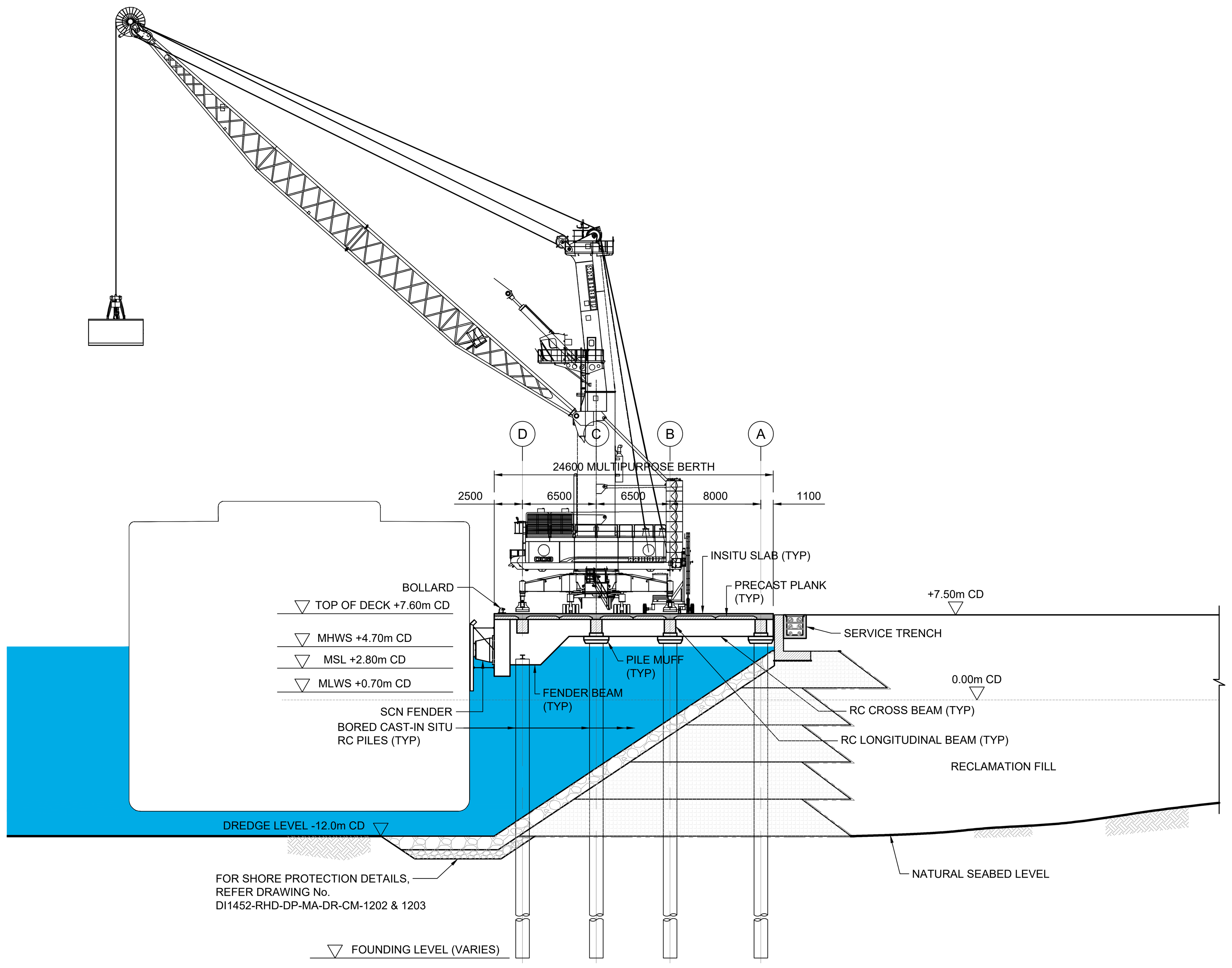
DRAWING No.	SUITABILITY	REVISION
DI1452-RHD-DP-MA-DR-CM-1205	S4	P03

DRG No.
DI1452-RHD-DP-MA-DR-CM-1206

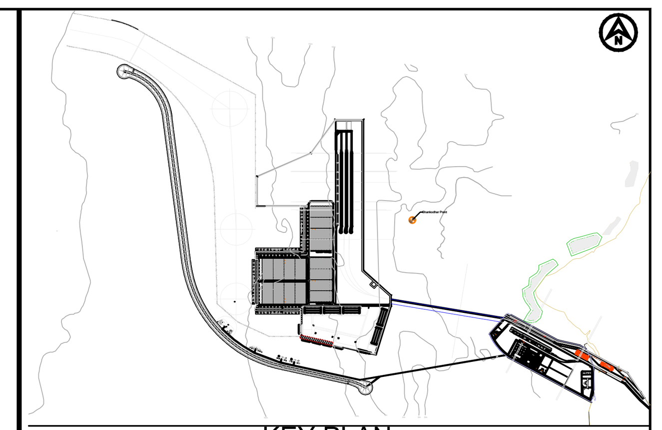
DO NOT SCALE



PLAN OF MULTIPURPOSE BERTH
(SCALE 1:500)
(NOTE : SHORE PROTECTION WORKS AND REAR SIDE OF THE BERTH ARE NOT SHOWN FOR CLARITY)



SECTION A-A
(SCALE 1:350)



NOTES:

1. ALL DIMENSIONS ARE IN MM, UNLESS NOTED OTHERWISE.
2. ALL LEVELS ARE IN METERS ABOVE CHART DATUM (MARKED ±0.00m CD).
3. THIS DRAWING SHOULD NOT BE SCALED. ONLY WRITTEN DIMENSIONS SHALL BE FOLLOWED.
4. MULTIPURPOSE BERTH -4 WILL BE DEVELOPED IN PHASE -2

SERVICE LEGEND:

SUPER CONE FENDER SCN1600-F1.8

BOLLARD-100T

LEGEND:

MHWS - MEAN HIGH WATER SPRING
MLWS - MEAN LOW WATER SPRING
MSL - MEAN SEA LEVEL
FGL - FINISH GROUND LEVEL

ISSUED FOR DPR

REV	DATE	DESCRIPTION	BY	CHK	APP
P03	19/10/21	ISSUED FOR DPR	AAB	MS	SD
P02	08/10/21	ISSUED FOR DPR	AAB	MS	SD
P01	05/02/21	ISSUED FOR DPR	SNJ	MS	SD

REVISIONS

CLIENT

JAWAHARLAL NEHRU PORT TRUST

CONSULTANT

502-505, 5th Floor, Platinum Techno Park Plot 17 & 18, Sector 30 A, Vashi Navi Mumbai - 400 703, INDIA Tel +91 (0) 22 61395000 Email info.india@rhdhv.com www.royalhaskoningdhv.com

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PROJECT

Consultancy services for Design and Detailed Engineering for Greenfield Vadhavan port project

TITLE

MULTIPURPOSE BERTH - GENERAL ARRANGEMENT PLAN AND CROSS SECTION

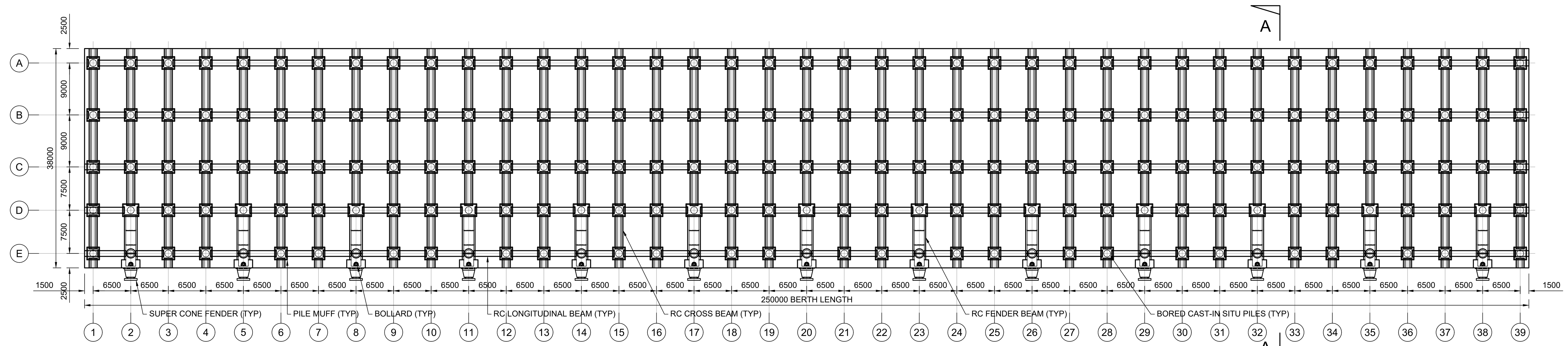
DRAWN	CHECKED	APPROVED
SNJ	MS	SD

DATE FEB 2021 | SCALE @A1 AS SHOWN | REF. -

DRAWING No.	SUITABILITY	REVISION
DI1452-RHD-DP-MA-DR-CM-1206	S4	P03

DRG No.
DI1452-RHD-DP-MA-DR-CM-1207

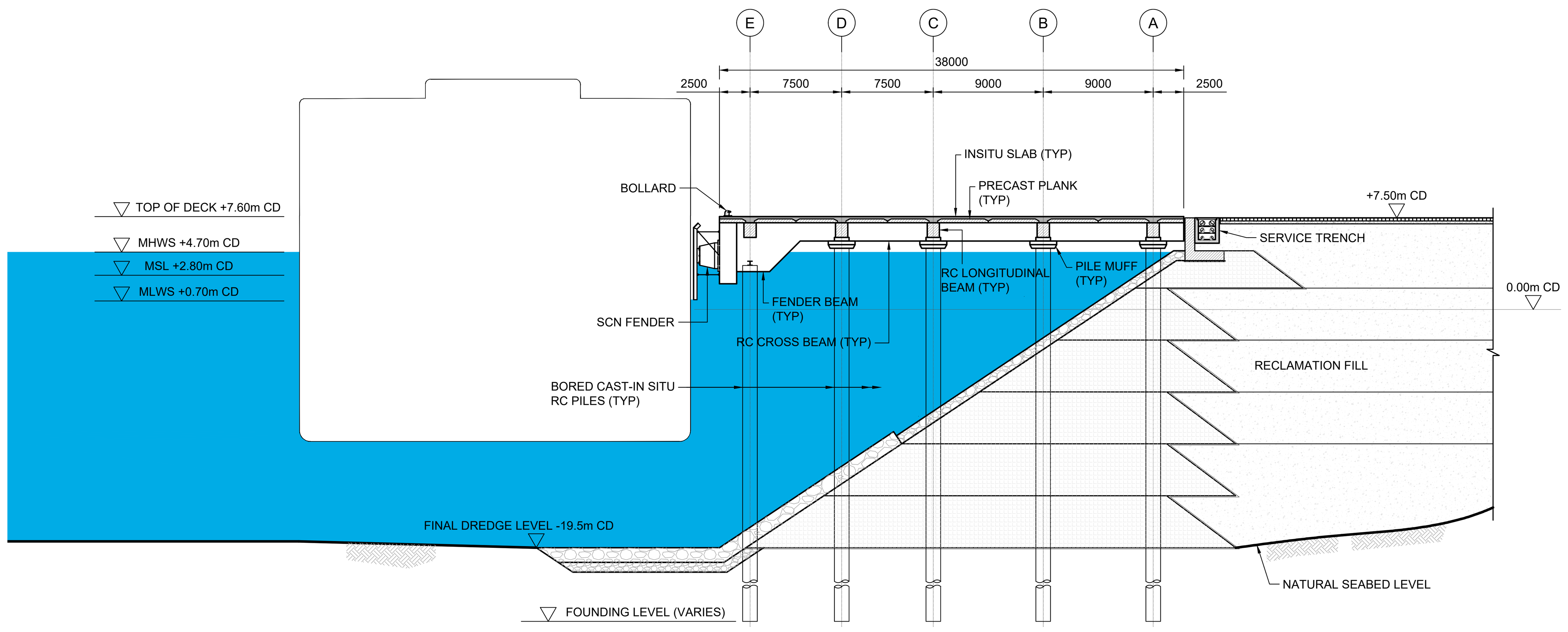
DO NOT SCALE



PLAN OF RO-RO BERTH

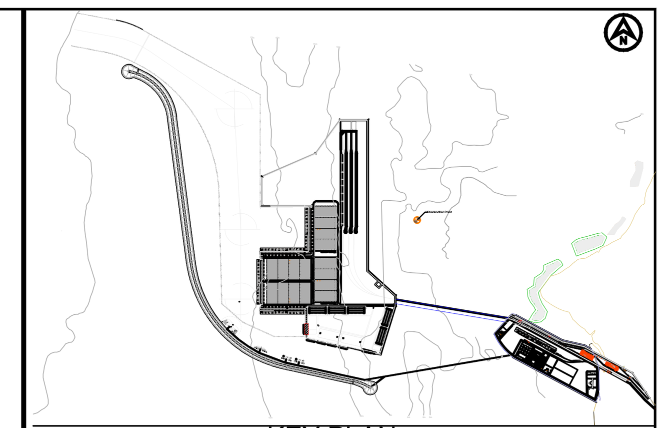
(SCALE 1:500)

(NOTE : SHORE PROTECTION WORKS AND REAR SIDE OF THE BERTH ARE NOT SHOWN FOR CLARITY)



SECTION A-A

(SCALE 1:350)



KEY PLAN

NOTES:

1. ALL DIMENSIONS ARE IN MILLIMETRES, UNLESS NOTED OTHERWISE.
2. ALL LEVELS ARE IN METERS ABOVE CHART DATUM (MARKED ±0.00m CD).
3. THIS DRAWING SHOULD NOT BE SCALED. ONLY WRITTEN DIMENSIONS SHALL BE FOLLOWED.

SERVICE LEGEND:

SUPER CONE FENDER SCN 1800- F1.7

BOLLARD - 100T

LEGEND:

MHWS - MEAN HIGH WATER SPRING
MLWS - MEAN LOW WATER SPRING
MSL - MEAN SEA LEVEL
F.G.L - FINISH GROUND LEVEL

ISSUED FOR DPR

REV	DATE	DESCRIPTION	BY	CHK	APP
P03	19/10/21	ISSUED FOR DPR	AAB	MS	SD
P02	08/10/21	ISSUED FOR DPR	AAB	MS	SD
P01	05/02/21	ISSUED FOR DPR	SNJ	MS	SD

REVISIONS

CLIENT

JAWAHARLAL NEHRU PORT TRUST

CONSULTANT

Royal HaskoningDHV
Enhancing Society Together

PROJECT

Consultancy services for Design and Detailed Engineering for Greenfield Vadhavan port project

TITLE

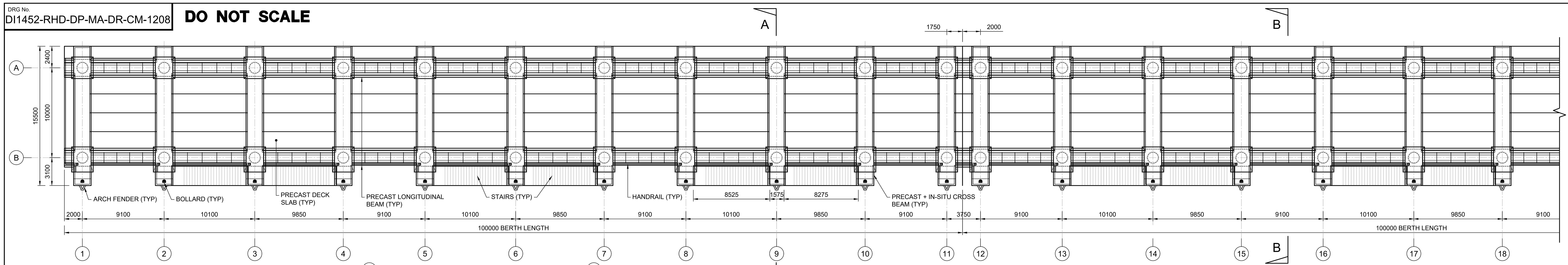
RO-RO BERTH
GENERAL ARRANGEMENT
PLAN & CROSS SECTION

DRAWN	CHECKED	APPROVED
SNJ	MS	SD
DATE FEB 2021	SCALE @A1 AS SHOWN	REF. -

DRAWING No.	SUITABILITY	REVISION
DI1452-RHD-DP-MA-DR-CM-1207	S4	P03

DRG No. DI1452-RHD-DP-MA-DR-CM-1208

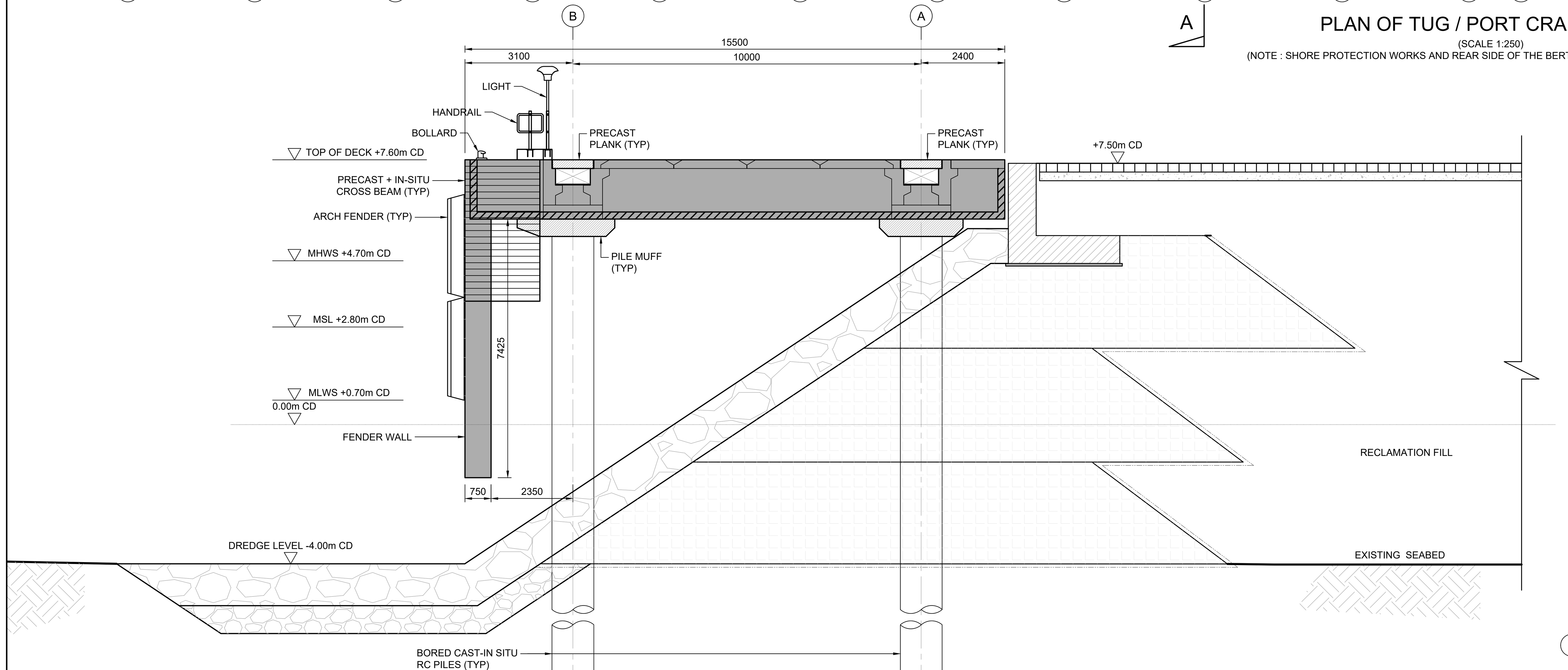
DO NOT SCALE



PLAN OF TUG / PORT CRAFT BERTH

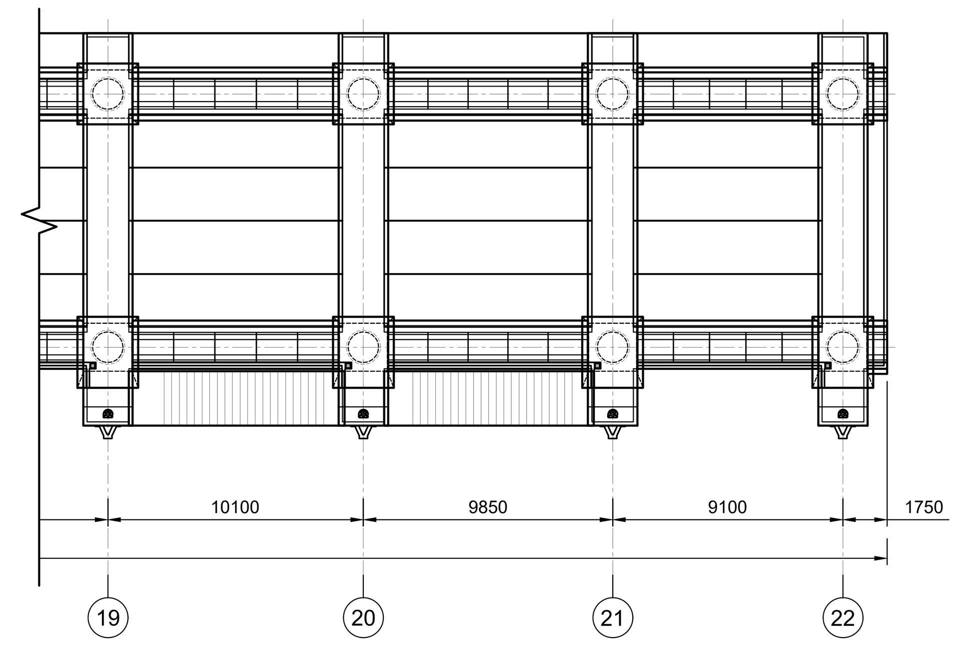
(SCALE 1:250)

(NOTE : SHORE PROTECTION WORKS AND REAR SIDE OF THE BERTH ARE NOT SHOWN FOR CLARITY)



SECTION A-A

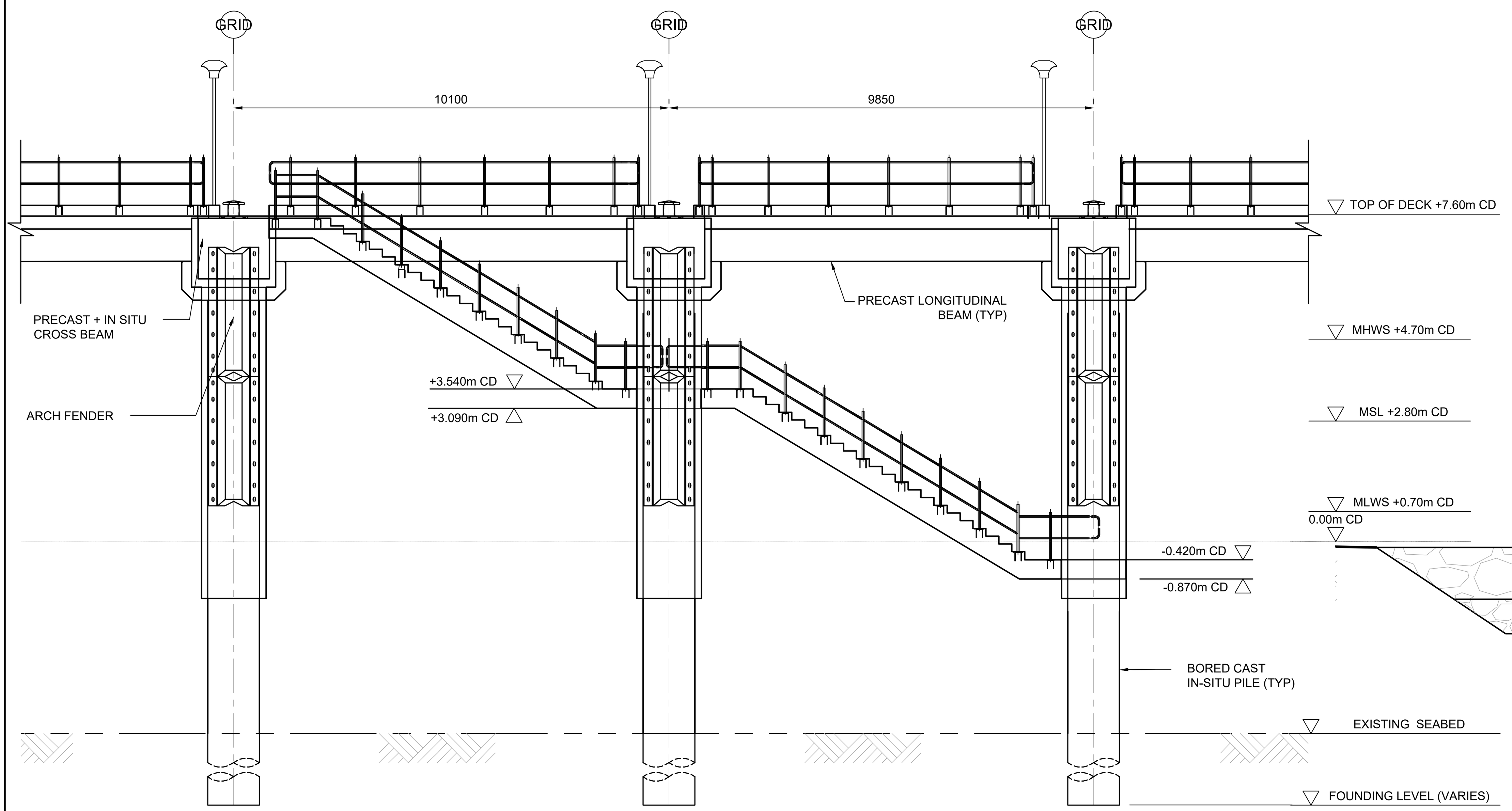
(SCALE 1:100)



PLAN OF TUG / PORT CRAFT BERTH

(SCALE 1:250)

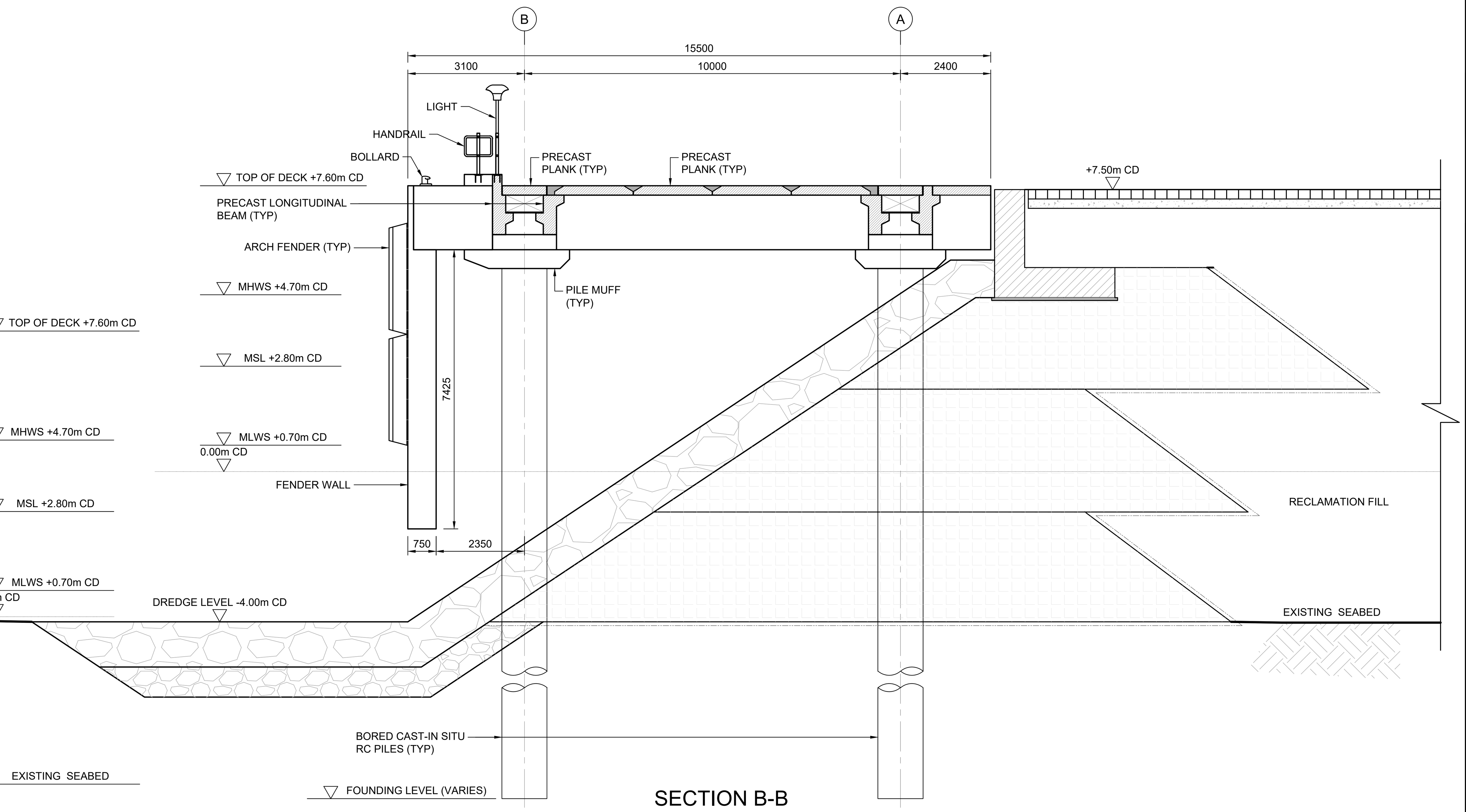
(NOTE : SHORE PROTECTION WORKS AND REAR SIDE OF THE BERTH ARE NOT SHOWN FOR CLARITY)



TYPICAL PART ELEVATION

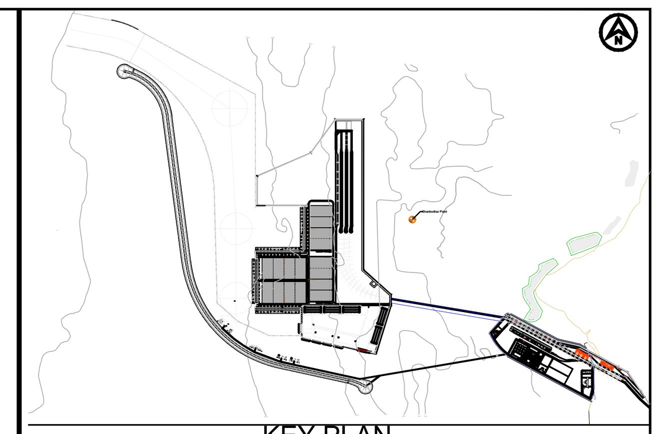
(SCALE 1:100)

(NOTE : SHORE PROTECTION WORKS AND REAR SIDE OF THE BERTH ARE NOT SHOWN FOR CLARITY)



SECTION B-B

(SCALE 1:100)



KEY PLAN

NOTES:

1. ALL DIMENSIONS ARE IN MM AND ALL LEVELS ARE IN METRE UNLESS NOTED OTHERWISE.
2. ALL LEVELS ARE IN METRES ABOVE CHART DATUM (MARKED ±0.00m CD).
3. THIS DRAWING SHOULD NOT BE SCALED. ONLY WRITTEN DIMENSIONS SHALL BE FOLLOWED.

SERVICE LEGEND:

ARCH FENDER (AN-500 E-1.5)

BOLLARD - 10 T

LEGEND:

MHWS	-	MEAN HIGH WATER SPRING
MLWS	-	MEAN LOW WATER SPRING
MSL	-	MEAN SEA LEVEL
FGL	-	FINISH GROUND LEVEL

ISSUED FOR DPR

REV	DATE	DESCRIPTION	BY	CHK	APP
P03	19/10/21	ISSUED FOR DPR	AAB	MS	SD
P02	08/10/21	ISSUED FOR DPR	AAB	MS	SD
P01	05/02/21	ISSUED FOR DPR	SNJ	MS	SD

REVISIONS

CLIENT

JAWAHARLAL NEHRU PORT TRUST

CONSULTANT

Royal HaskoningDHV
Enhancing Society Together

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Navi Mumbai - 400 703, INDIA
Tel +91 (0) 22 61395000
Email info.india@rhdhv.com
www.royalhaskoningdhv.com

PROJECT

Consultancy services for Design and Detailed Engineering for Greenfield Vadhavan port project

TITLE

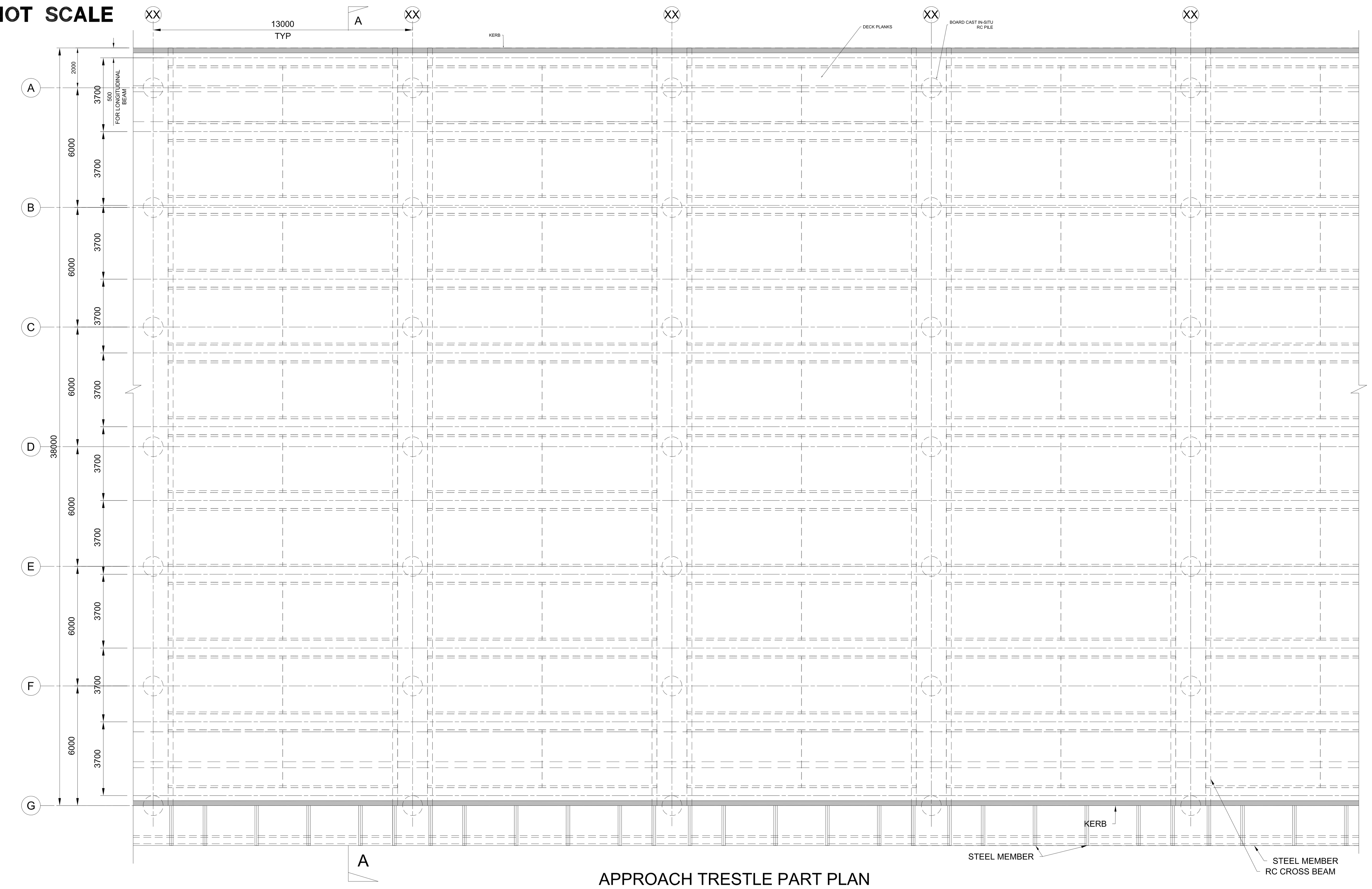
TUG/PORT CRAFT BERTHS
GENERAL ARRANGEMENT
PLAN & CROSS SECTIONS

DRAWN	CHECKED	APPROVED
SNJ	MS	SD
DATE FEB 2021	SCALE @A1 AS SHOWN	REF. -

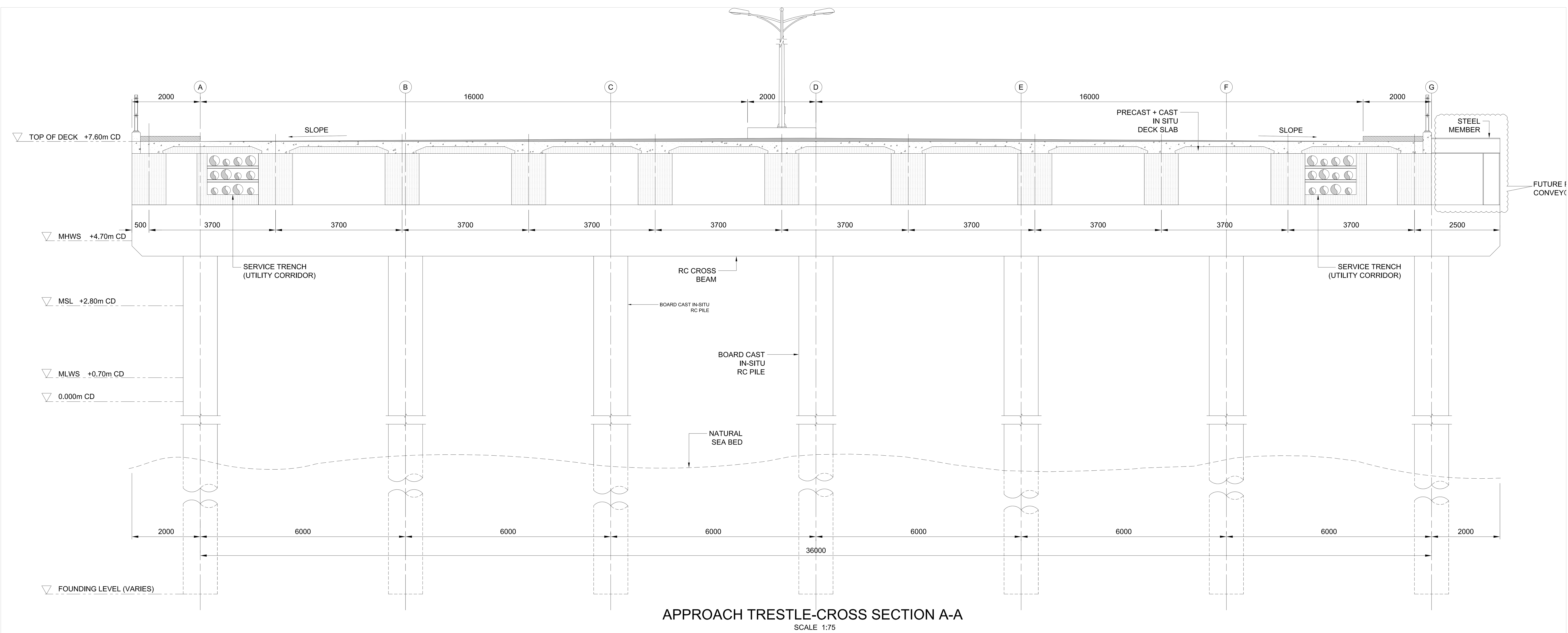
DRAWING No.	SUITABILITY	REVISION
DI1452-RHD-DP-MA-DR-CM-1208	S4	P03

DRG No.
DI1452-RHD-DP-MA-DR-CM-1209

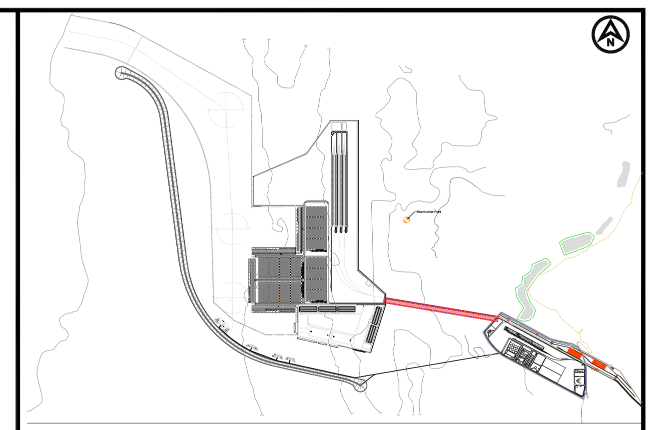
DO NOT SCALE



APPROACH TRESTLE PART PLAN
SCALE 1:200



APPROACH TRESTLE-CROSS SECTION A-A
SCALE 1:75



KEY PLAN

NOTES

1. ALL DIMENSIONS ARE IN MILLIMETERS, UNLESS NOTED OTHERWISE.
2. ALL LEVELS ARE IN METRES ABOVE CHART DATUM (MARKED ±0.00m CD).
3. THIS DRAWING SHOULD NOT BE SCALED. ONLY WRITTEN DIMENSIONS SHALL BE FOLLOWED.

LEGEND:

- MHWS - MEAN HIGH WATER SPRING
- MLWS - MEAN LOW WATER SPRING
- MSL - MEAN SEA LEVEL
- FGL - FINISH GROUND LEVEL

REFERENCE DRAWINGS:

1. DI1452-RHD-DP-MA-DR-CM-1001 VADHAVAN PORT MASTER PLAN

ISSUED FOR DPR

REV	DATE	DESCRIPTION	BY	CHK	APP
P03	29/10/21	ISSUED FOR DPR	SNJ	MS	SD
P02	08/10/21	ISSUED FOR DPR	SNJ	MS	SD
P01	05/02/21	ISSUED FOR DPR	SNJ	MS	SD

REVISIONS

CLIENT
JAWAHARLAL NEHRU PORT TRUST

CONSULTANT
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www.royalhaskoningdhv.com

PROJECT
Consultancy services for Design and Detailed Engineering for Greenfield Vadhavan port project

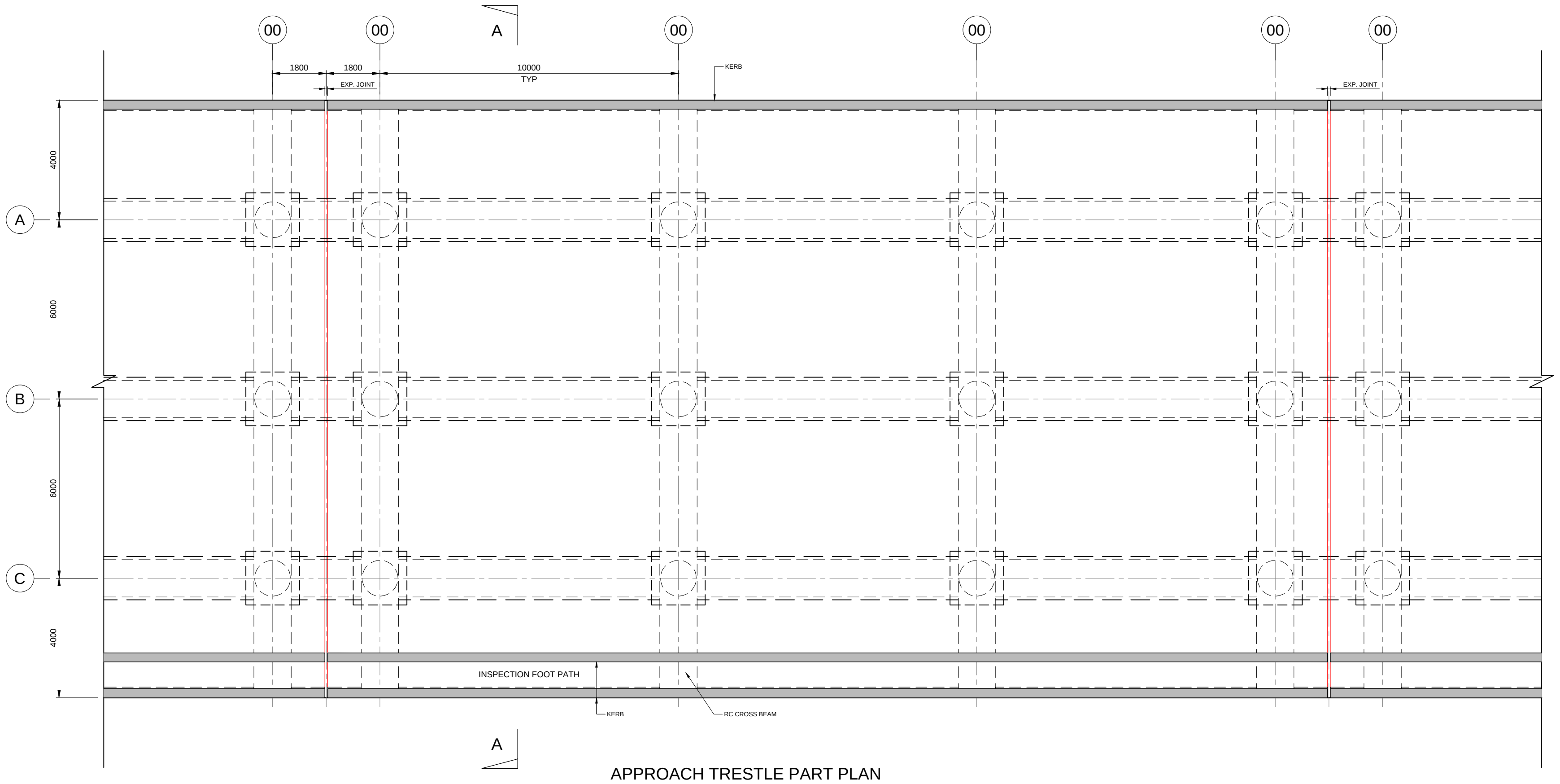
TITLE
PLAN AND SECTION OF APPROACH TRESTLE

DRAWN SNJ	CHECKED MS	APPROVED SD
DATE FEB 2021	SCALE @A1 AS SHOWN	REF. -

DRAWING No.	SUITABILITY	REVISION
DI1452-RHD-DP-MA-DR-CM-1209	S4	P02

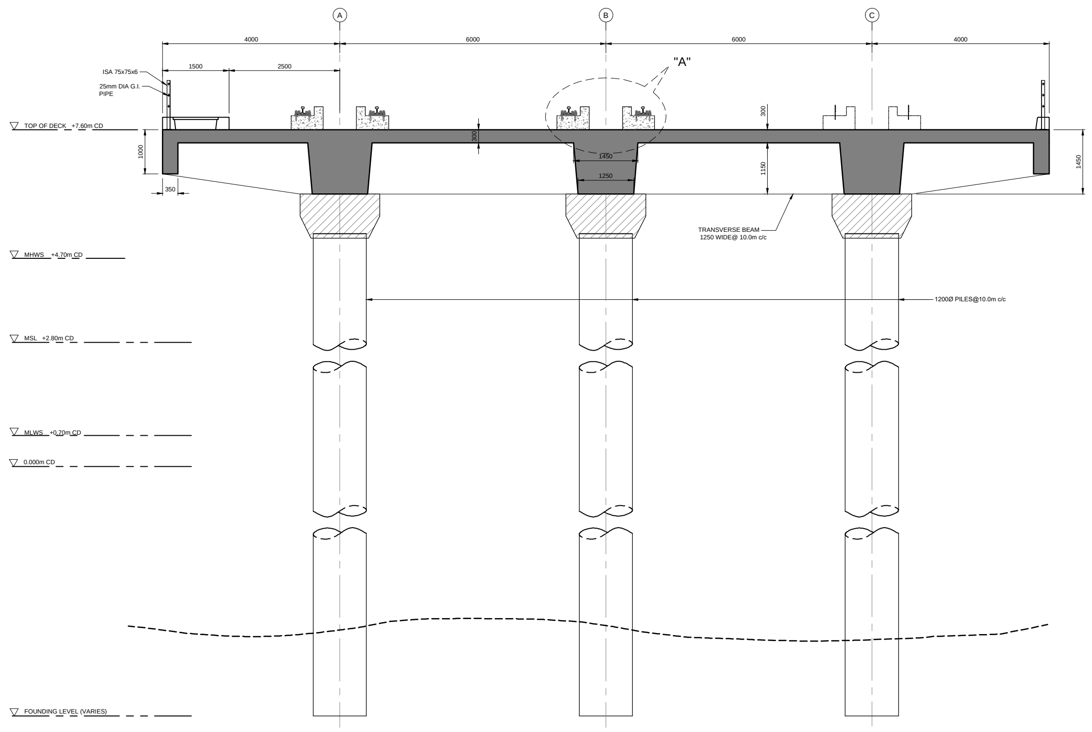
DRG No.
DI1452-RHD-DP-MA-DR-CM-1210

DO NOT SCALE



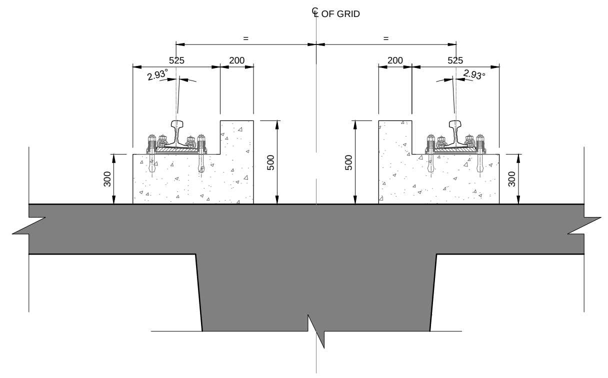
APPROACH TRESTLE PART PLAN

SCALE 1:100



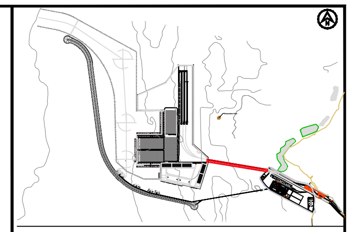
APPROACH TRESTLE CROSS SECTION A-A (
FOR RAIL)

SCALE 1:50



DETAIL - A

SCALE 1:20



KEY PLAN

NOTES

1. ALL DIMENSIONS ARE IN MILLIMETERS, UNLESS NOTED OTHERWISE.
2. ALL LEVELS ARE IN METRES ABOVE CHART DATUM (MARKED ±0.00m CD).
3. THIS DRAWING SHOULD NOT BE SCALED. ONLY WRITTEN DIMENSIONS SHALL BE FOLLOWED.

LEGEND:

MHWS - MEAN HIGH WATER SPRING
MLWS - MEAN LOW WATER SPRING
MSL - MEAN SEA LEVEL
FGL - FINISH GROUND LEVEL

REFERENCE DRAWINGS:

1. DI1452-RHD-DP-MA-DR-CM-1001 VADHAVAN PORT MASTER PLAN

ISSUED FOR DPR

REV	DATE	DESCRIPTION	BY	CHK	APP
P03	29/10/21	ISSUED FOR DPR	SNJ	MS	SD
P02	08/10/21	ISSUED FOR DPR	SNJ	MS	SD
P01	05/02/21	ISSUED FOR DPR	SNJ	MS	SD

REVISIONS

CLIENT
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www.royalhaskoningdhv.com

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Enhancing Society Together

PROJECT
Consultancy services for Design and Detailed Engineering for Greenfield Vadhavan port project

TITLE
PLAN AND SECTION OF APPROACH TRESTLE (RAIL)

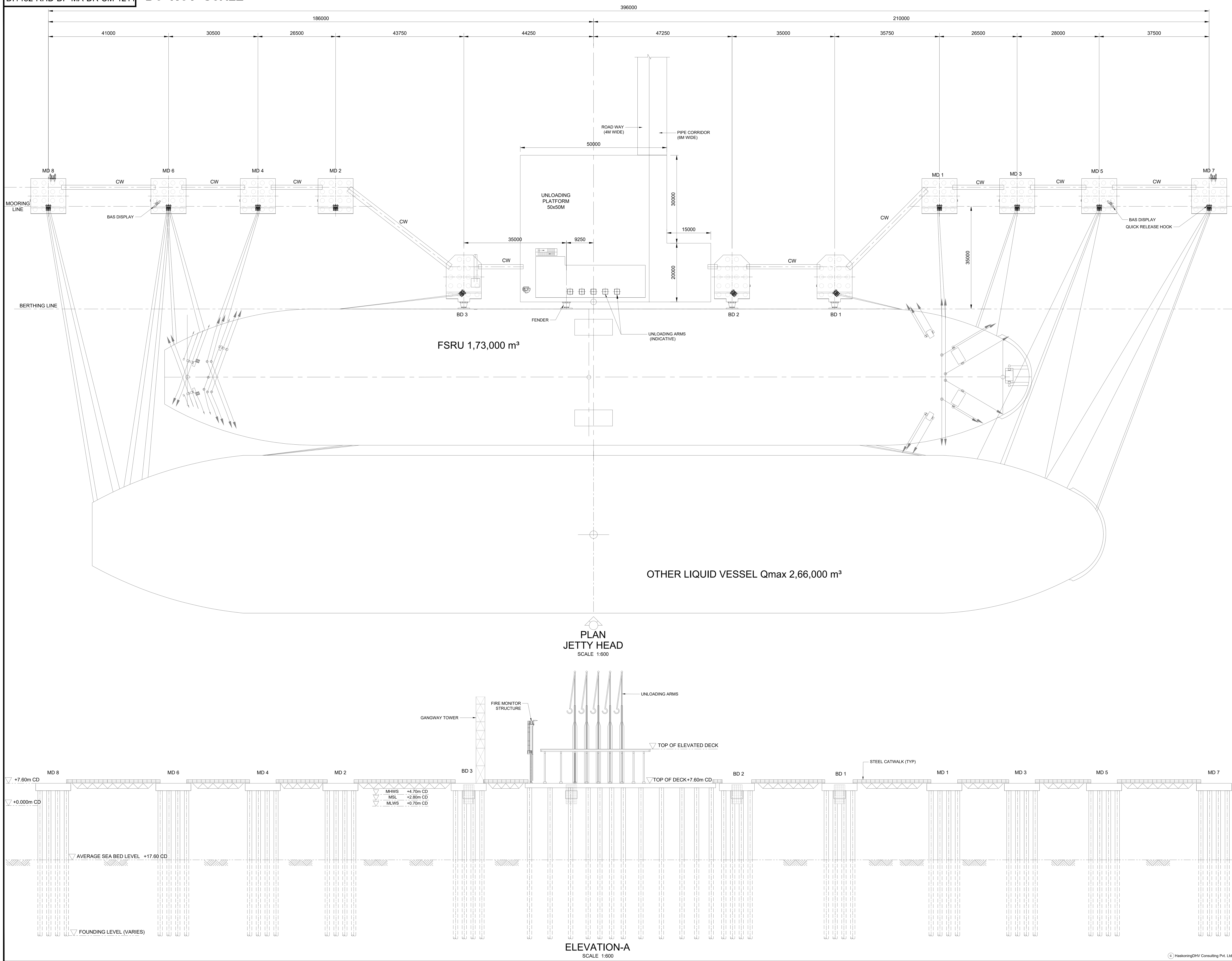
DRAWN	CHECKED	APPROVED
SNJ	MS	SD

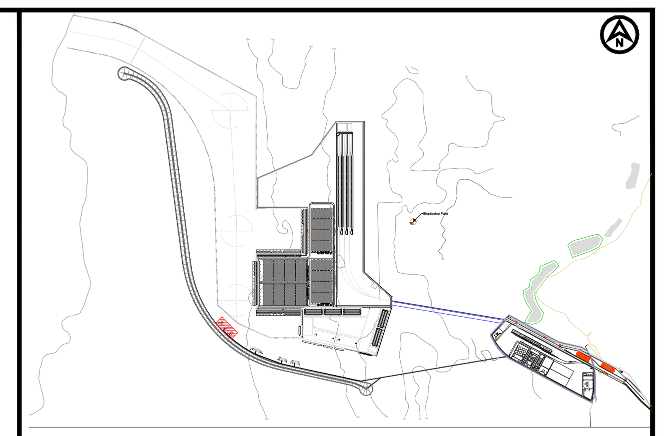
DATE	SCALE @A1	REF.
FEB 2021	AS SHOWN	-

DRAWING No.	SUITABILITY	REVISION
DI1452-RHD-DP-MA-DR-CM-1210	S4	P03

DRG No.
DI1452-RHD-DP-MA-DR-CM-1211

DO NOT SCALE





KEY PLAN

NOTES:

1. ALL DIMENSIONS ARE IN MM AND ALL LEVELS ARE IN METRE UNLESS NOTED OTHERWISE.
2. ALL LEVELS ARE IN METRES ABOVE CHART DATUM (MARKED ±0.00m CD).
3. THIS DRAWING SHOULD NOT BE SCALED. ONLY WRITTEN DIMENSIONS SHALL BE FOLLOWED.
4. MOORING ARRANGEMENT SHOWN IN THE DRAWING IS INDICATIVE ONLY.
5. LOCATION OF EQUIPMENT RELATED TO OTHER LIQUID PROCESS IS INDICATIVE ONLY. SAME SHALL BE DESIGNED AND FURNISHED BY TOP SIDE FACILITY DESIGNER.

LEGEND:

MHWS	-	MEAN HIGH WATER SPRING
MLWS	-	MEAN LOW WATER SPRING
MSL	-	MEAN SEA LEVEL
BAS	-	BERTHING AID SYSTEM
BD	-	BREASTING DOLPHIN
MD	-	MOORING DOLPHIN
QRMH	-	QUICK RELEASE MOORING HOOK
SWL	-	SAFE WORKING LOAD
CW	-	CATWALK

ISSUED FOR DPR

REV	DATE	DESCRIPTION	BY	CHK	APP
P03	15/09/23	ISSUED FOR DPR	SNJ	MS	SD
P02	08/10/21	ISSUED FOR DPR	SNJ	MS	SD
P01	05/02/21	ISSUED FOR DPR	SNJ	MS	SD

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PROJECT
Consultancy services for Design and Detailed Engineering for Greenfield Vadhavan port project

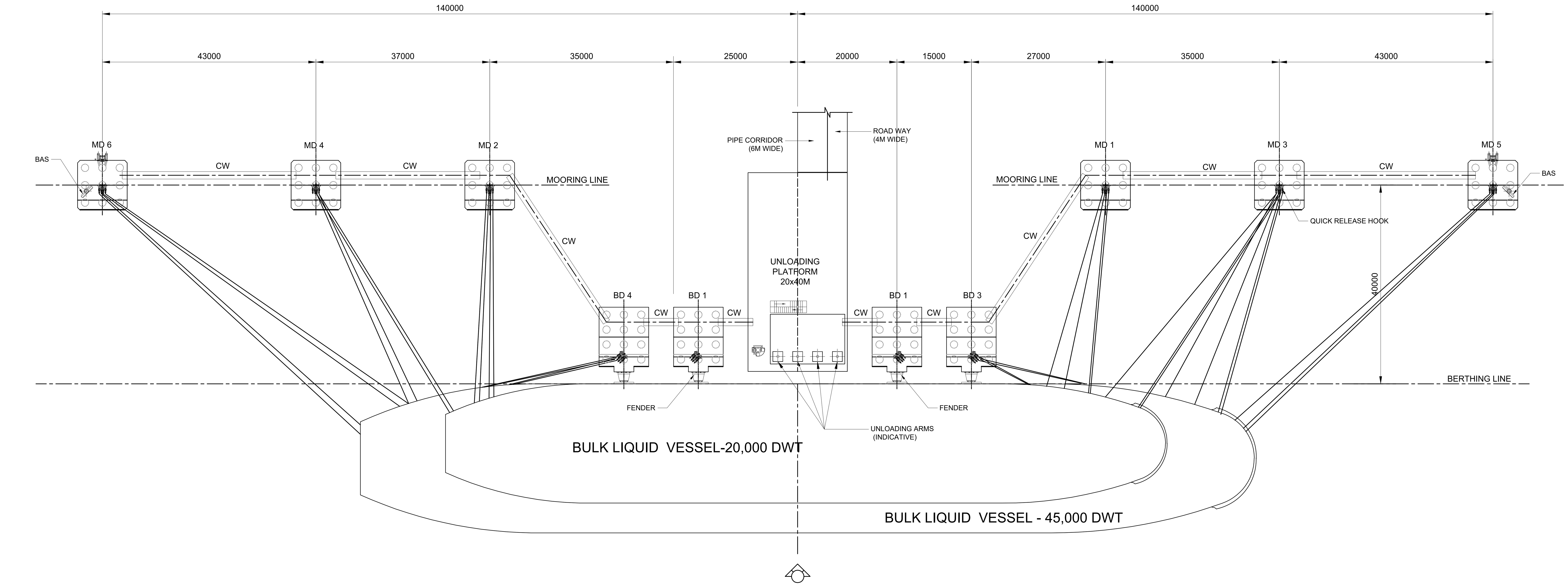
TITLE
OTHER LIQUID BERTH, JETTY HEAD GENERAL ARRANGEMENT PLAN AND ELEVATION

DRAWN	CHECKED	APPROVED
SNJ	MS	SD
DATE FEB 2021	SCALE @A1 AS SHOWN	REF. -

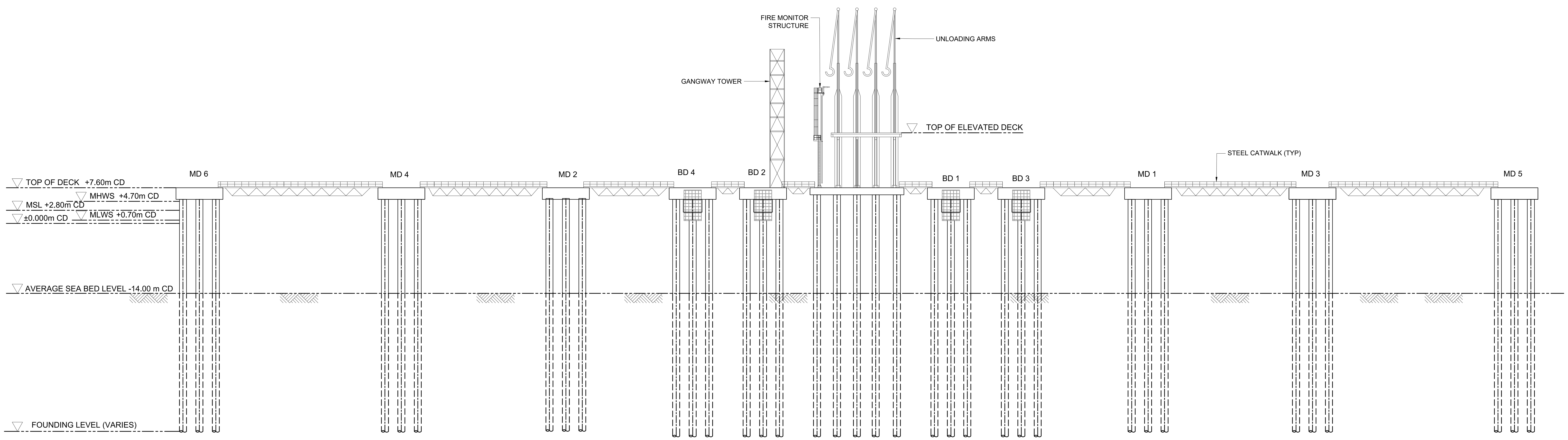
DRAWING No.	SUITABILITY	REVISION
DI1452-RHD-DP-MA-DR-CM-1211	S4	P03

DRG No.
DI1452-RHD-DP-MA-DR-CM-1212

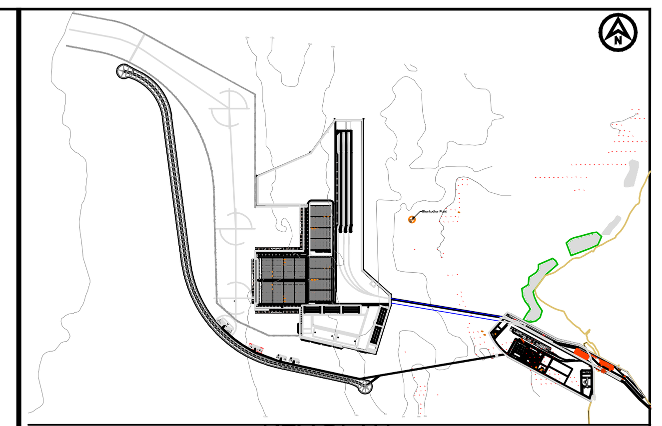
DO NOT SCALE



PLAN
BULK LIQUID -JETTY HEAD
SCALE 1:500



ELEVATION-A
SCALE 1:600



KEY PLAN

NOTES:

1. ALL DIMENSIONS ARE IN MILLIMETRES, UNLESS NOTED OTHERWISE.
2. ALL LEVELS ARE IN METRES ABOVE CHART DATUM (MARKED ±0.00m CD).
3. THIS DRAWING SHOULD NOT BE SCALED. ONLY WRITTEN DIMENSIONS SHALL BE FOLLOWED.
4. MOORING ARRANGEMENT SHOWN IN THE DRAWING IS INDICATIVE ONLY.
5. LOCATION OF EQUIPMENT RELATED TO BULK LIQUID PROCESS IS INDICATIVE ONLY. SAME SHALL BE DESIGNED AND FURNISHED BY TOP SIDE FACILITY DESIGNER.

LEGEND:

MHWS	-	MEAN HIGH WATER SPRING
MLWS	-	MEAN LOW WATER SPRING
MSL	-	MEAN SEA LEVEL
BAS	-	BERTHING AID SYSTEM
BD	-	BREASTING DOLPHIN
MD	-	MOORING DOLPHIN
QRMH	-	QUICK RELEASE MOORING HOOK
SWL	-	SAFE WORKING LOAD
CW	-	CATWALK

ISSUED FOR DPR

REV	DATE	DESCRIPTION	BY	CHK	APP
P04	15/09/23	ISSUED FOR DPR	SNJ	PK	SD
P03	20/10/21	ISSUED FOR DPR	AAB	MS	SD
P02	08/10/21	ISSUED FOR DPR	SNJ	MS	SD
P01	05/02/21	ISSUED FOR DPR	SNJ	MS	SD

REVISIONS

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Enhancing Society Together

PROJECT
Consultancy services for Design and Detailed Engineering for Greenfield Vadhavan port project

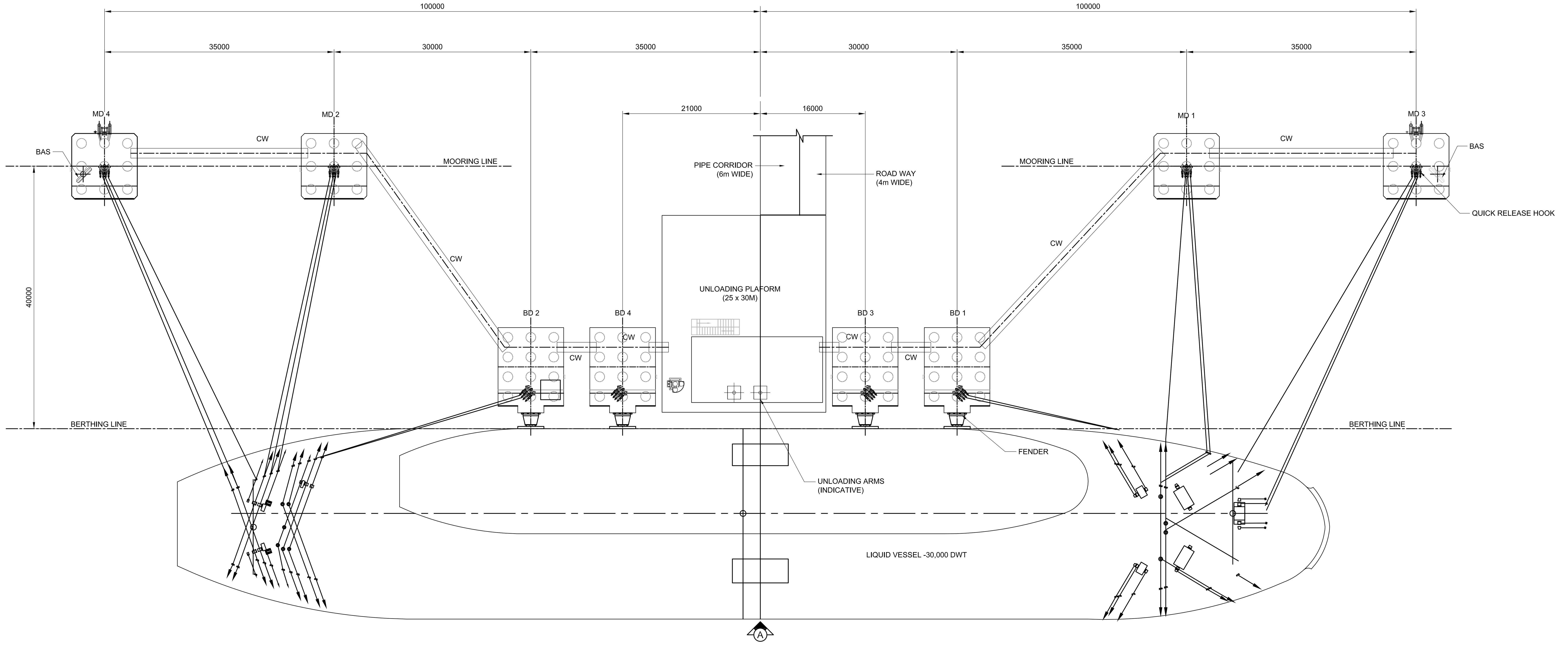
TITLE
BULK LIQUID BERTH, JETTY HEAD
GENERAL ARRANGEMENT
PLAN AND ELEVATION

DRAWN	CHECKED	APPROVED
SNJ	MS	SD
DATE: FEB 2021	SCALE @A1: AS SHOWN	REF.: -

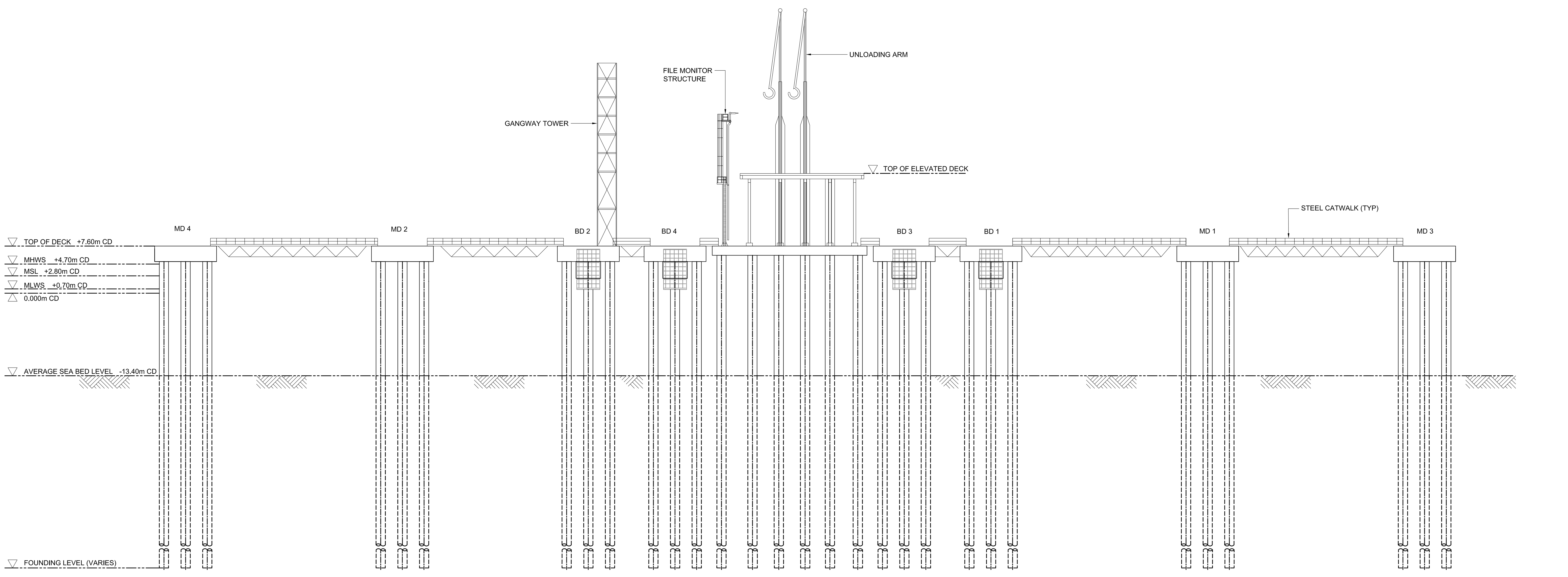
DRAWING No.	SUITABILITY	REVISION
DI1452-RHD-DP-MA-DR-CM-1212	S4	P04

DRG No.
DI1452-RHD-DP-MA-DR-CM-1213

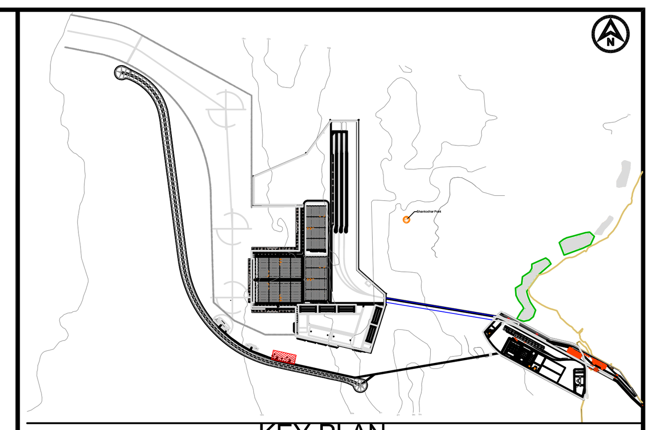
DO NOT SCALE



PLAN
LIQUID - JETTY HEAD
SCALE 1:400



ELEVATION - A
SCALE 1:400



NOTES:

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2. ALL LEVELS ARE IN METRES ABOVE CHART DATUM (MARKED ±0.00m CD).
3. THIS DRAWING SHOULD NOT BE SCALED. ONLY WRITTEN DIMENSIONS SHALL BE FOLLOWED.
4. MOORING ARRANGEMENT SHOWN IN THE DRAWING IS INDICATIVE ONLY.
5. LOCATION OF EQUIPMENT RELATED TO LIQUID PROCESS IS INDICATIVE ONLY. SAME SHALL BE DESIGNED AND FURNISHED BY TOP SIDE FACILITY DESIGNER.

LEGEND:

MHWS	-	MEAN HIGH WATER SPRING
MLWS	-	MEAN LOW WATER SPRING
MSL	-	MEAN SEA LEVEL
BAS	-	BERTHING AID SYSTEM
BD	-	BREASTING DOLPHIN
MD	-	MOORING DOLPHIN
QRMH	-	QUICK RELEASE MOORING HOOK
CW	-	CATWALK

ISSUED FOR DPR

REV	DATE	DESCRIPTION	BY	CHK	APP
P02	08/10/21	ISSUED FOR DPR	SNJ	MS	SD
P01	05/02/21	ISSUED FOR DPR	SNJ	MS	SD

REVISIONS

CLIENT
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PROJECT
Consultancy services for Design and Detailed Engineering for Greenfield Vadhavan port project

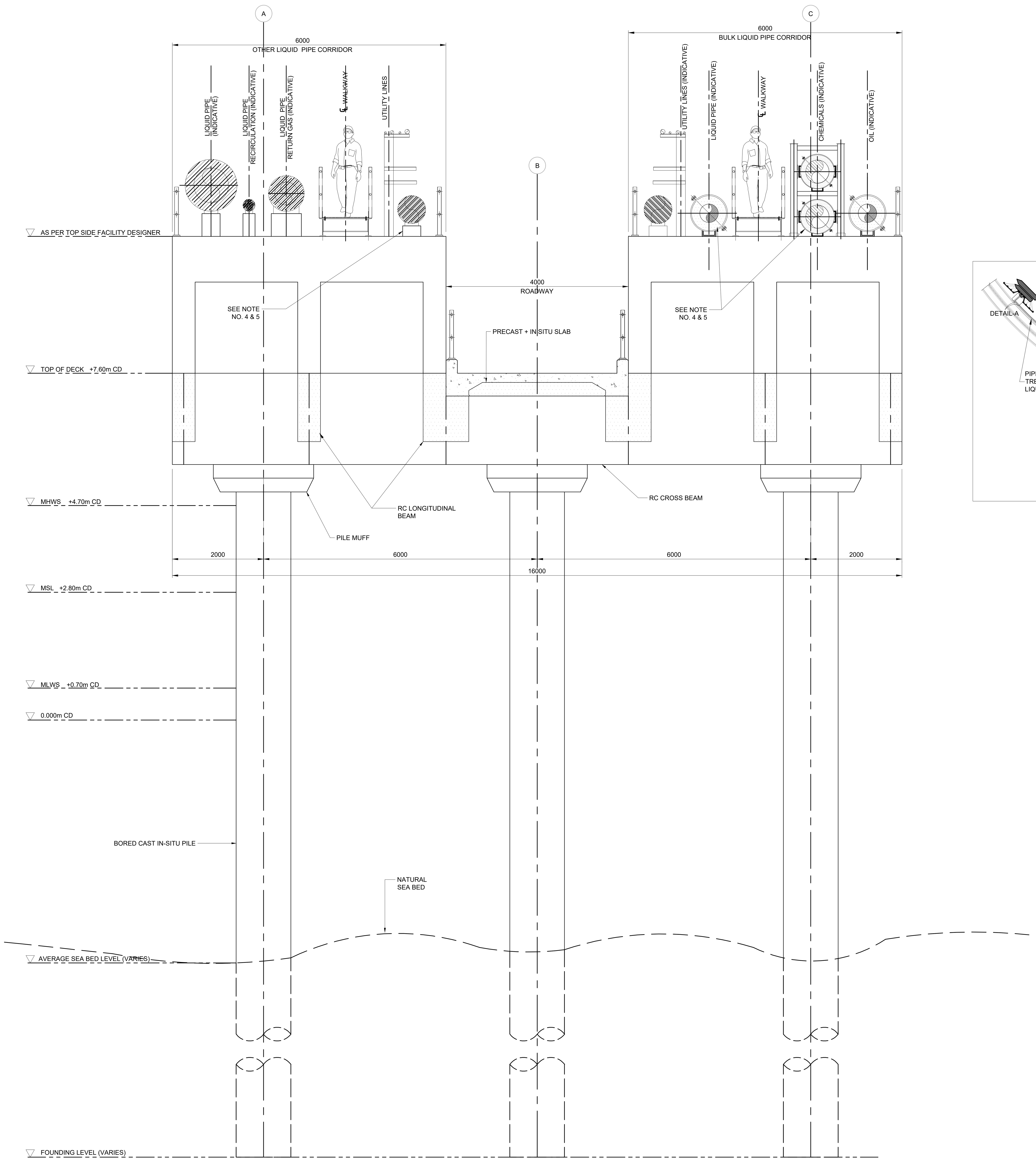
TITLE
LIQUID BERTH, JETTY HEAD GENERAL ARRANGEMENT PLAN AND ELEVATION

DRAWN	CHECKED	APPROVED
SNJ	MS	SD
DATE FEB 2021	SCALE @A1 AS SHOWN	REF. -

DRAWING No.	SUITABILITY	REVISION
DI1452-RHD-DP-MA-DR-CM-1213	S4	P02

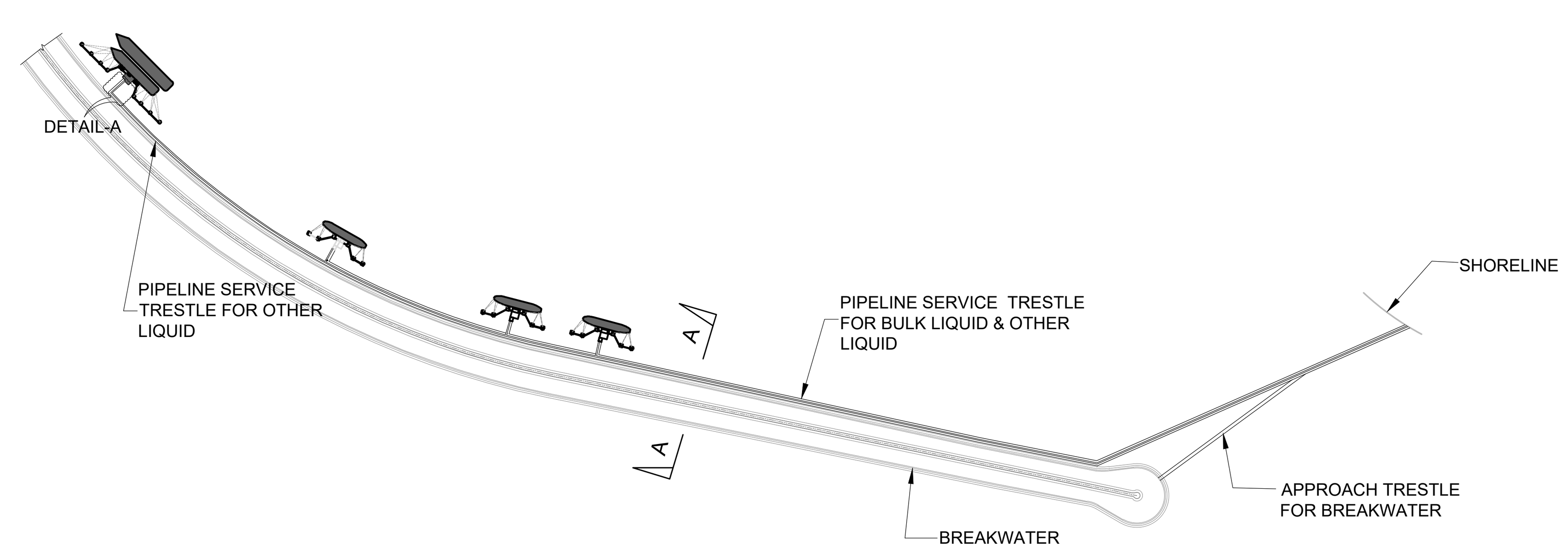
DRG No.
DI1452-RHD-DP-MA-DR-CM-1214

DO NOT SCALE



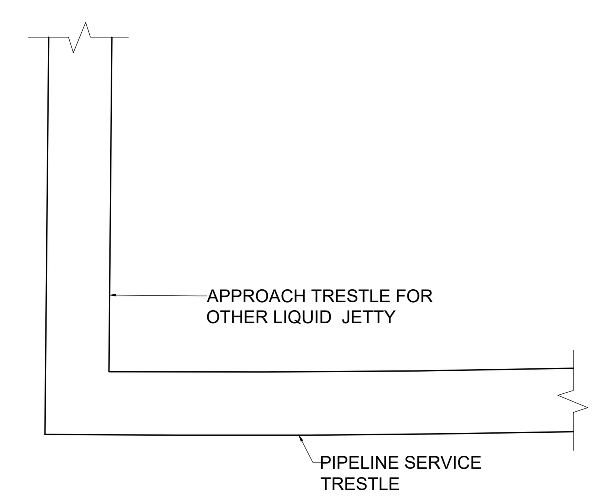
SECTION A-A OF PIPELINE SERVICE TRESTLE FOR OTHER LIQUID & BULK LIQUID JETTIES

SCALE 1:50



PLAN

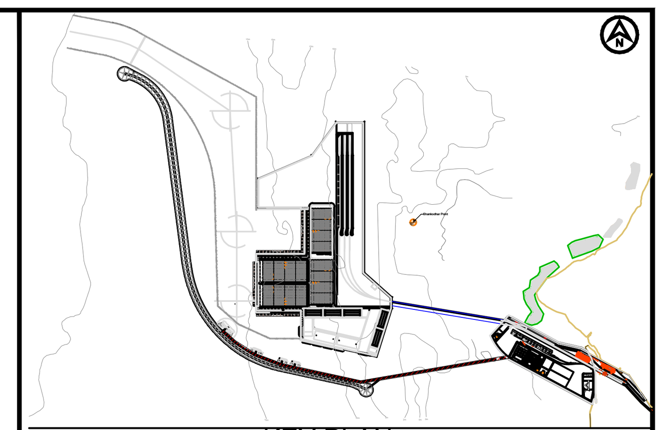
SCALE NTS



DETAIL-A

(SCALE 1:1000)

(NOTE:- SIMILAR ARRANGEMENT FOR OTHER ISLAND JETTIES)



KEY PLAN

NOTES:

1. ALL DIMENSIONS ARE IN MILLIMETRES, UNLESS NOTED OTHERWISE.
2. ALL LEVELS ARE IN METRES ABOVE CHART DATUM (MARKED ±0.00m CD).
3. THIS DRAWING SHOULD NOT BE SCALED. ONLY WRITTEN DIMENSIONS SHALL BE FOLLOWED.
4. ALL THE DETAILS SHOWN FOR TOP SIDE FACILITIES ARE INDICATIVE ONLY. SAME NEEDS TO BE CONFIRMED BY TOP SIDE FACILITIES DESIGNER.
5. SUPPORTS FOR PROCESS PIPELINES, CABLE TRAYS, UTILITIES AND OTHER FACILITIES ABOVE MAIN RC DECK ARE INDICATIVE ONLY. SAME SHALL BE DESIGNED AND FURNISHED BY TOP SIDE FACILITIES DESIGNER.
6. IN SECTION A-A, BREAKWATER CROSS SECTION HAS BEEN OMITTED FOR CLARITY PURPOSE.

LEGEND:

MHWS	-	MEAN HIGH WATER SPRING
MLWS	-	MEAN LOW WATER SPRING
MSL	-	MEAN SEA LEVEL
FGL	-	FINISH GROUND LEVEL

ISSUED FOR DPR

REV	DATE	DESCRIPTION	BY	CHK	APP
P03	15/09/23	ISSUED FOR DPR	SNJ	PK	SD
P02	08/10/21	ISSUED FOR DPR	SNJ	MS	SD
P01	05/02/21	ISSUED FOR DPR	SNJ	MS	SD

REVISIONS

CLIENT
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Email info.india@rhdhv.com
www.royalhaskoningdhv.com

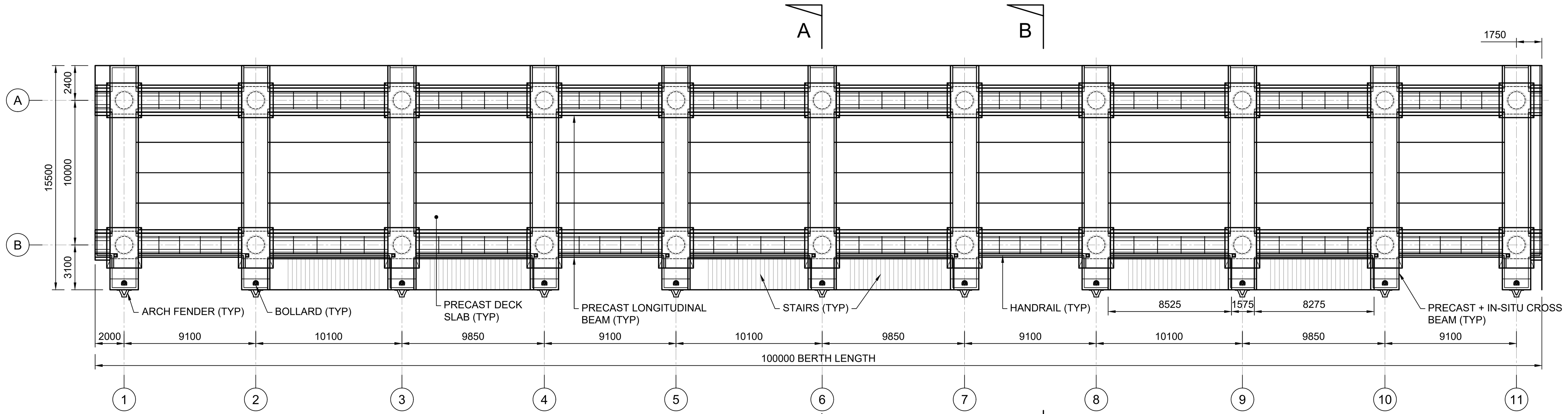
PROJECT
Consultancy services for Design and Detailed Engineering for Greenfield Vadhavan port project

TITLE
PIPELINE SERVICE TRESTLE CONFIGURATION FOR OTHER LIQUID , BULK LIQUID TERMINALS

DRAWN SNJ	CHECKED MS	APPROVED SD
DATE FEB 2021	SCALE @A1 AS SHOWN	REF. -
DRAWING No. DI1452-RHD-DP-MA-DR-CM-1214	SUITABILITY S4	REVISION P03

DRG No.
DI1452-RHD-DP-MA-DR-CM-1215

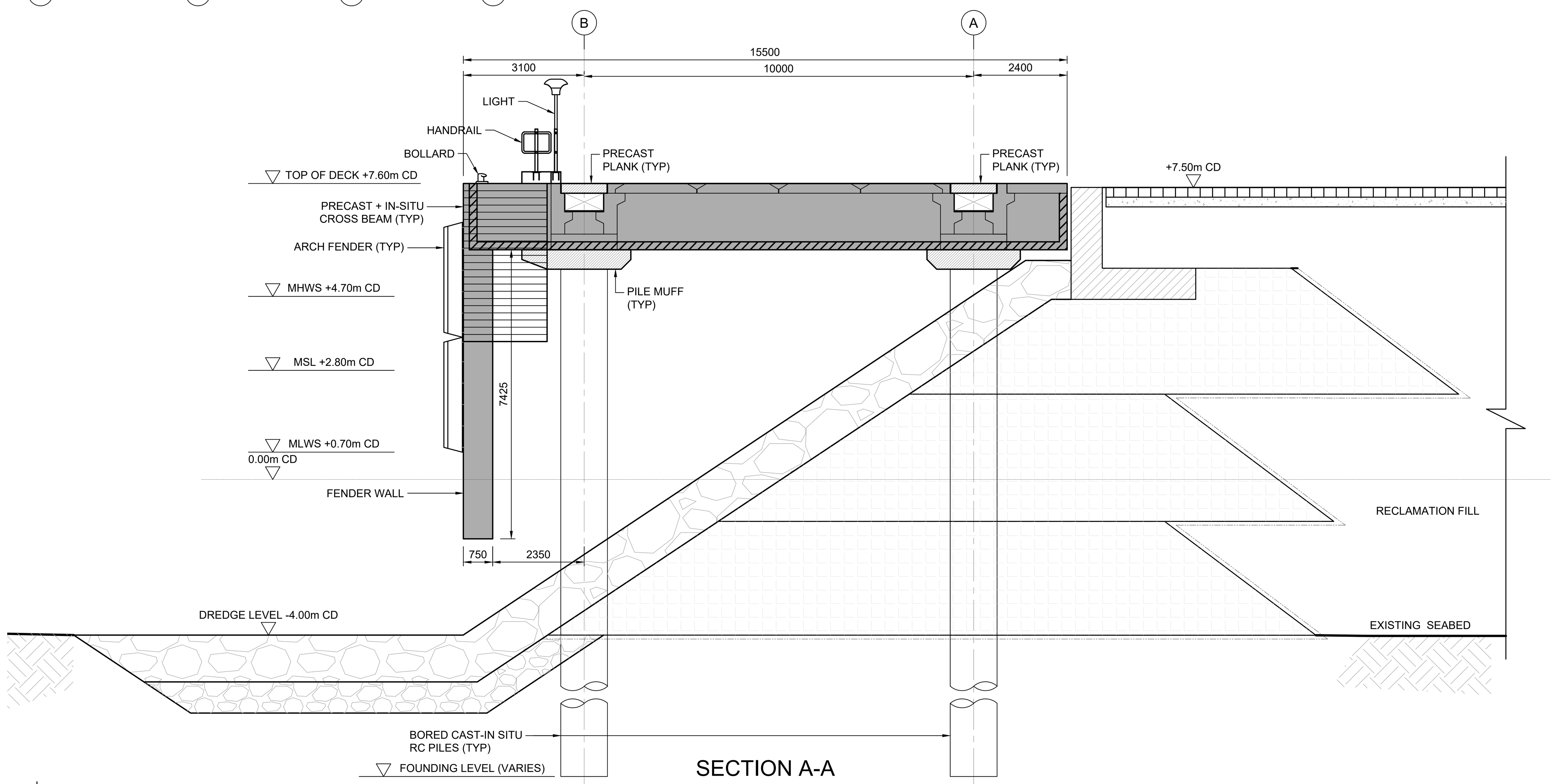
DO NOT SCALE



PLAN OF COAST GUARD BERTH

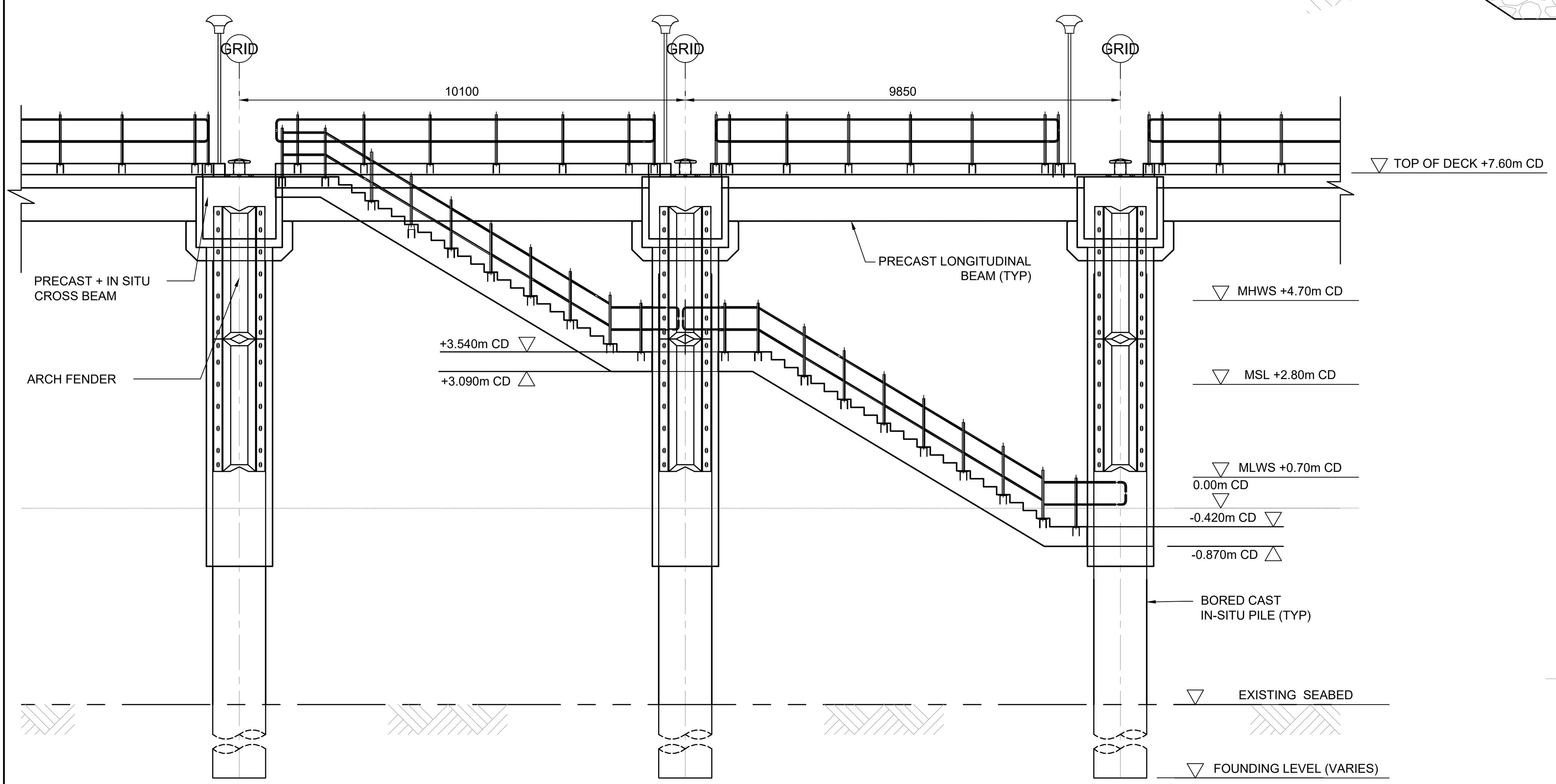
(SCALE 1:250)

(NOTE : SHORE PROTECTION WORKS AND REAR SIDE OF THE BERTH ARE NOT SHOWN FOR CLARITY)



SECTION A-A

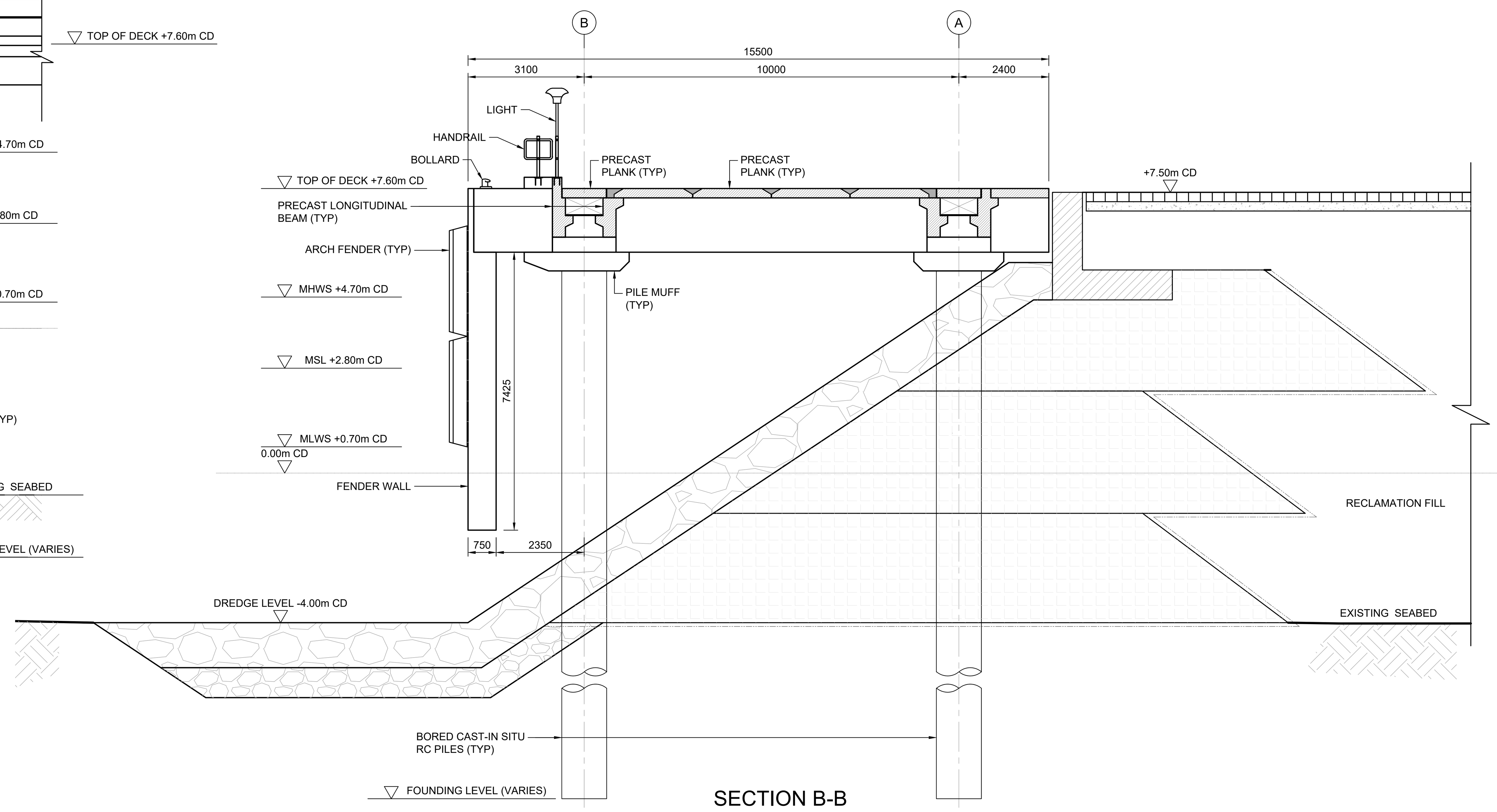
(SCALE 1:100)



TYPICAL PART ELEVATION

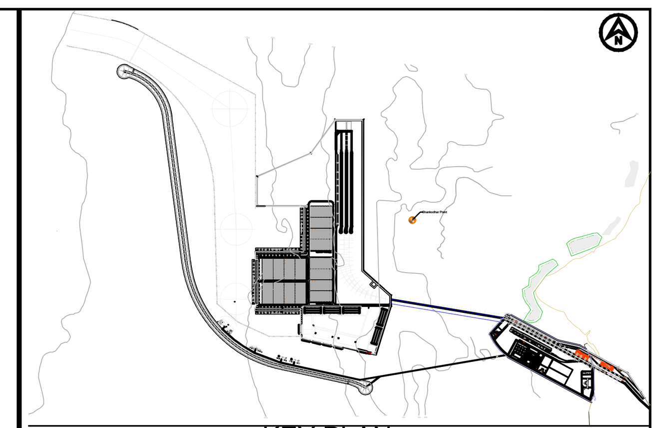
(SCALE 1:100)

(NOTE : SHORE PROTECTION WORKS AND REAR SIDE OF THE BERTH ARE NOT SHOWN FOR CLARITY)



SECTION B-B

(SCALE 1:100)



KEY PLAN

NOTES:

1. ALL DIMENSIONS ARE IN MM AND ALL LEVELS ARE IN METRE UNLESS NOTED OTHERWISE.
2. ALL LEVELS ARE IN METRES ABOVE CHART DATUM (MARKED ±0.00m CD).
3. THIS DRAWING SHOULD NOT BE SCALED. ONLY WRITTEN DIMENSIONS SHALL BE FOLLOWED.

SERVICE LEGEND:

ARCH FENDER (AN-500 E-1.5)

BOLLARD - 10 T

LEGEND:

MHWS	-	MEAN HIGH WATER SPRING
MLWS	-	MEAN LOW WATER SPRING
MSL	-	MEAN SEA LEVEL
FGL	-	FINISH GROUND LEVEL

ISSUED FOR DPR

REV	DATE	DESCRIPTION	BY	CHK	APP
P02	20/10/21	ISSUED FOR DPR	AAB	MS	SD
P01	09/10/21	ISSUED FOR DPR	SNJ	MS	SD

REVISIONS

CLIENT

JAWAHARLAL NEHRU PORT TRUST

CONSULTANT

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www.royalhaskoningdhv.com

PROJECT

Consultancy services for Design and Detailed Engineering for Greenfield Vadhavan port project

TITLE

COAST GUARD BERTH GENERAL ARRANGEMENT PLAN & CROSS SECTIONS

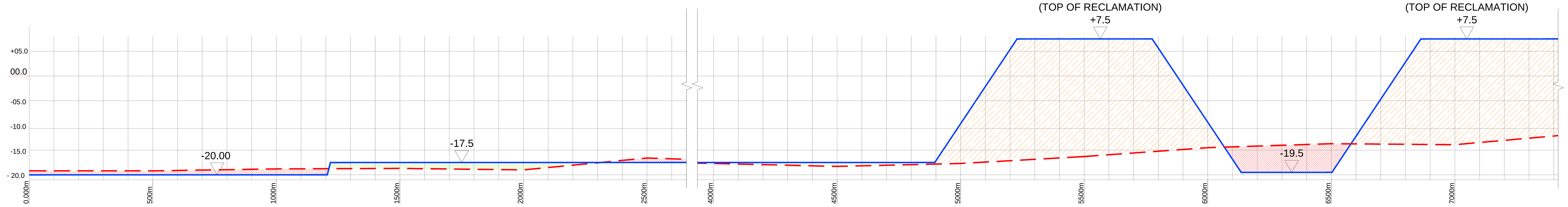
DRAWN	CHECKED	APPROVED
SNJ	MS	SD
DATE SEP 2021	SCALE @A1 AS SHOWN	REF. -

DRAWING No.	SUITABILITY	REVISION
DI1452-RHD-DP-MA-DR-CM-1215	S4	P02

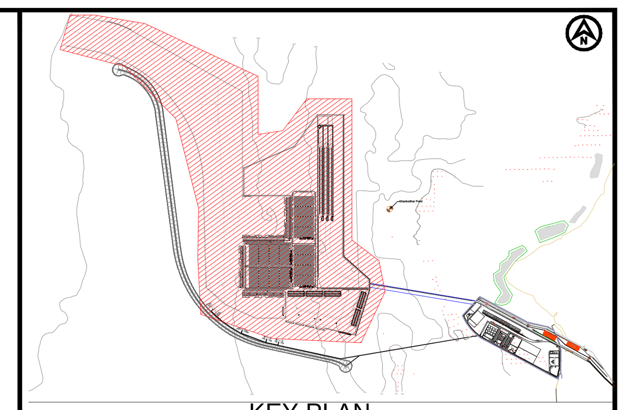
DRG No. DI1452-RHD-DP-MA-DR-CM-1301

DO NOT SCALE

PART PLAN - VADHAVAN PORT PHASE 1



SECTION A-A



KEY PLAN

NOTES

1. ALL DIMENSIONS AND LEVELS ARE IN METERS, UNLESS NOTED OTHERWISE.
2. DRAWINGS ARE NOT TO BE SCALED, WRITTEN DIMENSIONS SHOULD BE FOLLOWED AND VERIFIED WITH THE DETAILS.
3. ANY DISCREPANCIES FOUND IN DRAWINGS ARE TO BE REPORTED TO THE ENGINEER.

LEGEND

- APPROACH CHANNEL
- TURNING CIRCLE /MANEUVERING AREA
- RECLAMATION AREA

ISSUED FOR DPR

REV	DATE	DESCRIPTION	BY	CHK	APP
P03	12/11/2021	ISSUED FOR DPR	SNJ	MS	SD
P02	08/10/2021	ISSUED FOR DPR	YSK	MS	SD
P01	29/01/2021	ISSUED FOR DPR	SNJ	MS	SD

REVISIONS

CLIENT

JAWAHARLAL NEHRU PORT TRUST

CONSULTANT

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www.royalhaskoningdhv.com

Royal HaskoningDHV
Enhancing Society Together

PROJECT

Consultancy services for Design and Detailed Engineering for Greenfield Vadhavan port project

TITLE

VADHAVAN PORT
DREDGING AND RECLAMATION PLAN
(PHASE 1)

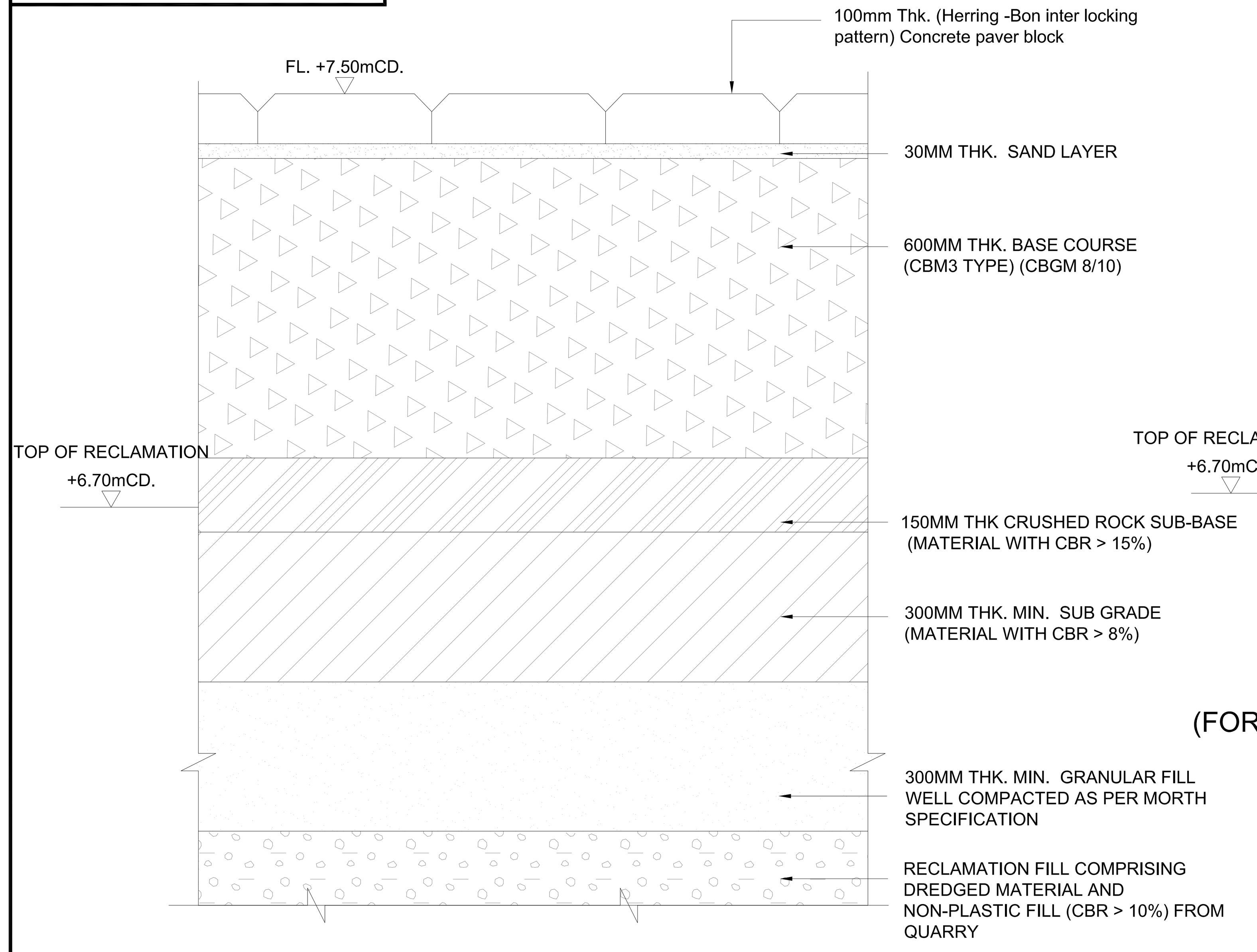
DRAWN SNJ	CHECKED MS	APPROVED ASM
DATE SEP ' 2021	SCALE @A1 N.T.S.	REF.

DRAWING No.	SUITABILITY	REVISION
DI1452-RHD-DP-MA-DR-CM-1301	S4	P03

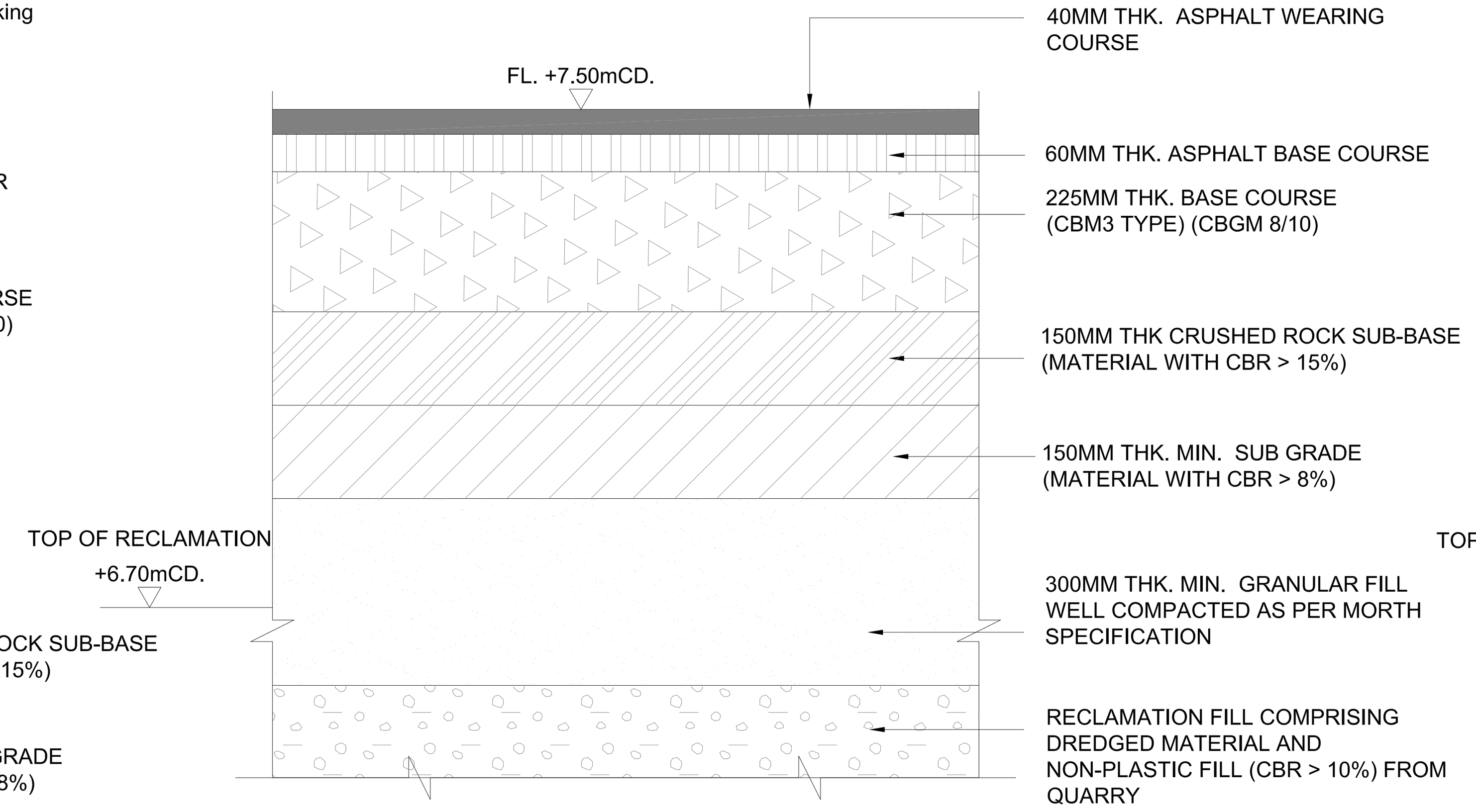
FILE INFO C:\Users\231401\Box\DI1452 Vadhavan Port\Master File Folder\20211029_Final Drawing\20211112_Drawings\DI1452-RHD-DP-MA-DR-CM-1301-S4-P03\DI1452-RHD-DP-MA-DR-CM-1301-S4P03.dwg 12-Nov-21

DRG No.
DI1452-RHD-DP-OS-DR-CM-1302

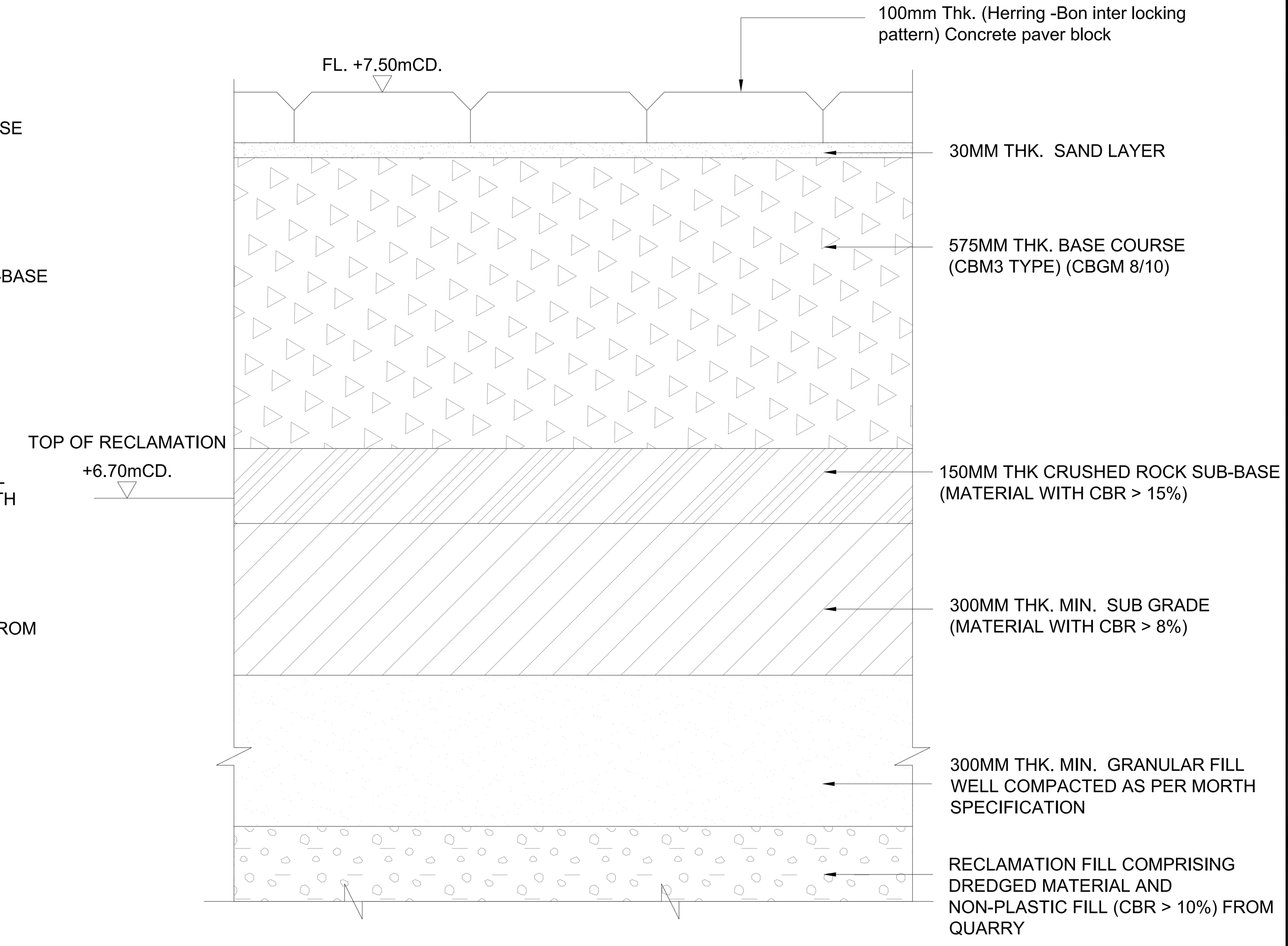
DO NOT SCALE



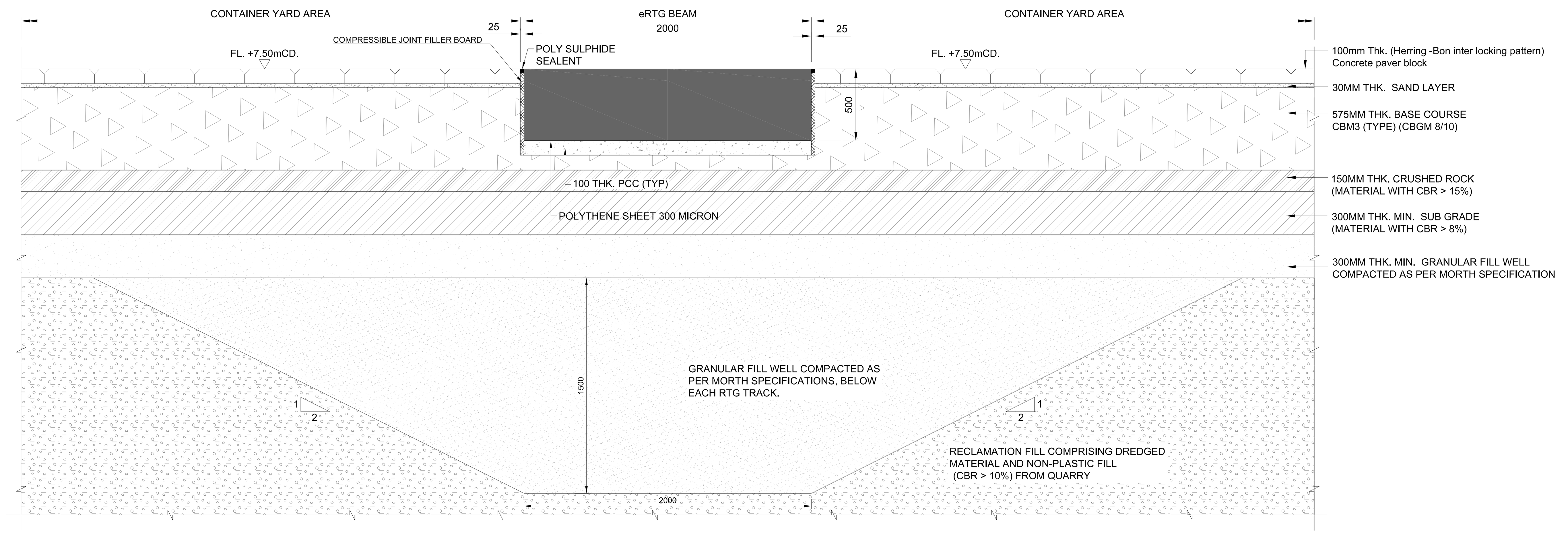
TYP. PAVER BLOCK PAVEMENT SECTION FOR ROADS
(FOR MAJOR ROADS, HEAVY TRAFFIC AREAS AND STORAGE AREAS)
SCALE 1:10



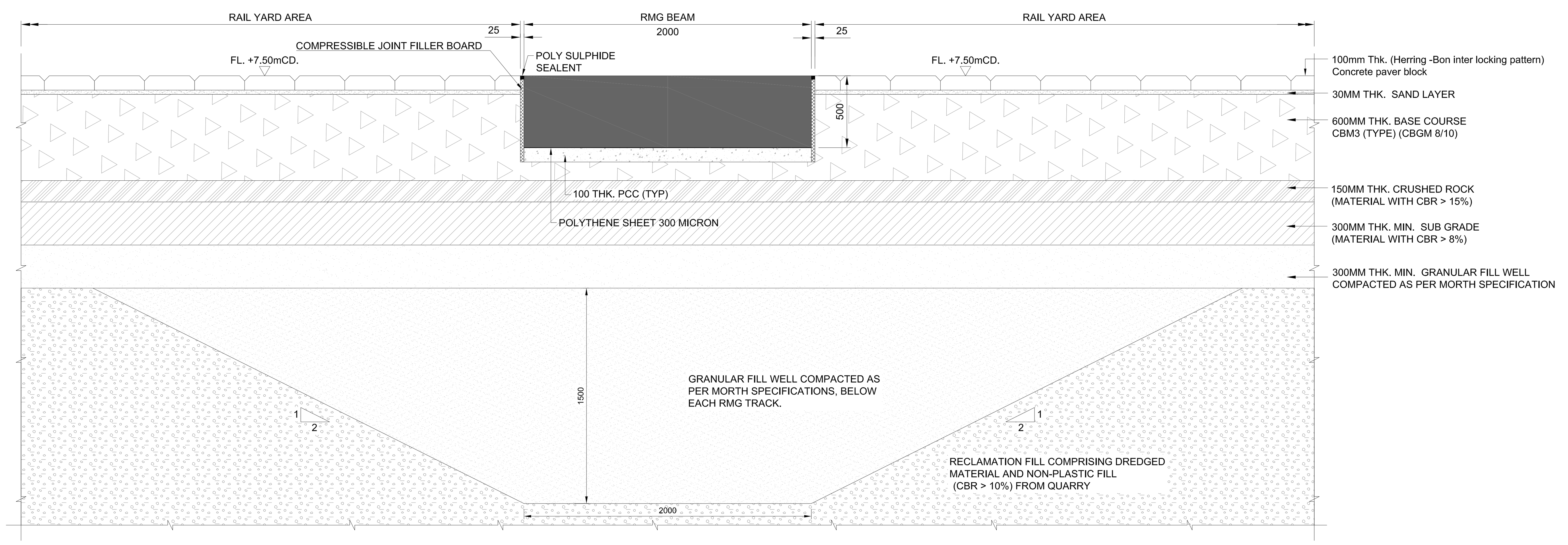
TYP. SECTION FOR ROADS (ASPHALT)
(FOR LIGHT TRAFFIC AREAS (INTERNAL ROADS) AROUND BUILDINGS)
SCALE 1:10



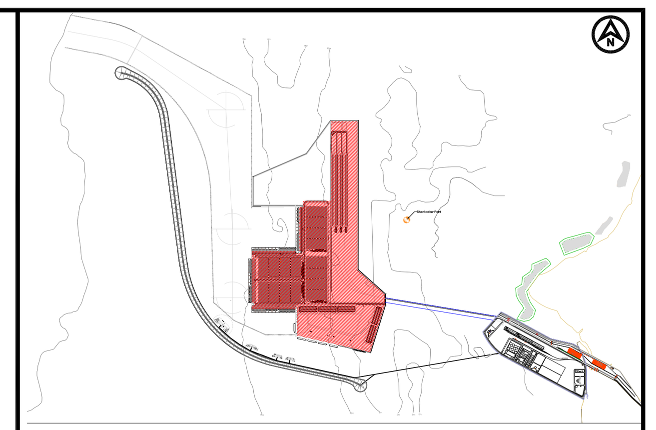
TYP. SECTION FOR PAVER BLOCK PAVEMENT
(FOR CONTAINER YARD AREA)
SCALE 1:10



TYPICAL CROSS SECTION OF RCC BEAM BELOW eRTG
SCALE 1:25



TYPICAL CROSS SECTION OF RCC BEAM BELOW RMG (FOR RAIL CORRIDOR)
SCALE 1:25



KEY PLAN

NOTES:

1. ALL DIMENSIONS ARE IN MILLIMETRES, UNLESS NOTED OTHERWISE.
2. THIS DRAWING SHOULD NOT BE SCALED. ONLY WRITTEN DIMENSIONS SHALL BE FOLLOWED.
3. THE CROSS-SLOPE OF 2.5% SHALL BE PROVIDED IN THE ROADS.

LEGEND:

FL - FINISHED LEVEL

ISSUED FOR DPR

REV	DATE	DESCRIPTION	BY	CHK	APP
P02	08/10/21	ISSUED FOR DPR	TSM	MS	SD
P01	08/02/21	ISSUED FOR DPR	TSM	MS	SD

REVISIONS

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www.royalhaskoningdhv.com

PROJECT
Consultancy services for Design and Detailed Engineering for Greenfield Vadhavan port project

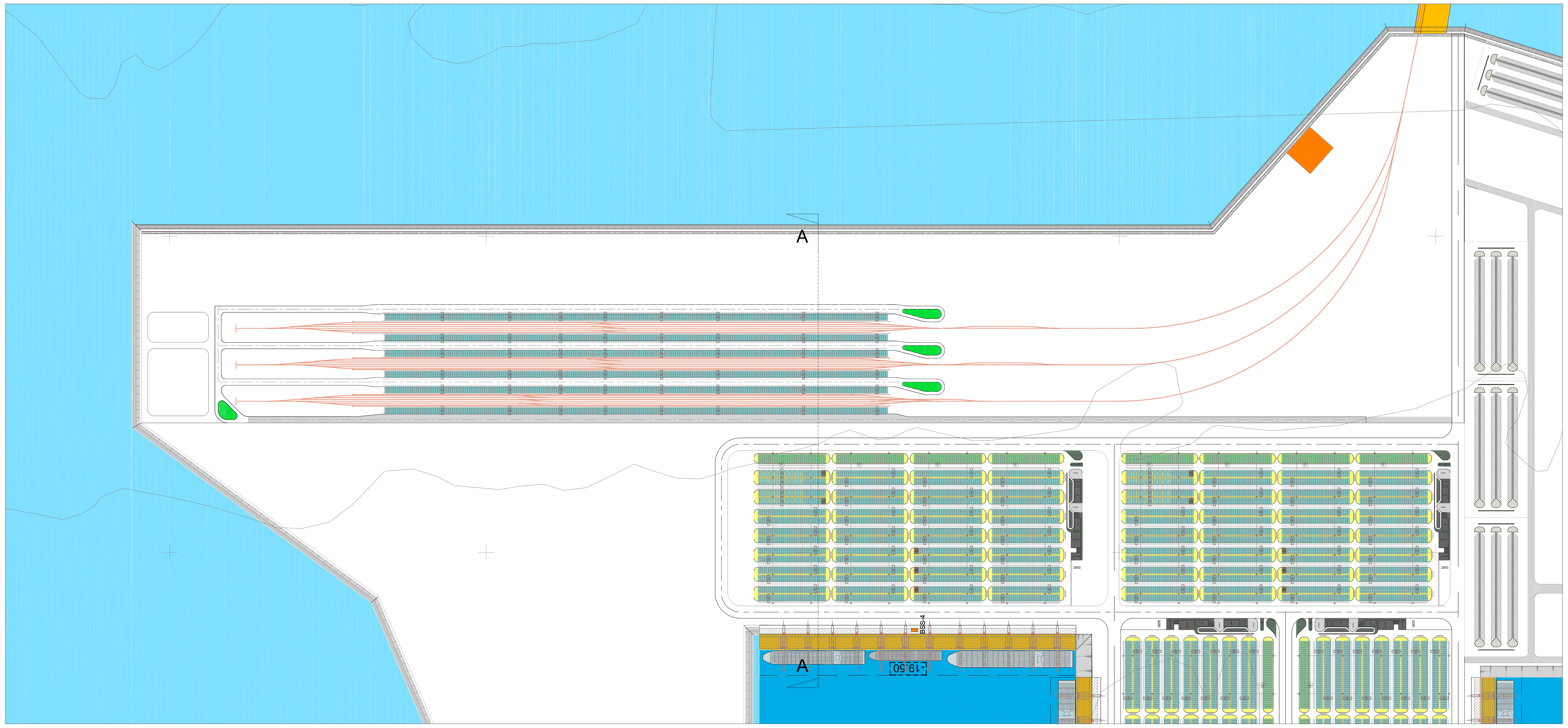
TITLE
PAVEMENT DETAILS - ROADS, CONTAINER YARD PAVEMENT

DRAWN	CHECKED	APPROVED
SNJ	MS	SD
DATE FEB 2021	SCALE @A1 AS SHOWN	REF. -

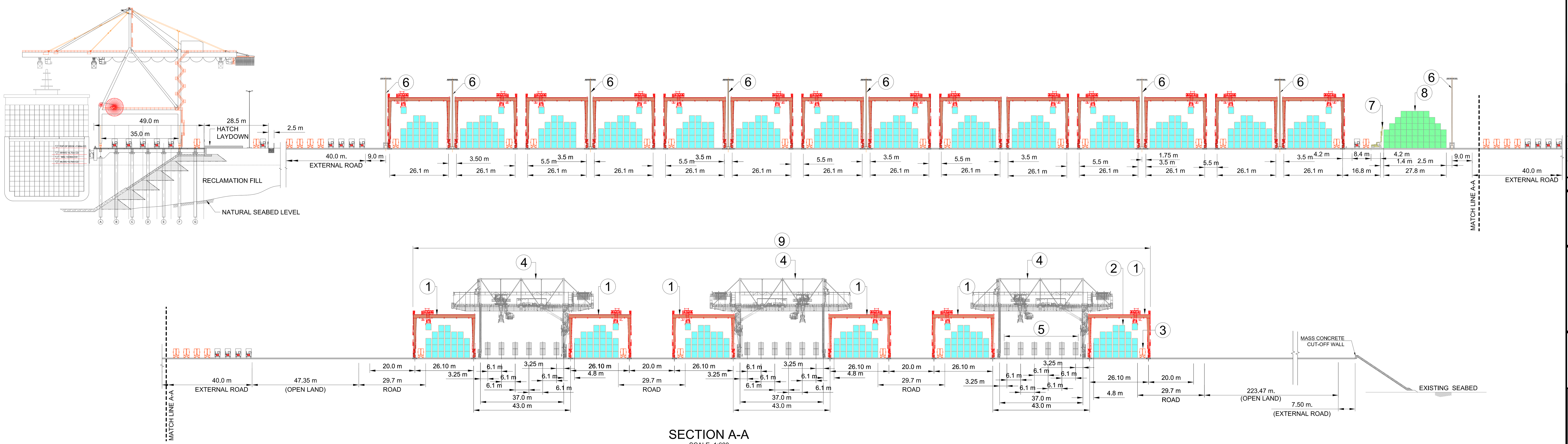
DRAWING No.	SUITABILITY	REVISION
DI1452-RHD-DP-OS-DR-CM-1302	S4	P02

DRG No.
DI1452-RHD-DP-OS-DR-CM-1303

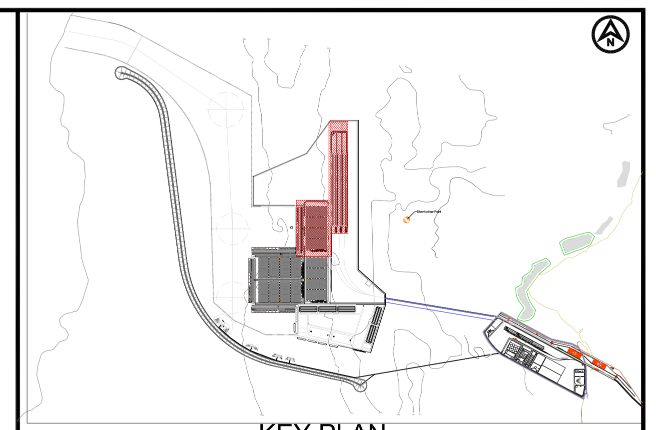
DO NOT SCALE



LAYOUT FOR PHASE 1 CONTAINER TERMINAL YARD
SCALE 1:600



SECTION A-A
SCALE 1:600



KEY PLAN

NOTES:

1. ALL DIMENSIONS ARE IN METER, UNLESS NOTED OTHERWISE.
2. THIS DRAWING SHOULD NOT BE SCALED. ONLY WRITTEN DIMENSIONS SHALL BE FOLLOWED.
3. THE CROSS SLOPE OF 2.5% SHALL BE PROVIDED IN THE ROADS.
4. THE CONCESSIONAIRE FOR THE PARTICULAR TERMINAL HAVE TO CHECK THE EXCAVATION REQUIRED TO BE CARRIED OUT BEFORE CONSTRUCTION, AS THE PAVEMENT SECTIONS ARE DEEPER THAN THE RECLAMATION LEVEL.
5. RECLAMATION WORKS SHALL INCLUDE ALL GENERAL FILL, EARTHWORKS & GROUND TREATMENT UP TO A LEVEL OF 600mm BELOW THE REQUIRED FINAL SURFACE LEVEL. THE FINAL 600mm MATERIAL SHALL BE CONSIDERED AS "FILLING".

LEGEND:

FL - FINISHED LEVEL
CT - CONTAINER TERMINAL

KEYNOTES

1. RTG CRANE
2. LOADED CONTAINERS
3. CONTAINER TRAILER
4. RMG OPERATION
5. DFCC RACKS
6. HIGH MAST
7. EMPTY LAND LOD
8. EMPTY CONTAINERS
9. NESTED RMGC - RTGC OPERATIONAL AREA

ISSUED FOR DPR

REV	DATE	DESCRIPTION	BY	CHK	APP
P02	10/28/2021	ISSUED FOR DPR	TSM	MS	ASM
P01	08/02/2020	ISSUED FOR DPR	KMP	MS	SD

REVISIONS

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www.royalhaskoningdhv.com

PROJECT
Consultancy services for Design and Detailed Engineering for Greenfield Vadhavan port project

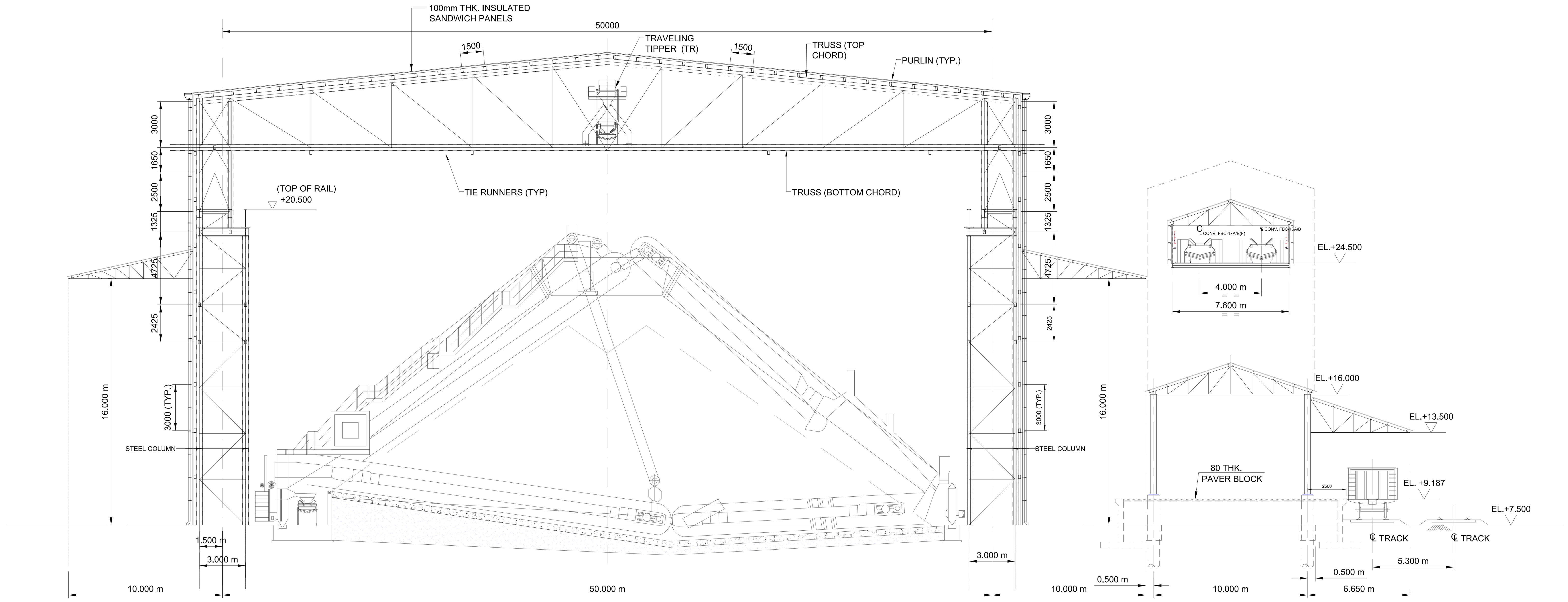
TITLE
PHASE-1
CONTAINER TERMINAL YARD
TYPICAL LAYOUT AND SECTIONS

DRAWN	CHECKED	APPROVED
SNJ	MS	ASM
DATE DEC. 2020	SCALE @A1 AS SHOWN	REF. -

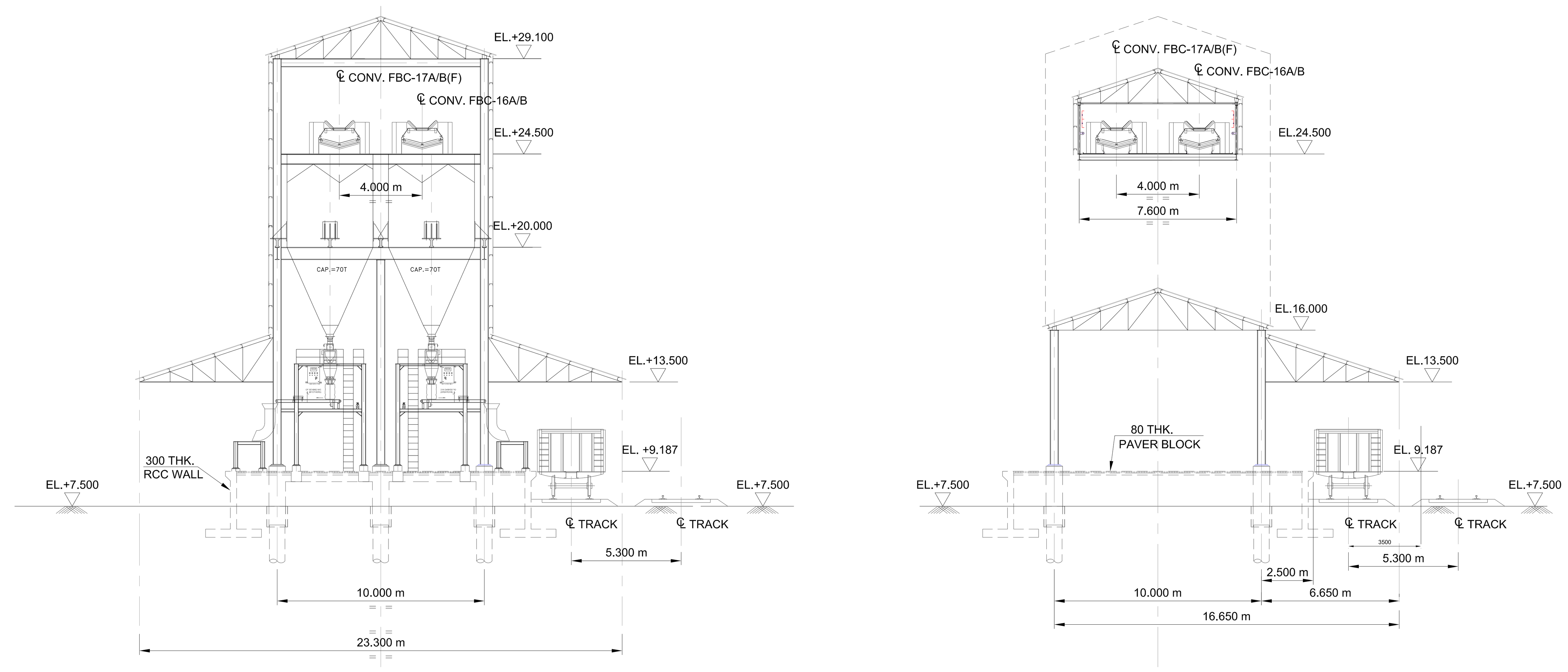
DRAWING No.	SUITABILITY	REVISION
DI1452-RHD-DP-OS-DR-CM-1303	S4	P02

DRG No.
DI1452-RHD-DP-OS-DR-CM-1304

DO NOT SCALE

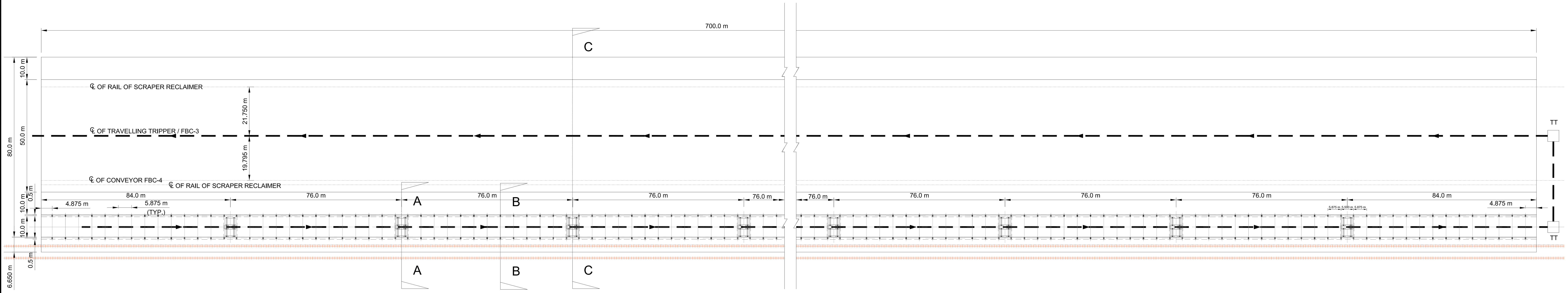


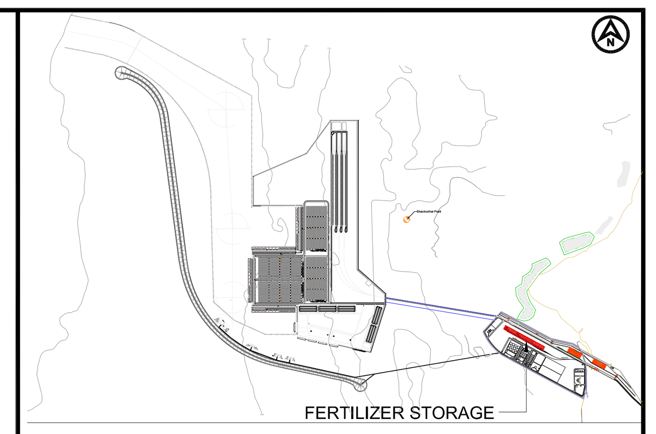
SECTION C-C
SCALE 1:200



SECTION A-A
SCALE 1:200

SECTION B-B
SCALE 1:200





KEY PLAN

NOTES

1. ALL DIMENSIONS AND LEVELS ARE IN METERS, UNLESS NOTED OTHERWISE.
2. ALL DRAWINGS TO BE READ IN CONJUNCTION WITH THE SPECIFICATIONS, THE BILL OF QUANTITIES AND OTHER RELEVANT DRAWINGS.
3. DRAWINGS ARE NOT TO BE SCALED, WRITTEN DIMENSIONS SHOULD BE FOLLOWED AND VERIFIED WITH THE DETAILS.
4. ANY DISCREPANCIES FOUND IN DRAWINGS ARE TO BE REPORTED TO THE ENGINEER.

LEGEND :-

TT = Transfer Tower
OH = Overhead Conveyor
TR = Overhead Traveling Tripper
B1 TO B3 = Bagging and Stitching Plant
FL = Finished Level

Bagging Conveyor
Overhead Conveyor
Railway Line
Mobile / Fixed Hoppers

ISSUED FOR DPR

REV	DATE	DESCRIPTION	BY	CHK	APP
P02	08/10/2021	FOR DETAILED PROJECT REPORT	TSM	BVD	ASM
P01	17/02/2021	FOR DETAILED PROJECT REPORT	TSM	BVD	ASM

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PROJECT
Consultancy services for Design and Detailed Engineering for Greenfield Vadhavan port project

TITLE
PHASE-1
FERTILIZER STORAGE
LAYOUT AND SECTIONS

DRAWN	CHECKED	APPROVED
SNJ	MS	SD
DATE FEB ' 2021	SCALE @A1 AS SHOWN	REF. -

DRAWING No.	SUITABILITY	REVISION
DI1452-RHD-DP-OS-DR-CM-1304	S4	P02

APPENDIX 2 – DETAILED COST BREAKUP

Vadhavan Port - Detailed Design Estimates

S. No.	ITEM			Phase 1 QUANTITY	UNIT	RATE (Rs.)	JNPT AMOUNT (Rs.)	Terminal Developer AMOUNT (Rs.)
1	**PROJECT PRELIMINARIES AND SITE DEVELOPMENT**							
	1.1		Project Studies and Surveys	1	LS	500,000,000	500,000,000	
	1.2		Land Acquisition	0	LS		0	
	1.3		Site Clearing and Site Development	1	LS	100,000,000	100,000,000	
	Total (1)						**600,000,000**	
2	**DREDGING**							
	2.1		**Inner Approach Channel & Harbour Basin**					
		a.	Soil dredging	2,750,000	cum	300	825,000,000	
		b.	Rock dredging	3,540,000	cum	2,350	8,319,000,000	
	2.2		**Outer Approach Channel**					
		a.	Soil dredging	720,000	cum	300	216,000,000	
		b.	Rock dredging	0	cum	2,350	0	
	Total (2)						**9,360,000,000**	
3.0	**RECLAMATION**							
	3.1		Near Shore land					
		a.	Reclamation through marine burrow pit	4,320,000	Cum	570	2,462,400,000	
		b.	Reclamation through dredged material	6,910,000	Cum	300	2,073,000,000	
	3.2		Offshore land					
		a.	Reclamation through marine burrow pit	155,565,000	Cum	570	88,672,050,000	
		b.	Reclamation through dredged material	0	Cum	300	0	
	Total (3)						**93,207,450,000**	
4.0	**SHORE PROTECTION WORKS**							
	4.1		Near shore reclaimed land protection works					
		a.	Rock					
			Rock 0.3 to 1 MT	396,719	MT	1,763	699,416,537	
			Rock 3 to 6 MT	897,110	MT	1,878	1,684,774,974	
		b.	Core and Bedding					
			Core 10 to 100kg	2,326,764	MT	1,300	3,024,793,368	
			Filter layer 1m thk	230,963	MT	1,300	300,252,364	
			Geotextile	125,919	Sq. m	211	26,568,865	
	4.2		Offshore reclaimed land protection works					
		a.	Rock					
			Rock Armour 0.06-0.3T	866,800	MT	1,729	1,498,265,808	
			Rock 0.3 to 1 MT	501,183	MT	1,763	883,587,128	
			Rock 1 to 3 MT	697,040	MT	1,809	1,260,946,961	
		b.	Core and Bedding					
			Toe Protection - 1-500 Kg	156,352	MT	1,300	203,258,052	
			Core 10 to 100 kg	10,430,453	MT	1,300	13,559,588,850	
			Geotextile	1,220,298	Sq. m	211	257,482,959	
		c.	Crown Wall, Cast-In-Situ M40 Mass Concrete	41,543	Cum	10,000	415,433,750	
	Total (4)						**23,814,369,615**	
5.0	**BREAKWATER**							
	5.1		**Breakwater**					
		a.	Accropodes					
			Accropod 11 Cum	591,296	Cum	13,750	8,130,320,336	
			Accropod 13 Cum	34,658	Cum	13,750	476,553,520	
		b.	Rock					
			Rock 0.3 to 1 MT	1,232,048	MT	1,763	2,172,104,342	
			Rock 2 to 4 MT	2,707,935	MT	1,809	4,898,662,587	
			Rock 3 to 6 MT	24,298	MT	1,878	45,631,717	
			Rock 4 to 6 MT	375,784	MT	1,878	705,723,486	
		c.	Core and Bedding					
			Core 10 to 100 Kg	25,245,154	MT	1,300	32,818,700,200	
			Filter layer 0.30m thk upto 10 kg	689,026	MT	1,300	895,733,800	
		d.	Wave Wall	347,048	Cum	10,000	3,470,478,700	
	Total (5)						**53,613,908,688**	
6	**BERTHS**							
	6.1		**Container Terminal 1 (CT1)**					

S. No.			ITEM	QUANTITY	UNIT	RATE (Rs.)	AMOUNT (Rs.)	AMOUNT (Rs.)
		a.	Berth	48,120	Sq. m	138,000		6,640,604,850
		b.	Earthworks for Sub-base preparation (Filling from +5.0 mCD to +6.8mCD)					
			Burrowed earth	1,043,534	Cum	850		887,003,730
		c.	Yard Pavement					
			Pavement for the yard other than eRTG lane	502,076	Sq. m	4,281		2,149,386,478
			Pavement for eRTG lanes	59,920	Sq. m	12,311		737,700,805
			Pavement behind the berth	28,500	Sq. m	4,281		122,008,500
			Striping and signages	5,383	Sq. m	623		3,353,858
		d.	Terminal buildings					
			Terminal admin building	1,000	Sq. m	40,000		40,000,000
			Substation	600	Sq. m	40,000		24,000,000
			Workshop	1,500	Sq. m	25,000		37,500,000
			Equipment parking area	700	Sq. m	3,800		2,660,000
			Reefer wash area	197	Sq. m	3,800		748,600
			Custom office	400	Sq. m	40,000		16,000,000
			Pumphouse	225	Sq. m	25,000		5,625,000
			Terminal gate house	120	Sq. m	25,000		3,000,000
			Landscaping	5,051	Sq. m	8,000		40,408,000
			Security guard house	10	Sq. m	12,000		120,000
			Hazardous cargo storage	5,131	Sq. m	3,800		19,497,800
			STP area	80	Sq. m	50,000		4,000,000
		e.	Asphalt road to terminal buildings and parking facilities	4,275	Sq. m	3,262		13,943,525
		f.	Equipment					
			Rail Mounted Quay Cranes	12	No.	800,000,000		9,600,000,000
			e-Rubber Tyre Gantry Cranes	36	No.	127,500,000		4,590,000,000
			ITVs	0	No.	4,800,000		0
			Reach Stacker	0	No.	38,250,000		0
			Empty Handlers	0	No.	15,000,000		0
			Other Miscellaneous Equipment and Spares (5% of net equipments above)	5%	%	14,190,000,000		709,500,000
			Workshop Equipments	1	LS	50,000,000		50,000,000
		g.	Utilities					
			Electric Supply, Distribution lines,Communication,IT,Street/Highmast lighting and	1	LS	717,264,394		717,264,394
			Fire Fighting	1	LS	159,981,250		159,981,250
			Water Supply & Distribution System	1	LS	11,893,517		11,893,517
			Drainage and Sewerage	1	LS	291,138,084		291,138,084
			Miscellaneous cost @1%	1	LS			11,802,772
		h.	Yard fencing	2,000	m	2,613		5,226,000
		i.	Project Studies and Surveys	0	LS	500,000,000		0
	Total (6.1)							**26,894,367,163**
	6.2	**Container Terminal 2 (CT2)**						
		a.	Berth	47,500	Sq. m	138,000		6,555,000,000
		b.	Earthworks for Sub-base preparation (Filling from +5.0 mCD to +6.8mCD)					
			Burrowed earth	1,013,292	Cum	850		861,298,200
		c.	Yard Pavement					
			Pavement for the yard other than eRTG lane	510,601	Sq. m	4,281		2,185,884,405
			Pavement for eRTG lanes	59,920	Sq. m	12,311		737,700,805
			Pavement behind the berth	28,500	Sq. m	4,281		122,008,500
			Striping and signages	5,184	Sq. m	623		3,229,757
		d.	Terminal buildings					
			Terminal admin building	1,000	Sq. m	40,000		40,000,000
			Substation	600	Sq. m	40,000		24,000,000
			Workshop	1,500	Sq. m	25,000		37,500,000
			Equipment parking area	700	Sq. m	4,281		2,996,700
			Reefer wash area	197	Sq. m	4,281		843,357
			Custom office	400	Sq. m	40,000		16,000,000
			Pumphouse	225	Sq. m	25,000		5,625,000
			Terminal gate house	120	Sq. m	25,000		3,000,000
			Landscaping	5,051	Sq. m	8,000		40,408,000
			Security guard house	10	Sq. m	12,000		120,000
			Hazrardous cargo storage	5,131	Sq. m	4,281		21,965,811
			STP area	80	Sq. m	50,000		4,000,000

S. No.	ITEM			QUANTITY	UNIT	RATE (Rs.)	AMOUNT (Rs.)	AMOUNT (Rs.)
		e.	Asphalt road to terminal buildings and parking facilities	4,275	Sq. m	3,262		13,943,525
		f.	Equipments					
			Rail Mounted Quay cranes	12	Nos	800,000,000		9,600,000,000
			e-Rubber Tyre Gantry Cranes	36	Nos	127,500,000		4,590,000,000
			ITVs	0	Nos	4,800,000		0
			Reach Stacker	0	Nos	38,250,000		0
			Empty Handlers	0	Nos	15,000,000		0
			Other Miscellaneous Equipment and Spares (5% of net equipments above)	5%	%	14,190,000,000		709,500,000
			Workshop Equipments	1	LS	50,000,000		50,000,000
		g.	Utilities					
			Electric Supply, Distribution lines,Communication,IT,Street/Highmast lighting and	1	LS	762,094,563		762,094,563
			Fire Fighting	1	LS	176,711,861		176,711,861
			Water Supply & Distribution System	1	LS	22,498,767		22,498,767
			Drainage and Sewerage	1	LS	322,431,299		322,431,299
			Miscellaneous cost @1%	1	LS			12,837,365
		h.	Yard fencing	3,000	m	2,613		7,839,000
		i.	Project Studies and Surveys	0	LS	500,000,000		0
	Total (6.2)							**26,929,436,914**
	6.3	**Container Terminal 3 (CT3)**						
		a.	Berth	48,120	Sq. m	138,000		6,640,604,850
		b.	Earthworks for Sub-base preparation (Filling from +5.0 mCD to +6.8mCD)					
			Burrowed earth	1,041,734	Cum	850		885,473,730
		c.	Yard Pavement					
			Pavement for the yard other than eRTG lane	502,076	Sq. m	4,281		2,149,386,478
			Pavement for eRTG lanes	59,920	Sq. m	12,311		737,700,805
			Pavement behind the berth	28,500	Sq. m	4,281		122,008,500
			Striping and signages	5,383	Sq. m	623		3,353,858
		d.	Terminal buildings					
			Terminal admin building	1,000	Sq. m	40,000		40,000,000
			Substation	600	Sq. m	40,000		24,000,000
			Workshop	1,500	Sq. m	25,000		37,500,000
			Equipment parking area	700	Sq. m	4,281		2,996,700
			Reefer wash area	197	Sq. m	4,281		843,357
			Custom office	400	Sq. m	40,000		16,000,000
			Pumphouse	225	Sq. m	25,000		5,625,000
			Terminal gate house	120	Sq. m	25,000		3,000,000
			Landscaping	5,051	Sq. m	8,000		40,408,000
			Security guard house	10	Sq. m	12,000		120,000
			Hazrardous cargo storage	5,131	Sq. m	4,281		21,965,811
			STP area	80	Sq. m	50,000		4,000,000
		e.	Asphalt road to terminal buildings and parking facilities	4,275	Sq. m	3,262		13,943,525
		f.	Equipments					
			Rail Mounted Quay cranes	12	No.	800,000,000		9,600,000,000
			e-Rubber Tyre Gantry Cranes	36	No.	127,500,000		4,590,000,000
			ITVs	0	No.	4,800,000		0
			Reach Stacker	0	No.	38,250,000		0
			Empty Handlers	0	No.	15,000,000		0
			Other Miscellaneous Equipment and Spares (5% of net equipments above)	5%	%	14,190,000,000		709,500,000
			Workshop Equipments	1	LS	50,000,000		50,000,000
		g.	Utilities					
			Electric Supply, Distribution lines,Communication,IT,Street/Highmast lighting and	1	LS	699,901,982		699,901,982
			Fire Fighting	1	LS	159,971,493		159,971,493
			Water Supply & Distribution System	1	LS	12,348,587		12,348,587
			Drainage and Sewerage	1	LS	291,138,084		291,138,084
			Miscellaneous cost @1%	1	LS			11,633,601
		h.	Yard fencing	2,000	m	2,613		5,226,000
		i.	Project Studies and Surveys	0	LS	500,000,000		0
	Total (6.3)							**26,878,650,360**

S. No.			ITEM	QUANTITY	UNIT	RATE (Rs.)	AMOUNT (Rs.)	AMOUNT (Rs.)
	6.4		**Container Terminal 4 (CT4)**					
		a.	Berth	47,500	Sq. m	138,000		6,555,000,000
		b.	Earthworks for Sub-base preparation (Filling from +5.0 mCD to +6.8mCD)					
			Burrowed earth	1,061,818	Cum	850		902,545,470
		c.	Yard Pavement					
			Pavement for the yard other than eRTG lane	494,194	Sq. m	4,281		2,115,642,429
			Pavement for eRTG lanes	59,920	Sq. m	12,311		737,700,805
			Pavement behind the berth	28,500	Sq. m	4,281		122,008,500
			Striping and signages	5,184	Sq. m	623		3,229,757
		d.	Terminal buildings					
			Terminal admin building	1,000	Sq. m	40,000		40,000,000
			Substation	600	Sq. m	40,000		24,000,000
			Workshop	1,500	Sq. m	25,000		37,500,000
			Equipment parking area	700	Sq. m	4,281		2,996,700
			Reefer wash area	197	Sq. m	4,281		843,357
			Custom office	400	Sq. m	40,000		16,000,000
			Pumphouse	225	Sq. m	25,000		5,625,000
			Terminal gate house	120	Sq. m	25,000		3,000,000
			Landscaping	5,051	Sq. m	8,000		40,408,000
			Security guard house	10	Sq. m	12,000		120,000
			Hazrardous cargo storage	5,131	Sq. m	4,281		21,965,811
			STP area	80	Sq. m	50,000		4,000,000
		e.	Asphalt road to terminal buildings and parking facilities	4,275	Sq. m	3,262		13,943,525
		f.	Equipments					
			Rail Mounted Quay cranes	12	No.	800,000,000		9,600,000,000
			e-Rubber Tyre Gantry Cranes	36	No.	127,500,000		4,590,000,000
			ITVs	0	No.	4,800,000		0
			Reach Stacker	0	No.	38,250,000		0
			Empty Handlers	0	No.	15,000,000		0
			Other Miscellaneous Equipment and Spares (5% of net equipments above)	5%	%	14,190,000,000		709,500,000
			Workshop Equipments	1	LS	50,000,000		50,000,000
		g.	Utilities					
			Electric Supply, Distribution lines,Communication,IT,Street/Highmast lighting and	1	LS	777,710,570		777,710,570
			Fire Fighting	1	LS	178,175,617		178,175,617
			Water Supply & Distribution System	1	LS	12,955,347		12,955,347
			Drainage and Sewerage	1	LS	401,707,514		401,707,514
			Miscellaneous cost @1%	1	LS			13,705,490
		h.	Yard fencing	2,000	m	2,613		5,226,000
		i.	Project Studies and Surveys	0	LS	500,000,000		0
	Total (6.4)							**26,985,509,892**
	6.5		**Multipurpose Terminals - 3 No.**					
		a.	Berths	19,200	Sq. m	140,000		2,688,000,000
		b.	Earthworks for Sub-base preparation (Filling from +5.0 mCD to +6.8mCD)					
			Burrowed earth	757,181	Cum	850		643,603,680
		c.	Yard Pavements					
			Asphalt terminal roads	56,000	Sq. m	3,262		182,661,465
			Storage Yard	200,000	Sq. m	4,281		856,156,076
		d.	Equipments'					
			MHCr	6	No.	320,000,000		1,920,000,000
			Front end loaders	4	No.	2,000,000		8,000,000
			Dumpers	0	No.	4,500,000		0
			Payloaders	4	No.	2,500,000		10,000,000
			Berth Conveyors	0	m	0		0
			Yard Conveyors	0	m	0		0
			Bagging plant	11	No.	2,500,000		27,500,000
			Portable Conveyor	5	No.	300,000		1,500,000
			Forklifts	6	No.	1,000,000		6,000,000
			Weigh bridge	1	No.	2,000,000		2,000,000
			Other Miscellaneous Equipment and Spares (5% of net equipments above)	5%	%			98,750,000
		e.	Terminal buildings					

S. No.			ITEM	QUANTITY	UNIT	RATE (Rs.)	AMOUNT (Rs.)	AMOUNT (Rs.)
			Terminal admin building	500	Sq. m	40,000		20,000,000
			Custom office	200	Sq. m	40,000		8,000,000
			Terminal gate house	100	Sq. m	25,000		2,500,000
			Security guard house	10	Sq. m	12,000		120,000
			Fertiliser Shed	60,655	Sq. m	25,000		1,516,375,000
			Miscelleneous terminal buildings	500	Sq. m	25,000		12,500,000
		f.	Utilities					
			Electric Supply, Distribution lines,Communication,IT,Street/Highmast lighting and	1	LS	72,644,522		72,644,522
			Fire Fighting	1	LS	127,760,603		127,760,603
			Water Supply & Distribution System	1	LS	36,154,995		36,154,995
			Drainage and Sewerage	1	LS	355,139,388		355,139,388
			Miscellaneous cost @1%	1	LS			5,916,995
		g.	Yard fencing	1,830	m	2,613		4,781,790
		h.	Project Studies and Surveys	0	LS	100,000,000		0
	Total (6.5)							**8,606,064,513**
	6.6	**RO-RO Terminal**						
		a.	Berth	9,700	Sq. m	126,000		1,222,200,000
		b.	Earthworks for Sub-base preparation (Filling from +5.0 mCD to +6.8mCD)					
			Burrowed earth	299,687	Cum	850		254,734,290
		c.	Yard development - Paved area	81,568	Sq. m	3,153		257,195,342
		d.	Terminal roads	23,560	Sq. m	3,262		76,848,288
		e.	Buildngs					
			PDI Building	400	Sq. m	40,000		16,000,000
			Gate house	100	Sq. m	25,000		2,500,000
		f.	Utilities					
			Electric Supply, Distribution lines,Communication,IT,Street/Highmast lighting and	1	LS	10,000,000		10,000,000
			Fire Fighting	1	LS	43,902,736		43,902,736
			Water Supply & Distribution System	1	LS	14,073,013		14,073,013
			Drainage and Sewerage	1	LS	135,773,307		135,773,307
			Miscellaneous cost @1%	1	LS			2,037,491
		g.	Terminal fencing	1,220	m	2,613		3,187,860
		h.	Project Studies and Surveys	0	LS	50,000,000		0
	Total (6.6)							**2,038,452,327**
	6.7	**LNG Jetty**						
		a.	Jetty					
			Unloading Platform	0	Sq. m	180,000		0
			Mooring Dolphins	0	Sq. m	299,000		0
			Berthing Dolphins	0	Sq. m	278,000		0
			Approach Trestle	0	Sq. m	146,000		0
		b.	Earthworks for Sub-base preparation (Filling from +5.0 mCD to +6.8mCD)					
			Burrowed earth	0	Cum	850		0
		c.	Top side development					
			Pipelines		LS	0		0
			FSRU		LS	0		0
		d.	Buildings					
			Terminal admin building	0	Sq. m	40,000		0
			Gate house	0	Sq. m	25,000		0
			Pumphouse	0	Sq. m	25,000		0
		e.	Terminal roads	0	sqm	3,700		0
		f.	Equipments					
			Unloading arms	0	No.	70,000,000		0
			Other Miscellaneous Equipment and Spares (5% of net equipments above)	0%	%			0
		g.	Utilities					

S. No.	ITEM			QUANTITY	UNIT	RATE (Rs.)	AMOUNT (Rs.)	AMOUNT (Rs.)
			Electric Supply, Distribution lines,Communication,IT,Street/Highmast lighting and	0	LS	207,388,970		0
			Fire Fighting	0	LS	203,533,140		0
			Water Supply & Distribution System	0	LS	14,000,000		0
			Drainage and Sewerage	0	LS	34,200,000		0
		h.	Terminal fencing	0	m	2,613		0
		i.	Project Studies and Surveys	0	LS	250,000,000		0
	Total (6.7)							
	6.7	**LPG Jetty**						
		a.	Jetty					
				5,529	Sq. m	320,000		1,769,280,000
		b.	Earthworks for Sub-base preparation (Filling from +5.0 mCD to +6.8mCD)					
			Burrowed earth	178,506	Cum	850		151,730,100
		c.	Top side development					
			Pipelines		LS	0		0
			Tankfarms		LS	0		0
		d.	Buildings					
			Terminal admin building	400	Sq. m	40,000		16,000,000
			Gate house	200	Sq. m	25,000		5,000,000
			Workshop	400	Sq. m	25,000		10,000,000
			Fire Pumphouse	100	Sq. m	25,000		2,500,000
		e.	Terminal roads	27,100	Sq. m	3,262		88,395,102
		f.	Equipments					
			Unloading arms	0	No.	55,000,000		0
			Other Miscellaneous Equipment and Spares (5% of net equipments above)	5%	%			0
		g.	Utilities					
			Electric Supply, Distribution lines,Communication,IT,Street/Highmast lighting and	1	LS	70,321,188		70,321,188
			Fire Fighting	1	LS	225,245,208		225,245,208
			Water Supply & Distribution System	1	LS	4,817,504		4,817,504
			Drainage and Sewerage	1	LS	44,034,189		44,034,189
			Miscellaneous cost @1%	1	LS			3,444,181
		h.	Terminal fencing	1,475	m	2,613		3,854,175
		i.	Project Studies and Surveys	0	LS	250,000,000		0
	Total (6.7)							**2,394,621,648**
	6.8	**Liquid Jetty - Edible and Chemical - 2Nos**						
		a.	Jetty					
			0	8,808	Sq. m	258,000		2,272,464,000
		b.	Earthworks for Sub-base preparation (Filling from +5.0 mCD to +6.8mCD)					
			Burrowed earth	208,177	Cum	850		176,950,620
		c.	Top side development					
			Pipelines		LS	0		0
			Tankfarm development		LS	0		0
		d.	Buildings					
			Terminal admin building	800	Sq. m	40,000		32,000,000
			Gate house	400	Sq. m	25,000		10,000,000
			Workshop	800	Sq. m	25,000		20,000,000
			Fire Pumphouse	200	Sq. m	25,000		5,000,000
		e.	Roads	38,407	Sq. m	3,700		142,105,900
		f.	Equipments					
			Unloading arms	0	Nos	55,000,000		0
			Other Miscellaneous Equipment and Spares (5% of net equipments above)	5%	%			0
		g.	Utilities					
			Electric Supply, Distribution lines,Communication,IT,Street/Highmast lighting and	1	LS	138,057,043		138,057,043
			Fire Fighting	1	LS	108,175,637		108,175,637
			Water Supply & Distribution System	1	LS	6,486,956		6,486,956
			Drainage and Sewerage	1	LS	73,994,112		73,994,112
			Miscellaneous cost @1%	1	LS			3,267,137

S. No.		ITEM	QUANTITY	UNIT	RATE (Rs.)	AMOUNT (Rs.)	AMOUNT (Rs.)
	h.	Terminal fencing	1,575	m	2,613		4,115,475
	i.	Project Studies and Surveys	0	LS	200,000,000		0
	Total (6.8)						**2,992,616,880**
7	**COMMON PORT INFRASTRUCTURE**						
	7.1	Earthworks for Sub-base preparation (Filling from +5.0 mCD to +6.8mCD)					
		Burrowed earth	3,177,666	Cum	570	1,811,269,620	
	7.2	Approach trestles					
		Approach trestle to offshore reclaimed land	103,275	Sq. m	61,000	6,299,775,000	
		Pipeline service trestle for island jetties	126,380	Sq. m	88,000	11,121,440,000	
		Approach trestle to breakwater head	2,235	Sq. m	156,000	348,660,000	
	7.3	Port Buildings					
		Main Substation (admin Cluster)	400	Sq. m	38,000	15,200,000	
		Fire Statiom (Admin Cluster)	600	Sq. m	42,000	25,200,000	
		Admin Building	9,680	Sq. m	60,000	580,800,000	
		Guest House	2,400	Sq. m	54,000	129,600,000	
		Port User Building (outside Customs)	12,000	Sq. m	54,000	648,000,000	
		Port Operations Building +VTMS+facilitation Center	10,000	Sq. m	54,000	540,000,000	
		MRSS	1,600	Sq. m	38,000	60,800,000	
		Maintainance Workshop	3,500	Sq. m	45,000	157,500,000	
		Watch towers	180	Sq. m	24,000	4,320,000	
		Overhead Water Tank	1	LS	33,849,120	33,849,120	
		UG tank and Pump room	1	LS	108,091,050	108,091,050	
		STP	0	LS	0	0	
		Other Miscellaneous Buildings	5,000	Sq. m	35,000	175,000,000	
	7.4	Tug/ Port craft berths					
		Berth	3,700	Sq. m	191,000	706,700,000	
		Utilities	1	LS	2,500,000	2,500,000	
	7.5	Roads					
		Primary roads within the port	1,105,013	Sq. m	6,225	6,878,846,124	
		Asphalt roads within the port	168,626	Sq. m	3,262	550,027,203	
		Parking Area	438,472	Sq. m	4,281	1,877,100,173	
	7.6	ROB	1	LS	1,235,711,251	1,235,711,251	
	7.7	Underpass for PCU	1	LS	190,438,474	190,438,474	
	7.8	Utilities					
		Electric Supply, Distribution lines,Communication,IT,Street/Highmast lighting and etc.	1	LS	783,950,033	783,950,033	
		Fire Fighting	1	LS	694,315,134	694,315,134	
		Water Supply & Distribution System	1	LS	433,827,308	433,827,308	
		Drainage and Sewerage	1	LS	1,788,888,292	1,788,888,292	
		Utilities for Green area development	1	LS	72,000,000	72,000,000	
	7.9	Compound wall and fencing	7,000	m	8,000	56,000,000	
	Total (7)					**37,329,808,782**	

S. No.		ITEM	QUANTITY	UNIT	RATE (Rs.)	AMOUNT (Rs.)	AMOUNT (Rs.)
8	ROADS AND RAILWAYS						
	8.1	Roads - External					
		External Road from NH8 to Port	33.6	km	663,095,238	22,280,000,000	
	8.2	Railway Lines and Sidings - External					
		External Rail Link to Existing Rail Line	12,400	m		7,709,767,310	
		Marshalling yard at Phalghar Station	16,000	m		1,490,232,690	
	8.3	Approach trestle for the common port railyard	51,000	Sq. m	63,000	3,213,000,000	
	8.4	Railway Yard - In-Port					
	8.41	Railway Lines and Sidings - In-Port					
		Rail sidings In-port Rail yard - Containers & other cargoes		LS		2,722,000,000	
	8.42	Rail Yard Pavement					
		Pavement for the yard other than eRTG/RMGC lane	185,866	Sq. m	4,281	795,693,202	
		Pavement for RMGC lanes	9,599	Sq. m	13,257	127,262,324	
		Pavement for eRTG lanes	47,859	Sq. m	12,311	589,212,664	
		Heavy Duty Pavement	269,382	Sq. m	4,281	1,153,225,840	
		Striping and signages	20,967	Sq. m	623	13,062,217	
	8.43	Earthworks for Sub-base preparation (Filling from +5.0 mCD to +6.8mCD)	5,233,875	Cum	850	4,448,793,750	
	8.44	Equipments'					
		Rail Mounted Gantry Cranes	5	No.	212,500,000	1,062,500,000	
		e-Rubber Tyre Gantry Cranes	16	Nos	127,500,000	2,040,000,000	
		Other Miscellaneous Equipment and Spares (5% of net equipments above)	5%			155,125,000	
	8.45	Utilities					
		Power and controls	1	LS	55,050,500	55,050,500	
		Drainage and Sewerage	1	LS	1,051,362,576	1,051,362,576	
		Fire fighting & water	1	LS	57,499,162	57,499,162	
	8.46	Rail master Building	400	Sq. m	42,000	16,800,000	
	Total (8)					**48,980,587,234**	
9	**LANDSCAPING**						
	9.1	Landscaping	1	LS	903,000,000	903,000,000	
	Total (9)					**903,000,000**	
10	**EXTERNAL UTILITIES AND OTHERS**						
	10.1	Power utilities from tapping source	1	LS	475,100,000	475,100,000	
	10.2	MUSS scada	1	LS	15,739,600	15,739,600	
	10.3	Supply and Installation of Manholes, Cable Trenches as required.	1	LS	74,000,796	74,000,796	
	10.4	Fees for TAPS	1	LS	2,600,000,000	2,600,000,000	
	10.5	Cost of pipe routing from Kiwdas dam to the port	1	LS	75,500,000	75,500,000	
	10.6	Port Township at Palghar	1	LS	150,000,000	150,000,000	
	Total (10)					**3,390,340,396**	
11	**PORT CRAFTS AND NAVIGATIONAL AIDS**						
	11.1	Tugs					
		65 T bollard pull	0	No.	900,000,000		
		100 T bollard pull	0	No.	1,050,000,000	**LEASED**	
		Standby tugs	0	No.	900,000,000		
	11.2	Pilot-cum-Survey Launches	1	No.	75,000,000	75,000,000	
	11.3	Mooring Launches	2	No.	30,000,000	60,000,000	
	11.4	Navigational Aids					
		Fair buoy	1	No.	2,300,000	2,300,000	
		Channel and Harbour Marker Buoys	11	No.	1,800,000	19,800,000	
		Breakwater Lights	1	No.	1,500,000	1,500,000	
		Racon	1	No.	1,000,000	1,000,000	
		VTMS	1	LS	181,116,000	181,116,000	
	Total (11)					**340,716,000**	
12	**GATES COMPLEX**						
	12.1	Pre Gate	320	Sq. m	34,000	10,880,000	
	12.2	In Gate	4,400	Sq. m	42,000	184,800,000	
	12.3	Out Gate	4,400	Sq. m	42,000	184,800,000	
	12.4	Weigh Bridge (Entry + Exit Gate) for Trains	4	No.	1,200,000	4,800,000	
	12.5	Weigh Bridge (Entry + Exit Gate) for Trucks	12	No.	800,000	9,600,000	
	12.6	Utilities for Gate complex	1	LS	5,000,000	5,000,000	

S. No.	ITEM	QUANTITY	UNIT	RATE (Rs.)	AMOUNT (Rs.)	AMOUNT (Rs.)
	Total (12)				399,880,000	
	Total (1+2+3+4+5+6+7+8+9+10+11+12)				271,940,060,715	#REF!

Vadhavan Port - Capital Cost Estimates

S. No.			ITEM	QUANTITY	UNIT	RATE (Rs.)	Phase 2 JNPT AMOUNT (Rs.)	Phase 2 Terminal Developer AMOUNT (Rs.)
1	**PROJECT PRELIMINARIES AND SITE DEVELOPMENT**							
	1.1		Project Studies and Surveys	1	LS	500,000,000	500,000,000	
	1.2		Land Acquisition	1	LS			
	1.3		Site Clearing and Site Development	1	LS	100,000,000	100,000,000	
	Total (1)						**600,000,000**	
2	**DREDGING**							
	2.1		**Inner Approach Channel & Harbour Basin**					
		a.	Soil dredging	12,143,852	Cum	300	3,643,155,570	
		b.	Rock dredging	5,893,608	Cum	2,350	13,849,979,035	
	2.2		**Outer Approach Channel**					
		a.	Soil dredging	2,717,361	Cum	300	815,208,300	
		b.	Rock dredging	787,811	Cum	2,350	1,851,355,850	
	Total (2)						**20,159,698,755**	
3.0	**RECLAMATION**							
	3.1		Offshore land					
		a.	Reclamation through marine burrow pit	37,420,725	Cum	450	16,839,326,381	
		b.	Reclamation through dredged material	20,056,511	Cum	450	9,025,429,820	
	Total (3)						**25,864,756,200**	
4.0	**SHORE PROTECTION WORKS**							
	4.1		Offshore reclaimed land protection works					
		a.	5T - Accropode	35,122	Cum	13,750	482,927,500	
		b.	Rock Armour 0.06-0.3T	201,376	MT	1,729	348,079,024	
		c.	Rock Armour 0.3-1T	606,348	MT	1,763	1,068,993,354	
		d.	Quarry Run Bund	6,956,184	MT	1,300	9,043,039,200	
		e.	Geotextile	734,383	Sq. m	225	165,236,175	
	Total (4)						**11,108,275,253**	
5	**BERTHS**							
	5.1		**Container Terminal 5 (CT5)**					
		a.	Berth	49,000	Sq. m	135,000		6,615,000,000
		b.	Earthworks for Sub-base preparation (Filling from +5.0 mCD to +7.5mCD)					
			Burrowed earth	1,770,833	Cum	850		1,505,207,625
		c.	Yard Pavement					
			Pavement for the yard other than eRTG lane	302,500	Sq. m	3,800		1,149,501,448
			Pavement for eRTG lanes	191,726	Sq. m	7,200		1,380,427,776
			Striping and signages	18,000	m	250		4,500,000
			Pavement behind the berth	50,000	Sq. m	3,900		195,000,000
		d.	Terminal buildings					
			Terminal admin building	1,000	Sq. m	40,000		40,000,000
			Substation	500	Sq. m	40,000		20,000,000
			Workshop	1,500	Sq. m	25,000		37,500,000
			Equipment parking area	700	Sq. m	3,800		2,660,000
			Reefer wash area	197	Sq. m	3,800		748,600
			Custom office	400	Sq. m	40,000		16,000,000
			Pumphouse	225	Sq. m	25,000		5,625,000
			Terminal gate house	120	Sq. m	25,000		3,000,000
			Landscaping	5,051	Sq. m	8,000		40,408,000
			Security guard house	10	Sq. m	12,000		120,000
			Hazrardous cargo storage	5,132	Sq. m	3,800		19,500,110
			STP area	80	Sq. m	50,000		4,000,000
		e.	Asphalt road to terminal buildings and parking facilities	4,275	Sq. m	3,700		15,816,682
		f.	Equipments					
			Rail Mounted Quay cranes	12	Nos	800,000,000		9,600,000,000
			e-Rubber Tyre Gantry Cranes	36	Nos	127,500,000		4,590,000,000
			ITVs	0	Nos	4,800,000		0

S. No.			ITEM	QUANTITY	UNIT	RATE (Rs.)	AMOUNT (Rs.)	AMOUNT (Rs.)
			Reach Stacker	0	Nos	38,250,000		0
			Empty Handlers	0	Nos	15,000,000		0
			Other Miscellaneous Equipment and Spares (5% of net equipments above)	5%	%	14,190,000,000		709,500,000
			Workshop Equipments	1	LS	50,000,000		50,000,000
		g.	Utilities					
			Electric Supply, Distribution lines and etc.	1	LS	577,377,960		577,377,960
			Fire Fighting	1	LS	33,381,886		33,381,886
			Water Supply & Distribution System	1	LS	14,500,000		14,500,000
			Drainage and Sewerage	1	LS	223,500,000		223,500,000
			Communication and IT & Terminal Security	1	LS	20,000,000		20,000,000
			High mast lighting	62	Units	1,700,000		105,400,000
			Street lighting	167	Units	31,000		5,177,000
			Miscellaneous Cost @ 1%	1	LS			9,793,368
			Electrical & ELV (Buildings)	4,000	Sq. m	7,300		29,200,000
		h.	Yard fencing	3,300	m	3,500		11,550,000
		i.	Project Studies and Surveys	0	LS	500,000,000		0
	Total (5.1)							**27,034,395,456**
	5.2		**Container Terminal 6 (CT6)**					
		a.	Berth	49,000	Sq. m	135,000		6,615,000,000
		b.	Earthworks for Sub-base preparation (Filling from +5.0 mCD to +7.5mCD)					
			Burrowed earth	1,770,860	Cum	850		1,505,231,000
		c.	Yard Pavement					
			Pavement for the yard other than eRTG lane	302,500	Sq. m	3,800		1,149,501,448
			Pavement for eRTG lanes	191,726	Sq. m	7,200		1,380,427,776
			Striping and signages	18,000	m	250		4,500,000
			Pavement behind the berth	50,000	Sq. m	3,900		195,000,000
		d.	Terminal buildings					
			Terminal admin building	1,000	Sq. m	40,000		40,000,000
			Substation	500	Sq. m	40,000		20,000,000
			Workshop	1,500	Sq. m	25,000		37,500,000
			Equipment parking area	700	Sq. m	3,800		2,660,000
			Reefer wash area	197	Sq. m	3,800		748,600
			Custom office	400	Sq. m	40,000		16,000,000
			Pumphouse	225	Sq. m	25,000		5,625,000
			Terminal gate house	120	Sq. m	25,000		3,000,000
			Landscaping	5,051	Sq. m	8,000		40,408,000
			Security guard house	10	Sq. m	12,000		120,000
			Hazrardous cargo storage	5,132	Sq. m	3,800		19,500,110
			STP area	80	Sq. m	50,000		4,000,000
		e.	Asphalt road to terminal buildings and parking facilities	4,275	Sq. m	3,700		15,816,682
		f.	Equipments					
			Rail Mounted Quay cranes	12	Nos	800,000,000		9,600,000,000
			e-Rubber Tyre Gantry Cranes	36	Nos	127,500,000		4,590,000,000
			ITVs	0	Nos	4,800,000		0
			Reach Stacker	0	Nos	38,250,000		0
			Empty Handlers	0	Nos	15,000,000		0
			Other Miscellaneous Equipment and Spares (5% of net equipments above)	5%	%	14,190,000,000		709,500,000
			Workshop Equipments	1	LS	50,000,000		50,000,000
		g.	Utilities					
			Electric Supply, Distribution lines and etc.	1	LS	583,413,977		583,413,977
			Fire Fighting	1	LS	33,715,726		33,715,726
			Water Supply & Distribution System	1	LS	14,500,000		14,500,000
			Drainage and Sewerage	1	LS	223,500,000		223,500,000
			Communication and IT & Terminal Security	1	LS	20,000,000		20,000,000
			High mast lighting	62	Units	1,700,000		105,400,000
			Street lighting	167	Units	31,000		5,177,000
			Miscellaneous Cost @ 1%	1	LS			9,857,067
			Electrical & ELV (Buildings)	4,000	Sq. m	7,300		29,200,000
		h.	Yard fencing	3,300	m	3,500		11,550,000
		i.	Project Studies and Surveys	0	LS	500,000,000		0
	Total (5.2)							**27,040,852,386**

S. No.			ITEM	QUANTITY	UNIT	RATE (Rs.)	AMOUNT (Rs.)	AMOUNT (Rs.)
	5.3		**Container Terminal 7 (CT7)**					
		a.	Berth	49,000	Sq. m	135,000		6,615,000,000
		b.	Earthworks for Sub-base preparation (Filling from +5.0 mCD to +7.5mCD)					
			Burrowed earth	1,523,285	Cum	850		1,294,792,250
		c.	Yard Pavement					
			Pavement for the yard other than eRTG lane	302,500	Sq. m	3,800		1,149,501,448
			Pavement for eRTG lanes	191,726	Sq. m	7,200		1,380,427,776
			Striping and signages	18,000	m	250		4,500,000
			Pavement behind the berth	50,000	Sq. m	3,900		195,000,000
		d.	Terminal buildings					
			Terminal admin building	1,000	Sq. m	40,000		40,000,000
			Substation	500	Sq. m	40,000		20,000,000
			Workshop	1,500	Sq. m	25,000		37,500,000
			Equipment parking area	700	Sq. m	3,800		2,660,000
			Reefer wash area	197	Sq. m	3,800		748,600
			Custom office	400	Sq. m	40,000		16,000,000
			Pumphouse	225	Sq. m	25,000		5,625,000
			Terminal gate house	120	Sq. m	25,000		3,000,000
			Landscaping	5,051	Sq. m	8,000		40,408,000
			Security guard house	10	Sq. m	12,000		120,000
			Hazrardous cargo storage	5,132	Sq. m	3,800		19,500,110
			STP area	80	Sq. m	50,000		4,000,000
		e.	Asphalt road to terminal buildings and parking facilities	4,275	Sq. m	3,700		15,816,682
		f.	Equipments					
			Rail Mounted Quay cranes	12	Nos	800,000,000		9,600,000,000
			e-Rubber Tyre Gantry Cranes	36	Nos	127,500,000		4,590,000,000
			ITVs	0	Nos	4,800,000		0
			Reach Stacker	0	Nos	38,250,000		0
			Empty Handlers	0	Nos	15,000,000		0
			Other Miscellaneous Equipment and Spares (5% of net equipments above)	5%	%	14,190,000,000		709,500,000
			Workshop Equipments	1	LS	50,000,000		50,000,000
		g.	Utilities					
			Electric Supply, Distribution lines and etc.	1	LS	567,559,577		567,559,577
			Fire Fighting	1	LS	31,362,088		31,362,088
			Water Supply & Distribution System	1	LS	14,000,000		14,000,000
			Drainage and Sewerage	1	LS	253,500,000		253,500,000
			Communication and IT & Terminal Security	1	LS	20,000,000		20,000,000
			High mast lighting	62	Units	1,700,000		105,400,000
			Street lighting	167	Nos	31,000		5,177,000
			Miscellaneous Cost @ 1%	1	Nos			9,969,987
			Electrical & ELV (Buildings)	4,000	Sq. m	7,300		29,200,000
		h.	Yard fencing	3,300	m	3,500		11,550,000
		i.	Project Studies and Surveys	0	LS	500,000,000		0
	Total (5.3)							**26,841,818,518**
	5.4		**Container Terminal 8 (CT8)**					
		a.	Berth	49,000	Sq. m	135,000		6,615,000,000
		b.	Earthworks for Sub-base preparation (Filling from +5.0 mCD to +7.5mCD)					
			Burrowed earth	1,820,745	Cum	850		1,547,633,250
		c.	Yard Pavement					
			Pavement for the yard other than eRTG lane	302,500	Sq. m	3,800		1,149,501,448
			Pavement for eRTG lanes	191,726	Sq. m	7,200		1,380,427,776
			Striping and signages	18,000	m	250		4,500,000
			Pavement behind the berth	50,000	Sq. m	3,900		195,000,000
		d.	Terminal buildings					
			Terminal admin building	1,000	Sq. m	40,000		40,000,000
			Substation	500	Sq. m	40,000		20,000,000
			Workshop	1,500	Sq. m	25,000		37,500,000
			Equipment parking area	700	Sq. m	3,800		2,660,000
			Reefer wash area	197	Sq. m	3,800		748,600

S. No.			ITEM	QUANTITY	UNIT	RATE (Rs.)	AMOUNT (Rs.)	AMOUNT (Rs.)
			Custom office	400	Sq. m	40,000		16,000,000
			Pumphouse	225	Sq. m	25,000		5,625,000
			Terminal gate house	120	Sq. m	25,000		3,000,000
			Landscaping	5,051	Sq. m	8,000		40,408,000
			Security guard house	10	Sq. m	12,000		120,000
			Hazrardous cargo storage	5,132	Sq. m	3,800		19,500,110
			STP area	80	Sq. m	50,000		4,000,000
		e.	Asphalt road to terminal buildings and parking facilities	4,275	Sq. m	3,700		15,816,682
		f.	Equipments					
			Rail Mounted Quay cranes	12	Nos	800,000,000		9,600,000,000
			e-Rubber Tyre Gantry Cranes	36	Nos	127,500,000		4,590,000,000
			ITVs	0	Nos	4,800,000		0
			Reach Stacker	0	Nos	38,250,000		0
			Empty Handlers	0	Nos	15,000,000		0
			Other Miscellaneous Equipment and Spares (5% of net equipments above)	5%	%	14,190,000,000		709,500,000
			Workshop Equipments	1	LS	50,000,000		50,000,000
		g.	Utilities					
			Electric Supply, Distribution lines and etc.	1	LS	584,825,177		584,825,177
			Fire Fighting	1	LS	31,362,088		31,362,088
			Water Supply & Distribution System	1	LS	14,500,000		14,500,000
			Drainage and Sewerage	1	LS	223,500,000		223,500,000
			Communication and IT & Terminal Security	1	LS	20,000,000		20,000,000
			High mast lighting	62	Units	1,700,000		105,400,000
			Street lighting	167	Units	31,000		5,177,000
			Miscellaneous Cost @ 1%	1	LS			9,847,643
			Electrical & ELV (Buildings)	4,000	Sq. m	7,300		29,200,000
		h.	Yard fencing	3,300	m	3,500		11,550,000
		i.	Project Studies and Surveys	0	LS	500,000,000		0
	Total (5.4)							**27,082,302,774**
	5.5		**Container Terminal 9 (CT9)**					
		a.	Berth	49,000	Sq. m	135,000		6,615,000,000
		b.	Earthworks for Sub-base preparation (Filling from +5.0 mCD to +7.5mCD)					
			Burrowed earth	1,892,218	Cum	850		1,608,384,875
		c.	Yard Pavement					
			Pavement for the yard other than eRTG lane	302,500	Sq. m	3,800		1,149,501,448
			Pavement for eRTG lanes	191,726	Sq. m	7,200		1,380,427,776
			Striping and signages	18,000	m	250		4,500,000
			Pavement behind the berth	50,000	Sq. m	3,900		195,000,000
		d.	Terminal buildings					
			Terminal admin building	1,000	Sq. m	40,000		40,000,000
			Substation	500	Sq. m	40,000		20,000,000
			Workshop	1,500	Sq. m	25,000		37,500,000
			Equipment parking area	700	Sq. m	3,800		2,660,000
			Reefer wash area	197	Sq. m	3,800		748,600
			Custom office	400	Sq. m	40,000		16,000,000
			Pumphouse	225	Sq. m	25,000		5,625,000
			Terminal gate house	120	Sq. m	25,000		3,000,000
			Landscaping	5,051	Sq. m	8,000		40,408,000
			Security guard house	10	Sq. m	12,000		120,000
			Hazrardous cargo storage	5,132	Sq. m	3,800		19,500,110
			STP area	80	Sq. m	50,000		4,000,000
		e.	Asphalt road to terminal buildings and parking facilities	4,275	Sq. m	3,700		15,816,682
		f.	Equipments					
			Rail Mounted Quay cranes	12	Nos	800,000,000		9,600,000,000
			e-Rubber Tyre Gantry Cranes	36	Nos	127,500,000		4,590,000,000
			ITVs	0	Nos	4,800,000		0
			Reach Stacker	0	Nos	38,250,000		0
			Empty Handlers	0	Nos	15,000,000		0
			Other Miscellaneous Equipment and Spares (5% of net equipments above)	5%	%	14,190,000,000		709,500,000
			Workshop Equipments	1	LS	50,000,000		50,000,000

S. No.	ITEM			QUANTITY	UNIT	RATE (Rs.)	AMOUNT (Rs.)	AMOUNT (Rs.)
		g.	Utilities					
			Electric Supply, Distribution lines and etc.	1	LS	609,146,777		609,146,777
			Fire Fighting	1	LS	31,362,088		31,362,088
			Water Supply & Distribution System	1	LS	14,500,000		14,500,000
			Drainage and Sewerage	1	LS	223,500,000		223,500,000
			Communication and IT & Terminal Security	1	LS	20,000,000		20,000,000
			High mast lighting	62	Units	1,700,000		105,400,000
			Street lighting	167	Units	31,000		5,177,000
			Miscellaneous Cost @ 1%	1	LS			10,090,859
			Electrical & ELV (Buildings)	4,000	Sq. m	7,300		29,200,000
		h.	Yard fencing	3,300	m	3,500		11,550,000
		i.	Project Studies and Surveys	0	LS	500,000,000		0
	Total (5.5)							**27,167,619,215**
	5.6	**Multipurpose Terminal**						
		a.	Berth	6,150	Sq. m	145,000		891,750,000
		b.	Equipments'					
			MHCr	2	No.	320,000,000		640,000,000
			Front end loaders	2	No.	2,000,000		4,000,000
			Dumpers	0	No.	4,500,000		0
			Payloaders	1	No.	2,500,000		2,500,000
			Berth Conveyors	6,000	m	0		0
			Yard Conveyors	4,000	m	0		0
			Scrapper reclaimer	1	No.	0		0
			Tripper conveyor	730	m	0		0
			Reclaiming conveyor	900	m	0		0
			Forklifts	4	No.	1,000,000		4,000,000
			Bagging plant	11	No.	2,500,000		27,500,000
			Portable Conveyor	5	No.	300,000		1,500,000
			Other Miscellaneous Equipment and Spares (5% of net equipments above)	5%	%			33,975,000
		c.	Project Studies and Surveys	0	LS	100,000,000		0
	Total (5.6)							**1,605,225,000**
6	**COMMON PORT INFRASTRUCTURE**							
	6.1	Earthworks for Sub-base preparation (Filling from +5.0 mCD to +7.5mCD)						
		Burrowed earth		1,054,458	Cum	850	896,289,300	
	6.2	Port Buildings						
		JNPT Adminstration Building		0	Sq. m	40,000	0	
		Common Users Building		800	Sq. m	40,000	32,000,000	
		Port user building		800	Sq. m	40,000	32,000,000	
		Customs Building		500	Sq. m	35,000	17,500,000	
		Harbour Master Block and control room		500	Sq. m	40,000	20,000,000	
		Signal Station		0	Sq. m	40,000	0	
		Other Miscellaneous Buildings		1,000	Sq. m	25,000	25,000,000	
		Trouble Kiosk & Restrooms		100	Sq. m	30,000	3,000,000	
		Railway Master Building		0	Sq. m	30,000	0	
		Maintenance workshop		1,000	Sq. m	25,000	25,000,000	
	6.3	Roads						
		Primary roads within the port		521,410	Sq. m	3,900	2,033,499,226	
		Secondary roads within the port		24,044	Sq. m	3,700	88,962,800	
		Parking Area		392,952	Sq. m	3,800	1,493,217,600	
	6.4	Utilities		1	LS	115,000,000	115,000,000	
	Total (6)						4,781,468,926	
7	**ROADS AND RAILWAYS**							
	7.1	Roads - External						
		External Road from NH8 to Port		0	km	23,842,685,555		0

S. No.		ITEM	QUANTITY	UNIT	RATE (Rs.)	AMOUNT (Rs.)	AMOUNT (Rs.)
	7.2	Railway Lines and Sidings - External					0
	7.3	Railway Yard - In-Port					
	7.31	Rail sidings In-port Rail yard - Containers & other cargoes		LS			1,648,000,000
	7.32	Equipments'					
		Rail Mounted Gantry Cranes	15	No.	212,500,000		3,187,500,000
		e-Rubber Tyre Gantry Cranes	24	No.	127,500,000		3,060,000,000
		Other Miscellaneous Equipment and Spares (5% of net equipments above)	5%				312,375,000
	7.33	Rail Yard Pavement					
		Pavement for the yard other than eRTG/RMGC lane	253,005	Sq. m	3,800		961,417,880
		Pavement for RMGC lanes	54,208	Sq. m	7,200		390,297,600
		Pavement for eRTG lanes	102,100	Sq. m	7,200		735,123,456
		Striping and signages	12,024	m	250		3,006,000
	7.34	Utilities					
		Power and controls	1	LS	30,000,000		30,000,000
		Drainage and Sewerage	1	LS	150,000,000		150,000,000
	Total (7)						**10,477,719,936**
8	**EXTERNAL UTILITIES AND OTHERS**						
	8.1	Power utilities from tapping source	1	LS	434,027,200	434,027,200	
	Total (6)					**434,027,200**	
9	**PORT CRAFTS AND NAVIGATIONAL AIDS**						
	9.1	Tugs					
		65 T bollard pull	0	No.	900,000,000	0	
		100 T bollard pull	0	No.	1,050,000,000	0	
		Standby tugs	0	No.	900,000,000	0	
	9.2	Pilot-cum-Survey Launches	0	No.	75,000,000	0	
						0	
	9.3	Mooring Launches	0	No.	30,000,000	0	
	9.4	Navigational Aids					
		Fair buoy	0	No.	2,300,000	0	
		Channel and Harbour Marker Buoys	5	No.	1,800,000	9,000,000	
		Breakwater Lights	0	No.	1,500,000	0	
		Racon	0	No.	1,000,000	0	
		VTMS	0	LS	100,000,000	0	
	Total (9)					**9,000,000**	
10	**GATES COMPLEX**						
	10.1	Inspection/Canopy (Entry + Exit Gate)	17,630	Sq. m	20,000	352,600,000	
	10.2	Gate Staff & Customs Building	7,200	Sq. m	25,000	180,000,000	
	10.3	Weigh Bridge (Entry + Exit Gate) for Trains	2	No.	1,200,000	2,400,000	
	10.4	Weigh Bridge (Entry + Exit Gate) for Trucks	46	No.	800,000	36,800,000	
	Total (8)					**571,800,000**	
	Total (1+2+3+4+5+6+7+8+9+10)					**63,529,026,334**	**147,249,933,284**
						6,352.9	**14,725**

APPENDIX 3 – TRAFFIC STUDY

A3 Traffic Study

Traffic Study chapter discusses the influence area of Vadhavan Port and the possible business that would be generated from it. Influence area of the proposed port is studied in detail to understand the type of traffic that port would attract in future. Hinterland profiling, industrial clusters, connectivity infrastructure, competition, etc. are assessed in depth to understand the need to develop Vadhavan Port

Vadhavan port has been conceptualised as gateway port to handle clean cargo. The existing detailed project report prepared by consultants namely Ernst & Young and Progen-Pentacle Consultants had found substantial potential for container cargo at Vadhavan Port. Containers constituted more than 84% of the trade volume by 2050 in the DPR. The other commodities including Crude Oil, Coal, Fertiliser, Chemicals and other General & coastal cargo constituted around 16% of the 2050 traffic share. Dirty cargo such as coal has been permanently discarded and Crude Oil temporarily discarded based on JNPA and Governments vision of developing Vadhavan port as clean cargo port.

All the analysis undertaken in this chapter for the Vadhavan port has larger analytical perspective to evaluate and quantify opportunities for container trade. The detailed analysis of other commodities has also been carried out. The section has undertaken a holistic analysis of all the trade happening in the ports of Gujarat and Maharashtra to identify promising cargo other than containers likely to be attracted at proposed Vadhavan port.

A3.1 Hinterland Analysis

India has vast land mass along with 7,512 km of coastline. Large number of Sea-ports located on the coast of India facilitate International and domestic trade. A substantial landmass of India is landlocked with no access to waterfront. They have to be dependent on coastal state and their ports for water based trade. There is always stiff competition among the ports to win-over trade volumes from landlocked hinterland.

Hence, the hinterland study identifies the influence area of proposed Vadhavan port based on geographical nearness, connectivity infrastructure, trade patterns followed over previous years and logistics advantages. The business opportunity for Vadhavan port would arise out of the identified hinterland. This section undertakes detailed assessment of analysis to identify hinterland of Vadhavan port.

A3.1.1 Hinterland Identification & Container Trade

India's demography divided into 3 regions i.e. North-West, North-East and South India. North, West and Central India encompasses the maximum hinterland with highest cumulative area, population and economic activities. This segment of India's demography has been categorised as North-West Hinterland. It also covers a segment of Central India. Population residing in Western India and Central India have a choice of both East Coast Ports and West Coast Ports for their sea borne trade. Historic statistics have confirmed that West Coast ports are preferred over East Coast ports due to better connectivity and faster as well as cost effective evacuation of cargo using West coast ports. The importance of West Coast ports increases further in containerised cargo segment. Container trade is dominated by Shipping Lines. Shipping lines find West Coast ports of India commercially more attractive compared to East Coast Ports due to relatively lower deviation from their mainline routes. Containers ports located in Maharashtra and Gujarat are preferred over others on west coast of India due to their vicinity to North and Western Hinterland. Vadhavan located in Maharashtra would be catering to North West Hinterland. Hence, all the analysis and economic prospects of Vadhavan port has been linked with the economic and trade growth in North and Western Hinterland of India. The figure below represents the same.

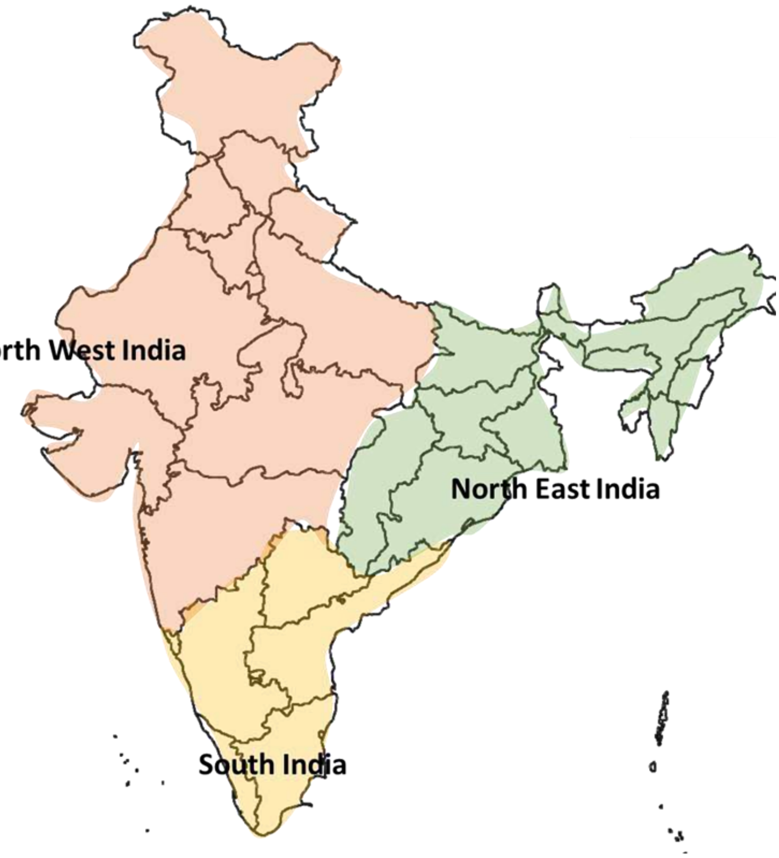

Figure A3-1 Region Distribution

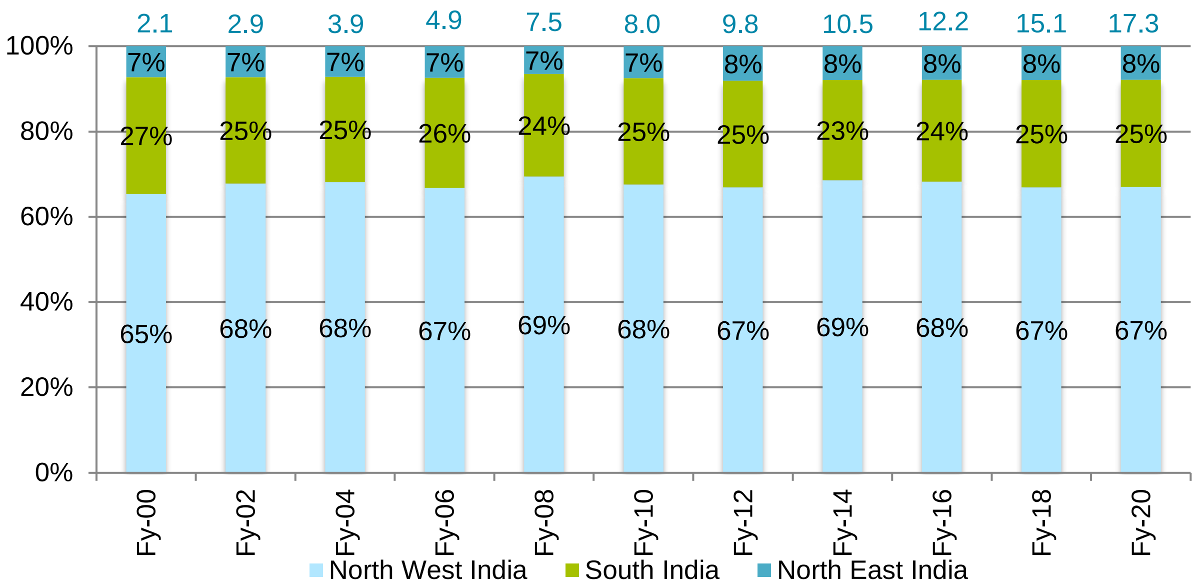

Figure A3-2 Region wise Market Share for container Trade

Royal HaskoningDHV

JNPA

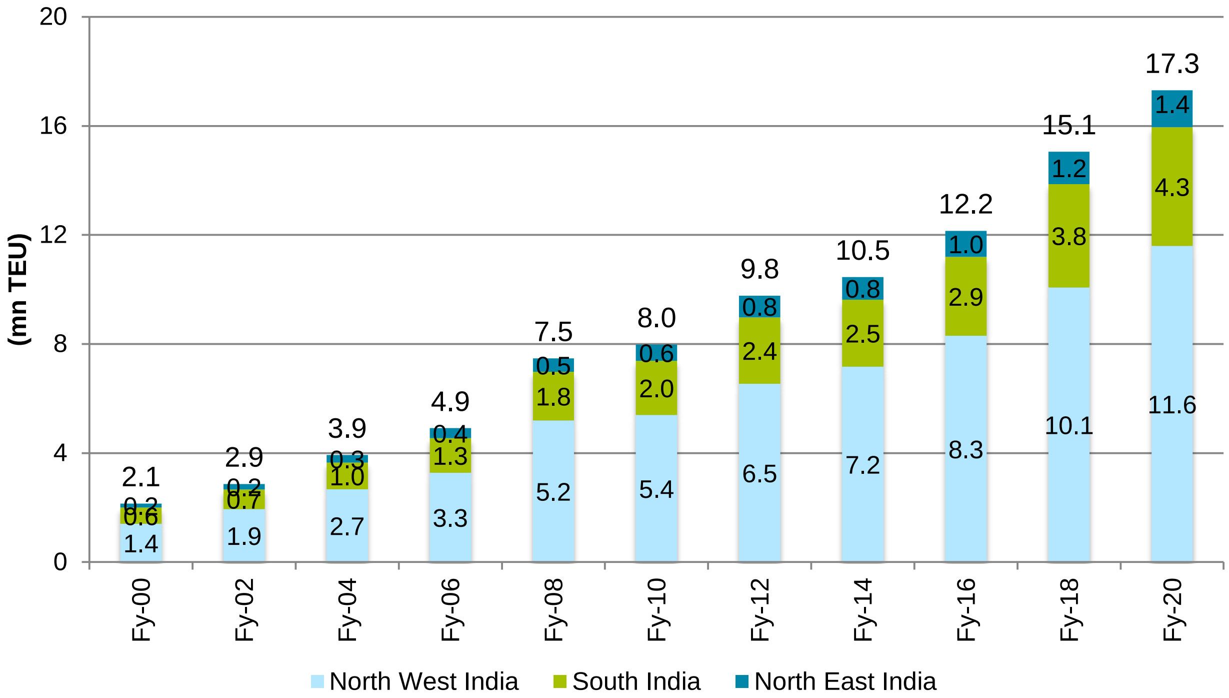

Figure A3-3 20 Years Container Trade of India

In the past decade, container trade in India has grown from 8 Mn TEUs to nearly 17.3 Mn TEUs, at a CAGR of around 8%. Container ports have been able to generate differential growth based on their market positioning and competitive advantage. The cumulative container port traffic of India in 20 years has grown by;

- Previous 5 years' growth 1.5 times
- Previous 10 years' growth 2.2 times
- Previous 15 years' growth 3.9 times
- Previous 20 years' growth 8.1 times

The growth of container traffic in North-West India too has taken place in the similar proportion to all India container port traffic. Ports catering to North-West India had a container traffic of 11.6 MTEU representing a market share of 67%, North-East India handled 1.4 MTEU container corresponding to 8% of the total share and South India with a container traffic of 4.3 MTEU has a share of 25%. The market share of North-West India region has remained consistent for more than 2 decades, except for minor fluctuation between 1% to 2% on occasional years.

Table A3- 1 20 Years Container Trade of India

	Historic Container Trade Growth Rate (CAGR)				
	5 Yrs.	**10 Yrs.**	**15 Yrs.**	**20 Yrs.**	**25 Yrs.**
North & West India	8%	8%	9%	12%	11%
South India	10%	8%	9%	11%	11%
North East India	9%	9%	10%	12%	10%
All India	9%	8%	9%	12%	11%

A3.1.2 Origin Destination Mapping

The movement of traffic from various states and regions of North West India was analysed and port region wise traffic was mapped. While shipping lines influence the import container traffic movement, freight forwarders affect the export container traffic movement. Non major ports in Gujarat and JNPA both handle a large share of Northern hinterland traffic. Specifically, Mundra, Pipava and Hazira handle Rajasthan and Gujarat based traffic while Maharashtra and Central India are handled by JNPA.

As rail is a cheaper mode of transportation for longer distances, traffic moves mostly through rail in the Northern region. Rail connectivity is thus a significant factor in attracting traffic from this region. For movement of container cargo from clusters near the Western ports, road is the predominant mode of transportation as for shorter distances road transportation becomes economical.

Figure A3-4 Origin Destination Mapping of Containers Handled in North West Ports

The hinterland mapping of containers traded using ports of Gujarat and Maharashtra showed extensive coverage. The geographical mapping of these locations found that containers go as far as Uttar Pradesh, Bihar and central India. Several of these locations are closer to ports of the East Coast of India than West Coast of India. This is primarily due to substantial cost savings by shipping lines calling to ports of North West Coast of India compared to North East Coast of India. The hinterland on East coast of India is dependent on Feeder terminals of North East Coast including Kolkata, Vishakhapatnam, etc. Cost of transportation using smaller feeder vessels are higher than dedicated service mainline vessels calling to ports near shipping routes.

This trend is believed to hold in future, even if there are deep draft container ports constructed on the North East Coast of India. The shipping lines would have to take longer deviation to reach container ports in West Bengal and Orissa. Hence, the container ports of West Bengal and Orissa are unlikely to be serviced by direct ships of large size. The North West coast ports would find cost competitiveness compared to North East Coast ports leading to larger hinterland for North West Coast ports.

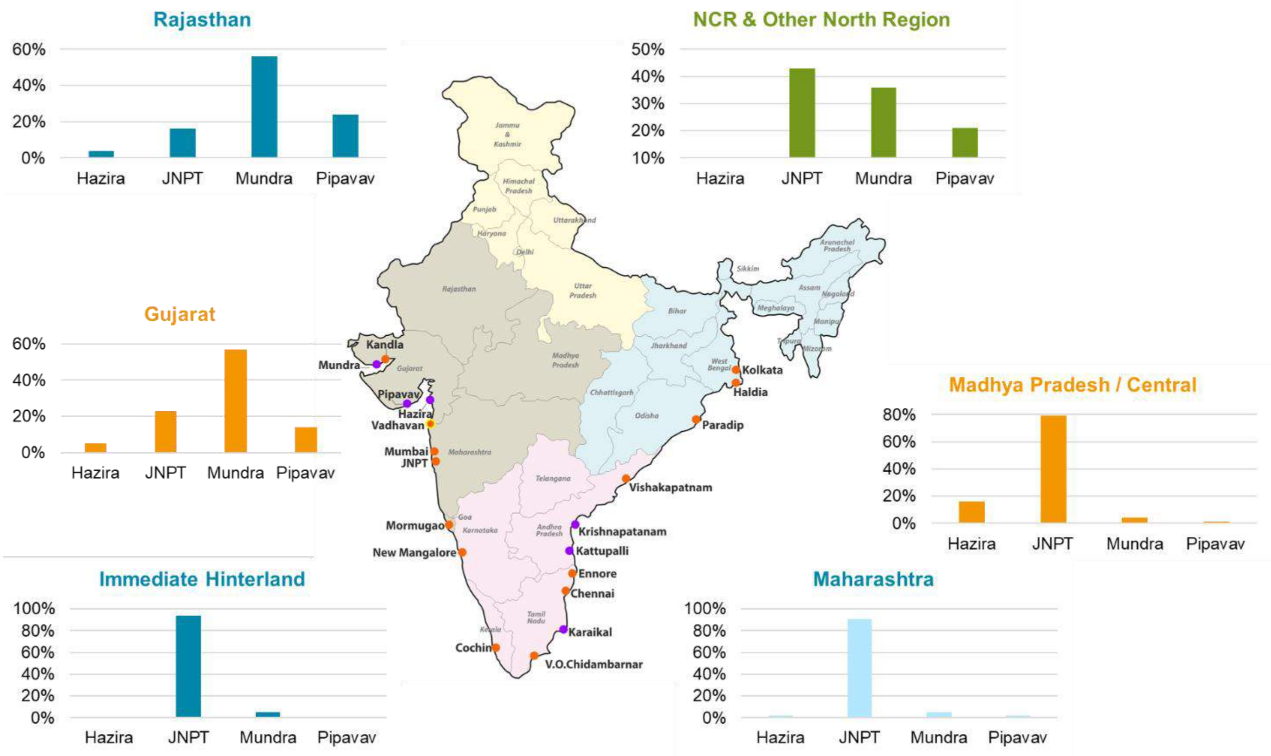

Figure A3-5 Principle Cargo Centers in the Hinterland

[Source: Based on E&Y's primary interaction with Stakeholders]

The traffic from the Northern hinterland primarily moves through rail, as for the longer distance, rail is cheaper mode of transportation. Hence, to attract the traffic from the Northern Hinterland, rail connectivity becomes a critical factor. A good share of Punjab based container traffic also travels through road and reaches the ports of West coast.

For the container cargo movement from the clusters near to the Western ports area (Gujarat, Maharashtra etc.), road is the pre-dominant mode of transportation, as for the shorter duration, the road is mostly the cheaper mode as compared to rail.

A3.1.3 Container Ports - North West (Hinterland)

Kandla, Mumbai and JNPA are the major ports of the country and operate under Ministry of Shipping, Government of India. Cargo handled at Mumbai Port and Kandla Port are primarily dominated by bulk commodities. Kandla is a container feeder port. Mumbai Port handles container for local consumption. The traffic movement between JNPA and Mumbai port is through barging operations. There is no mainline or feeder ship calls to Mumbai Port for container handling.

There are several ports under administrative/ regulatory control of state government predominantly categorised as non-major ports. These non-major ports include state ports owned and operated by state government nominated maritime boards, private ports and captive ports. Mundra, Pipavav and Hazira are private ports of Gujarat handling the container traffic. JSW port in Southern Maharashtra has plans to enter into container handling as part of Phase 2 expansion. The restrictions/ constraints due to connectivity and unavailability of local market would restrict container handling market for JSW. There are no container ports planned on the North West Coast of India.

A3.1.4 Hinterland Container Growth

Container trade dominates the ports on the west coast of the country more than any other cargo. The ports in this part cater to the whole of northern, central and western hinterland of India. These hinterlands have a large presence of industries and other consumption centres whose demands are met by the finished goods being hauled in containers. The growth of container traffic has been un-even in the region. Following figure describes changing market share of North-West container ports in last 20 years.

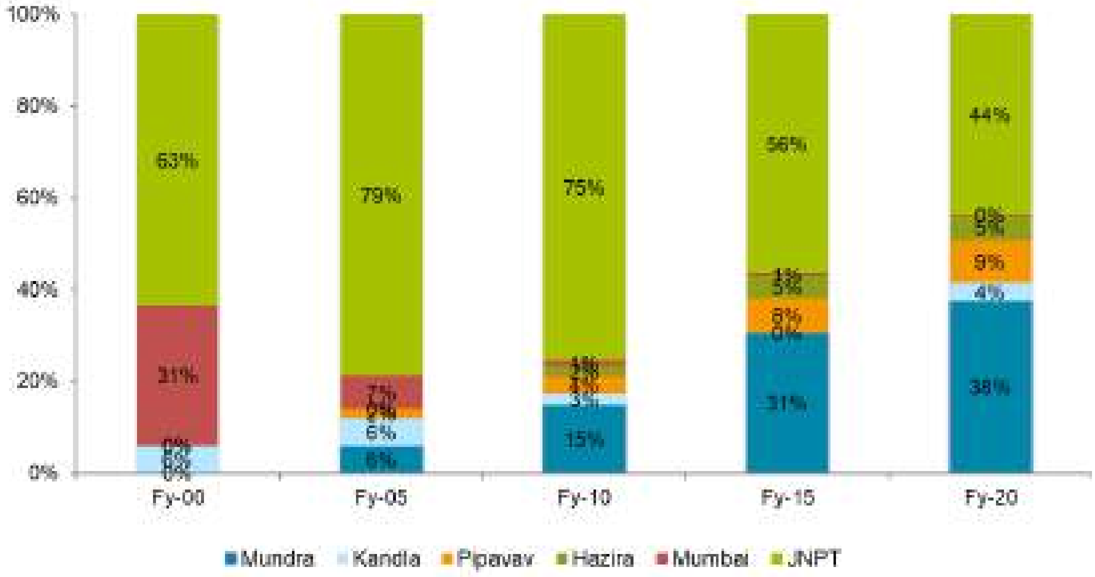

Figure A3-6 % Share Contribution of West coast ports in West India Container Trade

The above figure depicts the container trade growth at the ports along the west coast of the country for last 25 years. MbPT, Kandla, Pipavav, Mundra and JNPA are the only ports that handle container on the north west coast on a large scale, where JNPA occupies more than half the share. In 2020, these ports cumulatively handled 11.57 Mn TEUs of container, with JNPA handling 5 Mn TEUs.

At present, JNPA handles close to 29% of India's container traffic. Over the past decade, despite the steep rise of container traffic at JNPA, the terminal has been losing a small share to other ports, especially Mundra and Hazira in Gujarat. The container market share of JNPA has fallen in last 2 decades from 55% in the year 2002 to 29% in the year 2020. The traffic share of Mundra and Hazira has increased from 0% to 25% and 4% respectively.

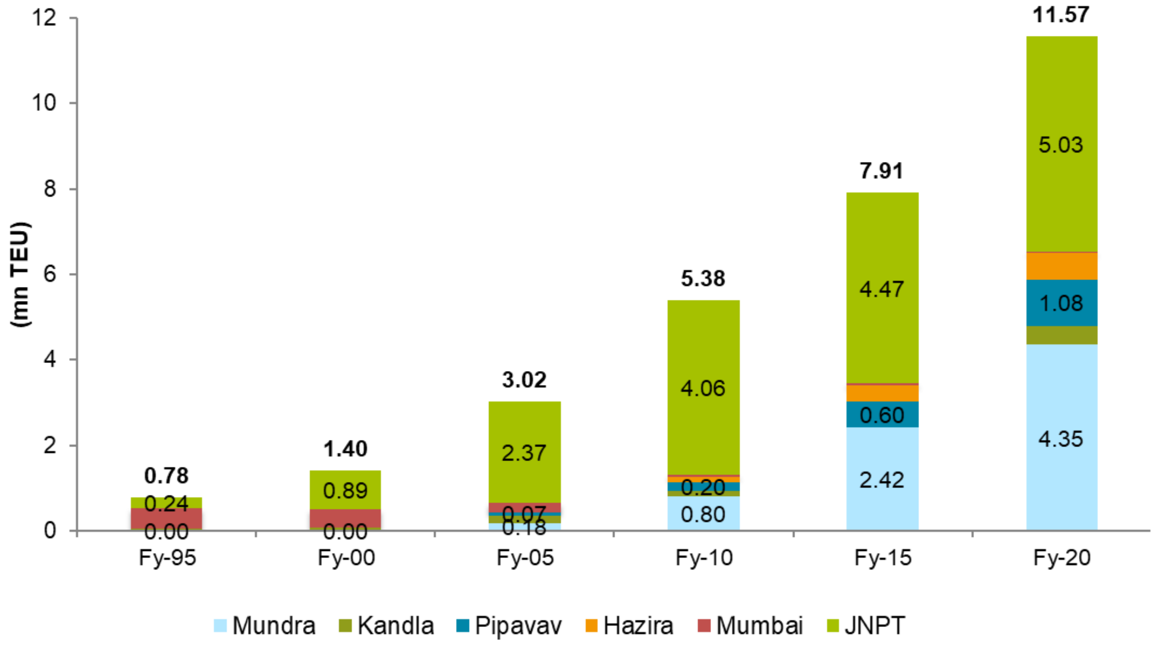

Figure A3-7 Container Trade distribution in West India

The JNPA terminals have been ailed with congestion, resulting into increased vessel turnaround times, but more importantly, loss of small volume of container business. The newer non major ports of Gujarat setup away from cities have been capitalizing on this factor and adding to their container traffic by attracting the spill over traffic from JNPA. For instance, in 2003-04, Mundra Port had a container throughput of 0.05 Mn TEU, while JNPA handled close to 2.27 Mn TEU. In 2020, JNPA's container traffic rose to 5 Mn TEU indicating a 16-year CAGR of nearly 8%. Mundra and Hazira port handled 4.4 million TEU and 0.6 million TEU respectively. The enormous container traffic growth at Mundra was, to a small extent, because of containers being diverted from the congested terminal of JNPA. The same development has been evident at Pipavav, which also has been attracting a small share of the excess traffic at JNPA.

JNPA has the largest presence in the container trade being carried out on the west coast. Therefore, the handling of the said commodity at JNPA could be used as a benchmark to derive certain container-handling logistics and other criteria involved in the trade. In 2020, JNPA's total container throughput stood at 5 Mn TEUs. Around 20%-25% of the total volume, which is 1.2 Mn TEUs, was generated locally, within the Mumbai metropolitan region. Rest of volume was generated in western regions, states like Gujarat, and other landlocked regions of northern India. This clearly indicates the sheer volume that the regions beyond the primary hinterland of JNPA contribute to the JNPA's yearly container traffic. The terminal employs railway transportation for long-distance distribution of the containers, while rest is carried out via roadways.

Both Mundra Port and JNPA share a common tertiary hinterland in the northern states of the country. This has inadvertently led to competition between the two, and where Mundra has managed to increase its share in the incremental traffic at JNPA over a period of time, which the latter has been losing out on account of evacuation delays. Mundra Port is now considered to be the fastest-growing container port in the country, with it already contributing nearly more than 4 Mn TEU to the country's total container traffic. The rising container handling at the Mundra Port along with its efficient handling has enabled the port to carve itself a niche in the container segment. Logistically speaking, Mundra Port is closer by 200 km to 300 km to Northern Hinterland compared to JNPA leading to inland transportation cost savings. The same set of equations and variables could be applied for the Port of Vadhavan, albeit on a moderate scale, since it will be utilizing feeder services to handle containers.

A3.1.5 North West Ports - Higher Market

The prominent ports handling containers are JNPA, Kamarajar, Chennai, Kolkata, Cochin, Vizag, Kandla, NMPT, Mormugao, Mundra, Pipavav, Hazira, Katupalli and Krishnapatnam. The ports have been divided into three categories based on their geographic location and mapping in the hinterland.

- North-West India Ports
- South India Ports
- North-East India Ports

The 20-year historic share of these zones has been summarised in the table below.

Table A3- 2 Historic Market Share of Regions for Container Trade

Geography	Fy00	Fy02	Fy04	Fy06	Fy08	Fy10	Fy12	Fy14	Fy16	Fy18	Fy20
North West India	65%	68%	68%	67%	69%	68%	67%	69%	68%	67%	67%
South India	27%	25%	25%	26%	24%	25%	25%	23%	24%	25%	25%
North East India	7%	7%	7%	7%	7%	7%	8%	8%	8%	8%	8%

The container traffic handled by all the container ports of India in last 30 years along with their market share has been summarised below.

Table A3- 3 Container Traffic Handled by Ports (million Tonnes)

Port Name	Fy-91	Fy-93	Fy-96	Fy-99	Fy-02	Fy-05	Fy-08	Fy-11	Fy-14	Fy-17	Fy-20
North-West Ports											
Mundra	0.0	0.0	0.0	0.0	0.0	0.2	0.6	1.1	2.1	2.9	4.4
Kandla	0.0	0.0	0.1	0.1	0.1	0.2	0.2	0.2	0.0	0.0	0.4
Pipavav	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.3	0.5	0.7	1.1
Hazira	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.3	0.4	0.6
Jawaharlal Nehru	0.1	0.1	0.3	0.7	1.6	2.4	4.1	4.3	4.2	4.5	5.0
Mumbai	0.3	0.3	0.5	0.5	0.3	0.2	0.1	0.1	0.0	0.0	0.0
North-West Ports	**0.4**	**0.5**	**0.9**	**1.3**	**1.9**	**3.0**	**5.2**	**6.1**	**7.2**	**8.6**	**11.6**
Share North-West	**62%**	**60%**	**64%**	**63%**	**68%**	**68%**	**69%**	**67%**	**69%**	**66%**	**67%**
South Ports											
Mormugao	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
New Mangalore	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.2
Kochi	0.0	0.1	0.1	0.1	0.2	0.2	0.3	0.3	0.3	0.5	0.6
Tuticorin	0.0	0.0	0.1	0.1	0.2	0.3	0.5	0.5	0.5	0.6	0.8

Port Name	Fy-91	Fy-93	Fy-96	Fy-99	Fy-02	Fy-05	Fy-08	Fy-11	Fy-14	Fy-17	Fy-20
Chennai	0.1	0.1	0.2	0.3	0.3	0.6	1.1	1.5	1.5	1.5	1.4
Ennore	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
Katupalli	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.7
Krishnapatnam	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.3	0.6
South Ports	**0.2**	**0.2**	**0.4**	**0.5**	**0.7**	**1.1**	**1.8**	**2.4**	**2.5**	**3.3**	**4.3**
Share South	**26%**	**29%**	**28%**	**26%**	**25%**	**25%**	**24%**	**26%**	**23%**	**25%**	**25%**
North East Ports											
Visakhapatnam	0.0	0.0	0.0	0.1	0.0	0.0	0.1	0.1	0.3	0.4	0.5
Paradip	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Kolkata	0.1	0.1	0.1	0.1	0.2	0.3	0.4	0.5	0.6	0.8	0.8
North-East Ports	**0.1**	**0.1**	**0.1**	**0.2**	**0.2**	**0.3**	**0.5**	**0.7**	**0.8**	**1.1**	**1.4**
Share North-East	**12%**	**11%**	**8%**	**11%**	**7%**	**7%**	**7%**	**7%**	**8%**	**9%**	**8%**
All India	**0.7**	**0.8**	**1.4**	**2.0**	**2.9**	**4.5**	**7.5**	**9.1**	**10.4**	**13.0**	**17.3**

Some of the key reasons for the higher share of the western ports in the total container traffic of India are as indicated in following sub-sections

A3.1.6 Per Capita Income

Lower per capita income leading to basic consumption on the Eastern Coast of India. Containers carry finished products. Households with lower incomes tend to spend all their earnings in basic needs of survival. Their contributions for procurement of items beyond basic needs of survival is lower compared to regions with high per capita income. Hence, North East India generates lower container trade compared to Western, North-West and Central India. South India too has high income. Therefore, the ports of South India have higher container traffic in proportion to population.

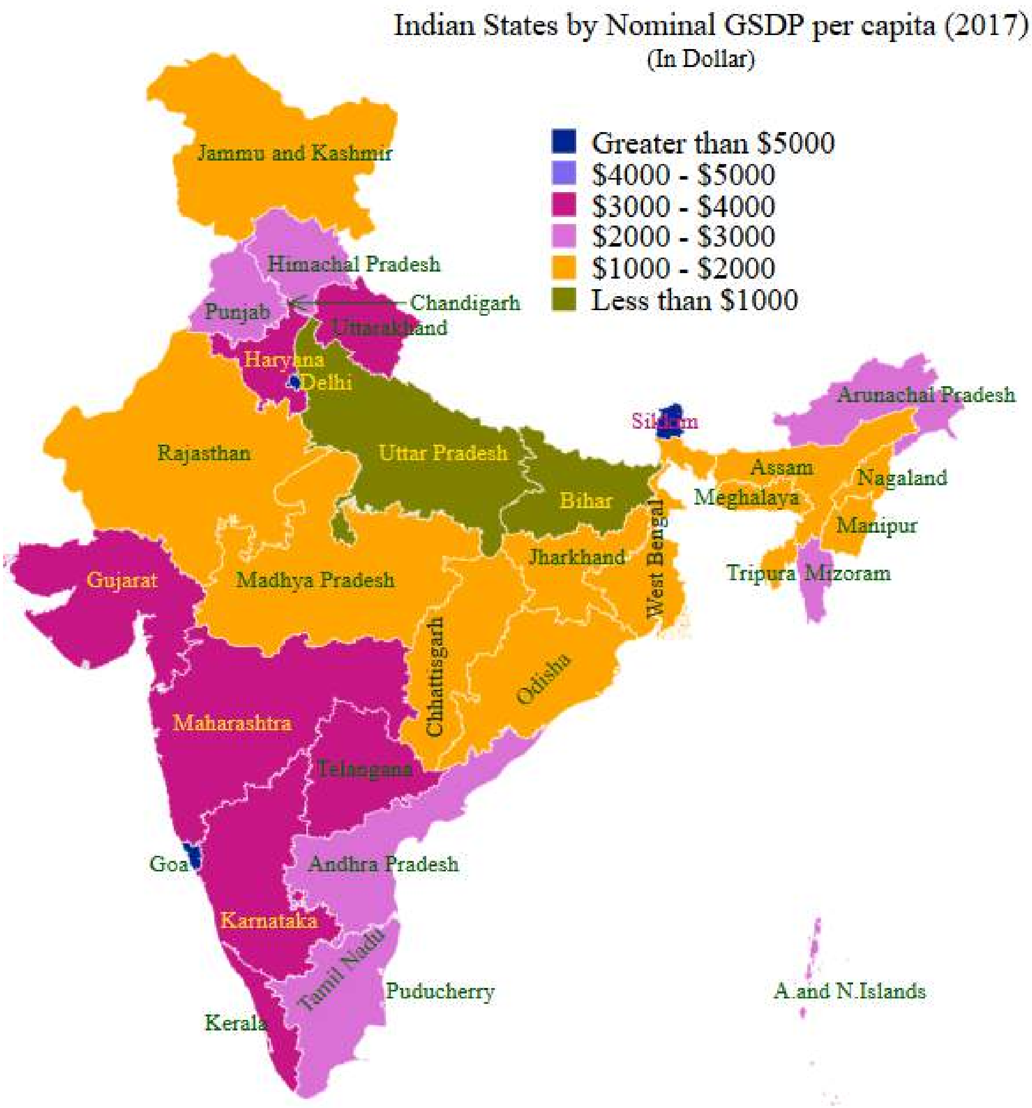

Figure A3-8 Nominal GSDP per Capita (2017)

Geographical Orientation of Container Trade

The Western ports are located in the established international trade route. Further, the substantial share of container cargo from India is west bound. The representative shipping line data for 12 months was compiled and analysed by Ernst & Young in their primary DPR. It was concluded that about 58% of the maritime container trade from the ports along Indian west coast is primarily west bound. Western ports provide the nearest outlet to the Middle East, Africa and Europe. Western ports are also nearest ports to the majority of the Northern hinterland and are well connected with this hinterland. Hence, most of the Northern hinterland for the container traffic is served by the ports located on the Western Coast.

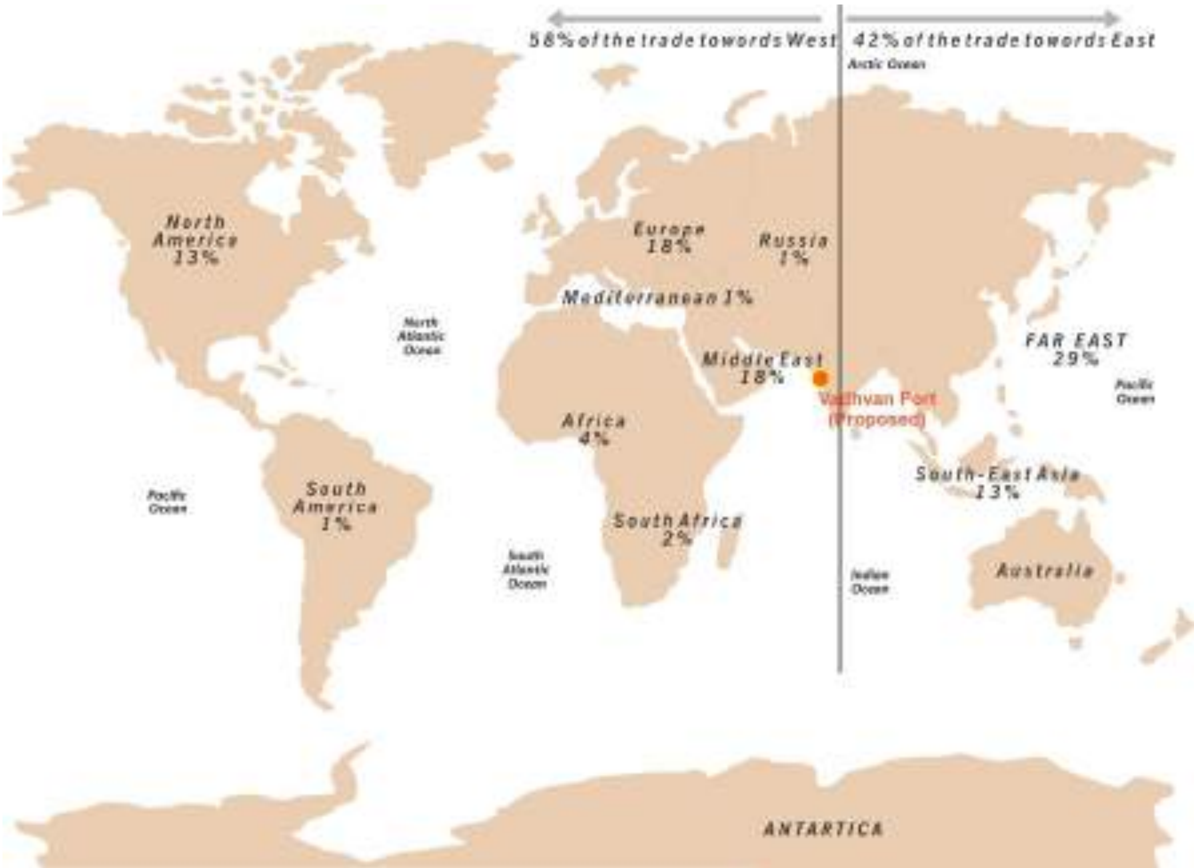

Figure A3-9 India's Container trade distribution by regions

Complete North-West hinterland covering the states of Punjab, Haryana, Uttar Pradesh, Delhi, Rajasthan, Madhya Pradesh, Gujarat, Maharashtra, parts of Andhra Pradesh and Karnataka are served by the Container Handling Ports on the Western coast. As future trends indicate that EXIM cargo though may shift to Asian countries, however, sea transport being cheaper, better and convenient; better infrastructure facilities would ensure that western ports will continue to dominate container transport business.

In view of the above factors, it is estimated that the dominance of the West Coast ports in handling the total container traffic of the country will continue.

Shipping Lines Tariffs

Shipping lines play a prominent role in deciding container port to be used for trade. The slot cost of 20 foot containers for trade between two ports is decided based on the deviation from trade routes, vessel capacity and frequency of visit. It has been observed that International shipping lines offer lower tariffs for ports located on West Coast of India compared to ports located on East Coast of India even though distance of trade is higher from the West. For example, the distance between JNPA and Port Klang is around 2,407 nautical miles whereas the distance between Chennai and Port Klang is around 1,661 nautical miles. Shipping lines have offered lower tariff for trade from JNPA to Port Klang compared with Chennai to Port Klang. Same pattern is visible for return cargo as well. Following table broadly describes around 7 international ports and compares their distance and tariffs with JNPA and Chennai.

Table A3- 4 Ocean Tariff Comparison Ports on East Coast and West Coast

Origin	Destination	Distance	Onward Tariff (US$)		Return Tariff (US$)	
		nautical miles	*Lowest 1*	*Lowest 2*	*Lowest 1*	*Lowest 2*
JNPA	Dubai	1,109	179	-	-	-
JNPA	Port Klang	2,407	53	272	263	431
JNPA	Hong Kong	4,432	-	-	1,071	-
JNPA	Singapore	2,637	53	-	363	494
JNPA	Shanghai	5,293	-	-	1,050	1,163
JNPA	Rotterdam	7,173	1,418	1,701	1,029	1,670
JNPA	Hamburg	7,451	1,418	1,701	1,029	1,670
Chennai	Dubai	2,114	431	-	63	-
Chennai	Port Klang	1,661	132	504	473	578
Chennai	Hong Kong	3,686	84	-	1,019	-
Chennai	Singapore	1,891	132	147	336	494
Chennai	Shanghai	4,547	147	-	1,271	-
Chennai	Rotterdam	7,949	1,260	1,313	1,134	1,670
Chennai	Hamburg	8,227	1,260	1,313	1,134	1,670

[Source: Searates.com as on Nov 25th, 2020]

As can be seen in the table above, majority of trade that takes place between India and Southeast Asia including China has lower tariffs from JNPA compared to Chennai. This happens despite of the fact that JNPA is around 750 nautical miles away from all these ports located on the east. It is primarily due to the mainline trade patterns for ships trading between Middle East/Red Sea routes and Eastern countries. Large volume of container ships is deployed at JNPA along with lower deviation costs as compared to Chennai. The trade volume between Eastern countries including China with Middle East and Europe is huge. This trade is mostly one way disproportionately in favour of China. The container vessels largely have empty slots on their return voyages. This leads to further discounting of tariffs for container trade from JNPA (or any west coast ports) to Eastern countries including China.

Evaluating India and Europe trade in the above table provides contrary tariffs with Chennai port offering lower tariffs compared to JNPA for Rotterdam/Hamburg trade even though Chennai is further away. A mother vessel deployed on East West international trade could pick containers belonging to Chennai from Colombo Transhipment Hub. There would be double handling of Chennai bound containers at Colombo. The shipping lines are able to offer discounted tariffs from Chennai due to economy of scale and lower deviation from the route. A container from JNPA would either have to go to European ports either in a smaller direct service vessel or it would have to get transhipped at a port (Colombo, Salalah, Jeddah, etc.) further away from JNPA with higher sailing of feeder vessels. These factors lead to lower tariffs.

Hence, for above mentioned reasons, the container ports on the West Coast of India would continue to dominate India's international trade compared to ports located on the East Coast of India. The costs rise as we move towards further northern ports on the East Coast of India.

A3.1.7 Competitive Ports of Hinterland

All the ports located in Gujarat and Maharashtra share the secondary and tertiary hinterland of Vadhavan Port. Vadhavan will be competing for cargo share from large ports with direct berthing and round the year operations. Gujarat has several smaller, lighterage, fair weather and captive ports. These ports would have different commodities and market segments. A large multipurpose port namely Vadhavan would not be competing in the market segment reserved for smaller ports, captive ports catering to local cargo. Hence, the major competitors of Vadhavan port would include JNPA, MbPT, HPPL, AHPPL, GPPL, Deendayal Port and Mundra Port. Several ports in Magdalla group and Dahej group would not have much competitive influence over market segment of Vadhavan Port. Following map shows prominent ports handling more than 5 MT cargo annually. Ports with less than 5 MT of annual cargo volume would not make any influence on the market segment of Vadhavan Port and therefore has been excluded from analysis.

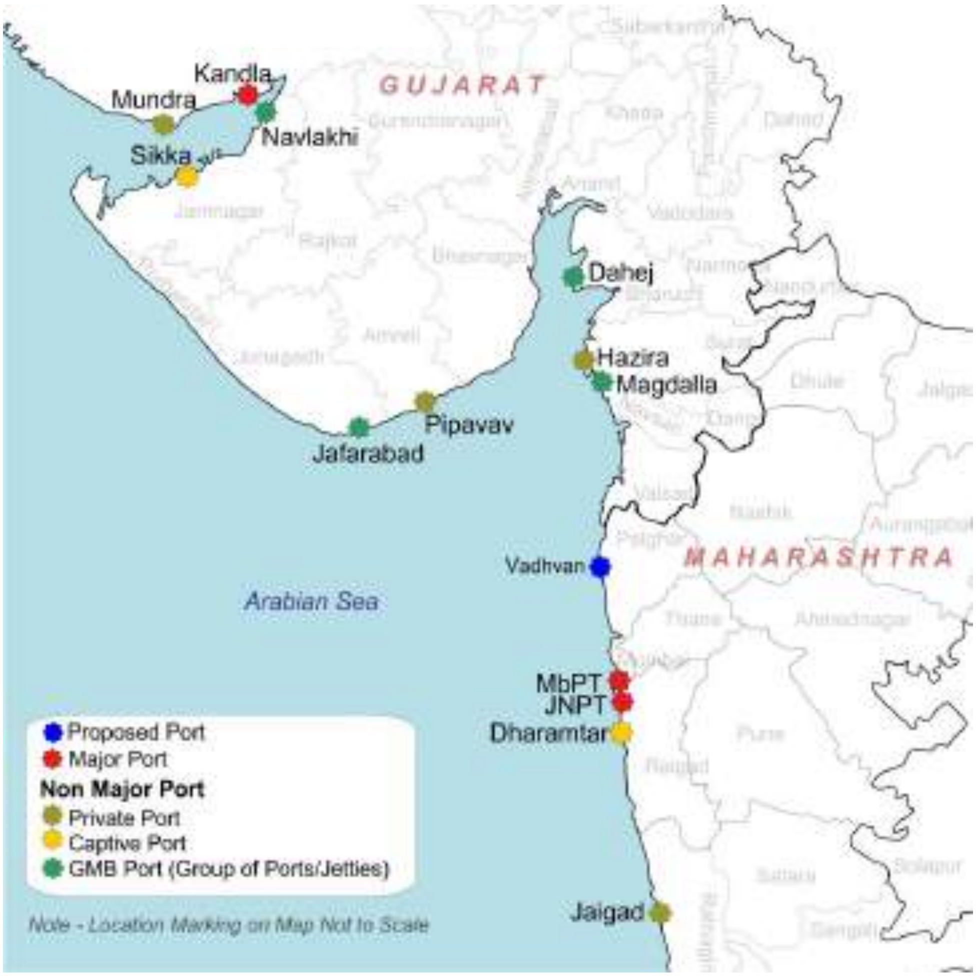

Figure A3-10 Prominent Ports of Gujarat and Maharashtra

The nearest ports cum industrial cluster in the North of Vadhavan includes Magdalla group of Ports and Dahej Group of Ports. Magdalla houses a number of smaller jetties including GMB Jetty, KRIBHCO, Reliance, L&T, etc. All these have been excluded from the analysis as they do not pose any competition to Vadhavan. Essar Bulk terminal is so far handling captive cargo for Arcellor Mittal and Nippon Steel (AM/NS). Dahej houses a number of private jetties operated by Dahej Harbour Infrastructure Ltd. (Birla Copper), Gujarat Chemical Port Ltd. (GCPL), Petronet LNG, Petronet Adani, etc. All these companies have their respective industries' plants located in the adjoining areas. Therefore, it is highly unlikely for these cargos to shift from their current point of entry to Vadhavan. The nature of the business dictates, cargo from captive jetties cannot be shifted to any other port, especially if the concerned parties' plants don't fall in the immediate vicinity of that port. Hence, these jetties have been excluded from further analysis of Vadhavan Port.

There exist 2 Major Ports namely Mumbai Port and JNPA in the nearest cluster to the South of Vadhavan. Both are multi-commodity commercial ports. JNPA is clean cargo port with prominent emphasis on Container cargo. Mumbai port has turned a clean cargo port with higher emphasis on Petroleum products due to HPCL and BPCL refineries in the adjoining areas.

Hence, the prominent competitors of proposed Vadhavan port for container cargo are JNPA, Mundra, Pipavav, Hazira and Kandla. The prominent competitors of all other commodities are JNPA, MbPT, Kandla, Mundra, Hazira, Pipavav and Adani Dahej.

A3.2 Need & Advantage of Vadhavan Port

A3.2.1 Requirement of New Port to Cater Growth

India's total port traffic for the year Fy-20 stands at 1,310 MT. The ports falling in North-West region (as defined in Hinterland section) handles around 707.2 MT (about 53.98%) of the total countries port traffic. The Ports in north-west region i.e. ports falling in Gujarat and Maharashtra, cater to nearly 50% of the country's population that reside in northern, central and western stretches of the country. In FY20, the North-West hinterland handled 707.2 MT of cargo, of which Gujarat handled more than 75% and Maharashtra handled close to 25% of the total port traffic of North-West hinterland.

The existing ports have strong customers base and have already established infrastructure, superior connectivity and logistic services, as well as years of experience. However, over the period of time, due to the restrictive expansion, the congestion at port has been a cause of serious concern for MbPT and JNPA, because of which some of the cargo destined for these ports are being routed to other immediately available ports, especially the ones falling in the north of the Mumbai cluster i.e. Adani Hazira, Pipavav, Kandla and Mundra. Proposed location of Vadhavan is nearest to JNPA in comparison with above listed ports. In such a scenario, Vadhavan will have a huge advantage due to its proximity to these ports, making it easier for the port to attract the spill over traffic, and be much more cost-effective in comparison with other ports falling further north of Vadhavan.

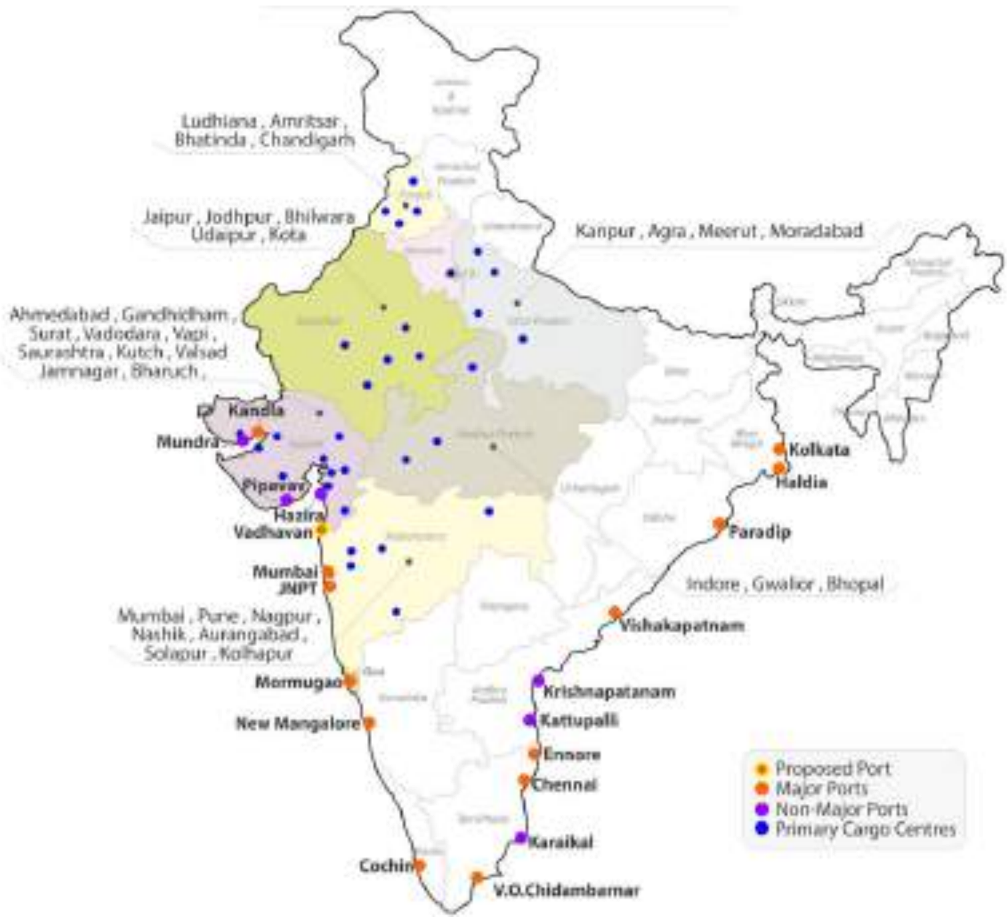

Figure A3-11 Cargo Centres in the Hinterland of Vadhavan Port

A3.2.2 Location Advantage

Vadhavan would have competitive advantage over JNPA due to its ability to berth larger ships and its closeness to Gujarat, Rajasthan, Northern and Central India. The logistics cost savings due to infrastructure and connectivity advantage by Vadhavan Port is likely to provide higher traffic gains for Vadhavan compared to other competing ports in the influence area.

The logistics cost analysis section broadly described marine side and inland cost savings at Vadhavan port. It was concluded, in **Error! Reference source not found.** and **Error! Reference source not found.**, that th e inland cost of Concor provided savings to Vadhavan as compared to JNPA. The costs compared to Hazira, Mundra and Pipavav would be competitive.

Transit time and cost for rail traffic to Vadhavan port is expected to be lower with direct connectivity to DFC. Whereas Pipavav/Hazira will be connected to DFC using feeder network resulting in delays at interchange points. Mundra port is likely to have direct connectivity to DFC. However, there is marginal difference in distance of less than 8% for Vadhavan compared to Mundra, inland price disadvantage would be marginal for Vadhavan. This marginal inland price disadvantage of Mundra could be an offset by competitive port tariffs and discounted shipping tariffs compared to Mundra.

With changing emission norms and imposed clampdown on overloaded trucks, cost of road transport is likely to increase. This would result in modal shift from road to rail and for rail, Vadhavan would be attractive using DFC.

A3.2.3 Capacity Constraints

The existing container ports of Gujarat and Maharashtra catering to North and West Indian hinterland would face capacity constraints. These ports are face following 5 major restrictions for capacity expansion.

- Unavailability of waterfront to create new Jetties/Terminals (JNPA, AHPPL-partially);
- Located further away from the route considered unproductive for shipping lines to divert (Kandla, Dahej);
- Heavy siltation/tidal issues rendering expansion of infrastructure extremely high (Hazira, Dahej);
- Legal & Regulatory issues embedded in the 30 years' concession agreement restricting expansion of private ports till the time they are sure of extension of Concession Agreement (Mundra and Pipavav);
- Limited availability of waterfront suitable for construction of Container port on the Coast of Maharashtra and Gujarat (discussed in detail in section Need for Vadhavan).

Vadhavan Port would gain containers in the Market place on following 2 parameters.

- Diversion of existing container traffic from competing ports on account of larger ship calls and overall logistics cost savings;
- Gain a share in the incremental traffic growth in the North West Region.

Several other ports such as Rewas, Dighi, Jaigarh, Nargol, etc. were proposed for container trade on the West Coast of India. The constraints of location, connectivity and marine issues have delayed implementation plans of these ports beyond reasonable time. Rewas has been in discussion for around 15 years to 20 years. The port was to be developed by India's largest private sector company, Reliance Industries Limited (RIL). RIL being a cash rich company with a track record for making large upfront investments to create substantially high economy of scale eventually leading to disproportionately high market share. Non development of Rewas port could be concluded as non-priority segment of Reliance Industries. Dighi port located on the West of Western Ghats would find it immensely difficult to create a railway connectivity with the hinterland, apart from more than 250 km of additional distance from Northern Hinterland. Jaigarh port faces similar difficulty. Dighi port faces severe siltation. It required extensive dredging to maintain a draft of more than 7 m. There are no serious container terminals planned on the Maharashtra and Gujarat coast of India.

Given the competitive environment in the region, it is expected that all future container volumes would be distributed between ports of Mundra, JNPA and Vadhavan, subject to available capacity at respective port.

In the event of capacity saturation at JNPA, Mundra and Pipavav, container traffic would primarily be handled at Vadhavan due to its proximity to Northern Hinterland. Hazira port has plans to get a railway connectivity. The competitiveness of Hazira port is restricted due to absence of railway connectivity. Moreover, Hazira port also faces capacity expansion. Hence, Vadhavan is the only planned alternative at the point of time.

There is no port planned in the near future either by Central Government or State Governments of Maharashtra and Gujarat for container handling. As discussed in the need for Vadhavan section, the possibility of new port at a new location is limited. Hence, it has been assumed that Vadhavan will be the only new large container port in Maharashtra catering to NCR region.

The proposed port of Vadhavan is comparable with Mundra port, especially due to competitive development of port ecosystem, scale of infrastructure and operating environment.

Vadhavan would be able to attract incremental increase in traffic over the years is then distributed as per the facilities and capacity constraints at different ports. Vadhavan having the highest potential with modern facilities, deep draft and no capacity constraints in the initial years is expected to gain a larger share in the traffic.

A3.2.4 Unavailability of better Alternate Location

The prominence of ports in Maharashtra and Gujarat for Northern, Western and parts of Central India have been established in hinterland definition section. India would need more ports to sustain its economic growth and trade. There has to be a suitable location providing optimum advantage from logistics point of you. The location should be conducive for establishing large and deep draft container port. The option available for new port is limited on the coast of Gujarat and Maharashtra. This section analyses various locations in Gujarat and Maharashtra along with its advantages and disadvantages for setting up a large and futuristic port with primary emphasis on Container trade along with other clean cargo. Following figure marks all the ports in state of Gujarat and Maharashtra. These markings include functional ports, ports at conceptual planning stage, locations notified for probable port in future.

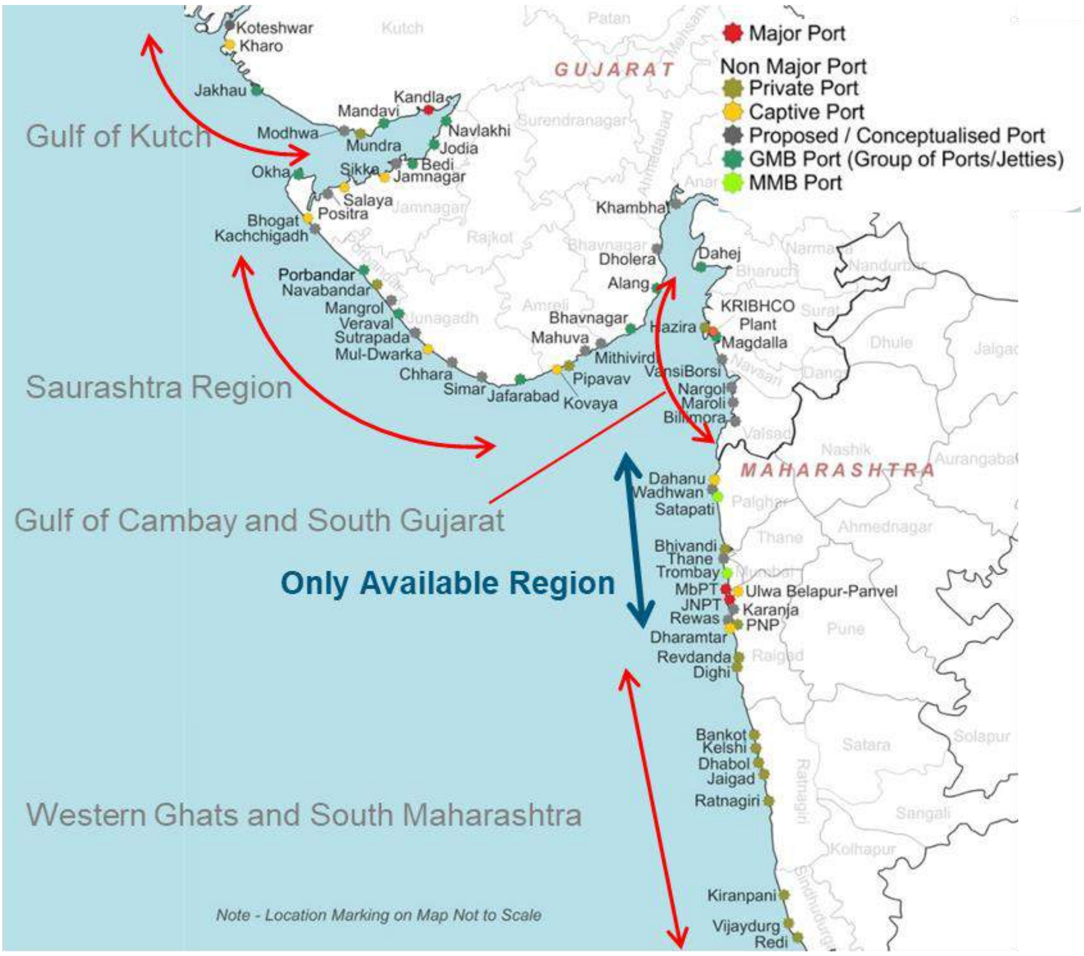

Figure A3-12 Location Analysis for Port Development on North West Coast of India

Gulf of Kutch has several ports that have access to industrial zones and hinterland. The region handles more than 35% of India's port traffic. There exists 2 large multi commodity commercial ports at Mundra and Kandla. A new container port with emphasis on container handling does not create additional advantage in the region. Gulf of Kutch region is away from shipping lines, primary trade route that requires mainline vessels higher diversion. Mundra port is closer to Northern cargo catchment area compared to JNPA. Several locations in this region would be closer to northern hinterland. Higher diversion from shipping routes makes them less preferred a location for development of container port. This has been primary reason for deferring investment plans on creation of large ports in the region including Okha and Positra. The port project at Positra got shelved on environmental grounds.

Saurashtra region has one container port privately operated by a shipping line APM. The port has been able to generate lower growth of container related cargo since its inception despite it has been owned and operated by a shipping line. Container port in Saurashtra region is away from Northern and central hinterland. The local demographics of Saurashtra does not generate large volumes of container trade essential to create an economy of scale that makes port competitive to JNPA or Mundra. This problem is likely to be witnessed by any future container port likely to developed in Saurashtra region. Hence, development of large futuristic port in this region has been discarded.

Gulf of Cambay and South Gujarat has one container port and multiple ports for handling bulk cargo. The Hazira container port acts as a gateway for local containers generated in the industrial region of South Gujarat. Hazira port has scope for developing additional two container berths. Any expansion beyond would technically be not feasible and commercially expensive. The other locations in south Gujarat is unsuitable due to high siltation and tidal variation in the region. Locations further north in Gulf of Cambay witness's tidal variations as high as 9 m. These two factors are likely generate very high recurring maintenance cost of port. Hence, a new port on a large scale that India needs in north and west part is unlikely in South Gujarat region.

Location on the South of JNPA is away from cargo centres of northern hinterland. JNPA itself is losing out to its competitor Mundra due to more than 200 km inland distance from northern India compared to Mundra. A port developed south of JNPA would increase inland distance disadvantage further. Coastal area to the south of JNPA has Western Ghats running parallel to the coast. Negotiating these Ghats to access waterfront by road or rail would be very expensive and cumbersome, this restricts seamless cargo movement to/from ports in the region. Also, ports in this region cannot berth large ships due to existing Oil and Gas pipelines on the seabed. Hence, all the locations to the South of JNPA has been discarded for development of large port focused on Container trade.

The stretch from JNPA to South Gujarat has the location window for development of large port. Mumbai Metropolitan Region has to be excluded from this enabling about 100 km window for development of large futuristic container port. Vadhavan falls in the region. Hence, it has been selected for development.

A3.2.5 Development Model

Vadhavan port is being developed on land-lord model with JNPA as nodal development authority. The ownership of the port is between JNPA and MMB. The development authority would act as a landlord responsible for following activities.

- Conceptualise the project
- All approvals needed for development of project
- Development of preliminary infrastructure;

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- Develop common port infrastructure;
- Inland connectivity including Rail and Road;
- Marine Connectivity including development of Channel and Dredging.

The port would be developed based on Public-Private Partnership (PPP) model devised by Government of India. The authority would invite private developers for further development of infrastructure. The responsibilities of private developers would include

- Development of respective Jetties;
- Installation of all material handling equipment’s;
- Creation of respective backup and other storage facilities;
- Other infrastructure exclusively for use of PPP developer.

The container terminal of Vadhavan is likely to attract global container terminal operators. A combination of transparency due to government initiation and deep draft would increase attractiveness of Vadhavan port for developers compared to other ports in the region. Larger shipping lines intend to own and operate container ports and container terminals. Several such instances are available in India. Hence, forging a partnership with the shipping line by the port developer is likely to increase commercial attractiveness of the port. Following are some of the key drivers for success of Container Terminals of Vadhavan Port.

- Futuristic Container Terminals with deep draft to cater largest container vessels available even on the design board;
- Proximity to hinterland clusters including upcoming Dedicated Freight Corridor (DFC) and DMIC corridor resulting in lower inland evacuation cost to the hinterland;
- The port is developed at a location of deep draft that would provide channel availability without recurring dredging. This would reduce maintenance cost of port, impacting favourable tariffs for container handling.

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A3.3 Logistics Competitiveness of Vadhavan

The port cost at Vadhavan would be lower on account of two factors, namely, less requirement of maintenance dredging and shortest channel distance. The lack of maintenance requirement would also lead to a lesser amount of pre & post berthing time. With a deep draft of 20 m, Vadhavan port will be able to handle bigger vessels resulting in lower shipping costs due to economies of scale.

Figure A3-13 Major Container Trade Route

A3.3.1 Vadhavan Port's Location Benefit

Figure A3-14 Positioning of Vadhavan Port

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A3.3.2 Ocean Freight Competitiveness

The tables below list the lowest and second lowest quote for the cost of transportation of 20' FCL from Indian ports to Foreign ports and vice-versa. The first table lists the lowest freight charges and second table represents the second lowest. The sea freight of shipping line is dynamic in nature and change based on the slot availability and timings. Companies with large volumes of container trade have discounted tariffs as part of long-term agreement with the shipping lines. Hence, following table describes lowest and 2nd lowest quotes from the shipping lines to remove erroneous tariffs due to desperate pricing. The table has tariff offered by shipping lines as on November 25th, 2020. These tariffs could marginally vary on any other day, but the proportion of difference is likely to remain same or similar.

Table A3- 5 Lowest Quote for FCL 20 Ft. between Indian and Foreign Ports (US$)

Foreign Ports →	Chittagong	Dubai	Colombo	Port Klang	Hong Kong	Singapore	Rotterdam	Hamburg
Arrival at Foreign Ports								
JNPA	788	179	473	53	-	53	1,418	1,418
Chennai	1,134	431	342	132	84	132	1,260	1,260
Mundra	893	399	630	158	-	158	1,418	1,418
Pipavav	1,397	987	746	613	-	105	1,418	1,418
Hazira	1,365	347	735	613	-	445	1,418	1,418
Departure from Foreign Ports								
JNPA	263	179	145	263	1,071	363	1,029	1,029
Chennai	-	63	84	473	1,019	363	1,134	1,134
Mundra	424	474	114	436	1,281	494	1,029	1,029
Pipavav	368	746	231	420	945	420	1,712	1,712
Hazira	599	221	641	578	1,375	420	1,187	1,187

Table A3- 6 Second Lowest Quote for FCL 20 Ft. between Indian and Foreign Ports (US$)

Foreign Ports →	Chittagong	Colombo	Port Klang	Singapore	Rotterdam	Hamburg
Arrival at Foreign Ports						
JNPA	1,397	578	273	-	1,701	1,701
Chennai	-	557	504	147	1,313	1,313
Mundra	1,376	683	-	-	1,733	1,733
Pipavav	-	-	-	-	-	-
Hazira	-	-	-	-	1,733	1,713
Departure from Foreign Ports						
JNPA	-	-	431	494	1,670	1,670
Chennai	-	405	578	494	1,670	1,670
Mundra	-	261	735	615	1,670	1,670
Pipavav	-	693	-	683	2,011	2,011
Hazira	-	-	-	945	1,932	1,932

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A3.3.3 Inland Logistics Cost Competitiveness

The table below lists the costs incurred during railway transportation of containers from the Northern, North – Central, Western, North – Western and Central region, which remains common to most of the ports on the west coast. Presently, Container Corporation of India (CONCOR) has the largest share in container transportation via railways, and the tariff below is with respect to the same company. In FY18, from the total 3.8 Mn TEUs of containers that CONCOR handled, nearly 80% of that traffic originated from Central, Northern, Western, North Central and North Western hinterland of the country. The containers originating and/or heading to the northern Inland Container Depot (ICD) of Tughlakabad was 22% of the overall western and northern container traffic. This leads to the fact that a large volume of container, via railways, passes through the western regions. The distance breakdown and the corresponding tariff from ICD of every region to Vadhavan and its competing ports is presented in the table below. Vadhavan and Mundra / Pipavav shares tertiary hinterland as common, while Vadhavan and MbPT / JNPA shares secondary and tertiary common hinterland. Hence, Vadhavan will be met with competition from these ports while looking to attract a fair share of container traffic from the northern hinterlands.

Mundra, Pipavav and JNPA have dedicated rail connectivity for evacuation, which adds to the advantage over Vadhavan. While, Hazira does not have direct rail connectivity. Port uses KRIBHCO's KRIL, situated at 16 km away, for rail transportation. This 16 km of stretch needs to be travelled by road transportation, that further adds to cost and increases overall logistics cost due to multiple handling. Adani Hazira does not provide tough competition to the Vadhavan as scale of cargo volume to be targeted is different. Adani Hazira have plans to extend KRIL railway line till their port, if this comes up in future then competition would favour Hazira over Vadhavan. However, once the Vadhavan gets fully developed with rail connectivity and till the time Hazira gets rail connectivity in case, then Vadhavan can enjoy its advantage of railway line connectivity and attract Hazira's share as well.

Table A3- 7 Inland Tariff Comparison – ICD to Port

Origin	Destination	Distance (km)	Charges (Rs./TEU)	Charges (US$/TEU)	Saving (Vadhavan) (US$/TEU)
Tughlakabad	Mundra Port	1,124	29,500	393	7
	Pipavav	1,210	29,000	387	13
	Hazira	1,126	28,500	380	20
	Vadhavan	1,269	30,000	400	-
	JNPA	1,446	32,000	427	-27
Dadri	Mundra Port	1,142	32,000	427	20
	Pipavav	1,227	30,100	401	45
	Hazira	1,152	31,100	415	32
	Vadhavan	1,300	33,500	447	-
	JNPA	1,472	35,200	469	-23
Ratlam	Mundra Port	704	18,400	245	-52
	Pipavav	726	18,400	245	-52
	Hazira	413	12,600	168	25
	Vadhavan	562	14,500	193	-
	JNPA	733	17,400	232	-39
Ankleshwar	Mundra Port	553	15,600	208	-101
	Pipavav	575	14,100	188	-81

Origin	Destination	Distance (km)	Charges (Rs./TEU)	Charges (US$/TEU)	Saving (Vadhavan) (US$/TEU)
	Hazira	72	-	-	107
	Vadhavan	221	8,000	107	0
	JNPA	392	10,400	139	-32
Nagpur	Mundra Port	1,330	30,200	403	-69
	Pipavav	1,352	37,300	497	-164
	Hazira	767	17,900	239	95
	Vadhavan	891	25,000	333	-
	JNPA	849	22,900	305	28

Table A3- 8 Inland Tariff Comparison – Port to ICD

Origin	Destination	Distance (km)	Charges (Rs./TEU)	Charges (US$/TEU)	Saving (Vadhavan) (US$/TEU)
Mundra Port	Tughlakabad	1,124	34,000	453	-27
Pipavav		1,210	34,100	455	-28
Hazira		1,126	34,000	453	-27
Vadhavan		1,269	32,000	427	-
JNPA		1,446	42,300	564	-137
Mundra Port	Dadri	1,142	31,100	415	52
Pipavav		1,227	33,100	441	25
Hazira		1,152	30,100	401	65
Vadhavan		1,300	35,000	467	-
JNPA		1,472	38,800	517	-51
Mundra Port	Ratlam	704	19,400	259	-59
Pipavav		726	19,400	259	-59
Hazira		413	13,600	181	19
Vadhavan		562	15,000	200	-
JNPA		733	18,900	252	-52
Mundra Port	Ankleshwar	553	16,600	221	-115
Pipavav		575	15,100	201	-95
Hazira		72	-	-	-
Vadhavan		221	8,000	107	-
JNPA		392	11,400	152	-45
Mundra Port	Nagpur	1,330	31,200	416	-123
Pipavav		1,352	38,300	511	-217
Hazira		767	21,000	280	13
Vadhavan		891	22,000	293	0
JNPA		849	23,300	311	-17

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JNPA

Vadhavan does have advantage logistically, when it comes to other ports in south of Gujarat, JNPA and MbPT. Choosing Vadhavan over Mundra and Pipavav in Maharashtra, South Gujarat and Central India leads to cost savings to the shipper. Hence, Vadhavan is at an advantageous position compared to ports in Gujarat. Vadhavan will, therefore, be in a position to compete with existing container ports in North-West India. It will be able to attract a share of existing traffic based on the logistics advantage. Vadhavan would also be able to capture substantial share of incremental traffic not handled at existing ports due to capacity constraints. Vadhavan would be 2nd container port in Maharashtra after JNPA and would act as Satellite port of JNPA. Vadhavan would be able to win back a share of JNPA container traffic that has shifted to other ports. It would also be able to berth ships that are unable to berth at JNPA due to infrastructure restriction at JNPA and will in turn compliment JNPA.

A3.4 Connectivity Analysis

A3.4.1 Road Connectivity

This section discusses the land connectivity i.e., rail and road of Vadhavan with prominent cargo clusters in the hinterland. Transport infrastructure plays a vital role in any product industry. Adequate transport capacities lead to lower the transit cost and time and provides smooth cargo movement. Vadhavan Port's hinterland comprises of Maharashtra as primary, Gujarat as secondary and other northern states and Madhya Pradesh as tertiary hinterland. The figure below represents the road connectivity of Vadhavan with entire demarcated hinterland.

Figure A3-15 Road Connectivity to Proposed Vadhavan Port

Proposed Vadhavan Port is located adjacent to NH8. This location is connected to Nashik with 2-lane SH30 (Dahanu-Jawahar road). Nashik is the nodal point that connects with northern states of India extending to

Agra and beyond. This route i.e., Vadhavan – Northern States via Nashik facilitates seamless cargo movement. This can also take up the cargo that would produce along the DMIC in future.

Vadhavan is also well connected with cargo centres within Maharashtra. SH30 also connects this port to Thane and further with ICDs in Maharashtra via NH8 that serves entire hinterland of Vadhavan of Maharashtra. MIDC Golden Quadrilateral project is under pipeline, once it gets operational it is going to enhance the connectivity with prominent centres even more. These centres are Aurangabad, Pune, Nashik and Mumbai, these four locations form a quadrilateral that is going to provide seamless cargo movement in the region. Proposed MIDC Golden Quadrilateral is presented in the figure below. Further, one more road connectivity project is under implementation i.e. Nagpur-Mumbai Super-Communication. This connectivity is going to free up the congestion from existing route.

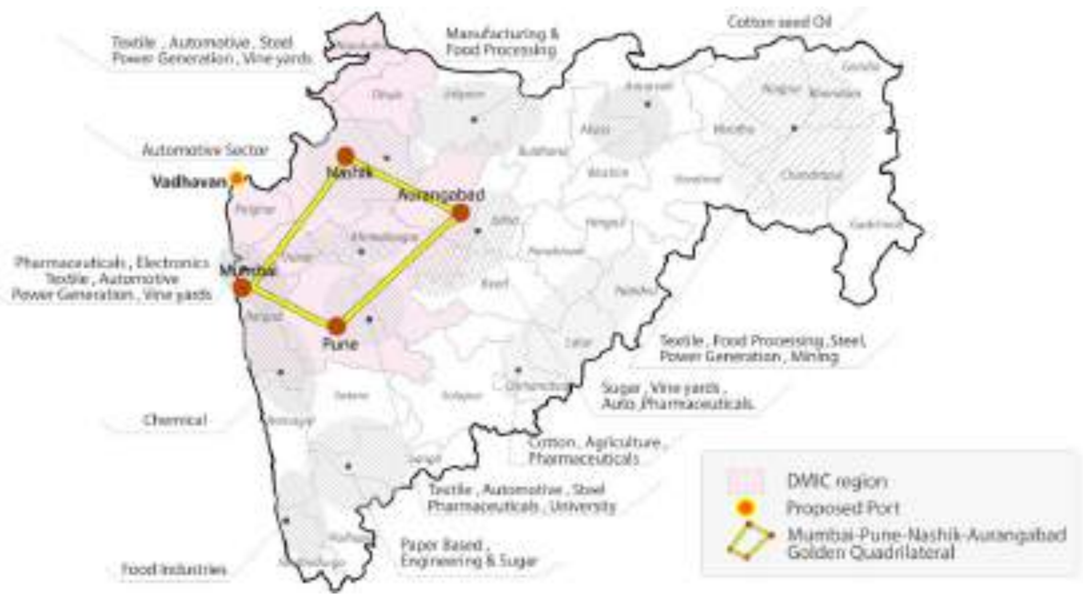

Figure A3-16 Upcoming DMIC Connectivity in the region

A3.4.2 Rail Connectivity

Vangaon is the nearest station to Vadhavan Port, it is around 16.2 km from the proposed location. Vangaon railway station is a part of Mumbai Central (BCT) division falling on western line between Umaroli and Dahanu. Western railway line runs parallel to the proposed location at approximately at 15 km. Kalyan is the nearest junction for connecting Vangaon to Nashik and Aurangabad and further to Madhya Pradesh. Connectivity with northern states is via Surat and Ahmedabad rail line and with southern states is by using Mumbai and Pune rail line. The figure below shows the rail connectivity around proposed port.

Figure A3-17 Rail Connectivity to Proposed Vadhavan Port

Rail Distance Matrix

The table below shows the rail distance matrix between Vadhavan's competitors and connecting ICD in the region. Tentative rail distance to/from Vadhavan is also assumed in the table below.

Table A3- 9 Rail Distance Matrix – ICDs and Ports (kms)

Ports →	Mundra	Pipavav	Hazira (KRIL)	Vadhavan*	JNPA
Northern Region					
Tughlakabad	1,124	1,210	1,126	1,269	1,446
Moradabad	1,266	1,351	1,254	1,398	1,574
Panipat	1,176	1,261	1,186	1,334	1,505
Ballabhgarh	1,142	1,228	1,108	1,257	1,428
Jodhpur	632	780	705	862	1,025
North - Central Region					
Dadri	1,142	1,227	1,152	1,300	1,472
Madhosingh	1,626	1,712	1,370	1,494	1,452
Agra	1,108	1,193	1,017	1,160	1,336
Gwalior	1,221	1,305	992	1,140	1,243
Kanpur	1,356	1,441	1,204	1,352	1,365
Western Region					
New Mulund	904	926	340	162	69

Ports →	Mundra	Pipavav	Hazira (KRIL)	Vadhavan*	JNPA
Turbhe	915	936	351	172	79
Dronagiri Node	940	961	376	198	21
Ratlam	704	726	413	562	733
North - Western Region					
Gandhidham	73	469	552	700	871
Ankleshwar	553	575	72	221	392
Central Region					
Nagpur	1,330	1,352	767	891	849
Raipur	1,634	1,658	1,073	1,197	1,155

Note: * - Proposed Port. Vangaon Railway Station + 16 km is considered for calculating rail distance to/from Vadhavan.

Freight Charges

The table below shows per TEU fare CONCOR charges to/from Vadhavan's competitors and connected ICDs in the hinterland. Vadhavan falls between Hazira and JNPA.

Table A3- 10 Freight Charges from ICD to Ports (INR per TEU)

To Container Ports →	Mundra	Pipavav	Hazira (KRIL)	JNPA
Northern Region				
Tughlakabad	29,500	29,000	28,500	32,000
Moradabad	31,200	31,800	-	35,900
Panipat	28,100	28,700	-	36,900
Ballabhgarh	28,000	30,600	-	32,300
Jodhpur	17,300	17,300	-	25,000
North - Central Region				
Dadri	32,000	30,100	31,100	35,200
Madhosingh	-	-	-	33,300
Agra	31,000	31,100	-	31,200
Gwalior	28,600		-	30,200
Kanpur	31,300	31,300	-	33,000
Western Region				
New Mulund	-	-	-	3,600
Turbhe	-	-	-	2,800
Dronagiri Node	23,000	25,500	-	2,500
Ratlam	18,400	18,400	12,600	17,400
North - Western Region				
Gandhidham	3,700	13,000	-	
Ankleshwar	15,600	14,100	-	10,400

To Container Ports →	Mundra	Pipavav	Hazira (KRIL)	JNPA
Central Region				
Nagpur	30,200	37,300	17,900	22,900
Raipur	41,300	42,800	-	27,600

Table A3- 11 Freight Charges from Ports to ICD (INR per TEU)

From Container Ports →	Mundra	Pipavav	Hazira (KRIL)	JNPA
Northern Region				
Tughlakabad	34,000	34,100	34,000	42,300
Moradabad	35,200	35,300	-	38,900
Panipat	31,600	32,700	-	44,900
Ballabhgarh	29,000	31,600	-	34,800
Jodhpur	17,600	20,800	-	26,000
North - Central Region				
Dadri	31,100	33,100	30,100	38,800
Madhosingh	-	-	-	35,300
Agra	28,500	32,100	-	32,200
Gwalior	29,600	-	-	31,700
Kanpur	32,300	34,800	-	34,800
Western Region				
New Mulund	24,000	24,000	-	4,600
Turbhe	-	-	-	
Dronagiri Node	24,000	26,500	-	2,600
Ratlam	19,400	19,400	13,600	18,900
North - Western Region				
Gandhidham	4,700	14,000	-	
Ankleshwar	16,600	15,100	-	11,400
Central Region				
Nagpur	31,200	38,300	21,000	23,300
Raipur	43,000	44,500	-	28,000

A3.5 Competition Analysis

Containerised goods are segment whose trade growth at the western-coast ports has been substantial. Since the past decade, nearly 72% of the container traffic was handled by the ports on the west coast. This high volume is demonstrative of the expansive presence of the container segment at the ports along the west coast. Since the past decade, the container trade on the western front of the country has grown at a CAGR of 12%. A large credit goes to the presence of the country's largest container terminal JNPA along the west coast. It is because of this port and the huge demand for such goods in the northern and central parts of the country, that the segment has seen such an exponential growth. The figure below shows the container ports in the hinterland that would pose competition to Vadhavan.

Figure A3-18 Proposed Vadhavan Port's Competitors

Presently, with the congestion obstructing any immediate boost in the container trade at JNPA, the excess cargo is bound to be routed to other suitable ports; currently being attracted by the port of Mundra. At the moment, ports like Kandla, Mundra and Pipavav cater to their captive market as well as the extra cargo arising out of congestion at the ports in the Maharashtra Cluster. However, once the Port of Vadhavan is set up, it can easily target this spill over container traffic from JNPA. The section below discusses the target market, available infrastructure and facilities and commodities handled with Vadhavan's perspective for traffic diversion.

A3.5.1 MbPT – Market and Facilities

Mumbai Port is one of the oldest ports in the region. It is categorized as major port, handling roughly 55 MT of cargo annually. The port is located close to 152 km south of Vadhavan. Mumbai port focuses both on the industrial as well as logistics cargo which is catering to be industrial belt located in the Mumbai region, adjoining region and some of the hinterlands located in the North.

Table A3- 12 Available Infrastructure at MbPT

Type	Description
Nature	• Dock Port and Multipurpose Terminals, Liquid/ POL terminals • All Weather Port • Direct Berthing Facility
Cargo handling equipment	• 5 Mode & 11 Wharf Cranes • 34 Forklift Truck • 5 Tractors
Storage Facilities	• Covered Area – 96,606 Sqm. Transit and 140,158 Sqm. Warehouse • Open Area – 739,238 Sqm. • Liquid Cargo – 38,800 KLs of Port and 470,864 KLs of Private User • Pipeline from jetty to storage tanks for POL, Chemical & Crude
Type of Jetties	• 7 for POL, 25 for Breakbulk

Type	Description
Commodities handled	POL products, Crude, Bulk Liquid, Chemicals, Coal, Iron & Steel, Cement, Fertilizer, etc.
Traffic Handled in FY20	Export – 18.83 mnT, Import – 41.86 mnT

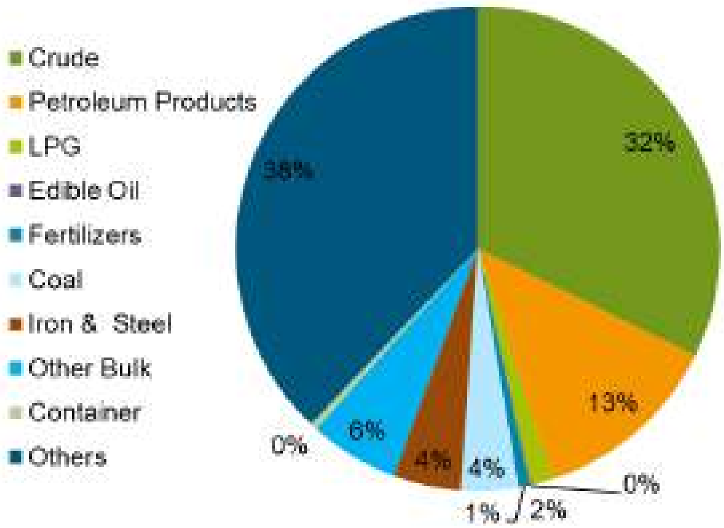

Figure A3-19 Commodity wise Share Distribution at MbPT

Mumbai Port would be one of the major competitors of Vadhavan in some of the cargo segments, as Mumbai Port handles a wide range of cargo, however crude and liquid cargo dominates the major commodities handled by Mumbai Port Authority. More than 50% of the cargo handled by Mumbai Port Authority is liquid which constitutes crude oil, petroleum products, edible oil and other liquids.

Table A3- 13 O-D Analysis of Cargo handled at MbPT

Commodity	Traffic (MT)		Vadhavan	Reasoning
	2010	2020	Perspective	
Crude	24.1	19.6	No	Pipelines laid till HPCL & BPCL refinery. Exclusive & dedicated facility at MbPT, cannot be attracted to Vadhavan.
Petroleum Products	10.2	7.7	No	Well-developed infrastructure at MbPT with pipelines & tank farms. Exclusive & dedicated facility at MbPT, cannot be attracted to Vadhavan
Bulk Liquid	0.3	0.9	Yes	Imported for domestic consumption, stored at MbPT tanks. Vadhavan could handle Bulk Liquid to serve Northern Maharashtra and Madhya Pradesh
Edible Oil	0.4	0.1	Yes	Mostly imported in handy size ships of 10,000 DWT to 20,000 DWT, requires exclusive storage tanks. This could be potential cargo for Vadhavan
Fertilizers	0.4	0.4	Yes	Imported for RCF at Chembur and partly goes to Hazira. This is clean cargo and Vadhavan falls midway between two consumption centers. Could be targeted

Commodity	Traffic (MT)		Vadhavan	Reasoning
	2010	2020	Perspective	
Coal	3.7	2.3	No	Imported for Tata Power and Reliance Power of Dahanu. For Tata Power it partly gets lightered followed by direct berthing at captive jetty. Dedicated facility for Tata Power at MbPT, less likely to be attracted.
Iron & Steel	4.6	2.7	No	End users are located nearby. Not an attractive cargo for Vadhavan
Other Bulk	2.2	3.6	No	Various commodity such as cement, food grains, sugar, sulphur, etc. handled in loose form and consumed within state
Container	0.6	0.3	Yes	Could be attracted to Vadhavan, if logistics cost works out.
Others	7.9	23.0	No	Mostly transhipment of finished products generated at refinery in Mumbai. Also, imports ATF for Domestic consumption. Difficult to handle as it requires dedicated infrastructure.
Total	**54.4**	**60.7**		

There is substantial Fertiliser traffic and some amount of edible oil and Bulk Liquid could be attracted as shown in the table above. Vadhavan could these commodities based on the facilities and services provided to cargo owner be competitive and also shifting to Vadhavan comes logistically cheaper.

A3.5.2 JNPA – Market and Facilities

The second major port located in the Mumbai region is Jawaharlal Nehru Port Authority (JNPA). JNPA is India's largest container port, handling more than 5 million TEU of container, which translate into roughly 59 million tons of containerized cargo. Apart from containers, it also handles POL, edible oil, cement and other liquids. JNPA is also located close to 152 km south of Vadhavan. The commodities such as edible oil, and container has high possibility of partly shipping to Vadhavan because of distance and logistics advantage, however petroleum products handled at JNPA is less likely to shift to Vadhavan, because there are already full-fledged infrastructure and pipeline laid down at JNPA for handling of petroleum products.

Table A3- 14 Available Infrastructure at JNPA

Type	Description
Nature	• Deep Draft Berths, Container Port • All Weather Port • Direct Berthing Facility
Cargo handling equipment	• 43 Cranes at Quay and 144 Cranes at Yard • 25 Forklift Trucks • 432 Tractors and Trailers
Storage Facilities	• Covered Area – 188,497 Sqm. Warehouse • Open Area – 2,691,857 Sqm. • Liquid Cargo – 34.86 Lakhs KLs of Private User • Pipeline from jetty to storage tanks for POL & Chemical
Type of Jetties	• 2 for POL, 10 for Containers, 3 for Breakbulk

Type	Description
Commodities handled	Containers, POL products, Crude, Bulk Liquid, Edible Oil, Other Liquid, Cement
Traffic Handled in FY20	Export – 27.60 mnT, Import – 40.85 mnT

The table above shows the features of JNPA and available infrastructure for cargo handling and storage. Commodity share breakup in JNPA's total traffic is depicted in the chart below, thereafter the movement of these commodities and potential opportunity they create for Vadhavan is discussed.

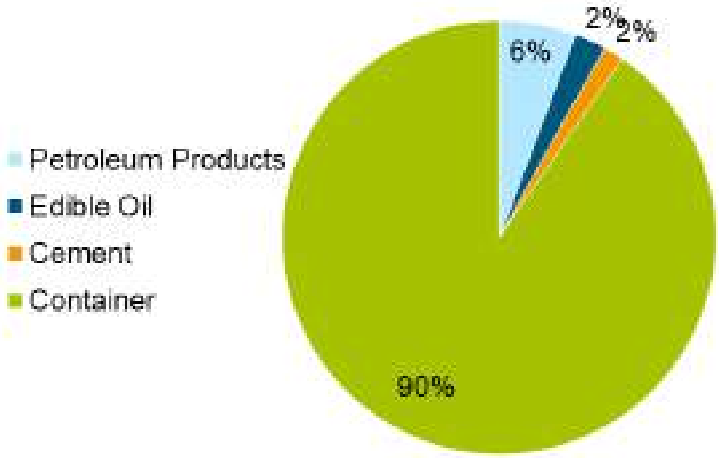

Figure A3-20 Commodity wise Share Distribution at JNPA

Table A3- 15 O-D Analysis of Cargo handled at JNPA

Commodity	Traffic (MT)		Vadhavan	Reasoning
	2010	2020	Perspective	
Petroleum Products	4.9	3.9	Yes	Well-developed infrastructure at JNPA with pipelines. Could be attracted to Vadhavan due to deep draft availability. Dedicated infrastructures needs to be developed.
Edible Oil	0.8	1.6	Yes	Option could be evaluated for additional spill over cargo
Cement	1.0	1.0	Yes	There is huge demand for Cement by the construction industry in Mumbai Metropolitan region. Vadhavan could provide space to cement companies to setup silos. This would attract demand for shift of cement cargo from rail to coastal.
Container	53.1	60.9	Yes	Vadhavan is close to 160 km nearer to northern and central hinterland. This reduces the land cost associated for container transportation. Hence, there is a very high potential of attracting it to Vadhavan
Others	0.9	1.0	No	-
Total	**60.8**	**68.4**		

A3.5.3 Kandla – Market and Facilities

Kandla Port is the third large major port which shares a common hinterland with Vadhavan Port; therefore, Kandla Port is one of the major competitors of Vadhavan. The table below shows the features of Kandla Port along with available infrastructure for cargo handling and storage.

Table A3- 16 Available Infrastructure at Kandla Port

Type	Description
Nature	Tidal Creek Port
Cargo handling equipment	• Pipelines for Liquid Bulk • 16 Wharf Cranes, 9 Trucks 7 Reach Stackers, 3 Tractors, 1 Trailer and 2 Excavator, etc.
Storage Facilities	• Covered Warehouse – Port (203,000 Sqm), Private (2,970 Sqm) • Open Area – 1.66 Mn Sqm • Tank Farms Storage – 3.3 Mn KLs
Type of Jetties	• 8 + 3SBM for POL, 2 for Fertilizer, 2 for Container & 19 for Break-Bulk
Commodities handled	POL & Other liquid, Iron Ore, Fertilizer, Coal, Food Grains, Sugar, Iron & Steel, Containers , etc.
Traffic Handled in FY20	Export – 33.94 mnT, Import – 88.67 mnT

Kandla Port currently handles close to 120 MT of traffic which constitute a wide range of commodity such as crude, petroleum products, edible oil, fertilizers, food grains, coal, iron and steel and containers. Apart from this, there are several other commodities which in smaller amount are being handled at Kandla Port. Crude and petroleum products are the commodities which has dedicated infrastructure. Both the commodities are linked with the refinery in the region and therefore it is unlikely for Vadhavan to attract any one of these commodity from Kandla Port. Apart from crude, petroleum product, Bulk Liquid and edible oil is also being handled at Kandla Port with the cumulative volume of close to 22 MT. However, it would be difficult to attract either of these commodities as both of them are imported to be used and consumed in the primary hinterland of the Kandla Port. Therefore, it is unlikely that these commodities would shift anywhere else other than Kandla Port.

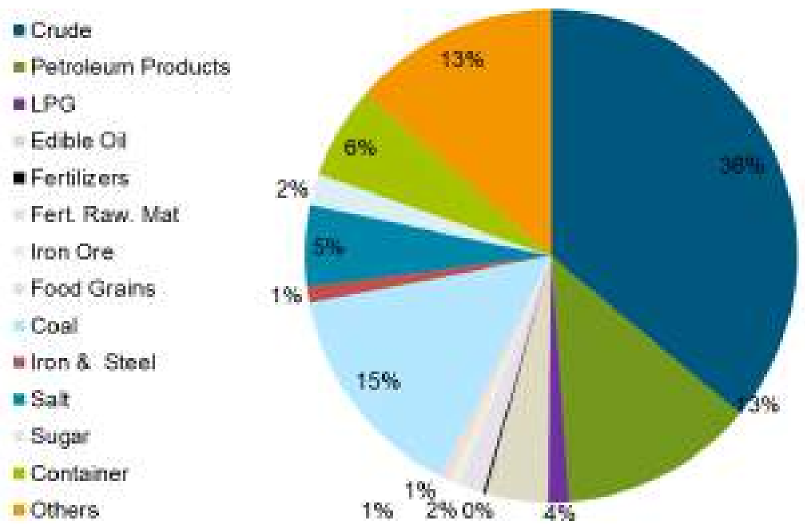

Figure A3-21 Commodity wise Share Distribution at Kandla

The other food related items handled at Kandla Port are food grains, salt, sugar. Food grains are imported again to be used in the primary hinterland. Kandla Port, located in the Kutch region. Kutch is one of the major exporters of salt, and the ports in the region are used as a gateway to export salt produced in the region. Kandla Port exports close to 6.5 MT of salt. This is again, since it is falling in the primary hinterland of Kandla Port, is unlikely to shift to any other location. Kandla Port also imports sugar for its local use.

Fertilizer is the commodity which could be targeted by Vadhavan as they share a common tertiary hinterland. Depending upon the logistics advantage, Vadhavan could target to attract these commodities in smaller portions. Kandla Port imports fertilizers in the finished and raw material form, the cumulative volume of fertilizers imported by Kandla Port is more than 6.5 MT. Part of it could be targeted by Vadhavan.

Table A3- 17 O-D Analysis of Cargo handled at Kandla

Commodity	Traffic (MT)		Vadhavan	Reasoning
	2010	2020	Perspective	
Crude	36.6	44.2	No	Dedicated pipelines up to refinery
Petroleum Products	10.4	15.6	No	Export & Import of Petroleum Products, well placed infrastructure already available.
Bulk Liquid	0.2	1.7	Yes	Growing demand of Bulk Liquid would require additional infrastructure or expansion in existing ones. Spill over traffic catering to south Gujarat and Central India could be attracted towards Vadhavan.
Edible Oil	0.8	5.0	Yes	Cargo to/from South Gujarat and Madhya Pradesh could look for an alternative based on the distance and cost benefit.
Fertilizers	4.9	0.2	Yes	Majority of the Fertilisers handled at Kandla is for Captive use of IFFCO, which has its plant in Kandla. There are two exclusive jetties dedicated for the handling of Fertilizers in Kandla Port. However, a share of Fertiliser is also imported plants located in the tertiary hinterland. Vadhavan could compete to target them
Fertilizer Raw Materials	2.6	2.0	Yes	
Iron Ore	0.7	0.8	No	Cargo is for primary Hinterland
Food Grains	0.6	0.8	No	Only for Local use, would not be viable to call to Vadhavan
Coal	3.2	17.9	No	Part of it goes to Rajasthan, Punjab, etc. Should be evaluated for Vadhavan
Iron & Steel	1.9	1.3	No	Iron & Steel Consignment in coils form is imported for consumer durable industry, automobiles in Delhi, NCR region, etc.
Salt	2.1	6.5	No	Locally produced and exported
Sugar	1.6	2.5	No	For local use only
Container	2.4	7.4	No	Small volume of container for feeder vessels. Cargo is for primary hinterland
Others	11.5	16.6	No	

Commodity	Traffic (MT)		Vadhavan	Reasoning
	2010	2020	Perspective	
Total	**79.5**	**122.6**		

A3.5.4 Mundra – Market and Facilities

Mundra Port has emerged as the largest private port handling multi-user, multi-commodity cargo, handled 69 Mn T of bulk, break-bulk and liquid cargo and 63.3 Mn T of containers. The major commodities handled by Mundra Port is liquid cargo comprising of crude and petroleum products, coal, containerized cargo, iron and steel, fertilizers, etc. Mundra Port has designed itself to emerge as an integrated industrial and logistics port, therefore the port has in addition to the infrastructure for handling commodities, it also has a special economic zone in the adjoining area.

Table A3- 18 Available Infrastructure at Mundra Port

Type	Description
Nature	• Deep Draft Berths and Multipurpose Terminals • All Weather Port no restrictions on vessel size • Direct Berthing Facility
Cargo handling equipment	• High Capacity Grab Unloaders, Mobile Harbour Cranes • Large Fleet Support Equipment - Excavator, Pay Loader, Mobile Equipment, etc. • Fully Integrated Conveyor System
Storage Facilities	• Covered Godown to store up to 0.63 Mn T cargo • Open Yard of 1.06 Mn Sqm area for Mineral, Steel, Timber & Project Cargo • 97 Tanks to store up to 0.426 Mn KL
Type of Jetties	• 26 Berths, 2 SPM
Commodities handled	Containers, Fertilizer, Agri, Minerals, Steel, Project Cargo, Liquid, etc.
Traffic Handled in FY20	Export – 36.71 mnT, Import – 95.73 mnT

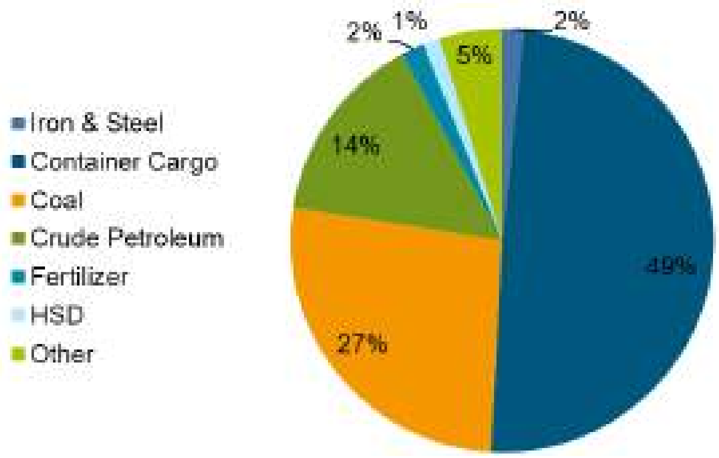

Figure A3-22 Commodity wise Share Distribution at Mundra

The table shows the commodity wise cargo owner, their movement and Vadhavan's potential to handle the share of it in future.

Table A3- 19 O-D Analysis of Cargo handled at Mundra

Commodity	Traffic (MT)		Vadhavan	Reasoning
	2010	2020	Perspective	
Iron & Steel	1.9	2.1	No	Iron & Steel coils, steel plates, etc. imported and exported from the Northern and central Hinterland less attractive to divert to Vadhavan
Container Cargo	11.1	63.3	Yes	Vadhavan and Mundra shares the same tertiary hinterland for containerised cargo. Based on the logistics cost advantage the cargo would either use port of Mundra, JNPA or Vadhavan for export or import
Coal	8.5	34.3	No	Coal imported at Mundra is for primary hinterland of Mundra. This coal is either used by the power plants located in the Mundra SEZ or the industries located in the Kutch region
Crude Petroleum	7.3	18.8	No	Mundra has the SBM for the refineries located at the Panipat. This would not sift anywhere.
Fertilizer	0.7	2.3	No	It is imported in small quantity for the Punjab region
HSD	3.6	1.6	No	-
Other	6.2	6.2	No	-
Total	**39.3**	**132.5**	-	

The special economic zone in the adjoining area has several power plants. It also has several industrial and logistics power plant. This leads to large amount of cargo for the port. Mundra Port is developing coal power plants by Tata Power and Adani Group, comprising more than 8,000 megawatts. This would lead to generation of captive coal requirement for the Mundra Port for a long-term.

These import requirements in the form of coal by Mundra Port would remain with the port and could not be attracted by any other competitive port because the power plants would fall in the primary hinterland of Mundra Port and would be located adjacent to the Mundra Port.

Apart from coal, Mundra Port also handles crude oil for IOC Panipat Refinery. The port has dedicated pipelines and SBM for handling coal, which is transported to Panipat Refinery. Due to the dedicated infrastructure at Mundra Port with SBM and pipelines, it is unlikely that the crude would shift to any other port for import.

A3.5.5 Pipavav – Market and Facilities

APM Pipavav is an all-weather port located around 675 km away from proposed Vadhavan port by roadways and 163 km by coastal route. Pipavav has handling capacity of 4 to 5 Mn T of dry bulk, 1.35 Mn TEU of containers and 0.25 Mn cars for ro-ro service. The port is equipped with dedicated cargo handling and storage facilities container and bulk cargo. Bulk and break bulk terminal handles Container, Urea, Coal, Fertilizer, Other Liquid, Bulk Liquid, Chemicals, Automobile, etc. Port has tie-up with Aegis, Gulf Petrochem and IMC to handle import and export of liquid cargo like Chemicals, POL, Edible Oil, etc. It has around 140 tanks of total 450,000 kl capacity to handle liquid cargo. Pipavav port handled 10.64 Mn T in FY20 showing 15.7% growth from 9.19 Mn T in FY16. Entire traffic at this port is dominated by container volume i.e. 70%.

Pipavav port is very well connected with roadways to the nearby hubs, SH105 connects the port with NH51 at 16 km. This port is also connected with railway line of 269 km from nearest national grid i.e., at Surendranagar railway station. This rail infrastructure is managed by Pipavav Rail Corporation Limited (PRCL). The figure below shows the commodity wise share break up at Pipavav port.

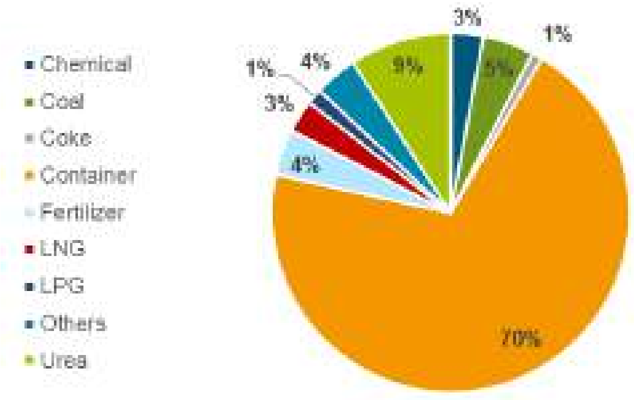

Figure A3-23 Commodity share contribution in Pipavav trade.

Around 70% of total traffic is by containers. Other commodities like chemical, urea and other liquids generally gets distributed within the nearby region. While port caters to container traffic from far-off region. Pipavav poses tough competition in container segment, as Vadhavan is going to be a deep draft port with direct berthing facility central India and South Gujarat traffic is likely to get diverted to Vadhavan based on distance and cost advantage.

A3.5.6 Adani Hazira – Market and Facilities

Adani Hazira (AHPPL) is deep draft, all weather, multipurpose port. Port has 5 operational berths, out of which 2 are dedicated for containers and 4 for bulk and liquid cargo handling. Multipurpose berths are equipped with pipelines for liquid evacuation to tank farms. Adequate storage area and infrastructure is developed to handle the bulk, liquid and container traffic. Container, Project Cargo and steel plates are the major export commodities and container, clinker, rock phosphate, gypsum, coal, steel, etc. are the major import commodities. AHPPL has direct national highway connectivity with Ahmedabad and Maharashtra i.e. NH-8 & NH-6 respectively. Port does not have their own rail connectivity, however, KRIBHCO's rail infrastructure i.e. KRIL serves them for urea and coal transportation. The figure below shows the type of traffic handled at the port.

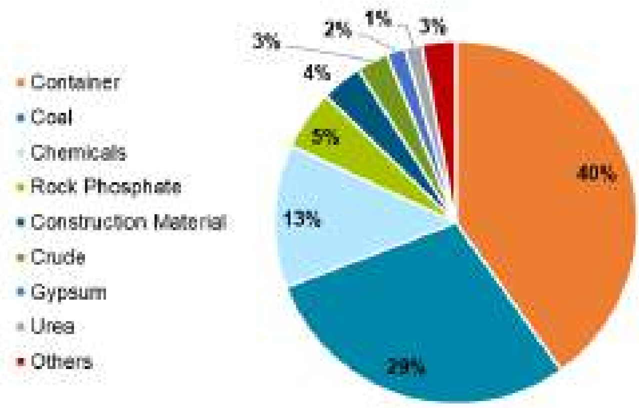

Figure A3-24 Commodity share contribution in Hazira (AHPPL) trade.

More than 80% of port's traffic is due to Containers, Construction Materials and Chemicals. Proposed Vadhavan port could act as a better option for the users located in South Gujarat, Central India and North Maharashtra region.

A3.5.7 Dahej – Market and Facilities

Dahej is direct berthing port located on the mouth of Narmada River. It is a natural deep water port with two deep draft berths capable of accommodating capsize vessels. It is a multi-cargo port and only solid cargo handling port in gulf of Khambhat. The port falls in the district of Bharuch and is connected to the same via Bharuch-Dahej Road at a distance of about 48km and via SH64 with at a distance of close to 68km. The port is 53km away from NH8, while it's at a distance of 45km and 79.6km from state highways like SH64 and SH161 respectively.

The port is home to many port-based industries like Birla Copper, IPCL who have developed their captive jetties at the site. Coal, Other Liquid, Bulk and Break bulk are the major commodities handled at this port. Port is majorly involved in import trade than exports. Fertilizer raw material, Rock Phosphate, Coal and Coke are the major commodities imported at this port. Nearby located fertilizer and coal-based industries are served by this port. Following are the infrastructure available at Dahej for handling multiple commodities.

- Adani Petronet Port Pvt. Ltd. operates the coal import terminal at Dahej, with the capacity to handle 20 million tonnes of coal per year.
- Dahej Port has a Petronet LNG import terminal for captive use.
- Birla Copper requires coal for its copper smelter in Dahej along with copper. To import these two raw materials, Birla Copper uses Dahej Harbour and infrastructure Limited (DHIL) as a captive jetty.
- Dahej imports small amounts of other liquid cargo (Chemicals) at GMB and DHIL.

Table A3- 20 Available Infrastructure at Dahej

Type	Description
Nature	Fair Weather, Operational between September to May Lighterage Port with anchorage at 5km from Old Jetty
Cargo handling equipment	Private Parties – Tugs, Barges, Launches and Cranes available Captive Jetties are fitted with all required handling equipment
Storage Facilities	1 Transit Godown (1,116 Sqm)

Type	Description
	5 Transit Sheds (1,690 Sqm) 5 Platforms available for storage (10,000 sq. m)
Type of Jetties	Private - GCPL, Petronet LNG, Solid Cargo Terminal Captive – DHIL and IPCL
Commodities handled	Liquid Chemical, Other Liquid, Copper, Coal, Gypsum, Fertilizer, Steel, etc.
Traffic Handled in FY20	Export – 0.45 mnT, Import – 32.21 mnT

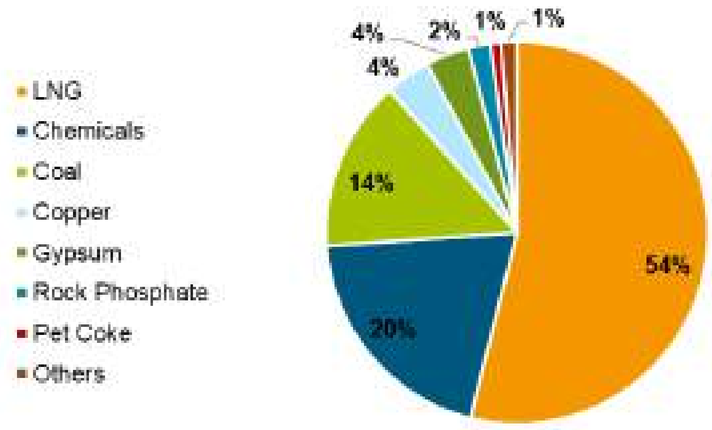

Figure A3-25 Commodity share contribution in Dahej Trade

Table A3- 21 O-D Analysis of Cargo handled at Dahej

Commodity	Traffic (MT)		Vadhavan	Reasoning
	2010	2020	Perspective	
Other Liquid	11.69	17.62	Yes	Petronet LNG has an exclusive Jetty in the location which undertakes handling of Other Liquid cargo. This cargo is connected to pipeline grid. The demand for Other Liquid in India is high. There is limited scope of expansion at Dahej. Hence, Vadhavan has opportunity to handle additional Other Liquid in future.
Chemical	2.04	5.38	Yes	IPCL has captive jetty Users of GCPL are located close by. GCPL also handles 3rd party chemicals for South Gujarat. They are evacuated using road. The 3rd party users look for an alternate port as GCPL give preferential berthing for their captive customers.
Coal	8.41	4.72	No	DHIL is a captive jetty of Birla Copper Coal handled at Adani Dahej gets distributed to central and northern states, more closer to Dahej than Vadhavan
Copper	1.48	1.3	No	DHIL is a captive jetty of Birla Copper

Royal HaskoningDHV

JNPA

Gypsum	-	1.2	No	Transported to Cement Plants located in MP & Gujarat.
Naphtha	0.68	1.14	No	Handled at GCPL, Plant is directed connected to Jetty through pipeline
Rock Phosphate	0.57	0.61	No	Fertilizer Plants located nearby imports raw material for fertilizer manufacturing
Pet Coke	-	0.3	No	Fragmented distribution with small parcel
Iron & Steel	-	0.12	No	Plant is located in Dahej region
Others	0.03	0.28	No	Fragmented distribution with small parcel
Total	**24.90**	**32.66**		

As shown in the table above, Dahej port does not create any opportunity for traffic diversion. Majority of cargo owner ae either locally based i.e., in Gujarat or Central and Northern region. These owners would not divert as for them Dahej is far nearer than Vadhavan.

Ports located in southern region of Gujarat and Mumbai falls in direct hinterland of Vadhavan. Dahej, Adani Hazira, Pipavav, MbPT and JNPA shares the same characteristics that Vadhavan holds i.e. deep draft, all weather, target commodities and end users, etc. Vadhavan would face tough competition from these ports as target segments and end users would be the same. Apart from this, Mundra and Kandla also provides competition in in-direct way. Mundra, Kandla and Vadhavan Port shares tertiary hinterland as common hinterland i.e. central region of India. Traffic diversion from Kandla and Mundra is possible based on certain parameters like Vadhavan's infrastructure and facilities to be in line with these ports, quick evacuation, time and cost savings, etc.

A3.5.8 Selected Other Commodities for Vadhavan

Apart from Container traffic, Vadhavan is likely to attract other bulk and breakbulk commodities as well. After evaluating the competing ports of Vadhavan and cargo movement in the respective region, it is understood that cargo diversion from these ports for other commodities exists. Cargo diversion is based on the time, distance and cost advantage over competing ports. The table below represents the commodities that could shift to Vadhavan from competing ports, if similar/ better facilities and infrastructure provided.

Table A3- 22 Prospects of Other Commodities for Vadhavan Port

Commodities	Kandla	Mundra	Pipavav	Hazira	Dahej	MbPT	JNPA
Chemicals	-	-	Y	Y	Y	-	-
Edible Oil	Y	-	-	-	-	Y	Y
Bulk Liquid	Y	-	-	-	-	Y	Y
Fertilizer	Y	-	Y	-	-	Y	-
General Cargo	-	-	-	Y	-	-	Y
Coastal Cargo	-	-	-	Y	-	-	Y
RO-RO	-	-	-	-	-	-	-
Other Liquid	-	-	-	-	Y	-	-
Containers	-	Y	Y	Y	-	Y	Y

Royal HaskoningDHV

JNPA

A3.6 Commodity wise Container Analysis

Container trade has been originated by converting breakbulk cargo to containers. Containers provides on door services and also facilates safety and protection in cargo handling and storage operation. Basically, breakbulk caters to finished and semi-finished products, which has gradually converted into containers due to the technology upgradation, change in regulation, containers being more efficient, etc. Liquids are also shifting to containers. Over the period of last 25 years at global level, breakbulk - container ratio has changed from 73:27 to 37:63. Transporting cargo in containers has become cost effective, time saver, safe and reduces handling loss as compared to breakbulk cargo. This has caused higher share of breakbulk conversion into containers and turn out to be one of the prominent reason for growth in container trade. Over the period of time, more and more commodities are containerised in parts and parcel and transported national and internationally.

A3.6.1 Commodities Identifications

The table below shows the container break-up of EXIM trade along with the region it belongs and the commodities originating from the region.

Table A3- 23 Region wise Share Contribution of Containerised Commodities

S. No	Region	% Share in West India Container Traffic	EXIM Commodities
1	North India + NCR	30%	Textile & RMG, Food Grains, Iron & Steel, Auto Components, Machineries, Paper Products, Aluminium, Plastic, Copper, etc.
2	Kutch & Saurashtra	20%	Electronics, Food Products, Scrap, Castings, etc.
3	Central Gujarat		Textile & RMG, Chemicals & Petrochemicals, Machineries, Steel, Building Materials, etc.
4	South Gujarat		Textile & RMG, Chemicals & Petrochemicals, scrap, etc.
5	Immediate Hinterland	33%	Textile & RMG, Food Products, Iron & Steel, Auto Components, Machineries, Leather, Paper, Chemicals, Spare Parts, Plastic etc.
6	Maharashtra	5%	Food Products, Textile, Auto Components, Parts & Accessories, etc.
7	Madhya Pradesh	4%	Food Products, Waste Paper, Prints, etc.
8	Rajasthan	5%	Building Materials, Machineries, Textile, Handicrafts, etc.
9	Others	3%	Chemicals, Granite, Pharmaceuticals, Food Products, Building Materials, etc.

[Source: Primary Survey by EY]

As per the table above, North India and NCR contributes to 30% in total container trade of India. This is due to the presence of production centres in that region and large consolidation happening in nearby ICDs. Large manufacturing base accounts Gujarat to contribute 20% in total trade. Though Maharashtra handles large share in the total traffic but the majority of cargo is generated from northern states, not within the state. Maharashtra state generates only 5% of total container traffic. Immediate hinterland in the direct influenced area of any port. Out of the total traffic, 33% is generated from the immediate hinterland. While rest of the 12% is handled by other states.

In coming future, growth of containers in India could be as unimaginable as has happened in past. A substantial growth of volume would come from conversion of breakbulk cargo to containerised form apart from natural growth of containers trade. Container trade is further analysed in detail by studying the containerised cargo break-up. Major commodities traded in containerised form internationally are identified based on the volume and frequency. The section below represents the commodity wise present market scenario, future prospect in India and opportunity it would create for Vadhavan for next 25 years.

Following table is summary of all the commodities carried in containers. A detailed analysis of commodities carried in containers found more than 200 categories of cargo. These cargo types have been summarised in 20 broad commodity types. Following table shows FCL containers list of 20 commodity types traded in the hinterland of Vadhavan port for last 10 years.

Table A3- 24 Summary of Containerised Commodities

S. No.	Commodity ('000 TEU)	2010	2013	2019
1.	Automobile	77.3	139.2	195.4
2.	Building & Construction Materials	72.3	100.9	310.2
3.	Chemical	318.4	505.8	818.6
4.	Electrical & Electronics	161.6	148.8	220.7
5.	Food Products	376.5	750.1	1,063.0
6.	Glass & Products	33.4	42.4	55.8
7.	Iron & Products	8.6	15.5	70.0
8.	Leather & Products	19.4	26.4	31.2
9.	Machinery & Spares	221.5	353.8	484.6
10.	Metals & Products	104.1	214.1	385.2
11.	Minerals	43.7	80.3	163.4
12.	Paints & Prints	60.0	70.8	64.4
13.	Paper & Products	183.2	260.7	413.2
14.	Parts & Accessories	74.3	82.4	141.4
15.	Pharmaceuticals	22.2	45.0	118.3
16.	Plastic & Products	53.1	107.6	257.7
17.	Rubber & Products	49.1	90.5	159.9
18.	Steel & Products	125.6	137.9	256.0
19.	Textile & RMG	351.0	549.9	690.6

S. No.	Commodity ('000 TEU)	2010	2013	2019
20.	Wood & Products	72.0	120.2	272.0
21.	Others	336.5	484.1	1,667.0
	Total FCL	**2,763.7**	**4,326.5**	**7,838.9**

A3.6.2 Automotive Components

Present Scenario

India is the world's largest two-wheeler and three-wheeler manufacturer and the world's 4th largest automobile market. The market includes passenger vehicles, commercial vehicles, three-wheelers, two-wheelers and quadricycles. India also holds a strong position in the heavy vehicles arena that includes tractors trucks and buses. The automotive industry has a 7.1% share in India's GDP and 4.3% share in India's total exports. The sector attracted 5.1% of total FDI amounting to $24.5 billion during April 2000 - June 2020.

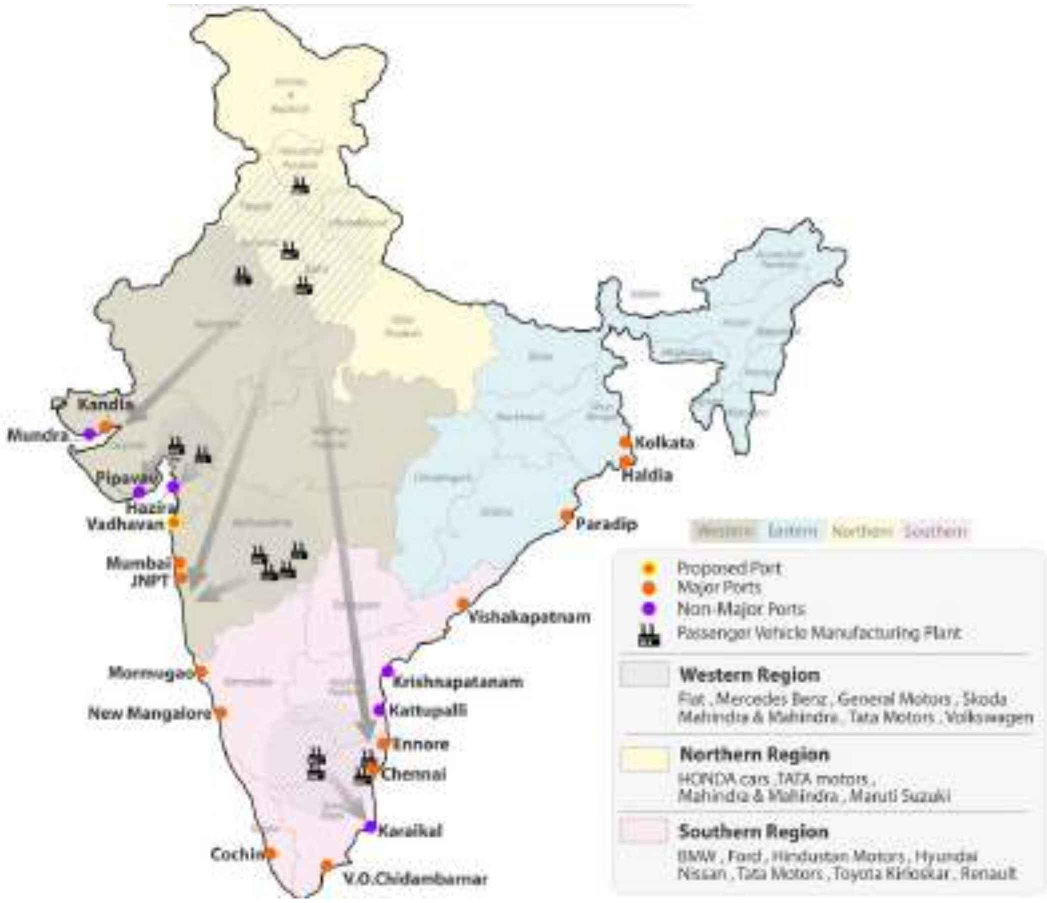

Figure A3-26 Automotive Clusters in India

The automobile industry manufactured 26.36 million vehicles in FY increasing to a 2.36% CAGR. India sold 21.5 million vehicles in the domestic market in FY20 averaging 1.29% CAGR during the last 5 years. Two-Wheelers & Passenger Cars dominate the Indian market contributing around 94% in total sales. Exports of automobiles reached 4.77 million in FY20, registering a growth of 6.94% over a period of 5 years. Number of units exported in terms of popular vehicles were 0.68 million Passenger Cars and 3.52 million Two Wheelers.

Ports of Maharashtra contributes 20% - 25% while Gujarat advances 2% - 3% of total automobile exports respectively. Maharashtra has major manufacturing industries in Mumbai, Pune, Nashik and Aurangabad while Gujarat has industries in Sanand, Bhuj, Halol and Vithalapur. Vadhavan lies close to these vehicle manufacturing industries and would be able to export passenger vehicles and two wheelers on a regular basis. Besides vehicles, Vadhavan can also export automotive components in containerised form as original equipment manufacturers are gaining traction in recent years. Key Players in this segment are as listed below.

- National - Tata Motors, Mahindra & Mahindra, Maruti Suzuki India, Hero MotoCorp, Bajaj Auto, Ashok Leyland, TVS Motors, Eicher Motors, Force Motors.
- International - Toyota Motor Corporation, Volkswagen Group, BMW, Tesla Inc., Ford, Nissan, Mercedes-Benz, Automobile Lamborghini, Aston Martin.

Future Prospects

India is expected to emerge as the world's third-largest vehicle market by 2022. The Automotive Mission Plan 2026 proposed by the Government of India envisions an increase in the sector's contribution in Indian GDP by FY26. This increase in GDP contribution from 7.5% to 12% would have substantial contribution of Trade. There will be large scale exports from Automobile components manufacturing hub of India to other locations. Majority of these automobile manufacturing hubs fall in the immediate hinterland of Vadhavan Port. This would, hence, lead to substantial containerised trade growth of automobile components from ports of Gujarat and Maharashtra including Vadhavan port.

The industrial analyst organization Mordor Intelligence has projected a growth of CAGR 15% from 2020 to 2026. The growth is likely to be lower than anticipated due to COVID impact on economy. Following table broadly describes growth assumptions taken for Gujarat and Maharashtra ports along with projected container traffic.

Table A3- 25 Projections for Automotive Components

Year	Y-o-Y Growth Rates	Volume (million TEUs)
FY25	9%	312.1
FY30	8%	458.7
FY35	8%	673.9
FY40	7%	945.2
FY45	6%	1264.9
FY50	6%	1692.7

The table indicates growth in the automobile components export at different rates over consecutive periods of 5-year durations. These growth rates are considered on the basis of the average GDP growth and population growth for the same durations. Another significant reason is that 8% of the country's R&D expenditure is in the automotive sector. For FY25, exports are expected to increase at a rate of 9%. From 2026 onwards, the export rates decrease by one progressively to reach 6% for FY46-50. In FY 25, overall trade in the automobile market would be 312.1 million TEUs. Indian automobile trade would rise year-on-year finally reaching 1692.7 million TEUs for the horizon year of the forecast.

Efforts to preserve the environment and reduce pollution have led to an ongoing gradual change from internal combustion engines to zero-emission vehicles. There is a plan to introduce low-cost Electric Vehicle (EV) to achieve India's vision of 100% electrical mobility by 2030. India is expected to hold 8% of the global EV 4-wheel component market by 2025.

Tata, Honda and Saic Motors have plants in Gujarat and Madhya Pradesh while Force, Bajaj Auto and General Motors have plants in Maharashtra. Vadhavan could enter into specific tie-ups/partnerships with these companies and import auto parts for them while exporting finished vehicles. These partnerships would be mutually beneficial providing dedicated export-import trade to Vadhavan and simpler profitable logistics for the companies. Growth drivers of automotive components industry is listed below.

- Growing income – 3X increase in average household income from 2020 to 2025
- India will become the youngest nation by 2025 with an average age of 25 years
- Production-Linked Incentive (PLI) Scheme offers tax benefits for manufacturing in India
- 100% FDI is allowed under automatic route

A3.6.3 Building & Construction Materials

Present Scenario

Construction is the third largest contributor to economic growth in India. The industry consists of the Real estate and the Urban development segment. Within its sphere, real estate covers residential, office, retail, hotels and leisure parks, while urban development includes water supply, sanitation, urban transport, schools, and healthcare.

Construction industry in India occupies a 9% share in India's GDP. In 2010, the industry showed a containerised trade of 72.3 million TEUs which increased to 100.9 million TEUs in 2013. Six years later in 2019, it has posted a trade of 310.2 million TEUs displaying a phenomenal CAGR of 17.57% for the past 9 years. Construction vehicles had the largest revenue share in the equipment market. The government has also increased its expenditure on infrastructure development by 20.9% raising it to US$ 89.2 billion in 2019.

Indian real estate sector reached a market size of $180 billion in 2020. The Gross Value Added by the Construction Sector in India is estimated to be about US$ 192 Billion in 2019-20. It is the second largest FDI recipient with FDI inflows of US$ 41.52 billion from 2000 to 2019. The activities that registered the highest growth include export cargo (10%), highway construction / widening (9.8%), power generation (6.6%), import cargo (5.8%) and cargo at major ports (5.3%).

Both Maharashtra and Gujarat have a high concentration of construction industries. Vadhavan can supply raw materials and equipment to these industries increasing its overall trade from these two states. The states also have comparatively larger populations which increases their infrastructural requirements. Vadhavan could be instrumental in developing housing and other utilitarian infrastructure near its surroundings. Vadhavan would also export construction cargo received from nearby industries. Key Players in this industry at national and international level are as listed below;

- National - Larsen & Toubro Engineering, Reliance Infrastructure Limited, Tata Projects Limited, NBCC, IRCON International Limited, Shapoorji Pallonji & CO. Ltd., GMR Infrastructure Limited, Hindustan Construction Company, DLF Limited
- International - Leighton Welspun Contractors, The Trump Organization, Alstom, EMAAR, Ascendas, Power Construction Corp. of China, TOYO Engineering

Future Scope

India is expected to be the world's 3rd largest construction market by 2025 with close to 20,000 ongoing projects. The Construction industry is expected to record a CAGR of 15.7% by 2022. Investments valued around US$ 965.5 million are expected to be required by the infrastructure sector by 2040 with 70% of funds needed for power, roads and urban infrastructure segments.

Many ongoing projects like Smart Cities, Industrial Corridors, Mega Ports, Green Buildings, etc. in construction lie in the influence area of Vadhavan port. A growth rate of 15.7 % will have tremendous impact on containerised trade of building and construction materials. Vadhavan may emerge as a prominent destination for export and import of materials that are transported to and from various nearby project sites. The following table shows growth assumptions in construction taken for ports of Maharashtra and Gujarat supplemented by trade projections.

Table A3- 26 Projections for Building and Construction Materials

Year	Y-o-Y Growth Rates	Volume (million TEUs)
FY25	9%	495.8
FY30	8%	728.5
FY35	8%	1070.4
FY40	7%	1501.3
FY45	7%	2105.6
FY50	6%	2817.7

Due to continuous urbanization, upcoming infrastructure projects and a growing population base, the construction industry in India is booming. Investments valued around US$ 965.5 Million are expected to be required by the infrastructure sector by 2040 with 70% of funds needed for power, roads and urban infrastructure segments. Based on these reasons, construction output is expected to grow on average by 9% during FY25. For the next 10 years, this growth is taken as 8% from FY26-35. For the last 5-year duration of FY46-50, the growth rate is further reduced to 6% per year. In FY50,

As the Delhi-Mumbai Industrial Corridor lies very near to Vadhavan's location, the port will become a primary import-export terminal for the corridor. Mumbai, Pune and Ahmedabad are mega cities and will act as sources of trade for the construction sector. With the development of more smart cities and adjoining railway lines, Vadhavan is well positioned to meet every requirement of its nearby locations. Growth drivers of this industry is as listed below;

- Population growth, urbanization, industrialization and rise in disposable income are key growth drivers of the industry.
- Programs like Smart Cities, Housing for All, Make in India and Atal Mission for Urban Rejuvenation and Transformation' (AMRUT) will further drive growth.
- The government has also made tremendous efforts to improve residential and transport infrastructure through these projects which is expected to attract foreign investment.
- Planned Projects
  - ✓ 100 smart cities to be developed by 2025
  - ✓ Five industrial corridors – Delhi-Mumbai, Bengaluru-Mumbai, Amritsar-Kolkata, Vizag-Chennai, Chennai-Bengaluru in development
  - ✓ 25 railway stations re-development besides 3,500 km line addition

✓ 6 mega ports in various stages
✓ Development of green buildings to provide a sustainable and clean environment.

A3.6.4 Chemicals

Present Scenario

Chemical industry in India is broadly classified into Bulk chemicals, Specialty chemicals, Agrochemicals, Petrochemicals, and Polymers. Out of these, Alkali Chemicals account for 71% of total production. India ranks 6th in the world in chemical trade and contributes nearly 3.4% to the worldwide chemical industry. Globally, it ranks 14th in export and 8th in import of chemicals. The Chemical industry in India occupies a share of 12.5% in India's total exports and accounts for 7% of India's GDP while contributing 9% to total FDI Equity Inflows.

Figure A3-27 Chemical Cluster in India

In 2010, chemicals posted a trade figure of 318.4 million TEUs. This number increased to 818.6 million TEUs in FY19. The industry showed a CAGR of 11% from FY10-19 but for a shorter and more recent period of 4 years between FY15 and FY19 it had a nominal CAGR of 4.78%. As of FY19, the chemicals and petrochemicals market grew at a rate of 14% and 5.4% respectively.

In FY18-19, import and export of chemicals and petrochemicals stood at 18.73 million tonnes and 11.2 million tonnes. Production and consumption of chemicals and petrochemicals for the same year reached 49.1 million tonnes and 56.8 million tonnes. Over the last 5 years from FY15 to FY19, import has shown a CAGR of 3.55% while export grew substantially at a CAGR of 15.40%. Key Players in India are as listed below;

- National - Pidilite Industries, Tata Chemicals, UPL, Gujarat Fluoro Chemicals, Gujarat Alkalies & Chemicals, Reliance Industries, Gas Authority of India Ltd.
- International – BASF, Dow, DuPont, SINOPEC, SABIC, ExxonMobil, Mitsubishi Chemical, Solvay, Yara

Future Prospects

The Government of India expects substantial growth in the Chemical industry. The Chemicals market is projected to reach from the current US$ 163 Billion to US$ 304 Billion by 2025. Demand of chemical products is expected to grow at approximately 9% per annum over the next 5 years. 100% FDI is allowed under the automatic route in chemicals sector except a few hazardous chemicals

The following table shows growth assumptions for chemicals at the ports of Maharashtra and Gujarat accompanied by traffic projections. The growth rates are based on generic and specific causes. Generic causes include rising disposable income, median age of population and demand from rural markets. There are two major specific causes for a growth of 6-8% in chemical trade. First is the shift in production and consumption towards Southeast Asian countries in terms of Chemicals and Petrochemicals. Second is the Production-Linked Incentive (PLI) Scheme introduced in the chemical sector to enhance exports with an outlay of INR 18,100 crore (US$ 2.45 billion). The increase in demand and implemented schemes will benefit Vadhavan in increasing their overall chemical trade.

Table A3- 27 Projections for Building and Construction Materials

Year	Y-o-Y Growth Rates	Volume (million TEUs)
FY25	8%	1247
FY30	8%	1832.2
FY35	7%	2569.8
FY40	7%	3604.2
FY45	6%	4823.3
FY50	6%	6454.6

For FY25 the assumed growth rate is 8%. For FY 21-30, it is 8% reducing to 7% for FY 31-40 and then to 6% for Fy 41-50. For FY 25, the projection is 1247 million TEUs and for FY 40, increase in exports and imports would give a chemical trade of 3604.2 million TEUs. In the horizon year FY50, the trade in chemicals is projected as 6454.6 million TEUs.

Both Gujarat and Maharashtra are well-favoured zones for chemical production and consumption. The agrochemical consumption in these states accounts for 13% of the total and its market is expected to grow at a CAGR of 8%. Roha, Pen, Nagothane, Rasayani are chemical hubs in Maharashtra located near Vadhavan. Two major companies, Dow Chemicals and Shell, are looking for a facility to set up a technology centre and 1 million tonne plant near Mumbai respectively. Dow Chemical also plans to increase its polyurethane facility located in Ratnagiri by 50% to strengthen its manufacturing and customer bases in India. Development of nearby facilities and chemical hubs will be instrumental in growing the EXIM trade of chemicals at Vadhavan.

A3.6.5 Electrical and Electronics

Present Scenario

With per capita disposable income and private consumption having doubled in the past 7 years, India has emerged as one of the largest markets for electrical and electronic products in the world. India is the 2nd fastest digitizing economy, 2nd largest manufacturer of mobile phones and has the 3rd largest start-up ecosystem. There are nearly 1.2 billion consumers of electronic and electrical goods in India who are engaged in rapid digitization. The global electrical and electronics market is estimated to be over $2 tn. India's share has grown from 1.3% in 2012 to 3% in 2019. The electrical and electronics market in India is valued at $120 billion in 2019 with a GDP contribution of 2.5%.

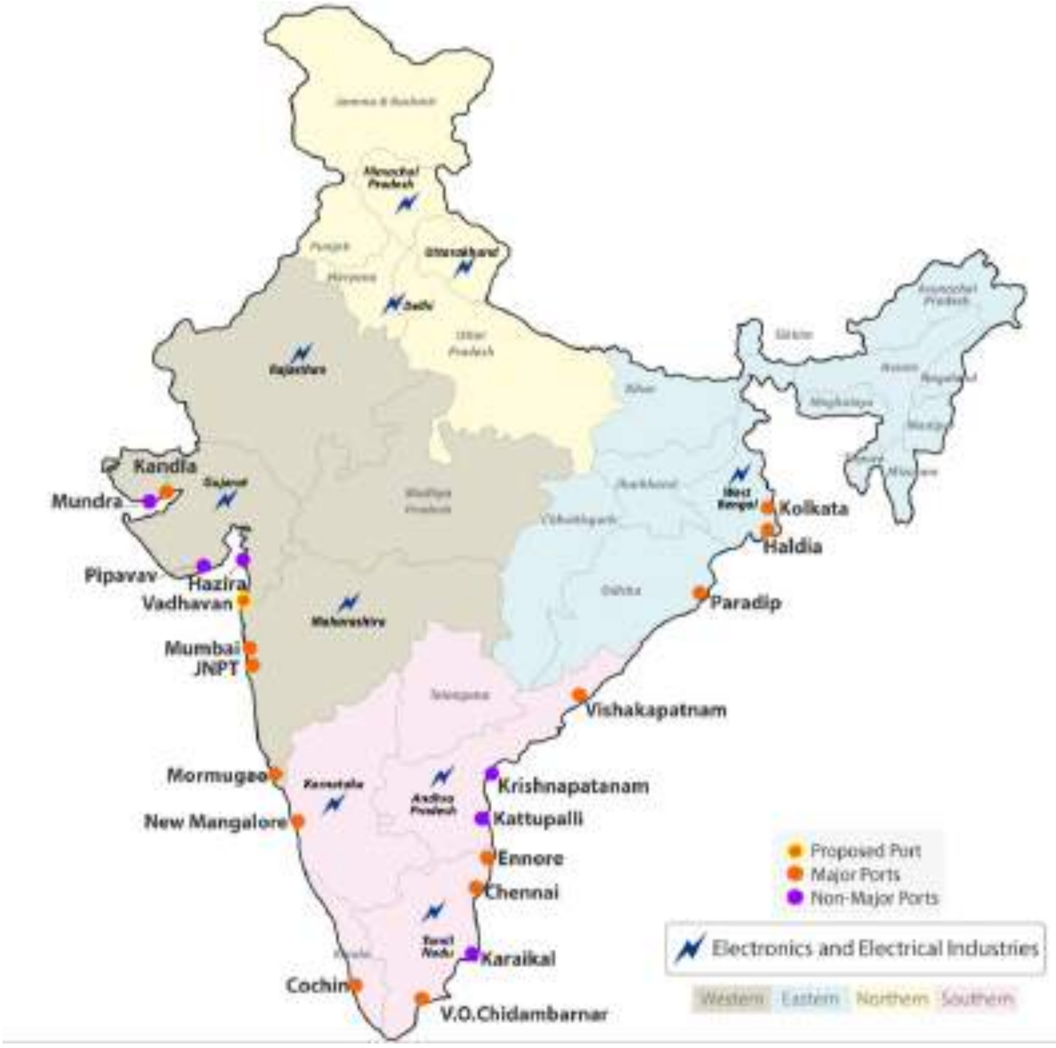

Figure A3-28 Presence of Electrical and Electronics Industries in India

The market is segmented as Mobile Phones (24%), Consumer Products (22%), Strategic (12%), Computer Hardware (7%), LEDs (2%) and Industrial Electronics (34%) comprising of Auto, Medical and other industrial products. In 2010, total EXIM trade in electrical and electronic goods was 161.6 million TEUs. Throughout the years, it remained relatively flat decreasing to 148.8 million TEUs in 2013 and increasing to 220.7 million

TEUs in 2019. Both exports and imports had a comparatively equal share with 100.6 million TEUs and 120.6 million TEUs in 2019.

The overall trade in the sector grew 7.7% year on year to reach US$ 191 billion in FY20. Domestic revenue for the industry was estimated at US$ 44 billion while domestic production grew twofold within 4 years to reach US$ 70 billion. India's imports touched a record US$ 55.6 billion in FY19. The exports of the goods for the year 2019 were also higher at US$ 8.8 billion as compared to previous years.

Vadhavan port is situated near a multitude of electronic product manufacturing units for LG, Jabil, Belden, NVidia, Oppo, Vivo, etc. It also has some electrical goods manufacturing plants in its vicinity like Havells India and others. As JNPA and MBPT handle a number of electrical and electronic goods, their surplus can be easily accommodated at Vadhavan. Vadhavan due to its deeper draft may also be able to attract a larger share of goods from these ports. Key players in India are as listed below;

- *International* - Nokia, LG, Samsung, Microsoft, Texas Instruments, Flextronics, Siemens, Schneider Electrical, Bosch, Kelvin Electricals, Jabil Circuits
- *National* - Bharat Electronics, Crompton Greaves, Bajaj Electricals, Wipro Lighting, Videocon, Sterlite Technologies, Centum Electronics

Future Scenario

The electrical and electronics markets in the world is anticipated to reach $400 billion by 2025 showing a CAGR of 17%. India's electronic system is expected to generate US$ 130 billion by 2022 while total market size of electrical machinery is anticipated to reach US$ 100 billion by 2022.The consumer electronics industry in India is expected to become the fifth largest in the world by 2025.

Technology transitions such as 5G networks and Internet of Things (IoT) are driving the accelerated adoption of electrical and electronics goods. Initiatives such as 'Digital India' and 'Smart City' projects have raised the demand for products. Smart users are expected to rise by 84% due to rapid digitization. All these reasons have been used in estimating a percentage rate for growth in electrical and electronic trade.

Table A3- 28 Projections for Electrical and Electronics

Year	Y-o-Y Growth Rates	Volume (million TEUs)
FY25	9%	352
FY30	9%	541.6
FY35	8%	795.8
FY40	7%	1116.2
FY45	6%	1493.7
FY50	5%	1906.4

The table describes growth assumptions in electrical and electronics market supported by trade projections for ports of Maharashtra and Gujarat. From FY25 to FY30, a 9% growth rate is assumed. This rate decreases by one for each subsequent 5-year duration. It is estimated as 5% for FY46-50. Trade projection increase from 352 million TEUs in FY25 to 1906.4 million TEUs in FY50. A volumetric growth of around 1554.6 million TEUS is expected in the next 50 years.

As export incentives of 2-3% are available under the Merchandise Export from India Scheme, Vadhavan can benefit from exporting larger quantities of electrical and electronics goods. Mobile phones and smart devices are bound to occupy a larger share of these products. Vadhavan is also situated near to approved greenfield electronic manufacturing clusters like Mundra Solar Techno Park in Gujarat and MP State Electronics Development. Its influence region also contains established manufacturing clusters in Maharashtra. Vadhavan's ability to cater to larger volumes in shorter time periods would lead to lowered costs and more flexibility. Thus, Vadhavan can play a significant role in providing import-export facilities for electrical and electronic goods. Growth drivers of this industry is as listed below,

- India is a global R&D destination, with 1140+ R&D Centres of MILLIONCs in India
- Electrical and Electronics sector in India has lower manufacturing costs
- All products can be freely imported with the exception of a few defence related items.
- 100% FDI is allowed under the automatic route and in case of items for defence, FDI up to 49% is allowed.

A number of new schemes have been initiated such as Production Linked Incentive Scheme (PLI), Scheme for Promotion of Manufacturing of Electronic Components and Semiconductors (SPECS) and Modified Electronics Manufacturing Clusters Scheme (EMC 2.0). Initiatives such as Make in India and Digital India have increased governmental spending in the sector. National Policy on Electronics 2019 envisage placing India as a global hub for Electronics System Design and Manufacturing.

A3.6.6 Food Products

Present Scenario

India offers the largest diversified food production base and is ranked 2nd globally in food production. India is the world's largest milk producing nation; largest producer, consumer and exporter of spices; second largest producer of food grains, fruits and vegetables. The Food market in India is dominated by Grocery and Retail. Food retail market constitutes almost 65% of the total retail market and 40% of consumer-packaged goods industry in India.

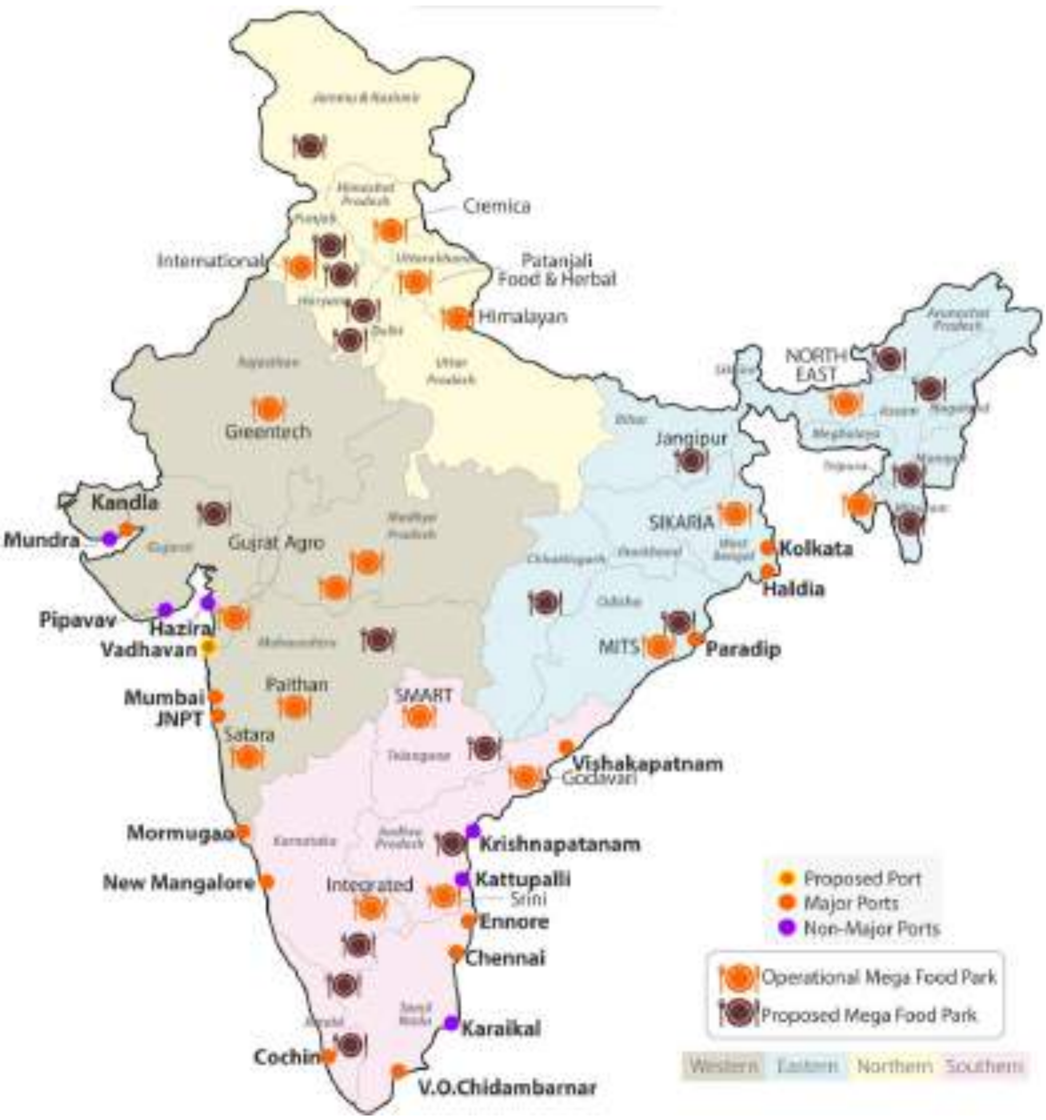

Figure A3-29 Mega Food Parks in India

India exports and imports agricultural products and processed foods to and from more than 100 countries with major exports to the Middle East, Southeast Asia, SAARC countries, the European Union (EU) and the US. In 2010, total food trade was 376.5 million TEUs which doubled in 2013 to 750.1 million TEUs. In 2019, 1063 million TEUs of food products were traded.

During 2019, India exported food products totalling US$ 38.49 billion including fruits and vegetables worth $1.4 billion and also shipped 12,89,651 MT of seafood worth $6.68 billion. The market size of the food industry across the nation was estimated to be around US$ 46 billion in 2020. The food sector has been growing at a CAGR of around 8.41% between 2014 and 2020.

Vadhavan is beneficially located near 3 operational Mega Food Parks - Satara and Paithan Mega Food Park in Maharashtra and Gujarat Agro Mega Food Park in Gujarat. Its proximity will help Vadhavan supply raw food materials for processing through imports. It will also be able to export finished and other packaged and non-packaged food products including fruits, vegetables, food-grains, poultry, meat and seafood. The government has also set up incentives for food parks which may help generate lower logistics cost and higher profit margins for Vadhavan. Key players in India are listed below;

* *International* - Coca-Cola, Pepsi, Unilever, Mars, Mondelez (Kraft Foods), Kellogg's, Del Monte, Cargill, Ferrero, Nestle, Danone, McCain, Hershey, Perfetti
* *National* - Kissan, Amul, Godrej Industries, Parle Agro, ITC Ltd., AgroTech Foods, Dabur India Ltd., Britannia, Sunfeast

Future Scope

The Food industry will potentially attract $ 33 billion investments and its output is expected to reach $ 535 Billion by 2025-26. By 2030, Indian annual household consumption will treble making India the 5th largest consumer. The Indian food industry is growing at 11% while it contributes 14% to the manufacturing GDP, 13% to exports and 6% to total industrial investment. Its Revenue is expected to show CAGR of 16.7% for 2020-2025

The important drivers of the food industry are growing populations and their vast demand for food, 'Make in India' and 'Startup India' Initiatives, increase in consumers purchasing power, access to all branded food materials even at the village level, changing lifestyle patterns and a thriving online food delivery system. These drivers are used as a basis for estimating an 8% growth in food exports from India with appropriate trade projections in the following table.

Table A3- 29 Projections for Food Products

Year	Y-o-Y Growth Rates	Volume (million TEUs)
FY25	8%	1198.8
FY30	7%	1681.4
FY35	7%	2358.3
FY40	6%	3155.9
FY45	6%	4223.3
FY50	5%	5390.1

In FY25 8% growth rate is assumed under food exports. For the next 10 years it is 7% and after that from FY36 to FY45 it is 6%. This growth rate reduces to 5% by FY46-50. All trade projections with regards to Food Products are estimated at a high level considering rapid urbanization and an explosive population growth. In FY30, 1681.4 million TEUs of food products are traded. This number doubles 3155.9 million TEUs in FY40. Total food traffic is anticipated to be 5390.1 million TEUs in FY50.

Maharashtra contains the largest number of cold chains (temperature controlled supply chains) in India. The specific numbers are 2 for marine, 6 each for dairy and meat, 14 for fruits and vegetables and 4 for multi-commodities. Vadhavan port is situated in Maharashtra and can exploit these cold chains to export food products through reefer containers. Imported products that require cold storage can be directly connected to these cold chains from the terminal itself. Furthermore, exemption of excise duties on refrigerated containers would help increase trade of reefers at Vadhavan

Projects and Partnerships

* Online food delivery players like Swiggy, Zomato, FoodPanda are setting up partnerships
* Amazon is planning to enter Indian food sector by investing US$ 515 million
* Government has sanctioned 37 Mega Food Parks
* 298 Integrated cold chain and value addition infrastructure projects were approved.

- 100% FDI is permitted in Food industries and trading of food products.

A3.6.7 Glass & Products

Present Scenario

The Indian glass market has evolved from a small-scale, decentralized manufacturing business to a relatively organized marketplace where performance is dependent on efficiency in energy consumption and adoption of technological advancements. Construction industry holds 80% of flat glass market while liquor holds 49% of container glass. The demand for flat glass has increased at an annual rate of 15% for the past 3 years and is expected to grow at around 3.8% per year. The demand for container glass has also grown by more than 30% annually in recent years. Uttar Pradesh, West Bengal, Maharashtra and Tamil Nadu are the main glass producing states and contribute the bulk of production.

In 2010, 33.4 million TEUs of glass products were traded. In the next 3 years by 2013, traffic increased to 42.4 million TEUs. In 2019, total EXIM trade of glass products was 55.8 million TEUs. Imports of glass industry grew from INR 23.44 billion to 31.57 billion while exports grew from INR 19.33 billion to 34.39 billion for FY17-19

South India dominated by Bangalore, Chennai, Hyderabad and parts of Kerala, contributes to 30% of the glass consumption. West India with Mumbai, Pune and parts of Gujarat as big consumers follows suit at 29%. North India, comprising mainly of Delhi and NCR accounts for 20%. East India currently contributes only 7% of the consumption but this is set to change with a renewed focus on real estate in West Bengal.

Maharashtra has 22 production factories with centres at Mumbai, Talegaon, Satara, Nagpur and Kolhapur. Vadhavan’s nearby location sets it up as an excellent port to export finished glass goods to domestic as well as international markets. With Mumbai, Pune and Gujarat being big consumers of glass, there is also a huge opportunity for Vadhavan to import both flat glass products for automobiles, houses and industries and container glass products for packaging. These imports would increase in the coming years with demand outpacing supply in these regions.

Some key players of India include companies such as Piramal Glass Private Limited, Asahi India Glass Limited, Saint-Gobain India, Nippon Sheet Glass Co., Ltd., Goldplus Group, Sejal Glass Ltd, Fuso Glass India Pvt. Ltd, Glass Wall Systems, Hindustan National Glass & Industries Limited and SCHOTT AG

Future Scope

The Indian glass market is expected to register a CAGR of 9% over FY21-35. The growth of the market can be attributed to the high demand from emerging application industries such as automotive, construction & solar energy. The real estate industry is likely to reach US$ 1 tn by 2030. The glass industry may also witness significant growth owing to large scale automotive export growth of CAGR 3.05% from 2021-2025.

Table A3- 30 Projections for Glass & Products

Year	Y-o-Y Growth Rates	Volume (million TEUs)
FY25	9%	89.1
FY30	9%	137.1
FY35	9%	211
FY40	8%	310.1

FY45	7%	434.9
FY50	7%	609.9

The table displays growth assumptions for glass exports and trade projections for the ports of Maharashtra and Gujarat. For a period of 10 years from FY25 to FY35, a growth rate of 9 % is anticipated. For the final 5-year duration of FY46-50, a 7% growth rate is expected. From 89.1 million TEUs in FY25 to 310.1 million TEUs in FY40, a larger growth is expected. Then onwards, the rate is reduced by 2% to achieve a traffic projection of 609.9 million TEUs in FY50

The demand for processed and reflective glass is on the rise due to its safety benefits and lesser energy consumption. This rise can also be attributed to an increased acceptance of green and sustainable architecture. Vadhavan with its newly built infrastructure and non-conventional power sources along with use of emerging technology would easily adapt to green architecture. This would lead to an increased trade in reflective and processed glass products with other industries in its surroundings.

West India is expected to witness an incremental growth rate in glass trade on account of increase in construction activity and high employment opportunities. Leading key players of India are entering and expanding their exports in the markets of Europe and America by diversification of product such as automotive glass and solar panels. If these companies are able to maintain a stronghold in international markets, they could use Vadhavan as a centralized location to increase their exports of conventional and alternate products.

A3.6.8 Leather & Products

Present Scenario

Leather industry in India accounts for 12.9% of the global leather market. It handles nearly 3 billion square feet of leather production on a yearly basis. It has registered a growth of 8% year-on-year for the last decade. India has an abundance of raw materials for leather with 20% of the world's cattle & buffalo population and 11% of the world's goat & sheep population.

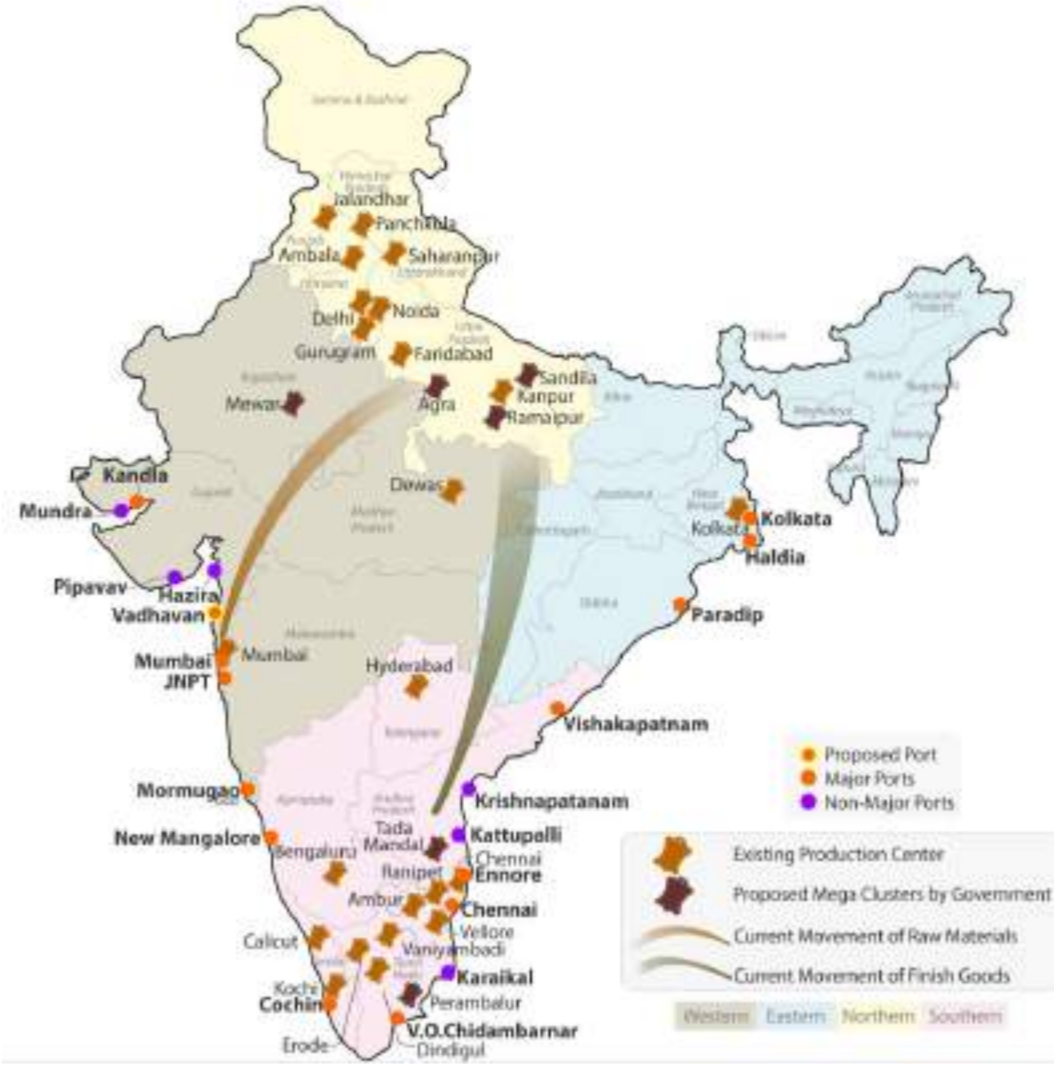

Figure A3-30 Leather Production Centres in India

Indian leather industry can be divided into 4 sectors:

- Footwear Sector – India is the 2nd largest footwear producer and consumer, with an annual production of 2.41 billion pairs and consumption of 2.49 billion pairs. Footwear holds a 48% share of the total leather industry and accounts for 9% of the world's footwear.
- Leather Garments Sector – India is the 2nd largest global exporter, with a global market share of about 17%. This sector covers 8.23% share of the total Indian market.
- Leather Goods & Accessories Sector including Saddlery & Harness – India is the 5th largest global exporter of leather goods and accessories. It occupies 28% share of total leather trade.
- Finished Leather – Finished leather covers a share of 10.34% of total leather trade.

The export of footwear, leather and leather products from India reached a value of US$ 5.69 billion during 2018-19 and US$ 5.07 billion in 2019–20. Major markets for Indian Leather & Leather Products are USA with a share of 15.70%, Germany 11.58%, UK 10.50%, Italy 6.48%, France 5.68%, Spain 4.54%, UAE 3.97%, Netherlands 3.42%, Hong Kong 3.34%, China 2.60%, Poland 2.02%, and Belgium 2.00%. These 12 countries together account for nearly 71.84% of India's total leather export.

In 2010, the total traffic in leather was 19.4 million TEUs. By 2013, there had been an increase of 5 million to bring the traffic total to 26.4 million TEUs. In 2019, the leather traffic rose up to 31.2 million TEUs. The table below shows the distribution of leather exports and imports in TEUs. The trade routes are connected from two ports in Maharashtra and two ports in Gujarat to different states across India.

Table A3- 31 Containerised Leather Trade in India

S. No	States	Export ('000 TEUs)			Import ('000 TEUs)		
	(To/From)	Mumbai	Mundra	Pipavav	Mumbai	Mundra	Pipavav
1.	Uttar Pradesh	3,746	2,492	129	332	14	96
2.	Delhi	710	616	86	1,731	163	1,284
3.	Rajasthan	11	120	32			9
4.	Punjab	69	162	31	98	40	14
5.	Haryana	26	161	16	13		17
6.	Gujarat	41	34	10	8		21
7.	Uttarakhand	1	4	1			
8.	Madhya Pradesh	131	5		7		
9.	Hyderabad	130			10		
10.	Maharashtra	102			168		
11.	Karnataka				12		
	Total	**4,967**	**3,594**	**305**	**2,379**	**217**	**1,441**

It can be clearly seen from the above table that for both exports and imports Mumbai handles more number of containers as compared to Mundra and Pipavav. Vadhavan being slightly farther along the coast from Mumbai can cater to most industries and clusters handled by Mumbai while also providing rail and road access to those industries located farther away from Mundra and Pipavav. Thus, Vadhavan has better prospects of handling larger leather trade traffic after starting its operation and may lead to further growth in trade

Future Scope

To promote market sustainability in the future, it is essential for India to increase its share of leather exports to developed nations. The Leather industry of Northern India is dependent on JNPA and partially to the ports of Gujarat. Vadhavan port being in the vicinity of these ports and having a larger section of North India in its influence region would be able to cater to leather EXIM trade more effectively as compared to the others.

A number of growth drivers such as High growth potential for exports, ready availability of leather, abundance of essential raw materials, rapid strides in the areas of capacity modernisation and expansion, skill development and environment management and favourable government policies have been considered as a basis for assuming growth rates in the following table. These growth drivers would also in part lead to an increase in Vadhavan's EXIM trade of leather products as Vadhavan being a newer port would be favoured by initial concession periods and larger capacity levels.

Table A3- 32 Projections for Leather Products

Year	Y-o-Y Growth Rates	Volume (million TEUs)
FY25	8%	47.6
FY30	8%	69.9
FY35	7%	98.1
FY40	7%	137.6
FY45	6%	184.1
FY50	6%	246.4

The table shows growth assumptions and traffic projections for Maharashtra and Gujarat ports. The rates are kept constant for a period of 5 years. So for FY25-30, the growth rate is 8%, for FY31-40, it is 7% and for FY41-50, it is 6%. In 2030, the traffic project is expected to be 69.9 million TEUs while in 2040, it would rise to 137.6 million TEUs. In the horizon year of FY50, leather traffic would be 246.4 million TEUs.

Vadhavan could become a major source of leather product exports and raw material import for Mega Leather Clusters located in its influence region. Moreover, GST concessions on all types of leather products and services would increase the share of leather in Vadhavan port's overall trade structure. Even the policies mentioned below are sure to enhance Vadhavan's attractiveness as a significant port for handling EXIM trade of leather from nearby industrial clusters while at the same time leading to an overall growth of the industry.

Policies

- National Manufacturing Policy identifies leather as a special focus sector
- Indian Footwear, Leather & Accessories Development Programme (IFLADP) has been launched with 4 projects to increase EXIM trade.
- GST concessions for finished leather, leather goods, footwear, leather garments and saddlery
- Development of huge production centres in the form of Mega Leather Clusters (MLC).

Key Investors

Apache Group (Taiwan) with a plant in Nellore, Andhra Pradesh, Feng Tay Shoes (Taiwan) having a unit in Cheyyar, Tamil Nadu and Itares (Italy) with a major unit in Ambur, Tamil Nadu.

A3.6.9 Machinery & Spares

Present Scenario

India's Machinery Industry acts as a backbone for manufacturing that takes place across the country by providing all the necessary equipment and machinery required for production. The machines are categorized into large scale, medium scale and small scale based on the equipment sector they are being used for. India is one of the leading exporters of machines required for the following industries -steel, mining, fertilizers, agriculture, textile, construction, cement, petrochemical, heavy engineering and electrical equipment.

Machinery, spares and capital goods contribute 12% to the overall manufacturing sector in India. The machinery industry has a market size of US$ 43.2 billion. The industry is divided into 10 sub-sectors where Electrical equipment is the largest sub-sector. The other sub-sectors are Process plant, Mining, Printing, Food processing, Moulds, Textile, Machine tools, Metals and Plastic machinery. In 2010, the machinery sector undertook trade of 53.6 million TEUs. In 2013, trade in machinery doubled to 132.3 million TEUs. In

2019, 180.3 million TEUs of machinery and spare products were traded. The market reached a production figure of US$ 13.6 billion in 2020 from US$ 7 billion in 2017 showing a growth rate of 18%.

Figure A3-31 *Machinery Industries in India*

Construction industry needed US$ 10 billion of machinery in 2020. Similarly, the domestic textile machinery industry hit US$ 2.9 billion. Growth in the power industry drove growth in the electrical equipment industry, which reached US$ 27.3 billion in 2019 growing by 19.1%. Even the Indian telecom equipment market has increased at a rate of 50%. Exports of telecom instruments have increased from US$ 880.75 million in 2016 to US$ 1,771.37 million in 2019. Key Players and Investors in India are listed below.

- National – Voltas, Telco Construction Equipment, Volvo Construction Equipment India, Larsen & Toubro, Ingersoll Rand India, Caterpillar India, Escorts Construction Equipment
- International - JCB India, Metso Minerals, Atlas Copco, Trane Technologies
- Foreign Investors - MHI (Japan), Hitachi (Japan), Babcock (UK), Alstom (France), Toshiba (Japan), Ansaldo (Italy), Colfax Corporation (USA), Schneider Electric (France), Legrand (France), GE (USA)

Future Scenario

India is expected to expand its machinery sector at a CAGR of 7% to US$ 115.17 billion by 2025. The decreased growth rate can be attributed to the adverse effects of Covid-19 pandemic and lockdowns on industries. Of the industry's sub-sectors, textile machinery would hit US$ 4.62 billion while engineering segment would increase fourfold to reach US$ 42 billion by 2025. The electrical sub-sector would target US$ 100 billion while transmission & distribution segment will reach $75 billion.

States in India offer incentives like subsidized land cost, relaxation in stamp duty, power tariff incentives, investment subsidies/tax incentives, special packages for mega projects, etc. under different schemes like Export Promotion Capital Goods, Duty Remission, Focus Product, and Focus Market. The Government of India has approved 15 SEZs for engineering sector, with a special focus on machinery. These factors have been taken into account to derive growth rates for machinery exports in the following table. The table also describes traffic projection for ports in Maharashtra and Gujarat.

Table A3- 33 Projections for Machineries

Year	Y-o-Y Growth Rates	Volume (million TEUs)
FY25	9%	288.5
FY30	8%	423.9
FY35	8%	622.8
FY40	7%	873.5
FY45	7%	1225.2
FY50	6%	1639.6

For the FY25, the estimated growth rate is 9%. For the next 5 years from FY26-35, the rate becomes 8%. Again the rate is reduced to 7% for FY36-45. For the last 5-year duration, the rate is kept at 6%. Trade projection for FY25 is expected to be 288.5 million TEUs, for FY30 it would be 423.9 million TEUs and for FY40 it would double to 873.5 million TEUs. In FY50, trade in machinery is expected to double once again to 1639.6 million TEUs,

As the machinery industry is made up of a number of sectors, it requires a port that can handle different equipment with a high degree of consistency. A versatile port like Vadhavan would be able to cater to demands of different sub-sectors of the machinery industry. Moreover, most of the state and export incentives are applicable for Vadhavan port. The area near Vadhavan also comes under a SEZ which would further benefit the port. Besides these, Vadhavan would also acquire initial concession incentives for the first 10 years after its establishment.

An essential condition for a higher turnover is efficient and timely handling of containers and ample storage space. Vadhavan port would have a huge amount of reserved storage space. It will also have an adequate number of container carrying cranes all linked to a central distribution system. This will help in effective loading/unloading of containers carrying machinery products. Some national manufacturers or foreign investors could also have a dedicated terminal on Vadhavan for a lease period of few years to facilitate movement of containers. Growth Drivers in Sub-Sectors of Machinery is as listed below;

- Government schemes help farmers buy agricultural machinery to increase their yield.
- Manufacturers use advanced textile machinery to produce better goods.
- Electrical machinery has been delicensed with 100% FDI allowance.
- Transmission & Distribution Sector can replace ageing equipment in the power industry.

- Potential exists to close EXIM gap as India's machinery imports are almost 3 times its exports.
- India is preferred by global manufacturing companies as an outsourcing destination, due to cost competitiveness, favourable investment conditions, better engineering and design capabilities with high-end manufacturing set ups to meet global requirements.

A3.6.10 Minerals

Present Scenario

The Mining industry in India provides basic raw materials and is characterized by a large number of small operational mines. India is home to 1,531 operating mines and produces 95 minerals, which include 4 fuels, 10 metallic, 23 non-metallic, 3 atomic and 55 minor minerals. The total value of mineral production (excluding atomic and fuel minerals) during 2019 has been estimated at US$ 16.53 Billion, which shows an increase of about 10.11% over that of the previous year. The Gross Value Added from the mining industry in 2019 accounted for 2.38% for the first quarter. During 2019, the private sector accounted for 67.33% of the total industry.

Figure A3-32 Minerals in India

In 2010, India's mineral trade in containerized form was 17.8 million TEUs and in 2013, it increased to 47.9 million TEUs. Containerized mineral trade in 2019 increased two fold to 104.2 million TEUs. In terms of value, India's mineral exports including re-exports achieved a level of US$ 329.53 billion in 2019. The growth in exports was from 5.2% in 2017 to 8.8% in 2019. Mineral imports fell from a high of US$ 490.7 billion in

Royal HaskoningDHV

JNPA

2013 to US$ 381 billion in 2016 and thereafter registered a sharp increase of 10.4% to US$ 514.03 billion in 2019. The growth in imports was from 0.9% in 2016-17 to 10.4% in 2018-19

Vadhavan's exact location is surrounded by mines for various minerals along with supplementary production facilities. The quarried minerals after refinement could be transported via trucks to Vadhavan and loaded onto containers for export. There are also many mineral processing plants near Vadhavan. Exports of finished mineral products in containerised form can also be transported to Vadhavan port from these processing plants.

Future Scenario

Rise in infrastructure development and automotive production is leading to growth in the mineral industry. The trade of minerals is expected to grow substantially over the next 15 years due to India's advantage in the cost of production and in conversion costs. Mineral products like asbestos, carbon, ceramic, charcoal, limestone, quartz, ferrous and graphite products are expected to witness double-digit growth as only 20% of the total reserves have been mined till now. The above reasons are taken into account to arrive at estimated values of growth rates for mineral trade in the following table.

Table A3- 34 Projections for Minerals

Year	Y-o-Y Growth Rates	Volume (million TEUs)
FY25	8%	159.2
FY30	7%	223.3
FY35	7%	313.2
FY40	6%	419.1
FY45	6%	560.9
FY50	6%	750.6

The table shows growth assumptions for containerised exports of minerals and trade projections for the ports of Maharashtra and Gujarat. In FY25, mineral trade is expected to grow at 8%. For the next 10 years FY26-35, the rate is held at 7% and for the last 15 years FY36-50, the rate is reduced to 6%. In 2030, trade is projected to be 223.3 million TEUs and in 2040, it is estimated as 419.1 million TEUs. For the horizon year of FY50, trade in minerals is expected to be 750.6 million TEUs

The Indian government has opened up the mining sector with provisions of longer mining leases of 20-30 years, mineral concessions to be granted through auctions and greater transparency in mine allocation. India has large reserves of limestone, quartz, carbon products, ferrous products and graphite products and its strategic location enables convenient exports. Vadhavan would be able to increase its mineral trade output due to the mining concessions which would also provide incentives to ports trading in mined products. Larger reserves would also assure a continuous supply of minerals to be exported from Vadhavan. Also, three container berths at Vadhavan can easily handle JNPA's spillage. They can also increase EXIM trade for minerals that are in demand.

Policies and Initiatives

- District Mineral Foundation (DMF) will address various mining issues.
- National Mineral Exploration Policy 2019 incentivizes regional and detailed exploration
- Mission Purvodaya emphasized to harness the untapped potential of different regions
- Budgetary allocation for the Ministry of Mines stands at US$ 117.6 Million
- Stronger penal provisions have been put in place to check illegal mining

- o FDI up to 100% under the automatic route is allowed in mining

A3.6.11 Paints & Prints

Present Scenario

The Indian paint industry is the second largest in the world. Indian paint industry is divided into two types: Decorative & Industrial Paints. Decorative paint has been further segmented into emulsions, enamel, distemper and cement paints while Industrial paint is segmented into automotive coatings, high performance coating, powder coating and coil coating. The paint sector is dominated by four players, namely Asian Paints, Nerolac Paints, Berger Paints and Dulux India (AkzoNobel) Paints.

Figure A3-33 Paint Manufacturing Facilities in India

The sector witnessed significant growth over the past 4-5 years. In 2010, the paint industry had a total trade output of 60 million TEUs. In 2013, the containerized trade volume was higher by around 10 million TEUs attaining a peak of 70.8 million TEUs. After this year, the trade volume kept on decreasing progressively until 2017. In 2019, India had more than 20,000 outlets in operation and the total trade stood at 64.4 million TEUs, its highest value compared to the last five years.

The size of paint industry in India is around 1000 million litres and is valued at approximately US$ 6.7 billion. Domestic and industrial sectors comprise 70% and 30% of the paint industry. The industry has grown at an overall CAGR of 12 to 13 % wherein the decorative / domestic paint market has a CAGR of 12.7% and the industrial paint market has CAGR of 9.5%.

During 2019, the trade value of Indian paint industry was over US$ 771 million. In FY19, the paint industry had expanded at the rate of 12% in volume terms and about 15% in value terms. The export value of Indian paint industry is around US$ 243.7 million whereas the import value is approximately US$ 528 million in 2019. Exports showed a growth of 20% year-on-year while imports increased at a rate of 25% year-on-year.

Delhi and Uttar Pradesh were major importers of paints while Gujarat and Punjab were major exporters. Mundra port had a larger share of both exports and imports as compared to Pipavav and Mumbai ports. Asian Paints, Berger and Kansai Nerolac hold a number of manufacturing and retail outlets in Western Maharashtra and Southern Gujarat. These regions fall in the influence area of Vadhavan. The port can cater to these industries by importing raw materials and exporting finished products. Vadhavan's focus would include both domestic and industrial paints.

Future Scenario

The Indian paint industry currently valued at around US$ 6.7 billion is expected to grow at 1.5 times to 2 times GDP growth rate in the next five years. It is expected to reach around US$ 9.47 billion by 2021-22. The global market is projected to grow from US$ 153.94 billion in 2019 to US$ 199.88 billion by 2024, at a CAGR of 5.4%. Future market growth is expected to be in the order of 11% p.a. overall. Considering the pandemic's impact, this value is reduced to 9% per annum for exports.

The Indian paint industry has seen a gradual shift in the preferences of people from the traditional white wash to higher quality paints like emulsions and enamel paints. Construction remains the key growth sector accounting for nearly 45% of the total national investment in infrastructure and is driving demand for decorative and protective coatings. On the housing sector front, rapid urbanization and availability of easy to secure housing loans, have become the prime drivers of growth in the decorative paint segment. Growth in the Indian car market is strong, at about 10-12% p.a., which is creating good demand for OEM coatings, and vehicle refinishes too in the long term. An average increase of growth of about 10% in the automobile sector contributes to 50% of the revenues in the industrial paints segment.

Regular monsoons, festival seasons, popularity of new variants, rising infrastructure, increasing per capita income of people, stability of crude oil prices and growth in the automotive, construction and real estate sectors, younger population inclined towards lavish lifestyle and efforts of manufacturers to introduce improved versions like eco-friendly, odour free and dust and water resistant paints, have propelled the growth of the paint market in India. These are all the factors used to determine growth rates for the paint industry in the following table.

Table A3- 35 Projections for Paints and Prints

Year	Y-o-Y Growth Rates	Volume (million TEUs)
FY25	9%	102.8
FY30	8%	151.1
FY35	8%	222
FY40	8%	326.2

FY45	7%	457.5
FY50	5%	583.9

The table represents the growth assumptions for containerized trade of paints along with traffic projections for the ports of Maharashtra and Gujarat. For FY25, the growth rate is assumed as 9%. This value reduces by one to 8% for the next 15 years from FY26 to FY40. For the next 5-year duration, the rate is taken as 7% and for the final 5-year duration, the growth rate is expected to be 5%. Trade in FY30 is estimated to be 151.1 million TEUs. This doubles in FY40 to 326.2 million TEUs. In the last year of the projections, traffic is expected to reach 583.9 million TEUs.

Vadhavan would also undertake Ro-Ro trade. The automotive sector would thus play a significant role for growth in paint EXIM trade on Vadhavan. Developing infrastructure around Vadhavan would also boost demand and supply of housing, in turn aiding growth of concrete and paintable houses in India.

A3.6.12 Paper & Products

Present Scenario

India's Paper Industry shows a huge potential with increasing domestic production. India is one of the fastest growing paper markets and is ranked 15th among paper manufacturing nations in the world. Demand for paper is growing due to an increase in demand for packaged products. Paper consumption in India is approximately 15-17 million tonnes per annum. The demand for domestic paper in India rose from 9.3 million tonnes in FY08 to 18.38 million tonnes in FY19. The paper industry has a growth rate of 7% to 8% every year.

In FY20 imports of paper increased by 11% to 1.6 million tonnes in FY19-20. In the last 9 years, imports have increased at more than 13% CAGR. Domestic production is not sufficient enough to meet rising demand of paper. Hence India imports paper in huge volume. Cheaper imports are meeting the demand at the cost of domestic production. Every year a decline in domestic production is seen that results in increase of imports. Production capacity of the country is presently under-utilized. Therefore, the government is planning to change import policy from free to restricted. COVID pandemic has further impacted domestic production. Taking advantage of this situation, imports have been raised to higher rates of 16% in 3rd Quarter of FY20

In terms of containerized trade in 2010, India obtained a total trade volume of 183.2 million TEUs. In 2013, this number was raised to 260.7 million TEUs. These container trade volumes include imports and exports. In 2019, the paper industry registered a trade volume of 413.2 million TEUs. The trade volume for the 9 years between 2010 and 2019 grew at a CAGR of 9.46%. A similar growth rate is assumed for the paper industry in the upcoming years.

The Western region of India is the lead consumer of paper based products especially in packaging segment and is expected to increase further in future. Majority of paper mills are concentrated in Maharashtra, Gujarat, MP, Punjab, etc. The port of Vadhavan lies on India's western coast and counts both Maharashtra and Gujarat among its influence areas. An increase in e-commerce and higher levels of online shopping has resulted in a significant rise in packaging requirements. Vadhavan could benefit from this by exporting paper products from nearby mills and importing packaging paper and cardboards for packaging industries. Key Players in India as listed below;

- *International* - Trident Group, Brother, Thomson Press

- *National* - Ballarpur Industries, Sirpur Paper Mills, West Coast Paper Mills, Pragati, Khanna Papers, JK Paper Ltd., Orient Paper & Industries Ltd., International Paper APPM Ltd., Anderson Printing House, ITC

Future Prospects

Indian paper & paper products market is projected to grow from $ 8.6 billion in 2018 to $ 13.4 billion by 2024, exhibiting a CAGR of 7.8% during 2019-2024. Demand for paper and products is expected to reach 20.8 million tonnes in FY 21 and increase to 23.5 million tonnes by FY25 growing at 6.7%. Paper consumption will further increase by 7.6% per year in the coming years. At current levels, demand for Packaging Paper & Board segment is also expected to grow at a CAGR of 8.9% and reach 11.1 million tonnes in FY21.

Growth drivers for the paper industry are greater emphasis on education and literacy by the government, demand for better quality writing & printing paper and growth in organised retail especially better quality packaging of FMCG products, over-the-counter medicines and increasing preference for ready-to-eat foods, etc. These factors have been considered to derive growth rates for paper products. All these factors along with an excessive upsurge in e-commerce will provide Vadhavan with an opportunity to increase imports of paper from South Korea, Indonesia, Brazil, Thailand, Europe and USA, with China being the main supplier even after trade restrictions.

Table A3- 36 Projections for Paper and Products

Year	Y-o-Y Growth Rates	Volume (million TEUs)
FY25	8%	623.7
FY30	7%	874.7
FY35	6%	1170.6
FY40	5%	1494
FY45	4%	1817.7
FY50	3%	2107.2

The table shows the growth rates for containerized paper trade. It also provides projections for trade in the ports of Maharashtra and Gujarat. Starting from FY2025, the rate is assumed as 8%. For all the subsequent 5-year durations, the rate is successively reduced by one. So for FY26-30 it is 7%, for FY31-35 it is 6%, for FY36-40 it is 5%, for FY41-45 it is 4 % and for FY46-50 it is 3%. In FY30, the trade projection is 874.7 million TEUs while in FY40 it is 1494 million TEUs. For the horizon year of FY50, the containerized trade is expected to be 2107.2 million TEUs.

The online e-commerce sector's growth in present times has led to an exponential growth in the cardboard paper segment. Nowadays, people order most of their requirements online from e-commerce giants like Amazon and Flipkart and almost all products are sent in a packaged form which requires paper. The pandemic has increased the number of products being ordered online. Consequently, this will lead to a larger growth in the paper industry as a whole. Since this sector is destined to grow by leaps and bounds, Vadhavan will be assured a steady supply of exports and imports related to this industry.

A3.6.13 Parts & Accessories

Accessories (Lab Equipment)

Present Scenario

The global lab equipment market size accounted for $27.6 billion in 2020. Based on product, the market is classified into equipment and disposables. Equipment is further divided into incubators, micro manipulation systems, centrifuges, lab air filtration system, and other equipment. Disposables segment is further classified into pipettes, tips, tubes, cuvettes, dishes, gloves, masks, and other consumables. The equipment segment accounted for the largest share of 63.0% in 2019 in the laboratory equipment and supplies market.

Pharmaceutical companies constituted 38 percent of the overall demand for lab equipment and supplies. Indian market earned revenues of more than $762.5 million in 2012 and this reached $2,906.0 million ($2.9 billion) in 2020.Top Indian exporters are Exportprop, Agni India Pvt, Imperial Lab Equipments, Sensors India and Komal Scientific Co. Exports are made to USA, Germany, UAE, UK, Qatar and other countries and the consignments are shipped from Cochin. Top Indian importers are Defence R&D Organization, RRL Bhopal, DCDA R&D. Imports are received from USA, Germany and Switzerland using JNPA.

The end-user segments covered include pharmaceuticals and life sciences, government and academic research institutions, environmental safety, agricultural analytic research, third-party and food and beverage testing laboratories, and chemicals and petrochemicals. Since a number of these segments surround the port of Vadhavan, EXIM trade of lab equipment has a huge potential at the port. As Kochi port handles the majority of trade in lab equipment, when Vadhavan becomes operational it can act as a convenient and better accessible port for most industries in the lab equipment market.

However, R&D costs are high and the inability of domestic small and medium enterprises, original equipment manufacturers, and distributors to meet these expenses, restrains market development. In addition, slow implementation of government laws and regulations in several consumer segments also dampen adoption process across different segments in this market. Key Players are listed below;

- *National* – Trivitron Healthcare, Skanray Technologies, MILLIONE Technologies
- *Foreign* – Agilent Technologies, Thermo Fisher Scientific, Hettich Instruments

Future Scenario

Global lab equipment market is expected to reach $38 billion by 2025, registering a CAGR of 5.7% from 2020 to 2025.The recent pandemic of the deadly COVID-19 is a key factor for the rapid growth of the lab equipment market. The booming investments in the development of new vaccines, a rapid increase in the number of sample tests and the rising funding by the governments to meet the response of COVID is also anticipated to significantly drive the market in the coming years. Recently, in April 2020, the Department of Biotechnology, India announced that around 16 companies were granted funds to boost their R&D for the development of drugs and vaccines.

Government funding serves as the fulcrum for laboratory equipment procurement in India as institutions and research laboratories continue to be key customers. Vadhavan may be able to benefit from a number of policies that India has adopted under its Make in India, Digital India and Startup India initiatives. These policies are aimed towards increasing export of lab equipment products from India to the western and middle eastern countries. Industrial growth factors are listed below;

- Continuous demand from pharma industry for high throughput, portable, and cost-effective lab equipment.

- Asia Pacific region shows robust growth opportunities owing to the rising prevalence of chronic diseases and growing investments in pharmaceutical research.
- Stable demand in North America, especially from the public sector

Accessories (Valves and Pipes)

Present Scenario

In 2019-20, India Exported valves worth 1.46 Million US$ and in 2018-19, it was 1.4 million US$. India occupies a share of 11% in the global valve and pipe manufacturing industry. Major factors for growth include upsurge in demand from irrigation & construction industries, rise in focus on water management and rapid urbanization. On the basis of applications, these accessories can be classified into Irrigation, Water Supply, Sewerage, Plumbing, Oil & Gas, Heating, Ventilation, and Air Conditioning (HVAC), and Others.

Companies in this industry manufacture metal industrial and fluid power valves, hose fittings, and pipe fittings. Major internationals companies include process control companies such as Emerson (US), Parker Hannifin (US), as well as valve manufacturers such as Crane (US), IMI (UK), Kitz (Japan), KSB (Germany), and Tianjin Dazhan Group (China). The key players operating in the Indian market are Signet Industries, Finolex Industries Ltd., Mauria Udyog Pvt Ltd, Ori-plast, Utkarsh India, and Dutron Group.

Future Scenario

The Indian pipe market was valued at $3,159 million in 2016, and is expected to reach $6,224 million by 2023, growing at a CAGR of 10.2% from 2017 to 2023. The global industrial valves market is forecasted to reach a value of $93.79 billion by 2026.Demand depends primarily on the level of manufacturing and construction activity in the chemical, petroleum, utilities, water treatment, and housing industries. The effective growth in the existence of both international as well as domestic players attached to new government initiatives has also generated a positive impression for the market's future.

The major growth drivers for this market are the growth of government infrastructural spending, increasing residential and commercial construction, industrial production, irrigation sector, and replacement of aging pipelines. A number of manufacturing units are located in Maharashtra's coastal region near Mumbai. The port of Vadhavan would be able to export valves, pipes along with other accessories from areas within its vicinity. The pipelines and their assortments required for the transport of liquid bulk from Vadhavan's terminals could also increase imports.

Consolidated Growth Assumptions for Parts and Accessories

The following table combines both sections of accessories – Lab Equipment and Valves & Pipes. These growth rates are based on historical trends as well as contemporary conditions. The factors considered for lab equipment were higher demand for portable and cost-efficient equipment, robust growth in the South-East Asia region due to increasing number of people being affected by various diseases, requirement of higher throughput and stable demand from overseas. The reasons taken into account for valves & pipes were increased governmental spending for residential and commercial construction, demand from the industrial production plants and facilities, growth in irrigation sector, and replacement of damaged and aging pipelines.

In 2010, the containerized trade of accessories was 74.3 million TEUs while in 2013, it was 82.4 million TEUs. The trade volume included both the segments of Lab Equipment and Valves & Pipes. In 2019, this volume increased to 141.4 million TEUs growing by a CAGR of 7% for the duration between 2010 and 2019. This is another factor used to determine growth rate for accessories.

Table A3- 37 Projections for Parts and Accessories

Year	Y-o-Y Growth Rates	Volume (million TEUs)
FY25	9%	225.8
FY30	8%	331.7
FY35	8%	487.4
FY40	7%	683.7
FY45	7%	958.9
FY50	7%	1344.9

The above table describes growth rates for accessory exports of lab equipment and valves & pipes. Growth Assumption for FY25 is 9%. For the next 10 years from FY25-35, it decreases to 8%. For the last 15 years from FY36-50 it is assumed as 7%. In FY30, the trade volume is projected to be 331.7 and in FY40, it would increase to 683.7 million TEUs. In the year 2050, the trade in accessories is projected to be 1344.9 million TEUs.

A3.6.14 Pharmaceuticals

Present Scenario

India is the largest provider of generic medicines globally, occupying a 20% share in global supply by volume. It is also the largest vaccine producer in the world and is home to more than 3,000 pharma companies with over 10,500 manufacturing facilities. India ranks 3rd worldwide for production by volume and 14th by value. Indian pharma industry has been growing at a CAGR of more than 15% over the last five years. Four Indian Companies are among top ten global generic companies – Sun Pharma, Dr. Reddy's, Aurobindo Pharma and Lupin. Pharmaceutical exports from these companies and others in India reached more than 200 nations including USA, West Europe, Japan, and Australia.

The industry supplies 62% of global demand for vaccines, 40% of generic demand in the US and 25% of all medicine in the UK. Generic drugs, with 71% market share, form the largest segment of the Pharma industry in India which is currently valued at $ 41 billion and generates over $ 11 billion of trade surplus every year. Domestic pharmaceuticals market turnover reached $20.03 billion in 2019, up 9.3% from 2018.

Figure A3-34 Pharmaceutical Clusters in India

In 2010, the containerized pharmaceutical trade volume was 22.2 million TEUs. Three years later in 2013, it was 45 million TEUs. In 2019, the volume was 118.3 million TEUs showing a phenomenal growth of 20% for the period from 2010 to 2019. In the same year, India's pharmaceutical exports were worth $19.3 billion with a growth of 10.72% year on year and stood at US$ 20.70 billion in FY. Pharmaceutical export includes bulk drugs, intermediates, drug formulations, biologicals and surgical products, Ayush and herbal products. The drugs and pharmaceuticals sector attracted cumulative FDI inflow worth US$ 16.50 billion between April 2000 and March 2020

There is an Established Bulk Drug Cluster in Tarapur, Captive and Contract R&D units in Pune and Mumbai. All three locations are near to Vadhavan and lie along NHs with direct connections. Transportation of raw materials and finished pharmaceutical products through truck carriers to and from these sites would be possible. Reefers and cold chains could also be used for those pharmaceutical medicines and vaccines that are temperature sensitive. Vadhavan would undertake the movement of these products in an efficient manner. Key players are as listed below;

- *International* - Teva Pharmaceuticals (Israel), Nipro Corporation (Japan), Procter & Gamble (USA), Pfizer (USA), Glaxo Smith Kline (UK), Johnson & Johnson (USA), Otsuka Pharmaceutical (Japan), AstraZeneca (Sweden-UK)

- *National* - Sun Pharmaceuticals Industries, Lupin, Aurobindo Pharma, Cipla, Dr Reddy's Laboratories, Glenmark Pharmaceuticals

Future Prospects

Indian pharmaceutical sector is expected to grow to $ 65 billion by 2024. Government of India has unveiled 'Pharma Vision 2020' to make India a global leader in end-to-end drug manufacture. India has offered US$ 1.3 billion fund and US$ 942.8 million production linked incentives to manufacture pharmaceutical ingredients domestically by 2023. It has plans to set up three mega bulk drug parks to drive sustainable cost competitiveness. These points have been used to estimate growth percentages in the following table.

Table A3- 38 Projections for Pharmaceuticals

Year	Y-o-Y Growth Rates	Volume (million TEUs)
FY25	9%	189.2
FY30	8%	278
FY35	8%	408.4
FY40	7%	572.8
FY45	7%	803.4
FY50	6%	1075.1

The table denotes growth rates of pharmaceutical exports and also details traffic projections for Maharashtra and Gujarat ports. In FY25, growth rate is estimated as 9%. For the next 10 years, from FY26-35, the rate is kept at 8%. For the next 10 years it is again reduced to 7%. For the last 5-year duration from FY46-50, it is estimated to be 6%. In FY35, the trade volume is expected to be a high value of 408.4 million TEUs. This volume increases by 2 times to 803.4 million TEUs in FY45. In FY50, another 200 million TEUs are added to make the overall total of 1075.1 million TEUs.

India holds 12% of all global manufacturing sites catering to the US market. The cost of manufacturing in India is approximately 33% lower than that of the US attracting huge amounts of FDI. Indian pharmaceutical industry's export to the US will get a boost as branded drugs worth US$ 55 billion will become off-patent during 2017-20. Biosimilar medicines from India can then be supplied to markets in US, Europe and other countries. Vadhavan can use this opportunity and other production linked incentives to increase its pharmaceutical exports. Growth drivers of this industry is as listed below;

- Investments in R&D to develop new complex generic drugs
- Medical tourism services at marginal costs compared to US, Europe, and South Asia
- National Health Protection Scheme is the largest government funded healthcare programme.
- Large raw material base, skilled workforce and expertise in low cost generic patented drugs gives the industry a definite competitive advantage.

Policies - Pharmaceuticals Promotion Development Scheme (PPDS), Scheme for Development of Pharma industry, Scheme for Promotion of Bulk Drug Parks

A3.6.15 Plastic & Products

Present Scenario

India is one of the largest producers of Plastic in the world with over 30,000 registered plastic processing units. Growth of the sector is at a CAGR of 12% in volume from 8.3 to 13.4 MMTPA over 2010-19. On the basis of value added share, the Indian Plastic industry contributes about 0.5% of India's GDP. The export of plastic products also yields about 1% of the country's exports. Approximately INR 100 billion (US$ 1.35 billion) are invested in the form of fixed assets in the plastic processing industry.

Figure A3-35 Plastic Manufacturing Plants in India

In 2010, the plastic sector registered a trade of 53.1 million TEUs. In 2013, the volume doubled to 107.6 million TEUs. In 2019, the volume almost quintupled to 257.7 million TEUs increasing at a CAGR of 19%. In FY20, plastic export from India stood at US$ 7.55 billion. Plastics formed 2.8% of India's overall merchandise exports. Plastic exports' contribution was from plastic raw material at US$ 2.91 billion, plastic sheets, films and plates at US$ 1.22 billion and packaging materials at US$ 722.47 million. Most of the plastic is exported from India to USA, UAE, Italy, UK, Belgium, Germany, Singapore, Saudi Arabia, China and Hong Kong. In FY20, top five importers of Indian plastic products were US (US$ 1,314.03 million), China

(US$ 1,281.65 million), UAE (US$ 579.51 million), Italy (US$ 451.41 million) and Germany (US$ 407.14 million)

Among the industry's major strengths is the availability of raw materials in the country. Thus, plastic processors do not have to depend on imports because raw materials can be manufactured domestically. Vadhavan can export a substantial amount of plastic products as it falls in the western region of India which covers a share of 47% in the plastic manufacturing industry. Leading Companies in India are Finolex Industries Ltd, Plastiblends India Limited, AGA Group International, Corporate Resource Group,
ACRY Plus, Kay Kay Global Suppliers

Future Scope

India is expected to become 3rd largest plastic manufacturer by 2021. Sector is estimated to grow at a CAGR of around 10.5% to gain 22 MMTPA from 2015-21. India is likely to dominate with the domestic per capita consumption of plastic set to double by 2025. The domestic Indian Plastic Industry also expects an investment of nearly $80 billion over the next four years.

The Indian Plastic industry will have a high growth rate of about 10%-12% in the coming years. This would be due to industries such as the automotive sector, where launching of new cars is expected to drive the demand. Plastic plays a significant role in the key sectors of the economy, including agriculture, water management, automobiles, transportation, construction, telecommunication and electronics, besides defence and aerospace, computers and power transmissions. Cheap labour, easy availability and low cost of raw materials are other factors that are driving Plastic Industry. The aforementioned reasons are used to estimate growth rates for the trade of Plastic products.

Table A3- 39 Projections for Plastic and Products

Year	Y-o-Y Growth Rates	Volume (million TEUs)
FY25	9%	411.2
FY30	8%	604.2
FY35	8%	887.7
FY40	7%	1245.1
FY45	7%	1746.3
FY50	5%	2228.8

The table shows growth rates for the plastic industry followed by trade projections for the ports of Gujarat and Maharashtra. A 9% rate is taken for FY25 which is decreased to 8% for the next 10 years from FY26 to 2035. It is further reduced to 7% for another 10-year duration of FY36-45. For the final 5-year duration of FY46-50, a rate of 5% is assumed. In FY30, the trade volume is projected to be 604.2 million TEUs. In 2040, the plastic trade doubles to 1245.1 million TEUs and for the horizon year of FY50, the projection is estimated as 2228.8 million TEUs.

The fragmented plastics industry in India is also beginning to consolidate while governmental regulations and trade barriers are coming down due to India's WTO membership. Some large North American plastic manufacturers have already setup businesses in India with a view to expand their operations in the future. These foreign companies are bound to setup industries near metro locations like Mumbai and in industrial hubs of Maharashtra and Gujarat in order to seize various incentives and opportunities. In the future, these industries could become prime customers for Vadhavan due to its proximity to their locations.

RIL, Supreme and Finolex have a plastic manufacturing plant located at Nagothane, Ratnagiri and Pune. All three cities fall in the influence region of Vadhavan. Moreover, both RIL and Finolex are expanding their plants to include more polymers of PP, PE, PVC and PET categories. Vadhavan would export finished plastic goods in the form of laminates, housewares, medical disposables, optical and packaging items. For these same industries, it could import plastic sheets, plastic films, plats, moulded and extruded goods.

A3.6.16 Rubber & Products

Present Scope

The Rubber Industry is a key sector with a turnover of around US$ 1.62 billion per annum. India is the third largest producer of natural rubber in the world and has a market share of 5.3% of the global natural rubber market. India is the second largest consumer of natural rubber and its consumption has increased from 1.11 million tonnes in 2018 to 1.21 million tonnes in 2019. Sheet rubber, block rubber and latex account for 47%, 43% and 8% respectively in Natural Rubber consumption. The automotive tyre sector accounts for 68% of Natural Rubber consumption in India.

The production capacity in India is around 900,000 tonnes, of which around 75% is tapped. Currently, Kerala is the largest producer of rubber in India, followed by Tamil Nadu and Karnataka. Traditional rubber-growing states comprising Kerala and Tamil Nadu account for 81% of production. Major non-traditional rubber growing regions are the North Eastern states of Tripura, Assam and Meghalaya, Odisha, Karnataka, Maharashtra and West Bengal.

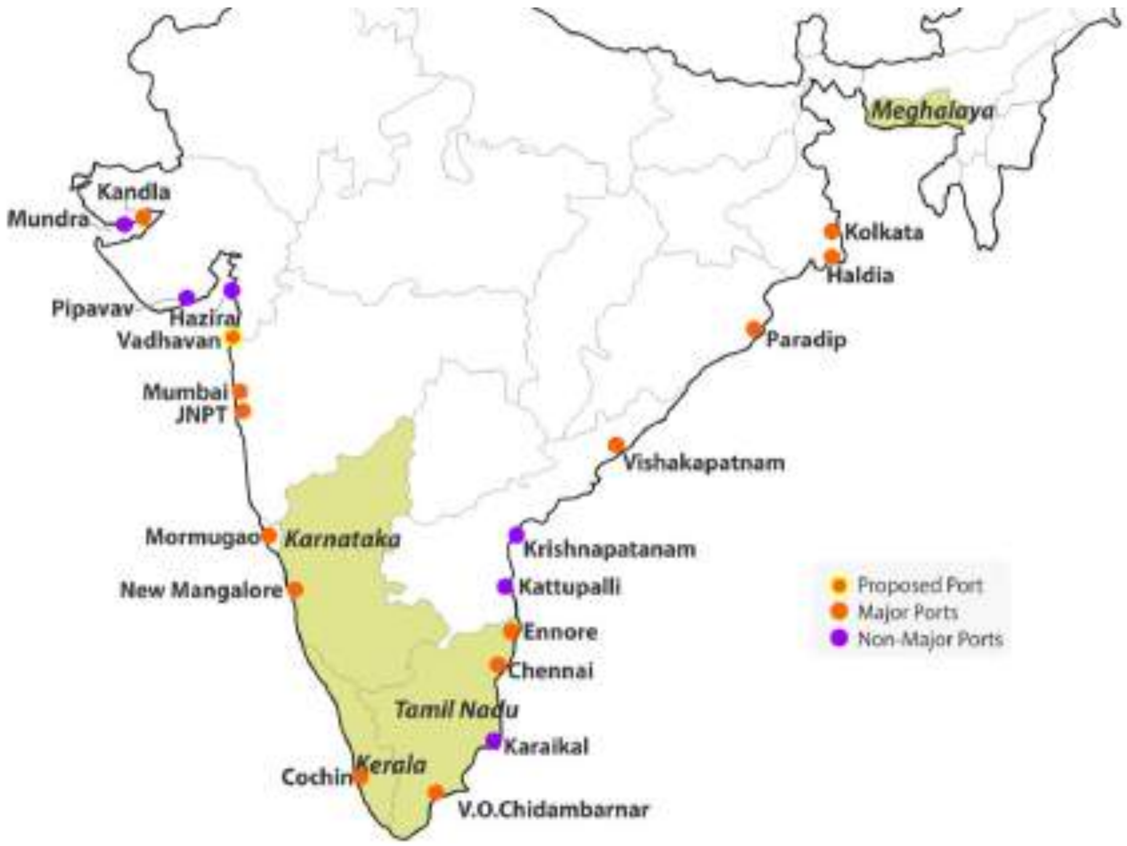

Figure A3-36 Rubber Producing States in India

In 2010, the overall containerized trade in rubber products was 49.1 million TEUs. This volume increased by 40 million to reach 90.5 million TEUs in 2013. Six years later, the trade volume rose to 159.9 million TEUs. This trend of an annual increase followed a CAGR of 14.02% over a period of 9 years from FY10 to FY19. The imports of rubber products increased by 24% in 2019 to 582,381 tonnes of which 81% was in the form of block rubber.

Due to deficit in the domestic market, low prices for rubber in the international market, price fluctuations and quality/technical considerations, Natural Rubber import has seen a significant rise over the years. With India's large population base and huge automotive sector, import of rubber products (excluding raw Natural Rubber) has also been increasing. Multinational tyre manufacturers are establishing production facilities in India. Vadhavan would mostly focus on imports of rubber for automotive sectors in and around Maharashtra and Gujarat. It could also import other rubber products like tubes, mountings and hoses.

Consumption of Synthetic Rubber in India in rubber products manufacturing sector increased from 4,11,830 tonnes in 2011 to 6,33,975 tonnes in 2018. Synthetic Rubber production increased from 1,10,340 tonnes in 2011 to 3,31,221 tonnes in 2018. Styrene Butadiene Rubber and Poly Butadiene Rubber accounted for 63% and 34% of Synthetic Rubber production in the country. Import of Synthetic Rubber amounted to 3,38,189 tonnes in 2018. Consumption of Synthetic Rubber in India is projected to reach 1.2 million tonnes by 2020. Top Rubber Companies in India are listed below;

- The largest rubber and tyre producing company in India is MRF (Madras Rubber Factory) with net sales of almost 16,000 crores (US$ 2.16 billion).
- It is followed by Apollo Tyres with net sales of 12,000 crores (US$ 1.62 billion).
- Both Apollo and MRF are placed in the Top 10 tyre manufacturers in the world by units.
- Other major players include JK Tyres, Ceat Tyres, Balkrishna Industries and others.

Future Scenario

Natural Rubber consumption in the country in 2030 is projected at around 2 million tonnes. It is envisaged that the domestic production is able to meet at least 75% of the Natural Rubber requirement in 2030. There would be an orderly and complementary growth of all links in the Rubber Industry Value Chain, viz., Natural Rubber production and processing, manufacturing of tyres and general rubber products, trading, ancillary activities, etc. Focussed efforts would be taken at synchronizing all initiatives and attempts towards growth of rubber industry as a whole.

The key factors which have contributed to the growth of Indian rubber industry are positive intervention of institutional agencies aiming at self-sufficiency, import substitution and growth of automotive industry. The brand Indian Natural Rubber distinguishes Indian rubber in the international market with its assured quality. Rubber consumption is driven by industrial growth as well as demand for consumer goods. Automobile industry is an important industry, for both tyre and non-tyre sectors and has emerged as the single-largest consumer of natural rubber. All these factors are cumulated to derive growth rates for the containerized trade of rubber products in the following table.

Table A3- 40 Projections for Rubber and Products

Year	Y-o-Y Growth Rates	Volume (million TEUs)
FY25	8%	243.6
FY30	7%	341.7
FY35	7%	479.3

Year	Y-o-Y Growth Rates	Volume (million TEUs)
FY40	6%	641.4
FY45	6%	858.3
FY50	5%	1095.4

The table details the growth rate for rubber exports and also projects trade volume for Maharashtra and Gujarat portsIn FY25, an 8% growth rate is estimated while from FY26-35, the rate is taken as 7%. For the next 10 years from FY36-45, the rate is reduced to 6% and it finally becomes 5% for FY46-50. In 2025, containerized trade of rubber products is expected to be 243.6 million TEUs which increases to 479.3 million TEUs and later to 858.3 million TEUs in 2035 and 2045 respectively. In 2050, trade is projected to be 1095.4 million TEUs.

During the last seven years while the value exports has grown at an average annual growth rate of 16.18 %, that of imports has grown at an average rate of 29.32%. NR is traditionally not an export-oriented commodity. Export of NR happens to adjust temporary demand-supply imbalances in the NR domestic market. Export from all rubber products (NR, SR and RR) was worth ₹20,915 crores (US$ 2.80 billion) in 2018. If possible, Vadhavan could export some specific forms of rubber that have a larger demand in the international market. Policies related to this industry is as listed below;

- Rubber Industry Development Plan included 19 Rubber Parks that are areas publicly procured, zoned and planned for the purpose of rubber based industrial development.
- Promotion of Rubber Usage in Roads would have twin advantages of boosting rubber consumption and infrastructure durability.
- Rubber Products Export Promotion Council was constituted to increase exports.

A3.6.17 Textiles & RMG

Present Scenario

The textiles and readymade garments (RMG) industry in India is highly diversified ranging from products of traditional handloom, handicrafts, wool and silk products to the organized textile industry. The organized textile industry uses capital-intensive technology for mass production and includes spinning, weaving, processing, and apparel manufacturing.

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JNPA

Figure A3-37 *Presences of Textile Industries in India*

The textiles industry contributes 2% to India's GDP, 7% of industry output in value terms and 12% of the country's overall exports. It is the second-largest employer after agriculture (45 million direct and 60 million allied). India is the largest producer of cotton and jute, second largest exporter of cotton, leading consumer of cotton and second largest producer of polyester, silk and fibre in the world. In recent times, India has become the second-largest manufacturer of Personal Protective Equipment in the world.

India contributes 5% in global trade in textiles and RMG. India has the largest acreage with 12.4 million hectares under cotton cultivation (around 36% of the world area). India accounts for about 70% of the world's jute production. Total raw silk production has increased by 11% (35,468 MT) during 2019 over the previous year 2018 (31,906 MT). Cumulative FDI in the textiles and apparel industry has reached up to $3.45 billion during 2020.

In 2010, India attained a containerized trade of 351 million TEUs which over 3 years gradually increased to 549.9 million TEUs in 2013. Further in 2019, the trade volume recorded was 690.6 million TEUs showing a CAGR of 8% for a period of 9 years from 2010 to 2019. India's domestic consumption of textiles was around US$ 100 billion and its overall textile exports have been US$ 40 billion in FY19. Exports comprised of textile exports at $20.5 billion, apparel exports at $16.1 billion and handlooms at $3.8 billion.

Raymond, Siyaram Silk Mills and Soma Textiles and Industries have textile manufacturing plants both in Gujarat and Maharashtra. Strategic tie-ups with these companies would help Vadhavan export textile products and branded garments to foreign countries. Vadhavan would also import required raw materials for these plants. Nearly 14 textile parks in Gujarat and 16 in Maharashtra would definitely boost the textiles and readymade garment EXIM trade from Vadhavan. Since some of these textile parks have already started production, Vadhavan can start exports from the first day of its operation. Key Players in India are listed below;

- *International* - Zara, Mango, Benetton, Levi's, Esprit, Forever 21, Vero Moda, H&M, Promod, Zambiati, Marks&Spencer, Monti
- *National* - Orient Craft, Victoria Mills, Loyal Group, Ruby Mills, Digjam, Richa Fabric, Vardhman, Mandhana, Sutlej Textiles, Premier Textile Mills, Bombay Rayon, Arvind Mills, ITC Wills Lifestyle, DCM

Future Scenario

Textile & readymade garments industry in India is expected to reach $ 223 billion by 2021 from $ 140.4 billion in 2018. It will be growing at a CAGR of 10.14% between 2009-21. Exports in the industry are expected to reach $300 billion by 2024-25 resulting in a tripling of Indian market share from 5% to 15%. More than 600 companies in India are certified to produce PPEs, whose global market worth is expected to be over $ 92.5 billion by 2025, up from $ 52.7 billion in 2019. From FY19 to FY21, the textile sector is expected to show a CAGR of 28%.

An abundance of raw materials in India such as cotton, wool, silk, jute and manmade fibres along with competitive manufacturing costs and availability of skilled manpower would increase the overall quantity of exports. There is also an increased focus on technical textiles like Medical textiles, agro-textiles, geotextiles and a preference for these products among the Indian population. The Government of India has announced a Special Package to boost textile exports by US$ 31 billion. To arrive at growth rates for the textile sector for the next 50 years, the above factors are carefully evaluated and then traffic projections are derived in the following table.

Table A3- 41 Projections for Textile & RMG

Year	Y-o-Y Growth Rates	Volume (million TEUs)
FY25	8%	1053.9
FY30	7%	1478.1
FY35	7%	2073.2
FY40	6%	2774.4
FY45	6%	3712.7
FY50	5%	4738.5

The table represents growth assumptions for textile products along with projections of traffic for ports along the coasts of Maharashtra and Gujarat. The textile industry occupies a major portion of the containerized trade and hence its volume is larger as compared to the other products. For FY25 a growth rate of 8% is assumed. This rate decreases progressively to 5% for the final 5-year duration of FY46-50. In FY25, the sector is projected to have the largest volume among all the containerized products at 1,053.9 million TEUs. This trend continues in 2030 with 1478.1 million TEUs, in 2040 with 2774.4 million TEUs and in 2050 with 4738.5 million TEUs.

Vadhavan has an excellent scope of becoming a major exporter of Technical Textiles. There are three Centres of Excellence in Maharashtra - One for Sportech in Thane, one for Agrotech in Mumbai and another for Geotech in Mumbai. These facilities are developing textiles using the latest R&D technologies. The current market size of Indian Technical Textile industry is US$ 19 Billion which is 12% of the Indian textile value chain. Owing to its immense potential, it has been recognized as a "Sunrise Sector" and is expected to grow at 12% per annum by 2024 to US$ 40 Billion. Vadhavan being a multipurpose port could facilitate trade in tech textiles by providing an entire chain from imports of fabric and technology to exports of finished sportech, geotech and agrotech products. Policies related to this industry is as listed below;

- Amended Technology Upgradation Fund Scheme (ATUFS)
- Scheme for Integrated Textile Parks (SITP)
- Technology Mission on Technical Textiles (TMTT)
- Integrated Processing Development Scheme (IPDS)
- Merchandise Exports from India Scheme (MEIS)
- National Technical Textiles Mission (NTTM)
- Integrated Scheme for Development of Silk Industry

Recent Initiatives

- Indian textile handicrafts have seen a resurgence due to Make in India initiative.
- Regional Economic Partnership connects ASEAN members for business prospects
- Under Jute Packaging Act, food-grains shall be mandatorily packed in diversified jute bags.
- India's first-ever high quality Khadi Fabric Footwear was launched.
- 59 Textile Parks have been sanctioned under SITP by the Ministry of Textiles

A3.6.18 Wood & Products

Present Scenario

India's forest and tree cover stands at 24.4% of total land area. The population's large demand for wood and fuelwood is met from forest trees, tree plantations, farms, and private lands. The government has estimated the total growing stock at 5,822 million cubic meters (mcm), of which 4,218 mcm is inside the forests and 1,603 mcm outside. Indian industrial demand for wood also jumped from 85 mcm in 2008 to 180 mcm in 2019.

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Figure A3-38 Furniture Manufacturers in India

India cannot meet its own demand for wood products with domestic supply and hence is one of the leading import countries. Logs dominate wood imports, but are decreasing year on year and have come down from 83% to around 48% in last 10 years. Poor level of processing by domestic sawmills has brought down the production and increased the dependency on imports and a shift is taking place from logs to lumber. Major imported wood species are meranti, teak, and pine. Domestic farmed and plantation timber includes teak, eucalyptus, poplar, spruce, pine, and fir.

In 2010, the containerized trade volume for wood products was 72 million TEUs and in 2013, it increased to 120.2 million TEUs. In 2019, there was a substantial growth in containerized trade to bring the total for the year to 272 million TEUs. Imports of round logs constituted almost 30% of total imports and were valued at $637 million mostly from New Zealand (Radiata pine) and Malaysia (Meranti), followed by $367 million worth of teak logs from Ecuador, Costa Rica and African countries.

Indian wooden furniture industry is estimated to be worth US$ 5,358 million. In 2018, wooden furniture exports reached US$ 515.1 million showing a 6.5% CAGR for the past 5 years. India exports furniture to countries like United States, United Kingdom, Germany, France, among many others. Jaipur and Jodhpur have emerged as the Indian hub for solid wood furniture and the recent boom in online furniture retailing has also fuelled export growth.

Gujarat is Asia's largest timber hub since most of the mills are located near Kandla Port. 70% of country's timber gets imported through Kandla Port and is dispatched further to the Northern & Western states. Kandla usually imports 5000 containers of teak wood on a monthly basis, which is now reduced to 2,500 containers after 1st quarter of FY21 due to the pandemic's impact. Percentage-wise distribution of total country's production for Maharashtra is around 1.6% and Gujarat is around 0.5%. Percentage-wise distribution of total country's consumption for Maharashtra is 4.4% and for Gujarat it is 4.4%. Vadhavan is located in Maharashtra and includes both states of Maharashtra and Gujarat in its influence area. Timber hubs and furniture markets in Maharashtra and Gujarat can use Vadhavan port for imports and exports of wood and furniture products. Key Players in the Furniture Industry in India are as listed below;

- *National* - Godrej, Zuari, Durian, Nilkamal, Featherlite
- *International – IKEA, Wayfair*

Future Prospects

Indian Furniture market is expected to grow at 12.9% CAGR in the next 5 years based on incentives in the National Forest Policy. Landmark initiatives – such as 'Make in India', 'Ease of Doing Business', 'Start-Up India', 'Digital India' and 'Smart Cities' – will provide further impetus to industries in this sector.

Increasingly a large number of hotels are shifting to wooden floorings that are quick to install, and offer a lot of variety. Another potential segment is the Indian wooden handicrafts and furniture manufacturing with re-exports of value added products. Finally, the increase in the overall construction activities including large residential complexes, buildings under affordable housing schemes, business parks and recreational zones are also driving demand. These factors and the above initiatives are used to derive growth rates for trade of wood and furniture products in the following table. They also help in estimating traffic projections in million TEUs in the last year of a 5-year period.

Table A3- 42 Projections for Wood & Products

Year	Y-o-Y Growth Rates	Volume (million TEUs)
FY25	9%	434.3
FY30	9%	668.2
FY35	9%	1028.2
FY40	7%	1442.1
FY45	7%	2022.6
FY50	5%	2581.4

The table represents the growth assumptions for wood and furniture exports along with traffic projections for ports of Maharashtra and Gujarat. The growth rate is taken as 9% from FY25 to FY35 for a duration of 15 years. It is then reduced by two and estimated as 7% for the next 10 years from FY36 to FY45. During the last 5-year period, it is once again reduced to 5% for FY46-50. The trade for wood products in 2030 is expected to be 668.2 million TEUs. In 2040, it is anticipated that the trade volume would exceed 1000 to reach 1442.1 million TEUs. In 2050, the traffic projection is estimated at 2581.4 million TEUs.

Vadhavan is located at a distance of 380 miles from Kandla by sea. Wood imports and other wood products could be sent to Kandla using daughter vessels after large shipments are received from deeper draft mother vessels at Vadhavan. Imports could also be distributed to sawmills and manufacturing units located in Maharashtra and Southern Gujarat by road.

Wood is largely processed in the unorganized sector but larger design firms are increasing in number, to serve both the export and growing domestic market for wood furniture and interior items. Dual income earning households, larger disposable incomes and changing lifestyle trends is driving growth for luxury and imported goods including luxury furniture. Similarly, the penetration of e-commerce in rural and urban areas, is spurring demand from various sectors such as housing, furniture, hospitality and handicraft.

A3.7 GDP Correlation of Container Trade

A3.7.1 Macro-Economic Analysis

The table displays an overview of India's economic growth in the last 35 years. India's population was 1,366 million in FY19 and grew at a rate of 2% for the last 35 years. Its GDP in US$ was 2875 billion. It showed an average growth of 8% over the last 10 years, increasing to 10% over the last 20 years and then decreasing back to 8% for more than 30 years. Its GDP per capita was US$ 2104 and showed a 35-year CAGR of 6%. India's GDP per capita at Purchasing Power Parity (PPP) was US$ 7,034. It grew at a similar rate of 6% as its GDP per capita.

Table A3- 43 GDP growth rate

India	Year	Historic CAGR						
Lower middle income	**2019**	**5 Yrs.**	**10 Yrs.**	**15 Yrs.**	**20 Yrs.**	**25 Yrs.**	**30 Yrs.**	**35 Yrs.**
Population (million)	1,366	1%	1%	1%	2%	1%	2%	2%
GDP (current US$ Billion)	2,875	7%	8%	10%	10%	9%	8%	8%
GDP per capita (current US$)	2,104	6%	7%	8%	8%	7%	6%	6%
GDP per capita, PPP (current international $)	7,034	6%	6%	7%	7%	6%	Data Not Available	
Exports (BoP, current US$ Billion)	537	3%	7%	10%	13%	12%	11%	11%
National income (current US$ Billion)	2,543	8%	8%	10%	10%	9%	8%	8%
National savings (current US$ Billion)	564	4%	5%	9%	11%	10%	10%	11%
Container port traffic (TEU million) - 2020	17.3	9%	8%	10%	12%	11%	14%	12%

Considering trade, India's exports in 2019 were US$ 537 billion while its National Savings were US$ 564 billion. Both components rose at a historic CAGR of 11%. India's National Income was US$ 2,543 billion. It had a similar growth trend as India's GDP being 8% through the last 10 years, then increasing to 10% for 20 years and finally decreasing back to 8% for more than 30 years. Container port traffic in 2020 was 17.3 million TEUs. Over the last 35 years, it has incrementally grown at a rate of 12%.

A3.7.2 Container Trade GDP Correlation

Regression analyses of India's historic container trade has been made with the Gross Domestic Product (GDP). Equation describing container trade relation with the GDP has been generated. An analysis and co-relation of container trade with Merchandise trade was made. The result showed better co-relation with the GDP. The equation generated from Merchandise trade gave cyclist of trade resulting in instances of lower container trade with rising trade. Hence, GDP method of correlating container trade was found to be better suited for projecting India's by correlating it to GDP. One of the fundamental region for better correlation with GDP could be impact of contributions from services sector and agriculture sector. India' services sector contributes more than 50% to the GDP of country. Services sector impacts container trade as well. Population employed in services sector buys items of necessity and luxury imparted in containerised form using earnings from services sector. The IT sector with higher dominance in export of services imports electronic and computer hardware's in large volume. The population employed with the sector is considered financially well off. Hence, the contribution from services sector to container trade of India is high. Following figure shows co-relation between GDP of India with container trade.

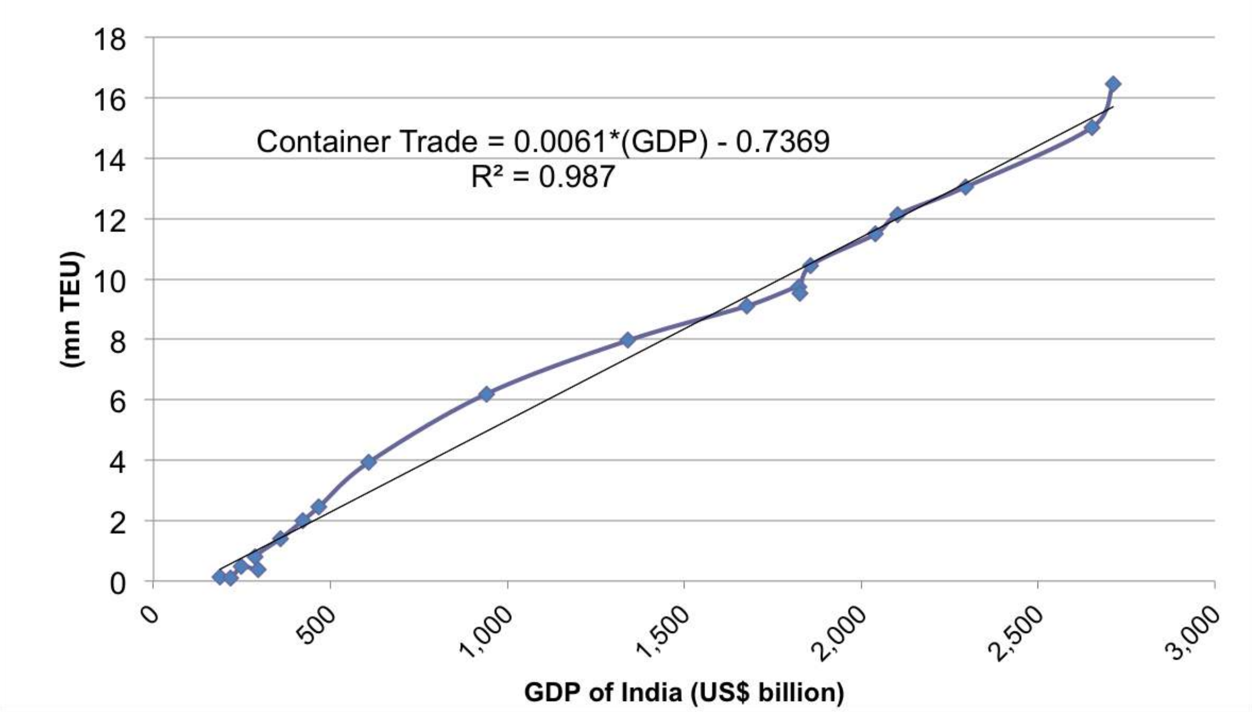

Figure A3-39 Equation deriving relation of Container Trade with GDP of India

Three scenarios of GDP have been analysed and factored in. India's GDP has been growing historically at the rate of 9% to 10%. Recent years have witnessed slight fall in the growth rates. It would be challenge to achieve consistent higher GDP growth for next 30 years. Rising GDP would also lead to higher absolute GDP leading to moderation of GDP growth.

Table A3- 44 Projection of India's container trade by co-relating with GDP

Container Traffic 'India'	2020	2025	2030	2035	2040	2045	2050
GDP '5%'	17.7	22.8	29.3	37.5	48.1	61.6	78.9
GDP '6%'	17.9	24.1	32.6	43.8	58.9	79.1	106.0
GDP '7%'	18.0	25.6	36.2	51.0	71.9	101.1	142.1

The following chart analyses country level Container trade with varying GDP from 5%, 6% and 7%.

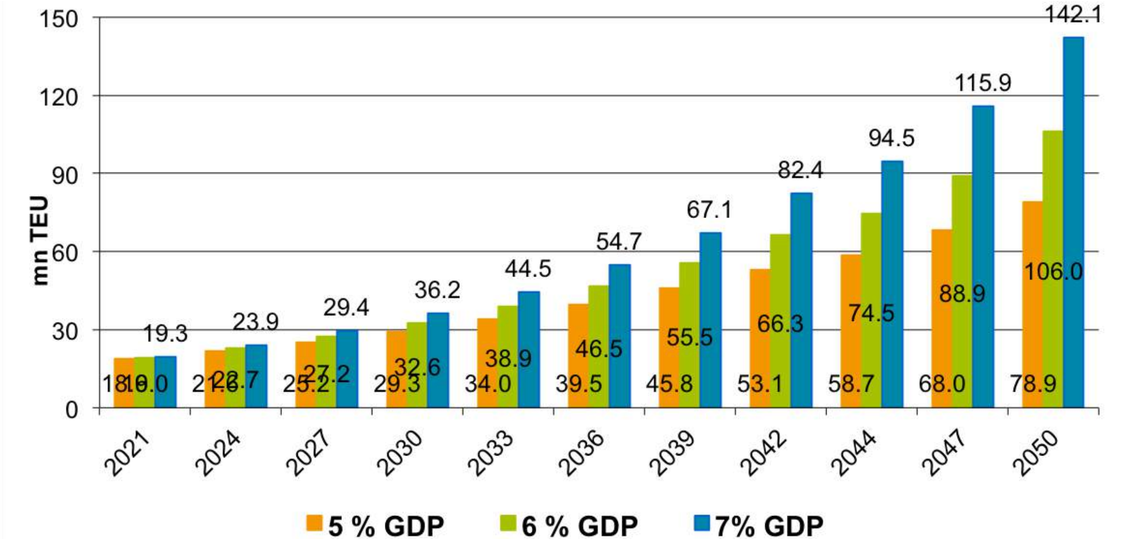

Figure A3-40 Projection of Container Trade of India correlating with GDP

The container trade of India would rise to 106 million TEU with 6% year on year GDP growth till 2050. An annual GDP growth of 6% for 30 years is likely. India has been growing at a higher GDP growth rate in recent past. The growth rate is likely to get moderated with rising GDP. Subsequent growth rates of future could be more rational leading to an average growth rate of 6% in long term future.

A3.8 Country Comparison

The table below shows country and region wise comparison based on container traffic, population and GDP per capita. The countries and regions selected include India, China, European Union, USA, Europe and Central Asia. This comparison shows how countries with population, container traffic, GDP per capita similar to India have grown their container trade in the past. China had a population and container volumes in 1995 similar to India. The GDP per capita of China in 1995 was around 35% of India's present GDP per capita. China achieved GDP per capita similar to India's GDP per capita of 2017 by the year 2017. European Union had a container volume of 17.8 million TEU in 1988 and it reached a container volume of 82 million TEU in 2008 and 105.6 million TEU in 2018.

Table A3- 45 Country Comparison of Historic Container growth over 30 years

	1988	1995	2005	2008	2015	2018	2019	2020
Container Traffic (million TEU)								
China	4.5	**17.6**	**90.1**	139.6	**195.3**	225.8	242.2	-
Europe & Central Asia	-	-	75.8	98.5	113.8	133.1	141.2	-
European Union	**17.8**	27.0	63.4	**82.0**	92.7	**105.6**	110.5	-
India	0.5	1.3	4.5	7.5	11.5	15.0	16.5	17.3
Population (million)								
China	1,102	1,205	1,304	1,325	1,371	1,393	1,398	1,404
Europe & Central Asia	833	855	871	881	907	918	921	924
European Union	418	426	436	440	445	447	448	448

India	837	964	1,148	1,201	1,310	1,353	1,366	1,380
GDP Per Capita (US$)								
China	284	**610**	**1,753**	3,468	8,067	9,977	10,262	-
Europe & Central Asia	8,578	12,690	19,222	26,415	22,552	25,171	24,696	-
European Union	**12,177**	19,464	27,331	36,912	30,474	35,660	34,843	-
India	354	374	715	999	1,606	2,006	**2,104**	2,153

Focusing on container traffic, China handled 17.6 million TEUs in 1995. In the next 10 years, China had a container traffic of around 90.1 million TEUs in 2005 nearly 5 times its previous value. After another 10-year leap, China's container traffic had risen to 195.3 million TEUs in 2015 increasing by more than 100 million TEUs. The European Union has also shown impressive growth from 17.8 million TEUs in 1988 to 105.6 million TEUs in 2018.

Looking at these numbers, it is not too far-fetched to believe that India too is capable of achieving such enormous growth in container traffic. India currently has a pan India container traffic of 17.3 million TEUs in 2020. A number of different policies such as the introduction of the Goods and Services Tax (GST), the Insolvency and Bankruptcy Code, path-breaking reforms in the labour sector, an enabling and investor-friendly FDI Policy, and various national programmes like Atmanirbhar Bharat, make in India, Digital India, Startup India and Skill India have brought about rapid transformation across trade in various sectors. Assuming a healthy level of growth in container traffic due to these factors, it is possible to achieve an All India container traffic of 65 million TEUs in 2030 and 100 million TEUs by 2050. Similar numbers have been derived under the Realistic Scenario for the Container Trade Projections.

The GDP per capita of China has more than tripled from US$ 610 in 1995 to US$ 2099 in 2006 in an interval of 10 years. Similarly, the European Union's GDP per capita has grown from US$ 12,177 in 1988 to US$ 35,660 in 2018 – more than 3 times in a period of 20 years. Both the increments in container traffic and GDP per capita show a similar pattern of growth for the regions of China and European Union. India had a GDP per capita of US$ 2104 in 2019 and it has undergone a number of economic and technological advancements that are bound to increase its GDP over a span of 30 years.

A3.8.1 Per Capita Container Trade in India

The table displays macro-economic factors for BRIC countries, developed nations and countries from South Asia. The factors include GNI per capita, GDP per capita, container trade and container per capita.

Table A3- 46 Country Comparison of Macro & Container Trade parameters

Region	Category	Population (Mn)	GDP (US$ Bn)	GNI Per Capita (US$)	GDP Per Capita (US$)	Container Trade (mn TEU)	Container per Capita (TEU)
BRIC							
Brazil	UMI	209	1,869	9,140	8,943	10.3	0.05
Russia	UMI	144	1,658	10,230	11,514	6.3	0.04
India	LMI	1,353	2,719	2,020	2,010	16.4	0.01
China	UMI	1,393	13,608	3,542	9,769	225.8	0.16

Region	Category	Population (Mn)	GDP (US$ Bn)	GNI Per Capita (US$)	GDP Per Capita (US$)	Container Trade (mn TEU)	Container per Capita (TEU)
Developed Nations							
United States	HI	327	20,544	6,308	62,826	54.7	0.17
United Kingdom	HI	66	2,855	41,770	42,997	11.7	0.18
Iran	UMI	82	454	5,470	5,550	2.4	0.03
Saudi Arabia	HI	34	786	21,600	23,393	8.7	0.26
Countries in South Asia							
Sri Lanka	UMI	21.6	89	4,060	4,116	1.4	0.06
Bangladesh	LMI	161	274	1,750	1,702	2.8	0.02
Myanmar	LMI	53.7	71	1,310	1,326	1.3	0.02

Note: HI: High Income; LMI: Lower Middle Income; UMI: Upper Middle Income

Among the BRIC group, Brazil, Russia and China fall under the upper middle income category. India is the only country under lower middle income category from the BRIC. India has a low GNI per capita of US$ 2,020 and the least Container per capita of 0.01 TEU (1 container per 100 people). Brazil has a GNI per capita of US$ 9140 and a Container trade per capita of 0.05 TEU. China has a slightly higher GNI per capita of US$ 3542 but the third highest container per capita of 0.16 TEU. In the same group, Brazil and Russia have comparatively higher GNI per capita than both India and China.

Currently, India's population is comparable to China and 6 times that of Brazil. Its GDP per capita is 20% of China and 24% of Brazil while its GNI per capita is 50% of China and 22% of Brazil. India's container traffic per capita is just 7% of China and 25% of Brazil. The GDP of India is expected to rise due to a number of policies brought forth by the Government. As GDP of India increases, its trade, GNI per capita and GDP per capita would rise proportionally.

If India is able to increase its container traffic per capita from 0.01 TEU to 0.06 TEU, it will break through to an upper middle income category which will lead to a sustainable cycle of growth for India's trade, GDP and GNI in comparison to its growing population. Assuming 6 containers per 100 people in the future, an increase from 17.3 million TEUs in FY20 to 103.8 (17.3 * 6) million TEUs beyond FY50 seems completely feasible. Moreover, under an Optimistic scenario it would be possible for India to reach higher container trade per capita numbers of 0.10-0.12 TEU. This would accelerate its entry into the upper echelons of the income category.

A3.9 Extrapolation of Historic Container Trade

A3.9.1 Historic container growth

Following table describes historic growth of containers at Indian ports. The historic growth has been evaluated for all India cumulative container throughput at container ports as well as region wise container throughput.

Table A3- 47 Region wise Historic Growth of Indian Container Trade

Region	FY20 (mn TEUs)	Historic Container Trade Growth Rate (CAGR)						
		5 Yrs.	10 Yrs.	15 Yrs.	20 Yrs.	25 Yrs.	30 Yrs.	35 Yrs.
North & West India	11.9	9%	9%	10%	12%	12%	18%	13%
North & East India	0.7	13%	9%	10%	10%	9%	10%	9%
South India	4.9	9%	8%	9%	12%	11%	10%	12%
All India	**17.3**	**9%**	**8%**	**10%**	**12%**	**11%**	**14%**	**12%**

The overall container trade growth for India in last 35 years has remained above 9%. The cumulative long-term CAGR growth has always remained witnessed a double-digit growth rate. The North and West part of India forming major hinterland of Vadhavan port grew by 9% CAGR for last 10 years. The growth of North and West coast of India was above 10% for 15 years and above 12% for last 20 years.

The historic long-term growth of container trade in India was substantially higher and hence been ignored for future projections. The historic longer term growth rate has been ignored on account of lower base effect. The overall container growth at individual regions as well as cumulative all India basis remained robust and sustainable in the past. The future growth of containers is likely to be driven by same historic dynamics leading to similar growth rates in future.

A3.9.2 Historic Market Share of Container Trade

The port distribution of container traffic in India has historically remained consistent. North and West region of India has dominated traffic share followed by South India. North and East India had minimal share among the three. Following table broadly describes historic container trade distribution between different regions on the coast of India.

Table A3- 48 Region wise Distribution of Indian Container Trade

Geography	Fy00	Fy02	Fy04	Fy06	Fy08	Fy10	Fy12	Fy14	Fy16	Fy18	Fy20
North West India	65.4%	67.8%	68.1%	66.8%	69.5%	67.6%	66.9%	68.6%	68.3%	66.9%	67.0%
South India	27.4%	24.9%	24.7%	25.8%	23.9%	24.9%	24.9%	23.4%	23.8%	25.2%	25.1%
North East India	7.3%	7.3%	7.2%	7.4%	6.6%	7.5%	8.1%	8.0%	7.9%	7.9%	7.9%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

As can be seen in the above table, North and West India historically, had higher share of container port traffic. This has primarily been due to better connectivity of North and Western India to the landlocked Northern hinterland along with lower deviation of shipping line.

Large Share of Indian Population staying in landlocked North & Central India, that could be accessed using ports located in Gujarat, Maharashtra and East Coast. East Coast of India lacks suitable connectivity for container transportation along with longer distance from trading routes. Hence, majority of the population residing in the landlocked North and Central India are dependent on container ports of Gujarat and Maharashtra for trade.

Ports located in South and East India has higher share of containers handled using Transshipment Terminal compared to North and West India. This zone handles disproportionately higher share of containers compared to other parts of India due to better infrastructure, inland connectivity and location of ports in the vicinity of Shipping routes. Reasonable assumptions have been considered in projections to factor in future variations in market share due to development of infrastructure in other parts of Indian Coast.

North and West India falls in the mainland trading route of Container Shipping lines. This has led to large volume of container fleet deployed in the trading zone passing by West Coast of India. Large fleet and container slots deployment on the trading zone lead to availability of higher capacity. Higher capacity and multiple vessels deployment along with lower deviation cost enable shipping line offer far lower tariff for picking up containers from the ports located on West Coast of India compared to East Coast of India. This is one of the primary reason why containers from landlocked areas equidistant from East Coast and West Coast ports prefer to use North and West coast port for trade. There are several districts and Industrial parks located in Uttar Pradesh, Madhya Pradesh and other central India that are closer to container ports of East Coast of India. However, they use ports on the West Coast for their container trade facilitation.

Figure A3-41 Region wise Distribution of Indian Container Trade

Large scale infrastructure and connectivity development is underway on Eastern and Central part of India. These infrastructure developments by government and private sector is likely to improve connectivity between East Coast ports with the hinterland. Better connectivity is likely to improve turnaround of container on the inland movement along with reduction in logistics cost of inland container transportation. This is likely to overall reduce inland transportation cost of containers to East Coast port, container handling cost at the East Coast as well. Even though the performance efficiency of Inland Container transport improves for East Coast ports, the North and West Coast container ports are likely to keep higher market share due to impact of lower shipping tariffs. Hence, the infrastructure argumentation on the east coast is unlikely to deter share of containers between different regions of India. The market shares for container ports and their respective regions is likely to remain same in future. It has been assumed that the strategic importance of ports closer to mainline routes would have dominance in future as well. Hence, Container ports located on the North and West India will continue to have higher market share compared to ports located on the other geography. Following table describes region wise distribution of container projection in various scenarios.

Table A3- 49 Projections for Region wise distribution of Indian Container Trade

Region	5 Yrs.	10 Yrs.	15 Yrs.	20 Yrs.	25 Yrs.	30 Yrs.
Pessimistic						
% Share (North West)	67.0%	66.0%	65.0%	63.5%	63.0%	63.0%
% Share (North East)	8.0%	8.5%	9.0%	10.0%	10.5%	10.5%
% Share (South India)	25.0%	25.5%	26.0%	26.5%	26.5%	26.5%
Realistic						
% Share (North West)	67.0%	67.0%	66.5%	66.0%	65.0%	64.0%
% Share (North East)	8.0%	8.0%	8.0%	8.5%	9.0%	9.5%
% Share (South India)	25.0%	25.0%	25.5%	25.5%	26.0%	26.5%
Optimistic						
% Share (North West)	67.0%	67.0%	67.0%	68.0%	69.0%	70.0%
% Share (North East)	8.0%	8.0%	8.0%	8.0%	7.5%	7.0%
% Share (South India)	25.0%	25.0%	25.0%	24.0%	23.5%	23.0%

There is larger emphasis by Government of India to improve connectivity of Eastern India along with development of new port infrastructure in the region. The infrastructure and connectivity development on the east coast of India might divert some of the containers presently using ports of Maharashtra and Gujarat. Hence, the pessimistic scenario assumes that there will be substantial improvement in the inland container infrastructure and port infrastructure on the East Coast of India leading to about 2.5% diversion of containers to North and East India. Since, overall container logistics and end to end container transportation cost is influenced by shipping lines, it is unlikely to impact beyond 2.5%.

The optimistic scenario assumes that ports in Gujarat and Maharashtra would become more efficient with time. The connectivity infrastructure of Gujarat and Maharashtra towards northern hinterland is likely to further improve transportation productivity leading to lower logistics cost. Hence, the market share of container ports in Gujarat and Maharashtra would further rise to about 70% by the year 2050.

The realistic scenario assumes marginal shift in containers from Gujarat and Maharashtra ports to North and East Coast and South coast. The share of containers handled at ports of Gujarat and Maharashtra would fall from 67% presently to around 64% in the year 2050. The fall in containers market share in Gujarat and Maharashtra by 3% would lead to gain in market share at ports in other region. The realistic scenario is most likely to be achieved in future. Hence, realistic scenario assumption has been taken to arrive at the traffic volume at Vadhavan.

Royal HaskoningDHV

JNPA

A3.9.3 Future Container Growth

Future growth of container in India would be linked to the overall growth of country. It would have influence of the historic growth achieved during previous years. The underline factors influencing the historic growth of container trade in India remains intact in today economic environment. The economic condition of India and general growth is likely to remain intact in future as well leading to robust container growth in future. Following table summarises historic container trade growth in last 35 years. Container volumes at Indian ports was minuscule prior to that.

Table A3- 50 Region wise Historic Growth of Indian Container Trade

Region	FY20 (mn TEUs)	Historic Container Trade Growth Rate (CAGR)						
		5 Yrs.	10 Yrs.	15 Yrs.	20 Yrs.	25 Yrs.	30 Yrs.	35 Yrs.
North & West India	11.9	9%	9%	10%	12%	12%	18%	13%
North & East India	0.7	13%	9%	10%	10%	9%	10%	9%
South India	4.9	9%	8%	9%	12%	11%	10%	12%
All India	**17.3**	**9%**	**8%**	**10%**	**12%**	**11%**	**14%**	**12%**

Analysis of long term growth provides long term sustainability of economy and container growth. It also mitigates temporary cyclicity of the economy and container trade. The future container trade growth would be moderate compared to historic trade growth due to change in base of the container volumes. India's container trade has been addicting on an average about 1.1 million TEU containers in last 5 years, around 0.9 million TEU in last 10 years, 0.8 million TEU in last 15 years and 0.7 million TEU in last 20 years. The growth of containers volume in absolute numbers have kept increasing despite rise in the absolute container volumes every year. This has been a good sign. It is likely continuing in future. Following table projects growth of container trade of India till 2050 at every 5 years' intervals.

Table A3- 51 All India container growth rate in future

Region	5 Yrs.	10 Yrs.	15 Yrs.	20 Yrs.	25 Yrs.	30 Yrs.
Pessimistic	8.0%	6.0%	5.0%	4.0%	3.0%	3.0%
Realistic	8.0%	7.5%	7.0%	6.0%	5.0%	4.0%
Optimistic	8.0%	8.0%	7.5%	7.0%	6.0%	5.0%

Cumulative container volume growth is expected to be 8% CAGR for next 5 years. The growth rate is likely to moderate to 6% GAGR in pessimistic scenario, 7.5% CAGR in the realistic scenario. Pessimistic scenario could be an outcome of India entering a recessionary phase with economic stagnation. Realistic scenario has higher prospects of realisation. Optimistic scenario would occur in case India enters a stage of very high growth.

	2020	2025	2030	2035	2040	2045	2050
Pessimistic	17.3	24.9	33.0	41.7	50.3	58.3	67.6
Realistic	17.3	25.3	36.1	50.2	66.5	84.0	102.3
Optimistic	17.3	25.4	37.1	53.0	73.7	97.7	124.7

The cumulative container traffic of India would get distributed in the region as described in previous sections. The ratio of container traffic distribution between various regions would primarily follow historic distribution share. Vadhavan falls in Maharashtra. The share of container traffic at Vadhavan would be arrived at distribution of container traffic among the ports of Gujarat and Maharashtra. Container traffic at Vadhavan would be a derived on account of following 2 aspects

- Shift of containers to Vadhavan port from existing container ports on account of better infrastructure and cost savings
- Spill over container trade on account of capacity saturation at container ports of Gujarat and Maharashtra.

A3.10 Container Port Capacity – North West India

Vadhavan port would cater to the spill over containers that existing ports are not able to handle. It would also divert some of the containers from existing ports based on the competitive advantage including logistics cost and time. This section analysis capacity augmentation plans of all the container ports in the North West India including Vadhavan port.

A3.10.1 Capacity of Container Ports - Gujarat

Gujarat presently has 4 container ports namely Mundra, Pipavav, Hazira and Kandla. Kandla Port is a major port with a small container terminal that acts as a feeder container terminal. Restriction of water depth, availability of at port and cargo focus restricts competitive advantage for the port. Kandla Port, moreover, has been a bulk port with major focus on dry bulk and liquid cargo. Hence, developing a large scale container terminal competitive enough to Vadhavan is unlikely at Kandla.

The other 3 non-major container terminals in Gujarat includes Mundra, Pipavav and Hazira. These have been developed based on Model concession agreement with government of Gujarat. These concession agreements are likely to expire in 2028 for Pipavav Port, 2031 for Mundra port and 2035 for Hazira port. The traffic study report and analysis by Ernest Young found limited for scope of extension of concession agreement. The ports did ask for a 20-year extension of concession agreement. There has been no confirmation by GMB on this effect. Hence, it has been assumed that the possible extension of concession agreement for these 3 container ports would either not happen or would be provided closer to the end of concession period. All the three ports would undertake their future expansions of infrastructure beyond 2028 and only after getting firm confirmation from Gujarat Maritime Board about extension of concession agreement.

As per APMT annual report and as per generally published data, the present capacity of Pipavav port is around 1.35 million TEU. The company has not declared any plans for expansion of its infrastructure or augmentation of container handling capacity. Hence, it has been assumed that the port would augment its capacity beyond renewal of concession agreements.

Mundra Port has an annual container handling capacity of 6 million TEUs. The port is undergoing expansion of container terminals. It is estimated to have an ultimate container handling capacity of around 8 million TEU. The port would not expand its capacity further on account of its concession term expiry by 2031. Hence, all capacity expansion plans of Mundra Port would get implemented beyond 2035 after the concession agreement of Mundra port is either extended to the existing port operator or new operator.

Hazira port has 2 container berths, 2 liquid berths and 2 dry bulk berths. Hazira port is presently constructing additional berth to augment liquid handling capacity. Following map of Hazira port indicates provision for development of 2 additional container terminals to the South of Existing container terminals. Addition of additional container terminals would add to the container capacity of around 1.6 million TEU.

Hazira port is planned to be connected to Dedicated Freight Corridor (DFC) as part of SagarMala initiatives. Hazira region is industrialised. There is limited space for creation of DFC. The DFC is likely to be elevated leading to large investment and delay. Hazira is expected to add additional capacity of 1.5 to 1.6 million TEU as its final expansion capacity. In view of the same, and considering that railway connectivity is being contemplated under SagarMala and proposed to be developed jointly with state government, it is assumed that the rail connectivity would come up in the next 4-5 years and another two container berths could be developed leading the maximum capacity to 3.0 million TEU.

Other proposed ports of Gujarat namely Nargol Port & Dahej (Sterling) Port: These are two ports that were in very advanced stage of development a few years back. Both the projects are understood to have been shelved. Nargol project was awarded to a consortium of developers more than 8 years back. The developers could not take up this project to development and commissioning stage. Sterling port at Dahej too is shelved. There are no other ports planned to be developed in South Gujarat.

A3.10.2 Capacity of Container Ports – Maharashtra

Maharashtra has 2 Major ports and several non-major ports. Major ports JNPA and MbPT handled containers. However, with time all containers trade of Maharashtra has shifted to JNPA and MbPT is dependent on Feeder option with JNPA (Across creek movements).

JNPA has infrastructure and waterfront limitations. The port is unlikely to expand in a big way post implementation 4th container terminal. Development plans for creating 5th container terminal is at conceptualisation stage. It has been assumed that location constraints, scalability of inland connectivity infrastructure to handle container volumes of 5th container terminal would make the project commercially unviable. City is growing around JNPA at a fast pace. This would lead to further congestion on inland connectivity from JNPA to hinterland. Hence, commissioning of development and commissioning of the 5th container terminal is unlikely to be realised. The Capacity of JNPA Container terminals would be capped post implementation of phase-II expansion of Terminal 4.

Mumbai Port would have feeder movement across channel to support consumption on the Island city. There is no scope for further expansion of port infrastructure for container handling. Hence, the container handling capacity of Mumbai Port has been retained at 0.2 million TEU.

Other ports proposed in Maharashtra namely Rewas, Dighi and Jaigarh were envisaged for large scale development. Rewas port is believed to be shelved. The port with Reliance Industries as primary promoter has not taken any development steps even after around 15 years of its conceptualisation and media reporting. The other 2 ports namely Dighi and Jaigad were developed at some stage. However, both the ports are in no stage of creating large container terminal that would challenge competitiveness of either JNPA or upcoming Vadhavan port. Dighi port is suffering from severe evacuation issue due to lack of proper inland connectivity. Jaigad port has primarily become a bulk port. The location of port limits container prospects due to limited market in immediate hinterland and large distance from major container consumption areas.

A3.10.3 Cumulative Container Capacity

Following table broadly summaries capacity augmentation plans of all the container ports in North West India.

Table A3- 52 Container Port Capacity in North West Indian Ports

Port Capacity (nm TEU)	Fy-20	Fy-25	Fy-30	Fy-35	Fy-40	Fy-45	Fy-50
Mundra	7.5	7.5	8.0	10.0	10.0	10.0	12.0
Kandla	0.6	0.6	0.6	0.6	1.0	1.0	1.0
Pipavav	1.4	1.4	1.4	2.0	2.0	3.0	3.0
Hazira	1.6	3.0	3.0	3.0	3.0	3.0	3.0
Jawaharlal Nehru	7.2	10.0	10.0	10.0	10.0	10.0	10.0
Mumbai	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Vadhavan	0.0	2.0	7.4	16.8	24.0	35.0	41.0
Total	**18.5**	**24.6**	**30.5**	**42.6**	**50.2**	**62.2**	**70.2**

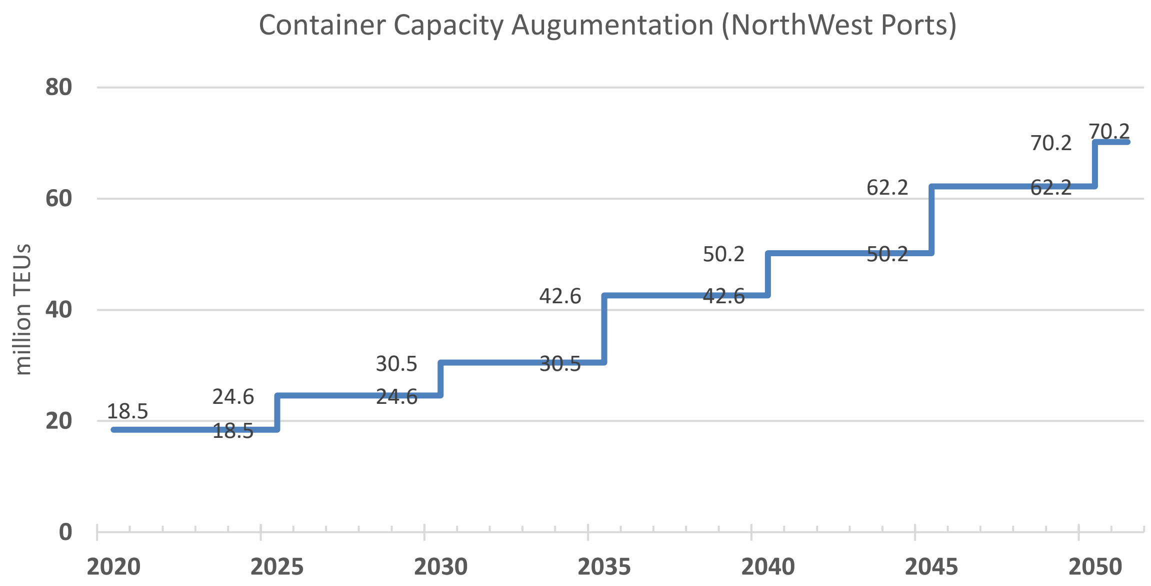

Figure A3-42 Cumulative Container Capacity in North-West India (million TEUs)

A3.11 Container Trade Projection for Vadhavan

Vadhavan is envisaged to be a container and clean cargo port. Container traffic is likely to dominate ports business. The infrastructure and equipment for container handling are specialised and can rarely be used for handling other commodities. Multiple methods of traffic analysis and projection for Vadhavan has been undertaken. Following are broad methods used in traffic projections of Vadhavan.

- Commodity wise detailed projection of containerised cargo of North and West India region
- Country comparison
- Extrapolation of historic trade
- Co-relation with GDP growth

The container projection arrived using above methods for India is distributed in the region. Market share for Vadhavan is arrived based on the capacity constraints at existing ports in North and West India region (Gujarat and Maharashtra).

A3.11.1 Container Projections for India

The section summarises container trade projections under pessimistic, realistic and optimistic scenario. All three scenarios have been applied to All India traffic, North West traffic and Vadhavan port traffic. The Pessimistic Scenario considers unfavourable conditions for the growth of container traffic leading to lower growth of container traffic at Indian ports. The Realistic Scenario takes into account factors are likely to retain present economic and container growth in India and its favourable impact on the container trade. The Optimistic Scenario considers highly favourable conditions for the growth leading to very high container traffic in India.

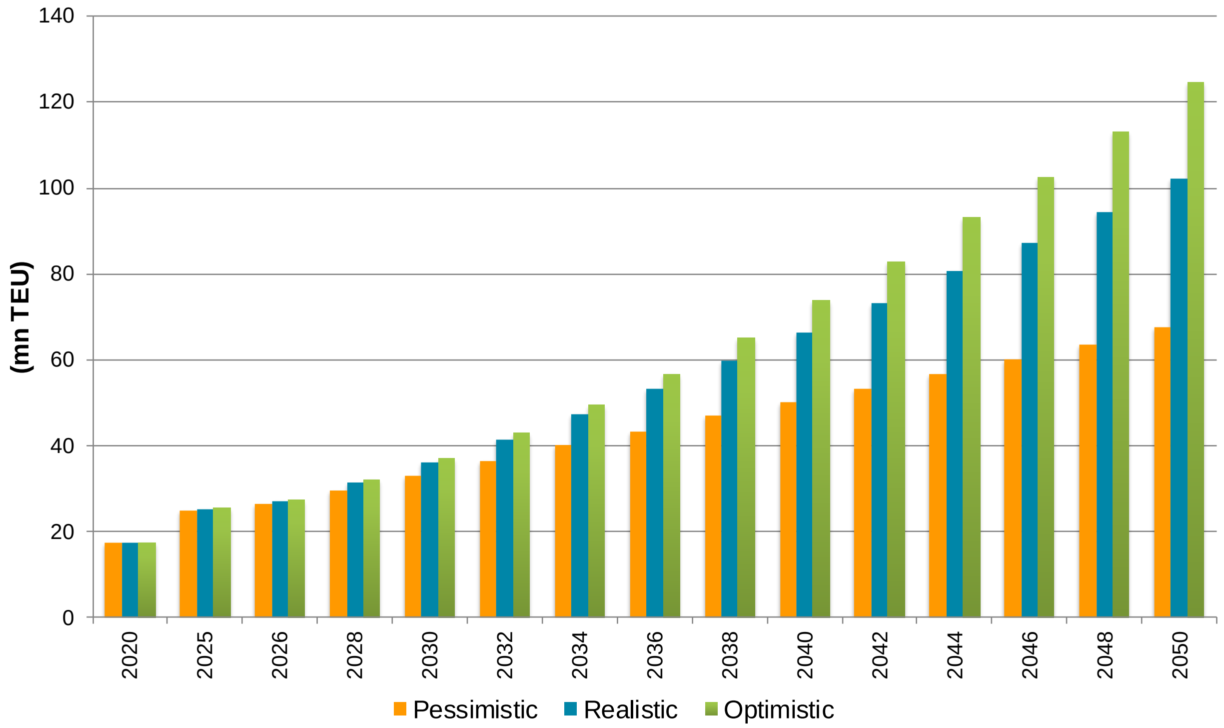

Figure A3-43 All India Container Trade Projections under Different Scenarios

The table above derives Vadhavan port's traffic from All India Container Projections. The container traffic in pessimistic scenario is likely to rise to 24.9 million TEU in 2025 and 67.6 million TEU in 2050. The realistic scenario is likely to achieve a traffic of 102.3 million TEU in the 2050. The optimistic scenario is likely to witness traffic growth to 124.7 million TEU in 2050.

A3.11.2 Container Projections for Vadhavan

Historic contribution of traffic from North West India has been used to arrive at cumulative container traffic volumes at North and West India. The region is likely to witness a container traffic of 43.3 million TEU by 2050 in pessimistic scenario, 65.4 million TEU by 2050 in realistic scenario and 83.5 million TEU by 2050 in optimistic scenario.

Potential container traffic at Vadhavan has been summarised in above table. Vadhavan is likely to achieve traffic share of realistic scenario. The port is projected to generate a traffic of 0.9 million TEU in the year 2025. The traffic would rise to 23.2 million TEU in the year 2040 and 39.4 million TEU in the year 2050. Following figure shows projected container traffic at Vadhavan in 3 scenarios.

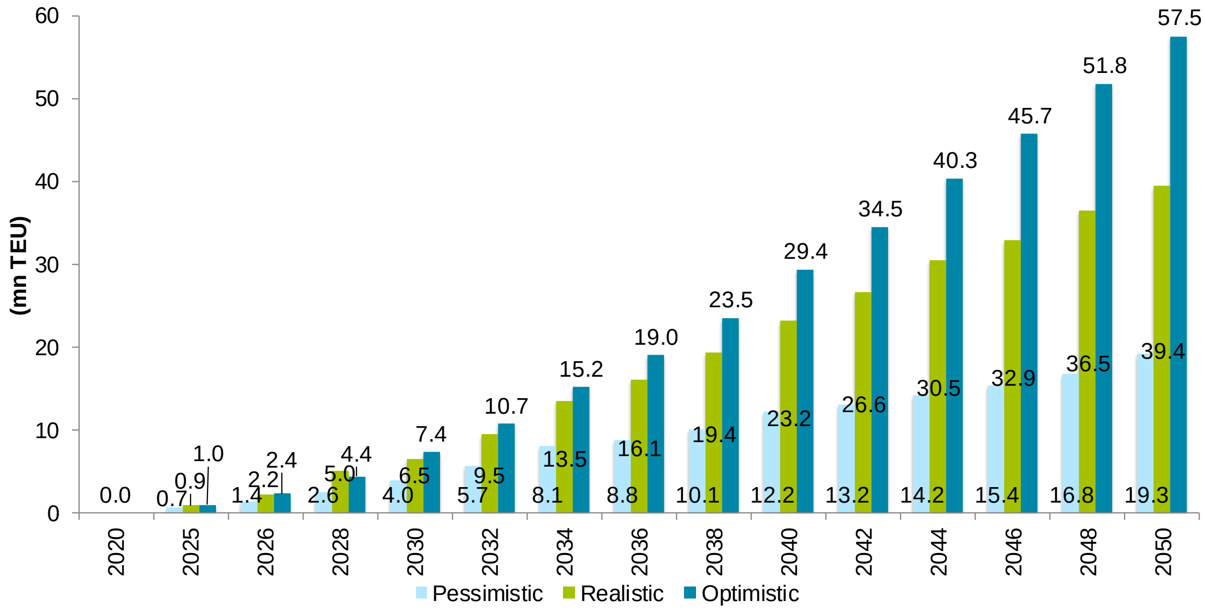

Figure A3-44 Container Traffic Projections for Vadhavan Port under Different Scenarios

Following table summarises traffic of Vadhavan with respect to North West India traffic and all India traffic in various scenario.

Table A3- 53 Derivation of Vadhavan Port's Traffic from All India Container Projections

India Traffic	2020	2025	2030	2035	2040	2045	2050
All India							
Pessimistic	17.3	24.9	33.0	41.7	50.3	58.3	67.6
Realistic	17.3	25.3	36.1	50.2	66.5	84.0	102.3
Optimistic	17.3	25.4	37.1	53.0	73.7	97.7	124.7
North West Traffic							

Pessimistic	11.6	16.7	21.5	26.7	32.2	37.3	43.3
Realistic	11.6	16.9	24.0	33.1	43.2	53.8	65.4
Optimistic	11.6	17.0	24.9	35.5	49.4	65.5	83.5
Vadhavan							
Pessimistic	0.0	0.7	4.0	7.7	12.2	14.8	19.3
Realistic	0.0	0.9	6.5	14.1	23.2	31.3	39.4
Optimistic	0.0	1.0	7.4	16.5	29.4	43.0	57.5

A3.12 Evaluating Transhipment Prospects

Vadhavan port is proposed as a deep draft port falling in trade route. The port largely meets infrastructure requirements of developing a transshipment terminal. This section evaluates prospects for handling transhipment container volumes at Vadhavan port for Indian feeder ports as well as international feeder ports.

Container shipping lines would follow Hub and Spoke model to optimize containerize cargo trade. The Hub acts as the large deep draft container transshipment terminal and the Spokes act as routes towards other smaller terminals. Mainline vessels ply between different Hubs with a large volume of containers. Feeder vessels connect hubs to smaller ports called feeder ports. Vadhavan port (Hub Port) would need Feeder Port) spokes for it to act as transhipment terminal as depicted in the figure below.

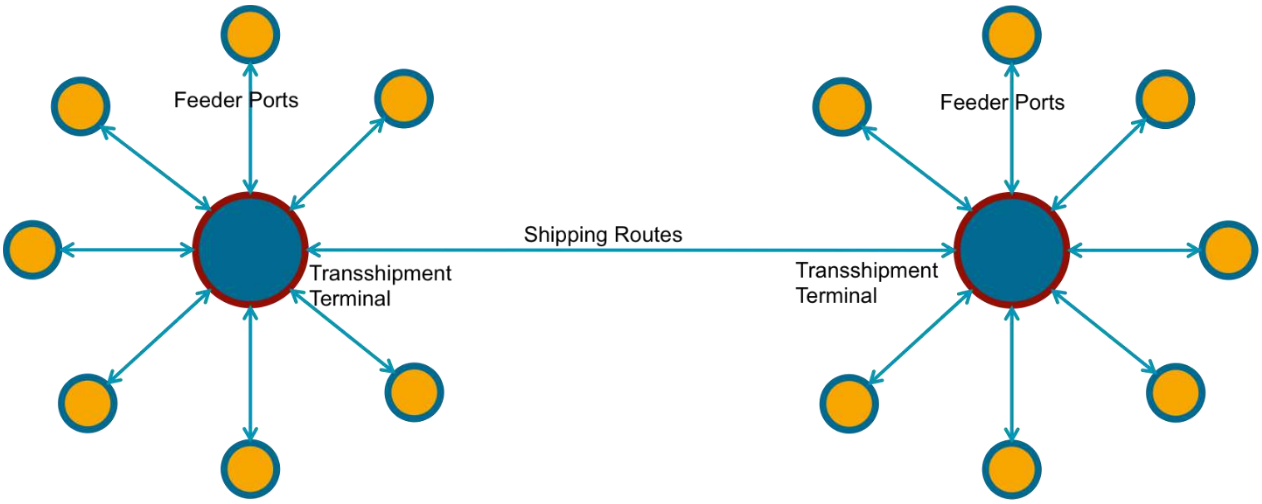

Figure A3-45 Transhipment Business from the perspective of Hub-Spoke model

The purpose of mainline vessels and feeder vessels in container transportation economics is to minimise overall cost of container transportation. Mainlines use transhipment terminals as intermediary aggregation point for ports that has lower depth, is away from their route or has lower volume to justify ship calls by a large container ship. The choice of transshipment terminal is decided based on volume of container likely to be offloaded along with feeder port distance from the transshipment terminal. Vadhavan port has the infrastructure that could act like a transshipment terminal. The positioning of Vadhavan port along with market dynamics of the region does not provide ample opportunity of Transhipment at Vadhavan Port. Following are 2 primary factors that would restrict transhipment prospects for Vadhavan Port.

- Prospects with Indian Feeder Ports : Divert India's containers transhipped at international transhipment terminals to Vadhavan Port
- Prospects with International Feeder Ports : Compete with International transhipment terminals for international market

The economics of transshipment and feeder terminal has largely changed due to rising size of mother vessel to ships of more than 20,000 TEU and feeder vessel sizes to ships in the range up to 8000 TEU

A3.12.1 Prospects with Indian Feeder Ports

The transshipment volumes declared by major ports of India has been summarised in the following table. It can be noticed that large ports located on the West Coast of India have fairly minimal share to transshipment terminal. The statistics excludes private port as they have not declared their detailed breakup of containers. It is assumed that private ports too would follow similar pattern.

Table A3- 54 Containers Handled at Major Ports of India (Lakhs TEUs)

Port	Transshipment						Coastal	Direct	Total
	Singapore	Klang	Colombo	Jebel Ali	Others	Total			
Kolkata	2.39	1.34	1.85	-	1.10	6.68	0.07	-	6.72
Haldia	0.28	0.18	0.56	-	0.01	1.02	0.67	-	1.69
Paradip				-		-	0.12	-	0.12
Visakhapatnam	0.64	0.88	1.34	-	1.34	4.20	0.38	0.46	5.04
Kamarajar				-		-	0.04	1.27	1.31
Chennai	1.12	0.25	2.27	0.07	4.14	7.85	0.72	5.27	13.84
V O Chidambaranar		0.12	5.43	0.05	0.20	5.80	1.66	0.58	8.04
Cochin	0.01	0.10	1.48	0.47	0.25	2.31	3.26	0.63	6.20
New Mangalore	-	-		-		-	1.53	-	1.53
Mormugao	-	-	0.24	-		0.24	0.07	-	0.32
Mumbai	-	-	-	-		-	0.26	0.01	0.27
JNPA	-	-	-	-		-	-	-	
- JNPCT	0.00	0.02	0.00	0.01	0.56	0.08	0.03	7.08	7.19
- NSICT	0.00	0.00	0.00	0.01	0.12	0.13	0.03	5.15	5.31
- GTIPL	0.08	0.01	0.03	0.03	0.17	0.31	0.17	19.37	19.85
- NSIGT	-		0.00	0.00	0.11	0.11	0.08	9.67	9.87
- BMCT	0.00	0.00	-	0.00	0.21	0.22	0.05	7.82	8.09
Deendayal			-		0.40	0.40	3.67	0.40	4.47

Port	Transshipment						Coastal	Direct	Total
	Singapore	Klang	Colombo	Jebel Ali	Others	Total			
Total	4.52	2.89	13.19	0.64	8.11	29.35	12.81	57.72	99.89

As can be seen that majority of the transshipment happen in the southern ports and ports located on the east coast. Prominent ports with large volume including private terminals of JNPA have higher share of direct ship calls. The mainline vessels with larger ships sizes would begin to call to Vadhavan port after its development. The scale and volume at which the port is planned would require multiple visits by largest container ships on a weekly basis. In such a scenario, there would not be any need for double handling by way of transshipment terminal for container is destined to North-West India. The mainline vessels would find it cost-effective to call directly to Vadhavan. It would be faster and cost-effective to evacuate those containers using land route than follow coastal route. Hence there would not exist any opportunity for transhipping Indian containers at Vadhavan.

A3.12.2 Prospects with International Feeder Ports

Vadhavan port competing with establish transshipment terminal of Jebel Ali and others to targeting feeder port of Gulf countries violates the ideal Hub and Spoke model of supply chain. The feeder ports have to act like to spokes of bicycle wheel for efficient transhipment dynamics. Following figure provides the detailed explanation for same.

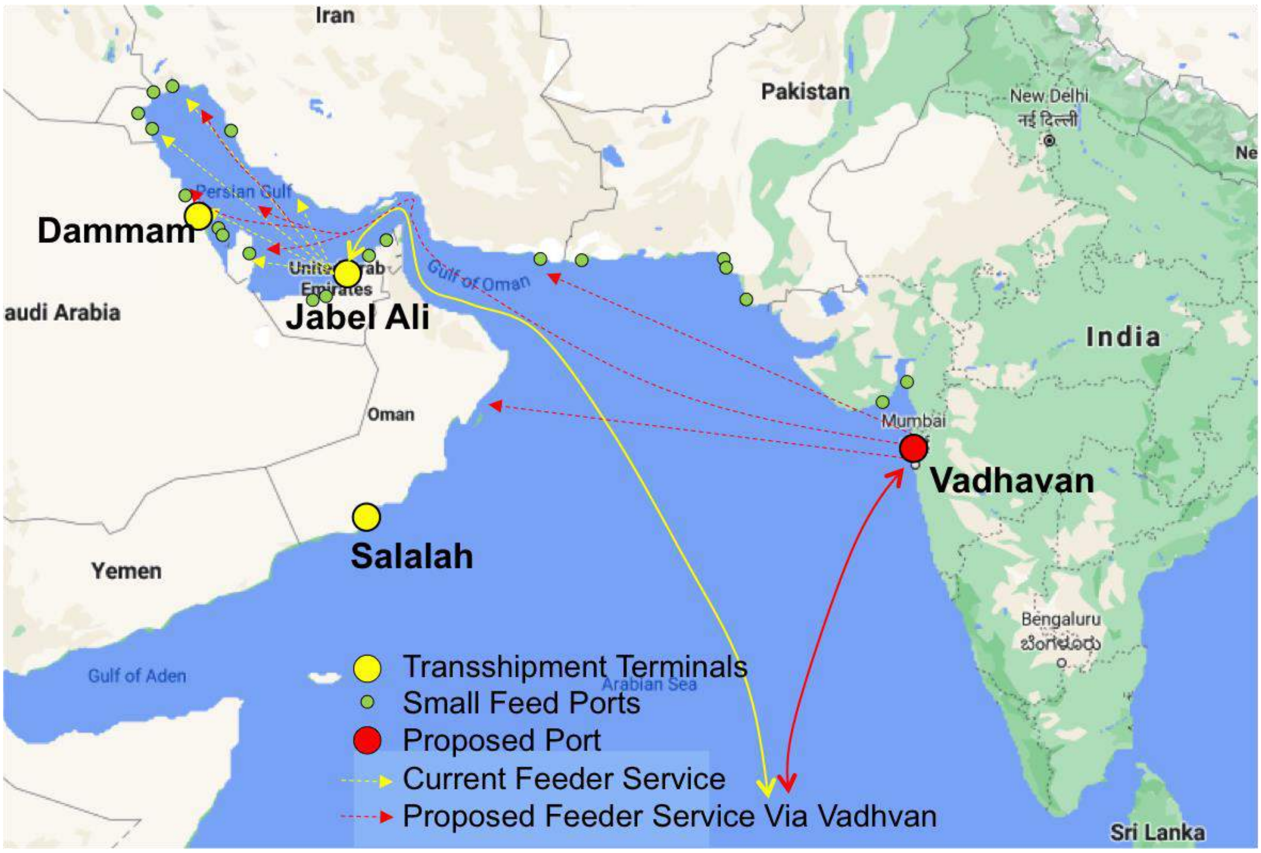

Figure A3-46 Transshipment Perspective Vadhavan (International Opportunities)

Holistically looking at the transshipment and feeder map above along with fuel cost per TEU in the table below provides insights on the dynamics of Transhipment and Feedering with respect to Vadhavan. It can be noticed that transshipment terminal of Jebel Ali and Dammam etc. are closer to feeder terminals of Middle East. It would be cost effective to distribute containers from transhipment terminals in Gulf to Feeder ports of Gulf. Shifting containers from Jebel Ali and Dammam to Vadhavan would lead to cost saving by mother vessel however it would increase the feeding cost by 2 to 3 times.

The slot cost of feeder vessel is several much higher than the slot cost of Mother vessel for same distance of sailing (travel). That has been primary factor for consistently rising container ship sizes. Hence mother vessels generally tend to offload containers at transshipment terminal is that has a cluster of feeder ports the vicinity. The Transhipment port acts as hub and feeder port acts as spoke, similar to shown in following figure.

Table A3- 55 Container Vessels Dimensions & Cost Heads

TEU	LOA (m)	Draft (m)	Breadth (m)	Consumption (Tonnes/Day)	Fuel (TEU/Day)	Categories
500	125	7	20.8	25	0.050	Local Shipping
1,000	133.7	7.8	22.7	31	0.031	
1,500	182.8	9.5	28	45	0.030	
2,000	174.4	11.9	30.6	65.5	0.033	
2,500	180	10.7	32.2	75	0.030	
3,000	216.3	11.4	32.2	120	0.040	Feeder Service
4,000	210	13.3	37.3	150	0.038	
5,000	294.1	13.6	32.3	182.5	0.037	
6,000	277	14	40	228	0.038	
7,000	300	13.5	42.8	220	0.031	
8,000	317.8	14.5	43.2	247.8	0.031	Direct Calls / Short Route Transshipment
9,000	334.6	14	45.8	226	0.025	
10,000	335.3	14	48.6	230	0.023	
11,000	330	16	48.2	235	0.021	
12,000	328.5	15.5	48.2	238	0.020	
13,000	365.8	15	48.4	270	0.021	
14,000	365.8	16	51.2	262.2	0.019	
15,000	368.5	15.5	51	288	0.019	Long Route /Transshipment
16,000	395	16	53.6	288	0.018	

Royal HaskoningDHV

JNPA

17,000	397.9	16	51	288	0.017	
18,000	399.9	16	59	295.5	0.016	
19,000	399.9	16	58.8	295.5	0.016	
20,000	399.8	14	58.6	305	0.015	
20,150	400	16	58.8	315	0.016	
23,756	399.9	16.5	61.5	325	0.014	

A3.12.3 Conclusion

The price rise of container transportation has been evaluated using impact of fuel cost in the above table. The price would rise further after including impact of Crew wages and other overheads by shipping lines. Hence, prospects of transhipment at Vadhavan has been discarded at this stage of planning. Vadhavan might receive limited opportunity for transhipment in future. That can be handled and catered to using planned infrastructure of the port. No additional planning or infrastructure creation is required.

A3.13 Other Principle Commodities – Market Assessment

The table summaries other principal commodities likely to call to Vadhavan port. These commodities are derived after undertaking the competition analysis and understanding the cargo movement to/from each competing port.

Table A3- 56 Prospects of Other Commodities for Vadhavan Port

Commodities	Kandla	Mundra	Pipavav	Hazira	Dahej	MbPT	JNPA
Edible Oil	Y	-	-	-	-	Y	Y
Fertilizer	Y	-	Y	-	-	Y	-
Chemicals	-	-	Y	Y	Y	-	-
Ro-Ro	-	-	-	-	-	-	-
Other Liquid	-	-	-	-	Y	-	-
Bulk Liquid	Y	-	-	-	-	Y	Y
General Cargo	-	-	-	Y	-	-	Y
Costal Cargo	-	-	-	Y	-	-	Y

Above listed commodities are further analysed in depth to understand the volume that Vadhavan could get over the period of next 25 years. The sub-section below represents the present market scenario, future prospect and growth drivers of each commodity at all India level, contribution of western region and % share diverted to Vadhavan. Detailed assumptions and projections for next 25 years i.e FY25 to FY55, is also mentioned below.

A3.13.1 Edible Oil

Present Scenario

India imports more than half of its edible oil requirement, making it the world's third-largest importer of edible oil. Amongst all edible oils imported into India, Palm oil's import share is around 60% and it is the most used oil in India due to its cost-effective offering. India is the fourth largest oilseed producing country in the world with a share of about 8%. As against the demand of edible oils, oilseed production in India has remained largely stagnant due to low productivity in under-irrigated areas and shifting of acreage from oilseeds to other crops.

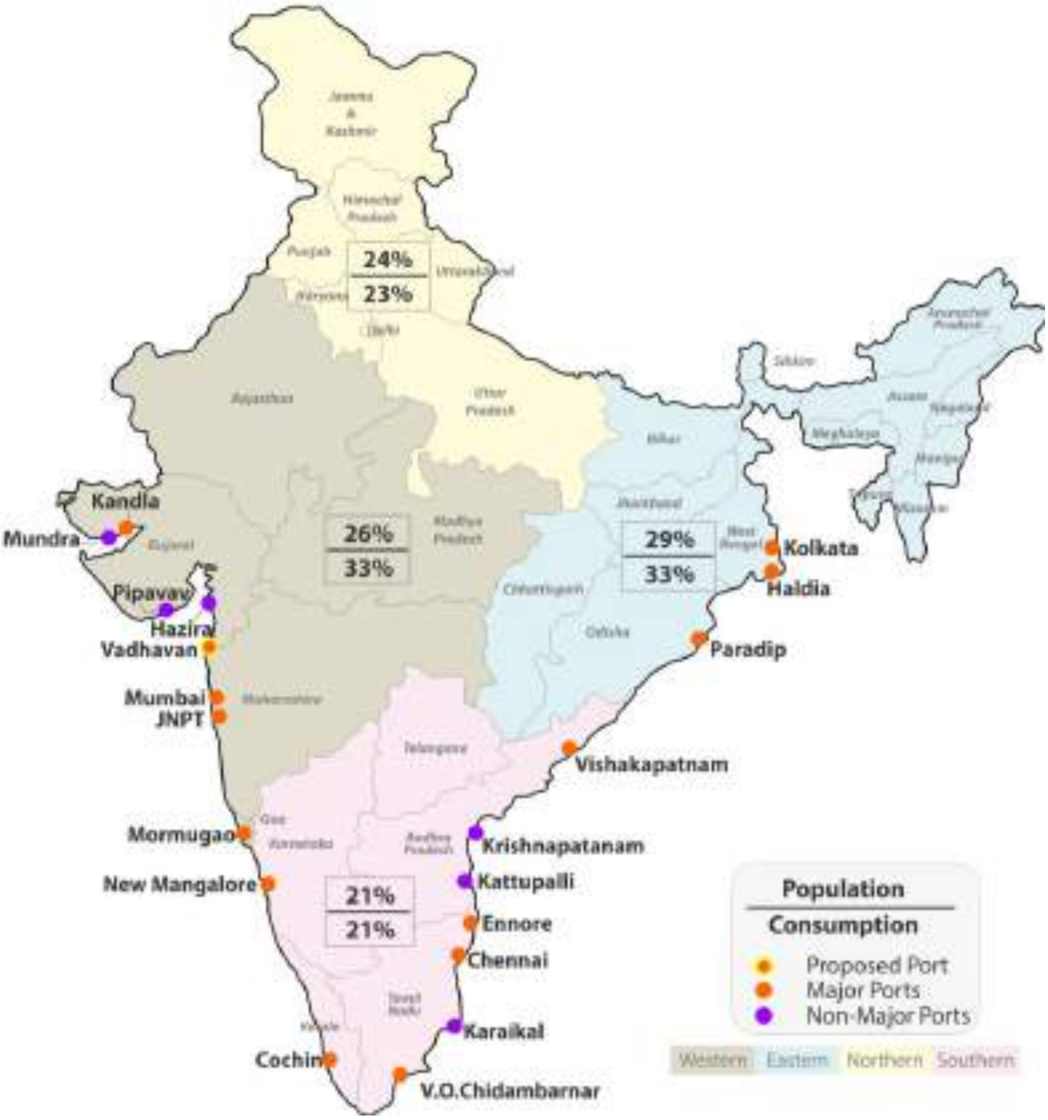

Figure A3-47 All India Edible Oil Consumption

The Western Region of India houses 26% of India's population and shows a 33% share of edible oil consumption. The Eastern Region displays a 33% share in consumption with a slightly higher 29% share of the Indian population. The Northern Region has a 24% share in India's population with an edible oil consumption of 23%. Lastly, the Southern Region consumes of 21% of total edible oil, the region occupies an identical share of 21% in India's population. Maharashtra & Gujarat Ports handle around 50% of total imports, and cater to the entire market of western and northern region of India. Western & Northern Region of India contributes to more than half of total Edible Oil Market in India

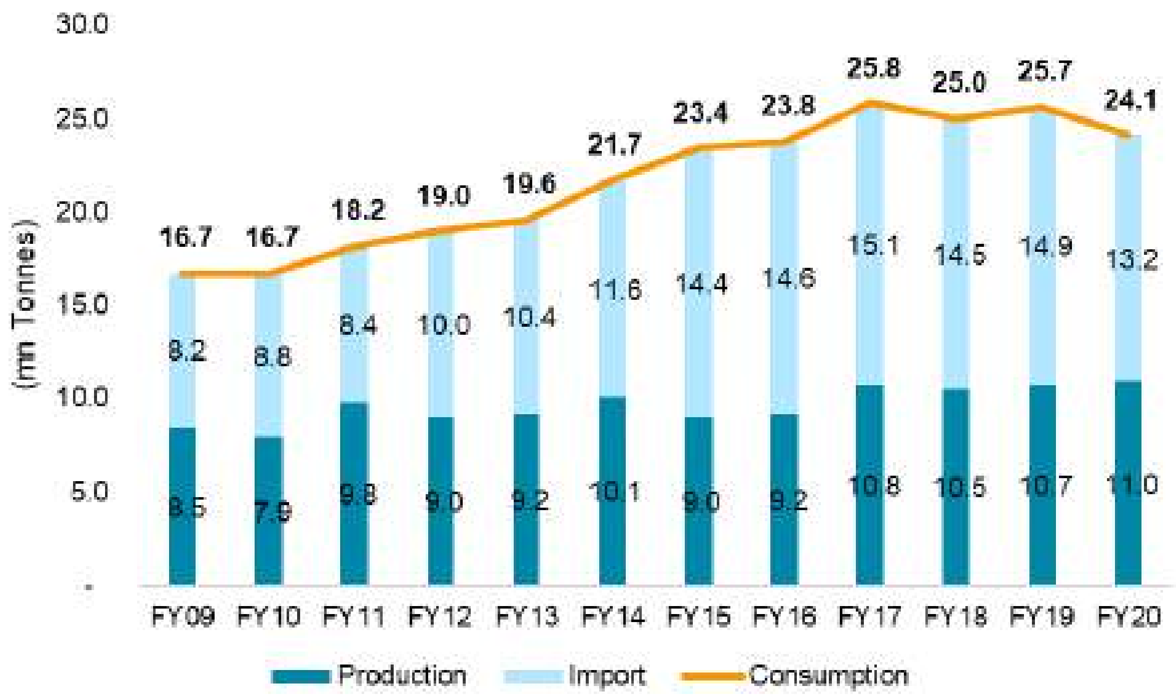

Figure A3-48 Historic Trend of Edible Production - Import - Consumption in India

The figure above indicates the growth in production, import and consumption of edible oil in million Tonnes. In 2019, the production of Edible Oil was 10.06 million tonnes while imports of Edible oil were 14.92 million tonnes. The total available quantity for domestic consumption in the same year was 24.23 million tonnes. 70% of India's edible oil is imported, which is a challenge to food security. Imports have been further incentivised by reduction in duties which has resulted in a surge in volumes that currently meet almost 55-60% of the domestic consumption requirements. Total edible oil imports for April 2020 dropped 34% year-on-year from around 1.2 million tons in April 2019 to less than 800,000 tons. Domestic prices of edible oils like groundnut, soybean, sunflower and mustard oils are higher than international prices while international price of palm oils show a weak trend.

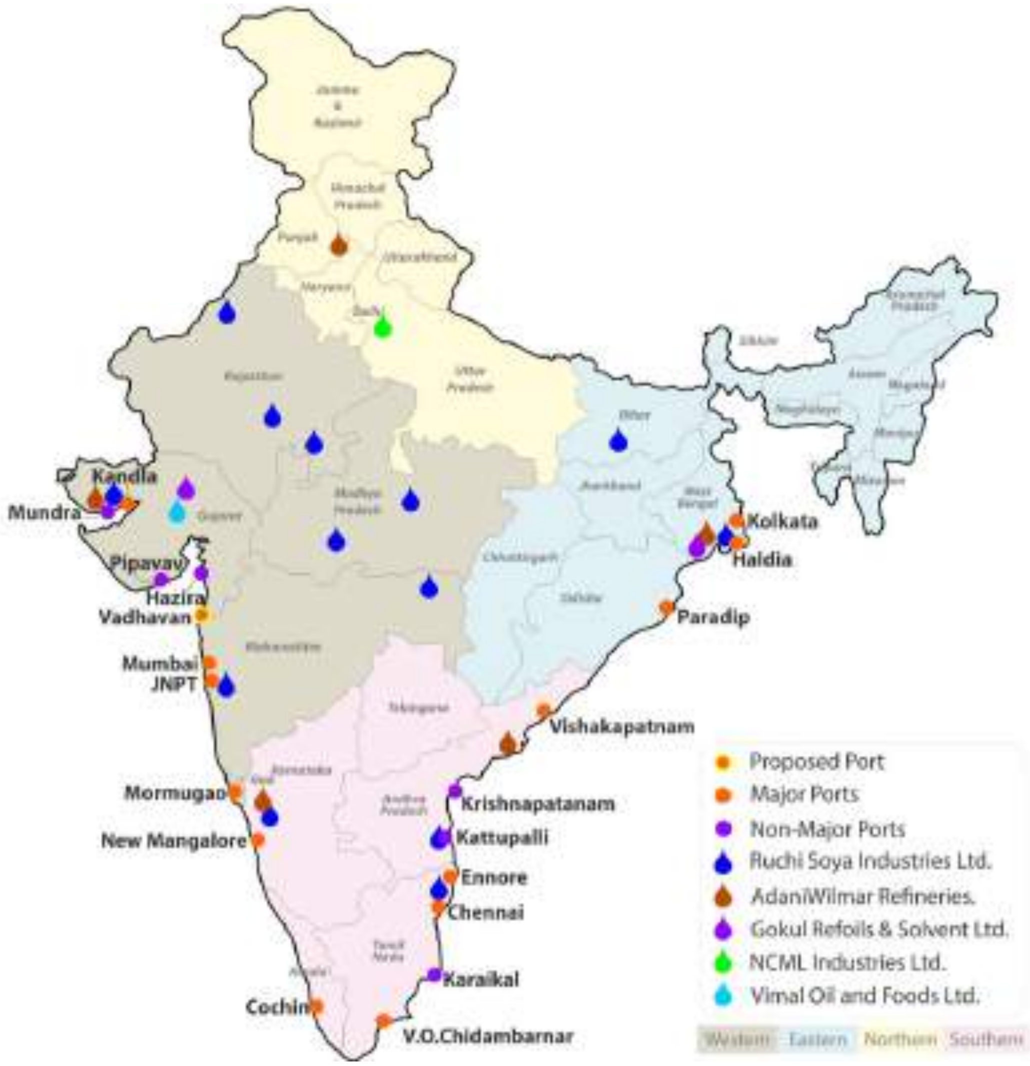

Figure A3-49 Edible Oil Refineries in India

Future Scenario

The dependence on imported edible oils is expected to increase in future due to anticipated domestic supply constraints and cost competitiveness of imported oils. The demand for edible oil is expected to grow by 3% CAGR till FY30. This assumes a per capita consumption increase of 4% and a population growth of 1.7% which translates to an overall growth in demand at 3% per annum. Future prices of edible oils are expected to increase over previous years.

Production of oilseeds is expected to increase from 30.64 million tonnes in 2018 to 45.00 million tonnes by 2023. Production of oils is expected to increase from 10.52 million tonnes to 16.34 million tonnes by 2023. Palm and coconut oil production would increase from 0.80 million tonnes in 2018 to 1.00 million tonne by 2023. Per capita requirement by 2023 would increase to 21.55 kg/person/year from 17.5 kg/person/year from 2018.

West India dominated the country's edible oil market in 2019, and the region is expected to maintain its dominance in the future. East and West regions also account for a significant market share, with the South region grabbing the smallest market pie. Some of the major players operating in Indian edible oil market include Adani Wilmar Limited (Fortune), Mother Dairy Fruit & Vegetable Pvt Ltd (Dhara), Cargill India (Nature Fresh, Gemini), Patanjali Ayurved Limited (Patanjali), Emami Agrotech Ltd. (Emami Healthy & Tasty and Himani Best Choice) and others.

Indian refineries have the capacity to process 20 million tons of oil, and right now they are hardly operating at 30% to 35% capacity. The refineries in India are under-utilised as the cost of imported oils is much cheaper than those produced in India. In this regards, edible oil consumption growth has been putting a lot of pressure on India's trade balance and budget due to the high dependence on imports. To reduce this burden, India needs to start utilizing its refineries at their maximum capacities.

Growth Drivers

Edible oil market in India is projected to grow from around $ 21.5 billion in 2019 to $ 35.2 billion by 2025 due to increasing disposable income and rising consumer awareness about healthy lifestyle & wellness. Moreover, strong marketing activities, changing tastes and preferences of consumers, expanding population, and shifting consumption pattern towards branded oils will be key drivers of consumption growth. Because of stagnant domestic supplies, import volumes will continue to fill the majority of the supply-and-demand gap over the next decade. Palm oil, soy oil, and sunflower oil are expected to penetrate regional markets with the packaged edible oil segment leading the way for future growth of the industry.

At present, export of all varieties of edible oils is free, except mustard oil. The import duty on all crude and refined edible oils was raised to 35% and 45% respectively. But there has been a hike in import duty on refined palm oil sourced from Malaysia from 45% to 50%. Refined palm oil and palm oil have been put under the Restricted category for imports since the beginning of FY20 and the restriction is applicable to imports from all countries. This is sure to help the domestic edible oil market grow in the future.

Assumptions & 25 years Projections

The national level edible oil traffic is projected based on historic consumption and domestic supply trend. Steady growth in population and personal income will improve per capita consumption of edible oil. In January 2020, Government of India has put restriction on import of refined palm oil. India has always been a deficit in edible oil and would likely to remain same because the production of edible oil cannot meet the total demand of the Indian market. Production of edible oil cannot surpass the demand due to weather conditions of the country. Hence, even though there would be restriction on the import volume, India would still continue to import edible oil. Looking at the micro and macro factors, moderate growth rate of 2% has been assumed for projecting all India edible oil imports. Current per capita consumption and demand are growing at CAGR of 1% and 3% respectively. India's imports will remain constant at around 70% of total demand.

Table A3- 57 Growth Rates Assumption for Edible Oil

Commodities	FY21-FY25	FY26-FY30	FY31-FY35	FY36-FY40	FY41-FY45	FY46-FY50
All India	3.0%	3.0%	2.0%	2.0%	2.0%	2.0%
			⇩			
Western Region Share	50.0%	50.0%	50.0%	50.0%	50.0%	50.0%
			⇩			
Vadhavan Share	5.0%	10.0%	10.0%	10.0%	10.0%	10.0%

The total edible oil EXIM trade at an all India level is assumed to grow at a rate of 3% for the first 10 years from FY 21 to FY30 and then at a rate of 2% for the next 20 years from FY31 to FY50. Western region ports i.e. Maharashtra & Gujarat would handle around 50% of total imports, and cater to the entire market of western and northern region of India. These regions would contribute more than half of total Edible Oil Market in India. Major ports of Maharashtra i.e. JNPA & MbPT handled around 1.56 million tonnes of edible oil in FY19. More than 80% of total Maharashtra edible oil traffic is handled at JNPA. In last 14 years, JNPA has shown compounded growth at 7%. It has well developed tank farms and other facilities to cater to imported edible oil. The Western Coast's share in All India edible oil consumption is 29.40% while its share in domestic production is 70%. From the Western Region's trade volume, Vadhavan is assumed to attract a 10% share of EXIM trade in edible oil for the next 25 years from FY 25 to FY 50. The figure below shows the 25 years' traffic projections of edible oil for Vadhavan Port.

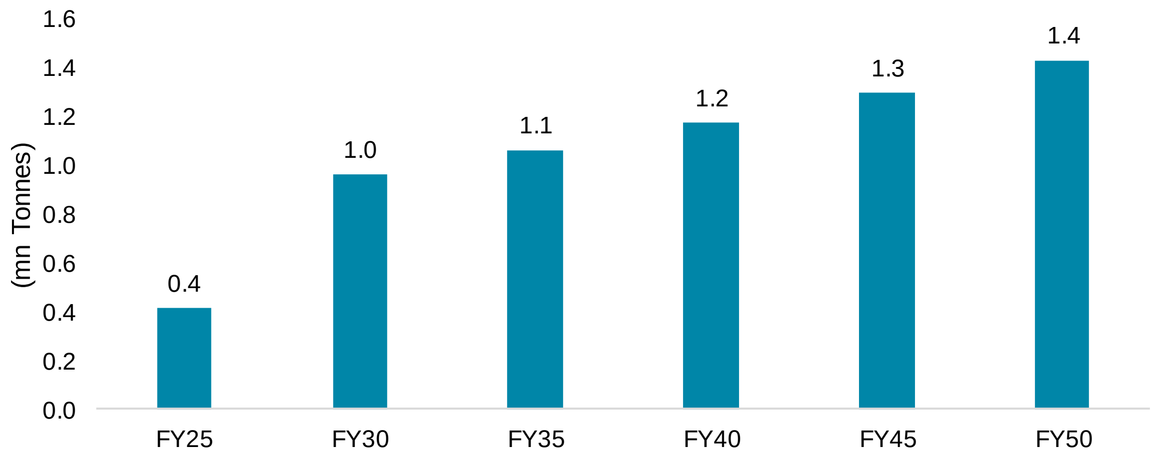

Figure A3-50 Edible Oil Projections for Vadhavan Port

A3.13.2 Fertilizer

The Indian fertilizer industry has played a pivotal support role in the Indian agricultural industry. Today India is the third largest producer and second largest consumer of fertilizers in the world. The Government of India subsidizes fertilizers to ensure that they are easily available to farmers and the country remains self-sufficient in agriculture. The Indian fertilizers market is largely dependent on imports, especially potash fertilizers.

Present Scenario

The Indian fertilizer industry can broadly be divided into two categories, depending on the nutrient composition i.e. nitrogenous fertilizers and phosphate & potassic (P&K) fertilizers. The production of fertilizers in India has increased at a CAGR of 3.11% during 2009-2020 and has reached 46.21 million tonnes in FY20 showing an increase of more than 11.40% in comparison to the previous year's 41.48 million tonnes. The overall fertilizer consumption in India has grown at a CAGR of 2.0% from 50.6 million tonnes in FY09 to 61.4 million tonnes in FY20. In FY20, the primary sales volumes for fertilizers grew at a moderate rate of 6.0% to 61.4 million tonnes in FY20 from 57.8 million tonnes in FY19, following the healthy monsoons. In terms of volume, the imports of the fertilizers increased during FY09 – FY20 at a CAGR of 2.84%. Fertilizers production increased by 6.3 % in FY20 over FY19.

The production of Urea during the year FY19 was 24 million tonnes and the production of DAP & Complex fertilizers were 12.9 million tonnes. Urea sales grew by 5.9% to 33.6 million tonnes in FY20 from 31.7 million tonnes in FY19, non-urea sales grew by 6.1% to 27.8 million tonnes in FY20 from 26.2 million tonnes in FY19. The rapid build-up of fertilizer production in the country has been achieved as a result of a favourable policy environment facilitating investments in the public, co-operative and private sectors.

As of now, the country has achieved 80% self-sufficiency in production capacity of Urea. As a result, India could manage its substantial requirement of nitrogenous fertilizers through the indigenous industry besides imports. Similarly, 50% indigenous capacity has been developed in respect of phosphatic fertilizers to meet domestic requirements. However, the raw-materials and intermediates for the same are largely imported. For potash (K), since there are no viable sources/reserves in the country, its entire requirement is met through imports.

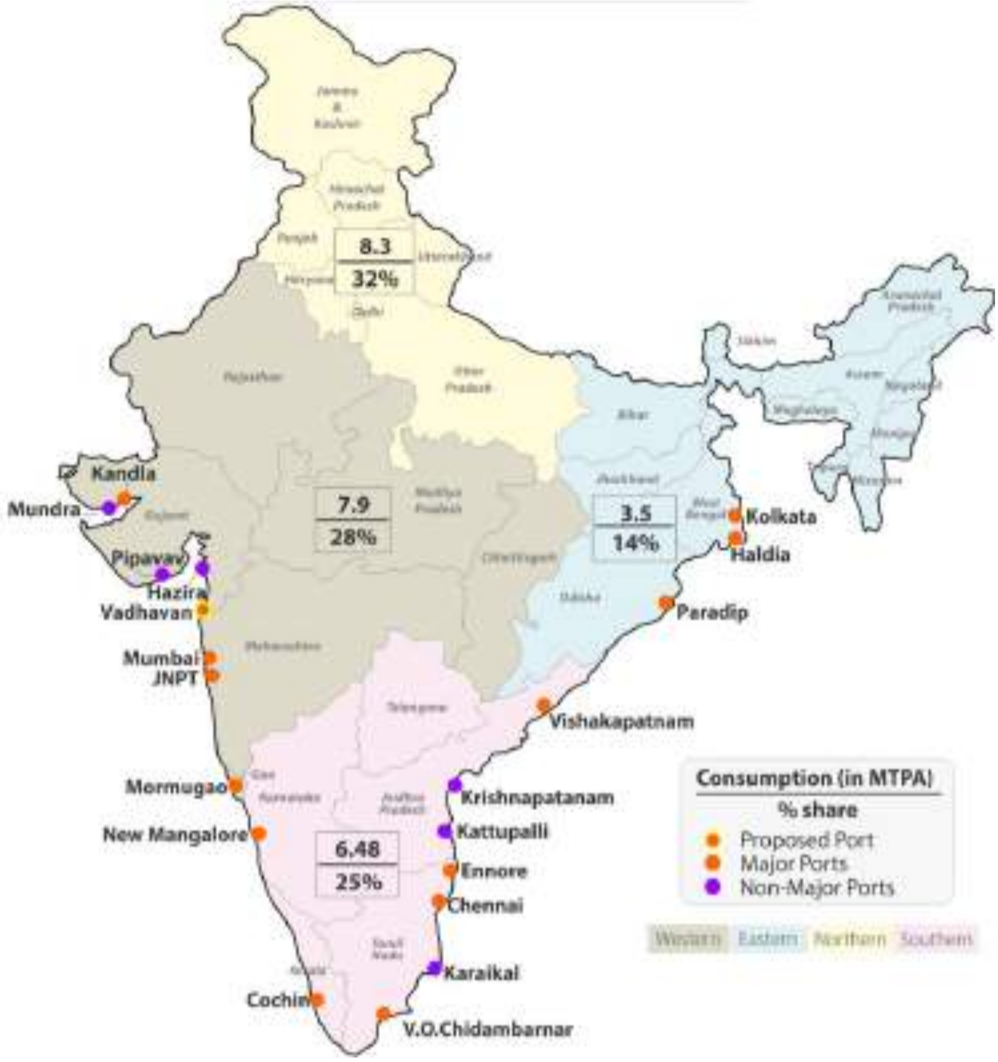

Figure A3-51 All India Fertilizer Consumption

Region-wise, North India exhibits a clear dominance in the Indian fertilizer market. It consumes 8.3 MTPA covering an overall share of 32%. West India comes in a close second with a 28% share consuming 7.9 MTPA. South India has a consumption of 6.48 MTPA occupying a share of 25%. Lastly East India consumes only 3.5 MTPA and covers only 14%. The fertilizer imports move from major ports on India's east and west coast to the inner agricultural regions while the raw materials are transported to nearby fertilizer production plants. Gujarat, Tamil Nadu, Uttar Pradesh, Maharashtra, Andhra Pradesh Punjab and Kerala are the main fertilizer producing states and account for about half of the total fertilizers produced in India. Orissa, Rajasthan, Bihar, Assam, West Bengal, Goa, Delhi, Madhya Pradesh and Karnataka are other producers.

Gujarat is the largest producer of fertilizers in India and accounts for more than one- fourth of the total production of nitrogenous as well as phosphatic fertilizers of the country. This state has more than 14% of the country's total installed capacity. Units at Vadodara and Kalol produce both nitrogenous and phosphatic fertilizers while units at Bharuch, Udhna, Kandla, Bhavnagar and Vadodara produce phosphates only. Two new plants have been set up at Hazira and Surat. Ahmedabad and Navsari are also important producers.

Figure A3-52 Fertilizer Movement in the Hinterland

Maharashtra accounts for over 11% of the nitrogenous and about 7% of the phosphatic fertilizers of the country. The state has six plants in all. Mumbai with three plants is the largest producer. The remaining three plants are located at Trombay, Ambarnath and Loni-Kalbhor.

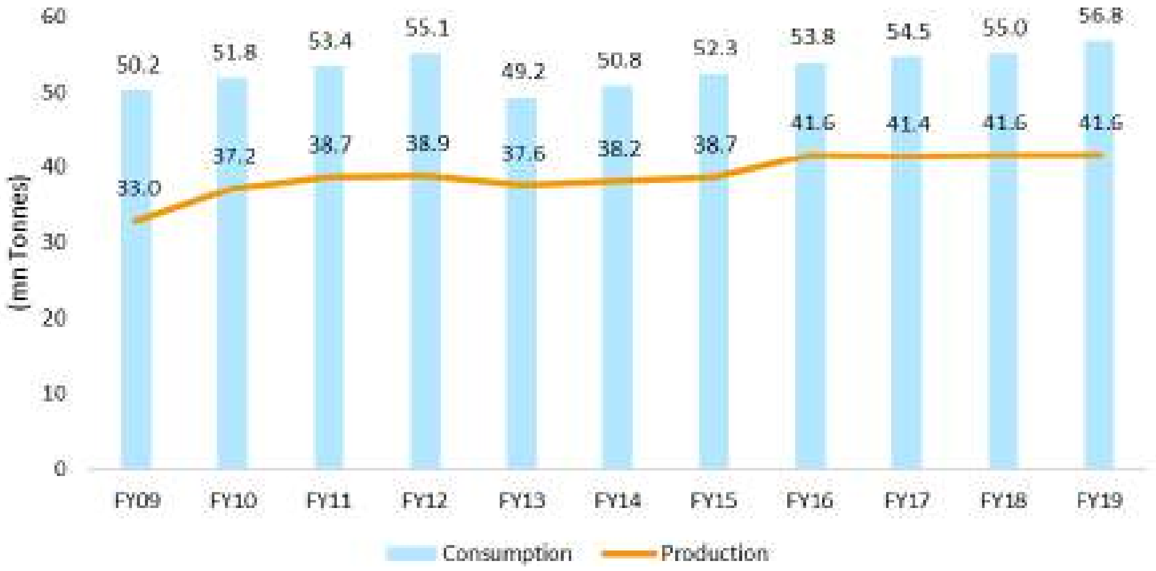

Figure A3-53 Historic Trend of Fertilizer Production - Consumption in India

In 2019, fertilizer consumption reached a high of 56.8 million tonnes with production coming in at 41.6 million tonnes. During the same year, India imported 19 Mn Tonnes of Fertilizer, out of which 54% was handled at Gujarat Ports and less than 2% at Mumbai Port. Majority of the Western and Northern Region of India is served by Gujarat. 35% - 40% of domestic fertilizer demand is met by imports that include Urea, NPK and MOP. At present, there are 32 large size urea plants in the country manufacturing urea, 19 units producing DAP & complex fertilizers and 2 units manufacturing Ammonium Sulphate as a by-product. Besides, there are about 64 medium and small scale units producing single superphosphate.

Future Scope

The fertilizer market is expected to increase by CAGR of 2.05% in FY2030. The demand of fertilizers in India has witnessed double digit growth rates over the past several years due to sustainable agriculture industry. Growth of agriculture and growth in fertilizer Industry complement each other. Rise in agricultural output leads to increased consumption of fertilizers. The Fertilizer Industry can thus, be studied in terms of demand and supply condition.

India's dependency on import at present is to the extent of 25% of our requirement of Urea, 90% in case of Phosphates, either as raw material or finished fertilizers (DAP/MAP/TSP) and 100% in case of Potash. The Make in India initiative is encouraging the production of fertilizers within the country to an extent the government wants to eliminate the imports of urea by 2022 and make India self-sufficient. Besides, the overall domestic output of fertilisers has been going up for the past three years and imports are falling.

Market Drivers

- Catalysed by a strong population growth over the next five years, food demand is also expected to exhibit a strong growth. Conversely, as a result of increasing urbanisation levels, available arable land is expected to decrease. Fertilizers will play a key role in increasing the average crop yields per hectare.
- Fertilizer consumption in India has very low penetration in a number of states in India. This leaves a lot of room for future growth.

- A number of government and non-government awareness campaigns have been setup to educate farmers and promote benefits of fertilizers through television, radio and customized rural workshops. These efforts will lead to an increase in the consumption of fertilizers in the coming years.
- Increasing rural incomes, coupled by easy availability of credit, are also likely to create a positive impact on fertilizers in the country.
- Contract farming, where inputs in terms of technology and training are provided to the farmer from the food processor (contractor), is also expected to increase fertilizer usage.
- Launch of Phase-II of Direct Benefit Transfer of Fertilizer Subsidy (DBT 2.0) with new initiatives like DBT Dashboards, PoS 3.0 Software and Desktop PoS Version is expected to bring trade of fertilizers to the online platform for farmers

Key Players of Fertilizer Industry

- The Indian Fertilizer Market is a consolidated market with major players such as Coromandel International Ltd, Indian Farmers Fertilizer Cooperative (IFFCO), Fertilizers and Chemicals Travancore (FACT), Deepak Fertilizers Ltd and Chambal Fertilizers Ltd, among others. The market is fragmented with a mix of government-owned and co-operatives garnering a high market share in the straight and complex fertilizer space and private companies engaged in a high degree of product innovation to tap the non-subsidy space.
- Public Sector - Fertilizer Corporation of India, National Fertilizers Ltd, Fertilizers & Chemicals Travancore Ltd, Rashtriya Chemicals & Fertilizers Ltd, Madras Fertilizers Ltd, Paradeep Phosphates Ltd, Pyrites, Phosphates & Chemicals Ltd, Hindustan Fertilizer Corporation Ltd
- Cooperative Sector - Indian Farmers Fertilizer Cooperative Limited (IFFCO), Krishak Bharati Cooperative Limited (KRIBHCO)
- Private Sector - Ajay Farm-Chem Private Ltd, Balaji Fertilizers Private Ltd, Deepak Fertilizer and Petrochemicals Corporation Ltd, Bharat Fertilizer Industries Ltd, Coromandal Fertilizers Ltd.

Assumptions & 25 years Projections

Majority of ports handling larger volume of fertilizer are located in Gujarat and have a distinct influence region for their imports and exports. Mundra and Pipavav ports have better cargo handling infrastructure than any other West Coast Port. Kandla is preferred in terms of distance matrix and caters to the northern region of India including the states of UP, Punjab, Rajasthan and Haryana. Hazira does not have direct rail connectivity and the nearest rail head is at Kosad. In Maharashtra, both MbPT and JNPA have had a steady growth rate of 5% in the fertilizer market for the last 15 years.

Table A3- 58 Growth Rate Assumption for Fertilizer

Commodities	FY21-FY25	FY26-FY30	FY31-FY35	FY36-FY40	FY41-FY45	FY46-FY50
All India	3.0%	2.5%	2.0%	2.0%	2.0%	2.0%
Western Region Share	50.0%	50.0%	45.0%	40.0%	40.0%	40.0%
Vadhavan Share	5.0%	5.0%	6.0%	6.0%	6.0%	6.0%

The past trend of fertilizer consumption shows a growth of CAGR 3%-3.4%. The total trade of fertilizers at an all India level including ports on both the East and the West Coast is assumed to grow at the rate of 3% for the first 5 years (FY21-25), 2.5% for the next 5 years (FY26-30) and 2% for the next 20 years (FY31-50).

The ports on the West Coast have a share of around 50% in All India trade of fertilizers. Majority of the western and northern regions are catered by Gujarat. The share of West Coast Ports is assumed as 50% of All India Trade for the first 10 years, 45% for the next 5 years and 40% thereafter for the next 15 years. Even though the distance of the fertilizer industries and plants from the port of Vadhavan is comparatively higher, traffic could be attracted to Vadhavan by providing good handling infrastructure. Maharashtra and Madhya Pradesh are two potential states for the Vadhavan port. Among the West Coast Ports, Vadhavan is assumed to attract a 5% share of EXIM trade in fertilizers for the first 5 years from FY 25 to FY 30. The share of Vadhavan is expected to rise to 6% for the next 20 years from FY 31 to FY 50.

Diversion analysis of fertilizer traffic reviews port infrastructure at Vadhavan and assesses existing and future development plans for handling fertilizers. Vadhavan might be able to divert minimal volume of Northern traffic from Mundra and Kandla on account of congestion at these ports. Vadhavan will handle Northern and Eastern Maharashtra fertilizer demand while Dighi will cater to Southern Maharashtra. The figure below shows the fertilizer traffic that Vadhavan Port would handle for 25 years.

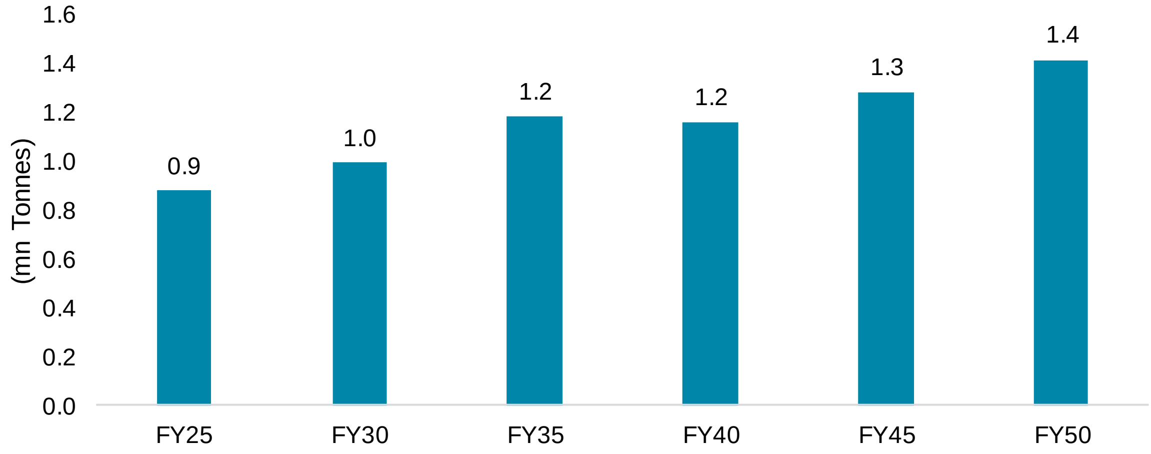

Figure A3-54 Fertilizer Projections for Vadhavan Port

A3.13.3 Chemicals

Present Scenario

Chemical industry in India covers more than 80,000 commercial products. It is broadly classified into Bulk chemicals, Specialty chemicals, Agrochemicals, Petrochemicals, and Polymers. India ranks 6th in the world in chemical sales and contributes nearly 3.4% to the total global chemical industry. The chemical industry occupies a share of 12.5% in India’s total exports. The chemical sector accounts for 7% of India’s GDP. India ranks 14th in export and 8th in import of chemicals (excluding pharmaceutical products) globally.

The chemical industry shows a CAGR of 4.78% for a period of 4 years between FY-15 and FY-19. India’s 50% export of Agro-chemicals is likely to continue. As of FY19, the specialty chemicals market size is witnessing a growth of 14% in the last five years. Demand for petrochemicals has grown at 5.4% CAGR during FY15-FY19.

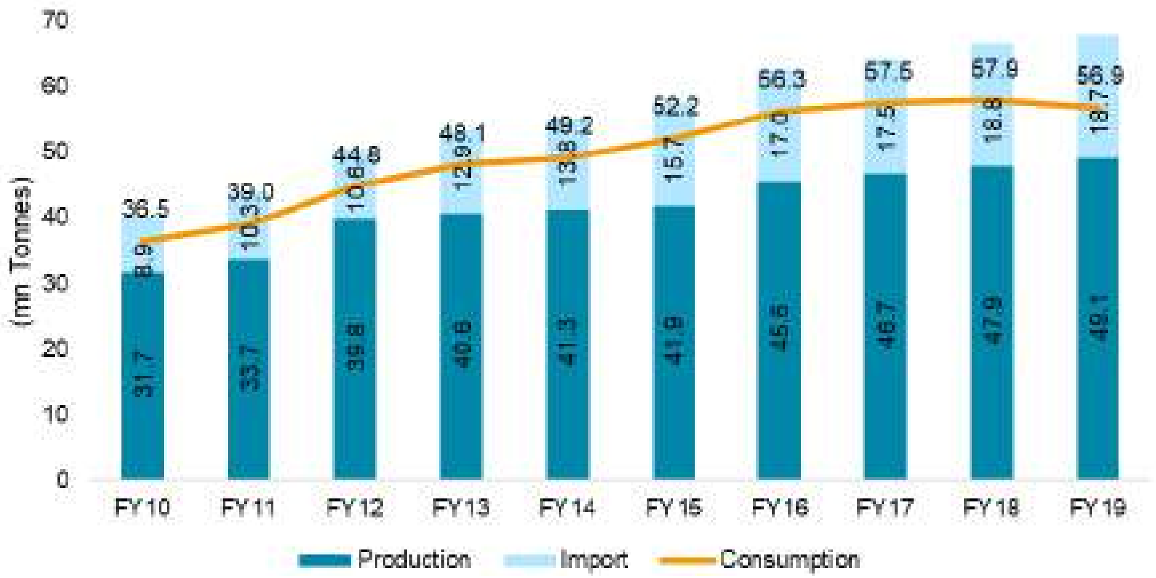

Figure A3-55 Chemical Trade in India

In FY18-19, import and export of chemicals stood at 6.38 Mn tonnes and 1.58 Mn tonnes. For the same Fiscal Year, import and export of petrochemicals was 12.35 Mn tonnes and 9.6 Mn tonnes. Thus, total import and export from the chemical sector for FY18-19 added up to 18.73 Mn tonnes and 11.2 Mn tonnes. Production and consumption of chemicals was 11.6 Mn tonnes and 16.6 Mn tonnes. For petrochemicals, both production and consumption were higher with 37.5 Mn tonnes and 40.2 Mn tonnes. Total production and consumption of chemicals and petrochemicals stood at 49.1 million tonnes and 56.8 million tonnes. Over the last 5 years from FY15 to FY19, import has shown a CAGR of 3.55% while export grew substantially at a CAGR of 15.40%. Western region contributes to the more than 55% in Indian chemical industry. South Gujarat and Maharashtra both together houses 54% of India's total chemical industries. Production segment in chemical industry does not satisfy the increasing demand on India. More than 90% of chemicals and 70% of petrochemical demand is filled by imported chemicals.

Future Prospects

The Government of India expects substantial growth in the Chemical industry. Demand of chemical products is expected to grow at approximately 9% p.a. over the next 5 years. 100% FDI is allowed under the automatic route in chemicals sector except a few hazardous chemicals. The petrochemical demand is expected to grow at 7.5% CAGR from FY19-23, with polymer demand growing at 8%. The specialty chemicals constitute 18% of total chemicals and petrochemicals market in India. The demand for speciality chemicals is expected to grow at 12% CAGR from FY19-23. Demand for organic chemicals is expected to grow at 9% CAGR from FY19-23, with phenol demand growing at 11%.

Dow Chemical plans to increase its polyurethane system production facility located in Ratnagiri by 50%, with an aim to expand and strengthen its manufacturing and customer bases in India. The company also plans to invest in a new technology centre in Mumbai to improve product quality. Roha, Pen, Nagothane, Rasayani are chemical hubs in Maharashtra located near Vadhavan. Shell is also looking for a facility to set up a 1mnT plant. Both Gujarat and Maharashtra are well-favoured zones for chemical production and consumption. The agrochemical consumption in these states accounts for 13% of the total and its market is expected to grow at a CAGR of 8%. The abovementioned reasons will be instrumental in growing the EXIM trade of chemicals at Vadhavan.

Growth Drivers

- Rising disposable income, median age of population, urbanisation and growing penetration and demand from rural markets
- Production-Linked Incentive (PLI) Scheme has been introduced in the Chemicals sectors for Enhancing India's Exports under Atmanirbhar Bharat Abhiyaan with an outlay of INR 18,100 crore (US$ 2.45 billion)
- Shift in production and consumption towards Southeast Asian countries leading to increasing demand for Chemicals and Petrochemicals

Assumptions & 25 years Projections

Consumption of Chemicals and Petrochemicals grew by 2.9% CAGR in last 5 years (FY14-FY19). Around 65% of consumption volume is met by domestic production and rest 35% by imports. Chemical imports have increased by 6.3% in last 5 years. All India production has shown 3.5% growth in last five years, 80% of total production is consumed locally while 20% is exported to other countries. Though exports hold very less share in Chemical trade, but in last 5 years it has shown 13.6% growth.

Table 59 Growth Rate Assumption for Chemical

Commodities	FY21-FY25	FY26-FY30	FY31-FY35	FY36-FY40	FY41-FY45	FY46-FY50
All India	3.0%	3.0%	2.0%	2.0%	2.0%	2.0%
Western Region Share	54.0%	54.0%	54.0%	54.0%	54.0%	54.0%
Vadhavan Share	5.0%	6.0%	6.0%	6.0%	6.0%	6.0%

All India consumption of Chemicals has increased at 4% in last 5 years. On an average 35% of total consumption is met by imports. Same trend is expected in future. Considering the development in Chemical sector and close proximity of chemical hub from Vadhavan Port, a nominal 3% growth rate is considered for next 10 years and 2% thereafter till FY50 for projecting future traffic. Gujarat and Maharashtra are the most preferred states by chemical industries. Both the states together contribute to around 54% in total imported supply of chemicals in India. Out of the 54% share that western region contributes in all India trade, Vadhavan Port would start attracting nearby 6% of total western region trade till FY50. The figure below shows the Chemical traffic that Vadhavan Port would handle for next 25 years

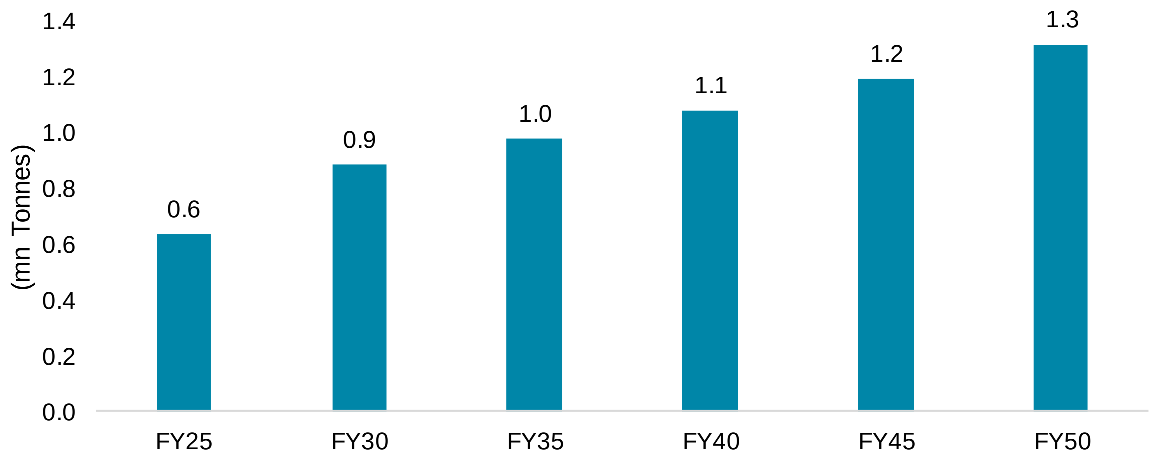

Figure A3-56 Chemical Projections for Vadhavan Port

A3.13.4 Ro-Ro

Present Scenario

India is the world's 4th largest vehicle market. The industry manufactured 26.36 Mn vehicles and sold 21.5 Mn vehicles in domestic market in FY20. The vehicles included Passenger Vehicles, Commercial Vehicles, Three Wheelers, Two Wheelers and Quadricycles, of which 4.77 Mn were exported in FY20, showing CAGR of 6.94% during last 5 years. In FY19-20, Automotive exports were 0.68 Mn Passenger Vehicles; 0.06 Mn Commercial Vehicles; 0.50 Mn Three Wheelers; 3.52 Mn Two Wheelers and 0.01 Mn Quadricycles. Automobile Production increased at 2.36% CAGR and domestic sales at 1.29% CAGR during last 5 years. Two-Wheelers & Passenger Cars dominate the Indian market contributing around 94% in total sales. Overall automobile exports registered a growth of 2.95% with passenger vehicles exports marginally increased by 0.17% and two-wheeler exports by 7.30%. The automotive industry has a 7.1% share in India's GDP and 4.3% share in India's total exports. The sector attracted $24.5 billion FDI during April 2000 - June 2020; accounting for 5.1% of the total FDI inflows.

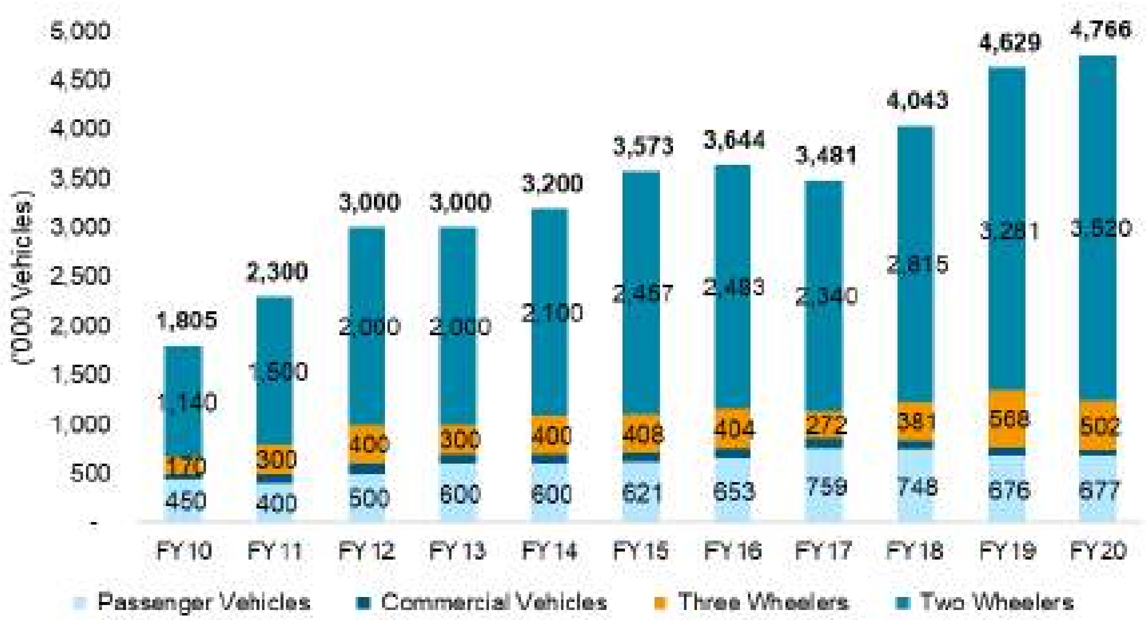

Figure A3-57 Automobile Exports of India

Maharashtra and Gujarat cluster contributes 20% - 25% and 2% - 3% of total automobile exports respectively. Maharashtra has automobile manufacturing industries in Pune, Nashik and Aurangabad while Gujarat has industries in Sanand, Bhuj, Halol and Vithalapur. Mundra Port and Mumbai Port are primary ports for export and import of automobile for North and West India. Primary hinterland of MbPT is Maharashtra, entire state is served by this port. MbPT is primary competition to proposed port Vadhavan due to its presence in Vadhavan's direct influence area. Vadhavan is located close to the vehicle manufacturing industries of South Gujarat and Maharashtra and hence would be able to export automobile.

Future Prospects

As per Automotive Mission Plan 2026, Automobile industry is expected to increase its contribution in Indian GDP from 7.5% to 12% by FY26. The automotive sector will also witness growth of 3.5 to 4 times in value in 2026 based on the average GDP growth of 5.8%. The $118 billion Automobile industry is expected to reach $300 billion by 2026. India will emerge as the world's third-largest passenger vehicle market by 2021.

Exports are expected to grow 5 times for vehicles and 7.5 times for auto components. Industry was expected to grow at CAGR 15% from 2020 to 2026. The change from internal combustion engines to zero-emission vehicles is one that has gained aggressive momentum in India. There is a plan to introduce low-cost Electric Vehicle to achieve Government's vision of 100% electrical mobility by 2030. India is expected to hold 8% of the global EV 4W component market by 2025. The EV sub-segment already attracted 19.3 billion USD between 2000 to 2018. In addition, it also enjoys the prospect of 2 major investments from Hyundai and Saic motors.

Tata, Honda and Saic Motors have plants in Gujarat and Madhya Pradesh and Force, Bajaj Auto and General Motors have plants in Maharashtra. Vadhavan could attract trade from these automobile companies for importing auto components and exporting the finished vehicles. Policies in this industry are as listed below;

- Automobile sector has a financial outlay of INR 51,000 crore under Atmanirbhar Bharat package
- India aims to reduce its carbon footprint by 33-35% by 2030 using Bharat Stage VI norms
- Production-Linked Incentive (PLI) Scheme offers tax benefits for manufacturing in India
- Under Voluntary Vehicle Fleet Modernization Programme (V-VMP), discounts are offered on replacing old vehicles with new ones

Assumptions & 25 years Projections

In last 5 years, Indian Automobile exports has shown 6% of CAGR. Considering the past trend, present market scenario and future growth trends, 5% y-o-y growth rate has been considered for initial 10 years and thereafter growth is assumed to stabilize at 3% till FY50. Western region of India handles around 50% to 55% of total automobile exports of India. Traffic projections for exports from Gujarat and Maharashtra is delivered based on the western region contribution in total exports i.e. 55% for initial 5 years and 56% thereafter till FY50. The table below shows the growth rates considered for all India traffic projections and estimated contribution of western region in it along with Vadhvan's share.

Table A3- 60 Growth Rate Assumption for Ro-Ro

Commodities	FY21-FY25	FY26-FY30	FY31-FY35	FY36-FY40	FY41-FY45	FY46-FY50
All India	5.0%	5.0%	3.0%	3.0%	3.0%	3.0%
			⇩			
Western Region Share	55.0%	56.0%	56.0%	56.0%	56.0%	56.0%
			⇩			
Vadhavan Share	4.0%	7.3%	9.8%	18.7%	18.7%	18.7%

Vadhavan Port's catchment area for Automobile segment in western region is limited to Maharashtra state only. Pune, Nashik, Aurangabad, Nagpur and Chakan are the major automobile hubs in Maharashtra. These hubs use MbPT to export and contributes to around 25% of total automobile exports of India. At present MbPT dominates in Maharashtra due to its proximity to the hubs, good connectivity, dedicated service available for handling ro-ro and availability of back-up land for storage. However, due to capacity saturation and less possibility for expansion MbPT is likely to face issues in handling growing traffic in future. Vadhavan could attract the spill-over traffic from MbPT. The table above shows the estimated share that Vadhavan would attract from entire western region. Initially 4% is considered and gradually kept share increasing till 9.8% by FY35, thereafter sudden raise is shown based on the MbPT's capacity saturation, 18.7% traffic diversion is assumed till FY50. The figure below shows the Ro-Ro traffic that Vadhavan Port would handle.

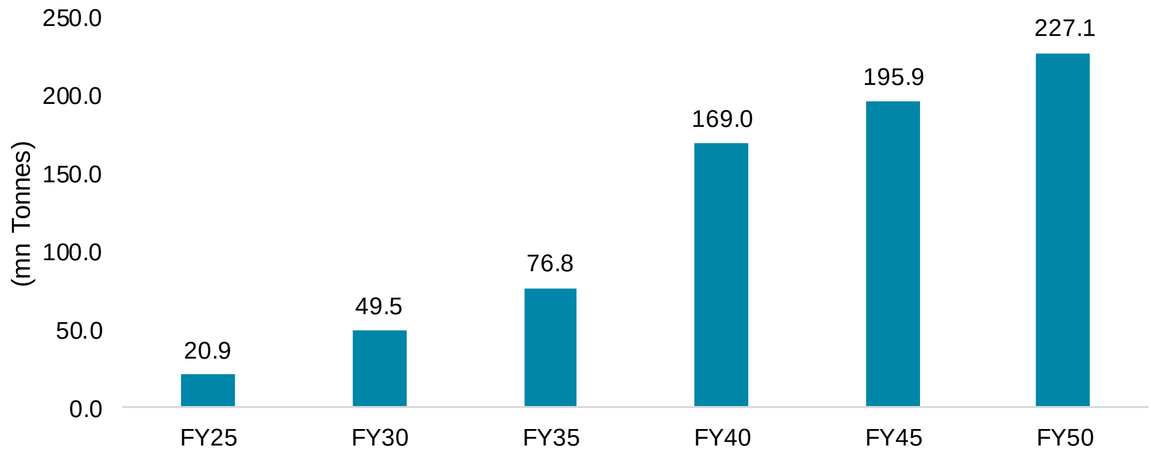

Figure A3-58 Ro-Ro Traffic Projections for Vadhavan Port

A3.13.5 Other Liquid

Natural gas is an important inherent party of global energy. Substituting natural gas in place of other polluting fuels, always improves the surrounding air quality and decreases emissions of carbon dioxide. In the past few years, Other Liquid imports have been successively priced at attractive cost. These cheaply priced imports have become highly competitive with prices of coal. Thus, imports of Other Liquid are slowly reducing the market share of coal in many power plants.

The trend of higher Other Liquid usage is likely to continue in India causing a larger demand for Other Liquid in comparison to coal in the coming years. India's policy of reducing the number of thermal power plants based on coal is also helping ramp up the overall consumption of Other Liquid in the industrial and commercial sectors. Gas consumption in power plants rose 11.7 % to 104.83 million standard cubic metres per day (mmscmd) in FY20.

Present Scenario

In India, onshore production fields located in Assam (northeast), Gujarat, Tamil Nadu, Andhra Pradesh. There are some very promising offshore production fields of natural gas that include the Krishna Godavari basin off the east coast. The share of natural gas in the domestic energy mix is a meagre 6%. Although some large discoveries of natural gas sources in the early 2000s fuelled the confidence about the speed of expansion but could not take off because of the lower than expected output from offshore domestic fields. The two factors that strongly affected the production of natural gas adversely in recent years. First, the start of the much-awaited production at the KG-D6 offshore field in 2009, and second, faster than expected decline in production because of the reported subsurface complexity.

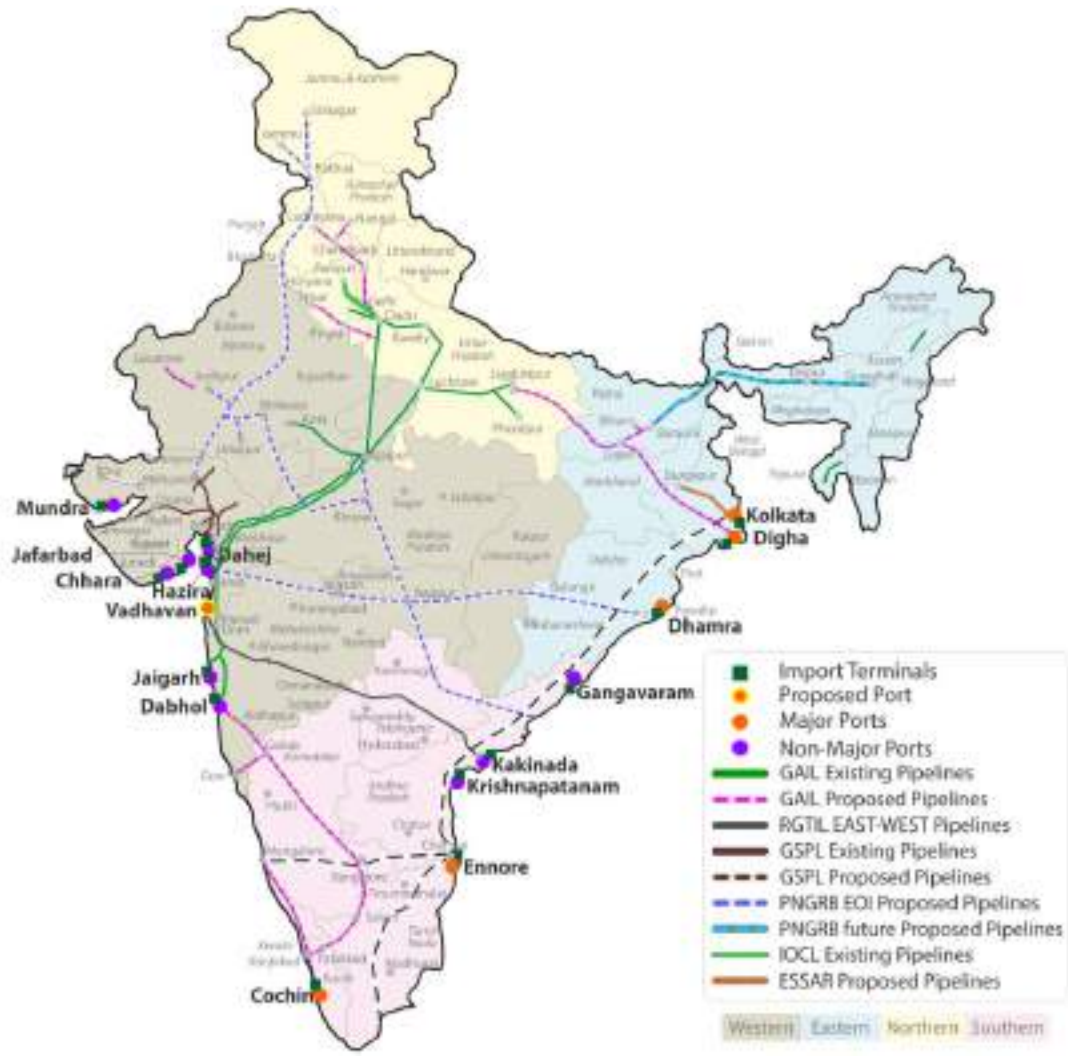

Figure A3-59 Other Liquid Pipeline Network and Import Terminals in India

The natural gas pipeline network is illustrated in the figure above. This pipeline network is for both domestic production supply and import supply. Gujarat based Other Liquid terminals have good connectivity to the pipeline network. The figure also depicts the connectivity of the Western and the Northern region. Both aggregate about 80% of the total natural gas consumption. The western region, in particular, uses over 50% of the total natural gas consumption. The western region is increasingly consuming its natural gas supply by using it for the city gas distribution and as CNG for automobiles.

Table A3- 61 *Other Liquid Terminals in India – Status and Capacity*

S. No.	Terminals	Developers	Capacity (MMTPA)
Existing Terminal			
1	Dahej	Petronet LNG Limited	17.5
2	Hazira	Royal Dutch Shell, Total Electricite	5
3	Dabhol	GAIL,NTPC	5
4	Kochi	Petronet LNG Limited	5
5	Ennore	Indian Oil Corp	5
6	Mundra	GSPC, Adani	5

S. No.	Terminals	Developers	Capacity (MMTPA)
	Total		42.5
Under construction			
7	Jaigarh (FSRU)	H Energy	4
8	Dhamra	Adani	5
9	Jafrabad (FSRU)	Swan	5
10	Chhara	HPCL & Shapoorji Pallonji	5
	Total		19
Proposed			
11	East coast	Petronet LNG Limited	5
12	Kakinada/Krishnapatnam/Karaikal	Others	2.5
13	Kolkata/Digha Port	H Energy	2.5
	Total		10
Total Capacity (Existing + Upcoming)			**71.5**

As represented in the figure below, Natural gas import began in 2002. Domestic consumption was limited to local production till 2002. India began to import natural gas to meet its energy demand by setting up Other Liquid import facilities. The natural gas imports have grown steadily since 2002. The conventional gas production output has been inadequate to meet the demand. The gap is met through Other Liquid imports and re-gasification of the imported Other Liquid via four terminals.

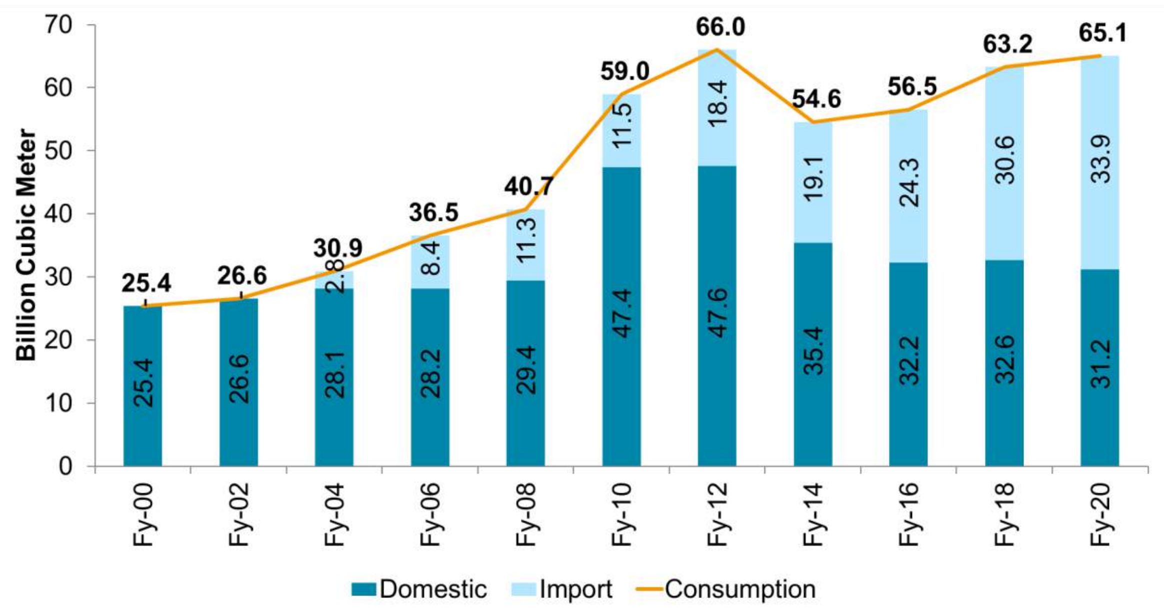

Figure A3-60 Other Liquid Trade in India

Considering the natural gas shortage in India, the government has laid down the policy guidelines to allocate domestic gas to various sectors. Marketers are, however, free to import Other Liquid and sell the Other Liquid to the consumers. Industries predominantly dependent on Domestic Natural Gas supply, use of imported Other Liquid in various sector is listed below;

- The power sector predominantly depends on the domestic supply sources of natural gas. The power industry gets a supply of about 80-90% of the domestic production.
- Industries dependent on both domestic production and imported natural gas
- The availability of domestic supply to the fertilizer industry varies over the years. The industry used to meet about 50% of its requirement from domestic production. This industry now increasingly depends on the imported natural gas supply.
- CGD and CNG industry is growing over the years and depends on both domestic production and imported natural gas. This could be one of the target industries for Vadhavan Port.
- Petrochemicals and Refineries largely depend on the imported natural gas supply. Only about 25% to 35% of the total requirement is met by domestic production at present. The petrochemicals industry uses much of this domestic production.
- Other Industries and small consumers like Gas-based Bulk Liquid
- plants, small consumers, and the steel industry largely depend equally on domestic and imported natural gas. The industrial units near the Vadhavan port are the key target industry for Vadhavan Port.

Looking at the current market scenario, CGD, CNG could be the target area for Vadhavan Port. This gas imported from the port is used CNG in Mumbai, local fertilizer industry. Supply to the industries in the immediate hinterland, steel industry in the local regions, and to any refineries that may come up near the port in the future.

Future Scope

Other Liquid usage is expected to see a considerable increase in India in the next few years. Oversupply of Other Liquid in the global markets will lower their import prices in India. Abundant gas reserves will also increase Other Liquid trade. A number of Other Liquid terminal projects and pipeline networks have been planned in India for the coming years. These projects will lead to an infrastructure induced demand. Purchase of Other Liquid will be supported by attractive incentives for consumers. This would lead to a steady replacement of coal by natural gas alternatives, thereby, helping India meet environmental and pollution control norms. The Indian government has also introduced a number of supportive policies like Push for CNG and Price pooling of Other Liquid for power and fertilizer segments. These policies are bound to expand the applications of Other Liquid.

The above mentioned drivers present a positive outlook for Other Liquid. Growth rates involving natural gas usage, demand and rate of increase are pegged to fertilizer growth, refinery capacity and increase in GDP respectively. India has been the world’s fourth-largest importer of Other Liquid terminals since 2011. There has been a gradual increase in Other Liquid imports as India’s domestic natural gas production declined and domestic consumption increased. India’s Other Liquid import capacity more than doubled during the past 10 years, and is expected to increase by a third in the next 3 years.

GAIL, the largest state-owned natural gas processing and distribution company, has signed 20-year contracts starting in 2018 to buy a supply of 2.5 MTPA of Other Liquid from both Gazprom PJSC (Russia) and Dominion Resources (US). These projects will help stem Natural Gas deficiency in India and increase the share of Other Liquid in power to 20 % by 2040. Several new Other Liquid terminals and capacity expansion projects in Kochi, Haldia and Mangalore are proposed on the East and the West coast of India. Besides these, a few pipeline projects connecting India to its neighbouring countries are also proposed as follows:

- TAPI pipeline at an estimated cost of $10 billion
- Iran-Oman-India sub-sea pipeline

- India-Bangladesh-Myanmar pipeline

At least, one of these pipelines needs to be completed by 2030 to meet India's growing needs.

Assumptions & 25 years Projections

All India requirement of natural gas over the years is estimated based on projecting the present industry-wise use of natural gas as per the industry-specific parameters. Other Liquid projections is derived from consumption, domestic production, supply from cross national pipelines and capacity of proposed Other Liquid terminals. Higher quantities of natural gas are being used for City Gas Distribution in Mumbai city. Vadhavan port being near to Mumbai can act as a source of Other Liquid by connecting incoming imports of Other Liquid at its port to power plants and refineries in Mumbai. Dahej-Uran-Panvel pipeline passes near Vadhavan. It has an additional capacity of 3.5 to 4.5 mmscmd that may be tapped into by Vadhavan. The port can also extend its supply of Other Liquid to several industrial and commercial units in its vicinity by transporting Other Liquid in tankers over short or long distances by road or rail. The estimation of the natural gas import requirement over the years is illustrated in the table below.

Table A3- 62 Growth Rate Assumption for Other Liquid

Commodities	FY21-FY25	FY26-FY30	FY31-FY35	FY36-FY40	FY41-FY45	FY46-FY50
All India	8.0%	7.0%	6.0%	5.0%	4.0%	4.0%
Western Region Share	80.0%	80.0%	70.0%	60.0%	60.0%	60.0%
Vadhavan Share	50.0%	50.0%	50.0%	50.0%	50.0%	50.0%

Over the last few years, the production of natural gas has decreased. According to the National Perspective Plan estimates, the present saturation may not improve substantially. The average growth of imports is estimated to be 8% for initial 5 years, 7% for next 5 years till FY30, 6% till FY35, 5% till FY40 and 4% till FY50. After studying the past trend, it is considered that for initial 10 years' western region will keep contributing 80% in the imports and thereafter 70% till FY35 and 60% till end i.e. FY50. Based on the announced projects list, there would not be much demand for Other Liquid terminals on the Western Coasts until FY2028. Thereafter, it is assumed that the existing Other Liquid infrastructure capacity will exhaust and lead to demand supply gap for Other Liquid. The 50% of this unmet demand could be tapped by Vadhavan Port and rest by upcoming infrastructure. The figure below shows the Other Liquid traffic that Vadhavan Port would handle for next 25 years

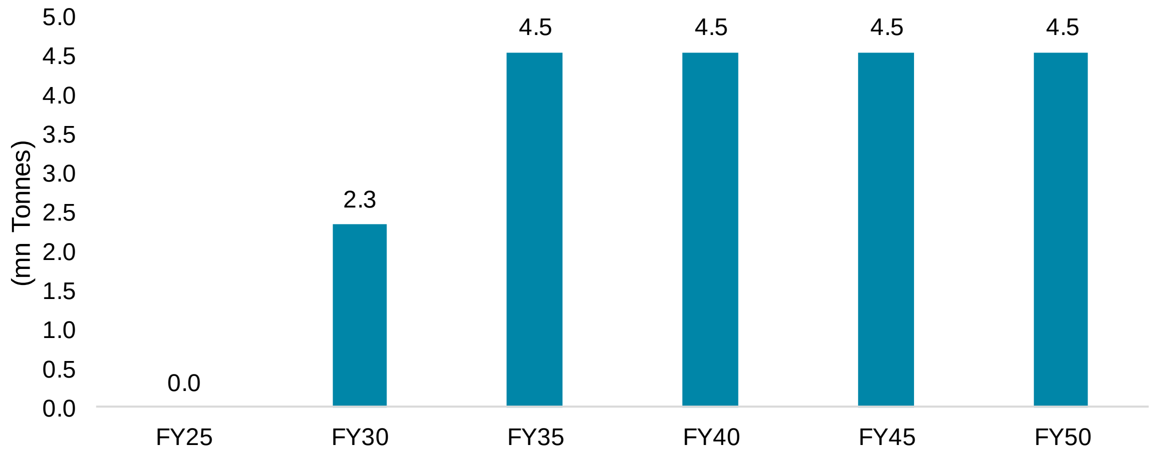

Figure A3-61 Other Liquid Traffic Projections for Vadhavan Port

A3.13.6 Bulk Liquid

Present Scenario

India's domestic production of Bulk Liquid is very low and cannot meet its consumption demand adequately. The main reasons for this low growth are the government's focus on petrol and diesel as important fuels for automobiles and various other sectors while side-lining the benefits of Bulk Liquid and the cost of producing and manufacturing Bulk Liquid in proper containers is high as compared to other fuels. Because of the mentioned reasons, most of India's Bulk Liquid consumption demands are met by imports of Bulk Liquid. These imports satisfy around 46% of Bulk Liquid demands in India.

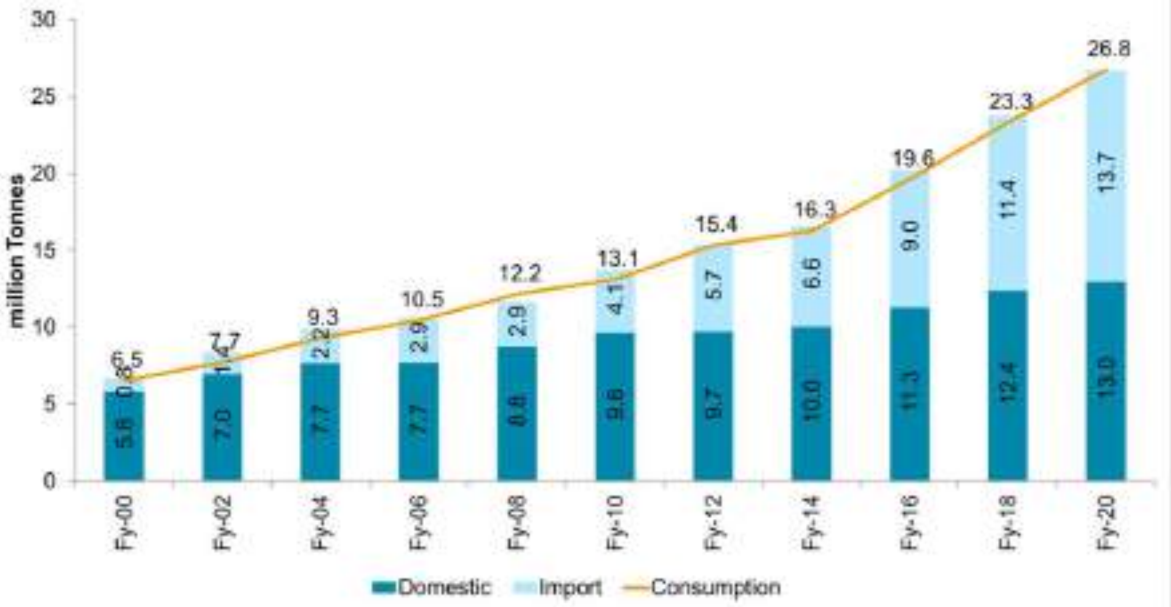

Figure A3-62 Bulk Liquid Trade in India

The figure above presents the Bulk Liquid production, consumption and imports in last 20 years. Considering the period of FY01 to FY20, India's Bulk Liquid consumption has grown at CAGR of 7%. Given the rising Bulk Liquid consumption in India, Bulk Liquid production, being at a CAGR of 4% during this period, is unable to meet the demand for Bulk Liquid consumption. The subdued growth rate in the domestic Bulk Liquid production can be attributed to the factors like production of petrol and diesel taking precedence over Bulk Liquid and the disinclination towards the deployment of capital intensive Bulk Liquid production technology. Therefore, the Import of Bulk Liquid has been the only solution to bridge the gap between the demand and the low production led short supply.

Bulk Liquid is mostly imported from Middle Eastern countries like Kuwait, Qatar and Saudi Arabia. Primary importers are the three major oil companies – Indian Oil Corporation, Hindustan Petroleum Corporation Limited and Bharat Petroleum Corporation Limited. All of these companies are Public Sector Undertakings that are either state-owned or owned by the central government. On the other hand, secondary importers like Super Gas, Aegis and IMC are privately owned companies. These companies also import from the same Middle Eastern countries but at a higher cost and in lower amounts. While secondary importers account for 5% of total Bulk Liquid imports, primary importers make up nearly a 95% proportion of total Bulk Liquid imports.

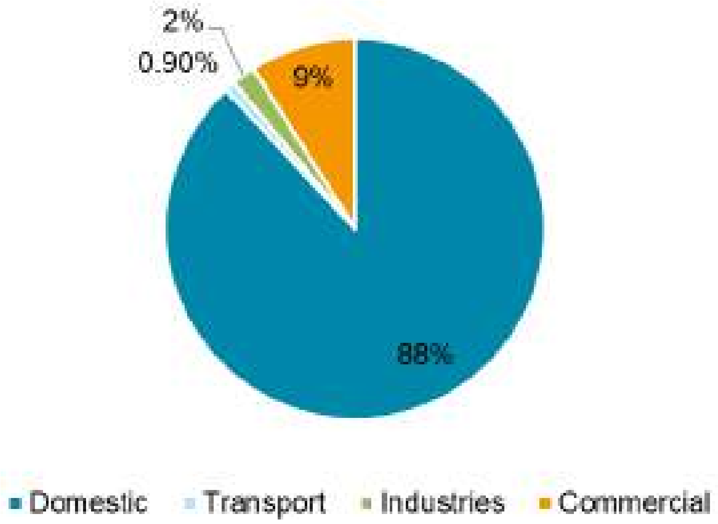

Figure A3-63 Sector wise Consumption of Bulk Liquid in India

In general, domestic sector uses up 88% of India's Bulk Liquid consumption while industries and factories consume 2% of Bulk Liquid. The transport sector makes up the remaining 0.9% of Bulk Liquid and commercial sector up to 9%. The figure below represents the Bulk Liquid classification on state-wise basis or rather a region-wise basis.

Figure A3-64 *Bulk Liquid Consumption Share in India*

North India consumes 32% of the total Bulk Liquid in India. Central India uses only 5% of India's total Bulk Liquid consumption. West India making up 18% of total Bulk Liquid consumption. Around 47% of the northern states total Bulk Liquid demands are met by domestic production of Bulk Liquid in refineries located very near to these states. The remaining 53% of Bulk Liquid demand share is satisfied by imports on the West Coast ports. India's current import capacity is 10 MMTPA, 65% imports are handled by 6 ports on the West coast while 35% imports are handled by 5 ports on the south and the east coast. Kandla, Dahej and Pipavav in Gujarat import 24% of Bulk Liquid while JNPA and Mumbai in Maharashtra make up nearly 11% of Bulk Liquid imports.

*Figure **Error! No text of specified style in document.**-65 Bulk Liquid Import Terminals and Pipeline Infrastructure*

The existing and upcoming Bulk Liquid ports and pipelines of India are represented in the figure above. It is worthy of seeing that in west coast, Maharashtra has 168 km long Uran to Chakan HPC pipeline of 1 Mn T under implementation. Also, Kandla to Gorakhpur 2,400 km long pipeline of 6 Mn T capacity is being implemented by IOC/HPC/BPC JV in Gujarat state. This pipeline would connect the Dahej Bulk Liquid import terminal to the HPCL bottling in Ujjain, Madhya Pradesh. It will ensure adequate Bulk Liquid supply to Madhya Pradesh for the horizon years. The Vadhavan port's ability to cater to the Bulk Liquid demand in the Madhya Pradesh regions would be limited. IOC, HPC and BPC in JV are planning to build Mundra – Kandla 90 km long pipeline of 4 Mn T capacity.

Table A3- 63 Capacity of Refineries in India

S. No.	Oil Company	State	Location	Capacity (MMTPA)
1.	IOCL	Bihar	Barauni	6.0
2.		Gujarat	Koyali	13.7
3.		West Bengal	Haldia	7.5
4.		Uttar Pradesh	Mathura	8.0
5.		Haryana	Panipat	15.0

S. No.	Oil Company	State	Location	Capacity (MMTPA)
6.		Assam	Guwahati	1.0
7.		Assam	Digboi	0.7
8.		Assam	Bongaigaon	2.4
9.		Odisha	Paradip	15.0
			Total - IOCL	**69.3**
10.	HPCL	Maharashtra	Mumbai	7.5
11.		Andhra Pradesh	Visakh	8.3
12.	HPCL & HMEL (JV)	Punjab	Bathinda	11.3
			Total - HPCL	**27.1**
13.	BPCL	Maharashtra	Mumbai	12.0
14.		Kerala	Kochi	15.5
15.	BPCL & BORL (JV)	Madhya Pradesh	Bina	7.8
			Total - BPCL	**35.3**
16.	CPCL	Tamil Nadu	Manali	10.5
17.		Tamil Nadu	Cauvery Basin	1.0
			Total - CPCL	**11.5**
18.	NRL	Assam	Numaligarh	3.0
19.	ONGC	Andhra Pradesh	Tatipaka	0.1
20.	ONGC & MRL	Karnataka	Mangalore	15.0
			Total - ONGC	**18.1**
			Total - PSU / JV	**161.3**
21.	RIL	Gujarat	Jamnagar (Dta)	33.0
22.		Gujarat	Jamnagar (Sez)	35.2
23.	NEL	Gujarat	Vadinar	20.0
			Total - Private	**88.2**
			Total - All India	**249.5**

Table A3- 64 Pipeline Capacity in India

S. No.	Oil Company	Pipelines	Length (km)	Capacity (MMTPA)
		Existing Pipelines		
1.	GAIL	Jamnagar – Loni	1,201.0	2.5
2.	GAIL	Visakhapatnam – Secunderabad	589.0	1.1
3.	IOC	Panipat – Jalandhar	273.0	0.7
4.	HPC	Mangalore-Hassan – Mysore	356.0	3.1
5.	IOC	Paradip-Haldia-Durgapur	710.0	1.4

S. No.	Oil Company	Pipelines	Length (km)	Capacity (MMTPA)
Under Implementation Pipelines				
6.	IOC	Durgapur – Barauni – Patna – Muzzafarpur	568.0	2.0
7.	HPC	Uran – Chakan	168.0	1.0
8.	IOC & BPC (JV)	Kochi – Coimbatore – Erode – Salem	458.0	1.5
9.	IOC, HPC, BPC (JV)	Kandla – Gorakhpur	2,400.0	6.0
Proposed Pipelines				
10.	IOC, HPC, BPC (JV)	Mundra – Kandla	90.0	4.0
11.	HPC	Hassan - Cherlapally	350.0	1.5
12.	IOC	Ennore – Trichy – Madurai	615.0	0.9

Bulk Liquid produced at the Gujarat's refineries help meet the overall Bulk Liquid demand of Gujarat. Gujarat enjoys a surplus of 4.07 Mn T from its Bulk Liquid production after satisfying the internal Bulk Liquid demand. This surplus is distributed to the regions of Northern, Central, and Western India. IOCL imports Bulk Liquid from Dahej's GCPTCL terminal to cater to the Madhya Pradesh market demand for Bulk Liquid consumption. One refinery at Madhya Pradesh produces about 0.19 Mn T of Bulk Liquid annually. Around 0.06 Mn T of Bulk Liquid imported at JNPA is also carried to Madhya Pradesh via railway. Maharashtra's Bulk Liquid consumption demand is one of the highest in the country, constituting about 15% of India's overall Bulk Liquid consumption. The total import aggregated at Dahej, Mumbai, and JNPA help meet the consumption demand of Maharashtra. The Bulk Liquid imported at the Mumbai terminal caters to Pune, Nasik, and Kolhapur to meet these regions' Bulk Liquid consumption demand.

Table A3- 65 Bulk Liquid Import Refineries in India

<table>
<tr><th>Region</th><th>Port</th><th>Import Terminals</th><th>Capacity (MMTPA)</th><th>Status</th></tr>
<tr><td rowspan="8">Western</td><td>Kandla</td><td>IOC</td><td>1.20</td><td>Operational</td></tr>
<tr><td>Mundra</td><td>Adani</td><td>1.36</td><td>Operational</td></tr>
<tr><td>Jamnagar</td><td>RIL</td><td>0.48</td><td>Operational</td></tr>
<tr><td>Porbandar</td><td>SHV</td><td>0.36</td><td>Operational</td></tr>
<tr><td>Pipavav</td><td>Aegis</td><td>0.36</td><td>Operational</td></tr>
<tr><td>Dahej</td><td>GCPTL</td><td>0.24</td><td>Operational</td></tr>
<tr><td>MbPT</td><td>Aegis</td><td>0.14</td><td>Operational</td></tr>
<tr><td>JNPA</td><td>BPC</td><td>0.60</td><td>Operational</td></tr>
<tr><td rowspan="5">Southern</td><td rowspan="2">New Mangalore</td><td>Total</td><td>0.36</td><td>Operational</td></tr>
<tr><td>HPC</td><td>1.32</td><td>Operational</td></tr>
<tr><td>Cochin</td><td>IOC</td><td>0.60</td><td>Under-Construction</td></tr>
<tr><td>VOC</td><td>SHV</td><td>0.12</td><td>Operational</td></tr>
<tr><td>Ennore</td><td>IPPL</td><td>1.32</td><td>Operational</td></tr>
</table>

Region	Port	Import Terminals	Capacity (MMTPA)	Status
	Vizag	EIPL	0.50	Operational
		SA Bulk Liquid	1.00	Operational
Eastern	Paradip	IOC	2.00	Under-Construction
	Haldia	IPPL	1.70	Operational
		Aegis	1.00	Operational
		BPC	1.00	Operational

At present, India's total import capacity, 10.7 MPTA, is distributed across 11 ports. The 8 of these ports are on the West Coast, while the rest are on the Southern and Eastern Coast Lines. The table represents the port-wise imported Bulk Liquid on west coast ports in last 5 years.

Table A3- 66 Bulk Liquid Imports in Western Region of India

State	Port	FY16	FY17	FY18	FY19	FY20
Gujarat	Kandla	0.03	1.00	1.22	1.79	1.72
	Dahej	-	-	0.06	-	-
	Jafrabad	-	0.04	0.32	0.15	0.15
	Porbandar	0.21	0.16	0.15	0.09	0.10
	Sikka	0.56	0.14	-	0.07	-
	Mundra	-	-	-	-	0.38
Maharashtra	MbPT	0.75	0.89	0.93	0.86	0.91
	JNPA	0.68	0.67	0.63	0.80	0.86
Total		**2.23**	**2.90**	**3.31**	**3.77**	**4.11**

West Coast Ports serve Northern Central and Western hinterland. Currently, the Bulk Liquid consumption demand for Northern Region stands at 8.6 Mn T. Domestic production caters to about 50% of the Bulk Liquid demand of the Northern region. The imports via West Coast ports help meet the deficit between the consumption demand and domestic Bulk Liquid production. Gujarat ports serve the Northern states Bulk Liquid imports demand. Bulk Liquid imports from these ports are transported via the Jamnagar Loni pipeline. Leveraging the availability of future pipeline capacity connecting the Gujarat ports to the Northern hinterland and the future capacity expansion plan at Gujarat ports, the Northern region will continue to meet the Bulk Liquid import demand. Therefore, the potential of Vadhavan to serve this hinterland would be limited.

Urbanization and population growth are expected to increase the Bulk Liquid consumption demand in the future. This will widen the Bulk Liquid deficit in both these states. There is a limited potential of the Dahej, JNPA, and Mumbai to cater to the rising deficit. Hence, Maharashtra and Madhya Pradesh would be the potential hinterland for the Vadhavan port. JNPA and MbPT would be the competitors of these ports.

Future Scope

Economic growth and rural penetration are the demand drivers for Bulk Liquid. Economic growth in India means an increase in per capita income and GDP of India. This growth would boost the transfer of fuel usage from conventional fuels like crude oil and coal to natural gas fuels like Bulk Liquid and Other Liquid. Bulk Liquid's rural penetration is expected to reach 31% in 2040 and would help to further fortify Bulk Liquid's hold on the domestic sector. The estimation of Bulk Liquid's demand is directly linked to India's population growth. It is estimated that Bulk Liquid's demand will rise by 100% at the urban level and by 30% at the rural level by the year 2040.

A cluster wise demand supply gap analysis found that surplus Bulk Liquid from Gujarat's port terminals will be supplied to the Northern states through dedicated pipelines. Import demand of Madhya Pradesh and Maharashtra will be handled by JNPA, MbPT, Dahej and Vadhavan. In the future, Maharashtra and Madhya Pradesh are guaranteed to face a shortage of Bulk Liquid and this extra demand can be met by Vadhavan.

Vadhavan's traffic potential is mapped out with respect to specific ports in its hinterland that can compete with Vadhavan for reception and transportation of Bulk Liquid imports on the West Coast. Maharashtra would act as the only potential market for Vadhavan in the beginning. This is because Madhya Pradesh would be catered by Dahej's pipe connection to HPCL plants in Ujjain.

The loss of Madhya Pradesh as a potential market would not have an adverse effect on Vadhavan as the import demand in Maharashtra would still remain strong in the absence of a dedicated Bulk Liquid terminal at JNPA. JNPA would not carry out additional capacity expansion for handling of Bulk Liquid. Vadhavan will, thus, be able to supply Bulk Liquid to restricted areas as well as those places with unmet demands. India's overall Bulk Liquid import demand is expected to be about 28.7 million tonnes by 2050. Out of the total amount, market size considering Maharashtra would be about 11.49 million tonnes. Vadhavan would provide 40% to 45% of western region import that comes to about 5.2 million tonnes by 2050.

Assumptions & 25 Years Projections

The northern region is likely to experience the highest Bulk Liquid supply deficit in the coming years. This deficit is expected to be met through the surplus availability of Bulk Liquid in Gujarat. As discussed earlier, Gujarat is an Bulk Liquid surplus state distributing its Bulk Liquid production surplus to the Northern region via the Jamnagar Loni pipeline while the Dahej port transports the Bulk Liquid production surplus to Maharashtra and Madhya Pradesh. It is assumed that till FY30 Vadhavan would attract 40% of western region Bulk Liquid imports and thereafter 45% till FY50. This is envisaging that in coming years Maharashtra will face a deficit because JNPA is primarily a container port. It has not been envisaged to have additional Bulk Liquid handling capacity coming up in the port soon. There are no plans to increase the Bulk Liquid handling capacity at the Mumbai Port as of now. Therefore, Vadhavan port has a strong potential to handle the import demand of Maharashtra.

Table A3- 67 Growth Rate Assumption for Bulk Liquid

Commodities	FY21-FY25	FY26-FY30	FY31-FY35	FY36-FY40	FY41-FY45	FY46-FY50
All India	**4.0%**	**3.0%**	**2.0%**	**2.0%**	**2.0%**	**2.0%**
			⇩			
Western Region Share	40.0%	40.0%	40.0%	40.0%	40.0%	40.0%
			⇩			
Vadhavan Share	40.0%	40.0%	45.0%	45.0%	45.0%	45.0%

The potential market of the Vadhavan port will cater within Maharashtra for the reason discussed above. It is estimated that the domestic supply will be able to cater to the Bulk Liquid demand up to 1.2 MTPA, while the Bulk Liquid import will help meet the deficit. The competitive ports would handle around 60% of import demand and Vadhavan would handle remaining 40% - 45%. Bulk Liquid traffic for Vadhavan is forecasted based on the import demand in India - share contribution of western region in it – share diversion towards Vadhavan from competing ports in western region. The figure below shows the Bulk Liquid traffic that Vadhavan Port would handle for next 25 years

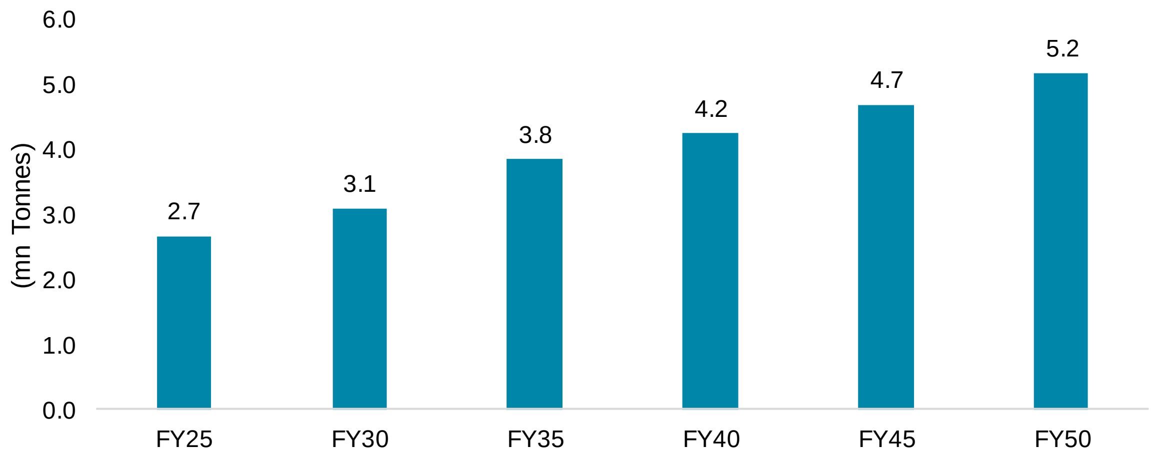

Figure A3-66 Bulk Liquid Traffic Projections for Vadhavan Port

A3.13.7 Coastal and General Cargo

Present Scenario

Ports act as gateway for trade. It also acts as a catalyst for economic growth in areas around the port. Every large international port has a city developed around it. Sea ports facilitate large scale economic development in the region. There would be large number of ancillary development to support seamless activity at the port.

Vadhavan and its surrounding area would have to grow into a large scale industrial and logistics hub. The port would support trade activity for growing demand for materials related to infrastructure development at the port.

- Vadhavan would become another Mumbai Metropolitan Region as it would have more than 3 times total sea ports traffic
- MMR region every year consumes more than 8 million tonnes of cement alone to keep its construction and development activities in pace
- Additional volumes of other commodities supplied to city

Vadhavan Port development would lead to infrastructure development in nearby region, ultimately demand for construction and building material would rise up. Vadhavan too would need large scale influx of construction materials in the form of Cement, Steel rods, etc. for building the city and upgrading it with rise of port volumes. Evaluating economic impact of development in the region, it is understood that demand of construction materials in the region is going to increase in future. This demand would have met by procuring materials from other states. Vadhavan port could grab this opportunity by catering this demand by supplying the required materials through coastal movement procurement. Keeping this as basis, general and coastal cargo is also considered to get handled at Vadhavan Port. General cargo includes the imported iron and steel rods / pipes and coastal cargo caters to the building materials like cement, stones, sand, etc. procured from other states.

Assumptions & 25 years Projections

As discussed in section above, General cargo consists of importing iron and steel rods and pallets and coastal cargo is for procuring construction materials. These cargos would be generated from port based development in the region. Development of Vadhavan port would lead to industrial and infrastructure enhancement of the region. Considering the FY21 base traffic as 2.4 Mn T for general cargo and 1.7 Mn T for coastal cargo, 10% y-o-y growth rate is assumed for initial 10 years, 8% for next 5 years till FY35. FY36 onwards 1% growth rate has been reduced at the interval of every 5 years i.e. 6% till FY40, 5% till FY45 and 4% till FY50.

Table A3- 68 Growth Rate Assumption for Coastal and General Cargo

Commodities	FY21-FY25	FY26-FY30	FY31-FY35	FY36-FY40	FY41-FY45	FY46-FY50
General Cargo	10.0%	10.0%	8.0%	6.0%	5.0%	4.0%
Coastal Cargo	10.0%	10.0%	8.0%	6.0%	5.0%	4.0%

Based on the above growth rates, next 25 years' traffic for coastal and general cargo has been projected. The figure below shows the same.

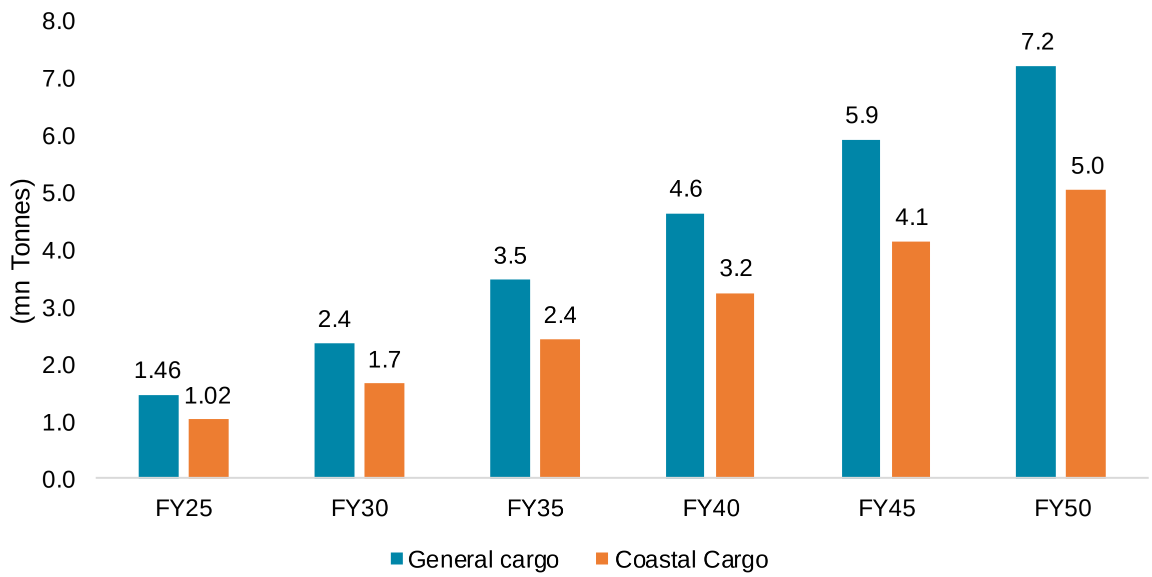

Figure A3-67 Coastal and General Cargo Traffic Projections for Vadhavan Port

A3.14 Traffic Summary

The section provides a summary of traffic projections for Vadhavan Port of container trade and other principle commodities like Edible Oil, Bulk Liquid, Other Liquid, Fertilizer, Chemical, General Cargo and Coastal Cargo and Ro-Ro. The table below represents the container projections made for the next 25 years up till FY50 using three scenarios – Pessimistic, Realistic and Optimistic.

Table A3- 69 Derivation of Vadhavan Port's Traffic from All India Container Projections (mn TEUs)

India Traffic	2020	2025	2030	2035	2040	2045	2050
All India							
Pessimistic	17.3	24.9	33.0	41.7	50.3	58.3	67.6
Realistic	17.3	25.3	36.1	50.2	66.5	84.0	102.3
Optimistic	17.3	25.4	37.1	53.0	73.7	97.7	124.7
North West Traffic							
Pessimistic	11.6	16.7	21.5	26.7	32.2	37.3	43.3
Realistic	11.6	16.9	24.0	33.1	43.2	53.8	65.4
Optimistic	11.6	17.0	24.9	35.5	49.4	65.5	83.5
Vadhavan							
Pessimistic	0.0	0.7	4.0	7.7	12.2	14.8	19.3
Realistic	0.0	0.9	6.5	14.1	23.2	31.3	39.4
Optimistic	0.0	1.0	7.4	16.5	29.4	43.0	57.5

The table shows the derivation of Vadhavan port's traffic from All India and North West Container Traffic. On an All-India Traffic level, the Realistic Scenario shows an increase from 17.3 million TEUs in 2020 to 99.9 million TEUs in 2050. Considering only the North West Traffic, container projections show a growth from 11.7 million TEUs to 65.9 million TEUs under the Realistic outlook. Vadhavan Port is expected to handle Container Traffic of 39.9 million TEUs under the Realistic Scenario

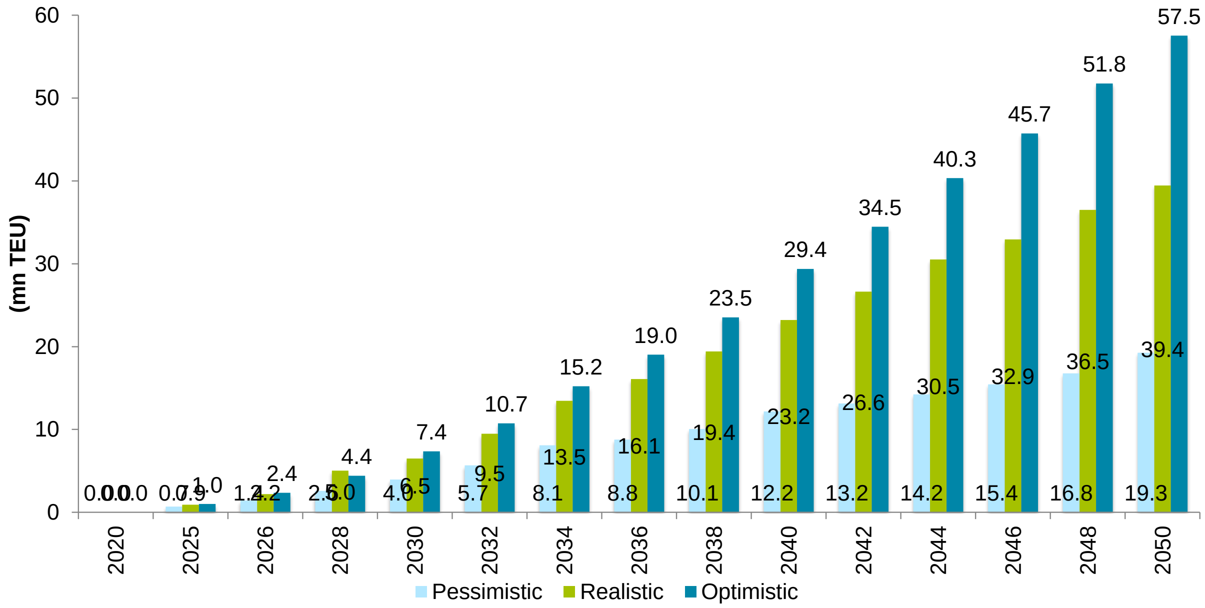

Figure A3-68 Container Traffic Projections for Vadhavan Port under Different Scenarios

The below figure depicts traffic projection of other principle commodities. Non-Container traffic at Vadhavan is estimated to be 5.7 Mn T in initial year i.e. FY21 and reach up to 26.1 Mn T in FY50. Bulk Liquid has a share of 5.2 million Tonnes while Other Liquid traffic would reach 4.5 million Tonnes in FY50. General Cargo would contribute around 7.2 million Tonnes to traffic in FY50. Ro-Ro Vehicles reaches up to 0.23 Mn vehicles till FY50, it has not been considered in this graph.

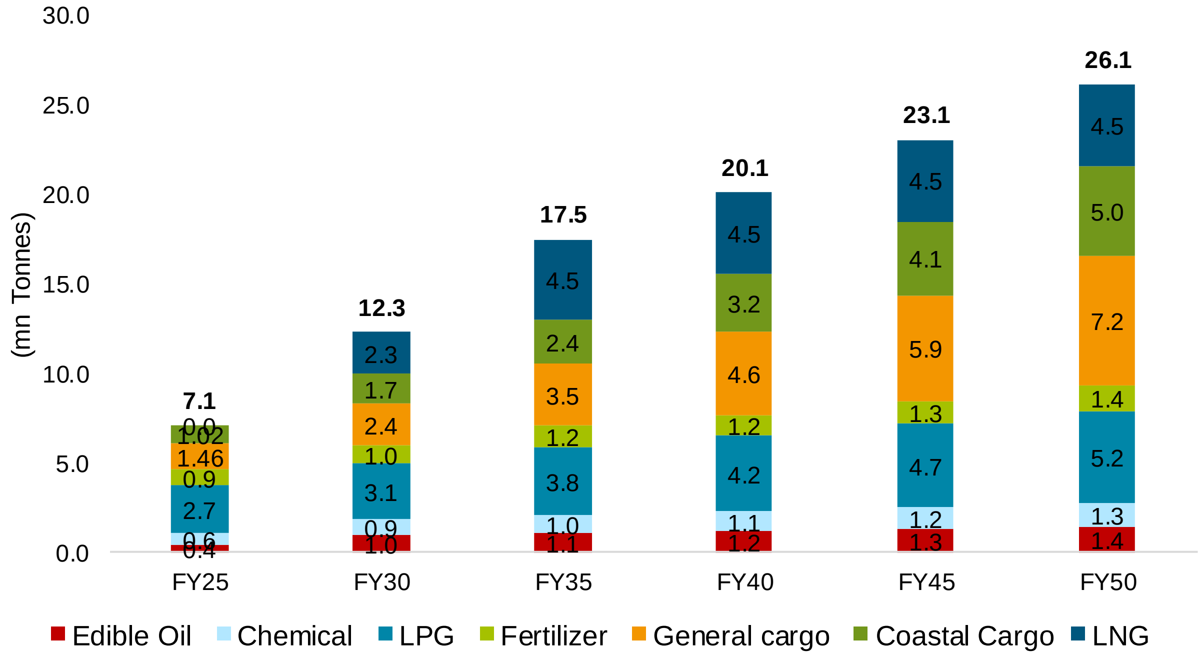

Figure A3-69 Commodity wise Traffic Projection for Vadhavan Port

The below table indicates Commodity Wise Traffic Projection for Vadhavan Port for the next 25 years until FY50.

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JNPA

Table A3- 70 Commodity wise Traffic Projection for Vadhavan Port (mn T)

Commodities	FY21	FY25	FY30	FY35	FY40	FY45	FY50
Edible Oil	0.0	0.4	1.0	1.1	1.2	1.3	1.4
Chemical	0.0	0.6	0.9	1.0	1.1	1.2	1.3
Bulk Liquid	0.0	2.7	3.1	3.8	4.2	4.7	5.2
Fertilizer	0.0	0.9	1.0	1.2	1.2	1.3	1.4
General cargo	0.0	1.5	2.4	3.5	4.6	5.9	7.2
Coastal Cargo	0.0	1.0	1.7	2.4	3.2	4.1	5.0
Other Liquid	0.0	0.0	2.3	4.5	4.5	4.5	4.5
Total	**0.0**	**7.1**	**12.3**	**17.5**	**20.1**	**23.1**	**26.1**
Ro-Ro ('000 Vehicles)	0.0	20.9	49.5	76.8	169.0	195.9	227.1

A3.15 Vessel Analysis

The following section details the fleet growth of container vessels of different capacities. A general trend seen globally is the usage of larger ships carrying more than 18,000 TEU of containers. The first few ship calls having a size of 20,000 TEU were seen in the year 2018. From then onwards there has been an increase in ship sizes leading to the 23,000+ TEU being used more frequently. The vessel analysis shows container fleet growth by number of ships and carrying capacity leading up to the year 2020 with discussions on 5-year and 10-year growth rates.

A3.15.1 Largest Container Ship

The size of container ships deployed on trade has consistently been increasing. The largest ship size on order is 24,100 TEU. Two ships of 24,100 TEU has been ordered for delivery in the year 2023. The largest container ship in operation has a carrying capacity of 23,964 TEU. The ship was contracted for new building in September, 2018 at the price of US$ 155.4 million and was delivered in 2020. There are 6 sister ships of same dimensions in operation owned by HMM. The principal particulars of the ships are as follows:

- Total TEU Capacities of 23,964 (Including 3,000 Reefer)
- Maximum TEU 9,932 in the Holds and 14,032 on Deck.
- Length Overall of 399.90 m
- Length Between Perpendiculars of 385.92 m
- Draught of 16.53 m
- Beam of 61.00 m
- Moulded Depth of 33.00 m.
- Gross Tonnage of 228,283
- MAN B. & W. Engine - Horsepower of 82,094
- Speed of 22.40 kts, Heavy Fuel Oil (IFO 380), Power Type: Diesel 2-Stroke, BWTS (Fitted), Scrubber (Installed), Other Liquid, Eco – Electronic Engine Modern.

A3.15.2 Fleet Growth

The graphs and tables in this subsection show the dominance of large capacity container shipping fleet presently deployed in the industry. Container ships in the intermediate segments have stopped being built.

They have been replaced with post Panamax ships. The container ships in this category cumulatively contribute to more than 70% of annual delivery and deployment of container ships in the industry.

The Indian container shipping industry is limited to handling lower draft container ships due to geographical constraints present at the port. The proposed Vadhavan Port with a natural water depth to accommodate larger size container ships would be able to complement existing lower draft container ports.

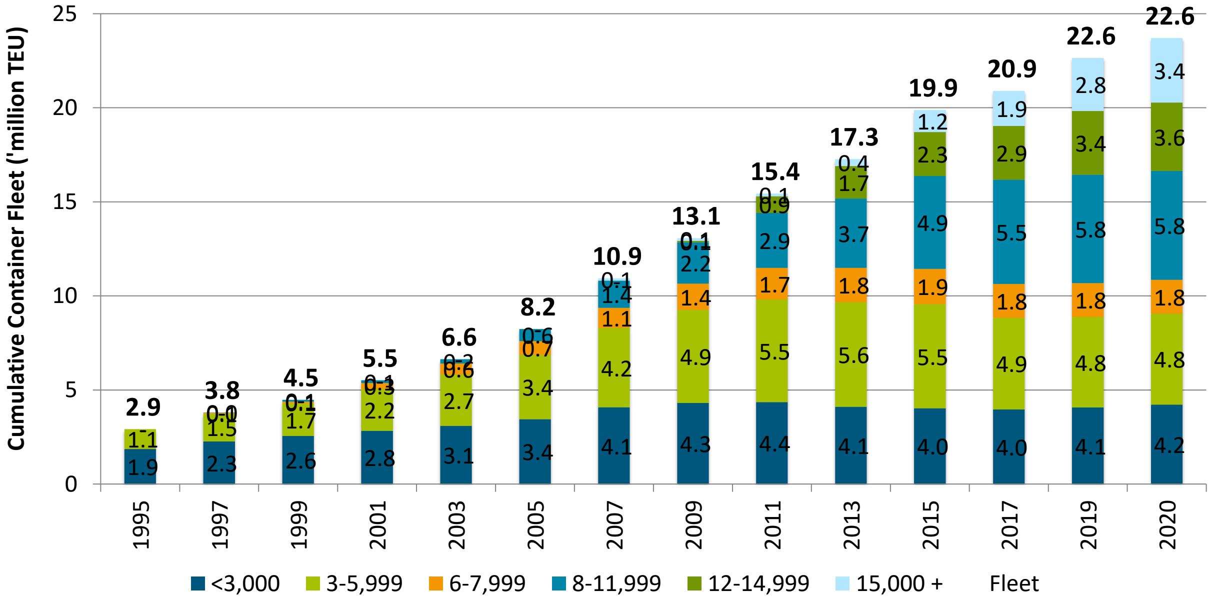

Figure A3-70 Container Fleet Delivery by Size in last 25 Years

The figure above displays the cumulative value in million TEU of container fleet delivery by size. Each of the bars in the graph are further divided based on the vessel carrying capacity. For example, in 1995, total container fleet size was 2.9 million TEU of which 1.8 Mn TEU were comprised of vessels of less than 3000 TEU capacity and the remaining 1.1 Mn TEU were vessels of 3,000 – 6,000 TEU capacity. Almost 25 years later in 2020, the total cumulative container fleet has increased to 22.6 M TEU. A large percentage of this volume, i.e., around 7 Mn TEU includes ships of more than 12000 TEU capacity. This equates to almost 27% of volume occupied by larger container ships. The midrange of 8 - 12,000 TEU covers another 5.8 Mn TEU in 2020. Hence, larger ship sizes have been more prevalent in recent years.

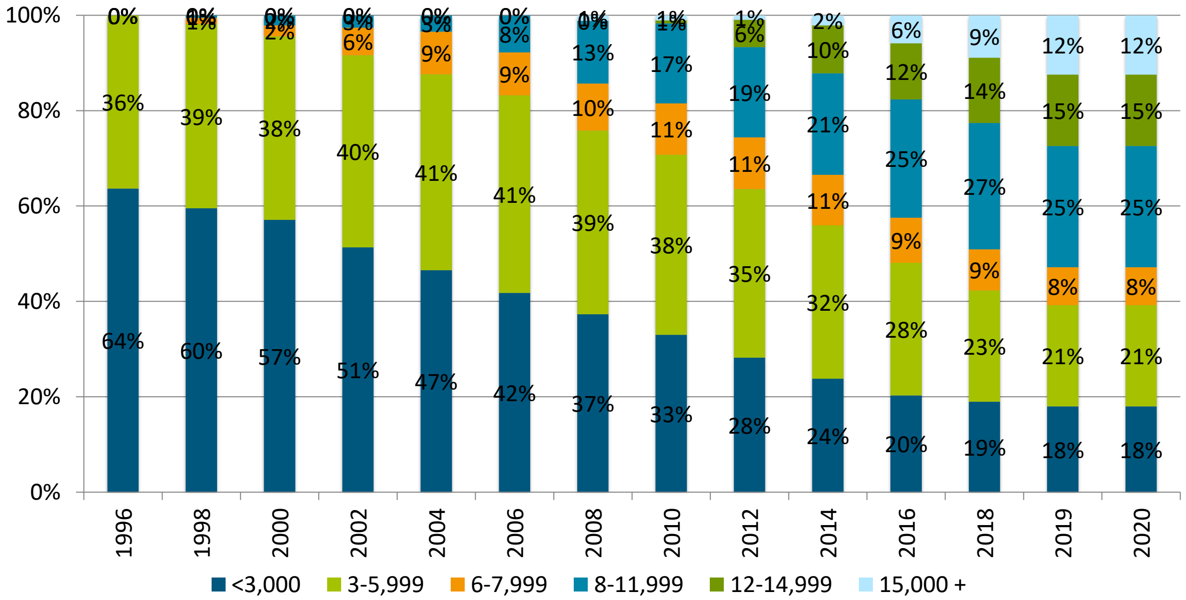

Figure A3-71 Container Fleet Delivery by Market Share in last 25 Years

The figure above indicates the percentage occupancy of container ships of different sizes. Vessels of less than 3000 TEU have seen a steep fall from 64% in 1996 to only 18% in 2020. On the other end of the spectrum, vessels of 12-15000 TEU and more than 15000 TEU have seen substantial growth in the last 5 years reaching 15% and 12% respectively. Even 8-12000 TEU vessels have increased from 2% in 2000 to 25% in 2020 during the last 20 years. But vessels of 3-6000 TEU have decreased year-on-year from 36% in 1996 to 21% in 2020. Thus, vessels handling container traffic are increasing in size globally and a higher percentage of vessels exceed more than 12000 TEUs

Table A3- 71 Container Fleet growth by Number of Ships

Start Year	<3,000 TEU	3-5,999 TEU	6-7,999 TEU	8-11,999 TEU	12-14,999 TEU	15,000 + TEU
2009	3,280	1,069	190	214	1	8
2010	3,228	1,130	211	244	6	8
2011	3,224	1,209	237	281	31	8
2012	3,215	1,242	252	324	66	8
2013	3,118	1,260	260	360	108	9
2014	3,033	1,247	274	409	130	21
2015	2,968	1,238	279	467	155	39
2016	2,959	1,234	282	542	174	65
2017	2,931	1,140	272	576	190	78
2018	2,925	1,088	270	603	210	101
2019	2,963	1,086	270	621	232	131
2020	2,990	1,076	270	623	250	161

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Start Year	<3,000 TEU	3-5,999 TEU	6-7,999 TEU	8-11,999 TEU	12-14,999 TEU	15,000 + TEU
5 Year CAGR	-1%	0%	2%	10%	45%	35%
10 Year CAGR	0%	-3%	-1%	6%	10%	33%

The above table shows growth in the container fleet with respect to the number of ships. Vessels of more than 15,000 TEU increased from 8 in FY09 to 161 in FY20 showing a 10-Year CAGR of 35%. Similarly, vessels of 12-15,000 TEU capacity grew exponentially from 1 in 2009 to 250 in 2020 showing the largest 10-Year CAGR of 45%. On the lower extreme, vessels of less than 3,000 TEU and 3-6000 TEU have shown 0% growths for 10-Year CAGR and a negative factor of -2% to -3% for 5-Year CAGR. Container ships in the intermediate range such as 6-8000 TEU have shown a nominal growth of 190 in 2009 to 270 in 2020 showing just a 2% CAGR while from 8-12,000 TEU container ships have shown a modest CAGR of 10% increasing to 623 vessels in 2020.

Table A3- 72 Container Fleet growth by Carrying capacity

Year Start	<3,000 TEU	3-5,999 TEU	6-7,999 TEU	8-11,999 TEU	12-14,999 TEU	15,000 + TEU
2009	4,368	4,649	1,264	1,917	14	143
2010	4,312	4,940	1,404	2,196	82	143
2011	4,343	5,296	1,576	2,531	420	143
2012	4,357	5,455	1,678	2,926	884	143
2013	4,211	5,572	1,732	3,251	1,440	159
2014	4,107	5,560	1,825	3,683	1,732	367
2015	4,033	5,542	1,858	4,230	2,070	692
2016	4,032	5,532	1,879	4,934	2,341	1,167
2017	3,961	5,109	1,815	5,265	2,571	1,412
2018	3,966	4,868	1,802	5,551	2,855	1,859
2019	4,063	4,851	1,802	5,747	3,165	2,446
2020	4,121	4,795	1,802	5,771	3,412	3,053
5 Year CAGR	0%	0%	3%	10%	45%	36%
10 Year CAGR	0%	-3%	-1%	6%	11%	35%

The table above shows container fleet growth by carrying capacity. The values of 10-Year and 5-Year CAGR show the highest growth of 45% in vessels of 12-15000 TEUs and a negative growth of -3% for vessels of 3-6000 TEUs. Vessels of 15000+ TEU have grown from 1,43,000 TEUs to 30,53,000 TEUs. Similarly, vessels of 12-15000 TEU have increased from just 14000 TEUs to 34,12,000 TEUs. Vessels of less than 3000 TEU and 3-6000 TEU have remained stagnant at the 42,00,000 TEU and 48,00,000 TEU marks. Vessels of 8-12000 TEU capacity have shown a small rise of 10% from 19,17,000 TEUs in 2009 to 57,71,000

TEUs in 2020. Thus, this table also shows a similar trend as compared to the previous table in regard to carrying capacity of the vessels.

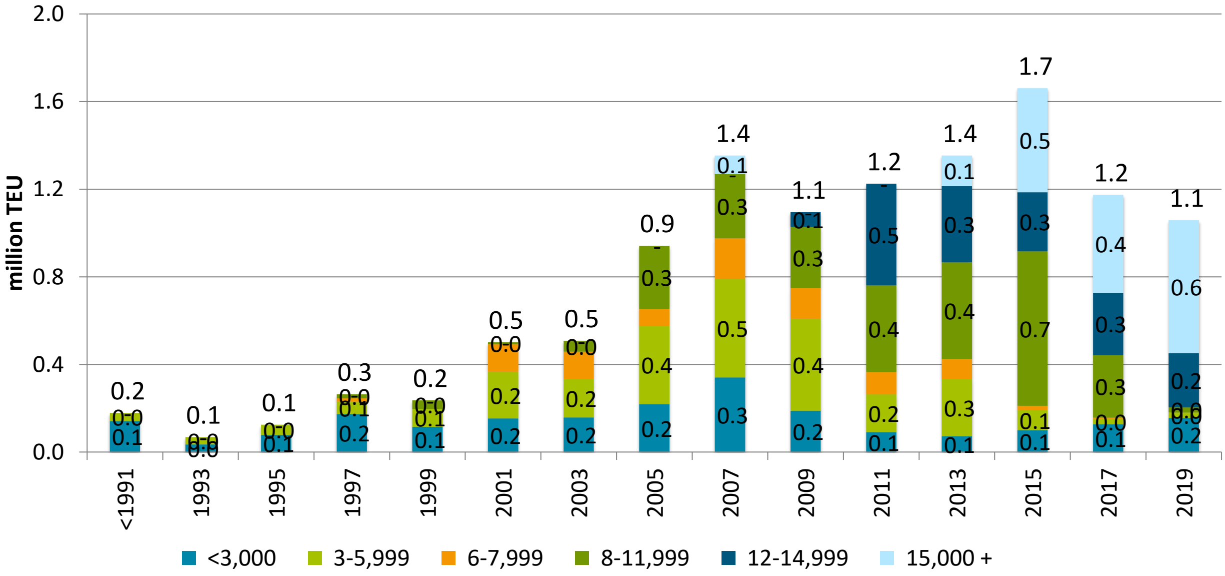

Figure A3-72 Container Fleet by Capacity

Figure above shows a wide scale superiority of large capacity container shipping fleet presently deployed in the industry. It displays a year wise distribution of vessel delivery for different container ship sizes. The larger ships have a capacity of 8-11999 TEU, 12-14999 TEU and more than 15000 TEU. Vessels with capacities in the midrange have gone out of demand and these ships of 6-7999 are no longer built. They have been replaced with post Panamax ships. The ships occupy around 70% of the delivery market share. In 2019, they contributed 0.8 million TEUs of a total of 1.1 million TEUs. Vessels of less than 3000 TEU contributed just 0.2 million TEUs in total. They have been fluctuating between 0.1 to 0.2 Mn TEUs for the past 10 years. The Indian container industry is slowly but surely moving towards larger capacity vessels overall.

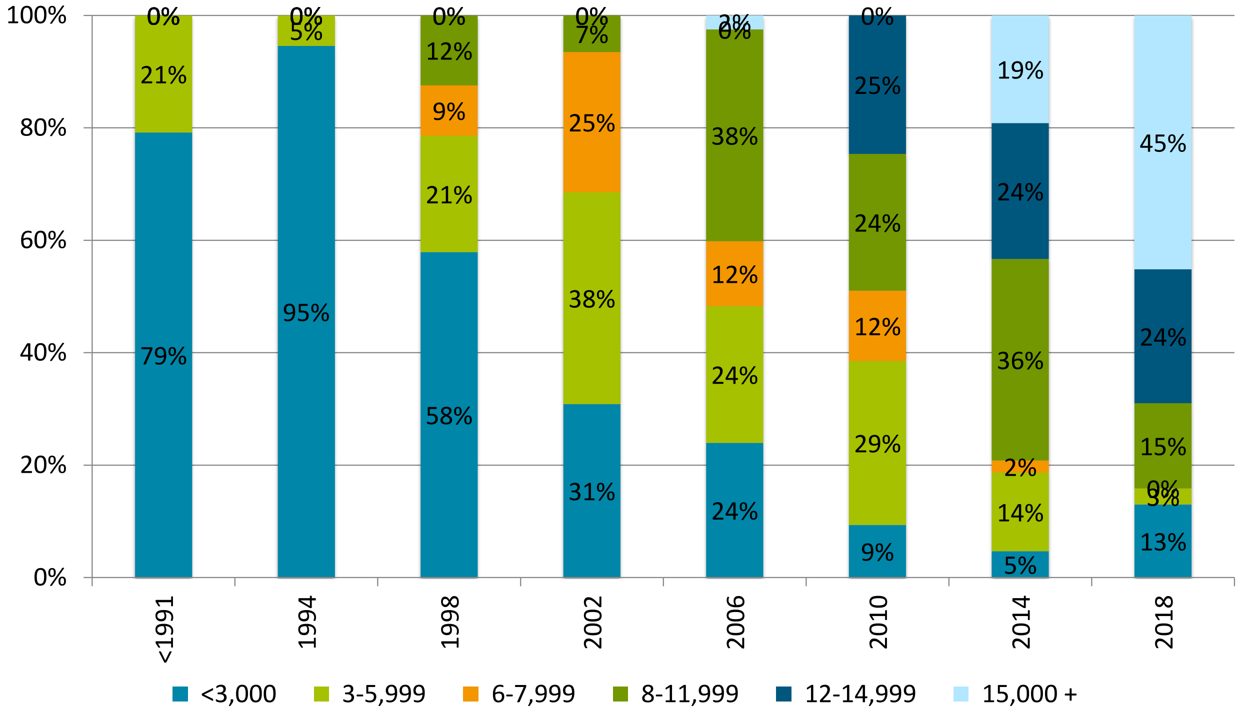

Figure A3-73 Container Fleet by Market Share

In the early 90's, the market share of container ship delivery was dominated by smaller ship sizes as evident from the above chart. Early 90's witnessed a 79% of delivery market share of less than 3,000 TEU capacity ships that reduced to 12% by 2018. The delivery market shares of 3-5,999 TEU capacity ships reduced from 21% in 1991 to mere 3% by 2018.This indicates a gradual increase in demand for larger ships and a consequent decrease in demand and production of smaller ships.

In the early 2000s ships with intermediate capacities were more in demand. Hence, the market shares of deliveries for 6-7,999 TEU capacity ships increased from 9% in 1998 to 25% in 2002. The dominance of 3-5,999 TEU container ships remained only till 2004. From 2004 onwards, larger capacity container ships were required by many shipping companies. The market trend showed increase in ships delivery of 8,000 TEU to 12,000 TEU from 2005 onwards. Further, from 2006 onwards, rise in demand for higher capacity ships increased the market share of 8-11999 TEU and 12-14999 TEU ships. From 2014 onwards, the market share was dominated by a larger share of 12-14,999 TEU and 15,000+ TEU ships. As per the current trend, the market has been consistent with 46% of 15,000+ TEU capacity ships followed by 24% of 12-14,999 TEU, and 15% of 8-11999 TEU delivery market share of ships in 2018.

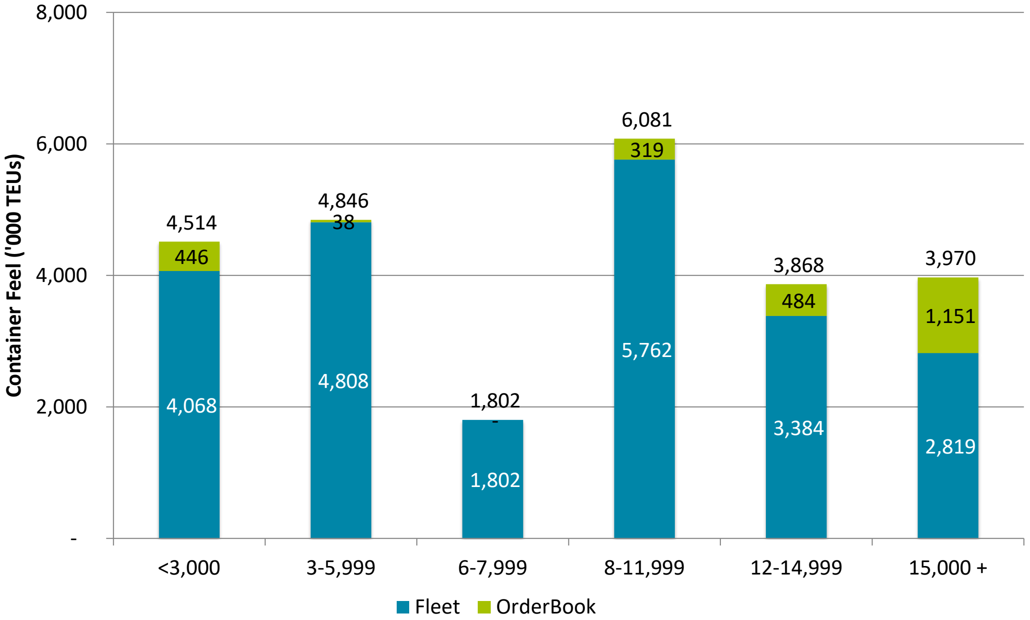

Figure A3-74 Capacity wise Container Fleet in Market

The figure above shows the total container fleet for vessels of different sizes. It also details the vessel order book. The delivered Fleet is represented by blue colour while the order book values are represented in green. Vessels of less than 3000 TEU have a current container fleet of 40,68,000 TEUs and an order book of 4,46,000 TEUs which totals to 45,14,000 TEUs. Vessels of 3-5,999 TEU have an order book of only 38,000 TEUs and a container fleet of 48,08,000 TEUs adding up to 48,46,000 TEUs. Vessels of 6-7,999 TEU have a container fleet of 18,02,000 TEUs which is underutilized. As no new ships are being built of this size, there is no order book for these vessels.

Vessels of 8-11999 TEU have a fleet of 57,62,000 TEUs and 3,19,000 TEUs. This category gives us the largest number in terms of TEUs, i.e., 60,81,000 TEUs. Vessels of 12-14999 TEU have a fleet of 33,84,000 TEUs and an order book of 4,84,000 TEUs. This adds up to 38,68,000 TEUs. Finally, vessels of more than 15000 TEU have a current container fleet of 28,19,000 TEUs and have the largest order book of 11,51,000 TEUs. This totals up to 39,70,000 TEUs for vessels of more than 15000 TEU

A3.16 Cargo Evacuation from Vadhavan Port

Cargo evacuation pattern from Vadhavan Port for each commodity is evaluated in this chapter. This evaluation is based on Traffic Projections, Evacuation pattern at competing ports, Availability of first/last mile connectivity and Development in transportation sector (Rail, Road, Pipeline). The sections below represent the Evacuation pattern proposed for Vadhavan for Container and other principle commodities along with reasoning behind selecting particular mode of transportation for evacuation.

A3.16.1 Containers

Seamless evacuation of container and cargo to the hinterland is essential for success of Vadhavan Port. The capacity of port is minimum of the capacity of berth, capacity of storage and capacity of cargo evacuation to the hinterland. Hence, inland evacuation capacity has to be augmented in line with the capacity of port. Any gap in the inland evacuation capacity is likely to force shift of cargo projected to be handled at Vadhavan Port to other competing port. Commissioning of Western Dedicated Freight Corridor

(W-DFC) is likely to benefit Vadhavan. It would help reduce logistics cost of evacuating containers from existing mode namely Indian Railways and Roadways. It would also help enhance otherwise restricted capacity of containers on Indian Railway and road.

The Indian Railway (IR) infrastructure has been common both for passengers as well as goods train in India. Passenger trains always take priority over goods train leading to in-efficiencies and delays in cargo transportation over railway network. The Government of India is developing Dedicated Freight Corridor to provide seamless cargo movement for longer distance. The DFC would have higher carrying capacity.

Vadhavan is likely to benefit from Dedicated Freight Corridor. The ports of Gujarat and Maharashtra would find better connectivity to land locked regions of northern India. The economy of scale and dedicated service provided by DFC is likely to reduce transportation cost of containers from ports in Gujarat and Maharashtra to northern hinterland.

The tariffs of Western Dedicated Freight Corridor are not declared. Tariffs are anticipated to be similar as those of Indian Railways. Railways is planning a Railway Tariff Regulatory Authority to regulate tariffs. The freight corridor is being developed at huge capital investment. The impact of capital investment on the commissioning of dedicated freight corridor could lead to moderately high. However, as DFC would have higher economy of scale along with longer return period, the tariffs are anticipated to be similar to existing railway network. This would fuel smooth shift of trade from IR network to DFC.

Preliminary discussion of consultant with senior officials in Ministry of Railway concluded that the dedicated freight corridor is designed for higher speed of transporting containers and other cargo. The average speed of dedicated freight corridor is likely to be 45 km/hour compared to 25 km/hour of goods train on normal IR. The DFC has been planned with a maximum speed of 100 km/hour. The higher speed of DFC would result in faster turnaround of rakes leading to reduction in logistics time and cost compared to existing mode of transportation using Indian railways and roadways.

The inland container and other cargo evacuation from Vadhavan port to Northern India has factored in commissioning of DFC before Fy-25 and operationalisation of DFC in the year Fy-25. The Western DFC would have special wagons that has higher tier weight as well as higher carrying capacity. Each wagon would have a carrying capacity of around 80 tonnes in addition to its own weight of around 20 tonnes. These wagons would have a higher axle load of 25 tonnes.

The DFC is likely to create distance slab for choosing origin-destinations. These slabs could be longer than Indian Railways but it would be similar to what is followed by Indian Railways. DFC would pick up containers and other cargoes for longer lead. DFC has not yet declared tariff and preferable distance slab that makes container evacuation on inland routes commercially attractive for DFC. Hence, the present analysis for arriving at model shift share to DFC assumes distance slabs longer than IR.

Indian railway prefers cargo with long lead of at least 600 km for transporting on its network. There are instances of cargo for around 300 km by Indian Railways. However, this is not preferable from commercial prospective and optimum utilisation of infrastructure. Further, Indian Railways do not book cargo of less than a ‘full train’ (railway Rake) load. The Western DFC runs over 1,500 km. It has been assumed that any movement below 1,000 km would be commercially unattractive for DFC.

Road would dominate container evacuation for less than 300 km from port. The containers evacuated over a distance between 300 km to 1,000 km should ideally have to choose between Indian Railways and DFC. However, the core purpose of creating DFC was to shift cargo from Indian Railway to DFC. The infrastructure of Indian Railway would primarily be focusing on augmenting passenger train movement. Hence, DFC network might pick up containers on relatively shorter haul due to absence of support from Indian Railways network on DFC route. It has been assumed that DFC could still pickup containers between 600 km to 1,000 km in the non-preferable segments. It could be similar to Indian Railways picking cargo for smaller haulage even though they prefer more than 600 kms lead.

For evacuation from Vadhavan Port all trains have to first travel on WDFC and then shift to IR at Junction Stations. The existing junction station on Delhi side is about 250 kms while on JNPA side it is close to JNPA. A new junction station between WDFC and IR will have to be established to avoid long travel on DFC for IR trains. All short haulage movements of containers from Vadhavan port would take place using road. Rail distribution statistics in the existing DPR prepared in Fy-18 provides following distribution for rail movement of containers.

Table A3- 73 Distance slab for container evacuation using Indian Railways from Ports

Distance Slab (km)	JNPA	Mundra	Pipavav
0-250	-	-	-
250-750	49%	12%	18%
750-1,500	50%	88%	82%
1,500 and Above	1%	-	-

Around 51% of container of rail container at JNPA falls in the distance slabs of 750 – 1500 km. Mundra and Pipavav port have further higher proportion of cargo movement using Railways for over longer distance. it was assumed that, the containerized traffic within the distance of 250 km from the port will be predominantly moved through road. This translates, the existing container movement from region of south Gujarat, Nashik, Pune etc. for Vadhavan will be moved via road. The northern hinterland i.e. Jaipur, NCR, Punjab etc. will have more potential to move the container traffic through rail. As per the existing OD movement data, around 35% of the container which are handled by JNPA is from NCR & Rajasthan region. Rest of the traffic which is handled at JNPA is either from south Gujarat or from immediate catchment.

The container movement distribution has been categorised in 3 geographical regions

- NCR and Other Northern Stages (Presence of DFC)
- Gujarat (Mostly South Gujarat, Central Gujarat, etc.)
- Immediate Hinterland of Maharashtra, MP and Central India

Following table broadly describes percentage share for various modes of transportation and share distribution for containers evacuation

Table A3- 74 Model share used for container evacuation to various OD pairs

Mode	Fy-21	Fy-25	Fy-30	Fy-35	Fy-40	Fy-45	Fy-50
NCR and Northern States (accounting for 35% of Vadhavan Traffic)							
Road	0.0%	25.0%	15.0%	10.0%	9.0%	5.0%	5.0%
Rail (IR)	0.0%	75.0%	73.0%	50.0%	20.0%	0.0%	0.0%
Rail (DFC)	0.0%	0.0%	12.0%	40.0%	71.0%	95.0%	95.0%
Gujarat (accounting for 20% of Vadhavan Traffic)							

Road	0.0%	95.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Rail (IR)	0.0%	5.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Rail (DFC)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Immediate Hinterland + MP + Others (Account to around 45% of Vadhavan Traffic)							
Road	0.0%	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%
Rail (IR)	0.0%	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%
Rail (DFC)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Total Number of Daily Vehicles Movement for Evacuation							
Road	0%	70.5%	68.00%	66.3%	65.90%	64.5%	64.50%
Rail (IR)	0%	29.50%	2.25%	2.25%	2.25%	2.25%	2.25%
Rail (DFC)	0%	0.0%	29.75%	31.5%	31.85%	33.3%	33.25%

- NCR + Rajasthan + northern states: At present, 75% of the traffic is moved through rail and 25% through road. However, with commissioning of DFC it is assumed that gradual shift of container traffic from existing IR network will be shifted to DFC line. This shift will be primarily on account of operational efficiency and cost benefits which the DFC will bring in for container movement. In initial years, it is assumed that the containerized traffic from DFC will be around 5% in the 1st year (Fy-26) of fully commissioned operation. The share will gradually increase with inducement of newer wagons and more rakes on DFC. The share on DFC for north bound cargo to increase exponentially. It is proposed to rise to 40% by Fy-35, 71% by Fy-40 and 95% by Fy- 45. It has been assumed that commencement of DFC will remove containers from IR network on DFC routes. The balance 5% of the containers would be evacuated using road route.

- Gujarat: Most of the traffic is originating from southern Gujarat (Baroda, Surat-Vapi-Valsad, Bharuch-Ankleshwar region) and is currently moved via road and get containerized near the CFS facilities operating in JNPA. The average lead distance is around 250-300 km. At present, 95% of the containerized traffic is moving through road and 5% is moved via rail. It is assumed that, post commissioning of DFC the volume which is currently moving through conventional rail will shift to Road. The road distance of South Gujarat to Vadhavan port is around 300 km. DFC would find it commercially unattractive to pick up cargo or containers for smaller haulages. IR would be using DFC corridor for certain stretch in the beginning. This will restrict IR evacuating containers from Vadhavan port. Small volumes on rake for smaller distance of around 300 km would lead to capacity constraints on the DFC. Moreover, commissioning of DFC would lead to release of capacity on Indian railways for passenger trains and traffic. Hence, even IR may not be keen to pick up cargo for short run from Vadhavan to South Gujarat. Containers originating is Central Gujarat and other regions would be preferring Mundra Por.

- Immediate hinterland: Containerized traffic originated from the immediate region will be predominantly divert the containerized traffic via road. Containers of immediate hinterland designate containers originated in less than 250 kms of radial distance from Vadhavan and JNPA. It has been assumed that containers generated further south of Pune, Northern Karnataka would continue to use JNPA and would not spill over to Vadhavan. Moreover, any IR evacuation of containers from Vadhavan to Eastern parts of Maharashtra and Central India would require containers to either travel 160 kms north of Vadhavan or 150 km south of Vadhavan before they take diversion. There are no direct railway linkages from Vadhavan to Eastern parts of Maharashtra or Central India. Indian railway, as of now, has no such plans of connecting Vadhavan directly to other cities of Maharashtra and Central India. The issue of railway connectivity at Vadhavan could be understood from below railway connectivity map.

Figure A3-75 Rail Connectivity to Proposed Vadhavan Port

Following table summarises total container movement in the hinterland using various modes of transportation. It is estimated that about 13.5 million TEU containers will moving using road, 4.8 million TEU using Indian Railways and 6 million TEU using DFC in Fy-40. The share will increase to about 22.4 million TEU containers will moving using road, 5.3 million TEU using Indian Railways and 13.5 million TEU using DFC in Fy-50.

Table A3- 75 Container volumes distribution to various OD pairs

Mode	Fy-21	Fy-25	Fy-30	Fy-35	Fy-40	Fy-45	Fy-50
NCR and Northern States (accounting for 35% of Vadhavan Traffic) - million TEU							
NCR	**0.0**	**0.3**	**2.3**	**4.9**	**8.1**	**11.0**	**13.8**
Road	0.0	0.1	0.3	0.5	0.7	0.5	0.7
Rail (IR)	0.0	0.2	1.7	2.5	1.6	0.0	0.0
Rail (DFC)	0.0	0.0	0.3	2.0	5.8	10.4	13.1
Gujarat (accounting for 20% of Vadhavan Traffic) - million TEU							
Gujarat	**0.0**	**0.2**	**1.3**	**2.8**	**4.6**	**6.3**	**7.9**
Road	0.0	0.2	1.3	2.8	4.6	6.3	7.9

Rail (IR)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Rail (DFC)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Immediate Hinterland + MP +Central India (Around 45% of Vadhavan Traffic) - million TEU							
Immediate	**0.0**	**0.4**	**2.9**	**6.3**	**10.4**	**14.1**	**17.8**
Road	0.0	0.4	2.8	6.0	9.9	13.4	16.9
Rail (IR)	0.0	0.0	0.1	0.3	0.5	0.7	0.9
Rail (DFC)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cumulative Annual Traffic from Vadhavan using Various Modes - million TEU							
Total	**0.0**	**0.9**	**6.5**	**14.1**	**23.2**	**31.3**	**39.4**
Road	0.0	0.7	4.4	9.3	15.3	20.2	25.4
Rail (IR)	0.0	0.3	0.1	0.3	0.5	0.7	0.9
Rail (DFC)	0.0	0.0	1.9	4.4	7.4	10.4	13.1

Following table summarises dialling container evacuation capacity required at all the 3 modes of transportation from Vadhavan Port. Any gap in the capacity augmentation for evacuation infrastructure would eventually lead to downward re-ratting of container handling capacity at Vadhavan port. Hence, the daily container evacuation infrastructure has to be upgraded to capture the volumes projected in the table below.

Table A3- 76 Daily evacuation of containers to various OD pairs

Mode	Fy-21	Fy-25	Fy-30	Fy-35	Fy-40	Fy-45	Fy-50
NCR and Northern States (accounting for 35% of Vadhavan Traffic)							
Road	-	148	624	902	1,336	1,001	1,261
Rail (IR)	-	8	-	-	-	-	-
Rail (DFC)	-	-	20	44	64	90	110
Gujarat (accounting for 20% of Vadhavan Traffic)							
Road	-	322	2,377	5,152	8,482	11,431	14,410
Rail (IR)	-	-	-	-	-	-	-
Rail (DFC)	-	-	-	-	-	-	-
Immediate Hinterland + MP + Others (Account to around 45% of Vadhavan Traffic)							
Road	-	723	5,080	11,013	18,129	24,434	30,800
Rail (IR)	-	1	5	10	16	22	28
Rail (DFC)	-	0	0	0	0	0	0
Total Number of Daily Vehicles Movement for Evacuation							
Road	-	1,193	8,081	17,067	27,947	36,866	46,471

Rail (IR)	-	10	5	10	16	22	28
Rail (DFC)	-	0	20	44	64	90	110
Total Rail	-	10	25	54	80	112	138

A3.16.2 Other Principle Commodities

The preferred modes of transportation for evacuating different commodities from Vadhavan port is presented in the table below. It also includes the reasoning for selecting a particular mode. Eight commodities are considered in the table while 3 modes of transportation are implemented. Some commodities would be evacuated via only a single mode of transportation while other commodities would have access to all three modes of transportation.

Table A3- 77 Preferred Modes for Cargo Evacuation from Vadhavan Port

Commodities	Mode	Reasoning
Edible Oil	Roadways	Majority of Consumption Centers are located nearby and well connected with roadways
	Railways	Far-off consumption centres with rail connectivity
Chemical	Roadways	Caters to Northern & Central Maharashtra Region, well connected with roadways
Bulk Liquid	Pipeline	Once Port gets connected to nearest Bulk Liquid pipeline grid, 80% of total traffic would get shifted to Pipeline (FY26 onwards).
	Road	Initial 5 years, Roadway & Railway preferred, later on Pipeline gets developed at Port share would get down to 15% & 5% respectively.
	Railway	
Fertilizer	Roadways	Nearby located users would be served by roadways
	Railways	Plants in Central and North India are well connected with railway line and prefers railways for bulk cargo
General Cargo	Roadways	Mostly unloaded cargo, transported within immediate hinterland. This type of cargo includes raw material required for infrastructure development in and around port area.
Coastal Cargo	Roadways	
Other Liquid	Pipeline	100% volume to be evacuated using Pipelines
Ro-Ro	Roadways	Caters to North Maharashtra region, railway movement not viable for small distance transportation. Ro-Ro in rakes are mostly preferred for North – South movement (long distance)

Edible oil could be evacuated via roads and rails. Most centres located nearby are well connected by roads while far-off centres would use rails. Chemicals have a single option of roadways as Vadhavan would cater to Maharashtra’s North and Central region that is well connected by roads. Bulk Liquid enjoys the privilege of having three options for evacuation. Pipeline is a future option that would depend on Vadhavan getting connected to the Bulk Liquid grid. In the initial years, before the pipeline connection, roads and railways would be used for cargo evacuation. Fertilizer has a similar modal split with respect to edible oil. Roadways would be used for nearby centres while rails would be used for faraway places.

General Cargo and Coastal Cargo would be mostly unloaded cargo being transported to the immediate hinterland. This cargo includes raw materials used for development around the port area. Other Liquid can be evacuated by pipelines since an Other Liquid grid lies very near to the port of Vadhavan. Ro-Ro could use only roadways as rail movement of is not viable for short distances. Share distribution of traffic under preferred mode for each commodity is presented in the table below.

Table A3- 78 % Distribution of Traffic under each Mode

Commodities	Mode	Capacity	FY21	FY25	FY30	FY35	FY40	FY45	FY50
Edible Oil	Roadways	18 T Truck	0%	85%	85%	85%	85%	85%	85%
	Railways	2,500 T Rake	0%	15%	15%	15%	15%	15%	15%
Chemical	Roadways	10 T Truck	0%	100%	100%	100%	100%	100%	100%
Bulk Liquid	Pipeline	-	0%	5%	5%	5%	5%	5%	5%
	Roadways	18 T Truck	0%	15%	15%	15%	15%	15%	15%
	Railways	2,500 T Rake	0%	80%	80%	80%	80%	80%	80%
Fertilizer	Roadways	12 T Truck	0%	30%	30%	30%	30%	30%	30%
	Railways	3,600 T Rake	0%	70%	70%	70%	70%	70%	70%
General Cargo	Roadways	10 T Truck	0%	100%	100%	100%	100%	100%	100%
Coastal Cargo	Roadways	10 T Truck	0%	100%	100%	100%	100%	100%	100%
Other Liquid	Pipeline	-	0%	100%	100%	100%	100%	100%	100%
Ro-Ro	Roadways	5 Vehicle	0%	100%	100%	100%	100%	100%	100%

The table indicates the capacity for each mode of transportation carrier. It also gives the percentage distribution for the modes for the next 25 years. Edible oil will be evacuated by roads using an 18 Tonne truck and by rails using a 2,500 Tonne. Road and rails occupy 85% and 15% of traffic distribution respectively. Chemicals only use roadways with 10 Tonne truck. General and Coastal Cargo also use only roadways with a 10 Tonne truck, as this cargo would be distributed locally. Other Liquid will be evacuated via pipelines while Ro-Ro would get evacuated in carrier with capacity of 5 vehicles at a time on road. Fertilizers would use 12 Tonne trucks on roads and 3,600 Tonne rakes on rails. Distribution would be 30% for roads and 70% for rails. Bulk Liquid would be evacuated via all three modes i.e. 18 Tonne truck on roads, 2,500 Tonne rakes on rails and pipeline. The distribution is 15%, 80% and 80% respectively.

Table A3- 79 Selected MoT wise Traffic Spilt for Evacuation (mn T)

Commodities	MoT (% Share)	FY21	FY25	FY30	FY35	FY40	FY45	FY50
Edible Oil	Road	0.0	0.4	0.8	0.9	1.0	1.1	1.2
	Rail	0.0	0.1	0.1	0.2	0.2	0.2	0.2
Chemical	Road	0.0	0.6	0.9	1.0	1.1	1.2	1.3
Bulk Liquid	Pipeline	0.0	0.1	0.2	0.2	0.2	0.2	0.3
	Road	0.0	0.4	0.5	0.6	0.6	0.7	0.8
	Rail	0.0	2.1	2.5	3.1	3.4	3.7	4.1
Fertilizer	Road	0.0	0.3	0.3	0.4	0.3	0.4	0.4
	Rail	0.0	0.6	0.7	0.8	0.8	0.9	1.0
General Cargo	Road	0.0	1.5	2.4	3.5	4.6	5.9	7.2
	Rail	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Coastal Cargo	Road	0.0	1.0	1.7	2.4	3.2	4.1	5.0

Commodities	MoT (% Share)	FY21	FY25	FY30	FY35	FY40	FY45	FY50
	Rail	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Other Liquid	Pipeline	0.0	0.0	2.3	4.5	4.5	4.5	4.5
Total	Road	**0.0**	**4.1**	**6.5**	**8.7**	**10.9**	**13.4**	**16.0**
	Rail	**0.0**	**2.8**	**3.3**	**4.1**	**4.4**	**4.8**	**5.3**
	Pipeline	**0.0**	**0.1**	**2.5**	**4.7**	**4.8**	**4.8**	**4.8**
Ro-Ro ('000 Vehicles)	Road	0.0	20.9	49.5	76.8	169.0	195.9	227.1

[Note: Total excludes Ro-Ro Traffic]

The table describes the traffic for the various commodities by different modes of transportation spanning a period of 25 years. In FY50, the total volume by roads would be 16 million tonnes, by rails would be 5.3 million tonnes and by pipeline would be 4.8 million tonnes. Ro-Ro vehicles are excluded from the total as they are tallied based on the number of units. In 2050, 227,100 vehicles would be evacuated by road from Vadhavan.

Table A3- 80 Weekly Cargo Evacuation from Vadhavan Port

Commodities	Per Week	FY21	FY25	FY30	FY35	FY40	FY45	FY50
Edible Oil	Truck	0.0	377	873	964	1,065	1,175	1,298
	Rakes	0.0	1	2	2	2	2	2
Chemical	Trucks	0.0	1,224	1,703	1,880	2,076	2,292	2,530
Bulk Liquid	Pipeline (T)	0.0	2,564	2,973	3,692	4,077	4,501	4,970
	Truck	0.0	962	1,115	1,385	1,529	1,688	1,864
	Rakes	0.0	19	22	27	30	33	37
Fertilizer	Truck	0.0	422	477	569	558	616	681
	Rakes	0.0	4	4	5	5	5	6
Ro-Ro	Truck	0.0	81	191	296	650	754	874
General Cargo	Truck	0.0	2,816	4,535	6,663	8,917	11,380	13,845
Coastal Cargo	Truck	0.0	1,971	3,175	4,664	6,242	7,966	9,692
Other Liquid	Pipeline (T)	0.0	0	45,005	87,456	87,456	87,456	87,456
Total	Truck	0.0	7,853	12,069	16,421	21,037	25,871	30,784
	Rakes	0.0	24	28	34	37	40	45
	Pipeline (T)	0.0	2,564	47,977	91,148	91,532	91,957	92,425

The table details the number of trucks and rakes that would be used to evacuate the different commodities by roads and rails on weekly basis. For the pipeline mode of transportation, numbers indicate the volume evacuated in tonnes. In 2050, the total number of trucks used for weekly cargo evacuation by roads from Vadhavan would be 30,784 while the total number of rakes used for cargo evacuation by rails would be 45. For the pipeline, a total of 92,425 tonnes would be evacuated weekly.

A3.17 Vessel Calls at Vadhavan Port

Vessel calls signify the number of vessels docking at the port to load or unload their cargo. The following sections give the statistics for the next 25 years in terms of parcel size of the vessels and the number of weekly vessel calls. These values are given for proposed container and other principle commodities volume proposed for Vadhavan Port.

A3.17.1 Containers

Table A3- 81 Container Vessel Capacity and Parcel Size Assumptions

Design Capacity of Vessels	Carrying Capacity @ 14 T	Parcel Sizes
1,500	1,050	683
2,000	1,400	910
5,000	3,500	2,275
8,000	5,600	3,640
12,000	8,400	3,360
14,000	9,800	3,920
16,000	11,200	4,480
18,000	12,600	5,040
20,000	13,000	4,800
24,000	15,000	6,000

- Local Trade of Middle East & Asia in Ships less than 8,000 TEU
- Parcel Assumed 60% of Carrying Capacity
- Long Distance trade to East & West in Ships more than 12,000 TEU
- Parcel Assumed 30% of Carrying Capacity

Table A3- 82 Weekly Vessel Calls for Container Volume

Mode	Fy-21	Fy-25	Fy-30	Fy-35	Fy-40	Fy-45	Fy-50
East Bound Trade							
12,000	0	1	2	2	3	4	5
14,000	0	1	2	3	4	4	4
16,000	0	1	3	5	8	11	14
18,000	0	1	3	5	8	11	14
20,000	0	1	3	6	10	13	16
24,000	0	1	2	4	6	10	12
West Bound Trade							
12,000	0	1	2	2	3	4	5
14,000	0	1	2	3	4	4	4
16,000	0	1	3	5	8	11	14
18,000	0	1	3	5	8	11	14
20,000	0	1	3	6	10	13	16

Mode	Fy-21	Fy-25	Fy-30	Fy-35	Fy-40	Fy-45	Fy-50
24,000	0	1	2	4	6	10	12
Asian Trade							
1,500	0	1	2	4	0	0	0
2,000	0	1	3	6	5	0	0
5,000	0	1	5	10	18	24	31
8,000	0	1	4	7	13	19	23
Cumulative Weekly Calls							
1,500	0	1	2	4	0	0	0
2,000	0	1	3	6	5	0	0
5,000	0	1	5	10	18	24	31
8,000	0	1	4	7	13	19	23
12,000	0	2	4	4	6	8	10
14,000	0	2	4	6	8	8	8
16,000	0	2	6	10	16	22	28
18,000	0	2	6	10	16	22	28
20,000	0	2	6	12	20	26	32
24,000	0	2	4	8	12	20	24
Total	0	16	44	77	114	149	184

A3.17.2 Other Principal Commodities

The table below indicates parcel sizes for different commodities. Edible oil vessels would have a parcel size of 9,000 DWT in FY21 rising to 27,000 DWT in FY50. Chemical parcel sizes for the same years would be 4,500 DWT and 9,000 DWT. Other Liquid would remain constant at 30,000 DWT. Fertilizer would get handled in 16,200 DWT initially and 54,000 DWT by FY50. The Ro-Ro is indicated in terms of vehicles. So, in FY21 Vadhavan would call vessel of 1,800 vehicles parcel size and in FY50 it would increase to 5,580 vehicles. General cargo and Coastal Cargo would have parcel sizes of 18,750 DWT and 13,500 DWT respectively in FY21 and 41,250 DWT and 30,000 DWT respectively by FY50.

Table A3- 83 Commodity wise Vessel Parcel Size

Parcel Size	FY21 – FY30	FY31 – FY40	FY41 – FY50
Edible Oil	9,000	16,200	27,000
Chemical	4,500	9,000	9,000
Bulk Liquid	22,500	31,500	54,000
Fertilizer	16,200	31,500	54,000
Ro-Ro	1,800	3,600	5,580
General cargo	18,750	30,000	41,250
Coastal Cargo	13,500	18,750	30,000

Parcel Size	FY21 – FY30	FY31 – FY40	FY41 – FY50
Other Liquid	30,000	30,000	30,000

The table below describes weekly vessel calls for different commodities. The vessel calls depend on the parcel size of the vessel and traffic projected.

Table A3- 84 Commodity wise Weekly Vessel Calls

Weekly Vessel Calls	FY21	FY25	FY30	FY35	FY40	FY45	FY50
Edible Oil	0	1	3	2	2	1	2
Chemical	0	3	4	3	3	3	3
Bulk Liquid	0	3	3	3	3	2	2
Fertilizer	0	2	2	1	1	1	1
Ro-Ro	0	1	1	1	1	1	1
General cargo	0	2	3	3	3	3	4
Coastal Cargo	0	2	3	3	4	3	4
Other Liquid	0	0	2	3	3	3	3
Total	0	**14**	**21**	**19**	**20**	**17**	**20**

A3.18 Tariff Assessment

The port tariff offered by Vadhavan port to shipping lines would influence attractiveness of port. Vadhavan port tariffs has been analysed on following three parameters

- Benchmarking of Port Tariff
- Competitive Integrated Logistics Cost
- Commercial Viability of Port

Port Tariff would play a significant role in commercial attractiveness of port. Hence, Vadhavan port tariffs has been compared to other competing ports in the region namely Adani Port at Mundra, APMT at Pipavav, Adani ports at Hazira and the existing terminals of JNPA.

The tariff offered at the port should overall reduce integrated cost of transporting containers from hinterland of Vadhavan to the final decision destination. An extensive analysis of integrated logistics cost that includes inland cost, port tariffs, shipping cost has been undertaken. The integrated logistics cost analysis has been undertaken to establish shipping lines would save on logistics cost by shifting their containers from other terminals to Vadhavan port.

The tariff selected for Vadhavan port should be adequate enough to recover the construction and operational cost of port. Vadhavan port would be developed on PPP model. JNPA as landlord would develop common port infrastructure. The terminals would be allocated to Concessionaires who would develop and operate terminal. Concessionaire would share a percentage of their revenue as royalty to JNPA. The tariff of Vadhavan port should be adequate enough to provide good rate of return for Concessionaire and JNPA.

This section analysis competitive tariffs for Vadhavan port factoring in above mentioned parameters. The tariffs of JNPA 4th Container Terminal (BMCT) have been taken as Benchmark for all calculations of Vadhavan Port.

A3.18.1 Shipping Distance for Containers

The trade using Vadhavan port along with its competitors (Ports in North-West India) could broadly be divided into 4 categories.

- Trade originating/destined at Middle East
- Trade originating/destined from western countries crossing over red Sea
- Trade originating/destined in Western African countries and crossing over Cape of good Hope
- Trade that is originating/destined from East of India

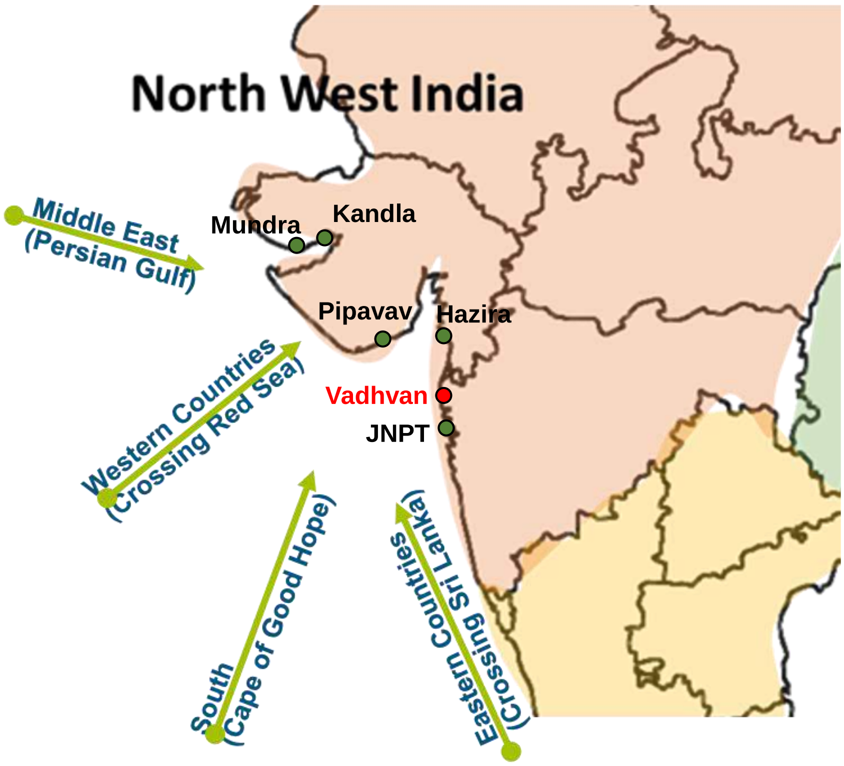

Figure A3-76 Major Trade Routes to North West Ports

The above map in the figure and subsequent tables below broadly describe positioning of important ports in north and west part of India along with distances in major trading routes. The distance of ports along with deviation incurred by shipping lines to reach Vadhavan would help calculate competitiveness of shipping costs at Vadhavan.

Table A3- 85 Distance of Mundra, JNPA and Vadhavan from prominent trade zones (nautical miles)

Port	Hong Kong (East)	Jebel Ali (Middle East)	Rotterdam (West)	Durban (South)
Mundra	4,146	872	6,156	3,877
Vadhavan	3,871	1,093	6,269	3,836
JNPA	3,824	1,130	6,275	3,809

The trades originating from Middle East for India would find Mundra port most competitive compared to Vadhavan or JNPA. It has lowest distance compared to other prominent competitors namely JNPA and proposed Vadhavan Port. Trades originating in the Western countries and crossing over Red Sea to reach ports in Gujarat and Maharashtra (North West India) is marginally closer to Mundra Port. Similarly, trades originating from South Africa or trade crossing over Cape of Good Hope find JNPA and Vadhavan marginally closer compared to Mundra Port.

Table A3- 86 Deviation in hours to reach Vadhavan from prominent trade zones

Total Deviation in Hours from JNPA				
Port	**East**	**Middle East**	**West**	**GoodHope**
Mundra	36	-29	-14	8
Vadhavan	6	- 5	-1	3
Total Deviation in Hours from Mundra				
Port	**East**	**Middle East**	**West**	**GoodHope**
Vadhavan	-31	25	13	-5
JNPA	-36	29	14	-8

Shipping lines would look for additional commercial gains and marginal change in shipping cost would not be the sole criteria. All trades originating in Eastern part (i.e., trade crossing over Sri Lanka to reach ports on the North West would find JNPA and Vadhavan offering lower shipping costs compared to Mundra or other Gujarat ports.

A3.18.2 Deviation Cost – Container Trade

Following charts are plotted to establish per TEU slot cost related to deviation for Vadhavan, JNPA and Mundra. The deviation cost varies depending upon origin of cargo, route and port. The following charts have been plotted for all four major routes that trade would follow. Deviation cost would also depend upon the size of vessel and volume of trade in route. Following chart has been plotted for various sizes of container ships. It has also considered varying capacity utilisation of container ships to accommodate impact of volume deployment in the route. Higher volume of trade would lead to deployment of larger volume ships. The capacity utilisation of larger volume ships would be higher in routes with large volume. Hence, varying container ship sizes and capacity utilisation has been considered for assessing sensitivity impact on the shipping cost of container trade to all the ports.

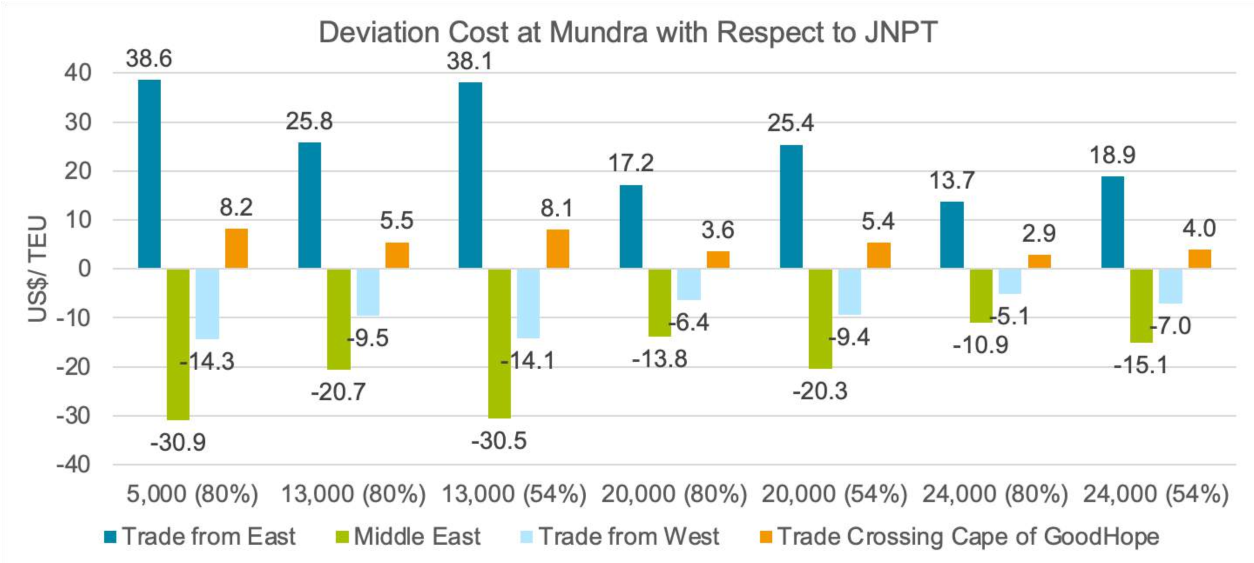

Figure A3-77 Deviation Cost at Mundra with respect to JNPA

Following in inferred from the above chart

- The deviation cost savings of trade at Mundra with respect to JNPA has been found to be higher for trade originating from East and trade crossing Cape of Good hope.
- The shipping cost of containers to Mundra is cheaper compared to JNPA for trade originating from Middle East and trade crossing over Red Sea.

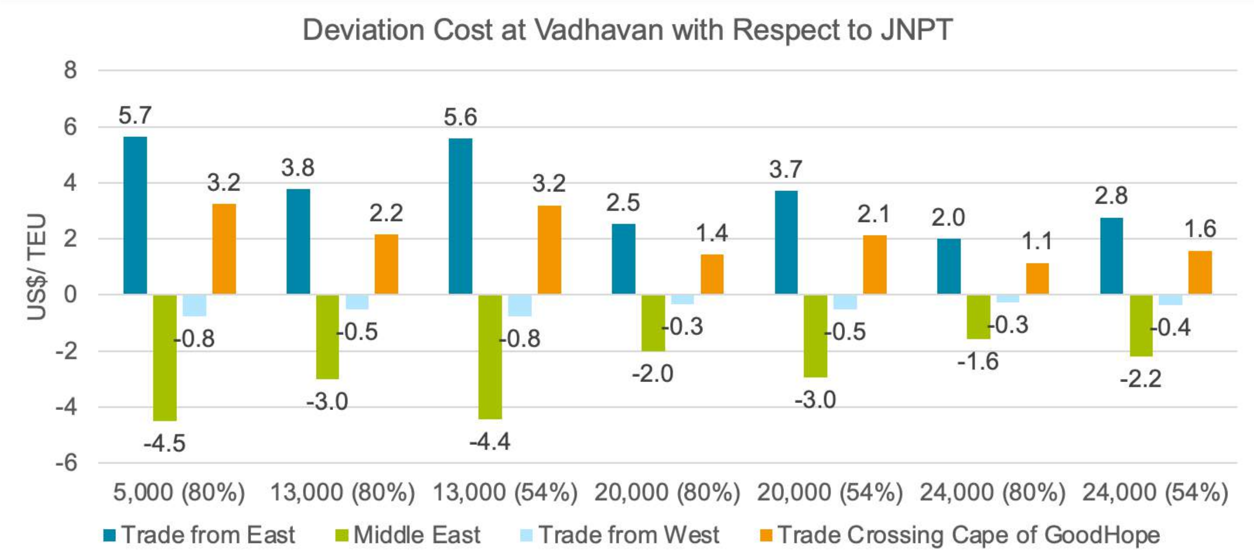

Figure A3-78 Deviation Cost at Vadhavan with respect to JNPA

- The deviation cost savings of trade at Vadhavan with respect to JNPA has been found to be marginally higher for trade originating from East and trade crossing Cape of Good hope.
- The shipping cost of containers to JNPA is marginally cheaper compared to Vadhavan for trade originating from Middle East and trade crossing over Red Sea.

The shipping cost of containers calling to JNPA and Vadhavan could be considered same due to negligible cost difference visible in the above chart. The trade originating at Middle East too would find Vadhavan competitive from shipping cost as Vadhavan would be able berth largest ships whereas JNPA would have capacity capping at 15,000 TEU vessels. Hence, the economy of scale for shipping would benefit Vadhavan.

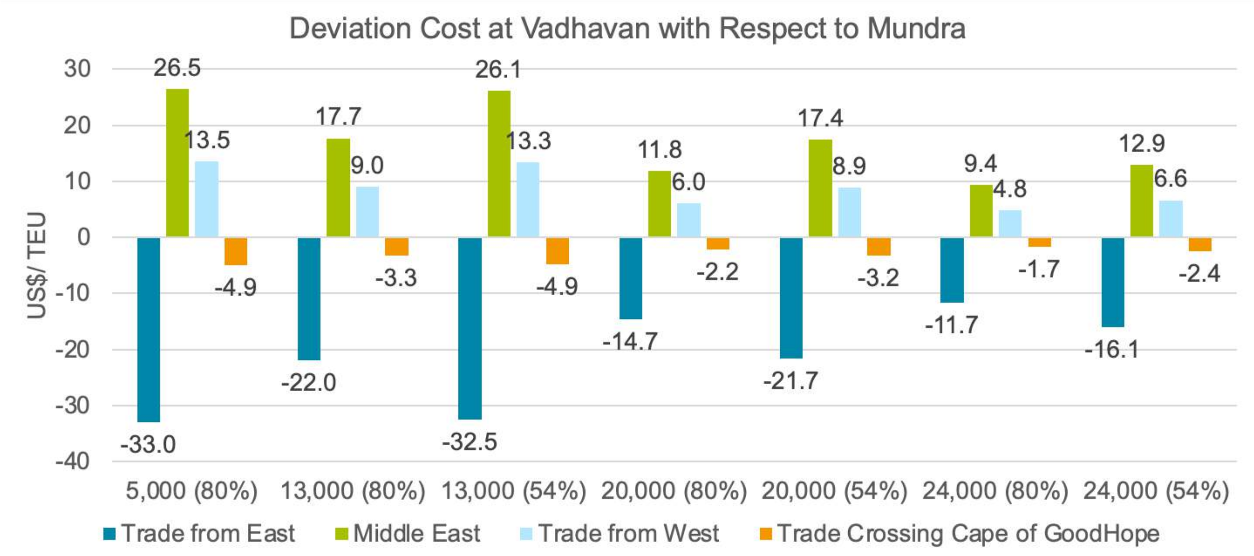

Figure A3-79 Deviation Cost at Vadhavan with respect to Mundra

The deviation cost savings of trade at Vadhavan with respect to Mundra has been found to be substantially higher for trade originating from East and trade crossing Cape of Good hope. Mundra port due to its geographical location offers substantial savings for trade originating in Middle East compared to Vadhavan. Trade crossing over Cape of Good Hope offers negligible advantage to Mundra with less than US$ 5/TEU for small size container ships of 5,000 TEU. The cost savings to the container vessel operator due to strategic location of Vadhavan port along with ports ability to berth largest available vessels could be incorporated in the port tariffs or could be passed on to trade.

The shipping cost of containers to Mundra is marginally cheaper compared to Vadhavan for trade originating from Middle East and trade crossing over Red Sea. The shipping cost of containers calling to JNPA and Vadhavan could be considered same due to negligible cost difference visible in the above chart. The trade originating at Middle East too would find Vadhavan competitive from shipping cost as Vadhavan would be able to handle largest ships whereas JNPA would have capacity capping at 15,000 TEU vessels. Hence, the economy of scale for shipping would benefit Vadhavan.

Following table shows the tariff declared by one of the mainline operators for container evacuation from all the prominent container terminals of India. As can be seen in the table below that the tariffs have wide variations depending upon the location of container port and volumes handled by them. Haldia and Kolkata port handling a smaller volume of trade has a tariff of INR 10,250/TEU for export containers and INR 10,600/TEU for import containers. This is far higher compared to tariff offered at JNPA and Mundra. This could be primarily due to higher tariff fixed at Kolkata and Haldia port by Tariff Authority for Major Ports (TAMP). Newly operationalised container terminal at Kandla is offering INR 4,500/TEU far lower than that of other container terminals of India.

Hence, it could be concluded that there is large influence of market and traffic attractiveness on the port tariffs. This does not provide ports the freedom to charge any amount. However, a variation of INR 3,000/TEU to INR 6,000/TEU would not make substantial impact on the commercial competitiveness of Vadhavan Port for container handling.

Table A3- 87 Shipping Lines (CMA-CGM) port tariffs effective May 1st, 2021 (INR/TEU)

Gateway Port	Terminal	Exports -THC – CY/CY			Imports -THC – CY/CY		
		DRY		Reefer	`Dry		Reefer
		20'	40'	20'	20'	40'	20'
Chennai	CCTTL/CITPL	6,300	8,700	15,100	6,300	8,700	16,000
Ennore	AECTPL	6,300	8,700	15,100	6,300	8,700	16,000
Cochin	ICTT	10,000	14,300	18,300	10,600	14,300	18,300
Goa	MPT	7,800	12,000	19,130	9,350	13,460	19,130
Haldia	HDC	10,250	15,200	12,000	10,250	15,200	12,000
Hazira	ADANI	8,450	12,450	17,900	8,450	12,450	10,350
Kandla	KCTL	4,500	7,000	7,100	4,500	7,000	6,750
Karaikal	MKP	6,300	8,700	15,100	6,300	8,700	16,000
Kolkata*	CPY/MHC	10,250	15,200	12,000	10,250	15,200	12,000
Krishnapatnam	KPCT	6,300	8,700	15,100	6,300	8,700	16,000
Kattupalli	ADANI	6,300	8,700	15,100	6,300	8,700	16,000
Mangalore	NMPT	7,300	9,000	15,350	7,700	9,850	15,350
Mundra	**ADANI/MICT**	**9,500**	**13,050**	**18,600**	**9,500**	**13,050**	**12,050**
Nhava Sheva	**All**	**8,600**	**14,000**	**19,600**	**8,600**	**14,000**	**10,800**
Pipavav	GPPL	8,665	12,765	23,165	8,665	12,765	23,165
Tuticorin	PSTIL	6,150	8,300	6,300	6,150	8,300	6,300
Vizag	VCTPL	7,100	10,800	17,100	7,100	10,800	17,100

A3.18.3 Integrated Logistics Cost - Containers

Port tariffs constitute a small component of the integrated logistics cost of container trade. The ports cost could fall in the 2% to 5% depending upon the route and sector followed by the shipping lines. The ocean freight cost offered by shipping lines constitutes highest component followed by inland cost of evacuation. Shipping cost is volatile and has maximum impact. Hence, shipping lines tend to deploy large container vessels in region and routes of high volume. Vadhavan port falls in the high trade volume route both from international trading route perspectives as well as India's gateway container ports.

Port tariffs have 2 components namely,

- Vessel Related Charges (VRC) and
- Terminal Handling Charges (THC).

The VRC component has been factored in the Sea Freight calculation. Other cost component include cost associated with documentation and other miscellaneous charges. A component of inventory cost has been introduced due to possible delay occurred in bringing containers to JNPA due bottlenecks at some of the road junctions. Container yard cost includes loading containers on to rakes. Sea Freight Calculation includes the parameters mentioned in following chart.

Cost Calculation Parameters

- Vessel Direct Operating Cost
  - ✓ Charter Hire (Capex, R&M , Insurance, etc)
  - ✓ Fuel Cost
  - ✓ Crew Wages
- Route of Deployment
- Port Tariffs (Vessel Related Charges)
- Additional- Panama, Piracy protection, etc

Sea Freight (Tariffs)

- All Costs (Operating)
- Profit Margins
- Scale of Operation (Volume on Route)
- Container carrying capacity deployed

Slot Cost : = (All the Costs)/(Parcel Size)

Slot Tariff : = Tariff Quoted by Shipping Lines

*Figure **Error! No text of specified style in document.**-80 Sea Freight Comparison Parameters – Cost v/s Tariffs*

The chart above also discusses the comparison between Sea Freight Tariff and Sea Freight Cost.

- A route with lower slot cost could have very high tariffs if trade volumes are low
- Routes with high slot cost could have lower tariffs if cumulative capacity of containers deployed are high
- JNPA with depth limitation enjoyed lower tariffs compared to ports with deeper depth due to large volume
- Shipping Lines offered lower tariffs to ships calling to JNPA compared to Mundra, even though Slot Cost at Mundra is low
  - o It could change in Mundra favour with Mundra volumes exceeding JNPA volumes
- Vadhavan with best of JNPA & Mundra features could have competitive tariffs

The table below shows the actual ocean freight tariff rates from shipping line for the containers moving to and from India.

Table A3- 88 Lowest Quote for FCL 20 ft. as on May 2021 (US$)

Foreign Ports →	Chittagong	Dubai	Colombo	Port Klang	Hong Kong	Singapore	Rotterdam	Hamburg
Arrival at Foreign Ports (Export Containers)								
JNPA	1,650	880	1,155	275	671	275	3,377	2,728
Chennai	4,862	990	633	83	748	83	2,673	2,673
Mundra	1,320	946	1,155	358	NA	358	3,432	2,728
Pipavav	3,872	1,089	1,122	693	682	770	2,728	2,728
Hazira	3,872	1056	1122	693	682	770	2,728	2,728
Departure from Foreign Ports (Import Containers)								
JNPA	286	363	407	853	1,606	1073	1,936	1,798
Chennai	374	352	187	743	1,804	1045	2,046	2,046
Mundra	1045	110	737	853	1,859	1073	1,936	1,936
Pipavav	396	946	737	2420	1606	1265	NA	2,706
Hazira	649	396	737	2244	1,606	1639	2,706	2,101

Following chart shows comparative logistics cost of container trade from NCR region to East, West and Middle East region. Dadri Inland Container Depot (ICD) has been considered for comparison of landed logistics cost of containers in NCR region. These charts have been analysed to assess the impact of port tariff on the overall logistics cost for Vadhavan along with its other competing ports. The ocean freight component has been arrived at by calculating cost of container vessel operation.

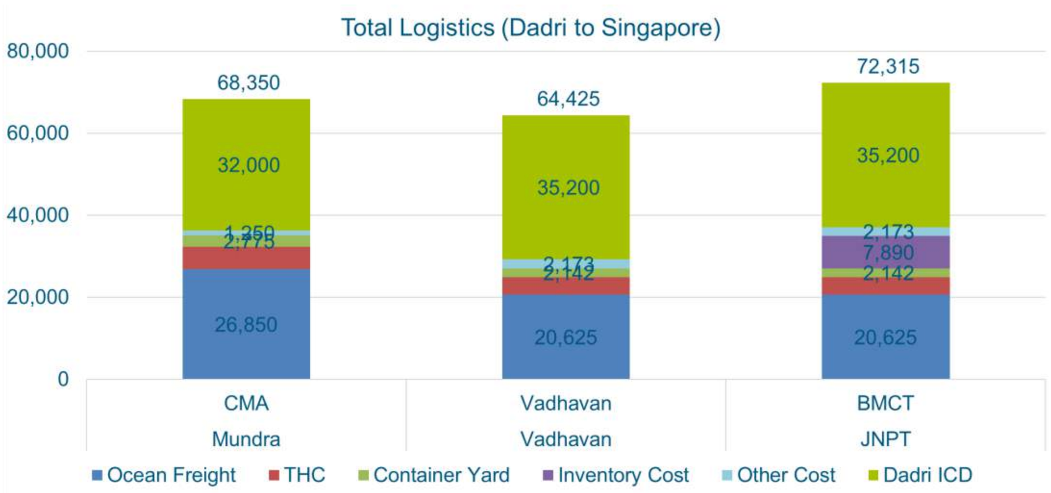

Figure A3-81 Total Logistics Cost from Dadri ICD to Singapore

The above chart shows that Vadhavan is able to offer about INR 3,925/TEU compared to CMA Mundra container terminal and INR 7,990/ TEU compared to BMCT terminal of JNPA on the East route.

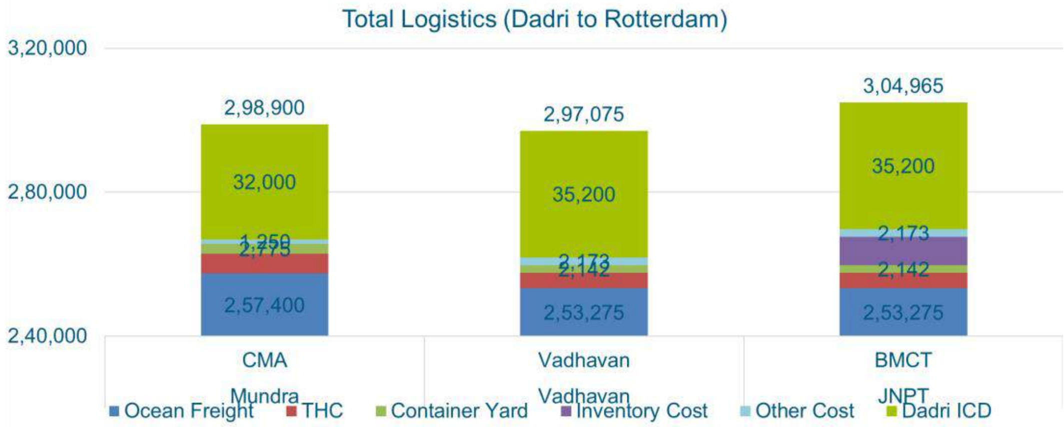

Figure A3-82 Total Logistics Cost from Dadri ICD to Rotterdam

Vadhavan is able to offer marginal savings of INR 1,825/TEU compared to CMA Mundra container terminal and INR 7,890/ TEU compared to BMCT terminal of JNPA. The cost savings is less than 0.5% compared to Mundra and around 2.5% compared to BMCT terminal of JNPA.

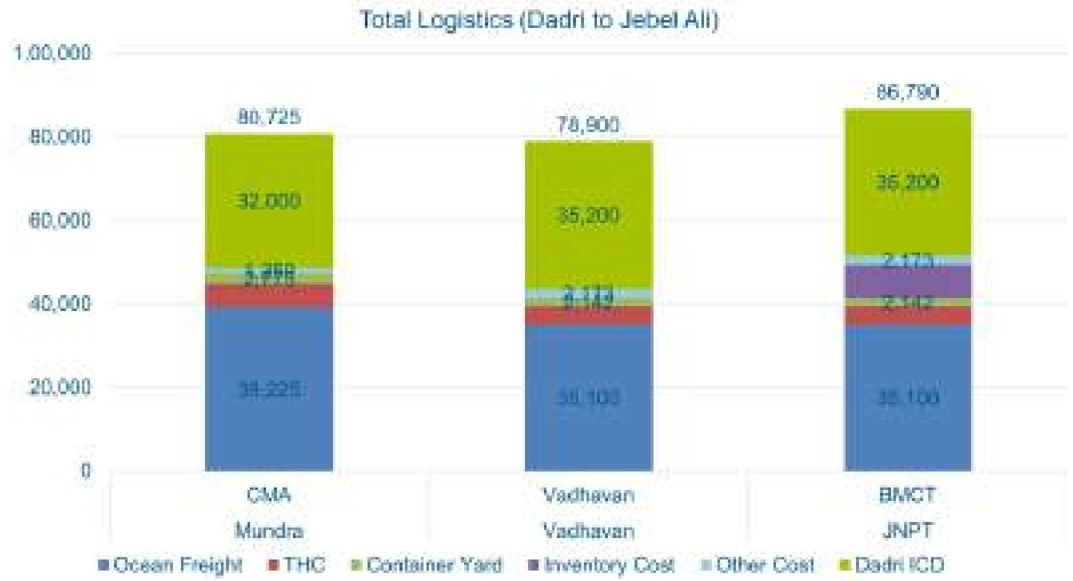

Figure A3-83 Total Logistics Cost from Dadri ICD to Jebel Ali

The integrated logistics cost is found to be in the range of INR 80,000/TEU for Middle East sector. Vadhavan is able to offer marginal savings of INR 1,825/TEU compared to CMA Mundra container terminal and INR 7,890/ TEU compared to BMCT terminal of JNPA. The cost savings is around 2.5% compared to Mundra. This is contradictory to theoretical calculation of ocean freight where Mundra would be cheaper compared to JNPA due to their vicinity to Middle East. However, shipping lines tend to rationalise their tariffs based on market demand, slot deployed for routes and container terminal, etc. leading to differential tariff. Hence, even though Mundra theoretically has lower ocean transportation cost the actual freight offered by shipping lines make Vadhavan and JNPA marginally competitive compared to Mundra.

This analysis has been carried out for several combination of routes and destination. The findings of integrated logistics cost have been found to show similar conclusions.

BMCT terminal of JNPA has been considered to calculate integrated logistics cost of transporting containers using Vadhavan port. The ports tariff is found to be suitable benchmarking with both the prominent competitions namely JNPA and CMA Mundra terminal. It has also been concluded that port tariffs constitute small component of the total container logistics cost. Hence, small deviation in the port tariff would have marginal impact on the selection of port by mainline operators. The choice of Vadhavan port over its competitors would be decided based on several other favourable parameters discussed in detail in traffic section.

Inland tariff offered by shipping lines are in favour of JNPA. This is clearly visible in the tariff declared and presented in the above table. Vadhavan port would be offering lower distance compared to existing JNPA. Since, railway tariffs are distance linked, the inland evacuation cost from Vadhavan port to hinterland is expected to be further lower compared to JNPA. This location advantage of Vadhavan port would enable it to either allow cost benefit of inland logistics to be passed on to trade or increase port tariff marginally.

A3.18.4 Tariff Structure for Other Principal Commodities

Overall logistics cost is influenced by the tariff charged by ports / terminals for each commodity. Tariff structure of each port is divided into two sections i.e., Vessel Related Charges and Terminal Handling Charges. The tariff rates are linked to the type of cargo (liquid, bulk, break-bulk) and commodities, vessel size and type, operational hours of terminal, assistance and service taken from terminal management, storage facilities, etc. The table below shows the tariff structure comparison between competing ports of Vadhavan i.e., Kandla, Mundra, Pipavav, Hazira and MbPT for each principal commodity.

Table A3- 89 Edible Oil Handling Charges at Competing Ports (US$)

Components	Kandla	Mundra	Hazira	Pipavav
Anchorage	**0.001** GRT/Hr.	**0.001** GRT/Hr.	**0.001** GRT/Hr.	**0.02** GRT/6 Hrs
Berth Hire	**0.01** GRT/Hr.	**0.01** GRT/Hr.	**0.05** GRT/8 hour (15,001 to 30,000)	**0.02** GRT/Hr.
	N/A	N/A	**0.07** GRT/8 hour (15,001 to 30,000)	N/A
	N/A	N/A	**0.08** GRT/8 hour (above 30,000)	N/A
Mooring	**0.002** GRT/Hr.	**0.03** GRT/VCN	**0.02** per GRT	N/A
Port Dues	**0.48** GRT/Vessel	**0.05** GRT/Vessel	**0.05** per GRT	**0.31** GRT/Vessel
Pilotage	**0.97** per GRT <30,000	**0.70** per GRT (<10,000)	**1.01** per Tanker (<15,000 GRT)	**0.61** per GRT (<60,000)
	29,085 for 1st 30,000 GRT + **0.77** per GRT (30,001 to 60,000)	**0.83** per GRT (>10,000)	**1.01** per Tanker (15,001 to 25,000 GRT)	N/A
	52,322.68 for 1st 60,000 GRT + **0.68** per GRT (>60,000)	N/A	**1.07** per Tanker (>25,000 GRT)	N/A
Warping	N/A	50% of applicable pilotage charges		N/A
Tug / Boat hire	N/A	**1,755** per trip	N/A	N/A
Wharfage	**0.75** per Ton	**0.88** per Ton	**1.20** per Ton	**1.07** per Ton
Stevedoring	N/A	N/A	N/A	N/A
Pipeline /Cargo Throughput	N/A	**0.04** per Ton	**0.03** per Ton	**0.17** per Ton

Table A3- 90 Fertilizer Handling Charges at Competing Ports (US$)

Components	Kandla	Mundra	Hazira	Pipavav
Anchorage	**0.001** GRT/Hr.	**0.001** GRT/Hr.	**0.001** GRT/Hr.	**0.02** GRT/6 Hrs.
Berth Hire	**0.01** GRT/Hr.	**0.01** GRT/Hr.	**0.07** GRT/8 Hrs.	**0.01** GRT/Hr.
Mooring	**0.002** GRT/Hr.	**0.03** GRT/Hr.	**0.02** per GRT	N/A
Port Dues	**0.48** GRT/Vessel	**0.05** GRT/Vessel	**0.05** per GRT	**0.19** GRT/Vessel
Pilotage	**0.97** per GRT <30,000	**0.70** per GRT <10,000	**1.01** per GRT <3,000	**0.55** per GRT <60,000
	29,085 for 1st 30,000 GRT + **0.77** per GRT (30,001 to 60,000)	**0.83** per GRT >=10,000	**1.01** per GRT (3,001 to 15,000)	**0.60** per GRT >60,000
	52,322.7 for 1st 60,000 GRT + **0.68** per GRT (>60,000)	N/A	**1.01** per GRT (15,001 to 60,000)	N/A
Warping	N/A	50% of applicable pilotage charges		N/A
Tug / Boat hire	N/A	**1,755** per trip	N/A	N/A
Wharfage	**0.83** per Ton	**0.87** per Ton	**0.93** per Ton	**0.73** per Ton

Table A3- 91 Chemical Handling Charges at Competing Ports (US$)

Components	Kandla	Mundra	Hazira	Pipavav
Anchorage	**0.001** GRT/Hr.	**0.001** GRT/Hr.	**0.001** GRT/Hr.	**0.02** GRT/6 Hrs.
Berth Hire	**0.01** GRT/Hr.	**0.01** GRT/Hr.	**0.05** GRT/8 Hrs.	**0.02** GRT/Hr.
Mooring	**0.002** GRT/Hr.	**0.03** GRT/VCN	**0.02** per GRT	N/A
Port Dues	**0.48** GRT/Vessel	**0.05** GRT/Vessel	**0.05** per GRT	**0.31** GRT/Vessel
Pilotage	**0.97** per GRT <30,000	**0.70** per GRT <10,000	**1.01** per Tanker (<15,000 GRT)	**0.61** per GRT <60,000
	29,085 for 1st 30,000 GRT + **0.77** per GRT (30,001 to 60,000)	**0.83** per GRT >=10,000	**1.01** per Tanker (15,001 to 25,000 GRT)	N/A
	52,322.7 for 1st 60,000 GRT + **0.68** per GRT (>60,000)	N/A	**1.07** per Tanker (>25,000 GRT)	N/A
Warping	N/A	50% of applicable pilotage charges		N/A
Tug / Boat hire	N/A	**1,755** per trip	N/A	N/A
Wharfage	**0.75** per Ton	**1.107** per Ton	**1.33** per Ton	**1.20** per Ton
Pipeline/Cargo Throughput	N/A	**0.04** per Ton	**0.03** per Ton	**0.17** per Ton

Table A3- 92 Bulk Liquid Handling Charges at Competing Ports (US$)

Components	Kandla	Mundra	Hazira	Pipavav
Anchorage	**0.001** GRT/Hr.	**0.001** GRT/Hr.	**0.001** GRT/Hr.	**0.02** GRT/6 Hrs.
Berth Hire	**0.01** GRT/Hr.	**0.01** GRT/Hr.	**0.08** GRT/8 Hrs.	**0.02** GRT/Hr.
Mooring	**0.002** GRT/Hr.	**0.03** GRT/VCN	**0.02** per GRT	N/A
Port Dues	**0.48** GRT/Vessel	**0.05** GRT/Vessel	**0.35** per GRT	**0.30** GRT/Vessel
Pilotage	**0.97** per GRT <30,000	**0.70** per GRT <10,000	**1.01** per Tanker (<15,000 GRT)	**0.55** per GRT <60,000
	29,085 for 1st 30,000 GRT + **0.77** per GRT (30,001 to 60,000)	**0.83** per GRT >=10,000	**1.01** per Tanker (15,001 to 25,000 GRT)	N/A
	52,322.7 for 1st 60,000 GRT + **0.68** per GRT (>60,000)	N/A	**1.07** per Tanker (>25,000 GRT)	N/A
Warping	N/A	50% of applicable pilotage charges		N/A
Tug / Boat hire	N/A	**1,755** per trip	N/A	N/A
Wharfage	**1.87** Cu.m	**4.67** per Ton	N/A	**3.33** per Ton
Pipeline/Cargo Throughput	N/A	**0.04** per Ton	**0.03** per Ton	**0.17** per Ton

Table A3- 93 Other Liquid/CNG Handling Charges at Competing Ports (US$)

Components	Mundra	Hazira	Pipavav
Anchorage	**0.03** GRT/Hr.	**0.001** GRT/Hr.	**0.02** GRT/6 Hrs.
Berth Hire	**0.21** GRT/Hr.	**0.08** GRT/8 Hrs.	**0.02** GRT/Hr.
Mooring	**-**	**0.02** per GRT	N/A
Port Dues	**0.05** GRT/Vessel	**0.35** per GRT	**0.30** GRT/Vessel

Components	Mundra	Hazira	Pipavav
Pilotage	**1.05** GRT/Vessel	**0.60** per GRT	**0.55** per GRT <60,000
Warping	50% of applicable pilotage charges		N/A
Tug / Boat hire	**1,755** per trip	N/A	N/A
Wharfage	**2.39** per Ton	N/A	**3.67** per Ton
Pipeline/Cargo Throughput	**0.04** per Ton	**0.03** per Ton	**0.17** per Ton

Table A3- 94 Ro-Ro Tariff Charges at Competing Ports (US$)

Components	Mumbai	Mundra	Pipavav
Anchorage	**0.06** GRT/Hr.	**0.001** GRT/Hr.	**0.02** GRT/6 Hrs.
Berth Hire	**0.01** GRT/Hr.	**0.01** GRT/Hr.	**0.01** GRT/Hr.
Mooring	N/A	**0.03** GRT/VCN	N/A
Port Dues	**0.03** per GRT >30,000	**0.05** GRT/Vessel	**0.20** GRT/Vessel
Pilotage	**0.49 per** GRT =<30,000	**0.70** GRT <10,000	**0.55** per GRT
	14,844 for 1st 30,000 GRT + **0.40** per GRT (30,001 to 60,000)	**0.83** per GRT =>10,000	N/A
	26,718 for 1st 60,000 GRT + **0.35** per GRT (>60,000)	N/A	N/A
Warping	N/A	50% of applicable pilotage charges	N/A
Tug / Boat hire	N/A	**1,755** per trip	N/A
Wharfage	N/A	N/A	N/A

A3.19 Conclusion

Vadhavan port container terminal has been found to be commercially competitive using container tariff of JNPA's BMCT container terminal. Hence, it is concluded that Vadhavan could adopt existing tariffs of BMCT terminal for THC, CY and other charges. It could follow JNPA vessel related charges. Following table summarises proposed container related tariffs for Vadhavan Port.

Table A3- 95 Proposed Tariff Structure for Vadhavan port

Sr.	Components	Foreign (US$)	Coastal (Rs.)
1	**Port Dues**		
a	Bulk Carriers	**0.22** GRT/Vessel	**5.87** GRT/Vessel
b	Container vessel	**0.17** GRT/Vessel	**4.51** GRT/Vessel
c	Car Carrier Vessels (RoRo)	**0.11** GRT/Vessel	**2.92** GRT/Vessel
2	**Professional Pilot cum towage Fees**		
a	=<30,000 GRT	**0.38** per GRT	**10.05** per GRT
b	30,001- 60,000 GRT	**11,505** for first 30,000 GRT + **0.3073** for every additional GRT	**3,01,392** for first 30,000 GRT + **8.0347** for every additional GRT
c	>60,000 GRT	**20,724** for first 60,000 GRT + **0.2689** for every additional GRT	**5,42,433** for first 60,000 GRT + **7.0349** for every additional GRT
3	**Berth Hire Charges**		
a	For occupying JNPA Berth All Berths including Landing Jetty	**0.006** GRT/Hr.	**0.145** GRT/Hr.

b	For occupying Anchorage Berth	**0.0029** GRT/Hr.	**0.0644** GRT/Hr.

Table A3- 96 Terminal Handling Charges (THC) for Vadhavan Container Terminal

Sr	Components	20 Ft. Container (Per TEU/Rs.)			
		Foreign		Coastal	
		Loaded	Empty	Loaded	Empty
1	**Normal Containers**				
a	Terminal Handling Cost	4,284.8	3,460.8	2,570.9	2,076.5
b	Inland Evacuation – Rail	2,142.4	2,142.4	2,142.4	2,142.4
c	Inland Evacuation – Road	659.2	659.2	659.2	659.2
2	**Reefer Containers**				
a	Terminal Handling Cost	4,284.8	3,460.8	2,570.9	2,076.5
b	Inland Evacuation - Rail	2,142.4	2,142.4	2,142.4	2,142.4
c	Inland Evacuation - Road	659.2	659.2	659.2	659.2
3	**Hazardous Containers**				
a	Terminal Handling Cost	5,357.0	0.0	3,214.6	0.0
b	Inland Evacuation - Rail	2,677.5	0.0	2,677.5	0.0
c	Inland Evacuation - Road	824.0	0.0	824.0	0.0
4	**Transhipment Containers**				
a	1 – 3000 TEUs	4,944.0	4,284.8	2,966.4	2,570.9
b	3001 – 6000 TEUs	4,614.4	3,955.2	2,768.6	2,373.1
c	6001 – 9000 TEUs	4,284.8	3,625.6	2,570.9	2,175.4
d	Thereafter.	3,955.2	3,296.0	2,373.1	1,977.6
5	**Over Dimensional Cargo Containers**				
a	Terminal Handling Cost	8,569.6	6,921.6	5,141.7	4,152.9
b	Inland Evacuation - Rail	4,284.8	4,284.8	4,284.8	4,284.8
c	Inland Evacuation - Road	1,318.4	1,318.4	1,318.4	1,318.4

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