DEVELOPMENT OF GREENFIELD VADHAVAN PORT

DISPERSION OF SILT DURING DREDGING FROM MARINE BURROW PIT FOR RECLAMATION

Consultant

Prof. S. Nallayarasu

DEPARTMENT OF OCEAN ENGINEERING
INDIAN INSTITUTE OF TECHNOLOGY MADRAS
CHENNAI – 600 036

JAWAHARLAL NEHRU PORT AUTHORITY
Port Office, Administrative Building,
Sheva Taluka - Uran, Raigad,
Navi Mumbai– 400 707.

OCTOBER 2022

TABLE OF CONTENTS

1.0 INTRODUCTION

1.1 General

Jawaharlal Nehru Port Trust (JNPT) and Maharashtra Maritime Board (MMB) planned to develop a new multi-purpose port at Vadhavan near Dahanu in Palghar Dist. Maharashtra. The major components of the greenfield port development include the following.

- Break water
- Dredging and Reclamation
- Berths and Approach

Figure 1.1 Proposed Vadhavan Port

It can be seen from figure 1.1 that the container yard is located on the reclaimed area and is connected through the approach bridge to land.

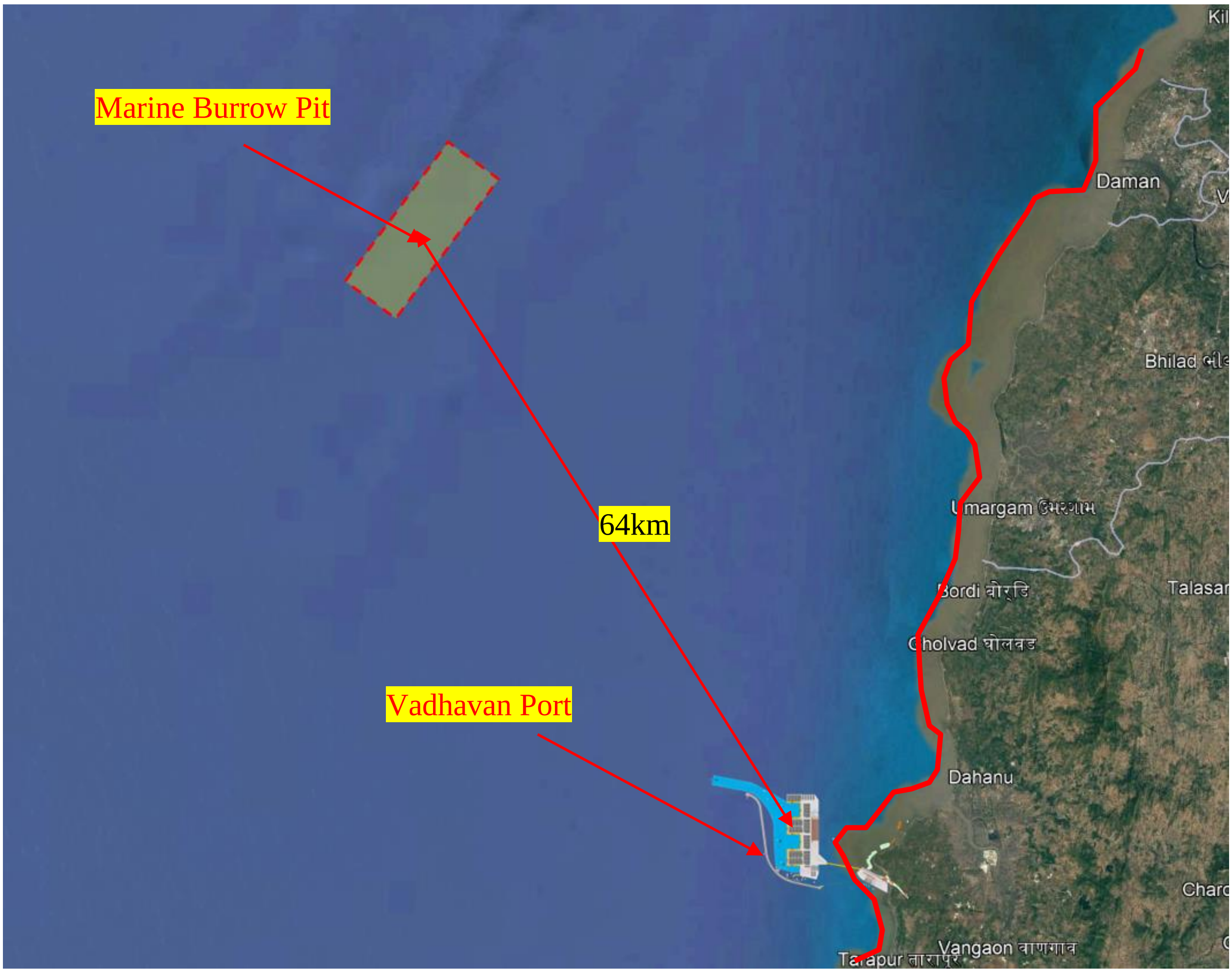


Figure 1.2 Location of Marine Burrow Pit identified

JNPA has identified a burrow pit at around 50-65 kms into sea from the proposed Vadhavan port for obtaining sand for creating reclaimed land at the proposed Vadhavan port. The marine sand will be dredged using Trailing Suction Hopper Dredger (TSHD) and the sand will be transported and dumped at the reclamation location.

It is essential to study the dispersion of the silt and sand during dredging operations to ascertain its effect on the coastal sedimentation and shoreline changes if any. Hence a comprehensive simulation has been carried out to simulate the hydrodynamic conditions and corresponding silt that escapes during the dredging using TSHD has been presented in this report.

1.2 Scope of this report

The following aspects need to be covered in the study.

a) Setup a hydrodynamic model covering the area of interest and calibrate the hydrodynamic model with observed or published currents and tidal elevation data
b) Device a suitable dredging methodology
c) Simulate the dredging operations in the hydrodynamic model for different seasons expected at site location i.e., monsoon and non-monsoon.
d) Estimate the changes in the suspended sediment concentrations of the water column, changes in the seabed in the vicinity of the burrow pit and nearby coastline due to the spill generated by the dredging operations based on the results from the above study
e) If it is found that the sea water column, seabed, and coastline are adversely impacted by the dredging operations, modify the dredging methodology such that the effect of the dredging on the surrounding areas of the burrow pit is minimized.

1.3 References

Following documents were used as reference.

Table 1.1 Reference drawings and Report

No	Document No	Document Description	Date / revision
1.	-	Geophysical survey for Marine Burrow Pit nearby Vadhavan - Seabed & Geological Profile Chart (5 Sheets)	Rev 1 03.06.2022
2.	-	Bathymetry Chart (7 Sheets)	Rev1 03.06.2022
3.	-	Bathymetry Contour (7 Sheets)	Rev 1 03.06.2022
4.	-	Isopach Chart (7 Sheets)	Rev 1 03.06.2022
5.	-	Isopach Contour (7 Sheets)	Rev 1 03.06.2022
6.	SGS/ROS/JNPT/2022/01	Geophysical survey for Marine Burrow Pit nearby Vadhavan	15.06.2022
7.	210	Bathymetry and Isopach Survey – Figure No. 3.0	24.12.2020
8.	DI1452-RHD-DP-MA-DR-CM-1001	Vadhavan port master plan (phase 2 layout)	P07 24.12.2021

1.4 Codes and standards

Following codes and standards were used as the basis for the Dredging assessment.

Table 1.2 Codes and standards

Code	Description
BS 6349	Code of practice for maritime structures
Part 1	General Criteria
Part 5	Code of practice for dredging and land reclamation
PIANC Report No. 6	MarCom WG 6- Classification of Soils and Rocks to be Dredged (Revision of 1972 Report) (1984)
PIANC Report No. 19	Beneficial use of dredged Material
PIANC Report No. 100	Dredging Management Practices for the environment
PIANC Report No. 104	Dredged Material as a resource
PIANC Report No. 10	MarCom WG 10-Supplement to bulletin 52-1986-Disposal of dredged material at sea
PIANC Report No. 23	MarCom WG 23-2000-Site investigation requirements for dredging works
PIANC Report No. 144	MarCom WG 144-2017-Classification of Soils and Rocks for the Maritime Dredging Process

2.0 PHYSICAL PARAMETERS

2.1. Tides

The tides at Daman are of mixed semi-diurnal type characterized by large tidal ranges. The Mean High Water Spring reported at Daman is 6.2 m. The design tide levels with respect to chart datum for Daman as published by Survey of India in NHC No. 209 is listed below

Heights in meters above chart datum

Mean High water Spring	:	6.2 m
Mean High Water Neap	:	4.9 m
Mean Sea Level	*:*	*3.8 m*
Mean Low Water Neap	:	2.7 m
Mean Low Water Spring	:	1.4 m

2.2. Winds

Based on the available inhouse wind data, the wind characteristics are compiled, the monthly and annual wind roses are shown in **Fig. 2.1.** It is observed that the wind speed varied 2 m/s – 12 m/s and the wind direction varied between 0° - 45° & 225° - 360°.

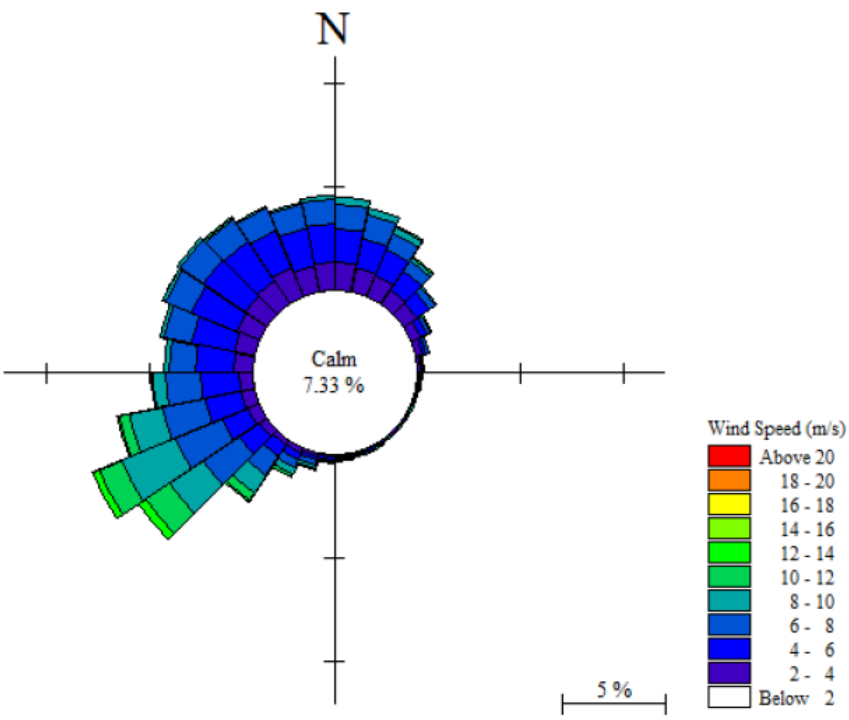


Figure 2.1. Annual Wind Roses

2.3. Waves

Based on the available In-house wave data, the wave characteristics are compiled, the annual wave rose is shown in **Fig. 2.2.** It is observed that the significant wave height is varying between 0.5 m and 3.0 m. The predominant wave direction remains between 202.5° and 270°. The wave period varies between 4 s to 14 s.

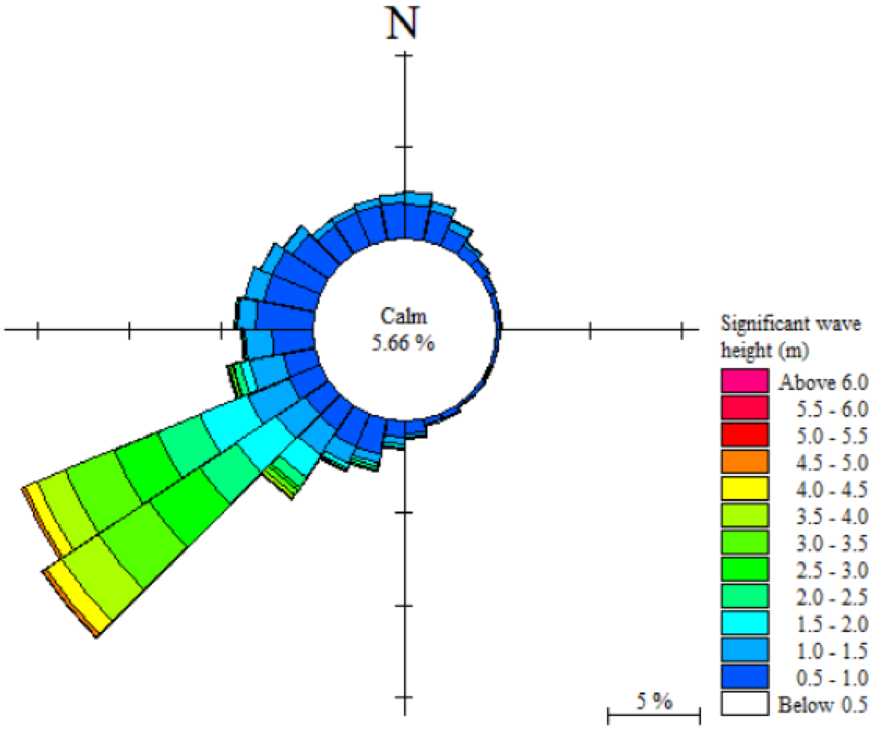


Figure 2.2. Annual Wave Rose

2.4. Currents

Based on the available data at offshore near Vadhavan, the maximum current speed during the measurement period is 0.70 m/s. The predominant current direction remained towards 200° during flood tide and 25° during ebb tide.

2.5. Cyclones

Based on Tracks of Cyclones in the Cyclone e-Atlas provided by the India Meteorological Department (IMD), the cyclones which have crossed within 100 km radius of the project site during the period from 1922 to 2021 are given in **Table 2.1.** It shows that totally 6 cyclones had passed within 100 km radius of the project site.

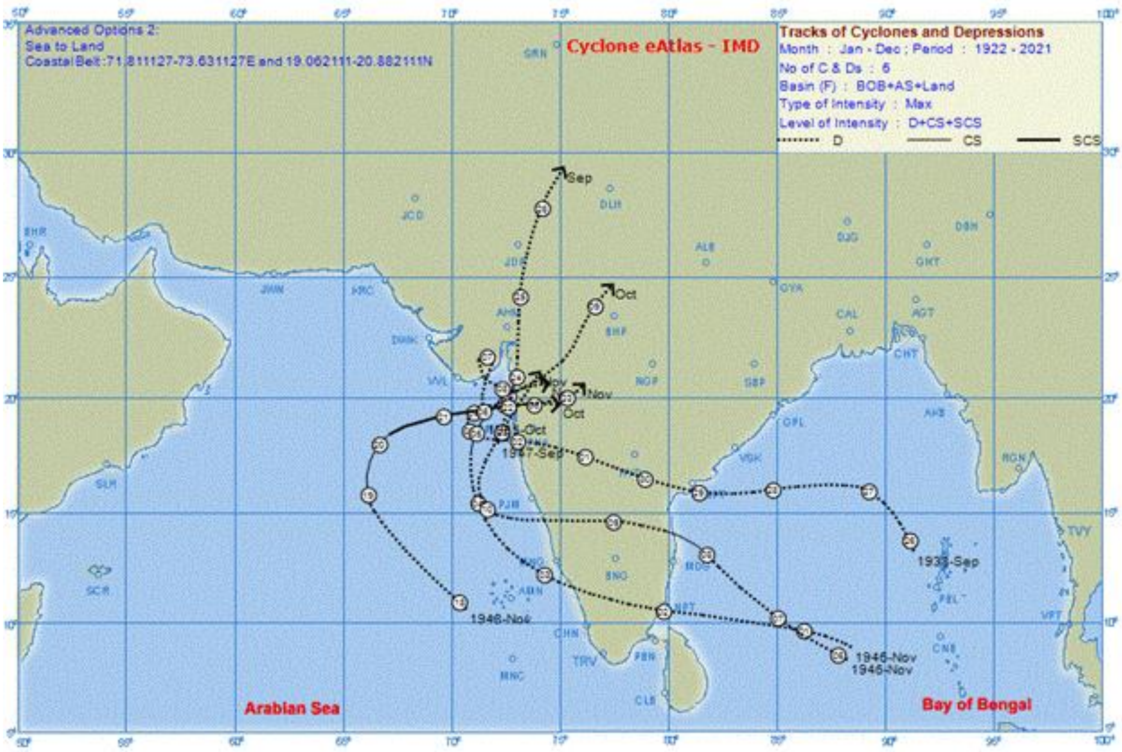


Table 2.1. Number of cyclones crossed within 100 km project radius

Month	Cyclones crossed within 100 km project radius
January	-
February	-
March	-
April	-
May	-
June	-
July	-
August	-
September	2
October	1
November	3
December	-
Total	6

Source: cyclone e-atlas published by IMD – 2021

2.6. Dredging Quantity

The dredging quantity expected from the project is 200 x 10^6 m^3 and generally consists of sandy silt.

2.7. Dredging Soil Characteristics

The existing data indicates that the surface soil up to 11m is made of recent deposition of silty sand of particle size varying from 0.075mm to 0.2mm. Hence the representative soil particle size should be 0.15mm.

3.0 MODELLING APPROACH

3.1. Study Requirement

The development of the proposed greenfield port Vadhavan requires a huge quantity of sand for reclamation as the port is proposed for development at offshore. Dredging must be done to extract sand for the fullest requirement. In connection to this, geophysical investigations were done to explore the subsurface geology to sort out the possibilities of sand patches in the project region. The proposed quantity of dredging is 200 x 10^6 m^3 using 7 Nos of Trailing Suction Hopper Dredger. This study is mainly focused on assessing the impact of dredging and removal of sand at offshore in Vadhavan.

The location map and the satellite imagery of the project location illustrating Vadhavan, and the dredging ground identified at offshore is shown in **Fig. 3.1 & Fig. 3.2** respectively. The details of the dredging ground are given in **Table 3.1**.

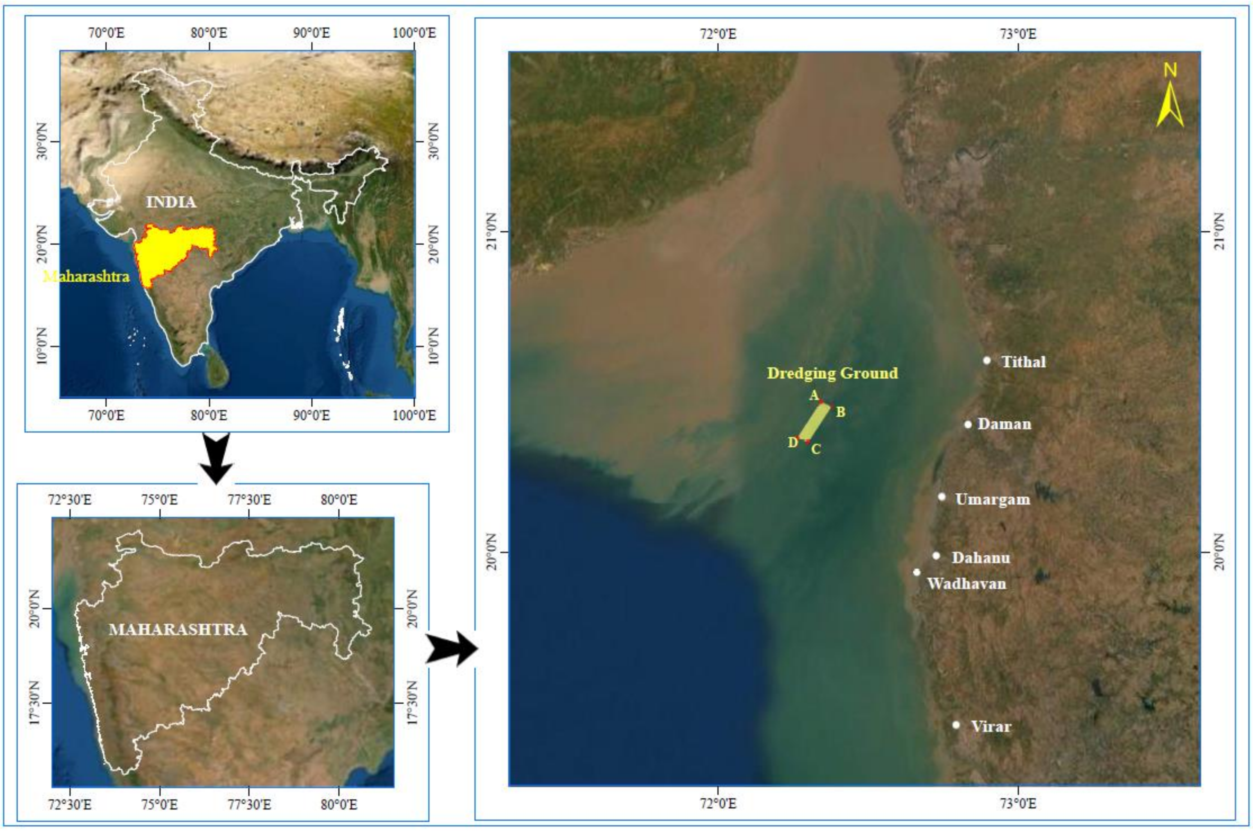


Figure 3.1 Location Map

Table 3.1. Details of dredging ground

Boundary Corners	Geographical Coordinates	
	Latitude (N)	Longitude (E)
A	20°28'08.39"	A
B	20°27'12.58"	B
C	20°20'30.87"	C
D	20°21'25.23"	D
Approximate area of the dredging ground: 14 km x 4 km		

Source: SGS & CO Survey Report

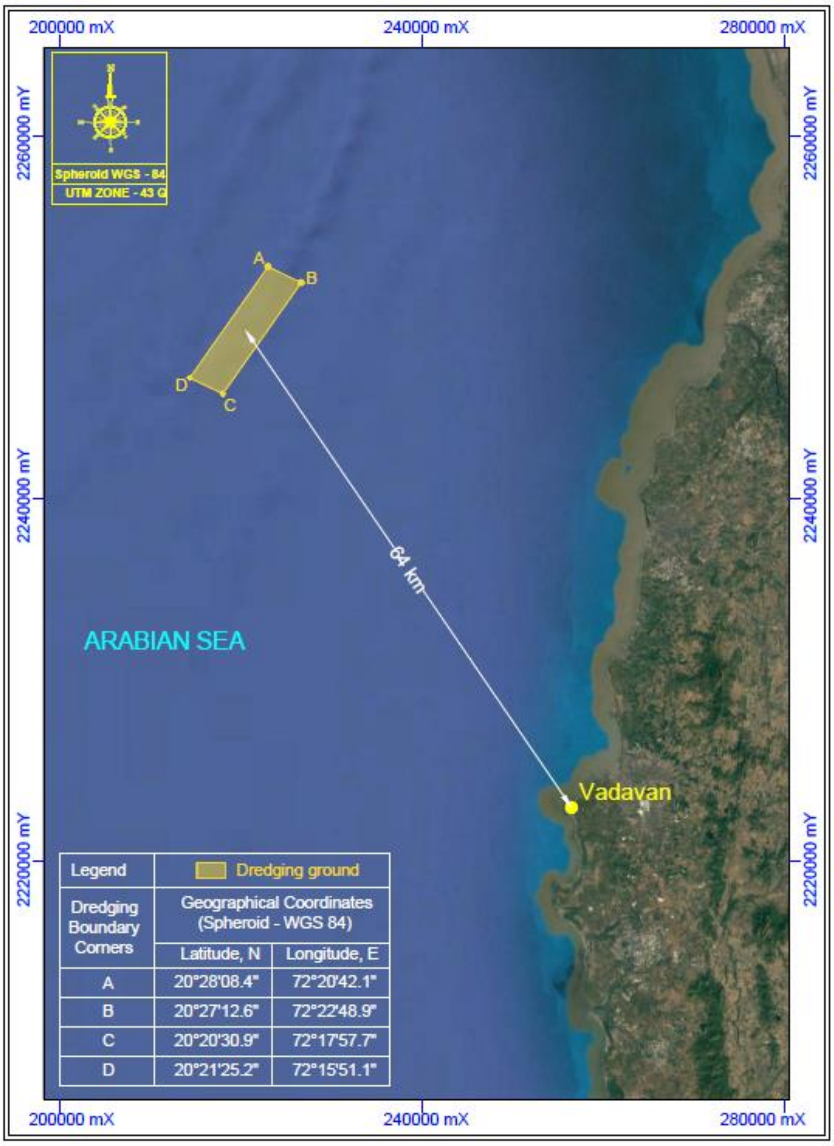
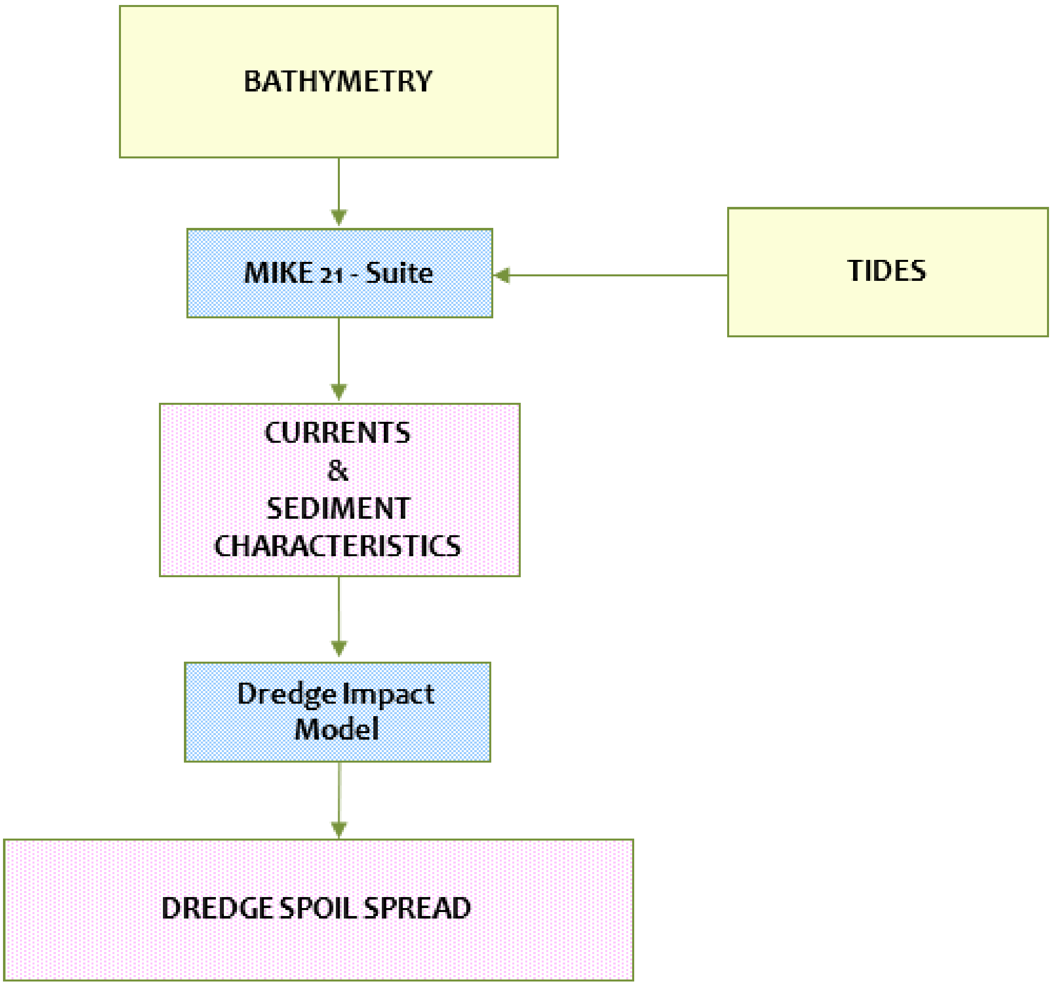


Figure 3.2 Satellite imagery of Project Location

3.2. Modelling Approach

In order to identify the ideal location for the disposal of dredge spoil, it is essential to understand the tide and flow characteristics in the project region during different tidal condition over a Spring - Neap tidal cycle. It is convenient to use mathematical modelling studies to simulate the variation of tides and currents under different tidal condition. DHI - MIKE 21 suites were used to study the variation of tides and currents in the project region. DHI - MIKE 21 models have been developed by Danish Hydraulic Institute (DHI), Denmark, and are being used worldwide for many coastal engineering applications. The study was carried out using the Mike21 software suite available with Indomer Coastal Hydraulics (P) Ltd. The flow chart of the model describing the approach followed in the present study is given below.

MODELLING APPROACH



4.0 FLOW MODEL – MIKE 21 HD

4.1. Model setup

Units: Units of all parameters and variables in the model study are according to international SI conventions. *Coordinate system:* The coordinate system used for model grid generation and other horizontal positioning was UTM based on WGS 84 spheroid. *Vertical reference level:* The depth information used in the tidal flow models is relative to Mean Sea Level (MSL); depths below MSL are defined negative.

Directions: *Current* – Ocean current directions refer to the direction *towards* which the flow is taking place. Directions of the flow are always given clockwise with respect to North. The Unit is degrees, where 360 degrees cover the circle. *Wind* - Wind directions refer to the direction *from* which the wind is approaching the observer. Directions of the wind are always given clockwise with respect to North. The Unit is degrees, where 360 degrees cover the circle. *Wave* - Wave directions refer to the direction *from* which the wave (orthogonal) is approaching. Directions of the wave are always given clockwise with respect to North. The Unit is degrees, where 360 degrees cover the circle.

4.2. Model domain

The model domain close to the project location, which contains all the characteristics of the local geometry and site-specific conditions **(Fig. 4.1).** The high-resolution grid covers the area of approximately 139.3 km x 98.7 km (north - south x east - west). The grid spacing is 150 m in both the directions. The grid approximately comprised of 6,09,696 computational points. The relevant hydrodynamic processes in the vicinity of the disposal area have been generated.

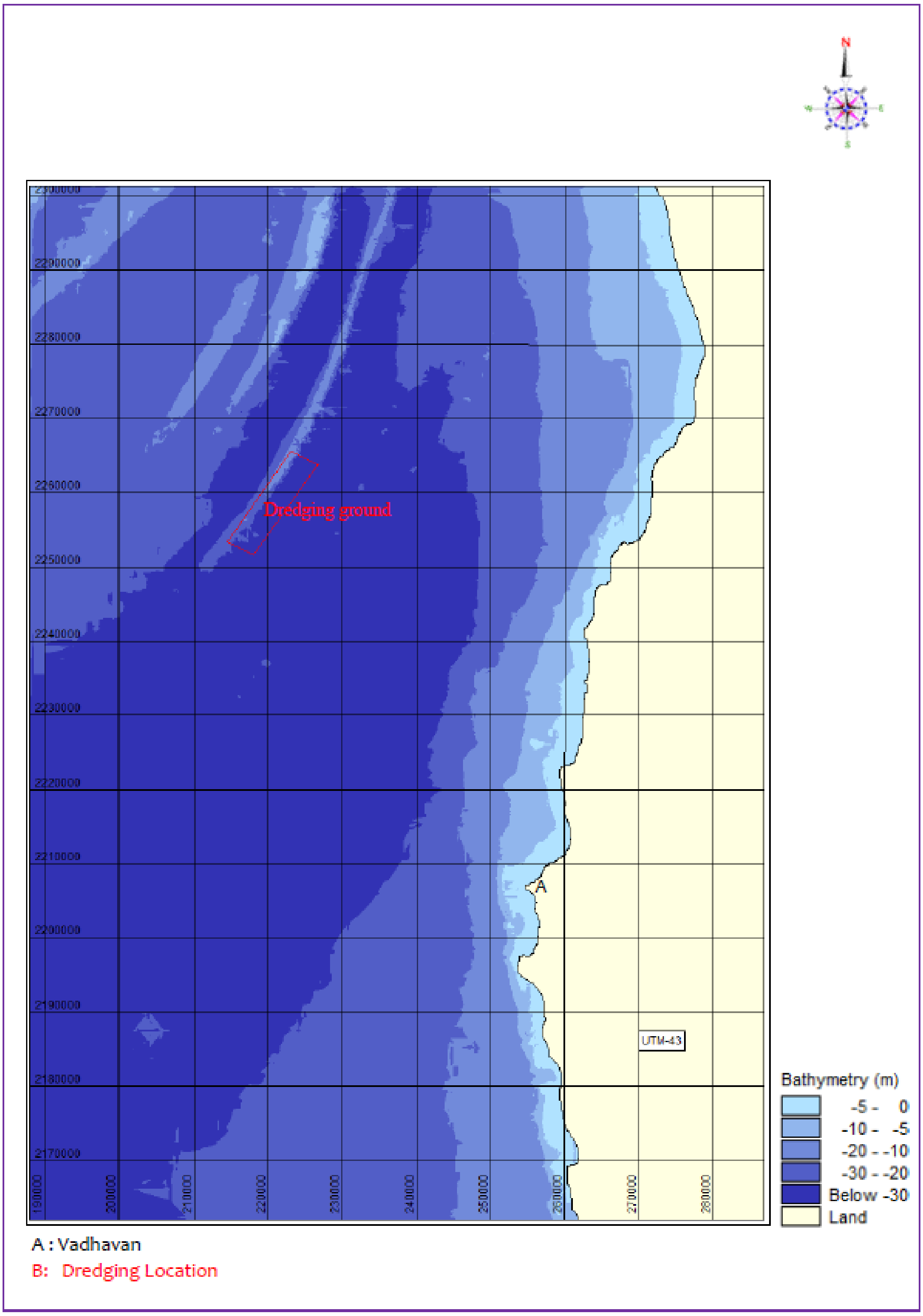


Fig. 4.1. Bathymetry

4.3. Data requirements

The data for the MIKE 21 HD module is described below:

i) Bathymetry

ii) Initial Conditions:
Water surface levels and
Flux densities in x and y directions

iii) Boundary Conditions:
Water levels or flow magnitude and Flow direction

iv) Other Driving Forces:
Wind speed and direction
Source/sink discharge magnitude and speed.

4.4. Depth schematization

For the schematization of depths in the flow model, the water depths were extracted from: i) DHI MIKE 21 – C Map data base, ii) Indian Naval Hydrographic Charts corresponding to this region and iii) Surveyed bathymetry data provided by the client. The bathymetry generated and used for the modelling study is shown in **Fig. 4.1.**

4.5. Flow model – MIKE 21 HD

The tide and wind induced flow field over the project area is determined using hydrodynamic (HD) module of MIKE 21 – suite. This model was developed by Danish Hydraulic Institute (DHI), Denmark and is being widely used worldwide for many coastal engineering applications.

4.5.1. Model description

The MIKE 21-Flow module is a multi-dimensional 2D or 3D hydrodynamic flow simulation model (in the present case a 2D model), which solves shallow-water equations for given boundary conditions to compute non-steady flow fields in response to a variety of environmental forcings and processes in natural water bodies. The environmental forcings and processes include: *bottom shear stress, wind shear stress, barometric pressure gradients, Coriolis force, momentum dispersion, sources and sinks, evaporation, flooding and drying and wave radiation stresses.*

The tide and wind induced flow field over the project area is simulated using the MIKE 21 Hydrodynamic Module (HD). This module is applicable for the simulation of flow fields in natural water bodies, such as lakes, estuaries, bays, coastal areas and seas, wherever stratification can be neglected. This module can be used to model the following processes viz., Tide and wind-driven flows, stratified and density driven flows, thermal stratification in lakes, seas and reservoirs, cooling water recirculation, transport of dissolved material and pollutants and wave-driven currents.

This model uses an Alternate Direction Implicit (ADI) Finite Difference Method on staggered orthogonal grids and also has the option to use Finite Element Method. The basic shallow-water equations in the Cartesian co-ordinate system used in the HD flow module are:

Continuity equation:

$$\frac{\partial \zeta}{\partial t} + \frac{\partial p}{\partial X} + \frac{\partial q}{\partial Y} = S - e$$

Momentum equations in x- and y- directions:

$$\frac{\partial p}{\partial t} + \frac{\partial}{\partial X}\left[\frac{p^2}{h}\right] + \frac{\partial}{\partial Y}\left[\frac{p.q}{h}\right] + gh\frac{\partial \zeta}{\partial X} + F_{bx} - K_a W W_X - \frac{h}{\rho_W}.\frac{\partial p_a}{\partial X} - \Omega q - F_{EX} = S_{iX}$$

$$\frac{\partial q}{\partial t} + \frac{\partial}{\partial X}\left[\frac{p.q}{h}\right] + \frac{\partial}{\partial Y}\left[\frac{q^2}{h}\right] + gh\frac{\partial \zeta}{\partial Y} + F_{by} - K_a W W_Y - \frac{h}{\rho_W}.\frac{\partial p_a}{\partial Y} + \Omega p - F_{EY} = S_{iY}$$

Symbol List:

$$F_{EX} = \left[\frac{\partial}{\partial X}\left[\varepsilon_X.h.\frac{\partial u}{\partial X}\right] + \frac{\partial}{\partial Y}\left[\varepsilon_Y.h.\frac{\partial u}{\partial Y}\right]\right]$$

$$F_{EY} = \left[\frac{\partial}{\partial X}\left[\varepsilon_X.h.\frac{\partial u}{\partial X}\right] + \frac{\partial}{\partial Y}\left[\varepsilon_Y.h.\frac{\partial u}{\partial Y}\right]\right]$$

$$F_{bx} = \frac{g}{C^2}\sqrt{\frac{p^2}{h^2} + \frac{q^2}{h^2}}.\frac{p}{h}$$

$$F_{by} = \frac{g}{C^2}\sqrt{\frac{p^2}{h^2}+\frac{q^2}{h^2}}\cdot\frac{q}{h}$$

Where

ζ (x, y, t)	- Water surface level above datum (m)
p (x, y, t)	- flux density in the x-direction ($m^3/s/m$)
q (x, y, t)	- flux density in the y-direction ($m^3/s/m$)
h (x, y, t)	- water depth (m)
S	- source magnitude per unit horizontal area ($m^3/s/m^2$)
S_{iX},S_{iY}	- source impulse in x and y-directions $m^3/s/m^2.m/s$)
e	- evaporation rate (m/s)
g	- gravitational acceleration (m/s^2)
C	- Chezy resistance No. ($m^{1/2}/s$)
Ka	- $C_w \frac{\rho_{air}}{\rho_{Water}}$
C_W	- wind friction factor
W, W_X, W_Y (x,y,t)	- wind speed & components in x & y directions(m/s)
pa (x, y, t)	- barometric pressure ($Kg/m/s^2$)
ρz	- density of water (kg/m^3)
Ω	- Coriolis coefficient (latitude dependent) (s^{-1})
ε(x,y)	- eddy or momentum dispersion coefficient (m^2/s)
x,y	- space coordinates (m)
t	- time (s)

4.5.2. Boundary conditions

The coarse resolution model is forced by the tidal water level variations along the open sea boundaries. For the generation of these boundary conditions, the MIKE 21 C-Map data base or DHI - KMS tide data base can be used. These boundary conditions for the coarse resolution model are prescribed as time series of tidal water level variations along the open boundaries of the model.

If the tidal constituents along the boundaries of the coarse resolution model are available, then the boundary conditions are represented by:

$$h_t = A_o + \sum_{i=1}^{n} f_i A_i \cos(\omega_i t + (v_o + u)i - g_i)$$

With:

h_t	=	water level at time = t
A_o	=	mean value of the signal
A_i	=	amplitude of component i
f_i	=	nodal amplitude factor of component i
ω_i	=	angular frequency of component i
$(v_0+u)_i$	=	astronomic argument of component i
g_i	=	phase lag of component i

4.5.3. Calibration

The model is calibrated using predicted tides and a good agreement was observed between the simulated tides and the predicted tides at the project region and the comparison is shown in **Fig. 4.2.**

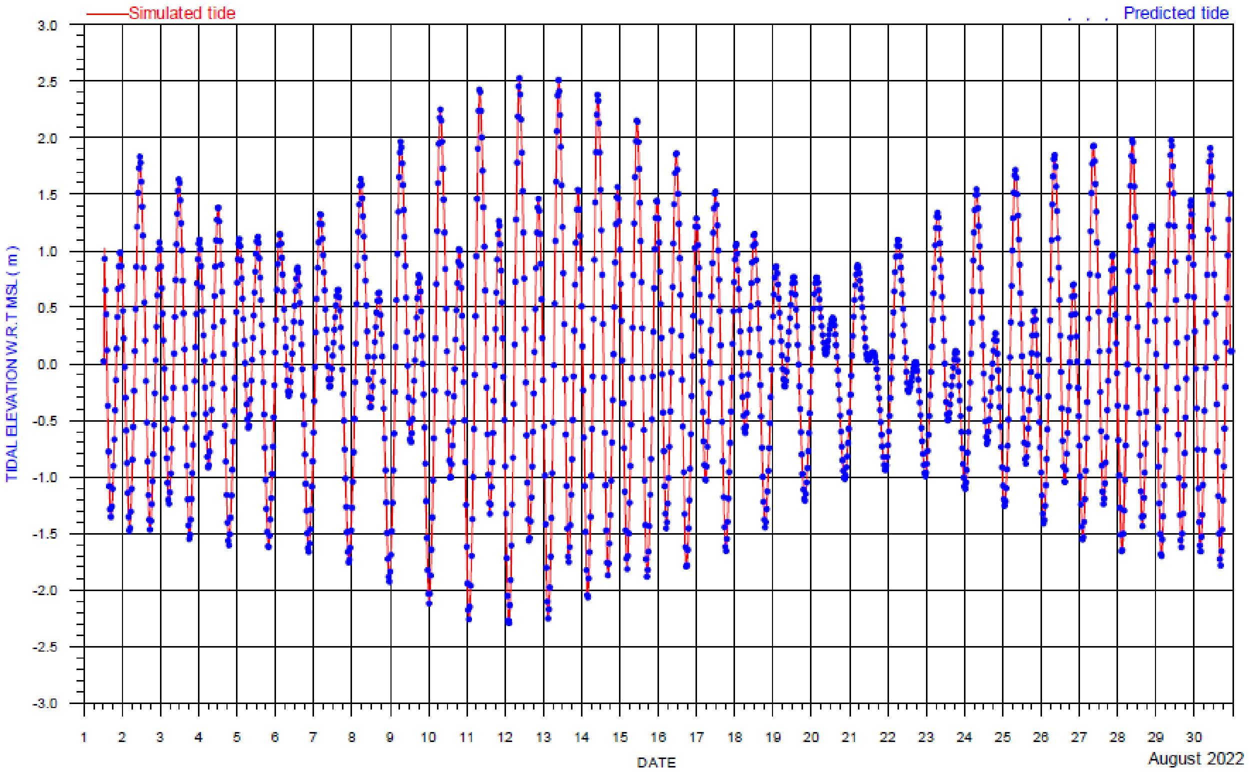


Fig. 4.2. Comparison of simulated and predicted tide

4.5.4. Simulations

The flow field was simulated for a period of two years between 1st January 2021 and 31st December 2022. The typical flow field in the project region were extracted for a period of one lunar cycle covering two seasons viz: non-monsoon and monsoon.

4.5.5. Results

Non-monsoon

During non-monsoon, the wind speed over the sea remains low. The sea would be relatively calm with low wave activity and less currents.

Flood phase of the spring tide: The flow field during the flood phase near the project region representing spring tidal day in a non-monsoon is shown in **Fig. 4.3.** The simulated flow field shows that the current speed at the dredging ground is of the order of 0.48 m/s towards northeast direction.

Ebb phase of the spring tide: The flow field during the ebb phase near the project region representing spring tidal day in a non-monsoon is shown in **Fig. 4.3.** The simulated flow field shows that the current speed at the dredging ground is of the order of 0.42 m/s towards southwest direction.

Flood phase of the neap tide: The flow field during the flood phase near the project region representing neap tidal day in a non-monsoon is shown in **Fig. 4.4.** The simulated flow field shows that the current speed at the dredging ground is of the order of 0.30 m/s towards northeast direction.

Ebb phase of the neap tide: The flow field during the ebb phase near the project region representing neap tidal day in a non-monsoon is shown in **Fig. 4.4.** The simulated flow field shows that the current speed at the dredging ground is of the order of 0.25 m/s towards southwest direction.

The time series variation of simulated tides, current speed and direction extracted close to the proposed dredging ground during non-monsoon is shown in **Fig. 4.5**.

Monsoon

During monsoon, the wind speed over the sea remains high. The sea would be relatively higher wave activity and currents.

Flood phase of the spring tide: The flow field during the flood phase near the project region representing spring tidal day in a monsoon is shown in **Fig. 4.6.** The simulated flow field shows that the current speed at the dredging ground is of the order of 0.61 m/s towards northeast direction.

Ebb phase of the spring tide: The flow field during the ebb phase near the project region representing spring tidal day in a monsoon is shown in **Fig. 4.6.** The simulated flow field shows that the current speed at the dredging ground is of the order of 0.56 m/s towards southwest direction.

Flood phase of the neap tide: The flow field during the flood phase near the project region representing neap tidal day in a monsoon is shown in **Fig. 4.7.** The simulated flow field shows that the current speed at the dredging ground is of the order of 0.38 m/s towards northeast direction.

Ebb phase of the neap tide: The flow field during the ebb phase near the project region representing neap tidal day in a monsoon is shown in **Fig. 4.7.** The simulated flow field shows that the current speed at the dredging ground is of the order of 0.34 m/s towards southwest direction.

The time series variation of simulated tides, current speed and direction extracted close to dredging ground during monsoon is shown in **Fig. 4.8**.

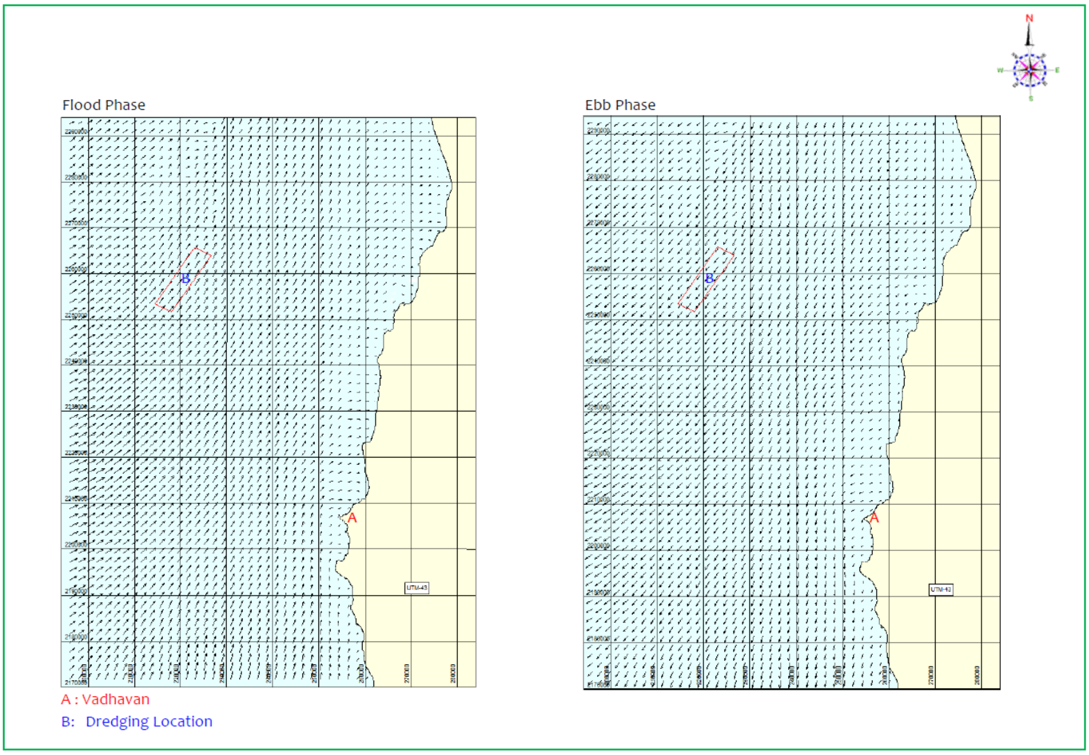


Fig. 4.3. Flow Field – Non monsoon - Spring Tide

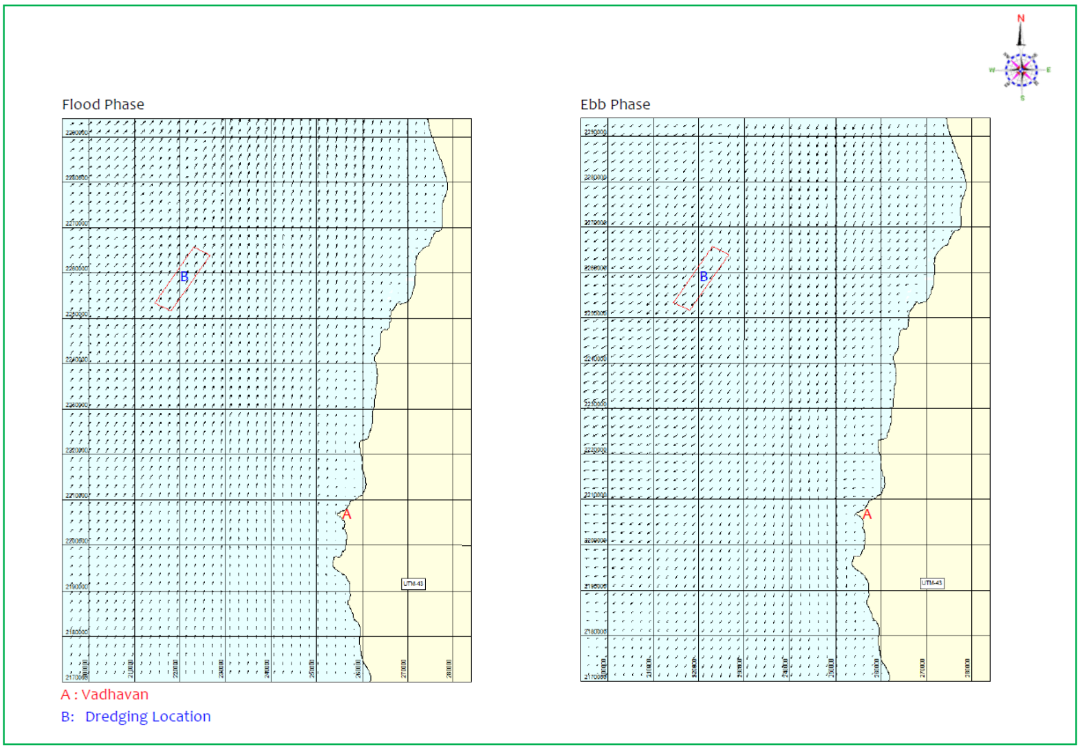


Fig. 4.4. Flow Field – Non monsoon - Neap Tide

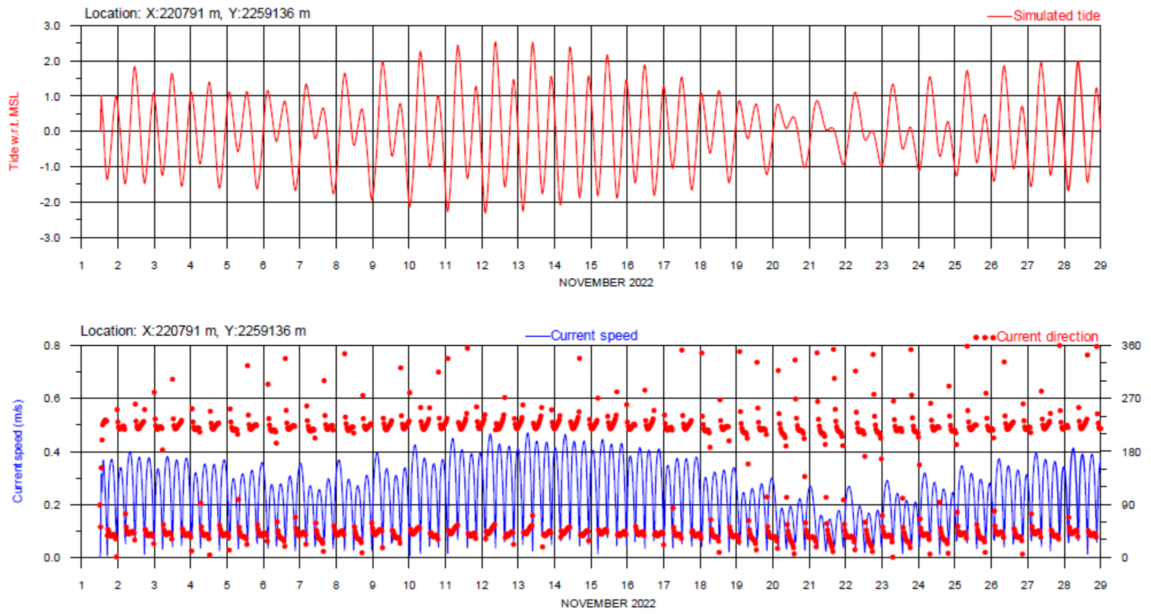


Fig. 4.5. Variation of Simulated Tides & Currents Near to Dredge Ground - Non Monsoon

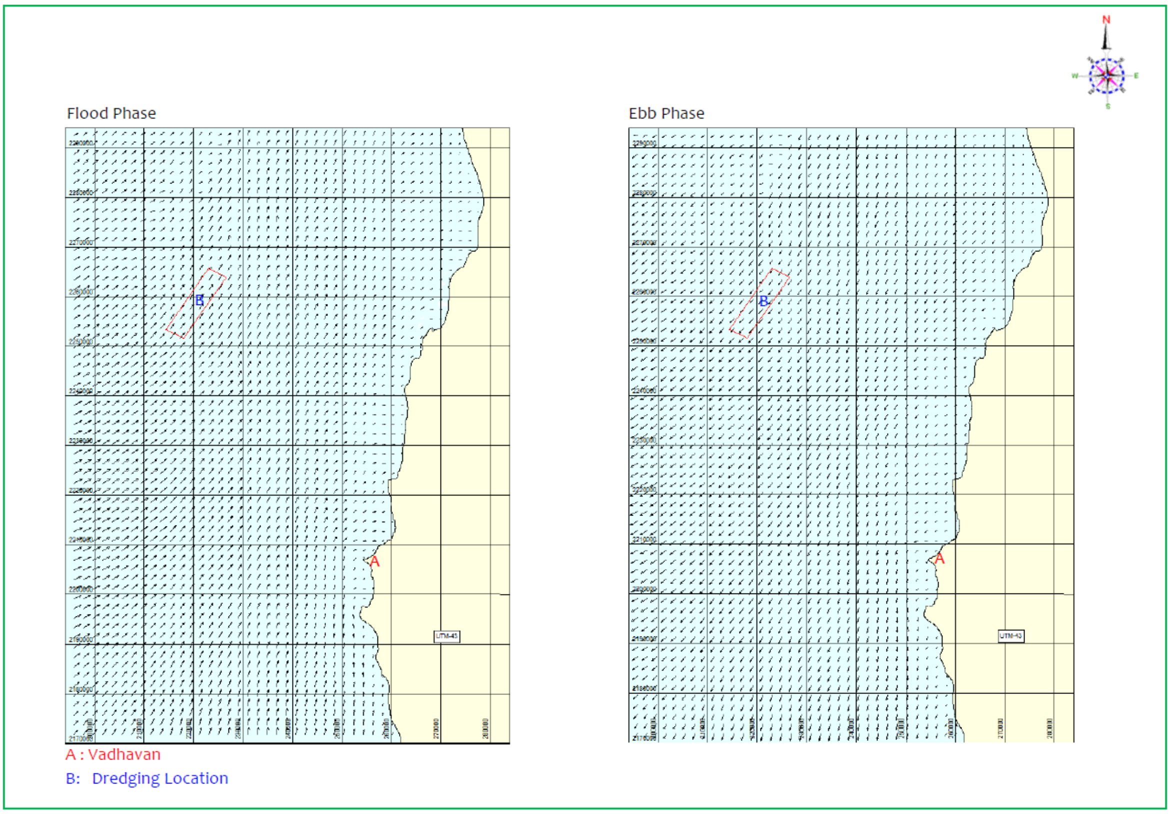


Fig. 4.6. Flow Field – Monsoon - Spring Tide

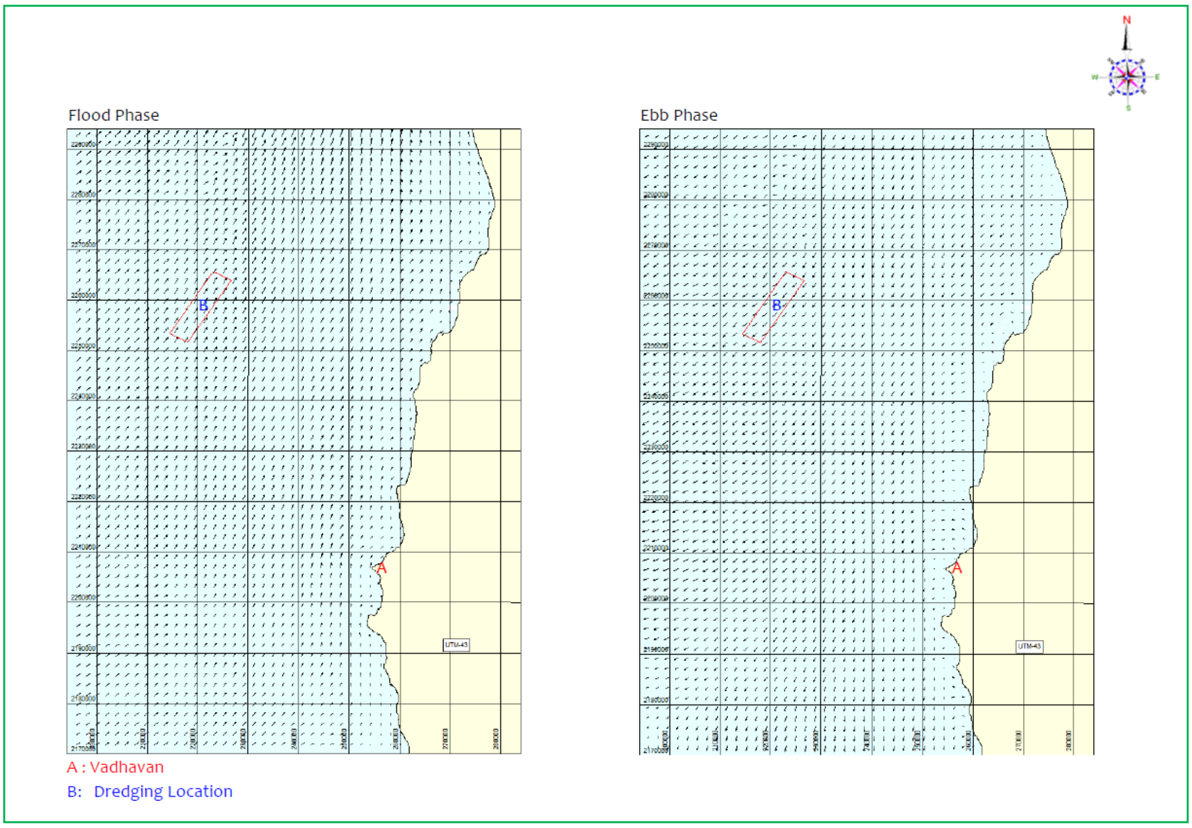


Fig. 4.7. Flow Field – Monsoon - Neap Tide

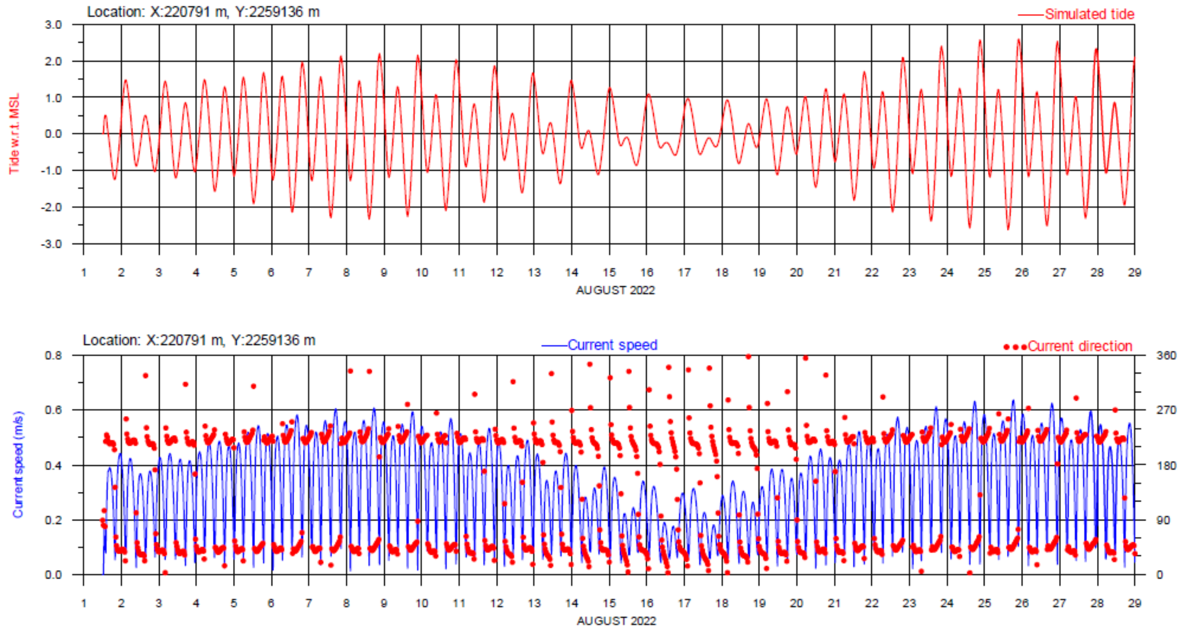


Fig. 4.8. Variation of Simulated Tides & Currents Near To Dredging Ground – Monsoon

5.0 MODELLING STUDY FOR IMPACT DUE TO DREDGING

The impact of dredging will occur during the process of dredging itself where the fine sediments mobilize from drag heads of Trailing Suction Hopper Dredger (TSHD) and during the transport of material from drag head to hopper. It results in overflow of the surplus dredged material from the hopper storage tanks. The assumptions made for Plume trajectory tracking from dredging activity is presented in **Table 5.1**.

Table 5.1. Assumptions for Plume trajectory tracking from Dredging activity

Factors	Case study	Assumptions made
Sediment Plume Sources	Case 1	Plume can be generated by two sources 1. Fine sediments mobilizing from the drag heads during excavation for each load. 2. Overflow water from the hopper barges.
	Case 2	
	Case 3	
Material Loss	Case 1	From Drag heads: Materials upto 10 percent of total excavated sediments. Out of which 8 percent reaches surface. From Hopper overflow: Materials upto 2 percent in suspension from the overflow hopper.
	Case 2	From Drag heads: Materials upto 20 percent of total excavated sediments. Out of which 18 percent reaches surface. From Hopper overflow: Materials upto 2 percent in suspension from the overflow hopper.
	Case 3	From Drag heads: Materials upto 30 percent of total excavated sediments. Out of which 28 percent reaches surface. From Hopper overflow: Materials upto 2 percent in suspension from the overflow hopper.
Quantity of sediments influencing the plume behavior	Case 1	It is proportional to the total material loss (Bucket + Hopper overflow) = 10 percent of total dredge quantity is responsible for plume behavior at surface.
	Case 2	It is proportional to the total material loss (Bucket + Hopper overflow) = 20 percent of total dredge quantity is responsible for plume behavior at surface.
	Case 3	It is proportional to the total material loss (Bucket + Hopper overflow) = 30 percent of total dredge quantity is responsible for plume behavior at surface.

MIKE 21 module is based on the Lagrangian discrete parcels method in which an ensemble of particles is followed instead of solving the Eulerian advection-diffusion equation. The Lagrangian discrete parcel scheme calculates the displacement of each particle as the sum of an advective deterministic component and an independent, random Markovian component, which statistically approximates the random and/or chaotic nature of time-averaged tidal mixing.

In MIKE 21 module, which is designed to simulate the surface and subsurface transport, the spoil/waste/pollutant released into the water bodies are divided into discrete parcels and sets of spatial coordinates are assigned to each parcel. It is assumed that these parcels advect with the surrounding water body and diffuse as a result of random processes. These flow processes occur simultaneously at different spatial and temporal scales with continuous spectrum ranging from molecular agitation to tidal, baroclinic residual flows. The advective velocities are (usually) obtained from hydrodynamic simulations (MIKE 21 HD), whereas the turbulent contributions are controlled by the dispersion coefficients. In this Mike module, the discrete path of the pollutant parcels released in the water body are followed and recorded as a function of time relative to the reference grid system fixed in space. Then the density distributions of the ensemble are interpreted as the concentration of the spoil/waste/pollutant.

The properties of the released particles are described by distribution of grain sizes or settling velocities. It is possible to specify the number of particles released per time step. The sediment is released at a specified depth, and the particles settle with a constant or randomly generated settling velocity. The particles are deposited when they reach the bottom. The mass of the particle cloud can also change due to re-suspension and furthermore due to a linear decay.

This simulation method gives the possibilities of calculating the concentration of suspended material at different depths. The particles can be advected by a three-dimensional velocity field or by logarithmic velocity profiles established from the depth-integrated velocities specified in the Hydrodynamic model. The velocity profiles can be superimposed with a wind induced current profile if wind is applied to the model. The model calculates the frequency function for settling velocity by using Stokes law. A settling velocity chosen at random from this distribution is assigned to each particle when it is released.

5.1. Model setup

The flow field simulated using the MIKE 21 HD module for a period of two years between 1st January 2021 and 31st December 2022 was used as input for module for a dredging area of 14000 m x 4000 m. The other necessary inputs on dispersion parameters and sediment characteristics are specified in the model.

As provided by the client, the modelling study has been carried out for a total dredging of 200 x 10^6 m^3 of sediments in the proposed dredging ground at offshore of Vadhavan.

5.2. Model input

i) Bathymetry – as explained in section 4.2
ii) Flow obtained from MIKE 21 Flow model as explained in section 4.5.5
iii) Sediment grain size D50– 0.15 mm
iv) Duration of dredging – 2 years

5.3. Plume behaviour of the dredged soil

The dredge impact modelling study has been carried out at the proposed dredging ground 64 km northwest of Vadhavan with reference to the coordinates encompassed in **Table 3.1** with water depth varying between 10 and 30 m.

It is observed from the flow simulation studies that the currents were dominated by tides reversing their direction i.e., towards northeast during flood tide and southwest during ebb tide.

The modelling study shows that the plume of dredged material at dredging ground will spread in north-easterly direction during flood tide and south-westerly direction during ebb tides and will get evenly dispersed on the seafloor without reaching the shore. The simulation was carried out for dredging with 7 Nos of Trailing Suction hopper Dredgers (TSHD).

As per the assumptions made for the model (ref. **Table 5.1**), the plume behaviour for the dredged soil is studied for three cases, each compiling two scenarios, which are designated as follows.

- **Scenario 1:** Initial plume concentration
- **Scenario 2:** Cumulative plume concentration

Case 1 (10% Dispersion):

Scenario 1: The concentration of turbid plume arising out of dredging varies from 10 g/l to 40 g/l. The initial concentration of dredged plume over the entire dredging ground is shown in **Fig. 5.1.**

It can be inferred that the total spread of plume covers approximately 11 km in length (northeast-southwest), out of which 5.2 km is subjected to moderately concentrated plumes and remaining length depicts less concentrated plume. The width of the plume spreads over an extent of 1.7 km (northwest-southeast). The simulation shows that the dispersion pattern of the dredged plume gets gradually increasing and it neither reaches the shore nor causing any impact on the marine environment.

Scenario 2: The concentration of turbid plume arising out of dredging varies from 20 g/l to 100 g/l. The cumulative concentration of turbid plume over the entire dredging ground due to simultaneous operation of all the dredgers is shown in **Fig. 5.2.**

It is observed that the total spread of plume covers approximately 17 km in length (northeast-southwest). The width of the plume spreads over an extent of 2.6 km (northwest-southeast). However, there are some sporadic patches of less turbid plume extending in northeast-southwest direction bounded within the boundaries (**Fig. 5.2**) of the dredging ground.

Case 2 (20% Dispersion):

Scenario 1: The concentration of turbid plume arising out of dredging varies from 15 g/l to 50 g/l. The initial concentration of dredged plume over the entire dredging ground is shown in **Fig. 5.3.**

The total spread of plume covers approximately 12 km in length (northeast-southwest), out of which 7 km is subjected to moderately concentrated plumes and remaining length accumulating less concentrated plume. The width of the plume is approximately 2.2 km (northwest-southeast). The dispersion pattern of the dredged plume gets gradually increasing and it has no impact on the maritime environment as wells as not in acquaintance with the shore.

Scenario 2: The concentration of turbid plume arising out of dredging varies from 20 g/l to 120 g/l. The cumulative concentration of turbid plume over the entire dredging ground due to simultaneous operation of all the dredgers is shown in **Fig. 5.4.**
It is observed that the total spread of plume covers approximately 18.3 km in length (northeast-southwest). The width of the plume spreads over an extent of 3.5 km (northwest-southeast). Intermittent patches of less turbid plume extending in northeast-southwest direction and are bounded within the boundaries (**Fig. 5.4**) of the dredging ground.

Case 3 (30% Dispersion):

Scenario 1: The concentration of turbid plume arising out of dredging varies from 20 g/l to 60 g/l. The initial concentration of dredged plume over the entire dredging ground is shown in **Fig. 5.5.**

The total spread of plume covers approximately 13.3 km in length (northeast-southwest), out of which 8.1 km is subjected to moderately concentrated plumes and remaining length depicts less concentrated plume. The width of the plume spreads over an extent of 2.7 km (northwest-southeast). The plume dispersion pattern gradually intensifies and it neither reaches the coast nor has any negative effects on the marine environment.

Scenario 2: The turbid plume concentration varies from 30 g/l to 150 g/l. The cumulative concentration of turbid plume over the entire dredging ground due to simultaneous operation of all the dredgers is shown in **Fig. 5.6.**

It is observed that the total spread of plume covers approximately 18.9 km in length (northeast-southwest). The width of the plume spreads over an extent of 4.2 km (northwest-southeast). However, there are a few irregular patches of a less turbid plume that extends in a northeast-southwest direction and are enclosed within the dredging ground itself (**Fig. 5.6**). The observations made for all the three cases are presented in the table below.

Table 5.2. Plume Concentration

Case Study	% Dispersion	Scenario 1 (g/l)	Scenario 2 (g/l)
Case 1	10	10 - 40	20 - 100
Case 2	20	15 - 50	20 - 120
Case 3	30	20 - 60	30 - 150

As the offshore environment is dynamic in nature with turbulent sea, high tidal range and associated strong currents, the concentration of the plume gets weakened post the dredging activity. The model simulation shows that the turbid plume does not reach the shore. Based on the above scenarios, it can be observed that, the plume trajectory of the dredged sediment does not move towards the coast, and they appear not to cause any impact on the shore and the marine environment.

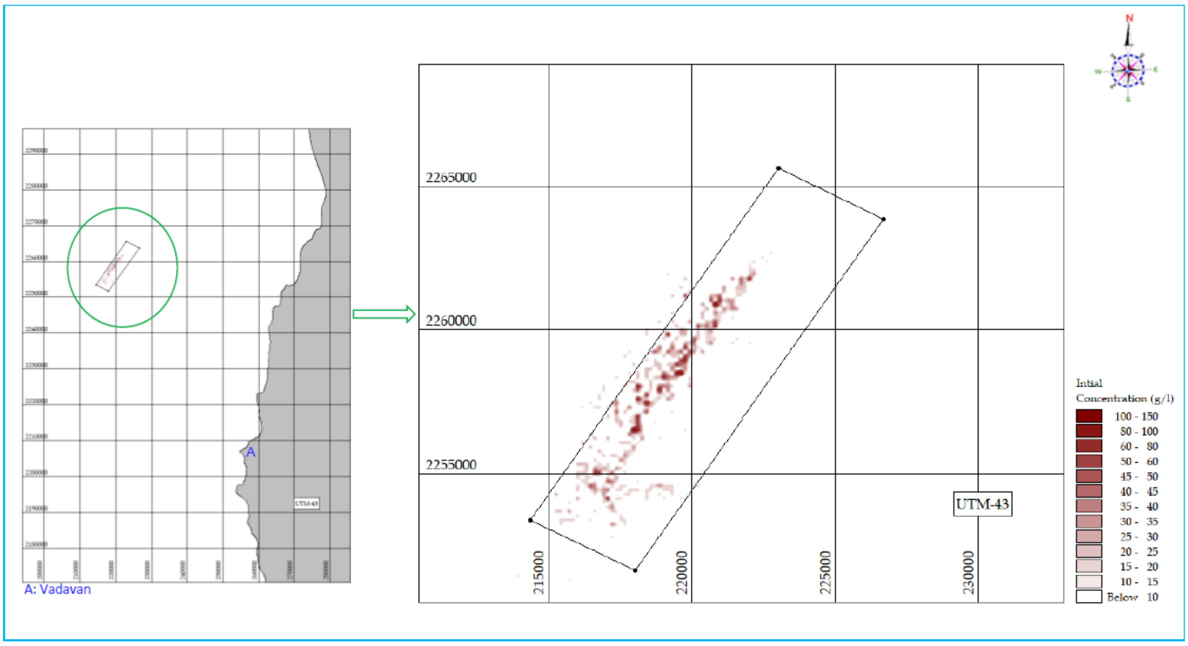


Fig. 5.1. Initial concentration of plume over the entire dredging ground – Case I (10 % Dispersion)

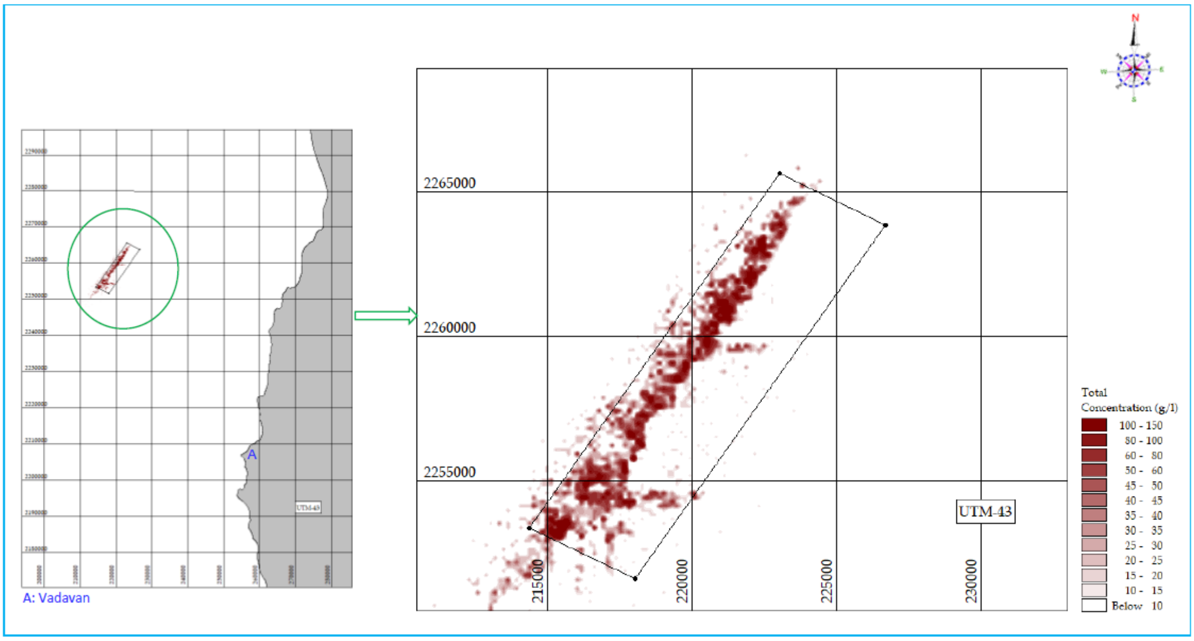


Fig. 5.2. Cumulative concentration of plume over the entire dredging ground – Case I (10 % Dispersion)

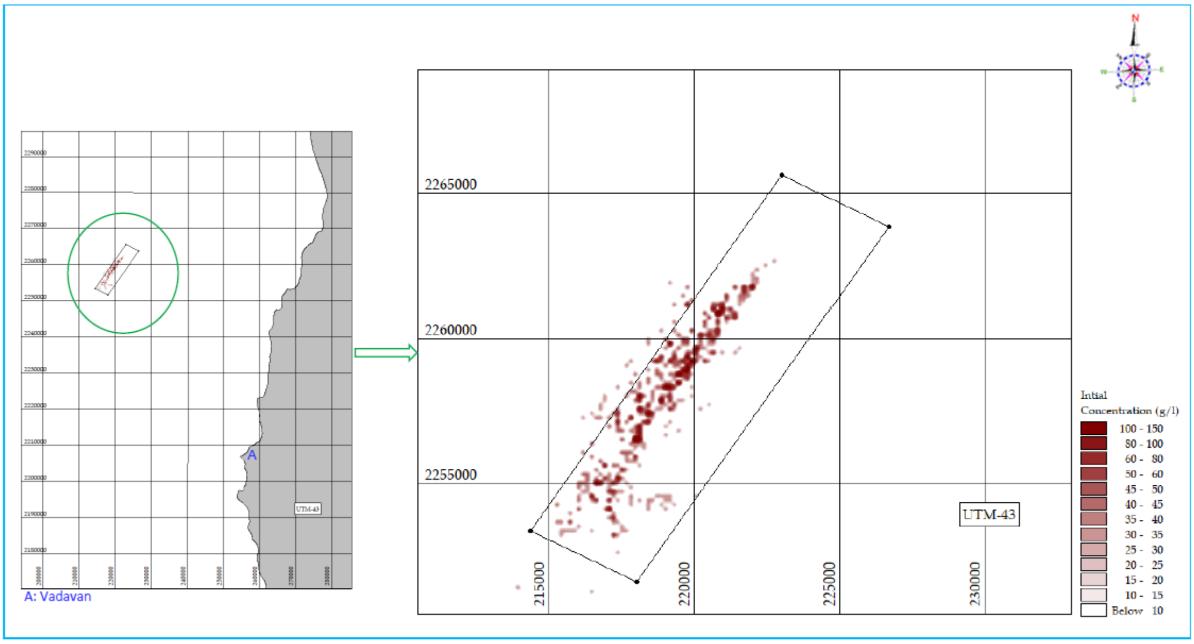


Fig. 5.3. Initial concentration of plume over the entire dredging ground – Case II (20 % Dispersion)

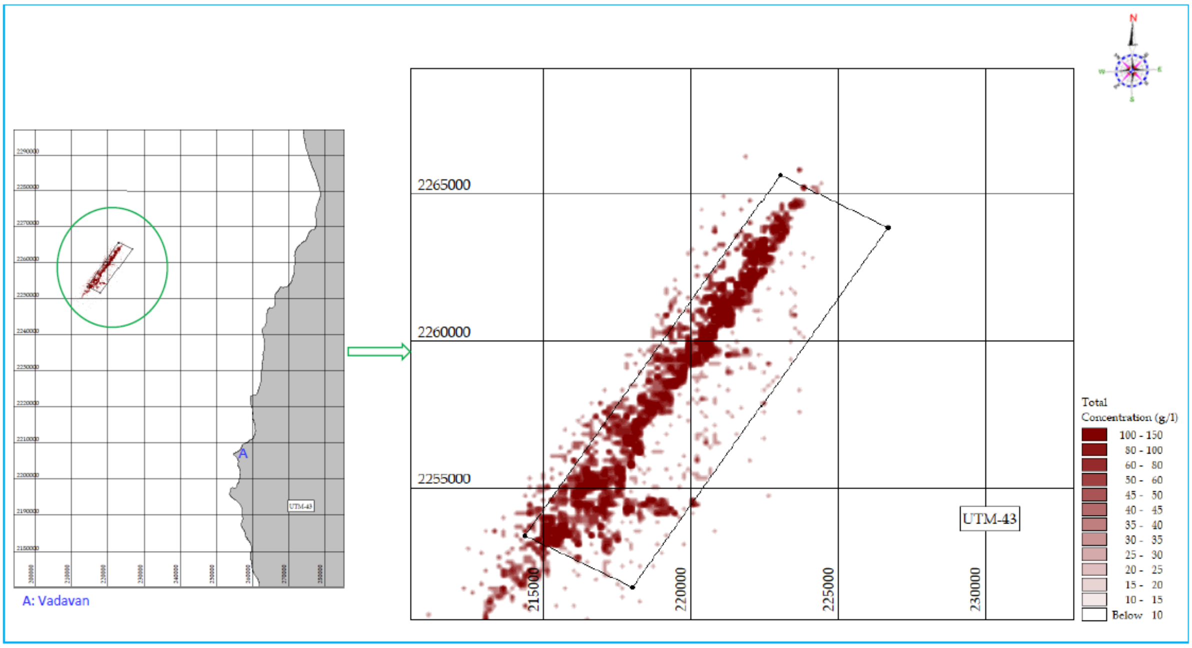


Fig. 5.4. Cumulative concentration of plume over the entire dredging ground – Case II (20 % Dispersion)

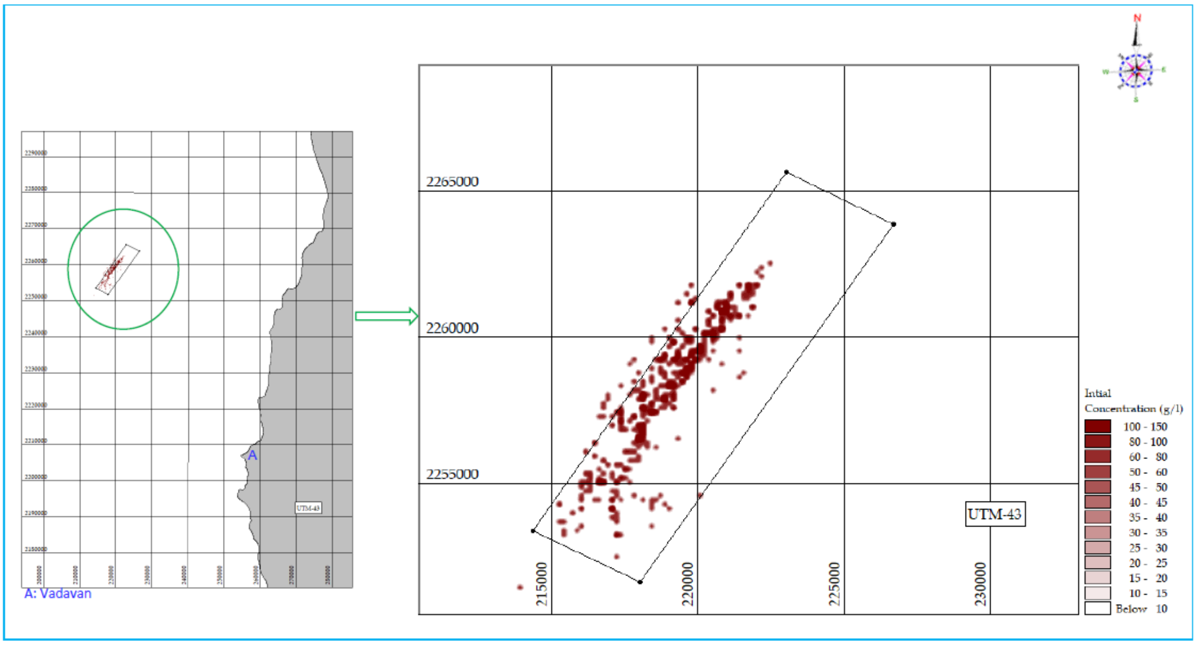


Fig. 5.5. Initial concentration of plume over the entire dredging ground – Case III (30 % Dispersion)

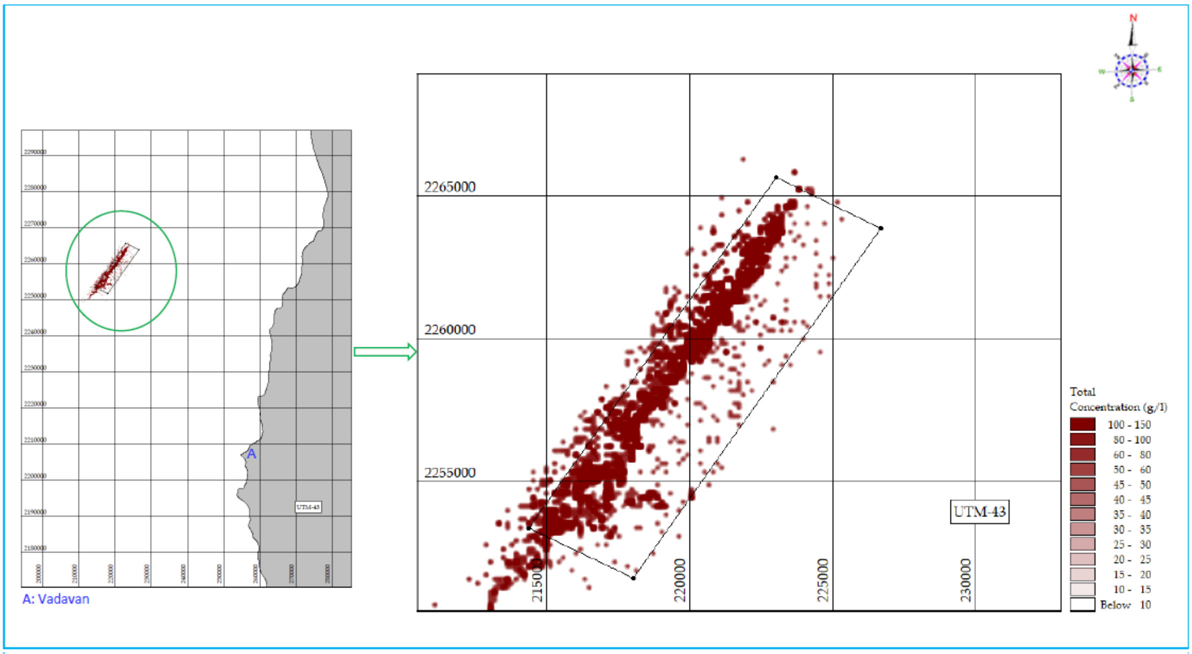


Fig. 5.6. Cumulative concentration of plume over the entire dredging ground – Case III (30 % Dispersion)

6.0 CONCLUSION AND RECOMMENDATION

Simulation study has been carried out to study the impact of sediment transport from the marine burro pit towards the coastal region of Vadhavan port. Following scenarios has been investigated.

(a) Sediment loss from the drag head of Trailing Suction Hopper dredger (TSHD)
(b) Overflow from Hopper

Sensitivity study has been carried out for 10%, 20% and 30% sediment loss.

As the marine burrow pit location far away from the coastal region approximately 50km to 60km with high tidal range and associated strong currents, the concentration of the sediment plume gets weakened immediately during the dredging activity.

The model simulation shows that the turbid plume does not reach the shore. Based on the above scenarios, it can be observed that, the plume trajectory of the dredged sediment does not move towards the coast, and they appear not to cause any impact on the shore and the marine environment.