Annexure II

CRZ notification 2011 para 4.2 requirement		
Sl. No.	**TOR**	**Reference**
1	Form-1 (Annexure-IV of the notification)	Form I attached.
2	Rapid EIA Report including marine and terrestrial component except for construction projects listed under 4(c) and (d)	EIA report prepared.
3	Comprehensive EIA with cumulative studies for projects in the stretches classified as low and medium eroding by MoEF based on scientific studies and in consultation with the State Governments and Union territory Administration;	Rapid EIA was done. Hence, it is not needed.
4	Disaster Management Report, Risk Assessment Report and Management Plan;	EIA report prepared and presented in Chapter 6, Section 6.1, Page 6.1.
5	CRZ map indicating HTL and LTL demarcated by one of the authorized agency (as indicated in para 2) in 1:4000 scale;	Extract copy of the CRZ map is shown in Fig. 1.2.
6	Project layout superimposed on the above map indicated at (V) above;	Extract copy of the CRZ map is shown in Fig. 1.2.
7	The CRZ map normally covering 7 km radius around the project site.	Extract copy of the CRZ map is shown in Fig. 1.2.
8	The CRZ map indicating the CRZ-I, II, III and IV areas including other notified ecologically sensitive areas;	Extract copy of the CRZ map is shown in Fig. 1.2.

Annexure - III

DREDGING IN THE HARBOUR BASIN AND NAVIGATIONAL CHANNEL PMC FOR PHASE I DEVELOPMENT OF PONDICHERRY PORT – NUMERICAL 2 DIMENSIONAL MODELLING

Document No: IC/18-19/OEC/PDY (PMC)/RSUN – 03

Client:

सत्यमेव जयते
Government of Puducherry

Port Department,

Government of Puducherry

Consultant:

Prof. R. Sundaravadivelu., FNAE

Institute Chair Professor,

Member BOG IIT Madras,

Department of Ocean Engineering,

IIT Madras, Chennai – 600 036.

CONTENTS

LIST OF FIGURES

LIST OF TABLES

1.0 INTRODUCTION

Port Department, Pondicherry has awarded PMC work to Prof. R. Sundaravadivelu F.N.A.E, Department of Ocean Engineering on dredging in the harbor basin and navigational channel as part of phase I development of Pondicherry Port under Sagarmala scheme. This report highlights the details of 2 dimensional tidal model studies.

2.0 SCOPE OF THE STUDY

The scope of the study includes,

- Tidal Propagation with existing scenario
- Tidal Propagation with dredging scenario

3.0 STUDY AREA

The Union Territory of Pondicherry comprises of four regions namely Pondicherry, Karaikal, Mahe and Yanam, which are not geographically contiguous. Pondicherry is located in the East Coast, about 162 km south of Chennai. This is the largest among the four regions and consists of 12 scattered areas interspersed with enclaves of Villupuram and Cuddalore Districts of Tamil Nadu.

Pondicherry region is situated on the Coromandel Coast between 11°45" and 12°03" N latitudes and 79°37" and 79°53" E longitudes with an area of 293 km^2. Ariyankuppam River is a distributary of Sankaraparani River. It branches off Sankaraparani near Thirukanchi Ariyankuppam River and drains into Bay of Bengal at Puducherry Fishing Harbour. The existing port of Pondicherry (11° 56"N latitude and 79° 50" E longitude) is suitable for lighterage operations during fair weather months (February to September). The coast is of open type with estuaries. Though the regional coastline appears to be almost straight, it is a part of a larger concave coast. The current port was built south of the New Pier in the late 1980’ s. The shoreline is tilted approximately 20^0 from the North. The study area is shown in Fig. 3.1.

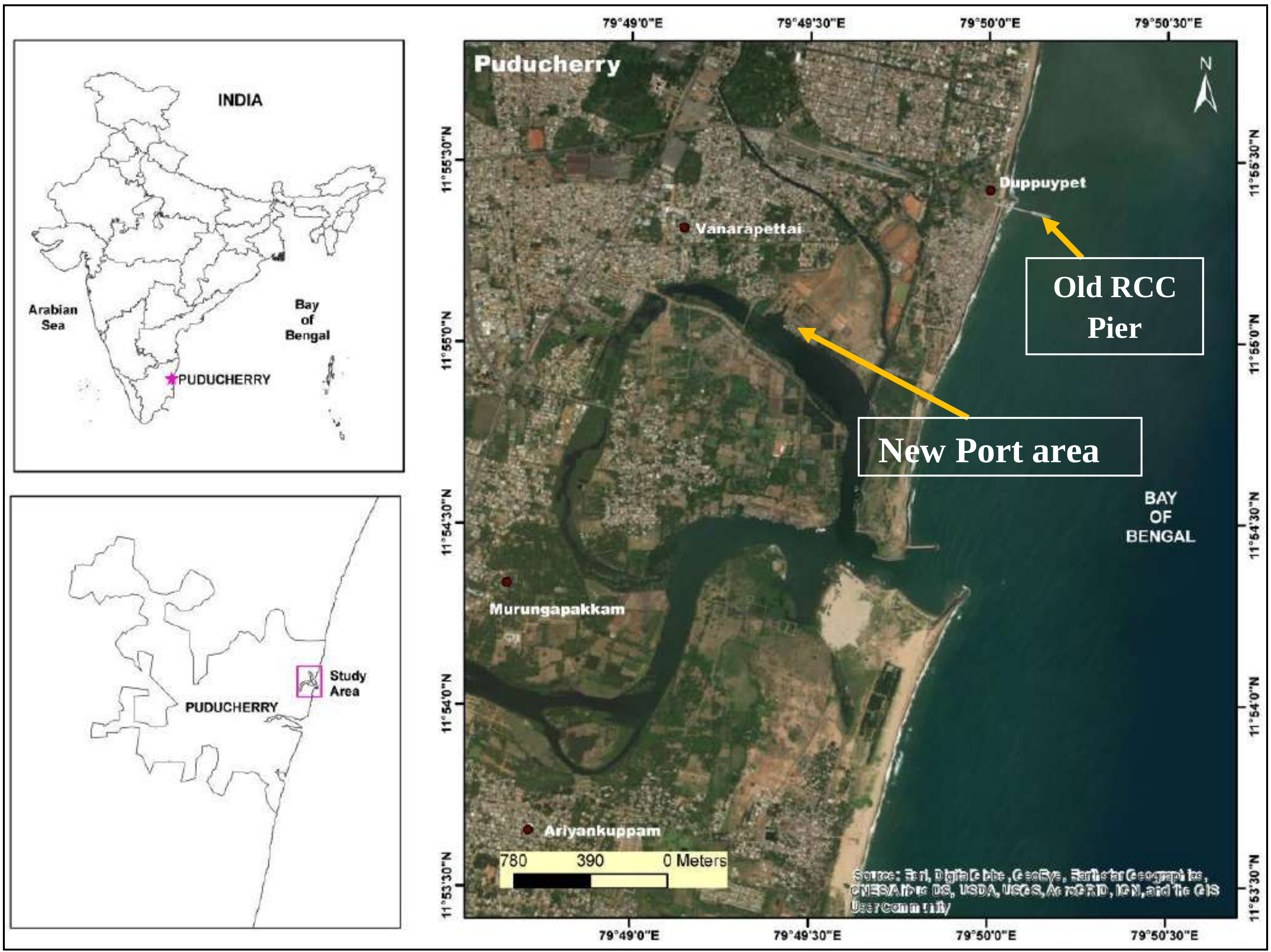


Figure 3-1: Study area

4.0 MODELLING OF TIDES (2D computations)

4.1 Scientific background

The MIKE21 Flow model FM-HD module simulates water level variations and flows in response to a variety of forcing functions in lakes, estuaries and in coastal regions. It simulates unsteady two dimensional flows in one layer (vertically homogeneous) fluids and has been applied in a large number of studies (DHI 2007b).

The Hydrodynamic module is based on the numerical solution of two dimensional shallow water equations i.e. the depth integrated incompressible Reynolds averaged Navier-Stokes equations. Thus the model consists of continuity, momentum, temperature, salinity and density equations. The local continuity equation integrated over a depth (2D) can be written as:

$$\frac{\partial z}{\partial t} + \frac{\partial uh}{\partial x} + \frac{\partial vh}{\partial y} = 0$$

The depth averaged horizontal momentum equations for x and y directions are, respectively,

$$\frac{\partial u}{\partial t} + u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y} + g\frac{\partial z}{\partial x} - C_{fv} + \tau_{bx} - E_C\nabla^2 u = 0.$$

$$\frac{\partial v}{\partial t} + u\frac{\partial v}{\partial x} + v\frac{\partial v}{\partial y} + g\frac{\partial z}{\partial y} - C_{fu} + \tau_{by} - E_C\nabla^2 u = 0.$$

Where

z - Water surface elevation above the datum

u - X-component of velocity

v - Y-component of velocity

d - Depth of flow below datum

h – Total depth of flow (d+z)

C_f - Coriolis force

τ_b – Bed shear stress

E_C – Eddy viscosity coefficient

The Hydrodynamic model was developed using a flexible mesh structure generally consistent with the major tidal flow. The model was driven using tides as boundary condition. A low order, fast algorithm solution technique was applied with a CFL number of 0.8. The minimum and maximum time step was given as 0.01s and 3600s respectively. Eddy viscosity was applied using Smagorinsky formulation with the default constant coefficient of 0.28. The North and south boundaries were given the time series of predicted water level data based on the tidal constituent.

The bathymetry and topography from field survey data was applied to the study area covering Puducherry Port. For the larger domain in the mesh, a resolution of 1.5 km was used (Figure 4.1) progressively reducing to 200m and for the coastline of interest. The total number of elements used in the mesh is 10400 with 5600 nodes. The Courant–Friedrichs–Lewy (CFL) number was chosen as 0.8 for stability as recommended.

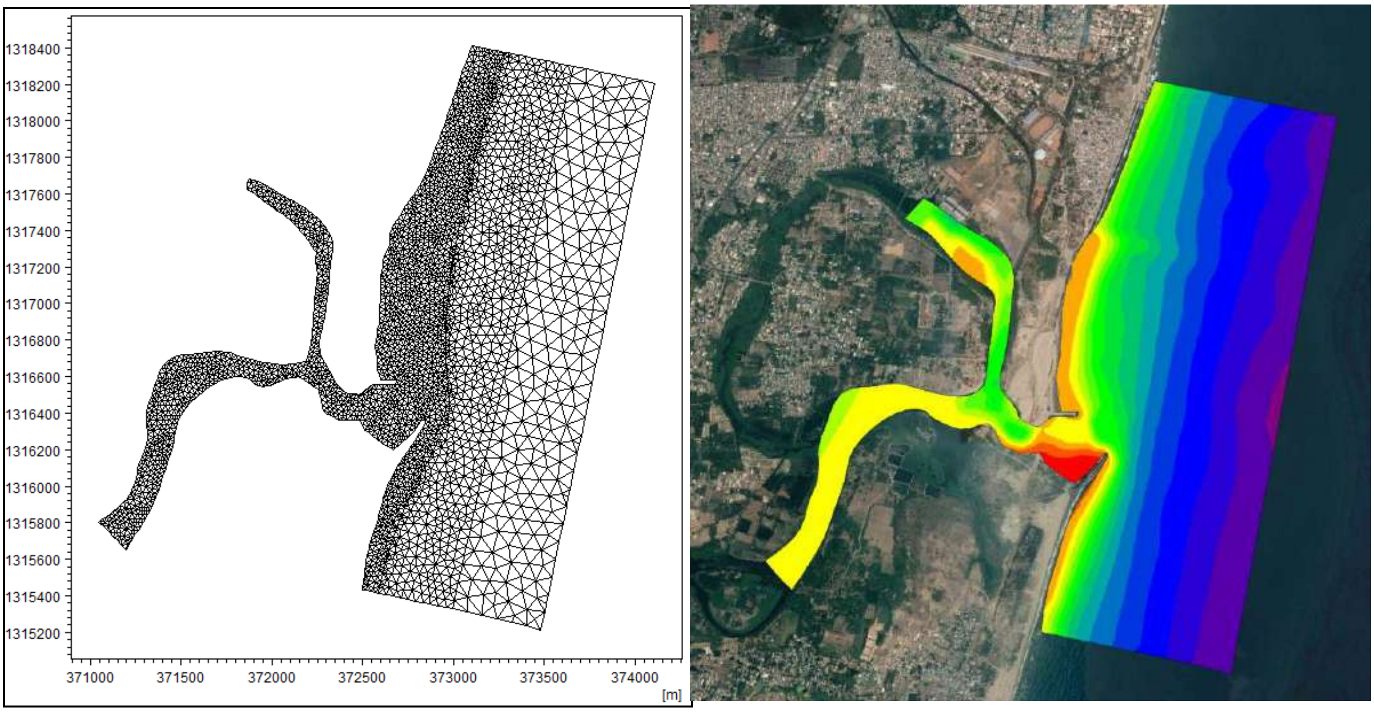


Figure 4-1: Bathymetry for Present Port

4.2 Analysis of Water level - Present scenario

Tides in Puducherry are semidiurnal in nature as the sea level reaches its highest level in November and lowest in March along the south east coast of India, the tidal range in varied between 0.5 m (neap tides) and 0.7 m (spring tides) .The observed tide at any given port is the result of many factors, including the response of the ocean basin to the tide producing forces, to the modifications of the tide due to shallow water effects of local embayment and rivers, to the regional and local effects of weather on water levels. The time series for variation in water level for present condition is shown in Fig. 4.2.

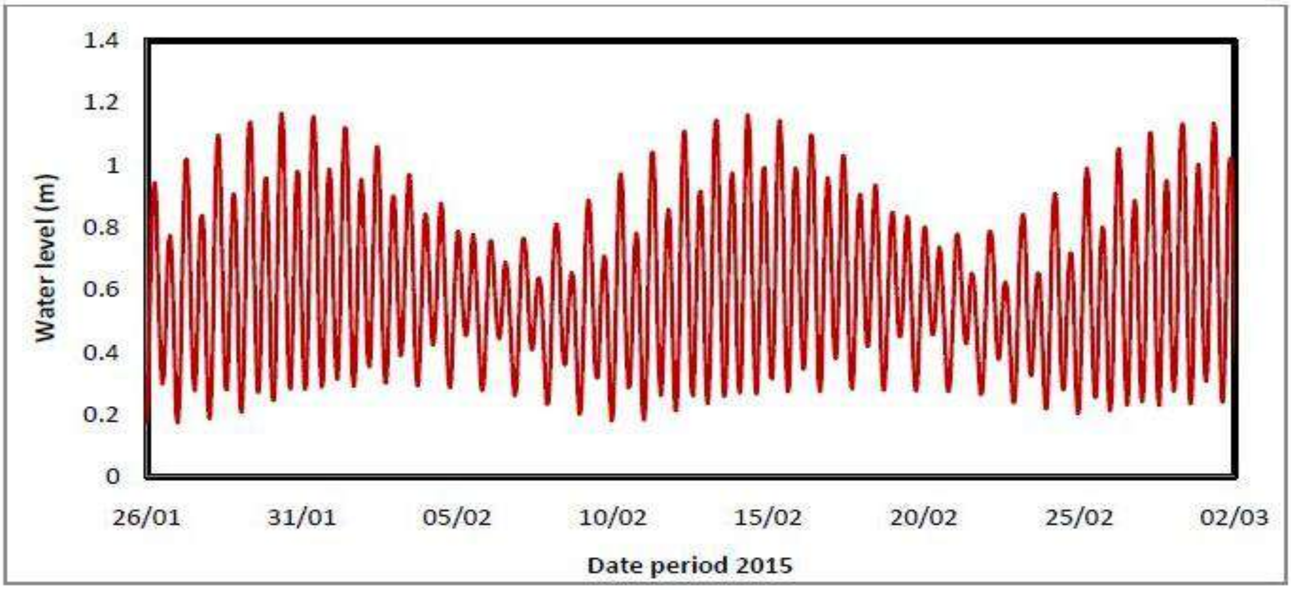


Figure 4-2: Time series of Water level Variation before dredging

The design water levels for Puducherry are given below,

Mean High Water Spring : 1.3 m

Mean High Water Neap : 0.8m

Mean Sea Level : 0.6 m

Mean Low Water Neap : 0.5 m

Mean Low Water Spring : 0.2 m

Tidal harmonic analysis of the tide gauges data is carried out using Mike 21 package (Danish Hydraulic Institute). The tides along the coast of Puducherry are semi-diurnal with form number 0.22. Form number is defined as the ratio of the sums of the amplitudes of the constituents of (K1 and O1) to that of the constituents (M2 and S2).The frequencies and amplitudes of tidal constituents are given vide table 4.1.

Table 4.1: Frequencies and amplitudes of tidal constituents

Type	Tidal Constituents	Tidal Amplitude(m)	Phase(degrees)
Diurnal	O1	0.0267	336.92
	P1	0.0302	336.73
	K1	0.0913	330.28
Semidiurnal	M2	0.3098	223.84
	S2	0.1558	278.62
	K2	0.0424	301.02
Quarter diurnal	M4	0.0027	122.97
	MS4	0.0043	280.90
	S4	0.0035	82.25

4.3 Numerical Modeling - Dredging Scenario

It is proposed to develop the present port area in Pondicherry adjacent to Ariyankuppam drain, which include construction of additional berth and dredging.

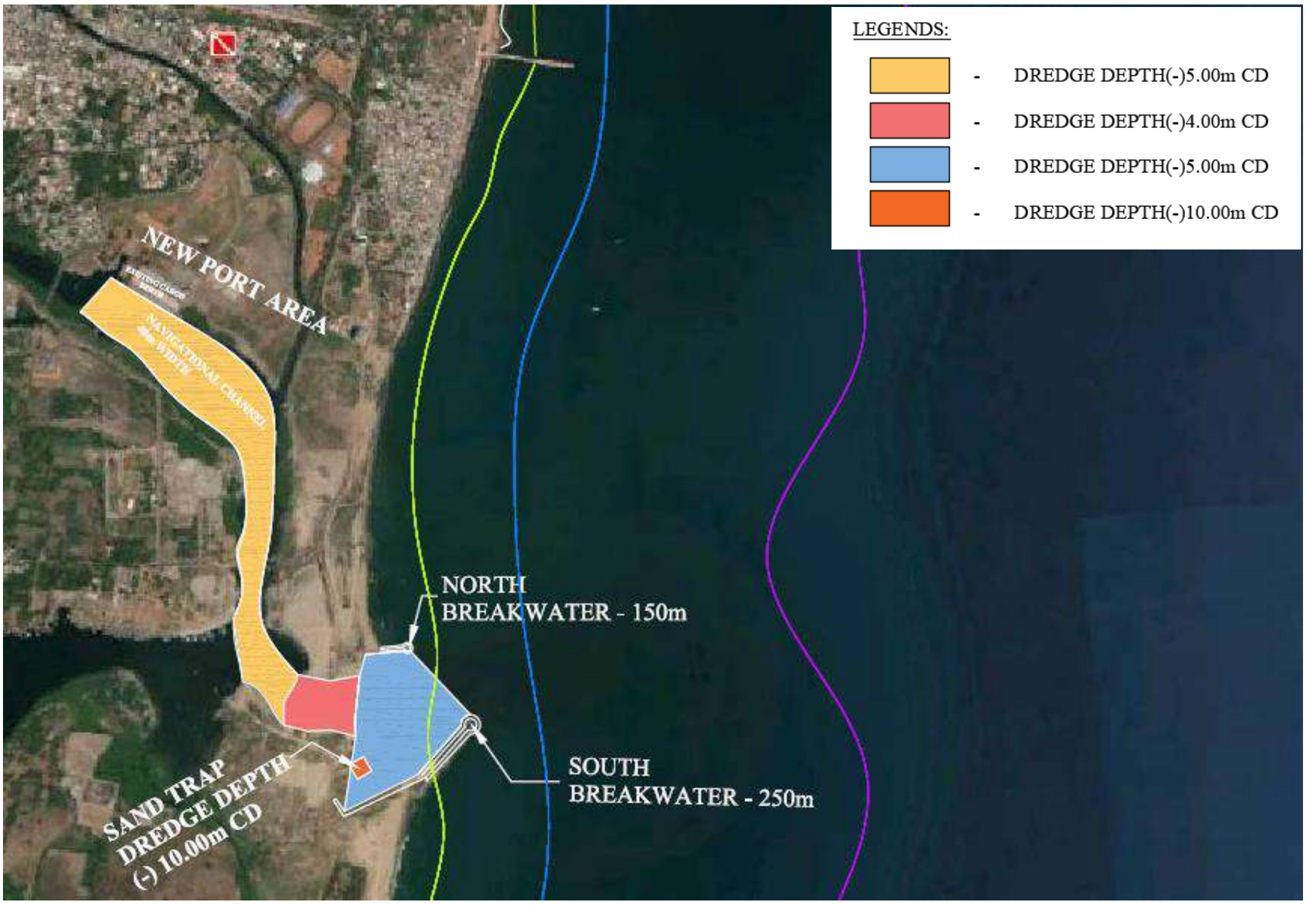


Figure 4-3: Proposed dredging layout

Hydrodynamics with the proposed dredging were simulated by incorporating the defined dredging port layout as described in Figure 4.3 into the model bathymetry and simulating the hydrodynamic model keeping all other parameters unchanged from the baseline condition simulation. The bathymetry prepared considering the dredging plan for Numerical modelling is shown in Figure 4.4.

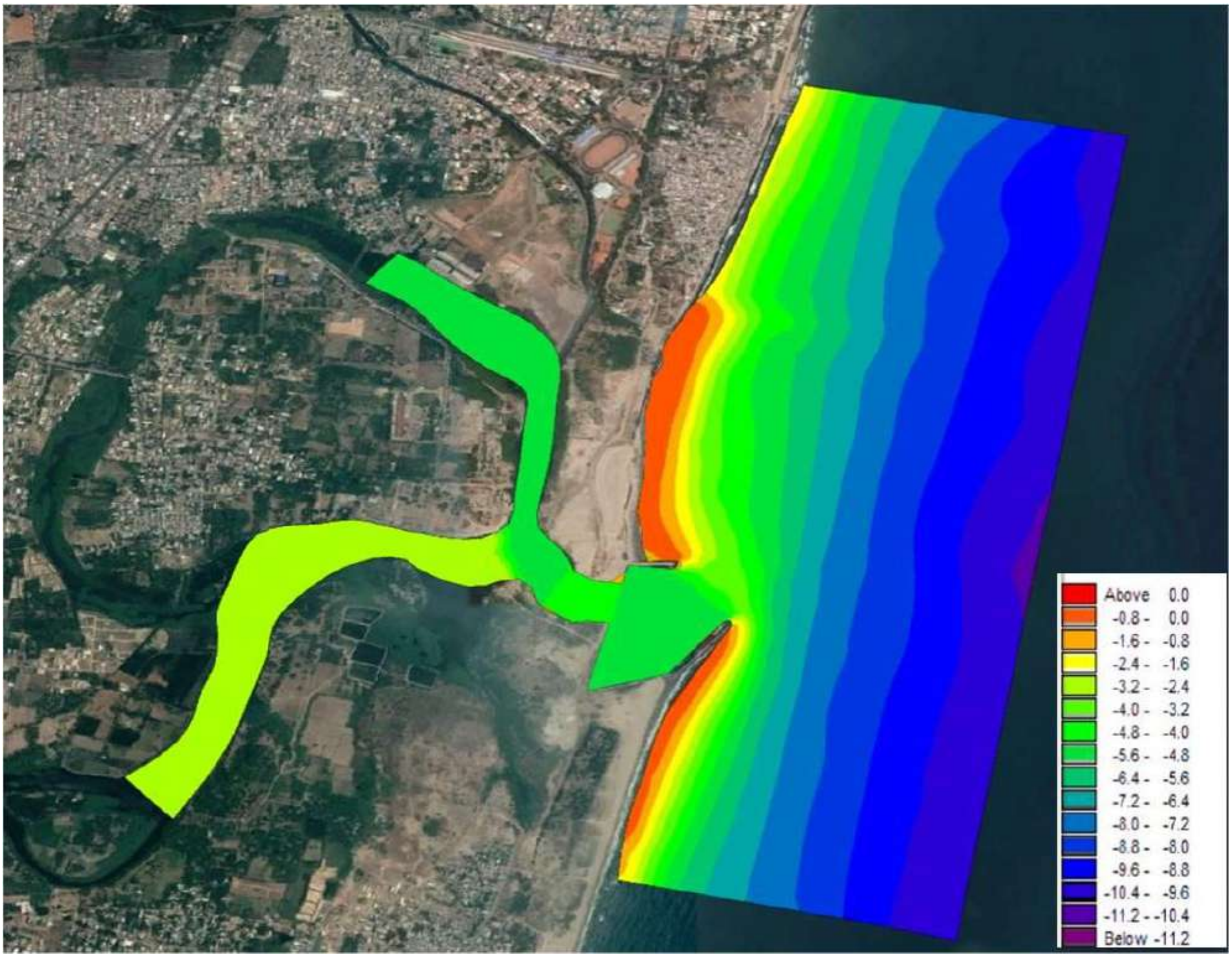


Figure 4-4: Model Bathymetry incorporating the dredging layout

4.3.1 Analysis - Existing and Dredging Scenario

Water level variation at various locations inside the creek is compared to understand the tidal propagation with the influence of dredging. The analysis highlights that high water levels are unchanged, spring tide low water levels are slightly reduced, and by up to 11mm. Therefore, the spring tidal range inside Ariyankuppam Port would be increased by up to 11mm as a result of the channel deepening. With dredging the tidal amplitudes does not vary significantly whereas the total depth variations changes due to channel deepening.

The quantity of the discharge into the Port for the spring and neap periods of flood and ebb tides were estimated at various locations as shown in Figure 4.5.It is clearly evident that more water is drawn into the Port as a result of dredging and the sections conveys increased discharge compared to existing scenario as shown in Figure 4.6.

The tidal prism inside the Port is estimated for existing and dredging scenario in spring and flood condition and is given in Table 4.2. Within Port the effect of the dredging appears to draw more flow and the flushing of water inside the Port is increased during both spring and flood condition.

Table 4.2: Estimated Tidal Prism at Various sections in Existing and predicted scenario

Location	Discharge($\times 10^5$) m^3			
	Existing Scenario		Dredging Scenario	
	Spring	Neap	Spring	Neap
1	5.908	2.239	6.644	2.534
2	3.588	1.355	5.469	2.093
3	0.919	0.660	1.744	0.669
4	0.906	0.350	0.923	0.354
5	2.836	1.082	2.878	1.103

This increase in tidal volume exchange explains the slight increase in the flood and ebb tide current inside the Port entrance as shown in Figures 4.7 and 4.8.

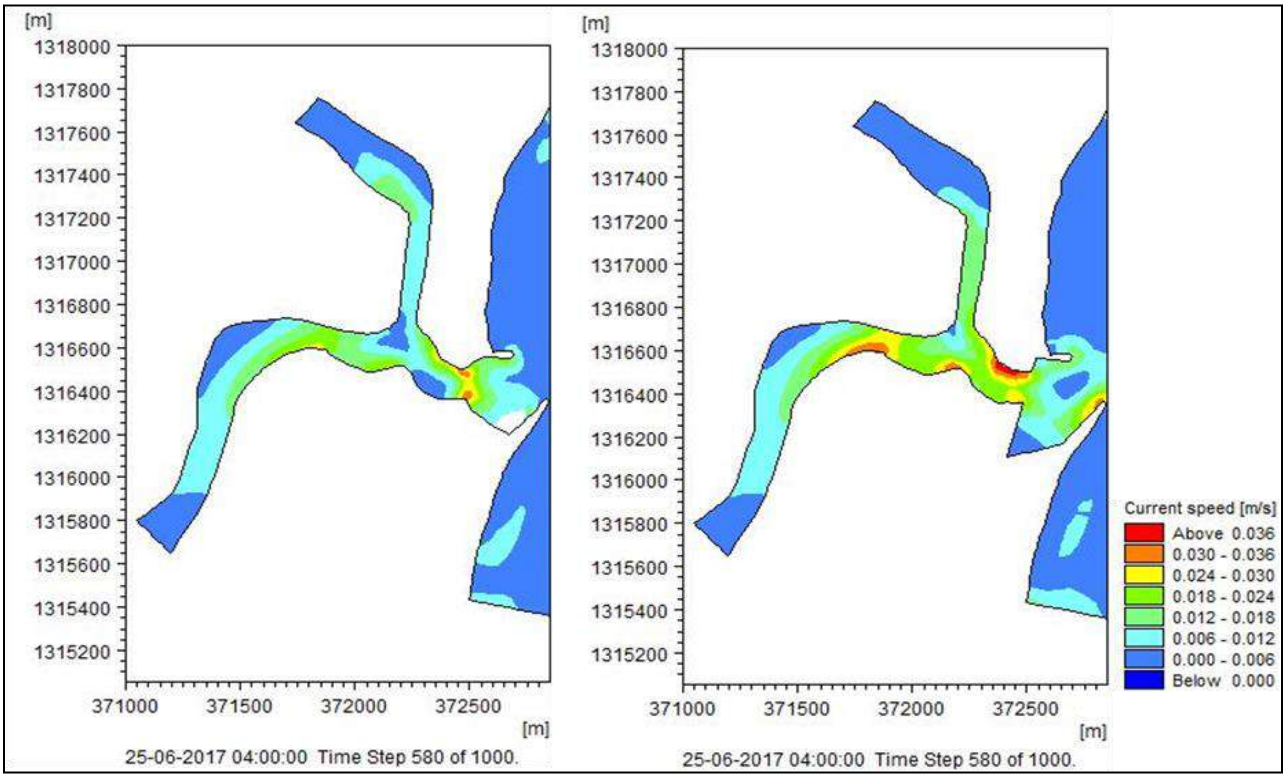


Figure 4-5: Spring tide peak flood current speed - Existing and Dredging scenario

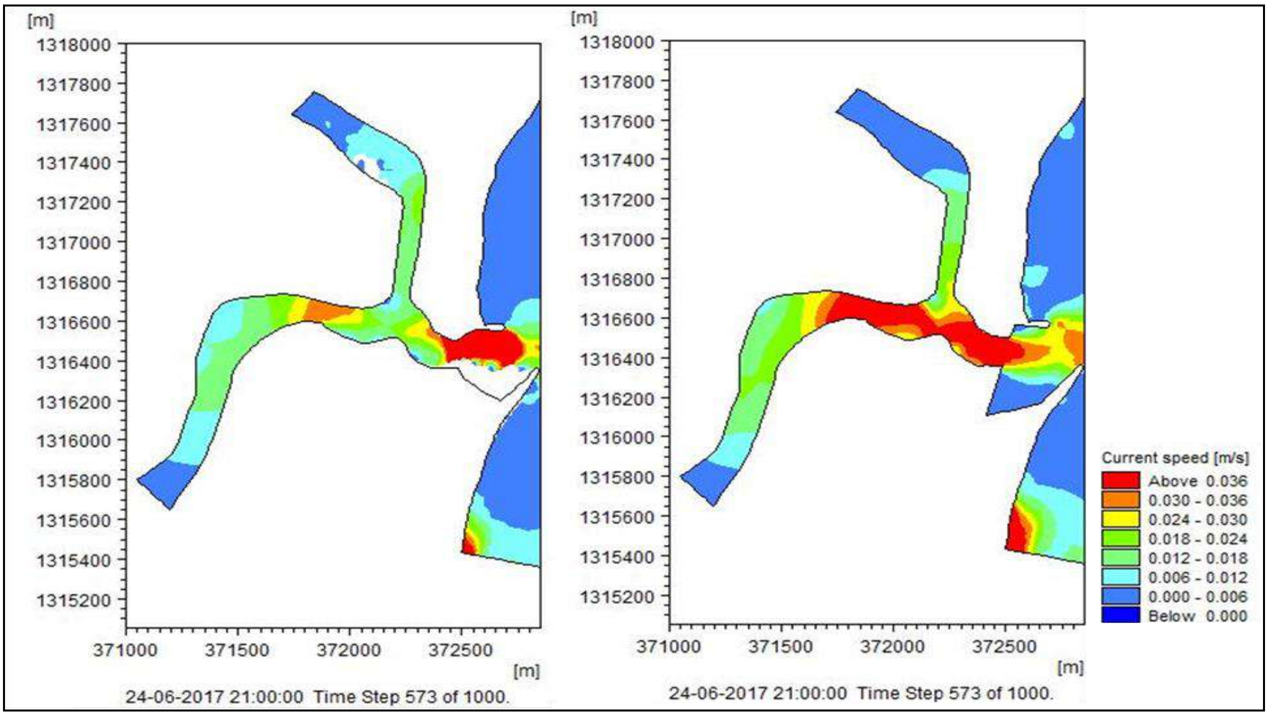


Figure 4-6: Spring tide peak ebb current speed - Existing and Dredging scenario

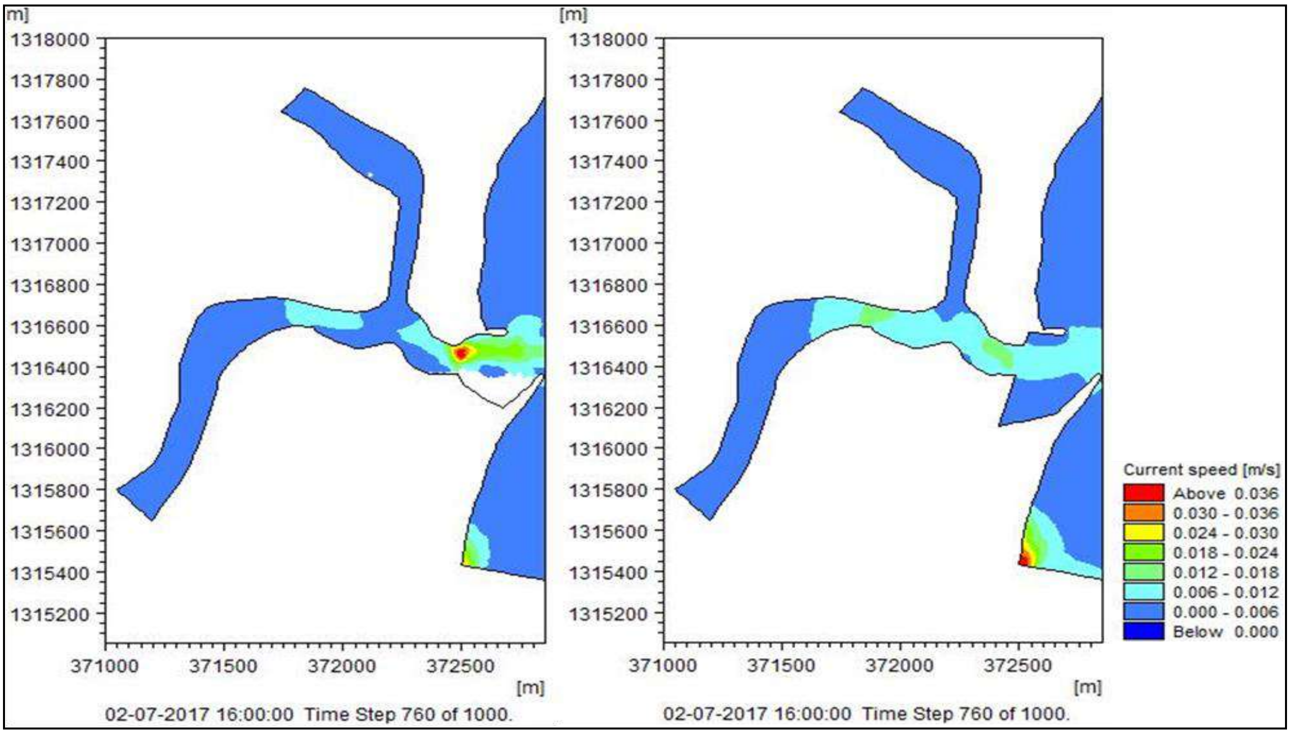


Figure 4-7: Neap tide peak flood current speed - Existing and Dredging scenario

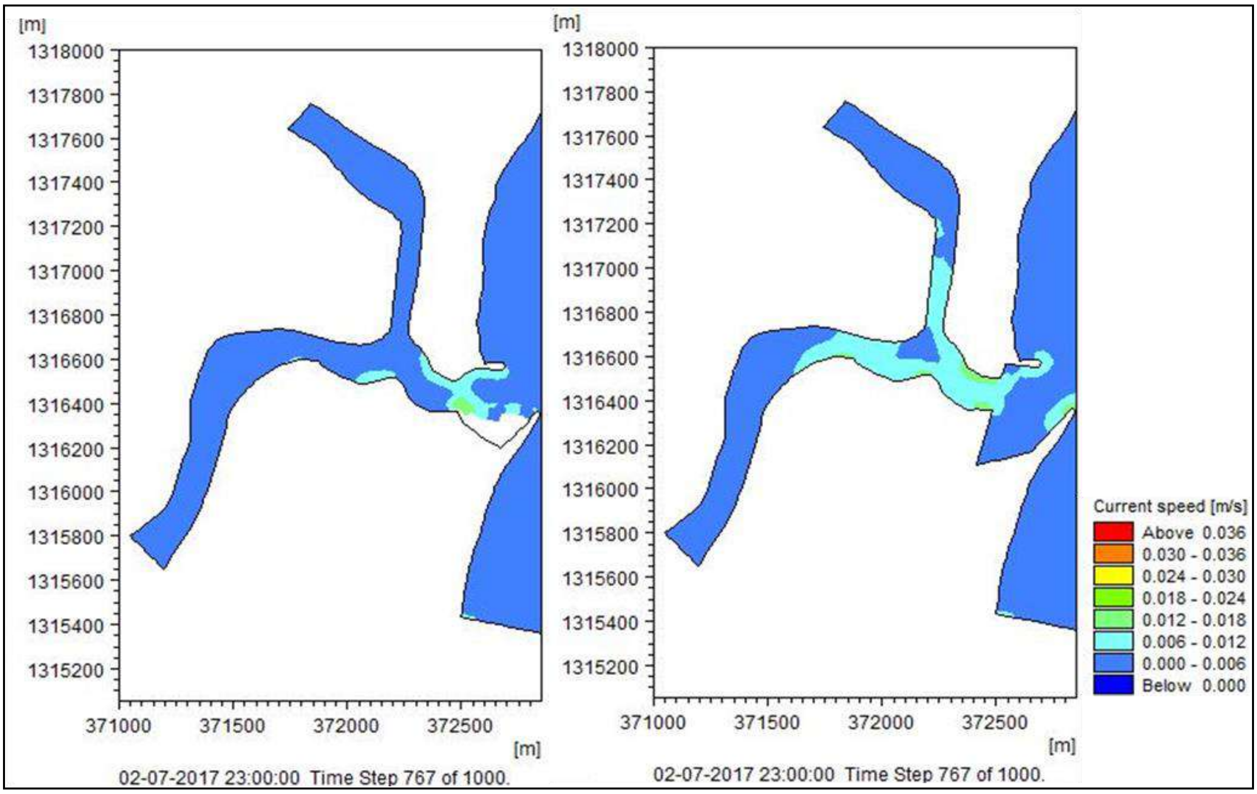


Figure 4-8: Neap tide peak ebb current speed - Existing and Dredging scenario

5.0 CONCLUSIONS

The 2 dimensional representations of results plan area of study reach is given. . The results indicate that dredging inside the Port and increase in water spread area inside the Port results in the change in current speed with an increase of up to 0.6cm/s during flood tide and 1.2cm/s during ebb tide inside the Ariyankuppam River.

Annexure - IV

DREDGING IN THE HARBOUR BASIN AND NAVIGATIONAL CHANNEL PMC FOR PHASE I DEVELOPMENT OF PONDICHERRY PORT – SHIP NAVIGATIONAL STUDY.

Document No: IC/18-19/OEC/PDY(PMC)/RSUN – 07

Client:

Port Department,

Government of Puducherry

सत्यमेव जयते

Government of Puducherry

Consultant:

Prof. R. Sundaravadivelu., FNAE

Institute Chair Professor,

Member BOG IIT Madras,

Department of Ocean Engineering,

IIT Madras, Chennai – 600 036.

CONTENTS

LIST OF FIGURES

LIST OF TABLE

1.0 INTRODUCTION

The Minor port of Pondicherry is located in the east coast of India between two major ports of India namely Chennai and Tuticorin. Pondicherry port has been a trading port since 100 B.C and prominent during Chola period trading with the Chinese and was an open roadstead anchorage port situated about 150 kms south of Chennai since French rule from 17th century till the late 1980s when the new port was constructed between 1986-1989 with North and South breakwater, 40 m wide channel, 2000m long channel, almost 150 acres land area and having 150m long cargo berth. The new development consists of offshore (south) break water connected by a trestle and north break water. A sand trap with submarine tunnel between south and north break water is also built as per the recommendation of Central Water and Power Research Station (CWPRS), Pune during the Development of the Port. Subsequently a general cargo berth was built. This study involves understanding the navigational aspects of the barge vessel movement inside the harbour area under the thresholds of prevailing environmental conditions.

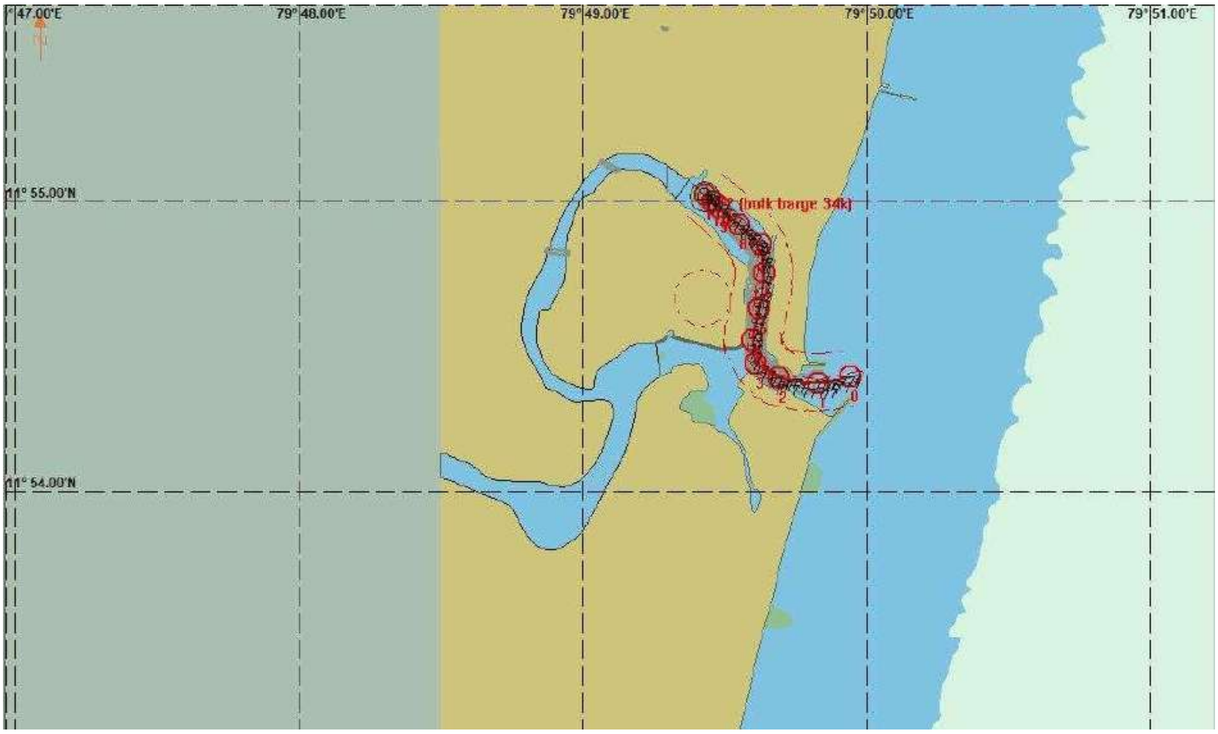


Fig 1-1: A typical set up of the simulation study conducted in ARI bridge simulator

2.0 NAVIGATION SIMULATION STUDIES

The results on the study in connection with the manoeuvrability are presented in this report.

a) Navigation study is conducted as per the wave, wind and current conditions of the area.

2.1 Simulation software and study details

In this project, all the simulations have been performed using ARI Bridge simulator. A digitized map of the Pondicherry port with all the navigational depths incorporated has been used for the simulations. The model set up created using the software is shown in Fig.1.1

2.2 Details of the design vessel used for the study

1. LoA – 70 m
2. Beam width – 14.00 m
3. Draft – 3.5 m
4. Max speed of the vessel considered – 11 knots

2.3 Model Inputs and environmental scenario

The bridge simulator is capable of handling several environmental inputs and has wide range of library files related to ship design, port layout and water dynamics. Some of the model capabilities in terms of inputs are listed below.

1. Waves – wind waves and swell waves (height and direction)
2. Wind – breeze, gale, storm etc. (speed and direction).
3. Currents – tidal currents and combination of currents and waves (speed and direction).
4. Other inputs – rain, radius of wind influence, navigational depths, tracks etc.

2.4 Placement and operating of ships

A ship model can be selected either:

i. From the Model list of predefined ship models, or

ii. By providing a ship model data file that you create.

Provisions are available for creating a ship with its hydrodynamic properties. The user can select from one of three types of modes to launch a ship:

i. User Controlled

ii. Standard Manoeuvre

iii. Autopilot Itinerary

2.5 Simulation scenarios

The simulations are conducted for highly prevailing condition for the East Coast of India. The several cases of wave height and wave direction are considered and the current is considered to be tidal currents in both flooding and ebbing condition for the respective test cases. Table1.1 below summarizes simulation scenarios that are considered. The considered condition is expected to prevail in the study region, special zones of tranquil conditions are created around which the navigational study is executed. Fig 2.1 and 2.2 shows the navigational channel and three different zones considered for the study respectively. The input dialogues considered for the all test conditions are shown in Fig.2.3-3.3.

***Table** 2-**1:**Test Conditions*

Sl. No	Wave height (m)	Wave Direction	Wind speed (knots)	Direction	Tide				Current (m/s)
					LL	LH	HL	HH	
Zone1	0.3	92	10, 15, 20	62(NE)	0.5	1.1	0.7	1.3	0.5
Zone2	-	-	10, 15, 20	58(NE)	0.5	1	0.7	1.2	0.4

Zone3	-	-	10, 15, 20	64(NE)	0.5	1	0.7	1.3	0.3
Zone1	0.3	268	10, 15, 20	214(SW)	0.5	1.1	0.7	1.3	0.5
Zone2	-	-	10, 15, 20	208(SW)	0.5	1	0.7	1.2	0.4
Zone3	-	-	10, 15, 20	216(SW)	0.5	1	0.7	1.3	0.3

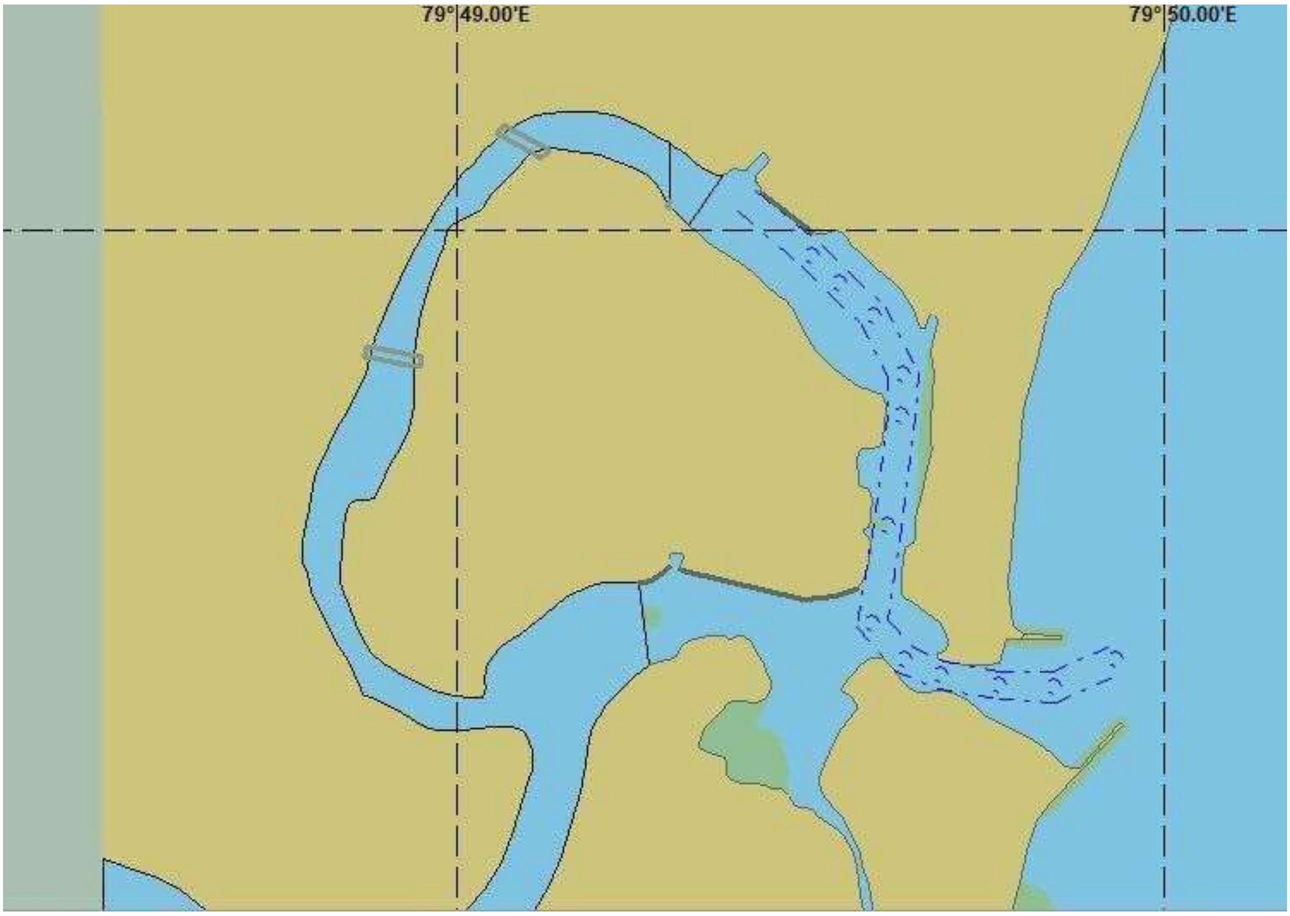


Fig 2-1: Navigational Channel inside the port

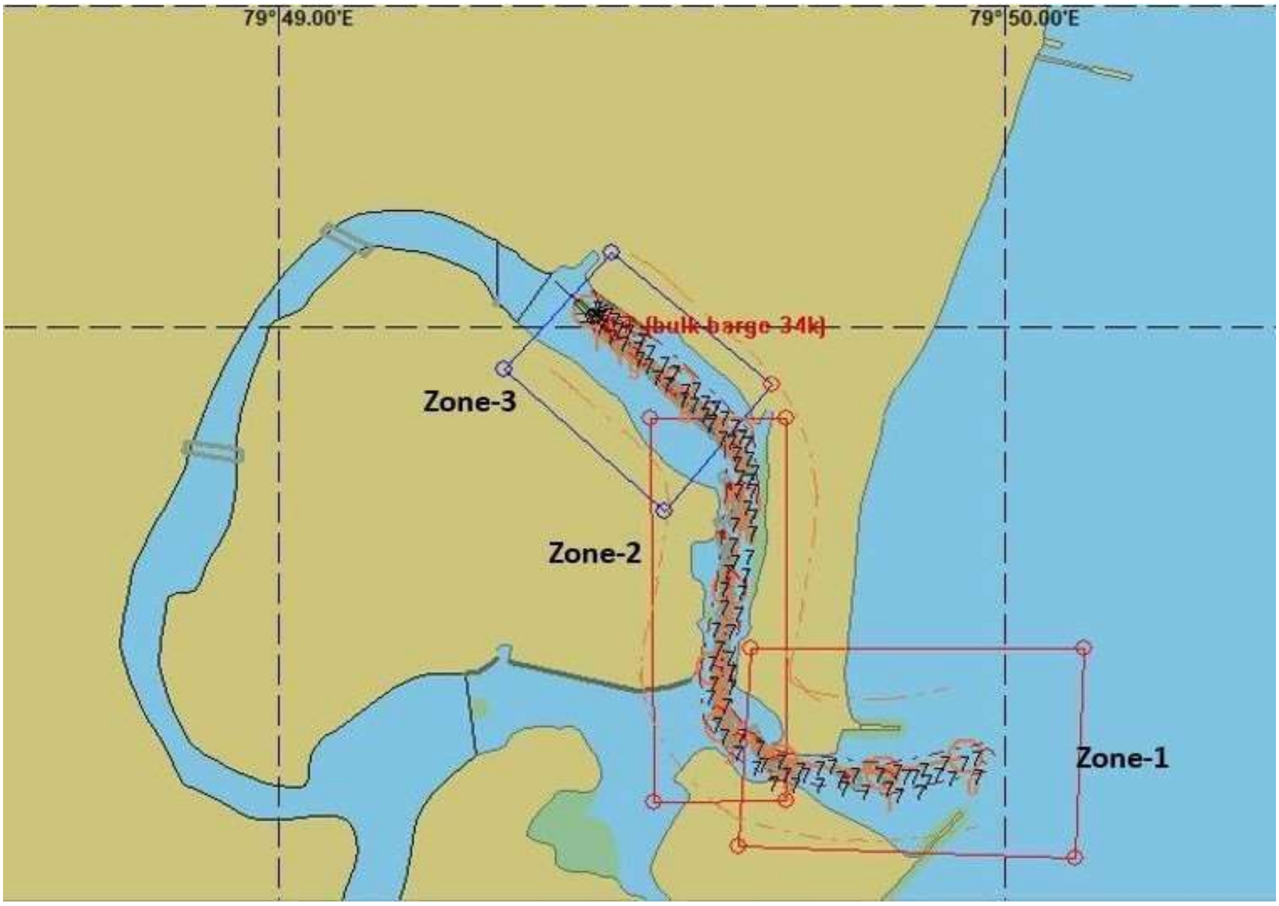


Fig 2-2: Three different zones considered for the study

Fig 2-3: Typical input parameters for Zone-1

Client	Port Department, Pondicherry Port	**Date**	**06.06.2019**	
Project	Dredging in the harbour basin and navigational channel PMC for Phase I Development of Pondicherry Port	**Sheet No.**	9	
Subject	Ship Navigational Study	**By**	IITM	

Fig 2-4: Typical input parameters for Zone-2

Fig 2-5: Typical input parameters for Zone-3

3.0 RESULTS AND DISCUSSIONS

During the above cases, the speed of the vessel is maintained at 2-3 knots while in the main route considered and the approaching area respectively. The speed while manoeuvring near the berthing jetty is maintained at 0.3-0.5 knots. Clear tracks were implemented for the vessel to sail.

The entire study region is classified into three different zones based on the wind blowing conditions & directions and the details are mentioned in Fig.2.2. Zone-1 is located at the entrance of the harboured area and the remaining zones are created inside the tranquility area. The environmental details of the zones are shown in Fig 2.3-2.5. The tide settings and environmental set up used for the study is shown in Fig 3.1 and 3.2. The above all mentioned inputs are based on measured data for waves, currents and tide. The vessel was able to navigate through the path near from shore to inside the north break water berthing area with some difficulty. The test navigation involved regular changes in heading position to keep the vessel in navigation path. It was observed that there were difficulties during manoeuvring and near the bends. In order to sail the vessel without much difficulty inside the harbour the channel width of 40 m, is found to be choking. The pilots have to manoeuvre with difficulty during the entire navigational study, due to the narrowness of the channel and the unavailability of sufficient depths on either side of the channel, in case of any overshooting or lateral movement of the barge due to cross currents. The tracks traced by the barge vessel while manoeuvring towards the berthing jetty are shown in Fig 3.3 and 3.4. At less speed of range 3-4 knots the barge is able to sail normally but with caution at the bends.

With higher wind speeds at 15-20 knots strong drifting of vessel is observed. Very low speed will contribute to the drifting of the barge, due to its relatively smaller dimensions. Hence the maintenance of manageable speed i.e., 3-4 knots is required. It is not advisable to manoeuvre, at wind speed greater than 20 knots.

Client	Port Department, Pondicherry Port	Date	06.06.2019
Project	Dredging in the harbour basin and navigational channel PMC for Phase I Development of Pondicherry Port	Sheet No.	11
Subject	Ship Navigational Study	By	IITM

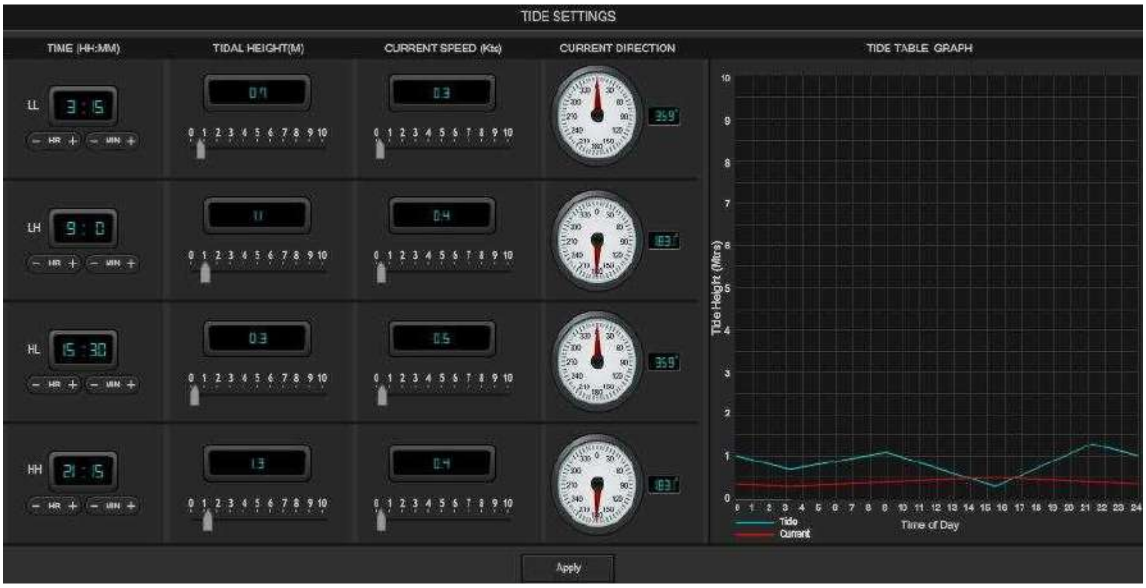


Fig 3-1: Typical tide setting considered for the study

Fig 3-2: Environmental set up for the navigation study

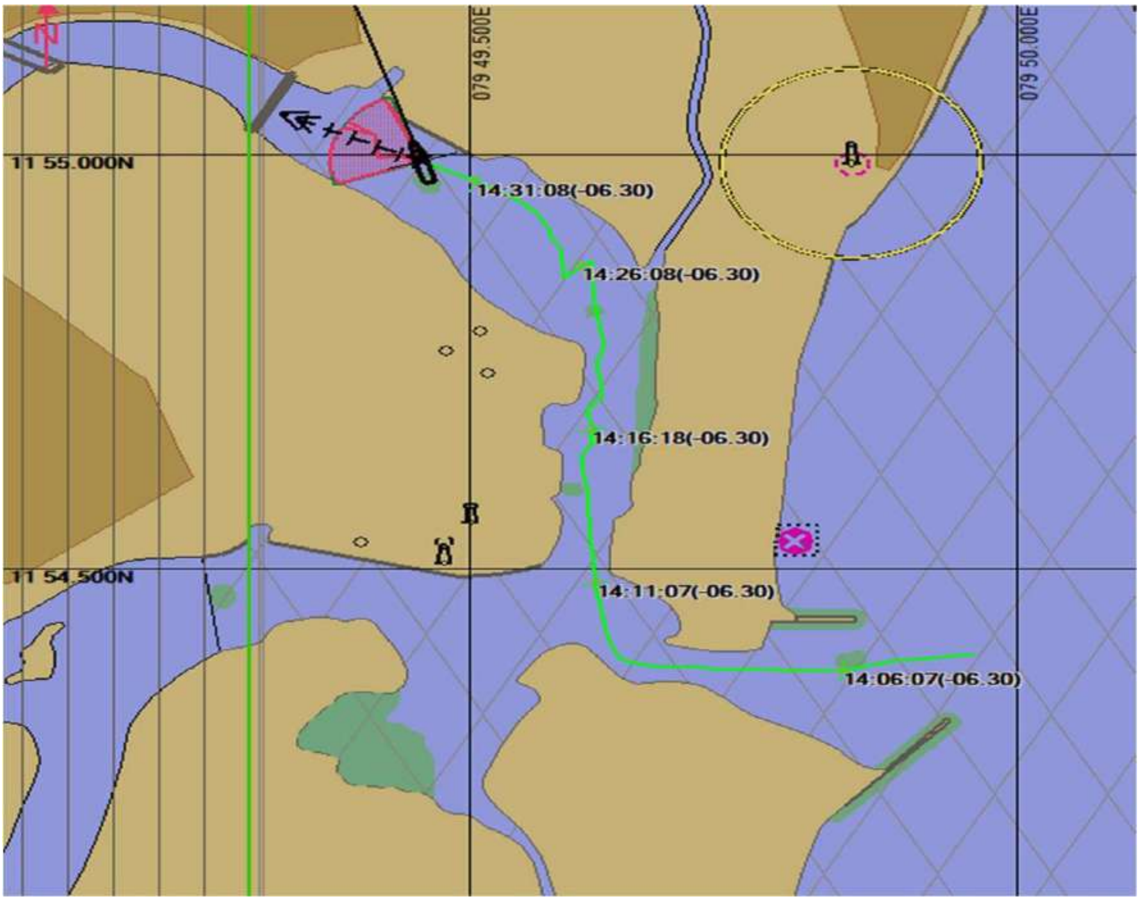


Fig 3-3: Tracks traced by the barge vessel while maneuvering towards the berthing jetty

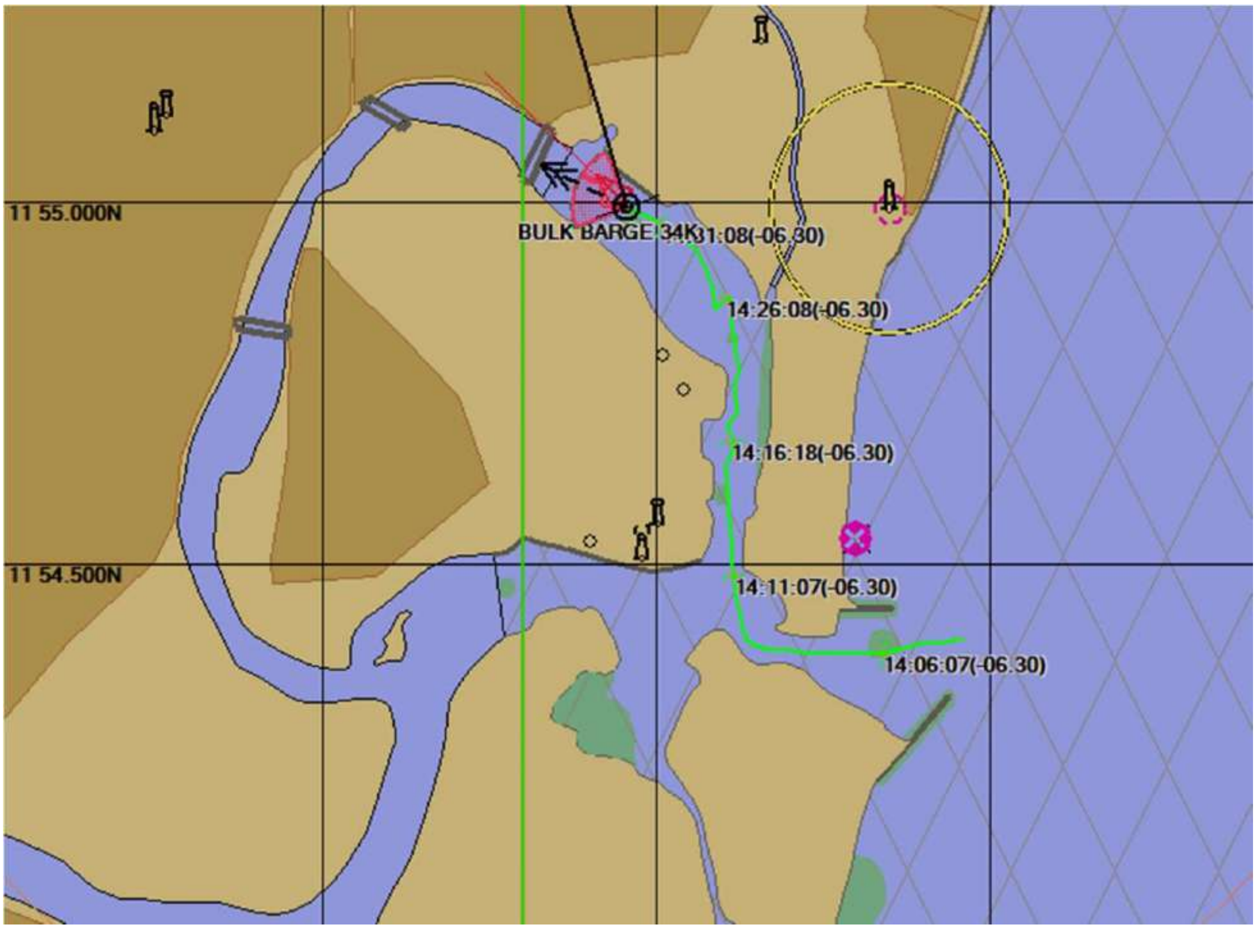


Fig 3-4: Tracks traced by the barge vessel while maneuvering towards the berthing jetty

4.0 SUMMARY

Due to the sheltered region, the location is protected from storm waves. The navigational simulation study for manoeuvring of the design barge vessel depicts that due to cross current that tend to be experienced during the vessel turning along the bends in the channel, the vessel may encounter drifting. However the simulation shows this is a manageable situation by trained captains, with very low navigational speed of 3-4 knots. During wind conditions with wind speed greater than 20 knots, it is no advisable to manoeuvre, as per the navigation study.

No. 1618 /PW/PHD/DB-DRI/F No. Genl. /2019-20
GOVERNMENT OF PUDUCHERRY
PUBLIC HEALTH DIVISION
P.W.D., PUDUCHERRY

OFFICE OF THE EXECUTIVE ENGINEER
PORT DEPT PUDUCHERRY
Receipt No. 786
Received on 4-6-19
Despatched on:

Puducherry, the 4/6/19

To

The Executive Engineer,
Port Department
Puducherry

Sir,

Sub: PW – PHD – Development of Puducherry Port under Sagarmala – Discharging of Waste Water into Public Sewerage – NOC – Issued – Reg.

Ref: No.3256/ EE/Port/Sagarmala/EIA/2019-20/166, dt. 10-05-2019

With reference to the above, it is hereby informed that, as the existing Public Health Sewerage system is available at the Ambedkar salai, Uppalam, NOC is hereby accorded to discharge the anticipated waste water generated to the extent of 5 KLD into the nearby available sewer appurtenances by the Executive Engineer, Port Department, Puducherry.

Yours faithfully,

(R. RAVICHANDRAN)
EXECUTIVE ENGINEER
PUBLIC HEALTH DIVISION
P.W.D., PUDUCHERRY

Copy to:
1. The Assistant Engineer, Dr.I sub division, PHD, PWD, Puducherry
2. S.F/O.C

ANNEXURE VI

OFFICE OF THE EXECUTIVE ENGINEER
PUBLIC HEALTH DIVISION
PWD. PUDUCHERRY
-oOo-

No. 1340 /PW/PHD/EE /F.No. /2019-20 Puducherry, the 23/5/19

OFFICE OF THE EXECUTIVE ENGINEER
PORT DEPT PUDUCHERRY
Receipt No 737
Received on 23/5/19
Despatched on

To

The Executive Engineer,
Port Department,
Puducherry.

Sir,

AE (MJ)

Sub: PW – PHD – EE - Supply of water to the project – Certificate issued – Regarding.

24.5.19

Ref: No.3256/EE/Port/Sagarmala/EIA/2019-20/167 Dt. 10.05.2019
-oOo-

With reference to the subject cited above, it is stated that the Public Health Division, Public Works Department can supply 15 KL water per day to facilitate the proposed project of "Development of Pondicherry Port under Sagarmala Scheme" in Puducherry.

Yours faithfully,

EXECUTIVE ENGINEER
PUBLIC HEALTH DIVISION
PWD., PUDUCHERRY

Copy to: The Assistant Engineer, WW, PHD., PWD., Puducherry.

Office copy

ORIGINAL

0012247

GOVERNMENT OF PUDUCHERRY, ELECTRICITY DEPARTMENT
H.T. ENERGY CONSUMPTION, BILL FOR THE MONTH OF FEBRUARY 2019

BILL NUMBER : 5542/2018-2019
CONSUMER CODE: 164
CONSUMER NAME & ADDRESS :
THE DIRECTOR-PORT,
PORT DEPARTMENT,
NEW PROJECT,
PONDICHERRY.

GST No.:34AAAGT0540F1ZP

BILL DATE : 07/03/2019
PAY BY DATE : 21/03/2019
TARIFF UNITS : Rs. 6.50
DEMAND : Rs. 450

DETAILS	PREVIOUS READ	PRESENT READ	DIFFERENCE	MULTI FACTOR	CONSUMPTION
KWH	545.300	562.500	17.200	400.000	6880.000
KVAH	719.600	742.800	23.200	400.000	9280.000

CONSUMER GENERAL DATA		CONSUMPTION DETAILS		CLAIM DETAILS	
Service Date	28/02/1994	KWH Units	6,880	HT Unit Charge	44,720
Category	HT-II	Comp. Units	0	LL Unit Charge	0
Metering	HT	Trans. Loss	0	Qtr Unit Charge	0
BPSC Applicable	Yes	STOA Units		Demand Charges	1,14,750
S.T. Percentage	0.00 %	Total Units	6,880	LPF Penalty	25,515
Sanction Demand	300	KVAH Units	9,280	Meter Rent	500
Seasonal Firm	No	Lag Units	0	Trans. Rent	0
S.D. on Account		Lead Units	0	Serv. Charge	0
Trans. Loss %	0.00 %	Power Factor	0.74	F.Serv. Charge	0
Section Code	P3121	L.L. Units	0	FPPCA Charge	
Section Name	JE/SOUTH	Qtrs. Units	0	Misc. Charge	0
		Recd. Demand	24.00	Other Charges	0
		Char. Demand	255.00	Exec. KWH Charge	0
		Exce. Demand	0.00	Surcharge Amt	6,379
		KWH Excess	0	Other Adj. (-)	0
				Int. on S D (-)	0
				P.F. Incentive (-)	0
				Prompt Pay Reb (-)	0
				Adv. Pay Rebate (-)	0

Supply will be disconnected without notice if payment is not made even after fifteen days from the due date mentioned in the bill and in the event of cheque being dishonoured.

TIN NUMBER : 34220013340
Dept GST NUMBER : 34AAAG00342Q1Z7

CERTIFICATE
Certified that the readings have been verified and found correct
[signature]
JUNIOR ENGINEER O/C
PORT DEPARTMENT
GOVT. OF PUDUCHERRY.
11/03

Bill Amount + GST	1,91,864
Sales Tax	90
B.P.S.C. Amount	0
Total Bill Amount	1,91,954
Arrears Amount	4,04,902
Net Bill Amount	5,96,856

RUPEES Five Lakhs Ninety Six Thousand Eight Hundred Fifty Six only

TAX BREAKUP : 0(Sales Tax) + 90(GST)

ARREARS BREAKUP 389456(Arrear) + 15266(BPSC) + 0(S.Tax) + 180(GST)

*- For Online Payment visit: https://www.onlinesbi.com/sbicollect/icollecthome.htm?corpID=357165

[signature]
Financial Controller /
Senior Accounts Officer - I

C.C. TO :

THE EXECUTIVE ENGINEER-URBAN O&M

ANNEXURE VII

OFFICE OF THE EXECUTIVE ENGINEER
PORT DEPT PUDUCHERRY
Receipt No 656
Received on 6/5/19
Despatched on

PUDUCHERRY MUNICIPALITY
PUDUCHERRY

No. /PM/MHO/2019-20/OM/Disposal of Municipal Solid Waste Date: 30/4/2019

To

The Director of Ports,
Port Department
PUDUCHERRY

Sir,

Sub: PM- Disposal of Municipal Solid Waste-Certificate of Clearances of Environment Impact Assessment (EIA)-Development of Pondicherry Port under Sagarmala-Reg.

Ref: Your Letter No.3256/EE/Port /Sagarmala/EIA/2018-19/26 of the Director of Ports, Puducherry, dated 27.03.2019.

AE(M3) 6/5/19

****

With reference to the subject cited above, it is informed that Pondicherry Municipality is collecting and transporting the Municipal Solid Waste (MSW) in its limit through M/s. Swachatha Corporation, an outsourcing agency of PUDA. It is indicated in your letter that the port is expected to generate about 500 kgs of MSW on a daily basis during the commercial cargo handling operations in coming months. In this regard it is stated that the Pondicherry Municipality is equipped with all the necessary civic capacities of handling the MSW and has adequate capability to cater to the MSW generated from the project. As the Municipal Solid Waste is exceeding 100 kg limit, it is categorized as Bulk Waste Generator (BWG). The Swachatha Corporation will collect and transport the Municipal Solid Waste from port area and Bulk Waste Generators have to pay to Pondicherry Municipality by cheque for the MSW on weighment basis as per the rate fixed by the Municipality.

7.5.2019

2. The necessary clearance certificate for handling MSW generated by the port Department is annexed.

Yours faithfully

(ARJUN RAMAKRISHNAN)
COMMISSIONER

Copy Submitted to:

1. The Director, Local Administration Department, Puducherry

Copy to:

1. The Executive Engineer, Pondicherry Municipality, Puducherry.
2. The Municipal Health Officer, Pondicherry Municipality, Puducherry
3. Office Copy.

ANNEXURE VIII

PUDUCHERRY MUNICIPALITY
PUDUCHERRY

No. /PM/MHO/2019-20/ Disposal of Municipal Solid Waste Date: 30 APR 2019

CERTIFICATE

Certified that Pondicherry Municipality is collecting and transporting the Municipal Solid Waste (MSW) in its limit through M/s. Swachatha Corporation, an outsourcing agency of PUDA. The Pondicherry Municipality is equipped with the necessary civic capacity for handling the MSW and has adequate capability to cater to the MSW generated from the Commericial Cargo handling project of Port Department.

Yours faithfully

(ARJUN RAMAKRISHNAN)
COMMISSIONER

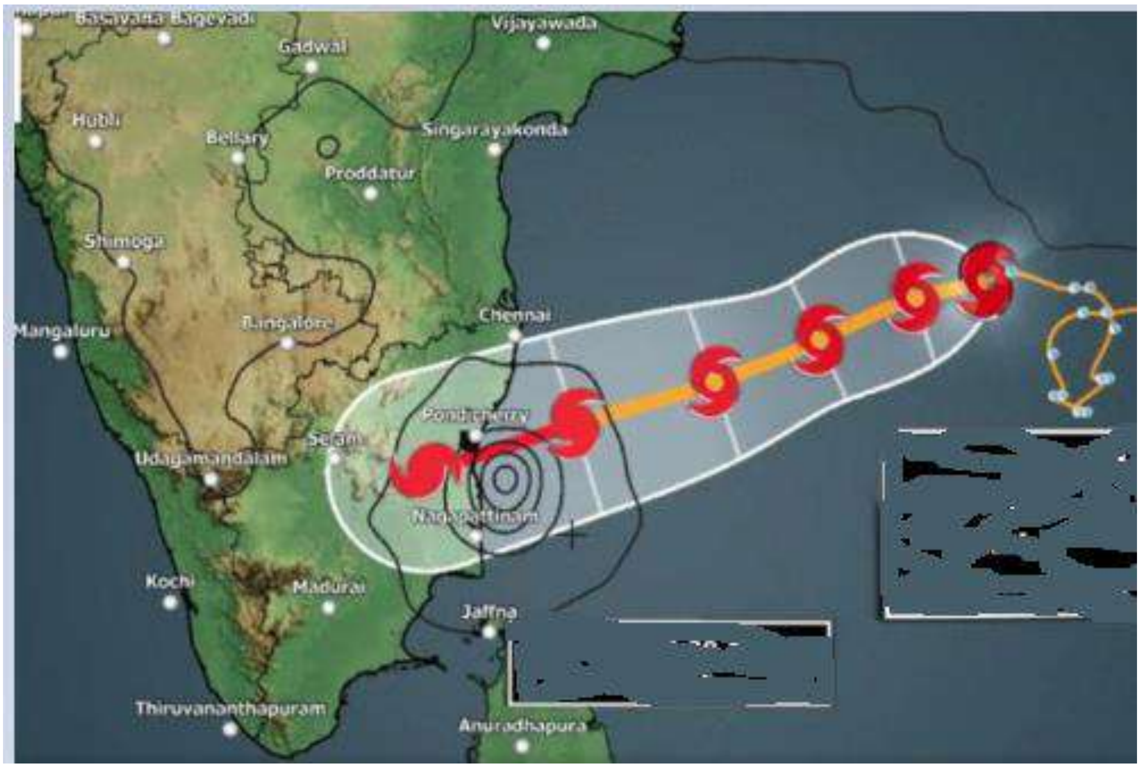
To

The Director of Ports,
Port Department
PUDUCHERRY

ANNEXURE VIII

Annexure - IX

DREDGING IN THE HARBOUR BASIN AND NAVIGATIONAL CHANNEL PMC FOR PHASE I DEVELOPMENT OF PONDICHERRY PORT – STUDIES ON FLOODING AND RELATED IMPACT ON CREEK AND CONTROL AREA DURING CYCLONIC STORM



Document No: IC/18-19/OEC/PDY (PMC)/RSUN – 06

Client:

सत्यमेव जयते

Government of Puducherry

Port Department,

Government of Puducherry

Consultant:

Prof. R. Sundaravadivelu., FNAE

Institute Chair Professor,

Member BOG IIT Madras,

Department of Ocean Engineering,

IIT Madras, Chennai – 600 036.

CONTENTS

LIST OF FIGURES

LIST OF TABLES

1.0 INTRODUCTION

The coast of Tamilnadu is having major ports at Chennai and next major port is at Tuticorin located at about 600km. Hence the proposed port of Pondicherry will be an intermediate one. The Minor Port of Pondicherry is situated in the East Coast of India between two Major Ports of India namely, Chennai and Tuticorin. Pondicherry Port has been a trading port since 100 B.C and prominent during Chola period trading with the Chinese people. There is an evidence for an ancient port town situated on the bank of Ariyankuppam River about 8 km south of Pondicherry and draining in to Bay of Bengal.

Figure 1-1: Site Location (A)

This port town has a history that dates back to the second century BC. Archeological survey of India' s excavation at Arikamedu established the strong trade links with Rome and Greece

Client	Port Department, Pondicherry Port	Date	06.06.2019
Project	Dredging in the harbour basin and navigational channel PMC for Phase I Development of Pondicherry Port	Sheet No.	5
Subject	studies on flooding and related impact on creek and control area during cyclonic storm	By	IITM

between 100 BC and 100 AD of this port town. The location of Pondicherry port is shown in Fig. 1-1 & 1-2.

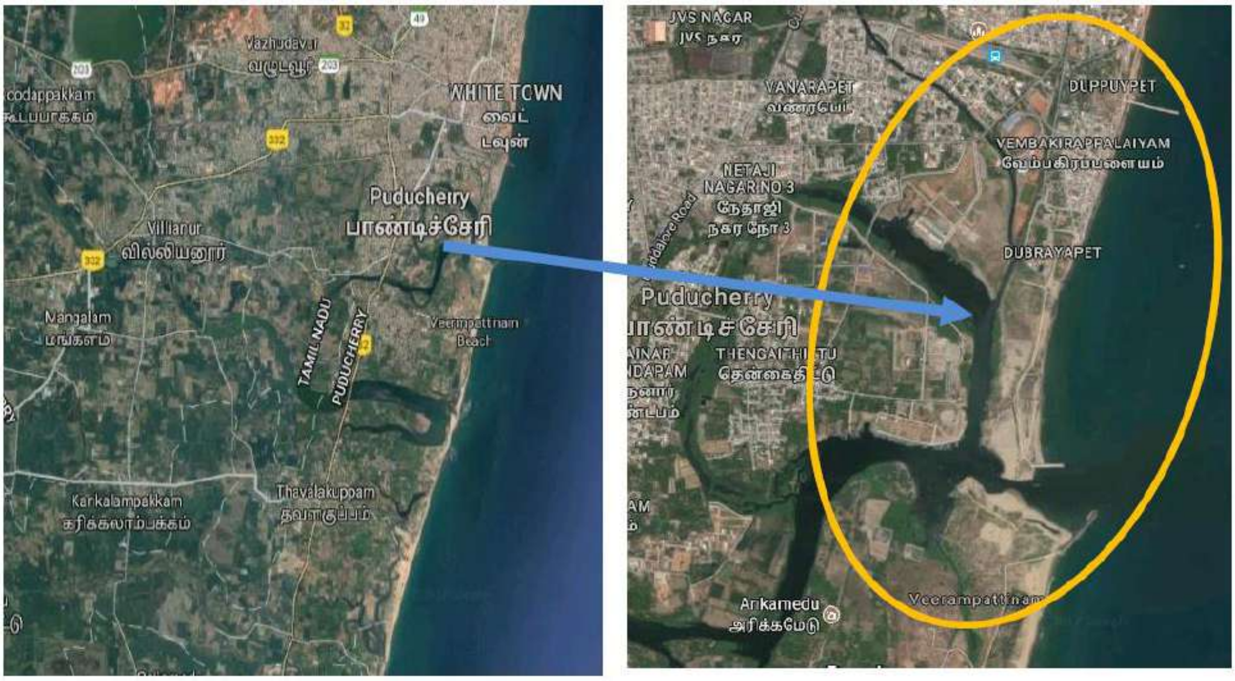


Figure 1-2: Site Location (B)

2.0 PRESENT SCENARIO

In 1962 a new Pier and port was built south of the town. New pier port was constructed to associate the old port. This 11 acre new pier port was used to berth small lighters that transshipped goods from the ship that lay another anchor off the boats. The structural members of the pier port are severely corroded declaring the pier unsafe for usage, therefore it is largely unused. Hence the current port was built in 1993. It has been indicated by the port that the maximum cargo handling rate will be 2,000 TPD with one ship at a time. Accordingly the overall capacity of the port will be about 3 to 4 lakh tons per annum. The port was in operation for 13 years from 1993 till 2006-07. Afterwards, the regular maintenance dredging was not carried out and the mouth got silted up. For the past 12 years, there is no operation at the Port and the existing facilities are idling without generating revenue. The availability of depth all along the channel is around 3m depth. The proposed development of port is designed to handle about 6000TEU per month.

3.0 OBJECTIVE

- Studies on flooding and related impact on creek and control area during cyclonic storm

4.0 METHODOLOGY

- Bathymetric Survey,
- Tide details,
- Hydrology of Ariyankuppam drainage
- Model using HECRAS software

4.1 Bathymetry Details

The bathymetry survey indicates that the water depth contours runs nearly parallel to the coastline up to (-) 15 m water depth. The water depth of 2 m, 4 m, 6 m, 8 m, 10 m, 12 m and 15 m occur at distances of 121 m, 248 m, 444 m, 720 m, 1193 m, 1693 m, and 3175 m respectively. The numerical modeling of existing bathymetry and proposed dredging bathymetry is shown in Fig 4.1.

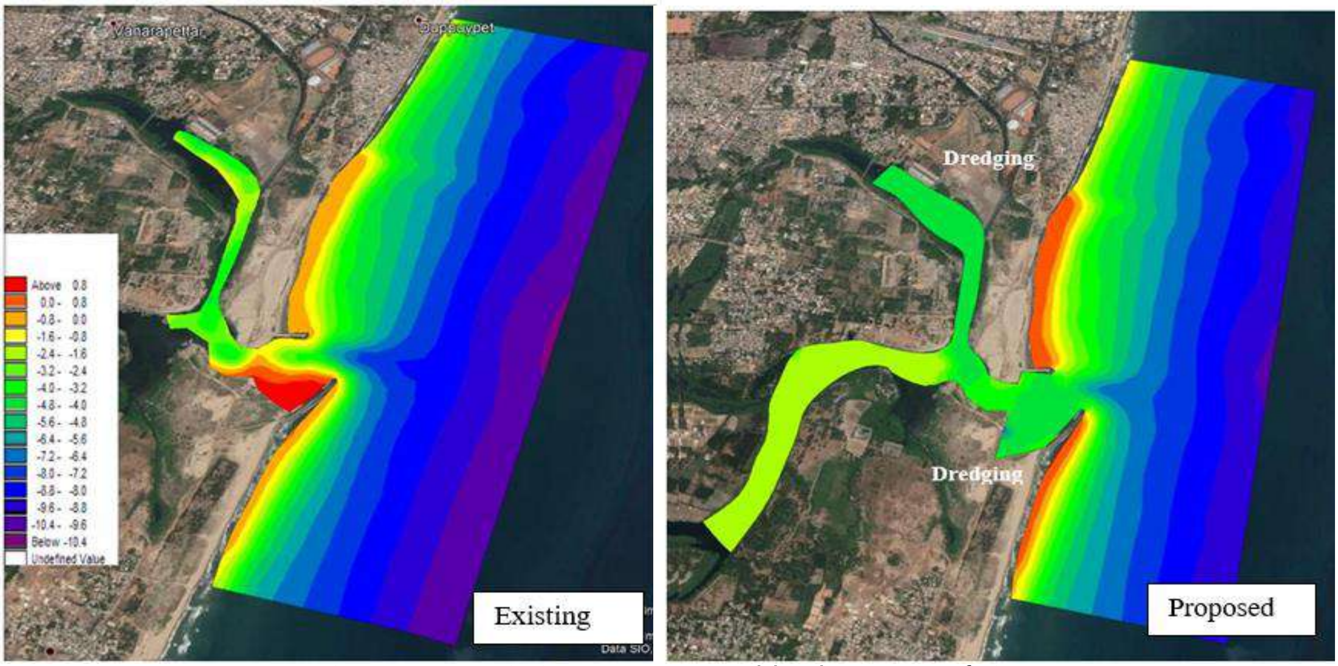


Figure 4-1: Existing & proposed bathymetry of site

4.2 Tides

The tidal level at Pondicherry Port with respect to Chart Datum (CD),

Mean high water Spring (M.H.W.S) : (+) 1.30 m

Mean High Water Neaps (M.H.W.N) : (+) 1.00 m

Mean Low Water Neaps (M.L.W.N) : (+) 0.70 m

Mean Low Water Spring (M.L.W.S) : (+) 0.50 m

Tidal harmonic analysis of the tide gauges data is carried out using **Mike 21 package** (Danish Hydraulic Institute). The tides along the coast of Puducherry are semi-diurnal with form number 0.22. Form number is defined as the ratio of the sums of the amplitudes of the constituents of (K1 and O1) to that of the constituents (M2 and S2). The observation points are given below in Table 4.1.

Table 4-1: Frequencies and amplitudes of tidal constituents

Type	Tidal Constituents	Tidal Amplitude(m)	Phase(degrees)
Diurnal	O1	0.0267	336.92
	P1	0.0302	336.73
	K1	0.0913	330.28
Semidiurnal	M2	0.3098	223.84
	S2	0.1558	278.62
	K2	0.0424	301.02
Quarter diurnal	M4	0.0027	122.97
	MS4	0.0043	280.90
	S4	0.0035	82.25

4.3Hydrology of Ariyankuppam

River Sankaraparani, drains into the Bay of Bengal on the southern side of Pondicherry region. Also known as river Gingee or Varahanadhi, it has its source at the hills of Malayanur in the South Arcot District of Tamil Nadu. The River splits off into two branches namely Chunnambar in the south and Ariankuppam River in the north. This river is not a perennial river and it flows only during rainy season and floods. (Source: Drainage Map of Pondicherry, Pondicherry Town Planning Authority)

Ariankuppam River and Estuary is situated in Pondicherry, between Latitude 11°55′ N and 12°30′ N and Longitude 70°05′ E and 80°05′ E (Fig.4.2). This is a fan medium river basin with drainage of about 100Sq.kms. Ariankuppam River, which originates from the River Sankaraparani, at Nallareddy Palayam (about 10 kms from the sea shore) usually gets cut off from River Sankaraparani, during non-monsoon period and the water is more or less stagnant during other seasons. The maximum one day rainfall that has taken place in Pondicherry is 22cm in 2015. Based on the assessment of area of basin and run off calculation as per SCS method & the runoff was 3500cusecs. The stretch is also liable to cyclone crossing.

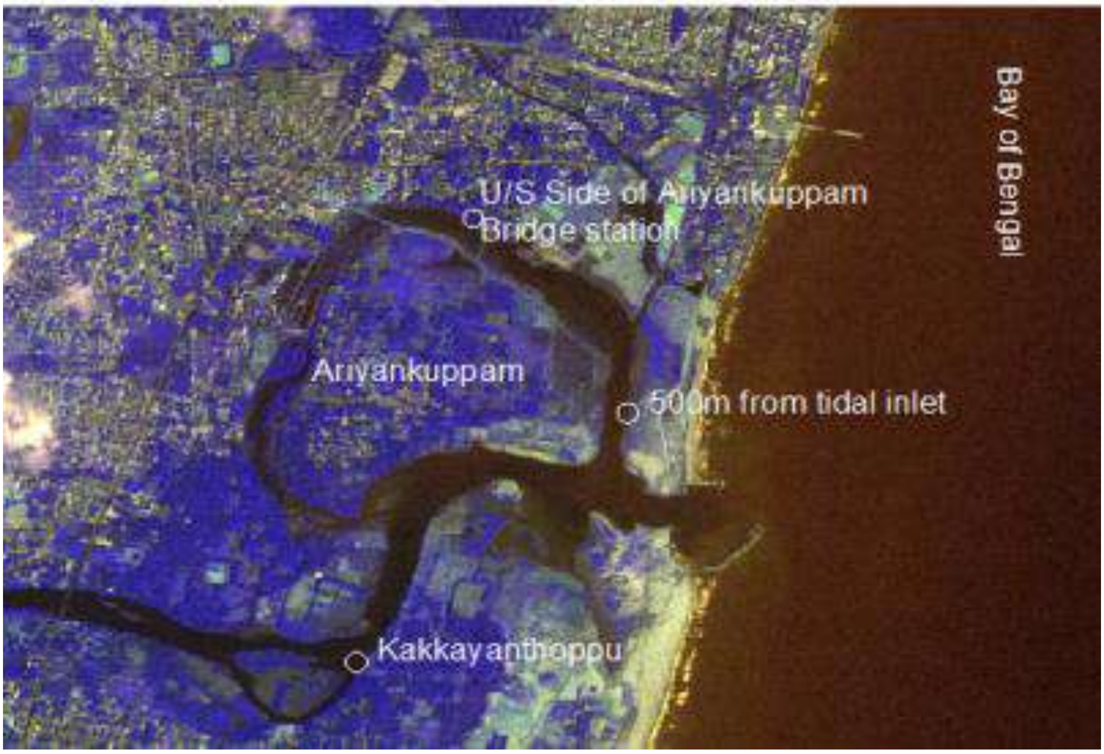


Figure 4-2: Ariyankuppam drainage basin

4.4 Numerical model studies (HECRAS)

As a part of project the numerical model studies are to be carried out for assessing the tidal propagation with existing bathymetry and proposed dredge depth details.

Hydrodynamics with the proposed dredging were simulated by incorporating the defined dredging port layout as described in Figure 4.3 into the model bathymetry and simulating the hydrodynamic model keeping all other parameters unchanged from the baseline condition simulation. It is proposed to develop the present port area in Pondicherry adjacent to Ariyankuppam drain, which include construction of barrier and capital dredging.

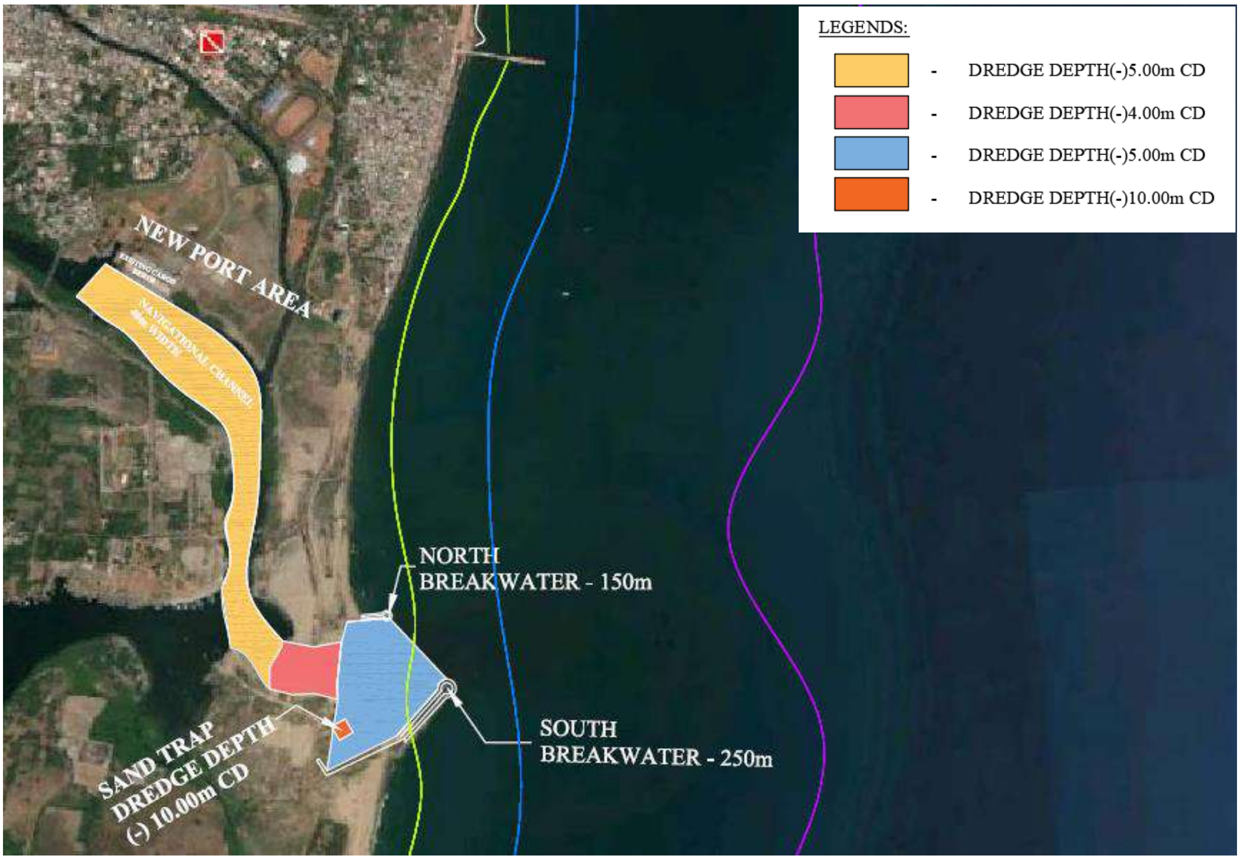


Figure 4-3: Proposed dredging layout

5. HEC-RAS MODELING PROCEDURE

In order to assess the existing hydraulic conditions of the field, numerical model studies were made. For the present study the U.S. Army Corps of Engineers' River Analysis System (HEC-RAS) software is used. This software is developed by the Hydrologic Engineering Center (HEC), which is a division of the Institute for Water Resources (IWR), U.S. Army Corps of Engineers. HEC-RAS allows users to perform one-dimensional steady and unsteady flow calculations (HEC, 2002). In a HEC-RAS steady state simulation, water surface profiles are computed from one cross-section to the next by solving the standard step iterative procedure to solve the energy equation. The energy equation is intended to calculate water surface profiles for steady gradually varied flow.The input are geometric, flow and boundary data. The geometric data consisting of cross section and chainages were keyed in after making a base map of the study area. The flow data adopted was the maximum value as suggested by the field engineers. The upstream and downstream slopes were given as boundary conditions. 'The steady flow water surface profiles' is one of the component of Hydrologic Engineering Centre River Analysis System (HEC-RAS) which is used in the flood plain management and in flood insurance studies. HEC-RAS analyses the network of natural and man-made channels and computes the water surface profiles based on One-Dimensional flow hydraulics. It is capable of modeling subcritical, supercritical and mixed flow regimes for the streams. The basic computational procedure is based on the solution of one dimensional energy equation. Energy losses are evaluated by friction (Manning' s Equation) and contraction and expansion coefficient.

The Figure 5.1 shows the Representation of the Terms in Energy Equation.

$$Y_2 + Z_2 + \frac{\alpha v_2^2}{2g} = Y_1 + Z_1 + \frac{\alpha_1 v_1^2}{2g} + h_e \quad ...3.4$$

Where,

Y_1, Y_2=depth of water at cross-sections

Z_1, Z_2 =elevation of main channel inverts

α_1, α=velocity weighting factor

g=gravitational acceleration

h_e=energy loss

V_1, V_2 = average velocities

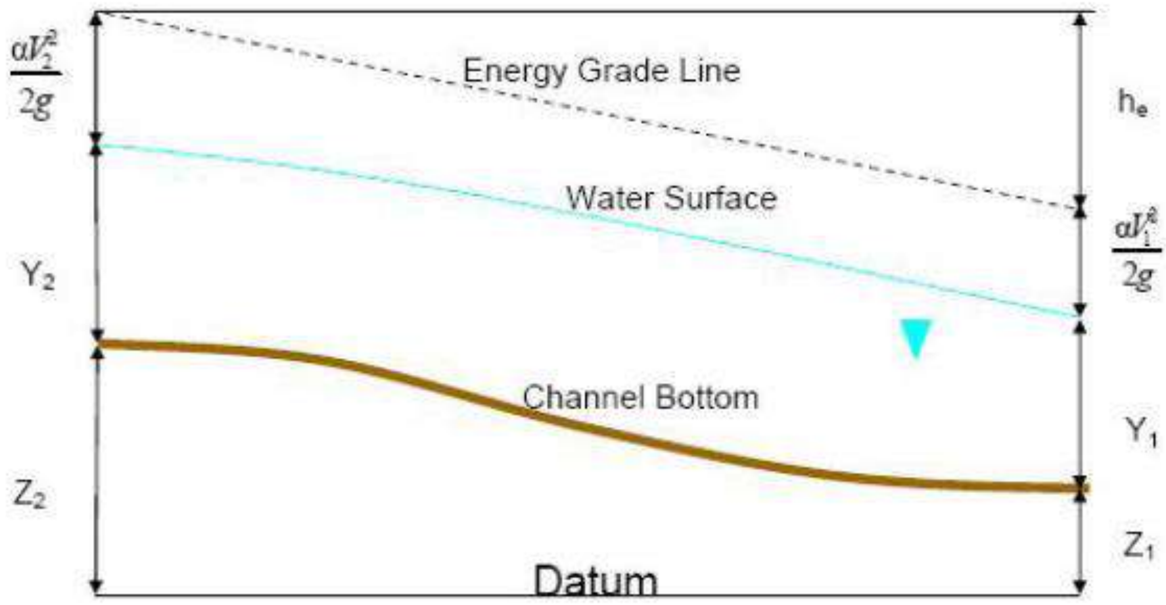


Figure 5-1: Representation of terms in the Energy equation

5.1 HEC-RAS Input Parameters

Four files namely project, plan, geometry and flow files are required to run a HEC-RAS project. The project file acts as file management tool and identifies which files are to be used in the model. The plan file sets the model conditions as subcritical, supercritical or mixed flow and runs the simulation

5.2 Scenarios of model run

The trial runs were made for the inner river portion where it is proposed to have dredging up to (-)5m below chart datum. The model trial runs are carried out to assess the water level for a maximum discharge of 3500 cusecs or 100 cumecs for the following water level conditions (Fig 5.2).

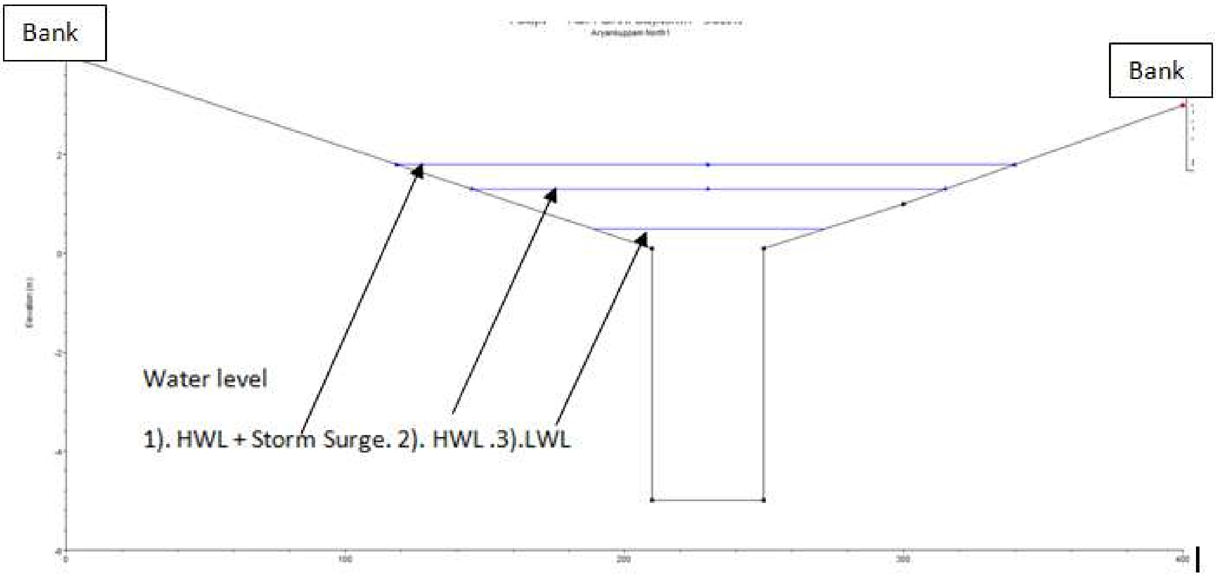


Figure 5-2: Water levels along proposed site

5.3 Results & Discussion

The studies indicate that the banks of the project area are not overflowing and the dredging has resulted in more depth.

6 CONCLUSION

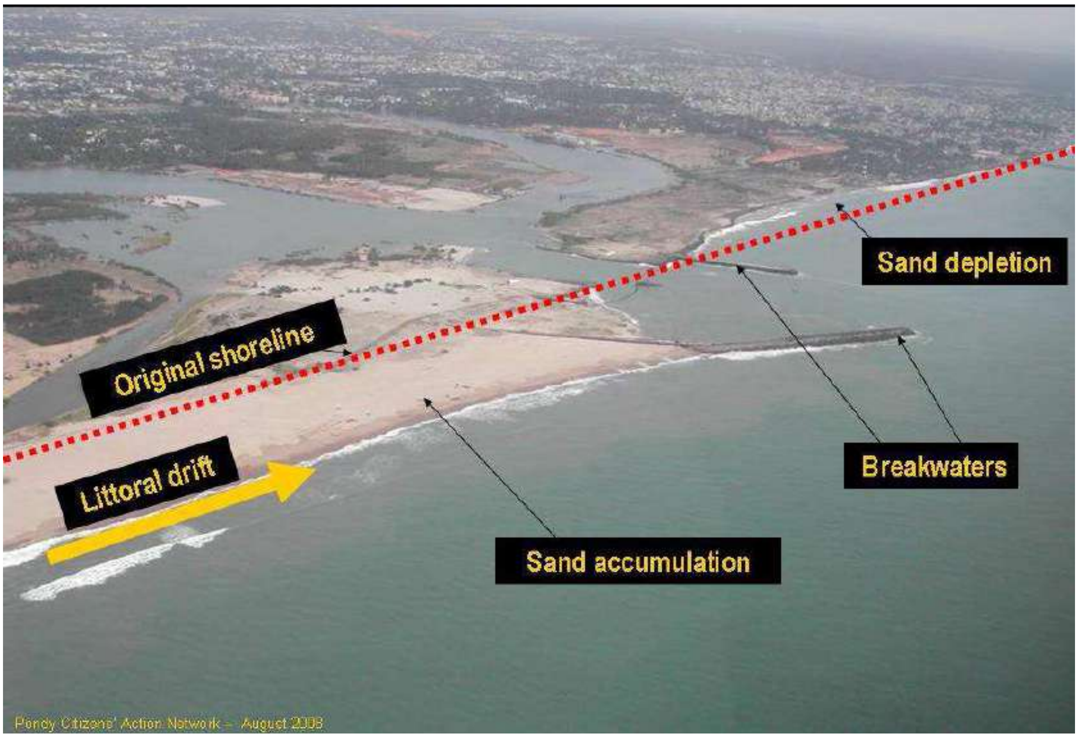
The studies were conducted to assess the top level conditions of the banks during high tide and combination of high tide & storm surge during cyclone. The dredging has resulted in non overflow over banks and hence safe**.**

REFERENCE

US Army corps of engineers Hydrologic Engineering Center HEC-RAS River Analysis System Application guide March 2008

Annexure - X

DREDGING IN THE HARBOUR BASIN AND NAVIGATIONAL CHANNEL PMC FOR PHASE I DEVELOPMENT OF PONDICHERRY PORT – SHORELINE EVOLUTION.



Document No: IC/18-19/OEC/PDY (PMC)/RSUN – 07

Client:

सत्यमेव जयते
Government of Puducherry

Port Department,

Government of Puducherry

Consultant:

Prof. R. Sundaravadivelu., FNAE

Institute Chair Professor,

Member BOG IIT Madras,

Department of Ocean Engineering,

IIT Madras, Chennai – 600 036.

CONTENTS

LIST OF FIGURES

LIST OF TABLES

1.0 INTRODUCTION

Port Department, Pondicherry has awarded PMC work to Prof. R. Sundaravadivelu, F.N.A.E, Department of Ocean Engineering for Phase I development of Pondicherry Port under Sagarmala scheme. This report highlights the details of Estimation of possible sedimentation involving currents and waves including the littoral transport estimate as load from the seaside, shoreline evolution and nourishment

2.0 OBJECTIVE

The scope of the study includes,

- ❖ Estimation of possible sedimentation involving currents and waves including the littoral, shoreline evolution and effect of nourishment.

A quantitative understanding of wave characteristics in the near shore is essential for the estimation of sediment transport and morphological changes along the coastal areas. Unfortunately measured or visually observed wave data is available only for locations of port. Hence, numerical models were resorted to for the simulation of wave climate. In the present study, two numerical models were employed to derive monthly near shore wave climate. These models are then validated with deep water buoy observations. Based on the near shore wave data, prediction littoral drift. The coast is influenced by two monsoons namely south west and north east monsoons as stated in earlier chapter. Waves are predominantly from southeast (100–160^o) during the Southwest monsoon (June–September) and Northeast (80–90^o) during northeast monsoon (October–December).

3.0 MODELLING OF WAVES

The regional wind to wave model was carried out for the Indian Ocean with the aim of hind casting offshore wave characteristics using available wind data. The model simulates the growth, decay and transformation of wind-generated waves and swells in offshore and coastal areas.

3.1 Basic Formulation

Spectral Wave Model in MIKE 21 has two spectral formulations:

1. Directionally decoupled parametric formulation
2. Fully spectral formulation

Directionally decoupled parametric formulation is typically used for the assessment of wave conditions in nearshore and coastal areas which often involves transformation of known offshore wave statistics. Fully spectral formulation is usually used for simultaneous wave prediction and analysis on large and local scale. Although fully spectral formulation is computationally demanding, it is more accurate.

The governing equation is the wave action conservation equation formulated in either Cartesian co-ordinates or Spherical co-ordinates. In horizontal Cartesian co-ordinates, the conservation equation for wave action can be written as

$$\frac{\partial N}{\partial t} + \nabla.(\tilde{v}.N) = \frac{S}{\sigma}$$

where N ($\underset{x}{\rightarrow}$, σ, θ, t) is the action density, t is the time, $\underset{x}{\rightarrow}$ = (x, y) is the Cartesian co-ordinates, $\tilde{v}$ = (c_x, c_y, c_σ, c_θ) is the propagation velocity of a wave group in the four dimensional phase space $\underset{x}{\rightarrow}$, σ and θ, and S is the source term for the energy balance equation.

3.2 Model Domain and Bathymetry

In order to simulate waves in the Indian Ocean, a large domain, which ranges from 0° to 25° N Latitude and 60°E to 120°E Longitude was selected. An unstructured triangulated mesh is generated with varying sizes of triangles elements; 0.5° (Indian Ocean), 0.125° (Coastal).

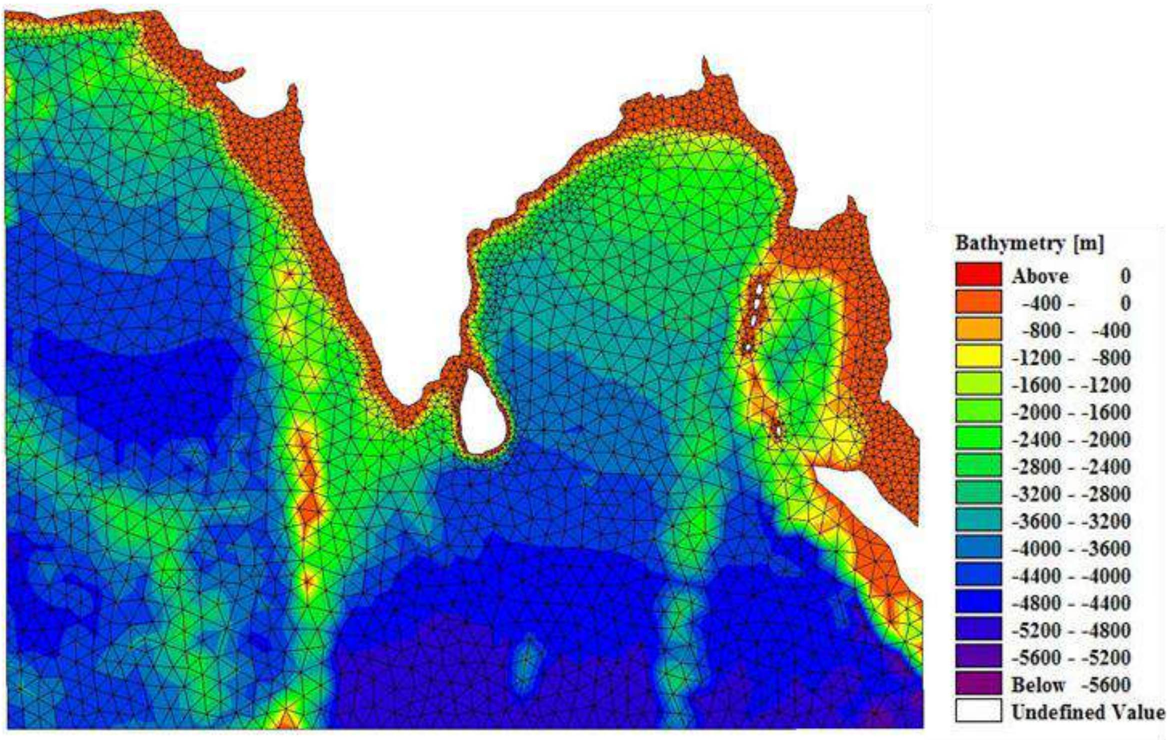


Figure 3-1: Model domain and Bathymetry of Indian Ocean

C-MAP data for deep water regions along Indian Ocean and bathymetry data sets of measured data are applied to shallow water regions in the study area, by interpolating them to each element in the flexible mesh bathymetry. The horizontal datum is referenced to World Geodetic System 1984 (WGS-84) and the vertical datum is referenced to Mean Sea Level (MSL). Figure 3.1 shows the model domain, flexible mesh bathymetry used for wave simulations in the Indian Ocean.

3.3 Wind Forcing

Wind is the basic input parameter for wave simulation. Successful wave hind cast and forecast depend on accurate wind fields deduced from meteorological models and analysis.

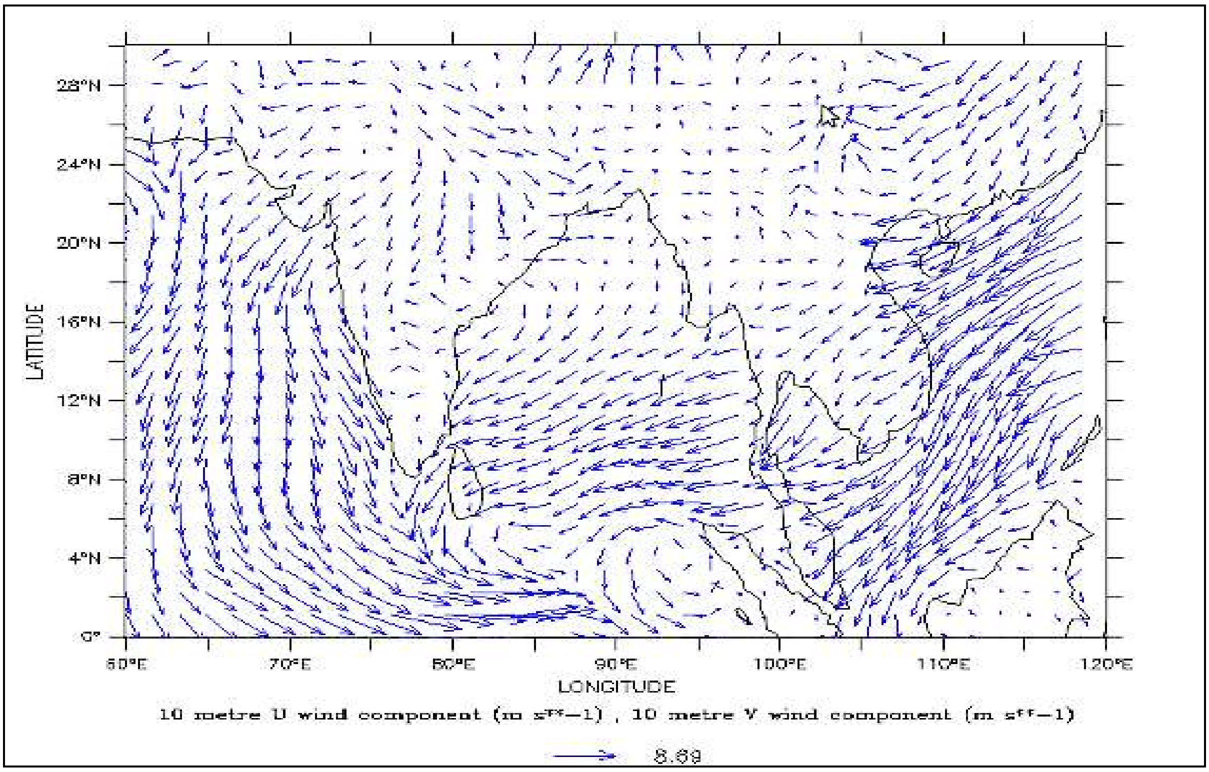


Figure 3-2: 10 m U wind component vectors as on 01-Jan-2016

In the present study, wind data is obtained from the database of ECMWF's interim reanalysis (ERA-Interim). Wind data for Indian Ocean region (60°E to 120°E and 0° to 25°N) was collected from ECMWF database for regional wave modelling. The wind data was obtained for a period from January 2016 to December 2016 with spatial resolution of 0.25 × 0.25 degree and temporal resolution of 3 hours. The data for wind was obtained as U & V components of wind velocity (m/s) at 10 m height. U and V components of the wind velocity are calculated from decomposing the wind magnitude and direction along the two horizontal axes: x and y and the typical wind pattern is shown in Figure 3.2.

3.4 Model Validation

The wave rider buoy data of year 2016 deployed at water depth of 30m deployed off Puducherry coast was used for the validation of regional model. The modeled wave heights are in good agreement with observed wave heights with the correlation coefficient of 0.83 (Fig 3.3) which proves the reliability of the model.

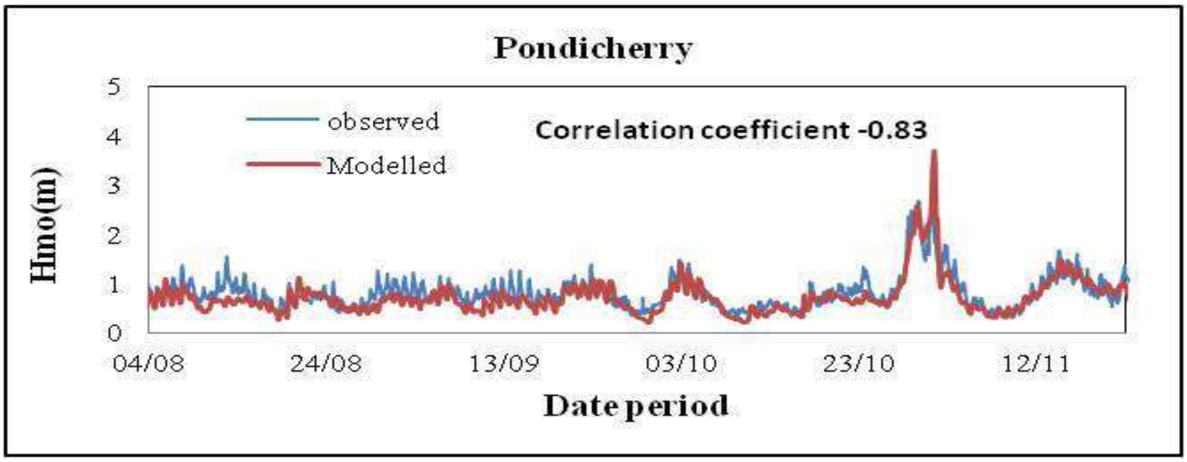


Figure 3-3: Comparison between modeled and observed wave heights at WRB location

4.0 GENERATION OF OFFSHORE WAVE CLIMATE

From the validated model the wave climate off Pondicherry Port is extracted for the period of one year at the location as shown in Figure 4.1.

Figure 4-1: Location of Offshore wave climate

4.1 Offshore waves

The wave rose diagram (Fig 4.2) shows that the wave approaches the Puducherry from southeast by direction for about 9 months in a year and approaches from east direction for the rest of the year. The wave height ranges from 0.3 m to 1.3 m during southwest monsoon with SE direction. The significant wave height during the NE monsoon period ranges from 0.3 m to 3 m. The wave periods ranges between 3 - 18 sec throughout the year. The characteristics of waves off Pondicherry Port for the year 2017 are shown in Table 4.1.

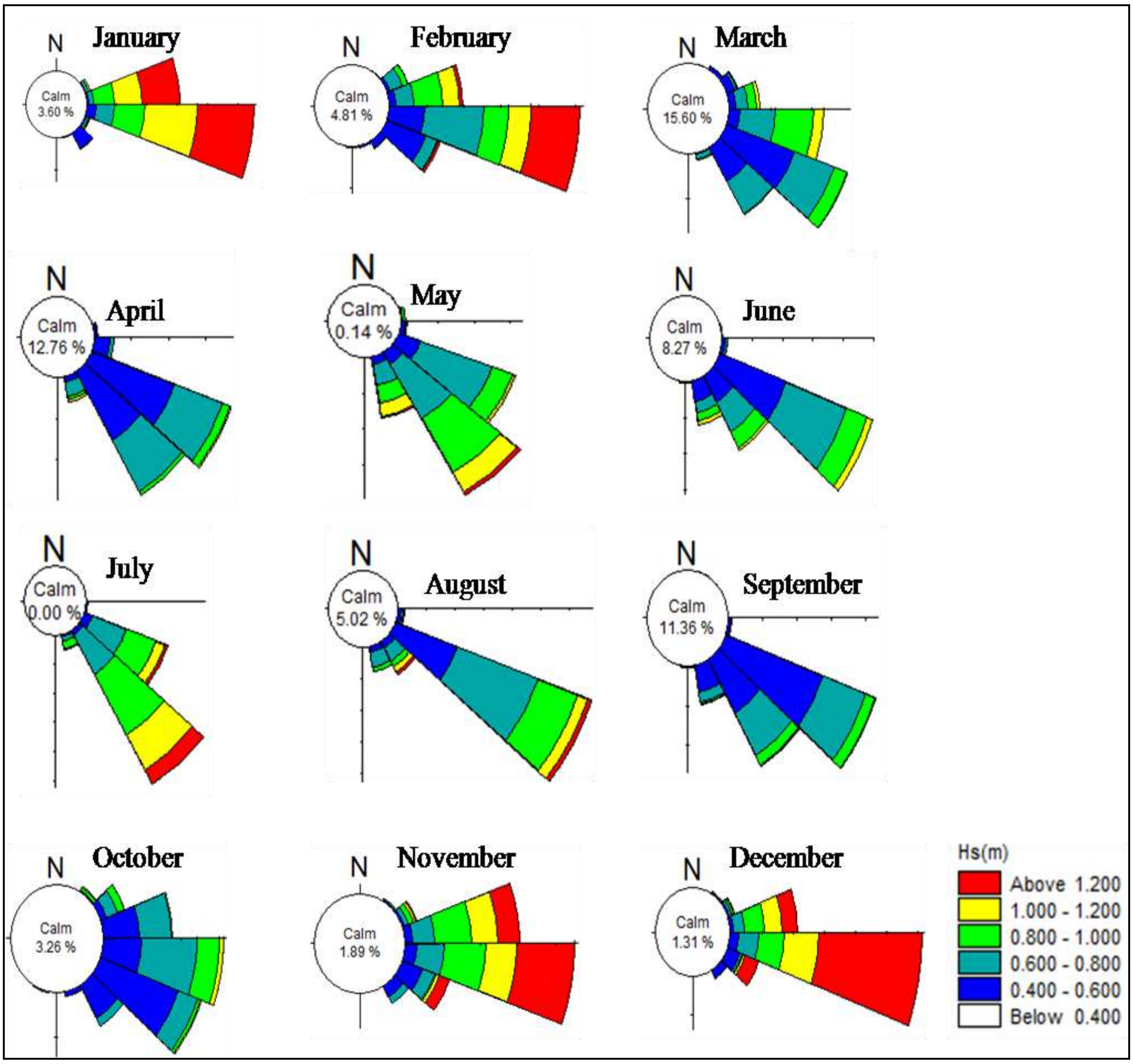


Figure 4-2: Monthly wave climate extracted off Puducherry coast

Table 4-1: Monthly wave statistics of Pondicherry Port

Season		Hs			Tp			MWD		
		Max	Min	Mean	Max	Min	Mean	Max	Min	Mean
Fair weather	February	1.70	0.33	0.82	11.76	3.23	6.23	98.58	49.20	98.58
	March	1.18	0.25	0.61	14.29	2.86	7.31	150.50	50.60	115.60
	April	1.05	0.28	0.56	15.38	2.63	7.25	158.90	67.50	128.44
	May	1.16	0.44	0.77	14.29	3.33	7.06	157.50	83.00	136.21
Southwest Monsoon	June	1.07	0.31	0.63	18.18	3.23	9.32	171.60	101.30	129.61
	July	1.37	0.42	0.87	15.38	3.57	8.16	160.30	112.50	132.96
	August	1.34	0.33	0.69	16.67	2.50	9.41	164.50	92.80	126.58
	September	1.18	0.34	0.56	15.38	3.33	9.88	227.80	111.10	132.20
Northeast Monsoon	October	1.19	0.32	0.61	16.67	2.86	8.10	143.40	47.80	102.03
	November	2.26	0.39	0.97	15.38	3.23	7.03	136.40	50.60	97.26
	December	3.08	0.99	1.44	13.33	6.67	8.32	119.50	83.00	99.87
	January	1.74	0.34	1.02	11.11	3.13	6.98	184.20	59.10	97.35

4.2 Breaker angle variation

The direction and quantity of sediment transport depends on the wave breaker angle. The breaker angle was predicted from every six hourly wind data from NCEP for the year 2004. The monthly average breaker angles respect to shore normal for the stretches, Chennai to Cuddalore. Herein the negative and positive signs indicate the direction of the wave towards north and south respectively. The results for the coast clearly show that during March to October, the breaker angles are negative suggesting that drift will be directed towards the North, whereas, during the other months it would be towards the south. The methodology adopted by VanRijn (2001) was adopted.

Formula of Van Rijn (2001)

Q = $40\, K_{swell}\, K_{grain} K_{slope} (H_{sb})^{3} \sin(2\alpha_{b})$

Q = alongshore sediment transport (kg/s),

T_P = Peak period, Swell correction factor,

K_{swell} = $T_P/6$,

D_{50} = Particle size (mm),

K_{grain} = Particle size correction factor = 0.20 / D_{50},

K_{slope} = Slope correction factor = $(\tan\beta/0.01)^{0.5}$

Estimation of shoreline evolution and alongshore sediment transport the wave climate of 2004 was adopted. The alongshore sediment transport (Fig 4.4 & Table 4.2) was calculated using the approach of Van Rijn (2001) for the coast

The breaker angle with respect to shore normal were calculated and furnished vide figure 4.3. The minus sign indicate direction towards north and plus sign indicates towards south. The breaker angle during most of the time is found to be directed towards north.

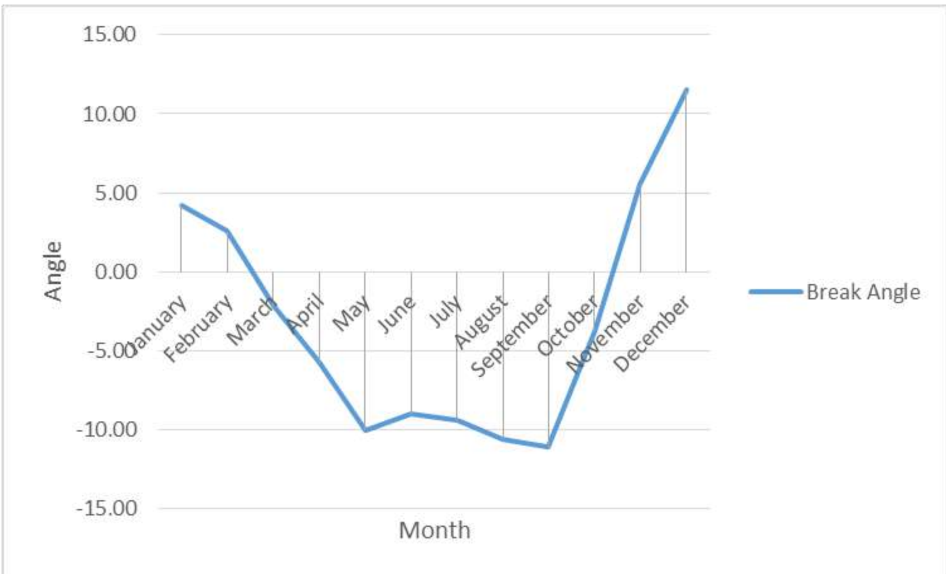


Figure 4-3 Breaker angle

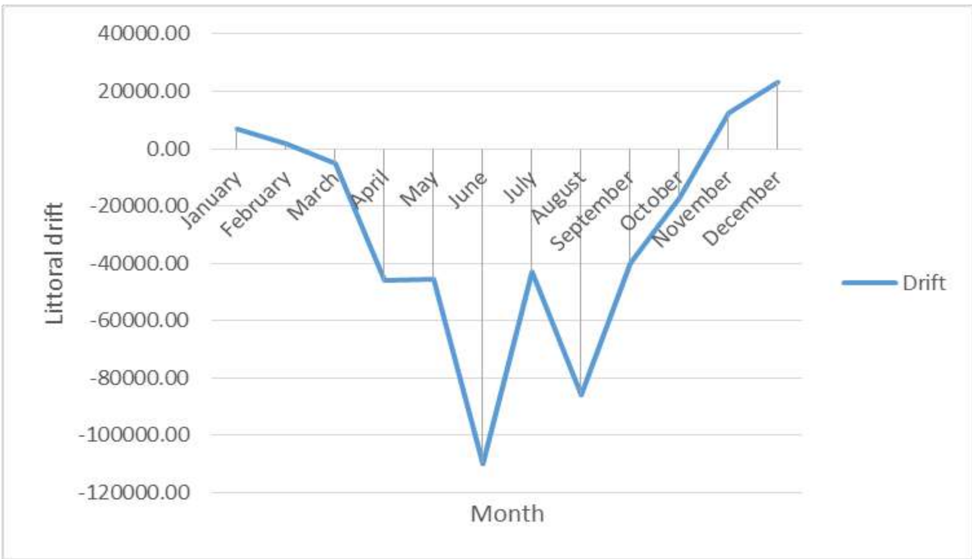


Figure 4-4 Littoral drift

Table 4-2: Littoral drift

Month	Littoral Drift (Cum)
January	6964.71
February	1855.17
March	-5176.31
April	-45983.65
May	-45538.02
June	-109801.72
July	-42957.30
August	-85850.53
September	-39894.63
October	-17047.71
November	12542.83
December	23250.77

5.0 SHORELINE EVOLUTION MODEL - *SHORELINE*

Mathematical modelling of coastline evolution is an effective tool in understanding the shoreline behavior. The numerical model SHORELINE was developed based on the formulation of Suresh & Sundar (2009) .The model essentially relates the changes in the shoreline, to the rate of material transported from the beach. The general wave climate adopted is shown vide fig 5.4 to 5.6

When the changes in the mean sea level and beach slope are not significant, the governing equations describing the shoreline evolution is given by,

$$(b + D_c)\, \partial y / \partial t = - \partial Q/\partial x + q(x) \qquad (1)$$

Where

y: Shoreline position positive towards offshore and a function of ‘x’ measured along the shore and time t,

b: height of berm

D_c : limit of active sand transport and is one of the important parameters in one-line models and it depends upon the wave characteristics. Due to the random nature of the wave conditions, it is difficult to define the position D_c. Kraus and Harikai (1983) suggested the use of Hallermier's (1981) expression.

Q: wave induced sediment.

q(x): quantity of sediment added .

As most of the rivers are not flowing and the estuary is choked by the formation of sand bar. Hence for the present study the term q(x) is not considered. Hence, to simulate the long term shoreline evolution adjacent to coastal structures accurate estimates of the long shore transport in the coastal regions become essential. The wave induced sediment transport processes is a complex one and because of the limitation on the information available on this phenomenon, the procedures for estimating the transport rate are mostly based on empirical relationships. These empirical relationships correlate the rate of alongshore transport 'Q' with the wave energy flux 'E' in the alongshore direction. The empirical formulas adopted for the study are explained in detail.

Formula of Van Rijn (2001)

$$Q = 40\, K_{swell}\, K_{grain} K_{slope} (H_{sb})^3 \sin(2\alpha_b) \quad (2)$$

Q = alongshore sediment transport (kg/s),

T_P= Peak period, Swell correction factor,

K_{swell} = $T_P/6$, D_{50} = Particle size (mm),

K_{grain}= Particle size correction factor = 0.20 / D_{50},

K_{slope}= Slope correction factor = $(\tan\beta/0.01)^{0.5}$

Converting Eqn (13) in to volumetric units

$$Q = \mathbf{A}\, (K_{swell}\, K_{grain} K_{slope})\, (H_{s,br})^3 \sin(2\alpha_b)\ (m^3/year). \quad \mathbf{(3)}$$

Transport coefficient A = (1261440/ ρ)

The model thus developed was then applied to predict the shoreline evolution adjacent to the shore connected structures for the study area considered. The results on the application of the model for the prediction of shoreline changes are discussed

When the point under consideration is not in the diffracted wave region, the diffraction coefficient Kd = 1.In the geometric shadow region of the breakwater, as projected in Fig 5.1, following the procedure of Dean and Dalrymple (1984) the values of K_d are assigned as presented in **Table 5.1**. The shoreline evolution equation and the long shore transport equation in non-dimensional form of Eqn 1 becomes,

$$\partial\hat{y}/\partial\hat{t} = -(\partial\hat{Q}/\partial\hat{x}) + \hat{q}(x) \quad (4)$$

Defining the non-dimensional quantities (quantities with hats) as follows,

$\hat{x} = x/(b + D_c)$;

$\hat{y} = y/(b + D_c)$

$\hat{t} = t(A/(b + D_c)^3)$;

$\hat{Q} = Q/A$,

$$\hat{q} = q(b + D_c) / A$$

Table 5-1: K_d values

$K_D = f(u)$	u	$K_D = f(u)$	u
0.10	-2.25	0.80	0.486
0.15	-1.44	0.90	0.631
0.20	-1.02	1.00	0.779
0.30	-0.528	1.17	1.218
0.40	-0.225	1	1.610
0.50	0	0.88	1.878
0.60	0.184	1.00	2.124
0.70	0.241		

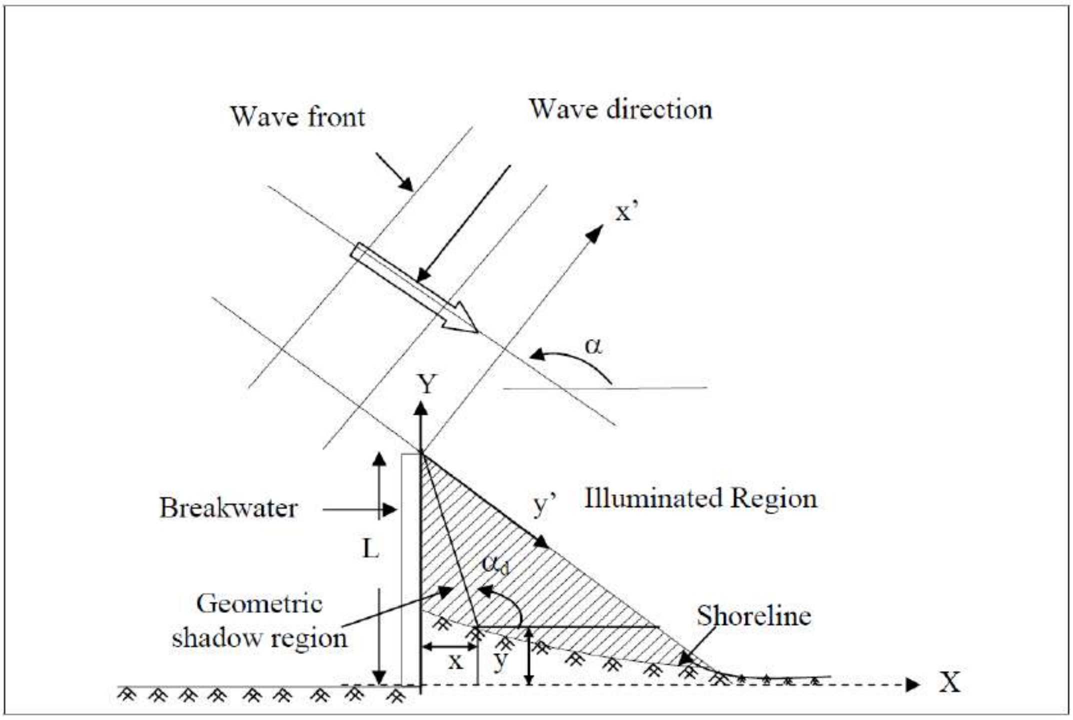


Fig 5-1: Diffraction regiones

5.1 Numerical model

Kraus and Harikai (1983) proposed a numerical scheme to solve the one line model using Crank Nicholson implicit finite difference method. Is discussed below the non-dimensional equation of shoreline evolution is expressed in finite difference scheme as

$$\hat{y}_{n,\hat{t}+1} = B(\hat{Q}_{n,\hat{t}+1} - \hat{Q}_{n+1,\hat{t}+1}) + C_n \qquad (5)$$

Where $B = \delta\hat{t} / 2(\delta\hat{x})$ and $Cn = \hat{y}_{n,\hat{t}} + B(\hat{Q}_{n,\hat{t}} - \hat{Q}_{n+1,\hat{t}}) + 2.\delta\hat{x}.\hat{q}_{n,\hat{t}})$

The non-dimensional shoreline is divided in to N grid points at equal non dimensional interval $\delta\hat{x}$. Then shoreline changes over a non-dimensional time $\delta\hat{t}$ are calculated using Crank-Nicholson finite difference scheme. The schematic diagram for finite difference scheme employed is shown in **Fig 5.2**. Following Kraus and Harikai (1983), the long-shore transport $\hat{Q}$ at the time step $(\hat{t}+1)$ is expressed in terms of the shoreline co-ordinate $\hat{y}$ by first isolating the term involving α_{sp} (angle of shore normal to X axis in Fig 5.3) using trigonometric identities. One of the term involving α_{sp} is then expressed as first order quantities in $\hat{y}$ at the time step $(\hat{t}+1)$.

$$\hat{Q} = K_r^{\,2} K_d^{\,2} \cos(\alpha_b - \alpha_{sp}) \sin(\alpha_b) \qquad (6)$$

$$= Kr^2 Kd^2 (\cos\alpha_b \sin\alpha_{sp} \cot\alpha_{sp} + \sin\alpha_b \sin\alpha_{sp}) \sin\alpha_b$$

Then $\hat{Q}$ at time level $(\hat{t}+1)$ is approximated by expressing cot α_{sp} in the above equation in terms of $\hat{y}$ at the time level $(\hat{t}+1)$ and the remaining terms at the time level t as,

$$\hat{Q} = E_n(\hat{y}_{n-1,\hat{t}+1} - \hat{y}_{n,\hat{t}+1}) + F_n \qquad (7)$$

Where $En = K_d^{\,2} \cos(\alpha_{b},_{\hat{t}}) \sin(\alpha_{sp},_{\hat{t}}) \sin(\alpha_{b},_{\hat{t}}) / \delta x$

$$F_n = K_d^{\,2} \sin(\alpha_{b},_{\hat{t}}) \sin(\alpha_{sp},_{\hat{t}}) \sin(\alpha_{b},_{\hat{t}})$$

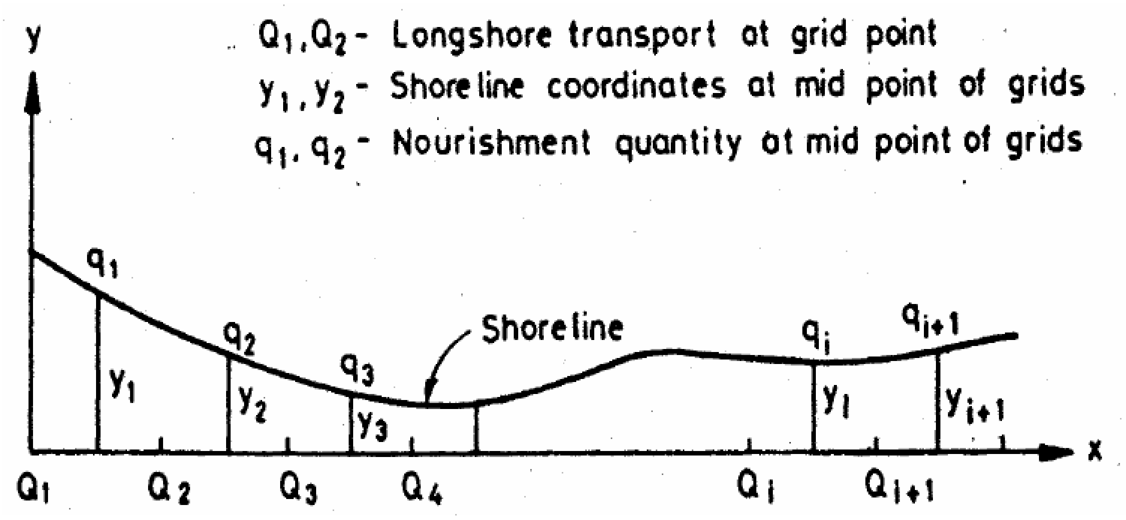


Fig 5-2: Schematic diagram

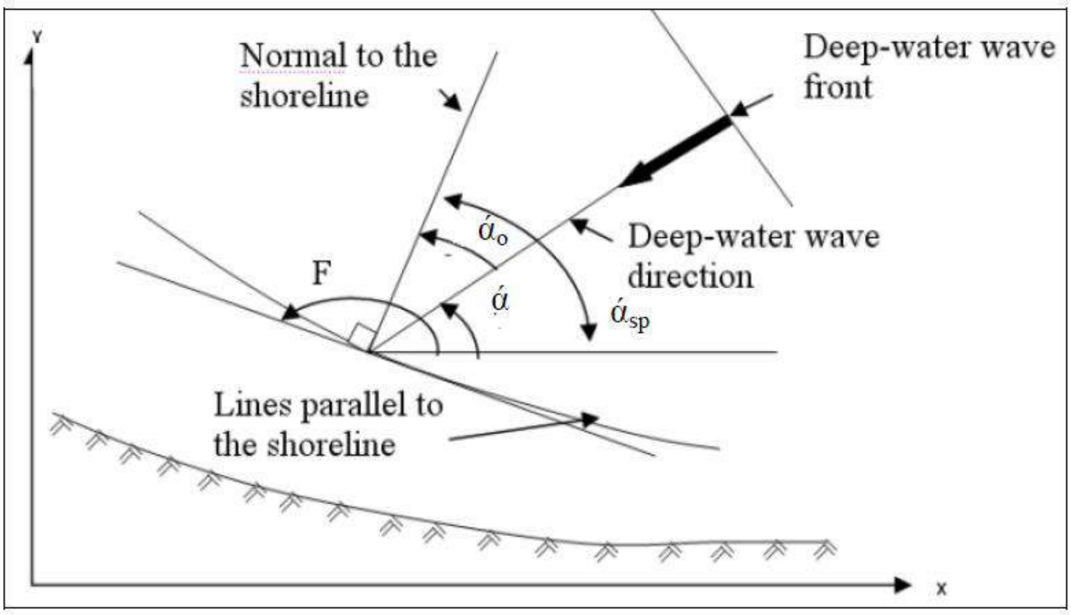


Fig 5-3: Details of angles

Substitution of Eqn. (7) into Eqn. (3) gives,

$$BE_n\hat{Q}_{n-1,\hat{t}-1} - (1+2BE_n)\hat{Q}_{n,\hat{t}+1} + BE_n\hat{Q}_{n,\hat{t}+1} = E_n(C_n - C_{n-1}) - Fn \qquad (8)$$

For n = 2 to N, the above equation represents a set of (N-1) linear equations in (N-1) unknowns. The end values $\hat{Q}_1 \text{and} \hat{Q}_{N+1}$ are specified from boundary conditions, $\hat{Q}_1 = 0$ and $\hat{Q}_{N+1} = \hat{Q}_N$. Now the linear system of equations defined by Eqn.(8) is in a tri-diagonal form and can be solved for $\hat{Q}$ values using a standard procedure. Then $\hat{y}$ can be determined using the Eqn. (7). This procedure is repeated to simulate the evolution of the shoreline with time and the non-dimensional quantity is converted to real quantities using scale factors.

The transport parameter "A" (m^3/year) in Eqn (3) is calculated adopting CERC of SPM (1984) expression. However it is to be mentioned that the CERC (1984) expression does not take the effects of particle size and beach slope. Hence, numerical experiments were repeated by changing the value of transport parameter "A" as per the following empirical relations of Kamphuis et al (1986) and Van Rijn (2001).

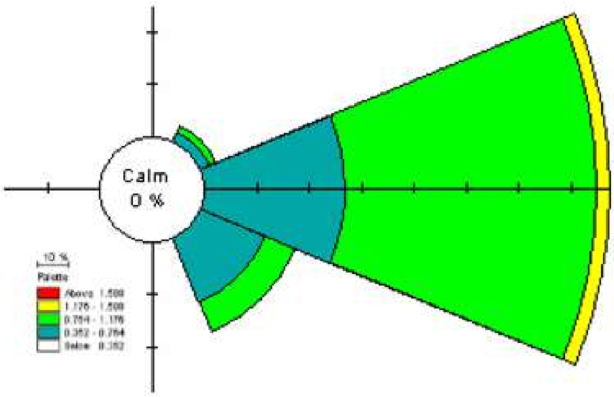


Fig 5-4: Non Monsoon

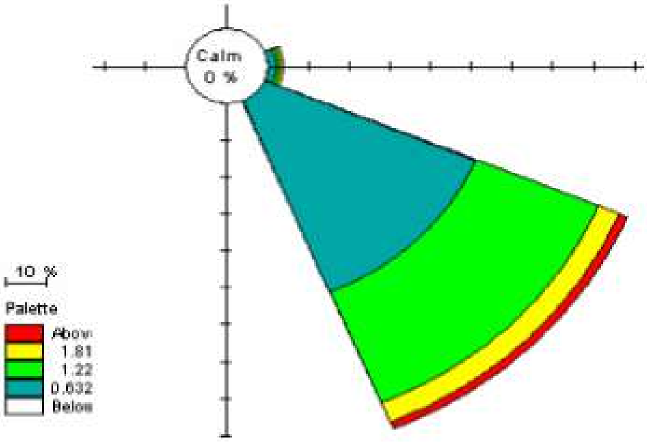


Fig 5-5: South west Monsoon

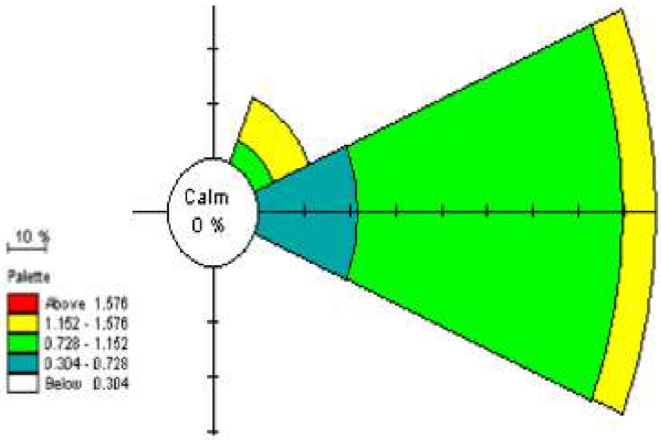


Figure 5-6: North east Monsoon

The model run was performed for assessing the following conditions

1.Existing sea bed conditions and assessing shoreline evolution for one year

2.Existing sea bed conditions with nourishment of 0.30 mcum and assessing shoreline evolution for one year

3. Existing sea bed conditions and assessing shoreline evolution for five years.

6.0 RESULTS & DISCUSSION

Initially the assessment made with one year shoreline evolution indicated that effect of erosion is felt up to a distance of 800m north side with a maximum value of 100m (Fig 6.1) and accretion of 120m up to a distance of 1000m south side (Fig 6.2). Hence it was assessed that nourishing the north side will prevent the erosion of north side .The shoreline studies for five years indicate accretion of about 265m and erosion of 250m (Fig 6.3). Hence the nourishment should be continuously made so as to balance the sediment transport

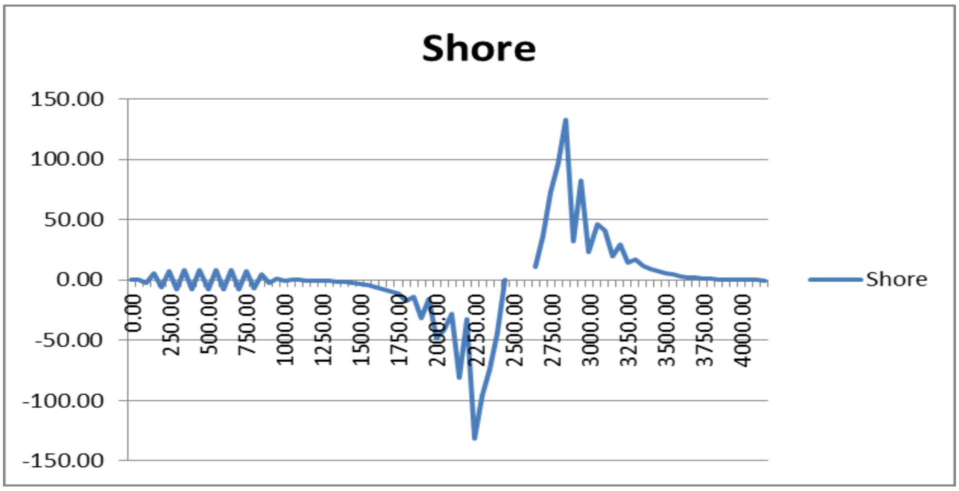


Figure 6-1: Shoreline evolution for 1 year

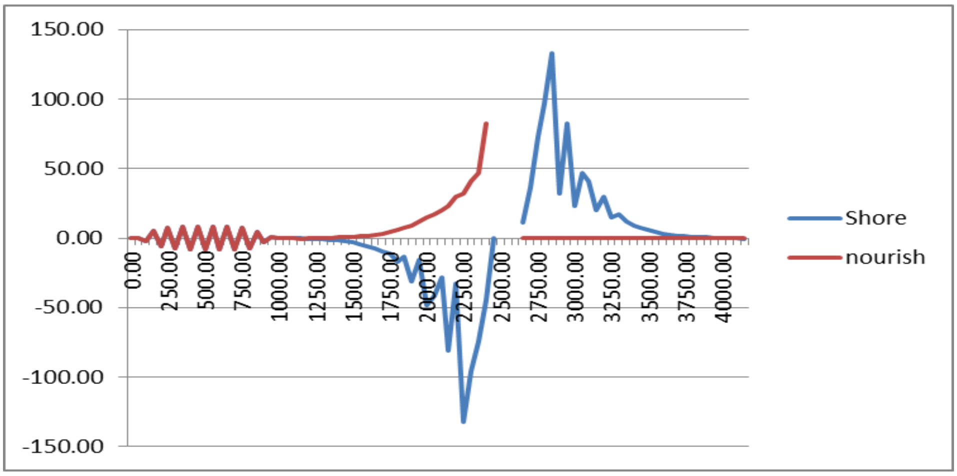


Figure 6-2: Shoreline evolution with nourishment for 1 year

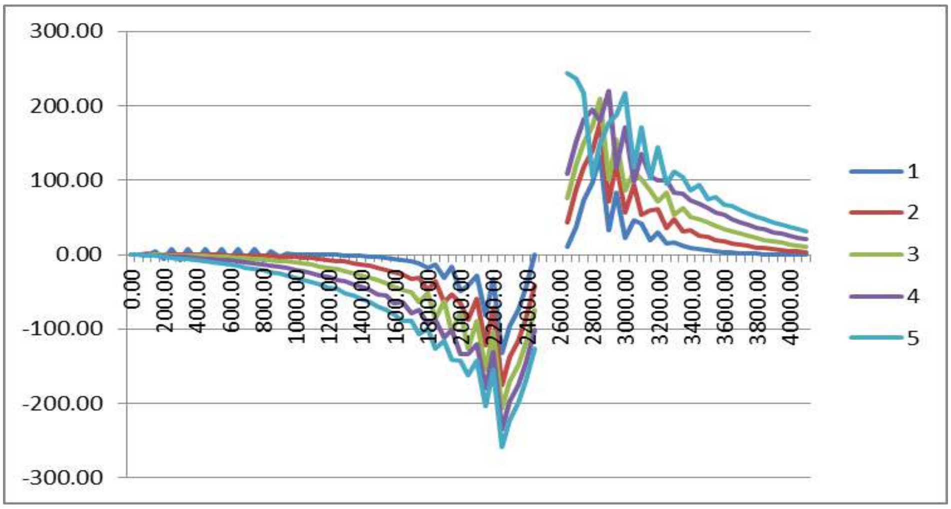


Figure 6-3: Shoreline evolution for 5 year

7.0 CONCLUSION

The estimation of and direction of littoral drift along the coast of Pondicherry was estimated. The net transport is about 0.35 * 10^6 $m^{3.}$ It is directed towards north. The shoreline evolution indicates a trend of erosion and accretion on north and south side of Port. Hence the nourishment of sand should be done so as to compensate the erosion.

REFERENCES

Kraus, N.C., and Harikai, S., 1983. Numerical model of shoreline change at Orai beach. Coastal Engineering, 7, pp. 1-28.

Suresh,P.K and Sundar,V (2009): "Simulation of Shoreline Changes and Estimation of Littoral Drift" HYDRO-2009,Central Water Power Research Station,Pune pp 303-308

Van Rijn, L.C (2001) "Longshore Sediment Transport" Delft Hydraulics

Hallermeier, R. J. (1981). A Profile Zonation for Seasonal Sand Beaches from Wave Climate. Coastal Engineering, Vol. 4, 253-277.

Annexure - XI

DREDGING IN THE HARBOUR BASIN AND NAVIGATIONAL CHANNEL PMC FOR PHASE I DEVELOPMENT OF PONDICHERRY PORT – ANALYSIS OF OFFSHORE WAVE CLIMATE FROM THE AVAILABLE SOURCES IN VIEW OF THE CAPITAL DREDGING WITH THE PRESENT BREAKWATERS

Document No: IC/18-19/OEC/PDY(PMC)/RSUN – 03

Client:

सत्यमेव जयते

Government of Puducherry

Port Department,

Government of Puducherry

Consultant:

Prof. R. Sundaravadivelu., FNAE

Institute Chair Professor,

Member BOG IIT Madras,

Department of Ocean Engineering,

IIT Madras, Chennai – 600 036.

CONTENTS

LIST OF FIGURES

LIST OF TABLE

1.0 INTRODUCTION

Port Department, Pondicherry has awarded PMC work to Prof. R. Sundaravadivelu, F.N.A.E, Department of Ocean Engineering for Phase I development of Pondicherry Port under Sagarmala scheme. This report highlights the details of Analysis of offshore wave climate from the available sources, Littoral transport estimate and analysis of shoreline profiles in view of the capital dredging with the present breakwaters

2.0 OBJECTIVE

The scope of the study includes,

- Analyses of offshore wave climate
- Littoral drift

3.0 MODELLING OF WAVES

The regional wind to wave model was carried out for the Indian Ocean with the aim of hind casting offshore wave characteristics using available wind data. The model simulates the growth, decay and transformation of wind-generated waves and swells in offshore and coastal areas.

3.1 Basic Formulation

Spectral Wave Model in MIKE 21 has two spectral formulations:

1. Directionally decoupled parametric formulation
2. Fully spectral formulation

Directionally decoupled parametric formulation is typically used for the assessment of wave conditions in nearshore and coastal areas which often involves transformation of known offshore wave statistics. Fully spectral formulation is usually used for simultaneous wave prediction and analysis on large and local scale. Although fully spectral formulation is computationally demanding, it is more accurate.

The governing equation is the wave action conservation equation formulated in either Cartesian co-ordinates or Spherical co-ordinates. In horizontal Cartesian co-ordinates, the conservation equation for wave action can be written as

$$\frac{\partial N}{\partial t} + \nabla.(\tilde{v}.N) = \frac{S}{\sigma}$$

where N ($\vec{x}$, σ, θ, t) is the action density, t is the time, $\vec{x}$ = (x, y) is the Cartesian co-ordinates, $\tilde{v}$ = (c_x, c_y, c_σ, c_θ) is the propagation velocity of a wave group in the four dimensional phase space $\vec{x}$, σ and θ, and S is the source term for the energy balance equation.

3.2 Model Domain and Bathymetry

In order to simulate waves in the Indian Ocean, a large domain, which ranges from 0° to 25° N Latitude and 60°E to 120°E Longitude was selected. An unstructured triangulated mesh is generated with varying sizes of triangles elements; 0.5° (Indian Ocean), 0.125° (Coastal).

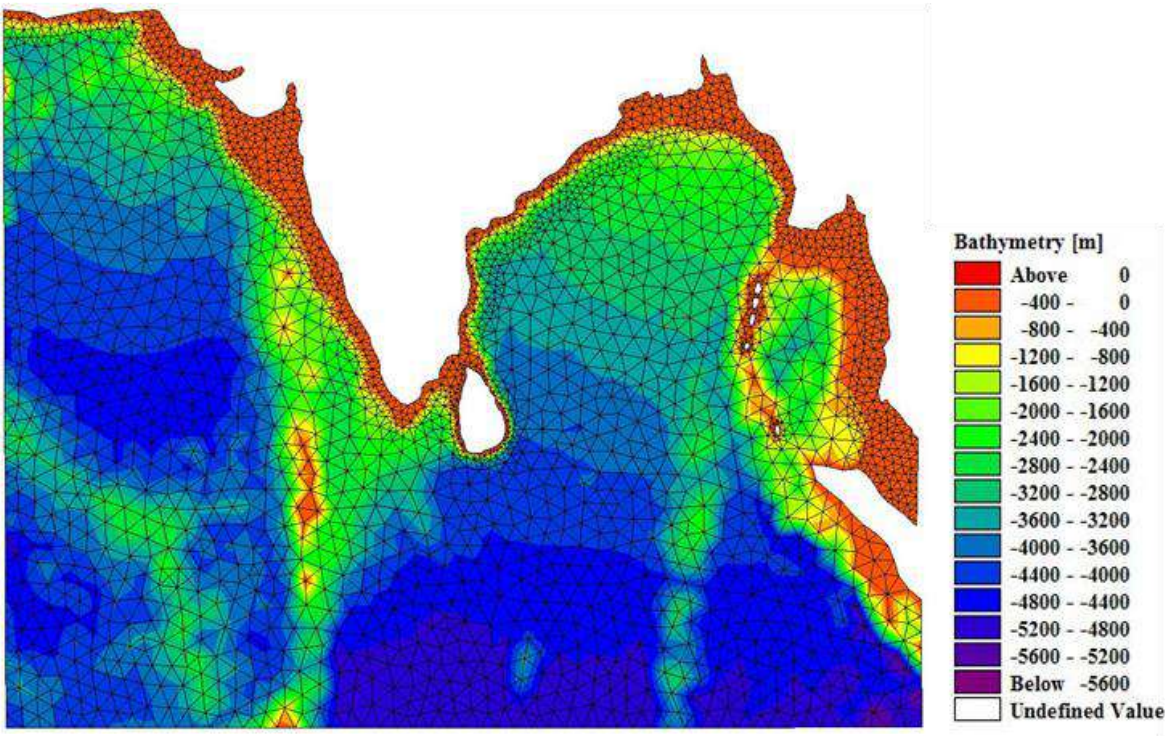


Figure 3-1: Model domain and Bathymetry of Indian Ocean

C-MAP data for deep water regions along Indian Ocean and bathymetry data sets of measured data are applied to shallow water regions in the study area, by interpolating them to each element in the flexible mesh bathymetry. The horizontal datum is referenced to World Geodetic System 1984 (WGS-84) and the vertical datum is referenced to Mean Sea Level (MSL). Figure 3.1 shows the model domain, flexible mesh bathymetry used for wave simulations in the Indian Ocean.

3.3 Wind Forcing

Wind is the basic input parameter for wave simulation. Successful wave hindcast and forecast depend on accurate wind fields deduced from meteorological models and analysis.

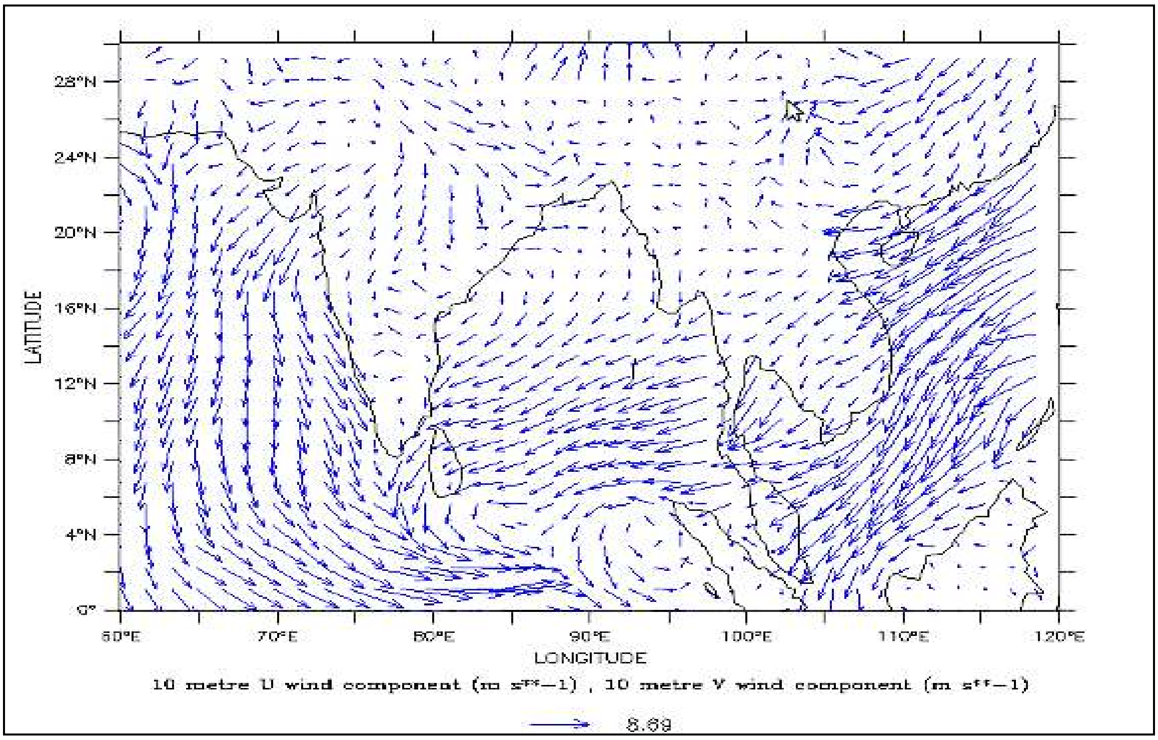


Figure 3-2:: 10 m U wind component vectors as on 01-Jan-2016

In the present study, wind data is obtained from the database of ECMWF's interim reanalysis (ERA-Interim). Wind data for Indian Ocean region (60°E to 120°E and 0° to 25°N) was collected from ECMWF database for regional wave modelling. The wind data was obtained for a period from January 2016 to December 2016 with spatial resolution of 0.25 × 0.25 degree and temporal resolution of 3 hours. The data for wind was obtained as U & V components of wind velocity (m/s) at 10 m height. U and V components of the wind velocity are calculated from decomposing the wind magnitude and direction along the two horizontal axes: x and y and the typical wind pattern is shown in Figure 3.2.

3.4 Model Validation

The wave rider buoy data of year 2016 deployed at water depth of 30m deployed off Puducherry coast was used for the validation of regional model. The modeled wave heights are in good agreement with observed wave heights with the correlation coefficient of 0.83 which proves the reliability of the model.(Fig 3.3).

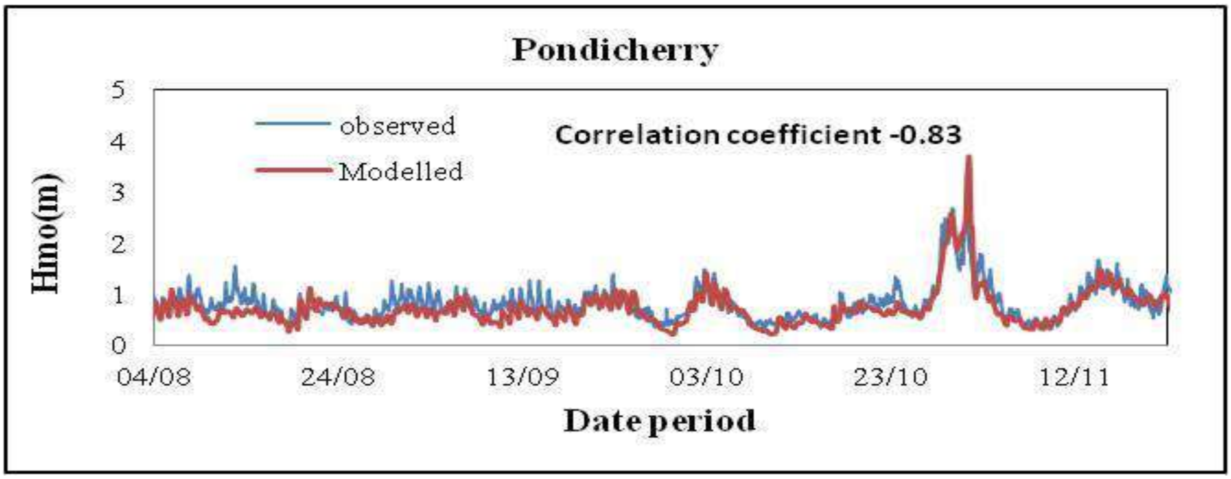


Figure 3-3:Comparison between modeled and observed wave heights at WRB location

4.0 GENERATION OF OFFSHORE WAVE CLIMATE

The wave climate was formulated using the wind-wave generation model. The generated data was initially calibrated with the measured data. From the validated model the wave climate off Puducherry Port is extracted for the period of one year at the location as shown .(Fig 4.1).

Figure 4-1:: Location of Offshore wave climate

4.1 Offshore waves

The wave rose diagram shows that the wave approaches the Puducherry from southeast by direction for about 9 months in a year and approaches from east direction for the rest of the year. The wave heights ranges from 0.3 m to 1.3 m during southwest monsoon with SE direction. The significant wave height during the NE monsoon period ranges from 0.3 m to 3 m. The wave periods ranges between 3 - 18 sec throughout the year. The characteristics of waves off Puducherry Port for the year 2017 are shown in Table 5.1.(Fig 5.1)

5. DREDGING PROPOSAL

The availability of depth all along the channel is around 3m depth. Hence in the present proposal dredging of approach channel (Fig 6.1) and harbor area are suggested for improving the port activity.The existing bed profile and post dredging profiles are furnished .(Fig 6.2). The wave height also had slight variation from 0.6m to 0.70m. The annual average wave height prevailing is 1.5m.The wave direction will be almost normal to the proposed project area for January to March it is the most critical one. During the months from April to September the wave directions will be from around 120^0 N and during October to December it will be around 60^0 N. Hence wave penetration will be more during January to March. The wave model observations indicates that wave height in the proposed scenario is in the range of 0.70 m which will not affect the required tranquility

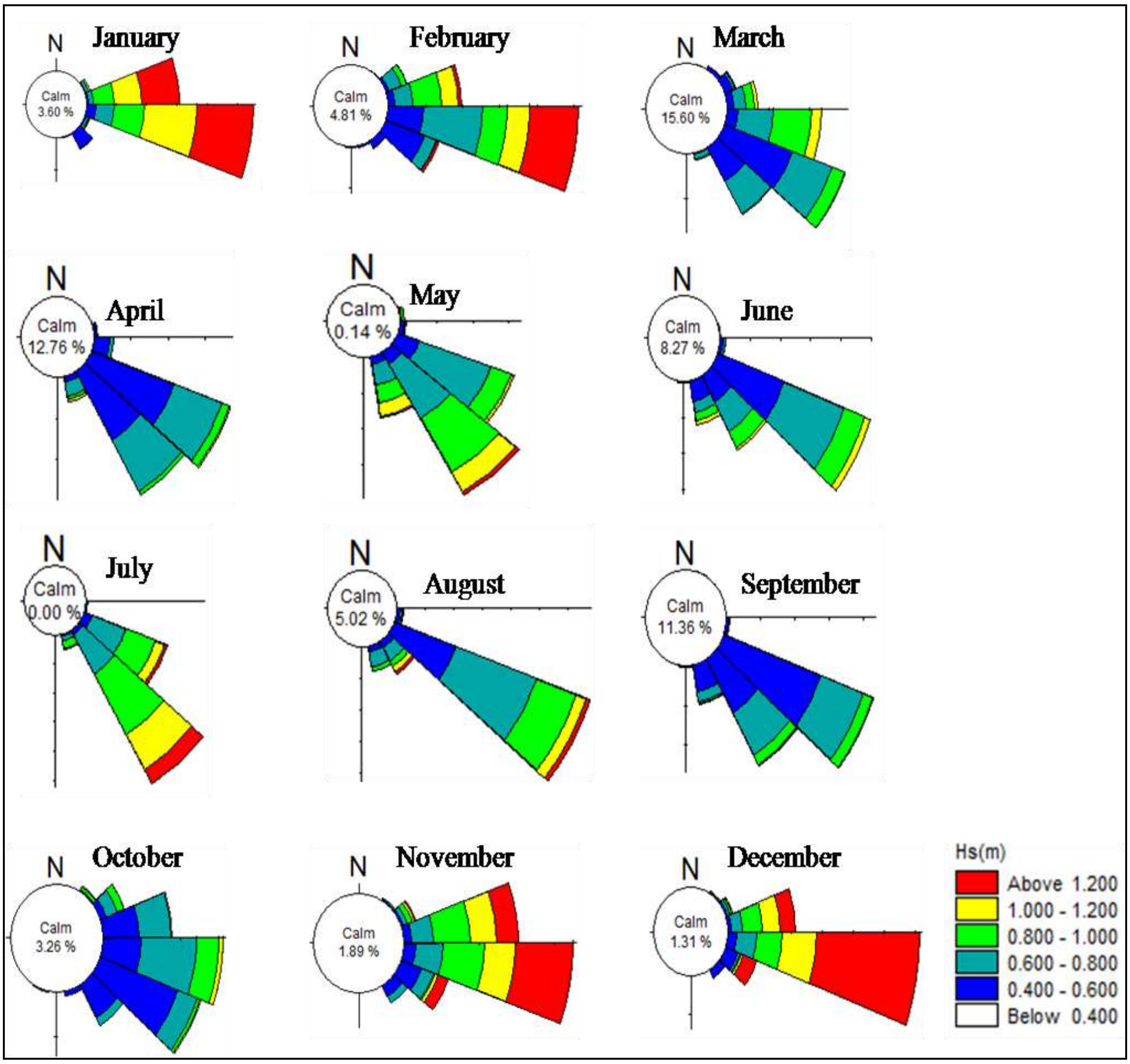


Figure 5-1: Monthly wave climate extracted off Puduchery coast

6. LITTORAL DRIFT

The coast of Pondycherry along Aryankuppam is highly sensitive to sediment dynamics. The coast experiences both south west and north east monsoon climate waves. The waves approach from south and south east directions from A[pril to September. During the months of Oct to March the dominant directions are east and north east. The waves after deformation approach the coast resulting formation of longshore current which results in sediment movement or littoral drift along the coast. The direction from April to September is towards north and southward rest of the mponth. The net drift is towards north and works out to 0.36 $*10^6$ m^3.

Table 5-1: Monthly wave statistics off Puducherry Port

Season		Hs			Tp			MWD		
		Max	Min	Mean	Max	Min	Mean	Max	Min	Mean
Fair weather	February	1.70	0.33	0.82	11.76	3.23	6.23	98.58	49.20	98.58
	March	1.18	0.25	0.61	14.29	2.86	7.31	150.50	50.60	115.60
	April	1.05	0.28	0.56	15.38	2.63	7.25	158.90	67.50	128.44
	May	1.16	0.44	0.77	14.29	3.33	7.06	157.50	83.00	136.21
Southwest Monsoon	June	1.07	0.31	0.63	18.18	3.23	9.32	171.60	101.30	129.61
	July	1.37	0.42	0.87	15.38	3.57	8.16	160.30	112.50	132.96
	August	1.34	0.33	0.69	16.67	2.50	9.41	164.50	92.80	126.58
	September	1.18	0.34	0.56	15.38	3.33	9.88	227.80	111.10	132.20
Northeast Monsoon	October	1.19	0.32	0.61	16.67	2.86	8.10	143.40	47.80	102.03
	November	2.26	0.39	0.97	15.38	3.23	7.03	136.40	50.60	97.26
	December	3.08	0.99	1.44	13.33	6.67	8.32	119.50	83.00	99.87
	January	1.74	0.34	1.02	11.11	3.13	6.98	184.20	59.10	97.35

Figure 6-1: Navigational channel for Pondicherry port

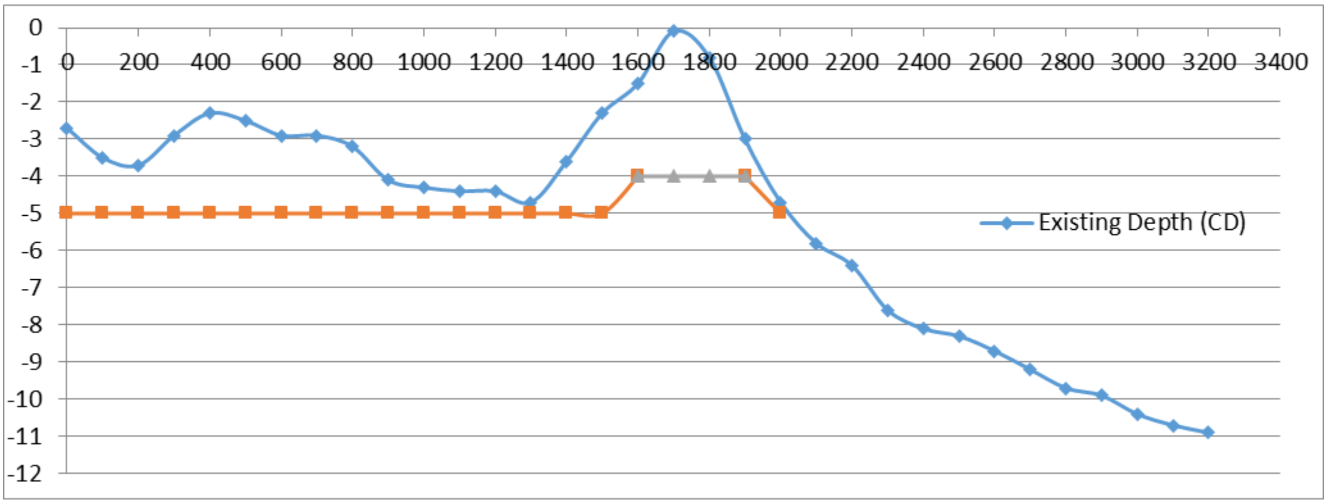


Figure 6-2: Existing & Proposed profile.

7. CONCLUSIONS

The present proposal is formulated in such a way that no protruding structural measures are to be designed. The wave climate prevailing in the post project conditions does not affect the tranquility. The dredging results in more draft and most of the time the basin is having good tranquility condition.