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No.PH-I/ MMCE/PROJ/2021 Dated:13.12.2021

To,

The Chief Manager(PPD),
Jawaharlal Nehru Port(JNPT),
Administrative Building, Sheva
Taluka - Uran Navi Mumbai- 400007

Subject : Mathematical Model Studies for Assessment of Wave Tranquility for the Development of Modified Final Layout for the Proposed Port at Vadhavan, Maharashtra .

Sir

Enclosed please find Technical Report No. 5971 titled 'Mathematical Model Studies for Assessment of Wave Tranquility for the Development of Modified Final Layout for the Proposed Port at Vadhavan, Maharashtra ' for your kind perusal and comments. The receipt of the same may please be acknowledged..

Thanking you,

Yours faithfully,

(Dr. Prabhat Chandra)
Scientist 'E'

A. REPORT DOCUMENTATION SHEET

Technical Report No. 5971	Date: November 2021

Title: Mathematical Model Studies For Assessment Of Wave Tranquility For The Development Of Modified Final Layout For The Proposed Port At Vadhavan, Maharashtra

Officers Responsible for Conducting the Studies :

Shri A.S.Borkar, Scientist 'C', under the overall supervision of Dr. Prabhat Chandra, Scientist "E".

Name and Address of Organization Conducting the Studies :

Mathematical Modelling in Coastal Engineering, Coastal and Offshore Engineering Laboratory, Central Water and Power Research Station, Pune, India.

Name and Address of Authority Sponsoring the Studies

The Chief Manager(PPD), Jawaharlal Nehru Port(JNPT),Mumbai -400707

Synopsis

Jawaharlal Nehru Port Trust (JNPT) have a proposal for development of a satellite port at Vadhavan, located on the west coast of India . The port is being planned with a 10.3 km long length of breakwater. M/s JNP requested CWPRS to carry out the various hydraulic model studies to finalize the conceptual layout for the proposed port at Vadhavan. The mathematical model studies for assessment of wave tranquility for the development of proposed port at Vadhavan, Maharashtra were conducted at CWPRS in two stages viz., estimation of nearshore wave climate using spectral wave model MIKE 21-SW to derive near-shore wave climate at -24m depth and, assessment of wave tranquility in the Port basin using MIKE21–BW model. The detailed wave tranquility studies and recommendations for the Initial and the Final layouts were submitted to the project authorities. The JN Port Official further requested for additional model studies for the revised master plan layout with and without North Breakwater .

The preliminary wave tranquility studies carried out for hydrodynamic and wave tranquility indicated that the revised master plan layout with North Breakwater was not suitable from the considerations of hydrodynamic, siltation and wave. Subsequently, revised Final modified master plan Layout was proposed by JN port officials and studies are carried out for the proposed port layout. The predominant wave directions at -24 m depth were found to be from SW, WSW, West, WNW and NW directions. Maximum significant wave height would be of the order of 3.0m. The wave tranquility studies using MIKE-BW for the Final modified master plan Layout with incident significant wave heights of, 2.5m from West, 1.5m from WNW and 1.5m from NW direction indicated that significant wave heights in the port basin are generally in the range of 0.2m to 1.0m . Higher significant wave height of about 1.0m is observed at CT07 Jetty. The downtime will not exceed 10 to 12 days in a year.

Keywords

Port, Mathematical Model, Wave transformation, Wave tranquility

GOVERNMENT OF INDIA
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MATHEMATICAL MODELLING FOR COASTAL ENGINEERING

TECHNICAL REPORT No. 5971

NOVEMBER 2021

MATHEMATICAL MODEL STUDIES FOR ASSESSMENT OF WAVE TRANQUILITY FOR THE DEVELOPMENT OF MODIFIED FINAL LAYOUT FOR THE PROPOSED PORT AT VADHAVAN, MAHARASHTRA.

A. K. AGRAWAL
DIRECTOR

MATHEMATICAL MODEL STUDIES FOR ASSESSMENT OF WAVE TRANQUILITY FOR THE DEVELOPMENT OF MODIFIED FINAL LAYOUT FOR THE PROPOSED PORT AT VADHAVAN, MAHARASHTRA.

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MATHEMATICAL MODEL STUDIES FOR ASSESSMENT OF WAVE TRANQUILITY FOR THE DEVELOPMENT OF MODIFIED FINAL LAYOUT FOR THE PROPOSED PORT AT VADHAVAN, MAHARASHTRA

TECHNICAL REPORT NO. 5971 **NOVEMBER 2021**

1. INTRODUCTION

Jawaharlal Nehru Port Trust (JNPT) have a proposal for development of a satellite port at Vadhavan, located on the west coast of India (Fig.1). The port is being planned with a 10.3 km long length of breakwater. M/s JNP requested CWPRS vide their letters JNP/PPD/Vadhavan/2017/422 and JNP/PPD/Vadhavan/2017/426 both dated 10th March 2017 to carry out the various hydraulic model studies to finalize the conceptual layout for the proposed port at Vadhavan. JNPT referred mathematical model studies to CWPRS to examine the adequacy of the proposed Port layout to provide desired wave tranquility in the Port. The mathematical model studies for assessment of wave tranquility for the development of proposed port at Vadhavan, Maharashtra were conducted at CWPRS in two stages viz., estimation of nearshore wave climate using spectral wave model MIKE 21-SW to derive near-shore wave climate at -24m depth and, assessment of wave tranquility in the Port basin using MIKE21–BW model. The detailed wave tranquility studies and recommendations for the Initial and the Final layouts as shown in Figs. 2A and 2B and were submitted to the project authorities vide Technical report No.5558 of January 2018 respectively and a short note on proposed Phase-I construction of Breakwater was submitted in February 2019.

The Chairman, JN Port along with senior Port officials and their consultants subsequently visited CWPRS on 12th February 2021 for discussions on various aspects associated for the development of port at Vadhavan. During the discussion, the layout initially proposed with current deflecting wall reported earlier in the report No. 5558 was discussed and JN Port officials requested CWPRS to assess wave tranquility for the revised modified layout submitted without current deflecting wall and with North Breakwater (approximate length 3.5 km) as per Fig. 3A to get better tranquility during non monsoon season for incident waves from North West direction. The proposed revised layout has reclamation shifted near to the breakwater. JN Port also proposed another layout without the North breakwater with same configuration of reclamation and main breakwater Fig. 3B.These layouts have Jetty very near to the mouth opening which is prone for Westerly and North Westerly waves. Based on the new layouts proposed by the project

authority, studies for revised mathematical model studies for wave tranquility were conducted for master plan layout; with and without North breakwater.

The tidal hydrodynamic studies in CWPRS indicated that the above master plan layout proposed with North breakwater would not be suitable from the considerations of currents and siltation. These observations were also discussed in VC meeting held between JN Port Officials, Consultants and CWPRS on 20th July 2021 and it was decided unanimously that the North breakwater may be excluded from the said preferred master plan layout.

Further, during the VC meetings held on 2nd & 14th August 2021, the consultant submitted revised Final modified master plan Layout (Fig.4A) and Phase-I layout plan (Fig.4B). The Final master plan layout is having Jetty facility slightly in the shadow of breakwater as compared to the earlier proposed modified layout. In the present report, the detailed wave tranquility studies for the revised master plan layout with and without North Breakwater have been described as well wave tranquility studies for Final modified master plan and Phase-I studies are described.

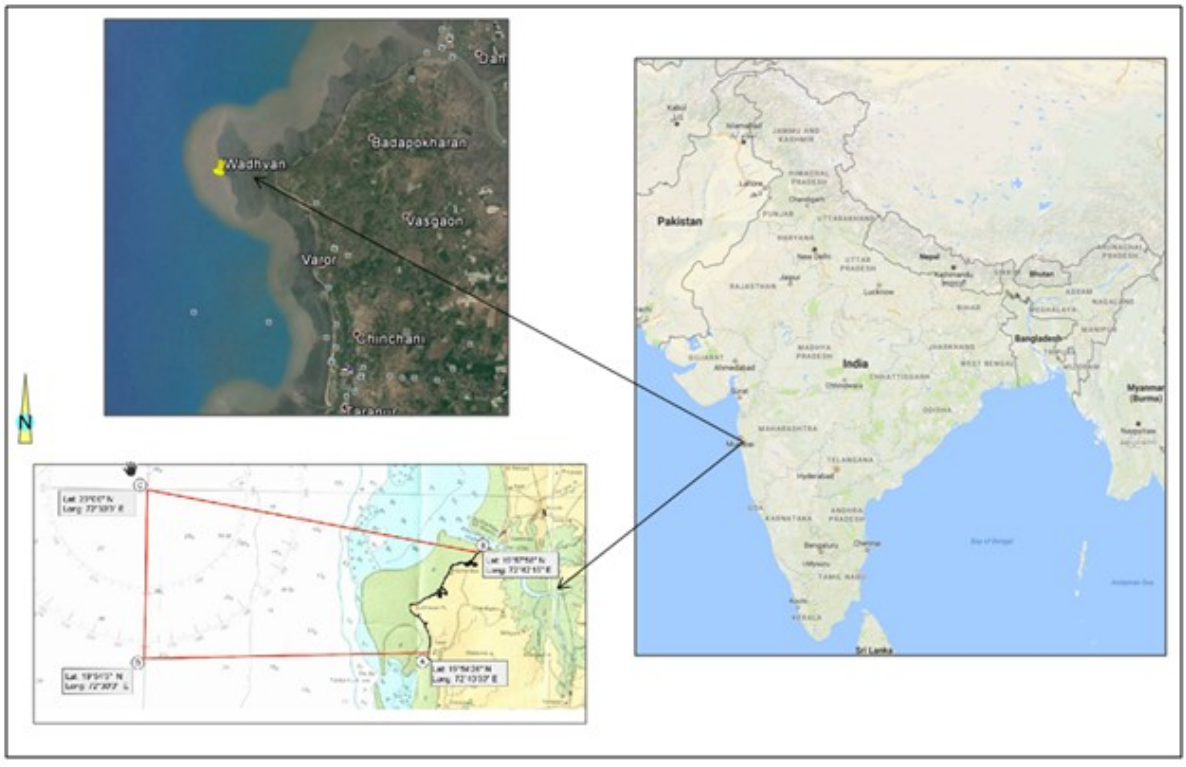

Fig.1 : Location Map of Vadhavan, Maharashtra

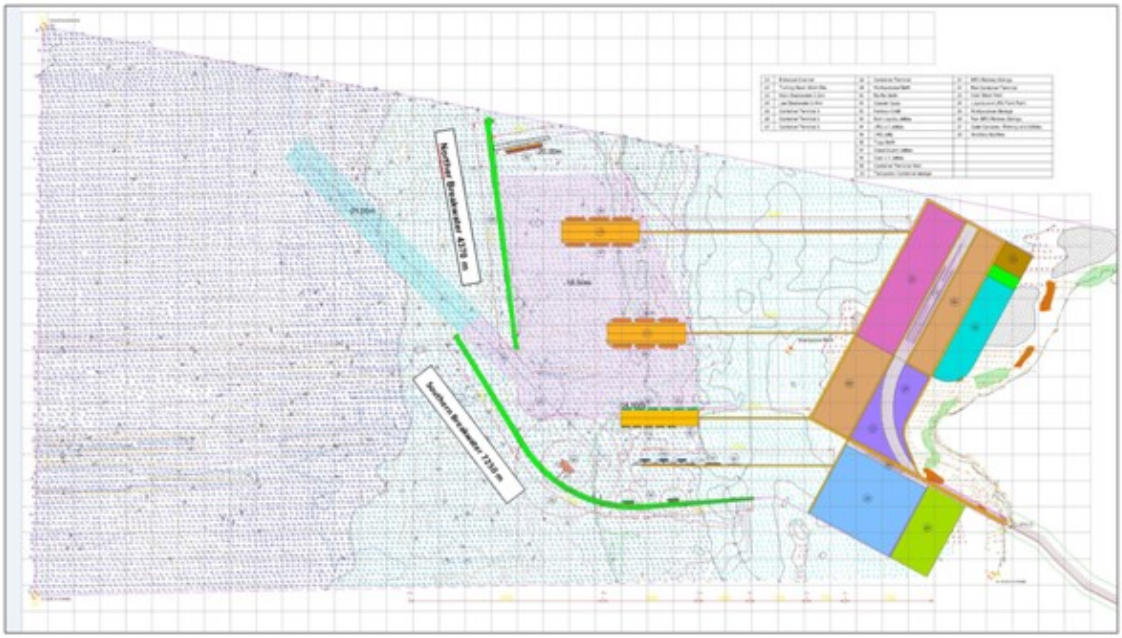

Fig.2A: Proposed Initial Port Layout at Vadhvan

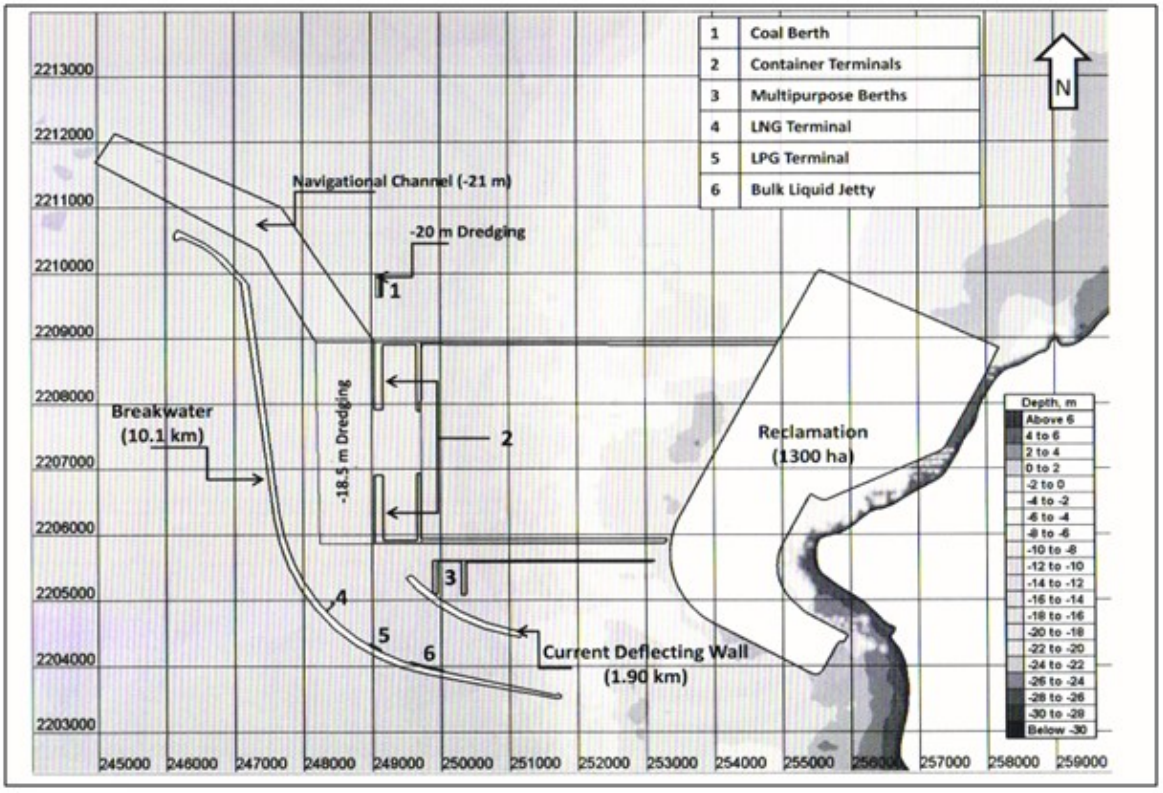

Fig.2B: Proposed Final Port Layout at Vadhvan

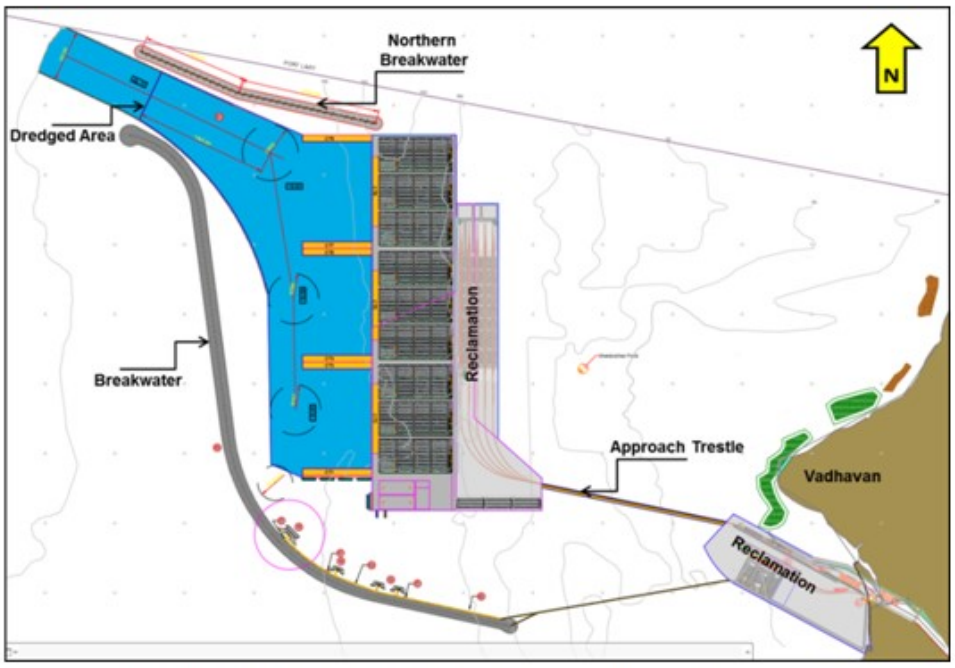

Fig.3A: Proposed Modified Master Plan Layout at Vadhvan with North Breakwater

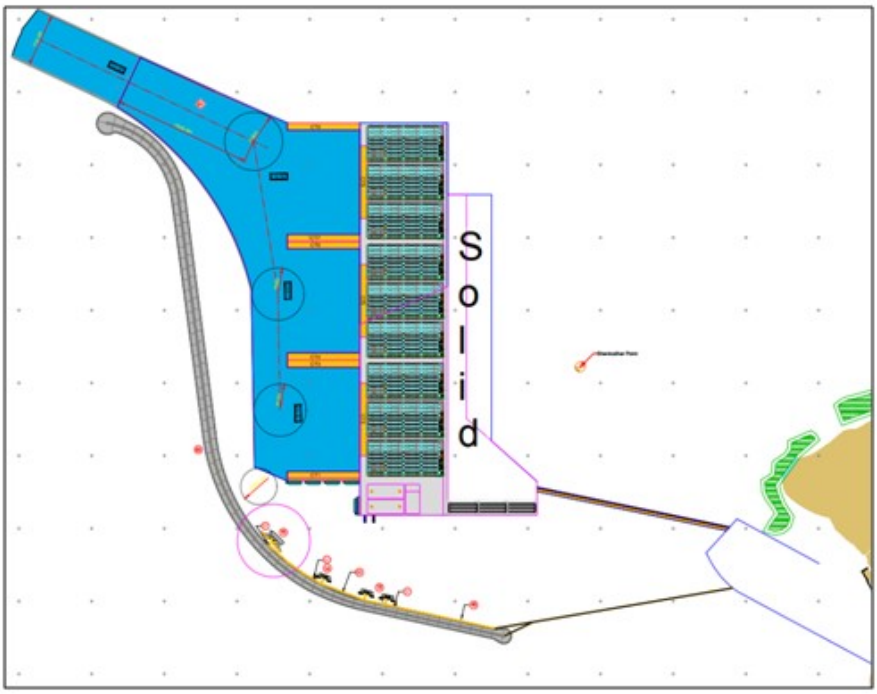

Fig.3B: Proposed Modified Master Plan Layout at Vadhvan without North Breakwater

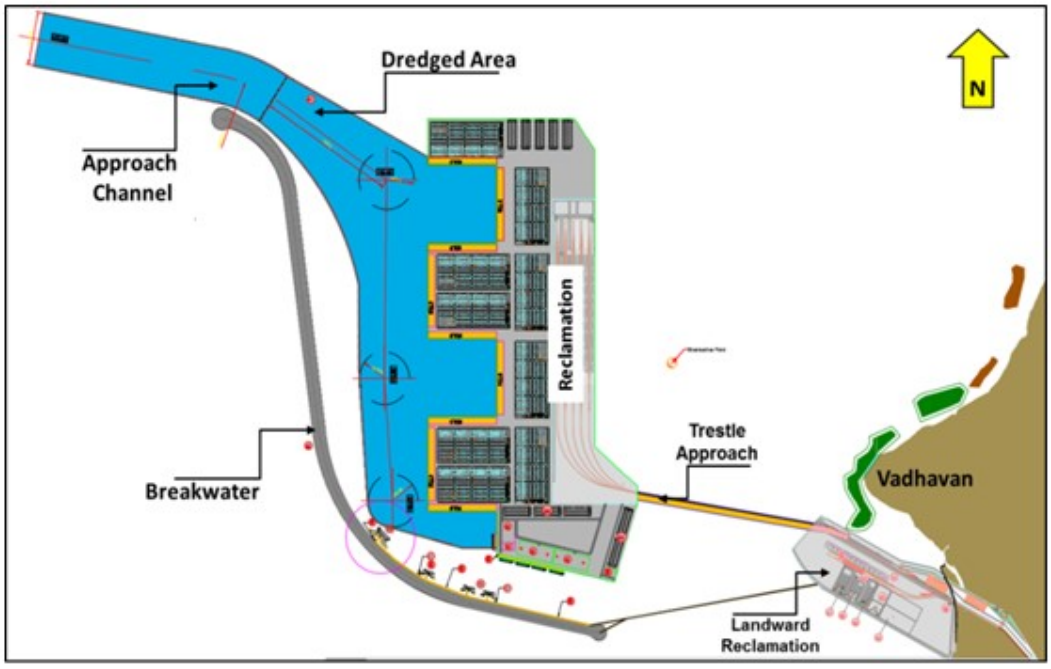

Fig.4A: Proposed Final Modified Master Plan Layout at Vadhvan

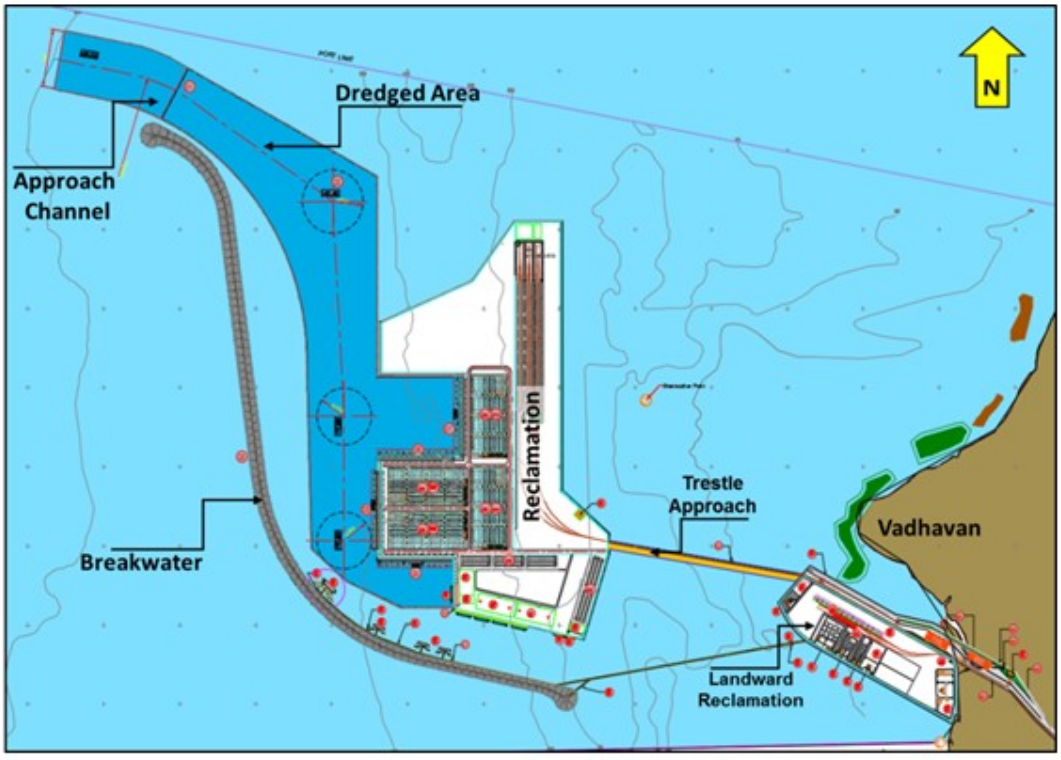

Fig.4B: Proposed Final Modified Phase-I Layout at Vadhvan

2. SCOPE OF STUDIES

Mathematical model studies for the proposed for the revised master plan layout with and without North Breakwater as well studies for Final modified master plan and Phase-I studies for development of Port at Vadhvan, were carried out in two stages:

i) Transformation of wave height and wave direction while traveling from deep waters to -24 m depth contour near the Port using mathematical model MIKE21-SW.

ii) Simulation of wave propagation in the Port to compute wave heights in the Port area and check the adequacy of the proposed Port layout using mathematical model MIKE21-BW.

3. SITE CONDITIONS

3.1 Wave Data In Deep Sea

The offshore wave data available at CWPRS data bank, at a location at 19.17^{0}N latitude and 71.00^{0}E longitude, in deep waters off Vadhavan for a period from 28th May 1999 to 30th April 2012 were analyzed. This wave data information was considered at the offshore end of the model limits. The frequency distribution of wave heights for the entire year for the offshore data was obtained and is given in Table 1. The corresponding wave rose diagram is presented in Fig.5.`

TABLE 1 :
PERCENTAGE OCCURRENCE OF WAVE HEIGHT & WAVE DIRECTION OFF VADHAVAN FOR ENTIRE PERIOD (JAN-DEC)

Wave Height (m)	0.-0.5	0.5-1	1-1.5	1.5-2	2-2.5	2.5-3	3-3.5	3.5-4	4-4.5	Total
Directions (Deg)										
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
22.5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
45	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
67.5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
112.5	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.02**
135	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
157.5	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.02**
180	1.76	0.53	0.03	0.00	0.00	0.00	0.00	0.00	0.00	**2.32**
202.5	7.20	3.44	0.24	0.02	0.00	0.00	0.00	0.00	0.00	**10.89**
225	4.38	12.60	5.99	1.02	0.15	0.08	0.07	0.02	0.00	**24.30**

247.5	3.11	21.55	18.57	7.93	2.76	0.87	0.32	0.13	0.06	**55.30**
270	0.14	1.09	1.44	0.63	0.09	0.02	0.00	0.00	0.00	**3.40**
292.5	1.17	1.39	0.19	0.01	0.01	0.00	0.00	0.00	0.00	**2.77**
315	0.33	0.20	0.07	0.00	0.01	0.00	0.00	0.00	0.00	**0.61**
337.5	0.17	0.06	0.01	0.00	0.00	0.00	0.00	0.00	0.00	**0.24**
360	0.08	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.15**
Total	**18.37**	**40.92**	**26.53**	**9.61**	**3.01**	**0.97**	**0.38**	**0.14**	**0.06**	**100.00**

From the Table1 and Fig.4, it can be observed from the wave climate during the entire year that the predominant wave directions in deep water are from SSW, SW,WSW,West,WNW and NW directions with 11%, 24% , 55% , 4%, 3%, and 1% occurrence respectively with the maximum wave heights of the order of 4.5m. However, its percentage of occurrence is very small. From NW direction (315 degrees), significant waves of 1.5 m are observed but the percentage occurrence is very less i.e. 0.07% . As the proposed layout is exposed to waves from NW direction, the project authority proposed 1.5 m wave height to be considered in the wave tranquility studies.

In the absence of measured wave data of at least one year near the site of development, these deep water wave data were transformed by MIKE- SW wave model to get the nearshore wave climate at -24m depth near the site of proposed port at Vadhavan.

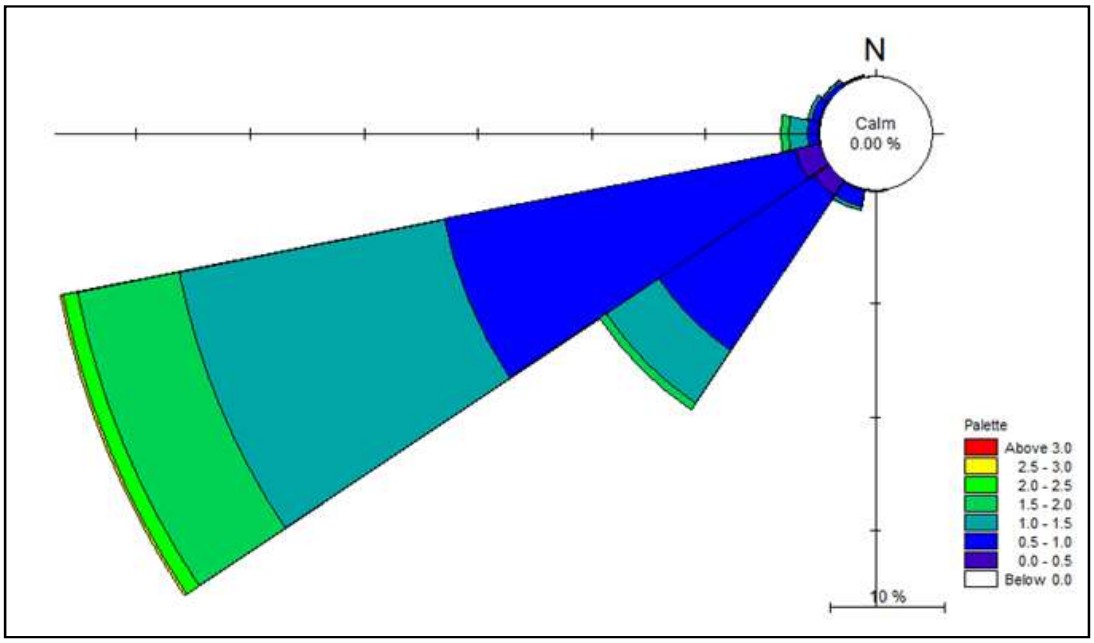

Fig.5: Offshore rose diagram at Vadhvan at -60 m depth (UKOMO)

3.2 Tidal Levels

The tidal levels are given in Table 2 as below:

TABLE 2 :Tidal Levels at Vadhvan

Tidal Levels	
Highest Water level (HWL)	+5.50 m
Mean Highest Water Spring (MHWS)	+5.00 m
Mean Highest Water Neap (MHWN)	+4.70 m
Mean Lowest Water Neap (MLWN)	+1.00 m
Mean Lowest Water Spring (MLWS)	+0.16m
Lowest Low Water	0.00

Tidal levels are taken from the feasibility report given by the project authority.

4. MODELLING TECHNIQUES

Mathematical models MIKE21-SW and MIKE21-BW were used for assessment of nearshore wave field and wave disturbance in the Port respectively. Brief description of these models is given below.

4.1 MIKE21-SW Model

As waves travel from deep sea to shallow coastal waters, they undergo changes in direction and height due to the processes of refraction and shoaling. The simulation of wave transformation from deep to shallow coastal waters was carried out using MIKE 21- SW model.

The model simulates the growth, decay and transformation of wind-generated waves and swells in offshore and coastal areas. It involves directional decoupled parametric formulation, which is based on a parameterisation of the wave action conservation equation. The parameterisation is made in the frequency domain by introducing the zeroth and first moment of the wave action spectrum. The discretisation of the governing equation in geographical and spectral space is performed using cell-centerd finite volume method. In the geographical domain, an unstructured mesh technique is used. The time integration is performed using a fractional step approach where a multi-sequence explicit method is applied for the propagation of wave action.

4.2 MIKE21-BW Model

Mathematical model MIKE21-BW was used for studying the wave disturbance in the port. The model is based on time dependent Boussinesq equations of conservation of mass and

momentum obtained by integrating the three-dimensional flow equations without neglecting vertical acceleration. They operate in the time domain, so that irregular waves can be simulated. These equations include nonlinearity as well as frequency dispersion. The frequency dispersion is included in the flow equations by taking into account the effect of vertical acceleration and the curvature of stream lines on pressure distribution. The model simulates the processes of shoaling, refraction, diffraction from breakwater tips and bed friction.

5.0 WAVE TRANSFORMATION USING MIKE21-SW MODEL

In the absence of measured wave data at the site, the nearshore wave climate required for the wave tranquility studies was derived by transforming the offshore wave data available at CWPRS data bank using MIKE-21 SW model. Model area considered for SW model is shown in Fig.6. Bathymetry in the model area of about 120 km by 170 km was schematized. The model was run to obtain nearshore wave climate at the Inshore Point in -24 m depth for entire year [Table 3]. The corresponding wave rose diagram is shown in Fig.7.

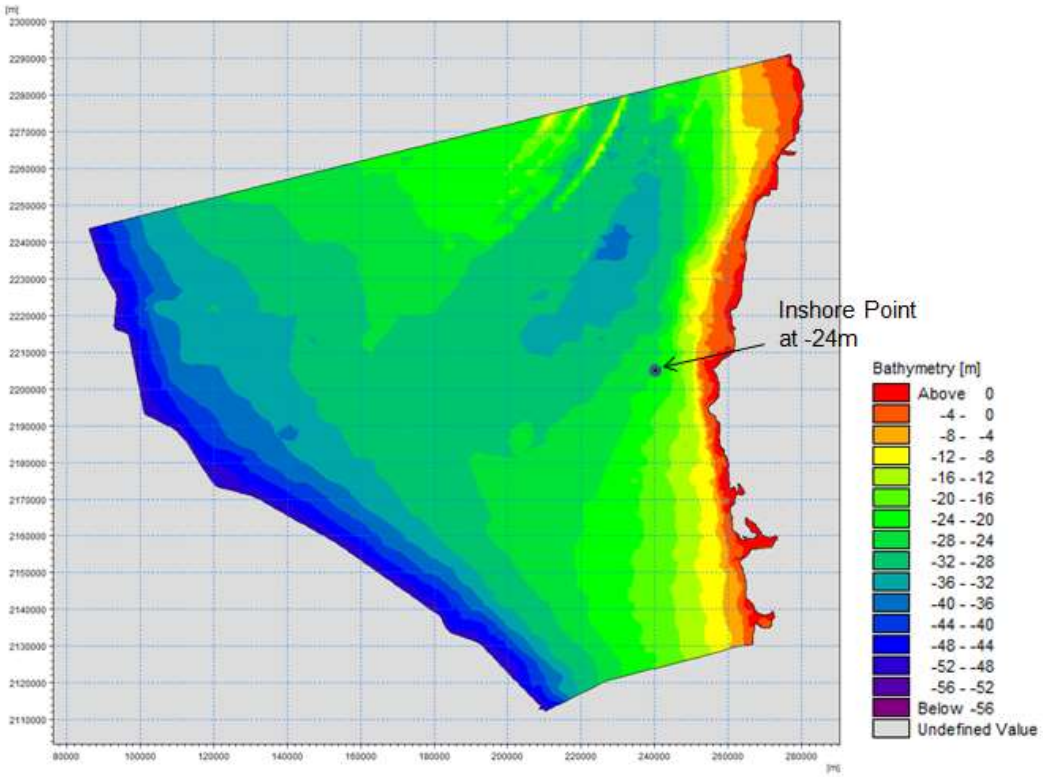

Fig.6: Model Area for Wave Transformation Studies with MIKE 21 SW Model

TABLE 3 :
Percentage Occurrence of Wave Height & Direction Near VADHAVAN in -24 m Depth during Entire Year (January-December)

Wave Height (m)	0.5-1	1-1.5	1.5-2	2-2.5	2.5-3	3-3.5	3.5-4	4-4.5	Total
Directions (Deg)									Calm 54.49%
180 (S)	0.35	0	0	0	0	0	0	0	**0.35**
202.5 (SSW)	1.11	0	0	0	0	0	0	0	**1.11**
225 (SW)	5.28	0.21	0.63	0.35	0	0	0	0	**6.47**
247.5 (WSW)	2.13	7.61	13.27	5.35	0.35	0	0	0	**28.71**
270 (W)	3.27	1.9	0.49	0	0	0	0	0	**5.66**
292.5 (WNW)	3.07	0.07	0	0	0	0	0	0	**3.14**
315 (NW)	0.07	0	0	0	0	0	0	0	**0.07**
Total	**15.28**	**9.79**	**14.39**	**5.7**	**0.35**	**0**	**0**	**0**	**100.00**

From Table 3, it is seen that the predominant directions at -24 m depth are SW, WSW, West, and WNW direction.

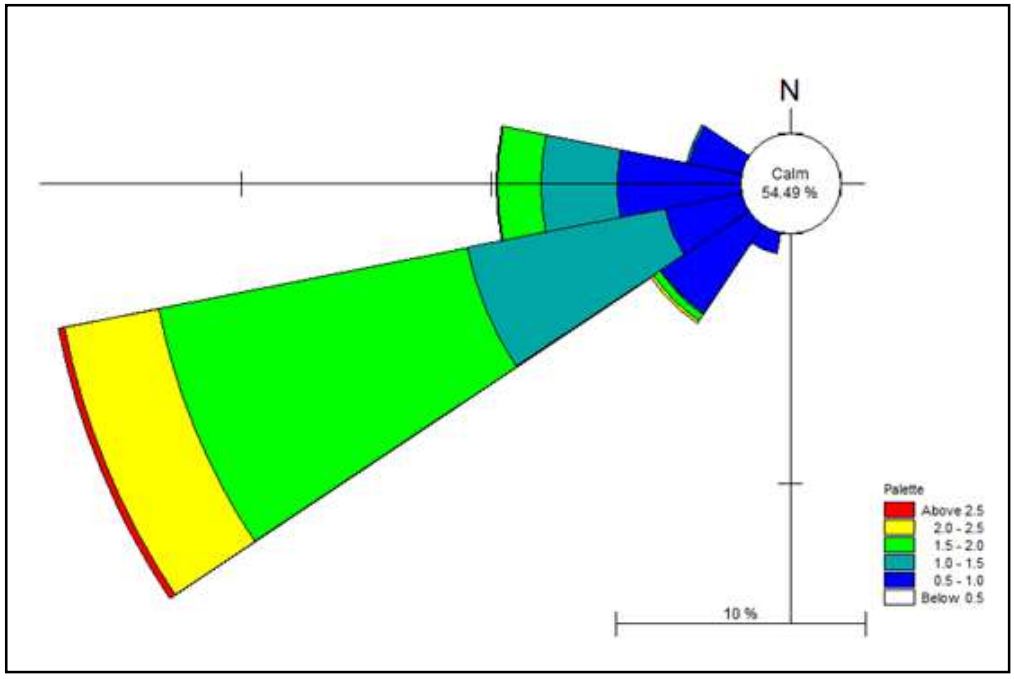

Fig.7: Inshore Rose Diagram at Vadhvan (at -24m)

On the basis of the wave transformation studies, the predominant significant wave height conditions were considered as per Table 4 for the wave tranquility studies.

TABLE 4 : Input Wave Conditions for MIKE21-BW Model

Wave direction (deg.N)	Significant Wave height(m)
270 (W)	2.5
292.5(WNW)	1.5
315 (NW)	1.5
Peak wave period Tp: 10 sec	

6. WAVE TRANQUILITY STUDIES

The present studies include the wave tranquility studies for the following layouts / conditions for the predominant incident waves from West, WNW and NW directions:

1) Wave tranquility Studies for proposed Modified Master Plan Layout at Vadhvan with North Breakwater (Fig.3A).
2) Wave tranquility Studies for proposed Modified Master Plan Layout at Vadhvan without North Breakwater (Fig.3B).
3) Wave tranquility Studies for proposed Final Modified Master Plan Layout at Vadhvan (Fig.4A).
4) Wave tranquility Studies for proposed Modified Final Phase-I Port Layout at Vadhvan (Fig.4B).

The detailed studies have been described in subsequent paragraphs.

6.1 Permissible Wave Heights

The permissible wave disturbance at the berthing place depends on the ship size, mooring and berthing system, the method of loading and unloading used at berth and on orientation of the berth with respect to wave direction etc. The acceptable wave heights for different types of commercial vessels and small crafts recommended by the International Association of Ports and Ports are given in Table 5.

TABLE 5 :
ALLOWABLE WAVE HEIGHTS NEAR THE BERTHS
(IPA Norms)

Type of vessels	Approximate acceptable wave heights - H_s(m)	
	Incident angle 0^0 (head on)	Incident angle (45^0 – 90^0)
Conventional general cargo vessels	1.0	0.8
Container vessels	0.5	0.4
Dry bulk carrier 30-100,000 DWT (loading)	1.5	1.0
Dry bulk carrier 30-100,000 DWT (unloading)	1.0	0.8 – 1.0
Tankers 30-200,000 DWT	1.5 - 2.5	1.0 – 1.2

As per IS 4651 (Part V), for commercial ships, the wave disturbance within the port should not exceed the tranquility conditions given in Table 6.

TABLE 6 :
ALLOWABLE WAVE HEIGHTS NEAR THE BERTHS
(IS-4651)

Type of vessels	Approximate acceptable wave heights - H_s(m)	
	At berth	Turning circle
General cargo	0.65	0.90
Bulk cargo	0.90	1.20
Container cargo	0.65	1.20
Dredgers	-	0.45 – 2.0

In view of above considerations, permissible wave height of 0.65 m at the berths (Container Jetty) and a permissible limit of 1.0 m wave height in the turning circle for 100,000 DWT class bulk carriers which are brought at the berths were considered for the wave tranquility studies.

6.2 Wave Propagation in the Proposed modified Master Plan Layout at Vadhvan with North Breakwater

Wave propagation inside the Port was simulated for the modified master plan Layout with North breakwater proposed by Project Authorities with change in dredging and alignment of jetty as shown in Fig.2A and Fig 8. From the results of nearshore wave transformation (Table 3), wave conditions shown in Table 4 were considered for simulation of wave propagation in the port using MIKE21-BW model. Wave propagation was simulated for the waves incident from West, WNW and NW directions. The proposed final Port layout consists of breakwater of length 10.3 Km.. The bathymetry plot for the port area is shown in Fig.8. Area of 15 km by 15 km was discretised with a grid size of 5m by 5 m. Simulations were carried out for the tidal level 5.55 m corresponding to HWL. Wave height distribution in the port basin for waves coming from West, WNW and NW direction respectively are shown in Figs.9 to 11 for peak wave period of 10 sec. From these figures, it is seen that wave heights in the port basin are generally in the range of 0.2 m to 0.85 m for wave incident from West, WNW and NW directions with peak wave period of 10 sec.

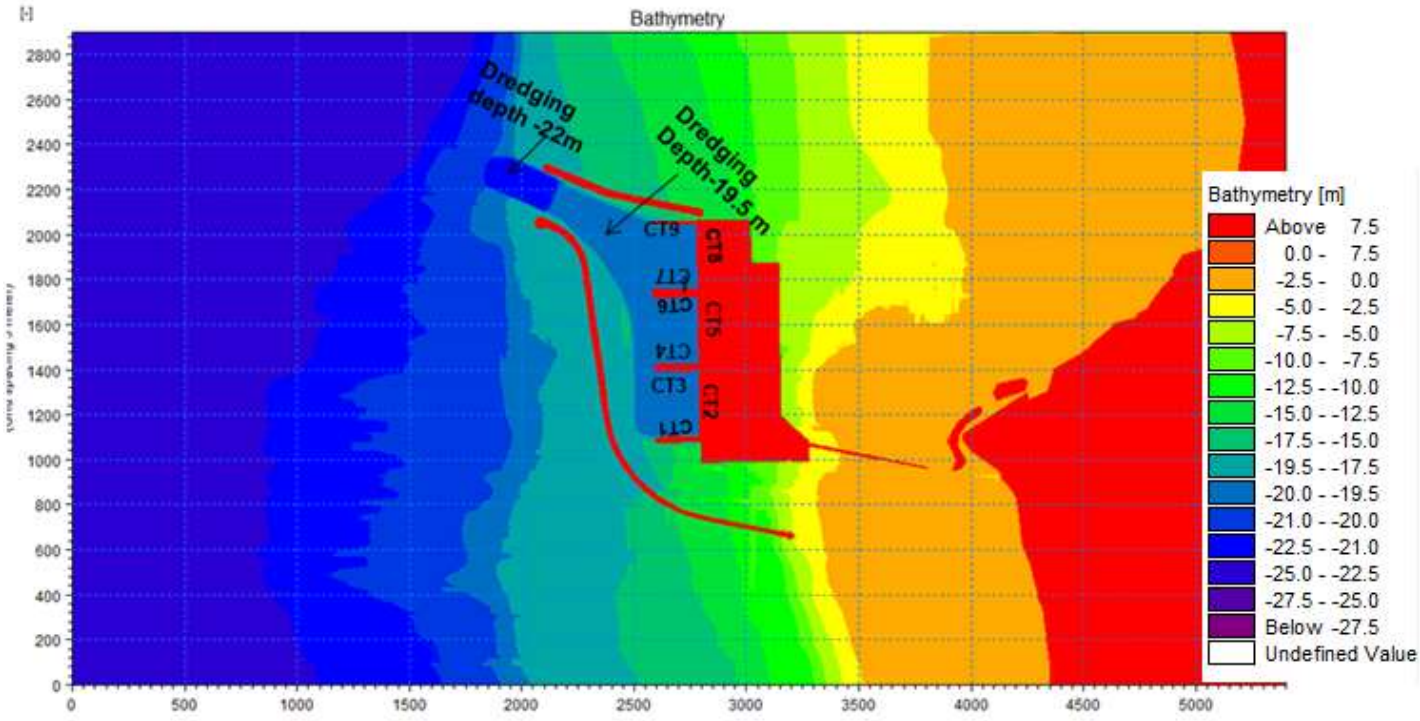

Fig. 8: Bathymetry of study area for modified Master Plan Layout with North Breakwater at Vadhvan

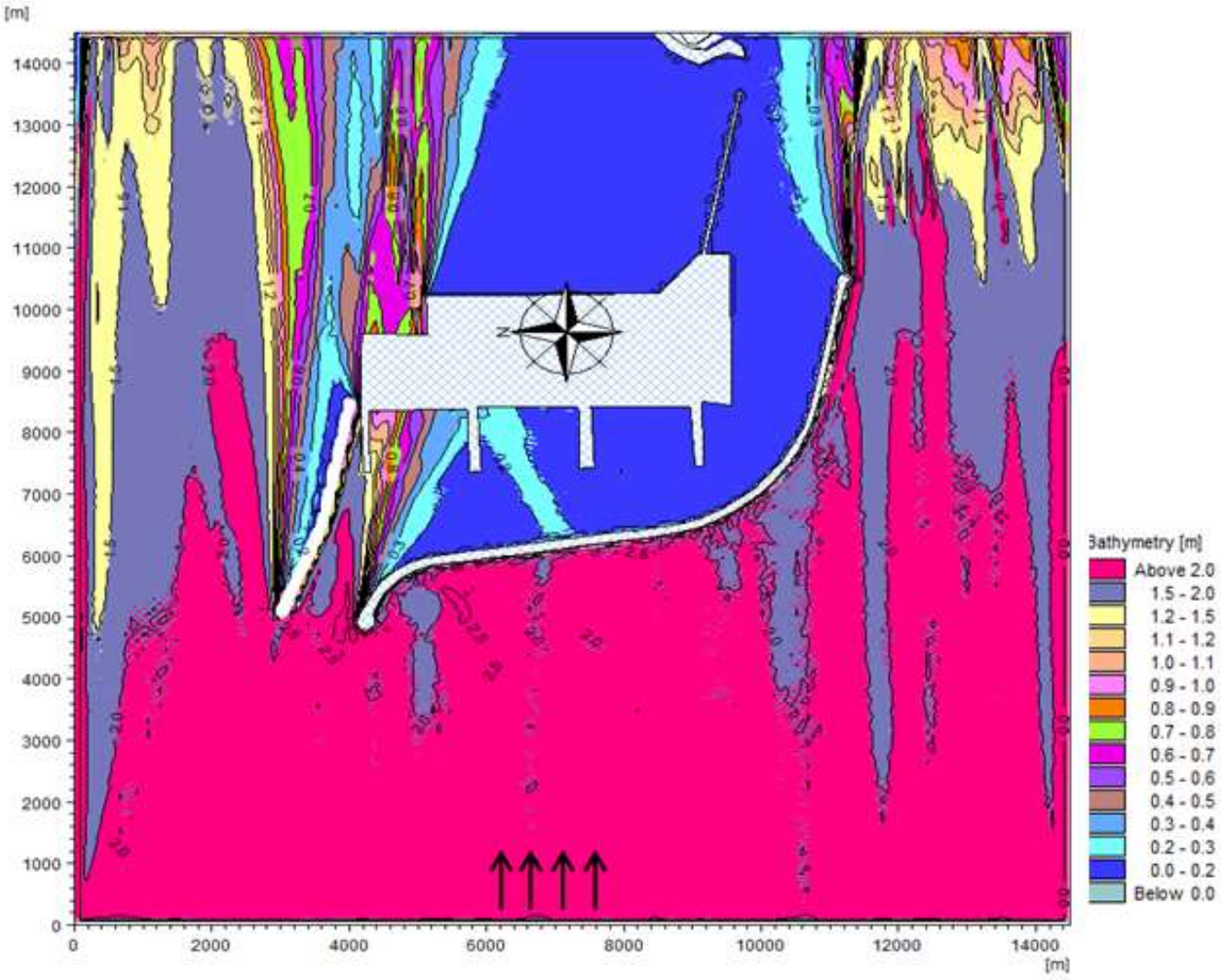

Fig. 9: Wave Height Distribution for waves From West Direction for modified Layout with North Breakwater at Vadhvan (Wave Height of 2.5m and Wave Period of 10 seconds)

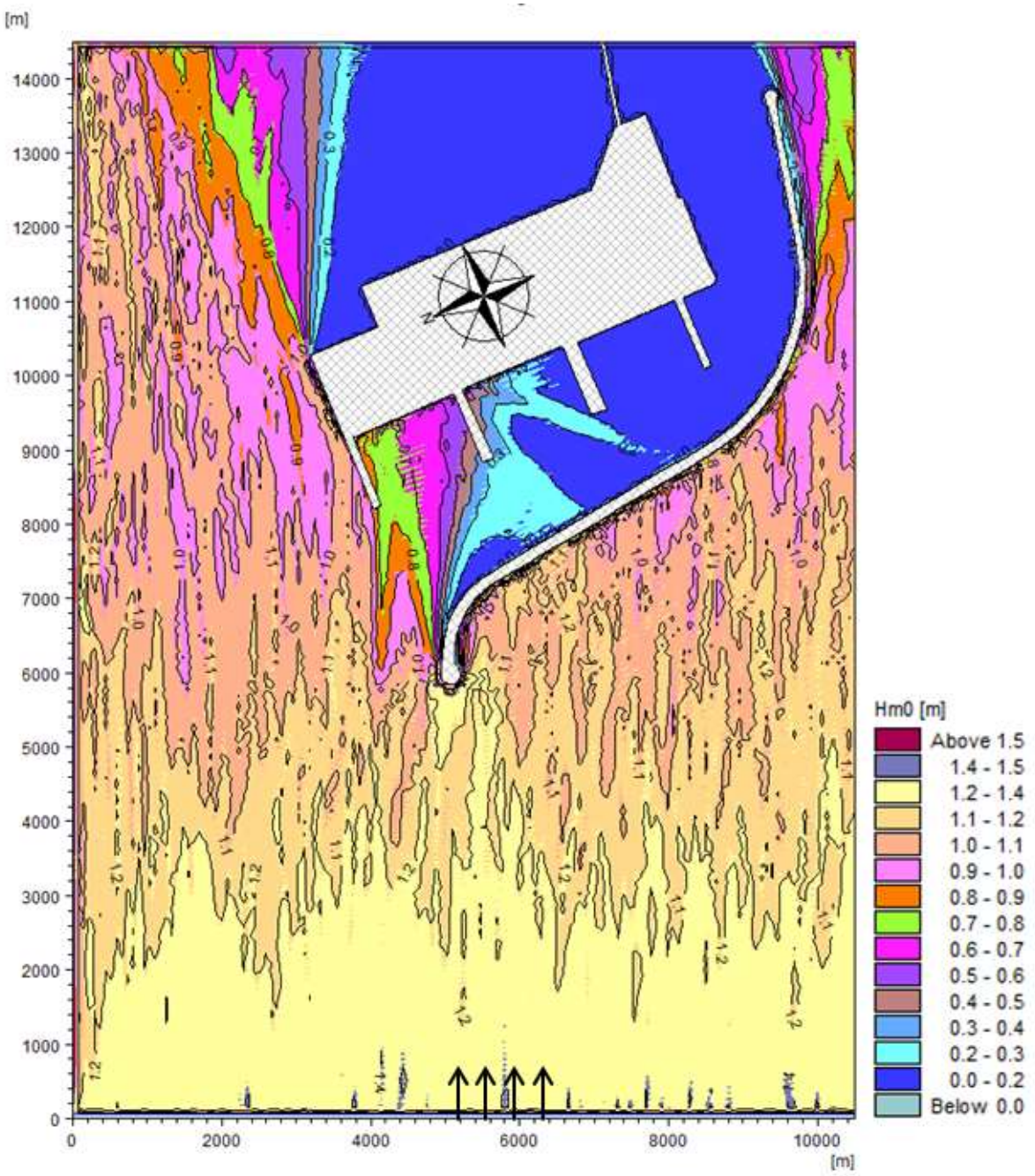

Fig. 10: Wave Height Distribution for waves From WNW Direction for modified Layout with Breakwater at Vadhvan (Wave Height of 1.5m and Wave Period of 10 seconds)

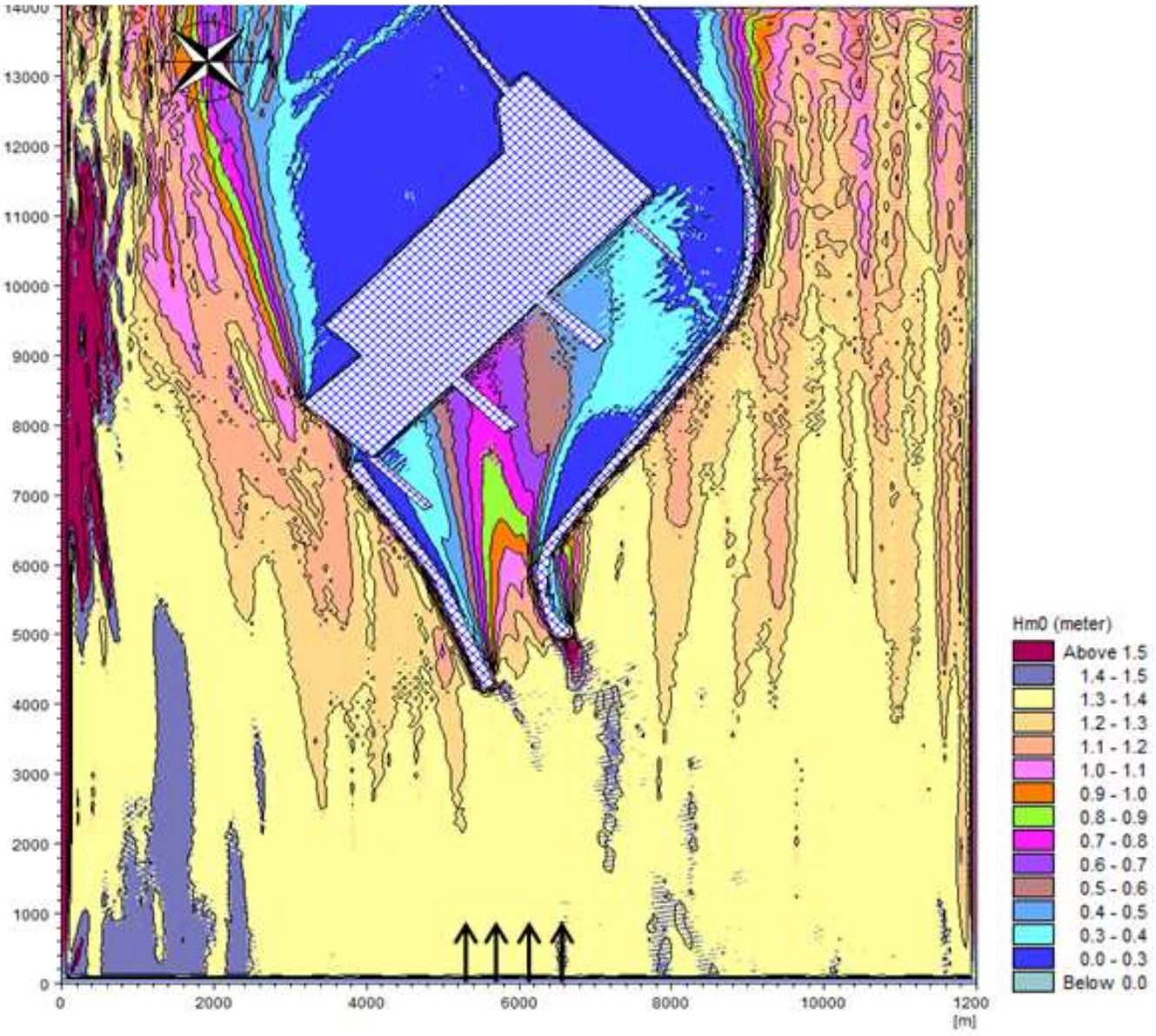

Fig. 11: Wave Height Distribution for waves From NW Direction for modified Layout with North Breakwater at Vadhvan (Wave Height of 1.5m and Wave Period of 10 seconds)

TABLE 7 :Average Significant Wave Height at the Jetties

Wave direction/ Wave height	Average Significant Wave height (m) at Jetties								
	CT01	**CT02**	**CT03**	**CT0T4**	**CT05**	**CT06**	**CT07**	**CT08**	**CT09**
270 (West)/ 2.5m	**0.28**	**0.28**	**0.28**	**0.28**	**0.28**	**0.3**	**0.3**	**0.60**	**0.75**
292.5 (WNW)/1.5m	**0.30**	**0.30**	**0.30**	**0.35**	**0.45**	**0.50**	**0.65**	**0.75**	**0.90**
315 (NW)/1.5m	**0.38**	**0.45**	**0.5**	**0.6**	**0.6**	**0.70**	**0.85**	**0.60**	**0.43**
Peak wave period Tp: 10 sec									

It is observed from the above results (Table 7) that most critical incident wave direction for the Final layout are from West, WNW and NW direction respectively during the monsoon and non monsoon seasons. Higher significant wave height of about 0.85 m is observed at CT07 Jetty during non monsoon season. The downtime would not exceed 6 to 8 days in a year. During the VC meeting held between JN Port Officials, Consultants and CWPRS on 20th July 2021, it was decided unanimously that the North breakwater layout proposal may be excluded.

6.3 Wave Propagation in the Proposed Modified Master Plan Layout at Vadhvan without North Breakwater

Wave propagation inside the Port was simulated for the modified Layout without North breakwater proposed by Project Authorities with change in dredging and alignment of jetty as shown in Fig.2 B and Fig 12. From the results of nearshore wave transformation (Table 3), wave conditions shown in Table 4 were considered for simulation of wave propagation in the port using MIKE21-BW model. Wave propagation was simulated for the waves incident from West, WNW and NW directions. The proposed final Port layout consists of breakwater of length 10.3 Km.. The bathymetry plot for the port area is shown in Fig.12. Area of 15 km by 15 km was discretised with a grid size of 5m by 5 m. Simulations were carried out for the tidal level 5.55 m corresponding to HWL. Wave height distribution in the port basin for waves coming from West, WNW and NW direction respectively are shown in Figs.13 to 15 for peak wave period of 10 sec. From these figures, it is seen that wave heights in the port basin are generally in the range of 0.2 m to 1.2 m for wave incident from West, WNW and NW directions with peak wave period of 10 sec.

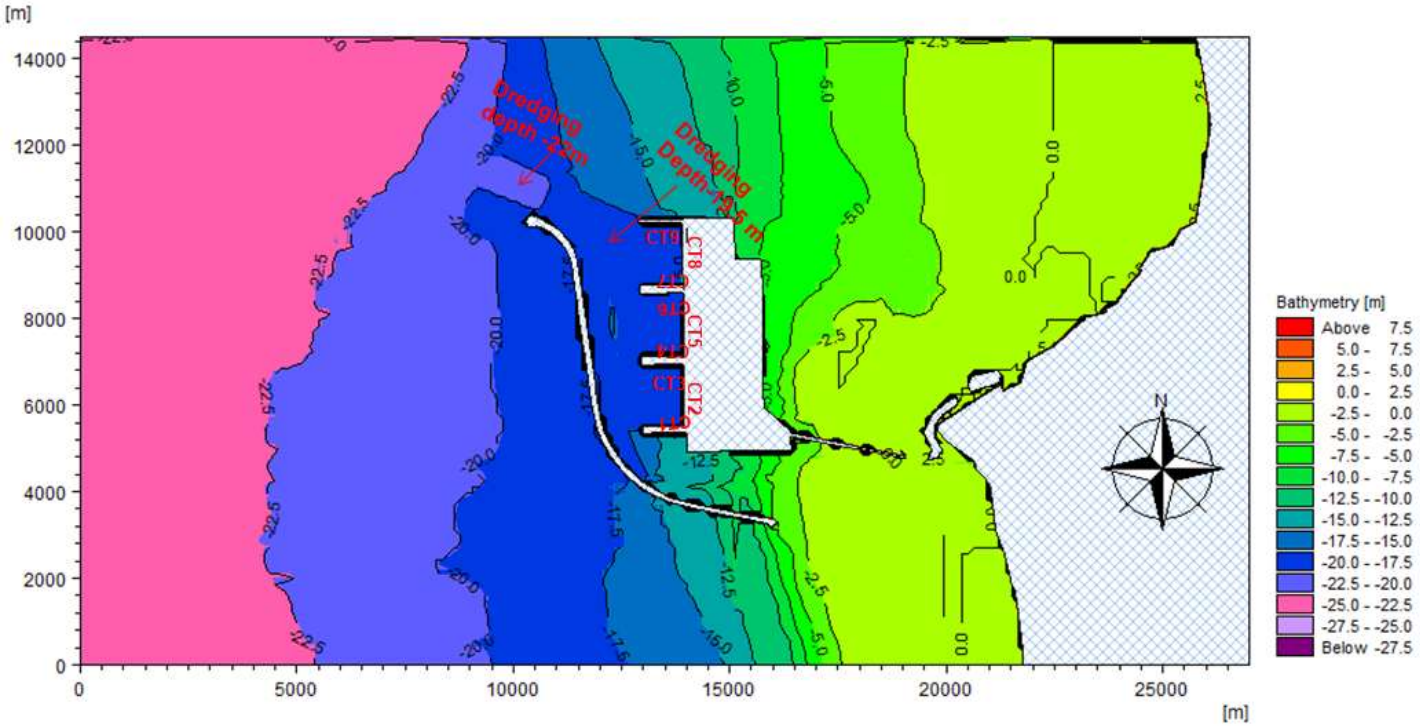

Fig. 12: Bathymetry of study area for Modified Master Plan Layout at Vadhvan Without North Breakwater at Vadhvan

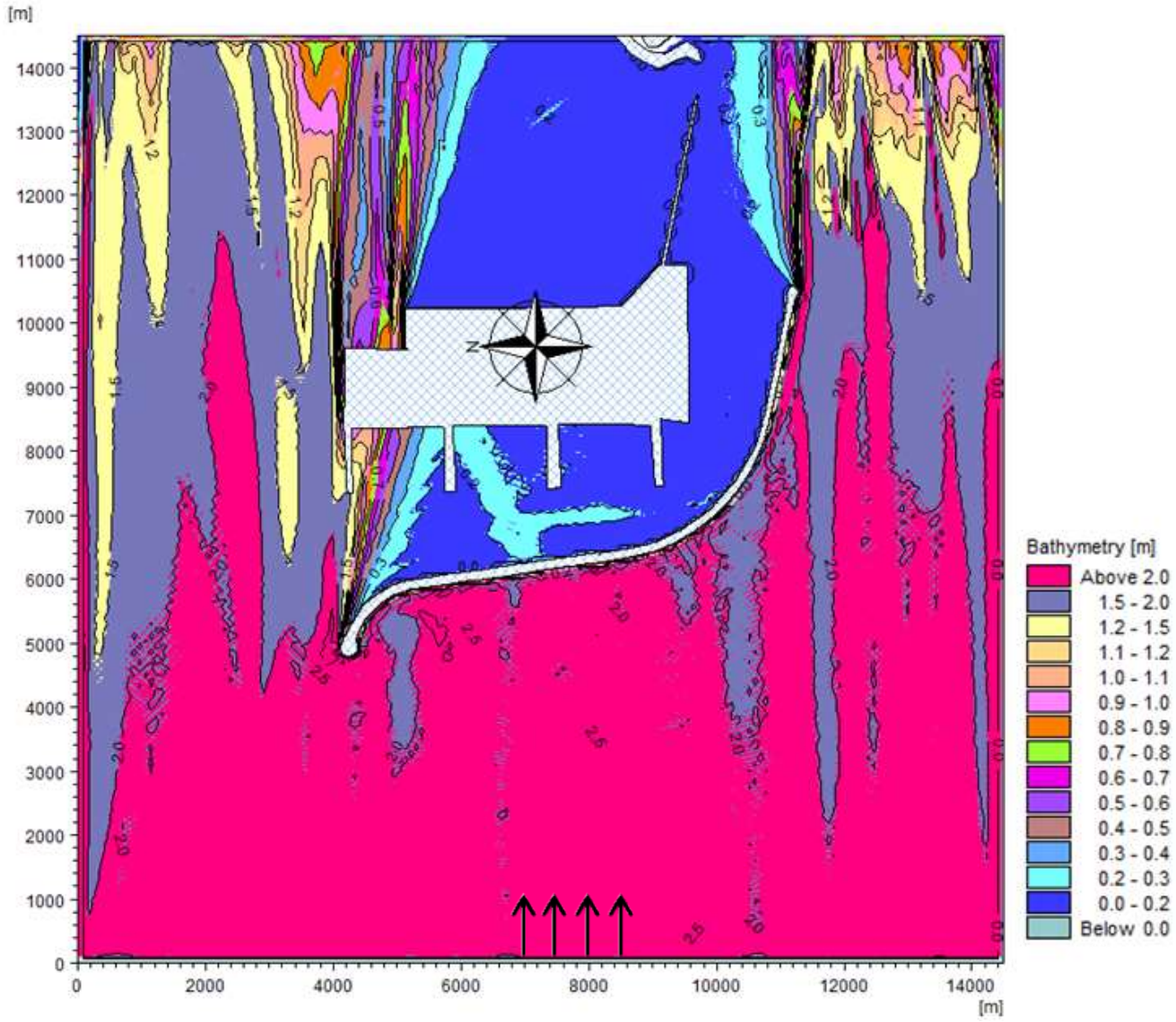

Fig. 13: Wave Height Distribution for waves From West Direction for Modified Layout Without North Breakwater at Vadhvan (Wave Height of 2.5m and Wave Period of 10 seconds)

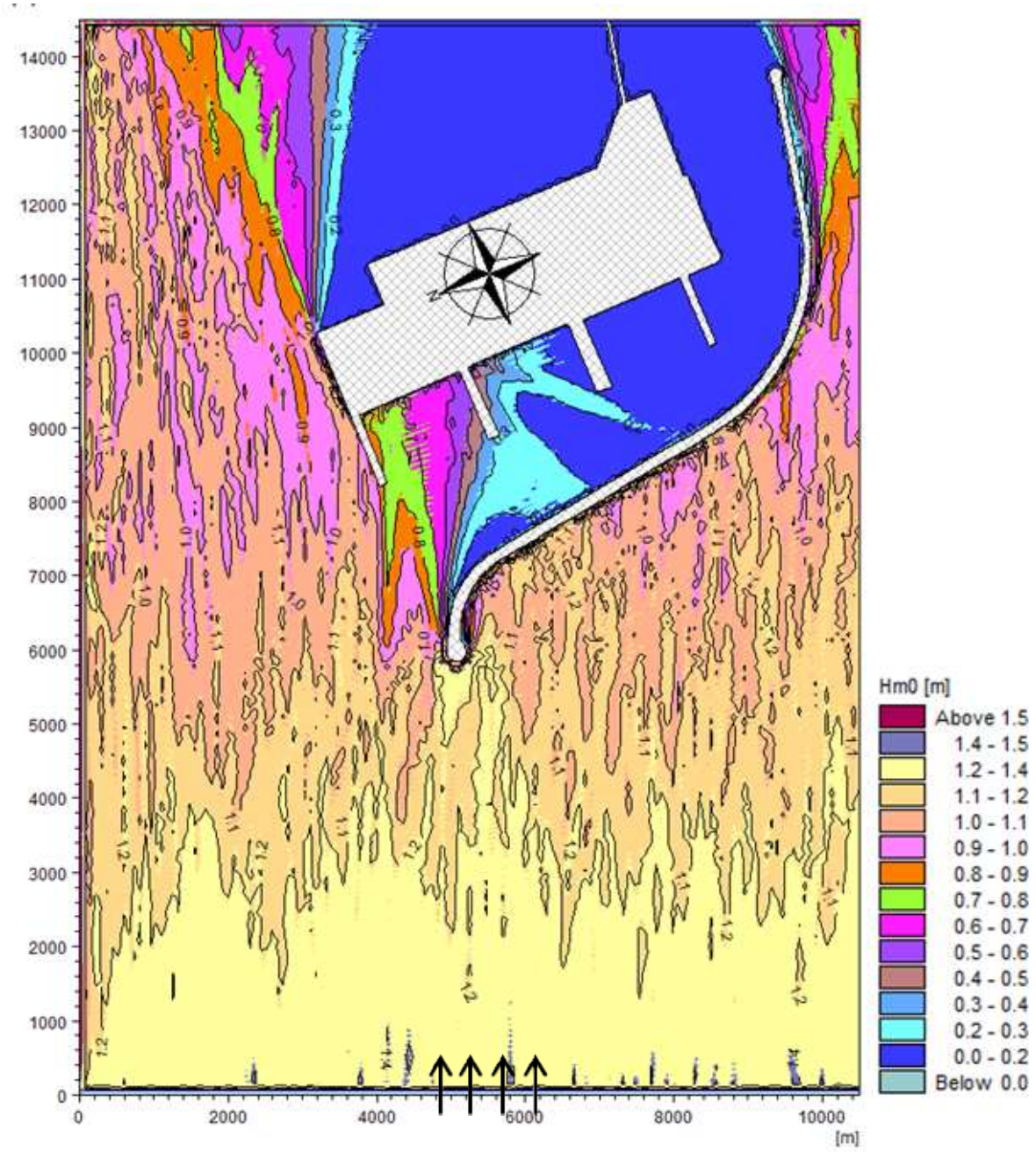

Fig. 14: Wave Height Distribution for waves From WNW Direction for Modified Layout Without North Breakwater at Vadhvan (Wave Height of 2.5m and Wave Period of 10 seconds)

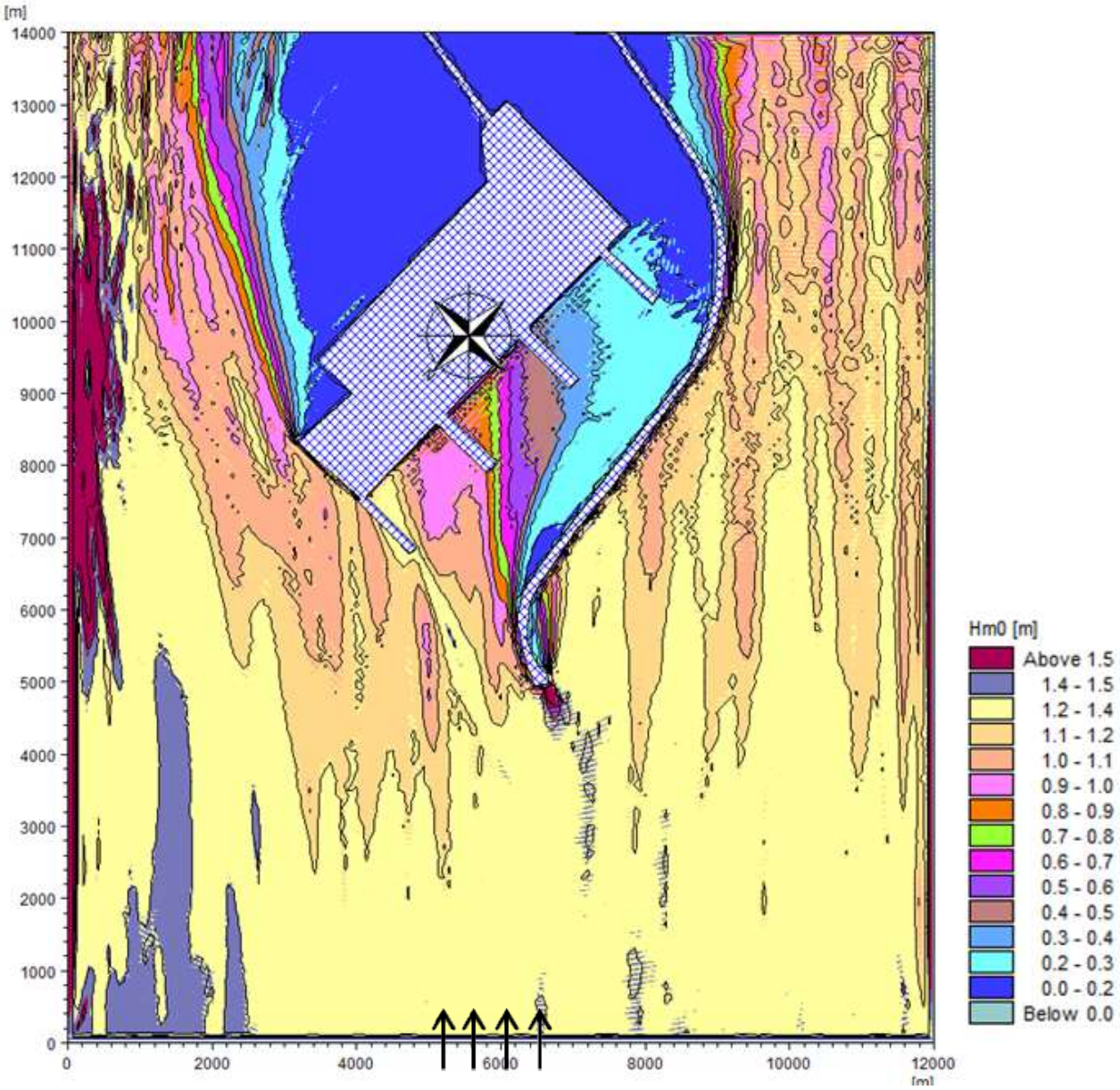

Fig. 15: Wave Height Distribution for waves From NW Direction for Modified Layout without North Breakwater at Vadhvan
(Wave Height of 2.5m and Wave Period of 10 seconds)

TABLE 8 :Average Significant Wave Height at the Jetties

Wave direction/ Wave height	Average Significant Wave height (m) at Jetties								
	CT01	**CT02**	**CT03**	**CT0T4**	**CT05**	**CT06**	**CT07**	**CT08**	**CT09**
270 (West)/ 2.5m	**0.2**	**0.28**	**0.28**	**0.28**	**0.32**	**0.35**	**0.38**	**0.70**	**1.1**
292.5 (WNW)/1.5m	**0.2**	**0.28**	**0.30**	**0.30**	**0.45**	**0.60**	**0.65**	**0.80**	**0.85**
315 (NW)/1.5m	**0.38**	**0.45**	**0.50**	**0.65**	**0.70**	**0.80**	**0.9**	**1.0**	**1.2**
Peak wave period Tp: 10 sec									

It is observed from the above results (Table 8) that most critical incident wave direction for the Final layout are from West, WNW and NW direction respectively during the on monsoon and non monsoon seasons. Higher significant wave height of about 1.2 m is observed at CT09 Jetty during non monsoon season. The downtime would not exceed 12 to 14 days in a year. This proposal layout was revised during the VC meetings held on 2nd & 14th August 2021, the consultant submitted revised Final modified master plan Layout the detail are explained below.

6.4 Wave Propagation in the Proposed Final Modified Master Plan Layout

Wave propagation inside the Port was simulated for the Final modified Master Plan Layout proposed by Project Authorities with change in dredging and alignment of jetty as shown in Fig. 3 A and Fig 16. From the results of nearshore wave transformation (Table 3), wave conditions shown in Table 4 were considered for simulation of wave propagation in the port using MIKE21-BW model. Wave propagation was simulated for the waves incident from West, WNW and NW directions. The proposed final Port layout consists of breakwater of length 10.3 Km.. The bathymetry plot for the port area is shown in Fig.16. Area of 15 km by 15 km was discretised with a grid size of 5m by 5 m. Simulations were carried out for the tidal level 5.55 m corresponding to HWL. Wave height distribution in the port basin for waves coming from West, WNW and NW direction respectively are shown in Figs.17 to 19 for peak wave period of 10 sec. From these figures, it is seen that wave heights in the port basin are generally in the range of 0.2m to 1.0m for wave incident from West, WNW and NW directions with peak wave period of 10 sec.

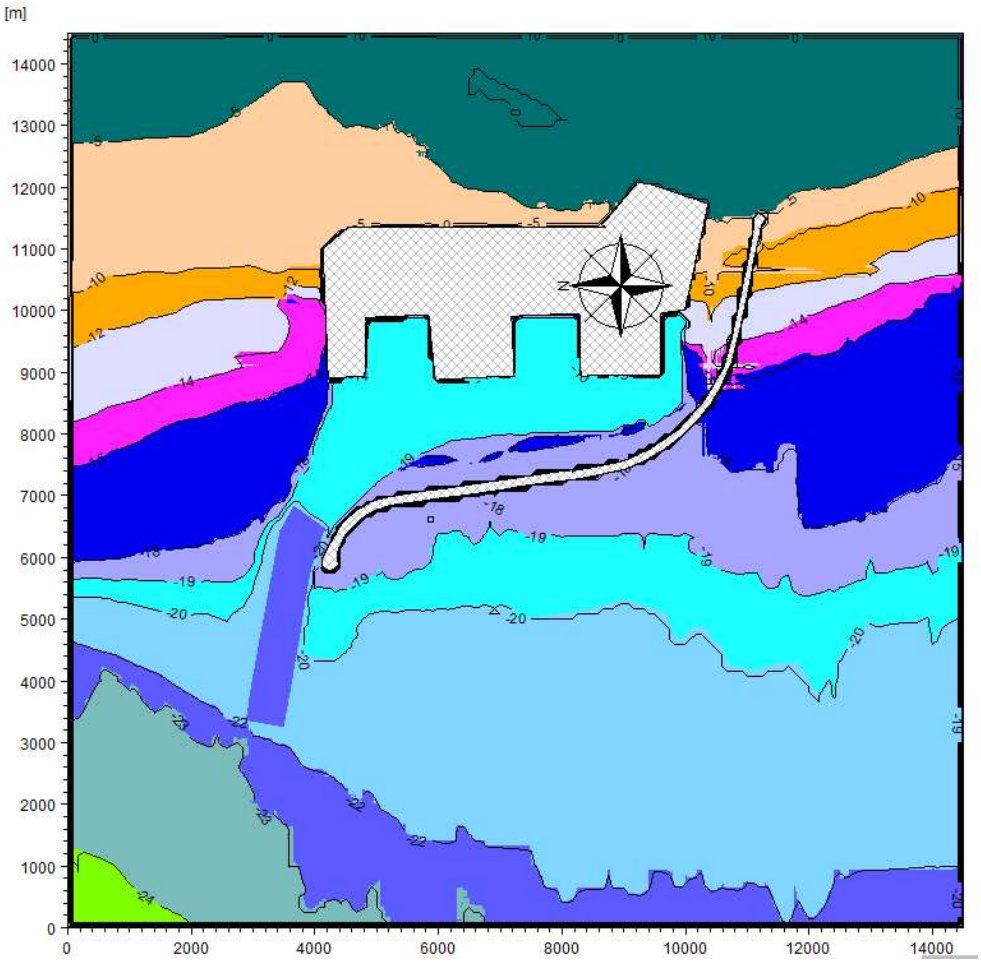

Fig. 16: Bathymetry of study area for Final Modified Master Plan Layout at Vadhvan

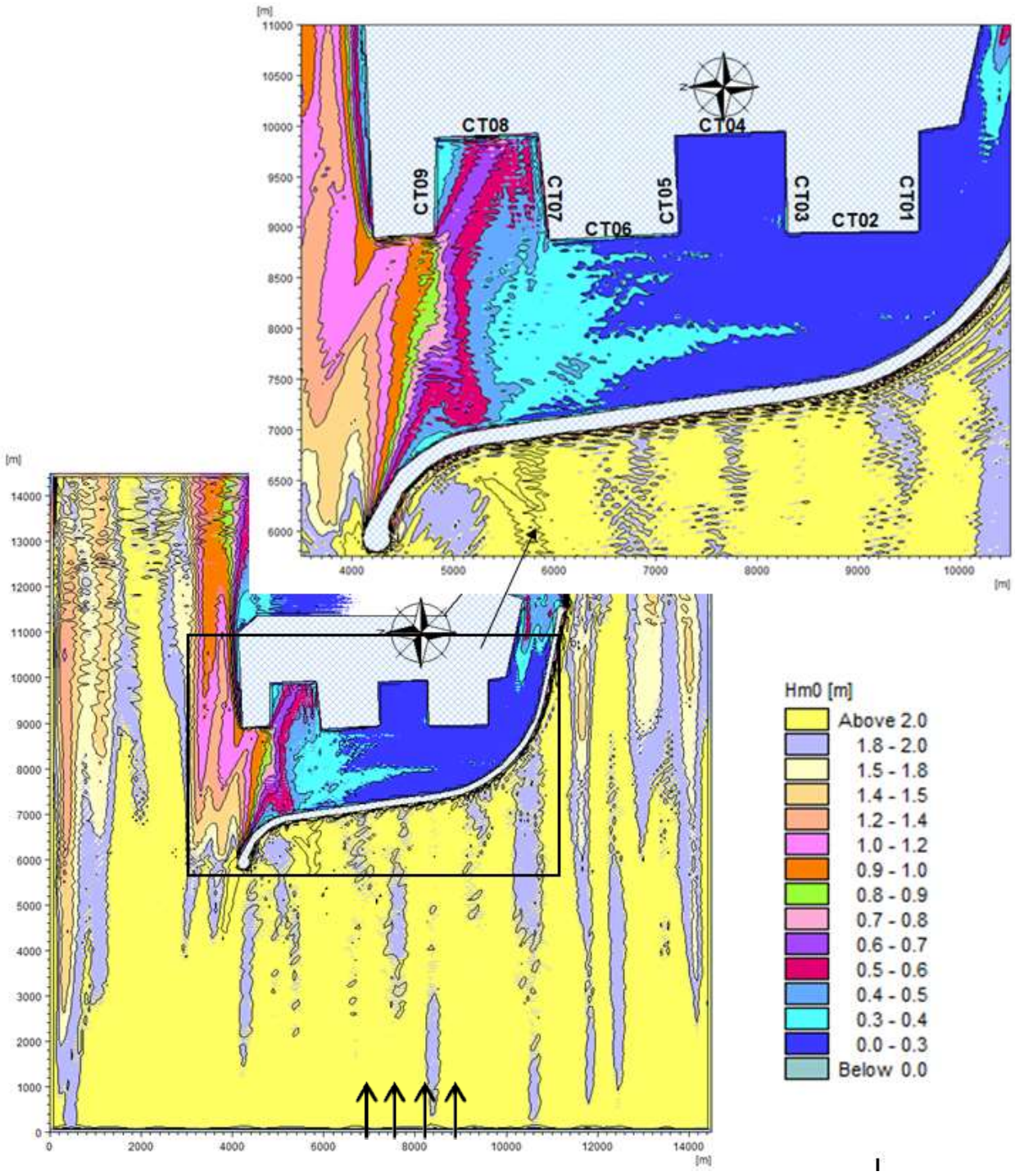

Fig. 17: Wave Height Distribution for waves From West Direction for Modified Final Layout at Vadhvan (Wave Height of 2.5m and Wave Period of 10 seconds)

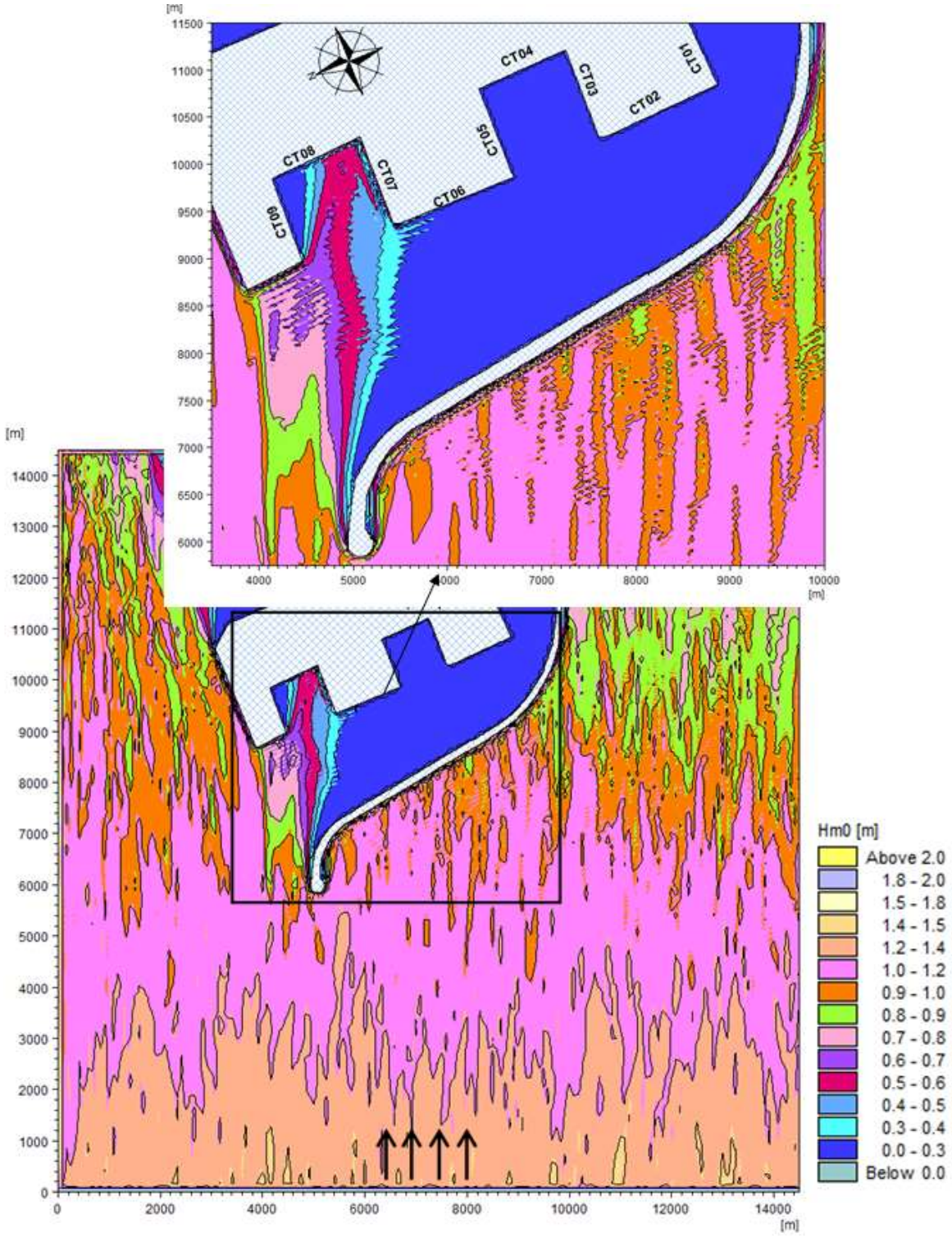

Fig. 18: Wave Height Distribution for waves From WNW Direction for Modified Final Layout at Vadhvan (Wave Height of 1.5m and Wave Period of 10 seconds)

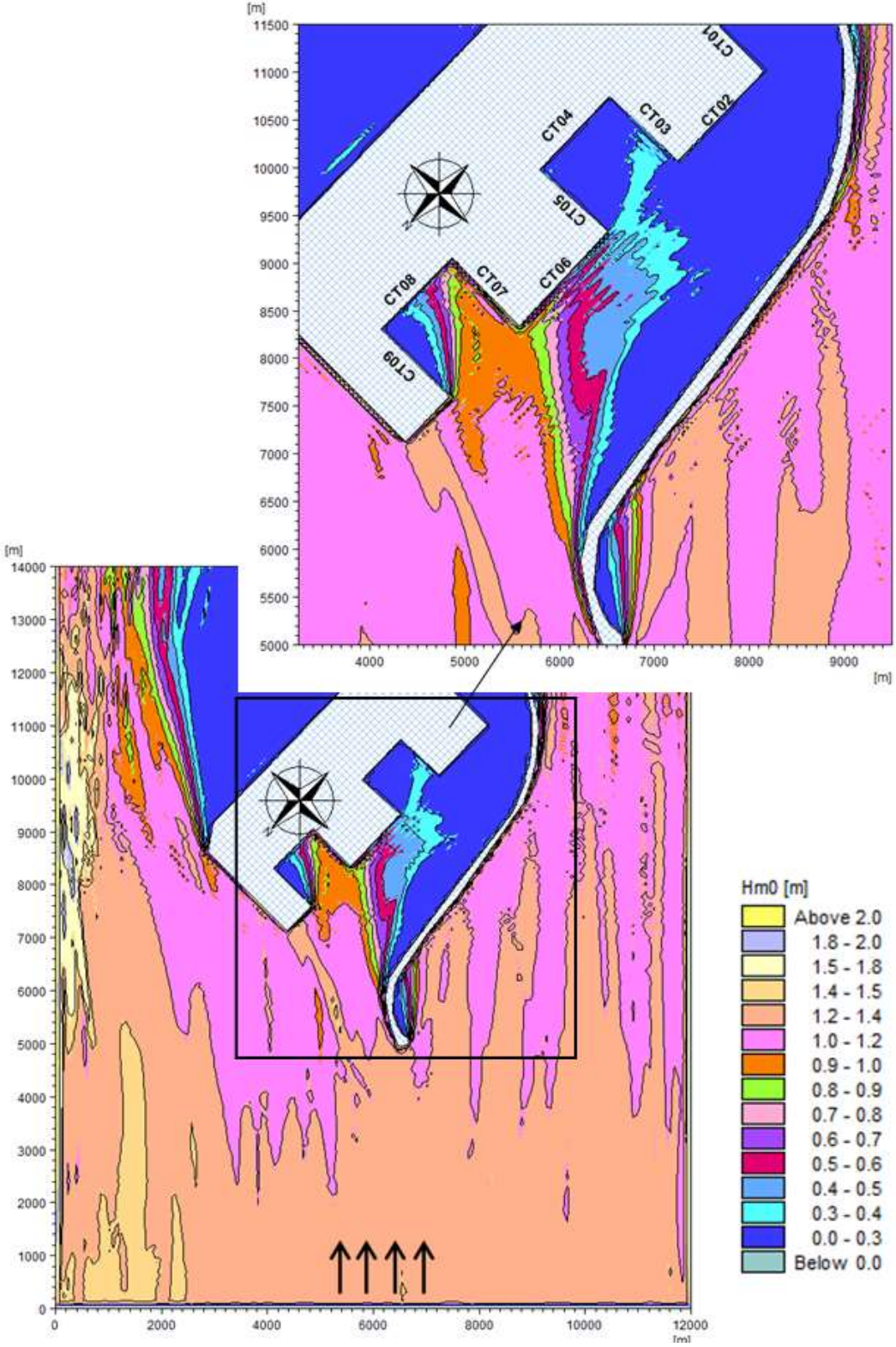

Fig. 19: Wave Height Distribution for waves From NW Direction for modified Final Layout at Vadhvan (Wave Height of 1.5m and Wave Period of 10 seconds)

TABLE 9 :Average Significant Wave Height at the Jetties

Wave direction/ Wave height	Average Significant Wave height (m) at Jetties								
	CT01	**CT02**	**CT03**	**CT0T4**	**CT05**	**CT06**	**CT07**	**CT08**	**CT09**
270 (West)/ 2.5m	**0.25**	**0.25**	**0.25**	**0.28**	**0.30**	**0.35**	**0.63**	**0.60**	**0.40**
292.5 (WNW)/1.5m	**0.20**	**0.30**	**0.30**	**0.25**	**0.25**	**0.45**	**0.65**	**0.70**	**0.4 0**
315 (NW)/1.5m	**0.20**	**0.3**	**0.30**	**0.25**	**0.25**	**0.65**	**0.95**	**0.50**	**0.3 0**
Peak wave period Tp: 10 sec									

It is observed from the above results (Table 9) that most critical incident wave direction for the Final layout are from West, WNW and NW direction respectively during the on monsoon and non monsoon seasons. Higher significant wave height of about 1.0m is observed at CT07 Jetty during non monsoon season. The downtime would not exceed 10 to 12 days in a year.

6.5 Wave Propagation in the Proposed Modified Final Phase-I Port Layout

Wave propagation inside the Port was simulated for modified Final Phase-I Port Layout proposed by Project Authorities with change in dredging and alignment of jetty as shown in Fig.3 B and Fig.20. From the results of nearshore wave transformation (Table 3), wave conditions shown in Table 4 were considered for simulation of wave propagation in the port using MIKE21-BW model. Wave propagation was simulated for the wave's incident from West, WNW and NW direction. The proposed modified Final Phase-I port layout consists of breakwater of length 10.3 Km and reclamation. The bathymetry plot for the Final Phase-I port layout area is shown in Fig.20. Area of 15 km by 15 km was discretised with a grid size of 5m by 5 m. Simulations were carried out for the tidal level 5.55 m corresponding to HWL Wave height distribution in the port basin for waves coming from West, WNW and NW respectively are shown in Figs.21 to 23 for peak wave period of 10 sec. From these figures, it is seen that wave heights in the port basin are generally in the range of 0.2m to 0.5 .0m for wave incident from West, WNW and NW directions with peak wave period of 10 sec.

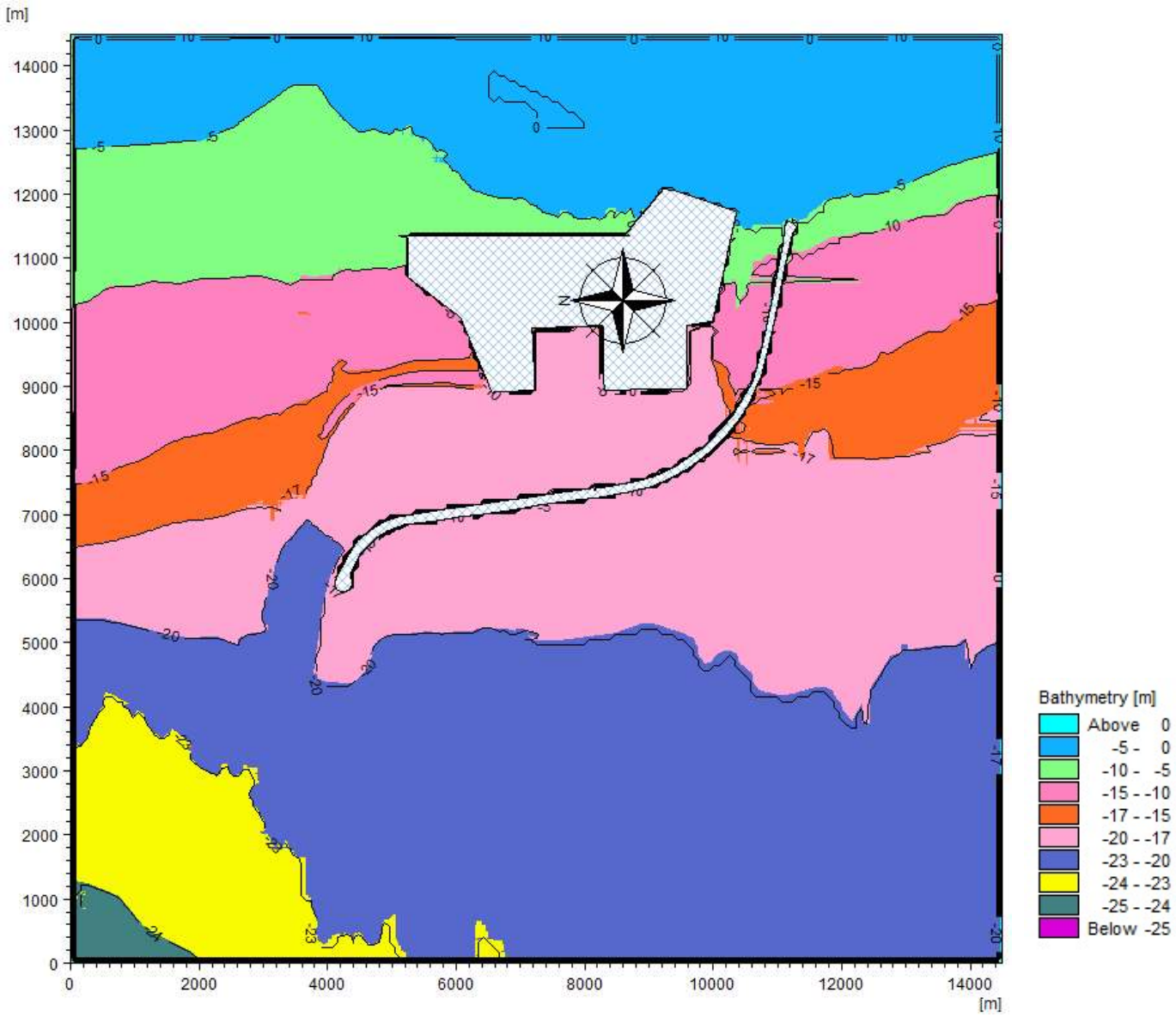

Fig. 20 : Bathymetry of study area for modified Final Phase-I Layout at Vadhvan

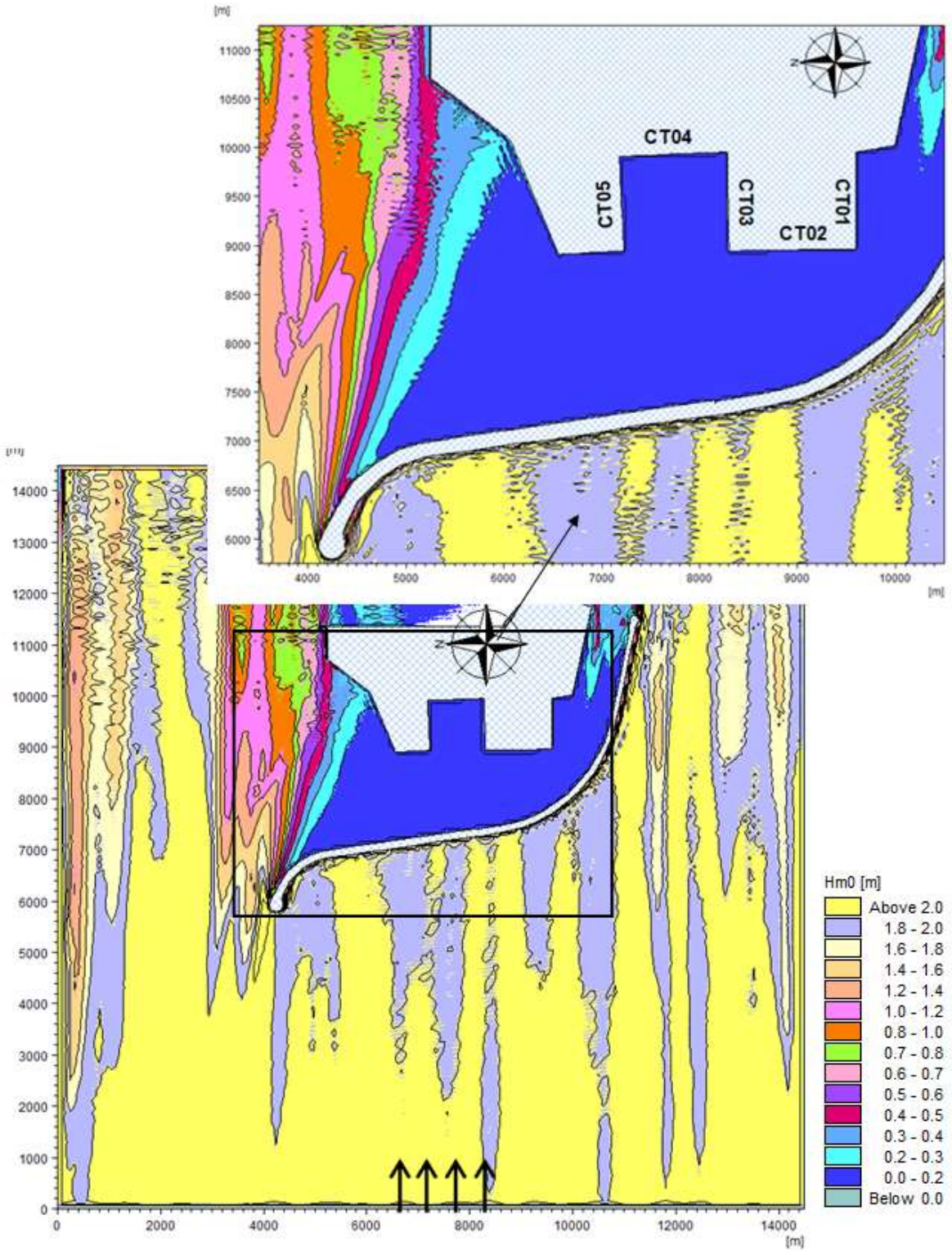

Fig. 21: Wave Height Distribution for waves From West Direction for modified Phase-I Layout at Vadhvan (Wave Height of 2.5m and Wave Period of 10 seconds)

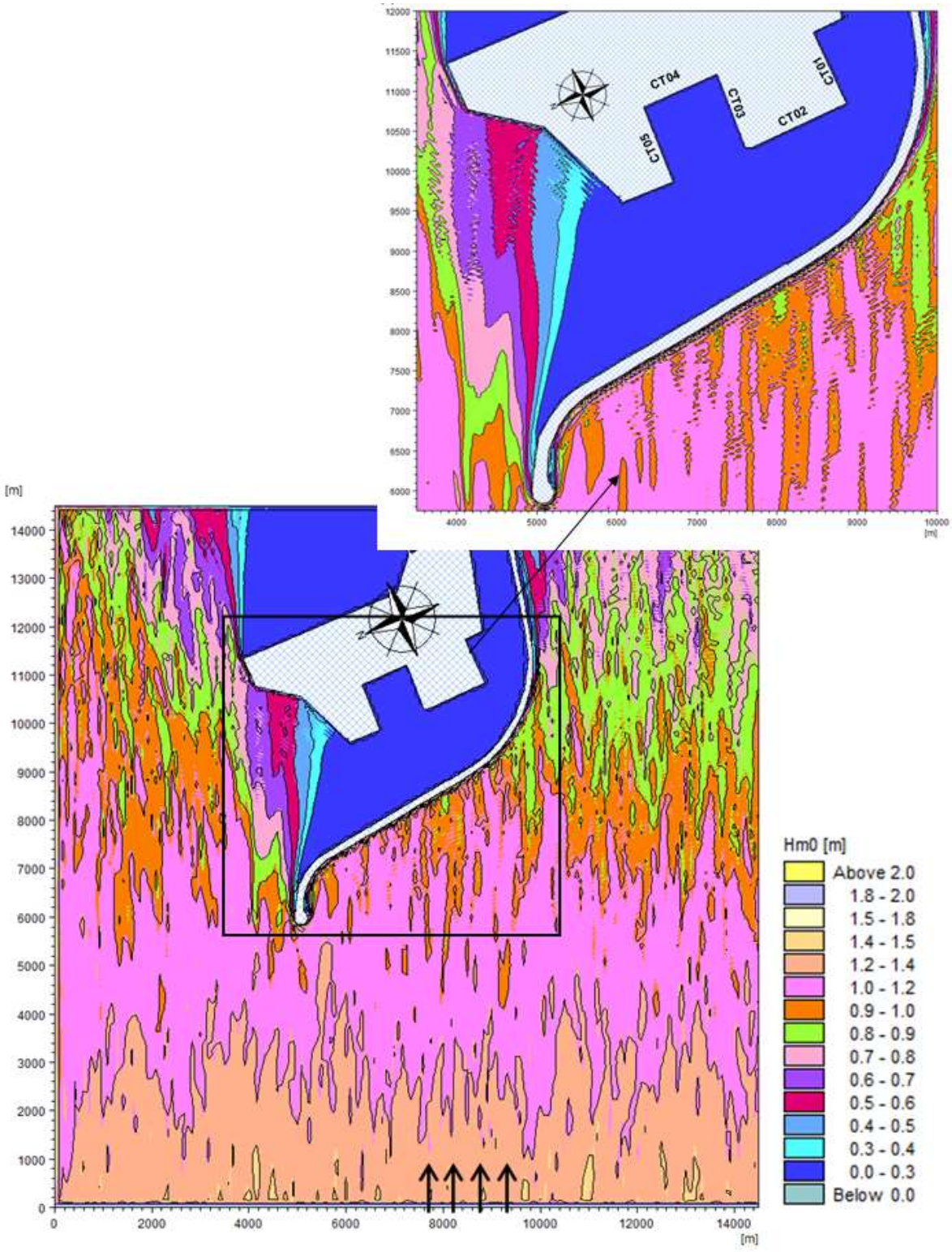

Fig. 22: Wave Height Distribution for waves From WNW Direction for modified Phase-I Layout at Vadhvan (Wave Height of 1.5m and Wave Period of 10 seconds)

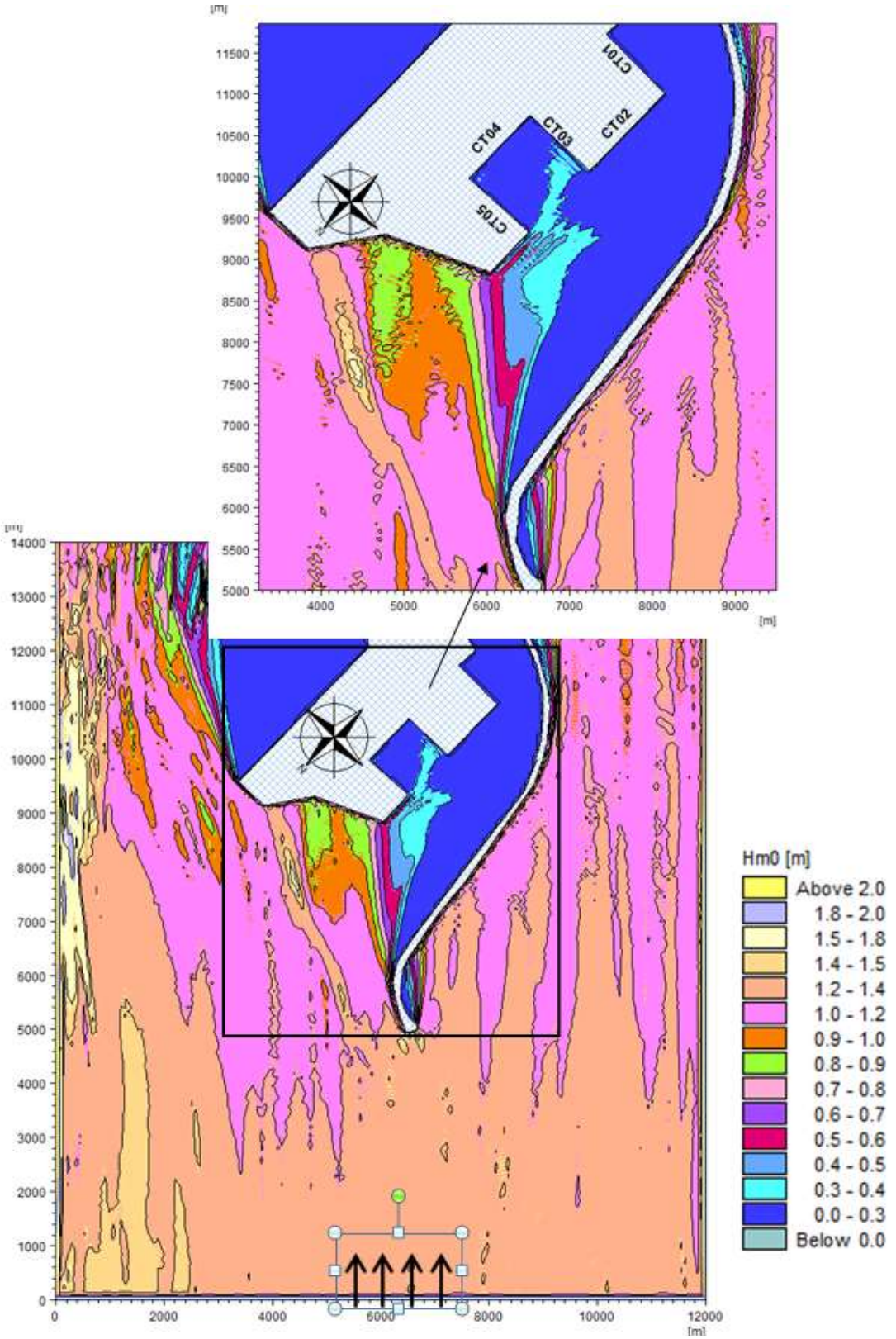

Fig. 23: Wave Height Distribution for waves From NW Direction for modified Phase-I Layout at Vadhvan (Wave Height of 1.5m and Wave Period of 10 seconds)

TABLE 10 :Average Significant Wave Height at the Jetties

Wave direction/ Wave height	Average Significant Wave height (m) at Jetties						
	CT01	**CT02**	**CT03**	**CT0T4**	**CT05**		
270 (West)/ 2.5m	**0.25**	**0.25**	**0.25**	**0.28**	**0.30**		
292.5 (WNW)/1.5m	**0.20**	**0.30**	**0.30**	**0.25**	**0.25**		
315 (NW)/1.5m	**0.2**	**0.3**	**0.4**	**0.35**	**0.36**		
Peak wave period Tp: 10 sec							

It is observed from the above results (Table 10) that most critical incident wave direction for the Final Phase-I modified layout are from West, WNW and NW direction respectively during the on monsoon and non monsoon seasons. Significant wave height of about 0.4m is observed at CT03 Jetty and all Jetty in Phase-I layout have significant wave height less than 0.35 m, during non monsoon season and monsoon season. No Downtime has been observed for Phase-I modified layout.

7.0 CONCLUSIONS

- Wave transformation studies carried out for estimation of nearshore wave climate indicated that in -24m depth predominant incident wave directions are from SW, WSW, West, and WNW direction. Maximum significant wave height would be of the order of 3.0 m.
- Wave tranquility studies carried out for assessment of wave disturbance in the port basin for the Modified Master Plan Layout at Vadhvan with North Breakwater (Fig.3A) indicated that the significant wave heights in the port basin are generally in the range of 0.2m to 0.85 m . Higher significant wave height of about 0.85 0m is observed at CT07 Jetty. The downtime would not exceed 6 to 8 days in a year. In the VC meeting held between JN Port Officials, Consultants and CWPRS on 20th July 2021 and it was decided unanimously that the North breakwater layout proposal may be excluded.

- Wave tranquility studies carried out for assessment of wave disturbance in the port basin for the Modified Master Plan Layout at Vadhvan without North Breakwater (Fig.3B) indicated that significant wave heights in the port basin are generally in the range of 0.2m

to 1.2 m . Higher significant wave height of about 1.2 m is observed at CT07 Jetty and the downtime would not exceed 12 to 14 days in a year. This layout was further revised during the VC meetings held on 2nd & 14th August 2021 and the consultant submitted revised Final modified master plan Layout and Phase-I layout plan.

- Wave tranquility studies carried out for assessment of wave disturbance in the port basin for the Modified Final Modified Master Plan Layout (Fig.4A) indicated that significant wave heights in the port basin are generally in the range of 0.2m to 1.0m . Higher significant wave height of about 1.0m is observed at CT07 Jetty. The downtime will not exceed 10 to 12 days in a year.

- Wave tranquility studies carried out for assessment of wave disturbance in the port basin for the Modified Final Phase-I layout (Fig.4B) indicated that significant wave heights in the port basin are generally in the range of 0.2m to 0.4 m . No Downtime has been observed for Phase-I modified layout.