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THE EFFECT OF CONSTRUCTED BREAKWATER ON THE WAVES PATTERN IN BOLKHEIR PORT USING MIKE 21 SOFTWARE

Emran Moradpour Tayebi[1], Maryam Rahbani[1*], Ehsan Esmaili[2]

[1] Physical Oceanography, Hormozgan University, Bandar- Abbas, Iran
[2]Ports and Maritime Organization of IRAN, Tehran, Iran

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A B S T R A C T

The effect of a constructed breakwater in Bolkheir Port on the direction and height of the waves in an Iranian coast of the Persian Gulf is considered in this research. The MIKE 21 software was used for this purpose. The simulation was performed for one year period in two scenarios, with and without the new constructed breakwater. The findings of the two scenarios show that the breakwater creates calm conditions not only inside the port basin, but also on the southern side of the breakwater to about 1 kilometer. That is; while the northern sides of the breakwater experience some wave height increase in the 270 to 300 degree sectors, and the impact is significant in that direction.

1.0 Introduction

Hydrodynamic studies to determine the pattern of currents in ports are crucial part of coastal engineering, and are prelude to study sediment suspension and transport. The speed and direction of a wave and/or a current can be caused erosion in one place and sedimentation in another, which make the coastline proceed or recede accordingly. The coastline feature as well can affect the hydrodynamic pattern of an area. It is therefore, very important to study the consequence of artificial construction on the hydrodynamic pattern of the area, before the structure has been taken placed. Port of Bolkheir, in southwest of Iran, has been redeveloped recently construction new breakwater.

With a history of 80 years, this port is located some 60 kilometers south of Bushehr Port (28.53° N, 051.09° E). It has been one of the traditional commercial centers in the central Persian Gulf, and played a significant role in fostering trades in the region.Until 2010, the port had one stone breakwater with the length of 440 m, and the width of 2.5 m (Figure 1). In the year 2011 the length of this breakwater was extended to 825 m and another breakwater was also constructed with a length of 700 m (Figure 2).With the construction of these two breakwaters, it was found necessary to study the effect of these new structures on the pattern of wave and current. For this purpose, the Spectral Wave (SW) Module of MIKE 21, developed by Danish Hydraulic Institute, was employed.

2.0 Materials and Methods

The model has two formulation types, namely the directionally decoupled parametric formulation and the fully spectral formulation. The former is based on making parameters of the wave continuity equation, which only considers wave transfer, but not its growth or weakening. In the fully spectral formulation, on the other hand, apart from wave transfer, its growth resulting from wind impact and weakening from phenomena such as white capping are also brought into consideration (Hasselmann 1974) and (Sørensen 2004)).

Both of the above mentioned methods can be employed to simulate the wave progression from offshore towards the nearshore (Holthuijsen,et.al. 2007). Since the directional decoupled parametric formulation is proper for the areas where the local waves generated wind are negligible (Johnson 1998), the latter method, fully spectral formulation, has been found proper to use in this study.

Figure 1: Satellite Image of Bolkheir Commercial Port (before New Constructions)

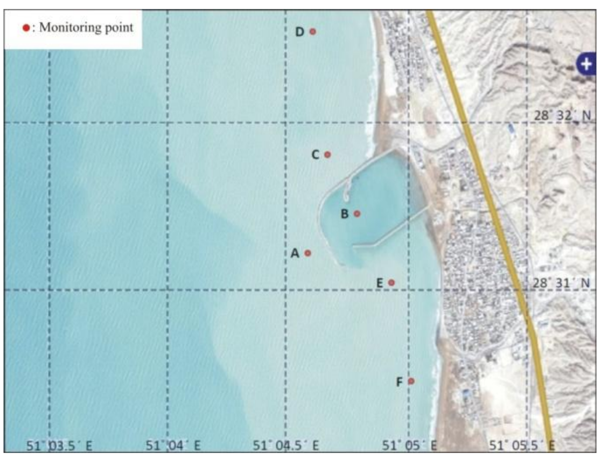

Figure 2: Satellite Image of Bolkheir Commercial Port (after New Constructions)

The basic mathematical energy conservation equation for spectral wave is as follow:

$$\frac{\partial N}{\partial t} + \nabla.(\vec{v}N) = \frac{S}{\sigma} \quad (1)$$

Where $N(\vec{x}, \sigma, \theta, t)$ is the action density, and includes spectral parameters, $\vec{v}(c_x, c_y, c_\sigma, c_\theta)$ is the propagation velocity of a wave group in the four-dimensional phase space, σ is the wave angular frequency, and S includes terms defined below.

$$S = S_{in} + S_{nl} + S_{ds} + S_{bot} + S_{surf} \quad (2)$$

Where S_{in}, S_{nl} and S_{ds} relate to wave production and growth, which are not particularly useful for the present study that only considers wave transport. On the other hand, the terms S_{bot} for bottom dissipation and S_{surf} for wave breaking are of high significance in this study.

S_{bot} is defined as follows:

$$(f,\theta) = -\left(C_f + f_c\left(\bar{u}.\bar{k}\right)/k\right)\frac{k}{\sinh 2kd}E(f,\theta)$$
(3)

In this equation f is frequency and θ is direction, C_f is the bottom roughness coefficient for the wave impact and has been considered as calibration coefficient in this research, f_c is the roughness coefficient resulting from currents with a u velocity, and k and d are the wave number and the water depth respectively (Janssen 1992).

S_{surf} is defined as follows:

$$S_{surf}(f,\theta) = -\left(\frac{2\alpha_{BJ}Q_b\bar{f}}{X}\right)E(f,\theta) \quad (4)$$

Where α_{BJ} is an experimental coefficient, usually considered as 1, and $\bar{f}$ is the average wave frequency. X and Q_b is defined as follows:

$$X = \frac{E_{tot}}{(H_m^2/8)} = \left(\frac{H_{rms}}{H_m}\right)^2 (5)$$

$$H_{rms} = \sqrt{8\,E_{tot}} \quad (6)$$

$$\frac{Q_b - 1}{\ln Q_b} = X = \left(\frac{H_{rms}}{H_m}\right)^2 \Leftrightarrow Q_b = exp\left(\frac{-(1-Q_b)}{(H_{rms}/H_m)^2}\right) \quad (7)$$

In the above mentioned equations E_{tot} stands for the total energy. H_m is calculated using $H_m = \gamma d$, where γ is the breaking parameter and is considered between 0.55 and 1, and can be used as the calibration coefficient. In the SW Module of the software, there are two initial conditions for the wave spectrum. One is the zero spectral, where the wave action function is considered zero in all areas, and the other is the results derived from experimental formulation on three bases:

JONSWAP, SPM 1982 in shallow waters, and SPM 1973 in deep waters (Al-Mashouk, et.al. 1998).

In the present study, the shallow water conditions were considered and the JONSAWP method was therefore employed, the details of which is presented in Table 1.

Table 1: Initial Conditions for JONSWAP Spectrum (Hasselmann, et.al. 1973)

JONSWAP Spectrum Parameters		Condition	
Sigma a	0.07	Max length of Fetch	1000 m
Sigma b	0.09	Max Frequency of Peak	0.4 Hz
Crest Parameter	3.3	Max of Phillips Constant	0.0081

2.1 Required Data for Model Implementation

The bathymetry file and information required for boundary conditions to implement to the model were extracted from the hydrographic data provided by the Ports and Maritime Directorate General of Bushehr Province for the Bolkheir Port, as well as relevant nautical charts and the data from the Iranian Sea Wave Modeling Project (ISWM). For the grid points, the unstructured mesh has been employed, with 6,855 nodes and 13,068 elements. The boundaries were assumed far enough from the area under investigation, so that they would not affect the wave simulations of the area. The mesh size of each element in deep water is about 4,500 m., while it decreases to about 30 m. in shallow water area (Figure 3).

Figure 4 shows the boundaries of the area. As it can be seen there are three open boundaries in north, west, and south, and one closed boundary in the east side of the model. The prevalent height, period and mean directions of waves to apply to the lateral boundaries were determined using the ISWM data.
In considering the wind speed and direction, the modified wind data from European Center of Median Range

Weather Forecasts (ECMWF) were used, which provides the results of a 2-D meteorological model with a 6-hour time step and $0.5° \times 0.5°$ position distances. The data was interpolated for use and placed in a mesh with $0.125° \times 0.125°$ position distances. The data for Significant Wave Height (H_s), Mean Wave Direction, Wave Period, Wind, and bathymetry are received from Ports and Maritime Organization of Iran (PMO).

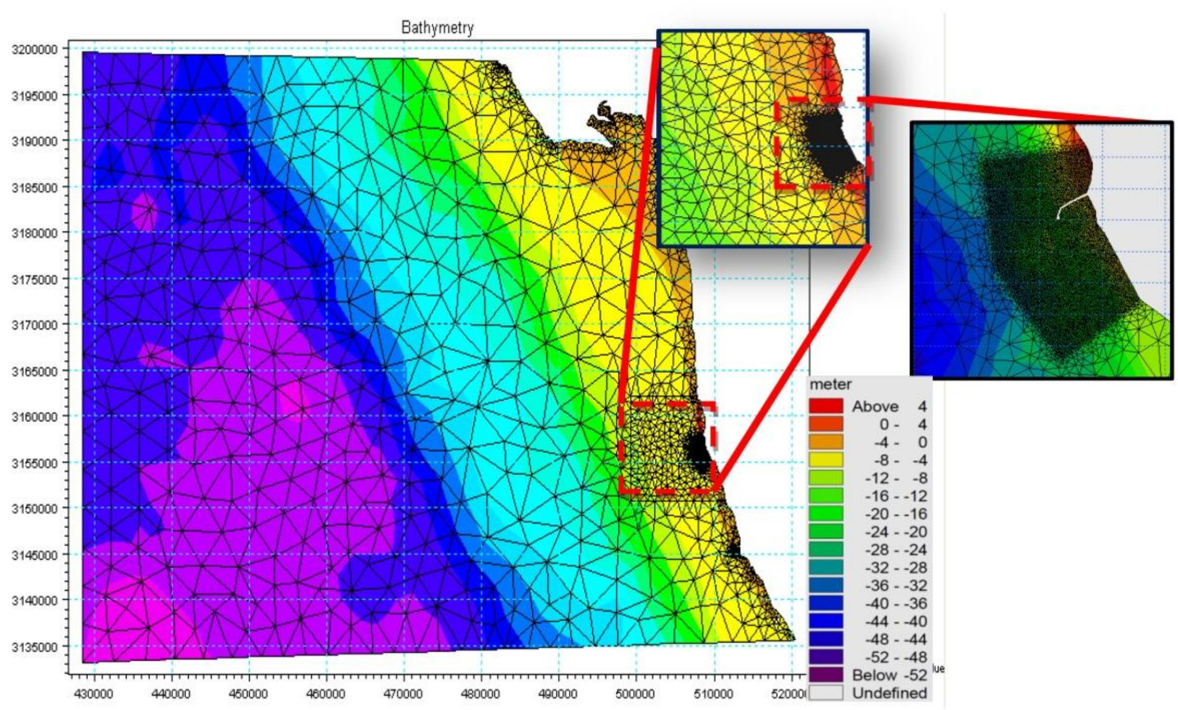

Figure 3: Meshing Outline of the Area Being Studied (Old Breakwater)

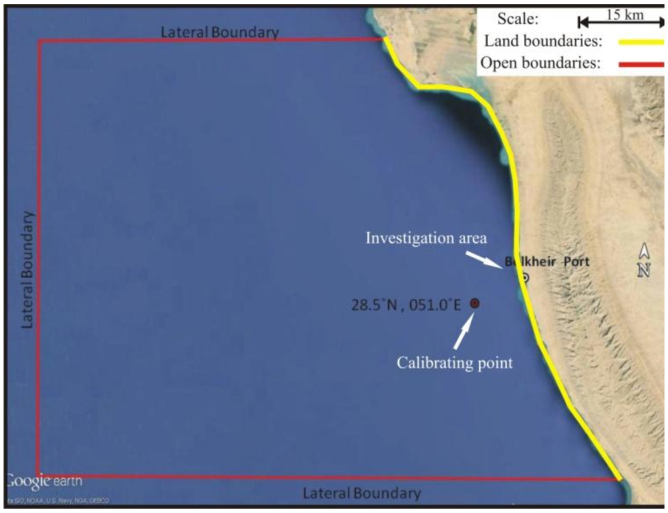

Figure 4: Lateral Boundaries and Calibration Point

2.2 Model Calibration

Since the ISWM data was available for a location at 28.5° N, 051.0° E (Figure 4), the model calibration was executed at this point. That is; the significant wave height, wave period and mean direction were derived out from the model for this observation point and are compared with those of ISWM for the relevant time.
Figure 5 show the wave roses obtained from ISWM Project and the present modeling after calibration, respectively for the location being considered (28.5° N, 051.0° E).
It can be seen from the figures that the model can simulate the area properly. In order to compare the accuracy of significant wave height results derived from the present modeling in compare with those of the ISWM the root mean score error (RMSE) as statistical parameter was used. According to Cox &Swail, (2000), Cairesm&Strel (2001), and Cairesm et.al. (2002), the ideal range of RMSE for significant wave height is below 0.5m, however the normal range or acceptable domain is between 0.1 and 0.7m.

$$RMSE = \sqrt{\frac{1}{n}\sum(y_i - x_i)^2} \qquad (8)$$

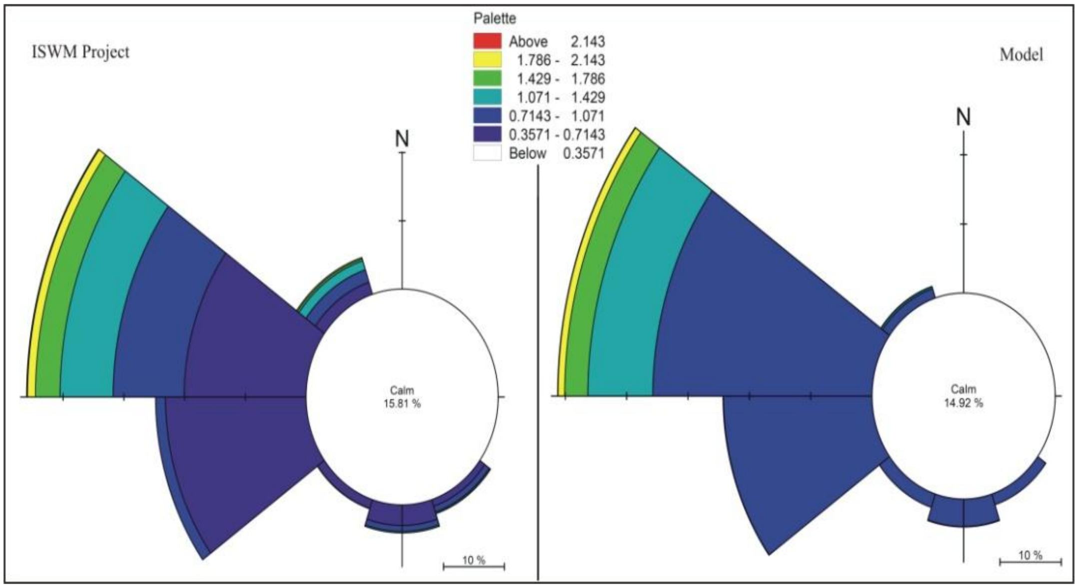

Figure 5: Wave Rose for ISWM Data (left hand side) and Present Modeling (right hand side)

Fig. 6 shows the scatter diagram related to the significant wave height resulting from the present modeling and the ISWM project. The trendline, drown for the presented data, show that the R^2 is about 0.97. Also, the corresponding RMSE for the data was calculated as 0.58 m which is among the normal range according to the literatures.

After assuring about the accuracy of the performance of the model two scenarios were carried out; one with consideration of old breakwater in Bolkheir Port, and one with the consideration of new breakwater, from now on called as scenario 1 and 2 accordingly (Figure 7 A and B).

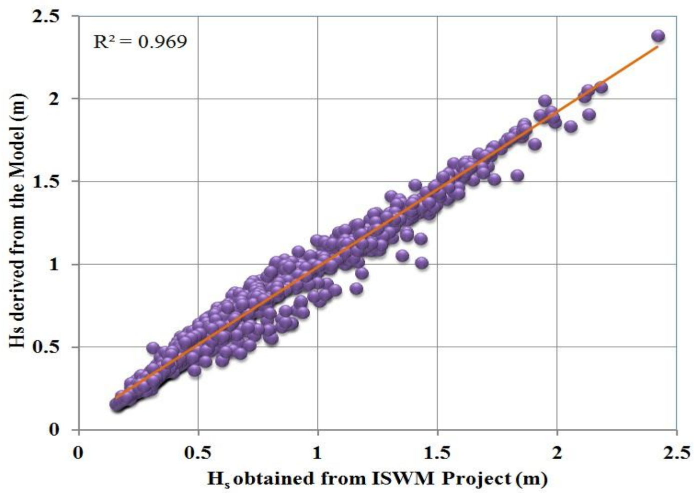

Figure 6: Scatter Diagram for Significant Wave Height derived from the Present Model and ISWM Data

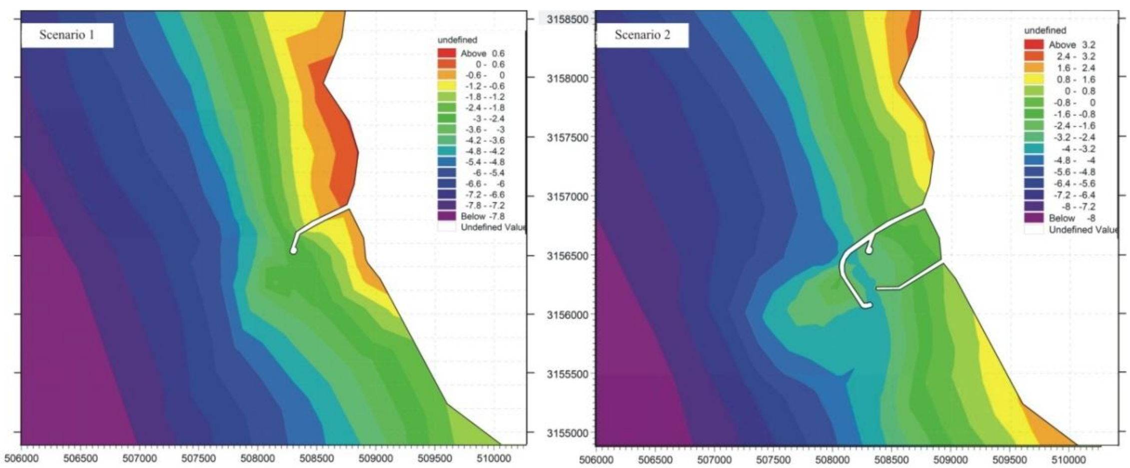

Figure 7: Wave Simulation for the Bolkheir before and after Breakwater Construction (Scenarios 1 and 2)

3.0 Results

Two similar models were conducted for scenarios 1 and 2, and for each scenario, six points A to F were chosen as observation points (Figure 2). The findings of the similar points and time in each scenario were extracted and compared in order to determine the impact of the new constructed breakwater on wave height and direction. The distances of the observation points from the breakwater are mentioned in Table 2.

Table 2: Observation Points Distances

Point	Distance (m)
A	100
B	200
C	350
D	1,000
E	250
F	1,000

According to figures 8 to 13, the results have been displayed as wave roses for the two scenarios.Figure 8 Shows the results for the point A (see Figure 2). As shown in the Figure, wave directions do not differ significantly in Point A under the two scenarios. However, waves higher than 1.3 meters are more frequently observed under Scenario 2 (the right hand image), meaning that the 12% calm conditions observed under Scenario 1 (the left hand image) had undergone a decrease by 10%.

In Point B (Figure 9), conditions are totally calm under Scenario 2 (the right hand image), and almost no waves were observed, meaning that the construction of the new breakwater had registered a significant impact in calming the water inside the port. In Point C (Figure

10), wave directions show no significant differences and are mostly within 210 to 270 degree sectors. That is; while the general wave heights in directional sectors 270 to 300 degrees showed a large increase in Scenario 2.

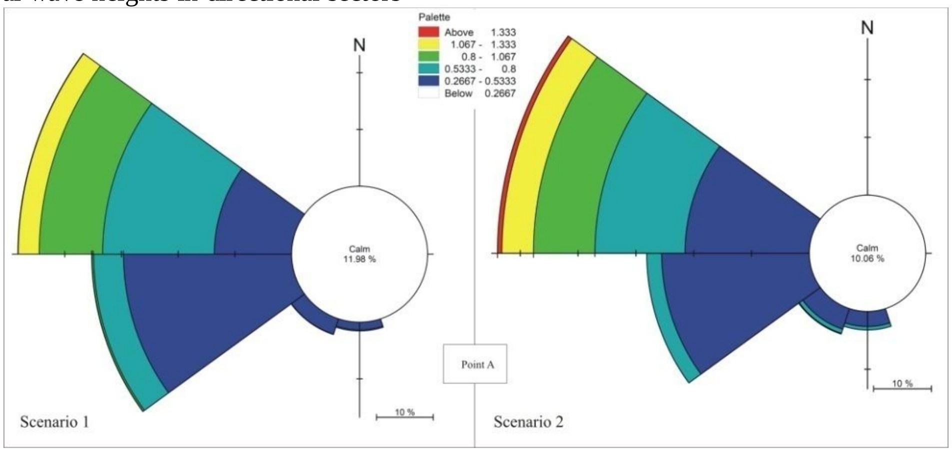

Figure 8: Wave Roses in Point A for Scenario 1(left side) and 2 (right side)

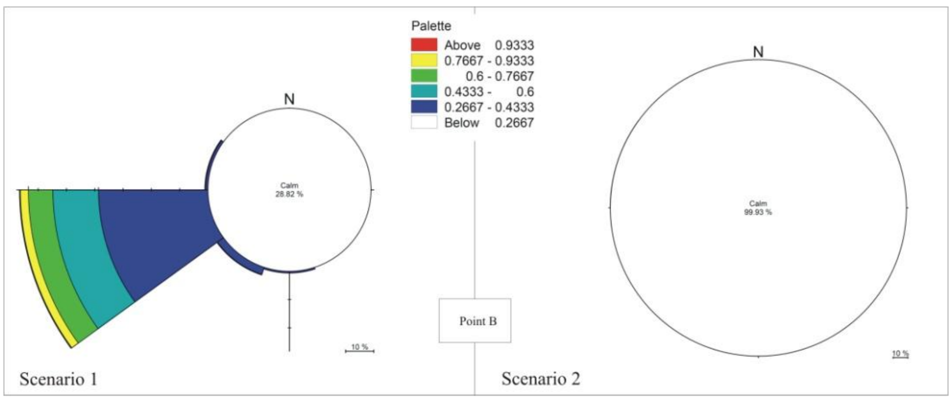

Figure 9: Wave Roses in Point B for Scenario 1 (left side) and 2 (right side)

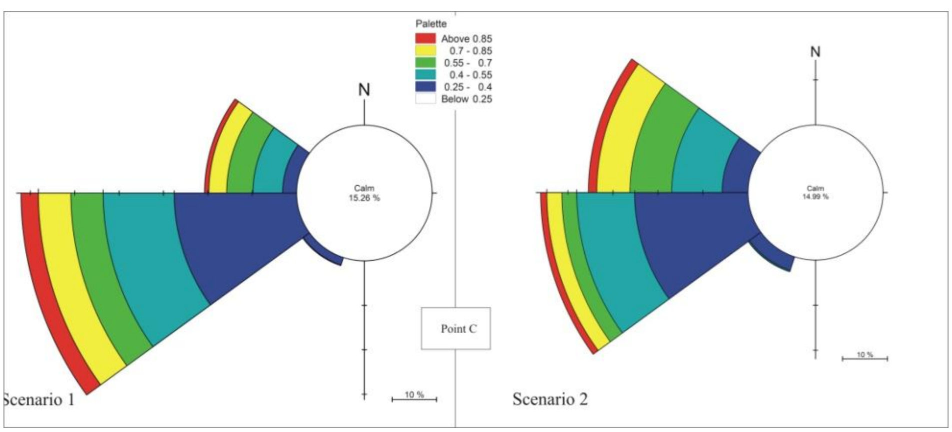

Figure 10: Wave Roses in Point C for Scenario 1(left side) and 2 (right side)

Figure 11 shows that in Point D, similar to Point C, waves propagate in similar directions in both scenarios. Yet, the wave heights registered a significant increase in the second scenario (right hand side), especially within the directional sectors 270 to 300 degrees. It was also observed that the breakwater construction had decreased calm conditions from 3.5% to only 1%.

In Point E (Fig. 12), waves in the two scenarios differ in direction, and waves do not occur in the directional sectors 270 to 300 degrees in Scenario 2 (left hand side), which housed some waves under the first scenario. The situation is reverse for the 150 to 210 degree sector, which was without and with waves in Scenarios 1 and 2 respectively.

As for wave frequency, the 240 to 270 degree sector received fewer waves in the second scenario, while calm sea conditions had almost doubled (from 21% to 49%) after the construction of the breakwater.At point F (Figure 13) again breakwater construction had changed the wave directions greatly and had led to elimination of waves from the directional sectors 270 to 300 degrees. The wave heights however, had not been affected significantly, only small increases for wave heights of 0.2 to 0.4 m. within the 210 to 240 degree sector was observed.In Scenario 2, wave heights of 0.27 to 0.6 m. are increased in the directional sector of 210 to 240 degrees, while no wave heights were observed within the 270 to 300 degree sector.

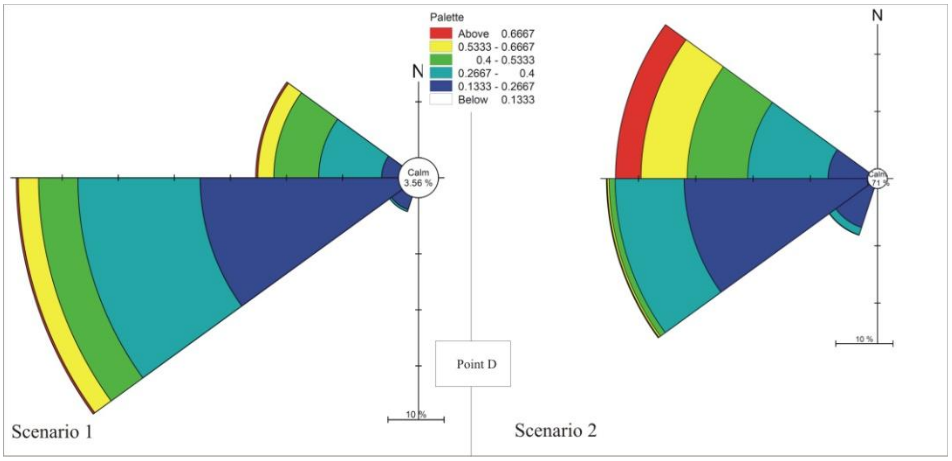

Figure 11: Wave Roses in Point D for Scenario 1 (left side) and 2 (right side)

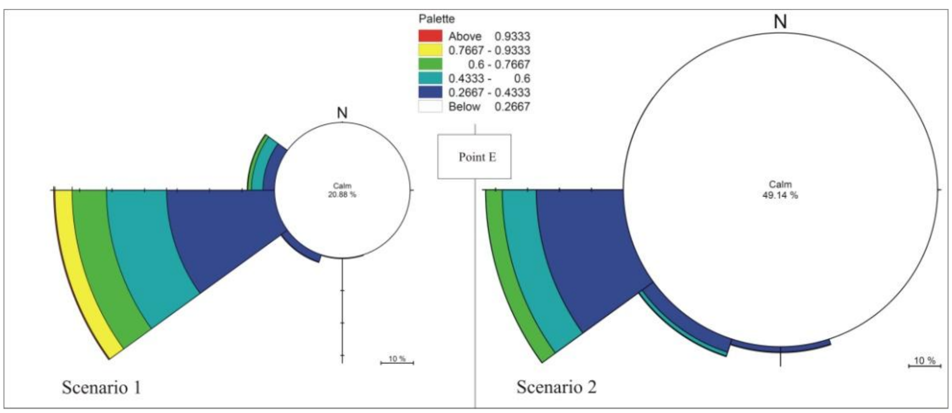

Figure 12: Wave Roses in Point E for Scenario 1 (left side) and 2 (right side)

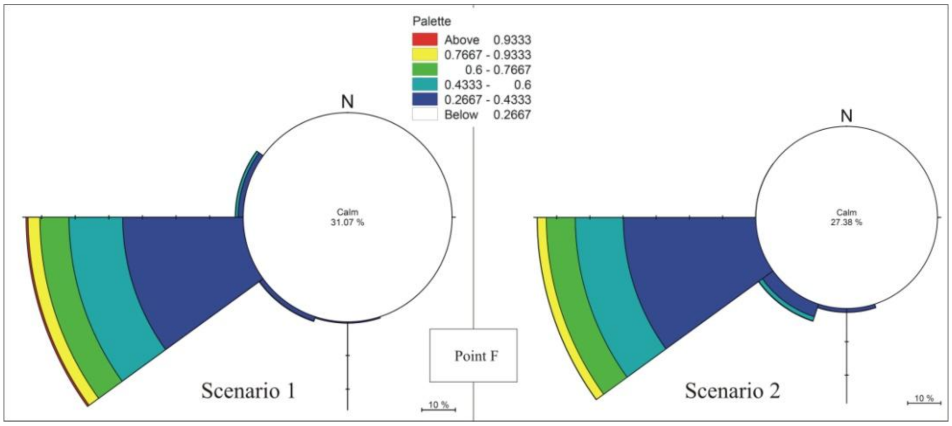

Figure 13: Wave Roses in Point F for Scenario 1 (left side) and 2 (right side)

4.0 Conclusions

The findings showed that the construction of the new breakwater on the Bolkheir Port had resulted in an increase of wave heights behind the breakwater (Point A in Figure 2). That is while; the calm conditions inside the basin resulting from that construction paved the way for the desired activities.

The findings also point to the waves on the up and downside of the breakwater being affected differently, meaning that on the upside of the port (Points C and D in Figure 2) the breakwater caused only the increase of the wave heights, with no particular effect on the wave directions. This is most tangible in the 270 to 300 degrees sector, while the calm conditions had decreased in these two points.

On the downside of the port (Points E and F in Figure 2), wave directions changed some 30 degrees and were transferred from the 210 to 300 degree sector to 180 to 270 degrees. The breakwater had also caused the decrease of wave heights in the mentioned areas, which was specially observed in Point E, which is almost 250 m. away from the breakwater.

Acknowledgments

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