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Numerical Modeling of Effective Factors on Sediment Transport of the Entrance of Bassaidu Fishery Port, Qeshm

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ABSTRACT

Bassaidu port is known to be active as a fishery port which is located at most western side of Qeshm Island. In this study, according to sedimentation problem in the entrance mouth of the port, factors affecting sedimentation in Bassaidu-Qeshm including wind, waves and tidal currents will be discussed. Modeling of this study has been conducted by numerical method using Mike21 software model. The used data has been presented by Ports and Shipping Organization of Iran. Pattern of wave propagation in SW modules and coast and tidal currents in HD hydrodynamic model has been simulated supported by collected data from studied region and finally the obtained results of the model has been compared and validated with the field measurements results in Bassaidu port (studied region) to ensure the accuracy of the modeling done in this study.
KEYWORDS: numerical modeling, Bassaidu port, Mike21, tidal.

INTRODUCTION

Today, seas and open seas are considered as the most important routes for goods transportation around the world. Also, seas are among the most important sources of protein for most people around the world. Therefore, changing the properties of sea water will have a profound effect on people's lives.

Waves and ocean currents are of important and influential factors in determining the geometry of beaches and erosion sequestration around marine structures. The importance makes coastal and ports engineer to seek the best method of study meaning implementing numerical modeling on small or large water zones for predicting future conditions. Considering that water projects are often costly, initial studies using numerical model to achieve move regime, ocean currents and sediment transport are of special engineering importance and can prevent from loss of national assets such as repeated dredging in addition to continuous use of ports during the year.

The first step toward understanding the influential factors on marine environments and coastal areas is determining pattern of waves and currents of that region. In this study, due to serious problems in exploiting Bassaidu Qeshm fishery port because of sedimentation in the entrance mouth of breakwater, factors affecting sedimentation including wind, waves and tidal currents will be examined.

Bassidu village is located on 120 kilometers west of large and beautiful Qeshm Island in the Persian Gulf. The presence of fishing zone of commercial fish and activity of fishing vessels are grounded for abundant employment in the region.(Long:55˚ 16΄ 20 , Lat:26˚ 39΄ 38)

In a study Meer [2] have evaluated the change of coastline by Mediterranean coastal currents and calculated sediment transport rate according to currents rate at various places using Mike21 numerical model.

In the following, Babu et al [4] have simulated and investigated tidal current in Kachchh located in southwestern India using hydrodynamic Mike21 mathematical model. These researches have validated the results of their model using field information of the obtained currents in three different times; and the obtained results of the model were in good agreements with the field information of currents.

In 2002, Shafeiee far et al [2] have investigated and analyzed the sediment transport in Khoor region and Genaveh port using Mike21 numerical model. In this study, by using the obtained information, solutions have been proposed to deal with the problem of sedimentation in Khoor region and Genaveh port.

Azarm sa et al [2] have examined the process of sediment transport in Pazm gulf using Mike21 software. Thus, the overall pattern of waves and currents has been evaluated before and after breakwater construction in the gulf.

In this study due to serious problems in exploiting from fishery port of Bassaidu-Qeshm because of sedimentation in mouth entrance of breakwater; hydrodynamic numerical and sediment of this port has been examined using Mike21 model. After preparing the input information, the model has been operated and calibrated and ultimately the results have been verified with available field information. On the other hand for validating the studies, the results of various models will also be compared.

MATERIALS AND METHODS

Scope of the study

Bassidu port is known to be an active fishery port in Hormozgan Province and Qeshm Island which has been used as the scope of study in this research. In figure 1 you can observe a schematic picture of the studied scope.

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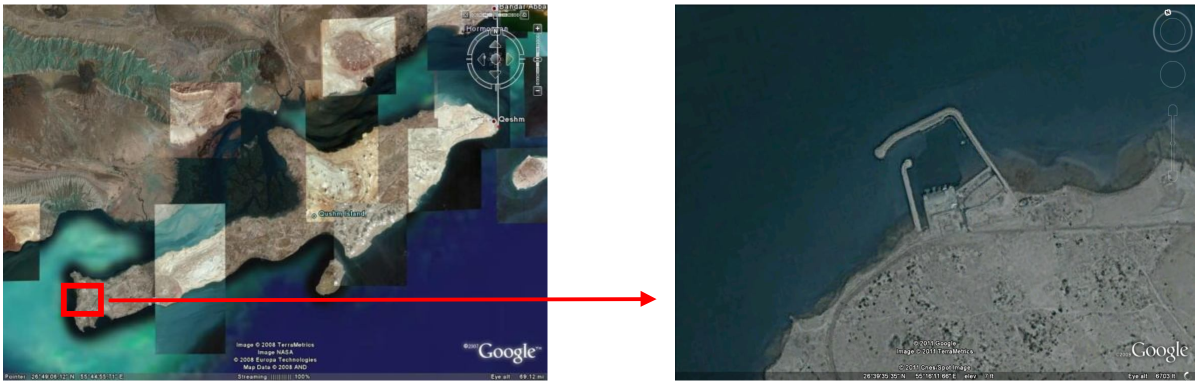


Figure 1. The boundary of Bassaidu port

Hydrodynamic module

HD module is one of the most basic Mike21 software modules, such that so many other modules of this model have been developed based on the obtained results of this model. Water level, current flows in estuaries, lakes and coastal areas can be modeled due to wind and tidal effects using this module.

Governing equations

Governing equations in the hydrodynamic module are mass conservation and momentum equations, that by applying them in a two dimensional current system, in a homogenous layer of depth; this module is able to model water and currents levels in tidal rivers, gulfs, coastal and portal areas, using numerical methods.

Continuity equation:

$$\frac{\partial \eta}{\partial t} + \frac{\partial p}{\partial x} + \frac{\partial q}{\partial y} = 0$$

Navier equation in X direction:

$$\frac{\partial p}{\partial t} + \frac{\partial}{\partial x}\left(\frac{p^2}{h}\right) + \frac{\partial}{\partial y}\left(\frac{pq}{h}\right) + gh\frac{\partial \eta}{\partial x} + \frac{gp\sqrt{p^2+q^2}}{c^2h^2} - \frac{1}{p_w}\left[\frac{\partial}{\partial x}(h\tau_{xx}) + \frac{\partial}{\partial y}(h\tau_{xy})\right] - \omega q - fvv_x + \frac{h}{p_w}\frac{\partial}{\partial x}(p_a) = 0$$

Navier equation in Y direction:

$$\frac{\partial p}{\partial t} + \frac{\partial}{\partial x}\left(\frac{q^2}{h}\right) + \frac{\partial}{\partial y}\left(\frac{pq}{h}\right) + gh\frac{\partial \eta}{\partial x} + \frac{gp\sqrt{p^2+q^2}}{c^2h^2} - \frac{1}{p_w}\left[\frac{\partial}{\partial x}(h\tau_{xx}) + \frac{\partial}{\partial y}(h\tau_{xy})\right] - \omega q - fvv_x + \frac{h}{p_w}\frac{\partial}{\partial y}(p_a) = 0$$

The base of hydrodynamic module, in three-dimensional model is also solving three dimensional incompressible Reynolds equations with moderate Navier equations. Thus, the model consists of continuity, momentum, temperature, salinity and density equation which have been limited by turbulence formula.

To generate a mesh on the physical space, a non-organized network has been used, creating flexible mesh is a very difficult task in the modeling process, a mesh file connects the depths to various situations and contains information of boundary conditions, water depths and computational grid. A computational grid which determines the boundary of the area is a flexible mesh grid.

The studied area for hydrodynamic studies was considered a relatively large area to provide the verifiability of field information recorded in the intended area in the simulation period in addition to scrutinize in tidal currents model and on the other hand, provide the opportunity of regional study of the current. It's necessary to mention that the used mesh which has three different sizes was selected in order of region sensitivity. Thus, the mesh in the vicinity of the port was selected in smaller size.

For modeling water level swings in order to simulate the tidal currents in Bassaidu port; harmonic constants of geological survey organization in open borders of the region were used. The open borders of the studied region according to the figure 2 include Khamir port, Salakh port, tonbe bozorg island, Abumoosa and Lenge port and its swings were applied to the borders after modeling.

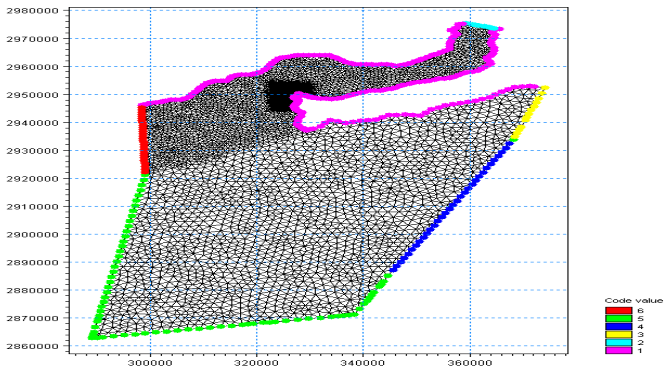


Figure 2.Closed and open position boundaries in hydrodynamic models

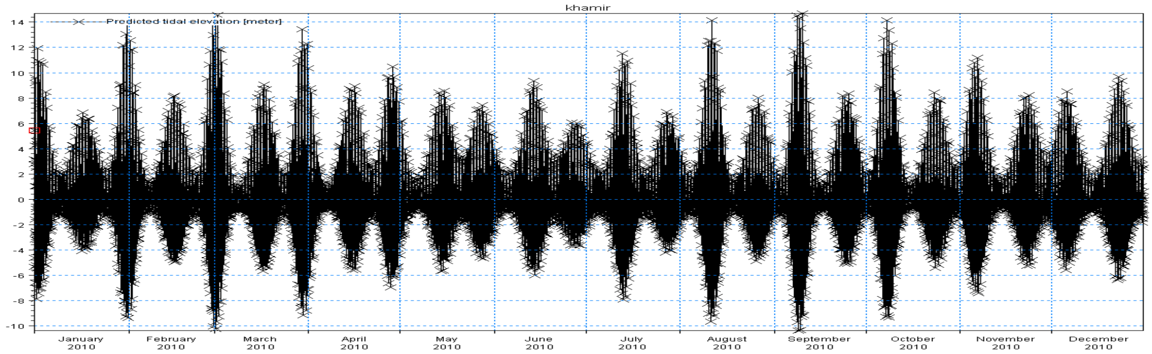


Figure 3.Code 2) Khamir port

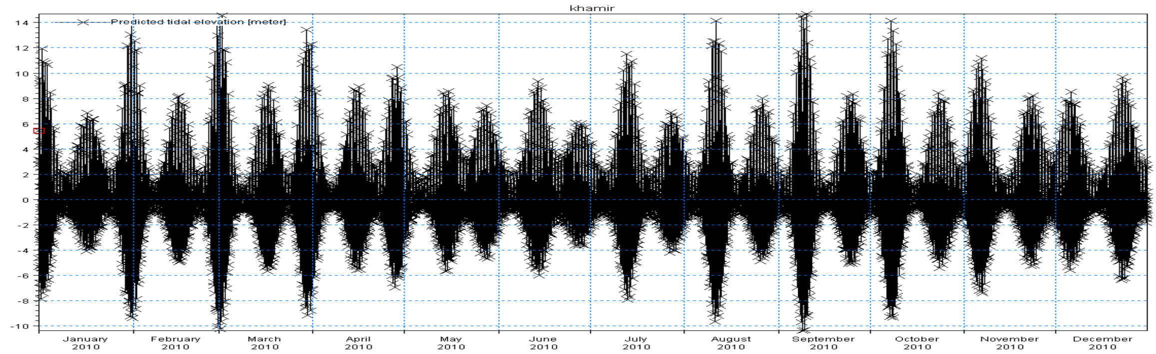


Figure 4.Code 3) Salakh port

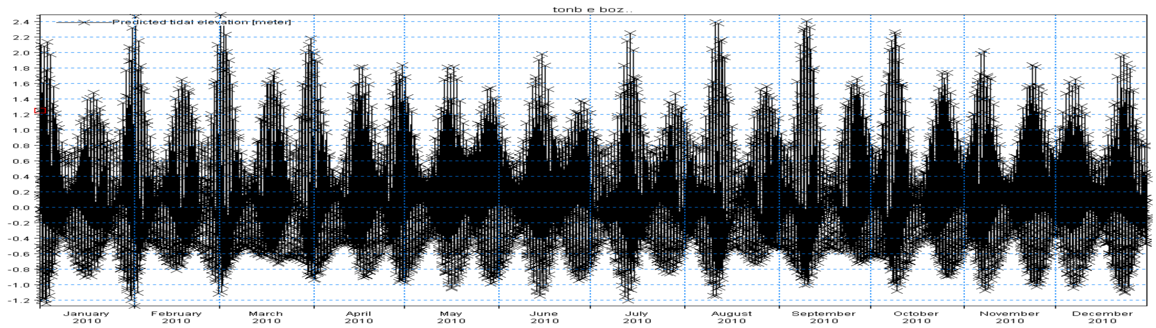
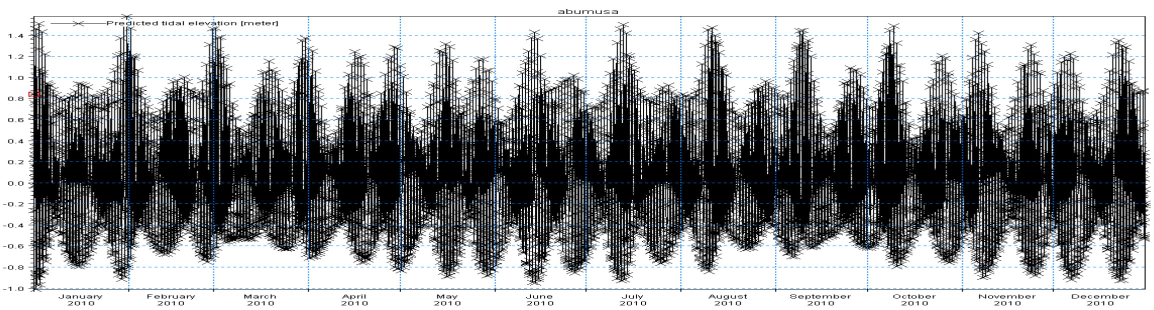


Figure5.Code 4) Greater Tunb Islan



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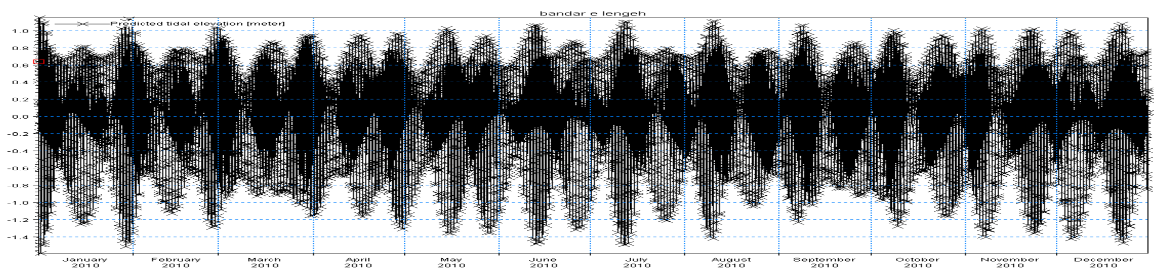

Figure7.Code 6) Lengeh port

Wave model

In order to understand the situation and determine the pattern of wind and wave distribution, available statistical sources and references have been investigated which can help in this area and somehow show the pattern of these phenomena in the plan scope, these sources include statistics of Qeshm synoptic station, statistics of Qeshm airport synoptic station, statistics of Lengeh port synoptic station, the results of Hormozgan province coastal monitoring and simulating project.

Wind information

In order to study the profile of wind and wave influential in the project zone, all available sources that could affect the final decision-making were used which have been introduced in the following. In the following figure, the region of recorded available information around Hormoz strate is shown.

Nearest sites of recorded wind information are Lengeh port and Qeshm synoptic stations which can be used for wind data analysis of the studied region. Information of Lengeh port site and information of Qeshm site from 1996 to 2010 and the wind information of Qeshm airport have been recorded in 2010.

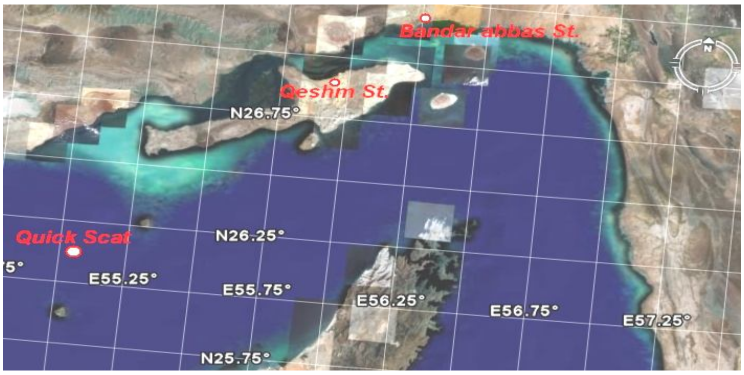

Figure 8. the scope of collecting the studied data in wind and wave statistical sources around Hormoz strate.

As it can be observed from the obtained wind roses of two Qeshm and Lengeh port stations (according to figure 9); the prevailing winds of the region are along the north south. Yet half of the year flow is calm.

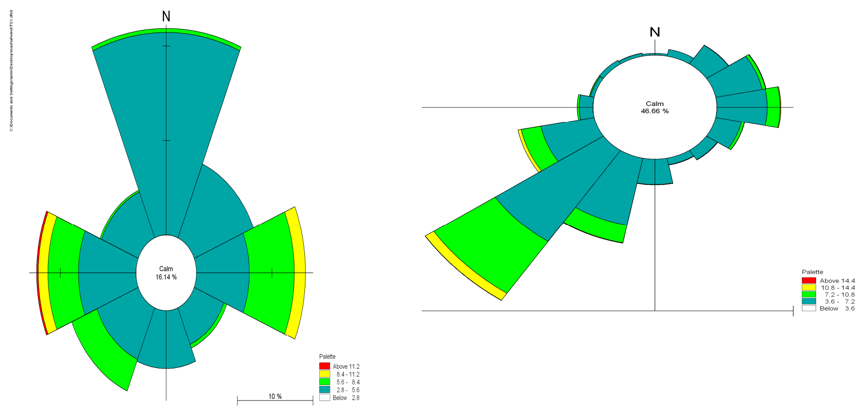

Figure 9: a) annual wind rose of Qeshm airport synoptic station b) wind rose of Lengeh port

It is observed that there is a significant difference between the two wind roses of Qeshm airport and Lengeh port stations. According to special topography of Lengeh port, the recorded wind rose has been influenced by these factors and cannot be defined for simulation zone. Therefore wind information of Qeshm airport station was used in the modeling.

Spectral wave model (SW)

The most important factor in non sticky sediment transport in coastal areas is waves. Waves in addition to have a major role in moving seabed sediments, cause permanent currents like current along the coastline, the return current due to waves on the coast. Making required speed for mass transfer and sediments transfer. On the other side, the most impacts of waves on bed occur in an area called surf zone (the area between breaking line of waves and coastline).

SW module is in Mike21 software package, a model of third generation of simulating the wave production and propagation processes due to wind in a water zone. In this model, phenomena related to waves production due to wind in deep water such as white capping, quad wave-wave interaction, wind-wave coupling on the one hand and processes related to waves propagation such as refraction, shoaling, bed induced diffraction on the other hand are considered.

Wave processes propagation in shallow water in area of energy dissipation and wave breaking are also calculated by this model.

Wave energy solving equations are based on control volume method and are done on a flexible triangular grid which can obtain better estimates of wave characteristics by more fining the dimensions of the grid in the intended scope. In this section, SW model have been only used for modeling processes associated with the propagation of wave energy from deep water to coastal waters. The base of this model for wave transport is solving the equation of energy transfer along with springs and wells terms. In order to consider the random nature of sea waves, energy transport equation was used in its spectral form.

RESULTS AND DISCUSSION

Mesh generation

As previously mentioned, in order to generate flexible grid, the initial meshes are not sensitive to depth. But given the high sensitivity of current to depth changes, the size of meshes are reconstructed based on the depth changes to increase the sensitivity of current parameter with depth reduction.

For this purpose the area of each element was considered as a linear function of depth. Thus by depth reduction, the mesh areas are reduced to increase the accuracy and sensitivity of the desired parameters and the secondary meshing is generated after reconstruction and re-interpolation.

On the other hand, according to the effect of wave and current phenomena, the mesh used in each module was reconstructed and thus the two main models of wave and current are calibrated and the two specific meshes of that model were stabilized.

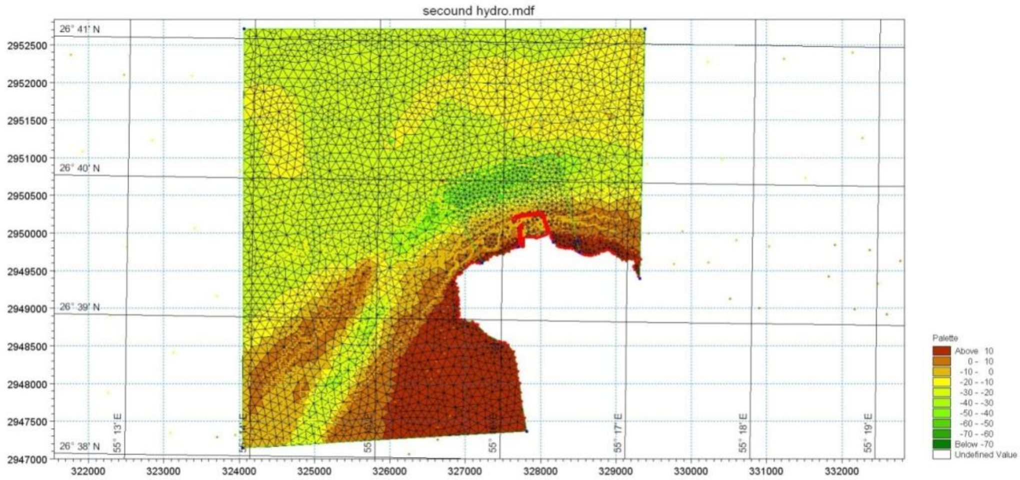

Figure 10. A sample of refine mesh generation

The hydrodynamic model

After applying the initial conditions on computational nodes, the hydrodynamic model was implemented. Modeling was calculated in the field information collection in the time limit in 2 seconds time steps for 1200000 time steps. Hence, a two dimensional modeling was performed for a complete tidal period (feb 2010).

Hydrodynamic model validation

Module calibration will be necessary before running the final HD module. In order to achieve more consistency between the simulation results with field information and regional findings; calibration of the two dimensional model is recommended by changing the roughness coefficient (Maning's coefficient) in the range of coefficients and model is implemented in a specified timeframe (Feb 2010) and the model results are compared for every roughness coefficients by measuring water level in Bassadu port. In this study the obtained results of model are compared and validated with results of field measurements in Bassadu port (the studied area).

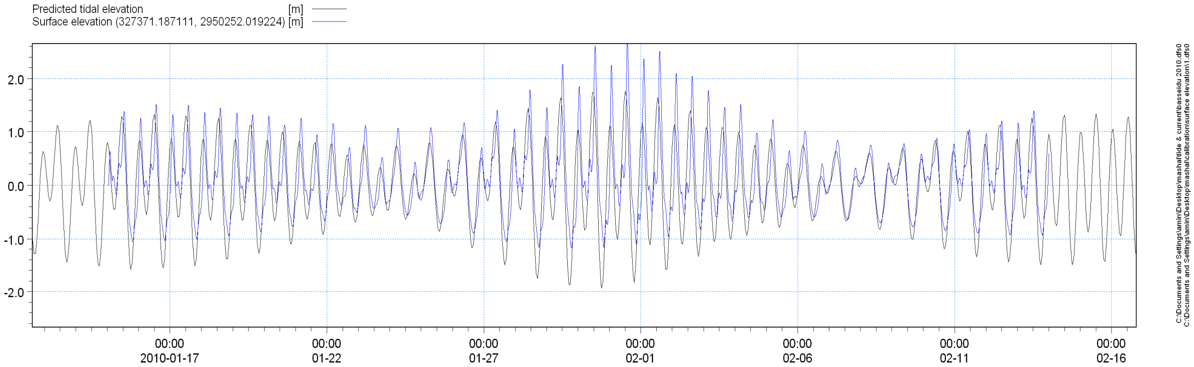

Figure 11: comparison of model results for water level swings with field data in the simulation period in Bassaidu port.

In the figure 12, statistical scatter diagram related to field and modeling data in the timeframe is shown.

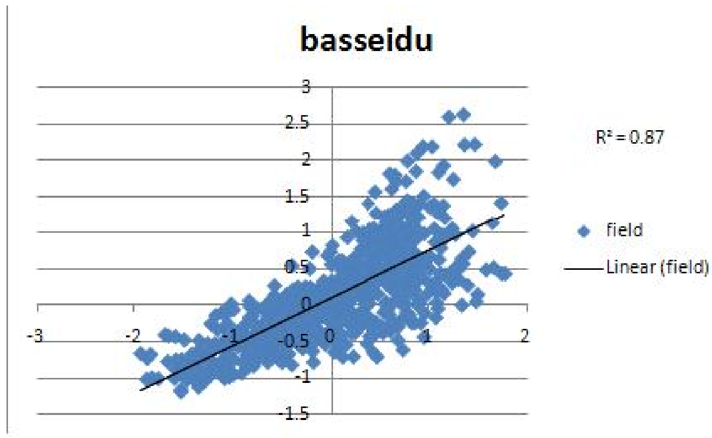

Figure 12: frequency graph of model and field data for water level changes in Bassaidu port R=0.93, RMSE=5.2 cm/s

Wave model

Wave profile will be required in coastal zone in later studies including in determining billow profile due to wave, sediment transport and coastal morphology, designing coastal structures and coastal security systems. In order to determine the wave profile in shallow coastal zones, SW model of Mike21 software package was used.

Wind- induced wave model

In order to model wind- induced waves, a larger area was simulated in order to model the real effect of wind on the desired area.

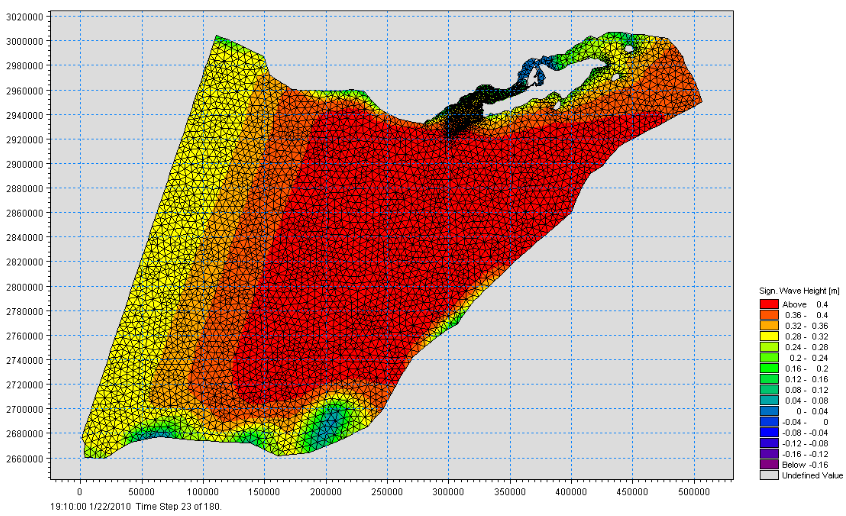

Figure 13: an example of the used mesh in production of wind-induced waves

Calibration coefficients

These coefficients include wave breaking and bed friction that the calibrated values of these coefficients in implementing local model of Bassaidu Qeshm port are considered based on the proposed values of Iranian water waves modeling project. After wind-induced waves modeling, the modeling results were controlled with recorded field information of Kong port in the simulation period, and due to the initial mismatch of the model; by changing white capping coefficient and selecting cdis=50, the initial model was in good agreement with the above mentioned field information and the results are available by the following graphs:

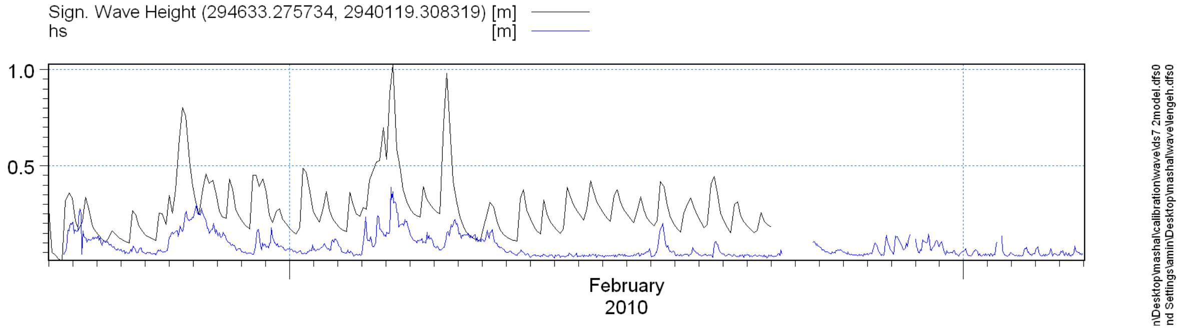

Figure 14: comparison of model results with field information with ds=20 modeling

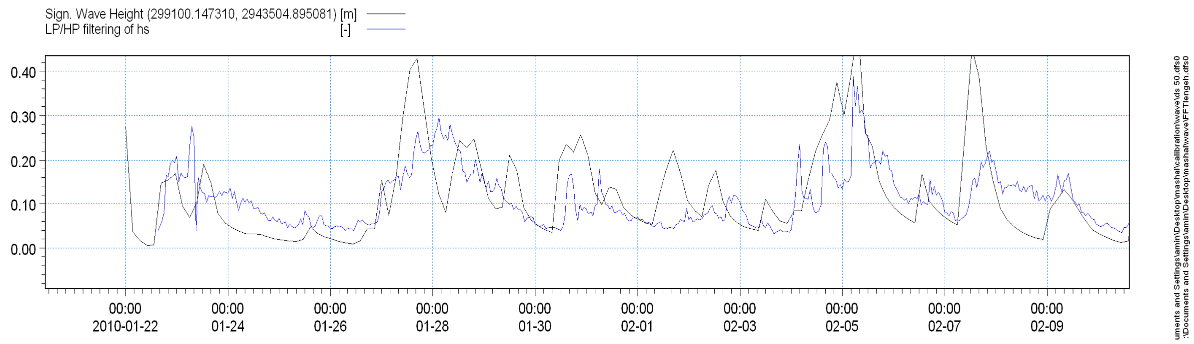

Figure 15: comparison of model results with field information with ds=50 modeling

In the figure below, wave sea of Bassaidu (in relatively deep water across the port) has been extracted from the model. It is observed that the dominant wave direction is from southwest to northeast. However, this value for entrance mouth of port depending on the geometry of the environment is a little different.

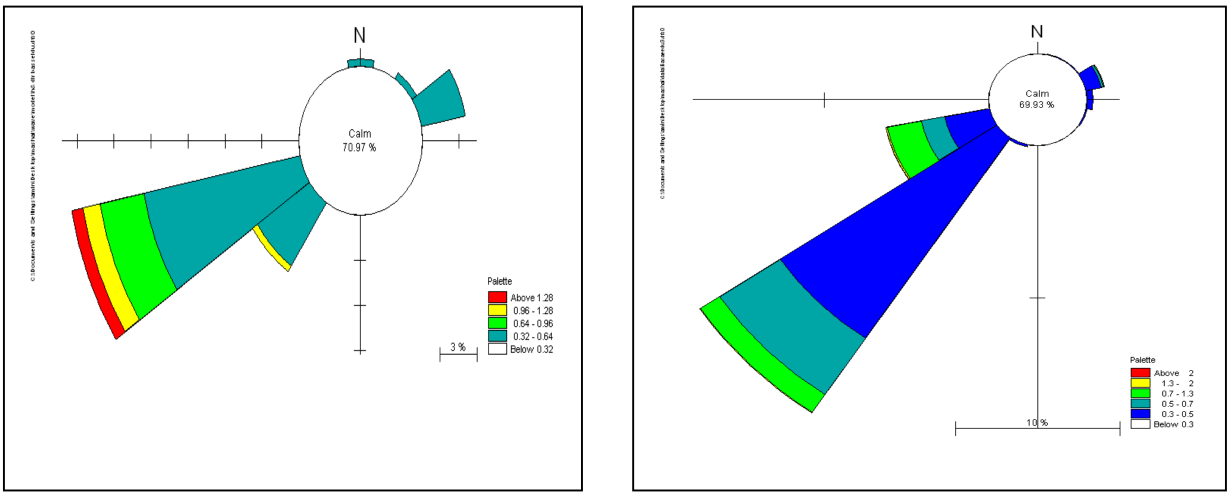

Figure 16: A) Bassaidu wave rose in relatively deep water across the port
B) Bassaidu wave rose in front of entrance mouth of the port

Considering the comparison of wind rose with port wave rose, it s observed that the wind blows from northern half has not much significant effect on wave generation according to little wind basin

Wind-induced current model

To determine the wind induced current, hydrodynamic model was modeled separately using the wind of Qeshm airport and the effect of wind-induced current in shallow regions with low slope was remarkable.

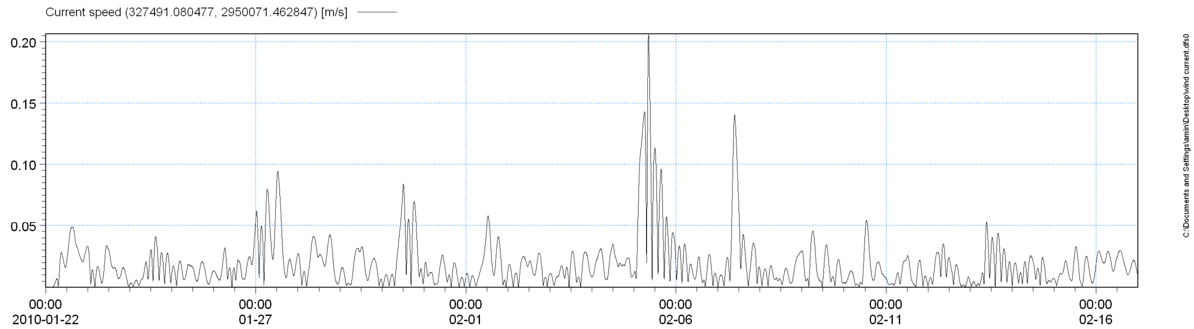

Figure 16: speed rate of wind-induced current

Wave-induced current model

By calling radiation stresses of wave model and placing it in hydrodynamic model, it is noticeable that its effect in current production is negligible.

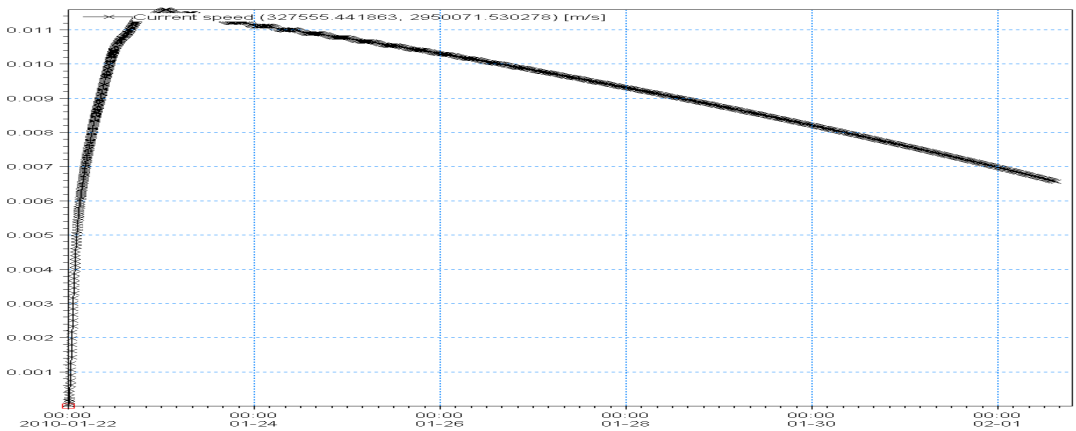

Figure 17: speed rate of wavw-iduced current

3-7 sensitivity analysis and determination of the governing phenomena of sediment transport in Bassaidu port:

According to the modeling of each influential phenomena separately, in this step, the sum of results and determination of governing phenomena in generating the influential current for sediment transport are presented; the summary of the obtained results is as follows:

1-tidal-induced currents have relatively high values.

2-the effect of waves in current generation is low in this region.

3-the effect of wind in current generation in shallow coastal regions with low slope is significant.

According to comparison of results as the figure18 we have:

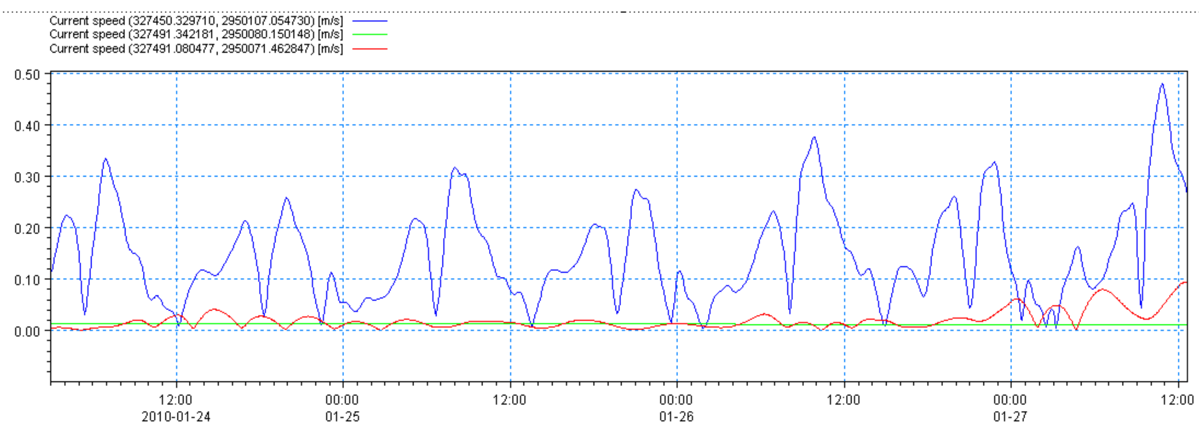

Figure 18: comparison of tidal currents value wind and wave-induced current

The effect of tidal currents is dominant in project region compared to two other phenomena in the sediment transport. These results are well consistent with the finding that Babu et al [2].

CONCLUSION

In this study due to serious problems in exploiting from fishing port of Bassaidu-Qeshm because of sedimentation in mouth entrance of breakwater; hydrodynamic numerical and sediment of this port has been examined using Mike21 model. After preparing the input information, the model has been operated and calibrated. The obtained results of the model has been compared and validated with the field measurements results in Bassaidu port (studied region) to ensure the accuracy of the modeling done in this study and according to the performed modifications, there is a good agreement between this numerical simulation and field data which indicates the accuracy of the modeling. The results of this study showed that: the effect of waves in current generation is low in this region. The effect of wind in current generation in shallow coastal regions with low slope is significant. These results are in good agreement with previous findings

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