INTERNATIONAL JOURNAL OF MARITIME TECHNOLOGY

IJMT Vol.10/No. 18/autumn & winter 2023 (49-56)

Available online at: www. ijmt.ir

# Hydrodynamic and Sediment Transport Studies of Gorgan Bay (Case Study: Khozeini Channel and Investigation of Jetty's Role in Reducing Active Sedimentation After Channel Dredging)

**Mohammad Adibzade[1], Ebrahim Shabani[2], Mahdieh Givehki[3]**

[1] Department of Civil Engineering, Tarbiat Modares University; Email: mohammad.adibzade@modares.ac.ir
[2] Faculty of Engineering, Ahvaz Azad University; Email: m.e.shabani@gmail.com
[3] Department of Civil Engineering, Sharif University of Technology; Email: mahdiehgiveki@gmail.com

**ARTICLE INFO**

*Article History*:
Received: 13 Jun 2022
Accepted: 26 Jan 2023

*Keywords*:
Khozeini Channel
Sediment Transport Modelling
Gorgan Bay
Mike-21

**ABSTRACT**

Gorgan Bay is one of the greatest economic and ecological areas in Iran and is used as a recreational and fishery center by the region's residents. This bay connects to the Caspian Sea through two channels, Ashuradeh and Chapoqli. The hydraulic connection of Gorgan Bay with the Caspian Sea greatly impacts water recirculation and aquatic life in this region. As a result, the decrease in the water level of the Caspian Sea, and the disruption of the hydraulic connection between them have caused problems with the water quality in the bay in recent years. Several solutions have been proposed to solve these problems, including dredging the Ashuradeh and Chapoqli channels, reopening the Khozeini channel, and transferring water by pipeline to the west of the bay. Although the mentioned actions can increase the volume of water exchanges and reduce water retention time, each action requires careful consideration to estimate its long-term effectiveness. Considering the possibility of re-sedimentation in each of the above channels, studying sedimentation and erosion patterns in this area can help determine the shape, depth, and duration of dredging and the economic justification of jetty construction at the channels' mouth. Hence, in this study, the amount of sediment load beside the patterns of erosion and sedimentation after dredging the Khozeini channel as well as the effects of implementing jetties have been determined using Mike 21. Based on the simulation results, the area has an active sedimentary pattern that can impact the bed level inside the channel. These effects can be reduced at the channel's mouth by constructing two jetties on its sides.

## 1. Introduction

Gorgan Bay is the only Persian bay on the southern shores of the Caspian Sea, a habitat registered in the Ramsar Convention. Due to the continuous decrease of the Caspian Sea water level and the problems created in this bay, it is necessary to examine the requirements for increasing the hydraulic exchanges of this bay with the Caspian Sea. According to the modelling done by engineering companies under the supervision of the Ports and Maritime Organization of Iran, the reopening of the Khozeini channel can increase the volume of annual water exchanges to 6.94 billion cubic meters, which is 1.25 billion cubic meters more than the Chapoqli and Ashuradeh channels; It will also reduce the water retention time by 63 days [1].

Due to the importance of sediment recognition and its behavior, many studies have been conducted around the world, which can be mentioned in the research conducted by Wang et al. on the Adriatic Sea [2], and Margvelashvili et al. by studying a one-dimensional and three-dimensional model of sediment transport in the Torres region of northern Australia [3]. Moreover, Zavattero et al. used the Mike FM model to investigate the sediment transport in the Var River in France [4]. In addition to these examples, Sravanthi et al. used MIKE 21 Mud Transport (MT) to find sediment transport patterns on the west coast of India [5]. Pradhan et al. used Mike 21 to simulate cohesive sediment in the Chilika lagoon located along the east coast of India [6]. The simulation results showed that suspended sediment concentration is high in the north-east portion of the lagoon. Gelfort et al. simulated Jade estuary in Germany using Mike 21 [7]. In this study, they investigated the effect of port construction on morphology changes. In another study, a bed-load sediment transport model using Mike 21 was applied to investigate coastal morphodynamics by Kozyrakis et al [8].

Also, in the Gorgan Bay region and the southern coastlines of the Caspian Sea, several studies have been conducted in the field of sediments, currents and wave patterns, which can be briefly mentioned by Ajami et al [9]. They used numerical modelling Mike 21 in Miankaleh coastlines to investigate the flow regime. According to the results of this modelling, the direction of flow in Gorgan Bay for one year is counterclockwise and from west to east, and the amount of sediment transfer is less than 0.00002 $m^3/s/m$. Miankaleh beaches are also part of the dissipative beaches, and the numerical model "Mike" is suitable for low slope beaches with dissipative beaches' properties. In another study, Gorgan Bay was examined in terms of climatic conditions after separation from the Caspian Sea under two scenarios by Sharbati [10]. The future of the bay after its separation from the Caspian Sea has been explored by Mike-21. Furthermore, Ruode et al. have examined the prevailing pattern of wave propagation and current along the coast of Gorgan Bay [11]. According to the parallel flow produced in the wave refraction zone, the movement of sediment particles in the shoreline has been analyzed. This simulation shows that the sediment particles are moved to the east due to the direction of propagation of the waves from the northwest. Another condition affecting Gorgan Bay is the fluctuations in the water level of the Caspian Sea. According to the results of modelling done by Sharbati, if the water level decreases by one centimeter per year, Gorgan Bay will lose its hydraulic connection with the Caspian Sea at -27.5 m [12]. Also, Kheirabadi et al. obtained a general flow pattern in Gorgan Bay using Mike's 3D model [13]. The most important force influencing the flow in this simulation is the wind field. The flow simulation results show that most of the time, the flow is in line with the wind direction and is from west to east and also, the flow pattern inside the bay is counterclockwise. Moreover, Gharibreza et al. investigated the sediment transport mechanism in Gorgan Bay using field measurements, physical studies of sediment grains and GIS studies [14]. This study placed sedimentary particles in this region in four groups, which the accumulated sediment particles that had the same origin and conditions of sediment transport were separated from other sediment grains, and their physical, chemical and initial properties were evaluated. The results show that currents and waves transport the sediments to the estuaries of the bay. some sediments will be deposited inside the bay, the part between the Gorgan River and Chapoqli and parts of them in Ashuradeh and Chapoqli mouths.

In another modelling performed by Sharbati et al. the effects of dredging the Khozeini channel have been investigated on the water retention time in Gorgan Bay [15]. In this research, two Mike 21 modules have been used for modelling. The parameters considered for this simulation are wind field, precipitation, and evaporation during the simulation period. The recommended width for dredging this channel is 170 meters. The modelling results showed that the dredging of the channel, considering that the flow pattern inside the bay is counterclockwise, can reduce the water retention time and, consequently, the renewal time by about 13 days. In addition, Khoshravan introduced self-adaptation to global warming as a solution to preserve and revitalize Gorgan Bay [16]. This study identified the morphological deformations of coastlines resulting from water level fluctuations using satellite images. The results showed that dredging of the channels of this bay is not very suitable as a long-term solution. He suggested that for hydrological stability, engineering solutions need to be adapted to the natural conditions of this bay. Also, hydrogeochemical studies showed that the most crucial factor affecting sediment and chemical factors of water in the bay is the Caspian Sea currents, and the impact of rivers around the bay is negligible. Shabani et al. have attempted to simulate this bay to obtain the flow pattern in Gorgan Bay after dredging and reopening the Khozeini channel using the Mike numerical model [17]. The results of this simulation showed that changing the width of the Khozeini channel from 200 to 400 meters does not affect the general pattern of currents, which is counterclockwise, and they only saw a change in the direction of sediment movement in the areas very close to the channel.

This study intends to investigate the efficiency of one proposed method that can maintain the connection between the Caspian Sea and the Gorgan Bay. Due to the global change, the Caspian Sea water level has declined in recent years, and the growth of the Miankaleh spit and its increase in width to the Gorgan Bay has blocked the Khozeini channel. Considering that the reopening of the Khozeini channel can increase the amount of water exchanges between the Caspian Sea and the Gorgan Bay so that, this study investigates the scenarios related to the dredging of the Khozeini channel and the medium-term impacts of the jetty construction on sedimentation and erosion patterns in the region.

## 2. The Study Area

Gorgan Bay, with an approximate length of 60 km, a maximum width of 12 km, an average depth of 1.5 m, and an approximate area of 400 $km^2$, is a semi-enclosed water basin that is surrounded by the

Miankaleh, Mazandaran, and Golestan provinces and its geographical location is shown in Figure 1. This bay is hydraulically connected to the Caspian Sea in the northeastern part through two channels, Chapoqli and Ashuradeh. The Khozeini channel was also the communication route between Gorgan Bay and the Caspian Sea, built in the past to develop shipping, which has been blocked in recent years by decreasing the Caspian Sea water level and increasing sedimentation. Among the adjacent rivers, Gharesoo and Gorganrood rivers have the most impact on sedimentation in this area. The total volume of annual flows is 131.43 M.C.M in this basin, and their total sediment flux is 3.5 million tons per year [1].

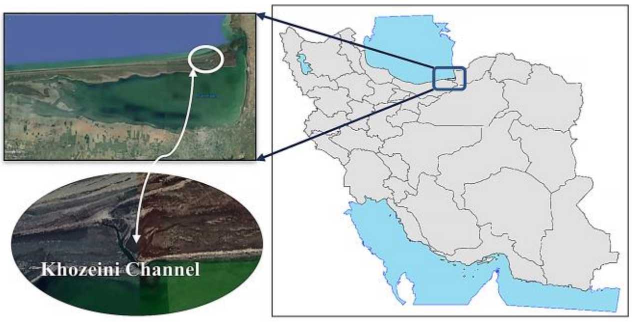



**Figure 1- Gorgan Bay and Khozeini Channel**

According to the Caspian Sea water level (Figure 2), the growth of the Miankaleh spit can be seen. [18]. Therefore, it is necessary to provide solutions that not only can solve the problem of water retention time and water quality but also are economic and impose the least environmental threats to the region. Examination of the results of the previous modelling shows that water exchange in Gorgan Bay through channels has played an effective role in changing the renewal rate.

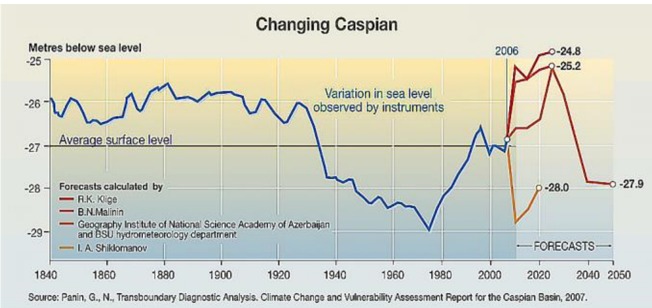
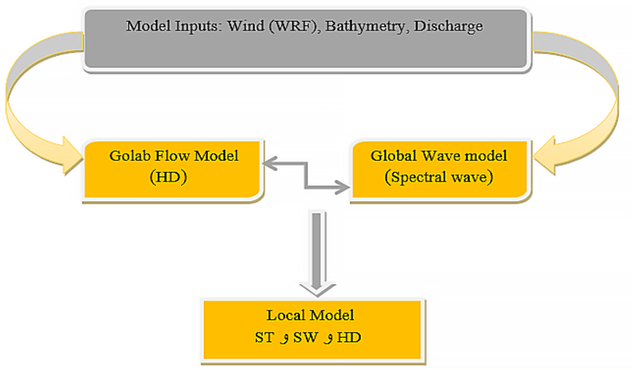



**Figure 2- Water level fluctuations of the Caspian Sea in recent years**

## 3. Model

In this study, the erosion and sedimentation patterns resulting from currents and waves were examined using the Sand Transport (ST) module of Mike software. In order to set a sediment model, the wave and current model for this region are first set. In HD model simulation, effective parameters include bed roughness, wind coefficient, density, eddy viscosity, and wave radiation. Also, wave breaking, White capping, and wave refraction affect the output of the wave model. Sediment transport was simulated after setting the hydrodynamic model and calibrating it using ADCP and the Amirabad buoy. According to the received sediment samples, the major sediments are sand, so the sand transport module was used for this simulation. In the ST module, flow-related outputs are used from the hydrodynamic model and since the simultaneous effects of currents and waves are seen in the mouth of the Khozeini channel, the simulation is based on both of them. It should be noted that important input parameters include $d_{50}$ and bed roughness for the sediment model.




**Graph 1- Modelling sequence**

## 4. The Governing Equations

The governing equations in this numerical model are solved using the finite volume method. The basis of the governing equations in the flow model is the equation of the law of conservation of mass and momentum. These equations for shallow water are as follows:

$$\frac{\partial h}{\partial t}+\frac{\partial h\bar{u}}{\partial x}+\frac{\partial h\bar{v}}{\partial y}=hS \quad (1)$$

$$\frac{\partial h\bar{u}}{\partial t}+\frac{\partial h\bar{u}^2}{\partial x}+\frac{\partial h\bar{v}\bar{u}}{\partial y}=f\bar{v}h-gh\frac{\partial \eta}{\partial x}-\frac{h}{\rho_0}\frac{\partial p_a}{\partial x}-\frac{gh^2}{2\rho_0}\frac{\partial \rho}{\partial x}+\frac{\tau_{sx}}{\rho_0}-\frac{\tau_{bx}}{\rho_0}-\frac{1}{\rho_0}\left(\frac{\partial s_{xx}}{\partial x}+\frac{\partial s_{xy}}{\partial y}\right)+\frac{\partial}{\partial x}(hT_{xx})+\frac{\partial}{\partial x}(hT_{xy})+hu_s \quad (2)$$

$$\frac{\partial h\bar{v}}{\partial t}+\frac{\partial h\bar{u}\bar{v}}{\partial y}+\frac{\partial h\bar{v}^2}{\partial x}=f\bar{u}h-gh\frac{\partial \eta}{\partial y}-\frac{h}{\rho_0}\frac{\partial p_a}{\partial y}-\frac{gh^2}{2\rho_0}\frac{\partial \rho}{\partial y}+\frac{\tau_{sy}}{\rho_0}-\frac{\tau_{by}}{\rho_0}-\frac{1}{\rho_0}\left(\frac{\partial s_{yx}}{\partial x}+\frac{\partial s_{yy}}{\partial y}\right)+\frac{\partial}{\partial x}(hT_{xy})+\frac{\partial}{\partial y}(hT_{yy})+hv_sS \quad (3)$$

## 5. Input Data

Input parameters include the wind field (WRF) of 2013, river discharges, boundary conditions, and hydrographic data for the HD and SW models. Due to the interaction of wave and current near the channel, it is necessary to consider the effect of these two parameters on each other using the radiation wave parameter. Also, global modellings were first conducted for the Caspian Sea, considering the lack of boundary conditions; then, data related to water level, current, wave and velocity for open boundaries were extracted from the global models for one year. According to the input and output data of the `models, observational data were used in order to calibrate these two models, which is discussed in the following sections. Also, 2018 and 2016 bathymetries were used for the sediment calibration process. Mean sea levels (MSL) were -26.5 m and -26.85 m for 2016 and 2018 years which are subtracted from raw data to produce bathymetry files. It should be noted that 2016 bathymetry includes data for Ashuradeh and Chapoqli channels which was used for sediment transport model calibration (Figure 3).

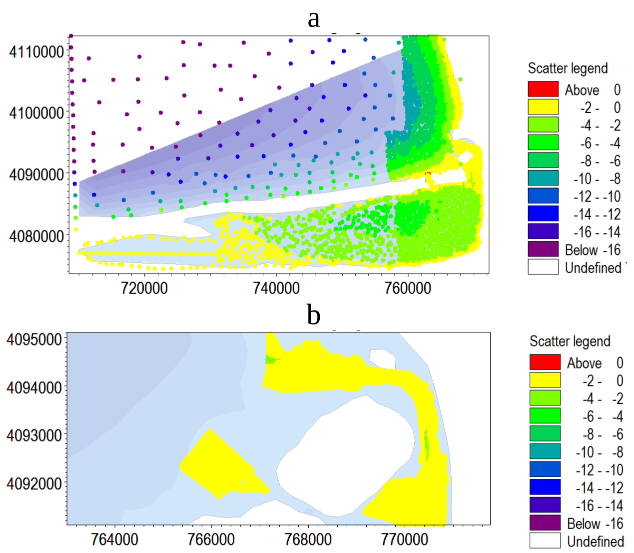



**Figure 3- a: 2018 bathymetry which is used for simulations, b: 2016 bathymetry used for calibration the sediment model**

## 6. Local Models

One of the important input parameters is the model geometry and the bathymetry file, according to Figure 4 which was introduced to the model in the form of a mesh file. In order to perform optimal modelling, flexible mesh capability has been used. Also, due to the importance of currents and waves in the channel mouth, the desired networking in this area has been made smaller at different distances to see the effects of currents and waves clearly. After sensitivity analysis of the mesh size, the mesh was finally selected for wave and current modelling, according to Figure 5. Based on this figure, the number of nodes and elements is 3600 and 6746, respectively. Also, the smallest allowable angle is equal to 26°. The Boundary conditions for the SW model were Sign. Wave Height, Peak Wave Period, Mean Wave Direction and Dir. Stand. Deviation for western and northern boundaries. Also, the boundary conditions used for the HD model included water level and flow velocity at the western open boundary and flow discharge at the northern boundary. Moreover, the duration of the global and local models was equal to one year, which ten first days of each model were considered as a warm-up.

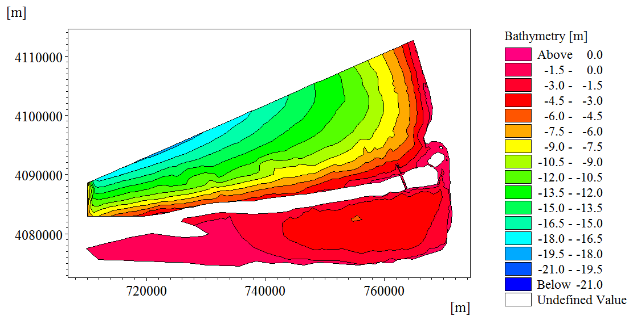



**Figure 4-Bathymetry introduced to the model**

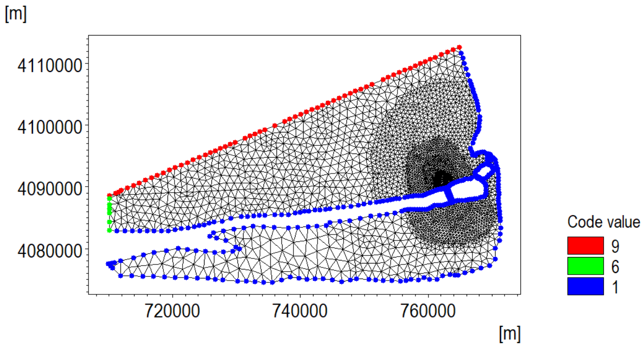



**Figure 5-Mesh introduced to the model**

## 7. Validation

For calibration and validation of the wave model, the information of the Amirabad buoy in coordinates 712682.27 N and 4092338.43 E and for the flow model calibration, the information of the ADCP device located in a position with a longitude of 714792.003 and a latitude of 48088075.97 were used according to Figure 6. For model validation, significant wave height and flow velocity were used to validate SW and HD models (Figure 7 and Figure 8).

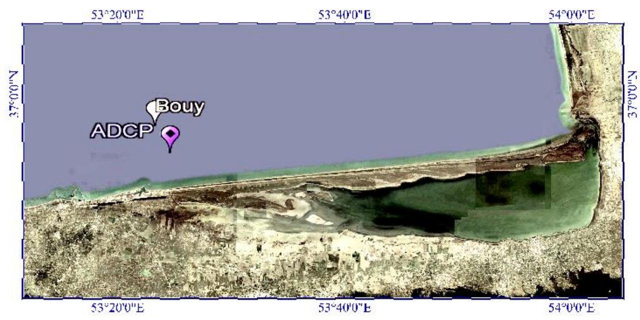



**Figure 6- Location of ADCP and Amirabad Buoy**

In the following, the degree of convergence of observational data and modelling results was calculated using statistical parameters. In Table 1, correlation coefficients (CC) and root mean square error coefficients (RMSE) for each parameter are presented, and their values are acceptable.

$$CC = \frac{\sum (x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum (x_i - \bar{x})^2 \sum (y_i - \bar{y})^2}} \quad (12)$$

$$RMES = \sqrt{\frac{1}{n}\sum (y_i - x_i)^2} \quad (13)$$

Based on these coefficients, the wave model shows a proper correlation with the measurement data and RMSE is 0.14. The flow model correlation with observed data is also equal to 0.63%, and the root mean square error is 0.045. Moreover, the annual wave rose indicates the predominant direction of the waves, which are north to west according to Figure 9, and the collision of these waves with the Miankaleh spit causes parallel currents aligned to the coast, which can increase the transfer of sediments from west to east and give rise to sedimentation near the channel month.

**Table 1- The normal and ideal range of each statistical parameter**

| Parameter | Normal Range | Ideal Range |
|---|---|---|
| CC | 0.0-0.75 | <0.8 |
| RMSE | 0.0-1.7 | >0.5 |

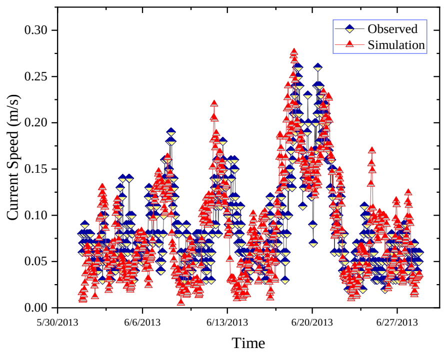



**Figure 7-Current velocity validation of Mike-HD model**

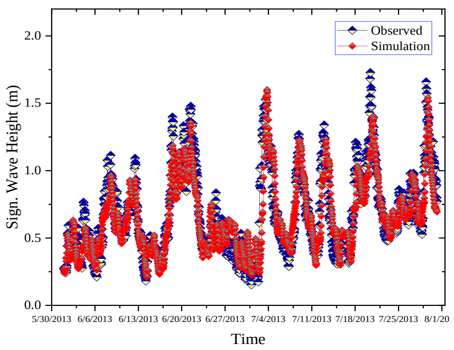



**Figure 8-Wave height validation of Mike-SW model**

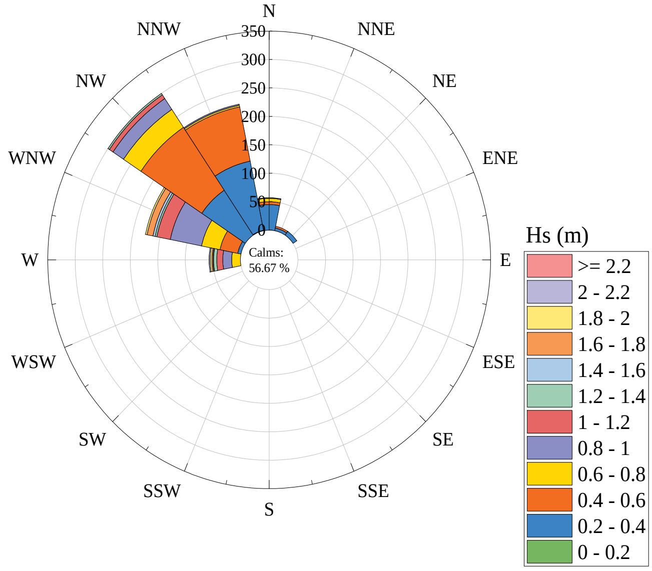



**Figure 9- The direction of the simulated waves using SW model near Khozeini Channel mouth**

## 7. Sediment Transport Modelling

The sediment transport model was somewhat calibrated using calibrated flow and wave models and two available bathymetries in the Ashuradeh channel for two different years along a line, according to Figure 10. After ensuring the validity of hydrodynamic and sediment models using measured data by considering statistical coefficients and according to the average particle diameter ($d_{50}$) in the direction of the Miankaleh spit, the Sand Transport module of Mike 21 software package has been used for one year simulation period. This module can simulate the erosion and sedimentation pattern under the combination of wave and current or a pure current form. In this model, the horizontal component of velocity is used, and the vertical component of velocity is assumed to be logarithmic.

During simulation, the sediment transport rate is obtained from continuous simulation by linear interpolation sediment transport table, which is set based on input data. In this table, the critical shield parameter and the minimum error were equal to 0.05, and 0.0001; Also, according to the granulation of sediments, $d_{50}$ was equal to 0.2mm, and the average water temperature was 15°. Because of the wave and current conditions near the Khozeini channel, the combination of wave and current forces has been used to determine the sedimentation pattern. By selecting the mentioned forces, it is necessary to determine the sediment size and porosity coefficients for the ST module. Due to the lack of appropriate measurement information, software presuppositions have been used to determine these coefficients.

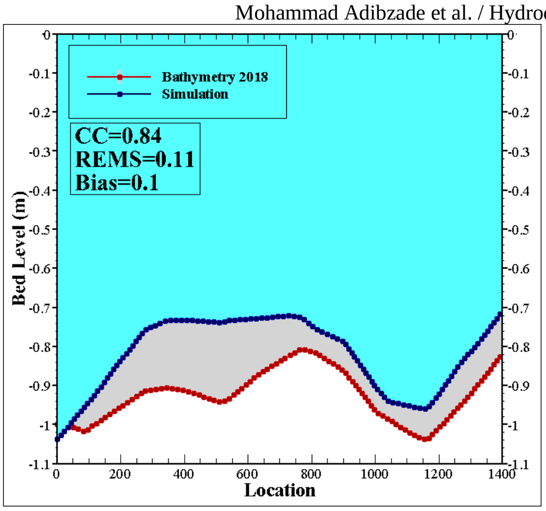



**Figure 10- Validation of Sediment Transport Model using 2016 and 2018 bathymetries along a line near the Ashuradeh's mouth**

## 8. Scenarios

Due to the importance of the Khozeini channel in recirculation and water quality in Gorgan Bay and the increase in annual water volume exchanges in case of its reopening, the channel has been dredged. The dimensions of dredging areas are 2500 meters in length, 250 in width, and reaching an average depth of 1.6 meters in accordance with Figure 11. Then, three scenarios were examined to investigate sedimentation and erosion patterns in the desired area. In the first scenario, the hydrodynamic conditions and sediment transport patterns were investigated for one year, and in the other two scenarios, the effects of jetties on sedimentation and erosion were simulated.

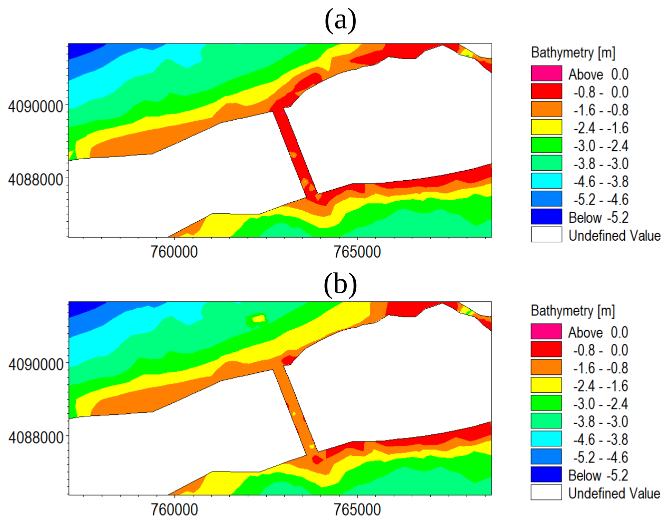



**Figure 11- (a) and (b): Khozeini Channel before and after dredging**

## 9. Results and discussion

The results of HD and sediment modelling showed the flow speed increases near the Khozeini channel; Also, the sediment transfer is in the direction of the Miankaleh spit, west to east. This issue can be the main factor in intensifying sedimentation at the mouth of the Khozeini channel that gives rise to sediment deposition in the channel mouth and block currents. The maximum amount of total load along Miankaleh spit is less than 0.000032 $m^3/s/m$ according to Figure 12. For better comparison of scenarios and due to the importance of bed level changes in the channel and its mouth, this parameter is presented as an average over a period of one year in the three scenarios. Accordingly, bed level change and bed level are shown in Figure 13. The second scenario has been investigated using only one jetty, and in the third scenario, two jetties' effects have been studied in controlling the sedimentation rate in the month and Khozeini channel. The length and width of the jetties are 2000 m length and 30 m width. Also, the jetties' direction is normal to the coast in the location. It should be noted that the accurate dimension of jetties must be calculated based on long-term simulations and using different guidelines which they were ignored in this study.

According to the simulation results and without considering the jetty effect, the bed level changes at the mouth of the Khozeini channel was significant. Considering the alongshore currents and the repetitive nature of the currents and waves in this area, the possibility of sedimentation and bed level changes are high that can interrupt channel currents by blocking its mouth. In addition to the above changes, bed level changes indicate erosion -0.6 m with increasing flow velocity in the middle of the channel; As a result, if sediment accumulation is prevented at the channel entrance, the depth of the middle and end part of the channel will meet navigation needs and water flow. Also, the bed level along the entire length of the channel and its mouth is less than -1.6m at the end of the simulation period, which indicates sedimentation in the area. Maximum bed level change is 0.45 m in the mouth of the channel which is equal to 1.2 m depth in the inlet and maximum sedimentation in the channel indicated bed level changes less than 0.3 m. Also, the volume of sedimentation in the channel based on mean bed level change after the simulation is 19572 $m^3$ and the mouth of the channel is 76037$m^3$.

The second scenario investigated a jetty effect on sedimentation rate and bed level changes at the Khozeini channel mouth according to the second Figure 13. Based on the presented results, placing one jetty on the left side of the Khozeini channel can limit the sediment's entry into the channel, considering the west-east direction of sediment transport patterns. Based on the results the bed level change around the jetty is more than 0.5 m and in the channel is less than 0.3 m confirming the favorable effects of the jetty construction. Furthermore, the sedimentation volume in the channel was calculated based on statistical mean bed level change which was 14123 $m^3$in the channel and 56602 $m^3$ in the mouth of channel. The bed levels in the channel are more than Sce.1 and are more than -1.5 m which indicated the stability of the channel. It should be noted that due to the sediment deposition around the jetty, the wave break locations will gradually shift around the jetty, so in the future study it needs to be considered for long run simulation. In the third scenario, the effects of using two jetties in the western and eastern parts of the Khozeini channel were investigated. Due to the collision of the north and west streams at the mouth of the Ashuradeh channel, there is a possibility that the sediments may be suspended and moved to the west. Therefore, using a jetty may help stabilize the channel mouth. Based on the results, it can be concluded that the sedimentation area has decreased at the mouth of the channel. Accordingly, bed level changes at the channel mouth are reduced but the maxim of statistical mean bed level change is the same. Also, the bed level at the end of the simulation period shows that if jetties were constructed, the bed level in the channel would not change, and the average value would be -1.6m. Moreover, maximum bed level changes can be seen around jetties which indicate sedimentation equal to 0.6 m in the left jetty and approximately less than 0.3 m around the right jetty and the sedimentation less than 0.3m in the channel the bed levels in the end of simulation show that bed levels are -1.6 m. Based on these results, sedimentation volume are 13524 $m^3$ in the channel and 48622 $m^3$ at the mouth of the channel. Based on the results of the sediment model at the mouth of the channel inside Gorgan Bay, severe sedimentation and erosion are not observed in any of the scenarios due to the low flow rate inside it; so currents are not able to carry sediments in this area.

a b

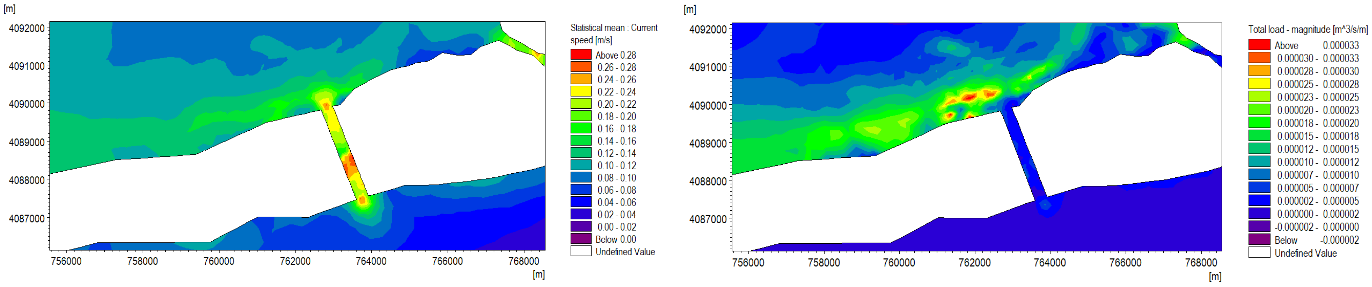



**Figure 12- a: flow velocity near the Khozeini channel, b: bed load in the direction of the Miankaleh spit**

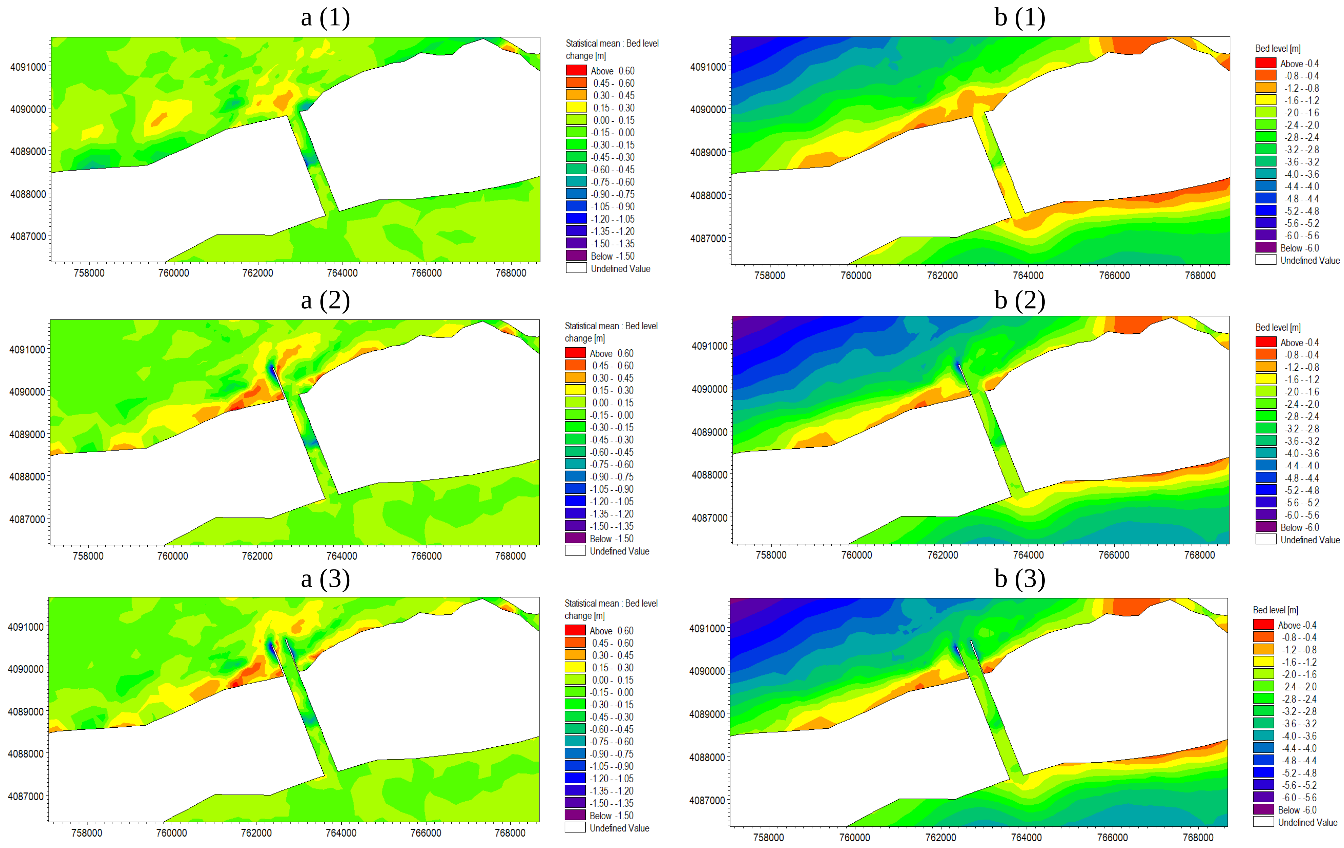



**Figure 13-a (1) and b (1): bed level change and bed level in Sce.1; a (2) and b (2): bed level change and bed level in Sce.2; c (1) and c (2): bed level change and bed level in Sce.3**

## 10. Conclusion

The simulation results indicate that sedimentation is a dominant phenomenon near the Khozeini channel which can lead to the closure of the dredged channel in the long run. The bed level changes near the mouth of the channel in all three scenarios are significant compared to the channel itself. The maximum bed level change in this area is more than 0.15 m higher than the channel which will be a treat for flow passage. Over time, the channel capacity will be lowered due to sedimentation at the mouth of the channel. It was illustrated that using jetties can play an effective role in protecting against sedimentation and preserving flow passages at the channel's mouth. Based on the results, the volume of sedimentation at the mouth of the channel decreased by more than 19000 $m^3$ in the case of building one jetty, and 27000 $m^3$ by constructing two jetties compared to the first scenario. Also, the sedimentation volume decreased in the channel by more than 5000 $m^3$ and 6000 $m^3$ by using one and two jetties. These results show that the channel has more hydrodynamic stability. Hence, by mitigating sedimentation at the mouth, the channel can preserve its connection with the Caspian Sea for a longer time. It should be noted that construction and dredging costs must be compared to each other in order to make decisions.

## 11. References

[1] Technical Report, Pouya Tarhe Pars. (2018).

[2] Wang XH, Pinardi N, Malacic V., (2007), *Sediment transport and resuspension due to combined motion of wave and current in the northern Adriatic Sea during a Bora event in January 2001: A numerical modelling study. Cont Shelf Res, Coastal shelf research*, Vol. 27(5), p.613–33 https://doi.org/10.1016/j.csr.2006.10.008.

[3] Margvelashvili N, Saint-Cast F, Condie S., (2008), *Numerical modelling of the suspended sediment transport in Torres Strait. Cont Shelf Res*; Vol.28(16),p2241–56. https://doi.org/10.1016/j.csr.2008.03.037.

[4] Zavattero E, Du M, Ma Q, Delestre O., (2016), Gourbesville P. 2*D Sediment Transport Modelling in High Energy River – Application to Var River*, France. Procedia Eng; Vol.154, p.536–43. https://doi.org/10.1016/j.proeng.2016.07.549.

[5] Sravanthi N, Ramakrishnan R, Rajawat AS, Narayana AC., (2015), *Application of Numerical Model in Suspended Sediment Transport Studies along the Central Kerala, West-coast of India.* Aquat Procedia; Vol.4, p.109–16. https://doi.org/10.1016/j.aqpro.2015.02.016.

[6] Pradhan S, Samal RN, Choudhury SB, Mohanty PK., (2018), *Hydrodynamic and cohesive sediment transport modeling in chilika lagoon. ISPRS Ann Photogramm Remote Sens Spat Inf Sci*; vol.4, p.141–9. https://doi.org/10.5194/isprs-annals-IV-5-141-2018.

[7] Gelfort A, Ladage F, Stoschek O., (2011), *NUMERICAL MODELING OF MORPHODYNAMIC CHANGES IN THE JADE ESTUARY – GERMANY.* Coast Eng Proc, p.1–11.

[8] Kozyrakis G V, Delis AI, Alexandrakis G, Kampanis NA., (2016), *Numerical modeling of sediment transport applied to coastal morphodynamics*. Appl Numer Math, Vol.104, p.30–46.

[9] Khoshravan H., (2018), *Comparison of Numerical Model Results and Mofological Field Evidence and Complications in Miankaleh Coasts*, Vol.13, p.37–53. https://dx.doi.org/10.30482/jhyd.2018.60136.

[10] Sharbati S., (2018) *Investigation of the possible future of Gorgan Bay after separation from the Caspian Sea from the perspective of ecological sequence, Journal of environmental science and technology* Vol.6(1), p.41–53. https://dx.doi.org/10.22069/japu.2018.14612.1426

[11] Roude H., Lorestani F., and Valikhani S., (2013) *Simulation of wave dynamics and sand transport on the Caspian Sea coast (Gorgan Bay area)*, Quantitative morphological research, Vol.2(2), p.1-18.
https://dx.doi.org/10.22069/japu.2018.14612.1426. 8-

[12] Sharbati S., (2016), *The need to study the effects of lowering the Caspian Sea water level on the situation in the Gulf of Gorgan and provide a way out of the crisis in the coming years*, Journal of Aquatic Exploitation and Breeding, Vol.5(1), p.83–106.
https://dx.doi.org/10.22069/japu.2017.11452.1310

[13] Kheirabadi, H., Valisamani, J., Nouri, H., and Ranjbar, H., (2015), *Three-dimensional simulation of Gorgan Bay hydrodynamics by MIKE3 FM model*, Iran Hydraulic Conference, Vol. 14, p.1–7.

[14] Charibreza, M., Motamed, A., RahimPour., and anaraki H., (2006), *Sediments and transport and deposition mechanism in Gorgan Bay*, p.1-7 https://www.civilica.com/PaperICOPMAS07-ICOPMAS07_007.html

[15] Sharbaty, S., and Nasimi, S., (2018), *Modeling of Possible Dredging Effects of Khozeini Channel on the Water Renewal Time in Gorgan Bay, Southeast of tmj nhe Caspian Sea, Journal of environmental science and technology*, Vol.20(1), p.15-28

[16] Khoshravan, H., and Nasimi, S,. (2017), *Water exchange solution between Gorgan Bay and Caspian Sea*, Vol.245:130–134.

[17] Sharbati, S., and Shaabani, A., (2016), *Effects of reopening of Khozeini channel on the general flow pattern in Gorgan Bay (southeast of Caspian Sea)*, Quarterly Journal of Environmental Science and Technology, Vol.18, p.67–80.

[18] Ataei, S., Adjami, M., Lashteh Neshaei, MA. Ya'asubi, SH., (2017), *The Effect of Sea Level Fluctuations on the Caspian Sea Coastline Changes. Int J Marit Technol,* Journal of marine engineering, Vol.12, p.103–13., and, p.105–116.