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The impact of buildup proposed barrage on tidal hydrodynamics in the Shatt Al-Arab River, South of Iraq

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Abstract -. The influence of the suggested regulator barrage of the Shatt Al-Arab river on water level fluctuations was tested by using a one-dimensional model. The numerical model period covered six months in 2017. The performance of the model was evaluated by comparing the estimated water level at two locations, Sihan, and Abu Flous. A good fit between the observed and simulated water levels at the two locations was achieved with root mean square error at 0.13 and 0.06 m, respectively. The model results showed that there is an increase in high water levels near areas located below the barrage in both the spring and neap tidal phases. The increasing of water level below the barrage could be attributed to behave the river as a convergent tidal channel that characterizes by the increasing water level as tidal wave propagated further toward inland areas. The highest increase in the water level reaches about 0.4 m below the barrage. Additionally, the tidal range also increased along the river course. The maximum increase in tidal range reaches about 0.9 m below the barrage. The results obtained could be useful for a general assessment of the hydrodynamic of the Shatt Al- Arab river and could give a general view in the case of the construction of such a barrage to tackle the salinity intrusion problem in this river.

تأثير السدة المقترحة انشاؤها على المناسيب المدية في نهر شط العرب ، جنوب العراق

صادق سالم عبدالله ، عادل جاسم الفرطوسي، علي عبدالرضا لفتة
مركز علوم البحار – جامعة البصرة– العراق

المستخلص - تم تقييم تأثير السدة التنظيمية المقترح أنشاؤها في شط العرب بالقرب من أبو الخصيب على تذبذبات منسوب المياه باستخدام حزمة برامجيات Mike11، وهي تقنية النمذجة العددية أحادية البعد. تم تشغيل النموذج لمدة ستة الاشهر الاولى من عام ٢٠١٧. تم تقييم كفاءة النموذج من خلال مقارنة مستوى المياه في موقعين، سيحان وأبو فلوس. تم حصول على توافق جيد بين مستويات المياه المقاسة والمحاكاة في الموقعين مع جذر متوسط الخطأ التربيعي عند ٠.١٣ و ٠.٠٦ متر على التوالي. أظهرت النتائج أن هناك زيادة في مستويات المياه المرتفعة بالقرب من المناطق الواقعة اسفل السدة في كل من الطورين الربيعي والمحاقي. يمكن أن يُعزى ارتفاع منسوب المياه اسفل السدة إلى تصرف النهر كقناة مدية متقاربة تتميز بارتفاع مستوى المياه مع انتشار موجة المد أكثر نحو المناطق الداخلية. أعلى ارتفاع في منسوب المياه يصل إلى حوالي ٠.٤ متر اسفل السدة. بالإضافة إلى ذلك، ازداد المدى المدي على طول مجرى النهر. تصل أقصى زيادة في قيمة المدى المدي إلى حوالي ٠.٩ متر اسفل السدة. النتائج التي تم الحصول عليها يمكن أن تكون مفيدة لتقييم عام ليهدروديناميكية نهر شط العرب ويمكن أن تعطي نظرة عامة في حالة بناء مثل هذه السدة التنظيمية لمعالجة مشكلة توغل الملوحة البحرية أعلى النهر.

الكلمات المفتاحية: نهر شط العرب، مايك ١١، توغل الملوحة، السدة التنظيمية، الخليج العربي.

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Introduction:

Tidal rivers, that have a free connection with the sea are exposed to the influence of two factors: the first is the freshwater inflow from the land and the tidal phenomenon from the open sea. However, these two forces exchange roles between them according to their strength (Lafta, 2022a). When the amount of freshwater arriving at the tidal river is large, then this force work against the salty water and pushes it down towards the open sea. In contrast, when the amount of freshwater is low, then the saline water penetrates the river and intrudes towards the upstream of the tidal river causing a change in the water quality, especially in the downstream region, because this region is more closely affected by marine waters (Al-Fartusi, 2018). Therefore, the hydrodynamics and water quality of the tidal rivers (including the Shatt Al-Arab river) depend on the interaction between these two energies (Savenije, 2012). The salinity intrusion issue is a common problem in tidal rivers and has very high attention from scientific researchers around the world, in particular in the estuarine regions, due to its economic, industrial, and environmental importance to these populations. There are several studies that highlighted this issue (Gong and Shen, 2011; Al-Taei *et al.*, 2014; Liu *et al.*, 2014; Abdulla, 2016; Lafta, 2022b).

During the last years, the freshwater inflow arriving at the Shatt al-Arab has decreased sharply to less than (50 m^3/sec) as a result of the change in the hydrological conditions of the river basin. However, the decreasing freshwater inflow of the river is a direct result of the continuous development of water resources in upstream countries by the construction of dams on the course of the river or by diverting the course of the river's tributaries. These actions led to a decrease in the amount of freshwater coming into the Shatt Al Arab River. Consequently, the effect of the tidal phenomenon is exceeding the other force, i.e. freshwater inflow, and becomes the main influencer. Hence, the tidal flow propagates further towards inland areas leading to a salinity intrusion becoming more frequent in Basrah province. The salinity intrusion problem has a very high negative effect on the quality of the water and made it unfit for human, industrial, agricultural and other consumption. This situation also caused an increase in the flushing time of the Shatt Al-Arab waters (Abdullah *et al.*, 2016). From here, the idea came for constructing a barrage on the river to prevent the salinity from reaching the upper reaches of the Shatt al-Arab river.

The environmental impact assessment of any project related to nature represents a high priority for the decision-maker since human intervention in nature may cause damage to the environment. Neill *et al*. (2018) asserted that any regulatory installation could have a significant impact on the river environment and that impacts should be taken into account before installation. Qian Ma *et al*. (2019) studied the effect of a tidal barrage on coastal flooding resulting from a storm surge at the Severn Estuary. They illustrated that the installation of such a construction could assist to mitigate the effect of storm surges on coastal flooding Fairley *et al*. (20114) studied the influence of a Severn Barrage on the behavior of waves in the Bristol Channel and confirmed that the implementation of the regulatory dam will affect tidal currents and wave heights. Significant changes are caused in the hydrodynamic and morphology of estuaries and tidal areas when there are closed dams, Manuel *et al.* (2012). Ali and Al Thamiri (2021) found that the dam in Shatt Al-Arab will increase sedimentation operations in the river. The objective of current study aims to know the mechanism and extent of the effect of the proposed barrage on the nature of the tidal wave below the barrage. To fulfill this objective, a one-dimensional hydrodynamic model will be used to compare the hydrodynamic condition before and after install of the proposed barrage on the river stream.

The Study Area:

Historically, the Shatt Al-Arab River is formed from the confluence of two rivers, the Tigris and Euphrates at the city of Qurna and extends beyond it for a distance of about 204 km and flows into the Arabian Gulf at Faw city. It is located between two latitudes (38ºN, 39ºN) (Fig. 1). The hydrological conditions of the river varied as a result of the reduction of the freshwater flows coming from the Tigris, Euphrates, and Karun rivers. The Euphrates River was closed and there is a sharp decrease in the amount of water arriving from the Karun River. So, the Tigris River is the main source of supplying Shatt Al-Arab with fresh water (Lafta, 2021). The average width of the river is 400 m, and its depths range between 20-8 m (Al-Wahili, 2012). The Shatt Al-Arab River is a tidal river, and the tides in it are of a mixed type, the predominant semidiurnal (Abdullah, 2014; Lafta 2022a). The average tides (tidal range) are 1.84 m, 1.75 m, and 1.1 m in the Outer Bar, Al-Faw, and Basrah areas, respectively. The water level reaches 3 meters in the Outer Bar during the flood condition (Abdullah, 2014).

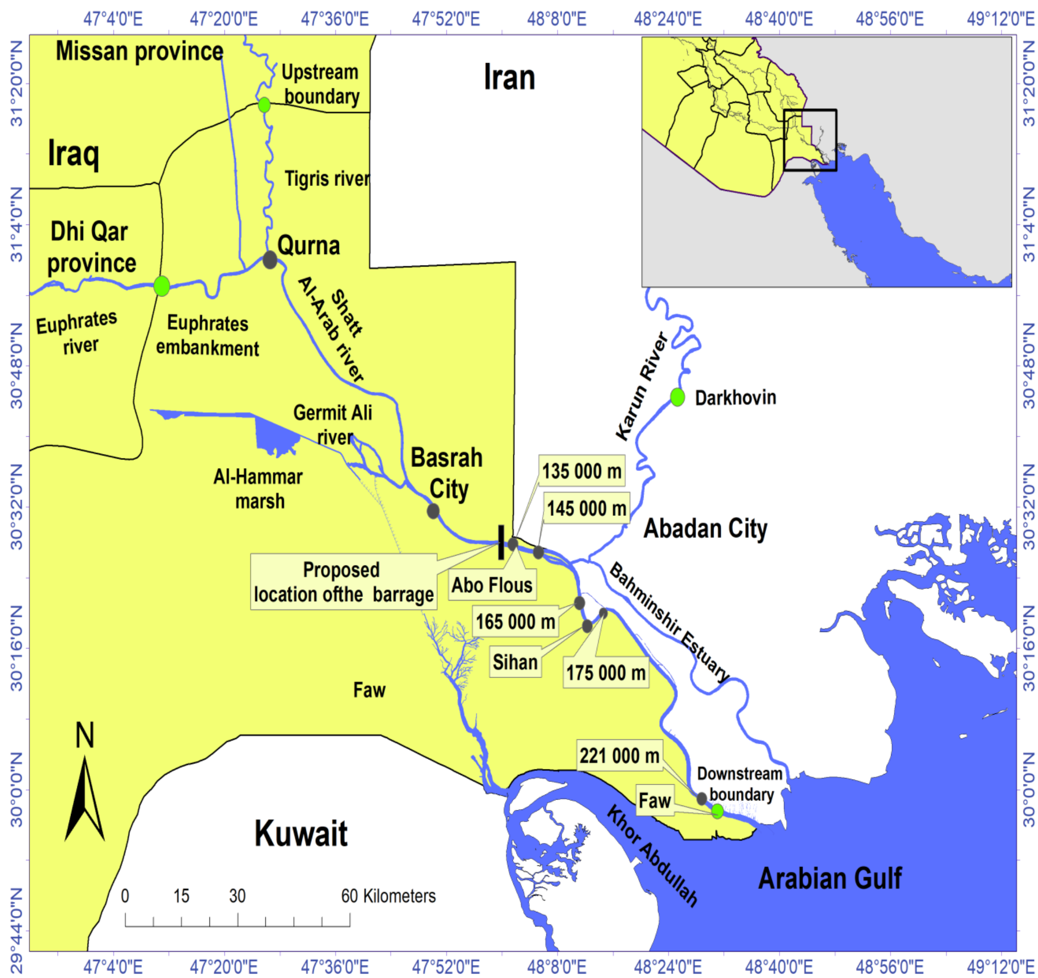

Figure 1. The location map of the study area shows the measurements stations of water level, model boundaries (green circles), the location of a proposed barrage, and locations of comparison areas (Lafta, 2022b).

Methods and Model Preparation:

The study consists of two parts: the field side, as stations were selected for measurement and sample collection, and the other side is the preparation and simulation of a numerical model.

Fieldwork:

A field survey (reconnaissance of the study area) in addition to collecting relevant data and previous studies, that are suitable for the site choice of the construction of the barrage was planned taken at the measurement stations according to the possibility of collection field measurements. The work included field measurements for calibration and verification of the model, which is the measurement of discharge, currents speed, and direction at several locations (135000 m, 145000 m, 165000 m,175000, and 221000 m) along the southern part of the river (Fig. 1). The water level in two locations along the Shatt Al-Arab river was measured by installing pressure divers at Sihan and Abu Flous (Fig. 1). These measurements were conducted in March 2018.

Barrage Site:

When thinking about building a barrage on the Shatt Al-Arab River, a question comes to mind regarding the appropriate place to construct such a barrage relative to ports, and international border areas. Therefore, the hydrodynamic impact of the natural flow of the river must be taken into account so as not to affect it and not be affected by it as much as possible. However, our study does not concentrate on choosing the type of barrage, but on the potential changes in tidal wave behavior below the proposed barrage. Attention was focused on the construction of the barrage on the Iraqi private part of the river, specifically from the Hartha area in the north to Umm Al-Rasas Island in the south. According to the study that conducted by Marine Sciences Center (2018), four sites were proposed for the construction of the barrage, but the third site, i.e., the Abu Al-Khaseeb site was preferred as the most appropriate place to set up such a barrage (Fig. 1) at the geographical location (57.29'27°34'N 47°58'6.50'). The reasons behind choosing this site are:

1- It is about 4 km away from the buo Flous port.
2- It is 11 km from Umm Al-Rasas Island.
3- It does not affect navigation downstream.
4- The two banks of the river are located inside the Iraq border.

Therefore, a mathematical model was prepared and a regulatory barrage was established using the Mike11 software package on this site to show its impact on the tide nature of the river below the barrage.

Description of the Mathematical Model:

Mike11 is a scientific software package developed by the Danish Hydraulics Institute (DHI), this technology was obtained by a Danish donor (DANIDA) to the Marine Science Center/University of Basrah. Through, this it is possible to obtain formulas that simulate the speed of currents, water quality, sediments transport in rivers, estuaries, and other waterways. The model depends on solving (Saint-Venant) equations, which include the equations of continuity, motion and diffusion, as follows (DHI, 2007):

$$\frac{\partial Q}{\partial x} + \frac{\partial A}{\partial t} = q \ldots\ldots\ldots\ldots\ldots\ldots(1)$$

$$\alpha\frac{\partial Q}{\partial t} + \frac{\partial\left(\beta\frac{Q^2}{A}\right)}{\partial x} + gA\frac{\partial h}{\partial x} + \frac{Q|Q|}{c^2 RA} = 0 \ldots\ldots\ldots(2)$$

Where: Q = discharge, A = cross-sectional area, h = water surface elevation above an arbitrary horizontal datum, n = Manning's coefficient of roughness, R = hydraulic radius, g = acceleration of gravity, α = kinetic energy coefficient (α =1.041), x = distance along the watercourse and t = time. The model calculates the distribution of water levels, velocity, and discharge according to time and cross-section.

Preparing the Mathematical Model:

The bathymetric file is the main artery and backbone on which all simulation models of rivers, estuaries, and open waters depend. It contains field data measured according to the specifications of the International Organization for Hydrographic measurements, and these data are related to the local datum, the mean sea level. The data for the topographical and bathymetric survey of the Shatt Al-Arab River by the Marine Consulting Office at the Marine Sciences Center/ University of Basra during the years 1998-2005 were used, (Marine Science Center, 1998 and 2006) and entered into the bathymetric file required to create the geometry of the river.

A satellite image of the study area was entered into the Mike11 program to be in the appropriate position, as it acquired its geographical position, according to the geographical coordinates. The river was represented by a set of points to form a network (gird). The spatial discretization of the model (Δx) is chosen to be 250 m. The first point begins at the top of the river (upstream) and is given a value of zero and is called within the program (Chainege, 0.0) and so on to the last point (downstream). The main tributaries of the Shatt al-Arab river have been added to the Shatt Al-Arab model as lateral branches to reach a reasonable representation of the river situation by model simulation.

The downstream boundary condition is located at Faw (Fig. 1). The time series of water level variations in Faw city (Fig. 2) was used as boundary conditions at the lower reaches of the model. It is worth noting that, due to the absence of water level records at Faw, these data were acquired from the Total tide software (UKHO, 2003). In the upper reaches of the model, the freshwater inflow from the Tigris River was used as an upstream boundary condition. Furthermore, the freshwater discharge by the Karun River at the Darkhovin region was included in model boundaries (Fig. 1). The model was engaged for six months, from 1st January to 30th June of 2017. The stability of the model was accomplished by selecting a time step of 120 sec.

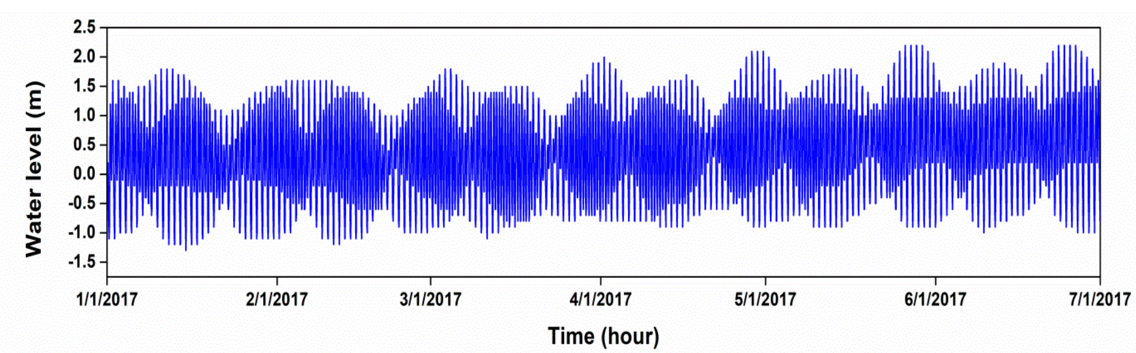

Figure 2. Water level (m) at Faw site for six months.

The results of the model were examined by comparing the estimated water level by the model with the measured water level at Sihan and Abo Flous stations. RMSE (root mean squares error) ($RMSE = \sqrt{\frac{\sum_{i=1}^{N}(Mi-Ci)2}{N}}$), the statistical scale that measures the estimated results by the model with the observed ones was utilized. Where, M_i and Ci are a sum of observed and estimated values respectively, and N is a number of values. The better results of the model were reached by putting the manning number of 0.17 ($m^{1/2}$/sec) and Tigris and Karun inflows of 50 m^3/sec and 5 m^3/sec, respectively. Figure (3) illustrates the comparisons between the estimated and observed data at Sihan and Abo Flous regions. The RMSE were 0.13 and 0.06 m in Sihan and Abo Flous, respectively.

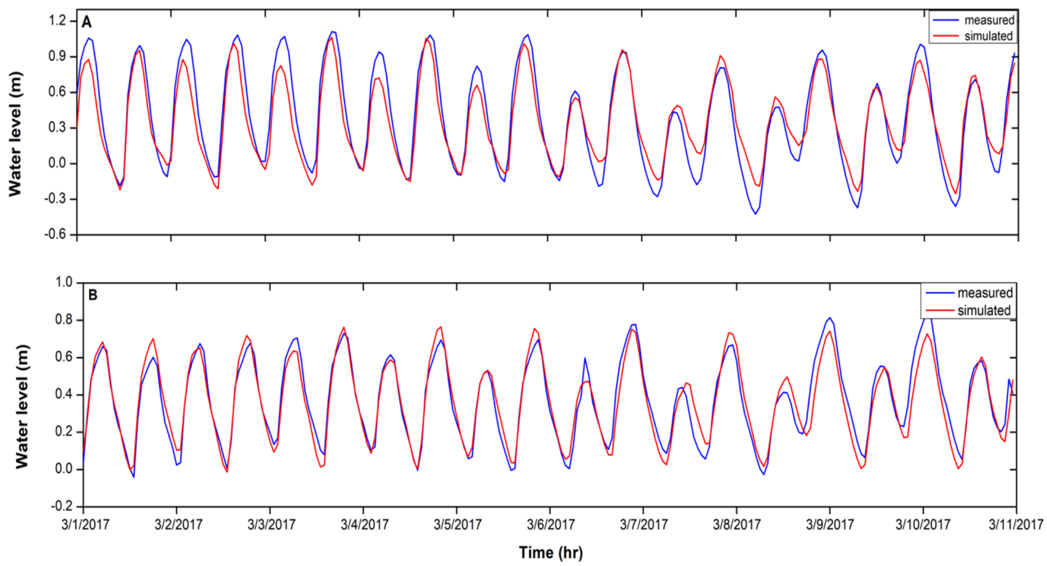

Figure 3. Comparison between estimated and observed water level at (A: Sihan, B: Abo Flous).

Results and Dissection:

The model was run to find the water level in two cases, first when there is no barrage, and the second when there is a barrage working as an embankment in the Abu Al-Kaseeb area. Hence, fresh water will prevent to reaches towards lower reaches of the river.

After implementation the model for a period of six months, the required results were obtained and five sites were selected below the barrage to compare the results between the two cases mentioned above, i.e., with and without barrage on the river stream. The comparison between the values of water levels in the two cases at chosen locations, i.e., at 135000 m, 145000 m, 165000 m, 175000 m, and 221000 m (Fig. 1) are presented in Figure (4). However, from the first look at the (Figs. 4 and 5), it is obvious there is a difference in the water level of the two cases. Additionally, it is obvious that the magnitude of the difference depends on the distance of the chosen location from the barrage. The magnitude of the difference increases as we close to the barrage and decreases in areas further away from it. The location of the barrage in this place made the tidal wave act in a tidal convergent channel, wide inlet and narrow at its closed upper end. Thus, the tidal river below the barrage will behave as closed-end lagoons, i.e., the height of the tidal wave increases as we move toward the inland direction near the barrage, similar results were previously observed in Khor Al-Zubair tidal convergent channel by Al-Sayab (1989) and

Lafta *et al.* (2020), addition, the barrage acted as a closed dam, affecting the hydrodynamics of the river (Manuel *et al.*, 2012) ,which was reflected in the behavior of the tidal wave.

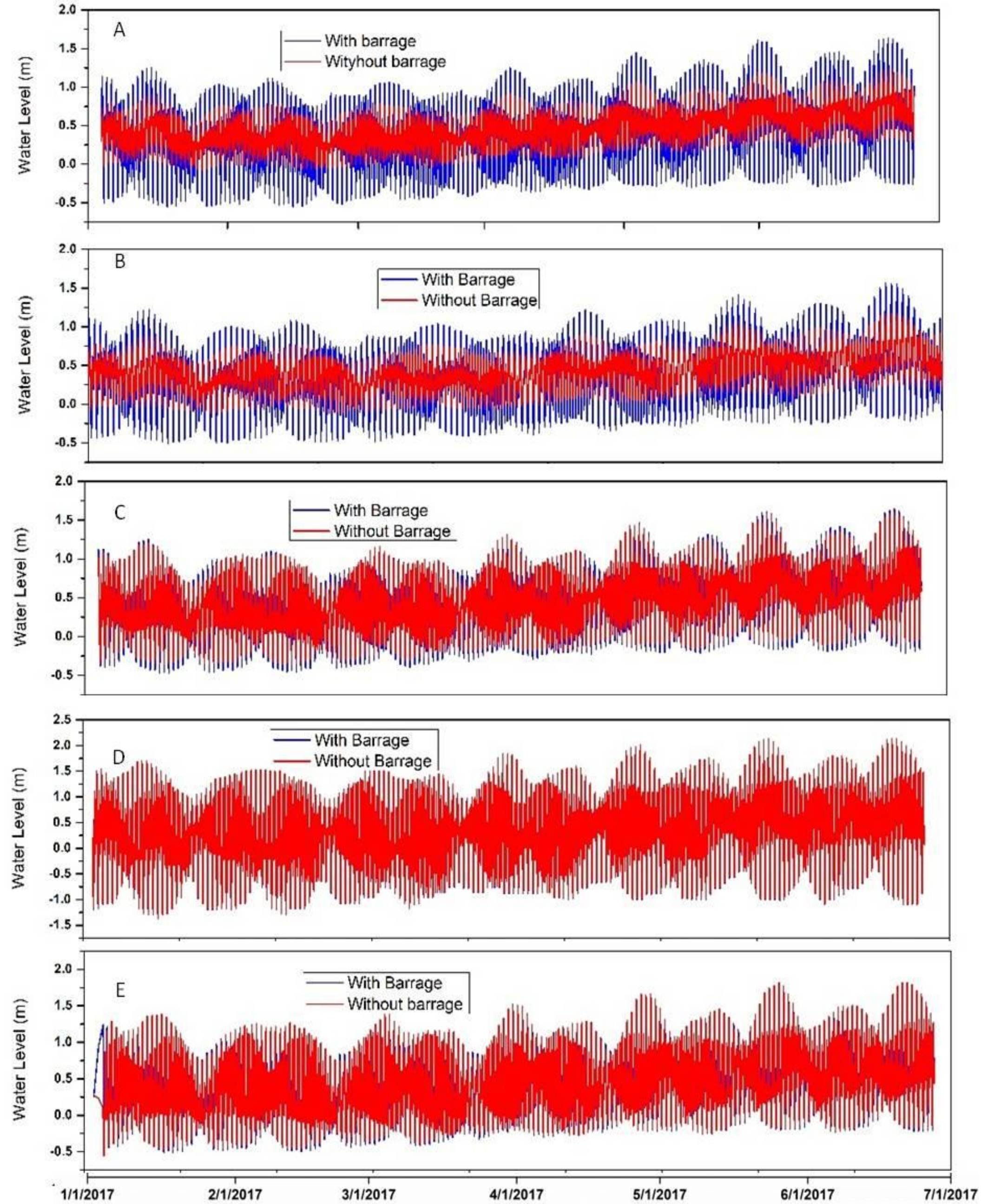

Figure 4. Comparison between the water level in the presence and absence of a Barrage for six months at (A: 135000 m, B: 145000 m, C: 1٦5000 m, D: 175000 m, E: 221000 m).

The differences in the water levels in the two cases are more evident in the first station 135000 m, near the barrage, where the value of the difference reaches 0.409 m and was on 16/6/2017 as shown in Table (1), the differences in the water level gradually decrease as we moved away from the barrage, and this is what the results indicate in table 1. As for the last station 221000, which represents the Al-Faw region, the differences are very small between the state of the barrage's presence and the state of its absence, and the same applies to the station before it, i.e, 175000 m.

Table 1. The minimum and maximum values of water levels at the study stations in the presence and absence of the barrage for a period of six months.

Station	With Barrage				Without Barrage			
	Max.	Date	Min.	Date	Max.	Date	Min.	Date
135000	1.636	25/6/2017	-0.556	13/2/2017	1.227	25/6/2017	-0.076	24/1/2017
145000	1.604	25/6/2017	-0.504	16/1/2017	1.213	26/6/2017	-0.113	24/1/2017
165000	1.643	25/6/2017	-0.472	15/1/2017	1.593	25/6/2017	-0.359	11/2/2017
175000	1.805	25/6/2017	-0.516	16/1/017	1.822	25/6/2017	-0.557	1/1/2017
221000	2.135	25/6/2017	-1.373	15/1/2017	2.144	25/6/2017	-1.374	15/1/2017

Tidal Range:

The changes in the values of water levels for two successive days in the study stations were plotted to calculate tidal range values as in Figure (6). However, it is clear from this figure that there is a difference in the water level values at the first two high tides (HW) as well as in the two successive low tides (LW) for the two cases of the barrage's existence and its non-existence. Additionally, there is almost identicalness in the values of the second high tide (HW) for both cases. The reason may be attributed to the difference in the values of the tidal constituents during the day, i.e. between night and day. This behavior is clear in the two stations 135000 and 145000 m. Hence, and for more clarity, the comparison was plotted for four successive days, as shown in Figure (7). The congruence in the water levels is identical as we moved towards the lower reaches of the river, i.e., towards station 221000 m.

These results are reflected in the tidal range values in all stations. The highest value of tidal range reaches 1.636 m was recorded in the first station, i.e., 135000 m in the case of the presence of the barrage. Meanwhile, the tidal range in this station does not exceed 0.764 m in case of removing the barrage (Table 2). However, this is not a surprising result, as the river behaves as a convergent channel when the tidal range is increased as moved further away from the source of tidal energy (Vinita *et al.*, 2015). The normal behavior of the tidal wave is evident in the last station, where the changes of the tidal range values means that the impact of the barrage is small in this station, not exceeding a few centimeters.

The presence of the barrage in the location near Abo Al-Kaseeb affects the nature of the tidal wave downstream of the barrage. The differences in heights of the high tide in the case of the presence of the barrage and the absence of it are clear, especially in the areas near the barrage. However, the difference in water level vanishes as we move away from the barrage, and this is clear in the Al-Faw region when the difference seems to not exceed some centimeters.

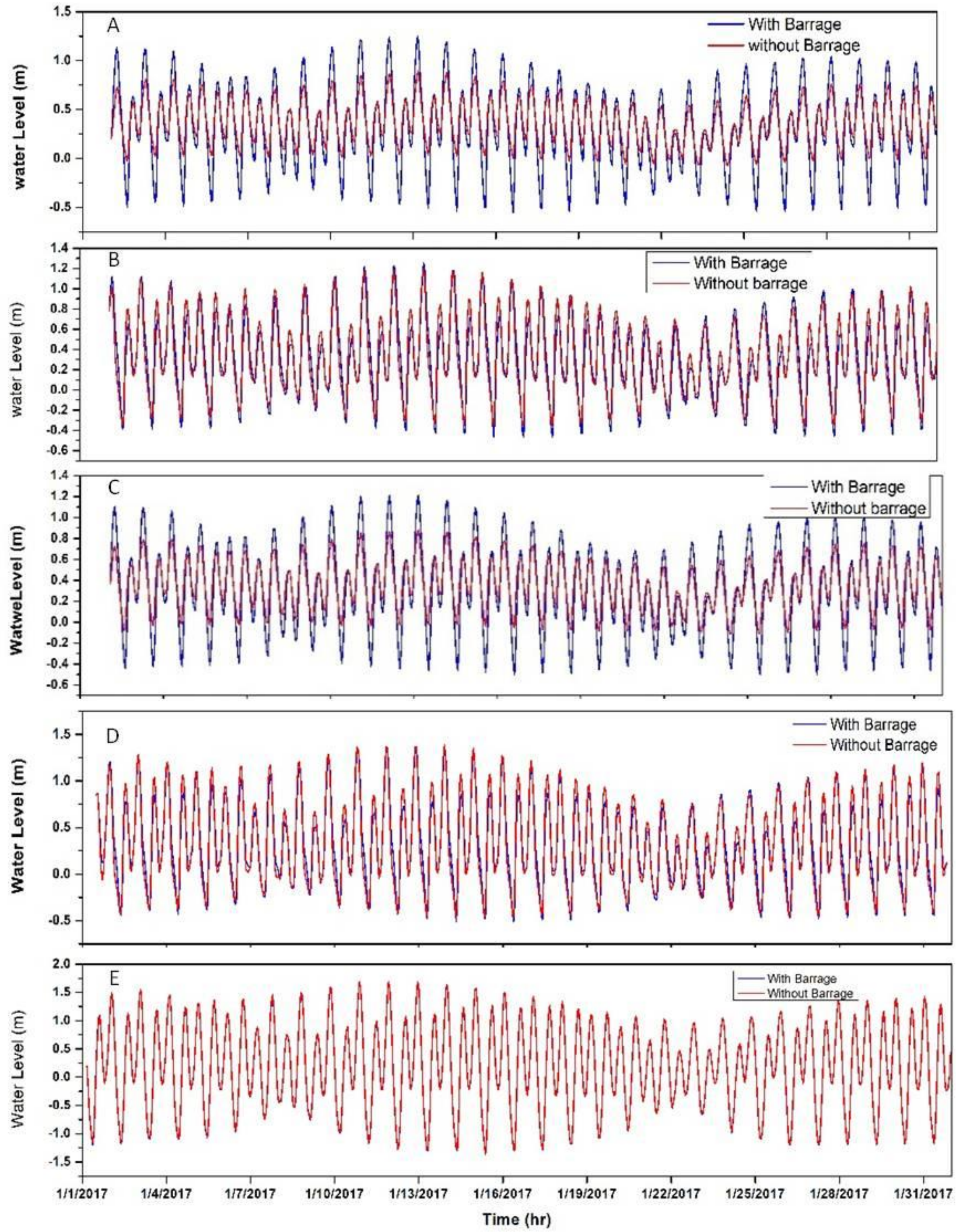

Figure 5. Comparison between the water level in the presence and absence of a Barrage for one month at (A: 135000 m, B: 145000 m, C: 165000 m, D: 175000 m, E: 221000 m).

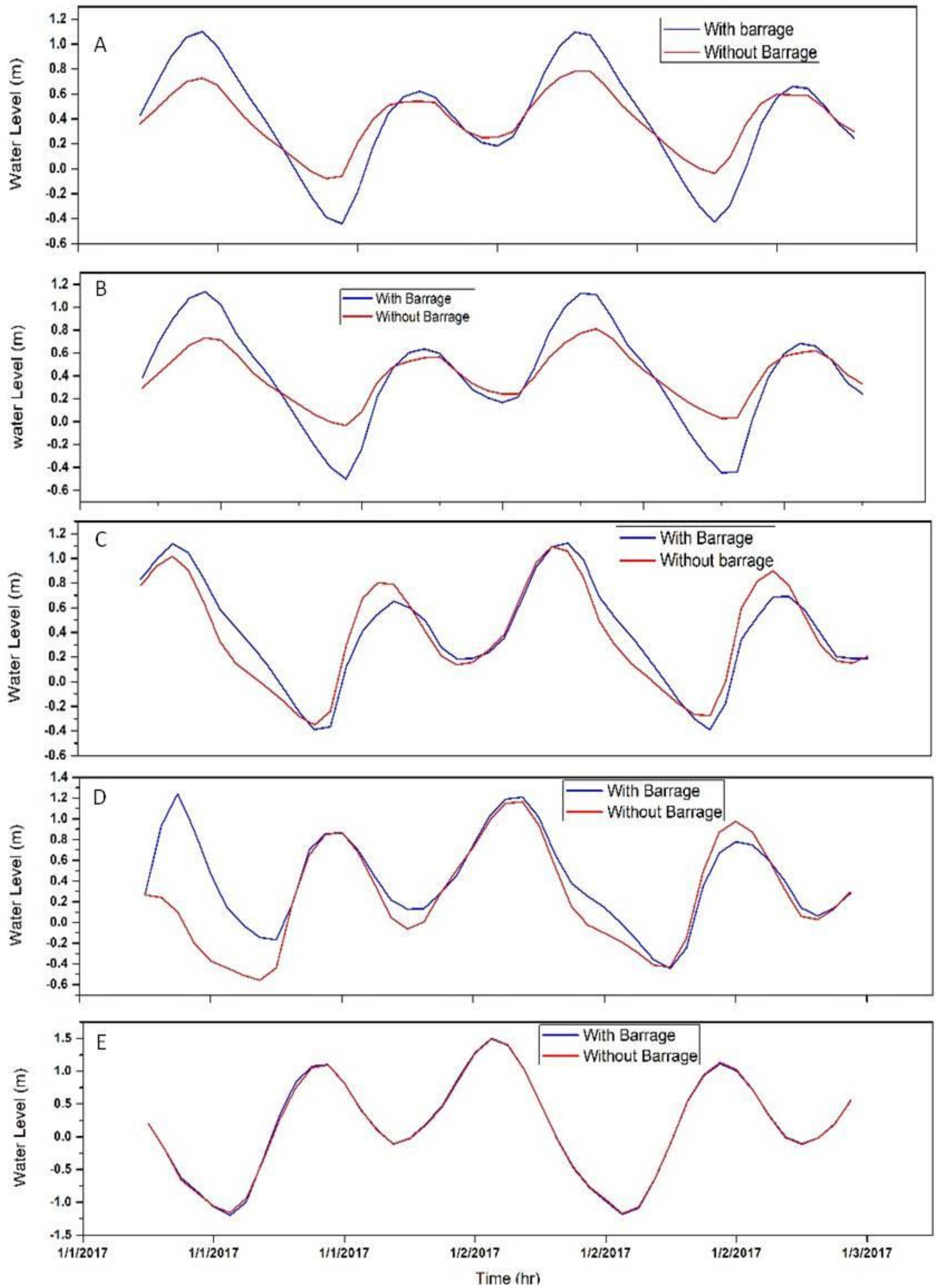

Figure 6. Comparison between the water level in the presence and absence of a Barrage for two days at (A: 135000 m, B: 145000 m, C: 165000 m, D: 175000 m, E: 221000 m).

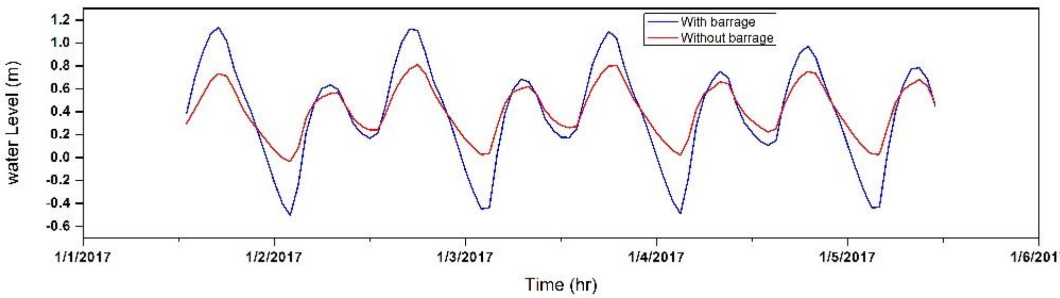

Figure 7. Comparison between the water level in the presence and absence of a Barrage for four days at 135000 m.

Table 2. Tidal range at study stations in cases of the presence and absence the barrage.

Station	With Barrage Tidal Range (m)	Without Barrage Tidal Range (m)
135000	1.636	0.764
145000	1.542	0.807
165000	1.506	1.368
175000	1.411	0.932
221000	1.189	1.203

Conclusions:

A one- dimensional hydrodynamic model for the Shatt Al-Arab River was set up based on Mike 11 technique. The model was examined by comparing the observed water level with the estimated by the model at two locations. A reasonable agreement between the observed and estimated water level was achieved. However, the calibrated model was utilized to study the variations in water level before and after installing the barrage at the river stream. The result revealed that there is a maximize in water level in areas near the barrage.

The highest increase in the water level reaches 40 cm. Additionally, the results illustrated that there is a slight increase in the tidal range in areas near the barrage. As a recommendation, and based on the increase in water level below the barrage it is preferred to strengthen the two banks of the river south of the barrage. Additionally, the hydrodynamic situation, as well as the water quality of the river north of the barrage should be studied deeply before installing such a construction.

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References:

Abdullah, A.D. 2016. Modelling approaches to understand salinity variations in a highly dynamic tidal river: The case of the Shatt Al-Arab river. 1st ed. CRC Press. https://doi.org/10.1201/9781315115948

Abdullah, S.S. 2002. Analysis of tide wave in Shatt Al-Arab Estuary, South of Iraq. Marina Mesopotamica, 17(2): 305-315.

Abdullah, S.S. 2014. Tide phenomenon in the Shatt Al Arab River, South of Iraq. The Arab Gulf Journal, 42(3-4): 133-155. https://www.iasj.net/iasj/download/f36876191bb2e1b3.

Abdullah, S.S., Lafta, A.A., Al-Taei, S.A. and Al-Kaabi, A.G. 2016. Flushing time of Shatt Al-Arab River, South of Iraq. Mesopotamian Journal of Marine Sciences, 31(1): 61-74. https://doi.org/10.58629/mjms.v31i1.110

Al-Fartusi, A.J. 2018. The low discharge simulation of the Shatt Al-Arab River and its influence on water quality. Mesopotamian Journal of Marine Science, 33(1): 1-18. https://doi.org/10.58629/mjms.v33i1.55.

Ali, A.A. and Al-Thamiry, H.A. 2021. Controlling the salt wedge intrusion in Shatt Al-Arab River by a Barrage, December 2021. Journal of Engineering, 27(12):69-86, https://doi.org/10.31026/j.eng.2021.12.06

Al-Sayab, H.A.S. 1989. One dimensional numerical model for tidal movement in Khor Al-Zubair. MSc Thesis, College of Science, University of Basrah, 90p.

Al-Taei, S.A., Abdullah, S.S. and Lafta, A.A. 2014. Longitudinal intrusion pattern of salinity in Shatt Al-Arab estuary and reasons. Journal of King Abdulaziz University: Marine Sciences; Jeddah, 25(2): 205-221. http://dx.doi.org/10.4197/Mar.25-2.10.

Al-Taei, S.A., Al-Fartusi, A.J. and Abdulhussein, I.A. 2019. Determination of hydrodynamic resistance coefficient (Manning's Coefficient) in Shatt Al Arab River, Southern of Iraq-Basrah. Journal of Engineering and Sustainable Development, 23(3): 78-88**.** https://doi.org/10.31272/jeasd.23.3.6

Al-Wahili, O.Q. 2009. Sedimentation and geomorphology of the Shatt Al-Arab Islands between the cities of Basra and Siba. M.Sc. thesis, College of Science, University of Basrah (in Arabic). URL.

DHI (Danish Hydraulic Institute) 2007. Mike11a modeling system for river channels, short introduction tutorial**.** www.dhigroup.com**.**

Fairley, I., Ahmadian, R., Falconer, R., Willis, M. and Masters, I. 2014. The effects of a severn barrage on wave conditions in the Bristol channel. Renewable Energy, 68: 428-442. https://doi.org/10.1016/j.renene.2014.02.023

Gong, W. and Shen, J. 2011. The response of salt intrusion to change in river discharge and tidal mixing during the dry season in the Modaomen Estuary, China. Continental Shelf Research, 31: 769-788. https://doi.org/10.1016/j.csr.2011.01.011.

Lafta, A.A. 2022a. Investigation of tidal asymmetry in the Shatt Al-Arab river estuary, northwest of Arabian Gulf. Oceanologia, 64(2): 376-386. https://doi.org/10.1016/j.oceano.2022.01.005.

Lafta, A.A. 2022b. Numerical assessment of Karun River influence on salinity intrusion in the Shatt Al-Arab River Estuary, Northwest of Arabian Gulf. Applied Water Science, 12, Article 124. https://doi.org/10.1007/s13201-022-01640-4.

Lafta, A.A., Altaei, S.A. and Al-Hashimi, N.H. 2020. Impacts of potential sea-level rise on tidal dynamics in Khor Abdullah and Khor Al-Zubair, northwest of Arabian Gulf. Earth Syst. Environ., 4: 93-105. https://doi.org/10.1007/s41748-020-00147.

Lafta, A.A. 2021. Estimation of Tidal excursion Length Along The Shatt Al-Arab Estuary, Southern Iraq. Vietnam Journal of Science and Technology 59 (1). https:// doi. org/10.15625/2525-2518/59/1/15433.

Liu, W.C. and Liu, H.M. 2014. Assessing the impacts of sea level rise on salinity intrusion and transport time scales in a tidal estuary, Taiwan. Water, 6: 324-344. https://doi.org/10.3390/w6020324

Marine Science Center 2018. Shatt Al-Arab - the future of Basrah, a technical study for the establishment of the regulatory dam in North Abu Al-Flous and environmental impact assessment. 229p. (in Arabic)

Marine Science Center, Marine Consulting Office 1998. Final Report of the Shatt Al-Arab Survey Project from Al-Maqal to Ras Al-Bishah", a work contract for the Ministry of Irrigation / Al-Furat Center for Studies and Design of Irrigation Projects (unpublished study).

Marine Science Center, Marine Consulting Office 2006. Final Report of the Shatt Al-Arab Survey Project from Al-Qurna to Umm Al-Rasas Island, a work contract for the Iraqi Institute - Baghdad (unpublished study).

Minguito, M.D., Baquerizo, A., Sánchez, M.O.I. and Losada R.M.Á. 2012. Tidal wave reflection from the closure dam in the Guadalquivir estuary(SW Spain). Coastal Engineering Proceedings ICCE2012, 1(33), currents-58. https://doi.org/10.9753/icce.v33.currents.58

Ministry of Water Resources, Center for Studies and Engineering Designs 2012. Irrigation project for the Shatt Al-Arab River, work contract with Med Ingegneria, Sgi Studio Galli Ingegneria, El Concorde Constructi0n, Baghdad (unpublished data).

Neill, S.P., Angeloudis, A., Robins, P.E., Walkington, I., Ward, S.L., Masters, I., Lewis, M.J., Piano, M., Avdis, A., Piggott, M.D., Aggidis, G., Evans, P., Adcock, T.A., Židonis, A., Ahmadian, R. and Falconer, R. 2018. Tidal range energy resource and optimization-past perspectives and future challenges. Renew Energy, 127: 763-778. https://doi.org/10.1016/j.renene.2018.05.007**.**

Qian, M., Tulio, M.M. and Thomas, A.A. 2019. The impact of a tidal barrage on coastal flooding due to storm surge in the Severn Estuary. Journal of Ocean Engineering and Marine Energy, 5: 217-226. OIClick to copy the URI to your clipboard. https://doi.org/10.1007/s40722-019-00143-w.

Savenije, H.G. 2012. Salinity and Tide in alluvial estuaries. Delft University of Technology Delft, The Netherlands, second edition, 163 p. https://hubertsavenije.files.wordpress.com/2014/01/salinityandtides2_21.pdf.

Vinita, J., Shivaprasad, A., Manoj, N.T., Revichandran, C., Naveenkumar, K.R., Jineesh, V.K. 2015. Spatial tidal asymmetry of Cochin estuary, West Coast, India. Journal of Coastal Conservation, 19: 537-551. https://doi.org/10.1007/s11852-015-0405-9.