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Estimation of Residence Time in Khor Abdullah and Khor Al-Zubair Northwest of Arabian Gulf, Using Numerical modeling Technique

Ali A. Lafta [1,2] Samer A. R. Altaei [2] Noori H. N. Al-Hashimi [1]

[1] *Department of Physics, College of Education for Pure Science, University of Basra, Basra, Iraq.*

[2] *Department of Marine Physics, Marine Science Center, University of Basra, Basra, Iraq.*

alilifta@yahoo.com

ABSTRACT

A two dimensional depth-average hydrodynamic model that combined with a transport model was applied to study the hydrodynamic characteristics and residence time distribution in Khor Abdulla and Khor Al-Zubair which locate in the northwest of Arabian Gulf. The model was run for two months with a time step of 5 sec. The model results of water level and flow velocities were in a good agreement with measurements. The result of simulations and measurements indicate that there are asymmetries in the tidal wave that propagates farther in inland direction with a gradual increase in their amplitude and hence in its tidal range. The results indicate that residence time in the study area is a site-specific, and show a heterogeneous distribution. However, the longest residence time is observed in two sites, UMR1 with 12 days and KZL with residence time that exceeds 25 days. The data provide useful information and will be significant in the future assessments of coastal developments in this region.

Key words: *Hydrodynamics, Numerical Modeling, Transport model, Residence time, Tracer.*

1. INTRODUCTION

The identification of hydrodynamic characteristics and flushing capability of estuaries, lagoons, and coastal areas has a high priority for environmental impact studies, as well as for the assessment of the fate and effect of undesirable elements such as contaminants that significantly affect the aquatic ecosystem [1-4]. There are many concepts to determine the average time for renewing or exchanging water of the system with the other water bodies, such as Flushing Time, Age and Residence Time [5]. Flushing time is a bulk or integrative factor which describes the general exchange properties of a water body without quantifying their spatial distribution [5,6]. Age according to Zimmerman and Kjerfve [7] is defined as the time required for a parcel of water to travel from a boundary to a particular location within the water body. Whereas residence time represents the time that a parcel of water needed, starting from a specific location within the system to exit from open boundary [5,8], so it can represent a lifetime of water parcel in the system [9]. Flushing time, although it can be used to calculate the whole flushing capability of the system, it does not provide a spatial and temporal variations in large water bodies, where the transport could vary substantially in different locations and time periods. So the knowledge of spatial distribution and temporal variation of residence time is desirable since it can be applied to quantify the impact of hydrodynamics on biochemical processes and associated water quality and the transport of pollutants [10]. The field experiments for the calculation of residence time are very expensive, so the whole spatial and temporal distributions of it cannot be surveyed. However, the hydrodynamic modeling is the most available method for estimation the residence time nowadays. Hydrodynamic models linked with dye-tracer approach are used to examine pollutant transport processes and associated residence time in several water bodies, such as, the Venice Lagoon [11], the York River [12], Danshuei River [13], Poyang Lake [14], Chesapeake Bay [10] and Chilika Lagoon [15]. These studies point out that hydrodynamic models are effective to examine the residence time since both advection and dispersion processes are included using a combined dye tracer-based approach. In addition to that, the hydrodynamic model can be utilized to test hypotheses and to make several scenarios that can affect the derived transport time scale without the release of contaminants into the system [14]. The Iraqi marine waters (Khor Abdulla and Khor Al-Zubair) situated in the northwest of the Arabian Gulf (Fig. 1) is the most important part of Iraqi marine waters that used for many purposes such as, navigation, fisheries, transportation, industry, and recently introduced in oil production processes and hence they are at risk of contamination. Based on our knowledge no estimations were done to residence time in this area, so the current study represents the first attempt to use the combined hydrodynamic model with transport model to study the hydrodynamic characteristics and residence time in this region through giving comprehensive insights into the transport behaviors by using numerical simulation with artificial conservative tracers.

2. MATERIALS AND METHODS

2.1. Study Area

Khor Abdulla (KA) and Khor Al-Zubair (KZ) are located in the south west of Basrah province in the southern of Iraq, have a special important since they represent the only maritime way of this country and the only external contact with the outside world through the sea. Khor Abdulla which characterized by their funnel shape (Fig. 1), it's shallow water with depth ranged 7-14 m and averaged about 10m [16]. The total length of KA reaches to 40 km and their width of about 17 km in its boundary to the Arabian Gulf and decreased to 6.5 km in its upstream end south of Warba island when it forming Khor Bobian that connect it with Khor Al-Subia and Khor Shytana which connected it with KZ. The east bank of KA is characterized by a moderate slope compared with the steep decline of the west bank. Therefore, the international navigation channel in KA is located near the Kuwait side. However, Khor Al-Zubair channel is an extension of a Khor Abdulla with an average area that covered by water is approximately 60 km^2 and with a mean tidal rang exceed 4 m at spring tide [17]. The depth of the navigation channel in KZ ranges between 10 and 20 m. The northern part of the KZ is composed of several irregular shallow tidal lagoons with complex geometry that formed a characteristic shaped like tree fronds. In 1983, an artificial canal (Shatt Al-Basrah canal) was opened that connect the Euphrates River, after it emerges from Al-Hammar marsh, with Khor Al-Zubair, changing the environment of KZ from a hypersaline lagoon with salinity that exceed 45 PSU to an estuarine lagoon. In 1993, Shatt Al-Basrah canal connection with Euphrates River was closed, and new connection made with MOD (Main Outfall Drain) at about 10 km from a head of the canal. The flow in the Shatt Al-Basrah canal was controlled by a barrage (Al-Basrah Barrage) located at about 22 km from canal head that prevents the sea water from Khor Al-Zubair to the canal during the flood tide. However, through the Gulf war, this barrage was demolished and hence the environment of

KZ and Shatt Al-Basrah canal turn to a hypersaline environment with salinity reaches 44 PSU through summer months [18]. The MOD canal which contains the water of the drained regions of the Euphrates basin is agricultural water drainage through Shatt Al-Basrah canal then discharged towards the Arabian Gulf through KZ and KA [19]. In the last years, the inflow of MOD was converted towards the Iraqi marshlands and in the present time, a very little amount of water (do not exceed 10 m^3/sec) discharged in the Shatt Al-Basrah canal. Several activities took place whithin KZ that probably induced serious degradation to the marine environment and which may lead to a nagatively changing in the water quality regimes. There are three plants near KZ, Pertochemical plant, stell plants, and fertilizer plant as well as Khor Al-Zubair station for electricity production in addition to commercial ports and oil and gas ports. The climate of the region is characterized by an arid desert climate with two distinct seasons, the summer which is a hot and long that reaches about 230 days and winter that represent a cold and rainy season. There are two types of prevailing winds in the study area, northwest winds, which causes dust storms in the summer, and locally known as Al-Shammal which is a characteristic of the region and southeast winds mostly during autumn and winter that is relatively warm and moist and brings rainy clouds occasionally [20].

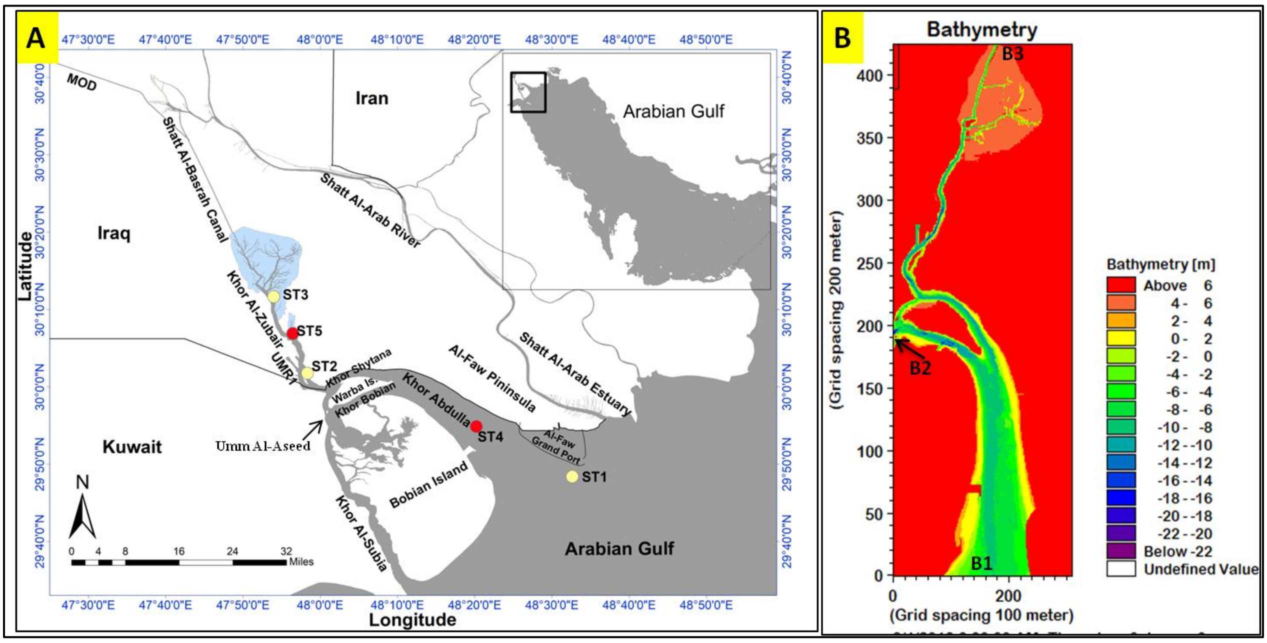

Figure 1: Geographical location (A) and Bathymetric Characteristics (B) of the study area.

2.2. Model Description

To model the hydrodynamics and residence time in KA and KZ, Mike21 a depth- averaged two dimensional modeling system was used. A hydrodynamic (HD) module represents the core of this model, it simulates the water level fluctuations and flows in response to many of forces, such as, tides, metrological effects and density-driven flows arising from temperatuare and salinity variations in estuaries, lagoons, bays, and coastal areas [21]. The water hights and current velocities (flow) are resolved on a grid that covering the entire area (model domain) when provided with the bathymetry, boundary and initial conditions, wind speed and direction, and bed resistance coefficients. In the 2-D hydrodynamic model of Mike21, the following equations are used to obtain the conservation of mass and momentum integrated over the vertical flow and water level variation at all grid point. The continuity equation given,

$$\frac{\partial \zeta}{\partial t} + \frac{\partial p}{\partial x} + \frac{\partial q}{\partial y} = \frac{\partial d}{\partial t}$$

Where; ζ is the Water surface level above specific datum (m); p and q are flux densities in the x and y directions ($m^3/s/m$). While, the momentum equation in the x and y directions are given as,

$$\frac{\partial p}{\partial t}+\frac{\partial}{\partial x}\left(\frac{p^2}{h}\right)+\frac{\partial}{\partial y}\left(\frac{pq}{h}\right)+gh\frac{\partial \zeta}{\partial x}+\frac{gp\sqrt{p^2+q^2}}{C^2.h^2} -\frac{1}{\rho_w}\left[\frac{\partial}{\partial x}(h\tau_{xx})+\frac{\partial}{\partial y}(h\tau_{xy})\right]-\boldsymbol{\Omega}_p - fVV_x+\frac{h}{\rho_w}\frac{\partial}{\partial x}(p_a)=0$$

$$\frac{\partial p}{\partial t}+\frac{\partial}{\partial y}\left(\frac{q^2}{h}\right)+\frac{\partial}{\partial x}\left(\frac{pq}{h}\right)+gh\frac{\partial \zeta}{\partial y}+\frac{gq\sqrt{p^2+q^2}}{C^2.h^2} -\frac{1}{\rho_w}\left[\frac{\partial}{\partial y}(h\tau_{yy})+\frac{\partial}{\partial x}(h\tau_{xy})\right]-\boldsymbol{\Omega}_p -fVV_y+\frac{h}{\rho_w}\frac{\partial}{\partial xy}(p_a)=0$$

Where; $h(x,y,t)$ is water depth (m); C is Chezy resistance No. ($m^{1/2}/s$); $\boldsymbol{\Omega}_p$ is a Coriols factors (1/s); p_a is atmospheric pressure ($kg/m/s^2$); f is the wind friction parameter; ρ_w is the density of water (kg/m^3); V, V_x and V_y wind speed components in x and y directions (m/s); and τ_{xx}, τ_{xy} and τ_{yy} are the effective shear stress components (N/m^2). The solving of these equations based on the shallow water assumptions as, the characteristic horizontal length is much larger than the vertical length and the characteristic vertical velocity is small comparing with the horizontal velocity [21].

physical transport processes, which through it pollutants or other substances move in surface water, have particular interest to those working in physical or environmental sciences. Advection in the fields of physical sciences, engineering, and earth sciences represents the transport of any element by the movement of the fluid as a whole or so-called bulk motion, so the properties of the element are carried with it during this process such as energy. A common example of advection is the transport of pollutants or the transfer of salinity into rivers by the flow of seawater towards the river upstream. During the Advection process, the fluid during its movement can transport some materials or conserved quantities. The advection process requires currents in the fluid so it does not occur in rigid solids. Diffusion, on the other hand, is a mass transition due to the movement of molecules from a region of high concentration to a region of low concentration as a result of the random movement of molecules (collision of molecules), thus in this process the fluid properties such as salinity, can be transferred without moving the fluid itself. While dispersion is a mass or long-range mass transfer by spreading particles due to differences in inflow velocity between fluid layers. In Mike21 model, the mass taransport processes are represented through the Advection-Dispersion equation (AD module) that simulates the spreading of a materials or pollutions in a aquatic environment under the influence of water transport and associated dispersion [22]. This substance can be any type of contaminant, conservatives, non-conservatives, organic or inorganic, or any substance that affects the water quality of a system. The concentration of the substance is calculated at each grid point of the model domain in the same manner as in the calculations of the hydrodynamic model, by solving the transport equation for any dissolved or suspended element using the two-dimensional finite difference scheme [23],

$$\frac{\partial}{\partial t}(hc)+\frac{\partial}{\partial x}(uhc)+\frac{\partial}{\partial x}(vhc)=\frac{\partial}{\partial x}\left(h.D_x.\frac{\partial}{\partial x}\right)+\frac{\partial}{\partial y}\left(h.D_y\frac{\partial}{\partial y}\right)-F.h.c+Q_s(C_s-C)$$

Where; c is the concentration of substance; u and v are horizontal velocity components (m/s); D_x and D_y are dispersion coefficients in x and y directions (m^2/s), F is a decay coefficient (1/s), Q_s is the source or sink discharge ($m^3/s.m^2$); C_s is a substance concentration in the source/sink discharge. The information like water level variations and flow velocities needed for the AD module are provided by the HD module at each grid point of the model domain [21].

2.3.Data Collection

Several types of data are used in this study that included, bathymetry, water level measurements, flow velocity, salinity, Temperatuare, and wind fields. Bathymetry of the study area obtained from many sources, marine science center/ Basrah university surveys conducted in 2005 [24], Admiralty charts No. 1235 modified by British Hydrographic Office in 2010, and the surveyed that conducted by Tatweer Office to South Oil company/ Iraq [25], and other data set that obtained through field surveys. Topographical data on the tidal flats and surrounding lands are obtained from the digital elevation model of Shuttle Radar Topography Mission (STRM) (earthexplorer.usgs.gov) by using GIS extracted tools. Horizontal coordinates are given in easting and northing projection coordinates systems, Universal Transverse Mercator (UTM) and the water depths were referenced to the chart datum (CD), Lowest Low water in the region. A continuous record of water levels at three locations were conducted, the first located at the entrance of KA (ST1 in Fig.1), these data for year 2018 is obtained from Daewoo Engineering and constructing company, that constructe the western breakwater of Grand Al-Faw port. The water levels data in the second station that locate in Umm Qasr town (ST2 in Fig.1) are collected by installing a Valeport TideMaster Portable Tide Gauge with pressure sensor for year 2018, , while a Valeport TideMaster Portable Tide Gauge but with sonar sensor was installed by Khor Al-Zubair Port Authority in the last station (ST3 in Fig.1). All these data are hourly records and references to the local chart datum. However, the flow velocity measurements are surveyed in two locations whithin the study area (ST4 and ST5 in Fig.1). An Acoustic Doppler Current Profile (ADCP) is used to measure the velocity field. And an hourly record on a full tidal cycle is utilized on the 16th to 17th of March 2018 and on the 22nd to 24th April 2018. While the metrological data involving the winds speed and direction and water and air temperatures are obtained also from the weather station that set up by Daewoo Engineering and constructing company at (ST1 in Fig.1). During the March, the water temperature ranged between 19 to 23º C, while through the April it varied from 23 to 26º C as shown in figure 2. Temperature and Salinity also are measured during the flow velocity surveying by using Horiba Water Quality Meters type U-50 in the same locations and at three points along water collum (surface, middle, and near the bottom). The salinity is ranged between 42 to 42.3 ppt in ST5 and 40 to 40.2 ppt in ST4. The measurements indicate that there are no noticeable differences in salinity or water temperature along the water column, and hence no stratification and well-mixed water was observed.

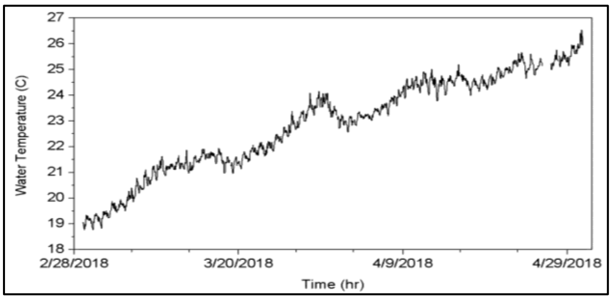

Figure 2: Water Temperatuare for the March and April for 2018.

2.4.Model Setup

The bathymetry of the calculation domain is developed from the aforementioned bathymetry data, and constructed with a rectangular grid system of spatial discretization 100×200 m by using the Bathymetric generation tool in the MikeZero environment. There are 310×425 grid points through x and y directions, respectively. Three open boundary conditions exists, KA inlet, Khor Bobian inlet at Umm Al-Aseed, and Shatt Al-Basrah canal linked with KZ upper end as shown in figure 1(B). The model was forced by water level variations and wind field that utilize as a constant in the domain but varying in time as illustrated in figure 3.

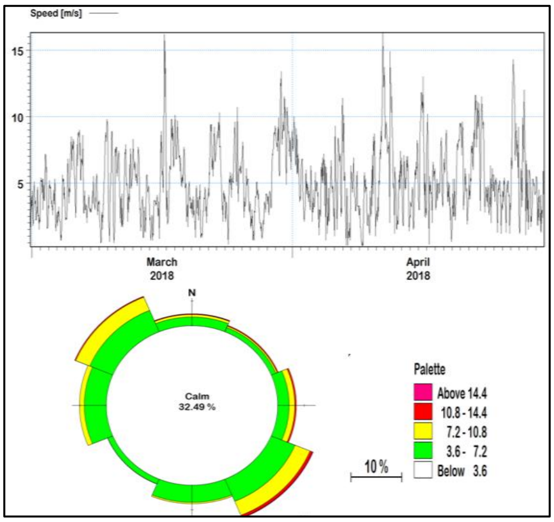

Figure 3: Wind speed and wind rose.

The water level measurements at ST1 is used at the first open boundary B1 as a time series of an hourly records in the boundary file of Mike21 HD module. The water level variations at B2 obtained by the Total Tide software which is a predictive tidal tool propose by the United Kingdom of Hydrographic Office. However, there are no available measurements at the B3, so to obtain a time series of data in this location, the output result from the Shatt Al-Basrah model implement by Mike11 model is used [19]. This model is well calibrating of the year 2009, so some modulations are added to implement it in current conditions, first the south open boundary of this model is extended to be at ST2 that include entire KZ, and water level measurements at ST2 are used as a boundary condition, and the flow of Shatt Al-Basrah at current time introduce to be 10 m^3/s, then the model was run and calibrate and validate through water level and flow velocities at ST3 and St5 respectively, and the results of this calculation is used as a boundary condition at B3. The cold start was used as an initial conditions of the model, water elevation and velocity are set to be zero at the beginning of the simulation at all grid points of the working domain. The caculations are carreid out for two months that cover the period start from 1st March to 30th April of 2018. To ensure a high stability of a model performance, a time step of 5 s is chosen that lead to a maximum courant number of 0.729, a couranr number of < 1 given a best numerical stability [21]. However, there are another parameters that affect the HD model estimations, the flooding and drying depths, especially in the areas that suffering from a successive flooding and drying such as a tidal flat regions that exist at study area. The value of 0.005 m is used for flooding and 0.06 m for drying depths which are considerd as a good approximination in reproduces hydrodynamics parameters throught out the studying area. The wind shear stress is also taken into account, with a wind drag coefficient of 0.0024.

2.5.Model Calibration and Validation

Various sensitivity analysis were carried out to obtain the optimum performance of the HD model through changing the calibration parameters like bottom friction coefficient and eddy viscosity. The bottom friction (Maning number M) of 50 $m^{1/3}$/sec and a Smagorinsky constant for Eddy viscosity of 0.3 were selected to given a best fitting between measured and simulated values. Two statistical parameters, Root Mean Square Error (RMSE), and Nash-Sutcliffe Efficiency Coefficient (NSE) [26], are used to compare the model result with field measurements including water level and flow velocities,

$$\text{RMSE} = \sqrt{\frac{\sum_{i=1}^{N}(Mi-Ci)2}{N}}$$

$$\text{NSE} = 1 - \frac{\sum_{i=1}^{N}(M_i - C_i)^2}{\sum_{i=1}^{N}(M_i - \overline{M_i})^2}$$

Where, M_i is a sum of measured values and Ci is the sum of simulated values and N is a number of values, $\overline{M_i}$ is an avarege of measured values. The data collected through the March of 2018 was used in model calibration. Time series comparsions between the simulated and observed water level at ST2 and ST3 are shown in figure 4, and between simulated and measured flow velocities at ST4 and ST5 are shown in figure 5. However, for the model validation purpose, the measurements of April of 2018 were used. Figure 6 shows the comparison between measured and simulated water level at ST3 and ST2 and figure 7 depict the comparison between simulated and measured flow velocities for that period.

Table 1 summarizes the values of RMSE and NSE for these calibrations and validations efforts.

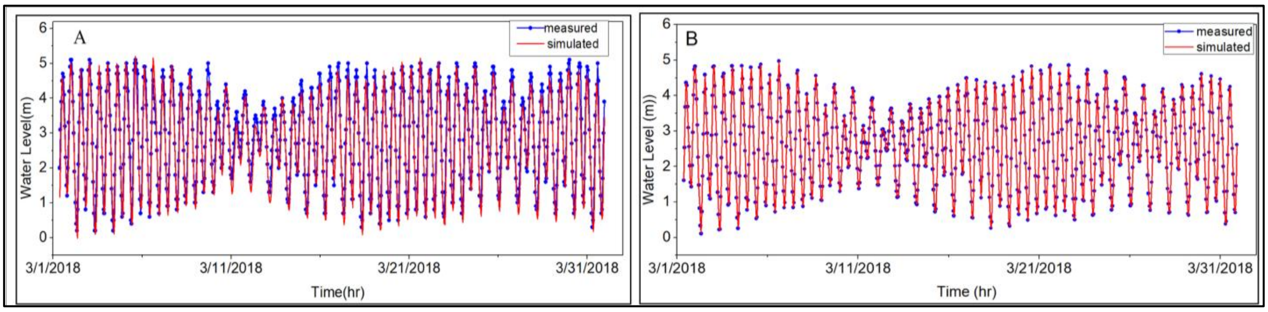

Figure 4: Comparsion between measured and simulated water level (A) at station ST3, (B) at ST2.

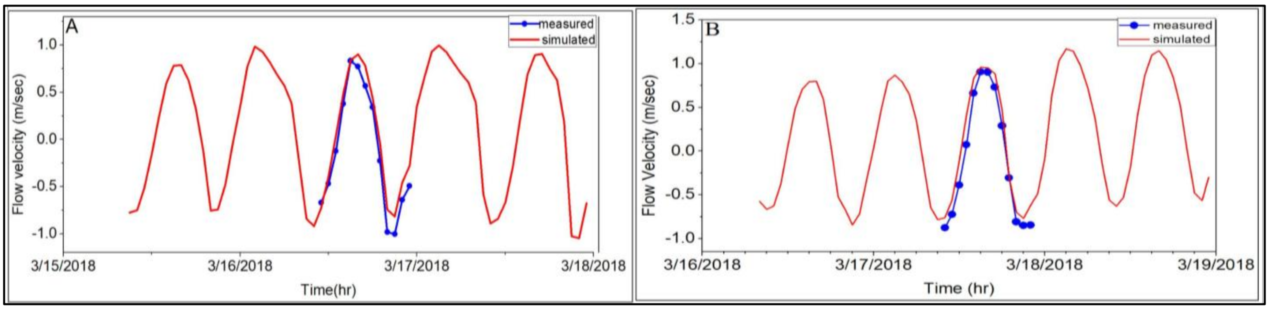

Figure 5: Comparsion between measured and simulated flow velocities (A) at station ST5, (B) at ST4.

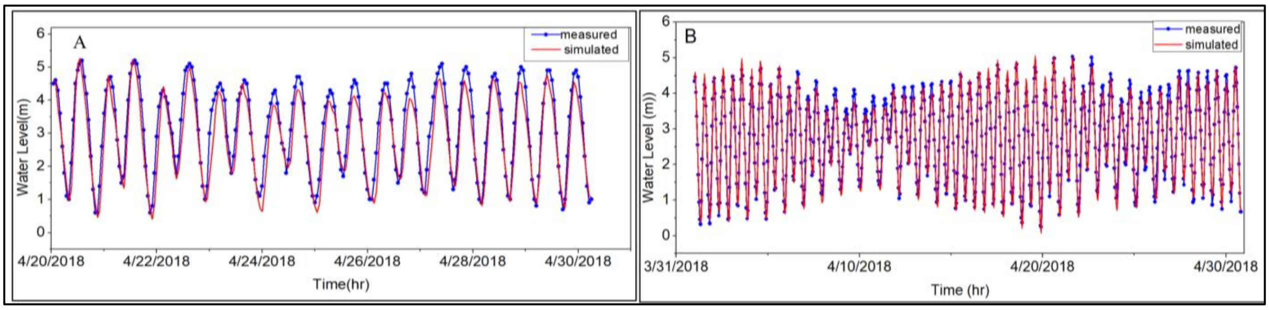

Figure 6: Comparsion between measured and simulated water level (A) at station ST3, (B) at ST2.

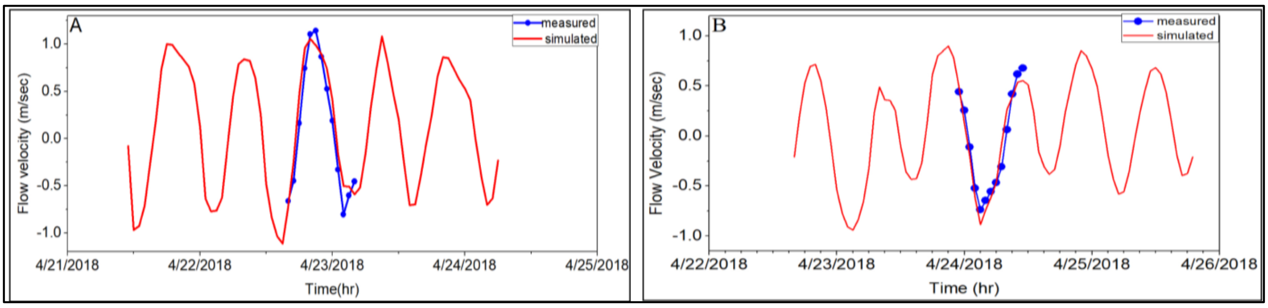

Figure 7: Comparsion between measured and simulated flow velocities (A) at station ST5, (B) at ST4.

Table 1: Root Mean Square Error and Nash-Sutcliffe Efficiency Coefficient for the calibration and validation periods.

Stations	Calibration period		Validation period	
	RMSE	NSE	RMSE	NSE
ST2 (water level)	0.26 m	0.997	0.27 m	0.99
ST3 (water level)	0.45 m	0.991	0.47 m	0.98
ST4 (flow velocity)	0.17 m/sec	0.95	0.12 m/sec	0.97
ST5 (flow velocity)	0.15 m/sec	0.96	0.32 m/sec	0.99

A satisfying agreement in both water level variations and flow velocities has been achieved for the four locations. The model also reproduced the spring-neap cycles through the simulation period at all of the stations. It is worthy to mention, in ST3 there are interruptions in recordings of water level for twenty days through April 2018 and the validation of the model was carried out by utilizing only the last ten days in this station. In general, the model reasonably well reproduced the surface level and flow velocities and give satisfactory results that can be used for future assessments of hydrodynamic characteristics in the study area.

3.RESULT AND DISCUSSION

To estimate the residence time within the KA and KZ, a tracer approach model called the e-folding method is used. However, According to this method, the residence time is defined as the time that required to flush out of 63% of tracer that is uniformly distributed at time 0, or the time require to reduce the tracer concentration in the working area to 37% of its initial value [5,27]. Combined hydrodynamical model with a transport model (Advection- Dispersion) is set up to track the spatial and temporal distributions of a conservative tracer. At a first time step (t=0), the uniform distribution of the tracer throughout all grid points of the model domain (initial concentration) corresponding to 100% (or 1 kg/m^3) and a concentration that equal to 0% (0 kg/m^3) at outside of the computational domain [14,28,29]. Consequently, the spatial distributions of residence time are obtained for each computational grid point of the hydrodynamical model by tracking the conservative tracer concentration fluctuations due to the effected dominant physical processes in that location. However, hydrodynamical regime has significant influences on the distribution and transport of pollutants within the study area. Hence, the general dynamical characteristics which are generated by the hydrodynamic module must be discussed first.

The tides in study area followed a similar rhythm in all locations, a mixe with the dominantly semi-diurnal tide [17], i.e. there are two high and two low tides per day with diurnal inequality. It is worthy to note that, a gradual increase in tidal ranges are observed from ST1 moving towards ST3, and hence a gradual increase in tidal amplitude that travels upstream due to the convergence nature of the study area, and a model has adequately reproduced such variations in these assesse locations. The maximum mean tidal range was observed in the ST3 through the spring tide that exceeded 4.25 m and reduced to about 2.2 m in the neap tide phase. The mean spring and neap tidal range varies between 2.53 and 1.25 m at ST1, and 3.73 and 1.89 m at ST2. The tidal range in ST3 that exceed 4 m at spring tide represents the highest tidal range that observed of the entire Arabian Gulf, beside the same magnitude that recorded in Kuwait Bay [30].

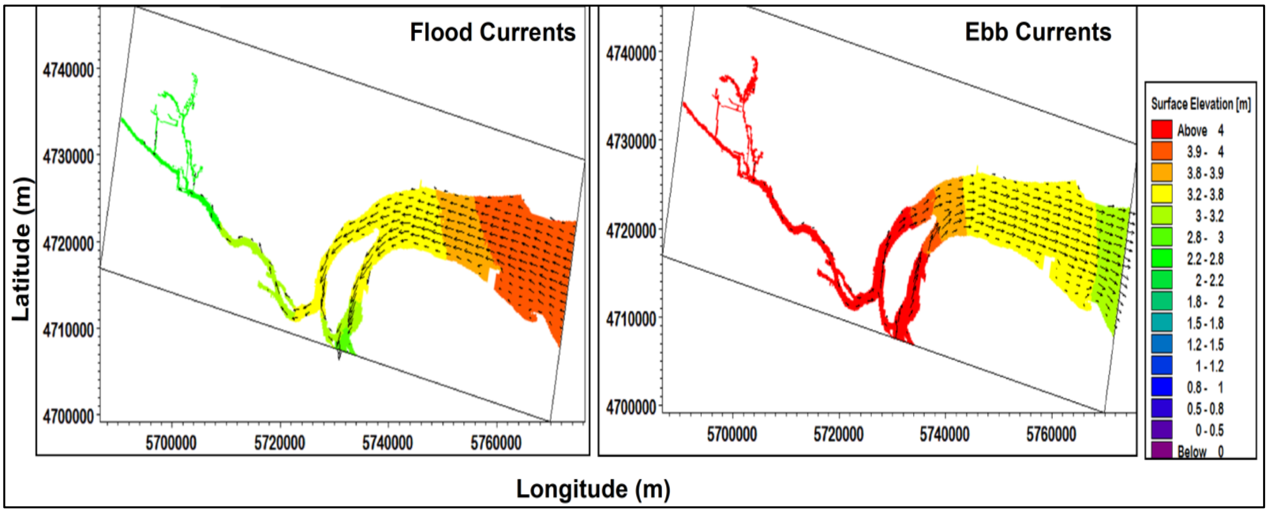

Figure 8: Tidal currents direction and surface elevation.

As illustrate in figure (8), the tidal current directions are rectilinear (currents move along the longitudinal axis) with two distinguish directions, a northwestward through the flood tide and southeastward during ebb tide. The current velocity of the order of 1 m/s is a characteristic feature of the study area during both ebb and flood. The spring- neap currents velocity are ranged between 1.1 and 1.01 m/sec and, 1.472 and 1.16 m/sec in KA and KZ respectively. Nevertheless, due to the shallow water nature of the area, the tidal asymmetry leads to the ebb period is longer than the flood period, and hence a flood currents is higher than an ebb currents in the most locations in the study area, which consistent with the study of Al-Mahdi and Mahmood [31], Lafta et al. [32], Al-Mahdi et al. [33] and Al-hasem [34].

The hydrodynamic regimes have a pronounced influence on residence time distribution. Tides is a dominant force that controls the water circulation in KA and KZ after a reduction of the Shatt AL-Basrah Inflow.

The simulation results revealed that there are substantial differences in water residence time and hence in flushing capability between areas of KA and KZ. However, there is an exponential decay in the tracer concentration, and by inserting 5 points at different locations as shown in figure 9 (A), the residence time has been estimated according to the aforementioned e-folding method and presented in figure 10. The faster tracer removal was observed in K1 due to their located near to KA inlet towards the Arabian Gulf, and hence such a rapid decrease in the tracer concentration suggests that the residence time in this region is relatively shorter than it in other locations. However, the water residence time was 3 days in K1 station as illustrated in figure 10, and after about 12 days all the tracer flushed out from this region. However, although K2 station is located far from the inlet, it also displays approximately a rapid decreases in tracer concentration caused by hydrodynamics features of this area, leading to a residence time 4.3 days.

Furthermore, the water residence time observed in KZ at K3 station was 3.5 days. However, the short residence time recorded in KZ due to that, KZ is a highly dynamic system with high flood and ebb currents that enhance the mixing processes and contribute in the advection of tracer out the system. The longest residence time was observed in Umm Qasr river1 (UMR1) and at small lagoons of Khor Al-Zubair (KZL), these two regions is a semi-enclosed with one inlet that displays stagnant regions in its upper limits. The residence time was 12 days and 25 days in UMR1 and KZL respectively.

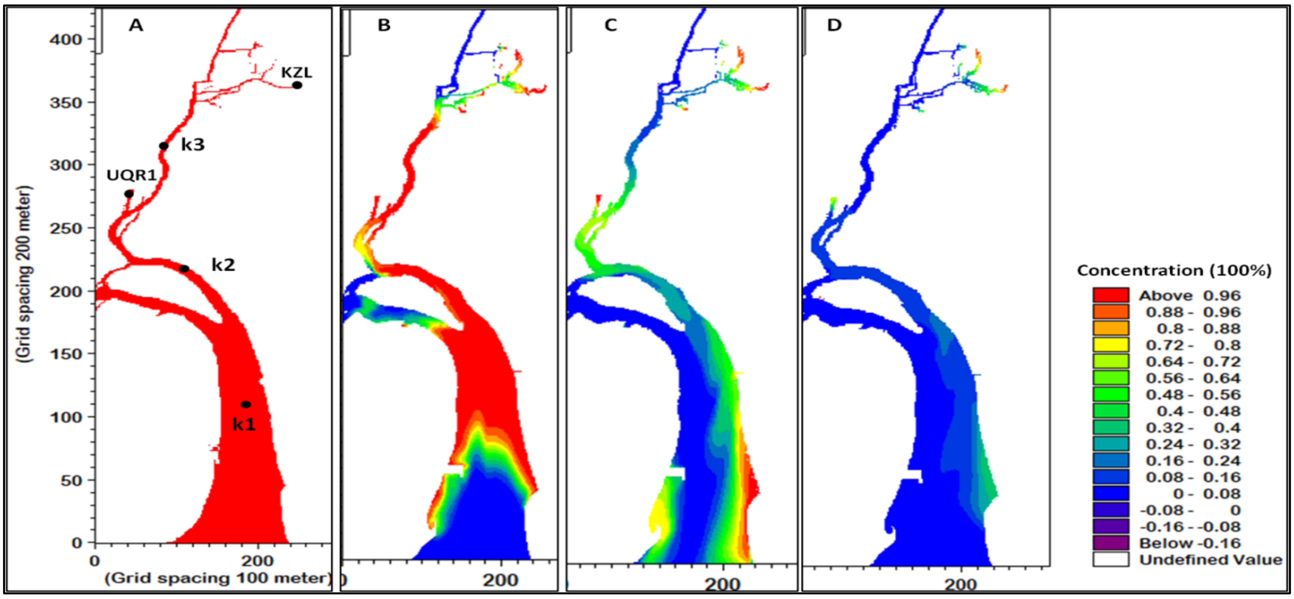

Figure 9: Spatial distribution of tracer concentration after, (A) 0 day, (B) 1 day, (C) 3 days and (D) 7 days.

However, the region with long residence time suggests the potential for substantial deterioration in water quality and its an ecosystem [5,35]. Such places with long residence time experience from a potential accumulate of heat, dissolved substance, and Plankton growth. .

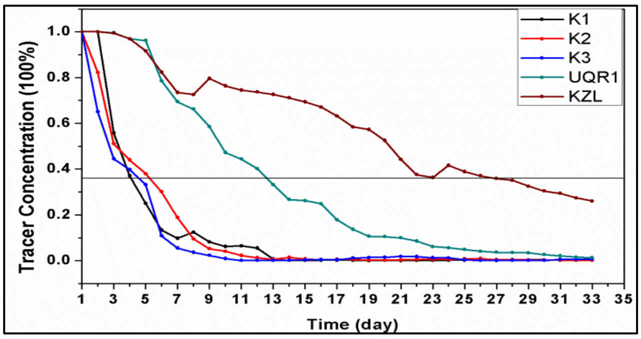

Figure 10: Estimated residence time.

The results of the simulation also indicate that the fluctuations of the tracer concentration at most locations in KA and KZ were predominantly associated with the tidal flow (tracer concentration is rise and fall during successive tidal cycles) until it reaching to the e-folding value (Fig. 11,A), thus, advection is the main process that responsible for the physical transport processes in most locations of KA and KZ. While, at UMR1 and KZL, there is a gradual reduction in the tracer concentration until reaching the e-folding value as shown in figure (11,B), and hence a relatively long residence time, thus diffusion has a relatively significant contribution in the transport characteristics at such places.

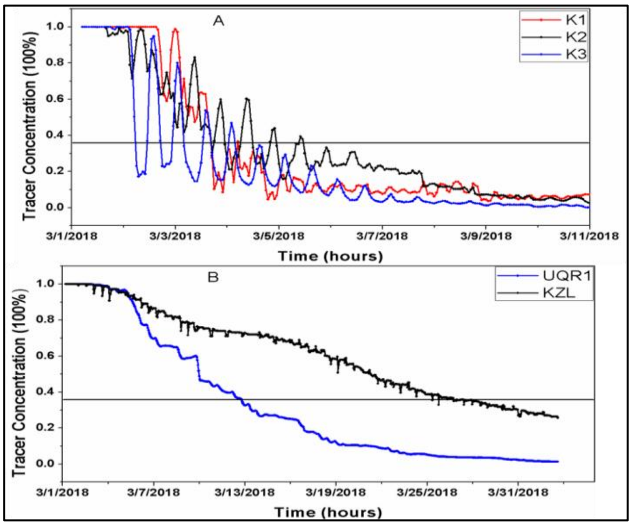

Figure 11: Concentration reductions.

4.CONCLOSION

Hydrodynamics and residence time distributions of Khor Abdulla and Khor Al-Zubair are studied using the combined hydrodynamic and transport models. The field measurements are used in the calibration and validations. Flushing characteristics of KA and KZ are examined by tracking the evolution of tracer concentration, and the residence time is estimated according to e-folding method. The result of simulations and measurement indicate that there are asymmetries in the tidal wave that propagates farther in inland direction with a gradual increase in their amplitude and hence in its tidal range. Additionally, the strong tidal currents of order 1 m/s were observed in flood and ebb phases, and the ebb period was longer than the flood period. In general, there are two distinct directions for tidal currents, a northwest and a southeast that follow the flood and ebb phases respectively. The simulation results indicate that residence time is a site-specific, and show a heterogeneous distribution due to the bathymetric and configuration nature of that site. The longest residence time is observed in two sites, UMR1 with 12 days and KZL with residence time that exceeds 25 days. By taking into account the continuous anthropogenic activities and associated pollutants threat, the short residence time is beneficial for the elimination of pollutants in area under study. In contrast, the long residence time may result in water quality deterioration and hence several implications in the ecosystem.

5.ACKNOWLEDGMENT

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6. REFRENCES

[1] Choi, K. W., and Lee, J. H. 2004. "Numerical Determination of Flushing Time for Stratified Water Bodies." *Journal of Marine Systems* 50(3–4): 263–81.

[2] Deleersnijder, E., Jean-Michel, C., and Delhez, E. J. M. 2001. "The Concept of Age in Marine Modelling: I. Theory and Preliminary Model Results." *Journal of Marine Systems* 28(3–4): 229–67.

[3] Delhez, E. J. M. 2006. "Transient Residence and Exposure Times." *Ocean Science* 2(1): 1–9.

[4] Fischer, H., List J., Koh R., Imberger, J., Brooks, N., 2013. Mixing in Inland and Coastal Waters *Mixing in Inland and Coastal Waters*. Elseiver, 483 pp.

[5] Monsen, N. E., James E. C., Lisa V. L., and Stephen G. M. 2002. "A Comment on the Use of Flushing Time, Residence Time, and Age as Transport Time Scales." *Limnology and Oceanography* 47(5): 1545–53.

[6] Dyer, K. R. 1973. *Estuaries: A Physical Introduction*. John Wiley & Sons, New York.

[7] Zimmerman, J., and Kjerfve, B. 1988. "Estuarine Residence Times." *Hydrodynamics of estuaries* 1.

[8] Zimmerman, J. 1976. "Mixing and Flushing of Tidal Embayments in the Western Dutch Wadden Sea Part I: Distribution of Salinity and Calculation of Mixing Time Scales." *Netherlands Journal of Sea Research* 10(2): 149–91.

[9] Takeoka, H. 1984. "Fundamental Concepts of Exchange and Transport Time Scales in a Coastal Sea." *Continental Shelf Research* 3(3): 311–26.

[10] Du, J., and Jian S. 2016. "Water Residence Time in Chesapeake Bay for 1980--2012." *Journal of Marine Systems* 164: 101–11.

[11] Cucco, A., and Umgiesser, G. 2006. "Modeling the Venice Lagoon Residence Time." In *Ecological Modelling*, , 34–51.

[12] Shen, J., and Larry H. 2004. "Calculating Age and Residence Time in the Tidal York River Using Three-Dimensional Model Experiments." *Estuarine, Coastal and Shelf Science* 61(3): 449–61.

[13] Liu, W. C., Chen, W.B., and Ming-Hsi H. 2011. "Using a Three-Dimensional Particle-Tracking Model to Estimate the Residence Time and Age of Water in a

Tidal Estuary." *Computers & Geosciences* 37(8): 1148–61.

[14] Li, Y., Zhang Q., and Yao J. 2015. "Investigation of Residence and Travel Times in a Large Floodplain Lake with Complex Lake-River Interactions: Poyang Lake (China)." *Water* 7(5): 1991–2012.

[15] Mahanty M.M., Mohanty P.K., Pattnaik A.K., Panda U.S., Pradhan S., and Samal R.N. 2016. "Hydrodynamics, Temperature/Salinity Variability and Residence Time in the Chilika Lagoon during Dry and Wet Period: Measurement and Modeling." *Continental Shelf Research* 125: 28–43.

[16] Darmoian, S. A., and Lindqvist, K. 1988. "Sediments in the Estuarine Environment of the Tigris/Euphrates Delta; Iraq; Arabian Gulf." *Geological Journal* 23(1): 15–37.

[17] Al-Ramadhan, B. M. 1988. "Residual Fluxes of Water in an Estuarine Lagoon." *Estuarine, Coastal and Shelf Science* 26(3): 319–30.

[18] MOD. 2008. "Main Outfall Drain." Ministry of Water Resources, Main Outfall Drain Office, Baghdad, Iraq.(Unpublished Report).

[19] Lafta, A. A., Al-Aeaswi, Q. M., and Al-Taei, S. A. 2013. "Total Dissolved Solids Modeling in the Shatt Al-Basrah Canal, Using Mike 11." *Mesopotamian Journal of Marine Science* 28(2): 139–50.

[20] Saleh, Z., , Al-Ansari, N., and Knutsson S. 2013. "Historical and Future Climatic Change Scenarios for Temperature and Rainfall for Iraq." *Journal of Civil Engineering and Architecture* 7(12): 1574–94.

[21] DHI, Danish Hydraulic Institute. 2007. "Scientific Documentation, MIKE 21 Hydrodynamic Module, DHI Water and Environment."

[22] Gross, E. S., Bonaventura, L., and Rosatti, G. 2002. "Consistency with Continuity in Conservative Advection Schemes for Free-Surface Models." *International Journal for Numerical Methods in Fluids* 38(4): 307–27.

[23] Ekebjærg, L., & Justesenu, P. (1991). An explicit scheme for advection-diffusion modelling in two dimensions. *Computer Methods in Applied Mechanics and Engineering*, *88*(3), 287–297.

[24] MSC. 2005. "Al-Faw Grand Port Marine Survey". *Report Conducted by Marine Science Center / Basrah University to General Company Of Iraq Ports (Unpublished Report).*

[25] SOC. 2014. " Common Seawater Supply Project,High Priority Survey, Bathymetry Survey" *Report and Drawings, Report Introduced by Tatweer LTD to South Oil Company, Iraq (Unpublished Report).*

[26] Nash, J. E., and Sutcliffe, J. V. 1970. "River Flow Forecasting through Conceptual Models Part I: A Discussion of Principles." *Journal of hydrology* 10(3): 282–90.

[27] Miller, R. L., and Benjamin, F. M. 1991. "Estimating Estuarine Flushing and Residence Times in Charlotte Harbor, Florida. via Salt Balance and a Box Model." *Limnology and Oceanography* 36(3): 602–12.

[28] Hong, B. and Shen, J. 2012 "Responses of estuarine salinity and transport processes to potential future sea-level rise in the Chesapeake Bay," *Estuar. Coast. Shelf Sci.*, vol. 104, pp. 33–45.

[29] Jiang, C., Liu,Y. and Long, Y. 2017."Estimation of residence time and transport trajectory in Tieshangang bay, China," *Water (Switzerland)*, vol. 9, no. 5.

[30] Alosairi, Y., Pokavanich, T., and Alsulaiman, N. 2018. "Three-Dimensional Hydrodynamic Modelling Study of Reverse Estuarine Circulation:

Kuwait Bay." *Marine pollution bulletin* 127: 82–96.

[31] Al-Mahdi, A. A., and Mahmood, A. B. 2010. "Some Features of Tidal Currents in Khor Abdullah, North West Arabian Gulf." *Journal of Marine Science for King Abdul Al-Aziz Univ* 21(1): 162–82.

[32] Lafta, A. A., Al-Taei, S. A., and Al-fartusi, A. J. 2015 "One Dimensional Hydrodynamics Model For Khor Al-Zubair Channel, South West of Iraq," *J. Int. Acad. Res. Multidiscip.*, vol. 3, no. 4, pp. 437–445.

[33] Al-Mahdi, A. A., Abdullah, S. S., and Husain N. A., 2009 "Some features of the physical oceanography in Iraqi marine water," *Mesopotamian J. Mar. Sci*, vol. 24, pp. 13–24,.

[34] Al-hasem, A. M., 2018 "Tidal Current Behaviors and Remarkable Bathymetric Change in the South-Western Part of Khor Abdullah , Kuwait," *Int. J. Mar. Environ. Sci.*, vol. 12, no. 2, pp. 118–125.

[35] Dettmann, E. H. 2001. "Effect of Water Residence Time on Annual Export and Denitrification of Nitrogen in Estuaries: A Model Analysis." *Estuaries* 24(4): 481–90.

حساب زمن البقاء في خور عبدالله وخور الزبير شمال غرب الخليج العربي باستخدام تقنية النمذجة العددية

علي عبدالرضا لفته [1,2]   سامر عدنان الطائي [2]   نوري حسين الهاشمي [2]

[1,2]قسم الفيزياء/ كلية التربية للعلوم الصرفة/ جامعة البصرة

[2]قسم الفيزياء البحرية/ مركز علوم البحار/ جامعة البصرة

الخلاصة

تم تطبيق نموذج هيدروديناميكي ثنائي البعد لدراسة الخصائص الهيدروديناميكية وتوزيع زمن البقاء في خور عبدالله وخور الزبير من خلال الموائمة بين النموذج الهيدروديناميكي ونموذج الانتقال. تم تطبيق النموذج لمدة شهرين وبخطوة زمنية 5 ثانية. عملية المعايرة للنموذج تمت من خلال مقارنة النتائج مع القياسات لكل من تذبذب سطح البحر وسرع التيارات اذ تم التوصل الى توافق جيد مع القياسات الميدانية. أشارت نتائج المحاكاة والقياسات الميدانية الى وجود زيادة تدريجية في سعة الموجة المدية عندما تنتشر باتجاه المقتربات العليا لمنطقة الدراسة. اظهرت النتائج ان توزيع زمن البقاء يكون دالة للموقع وان اطول زمن بقاء تم تسجيله في نهر ام قصر 1 وفي تفرعات خور الزبير والذي بلغ 12 يوم و25 يوم على التوالي.

الكلمات المفتاحية: الهيدروديناميك، النمذجة العددية، نموذج الانتقال، زمن البقاء، المتقفي.