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Impact of Al Ain El Sokhna Port Extension on Water Renewal

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ABSTRACT

Ports basins have to be designed in a way to guarantee an adequate exchange of water. Water quality is often determined not only by physical processes, but also by various biological, chemical, and ecological processes. However, flushing is generally a good indicator of the potential water quality and provides a valuable tool for evaluating and improving circulation.

In the current study, a two-dimensional hydrodynamic model based on Delft3D is established to study the circulation patterns which were then used to estimate the flushing characteristics within Al Ain Sokhna port under the tide effect. The circulation patterns were simulated by depth average model for the condition of 2019 (Case1) and including two port extensions, i.e., Case 2 (after dredging the second basin) and Case 3 (considering the final extension as per the master plan). The residence time, flushing exchange coefficients and flushing uniformity have been evaluated. The diffusion parameter used in the modelling exercise was 5 m^2/s (sensitivity of the diffusion parameter of 2 m^2/s has been investigated and hence the flushing times become double). The flushing time (T_{37}) was 9.8 days in the base configuration of the basin (Case 1) while it is increased to 13.3 days for Case 2 and 31 days for Case 3 (final development plan of the port). Based on these results, the water renewal is not good according to standards (USACE, USEPA and PIANC). Measures to improve the flushing efficiency is required, especially at the poorly flushed basin ends in-addition to pollutants & debris-collection and removal.

Keywords: *Tidal current; Residence time; Flushing exchange coefficient; Flushing uniformity; Delft3d.*

1. Introduction

Sea ports are commonly a complex of varies activities that may potentially generate wastes and thus considered as a hot spot of coastal pollution. Water exchange and circulation between the harbour basins with the surrounding coastal water is a crucial aspect for designing ports. Water quality within ports basins depends on how well the basin is flushed that is affected by water movement controlled by tides, wind, wave climate and ship movements. One or more of these conditions can dominate flushing mechanisms. Slower water exchange increases flushing time inside the basin. This leads to build-up of pollutants, debries, higher temperature, salinity, Dissolved Oxygen ranges, and increased tendency for anaerobic conditions.

The water quality within ports basin and at the nearby coastal zones have to be monitored and assed periodically. [1] proposed a new methodology for assessing the environmental risk of water quality in harbor areas to be applied to ports of Europe. [2] investigated the water quality within Dekhila harbour in Alexandria while [3] studied the water quality at different ports along the Suez Gulf and detect oil spills and specifying the source of this pollution along the Suez-AinSokhna coastal zone.

The result of organic parameters (Total Organic Carbon (TOC) and Oil & Grease) indicated that oil pollution is concentrated in the three main harbors at the area of study: Port Tawfeek, El Attaka and Al Ain Sokhna.

Al Sokhna region has valuable natural resources and habitats. It is among the most developed parts in Egypt where many industries, fisheries and recreational activities are settled and developed near the coastal belts, especially, around major harbours like Al Ain Sokhna port. This has ultimately contributed to severe pollution hazards. Consequently, more care to potential hazardous should be monitored tightly in order to keep the area flourished as described in [4].

Circulation patterns within a harbour should minimize and preferably eliminate areas of stagnant water, which cause elevated pollution levels and may cause fine sediment deposition. Flushing and water circulation are enhanced by maintaining positive gradients in channel size and depth from the start towards the entrance channel. Flushing culverts may be introduced inside the breakwaters to increase water renewals as in ACI Marina Opatija in northern Croatia. [5] studied the water renewal through the flushing culverts constructed within the Marina breakwater. The water quality depends crucially on flushing rate, which is a measure of how the tide flush and remove pollutant from water body as

explained in [6]. Tidal prism is the traditional method for estimating flushing times where tidal prism methods assume full mixing and hence produce optimistic flushing rates. Methods of evaluating water circulation and exchange in harbours vary from simple methods, such as the exchange coefficient (E), flushing efficiency and water residence time as in [7], to mathematical models involving complicated numerical solutions of water movement equations (e.g., Delft3D, MIKE 21, RMA-10, RMA-11, etc.) and field studies and parameters for evaluating the water circulation terms, such as the exchange coefficient, flushing efficiency and water residence [8].

Previous studies [9] and [10] built laboratory models to investigate the influence of the geometry, entrance width and tidal range on the exchange and flushing characteristics of a simple-shaped harbour. They concluded that optimum tidal flushing occurred when the length to width ratio is between 0.5 and 2, and the best configuration was a square harbour. They also noted that varying the entrance width affected the flushing efficiency. [10] found that the spatial average flushing of a rectangular harbour and a lagoon with dimensions L and B varied parabolically with the ratio of L/B.

[11] studied the flushing characteristics of a marina through a comprehensive field study. A large discrepancy was observed between the flushing time of 5 days measured during the experiment and the optimal total flushing time of 11 days based on the tidal prism method.

[12] used Delft3D (a three-dimensional flow and transport model) to study the flushing characteristics of 216 rectangular, sea-connected lagoons and harbours (connected through only one gap) under semidiurnal and diurnal tidal conditions to develop a simple equation for calculating the concentration ratio after each tidal cycle. The equation included the effects of the tidal range/depth, basin width/basin length and gap width/basin length. [13] used Delft3D to study how Kuwait Bay is flushed in summer. [14] employed MIKE 21 to study the tidal recirculation characteristics of the Shaab Yacht club marina. They found that the flushing efficiency tended to increase as the water depth linearly increased towards the entrance. The calculated flushing time of this marina was 3 days based on the tidal prism method and 6 days based on the MIKE 21 results.

In this study, Delft3D is used to assess the water flushing and circulation characteristics within Al Ain Sokhna port with its extensions (current extension and future extension).

The objectives of the current study are:

- Study the current velocities and the circulation inside the port basin;
- Investigate the impact of the port extensions on the tidal flushing time. Three cases were considered in the current study.

2. Site Conditions

2.1 Description of the Study Site

Al Ain Sokhna port is located on the western coast of the Suez Gulf, which is a part of the Red Sea, 43 km away from the Suez city (latitude 29^o 38.695'N and longitude 32^o 21.562' E) as shown in Figure (1). The total port area is around 23.5 km^2 with a water area of 1.5 km^2 that will be increased to 2.0 km^2 after adding basin no. 2 (already excavated). The water area will exceed 5.5 km^2 after finalizing the planned master plan. The port established to increase the trade potential along the Suez Gulf coast, with trading capacity up to 4.75 million tons a year as General Cargo, 3.75 million tons a year as Containerized cargo and 400,000 TEU Capacity per year (Maritime Transport Sector). Currently the port is subjected to an extension by excavating a new basin (basin 2. already excavated). As per the original master plan of the port, new extensions are still expected in the future. Figure (1) shows the situation at year 2019 and the two future extensions considered in the current study.

2.2 Bathymetry

The bathymetric data used in this study is digitized from the Admiralty Chart No. 2133, Figure (2). Also, data of the bathymetry inside the harbour has been extracted from the port master plan (water depth measured from MSL is considered uniform, 17m).

A single data file for the bathymetry was generated. The data was converted to the UTM system for Zone 36. This data was used to determine the depths over the numerical grid for three cases i.e., the base case, the case after excavating the new basin and after executing the final port layout as per the master plan, Figure (1).

2.3 Water Levels and Current Velocity

The tide at the project site is high (HAT reaches 2.2 m) and thus tidal level variations are important for the project site.

Table (1) summarizes the tidal planes northern and southern the project site extracted from Admiralty Chart.

Table (1). Tidal Planes at Suez and Zafarana

.Loc	HAT	MHWS	MHWN	MSL	MLWN	MLWS	LAT
Suez	2.2	1.9	1.6	1.14	0.7	0.4	0.1-
Zafarana	1.8	1.5	1.2	0.9	0.6	0.4	0.1

Generally, the tidal currents in the Gulf of Suez are northwards when the tide is rising at Suez and southwards when the tide is falling at Suez. In mid-Gulf on spring tides the rate is 0.75m/s and 0.25m/s on neap tides (Admiralty, 1993). In other parts of the Gulf, speed and direction are uncertain. Measurement of current velocity in front of Al Sokhna power plant, southern the project site; shows that it is less than 0.25 m/s [15]. This measurement will be used in the current hydrodynamic model calibration.

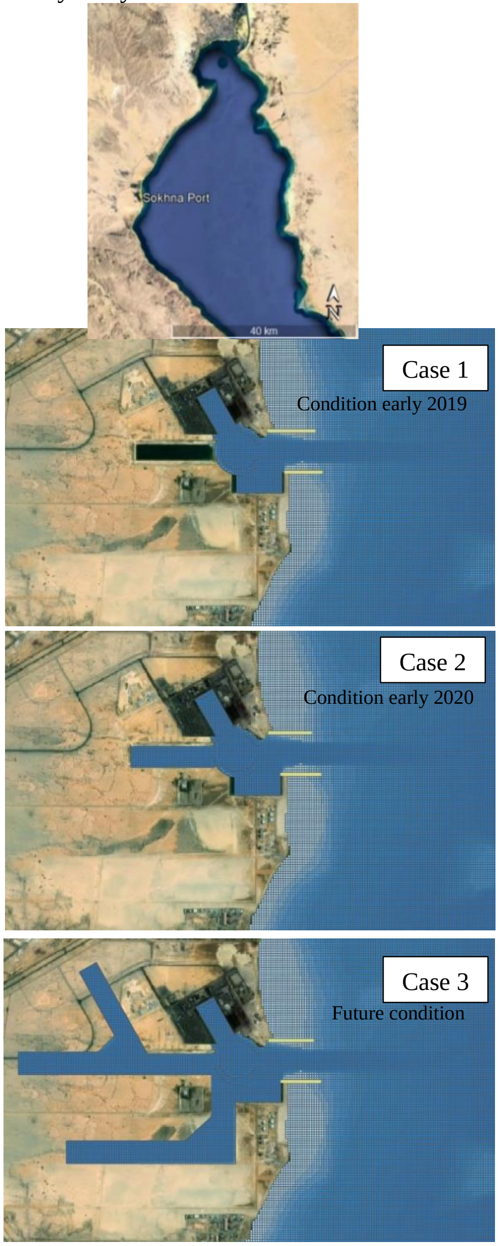

Figure 1- Exiting (Case 1) and Extension of Sokhna Port Including Excavation of Basin 2 (Case 2) and after Finalizing the Master Plan (Case 3)

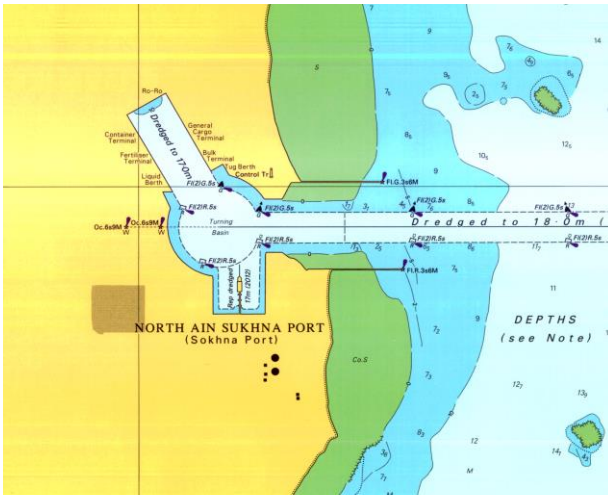

Figure 2- Admiralty Chart Used in Bathymetry Detection

3. Flushing Criteria

There are various indicators to evaluate flushing, including Residence times, Flushing exchange coefficients and Flushing uniformity indicators.

Residence time "often used interchangeably with "flushing time" is usually used as a measure of water mass retention within a defined volume [16]. Shorter residence times correspond to more rapid flushing of a water body. In conventional flushing studies, the definition of residence time is usually linked to a target flushing criterion (e.g., the time taken for the mean concentration of a conservative tracer introduced to a water body to fall below a certain percentage of its initial value). The concentration of a given tracer will exponentially decrease with time, as confirmed by the model results, as follows:

$$C = C_o \, exp(-t/T) \tag{1}$$

where C_o is the initial concentration of the tracer and T is the retention time.

Three different definitions of residence times are presented in the current paper:

– T_{50} - the "half-life" residence time, defined as the time taken for the average concentration of a conservative tracer introduced to a volume of water to reach 50% of its initial value; and

– T_{37} - the "E-folding" residence time, defined as the time taken for the average concentration of a conservative tracer introduced to a volume of water to reach 37% of its initial value.

– T_{10} - the "E-folding" residence time, defined as the time taken for the average concentration of a conservative tracer introduced to a volume of water to reach 10% of its initial value.

The efficiency of tidal flushing in ports is commonly assessed by evaluation of the mean flushing exchange coefficient (E), which measures the fraction of water within the marina exchanged with the sea outside during each tidal cycle [17]. At each location i within the port basin, the exchange coefficient can be defined as:

$$E_i = 1 - \left(\frac{C_i(n)}{C_{i,0}}\right)^{\frac{1}{n}} \qquad (2)$$

Here, $C_i(n)$ is the concentration of a conservative (non-decaying) tracer at location i after n tidal cycles and $C_{i,o}$ is the initial concentration. Larger exchange coefficients imply more rapid replenishment of water. The mean flushing exchange coefficient for the basin (E) is computed by averaging over the entire marina. Higher mean exchange coefficients correspond to shorter residence times.

Purely port-averaged flushing indicators (such as mean flushing exchange coefficients) do not provide any information about the potential for formation of isolated pockets of poorly flushed water. Some ports with generally good water exchange characteristics may contain very small pockets of stagnant water that skew estimates of mean flushing exchange coefficients. Conversely, a port with very good exchange near the mouth but with large “dead zones” or areas of poor circulation inside, may exhibit a deceptively high mean exchange coefficient. The most recent published guidance by PIANC [17] for flushing of marinas suggests considering an overall flushing exchange coefficient (Section 2.5.2) along with a flushing uniformity index for the water body being assessed. The flushing uniformity index (ψ) is the difference between the mean flushing exchange coefficient (E) and the spatial standard deviation of the exchange coefficient (S), i.e.: $\psi = E - S$. Higher values of ψ correspond to more uniform flushing, reducing the likelihood of localized “dead” or stagnant zones. Available standards for good flushing criteria are summarized in Table (2).

Table 2- Summary of Flushing Criteria

Reference	Guidance	Criterion Duration
Marina Flushing Criterion 1 [18] (USACE,1993)	E>0.18	Average daily assuming semi-diurnal tides
Marina Flushing Criterion 2 (USEPA, [19] (1985	days 4 ≥ $_{37}$T	After 4 days or 8 tidal cycles
Marina Flushing Criterion 3 (PIANC, [17] (2008	*Ei* > 0.15 for at least 95% of the > 0.1ψbasin;	After at least 4 tidal cycles and averaged over 1 tidal cycle

4. Flushing Model

4.1 Model Description

The Delft3D is a multidimensional (2D or 3D) modelling framework that can simulate hydrodynamics, transport of constituents (i.e., salinity, temperature, and other constituents), short-wave generation and propagation, and sediment transport and morphological changes [20]. The model solves the Navier–Stokes system of equations for incompressible free surface flow, under the Boussinesq approximations. The hydrodynamic solver includes several “vertical” turbulent closure models which are available in the Delft3D model. The vertical turbulent closure models included are a “constant coefficient”, “algebraic”, “k–l”, and the “k–ε”, which represent a two zero-order closure schemes, a first-order scheme, and a second-order scheme, respectively. The bottom roughness can be computed with Chezy, Manning, etc., and can be spatially varied. The model has a tracer module which is basically tracks a tracer through the computation of the advection-diffusion equation over the same hydrodynamic grid in a Eulerian frame of reference which is used in the current study.

4.2 Model Grid and Bathymetry

The hydrodynamic/flushing grid axis was oriented shore parallel. Figure (1) presents the model extent which is approximately 8 km x 8.5 km with a grid resolution of 40 m × 40 m. The grid for different cases were shown in Figure (1).

Model bathymetry comprised of Admiralty charts and bathymetry from the port master plan. Figure (3) presents the bathymetric data interpolated onto the computational domain for all cases up to case 3.

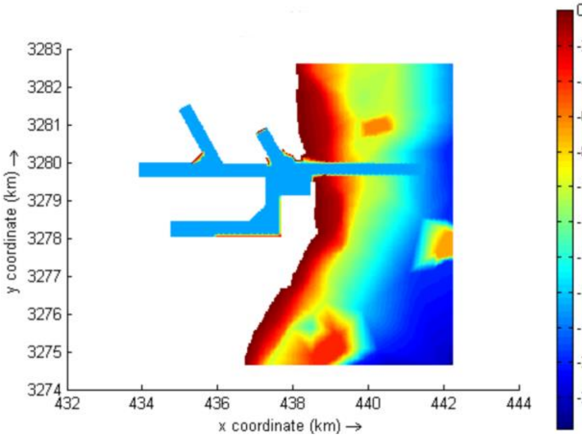

Figure 3- Seabed Levels

4.3 Boundary Conditions

Tidal boundaries were set on the east, north and south of the grid. The tidal boundaries were extracted from the TPXO-8.0 global tidal model [21], which varies along the boundary segment at each end. Sample of water levels at the eastern boundary is presented in Figure (4).

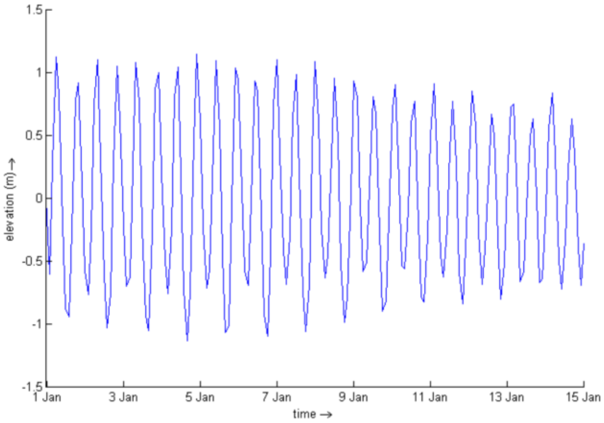

Figure 4- Sample Water Level Variation at the Eastern Boundary

4.4 Model Calibration

This task is essentially required to ensure that the numerical model accurately reproduces reliable hydrodynamic for current field at the study site. Current velocity measurements were available southern Al Ain Sokhna port Infront of Al Sokhna power plant in April 2008 [15]. The model was run at the same period of measurements considering tide and wind. Figure (5) shows the comparison of field observation and numerical model results of current speed. The comparison shows reasonable agreement.

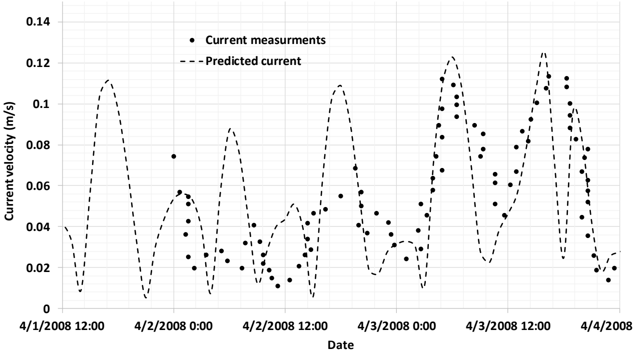

Figure 5- Comparison of Field Observation [15] and Numerical Model Results of Current Velocity

4.5 Dispersion Coefficient

Values for the tidal mean dispersion coefficient range over three orders of magnitude which depend on the spatial extent and tidal characteristics of a coastal system. In addition, dispersion coefficient values vary spatially and temporally within a coastal system [22]. There are no deterministic or empirical methods for the estimation of the dispersion coefficient accurately. The only accurate method of estimation is by conducting a tracer study which is typically costly and impractical. Elder's method [22] can be used to characterize dispersion due to sub-grid scale velocity shear and diffusion (molecular and turbulent) as per the velocity and water depth but it is not applicable at all cases.

A general range of values for the dispersion coefficient in marinas is 1-20 m^2/s. [15] studied the dispersion and diffusion of the thermal effluent released from an existing outfall southern the project site and as per calibration of his model, he founds that the tuning parameters employed for the calibration process are the horizontal eddy viscosity and diffusivity of 1m^2/s and 5 m^2/s, respectively

A dispersion coefficient of 5 m^2/s was selected for simulation runs in the current study. As the dispersion is expected to be less inside the port compared to the nearshore, sensitivity of using dispersion coefficient of 2 m^2/s was investigated.

5. Model Results

5.1 Hydrodynamic Results

The current plan of the port has a total water area of 1.5 million m^2. The water area will be increased to 2 million m^2 after excavating basin no.2 and to 5 million m^2 as per the planned master plan. The width of the port entrance is approximately 690 m (the distance between the breakwaters). The water depth inside the port is around 17 m. Several points have been defined within the port basin to investigate the tidal current velocity and the flushing characteristics (the locations of the monitoring points are shown in Figure (6).

2D plots of tidal current magnitude at two sample time steps, i.e., ebb and flood tide are presented in Figure (7). Current vectors are superimposed on the 2D plots showing flow direction.

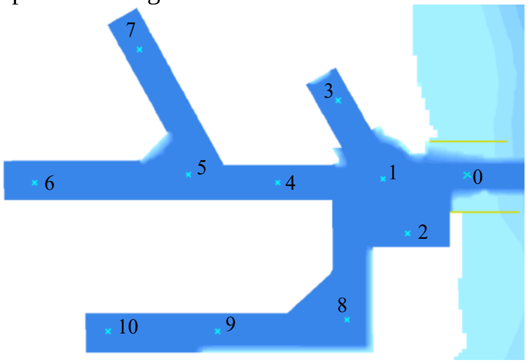

Figure 6- Location of Monitoring Stations

Time series plots of current magnitude at four representative locations (point 0, 1, 5 and 6) are presented in Figure (8). From the plots, current magnitudes typically range from 1mm/s to 25 cm/s.

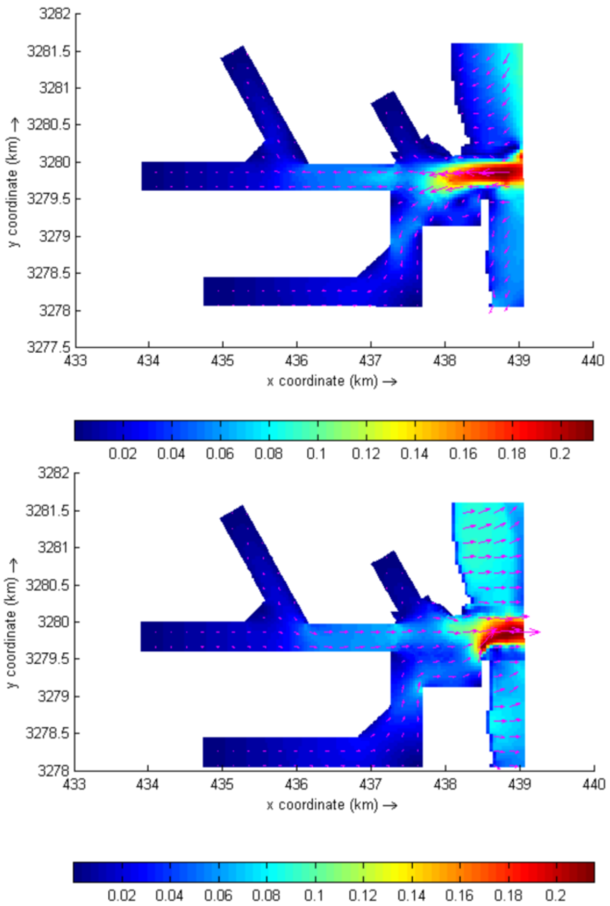

Figure 7- Simulated Flow Fields Under Tide Effect Without Wind; A) Flood tide, B) Ebb tide

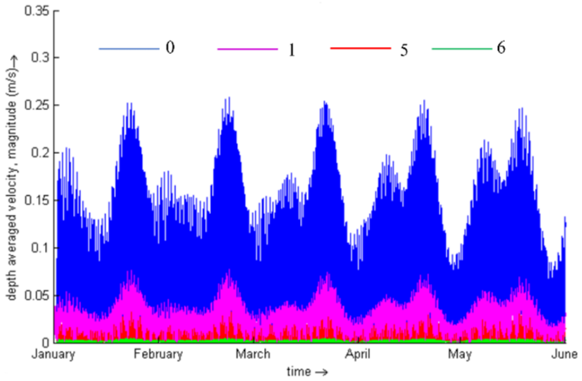

Figure 8- Time Series of Current Magnitude at Four Locations (0, 1, 5 and 6)

5.2 Advection Dispersion Results

It is assumed that pollution will occur only inside the port. An initial tracer concentration of 100% was introduced to the whole water area. 2D plots of tracer dilution every 4-day showing concentration per time step are presented in Figure (9) & Figure (10) for Case 1, Figure (11) & Figure (12) for Case 2 Figure (13) & Figure (14) for Case 3 for a dispersion coefficient (D) of 5 and 2 m^2/s respectively. The concentration is lowest near the port entrance and increases toward the land boundary toward the inner parts. The worst part within the port area is located at the far end inland. The retention/residence time as per the worst location is summarized in Table (3). T_{50}, T_{37} and T_{10} is summarized in Table (3) while T_{37} will be used as a flushing time in the current study. To show the flushing variability within the port basin, the flushing time (T_{37}) is estimated at several locations within the port and summarized in Table (4).

Table 3- Summary of Residence Time of Worst Point (Wind=0 m/s)

Percentage (C/Ci)	D= 5 m^2 / s			s / ^{2}m 2 =D		
	Case 1	Case 2	Case 3	Case 1	Case 2	Case 3
%50	6.3	9.7	24.4	14.3	21.4	46
%37	8.8	13.3	31.2	19.5	27.6	60
%10	19.8	27.3	63.6	40.7	56.6	120.9

Table 4- Summary of Residence Time of Several Points (T_{37}- Wind=0 m/s)

Points	days -($_{37}$Flushing time (T					
	s / ^{2}D= 5 m			s / ^{2}m 2 =D		
	Case 1	Case 2	Case 3	Case 1	Case 2	Case 3
1	7.9	10.5	15.1	17.2	20.4	20.7
2	7.4	9.5	15	16.1	19.3	18.7
3	8.8	11.7	16.8	19.4	23.8	20.5
4		13.2	24.9		27.5	43.4
5			28.6			54.4
6			31			60
7			30.6			59
8			21.3			31.2
9			24.9			44.6
10			26.4			47.8
Worst point	8.8	13.3	31.2	19.5	27.6	60

From the results above, it was concluded that the longest time necessary to reduce tracer mass to 37% (T_{37}) was found to be 8.8 days for Case 1, 13.3 for Case 2 and 31.2 days for Case 3. These times become near double when the diffusion parameter of 2 m^2/s is used.

As such, it is worth to mention that enlarging the inner basin (Case 3) will have a negative impact on the flushing time against that of the base configuration (Case 1). As long as the basin is extended inland, the flushing time increases. In Case 1, the variability within the basin is small while in Case 3, the variability is high where the flushing at the far end inland (point 6) is more than double/triple the flushing time at point 1.

Looking at the exchange coefficient at the first 4 days for case 1 (D=5m^2/s), the values were found 0.09, 0.08 and 0.1 & flushing uniformity index was found 0.04, 0.05 and 0.07 respectively. These values show that the water flushing is not good in Case 1 (not matching the good flushing criteria as per the available standards, Table (2) and it will be much worse after extending the port inland, Cases 2 and 3. The port entrance width is much smaller than the extend of the inner basin (1/5 to 1/7). It is worth to mention here that the standards do not show variations with different port sizes (water area).

As a kind of mitigation measure to improve the flushing characteristics of Case 3, a trial of adding discharge (source) points near the end of the three basins; have been tested, i.e., 3.0 m^3/s near points 6 &7 and 2.0 m^3/s near point 10. However, the discharge is very huge and may not be applicable practically, it decreases the flushing time to 25.5 days & 37.5 day considering D= $5m^2/s$ and 2 m^2/s respectively.

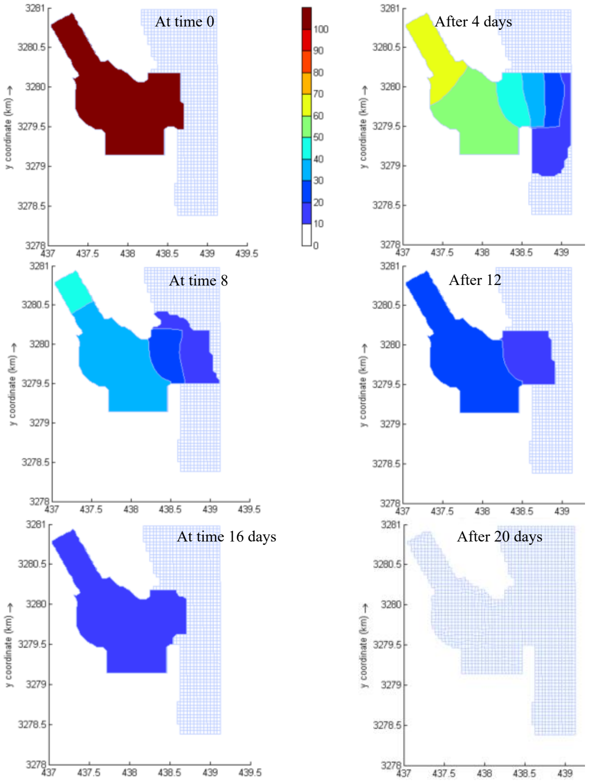

Figure 9- Concentration of Tracer at Different Times (Case 1- D= 5 m^2/s)

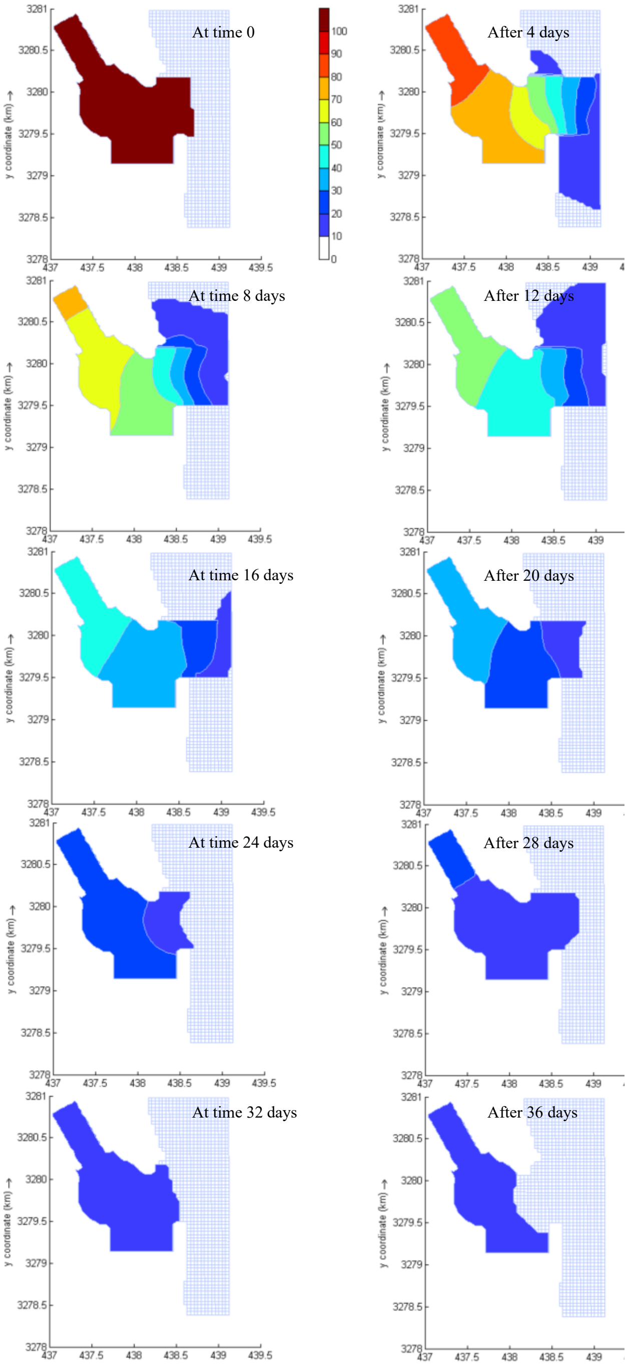

Figure 10- Concentration of Tracer at Different Times (Case 1- D= 2 m^2/s)

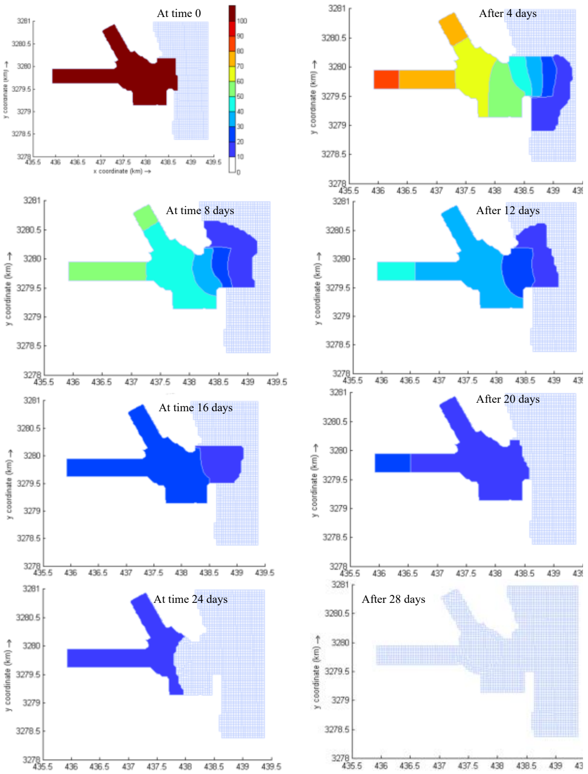

Figure 11- Concentration of Tracer at Different Times (Case 2- D= 5m^2/s)

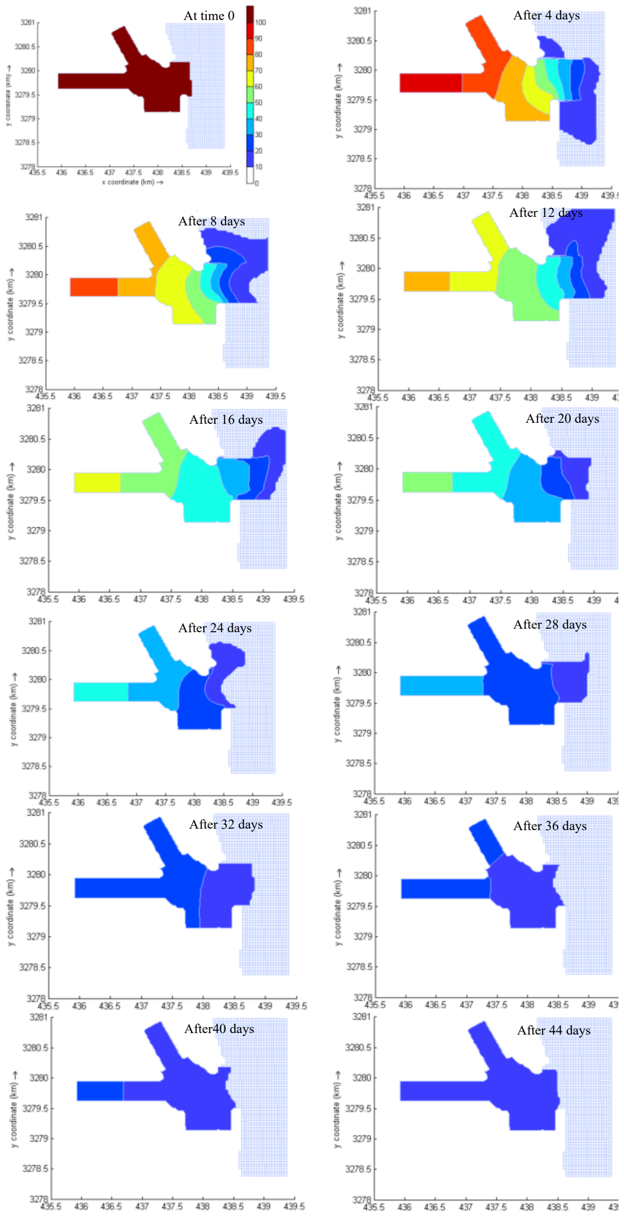

Figure 12- Concentration of Tracer at Different Times (Case 2- D= 2 m^2/s)

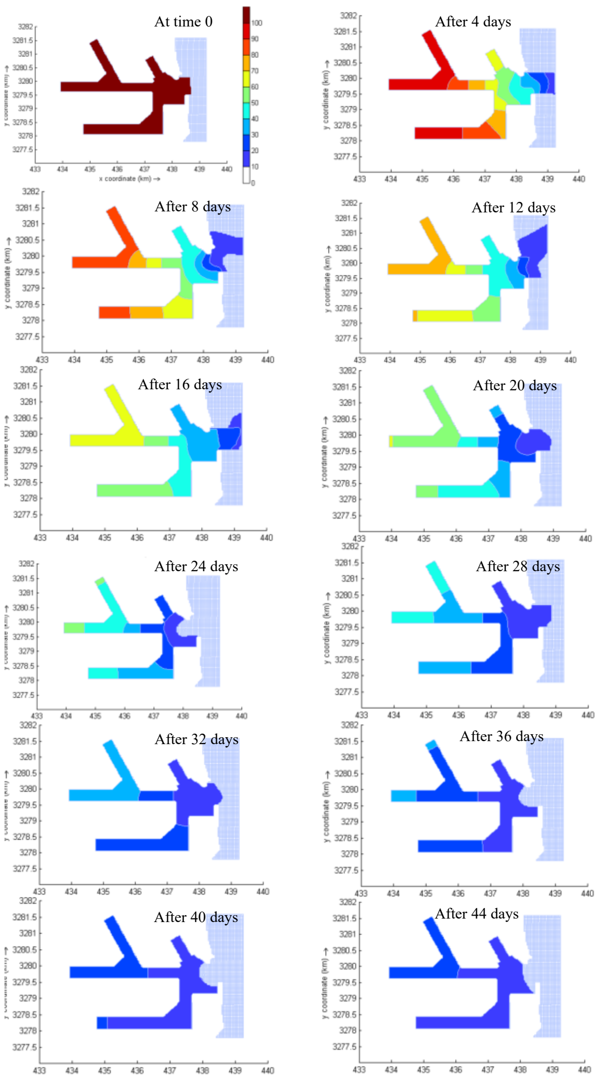

Figure 13- Concentration of tracer at Different Times (Case 3- D= 5 m^2/s)

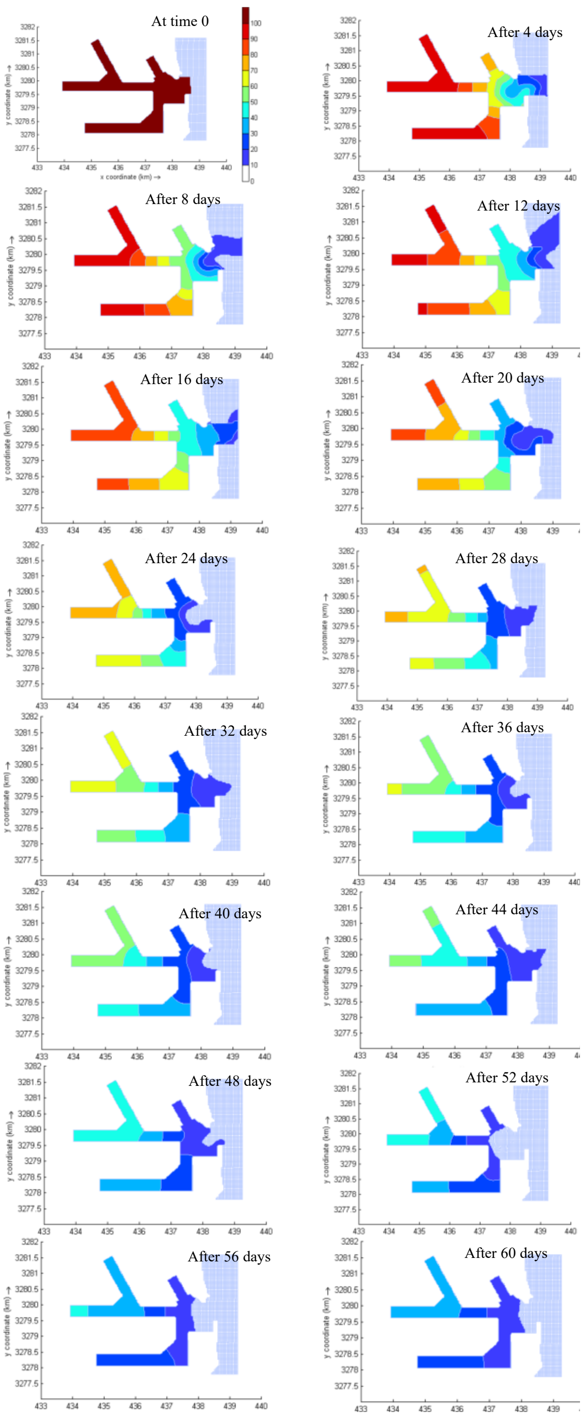

Figure 14- Concentration of Tracer at Different Times (Case 3- D= 2 m^2/s)

Conclusions

A numerical modelling study was undertaken to model flushing of Al Ain Sokhna port during different expansion phases.

Delft3D hydrodynamic (advection dispersion module) was used to model flushing of the port basins. The model results showed that water exchange between the port and the Suez Gulf is not good as per available standards. It was concluded that the longest time necessary to reduce tracer mass to 37% (T_{37}) was found to be 8.8 days for Case 1 (first configuration of early 2019), 13.3 days for Case 2 (after excavating basin no. 2- current situation in 2021) and 31.2 days for Case 3 (after developing the whole port as per the master plan) considering diffusion parameter of 5 m^2/s. These times become double when diffusion parameter of 2 m^2/s was used. Even if the current flushing time is accepted for Case 1 configuration, it will be increased to three time when the basin entirely extended as per the master plan.

It is worth to mention that the current study considered only tide as a driving force while the wind and vessel motions will enhance the situation.

Further investigation is required to evaluate the water quality through the basin in the current stage after excavating basin 2. As the result is highly impacted by the diffusion parameter, it is recommended to collect water samples, do field tracer test and measure the current velocity to enhance the model calibration.

Adding discharge (source) points near the end of the basins improved the situation slightly, however the proposed discharge rates might not be practical feasible. Other mitigation(s) will be needed. Attention should be given to the inner parts of the basin including pollutants & debris collection/removal.

6. References

[1] A. Gomez, B. Ondiviela and A. Puente, "Environmental risk assessment of water quality in harbor areas: A new methodology applied to European ports. Journal of Environmental Management," *Journal of Environmental Management,* 2015.

[2] M. Fahmy, N. Abdel-Azizl and M. Dorgham, "Water quality observations in the Dekhaila Harbour, Alexandria, Egypt," *Arab Gulf Journal of Scientific Research,* vol. 22, pp. 206-216.

[3] M. A. A. M. Eed, I. s. Ismael, M. F. Kaiser and K. O. Ghodief, "Monitoring of Oil Spills along Suez-Ain Sokhna Coastal Zone," *Journal of Environmental Science, Toxicology and Food Technology,* vol. 10, no. 2, pp. 6-16, 2016.

[4] A. Abdallah, "Monitoring Environmental Changes in El-Ain El-Sokhna Area, Gulf of Suez, Egypt," in *Nine conference for geographical and GIS*, Alexandria, 2007.

[5] B. Ivana, L. Goran, B. Damjan and C. Dalibor, "The Flow Generator Relations for Water Renewal through the Flushing Culverts in Marinas," *Water,* vol. 10, p. 936, 2018.

[6] J. Mao, K. Wong, 李行伟, Joseph and K. 蔡景华, "Tidal flushing time of marine fish culture zones in Hong Kong," *China Ocean Engineering,* vol. 25, 2011.

[7] R. V. Thomann and J. A. Mueller, Principles of surface water quality modeling and control, New York : Harper & Row, 1987.

[8] E. R. Nece and E. P. Richey, "Application of Physical Tidal Models in Harbor and Marina Design," in *Proceedings of the Symposium on Modelling Techniques, American Society of Civil Engineers, New York, USA*, August, San Francisco, California, USA, 1975.

[9] J. X. Jiang and R. A. Falconer, "On the TIDAL Exchange Characteristics of Model Rectangular Harbours," in *ICE Proceedings, Vol. 75, Issue 3, 01, pages 475 –489*, 1983.

[10] R. A. Falconer, "Modelling of Planform Influence on Circulation in Harbors," in *Proceedings of 17th International Conference in Coastal Engineering; 12–15*, Sydney, Australia. American Society of Engineers, New York, USA, 1980.

[11] R. Schwartz and J. Imberger, "Flushing Behaviour of a Coastal Marina," in *Coastal Engineering Proceedings, 1(21), 195*, 1988.

[12] S. Essa, "Equations for Designing Tidally Affected Harbours and Lagoons, and for Calculating Water Exchange in Coast-Connected Lakes," *Journal Lakes & Reservoirs: Research & Management,* vol. 9, no. 2, pp. 153-159, 2004.

[13] T. a. A. Y. Pokavanich, "Summer Flushing Characteristics of Kuwait Bay," *Journal of Coastal Research,* vol. 297, pp. 1066-1073, 2014.

[14] M. A. Alkhalidi, M. A. Tayfun and A. B. AlMershed, "Tidal recirculation of a marina: a case study in Kuwait Bay," *Kuwait Journal of Science and Engineering,* vol. 38, no. 1B, pp. 1-17, 2011.

[15] M. A. S. Ahmed, "Modeling of Thermal Effluents Into Al-Ain Al-Sokhna Coastal Region by a Cooling System of New Power Plant, Suez

Gulf, Egypt," in *ARWADEX*, Riyadh, KSA, 2012.

[16] K. Mangor, I. Broker and D. Haslov, "Waterfront Developments in Harmony with," Terra et Aqua," no. 111, pp. No. 111, pages 21-30, 2008.

[17] PIANC, "Protecting Water Quality in Marinas. Report No98, Recreational Navigation Commission Working Group 98," Brussels, 2008.

[18] USACE, "Environmental Engineering for Small Boat Basins," Engineer Manual 1110-2-1206, Washington D.C, 1993.

[19] USEPA, "Coastal Marinas Assessment Handbook. U.S. Enviromental Protection," Atlanta, GA, 1985.

[20] Deltares, "Delft3D-Flow, Simulation of multi-dimensional hydrodynamics flows and transport phenomena, including sediment- User manual, hydromorphodynamics.," Delft, Netherlands,185, 2011.

[21] G. D. Egbert and S. Y. Erofeeva, "Efficient inverse modeling of barotropic ocean tides," *Journal of Atmospheric and Oceanic Technology,* vol. 19, no. 2, pp. 183-204, 2002.

[22] H. B. Ficher, E. J. List, R. C. Y. Koh, J. Imberger and N. H. Brooks, Mixing in Inland and Coastal Waters, New York,NY,USA: Academic Press, 1979.