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Effect of the Proposed Outlets on the Hydrodynamic Behavior and Water Quality of the South-West Part of the Al Hammar Marsh

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ABSTRACT

The current study aims to find a new plan to manage the water quality of the western part of the Hammar Marsh to reduce the salts that cause problems for the marshes and preserve their environmental life by isolating the southwestern part of the Hammar Marsh by closing the outlet under the railway embankment. The outlet is discharging saline water to the east-western part of Al Hammar Marsh. After isolating the southwestern part of the marsh, a new outlet is proposed. The impact of the flow hydrodynamics on improving the water quality was simulated using the SMS model. The hydrodynamics and water quality simulation models for the marsh are: a hydrodynamic model and average depth (SMS RMA2) and a two-dimensional water quality model (SMS RM4). The Civil3D was used to determine the area elevation curve for the marsh, while the shape file for the study area was prepared using the Arc-GIS model. The first model is used to simulate the flow conditions in the marsh (water depth and velocity vectors), while the second model is used to simulate the salinity of the water (Total Dissolved Solids (TDS)). For calibration and verification of the models, water samples were taken from ten selected locations within the marsh. The measurements were conducted on 1st January and on 2nd February 2022. The simulation results were validated with the field measurement, and the discrepancy between the simulated and measured water depth was found to be 11%. Many scenarios are based on the proposed recommended outlet that considerably reduces TDS concentration in the Al Hammar marsh. Three scenarios were run on the proposed outlet to maintain a submerged area of 88 km^2, and to compare the three scenarios, ten points were selected in different locations, where the average TDS ratio for the first scenario was 7528 mg/l, the second scenario was 6982 mg/l and for the third scenario was 8069 mg/l. Results showed that the proposed outlet would improve the hydrodynamics of the flow and reduce the TDS concentration by 10% in addition to controlling the contamination of east western part of the marsh.

Keywords: SMS, RMA2, RMA4, TDS, Al Hammar marsh, MOD, Al Khamissiya Chanel

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تأثير المنفذ المقترح على السلوك الهيدروديناميكي وجودة المياه للجزء الجنوبي الغربي من هور الحمار

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الخلاصة

تهدف الدراسة الحالية الى إيجاد خطة جديدة لإدارة نوعية المياه في الجزء الغربي لهور الحمار وذلك من خلال عزل الجزء الجنوبي الغربي من هور الحمار عن طريق اغلاق المنافذ أسفل سكة القطار والتي تمر المياه المالحة من خلالها الى الجزء الشرقي الغربي من هور الحمار. بعد عزل الجزء الجنوبي الغربي من هور الحمار تم اقتراح منفذ جديد لتصريف المياه المالحة باتجاه قناة المصب العام (MOD). تمت محاكاة تأثير ديناميكيا الجريان على تحسين جودة المياه باستخدام برنامج (SMS) وهو برنامج الديناميكيا المائية وجودة المياه للأهوار ثنائية الابعاد والذي يتضمن نموذج (SMS RMA-2) و(SMS RMA-4) حيث يستخدم الأول لمحاكاة ظروف التدفق في الاهوار (متجهات عمق المياه والسرعة) بينما الثاني يستخدم لمحاكاة ملوحة المياه (اجمالي المواد الصلبة الذائبة TDS). تم استخدام برنامج Civil3D لتحيد منحني المساحة والمنسوب بينما تم تحديد منطقة الدراسة باستخدام برنامج Arc-GIS. لمعايرة النماذج والتحقق منها تم اخذ عينات من المياه مع قياس أعماق المياه لنفس العينات من عشرة مواقع مختارة داخل الهور. أجريت القياسات واخذ العينات بفترتين مختلفتين الأولى في 2022/1/9 والثانية في 2022/2/17.تم التحقق من صحة نتائج المحاكاة من خلا المقارنة بين عمق الماع المقاس فعليا والمحسوب من الموديل ووجد الفرق بينهما بحدود 11%. تم تشغيل ثلاثة سيناريوهات على المنفذ المقترح للحفاظ على منطقة مغمورة تبلغ 88 كم^2 وللمقارنة بين السيناريوهات الثلاثة، تم اختيار عشر نقاط في مواقع مختلفة، حيث كان متوسط نسبة المواد الصلبة الذائبة للسيناريو الأول 7528 مجم / لتر. السيناريو الثاني كان معدل المواد الصلبة الذائبة 6982 ملغم / لتر. بالنسبة للسيناريو الثالث، كان معدل المواد الصلبة الذائبة 8069 مجم / لتر. أظهرت النتائج ان المنفذ المقترح سيحسن الديناميكيا المائية للتدفق ويقلل تركيز المواد الصلبة الذائبة بنسبة 10% بالإضافة الى السيطرة على التلوث في الجزء الشرقي الغربي من المستنقع.

الكلمات الرئيسية: SMS، RMA2 ، RMA4 ، TDS، هور الحمار، MOD، قناة الخماسية .

1. INTRODUCTION

Wetlands are permanently or seasonally flooded low-lying areas formed from hydric soils and include types of plants. Wetlands are commonly found in many forms, such as marshes, bogs, swamps, etc. A wetland may be dry for prolonged durations, but the water table is shallow during the year, which covers the area of the wetland to sustain aquatic plants. The populations of plants and animals that grow and respond to these conditions differ from those contained in other water bodies such as lakes, rivers, or dryland ecosystems. Depending on the form, wetlands can be mainly made up of plants, grasses, shrubs, or moss (**Haslam 2003**) **and** (**US. Department 2021**).

The marshlands of Iraq are located in the country's south, at the confluence of the Tigris and Euphrates rivers. They cover approximately 15000-2000 km^2 of land **(Yasir et al., 2018).** The marshlands of Mesopotamia are the largest wetland ecosystem in the Middle East and western Eurasia (**Marghany et al., 2006**). The three major marshes areas that comprise Iraq's wetlands are Al Hammar Marshes, Central Marshes, and Al Hawizeh Marshes (**Kugaprasatham, 2014**). Each major marsh zone is comprised of a network of hydraulically linked shallow lakes and ponds (**Yasir et al., 2018).** The Tigris and Euphrates Rivers, as well as their branches, are the principal sources of water that drain into the marshes, but inflows into the marshes have decreased recently because large hydraulic structures and dams were built in both rivers' upstream zones in Turkey and Syria **(Al-Ansari, 2013)** and **(Al-Ansari and Knutsson, 2011).** Also, the marshes were destroyed by a combination of the effects of massive drainage in southern Iraq. by the previous regime from 1980 to 1990, as well as upstream damming **(Yasir et al., 2018).** After 1991, five major drainage projects were implemented to prevent or limit water flow from the Tigris and Euphrates Rivers into the marshland area for political reasons **(Ali, 2013).** As a result of these practices, the marshes area was reduced to less than 15%. This ecological disaster reached about 10% of the original area by 2001 **(Kadhim, 2005).** The marshland area ranges from 2800 km^2 to 4500 km^2 in the wet seasons **(Azhar Al-Saboonchi et al., 2011).** In the marsh, the maximum and minimum water depth range between 1.8 to 3.0m **(Foundation, 2003)**. The marshland witnessed a dry period from 2005 to 2009 which was disrupting and affecting the flora and fauna. Additionally, the UN Environment Program (UNEP) and the United Nations Educational, Scientific, and Cultural Organization (UNESCO) have partnered to ensure the long-term improvement of the Iraqi Marshlands by adding them to the World Heritage List, as these distinctive wetlands represent a region of outstanding universal historical, cultural, environmental, hydrological, and socio-economic value **(Al-Gburi et al., 2017)** and (**UNEP-DTIE-IETC, 2009).** After 2003, a great deal of effort and activity was put into reestablishing the marshes and revitalizing the wetlands environment. Modeling software is a powerful simulation tool that was used in rivers and coastal simulation for multiple purposes under different conditions **(Ali and Al Thamiry, 2021), (Al-Zaidy and Al-Thamiry, 2020) and (Azzubaidi and Abbas, 2020)**. This study focused on appropriate regulations for the used water of (MOD) and Um Elwada to feed the western part of Al Hammar marsh between the Al-Khamissiya channel and railway embankment and suggested a suitable location for an outlet that improves the water quality of the march. The outlet will discharge the water from the marsh toward (MOD). In the studied scenarios, the existing outlet under the railway embankment is suggested to be closed to improve the water circulation and to isolate the inlets from the river Euphrates from the inlet feeding the marsh with high salinity water.

2. DESCRIPTION OF THE MARSH

The southwestern part of Al Hammar Marsh (S.W.A.H.M) is located in Dhi Qar Governorate between (E639533, N3417056, E635349, N3413361, E648165, N3401385, E654347, N3406737) with an area of approximately 88 km^2. It is bordered on the north by the Euphrates River, on the south by the main outfall drain(MOD), on the east by the Al Hammar marsh, and on the west by the city of Suq Al-Shuyukh. **Fig. 1** represents the general layout of the southwestern part of Al Hammar marsh, including inlets and outlets. The inlets are the Al Khamissiya canal, which supplies the march with saline water from MOD, while Um Elwada supplies water to the marsh from the Euphrates river through six channels, as shown in **Fig. 2.**

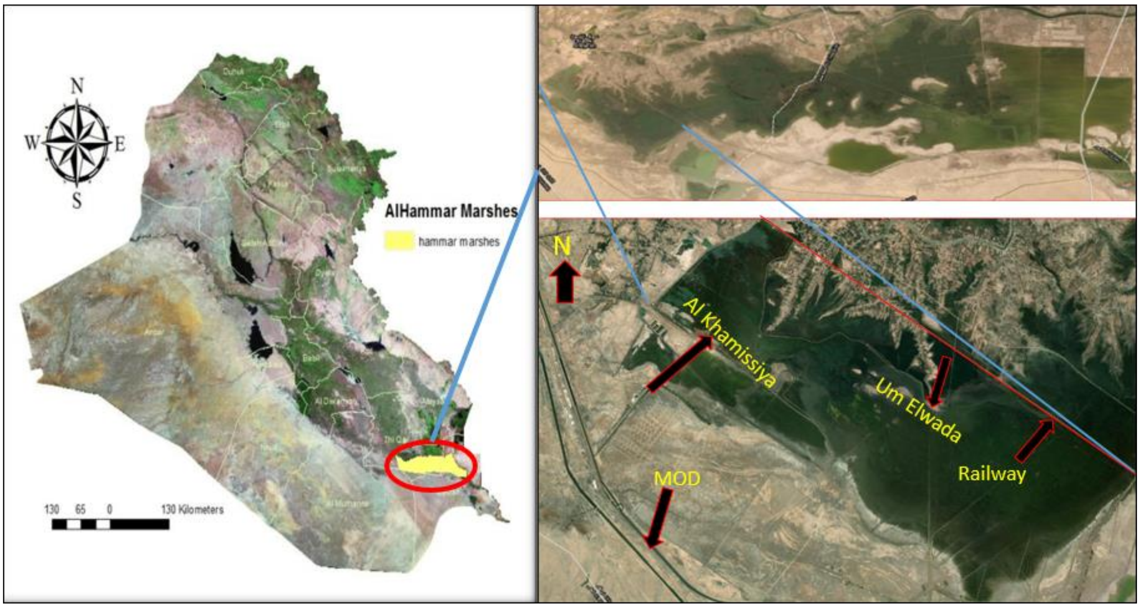

Figure 1. The layout of the main feeders of South Western Al- Hammar Marsh

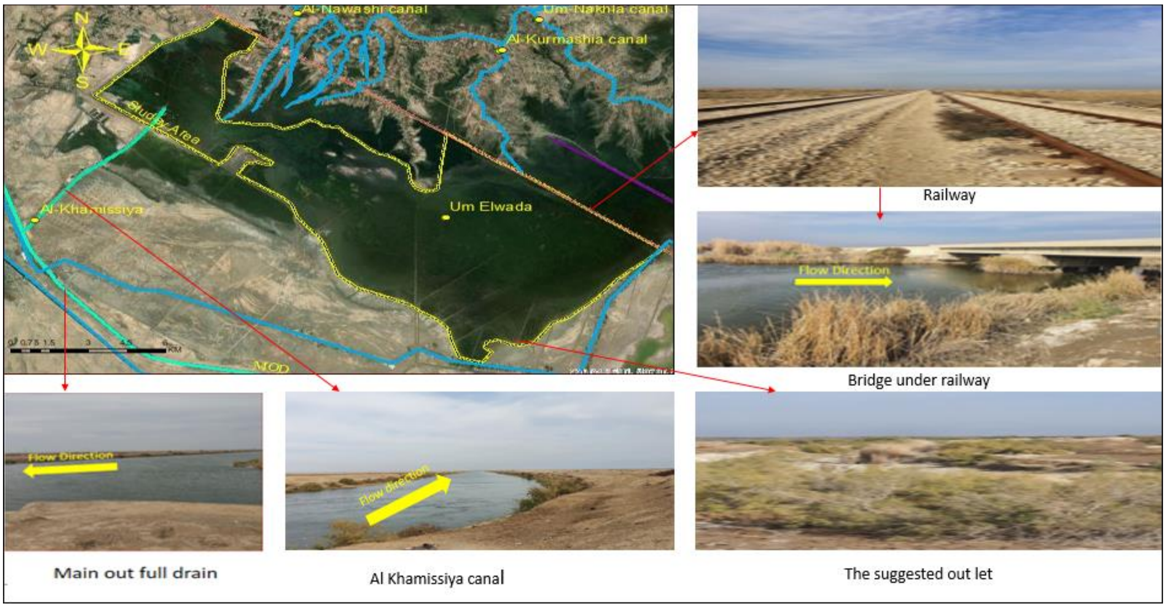

Figure 2. Site map of inlet and outlet for the study area

3. FIELD WORKS AND COLLECTED DATA

The fieldwork included collecting and supplementing the lack of data necessary to complete the requirements of the study, in addition to the fact that field visits to the study area are important to understand its characteristics and nature. Through its verification, the validation was done using measured data such as evaluating the water depth in different locations within the southwestern part of the Al Hammar marsh. **Fig. 3** shows the locations of field measurements, while **Fig. 4** shows the sampling and water depth measurements. The Center for the Restoration of Iraqi Marshlands (CRIMW) provided topographical information, marsh evapotranspiration (Eto), as in **Fig. 5**, marsh precipitation **Fig. 6** feeder discharge, and marsh feeder total dissolved solids (TDS) concentration (CIRM2010).

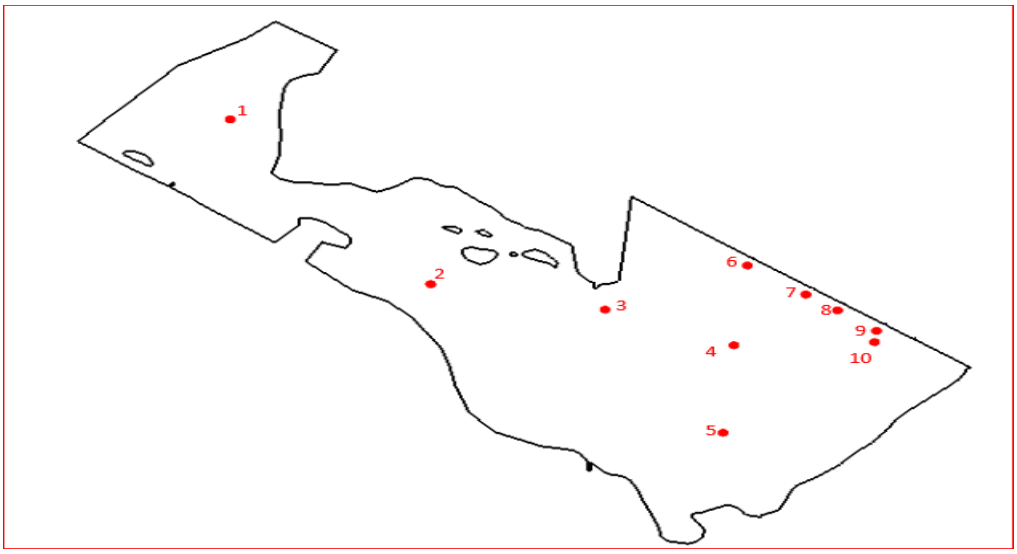

Figure 3. Map of selected points in southern west at Al-Hammar marsh

Figure 4. Snapshot while measuring the marsh's water depth and collection of water samples

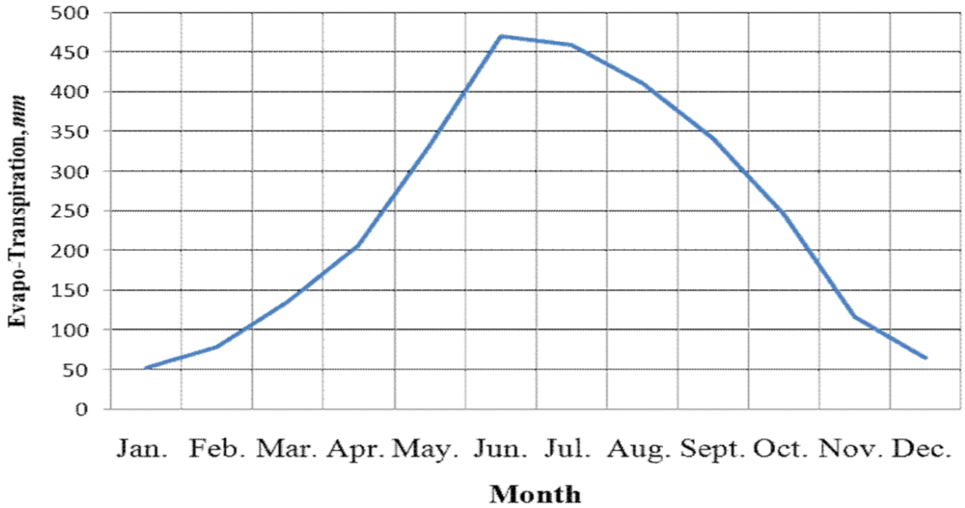

Figure 5. Evapotranspiration of the Marsh **(CRIM 2010)**

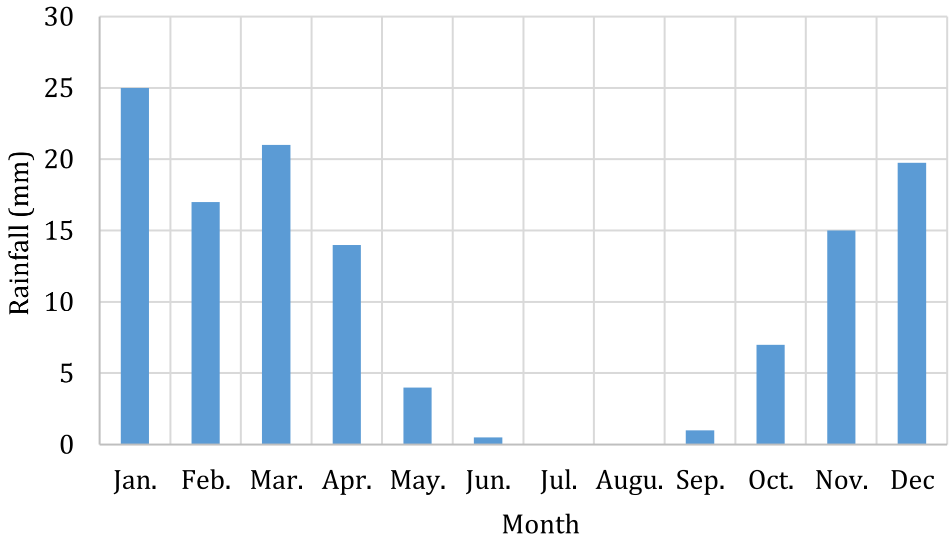

Figure 6. Precipitation of the Marsh (CRIM 2010)

4. MEASURING THE WATER DEPTH AND COLLECTING WATER SAMPLES WITHIN THE MARSH.

The depths of the water were measured in ten selected points distributed within the study area of the studied marsh. The surveying staff and a GPS apparatus were used to determine the locations. A boat was used to collect water samples and measure water depths, as shown in **Fig. 3**. The measurements were conducted on (9/1/2022) and on (17/2/2022). The water level was (1.8) meters above mean sea level (m.a.m.s.l), as well as the nutrient of Khamissiya and UmElwadaa were obtained from (CRIMW), as shown in **Tables** 1 to **5.**

Table 1. TDS Concentration and Discharge measured within inlets on (9/1/2022)

Feeder	Measured discharge (m^3/sec)	The concentration of TDS (mg/l)
Al-Khamissiya	15	10234
UmElwadaa	6	3660

Table 2. TDS Concentration and Discharge were measured within inlets on (17/2/2022)

Feeder	Measured discharge (m^3/sec)	The concentration of TDS (mg/l)
Al-Khamissiya	17	9788
UmElwadaa	4	3120

Table 3. Measurements of water depths and TDS for the Marsh, at a water surface elevation of 1.8 (m.a.m.s.l) 9/1/2022.

Point	Location		Measured water depth (m)	The concentration of (TDS) mg/l
	E	N		
1	638610	3414110	0.54	8975
2	642870	3409210	1.65	9200
3	646570	3408450	1.15	5100
4	649310	3407390	0.66	8280
5	649079	3404789	1.18	8000
6	649597	3409763	1.4	7000
7	650836	3408899	1.87	8680
8	651510	3408429	1.95	8159
9	652337	3407820	1.85	8230
10	652296	3407483	1.9	8200

Table 4. Measurements of water depths and TDS for the marsh at a water surface elevation of 1.8 (m.a.m.s.l) 17/2/2022

Point	Location		Measured water depth (m)	The concentration of (TDS) mg/l
	E	N		
1	638610	3414110	0.54	9500
2	642870	3409210	1.59	9900
3	646570	3408450	1.09	5800
4	649310	3407390	0.6	8400
5	649079	3404789	1.12	8275
6	649597	3409763	1.45	6900
7	650836	3408899	1.82	8210
8	651510	3408429	1.9	8200
9	652337	3407820	1.84	7900
10	652296	3407483	1.96	7880

Table 5. Discharge and total dissolved solids (TDS) in the marsh on 2020

No	Feeder	Discharge (m^3/sec)			The concentration of (TDS) mg/l		
		Max.	Min.	Average	Max.	Min.	Average
1	UmElwadaa	5.5	3.3	4.58	4165	2181	3206
2	Al-Khamissiya	35	11.1	23	8050	5062	6008

The difference in the concentrations of TDS measured for points and nutrients is caused by the fact that the water of the Khamissiya Canal has high salinity as it is supplied with water from the Main Outfall Drain (MOD), while Umm Elwada is supplied with water from the Euphrates River. Therefore, the points near Umm Elwada' have less salt than those near the Khamissiya Canal.

5. MATHEMATICAL MODELING

5.1. Surface-water Modeling System (SMS): Models of Hydrodynamics and Water Quality

The creation of numerical simulations that can accurately simulate changes in water quality and hydrodynamic behavior within (S.W.A.H.M) is described in this section. The Waterway Experiment Station, WES, RMA2, and a two-dimensional finite element numerical model were used to calculate the elevation of the water surface, water depth, velocity (magnitude and direction), and flow rate. The TDS concentrations inside the marsh were simulated using the WES, RMA4 finite element numerical, two-dimensional water quality model. The two models mentioned above were developed for the Walla District Corps of Engineers by Water Resources Engineers Norton, King, and/or lop and delivered in 1973 **(2009, Donnell).**

5.2. Governing Equations

The governing equations for the flow hydrodynamic in two directions, RMA2 solves momentum conservation from Equations (1) and (2), as well as the continuity equation, Equation (3). **(Donnell, 2009 a).**

$$h\frac{\partial u}{\partial t}+hu\frac{\partial u}{\partial x}+hv\frac{\partial u}{\partial y}-\frac{h}{\rho}\left[\mathrm{Exx}\frac{\partial^2 u}{\partial x^2}+Exy\frac{\partial^2 u}{\partial y^2}\right]+gh\left(\frac{\partial a}{\partial x}+\frac{\partial h}{\partial x}\right)+\frac{gun^2}{\left(1.486h^{1/6}\right)^2}(u^2+v^2)^{0.5}-\zeta V_a{}^2\cos\Psi-2hv\omega v\sin\phi=0 \quad (1)$$

and

$$h\frac{\partial v}{\partial t}+hu\frac{\partial v}{\partial x}+hv\frac{\partial v}{\partial y}-\frac{h}{\rho}\left[Eyx\frac{\partial^2 v}{\partial x^2}+Eyy\frac{\partial^2 v}{\partial y^2}\right]+gh\left(\frac{\partial a}{\partial y}+\frac{\partial h}{\partial y}\right)+\frac{gvn^2}{\left(1.486h^{1/6}\right)^2}+(u^2+v^2)^{0.5}-\xi V_a^2\sin\Psi-2h\omega v\sin\phi=0 \quad (2)$$

$$\frac{\partial h}{\partial t}+h\left(\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}\right)+u\frac{\partial h}{\partial x}+v\frac{\partial h}{\partial y}=0 \quad (3)$$

where

h: Water depth, m
v, u: Cartesian coordinates velocities, m/sec
x, y: Coordinates in Cartesian, m
t: Time, sec

ρ: Fluid density, kg/m^3
Exx: On the x-axis surface, the Eddy viscosity coefficient, in Pa.s
Eyy: On the y-axis surface, the Eddy viscosity coefficient, in Pa.s Exy, and Eyx are the shear directions on each surface, Pa.s
ζ: Wind shear confinement based on empirical data, dimensionless
g: Gravitational acceleration, m/sec^2
n: The roughness n-value of Manning, sec/ $m^{1/3}$
a: Elevation of the Land, m
Va: the speed of the wind, km/h
Ψ: the path of the wind, degrees
Ω: Earth's angular rotation, rate, time /time, and
Φ: Local latitude, degrees.
While RMA4 employs formulae to solve the transport and mix the phase on a depth-averaged basis, equations are used in equation 4.

$$h\left[\frac{\partial c}{\partial t}+u\frac{\partial c}{\partial x}+v\frac{\partial c}{\partial y}-\frac{\partial}{\partial x}D_x\frac{\partial c}{\partial x}-\frac{\partial}{\partial y}D_y\frac{\partial c}{\partial y}-\sigma+k_c+\frac{R(c)}{h}\right]=0 \quad (4)$$

where:

h: Water, depth, m
c: Pollutant concentration, for a particular constituent, mg/l
Dx and Dy: Coefficients, dispersion, and turbulent mixing, m^2/sec
Kc: Pollutant decay in the first order, sec^{-1}
R(c): Level of rainfall/evaporation, dimensionless, and
σ: constituent source/sink, mg /m^3. sec^{-1}

The depth-averaged transport equation is solved using Galerkin weighted residuals and the finite element method.

5.3 Model Parameters

The hydraulic properties of water bodies, as represented by the equations of motion, transport, and mixing, are the parameters of the RMA2 and RMA4 models. It is impossible to estimate parameters directly; however, after developing the field, they can be identified. The boundary conditions were defined based on the meshing based on previous research; then, it was double-checked after the calibration. Manning's coefficient (n), coefficients of turbulent exchange, and eddy viscosity are all variables to consider. The effects of wind, the decay of pollutants, and the source of the constituent were not taken into account.

5.4 Boundary Conditions

When introducing boundary criteria at any node, there are several restrictions to choose from:

i. the condition of parallel flow at the boundary (slip flow).
ii. flow boundary status.
iii. Current water condition - level limit (head).
iv. Stagnation Point Boundary Status
v. A limiting case of absorption and reflection.

vi. The current state of the wind field boundary.
vii. Wave field limit.

Two sets of boundary conditions are required to operate the RAM2 model and these are water level and discharge. The water levels are set for the outer boundary nodes of the outputs, while the fine flow discharge boundary is set for the inlet boundary nodes.

6. THE SCENARIOS

The southern waste part of Al Hammar marsh (S.W.A.H.M.) hydrological routing was based on the mass conservation principle, with an equilibrium between inflow and outflow rates. The necessary input into the marshes must ensure a steady marshes water surface area. This inflow must be equal to or greater than the water consumption rate and the evapotranspiration rate plus the appropriate outflow rate. When there is a surplus inflow, it might help to dilute the salt concentration in the water stored in the S.W.A.H.M. The high salt content in the water of the Al Khamissiya canal contributes to the deteriorating quality of water in the Al Hammar marsh. To prevent the saline water from Al Khamissiya canal from reaching the Al Hammar marsh through the outlet under the railway embankment, the outlet is proposed to be closed, and a new outlet should be opened with the control conditions such as a fixed surface area of the marsh 88 km^2, and varying discharge of inlet at UmElwadaa (fixed, increased by 35% and decreased by 35%) through scenarios A, B, and C. The above conditions were investigated for the proposed location of the outlet, which is recommended based on the percentage reduction in the TDS concentrations at selected points in the marsh. The detailed results of each scenario were discussed separately to show the impact of the inlet and outlet on both the hydrodynamic and water quality of S.W.A.H.M. **Table (6)** shows the summary of the scenario

Table 6. The RMA2 model's upstream and downstream boundaries

Case	Area Km^2	Upstream boundary discharge m^3/sec		Downstream boundary water level (m.a.m.s.l)
		Al-Khamissiya	UmElwadaa	
1	88	17.82	4.58	2
2	88	15.97	6.17	2
3	88	19.65	2.97	2

7. AREA ELEVATION CURVE

The area and level curve were created using the Civil 3D program, after feeding it with topographical surveys. The area was divided into specific levels, and for each level its area, and after these areas were cumulatively collected, the curve was drawn, which is relied upon to determine the water levels for each area to be maintained submerged. in the water while applying the required scenarios. **Fig. 9** shows the curve.

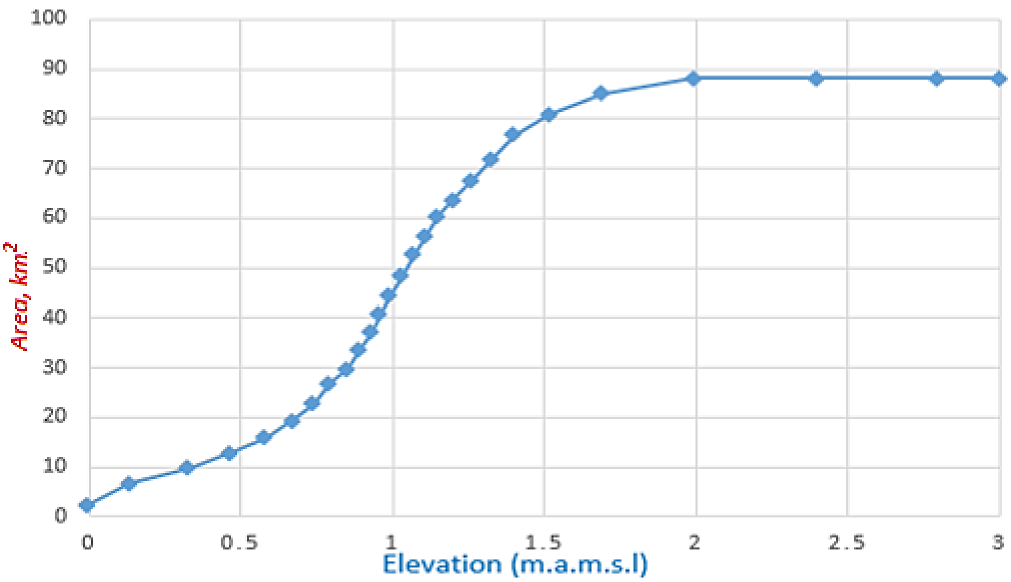

Figure 9. The curve of the area elevation for S.W. A.H.M

8. SELECTING THE LOCATION OF THE OUTLET

To reduce the salt concentration in the southern waste part of Al Hammar marsh, a new outlet should be considered in addition to closing the existing outlet under the railway embankment. This will help control the saline water source from MOD to the Al Hammar marsh. The proposed change in the hydraulic system of Al Hammar marsh is shown in **Fig. 10**. The simulation of the hydrodynamics in the (S.W.A.H.M) is mainly aimed at investigating how the isolation of saline water sources will impact the water quality at Al Hammar marsh.

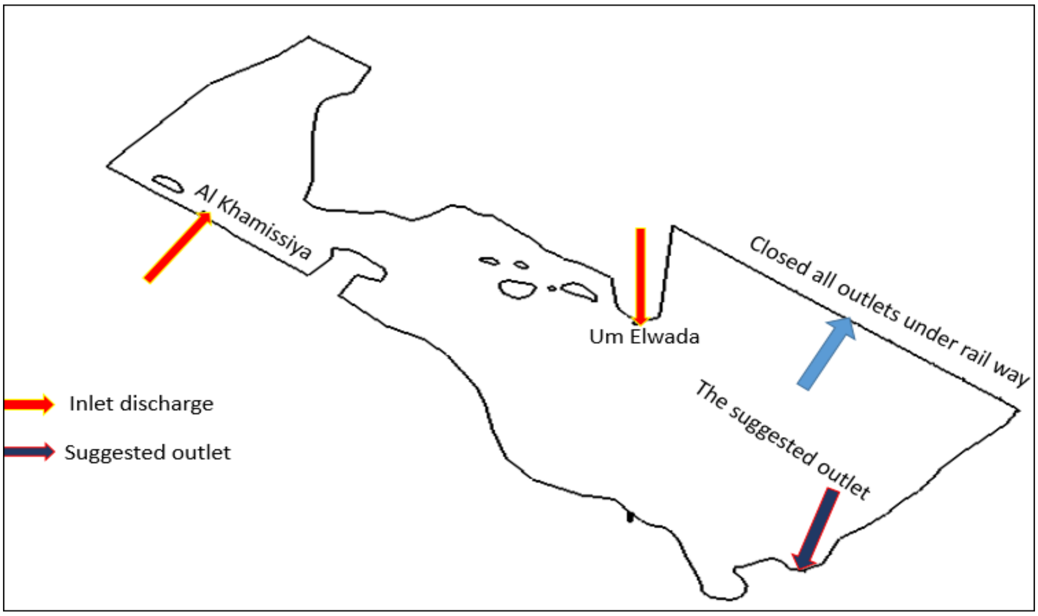

Figure 10. The proposed change and suggested outlets in the hydraulic system of (S.W.A.H.M)

9. MODEL CALIBRATION

Calibration is the process of adjusting the values of parameters that have a high degree of uncertainty. The model input parameters were adjusted as part of the calibration process under the same conditions to achieve a high similarity between the simulated and observed/measured data **(Bagtzoglou and Novikov, 2006).** The calibration procedure included eight iterations, each with an adjusted Peclet Number value. The Peclet Number values with the lowest error between measured values will be used in subsequent model runs and predicted values. In RMA2 model runs, used measured water depths in the calibration process. The Peclet Number was used to calculate the least error between model results and measured water depths. The Peclet Number of 25 was used to determine the model run results with the smallest possible amount of error between measured water depths. **Fig. 12** compares the RMA2 model results to the measured water depths. Some incorrect marsh topography causes a slight discrepancy in water depth between measurements and calculations.

The Um Elwada feeder had an immediate impact. The measured TDS concentration data set was employed to calibrate the Peclet Number value in the runs of the RMA4 model. A Peclet Number of 21 was used to obtain the smallest error between measured data and model run results. This value was reached after seven iterations. **Fig.13** compares the TDS concentration for field measurements with the results of the RMA4 model when using the calibrated Peclet number values in the RAM4 model run. The maximum error rate was 12 percent. **Fig .11** depicts the projected relationship between Manning Roughness Coefficients utilized; Manning's n = 0.035 for non-vegetated areas; and Manning's n equals 0.055 for vegetated areas when the water depth is less than 2m**.**

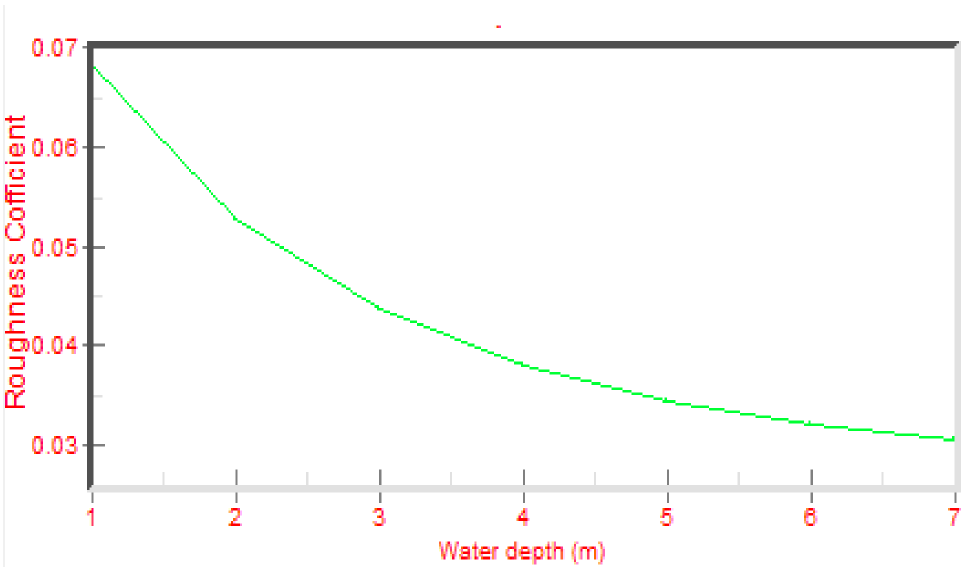

Figure 11. Projected relationships between Manning roughness coefficient for vegetated and un-vegetated area Water depth for S.W.P.A. H.M

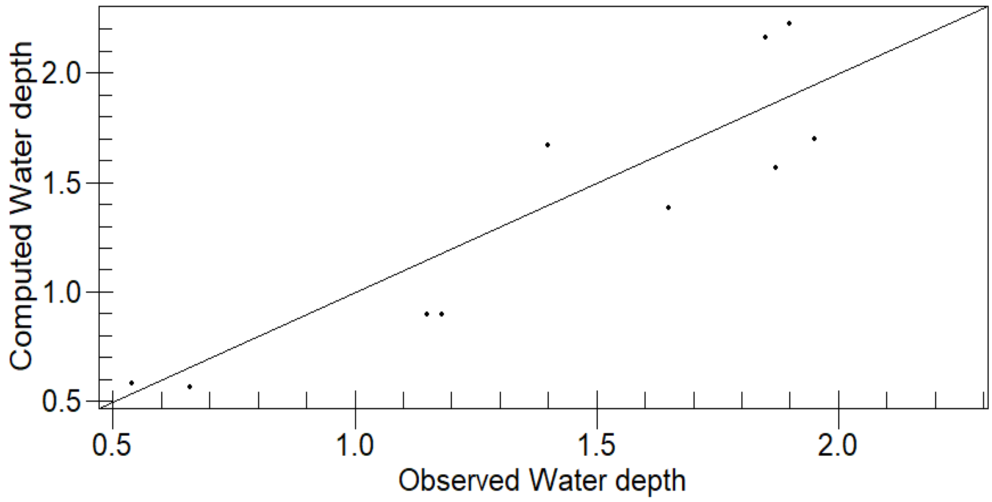

Figure 12. Calibration of mathematical models (RMA2)

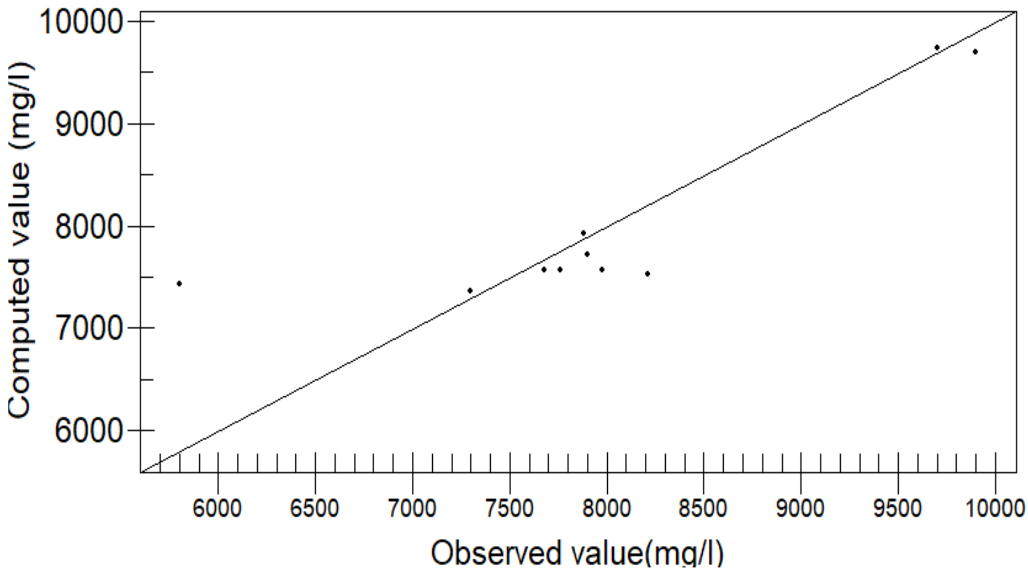

Figure 13. Calibration of mathematical models (RMA4)

10. SCENARIO A

Table 7 shows the required inflow to maintain S.W.A.H.M area of 88 km^2 discharge of Al-Khamissiya channel is 17.82 m^3/s with a minimum outflow of 7 m^3/s. **Fig. 14** shows the results obtained from the mathematical model under the conditions of scenario A for the first outlet which shows the variation of the water depth (**Fig. 14 A**), the velocity vectors (**Fig. 14 B**), and the TDS distribution of the marsh (**Fig. C**). The location of inlets, inlet discharge, TDS concentration in the inlet water, location of the outlet, topography upstream, and evapotranspiration are factors affecting the water depth, directions of velocity vectors, and TDS concentration. The concentrations of dissolved solids at the outlet were found to be 8043 mg/l. High water levels at the proposed outlet are caused by relatively high ground levels and shoaly water depths with high roughness upstream. Table 8 shows the Values of (TDS mg/l) in 10 selected points.

Table 7. The required inflow to maintain the S.W. A.H.M area of 88 km^2 discharge of Al-Khamissiya channel is 17.82 m^3/s with a minimum outflow of 7 m^3/s during 2020

Month	Day	Area (km^2)	Eto (mm)	Eto (m^3/sec)	R (mm)	R (m^3/sec)	Supplied discharge of UmElwadaa (m^3/sec)	Out flew (m^3/sec)
Jan.	31	88	50	1.64	25	0.821	4.6	21.6
Feb.	29	88	75	2.63	17	0.59	4.6	20.38
Mar.	31	88	130	4.27	20	0.65	3.8	18
April	30	88	200	6.79	14	0.47	3.3	14.8
May	31	88	350	11.49	4	0.131	4.3	10.761
June	30	88	475	16.12	0	0	5.3	7
July	31	88	450	14,78	0	0	5.5	8.54
Aug.	31	88	410	13.47	0	0	4.8	9.15
Sept.	30	88	350	11.88	1	0.03	5	10.97
Oct.	31	88	250	8.21	6	0.197	4.5	14.3
Nov.	30	88	120	4.07	15	0.5	4.3	18.55
Dec.	31	88	75	2.46	19	0.62	5	20.98
Averages			244.6	8.018	10.08	0.33408	4.58	14.5859

Table 8 Values of (TDS mg/l) in 10 selected points for Scenario (A)

	Name	X	Y	Computed value
1	Point 1	638610	3414110	9632.351
2	Point 2	642870	3409210	9719.368
3	Point 3	646570	3408450	7352.934
4	Point 4	649310	3407390	7658.934
5	Point 5	649079	3404789	8421.573
6	Point 6	649597	3409763	5344.033
7	Point 7	650836	3408899	6003.606
8	Point 8	651510	3408429	6578.754
9	Point 9	652337	3407820	7249.621
10	Point 10	652296	3407483	7327.088

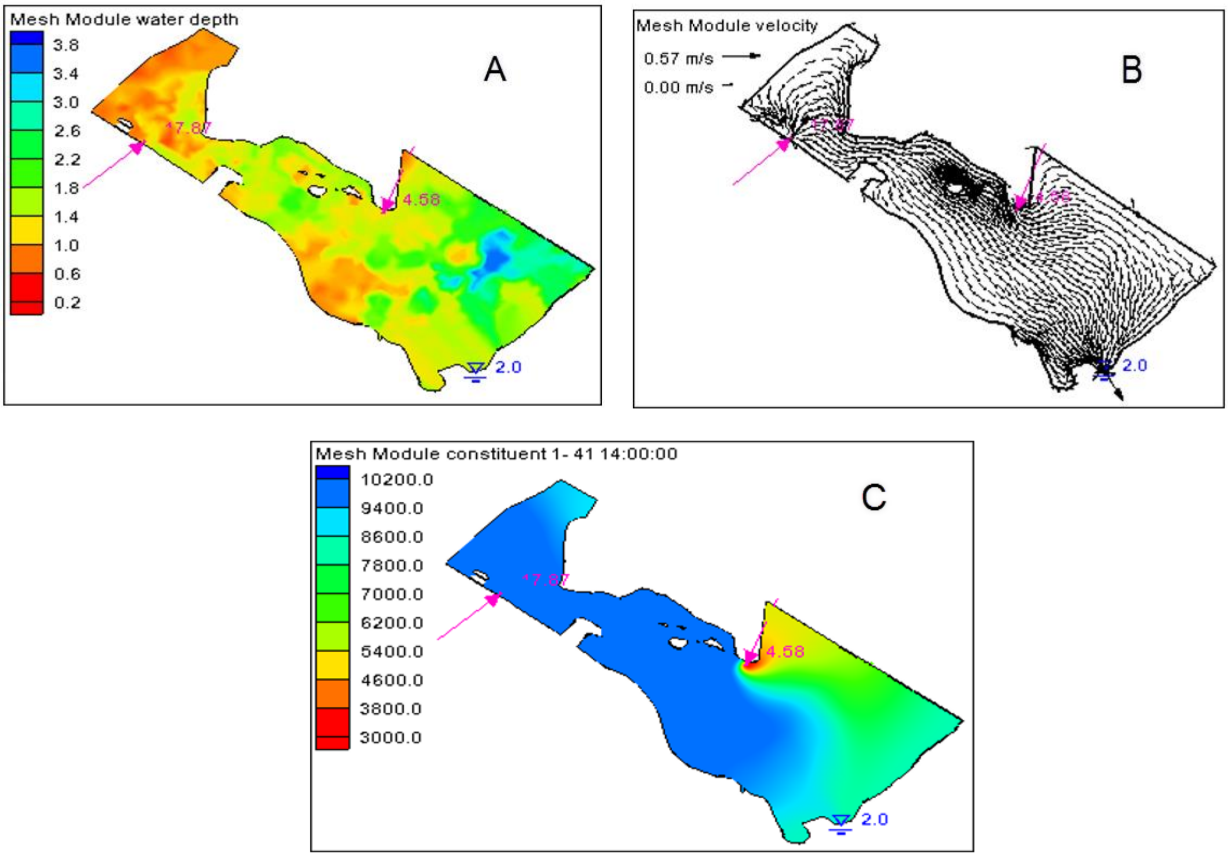

Figure 14 Results of the operating model for Scenario (A) with suggested outlet.

11. SCENARIO B

The results of the mathematical model with stated conditions shown in **Table 9** and the defined location of the outlet are shown in **Fig. 15,** which includes the variation in water depth (**Fig. 15 A**), velocity vectors **(Fig. 15 B**), and TDS distribution at the marsh (**Fig. 15 C**). **Table 10** shows the TDS at selected points in the marsh for scenario B. The inlet discharge from UmElwadaa was increased by 35% in this scenario compared to the measured discharge. The average TDS concentrations at the marsh were found to be 7% smaller than that in scenario A. The TDS concentration at the outlet was found to be 7788 mg/l.

Table 9. The required inflow to maintain the S.W.P.A.H.M area of 88 $\mathbf{km^2}$, discharge of Al-Khamissiya channel is 15.97 m^3/s with a minimum outflow of 7 m^3/s during 2020.

Month	Day	Area (km^2)	Eto (mm)	Eto (m^3/sec)	R (mm)	R (m^3/sec)	Supplied discharge of UmElwadaa (m^3/sec)	Out flew (m^3/sec)
Jan.	31	88	50	1.64	25	21.27	6.21	21.27
Feb.	29	88	75	2.63	17	20.14	6.21	20.14
Mar.	31	88	130	4.27	20	17.48	5.13	17.48
April	30	88	200	6.79	14	14.1	4.45	14.1
May	31	88	350	11.49	4	10.41	5.8	10.41
June	30	88	475	16.12	0	7	7.15	7
July	31	88	450	14,78	0	8.61	7.42	8.61
Aug.	31	88	410	13.47	0	8.98	6.48	8.98
Sept.	30	88	350	11.88	1	10.87	6.75	10.87
Oct.	31	88	250	8.21	6	13.95	6	13.95
Nov.	30	88	120	4.07	15	18.2	5.8	18.2
Dec.	31	88	75	2.46	19	20.88	6.75	20.88
Averages			244.6	8.018	10.083	0.3340	6.17	14.3241

Table 10. Values of (TDS mg/l) in 10 selected points for Scenario (B)

	Name	X	Y	Computed value
1	Point 1	638610	3414110	9587.625
2	Point 2	642870	3409210	9699.285
3	Point 3	646570	3408450	5702.305
4	Point 4	649310	3407390	6826.240
5	Point 5	649079	3404789	7981.067
6	Point 6	649597	3409763	4574.304
7	Point 7	650836	3408899	5317.382
8	Point 8	651510	3408429	6061.738
9	Point 9	652337	3407820	6981.822
10	Point 10	652296	3407483	7095.396

12. SCENARIO C

The results of the mathematical model with stated conditions shown in **Table 11** and the defined location of the outlet are shown in **Fig. 16,** which includes the variation in water depth (**Fig. 16 A**), velocity vectors (**Fig. 16 B**), and TDS distribution at the marsh (**Fig. 16 C**). **Table 12** shows the TDS at selected points in the marsh for scenario C. The inlet discharge from UmElwadaa was decreased by 35% in this scenario compared to the measured discharge. The average of TDS concentrations at the marsh was found to be 7% and 13% greater than that in scenarios A and B, respectively. The TDS concentration at the outlet was found to be 8285 mg/l.

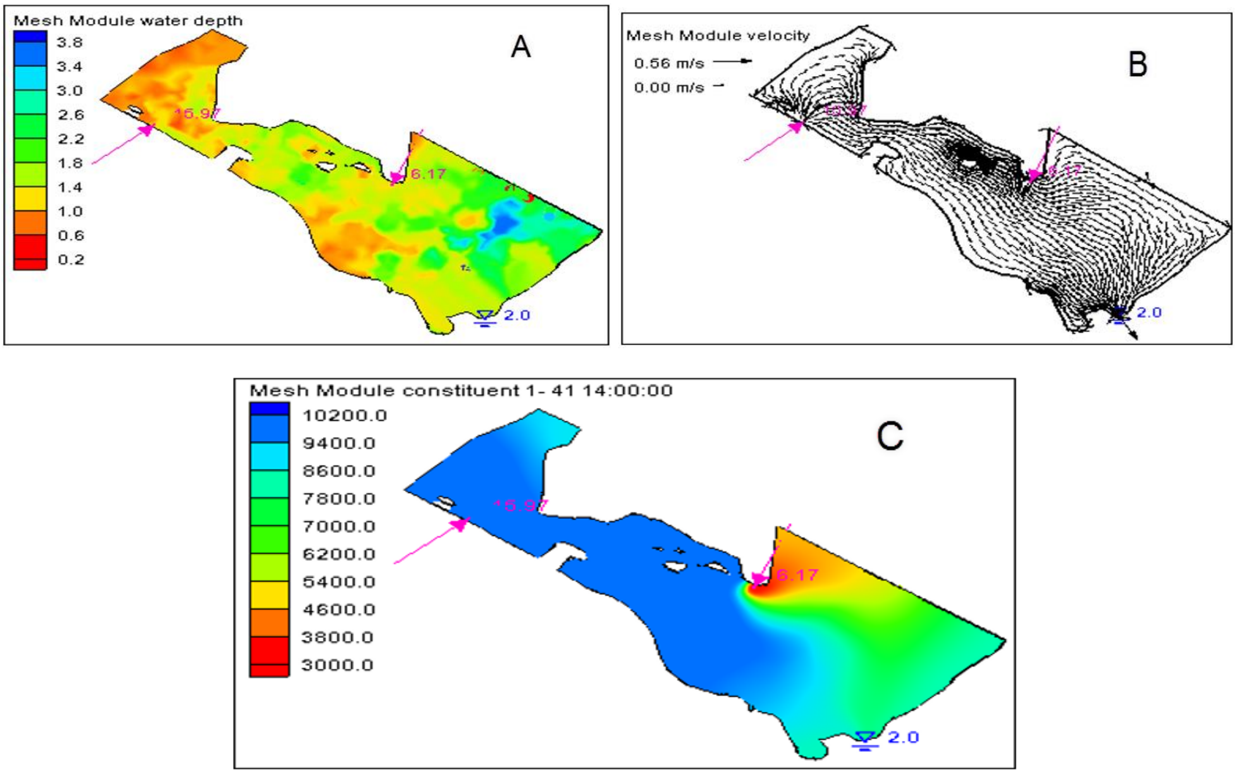

Figure 15 Results of the operating model for Scenario (B) with suggested outlet.

Table 11. The required inflow to maintain the S.W.P.A.H.M area of 88 km^2, discharge of Al-Khamissiya channel is 19.65 m^3/s with a minimum outflow of 7 m^3/s during 2020**.**

Month	Day	Area (km²)	Eto (mm)	Eto (m³/sec)	R (mm)	R (m³/sec)	Supplied discharge of UmElwadaa (m³/sec)	Out flew (m³/sec)
Jan.	31	88	50	1.64	25	0.821	2.99	21.82
Feb.	29	88	75	2.63	17	0.59	2.99	20.6
Mar.	31	88	130	4.27	20	0.65	2.47	18.5
April	30	88	200	6.79	14	0.47	2.14	15.47
May	31	88	350	11.49	4	0.131	2.79	11.08
June	30	88	475	16.12	0	0	3.445	7
July	31	88	450	14,78	0	0	3.57	8.44
Aug.	31	88	410	13.47	0	0	3.12	9.3
Sept.	30	88	350	11.88	1	0.03	3.25	11
Oct.	31	88	250	8.21	6	0.197	2.92	14.55
Nov.	30	88	120	4.07	15	0.5	2.79	18.87
Dec.	31	88	75	2.46	19	0.62	3.25	21.06
Averages			244.6	8.018	10.083	0.33408	2.97	14.8075

Table 12. Values of (TDS mg/l) in 10 selected points for Scenario (C)

	Name	X	Y	Computed value
1	Point 1	638610	3414110	9668.653
2	Point 2	642870	3409210	9735.442
3	Point 3	646570	3408450	8725.661
4	Point 4	649310	3407390	8373.726
5	Point 5	649079	3404789	8747.590
6	Point 6	649597	3409763	6362.658
7	Point 7	650836	3408899	6811.412
8	Point 8	651510	3408429	7145.702
9	Point 9	652337	3407820	7537.502
10	Point 10	652296	3407483	7587.523

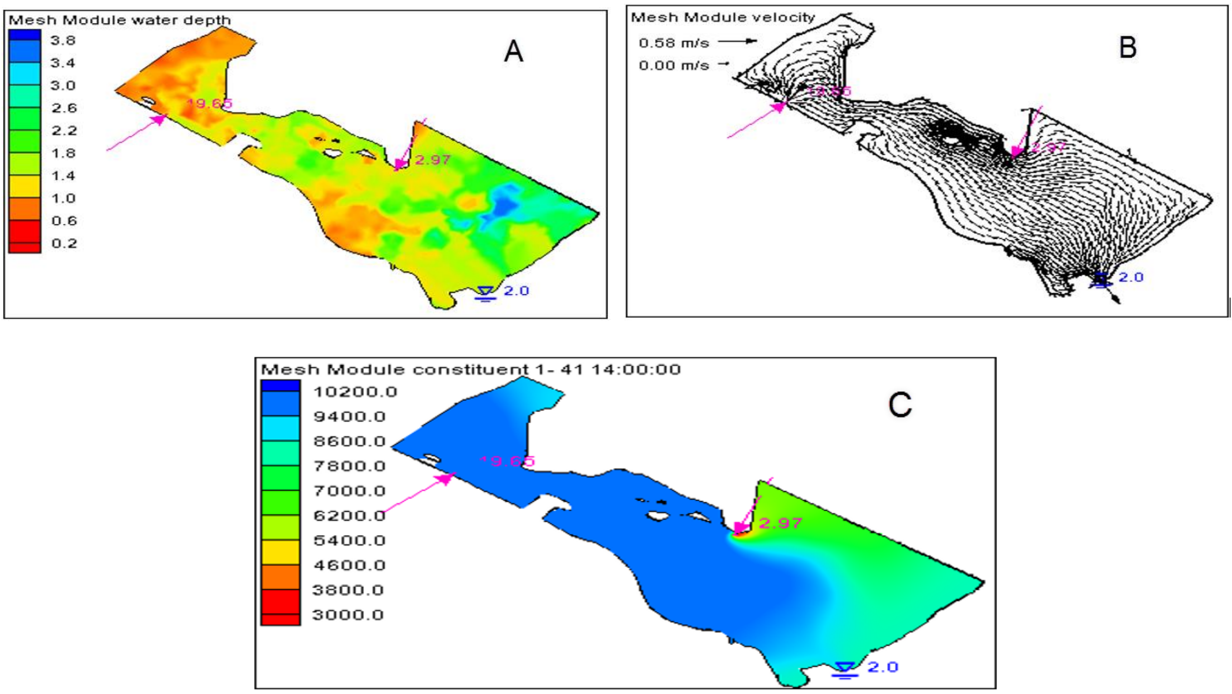

Figure 16. Results of the operating model for Scenario (C) with suggested outlet.

13. SUMMARY OF THE RESULTS

Table (13) shows a summary of the results for the three scenarios and the implementers**.** It summarizes the location of the outlets, the topography of the area, the depths of the water, the presence of plants, the dimensions of the outlet, and the quantities of discharge supplied from the Al-Khamissiya Cannel and the Euphrates River have an impact on improving the water quality in the marsh. The results that appeared for the three scenarios indicated that the second scenario was better than the other scenarios and that the scenarios can be arranged from best to worst as follows (B, A, and C).

Table 13. Results of all Scenarios

Discharges and TDS		Scenarios		
		A	B	C
Discharge m^3/sec	AlKhmissiya	17.82	15.97	19.65
	UmElwadaa	4.58	6.17	2.97
	Outlet	14.38	14.41	13.3
The concentration of TDS at outlet mg/l		8043	7788	8285
the concentration of TDS in selected points mg/l	1	9632.351	9587.625	9668.653
	2	9719.368	9699.285	9735.442
	3	7352.934	5702.305	8725.661
	4	7658.934	6826.240	8373.726
	5	8421.573	7981.067	8747.590
	6	5344.033	4574.304	6362.658
	7	6003.606	5317.382	6811.412
	8	6578.754	6061.738	7145.702
	9	7249.621	6981.822	7537.502
	10	7327.088	7095.396	7587.523
Average		7528.8262	6982.7164	8069.5869

14. CONCLUSIONS

After calibration and validation of the mathematical models, simulation was made in three scenarios. The canaries include closing the existing outlet under the railway embankment and changing the marsh's discharges and water surface area. Based on the obtained results, the following conclusions can be made:

1. The TDS concentrations in the inlets, the discharge, the location of the outlet, evapotranspiration, and topography are affected by the velocity distributions, water depth, and TDS concentration in the outlet.

2. The numerical model of (S.W.A.H.M) was improved through the proposed outlet, where the average TDS before choosing the proposed outlet of ten selected points was 7876 mg/l. In comparison, the average TDS for the same ten points sites and after operating the proposed outlet was 7597 mg/l. It is worth noting that the study took into account the effect of vegetation covers on the movement of flow within the region, where the Manning coefficient was determined in areas where the water depth is more than 2 m by 0.055 and for areas where the water depth is less than 2 m by 0.035, the effect of the islands in the region was also taken into consideration.

3. Three scenarios were selected for the proposed outlet for the southwestern part of Hammar Marsh. To compare the three scenarios, ten points were selected in different locations, where the average TDS for the first scenario was 7528 mg/l, and for the second scenario, the TDS rate was 6982 mg/l. As for the third scenario, the TDS rate was 8069 mg/l; therefore, the best results for hydraulic behavior with navigator concentrations were obtained in the second scenario.

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