Operation of the Iraqi Part of Al-Huweizah Marsh

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ABSTRACT

Al-Huweizah Marsh is considered as the largest in Iraq. This research aims to maintain the sustainability of Al-Huweizah Marsh under all circumstances and within the limits of the available natural resources from the Iraqi side and the absence of feeding from the Iranian side due to the recent Iranian separation dike along the international boundaries within the marsh. Twelve scenarios have been suggested as a first step to restore the whole marsh. But the uncontrolled Iranian feeders and exiguity of their discharges recently, it was necessary to study only the northern part of the marsh as an alternative case to ensure reasonable amounts of water for the purpose of maintaining and restore the marsh. Hydrological routing model was used to calculate the quantities required to restore the whole marsh, as well as the northern part. In this research, the total dissolved solid (TDS) was adopted as the water quality parameter considering, three concentrations of TDS (1500, 1750, and 2000*ppm*). A two-dimensional flow mathematical simulation model was prepared using the SMS package (surface water modeling system) where RMA-2 and RMA-4 software's are used to study the flow and water quality patterns, respectively. In order to improve the water quality in the marsh according to the acceptable water quality determinants and the current conditions, we studied diverting some of Tigris River water, which is one of Shatt-Al-Arab feeders, into the marsh and releasing this amount into Tigris River through Al-Kassara control structure into Shatt-Al-Arab. A significant water quality improvement in the marsh was noticed as a result of mixing 25% or 50% of the Tigris River water which is suppose to go to Shatt Al-Arab. According to the results of this study, it was found that the restoration of the whole marsh cannot be achieved under the current circumstances because of the limited water discharges from Iraqi feeders of the marsh and receding of feeding from Iranian side. The best scenario was that of 3650*million cubic meters/year* for an area 338km^2 and water surface elevation of 3*m.a.m.s.l.* The results also show that Al-Kassara control structure is unable to pass the required outflow at low level to improve water quality according to the required standard determinants.

Key words: Al-Huweizah Marsh; hydrological routing model; discharge; TDS; SMS.

تشغيل الجزء العراقي من هور الحويزه

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الخلاصة

يعد هور الحويزه من اكبر الاهوار الواقعة في العراق. يهدف هذا البحث الى ايجاد وسائل للمحافظه على ديمومة هور الحويزه في كافة الظروف مع الاخذ بنظر الاعتبار محدودية مصادر المياه المتوفره من الجانب العراقي وبغياب التغذيه من الجانب الايراني بسبب وجود السده الايرانيه الفاصله على طول الحدود الدوليه الممتدة عبر هور الحويزه. أثنا عشر سيناريو أقترحت كخطوه اولى لغرض انعاش وديمومة الهور بالكامل. ولعدم امكانية السيطره على مغذيات من الجانب الايراني اضافة لانحسار تصاريفها موخرا لذلك كان من الضروري دراسة الجزء الشمالي من هور الحويزه كخطوه بديله لضمان توفير كميات كافيه من المياه لغرض المحافظه على انعاش وديمومة الهور في ظل التحديات الراهنه. استخدم نموذج الاستتباع الهيدرولوجي لحساب الكميات المطلوبه لانعاش الهور بالكامل اضافه الى الكميات المطلوبه لانعاش الجزء الشمالي فقط. في هذا البحث ان كمية الاملاح الذائبه اعتمدت كمحدد لنوعية المياه وتم تحددبد ثلاث محددات لقيمها وهي (2000,1750,1500) جزء بالمليون. أعد نموذج عددي ثنائي الابعاد باستخدام البرنامج الجاهز SMS (نظام نمذجة المياه السطحيه) حيث استخدم RMA2، RMA4 لدراسه حركه ونوعية المياه. ولتحسين نوعية المياه داخل هور الحويزه وفقا للمحددات نوعية المياه اضافه الى التحديات الراهنه. درسنا امكانية تحويل جزء من مياه نهر دجله والمخصصه لشط العرب الى الهور ومن ثم اطلاق نفس الكميه الى نهر دجله من خلال منفذ الكساره ، حيث لوحظ تحسن كبير في نوعية مياه هور الحويزه كمحصلة خلط 25% او 50% من مياه نهر دجله والمخصصه لشط العرب. لوحظ من خلال الدراسه ان استعاده الهور وديمومته بأكمله لايمكن ان يتحقق في ظل الظروف الحاليه حيث محدودية مغذيات الهور (من الجانب العراقي) وكذلك انحسار التغذيه من الجانب الايراني. كما اتضح ان السيناريو الافضل كان بكمية مياه مطلوبه هي 3650 مليون متر مكعب لكل سنه والذي يقابل مساحة قدرها 338 كيلومتر مربع و منسوب سطح الماء يساوي 3 متر فوق مستوى سطح البحر كذلك تبين ان ناظم الكساره الحالي غير قادر على امرار التصاريف المطلوبه عند المناسيب المياه الواطئة لتحسين نوعية المياه وفقا للمحددات القياسيه المطلوبه.

الكلمات الرئيسية: هور الحويزه، الاستتباع الهيدرولوجي، التصريف، كمية الاملاح الذائبه ، نمذجه المياه السطحيه.

1. INTRODUCTION

Al-Huweizah Marsh is the largest marsh in Iraq with total area of 2060km^2 of it 1360km^2 within Iraq, **Al-Thamiry, 2009**. It is located at the east side of Tigris River at Mayssan and Al-Basrah Governorates, extending from AsSanna’f Marsh outfall down to the south to the outlet of AsSwaib River. Iran has constructed a dike along the Iran-Iraq border; this dike contains seven hydraulic structures, **Fig. 1**, extending from the northern of the Ghzayla bridge, in Mayssan Governorate, down to outlet Southern at AsSwaib, in Al-Basrah Governorate, at level 6 meters above mean sea level (*m.a.m.s.l.*), and a width 10*m* from top. It led to the separation of the marsh into two marshes and to prevent the flow of water from Iranian side, Al-Azim Marsh, to the Iraqi part of Al-Huweizah Marsh. As a result, the environmental and hydrological consequences of these changes are great, **CRIMW, 2012**.

The main problem that faces improvement the ecosystem in any Iraqi marshland is the absence of scientific management and the limited discharges of Iraqi feeders. In order to reduce the environmental impact of the Iranian dike on the Iraqi part of Al-Huweizah Marsh, Iraq has recently started constructing a dike, parallel to the Iranian dike and about 250*m* apart, in order to achieve proper water management system that will be built on a scientific basis and to ensure security of workers in Iraqi marsh, and this will contribute significantly to knowledge of the circumstances of this region in terms of social, environmental and hydrological. The construction of this dike will prevent the inflow of Iranian drainage water into Iraqi part but the water resources deficit must be compensate from Iraqi feeders.

2. PREVIOUS STUDIES

Studies on the marshes are divided into two parts; the first is concerning on the hydrological studies while the second is focused on environmental studies. One of the hydrological study that prepared by, **Ministry of Environment, et al., 2006**. With main objective of studying the current and future water resources requirements in the marshlands area by using a set of numerical tools capable of providing valid presentation of the hydrodynamic phenomena in the marsh. This study included many Iraqi marshes, Abu Zirig marsh, the Central Marshes and Al-Huweizah Marsh. The scope of this work included identification of typical annual hydrological cycles for the marshes (inflow, outflows, evaporation, storage and water surface elevation variation) and provided a first set of circulation models was which prepared using the software's (flow-2d) and RMA2 to identify and analysis the development of the marshes re-flooding and point out which amount of water necessary to obtain the flooding extensions related to the investigated scenarios; more over the results variation during time were studied, in terms of water depth and of flooded area extension. The general scope of the modeling process is the identification of the best management way for water necessary for the wetlands, minimizing the inflow volumes and the evaporated volumes, keeping the water variation level necessary for the biological development. **Yousef, 2006**, prepared a study with main objectives were to over viewing the monitoring field data of Al-Huweizah Marsh concerning hydraulic and water quality aspects. The research used RMA2 model to calculate depth, averaged velocity gradients, water depths and surface water elevations for Al-Huweizah marsh according to date of measurements. From the comparison between the surface water area of the marsh before and after drying, it has been found that the surface water area is reduced to 28% of its area before drying 1976.

Al-Thamiry, 2009, prepared a study on Al-Huweizah Marsh. This study included hydrological and environmental influences on the Iraqi part resulting from the constructing of the Iranian separation dike through hydrological routing for two cases, case one; in the absence of Iranian dike and case two; the existence of the dike. The main results of the comparison showed that there is no contribution from Al-Karkheh River into the Iraqi part of the marsh during dry years; while the contribution of this river will be 36% and 31% from its inflow into the marsh during wet and normal years respectively.

In the environmental field, **Shaimaa, 2008**, studied the effect of Al-Huweizah Marsh boundary configuration on the velocity patterns and water quality distribution. This study has been achieved by using a two dimensional depth-average hydrodynamic model and a two dimensional water quality transport model. These models were built using RMA2 and RMA4 models under surface water modeling system package. This model has been applied on three hypothetical scenarios. Selection of these scenarios are mainly based on the marsh boundary configuration and the results of the hydrological and routing carried out by CRIM. Results of this study show that the construction of the earth dike along the Iraq-Iran boundary line causes variation in the direction of water flow in all portions of the marsh and also it has an influence on the variation of water quality for all parameters within the marsh.

Al Khafaji, 2013, prepared a study on Al-Huweizah Marsh which includes two cases, case one: without existence of the Iranian dikes and case two: with the Iranian dikes. The electrical conductivity, EC, value was adopted to be the indicator for the water salinity within the marsh. A steady two-dimensional water quality model was implemented by using the RMA2 and RMA4 software within the SMS computer package to estimate the seasonal distribution of the EC values within the marsh during the wet, normal and dry water years, the main results of this study showed that the estimated distribution patterns of EC values with the existence of the Iranian dikes, Case2,deteriora water salinity within most of the Iraqi part of the marsh during the four seasons of the wet, normal and dry water years.

3. AL-HUWEIZAH MARSH FEEDERS

Fig. 2, shows a schematic diagram of the main water resources of Al-Huweizah Marsh which can be classified into two types depending on the existence of water control structures. The first, controlled feeders, are Al-Musharrah, and Al-Kahla'a Rivers which are sharing the same intake located north of Al Amarah Barrage on Tigris River and controlled by a head regulators located upstream of each river. The second, uncontrolled feeders, are Al Karkheh River and AsSanna'f Marsh, which is feeding by AtTeeb, Dwayreach, Kmait Rivers, the surface runoff of AShama'ashir area and the drain water of Sa'ad River irrigation project.

The main discharge outlets of Al-Huweizah Marsh are Al-Kassara and AsSwaib Rivers. Al-Kassara River water is discharged to Tigris River through two sets of pipes. These pipes will be replaced by a control structure with a design discharge of 125m^3/sec. AsSwaib River flows from the southern part of Al-Huweizah Marsh and directly outfalls in Shatt Al-Arab River with an average flow capacity of 600 m^3/sec. A control structure with a design discharge of 200 m^3/sec has been designed to control the outflow of this river into Shatt Al-Arab River, **Ministry of Water Resources, el. at 2007**.

4. TOPOGRAPHY OF AL-HUWEIZAH MARSH

Different estimations of Al-Huweizah Marsh area may be found in literature. According to the study that carried out by **Ministry of Water Resources, 2003**. The estimated area of Al-Huweizah Marsh is about 1500km^2 including AsSanna'f Marsh area. During the autumn season, the marsh reaches its minimum area, about 650km^2. Only the deep parts of the marsh remains forming water ponds such as Um Al-Na'aj, and Al-Azim. These water ponds are connected to each other by water paths that pass through dense areas of weeds, reeds, and other water bushes types which make the movement within the marsh so difficult, **CRIM, 2008.**

CRIM, 2006, developed a complete topographical map for Al-Huweizah Marsh, **Fig. 3,** using the topographical survey which has been carried out for the Iraqi part of the Al-Huweizah Marsh, using the ultra sonic device and the topographical map of the Iranian part of the marsh which is presented in the Azadegan Environmental Baseline Studies, **UNEP, IRAN, 2004.**

5. AREA AND STORAGE ELEVATION CURVES

Depending on the achieved DEM of the marsh and using Arc-view GIS software assuming that the water surface profile is horizontal within the marsh (hypothetical case), the area and storage elevation curves for the Iraqi part (total marsh) of the marsh were obtained by **CRIM, 2008**. In the present study, according to the same above assumptions, the area and storage elevation curves for north part of the marsh are computed and presented in **Figs. 4** and **5**.

6. CONSUMPTION DISCHARGES FOR IRRIGATION FROM IRAQI FEEDERS

Marsh feeders are flow several kilometers before they reach the marsh boundary. Along these rivers, there are many intakes for irrigation purposes for the nearby farms. The monthly required water for irrigation was calculated according to the difference between the diverted discharges through Al-Musharrah and Al-Kahla’a regulators and that reach the marsh through feeders and their tributaries. The estimated irrigation requirement will help decision maker to identify the required discharges at the inlets of Al-Musharrah and Al-Kahla'a regulators so as to ensure the marsh share of water, **Table 1**. It must be noticed that the actual feeder of the marsh during the last years is Al-Kahla'a River only since the whole water within Al-Musharrah River was used for irrigation, **Figs. 6** and **7**.

7. HYDROLOGICAL ROUTING OF AL-HUWEIZAH MARSH

The hydrological routing of Al-Huweizah Marsh was carried based on the mass conservation law and has the form of a mass balance equation, that is:

$$dV_m / dt = I - O - ET_o * A \qquad (1)$$

V_m is the volume of water within the marsh (*cubic meters*); t, I, O, A and ET_o represent the time (*sec*), inflow, outflow (m^3/s), area (m^2) and evapo-transpiration (*m/sec*), respectively.
Since Al-Huweizah Marsh lies within a region of high ET_o and according to the above equation, ET_o will be the key factor affecting the required water to maintain the marsh area and the water quality deterioration. To minimize the losses due to ET_o, a suggestion is made to minimize the marsh area to a value that keeps continuous lake during the period of high ET_o and to be increased up during the period of low ET_o. This suggestion simulates the natural fluctuation in the marsh area that was occurred before. Twelve scenarios of the total Iraqi Marsh boundary are suggested as the first step for the water management of the Iraqi marsh. But, since the Iranian feeders are uncontrolled feeders it must be study the absence of Iranian water, so the northern part of Al-Huweizah Marsh were taken as another alternative that will ensure the reasonable amount of water to maintain a permanent marsh, especially with the present challenges.

8. AL-HUWEIZAH MARSH WATER QUALITY

In this research, TDS is water quality parameter that was used as a measure of the salinity of the water. The effects of human activities on water quality are both widespread and varied and in the degree to which they disrupt the ecosystem and restrict water use. Pollution of water by human faces, for example, is attributable to only one source, but the reasons for this type of pollution, its impacts on water quality and the necessary remedial or preventive measures are varied. The marsh feeders, AsSanna'f Marsh (which is a seasonal marsh), Al-Karkheh River, Al- Musharrah River and Al-Kahla’a River, can be classified into three types depending on the existence of water control structures on these feeders; the locations of these control structures and the way of controlling the discharges of these feeders. These types are: uncontrolled feeders (AsSanna'f Marsh), controlled Iranian feeders (Al- Karkheh River) and controlled Iraqi feeders (Al-Musharrah and Al-Kahla’a Rivers).
Historically, the salinity was less than 700 mg/l, **Abbas, 2006**. But the water quality of the marsh varies with time. This variation depends on the source of water and whether the water passes urban area. Except the dissolved Oxygen, DO, the electrical conductivity, EC (or TDS), all other water quality parameters are about or within the acceptable limits for drinking water standards. The maximum recorded EC at Al Musharrah River, Al Ma’eel channel, Um AtToos River, Al Husa'chi River, Al-Kassara River, and AsSwaib River is slightly higher than the acceptable limit. While the maximum recorded EC at AsSanna'f Marsh outfall , AtTeeb River, Dwayreach River, Kmait River, and Sa'ad Drain let stations was 9000 μs/cm and it is higher than the acceptable

limit in most of the measurements, **CRIM, 2006**. Available information on Karkheh River water quality is restricted to the chemical elements such as total dissolved salts (TDS), pH, Electrical conductivity, anions and cat ions for the main stations. According to the available information, the salt content of the river water is mainly composed of sodium chloride followed by calcium sulfate and calcium carbonate. During the low flow periods, Sodium Chloride very clearly dominates other than salts while during the high flow periods; the composition is almost uniform, **UNEP, 2004**. The balance of the ecological system of the Al-Huweizah Marsh has a large effect on the balance of the overall ecological system because of the large area, location, variety of feeding sources and variety of ecological and biological systems of this marsh.

9. WATER QUALITY MODEL

The mass conservation law also applied to TDS, that is:

$$C_m * dV_m/dt + V_m * dC_m/dt = C_i * I - C_m * O + C_m * ET_o * A \qquad (2)$$

Where C_m= Concentration of the marsh, *ppm,* C_i = Concentration of the feeder's marsh, *ppm,* V_m= Storage, m^3, I and O= Inflow and Outflow, m^3/s, ET_o= Evapotranspiration, *m/s,* A= Area of marsh, m^2. In this study, TDS is water quality parameter that was used as a measure of the salinity of the water. TDS fairly indicates the level at which salinity problem is likely to occur. The TDS is an indicator to presence of calcium, magnesium, potassium, sodium, bicarbonates, chlorides and sulfates salts. Water quality of the northern part of Al-Huweizah Marsh was studied with the six adopted scenarios and the total dissolved solids TDS was limited to be below 1500, 1750 and 2000 *ppm* within the marsh. In order to improving water quality in the marsh, we studied diverting some of Tigris River water, which is one of Shatt-Al-Arab feeders, into the marsh and releasing this amount into Tigris River through Al-Kassara control structure into Shatt-Al-Arab. Additional 25% of Tigris River is to be diverted into the marsh when the value of the TDS of Tigris River at Qalat Saleh is greater than 1000 *ppm* and about 50% of Tigris River water when the value of the TDS of Tigris River at Qalat Saleh less or equal to1000 *ppm*.

10. THE SIMULATION MODELS

The Surface Water Modeling System, SMS, RMA2 is a two-dimensional, finite element hydrodynamic modeling code that supports subcritical flow analysis. It computes a finite element solution of the depth-integrated equations of fluid mass and momentum conservation in two horizontal directions. Friction is calculated with the Manning's formula, and eddy viscosity coefficients are used to define turbulence characteristics, **Donnell, 2004 a**. RMA2 model was used to compute the water surface elevation and velocity variation over Al-Huweizah Marsh. The Surface Water Modeling System, SMS, RMA4, is a companion model to RMA2, is a finite element water quality transport numerical model. RMA4 is applied to represent the transport of a contaminant, salinity intrusion in a system. RMA4 was used to investigate the water quality inside Al-Huweizah Marsh.

11. BOUNDARY CONDITIONS SIMULATION

There are two hydraulic models the first is of the Iranian side no feeding and the second for the Iranian side feeding. The downstream boundary conditions for the both models are the same which are Al-Kassara Rivers while the difference in the upstream boundary conditions is the feeding water that enters the marsh from Al-Karkheh Rivers. The reason of the difference is the existence of the presumed Iranian dike that will prevent the incoming water from the river from entering the Iraqi part of the marsh when the water levels within the Iranian part of the marsh is lower than 6*m.a.m.s.l* and then the water will spill over this dike when the water level exceeds 6*m.a.m.s.l.* Al-Huweizah marsh has five inlets: Al-Karkheh River, AzZubair River, Um Al-Toos River, Al-Husa'chi River and AsSanna'f Marsh and Al-Musharrah River were treated as a one source point, since Al-Musharrah River flows into AsSanna'f Marsh before AsSanna'f Marsh feed the Al-Huweizah Marsh as shown in **Figs. 8** and **9**.

12. RESTORATION THE WHOLE AND NORTHERN PART OFAL-HUWEIZAH MARSH

Table 2, shows a comparison between the mean annual volume required to restore the whole area and the northern part of Al-Huweizah marsh according to the studied scenarios. The table reveals that the percentage mean annual volume ratio between the required volume to restore the northern marsh and the whole marsh is about 58%.

13. RESTORATION THE NORTHERN PART WITH AND WITHOUT IRANIANS FEEDERS

Table 3, shows the comparison between the mean annual volume that required to restore the northern part of Al-Huweizah Marsh due to the adopted scenarios including and excluding Iranians feeders. It is clear that the absence of Iranian feeders reduces the water resources of the marsh by about 1000*MCM*, (in normal year).

14. WATER QUALITY ANALYSIS OF NORTHERN PART WITHOUT IRANIAN FEEDERS

Table 4, presents inflow and outflow for restoration of the northern part of Al-Huweizah Marsh in all scenarios. The results of these scenarios are used as a first run for the water quality study and then the inflows and outflows are corrected according to water quality requirements**. Table 5,** shows the amount of the inflow and outflow required discharges for northern marsh area due to hydrological and environmental model for two consecutive years, namely, in the years 2009-2010 and 2010-2011, for limit 1500 *ppm*.

15. AL-KASSARA STRUCTURE OUTLET

According to water quality model of the northern part of Al-Huweizah Marsh in the presence of Al-Kassara structure had no flexibility to pass the large outflow values at the low level of water due to the absence of feeding from the Iranian side therefore the value of TDS cannot be improved. To solve this problem, an additional outlet structure is needed to give the required flexibility to discharge higher flow rates than in the present condition. **Fig. 10** shows comparison between TDS, if the downstream control structure is only Al-Kassara structure or an alternative structure for the first scenario when the maximum allowable TDS is 1500*ppm*. It can be noticed significant improvement in TDS due to the alternative structure when it compared with that of the existing of Al-Kassara structure. The main reason is that Al-Kassara structure currently cannot passed the outflow required to achieve the water quality accordance to required determinants. As an example, it is noticed from the **Fig. 10** at September, the concentration of TDS was 8808*ppm* with Al-Kassara structure while it was 1499*ppm* at the same month in the case of alternative structure, where the percentage mean annual TDS ratio (improvement ratio) was 83%.

16. AL-HUWEIZAH MARSH BEFORE AND AFTER MIXING WITH ADDITIONAL SHARE

Significant water quality improvement in the marsh was noticed as a result of mixing additional share of the water allocated of Shatt Al-Arab. **Figs. 11, 12, 13, 14, 15** and **16**, show the monthly variation of TDS in Al-Huweizah Marsh and Shatt Al-Arab before and after mixing with additional share of Shatt Al-Arab for limit 1500 ppm. **Table 6** presents the percentage ratio of mean annual TDS among the suggested scenarios for the northern part of Al-Huweizah Marsh. The percentage annual TDS ratio (TDS improvement ratio) is used in comparison between the different scenarios, **Table 6**. When the maximum allowable TDS in the marsh is 1500*ppm*, the TDS of the marsh before mixing is 1492*ppm* and after mixing is 1353*ppm*, the improvement ratio (percentage mean annual TDS ratio) in TDS of the marsh is 9% and the percentage of deterioration in TDS of Tigris River after mixing is 24% in the first scenario. In other scenarios the improvement ratio in the marsh after mixing is approximately 8% and the percentage of deterioration in TDS of Tigris River after mixing is 23%.

17. SEASONAL DISTRIBUTION OF TDS IN THE MARSH WITHOUT IRANIAN FEEDING

A larger area of the marsh has a good quality during Summer, but it will be worst during Winter with or without mixing. It is to be noticed that the east part of the marsh near the Iraq-Iran international boundary is almost stagnant. The contribution of the extra water (with mixing) will lower the upper limit of TDS in the marsh while the TDS distribution is same**, Figs. 17** and **18**.

18. SEASONAL DISTRIBUTION OF TDS IN THE MARSH WITH IRANIAN FEEDING

The water quality of the marsh with the feeding from Iranian side is very bad in spite of good mixing process, so it is necessary to avoid the Iranian side feeding by complete the construction of the Iraqi separation dike along the boundary to prevent the deterioration within the marsh area, **Fig. 19**.

19. CONCLUSION

The hydrological routing was carried out based on marsh operation, which minimizes the evaporation from the marsh, and with different scenarios of inflow and outflow discharges. The variation of the marsh area, water level, inflow and outflow discharges, water volume, and the water quality within the marsh were specified for each scenario. Based on the hydrological routing analysis, a mathematical water quality models was used to study the variation of the water quality within the marsh. The following conclusions were extracted:

1. Restoration of the whole marsh cannot be achieved since the required annual volume of water is 1384 million cubic meters which is very difficult to be supplied according to the current circumstances of Al-Huweizah Marsh feeders. Whereas, the northern part restoration need 62% of that required for the whole marsh area.
2. The current Al-Kassara control structure fail to pass the required outflow in order to satisfy the required water quality limitations within the marsh area.
3. Significant water quality improvement in the marsh was noticed as a result of mixing additional share of the water allocated of Shatt Al-Arab.
4. Restoration of Al-Huweizah marsh according to the hydrologic and environment considerations is required 3650 million cubic meters from Iraqi feeders which are more than 4

times of that for the hydrological requirements only. This amount of water is sufficient to preserve the concentration of water contaminants within the acceptable determinants.

5. When the maximum allowable of TDS in the marsh water is equal to 1500*ppm* (whether with or without extra inflow) it is noticed that TDS in 5th scenario is similar to that of the 2nd, 3rd and 4th scenarios.

6. It is clear that the absence of Iranian feeders reduces the water resources of the marsh by about 1000 million cubic meters (in normal year).

0. REFERENCES

- Abbas, S. F., 2006, *Application of Hydrodynamic Model in Abu Zirig Marshland*, M. Sc., Thesis, University of Mustansiriya.
- Al Khafaji, M. S., 2013. *Effect of the Iranian Separation Dikes on the Water Salinity Patterns Within Al-Huweizah Marsh* Journal of Engineering, College of Engineering . University of Baghdad. Baghdad/Iraq. No.1, Vol.19, p35-51.
- Al Thamiry, H. A., 2009. *Hydrological Damage of Iranian Separation Dike on the Iraqi Part of Al-Huweizah Marsh*, The 6th Engineering Conference/ College of Engineering / Baghdad University (5-7 April 2009) Vol. V, p 112-126.
- CRIM (Center for the Restoration of Iraqi Marshlands), 2006. *Study the Rehabilitation of Al-Huweizah Marsh Ecological System* Vol.1 to Vol.7.
- CRIM, 2008. *Study The Hydrological And Ecological Effect For The Construction Of An Earth Dyke By The Iranian Administration To Separate The Part Of Al Huweizah Marsh Which Is Located Within The Iranian Territories*.
- CRIM, 2012. *Report about Dike Construction Along the Iraq-Iran Border in Al-Huweizah Marsh.*, Unpublished, (Arabic).
- Donnell, B. P., 2004. (a), User Guide to WES-RMA2 Version 4.5, "*Water Ways Experiment Station, Costal and Hydraulics Laboratory*", California, Davis, U.S.A.
- Ministry of Environment, Ministry of Water Resources, Ministry of Municipalities and Public Works Iraq and Italian Ministry for the environment and Territory and the Free Iraq Foundation , 2006. *New Eden Master Plan for Integrated Water Resources Management in the Marshlands Area*" Italy, Iraqi.
- Ministry of Water Resources, Ministry of Environment, Municipalities and Public Works Iraq and Italian Ministry for the Environment, Land and Sea, 2007. *The New Eden Project - Master Plan for Integrated Water Resources Management in the Marshlands Area*; Outlet of Al-Huweizah Marsh Along Al-Kassara River & AsSwaib River, technical Report, phase II.
- Nicholson, E. and P .Clark (Eds), 2002. *The Iraqi Marshlands: A Human and Environmental Study* The AMAR Appeal International Charitable foundation.

- Partow, H., 2001, *The Mesopotamian Marshlands: Demise of an Ecosystem* Report United Nations Environmental Program.
  Available online at.
  (http://earthobservatory.nasa.gov/Newsroom/NewImages/Images/meso2.pdf).

- Shaimaa, A., 2008. *Effect of Al Huweizah Marsh Boundary Configuration on the Velocity Patterns and Water Quality Distribution*. M. Sc. Dissertation. Collage of Engineering. University of Baghdad.

- *UNEP, 2003. Environment in Iraq:* UNEP Progress Report, UNEP. Geneva, Switzerland.

- *UNEP, 2004. Azadegan Environmental Baseline Studies.* The Natural Environment, Iran.

- *Yousef, S. S., 2006. Application of Steady Flow Model for Analysis of the Flow in Al-Huweizah Marsh. M. Sc.* Thesis- Building and Construction Engineering Dept., University of Technology.

Figure 1. Hydraulic structures in Iranian dike at the coordinate in UTM (N=3474521.24891*m*, E =755381.586716 m), **during 5-12-2012**.

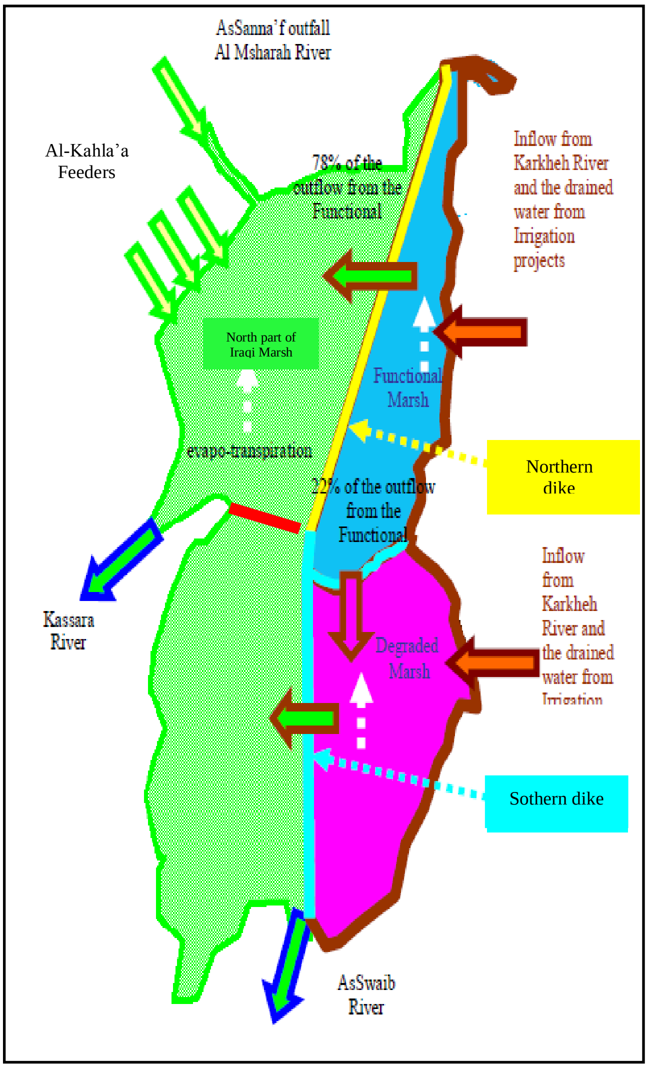


Figure 2. Schematic diagram for the hydrological interference, ***CRIM, 2008***.

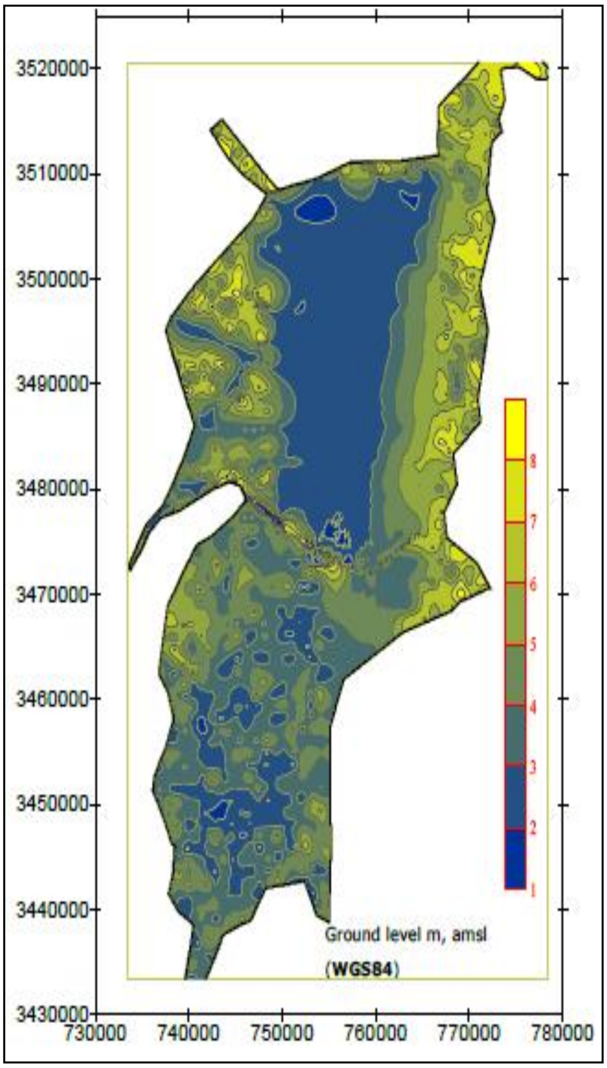


Figure 3. Digital elevation model (DEM) of Al-Huweizah Marsh, ***CRIM, 2006***.

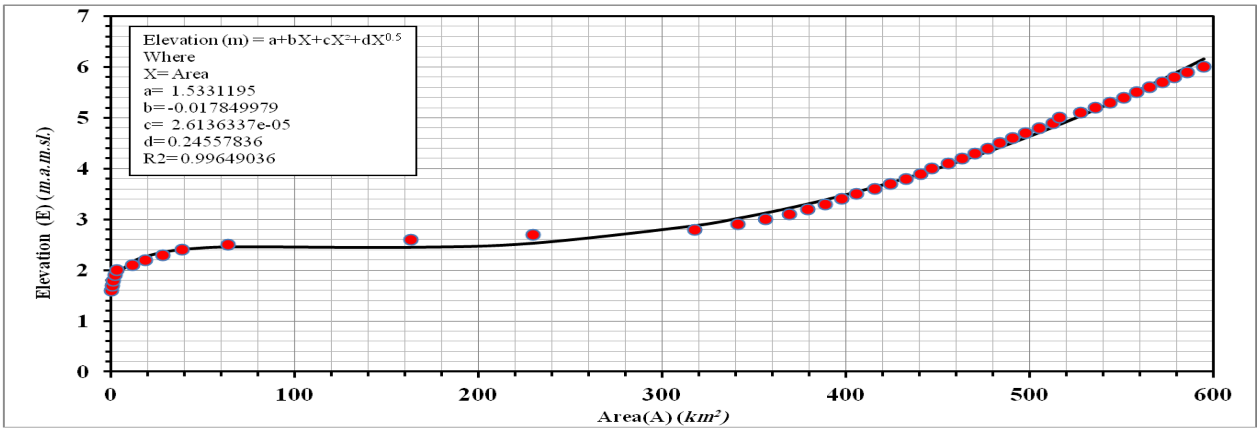


Figure 4. Area-elevation curve of the north Iraqi part of Al-Huweizah Marsh.

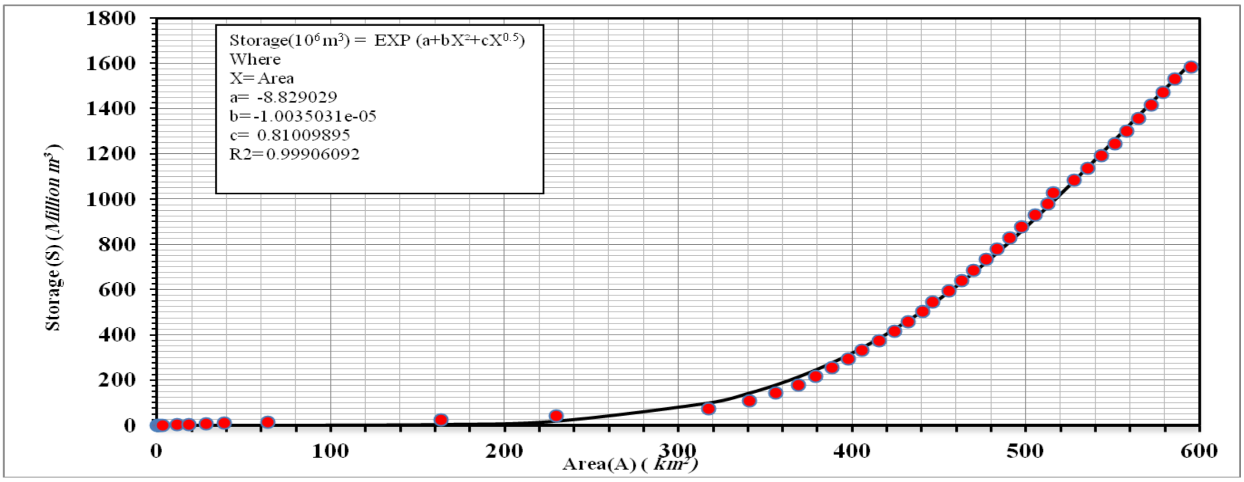


Figure 5. Area-storage curve of the north Iraqi part of Al-Huweizah Marsh

Table 1. Monthly average water consumption in m^3/sec along Al-Musharrah and Al-Kahla'a Rivers.

	Month	Al-Kahla'a River			Al-Musharrah River		
		River inflow	Total consumption	Marsh inflow	River inflow	Total consumption	Marsh inflow
2009 - 2010	Oct	28.52	9.77	18.75	6.42	6.42	0
	Nov	22.37	10.37	120	4.43	4.43	0
	Dec	28.64	9.14	19.50	6.04	6.04	0
	Jan	22.74	9.99	12.75	5.26	5.26	0
	Feb	17.68	4.93	12.75	6.64	6.64	0
	Mar	17.67	6.86	10.81	5.90	5.90	0
	Apr	21.10	4.32	16.78	7.80	7.80	0
	May	29.23	9.46	19.77	7.19	7.19	0
	Jun	22.63	9.08	13.55	5.30	5.30	0
	Jul	17.89	5.61	12.28	4.04	4.04	0
	Aug	19.58	8.23	11.35	6.04	6.04	0
	Sep	20.07	8.52	11.55	6.40	6.40	0

Figure 6. Al Jdeda regulator on Al-Musharrah River at the coordinate in UTM (N=3525693m, E =722787m), ***during5/ 1/2012***.

Figure 7. Al Alah regulator on Al-Musharrah River at the coordinate in UTM(N=3525151m, E =711674m), ***during 5/ 1/2012***

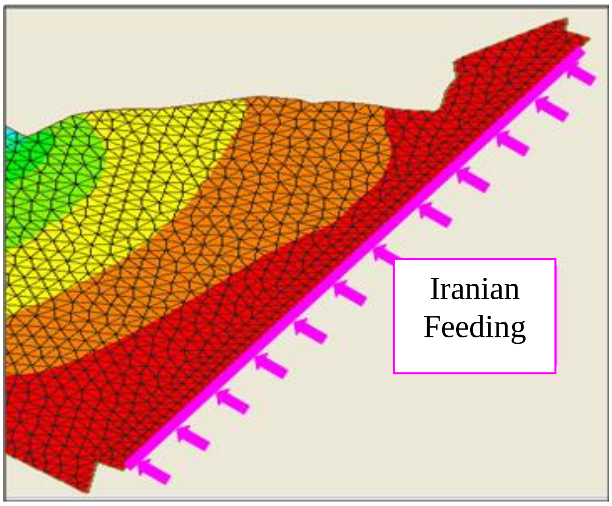


Figure 8. The inflow from Iranian part into the Iraqi part of the marsh.

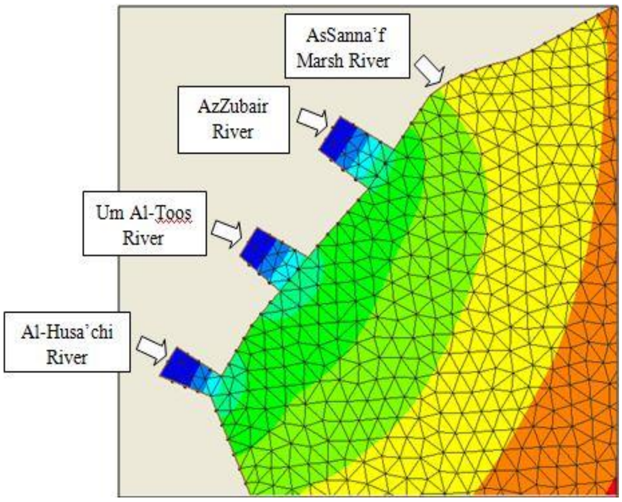


Figure 9. Iraqi feeders of Al-Huweizah Marsh.

Table 2. Comparison of the required means annual volumes of water in MCM for restoration of the whole and northern part of Al-Huweizah marsh area.

Scenario	1	2	3	4	5	6	7	8	9	10	11
Northern Marsh	857	1076	1105	1155	1181	1179	1591	1615	1659	1674	1655
Whole Marsh	1384	1797	1839	1912	1948	1944	2871	2904	2960	2966	2913

Table 3. Comparison the mean annual volumes of water in MCM for the suggested scenarios with and without Iranians feeders.

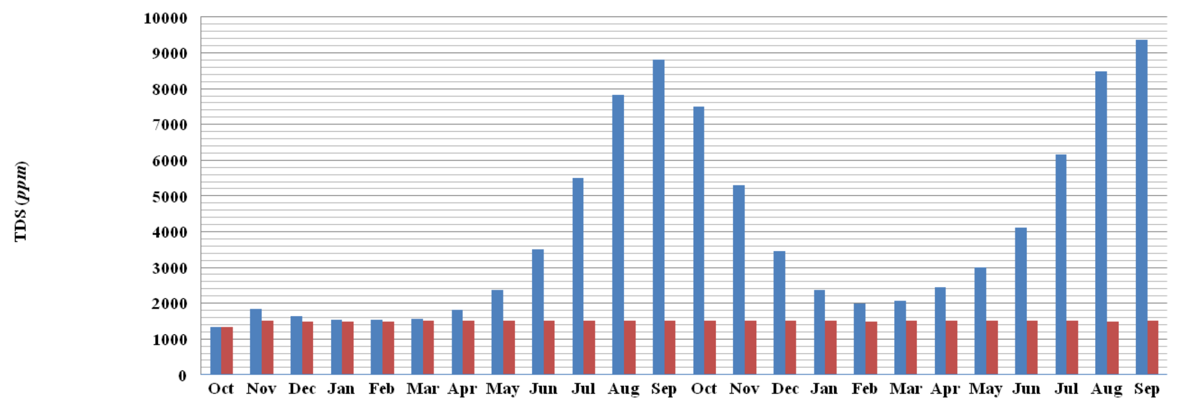
Scenario	1	2	3	4	5	6
Including Iranian Feeders	1842	2060	2089	2139	2162	2146
Excluding Iranian Feeders	857	1076	1105	1155	1181	1179

Table 4. Net required monthly inflow (I), outflow (O)and annual volume in MCM for two consecutive years for northern part.

			Discharge, m^3/s													
			Oct	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Mean Annual**	**Volume**
S-1	**I**	1st year	22	13	7	7	11	16	26	35	49	53	49	36	27	857
		2nd year	22	13	7	7	11	16	26	35	49	53	49	36	27	857
	O	1st year	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		2nd year	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S-2	**I**	1st year	51	44	42	20	0	0	0	35	49	53	49	36	32	1007
		2nd year	54	57	65	33	0	0	0	35	49	53	49	36	36	1144
	O	1st year	0	0	0	31	42	24	5	0	0	0	0	0	8	262
		2nd year	0	0	0	31	42	24	4	0	0	0	0	0	8	260
S-3	**I**	1st year	40	47	45	22	0	0	14	35	49	53	49	36	33	1036
		2nd year	39	59	71	38	0	0	14	35	49	53	49	36	37	1175
	O	1st year	0	0	0	37	49	27	3	0	0	0	0	0	10	298
		2nd year	0	0	0	37	49	27	3	0	0	0	0	0	10	298
S-4	**I**	1st year	25	36	60	31	0	9	26	35	49	53	49	36	34	1088
		2nd year	22	39	88	53	0	9	26	35	49	53	49	36	38	1222
	O	1st year	0	0	0	57	68	17	0	0	0	0	0	0	12	361
		2nd year	0	0	0	57	68	17	0	0	0	0	0	0	12	361
S-5	**I**	1st year	25	15	56	54	6	16	26	35	49	53	49	36	35	1117
		2nd year	22	13	71	92	6	16	26	35	49	53	49	36	39	1245
	O	1st year	0	0	0	104	51	0	0	0	0	0	0	0	13	401
		2nd year	0	0	0	104	51	0	0	0	0	0	0	0	13	401
S-6	**I**	1st year	25	15	9	97	11	16	26	35	49	53	49	36	35	1118
		2nd year	22	13	7	150	11	16	26	35	49	53	49	36	39	1240
	O	1st year	0	0	0	162	0	0	0	0	0	0	0	0	14	435
		2nd year	0	0	0	162	0	0	0	0	0	0	0	0	14	434

Table 5. Net required monthly inflow (I), outflow (O) and annual volume in MCM for two consecutive years for northern part, (maximum allowable TDS in the marsh is 1500ppm).

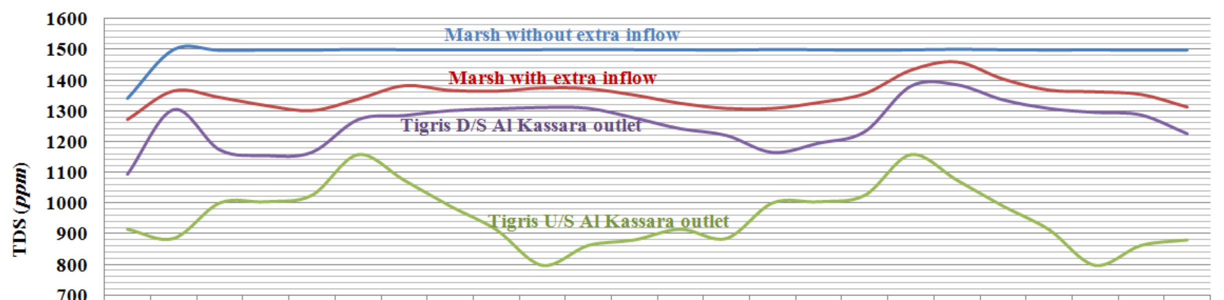
			Discharge, m^3/s													
			Oct	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Mean annual**	**Volume**
S-1	**I**	1st year	22	116	28	30	39	69	106	137	188	226	195	139	108	3412
		2nd year	89	69	33	47	69	159	156	142	182	210	184	135	123	3887
	O	1st year	0	103	21	23	29	53	80	102	139	173	146	103	81	2560
		2nd year	67	56	26	40	59	143	130	107	133	157	135	99	96	3036
S-2	**I**	1st year	51	44	42	20	50	80	111	137	188	229	194	140	107	3385
		2nd year	96	77	65	33	76	185	164	139	182	212	182	135	129	4075
	O	1st year	0	0	0	31	92	104	114	102	139	176	145	104	84	2641
		2nd year	43	21	0	31	118	210	168	104	133	159	133	99	101	3194
S-3	**I**	1st year	40	47	45	22	49	75	111	140	187	226	196	140	107	3369
		2nd year	89	75	71	38	57	181	159	144	182	211	183	135	127	4014
	O	1st year	0	0	0	37	98	102	100	105	138	173	147	104	84	2634
		2nd year	49	16	0	37	106	209	148	109	133	158	134	99	100	3143
S-4	**I**	1st year	25	36	66	31	31	81	106	138	187	228	194	140	105	3337
		2nd year	90	67	88	53	0	202	156	140	182	213	181	135	126	3991
	O	1st year	0	0	6	57	99	89	80	103	138	175	145	104	83	2615
		2nd year	68	27	0	57	68	210	130	105	133	160	132	99	99	3134
S-5	**I**	1st year	25	43	70	54	28	66	106	140	187	225	197	141	107	3386
		2nd year	88	68	73	92	6	200	156	140	182	213	181	135	128	4062
	O	1st year	0	28	14	104	73	50	80	105	138	172	148	105	85	2675
		2nd year	66	55	2	104	51	184	130	105	133	160	132	99	102	3221
S-6	**I**	1st year	25	39	48	97	11	74	106	137	187	229	193	140	107	3406
		2nd year	92	68	35	150	11	181	156	141	182	212	182	135	129	4088
	O	1st year	0	24	40	162	0	58	80	102	138	176	144	104	86	2728
		2nd year	70	55	27	162	0	165	130	106	133	159	133	99	103	3284



Month	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Al-Kassara structures	1342	1844	1635	1548	1536	1569	1813	2368	3494	5505	7838	8808	7504	5310	3460	2374	1983	2061	2446	3013	4121	6147	8474	9368
With alternative structures	1342	1499	1497	1498	1498	1500	1499	1498	1499	1499	1500	1499	1498	1498	1500	1499	1497	1498	1500	1499	1498	1499	1497	1498

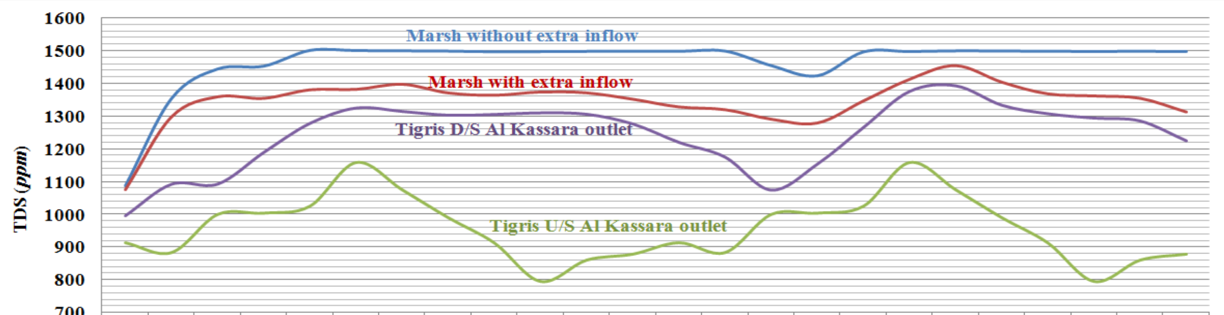
Month

Figure 10. Monthly variation of TDS within the marsh with and without Al-Kassara structure.



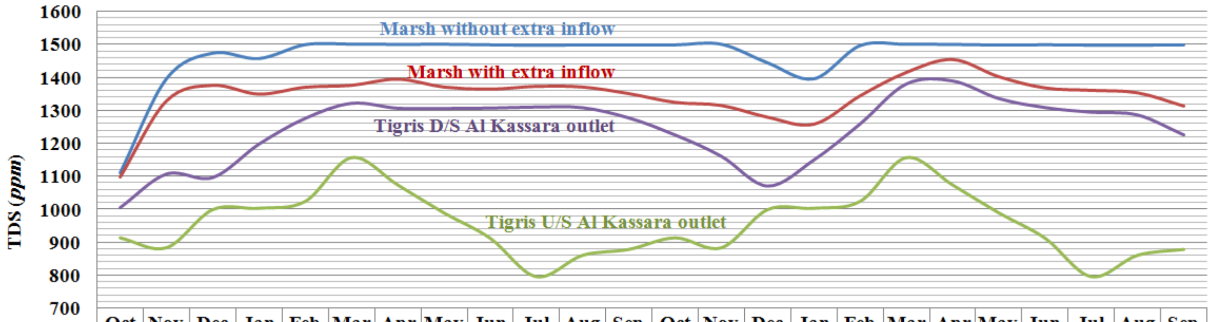
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
— (blue)	1342	1499	1497	1498	1498	1500	1499	1498	1499	1499	1500	1499	1498	1498	1500	1499	1497	1498	1500	1499	1498	1499	1497	1498
— (red)	1272	1366	1345	1318	1302	1339	1383	1368	1365	1376	1373	1352	1325	1309	1309	1328	1357	1433	1460	1405	1369	1363	1354	1313
— (green)	914	884	1000	1004	1025	1158	1075	990	913	796	861	879	914	884	1000	1004	1025	1158	1075	990	913	796	861	879
— (purple)	1092	1303	1172	1153	1163	1271	1284	1300	1306	1311	1308	1276	1241	1219	1163	1194	1231	1380	1385	1336	1307	1294	1286	1225

Figure 11. Monthly variation of TDS in Al-Huweizah Marsh and Tigris River for the 1st scenario, (maximum TDS in the marsh is below 1500ppm).



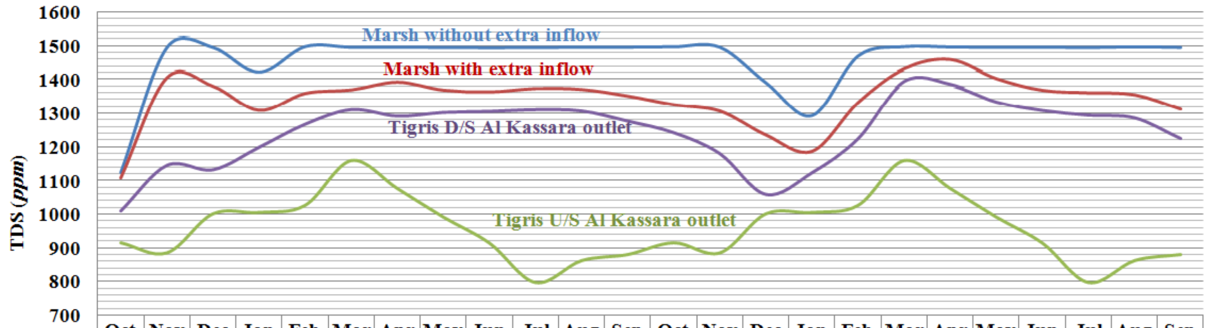
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
— (blue)	1088	1354	1444	1452	1500	1500	1499	1498	1496	1497	1497	1498	1497	1498	1454	1423	1496	1497	1499	1498	1497	1497	1498	1497
— (red)	1076	1298	1359	1354	1381	1382	1397	1371	1364	1374	1371	1352	1328	1320	1291	1279	1347	1413	1454	1404	1368	1362	1355	1313
— (green)	914	884	1000	1004	1025	1158	1075	990	913	796	861	879	914	884	1000	1004	1025	1158	1075	990	913	796	861	879
— (purple)	994	1091	1092	1189	1278	1325	1314	1303	1305	1310	1306	1276	1220	1174	1073	1153	1265	1376	1393	1334	1307	1294	1285	1224

Figure 12. Monthly variation of TDS in Al-Huweizah Marsh and Tigris River for the 2nd scenario, (maximum TDS in the marsh is below 1500ppm).



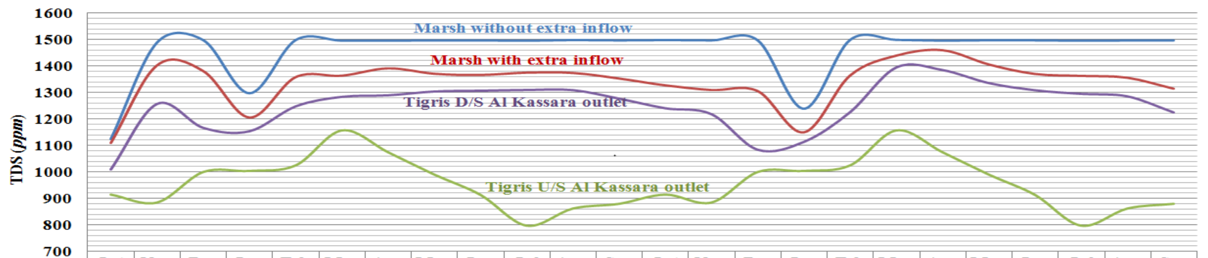
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
	1112	1396	1473	1457	1499	1500	1499	1500	1498	1497	1498	1498	1498	1500	1444	1396	1496	1500	1499	1497	1498	1497	1497	1498
	1097	1329	1377	1350	1371	1377	1396	1372	1365	1374	1372	1352	1325	1316	1280	1258	1345	1416	1456	1403	1369	1362	1354	1314
	914	884	1000	1004	1025	1158	1075	990	913	796	861	879	914	884	1000	1004	1025	1158	1075	990	913	796	861	879
	1005	1107	1096	1197	1275	1320	1306	1305	1306	1309	1307	1276	1225	1160	1070	1149	1258	1379	1388	1335	1308	1294	1285	1225

Figure 13. Monthly variation of TDS in Al-Huweizah Marsh and Tigris River for the 3rd scenario, (maximum TDS in the marsh is below 1500ppm).



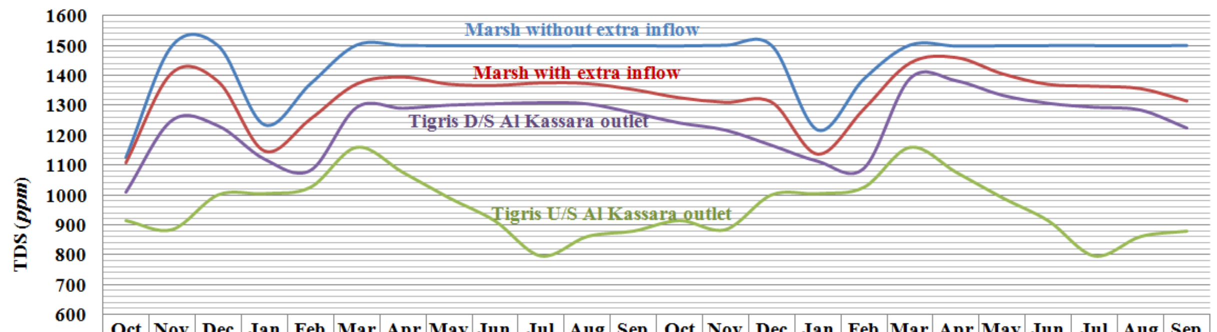
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
	1125	1497	1497	1423	1500	1498	1498	1497	1496	1497	1497	1498	1499	1497	1391	1294	1472	1500	1498	1497	1498	1497	1499	1497
	1109	1406	1381	1309	1359	1370	1393	1369	1364	1374	1371	1352	1326	1307	1236	1187	1332	1432	1459	1404	1369	1361	1356	1313
	914	884	1000	1004	1025	1158	1075	990	913	796	861	879	914	884	1000	1004	1025	1158	1075	990	913	796	861	879
	1011	1145	1132	1199	1267	1310	1291	1302	1305	1310	1306	1276	1242	1180	1059	1123	1224	1392	1384	1334	1308	1294	1286	1225

Figure 14. Monthly variation of TDS in Al-Huweizah Marsh and Tigris River for the 4th scenario, (maximum TDS in the marsh is below 1500ppm).



	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
	1125	1490	1499	1298	1499	1497	1497	1498	1498	1497	1499	1498	1499	1498	1498	1240	1500	1500	1497	1498	1498	1497	1498	1498
	1109	1401	1380	1205	1357	1362	1390	1370	1365	1374	1373	1352	1326	1308	1304	1149	1363	1438	1458	1405	1369	1361	1355	1313
	914	884	1000	1004	1025	1158	1075	990	913	796	861	879	914	884	1000	1004	1025	1158	1075	990	913	796	861	879
	1011	1257	1167	1154	1247	1283	1289	1303	1306	1309	1308	1276	1240	1218	1085	1114	1226	1393	1383	1335	1308	1294	1285	1225

Figure 15. Monthly variation of TDS in Al-Huweizah Marsh and Tigris River for the 5th scenario, (maximum TDS in the marsh is below 1500ppm).

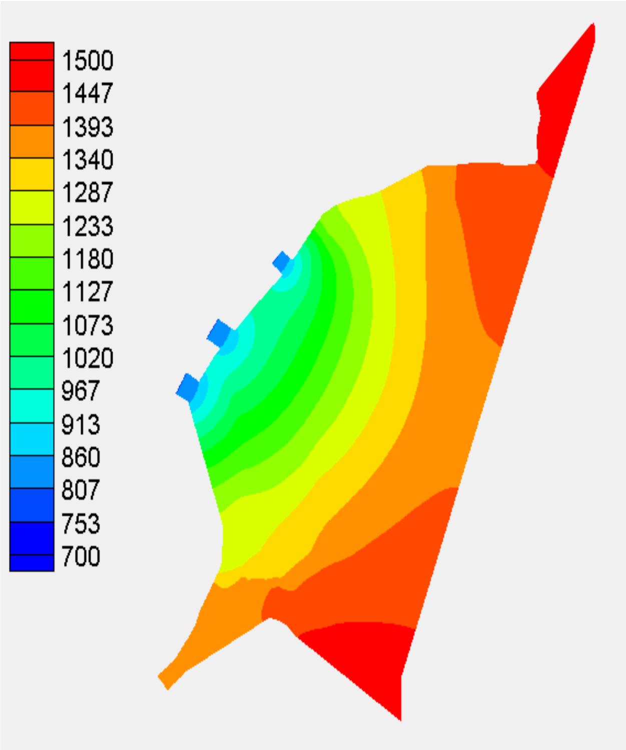


	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
	1125	1498	1498	1235	1371	1500	1499	1498	1498	1497	1498	1498	1497	1499	1499	1216	1387	1500	1497	1498	1498	1498	1498	1499
	1109	1407	1378	1148	1254	1370	1393	1370	1365	1374	1372	1352	1325	1309	1310	1137	1287	1440	1458	1404	1369	1363	1355	1314
	914	884	1000	1004	1025	1158	1075	990	913	796	861	879	914	884	1000	1004	1025	1158	1075	990	913	796	861	879
	1011	1251	1232	1122	1084	1294	1291	1302	1306	1310	1306	1276	1242	1218	1167	1114	1091	1391	1383	1335	1308	1295	1285	1225

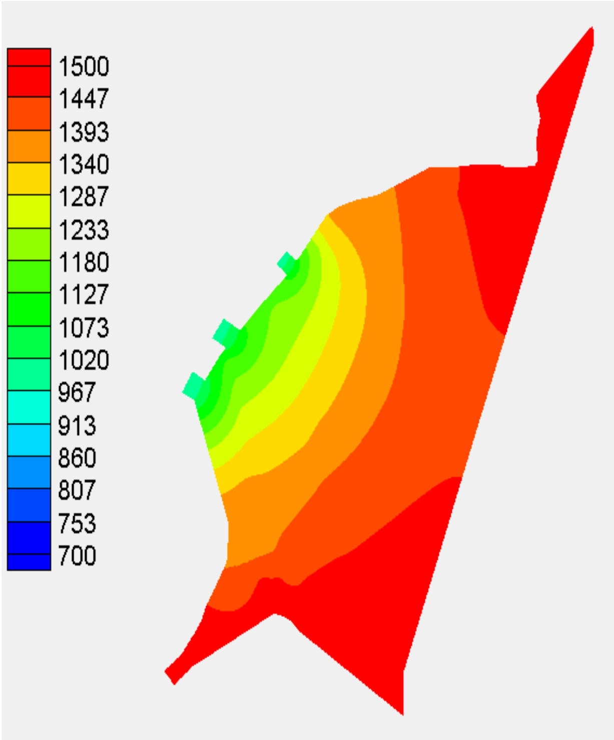
Figure 16. Monthly variation of TDS in Al-Huweizah Marsh and Tigris River for the 6th scenario, (maximum TDS in the marsh is below 1500ppm).

Table 6. Variation of TDS for Al-Huweizah Marsh before and after mixing with a share of Tigris River water (allocated to Shatt Al-Arab) for two consecutive years.

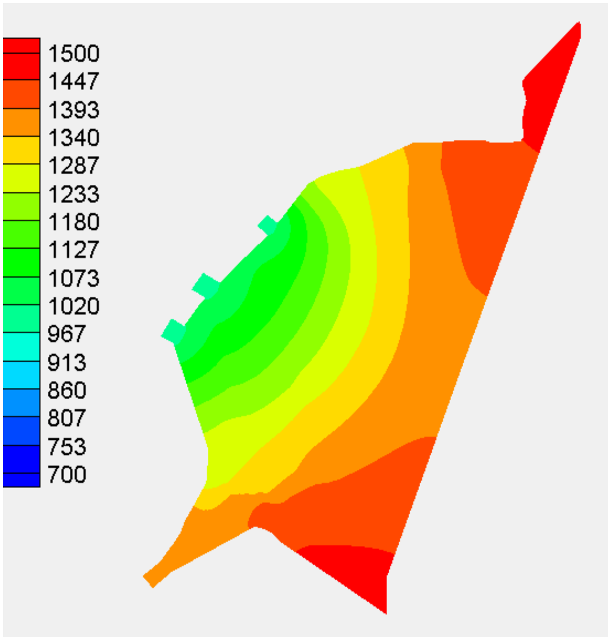
Maximum allowable TDS in *ppm*	**Scenarios**	**Al-Huweizah Marsh**			**Tigris River**		
		TDS, *ppm*		**Percentage of improvement**	**TDS, *ppm***		**Percentage of deterioration**
		without extra inflow	**with extra inflow**		**Before mixing**	**after mixing**	
1500	**S-1**	1492	1353	9	958	1258	24
	S-2	1466	1346	8	958	1245	23
	S-3	1469	1347	8	958	1245	23
	S-4	1465	1343	8	958	1246	23
	S-5	1463	1341	8	958	1251	23
	S-6	1450	1332	8	958	1243	23
1750	**S-1**	1731	1483	14	958	1341	29
	S-2	1664	1464	12	958	1323	28
	S-3	1664	1462	12	958	1322	28
	S-4	1654	1455	12	958	1322	28
	S-5	1663	1460	12	958	1325	28
	S-6	1660	1456	12	958	1319	27
2000	**S-1**	1962	1596	19	958	1409	32
	S-2	1852	1561	16	958	1385	31
	S-3	1849	1558	16	958	1385	31
	S-4	1835	1547	16	958	1384	31
	S-5	1847	1554	16	958	1387	31
	S-6	1855	1556	16	958	1379	31



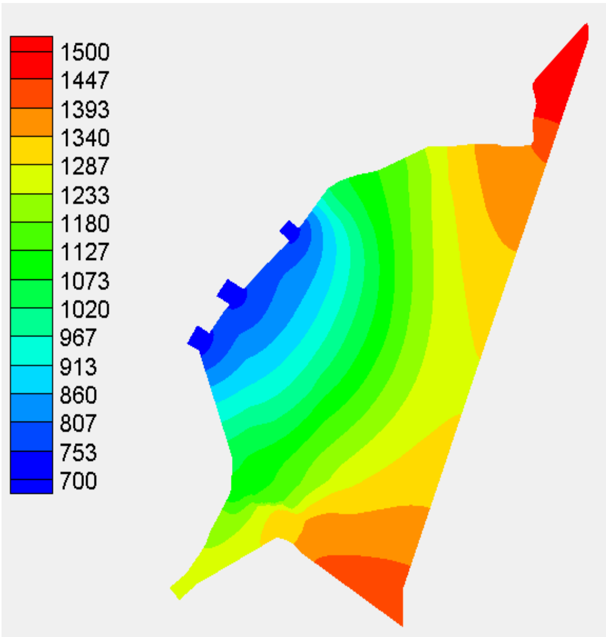
a. Autumn



b. Winter

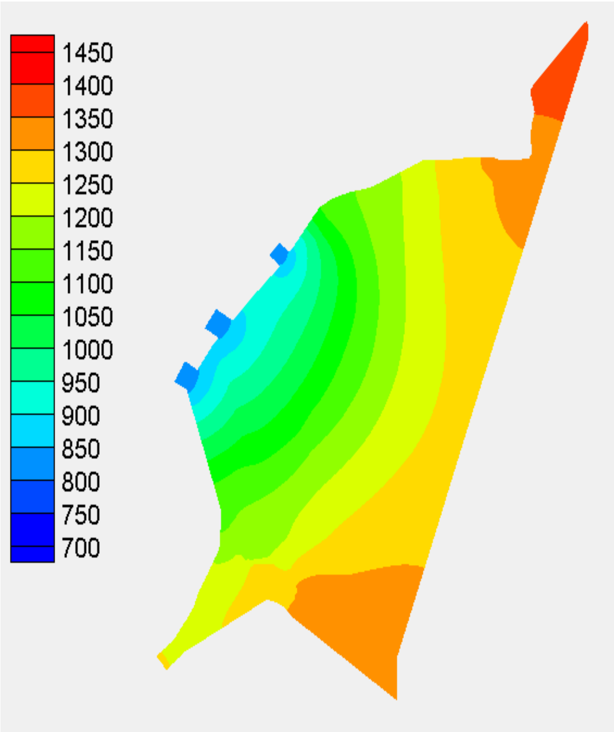


c. Spring

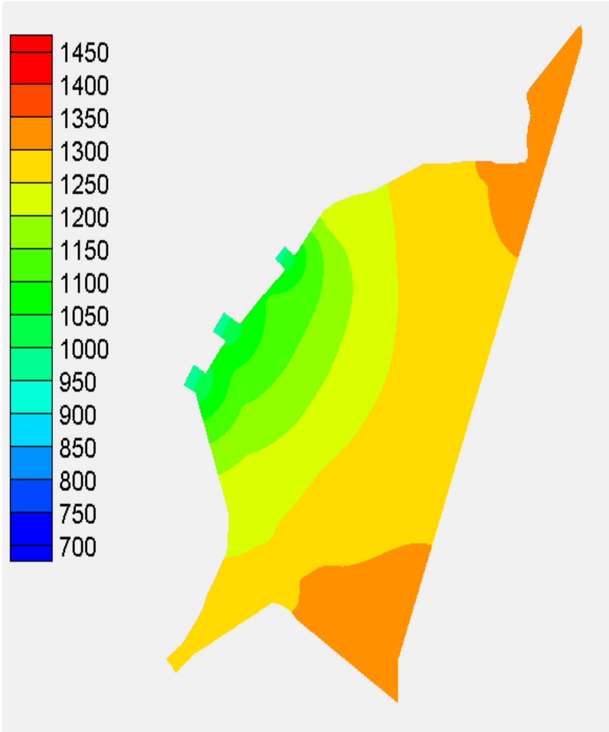


d. Summer

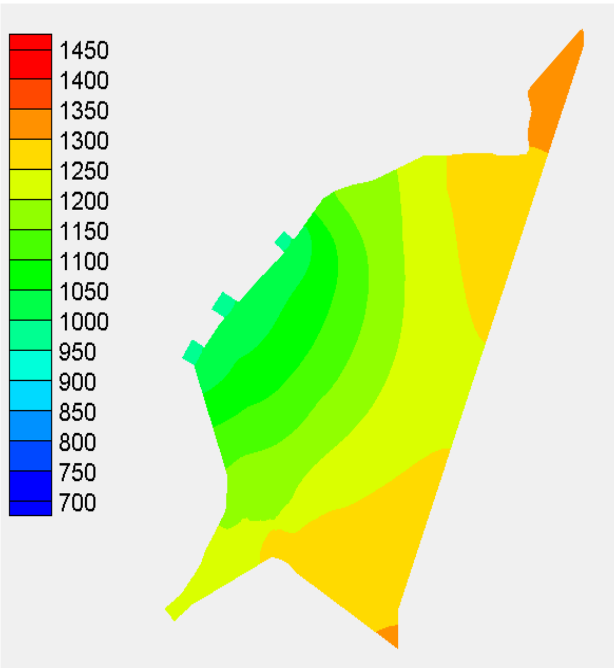
Figure 17. Seasonal TDS distribution within the marsh for 1st scenario without mixing with additional share.



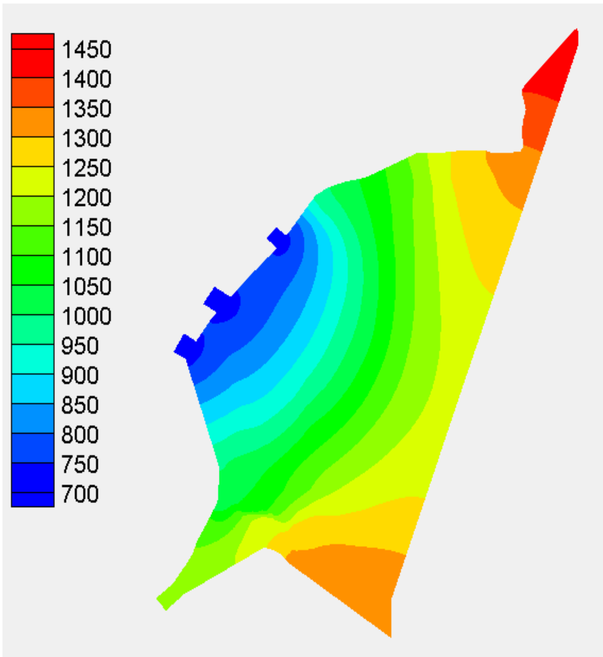
a. Autumn



b. Winter



c. Spring



d. Summer

Figure 18. Seasonal TDS distribution within the marsh for the 1st scenario with mixing with additional share.

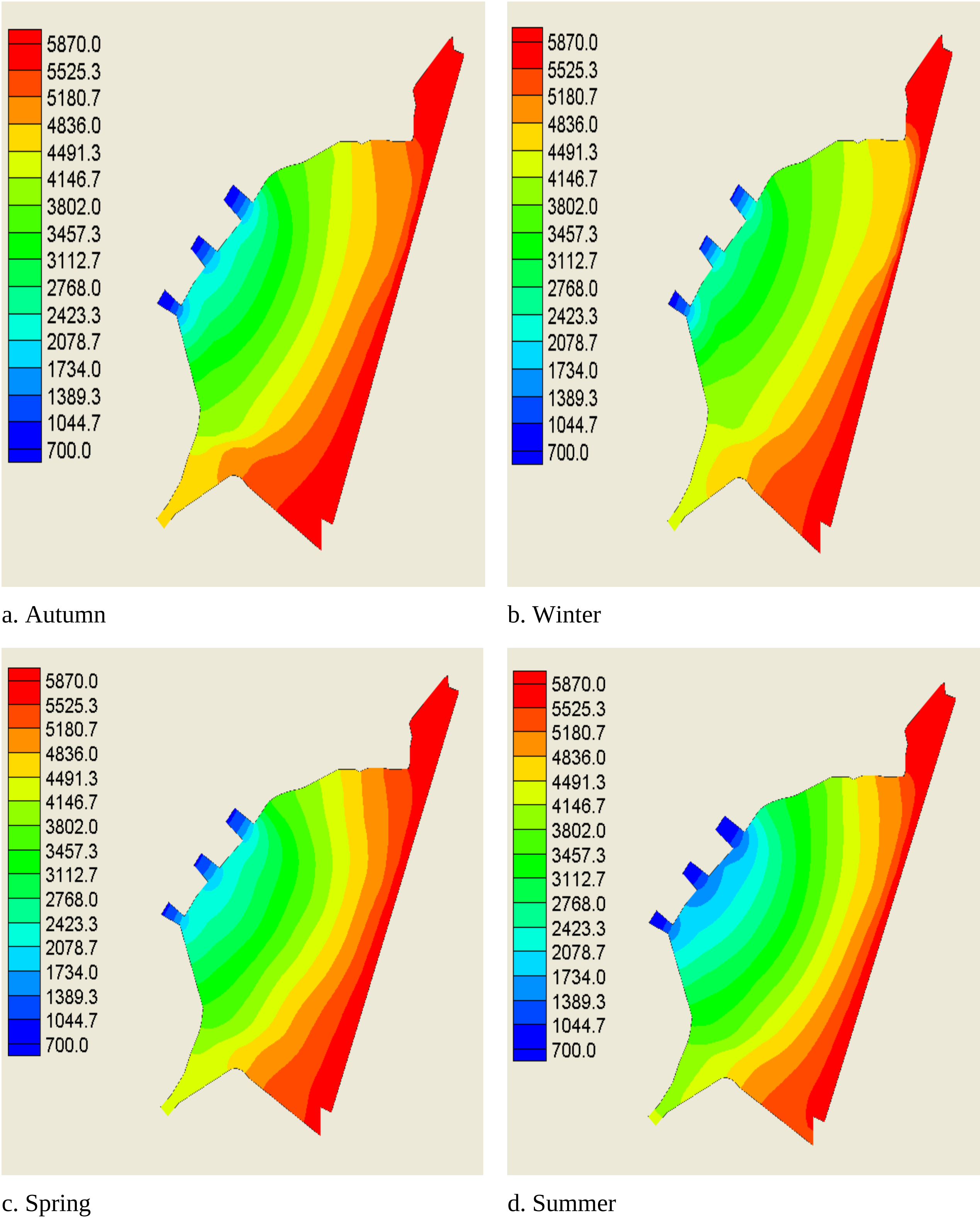


Figure 19. Seasonal TDS distribution within the marsh area with Iranian feeders for the 1st scenario without maxing with additional share.