Hydrological Operation Requirements for Restoration and Improving Water Quality of Al Qurna Marsh

Dr. Ali S. Al Saady*
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Abstract

A hydrological routing study for Al Qurna Marsh was carried out to estimate the hydrological state within the marsh for the Present and future conditions of the marsh.

The water surface elevation, area and storage within the marsh at the present and for the future conditions were estimated and the effect of uncontrolled outlets on the hydrological and water quality state of the marsh at the present conditions was specified.

The salt mass - balance equation was used to estimate the inflow and outflow discharges that required for reducing the effect of evapotranspiration on the water quality and flashing out the accumulated mass of salts and then improving the marsh water quality. This equation was applied on the future conditions of the marsh and inflow and outflow discharges that required for this purposes were estimated.

Results of the hydrological routing for the present conditions showed that the maximum water surface area is 785 km^2 which occur during October. While it is 431km^2 during September and it can not be increased during these months since the outlet of the marsh is uncontrolled. The TDS concentration within the marsh increases during the months of high evapotranspiration although the inflow increases during these months.

For the future conditions, the inflow discharges required to sustain the restoration requirements must be increased to decrease the deterioration in the marsh water quality. These discharges increase with the increase in the marsh area during the months of high evapotranspiration values.

Keywords: Hydrological Operation, Restoration, Improving Water Quality and Al Qurna Marsh.

متطلبات التشغيل الهيدرولوجية لإنعاش وتحسين نوعية مياه هور القرنة

الخلاصة

تم تنفيذ دراسة إستنباع هيدرولوجي لهور القرنة لتحديد الوضع الهيدرولوجي في الهور وفقاً للظروف الحالية والمستقبلية للهور.

تم حساب منسوب ومساحة سطح الماء والخزن في الهور للظروف الحالية والمستقبلية وتم تحديد تأثير المنافذ غير المسيطر عليها على الوضع الهيدرولوجي وعلى نوعية المياه في الهور للظروف الحالية.

تم إستخدام معادلة الموازنة الملحية لتحديد التصاريف التي يجب إدخالها وإخراجها من الهور لتقليل تأثير التبخر- نتح على نوعية المياه و تصريف كتلة الأملاح المتجمعة وبالتالي تحسين

* Building and Construction Engineering Department, University of Technology/ Baghdad

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2412-0758/University of Technology-Iraq, Baghdad, Iraq

نوعية مياه الهور. تم تطبيق هذهِ المعادلة على الظروف المستقبلية للهور وتم إيجاد التصاريف المطلوبة لهذا الغرض.

بينت نتائج الإستتباع الهيدرولوجي للظروف الحالية إن اقصى مساحة لسطح الماء هي 785كم^2 وتحصل في شهر تشرين الأول في حين تنخفض الى 431 كم^2 في شهر ايلول ولايمكن زيادتها اكثر من ذلك بسبب محدودية المياه المتوفرة ولعدم وجود منشأت سيطرة على منافذ الهور. كما إن تراكيز المواد الصلبة الذائبة تزداد في الهور خلال تلك الأشهر على الرغم من زيادة التصاريف خلال هذهِ الأشهر.

إن التصاريف المطلوبة لتلبية متطلبات إعادة الإغمار يجب زيادتها لتقليل التدهور في نوعية مياه الهور وهذهِ الزيادة تزداد مع زيادة مساحة الهور خلال الأشهر التي تكون فيها قيم لتبخر–نتح عالية.

Introduction

Al Qurna Marsh, is located to the east of Al Nassiriya City, south of the Tigris River branches in Amarah Governorate, and to the north of Euphrates River, Figure (1).

The wet area of Al Qurna Marsh is approximately 3000 km^2 during flood seasons. It can hold floodwater of 100 years recurrence interval. This area reduced to 600 km^2 during normal flow seasons.

The decrease in water discharges into the marsh during the last two decades destroyed the ecological system of this marsh.

During spring 2003, water has been flowing into this marsh again, the inundated area has increased, and vegetation appears to be regrowing.

Ministry of Water Resources, MoWR, and Center of Restoration of the Iraqi Marshland, CRIM, proposed and design two hydraulic structures, on the marsh feeders, and eight outlets to control and develop the hydraulic and environmental conditions of the marsh.

Restoration and conserving the ecological system of this marsh required continuous monitoring and control to the hydrological and water quality conditions in this marsh. Hydrological routing was used to estimate the hydrological conditions within the marsh for the Present, before constructing the proposed hydraulic structures, and Future, after constructing the proposed hydraulic structures, conditions. The salt mass-balance equation was used to estimate the required inflow and outflow discharges for reducing the effect of evapotranspiration on the marsh water-quality.

Hydrological System of the Marsh

The main water sources for Al Qurna Marshes are three rivers, Al Bittera, Al Areedh and Al Majer Al Kabeer Rivers, branches from the right side of Tigris Rive.

Al Bittera and Al Areedh are branched from the right side of Tigris River at about 15 km from the upstream of Al Amarah city. While Al Majer Al Kabeer River is branched from the same side of Tigris River at about 22 km downstream of Al Amarah city.

Another source of water for the marsh is the water flows from Abu Zirig Marsh through an aperture (Aperture 1) between these two marshes.

Water leaving the marsh through eight culverts connect the marsh with Euphrates River, Figure (1).

Two hydraulic control structures are designed to be built at the inlets of the marsh to control the inflow discharges in to the marsh. The first will be on Al Bittera River which modifying the flow of Al Areedh and Al Majer Al Kabeer Rivers to accommodate at a point upstream of this structure. The second will be on the aperture (Aperture 1) between Al Qurna and Abu Zirig Marsh.

Ground Surface Elevation

Al Qurna Marsh topographical survey data presented in New Eden Water and Energy Project in Southern Iraq, (IMET, 2006), were adopted to implement the DEM for this marsh. Figure (2). According to the implemented DEM the area-elevation and storage-elevation curves of this marsh were constructed and shown in Figures(3) and (4) respectively.

The Inflow and Outflow Discharges

The inflow and outflow discharges of the feeders and outlets of the marsh were studied and tabulated according to the present and future conditions. The measured discharges of the feeders and outlets of the marsh during the year 2008 for the period from February to December, CRIM (2008), were adopted for the present conditions. While, for the future conditions, the discharges of the feeders and outlets of the marsh were specified according to the historical data and the recommendations of the studies and plans concerning these marshes, especially that of the Ministry of Water Resources.

The Inflow and Outflow Discharges for the Present Conditions

The inflow and outflow discharge of the feeders and outlets of the march measured, seasonally, during the year 2008 (CRIM, 2008) for the period from February to December. These discharges listed in Table (1).

The Inflow and Outflow Discharges for the Future Conditions

The inflow discharges of the marsh for the Wet, Moderate and Dry water years were specified by MoWR (MoWR and IMELS, 2007), according to the restoration requirements of the marsh ignoring the water quality requirements, Table (2). So, these discharges were adopted in the hydrological routing of this marsh. The 100%, 75% and 50% restoration requirements were considered for the Wet, Moderate and Dry years, respectively. The two aperture, (Aperture 1 and Aperture 2), will be closed.

The outlets of this marsh will controlled by control structures designed by MoWR to compassing the positive operation for the hydraulic system of this marsh.

These control structures are designed to build at the outlets of the marsh. These structures can manage both low flows (up to $12m^3/s$) and can pass a 100-year flow event, equal to $80m^3/s$. Every structure is comprised of 2 gates plus a boat passage and a weir system.

Evapotranspiration within the Marsh Area

Since the monthly evapotranspiration represent the major losses within the marsh area, the estimated evapotranspiration by New Eden Master Plan (MoWR and IMELS, 2007), was adopted. The calculated monthly Evapotranspiration for the marsh area is listed in table (3). The annual precipitation within the marsh are approximately 150 mm which less than 10 % of the existing evapotranspiration within the marsh area. Accordingly, the effective rainfall was not be considered in the hydrological routing.

Marsh Water Quality

Because there is no systematic monitoring for the quality of the marsh water, the new hydraulic situation since 2003, and the available recorded data concerning the water quality, within the marsh and their feeders, is not covered the whole contaminants and is not continuous or consequential for an enough period to ensure the accurate estimation for the seasonal average concentration of the water contaminants during the Wet, Moderate and Dry water years, then the seasonal average concentration of the water contaminants for the marsh feeders were estimated based on the available recorded data as follows

Dry years

The collected water samples at the feeders and outlets of the marsh during the year 2008 for the period from February to December, (CRIM, 2008), were used in this study. The measured TDS concentrations during this period are listed in table (4).

Moderate years

The water quality of Tigris River at Al Amarah Governorate were adopted as the water quality for the feeders of this marsh during such year since there is no other useful recorded data, (MoWR, 2008). table (4).

Wet years: The estimated water quality of the moderate years was adopted for the wet years since there is no recorded data during such year.

Hydrological Routing

Water balance equation, Eq. (1), was used to determining the flow hydrographs for the marsh inlet and outlet, the area and storage variation with time within the marsh. This routing requires hydraulic data (discharges and stages) for the marsh feeders and outlets, climatological and topographical data.

$$S(i+1) = S(i) + [Qin(i) - Qout(i) - Qe(i)]\Delta T \quad ..(1)$$

where

S is the storage (L^3).

Qin is the inflow discharge (L^3/T) from the marsh feeders.

Qout is the outflow discharge (L^3/T) from the marsh outlets.

Qe is the evapotranspiration discharge (L^3/T) from the marsh area.

ΔT is the time interval of the hydrological routing (T).

i is the time index of the hydrological routing, (i = 0, 1, 2, 3, ……,n), n is the total period of the hydrological routing.

The hydrological state of the marsh was studied according to the present and future conditions of the marsh, and accordingly, two monthly hydrological routings were implemented and applied for the marsh. The first; concerns the present conditions, and the second; concerns the future conditions.

Hydraulic Operation Requirements for Improving the Marsh Water Quality

The inflow discharges into the marsh during the Wet, Moderate and Dry years were specified by CRIM (CRIM, 2007) according to the restoration requirements, as previously mentioned, ignoring the water quality issue. Then these discharges were studied and re-estimated considering the water quality requirements. Based on the salt mass-balance equation, Eq.. (2), and using the TDS concentration within the marshes and their feeders and considering the evapotranspiration effect on the water quality of the marsh, the hydraulic operation requirements were specified.

$$S(i+1)\,Cm(i+1) - S(i)\,Cm(i) = (Qin(i)\,Cin(i) + Qe(i)\,Cm(i) - Qout(i)\,Cout(i))\,\Delta T \quad \ldots (2)$$

where

Cm is the TDS concentration within the marsh (M/L^3).

Cin is the TDS concentration of the inflow discharge (M/L^3).

Cout is the TDS concentration of the outflow discharge (M/L^3).

Taking in consideration that the flow velocity within the marshes is low, because of the flat topography of the marshes and the effect of vegetation. Then the TDS concentration of the outflow water (Cout(i)) can be estimated considering the effect of Evapotranspiration on the marsh quality at the time interval (i) using equation (3).

$$Cout(i) = \frac{(Qe(i)Cm(i)\Delta T + S(i)Cm(i))}{S(i)} \quad \ldots\ldots (3)$$

In order to reduce the effect of the evapotranspiration and conserving the water quality within the marsh, to be near to that of the inflows water into the marsh, an equally extra inflow into the marsh and outflow from the marsh is required. This value of extra inflow and out flow must be added to the required inflow and outflow that specified by CRIM, 2007, to maintain the restoration requirements. The total change in the mass of the TDS due to the extra inflow minus extra outflow must be equal to that due to the evapotranspiration, so:

$$Qe(i)Cm(i) = Qextout(i)Cout(i) - Qextin(i)Cin(i) \quad \ldots..(4)$$

where

Qextin is the extra inflow required to decrease the TDS concentration and to flash out the accumulated TDS.

Qextout is the extra outflow required to flash out the accumulated TDS.

Since; $Qextin(i) = Qextout(i)$, as mentioned above, then

$$Qe(i)Cm(i) = Qextin(i)Cout(i) - Qextin(i)\,Cin(i) \quad \ldots (5)$$

$$Qextin(i) = \frac{Qe(i)\,Cm(i)}{Cout(i) - Cin(i)} \quad . (6)$$

then by substituting eq. (3) in eq. (6).

$$Qextin(i) = \frac{Qe(i)\,Cm(i)}{\frac{Qe(i)\,Cm(i)\,\Delta T + S(i)\,Cm(i)}{S(i)} - Cin(i)} \quad \ldots.(7)$$

Equation (7) was used to estimate the required inflow and out flow to develop Water Quality of the marsh during the present and future conditions.

Results

Based on the constructed area and storage elevation curves for the marsh, Figures (3) and (4), and the estimated evapotranspiration, Table (3), and using the tabulated discharges of the feeders and outlets of the marsh, Table (1), for the present condition and the tabulated discharges of the feeders and outlets of the marsh, Table (2), for the future conditions the hydrological routing of the marsh for the present and future conditions was carried out using equation (1). According to the above conditions the variation of water surface area and storage within the marsh were obtained and shown in Figures (5) and (6) for the present condition, and Figures (7) and (8) for the future conditions.

According to the tabulated TDS concentration, Table (4), area and storage and inflow discharges for the future conditions of the marsh and applying equation (7), the estimated required inflow and outflow discharges for the marsh during the Wet, Moderate and Dry water years are shown in Figures (9) to (11).

Discussion

Results of the hydrological routing for the present conditions, Figures (5) and (6), showed that the water surface area and storage are decreased during the period from June to November Although the inflow discharges into the marsh increase because of the high flow in Tigris River during these months, but this increase concedes with increase in the outflow from the marsh, since the outlets of the marsh are uncontrolled, and the evapotranspiration values are high during these months. The effect of losses due to evapotranspiration on the marsh during these months is greater than the gain due to the net inflow (inflow minus outflow). The losses due to evapotranspiration cause an increase in the TDS concentration during these months.

To decrease this effect the inflow and outflow discharges must be increased during these months to flash out the accumulated TDS in the marsh.

Results of the hydrological routing for the future conditions, Figures (7) and (8), showed that the marsh area can be increased during the period from October to June to be greater than 2077 km^2, for the Wet, Moderate and Dry water years, by making use of the proposed control structure at the outlet of the marsh.

Increasing the area of the marsh during this period causing an increase in the water losses due to evapotranspiration during the months of high evapotranspiration values. More TDS will accumulate in the marsh due to these losses.

The required inflow and outflow discharges to flash out the accumulated TDS, Figures (9) to (11), are increasing with the increase in the marsh area during the months of high evapotranspiration values.

Conclusions

The following conclusions are obtained:

1- The low inflow into the marsh decreases the water surface area of the marsh to be with maximum of 785 km^2, with water surface elevation 2.6 (m.a.m.s.l), at October and minimum of 431 km^2, with water surface elevation 1.8 (m.a.m.s.l), during September.

2- The TDS concentration within the marsh increases during the months of high evapotranspiration although the inflow is increasing during these months. Therefore, the inflow and outflow discharges during these months must be increased to flash out the accumulated TDS.

3- The water surface area of the marsh can not be increasing during the months of low flow since the outlet of the marsh is uncontrolled.

4- After constructing the proposed control structure, the area of the marsh can be increased during the months of low flow.

5- The inflow and outflow discharges that specified by CRIM, 2007, to sustain the restoration requirements must be increased to decrease the deterioration in the marsh water quality through flashing out the accumulated TDS.

6- The inflow and outflow discharges that required to flash out the accumulated TDS increase with the increase in the marsh area during the months of high evapotranspiration values.

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Table (1) Measured inflow and outflow discharges at the feeders and outlets of the marsh(m^3/s) (*After CRIM, 2008*).

Feeders and outlets		Season			
		Spring	**Summer**	**Autumn**	**winter**
Feeders	Al Bittera	2.1	2.4	2	2.2
	Al Areedh	4.0	4.0	4.1	4.0
	Al Majer Al Kabeer	1.0	1.3	0.8	1.0
	Az1	1	0.8	0.7	0.9
	Az2	0.5	0.4	1.1	0.6
	Total inflow	8.6	8.9	8.7	8.7
Outlets	Al-Sbaghea	2.5	2.5	0.0	1.7
	Abu-nersy	0.6	1.0	0.0	0.5
	Abu-Sobat	0.3	0.2	2.0	0.8
	Abu-Jwelan	0.5	0.5	0.0	0.3
	Al-Badreea river	0.4	0.4	0.4	0.4
	Al-kehala river	0.3	0.3	0.4	0.3
	Al Shafiea River	0.5	1.0	0.0	0.5
	Al-khenzeeri	0.6	0.4	0.7	0.6
	Total outflow	5.7	6.3	3.5	5.1

Table (2) Discharges of the feeders (m^3/sec). (*after MoWR and IMELS, 2007*).

Month	Water Year		
	Wet Year	**Moderate Year**	**Dry Year**
Oct.	245	126	90
Nov.	250	150	117
Dec.	350	200	126
Jan.	350	225	130
Feb.	357	225	116
Mar.	220	180	80
Apr.	180	125	67
May.	120	100	55
Jun.	80	60	24
Jul.	60	60	10
Aug.	60	60	22
Sep.	60	60	57

Table (3) Estimated monthly Evapotranspiration (mm/month) for the marsh area (*after MoWR and IMELS, 2007*).

Month	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Yearly
ETo	48	48	48	48	48	48	48	48	48	48	48	48	48

Table (4) TDS concentration (PPM) at the feeders and outlets of the marsh for the Dry , Moderate and Wet water year (*after CRIM, 2007 and CRIM 2008*).

Water Year	station	Season			
		winter	Autumn	Summer	Spring
Dry	Al Bittera	3270	4116	4962	1100
	Al Areedh	3490	3846	4201	1140
	Al Majer Al Kabeer	3569	3775	3980	952
	Az1	1191	1090	1292	665
	Az2	1272	1234	1309	710
	Outlet	2867	4434	6000	4442
Moderate	Al Bittera	636	645	675	627
	Al Areedh	636	645	675	627
	Al Majer Al Kabeer	636	645	675	627
	Az1	636	645	675	627
	Az2	636	645	675	627
	Outlet	636	645	675	627
Wet	Al Bittera	636	645	675	627
	Al Areedh	636	645	675	627
	Al Majer Al Kabeer	636	645	675	627
	Az1	636	645	675	627
	Az2	636	645	675	627
	Outlet	636	645	675	627

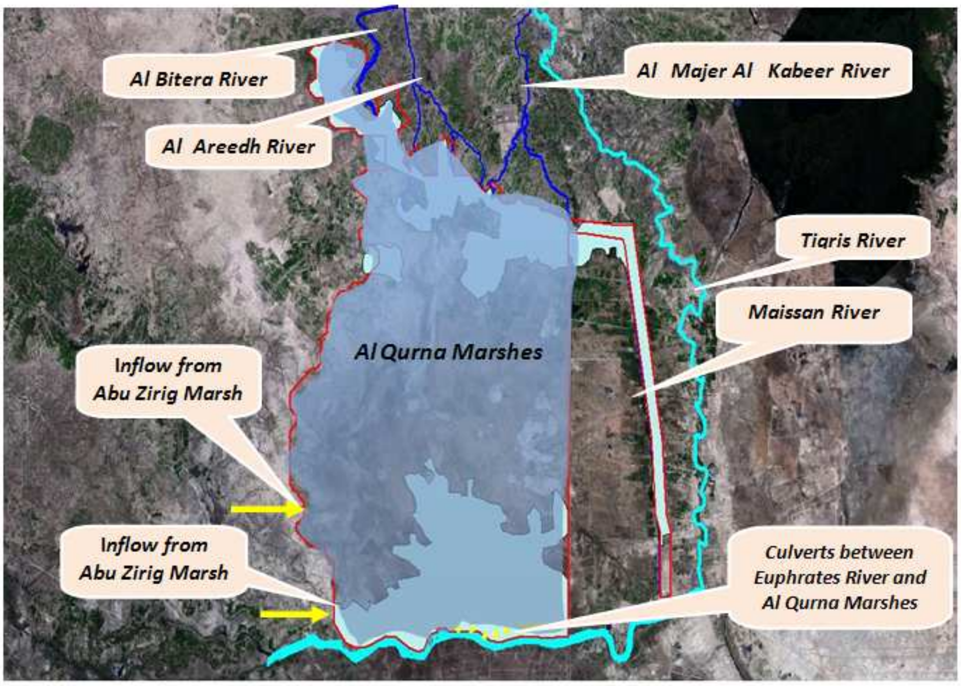

Figure (1) General Satellite Image of Al–Qurna marshes.
(After Mr. Sid software)

m,a,m,s.l

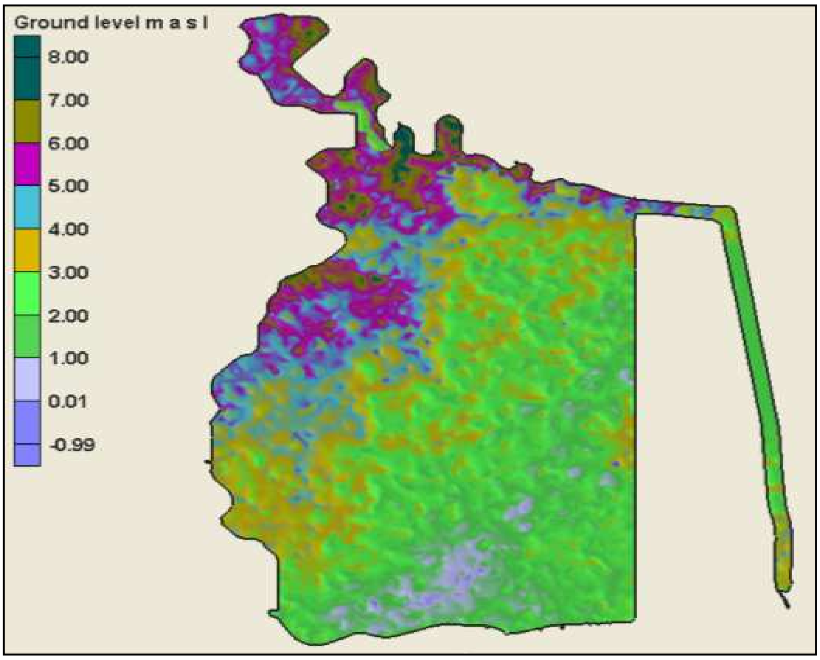

Figure (2) Digital Elevation Model (DEM) of Al Qurna Marsh.

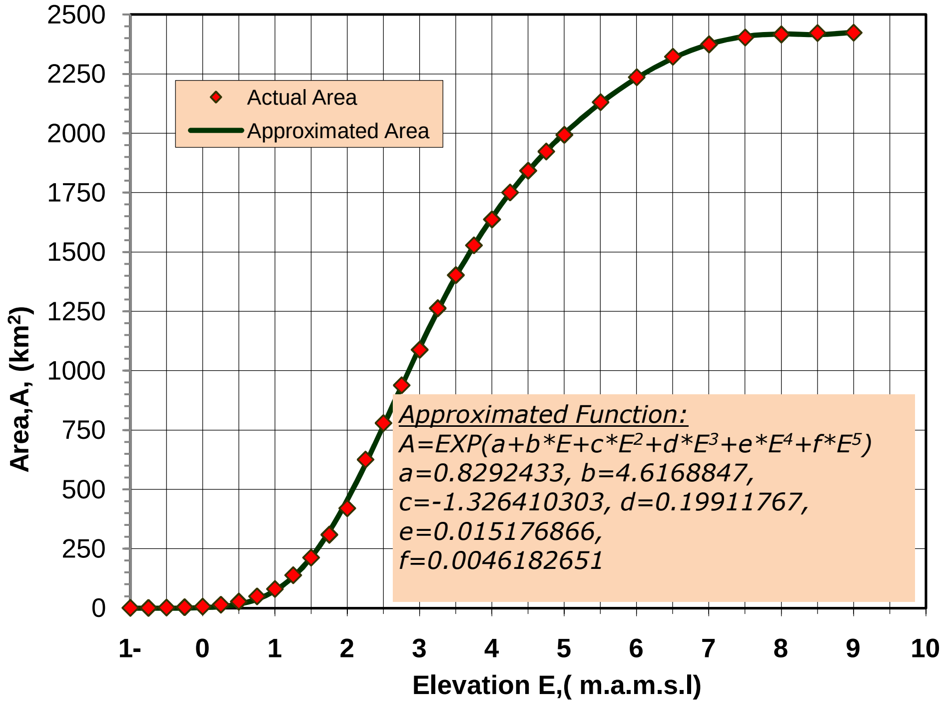

Figure (3). Area-Elevation Curve of Al Qurna Marsh.

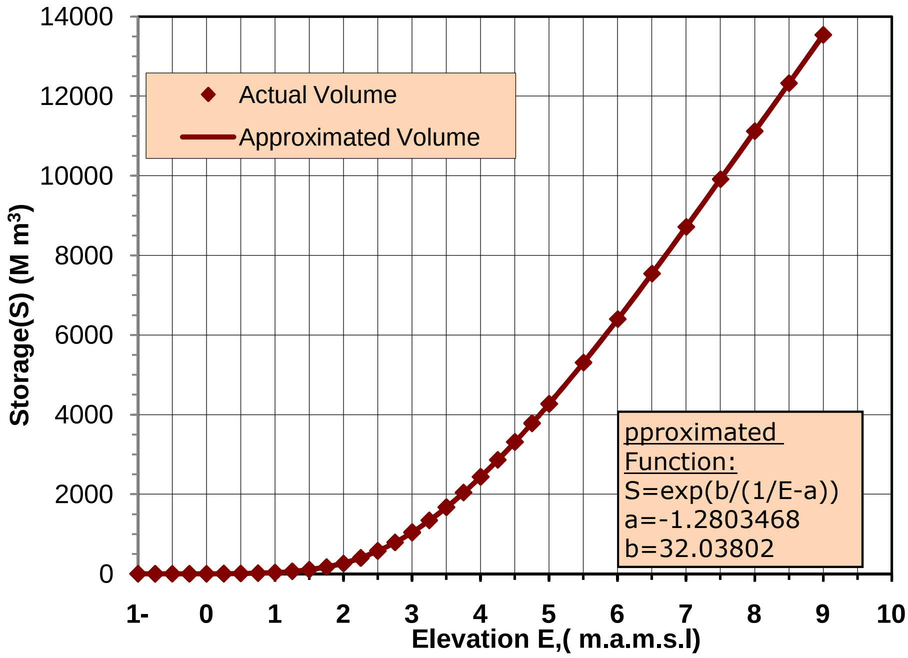

Figure (4). Storage-Elevation Curve of Al Qurna Marsh.

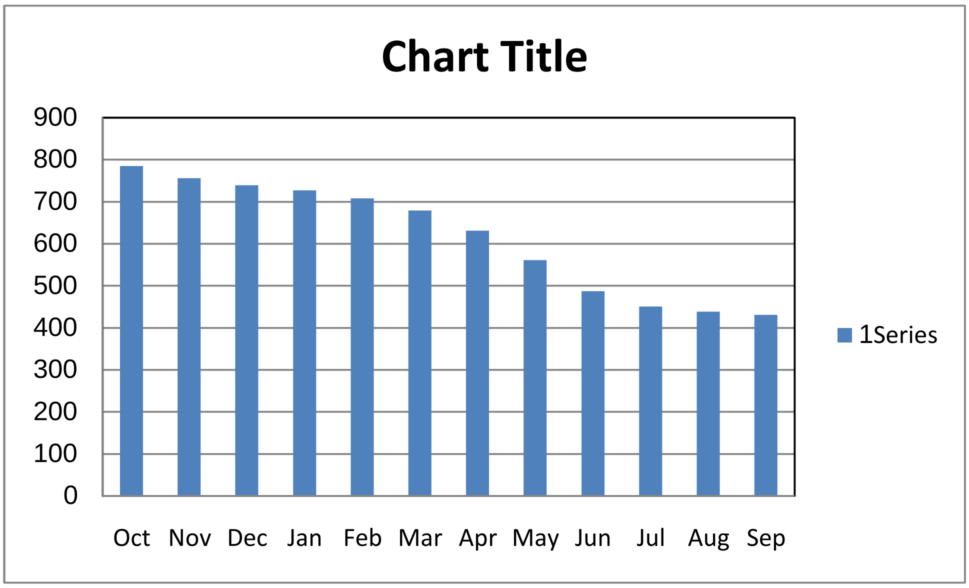

Figure (5) Variation of Water Surface Area within the marsh during the present conditions.

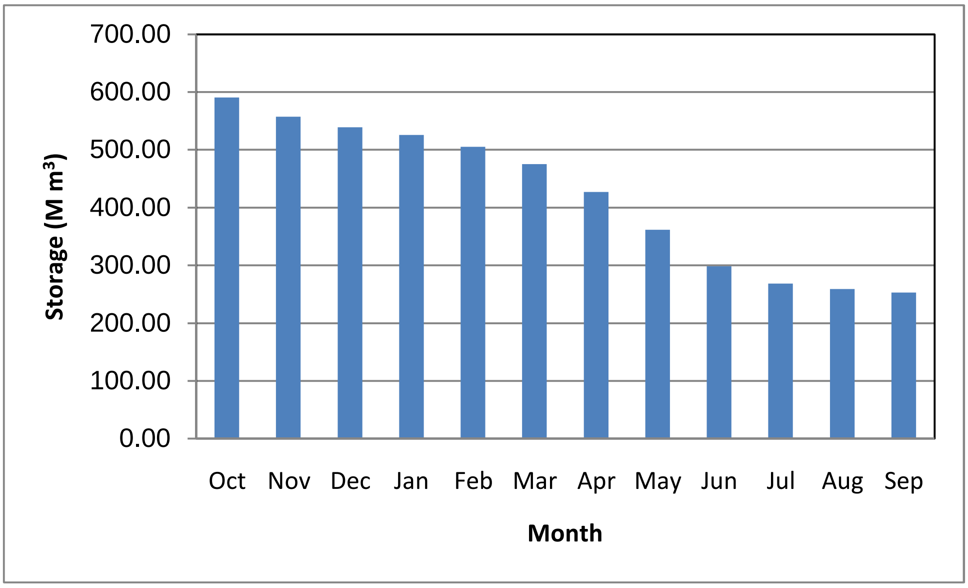

Figure (6) Variation of storage within the marsh during the present conditions.

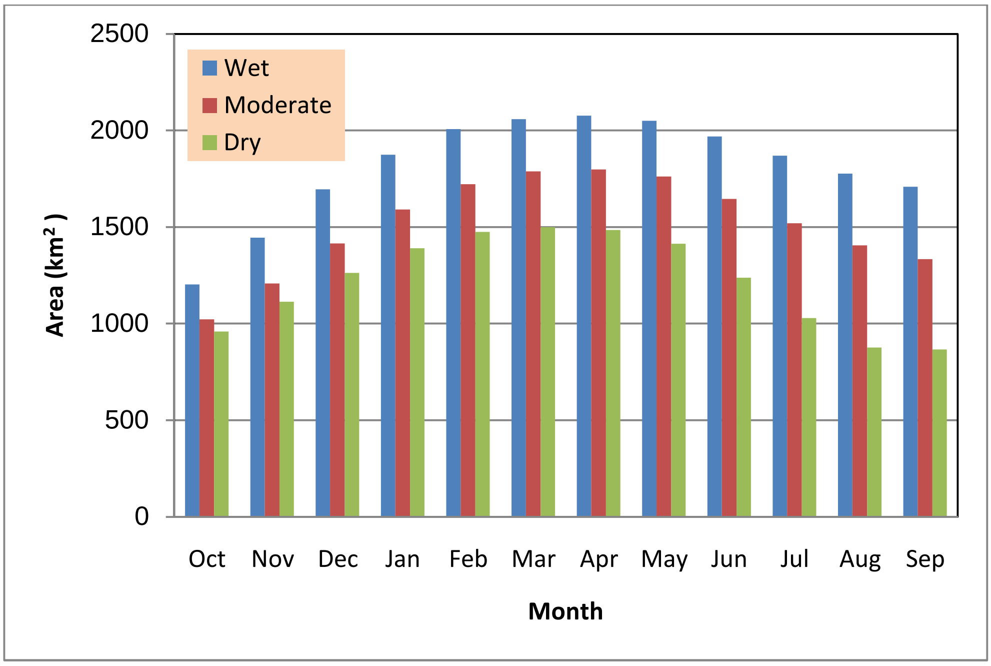

Figure (7) Variation of water surface area within the marsh during Wet, Moderate and Dry years for the future conditions.

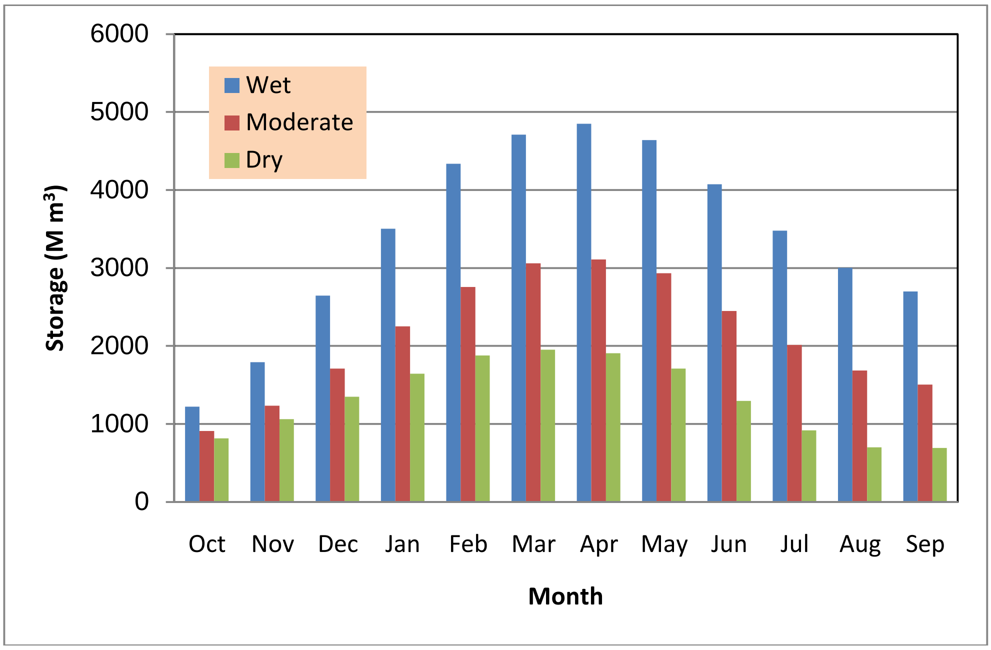

Figure (8) Variation of storage within the marsh during Wet, Moderate and Dry years for the future conditions.

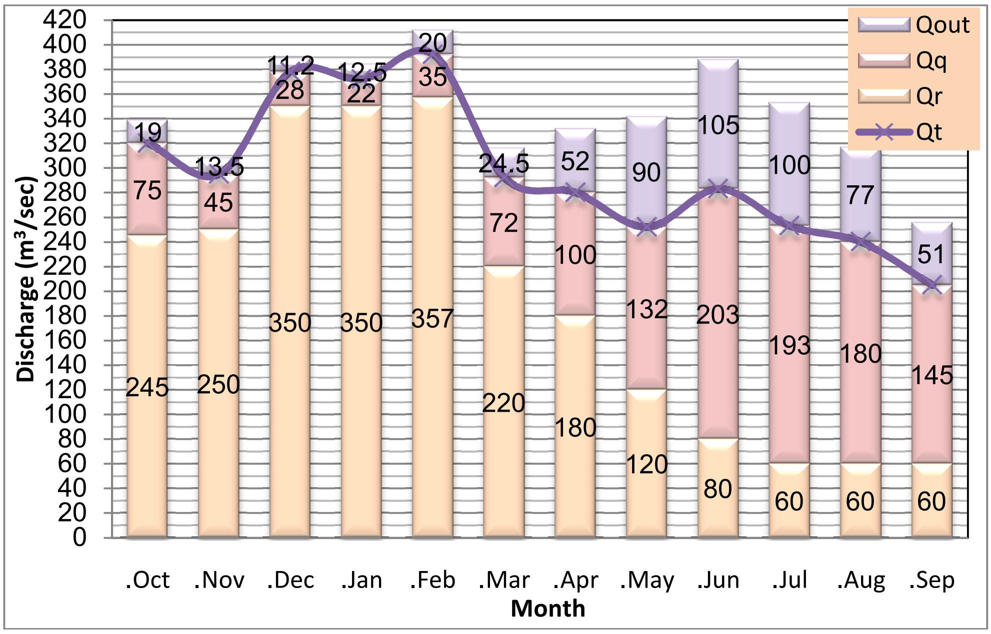

Figure (9) Required inflow and out flow for Restoration, Qr, and for Water Quality Development, Qq, during the Wet year.

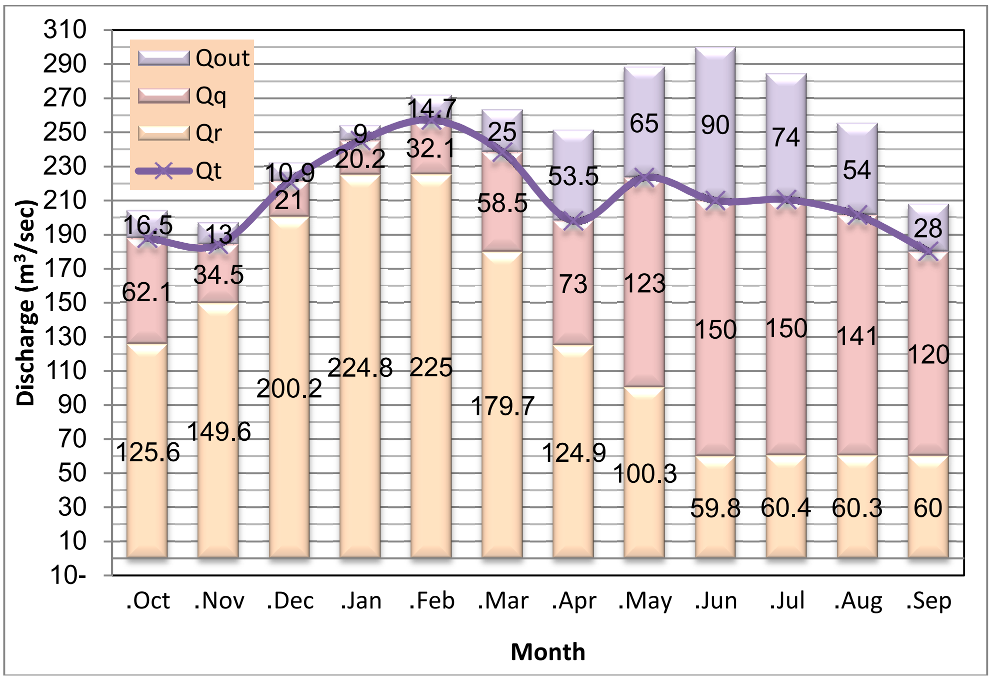

Figure (10) Required inflow and out flow for Restoration, Qr, and for Water Quality Development, Qq, during the Moderate year.

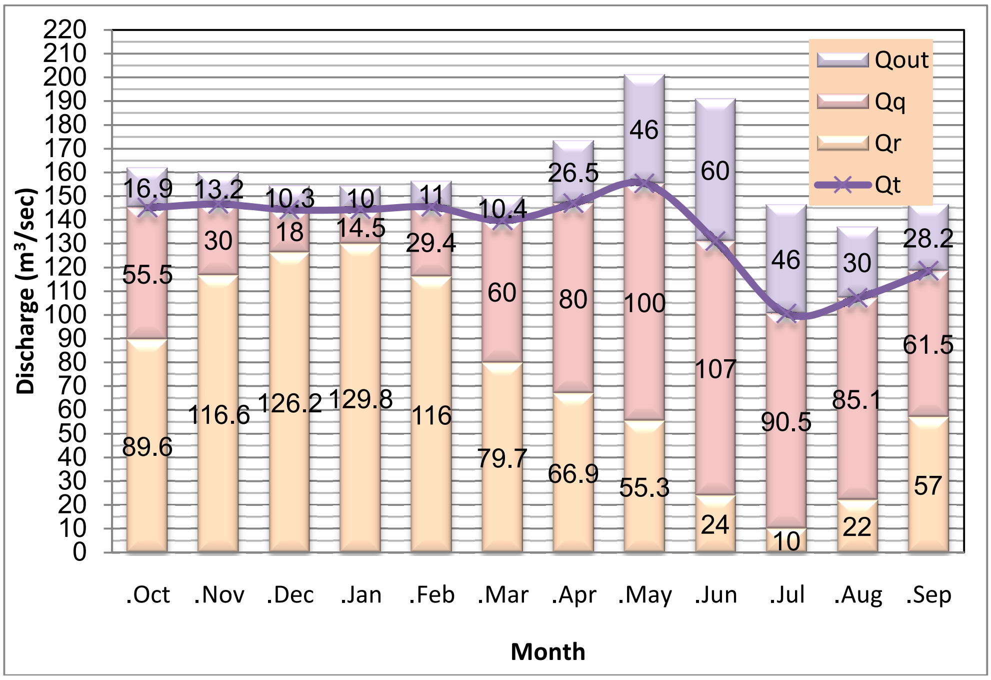

Figure (11) Required inflow and out flow for Restoration, Qr, and for Water Quality Development, Qq, during the Dry year.