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WATER BUDGET FOR ABU ZIRIG MARSH IN SOUTHERN IRAQ

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Abstract: The marshes of Iraq are located in the southern part of the country with small portion that is located in Iran. They cover an area of about 15000-20000 km^2. The marshes consist of hydraulically connected shallow lakes and scattered ponds. Three major marsh areas are considered the core of the wetlands of Iraq: (i) Al Hammar Marshes; (ii) the Central Marshes and (iii) Al Hawizeh Marshes. During the last two decades of the twentieth century, the marshes were subjected to natural and deliberate dryness and destruction and their area reduced to about 10% of the original area. The Iraqi regime in the early nineties of the last century has cut off the marshes' inflow supplies and dried out the majority of the core marshes permanently. The regime has constructed numerus dykes, manmade cannels to implement the draining the drying process. Efforts are underway to restore the dried marshes. The restoration process requires sustained surface water supplies to re-flood the area and sustain it. Abu Zirig is a small marsh that is part of the Iraqi Central Marshes (ICM). The marsh constitutes a natural depression at the mouth of al Gharraf River. It is situated about 40 km to the east of Nassiriah city. The marsh was one of the marshes dried by diverting flows away from it via manmade embankments. Abu Zirig was part of the re-flooded marshlands. The embankments were removed immediately following the fall of Saddam's regime on the year of 2003. Its restored area was about 120 km^2. The marsh consists of two parts separated by manmade dyke; upper and lower parts. This paper is an attempt to study the hydrology of the Abu Zirig Marsh, specifically, the water budget. Determination of water budget component in situ (i.e. the marshes area) is needed to evaluate the restoration process. It was found that the only inflow source was surface water flowing from al Gharraf River. Losses were to infiltration and evaporation. The marsh was considered operating on steady state, so that change in storage during the study period was zero.

Keywords: *Abu Zirig Marsh, water budget, Iraqi Southern Marshes, al Gharraf River, Water Resources of Iraq.*

الموازنة المائية لهور أبو زرك الواقع في الجنوب العراقي

الخلاصة: تقع الاهوار في الجزء الجنوبي من العراق في معظمها مع جزء صغير منها يقع في ايران، تقدر مساحتها بحوالي 15000-20000 كم^2. تتألف الاهوار من بحيرات متصلة هيدروليكياً او من بحيرات او مسطحات مائية متوزعة بشكل عشوائي. الا ان الأهوار الرئيسية التي تشكل الجزء الاساسي لاهوار العراق هي ثلاثة: (أ) هور الحمار (ب) الاهوار المركزية (ج) هور الحويزة. وقد تعرضت هذه الاهوار خلال العقدين الاخيرين من القرن العشرين الى التجفيف الطبيعي والبشري المتعمد الذي ادى الى تدمير هذه البيئة الطبيعية اذ

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انخفضت مساحتها الى حوالي 10% من مساحتها الاصلية. حيث قامت الحكومة العراقية في مطلع التسعينيات من القرن الماضي بقطع المياه عن الاهوار وتجفيف معظم الاهوار الرئيسية بشكل دائم. وقد شيد النظام العديد من السداد والقنوات لتنفيذ عملية التجفيف. بعد سقوط النظام عام 2003 بذلت الجهود لانعاش الأهوار المجففة واعادتها إلى سابق عهدها. ان عملية انعاش الاهوار تتطلب تجهيز مياه سطحية مستمرة لاعادة غمر المنطقة والحفاظ عليها. ابو زرك هو احد الاهوار الصغيرة التي تقع ضمن الاهوار المركزية اذ يشكل منخفض طبيعي في نهاية مجرى نهر الغراف، ويقع على بعد 40 كم الى الشرق من مدينة الناصرية. ويعتبر احد الاهوار التي تعرضت الى التجفيف من خلال تحويل جريان المياه عن مسارها الطبيعي باستخدام السداد الصناعية. يعتبر هور ابوزرك من اول الاهوار التي اعيد غمرها بالمياه من خلال ازالة السداد مباشرة بعد سقوط النظام السابق في عام 2003، اذ بلغت المساحة التي اعيد اغمارها حوالي 120 كم^2. تتالف هذه المساحة من جزئين يفصل بينهما حاجز تم استخدامه كطريق يفصل بين الجزء العلوي والسفلي من الهور. هذا البحث هو محاولة لدراسة الخصائص الهيدرولوجية لهور ابو زرك، وعلى وجه التحديد دراسة الموازنة المائية. ان حساب الموازنة المائية هو احد المتطلبات الرئيسية لتقييم عملية انعاش الهور. وقد تبين في البحث ان مصدر المياه الداخلة الى الهور هو احد الجداول المتفرعة من نهر الغراف. ويعاني الهور من خسائر في كميات المياه نتيجة الرشح والتبخر. وبما ان الهور يكون بحالة مستقرة لذا فان مقدار التغير في الخزين المائي خلال فترة الدراسة كان صفراً.

1. Introduction

Marshes of Iraq (al-Ahwaar) are located in the Southern part of the country; representing the largest wetland ecosystem in the Middle East, have environmental, historical, and sociocultural significance. Specifically, the marshes are Located in the area ssurrounding the confluence of the Euphrates and Tigris rivers in the governorates of Basra, Maysan, and Thiqar in southern Iraq [1]. The marshes covered in 1970 an estimated area between 15,000– 20,000 square kilometers [2]. However, there are three major marshes considered the core of the wetlands of Iraq: (i) Al Hammar Marshes; (ii) the Central Marshes and (iii) Al Hawizeh Marshes. They cover an area of about 8800 km^2, mostly in Iraq, and small portion in Iran [2]. Each major marsh zone consists of hydraulically connected shallow lakes and scattered ponds.

Inflows to the marshes reduced starting on 1975 due to the upstream hydraulic structures and reservoirs. In addition, the marshes have been devastated by the combined impact of massive drainage works implemented in southern Iraq in the late 1980s/early 1990s (the previous regime) and upstream damming. Consequently, the deliberate destruction undertaken by the government during the 1990s and the reduction to <15% of the natural wetland extent was an environmental disaster [2] and reached to about 10% by the year 2001 of the original area [3].

The marshes area includes as well other small marshes scattered all over the area. Some of these small scattered marshes receive their inflow from the Gharraf River. The Gharraf branches from the right bank of the Tigris River just upstream of the Kut Barrage. The Gharraf flows through the southern part of Wasit and the northern Part of Thi Qar Governorates. The river ends at the western edge of the marshes area forming several minor marshes. Abu Zirig marsh is one of them. The marsh is located south and southeast of al Islah town, north to northeast of al Fuhud town, and about 30 km east of al Nassiriah City. Al Nassiriah is the capitol of Thi Qar Governorate, Figure 1.

The previous Iraqi Regime dried the Abu Zirig marsh, as most of the Iraqi marshes. The present authority is conducting a major initiative to restore the marshes. However, the water shortage is obstructing the restoration processes. Nevertheless, the restoration of the Abu Zirig marsh was visible especially during the years 2004 and 2005. Two previous authors studied the hydrological and the environmental parameters of the marsh [4, 5]. They have concluded, for one thing, that water budget determination for the marsh was a complex task and have ignored it. Al Zubaidy, et al. carried out study to predict missing hydrological data, a procedure was developed and applied for this purpose, and to be used with the available hydrological and topographical data for modeling and analysis the hydrological properties of AsSanna'f Marsh[6]. Al Saady,2011 carried out A hydrological routing study for Al Qurna Marsh to estimate the hydrological state within the marsh for the Present and future conditions of the marsh [7] . Another same study was carried out for Abu Zirig Marsh by Al Khafaji, et al. to study the hydrological operation Requirements for restoration and improving water quality of Abu Zirig marsh [8]. The conclusions of the previous works that the most of the previous studies concerning the optimum allocation and operation of the Iraqi marshes deal with water quantity parameter only.

This paper is an attempt to quantify the water budget components of the Iraqi marshes. The Abu Zirig marsh was selected as a case study for the purpose of the water budget determination.

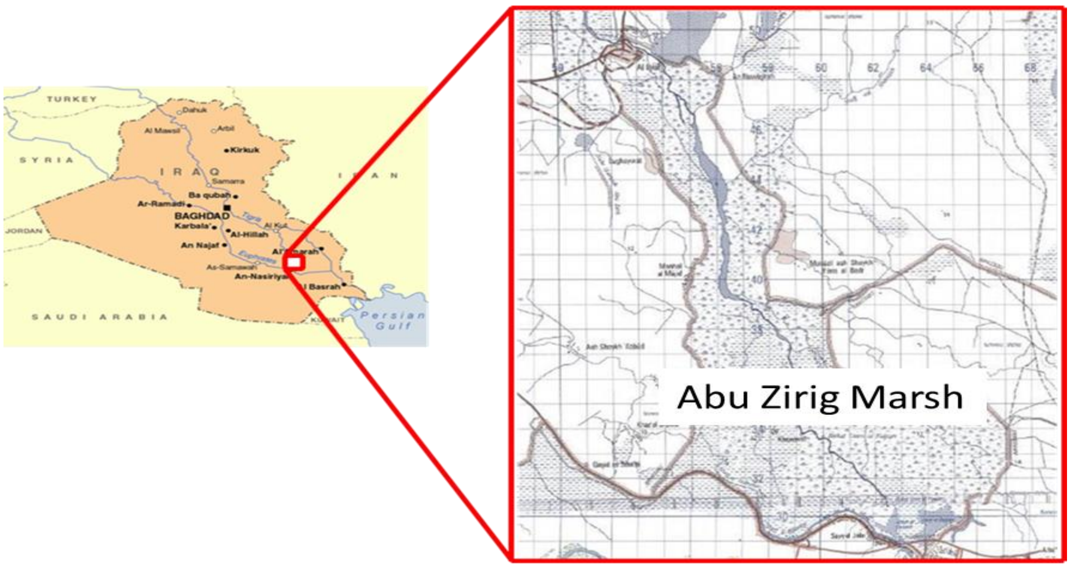

Figure 1. Location map of Abu Zirig marsh

2. Abu Zirig Marsh

The Abu Zirig Marsh is a natural depression surrounded by manmade dykes, constructed in 1920, to confine the water within the depression. The marsh is located south and southeast of al Islah town, north to northeast of al Fuhud town, and about 30 km east of al Nassiriah City (Figure 1). The main source of water to the marsh is through Shatt Abu Lihia (a lower branch of al Gharraf River). The Abu Lihia channel continues running until it disappears in the Central Marshes of al Qurna. Abu Zirig marsh is about 3% of all marshes area and was included in the dryness processes of 1991 (Figure 2). The marsh is divided into two parts separated by a road; the first is the upper zone includes the northwest part, and the other zone is the lower part, Figure 3. Several pipe culverts and irregular openings hydraulically connect the two parts [9].

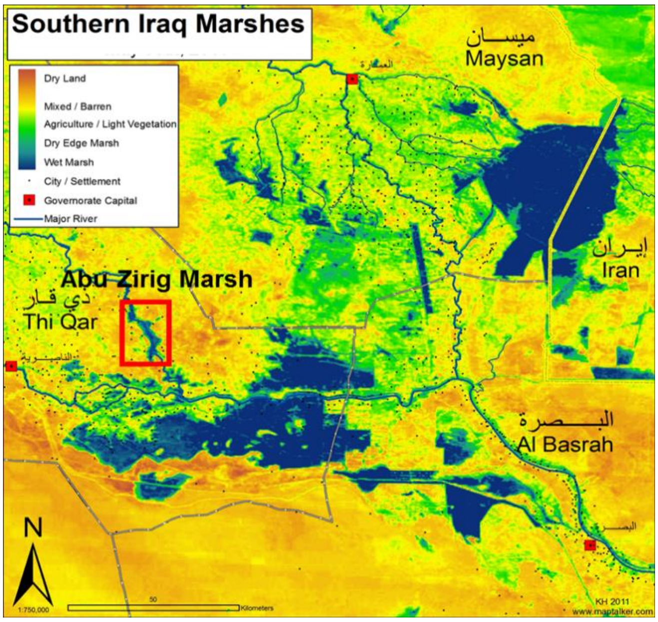

Figure 2. Abu Zirig marsh compared to the entire marsh area

On June 2003, re-flooding processes has started for the marsh. The re-flooded area was about 120 km^2 (out of 160 km^2 total area of the marsh). Inflow and outflow for 12 months between the years 2004 and 2005 are shown in Table 2. This period characterized by continues and sustained inflow, which is necessary for the water budget analysis. While inflow was coming from one inlet, outflow was taking place from about 20 small outlets located in the surrounding embankment. Outflow from the marsh either used for irrigation or entered the neighboring Central (Qurna) marshes [4].

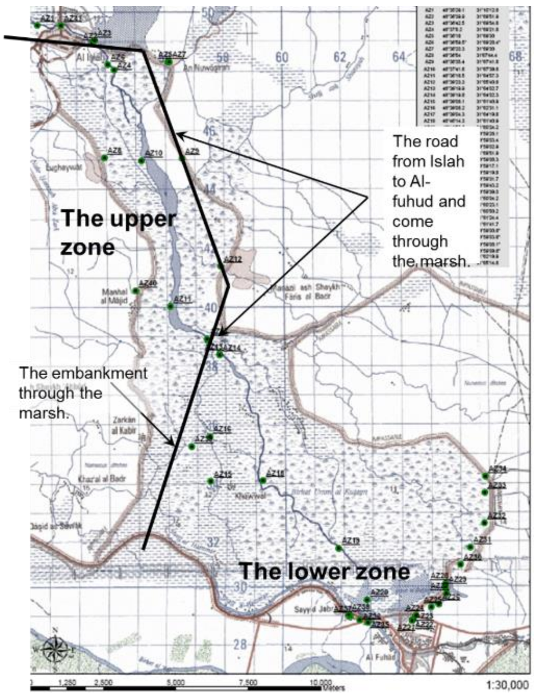

Figure 3. The Upper & Lower parts in Abu Zirig marshes.

3. Water Balance (Water Budget)

Water budget (balance) calculation methods are based on the principles of conservation of mass (or energy), applied to subsystem of the hydrologic cycle. Water balance is defined by the Eurpean Union [10] as “the numerical calculation accounting for the inputs to, outputs from, and changes in the volume of water in the various components (e.g. reservoir, river, aquifer) of the hydrological cycle, within a specified hydrological unit (e.g. a river catchment or river basin) and during a specified time unit (e.g. during a month or a year), occurring both naturally and as a result of the human induced water abstractions and returns.” Figure 4 shows a simplified one-cell model to represent the water budget where only surface water is concerned. In terms of mass conservation, a generalized water budget equation is:
mass inflow – mass outflow = change in storage for specified time period.
The equation may be written for the Abu Zirig marsh as

$$Q_{in} + P - I - E - Q_{out} = \frac{dS}{dt} \qquad (1)$$

where Q_{in} – inflow; P – precipitation; I – losses to groundwater (infiltration and/ or seepage); E –evaporation; Q_{out} – outflow; S – storage; and t – specified time period.
All terms in Equation 1 have dimensions of volume or depth per time t.

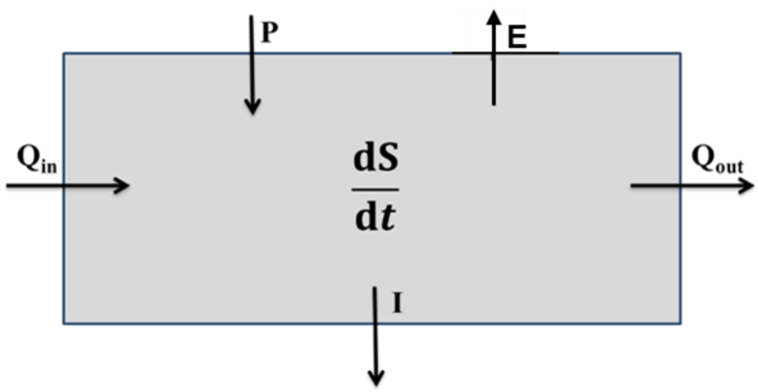

Figure 4. Simplified hydrologic subsystem representing a surface water body

3.1. Inflow

Even though the Abu Zirig marsh is separated by an embankment into two parts, it will be treated as one unit for the water budget calculations (Figure 5). Inflow (Q_{in}) to the marsh comes as surface inflow and precipitation. Annual precipitation is so small compared to evaporation and is neglected (Table 1). Surface inflow to the system is through an uncontrolled inlet called the Islah Breach. Inflow measured monthly for 12 months during the years 2004 and 2005 (Table 2). This period selected because flows were available and continued to the marsh with almost no interruption. The annual inflow less the month of April was calculated to be $7.982*10^{-1}$ billon cubic meter (bcm).

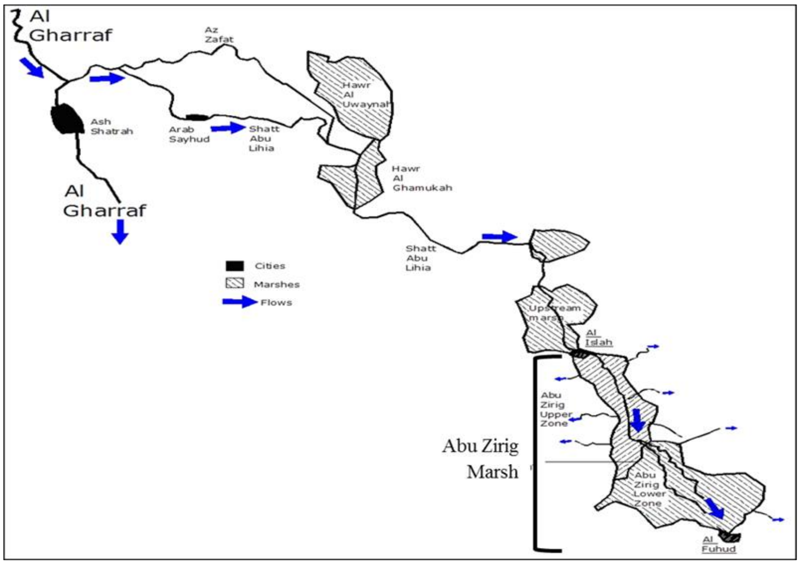

Figure 5. The hydrologic network and the road halves Abu Zirig marsh to the upper and lower part [11].

The month of April is excluded from the water budget calculation because the marsh was under unsteady conditions during that month (filling process). Other researcher used different modeling approach to study the water balance for the marsh, also, used a one year worth of data [12, 13].

Table 1. Precipitation rate for various stations in southern Iraq (mm), 1990-2000[14]

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Dec	Oct	Nov	Dec	total
Hai	35.54	20.95	24.08	11.86	1.69	0	0	0	1.5	4.04	24.2	21.01	144.8
Nasiriya	33.61	25.51	25.21	13.12	4.25	0.02	0	0	0	7.8	17.27	17.92	144.7
Amara	38.35	22.64	46.71	18.36	1.93	0.083	0	0	0	3.16	22.37	35.37	189
Basra	52.66	20.98	26.91	15.70	2.646	0	0	0	0.015	9.92	12.32	29.88	171.1

3.2. Outflow

Outflow components of Equation 1 include infiltration (I), evaporation (E), and surface water outflows (Q_{out}). Infiltration (I) is water lost to groundwater. Infiltration rate was estimated for the Abu Zirig as about one millimeter per day. The estimation is based on the study of Hour al Shwiacha [15, 16]. Hour al Shwiacha is located to the north and northeast of al Kut City in Iraq. It is of similar hydrogeological and geotechnical conditions to the marshes area of southern Iraq. The resulted annual infiltration losses for the Abu Zirig marsh, based upon the above bases, were about $4.38*10^{-2}$ bcm.

Evaporation (E) components of Equation 1 for the marsh are assumed equal to evaporation losses from free water surface. The evaporation losses estimated based on the U. S. Bureau of Reclamation Class A Evaporation pan located at the Nassiriah Meteorological Station (Table 3). The Nassiriah Station was chosen because of its geographical proximity to the marsh area. The pan coefficient used is 0.7. Annual evaporation losses calculated for the purpose of this study is about $2.483*10^{-1}$ bcm.

Surface water outflow (Q_{out}) components of the water budget include all discharges from the marsh area. Most of these discharges flow to the Central Marshes area. Surface outflows, as measured by previous investigators, are listed in Table 2. The calculated surface out flow is about $4.118*10^{-1}$ bcm.

3.3. Change in Storage ($\frac{dS}{dt}$)

Storage capacity and storage-area-elevation of the marsh were not available. Therefore, it is not possible to determine the $\frac{dS}{dt}$ term of Equation 1. If the hydrologic system operates at steady state condition, $\frac{dS}{dt}$ will go to zero. A steady state condition is assumed for the marsh for eleven months out of the twelve months study period. Steady state achieved after of April 2004. Most of the April flow went to replenish and fill the marsh to its maximum capacity. If $\frac{dS}{dt}$ equals zero, Equation 1 will take the steady state form

$$Q_{in} + P - I - E - Q_{out} = 0 \tag{2}$$

Table 2. Water balance between Upstream, Upper &lower zone [4,11,12]

months	Surface water cms					Evaporation cms	Infiltration cms
	Upstream	Upper zone		Lower zone			
		In	Out	In	Out		
Apr	46.01	32.133	18.33	18.33	1.43	7.19	1.39
May	33.28	22.42	14.52	14.52	12.49	9.95	1.39
June	34.23	28.06	18.06	18.06	16.63	13.16	1.39
July	25.08	24.42	16.303	16.303	15.868	14.00	1.39
Aug	19.28	17.5	15.214	15.214	14.703	13.51	1.39
Sep	32.167	28.12	16.938	16.938	15.62	10.95	1.39
Oct	42.067	31.774	25.882	25.882	5.877	7.75	1.39
Nov	24.574	18.5	9.278	9.278	6.369	4.54	1.39
Dec	27.45	19.867	11.25	11.25	9.375	2.20	1.39
Jan	42.45	33.32	21.75	21.75	17.5	2.72	1.39
Feb	44.56	32	20.55	20.55	17.765	3.31	1.39
Mar	38.65	22.42	13.45	13.45	11.45	4.54	1.39

Table 3. Evaporation rate, for various stations in southern Iraq (mm), 1990-2006[14]

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Dec	Oct	Nov	Dec	total
Hai	76	117	139	208	357	497	488	460	406	262	134	77	3221
Nasiriya	84	102	140	222	307	406	432	417	338	239	140	68	2895
Amara	60	95	153	245	369	495	552	509	344	250	125	70	3265
Basra	71	104	195	279	423	535	583	520	400	209	131	80	3528

4. Rating Curve

Rating curve or stage-discharge relation is a relation between discharge and water depth at any station of measurement, this curve can be obtained from collecting data about discharge for surface water and recorded elevation of it at same time [17]. For most stations a simple plot of stage versus discharge, such a curve is approximately parabolic but may show some irregularities if the control changes within the range of flows experienced or if the cross section is irregular [18].

The Islah breach is a possible location for a control structure to control water entering the marsh. Flow measurements at this site provide, to some extent, a mean to estimate a rating curve for this site of Abu Zirig marsh. Data of discharge and water depth were collected from this point [19] and presented in Figure (6).

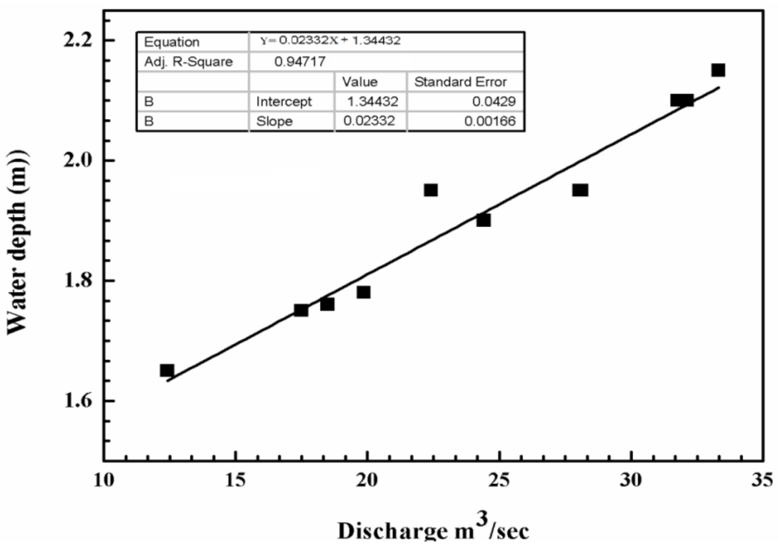

Figure 6. Rating curve for Islah breach in Abu Zirig marsh.

5. Results and Discussion

Using Equation 2 to calculate the water budget, the result of the equation should equals to zero. However, when the calculated water budget components at sections 3.1 through 3.3, the result was $9.418*10^{-2}$ bcm. The unaccounted for balance in the equation makes about 13% of the total inflow. This discrepancy may be attributed to measuring errors and/or unmeasured outflows. Furthermore, both infiltration and evaporation were estimated based on results obtained from other locations or from meteorological stations. While pan evaporation is accepted widely for the determination of evaporation losses from an open surface water body, the infiltration is much more complicated to determine. Regardless of the short coming, the results obtained can serve as bases to determine the discharges needed to restore and maintain the marshes area.

Results show that a continuous inflow of about 9.25 cms is required to maintain the Abu Zirig marsh. The maintained marsh area was about 120 km^2. The Iraqi Ministry of Environment (IME) [12] came with water requirement of 10 cms to re-flood 100% of the marsh.

Based on the obtained flow, water requirement to restore the central marshes area is about 77 cms is per 1000 km^2 of marshes. To restore and maintain the completely Central Marshes (an area of about 3000 km^2), an inflow of about 230 cms is needed. IME (2006), stated that 270 cms is needed to restore the Central Marshes. Such high flows are difficult to secure at the time being where Iraq is experiencing a sever water shortage. The estimates of the Ministry of Water Resources are about 65 cms for each 1000 km^2 (apparently accounting for evaporation losses only).

The water budget findings can help the decision makers to plan and priorities the marshes restoration processes. Further research is recommended to improve the determination of the water budget variable components. The two particular components of Equation 1 that need more investigation are Evaporation and infiltration.

6. Summary and Conclusions

Abu Zirig is a small marsh and it is part of the Iraqi Marshes. The marsh is a natural depression at the mouth of al Gharraf River. It is located about 40 km to the east of the Nassiriah city. The marsh was one of the marshes dried by diverting flows away from it via manmade embankments. It was also part of the re-flooded marshlands. The re-flooded immediately following the fall of Saddam's regime on the year of 2003. Its restored area was about 120 km^2. The marsh consists of two parts separated by manmade dyke; upper and lower parts.

The purpose of this paper was to determine the water budget for the Abu Zirig marsh. Results show that a continuous inflow of about 9.25 cms is required to sustain the Abu Zirig marsh. The preserved marsh area was about 120 km^2. If this result to be generalized for the greater central marshes area, an inflow of about 77 cms is required for every 1000 km^2 of marshes. To restore and sustain the central marshes completely (an area of about 3000 km^2), an inflow of about 230 cms is needed. These discharges are difficult to secure at the time being where Iraq is experiencing a sever water shortage.

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