The Hydraulic and Environmental Operation for the Main Outfall Drain of Ad Dalmaj Lake and Al Hammar Marsh System

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ABSTRACT

Iraqi Marshlands which are located within the southern part of Iraq were dried after 1991. The dried marshes were re-flooded after year 2003. Because of the shortage of water that feeds the marshes during the last years, these marshes began to dry again. Therefore, finding new feeding sources became very necessary matter. The Main Outfall Drain, MOD, is suggested to be one of these sources to feed Al Hammar Marsh during the dry water years. Ad Dalmaj Lake which is located upstream of Al Hammar Marsh is mainly feeding by the MOD water and then the outfall of this lake is discharge again into the MOD. Therefore, the hydrological operation of this lake and then the quantity and quality of the outflow water from this lake into the MOD affected the water quality of Al Hammar Marsh when using the MOD water to feed the marsh.

A hydrological and water quality routing model was prepared based on mass conservation low, mass balance model, and two scenarios were applied for Ad Dalmaj Lake feeding, constant inflow with variable outflow and constant outflow with variable inflow, based on the incoming and outgoing discharges. Each scenario includes six cases of lake maximum inundation area; 100%, 90%, 80%, 70%, 60% and minimum inundation. For each case the inundation area varied with respect to the ET_0 variation from minimum area during the month of maximum ET_0 to maximum area, of this case, during the month of minimum ET_0. TDS concentration was used as a measure of the salinity of the water because it fairly indicates the level of salinity problem. The variation of inflow and outflows discharges, water level, lake and marsh area, storage volume, and the water salinity within the lake and marsh were

Results of applying these models with these flow scenarios and inundation cases show that the water salinity within Ad Dalmaj Lake and Al Hammar Marsh was out of the acceptable range of international standards for most of the studied cases. While for other cases it was unpalatable for drinking, several restrictions must be imposed when used for irrigation to prevent salts effects on crops, soil, and ground water, and not acceptable for livestock and unfit for poultry in most of the

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months during two operation years and in some months in the beginning of the first year, the water can be used for growing livestock and poultry.

Keywords: Iraqi Marshlands, Al Hammar Marsh, Hydrological Routing, Main Outfall Drain and Ad Dalmaj Lake.

التشغيل الهيدروليكي والبيئي لمنظومة المصب العام وبحيرة الدلمج وهور الحمار

الخلاصة

الاهوار العراقية الواقعة في جنوب العراق جففت بعد عام ١٩٩١ ثم اعيد اغمارها بعد عام ٢٠٠٣. بسبب شحة المياه خلال السنوات الاخيرة بداءت هذهِ الاهوار تجف مرة اخرى. لذلك اصبح من الضروري ايجاد مصادر جديدة لتغذيتها.

اقترحت وزارة الموارد المائية ان يتم استخدام مياه المصب العام لتغذية هور الحمار خلال سنوات الجفاف.

ان بحيرة الدلمج تقع في مقدم هور الحمار ويعتبر المصب العام المصدر الرئيسي لتغذيتها ومن ثم يتم تصريف مياهها الى المصب العام. لذلك فأن التشغيل الهيدروليكي لبحيرة الدلمج وكمية ونوعية المياه المطلقة منها الى المصب العام تؤثر على نوعية مياه هور الحمار في حالة استخدام مياه المصب العام لتغذية الهور.

تم في هذا البحث اعداد نموذج استتباع لكمية ونوعية المياه اعتماداً على قانون حفظ الكتلة وتم تطبيق النموذج على سيناريوهين لتغذية بحيرة الدلمج (تغذية ثابتة مع تصريف متغير وتصريف ثابت مع تغذية متغيرة) اعتماداً على التصاريف الداخلة والخارجة. كل سيناريو تضمن ستة حالات لاقصى اغمار للبحيرة ١٠٠% و٩٠% و٨٠% و٧٠% و٦٠% واقل اغمار ممكن. لكل حالة تم تغيير مساحة الاغمار وفقاً لتغير التبخر- نتح من اقل مساحة خلال فترة اقصى قيمة للتبخر- نتح الى اكبر مساحة خلال فترة اقل تبخر- نتح. تم اعتماد تركيز المواد الذائبة الكلية كمؤشر لملوحة المياه.

تم حساب التغير في التصاريف الداخلة والخارجة ومنسوب الماء والمساحة وحجم الخزن وملوحة المياه في البحيرة والهور لكل سيناريو.

بينت نتائج تطبيق نموذج الاستتباع للسيناريوهين ولكل الحالات ان ملوحة المياه في بحيرة الدلمج وهور الحمار تكون خارج الحدود المسموح بها في المواصفات العالمية لمعظم حالات الإغمار وفي حالات قليلة تكون غير مستساغة للشرب مع وجود قيود كثيرة على استخدامها لاغراض الزراعة لتفادي تأثير الملوحة على النباتات والتربة والمياه الجوفية وغير مسموح باستخدامها لتربية الماشية والدواجن خلال معظم الاشهر للسنة الثانية من التشغيل في حالة استخدام مياه المصب العام لسنتين متتاليتين. في حين يمكن استخدامها لتربية الماشية والدواجن خلال السنة الاولى.

INTRODUCTION

During the last decade, there was a grate shortage in the water required to maintain Al Hammar Marsh. The area of the marsh was reduced greatly threatening the ecological system and economics of the marsh residents. A suggestion made by the Center for Restoration of the Iraqi Marshlands, CRIM, of the Ministry of Water Recourses, MoWR, and other related ministries to make use of the Main Outfall Drain, MOD, water to feed the marsh as a temporary solution that will prevent the marsh to dry again during dry years. Ad Dalmaj Lake is located upstream of Al Hammar Marsh. It is feeded by MOD water and then the outflow water is discharged again into MOD before conveying part of the MOD water into Al Hammar Marsh through Al Khamissiya canal. The quantity and quality of water that inflow and outflow from Ad Dalmaj Lake must be controlled to decrease the effect of using the MOD water on the ecological system in Al Hammar Marsh.

AREA OF STUDY

The area of study is located in an arid zone and extended from the northern part of Baghdad city to Shatt-Al Basrah Governorate. Between latitude 30 39' N and 33 22' N, and longitude 45 11' E and 47 58' E. The area of study consists of the Main Outfall Drain (MOD), Ad Dalmaj Lake and Al Hammar Marsh, Figure (1).

THE MAIN OUTFALL DRAIN

It is the third river in Iraq. The basic idea of the MOD, Figure (2), which was suggested in the beginning of the last century, was to construct a main channel to collect saline drained water of the irrigation projects within central and southern parts of Iraq and discharge it down to the Arabian Gulf. The MOD was designed to flow between the Tigris and Euphrates Rivers, and then it crosses the Euphrates river bed, Via large pump station east of the Nassiriyah city, toward the Arabian Gulf.

The construction of some parts of the MOD started during the 1950s and more were completed in the 1960s. The entire project was not completed until December 1992, when the final section, linking the seaward end to that built at Ad Delmaj Lake northwest of Al Nassiriyah, was constructed. The MOD crosses the Euphrates River just east of Al Nassiriyah, beneath the river bed in large pipes limiting its discharge to 140 m^3/s which was then replaced by a huge pumping station of 220m^3/s in 2009.

The total length of the MOD is 565 km, which is divided into three sectors based on the construction stage as follow, (MoWR, 2005).

The north sector: the total length of this part is 206 km, starts from the Esʾhaki Main Drain north of Baghdad down to Ad Dalmaj Lake. The discharge of this sector at Ad Dalmaj Lake is 88 m^3/sec.

The central sector: this sector starts north of Ad Dalmaj Lake and ends at the point where the MOD crosses the Euphrates with a length of 187 km. The maximum capacity of this sector is 220 m^3/sec. This sector is connected to Ad Dalmaj Lake insure the required water levels for navigation during the whole year.

The southern sector: this sector started at the point, where the MOD crosses the Euphrates River down to Shatt Al Basrah with a length of 172 km. Its capacity at Shatt Al Basrah is 200 m^3/sec.

Ad Dalmaj Lake

Ad Dalmaj lake, **Figure (3)**, is one of the salty lakes in Iraq . It is located 40*km* south west of Kut city, Waist Governorate. It is about 50*km* long with an average width of about 10*km*. Its feeders are the overflow of the irrigation canals and floodwater of Tigris River during the wet year and mainly from the MOD through a canal with a control structure of a maximum capacity of 53m^3/s. Ad Dalmaj Lake circulate its water into MOD again through a controlled escape structure of a maximum capacity of 46m^3/s, (CEB, 2010). The lake area reaches its maximum extends during March to May and reduces due to evapotranspiration rates during

July to September. The average water depth within the lake varies between 1.5 to 2.5*m*.

AL HAMMAR MARSH

Al Hammar Marsh is considered as one of the largest marshland in Iraq. It is located between the Nassiryah city on the west side and the Basrah governorate on the south east side. The marsh is located between latitude 46◦ to 47◦, and longitude 30◦ to 30.5◦. bounded by Euphrates river as the north boundary, Shatt Al Arab river as the east boundary, and the Basrah water supply project main supply channel and the Main Outfall Drain as the south boundary, and suq Ashshukh as the west boundary. Figure (4**)** show the general layout of Al Hammar Marsh, (CRIM, 2011).

CRIM is planning to construct a hydraulic structure, that will separate Al Hammar Marsh into two parts, Figure (4), shows the two parts of Al Hammar Marsh, the east and west parts. The control structure will control the outflow from the west part toward the east part. and was designed to discharge 2300m^3/sec. This control structure has twenty seven pipes with diameter of 1.2*m* controlled by gate valves, and a weir of 2100*m* in length. The weir crest is at elevation of 2*m.a.m.s.l*, (CRIM, 2011).

Several branches from Euphrates River feed Al Hammar Marsh. Some of these branches controlled by head regulators of different capacities varying between 50-500m^3/s, with a total capacity of 1300m^3/s. Al Hammar Marsh is also fed directly from an opening through the right embankments of Euphrates River with a capacity of 500m^3/s. During flood seasons, Tigris River flow through Al Qurna Marshes then to Al Hammar Marsh through culverts and escapes that were constructed for this purpose, sometime the water of Al Qurna Marshes reaches high levels and flood toward Al Hammar Marsh over the road parallel to Euphrates River conveying. The main outlets of Al Hammar Marsh are AshShafi, Al Ghameej and Garmat Ali Rivers. These rivers discharge its flow to Shatt Al Arab River, (CRIM, 2008).

AVAILABLE DATA

Topographical data for Ad Dalmaj Lake carried out by Russian, 1984. Hydrological and water quality for Main Outfall Drain and Ad Dalmaj Lake carried out by Directorate of Main Outfall Drain, 2010. Topographical, hydrological, and water quality data for Al Hammar Marsh are available in a study carried out by CRIM, 2008. CRIM is carrying out water quality measurement during six months each two weeks, starting from October 2009. These measurements include the temperature (T), dissolved oxygen (DO), total dissolved solids (TDS), electrical conductivity (EC) and turbidity, in addition to discharge and the water levels that are recently being measured. The metrological data for the area of study, that necessary to estimate the evapotransperation (ET_0) within the area of study were collected by ministry of Sciences and Technology, 2010, for three station in the southern of Iraq.

HYDROLOGICAL AND WATER QUALITY DATA

TDS concentration and water discharge of the Main Outfall Drain (MOD) before Ad Dalmaj Lake intake were collected from Directorate of Main Outfall Drain, 2009 and 2010. As are presented in Table (1). And the recorded TDS concentration in Ad Dalmaj Lake in September, 2009 was 7110 mg/l. This value was adopted to be the initial TDS concentration within the lake.

Ad Dalmaj Lake lies within a region of high ET_0 with an annual value of 2775*mm*. The average monthly ET_0 is 231*mm.* It is 62 *mm* during January, increased to 430 *mm* during July, which is 6.94 times that of January.

TDS measurements carried out by CRIM during 2007 and 2008 are presented in Table (2), (CRIM, 2008).

TDS measurements carried out by CRIM during 2009 are presented in Table (3).

Measured TDS values of AshShafi River show a strange behavior, they are much less than it expected to be. Moreover, TDS values that were measured during 2009, presented in Table(3) , were much less than that measured during 2007 and 2008 that are listed in Table(2).

Al Hammar Marsh lies within a region of high ET_0 with an annual value of 2554*mm*. The average monthly ET_0 is 213*mm.* It is 65 *mm* during January, increased to 376 *mm* during July, which is 5.78 times that of January.

The annual precipitation within the marsh is approximately 150*mm.* The effective rainfall was considered small compared with the evaporation and was neglected in the hydrological routing, (CRIM, 2008).

TOPOGRAPHICAL DATA

The topography of Ad Dalmaj Lake was developed based on morph metric characteristics data of this lake, Table (4). The area-elevation and storage-elevation curves were obtained based on these data using table curve software to find the best fit equation as shown in Figure (5 and 6), respectively.

The topography of Al Hammar Marsh was developed based on the available digital elevation model, DEM, obtained from Shuttle Radar Topographical Mission Data SRTM, and of 90 meters definition in the investigated area and the bathymetric surveys provided by CRIM, (CRIM, 2007).

CRIM intends to construct a control structure that will separate Al Hammar Marsh into two parts, the east and west parts. The control structure will control the outflow from the west part toward the east part. The structure has fifteen gates and a weir of 2100*m* in length. The gates are of 1*m* in height and 2*m* in width with an invert level of 0.25*m.a.m.s.l.* The weir crest is at elevation of 2 *m.a.m.s.l*.

At an elevation of 1.25*m* the marsh area is that kept as a contiguous lake with an area of 250km^2. At the elevation of 2m, which is the weir crest elevation the marsh area is 740km^2.

METROLOGICAL DATA

The metrological data collected for three station in the southern of Iraq , the Hai, the Nassiriyah and the Basrah(Ministry of Sciences and Technology, 2010). The metrological data of the Hai station were used to estimate ET_0 of Ad Dalmaj Lake. But, Al Hammar Marsh is extended within two governorates (the Nassiriyah and the Basrah). Therefore, the metrological data of the Nassiriyah and the Basrah stations were used to estimate the ET_0 of Al Hammar Marsh; the average values for these stations were calculated and then input into the CROPWAT8 software.

WATER QUALITY EVALUATION

In this study, TDS is water quality parameter that was used as a measure of the salinity of the water.

The Food and Agriculture Organization, FAO, guidelines for the evaluation of water quality for irrigation purposes suggests that there need be no restrictions on the use of irrigation water with a TDS concentration of less than 450 *mg/l*, slight to moderate restrictions if concentrations are in the range between 450and 2000*mg/l*, and severe restrictions for irrigation water with a TDS concentration of more than 2000*mg/l*. (FAO, 1994).

According to the TDS measurements of Al Hammar Marsh feeders, listed in Table (2 and 3), and that for the MOD, listed in Table (1), and the above mentioned water quality specifications guidelines, Al Hammar Marsh feeders and the MOD are considered unpalatable for drinking, severe restrictions must be imposed when used for irrigation to prevent salts effects on crops, soil, and ground water, and are within the range that are satisfactory for livestock and unfit for poultry in some months and of limited use for livestock and not acceptable for poultry in other months.

AREA AND STORAGE VERSUS ELEVATION RELATIONS

The area-elevation and storage-elevation curves for Ad Dalmaj Lake were obtained based on morph metric characteristics data of this lake, Table (1) and using table curve software to find the best fit equation, that presented in Figures (5 and 6), respectively.

CRIM intends to construct a hydraulic structure which will separate Al Hammar Marsh into two parts, the west and east part as was mentioned above and shown in Figure (4). Area-elevation and storage-elevation relationships were obtained separately for each part of the Marsh, based on the developed DEM, which are shown in Figures (7 and 8). Figure (9) shows the Area-storage relationship of the two parts of the marsh that were derived from the area-elevation and storage-elevation relationships.

MODELS THEORETICAL BASES

A hydrological and water quality routing models that were implemented based on the MOD water discharge, quality, the hydrological and environmental operation requirements, and constraints of Ad Dalmaj Lake and Al Hammar Marsh for all operation cases within the hydrological operation constraints. The variation of inflow and outflow discharge, water level, lake and marsh area, water volume, and water quality within the lake and marsh were estimated. The decision of which lake and marsh operation case is the best; is based on minimizing and balancing the water quality deterioration within Ad Dalmaj Lake and Al Hammar Marsh.

The hydrological routing model was implemented based on the mass conservation law, that is:

$$S_{(i+1)}-S_{(i)} = (P_{(i)} + Q_{in\,(i)} + GW_{in\,(i)} - Q_{e\,(i)} - Q_{out\,(i)} - GW_{out\,(i)}) \times \Delta T \quad \dots(1)$$

Where:

S: storage, (m^3).

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

n: total period of the hydrological routing.

$S_{(i+1)}-S_{(i)}$: change in storage, (m^3).

P: precipitation, (m^3/sec).
Q_{in} : inflow discharge, (m^3/sec).
GW_{in}: groundwater input, (m^3/sec).
Q_e : evapotranspiration discharge, (m^3/sec).
Q_{out}: outflow discharge, (m^3/sec).
GW_{out}: groundwater leaving the basin, (m^3/sec).
ΔT: time interval of the hydrological routing, (sec).

Precipitation volume is neglected, because the model implemented for an area located within the arid region, GW_{in} and GW_{out} across the basin boundary are assumed to be negligible, because of the sedimentary effect that coated the bottom of the marshes, Eq. (1) becames:

$$S_{(i+1)} = S_{(i)} + (Q_{in(i)} - Q_{out(i)} - Q_{e(i)}) \times \Delta T \quad \ldots(2)$$

Accordingly; the volume of the inflow water can be estimated as follow.

$$Q_{in(i)} = (S_{i+1} - S_i)/\Delta t + Q_{out(i)} + Q_{e(i)} \quad \ldots(3)$$

The mass conservation law, **Eq. (4)**, was used to estimate the concentration of contamination within Ad Dalmaj Lake, MOD and Al Hammar Marsh.

$$S_{(i+1)} \times C_{(i+1)} - S_{(i)} \times C_{(i)} = (Q_{in(i)} \times C_{in(i)} - Q_{e(i)} \times C_{e(i)} - Q_{out(i)} \times C_{out(i)}) \times \Delta T \quad \ldots(4)$$

Where:
C: the contaminant concentration within the lake or marsh, (mg/L).
C_{in}: the contaminant concentration of the inflow discharge, (mg/L).
C_{out}: the contaminant concentration of the outflow discharge, (mg/L).
C_e: the contaminant concentration due to evapotranspiration, (mg/L).

Ad Dalmaj Lake and Al Hammar Marsh lies within a region of high ET_0, and according to the above equations, ET_0 will be the key factor affecting the water required to maintain the marsh area and the water quality deterioration

To estimate the ET_0 within the area of study, the necessary recorded metrological data for the nearby metrological stations and using CROPWAT8 software. This software estimate the ET_0 by using FAO-Penman Monteath equation (Food and Agriculture Organization of the UN, 2006). The estimated ET_0 values for Ad Dalmaj Lake and Al Hammar Marsh are shown in Figures (10) and (11), respectively.

VARIATION OF AREA WITH TIME (AREA CYCLE)

To minimize the losses due to ET_0, the area of Ad Dalmaj Lake and Al Hammar Marsh were minimize during periods of high ET_0 and maximize during periods of low ET_0.

Ad Dalmaj Lake area was minimize to 170 km^2 during July, when ET_0 is maximum (430mm), and maximize to 314 km^2 during January, when ET_0 is minimum (62mm), (the maximum and minimum area of Ad Dalmaj Lake were specified by Russian,1984), while Al Hammar Marsh area minimize to 250 km^2 during July, when ET_0 is maximum (376mm) and maximize to 700 km^2 during January, when ET_0 is minimum (65mm), (the maximum and minimum area of Al Hammar Marsh were specified by CRIM, 2007 when using the MOD water to feed the marsh). Accordingly; using interpolation between the maximum area with minimum ET_0 and minimum area with maximum ET_0. The area of Ad Dalmaj Lake and Al Hammar Marsh that is corresponding to the ET_0 values during each month were estimated. The proposed area-cycle of Ad Dalmaj Lake and Al Hammar Marsh during dry year are shown in Figures (12) and (13), respectively.

HYDROLOGICAL ROUTING OF AD DALMAJ LAKE

To estimate the effect of Ad Dalmaj Lake operation on the MOD water and then on Al Hammar Marsh and to include all the operation cases, as much as possible, within the hydrological operation constraints of Ad Dalmaj lake. Four cases of area-cycle of Ad Dalmaj Lake were considered in addition to that shown in Figure (12) which was ranged between minimum Dalmaj area, AD_{min}, equal 170 km^2 and maximum Dalmaj area, AD_{max}, equal 314 km^2. This is by reducing the maximum Dalmaj area 10%, 20%, 30% 40% and to AD_{min}. Using interpolation as in estimate of area, the considered in Figures (12 and 13).The consider area cycles with each case and the corresponding storage and water surface elevation are shown in Figures (14) to (16), respectively.

Two operation scenarios were suggested to feed Ad Dalmaj Lake. The **first operation scenario** is to feed Ad Dalmaj Lake with the inflows required to maintain each one of the lake area cycles, plus inflows equal to an assumed constant outflows from Ad Dalmaj Lake, the assumed constant outflows from Ad Dalmaj Lake are the water discharges required to flush out some of the accumulated salts, due to ET_0, and to feed Al Hammar Marsh. Depending on the availability of water, the required inflows of the above mentioned scenario could be totally supplied from MOD.

The **second operation scenario** is to feed Ad Dalmaj Lake with constant inflow during the year. This inflow is equal to the maximum monthly inflow that required to maintain each one of the area cycles of Ad Dalmaj Lake during the year. The outflows from Ad Dalmaj Lake were obtained using the hydrological routing, which are drained in to the MOD and then mixed with drained water from three drains located between the lake outlet and Al Hammar inlet and then the water inflow into Al Hammar Marsh.

A hydrological routing model was implemented based on the mass balance equation, Eq. (3) is used to estimate the monthly inflows required to maintain the area cycles of Ad Dalmaj Lake for two successive years based on the difference in storage of successive months plus the ET_0 losses and with outflow, $Q_{out}=0$. The estimated inflows required to maintain the area cycles of Ad Dalmaj Lake are as shown in Figure (17).

A-First operation scenario

A hydrological routing for Ad Dalmaj Lake was implemented according to the first operation scenario with different constant outflow of 10, 30 and 46 m^3/sec. This outflow must be added to the inflow required to maintain the lake area cycle. The inlet of Ad Dalmaj Lake is controlled by gated control structure with maximum capacity of 53 m^3/sec. In several months, the inflow required to maintain the area-cycles that shown in Figure (17) plus the constant outflow exceed the maximum capacity of the inlet control structure. Therefore, the Lake area during this month must be reduced. The total inflow required to maintain the area cycles varied according the new Area cycles.

Since Ad Dalmaj Lake inlet and outlet are controlled by gated control structures with maximum capacity of 53 and 46 m^3/sec, respectively. Therefore, the constant outflow 30 and 46 m^3/sec cannot discharge from the lake in some months. This will change the area cycles during these months. So, this outflow must be reduced.

B-Second operation scenario

A hydrological routing for Ad Dalmaj Lake was implemented according to the second operation scenario, based on assuming constant inflow equal to the maximum monthly inflow required to maintain the area cycles of Ad Dalmaj Lake. For the cases were the maximum area of Ad Dalmaj Lake are (AD_{max}=AD_{max}, AD_{max}=90%AD_{max}, AD_{max}=80%AD_{max}, AD_{max}=70%AD_{max}, AD_{max}=60%AD_{max}, and AD_{max}=AD_{min}), the maximum inflow were 53, 46, 38, 33, 29, and 28 m^3/sec, respectively. Since Ad Dalmaj Lake inlet and outlet are controlled by gated controls structures with maximum capacity of 53 and 46 m^3/sec, respectively. Therefore, the constant inflow for the cases AD_{max}=AD_{max} and AD_{max}=90%AD_{max}, which are 53 and 46 m^3/sec, cannot be discharged during some months. So, these constant inflows should be reduced to be as shown in Figure (18).

The implemented hydrological routing was used to estimate the outflow from Ad Dalmaj Lake which is the surplus water from that required to maintain the area cycles, Because the outlet of Ad Dalmaj Lake is controlled by gated control structure with maximum capacity 46 m^3/sec and in some months the outflow from this lake excess the maximum capacity of this control structure, therefore the maximum inflow must be reduced to maintain the area cycles. The estimated outflow from Ad Dalmaj Lake is as shown in Figure (19).

WATER QUALITY OF AD DALMAJ LAKE

Salinity in Ad Dalmaj Lake water can be estimated by TDS parameter. TDS indicate fairly the level at which salinity problem is likely to occur. TDS is an indicator to the presence of calcium, magnesium, potassium, sodium, bicarbonates, chlorides and sulfates salts.

The recorded TDS concentration in Ad Dalmaj Lake in September, 2009 was 7110 mg/l; (Directorate of Main Outfall Drain, 2010). This value was adopted to be the initial TDS concentration within the lake and accordingly the TDS concentration within the lake was estimated for two successive years according to the first operation scenario and second operation scenario by using Eq. (4).

HYDROLOGICAL ROUTING OF AL HAMMAR MARSH

The quantity and quality of the water inflow into Al Hammar Marsh from MOD affected by the quantity and quality of the MOD water before the intake of Ad Dalmaj Lake and Ad Dalmaj Lake hydrological operation, and that of three drains that drainage to the MOD after the outlet of Ad Dalmaj Lake. The MOD discharges after the outlet of Ad Dalmaj Lake and before the intake of Al Hammar Marsh were estimated as follow:

$$Q_{3MOD}=Q_{2MOD}+Q_{Dout}+Q_{Dr\,T} \quad \dots \quad (5)$$

$$Q_{2MOD}=Q_{1MOD}-Q_{Din} \quad \dots \quad (6)$$

Where:

Q_{3MOD}: MOD discharge between the outlet of Ad Dalmaj Lake and the intake of Al Hammar Marsh, (m^3/sec).
Q_{2MOD}:MOD discharge after the intake of Ad Dalmaj Lake, (m^3/sec).
$Q_{D\ out}$: outflow discharge from Ad Dalmaj Lake, (m^3/sec).
$Q_{Dr\ T}$: total discharge of the three drains that drainage to the MOD after the outflow of Ad Dalmaj Lake, (m^3/sec).
Q_{1MOD}: MOD discharge before the intake of Ad Dalmaj Lake, (m^3/sec).
$Q_{D\ in}$: inflow discharge into Ad Dalmaj Lake, (m^3/sec).

The water quantity between the outlet of Ad Dalmaj Lake and inlet of Al Hammar Marsh, after drained water from three drains located between the lake outlet and Al Hammar Marsh inlet were estimated.

The minimum water discharge in the MOD between Ad Dalmaj Lake outlet and Al Hammar Marsh intake and during two successive operation years were adopted to be the inflow discharged into Al Hammar Marsh after deducted 10m^3/sec continue to flow in the MOD, this operation case was applied to study the water deterioration within Al Hammar Marsh during the worse situation of dry year that may occur in the future.

According to the CRIM, 2010, the best feeding scenario for feeding Al Hammar Marsh is to discharge as much as possible of the MOD water into Al Hammar Marsh to flush out the accumulated salts. Therefore, all the water in the MOD must be discharged into Al Hammar Marsh except 10 m^3/sec continue to flow in MOD.

According to the first operation scenario of Ad Dalmaj Lake and when the outflow from this lake is 10m^3/sec, for all cases of Ad Dalmaj Lake area. The maximum possible inflow into Al Hammar Marsh from MOD are 88m^3/sec when AD_{max}=AD_{max} and AD_{max}=90%AD_{max} and 89, 90, 91, and 93 m^3/sec when AD_{max}=80%AD_{max}, AD_{max}=70%AD_{max}, AD_{max}=60%AD_{max} and AD_{max} = AD_{min}, respectively. And the outflows from Al Hammar Marsh are shown in Figure (20).

In the cases when outflow from Ad Dalmaj Lake equal 30 and 46 m^3/sec, the inflow into Al Hammar Marsh equal 93 m^3/sec and the outflow from Al Hammar Marsh is as shown in Figure (21), for all cases of Ad Dalmaj Lake area.

For the second operation scenario of operating Ad Dalmaj Lake and in same method as in the first operation scenario, the water discharge in the MOD between Ad Dalmaj Lake outlet and Al Hammar Marsh intake was estimated.

The inflow into Al Hammar Marsh are 84, 87, 78, 83, 88, and 90 m^3/sec when Ad Dalmaj Lake area are AD_{max}=AD_{max}, AD_{max}=90%AD_{max}, AD_{max}=80%AD_{max}, AD_{max}=70%AD_{max}, AD_{max}=60%AD_{max}, and AD_{max}=AD_{min} , respectively. The outflow from Al Hammar Marsh were as shown in Figure (22).

WATER QUALITY OF AL HAMMAR MARSH

The water quality of Al Hammar Marsh is affected by the quality of the MOD water before the intake of Al Hammar Marsh, Al Khamissyh canal, and the outflow water from Ad Dalmaj Lake that is discharged into the MOD and the water of three drains, located between the outlet of Ad Dalmaj Lake and the inlet of Al Hammar Marsh that is discharged into the MOD. Therefore, the water quality (TDS) in the MOD according to the first operation scenario were estimated by using Eq. (7).

$$C_{3MOD}=(Q_{Dr\ T} \times C_{Dr\ T}+ Q_{D\ out} \times C_{D\ out}+ Q_{2MOD} \times C_{2MOD})/Q_{3MOD} \quad \ldots(7)$$

Where:

C_{3MOD}:TDS in the MOD between the outlet of Ad Dalmaj Lake and the intake of Al Hammar Marsh, (mg/L).

C_{DrT}: TDS of the total discharge of the three drains, (mg/L).

C_{Dout}: water quality for water outflow from Ad Dalmaj Lake, (mg/L).

C_{2MOD}:water quality for water discharge after Ad Dalmaj Lake intake, (mg/L).

TDS concentration within Al Hammar Marsh based on the first and second operation scenarios for all the area cases of Ad Dalmaj Lake are estimating. As listed in Table (5).

Hydrological Routing of Ad Dalmaj, MOD and Al Hammar Marsh system

The decision on which operation scenario is the best will be based on the level of the water quality deterioration within Ad Dalmaj Lake and Al Hammar Marsh that were obtained through the hydrological routing.

CONCLUSIONS

From the collected and estimated data and results of the hydrological and water quality routing models, the following conclusions are extracted.

1- The collected MOD hydrological and water quality data showed big aberrance from the MOD project design objectives and criteria, such as disposal of wastewater into the MOD and uncompleted irrigation drainage system.

2- The MOD water quality is considered unpalatable for drinking, severe restrictions must be imposed when used for irrigation, and usable for all classes of livestock and poultry. May cause temporary diarrhea in livestock. Also Ad Dalmaj Lake water quality is unpalatable for drinking and not acceptable for irrigation and livestock and unfit for poultry in all the month during the year for all the operation cases, since Ad Dalmaj Lake is mainly feeding from the MOD water.

3- Because of the topographical characteristics of Ad Dalmaj Lake and Al Hammar Marsh, high rate of change in water surface area with respect to water depth, the hydrological operation of the lake and marsh has a great effect on the water quality of the lake and marsh especially during the months of high ET_0.

4- The estimated ET_0 values, by using the CROPWAT8 software based on Penman-Monteith equation and using the metrological data to estimate ET_0 of Ad Dalmaj Lake and Al Hammar Marsh, were ranged between 62mm during January to 430mm during July within Ad Dalmaj Lake and 65mm during January to 376mm during July within Al Hammar Marsh.

5- The TDS concentration within Ad Dalmaj Lake and Al Hammar Marsh are inversely related to the total inflow, that is, as the outflow increases more salts being flushed out because Ad Dalmaj Lake and Al Hammar Marsh quality are worse than that of the MOD water.

6- The case of AD_{max}=70%AD_{max}, regarding the specified area cycle, and the total required constant inflow into Ad Dalmaj Lake during the year is 33m^3/sec is better than the other cases, because the water deterioration within Al Hammar

Marsh and Ad Dalmaj Lake are well-balanced and the total inflow required to maintain the area cycles for Ad Dalmaj Lake is less than that of the other cases.

7- The water quality deterioration within Ad Dalmaj Lake and Al Hammar Marsh can be reduced by increasing the outflow from Ad Dalmaj Lake. This operation required to discharge high inflow into Ad Dalmaj Lake, which cannot be preserved during the dry water years.

8- For the case when $AD_{max}=AD_{min}$, the water deterioration in Al Hammar Marsh and Ad Dalmaj Lake is lower than that of all other cases and the required total inflow is less than that of all other cases. But this case cannot be considered as the best one because it causes backing away in Ad Dalmaj Lake economic feasibility.

9- The water quality within Ad Dalmaj Lake and Al Hammar Marsh for all operation cases are considered unpalatable for drinking, severe restrictions must be imposed when used for irrigation, and not acceptable for livestock and unfit for poultry in all the month during two operation years. Therefore, utilizing the MOD water for feeding the marsh can be accepted as a temporary solution during the dry years for no more than one year and in very importunate cases for two years only.

10- According to the operation scenario when all the water in the MOD discharged into Al Hammar Marsh except 10 m^3/sec continue to flow in MOD, the TDS within Al Hammar Marsh reduce because more accumulative salt flushing out.

REFERENCES

[1].Center for the Restoration of Iraqi Marshlands, CRIM, 2007, Restoration of Al Hammar Marsh Study.

[2].Center for the Restoration of Iraqi Marshlands, CRIM, 2008, Study of Improving the Environmental Present Condition of Southern Marshes.

[3].Center for the Restoration of Iraqi Marshlands, CRIM, 2011, Possibility of Using the Water of the Main Outfall Drain to Restore Al Hammar Marsh after Operating the Pumping Station in Nassiriyah City.

[4].Consulting Engineering Bureau, CEB, Crops of Engineering & Collage of Engineering, University of Bagdad, 2010, "the Main Outfall Drain water treatment study central Iraq".

[5].Directorate of Main Outfall Drain, 2010, Data of water quantity and quality in the MOD and entering of Ad Dalmaj Lake from 2009 to end of 2010.

[6].FAO: Ayres, R. S. and D. W. Westcot. 1994. Water Quality for Agriculture. FAO Irrigation and Drainage Paper 29 Rev 1.

[7].Food and Agriculture Organization of the UN, 2006, CROPWAT software.

[8].Ministry of Water Resource, MoWR, 2005, Encyclopedia of Irrigation Services in Iraq, since March 1918 to March 2000.

[9].Ministry of Sciences and Technology, 2010, Climatically data for the southrain station (Hai, Nassiriyah, Basrah).

[10].Russian, 1984, " Tigris- Euphrates Main Outfall Drain, Middle part " project report prepared by Russian, part II, Hydraulic structures and canals, Volume I.

Table (1) TDS concentration and water discharge of the main outfall drain (MOD) before Ad Dalmaj Lake intake, (after Directorate of Main Outfall Drain, 2010).

Month	TDS,(mg/L)	Q, (m^3/sec)
Sep.	2793	57
Oct.	2667	65
Nov.	2767	70
Dec.	2830	76
Jan.	2166	68
Feb.	2587	72
Mar.	2988	70
Apr.	2961	75
May	3000	68
Jun.	3157	56
Jul.	3314	44
Aug.	3229	43

Table (2) TDS measurements in *ppm* during 2007-2008,*(CRIM, 2008)*.

Month	Um Nakhla	Al Kurmashia	Al Malha	AshShafi	Al Ghameej
Oct.	6070	6240	6419	----	6300
Nov.	5800	5980	6405	5790	6000
Dec.	5800	5980	6405	5790	6000
Jan.	5800	5980	6405	5790	6000
Feb.	2218	2012	3600	2470	2650
Mar.	2218	2012	3600	2470	2650
Apr.	2218	2012	3600	2470	2650
May	6340	6500	6428	6338	6600
Jun.	6340	6500	6428	6338	6600
Jul.	6340	6500	6428	6338	6600
Aug.	6070	6240	6419	6064	6300
Sep.	6070	6240	6419	6064	6300

Table (3) TDS measurements of the marsh feeders in ppm during 2009, *(After CRIM, 2009)*.

Month	U m-Nakhla	Kurmashia	Garmat Beni Sied	Ash Shafi	Al Mushab	As Slal
Oct.	3360	3420	3260	885	5670	5960
Nov.	3830	3860	3840	1000	7350	6900
Dec.	2155	2160	2170	1010	6070	5850

Table (4) Topographical characteristics of Ad Dalmaj Lake, (after Russian, 1984).

Level (a.m.s.l)	11.5	12	12.5	13	13.5	14	14.5	15
Area(km^2)	18	68	98	137	196	269	344	453
Storage($millm^3$)	8	25	74	127	215	330	495	691

Table (5) TDS concentration, ppm, within Ad Dalmaj Lake and Al Hammar Marsh according to the first and second operation scenarios.

First operation scenario(when inflow variable and outflow constant)						
	At the end of the 1st year		At the end of the 2nd year		Max	
	C_D	C_H	C_D	C_H	C_D	C_H
1-$AD_{max}=AD_{max}(Q_{out}=10)$	62200	38776	191397	75368	191397	75368
2-$AD_{max}=90\%AD_{max}(Q_{out}=10)$	57646	37240	173238	71315	173238	71315
3-$AD_{max}=80\%AD_{max}(Q_{out}=10)$	54249	30117	152165	63879	152165	63876
4-$AD_{max}=70\%AD_{max}(Q_{out}=10)$	47008	32715	131879	56159	131879	56159
5-$AD_{max}=60\%AD_{max}(Q_{out}=10)$	42418	30304	107572	47749	107572	47749
6-$AD_{max}=AD_{min}(Q_{out}=10)$	40890	27672	92864	41251	92864	41251
7-$AD_{max}=AD_{max}(Q_{out}=30)$	28153	26109	22855	25462	28153	34042
8-$AD_{max}=90\%AD_{max}(Q_{out}=30)$	26305	25550	21487	25046	26305	33027
9-$AD_{max}=80\%AD_{max}(Q_{out}=30)$	24357	30309	19803	29046	24357	34863
10-$AD_{max}=70\%AD_{max}(Q_{out}=30)$	22447	24202	18077	23665	22447	30737
11-$AD_{max}=60\%AD_{max}(Q_{out}=30)$	20529	28045	16009	26304	20529	32099
12-$AD_{max}=AD_{min}(Q_{out}=30)$	19616	23049	14939	22039	19616	28803
13-$AD_{max}=AD_{max}(Q_{out}=46)$	18664	22656	13498	21165	18664	28940
14-$AD_{max}=90\%AD_{max}(Q_{out}=46)$	18567	22607	13497	21163	18567	28868
15-$AD_{max}=80\%AD_{max}(Q_{out}=46)$	18544	22593	13497	21162	18544	28849
16-$AD_{max}=70\%AD_{max}(Q_{out}=46)$	18543	22589	13497	21162	18543	28846
17-$AD_{max}=60\%AD_{max}(Q_{out}=46)$	18542	22586	13497	21162	18542	28843
18-$AD_{max}=AD_{min}(Q_{out}=46)$	18541	22584	13497	21162	18541	28841
Second operation scenario(when inflow constant and outflow variable)						
19-$AD_{max}=AD_{max}(Q_{in}=53)$	27329	33427	27075	41957	27329	46897
20-$AD_{max}=90\%AD_{max}(Q_{in}=46)$	27459	27934	27382	33229	27693	38186
21-$AD_{max}=80\%AD_{max}(Q_{in}=38)$	27080	43167	34252	60124	34252	60124
22-$AD_{max}=70\%AD_{max}(Q_{in}=33)$	31836	32123	43932	40631	43932	42546
23-$AD_{max}=60\%AD_{max}(Q_{in}=29)$	35655	24685	50209	27452	50209	27452
24-$AD_{max}=AD_{min}(Q_{in}=28)$	35053	22902	44338	23539	45314	28209

Figure (1) Location of study area.

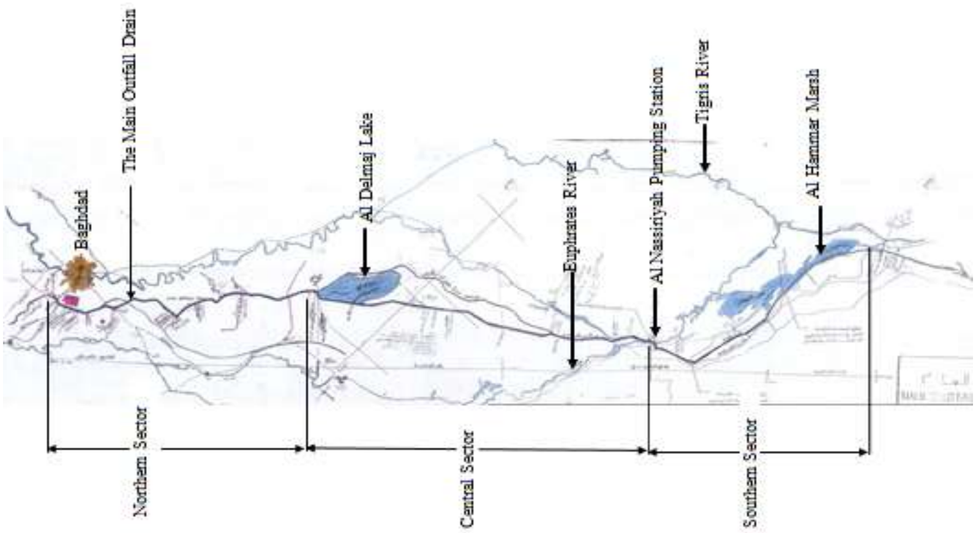


Figure (2) General layout of the MOD, Directorate of the MOD, 2008.

Figure (3) General Layout of Ad Dalmaj Lake.

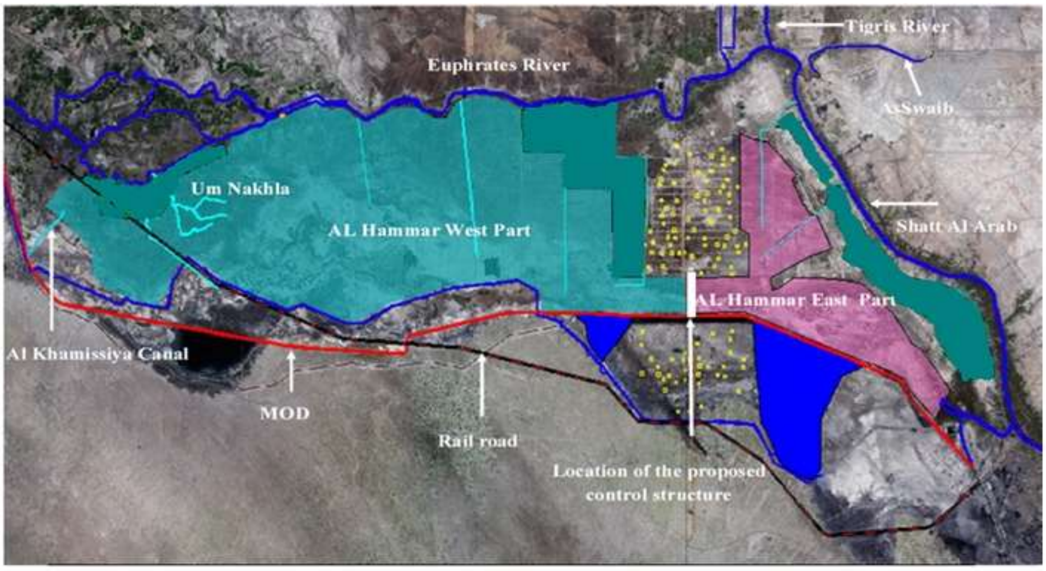


Figure (4): General layout of Al Hammar Marsh, with the proposed control structure.

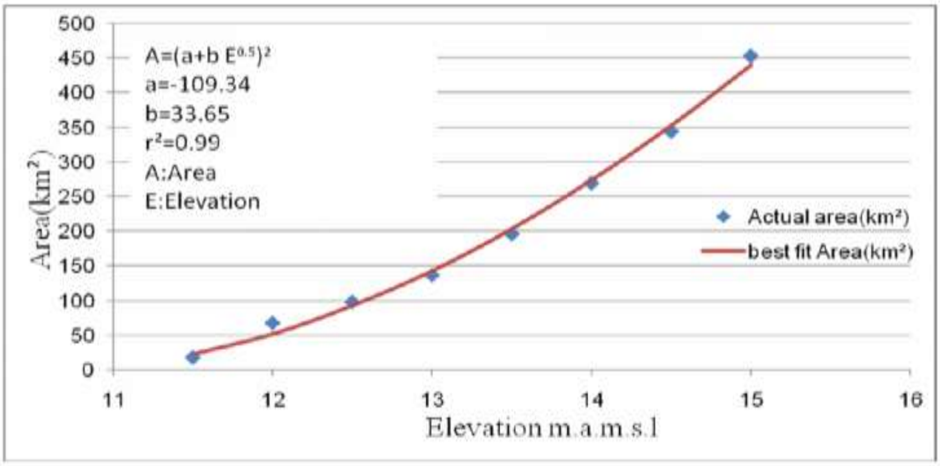


Figure (5) Area-Elevation curves of Ad Dalmaj Lake.

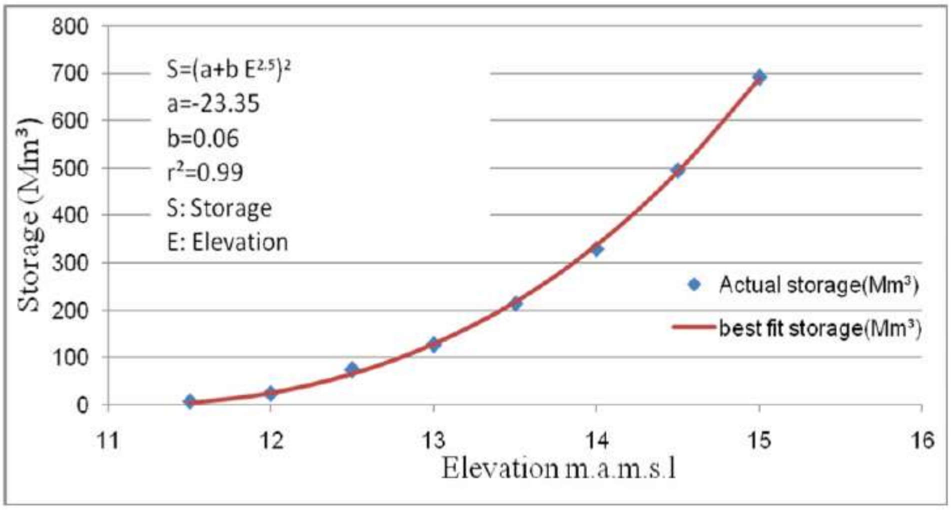
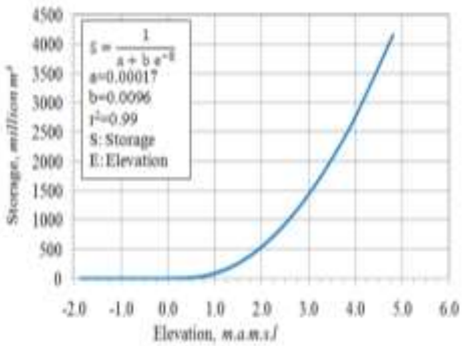
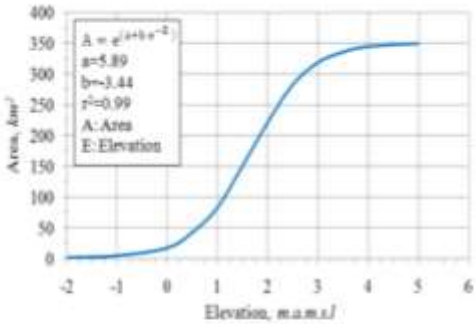


Figure (6) Storage-elevation curves of Ad Dalmaj Lake.



a- West part of Al Hammar Marsh



b- East part of Al Hammar Marsh.

Figure (7) Area-elevation curves of Al Hammar Marsh.

c- West part of Al Hammar Marsh d- East part of Al Hammar Marsh.

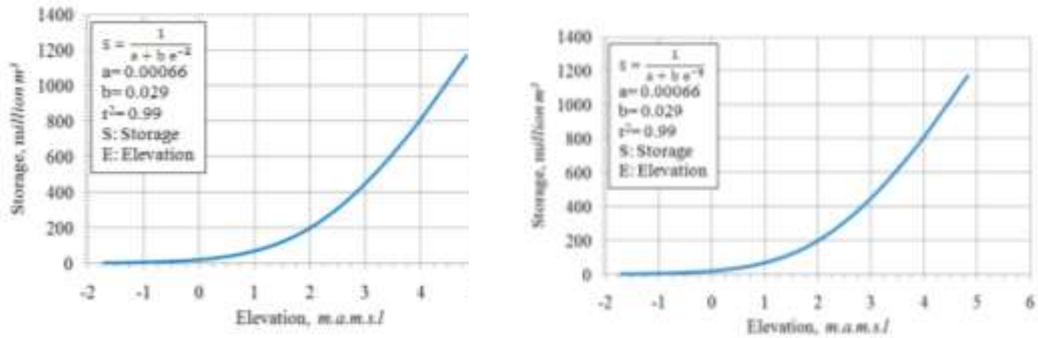
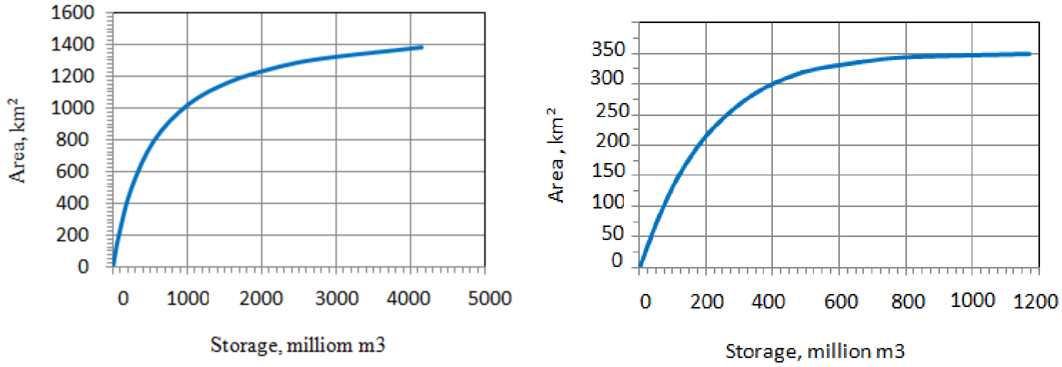


Figure (8) Storage-elevation curves of Al Hammar Marsh.



e- West part of Al Hammar Marsh f- East part of Al Hammar Marsh.

Figure (9) Area-storage curves of Al Hammar Marsh.

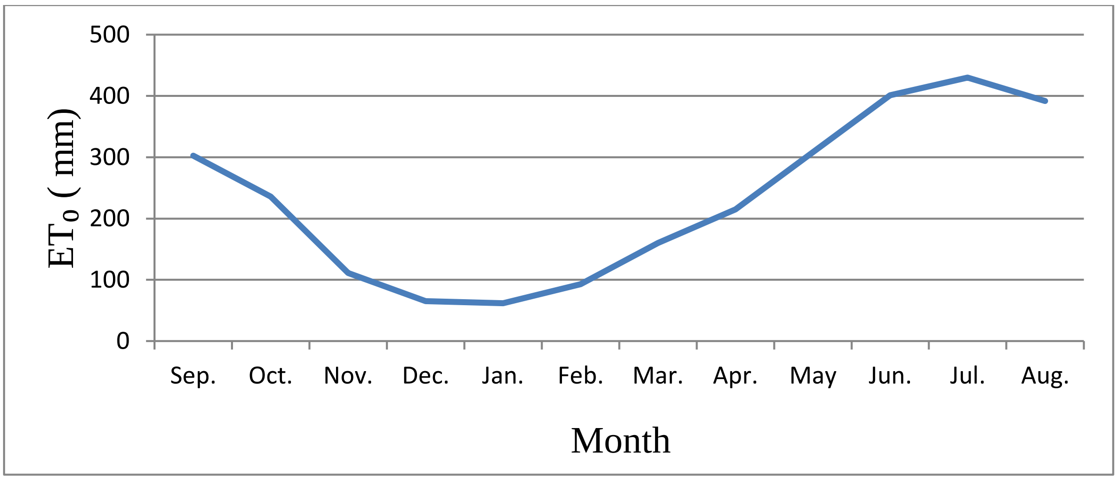


Figure (10) Estimating Evapotranspiration within Ad Dalmaj Lake Region.

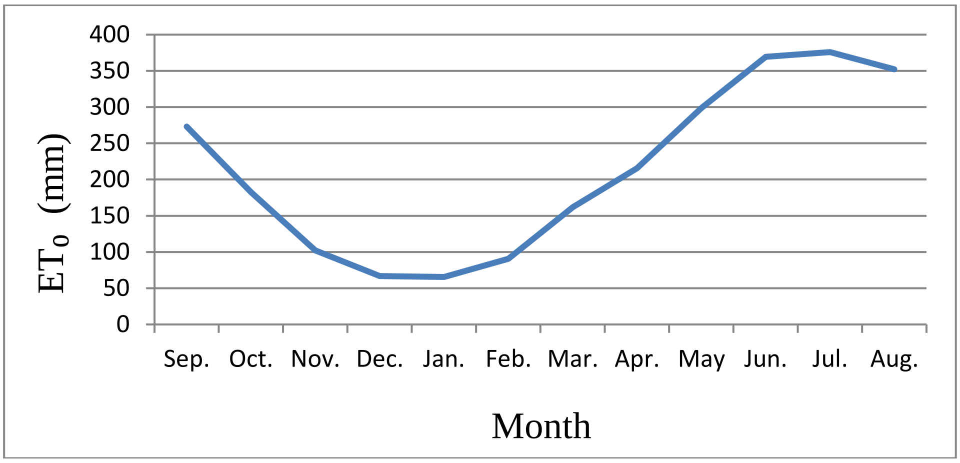


Figure (11) Estimating Evapotranspiration within Al Hammar Marsh Region.

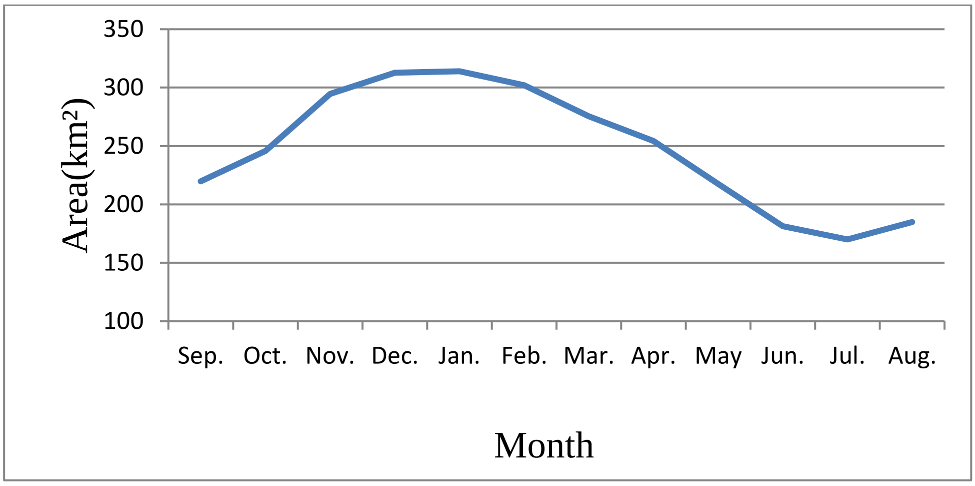


Figure (12) Area cycle of Ad Dalmaj Lake.

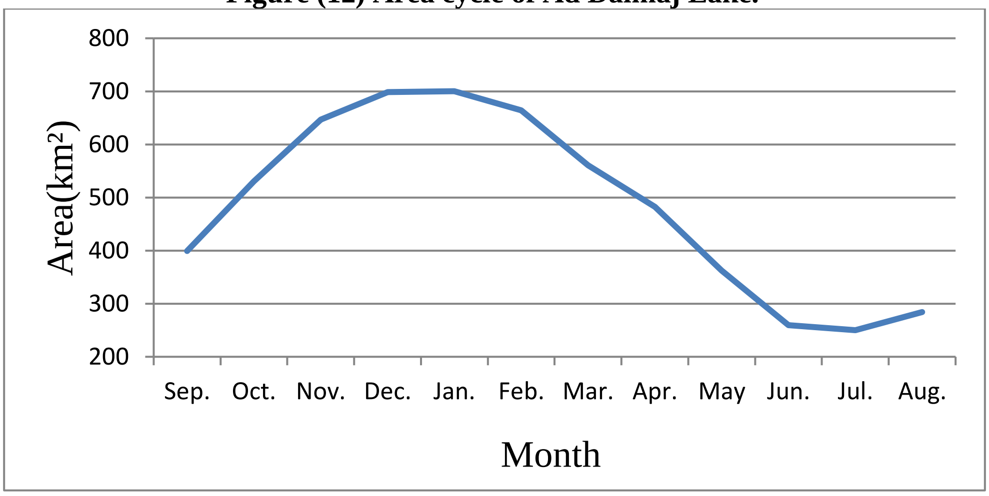


Figure (13) Area cycle of Al Hammar Marsh.

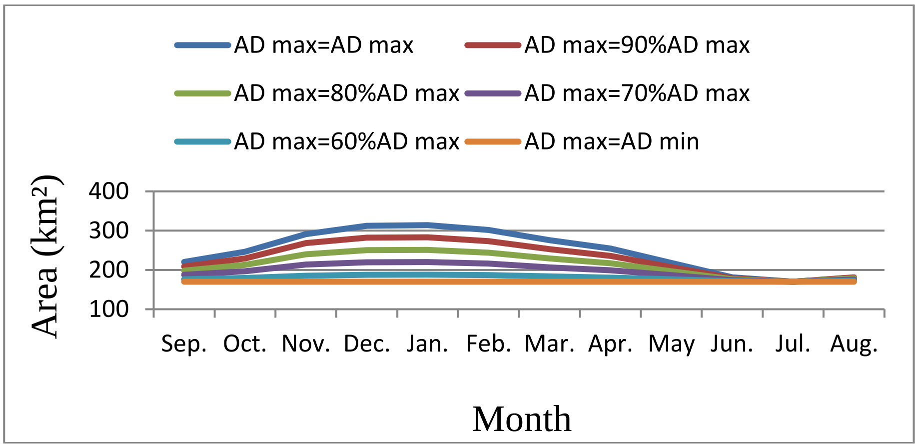


Figure (14) Area cycle variation of Ad Dalmaj Lake.

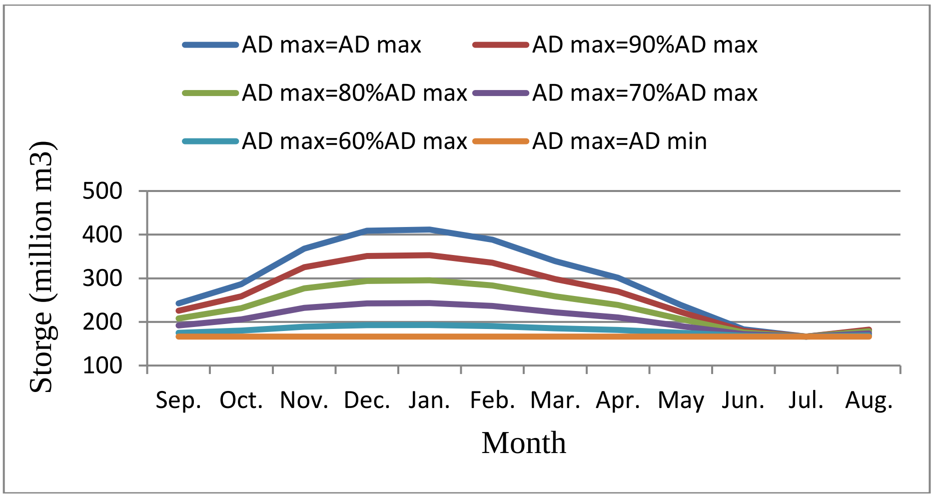


Figure (15) Storage cyclic variation of Ad Dalmaj Lake.

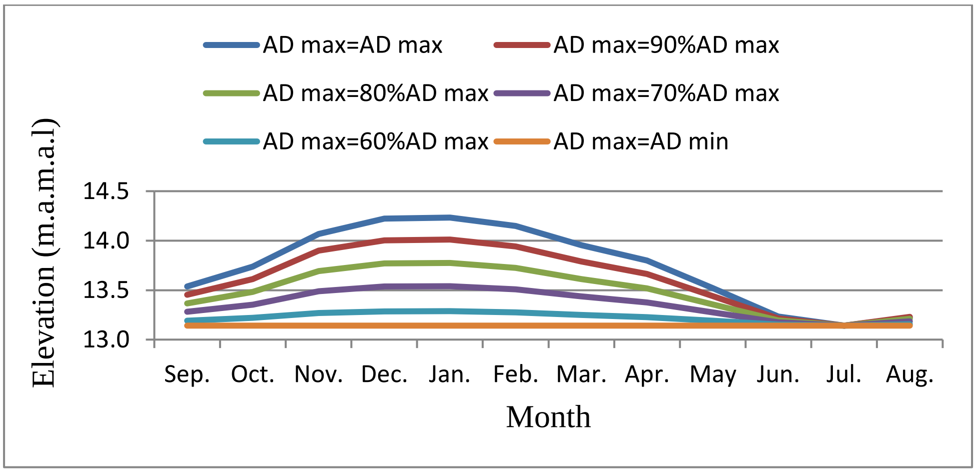


Figure (16) Elevation cyclic variation of Ad Dalmaj Lake.

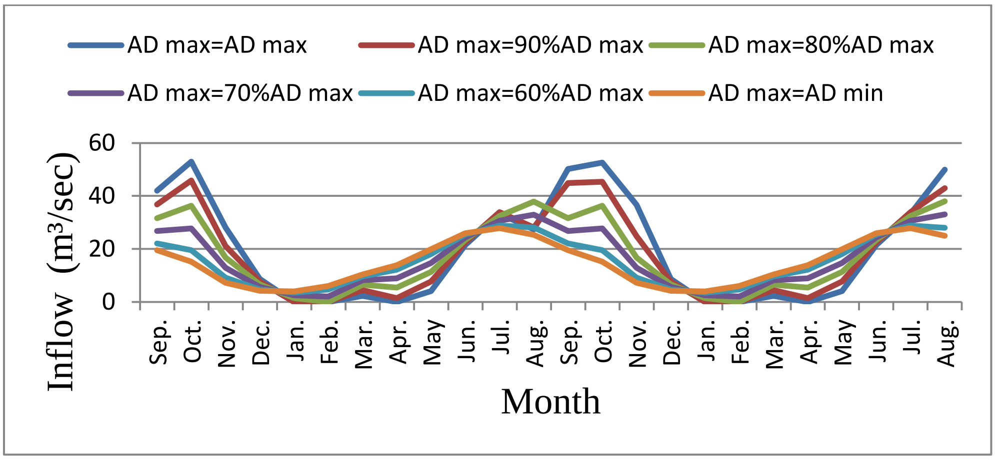


Figure (17) Total inflow required to maintain the area cycle of Ad Dalmaj Lake with Q out=0.

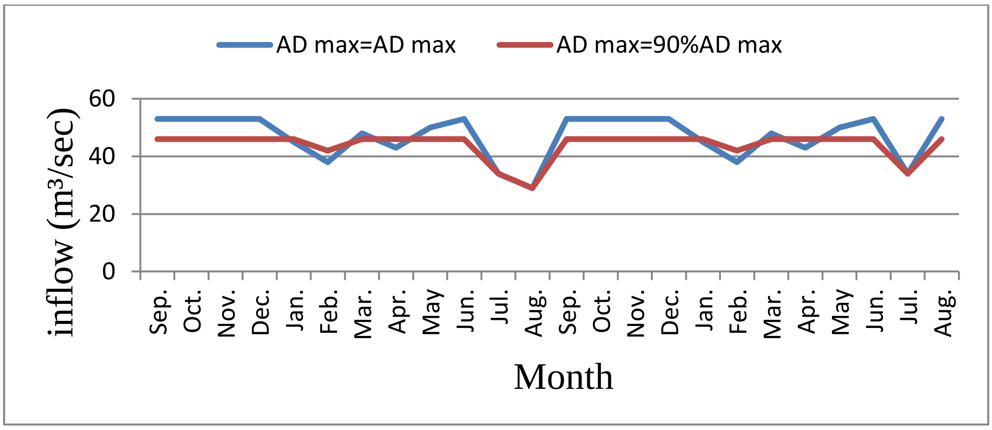


Figure (18) Inflow to Ad Dalmaj Lake based on the second operation scenario.

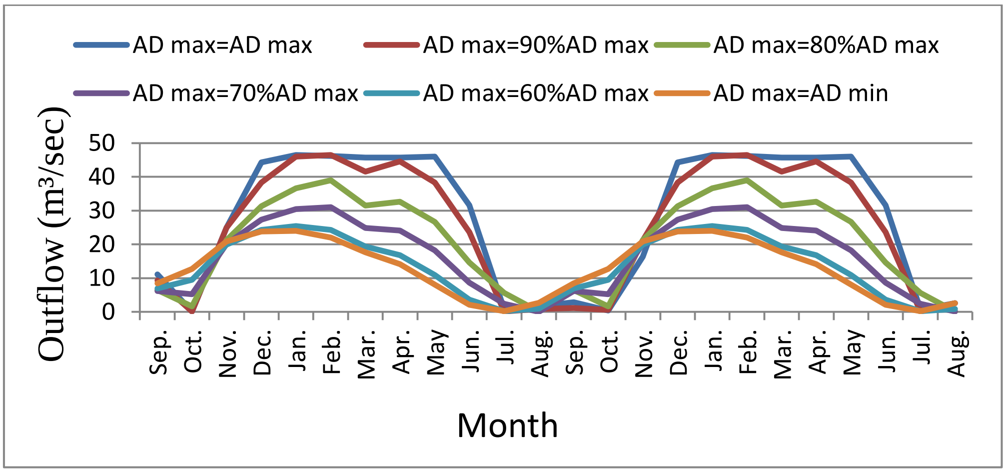


Figure (19) Outflow from Ad Dalmaj Lake based on the second Operation scenario.

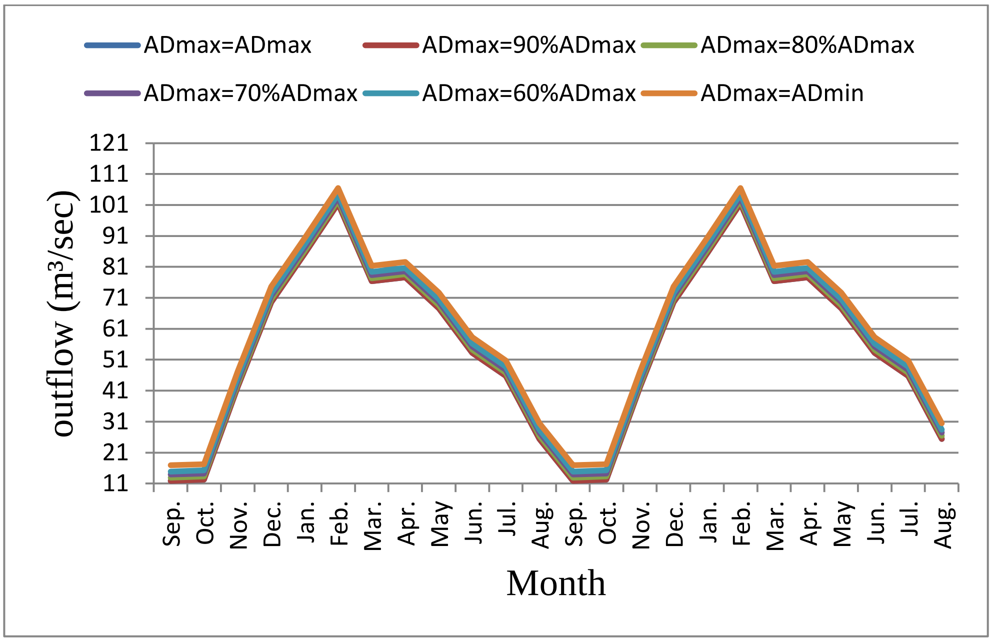


Figure (20) Outflow from Al Hammar Marsh according to the first Operation scenario of Ad Dalmaj Lake when $Q_{D\ out}$=10m^3/sec for all cases of Ad Dalmaj Lake area.

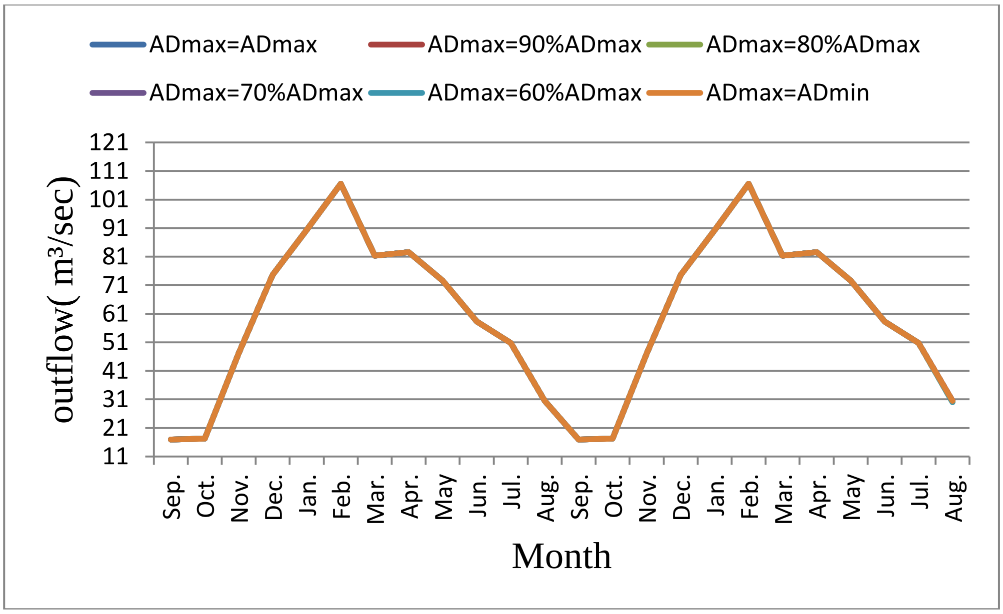


Figure (21) Outflow from Al Hammar Marsh according to the first Operation scenario of Ad Dalmaj Lake when $Q_{D\ out}$=30 and 46m^3/sec for all cases of Ad Dalmaj Lake area.

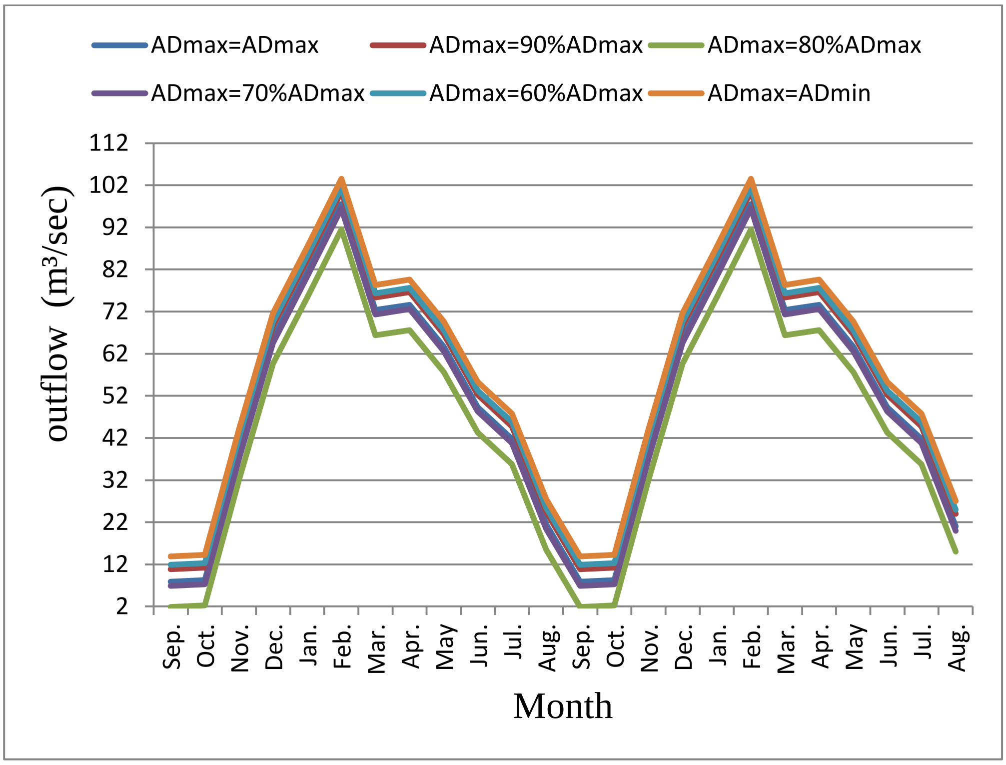


Figure (22) Outflow from Al Hammar Marsh based on second operation scenario of Ad Dalmaj Lake for all cases of Ad Dalmaj Lake area.