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Effects of Flow Rate in Euphrates River on Salinity Concentrations

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Abstract
The main objective of the study is to know the extent of the effect of the flow rate on the water quality, especially about the salinity concentrations in the Euphrates River basin and the relationship between them during the period (1986-2005). In this study, the observed data for the flow rate is a correlation with the measured total dissolved solids (TDS) rates in the Euphrates River as the main indicator of salinity. The result has shown that the salinity between Haditha Dam and Ramadi Dam of the Euphrates Rivers (depending on the TDS values) is not too much affected. The salinity concentrations and TDS values increased substantially at a Fallujah Barrage site than at the Ramadi Dam site, although the distance from each site is no more than 50 km due to its high salinity because of the impact of the water flow to the Euphrates from Tharthar Lake. The results show the minimum release discharge from Haditha Dam is 153m^3/s to maintain the salinity at an acceptable limit (1000 ppm) until Fallujah Barrage and must prevent irrigation water return to the river along river main channel after this site.

Keyword: *Flow Rate, Euphrates River, Salinity, water quality, TDS*

I. Introduction

Euphrates River is the longest river in South-Western Asia. It starts to flow in eastern Turkey until the end in the gulf south of Iraq (fig.1) with a total length of the river about 2,786 km. There are three riparian's for the river, but as shown in fig.1 the basin of it is distributed among five countries: Turkey, Syria, Iraq, Saudi Arabia, and Jordan. The catchment area of the Euphrates Basin about 440,000 km2 distributed as in fig 2[1].

Water management requires an understanding of river fluctuation cycles in physical and chemical concentrations, including nutrients, as well as the distinction of physical and biogeochemical processes' effects [2,3,4].

Because of large dams that were built on the Euphrates River basin in Turkey and Syria (fig.1), the discharge of river to Iraq decreased to about 25% of the total discharge before dams building in 1980 and after. The estimations refer to a decrease incoming revenues for Iraq to 24% in 2035 If Turkey and Syria continue to implement their projects and complete these full plans, (Fig. 3). Dams may change the nature of the water environment, and affecting the flow system, as well as the river ecosystem such as transport materials and mixing of it, and water quality [6]. Modified flow rates downstream of dam reservoir occur commonplace in drought conditions because of low inflow rate or low storage volumes and a high rate of evaporation prevent or decrease discharging water downstream [7].

According to the available data in the city of Hit located 200 km from the Syrian border, the flow rate was 33 BMC/year until 1970 decreased to 8 BMC/year in 1980. The decreasing discharge in the Euphrates River led to many problems of water quality which is deteriorated resulted from high levels of salinity. For example, the average concentration of TDS in the river at Hit had increased to 700 ppm from less than 500 ppm and can reach the high dangerous level of salinity in the cities of south Iraq[8]. The high level of salinity and water quality deteriorates effects on agriculture activity because of decreasing the crop productivity as well as its effect on public health.

Until 1973, the water of the Euphrates River relatively had low salinity and did not exceed 1,000 ppm along river course in Iraq in comparison with 1000 ppm in Al Qaim, 1100 ppm in Al Hindia, 3000 ppm in Al Samawa and 4000 ppm in Al Nassiriah measured in 2000-2001[9].

Climate change is the additional scenario that shows considerable changes in river hydrology; especially decreasing discharge and its fluctuation [10]. Climate change and dam projects in Turkey and Syria cause dramatic variation in average discharge from year to year. As well as leads to a change in outflow distribution during the year when more frequently occurring extreme phenomena for example floods during the winter and droughts during summer and autumn. These changes especially that related to hydrological drought can cause significant changes in water quality which means a decrease in available water resources, and render these resources useless for the

population in addition to the damage to the environment. The river ecosystem state is influenced significantly by the effects of low flow in the River which is dependent on the stream characteristics in the region.

In the present study, an attempt is achieved to find out the extent to which the flow rate or discharge in the Euphrates River can affect the quality of water, especially about the issue of salinity. This problem has become a major problem affecting the quality of water as well as its negative effects on crops and their productivity in addition to their impact on public health. After the Haditha dam was constructed and operated in 1986, became the main control tool on the flow rate in the Euphrates River and its water quality. Knowing the effect of water releases from the Haditha dam on water quality, and what are the ranges of discharge that can be adopted from these releases to maintain water quality is one of the most important functions of dam operation.

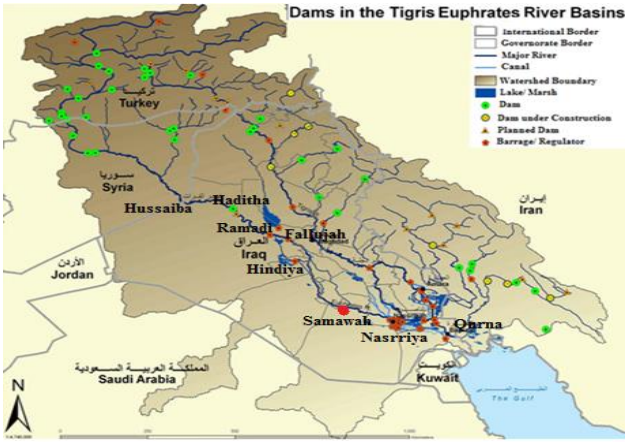

Fig.1 Euphrates River Basin

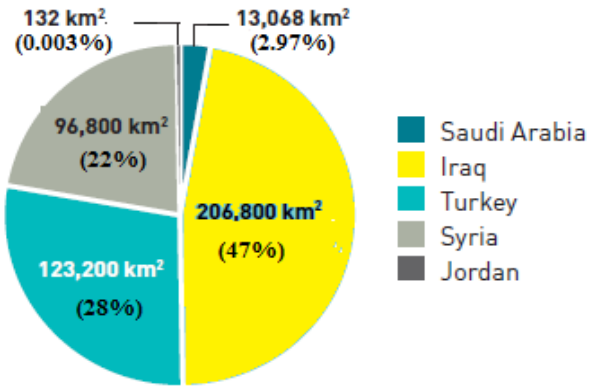

Fig.2, catchment area distribution in riparian countries

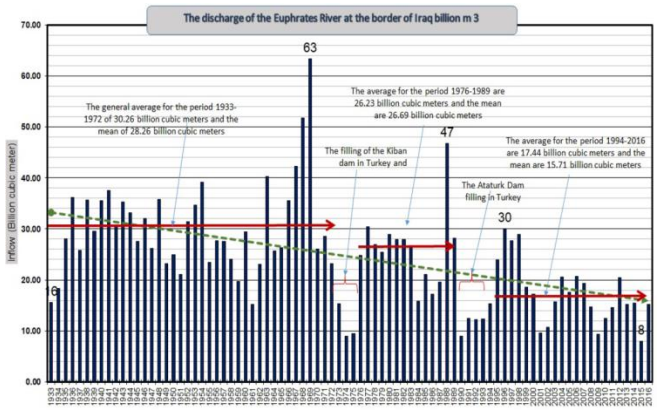

Fig. 3 annual discharge of the Euphrates River at Iraq-Syria border [5]

Effect of Water Quantity and Quality on River Ecosystems

In the present time, rivers are suffering from the massive load because of the different anthropogenic activities, such as sewage waste, industrial and riverbed mining activity that cause deterioration of water quality in rivers appreciably and affected the aquatic and human life [11, 12, 13. 14, 15].

Water quality includes the constituents with their different concentration in the water in addition to their temperature and state [16]. Many characteristics of water quality and quantity are interlinked in rivers closely. Water quality importance can vary depending on the river flow rate (actual water quantity). Ecosystems and their components are involved in the water quality and resultant water quantity relationship [17]. Water quality has the same importance as the quantity and temporal patterns of flows [18]. With the quick developments in the past decade, scientists have concluded water quantity is inadequate to determine the river ecosystem function. Ecosystem and many parameters of its biota are together determined by water quantity and quality [16,19].

However, most models and techniques for dams and reservoir operation assessment depend principally on the discharge or flow rate (quantity of water) required to satisfy the demands or keep ecosystem integrity, in comparison with developed unequal pace methods for water quality assessment [19]. Water quality and its assessment for irrigation, domestic use, conservation, in addition to industrial usage, are among the most important strategy for the safety of food and human health. The evaluation of it aims to identify the pollution sources of water and develop a sustainable water management strategy, maintaining human health and economic growth for any community [20].

II. Methodology

In the present study, observed and measured data of annual flow rate in the Euphrates River released from the Haditha Dam were used with the annual rates of the river's water salinity based on (TDS) parameter.

The data includes the measured data during the period from 1986, the date of operation of the Haditha Dam to the year 2005, when most of the projects on the Euphrates River basin in Syria and Turkey ended, and thus the river's condition became somewhat stable. The above period (1986-2005) is characterized by several stages through which it is possible to identify and determine the most important factors affecting the flow rate in the river with the extent of this impact on water quality. The first period is the operation of the Haditha Dam that considers the main controller of the flow rate in the Euphrates River inside Iraq in 1986. The second period is the start of the operation of the huge Ataturk Dam on the Euphrates River Basin in Turkey and its great impact on the flow rates after 1991. While the period from 2000 to 2005 is considered to have been completed the most of the Euphrates basin projects in addition to the impact of climate change, began to be taken into consideration during this period.

The salinity was taken into consideration depending on measurements of TDS along the Euphrates River and the extent of the impact of releases from a Haditha dam on this parameter at locations of the Ramadi barrage, the Fallujah barrage, and the Hindiyah barrage. The relationship between recent dam.

releases and salinity (TDS) values were determined in these control locations to determine the optimum discharge values, with which to ensure that salinity levels remain within acceptable levels.

Effect of Environmental Issues on Water quality:

Irrigated agriculture is widely used in the Euphrates Basin, causing a considerable amount of drainage water return flow which in turn causes high salt levels. Salts tend to accumulate along the river stream because they are not removed naturally. The Euphrates start discharge water from its headwaters in Turkey. Then it flows through a semi-arid region for over 1,500 km, with high rates of evaporation. The river flows through regions with gypsiferous soil in Syria, which has a high potential for salt motivation and thus contributes to more salinization. These characteristics lead to increasingly affects users downstream of the Euphrates River. The area south of the Euphrates River has also been affected by upstream dams and reservoir projects which led to the salinization of the Shatt al Arab River and heavy losses in river flow rate.

III. Results and Discussion

Figure (4) shows the annual TDS measured during the period 1986-2005 at the control location. The figure shows that the salinity of the Euphrates River (depending on TDS values) between Haditha Dam and Ramadi Barrage is not affected too much, especially the period from 1986 until the start of the operation of the Ataturk Dam in Turkey after 1991, which led to an increase in TDS concentrations due to the shortage of water inflow imports to Syria and Iraq. It is also noticed during the period (1986 - 1991) that salinity concentrations increased and TDS values increased significantly at the site of the Fallujah Barrage than in the site of the Ramadi Barrage, although the distance between them is not more than 50 km due to the effect of the water inflow to the Euphrates River from Tharthar Lake, which is characterized by its high saltiness.

At the site of the Al-Hindiya barrage, TDS values do not affect or change significantly from that of the Fallujah barrage. There are significant differences and changes in salinity concentrations between Haditha Dam and the rest of the sites after 2000 due to the decreasing discharge imports to Haditha Dam. The shortage of inflow flow rate to the Haditha reservoir leads to the decrease of discharge releases to the downstream areas that require compensation from the salty Tharthar Lake, whose waters enter the Euphrates River before the city of Fallujah.

Figure (5) shows the relationship between the annual flow rate releases from the Haditha dam and the annual TDS at the Ramadi Barrage site. It is noticed that the relationship tends to decrease (TDS) values with an increase of flow rate release from the reservoir, which indicates a positive effect on water quality. The relationship between the average annual releases from the Haditha Dam and the TDS values at the Fallujah Barrage site is shown in Figure (6). It indicates a decrease in the impact of the Haditha dam on water quality. Although the relationship tends to decrease in saline concentrations with increasing discharges, the correlation coefficient in Fallujah barrage ($R2 = 0.39$) compared with ($R2 = 0 .7$) in Ramadi barrage. As mentioned before, it is due to the effect of Lake Tharthar.

Figure (7) shows the relationship between the salt concentrations at the Fallujah barrage with the salt concentrations at the Al Hindiya barrage, which clearly indicates that the TDS values in Al Hindiya depend directly on these values at the Fallujah barrage. This influence continues beyond the Al-Hindiya barrage to reaches the city of Diwaniyah. After that, the TDS concentrations increase dramatically to reach about 1600 ppm in the Shanafiyah region due to the presence of many drainage wastes of irrigation water from crops directly into the river. TDS values continue with these high rates in Samawah and Nasiriyah until the city of Qurna, where salt concentrations decrease slightly due to its interference with the water of the Tigris River which characterizes by the least salty, as shown in Figure (8).

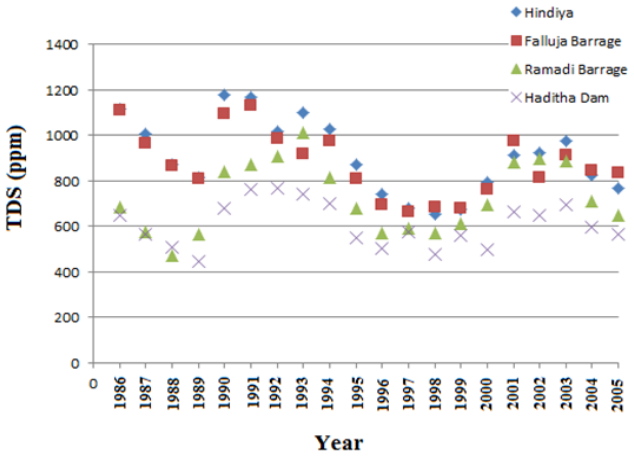

Fig.4 annual of TDS (1986-2005)

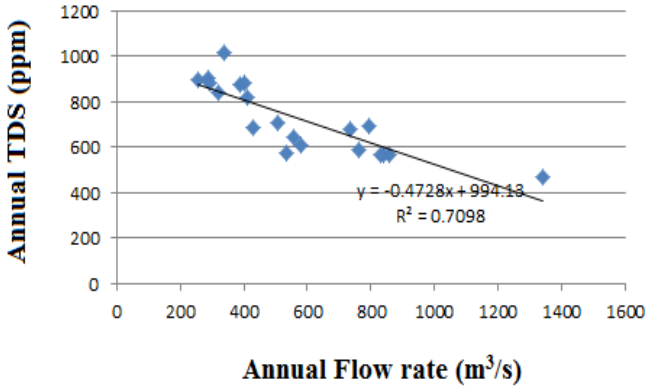

Fig.5 Relationship Flow rate and TDS in Ramadi

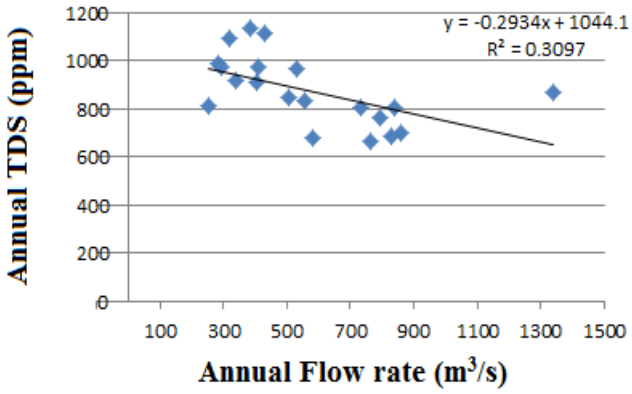

Fig. 6 Relationship Flow rate and TDS in Fallujah

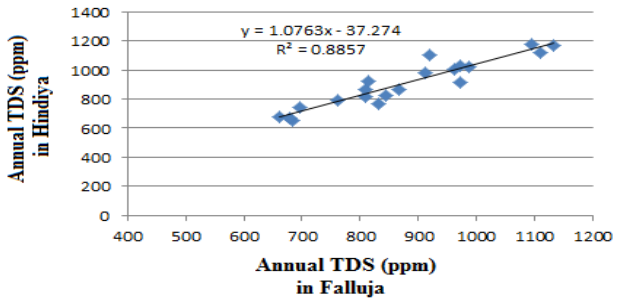

Fig.7 Relationship TDS of Hindiya and TDS of Fallujah

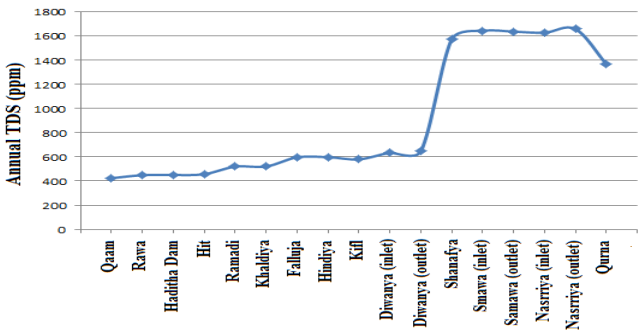

Fig. 8 annual TDS of Euphrates region

Discharge–Salinity Relations

For the years 1998 and 2001, the observed discharges at four measuring stations were combined with the observed TDS determined at (Haditha, Ramadi, Fallujah, Samawah, and Nasrriya) stations. These are the years when the Euphrates River enters a steady flow regime after all of the projects in Turkey and Syria are completed and operational. The data is fitted with a regression model, which is shown in Figures (9, 10, 11, 12, and 13).

The relationship (power-law) with the salinity regression formula as a function of discharge is estimated by eq.1:

$$T_{DS} = aQ^{-b} \dots\dots\dots (1)$$

Where T_{DS} represent the salinity measured as TDS in (ppm), Q is the river discharge in (m^3/s), and a, b are the coefficients depends on the location or region of the measurement station. The minimum discharge (Q^3/s) in the river depending on suitable water irrigation limit is calculated in the table (1).

Table (1), shows the effects of releasing discharge from Haditha dam is decrease with distance from the dam that becomes very difficult to maintain the water quality along the river. The maximum daily release discharge from Haditha dam during the period 1986-2005 is 2100 m3/s that is measured in 23-3-2004. It is also the maximum daily discharge release from Haditha dam until March-2021 which means the salinity will have a high level along Euphrates River after Fallujah Barrage until Qurna. The salinity control solutions are viable for reducing or reversing the Euphrates'

salinity-increasing mechanisms. The management options include halting water releases from Al Tharthar Lake and diverting irrigation return discharge away from the dam. The steps could be enforced without too much difficulty, but they would necessitate the riparian countries' cooperation. According to table 1, for TDS=1000 ppm, the minimum release discharge from Haditha dam is 153m3/s until Fallujah Barrage which is approximately one-third of the annual release discharge from the dam. To enhance the water quality and protect the Euphrates' environment, this flow should be sustained at all times within the river's course.

Based on the above, the problem of decreasing the discharge of the Euphrates River and its effect on the water quality, and consequently the environment of the Euphrates River in general, is linked to three important reasons. First: External reasons, represented by the absence of agreements and treaties regulating the equitable sharing of the Euphrates River waters. These can reduce the negative effects resulting from water investment in the upstream countries, Syria and Turkey, on the water revenues arriving in Iraq, its quality, and its repercussions on the environment of the river. Second: internal reasons related to the use of modern methods of irrigation and reducing water waste as a result of using the old traditional methods and methods of water resources management in Iraq and seriously thinking about reconsidering the management of these resources. There is a persistent need for conducting serious studies on the feasibility of storing water in the lake of Tharthar with high salinity concentration and then converting it to Euphrates River. The return irrigation water must also be treated before returning to the Euphrates River, with a system to monitor the water quality in the river. Third: the absence of environmental laws and legislation to protect the environment of the Euphrates River from deterioration due to the above reasons. The environment of Iraq has been affected in general as a result of the impact of the environment of rivers and the quality of water in it, especially the Euphrates River, which led to an increase in desertification and the decline of agricultural lands in addition to the impact of aquatic organisms (Fig. 14).

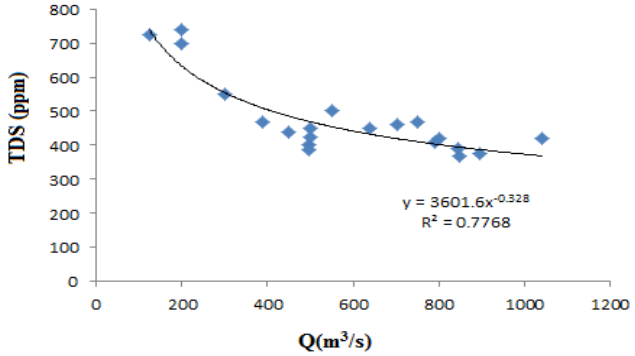

Fig.9, The relation of TDS and discharge at Hadith

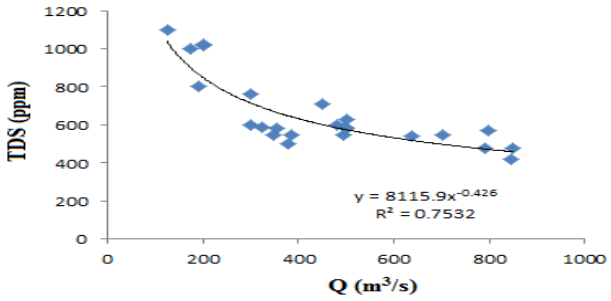

Fig.10, The relation of TDS and release discharge from Hadith Dam at upstream Ramadi Barrage

Standard	TDS(ppm)	Ramadi Barrage	Fallujah Barrage	Samawah	Nasiriya
Water for which no detrimental effects will usually be noticed [21,22,23]	500	425	651	7459	5193
Water that may have detrimental effects on sensitive Crops [21,22,23]	1000	137	153	2702	2194
A&M Texas [24]	1400	62	59	1384	1202

Table 1, TDS concentration with required discharge release from Hadith dam (Q^3/s) at four measured station

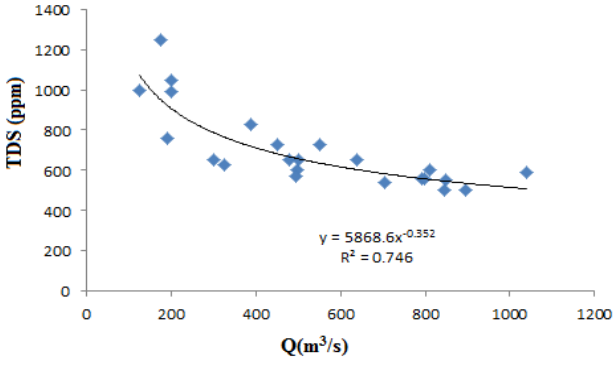

Fig.11, The relation of TDS and release discharge from Hadith Dam at upstream Fallujah Barrage

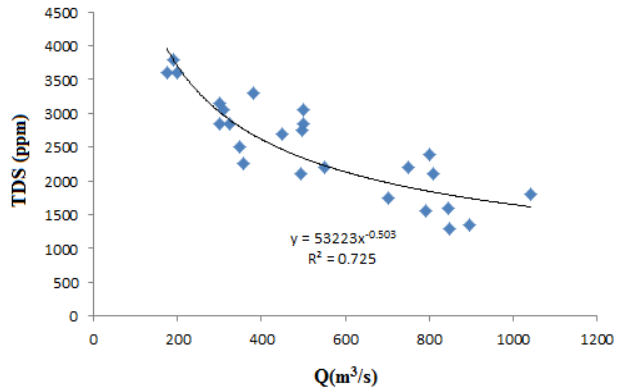

Fig.12, The relation of TDS and release discharge from Hadith Dam at Samawah

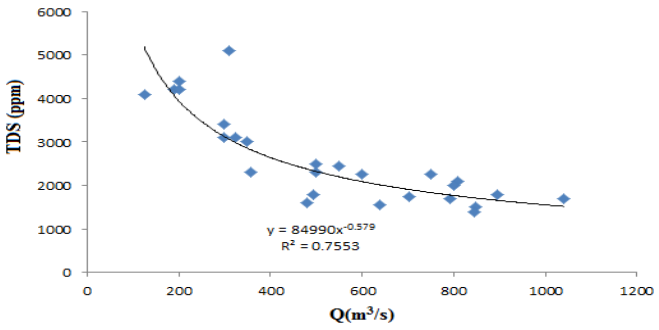

Fig.13, The relation of TDS and release discharge from Hadith Dam at Nasiriya

Fig 14, Fishkill on the Euphrates River near the Hindiya Barrage, Hilla, Iraq, 2 November 2018, Source: AFP

IV. Conclusion

- The decrease in the flow rate in the Euphrates led to an increase in salinity depending on the dissolved solids (TDS), especially in the southern regions of the river.
- There are negative effects of water diverted from Tharthar Lake to Euphrates River which need to solve and deal with this problem and put the acceptable solution
- Water irrigation return to Euphrates River One of the most effective reasons for the high salinity in the river which need to proposed a project to prevent or treat it.
- The effects of discharge release from the Haditha dam decrease with the distance from the dam. The discharge 153 m3/s release from the dam is effective to dilute the salinity until Fallujah and Hindiya Barrages after these sites the salinity affected mainly with return irrigation water to the river.

Acknowledgments

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