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IMPACT OF CLIMATE CHANGES ON THE HYDROGEOLOGICAL AQUIFERS- CASE STUDY DIBDIBA AQUIFER AT KARBALA – NAJAF AREA, IRAQ

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ABSTRACT

The climate parameters data for more than forty years for Karbala meteorological stations were studied .The results show good evidence of climate change indicated by the remarkable decrease of the average means annual rainfall in the studied stations, with the remarkable increase of the average mean annual temperature. MODFLOW program is applied. GIS, 3D spatial analyst is used to prepare future planning to drill more water wells. The impact of the climatic change on the groundwater was obvious in decreasing the water table as studied in the unconfined aquifer in Karbala – Najaf area. The Dibdiba aquifer in this basin represents the shallow aquifer which recharged mainly from rain water. Since this source is scarce, the aquifer gains its water slowly in a rate less than the rate of losing it by both evaporation and abstraction wells. The designed model and the water budget calculations confirm this state that the aquifer is worn out and predict that within the year 2014 several sites were depleted especially the eastern parts of the Dibdiba aquifer.

Keywords: *Climate change, Groundwater Modeling, Karbala - Iraq.*

1.INTRODUCTION

The climate of Iraq is characterized by hot–dry summers and cold–rainy winters. Roughly 90% of the annual rainfall occurs between November and April. The temperature in Iraq ranges from 53°C in July and August to freezing point in January.

Water resources systems need to be operated to cope with variability of climate changes; mainly the expected changes in (temperature and precipitation) then there are great need for an emergency or risk water resources management practices. Actually, current water management practices are very likely to be inadequate to reduce the negative impacts of climate change.

Water resources systems, traditionally, designed on the assumption that the statistical characteristics of the hydro-meteorological processes are almost expected annually and on the long run, but now, it is absolutely necessary taking into account the fact that all these parameters are expected to change accordingly with the effects of the global climate change.

Several studies were submitted concerning the hydraulic characteristics and the hydrochemical properties of the groundwater in Iraq (Al-Ani, 2004, Ali, 1994, Consortium Yugoslavia, 1977), but none deals with the effect of the climatic changes on the future utilization of the groundwater basins in Iraq. The impact of the climatic change on the groundwater was obvious in decreasing the water table as studied in the unconfined aquifer in Karbala – Najaf area. The Dibdiba aquifer as case study was chosen in this basin represents the shallow aquifer which recharged mainly from rain water. Since this source is scarce, the aquifer gains its water slowly in a rate less than the rate of losing it by both evaporation and abstraction wells. Dibdiba basin is one of the important hydrogeological basins in the western parts of Iraq, to the west of the Euphrates River and south Razzazah Lake (Fig.1). The basin covers an area of 2845 km^2 and is located between Karbala and Najaf Governorates between 45^o 09 $^/$ – 45^o 36 $^/$ E and 34^o 12 $^/$ – 34^o 39 $^/$ N in the central part of Iraq. The main shallow aquifer of the basin extends within the clastic sediments of the Upper Pliocene-Pleistocene named Dibdiba formation. The aquifer recharged mainly from rainfall and due to reduction of precipitation with time, the aquifer is not fully saturated and wide parts are lacking sufficient groundwater. The quality and quantity groundwater of the study area has been recently appeared in the last two decade to suffer pollution, depletion, bad quality and quantity of groundwater, due to heavy and excessive pumping of groundwater and planting the area, especially during the dry long period (April – October) in Iraq. Pollution mainly comes from human activities, such as irrigation water that mixed with fertilizes and from the waste disposal (solid or liquid).

This study is performed to determine quantity and quality for ground water and prepare an initial study to available consequences in order to forming a complete idea to prepare a brief study in the future depends mainly about planning to drill more water wells in the region and due to the indicators of water depletion in the existing ground water wells, this study aims to give a confirmation on the Dibdiba aquifer exploitation based on the modeling technique.

2. MATERIALS AND METHODS

A. Climatic parameter analysis

Karbala meteorological station was chosen in order to analyze the general climatic elements. The available data for about forty years (1971 t0 2009) records of the climatic elements were studied, such as temperature, evaporation and rainfall **(**Mahmud, et al, 2013)**.**

B. Groundwater Flow Modeling of Dibdiba shallow aquifer

Groundwater flow model of Chiang and Kinzelbach, 2003, which was based on finite difference method of implicit solution, was applied. The use of this model is to develop a numerical quasi three dimensional groundwater flow of the shallow aquifer in the studied basin within the U. Pliocene-Pleistocene sediments.

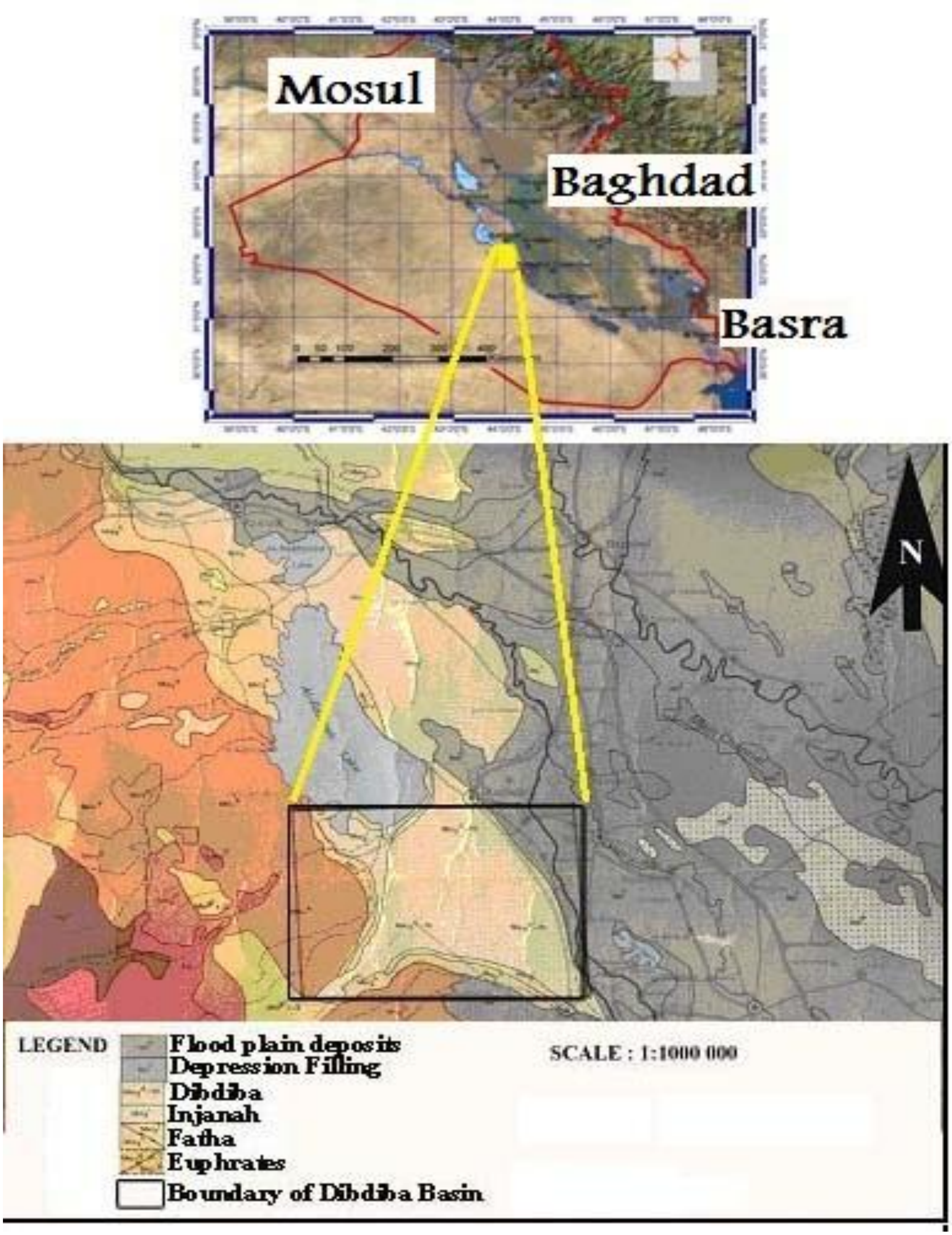

Fig.1: Geological and location map (Sissakian, et al, 2000).

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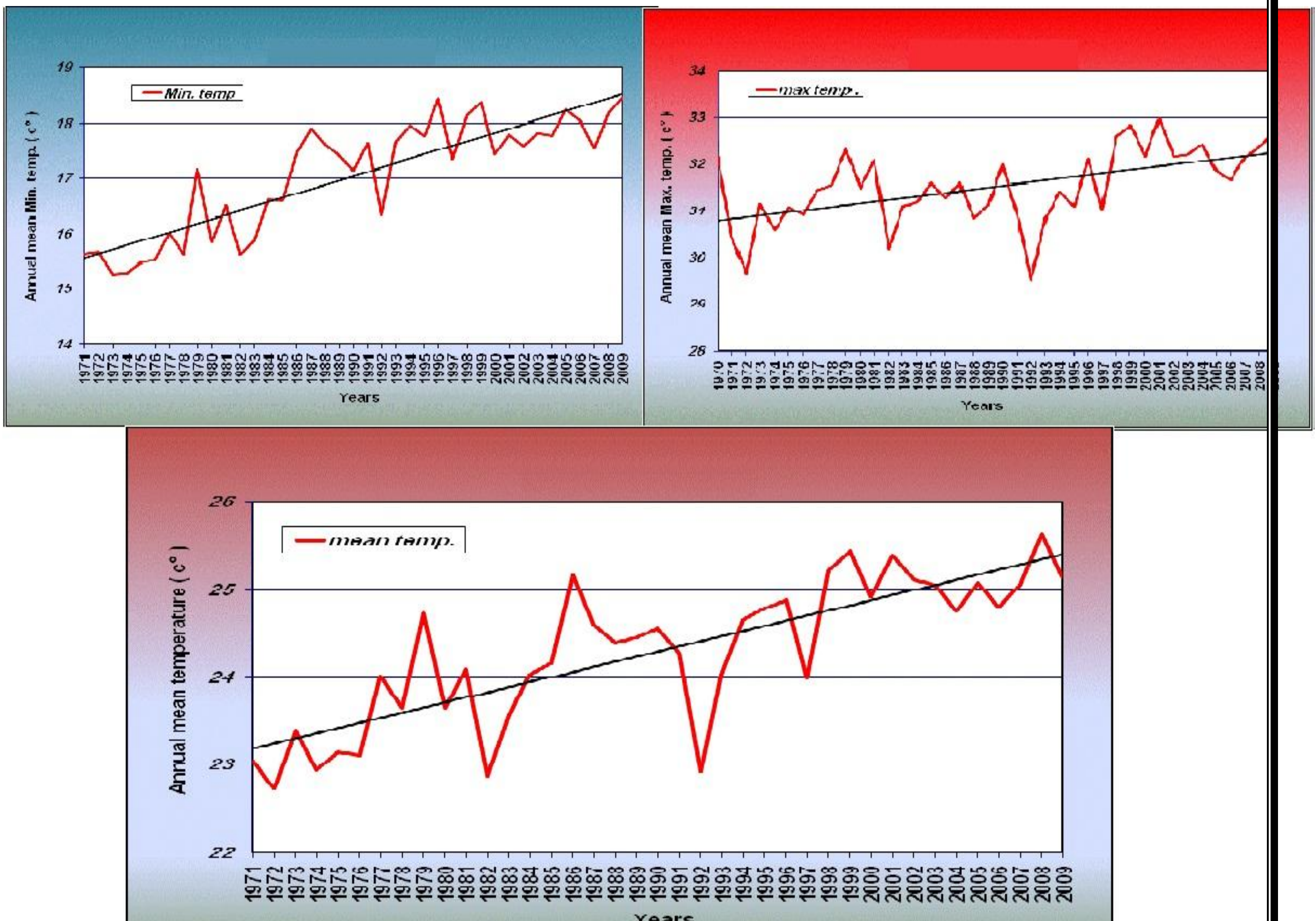

Figure 2: The Linear trend of annual mean temperature, mean annual minimum temperature and mean annual maximum temperature (^oC) time series of Karbala meteorological stations for years 1971–2009 (Mahmud, et al, 2013).

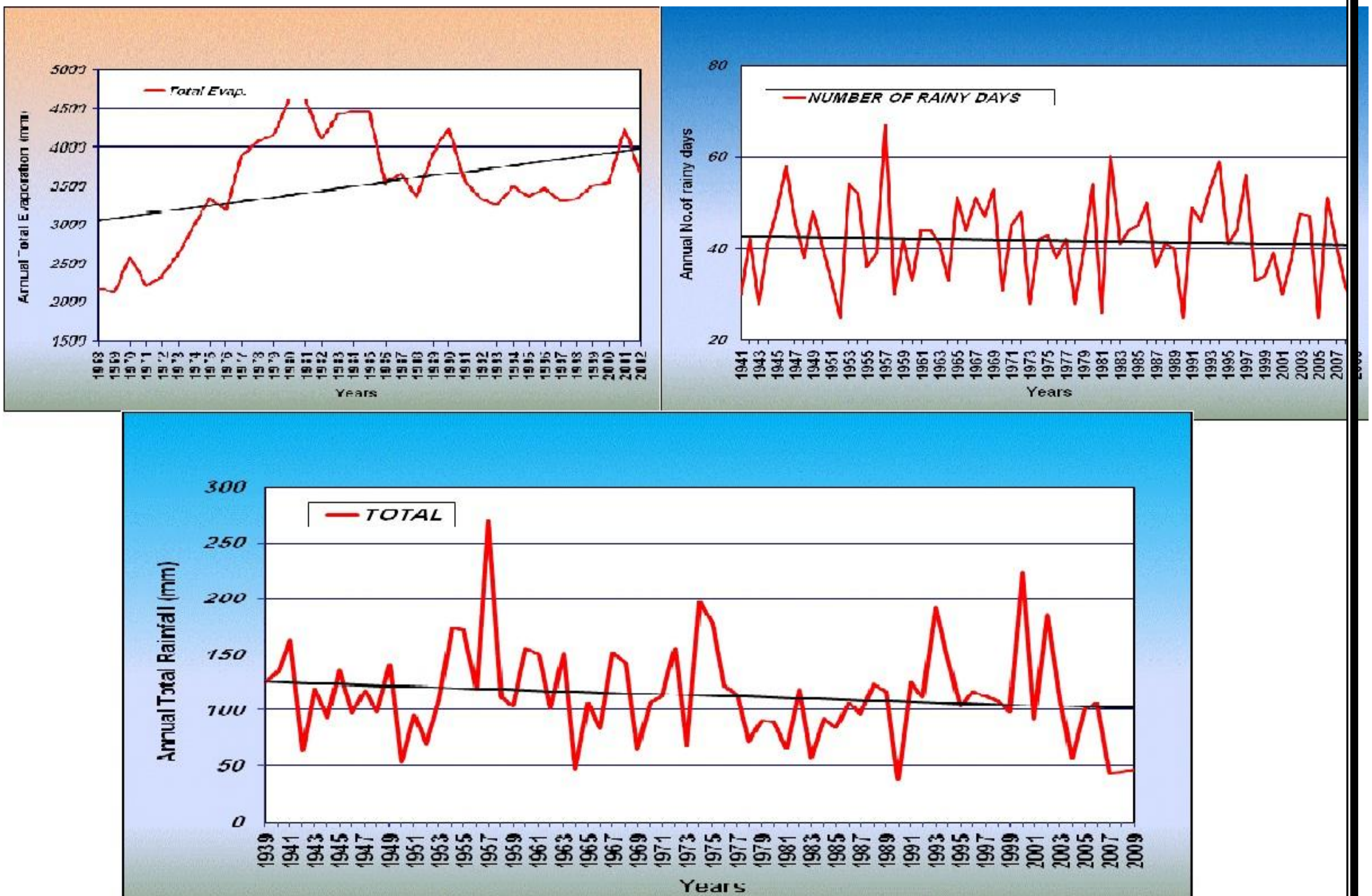

Figure 3: The Linear trend of annual total Rainfall , Number of rainy days and annual total Evaporation (mm) time series of Karbala meteorological stations for years 1939–2009 (Mahmud, et al, 2013).

3. RESULTS AND DISCUSSION

A-Climate

The mean annual temperature, the mean annual minimum and maximum temperature of Karbala meteorological station for the year from 1941–2009 (°C) frequency curves were studied for available data. The relationship between temperature and time seems positive with remarkable increase in temperature values were indicating from the general trend line, (Fig. 2).

The mean annual rainfall (mm) and number of rainy days frequency curves for the years 1939–2009, were studied for available data of Karbala meteorological station. The relationship between rainfall and number of rainy days with time seems negative, (Fig. 3). Remarkable increase in annual total evaporation was indicating as well from the general trend line (Fig. 3).

B-Applying Groundwater Flow Modeling

Since rainfall is the main source of groundwater recharge in the Dibdiba aquifer and as the basin is heavily exploited. The ground water flow model was designed to predict the probable changes in the groundwater level with time as a result of rainfall reduction and wells abstraction. The Dibdiba aquifer is generally unconfined in its western parts and as moving to the east, the aquifer lies down below a cover of Quaternary deposits. Therefore, the presence of marl and clay lenses within the Dibdiba formation reserves the water in an isolated sand lenses. The saturated thickness of the aquifer increases toward the west .The hydraulic parameters are varied laterally, where high values for both transmissivity and storage coefficient occurs due north. The aquifer recharged mainly from rainfall and since the basin is located within an arid environment, where rains are scarce and limited within a few winter months, hence the aquifer is not fully saturated and wide parts of the aquifer lacks sufficient groundwater (Al-Furat center for studies and designing irrigational projects, 1993, Al-Ani, 2004, Al-Shamma'a, and Al-Dabbas, 2009).

The piezometric map illustrates the direction of groundwater flow from the west toward the east, northeast and southeast directions (Fig.4). It also shows the presence of groundwater divide in the southwest corner of the basin. The hydraulic characteristics of the aquifer were evaluated using pumping test data. The pumping test was run on four selected wells (P1, P2, P3, and P4), and the data were treated analytically in order to evaluate the hydraulic parameters (Table 1)(Al-Ani, 2004, Al-Shamma'a, and Al-Dabbas, 2009).

To evaluate the hydrogeological parameters of the aquifer, pumping tests were carried out on four wells. The data were treated analytically and the results obtained were set in groundwater flow model to design a flow model for the shallow aquifer in the area and to be used for prediction as well. This kind of models is important in areas where surface waters are scarce and careful planning for water consumption is needed. The model forecasts future water drawdown in the basin as a result of the given abstraction rates and the suggested sites for new wells to cover the progressive needs.

The model was based on the initial conditions recorded in January 1992, then followed for the successive years until 2007. For prediction purposes, the model was run for twenty coming years and shows that random investment of groundwater from the Dibdiba formation in this basin is very risky, and that selecting sites for drilling new wells are governed by the variation of hydrogeological characteristics in different parts of the basin on one hand and the amount of recharge on the other hand.

The use of Groundwater flow model of Chiang and Kinzelbach, 2003 is to develop a numerical quasi three dimensional groundwater flow of the shallow aquifer in the studied basin within the U. Pliocene-Pleistocene sediments. The predicted changes in water levels as a result of groundwater utilization for agricultural projects were estimated. Previous studies on Dibdiba basin show that the western parts of the basin are almost dry and hence are unfeasible for utilization projects, where the eastern parts are considered more promise (Al-Furat center for studies and designing irrigational projects, 1993, Al-Ani, 2004, Al-Shamma'a, and Al-Dabbas, 2009). Therefore, pilot sample was chosen for modeling in the eastern parts of the basin. The model is based on the initial conditions recorded in January 1992, and the model network consists of 18 rows and 19 columns, where each cell covers an area of (1 km2). The specific representation of the hydrologic boundaries as model boundary conditions (Reilly, 2001) is as follows:

B-1.Boundary conditions associated with physical features at the lateral extent of the model

Two water divides are recognized in the western side of the model network and they were considered as impervious boundary a type of constant flux of non-zero, while part of the northern margin where water runs parallel to the boundary were treated as impervious boundary a type of constant flux of zero. Since the modeled area occupy part of the basin, the rest of the network cells were considered as head-dependent flow boundaries as long as they represent the major discharge boundaries for the system under natural conditions.

B-2.Boundary conditions associated with physical features at the bottom of the model

The bottom of the model was considered as a no-flow boundary condition, where the impervious beds of Injana formation represent the lower boundary of the modeled basin.

B-3.Boundary conditions associated with physical features at the top of the model

The top of the model was represented by the water table elevation changes in the unconfined parts of the modeled aquifer and by the elevation of the upper boundary of the semi-confined aquifers in the eastern parts where Dibdiba is overlain by the Quaternary deposits.

B-4.Application of the model in pre-development condition

The model was designed using a discharge rate of about 22 l/s abstracted from four wells: P2 (9.6 l/s), P3 (4.6 l/s) and P4 (7.9 l/s). Note that P1 was ignored because it gets depleted after pumping was started in few minutes and the water level drops down below the pump level. The steady state calibration shows that the system is highly sensitive to the hydraulic conductance parameter. Calibration involved making minor adjustments to this parameter until steady state model was successfully calibrated. The calibration criteria involved a good visual comparison between the measured and the simulated potentiometric surfaces (Fig.5) (Anderson and Woessner, 1992).

B-5.Application of the model in Prediction and future investments of the basin

The random investment of groundwater in the Dibdiba formation of this basin is very risky, because, different parts of the basin assign positive and negative returns to the water utilization simultaneously (Buxton and Smolensky 1999, Leijnse and Hassan Zadah, 1994). The advantage of the groundwater exploitation in the western parts of the basin is defined in the direct surface recharge, where Dibdiba exposed along wide extended outcrops and therefore, this will increase the saturated thickness in there .Drilling wells with a simulated discharge rate of 10m3/day near and along the strategic oil line will keep on yielding for a time not less than 20 coming years. But the negative side of utilization in this part of the basin is that dewatering for long time will affect the quantity of water to reach the eastern parts of the aquifer and hence will reduce the well yield there. Looking to the eastern parts, the positive side of drilling wells in this part of the aquifer is that the aquifer here posses embolden hydraulic characteristics (i.e. high transmissivity and specific yield) which presumed the new suggested wells to be succeeded. But, the reduction in the saturated thickness and the slow well recovery; impose us to be cautious in choosing the best sites for the new wells and the period of utilization. Therefore, short lived wells with a discharge rate of 5m3 /day is recommended for utilization in this part of the basin. First, we omit the former three wells because nor their location neither their abstraction rate were correctly chosen.

Accordingly, 49 new wells of (5m3/day) discharging rate in addition to 12 new wells of (10m3/day) were suggested to be drilled, which makes the whole water withdrawal about (365 m3/day). The model was designed considering a total working hours for the pump as (12 hours/day), taking into account the less use of groundwater in the rainy days. The model shows that after (7 Years) of water withdrawal, the maximum water level drawdown will not exceed (24 m.), with an average drawdown of (3.4 m. / year) (Figs. 6,7,8,9 and 10).

After 7 years (i.e. after the year 2014) the wells at the eastern parts will depleted but the ones at the western parts will continue producing water. Those wells may last for a longer time since they are located within the recharge area and near the water divides (Fig.11).

Another trial was attempt to reduce the drawdown and prolong the well production by reduce the number of wells to 29 new wells of (5 m3/day) discharging rate and 8 new wells of (10 m3/day) discharging rate. The result of running the model for the coming 7 years shows a drawdown of (18 m.) (Fig.12), then some of the wells at the eastern parts start to deplete while the western ones can keep on producing for about 20 years (Fig.13). The benefit of this scheme is that we can get a good water reserves at the middle parts of the basin which could be successfully exploited.

Table1 : Hydraulic parameters of the Dibdiba aquifer

WELL NO.	Transmissivity m^2/day	Storage Coefficient	Method of analysis	Aquifer type
P1	55.12	$2.4*10^{-3}$	Jacob&Theis	Unconfined
P2	406	$9.7*10^{-3}$	Bolton&Hantush	Leaky
P3	14.46	$3.6*10^{-4}$	Bolton&Hantush	Leaky
P4	903	$5.3*10^{-3}$	Jacob	Unconfined

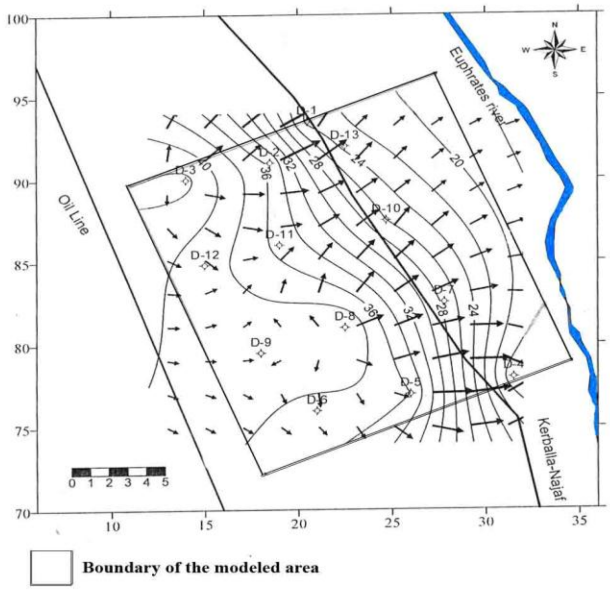

Figure 4: Piezometric map of Dibdiba aquifer

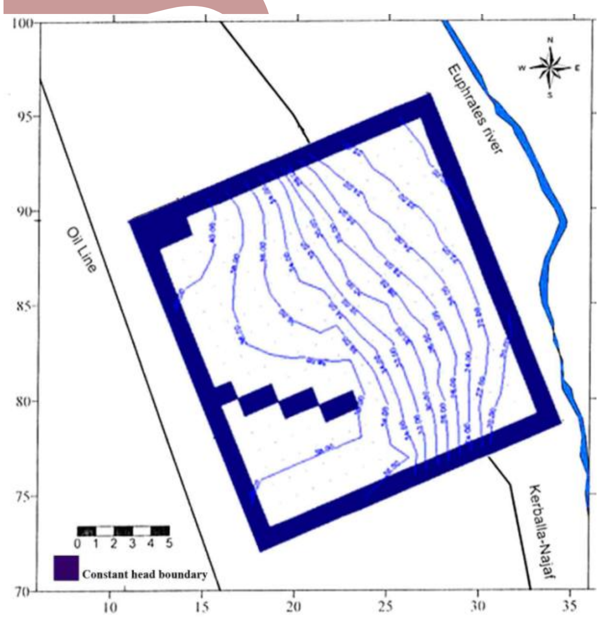

Figure 5: Simulated steady-state head of the Dibdiba aquifer

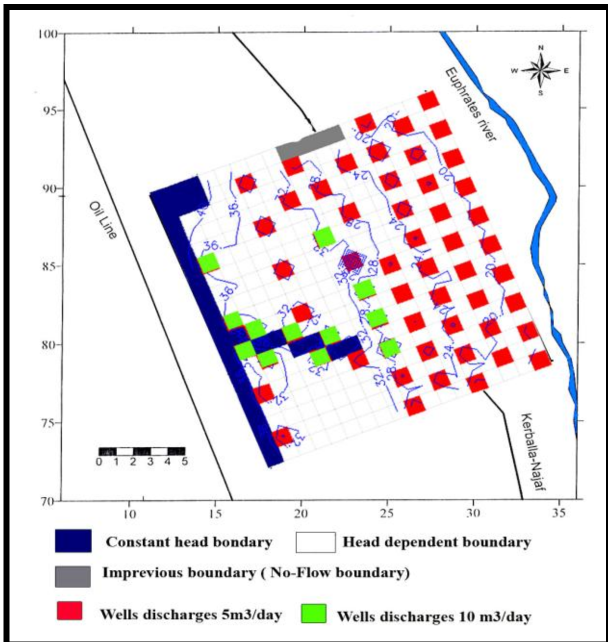

Figure 6: Simulated hydraulic head distribution in the year 2007(Q=365 m^3/day)

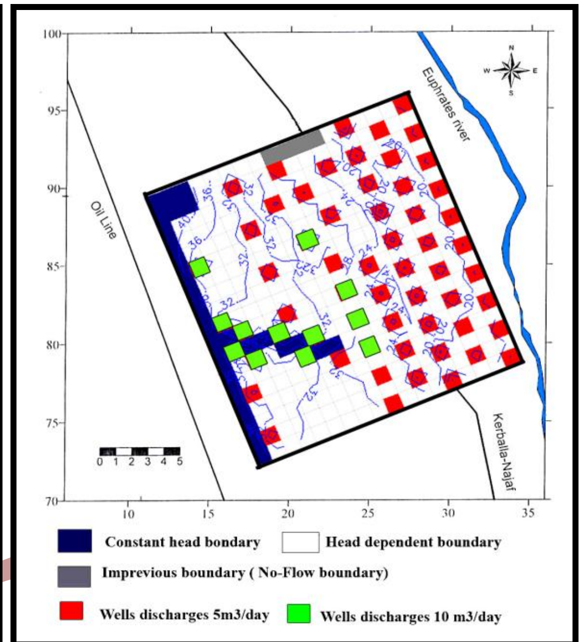

Figure 7: Simulated hydraulic head distribution in the year 2008 (Q= 365 m^3/day)

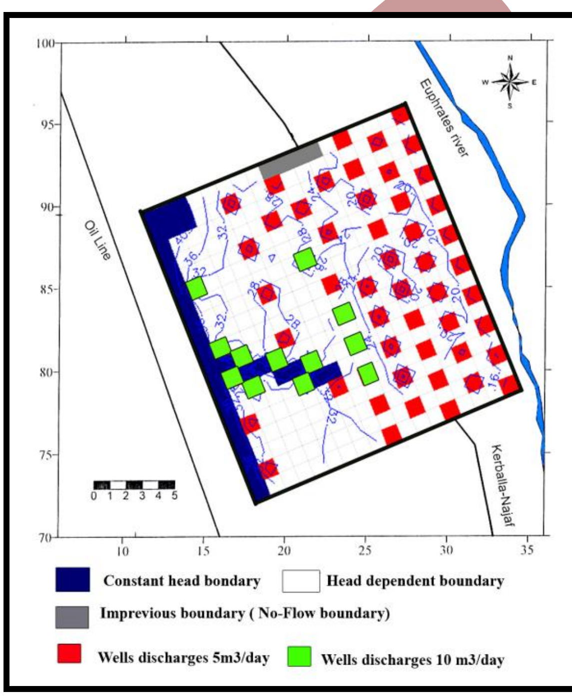

Figure 8 : Simulated hydraulic head distribution in the year 2009 (Q= 365 m^3/day)

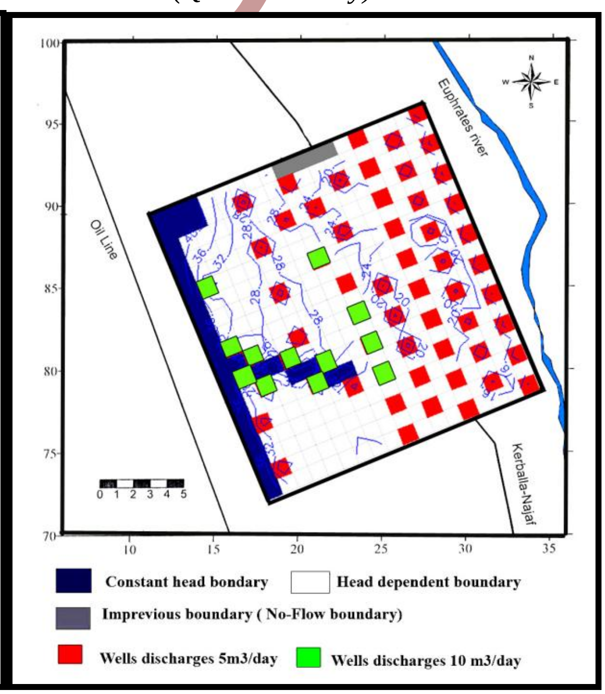

Figure 9: Simulated hydraulic head distribution in the year 2010 (Q=365 m^3/day)

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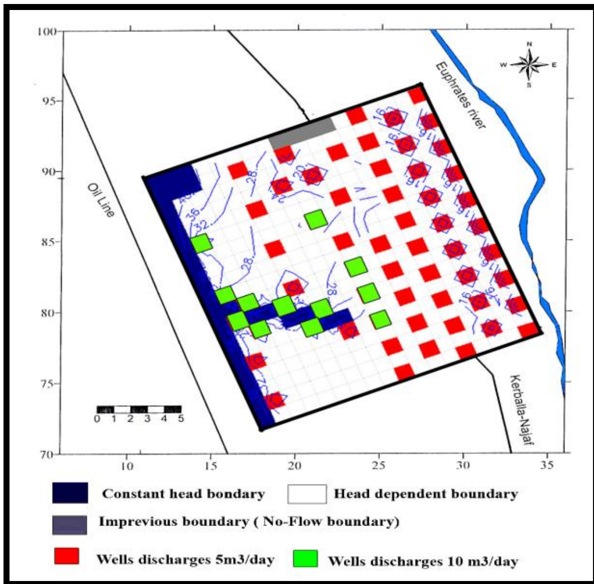


Figure 10: Simulated hydraulic head distribution in the year 2014 (Q=365 m^3/day)

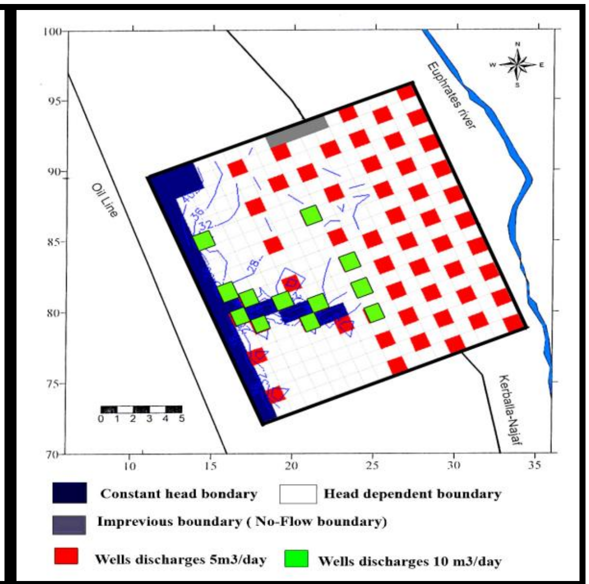
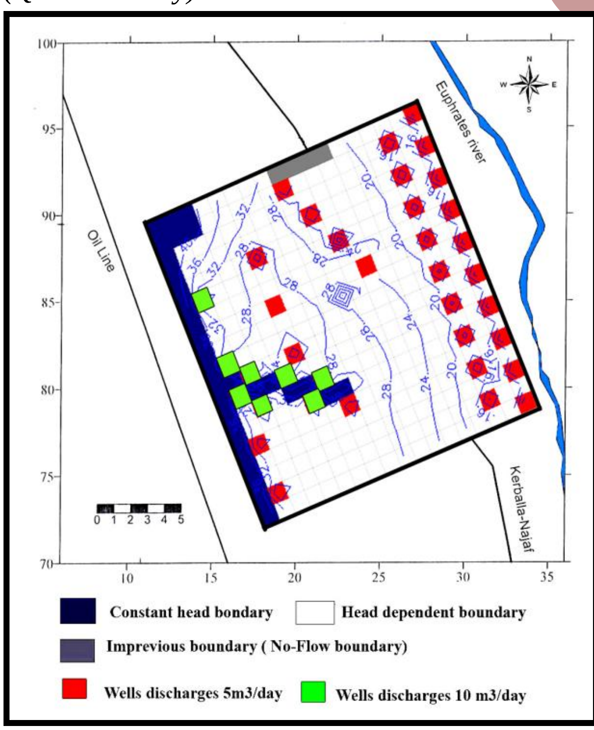


Figure 11: Simulated hydraulic head distribution after 20 years (Q= 365 m^3/day)



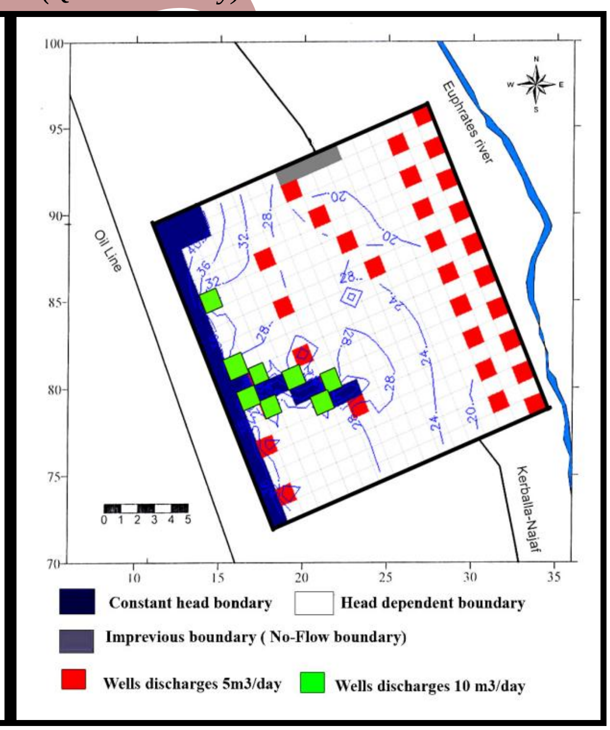


Figure 12: Simulated hydraulic head distribution in the year 2014 (Q=225m^3/day)

Figure 13: Simulated hydraulic head distribution after 20 years (Q= 225 m^3/day)

B-6.The water budget of the system

The water budget calculations come to ascertain the debility condition of the aquifer (Domenico and Schwartz, 1999). Before the basin exploitation and the suggesting of drilling new wells, the water budget shows a water surplus condition and this result is encouraging (Table 2). But since we locate the position of the new suggested wells and their discharging rates, the water budget show compensation for the first year (Table 3), and after that the budget start showing a water deficit case, and this continue through 7 years (i.e. to the year 2014) (Tables 4,5,6). As long as several eastern located wells were depleted after that time, excess of water will accumulate in the western part of the basin and this gives the wells there, the possibility of production for another 20 years (Table 7).

Table 2: Simulated water budgets for the Dibdiba Basin for predevelopment 2007 (All values are in acre m/day)

Year	**2002**		
Flow term	**IN**	**OUT**	**NET(in-out)**
Storage	0.0000000E+00	7.0074430E+00	-7.0074430E+00
Constant head	4.8093958E+00	3.4166612E-02	4.7752290E+00
Wells	0.0000000E+00	0.0000000E+00	0.0000000E+00
Recharge	2.2328999E+00	0.0000000E+00	2.2328999E+00
SUM	7.0422955E+00	7.0416098E+00	6.8569183E-04

Table 3: Simulated water budgets for the Dibdiba Basin for post-development 2007 (All values are in acre m/day)

Year	**2002**		
Flow term	**IN**	**OUT**	**NET (in-out)**
Storage	2.8503333E+02	2.1193294E-02	2.8501215E+02
Constant head	7.8014946E+01	0.0000000E+00	7.8014946E+01
Wells	0.0000000E+00	3.6500000E+02	-3.6500000E+02
Recharge	1.9728998E+00	0.0000000E+00	1.9728998E+00
SUM	3.6502118E+02	3.6502118E+02	0.0000000E+00

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Table 4: Simulated water budgets for the Dibdiba Basin for post-development 2008 (All values are in acre m/day)

Year	2002		
Flow term	IN	OUT	NET (in-out)
Storage	1.5581104E+02	2.4380047E+01	1.3143098E+02
Constant head	9.1596046E+01	0.0000000E+00	9.1596046E+01
Wells	0.0000000E+00	2.2500000E+02	- 2.2500000E+02
Recharge	1.9728998E+00	0.0000000E+00	1.9728998E+00
SUM	2.4937997E+02	2.4938005E+02	-7.6293945E-05

Table 5: Simulated water budgets for the Dibdiba Basin for post-development 2009 (All values are in acre m/day)

Year	2002		
Flow term	IN	OUT	NET(in-out)
Storage	1.3500237E+02	8.4940672E+00	1.2650830E+02
Constant head	9.6518654E+01	0.0000000E+00	9.6518654E+01
Wells	0.0000000E+00	2.2500000E+02	- 2.2500000E+02
Recharge	1.9728998E+00	0.0000000E+00	1.9728998E+00
SUM	2.3349391E+02	2.3349406E+02	-1.5258789E-04

Table 6: Simulated water budgets for the Dibdiba Basin for post-development 2014 (All values are in acre m/day)

Year	2002		
Flow term	**IN**	**OUT**	**NET(in-out)**
Storage	1.1230270E+02	1.5024248E+00	1.1080027E+02
Constant head	1.0222681E+02	0.0000000E+00	1.0222681E+02
Wells	0.0000000E+00	2.1500000E+02	- 2.1500000E+02
Recharge	1.9728998E+00	0.0000000E+00	1.9728998E+00
SUM	2.1650241E+02	2.1650243E+02	-1.5258789E-05

Table 7: Simulated water budgets for the Dibdiba Basin for post-development after 20 years (All values are in acre m/day)

Year	2002		
Flow term	**IN**	**OUT**	**NET(in-out)**
Storage	1.1396155E+00	5.4918451E+00	-4.3522296E+00
Constant head	1.0237940E+02	0.0000000E+00	1.0237940E+02
Wells	0.0000000E+00	1.0000000E+02	- 1.0000000E+02
Recharge	1.9728998E+00	0.0000000E+00	1.9728998E+00
SUM	1.0549192E+02	1.0549184E+02	7.6293945E-05

4. CONCLUSION

The Dibdiba aquifer represents the shallow aquifer which recharged mainly from rain water. The designed model and the water budget calculations confirm this state that the aquifer is worn out and predict that within the year 2014 several sites were depleted especially the eastern parts of the aquifer, while the western parts where the formation crops out and near the water divides may still produce water for the twenty coming years at most. The model indicates that the western parts of the aquifer can be utilized for a longer time in compared with the eastern parts , nevertheless, the whole aquifer recharge is decline with time and the rate of losing groundwater by both evaporation and abstraction is raising. The model and the water budget calculations as well confirm that the aquifer in its way to deplete if the amount of rainfall persists in falling down and that drilling deep wells to reach a deeper aquifer is needed to carry on the agricultural activities in this basin. Therefore, it is recommended to do the necessary investigations for drilling deep wells in this basin for the future utilization.

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