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Calculating of Groundwater Recharge using Meteorological Water Balance and Water level Fluctuation in Khan Al-Baghdadi Area

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Abstract

Climate and hydrological conditions in any hydrological basin are multi-combined reflection of natural factors of morphology and soil nature, as well as the changing in climate factors that affect directly on hydrological cycle. Water balance techniques are a means of solution of important theoretical and practical hydrological problems, while estimating the physical properties of water-bearing layers is an essential part of groundwater studies. One of the most effective ways of determining these properties is to conduct and analyze aquifer tests. The aim of this research is to compare groundwater recharge in Khan Al-Baghdadi area which located to northwest of Anbar governorate in the west of Iraq, depending on meteorological water balance and calculated hydraulic parameters of groundwater aquifers in order to predict the suitable methods to determine groundwater recharge. Geographical position, elevations, static water levels, depths, thicknesses and maximum yields were carried out during field work. Meteorological parameters of Hit station during the period (1995-2010) was used to calculate water surplus using Thorntwaite formula, while cooper-Jacob and Theis recovery solutions were used to calculate transmissivity and storage coefficient. The result indicate that water surplus was (16.71) mm. divided into (10.13) mm as runoff and (6.58) mm as groundwater recharge. The average annual of groundwater recharge in the area was (41.38) million cubic meters depending on water balance technique, while annual groundwater recharge calculated based hydraulic parameter was (41.51) million cubic meters.

Keywords: Meteorological Water Balance, Hydraulic Parameters, Groundwater Recharge. West of Iraq.

حساب تغذية المياه الجوفية باستخدام الموازنة المائية المناخية وتذبذب مناسيب المياه في منطقة خان البغدادي

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الخلاصة

ان الظروف المناخية والهيدرولوجية في أي حوض هيدرولوجي هي انعكاس مشترك ومتعدد للعوامل الطبيعية للاشكال الارضية وطبيعة التربة بالاضافة الى التغير في العوامل المناخية التي تؤثر بصورة مباشرة على الدورة الهيدرولوجية. تعد تقنيات استخدام الموازنة المائية وسيلة لحل المشاكل الهيدرولوجية النظرية والعملية المهمة ، في حين أن تخمين الخصائص الفيزيائية للطبقات الحاملة للمياه يعتبر جزء أساسي من

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دراسات المياه الجوفية. ان واحدة من أكثر الطرق فعالية لتحديد هذه الخصائص هو إجراء وتحليل اختبارات مكامن المياه الجوفية حيث ان الهدف من هذا البحث هو مقارنة تغذية المياه الجوفية في منطقة خان البغدادي التي تقع إلى الشمال الغربي من محافظة الأنبار في غرب العراق بالاعتماد على تقنية الموازنة المائية المناخية والمعاملات الهيدروليكية المحسوبة لمكامن المياه الجوفية من أجل التنبؤ بالطريقة المناسبة لتحديد مستويات هذه التغذية. تضمنت الدراسة الحقلية للمنطقة تحديد الموقع الجغرافي والارتفاع ومناسيب المياه الجوفية الثابتة والأعماق وسمك المكمن الجوفي بالاضافة الى انتاجية الابار. تم الاعتماد على البيانات المناخية المسجلة لمحطة انواء هيت خلال الفترة (1995– 2010) لحساب الفائض المائي باستخدام طريقة ثورنتوايت، في حين تم استخدام طريقتي كوبر – جاكوب وثايس لعودة المنسوب لغرض تحليل بيانات الابار وحساب معاملي الناقلية والخزن. اشارت النتائج إلى أن الفائض المائي بلغ (16.71) ملم موزع إلى (10.13) ملم جريان سطحي و(6.58) ملم تغذية للمياه الجوفية . بلغ المعدل السنوي لتغذية المياه الجوفية في المنطقة بحدود (41.38) مليون متر مكعب اعتمادا على تقنية الموازنة المائية فيما بلغ معدل هذه التغذية المحسوبة بالاعتماد على المعاملات الهيدروليكية بحدود (41.51) مليون متر مكعب.

Introduction

The study of the water balance structure of lakes, river basins, and ground-water basins forms a basis for the hydrological substantiation of projects for the rational use, control and redistribution of water resources in time and space. Knowledge of the water balance assists the prediction of the consequences of artificial changes in the regime of streams, lakes, and ground-water basins [1].

Worldwide, more than a third of all water used by humans comes from ground water. In rural areas the percentage is even higher: more than half of all drinking water worldwide is supplied from ground water [2, 3].

The continuing of groundwater extraction from the aquifers for all purposes is contributing to groundwater depletion in many parts of world [4]. Estimating the physical properties of water-bearing layers is an essential part of groundwater studies. One of the most effective ways of determining these properties is to conduct and analyze changing, with time, water levels (or total heads) of aquifers caused by withdrawals through wells [5].

Evaluate and analyze the data of aquifer test is a science because it is based on theoretical models, where the geologist or engineer must understand on thorough when they conducting the test investigations on geological formations in the area. The analysis data and aquifer test evaluation, the main distinguished three types of aquifer are: confined, unconfined, and leaky aquifer [6]

Khan Al-Baghdadi area locate to northwest of Anbar Governorate in the west of Iraq. The area covers (6290) km^2 within (41º 50'- 42 º 45') E and (33 º 30 ' - 34 º 15') N, Figure-1.

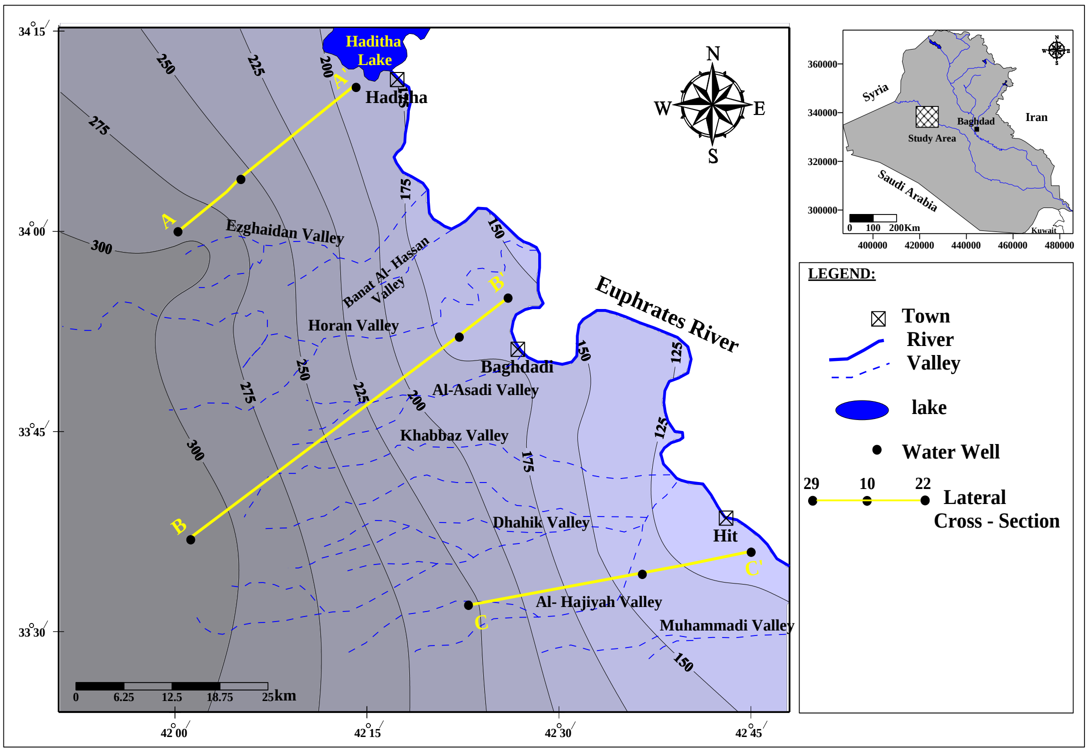

Figure 1 - Topographic Map of Khan Al-Baghdadi Area.

The climate of area, according to the climatic atlas of Iraq (1951-2000) characterized by mean annual temperature of 20-22°C, mean annual relative humidity of 35-40 %, dryness index of 20-25 , mean annual amount of evaporation is 3000 mm, mean annual amount of rainfall is 100-125 mm and mean annual number of days with snow, fog, frost, dust storm and thunderstorm are zero, 10-12, 10-15, 8-12 and 8-10 days, respectively [7].

In general, several previous studies have been done in western desert as mentioned below although these studies was not address the comprehensive details of meteorological water balance except number four:

1- Hydrogeology of groundwater aquifers in the Western Desert - west and southwest of the Euphrates River [8].
2- Assessment of groundwater resources in Iraq and management of their use [9].
3- Transboundary aquifers between Iraq and neighboring countries [10].
4- Hydrogeological study of Khan Al-Baghdadi area in Anbar governorate - West of Iraq [11].
5- Evaluation of groundwater recharge in arid and semiarid regions [12] .

The aim of this research is to compare groundwater recharge in Khan Al-Baghdadi area depending on meteorological water balance and calculated hydraulic parameters of groundwater aquifers in order to predict the suitable methods of determine groundwater recharge as well as achieve optimum use of groundwater in term of sustainable water management.

Geological Condition

The area is built up of sedimentary rocks ranging in age from lower Oligocene to Pliocene with different types of Quaternary deposits (Pleistocene-Holocene), Figure-2.

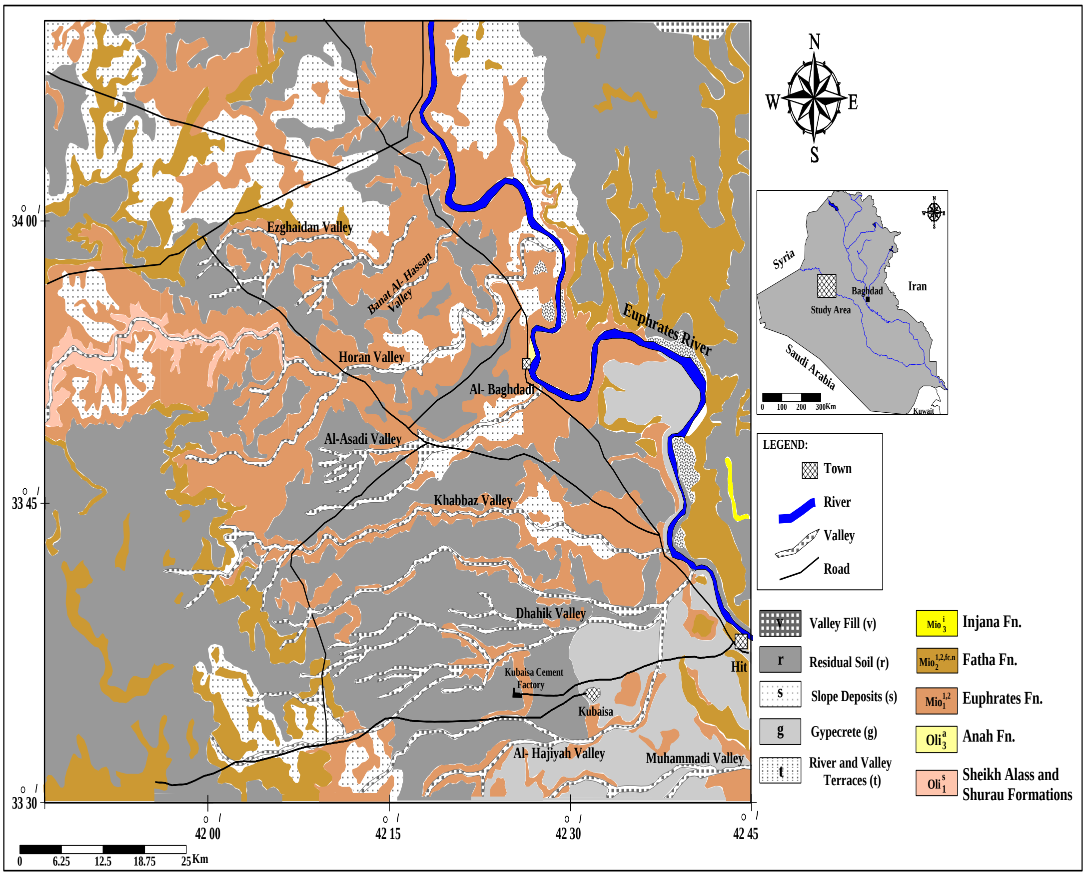

Figure 2 - Geological map of Khan Al-Baghdadi Area [13].

- Anah formation (Lower Oligocene): The formation consists of massive, coralline, creamy, very hard limestone and dolomite limestone, which are locally strongly Karstified leading to cavities and caverns of different sizes.
- Euphrates formation (Lower Miocene): It consists of thin basal conglomerate or basal clastic with recrystallizedy cherty, silicified, ferruginous and marly limestone, and greenish marl.
- Fatha (Lower Fars) formation (Middle Miocene): Its normal lithological constituents of cyclic nature (marl, limestone , gypsum and claystone).
- Quaternary deposits consist of:
- River terrace (Pleistocene): Composed of medium grained, well rounded pebbles which consist of chert, flint and limestone with admixture of igneous and metamorphic rocks.
- Gypcrete (Pleistocene-Holocene): Composed of secondary gypsum or highly gypiferous soil.
- Slope deposits (Pleistocene -Holocene): The lithology of these deposits is sand, silt and clay with rock fragments. Sometime it is rich in secondary gypsum mixed with loamy soil.
- Residual Soil (Pleistocene-Holocene): It is considered as gypcrete due to very high content of secondary gypsum. In areas where gypsum is absent, the residual soil consists of sandy, silty clayey, brown soil with limestone fragments.
- Valley fill deposits (Holocene): The floor of deep valleys in the area is covered by gravels mixed with sand and high admixture of rock fragments. The shallow valleys are filled by loam, which is locally gynsiferous, Table-1 [13].

Table 1- Stratified sequence of geological formations in the studied area [13].

Era	Period	Epoch	Age	Formation			Lithology
CENOZOIC	Quaternary	Holocene		Valley Fill (v) , Flood Plain (f)			v
		Holocene		Residual Soil (r) , Slope Deposits (s) , Gypecrete (g)			r s g
		Pleistocene		River and Valley Terraces (t)			t
	Tertiary	Miocene	Upper	Injana (U.Fars) Formation			
			Middle	Fatha (L. Fars) Formation	Upper Member	Clastic Member	
					Lower Member	Nfayil Beds	
			Lower	Euphrates Formation		Upper Member	
						Lower Member	
		Oligocene	Lower	Anah Formation			
				Sheikh Alass ans Shurau Formations			

Vertical Sacle : 1Cm.= 10 M.

The area lies within different structural zones from east to west, The Tigris subzone up the Mesopotamian zone of the Unstable Shelf and the Salman and Rutba-Jazira zones of the Stable Shelf. The area lies partly within the Stable Shelf represented by two zones (Al-Rutbah and Al-Jazira-Salman zones), and partly within the Unstable Shelf, represented by Mesopotamian zone (Tigris Subzone).

There are two transversal deep seated faults, within the area, these are Anah - Fatha Qalat Dizah Fault and Amij - Samarra - Halabcha Fault, both of them have NE-SW. Another important structural feature is Abu-Jeer fault zone which is also sub surface fault, running N-S. The indications of this fault on the surface are well expressed by numerous springs (in Hit, Kubaisa and Abu-Jeer vicinities which yield mineralized water and bitumen seepages.

Materials

The materials used in this study were:

1- Topographic and geological maps of area with different map scale.
2- GPS device to determine wells locations and elevations as well as others hydrogeological properties.
3- Meteorological parameters of Hit meteorological station during the period (1995-2010) [14].
4- Runoff coefficient method.
5- Stratigraphic sheets and hydrogeological data bank [15].
6- Grapher and Surfer programs demonstrating graphs and contour maps.

Methodology

Depending on Hit meteorological station located in the southeast of the area and its monthly parameters during (1995-2010), the Thornthwaite water balance [16] uses an accounting procedure to analyze the allocation of water among various components of the hydrologic system. The water surplus was calculated depends on estimation of potential evapotranspiration by using Thornthwaite method applying Wilson formula [17], while annual runoff was calculated using runoff coefficient method [18]. The next step was comparing the stratigraphic sheets of (29) inventoried wells and (18) wells obtained from hydrogeological data bank [15] with Table-1, taking into consideration the water levels measured in these wells as well as types of water bearing layers in order to estimate aquifer hydrogeological properties. The aquifer was investigated during fieldwork where geographical position, elevations, static water levels, depths, thicknesses and maximum yields has been carried out. The hydraulics parameters calculation of groundwater aquifers depends on (cooper - Jacob) [19] and Theis Recovery Test methods [20]. The mathematical programs (Grapher and Surfer) were used to demonstrate the results and draw contour map.

Rustles and Discussion:

1- Water Balance Calculation:

The inputs of water surplus model are monthly temperature and precipitation while outputs include monthly potential and actual evapotranspiration, soil moisture storage, snow storage, surplus, and runoff. Depend on the climatic data of Hit meteorological station located in the southeast of the area and its monthly parameters during (1995-2010) mentioned in Table-2, the Thornthwaite water balance [19] used to estimate potential and actual evapotranspiration as shown in Table-3. Potential Evapotranspiration was calculated by applying Wilson formula [17]:

$$PE = 16\left[\frac{10tn}{J}\right]^{a} \quad \text{……………………………………………………………..(1)}$$

$$J = \sum_{1}^{12} j \quad \text{……………………………………………………….(2)}$$

$$j = \left[\frac{tn}{5}\right]^{1.514} \quad \text{……………………………………………………….(3)}$$

$$a = 0.016J + 0.5 \quad \text{……………………………………………………..(4)}$$

PE: potential evapotranspiration, J: Heat Index, j: Coefficient monthly temperature (° C), a: Constant, tn: Average monthly temperature (° C).

Table 2-Monthly average of meteorological parameters of Hit station during (1995-2008) [17].

Month	**P (mm)**	**T º C**	**Epan (mm)**	**Month**	**P (mm)**	**T º C**	**Epan (mm)**
Oct.	6.6	25.3	245.3	Apr.	10.2	23.5	188.9
Nov.	15.6	16.5	110.9	May	2.7	29.8	273.9
Dec.	16.0	10.1	72.3	June	0.0	34.2	328.2
Jan.	18.2	9.0	72.6	July	0.0	36.9	380.3
Feb.	21.3	11.5	92.4	Aug.	0.0	36.3	314.9
Mar.	10.7	17.6	142.7	Sep.	0.0	31.6	285.9
Sum				101.3			2508.3
Avg.						23.52	

Based on the geological sequence in the Khan al-Baghdadi area and the nature of Quaternary deposits, the slope deposits and valley fill deposits are the only sediments containing silt and mud which extending along seasonal valleys in the area. These deposits have relatively small exposure and containing rock fragments of limestone and gypsum of not more than one meter thick. Thus, it can assume that soil moisture is (15) mm. The generated water surplus moves quickly towards runoff or infiltrating into groundwater horizon within fractures and joints in limestone and dolomite geological formation represented by Anah, Euphrates and Fatha [11]. The water surplus in the basin was (16.71) mm divided into natural recharge of groundwater, and surface runoff in seasonal valleys.

Table 3-Water balance calculation depending on average monthly parameters.

Month	P (mm)	T º C	PE (mm)	ETa (mm)	SM (mm)	WS (mm)	WD (mm)
October	6.6	25.3	85.85	6.6	0.0	0.0	79.25
November	15.6	16.5	27.71	15.6	0.0	0.0	12.11
December	16.0	10.1	7.55	7.55	8.45	0.0	0.0
January	18.2	9.0	5.57	5.57	15	6.08	0.0
February	21.3	11.5	10.67	10.67	15	10.63	0.0
March	10.7	17.6	32.68	10.7	0.0	0.0	7.16
April	10.2	23.5	70.67	10.2	0.0	0.0	60.47
May	2.7	29.8	132.37	2.7	0.0	0.0	129.67
June	0.0	34.2	190.43	0.0	0.0	0.0	190.43
July	0.0	36.9	232.90	0.0	0.0	0.0	232.9
August	0.0	36.3	223.21	0.0	0.0	0.0	223.21
September	0.0	31.6	154.51	0.0	0.0	0.0	154.51
Sum	101.3	23.52	1174.30	69.59	15	16.71	1089.71

Runoff coefficient method [18] was used to calculate runoff by applying formula:

$$Q = KP \qquad \ldots\ldots(5)$$

Where, Q: Runoff P: Precipitation and K: A constant having a value less than (1) or at most equal to (1). The value of K depends upon the imperviousness of the drainage area. Its value increases with the increase in, imperviousness of the catchment area, and may approach unity (1.0) as the area becomes fully impervious. The value of K depending on roof type where it was selected as a soil surface in the area represented by residual soil of Quaternary deposits with low rate of infiltration. K value was (0.1) and calculations indicate that runoff was (10.13) mm. and percentage of runoff from annual precipitation equal (10%) discharge into seasonal valleys towards Euphrates river. Finally, (6.58) mm was natural groundwater recharge of (6.5%) percentage of annual rainfall. The average annual of groundwater recharge in Khan Al-Baghdadi area was (41.38 million) m^3. The percentage of water surplus estimated from annual rainfall was (16.5%) and (83.5%) as a water deficit represented as actual evapotranspiration and soil moisture.

2- Hydrogeological properties of confined aquifer:

According to (47) wells investigated in area, the results showed that Khan Al-Baghdadi area has only confined aquifer within the geological formation extended in area, Figure-3. The geological water bearing formations gradually formed by Tayarat, Umm Er-Radhuma and Dammam (subsurface) formations in the western part, Umm Er-Radhuma and Dammam formations in the central part, Euphrates as essential formation and Anah with Fatha as an occasional formations in the east and northeast part of the area [11].

3- Hydraulic Parameters calculation:

Hydraulic conductivity, transmissivity and storage coefficient are most important parameters that controlling aquifers ability on storage and productivity, where number of mathematical methods and equations are used to obtain the values of these parameters, such as the (Cooper-Jacob, 1946) [19] and Theis Recovery Test methods (Theis, 1935) [20] in the case of unsteady flow, using following equations [21]:

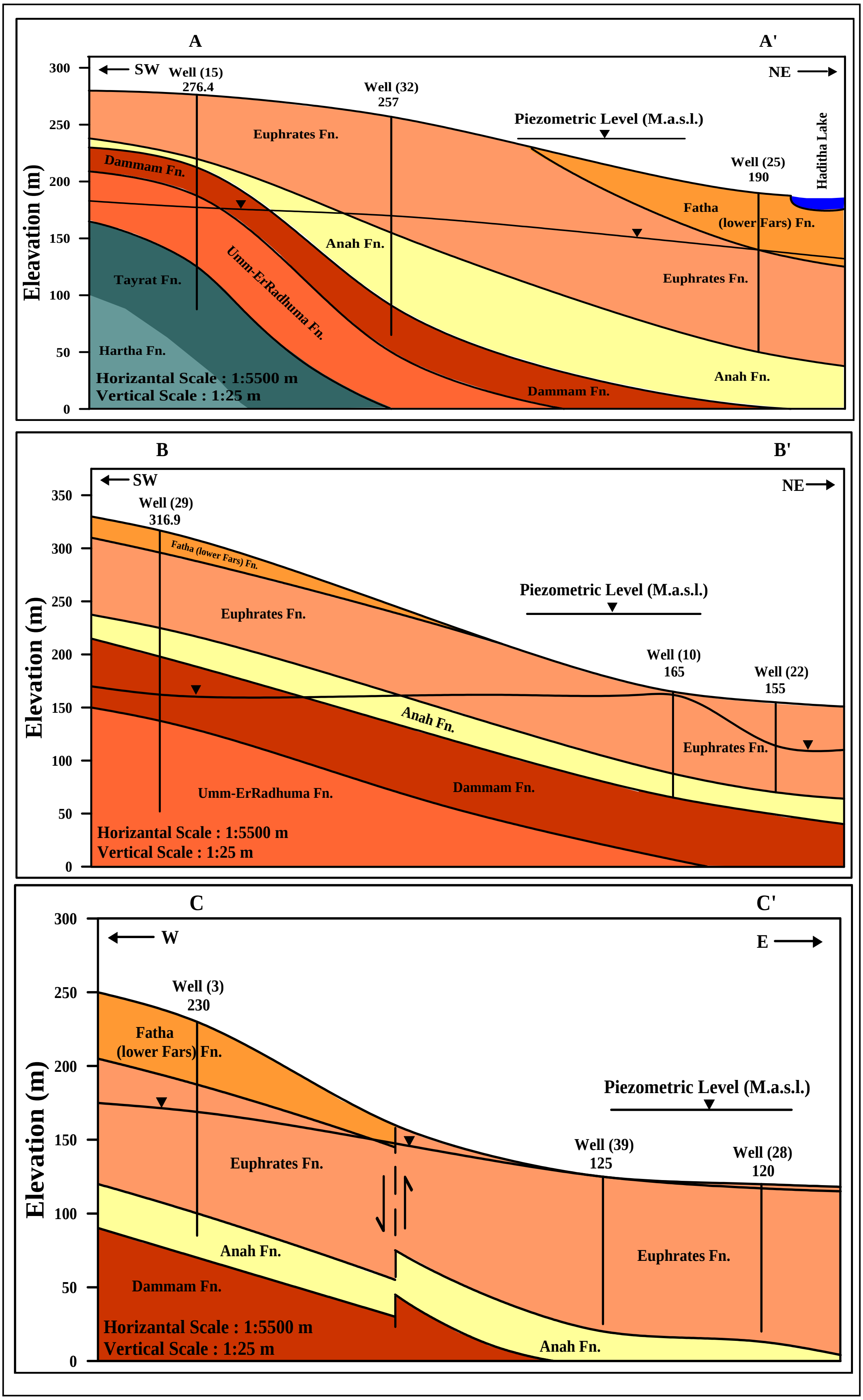

Figure 3-Lateral cross -sections in studied area showing geological water bearing formations.

$$T = \frac{2.3Q}{4\pi \Delta S} \quad \text{……(6)}$$

Cooper - Jacob Solution

$$Sc = \frac{2.25Tt_{\circ}}{r^2} \quad \text{……(7)}$$

$$T = \frac{2.3Q}{4\pi \Delta S'} \quad \text{……(8)}$$

Theis Recovery Solution

ΔS، $\Delta S'$: Drawdown in one logarithmic cycle (m). to: Time at zero drawdown (Day).
r = Radius between pumping well and observation well (m). Q= Well discharge (m^3/day).
T: Transmissivity (m^2/day). Sc: Storage coefficient.

Table-4 shows the data of the pumping wells drilled in the Khan Al- Baghdadi area, which were used to obtain the values of the hydraulic parameters of groundwater aquifer, while Figure-1 shows location of these two wells. The pumping test operations were carried out in two steps:

1- Pumped water and measuring water levels and recovery in observations well at 20/11/2010 and 27/12/2010.
2- Pumped water and measuring the water levels in pumping wells at 27/12/2010.

Table-5 showed the calculated hydraulics parameters of groundwater aquifer in the area.

Table 4 - Pumping wells data drilled in the Khan Al-Baghdadi area.

Well Name	**Elevation (m)**	**S.W.L. (m)**	**Depth of Pump. well (m)**	**Depth of Obs. well (m)**	**Saturated Thickness (m)**	**Discharge (m^3/Day)**
A (Alus)	195	47	100	80	55	864
B (Baider)	110	41	100	50	59	864

Table 5-Hydraulics parameters of groundwater aquifers in Khan Al-Baghdadi area.

Well No.	**A (Alus)**			**B (Baider)**		**Date**
Cooper-Jacob Solution	to (min)	4	Observation Well	12.7	Observation Well	20/11/2010
	△S (m)	3.5		0.17		
	T_1 (m^2/Day)	45.18		930		
	Sc	$3.1*10^{-4}$		$7.3*10^{-3}$		
	to (min)	6.5		130		27/12/2010
	△S (m)	3.8		0.2		
	T_1 (m^2/Day)	41.61		790.6		
	Sc	$4.7*10^{-4}$		$6.4*10^{-2}$		
Theis Recovery Solution	to (min)	1.15		1.46		20/11/2010
	△S (m)	6.25		0.25		
	T_1 (m^2/Day)	25.3		632.5		
	Sc	$5*10^{-5}$		$5.7*10^{-4}$		
	to (min)	1.38		9		27/12/2010
	△S (m)	6.375		0.08		
	T_1 (m^2/Day)	24.8		1976		
	Sc	$5.9*10^{-5}$		$1.1*10^{-2}$		
Cooper-Jacob Solution	△S' (m)	4.8	Pumping Well	0.135	Pumping Well	27/12/2010
	T_2 (m^2/Day)	32.94		1171		
Average T (m^2/Day)		33.966		1100		
Average (Sc)		$2.2*10^{-4}$		$2.07*10^{-2}$		
Distance to observation well (m)		30		50		

to: Time at zero drawdown (Day). △S : Drawdown in a one logarithmic cycle in observation well (m). △S' : Drawdown in a one logarithmic cycle in pumping well (m).
T_1: Transmissivity obtained in observation well (m^2/day). T_2: Transmissivity obtained in pumping well (m^2/day).

4- Groundwater Recharge:

According to water balance technique, the water surplus was (16.71) mm divided into (10.13) mm as runoff and (6.58) mm natural groundwater recharge. The average annual of groundwater recharge in Khan Al-Baghdadi area was (41.38) million cubic meters. This quantity of water infiltrated and percolated to groundwater aquifer represented by Euphrates formation as the upper water bearing layer through fractures and joints extended on both ground surface and Euphrates formation due to effects of erosion and weathering. The long seasonal extended valleys in the area help to infiltrates water into aquifer layers.

Based on the monthly fluctuation measurement of groundwater levels in two wells (A and B) which carried out for one year (2010-2011), the change in the groundwater level within time can provide good information on groundwater recharge.

$$\text{Rnp} = A \times \Delta S \times Sc \qquad \ldots\ldots(9)$$

[22].

where Rnp; annual groundwater recharge (cubic meters). A: Area of the basin (Km^2).
ΔS: Average annual fluctuation (m). Sc: Storage coefficient.

The fluctuation data indicated in the Table-6, where annual recharge was calculated based on area of the basin as (6290) km^2, storage coefficient (0.011), annual fluctuation (0.6) m. to be (41.51) million cubic meters. It seem that annual recharge calculated by water balance technique and hydraulic parameter using ground water fluctuation were closed.

Table 6-Fluctuation of groundwater levels of two wells in Khan Al-Baghdadi area

Alus (A)				**Baider (B)**			
Date	**Water depth(m)**	**Date**	**Water depth(m)**	**Date**	**Water depth(m)**	**Date**	**Water depth(m)**
6/2010	46.0	12/2010	45.71	6/2010	41.0	12/2010	41.11
7/2010	46.0	1/2011	45.54	7/2010	41.7	1/2011	40.96
8/2010	45.8	2/2011	45.61	8/2010	41.03	2/2011	41.4
9/2010	46.0	3/2011	45.65	9/2010	41.05	3/2011	41.12
10/2010	46.0	4/2011	45.66	10/2010	41.1	4/2011	41.37
11/2010	45.74	5/2011	45.67	11/2010	41.0	5/2011	41.2

Conclusions

1- Depending on climate data (temperature, precipitation and evaporation) and using Thornthwaite methods, the calculated potential evapotranspiration was (1174.3) mm. while calculated actual evapotranspiration was (69.59) mm. The water surplus was (16.71) mm. divided into (10.13) mm as runoff and (6.58) mm as groundwater recharge.
2- The runoff percentage of annual precipitation equal (10%) while natural groundwater recharge percentage was (6.5%) of annual rainfall. The average annual of groundwater recharge in the area was (41.38) million cubic meters. The percentage of water surplus estimated from annual rainfall was (16.5%)) and (83.5%) as a water deficit represented as actual evapotranspiration and soil moisture.
3- According to (47) wells investigated in area, the results showed that Khan Al-Baghdadi area has only confined aquifer within the geological formation extended in area.
4- The average transmissivity and storage coefficient parameters which calculated using two wells drilled in the area were (33.966-1171) m^2/day and ($2.2*10^{-4}$ - $2.07*10^{-2}$) respectively dependent on cooper-Jacob and Theis recovery solutions.
5- The annual recharge calculated by water balance technique and hydraulic parameter using ground water fluctuation were closed, where annual groundwater recharge calculated based on water balance techniques was (41.38) and annual groundwater recharge calculated based on hydraulic parameter was (41.51) million cubic meters.

References

1. Sokolov, A. A. and Chapman, T. G. **1974**. *Methods for water balance computations, an international guide for research and practice.* UNESCO press. Paris. 127 p.
2. Harter, T. **2015**. Basic Concepts of Groundwater Hydrology, ANR Publication 8083, FWQP Reference Sheet 11.1, University of California.
3. Al-Sudani, H.I.Z. **2017b**. Groundwater Investigation in Iraqi Marshland Area. *Diyala Journal for Pure Sciences.* **13**(3): 12-29
4. Ramesh D. and Fritz F. **2016**. Water Balance to Recharge Calculation: Implications for Watershed Management Using Systems Dynamics Approach. *Journal of hydrology.* **3**(13). 19 p.
5. Ralph C. H. **2009**. *Groundwater Hydrology.* edited by (De Smedt . F.). U.S. Geological Survey. Water-supply Paper 2220, 1987, 84 p.
6. Delleur, J.W. (editor) **2000**. *The Handbook of Groundwater Engineering.* School of Civil Engineering Purdue University West Lafayette, Indiana. Corporate Blvd., N.W. Boca Raton, FL 33431, U.S.A.
7. Iraqi General Organization for Meteorological Information. **2010 a**. Atlas of Climate of Iraq for the years (1981–2000). Internal Report. Ministry of Transportation. Baghdad. Iraq.
8. Jawad, S.B.; Naom,F.H., Zamil,H.I., Mohammad Ali,B. **2001**. Hydrogeology of Groundwater aquifers in the Western Desert **-** West and Southwest of the Euphrates River. National Program of optimum use of water resources in Euphrates Basin. Axis IV, Ministry of Irrigation. Baghdad. Iraq. 100 p.
9. Jawad, S.B. and Ridha,S.A. **2008.** Assessment of groundwater resources in Iraq and management of their use. General Commission of Water Resources Management. Ministry of Water Resources. Baghdad.Iraq.19 p.
10. Jawad, S.B., Abdulrazaq, M.I. and Ahmed, A.M. **2008.** Transboundary aquifers between Iraq and neighboring countries. General Commission of Water Resources Management. Ministry of Water Resources. Baghdad.Iraq.52 p.
11. Al-Sudani, H.I. Z. **2017a**. Hydrogeological study of Khan Al-Baghdadi area in Anbar Governorate - West of Iraq. *Diyala Journal for Pure Sciences.* **13**(2): 192-207
12. Ramadhan , A.A. ,Ali , M.H., and Al-Kubaisy, R.K. **2013.** Evaluation of groundwater recharge in arid and semiarid regions (case study of Dibdiba formation in Karballa-Najaf plateau). *Iraqi Journal of Sciences.* **54**(4): 902-910
13. Sissakian, V.K.; and Hafidh, S. Q.**1994.** The Geology of the Haditha Quadrangle Sheet NI-38-5 (GM 13) Scale 1:250 000. Technical Report No. 2257. Directorate of Geological Survey. State Establishment of Geological Survey and Mining (GEOSURV). Baghdad. Iraq. 24 p.
14. Iraqi General Organization for Meteorological Information. **2010 b**. Meteorological data of Hit meteorological station for the years (1995–2010). Internal Report. Ministry of Transportation. Baghdad. Iraq.
15. General Commission of Groundwater, **2011**. Geological and Hydrogeological information of Groundwater wells in Anbar Governorate. Ministry of Water Resources. Baghdad. Iraq.
16. Thornthwaite, C.W. **1948.** An Approach toward a Relation Classification of Climate. *Geographical Review.* Elsevier, Amsterdam. **32**(55): 3-30.
17. Wilson, E.M. **1984**. *Engineering Hydrology.* The Macmillian Press Ltd., London. 3rd edition. 232 P.
18. Garg, S.K. **2013**. *Irrigation engineering and hydraulic structures.* Khanna Publishers, 27th Edition, New Delhi.
19. Cooper, H.H. and Jacob, C.E.**1946**. A generalized graphical method for evaluating formation constants and summarizing well field history, Am. *Geophys. Union Trans.* **27**: 526-534.
20. Theis, C.V. **1935**. The relation between the lowering of the piezometric surface and the Rate and duration of discharge of a well using water storage. *American Geophysical Union,* **16**: 519 – 524
21. Todd, D.K. and Mays, L.W. **2000**. *Ground Water Hydrology.* John Wiley and Sons, 3rd edition. 636 P.
22. Hassan, A. and Zeki, N. **1982**. Water Availability Periods and Water Balance Parameters. JRAWR, Vol. 1, Council for Scientific Research, Baghdad.