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Evaluation of hydraulic properties and climatic conditions of Yaychi area Southwest of Kirkuk - North of Iraq

Qusai Y. Al-Kubaisi[1], Sabah Ahmed Khorsheed[*2]

[1]Department of Geology, College of Science, University of Baghdad, Baghdad, Iraq.
[2]General Commission for Groundwater, Ministry of Water Resources, Baghdad, Iraq.

Abstract

This study includes determining the climatic conditions and the nature of the reservoirs in the region with the determination of the flow direction and the hydraulic characteristics of the aquifer. The meteorological data for the Kirkuk station for the period 1971-2015 showed that the values of the monthly rates of temperature, precipitation, evaporation, relative humidity, wind speed and Sunshine duration are (9.1 to 36.2 C), (0.03 to 65.8 mm), (51.4 to 412.7mm), (21.7 to 71.1%), (1.3 to 2.1 m / s), and (5.4 to 11.2 hour) respectively. And according to the annual rainfall rate is (348.13mm), found 18 years of the climatic period are wet years and 27 years are dry years. Thornthwait method was used to calculate the values of Potential Evapotraspiration (PE) then determine the annual value of WS and WD which equal 238.4mm and 852.8mm respectively. The study showed the existence of a shallow aquifer unconfined in the Quaternary deposits with the presence aquifer confined in the Bai-Hasan Formation. The flow net map is shown by mainly that the groundwater flow in the area, it is from the northeastern parts towards the southwestern parts. The information of single pumping test for five wells in the study area shows that the values of the transmissivity (T), hydraulic conductivity (K) and specific capacity (SC) were ranged from (88.1 to 829.7m2/d), (0.64 to 8.74m/d) and (33.28 to 295.75m2/d) respectively, where (T) and (K) calculated by using (AQTESOLV 4.5) software that depend on the methods of Cooper-Jacob and Theis recovery for analysis these information.

Keywords: Climatic conditions. Hydraulic properties. Water surplus. Yaychi area.

تقييم الخصائص الهيدروليكية والظروف المناخية لمنطقة يايجي جنوب غرب كركوك/ شمال العراق

قصي ياسين الكبيسي[1]، صباح احمد خورشيد[*2]

[1]قسم علم الارض ، كلية العلوم ، جامعة بغداد ، بغداد، العراق.
[2]الهيئة العامة للمياه الجوفية ، وزارة الموارد المائية ، بغداد ، العراق.

الخلاصة

تضمنت هذه الدراسة تحديد الظروف المناخية وطبيعة الخزانات في المنطقة مع تحديد اتجاه الجريان والخصائص الهيدروليكية للخزان الجوفي . بيانات الارصاد الجوية لمحطة كركوك للفترة من (1971-2015) تبين ان قيم المعدلات الشهرية لدرجة الحرارة والامطار والتبخر والرطوبة النسبية وسرعة الرياح ومدة شروق

*Email: asbah327@gmail.com

الشمس هي (9.1-36.2 C°), (0.03-65.8 mm), (51.4-412.7 mm), (21.7-71.1%) , (1.3-2.1 m/s), و(5.4-11.2 h) على التوالي. وبحسب المعدل السنوي للساقط المطري (348.13mm) يعتبر (18) سنة من الفترة المناخية اعلاه هي السنوات الرطبة و(27) سنة هي السنوات الجافة. تم حساب قيم التبخر- نتح الكامن (PE) بحسب طريقة ثورنثويت ثم تحديد قيمة الزيادة المائية السنوية (WS) وهي (238.4 mm), والنقصان المائي السنوي (WD) وهي (852.8mm). حيث بينت الدراسة وجود خزان ضحل غير محصور في ترسبات العصر الرباعي مع وجود خزان مائي محصور في تكوين باي حسن وان خارطة شبكة الجريان تبين وبشكل رئيسي ان اتجاه جريان المياه الجوفية هي من الاجزاء الشمالية الشرقية باتجاه الاجزاء الجنوبية الغربية. ومن معلومات الضخ التجريبي المنفرد لخمسة أبار تبين أن قيمة الناقلية (88.1 الى 829.7م^2/يوم) والتوصيل الهيدروليكي(0.64 الى 8.74 م/يوم) والقدرة النوعية (33.28 الى 295.75م^2/يوم) علما الناقلية والتوصيل الهيدروليكي محسوب من قبل برنامج (AQTESOLV 4.5) الذي يعتمد على طرق كوبر- جاكوب وثايس لتحليل هذه المعلومات.

Introduction

Iraq is a country rich in water resources because of the presence of the Tigris River, Euphrates, Zab and the Diyala River. Because of the low discharge of water in these rivers from neighboring countries, it is necessary to pay attention to groundwater as an alternative resource and use it by in proportion with the purposes. Water resources are decreasing continuously due to increasing demand for water for different purposes, prompting researchers to conduct hydrogeological studies and researches of water reservoirs and ways of investing them, groundwater is found in the rocky openings that carry water called aquifers [1].

The processes of rock weathering are strongly influenced by temperature and the amount of precipitation. The influence of climate on water quality of streams and produce characteristic plant communities and soil types [2]. The dominant factors in the climate, consist of: latitude, elevation, topography, proximity to large bodies of water, and atmospheric circulation [3]. The geological, morphological, and climatic factors which determine Hydrogeological conditions from during knowledge the spatial distribution of hydrogeological bodies and determine the groundwater recharge and discharge zones and the depth of the water table, while climatic conditions have determined the rate of groundwater recharge, the intensity of groundwater flow and water loss due capillary effects, evaporation and transpiration [4]. The previous studies which include study area are Parsons[5], which surveyed the groundwater resources comprehensively based on the hydro geological data of the Al-Adhaim basin. As well as, they suggested potential usage of agriculture and human purposes. Al-Naqash et al.[6], made a study was designed to evaluate and develop an operational program for wells which excavated during the period of 2001-2003, by the General Company for Water Well Drilling in the Kirkuk Province. Abdul- Razaq et al.[7], prepared a hydrology study of the upper Adhaim Basin, indicating two hydro geological systems, the first confined (Bai-Hassan formation) and second unconfined (quaternary and recent sediments). Saud and Mohammad[8], Saud[9], studied hydrogeology and hydrochemistry for Kirkuk quadrangle, which included the study area, and the study appears to exist the groundwater within two formations mukdadyia and Bai-Hassan as well as Quaternary deposits. The aim is study of climatic elements and determine the hydraulic characteristics of the aquifer in the Yaychi area.

Study Area

The study area is bounded by coordinates, UTM (3910147 N) and (3929372 N) in the north and (425358 E) and (440894 E) in the east, it covers area about 350 km^2, and which is located within the Kirkuk province in southwest of Kirkuk city, north east of Iraq Figure-1. Groundwater is the mainly source of agricultural and industrial uses in the study area. Geologically, the study area covers Pleistocene (Old Quaternary) deposits that Characterized by the presence of layers of gravel and sand with high permeability can be amenable to investment and it is difficult its dispersing with the layers of the Bai-Hassan Formation which located down it, through the drilling process because it composed of layers this Formation, and Holocene (Recent Quaternary) deposits has little thickness and composed of silt, clay and sand, and investing the water of this layer by drilling shallow wells [6], Figure-2. Bai- Hasan Formation is composed of boulder conglomerates interbedded with sandstone, siltstone and claystone. These conglomerates had been the main reason for considering it as an independent formation, and has continental depositional environment resulting from erosion of the high mountains [10], [11]. Tectonically, it is located on the unstable shelf within the foothill zone as part of the Chamchamal- Butmah subzone. This zone includes asymmetrical long anticlines and synclines characterized by high dip in some places associated with joints and faults [12].

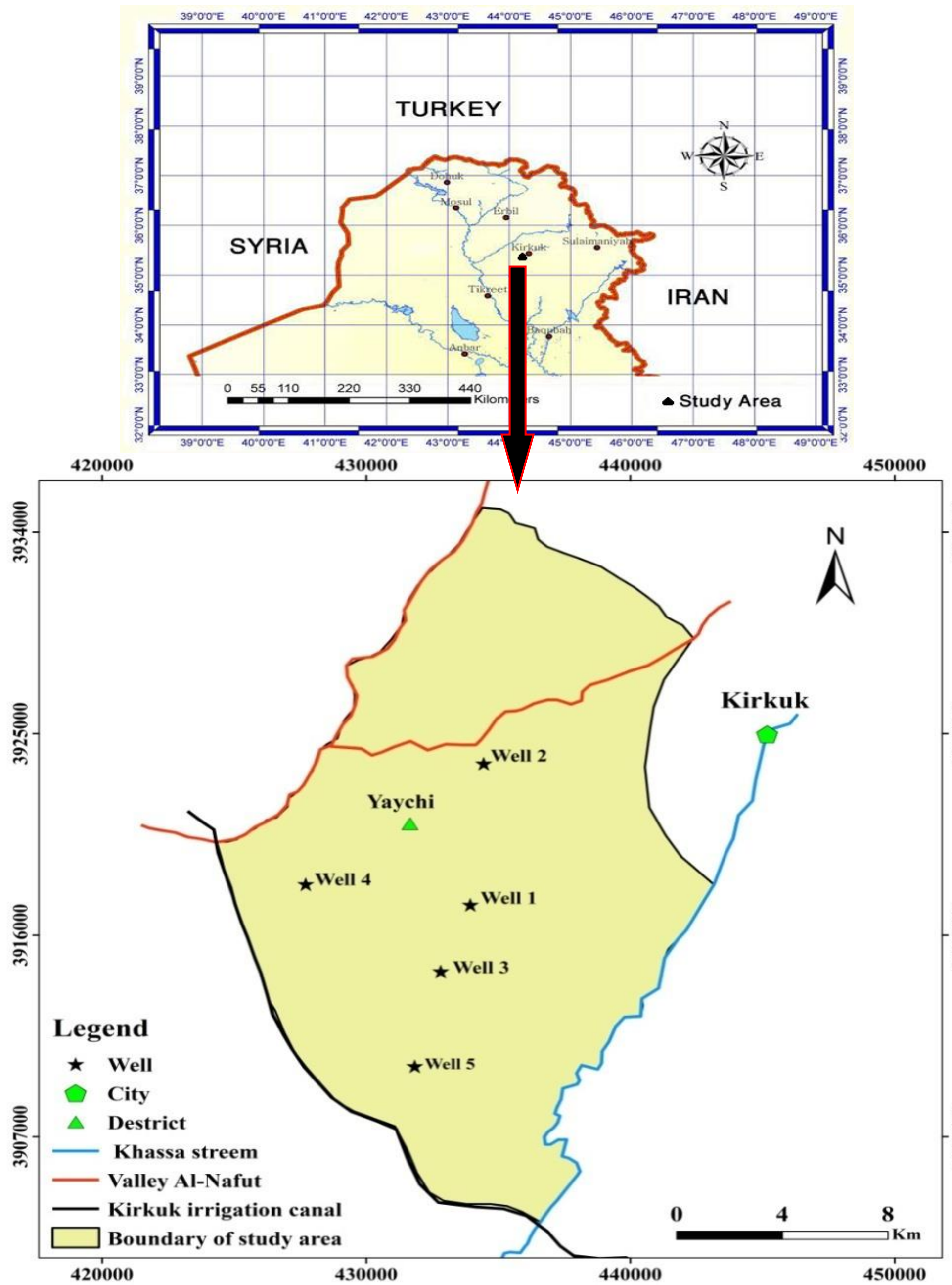

Figure 1- Location map of study area and pumping well sites

Climatic Setting

The climatological variables are temperature, rainfall, evaporation, relative humidity, wind speed and sunshine depend on the climate data recorded at the Kirkuk meteorological station during the period (1971-2015) where values of the annual and monthly averages of these variables through 45 year shown in the Table-1. The climate of the study area was characterized with a summer dry and hot, which begins from May to September, with winter cold and rainfall, which begin from October to

April. Temperature has directly relationship with evaporation and sunshine duration while the relationship is inverse with rainfall and relative humidity(RH%) as shown in Figure-3.

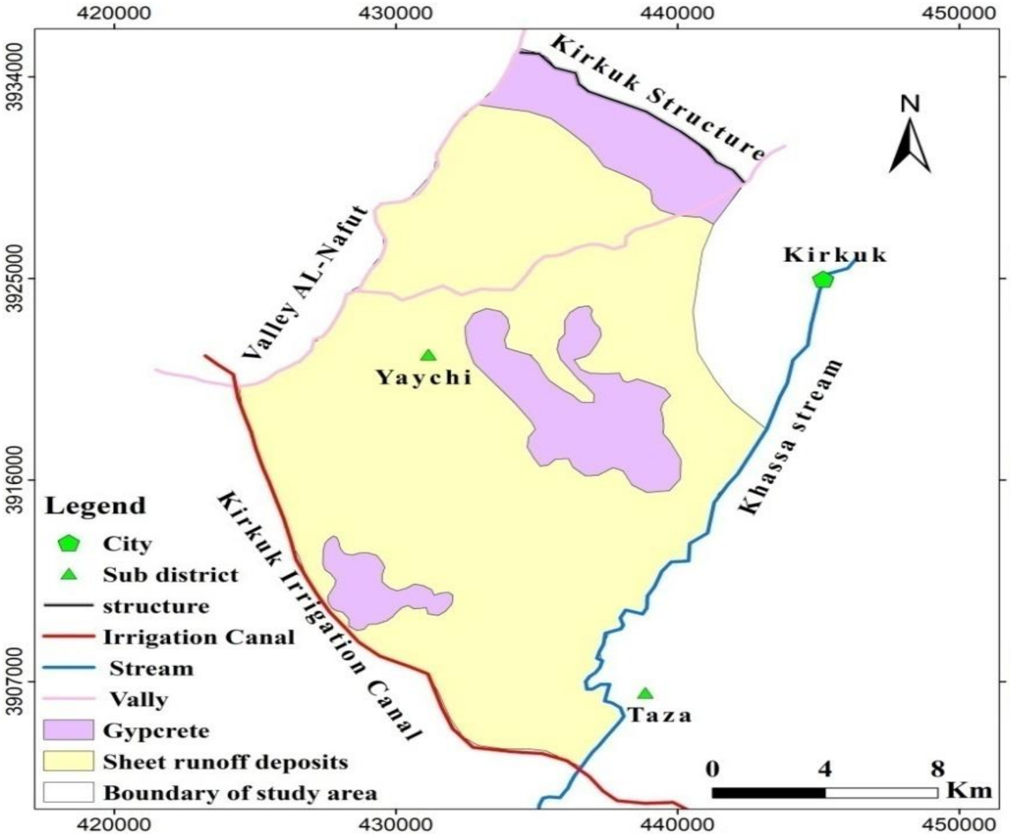

Figure 2-Geological map of the study area [13].

Hydrogeology Setting

The formation and part of the formation or group of geological formations defined as a hydrogeological unit which have permeability and porosity and allow the movement of water with different velocities, and the hydraulic characteristic determination for these formations has great importance in the investment and management of groundwater [14]. The study area is not considered as an independent hydrogeological basin, but it's located within big basin represented by the second basin of the Kirkuk region, which consist of two product hydrogeological units such as the Quaternary deposits and the Bai Hassan Formation [9]. Bai- Hassan Formation is confined aquifer between the underlying Mukdadyia Formation and the overlying Quaternary deposits and it has good porosity and permeability [15]. It is consider as main hydrogeological productive aquifer in the study area. The groundwater levels in the study area are ranges from 3m to 13.9m and the depth of wells from 52 m to 142 m, and penetrating of the wells of the area for Bai–Hassan Formation is partially by different depths according to the available information of the wells drilled by general commission for groundwater - branch of Kirkuk.. Study of groundwater levels of the wells illustrated that the groundwater flow direction from the northeast, which be hydraulic head is equal (300.6m.a.s.l), in well 18 to the southwest, which be hydraulic head is equal (227.9m.a.s.l), in the well 2. The average value of the hydraulic gradient in the study area is (0.0045). The general direction of groundwater flow in the area is from the recharge areas in the northeast to the discharging areas in the southwest as shown in Figure-4.

Table 1- Monthly averages of the climate elements for the period (1971-2015) of Kirkuk meteorological station.

Months	Temperature (c◦)	Rainfall (mm)	Evaporation (mm)	Relative humidity%	Sunshine Duration (hours)	Wind speed (m/s)
Oct.	24.9	13.5	202.9	37.1	8	1.42
Nov.	16.4	40.8	93.3	56.6	6.6	1.22
Dec.	10.8	56.8	54.4	69.3	5.5	1.16
Jan.	9.1	65.8	51.4	71.1	5.4	1.28
Feb.	10.9	59.8	67.7	65.5	6.2	1.64
Mar.	15	55.7	109.4	57.5	7.2	1.7
Apr.	20.8	41.2	163.7	49.8	7.8	1.9
May	27.6	13.6	267.4	33.7	9.2	2.03
Jun.	33.3	0.1	362	23.1	11.2	1.96
July	36.2	0.2	412.7	21.7	11.1	1.92
Aug.	35.7	0.03	393	23.1	11	1.76
Sep.	31.3	0.6	302.4	25.9	10.2	1.4
Total	**272**	**348.13**	**2480.3**	**534.4**	**99.4**	**19.39**
Average	**22.66**			**44.53**	**8.28**	**1.62**

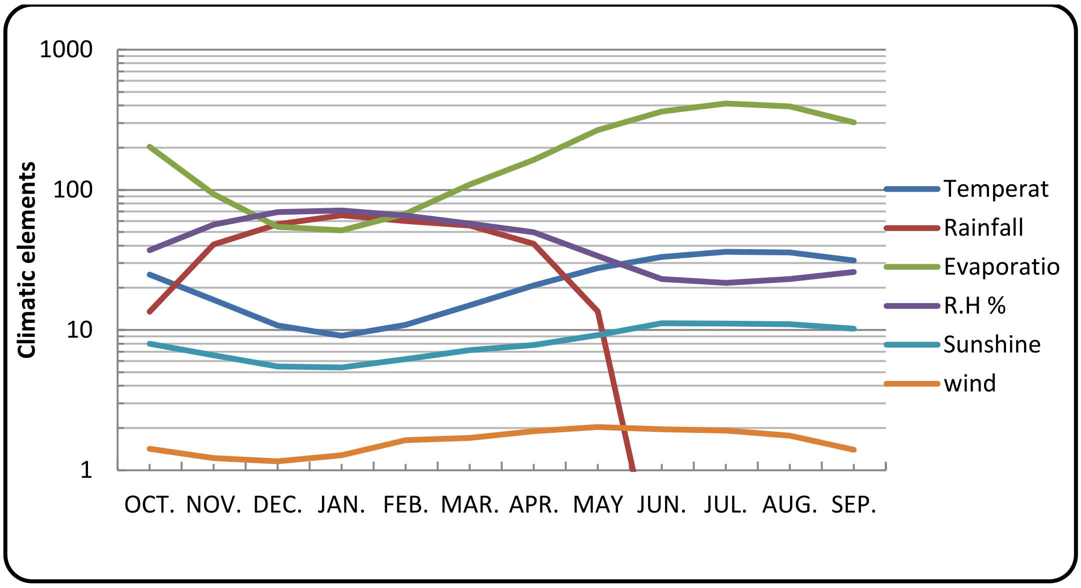

Figure 3-Relationship between different climatic variables

Materials and methods

Climate elements used to calculate the water balance of the study area are temperature, precipitation, evaporation, relative humidity, wind speed and sunshine, which taken from the Kirkuk meteorological station for the period from 1971 to 2015 with monthly averages as shown in Table-1. The Thornthwaite method [16] was used to estimate the value potential Evapotranspiration (PE), which depends on the air temperature (Tc), and then calculate the value of water surplus and water deficit in the study area by depending on this value. The Cooper – Jacob [17] and Theis [18], methods was used to analyze single pumping test and recovery test data to determine hydraulic properties such as Transmissivity (T), Hydraulic conductivity (k) and Specific capacity (SC) of the aquifer in the study area.

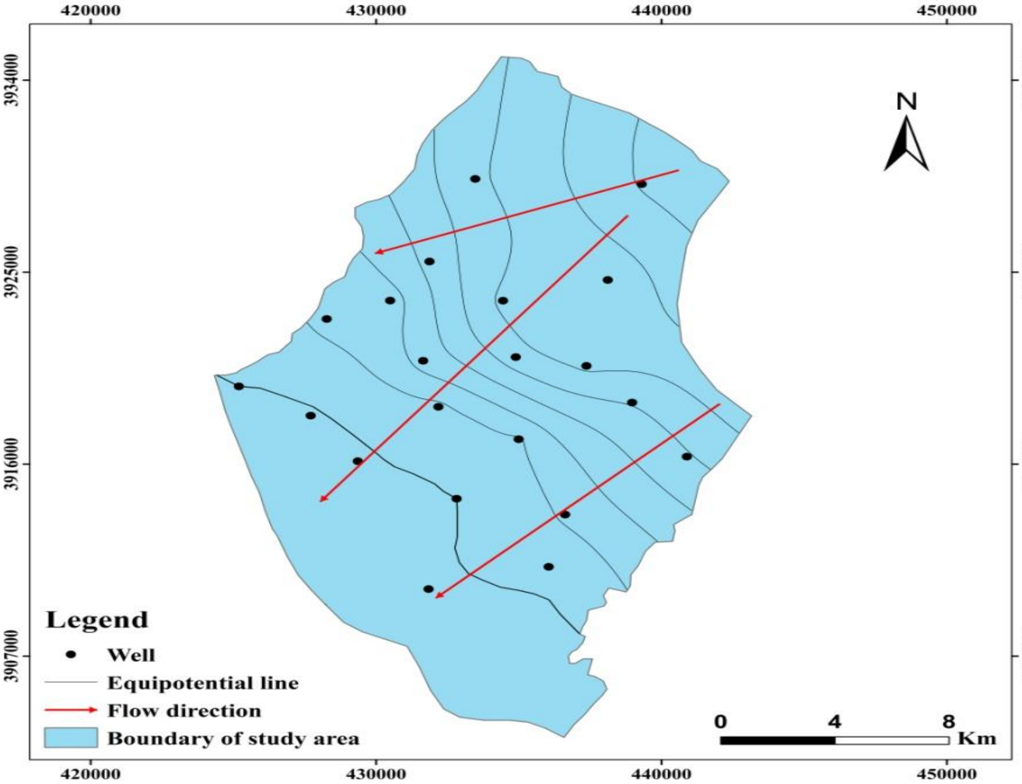

Figure 4-The flow net of the study area.

Results and discussion

1. Climate:

The average annual rainfall during the period 1971 to 2015 is 348.13, which can be relied upon to know the dry and wet years, where 27 dry years were found, equivalent to 60% and 18 years wet, equivalent to 40%, as shown in the Table-2 and Figure-5.

The climate of the study area is classified as Humid to Moist according to classification [19] which is depending on annual total rainfall (mm) and annual average temperature (TC◦) where representation of the aridity index (AI) as shown in Table-3 and the equations below:

$$AI.1 = (1\times P)/(11.525\times T) = 1.33 \quad ....(1)$$

$$AI.2 = \sqrt{P/T} = 3.92 \quad ....(2)$$

Where:

AI: Aridity index, P: Annual total rainfall (mm), T: Annual average temperature (c◦).

Values of Potential evapotranspiration were calculated theoretically at assumption the number of days in the month 30 days and the number of hours the sunshine 12 hours per day, they are not compatible with reality. Therefore, can be using equation(7) [20] to obtaining values of the corrected potential evapotranspiration as shown in Table-4. by using equations below:

$$\mathbf{PE} = 16\left(\frac{10\,t}{J}\right)^{a} \quad ....(3)$$

$$\mathbf{J} = \sum_{j=1}^{12} j \quad ....(4)$$

$$\mathbf{j} = \left(\frac{t}{5}\right)^{1.514} \quad ....(5)$$

$$\mathbf{a} = 0.016\,J + 0.5 \quad ....(6)$$

Where:

PE: potential evapotranspiration (mm), t: Mean monthly air temperature (C°), J: Annual temperature parameter(C°), j: monthly temperature parameter (C°), a: Constant (2.53).

PEc = PE ×K (K=DT/360) ....(7)

Where:

PEc: Corrected potential evapotranspiration (mm), PE: potential evapotranspiration (mm),
K: Correction factor, D: number of days in the month, T: monthly average sunshine duration (hour/day).

Table 2- Annual average of rainfall for period from 1971 to 2015 in the Kirkuk station

Year	Annual rainfall	Year	Annual rainfall	Year	Annual rainfall	Year	Annual rainfall	Year	Annual rainfall
1971	361.1	1980	360.6	1989	346.8	1998	287.7	2007	173.1
1972	455.4	1981	489.4	1990	244.4	1999	229.8	2008	134.9
1973	260.9	1982	532.0	1991	395.5	2000	236.3	2009	225.8
1974	695.9	1983	201.7	1992	669.4	2001	277.0	2010	267.2
1975	420.8	1984	271.6	1993	594.7	2002	461.6	2011	221.8
1976	351.0	1985	343.6	1994	365.3	2003	183.6	2012	292.1
1977	346.0	1986	313.2	1995	285.5	2004	312.1	2013	394.3
1978	243.0	1987	306.0	1996	398.5	2005	249.4	2014	319.0
1979	292.0	1988	458.1	1997	495.3	2006	458.4	2015	315.5

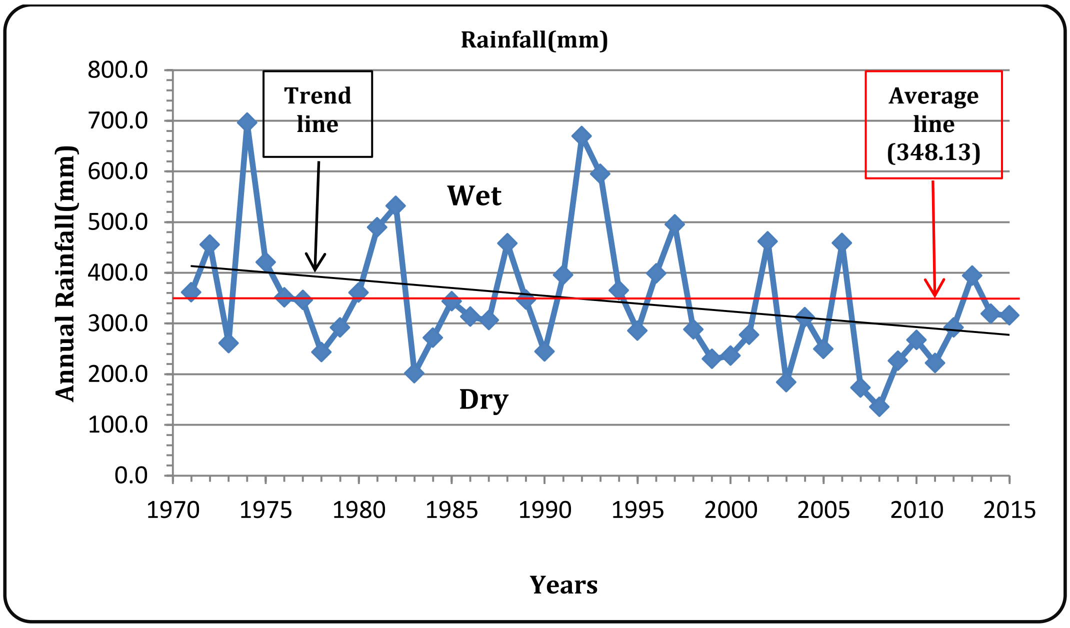

Figure 5-Trend line wet and dry average of annual rainfall of the Kirkuk meteorological station from 1971 to 2015.

Table 3-classification of climate, according to [19]

Type 1	Evaluation	Type 2	Evaluation
AI. 1 > 1.0	Humid to Moist	**AI. 2 ≥ 4**	Humid
		2.5 ≤AI. 2 < 4	Humid to Moist
		1.85 ≤AI. 2 < 2.5	Moist
		1.5 ≤AI. 2 < 1.85	Moist to Sub arid
AI. 1 < 1.0	Sub arid to Arid	**1.0 ≤AI. 2 < 1.5 2.0**	Sub arid
		AI. 2 < 1.0	Arid

Table 4- PEc values for the period (1971-2015) by Thornthwaite method.

Month	T (c°)	$j=(t/5)^{1.514}$	$(10t/J)^{a}$	PE (mm)	K=DT/360	PEc=PE×K (mm)
Oct.	24.9	11.37	5.5	88	0.69	60.72
Nov.	16.4	6.04	1.91	30.6	0.55	16.83
Des.	10.8	3.21	0.66	10.63	0.47	5
Jan.	9.1	2.48	0.43	6.89	0.47	3.24
Feb.	10.9	3.25	0.68	10.88	0.48	5.22
Mar.	15	5.28	1.53	24.41	0.62	15.13
Apr.	20.8	8.66	3.49	55.82	0.65	36.28
May	27.6	13.28	7.14	114.18	0.79	90.2
Jun.	33.3	17.65	11.48	183.61	0.93	170.76
Jul.	36.2	20.03	14.17	226.8	0.96	217.73
Aug.	35.7	19.61	13.68	218.95	0.95	208
Sep.	31.3	16.07	9.81	156.97	0.85	133.42
SUM		**J = 126.93**		**1127.74**		**962.53**

Water Surplus (WS)

Water surplus represents an increase of average rainfall (P) more than averages to potential evapotranspiration (PE) during a determined months of the year. Therefore become potential evapotranspiration (PE) values equal to actual evapotranspiration (AE) [21] as in the following equation:

$P > PE$ where $PE=AE$ $\mathbf{WS = P - PE}$ ……………. …………(8)

Where:

WS: water surplus (mm), P: rainfall (mm), PE: potential eavpotranspiration (mm), AE: actual Potential eavpotranspiration (mm).

Values of the water surplus range from 62.56mm in January to 4.92mm in April with total annual is 238.4mm as shown in Table-5.

The value of WS can be used to determine the recharge volume for groundwater after calculating runoff. The surface runoff was calculated of the Al-Adhaim Basin, which consider the study area as part of this basin through an equation based on experimental work by [22] as follows:

SR (mm) = 0.167× [P (mm) – 180] ………………………....(9)

= 28.1mm represents 11.8 % from water surplus

Where:

SR: Surface runoff(mm), P: Total annual rainfall(mm).

Fetter [23] noted that the water surplus (WS) includes surface runoff (SR) and groundwater recharge (GR) as in equation below:

WS = SR + GR ……………………………….(10)

GR = 238.4 − 28.1 = 210.3 mm represents 88.2% from water surplus

VSR = A × SR = $350\times10^{6} \times 28.1\times10^{-3}$

= **9.8×10^{6} m^3/year**

VGR = A × GR = $350\times10^{6} \times 210.3\times10^{-3}$

= 73.6×10^{6} m^3/year

Where:

WS: Water surplus (mm), SR: Surface runoff(mm), GR: Groundwater recharge(mm), VSR: Volume surface runoff in the study area (m^3/year), VGR: Volume recharge of groundwater in the study area(m^3/year), A: Area(m^2).

Table 5-The monthly values for rainfall, Corrected potential evapotranspiration and water surplus

Month	P (mm)	PEc (mm)	AE (mm)	WS (mm)
Oct.	13.5	60.72	13.5	
Nov.	40.8	16.83	16.83	23.97
Dec.	56.8	5	5	51.8
Jan.	65.8	3.24	3.24	62.56
Feb.	59.8	5.22	5.22	54.58
Mar.	55.7	15.13	15.13	40.57
Apr.	41.2	36.28	36.28	4.92
May	13.6	90.2	13.6	
Jun.	0.1	170.76	0.1	
July	0.2	217.73	0.2	
Aug.	0.03	208	0.03	
Sep.	0.6	133.42	0.6	
Total	**348.13**	**962.53**		**238.4**

2. Hydraulic properties:

Pumping and the recovery test process was performed on five wells diffusive in the study area as illustrated in Figure-1. The data of this process has been entered into (AQTESOLV 4.5) software for the purpose of analyzing these data and know hydrogeological conditions as shown in Figures-(6, 7, 8, 9 and 10) then calculating the hydraulic properties of the aquifer in the area such as Transmissivity (T), Hydraulic conductivity (K) and Specific capacity (SC) by using [24] equitions below:

T = 2.3Q / 4πΔS ………………………...…(11)

Where:

T: Transmissivity (m^2 /day), Δs: Difference of the drawdown (m) per one log-cycle, Q: Discharge (m^3/day)

K = T / D …………………………...…(12)

Where:
K: Hydraulic conductivity (m/day), T: Transmissivity (m2/day), D: Saturated thickness of the aquifer (m).

SC = Q/s ……………………….…(13)
Where:
SC: Specific capacity (m^2/day), Q: Discharge (m^3/day), s: Total drawdown (m).

The value of the storage coefficient(S) can not be calculated because there are no observation wells in the study area. The characteristics of the pumping wells like level of static water, drawdown, discharge, saturated thickness and depth were presented in the Table-6, where found that the values these characteristics are range from 4 to 18.02m, 4.09 to 25.96m, 8 to 14 l/s, 32 to 75m and 83 to 142m respectively. The Figures from 6 to 10 represent the relationship between the drawdown and time and also between the residual drawdown with time for each pumping well, when interpreting this relationship and analysis of the curve will we obtain some hydraulic characteristics of the wells in the study area, as shown in Table-7. Where transmissivity values ranges from 88.1 to 829.7m^2/day and from 55.88 to 899.2m^2/day while hydraulic conductivity values ranges from 0.64 to 8.74m/day and from 0.41 to 9.48m/day according to Cooper-Jacob and Theis recovery methods respectively, and specific capacity values ranges from 33.28 to 295.75 m^2/day. Generally, The recovery test data are more reliable than the other because the water level rise in the well at a constant rate means the non presence of pumping effects. We note that the hydraulic properties of the wells in the study area are not identical due to differences in values of porosity and permeability of the water bearing layers.

Table 6-Coordinates and properties of pumping wells in the study area

Well No.	X(UT) East	Y(UTM) North	Ground water level (m)	Drawdown(s) (m)	Discharge(Q) L/S	Saturated(D) thickness (m)	Dept. (m)
W-1	433944	3917357	18.02	4.09	14	42	102
W-2	434450	3923662	6.92	25.96	10	32	83
W-3	432825	3914380	12.11	6.43	13	35	107
W-4	427711	3918277	8.12	8.31	10	35	140
W-5	431840.5	3910147	4	13.99	8	75	142

Table 7-Summary of results of pumping and recovery tests in the study area

Well No.	Cooper- Jacop (Drawdown)		Theis (Recovery)		Average		SC(m^2/d)
	T(m^2/d)	K(m/d)	T(m^2/d)	K(m/d)	T(m^2/d)	K(m/d)	
W-1	602.5	14.3	763.2	18.2	682.9	16.25	295.75
W-2	168.5	5.3	68.8	2.2	117.1	3.75	33.28
W-3	829.7	23.7	899.2	25.7	864.5	24.7	174.68
W-4	207.4	5.9	391.3	11.2	299.4	8.55	103.97
W-5	88.1	1.2	55.88	0.7	71.99	0.95	49.41
Average					**407.18**	**10.84**	**131.42**

Conclusion

Through comparison between of the annual rainfall rate for each year from 1971 to 2015 with total annual rainfall (348.13mm) shown that there are 27 dry years and 18 wet years, this means that the climate of the region tends to drought. The type of climate in the study area is Humid to Moist. The water surplus(WS) was calculated equal to 238.4 mm, equivalent to 68.48% from total annual rainfall, which was used in calculate the volume of surface runoff and groundwater recharge for the study area where equal 9.8×10^6 m^3/year and 73.6×10^6 m^3/year respectively. The direction of the groundwater movement is from the recharge area (northeast) to the discharge area (southwest) with the hydraulic gradient equal to 0.0045. Using the Cooper Jacob's and Theis recovery methods to analyze the results of the pumping test process for five wells distributed in the region, show that the value of T, K and SC have ranged from 71.99 to 864.5 m2/day with average 407.18 m2/day, 0.95 to 24.7m/day with average 10.84m/day and 33.28 to 295.75m2/day with average 131.41m2/day respectively. These values indicate that the hydraulic properties of the aquifer vary from one location to another in the study area, attributed to lithology heterogeneity for this aquifer.

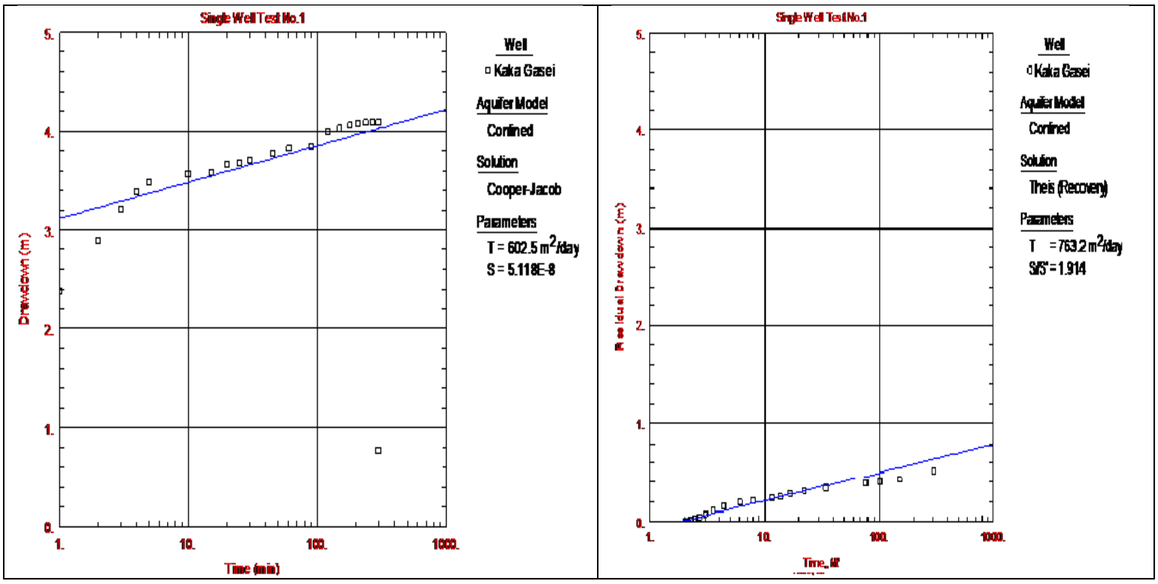

Figure 6 - Relation curves between time-drawdown and time - residual drawdown of well (W-1)

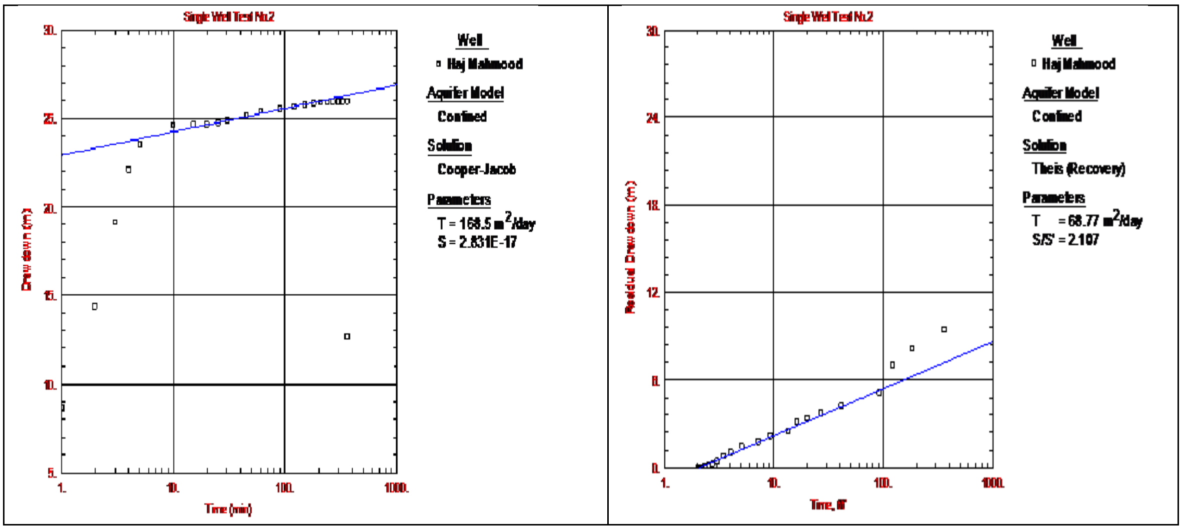

Figure 7- Relation curves between time-drawdown and time - residual drawdown of well (W-2).

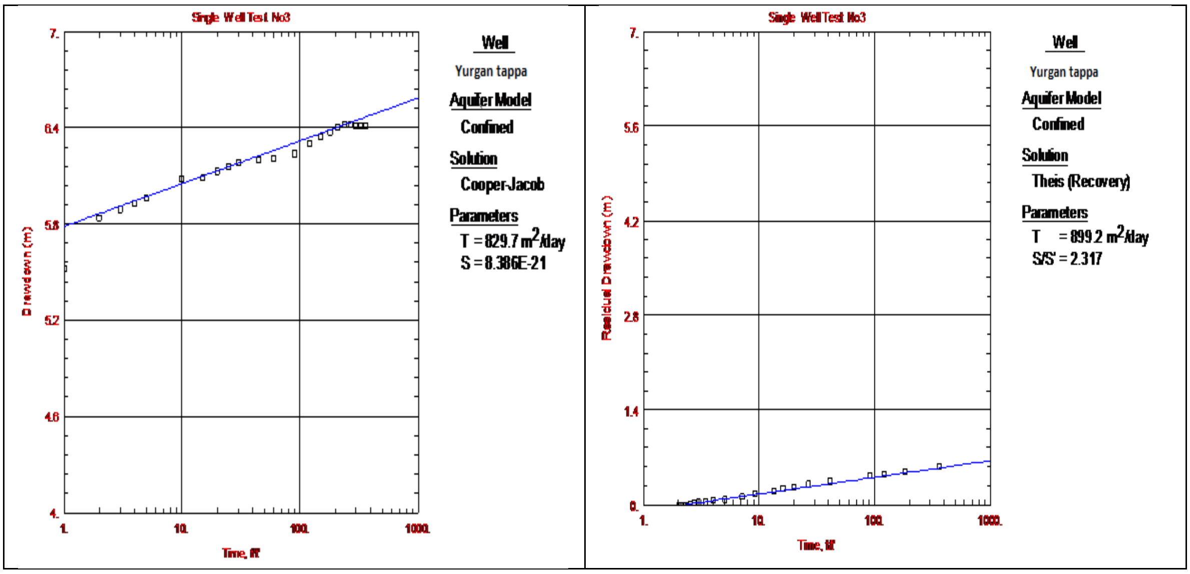

Figure 8- Relation curves between time-drawdown and time-residual drawdown of well (W-3)

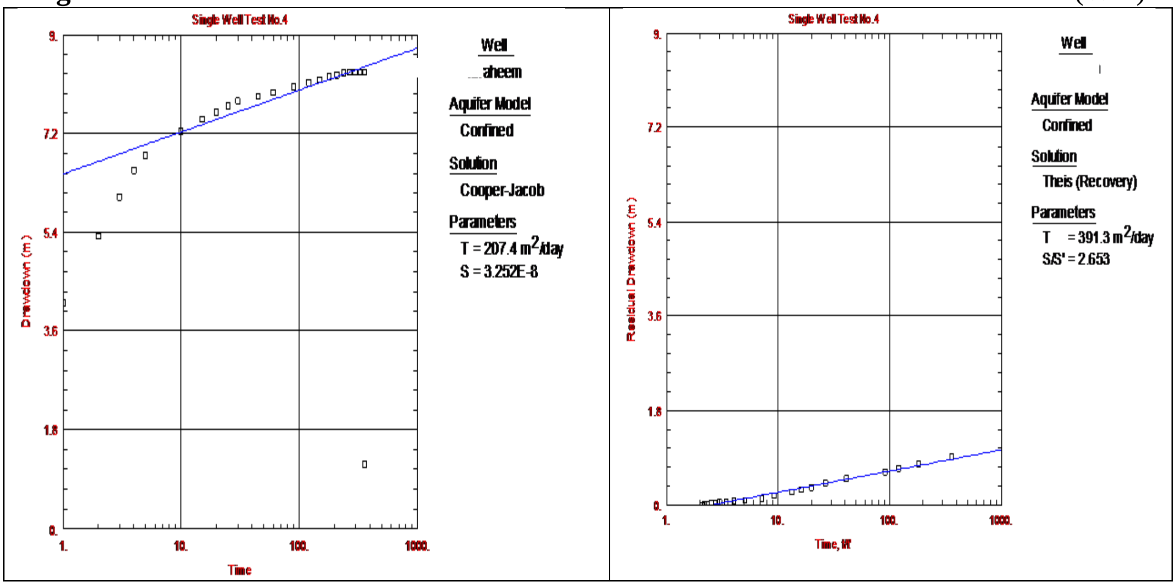

Figure 9 - Relation curves between time-drawdown and time - residual drawdown of well (W-4)

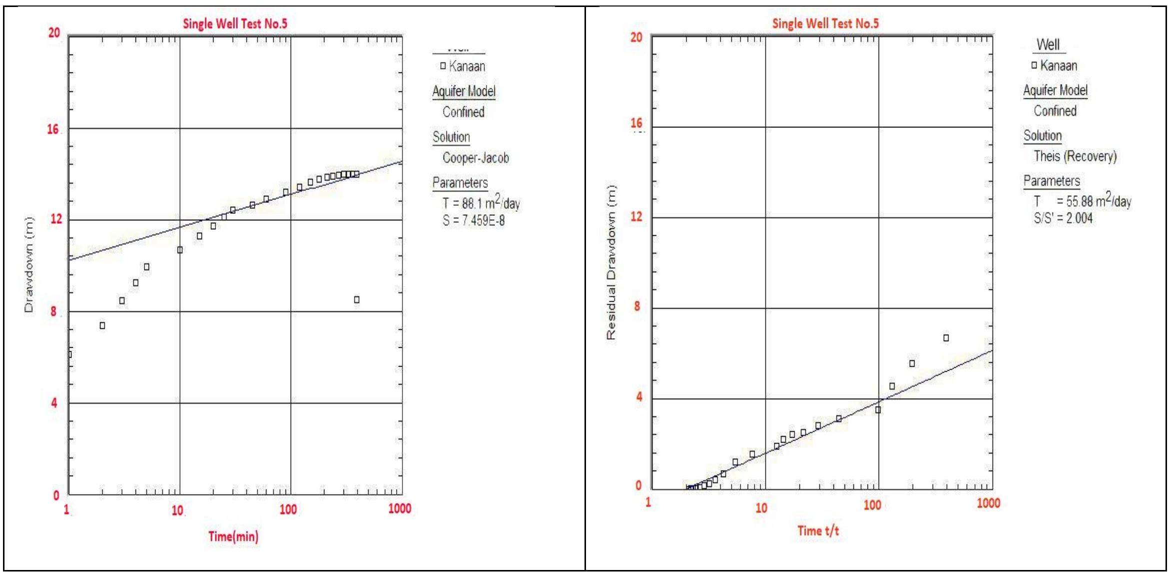

Figure 10 -Relation curves between time-drawdown and time - residual drawdown of well (W-5).

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