Hydraulic Characteristics of the Aquifer up Al-Khassa Dam Sub-Basin Kirkuk/NE Iraq

Sayhan Mahmood Mustafa Ali[1], Omer S.Ibrahiem Al-Tamimi[2]
[1]Master Student at Department of Applied Geology, College of Science, Kirkuk University-Iraq
[2]Environmental Research Unit, College of Science, University of Kirkuk-Iraq

Abstract

The aim of this study is to the evaluation of the general hydrogeology condition of the Al-Khassa sub-basin area. Pumping test has been done for five wells in the area. The hydrogeological characteristics (transmissivity, hydraulic conductivity and storage coefficient) were determined in the area by input data which obtained from the pumping test process into the (AquiferWin32, Version 5) software program. The data were analyzed using Copper-Jacob, Theis and Hantuosh methods for pumping, the values of hydraulic characteristics range from: transmissivity (0.98 to 19.57) m²/day in (W7-W9-W10-W12) sites and 416 m²/day in W1, hydraulic conductivity (0.051 to 0.305) m/day in (W7-W9-W10-W12) sites and 5.012 m/day in W1, storage coefficient 0.021 to 0.065, intendment that the water is pumped from semi-confined aquifer. By using the lithological information, the saturated thickness of where the minimum thickness of 47 m is observed in site W4, and a maximum thickness of 83 m are obtained in site W1, with an average of 67 m. Groundwater flow was 0.364 MCM annually. The flow direction of groundwater was drawn by calculated head values of the eleven wells, it was from the recharge areas in northeast and southeast towards the discharging areas at west.

Keywords: Hydraulic properties, Pumping test, Al-Khassa dam sub-basin, Flow net.

الخصائص الهيدروليكية للمكمن المائي أعلى الحوض الثانوي لسد الخاصة, كركوك / شمال شرقي العراق

سيهان محمود مصطفى[1]، عمر صباح ابراهيم التميمي[2]
[1]طالبة ماجستير في قسم الجيولوجيا التطبيقية ، كلية العلوم ، جامعة كركوك ، العراق
[2]وحدة البحوث البيئية ، كلية العلوم ، جامعة كركوك بالعراق

الخلاصة

الهدف من هذه الدراسة هو تقييم الحالة الهيدروجيولوجية العامة لمنطقة اعالي سد الخاصة. اجريت خمس اختبارات للضخ التجريبي على خمسة آبار في منطقة الدراسة. تم تحديد الخصائص الهيدروجيولوجية (الناقلية، توصيلية الهيدروليكية ومعامل التخزين) في المنطقة عن طريق إدخال البيانات التي تم الحصول عليها من عملية الضخ التجريبي في برنامج (AquiferWin32 ، الإصدار5). تم تحليل البيانات باستخدام طرق Theis Copper–Jacob،و Hantuosh، تراوحت قيم الخصائص الهيدروليكية من: ناقلية (0.98 إلى 19.57) م²/يوم في مواقع (W7–W9–W10–W12) و 416 م²/يوم فيW1 ، توصيل الهيدروليكي (0.051 إلى 0.305) م/يوم في مواقع (W7–W9–W10–W12) و 5.012 م/يوم فيW1 ، معامل التخزين 0.021 إلى 0.065 ، وهذا يعني أن المياه في هذه المنطقة يتم ضخها من المكمن المائي شبه المحصور. باستخدام بيانات الصخارية ، تم الحصول على سمك الطبقات المشبعة ، حيث لوحظ أدنى سمك هو 47 م في الموقع

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*Email:sayahnmahmood@gmail.com

W4 ، و أقصى سمك كان 83 م في الموقع W1 ، بمتوسط 67 م. مقدار تدفق المياه الجوفية 0.364 مليون

متر مكعب سنويا. تم رسم اتجاه تدفق المياه الجوفية من خلال قيم رأسية محسوبة لأحد عشرة بئراً، وكان اتجاه

الجريان من مناطق التغذية في الشمال الشرقي والجنوبي الشرقي نحو مناطق التفريغ في الغرب .

Introduction

In Iraq, there is an orientation to the exploitation of groundwater to meet the requirements for domestic, agricultural and industrial sectors because of shortage in water resources, particularly in surface water. Groundwater recharge of the area occurs through rainfall infiltration, riverbed, floods, and the irrigation return flow [1]. Groundwater is the main source of water in the basin. Due to population growth, the use of groundwater has increased dramatically, and excessive groundwater withdrawal has become a serious problem in the basin. Determination of aquifer characteristics and groundwater recharge is essential to the solution of several hydrological and hydrogeological problems. Transmissivity, hydraulic conductivity and storage coefficient are very useful in describing subsurface hydrology [2]. There are studies included the study area such as, [3], studied the hydrology of Kirkuk and northern part of Al-Adhaim Basin. [4], they designed an operational program for wells in Kirkuk. [5] Prepared a hydrology study of the upper Al-Adhaim Basin, indicating two hydrogeological systems, the first confined (Bai-Hassan Formation) and second unconfined (quaternary and recent sediments). [6] Submitted a study in Optimum Management of surface and subsurface water of Al-Adhaim basin. [7] Prepared a hydrology study of the upper Diyala River Basin and he studied future investment of groundwater in the study area. This paper is aim to determine the hydraulic characteristics and estimation of subsurface flow of the aquifer in the Al-Khassa dam Sub - basin area.

Study area

The study area (Al-Khassa Sub-basin) is located in the north of Iraq, the northeastern part of Kirkuk province, about 15 km from the center of Kirkuk city. It forms the north side of Al-Adhaim basin. The study area is located between longitude (44° 28' 00" E - 44° 49' 00"E), and the latitude (35° 43' 00" N - 35° 30' 00" N), with an area of 420 km^2, the lowest elevation of ground surface rises from 440 m a.s.l in the west near the reservoir, towards the east where it reaches 890 m a.s.l near Chamchamal North anticline. The study area is delimited by natural hydrological and structural boundaries (Figure-1). Groundwater is the only source of water for all daily uses, including domestic, agricultural, livestock, etc. Three formations are exposed in the area (Injana, Muqdadiya, Bai- Hassan formations and Quaternary deposits). The area is covered by sedimentary rocks from the Tertiary to the recent Quaternary deposits [8- 10]. Tectonically, it lies within the Unstable Shelf included in Chemchemal-Butmah subzone NE part of the Foothill zone. It is structurally the highest part of the zone [11].
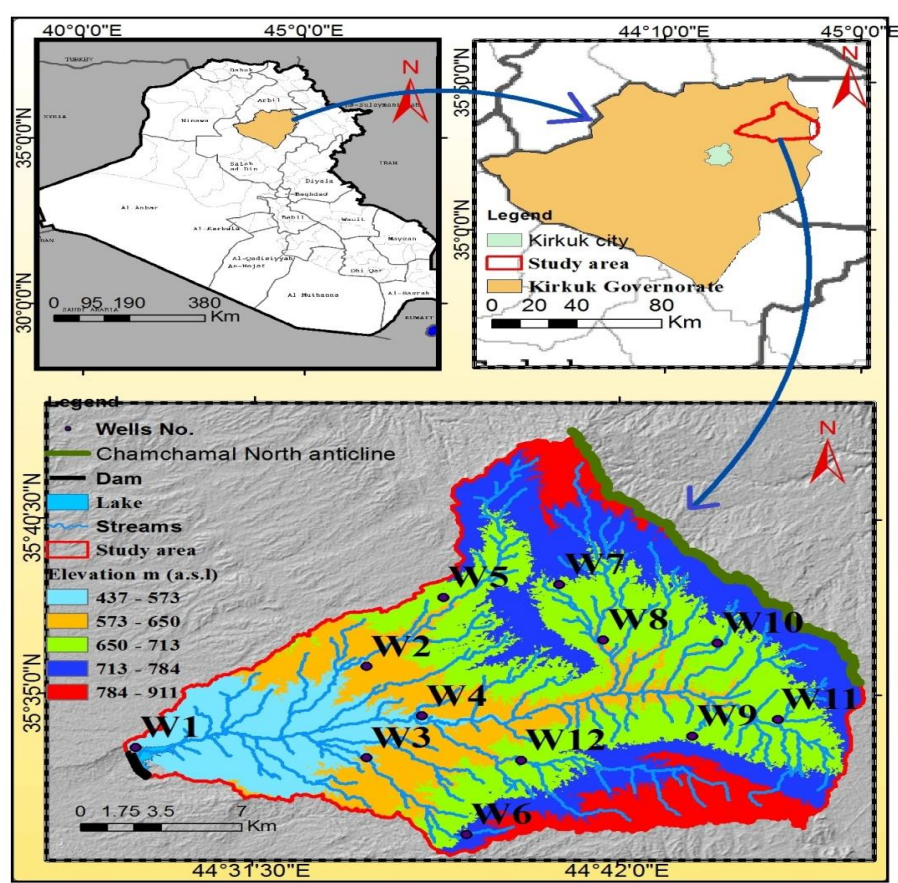
Figure 1-Location and Topographic Map of the Study Area

Hydrogeological setting

The study area is a part of the Al-Adhaim River basin (Al-Khassa Stream is one of the three main tributaries of Al-Adhaim River). Al-Adhaim basin is located in northeast of Baghdad and it is about ($12000 km^2$) [6]. According to the hydrogeological division the sub-basin is Mio.-Pliocene Sandstone [12]. The most important aquifers in the basin consist of Tertiary deposits (Muqdadiya and Bai-Hassan formations) as well as recent Quaternary deposits [5].

The Pliocene water bearing formations (Mukdadiya and Bai Hassan Formations) in the area is a medium to high production aquifer locally. Mukdadiya Formation is disconnected with semi-permeable siltstone or impermeable claystone. And Bai Hassan Formation is disconnected by impermeable claystone layers, partly confined, and covered by younger sediments. The estimated thickness of this unit is 650m [13]. The quaternary appears in the study area as slope deposits [5]. The slope deposits are medium to high production aquifers, fractioned by impermeable clay layers, mostly unconfined, its thickness ranges between (1-3) m [9]. The most of drilled wells are benefiting from the water of this aquifer, which is explored for different purposes like domestic, agriculture, and etc.

Material and Methodology

Pumping test method has been used to obtain the hydraulic properties (hydraulic conductivity, transmissivity, storage coefficient) of the aquifers show the velocity of the water of the porous media and the extent of the effect on the groundwater level. By pumping water from the wells at a constant discharge and observing the drawdown in the groundwater level of the well. The pumped water was discharged far away from the well or used to fill the water tanks of the inhabitants of that area. Because of the difference of salinity from one aquifer to another electrical conductivity is measured before and at the end of the pumping of each well to indicate that the pumping is from the same aquifer [14]. Five single pumping tests were performed in the study area, which is distributed in all of the parts of the study area. Pumping test data include drawdown versus time and well discharge. These data have been an input of the (AquiferWin32, Version 5) software program. The data were analyzed using Copper-Jacob, Theis and Hantush methods for pumping [15].

Copper-Jacob method equation:

$$T=\frac{2.3Q}{4\pi\Delta s}$$ ……… …………………………..(1)

Where:
T: Transmissivity (m² /day), ΔS:Difference in the drawdown (m) per log-cycle of t., Q: Discharge (m³/day)

$$S=\frac{2.25Tt^{°}}{r^2}$$ ……… ……………….(2)

Where :
S: Storage coefficient, T: Transmissivity (m² /day), $t^{°}$: (day), r^2: Radius effect (m²)
Theis method equation:

$$T=\frac{Q}{4\pi s}W(u)$$ ……… …………………(3)

Where :
T: Transmissivity (m² /day), Q: Discharge (m³/day), s : Drawdown (m), $W(u)$: Well function for non leaky

$$S=\frac{4uTt}{r^2}$$ ……………………………….. (4)

Where :
S: Storage coefficient, T: Transmissivity (m² /day), u: Dummy variable, t: Time since pumping started (day), r^2: Radius effect (m²)
Groundwater flow is calculated by using the method of Flow Net Analysis [16], Groundwater flow can be represented by the following equation:

$$i=\frac{dh}{L}$$ …………………………….. (5)
$$Q = T\,iL$$ …………………………… (6)

Where :
i : Hydraulic gradient
dh: total head difference (m)
L : Length of flow path (m)
T : Average of transmissivity (m² /day)
Q : Discharge (m³/day)
And a radius of the influence of the well is obtained from the following equation [16]:

$$r = 2.0\ \sqrt{(T*t\ /\ S)}$$ ……………………… (7)

Where :
r : Radius of influence of the well (m)
T: Transmissivity (m² /day)
t : The running time of the well (day)
S: Storage coefficient

Results and discussion

   Five single pumping tests were performed in the study area scattered in all of the parts of the study area (W1-W7-W9-W10-W12) as shown in (Figure-1). Single pumping tests were performed due to lack of monitoring wells conditions in the study area. Hydraulic properties (transmissivity, hydraulic conductivity and storage coefficient) of aquifer at the basin were obtained by analyze the results of the pumping test process applying the equations (1, 2,3and 4) as well as by inputting the tests result into (AquiferWin32, Version 5) software Figure-(2.a, b, c, d, e)

   The pumping wells information and pumping tests data were presented in the (Table-1) and (Table-2) respectively. Hydraulic characteristics values results was: transmissivity values range from (0.98 to 19.57) m²/day in study area and 416 m²/day in the western part of the study area Figure-3(A), hydraulic conductivity (0.051 to 0.305) m/day in study area and 5.012 m/day in the western part of the study area (Figure -3(B). The transmissivity and hydraulic conductivity values are almost similar across the entire area except for the western part of the study area. This is due to the estimate that the aquifer has a hydraulic relationship with the Al-Khassa reservoir and therefore the results of W1 well pumping are neglected during the drawing of hydraulic characteristic. The distribution of the thickness in the study area depending on borehole lithology of wells (Figure-4) drilled by (General Commission of Groundwater-Kirkuk), where a minimum thickness of 47 m is observed in south east, and a

maximum thickness of 83 m is obtained in west part of the study area, with an average of 67 m, (Figure-3(C). The storage coefficient value (it is assumed in the program that the radius of the well is equal to the radius of influences) in the study area (Figure-3(D) ranged from 0.021 to 0.065. The summary of the hydraulic properties results by the three methods in the study area is shown in (Table-3).

The flow direction of groundwater (Figure-5) was drawn by calculated head values of the eleven wells (Table-1), it was from the recharge areas in northeast and southeast towards the discharge areas at west.

These values indicate that the hydraulic properties of the aquifer almost similar from one point to another except for west part (around W1 site) in the study area due to the estimate that the aquifer has a hydraulic relationship with the Al-Khassa reservoir. Groundwater flow (Subsurface flow) by using equation (5, 6) was $0.364 * 10^6 \left(\frac{m^3}{y}\right)$. The geologic section of wells of the study area depending on borehole lithology of (Figure-6) and the hydraulic properties in the study area shows the main aquifer in the study area (Bai-Hassan formation), according to [17] we have the semi-unconfined aquifer. The optimal distance between the wells was 13.5 m (equation 7).

Table 1-Wells information's and coordinates

Well No.	Coordinates	Elevation (m)	G.W.L (m)	W.T (m)	Well depth (m)	Q (m³/day)	Saturated thickness (m)
W1	35°33'21"N - 44°27'55"E	535	77	458	296	570.24	83
W2	35°36'09"N - 44°35'22"E	599	12	587	50	95.04	----
W3	35°33'04"N - 44°43'45"E	579	43.2	536	150	77.76	----
W4	35°36'09"N - 44°28'02"E	572	20	552	180	112.32	----
W5	35°37'52"N - 44°37'20"E	672	12.15	660	120	60.48	----
W6	35°30'24"N - 44°37'41"E	745	76.50	668	280	----	----
W7	35°38'21"N - 44°40'12"E	694	16.40	678	90	77.76	75
W8	35°36'38"N - 44°41'27"E	662	11.7	650	60	103.68	----
W9	35°33'44"N - 44°44'09"E	704	17.50	687	80	172.8	47
W10	35°36'50"N - 44°44'45"E	744	53.7	690	100	60.48	----
W11	35°34'23"N - 44°34'47"E	704	14	690	150	267.84	----
W12	35°33'01"N - 44°39'16"E	677	56	621	110	108	64

Table 2-Pumping test data for W1, W7, W9, W10 and W12

Time(min)	Drawdown (m)				
	W1	W7	W9	W10	W12
1	0.40	0.70	1.50	0.9	1.00
2	0.60	1.10	2.60	2.8	1.70
3	0.71	1.40	3.50	4.3	1.80
4	0.75	1.80	4.30	5.6	1.90

5	0.78	2.10	4.90	6.4	2.00
10	0.82	3.20	8.50	8.6	2.30
15	0.86	3.97	12.00	10.3	2.40
20	0.89	4.51	14.00	11.0	2.50
25	0.90	4.93	15.00	11.2	2.55
30	0.92	5.25	17.00	11.2	2.55
45	0.94	5.85	18.40	11.2	2.55
60	0.95	6.25	19.10	11.2	2.55
75	0.99	6.45	19.10	--	--
90	0.99	6.70	19.10	--	--
105	0.99	7.03	--	--	--
120	--	7.03	--	--	--
135	--	7.03	--	--	--
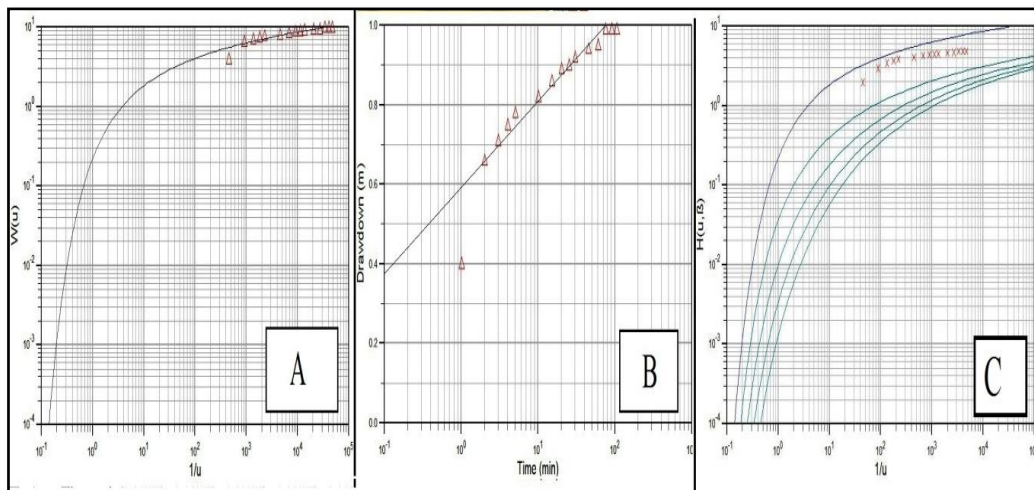
Figure 2 (a)-Pumping test data analysis of W1 by (A)Theis method, (B) Copper-Jacob method, and(C) Hantuosh method.
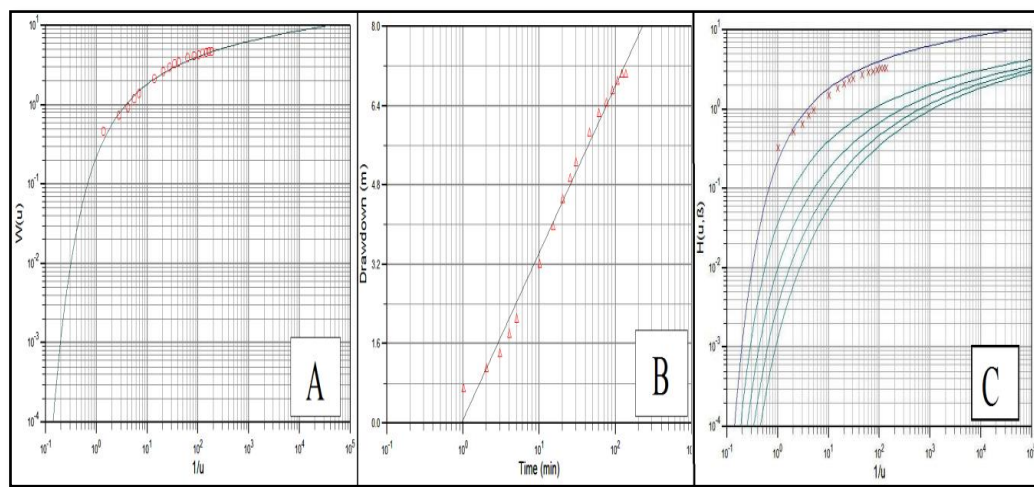
Figure 2(b)-Pumping test data analysis of W7 by (A)Theis method, (B) Copper-Jacob method, and(C) Hantuosh method.
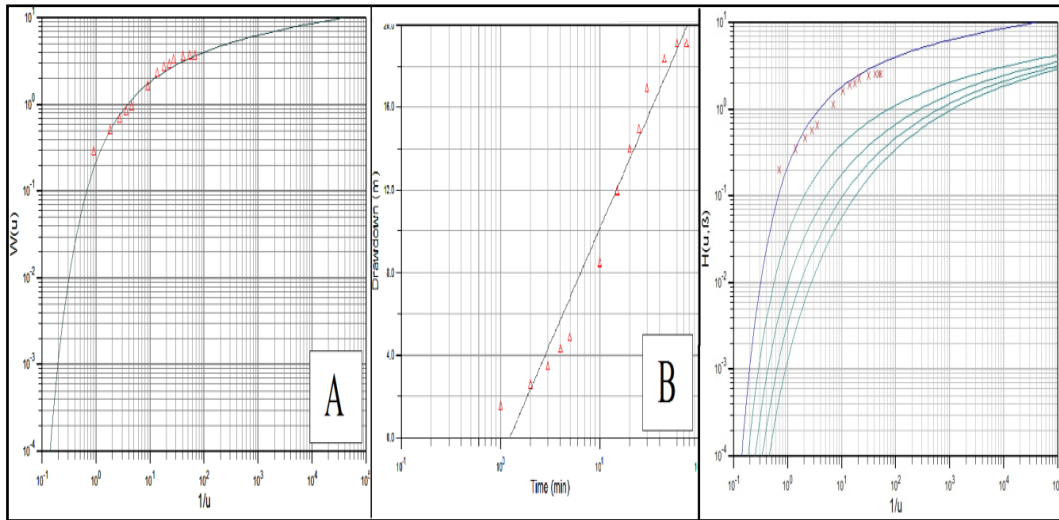
Figure 2(c)-Pumping test data analysis of W9 by (A)Theis method, (B) Copper-Jacob method, and(C) Hantuosh method.
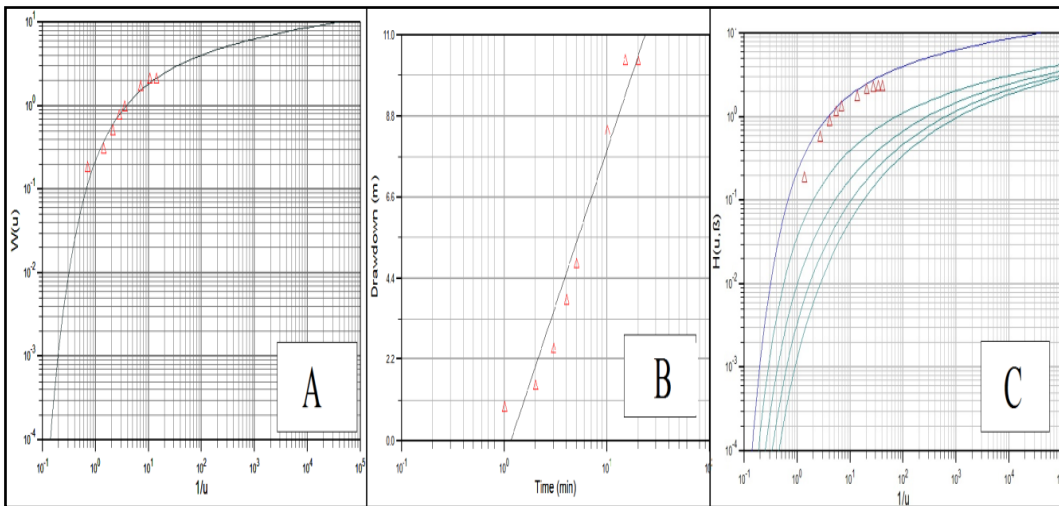

Figure 2(d)-Pumping test data analysis of W10 by (A)Theis method, (B) Copper-Jacob method, and(C) Hantuosh method.
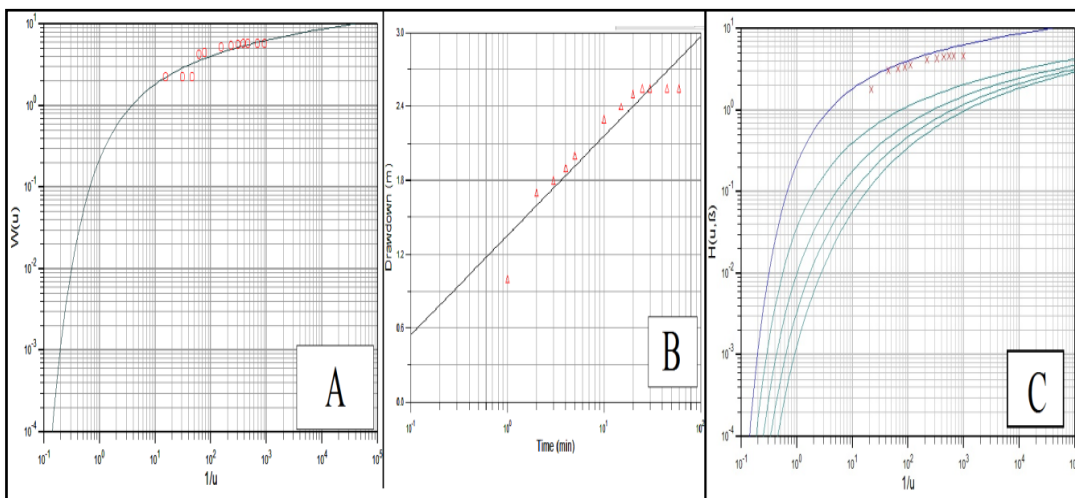

Figure 2(e)-Pumping test data analysis of W12 by (A)Theis method, (B) Copper-Jacob method, and(C) Hantuosh method.

Table 3-Results of hydraulic properties by three methods used in single well pumping test analysis for wells of the study area

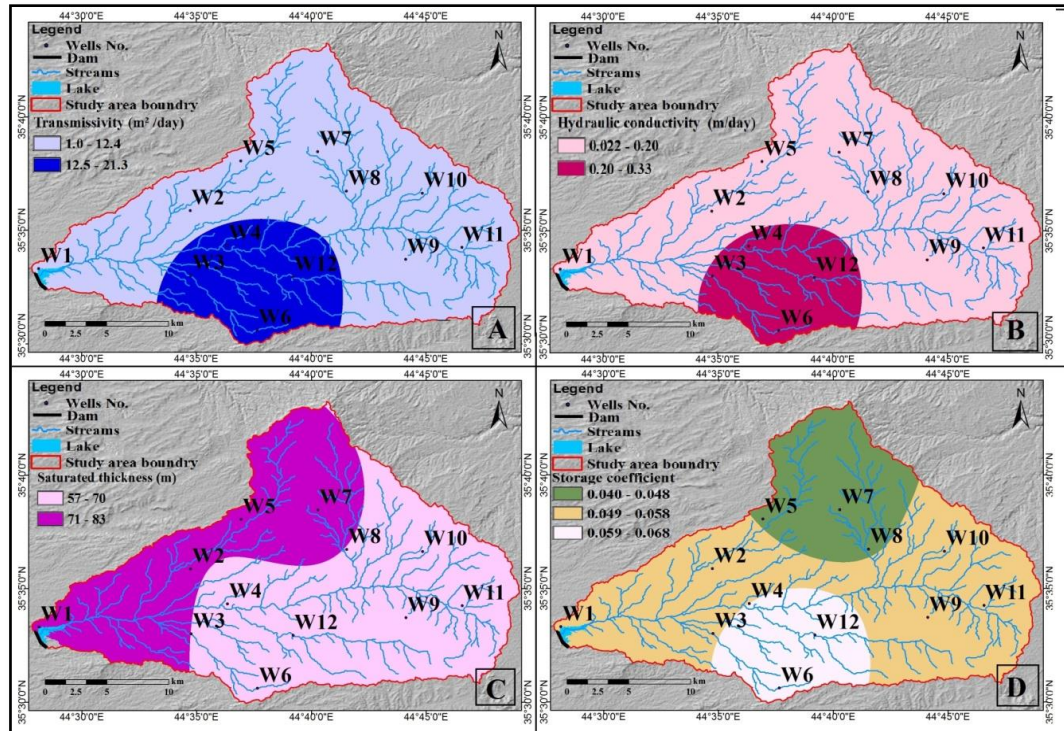| Well No.	Copper-Jacob method		Theis method		Hantush method		Average values		
	T (m²/day)	S	T (m²/day)	S	T (m²/day)	S	T (m²/day)	S	K (m/day)
W1	481	0.028	449	0.020	318	0.015	416	0.021	5.012
W7	4.20	0.038	4.24	0.043	3.91	0.039	4.11	0.040	0.054
W9	2.80	0.060	2.60	0.050	1.9	0.069	2.4	0.060	0.051
W10	0.98	0.050	0.97	0.051	0.99	0.048	0.98	0.050	----
W12	23.2	0.062	19.42	0.070	16.1	0.062	19.57	0.065	0.305

Figure 3-Hydraulic properties values A: Transmissivity value (m²/day), B: Hydraulic conductivity value (m/day), C: Saturated thickness value (m), D: Storage value.
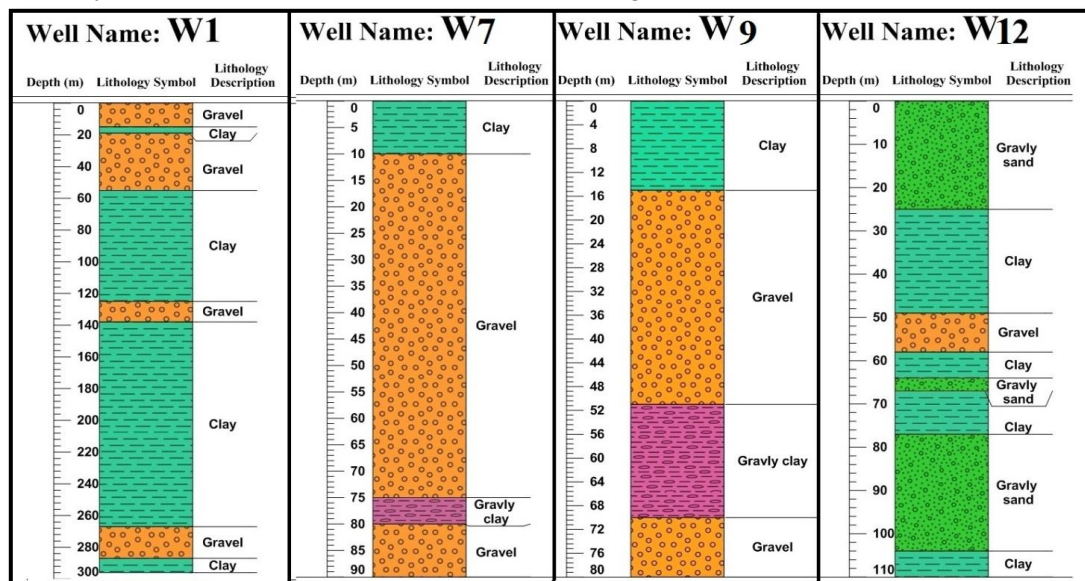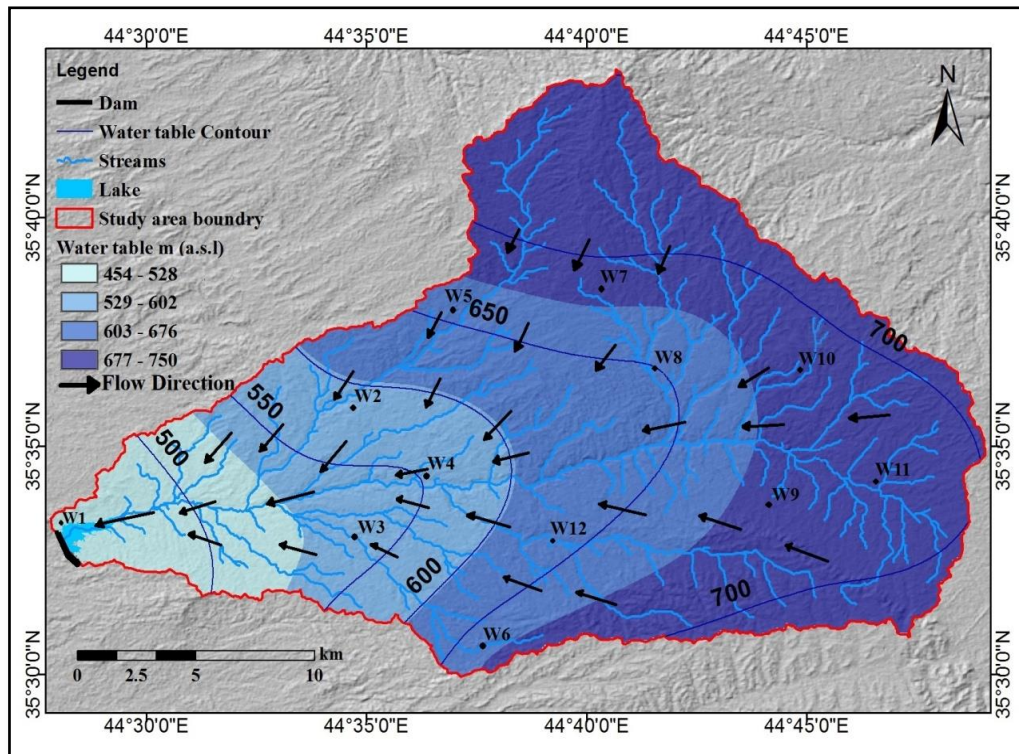

Figure 4-Profile of the W1-W7-W9-W12 wells.

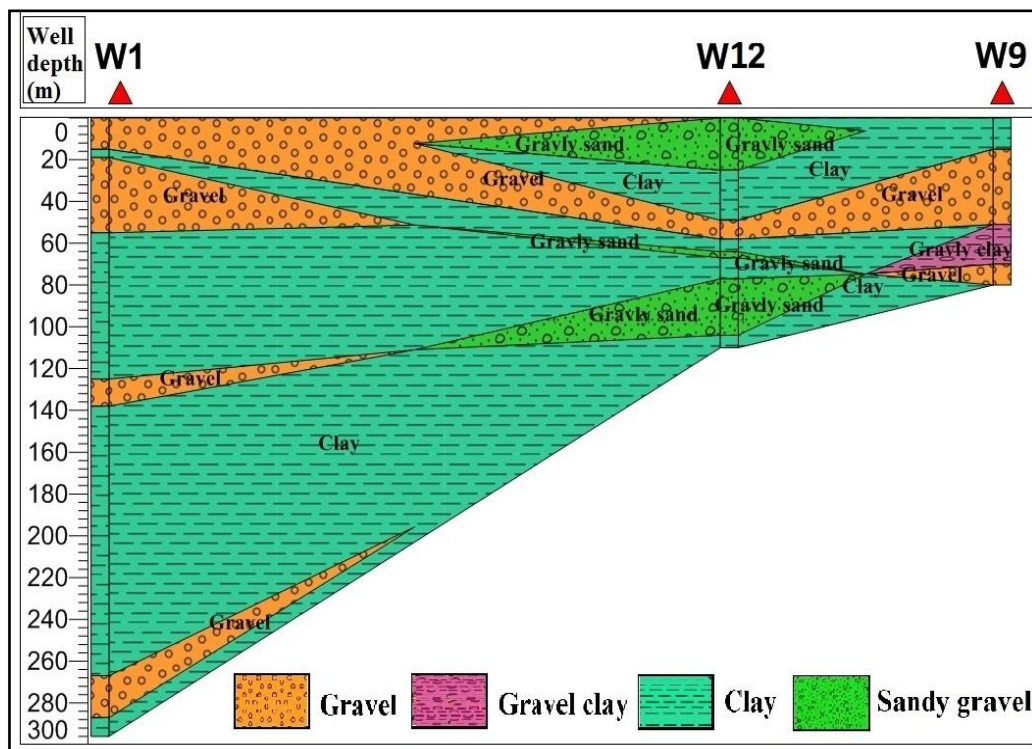**Figure 5-**Groundwater Flow net of the study area.

Figure 6-Geologic section between W1, W9 and W12 wells in the studied area.

Conclusion

The productive hydrogeological unit in the studied area is Bai-Hassan Formation semi-unconfined aquifer. The general direction of groundwater movement in the studied area (watershed) is from the recharge areas in northeast and southeast towards the discharging areas at west. Using the Cooper Jacob's, Theis and Hantuosh methods to analyze the results of the five single pumping test process, show that the hydraulic properties value in the study area was: transmissivity range from (0.98 to

19.57) m²/day and 416 m²/day in the western part of the study area, hydraulic conductivity (0.051 to 0.305) m/day and 5.012 m/day in the western part of the study area, storage coefficient value range from 0.021 to 0.065. These values indicate that the hydraulic properties of the aquifer almost similar from one point to another except for the west part (W1) in the study area, this is due to the estimate that the aquifer has a hydraulic relationship with the Al-Khassa reservoir and therefore the results of W1 well pumping were neglected during the drawing of hydraulic characteristic.

Recommendation

Insertion of well W1 within the studies of the area that comes after the study area (areas below the dam) which are reverting to the Al-Adhaim River basin, the hydraulic characteristics may change to the rest of the Al-Adhaim River basin.

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