Hydrogeological Conditions of Qazaniyah Sub-basin in Diyala / Iraq

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Abstract

The study area is located in the eastern part of the Diyala Governorate close to the Iraqi-Iranian border. This study was set to investigate the hydrogeological calculations of northeast of Qazaniyah wells where the groundwater moves in directions of from the northeastern parts towards the southwestern par, that is, the same direction of the topography and the same direction of the tendency of the layers t. The study's region is characterized by visible geological layers or those that can be penetrated to a reasonable depth by wells which are sedimentary rocks deposited in continental or semi-continental conditions in the bays. From the study of the hydraulic properties of the two hydrogeological and exemplary systems, the values of transmissivity, permeability and storage coefficient are ranged between 1.94- 5.73 m^2/day, 1.02- 3.92 m/day and 1.40 x 10^{-5}- 2.62 x 10^{-4}, respectively. While the estimated value of transmissivities, which are obtained from specific capacity, ranged between 6.27- 8.62 m^2/day. This variance in the values indicates the broad differences in the values Lithology of aquifers, which seems to be influenced by the strength and the number of fractures and joints.

Keywords: Qazaniyah aquifer, Hydrogeological investigation, flow direction.

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الظروف الهيدرولوجية لحوض قزانية في محافظة ديالى

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الخلاصة

تقع منطقة الدراسة شمال ناحية قزانية في الجزء الشرقي من محافظة ديالى بالقرب من الحدود العراقية – الايرانية. تم اجراء دراسة هيدرولوجية للابارفي شمال شرق قزانية. ان جريان المياه الجوفية هو باتجاه شمال الشرق، الشرق و الى الجنوب الغربي . تم تقييم الخصائص الهيدروليكية للابار حيث ان قيم الناقلية ، النفاذية ومعامل التخزين بين 5.73 –1.94 م ^{2} / يوم ، 3.92 –1.02 م / يوم و 2.62 –10^{-5} x 1.40 x 10^{-4} على التوالي. بينما قيم الناقلية التي خمنت من السعة النوعية بين 8.62 –6.27 م ^{2} / يوم. يشير هذا التباين سببها التغاير في صخارية الابار

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Introduction

The study area is located in the eastern part of the Diyala Governorate at the Iraqi- Iranian border by latitudes 33 ° 0 ', 0" and 33 ° 20' 0", and longitudes 45 °3'0" , 45 °24' 0" , 45°45' 0" and 46°6'0"E (Figure-1). It's about 120 km north - east of the city of Baghdad and the area of the basin about (8318) km² (Figure-1). The study area covers the Quaternary sediments, and the Tertiary sediments that appear along the edge of the Hamrin mountain range. As the

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boundaries of the Quaternary and Triple Age are characterized by the incompatible structures of the geological layers, the outcropping formations in the study area are configured from the oldest to the youngest by Mukdadyia (lower Pliocene), Bai Hassan Formation Tertiary Age Alluvial Fans Quaternary Sediments. Structurally, the study area is located within the central eastern part of the Mesopotamian plain and at the southwestern part of the feet of the mountains [1],(Figure -2).

These two regions represent the outer and middle part of the unstable range of the Nubio-Arabian Platform [1]. Since the region is part of the unstable range, it is affected by regional tectonic movements that led to the rise of the Hamrin complex located within the range of the feet of the mountains and the plain of Mesopotamia. The study area characterized by the geological formations that can be explained as follows (from older to younger) (Figure -2).

AL-Mukdadyia Formation (L.Bakhtiari) constituents make the formation a good aquifer, because of its porous nature. As for the sedimentary environment of the formation

Bai Hassan Formation(U.Bakhtiari). The total thickness of this formation reached to 300m where, it's characterized by thick layers of conglomerates inter bedded with sandstone, siltstone, and clay stone. Generally, the depositional environment of this formation is continental due erosion process[2]

Quaternary Sediments include valleys and depression fill sediments, consisting of mixture of clay, sand, silt, gravel, in addition to the calcareous soils. The thickness of the sheet run-off sediments stars from few meters, alongside the contact with alluvial fans and it may reach 14-15 m[3]

The main objective of this study is to determine the hydrogeologic characteristics of qazaniyah aquifers (quantitative evaluation) through pumping and recovery tests in four sites included wells(w4-w7-w14-w17) Figure 3**,** and determine the direction of groundwater movement, groundwater flux and groundwater flow velocity through observation and measurement of groundwater levels in (20) wells (Figure 2).

 In respect to the hydrogeology setting of the study area,

 the geological formation along with the   hydrogeological unit with permeability and porosity allow water to be moved with various wells (included w4-w7-w14-w17). The hydraulic properties for these formations are of importance for projects and groundwater conservation [4].For irrigation and agriculture, Qazaniyah depends on the use of ground water, in addition to rain water There are also seasonal springs and valleys in the study area on which the region depends for irrigation and Agriculture.

   Two aquifers (confined and unconfined) are present in the northeastern part of the study area, where they are within the formation of the Bai Hassan and the sediments of the Quaternary age. One of the most important water-bearing layers in the study area are sand, and gravels that belonging to the Bai Hassan Formation, which is thought to be 300 meters thick. These layers have a slope that may reach 20 degrees at the Iraqi-Iranian borders, and are located under the sediments of the Quaternary that follow. A confined layer with artesian pressure that may cause the groundwater to flow to the surface in some locations. In view of the discovery of this formation in the Iraqi-Iranian border areas and in the highland regions of Iran, it is expected that the layers of this formation will be recharged through the achieved water increase and the water produced from the valleys' streams [5].The thickness of the aquifer is about 25 m in the middle part of the study area. In general, the direction of groundwater movement is from the northeast to the southwest, and the groundwater recharge is from rainwater and sometimes from some valleys. The discharge area is represented by an aligned springs located east and the west of the study are and the valleys' streams Tarsag Valley, Belt Valley and Harran Valley.
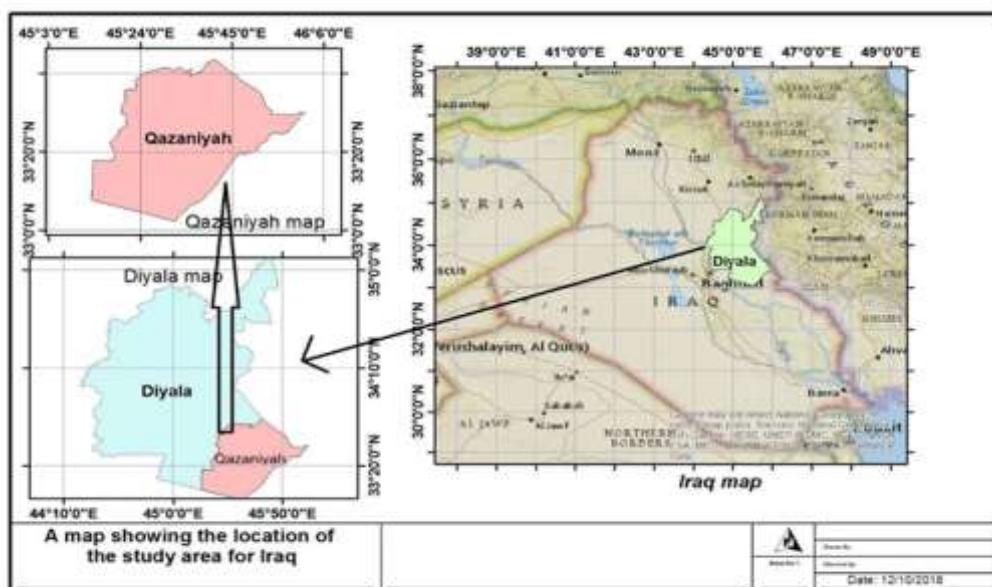
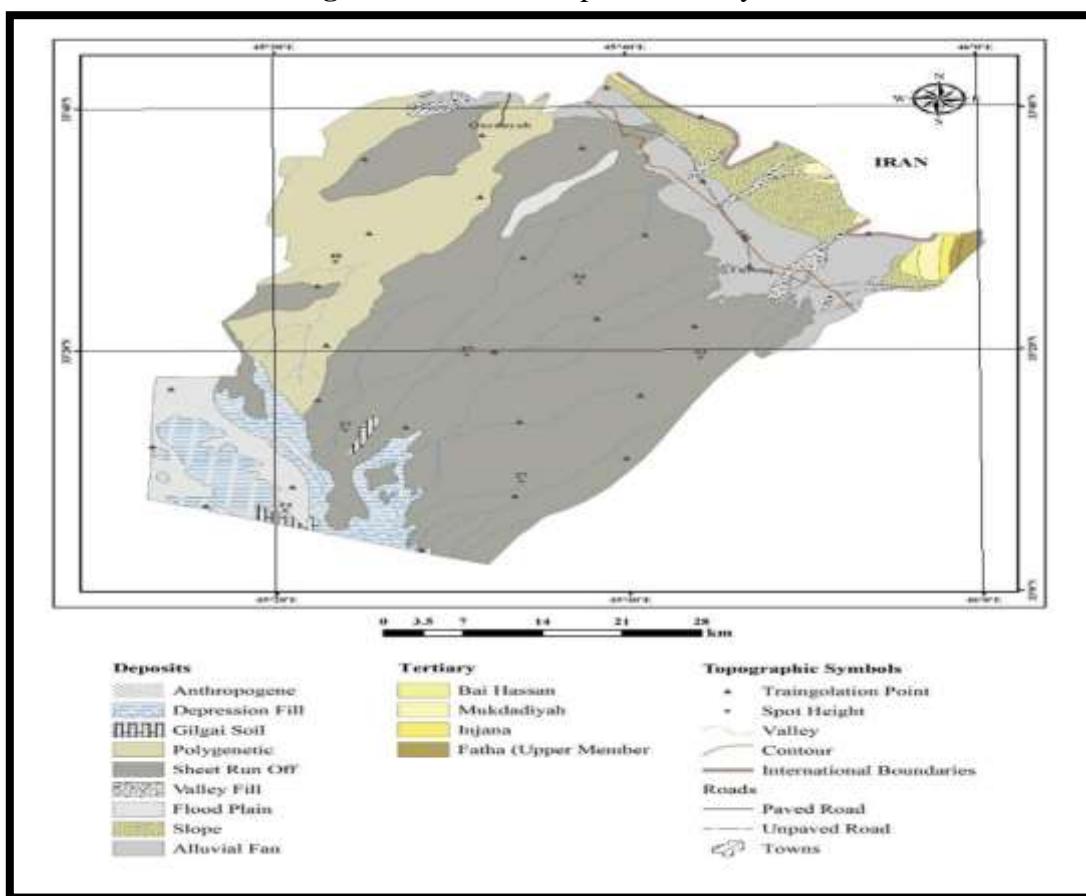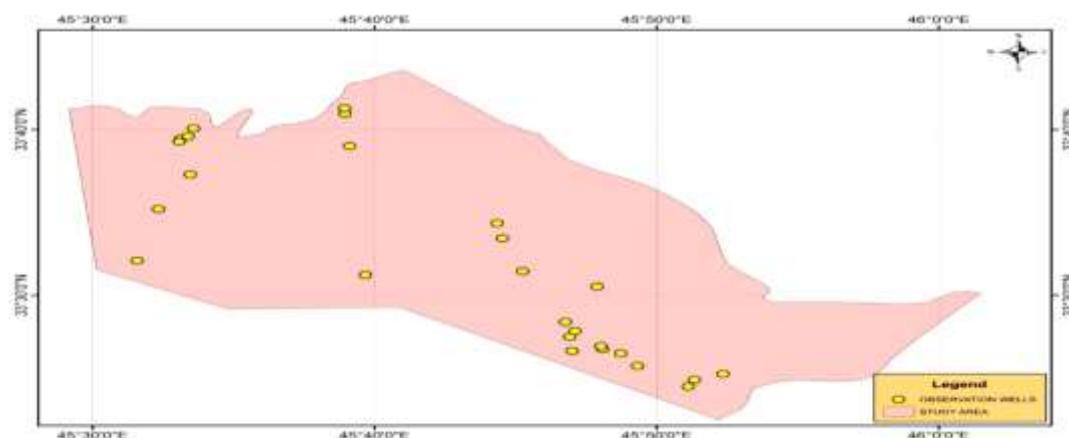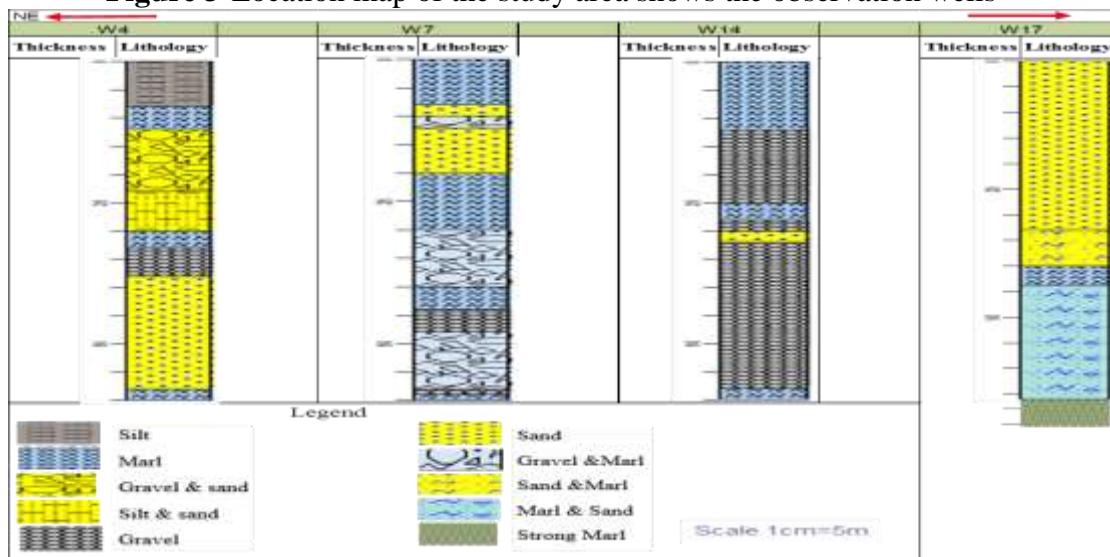**Figure 1**-Location map of the study area

Figure 2-Geological map of study area1:250.000

Figure 3-Location map of the study area shows the observation wells

Figure 4- Lithological sections of the pumping wells in study area.

Materials and Methods

The depth of the groundwater was measured by the Sounder instruments (Type 010, France) for the 20 wells selected to determine the direction of groundwater movement, groundwater flux and groundwater flow velocity, as shown in Table-1. The hydraulic parameters of the aquifer are estimated by the analysis of pumping test results carried out on the wells in three sites included wells W4, W-7 and W-14,W17) Figure 2. A computer program

(Schlumberger Aquifer Test 2011.1) is used to analyze the result of pumping and recovery
 tests to extract these parameters for Qazaniyah aquifer. This was achieved by utilizing Cooper-Jacob I [6] and Theis Recovery method [7]; Cooper-Jacob I method using the following equation:

$$T = 2.3 \, Q \, / \, 4 \, \pi \, \Delta s \tag{1}$$

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

Discharge (m³/day).

While Theis Recovery method employs the following equation:

$$T = \frac{Q}{4\pi \Delta S} \, \log(\frac{t}{t}) \tag{2}$$

Where: (T) Transmissivity (m²/day). (Q) Discharge (m³/day). (Δs') Difference in the residual drawdown, in (m) per logarithmic cycle of (t / t'), where: (t) Total time of pumping plus the recovery

time (minute). (t') Time since the cessation of pumping (Recovery time) (minute).
Equation (3), [8] utilized in estimating aquifer transmissivity from specific capacity data as follows:

$$T = \frac{Q}{SW} \frac{2.3}{4\pi} \log \frac{2.25Tt}{r^2 S} \qquad (3)$$

Where: (T): Transmissivity (m²/day). (Q/Sw): is the specific capacity of the well (m²/day/m). (t): isthe period of pumping (day). (r): is the radius of the pumping well (m). (T): is the aquifer

transmissivity (m2/day). (S): is aquifer storativity (dimensionless).
Laboutka classification was adapted to classify the investigated hydraulic [9] Table-2.

Table 1-Water table elevation above sea level for the studied wells

Well No.	Latitude	Longitude	Elevation *(m.a.sl.)	Static water level (m)	Ground water level	?
W1	33 27 28	45 46 55	81	6.30	64	60
W2	33 25 14.1	45 52 21	85	13.25	73	72
W3	33 26 44.4	45 48 04.9	86	12.72	68	60
W4	33 24 29.2	45 51 07.1	77	7.76	78	66
W5	33 40 04	45 33 35.5	63	0	67	72
W6	33 40 15	45 35 54	90	2	60	62
W7	33 26 38.1	45 47 00.1	76	7.60	57.8	61
W8	33 30 31	45 47 53	97	16	79	63
W9	33 26 28.7	45 48 43.7	89	12.5	68	67
W10	33 37 17	45 33 27.6	62	3.2	66	72
W11	33 26 55	45 48 01.5	87	14.50	79	72
W12	33 39 16	45 33 04.0	72	5.0	56	60
W13	33 31 26	45 45 115.1	84	0	55	70
W14	33 33 26.7	45 44 32.1	96	10	83	66
W15	33 25 53.4	45 51 20.1	91	14.5	67	90
W16	33 39 35.6	45 33 23.2	86	3	56	72
W17	33 34 20.5	45 44 20	101	13.5	98	60
W18	33 25 43.3	45 49 19.1	82	8.30	54	72
W19	33 27 49.7	45 47 06.4	87	14	66	66
W20	33 4057.4	45 38 57	96	6.7	65	60

Table 2- Laboutka classification of the investigated hydraulic parameters [9]

Class	Discharge m3/day	Specific capacity m3/day/m	Transmissivity m2/day	Permeability m/day
Very high	>2160	>864	>950	>864
High	432 - 2160	86.4 - 864	95 - 950	86.4 - 864
Middle	43.2 - 432	8.64 - 86.4	9.5 - 95	8.64 - 86.4
Low	<43.2	<8.64	<9.5	<8.64

Results and Discussion:

Ground water levels and flow direction

The static water levels of the investigated 20 wells were used to create a flow map for the study area. The static water level in the current study ranges between 2-16 m above sea level, as shown in Table 1. The study area has no surface water to recharge the groundwater, so the groundwater is fed by rain water. The map of the direction of groundwater flow shows that the amount of groundwater in the northeastern part increases due to the frequent rain. However, in the southwestern part of the direction map, the groundwater is low due to the lack of rain and the absence of surface water. The flow network consists of two sets of lines: The first group is called isoelectric lines that connect water points at the same height above sea level, and it was calculated by subtracting the height (measured by the global positioning system) of wells from the depth of water level (measured by sounder) in wells, and the second set is called flow lines which determine the direction of groundwater flow, Figure 4 shows

the flow direction map of study area.
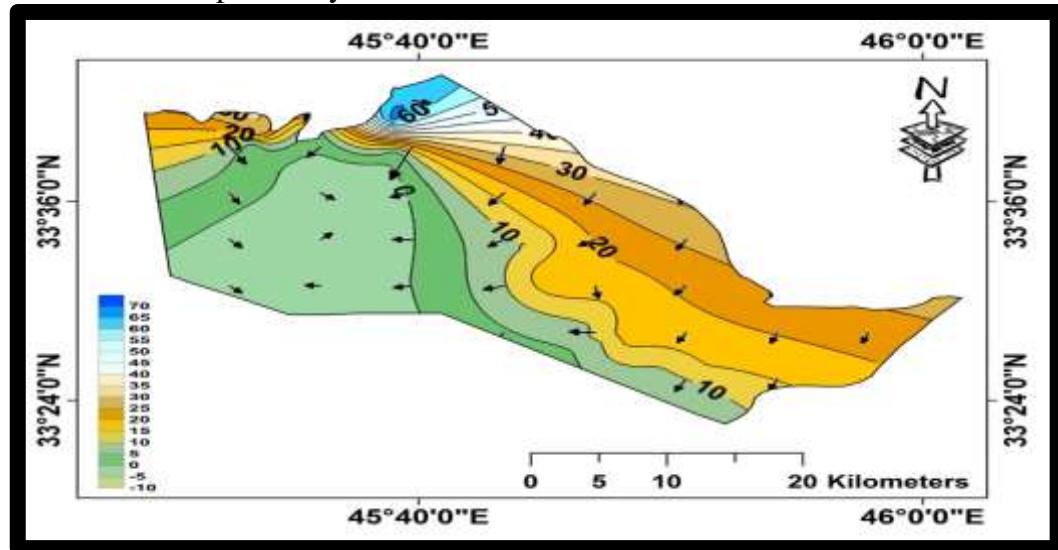
Figure 4-Groundwater flow map for studied area.

As it illustrated in Figure 4, the direction of groundwater movement of wells is from the north-east to the southwest. This is the same direction as the topography and the same direction of the stratigraphy, as the water movement descends from the high areas in the east and the northeast (the Iraqi-Iranian borders) to the southwest to the alluvial plain. The lines of equal fit were parallel, with irregular distances between them, reflecting a clear difference in the hydraulic properties, as the spacing of the lines means increasing the conductivity values and decreasing the hydraulic gradient and vice versa [9]. The flow map can be used to determine the flow paths. The hydrogeochemical changes occurring along these paths in selected area have the ability to identify the mineral transformations that could be investigated further.

Hydraulic properties and pumping test

The hydraulic properties of aquifer including hydraulic conductivity (K), Transmissivity (T), Storage coefficient (S) and Specific Capacity (Sc) were determined from aquifer pumping test data

are shown in Table 3 The analysis of curves form resulting data of the selected wells are shown in Figure 6. The values of

transmissivity (T) of aquifer ranged between 1.94 – 5.73 m2/day، with an average of 4.025 m2/ day(Table 2). While the values of the storage coefficient (S) of aquifer

ranged between 1.40x 10-5 and 2.62 x 10^{-4} . These values indicate that the aquifer is confined aquifers. The values of the hydraulic conductivity (K) of aquifer ranged between 1.02 - 3.92 m/day, with an average of 2.74 m/day, where the aquifer was classified as of low permeability depending on the suggested classification[9].

Table 3-Results of the hydraulic properties from pumping test analysis in the studied area

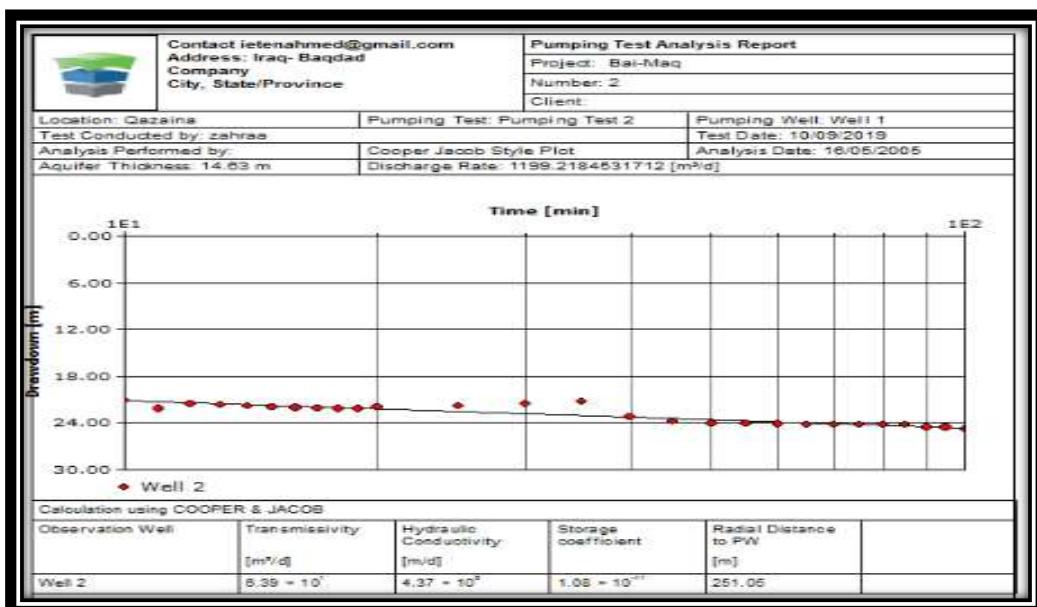| Well No.	Well depth (m	S.W.L (m)	b (m)	Q (m^3 /day)	T (m^2 /day)	K (m/day)	SC (m^2/day)	S
W4	70	6.5	15	9.54	1.94	1.02	6.27	1.40 x 10-5
W7	72	2.72	6	25.02	6.39	4.37	1.00	1.08 x 10-5
W14	75	6.35	8	10.49	2.04	2.48	7.05	2.38 x 10-5
W17	60	11.5	12	15.47	5.73	3.92	8.62	2.62 x 10-4

Figure 5-A graph dawn with time by using Cooper and Jacob ofW7
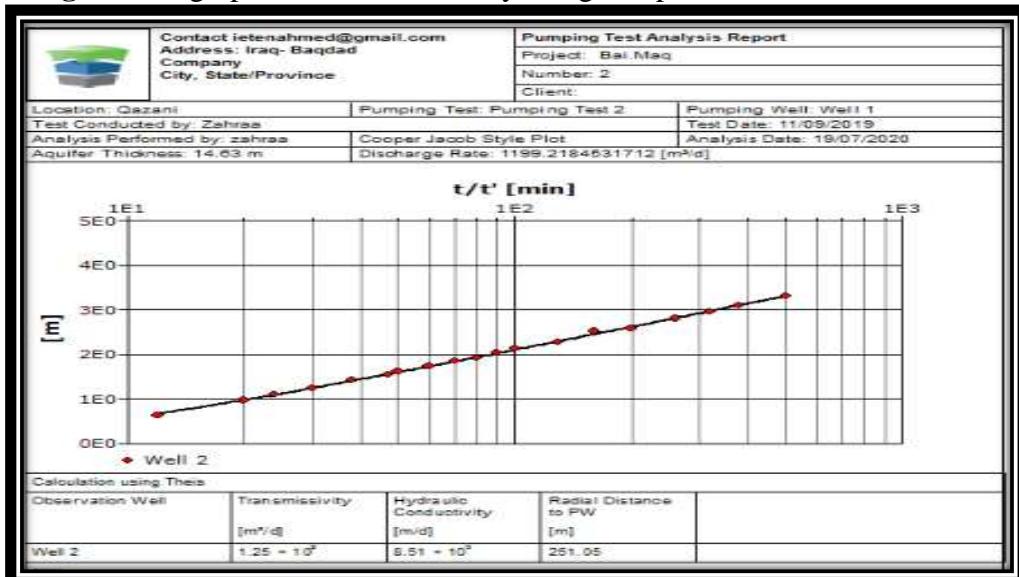

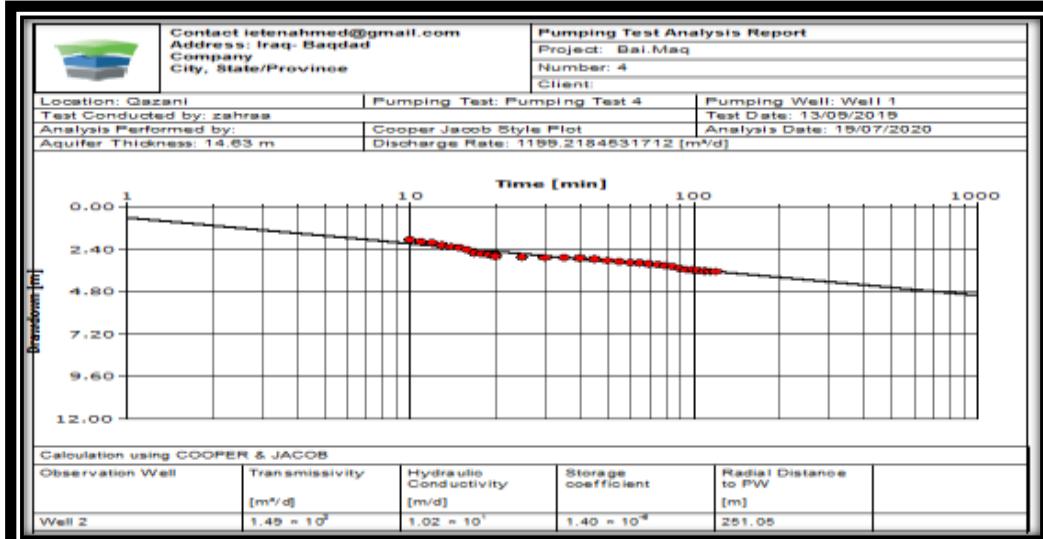**Figure 6**- A graph of recovery data analysis of Well W7 by Thies method

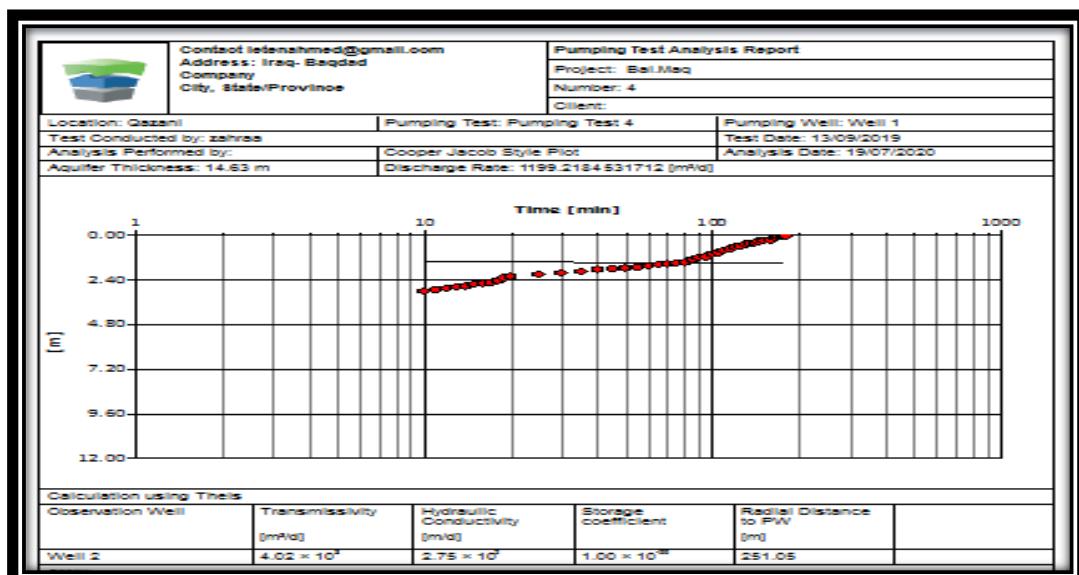**Figure 7-A** graph dawn with time by using Cooper and Jacob of W4

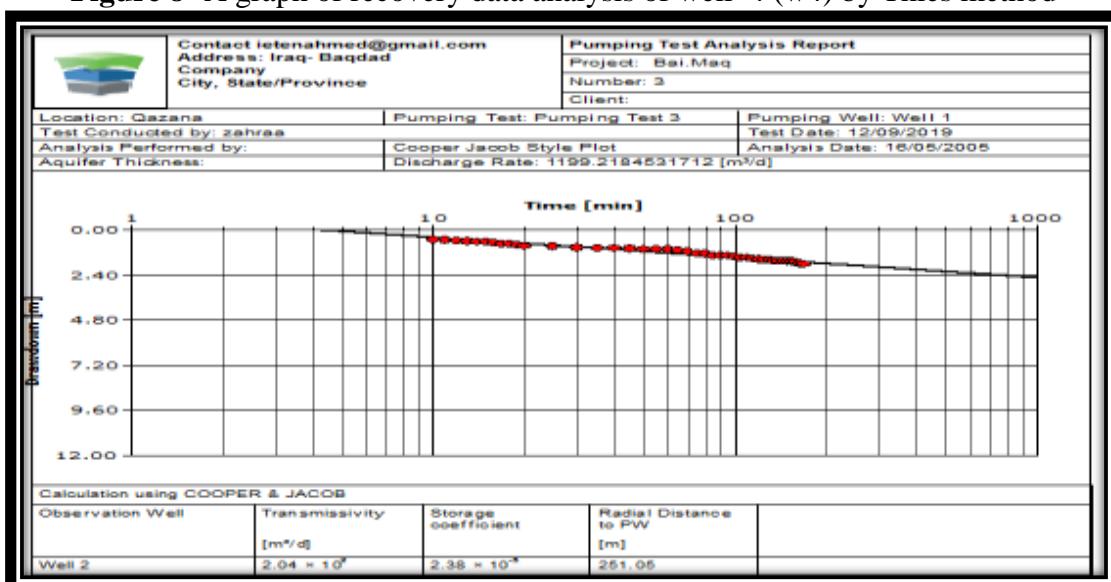**Figure 8-** A graph of recovery data analysis of well 4 (w4) by Thies method

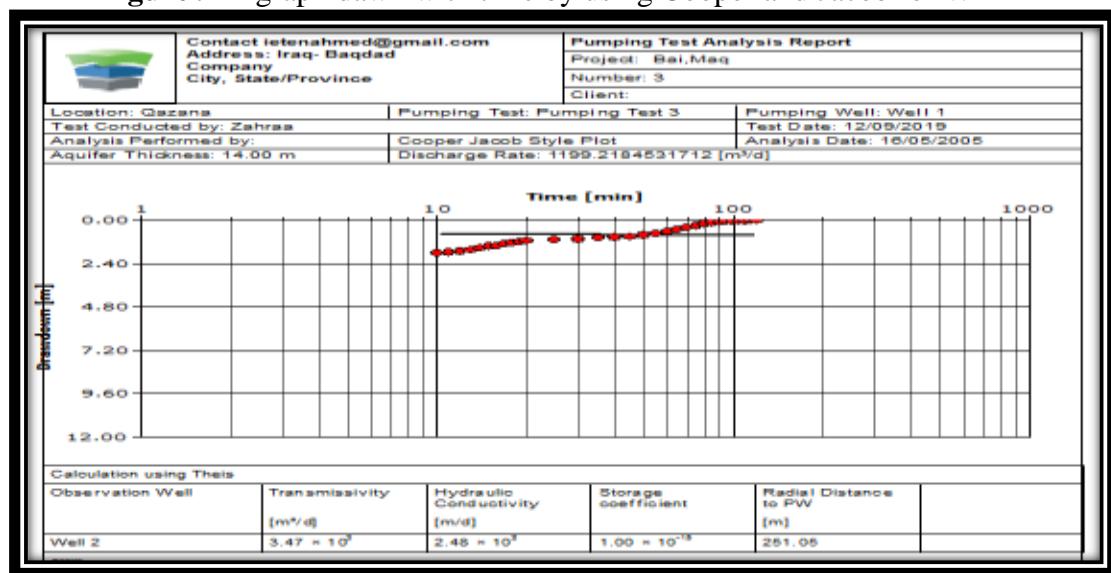**Figure 9-A** graph dawn with time by using Cooper and Jacob for W14

Figure 10-A Graph of recovery data analysis of Well w14 by Thies method
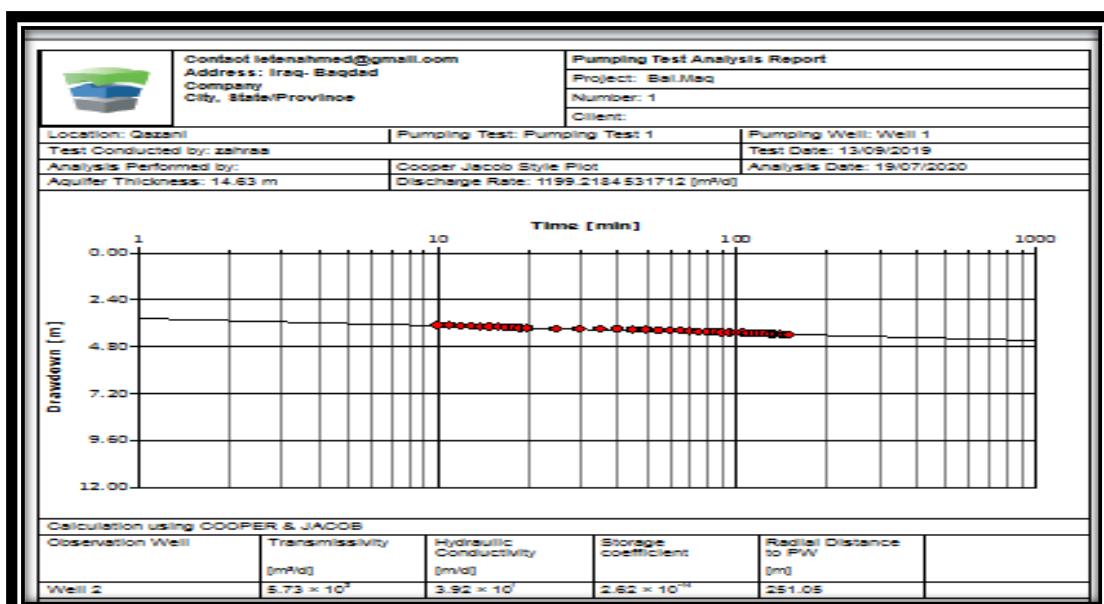
Figure 11-A Grph dawn with time by using Cooper and Jacob for well W17
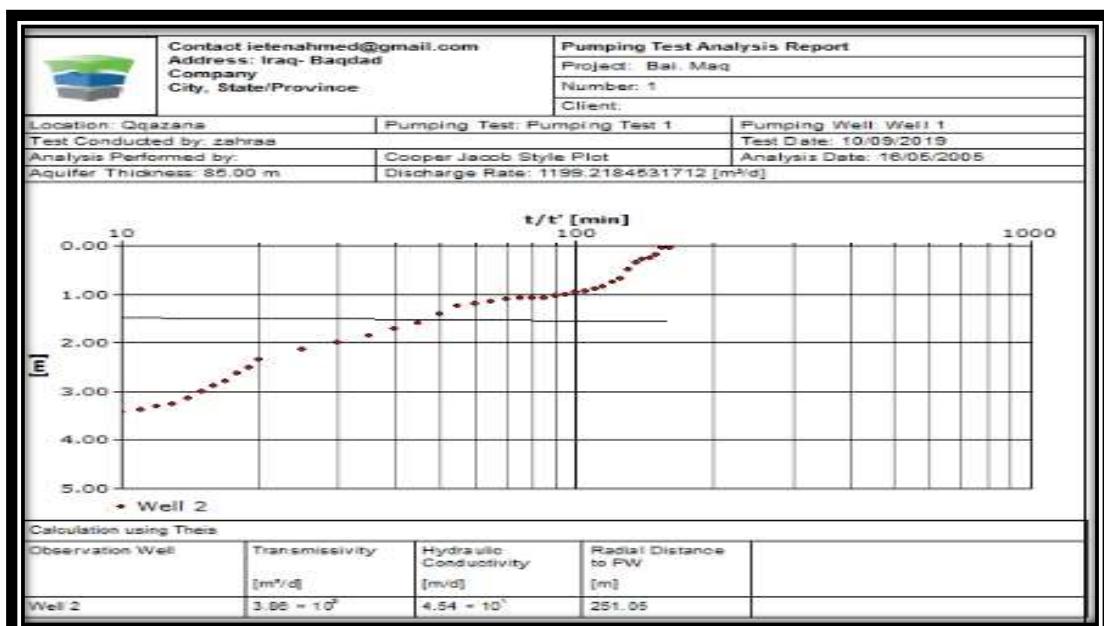

Figure 12-Graph Recovery data analysis w17 by Thies method

Estimates of aquifer transmissivity from specific capacity data

Transmissivity is one of the key parameters in groundwater studies. It is generally estimated from the pumping test. Also, it can be deduced from available specific capacity data by using empirical approaches. The use of the specific capacity of a well to estimate the transmissivity of an aquifer widespread because of the availability of specific capacity data from well drillers logs, as well as relatively high cost of these test. Many empirical relationships exist between aquifer transmissivity and specific capacity such as: [10].Equation is probably more accurate for alluvial water table aquifers or water table aquifers that have sedimentary properties similar to alluvium [11] as follows:

T= K*(Q/Sw) 0.67   (4).
T= 15.3* (Q/Sw) 0.67
Where:
K: Coefficient for common units of transmisivity and specific capacity, Table 3.
Q: Pumping rate measured (m³/day).
Sw: Drawdown (m).
The values of (T) which are obtained from SC are relatively different from the values obtained from the pumping test. This because of the aquifer test program that take into account the drawdown values, the time of pumping, static water level and pumping rates.

Table 4-Transmissivity values for pumping test wells in the study area by using two methods.

Well No.	SC (m²/day)	T= 15.3* (SC) 0.67	T (m²/day)
W4	6.27	52.34	1.94
W7	1.00	15.3	6.39
W14	7.05	56.62	2.04
W17	8.62	64.81	5.73

Generally, the present study results suggest the valuably of basic assessments in the unbiased estimation of transmissivity. However, the highly variable measurement can require several tests, including more accurate readings through pumping tests, to provide a good transmissivity estimate in order to assess aquifer hydraulics in the vicinity of the well.

Conclusions
1. The groundwater movement of the two hydrogeological systems is very similar, and their movement is distinguished from the northeast to the southwest, i.e. the same direction of the topography and the same direction of the inclination of the layers.
2. From the results of the analyzes and the volumetric data for the wells that underwent hydraulic evaluation, two hydrogeological systems were obse
First: It is represented by a free layer composed of quaternary deposits (layers of gravel, sand and a mixture of clay interactions where the higher   values of transmissivity, permeability and storage coefficient are 6.39 m²/day, 4.37 m/day and 2.62×10⁻⁵ and the lowest values for the transmissivity, permeability and storage coefficient that were 1.94 m²/day, 1.02 m/day and 1.08×10⁻⁵, respectively.
3. Value of transmissivity (T) which is obtained from the specific capacity (Sc) is relatively different from the values obtained from pumping test. Generally, specific capacity tests provide unbiased estimates of transmissivity..

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