Kirkuk University Journal /Scientific Studies (KUJSS)
Volume 14, Issue 1, March 2019, pp. (120-140)
ISSN: 1992-0849 (Print), 2616-6801 (Online)

Hydrogeological Characteristics of the Aquifer in Shwan Sub-Basin, Kirkuk Iraq

Omer S. Ibrahiem Al –Tamimi[1], Juma'a K. Mohammad Al – Shwani[2]

[1] Environmental Research unit, College of Science, University of Kirkuk, Kirkuk-Iraq.

[2] Department of Applied Geology, College of Science, Kirkuk University, Kirkuk, Iraq

[1] omeribrahiem@gmail.com, [2] jumaageology22@gmail.com

Abstract

This study includes determining the hydrogeological setting of the aquifer in the study area including groundwater measurement direction and the hydraulic characteristics of the aquifer. The study showed the existence of a shallow aquifer (unconfined) in the Quaternary deposits with presence of confined aquifer in the Bai-Hasan Formation. The construction of flow net showed that the groundwater flow is from the northeast to southwest (middle parts) of the study area and then to northwest towards the Lesser Zab River. The information of six wells three of them with observation well shows that the values of the transmissivity (T), hydraulic conductivity (K), Storage Coefficient (S) and specific capacity (SC) were ranged from (12.048 to 158.559 m^3/day/m), (0.0848 to 4.545 m/d), (2.1×10^{-4} - 4.67×10^{-3}) and (21. 6 to 166.956 m^3/d/m) respectively, where (T) and (K) calculated by using (Aquifer Win program) software that depend on the methods of Cooper-Jacob and Theis recovery for analysis these information. The saturated thickness values for each wells collected from bank information of General Commission for Groundwater Kirkuk branch is ranged between (33 – 142) m. The aim of the research is to calculate the hydraulic characteristics and the flow direction, as well as the renewable and constant storage and the distance between the drilling wells in the study area.

Keywords: Hydraulic Characteristics, Shwan sub-basin, Kirkuk, Iraq.

DOI: http://doi.org/10.32894/kujss.2019.14.1.9

Kirkuk University Journal /Scientific Studies (KUJSS)
Volume 14, Issue 1, March 2019, pp. (120-140)
ISSN: 1992-0849 (Print), 2616-6801 (Online)

الخصائص الهيدروليكية للخزان الجوفي لحوض شوان الثانوي كركوك/ شمال شرقي العراق

عمر صباح ابراهيم التميمي[1]، جمعة كريم محمد الشواني[2]
[1]وحدة البحوث البيئية، كلية العلوم، جامعة كركوك، كركوك، العراق.
[2]قسم علوم الأرض التطبيقية، كلية العلوم، جامعة كركوك، كركوك، العراق.
[1]omeribrahiem@gmail.com, [2]jumaageology22@gmail.com

الملخص

تتضمن هذه الدراسة تحديد الخصائص الهيدروجيولوجية لطبقة المياه الجوفية في منطقة الدراسة بما في ذلك رسم اتجاه الجريان للمياه الجوفية والخصائص الهيدروليكية لطبقة الحاملة. أوضحت الدراسة وجود طبقة حاملة لمياه الجوفية ضحلة غير محصورة في الرواسب الرباعية مع وجود طبقة مياه جوفية محصورة في تكوين باي حسن. وأظهرت شبكة الجريان أن أتجاه المياه الجوفية من الشمال الشرقي إلى الجنوب الغربي (الأجزاء الوسطى) من منطقة الدراسة ومن ثم إلى الشمال الغربي باتجاه نهر الزاب الصغير. وتبين المعلومات الخاصة بستة آبار ثلاثة منها بوجود آبار المراقبة أن قيم الناقلية (T) والتوصيل الهيدروليكي (K) ومعامل التخزين (S) وقابلية التخزن (SC) تراوحت من (12.048 إلى158.559 m^3/day/m)، (0.0848 إلى 4.545 m/d)، (2.1×10^{-4} - 4.67×10^{-3}) و (21. 6 إلى 166.956 m^3/day/m) على التوالي، حيث تم حساب (T) و (K) باستخدام برنامج (Aquifer Win) التي تعتمد على أساليب Cooper-Jacob and Theis recovery لتحليل هذه المعلومات. وتراوحت قيم السمك المشبع لكل مجموعة من الآبار المستحصلة من بنك المعلومات للهيأة العامة للمياه الجوفية فرع كركوك ما بين m(33–142). الهدف من البحث هو حساب الخصائص الهيدروليكية واتجاه شبكة الجريان في منطقة الدراسة وبالتالي حساب الخزين المتجدد والثابت في منطقة الدراسة وحساب المسافة المؤمنة بين حفر الآبار في منطقة الدراسة مستقبلاً لكي لا يؤثر ضخ بئر للآخر.

الكلمات الدالة: الخصائص الهيدروليكية، حوض الشوان الثانوي، كركوك، العراق.

DOI: http://doi.org/10.32894/kujss.2019.14.1.9

1. Introduction:

Iraq is a country rich in water resources due to presence of the Tigris, Euphrates, Zab, Diyala, and Aludaim Rivers. Due to the low discharge of water in these rivers from neighboring countries, it is necessary to utilize the groundwater resources as an alternative resource. Water resources are decreasing continuously due to increasing demands water for different purposes, researchers conducted hydrogeological studies and surface water reservoirs and the ways to exploit them. Groundwater is found in the rocky gaps that carry water called aquifers [1].

The geological, morphological, and climatic factors which determine Hydrogeological conditions throug knowledge of 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 [2]. The previous studies which include study area are Parsons [3], which surveyed the groundwater resources inclusively based on the hydrogeological data gathered for the Alton Kopry basin. In addition, they suggested potential use of groundwater resource for agriculture and human purposes. Al-Naqash et al.[4], estimated and developed an operational program for wells drilled during the period of 2001-2003, by the General Company for Water Well Drilling in the Kirkuk governorate.

A hydrological study of the Alton Kopry basin was conducted by Abdul Razzaq et al.[5], concluded to the existence of two hydrogeological systems, the first is confined (Bai-Hassan formation) and the second is unconfined (Quaternary). Saud and Mohammad [6], Saud [7], studied hydrogeology and hydrochemistry of Kirkuk governorate in quaternary period, which included the study area. Thus study indicates the presence of groundwater in the Bai-Hassan formations and Quaternary deposits.

The aim of the study are determines the hydraulic characteristics of the aquifer in the Shwan sub-basin area and construct the flow nets.

2. Study Area:

The study area is bounded by coordinates, latitude (35°48'50" – 35°32'31") N and longitude (44°06'50" – 44°37'37") E, it covers an area about (829 km^2), and which is located within the Kirkuk governorate in northeast of Kirkuk city and away from the city center with a distance of 20 km Fig. 1. Groundwater in Shwan sub-basin is one of the freshwater aquifers in Kirkuk and the region, which is mainly source used for the human demands, agriculture, and industry which has increased in recently. The topography of Shwan Sub-basin is characterized as a disparity terrain between the simple regressions to the semi-flat terrain. The study area elevation ranges between 200- 850m (m.s.l). The Sub-basin is a symmetrical shape surrounded by two parallel chains of mountains. The first series represent by Kany domalan which is considered a part of baba dome with a height of 450 m (m.s.l.) to the southwest of the sub-basin and the second is a series mountain (Khalkhalan Dagh) with a height of about 850 m (m.s.l) to the northeast of study area Fig. 2. Geologically, the study area covered by 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 separating with the layers of the Bai-Hassan Formation which located down it and Holocene (Recent Quaternary) deposits has little thickness and composed of silt, sand, and clay and investing the water of this layer by drilling shallow wells [4], Fig. 3. Bai- Hassan Formation is composed of boulder conglomerates inter bedded with siltstone, sandstone 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 [8], [9]. 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 [10].

Kirkuk University Journal /Scientific Studies (KUJSS)
Volume 14, Issue 1, March 2019, pp. (120-140)
ISSN: 1992-0849 (Print), 2616-6801 (Online)

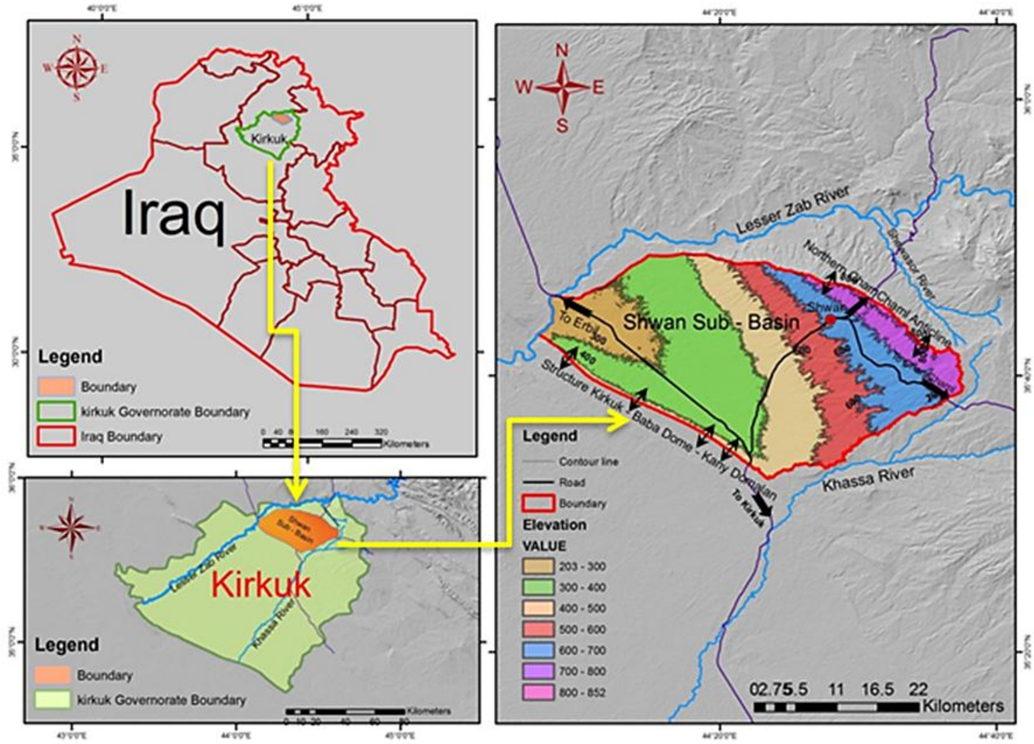


Fig. 1: Location of Study area & Location of pumping test.

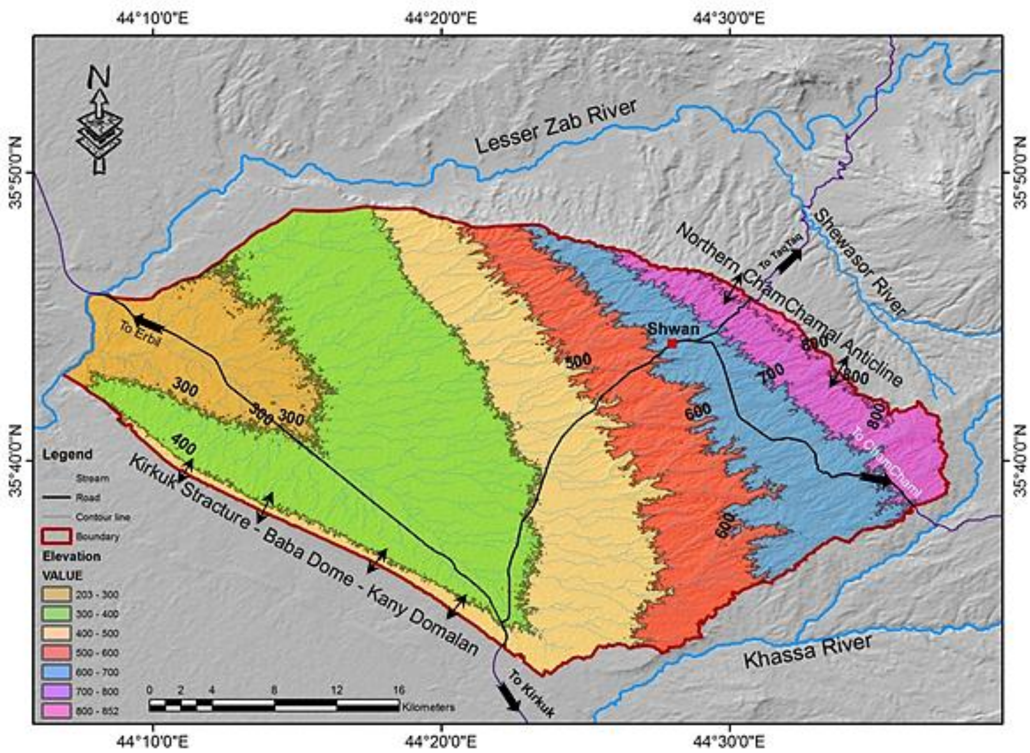


Fig. 2: Topography Map of Study Area.

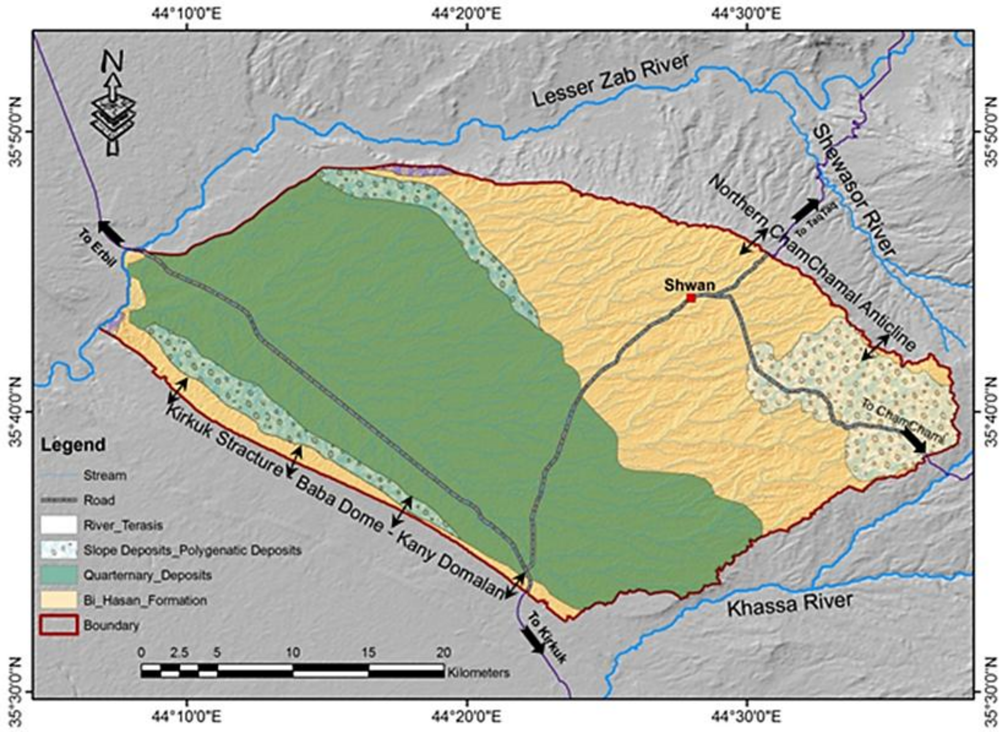


Fig. 3: Geological Map of Study Area.

3. Methodology:

Pumping test conducted for six different wells at different locations on site in the study area as shown in Fig. 1. The groundwater level was measured by sounder in the pumping well. The electric conductivity (E.C.) was measured at the started of pumping and the end of pumping, a slight difference and this indicates that the well draws water from one aquifer. The discharge was measured at the beginning of the pumping.

The water temperature were also recorded during pumping test. Observation well pumping test was carried out for (3) wells in the studied area with a constant discharge rate represented by: Well (W1) Jwa Jwa, Well (W2) Qizlqaya and Well (W3) Galozy. And single well pumping test data are available for (3) wells drilled in the study area that are obtained from General Commission for Groundwater represented by: Well (W4) Qafar, Well (W5) Biralik and Well (W6) Kalwer. Observation wells are not available in some sites in the study area, therefore these tests have been conducted without observation wells, and thus the storage coefficient is not determined.

Kirkuk University Journal /Scientific Studies (KUJSS)
Volume 14, Issue 1, March 2019, pp. (120-140)
ISSN: 1992-0849 (Print), 2616-6801 (Online)

4. Flow Nets:

Groundwater aquifers are very important in groundwater studies. They are considered to be specific factors in groundwater investment, their natural flow directions are determined, and groundwater maps are very important for any hydrological study because they are dependent on the design, flow direction and slope of groundwater flow. A study of groundwater piezometric heads in study area reveals that the direction of groundwater movements in two directions: the first is to the north-west and the second to the north-west direction. The groundwater level in recharge areas north-east of the study area was limited 741 meters msl, reaching 274 meters msl south west of the basin. The static depths were measured to the groundwater level in (12) wells in the study area by a sounder. The groundwater levels were established according to ground surface in each well, Groundwater levels ranged from 18.7 to 76.8 meters from ground surface. The geocoding events were determined using the Global Position System (GPS). The data were then transferred to the wells of the GIS program to map the contours of the aquifers. Then draw the flow lines in a vertical direction to perpendicular Equipotential Lines as shown in Fig. 4. Depth to groundwater is of great importance in hydrological studies. It reflects the nature of aquifers and varies of the area. It is a determining factor in groundwater utilization and is an important factor in the design of wells and drilling methods. Groundwater level map, reflecting the height of this depth to more than 70 meters in the north-east of the study area to reach less than 18 meters from ground surface in the south-east of the sub-basin in the study area Fig. 5.

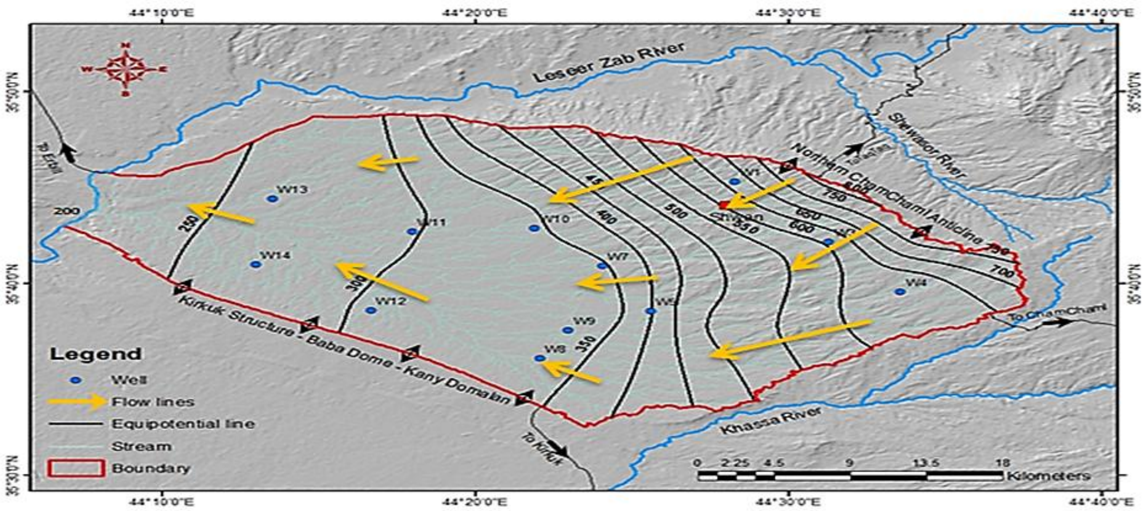


Fig. 4: Groundwater Flow Nets in study area.

Kirkuk University Journal /Scientific Studies (KUJSS)
Volume 14, Issue 1, March 2019, pp. (120-140)
ISSN: 1992-0849 (Print), 2616-6801 (Online)

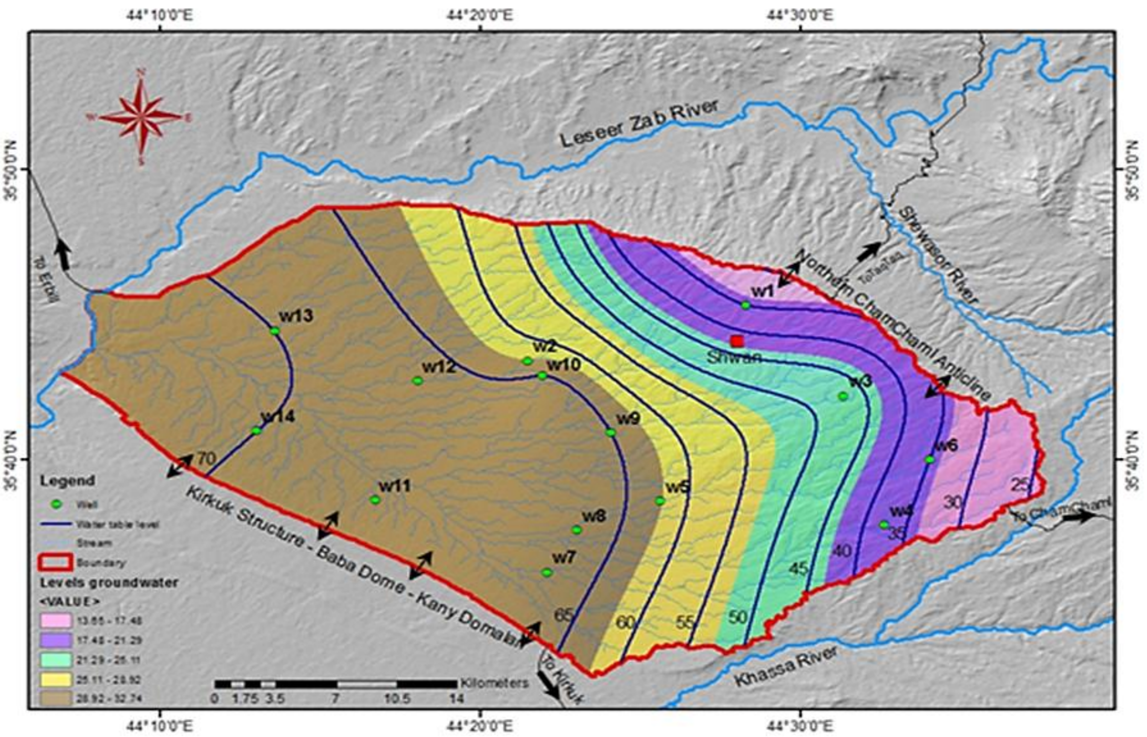


Fig. 5: Groundwater depth with respect to ground surface in the study area.

5. Hydraulic characteristics of the aquifer in the study area:

Pumping and the recovery test process were performed on six wells diffusive in the study area as illustrated in Fig. 1. The data of this process has been entered into (Aquifer Win Program) software for the purpose of analyzing these data and know hydrogeological characteristics as shown in Graphs A, B, C, D, E and F, then calculating the hydraulic properties of the aquifer in the area such as Transmissivity (T), Hydraulic conductivity (K), Storage Coefficient and Specific capacity (SC) by using Cooper and Jacob (1946) approximate draw down in non-leaky for confined aquifer equations below: [11]

$$T = 2.3Q / 4\pi\Delta s \qquad (1)$$

Where:

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

Q: Discharge (m^3/day)

$$K = T / D \qquad (2)$$

Kirkuk University Journal /Scientific Studies (KUJSS)
Volume 14, Issue 1, March 2019, pp. (120-140)
ISSN: 1992-0849 (Print), 2616-6801 (Online)

Where:

K: Hydraulic conductivity (m/day), T: Transmissivity (m^2/day),

D: Saturated thickness of the aquifer (m).

SC = Q/s (3)

Where:

SC: Specific capacity (m2/day), Q: Discharge (m^3/day), s: Total drawdown (m).

s= 2.25Tt°/ r2 (4)

Where: s: storage coefficient, T: Transmissivity (m^2 /day)

The characteristics of the pumping wells like level of static water levels, drawdowns, discharges, saturated thicknesses and depths were presented in the Table 1, where found that the values of these characteristics are range from 17.90 to 62.43 m, 0.83 to 8.80 m, 60.48 to 345.6 m^3/day, 33 to 142 m and 100 to 180 m respectively Fig. 6. The Graphs from A to F represent the relationship between the drawdown and time and also between the residual drawdown with time for each pumping well, using equation 1 - 4 and analysis of the curves A – F. The log hydraulic characteristics of the wells were determined in the study area, as shown in Table 2. The transmissivity values ranges from 12.05 to 158.56 m2/day Fig. 7 while hydraulic conductivity values ranges from 0.085 to 4.545 m/day Fig. 8 according to Cooper-Jacob [12] and Theis recovery methods [13] respectively, and specific capacity values ranges from 21.6 to 518.92 m2/day. Table 3 shows the Storage Coefficient of wells values obtained from pumping test data analysis by Jacob and Theis recovery methods. The average of Storage Coefficient values range between (2.1×10^{-4} - 4.67×10^{-2}) Fig 9 Accordingly, the type of aquifer is determined as confined to unconfined.

Generally, the recovery test data are more reliable than pumping test data because the water level rises in the well at a constant rate without pumping effects. We note that the hydraulic characteristics 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 1: Coordinates and factors of pumping wells in the study area.

Well No.	Location		Ground water level (m)	Drawdown (s) (m)	Discharge (Q) m^3/day	Saturated Thickness (D) (m)	Depth (m)
	Latitude	longitude					
W1	35° 45' 19"	44° 28' 17"	17.90	2.80	60.48	142	180
W2	35° 38' 29"	44° 25' 22"	39.4	8.80	345.6	110	120
W3	35° 43' 44"	44° 12' 40"	33.2	0.83	82.08	33	108
W4	35° 37' 49"	44° 32' 45"	24.00	3.75	345.6	80	100
W5	35° 43' 29"	44° 21' 24"	62.43	2.07	345.6	90	140
W6	35° 37' 43"	44° 18' 51"	40.15	2.37	192.0	75	132

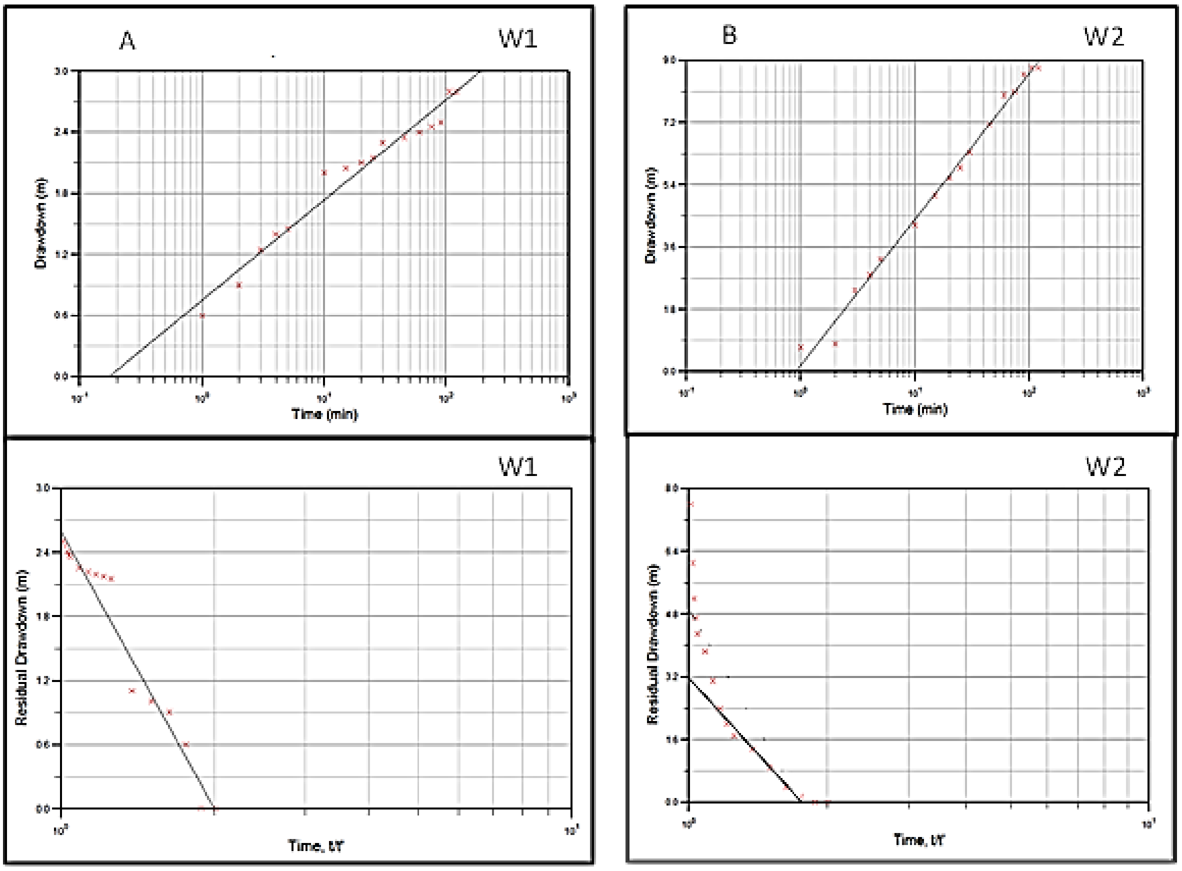
Table 2: Summary results of hydraulic characteristics in the study area.

Well No.	Jacob (Draw Dawn)		Theis (Recovery)		Average Jacob & Theis		Specific Capacity
	T m²/d	K m/d	T m²/d	K m/d	T m²/d	K m/d	SC m²/d
W1	11.28	0.079	12.82	0.09	12.05	0.085	21. 6
W2	20.01	0.166	26.06	0.25	23.04	0.209	39.27
W3	143.95	4.217	155.99	4.87	149.99	4.545	98.89
W4	70.65	1.500	76.33	2.61	73.49	2.043	92.16
W5	148.65	1. 380	168.46	2.14	158.56	1.762	166.96
W6	143.95	1.510	144.86	2.33	144.21	1.923	518.92
Ave.						1.761	

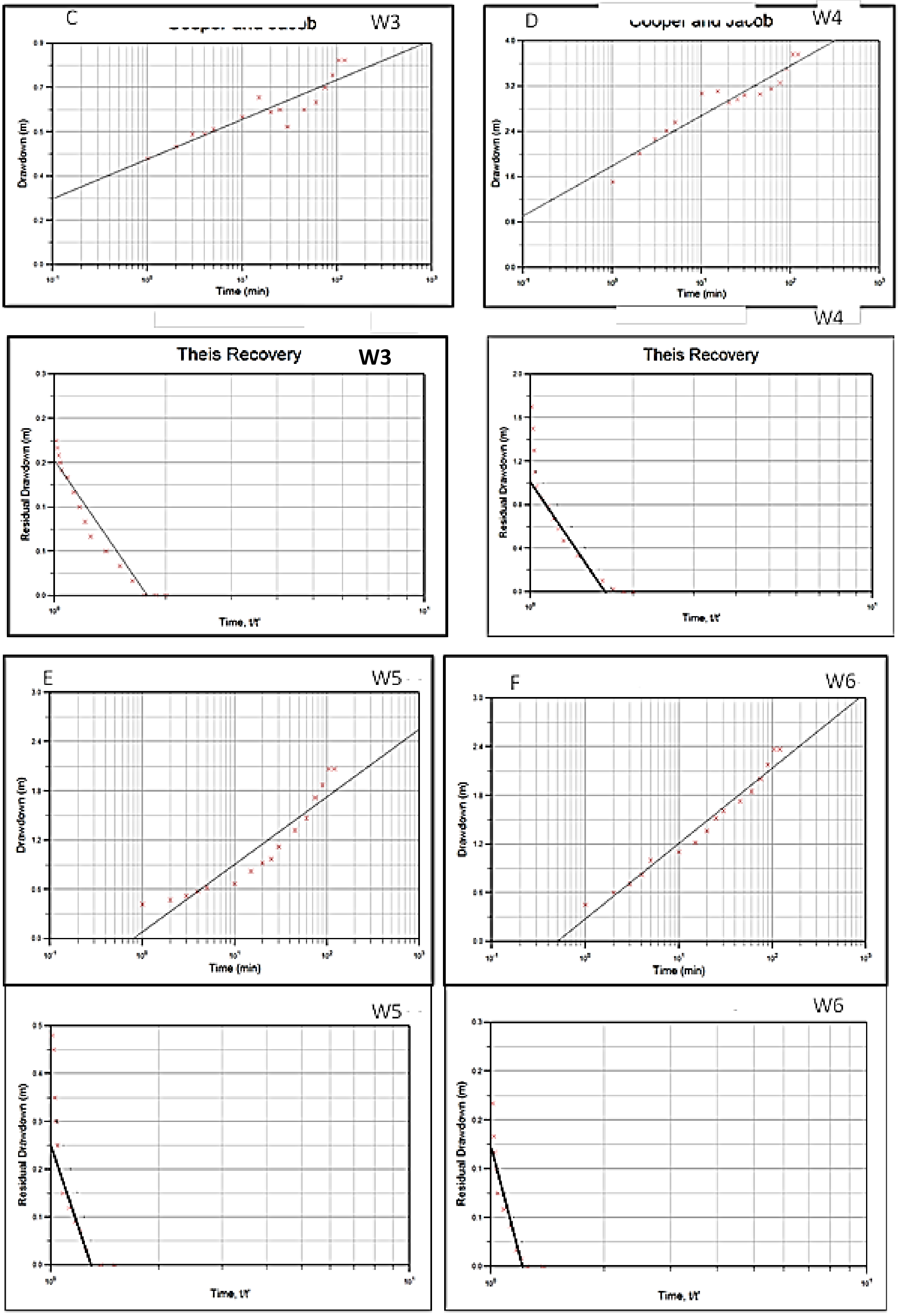
Kirkuk University Journal /Scientific Studies (KUJSS)
Volume 14, Issue 1, March 2019, pp. (120-140)
ISSN: 1992-0849 (Print), 2616-6801 (Online)

Table 3: Storage Coefficient of wells values obtained from pumping test data analysis by Jacob and Theis recovery methods.

Well No.	Jacob (Draw Dawn)	Theis (Recovery)	Average Jacob & Theis	Storage coefficient limit	Type of Aquifer
	S	S	S		
W1	2.59×10^{-4}	1.72×10^{-4}	2.10×10^{-4}	10^{-3} - 10^{-5}	Confined
W2	5.27×10^{-4}	1.21×10^{-4}	3.23×10^{-4}	10^{-3} - 10^{-5}	Confined
W3	8.14×10^{-4}	8.04×10^{-4}	8.09×10^{-4}	10^{-3} - 10^{-5}	Confined
W4	1.63×10^{-2}	7.71×10^{-2}	4.67×10^{-2}	10^{-1} - 10^{-2}	Unconfined
W5	6.03×10^{-2}	1.88×10^{-2}	3.96×10^{-2}	10^{-1} - 10^{-2}	Unconfined
W6	2.96×10^{-2}	1.97×10^{-2}	2.15×10^{-2}	10^{-1} - 10^{-2}	Unconfined



Kirkuk University Journal /Scientific Studies (KUJSS)
Volume 14, Issue 1, March 2019, pp. (120-140)
ISSN: 1992-0849 (Print), 2616-6801 (Online)



Graphs of drawdown and water level recovery with time for all wells by using Cooper and Jacob (Drawdown) and Theis (Recovery) methods (A, B, C, D, E, F).

Kirkuk University Journal /Scientific Studies (KUJSS)
Volume 14, Issue 1, March 2019, pp. (120-140)
ISSN: 1992-0849 (Print), 2616-6801 (Online)

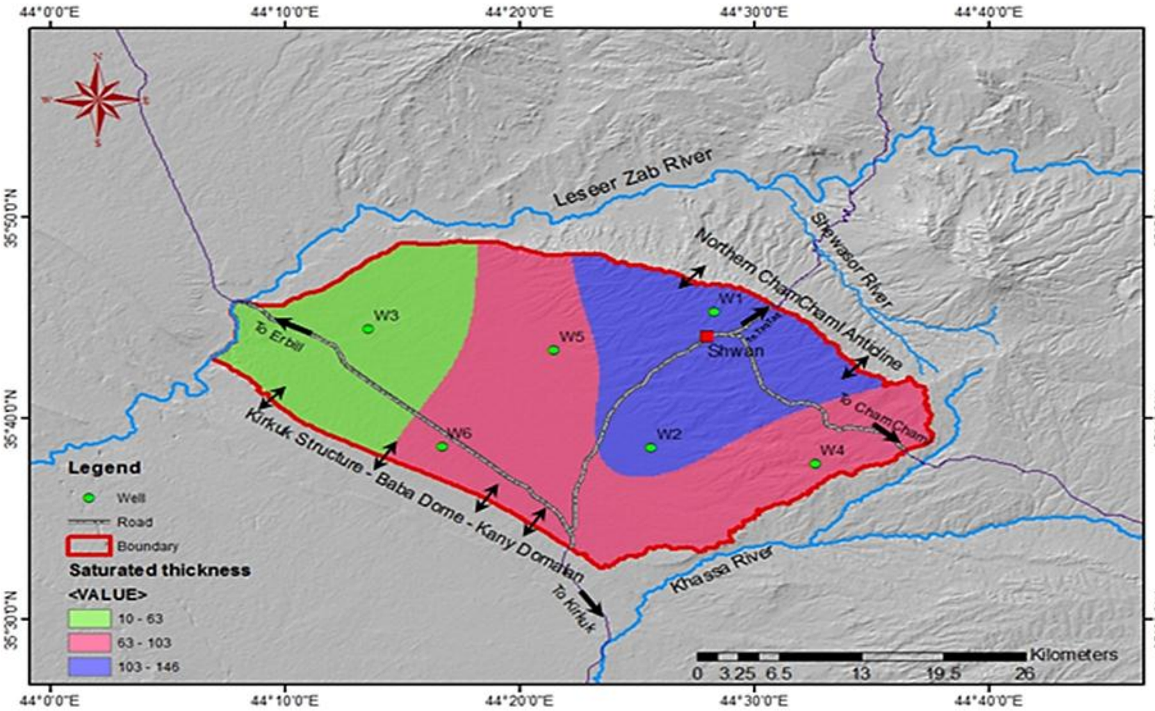


Fig. 6: Spatial distribution of saturated thickness in Study area.

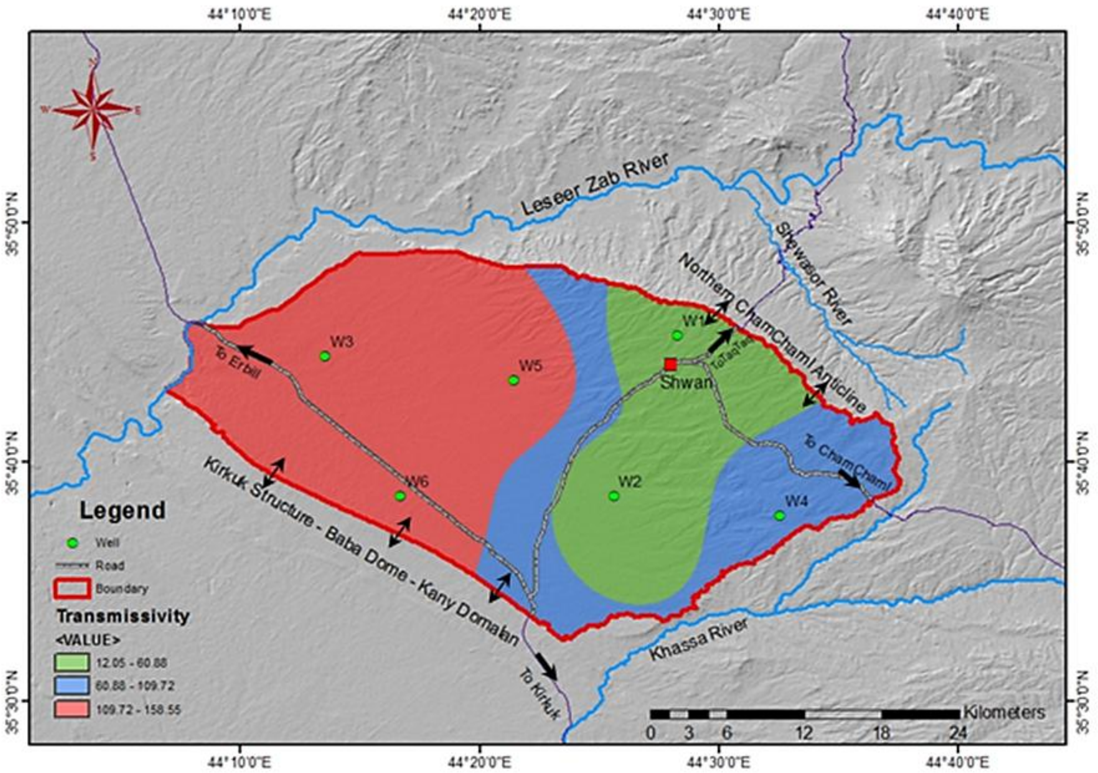


Fig. 7: Spatial distribution of Transmissivity (m^2/day) map in Study area.

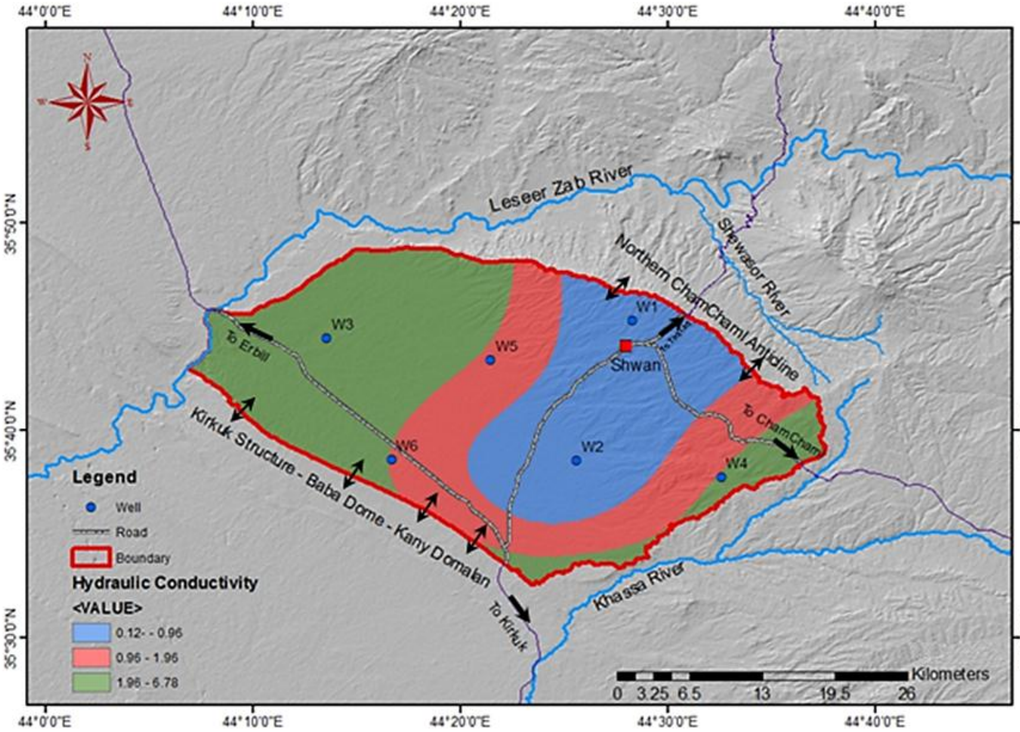


Fig. 8: Spatial distribution of Hydraulic Conductivity (m/d) in Study area.

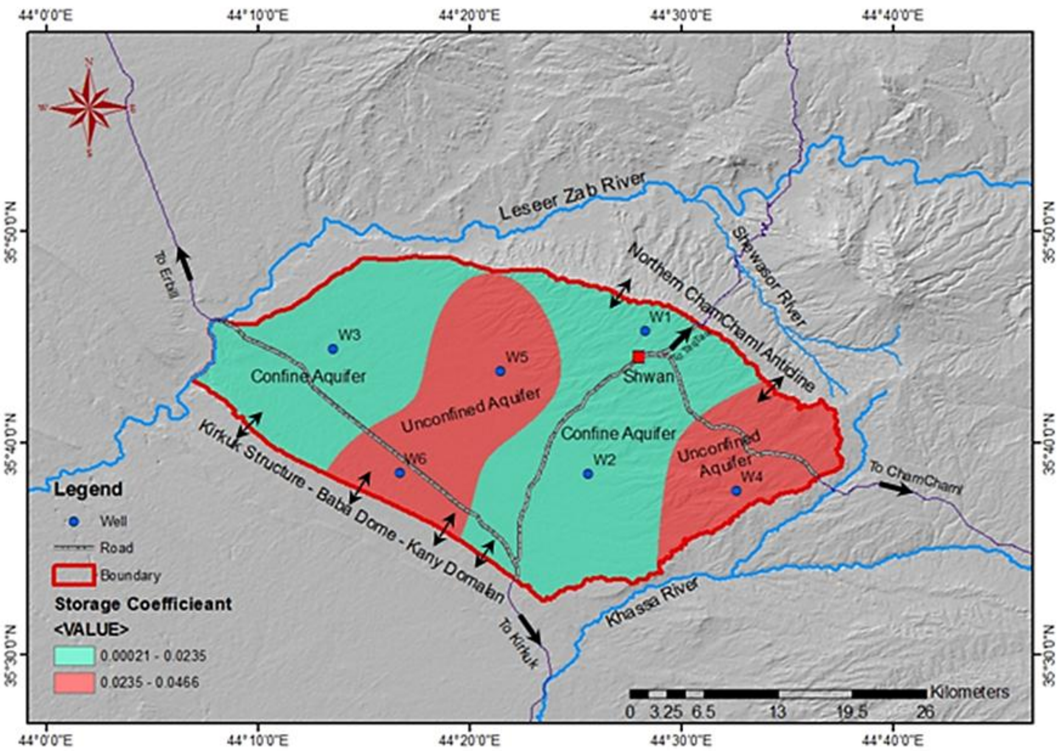


Fig. 9: Spatial distribution of Storage Coefficient in Study area.

Kirkuk University Journal /Scientific Studies (KUJSS)
Volume 14, Issue 1, March 2019, pp. (120-140)
ISSN: 1992-0849 (Print), 2616-6801 (Online)

6. Results and Calculations:

The experimental data and graphs for the six pumping tests wells in the study area and their locations are listed in Table 1. Cooper-Jacob and Theis recovery methods were used in the analysis of these data. From graphs in each pumping test it can be observed that some forms of data analysis of pumping tests by Jacob and Thies methods indicate the existence of high porous media, like (gravel) successive with the layers of clay within Bai-Hassan Formation, Quaternary Deposits. Table 2 includes the hydrogeological data of the aquifer (transmissivity, hydraulic conductivity and specific capacity). The average of transmissivity values range between (12.05 – 158.56 m^2/day) as shown in Fig. 7, and the average of hydraulic conductivity range (0.0848 - 2.043 m/day) with average 1.761 m/day as shown in Fig. 8. This reflects that the hydraulic property values of Bai- Hassan & Quaternary Deposits aquifer in study area are heterogeneous and variant, as a result of heterogeneity of Bai-Hassan and Quaternary Deposits aquifer due to variations in lithology and porosity of aquifer. Table 2 Results of hydraulic characteristics by two methods used in single and observation well pumping test analysis for wells of the study area. Table 3 shows the Storage Coefficient values which obtained from pumping test data analysis by Jacob and Theis recovery methods. The average of Storage Coefficient values range between (2.1×10^{-4} - 4.67×10^{-2}) according this values we determined the type of aquifer between (confine to unconfined). Depending on these values, the type of aquifer is determined, whether it is confined or not, and it has been shown that the sub - basin Shwan has two types of aquifer confine and unconfined Fig 9.

7. Hydraulic Gradient:

Groundwater moves from areas of high potential towards areas of low potential. The value of the hydraulic gradient of the study area is calculated according to the following equation [14]:

$$I = dh/dl \qquad (5)$$

Where: I: hydraulic gradient. dh: Head difference between two water points.

dl: Horizontal distance between the same two water points.

Kirkuk University Journal /Scientific Studies (KUJSS)
Volume 14, Issue 1, March 2019, pp. (120-140)
ISSN: 1992-0849 (Print), 2616-6801 (Online)

The value of the hydraulic gradient in the northeast , middle and southwest of the study area equal (0.031),(0.0056),(0.0049) respectively with an average of (0.0138) for all the study area.

8. Recharge and Storage of the Aquifer:

The bottom reservoir is the volume of water in the effective voids of the geological layer for the unconfined aquifer and the volume of water stored in the pores under the pressure of the artesian layers for the confined aquifer. In both cases, these reservoirs represent two quantities whose size varies from one reservoir to another. The first is a quantity with a dynamic function and time function the natural and border layer is known as renewable storage, and the second is the amount of static volume that is characteristic of the dimensions of the geological layer (its porosity and pressure) is known as constant storage [15]. The main water storage is the quaternary deposits. The geological map of the study area showed the extension of these sediments, and it was observed in the study area because it represents the main water reservoir in the basin, and the total discharge was calculated using the following equation [16]:

$$Q= TW\frac{dh}{dl} \qquad (6)$$

Were:

Q: discharge in the study area. T: Transmissivity. $\frac{dh}{dl}$: Hydraulic gradient. W: a max width of an aquifer

Q= 93.56 (m^2/d) × 0.0138 × 30750 (m) = 39702 m^3/d

Q= 14.49 MCM/year

These represent the total discharge of the study area per year, which represents surface water and groundwater. The area of open water reservoir (A) in the study area was calculated as well as the amount of water used in the aquifer as a renewable storage, which is a calculated percentage of the total rainfall.

First: calculation of renewable storage in the study area for the period (2003 - 2017): The amount of renewable groundwater in aquifers is calculated according to the following equation: [17].

Volume 14, Issue 1, March 2019, pp. (120-140)
ISSN: 1992-0849 (Print), 2616-6801 (Online)

Renewable storage (m^3 / year) = Area of recharge area (m^2) × Depth of water infiltration (m) (7)

After calculating the area of exposure of the main water reservoir of the basin in the study area, the calculations shall be as follows:

Open Reservoir (Quaternary Sediments):

Renewable storage = Area × depth of water infiltration

$= 829 \times 10^6 \times 0.069$

$= 57.20 \times 10^6\ m^3$/year.

Secondly, the constant storage (Ahmed et al., 2005)[19] mentioned a method for calculating it in a very approximate manner as follows:

For the open reservoir = the average of the saturated thickness (B)(m) × the area of its extension within the studied area (A)(m^2) × porosity affecting (ϕ)

The data of the data bank were obtained in order to obtain the saturated thickness ratio (B). The storage factor (S) was extracted from pumping test data.

Open Reservoir (Quaternary Sediments)

Constant storage = Average of Saturated thickness (B) × Area× Effect porosity (ϕ) (8)

$= 70 \times 829 \times 10^6 \times 0.018$

$= 1044.5 \times 10^6\ m^3$

It is noted from the previous calculations that the renewable storage in the unconfined aquifer $[(57.20 \times 10^6) / (1044.5 \times 10^6)] \times 100 = (5.48\%)$ of the constant storage.

9. Planning for Future Utilization of Groundwater in Study Area:

Unconfined System

Because the unconfined layer is the surface or near-surface layer covered by soil where porosity and permeability are high, the unconfined layer near the surface or surface feeds directly from rainwater, where the groundwater flows from the recharge areas towards the drainage areas. In addition, the water losses from the seasonal valleys, and losses of the system are mainly from the utilization of groundwater through the use of shallow wells, where the value of renewable storage (57.20×10^6) m^3/year taking into account the volume of water belonging to the aquifer mentioned above surplus irrigation water.

The annual recharge amount of the unconfined = (57.20×10^6) m^3/year. For the purpose of calculating the amount of water extracted from the wells withdrawal in the unconfined layer, this is as follows: [5]

Withdrawal = Number of wells × Productivity of one well (l / sec) × Run time for one day × Number of days of the year (9)

Withdrawal = 65 (well) × 8.23 (l / sec) × 10^{-3} × 8 (h) × 3600 × 365 (day)

= 5.62×10^6 m / year.

The number of wells (65) of the current utilization wells for the groundwater in the Shwan sub- basin was adopted as a data from bank information of General Commission for Groundwater Kirkuk branch. The following can be reached:

1- The system of the renewable free class, whose investment is about (57.20×10^6) m^3/year

2 - Currently invests from the unconfined (5.62×10^6) m^3/year, which is equivalent to [(5.62×10^6) / (57.20×10^6)] × 100 = (9.83%) of the estimated annual renewable resources. Therefore, the remaining annual investment of the unconfined of about 51.58×10^6 m^3/year can be planned. The nature of the investment and the conventional method of digging wells make it difficult to develop a fixed plan, but it is possible to develop general lines that define the method and the crew without specifying the location (randomly) as follows:

(57.20×10^6) m^3/year is to be carried out through drilling (680) wells, including the existing wells and the productivity of (8) liters/sec and the duration of operation equivalent to (8) hours per day and for the duration of (12) Month as follows:

Per well: (8/1000) × (3600) × (8) × (365) = 84096 m^3/year

= 57.20×10^6 (m^3/year) / 84096 (m3 / year) = 680 Total Number of wells expected to be digging.

Thus, the number of wells that can be drilled in the free layer for the purpose of investment = the number of wells calculated - the wells dug

Kirkuk University Journal /Scientific Studies (KUJSS)
Volume 14, Issue 1, March 2019, pp. (120-140)
ISSN: 1992-0849 (Print), 2616-6801 (Online)

Number of wells = 680 – 65 = 615 well

In fact, this number depends on the distances between wells. For the purpose of determining these distances, the equation for finding the effective or radius of influence radius of the well can be used as follows [5]

$$r^2 = 2.0 ((T \times t / S) \qquad (10)$$

Where: r: Effective radius. T: Transmisivity. t: Run time. S: Storage Coefficient. for that

$$r = 2.0 \times 2.0\sqrt{} (93.555 \times 8/24) / (0.018) = 2 \times 58.86 = 120 \text{ m (Diameter)}$$

That is, the distance between a well and another must be approximately 120 m

10.Conclusion:

There are two more than one direction of the groundwater movement in study area, the groundwater flow is from the northeast to southwest (middle parts) of the study area and then to northwest through the Juallac valley towards the Lesser Zab River (LZR), and the second direction from north-east of the Sub – basin to the north west. The direction of the groundwater movement is from the recharge area (northeast) to the discharge area (northwest) with the average hydraulic gradient equal to 0.0138. Using the Cooper Jacob's and Theis recovery methods to analyze the results of the pumping test process for six wells distributed in the region, show that the value of T, K, S and SC have ranged from 12.048 to 158.559 m^2/day with average 93.555 m^2/day, 0.0848 to 4.545 m/day with average 1.76 m/day, 2.35×10^{-5} to 1.258×10^{-1} and 21. 6 to 518.92 m^2/day with average 183.239 m^2/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. The total discharge was calculated in study area is Q= 14.49 MCM/year, these represent the total discharge of the study area per year, which represents groundwater. Of the storage accounts of the aquifer in the study area, and the amount of renewable water from the annual rainfall in the area that infiltrated to the groundwater was 57.20×10^6 (m^3 / year) and the constant storage was 1044.5×10^6 m^3 and the amount of water consumed in the shallow wells in the region for general purposes and irrigation was 5.62×10^6 m^3 / year and thus an additional the number of wells that can be drilled in the future in the studied area and 615 wells the distance between a well and another must be approximately 120 m.

References

[1] D. K. Todd, "***Groundwater Hydrology***", 3rd. Ed., John Wiley and Son New York, USA, (2005).

[2] S. Z. Jassim and J. C. Goff, "***Geology of Iraq***", 1st Ed., Pub. Doline (2006).

[3] R. M. Co Parsons, "***Groundwater Resources of Iraq***" Vol.4. Kirkuk Liwa. SOM Library, Baghdad (1955).

[4] A. B. Al-Naqash, S. Kh. Ismaeel, A. H. Hasan and Kh. M. Rahi,"***Evaluation study and setting of production program for wells of national campaign project for water well drilling in Kirkuk governorate***" internal report, Ministry of irrigation, General company for water well drilling, Baghdad, Iraq, 185 p, (2003).

[5] M. I. Abdul-Razaq, A. M. Ahmed, and A. Uroba,"***Hydrogeological Study for the Upper Al-Adhaim Basin***" internal report, Ministry of water resources G.D.F. Management of water resources, Groundwater Study Center (2007),.

[6] Q. J. Saud and R. A. Mohammad, "***Hydrogeological and hydrochemical study for the Kirkuk region and limited by sheet N-38-2, Scale 1: 250000***" State Company for Geological Survey and Mining, internal report no. 2986, (2007).

[7] Q. J. Saud, "***Hydrogeological and hydrochemical study of Kirkuk governorate; Northern Iraq***", Iraqi Bulletin of Geology and Mining, 5(1), 1 (2009). (In Arabic).

[8] T. Buday, "***Regional Geology of Iraq stratigraphy and paleogeography state organization of minerals***", Baghdad, Iraq, (1980).

[9] A. M. Barwary and N. A. Slewa, "***The geology of Samarra Quadrangle sheet NI- 38 - 6, scale 1:250000, GEOSURV***", Rept. No. 2227, Baghdad, Iraq, (1995).

Kirkuk University Journal /Scientific Studies (KUJSS)
Volume 14, Issue 1, March 2019, pp. (120-140)
ISSN: 1992-0849 (Print), 2616-6801 (Online)

[10] T. Buday and S.Z. Jassim**, "*The regional Geology of Iraq*"** Vol. 2, Tectonism, Magmatism and Metamorphism, 352p, (1987).

[11] G .P. Kruseman, and N.A. de Ridder,**"*Analysis and Evaluation of Test Data*"**, International Institute for Land Reclamation and Pumping Improvement, Wageningen, the Netherlands, 372p, (2000).

[12] H.H. Cooper, and C.E. Jacob, **"*Drawdown test to determine effective radius of artesian well*"** Transe. Amer., Civil Eng., Vol.1, 115 p, (1946).

[13] C.V. Theis,**"*The Lowering piezometric the surface and the rate and discharge of a well using water storage transaction*"** American Geophysical union, (1935).

[14] D. K. Todd,**"*Groundwater hydrology*"**, (3rd Ed.), Jhon Wiley and Sous, Third Reprint. Inc. India (2007).

[15] Th. A. Al - Jubouri, **"*Hydrology and geomorphology of Diyala River*"** Ph.D. Thesis submitted to the College of Science. University of Baghdad (1991).

[16] C. Ralph Heath **"*Basic Ground Water Hydrology*"** (4th Ed.), U.S. GEOLOGICAL SURVEY (USGS), USA, Dallas L. Peck, Directord (1987).

[17] Ahmed et al. **"*Hydrographic Study of Upper Diyala Basin*"** Ministry of Water Resources, Directorate General of Water Resources Management, Center for Groundwater Studies, 182p (2005).