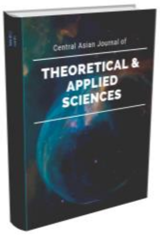

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Article

Utilization of Geographic Information Systems (GIS) to Evaluation of Hydrogeological Conditions, to the west Kirkuk secondary basin, Northern Iraq

Mohammed Abdulfattah Ali

Department of Science, College of Basic Education/ Al-Sharqat, University of Tikrit, Tikrit, Iraq

* Correspondence: mohammedjwhersaleh96@gmail.com

Abstract: The surface drainage network of the basin was derived using the (ArcGIS 10.3) software from a Digital Elevation Model (DEM) with a spatial resolution of (10x10) m per cell. The total stream order within the basin was six, with the number of streams varying across different orders. Other aspects of the hydrogeology of the West Kirkuk secondary basin were also investigated. Groundwater level contour map was developed from (23) wells data. This made it possible to map the flow net of the groundwater which demonstrated that the direction of water movement in the study area was from the northeast to the southwest. this is in line with the topographic gradients of the region in question. The hydraulic properties were also evaluated based on pumping rate data and groundwater level drawdown measurements from 8 out of the total number of wells. It was observed that the values of the transmissivity coefficient (T) ranged between (7.28- 31.47)m2/day, while the values of hydraulic conductivity (K) ranged between (0.10- 0.44) m/day.

Keywords: GIS; Hydrogeological Conditions; West Kirkuk; Transmssivity; Hydraulic Conductivity

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1. Introduction

Hence, groundwater is recognized as one of the major components of human freshwater resources in many parts of the world and particularly in the arid and semi arid regions. Water from confined aquifers has become fundamental in supplying water needs for farming, industries as well as in urban development[1], [2]. The study of groundwater flow and hydraulic properties thus becomes very important in the management of the resource [3], [4].

Geographic Information Systems (GIS) is a technique to analyse and map geographical location and distribution or any spatial data [5]. When it comes to groundwater GIS methodologies can be incorporated to determine the directions of flow of water and then map the flow field to very high accuracy [6]. They help in data gathering and modeling as well as in understanding groundwater processes and understanding the occurrences and distribution of the resource for effective planning for sustainability of the resource [7].

Groundwater directionality analysis using GIS is also done basically by assembling data from a variety of sources including topographical maps and hydrological data collected on the site. The foregoing data is then used in ArcGIS software to determine the directions and likely routes of the movement of groundwater [8],[9]. These analyses are helpful in establishing an appropriate flow network, hence, useful in formulating the right management plans concerning the groundwater management [10].

Over the years, a lot of developments have been made in GIS hence making GIS to be efficient tool in the determination of the directions of groundwater flow currently [11]. The use of these techniques assists in the determination of the flow and distribution of the groundwater hence assists in the management of the water resources to avoid wastage of these resources.

The research area is a developed agricultural land because of the access to groundwater. People also use groundwater in these areas for drinking purposes, but the number of sources is relatively limited; all of the sources analyzed for this research are situated within the hydrogeological basin that covers the Quaternary Alluvial and Bai Hassan formations that are considered to be good aquifers. These aquifers are also regarded as suitable from the point of hydrochemistry for these purposes.

2- Location of the study area

The west Kirkuk secondary basin west of Kirkuk Governorate in northern Iraq, between longitudes (43° 28' 31''E) and (43° 54' 23''E) and latitudes (35° 14' 50''N) and (35° 45' 16''N), covering an area of approximately (866) km^2. Fig (1) represents a map of Iraq showing the location of the study area.

The precise determination of the hydrogeological boundaries is one of the most important factors leading to accurate results for the hydrogeological studies of the basins, as groundwater is transient across administrative boundaries, and without this, it is not possible to predict the behavior of groundwater, its movement, and the directions of recharge and discharge [6]. Some of these boundaries are barrier boundaries, as is the case with the impermeable layers that impede the movement of groundwater in and out of the aquifer. These boundaries can also be recharge boundaries, such as rivers, seasonal valleys, lakes, and anticlinal folds, among others[12].

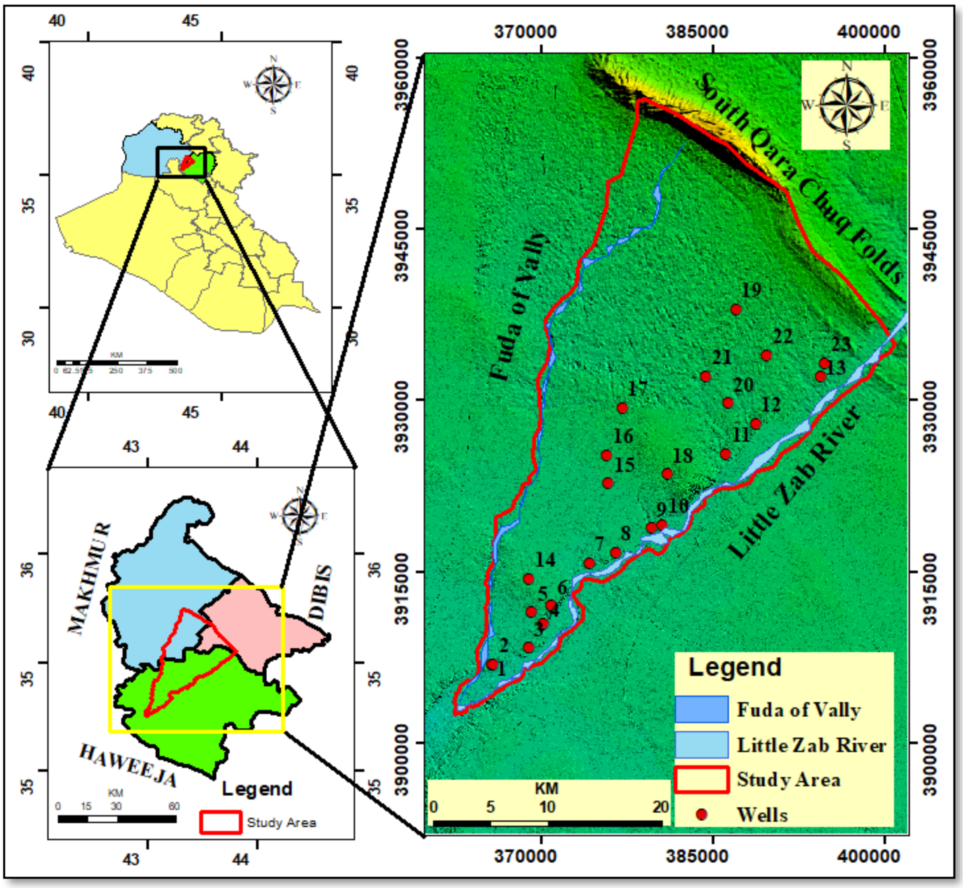

Fig. 1. Location map of the study area

The secondary west Kirkuk basin was delineated by deriving the surface drainage network based on elevation lines and water divide lines affected by it using the (ArcGIS) program. Through the surface drainage network, the basin was defined by three hydrogeological boundaries. It is bounded to the northeast by the southern Qarah Jauq Anticline, to the south and southeast by the little Zab River, and to the west and northwest by the Wadi Al-Fuda, which joins the little Zab River, as shown in Fig (2).

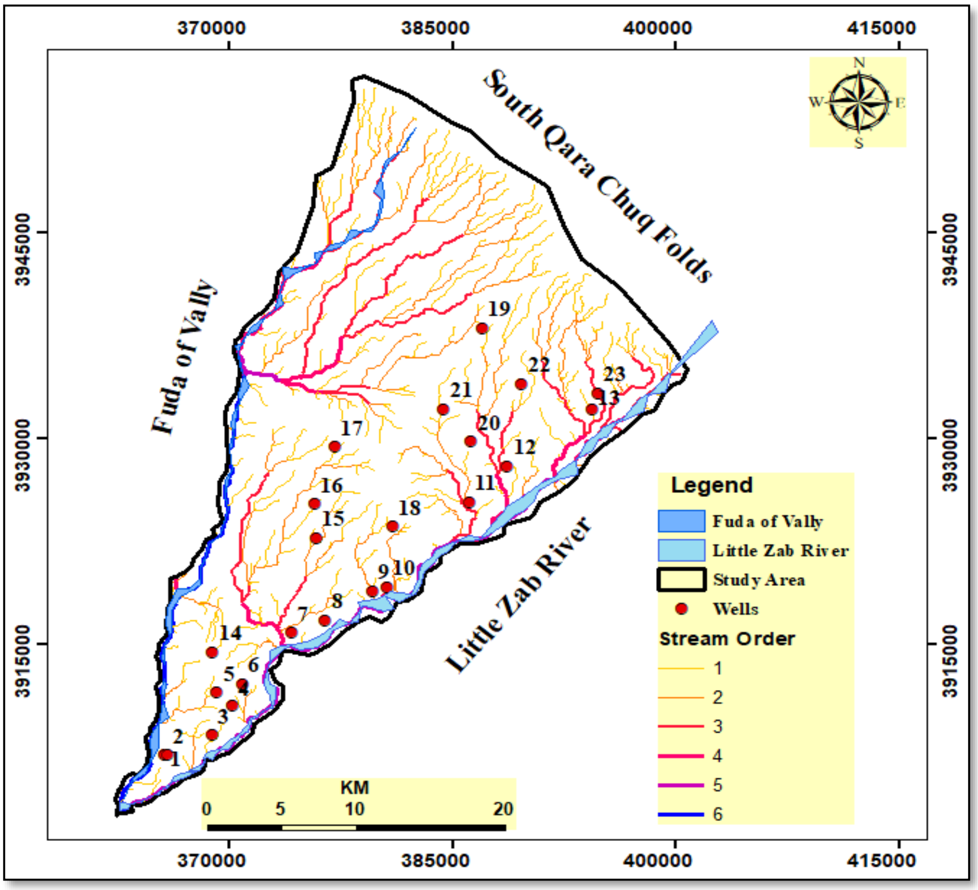

Fig 2. A map representing the surface drainage network of the west Kirkuk Secondary Basin

2. Materials and Methods

1. The geographical coordinates of the DEM cells of the study area were derived from (SRTM-DEM) data with a cells resolution of (10*10)m. The surface drainage network of the basin was generated from the digital elevation models by the use of the (Arc GIS 10. 3) program. There some six stream orders in the basin, and number of valleys differ from one order to another. The location of external limits of the basin as well as the water divide lines were also established.
2. Gathering the available data pertaining to the wells located in the study area, field surveys were undertaken in the course of which the (Groundwater depth detector) was used to determine the depth of the static water level in the wells. The easting and northing of these wells were also obtained, as well as a measurement of the depth of the ground surface above mean sea level. In all there were twenty three wells spread on the land under study. The degree of drawdown of the water table or the specific drawdown (Sw) was also recorded and was used in determining the hydraulic characteristics of the groundwater resevoirs. The draw-down, as well as the actual and static groundwater level were then analyzed using the Excel program after which the maps were made using the (Arc GIS 10. 3) program.

3. Results and Discussion

The groundwater levels are of great importance in groundwater studies, as they are determining factors in its utilization, and in identifying the direction of its movement and natural discharge [13].

Groundwater levels were measured in (23) wells in the study area, as shown in Table (1). Fig (3), plotted using the GIS program, represents the groundwater levels, which ranged between (139.97- 183.20) m above mean sea level.

It can be observed that the recharge area is located in the northeast of the study area, that is the south Qara Chuq folds, where the highest groundwater levels are recorded. The levels then decline towards the southwest of the study area, at the confluence of Wadi Al-Fuda with the little Zab River, which represents the discharge area and the lowest groundwater levels.

In order to understand the groundwater movement in the study area, an equipotential lines map was plotted, and then flow lines were drawn, which are perpendicular as much as possible to the equipotential lines. It was found that the general direction of groundwater movement is from the northeast towards the southwest of the study area, which is consistent with the topographic slope of the area [14], as shown in Fig (4).

Table (1). Groundwater levels above mean sea level in the study area wells.

B.H. No.	X	Y	Elevation (m)	Depth(m)	W.T(m)
Well-1	365583	3906907	158.99	19	139.99
Well-2	365789	3906907	158.65	18.68	139.97
Well-3	368803	3908364	166.06	25	141.06
Well-4	370160	3910487	169	25.45	143.55
Well-5	369117	3911464	170	25.95	144.05
Well-6	370830	3912083	184.7	27	157.7
Well-7	374107	3915817	168	14.38	153.62
Well-8	376413	3916711	176	19.79	156.21
Well-9	379522	3918876	177.04	17.55	159.49
Well-10	380529	3919147	173.95	15.9	158.05
Well-11	386060	3925343	190.45	25	165.45
Well-12	388603	3927980	201	31.8	169.2
Well-13	394279	3932069	194.09	19.23	174.86
Well-14	368849	3914396	184.35	23.88	160.47
Well-15	375763	3922755	185	21.66	163.34
Well-16	375660	3925231	193	22.21	170.79
Well-17	377002	3929359	195.54	24.18	171.36
Well-18	380923	3923580	215	35.23	179.77
Well-19	386908	3938028	218.2	35	183.2
Well-20	386186	3929772	189.01	20	169.01
Well-21	384329	3932145	199.24	27.9	171.34
Well-22	389591	3934003	207.61	30.09	177.52
Well-23	394648	3933281	193.48	19.03	174.45

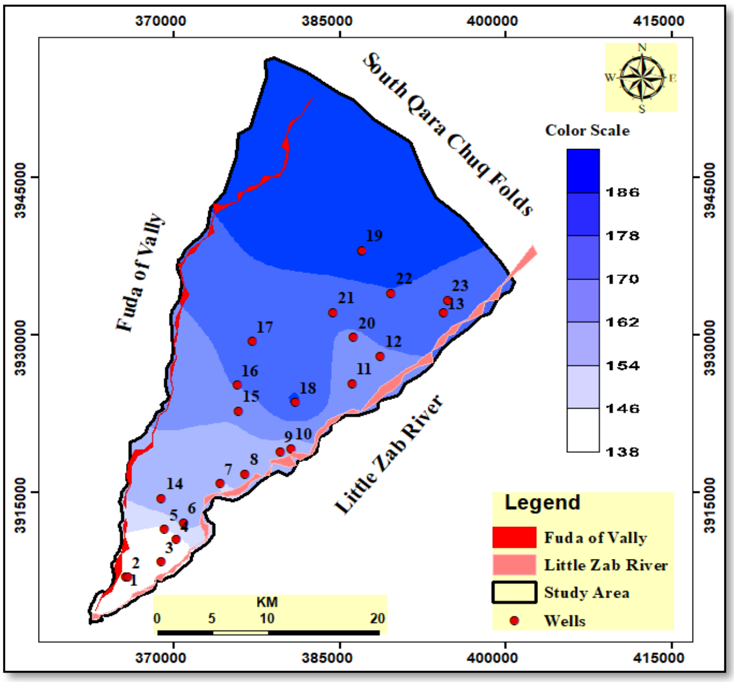

Fig. 3. Water level (a.s.l.) meter

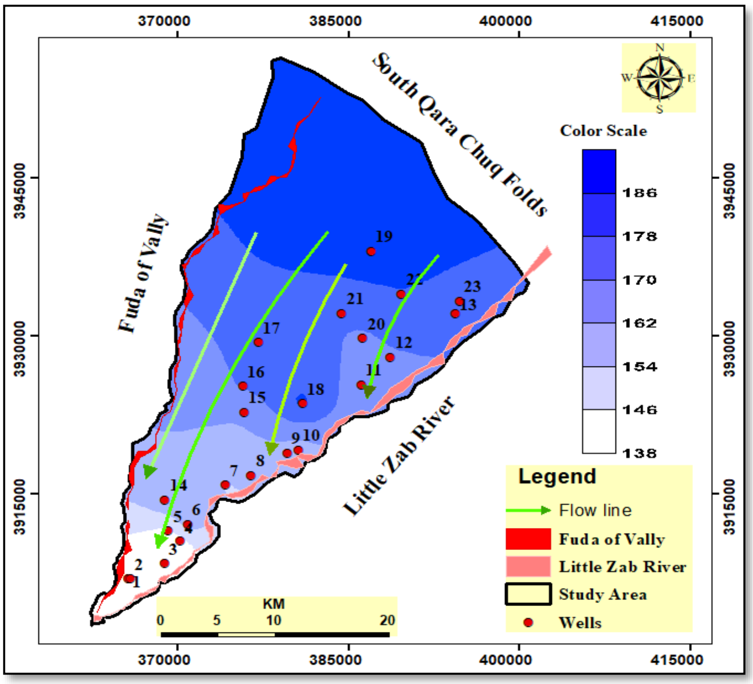

Fig. 4. Groundwater flow net of study area

The drawdown in the groundwater level (Sw) was also calculated for (8) wells. The drawdown can be calculated by subtracting the dynamic water level (D.W.L) from the static water level (S.W.L), as follows [15]:

Sw = S.W.L - D.W.L …………(1)

Also, it is necessary to mention that several factors determine the value of drawdown in the level (Sw) of groundwater: the storage coefficient, the specific yield, the specific storage, the transmissivity, hydraulic conductivity, the quality and productive capacity of the pumping equipment located in the well [16]. Fig (5) as illustrated below shows the variation in the rate of discharge of the groundwater level in the study area.

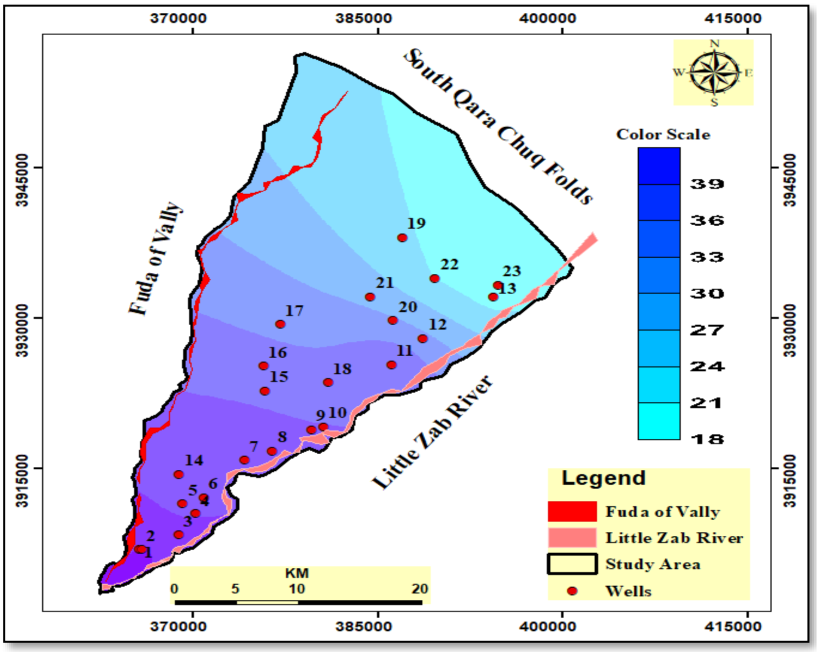

Fig. 5. A map representing the distribution of the decline in groundwater depth (Sw) in the wells of the study area

The following hydrogeological properties of the aquifer-bearing layers are important in the assessment of the hydrogeology of the area, selection of well drilling sites, methods of groundwater development, well performance, pumping crews and quality of the developed reservoirs. This assists in giving data on such other well parameters like the output or productivity of the well (Q), the drawdown level (Sw) and therefore the hydraulic features of the aquifer [7].

From the analysis of reports of the study area, it has been found that the hydrogeological basin falls within the Quaternary and the Bai Hassan aquifers. In this basin, the wells are from unconfined to confined according to the location of well and the layers which hold the water. There are several factors which lead to the confinement of an aquifer; one of them is the existence of impermeable layers on the top of the water table. But it is challenging to understand such layers since most of the drilled wells do not have lithological logs. Furthermore, since there are no wells that go down through the complete depth of the formation, it is difficult to come across the sort of saturated thickness of aquifer.

Because there was absence of observation wells within the standard distances from the pumping wells in the study area, pumping test could not be performed. In order to avoid the problem of fluctuation of the water table during the pumping test in the same well and to ascertain the hydraulic parameters (T) and (K) of the main aquifer in the studied area, Raghunath equation was employed [17]. This was done by using data on the static water level and discharge from the dynamic water level to determine the drawdown in the groundwater level (Sw) which was used to determine the transmissivity coefficient (T) using the following formula;

T = 1.2*Q/Sw ……………………. (2)

Where, Q is pumping rate (l/ Sec), Sw is the groundwater level (m) and T transmissivity coefficient is the (m^2/Sec).

The water depths in the wells ranged between (14.38- 35.28) m. The minimum decline in the groundwater level during water withdrawal was between (19.77-39.32) m meters, with a productivity of (2.5-9) l/sec. Using the equation mentioned earlier, the hydraulic properties were calculated after converting the units, as shown in the table (2). The values of transmissivity ranged between (7.28-31.47) m^2/day, as shown in Fig (6). The values of hydraulic conductivity ranged between (0.10 - 0.44) m/day, as shown in Fig (7). These figs show that the values of hydraulic properties increase towards the northeast of the study area, which is the recharge zone for the groundwater. They decrease towards the southwest, which is the discharge zone, with some limited anomalies. This variation may be due to the lateral heterogeneity of the lithology.

Table (2). It shows the hydraulic properties of some wells in the study area

B.H. No.	S.W.L.(m)	D.W.L.(m)	Sw (m)	Q (l/Sec)	Thickness (m)	T(m^2/d)	K(m/d)
Well-1	19	58	39	5	81	13.2923	0.1641
Well-2	18.68	58	39.32	4	71.32	10.5473	0.14789
Well-5	25.95	61	35.05	2.5	76.05	7.39515	0.09724
Well-7	14.38	50	35.62	2.5	70.32	7.27681	0.10348
Well-11	25	58	33	4	75	12.5673	0.16756
Well-13	19.23	39	19.77	6	70.77	31.4659	0.44462
Well-18	35.23	66	30.77	9	74.77	30.3256	0.40559
Well-22	30.09	51	20.91	4	60	19.8336	0.33056

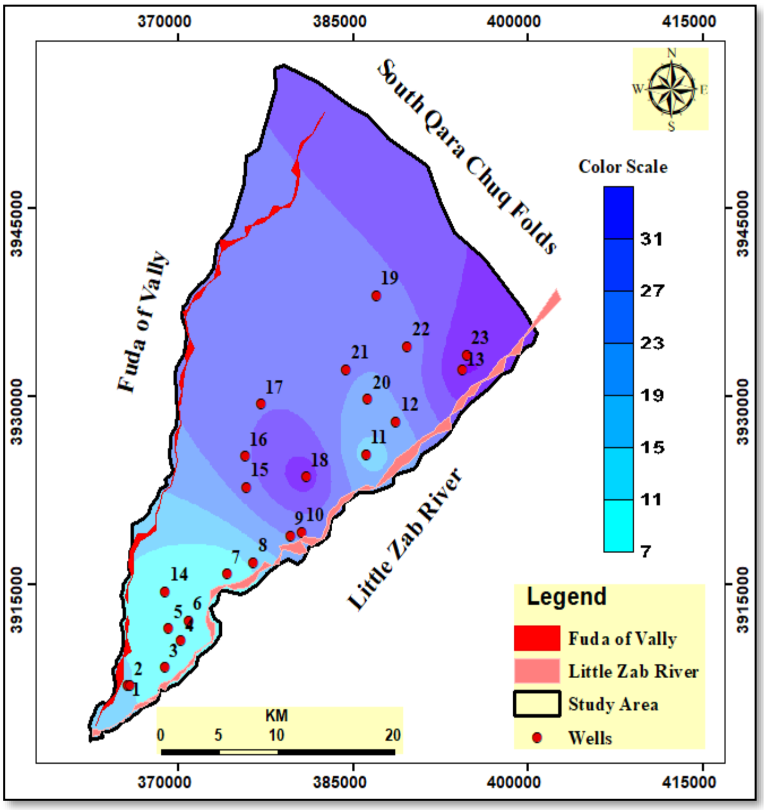

Fig. 6. A map representing the distribution of transmissivity (T)

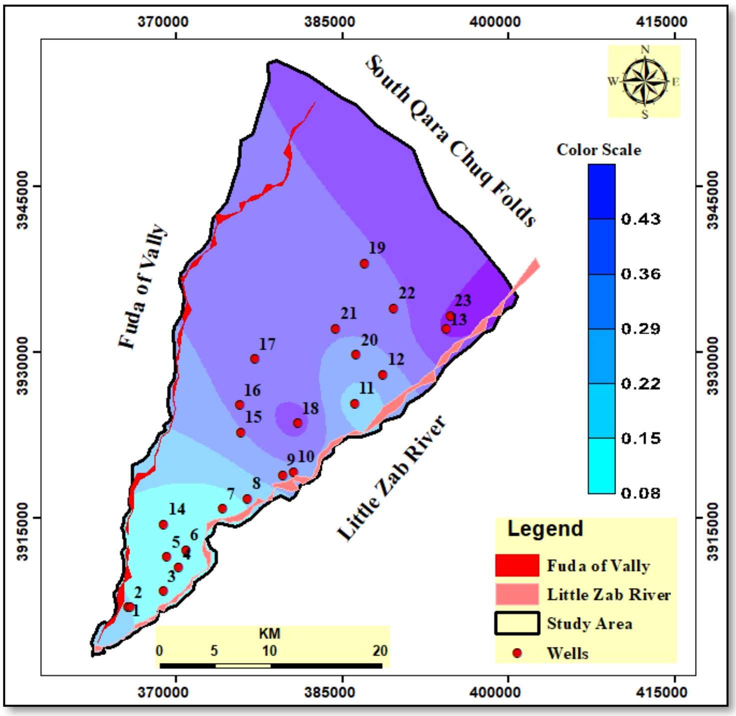

Fig. 7. A map representing the distribution of Hydraulic conductivity (K)

4. Conclusion

1. There are six orders of stream within the west Kirkuk secondary watershed, although the number of streams differs from one order to the other. The above variation of the stream orders and their numbers from one basin to the other is due to the direct ratio with the basin area; the larger the area of the basin, the more stream orders contains the basin. This in turn enhances the surface runoff process of the West Kirkuk Secondary Watershed as the surface runoff process is affected by the surface drainage density which has been enhanced by the enhancement of the draining channels.
2. The general direction of groundwater movement is in accordance with the topography of the area, as the direction of groundwater movement is from the northeast (recharge area) towards the southwest (discharge area), towards the confluence of Wadi Al-Fuda with the Little Zab River.
3. The highest values of the rates Sw are found in the discharge areas of the basin and decrease towards the recharge area. This could be as a result of the high pumping, you have a number of wells in that area and this has greatly enhanced the discharge and therefore reduced the depth to water because of depletion. Furthermore, the water abstracted from the groundwater reservoirs in those areas present sequences of clay deposits which in a way that decreases the permeability of the aquifers and in doing so, decreases the rate of replenishment of the wells.
4. The results of the calculations of the hydraulic properties values showed that the transmissivity (T) and hydraulic conductivity (K) rates are high in the recharge areas and decrease towards the discharge area. This variation in the values of the hydraulic properties may be due to the lateral change in the lithology and the difference in depths between the wells

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