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Hydraulic Characteristics of Groundwater of Khanaqin Sub-Basin, Diyala Governorate, Northeast of Iraq

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ABSTRACT

This study deals with the spatial distribution of hydrogeological and hydraulic characteristics of the groundwater in Khanaqin sub-basin. The study area is located between (45.00- 45.69) east (34.00 - 34.95) north. The raw data are taken from the hydrogeological technical report of the General Groundwater Authority. The study shows that the depths to groundwater vary as a result of the topographic variation and the lithological characteristics of the aquifer. Consequently, the depths range from (4 to 40) m. The groundwater levels vary between (45 and 564) m. The study shows that the groundwater flow trends are generally northeast to southwest on both banks of the Diyala River, which recharged from groundwater based on data from equipotential lines. The difference in depths and levels is reflected in the other hydraulic properties, as the values of transmissivity (T) range (from 40 to 549) m^2/day, and hydraulic conductivity (K) that also affected by the variation of the lithology and groundwater aquifer thickness from one place to another; they are elevated in northeast to southwest in the form of a strip parallel to Diyala River and range (from 1 to 25) m/day, and the pumping rate is also different, as its values range (between 59.27 to 4492) m^3/day. Therefore, the variation in the drawdown may be due to natural characteristics resulting from the lithology of the groundwater aquifers or due to the neglecting of the basic criteria in determining the suitable pumping equipment, as the values of the drawdown are (between 0.11 and 61) m.

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الخصائص الهايدروليكية للخزانات الجوفية لحوض خانقين الثانوي، ديالى، شمال شرقي العراق

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الملخص

تناولت هذه الدراسة التوزيع المكاني للخصائص الهيدروجيولوجية والهيدروليكية للمياه الجوفية في حوض خانقين الثانوي. تقع منطقة الدراسة بين (45.000 -45.69) شرقاً (34.00 -34.95) شمالاً. البيانات الأولية مأخوذة من التقرير الفني الهايدروجيولوجي للهيئة العامة للمياه الجوفية. أوضحت الدراسة أن أعماق المياه الجوفية اختلفت نتيجة التباين الطبوغرافي والخصائص الصخرية للخزان الجوفي، حيث تراوحت الأعماق من (4 إلى 40) متراً. تفاوتت مستويات المياه الجوفية مابين (45 إلى 564) متراً. وأظهرت الدراسة أن اتجاهات تدفق المياه الجوفية تكون بشكل عام من الشمال الشرقي إلى الجنوب الغربي على ضفتي نهر ديالى، والتي يتم إعادة شحنها من المياه الجوفية بناءً على بيانات من خطوط متساوية الجهد. انعكس الاختلاف في الأعماق والمستويات على الخصائص الهيدروليكية الأخرى، حيث تراوحت قيم النفاذية (T) (من 40 إلى 549) متراً مربعاً / يوم، كما تأثرت التوصيلية الهيدروليكية (K) باختلاف الطبقات الصخرية وسمك الخزان الجوفي من مكان إلى آخر، تم رفعها من الشمال الشرقي إلى الجنوب الغربي على شكل شريط موازٍ لنهر ديالى وتراوحت (من 1 إلى 25) متراً/ يوم، وكان معدل الضخ مختلفًا أيضًا، حيث تراوحت قيمها (مابين 59.27 إلى 4492) متراً مكعباً/ يوم. لذلك، قد يكون الاختلاف في الانخفاض بسبب الخصائص الطبيعية الناتجة عن الصخور لخزانات المياه الجوفية أو بسبب إهمال المعايير الأساسية في تحديد معدات الضخ المناسبة حيث كانت قيم التراجع (بين 0.11 إلى 61) متراً.

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Introduction

Groundwater has an important role in the development and investment of any civilian and residential area, where the development of population activities leads to the expansion of water use (Shivanna and Mustafa, 2015). It is one of the most valuable natural resources for nations, and it is the source of about 40 percent of the water used in the world for all purposes except for hydropower generation and electric power plant cooling. Groundwater is one of the main sources of water that meets agricultural, industrial and household requirements (Heath, 1983), in addition to that the groundwater has become a primary and important resource in many areas of the world, so it is significant to study its quality and quantity to identify its suitability for drinking, irrigation, industrial and other usages (Scanlon et al., 2006). The study area is located in Diyala Governorate, northeastern Iraq.

Geologically, Bai Hassan and Mukdadiyah formations are the top two main aquifers in the study area, while Quaternary deposits form a shallow unconfined aquifer above them in some parts of the study areas when the thickness of these deposits is suitable for water storage. There are several studies have been done to evaluate morphometric properties and the accessibility of groundwater in Diyala Governorate for domestic and agricultural uses (Hassan, 2007; Hassan et al., 2014; Jaluet and Majeed, 2015; Nada et al., 2010; Ramadhan et al., 2017; Al-Hathal and Iman, 2022; Salman, 2014; Al-Sudani, 2018; Al-Sudani et al., 2018; Barwary and Said, 1992). The majority of the groundwater pumping wells in this region is unsuitable for drinking due to extremely high concentrations of TDS, SO4, Mg, Ca, and Na concentrations (Aljibory, 2006).

Aim of study

This study aims to assess the hydrogeological conditions of the Khanaqin sub-basin, identify the variation of hydraulic properties of groundwater aquifers, consisting of transmissivity and hydraulic conductivity and determine the real drawdown due to pumping.

The Study Area Description

The study area is located between the coordinates (45.00- 45.69) east (34.000 - 34.95) north. The area is tectonically a part of the unstable shelf of Iraq, as it is within the alluvial plain range, low folded zone and high folded zone. Within the study area, there are groups of major towns and villages such as Khanaqin, Maidan, Jalawla, Kalar and Sa'adia. Diyala River passes the study area from the northeast towards the southwest, and part of the Hamrin dam reservoir is located within the area (Fig. 1).

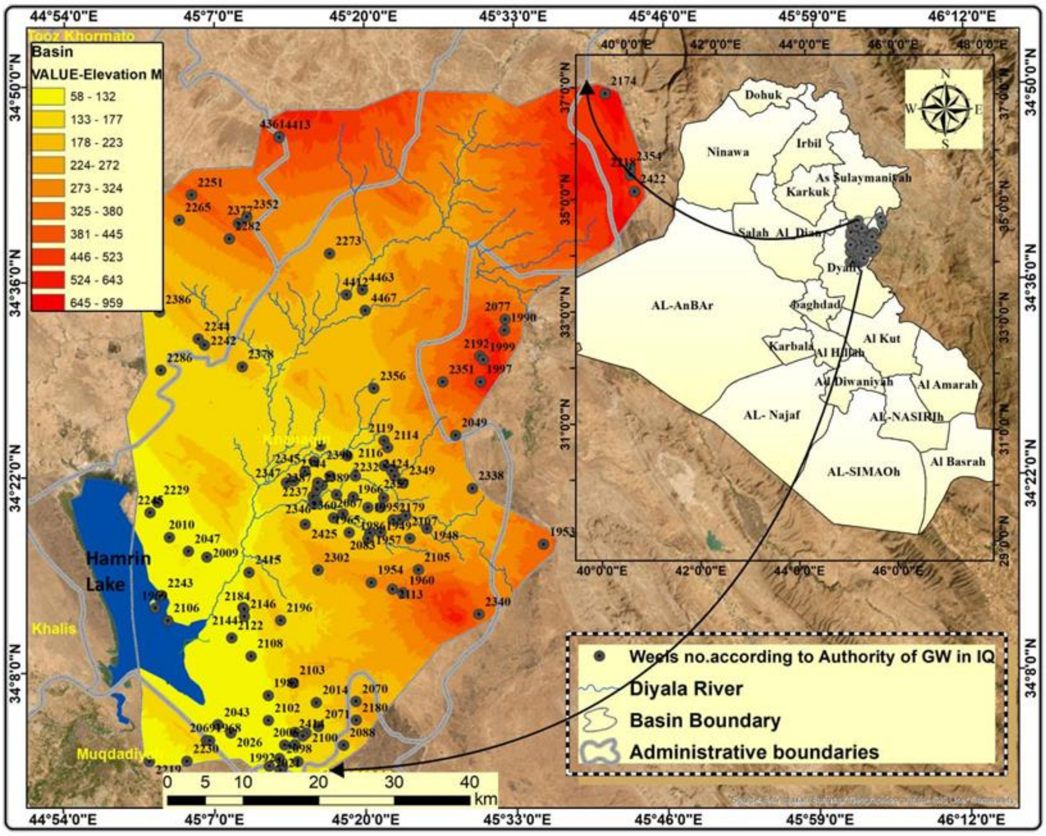

Fig. 1. Location map of the study area showing the sites of the wells.

The ages of the geological formations in the Khanaqin sub-basin range from Upper Jurassic to Recent. Mountains, hills, and flat landscape characterize the examined area, with several ridges serving as its most noticeable morphological features. Additionally, there are few hillocks that create a complex network of tiny valleys. The interior plains receive long and wide watersheds from the main ridges as well as second-order watersheds (Barwary and Said, 1992).

Structurally and tectonically, the area is well described by Jassim and Goff (2006) and the main control on groundwater aquifers divides as well. The climatic data of Khanaqin meteorological station describes the region's climate as having a mean annual temperature of 22 to 24 °C, a mean annual relative humidity of 45%, and a mean annual amount of rainfall of 200 to 300 mm (Iraqi General Organization for Meteorological Information, 2005). Pliocene deposits of Bai Hassan and Mukdadiyah formations represent the main upper aquifer for the most of the study area, while Quaternary deposits are important aquifer when such deposits are of appropriate thickness and make them capable of storing amounts of groundwater and along scattered parts of the area (Fig. 2).

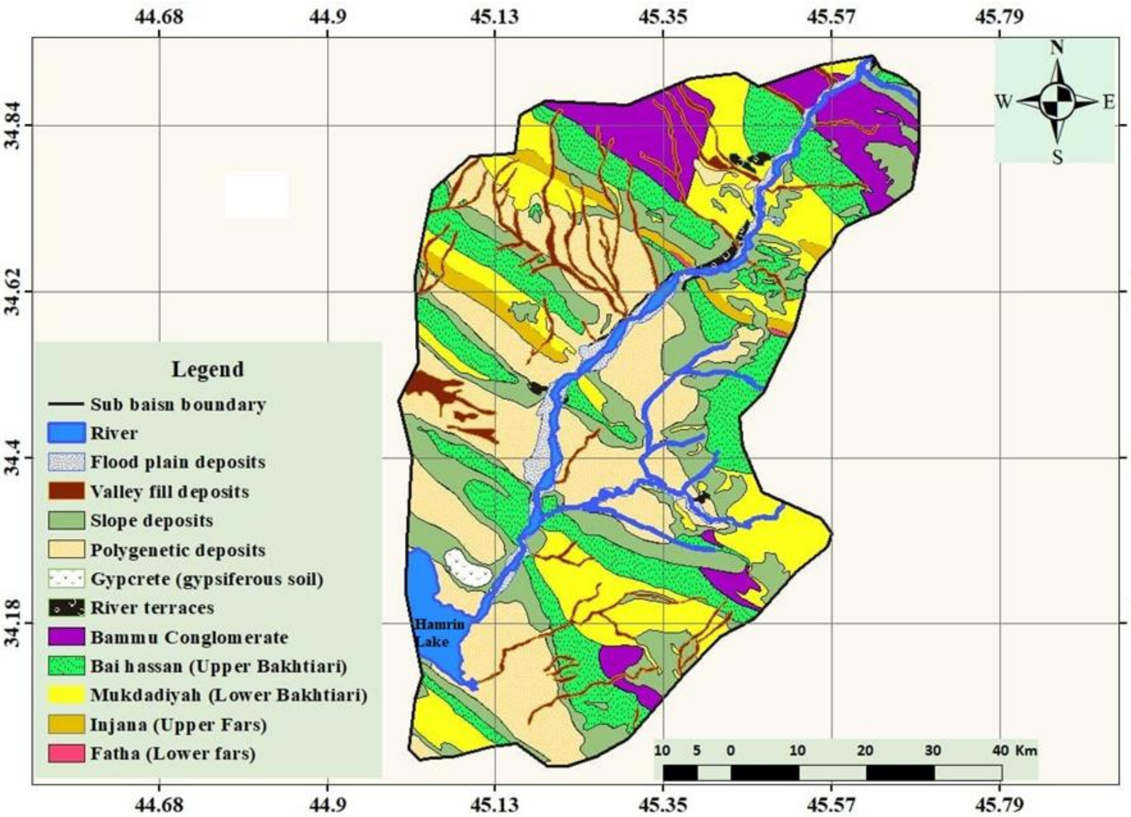

Fig. 2. Geological map of the study area showing the most important formations.

Methodology

Depth of groundwater in (117) wells, levels of groundwater, and drawdown data are collected from the report of Aljibory (2006) as expert in the General State of Geological Survey and Mining (GEOSURV), Department of Groundwater. This study of the spatial distribution is used to determine the variation in the hydraulic properties represented by transmissivity (T), hydraulic conductivity (K), pumping rate and drawdown of the levels. Arc map (10.8) has been used to generate maps of the spatial distribution.

Results and Discussion

Aquifers Description

1. Bai Hassan and Mukdadiyah aquifer in the study area.

The hydraulically connected Bai Hassan and Mukdadiyah formations represent the upper main groundwater aquifer in the study area. The depths to groundwater range (from less than 4 - 40) m, while the groundwater table (from 45 to 564) m a.s.l, Transmissivity (T) (from 4 to 549) m2/day, hydraulic conductivity (K) (from 0.1 to 25) m/day. The productivity (pumping rate) (from 59.27 to 4492) m3/day and the static water level (drawdown) range (from 0.11 to 61) m (Aljibory, 2006). The significant difference in the values of hydrogeological coefficient reflects the nature of these water-bearing geological formations and the heterogeneity of their lithological texture within the same location or different parts of the area (Jalal and Dara, 2022).

2. Quaternary aquifer in the study area.

This aquifer spans a large region of Khanaqin and is predominantly Holocene and Pleistocene in age; it is made up of gravel, sand, clay, loam, and conglomerate. The size of the particles ranges from coarse gravel to fine silt as well as clay (Aljibory, 2006). According to the available hydrogeological information and data about the wells in the area and from the pumping test conducted on the wells in recent deposits, the hydraulic parameters of these wells have been identified. Hydraulic conductivity values range (from 0.4 to 47.3) m/day, transmissivity (T) ranges (from 14 to 539) m2/day, productivity range (from 92 to 1623) m3/day and the static water level range (from 2 to 26) m below the land surface (Aljibory, 2006).

Groundwater characteristics in the study area

1. Depth to Groundwater

The area's topography and human activities, such as groundwater extraction, have an impact on the groundwater depths. It is one of the determining elements that affects drilling techniques, pumps used, and the number of wells. The depths of groundwater beneath the earth's surface are very crucial factors in investing groundwater, and its uses (Najeeb et al., 2021). The depth of water is high at the northeast of the study area and gradually decreases at the center of the area on both sides of the Diyala River, and then increases towards the southwest of the Hamrin Dam reservoir reaching the highest depth of 31 meters at the northeast until it reaches less than 5 meters at the middle of the study area (Fig. 3), This high variation of groundwater is due to the topographic variation in the area that the valleys run through it to the Diyala River.

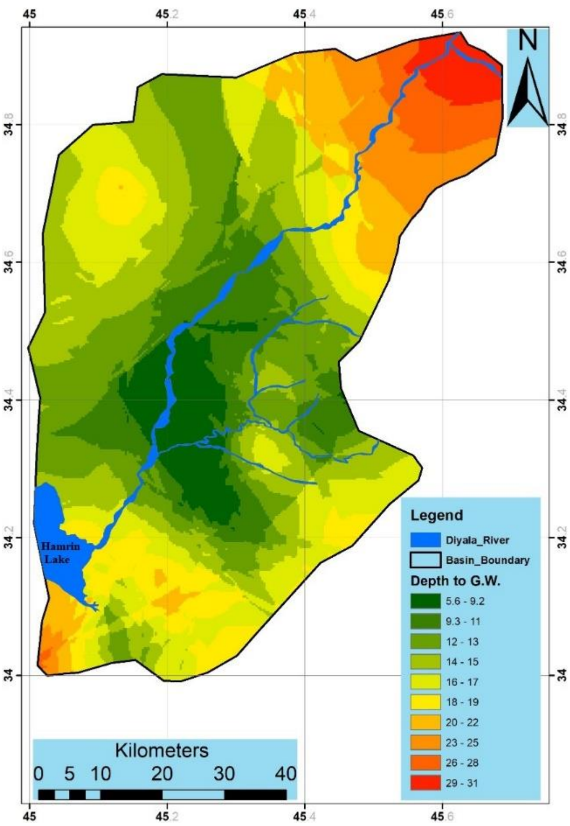

Fig. 3. Spatial distribution of depths to groundwater in the studied area.

2. Groundwater table in the area

Groundwater rises to its highest levels at the north and northeast of the study area, which may represent the recharge area of the basin where the water table reaches more than 564 m a.s.l., then the level gradually decreases to southwest towards Hamrin Dam Reservoir reaching about (45) m at the edge of the reservoir. The equipotential lines of groundwater levels curved upstream of Diyala River, and this is clear in all equipotential lines from the top of the northeast corner to the lowest-equipotential line near Hamrin reservoir. This is not applied only to Diyala River, but also to the main valleys at the eastern side of the river, which indicates that the river and its tributaries represent groundwater discharge areas (Fig. 4), That is, the flow is towards the river, and the groundwater level is therefore proportional to the depths.

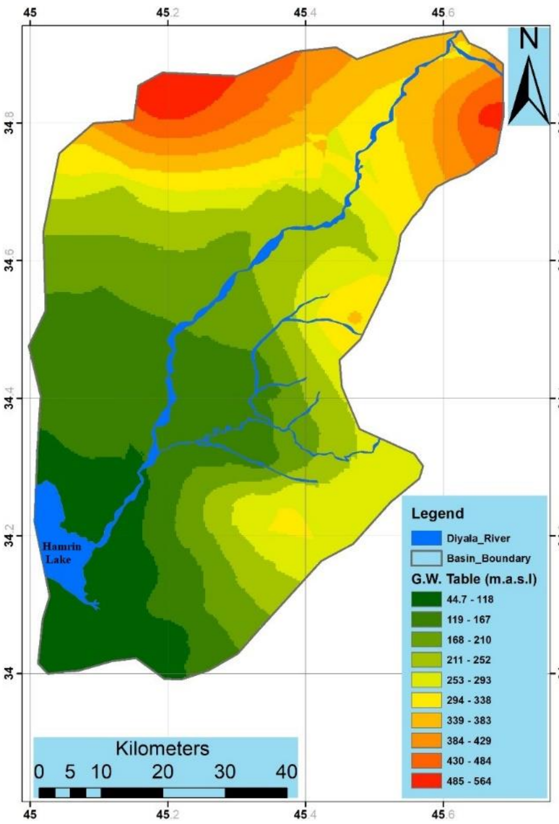

Fig. 4. Spatial distribution of groundwater levels in the study area.

3. Groundwater movement

The groundwater movement depends on the hydraulic heads in aquifer dipping and the inclination of water-bearing strata (Al-Sudani, 2018). Groundwater usually moves downward in the direction of the hydraulic head gradient, which is frequently but not always comparable to the land surface (Saleh et al., 2020). The general representation of groundwater movement within the study area is based on the presence of hydraulic conductivity of aquifers within the Quaternary, such as Bai Hassan and Mukdadiyah, which can be considered as the piezometric water level to be continuous. There is also a hydraulic connection between groundwater and surface water, where rivers constitute a hydrogeological boundary within their areas of presence; the nature of the property of the rivers can be identified as a discharge or recharge for groundwater after the water level in those rivers is known (Fig. 5).

The most important indicators of groundwater movement map within the study area is the following:

1. The overall decline of groundwater level is from the north and northeast towards the south and southwest, while Diyala River is a discharge zone for both sides within the study area.
2. There are piezometric depressions along the extension of the Diyala River, the capacity of this area around the riverbed naturally varies depending on the water level of the river and its surrounding area.
3. The groundwater recharge is through rainfall in the area and adjacent areas at the north and east, which are recharge areas during the wet seasons of the year. The depth of groundwater mostly reaches a few dozen meters, especially within the deposits of Bai Hassan and the Mukdadiyah formation (Fig. 5).

The surface water divides resulting by the geological structures are not clear in the area and not particularly apparent within the northern part of the study area because of lacking of wells excavated in this part of the study area, while the effect of geological structures is clear within the area around and south of Khanaqin City (Fig. 2).

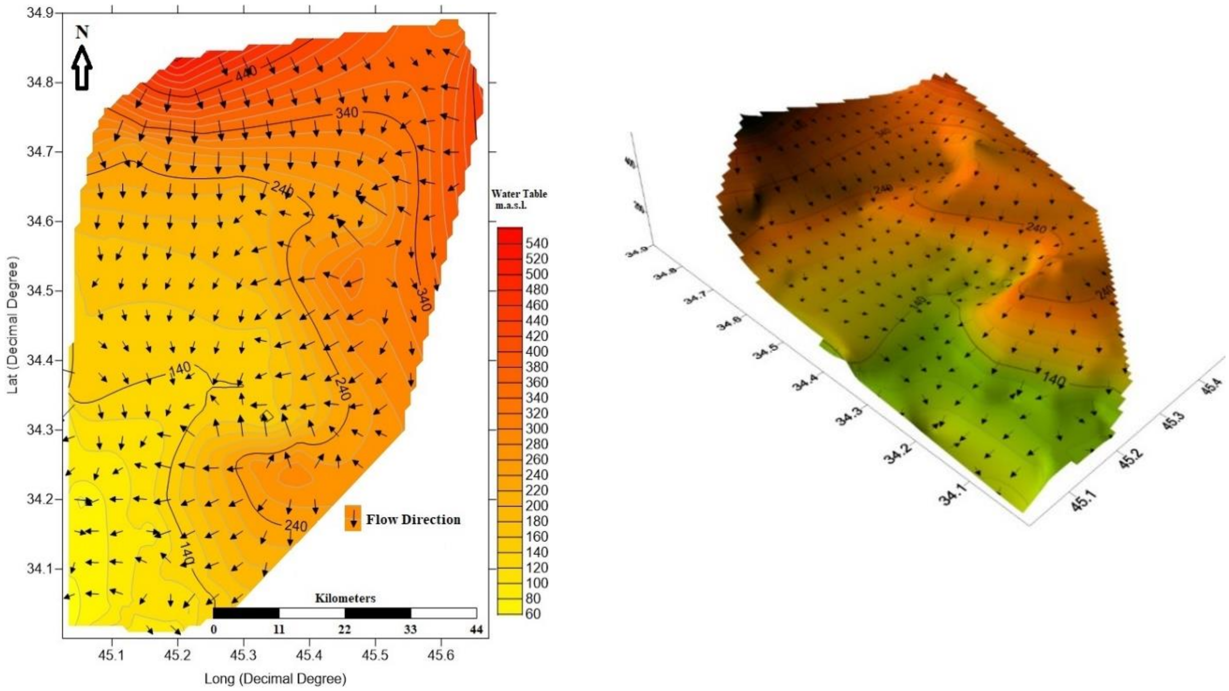

Fig. 5. Groundwater flow direction and groundwater surface topography.

4. Transmissivity (T)

The transmissivity data of the study area are estimated by the pumping test done by Aljibory (2006) that spatially distributed in Figure (6). The (T) value is low at northeast and then increases towards the middle of the study area on both sides of the river; then it increases in the direction of the west of the study area north of Hamrin Dam reservoir. It also increases to the east of the reservoir. The values of the conveyor range is more than 500 m2/day, and the lowest values of the transmissivity are at the middle of the study area, especially on the western side of the Diyala River (Fig. 6). The reasons for this variation are due to the lithological properties of the underground water-bearing formations, as well as the variation of saturated thicknesses of these main reservoirs belonging to the Mukdadiyah and Bai Hassan formations, which are essentially gravelly interspersed by low-conductivity clay layers.

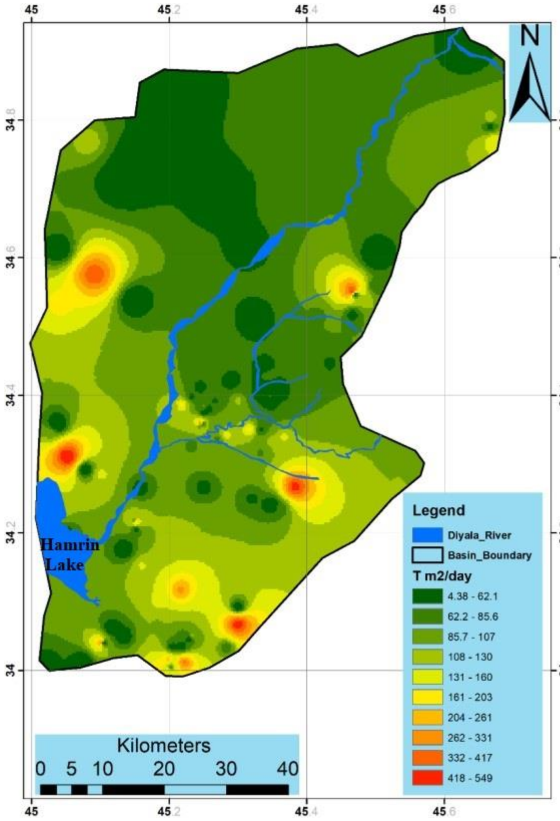

Fig.6. Spatial variation of the transmissivity of the studied aquifers.

5. Hydraulic conductivity (K)

Hydraulic conductivity data of the study area are estimated by pumping test of Aljibory (2006) that spatially distributed in Figure (7). The (K) values increase in the study area from the northeast to the southwest in the form of a strip parallel to Diyala River and on its banks, then decreased near the estuary of Diyala River to the northeast of Hamrin dam reservoir, and decrease towards the east and west directions, the highest hydraulic conductivity is found in the strip of floodplain and river terraces parallel to Diyala River, the highest conductivity is more than 20 m/day, while the lowest is less than 1 m/day. This variation is due to the difference in the lithological properties of the main beds and sub-basin in the area (Fig. 7).

6. Pumping rate

The pumping rate in the study area that was tested by Aljibory (2006) is spatially distributed in figure (8) reaching in the study area to more than 4,000 m3/day in the western bank, while it is less than 50 m3/day in the eastern bank. It varies to be as highest on the western bank of Diyala River and vice versa on the eastern bank. This variation is due to the reasons for the storativity and specific yield of the reservoir or drilling techniques used and the type of the pumping equipment (Fig. 8). Because the condition of the soil directly affects recharge, groundwater recharge depends on direct infiltration of water downward through the soil (Al-Abadi, 2012).

7. Drawdown

Drawdown values in the study area tested by Aljibory (2006) are spatially distributed in Figure (9) and are minimal in the river banks areas of the southwest region only, this is due to recharge groundwater from the river in those areas at the low groundwater levels, while the decreased values are high in the northwest side of the river bank where it gives a reverse state with discharge; this is due to the lithological properties of the water-bearing formations as well as the type of pumping equipment and drilling techniques used (Fig. 9).

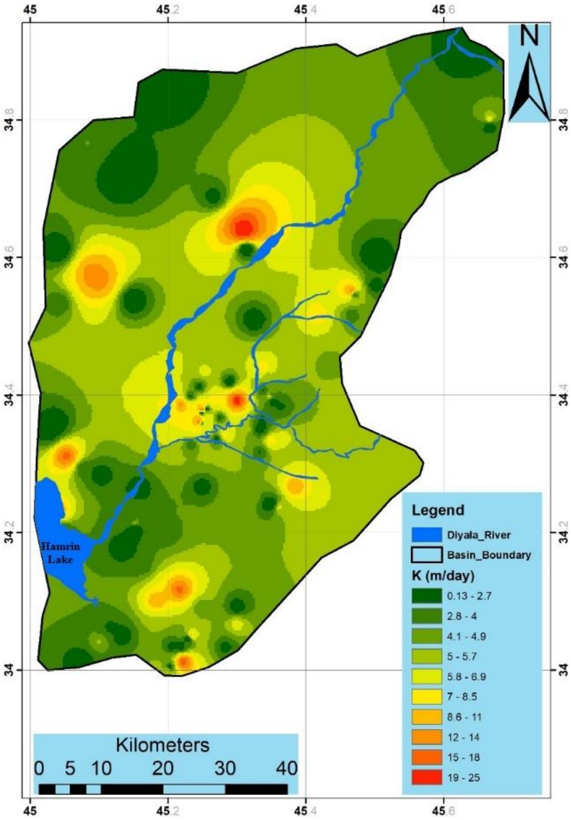

Fig. 7. Spatial distribution of hydroponic conductivity (K) values in the study area.

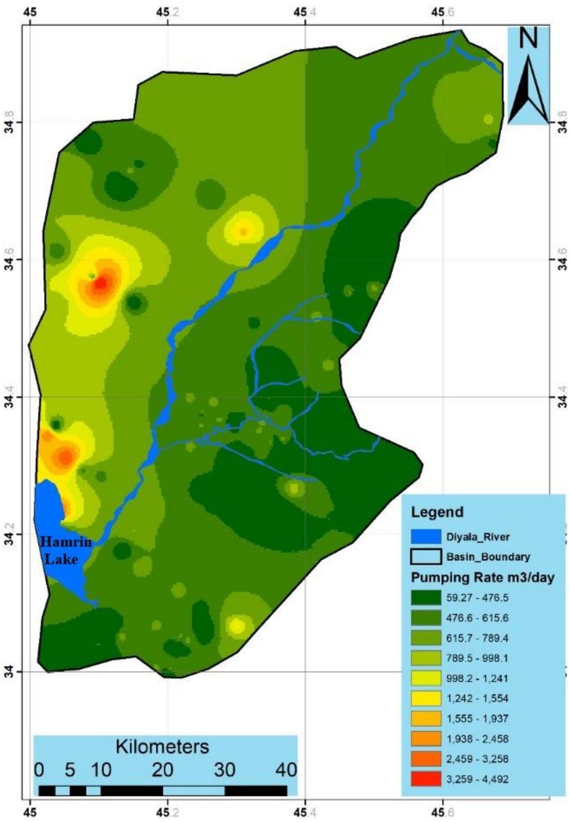

Fig. 8. Spatial distribution of pumping rate in the study area

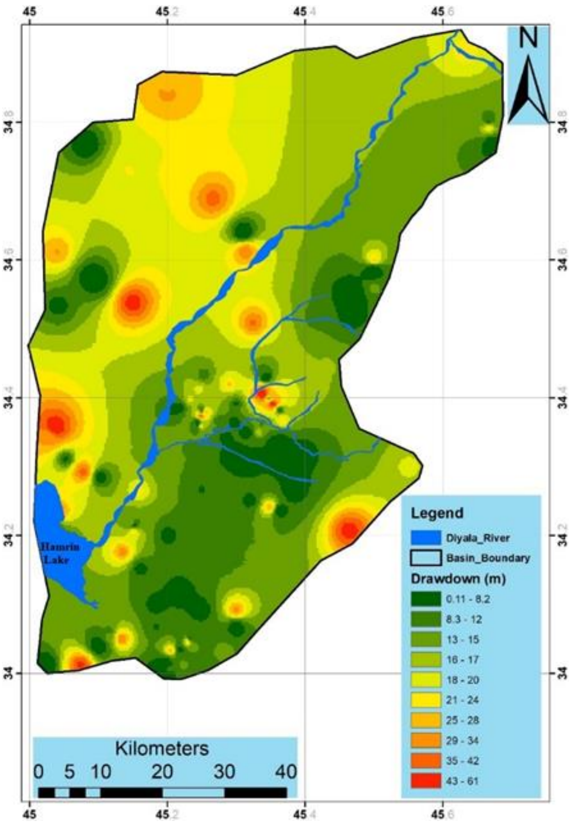

Fig.9. Spatial distribution of drawdown in the study area.

Conclusion

1. Bai Hassan and Mukdadiyah formations represent the same main upper aquifer within the study area, while Quaternary sediments form groundwater aquifer within scattered parts of the study area, where the thickness of such sediments is suitable for the storage and containment of groundwater.
2. Depths to the groundwater vary in the study area, where they increase at northeast and decrease towards southwest, and the lowest depth is at the middle of the study area as a result of variation in lithology and topography.
3. The groundwater table indicates that the direction of flow was from the northeast to the southwest.
4. The overall trend of the groundwater flow is in the same trend of the decline of topography as the overall decline of groundwater level is from the north and northeast towards the south and southwest.
5. The transmissivity and hydraulic conductivity of the aquifer also vary; the transmissivity is high at northeast and low at the middle of the study area, while the hydraulic conductivity is the highest on both sides of Diyala River and decreases when moving away from the river.
6. The pumping rate of wells varies in the study area due to the storativity and specific yield of aquifers or drilling techniques used and the type of pumping equipment, where the productivity of the wells is highest on the western bank of Diyala River in comparison with the eastern bank.
7. The drawdown of the water table in the wells vary as they are high at northwest and decreases near the Diyala River at southwest.

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