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Groundwater System of Khanaqin Basin in Diyala Governorate – East of Iraq

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Abstract

Land and water resources are generally depleting due to rapid increase in population, urbanization and industrialization. The demand has increased tremendously for these resources; hence optimal utilization of them is essential for sustainable development. The study area is located in Diyala Governorate in the east of Iraq covering 1920 km^2. The hydrogeological investigation of the basin divided groundwater aquifers into two main units, the unconfined and confined aquifers, where geographical position, elevations, static water levels, depths, thicknesses, maximum yields as well as water sampling and pumping tests have been carried out during these investigations. Quaternary deposits, Bai Hassan and Mukdadiyah formations reflect the unconfined aquifer while confined aquifer consists of Mukdadiyah and Injana formations. The promising zone of unconfined aquifer is located around Khanaqin city within the southern part of the basin, while two promising zones of confined aquifer are located to western part of the basin and near the border within north part of the basin.

1- Introduction

Ground water is one of the Nation's most valuable natural resources. It is the source of about 40 percent of the water used for all purposes except for hydropower generation and electric power plant cooling. Groundwater is the one of the main source of water that meets the agricultural, industrial and household requirements [1].

Subsurface water is generally divided into two major types: Phreatic water or soil moisture in the unsaturated zone, and groundwater in the saturated zone. This division is made mainly because of the differences in the physics of flow of water in the saturated versus the unsaturated zone. Problems of data quality and data quantity in quantitative assessment of groundwater properties are mainly functions of the heterogeneity of most geologic formations and their hydraulic properties and the difficulty and expense of drilling for good data. Pumping tests and other hydraulic tests have been developed which greatly improve our understanding of the hydraulics of aquifers and their potential for groundwater supplies. [2].

The scarcity of available surface water resources as well as the deterioration of its quality and coincided with the expansion of the agricultural area and reclamation of new land to meet the growing demand for food as a result of high rates of population growth , all these reasons give the priority attitude towards water exploitation from groundwater basins in order to exploit this natural resource optimally to ensure the possibility of restoration and maintain the strategic storage of these resources and control the quality and prevent contamination of these basins [3] .

The study area is located in Diyala Governorate in the east of Iraq and bordered by Iraqi - Iranian borders from the east and Diyala river from the west while Nadoman anticline fold and Bernand mountain chain surrounding the basin from south and north respectively. The area covers 1920 km^2 within (45º 10'- 45º 59') E and (34º 10 ' - 34º 45') N, figure (1).

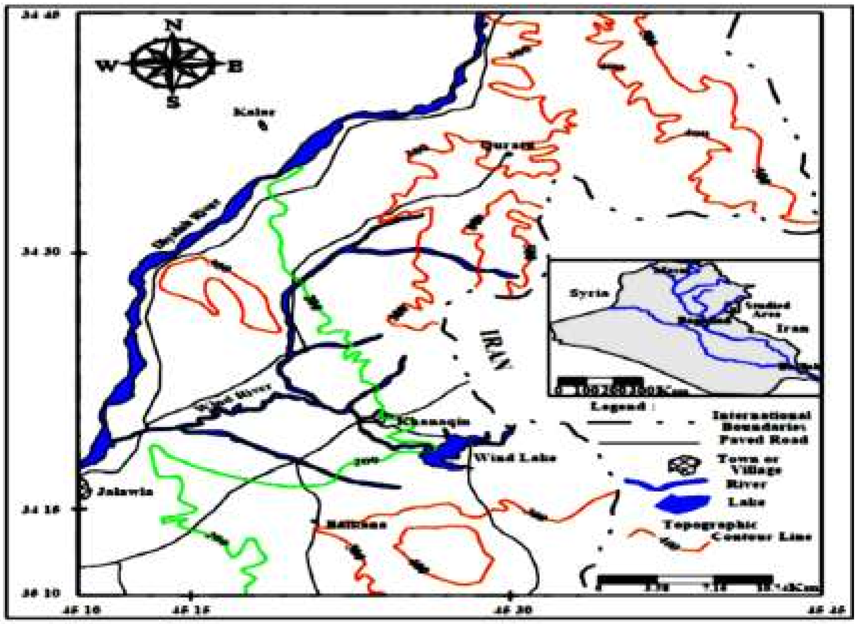

Figure (1): Location and topographic map of Khanaqin Basin.

The climate of the area, according to the climatic atlas of Iraq (1951-2000) is characterized by mean annual temperature of 22-24ºC, mean annual relative humidity of 45%, dryness index of 20, mean annual amount of evaporation is 3500-4000, mean annual amount of rainfall is 200-300mm and mean annual number of days with snow is zero, [4].

The aim of this study is to carry out hydrogeological investigation in Khanaqin basin within Diyala Governorate in the east of Iraq to evaluate the most important product groundwater aquifers and achieve optimum use of groundwater in term of sustainable water management.

Several studies have been done to evaluate the accessibility of groundwater in Diyala governorate for domestic and agricultural uses. (Hassan, M. A; 2007) [5] studied morphometric properties of Mandili area in Diyala in 2007. (Hassan et al 2014) [6] Studied Morphometric Properties of Bulkana (Naft Khanah) North-East Iraq from Topographic Maps. (Jalut, et.al.2015) [7] studied Hydrochemical analysis of groundwater resources in Kanan region. (Nada, et.al , 2010) [8] Studied under ground water assessment in Diyala bridge area. (Ramadhan, et. al, 2017) [9] used Statistical Analysis Approach to Evaluate the Groundwater Quality in Jisser Diyala Area.

The work plan in the studied area included the following items:

1- Office work including preparing data and preliminary information of the area (wells stratigraphic columns, maps, literature reviews, scientific references, hydrogeological data bank ...).

2- Field work including:

- Inventory of water wells and measuring water levels in the wells as well as determine geographical positions and levels of (43) water points.
- Drilling of (4) wells of (190-300) meters depths and (4) monitoring wells with (30-50) meters distance to pumping wells respectively to evaluate hydraulics properties through pumping test process.
- Water sampling of (34) wells within water surplus and water deficit periods during 2013-2014.
- Pumping test in (4) wells.
- Monthly monitoring of (20) wells for water levels measuring during 2013-2014.
- Monthly sampling of (34) water samples during 2013-2014.
- Laboratory analysis of (430) water samples to measure physical and chemical components and variation of ionic concentrations.

2- Geological Setting

Khanaqin basin is built up by geological formations ranging in age from upper Jurassic up to Recent. The studied area consists of mountainous, hilly and flat terrains, with many ridges as most prominent morphological features. Besides, presence of some hillocks which form dense network of small valleys. Main ridges provide long wide water sheds to the internal plains and also of second order sheds, [10] Figure (2). The main Stratigraphic sequence in the basin consists of Avanah, Oligocene group, Euphrates-Jerebi, Fatha, Injana, Mukdadiyah, Bai Hassan, Bamu Conglomerate formations and Quaternary deposits as shown in figure (3) [10].

Structurally, the area is a part of two zones, the High Folded Zone (north eastern part), and the majority of the area belongs to Foot-hill zone of the Unstable Shelf at Nubio-Arabian Platform. Tectonically, the Foot-hill zone here is divided into Hemrin-Makhul and Chemchemal-Butmah subzones. Chia Surakh, Ali Mire, Kiria Pika, Pulkhana, Naodoman are the main structural elements, they are asymmetrical and thrusted anticlines, separated by broad and asymmetrical synclines filled by Tertiary sediments, [11].

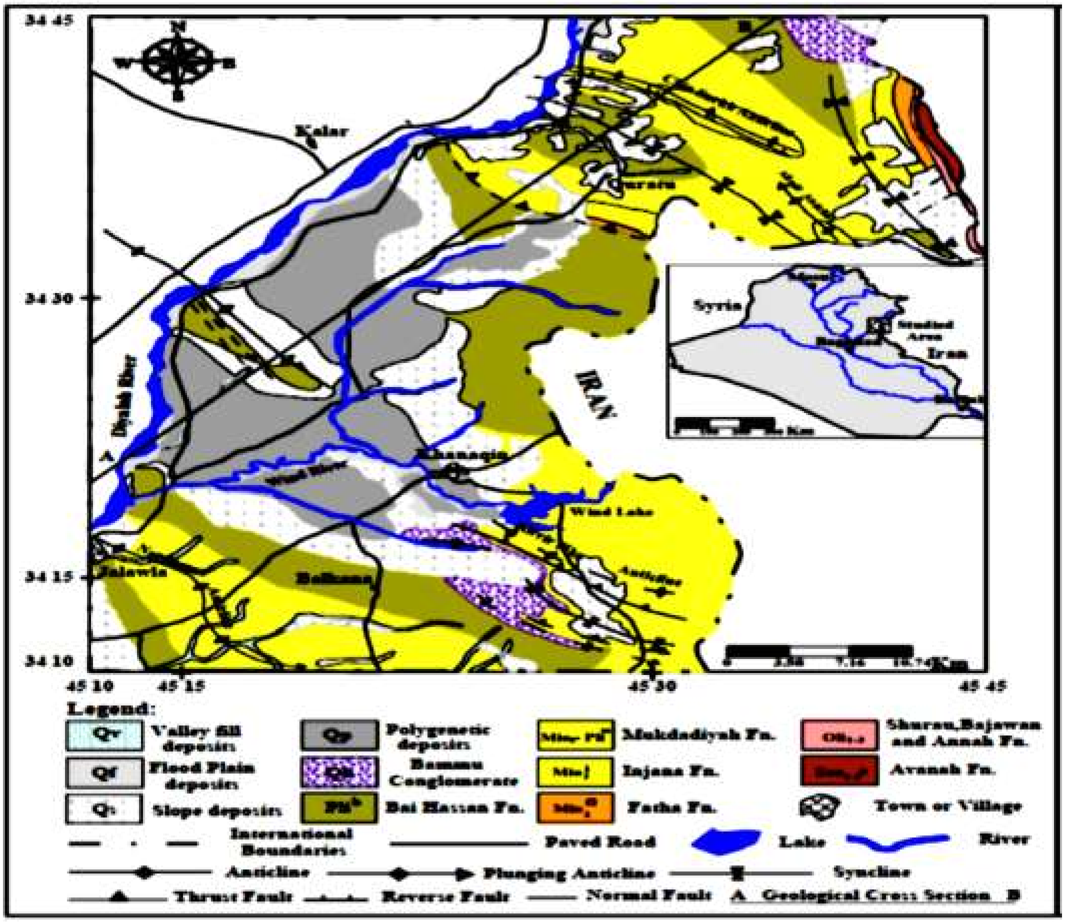

Figure (2): Geological map of studied area [10]

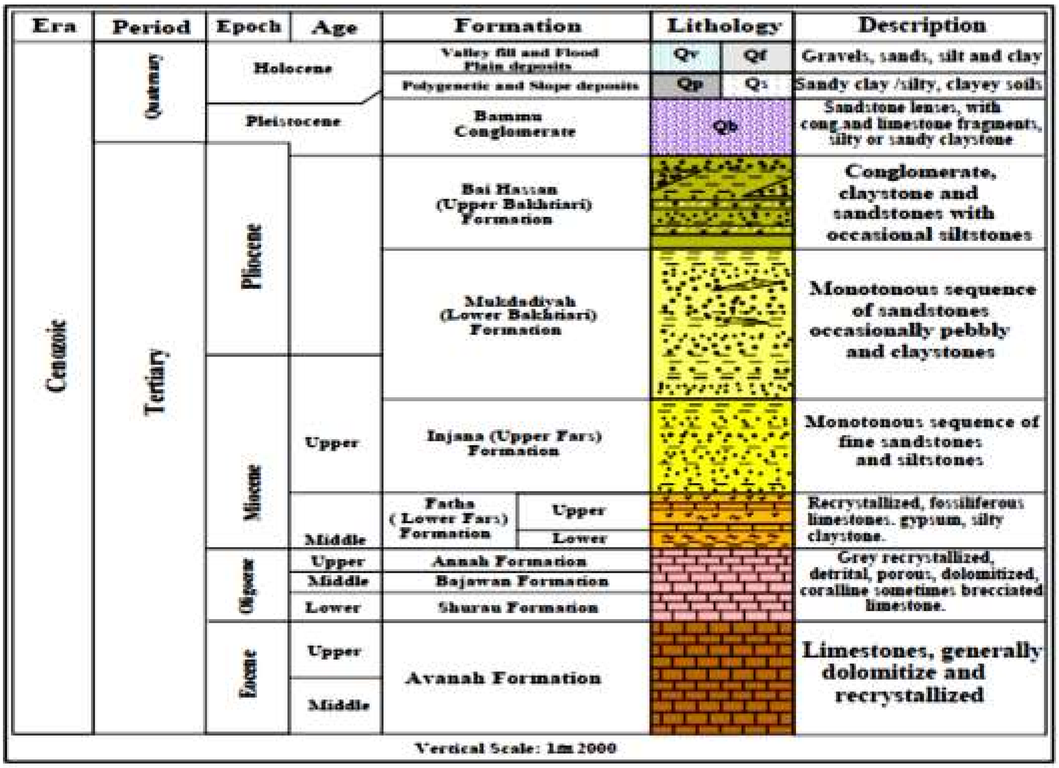

Figure (3): Geological formations sequence in the studied area [10].

3- Materials

1- Topographic maps at a scale of 1:250000.
2- GPS device to determine wells locations and elevations.
3- Stratigraphic sheets and hydrogeological data bank [12]
4- Mathematical programs (Surfer and Grapher) in analyzing data and information obtained and draw of all types of contour maps.

4- Methodology

Depending on (43) inventoried wells and (65) wells obtained from hydrogeological data bank, the stratigraphic sheets of these wells had been compared with figure (3), and taking into consideration the groundwater levels measured in these wells as well as types of water bearing layers; the aquifers were divided into two main units, the unconfined and confined aquifers. The aquifers were investigated during field work where geographical position, elevations, static water levels, depths, thicknesses, maximum yields as well as water sampling have been carried out. Mathematical programs (Surfer and Grapher) were used to demonstrate the obtained results in contouring maps of hydrogeological properties.

5- Rustles and Discussion

According to (90) wells investigated in area, the results showed that (38) wells belongs to unconfined aquifer while (52) wells belong to confined aquifer, figure (4).

1- Hydrogeological properties of unconfined aquifer:
The geological formations distributed and exposed in Khanaqin basin as shown in figure (2) determined the types of aquifers where unconfined aquifer composite of Quaternary deposits, Bai Hassan and Mukdadiyah formations according to their exposure on surface.

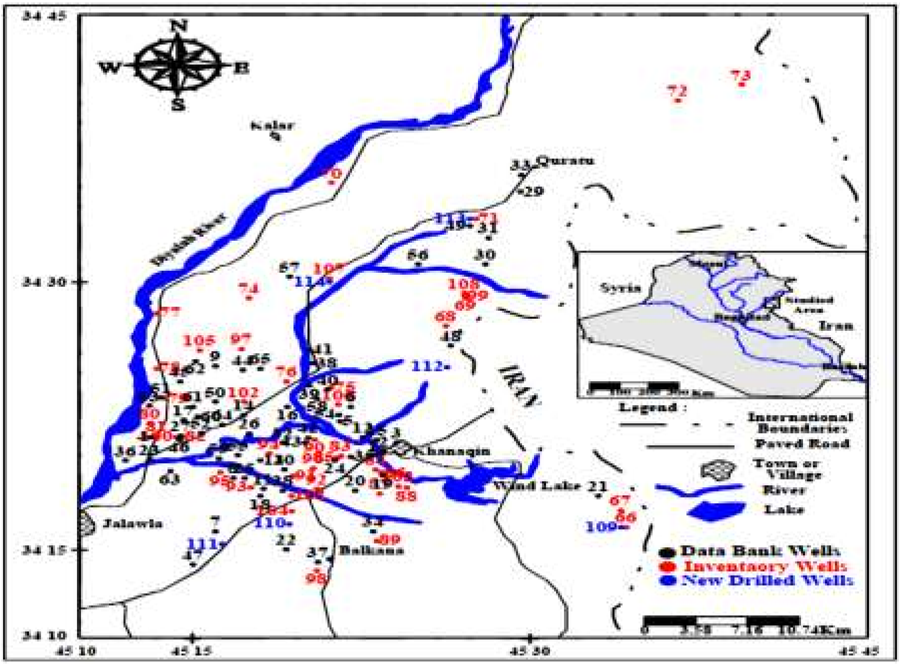

Figure (4): Inventory, data bank and drilled wells in Khanaqin basin

Both Bai Hassan and Mukdadiyah formations exposed in specific locations within the basin, producing the unconfined aquifer. On the other hand, whenever Bai-Hassan formation overlying Mukdadiyah formation turned the last one into confined aquifer combined with Injana formation. Table (1) shows the statistical data of hydrogeological properties of unconfined aquifers.

Table (1): Statistical data shows Hydrogeological properties of unconfined aquifer.

Statistic	Number of values	Minimum	Maximum	Mean	Standard deviation
Elevation (m)	38	124.2	300	183.9	42.70
Static water level (m.)	38	2	27	10.99	6.282
Water Table (m.a.s.l.)	38	97.2	293	172.9	42.74
Total depth (m)	38	16.7	148	48.04	31.921
Depth to water (m)	34	2	26	11	5.82
Thickness (m.)	34	9	130	36.11	28.01
Maximum yield (m^3/day)	37	92	743	338.9	207.6
Transmissivity (m^2/day)	32	6	104.6	104.6	179.4

Depth and thickness of this aquifer shown in figure (5) and (6) respectively, where topography and structural features of the area Chia Surakh Ali Mire Kiria Pika, Pulkhana, Naodoman anticlines were a major influence on distribution of decreasing depth and thickness towards southwest and northeast direction of area. The topographic map, figure (1) showed the differential inclination in topographic levels in the northeast according to Chia Surakh structural anticline while Kiria Pika and Naodoman anticlines to the south and southwest corner of the map area where the minimum depth and thickness where recorded. Maximum depth and thickness were recorded at east direction near the Iraqi -Iranian borders.

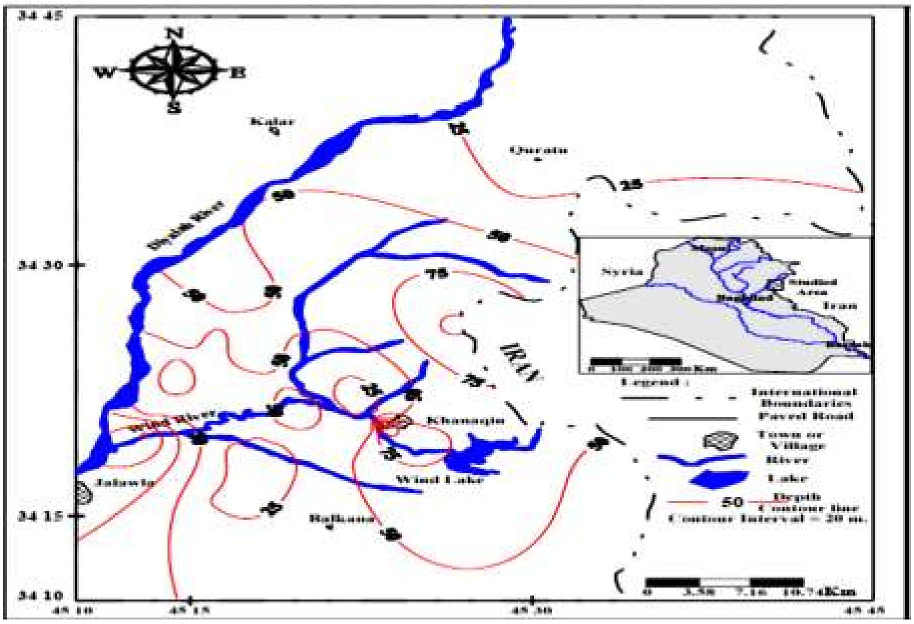

Figure (5): Isopach depth contour map of unconfined aquifer.

The transmissivity of this aquifer was determined by pumping test from (2) wells and (32) wells information obtained from hydrogeological data bank [12]. The results shown in figure (6) where increasing values was recorded in the south area due to increasing of aquifer thickness. The Kiria Pika and Naodoman anticlines which are located to southeast and southwest of area reflect the increasing of aquifer thickness where the limbs of two previous mentioned anticline were converged within this location. Maximum values of transmissivity was (792) m^2/Day.

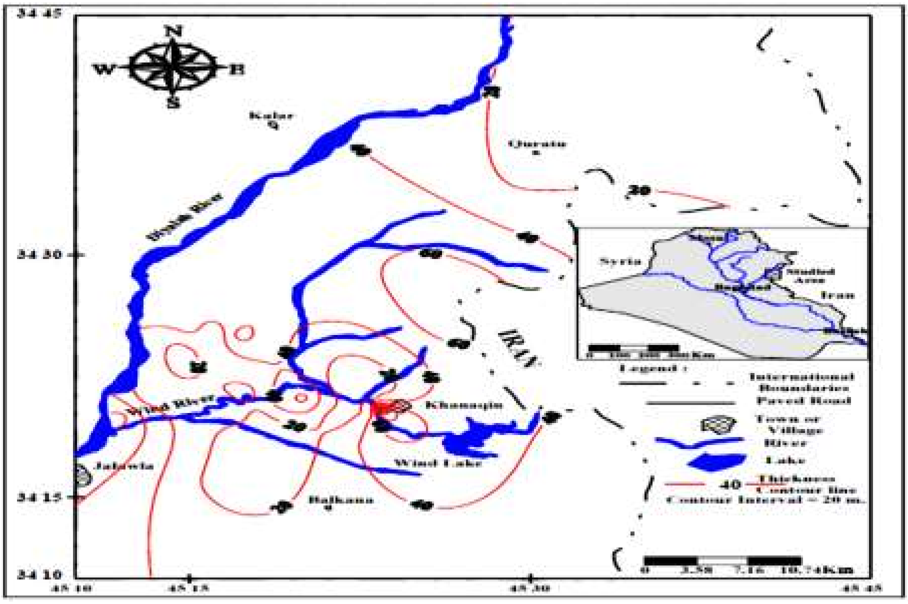

Figure (6): Isopach thickness contour map of unconfined aquifer.

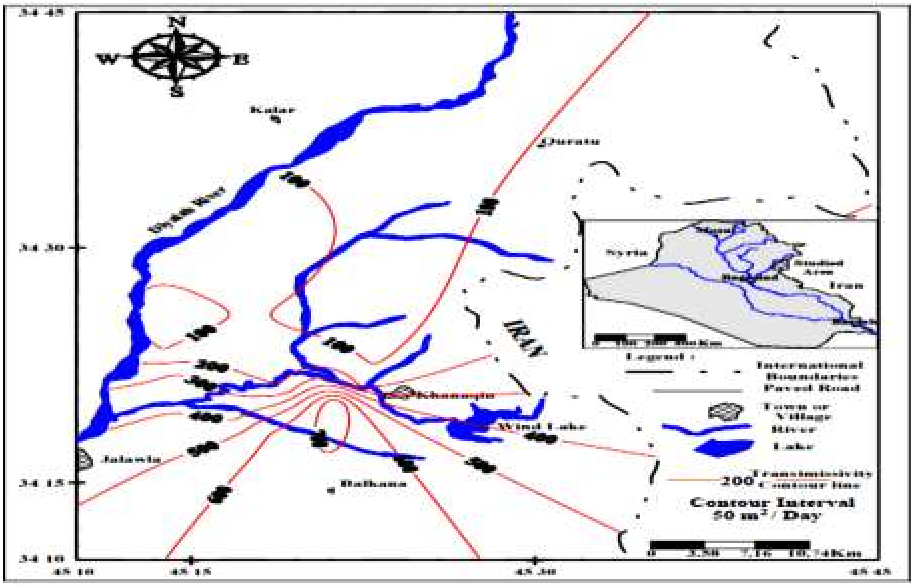

Figure (7): Isopach transmissivity contour map of unconfined aquifer.

Ground water moves from higher elevations to lower elevations and from locations of higher pressure to locations of lower pressure. In groundwater hydraulics, water pressure surface and water table elevation are referred to as the hydraulic head. Hydraulic head is the driving force of groundwater movement. Groundwater movement is always in the downward direction of the hydraulic head gradient. The hydraulic gradient is often but not always similar to that of the land surface [13]. The influence of topography and aquifer beds dipping due to structural influence were the major causes of groundwater movement in this aquifer as shown in figure (8). The water table (groundwater flow direction) map has a convergent flow from eastern boundary of the basin towards western side where some of groundwater discharges into Diyala river and Wind river. In the north part of the basin, groundwater flows to the northwest while in the south part of basin the groundwater flows towards Wind river. The nature of Quaternary deposits, Bai Hassan and Mukdadiyah formations helps percolating and infiltrating rainfall to recharge this aquifer.

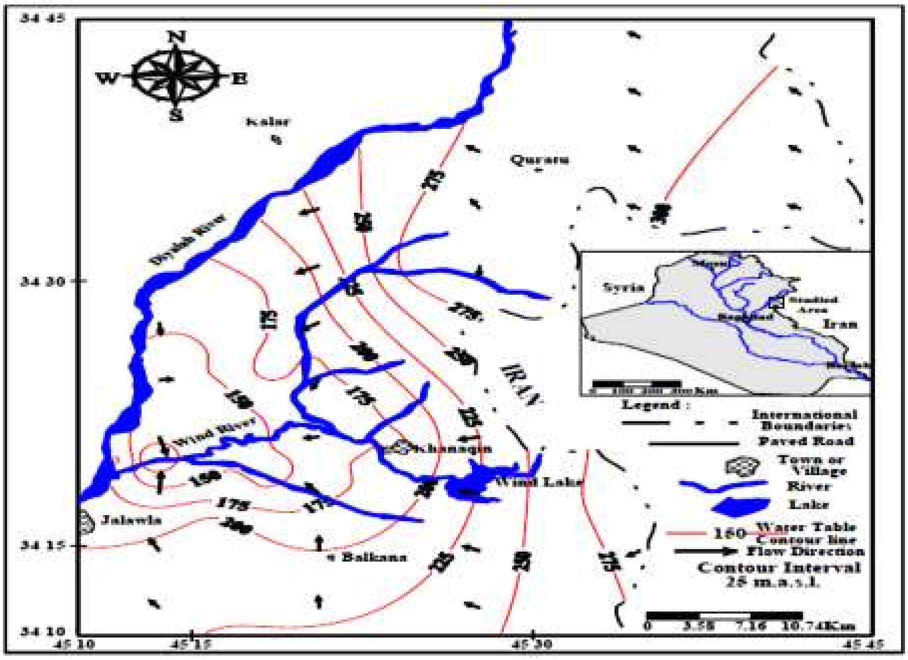

Figure (8): Water Table contour map of unconfined aquifer.

The maximum yield (well discharge) of (37) wells was demonstrated in figure (9) where maximum values were located in west and southwest part of the basin. Maximum yields depends on transmissivity and sedimentary facies of groundwater bearing as well as groundwater flow direction [14], taking in consideration thickness of aquifer. The hydrogeological properties of this aquifer indicate that thickness in this area was the largest values with maximum values of transmissibility and assembling of groundwater flow. Near Diyala river in the western part of the basin the yield has a maximum values although thickness was low as well as transmissivity was a moderate values, where polygenetic of Quaternary deposits covers flat areas in between topographically prominent ridges in this area and composed of sandy, silty clay admixture containing gravels at basal parts which increase maximum yields due to texture of this deposits as well as ground water flow direction which assembling in this area.

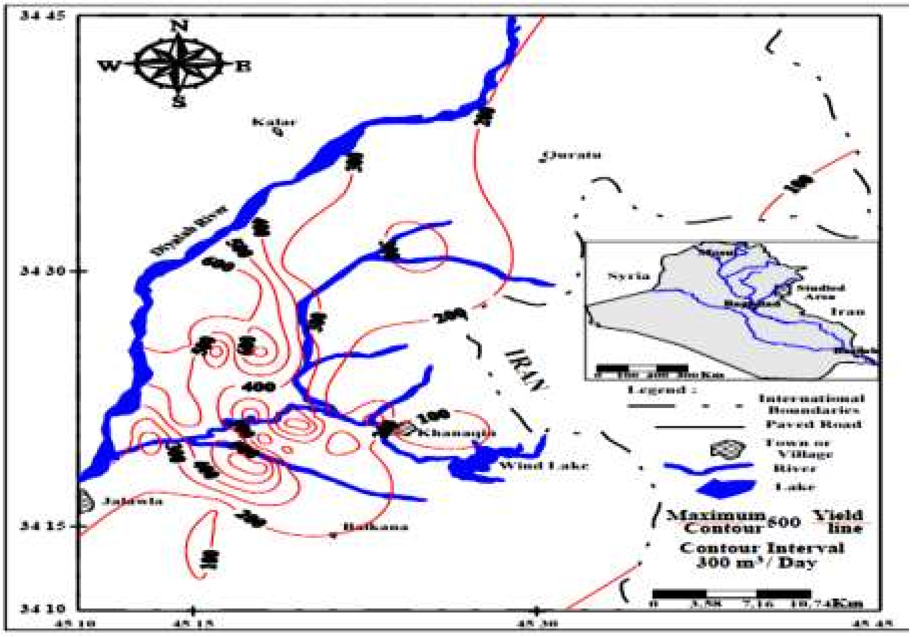

Figure (9): Maximum yields contour map of unconfined aquifer.

2- Hydrogeological properties of confined aquifer:
Table (2) shows the statistical data of hydrogeological properties of confined aquifer which mainly consist of Mukdadiyah (in specific locations) and Injana formations according to lithological columns of wells investigated in area.

Table (2): Statistical data shows Hydrogeological properties of confined aquifer.

Statistic	Number of values	Minimum	Maximum	Mean	Standard deviation
Elevation (m)	52	139	350	183.9	53.72
Static water level (m.)	52	0	40	14.28	10.14
Water Table (m.a.s.l.)	52	113	343.4	169.6	55.08
Total depth (m)	52	20	157	58.06	27.03
Depth to water (m)	27	7	63	22.3	11.4
Thickness (m.)	27	6	123	23.74	22.64
Maximum yield (m^3/day)	50	99	792	475.3	191.7
Transmissibility (m^2/day)	49	10	1303	142.9	235.3

Depth and thickness of this aquifer shown in figures (10) and (11) respectively, where topography has the same influence on distribution of increasing depth towards southern part of the basin, while thickness is increased in eastern part of the area near the international border. These increasing values of confined aquifer were due to interbedded of Mukdadiyah and Injana formations with large thickness as shown in figure (3). Gradually, decreasing of both depth and thickness can be seen in the western part of the basin according to increasing of unconfined aquifer depth and thickness in this area, where few deep wells have partial or full penetration of confined aquifer reducing subsequently total depth and thickness. The confined aquifer depth reached (63) m. while the thickness reached (123) m.

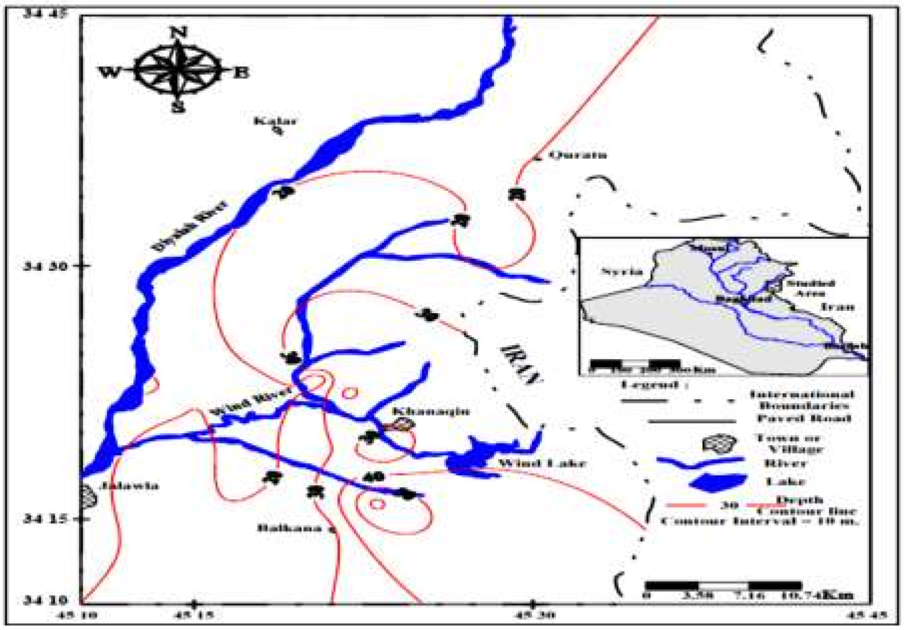

Figure (10): Isopach depth contour map of confined aquifer.

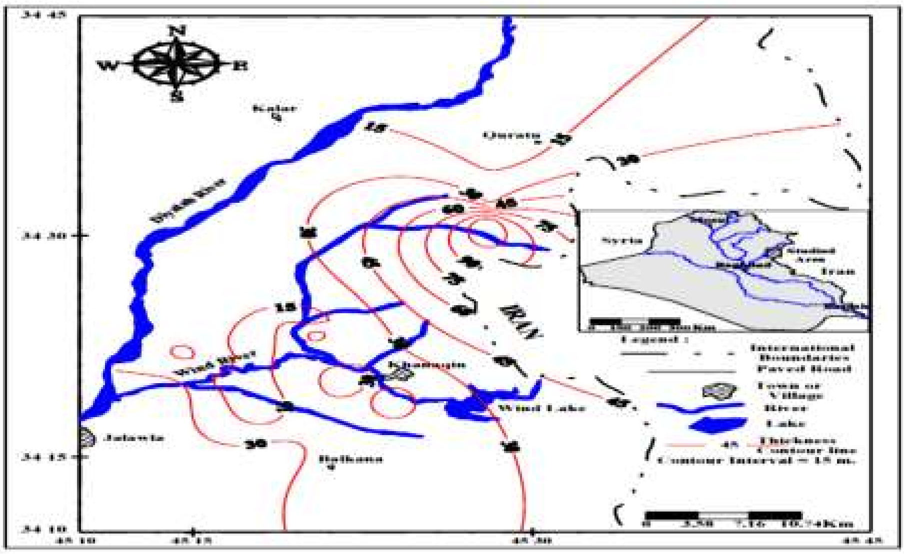

Figure (11): Isopach thickness contour map of confined aquifer.

The transmissivity of this aquifer was determined by pumping test from (2) wells and (49) wells information obtained from hydrogeological data bank. The results shown in figure (12) where increasing values was recorded in the west part of the basin.

The piezometric (groundwater flow direction) as shown in figure (13) has the same flow as unconfined aquifer from eastern boundary of the basin towards western side. In the north part of the basin, groundwater flows to the northwest while in the south part of basin the groundwater flow is towards northwest and central part of the basin.

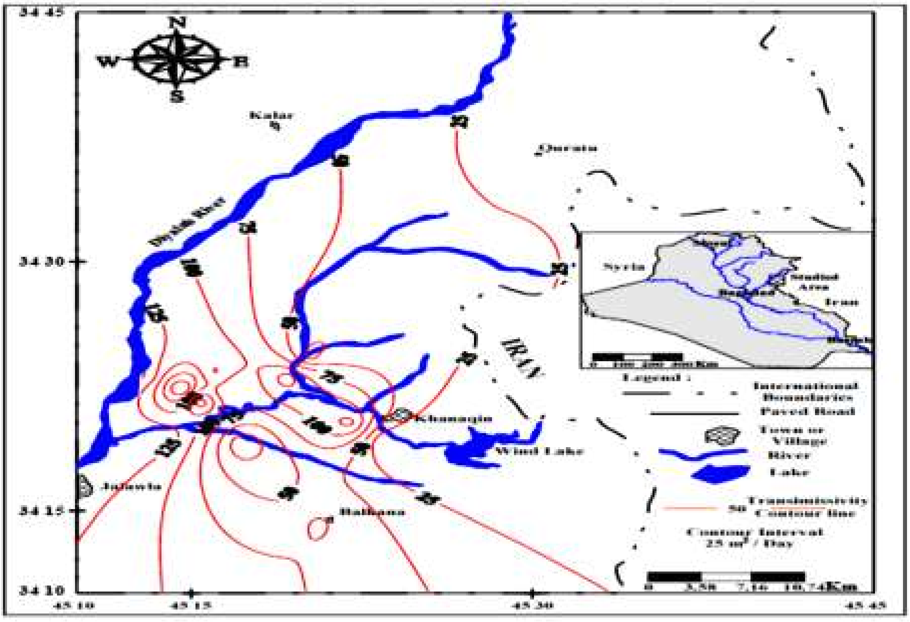

Figure (12): Transmissivity contour map of confined aquifer.

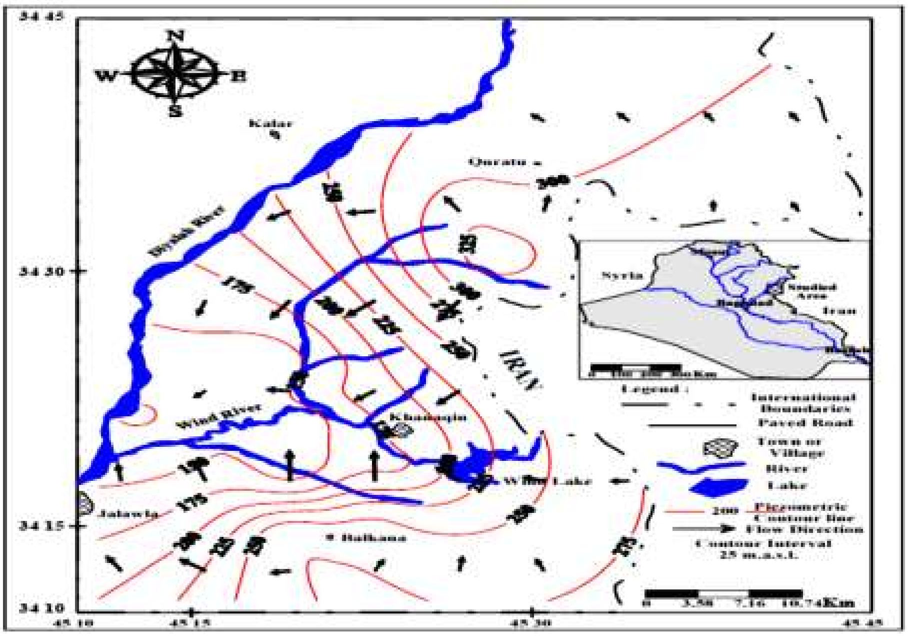

Figure (13): Piezometric contour map of confined aquifer.

Maximum yield (well discharge) of (50) wells was demonstrated in figure (14) where maximum values were located in south and western parts of the basin. As mentioned before, maximum yields depend on transmissivity and sedimentary facies of groundwater bearing as well as groundwater flow direction, all these factors reflect the increasing of the maximum yield to reach the (792) M^3/ Day.

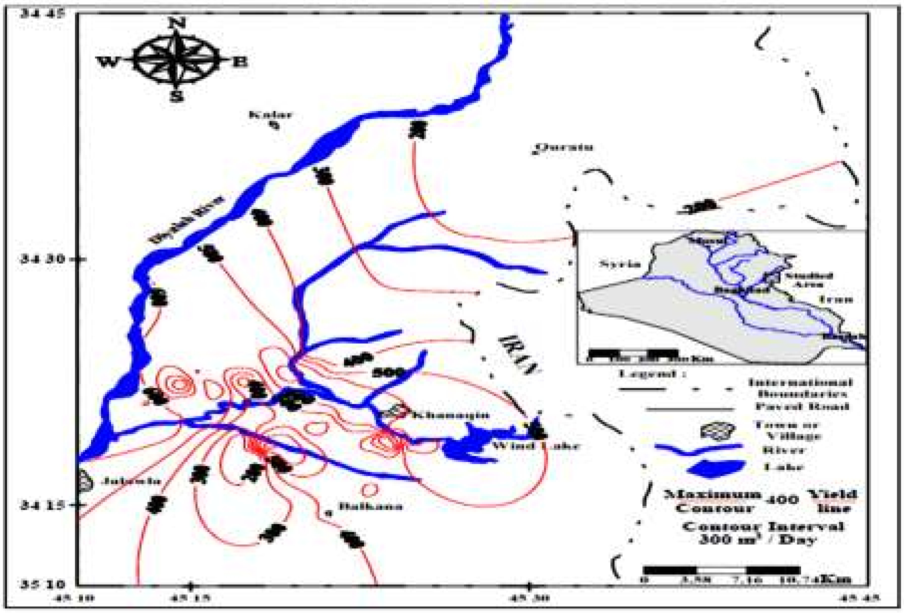

Figure (14): Maximum yields contour map of confined aquifer.

Conclusions

1- Depending on hydrogeological properties of unconfined aquifer, the promising zone for useful exploration of ground water is located around Khanaqin city within the southern part of the basin. Depth, thickness, transmissivity and groundwater flow direction nominate these locations to be promising zone although maximum yields of moderate values.

2- The first promising zone in the confined aquifer is located in the western part of the basin near the conjunction of Wind river by Diyala river, where all hydrogeological properties nominate this region to be suitable location for exploration. The second promising zone in the confined aquifer is located to the eastern part of the basin near the international boundary between Iraq and Iran where thickness with high values and low depth to aquifer with moderate maximum yield and low transmissivity.

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نظام المياه الجوفية لحوض خانقين في محافظة ديالى– شرق العراق

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الملخص

الموارد المائية والاراضي بشكل عام في استنفاذ مستمر بسبب الزيادة السريعة في عدد السكان والتمدن والتصنيع بكافة اصنافه. ولقد زاد الطلب بصورة هائلة على هذه الموارد لذا فإن الاستفادة المثلى منها ضرورية للتنمية المستدامة. تقع منطقة الدراسة في محافظة ديالى في شرق العراق والتي تغطي مساحة 1920 كم^2، وبينت التحريات الهيدروجيولوجية المنفذة في حوض خانقين بان مكامن المياه الجوفية مقسمة الى وحدتين رئيسيتين هما طبقات المياه الجوفية الحرة والمحصورة على التوالي، حيث اشتملت هذه التحريات على تحديد مواقع الابار ومناسيب المياه الجوفية وعمق وسمك المكامن الجوفية فضلاً عن التصريف البئري وعمليات الضخ الاختباري ونمذجة المياه الجوفية من الابار في المنطقة. يعكس المكمن المفتوح من ترسبات العصر الرباعي وتكويني باي حسن والمقدادية فيما تمثل تكوينات المقدادية وانجانة المكمن المحصور. بينت الخصائص الهيدروجيولوجية بان المنطقة الواعدة لاستثمار المياه الجوفية منها ضمن المكمن المفتوح تقع حول مدينة خانقين ضمن الجزء الجنوبي من الحوض، فيما تتواجد منطقتين واعدة لاستثمار المياه الجوفية من المكمن المحصور تقعان إلى الجزء الغربي من الحوض وقرب الحدود الدولية بين العراق وايران ضمن الجزء الشمالي من الحوض.

الكلمات المفتاحية: نظام المياه الجوفية ، حوض خانقين ، محافظة ديالى .