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Hydraulic Parameters of Groundwater Aquifers in Khan-Al-Baghdadi Area

Abstract - *The mainly objective of groundwater studies is assessment the physical characterizations of water-bearing layers. Conducting and analyzing aquifer tests is one of the most efficient ways to assessment these characterizations. The aim of this research is to carry out hydrogeological investigation in Khan Al-Baghdadi area within Anbar Governorate in the west of Iraq to evaluate hydraulic properties of the most important groundwater aquifers in order to achieve optimum use of groundwater in term of sustainable water management by using Cooper-Jacob and Theis Recovery Test methods to calculate transmissivity and storage coefficient after field investigation of aquifers extended in the area where geographical position, elevations, static water levels, depths, thicknesses and maximum yields were carried out. The results showed that Khan Al-Baghdadi area has only confined aquifer within the geological formation extended in area. The average transmissivity and storage coefficient parameters, which calculated using two wells, drilled in the area were (33.966-1171) m^2/day and ($2.2*10^{-4}$-$2.07*10^{-2}$) respectively, dependent on cooper-Jacob and Theis recovery solutions. Transmissivity distribution contour map showed increased values towards southwest part of the area while gradually decreased values was recorded in the eastern and southeast part of the area.*

Keywords*- Groundwater Aquifer, Hydraulic Parameters, Khan Al-Baghdadi area.*

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1. Introduction

Worldwide, more than a third of all water used by humans comes from ground water. In rural areas, the percentage is even higher: more than half of all drinking water worldwide is supplied from ground water [1]. The continuing of groundwater extraction from the aquifers for all purposes is contributing to groundwater depletion in many parts of world [2].

Ground-water hydrology is the subdivision of the science of hydrology that deals with the occurrence, movement, and quality of water beneath the Earth's surface. Estimating the physical properties of water-bearing layers is an essential part of groundwater studies. One of the most effective ways of determining these properties is to conduct and analyze changing, with time, water levels (or total heads) of aquifers caused by withdrawals through wells [3]. This type of study is referred to as an aquifer test and, in most cases, includes pumping a well at a constant rate for a period ranging from several hours to several days and measuring the change in water level in observation wells located at different distances from the pumped well [4].

Evaluate and analyze the data of aquifer test is a science because it is based on theoretical models, where the geologist or engineer must understand on thorough when they conducting the test investigations on geological formations in the area. The analysis data and aquifer test evaluation, the main distinguished three types of aquifer are: confined, unconfined, and leaky aquifer [5].

Khan Al-Baghdadi area locate to northwest of Anbar governorate in the west of Iraq. The area covers (6290) km^2 within (41º 50'- 42 º 45') E and (33 º 30 ' - 34 º 15') N, the area is relatively flat, rises gradually and gently westwards, except the northwestern part of the area, where slopes have gentle gradient towards north. The attitude, of the area, varies from 347m, above sea level in the western part and less than 100 m near Hit city to the east, Figure 1.

The work plan in the studied area included the following:

1- Office work including preparing data and preliminary information of the area.

2- Field work including:

- Inventory of wells and measuring water levels as well as determine Geographical positions and other hydrogeological properties of (29) wells using (GPS) device during (2010-2011).

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- Drilling (2) wells of (100) meters depths and (2) observations wells of (50-80) meters depth at (30-50) meters distance to drilled wells respectively.
- Pumping test operations in (2) wells to evaluate hydraulics parameters of aquifers.

The aim of this research is to carry out hydrogeological investigation in Khan Al-Baghdadi area within Anbar governorate in the west of Iraq to evaluate hydraulic properties of the most important groundwater aquifers in order to achieve optimum use of groundwater in term of sustainable water management.

In general, several previous studies have been done in western desert and the area of study as mentioned below:

1- Hydrogeology of groundwater aquifers in the Western Desert - west and southwest of the Euphrates River [6].

2 - Assessment of groundwater resources in Iraq and management of their use [7].

3 - Transboundary aquifers between Iraq and neighboring countries [8].

4- Hydrogeological study of Khan Al-Baghdadi area in Anbar governorate - West of Iraq [9].

5- Influence of Structural Factors on Groundwater System - West of Iraq [10].

6- Calculating of Groundwater Recharge using Meteorological Water Balance and Water level Fluctuation in Khan Al-Baghdadi Area [11].

2. Geological Setting

The area is built up of sedimentary rocks ranging in age from lower Oligocene to Pliocene, with different types of Quaternary deposits (Pleistocene-Holocene), Figure 2 [12].

The stratigraphic sequences of geological formations in the area of study as fellows [13]

- Shurau and Sheikh Alas formations (Lower Oligocene): Composed of limestone recrystallized, - Anah formation (Lower Oligocene): Consists of massive very hard limestone and dolomite limestone.
- Euphrates formation (Lower Miocene): It consists of thin basal conglomerate or basal clastic with recrystallizedy cherty, silicified, ferruginous and marly limestone, and greenish marl.
- Fatha (Lower Fars) formation (Middle Miocene): Its normal lithological constituents of cyclic nature (marl, limestone, gypsum and claystone).
- Quaternary deposits consist of:
- River terrace (Pleistocene): Composed of medium grained, well rounded pebbles
- Gypcrete (Pleistocene-Holocene): Composed of secondary gypsum or highly gypiferous soil.
- Slope deposits (Pleistocene -Holocene): Composed of sand, silt and clay with rock fragments.
- Residual Soil (Pleistocene-Holocene): Consists of sandy, silty clayey, brown soil with limestone fragments.
- Valley fill deposits (Holocene): Consist of gravels mixed with sand, Figure 2 and 3 [13].

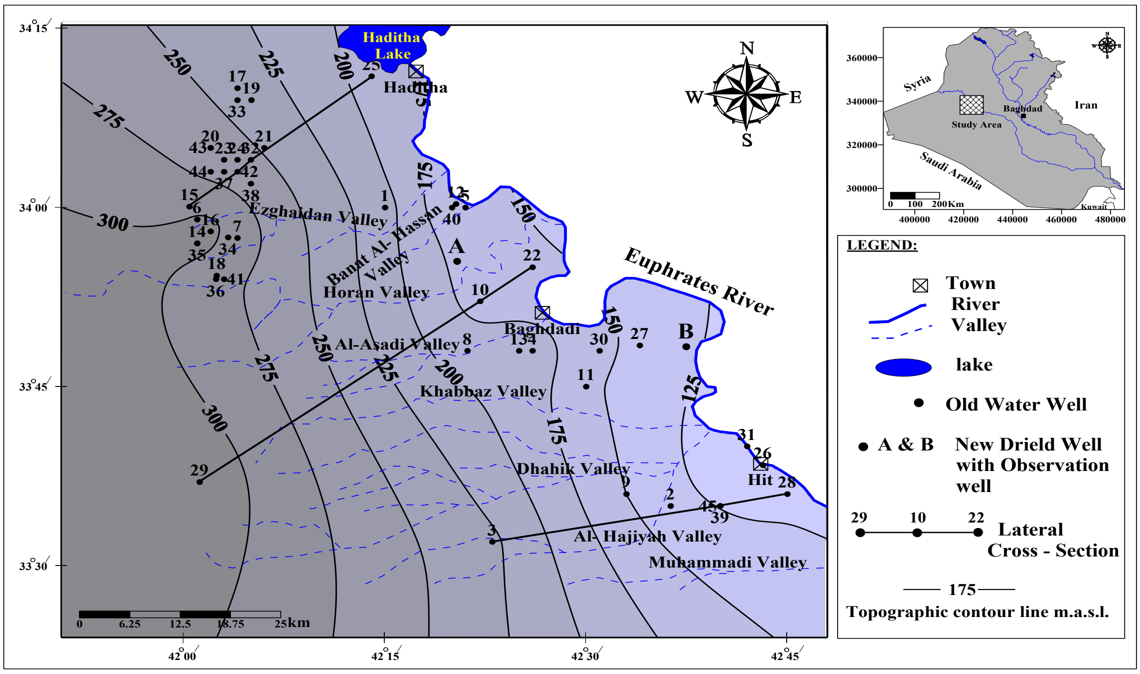

Figure 1: Topographic, geological cross sections and wells location map in Khan Al-Baghdadi Area [9]

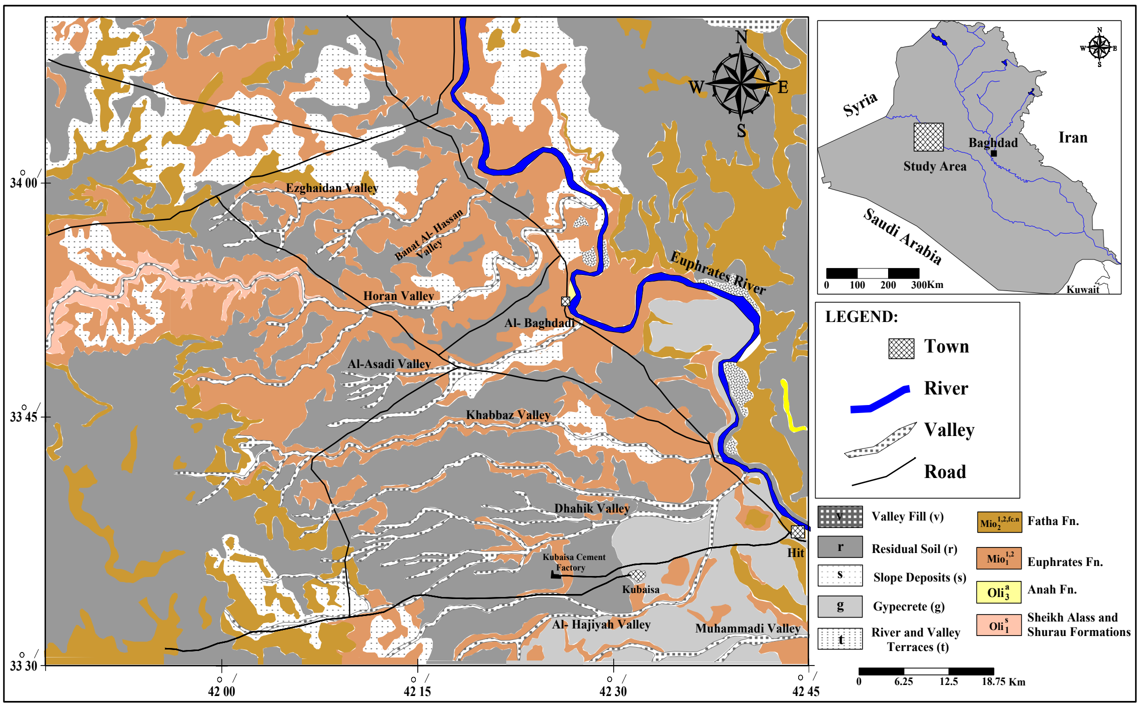

Figure 2: Geological map of Khan Al-Baghdadi Area [12].

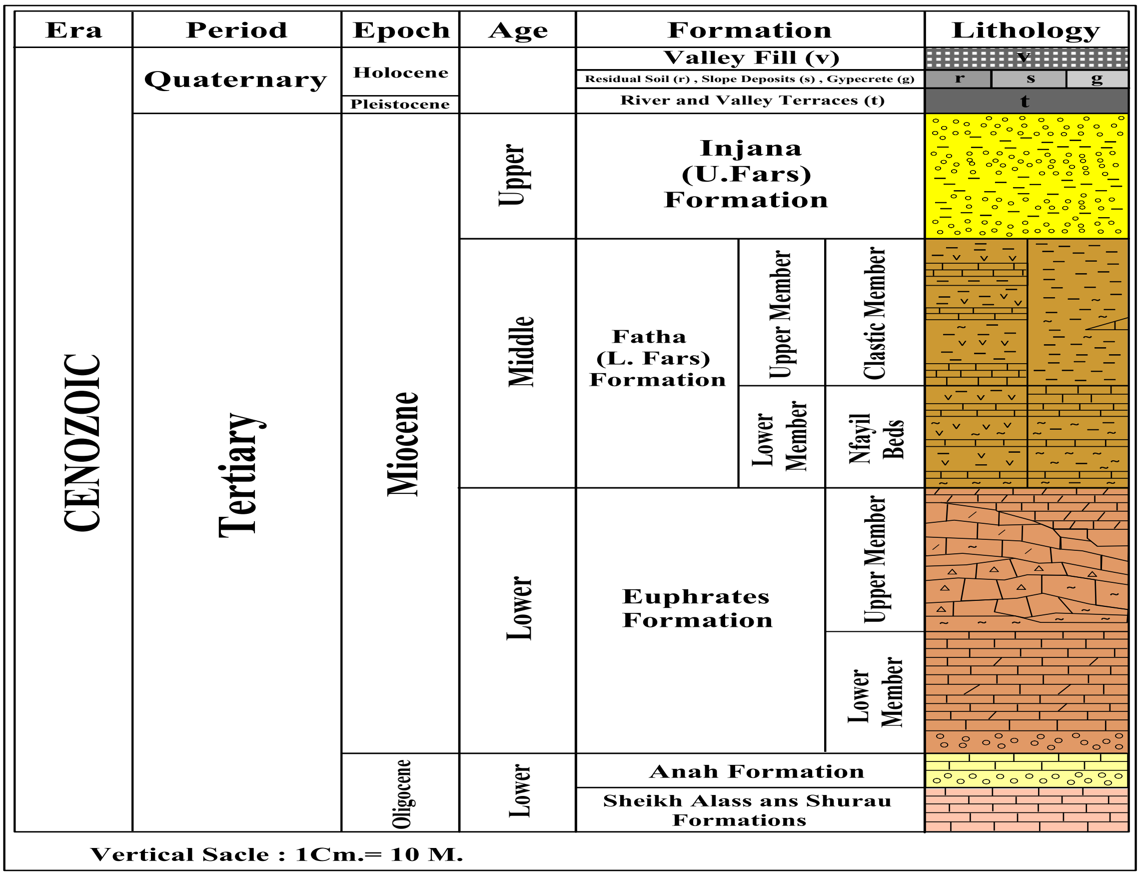

Figure 3: Stratified sequence of geological formations in the studied area [13].

3. Materials

The materials used in this study were:

1- Topographic, geological and tectonic maps of area with different map scale.

2- GPS device to determine wells locations and elevations as well as others hydrogeological properties.

3- Stratigraphic sheets and hydrogeological data bank [14].

4- Cooper - Jacob and Theis Recovery Test equations.

5- Grapher and Surfer programs demonstrating graphs and contour maps.

4. Methodology

Depending on 29 inventoried wells and 18 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 in order to estimate aquifer hydrogeological properties. The aquifer was investigated during fieldwork where geographical position, elevations, static water levels, depths, thicknesses and maximum yields has been carried out. The methodology depends on using (Cooper-Jacob) [15] and Theis Recovery Test methods [16] to evaluate hydraulics properties of groundwater aquifers. Pumping test operations was done in two steps; first step was pumped water and measuring water levels and recovery in observations wells at 20/11/2010 and 27/12/2010, while second step was pumped water and measuring the water levels in pumping wells at 27/12/2010. Mathematical programs (Grapher and Surfer) were used to demonstrate the obtained results in drawing Geological cross sections as well as contouring maps demonstrating hydrogeological properties of groundwater aquifer.

5. Rustles and Discussion

I- Hydrogeological properties of confined aquifer

According to 47 wells investigated in area, Figure 1, the results showed that Khan Al-Baghdadi area has only confined aquifer within the geological formation extended in area, Figure 4. It can be seen that geological water bearing layers in the western part of area consist of Tayarat, Umm Er-Radhuma and Dammam (subsurface) formations especially in the northwestern part of the area, (Figure 4) sections A,B. The groundwater is confined in Umm Er-Radhuma and Dammam formations in the central part of the western side, (Figure 4) sections B. Anah and Euphrates formations becomes the essential geological water bearing layers in the northeast part of the area, (Figure 4) section C. The most important characteristic of the geological formations and its aquifers in the eastern area of Western desert and in the north region of Anbar governorate is hydraulic connections among sequenced geological formations where groundwater moves from deeper water-bearing layers into lesser depth through groundwater flow to eastern direction [6,9]. Table 1 showed the statistical data of hydrogeological properties of aquifer in the area of study. According to this, Fatha, Euphrates and Anah formations are non water bearing layers or dry in the western area of the region, while gradation of groundwater aquifers from eastern side of the basin to the western side presented as Fatha, Euphrates, Anah, Dammam, Umm Er-Radhuma and Tayarat formations according to the vertical sequence of geological formations [10,11].

Table 1: Statistical data shows aquifer hydrologeological properties in the area

Statistic	Number of values	Minimum	Maximum	Mean	Standard deviation
Elevation (m)	32	100	316.9	217.72	67.781
Static water level (m.)	43	0	154.7	61.67	42.654
Dynamic water level (m)	42	1.5	155.9	73.324	39.011
Piezomteric level (m.a.s.l.)	31	69	219	161.97	36.264
Total depth (m)	47	45.5	902.6	152.03	122.07
Aquifer depth (m)	34	31	154.7	79.288	30.944
Thickness (m.)	42	15	110	62.11	26.61
Maximum yield (m^3/day)	45	76	6480	859	993.73

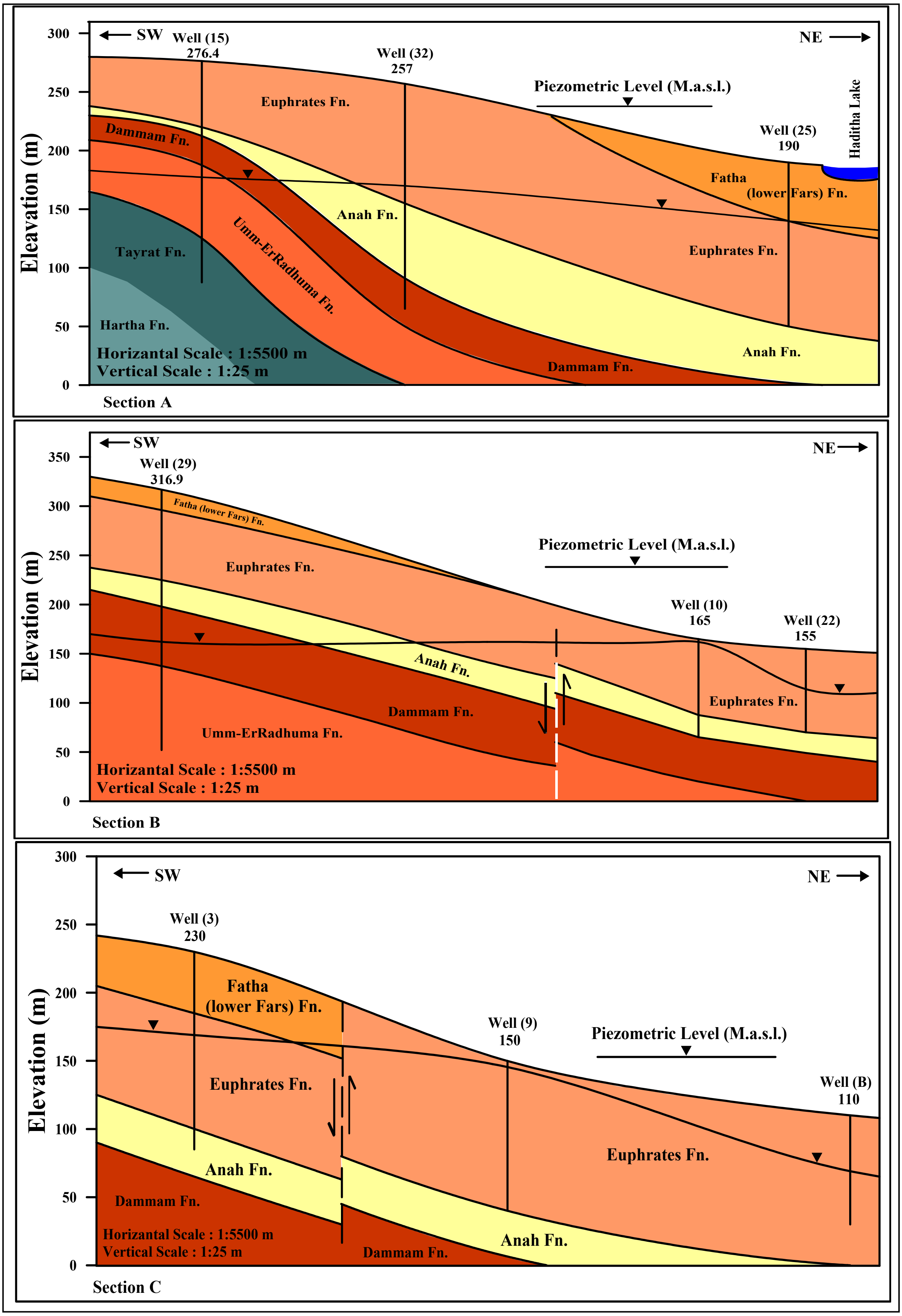

Figure 4: Lateral cross -sections in studied area [11].

Groundwater flow direction map prepared depending on (31) wells and table1 (Figure 5). Groundwater flow map shows increasing depth of water levels in the western side of the area and decreased gradually towards eastern side of the basin in a confined aquifer. The Plunging anticline, transverse fault and vertical fault affect on groundwater flow, as the western plunging anticline divided groundwater flow path into northeast, south and southeast. The groundwater which moves from right limb of plunging anticline merge with water moving from left side of transverse fault and Abu-Jeer sub surface fault indicated in south part of the basin producing several springs as shown in Figure (4) sections B and C [9,10].

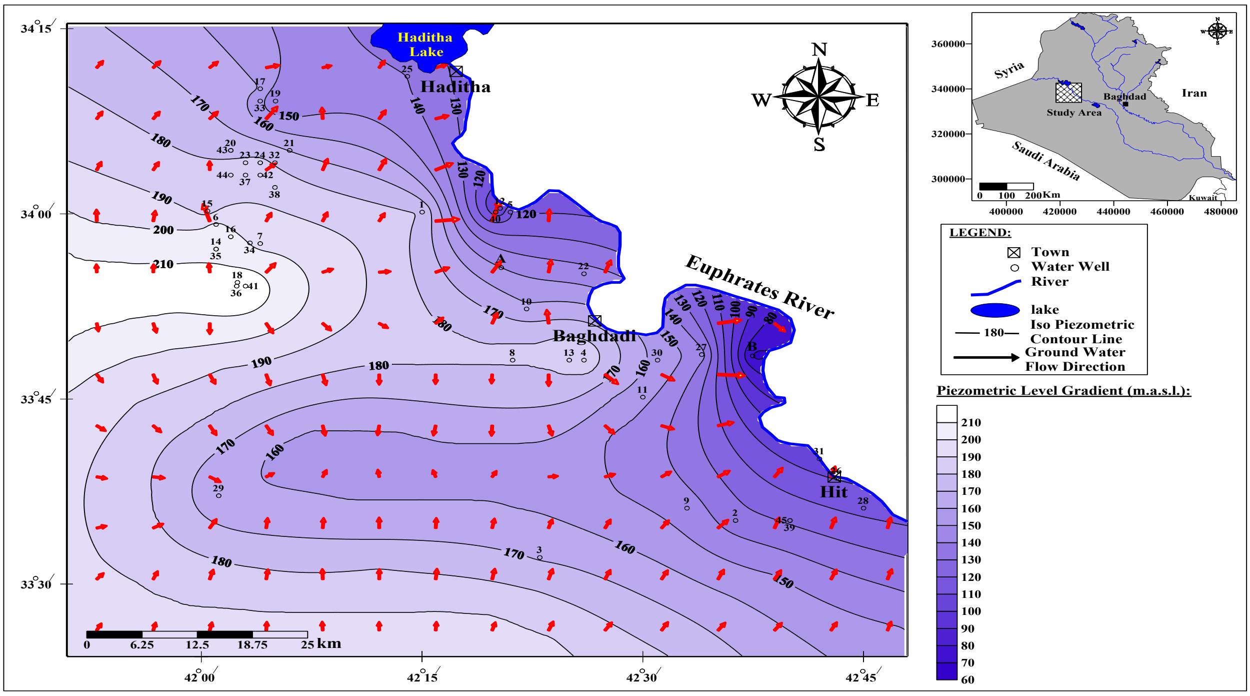

Figure 5: Groundwater flow direction in Khan Al-Baghdadi Area.

II- Hydraulic Parameters calculation

Aquifer test principle is simple: pumping water from a well penetrates the aquifer, and measuring the changing in water levels as well as in piezometers with continuous discharging water from the well at known distances from the pumping well. The water level changing induced by the pumping is known as the drawdown. In the literature, pumping tests referred to aquifer tests based on the analysis of drawdown during pumping [17,18]. Determining the yield of groundwater systems require, among other information, knowledge of:

1. The position and thickness of aquifers and confining beds.
2. The transmissivity and storage coefficient of the aquifers.
3. The hydraulic characteristics of the confining beds.
4. The position and nature of the aquifer boundaries.
5. The location and amounts of ground-water withdrawals. Acquiring knowledge on these factors requires both geologic and hydrologic investigations [18,19] .

Pumping test operations start by pumping water from the well drilled in aquifer, which reduces the water level (either water table or piezometric level) around the pumping well. This operation creates cone of depression rapidly due to discharge of the water stored in aquifer. Continuous discharge of water causing the cone of depression becomes wider and deeper with time as the compensation of the discharged quantity of water becomes lesser due to the resistance of porous media to the water movement towards the well leading to decrease the water storage in aquifer. This situation will cause increasing cost of pumping operations, decreased well productivity and depletion of groundwater aquifers [20]. Hydraulic conductivity, transmissivity and storage coefficient are most important parameters that controlling aquifers ability on storage and productivity, where number of mathematical methods and equations are used to obtain the values of these parameters, such as the (Cooper-

Jacob) [15] and Theis Recovery Test methods [16] in the case of unsteady flow, using following equations [21]:

$$T = \frac{2.3Q}{4\pi\Delta S} \quad \text{Cooper - Jacob Solution} \qquad (1)$$

$$Sc = \frac{2.25Tt_{\circ}}{r^2} \qquad (2)$$

$$T = \frac{2.3Q}{4\pi\Delta S'} \quad \text{Theis Recovery Solution} \qquad (3)$$

ΔS، $\Delta S'$: Drawdown in one logarithmic cycle (m).
to: Time at zero drawdown (Day).
r = Radius between pumping well and observation well (m).
Q= Well discharge (m^3/day).
T: Transmissivity (m^2/day).
Sc: Storage coefficient.

Table 2 shows the data of the pumping wells drilled in the Khan Al- Baghdadi area, which were used to obtain the values of the hydraulic parameters of groundwater aquifer, while Figure 1 shows location of these two wells. The pumping test operations were carried out in two steps:

1- Pumped water and measuring water levels and recovery in observations well at 20/11/2010 and 27/12/2010.

2- Pumped water and measuring the water levels in pumping wells at 27/12/2010.

Table 3 showed the calculated hydraulics parameters of groundwater aquifer in the area, while Figures (5-10) illustrate (Cooper-Jacob and Theis Recovery) of two wells drawings respectively.

According to pumping test results and depending on data available in pervious works [6,9] as well as data obtained from hydrogeological data bank, the transmissivity contour map was drawn in Figure 11.

The map showed that transmissivity increased towards southwest part of the area while gradually decreased values was recorded in the eastern and southeast part of the area. This variation of transmissivity distribution within the area resulted by horizontal and vertical fractures and joints effects on aquifer layers which formed by limestone, dolomite limestone and marly limestone of Umm Er-Radhuma, Dammam, Anah, Euphrates and Fatha formations [9].

The tectonic and structural geology of the area characterized by different structural zones from east to west, The Tigris subzone up to the Mesopotamian zone of the Unstable Shelf and the Salman and Rutba-Jazira zones of the Stable Shelf [12]. There are two transversal deep seated faults, within the area, these are Anah-Fatha Qalat Dizah Fault and Amij - Samarra - Halabcha Fault, and both of them have NE-SW. Another important structural feature is Abu-Jeer fault zone, which is also sub surface fault, running N-S. [12]. these faults and folds have a special affects on groundwater aquifers extended in the area represented by limestone and dolomitic limestone of Dammam, Anah, Euphrates and Fatah formations which increase or decrease fractures and cavities storing and transmits groundwater [10]. The obtained results of both transmissivity and storage coefficient were varied, especially of transmissivity coefficient which is strongly affected by the presence of fractures and cavities in carbonate rocks. Therefore, the distribution of these fractures and cavities were distributed irregularity within the aquifers, which affects the values of the results obtained from the pumping tests. Figure 4 section (B) showed lateral geological section where well (A) located just a few kilometers to the north of well (10) as seen in Figure 1, where vertical faults affects on aquifer which increased values of both transmissivity and storage coefficients. Well (B) located almost to the east of the area near Euphrates river where structural factors were less effectiveness on aquifer where hydraulic coefficients obtained from pumping test were decreased.

Table 2: Pumping wells data drilled in the Khan Al-Baghdadi area

Well Name	Elevation (m)	S.W.L. (m)	Depth of Pump. well (m)	Depth of Obs. well (m)	Saturated Thickness (m)	Discharge (m^3/Day)
A (Alus)	195	47	100	٨٠	55	864
B (Baider)	110	41	100	٥٠	59	864

Table 3: Hydraulics parameters of groundwater aquifers in Khan Al-Baghdadi area

Well No.		A (Alus)		B (Baider)		Date
Cooper-Jacob Solution	to (min)	4		12.7		
	△S (m)	3.5		0.17		
	T_1 (m^2/Day)	45.18		930		20/11/2010
	Sc	$3.1*10^{-4}$		$7.3*10^{-3}$		
	to (min)	6.5		130		
	△S (m)	3.8		0.2		
	T_1 (m^2/Day)	41.61		790.6		27/12/2010
	Sc	$4.7*10^{-4}$	Observation Well	$6.4*10^{-2}$	Observation Well	
Theis Recovery Solution	to (min)	1.15		1.46		
	△S (m)	6.25		0.25		
	T_1 (m^2/Day)	25.3		632.5		20/11/2010
	Sc	$5*10^{-5}$		$5.7*10^{-4}$		
	to (min)	1.38		9		
	△S (m)	6.375		0.08		
	T_1 (m^2/Day)	24.8		1976		27/12/2010
	Sc	$5.9*10^{-5}$		$1.1*10^{-2}$		
Cooper-Jacob Solution	△S' (m)	4.8	Pumping Well	0.135	Pumping Well	27/12/2010
	T_2 (m^2/Day)	32.94		1171		
Average T (m^2/Day)		33.966		1100		
Average (Sc)		$2.2*10^{-4}$		$2.07*10^{-2}$		
Radius (m)		30		50		

to: Time at zero drawdown (Day).
△S: Drawdown in a one logarithmic cycle in observation well (m).
△S': Drawdown in a one logarithmic cycle in pumping well (m).
T_1: Transmissivity obtained in observation well (m^2/day).
T_2: Transmissivity obtained in pumping well (m^2/day).

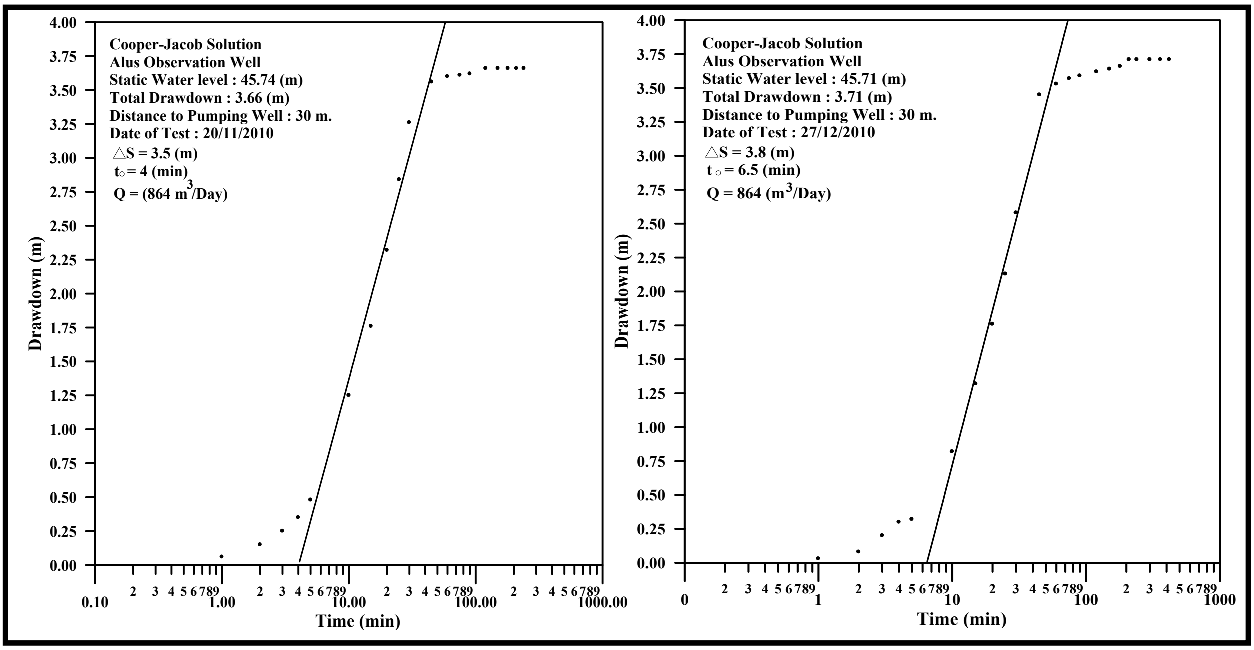

Figure 5: Pumping test (observation well - cooper-Jacob solution) results of well (A)

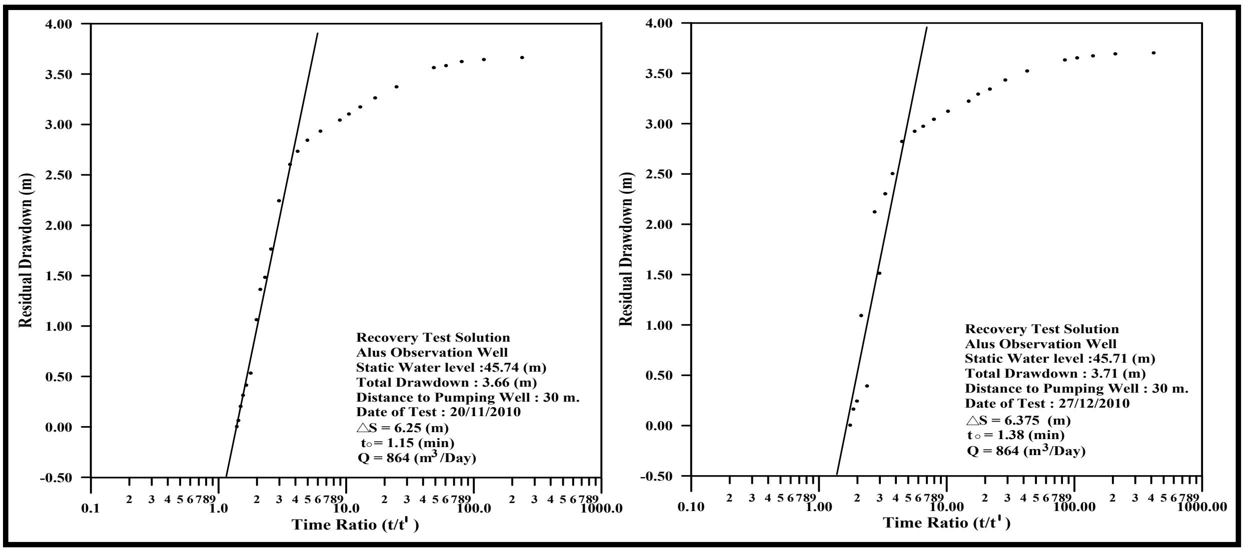

Figure 6: Pumping test (observation well - recovery solution) results of well (A).

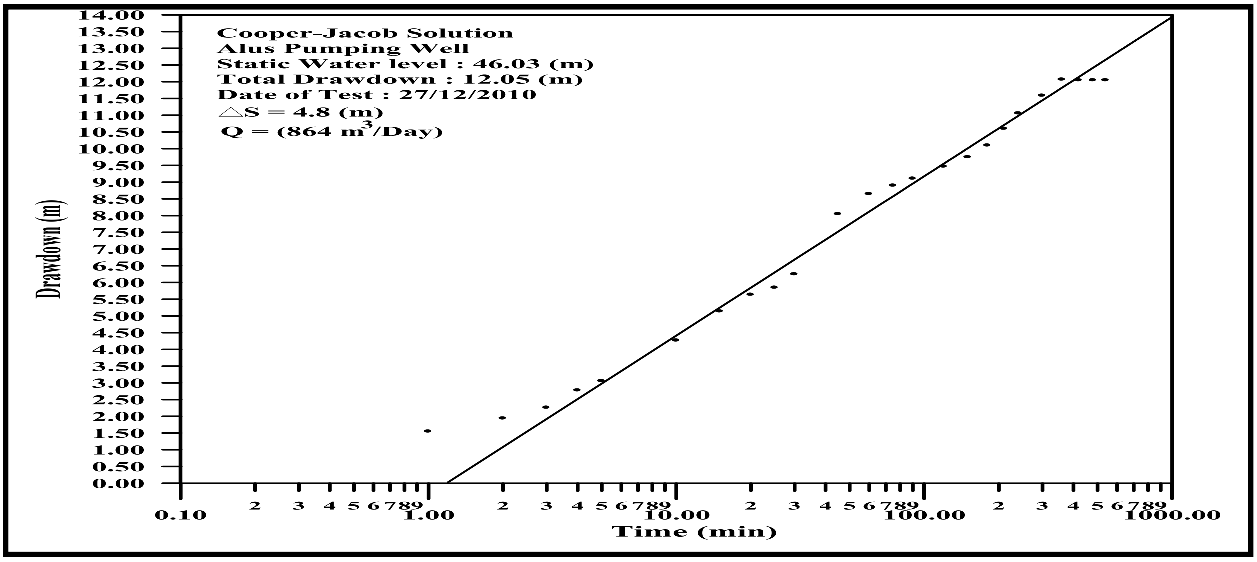

Figure 7: Pumping test (pumping well - recovery solution) results of well (A).

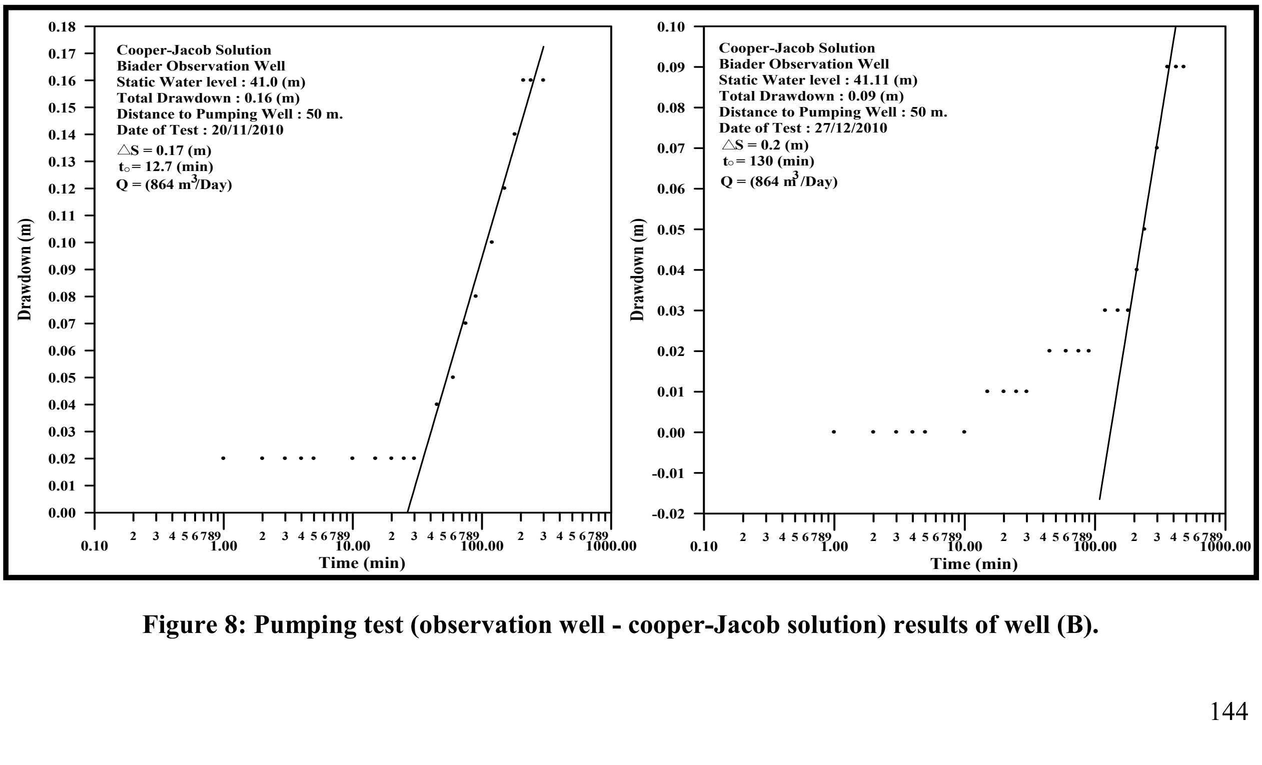

Figure 8: Pumping test (observation well - cooper-Jacob solution) results of well (B).

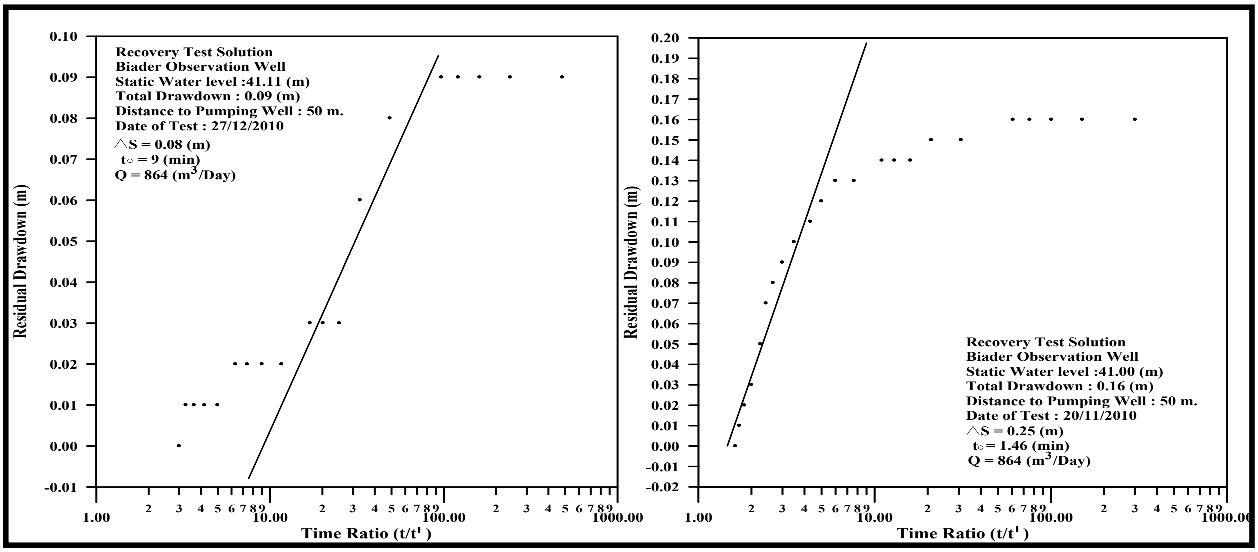

Figure 9: Pumping test (observation well - recovery solution) results of well (B).

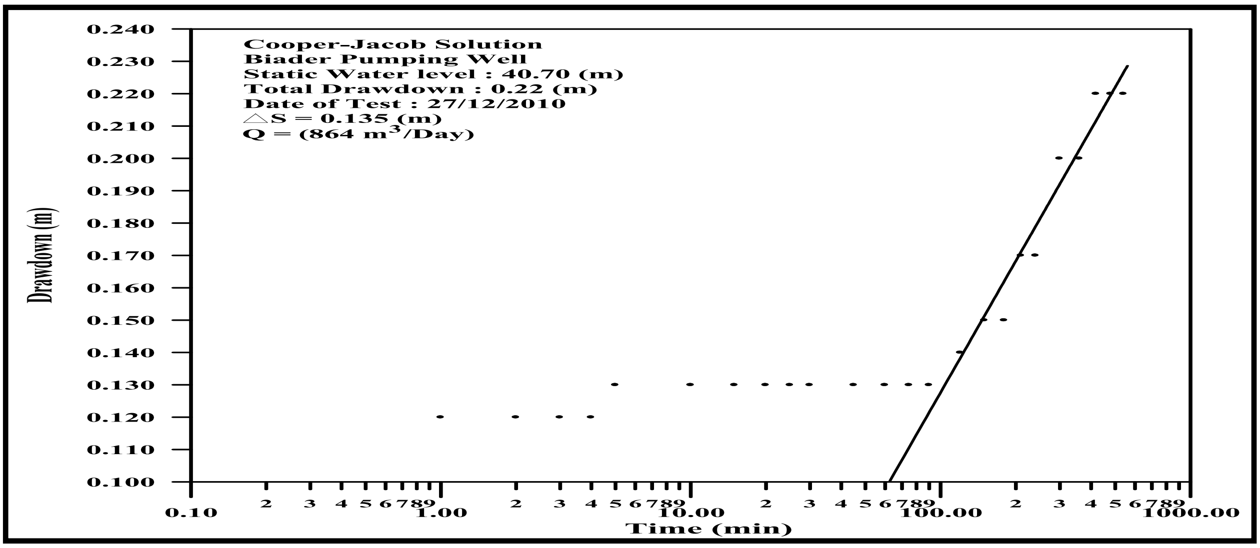

Figure 10: Pumping test (pumping well - recovery solution) results of well (B).

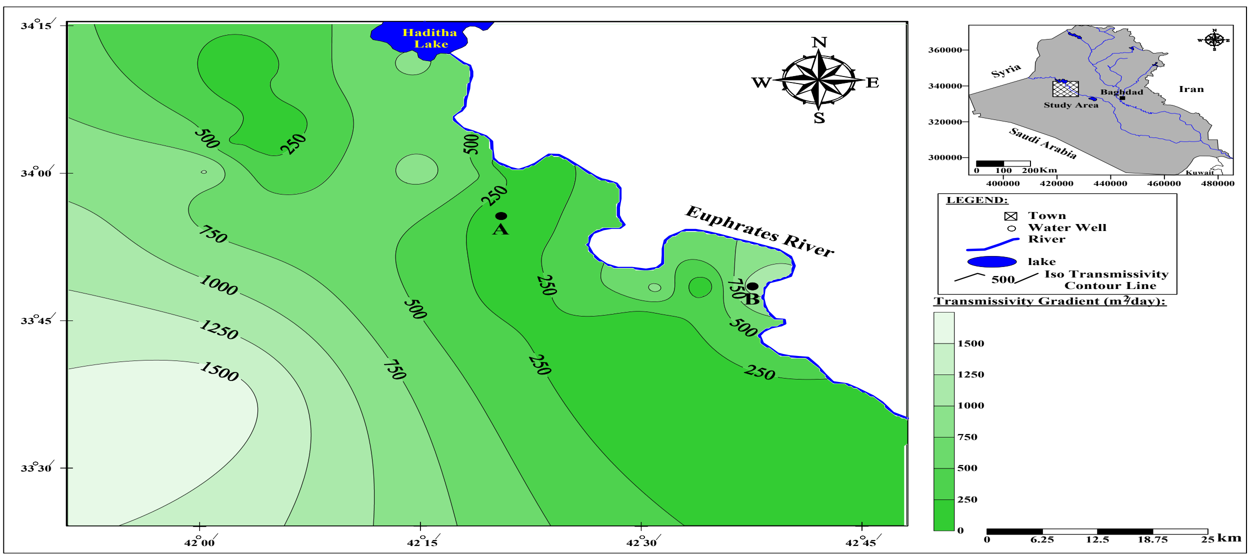

Figure 11: Transmissivity distribution contour map of aquifer in Khan Al-Baghdadi area.

6. Conclusions

1- According to 49 wells (investigated, data bank and drilled wells in area) the results showed that Khan Al-Baghdadi area has only confined aquifer within the geological formation extended in area.

2- Groundwater flow map shows increasing depth of water levels in the western side of the area and decreased gradually towards eastern side of the basin in confined aquifer.

3- The average transmissivity and storage coefficient parameters, which calculated using two wells, drilled in the area were (33.966-1171) m^2/day and ($2.2*10^{-4}$-$2.07*10^{-2}$) respectively dependent on cooper-Jacob and Theis recovery solutions.

4- Transmissivity distribution contour map showed increased values towards southwest part of the area while gradually decreased values were recorded in the eastern and southeast part of the area.

5- This variation of transmissivity distribution within the area resulted by horizontal and vertical fractures and joints effects on aquifer layers which formed by limestone, dolomite limestone and marly limestone.

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