Estimation the hydrogeological characteristics of Al-Dammam confined aquifer in the west and southwest of Karbala city, Iraq.

تقدير الخصائص الهيدروجيولوجية لمكمن الدمام الجوفي المحصور الواقع غرب وجنوب غرب مدينة كربلاء، العراق.

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Abstract

The main objective of the research is to identify the hydrogeological characteristics of the Dammam confined aquifer by selecting carefully nine wells of suitable properties for carrying out the pumping test within study area. The study area is located in Karbala Governorate between longitudes (43˚ 47′ 58″E - 43˚ 59′ 45″E), and latitudes (32˚ 26′ 54″N - 32˚ 33′ 16″N).The study area has a trapezoidal shape covering an area of about (134.6) km^2, which contains many geological formations and represents part of Karbala-Najaf plateau. The producing hydrogeological unit in the area is the Dammam aquifer. Type of this aquifer is karst confined aquifer. In this study, a pumping test was performed on November, 2012, at a wells on Karbala desert area then applying AQTESOLV software version 4.5 for pumping test analysis to determine wells hydraulics for the nine deep wells that partially penetrated the Dammam aquifer and distributed all over the studied area. The results indicate that the transmissivity value for the Dammam confined aquifer ranges from (26.19-4134.6) m^2/day and the hydraulic conductivity value ranges from (0.44-45.94) m/day.

Keywords: Irrigation Water Quality Index, GIS, Dammam aquifer, Karbala desert.

خلاصة

الهدف من هذا البحث هو التعرف على الخصائص الهيدروجيولوجية لمكمن الدمام عن طريق اختيار تسعة آبار مناسبة وموزعة في منطقة الدراسة لعمل الضخ الاختباري لها .تقع منطقة الدراسة في محافظة كربلاء بين خطي طول (43˚ 47′ 58″E - 43˚ 59′ 45″E) ودائرتي عرض (32˚ 26′ 54″N - 32˚ 33′ 16″N) ولها شكل شبه منحرف حيث تغطي مساحة تقدر بـ 134.6 كم^2 تقريبا ، محتوية على العديد من التكوينات الجيولوجية و تمثل جزءا من هضبة كربلاء- نجف. تمثل الوحدة الهيدروجيولوجية المنتجة في منطقة الدراسة مكمن الدمام الجوفي وهو(مكمن كارستي محصور).. تم اجراء عملية الضخ الاختباري للابار في شهر تشرين الثاني 2012.وبناءا على نتائج هذه الاختبارات تم استخدام برنامج (AQTESOLV) الخاص بتحليل نتائج الضخ الاختباري لتحديد المعاملات الهيدروليكية للابار ، لكون هذه الآبار تخترق مكمن الدمام جزئيا وموزعة في جميع أنحاء منطقة الدراسة، دلت النتائج أن قيمة معامل الأستنقال (Transmissivity) يتراوح من 26.19 إلى 4134.6 م^2/يوم وتراوحت قيمة الايصالية الهيدروليكية من 0.44 إلى 45.94 م/يوم.

1. Introduction

Water resources shortages have become an increasingly serious problem, particularly in arid and semi-arid area like Iraq. Iraq may be considered a fortunate country in water resources compared to other countries of the arid and semi-arid in the Middle East. Two important rivers Tigris and Euphrates, though originate in the heights of neighboring Turkey and Iran, flow ultimately through its territory before joining and discharging in the Arab Gulf. Moreover, Iraq possesses groundwater resources of some potential which are not yet totally accounted for. Nevertheless, with the steadily increase of Iraq water demand, the unsettled dispute among the riparian countries on the sharing of the resources of the two rivers, and the ongoing traditional methods of water resources management, Iraq will face a shortage in usable water resources in the near future.

Numerous studies have been conducted to investigate flow dynamics and associated parameters in aquifers and pumping wells. Kruseman and De Ridder (2000) presented the most important methods nowadays available for the evaluation of pumping test data. For a confined aquifer, several methods were proposed to determine hydraulic parameters from aquifer tests under transient radial flow (Cooper and Jacob, 1946; Hantush, 1956, 1960; Jacob, 1950; Neuman and Witherspoon, 1969; Theis, 1935; Walton, 1960). These methods were applicable to the data obtained from the field tests.

No detailed studies about the study area are available, but there are general hydrogeological studies. The main studies can be listed as follows:

Parsons (1957), made a comprehensive regional study of the western desert and the southern desert, taking into consideration the hydrogeological conditions of water resources including overall climatic and geologic information of the region. One of the most important studies on the western desert is that of the Consortium-Yugoslavia, (1977) to implement the study of the hydrogeology called (Block, 7) of the western desert which included investigations on an area of (60000) km^2 covering the sheets of 1:250,000 scale including AL bu Kamal, Haditha, H1, Wadi Tabbal, Ramadi ,Karbala and Shithathah. It assessed the sources of water resources, quality and suitability of groundwater for different purposes, and the system of the aquifer (locations and extensions of the unconfined and confined aquifers) that covered most of the area.

In 1989, Al Furat Center for Studies and Designs of Irrigation projects completed a national geological and hydrogeological study of western desert which included hydrogeological and geophysical sections, analysis of wells logging, calculation of specific yield, and the chemical analysis of groundwater for a number of drilled wells, it also included a calculation of water balance in Iraq. Eskander (1994) carried out a regional study for the hydraulic properties of Al-Dammam formation in western desert. Al-Basrawi (1996) studied the hydrogeology of Al-Razzaza Lake basin; the study concluded an evaluation of lake water balance which revealed that its recharge is from surface runoff and groundwater flow. Al-Jiburi (2002) carried out a hydrogeological study of Karbala Quadrangle, scale 1:250000.Krasny and others in Jassim and Goff (2006) carried out a regional hydrogeological study of Iraq including the involving area. Hassan (2013) developed the modeling to classify groundwater of the Umm Er Radhuma unconfined aquifer within Iraqi western desert area. The previous literature reflects the hydrogeological knowledge of Dammam formation in the West and South West of Karbala which is still insufficient in comparison with the importance of groundwater for present and future uses. So, this area can be considered a virgin area because there were no previous details studies for it.

2. Study Area

The study area is located in western south of Karbala province center under the south coast of Al-Razzaza lake in Iraq. It located between latitudes (32˚ 26′ 54″N - 32˚ 33′ 16″N), and longitudes (43˚ 47′ 58″E - 43˚ 59′ 45″E), it forms about (134.6) km2 as shown in Figure (1). The main soil types of the study area are sedimentations of sand, gravel and gravelly sand with the existence of clayey lenses which are generally take the form of compacted clayey balls interfered with small amount of sand and gypsum working as agent material. The study area could be described as of smooth and easy topographic features, having a general elevation ranging between 50m-95m above sea level (m.a.s.l).

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The topographic elevation is derived from the digital elevation model (DEMs) produced by U.S. Geological Survey (USGS). The US DEM data files are digital representation of cartographic information in a raster format. DEM consists of a number of terrain elevation ground positions at regular horizontal intervals. The wells point elevations were surveyed manually by the TOTAL STATION leveling in order to calculate the exact elevation. Khalaf and Hassan (2013) used irrigation water quality index (IWQI) for Dammam Aquifer at Karbala, Iraq. The groundwater in this aquifer should be used only with the soil having high permeability with some constraints imposed on types of plant for specified tolerance of salts.

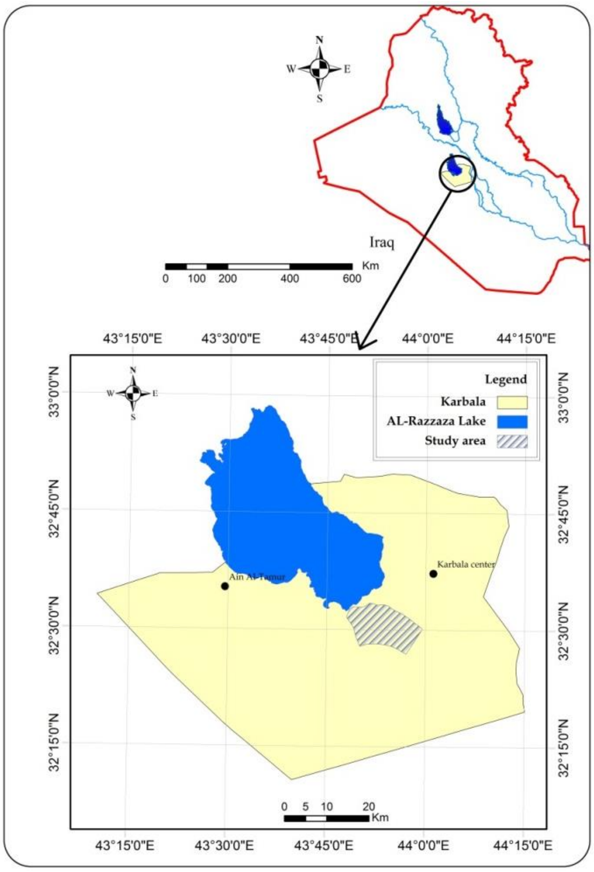

Figure (1): Geographical location of the study area relative to Iraq map.

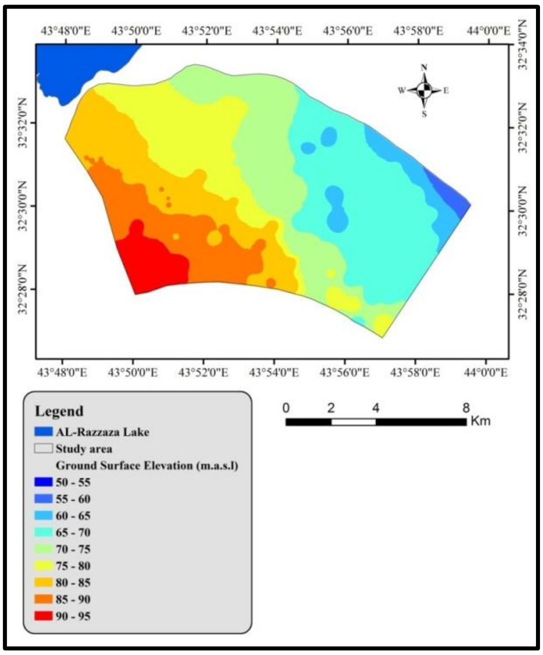

Figure (2): Topography of the study area (after US DEMs).

2.1 Geology of the area

Whole the study area is within the desert plain, a part of unstable shelf. It is with plain-like to slightly expressed hilly character. Generally, it is considered as a part of Karbala –Najaf plateau, which belongs to the Mesopotamia zone, and located in the central part of Iraq. All the studied area is covered by Gypcrete deposits. The lithology was obtained from 40 wells drilled by the General Commission of groundwater and the information obtained from coring well. The stratigraphic column in the study area consists of the following formations (in sequence from oldest to newest): Tayarat formation (Cretaceous), Umm Er Radhuma formation (Upper Paleocene), Dammam Formation (Eocene), Euphrates Formation (Early Miocene), Nfayil Formation (Middle Miocene), Fatha (Lower Fars) Formation (Middle Miocene), Injana (upper fares) Formation (Late Miocene) and Dibdibba Formation (Pliocene – Pleistocene).

2.2 Groundwater aquifer in study area

The geological formations, which contain groundwater and can be considered as water bearing formations within the basin in Karbala desert, are Tayarat, Umm Er-Radhuma, Dammam, Euphrates and Dibdibba formations. The geological investigations of the geological sections through deep boreholes showed the presence of rather complicated multi-aquifer system with impermeable sediments (mainly marl) being in lenses form, which locally separate the aquifers, (Al-Jiburi and Al-Basrawi, 2007). Among the above mentioned water bearing formations the most producing units within the study area are represented by the combination of two formations: Umm Er Radhuma and Dammam Formations, which represent the main reservoir of water produced in the region of study area, (Al-Jawad et al., 2002).

Figure (3); shows the extension of the Dammam formation and the stratigraphical position with other formations within study area.

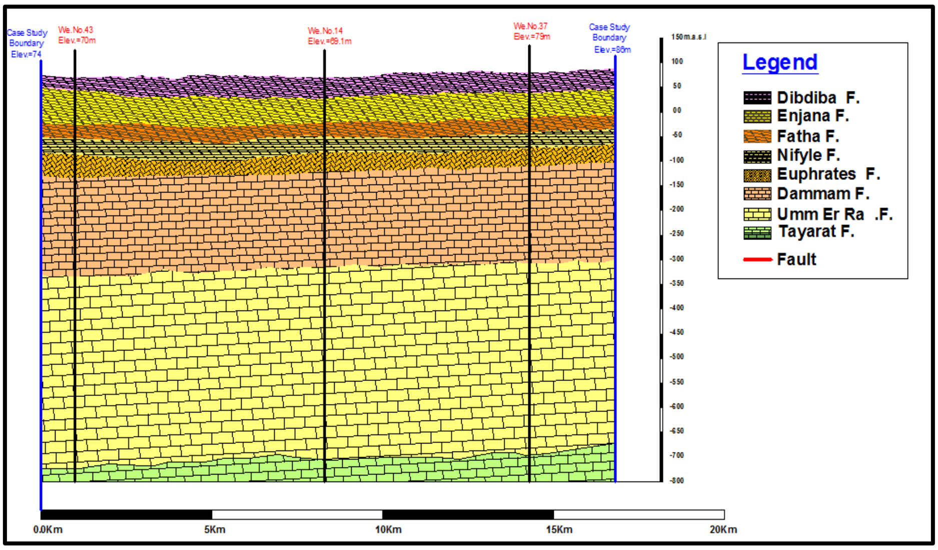

Figure (3): The stratigraphic correlation between the wells in the study area developed from (Consortium, 1977; Sissakian, 1995).

3. Dammam formation (Eocene)

Dammam Formation is one of the most important aquifers in South West Iraq. It is composed of variable carbonate rocks mainly limestone, dolomatic limestone and dolomite, with marl and evaporates. It is characterized by the presence of cavities and karstified canals in addition to fractures, fissures and joints, which cause the formation to have highest transmissivity and permeability, in most area (Jassim and Gaff, 2006).

Dammam formation extends throughout most of the Iraqi desert except areas affected by Rutba uplift. Figure (4) shows the distribution of Dammam exposed on the surface in desert of Iraq. The hydrogeological investigations in the Western and Southern Desert (Jassim et al., 1984) reflected that Dammam formation contains huge amount of groundwater. This aquifer is part of a complex hydrogeological unit within different formations and is considered as the main regional groundwater aquifer within the Western and Southern Desert, due to its wide extension and its content huge amounts of groundwater.

The transmissivity value of the Dammam varies between (3.1-4752) m^2/day reflecting a highly heterogeneous aquifer due to the variations in the density of its fractures and the porosity of its rocks (Al-Sa'adi, 2010). The storage coefficient values for the confined aquifer may attain a value of (1.2×10^{-4}) while the value of the specific yield is (2.45×10^{-2}) for the unconfined aquifer, (Al-Jawad and Khalail, 2001).The regional trend of groundwater movement in the western desert is generally towards the east and the northeast. But, locally, the flow of groundwater takes different directions throughout the region depending on geological, topographic and structural features, (Al Jiburi and Al Basrawi, 2007). Direction of flow in the Dammam aquifer, Figure (5) was generally from southwest to north east (i.e. towards Euphrates River) which it is within the regional groundwater flow direction of Iraq.

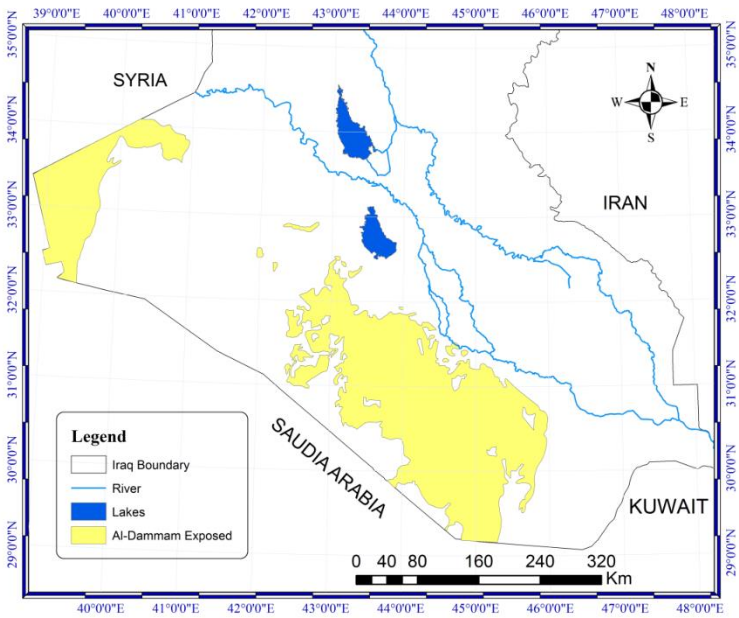

Figure (4): The distribution of Dammam outcrop on the surface in desert of Iraq developed from the Geological map of Iraq, 1995.

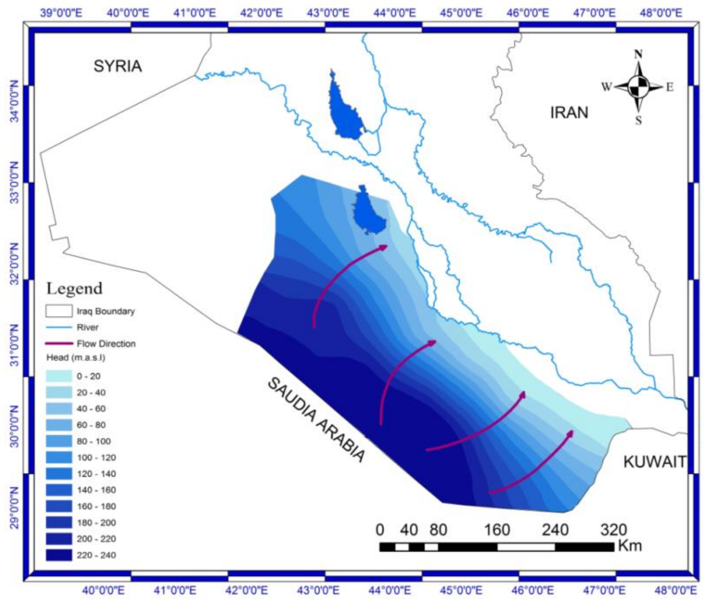

Figure (5): Groundwater movement of the Dammam aquifer.

4. The Pumping Test

When working on problems of groundwater flow, the engineer or geologist seeks to find reliable values for the hydraulic characteristics of the geological formations through which the groundwater is moving. Pumping tests were proven to be one of the most effective ways of obtaining such values. The principle of a pumping test involves applying a stress to an aquifer by extracting groundwater from a pumping well and measuring the aquifer response to that stress by monitoring drawdown as a function of time. These measurements are then incorporated into an appropriate well flow equation to calculate the hydraulic parameters of the aquifer. Numerous studies have been conducted to investigate flow dynamics and associated parameters in aquifers and pumping wells. Kruseman and De Ridder (2000) presented the most important methods nowadays available for the evaluation of pumping test data. Nine pumping tests were performed in the confined aquifer on nine scattered wells in the study area as shown in Figure (6).These tests have been conducted without observation wells. Thus the storage coefficient cannot be obtained. The data obtained from these tests were analyzed by Cooper - Jacob method, Kruseman and De Ridder (2000).

Due to the small quantity of expected from leakage between the two aquifers (Dammam and Umm Er Radhuma) and considering the large thickness of the Dammam aquifer (200m) with partial penetrating wells used in pumping test ,the aquifer could be adopted as a confined aquifer in pumping test analysis.

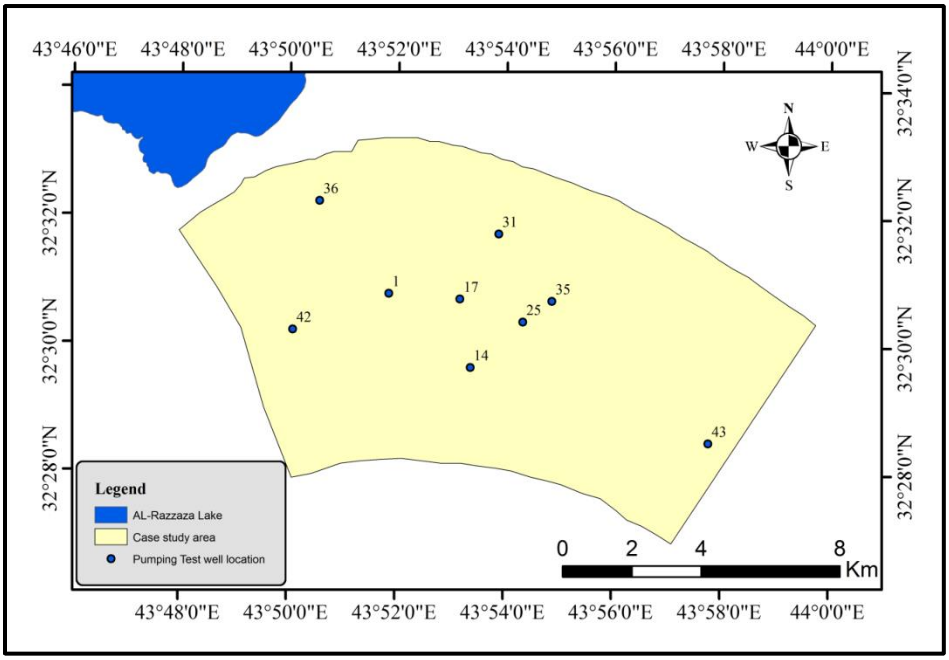

Figure (6): Location of the pumping test wells in study area.

5. Cooper-Jacob method

The Cooper-Jacob method initiated in 1946, commonly referred to as the straight-line method, is a simplification of the Theis solution developed in 1935 for flow to a fully penetrating well in a confined aquifer. The method may be used to analyze data from a single pumping well. For the Cooper-Jacob straight-line method, drawdown is plotted with an arithmetic scale on the y-axis versus time plotted with a logarithmic scale on the x-axis. Transmissivity (T) is estimated from the pumping rate (Q) and the change in drawdown per log-cycle (Δs) from the following equation (Kruseman and De Ridder, 2000):

$$T = \frac{2.3\,Q}{4\pi}\,\frac{1}{\Delta s} \qquad (1)$$

where,

T is aquifer transmissivity (L^2/T);

Q is the constant discharge rate (L^3/T); and

Δs is change in drawdown per log-cycle (L).

Well losses and partial-penetration have a minimal effect on transmissivity values that are estimated using the Cooper-Jacob method (Kruseman and De Ridder, 2000). The fitting field data to the Cooper-Jacob lines can be done by hand with logarithmic paper, but a software program, AQTESOLV v4.5, was used to apply an “automated-fit” method to this analysis. The AQTESOLV pumping test analysis provides a number of results for each well. These values include transmissivity, T, in m2/day and hydraulic conductivity K in m/day.

6. Results and Discussion

Figures (7) to (15) show time-drawdown data and AQTESOLV software output for each well that was analyzed. As a result, some of the time-drawdown lines generated using the Cooper-Jacob methods have better fits than others. Results are summarized in Table (1) and the distribution of transmissivity for study area is shown in Figure (16).

As shown in Table (1), the pumping test results indicate a wide range values for both transmissivity from 26 to 4134 m^2/day and hydraulic conductivities from 0.44 to 45.95 m/day. These wide range values are due to the type of Dammam aquifer, which is a karst confined aquifer double porosity. Most of the weak zones (fractures, joints, and bedding planes) consist of carbonate rocks (limestone and dolomite) which are highly soluble in water. This fact has been confirmed by the drilling of many wells for many projects whose depth ranged from (220m-280m). It was observed that these wells yield from 12 l/s to 30 l/s with a relatively small drawdown (less than one meter in some wells). In general, the porosities of this formation consist of cavities, solution channels and fractures; this is clear in the outcrop of this formation in Wadi Ubaiyid plate. Highest transmissivity value was found in well No.14, while low values were found in wells No. (25, 31, 35, 42 and 43).

Transmissivity (T) for a confined aquifer of thickness b is defined as $T=K\times b$, where K=aquifer hydraulic conductivity (L/T). The values of the hydraulic conductivity which has been obtained from pumping test analysis are extrapolated throughout the groundwater system in order to assign an appropriate value to each point within study area. This has been accomplished through preparing contour maps for the hydraulic conductivity values as shown in Figure (17).

7. Conclusion

applying AQTESOLV Professional software version 4.50 for pumping test analysis incorporated with the Cooper-Jacob method (1946) to evaluate the transmissivity (T) and the hydraulic conductivity (K) for nine deep wells that partially penetrated Dammam aquifer within west and southwest of Karbala city, Iraq and distributed all over the study area. The T- values ranged from (26.19-4134) m^2/day and the K- values ranged from (0.44-45) m/day. The hydraulic properties change from one location to another because of Dammam aquifer which is classified as a carbonate rocks aquifer and generally shows a variation in hydrogeological characteristics due to fracturing and dissolution.

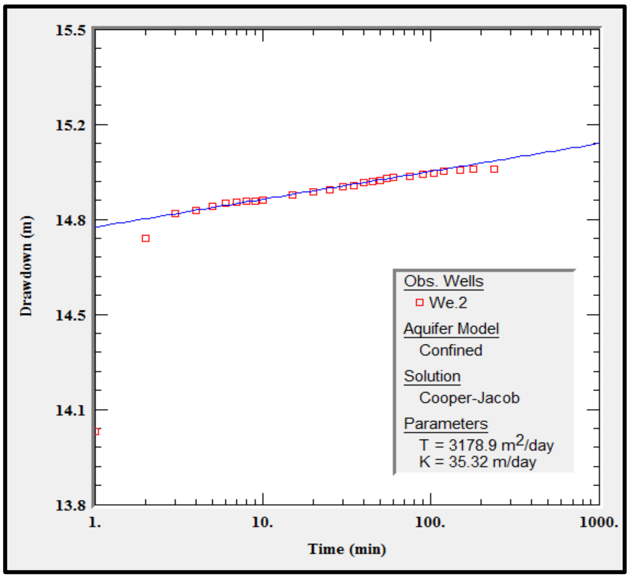

Figure (7): Time-Drawdown curve of well No.2.

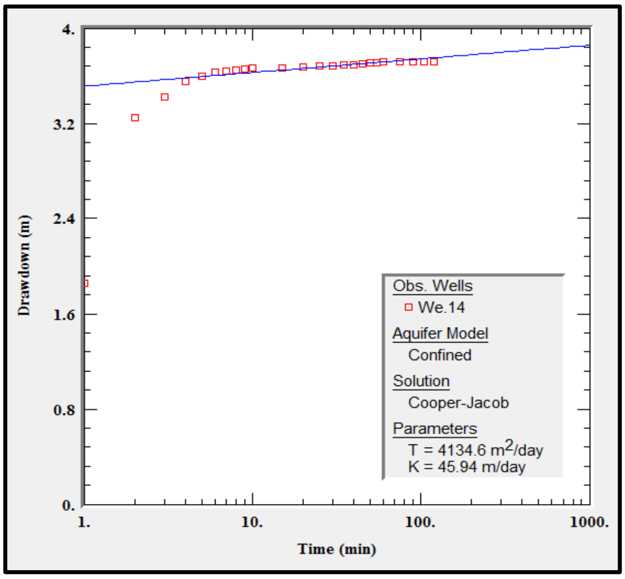

Figure (8): Time-Drawdown curve of well No.14.

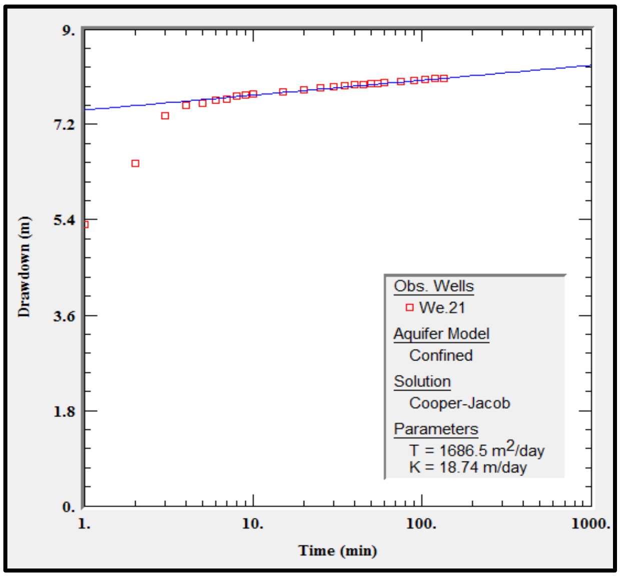

Figure (9): Time-Drawdown curve of well No.21.

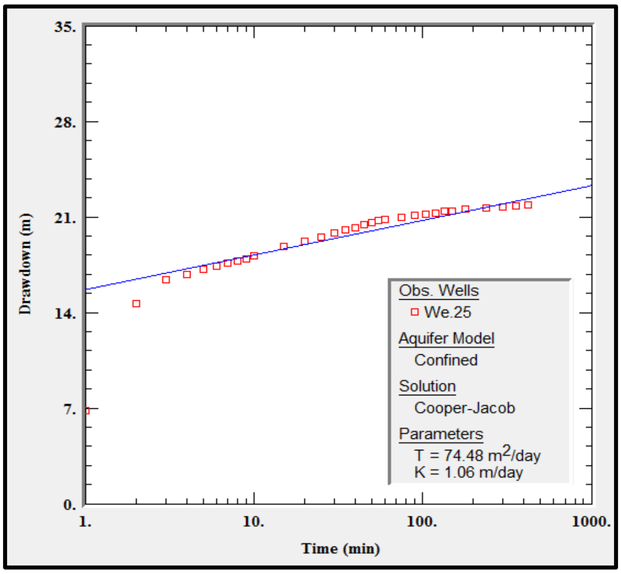

Figure (10): Time-Drawdown curve of well No.25.

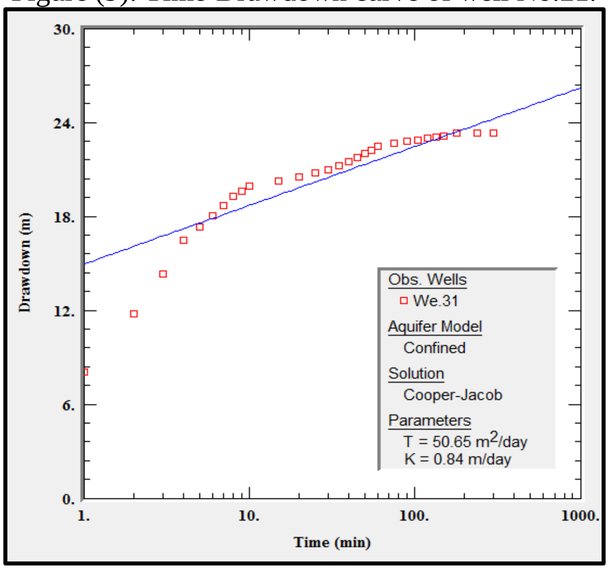

Figure (11): Time-Drawdown curve of well No.31.

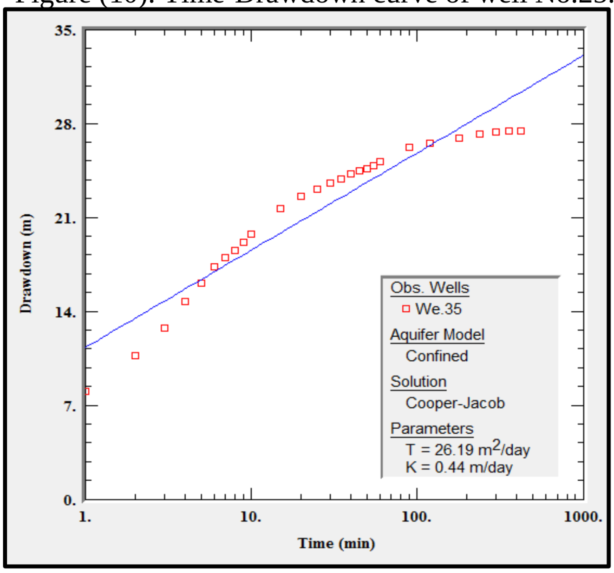

Figure (12): Time-Drawdown curve of well No.35.

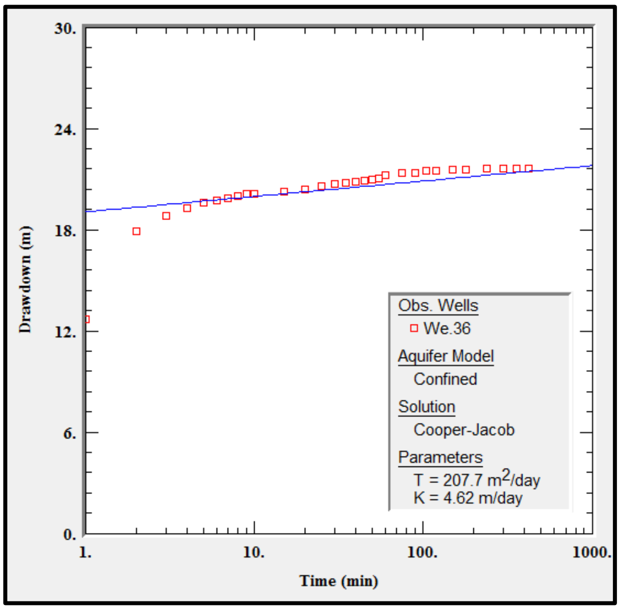

Figure (13): Time-Drawdown curve of well No.36.

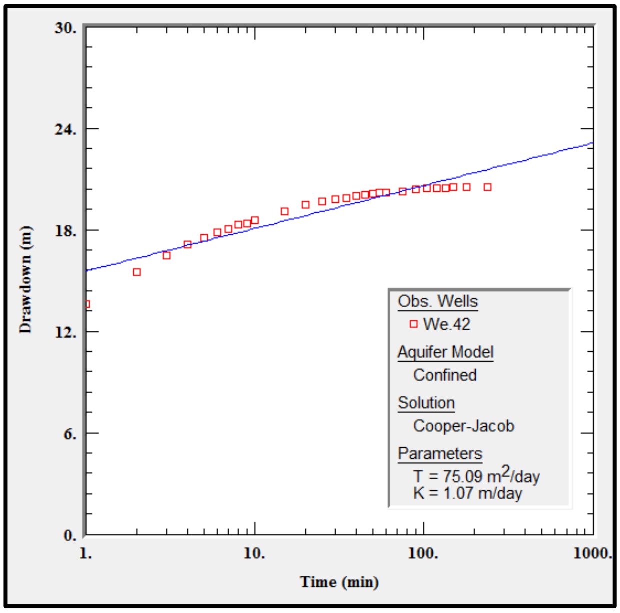

Figure (14): Time-Drawdown curve of well No.42.

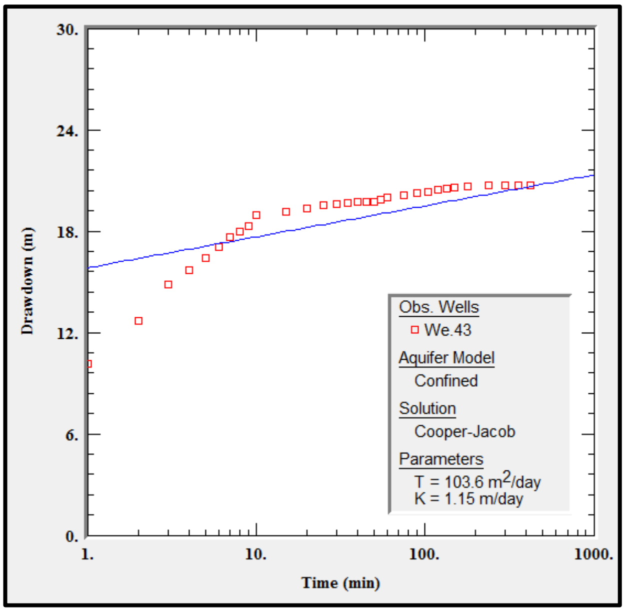

Figure (15): Time-Drawdown curve of well No.43.

Table (1): Summary results of pumping test analysis.

Well No.	Coordinates		Rate of discharge	Saturated thickness	Transmissivity	Hydraulic conductivity
	longitudes	latitudes	Q (l/s)	b (m)	T (m^2/day)	K (m/day)
2	43° 52′ 5.8″ E	32° 30′ 32.1″ N	22	90	3178.9	35.32
14	43° 53′ 21″ E	32° 29′ 38.8″ N	30	90	4134.6	45.94
21	43° 53′ 21″ E	32° 30′ 57.4″ N	30	90	1686.5	18.74
25	43° 54′ 19″ E	32° 30′ 21.9″ N	12	70	74.48	1.06
31	43° 53' 51" E	32°31' 44.3"N	12	60	50.65	0.84
35	43° 54' 51"E	32° 30' 41.6" N	12	60	26.19	0.44
36	43° 50′ 41″ E	32° 31′ 51.8″ N	12	45	207.7	4.62
42	43° 50′ 5.1″ E	32° 30′ 43.4″ N	12	70	75.09	1.07
43	43° 57′ 46″ E	32° 28′ 28.5″ N	12	90	103.6	1.15

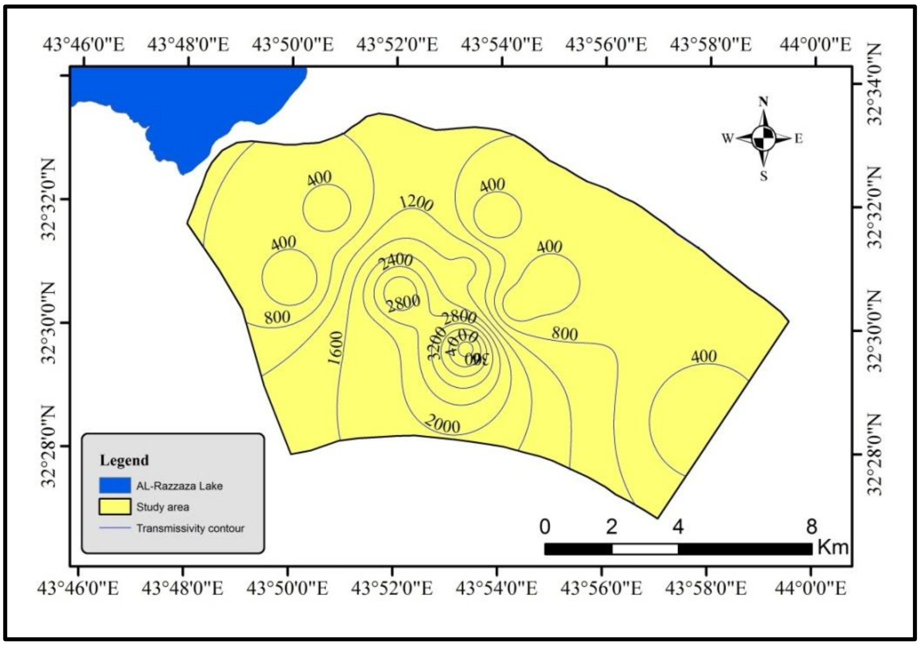

Figure (16): Spatial distribution of the transmissivity values for the aquifer (m^2/day).

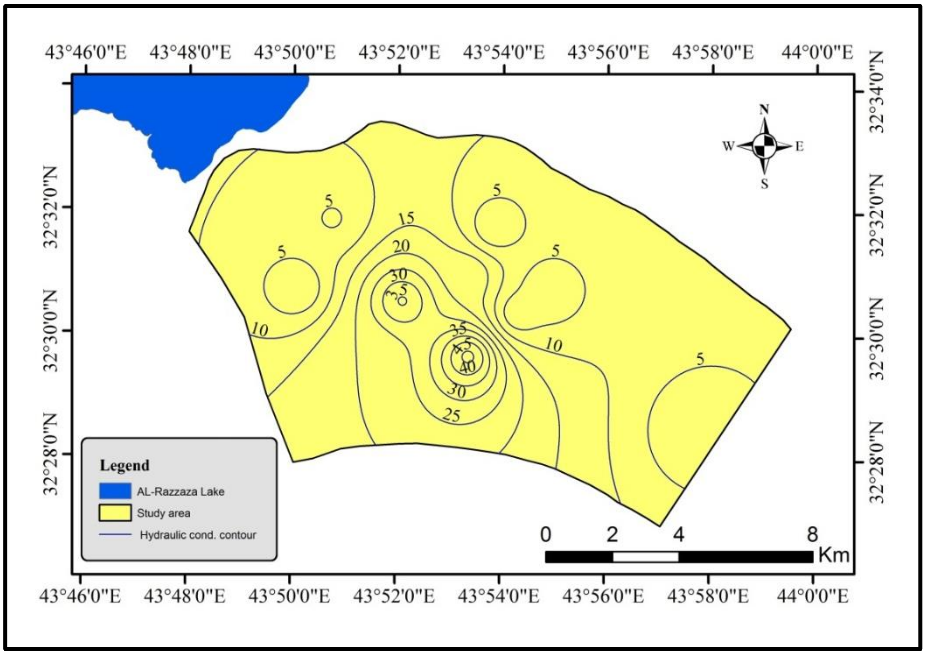

Figure (17): Spatial distribution of the hydraulic conductivity values for the Dammam aquifer (m/day).

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