Hydrogeological characteristics of Dammam confined aquifer, West Razzaza Lake, Iraq

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Abstract. The Rahhalia to Ekhedhur area to the west of the Razzaza Lake in central Iraq is chosen due to its distinguished hydrogeological nature through the existing systems of the faults. The Dammam Formation confined aquifer is one of the important basins of groundwater in Iraqi western desert. The flow map of Dammam basin shows the groundwater flow from the west of the basin, towards Razzaza Lake to the east. The objectives of the current research are to define the hydraulic properties for the Dammam Basin, west Razzaza Lake. Recovery and Pumping experiments for three wells distributed in the area were evaluated to determine the hydraulic properties. The values of Transmissivity (T), Hydraulic conductivity (k), and Specific capacity (SC) are ranged from (392 to 600.25 m²/day), (13.06 to 20.0 m /day), and (88.61 to 215.1 m²/day), respectively. Highest transmissivity value was found in well W 2, while low values were found in well W 1. Most of the weak zones (fractures, joints, and bedding planes) composed of carbonate rocks that are very soluble. The variations of hydraulic characteristics of the aquifer depend on the inhomogeneity of the Dammam basin that shows differences within the studied area. As well as, these variations of values are due to the type of Dammam aquifer, which is a karst confined aquifer

Keywords
Hydrogeological characteristics, Dammam confined aquifer, West Razzaza Lake, Iraq.

1. Introduction.
Iraq is experiencing a shortage in water resources, particularly in surface water; therefore, there is an orientation to exploitation of groundwater to meet the requirements for industrial, agricultural and domestic sectors. The selected area is the Dammam Basin, located to the west of Razzaza Lake, due to its importance for agricultural and industry. Groundwater is a significant water resource in the basin, where most of the villages in the basin are dependent on the groundwater as a main source of water in their supply systems. Recently, due to population and economic growth, the use of groundwater has increased dramatically, and excessive groundwater withdrawal has become a serious problem in the basin. Water resources systems need to be operated to cope with variability of climate changes. Several studies were conducted concerning the hydraulic characteristics of the groundwater in western desert in general but no one investigated the groundwater in Rahhalia, Shithatha and Ekhedhurat the western part Razzaza [1], [2], [3]. The area selected is located from latitude 32° 25´ 00 to 32° 50´ 00 N to longitude 43°15´00- 43° 40´00E (Figure 1). The climate of the western Razzaza area is of arid to semi-arid with 90 mm mean annual precipitation and 2954 mm mean annual evaporation [4]. Due to the lithology of the rock formation and geological nature, the area had distinctive hydrogeological
nature for the existence of the fault systems which penetrate it. The selected area is within the Razzaza sub-basin, according to hydrogeological basins divisions in the Iraqi western desert [5].

Groundwater movement is governed by the aquifer hydraulic properties like the hydraulic gradient and conductivity that flow from the highest levels at the west to the Razzaza Lake at the east as shown in flow map, Figures 2 and 3 [10]. The study area is characterized by a gentle slope (between 65-35 m. a.s. l.) and by many economic, industrial and agricultural products, for example, factory for production of washed sand and fractionalizing gravels which supply its water from groundwater by drilling wells in the area [6, 7 and 8].

The confined aquifer rocks are carbonate of the Dammam Formation and these are characterized by the existence of cavities and fractures that increase the permeability and transmissivity within the study area [9].

The objectives of the current research are to define the hydraulic properties of the confined aquifer for the Dammam Basin, west Razzaza Lake.

Figure 1. Geologic and Location map of western Razzaza, after [11].
Figure 2. Hydrogeological basins divisions in the western and the southern desert according to [5].

Figure 3. Groundwater flow of the Dammam confined aquifer [4].
2. Materials and methods.
In the current research, the hydrogeological characteristics of the confined aquifer are determined by applying the pumping and recovery experiments for three wells. To find the hydraulic properties of the aquifer, the pumping test was carried out on three wells during the dry period (October 2013). These wells (W1, W2, and W3) were distributed in the north, middle and south of the studied area. These wells are penetrating al-Dammam confined aquifer. These properties include Hydraulic conductivity (k), Transmissivity (T), Storage coefficient (S) and Specific capacity (SC). The following methods are used for drawdown and recovery: Cooper-Jacob method [16] and Theis [15]. While the aquifer properties are determined as follow [12]:

\[ T = \frac{2.3 \times Q}{4 \times \pi \times \Delta s'} \]  

Where:

- \( T \) (m²/day): Transmissivity.
- \( Q \) (m³/day): Discharge.
- \( \Delta s' \): variation in the residual drawdown (m) per one logarithmic scale of \((t / t')\), where:
- \( t \) (min.): pumping and recovery Total time.
- \( t' \) (min.): Recovery time.

The hydraulic conductivity (K) was calculated from:

\[ K = \frac{T}{b} \]  

Where:

- \( T \) (m²/day) = Transmissivity.
- \( b \) (m) = the aquifer Saturated thickness.

While the specific capacity (SC) is determined as follow:

\[ SC = \frac{Q}{Sw} \]  

Where:

- \( SC \) (m²/day) = Specific capacity.
- \( Q \) (m³/day) = Pumping discharge rate measured.
- \( Sw \) (m) = Total measured drawdown.

The storage coefficient (S) of a confined aquifer is determined according to the procedure following [14]. The storage refers only to the confined aquifer and the fluid [12]. It is a dimensionless unit. The storage coefficient (S) of the confined aquifers is as shown: 0.00005 < S < 0.005.

3. Results and discussion
3.1 Hydrogeology
The chosen area is considered as a part of hydrogeological basin that is located within great basin indicated by Western Desert subsurface basin according to hydrogeological basin divisions. The main hydrogeological formation in the chosen area is Dammam confined aquifer. Dammam confined
aquifer exists in the west of Razaza lake and moving eastwards toward the Euphrates river in areas that extend to Razaza lake when it lies under the Euphrates Formation that presents the vital source of water. The importance of studying this formation and specifying its hydrogeology is due to the facts that it is exposed to the surface or lies close to it, allowing easy penetration by wells and groundwater quality is relatively good as compared to other aquifers in this region.

3.2 Groundwater flow system and movement
The flow direction in the chosen area is from the west (as recharge location) to east (as discharge location) towards Razaza Lake (Figure 3). The map shows that all equipotential lines are relatively parallel. The parallelism and heterogeneity of equipotential lines are attributed to the hydraulic gradient and the density of the karsts and fractures that exist in Dammam confined aquifer; therefore an increase in hydraulic conductivity and transmissivity is expected.

3.3 The physical properties of the aquifer
Dammam aquifer consists basically of limestone, dolomitic limestone, dolomite and chalky limestone with thin marl beds. The upper contact of the aquifer is an impermeable confining layer representing the marl (8-10 meters). The lower contact of the aquifer is Um Erdhuma confined aquifer which lies beneath Al-Dammam Formation. The thickness of Dammam aquifer is about (95) meters in deep well KH1/7 that was drilled in Al-Ekhdarea area, which was located at depth from 25m-120m, the Formation usually contains karst features and fractures which are formed by dissolution and internal or external erosion at the Formation outcrop, this property gives big importance for Dammam aquifer as geological bed, in addition, to its regional extension in the study area. Dammam Formation wide exposures facilitate the recharge process from the rainfall and runoff. The recharge is effectively through the faults and subsurface canals.

3.4 Estimating hydraulic properties of the aquifer
Estimating the physical properties of water-bearing layers is an essential part of groundwater studies [13].

The hydraulic properties of the aquifer are found by the analysis of pumping test results on the wells. In this research three wells were selected one to the north, the other at the middle and the third at the south of the chosen area in the Dammam basin for pumping and recovery experiments. Then the specific capacity, hydraulic conductivity and Transmissivity were determined. From these field survey and experiments static water level, depth, discharge, saturated thickness and drawdown are given in Table 1. The figures and the best fit line determination of each well that was done for time-drawdown and time - residual drawdown are as shown in Figures 4, 5 and 6 for well 1, well 2 and well 3, respectively and the tests results are presented in Table 2. The results reflect different amounts and ranges for transmissivity between the range 392 to 600.25 m²/day and for hydraulic conductivities between 13.06 to 20.0 m/day. The specific capacity ranges between 88.61 and 215.1 m³/day. It is expected to see differences in the hydraulic characteristics due to the lithological differences that indicate the variation impermeability and porosity of rock forming aquifer. As well as, these variations of values are due to the type of Dammam aquifer, which is a karst confined aquifer. Highest transmissivity value was found in well W 2, while low values were found in well W 1. Most of the weak zones (fractures, joints, and bedding planes) reflect the high solubility of the Dammam carbonate rocks in water.

| Well | Coordinates | Well depth (m) | Elev. a. s. l. (m) | Water head on s. l. (m) | S.W.L (m) | Discharge (l/s) |
|------|-------------|---------------|-------------------|------------------------|-----------|-----------------|
|      | longitudes  | latitudes     |                   |                        |           |                 |

Table 1. The coordinates for the wells that tested for pumping in Dammam basin [4]
Table 2. The hydraulic properties from pumping test analysis for Dammam aquifer.

| Wells | Depth well(m) | S.W.L. (m) | b (m) | Q (m³/day) | K (m/day) | T (m²/day) | SC (m²/day) |
|-------|---------------|------------|-------|------------|-----------|------------|-------------|
| W1    | 120           | 32° 46' 58" | 50    | 48.5       | 1.5       | 2.3        | 10          |
| W2    | 95            | 32°33' 34.7" | 55    | 51         | 4         | 5          | 13          |
| W3    | 100           | 32°27' 32"  | 56    | 62.4       | 3.5       | 4.7        | 15          |

3.5 Theis recovery method [15]
In this experiment the residual drawdown (s') is plotted against (t / t') on semi log diagram with best fit line as shown by the plotted points. This method is applied on pumping well only with no need to apply to observation wells. Water level recovery is calculated directly after the pump stops in the pumping well.

3.6 Cooper-Jacob method [16]
Cooper and Jacob suggested this method for small values of (r) and large values of (t), and it was applied for the analysis of pumping test on well. It was noticed that values of transmissivity could be getting that the t/t₀ =10 (one log-cycle), then log t/t₀ =1; hence, if Δs is the drawdown variation per log cycle of t, then the equation below could determine (T) amount [14].

Terms of application in these two methods are same as in "Theis recovery equation", with the exception of applying drawdown.
Figure 4 B.

Figure 4: The relationship of drawdown (A) and recovery of water level (B) with time for well (W1) applying Cooper-Jacob (Drawdown) and Theis (Recovery) techniques.
Figure 5 B.

Figure 5: The relationship of drawdown (A) and recovery of water level (B) with time for well (W2) applying Cooper-Jacob (Drawdown) and Theis (Recovery) techniques.

Figure 6 A.

Figure 6 B.
Figure 6: The relationship of drawdown (A) and recovery of water level (B) with time for well (W3) applying Cooper-Jacob (Drawdown) and Theis (Recovery) techniques.

4. Conclusion.
Three experiments of Pumping and recovery techniques were done, according to Theis and Cooper-Jacob techniques, to reveal the hydraulic characteristics of confined aquifer. The amounts and ranges are of Transmissivity (T), Hydraulic conductivity (k), and Specific capacity (SC) between (392 to 600.25 m²/day), (13.06 to 20.0 m/day), and (88.61 to 215.1 m³/day), respectively. The differences are due to the aquifer heterogeneity of various lithological properties indicating the difference in permeability and porosity. As well as, these variations of values are due to the type of Dammam aquifer, which is a karst confined aquifer. Highest transmissivity value was found in well W 2, while low values were found in well W 1. Most of the weak zones (fractures, joints, and bedding planes) are reflecting the high solubility of the Dammam carbonate rocks in water.

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