

RESEARCH PAPER

Estimating the Storativity by Recovery data in Khabat area

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ABSTRACT:

The study presented a method for estimating aquifer storage coefficient from recovery test data meanwhile, it is hard to determine especially for single well test cases. The method involves an equation based on the principle of Jacob's modified Theis equation by measuring residual drawdown data versus recovery time in the production well. The main objectives of this study is to determine the reliability of this equation in the selected area and to evaluate and compare the results with the pumping test results as well. The method is starting by estimating the Aquifer parameters (Transmissivity and Storativity) which involves plotting residual drawdown as a function of time, later substituting the obtained test values in an appropriate transient groundwater flow equations based on the aquifer characteristics and types to find the parameter values. Finally, the study concluded that the proposed equation is reliable for determine the Storativity of the aquifer for the single well test, and also can be used as a check for the parameters that obtained from pumping test results and thus the method is verified the objective of the study.

KEY WORDS: Residual drawdown; Aquifer Parameters; Storativity; Transmissivity Diffusion.

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1.INTRODUCTION :

Generally, one of the most important subject in developing countries is determining the aquifer parameters. due to its importance in water resources management for the selected area. it is also has a crucial role in groundwater modeling for any basin. The current study tried to find the reliable method for estimating hydrogeological properties of the aquifer from the conducted pumping test and the recovery test as well. Furthermore, during of recovery period when the pump is turned off the drawdowns which starts to raise up to its original place are taken as it is considered in pumping tests.

drawdowns are is most cases considered more reliable than the pumping drawdowns when it is compared with the results obtained from the aquifer parameters. The time when the pump is shut-off is called as the recovery time.

On the other hand, conducting pumping tests include difficulties in keeping the pumping rate constant, taking account of drawdown in the pumping well due to well loss and turbulent flow in the vicinity of the testing well. However, the Recovery test data are free from these limitations.

Based on the literature, (Theis, 1935) recovery test method is mostly used to determine the Transmissivity from the recovery test data; but it cannot yield an estimate of the aquifer Storage Coefficient such as explained in (Todd, 1980). This can be seen is those cases when the last pumping drawdown is not considered a part of the recovery data. Later, Both (Chenaf and Chapuis,

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2002) and (Samani and Pasandi, 2003) used the Cooper-Jacob approximation of the Theis solution and gave straight-line plots in semi log graphs for calculating T and S from recovery data. While their work represented progress in applying the recovery data for estimating of the pumping test, and also their methods were limited due to using of the Cooper-Jacob approximation, which requires that both pumping and injection phases have proceeded for long enough that both arguments (u_1 and u_2 are no more than 0.01), to ensure sufficiently small truncation errors. While it is often reasonable to expect ($u_1 < 0.01$) to hold during the recovery phase, the requirement of ($u_2 < 0.01$) would exclude the use of many early-time recovery data.

In addition, a method selected to estimate T and S from only residual drawdowns observed at a single observation well was probably first proposed by (Case et al., 1974). Also, (Bardsley et al., 1985) provided a least- squares method to estimate T and S using only residual drawdowns. These methods cannot identify a changed storage coefficient during recovery; also, it can be ascertained using (Singh, 2003) method that the data used by the authors for the application of these methods do not pertain to confined aquifers, hence are inconsistent with the methods used. Estimating the accurate values of aquifer parameters required conducting pumping test on the production well and measuring drawdown in the monitoring well .but it needed high cost of economy, so in order to decrease cost of other well ,it is regarded to used many methods for that test which is known as single well test. There are a lot of attempt to estimate Storativity for single well test ,such as effective well bore storage (Choi, Byoung –Soo, 2007), Recovery test(P. N. Ballukraya and K.K. Sharma,1991), and (G.P. kruseman, and .de Ridder.1973) and (Mawlood D. K 2019a) which studied the sustainability for erbil basin. slug test,..ect. In this case due to the absence of the observation well the application of diffusion equation is selected for ground water flow in the vicinity of the well . Based on (Mustafa J. S , 2017) pumping test is conducted by pumping water from the well itself at a constant rate and measuring the drawdown in the well as a function of time. The test data are used to understand how water is stored and moves through the aquifer towards the well .The analysis

of test result is used to determine hydraulic properties of the aquifer .

2 MATERIALS AND METHODS

2.1. Study Area Location

Khabat District is located on the west of Erbil province in KRG, Iraq, near Greater zab river and The location is at the distance of about (37 km) from Erbil city, that is located on longitude of ($36^{\circ}16'20.48''$), and latitude of ($43^{\circ}40' 23.99''$) with the elevation varies between (200 to 400 m.a.s.l). see Fig No.1:



Figure 1: Satellite image of the study area location.

2.2. Methodology of the study

The study described a method for finding the Storativity of the aquifer by finding the Transmissivity from recovery test data, then by finding the radial distance from observation well through diffusion equations such as described in detail. the importance of the method is that the Storativity cannot be found without observation well distance, however in this study this radial distance presented to find out by diffusion equation then the results of the Storativity will be within the standard range of the aquifer parameters. Recovery test starts when the pump is turned off during pumping test and at the same time the water levels in the pumped wells will start to rise to its initial test level. The measuring water level in this period is known as residual drawdown, which can be represented by the distance from the static water level (SWL) to level during rising and the time also called time of the recovery test. It is verified that the residual drawdown test due to recovery is a good practice to calculate the accurate Transmissivity of the aquifer and to be used as check for the results. [

Kruseman and Di Ridder, 1990]. Moreover, the obtained residual drawdown data are more reliable than pumping test data, due to the constant rate of the recovery test, whereas keeping constant pumping rate at the time of pumping test is rather difficult.

The method is based on the principle of the superposition. Then the provided data on the plots substitutes in the derived equations and the parameters can be determined.

2.3 Application of Recovery test methods

All Usually the Recovery test starts when the pump is shut off during the well testing, the water level starts to rise and the system approach to the equilibrium, then water goes back to its original level and dynamic water levels (DWL) can be measured with respect to time. the study shows the appropriate methods for analyzing the recovery test of the conducted well by substituting the well test and recovery data in the proposed equation then finding the hydraulic properties of the Aquifer, the analyzing method based on the Theis well functions equation after modification by Jacob for long period of time the values of u near to zero so the long part of the Theis equation can be neglected and the equation can be used on this bases. If the following assumptions considered into account then Jacob modified Theis (1935) equation can be applied for the estimation of the recovery data, as follow;

For this principle, Theis (1935) showed that the residual drawdown s' can be given as:

$$s' = \frac{Q}{4\pi T} [W(u) - W(u')] \quad (1)$$

$$W(u) = \left[-0.5772 - \ln u + u - \frac{u^2}{2.2!} + \frac{u^3}{3.3!} + \dots \right] \quad (2) \quad u = \frac{r^2 S}{4Tt}$$

$$W(u') = \left[-0.5772 - \ln u' + u' - \frac{u'^2}{2.2!} + \frac{u'^3}{3.3!} + \dots \right] \quad (3) \quad u' = \frac{r^2 S'}{4Tt'}$$

where t and t' are the times since pumping started and stopped, respectively, s' is residual drawdown, Q is the constant well discharge, r is radial distance from pumped well, S and S' are the storage coefficients of pumping and recovery period, and T is Transmissivity.

It was noted by Cooper and Jacob (1946) and Jacob (1950) that for large values of time with u or u' small, that is, less than 0.01, the series terms

for $W(u)$ or $W(u')$ are negligible after second term. Then, the drawdown can be calculated as follows, with an assumption that

It should be noted that the Storativity in case of pumping test = Storativity during recovery test ($S=S'$):

$$s' = \frac{Q}{4\pi T} \left[\ln \frac{2.25Tt}{r^2 S} - \ln \frac{2.25Tt'}{r^2 S'} \right] \quad (4)$$

simplified the equation to obtain the following equation:

$$s' = \frac{Q}{4\pi T} \ln \left(\frac{t}{t'} \right) \quad (5)$$

or:

$$s' = \frac{2.3 Q}{4\pi T} \log \left(\frac{t}{t'} \right) \quad (6)$$

$$\text{Slope} = \Delta s' = \frac{2.3 Q}{4\pi T} \quad (7)$$

where

$W(u)$: well function of pumping test (unitless)

$W(u')$: well function of recovery test (unitless)

Q : Constant pumping Rate (L³/T)

s : Drawdown during pumping (L)

s' : Residual drawdown during recovery (L)

$\Delta s'$: Change

t : Time during pumping test (T)

t' : Time during recovery test (T)

r : Radial distance from pumping well to point of measuring drawdown (L)

T : Transmissivity (L²/T)

S : Storativity of pumping test (unit less)

S' : Storativity of recovery test (unit less)

However, (Jacob,1946) derived a method based on (Theis,1935) equation for large values of time (t) and small value of u and for time versus drawdown after considering Jacob's assumptions (C. W. Fetter, 1952). It can be used:

$$s = \frac{2.3Q}{4\pi T} \log_{10} \frac{2.25Tt}{r^2 S} \quad (8)$$

To calculate the value of Transmissivity through Jacob's equation:

$$T = \frac{2.3Q}{4\pi \Delta s} \quad (9)$$

Based on the (Kruseman and de Rider 1990), the above equation is used to estimate Transmissivity, the slope of the line (Δs) on the semi logarithmic plot are taken by measuring the difference between two drawdown per one log cycle, and the intercept of the straight line at zero drawdown determines the initial pumping test

time(t_0), then using it to estimate storage coefficient (S) in the equation below:

$$S = \frac{2.25Tt_0}{r^2} \quad (10)$$

After finding the Transmissivity and Storativity from pumping test data, then the results substitute in presented diffusion equation to find reliable S' value due to Recovery data. see test data in Table 1:

Table (2) : Pumping and Recovery test data

Time (min)	depth to water (m)	s (m)	t (min)	t' (min)	t/t'	s' (m)
0.00	63.00	0.00	140.50	0.50	281.00	8.88
0.50	68.40	5.40	141.00	1.00	141.00	6.68
1.00	70.40	7.40	141.50	1.50	94.33	4.15
1.50	71.30	8.30	142.00	2.00	71.00	2.38
2.00	72.10	9.10	143.00	3.00	47.67	1.79
3.00	73.10	10.10	144.00	4.00	36.00	1.49
4.00	73.60	10.60	145.00	5.00	29.00	1.29
5.00	74.10	11.10	146.00	6.00	24.33	1.09
6.00	74.50	11.50	147.00	7.00	21.00	1.00
7.00	74.75	11.75	148.00	8.00	18.50	0.90
8.00	74.80	11.80	149.00	9.00	16.56	0.80
9.00	74.90	11.90	150.00	10.00	15.00	0.70
10.00	75.00	12.00	155.00	15.00	10.33	0.40
15.00	75.00	12.00	160.00	20.00	8.00	0.20
20.00	75.00	12.00	165.00	25.00	6.60	0.10
30.00	75.00	12.00	170.00	30.00	5.67	
40.00	75.00	12.00	180.00	40.00	4.50	
50.00	75.00	12.00	190.00	50.00	3.80	
60.00	75.00	12.00	200.00	60.00	3.33	
80.00	75.00	12.00				
100.00	75.00	12.00				
120.00	75.00	12.00				

2.4 Recovery Test Data Analysis

The study is in the Khabat area which is belong to Erbil province and the test conducted on the single well in Khabat area and the well having the coordinate of Easting 381349m, Northing 4014240 m and also the elevation of (334 m) above sea level. Moreover the depth of the well is 265m and the casing diameter 0.22 m with the effective well radius of 0.16 m, also the static and dynamic water level were 82.7m, 106.2 m respectively the drawdown inside the pumped well

was 23.6m the well discharge is 1600.57 m³/day and the aquifer saturated thickness of the production well is 182.3m, based on (Ismail, O. Srwa, 2020).

By plotting data on semi-logarithmic paper the value of Transmissivity T can be obtained from the recovery data using Jacob modified Theis equation which is the graphical solution, and values directly substituted in the equation to obtain the Storativity of the aquifer as shown in Fig.2:

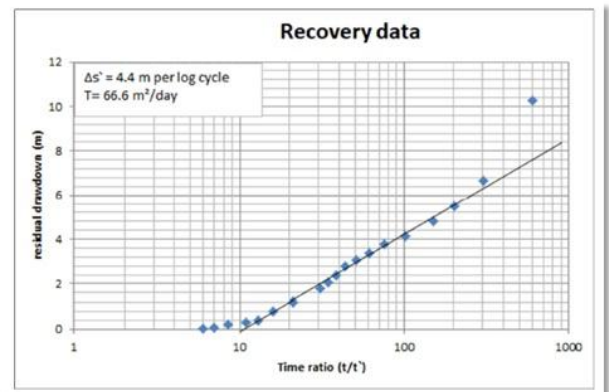


Figure 2: Recovery test data analysis.

Although the following steps should be taken into account during the calculation in order to get the values of both Transmissivity and Storativity as the following calculations:

$$T = \frac{2.3 \cdot 1600.57}{4 \cdot \pi \cdot (4.4)} = 66.61 \text{ m}^2/\text{d}$$

Storativity obtained from the test is (S=0.16) based on the study (Mawlood D. K 2019c) and finding Storativity based on radius of influence by diffusivity equation:

$$\eta \frac{1}{l^2} = \frac{1}{T} \quad (11)$$

$$l^2 = 4\eta T \quad (12)$$

$$L = 2\sqrt{\eta T t} \quad (13)$$

$$\eta = \frac{T}{S} = \frac{Kb}{Ssb} \quad (14)$$

$$\eta = Kb/Ssb \quad (15)$$

$$\eta = k/Ss = T/S \quad (16)$$

Where:

L: radial distance from pumping well to point of monitoring drawdown (L) (replacing L=r)

t: is time (T).

2 :Geometric term.

η : is aquifer diffusivity(L^2/T) which is equal to :

$$\eta = (7.71 \times 10^{-4}) / 0.16 = 0.005 \text{ m}^2/\text{s}$$

$r = 2\sqrt{Tt}$ (the equation based is based on the diffusion equation)

$$r = 2\sqrt{0.005 \times 140.5 \times 60}$$

$r = 13 \text{ m}$ (the distance from pumping well to monitoring well).
and Storativity:

$$S' = \frac{2.25 \times 0.0458 \times 120}{13^2} = 0.086$$

(which is reliable with the standard value)

The value of Storativity for unconfined aquifer type is within the range of (0.01-0.3) according to (Michael Kasenow,1997). the calculation is repeated for the other wells of (w-17, w-7, w-53, w-55, w-57, w-59) to verify the reliability of the results such as shown in Table 2:

Table (2) Transmissivity and Storativity Results

Well No.	Q m ³ /d	SWL m	DWL m	B m	T m ² /d	S
W-17	1600.56	82.7	106.3	182.3	66.6	0.037
W-7	1879.2	63	75	187	110.9	0.062
W-53	1458	49	81	201	35.11	0.019
W-55	1730.16	36	45	214	175.93	0.016
W-57	1697.8	50	61	200	97.1	0.054
W-59	952.56	55	70	173	69.74	0.039

As well as, the lithology profile of the selected well is shown in Figure below:

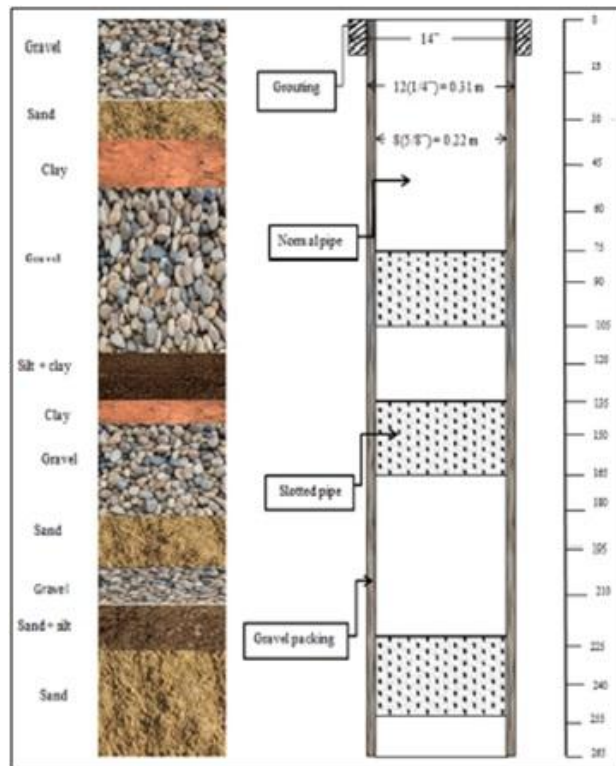


Figure 3: Lithology profile of the well.

3. RESULTS AND DISCUSSION

The presented method can be used to estimate the Storativity of the aquifer, according to the results, The value of Storativity such as shown in (Table 2) for unconfined aquifer is within the standard range of (0.01-0.3) according to (Michael Kasenow,1997). Therefore the study can satisfied that the values of the Storativity can be estimate from single well test by determining the radial distance from diffusivity equation then used to estimate the Storativity with the absence of the monitoring well, According to (Mawlood D. K 2019c), it is known that the values of Storage coefficient cannot find easily in case of the production well test due to the turbulent flow (well losses) in the vicinity of the testing well. The results of the study shows that the proposed method can be applied for the production well cases, that is satisfied based on the results obtained which are within standard limitations of the Aquifer parameters value as well. meanwhile this paper show that if the pumping and recovery test data available it can be substituted in the groundwater flow equations then find the Transmissivity value then Storativity can be found after calculating the distance form diffusivity equation in order to find the Storativity for the aquifer this can obtain the main goals of the study.

4. CONCLUSION

The presented study concluded that the method is more reliable for determining the aquifer Storativity for single well test which is a most powerful techniques because it is hard to find the Storativity in case of single well test due to the absence of the observation wells, so the paper presented a method to find the radius of the influence drawdown in order to achieve reliable and accurate results by applying diffusion principle for the distance measurement based on the pumping and Recovery test data the Storage coefficient can be estimated as well. this verified by finding the value which is within the standard range of Storativity for unconfined aquifer types which is between 0.01 to 0.3, (Michael Kasenow, 1997). thus the paper satisfied that the values of the aquifer parameters especially Storativity which can be find out from single well test by finding the radial distance through diffusivity equation and using this distance to calculate Storativity without existing monitoring well, however the application of this method can overcome the problems of the absence of the observation well and lead to reduce the cost of drilling observation well as well.

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