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Implementation of AQTESOLV software for Analyzing Single Well Pumping Test Recovery Data (Tazerbo Wellfield GMMP, Libya – As a Case Study)

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Abstract-Single well aquifer testing can provide the value of aquifer transmissivity, whereas impedes the cost access the multi-well aquifer testing. The motivation of this study is identify the transmissivity of Tazerbo well field in Al Kufra basin using this method by AQTESOLV 4.5 software and spreadsheet containing a simple analytical model. The area of study consists of 108 production wells distributed in 6 lines. The average value of the wellfield transmissivity obtained after the analysis was (T manually =2.23, TAQTESOLV=2.16 m2/min). The performance results of both software and spreadsheet analytical model showed a good agreement, therefore, offer reliable bases for further investigation and computation of groundwater potentialities in the study area using AQTESOLV program. Moreover, during the study, the software gives the impression about how much it is straightforward, saving time with good results. As well as AQTESOLV software has many other capabilities recommended these tests for analysis, and a high degree of confidence can be placed on the accuracy of analyses performed with this software.

Key words: Recovery Pumping Test, Aquifer Transmissivity, Tazerbo Wellfield, AQTESOLV software.

I. INTRODUCTION

The principle of a pumping test is to measure the discharge, and the drawdown in the well and piezometers at known distances which can substitute these measurements into well-flow equation and calculate the hydraulic characteristics of the aquifer. The most important method to estimate the aquifer parameters is testing with observation wells, but it costs more than conducting pumping test without observation well which is called single well test. Single well test is common due to the obvious advantage that only one well is needed. A recovery test is undertaken to determine aquifer characteristics, based on rising water levels after the pump is turned off. It is a useful check of aquifer test parameters derived from the pumping period. Residual drawdown data are more reliable than pumping drawdown test data because recovery occurs at a constant rate, whereas, a constant discharge during pumping is often difficult to achieve in the field, beside the measurement errors may occur in the drawdown and the discharge measurement in the field [1]. Overall, application of the type-curve method needs development of a conceptual model and a choice of the appropriate method of analysis. That requires a friendly, available computer programs (such as AQTESOLV software) facilitate the analysis of the pumping test data to determine the aquifer parameters. In most cases, this process results in a set of hydraulic parameters that adequately characterize the aquifer in the area of the test wells, and can be used for future predictions of drawdowns under various pumping conditions.

AQTESOLV is a commercial software package developed for the design and analysis of aquifer-test data. The software provides a model of the theoretical response used in pumping for the given input parameters. The software provides a comprehensive suite of solutions for confined, unconfined, leaky, and fractured aquifers [2].

The objective of this study is to use AQTESOLV software for estimating the aquifer transmissivity (T) of Tazerbo wellfield. The recovery pumping test data for the available 98 wells data from 108 wells were analyzed by this recovery method using spreadsheet analytical model and AQTESOLV program. In addition all results were compared to the data collected from Great Man Mead River Authority (GMMRA).

II. MATERIALS AND METHODS

1. *Area of Study*

The study area is Tazerbo wellfield located in two major sedimentary basins in central and southeast Libya. The thickness of the aquifer is 100-120 m, with a well-sorted, medium-grained, and poorly cemented sands. The depth to water is variable from site to another, from 260 m to 400 m. The capacity of the wellfield has been designed to yield 1 Mm^3 / day. However, at the present day, the yield of the wellfield is 490,000 m^3/day. The Tazerbo wellfield is distributed into three parallel lines; each line is divided in two sections, and each line is 50 km long and consists of 36 wells. The spacing between the wells is 1.3 km, and the distance between these three parallel lines is 10 km, as shown in Fig.1. Transmissivity of Tazerbo wellfield aquifer had been estimated based on the long-term pumping tests is between 3.71×10-2 to 7.92×10-3 m^2/s, and the storability is between 2.1 ×10-3 to 0.77×10-4 [3].

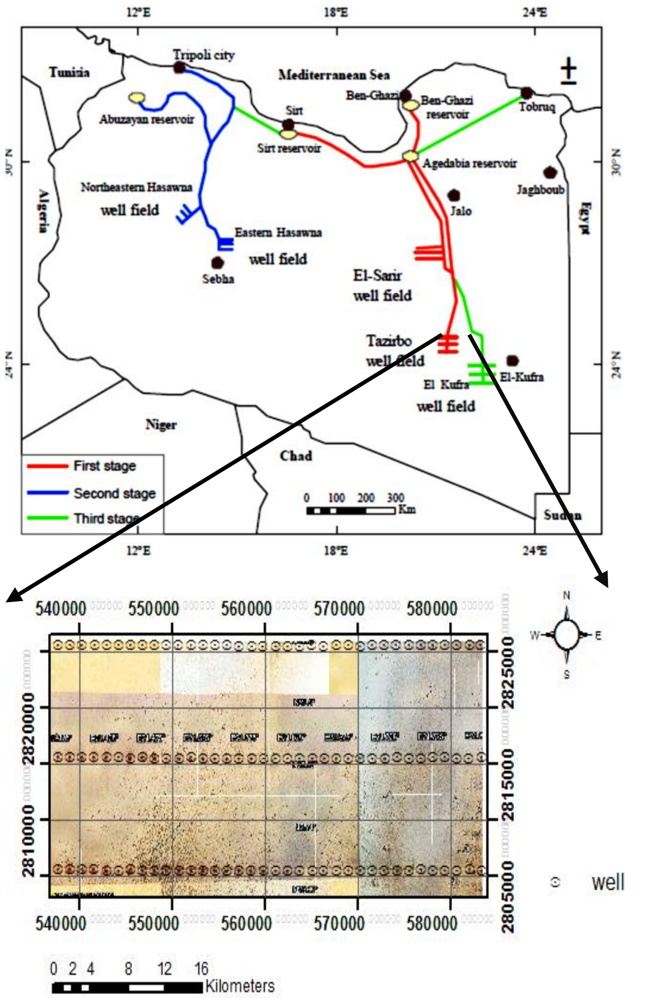

Figure 1. Layout of the Great Man-Made River Project, and Tazerbo Wellfield location- Libya.

2. This Recovery Method

When the pump is shut down after a pumping test, the water levels in the well and the piezometers will start to rise. This rise in water levels is known as residual drawdown s`. It is expressed as the difference between the original water level before the start of pumping and the water level measured at a time t` after stops of pumping. Figures 2, and 3 show the change in water level with time during and after a pumping test [1].

This (1935) recovery method is valid for confined aquifers which are fully penetrated by a well that is pumped at a constant rate. The procedure for analyzing recovery data is as follows [1]:

1. Take all the water levels measured during the recovery phase and convert them to residual drawdowns (s`) by subtracting the original rest-water level measured just before the start of the pumping phase.

2. The time elapsed since the start of the recovery phase is denoted by t`. For all the residual drawdowns, calculate, which is the time elapsed since the very start of the pumping phase of the test in minutes.

3. For all these pairs of times, divide t by t'.

4. Prepare a graph on semi-log graph paper, with residual drawdown s` on the (linear) y-axis, in meters, and t/t` on the (logarithmic) x-axis.

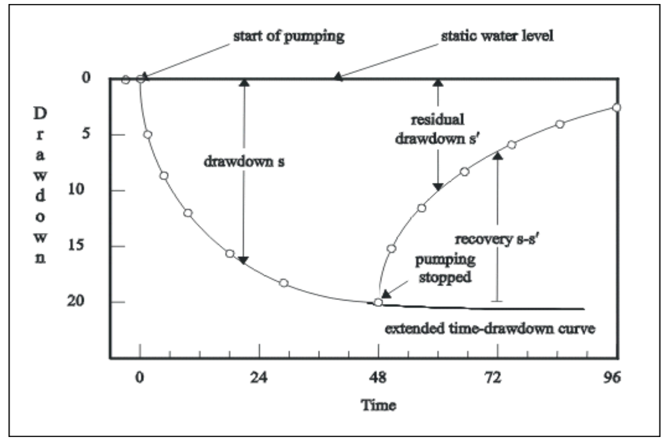

Figure. 2. Time drawdown and flow rate.

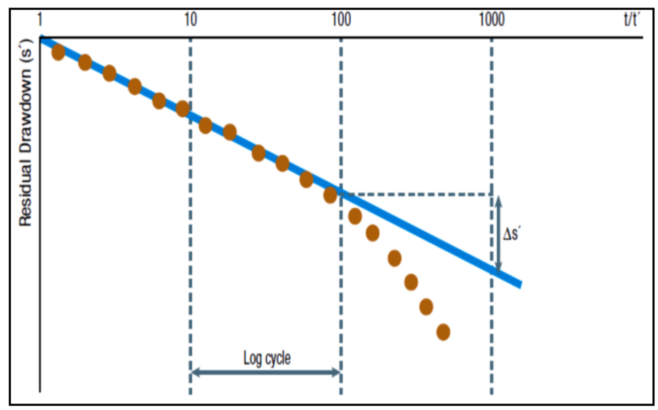

Figure. 3 .Recovery-test analysis by Theis method.

Transmissivity estimates by Theis recovery method, according to the following equation [4]:

$$T = \frac{2.3Q}{4\pi \Delta S} \tag{1}$$

Where:

T. Transmissivity, Q. Pumping rate, Δs. Change in residual drawdown over one log cycle of t/t`.

III. Analyzing of Pumping Test Recovery Data for Tazerbo Wellfield Aquifer:

1. Data Analysis:

The field measurement data, which includes, the well point elevation (Z m), aquifer thickness (b m), also the recovery pumping well test data (`s m, t min) was collected from GMMRA. Table I, represents statistical analysis of field measurements, and Fig. 4, showing the wellfield layout.

Table I. Statistical Analysis of Field Measurement, Tazerbo Wellfield.

	Z m	Aquifer transmissivity T GMMR m^2/min	The pumping rat discharge Q m^3/min	b m
Average value	275.68	2.594	7.178	149.589
Maximum value	286.57	5.748	7.323	196.070
Minimum value	238.02	1.296	7.030	102.010

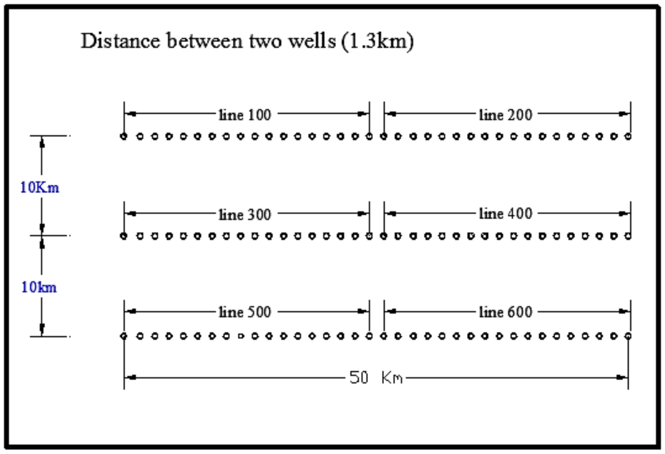

Figure. 4. The layout of The Pumping Wells (Tazerbo Well Field).

2. *Analyzing Pumping Test Recovery Data Applying Thies - Method by spreadsheet:*

This method consists of plotting the residual drawdown S` in the well versus the ratio of t/t`. In this part, it was developed a spreadsheet containing the residual drawdown S` plotted on y axis, and the ratio of t/t` plotted on x axis (Fig. 5 to 10). A straight line was fitted through the plotted water level recovery data, and the slope of the line is measured to estimate aquifer transmissivity. In this part, a 6 of 98 wells in Tazerbo wellfield is presented in this research to explain and show the solution analysis steps. To estimate the Transmissivity for the 6 wells with ID (101, 201, 301, 401, 501, 601) that were selected to apply .This recovery method, it was required including the following data, presents at Table II. The transmissivity was calculated using This recovery method, for all 98wells summarizes in Table IV.

Table II.Data Required for Theis Solution by spreadsheet (6 From 98 Wells As an Example) .

Well ID	Pw601	Pw501	Pw401	Pw301	Pw201	Pw101
static water level Hs m	11.27	11.64	5.53	6.21	0.53	0.40
Aquifer thickness b m	162.83	164.07	165.14	161.55	155.49	145.07
steady rat Q m^3/min	7.08	7.13	7.03	7.22	7.22	7.08
Slope time-residual drawdown curve Δs m	0.90	0.79	0.73	0.69	0.32	0.40

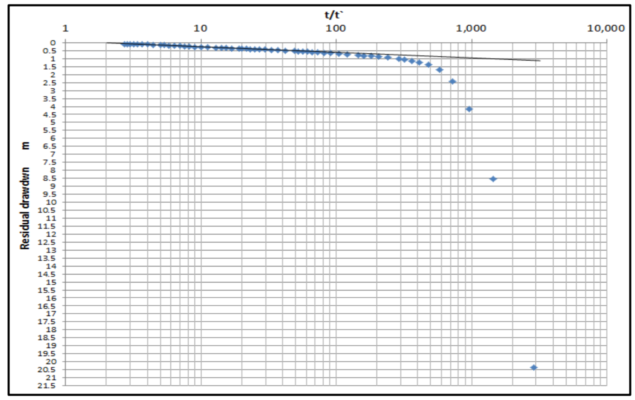

Figure. 5. Well No.101 time residual drawdown plot .

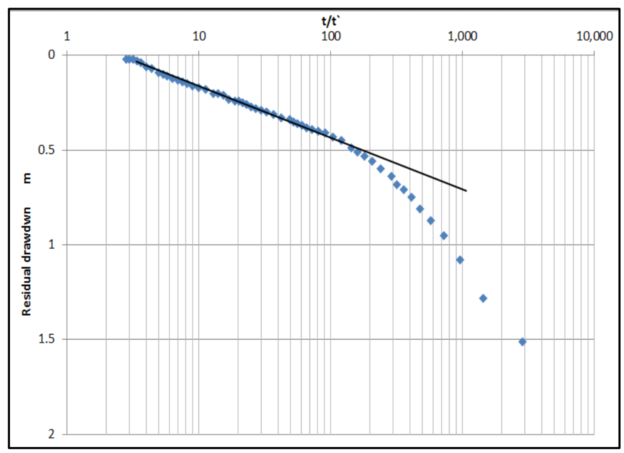

Figure. 6. Well No.201 time residual drawdown plot.

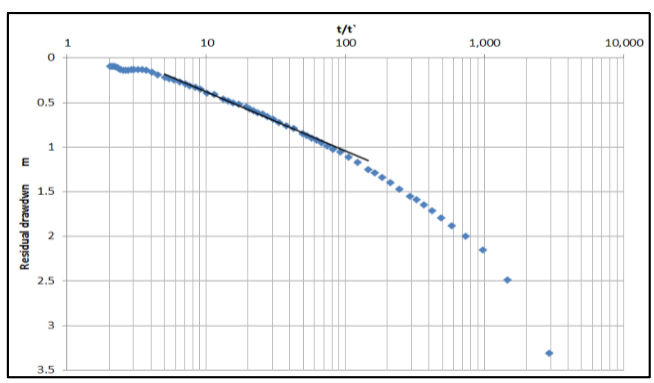

Figure. 7. Well No.301 time residual drawdown plot.

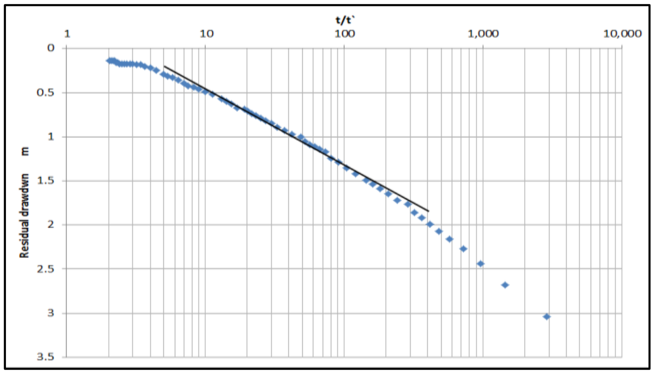

Figure. 8. Well No.401 Time Residual Drawdown Plot.

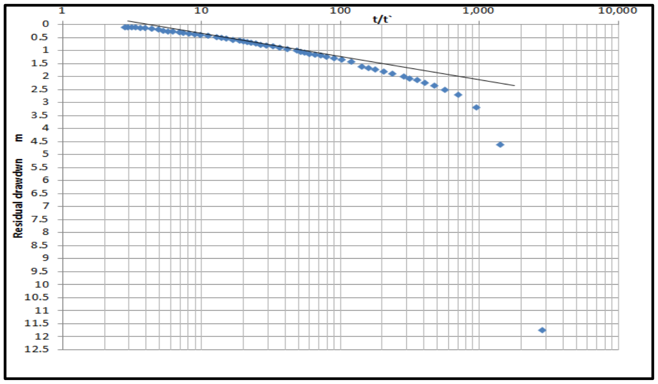

Figure. 9. Well No.501 Time Residual Drawdown Plot.

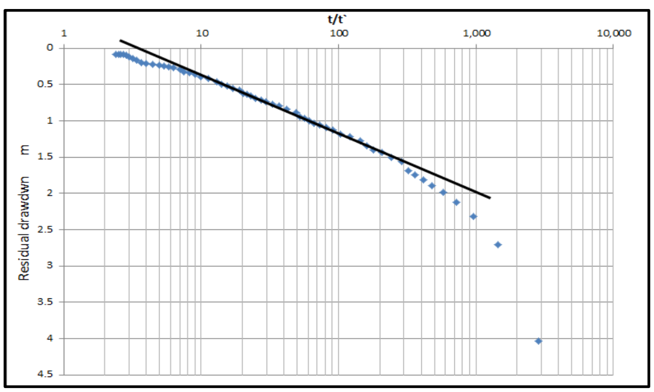

Figure. 10 Well No.601 time residual drawdown plot.

3. *Analyzing Pumping Test Recovery Data Applying AQTESOLV Software Version 4.5:*

AQTESOLV is a software designed to calculate hydraulic conductivity, storativity, and other aquifer properties from data sets collected during slug and aquifer (pumping) tests. The software can import text files. After importing, the raw data can be manipulated using mathematical functions. Once the data are entered, the software offers a variety of solutions, but user knowledge is important. AQTESOLV gives little guidance on selecting the appropriate solution for the data and hydrogeologic setting, and refers the user to the relevant literature for details on each solution. The software provides an automated matching feature, but manual fitting of the solution lines to the data is recommended. Detailed pumping times and rates for Tazerbo wellfield recovery tests were directly imported into the software by 98 text files. Aquifer-test data was formatted into elapsed time (minutes) and drawdown (m). The thicknesses (b) of the Tazerbo wellfield aquifer were input at m, with vertical to horizontal permeability (Kv/Kh) of 0.1.

Table 3 shows the required data for running AQTESOLV software. The Figures 11 to 16 present the time residual drawdown output plot for wells (101, 201, 301, 401, 501, 601) as an example. The transmissivity was calculated using Theis recovery method, for all 98 wells run by AQTESOLV4.5 summarized in Table IV.

Table III. Pumping Well (6 From 98 Wells As an Example) Data Required for Running AQTESOLV Software .

Well ID	Q m^3/min	Well radius rw m	b m
101	7.08	0.25	145.07
201	7.22	0.25	155.49
301	7.22	0.25	161.55
401	7.03	0.25	165.14
501	7.13	0.25	164.07
601	7.08	0.25	162.83

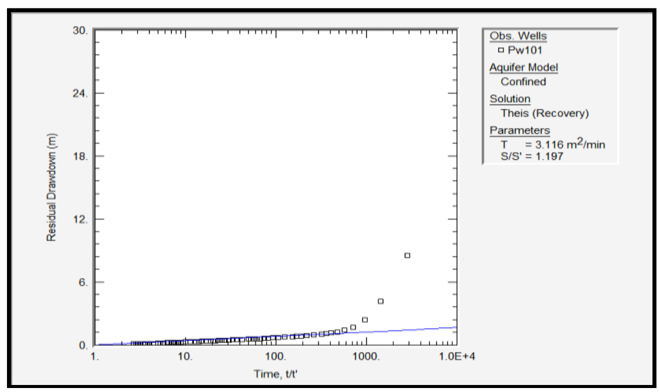

Figure.11. Well No.101 Time-Residual Drawdown AQTESOLV Plot.

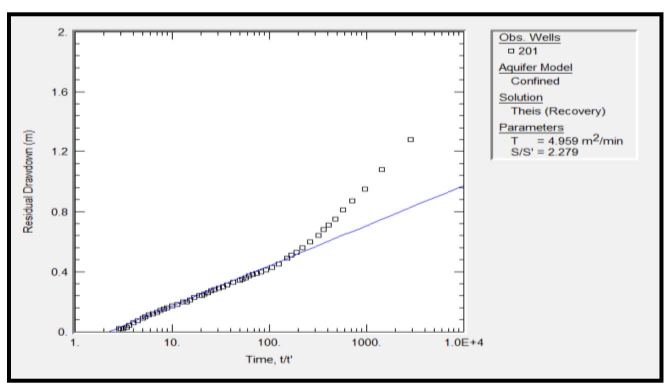

Figure. 12. Well No.201 Time- Residual Drawdown AQTESOLV Plot.

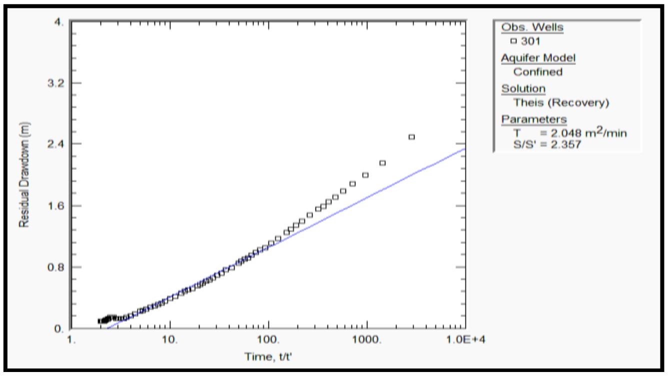

Figure .13. Well No.301 Time- Residual Drawdown AQTESOLV Plot.

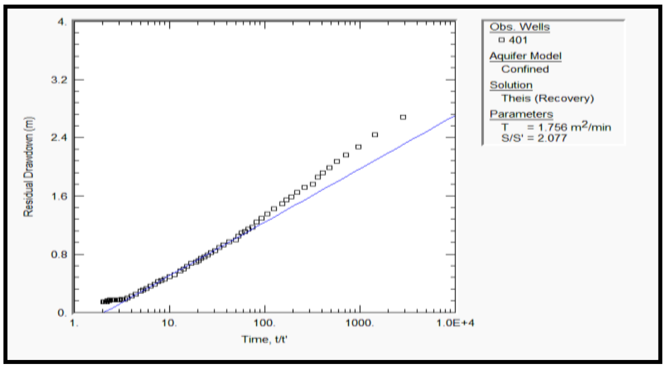

Figure.14. Well No.401 Time- Residual Drawdown AQTESOLV Plot.

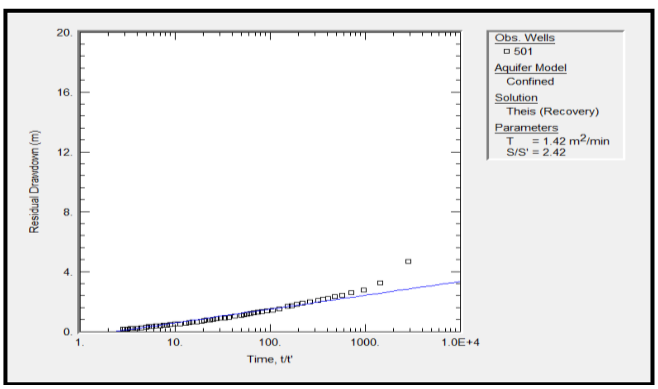

Figure.15. Well No.501 Time- Residual Drawdown AQTESOLV Plot

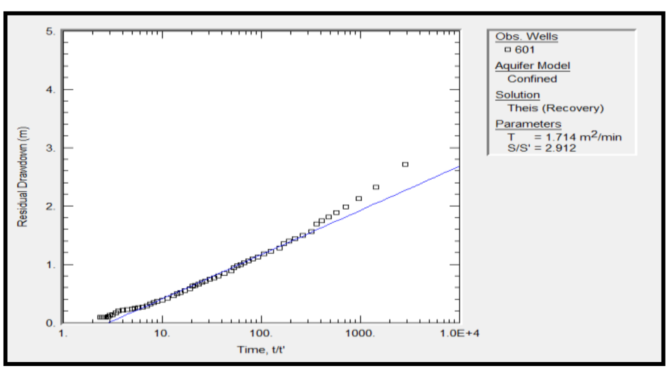

Figure. 16. Well No.601 Time- Residual Drawdown AQTESOLV Plot.

IV. Results Discussion

The plot of the residual drawdown versus time of recovery test data conducted of the area of study was carried out and analyzed for both software and spreadsheet containing a simple analytical model. Since no real values of transmissivity are available of the studied area, it could be could comparing the results relatively towards each other and with the values obtained from GMMR authority. According to the values shown in Table 4 and graph 17, the following can be:

1. There is close similarity between the transmissivity calculated by the spreadsheet and program (AQTESOLV4.5). Hence, it is recommended to use in analysis of pumping and recovery test data.
2. The spreadsheet and AQTESOLV4.5 analyses results of recovery test data are underestimated in comparison to the values obtained from GMMR authority. Because of that, the GMMR authority analyzing the recovery test data using period of “late-time data” as the flow begins to be in a steady state which did not come upon the assumption considered by the analysis method (This method). Moreover, water in the casing is removed first, and data recorded during this period (termed “early-time data”) will not yield a true measurement of the well’s productivity. For that reason, the recovery test data analyzed by spreadsheet and AQTESOLV4.5 software use the data during unsteady state condition which presents by the period (termed “Straight line-time data”).
3. This method assumes the aquifer to be vertically and laterally homogeneous, isotropic and has an infinite areal extent. In reality, the Tazerbo wellfield aquifer under test is laterally and vertically heterogeneous, and most likely to be anisotropic in terms of hydrogeological properties.
4. The results of recovery pumping test indicate a wide range values for transmissivity from 0.8m^2/min–5.5 m^2/min with an average value of 2.2 m^2/min. The indicates an aquifer with good performance in accordance to transmissivity scales. Moreover, the Highest results of transmissivity values were found in wells (101, 113, 117, 201, 202, 203, 204, 205, 309, 413, 506, 505, 611, 612) while the lowest value was found in well (617). These wide range values are due to the type of Tazerbo wellfield aquifer, which is a sandstone confined aquifer double porosity.

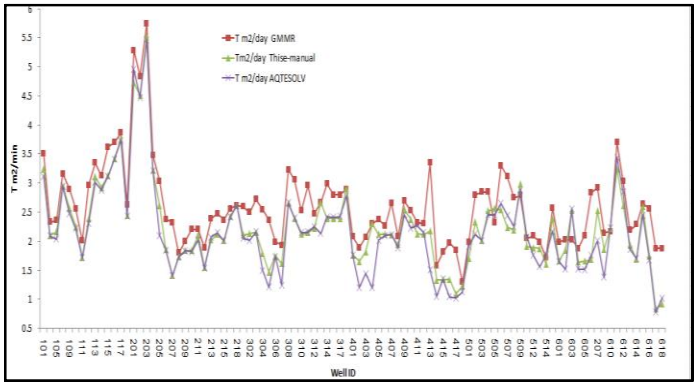

Figure. 17. Comparison Between The Results (T m^2/min).

Table IV. Comparison Between The Results.

Well No.	T m^2/min		
	GMMRA	**This-Recovery manual**	**AQTESOLV Software**
101	3.504	3.248	3.116
103	2.328	2.101	2.093
105	2.358	2.165	2.039
108	3.162	2.952	2.946
109	2.898	2.564	2.479
110	2.562	2.255	2.219
111	2.01	1.721	1.713
112	2.958	2.382	2.3
113	3.348	3.114	3.011
114	3.126	2.925	2.881
115	3.624	3.123	3.116
116	3.696	3.421	3.409
117	3.864	3.761	3.737
118	2.628	2.438	2.429
201	5.286	4.733	4.959
202	4.836	4.51	4.475
203	5.748	5.522	5.458
204	3.48	3.226	3.207
205	3.036	2.616	2.098
206	2.376	1.853	1.844
207	2.322	1.41	1.405
208	1.8	1.732	1.731
209	2.004	1.841	1.834
210	2.202	1.84	1.816
211	2.202	2.104	2.025
212	1.89	1.557	1.532
213	2.388	2.025	2.072
214	2.478	2.123	2.15
215	2.364	2.008	2.005
217	2.562	2.426	2.413
218	2.616	2.616	2.615
301	2.592	2.103	2.048
302	2.496	2.137	2.018
303	2.718	2.152	2.162
304	2.544	1.79	1.501
305	2.364	1.47	1.209
306	1.986	1.753	1.737
307	1.932	1.62	1.248
308	3.228	2.651	2.662
309	3.054	2.39	2.4
310	2.526	2.12	2.15
311	2.958	2.15	2.16
312	2.478	2.222	2.25
313	2.664	2.666	2.131
314	2.988	2.39	2.42
316	2.796	2.393	2.41
317	2.796	2.393	2.43
318	2.898	2.906	2.78
401	2.076	1.767	1.756
402	1.89	1.655	1.206
403	2.07	1.816	1.439
404	2.304	2.304	1.2
405	2.38	2.12	2.012
406	2.26	2.12	2.098
407	2.66	2.109	2.112
408	2.08	1.938	1.89
409	2.694	2.539	2.455
410	2.526	2.377	2.223
411	2.322	2.129	2.27
412	2.304	2.12	2.15
413	3.348	2.179	1.502
414	1.584	1.328	1.049
415	1.812	1.334	1.353
416	1.974	1.347	1.042
417	1.848	1.096	1.025
418	1.296	1.222	1.125
501	1.98	1.7	1.42
502	2.8	2.33	2.12
503	2.85	2.01	2.012
504	2.85	2.528	2.452
505	2.316	2.569	2.45
506	3.3	2.54	2.65
507	3.11	2.236	2.45
508	2.75	2.2	2.25
509	2.79	2.987	2.88
511	2.05	1.91	2.072
512	2.09	1.89	1.76
513	1.99	1.878	1.558
514	1.72	1.609	1.77
516	2.57	2.39	2.17
601	1.99	1.66	1.714
602	2.02	1.85	1.52
603	2.028	2.529	2.55
604	1.878	1.643	1.52
605	2.1	1.66	1.51
606	2.83	1.687	1.755
607	2.922	2.528	2.01
608	2.142	1.86	1.38

Well No.	T m^2/min		
	GMMRA	This-Recovery manual	AQTESOLV Software
610	2.17	2.222	2.23
611	3.7	3.247	3.44
612	3.03	2.614	2.85
613	2.19	1.93	1.86
614	2.29	1.69	1.7
615	2.646	2.597	2.45
616	2.56	1.743	1.68
617	1.878	0.833	0.78
618	1.878	0.927	1.02

V. CONCLUSION AND RECOMMENDATIONS:

This study focuses on identifying transmissivity (T) of 98 wells on one of GMMRP wellfields which is the Tazerbo wellfield. The data obtained from the test was analyzed by this method, spreadsheet, and AQTESOLV software version 4.5. It was concluded that, there is a good similarity between the values of the transmissivity spreadsheet and AQTESOLV4.5. Also, both methods underestimated the transmissivity compared to the values obtained from GMMR authority. Therefore, it is necessary to analyze the “late-time data” to calculating the (tc) transition between the early and late time for both pumping and recovery curves which is kept for further studies by author. Recommended to repeat the pumping and recovery tests to evaluate the influence of continuous pumping (which started since 1990) on to the transmissivity and the storage of study area until now. As well as, AQTESOLV software has many other capabilities that were not tested, it is recommended to test every method of analysis, however, a high degree of confidence can be placed on the accuracy of analyses performed with this software.

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