Estimate of Transmissivity of Injana aquifer from specific capacity data in two selected area within Ninewa Governorate

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Abstract

Transmissivity (T) is one of the most important parameters in groundwater studies, it is generally estimated from pumping tests. (T) can also be deduced from abundantly available specific-capacity (Sc) data by using empirical approaches, In this study the relation between transmissivity and specific capacity has been derived using a data set of fifty six deep wells which penetrate Injana sandstone aquifer, these wells distributed in Rabia and Debagah -Mukkumar- Basins in Ninewa governorate. Linear and logarithmic simple regression functions have been performed and it is found that the logarithmic relationship to predict the transmissivity from specific capacity data has a better correlation (r = 0.90) than linear one (r =0.85). This is logically true because both transmissivity and specific capacity are lognormally distributed, it is possibility of using the specific capacities of wells in other parts of the basins to predict the transmissivity in these areas if the wells digging within injana aquifer and under the same hydrogeological conditions.

Introduction :

Specific capacity is easy to measure ,it is the ratio of pumping rate to drawdown in the well. In fact that specific capacity is correlated with hydraulic-flow properties (Theis et al. 1963), It is a very valuable number that can be used to provide the optimal pumping rate or maximum yield for the well. It can be used to identify potential well, pump, or aquifer problems, and accordingly to develop a proper well maintenance schedule. Specific capacity is commonly used to estimate transmissivity of aquifers, because of the availability of specific capacity data from drillers' logs and the relative expense in obtaining transmissivity through aquifer test (Clifton 1981; Huntley et al. 1992).On the other hand, in groundwater mathematical models, the main problem facing the modeler is the limited number of the transmissivity values due to the small number of aquifer tests. In this case it is preferable to estimate the transmissivity values indirectly by correlation analysis. The use of the specific capacity of a well to estimate the tranmissivity of an aquifer widespread because of the availability of specific capacity data from well drillers log and Transmissivity is often estimated using specific capacity data when standard pumping test data are not available, as well as the relatively high cost of these tests. High specific capacities generally indicate a high coefficient of transmissibility, and low specific capacities generally indicate low coefficients of transmissibility. Theoretically the transmissivity is linearly proportional to the specific capacity of a well and the constant of proportionality can be obtained by the Dupuit-Thiem equation (Thomasson et al. 1960; Thesis et al. 1963; Brown 1963; Bradbury and Rothschild 1985; Razack and Huntley (1991). The aim of this paper is derived relationship between transmissivity and specific capacity to determine the possibility of using the specific capacities of wells in other parts of the Rabia and Debagah -Mukumar basins to predict the transmissivity in these areas. Several studies have analyzed the relationship between transmissivity and specific capacity. Razack and Huntley (1991) examined the relationship between transmissivity and specific capacity in an alluvial aquifer in Morocco. Huntley et al. (1992) proposed a relationship between transmissivity and specific capacity in fractured-rock aquifers in the Peninsular Ranges batholith of San Diego County. Mace (1997) applied a similar method to the analysis of specific capacity data in the karstic Edwards Aquifer of Texas. The researcher (Choi ,1999) applied the Cooper and Jacob equation to an unconfined aquifer model to establish a linear relationship between transmissivity and specific capacity in volcanic aquifers on Cheju Island.

Geology

All of studied wells dig in injana formation is basically a clastic sequence that consist of fining upwards cyclothems of carbonate –rich sandstone ,siltstone and claystone and was deposited dominantly in fluvial, coastal and near-shore river environments (Al-Banna , 1982; Al-Juboury, 2009), the thickness of this formation is variable, the thickest part is in the main basin of the formation which lies in the foothill zone area, but interrupted by the Mosul high where the formation is relatively thin ; the maximum thickness of formation is about 600 meters .The sandstone of Injana formation represent the main hydrogeological aquifer in the foothill zone of north and northeastern Iraq (krasny et.al 2006), this aquifer consist of fairly soft, friable porous sandstone which is fine to medium grained in the lower part and coarsen upward .sandstone are thick bedding and intercalated with siltstone and subordinate claystone up to several meters in thickness . The claystone alternate with sandstone mostly act as confined to semi-confined beds separating the aquifer into several water –bearing horizons .

Methodology of study:

Hydrogeological data including transmissivity, specific capacity, wells yield and wells depth, were obtained from water wells drilling company records in Mosul and General Directory of water in Ninewa

(2005) see table (1), for fifty six deep wells penetrated injana aquifer, 31 of these wells distributed in Rabia Plain, while the others distributed in Debagah- Mukummar Basin, see Fig (1). calculated draw down obtained from divide well yield in cubic meter per day to specific capacity in square meter per day. All these data of transmissivity obtained from pumping test based on more than six hour of continuous pumping. Standard statistics, graphical plots was applied to data; which include mean, variance, standard deviation, Skewness, Kurtosis, Minimum and Maximum. Graphical plots include frequency histograms normal and log normal distribution functions and the simple regression analysis linear and logarithm has been applied to derive the empirical relationship between specific capacity and transmissivity.

Table (1) Hydrogeological data for wells (water wells drilling company & General Directory of water)

Well No.	Specific capacity (m^2/ day)	T (m^2/day)	Well yield (m^3/hr)	Calculated Draw down (m)	Well depth (m)	Region
1	46.4	72	34.41	17.95	210	Rabia
2	90	95	20.52	5.47	180	Rabia
3	57.2	102	41.50	17.47	190	Rabia
4	19.5	15	13.53	17.09	140	Rabia
5	22.6	35	13.32	14.53	145	Rabia
6	42.8	51	54.97	31.41	178	Rabia
7	33.7	43	25.56	18.58	150	Rabia
8	56.7	92	39.6	16.76	185	Rabia
9	118	111	55.8	11.34	195	Rabia
10	47.1	59	36	18.38	200	Rabia
11	59.3	76	32.94	13.39	165	Rabia
12	51.8	46	21.6	10.16	150	Rabia
13	48	61	24.48	12.24	160	Rabia
14	124.4	121	31.68	6.13	180	Rabia
15	56.1	66	46.08	19.74	205	Rabia
16	19.5	26	18.36	22.59	145	Rabia
17	17.3	14.5	16.2	22.87	130	Rabia
18	92	101	45.72	11.92	184	Rabia
19	20.4	41	23.4	27.52	173	Rabia
20	19.4	11.7	21.6	26.72	185	Debagah -Mukkumar
21	14.4	15	15.84	26.4	100	Debagah -Mukkumar
22	38.3	45	22.32	13.98	170	Debagah -Mukkumar
23	52.7	46.8	21.96	10	172	Debagah -Mukkumar
24	22.6	16	15.12	16.05	180	Mukkumar
25	32.6	25.6	20.16	14.84	182	Mukkumar
26	15.9	28	39.24	59.23	190	Mukkumar
27	10.2	7.8	13.32	31.96	170	Rabia
28	48.2	77	40.32	20.07	180	Rabia
29	122.3	157	40.82	8.01	160	Rabia
30	57.7	98	46.8	19.46	185	Rabia
31	86	143	49.68	13.86	190	Debagah -Mukkumar
32	72.8	68	26.28	8.76	151	Rabia
33	44.6	71	25.2	13.74	180	Rabia
34	20.8	56	26.1	30.11	160	Debagah -Mukkumar
35	19.2	29	20.88	26.1	170	Debagah -Mukkumar
36	21.6	53	23.04	25.6	171	Rabia
37	28.8	47	29.88	24.9	150	Debagah -Mukkumar
38	33.5	42	24.48	17.53	183	Debagah -Mukkumar
39	40.2	73.6	27	16	120	Debagah -Mukkumar
40	13.8	17	14.4	25.04	124	Debagah -Mukkumar
41	33.5	61	40.5	29.01	154	Debagah -Mukkumar
42	159.8	112	26.64	4	180	Debagah -Mukkumar
43	141.3	94	32.4	5.50	135	Debagah -Mukkumar
44	67.2	86	37.8	13.5	150	Debagah -Mukkumar
45	45.1	67	24.48	13.05	154	Debagah -Mukkumar
46	31.7	68	32.4	24.52	151	Debagah -Mukkumar
47	36.9	45	32.76	21.30	155	Debagah -Mukkumar
48	36.5	54.7	29.52	19.41	170	Rabia
49	20.7	44.8	21.24	24.62	150	Debagah -Mukkumar
50	71.4	93	32.76	11	200	Debagah -Mukkumar
51	101.6	158	35.28	8.38	120	Debagah -Mukkumar
52	46.2	59.7	26.28	13.65	110	Debagah -Mukkumar
53	7.2	5	4.68	28.08	116	Rabia
54	4.8	8	8.1	48.6	123	Rabia
55	8.1	6.5	7.2	57.6	112	Rabia
56	13.3	23	9.94	17.95	210	Rabia

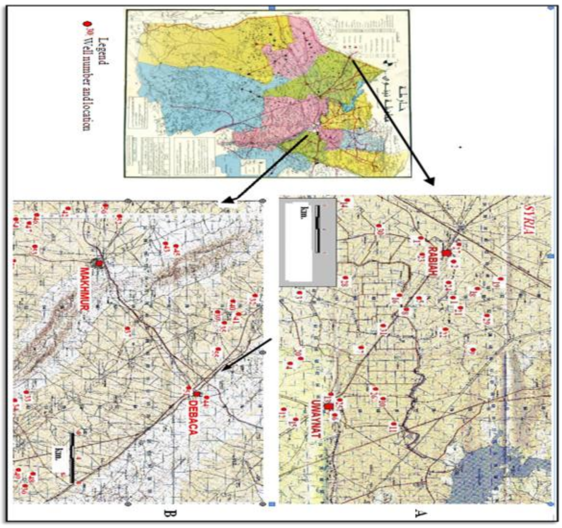

Fig (1) location map of the studied wells A) Rabia Basin and B) Debgah –

Results and discussion:

Descriptive statistics for the data of the studied wells are shown in table (1), there is a wide variation especially in transmissivity and specific capacity which is reflect high variance and standard deviation.

Table 2: The descriptive statistics of the studied wells

Variables / Descriptive	Transmissivity m^2/day	Specific capacity (m^2/ day)	Well yield (L/Sec.)	Calculated Draw down (m)
Mean	59.65	47.56	7.79	19.5
Standard Deviation	37.76	35.41	3.29	10.22
Variance	1426.04	1254.13	10.88	104.6
Skewness	0.69	1.36	0.36	1.44
Kurtosis	0.19	1.56	-0.29	3.64
Minimum	5	4.8	1.3	4
Maximum	158	159.8	15.5	59.23

Transmissivity of the studied wells varies from 5 to 158 m^2/day with a mean of 59.65m^2/day. 46.42% of wells Transmissivity ranged between 40-80 m^2/day and 28.58% of wells Transmissivity less than 40 m^2/day, Fig (2). Specific capacity varies from 4.8 to 159.8 m^2/day with a mean 47.56 m^2/day. 50% of wells specific capacity less than 40 m^2/m/day and 33.93% of wells specific capacity ranged between 40-80 m^2/m/day, Fig (3) . Wells yield varies from 1.3 to 15.5 (L/Sec.) about 37.5 % of wells yield ranged between 5-7.5(L/Sec.) and 19.46% of wells ranged between 7.5-10.5 (L/Sec.), see Fig (4). While calculated draw down ranged between 4-59.2m about 44.46% of wells draw down ranged between 10 -20 m followed 28.57% 20 -30 m, Fig (5). The frequency distribution of both specific capacity and transmissivity indicated that both variables are lognormally distributed, as shown in Fig.(6 and 7)

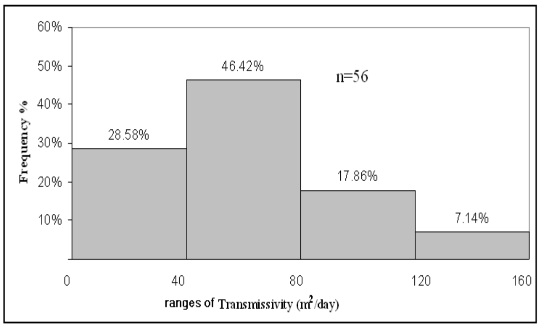

Fig (2) Frequency histogram to of transmissivity

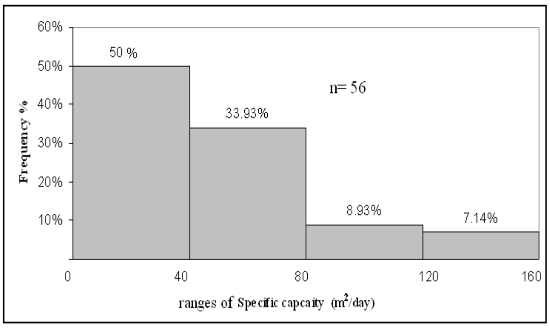

Fig (3) Frequency histogram to of specific capacity

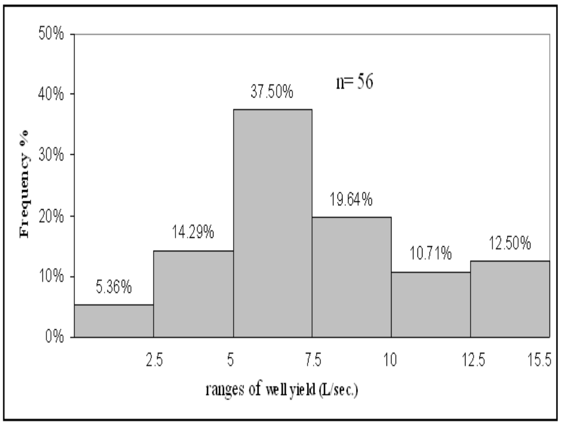

Fig (4) Frequency histogram to of wells yield

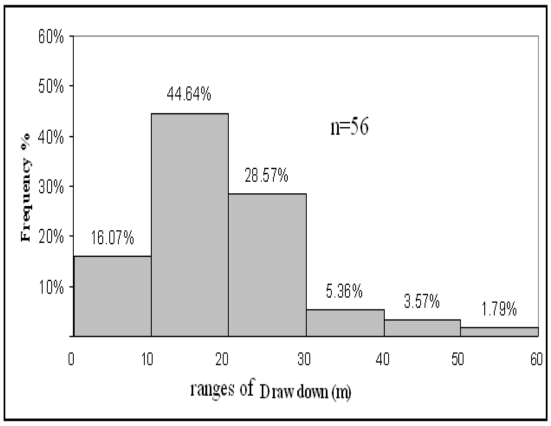

Fig (5) Frequency histogram to of calculated draw down

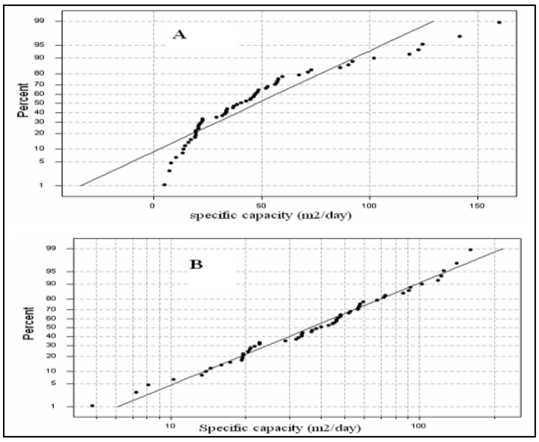

Fig (6) semi log fitted distribution to specific capacity data

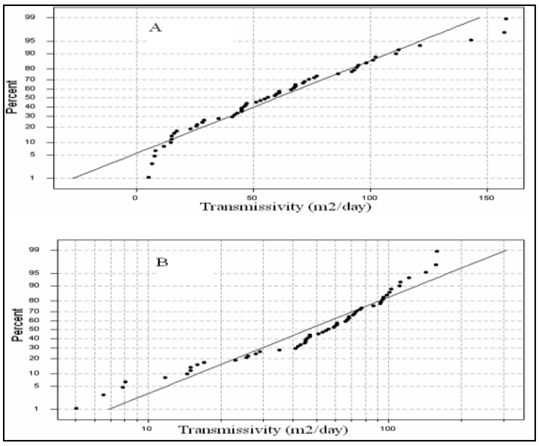

Fig (7) semi log fitted distribution to transmissivity data

Also transmissivity was plotted versus specific capacity using linear regression with a 95% confidence interval level as shown in Fig. (8) Thus, the residuals, which are the differences between the observed and predicted transmissivity values, are plotted versus specific capacity on Fig. (9) The following linear relation is obtained with a correlation coefficient of (r = 0.85)

$$T = 16.28 + 0.911 \times (Sc) \quad \ldots\ldots (1)$$

Where T is the estimated transmissivity (m^2/day) and (Sc) is the specific capacity (m^2/day). It should be noted that the values of the regression constants are specific units of transmissivity and specific capacity applied in this study. The standard error of estimation, which is measure of the scatter about the regression curve, is calculated using the following equation

$$S_E = \sqrt{\frac{\sum_{i=1}^{n}(y_i - \hat{y}_i)^2}{n-2}}. \quad \ldots\ldots.. (2)$$

Where S_E is the standard error of estimate of Y on X, when Y and X are the transmissivity and specific capacity, respectively. Yr is the estimated value of the transmissivity and n is the number of data set. However, the standard error of estimate of transmissivity for linear regression is calculated to be 19.76. On the other hand the transmissivity was plotted versus specific capacity using a log-log regression with a confidence limit of 95% as shown in Fig.(10). In addition, the residuals of the transmissivity values versus specific capacity are plotted on Fig (11) . The following relation is obtained with correlation coefficient of 0.9, however the standard error of estimate of transmissivity values is calculated to be 0.15

$$T = 1.41\,(Sc)^{0.976} \quad \ldots..(2)$$

It is clearly noted that the correlation coefficient obtained from linear regression (r = 0.85) is relatively lower than the correlation coefficient of logarithmic regression (r = 0.90). From a statistical point of view, the use of the log-log relation improved the correlation coefficient. This is right because the frequency distribution of transmissivity and the specific capacity data set are lognormally distributed.

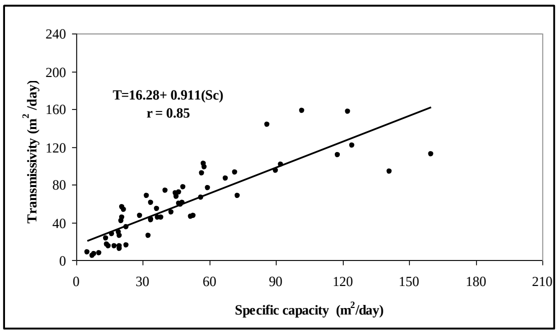

Figure (8) linear relationship between transmissivity and specific capacity with 95% confidence limit.

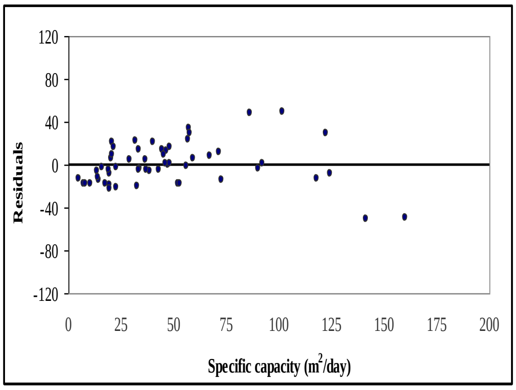

Figure (9)Plot of residual from Linear empirical equation versus specific capacity

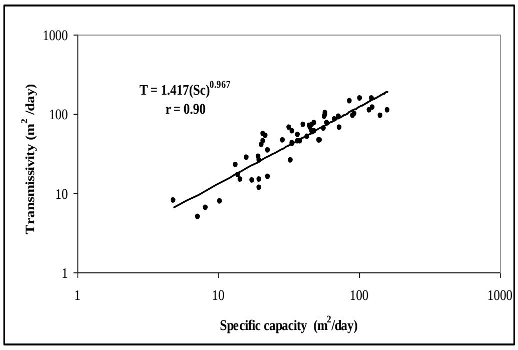

Figure (10) Logarithmic relationship between transmissivity and specific capacity with 95% confidence limit.

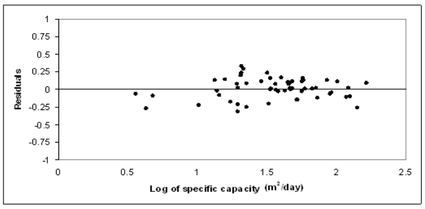

Figure (11) Plot of residual from Logarithmic empirical equation versus specific capacity .

the general form of the logarithmic regression equation (2) is $T=C\ (Sc)^{0.976}$, where C is constant given in table (3) for common units of transmissivity and specific capacity but these equation applied only in sandstone aquifer under same hydrogeoloical condition .From the results of data the variance of transmissivity and well yield in same aquifer related to many factory such as depth of wells , local vertical and lateral lithological variation beside the impact of dissolution and re-sedimentation which change permeability, and location of wells in sedimentary basin , which reflected to variance in transmissivity and well yield from one well to another

Table (٣) Values of the coefficient C in the equation $T=C\ (Sc)^{0.967}$

	Transmissivity				
	units	m^2/hr	m^2/day	ft^2/hr	ft^2/day
Specific capacity	m^2/hr	1.27	30.70	13.76	330.37
	m^2/day	0.059	1.41	0.63	15.25
	ft^2/hr	0.12	3.08	1.38	33.15
	ft^2/day	0.005	0.14	0.063	1.53

Conclusions:

From the main results of this study it can be concluded

1- According to frequency plots about 44.06% of the studied wells have a transmissivity ranged between 40 -80 m^2/day, about 47.45 % of the wells have a specific capacity less than 40 m^2/day, and about 33.59 % of the studied wells have yield ranged between 5-7.5 L/sec. Therefore drilling new wells in these aquifer in study area will be successful of about more the than 75% .

2. It is the necessity to use the logarithmic transformation of data from original data due to frequency distributions of transmissivity and Specific capacity data indicate that both are lognormally distributed.

4- A significant statistical relationship was found between the transmissivity and the specific but utilizing log-log regression analysis showed a better correlation coefficient (r = 0.90) than the linear regression correlation coefficient (r = 0.85).

5- The best –fit regression line for the sandstone aquifer data set is T=1.4١(Sc)$^{0.976}$ For transmissivity and specific capacity both in units of sq m/d .We recommended if available a large set of data of specific capacity andTransmissivity to other type aquifer to derived another empirical relation between them such as quaternary aquifer or pliaspa fracture limestone aquifer

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تقدير الناقلية المائية لخزان انجانة الجوفي من بيانات السعة النوعية في منطقتين مختارتين من محافظة نينوى

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الملخص

تعتبر الناقلية للخزانات الحاملة للمياه من اهم الخصائص التي تهتم بها دراسات المياه الجوفية ، والتي يتم حسابها بشكل عام من تحليل بيانات الضخ الاختباري . كما انه بالامكان تخمين قيم الناقلية المائية في حالة توفر معلومات عن السعة النوعية للابار باستخدام المعادلات التجريبية . في هذا البحث تم انشاء علاقة خطية ولوغارتمية بين الناقلية المائية و السعة النوعية لستة وخمسون بئر تخترق خزان انجانة منتشرة ضمن حوضي ربيعة وديبكة – مخمور في محافظة نينوى حيث وجد ان المعادلة اللوغارتمية تعطي معامل ارتباط اعلى ($r = 0.90$) من المعادلة الخطية ($r = 0.85$) وذلك كون الناقلية المائية والسعة النوعية للابار تكون مطابقة بشكل افضل للتوزيع اللوغارتمي الطبيعي من التوزيع الطبيعي . بالامكان ان تستخدم هده المعادلة في تخمين قيم الناقلية في حالة توفر معلومات عن السعة النوعية للابارفي مناطق اخرى ضمن حوضين الدراسة على شرط ان تكون الابار مخترقة لنفس الخزان المائي الجوفي وتحت نفس الظروف الهيدروجيولوجية .