World Academy of Science, Engineering and Technology
International Journal of Environmental and Ecological Engineering
Vol:9, No:9, 2015

Estimation of Aquifer Properties Using Pumping Tests: Case Study of Pydibhimavaram Industrial Area, Srikakulam, India

G. Venkata Rao, P. Kalpana, R. Srinivasa Rao

***Abstract*—**Adequate and reliable estimates of aquifer parameters are of utmost importance for proper management of vital groundwater resources. At present scenario, the ground water is polluted because of industrial waste disposed over the land and the contaminants are transported in the aquifer from one area to another area, which is depending on the characteristics of the aquifer and contaminants. To know the contaminant transport, the accurate estimation of aquifer properties is highly needed. Conventionally, these properties are estimated through pumping tests carried out on water wells. The occurrence and movement of ground water in the aquifer are characteristically defined by the aquifer parameters. The pumping (aquifer) test is the standard technique for estimating various hydraulic properties of aquifer systems, viz., transmissivity (*T*), hydraulic conductivity (*K*), storage coefficient (*S*) etc., for which the graphical method is widely used. The study area for conducting pumping test is Pydibheemavaram Industrial area near the coastal belt of Srikulam, AP, India. The main objective of the present work is to estimate the aquifer properties for developing contaminant transport model for the study area.

***Keywords*—**Aquifer, contaminant transport, hydraulic conductivity, industrial waste, pumping test.

I. Introduction

PUMPING tests are commonly used for evaluating aquifer parameters, though other methods such as slug tests, bail tests, and tracer tests are also employed for this purpose. The normal practice in a pumping test is to pump a bore well at a specified discharge rate and observe the draw down recovery in observation well(s) located at some distance(s) from the pumping well. The drawdown data so obtained can be used to estimate the aquifer parameters such as transmissivity and storativity by employing any one or more procedures such as Thesis, Cooper-Jacob's, and Chow's methods. One of the difficulties faced while conducting pumping tests is in keeping the discharge rate constant. The discharge rate tends to vary slightly with time because of: (1) is increasing discharge head, and (2) voltage [4] fluctuations in electric power supply to the pump motor. There are many areas in the world where large-diameter dug wells are used for domestic and agricultural supply. Efficient management and development of such areas necessitate knowledge of the physical parameters of the hydro geological system [1]. All aquifers are to some extent heterogeneous and this fact brings into question the validity of normal methods of pumping-test analysis, which assume homogeneity. While it is perhaps obvious that pumping tests tend to "average out" the properties of aquifers, it is natural to be suspicious of results obtained when the pumping well is situated in a region of the aquifer, which is considered to be atypical-especially if the only drawdown [2] measured, is that in the pumping well. The occurrence of groundwater in the region is controlled by various factors such as structure, geological sequence and stratigraphic disturbances. Groundwater recharge of the region occurs through direct rainfall infiltration, floods and riverbed as well as the lateral subsurface flow. In addition, the irrigation return flow can result in recharge [5]. The aim of our study is to demonstrate the use of aquifer parameters in the assessment and management of the shallow (sedimentary) groundwater resources and estimation of ground water pollution from industrial wastes of Pydibhimavaram Industrial Area Basin, which is located in the coastal belt of srikakulam (district), Andhra Pradesh India. Generally, clay/shale makes for good permeability barriers, while sand and gravel readily transmit fluids. However, secondary overprints such as structural deformation and digenetic alteration (post depositional changes in mineralogy) can drastically influence permeability and porosity.

G.Venkata Rao is with the Department of Civil Engineering, GMR Institute of Technology, Rajam-532 127 India, (Phone: 08941-251593; 08941-251591; e-mail: venkatarao.g@gmrit.org).
P. Kalpana is with the Department of Chemical Engineering, GMR Institute of Technology, Rajam-532 127 India, (e-mail: kalpana.p@gmrit.org).
R. SrinivasaRao is with the Department of Civil Engineering, GMR Institute of Technology, Rajam-532 127 India, (e-mail: srinivas.r@gmrit.org).

II. Study Area

The present study is conducted in Pydibhimavaram area, Ranasthalam Mandal, Srikakulam District, Andhra Pradesh, India. It is situated between 18.145N 83.627E and 18.099N 83.674E Latitudes and Longitudes. The area is recognized as an Industrial area by the Government of India. Many Industries viz. Andhra Organics, Dr. Reddy's Laboratories, Aurobindo, United breweries are situated in the Pydibhimavaram. The area is cultivated in 20 Sq.km and solely dependent on the ground water and this study area covers the villages like Pydibhimavaram, Boyapalem, Akkayyapalem, Naruva and Mentada. The chemical and pharmaceuticals industries located near this area and discharge their effluent on the low-lying areas and in river water, which is leads to the ground water pollution in and around the study area.

A. Geo-Electric Section along the Profile Perpendicular to the Study Area

The VES curves were obtained by plotting the apparent resistivity against electrode spacing, a computer program Genres , was used to reduce the geo-electrical sounding curves into values of thickness and resistivity of individual layers [6].

Vertical Electrical Sounding (VES) data has been acquired in perpendicular direction to the coast and it consists of three geo-electric layers. The first layer is the topsoil and is characterized by layer with resistivity values from 13.7 to34.9 ohm-m and its thickness is between 0.718 to 1.05m. The second layer underneath VES 1 is the suggestive of weathered granite and under the remaining two sounding points VES 2 and VES 6 is weathered or fractured Khondolite [7] with resistivity ranging from 12.2 to 10.4 ohm.m. The thicknesses vary from 6.44 to 8.16m. The third layer for all the VES points is Hard rock or electrical basement and the resistivity values are ranging from 6.49 to 7.85 Ohm.m. [3]. The thicknesses vary from 6.44 to 17.7m.By conducting the auxiliary point methods the Relationships between the representative aquifer resistivity and aquifer permeability and transmissivity are also determined [8], [9].

III. Procedure for Conducting Pumping Tests

A. In Large Diameter Wells

The large diameter or dug wells are common in Asian countries. They are source of irrigation as well as domestic water supply. In hard rock areas these wells are often shallow and of large diameter. The stored water is pumped and recuperation to the well requires a long time. These wells are often fitted with pumps. Therefore, they offer readily available means to conduct pumping test and determine the aquifer parameters. The family type curve as show in Fig. 1. In most of the methods described for pumping tests, it is assumed that the well storage is negligible. Hence, these methods cannot be used to analyse the pump test data from large diameter well. For large diameter well, the family type curves shown in the Fig. 1 has been used for the pumping test, which tap the unconfined aquifer [10].

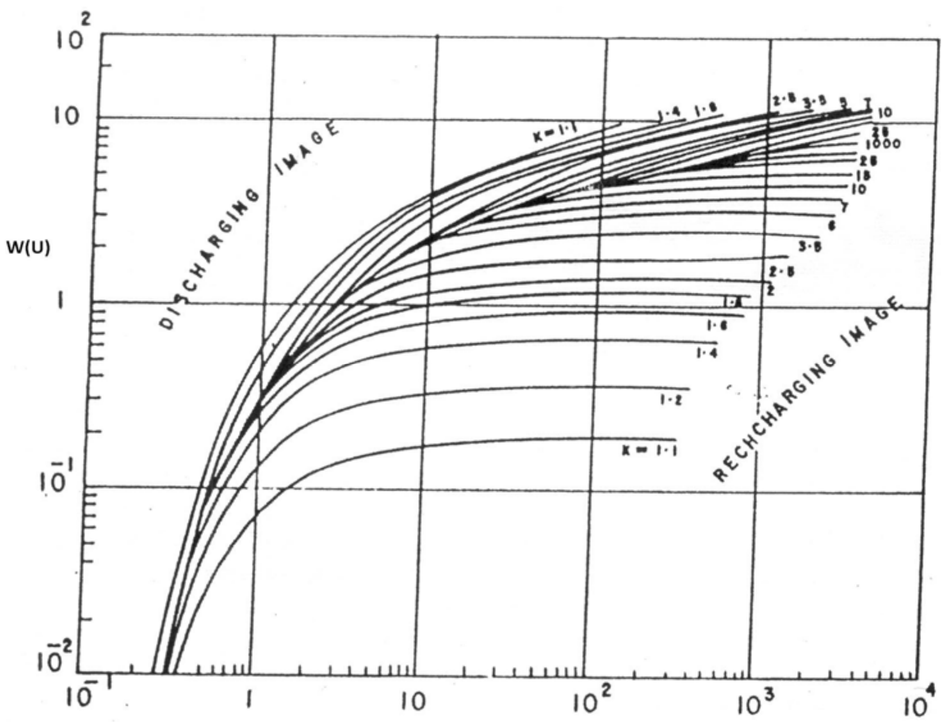

Fig. 1 Family type curve for semi confined aquifer

The assumptions made in addition to those described earlier are: 1) the well diameter is not negligible. 2) The flow towards the well is in unsteady state. 3) The well loss (entrance resistance) is negligible. The type curves are shown in Fig. 2 which is plotted for different values of β, a function of storage coefficient and ratio of well diameter (r_w) to the diameter of casing (r_c). The initial part of the curve shows straight line, which represents the linear behavior of time-drawdown due to the well storage. As the well storage effect diminishes, the curve deviates from the straight line. The yield curve is plotted on similar log-log paper as the type curve. A suitable match is found out using the curved part of the field curve together with initial straight-line part. The values of well function W (u,w, β), 1/u, s, t and β for the match point are noted. The aquifer parameters are calculated from the following equations:

$$T=(Q/4\pi s)W\ (u_w, \beta)$$

$$S=4Tt\ u_w/(r\ r)$$

IV. Estimated Aquifer Properties

A. Transmissibility

Transmissibility (T) is equal to the discharge rate at which water is transmitted through a unit of an aquifer under a unit hydraulic gradient. Thus:

$$T=k\,b$$

where, 'b' is the saturated thickness of the aquifer. b is equal to the depth of a confined aquifer. It is equal to the average thickness of the saturated zone of an unconfined aquifer. Transmissibility is usually expressed as m^2/s, or m^3 per day/m or liters per day/m. Transmissibility of the most formation lies between 1×10^4 and 1×10^6 liters per day/m, with an average value of 1×10^5 liters er day/m. Transmissibility is also called transmissivity.

B. Coefficient of Permeability

Permeability is the ease with which, water can flow in a soil mass (or a rock). The coefficient of permeability (k) is equal to the discharge per unit area of soil mass under unit hydraulic gradient. Because the discharge per unit area is equal to the velocity, the coefficient of permeability has the dimensions of the velocity [L/T]. It is usually expressed as cm/s,m/s,m/day, etc. The coefficient of permeability is also called hydraulic conductivity.

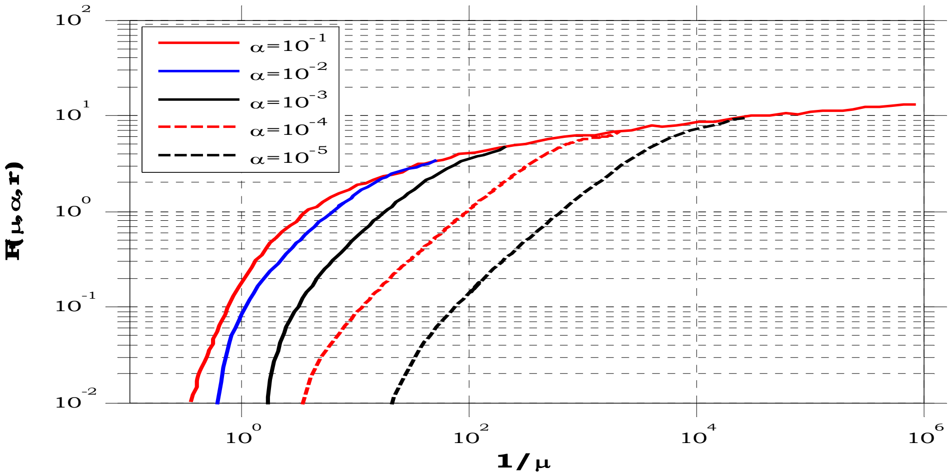

Fig. 2 Family type curves for large diameter wells

C. Specific Yield

Specific yield is the (S_y) is the ratio of the volume of water (V_w) in an aquifer, which can be extracted by the force of gravity (or by pumping from wells) to the total volume (V) of the saturated aquifer, it is expressed as a percentage.

$$S_y=(V_w/V) \times 100$$

All the water stored in a water bearing stratum cannot be drained out by gravity or by pumping, because a portion of the water is rigidly held in the voids of the aquifer by molecular and surface tension forces.

D. Specific Retention

Specific retention (S_r) is the ratio of the volume of water (Vr) that cannot be drained out to the total volume (V) of the saturated aquifer. It is also expressed as a percentage. Thus

$$S_r = (Vr/V) \times 100$$

Because the total volume of voids (V_v) is equal to the sum of the volume of water (V_w) drained out and the volume of water (V_r) retained, we have

$$V_v=V_{w+}V_r$$

V. Results

Pumping test location is 1. The following observations are made at Latitude18.1160^{0}and longitude83.6477^0.

TABLE I
Drawdown and Time Values for the Main Wellat Location1

S.no	Time (min)	Drawdown In 'm'	S.no	Time (min)	Drawdown In 'm'
1	5	0.638	15	75	1.321
2	10	0.706	16	80	1.349
3	15	0.774	17	85	1.376
4	20	0.838	18	90	1.406
5	25	0.899	19	95	1.43
6	30	0.955	20	100	1.452
7	35	1.008	21	105	1.473
8	40	1.057	22	110	1.486
9	45	1.103	23	115	1.51
10	50	1.147	24	120	1.53
11	55	1.188	25	125	1.548
12	60	1.225	26	130	1.559
13	65	1.26	27	135	1.568
14	70	1.29	15	75	1.321

Pumping test location is 2. The following observations are made at Latitude 18.1180^{0}and longitude 83.651^0.

TABLE II
DRAWDOWN AND TIME VALUES FOR THE MAIN WELL AT LOCATION 2

S.no	Time (min)	Drawdown In 'm'	S.no	Time (min)	Drawdown In 'm'
1	2	3.787	53	106	7.998
2	4	5.007	54	108	7.972
3	6	5.144	55	110	7.96
4	8	7.068	56	112	7.971
5	10	7.479	57	114	7.996
6	12	7.584	58	116	7.966
7	14	7.657	59	118	8.025
8	16	7.708	60	120	8.025
9	18	7.744	61	122	8.047
10	20	7.771	62	124	8.05
11	22	8.281	63	126	8.062
12	24	8.697	64	128	8.074
13	26	8.893	65	130	8.058
14	28	8.993	66	132	8.059
15	30	9.002	67	134	8.059
16	32	9.011	68	136	2.679
17	34	8.98	69	138	0.821
18	36	7.491	70	140	5.981
19	38	0.569	71	142	7.603
20	40	6.508	72	144	7.828
21	42	7.598	73	146	7.924
22	44	7.76	74	148	7.997
23	46	7.826	75	150	8.034
24	48	7.871	76	152	8.062
25	50	7.895	77	154	8.083
26	52	7.92	78	156	8.1
27	54	7.924	79	158	8.113
28	56	7.932	80	160	8.117
29	58	7.93	81	162	8.117
30	60	7.923	82	164	8.12
31	62	7.938	83	166	8.138
32	64	7.949	84	168	8.131
33	66	8.014	85	170	8.131
34	68	8.062	86	172	8.131
35	70	8.014	87	174	8.157
36	72	8.006	88	176	8.155
37	74	7.985	89	178	8.163
38	76	7.958	90	180	8.173
39	78	7.954	91	182	8.171
40	80	7.971	92	184	8.174
41	82	7.959	93	186	8.166
42	84	7.971	94	188	8.142
43	86	7.98	95	190	8.134
44	88	7.973	96	192	8.144
45	90	7.967	97	194	8.184
46	92	7.954	98	196	8.198
47	94	7.982	99	198	8.193
48	96	8.004	100	200	8.163
49	98	8.012	101	202	8.143
50	100	8.088	102	204	8.152
51	102	8.046	103	206	8.147
52	104	7.992	104	208	8.166

VI. CONCLUSIONS

From the study, it has been concluded that the aquifer in the study area is semi-confined aquifer and having the following range of properties. Transmissivity is in the range of 1.3696x$10^{-3}$$m^2$/sec to 3.1404x$10^{-7}$ m^2/sec. Storativity is the range of 3.3321x10^{-4} and 1.261x10^{-5}. Coefficient of Permeability range is in the range of 1.9196x10^{-4} m/sec to 2.5113x10^{-8} m/sec. Specific Capacity is in the range of 2.2066x10^{-3} to 1.261x10^{-5} and, the velocity of flow is in the range of 3.413x10^{-6} m/sec to 8.011x10^{-10} m/sec.

TABLE III
AQUIFER PROPERTIES OF TWO LOCATIONS

Properties At location 1	Properties At location 2
From graph, Drawdown (S) =7 m, Time(t)=8min, Well function [W(u)] = 2.4x10-3 1/u= 6x10-1 =>u=1.6666	From graph, Drawdown=5.5m, Time =6min $\frac{1}{u}$=0.7W(u)=6x10-
Transmissivity (T): T=$\frac{Q}{4\pi s}$W(u,r/l) T = 1.9955x10-7 m2/se	Transmissivity:(T) T=$\frac{Q}{4\pi s}$W(U,r/l)=3.1404x10-7 m2/sec
Storativity (s): S=$\frac{4Ttu}{r2}$=2.242x10-6 Well depth = 4.77m Aquifer = 18m	Storitivity:(s) S=$\frac{4Ttu}{r2}$=1.2617x10-5
Specific Storage (Ss): Ss = $\frac{s}{b}$=1.5712x10-7m	Specific storage :(Ss) SS=$\frac{s}{b}$ =1.0089x10-6
Coefficient of permeability (k): K = $\frac{T}{b}$=1.3983x10-8m/sec	Coefficient of permeability(K): K= $\frac{T}{b}$=2.5113x10-8m/sec
Velocity of flow(v): V = Ki= 2.486x10-10m/s	Velocity(v): V=ki=8.011x10-10 m/sec

ACKNOWLEDGMENT

The authors are thankful to the Department of Science and Technology (DST), Ministry of Science& Technology, New Delhi, Government of India, for granting necessary financial assistances to carry out this research project work.

REFERENCES

[1] Herbert. R. and R. Kitchinq- "Determination of Aquifer Parameters from Large-Diameter Dug Well Pumping". Ground water, Vol.19.No.6- December 1981.
[2] Barker. J. A. and R .Herbert- "Pumping Tests in Patchy Aquifers" Ground Water Vol. 20, No.2- -March-April1982.
[3] Venkatarao. G et.al "Groundwater Investigation Using Geophysical Methods-A Case Study of Pydibhimavaram Industrial Area". International Journal of Research in Engineering and Technology, Special Issue Volume 3,16thDecember2014.
[4] Ballukraya N. P and Sharma. K. K- "Estimation of Storativity from Recovery Data" Ground Water Vol. 29, No.4. July- August 1991.
[5] T.A. Tizro1, K.S. Voudouris and M. Kamali – "Comparative Study of Step Drawdown and Constant Discharge Tests to Determine the Aquifer Transmissivity: The Kangavar Aquifer Case Study, Iran". Journal of Water Resource and Hydraulic Engineering. Mar. 2014, Vol. 3 Iss. 1, PP. 12-21.
[6] Nyadawa, M. O. et.al-"Hydrogeophysical Parameter Estimation for Aquifer Characterization in Hard Rock Environments: A case study from Jangaon sub-watershed, India". Journal of Oceanography and Marine Science Vol. 2(3), pp. 50-62, March 2011.
[7] Pantelis M.et.al- "Estimation of Aquifer Hydraulic Parameters from Surficial Geophysical Methods: A case Study of Keritis Basin in Chania (Crete – Greece)". Journal of Hydrology (2007) 338, 122– 131.
[8] W. K. Kosinki and W. E. Kelly, "Geoelectric Soundings for Predicting Aquifer Properties," *Ground Water*, Vol.19, No. 2, 1981, pp. 163-171.
[9] J. F. Ayers, "Conjunctive Use of Geophysical and Geo-logical Methods in the Study of Alluvial Aquifer," *Ground Water*, Vol. 27, No. 5, 1989, pp. 625-632.

G. Venkata Rao, Professor, Department of Civil Engineering, GMR Institute of Tehnology born in Vizianagaram (District), Andhra Pradesh, India and in the month of August 1972 and he is a life member of Institution of Engineers (India). He has B.E in Civil Engineering, M.E in Hydraulics and Coastal Harbor Engineering and PhD in Water Resources Engineering .His major field of study is Surface Water Hydrology and Water Quality, Ground Water Hydrology and Sea Water Intrusion.

P. Kalpana, Associate Professor, Department of Chemical Engineering, GMR Institute of Tehnology born in Visakhapatnam (District), Andhra Pradesh, India and in the month of August 1981. She has B. Tech and M. Tech and PhD in Chemical Engineering. Her major field of study is Waste Water Treatment and Water Quality.

R. SrinivasaRao, Assistant Professor, Department of Civil Engineering, GMR Institute of Tehnology born in Vizianagaram (District), Andhra Pradesh, India and in the month of November 1984. He has M.Sc (Tech) in Geophysics and M. Tech in Engineering Geology. His major field of study is Hydrogeology and Geophysical exploration of ground water.