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Specific Yield Estimation by Pumping Test, Velliyur Wellfield, Araniyar - Kortaliyar (A.K Basin), Thiruvallur District, Tamil Nadu, India

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ABSTRACT

A well field consisting of one pumping well and six observation wells was constructed at Velliyur site, Thiruvallur district, Tamil Nadu, India which forms part of the Araniyar - Kortaliyar (A.K basin) basin. This basin has been a potential source for drinking water supply to Chennai Metropolitan city. Long duration pumping test for 10000 minutes was carried out with constant discharge of 4.5 litres per second (LPS) which has created 1.5 mts drawdown only. The results of pumping test were used for arriving specific yield parameter by three methods. The specific yield determined was 15 % from Volume dewatering method, 18 % from Ramsahoye – Lang method and 16.5 % from curve matching method (Neuman). Specific yield is an important factor used in the ground water resource estimation and assessment.

KEYWORDS

Araniyar - Kortaliyar (A.K basin), Pumping test, Specific yield, Volume dewatering method, Ramsang – Lang method & Curve matching method (Neuman).

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INTRODUCTION

The Araniyar –Koratliyar basin (A.K) has been a potential source for drinking water supply to Chennai Metropolitan city was having many well fields constructed by Chennai Metro water department and was pumping about 200 million litres per day (mld) to Chennai city. The present day groundwater pumping has reduced to 22.5 mld due to several issues[1]. In order to understand the aquifer parameters and for better hydrogeological characterization of this basin, a study to determine the aquifer parameter specific yield by conducting long duration pumping test was taken up. A well field comprising of 1 pumping well and 6 observation wells was constructed at Velliyur village for tapping the shallow unconfined alluvial aquifer. The well field was constructed at Velliyur village having a latitude of 13°13´17´´ N and longitude 80°00´10´´ E covered by Survey of India toposheet 66C/4. The study area is located near Thamaraipakkam village at Thiruvallur – Redhills road and is 20 km from Redhills and 12 km from Thiruvallur town. The plan of the Velliyur well field is shown below in Figure1.

Geology

The study area is underlain by alluvium formation which was deposited on the worn down and eroded surface of tertiary and gondwana rocks. The alluvium consists of fine to coarse sand, sandy clay, clayey sand and clay partings of various shades of grey and brown.

Hydrogeology

The groundwater in the study area occur in the unconsolidated & semi-consolidated formations forming important aquifer systems. Groundwater occurs under phreatic to semi-confined conditions in the inter-granular pore spaces in sands , sandstones , the bedding planes and thin fractures in shales. In the area underlain by Cretaceous sediments, groundwater development is rather poor due to the limited yield and the poor quality of the formation water. Quaternary formations comprising mainly sands, clays and gravels are confined to major drainage courses in the study area. The maximum thickness of alluvium is 40m whereas the average thickness is about 15m. Ground water occurs under phreatic to semi-confined conditions in these formations and is being developed by means of dug wells and shallow tube wells. Alluvium, which forms a good aquifer system along the Araniyar and Korattalaiyar river bed is one of the major sources of water supply to urban areas of Chennai city and also to the industrial units. The depth of the wells ranged from 8 to 15m bgl. The depth to water level in the study area

ranges between 1.6 – 13.36 m bgl during pre-monsoon (May) and 0.79 – 5.30 m bgl during post monsoon (January). The seasonal fluctuation shows a rise between 0.28 and 4.80 m bgl.

Geophysics

The geophysical survey comprising Vertical Electrical Sounding (VES) were carried out in the area by employing the Schlumberger Electrode Configuration with half current electrode separation (AB/2) of 50m. The obtained VES curves were plotted on double logarithmic graph paper of modulus 62.5 mm in field. The obtained field data were input for the VES interpretation technique with the aid of personal computer. The layer parameter was adjusted till the theoretically generated curves match with the filed curves. The interpreted VES results are presented in table no 1.

Table 1: Interpreted Results of VES in Velliyur site, Thiruvallur District, Tamil Nadu.

VES	Location	Interpreted Results							Remarks
		Resistivity (Ohm.m)				Thickness (m)			
		ρ1	ρ2	ρ3	ρ4	h1	h2	h3	
1	Velliyur	110	475	20	□	0.8	5.0	□	Ext

ρ_1=First layer resistivity,h_1=First layer thickness

The first layer indicating a resistivity of 110.0 Ohm.m with thickness of 0.8 m which sandy soil in nature. The second layer having resistivity of 475 Ohm.m with thickness of 5.0m sandy in nature. Third layer having resistivity 20.0 Ohm.m which sandy mixed clay extending with depth. The quality of the water may be good and potable.

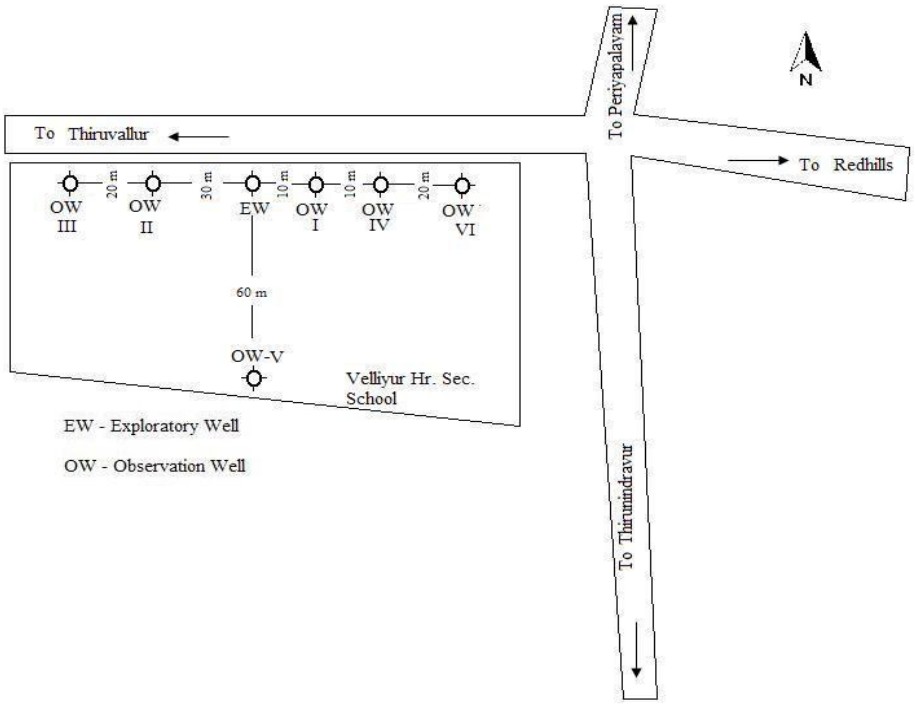

Figure 1: Layout of the Vellaiyur Well Field

Details of well field

Well field construction was carried out at Velliyur site by calyx rotary method by using bentonite clay as drilling media. One pumping well and six observation wells were constructed, tapping the shallow unconfined aquifer. The distance and direction details of EW (pumping well) and OWI to OWVI are tabulated below (Table II):

Table 2: Details of Wells

Type of the well	Distance from EW and its direction
EW	-
OWI	10 m. towards east
OWII	30 m. towards west
OWIII	50 m. towards west
OWIV	20 m. towards east
OWV	60 m. towards south
OWVI	40 m. towards east

The aquifer at Velliyur is made up of sand, brownish fine medium to coarse grained. They are well sorted, semi rounded to rounded quartz grains and intercalation of clay at different depths. These sediments are underlined by gravels and hard shale, in which calyx rotary drilling is difficult. Hence, it was considered as an unconfined aquifer, and pumping test has to be carried out to determine specific yield [2]. Table 3 shows the details of well location, aquifer zones tapped, the static water level, the depth of well and discharge.

Table 3: Salient Features of Velliyur Well Field

S. No	Well Type	Depth constructed (m)	Aquifer Zones Tapped (m)	Static Water Level (m.bgl)	Discharge Q (lps)	Remarks
1	EW	25.20	13□16 17□20 21-24	11.425	3.28	Fine medium coarse grained Sand brownish Intercalation black clay at 6.70□7.00m clayey sand from7.00□8.00 m
2	OW□I	25.10	13□16 17□20 21□24	11.550	3.28	Fine medium coarse grained Sand□brownish Black sticky clay from 6.70–7.70m
3	OW□II	25.00	13□16 17□20 21□24	11.360	2.45	Fine medium coarse grained sand□brownish
4	OW□III	23.70	12.7□18.7 19.7□22.7	11.410	2.45	Fine medium coarse grained sand□brownish Clay from 5–6m
5	OW□IV	25.00	13□16 17□20 21□24	11.870	3.28	Fine medium coarse grained Sand brownish Intercalation black clay at 6.70□7.00m clayey sand from 7.00□8.00 m
6	OW□V	20.60	12.5□15.5 16.5□19.5	18.500	0.43	Fine medium coarse grained Sand□brownish Black sticky clay from 6.70–7.70m
7	OW□VI	24.70	12.7□15.7 16.7□19.7 20.7□23.7	14.650	2.45	Fine medium coarse grained sand□brownish Clay from 5–6m

The aquifer material is brown is sand with fine, medium to coarse grained texture. The sand is well sorted, semi rounded to rounded, transparent quartz grain sand intercalation of clay at some depths. It is underlined by gravelly sandstone and shale of hard nature, which could not be penetrated by calyx rotary rig.

Pumping Test

Pumping test is performed to find out the behavior of aquifer as well as the well in response to the stress applied in the form of pumping. The well is pumped at a known constant discharge and the effect of pumping on the aquifer's hydraulic head (water level) is measured in the well itself and in a number of observation wells constructed nearby pumping well. The change in the water level induced by pumping is known as the drawdown. Aquifer parameters and well efficiency are estimated by pumping test. Long duration pumping test at Velliyur site was conducted for 10000 minutes[3].

Step Drawdown Test

Step drawdown test is a part of pumping test conducted in three or four stages in equal duration 100 or 60 minutes in a step fashion and recording the drawdowns. Step draw down test was conducted at Velliyur site for discharge rates of 1.5 litres per second (lps), 3 lps, 4.5 lps and 6 lps with four steps of each 60 minutes duration and drawdown observed were 0.24 m, 0.55 m, 0.93 m, and1.57 m respectively. Based on the test results, it was decided to adopt 4.5 lps (270 litres per minute) (388.8 m^3/day) for long duration Aquifer Performance Test (APT) (Table 4).

Table 4: Results of Step Drawdown Test at Velliyur

Step	Duration of step in minutes	Discharge (in lps)	Drawdown (in m.)	Specific capacity (lpm/m)
I	60	1.5	0.24	375
II	60	3.0	0.55	327
III	60	4.6	0.93	296
IV	60	6.0	1.57	229

The formation and well losses are computed by Jacob's graphical method (1969) using the following equation,

$$S= BQ+CQ,$$

Where, Q = Discharge in m^3/sec,

B = Formation loss Coefficient in s/m^2

C= Well loss coefficient in S^2/m^5,

S = Total draw down in m.

Computation of formation and well losses and the total draw down are given in the table 5.

Table 5: Step drawdown test computation of Velliyur site, Thiruvallur district, Tamil Nadu

Step	Discharge in m^3/sec Q	Drawdown observed in m.	Sp. draw down s/Q m/m/sec	Formation Loss Coefficient B s/m^2	Well Loss Coffic ientC S^2/m^5	Forma tion Loss BQ m	Wells Loss CQ^2 m	Total draw down $BQ+ CQ^2$ m
I	0.015	0.24	160	140	13333	0.21	0.029	0.29
II	0.003	0.55	183.3	140	13333	0.42	0.119	0.539
III	0.0046	0.93	202	140	13333	0.64	0.282	0.922
IV	0.006	1.57	261.6	140	13333	0.84	0.479	1.32

Aquifer Performance Test (APT)

The APT was carried out with total duration of pumping test was 10, 000 minutes. Static water level and height of measuring point for the exploratory and observation wells are given below (Table 6).

Table 6: SWL of Velliyur well field

S.no	Details	Ew	Ow□i	Ow□ii	Ow□iii	Ow□iv	Ow□v	Ow□vi
1	SWL m.bmp	18.405	18.130	17.910	17.93	18.23	17.300	18.36
2	Ht. of MP m.agl	0.850	0.550	0.500	0.450	0.500	0.590	0.580
3	SWL m.bgl	17.555	17.580	17.410	17.48	17.73	16.710	17.78

SWL□Static water level

Ht. MP–Height of Measuring Point,

m.bmp – meters below measuring point

m.agl – meters above ground level,

m.bgl – meters below ground level

Pumping test was conducted at a constant discharge rate of 4.5 lps (388.8 m^3/day). The draw down observed at the end of 10000 minutes is 1.525 m. The drawdown observed in OW□I, OW□II, OW□III, OW□IV, OW□V and OW□VI were 0.2m, 0.18m, 0.16m, 0.18m, 0.12 m and 0.24 m respectively. The details of draw down for all the wells are tabulated in table 7. Discharge is estimated as 4.5 lps or 388.8^3/day.

Table 7: Salient feature of Velliyur well field APT

S.No	Time in minutes	Drawdown in meters						
		Ew	Ow□i	Ow□ii	Ow□iii	Ow□iv	Ow□v	Ow□vi
1	1000	0.925	0.090	0.070	0.040	0.095	0.050	0.060
2	2000	0.955	0.110	0.090	0.080	0.090	0.450	0.070
3	3000	0.994	0.092	0.122	0.102	0.125	0.690	0.105
4	4000	1.035	0.147	0.125	0.100	0.120	0.073	0.105
5	5000	1.165	0.140	0.060	0.000	0.145	0.275	0.140
	6000	1.215	0.175	0.155	0.130	0.155	0.100	0.130
7	7000	1.314	□0.035	0.142	0.129	0.147	0.090	0.130
8	8000	1.265	0.190	0.180	0.155	0.178	0.560	0.150
9	9000	1.435	0.205	0.190	0.160	0.180	0.110	0.160
10	10000	1.525	0.200	0.180	0.160	0.180	0.120	0.240

EW–ExploratoryWell

OW–ObservationWell

The draw down data of observation well is plotted on double log paper against time figure number. The data is analyzed using type curve graphical method devised by Theis for unsteady state condition and it could not be matched so and it has shown three segments so it has been analysed by Neuman method. The interpreted results are given in table 8.

Table 8: Interpreted Results

Data	Pumped well	Ow□ I	Ow ii	Ow iii	Ow iv	Ow v	Ow vi
SWL MBGL	17.555	17.580	17.410	17.48	17.73	16.710	17.78
Discharge m^3/day	388.8	□	□	□	□	□	□
Duration of pumping in min.	10000	□	□	□	□	□	□
Maximum drawdown in m.	1.525	0.2	0.180	0.160	0.180	0.120	0.240
Sp. Capacity of 10000 minutes of pumping lit/min/m	177	□	□	□	□	□	□
Transmissivity of aquifer m^2/ day (T)	692						

Thesis recovery method

The residual draw down of pumping well is plotted against t/t' on Semi log paper and is analysed using straight line method. The computed transmissivity is 692 m^2/day.

Jacob's method

The draw down data of pumped well is plotted against time on semi log paper and the data plot is analysed by Jacob's straight line method. The computed transmissivity of aquifer is 615.5 m^2/day.

DETERMINATION OF SPECIFIC YIELD

Method-1: Volume dewatering method

Normally the cone of depression (Figure 2) calculated using the radius of influence that are is not dewatered completely. This can be observed if we have number of observation wells.

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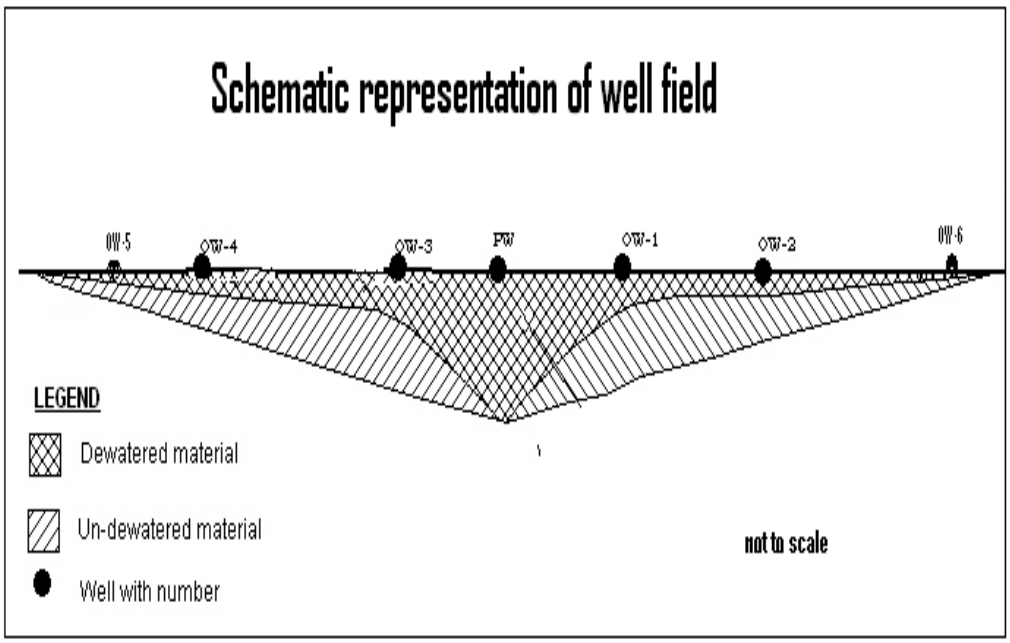

Figure 2: Schematic Representation of Well Field

This specific yield calculated assuming the entire cone of depression is dewatered gives less value of specific yield. This was rectified by constructing the cone of depression diagrammatically in the water level data in the observation wells. The actual volume of aquifer material dewatered (V3)

and the volume of water pumped out as measured (V4).

Actual volume of the material dewatered = V3.

Product of the area inside the cone of the depression = 20.96 m^3 (from the plotted graph)

Radius of influence i.e 0 m drawdown 140 m (from graph)

Circumference of the cone = 2

r = 2*3.142*140*20.96

V3 = 18439.7m^3

Volume of the water pumped out V4 = 388.8*6.94 days (10000 mts)

V4 = 2698.272m^3

Specific yield Sy = V4/V3 *100

2698.272/18439.7*100

Sy = 14.6 (Rounded off to 15%)

Method 2: Ramsahoye and Lang Method

The data collected using the test was analyzed the methodology suggested by Ramsahoye and Lang. For analysis of data using this method the transmissivity of the aquifer was computed from the recovery data of the pumping well.

Discharge (Q) = 4.5lps (i.e.388.8m^3/day)

ΔS=0.14m

$$T = \frac{2.3Q}{4 \prod \Delta S}$$

T = 498m^2/day

Computation of aquifer material dewatered

$$\text{Log } V = \left[\frac{\text{Log } Qr^2}{4T} \right] + \frac{5.45\, T\, s}{Q}$$

Where

T = Transmissivity = 498m^2/day

r = Distance from the pumping well to the Observation VI=40m

s = Drawdown observed in the OW VII at the end of 10000 minutes

= 0.24 m.

$$\text{Log } V = \text{Log} \left[\frac{388.8 \times 40 \times 40}{4 \times 498} \right] + \frac{5.45 \times 498 \times 0.24}{388.8}$$

Log V = 4.17

V=14791.1m^3

Specific Yield = Qxt / V

Where, t = 6.94 days (10000 mts)

Sy = (388.8x6.94x100) / 14791.1

Sy = 18.24%

Method 3: Curve Matching Method

Neuman (1972) developed a theory of delayed water table response which is based on well□defined physical parameters of the unconfined aquifer[4]. Neuman treats the aquifer as a compressible system and the water table as a moving material boundary. He recognizes the existence of vertical flow components and his general solution of the drawdown is a function of both the distance from the well and the elevation head. When considering an average draw down, he is able to reduce his general solution of function. Mathematically, Neuman simulated the delayed water table response by

treating the elastic Storativity '**SA'** and the specific yield '**S',** as constants. Neuman's draw down equation reads under early time conditions[4]. The equation describes the first segment of the time draw down curve and reduces to where

$$r^2SA = 4KDt$$

SA= volume of water instantaneously released from storage per unit surface

Under late time conditions, the above equation describes the third segment of the time drawdown curve and reduces to area per unit decline in head (= elastic early time storativity).

Where,

$$2Sy = 4KDt$$

S_y= volume of water released from storage per unit surface area per unit decline of the water table, i.e. released by dewatering of the aquifer (= specific yield)

Neuman's parameter p= r^2K,D2 &

Where,

K,= hydraulic conductivity for vertical flow, in m/d

Kh= hydraulic conductivity for horizontal flow, in m/d

For isotropic aquifers, K,= Kh, and p = r^2/D2.

Neuman's curve fitting method (figure 3) can be used if the following assumptions and conditions are satisfied:

The aquifer is isotropic or anisotropic;

The flow to the well is in an unsteady state;

The influence of the unsaturated zone upon the draw down in the aquifer is negligible;

Sy / SA > 10;

An observation well screened over its entire length penetrates the full thickness

The diameters of the pumped and observation wells are small, i.e. storage in the aquifer can be neglected.

As stated by Ne-Krusemen and De Rider, fully□penetrating observation wells allow the 'short circuiting' of vertical flow[5]. Consequently, the water levels observed in them will not always be equivalent to the average of groundwater heads in a vertical section of the aquifer, as assumed in Neuman's theory. The theory should still be valid, however, for piezometers with short screened sections, provided that the draw downs are averaged over the full thickness of the aquifer.

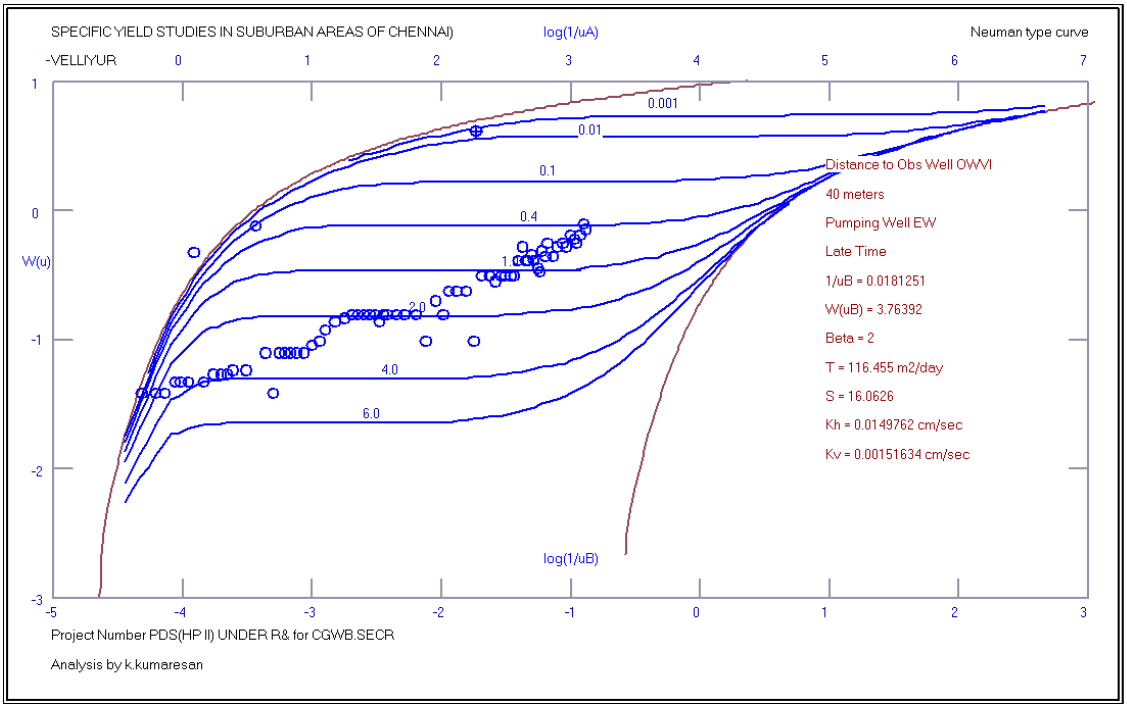

Figure 3: Analysis by Neuman Unconfined Aquifer Type Curve Method

- Site Name: VELLIYUR
- Location: Govt High School
- Pumping Well: EW
- Observation Well: OWVI

Analysis by Neuman Unconfined Aquifer Type Curve Method

Discharge Rate:

- 71.3237 gallons per minute
- 102706 gallons per day
- 13729.8 cubic feet per day
- 388.8 cubic meters per day
- Pumping Well Radius is 0.0003 inches
- Aquifer Thickness is 29.5272 feet
- Distance to Observation Well is 131.232 feet
- Match Points for time = 1 day and drawdown = 1 meter

Early match	**Late match**
181.250748 1/uA 2.000000 Early Beta 3.763916 W(uA, Beta)	0.018125 1/uB 2.000000 Late Beta 3.763916 W(uB, Beta)

Results for Early match:

Transmissivity	Horizontal Hydraulic Conductivity	Vertical Hydraulic Conductivity	Specific Yield
• 116.454514 m2/day • 1253.475392 ft2/day • 9376.622685 gal/day/ft	• 12.939390 m/day • 42.451551 ft/day • 317.558773 gal/day/ft2 • 0.014976 cm/sec	• 1.310113 m/day • 4.298220 ft/day • 32.152827 gal/day/ft2 • 0.001516 cm/sec	• 16.0600000 %

Results for Late match:

Transmissivity	Horizontal Hydraulic Conductivity	Vertical Hydraulic Conductivity	Specific Yield
• 116.454514 m2/day • 1253.475392 ft2/day • 9376.622685 gal/day/ft	• 12.939390 m/day • 42.451551 ft/day • 317.558773 gal/day/ft2 • 0.014976 cm/sec	• 1.310113 m/day • 4.298220 ft/day • 32.152827 gal/day/ft2 • 0.001516 cm/sec	• 16.5042626%

The results of the specific yield determined by all the three methods are tabulated in table 9.

Table 9: Specific Yield Determination with different Methods

Aquifer Parameter	Volume dewatering method	Ramsahoye-Lang method	Curve Matching method (Neuman)
Specific yield (%)	**15**	**18**	**16.5**

CONCLUSIONS

Well field was constructed in Velliyur village which forms part of the Araniyar - Kortaliyar (A.K basin) basin, A long duration pumping test was conducted for estimating specific yield parameter by three methods volume dewatering method, Ramsahoye and Lang method & curve matching (Neuman) method. The other parameters from Step drawdown and long duration pumping tests were also conducted and observations were recorded. The transmissivity of pumped well ranged from 615 to 693 m^2/day for the wells in the well field. The specific yield determined was 15 % from Volume dewatering method 18 % from Ramsang – Lang method and 16.5 % from curve matching method (Neuman). Based on this study, it is observed that the ideal method for determining specific yield is Volume Dewatering Method. Specific yield values of alluvial aquifer can be used in resource evaluation for ground water assessment of study area and also these values may be used for sandy aquifer of same character in other areas.

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