Bulletin of Pure and Applied Sciences.
Vol.39F, Geology (Geological Science), No.2,
July-December 2020: P.211-238
Original Article
Print version ISSN 0970 4639
Online version ISSN 2320 3234
DOI: 10.5958/2320-3234.2020.00019.0
Available online at www.bpasjournals.com

Estimation of Aquifer Parameter in Basaltic Region through Aquifer Performance Test: A Case Study of Laxmi and Sheri Nala Basin (KR 40 watershed) Around Sangli, Maharashtra (India)

[1]S.M. Patil*, [2]H.S. Patode, [3]K.S. Kumbhar, [4]O.R. Parab

Author's Affiliations:
[1]Research Scholar, School of Earth science, Swami Ramanand Teerth Marathwada University (SRTMU), Nanded, Maharashtra 431606, India
[2]Associate Professor, School of Earth science, Swami Ramanand Teerth Marathwada University (SRTMU), Nanded, Maharashtra 431606, India
[3]Assistant Professor, Department of Geology, Nowrosjee Wadia College, Pune, Maharashtra 411001, India
[4] GIS Analyst, Cybertech System and Software Ltd., Pune, Maharashtra, India

***Corresponding Author: S.M. Patil,** Research Scholar, School of Earth science, Swami Ramanand Teerth Marathwada University (SRTMU), Nanded, Maharashtra 431606, India

E-mail: psandip5@gmail.com

(Received on 30.05.2020, **Accepted on 17.10.2020**)

ABSTRACT

The estimating the aquifer parameters is an essential part of the groundwater studies to understand the origin and movement of groundwater which are the fundamental questions that addresses both the temporal and spatial aspects of ground water and water supply related issues in arid and semi arid climatic regions. As the study area i.e. Laxmi and Sheri nala basin (KR 40 Watershed) falls in semi arid region where water scarcity is the main problem, ultimately the groundwater is the major source. Thus the estimation of aquifer parameters is essential task is needed to carried out in the study area. There are several methods to estimate the accurate aquifer parameters (i.e. hydrograph analysis, Aquifer performance test etc.). In early days, these parameters are estimated either by means of in situ test or performing test on aquifer samples brought in the laboratory. The most common in-situ test is Aquifer performance test (APT) performed on wells, which involves the measurement of the fall and increase of groundwater level with respect to time. The alteration in groundwater level is caused due to pumping of water from the well i.e. drawdown and recovery. Theis (1935) was first to propose method to evaluate aquifer parameters from the pumping test on a bore well in a confined aquifer. It is essential to know the Specific capacity (C), transmissivity (T), storativity (S) and Specific yield (Sy) for the characterization of the aquifer parameters in an unknown area so as to predict the rate of drawdown of the groundwater table surface throughout the pumping test of an aquifer. The determination of aquifer's parameters is an important basis for groundwater resources evaluation, numerical simulation, development and protection as well as scientific management. Hence in the study area total nine aquifer performance tests (APT) has been carried out and accordingly the study area divided into high, moderate and lower groundwater potential zones.

KEYWORDS: *Aquifer performance test, Specific Capacity, Transmissivity and Storativity*

INTRODUCTION

The water demand for industrial, agricultural, and domestic uses is continuously increasing and freshwater resources are shrinking. Against this backdrop, groundwater management is a critical issue for current and future generations. Groundwater management entails both quantity and quality-related groundwater resource management. Hard rock aquifer occupies the first few tens of meters from the top (Taylor and Howard 2000) that is subjected to weathering process (Wyns et.al. 2002). Groundwater occurs in weathered and fractured layers under unconfined to semi confined conditions, which have specific hydrodynamic properties from the top to the bottom. Quantification of groundwater resources and understanding of hydrogeologic processes is a basic pre - requisite for efficient and sustainable management of groundwater resource development and management (Sophocleous 1991; Vander Gun and Lipponen 2010). This is particularly vital for India where 80 % of Indian peninsula is covered with hard rock coupled with widely prevalent semi-arid climate (Pathak 1984). Western and central India is occupied by tholeiitic basaltic lava flows of the Deccan traps sequence. The Deccan traps sequence consists of multiple layers of solidified lava flows. Each lava flow consists of an upper vesicular unit and a lower massive unit which may or may not be fractured and jointed. Two lava flows at some places are separated by inter-trappean alluvium area. Acute shortage of groundwater in hard-rock areas, such as the Deccan traps, is well known. Groundwater available in shallow, weathered mantle under unconfined condition above the Deccan traps is inadequate to meet the ever-increasing demand of water supply (Adyalkar et.al 1974; Deolankar, 1981). Hard rock's derive its status as an aquifer on the basis of secondary porosity that gets developed due to decompose and weathering processes over a period of time (Radhakrishna 1970). The aquifers in hard-rock are unconfined and their water table generally follows the surface topography. Therefore, there is a good match between the surface drainage (watershed) and groundwater system (aquifer geometry). Thus, it becomes imperative to understand the hard rock physiographic, its characteristics vis-a`-vis availability of groundwater (Khadri et.al 2016). The shallow aquifers are found to be occurring up to the depth of 10 –15 m underlain by massive rocks which forms the bottom of phreatic aquifer.

Study area

The present study is based on the Aquifer Performance test (APT) data obtained for large-diameter dug wells tapping unconfined aquifers. The study area is mainly drained by Laxmi and Sheri nala i.e. one of the watershed from Krishna river basin (KR 40), around Sangli town, Maharashtra. The study area is bounded between latitude 16°48'00" to 17°05'00'' N and longitude 74°30'00'' to 74° 47'00'' E in Survey of India (SOI) toposheets numbers 47K/12, 47K/16,47L/9 and 47L/13 with area about 359 sq.km figure 1. As per GSDA this study area falls in drought prone area project (DPAP) which receives rainfall less than 500 mm.

Geology of study area

The only geological formation in the study area is the deccan traps (*Cretaceous-Eocene*). The Deccan trap lava flows are found usually in the form of horizontal flow units. At places a gentle dip of about 5^0 to the west is noticed. The flows usually form flat-topped hills so characteristic of the trappean country. The traps belong to the type called 'plateau basalt'. They are more or less uniform in composition corresponding to dolerite or basalt. These traps are distinguished into vesicular and non-vesicular varieties. The non-vesicular types are hard, tough, compact and medium to fine-grained, and break with a conchoidal fracture. The vesicular types are comparatively soft and friable and break more easily. The amygdaloidal basalts are characterised by vesicles filled with quartz, chalcedony, calcite and zeolites. The inter-trappean beds generally form aquifers. In the study area which is composed of Deccan trap flows, the main aquifers are either the inter-trappean beds or the decomposed zones in the traps. The depth of the water-table is variable, generally being more than 6 meters. In general the deccan traps are unreliable sources of ground-water because of the sporadic distribution of their inter-trappean beds.

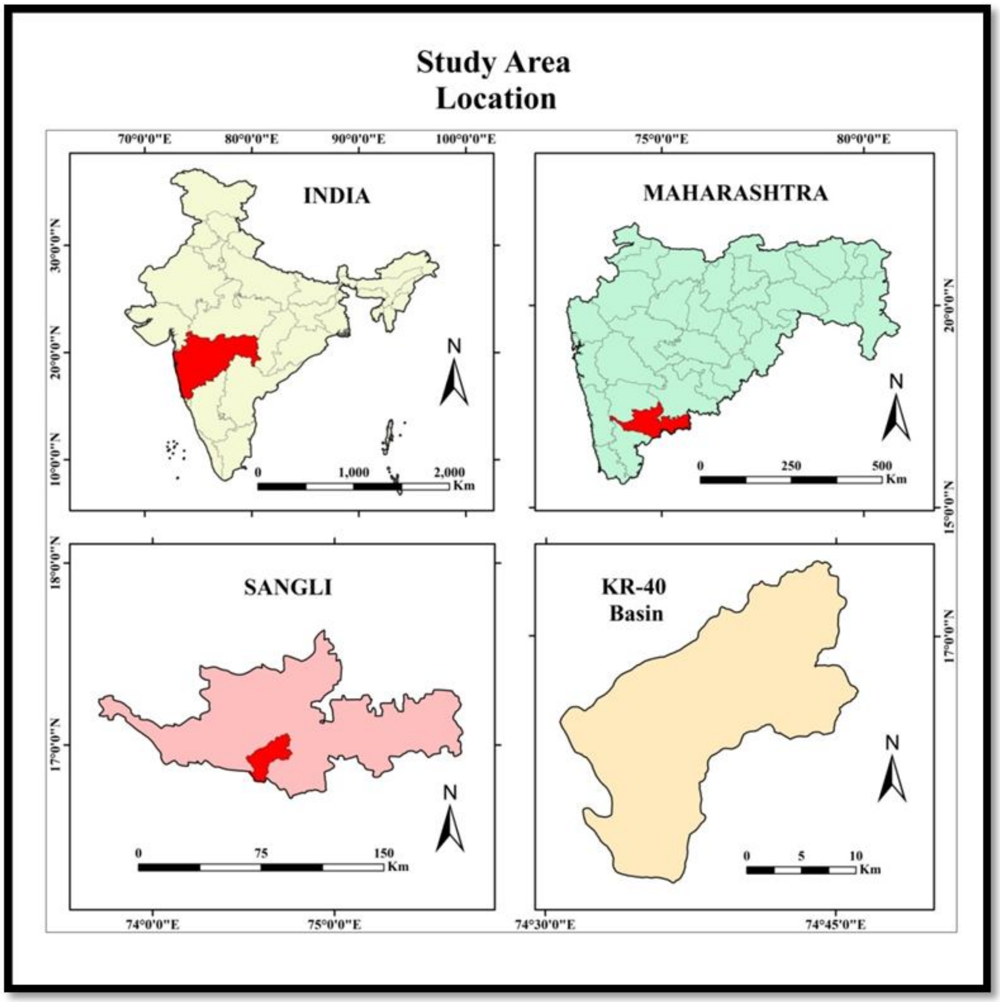

Figure 1: Location map of the study area

METHODOLOGY

In the present study, Aquifer performance tests were undertaken to study the aquifer characters in the study area. According to Physiography the study area is divided into three zones viz Upper reach, Middle reach and Lower reach. The essential data like diameters, depths, and initial water level were recorded for the well under study. The water was pumped continuously for 3 hours and changes in water level both for drawdown and recuperation were recorded. The dug wells selected for the Aquifer Performance Tests covers almost the whole area under study. The depth of the dug wells varied considerably from 11.00 to 18.20 m. All the wells selected were large diameter dug wells (5.20 to 10.10 m).

In the study area total of 9 Aquifer Performance Tests (APT) were conducted at different locations within the shallow basaltic aquifer. A location of pumping well has depicted in figures 2. Location details of pump test carried and data of hydrogeological parameters is presented in table 1 and 2.

To preparation of different types of maps like location map, specific capacity map, transmissivity map and specific yield map of study area (watershed KR 40) around Sangli is carried out by using Arc GIS software 10.2 version All the locations of APT locations were recorded with the help of Global Positioning System (Garmin GPS map 76 csx).

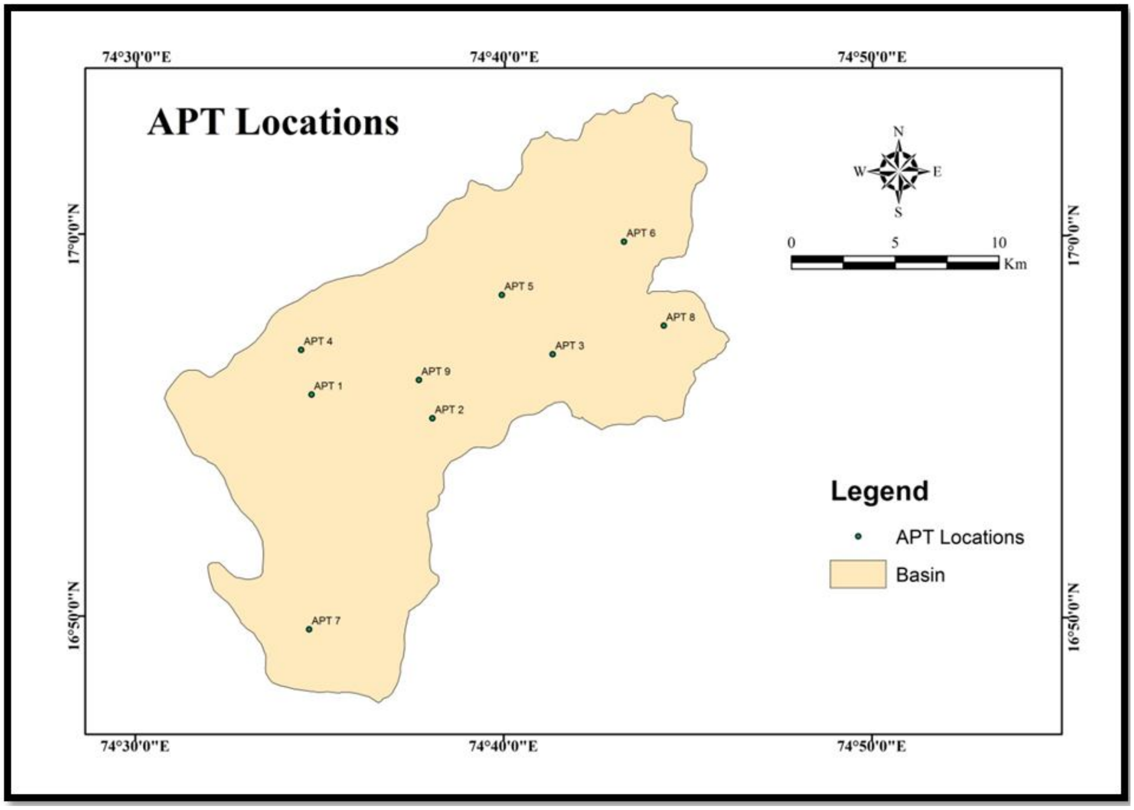

Figure 2: Location map of Aquifer Performance Test (APT)

RESULTS AND DISCUSSION

Analysis of Aquifer performance test (APT)

Aquifer performance test supplies the basic data for the determination of hydraulic properties, the nature and limits of aquifers. Analysis of pumping tests conducted for an aquifer is based on Darcy's law (1856), which states that the flow of water through a porous medium is directly proportional to the hydraulic gradient. The law is expressed as:

$$Q = PIA \quad (1)$$

Where, Q = Discharge in cubic meter per day
P = coefficient of permeability in cubic meter per day per square meter.
A = area of flow across section in square meter.

On the basis of Darcy's principle, a number of methods have been formulated in analysing pumping test data. The pump test data can be analysed by equilibrium or steady state method (Thiem 1906) and non equilibrium method or transient state method (Theis 1935) depending upon the nature of depletion of water level during the pump test. In addition, analytical methods have been proposed by Cooper and Jacob (1946) and Papadopulous (1965). In the present study, it was observed that the water level during the pump test was non equilibrium state and hence the analyses were done by transient method only. The aquifer parameters like Specific Capacity, Transmissivity and Storativity were calculated and the significance of these parameters is discussed below. All the wells on which aquifer performance test has carried are large diameter dug wells, therefore Slitcher's formula has been used for calculation of specific capacity.

Specific capacity

The specific capacity of a well is the well flow per unit fall of water level in the well. Specific capacity is not constant and is inversely proportional to discharge (Bouwer, 1978) devised a formula for the calculation of specific capacity of an aquifer using the recovery data and the equation is as follows.

$$C = 2.303 \frac{A}{T} \log \frac{S_1}{S_2} \quad (2)$$

Where,

C = specific capacity of well in cubic meters per minute unit of drawdown

A = area of cross section of well, in square meters

T = time in minutes after pump stopped.

S_1 = total draw down in meters just before pump stopped

S_2 = residual drawdown in time "t"

The specific capacity for the area under study is given in Table 2. It is observed that the specific capacity for wells in study area varies from 14.61 to 732.17 lit/min/m. The maximum specific capacity values are noticed at APT 2 (Rasulwadi) and APT 9 (Kaulapur kakadwadi road) with 732.17 and 544.92 lit/min/m. The specific capacity value of APT numbers 1,3,4,5 and 8 ranges between 123 to 200 lit/min/m. The poor specific capacity values are recorded at APT 6 (Yogewadi) and APT 7 (Inam Dhamni) figure 3.

Transmissivity

Theis (1935) introduced the term coefficient of transmissivity, which is semantically referred to as transmissivity in groundwater hydraulics study today. It is defined as a rate at which water of prevailing kinematic viscosity is transmitted through a unit width of aquifer under a unit hydraulic gradient.

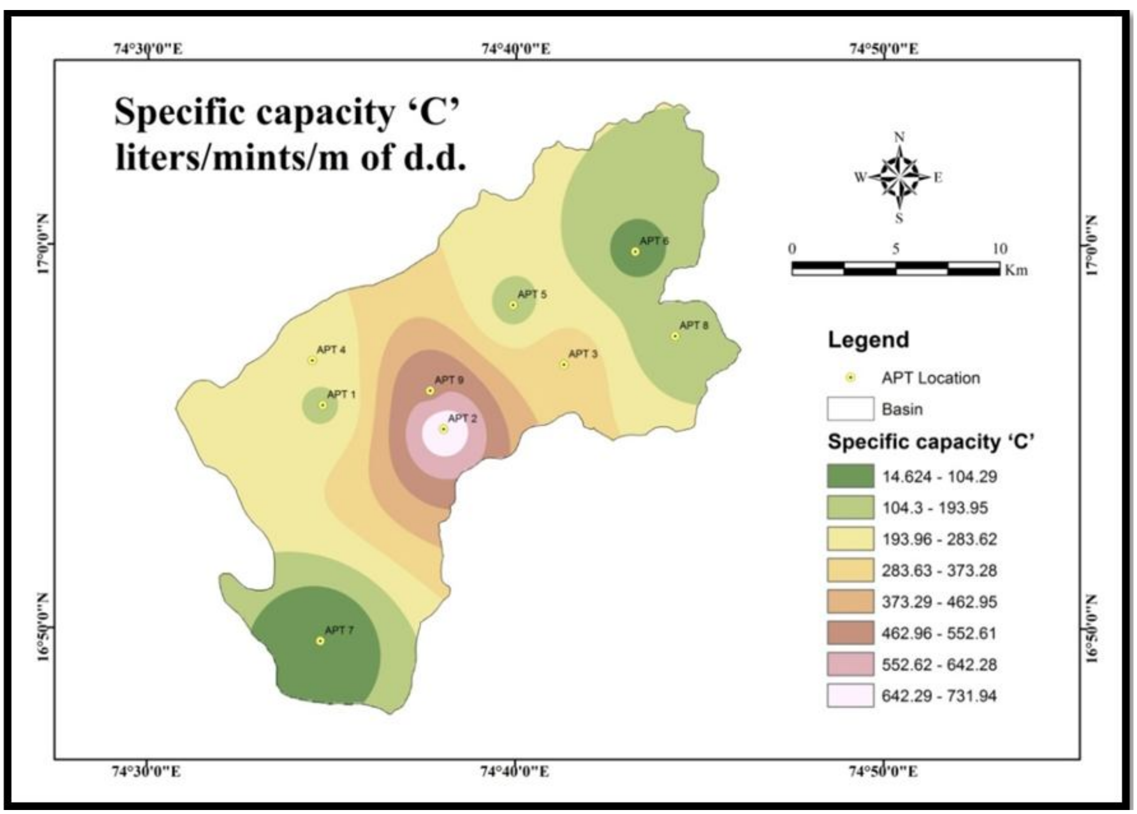

Figure 3: Specific capacity of study area Aquifer

According to Cooper-Jacob (1946) formula used for obtaining transmissivity values is:

$$T = \frac{2.3\ Q}{4\pi . \Delta S} \qquad (3)$$

Where,
T = Transmissivity in m^2/ day, Q = discharge
π = constant, ΔS = draw down difference

The transmissivity data for the wells studied is given in Table 2. The values of transmissivity for the wells vary from 51.99 to 230.52 m^2/ day. It is observed that the aquifer formations at APT numbers 1, 2, 3 and 9 have higher transmissivity. High transmissivity values are may be because of gentle slope of the area and presence of cobble, pebble, gravel and fractured and jointed basalt figure 4.

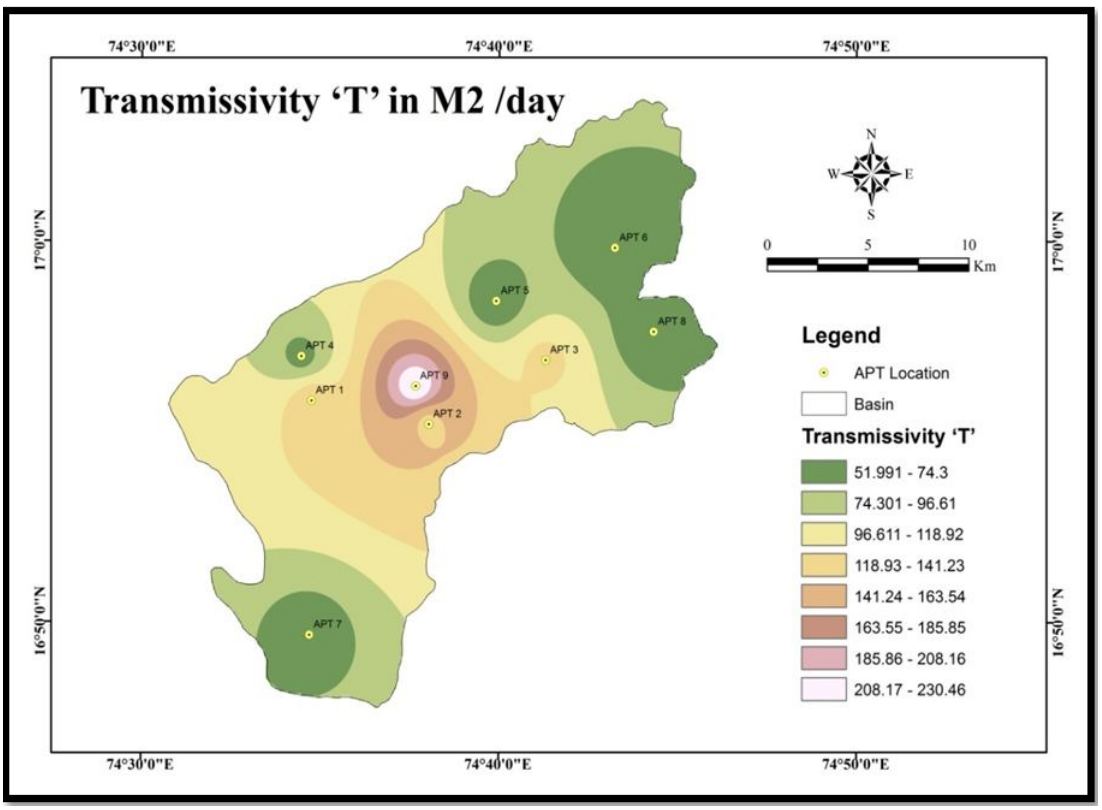

Figure 4: Transmissivity of study area Aquifer

The low transmissivity is observed, at APT numbers 4, 5, 6 and 8, this may be because of moderate slopes and less density of secondary porosity in the country rock.

Storativity

A major advancement in groundwater hydraulics was introduced by Theis in 1935 with his development of non equilibrium formula which introduces the time factor and the storativity. It is defined as a volume of water stored per unit surface area of the aquifer per unit change in the head normal to the surface. For calculations of storativity, the formula, according to Cooper-Jacob's method (1946),

$$S = \frac{2.25 \times T \times to}{r^2}$$

Where,

S = Storativity, T = Transmissivity

to = time, r = radial distance of well in meters

The storativity data of the study area are given in Table 2. The high storage coefficient values are noticed at APT 3 (Soni Kanchanpur road) APT 9 (kaulapur kakadwadi road) with 0.1192 and 0.1410 respectively. The low storage coefficient values are noticed at APT 6 (Yogewadi) with 0.0220 and APT 8 (Bhose) with 0.0385. The medium storage coefficient values are observed at APT numbers 1, 2, 4, 5 and 7 with 0.0682, 0.0699, 0.0581, 0.0670, and 0.0530.

Specific yield

Specific yield is defined as the volume of water released from storage by an unconfined aquifer per unit surface area. The amount of water that is actually available for groundwater pumping. It can be derived from storativity.

It is expressed in %. The simple formula for specific yield is

$$Sy = S*100 \quad (4)$$

Where, Sy = Specific yield, S = Storativity

Accordingly, as per Table 2 the maximum specific yield are noticed at APT 3 and APT 9 with 11.92% and 14.10% respectively. This may be due to moderate slope and presence of cobble, pebble and gravels. The minimum specific yield is may be characteristics of hard rock terrain and hilly portion of study area and noticed at APT 6 and APT 8 with 2.20% and 3.85%. The moderate specific yield is recorded at remaining APT locations, due to presence of weakly jointed and fractured rock figure 5.

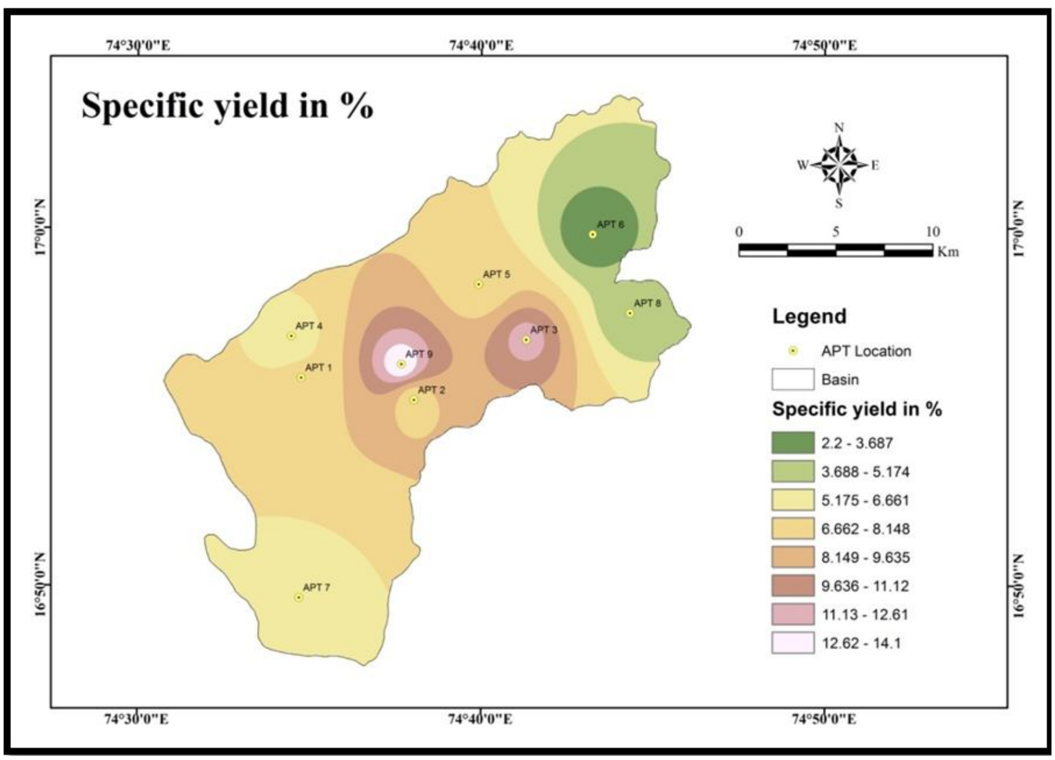

Figure 5: Specific Yield of study area Aquifer

Table 1: Location details of pump test carried in the study area.

Sr. No	Tahsil	WS no.	Village	DW No.	Latitude	Longitude	Altitude
1			Bisur	APT1	16° 55' 49"	74° 34' 46"	558
2			Rasulwadi	APT2	16° 55' 12	74° 38' 03"	585
3			Soni Kanchanpur Road	APT3	16° 56' 53"	74° 41' 19"	610
4			Khotwadi	APT4	16° 56' 59"	74° 34' 29"	558
5	Miraj	KR 40	Kumathe WS well	APT5	16° 58' 26"	74° 39' 56"	596
6			Yogewadi	APT6	16° 59' 50"	74° 43' 15"	649
7			Inam dhamani	APT7	16° 49' 40"	74° 34' 43"	543
8			Bhose	APT8	16° 57' 38"	74° 44' 20"	653
9			Kaulapur kakadwadi Road	APT9	16° 56' 12"	74° 37' 41"	573

Table 2: Pump test data and hydrogeological parameters for the wells in the study area.

Sr. No	WS no.	Village	APT No.	Diameter (m)	Depth (m)	Time in Min. for d.d.	Specific capacity 'C' liters/min/m of d.d.	Transmissivity 'T' in m^2/day	% Storage coefficient	Spec. yield
1		Bisur	APT1	9.50	13.35	180	173.60	131.00	0.0682	6.82
2		Rasulwadi	APT2	9.20	15.60	210	732.17	135.11	0.0699	6.99
3		Soni Kanchanpur Road	APT3	8.10	18.20	250	341.44	124.84	0.1192	11.92
4		Khotwadi	APT4	6.10	12.00	180	200.45	65.77	0.0581	5.81
5	KR 40	Kumathe WS well	APT5	5.20	14.80	150	161.13	55.09	0.0670	6.70
6		Yogewadi	APT6	8.10	11.00	180	76.00	51.99	0.0220	2.20
7		Inam dhamani	APT7	7.60	13.40	210	14.61	63.66	0.0530	5.30
8		Bhose	APT8	7.60	12.80	210	123.29	56.22	0.0385	3.85
9		Kaulapur kakadwadi Road	APT9	10.10	12.20	180	544.92	230.52	0.1410	14.10

Calculations for Aquifer parameters

Table 3: Data sheet of APT 1

APT 1									
Drawdown		**Recuperation**		**A/t**	**2303A/t**	**S2**	**S1/S2**	**log S1/S2**	**C = 2303A/t*log S1/S2**
Time in minutes	**D.D.in mts (S1)**	**Time in minutes**	**Recuperation in mts**						
10	0.15	10	0.03	7.084	16314.5	1.22	1.025	0.0106	172.12
20	0.22	20	0.06	3.542	8157.23	1.19	1.050	0.0214	174.26
30	0.32	30	0.09	2.361	5438.15	1.16	1.078	0.0325	176.48
40	0.38	40	0.125	1.771	4078.61	1.125	1.111	0.0458	186.63
50	0.46	50	0.15	1.417	3262.89	1.10	1.136	0.0555	181.15
60	0.52	60	0.18	1.181	2719.08	1.07	1.168	0.0675	183.61
70	0.60	70	0.195	1.012	2330.64	1.055	1.185	0.0737	171.67
80	0.67	80	0.22	0.886	2039.31	1.03	1.214	0.0841	171.45
90	0.74	90	0.24	0.787	1812.72	1.01	1.238	0.0926	167.84
100	0.80	100	0.26	0.708	1631.45	0.99	1.263	0.1013	165.22
110	0.87	110	0.28	0.644	1483.13	0.97	1.289	0.1101	163.35
120	0.92	120	0.305	0.590	1359.54	0.945	1.323	0.1215	165.15
130	1.00	130	0.33	0.545	1254.96	0.92	1.359	0.1331	167.06
140	1.04	140	0.35	0.506	1165.32	0.90	1.389	0.1427	166.25
150	1.10	150	0.37	0.472	1087.63	0.88	1.420	0.1524	165.78
160	1.14	160	0.395	0.443	1019.65	0.855	1.462	0.1649	168.19
170	1.18	170	0.425	0.417	959.674	0.825	1.515	0.1805	173.18
180	1.25	180	0.445	0.394	906.358	0.805	1.553	0.1911	173.22
190	S1	190	0.465	0.373	858.655	0.785	1.592	0.2020	173.48
200		200	0.490	0.354	815.723	0.760	1.645	0.2161	176.27
210		210	0.510	0.337	776.879	0.740	1.689	0.2277	176.88
220		220	0.535	0.322	741.566	0.715	1.748	0.2426	179.91
230		230	0.560	0.308	709.324	0.690	1.812	0.2581	183.05
240		240	0.580	0.295	679.769	0.670	1.866	0.2708	184.11
									173.60
									lit/min/mt of D.D.

APT 1

Specific capacity = 2303 A / t*logS1 / S2
= 173.60 Ltr / minutes / meter of dd 1

Quantity pumped = c*dd* 1440*10^{-3}
= 173.60*1.25*1440*10^{-3}
= 312.48 kiloliters / day 2

Transmissivity T = 2.3*Q / 4 ∏ΔS
= 2.3*312.48 / 4*3.14*0.435
= 131.00 m2 / day 3

Storage Coefficient S = 2.25*T*t0*6.96*10^{-4} / R^2
= 2.25*131.00*30*6.96*10^{-4} / 22.56
= 0.0682

Specific yield = 6.82% 4

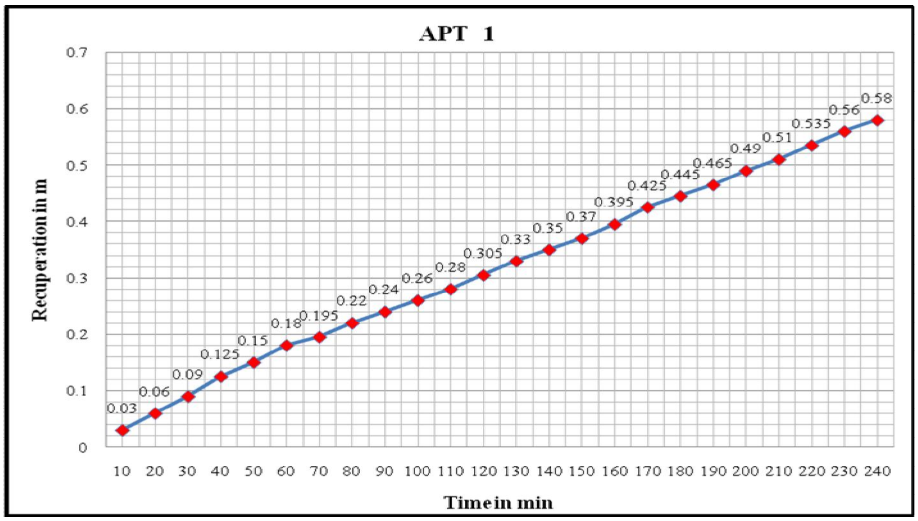

Figure 6: Drawdown graph of APT 1

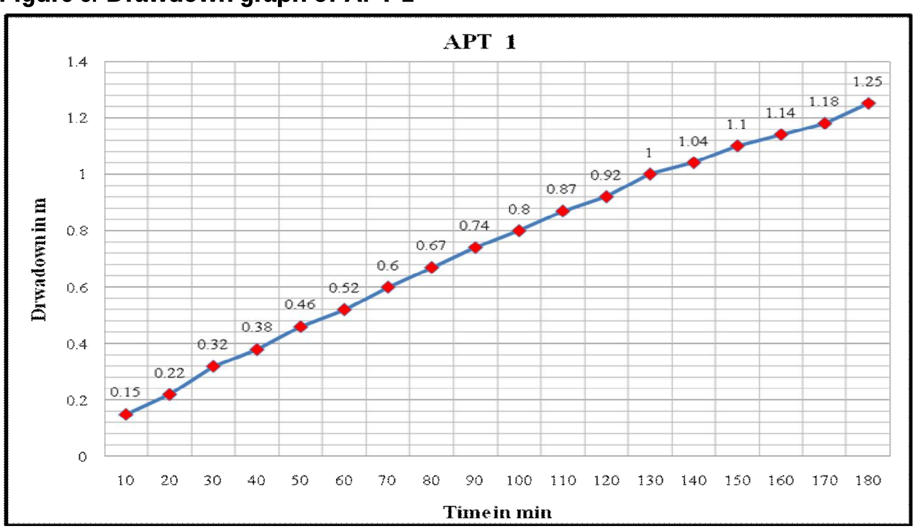

Figure 7: Recuperation graph of APT 1

Table 4: Data sheet of APT 2

APT 2									
Drawdown		**Recuperation**		**A/t**	**2303A/t**	**S2**	**S1/S2**	**log S1/S2**	**C = 2303A/t*log S1/S2**
Time in minutes	**D.D.in mts (S1)**	**Time in minutes**	**Recuperation in mts**						
10	0.07	10	0.03	6.644	15301.132	0.81	1.037	0.0158	241.67
20	0.135	20	0.11	3.322	7650.566	0.73	1.151	0.0610	466.35
30	0.17	30	0.17	2.214667	5100.3773	0.67	1.254	0.0982	500.88
40	0.22	40	0.225	1.661	3825.283	0.62	1.366	0.1354	517.96
50	9.76	50	0.29	1.3288	3060.2264	0.55	1.527	0.1839	562.83
60	0.25	60	0.315	1.107333	2550.1887	0.53	1.600	0.2041	520.54
70	0.34	70	0.410	0.949143	2185.876	0.43	1.953	0.2908	635.68
80	0.35	80	0.46	0.8305	1912.6415	0.38	2.211	0.3445	658.90
90	0.39	90	0.51	0.738222	1700.1258	0.33	2.545	0.4058	689.85
100	0.42	100	0.58	0.6644	1530.1132	0.26	3.231	0.5093	779.30
110	0.48	110	0.65	0.604	1391.012	0.19	4.421	0.6455	897.93
120	0.50	120	0.70	0.553667	1275.0943	0.14	6.000	0.7782	992.22
130	0.53	130	0.74	0.511077	1177.0102	0.10	8.400	0.9243	1087.89
140	11.73	140	0.78	0.474571	1092.938	0.06	14.000	1.1461	1252.65
150	0.63	150	0.85	0.442933	1020.0755	-0.01	84.000	1.9243	1962.91
160	0.67	160	0.77	0.41525	956.32075	0.07	12.000	1.0792	1032.04
170	0.71	170	0.95	0.390824	900.06659	-0.11	7.636	0.8829	794.64
180	0.75	180	1.005	0.369111	850.06289	-0.17	5.091	0.7068	600.83
190	0.79	190	1.055	0.349684	805.32274	-0.22	3.907	0.5918	476.62
200	0.82	200	1.105	0.3322	765.0566	-0.27	3.170	0.5011	383.34
210	0.84	210	1.145	0.316381	728.62533	-0.31	2.754	0.4400	320.57
220	0.84								15375.59
	S1								**732.17**
									lit/min/mt of D.D.

APT 2

Specific capacity = 2303 A / t*logS1 / S2
= 732.17 Ltr / minutes / meter of dd 1

Quantity pumped = c*dd* $1440*10^{-3}$
= $732.17*0.84*1440*10^{-3}$
= 885.42 kiloliters / day 2

Transmissivity T = 2.3*Q / 4 ∏ΔS
= 2.3*885.42 / 4*3.14*1.2
= 135.11 m2 / day 3

Storage Coefficient S = $2.25*T*t0*6.96*10^{-4} / R^2$
= $2.25*135.11*30*6.96*10^{-4} / 21.16$
= 0.0699

Specific yield = 6.99 % 4

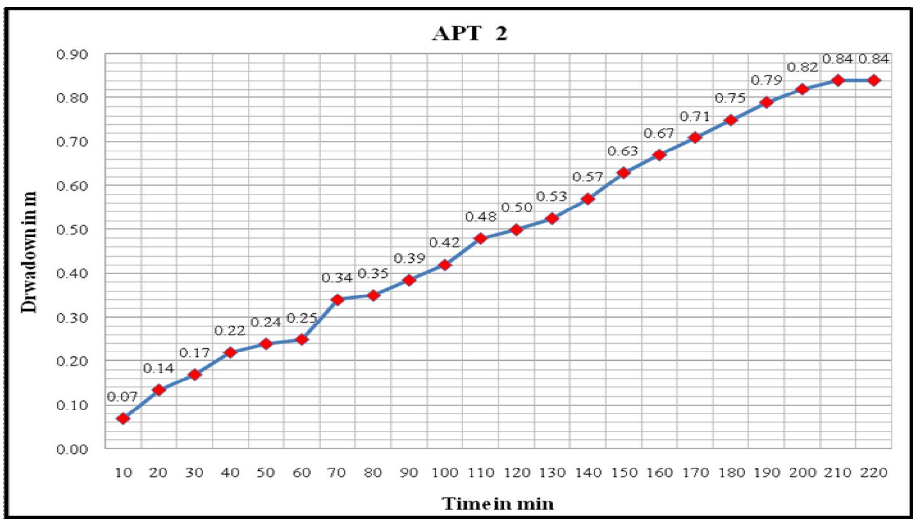

Figure 8: Drawdown graph of APT 2

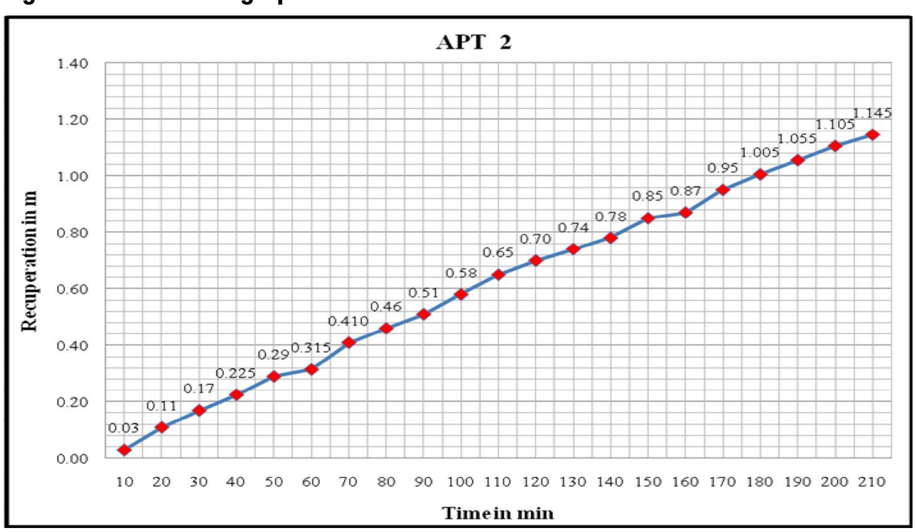

Figure 9: Recuperation graph of APT 2

Table 5: Data sheet of APT 3

APT 3									
Drawdown		**Recuperation**		**A/t**	**2303A/t**	**S2**	**S1/S2**	**log S1/S2**	**C = 2303A/t*log S1/S2**
Time in minutes	**D.D.in mts (S1)**	**Time in minutes**	**Recuperation in mts**						
10	0.036	10	0.012	5.150	11860.45	0.408	1.029	0.0126	149.31
20	0.040	20	0.050	2.575	5930.23	0.370	1.135	0.0550	326.44
30	0.050	30	0.067	1.717	3953.48	0.353	1.190	0.0755	298.39
40	0.058	40	0.092	1.288	2965.11	0.328	1.280	0.1074	318.38
50	0.060	50	0.108	1.030	2372.09	0.312	1.346	0.1291	306.22
60	0.078	60	0.124	0.858	1976.74	0.296	1.419	0.1520	300.38
70	0.100	70	0.144	0.736	1694.35	0.276	1.522	0.1823	308.95
80	0.142	80	0.160	0.644	1482.56	0.260	1.615	0.2083	308.78
90	0.162	90	0.180	0.572	1317.83	0.240	1.750	0.2430	320.28
100	0.198	100	0.201	0.515	1186.05	0.219	1.918	0.2828	335.42
110	0.218	110	0.224	0.468	1078.22	0.196	2.143	0.3310	356.88
120	0.250	120	0.236	0.429	988.37	0.184	2.283	0.3584	354.26
130	0.280	130	0.251	0.396	912.34	0.169	2.485	0.3954	360.71
140	0.304	140	0.278	0.368	847.18	0.142	2.958	0.4710	398.99
150	0.312	150	0.298	0.343	790.70	0.122	3.443	0.5369	424.52
160	0.340	160	0.317	0.322	741.28	0.103	4.078	0.6104	452.49
170	0.356	170	0.335	0.303	697.67	0.085	4.941	0.6938	484.07
180	0.382								5804.47
190	0.376								
200	0.380								
210	0.402								
220	0.404								
230	0.416								
240	0.422								
250	0.420	S 1							**341.44**
									lit/min/mt of D.D.

APT 3

Specific capacity	= 2303 A / t*logS1 / S2	
	= 341.44 Ltr / minutes / meter of dd	 1
Quantity pumped	= c*dd* 1440*10^{-3}	
	= 341.44*0.52*1440*10^{-3}	
	= 255.67 kiloliters / day	 2
Transmissivity T	= 2.3*Q / 4 ∏ΔS	
	= 2.3*255.67 / 4*3.14*0.375	
	= 124.84 m^2 / day	 3
Storage Coefficient S	= 2.25*T*t0*6.96*10^{-4} / R^2	
	= 2.25*124.84*30*6.96*10^{-4} / 16.40	
	= 0.1192	
Specific yield	= 11.92 %	 4

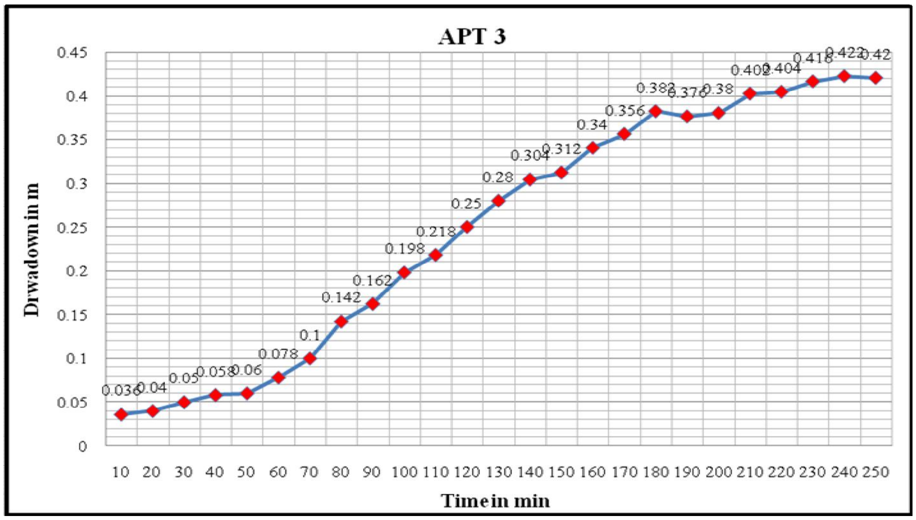

Figure 10: Drawdown graph of APT 3

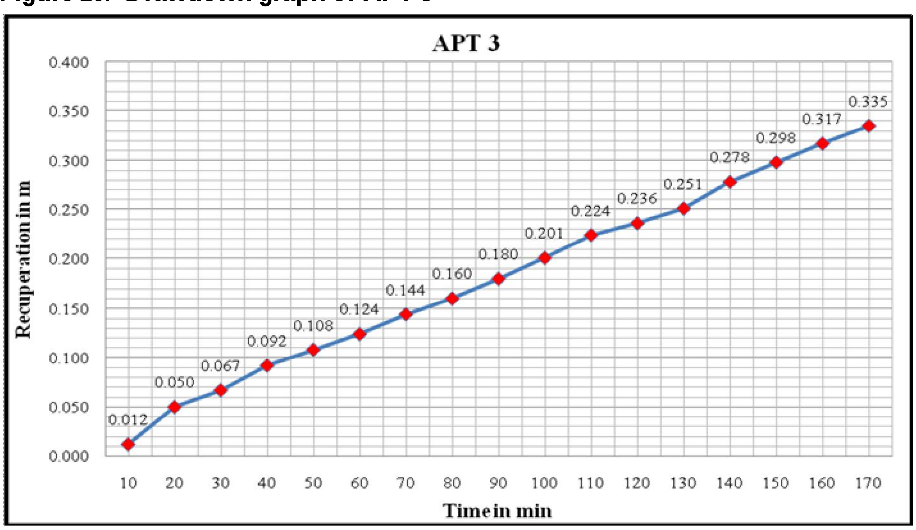

Figure 11: Recuperation graph of APT 3

Table 6: Data sheet of APT 4

APT 4									
Drawdown		**Recuperation**		**A/t**	**2303A/t**	**S2**	**S1/S2**	**log S1/S2**	**C = 2303A/t*log S1/S2**
Time in minutes	**D.D.in mts (S1)**	**Time in minutes**	**Recuperation in mts**						
10	0.098	10	0.098	2.920	6724.76	1.20	1.082	0.0342	230.01
20	0.184	20	0.186	1.460	3362.38	1.11	1.168	0.0674	226.61
30	0.300	30	0.206	0.973	2241.587	1.09	1.189	0.0753	168.80
40	0.356	40	0.308	0.730	1681.19	0.99	1.312	0.1181	198.48
50	0.494	50	0.374	0.584	1344.952	0.92	1.407	0.1481	199.25
60	0.568	60	0.446	0.487	1120.793	0.85	1.526	0.1835	205.71
70	0.648	70	0.516	0.417	960.68	0.78	1.663	0.2210	212.27
80	0.720	80	0.546	0.365	840.595	0.75	1.730	0.2380	200.09
90	0.788	90	0.596	0.324	747.1956	0.70	1.854	0.2681	200.31
100	0.848	100	0.651	0.292	672.476	0.64	2.012	0.3037	204.25
110	0.940	110	0.692	0.265	611.3418	0.60	2.150	0.3323	203.17
120	0.990	120	0.732	0.243	560.3967	0.56	2.302	0.3622	202.97
130	1.052	130	0.780	0.225	517.2892	0.51	2.518	0.4010	207.42
140	1.104	140	0.802	0.209	480.34	0.49	2.630	0.4200	201.73
150	1.148	150	0.846	0.195	448.3173	0.45	2.888	0.4607	206.52
160	1.198	160	0.866	0.183	420.2975	0.43	3.023	0.4805	201.95
170	1.248	170	0.892	0.172	395.5741	0.40	3.219	0.5077	200.84
180	1.294	180	0.906	0.162	373.5978	0.39	3.335	0.5231	195.43
	S1	190	0.908	0.154	353.9347	0.39	3.352	0.5253	185.94
		200	0.924	0.146	336.238	0.37	3.497	0.5437	182.82
		210	0.926	0.139	320.2267	0.37	3.516	0.5461	174.87
									4209.42
									200.45 lit/min/mt of D.D.

APT 4

Specific capacity	= 2303 A / t*logS1 / S2	
	= 200.45 Ltr / minutes / meter of dd	……………… 1
Quantity pumped	= c*dd* 1440*10^{-3}	
	= 200.45*1.294*1440*10^{-3}	
	= 373.51 kiloliters / day	……………… 2
Transmissivity T	= 2.3*Q / 4 ∏ΔS	
	= 2.3*373.51 / 4*3.14*1.04	
	= 65.77 m2 / day	……………… 3
Storage Coefficient S	= 2.25*T*t0*6.96*10^{-4} / R^2	
	= 2.25*65.77*30*6.96*10^{-4} / 9.30	
	= 0.0581	
Specific yield	= 5.81 %	……………… 4

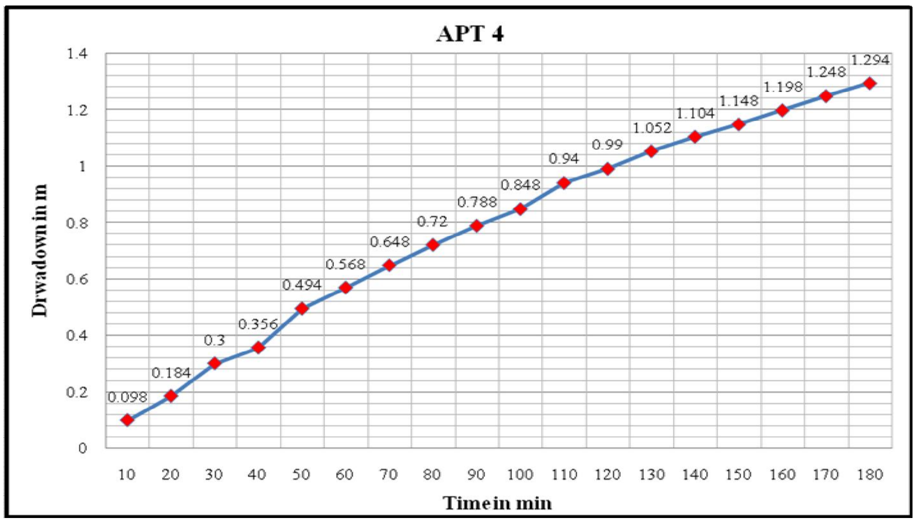

Figure 12: Drawdown graph of APT 4

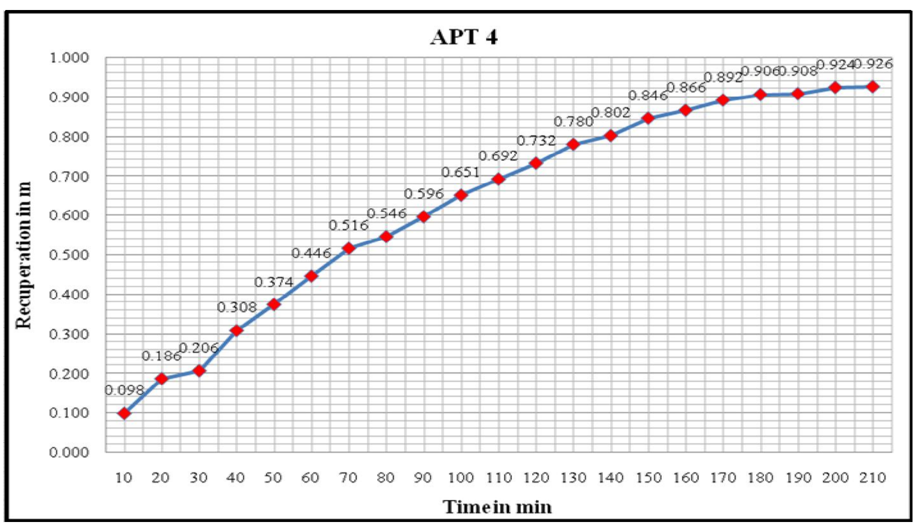

Figure 13: Recuperation graph of APT 4

Table 7: Data sheet of APT 5

APT 5									
Drawdown		**Recuperation**		**A/t**	**2303A/t**	**S2**	**S1/S2**	**log S1/S2**	**C = 2303A/t*log S1/S2**
Time in minutes	**D.D.in mts (S1)**	**Time in minutes**	**Recuperation in mts**						
10	0.286	10	0.598	2.12	4886.97	2.150	1.278	0.1066	520.84
20	7.500	20	0.610	1.06	2443.48				0.00
30	0.484	30	0.628	0.71	1628.99	2.120	1.296	0.1127	183.56
40	0.801	40	0.618	0.53	1221.74	2.130	1.290	0.1106	135.17
50	1.102	50	0.822	0.42	977.39	1.926	1.427	0.1544	150.87
60	1.282	60	0.938	0.35	814.49	1.810	1.518	0.1813	147.70
70	1.468	70	1.030	0.30	698.14	1.718	1.600	0.2040	142.42
80	1.642	80	1.120	0.27	610.87	1.628	1.688	0.2274	138.89
90	1.830	90	1.198	0.24	543.00	1.550	1.773	0.2487	135.04
100	7.500	100	1.300	0.21	488.70				0.00
110	2.094	110	1.384	0.19	444.27	1.364	2.015	0.3042	135.15
120	2.250	120	1.458	0.18	407.25	1.290	2.130	0.3284	133.75
130	2.418	130	1.558	0.16	375.92	1.190	2.309	0.3635	136.64
140	2.530	140	1.574	0.15	349.07	1.174	2.341	0.3693	128.93
150	2.748	150	1.652	0.14	325.80	1.096	2.507	0.3992	130.06
160	S1	160	1.718	0.13	305.44	1.030	2.668	0.4262	130.17
170		170	1.780	0.12	287.47	0.968	2.839	0.4531	130.26
180		180	1.848	0.12	271.50	0.900	3.053	0.4848	131.62
190		190	1.876	0.11	257.21	0.872	3.151	0.4985	128.22
									2739.27
									161.13
									lit/min/mt of D.D.

APT 5

Specific capacity = 2303 A / t*logS1 / S2
= 161.13 Ltr / minutes / meter of dd 1

Quantity pumped = c*dd* 1440*10^{-3}
= 161.13 *2.748*1440*10^{-3}
= 373.51 kiloliters / day 2

Transmissivity T = 2.3*Q / 4 ∏∆S
= 2.3*373.51 / 4*3.14*1.04
= 637.61 m2 / day 3

Storage Coefficient S = 2.25*T*t0*6.96*10^{-4} / R^2
= 2.25*637.61*30*6.96*10^{-4} / 6.76
= 0.067

Specific yield = 6.70 % 4

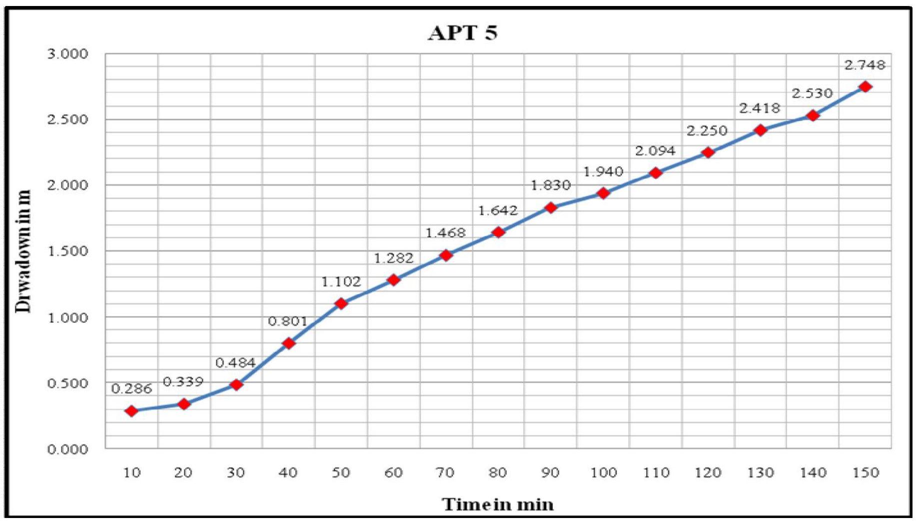

Figure 14: Drawdown graph of APT 5

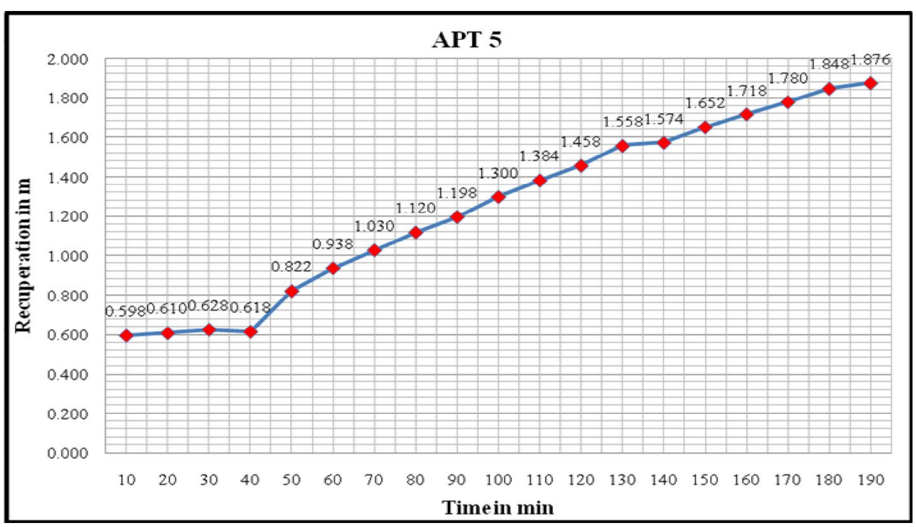

Figure 15: Recuperation graph of APT 5

Table 8: Data sheet of APT 6

APT 6									
Drawdown		**Recuperation**		**A/t**	**2303A/t**	**S2**	**S1/S2**	**log S1/S2**	**C = 2303A/t*log S1/S2**
Time in minutes	**D.D.in mts (S1)**	**Time in minutes**	**Recuperation in mts**						
10	0.120	10	0.024	5.150	11860.45	2.050	1.012	0.0051	59.95
20	0.250	20	0.054	2.575	5930.23	2.020	1.027	0.0115	67.94
30	0.360	30	0.084	1.717	3953.48	1.990	1.042	0.0180	70.99
40	0.500	40	0.112	1.288	2965.11	1.962	1.057	0.0241	71.49
50	0.610	50	0.142	1.030	2372.09	1.932	1.073	0.0308	73.06
60	0.742	60	0.174	0.858	1976.74	1.900	1.092	0.0381	75.23
70	0.860	70	0.204	0.736	1694.35	1.870	1.109	0.0450	76.19
80	0.982	80	0.230	0.644	1482.56	1.844	1.125	0.0510	75.68
90	1.094	90	9.354	0.572	1317.83	1.821	1.139	0.0565	0.00
100	1.202	100	0.284	0.515	1186.05	1.790	1.159	0.0640	75.85
110	1.316	110	0.324	0.468	1078.22	1.750	1.185	0.0738	79.54
120	1.424	120	0.274	0.429	988.37	1.800	1.152	0.0615	60.82
130	1.546	130	0.374	0.396	912.34	1.700	1.220	0.0864	78.79
140	1.660	140	0.404	0.368	847.18	1.670	1.242	0.0941	79.71
150	1.770	150	0.426	0.343	790.70	1.648	1.258	0.0999	78.95
160	1.864	160	0.458	0.322	741.28	1.616	1.283	0.1084	80.33
170	1.978	170	0.485	0.303	697.67	1.589	1.305	0.1157	80.71
180	2.074	180	0.515	0.286	658.91	1.559	1.330	0.1240	81.68
190	S1	190	0.538	0.271	624.23	1.536	1.350	0.1304	81.41
200		200	0.560	0.258	593.02	1.514	1.370	0.1367	81.06
210		210	0.580	0.245	564.78	1.494	1.388	0.1425	80.46
220		220	0.598	0.234	539.11	1.476	1.405	0.1477	79.64
230		230	0.616	0.224	515.67	1.458	1.422	0.1531	78.92
240		240	0.643	0.215	494.19	1.431	1.449	0.1612	79.65
									76.00
									lit/min/mt of D.D.

APT 6

Specific capacity = 2303 A / t*logS1 / S2
= 76.00 Ltr / minutes / meter of dd 1

Quantity pumped = c*dd* 1440*10^{-3}
= 76.00*2.074*1440*10^{-3}
= 226.97 kiloliters / day 2

Transmissivity T = 2.3*Q / 4 ∏ΔS
= 2.3*226.97 / 4*3.14*0.8
= 51.99 m2 / day 3

Storage Coefficient S = 2.25*T*t0*6.96*10^{-4} / R^2
= 2.25*51.99*18*6.96*10-4 / 16.40
= 0.022

Specific yield = 2.20 % 4

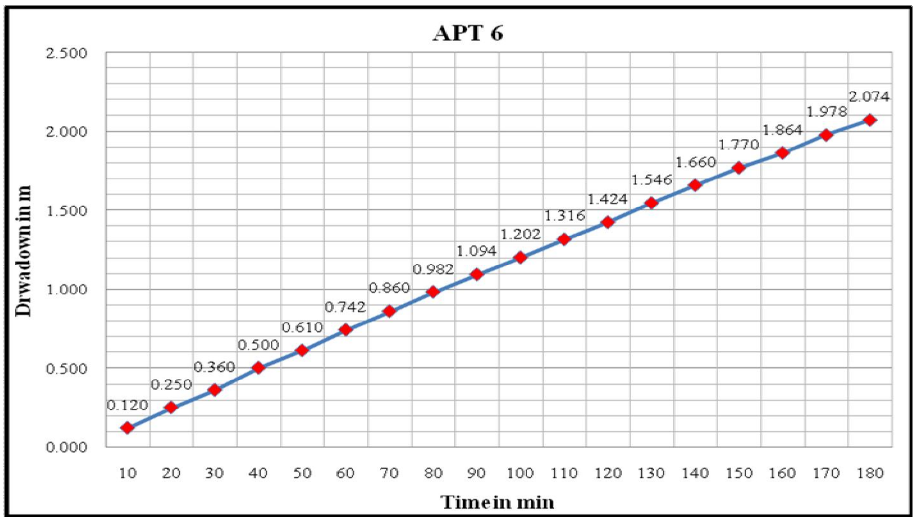

Figure 16: Drawdown graph of APT 6

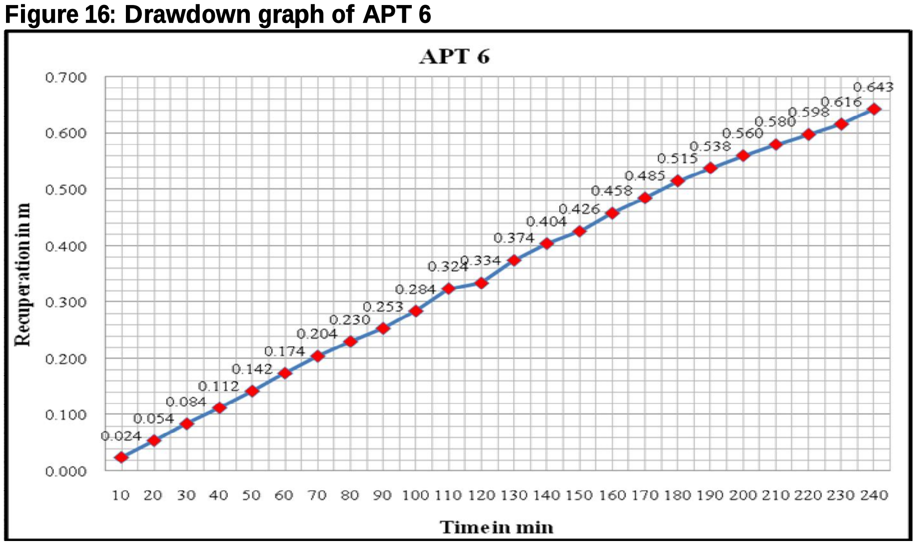

Figure 17: Recuperation graph of APT 6

Table 9: Data sheet of APT 7

APT 7									
Drawdown		**Recuperation**		**A/t**	**2303A/t**	**S2**	**S1/S2**	**log S1/S2**	**C = 2303A/t*log S1/S2**
Time in minutes	**D.D.in mts (S1)**	**Time in minutes**	**Recuperation in mts**						
10	0.202	10							
20	0.410	20	0.009	2.267	5220.901	2.386	1.004	0.0016	8.54
30	0.478	30	0.023	1.511	3480.601	2.372	1.010	0.0042	14.59
40	0.591	40							
50	0.720	50	0.035	0.907	2088.36	2.360	1.015	0.0064	13.35
60	0.840	60							
70	0.962	70	0.055	0.648	1491.686	2.340	1.024	0.0101	15.05
80	1.095	80							
90	1.230	90	0.073	0.504	1160.2	2.322	1.031	0.0134	15.60
100	1.330	100							
110	1.440	110	0.091	0.412	949.2547	2.304	1.039	0.0168	15.97
120	1.560	120							
130	1.680	130	0.117	0.349	803.2155	2.278	1.051	0.0218	17.47
140	1.830	140							
150	1.910	150	0.119	0.302	696.1201	2.276	1.052	0.0221	15.41
160	5.040	160							
170	2.142	170	0.133	0.267	614.2236	2.262	1.059	0.0248	15.24
180	2.261	180							
190	2.395	190	0.145	0.239	549.5685	2.250	1.064	0.0271	14.91
200	S1	200							
210		210							**14.61**
									lit/min/mt of D.D.

APT 7

Specific capacity = 2303 A / t*logS1 / S2
= 41.61 Ltr / minutes / meter of dd 1

Quantity pumped = c*dd* 1440*10^{-3}
= 14.61 *2.395*1440*10^{-3}
= 50.38 kiloliters / day 2

Transmissivity T = 2.3*Q / 4 ∏ΔS
= 2.3*50.38 / 4*3.14*0.145
= 63.66 m2 / day 3

Storage Coefficient S = 2.25*T*t0*6.96*10^{-4} / R^2
= 2.25*63.66*18*6.96*10-4 / 14.44
= 0.053

Specific yield = 5.30 % 4

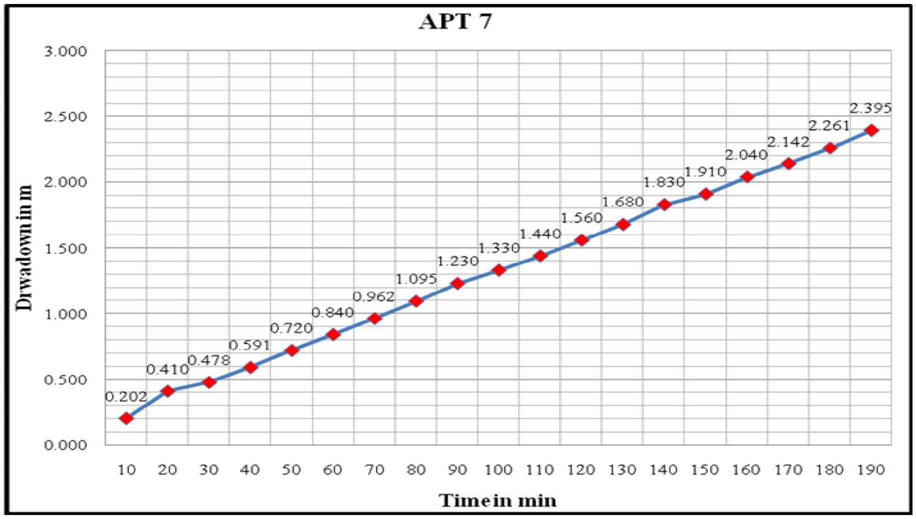

Figure 18: Drawdown graph of APT 7

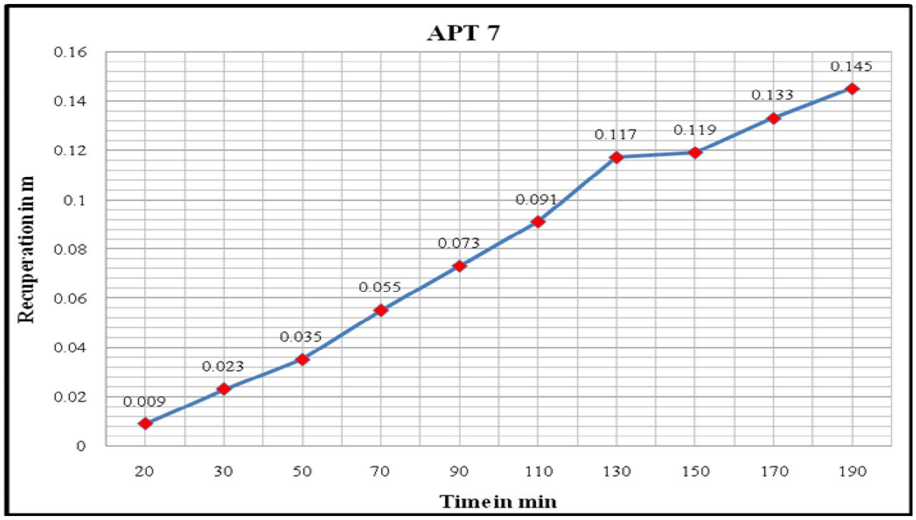

Figure 19: Recuperation graph of APT 7

Table 10: Data sheet of APT 8

APT 8									
Drawdown		**Recuperation**		**A/t**	**2303A/t**	**S2**	**S1/S2**	**log S1/S2**	**C = 2303A/t*log S1/S2**
Time in minutes	**D.D.in mts (S1)**	**Time in minutes**	**Recuperation in mts**						
10	0.080	10	0.040	4.534	10441.80	1.400	1.029	0.0122	127.75
20	0.160	20	0.090	2.267	5220.90	1.350	1.067	0.0280	146.34
30	0.250	30	0.110	1.511	3480.60	1.330	1.083	0.0345	120.12
40	0.340	40	0.150	1.134	2610.45	1.290	1.116	0.0478	124.71
50	0.410	50	0.185	0.907	2088.36	1.255	1.147	0.0597	124.71
60	0.510	60	0.220	0.756	1740.30	1.220	1.180	0.0720	125.31
70	0.600	70	0.245	0.648	1491.69	1.195	1.205	0.0810	120.82
80	0.670	80	0.270	0.567	1305.23	1.170	1.231	0.0902	117.70
90	3.720	90	0.310	0.504	1160.20	1.130	1.274	0.1053	122.15
100	0.810	100	0.345	0.453	1044.18	1.095	1.315	0.1189	124.20
110	0.880	110	0.375	0.412	949.25	1.065	1.352	0.1310	124.36
120	0.940	120	0.400	0.378	870.15	1.040	1.385	0.1413	122.98
130	1.010	130	0.430	0.349	803.22	1.010	1.426	0.1540	123.73
140	1.070	140	0.450	0.324	745.84	0.990	1.455	0.1627	121.37
150	1.130	150	0.475	0.302	696.12	0.965	1.492	0.1738	121.01
160	1.180	160	0.495	0.283	652.61	0.945	1.524	0.1829	119.38
170	1.240	170	0.530	0.267	614.22	0.910	1.582	0.1993	122.43
180	1.290	180	0.550	0.252	580.10	0.890	1.618	0.2090	121.22
190	1.340	190	0.570	0.239	549.57	0.870	1.655	0.2188	120.27
200	1.400	200	0.590	0.227	522.09	0.850	1.694	0.2289	119.53
210	1.440	210	0.610	0.216	497.23	0.830	1.735	0.2393	118.98
	S1								**123.29**
									lit/min/mt of D.D.

APT 8

Specific capacity	= 2303 A / t*logS1 / S2	
	= 123.29 Ltr / minutes / meter of dd	……………… 1
Quantity pumped	= c*dd* 1440*10^{-3}	
	= 123.29 *1.42*1440*10^{-3}	
	= 252.10 kiloliters / day	……………… 2
Transmissivity T	= 2.3*Q / 4 ∏ΔS	
	= 2.3*252.10 / 4*3.14*0.78	
	= 59.22 m2 / day	……………… 3
Storage Coefficient S	= 2.25*T*t0*6.96*10^{-4} / R^2	
	= 2.25*59.22*18*6.96*10-4 / 14.44	
	= 0.0385	
Specific yield	= 3.85 %	……………… 4

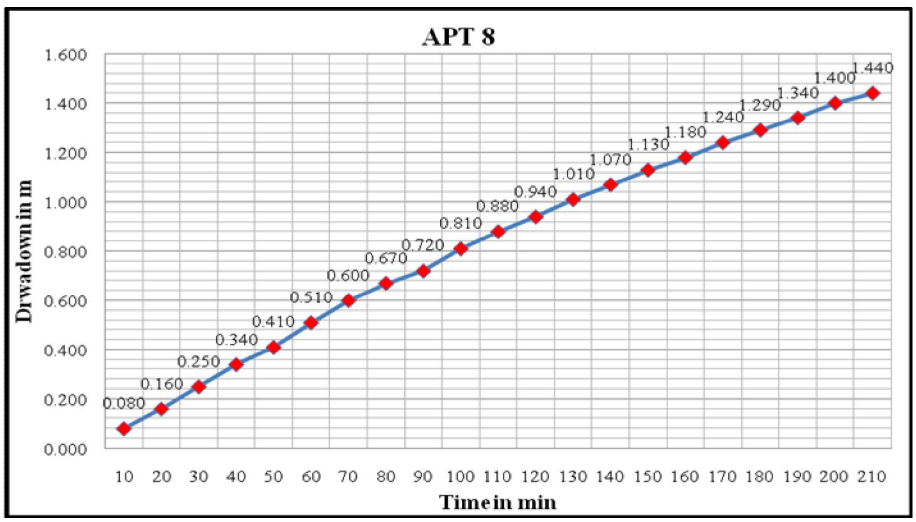

Figure 20: Drawdown graph of APT 8

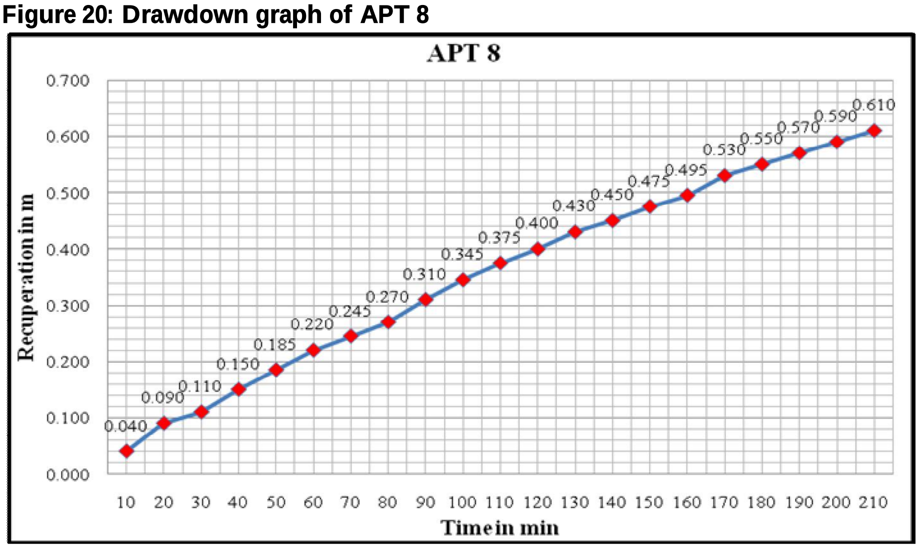

Figure 21: Recuperation graph of APT 8

Table 11: Data sheet of APT 9

APT 9									
Drawdown		**Recuperation**		**A/t**	**2303A/t**	**S2**	**S1/S2**	**log S1/S2**	**C = 2303A/t*log S1/S2**
Time in minutes	**D.D.in mts (S1)**	**Time in minutes**	**Recuperation in mts**						
10	0.036	10	0.026	8.007	18440.121	0.430	1.060	0.0255	470.16
20	0.060	20	0.046	4.004	9220.0605	0.410	1.112	0.0462	425.79
30	0.080	30	0.074	2.669	6146.707	0.382	1.194	0.0769	472.69
40	0.116	40	0.092	2.002	4610.0303	0.364	1.253	0.0979	451.15
50	0.138	50	0.118	1.601	3688.0242	0.338	1.349	0.1300	479.62
60	0.158	60	0.136	1.335	3073.3535	0.320	1.425	0.1538	472.73
70	0.188	70	0.151	1.144	2634.303	0.305	1.495	0.1747	460.12
80	0.214	80	0.168	1.001	2305.0151	0.288	1.583	0.1996	460.02
90	0.238	90	0.192	0.890	2048.9023	0.264	1.727	0.2374	486.33
100	0.260	100	0.210	0.801	1844.0121	0.246	1.854	0.2680	494.25
110	0.281	110	0.224	0.728	1676.3746	0.232	1.966	0.2935	491.98
120	0.310	120	0.244	0.667	1536.6768	0.212	2.151	0.3326	511.14
130	0.330	130	0.270	0.616	1418.4708	0.186	2.452	0.3895	552.43
140	0.360	140	0.272	0.572	1317.1515	0.184	2.478	0.3941	519.15
150	0.386	150	0.292	0.534	1229.3414	0.164	2.780	0.4441	545.98
160	0.414	160	0.311	0.500	1152.5076	0.145	3.145	0.4976	573.48
170	0.429	170	0.330	0.471	1084.713	0.126	3.619	0.5586	605.91
180	0.456	180	0.354	0.445	1024.4512	0.102	4.471	0.6504	666.27
	S1	190	0.378	0.421	970.53268	0.078	5.846	0.7669	744.27
		200	0.384	0.400	922.00605	0.072	6.333	0.8016	739.11
		210	0.403	0.381	878.101	0.053	8.604	0.9347	820.75
									544.92
									lit/min/mt of D.D.

APT 9

Specific capacity	= 2303 A / t*logS1 / S2	
	= 544.92 Ltr / minutes / meter of dd	……………… 1
Quantity pumped	= c*dd* 1440*10^{-3}	
	= 544.92*0.456*1440*10^{-3}	
	= 357.81 kiloliters / day	……………… 2
Transmissivity T	= 2.3*Q / 4 ∏ΔS	
	= 2.3*357.81 / 4*3.14*0.285	
	= 230.52 m^2 / day	……………… 3
Storage Coefficient S	= 2.25*T*t0*6.96*10^{-4} / R^2	
	= 2.25*230.52*18*6.96*10-4 / 25.50	
	= 0.141	
Specific yield	= 14.10 %	……………… 4

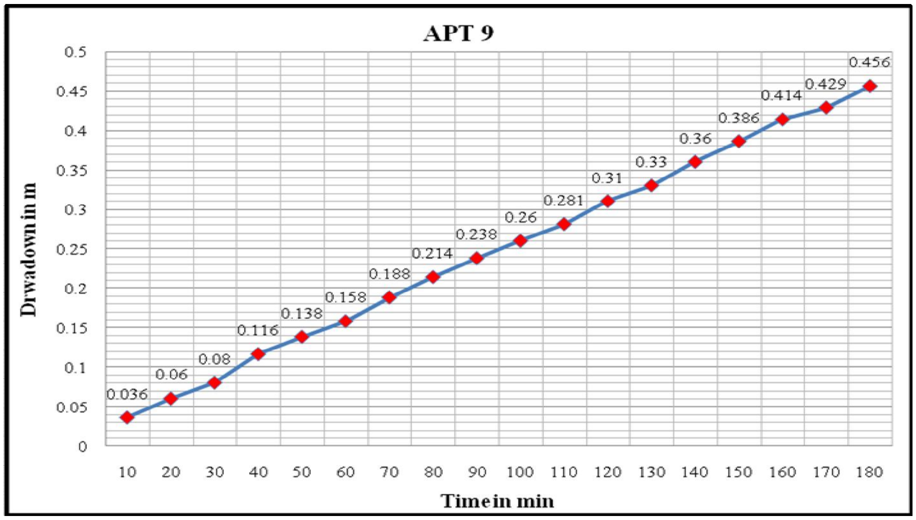

Figure 22: Drawdown graph of APT 9

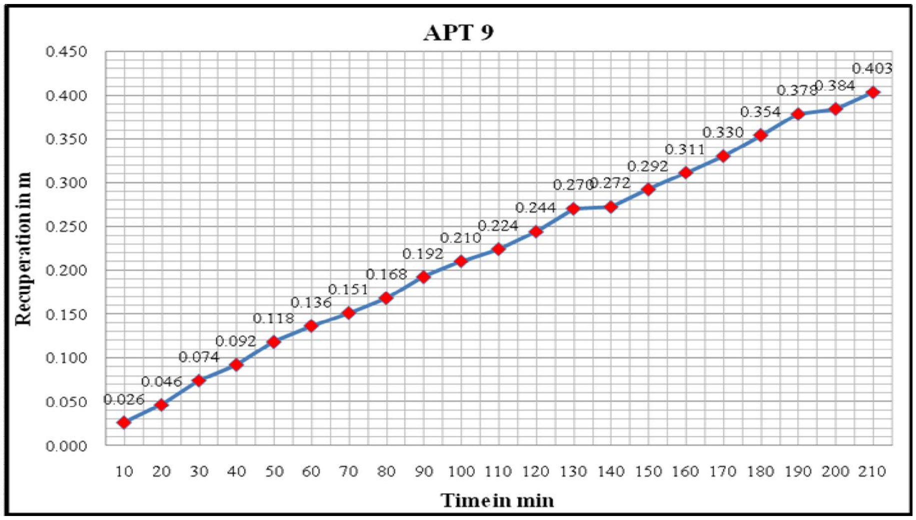

Figure 23: Recuperation graph of APT 9

CONCLUSION

In the study area total of Nine Aquifer Performance Test (APT) has been conducted at various locations within the shallow aquifers. In the North Eastern part i.e. upper reach of the study area, the APT analysis indicates that the specific capacity varies between of 76 to 123.29 lit/min/mt of d.d., Transmissivity varies between of 51.99 to 56.22 m^2/ day and the Specific yield is between 2.2 to 3.85%. In the central part i.e. middle reach of the study area, the specific capacity varies between of 161.13 to 732.17 lit/min/mt of d.d., Transmissivity varies between of 55.09 to 230.52 m^2/ day and the Specific yield is between 6.70 to 14.10%. Finally Western part i.e. lower reach the specific capacity varies between of 14.61 to 200.45 lit/min/mt of d.d., Transmissivity varies between of 63.66 to 131.00 m^2/ day and the Specific yield is between 5.30 to 6.82%. Hence, the analyses of APT data suggest that the upper reach is low groundwater potential zone, the central part is high groundwater potential zone and the lower reach is moderate groundwater potential zone.

Acknowledgements

The authors would like to thanks Dr. Vijay Kumar and Dr. P.B. Panaskar of School of Earth Sciences, SRTMU, Nanded for help during the research work of this manuscript. The authors also acknowledge the officials of Swami Ramanand Teerth Marathwada University, Nanded (India).

REFERENCES

1. Adyalkar, P.G. and Mani, V.V.S., (1974). Application of ground-water hydraulics to a basaltic water table aquifer. J. Hydrol., 21: 211-218. Bouwer H. (1978). Groundwater Hydrology. Mc-Graw Hill, 480 p.
2. Copper H. H. and Jacob C. E. (1946). A generalized graphical method for evaluating formation constants and summarizing well-field history. Trans. Amer. Geophysical Union, vol. 27 pp 526-534
3. Darcy H. (1856). Les Fountains Publiques de la Ville de Dijon, Dalmont, Paris.
4. Deolankar, S.B., (1981). The Deccan Basalts of Maharashtra, India, their potential as aquifers. Ground Water, 18(5): 434-437.
5. Detay M, Poyet P, Emsellem Y, Bernardi A, Aubrac G (1989). Development of the saprolite reservoir and its state of saturation: influence on the hydrodynamic characteristics of drillings in crystalline basement. C R Acad Sci Paris II 309:429–436
6. Khadri S. F. R. and Moharir Kanak (2016). Characterization of aquifer parameter in basaltic hard rock region through pumping test methods: a case study of Man River basin in Akola and Buldhana Districts Maharashtra India. Model. Earth Syst. Environ. (2016) Springer International Publishing Switzerland 2016, pp. 1 - 18
7. Papadopulous IS (1965). Nonsteady flow to a well in an infinite anisotropic aquifer. In: Proceedings of International Association of Scientific Hydrology, Dubrovnik Symposium on the Hydrology of Fractured Rocks, Paris, September 1965, pp 21-31.
8. Pathak BK (1984). Hydrogeological surveys and ground water resources evaluation in the hard rock areas of India. In: Proceedings of international workshop on rural hydrogeology and hydraulics in fissured basement zones, Roorkee, pp 14–15
9. Radhakrishna BP (1970). Problems confronting the occurrence of groundwater in hard rocks. In: Proceedings of seminar on groundwater potential in hard rock's of India, Bangalore, pp 27–44
10. Sophocleous MA (1991). Combining the soil water balance and water level fluctuation methods to estimate natural groundwater recharge: practical aspects. J Hydrol 124:229–241
11. Taylor R, Howard K (2000). A tectono-geomorphic model of the hydrogeology of deeply weathered crystalline rock: evidence from Uganda. Hydrogeol J 8(3):279–294
12. Theis C. V. (1935). The relation between the lowering of the piezometric surface and the rate and duration of discharge of a well using groundwater storage. Am. Geophys. Union Trans., vol. 16 pp 519-524.
13. Thiem, G. (1906). Hydrologist Methodology. Gebhardt, Leipzig.

14. Uhl V.W.Jr and Joshi V.G. (1986). Results of pumping tests in the deccan trap basalts of central india. *Journal of Hydrology,* 86 (1986) 147-168. Elsevier Science Publishers B.V., Amsterdam - Printed in The Netherlands
15. Vander Gun and J, Lipponen A (2010). Reconciling groundwater storage depletion due to pumping with sustainability. Sustainability 2:3418–3435
16. Walton W. C. (1970) Groundwater Resources Evaluation. McGraw Hill Book Co., New York, 664 p.
17. Wyns R, Baltassat J. M., Lachassagne P, Legchenko A, Vairon J, Mathieu F (2002). Application of magnetic resonance soundings to groundwater reserves mapping in weathered basement rocks (Brittany, France). Bull Soc Geol France, to be published