International Journal of Innovation and Scientific Research
ISSN 2351-8014 Vol. 13 No. 2 Feb. 2015, pp. 704-713

http://www.ijisr.issr-journals.org/

Annual and long term trends in water table fluctuations of a typical highland and midland sub-watersheds of Manimala River Basin, Kerala, South India and its correlation with rainfall data

V.B. Rekha[1], A.V. George[1], and M. Rita[2]

[1]School of Environmental Science, Mahatma Gandhi University,
Kottayam, Kerala, India

[2]Department of Chemistry, Govt. College, Kottayam,
Nattakam, Kerala, India

ABSTRACT: The present study encompasses an assessment of annual and long term variations in groundwater level of Peruvanthanam and Valiyathodu sub-watersheds and its correlation with rainfall occurrence. The seasonal variations in phreatic surfaces of both sub-watersheds reveal that unlike Peruvanthanam, Valiyathodu sub-watershed shows maximum fluctuations in groundwater level during post monsoon season. Average rainfall in Peruvanthanam sub-watershed during this period was 3832.28 mm and the average water levels in the observation wells CGWBp1 and CGWBp2 were 4.86m and 2.62m respectively. In 2007 when there was an increase of 1199.72 mm rainfall from the average. Well no. CGWBp1 shows a decrease in water level from 4.36 to 4.10m ie, 0.76 m (15.64%). The corresponding decrease in value observed in groundwater level of well no CGWBp2 was from 2.62m to 2.20m ie, 16.03%. When both the well data are compared, greater variations are observed, in well no.CGWBp2 during increase in rainfall. This is a reflection of the greater porosity and permeability of the ground material in an around the well. Similarly in 2000, there was a decrease of 1296.78mm in rainfall from the average. In well no CGWBp1 there was an increase in depth from 4.86m to 5.59m ie, 0.71m (14.61%). The corresponding value for well no CGWBp2 was from the average value of 2.62m to 2.95m ie, 0.33m (12.60%). Average rainfall of Valiyathodu sub-watershed was 4099.82mm and the average water level in CGWBv1 and CGWBv2 are 9.12m and 5.64m respectively. In 2005 when there was an increase of 1031.68mm rainfall from the average well no. CGWBv1 shows a decrease in value from 9.12 to 7.82 (14.25%). The corresponding variations observed in well no. CGWBv2 was from 5.64m to 5.16m (8.51%). In 2002 there was a decrease in rainfall to 3089.00mm from the average value of 4099.82mm. The variation in groundwater level observed in well no. CGWBv1 in accordance with this is from 9.12m to 10.01m ie, 0.89m (9.76%). The corresponding variations observed in well no. CGWBv2 is from 5.64m to 5.98m ie, 0.34m (6.03%). When both well data are compared, greater variations are observed in well no CGWBv1 during both increase and decrease in rainfall. This shows that sub surface phreatic aquifer material in around well no. CGWBv1 has more permeability compared to CGWBv2.

KEYWORDS: Phreatic surface, Water level, rainfall data, Peruvanthanam, Valiyathodu, Manimala.

1 INTRODUCTION

Groundwater level is an indicator of groundwater availability, groundwater flow, and physical characteristics of an aquifer or groundwater system [1]. Aquifer system reacts to hydraulic stresses by change in groundwater levels with respect to time and season. Hydraulic stresses include recharge and discharge from the system [2]. If the recharge exceeds the discharge the aquifer keeps the difference in storage and the water table rises. If the discharge exceeds recharge the difference is taken from the storage and water table level decreases [3]. Over a long time the discharge may balance the recharge and equilibrium may develop. This does not mean that the aquifer will be in equilibrium continuously. It depends on the nature of aquifer and rainfall. During a dry year the annual discharge may exceed the annual recharge resulting in the decrease in

Corresponding Author: V.B. Rekha

storage and lowering of the water table [4]. In wet year annual recharge may exceed annual discharge resulting in an increase in storage and rise in the water table. Over long period there may be several dry and wet years and average annual recharge may balance the average discharge resulting in long term equilibrium of groundwater levels [5], [6], [7], [8].

2 STUDY AREA

The areas selected for the present investigation ie, Peruvanthanam and Valiyathodu sub-watersheds belongs to a typical highland and midland segments of the Manimala river basin. Peruvanthanam sub-watershed (Fig.1) lies between $9^0$29'00" to $9^0$34'00" N latitude and $76^0$53'00" to $76^0$59'00" E longitude. The Valiyathodu sub-watershed (Fig.2) lies between $9^0$30'00" to $9^0$37'00" N latitude and $76^0$41'00" to $76^0$46'00" E longitude. Peruvanthanam sub-watershed covers an area of 56.42 km^2 and Valiyathodu 54.85 km^2.

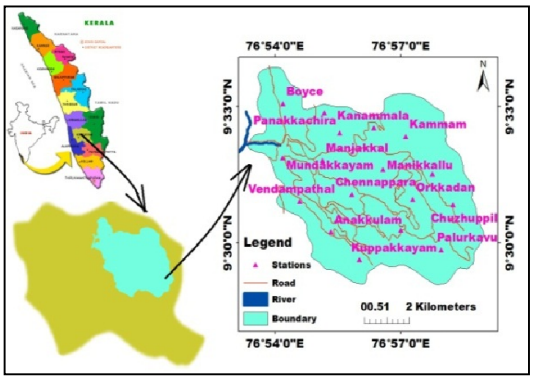

Fig. 1. Location map of Peruvanthanam sub-watershed

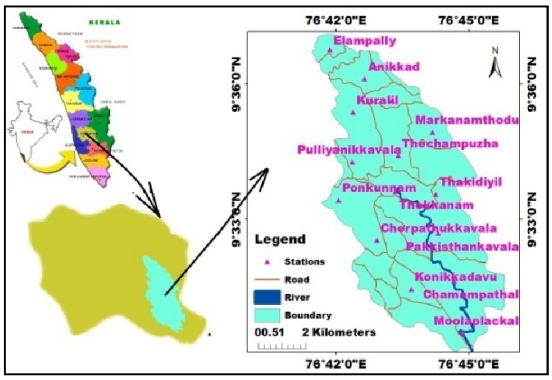

Fig. 2. Location map of Valiyathodu sub-watershed

3 METHODOLOGY

To find out the variation in groundwater level, and hydrological potential of the area, 17 observation wells in Peruvanthanam sub-watershed and 15 in Valiyathodu were fixed at definite intervals. Annual water table fluctuation studies were carried out for the period 2008 February to 2009 January. The study period was divided in to three seasons viz, pre monsoon (February, March, April and May), monsoon (June, July, August and September) and post monsoon (October, November, December and January). Water levels of the different observation wells of both sub-watersheds were monitored on 15th of every month. The depth of water table in each well was noted after deducting the length of wall height from the total height of the measuring point to the ground level. Monthly collected data from both sub-watersheds were grouped in to pre monsoon, monsoon and post monsoon seasons. Water levels of both sub-watersheds were analyzed and its variations are compared with the corresponding rainfall data of the concerned sub-watersheds.

4 RESULT AND DISCUSSION

The monthly water level data of Peruvanthanam sub-watershed is represented in table. 1 and its variations during pre monsoon, monsoon and post monsoon seasons are represented graphically in Fig. 3. From the table and figure it explicit that in all the wells maximum depth of water level was attained during the month of May and minimum during August. Graphical representation reveals that, during pre monsoon, the depth in water level varies between 4.85m and 10.9m. With the onset of monsoon, the depth decreases to the range 2.95m and 6.89m due to recharge by rainwater. During post monsoon it increases to 3.78m and 8.14m.

The monthly water level data of Valiyathodu sub-watershed is represented in table. 2 and it's variation during different seasons are represented graphically in Fig. 4. From the table data and figure it is explicit that in all the wells maximum depth of water level was attained during during the month of May and minimum during August. During pre monsoon season, depth of water level varies between 3.33m and 5.98m. With the onset of monsoon season, the depth decreases to 2.19m and 4.17m due to recharge by rainwater and it ascends to 2.73m and 5.30m during post monsoon season.

The seasonal variations in water level data (seasonal mean data) of Peruvanthanam sub-watershed, during pre monsoon, monsoon and post monsoon season, are represented in (Fig. 5, Fig.6 and Fig.7). During pre monsoon, the maximum depth of mean water level observed was at Peruvanthanam (P5) (9.65m)and minimum at Kuppakkayam (P9) (5.75m). During monsoon maximum value was observed at both Mundakkayam (P1) and Panakkachira (P4) (6.30m) and minimum at Chennapara (P7)

(3.30m). During post monsoon season the corresponding values observed were at Mundakkayam (P1) (7.54m) and Manikkallu (P8) (4.10m) respectively. The seasonal variations in water level (seasonal mean data) of Valiyathodu sub-watershed, during different seasons, are represented in (Fig. 8, Fig. 9 and Fig. 10). During pre monsoon, maximum depth of mean water level ie, 4.87m was observed at Anikkad (V2) and minimum ie, 3.74m at Ponkunnam (V8). During monsoon the maximum depth of mean water level ie, 3.68m was observed at Moolaplakal (V15) and minimum ie, 2.56m at Ponkunnam (V8). The maximum and minimum depth of mean water level during post monsoon 4.31m and 3.03m was observed at Anikkad (V2) and Ponkunnam (V8) respectively. A comparative study of the fluctuation data of both sub-watersheds (table.3) reveals that, compared to Valiyathodu, Peruvanthanam sub-watershed has more pronounced (approximately three times) variation in depth to water level. The more permeable nature of the phreatic aquifer may be the reason for this.

Table 1. Water level data of Peruvanthanam sub-watershed during different seasons for the period 2008 February to 2009 January

S	Month	Water level depth in meters (bgl)																
		PI	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15	P16	P17
	Feb	6.36	7.98	7.52	7.05	8.78	8.23	6.12	6.00	4.92	6.36	6.34	7.45	6.36	4.85	5.44	6.12	7.23
	Mar	7.54	8.91	8.75	7.55	9.20	8.76	6.50	6.10	5.55	7.04	6.58	7.05	7.24	5.68	5.34	6.18	7.30
1	Apr	8.40	9.54	8.98	8.64	9.68	8.98	6.56	6.28	5.98	7.30	7.24	7.28	7.30	5.98	7.78	6.21	7.34
	May	8.59	9.79	9.45	9.05	10.93	9.72	7.25	6.49	6.55	8.42	8.08	7.08	8.38	6.98	6.98	6.35	7.69
	M	7.72	9.06	8.68	8.07	9.65	8.92	6.61	6.22	5.75	7.28	7.06	7.22	7.32	5.87	6.39	6.22	7.39
	Jun	6.65	5.89	6.25	6.48	5.81	5.56	3.80	4.50	3.76	5.56	3.85	4.52	5.56	3.98	3.98	6.12	4.23
	July	6.32	5.05	6.14	6.21	6.49	5.45	3.31	3.92	3.48	4.56	3.67	4.46	4.87	3.28	3.78	5.05	3.98
2	Aug	5.34	5.00	5.09	6.00	5.45	4.04	2.95	3.02	3.15	4.48	3.11	3.34	3.78	3.83	3.50	4.10	3.21
	Sept	6.89	5.22	5.35	6.51	5.56	4.90	3.15	3.76	3.76	4.95	3.67	4.33	4.92	3.96	4.26	4.38	4.26
	M	6.30	5.29	5.71	6.30	5.83	4.99	3.30	3.80	3.54	4.89	3.58	4.16	4.78	3.76	3.88	4.91	3.92
	Oct	6.98	4.89	6.05	6.34	5.78	5.46	3.78	4.13	3.71	5.43	3.72	5.49	5.47	5.89	4.13	5.43	5.17
	Nov	7.21	6.78	7.34	6.58	6.28	6.78	3.81	3.98	4.67	5.59	4.54	6.98	5.51	5.05	3.98	5.69	5.85
3	Dec	7.96	6.86	7.89	7.24	6.58	7.78	3.84	4.11	5.78	5.88	4.97	7.78	5.56	5.00	4.14	5.88	6.53
	Jan	8.00	8.02	7.94	8.14	7.30	7.99	5.10	4.18	6.30	6.29	5.83	7.99	6.67	5.49	4.29	6.29	6.85
	M	7.54	6.64	7.31	7.08	6.49	7.00	4.13	4.10	5.12	5.80	4.77	7.06	5.80	5.36	4.14	5.82	6.10
S=Seasons; 1=Pre monsoon; 2=Monsoon; 3=Post monsoon; M=Seasonal mean; bgl=below ground level																		

Table 2. Water level data of Peruvanthanam sub-watershed during different seasons for the period 2008 February to 2009 January

S	Month	Water level depth in meters (bgl)														
		VI	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11	V12	V13	V14	V15
	Feb	3.95	4.6	3.3	4.1	4.3	4.3	4.3	3.5	3.4	3.7	4.3	3.4	3.6	3.3	4.5
	Mar	4.90	4.5	4.1	4.0	4.0	4.0	4.5	3.6	3.8	3.8	4.5	3.8	3.8	4.1	4.1
1	Apr	5.22	5.0	4.2	4.9	4.3	4.5	5.0	3.8	5.0	3.8	5.0	5.0	4.1	4.4	4.3
	May	5.37	5.3	5.9	5.2	4.5	4.2	5.1	3.8	5.8	5.1	5.2	5.8	5.1	5.9	4.3
	M	4.86	4.8	4.4	4.6	4.3	4.2	4.7	3.7	4.5	4.1	4.7	4.5	4.2	4.4	4.3
	Jun	3.50	3.6	4.0	3.3	3.0	3.0	3.1	3.0	3.2	3.6	3.0	3.4	3.1	3.1	4.1
	July	3.14	3.2	3.3	3.1	2.9	2.4	2.9	2.4	3.1	3.5	2.9	3.3	2.8	2.7	3.8
2	Aug	2.97	3.1	2.9	2.8	2.1	2.3	2.7	2.3	3.1	3.2	2.2	3.0	2.6	2.6	3.1
	Sept	3.37	3.5	3.1	3.3	2.7	2.4	2.9	2.4	3.0	3.3	2.6	3.4	2.8	2.8	3.4
	M	3.25	3.4	3.3	3.1	2.7	2.5	2.9	2.5	3.1	3.4	2.7	3.3	2.8	2.8	3.6
	Oct	3.55	4.3	3.4	3.7	2.9	3.7	3.0	2.7	3.2	3.6	3.0	3.4	3.0	2.8	3.7
	Nov	3.81	4.0	3.1	3.6	3.0	3.8	3.2	2.8	3.6	4.0	3.0	3.1	3.9	3.0	3.8
3	Dec	3.88	4.3	3.6	3.8	3.7	3.8	3.7	2.9	3.7	3.8	3.3	3.5	4.1	3.8	3.7
	Jan	3.92	4.5	3.8	4.0	3.9	5.1	3.8	3.5	3.9	4.4	3.4	3.7	4.6	3.8	5.3
	M	3.79	4.3	3.5	3.8	3.4	4.1	3.4	3.0	3.6	4.0	3.2	3.4	3.9	3.4	4.1
S=Seasons; 1=Pre monsoon; 2=Monsoon; 3=Post monsoon; M=Seasonal mean; bgl=below ground level																

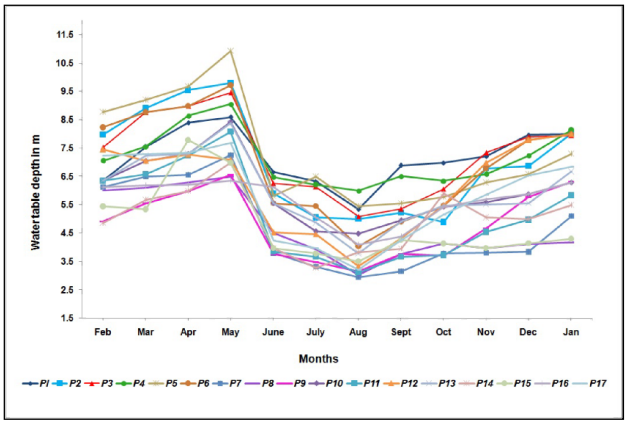

Fig. 3. Variation of water level in Peruvanthanam sub-watershed during different seasons

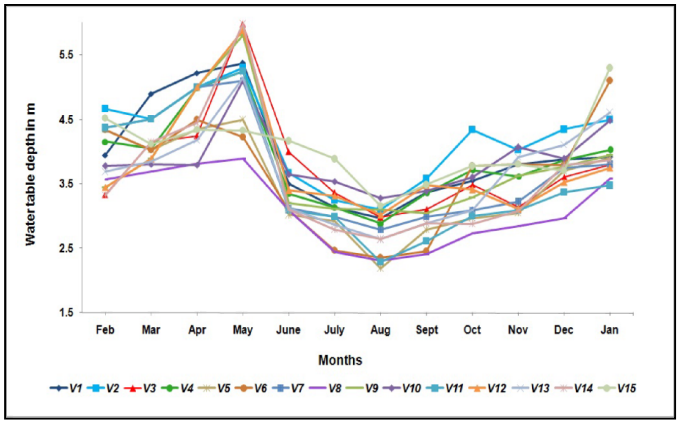

Fig. 4. Variation of water level in Valiyathodu sub-watershed during different seasons

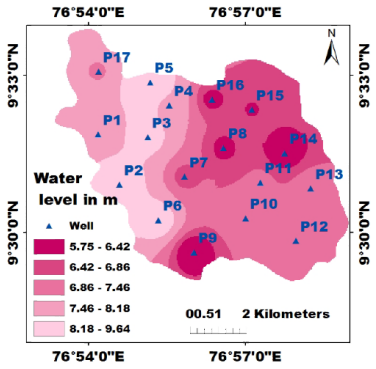

Fig.5. Variation of mean water level of Peruvanthanam sub-watershed during pre monsoon season

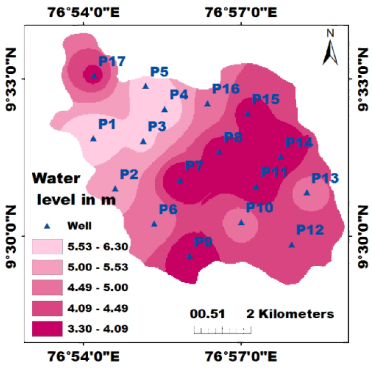

Fig.6. Variation of mean water level of Peruvanthanam sub-watershed during monsoon season

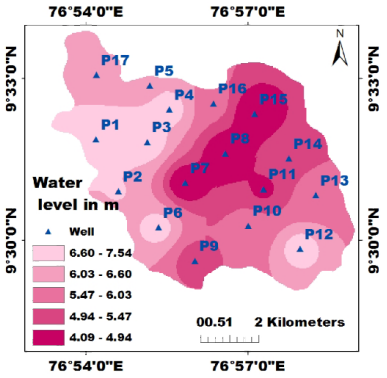

Fig.7. Variation of mean water level of Peruvanthanam sub-watershed during post monsoon season

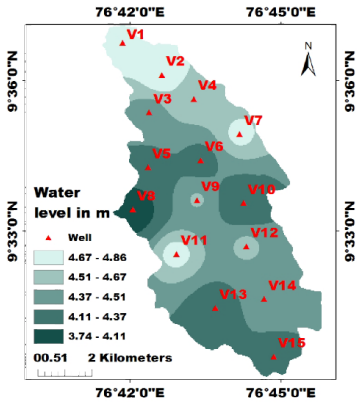

Fig.8. Variation of mean water level of Valiyathodu sub-watershed during pre monsoon season

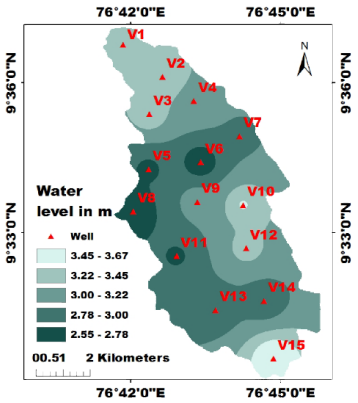

Fig.9. Variation of mean water level of Valiyathodu sub-watershed during monsoon season

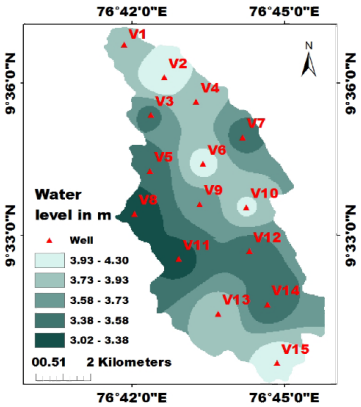

Fig.10. Variation of mean water level of Valiyathodu sub-watershed during post monsoon season

Table 3. Water table fluctuations in Peruvanthanam and Valiyathodu sub-watersheds during different seasons.

N	N.S	Seasons	Variation in depth to water table in m *(bgl)*			Variation in mean depth to water table in m *(bgl)*		
			Maximum	Minimum	Difference	Maximum	Minimum	Difference
P	17	Pre monsoon	10.90	4.85	6.05	9.65	5.75	3.90
		Monsoon	6.89	2.95	3.94	6.30	3.30	3.00
		Post monsoon	8.14	3.78	4.36	7.54	4.10	3.44
V	15	Pre monsoon	5.98	3.33	1.65	4.87	3.74	1.13
		Monsoon	4.17	2.19	1.88	3.68	2.56	1.12
		Post monsoon	5.30	2.73	2.57	4.31	3.03	1.28
N=Name of sub-watershed; N.S= Number of sample locations; P=Peruvanthanam sub-watershed; V=Valiyathodu sub-watershed; bgl=below ground level								

Long term water level fluctuation data analysis were carried out in wells of both Peruvanthanam and Valiyathodu sub-watershed, for the period 2000 to 2007 using the data provided by Central Ground Water Board. Water level data of observation wells (CGWBp1 and CGWBp2) of Peruvanthanam sub-watershed are represented in table. 4. Critical analysis of the water level data of CGWBp1 for 8 consecutive years shows that, maximum depth to water level was attained during the pre monsoon months of 2003 March (10.54m), 2004 April (10.37m) and 2004 March (10.23m) and minimum during 2005 September (0.68m). The maximum depth of water level observed in CGWBp2 was during 2003 March (4.83m), 2007 February (4.43m) and minimum depth in 2007 July (0.16m).

Water level data of observation wells of Valiyathodu sub-watershed (CGWBv1 and CGWBv2) for the period 2000 to 2007 are represented in table. 5. Critical analysis of water level fluctuation data of CGWBv1, revealed that maximum depth of water level was attained during pre monsoon season of 2000 April (15.56m), 2003 March (14.50m), 2004 April (14.25m) and minimum at 2002 July (2.29m). In the case of CGWBv2, maximum depth of water level was reported during the pre monsoon period of consecutive years ie, 2002 April (9.95m), 2003 April (8.48m) and minimum during 2003 June (3.02m).

Table. 4. Long term water level data (2000-2007) of observation wells CGWBp1 and CGWBp2 of Peruvanthanam sub-watershed

(a) Water level data of CGWBp1 in meters (bgl)													
Year	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Mean**
2000	6.19	6.51	5.40	5.12	4.47	4.26	5.08	1.77	3.25	6.58	8.36	9.85	5.57
2001	4.98	5.20	5.58	5.40	5.55	2.98	3.25	3.10	3.95	4.25	4.49	5.43	4.51
2002	4.87	5.82	7.38	7.23	8.56	3.45	3.25	3.87	4.90	5.02	4.12	3.26	5.14
2003	4.42	8.11	10.54	8.62	5.34	1.55	1.30	3.28	3.26	2.22	6.63	8.35	5.30
2004	6.72	8.01	10.23	10.37	2.55	1.90	2.13	2.78	1.46	2.61	3.38	6.99	4.93
2005	8.61	8.99	8.77	4.69	2.39	2.38	1.02	3.15	0.68	3.45	3.75	4.87	4.40
2006	8.80	9.20	9.45	9.43	2.94	3.85	1.02	3.10	2.17	2.71	2.76	3.69	4.93
2007	6.12	6.98	7.12	4.98	4.52	2.92	2.43	2.12	1.84	2.08	4.11	4.02	4.10
												Long term mean	4.86
(b) Water level data of CGWBp2 in meters (bgl)													
Year	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Mean**
2000	3.35	3.53	4.27	3.45	2.25	2.69	0.44	2.66	1.48	3.62	4.11	3.56	2.95
2001	2.92	2.15	2.38	2.76	2.11	1.32	1.55	2.35	2.69	2.95	2.19	2.23	2.30
2002	2.15	2.45	2.51	3.41	3.20	3.20	1.95	1.13	2.16	3.87	2.12	2.46	2.55
2003	3.52	4.37	4.83	3.42	3.02	0.98	1.10	2.52	2.29	1.66	2.69	3.14	2.80
2004	3.33	3.47	3.50	3.71	1.88	1.16	1.83	2.02	2.18	2.05	3.14	4.11	2.70
2005	3.53	4.12	3.58	3.73	2.75	2.13	2.02	1.98	1.71	1.92	2.15	2.23	2.65
2006	3.05	4.12	3.45	3.52	3.32	3.10	1.35	0.99	1.15	2.10	3.57	3.85	2.80
2007	3.38	4.43	4.06	2.74	0.68	1.81	0.16	2.53	0.98	2.58	0.63	2.47	2.20
												Long term mean	2.62
bgl=below ground level													

Table. 5. Long term water level data (2000-2007) of observation wells CGWBv1 and CGWBv2 of Peruvanthanam sub-watershed

(a) Water level data of CGWBv1 in meters (bgl)													
Year	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Mean**
2000	11.83	12.20	11.60	15.56	11.69	8.92	7.25	5.27	6.50	6.90	10.45	10.32	9.87
2001	8.65	9.65	10.30	9.35	9.24	8.24	7.34	8.85	9.49	9.55	9.50	10.02	9.18
2002	10.80	11.34	13.31	10.23	10.11	8.53	2.29	7.08	10.50	11.43	12.12	12.34	10.01
2003	10.78	14.05	14.50	13.50	6.32	8.52	7.10	8.36	6.95	8.98	10.55	10.12	9.98
2004	11.80	14.00	14.11	14.25	5.69	6.98	8.31	8.49	8.61	8.52	7.76	8.93	9.79
2005	7.89	7.79	7.19	7.51	8.44	8.15	7.50	8.26	7.67	8.38	6.53	8.52	7.82
2006	9.24	10.69	13.65	8.61	7.28	5.52	6.16	8.02	7.46	6.58	7.18	8.55	8.25
2007	7.27	8.21	8.73	9.72	8.13	7.70	7.68	8.56	6.93	5.89	8.12	9.65	8.05
												Long term mean	9.12
(b) Water level data of CGWBv2 in meters (bgl)													
Year	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Mean**
2000	5.80	6.23	6.60	6.32	5.15	6.65	6.18	4.57	5.32	5.48	6.15	6.35	5.90
2001	6.55	6.68	6.85	6.45	5.85	4.24	4.50	5.29	6.41	5.12	5.78	6.36	5.84
2002	5.91	6.75	7.98	9.95	5.92	5.67	5.58	4.05	4.12	4.23	5.53	6.10	5.98
2003	5.99	6.98	7.76	8.48	5.34	3.02	4.51	5.03	5.67	3.95	5.93	6.95	5.80
2004	6.30	6.66	6.89	6.97	5.82	4.67	5.33	3.55	5.61	4.75	5.47	5.78	5.65
2005	6.13	6.73	6.83	7.49	5.32	4.30	3.64	3.03	3.57	4.89	4.49	5.47	5.16
2006	6.81	6.43	6.53	7.03	5.83	5.59	4.00	4.04	4.12	4.83	4.87	5.87	5.50
2007	6.14	6.38	6.42	6.88	5.74	5.34	3.65	5.43	3.94	4.23	4.02	5.76	5.33
												Long term mean	5.64
bgl=below ground level													

The monthly average rainfall data for of both Peruvanthanam (Mundakkayam station) and Valiyathodu sub-watershed (Boyce estate station) from January 2000 to December 2007 is presented in table. 6. The hydrographs showing long term trends of both observation wells CGWBp1 and CGWBp2 of Peruvanthanam sub-watershed shows a declining trend which is in accordance with the increasing nature of rainfall pattern of Peruvanthanam sub-watershed (Fig. 11 and Fig. 12). When the water table fluctuation data for 8 consecutive years are compared with rainfall data of the corresponding period a perfect correlation is observed.

Long term trends in rainfall during 2000-2007 in Peruvanthanam and Valiyathodu sub-watershed are represented in table.7. In Peruvanthanam subwatershed (Mundakkayam station), critical analysis of rainfall data for the period 2000 to 2007, shows that, the maximum total rainfall was obtained in the year 2007 (5032.00mm) and the minimum in 2000 (2535.50mm). The average annual rainfall being 3832.28 mm. During the year 2007 there was an increase of 31.31 % (5032.00mm) than the annual average rainfall and during 2000 (2535.50mm), there was a decrease of 33.84 % than the average.

Long term trends in water table fluctuations in Peruvanthanam and Valiyathodu sub-watershed are represented in table.8. Average water level for the period 2000 to 2007 in well no CGWBp1 was, 4.86m and during 2007 the water level was, 4.10m with a decrease in depth of 15.64% than the average and during 2000 it increased by 14.61% to 5.57m. In the case well no CGWBp2, average water level was 2.62m and during 2007, the water level (2.20m) decreased by 16.03 % and during 2000, it increased by 12.60% to 2.95m. When the water level data of CGWBp1 and CGWBp2 was compared with rainfall data (Fig. 13 and Fig. 14) a direct correlation was observed ie, the depth of water level decreases with increase in rainfall and increases with decrease in rainfall during the period (2000 to 2007). This shows that the phreatic aquifer forming materials show permeability in response to rainfall [9], [10].

The long term behavior of hydrographs (Fig. 15 and Fig. 16) of both observation wells CGWBv1 and CGWBv2 of Valiyathodu sub-watershed shows a progressively declining trend. This is in accordance with the progressively increasing nature of long term rainfall pattern of Valiyathodu sub-watershed. In Valiyathodu sub-watershed (Boyce estate station), during the period 2000 to 2007, the maximum total rainfall was reported in the year, 2005 (5131.50 mm) and the minimum in 2002 (3089.10mm). The average annual rainfall is 4099.82 mm. During 2005 there was an increase of 25.16% (5131.50mm) from the average annual rainfall (4099.82 mm). During 2002 (3089.10mm), there was a decrease of 24.65 % from the average. Average water level during the period of 2000 to 2007 at CGWBv1 was, 9.12m and during 2002 the mean water

level was, 10.01m with an increase of 8.89% from the average. During 2005 it decreased by 14.25% to 7.82m. In the case of CGWBv2, long term average water level was 5.64m. During 2002, the mean depth to water level (5.98m) was increased by 6.03% and during 2005, it decreased by 8.51% to 5.16 m. Comparison of water level data of CGWBv1 and CGWBv2 with rainfall data (Fig. 17 and Fig. 18) during the period 2000 to 2007 shows that, the depth in water level decreases with increase in rainfall an increases with decrease in rainfall. This shows that Ground water development studies should be coupled with rainfall data for the conservation of ground water resources and its management [11].

Table. 6. Rainfall data of Peruvanthanam sub-watershed and Valiyathodu sub-watershed

(a) Rainfall data of Peruvanthanam sub-watershed in milli meters													
Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
2000	0.00	230.55	65.65	148.50	278.50	0.00	61.55	920.30	259.50	368.65	75.40	126.90	2535.50
2001	79.40	47.80	89.40	556.55	185.00	778.58	715.60	377.40	269.55	712.90	484.42	6.80	4303.40
2002	18.20	8.55	130.55	211.55	526.25	455.20	462.10	421.50	99.05	527.20	207.45	11.20	3078.80
2003	0.00	76.40	162.15	158.24	199.32	482.80	584.22	544.40	110.10	617.60	24.60	6.80	2966.63
2004	75.40	25.60	69.43	301.54	744.65	591.55	499.55	361.25	312.43	396.55	66.45	0.00	3444.40
2005	82.40	68.45	175.33	462.25	366.56	719.62	949.80	299.50	816.55	462.80	511.01	64.25	4978.52
2006	0.00	0.00	119.10	185.12	812.13	600.02	615.80	424.80	597.20	491.61	473.22	0.00	4319.00
2007	0.00	0.00	0.00	381.20	293.15	746.34	1074.11	542.20	839.21	816.15	312.04	27.60	5032.00
												Long term mean	3832.28
(b) Rainfall data of Valiyathodu sub-watershed in milli meters													
Year	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	
2000	0.00	361.60	28.80	235.15	312.20	860.80	368.15	975.05	294.90	314.70	69.12	150.03	3970.50
2001	2.20	32.00	87.20	461.15	239.80	839.40	786.40	428.80	395.20	653.15	490.10	23.00	4438.40
2002	13.60	20.60	106.55	222.55	683.20	430.15	452.61	432.05	77.40	467.58	174.86	7.95	3089.10
2003	0.00	95.60	220.25	130.15	178.10	526.80	596.10	555.20	163.80	656.40	23.40	23.05	3168.85
2004	44.20	40.60	68.30	276.25	697.83	701.65	550.65	421.60	363.84	432.33	64.65	19.80	3681.70
2005	68.20	60.65	170.15	474.25	390.54	660.25	951.56	338.88	850.68	428.40	679.40	58.54	5131.50
2006	0.00	0.00	168.25	177.75	810.20	483.40	672.60	436.80	541.10	555.45	555.75	0.00	4401.30
2007	0.00	0.00	0.00	344.12	428.95	801.65	1186.55	449.60	775.12	672.61	232.85	25.75	4917.20
												Long term mean	4099.82

Table. 7. Long term trends in rainfall during 2000-2007 in Peruvanthanam and Valiyathodu sub-watershed

N	Average rainfall in mm during 2000-2007	Maximum rainfall in mm during 2000-2007	Minimum rainfall in mm during 2000-2007	Increase in rainfall from average and its %	Decrease in rainfall from average and its %
P	3832.28	5032.00 (2007)	2535.50 (2000)	1199.72 (31.31%)	1296.78 (33.84%)
V	4099.82	5131.50 (2005)	3089.10 (2002)	1031.68 (25.16%)	1010.72 (24.65%)
N= Name of sub-watersheds; P= Peruvanthanam sub-watershed; V= Valiyathodu sub-watershed					

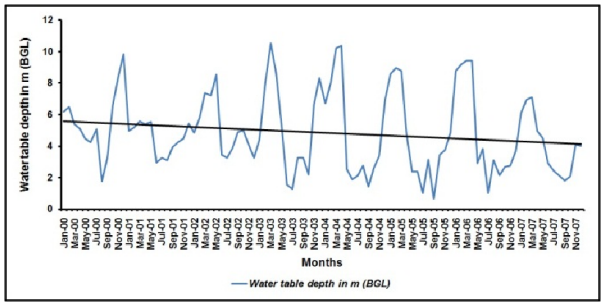

Fig. 11. Hydrograph of CGWBp1 showing long term behavior of water level in Peruvanthanam sub-watershed

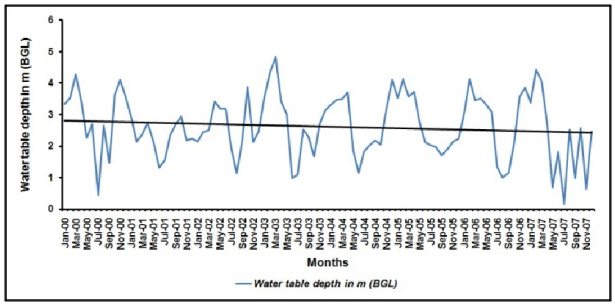

Fig. 12. Hydrograph of CGWBp2 showing long term behavior of water level in Peruvanthanam sub-watershed

Table. 8. Long term trends in water table fluctuations in Peruvanthanam and Valiyathodu sub-watershed

N	Average depth of water level in m (bgl) during 2000-2007		Maximum increase in depth to water level from the long term average in m		Maximum decrease in depth to water level from the long term average in m		Increase in depth to water level from the average value and its %		Decrease in depth to water level from the average value and its %	
P	CGWBp1	CGWBp2	CGWBp1 (2000)	CGWBp2 (2000)	CGWBp1 (2007)	CGWBp2 (2007)	CGWBp1 (2000)	CGWBp2 (2000)	CGWBp1 (2007)	CGWBp2 (2007)
	4.86	2.62	5.57	2.95	4.10	2.20	0.71 (14.61%)	0.33 (12.60%)	0.76 (15.64%)	0.42 (16.03%)
V	CGWBv1	CGWBv2	CGWBv1 (2002)	CGWBv2 (2002)	CGWBv1 (2005)	CGWBv2 (2005)	CGWBv1 (2002)	CGWBv2 (2002)	CGWBv1 (2005)	CGWBv2 (2005)
	9.12	5.64	10.01	5.98	7.82	5.16	0.89 (9.76%)	0.34 (6.03%)	1.30 (14.25%)	0.48 (8.51%)

N= Name of sub-watersheds; P= Peruvanthanam sub-watershed; V= Valiyathodu sub-watershed

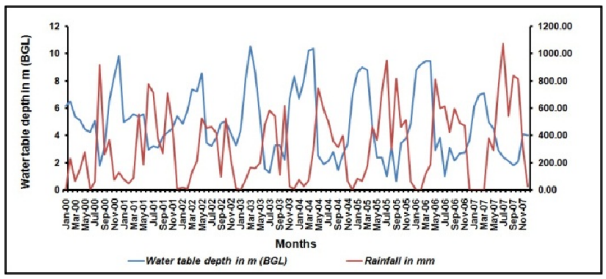

Fig. 13. Relationship between depth in water level of CGWBp1 and rainfall data of Peruvanthanam sub-watershed

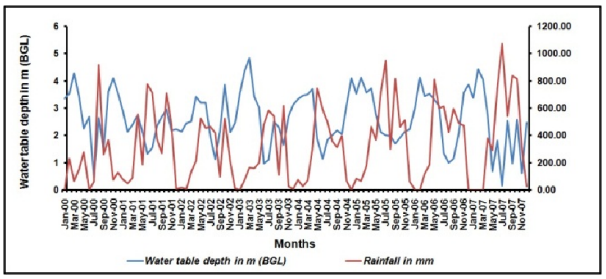

Fig. 14. Relationship between depth in water level of CGWBp2 and rainfall data of Peruvanthanam sub-watershed

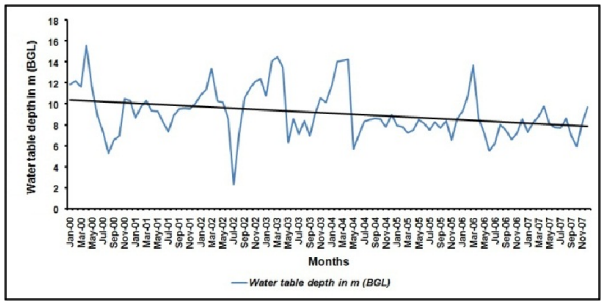

Fig. 15. Hydrograph of CGWBv1 showing long term behavior of water level in Valiyathodu sub-watershed

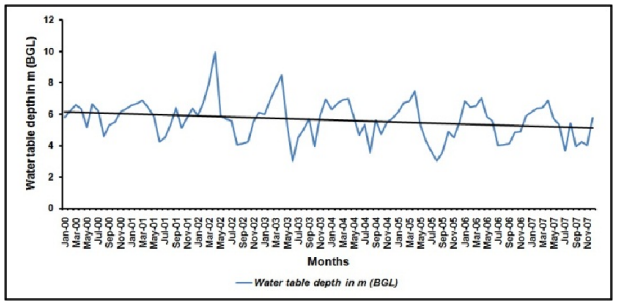

Fig. 16. Hydrograph of CGWBv2 showing long term behavior of water level in Valiyathodu sub-watershed

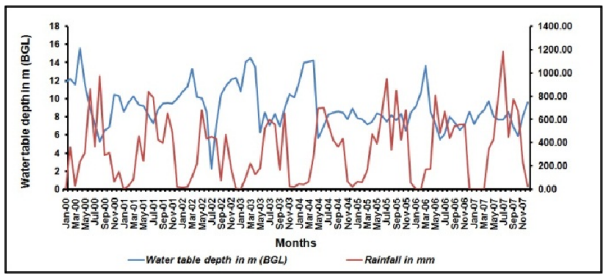

Fig. 17. Relationship between depth in water level of CGWBv1 and rainfall data of Valiyathodu sub-watershed

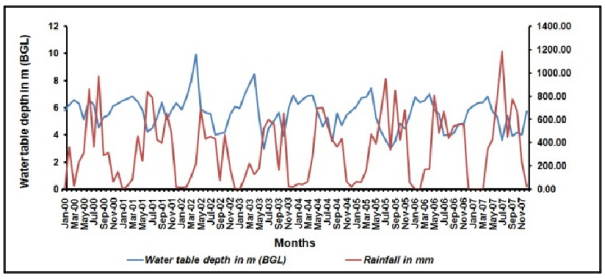

Fig. 18. Relationship between depth in water level of CGWBv2 and rainfall data of Valiyathodu sub-watershed

5 CONCLUSION

Analysis of annual variations in groundwater level data of Peruvanthanam sub-watershed during different seasons revealed that, in all the sample wells maximum depth of water level was attained during the month of May and minimum during the month of August. When the variation of depth in water level during different seasons of Peruvanthanam sub-watershed was compared, maximum variation of 6.05m is found during pre monsoon followed by post monsoon ie, 4.36m and monsoon season ie, 3.94m. The corresponding variation in Valiyathodu sub-watershed is 2.05m (pre monsoon), 1.98m (monsoon) and 2.57m (post monsoon). Unlike Peruvanthanam, in Valiyathodu sub-watershed, maximum fluctuation in water level was observed during post monsoon. This may be due to the differences in the porosity and permeability conditions of Peruvanthanam and Valiyathodu sub-watersheds. The hydrographs showing long term trends of both observation wells such as CGWBp1 and CGWBp2 of Peruvanthanam sub-watershed shows a sharp declining trend in accordance with the increasing nature of rainfall pattern of Peruvanthanam sub-watershed. The long term behavior of hydrographs of both observation wells CGWBv1 and CGWBv2 of Valiyathodu sub-watershed also shows a progressively declining trend. This can be correlated with progressively increasing nature of rainfall pattern of Valiyathodu sub-watershed. In Peruvanthanam sub-watershed, during the year 2007 there was an increase in rainfall than the average by 31.31%, with a corresponding water level decrease by 15.64% in CGWBp1 and during the year 2000, when the rainfall decreased by 33.84% the water level increased by 14.61%. Similarly the water level of CGWBp2 decreased by 16.03% and increased by 12.60% in the same years. In Valiyathodu sub-watershed, during 2005, when rainfall shows an increase by 25.16%, the corresponding water level decrease in CGWBv1 was 14.25%. During the year, 2002, the rainfall was decreased by 24.65% with corresponding increase in water level by 8.89%. Similarly, the water level of CGWBv2 shows an decrease of 8.51% and increase of 6.03% with variation in rainfall data. When the rainfall data and water level fluctuation data were compared, perfect correlation with rainfall was observed in both sub-watersheds.

ACKNOWLEDGMENT

The authors gratefully acknowledge the Director, School of Environmental Science, Mahatma Gandhi University, Kottayam, Kerala for the support extended and facilities provided during the course of study.

REFERENCES

[1] B.N. Goswami, V. Venugopal, D. Senguptha, M.S. Madhusoodanan, and P.K. Xavier, "Increasing trend of extreme rain events over India in a warming environment," *Science*, vol.314, no.3, pp.1442-1445, 2006.

[2] R.H. Kripalani, A. Kulkarni, S.S. Sabade and M.L. Khandekar, "Indian monsoon variability in global warming scenario," *Natural hazards*, vol.29, no.1, pp. 189-206, 2003.

[3] K.N. Krishnakumar, R. Prasad, G.S.L.H.V. and C.S. Gopakumar, "Rainfall trends in twentieth centuary over Kerala, India," *Atmospheric Environment*, vol.43, no. 11, pp.1940-1944, 2009.

[4] R.R. Sethi, A. Kumar, S.P. Sharma, and H. C. Varma, "Prediction of water table depth in a hard rock basin by using artificial neural network," *International Journal of Water Resources and Environmental Engineering,* vol.2, no. 4, pp. 95-102, 2010.

[5] A. Simon and K. Mohankumar, "Spatial variability and rainfall characteristics of Kerala," *Proceedings of the Indian Acadamy of Sciences (Earth and Planetary Sciences)*, vol.113. no. 2, pp. 211-221, 2004.

[6] V.B. Rekha, A.V. George and M. Rita, "morphometric analysis and micro-watershed prioritization of Peruvanthanam sub-watershed, The Manimala river basin, Kerala, South India," *Environmental Research, Engineering and Management*, vol. 3, no. 57, pp. 6 – 14, 2011.

[7] V.B. Rekha, A.P. Thomas, M. Suma and H. Vijith, **"**An integration of spatial information technology for groundwater potential and quality investigations in Koduvan ár sub-watershed of Meenachil river basin, Kerala, India**,"** *Journal of Indian Society of Remote Sensing,* vol. 39, no. 1, pp. 63–71, 2011.

[8] V.B. Rekha, A.V. George, K.R. Vineeth and U. Johnson, "Morphometric Analysis and Prioritization of Micro-watersheds in Valiyathodu Sub-Watershed of Manimala River, Kerala, India," *Proceedings of the Applied Geo informatics for Society and Environment (AGSC),* vol.109, pp. 77-81, 2010.

[9] B. Dinesh, J. Shilpa and M. Mohan Raju, "Prediction of water table elevation fluctuation through fuzzy logic and artificial neural networks," *International Journal of Advanced Science and Technology*, vol. 51, pp. 107-120, 2013.

[10] Faye, B.G. Cheikh, F. Abdoulaye, E. Andreas and W. Stefan, "Combined uses of water-table fluctuation (WTF),chloride mass balance (CMB) and environmental isotopes methods to investigate groundwater recharge in the Thiaroye sandy aquifer," *African Journal of Environmental Science and Technology*, vol.6, no.11, pp. 425-437. 2012.

[11] O. S. Enokela, N. A. Egarevba and M. O. Isikwue, "Trend in ground water fluctuation in Gidan Kwano Inland Valley of Niger State Nigeria," Journal of Engineering and Technology Research, vol.4, no. 7, pp. 129-135, 2012.