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Determination of Infiltration Rate for Site Selection of Artificial Water Recharge: An Experimental Study

Dr. Avinash S. Kadam

Assistant Professor, School of Earth Sciences, Swami Ramanand Teerth Marathwada University,
Nanded 431606, Maharashtra, India

Abstract: ***The micro leveled studies of geological and geomorphological parameters including climatological aspects have the basic requisites for application of any types of the artificial ground water recharge method. In case of direct surface techniques, it has necessary to check the soil and upper layer infiltration rate. Infiltration is a fundamental hydrological process, which determines the rate of runoff generation in an area. The present experimental work aims to determine the infiltration rate and discuss the various general physical parameters affecting on it. The special focus of the study has to identify the site suitability for application of direct surface recharge method. The single ring flooding infiltrometer has been used and quantitative determination of the infiltration rates has been made. For different seven sample locations, four field sites each have been taken to check the rate of infiltration on the basis of experimental work. For actual micro site selection for experiments, it has been considered all basic concerned aspects like slope of the surface land, thickness of the soil, percentage of sand, silt and clay in the soil etc. The average rate of infiltration varies between 2.65 and 6.73 cm/hrs. The range of maximum and minimum infiltration rate has been observed between 3.73 and 10.91 cm/hrs and 1.25 and 3.97 cm/hrs respectively. The rate of infiltration becomes more or less constant or showing rapid decline after completing an average period of 100 minutes. It has also observed that the rate of infiltration varies with time at an individual spot. It has concluded that four out of seven locations have strong potential, particularly for recharge variable method, which is one of the cost-effective and suitable artificial water recharge method. Rest of sites should go with other suitable artificial recharge method only.***

Keywords: Infiltration, Artificial Recharge Method, Direct Surface Techniques, Site Suitability, Recharge Variable

1. Introduction

Infiltration is one of the most important components of the hydrological cycle that determines the nature of hydrological losses and runoff generated in the basin. The rate of infiltration depends upon various geomorphological and morphometric parameters (Zhang et al., 2000; Saco et al., 2007) and even human activities. Type of surface rock, slope, structure of upper layer, moisture contents, thickness, texture and structure of the soil, vegetation cover, biological activities, human intervenes etc are the basic parameters affecting the rate (Dunne et al., 1991; Novak et al., 2000; Franzluebbers, 2002; Jagdale and Nimbalkar, 2012; Song and Bai, 2015). As stated by Mulani et al (2014), that climatological parameters like amount, duration and intensity of precipitation has also been the prime factors responsible for the unevenness and flexibility in infiltration rate. Thurow et al (1988) have given the importance to the grazing strategy, which has one of the primary factors influencing the hydrologic responses like infiltration. Jejurkar and Rajurkar (2012) has done extensive field experiments and analysed the data of infiltration with comparative approach. They found that the infiltration rate in summer has double than that of in winter. Cerda (1996) has also focused the seasonal variations in the rate of infiltration, considering slope as a prime parameter. Calvo-Cases et al (2003) opined that the slope, runoff generation, sediment movements and soil water behavior are the cause and effect of infiltration related issues. They have also been worried about the environmental disturbances in it.

Now days, scarcity of water at every level and soil erosion are sensitive issues, requires planning and management based on scientific approaches (Bouwer, 2000; Landge and Kadam, 2015; Shingote and Kadam, 2015), with micro leveled morphometric studies (Kadam, 2004; Avhad et al., 2013[a]). Droughts, famines, failure of crops, soil erosion, water and soil pollution, vegetation losses, issues relating to wildlife, human migration etc are the direct and indirect consequences of surface water loss, decline of ground water and unnecessary huge rainwater runoff (Ben-Dor et al., 2004; Kadam et al., 2012; Avhad et al., 2013[b]; Avhad et al., 2014; Dukare and Kadam, 2015;). For this, we should control or minimize the rainwater runoff and maximize the rate of infiltration for ground water recharge by applying artificial water recharge methods (Bouwer, 2002). The present investigation basically aims to identify the suitable sites for application of artificial water recharge methods. For this, it is necessary to check the rate of infiltration at micro level, especially for recharge variable method. The present paper is therefore mainly devoting to determine the rate of infiltration.

Horton (1945), a renowned scientist provided an understanding of the concept of infiltration with scientific base and the factors controlling the rate of infiltration. Actually, the concept of infiltration is easy for understanding but it is difficult to measure the actual rate at various locations and with different situations. For this, different approaches have been adopted to quantity the rate of infiltration. It includes theoretical methods and in-depth field experiments. Many scholars have also been tried to measure infiltration rate with taking variety of approaches like effect of soil moisture (Gray and Norum, 1968), contrasting biological soil crusts in patterned landscapes (Eldridge et al., 2000), infiltration rate related to sewer line (Ellis, 2001), variety of mountain slopes (Martin and Moody, 2001;

Harden and Scruggs, 2003), effect of urban soil compaction (Gregory et al., 2006), tank irrigation watershed (Srinivasan and Poongothai, 2013), effect of water repellent soil layer (Beyrami et al., 2014) etc. The estimation of infiltration in the field has always proved to be difficult. Therefore, most of the available estimates are based on theoretical calculations, considering parameters like slope, characteristics of soils, amount and duration of rainfall, runoff, etc. Sonaje (2013) has applied different scientific models for the same. In the present study an attempt has been made to estimate the rate of infiltration in the field. Different seven sites, located in Degloor tahsil of Nanded district (India) have been selected for the study.

2. Study Area

The study, basically aims to identify suitable sites for applications of artificial methods for water recharge. It is therefore different seven sites have been selected for the actual experimental work, which have been primarily suggested for application of recharge variable method of artificial water recharge. All of these broad sites are located in Degloor tahsil of Nanded district. The latitudinal and longitudinal extents have shown in the map (figure 1) with details of all seven sample locations and each of their four micro sites selected for experiments.

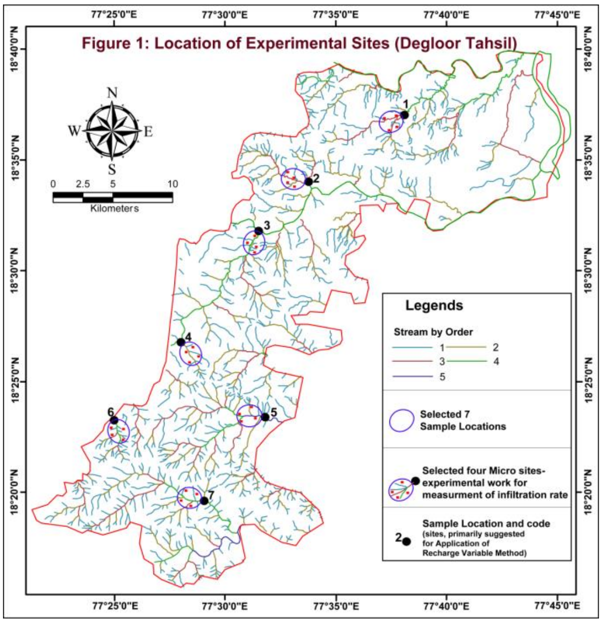


Figure 1: Location of Experimental Sites (Degloor Tahsil)

The tahsil receives 901 mm average annual rainfall and has average annual temperature ranges between 32.7°C and 34.1°C. It has dendritic drainage pattern, having 6 micro sub-basins. As per Strahler's (1957) stream ordering method, there are first to fifth ordered 797, 186, 36, 12 and 2 numbers of streams respectively.

3. Objectives

As already discussed above, the ultimate aims of the investigation have to identify suitable sites for application of various methods of artificial water recharge especially for recharge variable method. For this, it is necessary to measure rate of infiltration at micro level with scientific and experimental method. It is therefore the present attempt focused experimental field work for measuring infiltration rate.

4. Methodology and Techniques

To examine infiltration in the field, a single ring flooding infiltrometer has been used for the quantitative determination of the infiltration rate. As shown in the figure 2, the flooding infiltrometer is a small metal ring (diameter 100 mm, total height 130 mm). The ring has inserted into the soil to a depth of 3 cm.

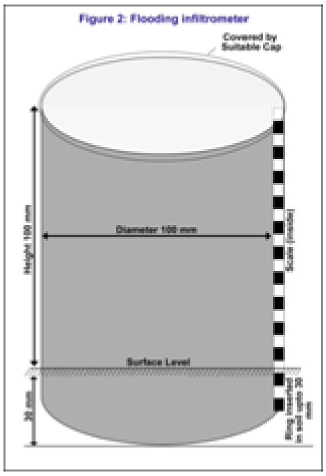


Figure 2: Flooding infiltrometer

The area enclosed in the ring has flooded with water and the time required for one centimeter of water to infiltrate have been measured. The ring has covered for reduction of evaporation losses during the test. Measurements have been continued until the rate became more or less constant or starts rapid lateral spread of water.

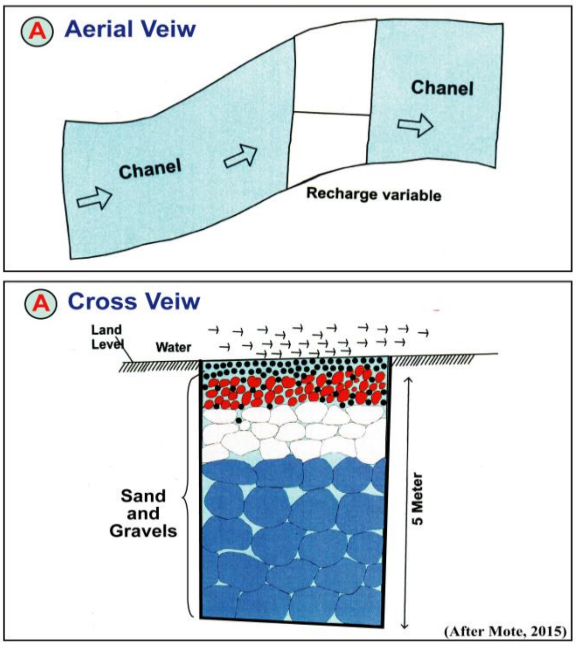
5. Results and Discussions

The present investigation has trying to identify suitable sites for applications of different methods of artificial water recharge. The current attempt has been selected seven sample locations, which are primarily suggested for application of recharge variable (*Char*) method. This method is cost-effective, suitable with geographical and hydrological point of view and also well accepted by the farmers / land owners from the rural base. It has shown in the figure 3 with its aerial and cross views.

It helps to increase the rate of infiltration rapidly at the exact point of the site, at the time of live rain water flow. It has therefore requires maximum natural infiltration rate round the site also. It supports to recharge the variable (*Char*) for long period of time, even the rain or live flow has not been there. Considering these facts in mind, the present attempt has tried to measure natural rate of infiltration for these seven sample locations.

For minimization of error, four micro sites have also been selected from each sample location for actual experiment, as shown in the figure 1. The results of all four micro sites have been averaged and considered as the average final results for the particular sample location. Such average results have been tabulated in the table 1. The table has been devoted to highlight all average results with their different levels, time, cumulative time, measured infiltration rate (maximum, minimum and average) and average soil thickness. The details of all sample locations have been discussed as below with the results of infiltration.

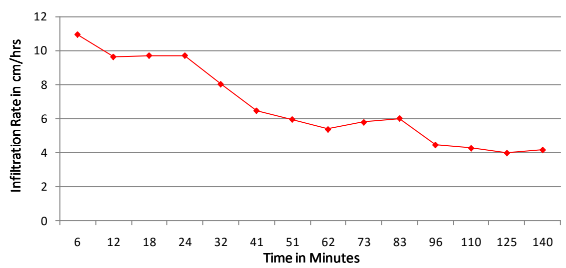
Figure 3: Recharge Variable
(An Artificial Water Recharge Method)



5.1 Sample Site 1

The first sample site is located in the northern part of the tahsil. The average soil thickness of four micro experimental sites is 11.40 cm. The spot is covered by thin grasses and have exposed bedrock. The maximum rate of infiltration has found 10.91 cm/hrs and that of minimum has 3.97 cm/hrs. The measured average rate is 6.73 cm/hrs. The infiltration rate has come at constant level only after 96 minutes and reached at stagnant after completion of 140 minutes (Figure 4). The maximum and even average rate has an unusually high due to thin, loose and coarse soil cover. The lateral spread component has observed as a dominant one.

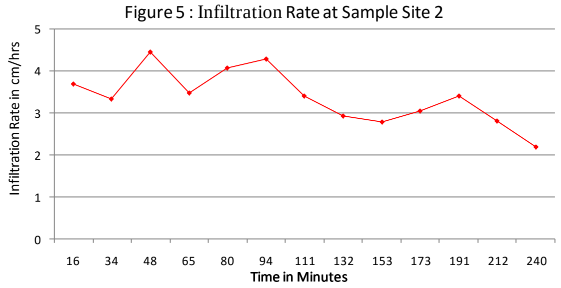
Figure 4 : Infiltration Rate at Sample Site 1



5.2 Sample Site 2

The second site is situated at the middle part of the sub-basin from northern part of the tahsil. The average soil thickness at this spot is 17.50 cm. The spot is covered by thin grasses and very thin semi dry deciduous scrubs. The measured average rate of infiltration is 3.37 cm/hrs. As shown in the figure 5, the infiltration rate has flexible at initial time period. Even though, there is least difference between maximum and minimum infiltration rate. It has come at rapid declining stage after completion of 191 minutes and ended with constant level at 240 minutes. Here also slight lateral spread component has observed.

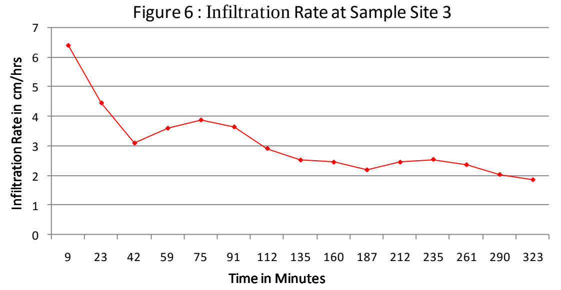
Figure 5 : Infiltration Rate at Sample Site 2



5.3 Sample Site 3

The third sample site is located at the middle part of the tahsil. It is situated at the lower part of the small hillock. Out of four micro experimental sites, two sites have been placed at the foothill zone of the hillock. The average soil thickness is 25.70 cm and has covered by very thin grasses. The site has disturbed by free grassing and other human activities. The maximum rate of infiltration has found 6.38 cm/hrs and that of minimum has 1.86 cm/hrs only. The measured average rate is 3.09 cm/hrs. The infiltration rate has come at constant level with slight decline after 135 minutes and reached at stagnant after completion of 323 minutes (Figure 6). Here, the lateral spread component has not been observed.

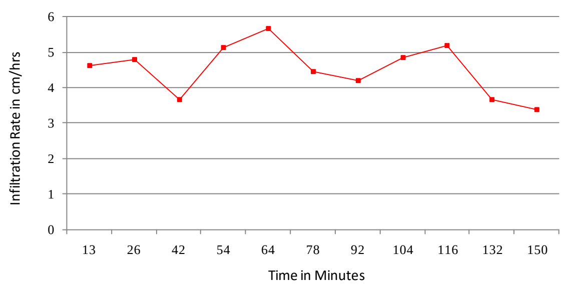
Figure 6 : Infiltration Rate at Sample Site 3



5.4 Sample Site 4

The forth sample site is located towards south from the site 3 in the tahsil. The average soil thickness is 14.80 cm and has not observed even with thin grasses cover around the site. It has also eroded by variety of human activities, which should be conserved by applying artificial soil-water and vegetation conservation methods. The maximum and minimum rates of infiltration have found 5.66 cm/hrs and 3.38 cm/hrs respectively. The measured average rate is 4.51 cm/hrs. The infiltration rate has observed very flexible at all levels (Figure 7).

Figure 7 : Infiltration Rate at Sample Site 4

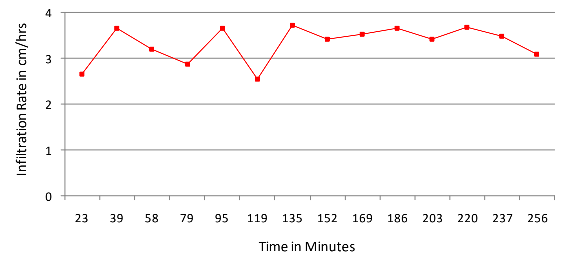


It has come at constant with fast declining position within 116 minutes only. Here, the lateral spread component has been observed as the main dominant factor. It is only because of absence of vegetation cover, shallow soil and exposed bed rock.

5.5 Sample Site 5

The fifth sampling site is situated in the southern part of the tahsil. It is the lower zone of sub-basin, having average 42.50 cm soil thickness. It is well covered by grasses and with moderately dense scrubs also. The maximum and minimum rates of infiltration have found 3.73 cm/hrs and 2.54 cm/hrs respectively. The measured average rate is 3.33 cm/hrs. The infiltration rate has observed very slight flexible at some of the first levels and became constant at half part of the period (Figure 8).

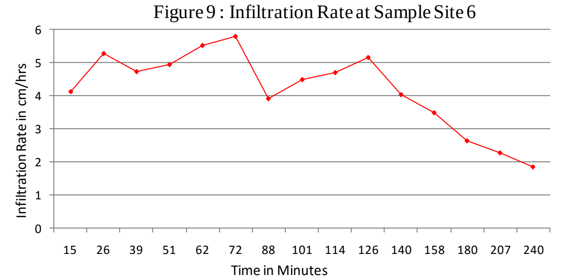
Figure 8 : Infiltration Rate at Sample Site 5



5.6 Sample Site 6

The sixth sampling site is also located in the southern part of the tahsil. Here the maximum and minimum infiltration rate has high difference than that of the previous site. It measured 5.77 cm/hrs and just 1.82 cm/hrs maximum and minimum infiltration rate respectively. It has observed high flexible at initial levels but sudden and fast decline have been started after completion of 126 minutes (Figure 9). It has reached at constant level after 240 minutes and has not been observed lateral spread component.

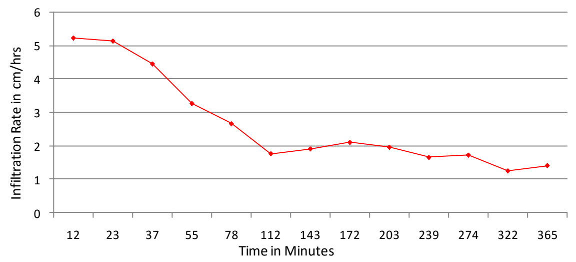
Figure 9 : Infiltration Rate at Sample Site 6



5.7 Sample Site 7

The last sampling site is situated at southern most corner of the tahsil. The average soil thickness at the site is 68.50 cm, which is higher than all other selected sampling sites. It has observed that the site has benefited by deposited deep soil cover, moderately thick grasses and other vegetation. As like the previous site, the difference between average maximum and minimum rate is high. The time taken for constant rate of infiltration has been recorded maximum with 364 minutes. The rate shows declining trend, right from the first level. After completing 112 minutes of time period, it stood as a constant (Figure 10).

Figure 10 : Infiltration Rate at Sample Site 7



6. Concluding Remarks

The present attempt has an experimental work, measured actual infiltration rate at different sample sites. It is necessary to check infiltration rate for identification of suitable sites for recharge variable, a method of artificial water recharge. There are other requisites and geographical conditions for the same, but it should be more feasible and suitable with sufficient natural rate of infiltration. Site 3, 5, 6 and 7 have observed more than sufficient potential and site 2 has also moderate capacity to infiltrate water for long period of time for maximum ground water recharge. Remaining two sites i.e. site 1 and 4 have not enough potential in case of surrounding infiltration rate. If these sites have also selected considering by strong suitability of other parameters, then it is necessary to maximize and change the width, depth and crossing angle of the recharge variable.

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Author Profile

Dr. Avinash S. Kadam received the Post Graduate and Doctoral degrees in Geography from Savitribai Phule Pune University (formerly the University of Pune), Pune (India) in 1997 and 2002 respectively. He has also completed his study for Post Graduate Diploma in Environmental Management from the same University (2003). In addition, he got LLB degree from SRTM University, Nanded (India) and studying legal aspects of Human and Natural Resource Management. He has worked as a Secretary General, Maharashtra Bhugolshastra Parishad, Pune for 10 years from 2000 to 2010. At present he is working at SRTM University, Nanded. Under his supervision, 3 Ph.D. and 7 M.Phil scholars have honoured by the degree.

Table 1: Infiltration rate measured on the basis of experimental observations

Level in cm	Average at Site 1			Average at Site 2			Average at Site 3			Average at Site 4			Average at Site 5			Average at Site 6			Average at Site 7		
	TM	CTM	F	TM	CTM	F	TM	CTM	F	TM	CTM	F	TM	CTM	F	TM	CTM	F	TM	CTM	F
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	5.50	5.50	10.91	16.25	16.25	3.69	9.40	9.40	6.38	13.00	13.00	4.62	22.60	22.60	2.65	14.60	14.60	4.11	11.50	11.50	5.22
2	6.25	11.75	9.60	18.00	34.25	3.33	13.50	22.90	4.44	12.50	25.50	4.80	16.40	39.00	3.66	11.40	26.00	5.26	11.70	23.20	5.13
3	6.20	17.95	9.68	13.50	47.75	4.44	19.40	42.30	3.09	16.40	41.90	3.66	18.70	57.70	3.21	12.70	38.70	4.72	13.50	36.70	4.44
4	6.20	24.15	9.68	17.25	65.00	3.48	16.70	59.00	3.59	11.70	53.60	5.13	20.90	78.60	2.87	12.20	50.90	4.92	18.40	55.10	3.26
5	7.50	31.65	8.00	14.75	79.75	4.07	15.50	74.50	3.87	10.60	64.20	5.66	16.40	95.00	3.66	10.90	61.80	5.50	22.60	77.70	2.65
1	9.30	40.95	6.45	14.00	93.75	4.29	16.50	91.00	3.64	13.50	77.70	4.44	23.60	118.60	2.54	10.40	72.20	5.77	34.10	111.80	1.76
2	10.10	51.05	5.94	17.60	111.35	3.41	20.60	111.60	2.91	14.25	91.95	4.21	16.10	134.70	3.73	15.40	87.60	3.90	31.50	143.30	1.90
3	11.20	62.25	5.36	20.50	131.85	2.93	23.80	135.40	2.52	12.40	104.35	4.84	17.50	152.20	3.43	13.40	101.00	4.48	28.60	171.90	2.10
4	10.40	72.65	5.77	21.50	153.35	2.79	24.50	159.90	2.45	11.60	115.95	5.17	17.00	169.20	3.53	12.80	113.80	4.69	30.70	202.60	1.95
5	10.00	82.65	6.00	19.75	173.10	3.04	27.40	187.30	2.19	16.40	132.35	3.66	16.40	185.60	3.66	11.70	125.50	5.13	36.40	239.00	1.65
1	13.50	96.15	4.44	17.60	190.70	3.41	24.50	211.80	2.45	17.75	150.10	3.38	17.60	203.20	3.41	14.90	140.40	4.03	34.90	273.90	1.72
2	14.10	110.25	4.26	21.40	212.10	2.80	23.60	235.40	2.54				16.30	219.50	3.68	17.20	157.60	3.49	48.10	322.00	1.25
3	15.10	125.35	3.97	27.50	239.60	2.18	25.40	260.80	2.36				17.20	236.70	3.49	22.80	180.40	2.63	42.70	364.70	1.41
4	14.45	139.80	4.15				29.50	290.30	2.03				19.40	256.10	3.09	26.40	206.80	2.27			
5							32.30	322.60	1.86							32.90	239.70	1.82			
Total	Maxi F		10.91	Maxi F		4.44	Maxi F		6.38	Maxi F		5.66	Maxi F		3.73	Maxi F		5.77	Maxi F		5.22
	Mini F		3.97	Mini F		2.18	Mini F		1.86	Mini F		3.38	Mini F		2.54	Mini F		1.82	Mini F		1.25
	Avg F		6.73	Avg F		3.37	Avg F		3.09	Avg F		4.51	Avg F		3.33	Avg F		4.18	Avg F		2.65
	AST		11.40	AST		17.50	AST		25.70	AST		14.80	AST		42.50	AST		38.90	AST		68.50

(Note: TM = Time in Minutes, CTM = Cumulative time in minutes, F = Infiltration rate in cm/hrs, AST = Average Soil thickness in cm.)