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Estimation of runoff volume from MCAET Ambedkar Nagar campus for ground water recharge

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Abstract
Water is our most precious resource, Due to its vital role in life, water is one of the most precious resources in the planet. The present study was conducted at MCAET, Ambedkar Nagar keeping in view the importance of rain water harvesting and ground water recharge. The catchment area of college building, workshop, barren land, cultivation land, road area and orchard area were measured and found as 10315 m^2, 3800 m^2, 2512 m^2, 1500 m^2, 3272 m^2 and 2882 m^2 respectively. The total area of campus is found to be 24281 m^2. The average seasonal rainfall of pre-monsoon, monsoon, post-monsoon and winter season is estimated as 49.63 mm, 833.51 mm, 26.38 mm and 32.21 mm respectively. The total runoff volume generated during pre-monsoon, monsoon, post monsoon and winter season is found as 714.13 m^3, 11824.94 m^3, 379.56 m^3 and 463.45 m^3 respectively. From the estimation of runoff volume generated from MCAET campus, it is found that a huge amount (13382.08 m^3) of runoff water is available for ground water recharge.

Keywords: Water harvesting, ground water recharge, runoff and monsoon seasons

Introduction
Water is one of the most valuable resources in the world due to its important role in life, recently the demand of water have dramatically increased due to growth of population and also to the change in the rainfall pattern because of climate change (Gray, 2017) [3]. Rainfall is basic input and an important factor that decides the feasibility of rain water harvesting system and severity of aridity in an accurate region. Water storing techniques such as rainwater harvesting, rainwater reserving system etc. all depends on rainfall. Hence, to use these techniques, it is very important to have all information on rainfall can be acclimated to predict future trends of rainfall occurrence in rain-fed agriculture areas. This will help in planning various other measures for rain water conservation (Schuetze, 2013) [4]. The rainfall runoff relationship is important for implying techniques like rain water harvesting.

The 21st century, numerous countries, including India, are growing water crisis. About 80 countries comprising 40% of world`s population suffer from serious water shortages (Nigam *et al.* 1997) [1]. In India, this crisis is already visible, contributing to enormous social, political and environmental costs that are affecting the economy and quality of life. Nearly 44 million people in India are affected by water quality problems either due to pollution, the prevalence of fluoride, arsenic and iron deposits in ground water, or due to ingress of sea-water into ground-water aquifers (Nigam *et al.* 1997) [1]. The precipitation, ground water and some surface water resource (viz. Lakes, Pondsand streams) are considered as exploitable water assets due to the spatial and temporal distribution of precipitation, which is uneven that they early mean are of little importance for all practical purposes. Hence, it is required to harvest the rain water soil can be utilized as the extra supply of water which will be important to fill the present gap between supply and demand (Helmreich and Horn, 2009) [2]. Ground water recharge is the result of an intricate relationship between energy and moisture occurring in the critical zone between the atmosphere and subsurface (Fan, 2015) [11].

The recharge process governs downward fluid flux across the water table, and relates the climate,vegetation, and subsurface characteristics for a given area (Smerdon, 2017) [5]. Thus, an understanding of the recharge process, including rates, timing and location, is important for hydrogeological characterization and ground water resource assessment (Chenini *et al*. 2010) [6].

Keeping in view the declining pattern of water resource because of environmental change and other factors, it becomes essential to conserve, develop and effectively utilize the available resources (Zhao, 2013) [7]. A great deal of water resource can be produced by the harvesting runoff water from college building, workshops, barren, road, cultivated land and orchard field of Mahamaya College of Agricultural Engineering and Technology (MCAET), Ambedkar Nagar.

Materials and Methods

The present study is carried out for ground water recharge by runoff generated from different land use of Mahamaya College of Agricultural Engineering & Technology (MCAET) Ambedkarnagar (U.P.) Campus.

Description of Study Area

The study area (college hostel and residential buildings, workshop, barren land, cultivated land, road area, and orchard area) is situated at MCAET Ambedkar nagar (UP). The campus is situated at 24.5 N latitude and 82 °E longitude. The average annual rainfall of Ambedkar nagar is 941.87 mm and the average annual temperature is 23 °C. The study area receives about 88% of rainfall during monsoon season only. The catchment area is large enough to yield surface runoff. The area of MCAET Campus was found to be sufficient for the purpose of ground water recharge and rainfall generated from different land uses of campus.

Estimation of runoff

The runoff coefficient for the roof-top and ground catchment the total runoff generate from the roof top of different buildings and catchments is estimated by multiplying average rainfall with corresponding area and their runoff coefficient of that particular catchment area were taken from the literature. The total amount of water received in the form of rainfall over an area is called rain water endowment of that area. Out of this, the amount that could be collected is called water harvesting potential (runoff). The water harvesting potential is calculated by three factors, viz., catchment area, runoff coefficient and rainfall, formula is given as:

$$(RO = RF \times A \times RC) \quad (1)$$

Where,

RO- Runoff (m^3)

RC- Runoff coefficient

RF- Rainfall (mm)

A-Catchment area (m^2)

Measurement of catchment area

The plan of the catchment area of college building, workshop, orchard, barren, cultivated, road of MCAET Ambedkar Nagar was prepared by tape measurements. The tape measurements were done with the A view of MCAET Campus showing different dimensions is presented as Fig.1 Plan for highest achievable accuracy under prevailing conditions.

Runoff coefficient

Runoff coefficient is represent integrated effect of catchment losses and hence depends upon nature of soil, surface slope, and rainfall intensity. The range of runoff coefficient for different catchment varies from 0.05 to 0.95.

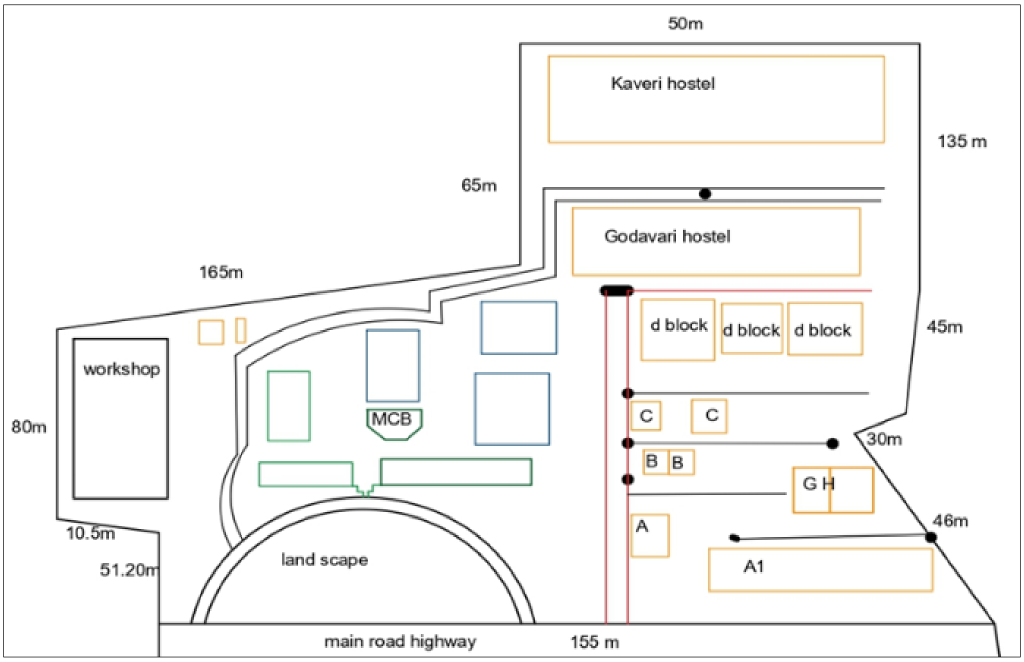

Fig 1: A view of MCAET campus showing different dimensions

Ground Water Recharge

Recharge pits are small pits of any shape (rectangular, square or circular) constructed with brick or stone masonry wall with weep holes at regular intervals. Recharge pits are constructed for recharging the shallow aquifer. Bottom of pit should be filled with filter media. The capacity of the pit will be designed on the basis of catchment area, rainfall intensity and recharge rate of soil. Usually the dimensions of the pit may be of 1 to 2 m width and 2 to 3 m depth depending on the depth of pervious strata (Akter, 2022) [8]. The excavated pit is lined with a brick/stone wall with openings (weep-holes) at regular intervals. The top area of the pit can be covered with a perforated cover. After excavation, the pits are refilled with pebbles and boulders. Water to be recharged, should be silt free. Cleaning of the pit should be done periodically. If the pit is of trapezoidal shape, the side slopes should be steep enough to avoid silt deposition.

Results and discussion

Results of the estimation of runoff volume from MCAET, Ambedkar nagar for ground water recharge are described in this chapter. The average monthly rainfall data for the year from 2002-2020 were analyzed and the results found are discussed here.

Rainfall Analysis

The average monthly rainfall of pre-monsoon (49.63 mm), monsoon (833.51 mm), post-monsoon (26.38mm) and winter season is (32.21 mm), as shown in Table 1. It is observed that the maximum rainfall during pre-monsoon (129.9 mm), monsoon (1243.5 mm), post monsoon (154 mm) and winter (140.9 mm) season occurred in the year 2015, 2003, 2013 and 2015 respectively. It is observed that the minimum rainfall during pre-monsoon, monsoon, post monsoon and winter season occurred in the year 2019, 2015, 2006 (2007, 2008, 2011, 2012, 2017, 2018, 2019) and 2006 (2008, 2019) respectively.

Table 1: Details of average seasonal rainfall data (mm) for different season

Year/Season	Pre-Monsoon	Monsoon	Post Monsoon	Winter
2002	51.2	659.95	29.6	71
2003	19.6	1243.5	4.9	61.95
2004	70.05	724.15	9.65	29.5
2005	8.8	1188.75	15.3	40.85
2006	57.85	405.95	0	0
2007	118.2	753.65	0	28
2008	9.2	1128.05	0	0
2009	79.75	696.45	138.3	9.65
2010	75.6	916	10.3	33.42
2011	10.4	1030.8	0	10.5
2012	3.2	924.4	0	30.64
2013	9.2	1146.2	154	27
2014	61.3	541.2	105	72.8
2015	129.9	369.56	20.1	140.9
2016	73.2	713.2	5	8
2017	41.3	736	0	6
2018	41.3	735.7	0	6
2019	1.4	905.6	0	0
2020	81.69	1017.74	9.13	35.85
Avg. Rainfall	49.63	833.51	26.38	32.21

Estimation of Runoff

Runoff volume from the different catchment area of MCAET campus is estimated using formula 3.1.

Catchment area of different land use

In the college campus there are several type of land use was observed. The entire land use patterns are thoroughly studied and their corresponding areas were measured. Different land use and their corresponding area are given in the Table 2. Total area of campus is found to be 24281 m^2.

Estimation of runoff volume

Total runoff generated form different catchment areas of MCAET campus during different seasons was estimated and presented under following sections.

Table 2: Corresponding area of different land use

S. No.	Land use	Area (m^2)
1	Road area	3272
2	Barren area	2512
3	Orchard area	2882
4	Workshop area (slanted roof)	3800
5	Building area (flat roof)	10315
6	Cultivated area	1500
Total area		24281

Runoff generated during pre-monsoon season

Total runoff generated during pre-monsoon season is estimated as 714.13 m^3 as shown in Table 3. The maximum runoff (383.95 m^3) generated from building area and minimum runoff (11.16 m^3) generated from cultivated land.

Table 3: Details of rainfall and runoff for pre-monsoon season (March – May)

Land use	Area (m^2)	Runoff Coefficient	Rainfall (mm)	Runoff (m^3)
Road	3272	0.85	49.63	138.03
Barren	2512	0.2	49.63	24.93
Orchard	2882	0.3	49.63	42.91
Workshop	3800	0.6	49.63	113.15
Building	10315	0.75	49.63	383.95
Cultivated	1500	0.15	49.63	11.16
Total				714.13

Runoff generated during monsoon season: Total runoff generated during monsoon season is estimated as 11824.94 m^3 as shown in Table 4. The maximum runoff (6448.24 m^3) generated from building area and minimum runoff (18.75 m^3) generated from cultivated land.

Table 4: Details of rainfall and runoff for monsoon season (June – Sept

Land use	Area (m^2)	Runoff Coefficient	Rainfall(mm)	Runoff(m^3)
Road	3272	0.85	833.51	2318.15
Barren	2512	0.2	833.51	418.75
Orchard	2882	0.3	833.51	720.65
Workshop	3800	0.6	833.51	1900.40
Building	10315	0.75	833.51	6448.24
Cultivated	1500	0.15	833.51	18.75
Total				11824.94

Runoff generated during post-monsoon season

Total runoff generated during post-monsoon season is estimated as 379.56 m^3as shown in Table 5. The maximum runoff (204.08 m^3) generated from building area and minimum runoff (5.93 m^3) generated from cultivated land.

Table 5: Details of rainfall and runoff for post-monsoon season (Oct. – Nov.)

Land use	Area (m^2)	Runoff Coefficient	Rainfall(mm)	Runoff(m^3)
Road	3272	0.85	26.38	73.36
Barren	2512	0.2	26.38	13.25
Orchard	2882	0.3	26.38	22.80
Workshop	3800	0.6	26.38	60.14
Building	10315	0.75	26.38	204.08
Cultivated	1500	0.15	26.38	5.93
Total				379.56

Runoff generated during winter season

Total runoff generated during winter season is estimated as 463.45 m^3 as shown in Table 6. The maximum runoff (249.18 m^3) generated from building area and minimum runoff (7.24 m^3) generated from cultivated land. Runoff generated during pre-monsoon season (March – May), monsoon season (June – Sept), post-monsoon season (Oct. – Nov) and winter season (Dec. – Feb) is estimated as 714.13 m^3, 11824.94 m^3, 379.56 m^3 and 463.45 m^3, respectively. Total annual runoff generated from MCAET campus is found as 13382.08 m^3 (Table 7).

Table 6: Details of Rainfall and runoff for winter season (Dec – Feb)

Land use	Area (m^2)	Runoff Coefficient	Rainfall(mm)	Runoff(m^3)
Road	3272	0.85	32.21	89.58
Barren	2512	0.2	32.21	16.18
Orchard	2882	0.3	32.21	27.84
Workshop	3800	0.6	32.21	73.43
Building	10315	0.75	32.21	249.18
Cultivated	1500	0.15	32.21	7.24
Total				463.45

Table 7: Total runoff generated from MCAET campus during different season

S. No.	Season	Runoff(m^3)
1	Pre-monsoon season (March – May)	714.13
2	Monsoon season (June – Sept.)	11824.94
3	Post-monsoon season (Oct. – Nov.)	379.56
4	Winter season (Dec. – Feb.)	463.45
Total		13382.08

Ground Water Recharge

From the estimation of runoff volume generated from MCAET campus, it is found that a huge amount (13382.08 m^3) of runoff water is available for ground water recharge. Recharge pit of suitable size (shown in Fig. 2) is planned to construct for recharge of ground water from the runoff water generated from different catchment areas of MCAET campus. Desilting chamber length 1 m and width is 1.5 m.

Three number of recharge pit is planned to construct in the MCAET campus for recharge of ground water. This pit is filled with layers in graded form with the boulders, gravels, and sand/Morang. Boulders are placed on bed of the pit, gravels in middle and thick sand is filled on top so that the silt coming in with runoff is deposited above thick sand or morang which can be removed later.

Fig 4.2 A view of planned ground water recharge pit

A mesh should be put at the drainage point on the roof so that leaves or other solid materials can be prevented to fell in the pit (Mara, 1984) [9]. A desilting/collection chamber can also be constructed on the surface to stop silt which can further prevent the flow of small molecules towards the pit. “Over Flow” system should be integrated for each recharge pit to counter the situations of heavy rains. Upper layer of sand/Morang should be cleaned time to time to maintain the recharge rate. Construction of recharge pit is easier and cheaper. It takes very less cost and suitable recharging can be managed with better planning. This is safer in comparison with other technics. So it should be widely adopted.

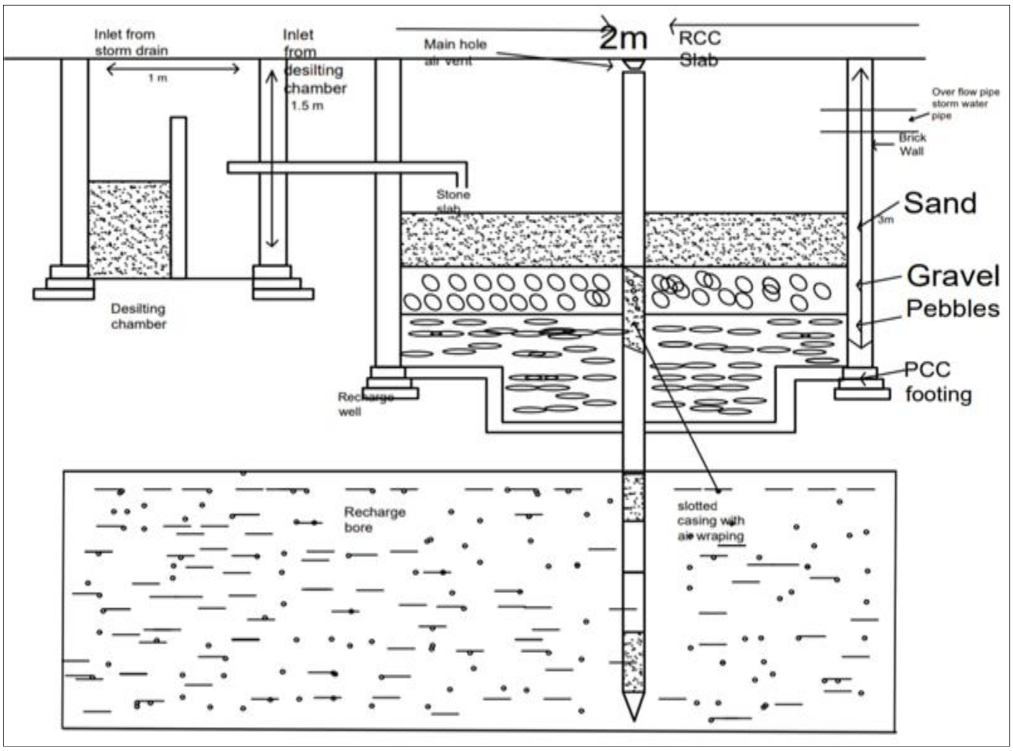

Fig 2: A view of planned ground water recharge pit

Summary and Conclusion

As current demand from surface and ground water supplies continues to decline, the world confronts rising demand for high-quality water in the future. There is always a need to balance the available water supply with ever-increasing needs. Utilising rainwater is one of the best techniques for restoring natural hydrological cycles and promoting sustainable urban development currently available. Given the low cost and ease of system installation, rainwater collecting is one of the most cost-effective and useful methods for supplying supplemental water sources. The two main types of rainfall catchment systems utilized for residential water delivery is land surface catchment systems and roof-top catchment systems.

In this project, ground water recharging was accomplished with harvested water from surface catchments and collected water from roof-top catchments. The present study was conducted at MCAET, Ambedkar Nagar keeping in view the importance of rain water harvesting and ground water recharge. The rainwater was harvested from college building, workshop, barren land, cultivation land, road area, orchard area.

The following conclusions were drawn from the investigation of this project: The catchment area of college building, workshop, barren land, cultivation land, road area and orchard area were measured and found as 10315 m^2, 3800 m^2, 2512 m^2, 1500 m^2, 3272 m^2, 2882 m^2, respectively. The total area of campus is found to be 24281 m^2.

- The average seasonal rainfall of pre-monsoon, monsoon, post-monsoon and winter season is estimated as 49.63 mm, 833.51 mm, 26.38 mm and 32.21 mm respectively.
- The total runoff volume generated during pre-monsoon, monsoon, post monsoon and winter season is found as 714.13 m^3, 11824.94 m^3, 379.56 m^3 and 463.45 m^3 respectively.
- From the estimation of runoff volume generated from MCAET campus, it is found that a huge amount (13382.08 m^3) of runoff water is available for ground water recharge.

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