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Design of Rooftop Rainwater Harvesting: A Case Study on Township in Gwalior

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Abstract: The demand of water is increasing day by day and the availability of water is reducing gradually. There are many techniques use to reduce the waste of rain water one of the most economical and effective method is Rainwater harvesting method. This method is suitable on all type of residential as well as commercial region like small household, big campus and township etc. Rainwater harvesting has two types one is surface rain water harvesting other is rooftop rain water harvesting. The present paper presents the case study of Rooftop rain water harvesting of a township (D.B. city township which is located at Sirol road Morar in Gwalior city MP India) in which, the area of township is around 101,031.88 sq. m. An analysis based on data of rainfall intensities, catchment area and local site condition is carried out. Here we design a storage tank for collecting rain water and supply for demand of drinking and cooking water, with rooftop rainwater harvesting technique for this township. In this study area Google Earth Pro and ArcGIS software is used for the calculation of catchment area. Rooftop rain water harvesting is effective technique to meet the water demand as well as reduce the wastage of purest form of water.
Keywords: RRWH, Arc GIS, Google earth pro, Rain water.

I. INTRODUCTION

The population growth rate of India is very high so the requirement of water is also increases day by day. Everyone needs good quality of water and sufficient water to fulfill their basic requirement like drinking, cooking, washing, bathing, and gardening etc. In agriculture area, the water plays a vital role because the water is used for farming to grow crops. In industrial area, the water is very essential. So keeping all these points in mind, many techniques are developed to utilize rain water. Rain water harvesting technique is one of the most effective technique. In this method rain water is collected into storage tank or diverted into ground. This method is very cost effective method. There are two type of rain water harvesting techniques, first is surface rain water harvesting and second is rooftop rainwater harvesting. In this study we use Rooftop rain water harvesting technique to utilize rain water.

II. ROOFTOP RAINWATER HARVESTING

Rooftop rain water harvesting is very simple technique which can be applied from small houses to a big town. After the precipitation the rain fall is collected on roof, after that it drains with drain pipe which is connected from roof to the filtration media where rainwater is get purified from debris and other impurities. After filtration media water is either collected in storage tank or directly diverted to ground to increase ground water level and then it can be use in future needs.

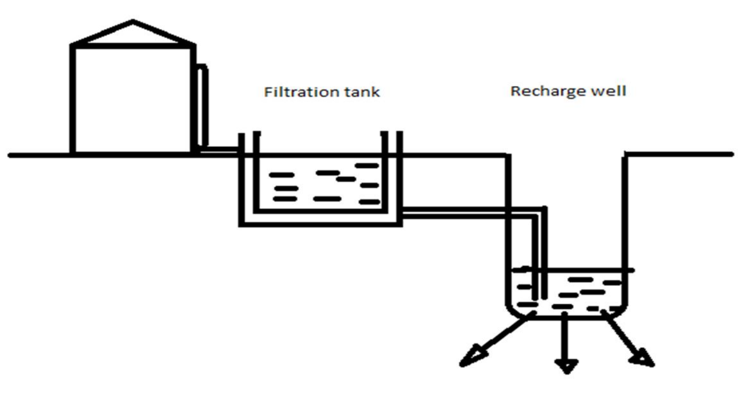

Figure 1 - Rooftop Rainwater Harvesting

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A. Rooftop Rainwater Harvesting Consists Of Four Elements

1) Catchment area
2) Drain pipe
3) Filter media
4) Storage tank

B. Classification of Rooftop Rainwater harvesting

1) Direct store in storage tank
2) Bore well recharge
3) Tube well recharge
4) Open well recharge
5) Recharging pit
6) Percolation tank recharge

C. Benefits of Using Rooftop Rainwater Harvesting Technique

1) To satisfied water demand for future basic needs like drinking, cooking, washing, bathing and gardening etc.
2) To increase the level of ground water table.
3) To lower the cost of water bill.
4) This technique is very less expensive.
5) To reduce the loss of rain water.
6) Very useful in summer season.
7) To reduce flooding.
8) To reduce soil erosion.

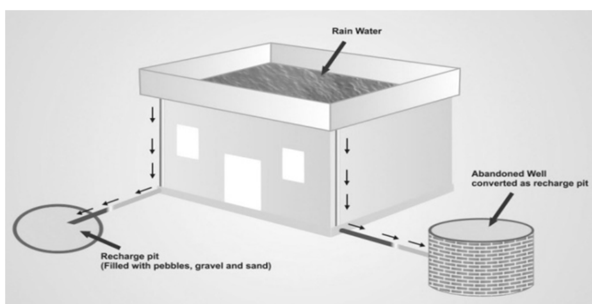

Figure 2 - Recharging pit and storage tank

III. STUDY AREA

Study area in the present research work is a township D.B. city in Gwalior (M.P.). The perimeter of a township is about 1489.00 meters and the area is about 101,031.88sq.m. Presently this is a one of the biggest township of Gwalior city. The township consists residential towers, duplexes and many more. In this research we consider only 5 residential towers of township for rooftop rain water harvesting. Roof top rain water harvesting potential is determine for each tower. The entire towers are ten storeys and there are eight flat on each storey in four towers and four flat on each storey in one of the tower. Roof type of all the tower is Reinforced Cement Concrete.

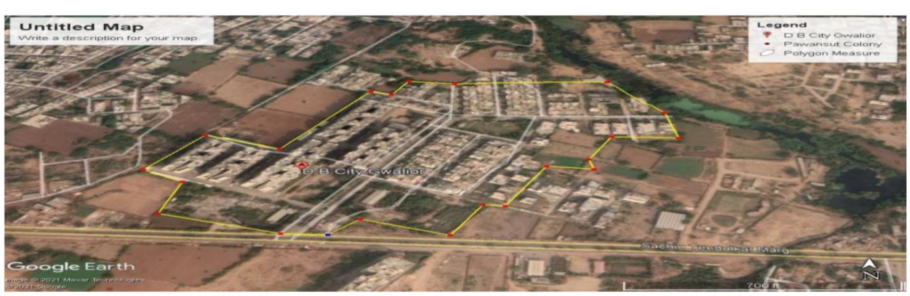

Figure. 3 Google image Township of Gwalior city

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IV. OBJECTIVE OF THE WORK

The main aim of the work is to determine the rain water harvesting potential and design storage tank for storing the rain water to satisfy the demand of drinking and cooking water in the township.

V. TOOL USED

Google earth pro and ARCGIS software are used to determine the catchment area of the township.

VI. METHODOLOGY

Following methodology is adopted

1) Digitization of rooftop of township by using Google Earth Pro. - In this the digitization of rooftop is done by Google Earth Pro software and type of roof is RCC.
2) Computation of catchment area of rooftop by using ArcGIS software. - Here the area calculation is done by geometric tool from ArcGIS software.
3) Rainfall data- Last ten year of Annual average rainfall data has been taken by the source of government of India website that is Indiawris.gov.in.
4) Runoff coefficient- In present paper, runoff coefficient factor was taken from the manual of artificial recharge of ground water, Government of India Ministry of Water Resource Central Ground Water Board, the tables II and III.
5) Determine the water potential of catchment area.
6) Estimate the water demand.
7) Design storage tank according to dry period (245 days) water demand.

A. Digitization of Rooftop

Figure 4 - Digitization of rooftop in Google Earth Pro software

B. Calculation of Catchment Area

Figure 5 - Catchment area in ArcGIS software

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Table 1 Roof area of all residential towers in D.B. City Township

S.NO.	RESIDENTIAL TOWERS	CATCHMENT AREA (in square meter)
1	Tower 1	1624.24
2	Tower 2	1712.99
3	Tower 3	2636.22
4	Tower 4	2464.31
5	Tower 5	1200.98

C. Data Collection of Rainfall

Average annual rainfall data for Gwalior for last ten years was taken from the site of government of India website that is given here. (Indiawris.gov.in). Average annual (actual) rainfall data from the year 2011 to 2020 are shown in table 2. From the rainfall data given in table 2 average annual rainfalls for Gwalior city is calculated as 751.9 mm, a value of 752 mm is adopted for calculation of RRWH potential.

Table 2 Past ten year average annual rainfall data of study area region

Years	Normal rainfall (mm)	Actual Rainfall (mm)
2011	879	823.98
2012	879	726.25
2013	879	1133.5
2014	879	718.28
2015	879	702.27
2016	879	640.78
2017	879	607.95
2018	879	850.29
2019	879	756.46
2020	879	559.37

The value of runoff coefficient to be used in calculation of RRWH potential is taken from the manual of artificial recharge of ground water, Government of India Ministry of Water Resources Central Ground Water Board. Runoff coefficient value for different surfaces is shown in table 3.

Table 3 Runoff coefficient values

Different surfaces	Runoff coefficient (k)
Roof Conventional	0.7-0.8
Roof Inclined	0.85-0.95
Concrete /Kota paving	0.6-0.7
Gravel	0.5-0.7
Brick Paving	0.7

The value for the runoff coefficient is here we adopted as 0.8 for conventional type of roofs.

D. Calculation Of Rooftop Rainwater Harvesting Potential

Rooftop rainwater harvesting Potential in the study area calculated by Gould and Nissen Formula (1999) or (Rational formula):

$$S = R \times A \times Cr$$

Where, S = Potential of roof rainwater harvesting (In cu. m.)
R = Average annual rain fall in m.
A = Roof area in Sq. m.
Cr = Coefficient of Runoff

Table 4 Calculation of roof rainwater harvesting potential

S. No	Residential building towers	Area (m^2)	Runoff coefficient	Annual rainfall in (m)	S = R*A*Cr Runoff (cu. m.)	S = R*A*Cr Runoff (in liters)
1	Tower 1	1624.24	0.8	0.752	977.142	977142
2	Tower 2	1712.99	0.8	0.752	1030.534	1030534
3	Tower 3	2636.22	0.8	0.752	1585.949	1585949
4	Tower 4	2464.31	0.8	0.752	1482.528	1482528
5	Tower 5	1200.98	0.8	0.752	722.509	722509
	Total	9638.74			5798.662	5798662

The above table shows the rain water harvesting potential for each residential tower and in which the tower number 3 has the maximum rain water harvesting potential. The total rain water potential has 5798.662 cu. m. or 5798662 liters of water.

E. Calculation of Water Demand of the D.B. City Township

As the data obtained by the D.B. city the approximate population in the city in the all residential towers is 1920. If we consider the threshold water requirement of 7 liters/day/capita for drinking (3 liters per person) and for cooking practices (4 liters per person) is sufficient for residential purpose. The drinking and cooking requirement is obtained from the per capita consumption of water for domestic use as per the norms of Central Public Health and Environmental Engineering Organization mentioned in table given below:-

Table 5 Per capita consumption of water for domestic use

Activities	Liters/Person
Drinking purpose	3
Cooking purpose	4
Bathing purpose	20
Flushing purpose	40
Washing Cloths purpose	25
Washing Utensils purpose	20
Gardening purpose	23
Total demand of water needed liters/person/day	135 liters/person/day

Formula used

1) Water demand = Per-Capita demand × population × number of days

a) Annual water demand for Drinking (3 liters per person)

$$3 \times 1920 \times 365 = 2102400 \text{ liters (or) } 2102.40 \text{cu.m}$$

b) Annual water demand for cooking purpose (4 liters per person)

$$4 \times 1920 \times 365 = 2803200 \text{ liters (or) } 2803.20 \text{cu.m}$$

c) Total LPCPD Annual water demand (7 liters per person)

$$7 \times 1920 \times 365 = 4905600 \text{ liters (or) } 4905.60 \text{cu.m}$$

d) Total overall domestic water demand (135 liter per person)

$$135 \text{ x } 1920 \text{ x } 365 = 94608000 \text{ liters (or) } 94608 \text{ cu.m.}$$

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Table 6 water demand of the study area

Approximate Population in the residential tower	Total Annual RRWH Potential (in Liters)	Total LPCPD Annual Demand of Water (@ 7 Liters)
1920	5798662	4905600

As we can clearly seen that our RRWH potential is 5798662 liters and the water demand of drinking and cooking is 4905600 liters. So it is completely satisfy the demand of drinking and cooking water demand for the residential towers

The remaining water of RRWH potential can be used for other domestic purposes.

Remaining RRWH potential water = Total RRWH potential – Total drinking & cooking water demand

= 5798662 liters – 4905600 liters

= 893062 liters or 893.062cu.m.

% of remaining water of RRWH potential after satisfying the demand of drinking & cooking

$= (893062/5798662) \times 100$

$= 15.40\%$

% of RRWH potential water satisfying the overall domestic purpose

$= (5798662/94608000) \times 100$

$= 6.12\%$

F. *Volume of Storage Tank*

The volume of storage tank is based on the dry period water demand in D.B. city township. As the climatic condition in this region the monsoon period (rainy season) is from June to September therefore the dry period if for 8 months or (245 days). However for supplying this water demand, we required a storage tank. So total water demand (drinking and cooking) and the water demand for domestic purpose, both calculations are required for design of storage tank. As a factor of safety we the volume of tank is increased by 20 % (As per CPWD manual Govt. of India).

Formula used

1) Water demand = Per-Capita demand × population × number of days

a) Water demand for drinking and cooking for dry period (245 days) (7 liter per person)

7 x 1920 x 245 = 3292800 liters or (3292.8 cu.m.)

b) Water demand of domestic purpose for dry period (245 days) (135 liter per person)

135 x 1920 x 245 = 63504000 or (63504 cu.m.)

Now we determine the actual volume of tank that is required to store the rain water potential water as per calculations we know that the 6.12% of overall domestic water demand is satisfy and now we need to obtain the required volume of tank along with factor of safety as 20% therefore the final actual volume of tank for individual residential tower required as per calculations given below.

Calculation as per Rain water harvesting and conservation manual Central Public Works Department Government of India (2002)

2) Volume of storage tank = (per capita water demand x population x number of dry period days x factor of safety)

For residential tower 1 –

Volume = 1.2 x 0.0612 x 10584

= 777.28 cu.m.

For residential tower 2 –

Volume = 1.2 x 0.0612 x 10584

= 777.28 cu.m.

For residential tower 3 –

Volume = 1.2 x 0.0612 x 18522

= 1360.255 cu.m.

For residential tower 4 –

Volume = 1.2 x 0.0612 x 18522

= 1360.255 cu.m.

For residential tower 5 –

Volume = 1.2 x 0.0612 x 5292

= 388.644 cu.m.

G. Calculations for Dimensions of Storage Tank

As the tower 1 and tower 2 are having same volume or discharge so we will calculate for both the towers.

Assume, depth of tank = 4m

Therefore area of tank = 777.28/4

=194.32sq.m.

For rectangular storage tank, we provide generally L=2B

Therefore, Area = L x B

194.32 = 2B x B

B = 9.85 m ~ (10 m)

L = 19.71 m ~ (20 m)

Dimensions of tank for tower 1 and tower 2 are **= (20 m x 10 m x 4 m)**

Similarly, for tower 3, 4 and 5we calculate the dimension of storage tanks.

Since all the tank design are shown below in the tabular format in table 7 and are clearly shown the volume and dimensions of the tank. We provide one storage tank for each residential tower. So we have total 5 storage tanks for five residential towers. And we will provide at the barren area as shown in the Figure 5. Hence, in this study rooftop rainwater harvesting potential in the D.B city township Gwalior completely (100%) satisfy the drinking and cooking water demand throughout the year.

Table 7 Dimensions of storage tank

S. No.	Storage tank for respective Residential towers	Actual volume of water that need to be store in the tank in (cu.m.)	Dimensions of tank (LXBXH)
1	Storage Tank 1	777.28	**20 m x 10 m x 4 m**
2	Storage Tank 2	777.28	**20 m x 10 m x 4 m**
3	Storage Tank 3	1360.255	**26 m x 13 m x 4 m**
4	Storage Tank 3	1360.255	**26 m x 13 m x 4 m**
5	Storage Tank 3	388.644	**14 m x 7 m x 4 m**

VII. CONCLUSION

Hence it was finally concluded, that implementation of ROOFTOP RAINWATER HARVESTING PROJECT to the D.B. city Gwalior will be the best method to fight with present and future scenario of water scarcity in all aspects. By adopting this approach we can make little noble cause for rain water conservation which will be beneficial to the township and also decreases the water load on the ground water. It also reduces the water bill of the township. As we seen in our study that the roof top rain water harvesting in study area is very effective measure to resolve the issue of water scarcity specially during the hot season. The methodology adopted to calculate volume of storage tank is economical. As we can observe in our study if we design storage tank as per rooftop rain water harvesting potential we need large volume of storage tank and which is uneconomical for the township. It also completely satisfied the drinking and cooking water demand. Therefore it is very beneficial and effective method to save the fresh water because it directly effects the environment and whole mankind.

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[21] Table no. 3.1- Average annual rainfall (in mm) data is collected from the source of government of India website that is (Indiawris.gov.in)

[22] Table no. 3.2 and 3.3- Government of India Ministry of Water Resource Central Ground Water Board, the tables II and III represents the runoff coefficient values adopted in our design.

[23] Table no. 4.4- Central Public Health and Environmental Engineering Organization, a table of per capita consumption of domestic water

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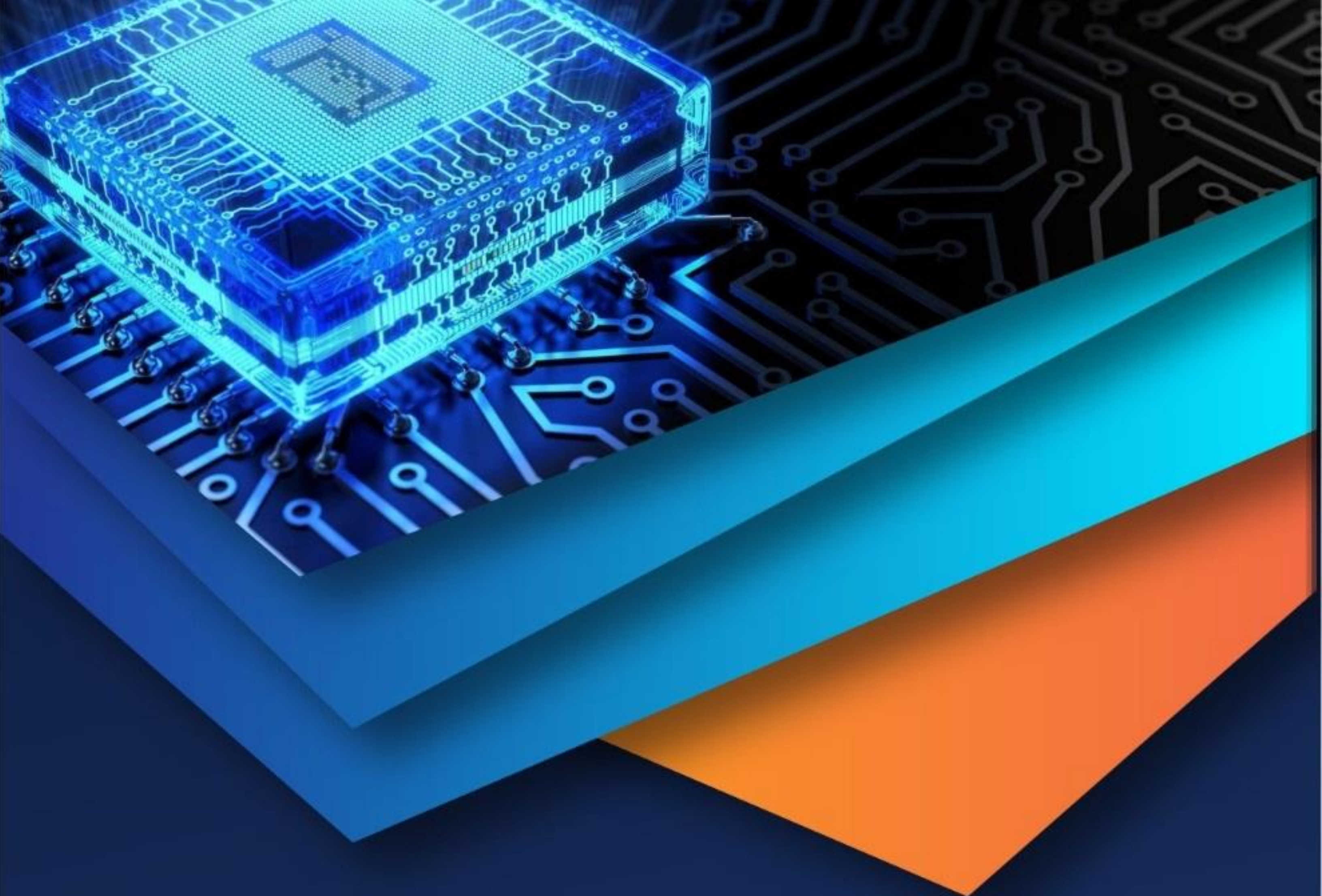

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