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Rainwater harvesting plan of an Educational Institution (Greater Noida)

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Abstract

Rainwater Harvesting Masterplan is a water conservation method adopted in modern times by our society . To develop such a masterplan we need to identify and demarcate the study area . In this case one educational institution has been selected to develop its masterplan .

Past historical rainfall data obtained from authentic source like Indian Metereological Department , Pune , India annual report is analyzed for the area under study .In this analysis , highest , lowest , mean and variation of rainfall is studied . A comparative analysis of the rainfall data is made and average frequency of rainy days is calculated . Next , average frequency of heavy rainfall days is calculated . This is compared with maximum Rainy day and maximum heavy rainfall day. Rainyday is compared with frequency of dry days for the peak month of August . After obtaining the frequency of rainy day , the rainfall return period is calculated . Once peak rainfall per day for the peak rainfall month of August is calculated , evaporation loss and evapotranspiration loss is estimated in this research paper .

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After estimationof peak rainfall per day alongwith losses , runoff volume is calculated for the Institution under study. To calculate the runoff volume , the roof top area , ground paved area , ground unpaved area is calculated .Also the runoff coefficient for roof top , ground paved , ground unpaved area is found from authentic data source like National Building Code 2016 ; and estimated for particular runoff surface . Once runoff volume is estimated for the institution under study , hydrogeological characteristics of the aquifer location area for the institution is studied and relevant authentic data sourced from district brochure of Gautam Buddha Nagar is compiled . After compilation of aquifer data , aquifer discharge is calculated for the institution under study .

Finally , in order to design the rainwater harvesting structure , average frequency of rainy day and rainfall return period data is compiled . Type of rainwater harvesting structure in this case recharge well , raingarden and recharge trench is finalized for this institution as suitable structure ; depending upon the type of catchment available within the institution . Design calculations are made for each type of structure and number of rainwater harvesting structure of different types are finalized . Here , factor of safety as a suitable percentage taken as 50% is taken to prevent overflow from the structure and allow zero runoff of rainwater outside the institution under study with complete infilteration into the groundwater reservoir aquifer . This forms the masterplan of rainwater harvesting system designed for an educational institution .

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Index Terms–Masterplan , Institutional Area ,Rainwater Harvesting Structure Design , Re-charge Well , Rain Garden, Re-charge Trench.

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I. INTRODUCTION

Masterplan of Rainwater Harvesting System gives a guideline and roadmap for execution and implementation of the compulsory construction of Rainwater Harvesting System within the premises of the Institution.

It gives an idea based on the covered area of the Institution , how many Rainwater Harvesting System needs to be constructed for 100% transfer of rainwater excluding losses and zero runoff outside the premises ; to the aquifer and groundwater recharge.

It helps the local administration and authority of the area to frame building bye-laws , rules and regulations for strict implementation of the Rainwater Harvesting Masterplan of the locality.

Masterplan of Rainwater Harvesting System is a complete mechanism for transfer of total rainfall of the locality into the ground and re-charge the aquifer .

Masterplan of Rainwater Harvesting System prevent accumulation and ponding of stagnant rainwater over the ground surface , thereby preventing a breeding place for disease carrying vectors (insects) and mosquitoes , indirectly preventing the spread of dengue , malaria and other viral diseases among the residents of the locality.

Rainwater Harvesting Masterplan promotes Water and Energy Conservation including adequate water for irrigation and drinking purpose , reducing the need for imported water to a great extent .

II. SCOPE OF RESEARCH

1. To identify the best practices of water conservation system adopted during ancient times in India and Worldwide.
2. To identify and demarcate the study area for Rainwater Harvesting Masterplan.
3. To analyze the rainwater harvesting potential in different parts of the study area.
4. To analyze the ground water Quantitative potential of the study area.
5. To delineate the aquifer system of the study area .
6. To find the suitable methods of rain water Harvesting for the area under study.
7. To design the rainwater Harvesting model for the study area.
8. To suggest location for the Rainwater Harvesting System within the study Area thereby forming the Masterplan .

III. METHODOLOGY OF RESEARCH WORK

Scope 1 :- To identify the best practices of water conservationsystem adopted during

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ancient times in India and Worldwide.

- A detailed study and Literature Survey was undertaken to discover the best practices of water conservation during ancient times in India and Worldwide.
- In sequence of the detailed study and Literature Survey undertaken above , two research papers were published and one International Conference was attended.

Scope 2 :- To identify and demarcate the study area for RainwaterHarvesting Masterplan.

- Study Area was demarcated on the Google Map of the Institution and Micro-Planning was undertaken.
- As a part of Micro-Planning , whole area of the Institution were divided into paved and unpaved area , paved area was futher divided into Roof Top area and Ground paved area .
- Rooftop Area , Ground Paved Area , Unpaved Area was estimated for the institution and Runoff Coefficient was allocated to each of them.

Scope 3 :- To analyze the rainwater harvesting potential indifferent parts of the study area.

- A detailed study of IMD Monthly Rainfall data of past 30 years ,1989 to 2018 was undertaken for Greater Noida and Uttar Pradesh as a whole.
- A comparative analysis was done for the study area and Maximim , Minimum Rainfall alongwith Mean and Coefficient of Variation was worked out.
- Maximum & Minimum Rainfall Data was compared with that of India as a whole and worldwide .
- Average Frequency of Rainy Days and Heavy Rainfall Days were worked out for the study area and compared to that of Uttar Pradesh.
- Based on the 70 year annual rainfall data 1901-1970 , annual average was worked out to be 700.6 mm as observed in nearest rain gauge station at Sikandrabad in Greater Noida where the Institution vicinity was located .
- The maximum rainfall occurs during monsoon period i.e June to September having normal value of 600 mm which is 85.7% of Annual rainfall.
- Hence , above data is combined with average frequency of Heavy Rainfall Days in Greater Noida for monsoon period i.e June to September found to be 1.0 to 1.6 Days .
- Abstractions and Losses from Precipitation Rainfall is being worked out .For Rooftop and Paved area , only Evaporation Losses are considered but for Vegetation and Bare Land area Evaporation , Evapotranspiration and Infilteration Losses have been considered

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- After working out the Losses , total Runoff Volume (R=P-L) would be worked out per square meter . This volume would be multiplied separate for permeable(unpaved) and impermeable(paved & rooftop) area of the Institutions which would give the rainwater harvesting potential for that Institution .

Scope 4 :-To analyze the ground water Quantitative potential of the study area.

- To observe nature of water level and its behavior, ground water monitoring well established in the district are being monitored four times in a year as per CGWB reports.
- Pre-monsoon and post-monsoon water level data are collected during May and November months respectively. Depth to water level maps for pre-monsoon and post monsoon periods have revealed that the entire area can be divided into different zones on the basis of depth to water ranges.
- Fairly a large area has shallow to moderate depth to water conditions. Water level in aquifer ranges from 3.35 to 14.40 m bgl during pre-monsoon period whereas it ranges from 2.00m to 13.95 mbgl during post monsoon period .
- Water levels greater than 9m bgl occur in most of the non-command areas of the district. Deeperwater levels occur in east of Jhajhar (Dankaur Block) and Dadri area.
- Deeper water levels (> 9 mbgl) also occur along Yamuna river which perhaps indicate that the water levels are deepening toward river thus forming the river effluent in nature.
- Average water table for the area is being worked out from the pre-monsoon and post-monsoon level data for the year 2006 upto 2011 sourced from reports of CGWB and District Brochure of Gautam Buddha Nagar where Greater Noida is Geographically located .

Scope 5 :-To delineate the aquifer system of the study area . "Aquifer system of the Institution and their properties"

- A three-tier aquifer system has been identified in Noida up to a depth of 450 mbgl.
- The first aquifer system extends down from a depth of 125 mbgl to 200 mbgl in the northern part of the district. The thickness of the aquifer decreases in the western part of the district and depth of bedrock is shallow. The aquifer material is medium to coarse-grained sand, the exception being the trans-Hindon area
- The second aquifer system exists in the depth ranges of 170–350 mbgl. The aquifer is medium to fine-grained sand with occasional coarse-grained sand. The tube

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wells yield 1,000–2,000 litres per minute (LPM), with a considerably high drawdown.

- The third aquifer system occurs below 350 m and continues down to an explored depth of 450 mbgl. Since no tube well has been constructed in this aquifer group, aquifer parameters are not known. As per the electrical log, the quality of water formation seems to be good.

Scope 6 :- To find the suitable methods of rain water Harvesting for the area under study.

- Suitable Infilteration concepts have been outlined to develop a RWH infilteration model to recharge the groundwater.
- The infilteration concept for low intensity rainfall recharge well has been adopted for developing the RWH infilteration structure .
- If the volume of estimated Runoff isvery small , one re-charge well is sufficient to re-chargethegroundwater .
- If the volume of estimated Runoff is large , alongwith re-charge well , rain garden and re-charge trench structure would bedesigned .

Scope 7 :- To design the rainwater Harvesting model for the study area

- Depth of RWH re-charge well would be determinedwithin one-third or two-third the average depth of water table for Greater Noida.
- If the volume of run-off is large , re-charge well, rain garden and re-charge trench per RWH model would be designed somemay be terminated at one third and/or another at two-third the average depth of water table.
- 3-4 feet diameter of the re-charge well is being considered upto 15 feet deep , however this may increase if runoff volume is large .

Scope 8:-To suggest area wise location and number ofRainwater Harvesting System cum model within the studyArea of the Institution under consideration thereby forming the Masterplan .

IV. TO CALCULATE THE PAVED AND UNPAVED AREA OF THE INSTITUTION UNDER STUDY

In this research work, we calculated the total paved and unpaved area of one of the institution in Greater Noida using Google Earth Software. We selected IIMT Group of Colleges located in Knowledge park III. The process we followed in this work are as follows.

Initially, we choose one college building block at a time and selected the area with Google Earth cursor, then the total roof top area (RT –the outside of the roofs of the

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buildings) is identified and coded as RT1, RT2…

Secondly, the ground paved area, which is to be calculated, (GP i.e the ground which is covered by the impermeable lining) is coded as GP1, GP2…

Thirdly, the ground unpaved (permeable area) which is to be calculated (GU, the ground which is not covered by impermeable lining) is coded as GU1, GU2…

And then, finally the total paved area and total unpaved area was calculated.

Total Paved Area (TPA)= RT + GP

Total Covered Area (TCA)= GU + TPA

IIMTGroupofCollegesisoneofthelargested ucationalgroupinNorthernIndia,establishe d in 1994. The group has 6 institutions located in Greater Noida and2 campusesin Meerut, UttarPradesh.

InstitutionCode	**NameofInstitution**	**RooftopCode**	**RooftopArea**	**GroundPavedCode**	**GroundPavedArea**	**GroundUnpavedCode**	**GroundUnpavedArea**	**TotalPavedArea(TP)**	**TotalCoveredArea(TCA)**
								TPA =RT+GP	TCA=GU+ TPA
I–1	**IIMT**	**RT1**	4050	**GP1**	1841	**GU1**	352	5891	6243
		RT2	2566	**GP2**	1352	**GU2**	443	3918	4361
		RT3	1459	**GP3**	1661	**GU3**	432	3120	3552
		RT4	1305	**GP4**	1697	**GU4**	248	3002	3250
		RT5	3541	**GP5**	652	**GU5**	209	4193	4402
		RT6	1818	**GP6**	390	**GU6**	569	2208	2777
		RT7	1086	**GP7**	0	**GU7**	871	1086	1957
		RT8	1525	**GP8**	0	**GU8**	1539	1525	3064
		RT9	344	**GP9**	0	**GU9**	10125	344	10469
		RT10	0	**GP10**	0	**GU10**	914	0	914

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		RT11	0	GP11	0	GU11	711	0	711
		RT12	0	GP12	0	GU12	2881	0	2881
		TOTAL	17,694		7,593		19,294	25287	44581

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Google Earth Images of IIMT Group of Colleges.

V.TOESTIMATETHERAINWATER HARVESTING POTENTIAL OF THEINSTITUTIONUNDER STUDY.

(i)**Rainfall Data Analysis for Greater Noida**

As per "Climate Research & Services" , IMD , Ministry of Earth Sciences ,Government of India , Pune , Maharashtra (India) data ; maximum frequency of dry days for Greater Noida for month of `August` is 21 days . Average frequency of rainy day in Greater Noida is 8-9 for the month of August. Now taking 9 rainy day with peak rainfall for the month of August as 205.8 mm (Data Source - District Brochure of Gautam Buddha Nagar) .

Calculation of peak rainfall per day for August = 205.8mm/9 = **22.87mm** per day for Greater Noida,U.P.

(ii).**Estimation ofRainfall Runoff Losses for Greater Noida.**

(a) Evapotranspiration Loss

As per data sourced from District Brochure of Gautam Buddha Nagar , annual Potential Evapotranspiration for Greater Noida is 1545.3 mm.

Therefore , Potential Evapotranspiration Loss per day = 1545.3mm/365 = **4.234 mm** per day .

(b) Evaporation Loss

As per data sourced from District Brochure of Gautam Buddha Nagar , U.P and using Meyers formula for lake evaporation(E_{loss}) .

$E_{loss} = C (e_w – e_a) (1 + v/k)$, where k (a constant) = 16 for wind speed at 9 m above ground surface .

C (a constant) = 0.36 for deep water and 0.5 for shallow water .

e_w = maximum vapour pressure (mmHg) at water surface corresponding to its temperature.

e_a = actual vapour pressure (mmHg) at monthly mean temperature and relative humidity in atmosphere.

v = velocity of wind in km/hr.

$U_h = U_1 h^{1/7}$ where U_1 = wind velocity at 1 m above ground surface .

e_a / e_w = Relative Humidity in percentage.

Available Data is sourced from District Brochure of Gautam Buddha Nagar(2008-

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2009). The district where Greater Noida belongs .

Available Data :

Mean monthly maximum relative humidity in morning of August = 84%

Normal annual mean wind speed (presumed at 1 m above ground)= 6.7 km/hr.

Average High Temperature for August = 34^o C .

From standard table : e_w at 30^o C = 31.80 mmHg ; e_w at 37^o C = 47.07 mmHg

Calculations :

Interpolating above values at 34^o C we get e_w = 40.53 mmHg.

Calculating wind velocity at 9 m above ground . 1/7 = 0.1428

$U_9 = U_1\ 9^{1/7}$ = 6.7 (1.37) = 9.179 km / hr.

Relative Humidity = 84 % Therefore e_a = 0.84 (40.53) = 34.05 mmHg

Therefore $e_w - e_a$ = 40.53 – 34.05 = 6.48 ; v/16 = 9.179/16 = 0.574

Putting all the values in Meyer`s Formula :-

$E_{loss} = C (e_w - e_a) (1 + v/k)$, taking C = 0.5 for shallow water conditions during rainfall .

E_{loss} = 0.5 (6.48)(1+0.574) = 0.5 (6.48)(1.574) = 5.1 mm/day.

But gross rainwater available for harvesting is 22.87mm/day .

Total Losses = Evapotranspiration Loss + Evaporation Loss = 4.234mm + 5.1mm = **9.334 mm**

(iii)**Net Rainwater Harvesting Potential For Unpaved Area under Study :-**

This area consist of grasses , plants and vegetation ; hence alongwith evaporation loss , evapotranspiration loss is also considered .

Net Rainwater Harvesting Potential = Gross Rainwater-Evapotranspiration Loss-Evaporation Loss for unpaved area

= 22.87mm – 9.334mm = 13.536mm/dayfor unpaved area.

(iv)**Net Rainwater Harvesting Potential For Rooftop/Ground Paved Area under Study :-**

Since rooftop and ground paved areas do not have plants and vegetation , hence no evapotranspiration occurs here , only evaporation loss is considered .

Net Rainwater Harvesting Potential = Gross Rainwater – Evaporation Loss for rooftop/ground paved area.

= 22.87mm – 5.1mm = 17.77mm/dayfor rooftop/ground paved area

VI. TO ESTIMATE THE NET RUNOFF VOLUME FOR INSTITUTION UNDER STUDY.

Using “Rainfall Method” also known as “Rational Method” to calculate net runoff volume .This is one of the oldest and best

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known method widely used in design of sewers .

Formula Used :-

Q = C . I . A

Where

Q -- Discharge of runoff in Cu m /sec.

C -- percentage co-efficient of runoff

I -- Intensity of rainfall in m/day

A – Catchment Area in Sq m

(i) As per NBC 2016 , runoff co-efficient (C)for following surfaces are calculated :-

a) Concrete Roof Area ---------- 0.9

b) Paved Podium and Asphalted Roads --------- 0.8

c) Unpaved Ground ---------- 0.3

d) Lawns , Gardens & Park ---------- 0.15

Considering average of the (c) and (d) above = (0.3+0.15)/2 = 0.45/2 = 0.225 for unpaved area consisting of Lawns , Gardens and Barren Land .

(ii) Calculation of net runoff volume for Ground Unpaved(GU) area.

Calculation Formula :-

Q = C.I.A ; for Ground Unpaved Area , C = 0.225 , I = 13.536 mm/day , A = 19,294 m^2

Converting I in m/day I = 0.01354 m/day

Therefore Q = 0.225 x 0.01354x 19,294 = **58.77 Cum/day** is net runoff volume for GU Area.

(iii) Calculation of net runoff volume for Ground Paved(GP) area.

Calculation Formula :-

Q = C.I.A ; for Ground Paved Area , C = 0.8 , I = 17.77 mm/day , A = 7,593 m^2

Converting I in m/day I = 0.01777 m/day

Therefore Q = 0.8 x 0.01777 x 7,593 = **107.94 Cum/day** is net runoff volume for GP Area

(iv) Calculation of net runoff volume for Roof Top(RT) area.

Calculation Formula :-

Q = C.I.A ; for Roof Top Area , C = 0.9 , I = 17.77 mm/day , A = 17,694 m^2

Converting I in m/day I = 0.01777 m/day

Therefore Q = 0.9 x 0.01777 x 17,694 = **282.98 Cum/day** is net runoff volume for RT Area

(v) Calculation of Total runoff volume for the Institution under Study.

Total Runoff volume for the Institution = (ii) + (iii) + (iv) = 58.77+107.94+282.98= <u>449.69 Cum/day</u>

VII. HYDROGEOLOGICAL CHARACTERISTICS OF AQUIFER .

(Data sourced from District Brochure (2008-2009) of Gautam Buddha Nagar , U.P.)

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(a) Coefficient of Transmissivity at Tughalpur , Haldona is 1759 m^2/day

(b) Storage Coefficient = 4.84 x 10^{-4}

(c) Aquifer Discharge = 8 to 16 litres/second for deep wells from 80 – 350 mbgl.

(d) Aquifer Discharge = 82 to 100 litres/minute for shallow wells upto 50 m .Here average aquifer discharge = (82+100)/2 = 91 litres/minute .

(e) Minimum Ground Water Table = 2 m to 13.95 m approx. 14 m . Here average Ground Water table = (2+14)/2 = 8 m .

VIII. CALCULATIONOF AQUIFER DISCHARGEFOR THE INSTITUTIONUNDER STUDY .

Since , Rainwater Harvesting structure is to be constructed within 50 m depth of the aquifer under study . Here , the average aquifer discharge is 91 litres/minute.

(Data sourceis District Brochure 2008-2009 of Gautam Buddha Nagar , U.P)

Calculation :-

Aquifer Discharge in litres/hr. = 91 x 60 litres/hr. = 5460 litres/hr.

Now , 1 m^3 = 1000 litres . Therefore 5460 litres/hr. = 5.46 m^3/hr.

Now 1 day = 24 Hours . Therefore 5.46 m^3/hr = 5.46 x 24 m^3/day = **131.04 Cum/day** is aquifer discharge for the Institution under study .

IX. DESIGN OF RAINWATER HARVESTING STRUCTURE FOR THE INSTITUTION UNDER STUDY .

Average frequency of rainy day in Greater Noida is 8-9 for the month of August.

(Data Source - per "Climate Research & Services" , IMD , Ministry of Earth Sciences ,Government of India , Pune , Maharashtra (India))

Now month of Augustis having 31 days . Average Rainfall Return Period = 31/9 = 3.444 days approx. 4 days .

Now , rainfall re-occurs on every 4th day in the month of August . Therefore , for aquifer discharge 3 days is available for 100% inflowintothe ground with zero surface runoff outside the Institution under study .

Design Calculation :-

Now , Total Volume of Rainfall available for harvesting = 449.69 Cum/day.

(Clause VI(v) above)

But , aquifer discharge is 131.04 Cum/day . (Clause VIII above)

Therefore , total number of Rainwater Harvesting Structures required for 100% inflow into the ground with zero surface runoff outside the Institution under study = 449.69/131.04 =3.432 No. = **4 sets of structures** are required to be built-up.

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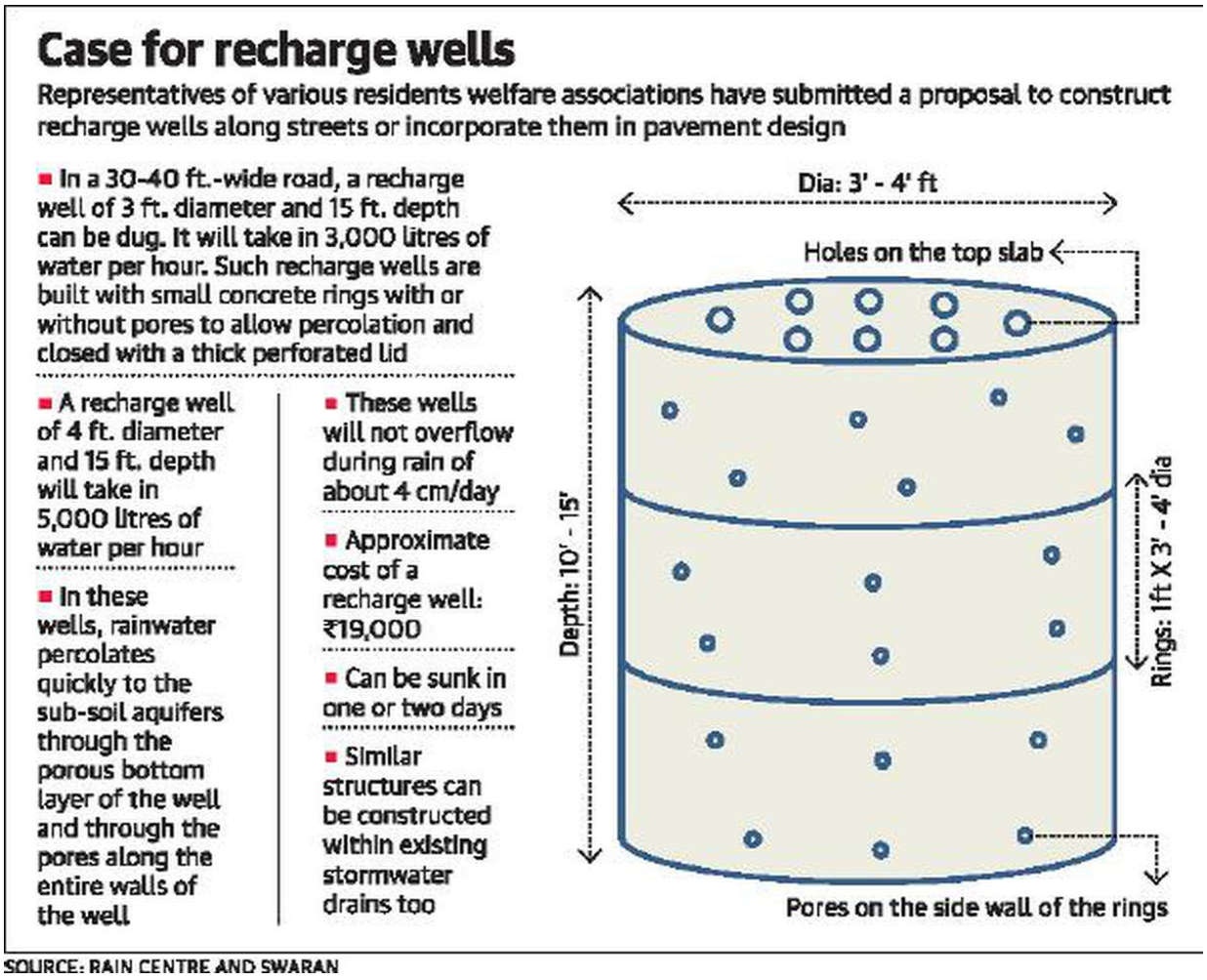
Types of Groundwater Recharge Structure :-

a) Recharge Wells



Alongside pavements , roads but 30 feet away from building,soakpits,basement.

Recharge Capacity of Recharge Well size 4 feet diameter and 15 feet depth .

Now it will recharge 5000 litres per hour = 5 Cum/hr. = 24 x 5 Cum/day = 120 Cum/day.

Taking Factor of Safety as 50% .

Design Recharge = 120/2 = **60 Cum/day** for recharge well.

But aquifer discharge is 131.04 Cum/day .

Balance runoff volume for design of structure = 131.04 – 60 Cum/day= **71.04 Cum/day** balance

to design rainwater harvesting structure further .

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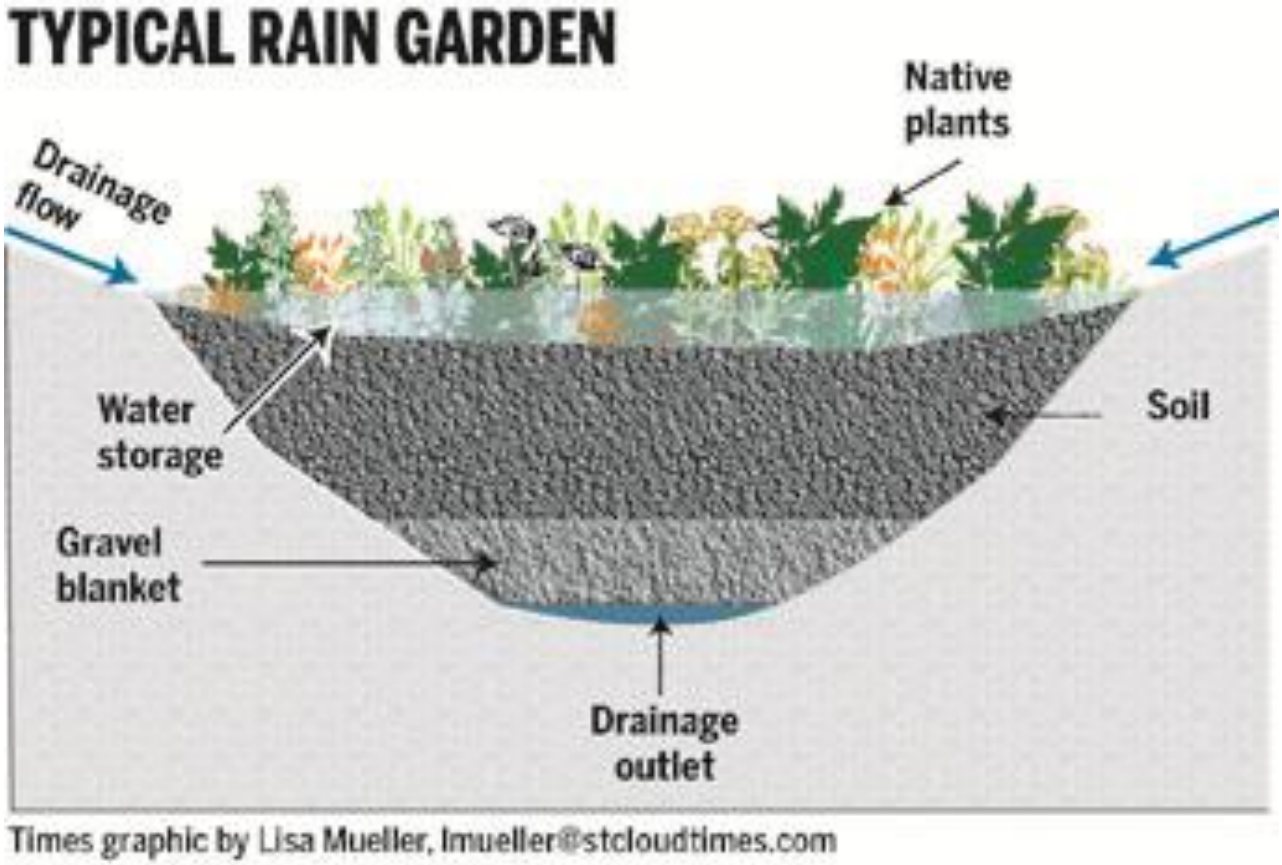
b) Rain Garden



For discharge of 1 inch/hr. with 3 to 6 inch depth of sandy alluvium soil . To determine the surface area of raingarden required .

Design Calculation for Raingarden :-

Volume of Rainwater = 1 x A inch^3/hr.

= 0.0254 x A m^3/hr.

= 24 x 0.0254A m^3/day = 0.6096A m^3/day.

But balance volume of rainwater required to design rainwater harvesting structure in the form of Raingarden = 71.04 Cum/day

Therefore 0.6096A = 71.04 m^3/day ; solving this equation to find the value of "A" .

A = 117 m^2; A = L^2 where L is the length of a square area raingarden.

L^2 = 117 m^2 ,

finally **L = 10.82 meter is one side of a square rain garden**.

Taking factor of safety = 50 %

Structure will cater to 71.04/2 = 35.52 Cum/day for 117 m^2 of raingarden .

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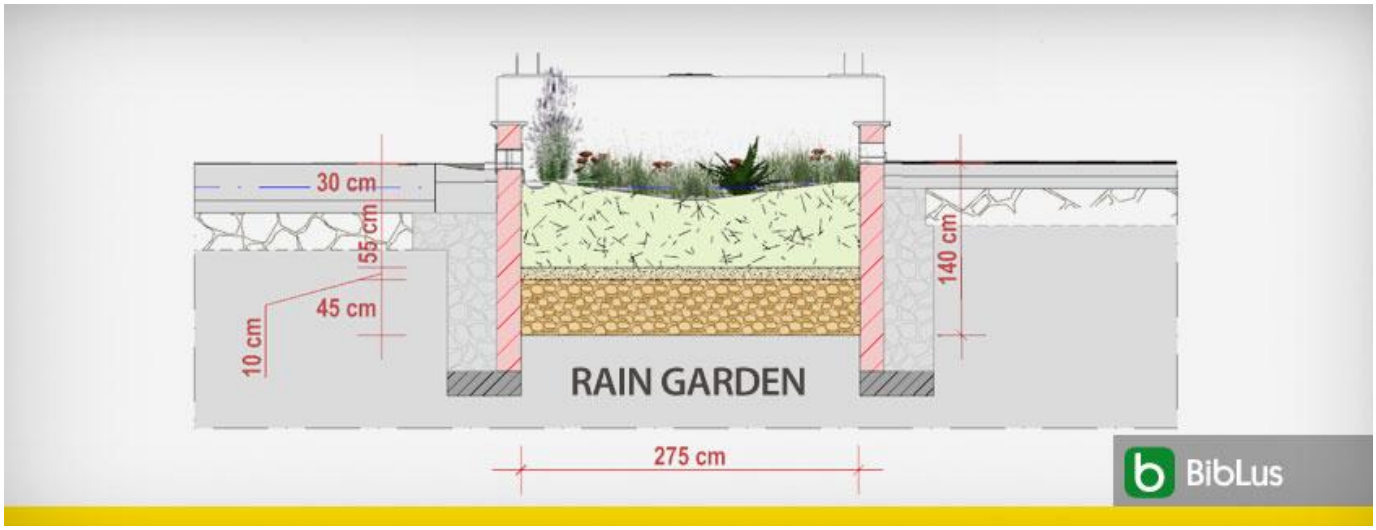
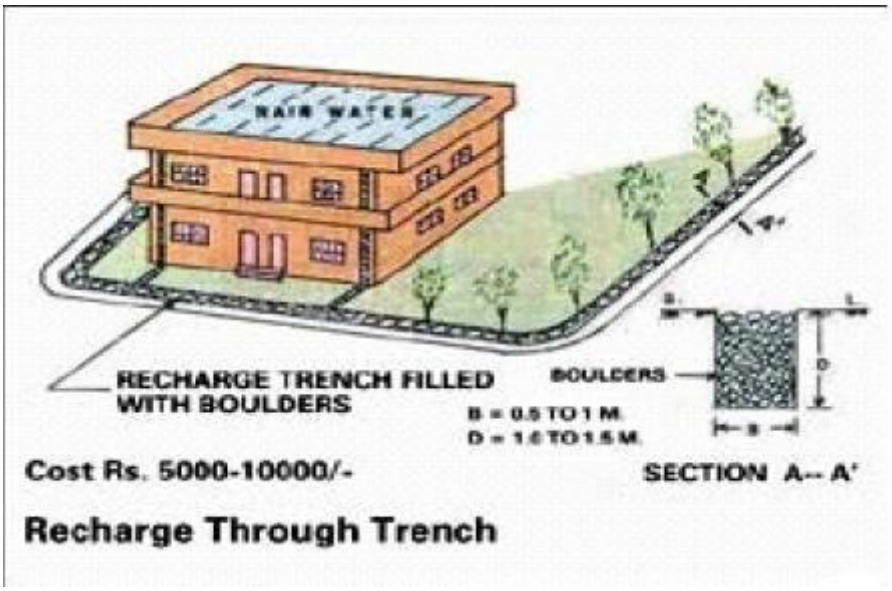


Balance runoff volume for design of struc [10.82 m] 131.04 – 60 – 35.52 Cum/day = **35.52 Cum/day** balance

to design rainwater harvesting structure further .

c) Recharge Trench



To design a recharge trench having top width 1 m wide for discharge of 1 inch/hr. with 3 to 6 inch depth of sand .

Design Calculations :-

From above , 35.52 m^3/day discharge into 117 m^2 area as per raingarden design.

Here factor of safety of 50% is already inculcated into the design .

Now for 1 m^3/day discharge into the trench = 117/35.52 = 3.3 m^2 .

For a rectangular cross-section trench of 1 m width , 1 m^3 rainwater discharge into 3.3 metre of recharge trench .

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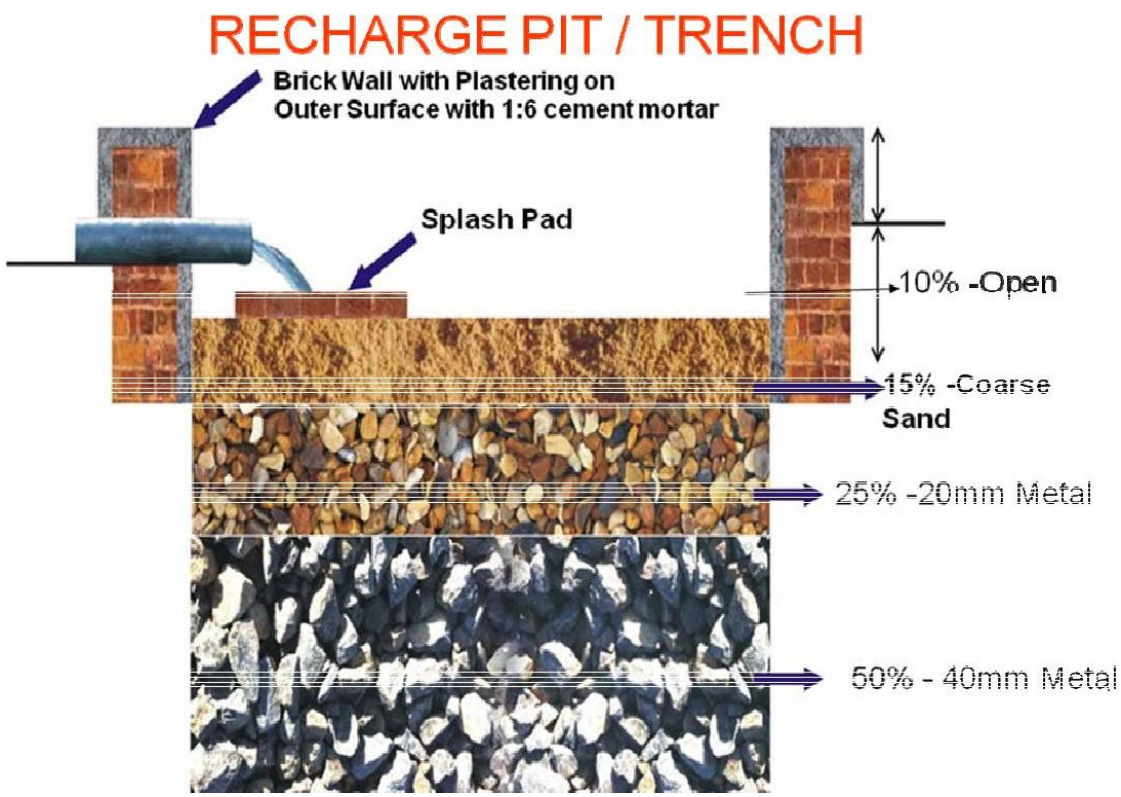
Therefore for 35.52 m^3/day discharge into the recharge trench ; length of recharge trench will be = 3.3 x 35.52 = **117.216 m of recharge trench top width 1 metre .**



X. FINAL MASTERPLAN OF THE INSTITUTION UNDER STUDY.

The masterplan of the rainwater harvesting system for IIMT Group of Colleges , Knowledge Park III , Greater Noida , Uttar Pradesh is as follows :-

a) 4 No. of Recharge Wells of size 4 feet diameter and 15 feet depth.

b) 4 No. Square Raingarden of 10.82 x10.82 meter size.

c) Recharge Trench of length = 3.432 x 117.216 =402.285 m **Recharge Trench of 403 m** need to be constructed .

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