International Journal of Engineering Research
Volume No.7, Issue Special 4, pp : 464-469

ISSN:2319-6890 (online),2347-5013(print)
9,10 March 2018

Design of Rain Water Harvesting System

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Abstract: Water is a major source of human survival and all the major activities like urbanization, agriculture and pro-duction depends on it. But because of uneven rainfall and consumption of water at a faster rate, scarcity of water has be-come an alarming situation. With the depletion of water from both surface and underground water resources like wells, rivers and reservoirs, it is time to implement water conservation techniques. Rain water harvesting is a potential method and can be implemented for the same. The present study focuses on importance of rain water harvesting and design of rain water harvesting system for University campus of DeenBandhu Chhotu Ram University of Science and Technology (DCRUST), Murthal, Sonipat in Haryana to meet the demand of water and reduce the pressure on conventional source of water supply. The aim of the study is to collect water from campus library building and its vicinity and design RWH sys-tem for both storage and recharge purpose.

Keywords: Water scarcity, Rain water Harvesting, Recharge Tanks, Storage Tanks.

1. INTRODUCTION

Water is an important essence to human life and almost all the activities like agriculture, production, household works depends on it. With growing urbanization, indus-trialization and increasing population, the demand of water is further exuberated. As most of the surface water available from oceans cannot be used for drinking pur-poses and is difficult to filter, dependency especially on ground water increases. According to a 2016 report by the Indian parliamentary committee on restructuring the Central Water Commission and the Central Ground Wa-ter Board, the growing dependence on groundwater has taken the form of unsustainable over-extraction, which is lowering the water table and adversely impacting drink-ing water security [1]. Depletion of water is a result of un-even rainfall, over consumption of water which does not provide sufficient time to aquifers for replenish, change in climatic conditions, etc. Agricultural activities depend mainly on rainwater and as monsoon period in India is from June to September, the rain water is available only for a limited period. With absence of structures that can store and retain the rain water, most of it gets lost as sur-face runoff. Along with depletion of water, the problem of quality of ground water is also a serious problem. Water is contaminated because of addition of sewage, arsenic, flu-oride and uranium. Depletion and contamination of water is a serious threat to survival of living beings and hence it becomes essential to conserve water.

Rainwater Harvesting system, an ancient water conserva-tion technique is one of the solutions to these problems. The process of collection and storage of water along with recharge of ground water comes under RWH. The tech-nique is used globally and is successful to reduce load and improving quality of water.

2. RAINWATER HARVESTING

Rain water harvesting is the technique of collection and storage of rain water at surface or in sub-surface aquifers, before it is lost as surface run-off. The water collected can be used for storage purpose after primary treatment that can serve different purpose or can also be used for re-charging ground aquifers, it also improves water quality of aquifers.

Kim [2] suggested that RWH system can be used as one of the effective measure for recovering natural hydrologic cycle and hence enables sustainable development in ur-ban areas. It has the potential to reduce load on present water supply system and storm water system. Its imple-mentation has the potential to improve living standard of humans. Benefits of rain water harvesting system:

- Rainwater is a comparatively clean and totally free source of water.
- It can be used as a substitute for other water supply sources like groundwater or municipal water.
- It is socially acceptable and environmentally re-sponsible.
- The RWH system is inexpensive and uses simple technologies. The only cost incurred in collection or storage of rainwater.
- Reduces soil erosion as surface run-off is reduced
- It reduces the contamination of surface water with sediments, fertilizers and pesticides from rainwater run-off resulting in cleaner lakes, riv-ers, oceans and other receivers of storm water.
- It is used in the areas where water resources are insufficient or reducing.
- It is good for laundry use as rainwater is soft and lowers the need for detergents.
- It can be used to recharge groundwater and hence can promotes adequacy of underground water.
- It minimizes the runoff which blocks the storm water drains. Thus, it can also be used as a pre-ventive measure to reduces flood hazards.
- It will decrease load on storm water disposal sys-tem.
- It improves quality of ground water table and hence save energy.

- The land requirement for storage and recharge purpose is minimal.

Need of RWH System:

- Scarcity and lack of availability of quality water is an alarming situation. So there is need to adopt this system for self-sufficiency.
- To prevent depletion and pollution of ground water.
- To prevent soil erosion that results from un-checked surface runoff.
- As urban water supply system is under tremen-dous pressure for supplying water to ever in-creasing population.
- To reduce health problems caused by contamina-tion of water.

2.1. Rainwater Harvesting Studies around the World

Kahinda et al. [3] defined RWH as the collection, storage and use of rainwater for small scale productive purposes. Oweis [4] defined it as the concentration of rainwater through runoff into smaller target areas for beneficial use. Mati et al. [5] defined RWH as the deliberate collection of rainwater from a surface known as catchment and its storage in physical structures or within the soil profile. Water harvesting is an ancient practice that has been in-creasingly receiving attention in the world, fueled by wa-ter shortages from droughts, pollution and population growth (Meera and Ahameed [6]).

Deepak Khare et al [7] have reviewed the impact assess-ment of RWH on ground water quality at Indore and De-was, India. The impact assessment of roof top improves the quality and quantity of Ground Water. The roof top rainwater was used to put into the ground using sand filter as pretreatment system. This lead to a reduction in the concentration of pollutants in ground water which indicated the effectiveness of increased.

Recharge of aquifer by roof top rain water. He observes that in certain areas, the amount of total and faceal coli-form were observed high in harvested tube well water than normal tube well water. The reason of this increase was poor cleanliness of roof top and poor efficiency of filter for bacterial removal. The author concludes that quality mounting of rainwater harvesting is an essential prerequisite before using it for ground water recharge.

Venkateswara Rao [8] in his article has reviewed the im-portance of artificial recharge of rainfall water for Hyder-abad city water supply. Rainfall water from the roof tops of the buildings recharged through specially designed recharge pits in order to augment the ground water re-source in the city. This Water meets almost 80% of do-mestic water requirements, storm runoff from the public places like roads, parks play grounds etc., is recharged through naturally existing tank within the city by not al-lowing municipal sewage and industrial effluents in these tanks. He finally suggests that, wherever natural tanks are not existing, community recharge pits are to be con-structed at hydro geologically suitable location.

Ravikumar et al [9] describe the roof top rainwater har-vesting in Chennai Airport using GIS. They explain the estimation of surface runoff using SCS method and design of rainwater harvesting structures in Chennai Airport Terminal buildings. Thematic maps were digitized in map Info GIS software and roof drainage delineation was done in GIS environment. Based on the topography and lithol-ogy of airport, the artificial recharge structures like re-charge shaft, recharge well and recharge pit were de-signed and located.

2.2. Methods of Rainwater Harvesting

RWH by Storage- In this method, Rainwater is stored directly in above ground or underground sumps, over-head tanks after giving proper treatment and is used di-rectly for flushing, gardening, washing etc.

RWH by Recharge- In this method, runoff from roof and ground area is used for recharging ground aquifers. The water is made to travel to a recharge structure consisting of filtration unit, so as to maintain quality of aquifer. The various methods of recharging subsurface aquifers are:

- Recharge through recharge pit.
- Recharge through abandoned hand pump.
- Recharge through abandoned dug well/open well.
- Recharge through recharge trench.
- Recharge through shaft.
- Recharge trench with bore.

3. AREA OF STUDY

Rain water harvesting system was designed for Deen-Bandhu Chhotu Ram University of Science & Technology, Murthal (DCRUST), Sonipat, Haryana. It is located near New Delhi and is considered as a part of National Capital Region. It is located at 28.98'N and 77.02'E and has an average elevation of 224.15 m above mean sea level. Sonipat's climate is a local steppe climate. There is little rainfall throughout the year and it receives its maximum rainfall during monsoon season, from July to September. The average annual temperature is 24.9 °C in Sonipat. About 610 mm of precipitation falls annually and a peak hourly rainfall of about 90 mm (based on 25 year frequen-cy) and 15 minutes peak rainfall is 22.5 mm/hr, say, 25 mm, according to Central Ground Water Board data [10]. The soil profile of the area was determined from bore log chart and data sheet prepared during soil exploration of University. There is firm starta at top 1m, then there is compacted sand and compacted clay till 5m depth in dif-ferent regions and there after compacted sand. The CGWB (Central Ground Water Board) [10] assessed the total groundwater potential to be 292 million cubic me-ters (MCM) in 2003 as compared to

ISSN:2319-6890 (online),2347-5013(print)
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428.07 MCM in 1983, showing an overdraft and reduction of around 130 MCM over the past 20 years. During 60s the average ground water was at 2-5 m. In 1977 the water table was by and large within 6 m below ground, in 1995 the extent of area with water table in the range of 10-20 m has increased substantially. However the situation remains so and the water table is going further down , in 2002 ground water table started increasing to more areas with 20-30 m depth particularly in parts of South and West Delhi. RWH is seen as a potential measure to check depletion of water table and prevents its replenishment. That's why RWH system was designed for University building as a measure to curb this problem.

4. DESIGN

RWH system for building is designed for both storage and recharge purpose. A part of rain water will be used for storage purpose after giving primary treatment process to it & the remaining for recharge purpose. Storage water was considered from roof top runoff only, whereas runoff from parking, landscape and from roof was considered for recharge purpose. Figure 1 shows University's library building and its adjacent ground area for which RWH system was designed.

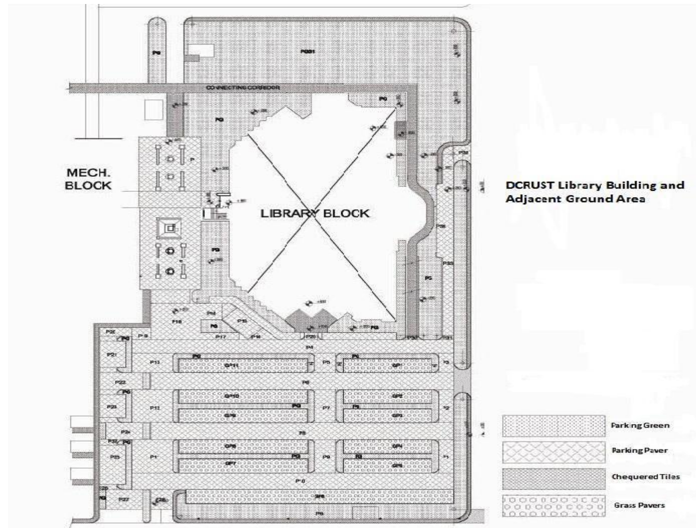
4.1. For Storage Purpose

The RWH system for storage was designed for peak rain-fall intensity and runoff from roof top was considered for this purpose. For assessment of runoff in rainwater har-vesting design, rational formula is universally used. Math-ematically it can be defined as-

$$Q=KiA \quad (4.1)$$

Where Q is runoff (m^3/hr), k is runoff coefficient, i is peak rainfall intensity (m/hr) and A is area of roof top (m^2). Table 1 shows the area of roof top and adjacent ground area, their respective runoff coefficients and runoff con-tribution. Water from roof top through various RWH pipes was collected in Holding tanks. A part of it was transferred to filtration tanks for primary treatment and there after pumped back to Storage tank at roof top that will be used for different building purpose. Figure 2 shows a schematic representation of water flowing from roof top to treated water again transferred back to storage tank. Table 1 shows runoff available from different areas.

A total of four Holding tanks each collecting water from eight RWH pipes were considered as per design standards from Rain Water Harvesting and Conservation Manual, Govt. of India, Consultancy Service Organization, Central Public World Department [11]. Holding tanks of cross sectional area 1 m^2 and depth 1 m were designed.



"Figure 1. DCRUST Library Building and Adjacent Ground Area"

Table 1 Runoff Calculations from Different Area of Library Building

Area Type	Area(m^2)	Runoff Coeffi-cients	Runoff (m^3/hr)
Roof Top	3372	0.85	71.65
Parking Green	5206	0.15	19.53
Parking Pavers	4661	0.35	40.78
Grass Pavers	1584	0.25	9.9
Cheq-uered Tiles	1464	0.85	26.72

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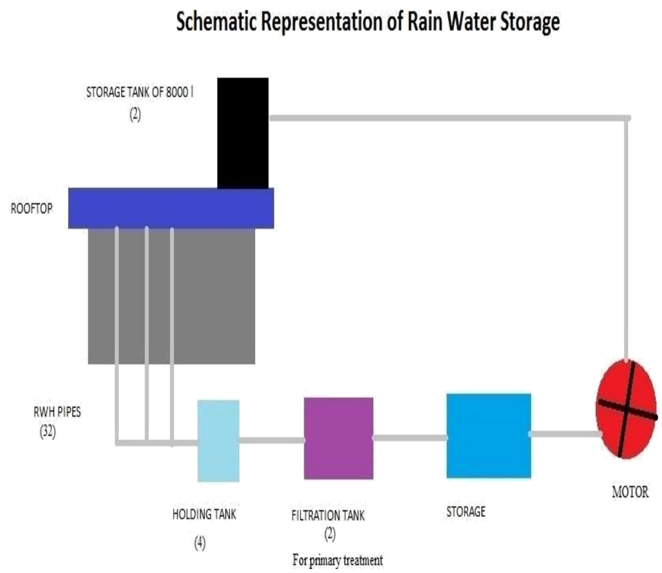


"Figure 2. Schematic Representation of RWH for Storage Purpose"

A part of water from holding tanks was transferred to Filtration tanks designed as per IS 11401 (Part2) for prima-ry treatment [12]. Two rectangular slow sand filtration tanks each of cross sectional area of 20 m^2, depth 2 m and rate of filtration of 200 $l/hr/m^2$ were designed. Figure 3 shows filtration tank and Table 2 shows detailed distribu-tion of depth of the tank.

Water for recharge purpose is made available from runoff from roof top and ground areas like parking green, green pavers, parking pavers and chequered tiles. Table 1 shows runoff available from different areas. Runoff collected from these areas passes through de-silting chamber and finally entire runoff is diverted into recharge structure. Figure 4 shows schematic representation of runoff from different areas to recharge structure.

Provision of Gutter Channel: Gutter channels were pro-vided along parking green to collect runoff and divert it to de-silting chambers. Cast iron pipes of slope 3%, diameter 160mm and width of 250 mm were designed.

Table 2 Depth Distribution of Filtration Tank

Type	Size range(mm)	Size adopt-ed(mm)	Thick-ness(m)
Free board			0.4
Coarse Sand(Cu=2)		2	1.0
Gravel (1st layer)	6-20	15	0.3
Gravel(2nd layer)	20-40	30	0.2
Gravel (3rd layer)	40-65	50	0.1

"Figure 3. Slow Sand Filtration Tank for Primary Treatment"

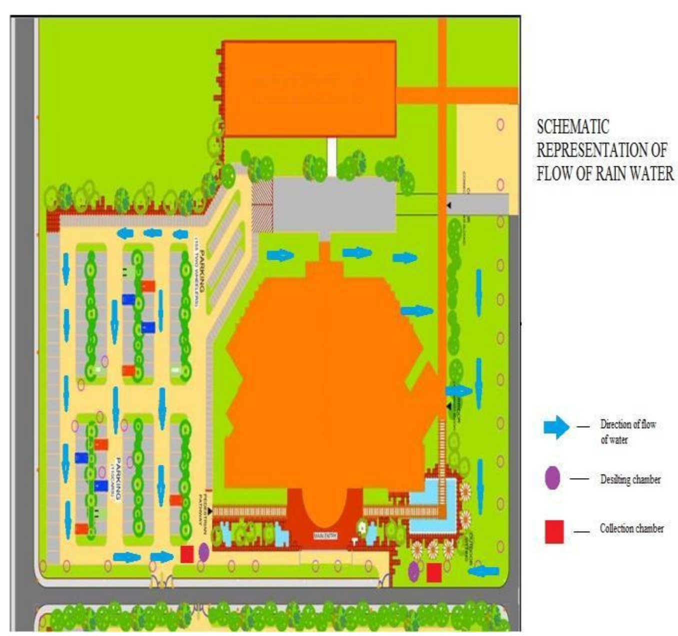


Figure 4. Schematic Representation of Runoff to Recharge Structure"

4.2. For Recharge Purpose

Recharge Structure: For roof area more than 2000 m^2, recharge shafts are provided (From Rain Water Harvest-ing Manual, Indian Railway Institute of Railway Engineer-ing, Pune, August 2006) [13]. Provide a recharge shaft of 10 m depth and 2.3 m dia.

In the recharge shaft a filtration unit is provided, so as to filter the incoming water and remove the contamination present in water, so that it would not affect the quality of ground water. Generally, a slow sand filter (Gravity Filter) is provided as filter unit. The design of filter is as per Rain Water Harvesting Manual, Indian Railway Institute of Railway Engineering, Pune, August 2006(2) [12]. Figure 5 shows the details of recharge structure and safety grill. Table 3 shows the filter media for filtration unit in re-charge structure.

Table 3 Filter Media for Filtration Unit

Filter Media	Particle Size	Size Adopted	Thickness Range (m)
Coarse Sand	1-2 mm	2 mm	0.4-0.6
Gravel	5-10 mm	6 mm	0.5-0.7
Boul-ders	5- 20 cm	10 cm	0.8-1.2

Filters are generally cleaned by scrapping of top 30% of coarse sand layer by scrapper or racks before the start of a rainy season. If needed re-sanding is required, then it should be performed. When after repeated scrapings, the sand depth in a filter bed has fallen to its minimum de-sign level (0.2- 0.3 m above gravel) re-sanding has to be done and the sand depth restored to its design level (0.5-0.7 m).

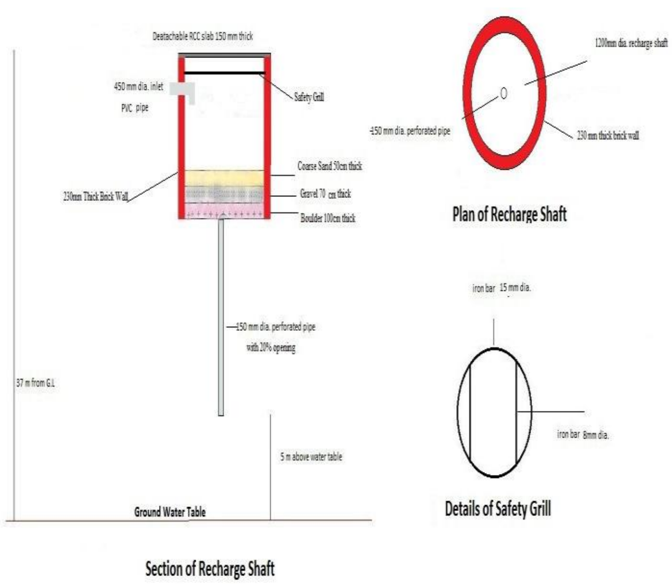
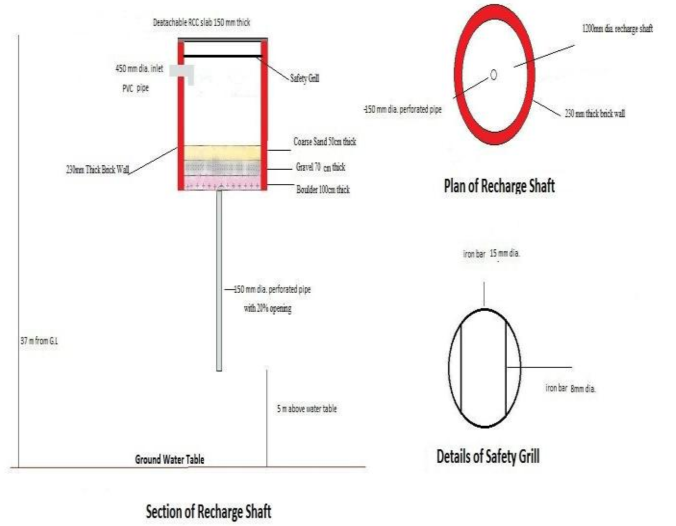


Figure 5. Details of Recharge Shaft and Safety Grill"



5. CONCLUSIONS AND DISCUSSIONS

The exponential growth of population in urban area and increase in per capita water demand has put severe stresses in fresh water resources of the world. It is more prominent and critical in semi acid region. Water conser-vation, water reuse, and harvesting of water are very im-portant and essential for sustainable development.

Rain water harvesting is one of the oldest and commonly used technologies in India. Rainwater Harvesting appears to be one of the most promising alternatives for supply of fresh water in the face of increasing water scarcity and escalating demands water harvesting also present an op-portunity for the augmentation of water supplies using this technology. There are many advantages of rainwater harvesting schemes that make it an attractive option for highly urbanized cities such as Delhi. Thus, Rain water harvesting system was designed for DCRUST library building for storage and recharge purpose. With the im-plementation of the rainwater schemes, following benefits are likely to achieve-

- Raising of ground water level at the sites.
- Reduction in flooding of roads.
- Water stored after primary treatment can be used to meet supply of water for different pur-poses that would reduce load on local water sup-ply.
- Prevention of choking of storm water drains.
- Tubewells will be saved from further deepening.
- Quality of underground water will be improved.
- Saving in energy required for lifting ground wa-ter would be achieved.

The following study can be carry forward to estimate cost analysis of the project and estimating the efficiency in implementation of Rain water harvesting system. Also, rise in underground water level over a period of time can be monitored after implementation of this project.

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