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Design of Rain Water Harvesting Structure for Engineering Block

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ABSTRACT
Present work is a case study of rainwater harvesting needs and the measures being adopted for the northern region of Haryana, India, covering the districts of Rewari and Mahendergarh. The study was necessitated following the notification by Haryana Urban Development Authority to make rainwater harvesting mandatory for its urban estates. As per the notification: "each individual plot holder having a rooftop area of 100 m^2 or more, is required to provide for suitable rainwater harvesting measures". Keeping in view the available soil strata, average rainfall, rainfall intensity, social acceptability etc., a plan has been drafted to comprehensively utilize the rainfall water falling in the campus of Central University of Haryana, Mahendergarh, a campus of around 488 acres of area. Land area requirement for different suggested modes is likely to be a very small percentage of the total catchment's area. In the first phase, ground water recharge structures for School of Engineering and Technology are suggested. Major objective of the study is to provide rainwater harvesting structures so that ground water storage is enhanced to an extent that it would suffice the drinking water needs of students and faculties residing in the campus. Another objective of the study is that these recharge structures will serve as models and infuse confidence in people to follow the good work initiated by the Haryana Urban Development Authority.

Keywords: rain water harvesting. ground water, recharge, water table, recharge trench.

INTRODUCTION

Water is of prime importance in the life and environment of man, affecting his activities in all spheres of his existence (Adugna et al., 2018). Water is a major component of the human body, animal, plant kingdom and the environment around the Earth. Water is the greatest resource of humanity (Diwan and Karanam 2020; Andavar and Ali 2020). It not only helps in survival but also helps in making life comfortable and luxurious (Campisano et al., 2017). The world's thirst of water is probable to become the most pressing sources of 21st century (Adugna et al., 2018). One-third of world's population is projected to be under water stress or scarcity by 2025 (Dismas et al., 2018; Hajani and Rahman 2014; Mandloi et al., 2011). Water on earth cannot increase rainfall and rainfall in its various forms. However, it is possible to reduce water loss due to evaporation, excessive surface runoff, etc. Various methods of artificial recharge of groundwater may increase that available amount of fresh water by increasing the availability of renewable supplies (Chadha 2020; Frycklund 2020) Rainfall in the state of Haryana is very scanty and erratic. It is highest (about 2,160 mm) in the Foot-hills, and lowest (250 to 380 mm) in the south. Monsoon rains from June to mid-September. About 80 percent of the total rainfall occurs in the period from July to September and sometimes the concentration of precipitation affects large areas. Artificial recharge is a process in which overload surface water is injected into the ground by burying it in ground, recharging natural reservoirs, or shifting natural conditions (Chadha 2019). This denotes the movement of water as earth's surface to groundwater-bearing water bodies through manmade systems (Sharma et al., 200). It also increases the availability of groundwater as compared to surface storage. The groundwater assessments carried out by National Bank for Agriculture and Rural Development (NABARD) (http://cgwb.gov.in) in collaboration with the Central Ground Water Board, India (CGWB) and Ground Water Cell, Haryana, India (GWC) (https://www.nabard.org), show that in Mahendragarh district of Haryana, Out of 6 blocks, 4 blocks come under the highly exploited category (Kumar et al., 2007). The study area has seen a drop of more than 25 m in the water table from 1974 to 2014 (Aneja 2017). Lowering of water table leads to construction of tube wells and increase in power consumption. Several projects are being taken up by various government and non-government organizations to replenish this resource of fresh water (Ahirwar et al., 2020; Saxena et al., 2010). Government of India is paying attention towards artificial recharge of ground water and Haryana Urban Development Authority (HUDA) is also taking some steps in this direction. Laws have been amended to make rainwater harvesting mandatory when buildings have roofs above 100 m^2 (Peters, 2020). The present work attempts to discuss the design of structures to be constructed to facilitate recharge of groundwater for the School of Engineering and Technology, Central University of Haryana, Mahendragarh.

BASIC REQUIREMENTS FOR A RECHARGE PROJECT

The vital requirements to recharge ground water reservoir are: (1) Accessibility of unoccupied and untimely excess monsoon flow; (2) Recognition of appropriate hydro-geologic sites for the construction of groundwater reservoirs through low cost artificial recharge processes. Artificial recharge projects are site specific and are based on local hydro-geological and hydrological conditions. So, the first step in the planning of a recharge project is to identify an area conducive for artificially recharge the groundwater. The campus of the Chair of Engineering and Technology, Central University of Haryana (CUH), Mahendragarh has been identified as the subject area (Fig. 1).

Source water availability and hydrological studies

The availability of a water source can be assessed by evaluating monsoon rainfall pattern, number of rainy days, maximal rainfall per day and their variation under space and time. The subject area (SoET, CUH, Mahendragarh) receives rainfall for about 40 days during July to September. 450 mm is the average annual rainfall. As per CGWB-India norms, a rainfall intensity of 20 mm/hr has been assumed for calculation of volume of recharge formations. Since there is no chemical hazardous industry in and around the subject area, rainwater is chemical free and can be recharged into the ground without any specific treatment. A suitable filter media is provided to filter the suspended matter. In the semi-arid areas of India, evaporation losses are considerable after January. Therefore, till this period all the stored water should be converted into ground water reservoir.

Hydro-geological studies

The district shows the complete sequence of the Delhi and the pre-Cambridge expansion of the Aravalli ranges, composed of quartzite, shales, phyllites, schists, etc., with different firearms. It is gradually leveled to separate alluvial and sandy plains, surrounded by sand dunes, isolated hills and ridges. The soil throughout the profile is mostly sand to loamy sand. The subject area is in the Indo-Gangetic alluvium from the Upper Pleistocene to the recent. Older alluvium consists mainly of inter-bedded litular and interbedded beds of clay, sand, gravel and silt interspersed with calcareous nodules. The new alluvium consists mainly of laticular beds of clay, sand and occasionally gravel (CGWB, 1998). A typical bore log data of the CUH campus is shown in Table 1. The soil layer below the top lens is an alluvial deposit in the form of a clay lens. These lenses are not inter-connected and therefore form a leaky

Figure 1. Study area of CUH campus

Table 1. Soil profile of the site (Courtesy Cpwd)

N-value	Depth	Sample	Soil description	Sparavity	Sieve analysis				Limits		Moisture content, %	Type of test	Cohesion kg/cm^2	Angle of int. (φ)
					gravels %	sand%	silt %	clay%	L.L.%	P.L.%				
	0	DS-1	light brown silty sand											
14	1.5	SPT-1	do											
	2.5	UDS-1		2.61	0	71	29	0	N	P	8.5	DST	0	31
22	3	SPT-2	4.5 m											
24	4.5	SPT-3	light brown silty sand											
	5.5	UDS-2	with gravels	2.62	4	72	24	0	N	P	9.9	DST	0	33
25	6	SPT-4	do											
30	7.5	SPT-5												
	8.5	UDS-3	do		6	74	20	0	N	P	10.7	DST	0	36
36	9	SPT-6												
44	10	SPT-7	do											

Note: DST – drained direct shear test, NP – non-plastic.

aquifer. The campus of this institute is located on the outskirts of Mahendragarh city. Residential accommodation is given with teaching staff and students. The total campus strength, involving students and staff, is approximate 3500. Therefore, this current strength and expansion, the complex must also enlarge their facilities and preservation demands. Therefore, taking into account all the beyond issues and the condition of the CUH campus, Mahendragarh, the administrative body focused on the problem of water shortage. Therefore, in this circumstance, the rainwater harvesting system may be assumed the better solution to combat water shortages in the premises.

The water table data of Mahendragarh has been studied in detail and it is observed that year after year the water table is continuously decreasing. Available details for the average depth of the water table below the ground surface portrays on Table 2. The data shows that the district has wide scope to fill the unconfirmed aquifer, which dried up at least to that level in the year 1974 through various artificial recharge schemes.

Table 2. Depth of water table in district Mahendergarh, Haryana

Year	Depth of water table (m)
1974	16.11
2001	31.86
2014	41.08

Draft plan for ground water recharge

The details of subject area are given in Table 3. According to Indian Standards Code of Practice, the daily water requirement per person is 135 lpcd. Considering the various other demands and hourly, daily and seasonal variations, the design demand stands at 270 lpcd.

Table 3. Details of subject area

Geographical location of Mahendergarh	Latitude: 27º47' to 28º28' Longitude: 75º53' to 76º22'
Geographical area of Mahendergarh	1367 km^2
Ground water table	170 m below ground level (as in year 2021)
Average annual rainfall	318 mm
Total area of CUH campus	1974448 m^2
Volume of rainwater received	627874.46 m^3
Population of campus: (students = 1500, families of faculty = 600, families of non-teaching staff = 1600, floating population = 300)	4000
Rain water availability (in lpcd) = 728460 x 1000 / (4000 x 365)	430 l/day

Design parameters

- Rainfall of 25.4 mm/hr is assumed as per CGWB India norms. The pit of the recharge structure serves from buffer tank. As the recharge rate of runoff cannot coincide with the water rate, the tank capacity must be sufficient to sustain the runoff generated by extreme rainfall conditions. The recharge rate becomes an important factor as compared to the runoff rate. However, since exact recharge rates are not available, the rates should be chosen such that the capacity of the recharge pit to sustain runoff from peak intensity of rain for at least 15 minutes (Water Harvesting Manual).
- Permeability of the aquifer.
- The level of entry point into the percolation well shall be at least 7.5 cm to 10 cm. Should be placed above ground level so that no waste water enters the system while washing floors etc.
- The mechanism at the entry point is designed to prevent the entry of the first shower of the season.
- Suitable filter media convenient to prevent sand and gravel infiltration should be provided in the well.
- Arrangement for drainage of excess water should be made at the entry point.
- In the study area, the bore hole should be at least 10 meters deep.

RESULTS OF CALCULATIONS

Salient features of the recharge project

Table 4 gives the salient features of the recharge project. To recharge the rooftop rainwater into the ground, houses with 100 m^2 to 200 m^2 of roof area are taken into account. For houses with 100 m^2 roof area, the use of shallow water harvesting pits (Figure 2) has been proposed. Whereas for roof area of 200 m^2 or more, use of recharge bore well arrangement with borehole of 100 mm diameter (Figure 3) is recommended. However the sides of the shallow pit should be kept perforated using honey comb brick masonry to have more surface area for the hole. It is desired that the top level of these holes should be kept lower than the foundation level of the building. Since the borehole in a bore well arrangement extends to the first layer of the dried aquifer, a proper filtering media must given to stop the entry of finely suspended particles into the aquifer

Optimum size of a recharge pit

The volume of a recharge pit should be sufficient to hold all the water that falls over the rooftop catchment of area A, with intensity of rainfall R and for a duration of T hours. Assumptions include all the water that falls over the rooftop catchment is collected in the recharge structure at once and the soil permeability is assumed to be insignificant during the period of collection.

$$V = R \cdot A \cdot T / e \quad (1)$$

where: e – void ratio of the recharge pit filled with gravel, coarse sand and fine sand.

The fill material comprising of gravel, coarse sand and fine sand will be proportioned in a manner such that porosity is of the order of 0.5. Block number 1 of engineering was considered for finding out the total volume of water. Total roof top area of the building was calculated 4810.68 m^2. The refill tank capacity is intended to retain runoff at least 15 minutes of full-intensity rain. For Mahendergarh, the maximal rainfall per hour is 80 mm (depending 25-year frequency) and maximal 15-minute rainfall is 20 mm/h, based on CGWB standards.

The calculations to determine the volume of recharge pit for such a house are as below:

- Annual rainfall intensity = 20 mm/hr,
- Area of catchment = 4810.68 m^2 ,
- Volume of water = 4810.68 × 0.020 × 0.8 = 76.97 = 77 m^3 ,

Table 4. Salient features of the recharge project

Type of Area	Rooftop and Paved area	Bare and green Land
Percentage of total area	10%	90%
Amount of water received (m^3)	29138	699322
Runoff coefficient	0.85	0.12
Amount of water for recharge (m^3)	24767	83920
Type of recharge structure	recharge pit and recharge bore-well	ponding
Recharge rate (lps)	0.581 (l/s)	0.78 (l/s)

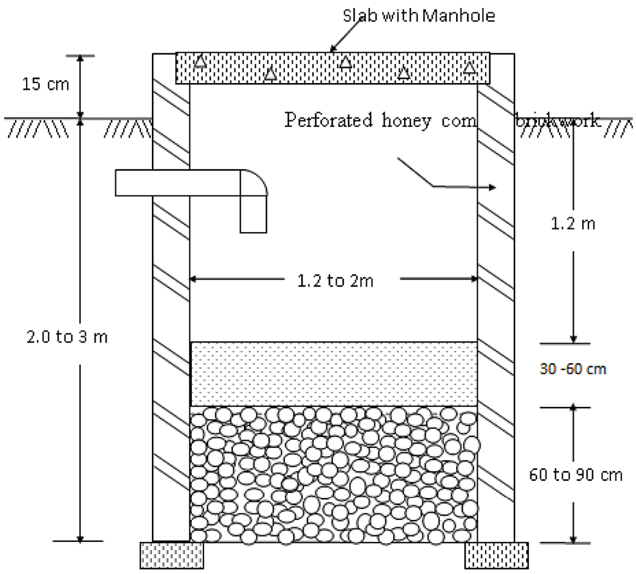

Figure 2. Recharge pit

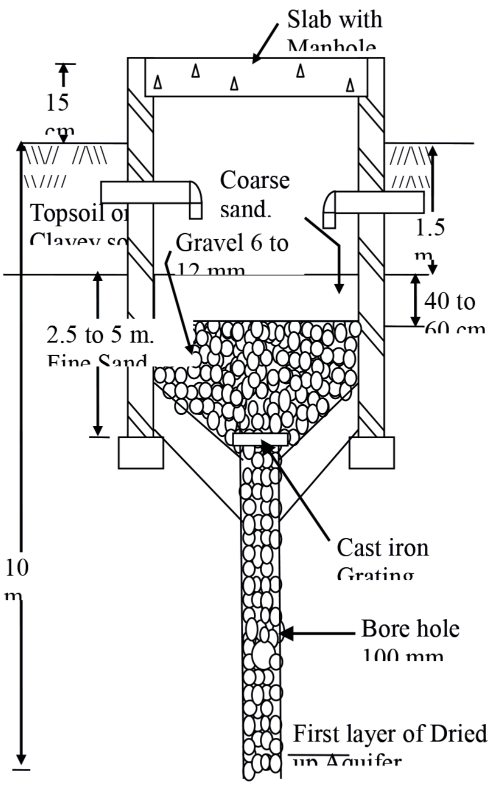

Figure 3. Recharge Bore-Well

- Consider the void ratio of 0.5, the necessary capacity of recharge tank = (4810.68 × 0.020 × 0.85)/0.5 = 154 cu. m. (154000 litres) = 1.6 × 2 × 50 = 160 m^3.

The performance of the recharge works (recharge pit and recharge bore well) as suggested by authors and executed by HUDA, is under observation. An average rooftop rainwater harvesting structure costs around INR 2.5 Lakh is required for 1000 sqm roof top area (GGWB, 2013). Though the initial investment is little high, the relief it brings is enormous. Considering the lifespan of a structure to be 20–25 years, the annual average expenditure for the structure comes down. Rainwater harvesters will soon be able to get relief from its property tax liability if the Central Groundwater Authority has their way. All eco-conscious citizens will get the benefit of this rebate.

Precautions for artificial recharge

Groundwater recharge will not be economically possible unless significant amounts are paid into the aquifers. So, the recharge process must be encouraged at community level instead of individual level. Recharge wells may fall into disrepair under the nonexistence of financial incentives; Laws or other regulations for encouraging landowners to effectively preserve these wells will eventually become sources of groundwater pollution.

CONCLUSION

This study was intended at designing a rooftop rainwater harvest structure of Old Engineering Block of Central University of Haryana. This novel work of water conservation will be able to fulfill requirement of water in the lean season.

Rainwater harvesting structure is designed for the old Engineering block of Central University of Haryana having roof top area of 4810 m^2. Rainwater harvesting structure is designed as per CGWB norms. A trench was designed having 50 m long along the building with 1.2 m width and 2 m depth. This trench is filled with a natural filter of sand, aggregates and boulders which will be helpful to clean rain water. It will store water about 154000 litres of water may decide that water scarcity issues through non-monsoon season. This water will enlarge that water supply for building work, gardening, cleaning of buildings. It will also help artificial recharge of ground water which will increase overall ground water level in that area.

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