PBL Report on:

Study, design and estimation of Rainwater Harvesting System

UNIVERSITY
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Submitted to:
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(Associate Professor)

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Class: 3rd year

Environment Engg. (CEL 0634)

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PREFACE

Water is one of the most essential natural resources for the survival of human beings, plants, and animals. With the rapid growth of urbanization and population, the demand for water has increased significantly, leading to depletion of groundwater resources in many regions. Rainwater harvesting is one of the most effective and sustainable methods for conserving water and improving groundwater recharge.

This Project Based Learning (PBL) report focuses on the **study, design, and estimation of a Rainwater Harvesting System at ITM University, Gwalior**. The project examines how rainwater falling on building rooftops and open areas can be collected, filtered, and recharged into the ground through a scientifically designed filtration tank.

The design considered in this project consists of a **cylindrical rainwater harvesting tank of 2000 mm diameter and 3000 mm depth**, with multiple layers of filtration media such as sand, gravel, charcoal, brick bats, boulders, and metal layers. The system also includes **inlet and outlet UPVC pipes (100 mm diameter)** and a **vertical recharge pipe (150 mm diameter)** to facilitate groundwater recharge.

The purpose of this project is to understand the **practical application of environmental engineering concepts**, especially **runoff water management, groundwater recharge, and sustainable water conservation techniques**. This study also investigates existing rainwater harvesting installations at ITM University and proposes improvements through engineering design and estimation.

Through this PBL research, I have gained practical knowledge about **water conservation methods, filtration techniques, runoff control, and the importance of sustainable infrastructure in modern civil engineering practices**.

ACKNOWLEDGMENT

I would like to express my sincere gratitude to all those who supported and guided me in the successful completion of my **Project Based Learning (PBL) research on Rainwater Harvesting at ITM University, Gwalior**.

First and foremost, I would like to thank **Dr. Rakesh**, the supervisor and coordinator of this PBL project, for his valuable guidance, encouragement, and academic support throughout the research. His explanations on **environmental engineering concepts such as rainwater harvesting techniques, runoff water management, and groundwater recharge systems** helped me understand the scientific and engineering aspects of this project.

I would also like to express my sincere appreciation to **Mr. Farhan Rahman**, faculty member of the **Civil Engineering Department at ITM University**, for his continuous assistance during the field study. He helped me identify and study **different locations of existing rainwater harvesting systems installed across the ITM campus**. His practical insights and technical support greatly assisted me in **designing and estimating the rainwater harvesting system for this PBL research project**.

I am also thankful to the **Civil Engineering Department of ITM University, Gwalior**, for providing the academic environment and resources required to conduct this study.

Finally, I would like to thank all the faculty members and my colleagues who indirectly supported me during the completion of this project.

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CHAPTER – 1

GENERAL

It is said that "If third world war take places it will be on water". Already so many water disputes are going on in our country between neighboring states for sharing river water. Same situation of sharing river water also exists with neighboring countries like Pakistan, Nepal and Bangladesh. The basic reason of all these disputes is scarcity of water and increasing requirement for human consumption as well as for industrialization.

We, the human beings, are largely dependent on water for our survival. Although water is as important for survival of human beings as is food, air etc. but we hardly pay any attention for its economical use and conservation of this precious resource. This is resulting in scarcity of water.

Due to indiscriminate pumping of ground water, the water table has already gone down abnormally in many parts of our country and if we do not wake up even now, then our future generations may have to face severe crisis of water.

In Delhi the water level in 1960 was, by and large, within 4 to 5 m from ground level but by 2001 it has gone down by 2-6 m in alluvial areas, 8-20 in south west district and 8-30 in south district. Due to rapid urbanization and indiscriminate pumping ground water table has gone very deep and due to high content of soluble solid, it has become un-potable in many area.

The rains are important source of water and if we can harvest rain water, the scarcity of water can be eliminated up to large extent. A major portion of rainwater that falls on earth surface runoff from stream to river to sea. On average only 8% of total rainfall recharges ground aquifers. This can be enhanced up to 50% with proper rainwater harvesting. Therefore, it is our bounden duty to conserve the rain water in the form of rain water harvesting.

Few basic facts we should know:

- Only 3% of water on earth is available for human use.
- Only 10% rain water is harvested currently. This can be enhanced to 50% if adopted as habit or movement. This can solve water problems of major part of country.
- On an average rain, occur only for about 100 hours every year.

Legislation on Rain Water Harvesting in India

- Under the sec 15 of Environment (protection) Act 1986 central ground water authority (ministry of water resources) has made mandatory to adopt rain water harvesting system for certain types of buildings / institutions located in specified regions of national capital territory.

- Ministry of Environment & forest (Govt. of India) has circulated draft Gazette Nomination regarding RWH in hilly area of entire country.
- New Delhi - MOUD has made RWH mandatory since June 2001 if roof area = 100sqm or plot area = 1000sqm.
- Mumbai: RWH mandatory since Oct 2002 for new buildings with area = 1000 sqm.
- Chennai: RWH has been made mandatory in all new buildings of three or more stores.
- Hyderabad: RWH made mandatory since June 2001 if area = 300 sqm.
- Kanpur: RWH made mandatory for new buildings with area = 1000 sqm.
- Indore:
  - RWH made mandatory for new buildings if area = 250 sqm.
  - Rebate of 6% in property tax as incentive for RWH.
- Rajasthan: RWH made mandatory for new buildings in urban areas if plot area = 500 sqm.
- Haryana:
  - HUDA has made RWH mandatory for new buildings in urban areas irrespective of area.
  - CGWA has asked all institutions and residential buildings in notified areas of Gurgaon and adjacent industrial areas to go for RWH.

Ministry of Railways (Railway board vide their letter dated 2013/LMB/9/1 did 09-9-2013 has issued policy instruction to adopt Rain water harvesting systems have been made mandatory in construction of all built-up assets. Indian Railways water policy -2017 also reiterates this policy.

1.0 Introduction

Water is the most common or major substance on earth, covering more than 70% of the planet's surface. All living things consist mostly of water. For example, the human body is about two third water. Worldwide distribution of water is given in table
1.1 of the total volume of water, only 2 percent (over 28,000,000 Km3) is fresh water, which can be used for consumption and for agriculture as given in table 1.2. The average runoff in the river system of India has been assessed as 1869 km3, of this, the utilizable portion by conventional storage and diversion is estimated as about 690 km3. In addition, there is substantial replenishable

ground water potential in the country estimated at 432 km3. The per capita availability of water at the national level has reduced from about 5,177 m3 in the year 1951 to the present level of 1,869 m3. For improving per capita water availability in the country, replenishment of ground water resources is a necessity which can be done very effectively through rain water harvesting.

Table 1.1 World-wide distribution of water

S N	Water Type	Volume ($1000km^3$)	Percentage of total Global Volume
1	Ocean	1,370,323	94.200
2	Ground water (fresh & saline)	60,000	4.100
3	Glaciers	24,000	1.650
4	Lakes and reservoirs	280	0.019
5	Soil moisture	85	0.006
6	Atmospheric water	14	0.001
7	River water	1.2	0.001
	Total	**1,454,703.2**	**100.000**

Table 1.2 World-wide distribution of fresh water

S N	Water Type	Volume ($1000km^3$)	Percentage of total Global Volume
1	Glaciers	24,000	85.000
2	Ground water	4,000	14.000
3	Lakes and reservoirs	155	0.600
4	Soil moisture	83	0.300
5	Atmospheric water	14	0.050
6	River water	1.2	0.004
	Total	**28,253.2**	**100.00**

Rain Water Harvesting:

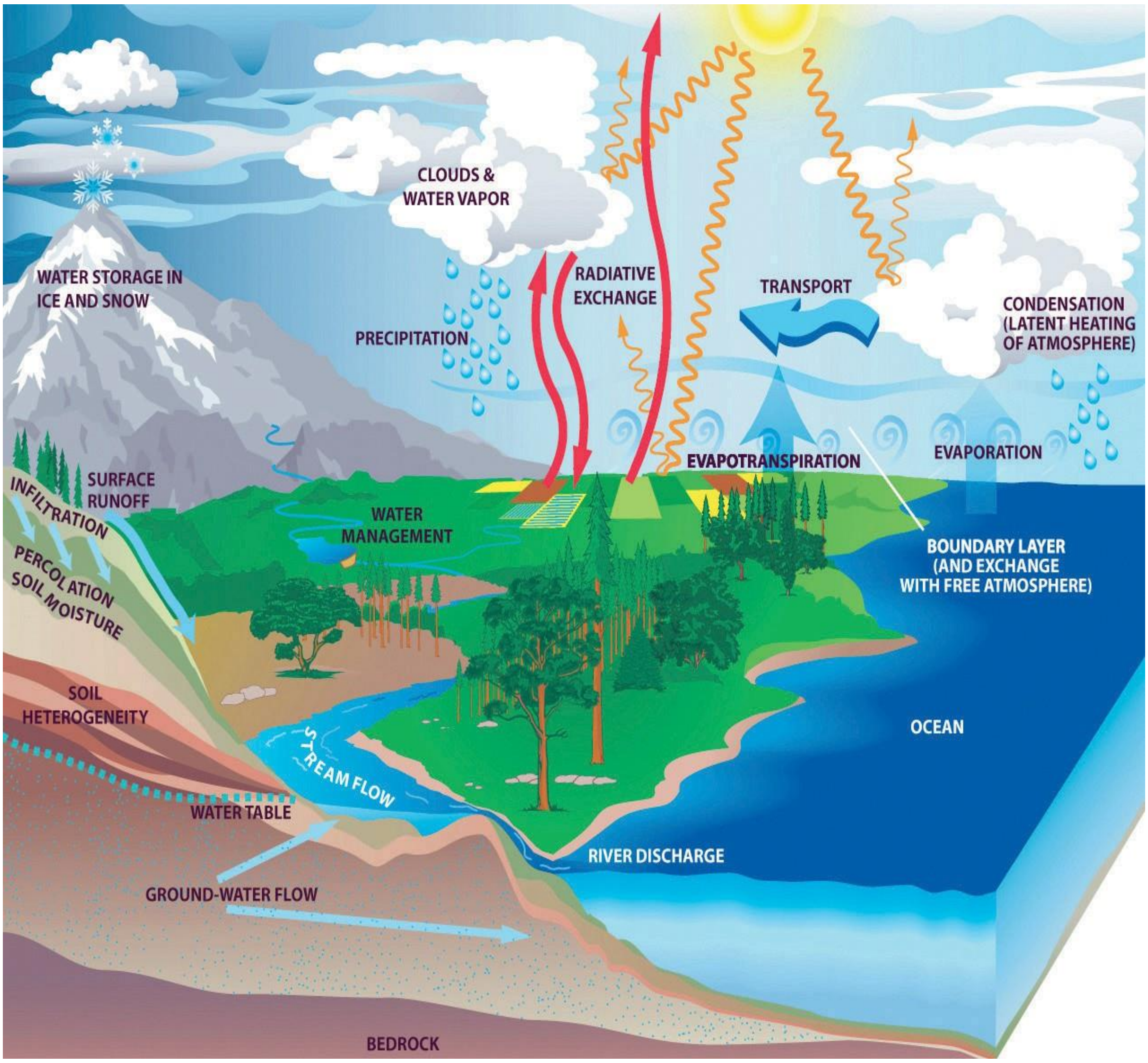
The concept of rain water harvesting means "Collecting Rain water when and wherever it falls for future use"...It is just like "bank account where you deposit the money when it is surplus & with draw when it is deficient".

Rain water harvesting is the technique of collection & storage of rainwater at surface or in subsurface aquifers. As most of rainfall water goes waste in form of surface run off to stream, river and sea, simple technique need to be developed to collect and store this water in storage tank or direct this water to recharge ground water aquifers (water bearing strata) to be tapped later on for use in dry periods.

1.1 Hydrologic Cycle

The never-ending exchange of water from the atmosphere to the oceans and back is known as the hydrologic cycle (Fig. 1.1). This cycle is the source of all forms of precipitation (hail, rain, sleet, and snow), and thus of all the water.

Fig. 1.1 Hydrologic cycle



Precipitation stored in streams, lakes and soil evaporates while water stored in plants transpires to form clouds which store the water in the atmosphere. Currently, about 75% to 80% of conventional water supply is from lakes, rivers and wells. Making efficient use of these limited resources is essential to avoid future water scarcity.

1.2 Advantages of Rain Water

The environmental advantage and purity of rain water make it a preferred choice, even though precipitation may vary year to year.

a. Environmental Advantage

Collecting rainwater from buildings for use is simple and promotes self-sufficiency. It conserves water and energy by reducing dependence on centralized systems. It also reduces erosion and flooding caused by runoff from surfaces like pavements and roofs.

b. Qualitative Advantage

Rainwater is one of the purest sources of water. Its quality is generally better than ground or surface water as it does not dissolve salts or get exposed to many pollutants. This makes it suitable for domestic use, gardening, and certain industries.

1.3 Rain Water Harvesting

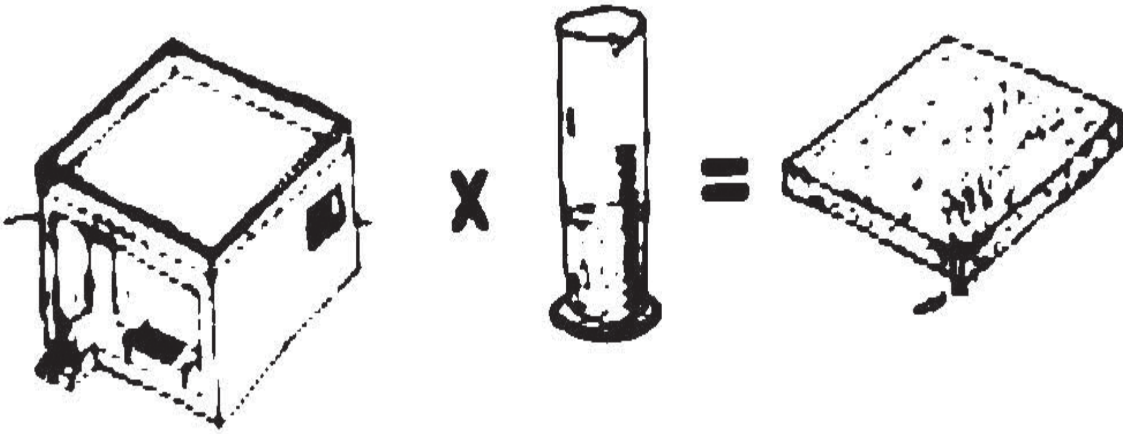
Rainwater harvesting is the collection and storage of rainwater at the place where it falls. It prevents runoff and allows storage on the surface or in underground aquifers for later use.

1.4 Advantages of Rain Water Harvesting

(a) Promotes underground water recharge
(b) Mitigates drought effects
(c) Reduces soil erosion
(d) Decreases load on storm water systems
(e) Reduces flood hazards
(f) Improves groundwater quality and reduces salinity
(g) Prevents seawater intrusion in coastal areas
(h) Improves groundwater table and saves energy
(i) Lower cost compared to surface storage
(j) Aquifers act as storage and distribution systems
(k) No land displacement required
(l) Environment friendly storage
(m) Rainwater is pure and soft
(n) Can be used at place and time of need
(o) Recharged aquifers help easy water extraction
(p) Infrastructure is simple and economical

1.5 From Where to Harvest Rain Water
i. Rooftop to storage tank or recharge point
ii. Unpaved areas for direct seepage
iii. Water bodies like ponds, tanks and lakes
iv. Storm water drains for groundwater recharge

1.6 Rain Water Harvesting Potential
The total rainfall over an area is called rainwater endowment, while the usable portion is the harvesting potential. Not all rainfall can be collected due to losses like evaporation and spillage, so harvested water is always less. Collection efficiency depends on runoff coefficient and first flush losses. Runoff depends on rainfall pattern, quantity and catchment characteristics. Rainfall data over a long period (preferably 10 years) is required for estimation.



Area of catchment x Amount of rainfall = Rain water endowment

For determining the pattern of rainfall, the information may be collected either from meteorological department or locally.

The pattern of rainfall in a particular catchment area influence the design of rain water harvesting system. In areas where rainfall is more but limited to very short period in a year, big storage tanks would be required to store rain water, if we are collecting rain water in storage tanks for direct use. In such areas, it is preferable to use rain water for recharging of ground water aquifers, if feasible, to reduce the cost of rain water harvesting system.

1.2 Factors Affecting Run Off from Catchment

i. Rainfall - quantity, pattern, intensity & duration High intensity in less duration may get same quantity but may get wasted due to high surface run off due to less infiltration capacity whereas mild rainfall with long duration will help in recharging ground water.

ii. Catchment area characteristic

Unpaved surface have greater capacity of retaining rain water & similarly green patches of grass can retain large proportion of rainwater.

Runoff depends upon the area and type as well as surface of catchment over which it falls as well as surface features. Runoff can be generated from both paved and unpaved catchment areas.

Paved surfaces have a greater capacity of retaining water on the surface and runoff from unpaved surface is less in comparison to paved surface. In all calculations for runoff estimation, runoff coefficient is used to account for losses due to spillage, leakage, infiltrations catchment surface wetting and evaporation, which will ultimately result into reduced runoff. Runoff coefficient for any catchment is the ratio of the volume of water that run off a surface to the total volume of rainfall on the surface. The runoff coefficient for various surfaces is given in table 1.3.

Table 1.3 Runoff coefficients for various surfaces

S. No.	Type of catchment Roof catchments	Coefficients
1	Tiles	0.8 - 0.9
2	Corrugated metal sheets Ground surface coverings	0.7 - 0.9
3	Concrete	0.6 - 0.8
4	Brick pavement Untreated ground catchments	0.5 - 0.6
5	Soil on slopes less than 10%	0.0 - 0.3
6	Rocky natural catchments	0.2 - 0.5

Source: Pacey, Arnold and Cullis, Adrian 1989, Rain water Harvesting: The collection of rainfall and runoff in rural areas, Intermediate Technology Publications, London pg-55.

Based on the above factors, the water harvesting potential of site could be estimated using the following equation:

Rain Water harvesting potential = Amount of Rainfall x Area of catchment x Runoff coefficient The calculation for runoff can be illustrated using the following example:

Consider a building with flat terrace area (A) of 100 sqm located in Delhi.

The average annual rainfall (R) in Delhi is approximately 611mm. The runoff coefficient (C) for a flat terrace may be considered as 0.85.

Annual water harvesting potential from 100

= A x R x C

= 100 x 0.611 x 0.85

= 51.935 cum,

i.e. 51,935 liters

1.3 Important Points Relating to Water Storage and Recharging

i. It is estimated that only 10 to 25% of rain water is utilized to charged ground water but artificially with rain water harvesting, it can be charged upto 50% (para 2.6.3 of manual

of rain water harvesting & conservation - Govt of India)

ii. Settlement tank need to be constructed in area. This helps in two ways, it arrests silt & floating impurities and secondly allow standing water to percolate in to soil to finally recharge ground water. Apart from the removing silt from desilting chamber, it act like a buffer in case of excess rain fall to arrest surface run off & store excess water. Its size can be decided on the basis of size of catchment, intensity of rain fall & rate of recharge depend on geological data like porosity, permeability etc of area.

CHAPTER - 2
METHODS OF HARVESTING RAIN WATER

2.1 Rain Water Harvesting Methods

There are three methods of harvesting rain water as given below:

(a) Storing rain water for direct use (Fig. 2.1)

(b) Recharging ground water aquifers, from roof top run off (Fig. 2.2)

(c) Recharging ground water aquifers with runoff from ground area (Fig. 2.3)

2.1.1 Storing rain water for direct use

In place where the rains occur throughout the year, rain water can be stored in tanks (Fig. 2.1). However, at places where rains are for 2 to 3 months, huge volume of storage tanks would have to be provided. In such places, it will be more appropriate to use rain water to recharge ground water aquifers rather than to go for storage. If the strata is impermeable, then storing rain water in storage tanks for direct use is a better.

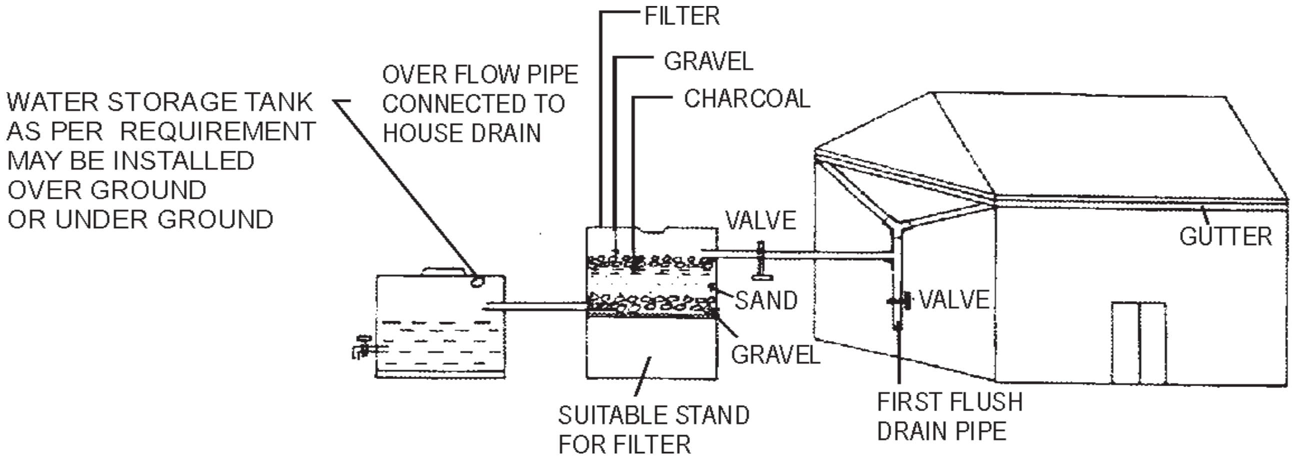


Fig. 2.1 Storing rain water for direct use method.

Similarly, if the ground water is saline/unfit for human consumption or ground water table is very deep, this method of rain water harvesting is preferable.

2.1.2. Recharging ground water aquifers from roof top run off

Rain water that is collected on the roof top of the building may be diverted by drain pipes to a filtration tank (for bore well, through settlement tank) from which it flows into the recharge well, as shown in Fig.2.2. The recharge well should preferably be shallower than the water table. This method of rain water harvesting is preferable in the areas where the rainfall occurs only for a short period in a year and water table is at a shallow depth. The various methods of recharging ground water aquifers from roof top runoff are discussed separately in Chapter 3.

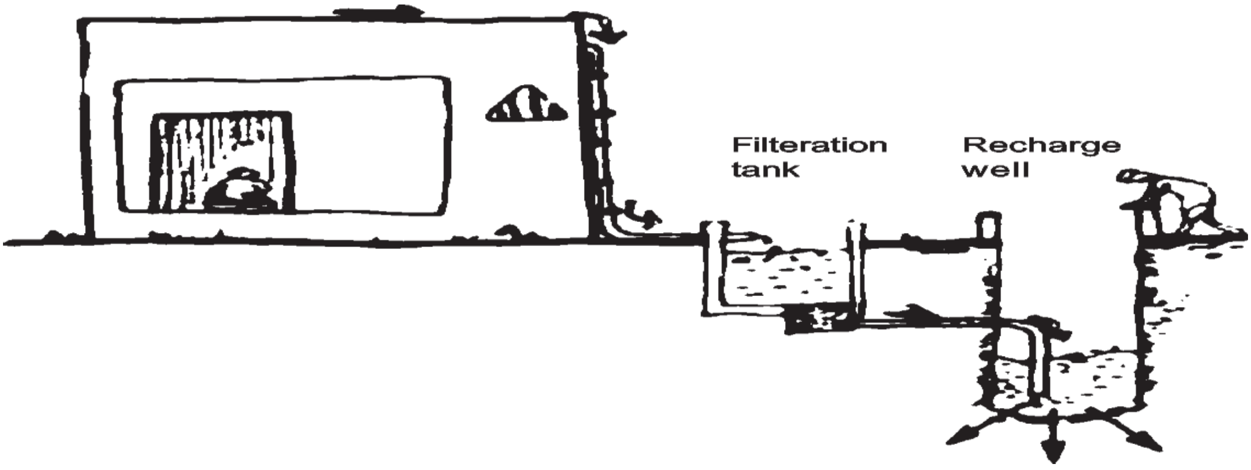


Fig. 2.2 Recharging ground water aquifers from roof top run off.

2.1.3 Recharging ground water aquifers with runoff from ground areas

The rain water that is collected from the open areas may be diverted by drain pipes to a recharge dug well / bore well through filter tanks as shown in Fig.2.3. The abandoned bore well/dug well can be used cost effectively for this purpose. The various methods

of recharging ground water aquifers with runoff from ground areas are discussed separately in Chapter 3.

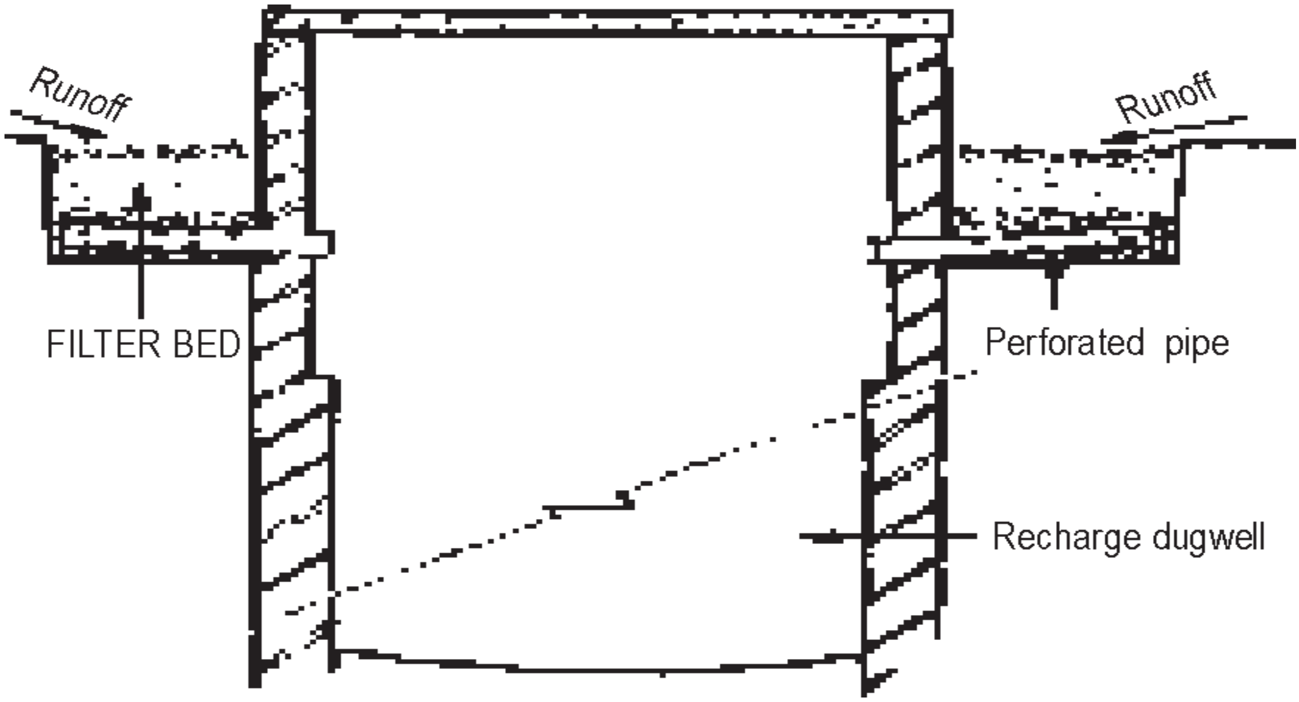


Fig. 2.3 Recharging ground water aquifers with runoff from ground areas.

2.1.4 Modular Rain Water Harvesting System

Modular Tank System is a subsurface water infiltration storage for storm water control and management system and hence known as modular rain water storage harvesting system and subsoil drainage It is efficient, cost effective and ecologically sustainable.

Its main function of modular tank is to allow on site natural water infiltration and this prevents surface runoff. This underground system is best suited for flat ground area for rainwater harvesting and storm water management.

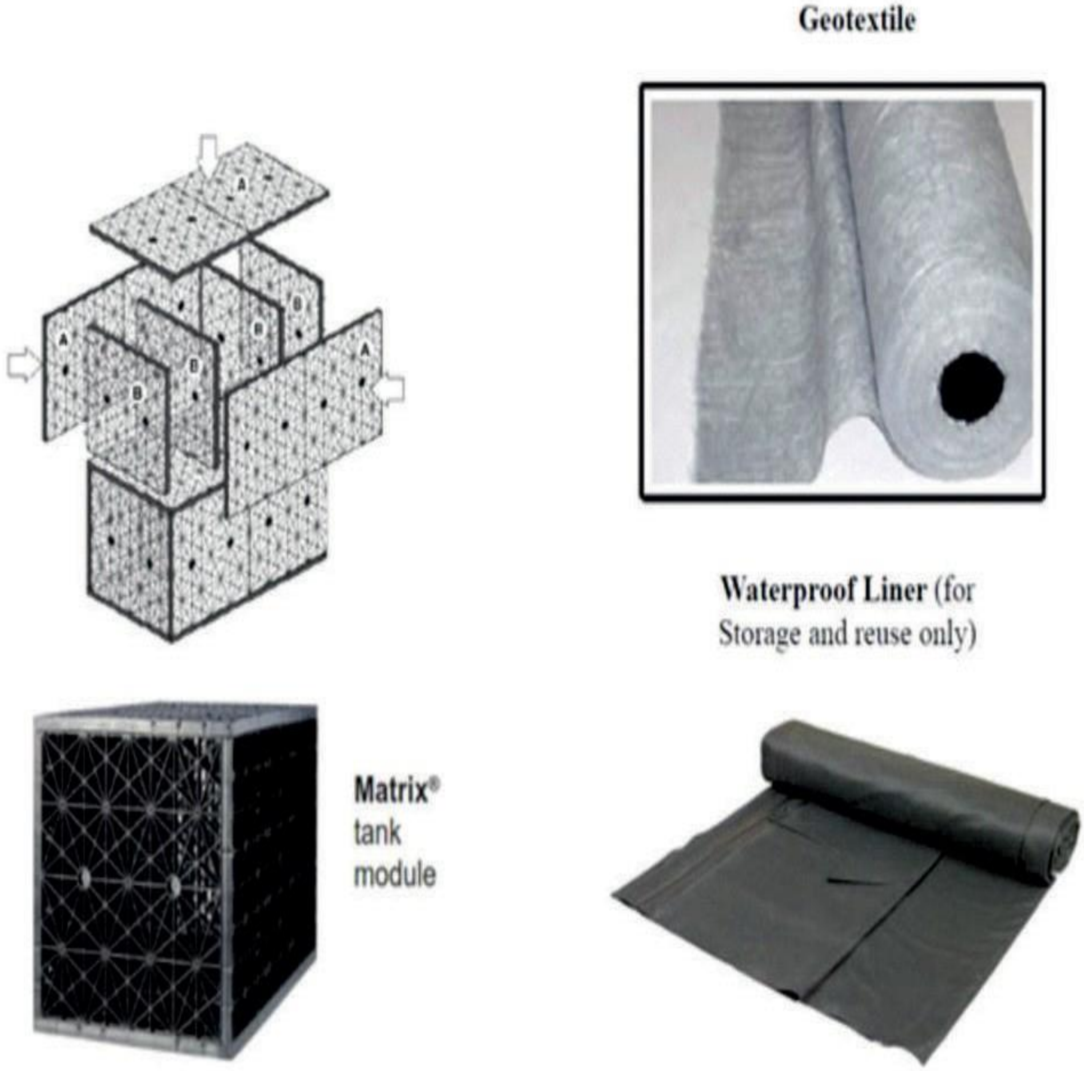
This system can be used to hold any volume of water. These systems are built out of modular plastic cubes. They are arranged to appropriate sizes, then wrapped in a liner and covered with soil and GI sheets. This allows the storm water to be managed underground and can be easily integrated into landscaping. This helps in creating load bearing void spaces for underground water storage. Modular boxes are made up of recycled plastics. These modules are 95 percent voids and are strong enough for vehicular traffic and parking.

Runoff water from surface and roof tops would be channelized to filtration unit. Filtration unit should consist of:

1) Sedimentation tank
2) Filtration through microfilters of FRP tank and similar arrangements
3) Sand filter with geotextile layer at the top.

Water would then be taken to modular rain water storage or similar arrangement as per site feasibility. (Fig. 2.4 (a), (b), (c))

FRP (or similar materials) Tank with micro-filter (Geotextile)



Materials used In Modular Tank

Fig. 2.4 (a)

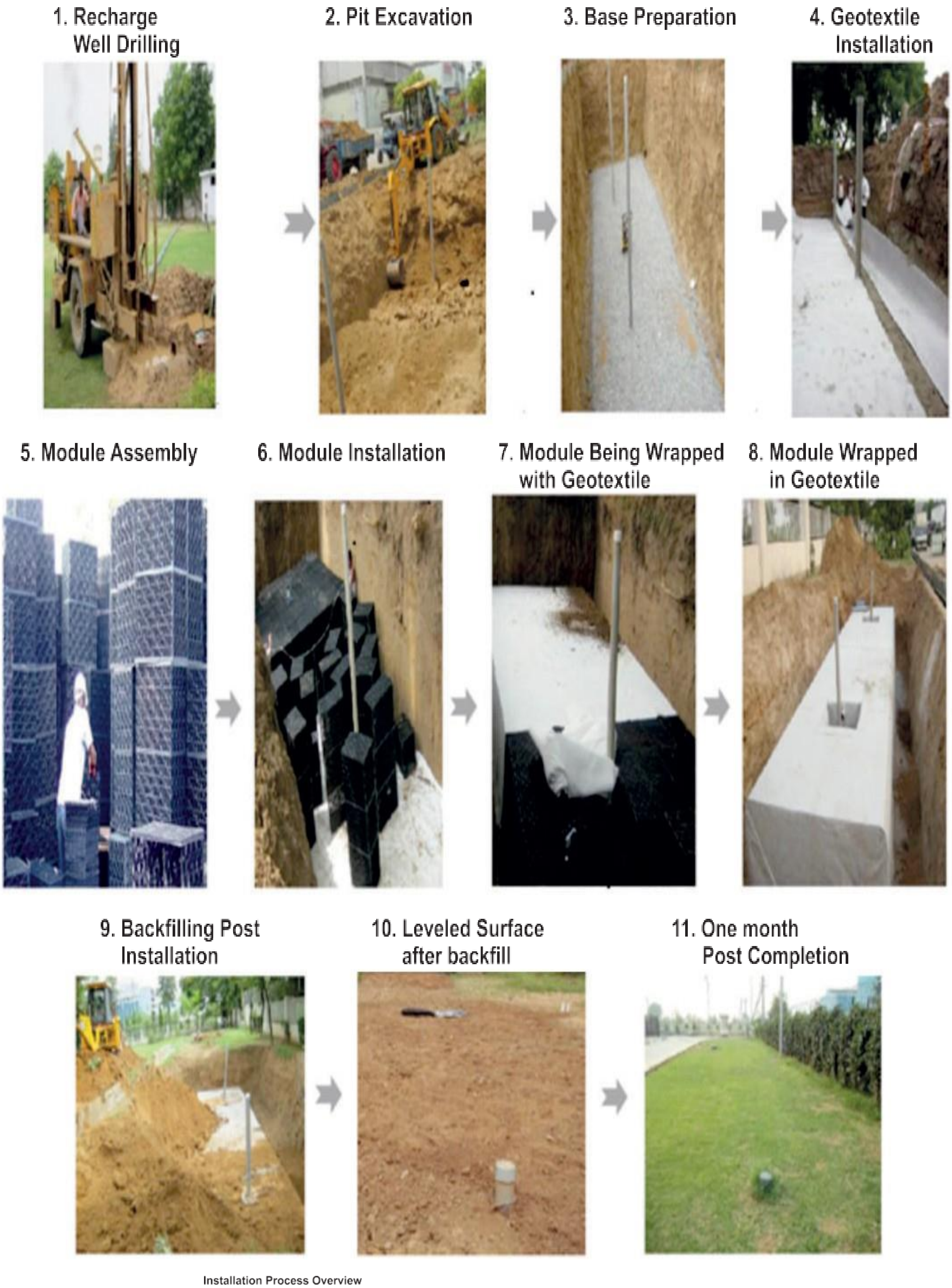
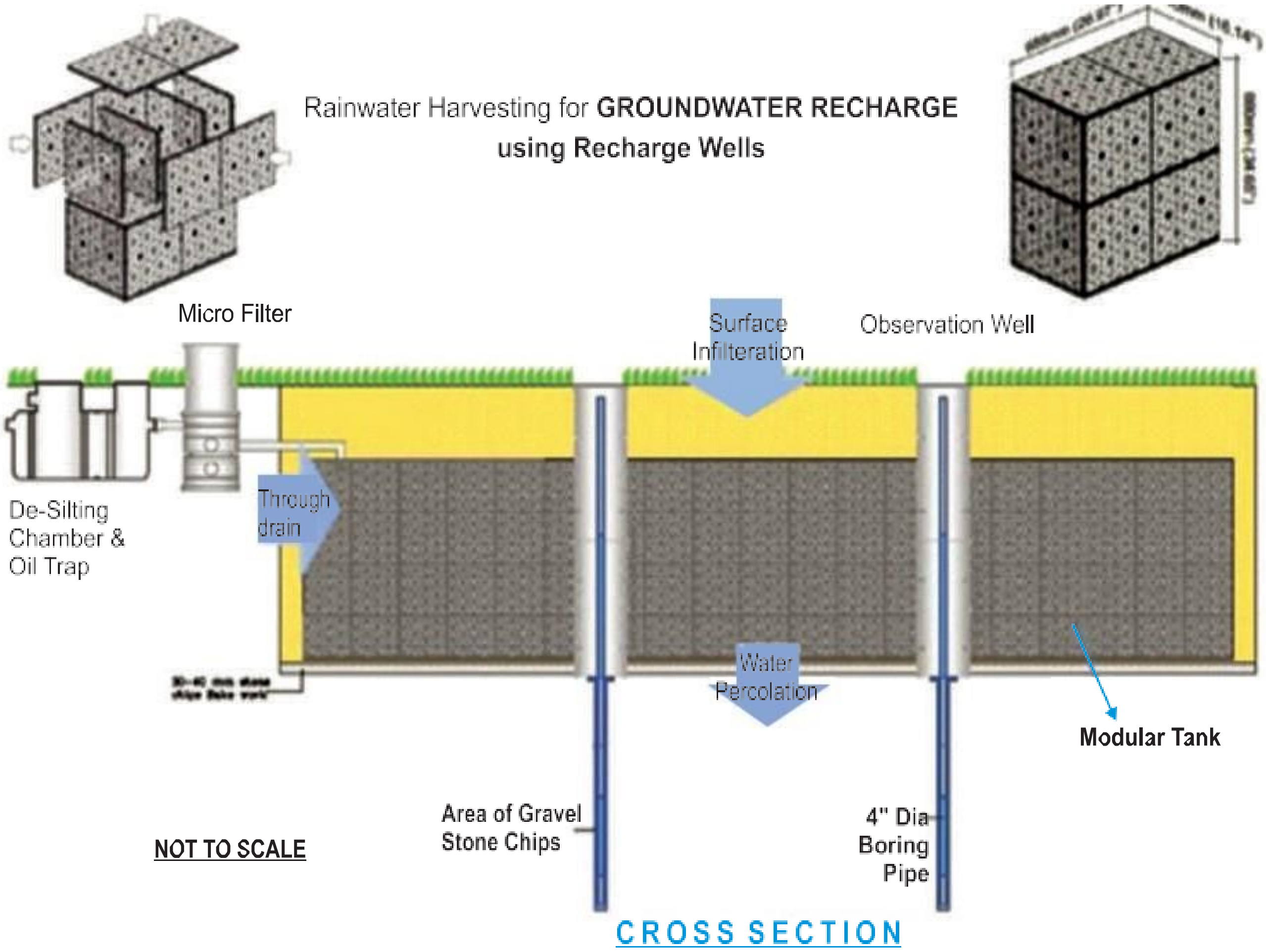

1. Recharge Well Drilling
2. Pit Excavation
3. Base Preparation
4. Geotextile Installation
5. Module Assembly
6. Module Installation
7. Module Being Wrapped with Geotextile
8. Module Wrapped in Geotextile
9. Backfilling Post Installation
10. Leveled Surface after backfill
11. One month Post Completion
Installation Process Overview

Fig. 2.4 (b)



Flexible Application of Modular Technology

Step - 1

De-Silting Chamber / Oil Filter

- Designed for any flow situations
- Pre-manufactured, short time of installation
- Designed for **easy and low cost maintenance**

Step - 2

Patented Micro-Filter

Easy Maintenance

- Removes particles up to 180microns in size
- Suitable for flow situations of 72 cum/hr
- Pre-manufactured, short time of installation
- **Extremely easy to maintain - at little or no cost**

Fig. 2.4 (c)

Courtesy: CPWD Rainwater Harvesting and Conservation Manual 2019

2.2 Components of Rain Water Harvesting

The rain water harvesting system consists of following basic components –

(a) Catchment area
(b) Coarse mesh / leaf screen
(c) Gutter
(d) Down spout or conduit
(e) First flushing device
(f) Filter
(g) Storage tank
(h) Recharge structure

2.2.1 Catchment area

The catchment area is the surface on which the rain water falls. This may be a roof top or open area around the building. The quality of water collected from roof top is comparatively much better than collection from the ground. Rain water harvested from catchment surfaces along the ground should be used for lawn watering, flushing etc., because of increased risk of contamination. This water can also be used for recharging ground aquifers after proper filtration.

The rain water yield varies with the size and texture of the catchment area. A smooth, cleaner and more improvised roofing material contributes to better water quality and greater quantity with higher value of runoff coefficient. (refer table 1.3 for runoff coefficient)

When roof of the house is used as the catchment for collecting the rain water, the type of roof and the construction material affect the runoff coefficient and quality of collected water. Roofs made of RCC, GI sheets, corrugated sheets, tiles etc. are preferable for roof top collection. But thatched roofs are not preferred as these add color and dissolved impurities to water. Water to be used for drinking purpose should not be collected from roof with damaged AC sheets or from roofs covered with asphalt and lead flashing or lead based paints as the lead contamination may occur in the collected water.

2.2.2 Coarse mesh / leaf screen

To prevent the entry of leaves and other debris in the system, the coarse mesh should be provided at the mouth of inflow pipe for flat roofs as shown in Fig. 2.5.

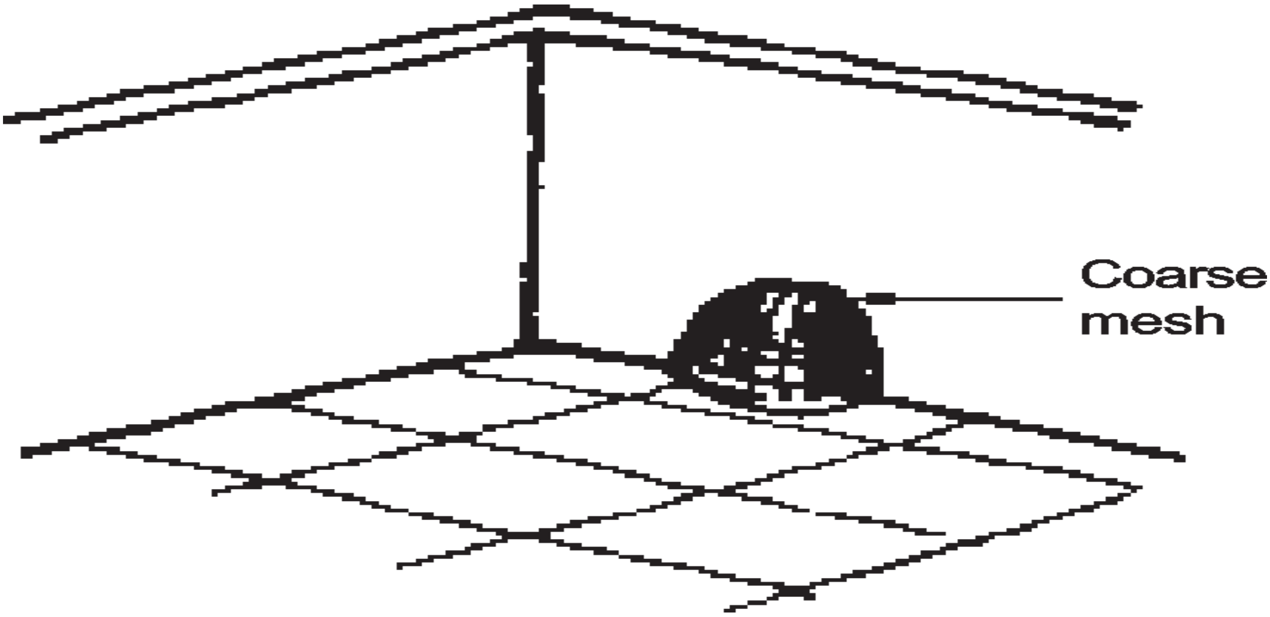


Fig. 2.5 Coarse mesh

For slope in roofs where gutters are provided to collect and divert the rain water to downspout or conduits, the gutters should have a continuous leaf screen, made of ¼ inch wire mesh in a metal frame, installed along their entire length, and a screen or wire basket at the head of the downspout (Fig. 2.6).

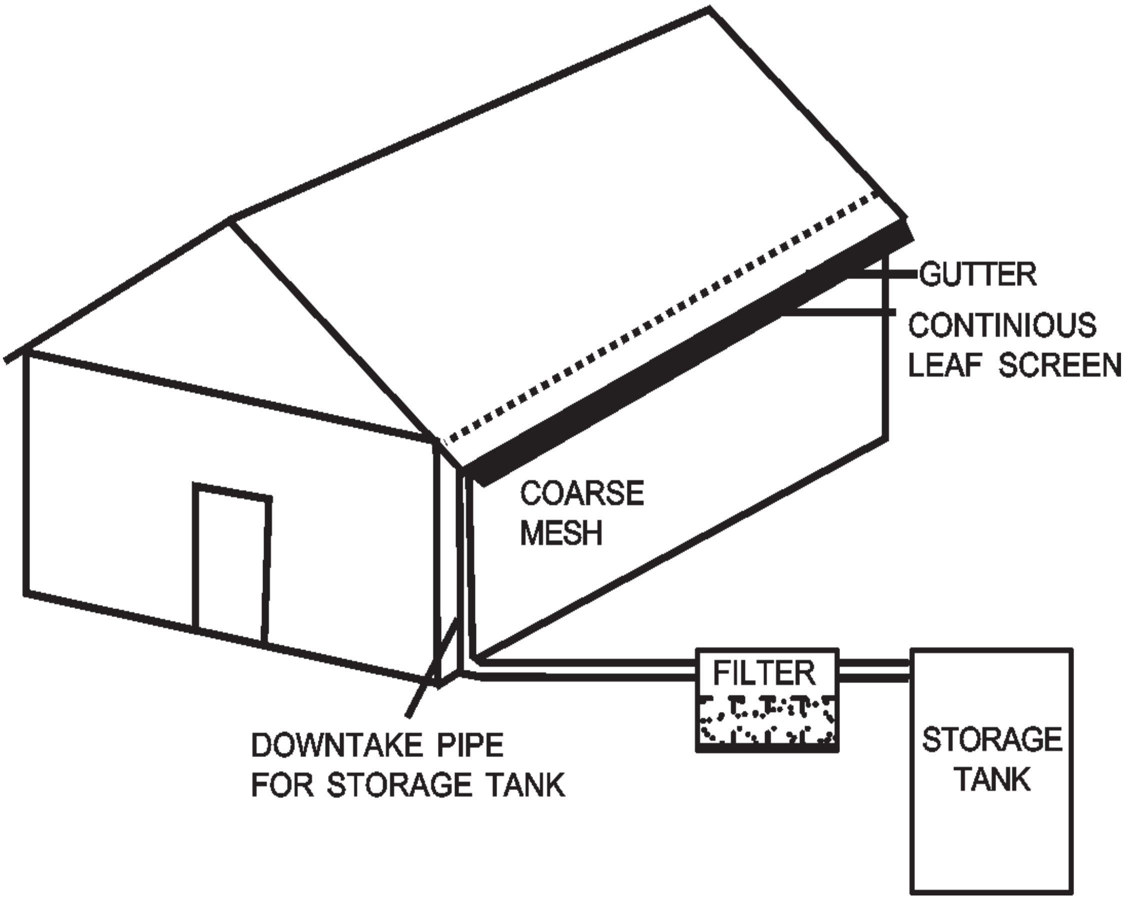


Fig. 2.6 Leaf screen

2.2.3 Gutter

Gutter is required to be used for collecting water from sloping roof and to divert it to downspout. These are the channels all around the edge of a sloping roof to collect and transport rain water to the storage tank. Gutters can be of semi-circular, rectangular or trapezoidal shape. Gutters must be properly sized, sloped and installed in order to maximize the quantity of harvested rain. Gutter can be made using any of the following materials:

(a) Galvanized iron sheet

(b) Aluminum sheet

(c) Semi-circular gutters of PVC material which can be readily prepared by cutting these pipes into two equal semicircular channels

(d) Bamboo or betel trunks cut vertically in half (for low cost housing projects)

The size of the gutter should be according to the flow during the highest intensity rain. The capacity of the gutters should be 10 to 15% higher. The gutters should be supported properly so that they do not sag or fall off when loaded with water. The connection of gutters and down spouts should be done very carefully to avoid any leakage of water and to maximize the yield. For jointing of gutters, the lead based materials should not be used, as it will affect the quality of water.

2.2.4 Down spout / conduit

The rain water collected on the roof top is transported down to storage facility through down spouts / conduits. Conduits can be of any material like PVC, GI or cast iron. The conduits should be free of lead and any other treatment which could contaminate the water. Table 2.1 gives an idea about the diameter of pipe required for draining out rain water based on rainfall intensity and roof area.

Table 2.1 Sizing of Rainwater pipes for Roof Drainage in mm/ hr.

Diameter of pipe (in mm)	Roof area in sqm for Average rate of rain fall (in mm/hr.)					
	50	**75**	**100**	**125**	**150**	**200**
50	29.70	19.80	14.85	11.88	9.90	7.42
65	57.23	38.15	28.61	22.89	19.08	14.31
75	81.84	54.56	40.92	32.74	27.28	20.46
100	168	112	84	67.20	56	42
125	293.48	195.66	146.74	117.39	97.83	73.37
150	462.95	308.64	231.48	185.18	154.32	115.74

Note: For Rainwater pipes of other materials, the Roof area shall be multiplied by (0.013/co-efficient of roughness of surface of that material)

Source: National Building Code -2016

2.2.5 First flushing device

Roof washing or the collection and disposal of the first flush of water from a roof, is very important if the collected rain water is to be used directly for human consumption. All the debris, dirt and other contaminants especially bird dropping etc. accumulated on the roof during dry season are washed by the first rain and if this water will enter into storage tank or recharge system it will contaminate the water. Therefore, to avoid this contamination a first flush system is incorporated in the roof top rain water harvesting system. The first flushing device, dispose off the first spell of rain water so that it does not enter the system. If the roof is of sloping type, then the simplest system consists of a pipe and a gutter down spout located ahead of the down spout from the gutter to the storage tank. (Fig. 2.7)

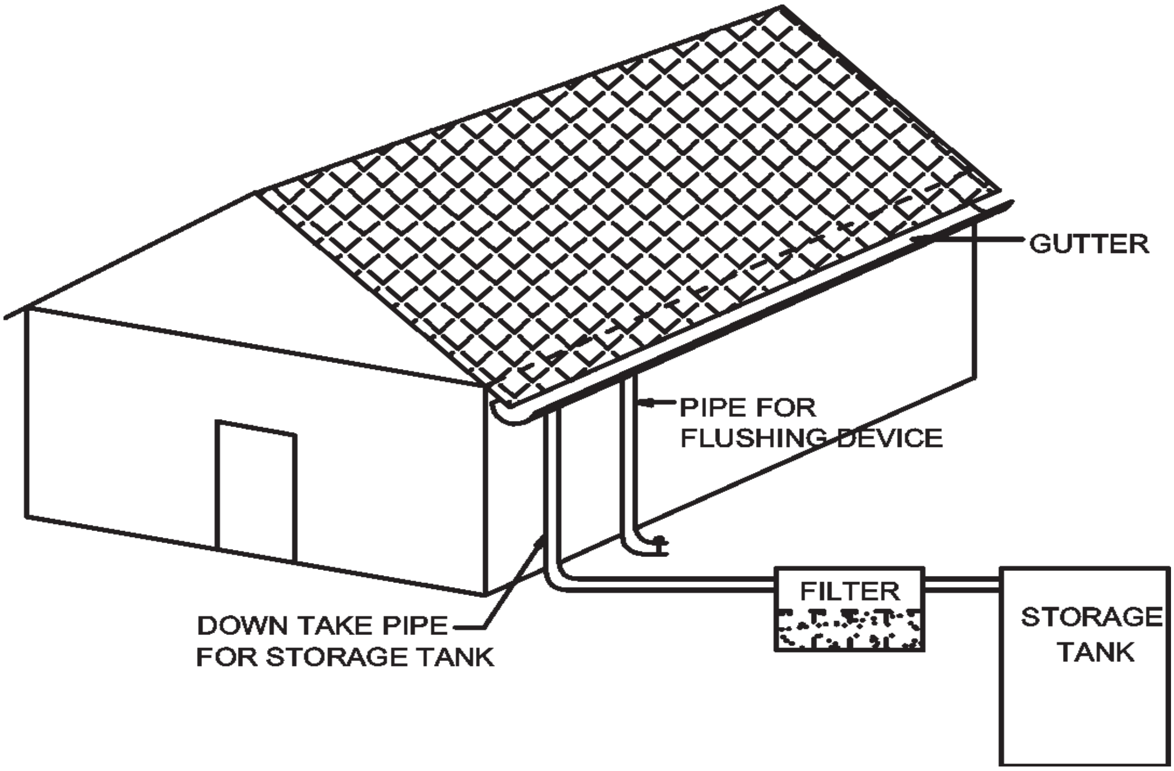


Fig. 2.7 First flushing device

The pipe is usually 6 or 8 inch PVC pipe which has a valve and cleanout at the bottom, most of these devices extend from the gutter to the ground where they are supported. The gutter down spout and top of the pipe are fitted and sealed so that water will not flow out of the top. Once the pipe has filled, the rest of the water flows to the downspout connected to storage tank. The alternate scheme for sloping roof is shown in Fig. 2.8.

This involves a very simple device which is required to be operated manually. In down take pipe at the bottom one plug/ valve is provided. When the rainy season start, this plug should be removed, and initial collection of roof top water should be allowed to drain. After 15 – 20 minutes, plug / valve should be closed so that collected rain water can be diverted to storage tank.

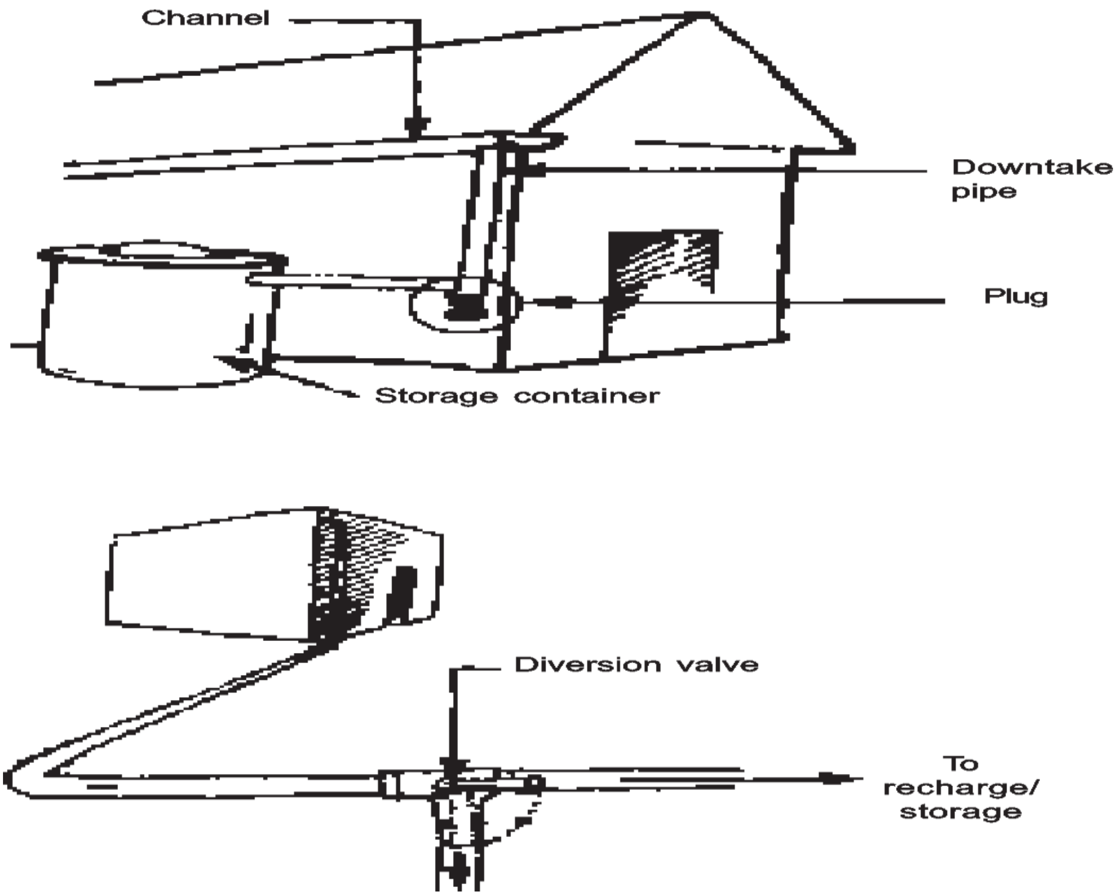


Fig. 2.8 First flushing device.

2.2.6 Filter

If the collected water from roof top is to be used for human consumption directly, a filter unit is required to be installed in RWH system before storage tank. The filter is used to remove suspended pollutants from rain water collected over roof. The filter unit is basically a chamber filled with filtering media such as fiber, coarse sand and gravel layers to remove debris and dirt from water before it enters the storage tank. The filter unit should be placed after first flush device but before storage tank. There are various type of filters which have been developed all over the

country. The type and selection of filters is governed by the final use of harvested rain water and economy. Depending upon the filtering media used and its arrangements, various types of filters available are described below.

2.2.6.1 Sand filter

In the sand filters, the main filtering media is commonly available sand sandwiched between two layers of gravels. The filter can be constructed in a galvanized iron or ferro cement tank. This is a simple type of filter which is easy to construct and maintain. The sand fillers are very effective in removing turbidity, color and microorganism. In a simple sand filter that can be constructed domestically, filter media are placed as shown in Fig. 2.9.

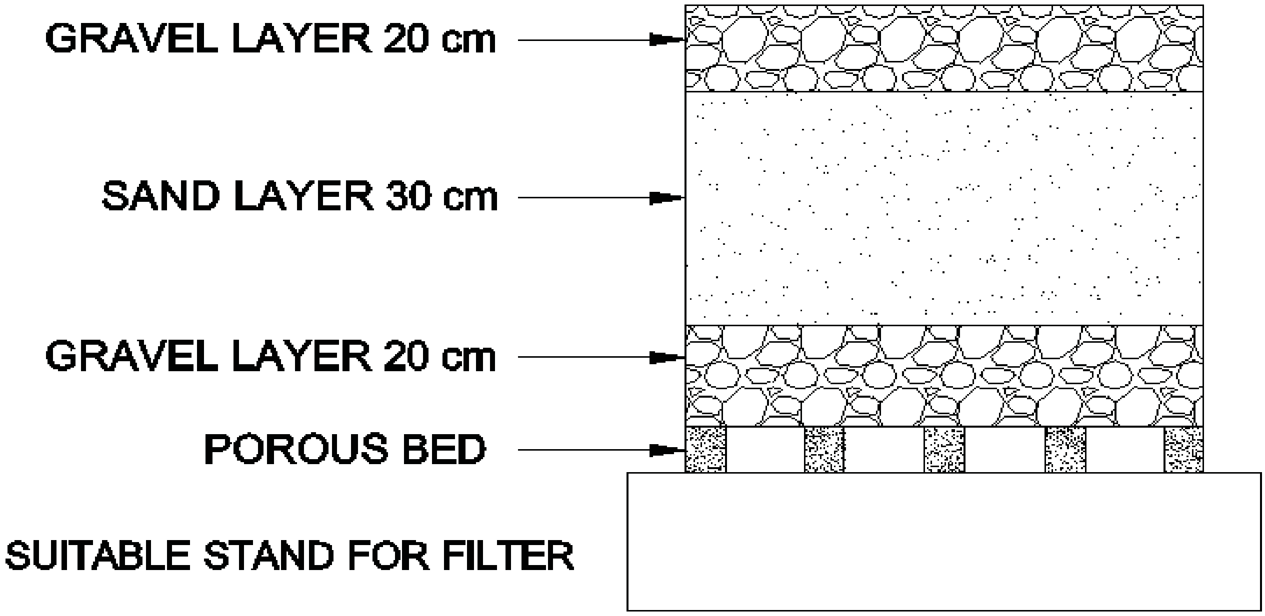


Fig. 2.9 Sand filter

2.2.6.2 Charcoal water filter

This is almost similar to sand filter except that a 10-15 cm thick charcoal layer placed above the sand layer. Charcoal layer inside the filter result into better filtration and purification of water. The commonly used charcoal water filter is shown in Fig. 2.10

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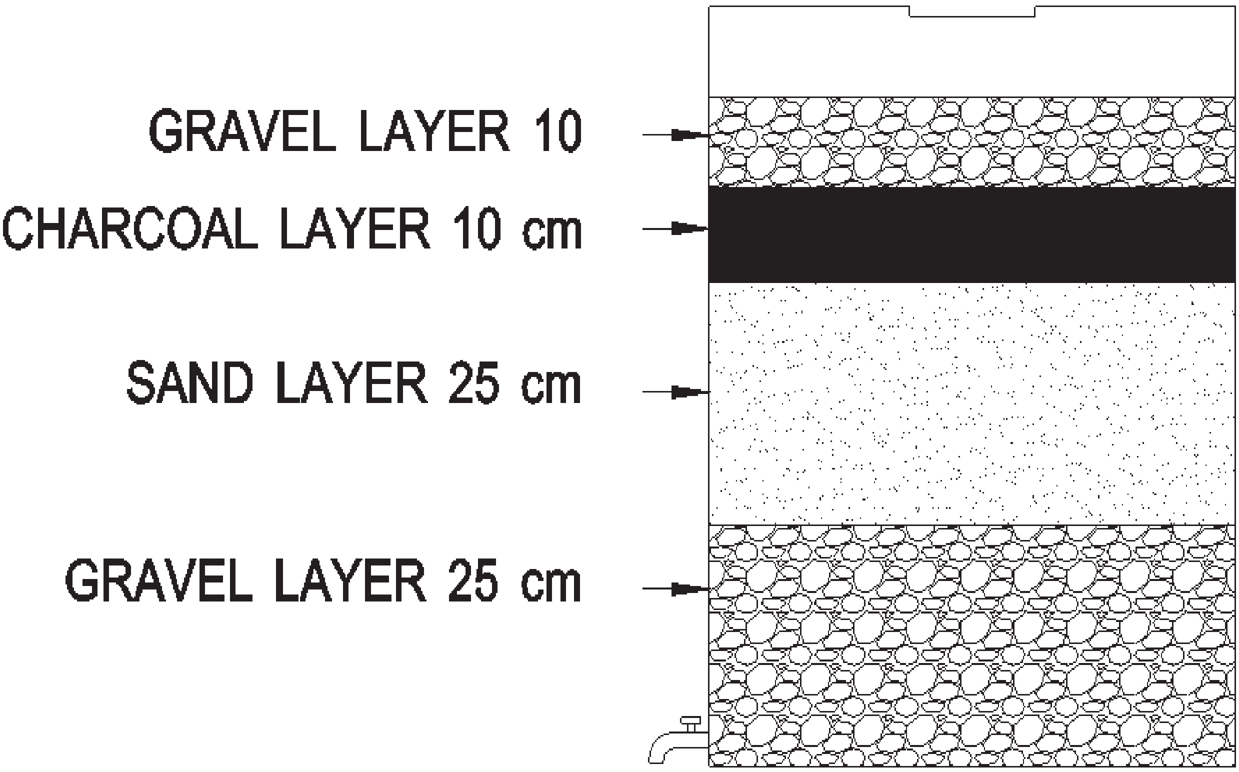


Fig. 2.10 Charcoal water filter

2.2.6.3 Dewas filter

This filter was developed by officials of Rural Engineering Services of Dewas. In Dewas, the main source of water supply is wells which are used to extract ground water for supply of water. Because of regular extraction of ground water, the water table is going down rapidly. To recharge the ground water, all the water collected from the roof top is collected and passed through a filter system called the Dewas filter (Fig. 2.11). The filtered water is finally put into service tube well for recharging the well.

The filter consists of a PVC pipe 140mm in diameter and 1.2m long. There are three chambers. The first purification chamber has pebbles of size varying between 2-6 mm, the second chamber has slightly larger pebbles between 6 to 12 mm and the third chamber has largest 12 – 20mm pebbles. There is a mesh on the out-flow side, through which clean water flows out after passing through the three chambers. This is one of the most popular filter types being used in RWH systems.

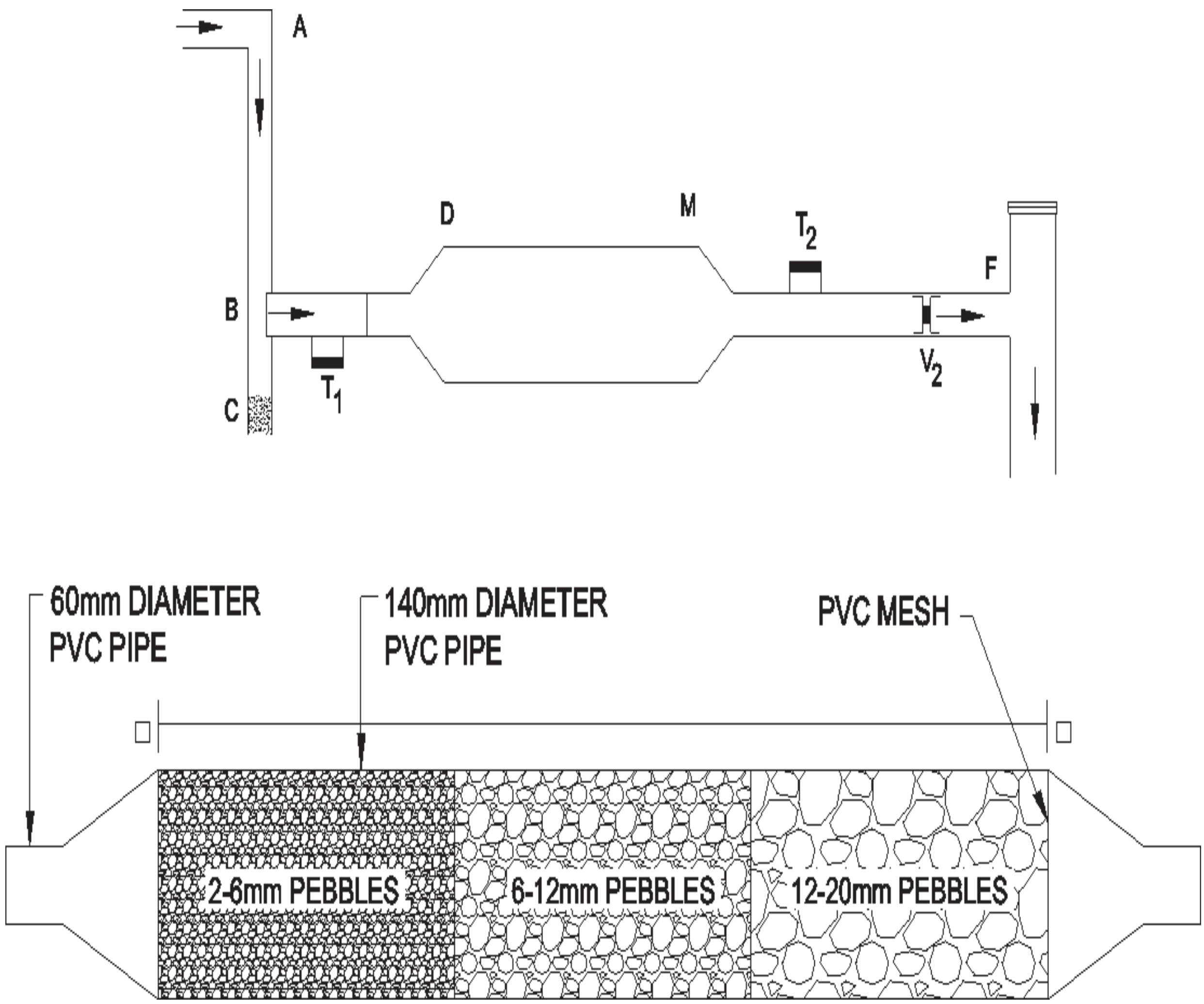


Fig. 2.11 Dewas filter

2.2.6.4 Varun

This filter has been developed by Shri S. Viswanath; a Bangalore based water harvesting expert. “Varun” is made from 90 lit. High Density Poly Ethylene (HDPE) drum. The lid is turned over and holes are punched in it.(Fig. 2.11) The punched lid acts as a sieve which keeps out large leaves, twigs etc. Rain water coming out of the lid sieve then passes through three layers of sponge and 150mm thick layer of coarse sand. Because of sponge layers, the cleaning of filter becomes very easy. The first layer of sponge can be removed and cleaned very easily in a bucket of water. Because of the layers of sponge, the sand layer does not get contaminated and does not require any back washing / cleaning. This filter can handle about 50mm per hour intensity rain fall from a 50 sqm roof area.

Fig. 2.12 Varun

2.2.6.5 Horizontal roughening filter and slow sand filter

This is one of the most effective filters for purification of water being used in coastal areas of Orissa. The horizontal roughening filter (HRF) acts as a physical filter and is applied to retain solid matter, while slow sand filter (SSF) is primarily a biological filter, used to kill microbes in the water. The water is first passed through the HRF and then through SSF.

The HRF usually consists of filter material like gravel and coarse sand that successively decrease in size from 25mm to 4mm. The bulk of solids in the incoming water is separated by this coarse filter media or HRF. The filter channel consists of three uniform compartments, the first packed with broken bricks, the second with coarse sand followed by fine sand in the third compartment. At every outlet and inlet point of the channel, fine graded mesh is implanted to prevent entry of finer material into the sump. The length of each channel varies accordingly to the nature of the site selected for the sump (Fig. 2.13).

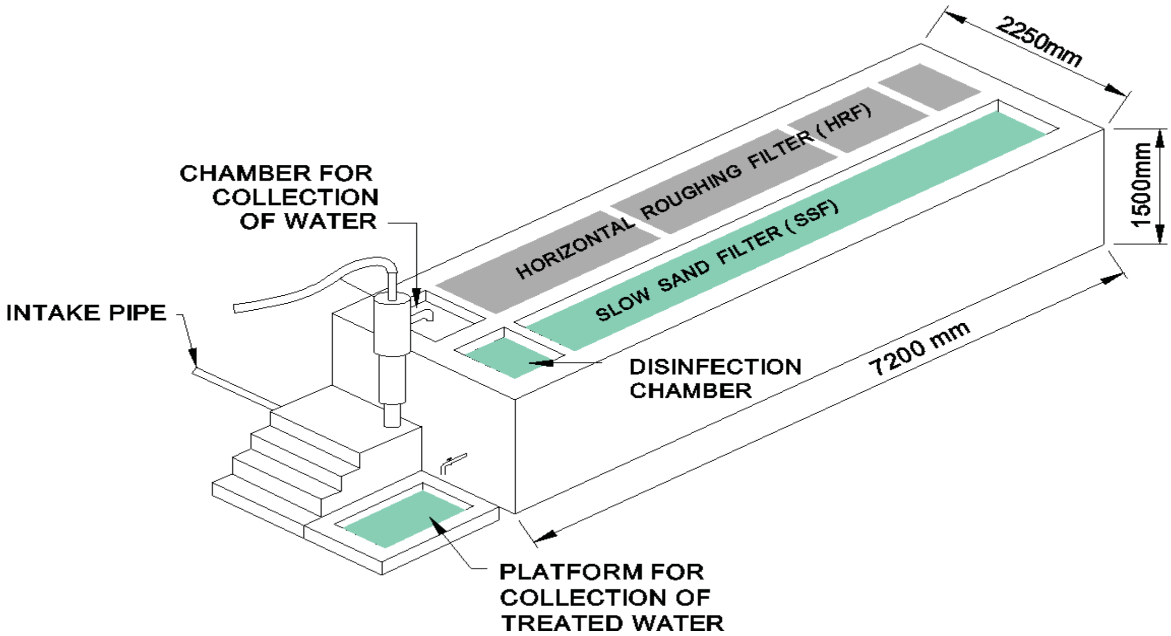


Fig. 2.13 Horizontal roughening filter and slow sand filter

The slow sand filter (SSF) consists of fine sand in a channel of size one sqm in cross section and eight meter in length, laid across the tank embankment. The water after passing through SSF is stored in a sump. From this sump water can be supplied through pipe line or can be extracted through hand pump.

Wherever the roof top area is very large, the filters of high capacity are designed to take care of excess flow. For large roof tops, a system is designed with three concentric circular chambers in which outer chamber is filled with sand, the middle one with coarse aggregate and the inner most layer with pebbles (Fig. 2.14). Since the sand is provided in outer chamber, the area of filtration is increased for sand, in comparison to coarse aggregate and pebbles. Rain water reaches the center core and is collected in the sump where it is treated with few tablets of chlorine and is made ready for consumption.

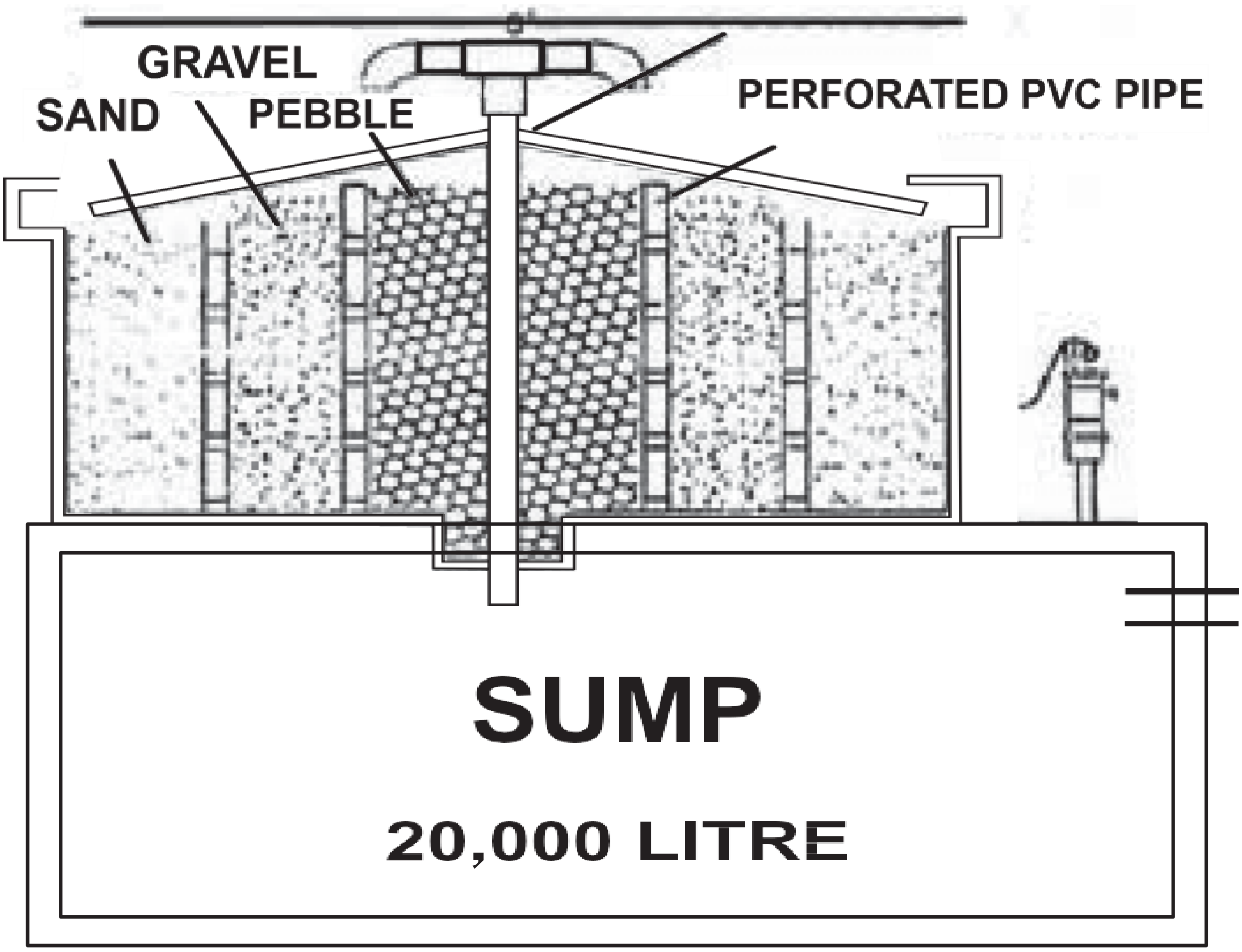


Fig. 2.14 Filter for large roof top

2.2.6.6 Rain water purification center

This filter has been developed by three Netherlands based companies for conversion of rain water to drinking water and is popularly known as Rain PC. Rain PC is made of ultra violet

resistant poly-ethylene housing and cover, stainless steel rods and bolts, a nickel-brass valve and an adapter for maintaining constant volume (Fig. 2.15).

This filter can effectively remove E-coli and other bacteria from water using Xenotex-A and active carbon cartridges along with ultra-membrane filtration modules. This filter is easy to operate and maintain and needs no power. This operates at low gravity pressure and maintains nearly constant volume irrespective of water pressure. The system is capable of providing a constant flow of about 40 lit. of rain water per hour. The Xenotex- A and activated carbon cartridges processes up to 20,000 liters of water and can be regenerated up to 10 times

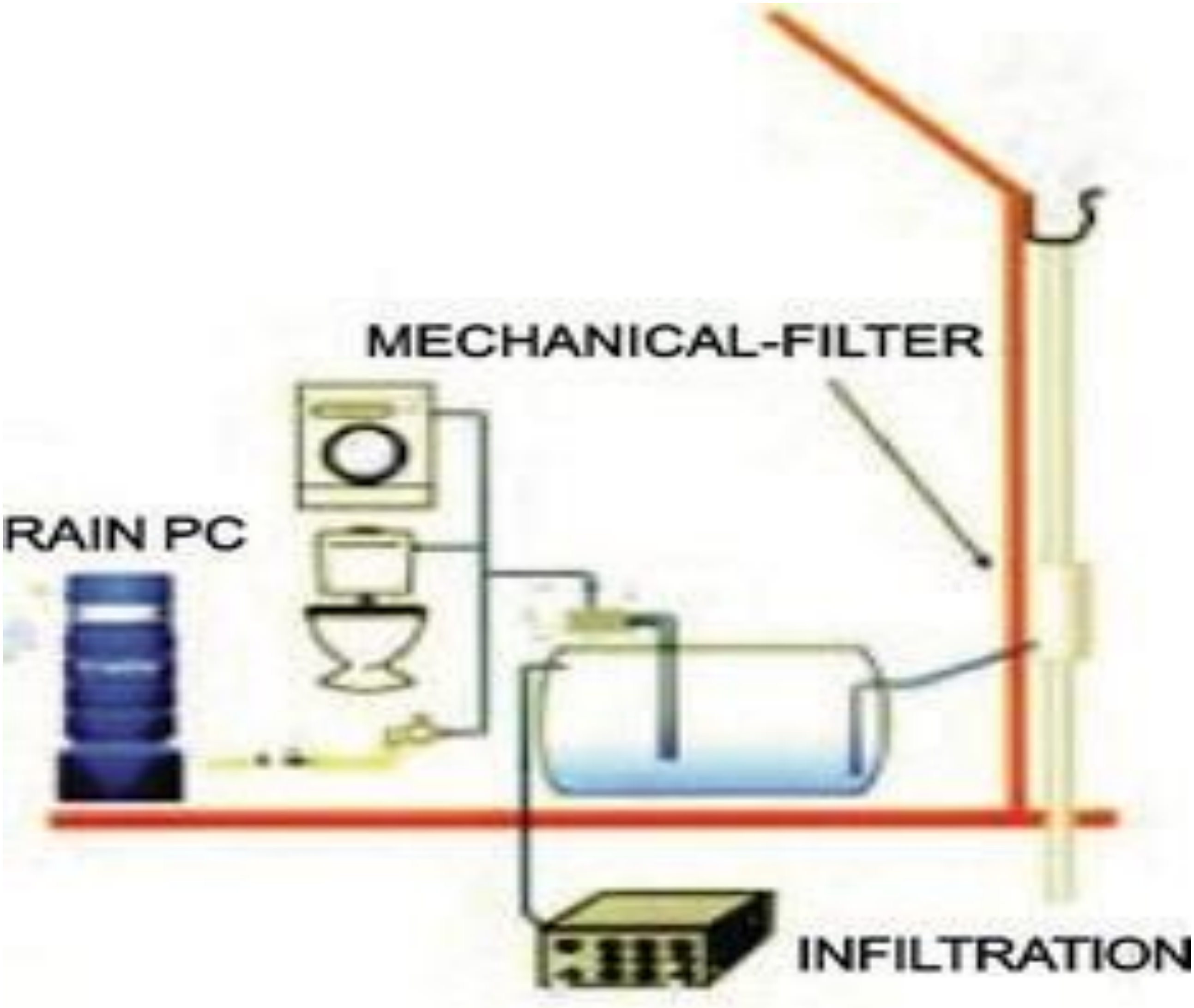


Fig. 2.15 Rain water purification center

2.2.7 Settlement tank

If the collected rain water from roof top / ground is used to recharge ground water reserve, it should be passed through a desilting pit/ settlement tank before entering the aquifer. The settlement tank facilitates the settling down of suspended material
i.e. silt and other floating impurities before the water recharge the aquifer. The settlement tank should have inlet, outlet and overflow device. Any container with adequate capacity of storage can be used as settlement tank. It can be either underground or over ground.

The settlement tank acts like a buffer in the system. In case of excess rainfall, the rate of recharge, especially of borewells, may not match the rate of rainfall. In such situations, the desilting chamber holds the excess amount of rain water, till it is soaked by recharge structures. The settlement tank can be prefabricated PVC or Ferro-cement tanks, masonry and concrete tanks (Fig. 2.16). In case of underground settlement tank, the bottom can be unpaved surface so that water can percolate through soil.

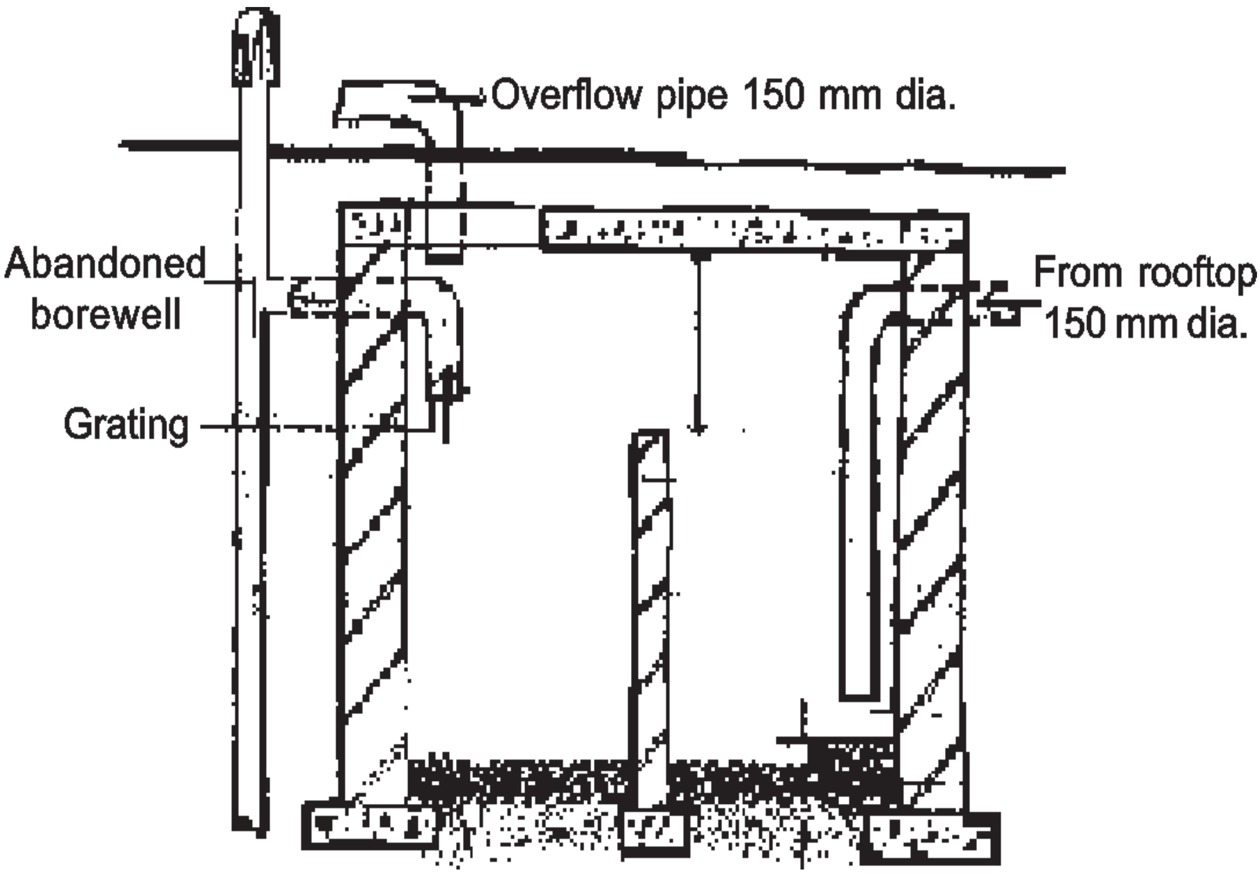


Fig. 2.16 Settlement tank

For designing the optimum capacity of the settlement tank, the following parameters need to be considered –

(a) Size of the catchment

(b) Intensity of rain fall

(c) Rate of recharge

The capacity of the tank should be enough to retain the runoff occurring from conditions of peak rainfall intensity. The rate of recharge in comparison to runoff is a critical factor. The capacity of recharge tank is designed to retain runoff from at least 15 minutes of rainfall of peak intensity.

For example, for Delhi peak hourly rainfall is 90mm (based on 25-year frequency) and 15 minutes peak rainfall is 22.5 mm say 25mm.

Area of roof top catchment (A) = 100 sqm. Peak rain falls in 15 min

(r) = 25mm (0.025m) Runoff coefficient (C) = 0.85

Then, capacity of settlement tank = A x r x C

= 100 x 0.025 x 0.85

= 2.125 cum

or 2,125 liters

2.2.8 Storage tank

Whenever the rain water collected from roof top is used directly for various purposes, storage tank is required. The storage tank can be cylindrical, rectangular or square in shape. The material of construction can be RCC, ferrocement, masonry, PVC or metal sheets. Depending upon the availability of space, the storage tank can be above ground, partially underground or fully underground. The design of storage tank is dependent on many factors which are listed below:

(a) Number of persons in the household – The greater the number of persons, more will be requirement of water.

(b) Per capita requirement – varies from household to household, based on standard of living. The requirement also varies with season. In summer the requirement is more in comparison to winter. Similarly, the per capita requirement is more in urban areas in comparison to rural areas.

(c) Average annual rainfall.

(d) Rainfall pattern – It has a significant impact on capacity of storage tank. If the rainfall is uniformly spread throughout the year, the requirement of storage capacity will be less. But if the rainfall is concentrated to a limited period in a year, the storage tanks of higher capacity will be required.

(e) Type and size of catchment – Depending upon the type of roofing material, the runoff coefficient varies which affect the effective yield from a catchment area. The size of the catchment also has a bearing on tank size. The more the catchment area, larger the size of storage tank.

The design of the storage tank, can be done using following three approaches:

(a) Matching the capacity of the tank to the area of the roof.

(b) Matching the capacity of the tank to the quantity of water required by its users.

(c) Choosing a tank size that is appropriate in terms of costs, resources and construction methods.

2.2.8.1 Matching the capacity of the tank with the area of the roof

In this approach, storage capacity of the tank is determined, based on the actual catchment area and total rain water harvesting potential. All the water collected from roof top is stored in storage tank and storage capacity is calculated based on the consumption pattern and rainfall pattern.

Illustration – Suppose the storage tank has to be designed for 200 sqm roof area in Chennai area where average annual rainfall is 1290mm. The runoff coefficient for roof top is 0.85, so for every 1mm rainfall, the quantity of water which can be harvested is 200 x 0.001 x 0.85 = 0.170m3 or 170 liters.

The monthly consumption of water is 20,000 liters. Table 2.2 given below illustrates the method of calculation of required storage capacity of the tank.

Table 2.2 Calculation of capacity of storage tank

Month	Monthly Rain fall in mm	Rain fall Harvested in liters	Cumulative rain fall harvested	Monthly Demand in liters	Cumulative	Difference between (4) & (6)
(1)	(2)	(3)	(4)	(5)	(6)	(7)
July	98	16660	16660	20000	20000	-3340
Aug	136	23120	39780	20000	40000	-220
Sept.	122	20740	60520	20000	60000	520
Oct.	282	47940	108460	20000	80000	28460
Nov.	354	60180	168640	20000	100000	68640
Dec.	141	23970	192610	20000	120000	72610
Jan.	30	5100	197710	20000	140000	47710
Feb.	8	1360	199070	20000	160000	39070
Mar.	5	850	199920	20000	180000	39920
Apr.	15	2550	202470	20000	200000	2470
May	38	6460	208930	20000	220000	-11070
June	61	10370	219300	20000	240000	20700

Total annual rain falls: 1290mm

From the above table, it can be seen that difference between cumulative rainfall harvested and cumulative demand is maximum in the month of December at 72610 liters. So, the capacity of storage tank should be 72610 liters, say 73000 liters.

2.2.8.2 Matching the capacity of the tank with the quantity of water required by its users

Suppose the system has to be designed for meeting drinking water requirement of a 4-member family living in the building with a roof top area of 200 sqm. The average annual rainfall in the Chennai region is 1290 mm. Daily drinking water requirement is 10 liters per person.

If area of catchment (A) = 200 sq.m.

average annual rainfall (R) = 1290 mm (1.290 m) and runoff coefficient

(C) = 0.85

Then, annual rain water

harvesting potential = 200 x 1.290 x 0.85

= 219.30 cum or 2,19,300 liters

The tank capacity is determined based on the dry period i.e., the period between the two consecutive rainy seasons. For example, with a monsoon extending over 5 months, the dry season is of 215 days.

Drinking water requirement for the family during dry season = 215 x 4 x 10 = 8600 liters. After keeping some factor of safety, the tank should have 20 percent more capacity than required above, i.e. 10,320 liters.

2.2.8.3 Choosing a tank size, appropriate in terms of costs, resources and construction methods.

In practice, the costs, resources and construction methods tend to limit the storage tank to smaller capacity in comparison to requirement as per approach 1 & 2. Depending upon the budget and space available, the construction of storage tank is done so that at least for some period dependence on municipal sources / water tankers can be minimized.

CHAPTER – 3

RECHARGING SUBSURFACE AQUIFERS

3.1 Methods of Recharging Subsurface Aquifers

The various methods of recharging subsurface aquifers are:

1. Through recharge pit.
2. Recharge through abandoned hand pump.
3. Recharge through abandoned dug well/open well.
4. Through recharge trench.
5. Recharge through shaft.
6. Recharge trench with bore.

3.1.1 Through recharge pit

This method is suitable where permeable strata is available at shallow depth. It is adopted for buildings having roof area up to 100 sqm. Recharge pit of any shape is constructed generally 1-2 m wide and 2-3 m deep. The pit is filled with boulders, gravel and sand for filtration of rain water. Water entering in to RWH structure should be silt free. Top layer of sand of filter should be cleaned periodically for better ingression of rain water in to the sub soil. Details are shown in Fig. 3.1.

3.1.2 Recharge through abandoned hand pump

In this method, an abandoned hand pump is used as recharging structure. It is suitable for building having roof top area up to 150 sqm . Roof top rain water is fed to the hand pump through 100 mm dia. pipe as shown in Fig. 3.2. Water fed in the Rain water harvesting structure should be silt free. Water from first rain should be diverted to drain through suitable arrangement. If water is not clear then filter should be provided.

3.1.3 Recharge through abandoned dug well / open well

In this method, a dry / unused dug well can be used as a recharge structure. It is suitable for buildings having a roof top area more then 100 sqm . Recharge water is guided through a pipe of 100 mm to the bottom of the well as shown in Fig. 3.3. Well cleaning and desilting is imperative before using it. Recharge water guided should be silt free, otherwise filter should be provided as shown in Fig. 3.3. Well should be cleaned periodically and chlorinated to control bacteriological contamination.

3.1.4 Through recharge trench

This method is used where permeable strata is available at shallow depth. It is suitable for buildings having roof top area between 200 & 300 sqm. In this method, trench of 0.5-1.0 m wide, 1-1.5 m deep and of adequate length depending upon roof top area and soil/subsoil characteristics should be constructed and filled with boulders, gravel and sand as shown in Fig. 3.4. Cleaning of filter media should be done periodically.

3.1.5 Recharge through shafts

This method is suitable where shallow aquifer is located below clayey surface. It is used for buildings having roof top area between 2000 & 5000 sqm. Recharge shaft of diameter 0.5-3 m and 10-15 m deep is excavated mechanically. The shaft should end in permeable strata. The shaft should be filled with boulders, gravel and sand for filtration of recharge water.

Top sand layer should be cleaned periodically. Recharge shaft should be constructed 10-15 m away from the buildings for the safety of the buildings. The details are given in Fig. 3.5.

3.1.6 Recharge trench with bore

This method is used where sub-soil is impervious and large quantity of roof water/ surface run off is available. In this, trench is made 1.5-3 m wide and 10-30 m length depending upon water availability. Wells of 150-300 mm dia. and 3-5 m deep (below pervious layer) are constructed in the trench. Numbers of wells to be dug are decided in accordance to water availability and rate of ingression. Trench is filled with filtration media as shown in Fig. 3.6. A suitable silt chamber is also inserted with grating for water diverting arrangements as shown in the figure.

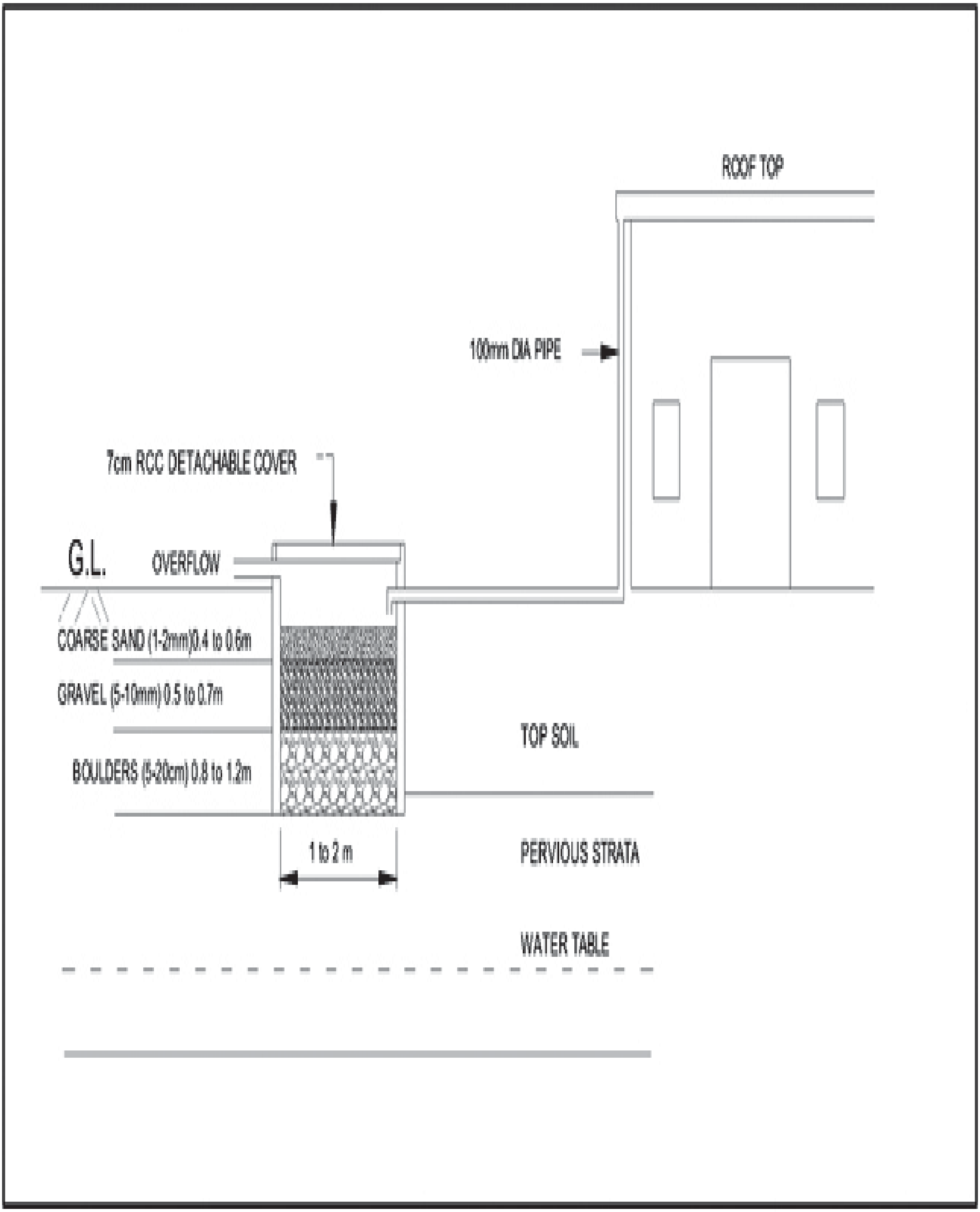


Fig. 3.1 Through recharge pit

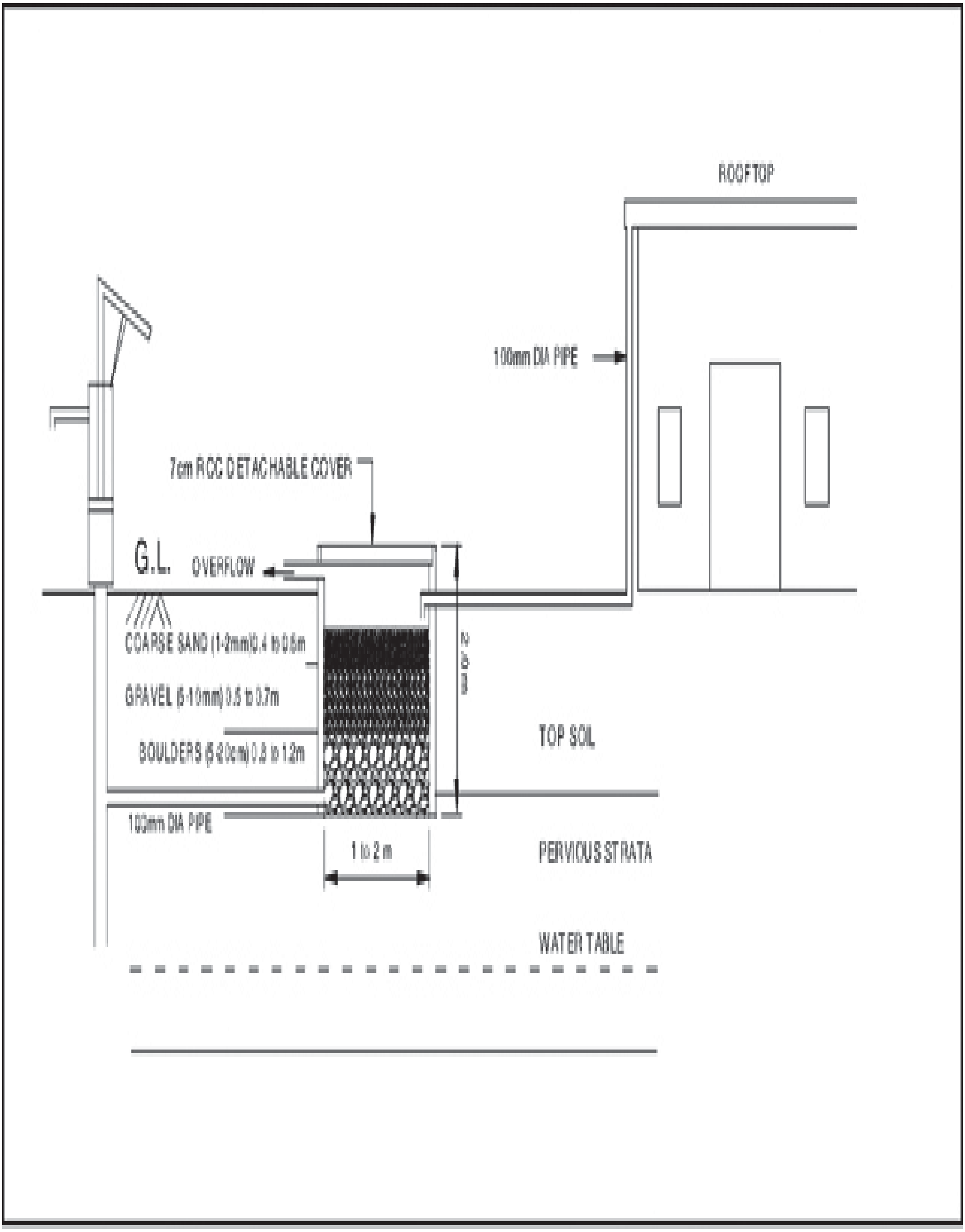


Fig. 3.2 Recharge through abandoned hand pump

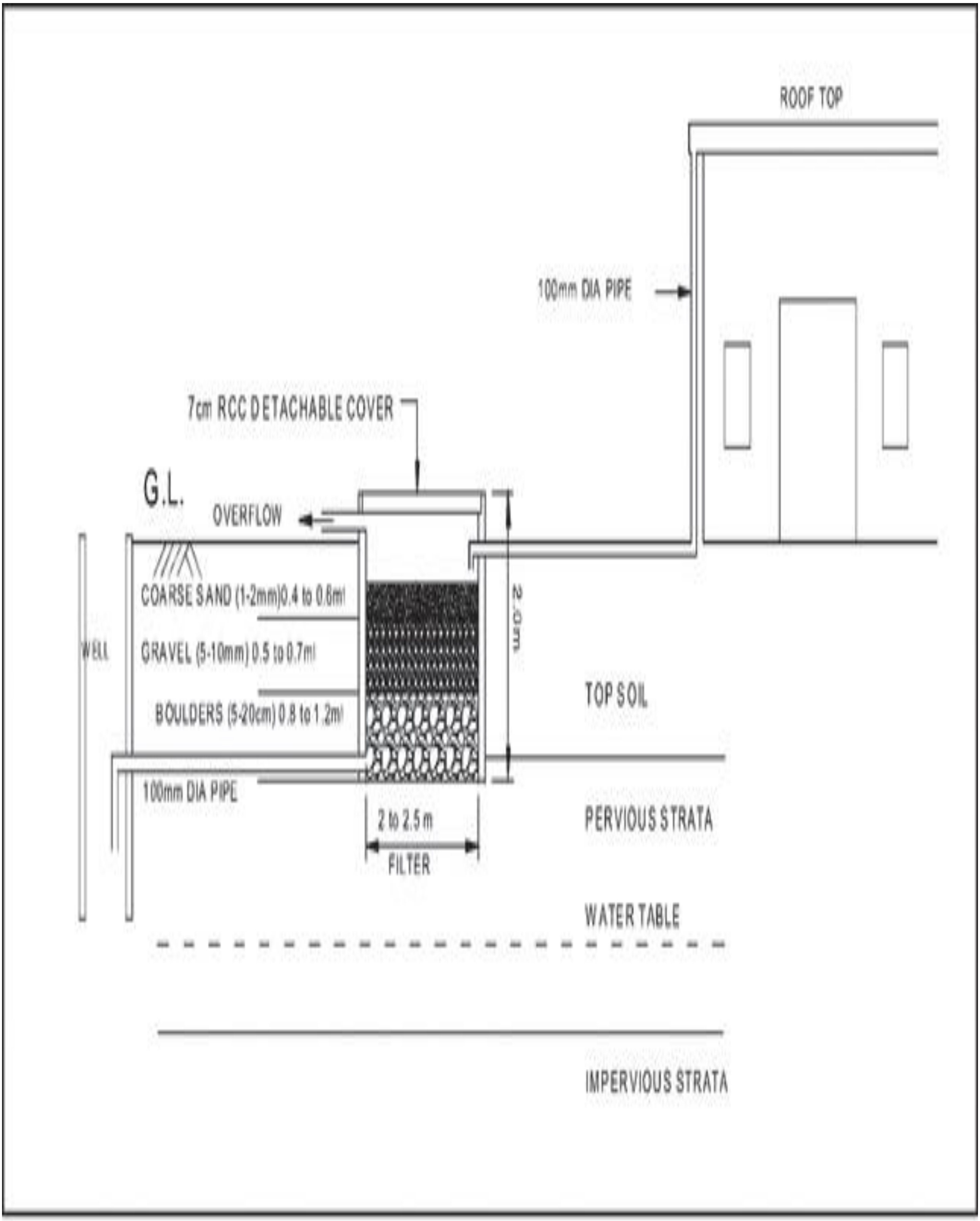


Fig. 3.3 Recharge through abandoned open well

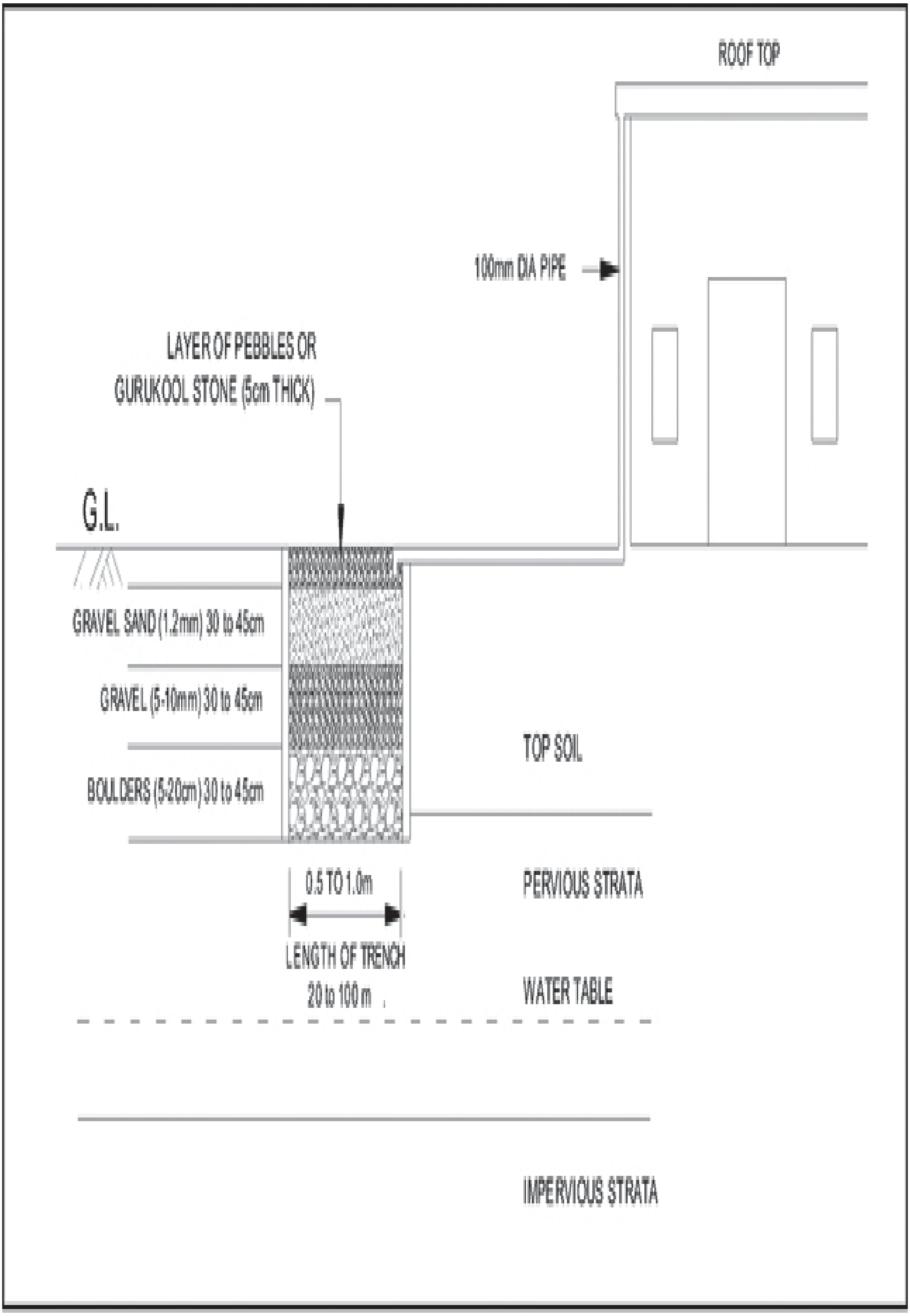


Fig. 3.4 Through recharge trench

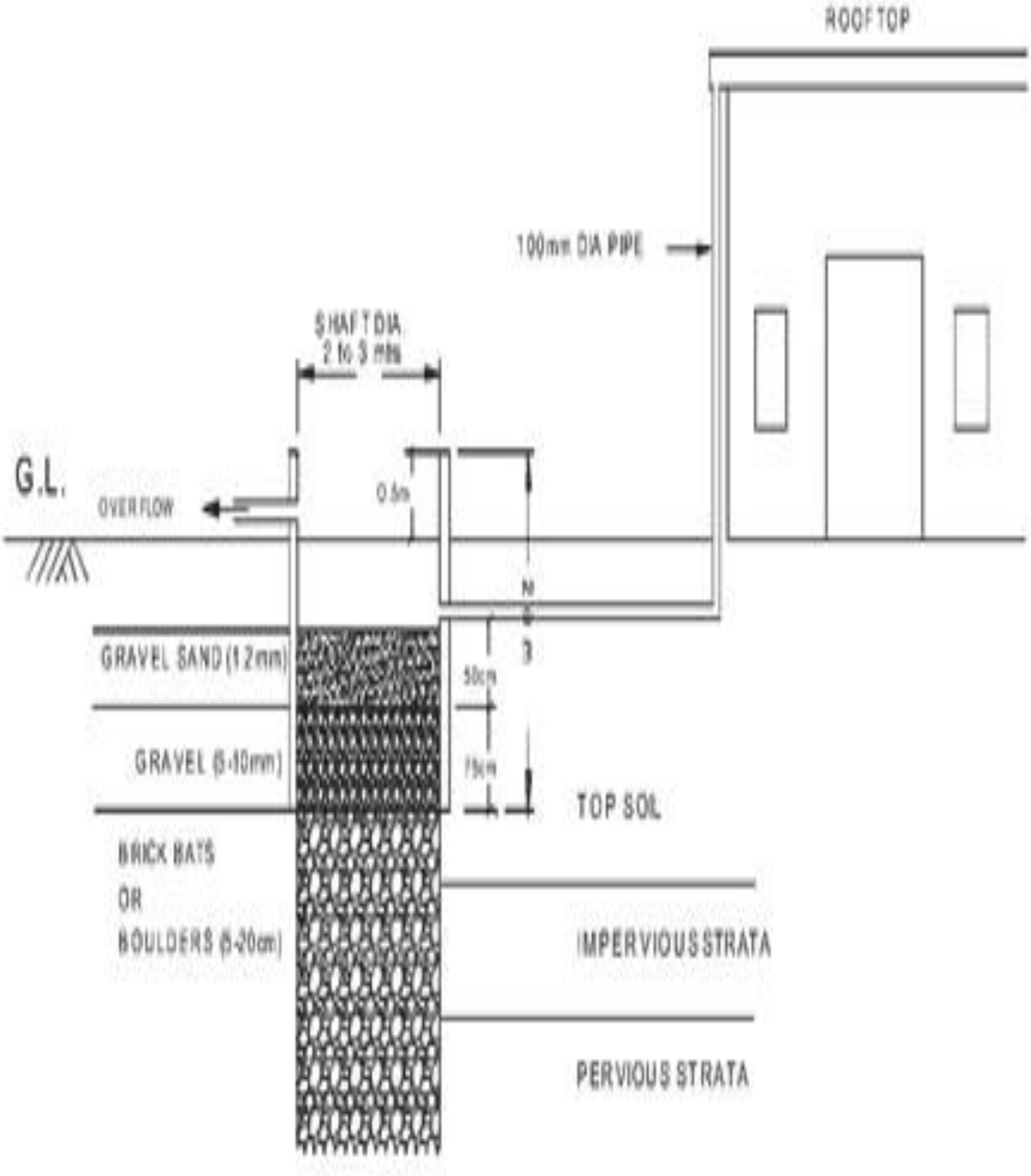


Fig. 3.5 Recharge through shaft

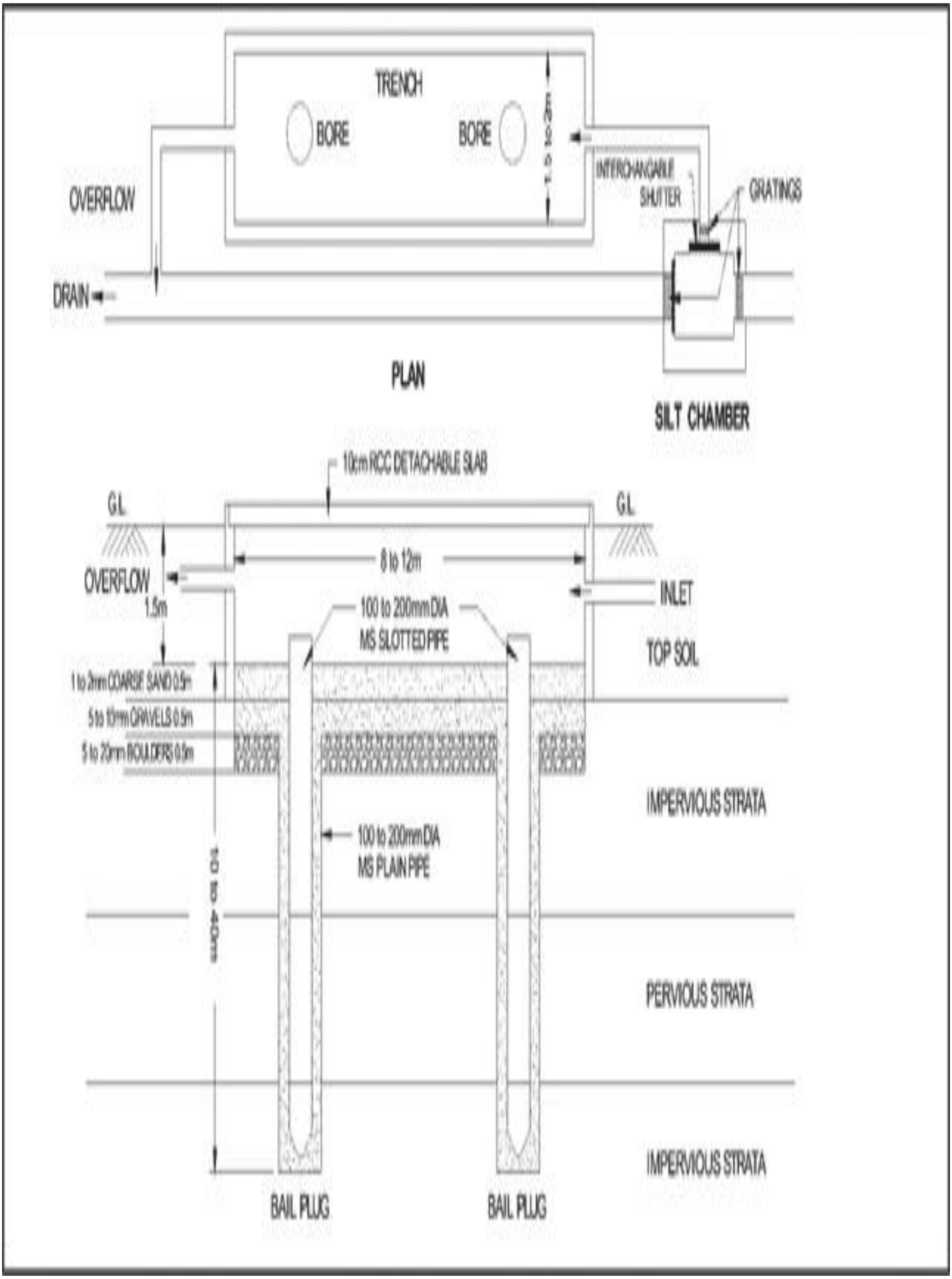


Fig. 3.6 Recharge trench with bore

CHAPTER – 4

CASE STUDY

Study of Rainwater Harvesting System at ITM University, Gwalior

1. Introduction

Rainwater harvesting is a sustainable technique used to collect, store, and recharge rainwater for future use. In educational institutions like ITM University, rainwater harvesting plays an important role in **reducing water wastage, improving groundwater recharge, and managing stormwater runoff**.

The campus of ITM University contains several buildings, roads, and open spaces which generate a large amount of **surface runoff during rainfall**. Without proper management, this runoff water can lead to soil erosion, waterlogging, and wastage of valuable freshwater resources**.**

Therefore, this case study focuses on the **design and analysis of a rainwater harvesting system installed within the ITM campus**.

2. Site Investigation

During the PBL research, a field investigation was conducted across the ITM University campus to identify existing rainwater harvesting structures. With the assistance of **Mr. Farhan Rahman (Faculty, Civil Engineering Department)**, several locations of rainwater harvesting installations were studied.

The site investigation included:

• Observation of rainwater collection points
• Study of inlet and outlet pipe systems
• Analysis of filtration media used in recharge pits
• Measurement of tank dimensions
• Evaluation of water flow direction and runoff management

These observations helped in developing an improved **engineering design model for the rainwater harvesting tank**.

Location of Rain Water Harvesting at ITM University, Gwalior

(Turari Campus)

1. At corner, near Hostel Tapti Block
2. Between High mast Pole and bore well. (LDV Block)
3. Near bore well & Nallah (Sports Complex)
4. Near bore well (Skating Track)

(Sithauli Campus)

1. Near bore well (New Girls Hostel).
2. Behind NAAD Amphitheatre, near new hostel (Nursery).
3. At Bus parking, Near Nallah, Behind old Boys Hostel.
4. Right side of Vishwakarma Block.

(Guest House)

1. Behind animal house.
2. Near Main Gate, Nallah side.

Near bore well & Nallah (Sports Complex)


2.63 m
Measure
Level


GPS Map Camera
Google
Lakhnotikhurd, Madhya Pradesh, India
46q5+f2q, Lakhnotikhurd, Madhya Pradesh 474001, India
Lat 26.140547° Long 78.207652°
Tuesday, 17/03/2026 12:18 PM GMT +05:30


GPS Map Camera
Gwalior,Madhya Pradesh,India
Sai Baba Mandir Road, Gwalior Gird, Gwalior, Madhya Pradesh 474001, India
Lat 26.136599, Long 78.207713
Monday, 09/03/2026 12:23 PM GMT+05:30
Note : Captured by GPS Map Camera


ITM
RAIN WATER HARVESTING
GPS Map Camera
Lakhnotikhurd, Madhya Pradesh, India
46q5+f2q, Lakhnotikhurd, Madhya Pradesh 474001, India
Lat 26.140794° Long 78.207575°
Tuesday, 17/03/2026 12:16 PM GMT +05:30

3. Rainwater Harvesting Tank Design

The rainwater harvesting structure designed in this project is a **cylindrical underground recharge tank**.

Tank Specifications

Diameter of tank = **2000 mm**
Depth of tank = **3000 mm**

Pipe Specifications

Inlet Pipe = **100 mm Ø UPVC pipe**
Outlet Pipe = **100 mm Ø UPVC pipe**
Vertical Recharge Pipe = **150 mm Ø**

The vertical pipe allows filtered water to **percolate into deeper soil layers**, thereby improving groundwater recharge.

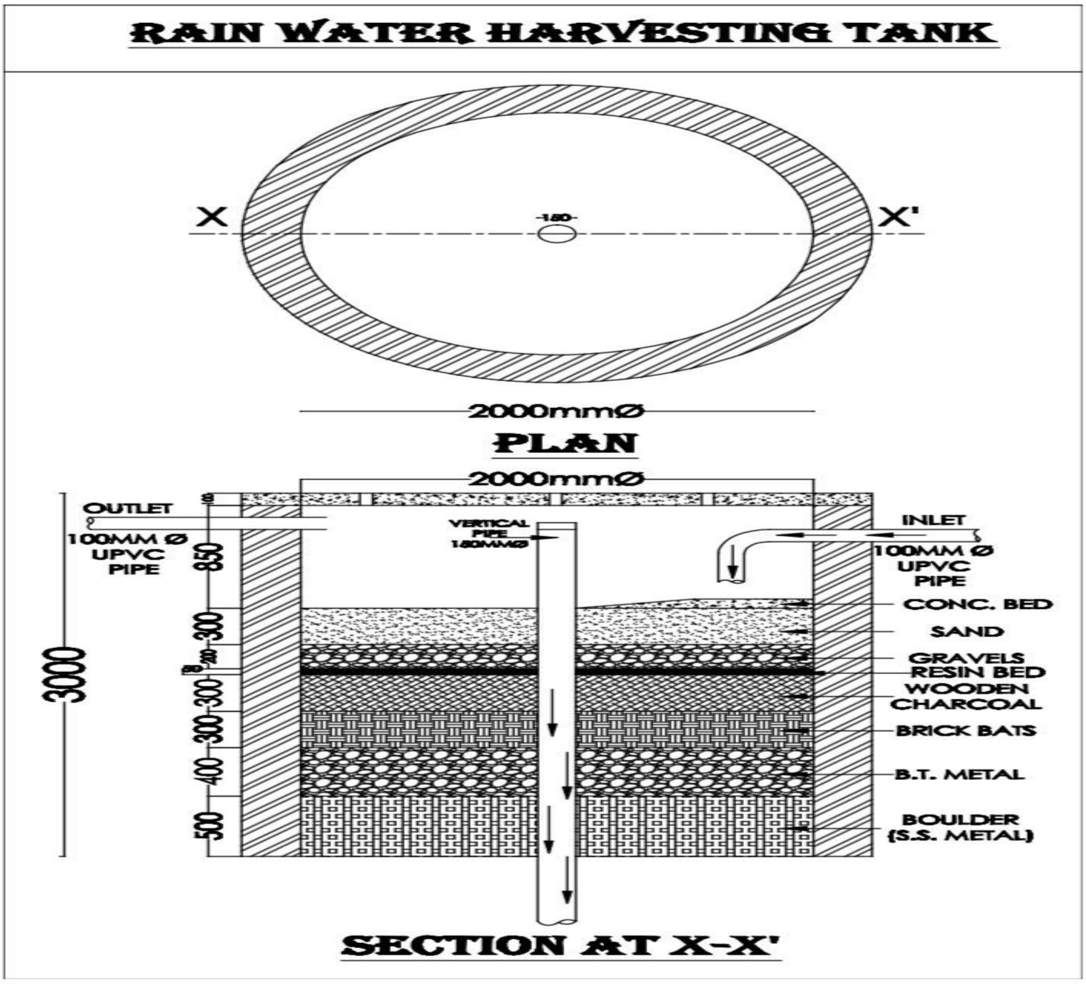


Fig. design of Rain Water Harvesting Tank

4. Filtration System

To ensure that the rainwater entering the recharge system is clean, the tank includes **multiple layers of filtration materials** arranged from top to bottom.

Filtration Layers

1. Concrete Bed
2. Sand Layer
3. Gravel Layer
4. Resin Bed
5. Wooden Charcoal Layer
6. Brick Bats Layer
7. B.T. Metal Layer
8. Boulder Layer

Each layer performs a specific filtration function:

- **Sand** removes fine suspended particles
- **Gravel** improves filtration and drainage
- **Charcoal** removes odor and organic impurities
- **Brick bats and boulders** provide structural support and water flow channels

This multilayer filtration system ensures that only **clean water enters the recharge pipe**.

5. Runoff Water Collection

Rainwater from building rooftops and paved areas is collected through drainage channels and pipes**.** This water is directed through the inlet UPVC pipe into the filtration tank.

The filtration layers remove impurities before the water enters the **vertical recharge pipe**, which directs the water into the underground aquifer.

This process helps to:

- Reduce stormwater runoff
- Prevent urban flooding
- Recharge groundwater resources
- Conserve freshwater

6. Environmental Engineering Importance

Rainwater harvesting is an essential component of **sustainable environmental engineering**.

The system provides several environmental benefits:

• Recharges groundwater levels
• Reduces pressure on municipal water supply
• Prevents soil erosion
• Reduces stormwater drainage load
• Promotes sustainable water management

In regions like **Gwalior**, where groundwater depletion is becoming a serious issue, rainwater harvesting is an important solution.

7. Estimated Cost of Rainwater Harvesting System

The estimated construction cost of the system includes:

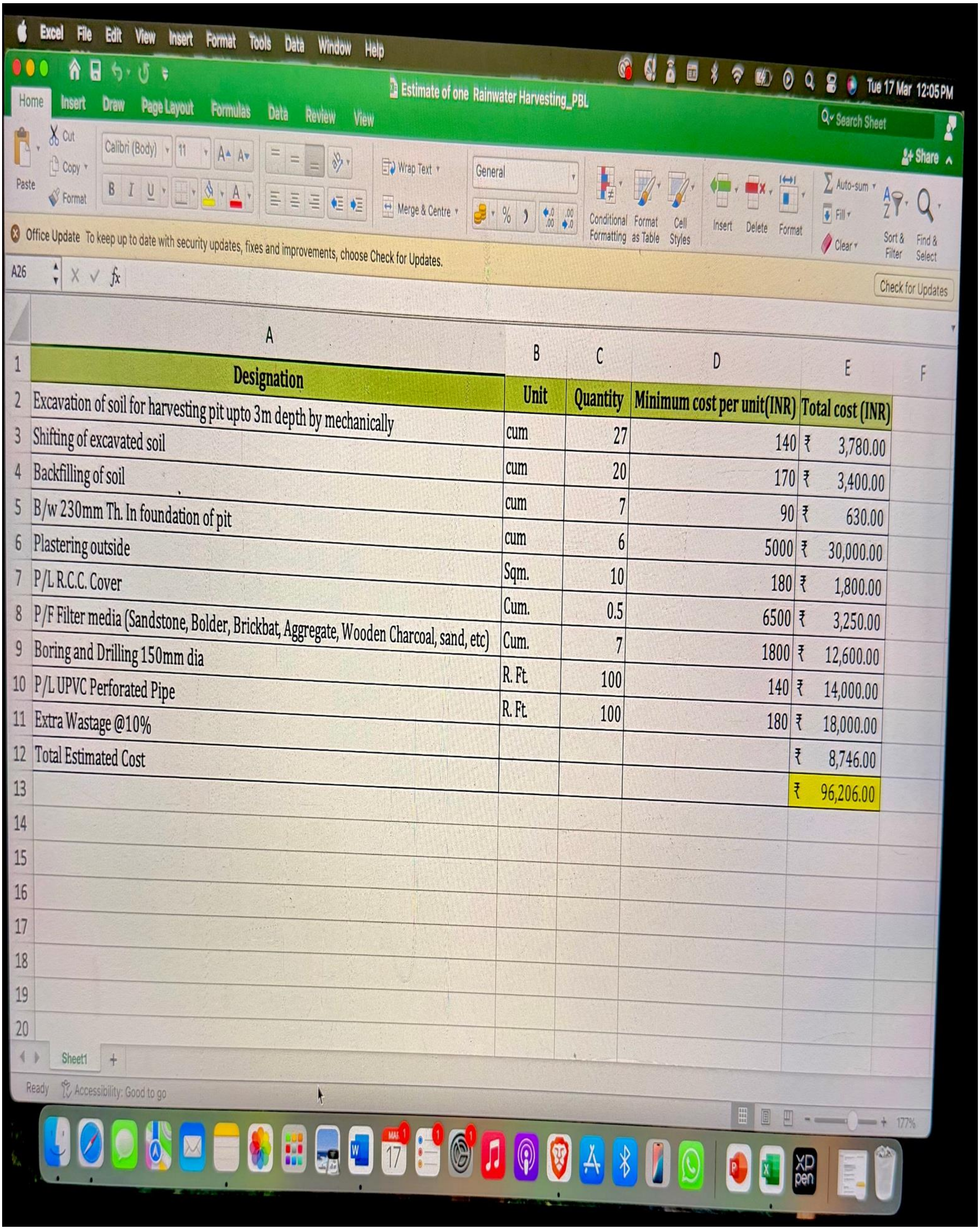
• Excavation and earthwork
• RCC tank construction
• Installation of UPVC pipes
• Filtration media materials
• Labour and finishing work

Total Estimated Cost: ₹97,000

Table estimate for design Rain Water Harvesting Pit

Particular	**Unit**	**Qty.**	**Rate**	**Amount**
Excavation of soil for harvesting pit up to 3m depth by mechanically	cum	27.0	140	3,780
Shifting of excavated soil	cum	20	170	3,400
Backfilling of soil	cum	7	90	630
B/w 230mm Th. In foundation of pit	cum	6	5000	30,000
Plastering outer side	Sqm.	10	180	1,800
P/L R.C.C. Cover	Cum.	0.5	6500	3,250
P/F Filter media (Sandstone Bolder, Brickbat, Aggregate, Wooden Charcoal, sand, etc.)	Cum.	7	1800	12,600
Boring and Drilling 150mm dia.	R Ft.	100	140	14,000
P/L UPVC Perforated Pipe	R. Ft.	100	180	18,000
Extra Wastage @10%				8,746
	Total Amount			**96,206/-**
	Say			**97,000/-**

(In Words = Rupees ninety-seven Thousand Only)



Designation	Unit	Quantity	Minimum cost per unit(INR)	Total cost (INR)
Excavation of soil for harvesting pit upto 3m depth by mechanically	cum	27	140	₹ 3,780.00
Shifting of excavated soil	cum	20	170	₹ 3,400.00
Backfilling of soil	cum	7	90	₹ 630.00
B/w 230mm Th. In foundation of pit	cum	6	5000	₹ 30,000.00
Plastering outside	Sqm.	10	180	₹ 1,800.00
P/L R.C.C. Cover	Cum.	0.5	6500	₹ 3,250.00
P/F Filter media (Sandstone, Bolder, Brickbat, Aggregate, Wooden Charcoal, sand, etc)	Cum.	7	1800	₹ 12,600.00
Boring and Drilling 150mm dia	R. Ft.	100	140	₹ 14,000.00
P/L UPVC Perforated Pipe	R. Ft.	100	180	₹ 18,000.00
Extra Wastage @10%				₹ 8,746.00
Total Estimated Cost				₹ 96,206.00

Excel estimated table photo

8. Conclusion of Case Study

The case study conducted at ITM University demonstrates that **rainwater harvesting is an effective and sustainable solution for water conservation**. The system designed in this project provides a practical method to **collect, filter, and recharge rainwater into the groundwater table**.

The support provided by **Mr. Farhan Rahman in identifying existing rainwater harvesting locations** and the academic supervision of **Dr. Rakesh** played a significant role in understanding the practical implementation of rainwater harvesting techniques.

This PBL research highlights the importance of implementing such systems in **universities, residential areas, industries, and urban infrastructure projects** to ensure sustainable water management for future generations.

CHAPTER - 5

QUALITY OF WATER

The rain water is one of purest form of water and does not contain suspended / dissolved impurities. However, when this water is collected through rain water harvesting, it gets contaminated because of contact with roof surface/ground and some of the impurities get mixed in it. These impurities are required to be removed before collecting the harvested rain water in storage tank or diverting it or recharging of ground water aquifers.

Following precautions should be taken to ensure quality of water:

1. Roof over which water falls, should be cleaned before rain fall.
2. The suitable type of first flushing device to be installed and initial 10 to 15 minutes of runoff should be diverted.
3. The water collected from roof top only, should be stored in storage tank for direct use.
4. The runoff from surface/ground should be preferably bemused for recharging ground water aquifers after proper filtration.
5. The rain water collected from roof top should passthrough suitable type of filter and only then it should be stored in storage tank / used for recharging ground water aquifers.

The harvested rain water may contain some toxic substances which may affect our health. The water collected from roof top after filtration can be used directly for lawn watering, washing etc. But if this water has to be used directly for drinking purpose, then quality of water must be ascertained before use.

The water used for drinking should comply with the provisions of IS-10500:2012 i.e., Indian Standard "DRINKING WATER – SPECIFICATION (First Revision)". The important test characteristics for drinking water as given in Table 1 of IS10500:2012 are reproduced in Table 5.1 for ready reference.

To test the quality of water, the water samples can be collected and testing can be done in testing laboratories but as a routine, the quality of water can also be checked with the help of testing kits by the users themselves. In case, water is not potable, treatment of water may be necessary to make it fit for human consumption. For treatment of water, the following measures can be taken at household level.

(a) Filtration of water should be done using suitable type of filter. The details of various type of filter are given in chapter 2.

(b) Chemical disinfection can be done by chlorination. Chlorination is done with stabilized bleaching powder, which is a mixture of chlorine and lime. Chlorination can kill all types of bacteria and make water safe for drinking purposes. Approx. 1 gm of bleaching powder is sufficient to treat 200 liters of water otherwise chlorine tablets, which are easily available in the market can be used for disinfection of water. One tablet of 0.5gm is enough to disinfect 20 liters of water.

(c) Boiling water is one of the effective methods of purification. Boiling water for 10 to 20 minutes is enough to remove all biological contaminants.

Table 5.1 Important test characteristics for drinking water

S N	Substance Characteristics	Requirement (Acceptable limit)	Undesirable Effect Outside the Desirable Limit	Permissible Limit in the Absence of Alternate Source	Method of Test (Ref. to IS)	Remarks
Essential Characteristics						
I	Color, Hazen units, Max.	5	Above 5. Consumer acceptance decreases	15	3025 (Part-4):193	Extended to 25 only if toxic substances are not suspected in absence of alternate sources.
II	Odor	Agreeable	-		3025 (Part-5): 1983	a) Test cold and when heated b) Test at several dilutions
III	Taste	Agreeable	-	Agreeable	3025 (Part 7&8): 1984	Test to be conducted only after safety has been established.
IV	Turbidity NTU Max.	1	Above 5, consumer acceptance decreases. Beyond this range the water will affect the mucous membrane and/or water supply system	5	3025 (Part 10): 1984	
V	pH Value	6.5 to 8.5	Beyond this range the water will affect the mucous membrane and/or water supply system	No relaxation	3025 (Part 11): 1984	

VI	Total Hardness (as CaCO3) mg/l, Max.	200	Encrustation in water supply structure and adverse effect on domestic use.	600	3025 (Part 12): 1983	
VII	Iron (ad Fe) mg/l Max.	0.3	Beyond this limit taste/ appearance are affected, has adverse effect on domestic uses and water supply structures, and promotes iron bacteria.	No relaxation	32 of 3025: 1964	

VIII	Chloride (as Cl) mg/l, Max. 0.3	250	Beyond this limit, test corrosion and palatability is affected.	1000	3025 (Part 32): 1988	
IX	Residual free chlorine mg/l Min	0.2* * When protection against viral infection is required, it should be minimum 0.5mg/l	-	- 1.0	3025 (Part 26): 1986	To be applicable only when water is chlorinated. Tested at consumer end. When protection is required, it should be Min 0.5 mg/l
X	Fluoride (as F) mg/l Max.	1.0	Fluoride may be kept as low as possible. High fluoride may cause fluorosis	1.5	23 of 3025 1964	
XI	Total Dissolved solid	500	Beyond this palatability decreases and may cause gastro intestinal irritation	2000	3025 (Part 16): 1984	

XII	Calcium (as Ca) mg/l Max.	75	Encrustation in water supply structure and adverse effect on domestic use	200	3028 (Part 40): 1991	
XIII	Magnesium (as Mg) mg/l	30	Encrustation to water supply structure and adverse effect on domestic use Astringent taste will be caused beyond this discoloration and corrosion of pipes, fitting and utensils.	100	16.33.34 of IS 3025 1964	
XIV	Copper (as Cu) mg/l Max.	0.05		1.5	36 of 3025 1964	
XV	Sulphate (as SO4)	200	Beyond this causes gastro intestinal irritation when magnesium or sodium are present.	400 (sec. col 7)	3025 (Part 24) 1986	Provided Magnesium (as Mg) does not exceed 30 mg/l
XVI	Nitrate (as NO2) mg/l Max.	45	Beyond this methemoglobinemia takes place	No relaxation	3025 (Part 34): 1988	

XVII	Cadmium (as Cd) mg/l Max.	0.003	Beyond this, the water becomes toxic	No relaxation	See Note 1	To be tested when pollution is suspected
XVIII	Arsenic (as As) mg/l Max.	0.01	Beyond this, the water becomes toxic	0.05	3025 (Part 37): 1988	To be tested when pollution is suspected
XIX	Lead (as Pb) mg/l, Max.	5	Beyond this, the water becomes toxic	No relaxation	See Note 1	To be tested when pollution is suspected
XX	Zinc (as Zn) mg/l, Max	5	Beyond this limit it can cause astringent taste & an opalescence in water	15	39 of 3925 1964	To be tested when pollution
XXI	Mineral Oil mg/l, Max.	1.00	Beyond this limit undesirable taste and odor after chlorination take place.	No relaxation	Gas chromato-graphic method	To be tested when pollution is suspected.

Note-1: Atomic absorption spectrophotometric method may be used.

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