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Government of India
Ministry of Railways

RAIN WATER HARVESTING

CAMTECH/2004/C/RWH/1.0

August - 2004

Centre
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Excellence in Maintenance

Maharajpur, GWALIOR - 474 020

RAIN

WATER

HARVESTING

FOREWORD

We have just started to walk in the 21st century, the time of great scientific revolutions and robust growth in every field. Rate of population growth is also very high. All these factors are causing a tremendous pressure on our natural resources. Water is also among them. Over exploitation and uncertainty of monsoon has further increased the pressure manyfold on this natural resource. To bridge the gap of availability and demand of water, various techniques are now being practiced. Harvesting rainwater is one of the important techniques.

Civil engineering branch of CAMTECH has made an excellent effort to bring out this handbook to provide elaborate and detailed conceptual knowledge, various techniques with practical examples in the form of case studies on **rainwater harvesting**.

I am sure that this book will certainly prove to be useful for field engineers and staff of Indian Railways.

CAMTECH/Gwalior **(R.N.Misra)**
Date : 26.08.2004 **Executive Director**

PREFACE

These days, the rainwater harvesting is the highly concerned topic of discussion in the intellectual community. In fact it is a matter of concern for every human being. It is equally true that it is the need of the hour. The increasing water demand, drying natural resources due to over exploitation, and often failure of monsoon have further worsen the situation, making the water a scare commodity. To cope up this problem, capturing the rain at place of fall i.e. rain water harvesting with a scientific approach is the best solution. A successful and effective rainwater harvesting needs large-scale collective community efforts. Indian Railways with its vast network can play a vital role to mitigate the water problem by adopting and implementing water-harvesting techniques.

The idea of brining out this handbook is to furnish the conceptual and technical information regarding rain water-harvesting systems for guidance of civil engineering personnel, responsible for water supply arrangements on Indian Railways.

This handbook covers in details, the concept, basic component and the various systems of rainwater harvesting. It also covers the requirement & suitability criteria of the various systems, for their selection & successful implementation in the field.

This handbook does not supersede any existing instructions from Railway Board, RDSO and zonal railways on the subject. This handbook is *not statutory* and content are for the purpose of guidance only.

We gratefully acknowledge Shri Siraj Khan, Hydro-geologist and Shri P.Srinivasan, Scientist, Centre Ground Water Board, Bhopal for providing technical data and their valuable advise for the preparation of this handbook.

I am grateful for the assistance given by Shri Anupam Sharma, CTA/Civil, who went through the complete text, collected information, data etc. and done text editing work. Nice data entry has done by Shri Ramesh Bhojwani, Console Operator, CAMTECH.

We welcome suggestions for further improvements in the contents of this handbook.

(Manoj Agarwal)
Director/Civil
IRCAMTECH/Gwalior

CAMTECH/Gwalior
Date : 25 August-2004

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ISSUE OF CORRECTION SLIPS

The correction slips to be issued in future for this handbook will be numbered as follows:

CAMTECH/2004/C/RWH/1.0/CS.# XX date ….....

Where "XX" is the serial number of the concerned correction slip (starting from 01 onwards).

CORRECTION SLIPS ISSUED

Sr. No. of C.Slip	Date of issue	Page no. and Item No. modified	Remarks

CHAPTER – 1

INTRODUCTION

"**JAL HI JEEVAN HAI**" we all have heard this phrase but very few have understood and implemented it. The result of its ignorance is now evident. Today we are facing acute shortage of fresh water even for drinking in most parts of the country. The main reasons are, high rate of population growth, modern life style and urbanisation with excessive extraction of ground water etc.

According to U.N. estimates, total amount of water on the earth is about 1400 million cubic kilometres, which is enough to cover the earth with the layer of 3000 m depth. However the *fresh water* constitutes a very small portion of this enormous quantity. Only 2.7% of the total water available on the earth is fresh water and the remaining is saline water in oceans. About 75.20% of available fresh water lies frozen at Polar regions and another 22.60% is present as ground water (50% of which is available within extractable depth). The rest is available in lakes, rivers and moisture in atmosphere, soil and vegetation.

On the earth, a recurring source of *fresh water* supply is rainfall under a hydrological cycle. Considering one hydrological cycle in a year as 100 units i.e. equal to mean annual global rainfall of 857 mm. Every year, from the oceans 84 units of water get evaporated and lifted to the atmosphere in the form of vapours, and from continents about 16 units of water vapour is lifted to the atmosphere by the evapo-transpiration of surface water bodies and plants. Out of these 100 units, 77 unit of water vapour condenses and falls as rain fall over the oceans itself and the remaining 23 units of water vapour after condensation falls as rain fall in the continental regions. This way a water balance is maintained through out the year and this process continues without any interruption.

Rainfall occurring on the continental regions (23% of total global rainfall), partially get stored in the surface water bodies, and as ground water through natural percolation, remaining over flows through the continental regions in the form of streams/rivers before merging in oceans i.e. saline water.

This supply of fresh water is available during a limited monsoon period during the year, that too non-uniform in spatial distribution and magnitude. Though the fresh supply is available for a limited period but the water is required for the survival of living beings throughout the year. This imbalance of availability and requirement is met by extracting the water stored in the surface bodies i.e. ponds, lakes etc. or from ground water storage.

Over a period, due to increase in population, modern life style and urbanisation the water requirement has increased tremendously whereas the storage in surface bodies and ground water has reduced drastically. The storage in surface bodies and ground water is gradually decreasing due to change in land use pattern and depleting trend of ground water recharge due to increase in impervious surfaces. All this, caused to over extraction of water from ground storage and surface water bodies thus making availability of potable water, an increasingly scare commodity everywhere.

This ever-increasing imbalance of water availability and requirement can be catered either by capturing the water overflowing the continental regions i.e. river/stream through dams and/or by capturing the available rain water at the place of supply it self. The captured rainwater may either be stored directly or as ground water through artificial recharge techniques. The process of capturing and storing rainwater is known as **rainwater harvesting**. *The successful rain water harvesting needs a collective community efforts.*

Indian railway has very large network spread throughout the country and requires a huge quantity of water for drinking and other purposes. At present this requirement is met through a municipal supply or extraction of ground water. Alternatively, the water requirement of railway can also be met by capturing the rainfall water on railway area for direct storage or recharging ground water thus reducing the dependency on municipal water. By recharging groundwater aquifers railway can also contribute in big way for augmenting ground water storage as a whole, for its own requirement and for the benefit to the nearby locality.

For implementing rainwater harvesting on Indian Railways, the basic concept of rainwater harvesting and the various methods/techniques for its field implementation have been explained in details in the subsequent chapters of this handbook.

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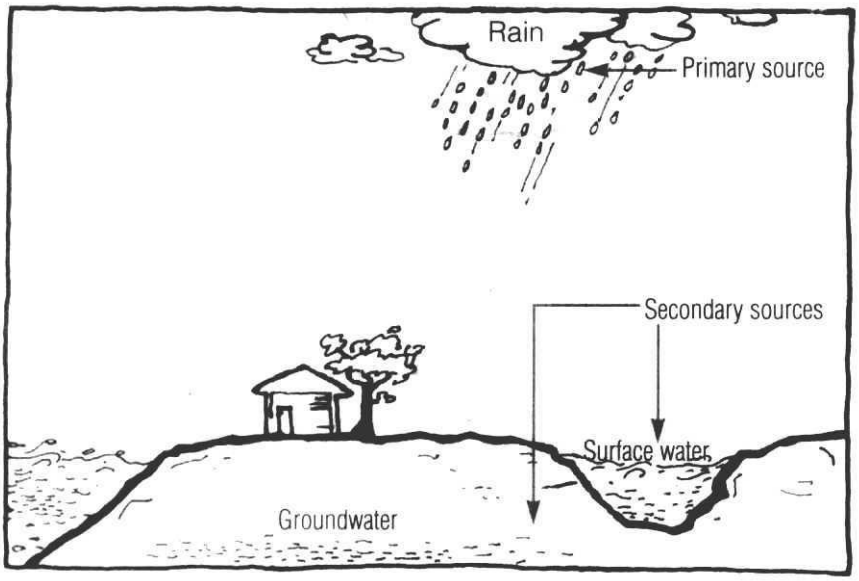
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CHAPTER – 2

CONCEPT OF WATER HARVESTING

In scientific terms, water harvesting refers to collection and storage of rainwater and also other activities aimed at harvesting surface and groundwater, prevention of losses through evaporation and seepage and all other hydrological studies and engineering interventions, aimed at conservation and efficient utilisation of the limited water endowment of physio-graphic unit such as a watershed.

In general, water harvesting is the activity of direct collection of rainwater. *The rainwater collected can be stored for direct use or can be recharged into the groundwater.* Rain is the first form of ***new fresh water*** that we know in the hydrological cycle, hence is a primary source of water for us.

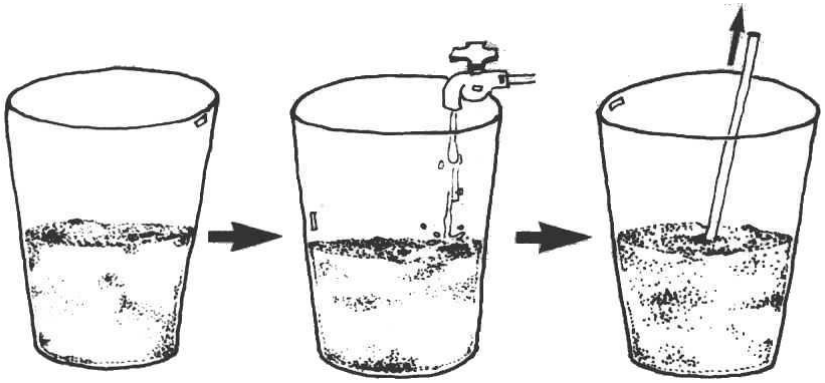


Rivers, lakes and groundwater are all secondary sources of fresh water. *In present times, we depend entirely on such secondary sources of water*. In the process, it is forgotten that-rain is the ultimate source that feeds all these secondary sources and remains ignorant of its value. Water harvesting means to understand the value of rain, and to make optimum use of rainwater at the place where it falls.

2.1 WHAT IS GROUNDWATER ?

Contrary to popular belief, groundwater reserves are not in the form of lakes or streams of water inside the ground. Water in the ground is stored in the interstices (inter-particulate spaces) of the soil or rock that forms the earth. It is similar to water being stored in a sponge-which is not visible, but can be 'squeezed' out (or drawn out). A simple experiment to under stand the nature of the ground water is illustrated below:

A sand filled in a glass… ..holds water … .. and yields it too.



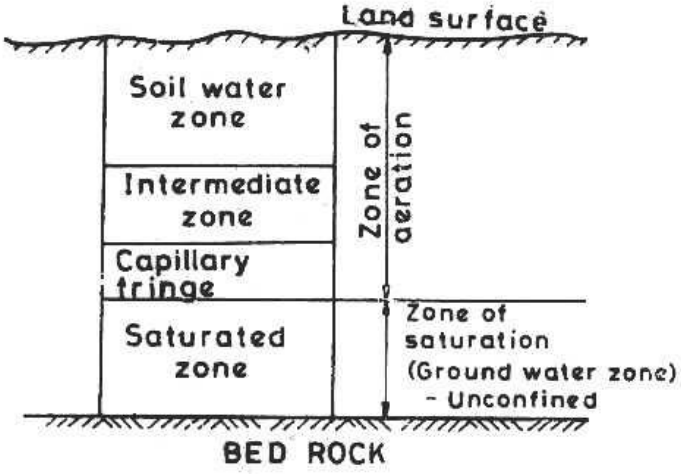
Understanding groundwater

The soil or rock formations in earth that contain water are called ground water aquifers. Below a certain depth in the ground, the earth is saturated (saturation is a state in which all the free spaces or interstices are filled with water). This level is referred as the **groundwater level**. This level may be just below the ground level or may be hundred metres below ground level.

2.1.1. Is all water in earth, forms ground water reserve?

Water in the soil or rock formation in earth, exists in two zones.

1. Saturated zone, and
2. Aeration zone



Classification of earth moisture

Saturated zone

This zone, also known as *ground water zone* is the space in which all the pores of the soil are filled with water. The water table forms its upper limit and marks a free surface, i.e. surface having atmospheric pressure.

Aeration Zone

In this zone the soil pores are only partially saturated with water. The space between the land surface and the water table marks the extent of this zone. Further, the zone of aeration has three sub-zones:

Soil water zone

This lies close to the ground surface in the major root band of the vegetation from which the water is lost to the atmosphere by evapo-transpiration.

Capillary Fringe

In this the water is held by capillary action. This zone extends from the water table upwards to the limit of the capillary rise.

Intermediate zone

This lies between the soil water zone and the capillary fringe.

The thickness of the zone of aeration and its constituent sub-zones depends upon the soil texture, moisture content and varies from region to region.

The soil moisture in the zone of aeration is of importance for agricultural activities and irrigation purpose.

Water in the saturated zone of formation can only be extracted, thus forms ground water source.

2.1.2 Whether all saturated formations are source of ground water ?

The extent of porosity, pore size and their interconnectivity varies from formation to formation. *From the consideration of ground water the porous formations with interconnected pores, through which water can move easily for recharge and extraction are of significance*. Depending upon extent of porosity, pores size and their interconnectivity formations are classified into four categories :

1. Aquifer
2. Aquitard
3. Aquiclude
4. Aquifuge

Aquifer : Aquifer is a saturated formation which is highly porous with interconnected pores, i.e. having *high storage capacity and transmissibility/permeability*. Therefore, these formation not only stores water but also yields it in sufficient quantity.

Unconsolidated deposit of sand and gravel, and highly fractured rock formation are good aquifers.

Aquitard : Aquitard is a saturated formation which is porous with interconnected pores but to lesser extent. These formation are *partially permeable*. Therefore though these formation stores water, but the yield is insignificant compare to an aquifer.

Aquiclude: Aquiclude is a formation which is porous but without interconnected pores. These formations are *impermeable*. Therefore though these formation may stores large quantity of water but the *yield is almost negligible*.

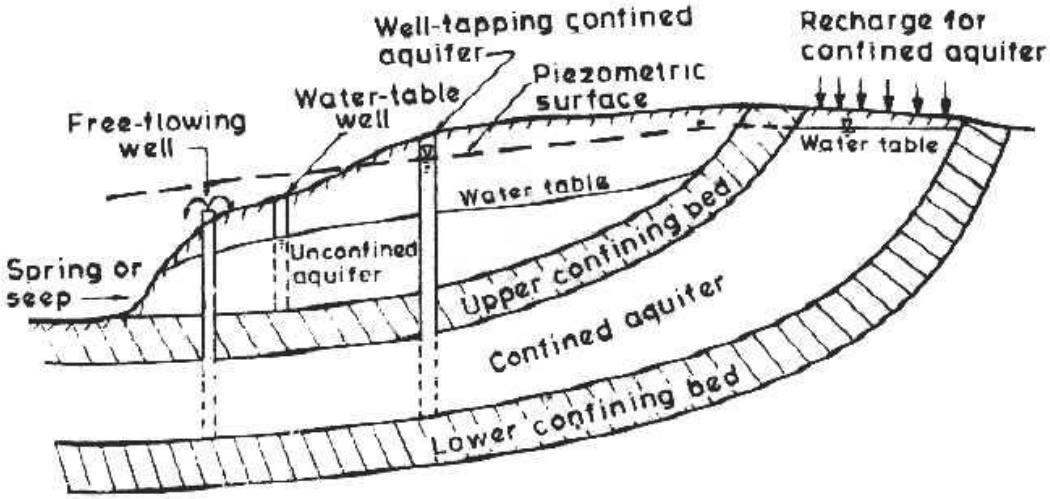
Clay is an example of aquiclude.

Aquifuge*:* It is a formation, which is *neither porous nor permeable*. These formation neither contains water and nor they transmits water.

Massive compact rock without any fractures is an example of aquifuge.

Aquifer and to some extent aquiclude are the only source of ground water.

- Aquifers are further classified as *unconfined* aquifers and *confined* aquifers on the basis of their occurrence and field situation.



Confined and unconfined aquifers

Unconfined aquifers is a one in which a free surface, i.e. water table exists. Recharge of this aquifer takes place through infiltration of rainwater from the ground surface. A well driven into an unconfined aquifer will indicate the static water level corresponding to the ground water level at that location.

Confined aquifer*,* also known as *artesian aquifer,* is an aquifer, which is confined between two impervious beds such as aquiclude or aquifuge. Recharge of this aquifer takes place only in the area where it is exposed at the ground surface. The water in the confined aquifer will be under pressure therefore, the piezometric level will be much higher than the top level of the aquifer. At some location the piezometric level may be higher than the ground surface, therefore well driven in to such aquifer will flow freely without the aid of any pump.

Unconfined aquifers are the most suitable formation for artificial recharge of ground water.

2.1.3 Which geological formations are more suitable as ground water aquifer?

The geological formation which are of importance for storage, extraction and recharge of ground water are broadly classified as:

(i) Unconsolidated deposits, and
(ii) Consolidated rocks

- ***Unconsolidated deposits*** of sand and gravel are highly suitable for ground water aquifer and they forms most of the existing important aquifers. They occurs as fluvial alluvial deposits, abandoned channels sediments, coastal alluvium and as lake and glacial deposits. The yield from these aquifers is generally good. In India, the *gangetic alluvium* and the *coastal alluvium* in the state of Tamilnadu and Andhra Pradesh are the example of this type of aquifers.

- ***Consolidated rocks*** formations are of following types:

Sedimentary rocks

With primary porosity such as sand stone are generally good aquifer. The extent of weathering and occurrence of secondary openings such as joints and fractures further enhances the storage and yield. Normally the yield from these aquifers is less than the alluvium deposits. In India, sandstones of Kathiawar and Kutch areas of Gujarat and of Lathi region of Rajasthan are some examples.

With secondary openings, such as lime stone containing numerous openings in the form of cavities formed by the solution action of flowing sub-surface water. Normally these formation forms highly productive aquifers. In Jodhpur district of Rajasthan, cavernous limestones of the vindhyan system are the example of such formation.

Igneous and metamorphic rocks

Basalt rock with permeable zones in the forms of vesicles, joints and fractures, provides good potential as aquifers. In India, in Satpura range some of the aquifers are of this type.

Weathered and fractured igneous and metamorphic rocks formations, also provides good potential as aquifers. Since weathered and fractured horizons are restricted in their thickness therefore these aquifers have limited thickness. The yields from these aquifers are fairly low. Aquifers of this kind are found in the hard rock areas of Karnataka, Tamilnadu, Andhra Pradesh and Bihar.

2.2 HOW IS GROUND WATER FORMED?

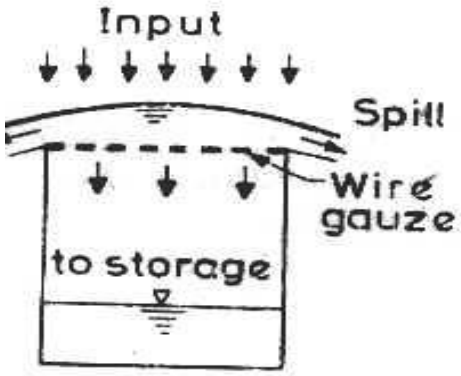
When rain falls on the earth surface, some amount of water is absorbed by the ground surface. Absorbed water percolates through the soil and moves downwards under the effect of gravity. When this percolated water reaches the permeable layers (aquifers) in the zone of

saturation, it get stored in the interstices of the soil/rock and constitutes groundwater source. Groundwater aquifers are formed over many years, as percolation from successive rains joins the existing groundwater.

When water moves through the soil, it is said to be *infiltrating*, i.e. it gets filtered in the process of passing through the pores of the soil. Therefore, ground water is normally free from suspended impurities, bacterial contamination and organic impurities.

2.2.1 What is natural recharge of ground water?

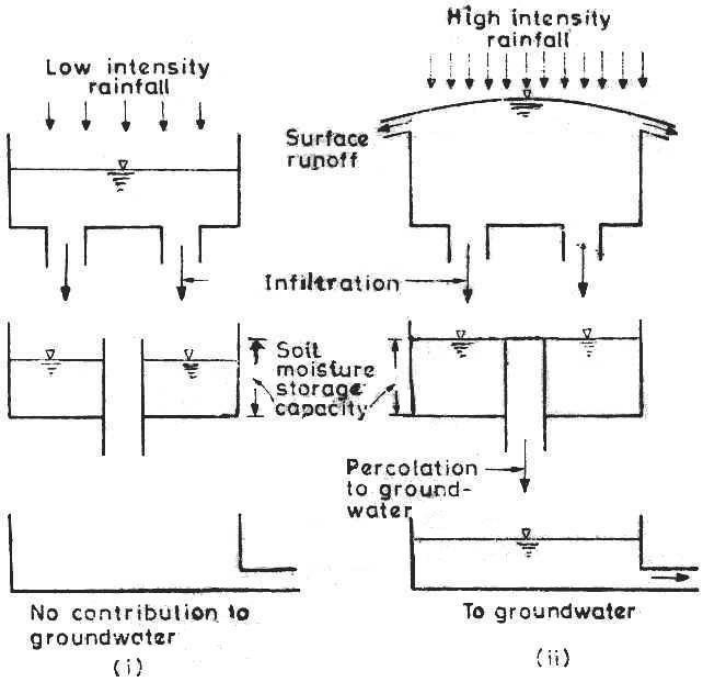
When the water is applied to the surface of the soil, a part of it seeps in to the soil. This movement of water through the soil is known as *infiltration*, and is a primary process of natural recharge of ground water. This process can be easily understood through a simple analogy. Consider a small container covered with wire gauze. When water is poured over the gauze, a part of it will go into the container and part overflows.



Input water ⇒ Rainfall,
Spill ⇒ Runoff,
Wire gauze ⇒ Ground surface,
To storage ⇒ Percolation

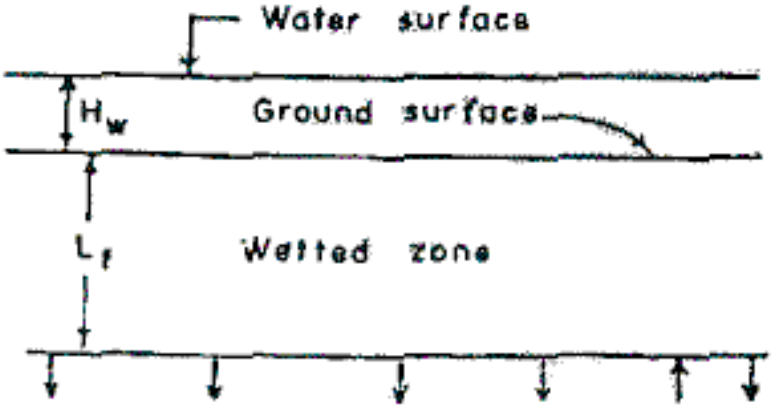
Analogy for natural recharge of groundwater

Infiltrated water may contribute to increase in soil moisture only or may also contribute for charging the ground water reserve. It depends upon the intensity and duration of the rainfall as illustrated in a self-explanatory figure given below.

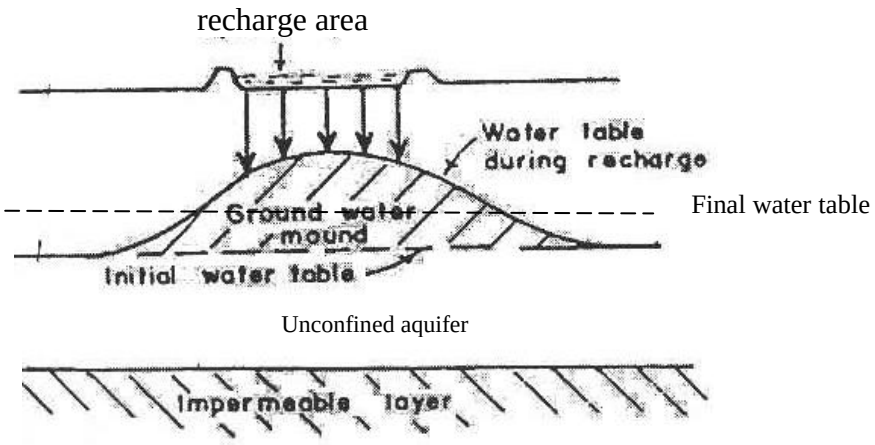


Infiltration model depicting charging of ground water

When the rainfall of adequate intensity and duration occurs, as soon as the top surface get wetted, the wetted front moves downward under the effect of gravity and joins the existing ground water reserve. With continuous percolation of water, *a ground water mound* is formed in the water table, which grows with time, causing rise in water table. With cessation of percolation/infiltration, water mound levels out giving rise to final water table. This recharge process is illustrated in the figures below:



(a) Movement of wetted front



(b) Formation of mound and rise of ground water level

Percolation will cause recharge of ground water reserve only when the rainfall is of adequate duration and intensity i.e. infiltrated/percolated water is more than that required for wetting of soil in the zone of aeration.

2.2.2 What are the factors affecting natural recharge?

The natural recharge of unconfined aquifer takes place through infiltration of the rainwater through a topsoil surface and then its downward movement i.e. percolation, through the soil in the zone of aeration, till it joins existing ground water table.

For the unconfined aquifer having pervious soil in the zone of aeration, rate of recharge will depend on the following factors provided rainfall is of adequate intensity and duration :

- *The type of top surface soil*, i.e. sand, silt or clay, its texture, structure & permeability affect the *infiltration rate* i.e. a maximum rate at which a given formation can absorb water. Loose permeable, sandy soils have higher infiltration capacity than well-compacted sand. Sandy soil is having higher infiltration capacity compare to silty or clayey soil.

  The infiltration capacity of a formation/soil is high when it is dry i.e. at the beginning of rainfall and then it decreases with time as the soil saturates, till it attains final steady rate.

- *Surface at entry*, i.e. top surface of the soil at entry point, if the pores are open the infiltration rate will be higher compare to when top pores are clogged with fines particles.

- *Presence of porous and highly permeable formation in the zone of aeration,* will permit higher *percolation rate* i.e. the rate at which the water is able to move downward through the soil. When the soil occurs in the layers the overall permeability of the soil layers will determine the effective rate of percolation.

- *Quality of water,* i.e. impurities in the infiltrating water, particularly in suspension form, affects the rate of infiltration. The turbidity of water, especially the clay and colloid content blocks the fine pores in the soil thus reducing infiltration capacity.

2.3 WHAT IS GROUNDWATER DEPLETION ?

When the extraction of groundwater is *excessive* compared to natural replenishment it leads to an imbalance in the groundwater reserves, causing depletion/lowering of the existing groundwater level with time. Depth of water table from the surface increases, and wells becomes dry.

2.4 NEED FOR RAIN WATER HARVESTING

We get lot of rain, yet we do not have water. Why ? Because we have not reflected enough on the value of the raindrop. The annual rainfall over India is computed to be 1,170 mm (46 inches). This is higher compared to the global average of 800 mm (32 inches). However, this rainfall occurs during short spells of high intensity.

Because of such intensities and short duration of heavy rain, most of the rain falling on the surface tends to flow away rapidly, leaving very little for the *recharge of groundwater under natural process*. This makes most parts of India experience lack of water even for domestic uses. Ironically, even Cherrapunji, which receives about 11,000 mm of rainfall annually suffers from acute shortage of drinking water. This is because the rainwater is not conserved and allowed to drain away. Thus it does not matter how much rain we get, if we don't capture or harvest it.

This highlights the need to implement measures besides natural storage as ground water and in surface water bodies etc , to ensure that the rain falling over a region is tapped as fully as possible, either for artificial recharge of groundwater aquifers or storage for direct use.

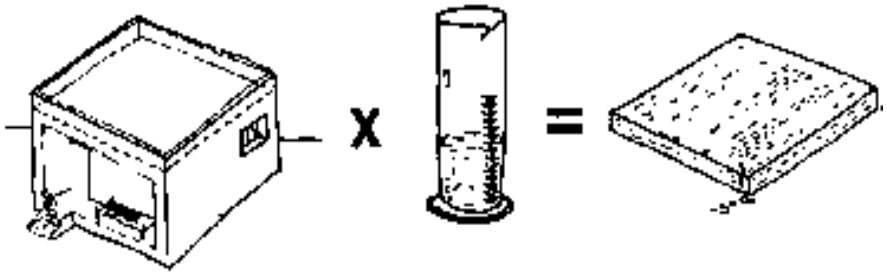
2.4.1 Where to harvest rain?

Rainwater is the primary source of *new fresh water*. Therefore, harvesting rainwater at the *point of supply* itself has many advantages as below:

- Rainwater is bacteriologically pure, free from organic matter and soft in nature.
- It help in reducing the flood hazard.
- It improves the quality of existing ground water through dilution.
- The recharged aquifer also serves as a distribution system.
- Rainwater may be harnessed at place of need and may be utilised at time of need.
- The structures required for harvesting the rainwater are simple, economical and eco-friendly.

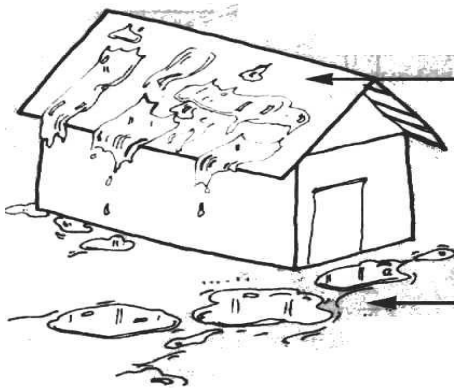
2.4.2 How much rain water can be harvested?

Area of catchment x Amount of rainfall = Volume of water received



The total amount of water that is received in the form of rainfall over an area is called the rainwater endowment of that area. Out of this, the amount that can be effectively harvested is called the *water harvesting potential*.

All the rainwater falling on the surface cannot be effectively harvested due to losses on account of evaporation, spillage, infiltration, losses in wetting the catchment surface etc. All these factors contribute in reducing the quantity of rainwater available for harvesting i.e. overflow from catchment, also known as runoff. *Runoff* is the term applied to the water that flows away from a catchment after falling on its surface in the form of rain.



Runoff from a surface

Total runoff from a catchment is the quantity of rainwater that can be harvested.

2.4.3 What are the factors affecting runoff from catchment?

Among the several factors that influence the rainwater harvesting potential of a site, eco-climatic conditions and the catchment characteristics are more important.

a. ***Rainfall***

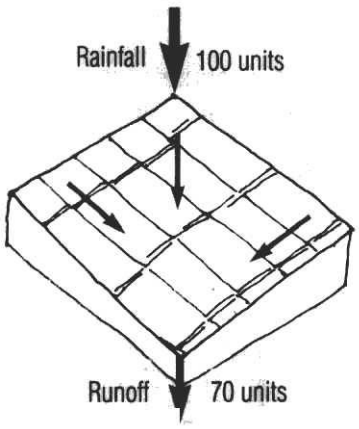
i) *Quantity :* To determine the potential rainwater supply form a given catchment, rainfall quantity is the most important parameter. For assessing rainfall quantity a reliable rainfall data are required, preferably for a period of at least 10 years. It can be determine by using rainfall data from the nearest raingauge station with comparable conditions.

ii) *Pattern:* The intensity, duration and aerial distribution of rainfall influences the rate and total volume of runoff. Total runoff from a given intensity rainfall depends on its duration, basically due to decrease in rate of infiltration with the time in the initial stages of rainfall. Therefore, though a rainfall of short duration may not produce any runoff, but the same intensity rainfall of longer duration will result in runoff.

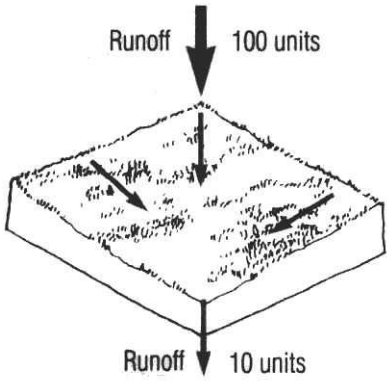
Rainfall intensity influences both the rate and the volume of runoff. An intense rainfall, which exceeds the infiltration capacity by a greater margin than a mild rainfall, will result greater total volume of runoff, even when the total rainfall is the same.

b. Catchment area characteristics

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



Runoff from a smooth tiled surface.



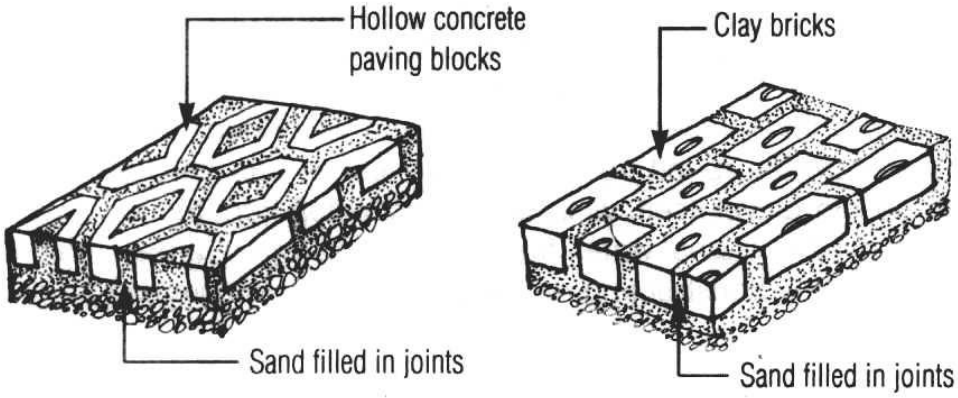
Runoff from a surface covered with grass.

For example, about 70% of the rainfall that occurs over surface of a terrace would flow as runoff while only 10% of the rainfall on a wooded or grassy area would flow, and the rest is retained on the surface and gets percolated into the ground.

Unpaved surfaces have a greater capacity of retaining rainwater on the surface. A patch of grass would retain a large proportion of the rainwater falling on it, yielding only 10 to 15

percent as run off. A considerable amount of water retained on such a surface naturally percolates in the ground contributing to the *natural recharge of groundwater.*

Therefore, if paving of ground surface is unavoidable, one may used pavements, which retain rainwater and allows it to percolate into the ground.



Permeable surface

2.4.4 How runoff is estimated?

For estimation of runoff, all losses due to spillage, leakage, infiltration, catchment surface wetting and evaporation etc., are accounted for by using runoff coefficient. *Runoff coefficient* for any catchment is the ratio of the volume of water that runs off a surface to the volume of rainfall that falls on the surface.

Runoff coefficient for various catchment surfaces are given in table below :

Table – Run off Coefficient for various surfaces

Type of catchment	Coefficient
Roof catchment	
-Tiles	0.8-0.9
-Corrugated metal sheets	0.7-0.9
Ground surface coverings	
-Concrete	0.6-0.8
-Brick pavement	0.5-0.6
Untreated ground catchment	
-Soil on slopes less than 10 percent	0.0-0.3
-Rocky natural catchment	0.2-0.5

The water harvesting potential i.e. runoff, of a catchment is estimated as under :

Water harvesting potential = Rainfall X Area of catchment X Runoff coefficient

2.4.5 From where to harvest rain?

Rainwater can be harvested from the following surfaces:

- ***Rooftops:*** If buildings with impervious roofs are already in place, the catchment area is effectively available free of charge and they provide a supply at the point of consumption. Organic/ thatched roofs, are normally not preferred for harvesting due to poor quality water i.e. high turbidity and dissolved organic material, which does not settles down.

  The harvesting system involving collection of rainwater from rooftop are known as ***rooftop harvesting system***.

- ***Paved and unpaved areas*** i.e., landscapes, open fields, parks, roads and pavements and other open areas can be effectively used to harvest the runoff. The main advantage in using ground as collecting surface is that water can be collected from a larger area. This is particularly advantageous in areas of low rainfall.

  From the point of view of quality, runoff can be divided into two types: runoff from paved surfaces (e.g., pavements and courtyards) and runoff from unpaved (e.g., lawns and playgrounds). Quality of runoff from paved surfaces is better since runoff from unpaved surfaces may have bacterial or other contamination. *If water is to be stored for drinking purposes, it is advisable that only runoff from paved surfaces is used for the purpose*.

  Harvesting system involving collection or rainwater from grounds, open fields etc. are known as ***surface runoff harvesting system***.

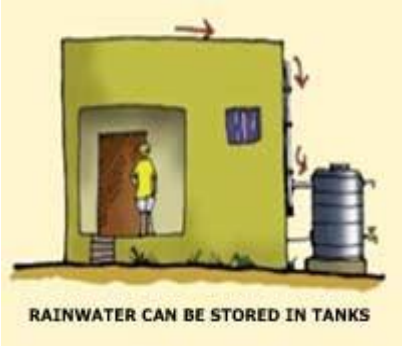
- ***Water bodies****:* The potential of lakes, tanks and ponds to store rainwater is immense. The harvested rainwater in water bodies can be used to meet water requirements of the city and also to recharge groundwater aquifers.

- ***Storm water drains:*** Most of the residential colonies have proper network of storm water drains. If maintained neatly, these offer a simple and cost effective means for harvesting rainwater.

2.5 RAIN WATER HARVESTING SYSTEMS

There are two main systems of rainwater harvesting;

- Storage on the surface for future use.
- Artificial recharge to ground water.





Storage of rainwater on surface is a traditional system and structures used are under/above ground tanks, ponds, check dams, weirs, etc. Artificial recharge to ground water is a relatively new concept of rainwater harvesting. Artificial recharge to ground water is a

process by which the ground water reservoir is augmented at a rate much higher than that under natural condition of replenishment. The structures generally used for recharge are : Recharge pit/trench/ shaft, recharge dugwell/borewell, recharge/injection wells etc.

In both the cases, the harvesting system comprises of catchment area, water inflow/conveyance network and the storage tank or ground aquifer recharge facilities. All these components are covered in detail in the next chapter, alongwith harvesting systems, design aspects as well as their suitability.

2.6 WHETHER STORED WATER IS SUITABLE FOR DRINKING PURPOSE?

Contrary to popular belief, water quality improves over time during storage in the tank due to sedimentation, floatation and bacterial die-off, if the water is not disturbed. Even pathogenic (harmful) organisms gradually die out during storage.

The main factors for the bacterial decline are :

- Algae die off due to lack of sunlight.
- Competition for food increases.
- Predation increases reducing the prey micro-organisms and ultimately starving out the predators.
- Removal of some bacteria due to flocculation and sedimentation.

Additionally biological contamination can be further removed by disinfecting the water. Many simple methods of disinfection now available can be used before consuming stored water for drinking purpose.

2.7 WHETHER ARTIFICIAL RECHARGE TO GROUND WATER IS POSSIBLE AT ALL PLACES?

Artificial recharge to ground water reservoir is possible only where favorable geological and hydro-meteorological conditions exist. There are basically two techniques of artificial recharge i.e. surface and sub-surface techniques.

In surface technique, unconfined aquifers are recharged through a process of infiltration/percolation through zone of aeration. In these techniques, infiltration is augmented either by, (i) increasing percolation time for runoff water by increasing its retention time on the surface before it flows away, or (ii) increasing the rate of percolation, by bye passing the top impervious/less pervious strata's, and/or (iii) by reducing the depth of percolation for recharge of ground water.

For successful recharge to ground water by surface techniques existence of following conditions are necessary.

- Surface soil must be of sufficient permeability to maintain high infiltration rate.
- Aeration zone must be permeable and free from clay layers or other fine materials that could restrict downward flow of water.
- Aquifer must be unconfined, permeable and thick enough to avoid excess amount of ground water mounds.

- Sufficient quantity of runoff water shall be available.

In sub-surface technique, the recharge structure lies below the ground surface and the collected water is carried down to the aquifer for direct recharging. These techniques are used for recharging deep aquifer having part depth in unsaturated condition. Aquifer may be either a confined aquifer or the aquifer overlain by a thick layer of impermeable formation i.e. clay etc.

In these techniques, harvested water joins the ground water aquifer directly through gravity flow under the hydrostatic head equivalent to depth of the aquifer.

For successful recharge of ground water through sub-surface techniques existence of following conditions are necessary,

- Presence of aquifer with part depth in unsaturated condition
- Availability of space for construction of recharge structure, and its cost.
- Recharge acceptance rate of aquifer.
- Availability of sufficient quantity of runoff water.

2.8 WHICH WATER IS SUPERIOR, DIRECTLY STORED OR THE GROUND WATER ?

Water which is stored for direct use is derived from rainfall hence the quality is normally good and free from harmful constituents. Groundwater is generally clear and colourless but harder than the surface water of the region. Bacterially, groundwater is much better than surface water except where sub-surface pollution exists.

However, rainwater stored as groundwater, comes in contact with organic and inorganic substances during percolation through the soil and acquires chemical characteristics representative of the strata it passes through.

The generally observed quality problems of ground water are as under :

1. Brackishness or salinity due to influence of rock strata, geological formation.
2. High level of hardness in lime stone formation.
3. Pollution due to percolation of industrial and municipal wastes.
4. Contamination in coastal area due to intrusion of seawater.
5. Pollution due to percolation of agro-chemicals and pesticides applied for agricultural purposes.

Storing rainwater as ground water reserve is generally advantageous only, when the existing ground water is of potable quality.

2.9 WHETHER RAINWATER IS TO BE STORED DIRECTLY OR AS GROUND WATER ?

The decision whether to use collected water for direct storage or for recharge of aquifer depends on the rainfall pattern and the potential to do so, in a particular region. The sub-surface geology also plays an important role in making this decision.

The total number of annual rainy days also influences the need and design of rainwater harvesting system. Fewer the annual rainy days or longer the dry period, more is the need for rainwater collection in a region.

- If the dry period is too long, big storage tanks would be needed to store rainwater. Hence in such regions, it is more appropriate to use rainwater to recharge groundwater aquifers rather than for direct storage.
- In places where sub-strata is impermeable recharging will not be feasible. Hence, it would be ideal to opt for direct storage.
- In places where the groundwater is saline or not of potable standards, the alternate system could be that of storing rainwater.

For example, Delhi, Rajasthan and Gujarat where the total annual rainfall occurs during 3 or 4 months, are examples of places where groundwater recharge is usually practiced. In places like Kerala, Mizoram, Tamilnadu and Bangalore where rain falls throughout the year barring a few dry periods, one can depend on a small sized tank for storing rainwater, since the period between two spells of rain is short.

Beyond generalisations, it is the requirement and feasibility that governs the choice of water harvesting technique.

2.10 QUALITY CONTROL REQUIREMENT OF HARVESTED WATER:

Rainwater collected is used either for direct storage or recharging ground water reserve. Recharging of ground water reserve can be carried out either through infiltration /percolation of the water through soil strata before it joins the ground water reserve or it can be charged directly to the ground water reserve through direct injection wells under gravity flow.

Irrespective of harvesting method, certain quality control measures are required for ensuring the quality of harvested water. Harvesting contaminated water may make the stored water unsuitable for drinking purpose or may cause irreversible contamination of ground water aquifer. To ensure the quality of harvested water following measures are generally adopted.

- ***For recharge of ground water through surface technique***, no elaborate or special quality measures are required since, infiltration through soil it self causes:

  (i) Removal of suspended particles
  (ii) Removal of pathogenic bacteria
  (iii) Retention to large extent of heavy metals, pesticides and radionuclides by absorption and ion exchange on the surface of clay materials.
  (iv) Decomposition of organic matters.

(v) Conversion of soluble inorganic compounds to insoluble compound.

However, it shall be ensured that the collection surface does not causes chemical contamination of harvested water.

- ***For direct storage or recharge of ground water through sub surface techniques***, it is essential to ensure that the water is free from air pollutions and surface contaminations i.e. dust, silt, debris, organic impurities etc.

Rainwater collected from *rooftops* contains air pollutants and surface contaminations, which can be prevented to a large extent by:

- Flushing off runoff from the first 10-20 minutes of rainfall
- Arresting debris carried by the water from the rooftop like leaves, plastic bags and paper pieces by the grill at the terrace outlet
- Removing remaining contaminants like silt and dirt by sedimentation (settlement) and filtration.

Water to be used for drinking purpose should not be collected from roof with damaged asbestos sheets or from roofs covered with asphalt and lead flashing or lead based paints as the poisonous lead contamination may occur in the collected water.

For rainwater collected from *ground surface* following actions are usually taken :

- Cleaning of surface of vegetation, organic and loose materials.
- Improving the vegetation management by changing ground cover if required.
- Smoothening the surface by mechanical compaction or surface binding treatment.
- Checking that the surface is free from all such chemical and organic material, which may cause chemical/bacterial contamination of harvested water.

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CHAPTER – 3

RAIN WATER HARVESTING SYSTEMS

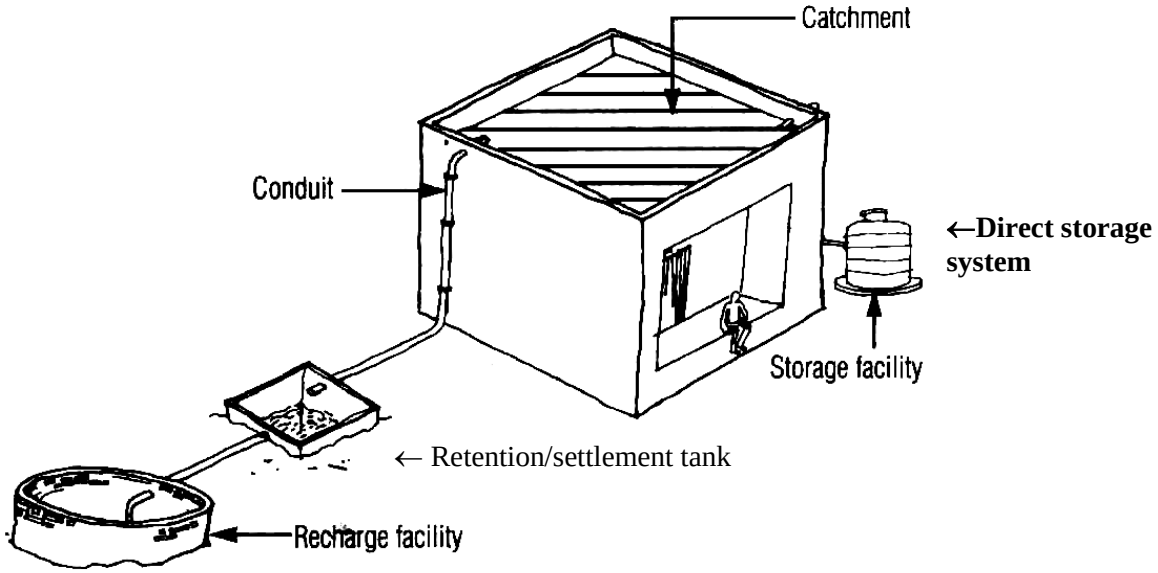
All rainwater harvesting system normally consists of three basic components:

- Collection area/catchment,
- Inflow-structures, and
- Storage structure.

Collection area in most cases is either the roof of house/building or ground. The effective collection area and the material used in the construction of the roof or the type and features of the ground surface influences the efficiency of collection and water quality.

Inflow-structures usually consist of *gutter, conduit, mesh filter, first flush device, water filter, and / or settlement tank.*

Storage structure: The water collected is either stored in a *storage tank or as ground water through artificial recharge.* Storage structure comprises of either above/underground storage tanks, or the retention/settlement tanks with ground water recharge facilities.



Artificial recharge system

Rain water harvesting systems

The details of various elements of a rainwater harvesting system are as under-

3.1 CATCHMENT

The catchment of water harvesting system is the surface, which receives rainfall directly and contributes the water to the system. It can be paved area like a terrace or courtyard of a building, or an unpaved area like a long or open ground.

The roof of the house is also used as the catchment for collecting the rainwater. The style, construction and material of the roof affect its suitability as a catchment. Roofs made of corrugated iron sheet, asbestos tiles or concrete can be utilised as such for harvesting the rainwater. But thatched roofs are not preferred as it gives some colour to water and also the water carries large quantity of suspended impurities.

*Water to be used for **drinking purpose** should not be collected from roof with damaged asbestos sheets or from roofs covered with asphalt and lead flashing or lead based paints as the poisonous lead contamination may occur in the collected water.*

3.2 INFLOW STRUCTURES

- **Gutters :**

Gutters collects rain water from the tapered/sloppy roof and transport it to the inflow-pipe. The gutters could be of various shapes, size and material.

- *Shape* of gutter can be semicircular or rectangular.
- *Material* of the gutter could be:
  - Aluminium or G. I. sheet.
  - Half cut PVC rigid pipe.
  - Half cut large diameter bamboo trunk.
- *Size* of the gutter should be according to the flow during the *highest intensity* rain. It is advisable to make them 10 to 15 percent over size. At the place of junction of the gutter and inflow pipe, the gutter may be enlarged to accommodate the greater influx of water at the bend.

To keep leaves and other debris away from entering the system, the gutter should be covered with wire mesh (jali) along the entire length.

- **Conduits**

Conduits are the pipelines or drains that carry rainwater from the rooftop to the harvesting system. Conduits may be made of any material like PVC, Asbestos or galvanised iron etc. that is commonly available.

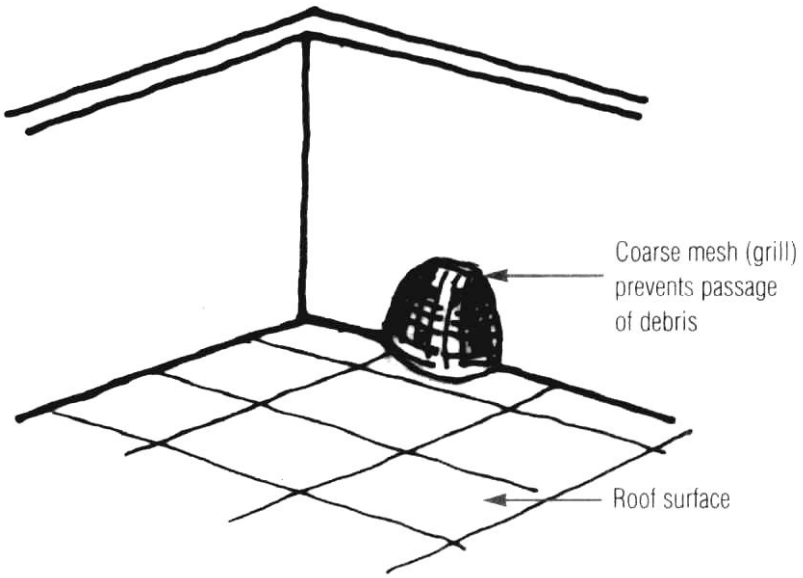
The following **table** gives an idea about the diameter of pipe required for draining out rainwater based on rainfall intensity and roof area:

Sizing of rainwater pipe for roof drainage

Dia meter of pipe (mm)	*Average rate of rainfall in mm/h*					
	50	**75**	**100**	**125**	**150**	**200**
	Roof area in square metre					
50	13.4	8.9	6.6	5.3	4.4	3.3
65	24.1	16.0	12.0	9.6	8.0	6.0
75	40.8	27.0	20.4	16.3	13.6	10.2
100	85.4	57.0	42.7	34.2	28.5	21.3
125	-	-	80.5	64.3	53.5	40.0
150	-	-	-	-	83.6	62.7
Mm/h = millimetre per hour; m –meters Source = National Building Code						

- **Mesh filter**

At the mouth of inflow-pipe a *mesh filter i.e grill* should be fixed to prevent the entries of debris leaves etc. with the water collected from roofs.



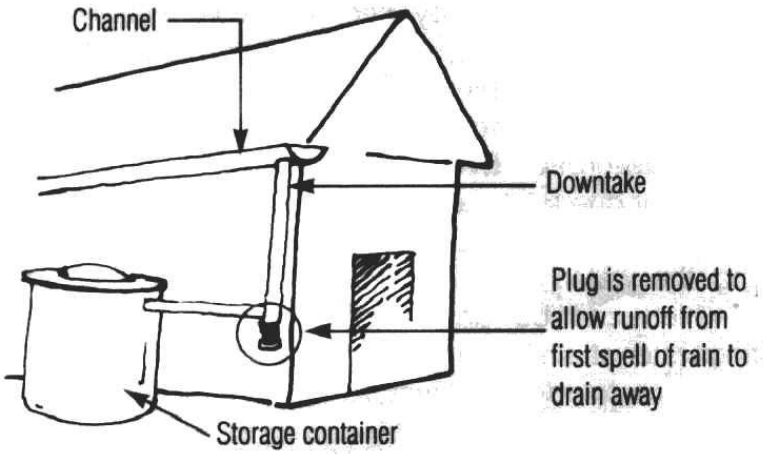
Mesh filter prevents debris from entering the drain pipe.

- **First flush device**

Debris, dirt and dust collect on the roofs during non-rainy periods. When the first rains arrive, this unwanted material will be washed into the storage tank or recharge system and contaminate the water.

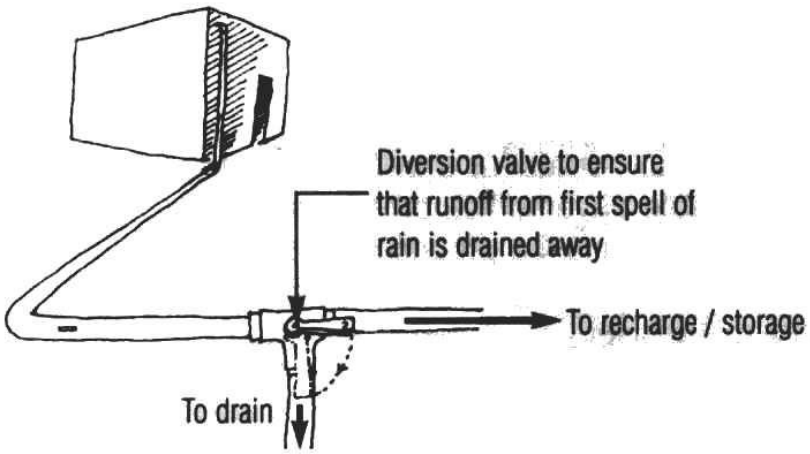
Therefore, a first flush system is incorporated in the Rooftop Rainwater Harvesting Systems particularly in direct storage type to dispose off the first spell of water so that it does not enter the system. Following systems are normally used:

Manual system, in this system the down pipe is manually moved away from the tank inlet and replaced again once the first spell of rain water has been disposed off.



A manual first-flush device

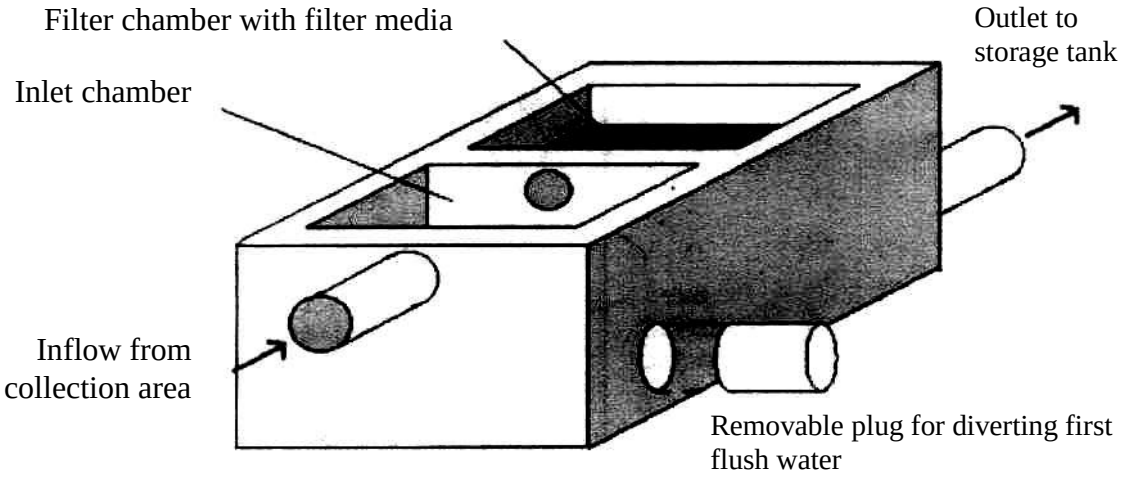
Semi-automatic system, in this system a separate vertical pipe is fixed to the down pipe with a valve provided below the T-junction as shown in figure.



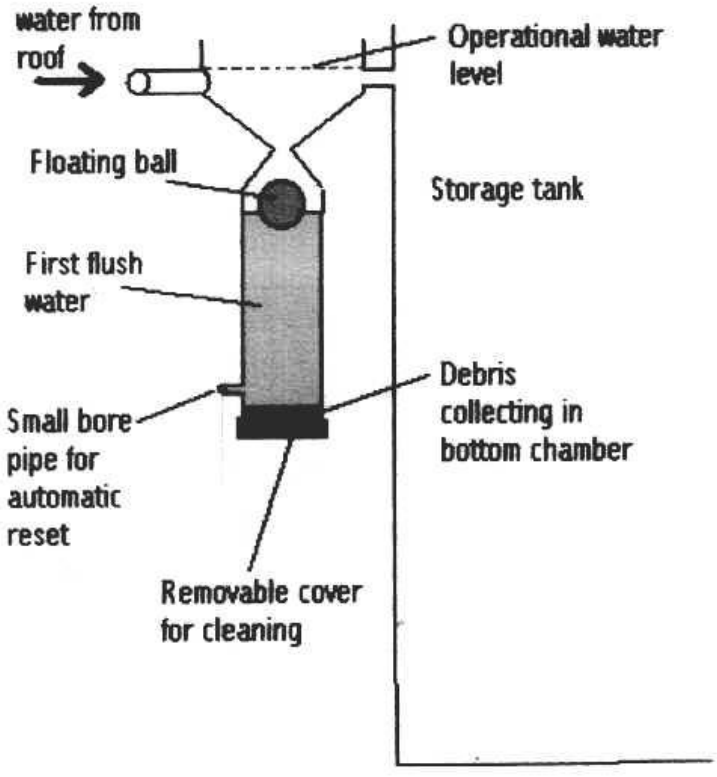
Semi-automatic type first flush device

After the first rain is washed out through first flush pipe the valve is closed to allow the water to enter the down pipe and reach the storage tank.

Fixed volume method, this system relies on the water simply filling a chamber of a set size (usually a length of down pipe) until it overflows. The method can be used either with or without a floating ball seal which helps in reducing mixing between early dirty water and later clean water.



Fixed volume type arrangement



Fixed volume with floating ball type arrangement

The manual/semi automatic systems are simple and widely recommended however they rely on the user both being at home and prepared to go out into the rain to operate the device.

- **Filter unit**

If the water stored is to be used for **drinking purposes**, a filter unit should also be provided in the conduit system before water is stored. It shall be placed after first flush device to remove suspended and floating pollutants/impurities from the collected rainwater.

- *It should also be provided if the water is used for recharging ground water aquifer through functional well/borewell/handpump/tubewell.*

A filter unit is a container or chamber filled with filter media such as coarse sand, charcoal, coconut fibre, pebbles and gravels, to remove the debris and dirt from water. The container is provided with a perforated bottom to allow the passage of filtered water. The height of filter chamber is kept at least one feet above the filter media to provide hydro-static head for filtration.

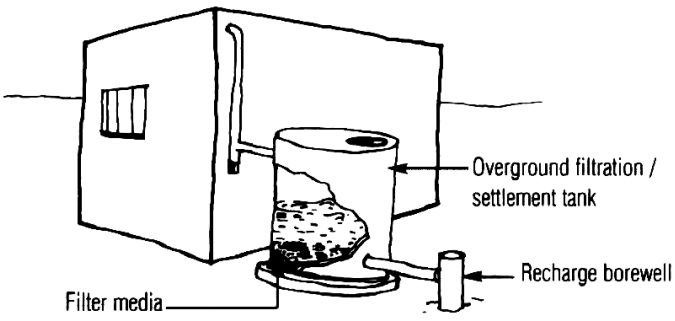
Another simple way of filtering the debris and dust particles that came from the roof along with rainwater is to use a fine cloth as filter media. The cloth, in 2 or 3 layers, can be tied to the top of a bucket or vessel with perforations at the bottom. The various filters commonly used in rainwater harvesting systems are described in detail in the next chapter.

- **Retention/Settlement tanks**

If the collected rainwater is used for recharging ground water reserve, it should be passed through a retention/settlement tank before it enters the aquifer. The passage of water through settlement tank is essential firstly to remove suspended material i.e. silt and other floating impurities from the water and to also act as a buffer in the system. In case of excess rainfall, the rate of recharge, especially of bore wells, may not match the rate of rainfall. *In such situations, settlement tank holds the excess amount of water till it is soaked up by the recharge structure*.

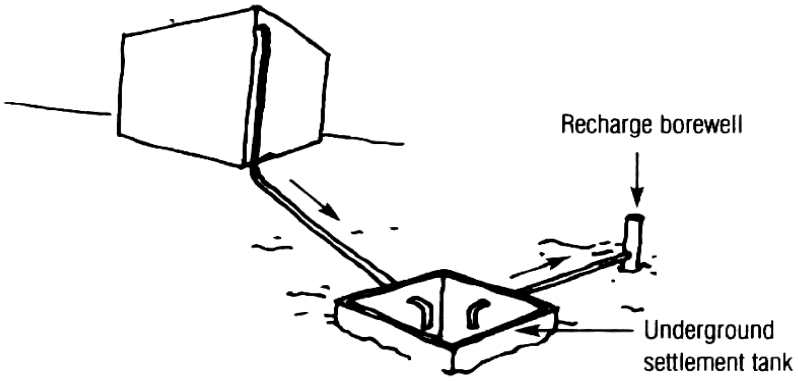
A settlement tank is like an ordinary storage container having provisions for in flow (bringing water from the catchment), outflow (carrying water to the recharge well) and overflow. Any container with adequate capacity of storage can be used as settlement tank. It can be either underground or over ground type.

Over ground tanks, beside masonry and concrete tanks, pre-fabricated, PVC or ferro-cement tanks can be used. Pre-fabricated tanks are easy to install, compared to masonry and concrete tanks.



Over-ground PVC settlement tank

Underground tank, are normally masonry and concrete tanks. These tanks may have an unpaved bottom surface to allow standing water to percolate through soil.



Underground masonry settlement tank

Design of settlement tanks:

For designing the optimum capacity of the tank, following aspects are considered

1. Size of the catchment
2. Intensity of rain fall
3. Settlement/detention tank
4. Rate of recharge

The desilting tank also acts as buffer tank. Therefore it is designed to retain a certain amount of rainfall for percolation through recharge facilities. This minimum capacity is mainly required due to rate of recharge may not be comparable with the rate of runoff. The capacity of the tank should be enough to retain the runoff occurring during peak rainfall intensity. *Normally, the settlement tank is designed to retain runoff from* ***atleast 15 minutes rainfall of peak intensity***.

Suppose the following data is available:

Area of rooftop catchment (A)	= 100 sq.m
Peak rainfall in 15 min. (r)	= 25 mm (0.025 m)
Runoff coefficient (C)	= 0.85

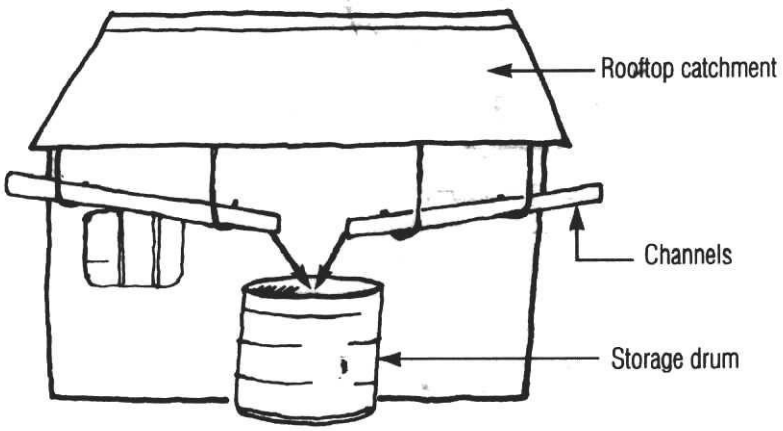
Then, capacity of settlement tank	= A x r x C
	= 100 x 0.025 x 0.85
	= 2.125 cu. m. (2,125 litres)

3.3 RAIN WATER HARVESTING SYSTEMS:

Collected run off can be used either for:

- Storage for direct use, or
- Artificial recharge of groundwater aquifers.

3.3.1 Storage for direst use



A simple water storage system

Generally, runoff from only paved surfaces is used for storing, since it is relatively free of bacteriological contamination. Drainpipes that collect water from the catchment (rooftop) are diverted to the storage container.

Rainwater can be stored in any commonly used storage containers like RCC, masonry or plastic water tank. There are unlimited options for the construction of storage tank with respect to the shape, size and the material of construction. For domestic water needs ferro-cement tanks of cylindrical shape are more suitable for the capacity between 4,000 to 15,000 litres. Plain / reinforced cement concrete tanks are used for capacity more than 50,000 litres, and brick or stone masonry tanks are used for capacity between 15,000 to 50,000 litres.

Storage tank is provided with a cover to avoid contamination from external sources. Tank is also provided with outlet, overflow and the drainpipe. Some maintenance measures like cleaning and disinfection are also required to ensure the quality of stored water.

Design of storage tank:

The quantity of water stored in a water harvesting system depends on the size of the catchment area and the size of the storage tank. The storage tank has to be designed according to the water requirements, rain fall and catchment availability.

Design parameters for storage tanks are:

1. Average annual rainfall
2. Size of the catchment
3. Drinking water requirement

Suppose, the system has to be designed for meeting drinking water requirement of a 5 member family living in a building with a roof top area of 100 sq.m. Average annual rainfall in the region is 611 mm. Daily drinking water requirement per person is 10 litres.

First calculate the max. amount of rain fall that can be harvested from the roof top :

Area of the catchment (A) = 100 sq.m
Average annual rainfall are (R) = 611 mm
Run of co-efficient (C) = 0.85

Annual water harvesting from 100 sq. m roof = A x R x C
= 100 x 0.6 x 0.85
= 51 m^3 (51000 litres)

The tank capacity has to be designed for the dry period, i.e. the period between the two consecutive rainy seasons. With a monsoon extending over 4 months, the dry season is of 245 days.

Drinking water requirement for the family (dry season) = 245 x 5 x 10 = 12250 litres

As a safety factor the tank should be built 20% larger than the required i.e. 14,700 litres. This tank can meet the basic drinking water requirement of a small family for the dry period.

- ***Direct storage system comprises of catchment area i.e. roof, mesh filter, gutter and conduits layout, first flush device, filter unit and the storage tank.***

3.3.2 Artificial recharge of groundwater aquifers:

Artificial recharge of ground water is the process by which the ground water is augmented at a rate much higher than those under natural condition of replenishment.

Various techniques can be used, to augment the percolation of rainwater in the ground instead of draining away from the surface. While some structures promote the percolation of water through soil strata at shallower depth (e.g., recharge trenches, permeable pavements), others carry water to greater depths from where it joins the groundwater (e.g., recharge wells) directly.

At many locations, existing features like wells, pits and tanks can be modified to use as recharge structures, eliminating the need to construct any structures afresh.

3.4 ARTIFICIAL RECHARGE TECHNIQUES

Various artificial recharge techniques applicable for **Railway area** are as under, though innumerable innovations and combinations of these techniques are possible*:*

1) Recharge pit /Trench
2) Recharge shafts
3) Borewell/dugwell
4) Recharge pit/trough with Soakaways
5) Recharge tube well (injection well)

3.4.1 Recharge Pit /Trench

This *surface technique* is used for recharging *shallow aquifers*, with thin impervious layer at top. In this technique, collected water, after bypassing impervious layer is applied over a pervious surface in pit/trench to percolate for recharging ground water. *However, bottom of these structures is kept above the ground water level to drive the advantages of infiltration*.

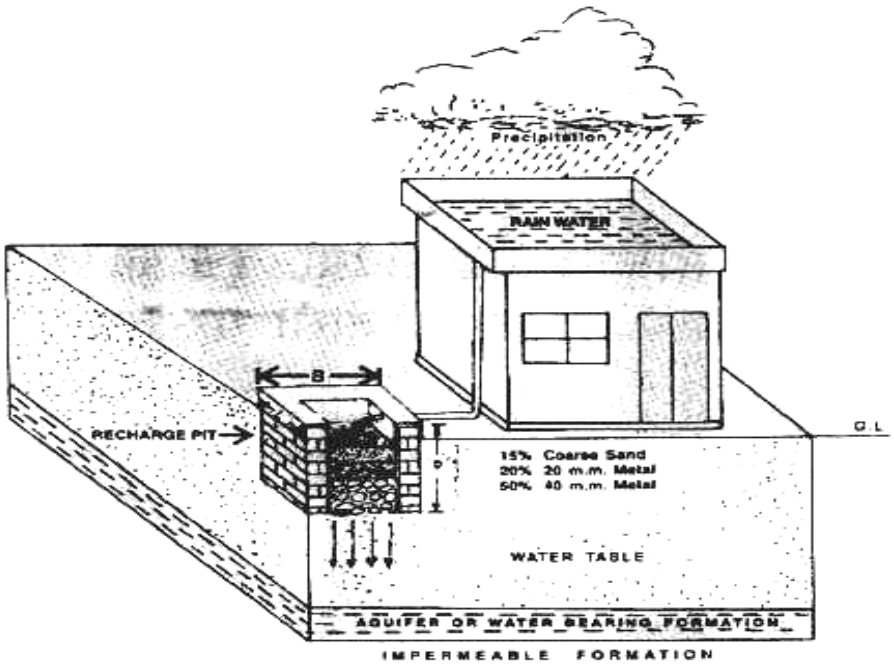
In this technique, few precautions are required to maintain the quality of rainfall run off. For these structures, there is no restriction on the type of catchment from which water is to be harvested that is, both paved and unpaved catchment can be tapped.

Details of these structures are as under:

- ***Recharge pit***

  - 1 to 2 m wide and 2 to 3 m deep recharge pit is constructed. The pit may be lined with a brick/stone wall with opening at regular interval.
  - The collected water from the rooftop is diverted into the pit through a drainpipe.
  - Water to be recharged, should be silt free.
  - For *recharging silt-laden water* it should be either pass through the separate settlement chamber or by providing inverted filter in the pit.
  - For providing inverted filter, pit is filled with boulders and pebbles at the bottom followed by gravel and then sand at the top. (for detail, refer chapter on filters)
  - The top of the pit may be cover with perforated cover.
  - The sand layer in the pit should be removed and replaced every year after rainy season.
  - Recharge pit may be of any shape i.e. circular, square or rectangular.
  - If the pit is of trapezoid shape, the side slopes should be steep enough to avoid silt deposition.

It is suitable for small buildings having the roof top area up to ***100 sq. m.***

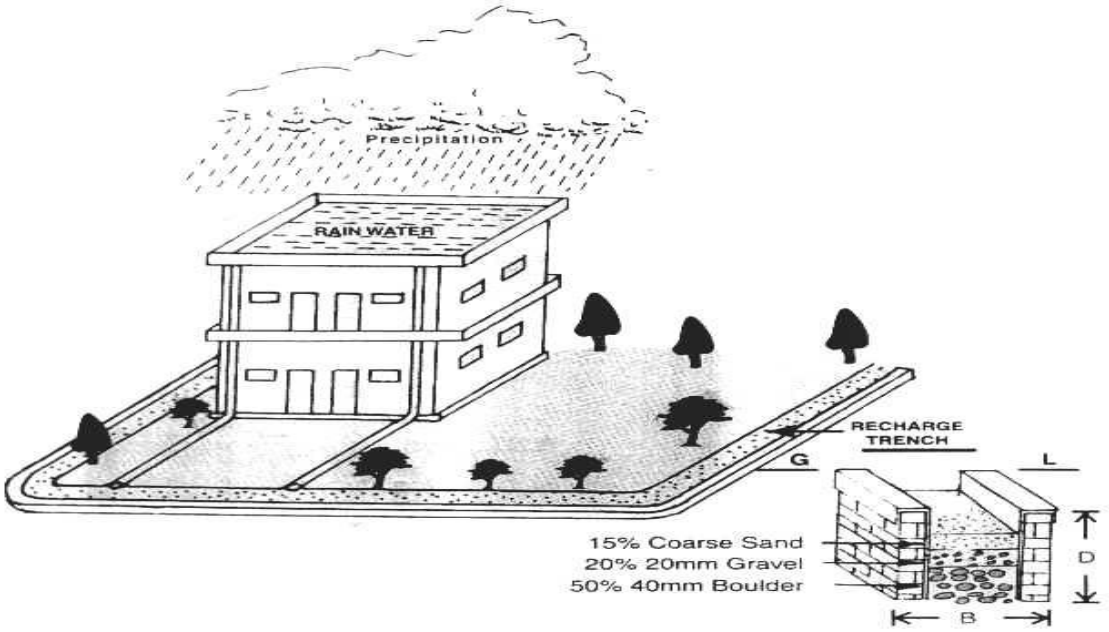


Recharge of ground aquifer by recharge pit

- ***Recharge trench***

- It is a continuous trench constructed when permeable strata of adequate thickness are available at shallow depth.
- A recharge trench can be 0.5 m to 1 m wide and 1 m to 1.5 m deep. The length of the recharge trench is decided as per the amount of runoff expected.
- The collected water from the rooftop is diverted into the trench through a drainpipe.
- Water to be recharged, should be silt free.
- For *recharging silt-laden water* it should be either pass through the separate settlement chamber or by providing inverted filter in the trench.
- For providing inverted filter, trench is filled with boulders and pebbles at the bottom followed by gravel and then sand at the top. (refer chapter on filters)
- The top of the trench may be cover with perforated cover.
- The sand layer in the trench should be removed and replaced every year after rainy season.
- The recharge trench without filter media should be periodically cleaned of accumulated debris to maintain the intake capacity.
- In surface runoff methods, these are constructed across the land slope.

It is suitable for the building having the roof area of **200 to 300 sq. m**.



Recharge of rooftop/surface runoff by recharge trench

In this technique pit/trench itself acts as a buffer tank. If the water contains suspended impurities i.e. silt etc. then to remove them an inverted filter is provided in the pit/trench itself.

Design of recharge pit/ trench:

The methodology of design of a recharge pit/trench is similar to that for designing a settlement tank. The difference is that the water holding capacity of a recharge pit/trench is less than its gross volume when it is filled with porous material for providing inverted filter. A factor of loose density (voids ratio) of the media has to be applied to the equation.

Using the same method as used for design of settlement tank :

Area of rooftop catchment (A) = 100 sq.m.
Peak rainfall in 15 min. (r) = 25 mm (0.025 m)
Runoff coefficient (C) = 0.85
Voids ratio (D) = 0.5 (assumed)

Required capacity of recharge tank = A x r x C/D
= (100 x 0.025 x 0.85)/0.5
= 4.25 cu. m. (4,250 litres)

The voids ratio of the filler material varies with the kind of material used, but for the commonly – used materials like brickbats, pebbles and gravel, a voids ratio of 0.5 may be assumed.

In designing a recharge trench, the length of the trench is an important factor. Once the required capacity is calculated as illustrated above, length can be calculated by considering a fixed depth and width.

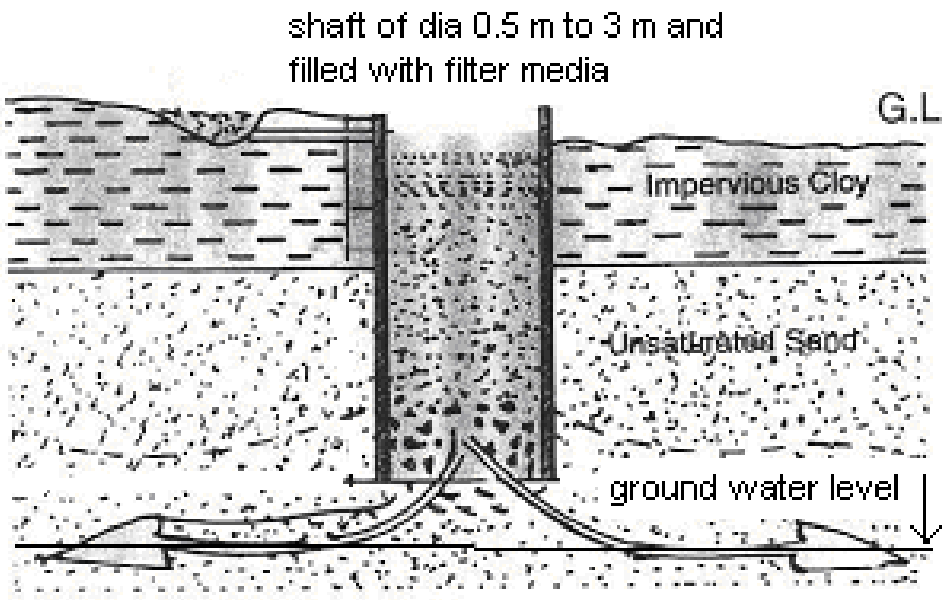
In terms of the recharge rates, recharge pit/trenches are relatively less effective since the soil strata at depth of about 1.5 metres is less permeable. To enhance the recharge rate soakaways can be provided at the bottom of the pit/trench.

3.4.2 Recharge shafts

It is a *surface technique* used for recharging *shallow aquifers*, located below clayey surface at a depth of 10 to 15 m. In this technique shaft of 0.5 to 3 metres diameter and 10 to 15 metre depth is constructed and back filled with boulders, gravels & coarse sand. In upper portion of 1 or 2 m depth, the brick masonry work is carried out for the stability of the structure.

- Diameter of shaft varies from 0.5- 3.0 metre depending upon the availability of water to be recharged.
- Shaft is dug to a depth so that it ends in permeable strata i.e. sand. Bottom of the shaft shall be kept above the water table.
- Shaft is backfilled with a boulder, gravel and coarse sand to provide inverted filter.
- It should be cleaned regularly by scraping top sand layer and refilling it periodically.

Recharge shaft are normally used for recharging surface runoff or the rainwater collected from large roof top area.



Recharge shaft

Shaft should be constructed 10- 15 meters away from the building for their safety.

✍ ***In this technique, shaft itself acts as buffer tank and the suspended/floating impurities are removed through inverted filter action of filled porous material.***

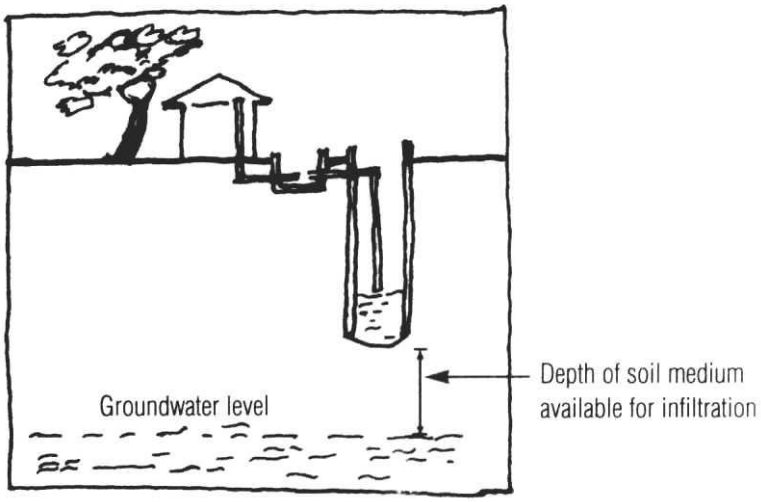
3.4.3 Borewell/Dugwell

In this *surface/subsurface technique,* borewell/dugwell are used to recharge *shallow/deep aquifers*. This system is suitable for the areas where the water table is deep and/or impermeable layer lies between the surface and the aquifer. Rainwater collected from the rooftop is diverted through a drainpipe to a settlement and/or filtration tanks, from where it flows into the recharge structure, which may be either defunct or functional dugwell/ borewell.

☞ With defunct or dry borewell/dugwell ground water is recharged by percolation/infiltration process i.e. through *surface technique*.

☞ With a functional borewell/dugwell, ground water is recharged directly i.e. through *sub-surface technique*.

In surface technique, it is preferred that the dugwell or borewell used for recharging is shallower than the water table. This ensures that the water recharged through the well has a sufficient thickness of soil medium through which it has to pass before it joins the groundwater, to have the benefit of improvement in water quality as explained in previous chapter. Any old well, which has become *defunct,* can be used for recharging, since the depth of such wells is above the water level.

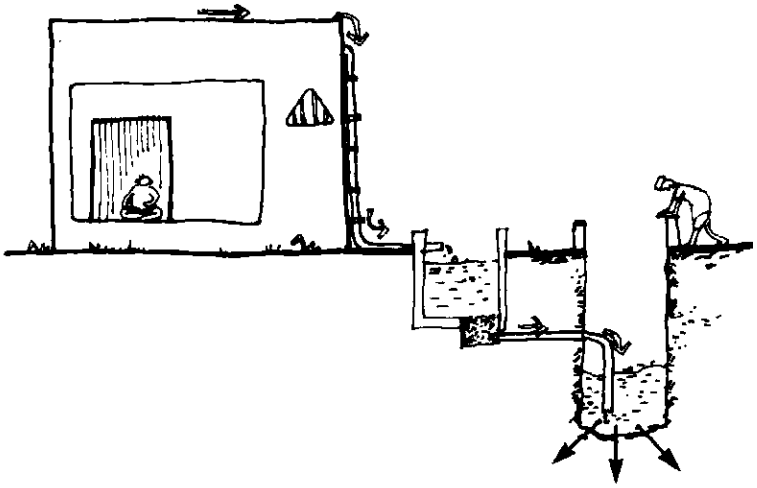


Dugwell/borewell should preferably by shallower than the water table

In both the cases precautions should be taken to ensure that physical matter in the runoff like silt and floating debris do not enter the well since it may cause clogging of the recharge structure. The quality of water entering the recharge structure can be ensured by providing following elements in the system.

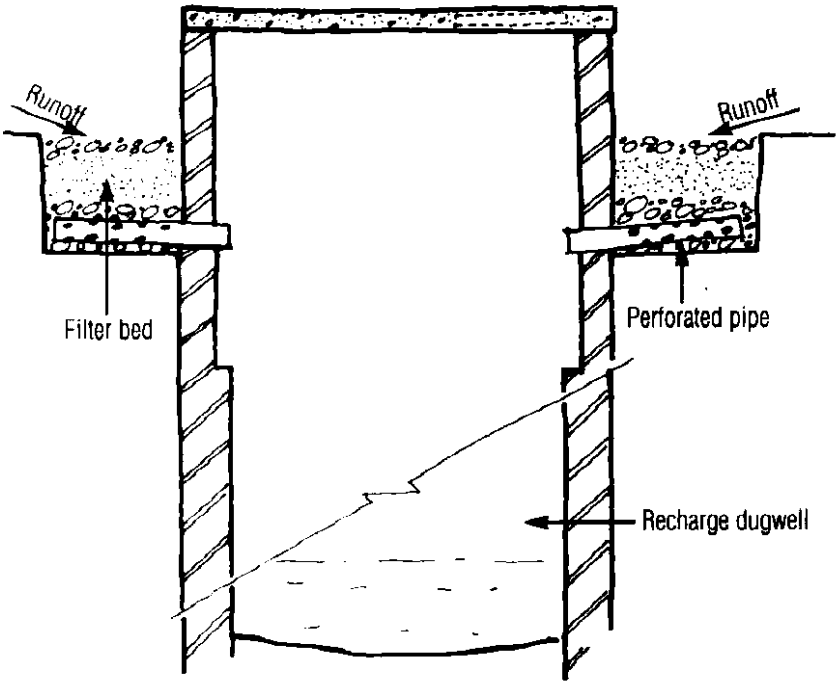
1. Filter mesh at the entrance point of roof top drains.
2. Settlement chamber.
3. First flush device
4. Filter unit/pit.

- ***If a dugwell*** is used for recharge, the well lining should have openings (weep-holes) at regular intervals to allow seepage of water through the sides. Dugwells should be covered to prevent mosquito breeding and entry of leaves and debris. The bottom of recharge dugwell should be desilted annually to maintain the intake capacity.



Recharge assembly for dugwell with rooftop runoff

For recharging water collected from ground surface, water is diverted to a filter unit provided around the dugwell. A typical arrangement is shown in figure below.



Recharge assembly for dugwell with runoff from ground area

Salient feature of dugwell

- A dry/unused or functional dug well can be used as a recharge structure.
- Water to be recharged is guided through a pipe to the bottom of the dry/unused dug well or below the water level of functional well to avoid scouring of bottom and entrapment of air bubbles in the aquifer.
- Bottom of the dug well should be cleaned and all fine deposits should be removed before its use for recharge.
- Recharge water should be silt free otherwise it should be passed through a settlement chamber/filter.
- The well should be cleaned regularly,
- During the period the water is being recharged, water extracted from the functional dugwell should be used after proper chlorination.

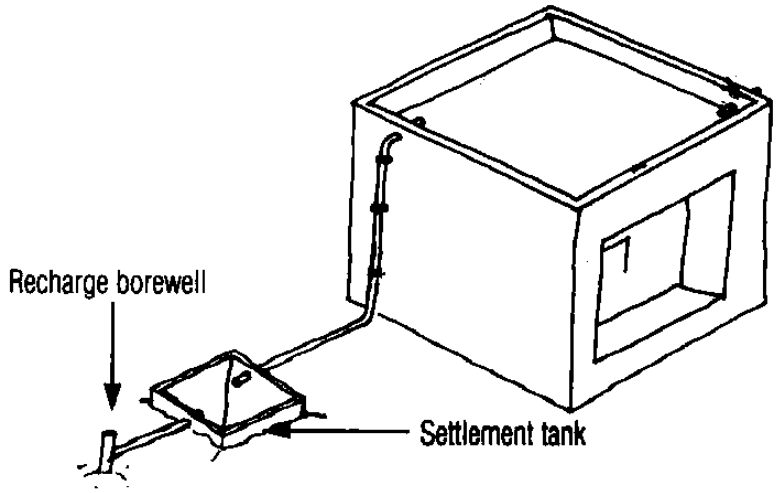
*This method is suitable for large buildings having the roof area of more than **1000 sq.m**.*

For dugwell a separate settlement chamber is normally not required, as dugwell itself acts as a buffer. However if the collected water carries suspended impurities then it should be passed through a filter pit before entering a dugwell.

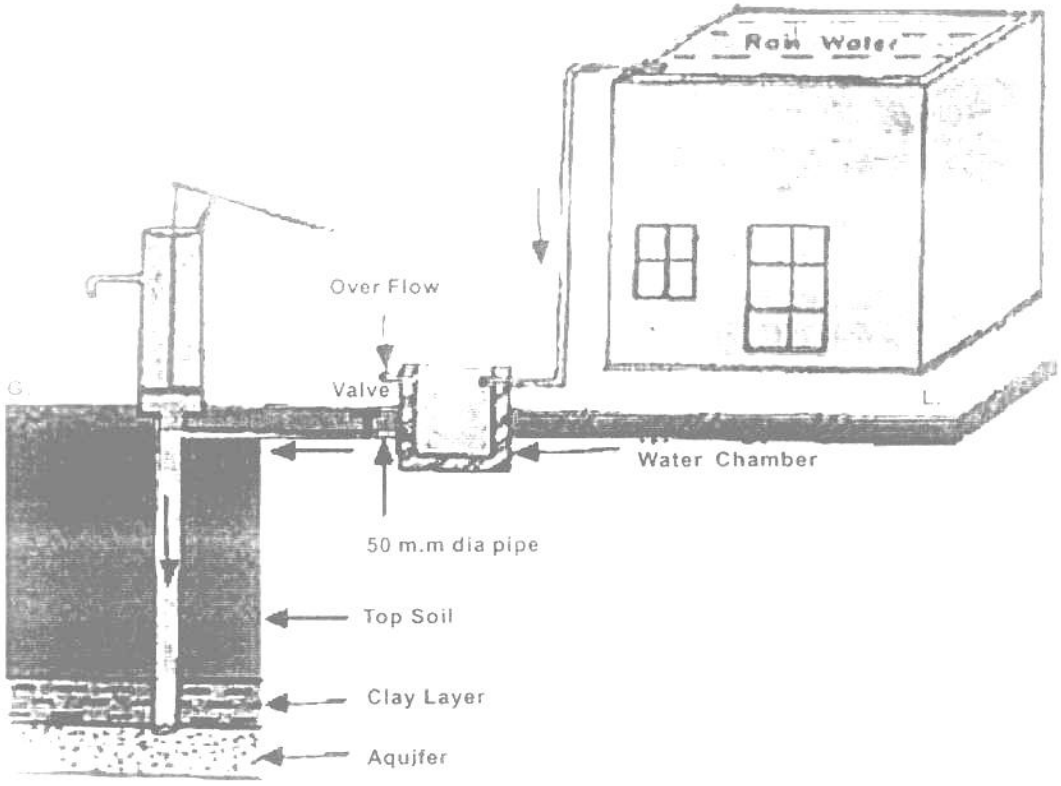
For functional dugwell collected water shall be invariably be passed through a filter pit before entering a dugwell.

- ***If a borewell*** is used for recharging, then the casing (outer pipe) of the borewell should preferably be a slotted or perforated pipe so that more surface area is available for the water to percolate. Developing a borewell would increase its recharging capacity (developing is the process where water or air is forced into the well under pressure to loosen the soil strata surrounding the bore to make it more permeable).

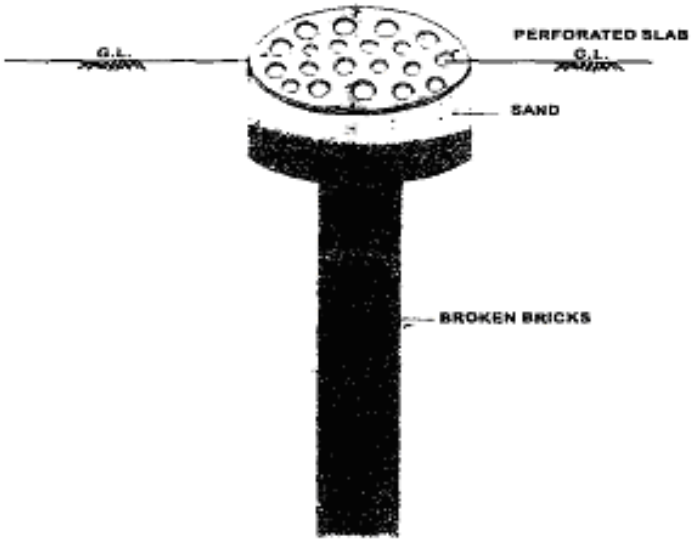
Typical systems of recharging through bore wells with rooftop runoff are as under :



Recharge assembly for borewell



Recharge assembly for functional borewell/hand pump



Recharge assembly for defunct borewell

Salient features of borewell

- An abandoned/running borewell can be used for recharge.
- Water is diverted from the rooftop to the borewell through pipe.
- Water to be recharged is guided through a pipe to the bottom of the dry/unused dug well or below the water level of functional well to avoid scouring of bottom and entrapment of air bubbles in the aquifer.
- Recharge water should be silt free otherwise it should be passed through a settlement chamber/filter.
- During the period the water is being recharged, water extracted from the functional borewell should be used after proper chlorination.

This method is suitable for small buildings having the roof area up to ***150 sq. m.***

For borewell a separate settlement tank is normally required to act as a buffer. If required for removal of suspended impurities filter shall be provided at the bottom of settlement tank.

For functional borewell collected water shall be invariably be passed through a filter pit before entering a borewell.

- **Settlement chamber and the filter are designed as already explained.**

3.4.4 Recharge pit/trough with Soakaways

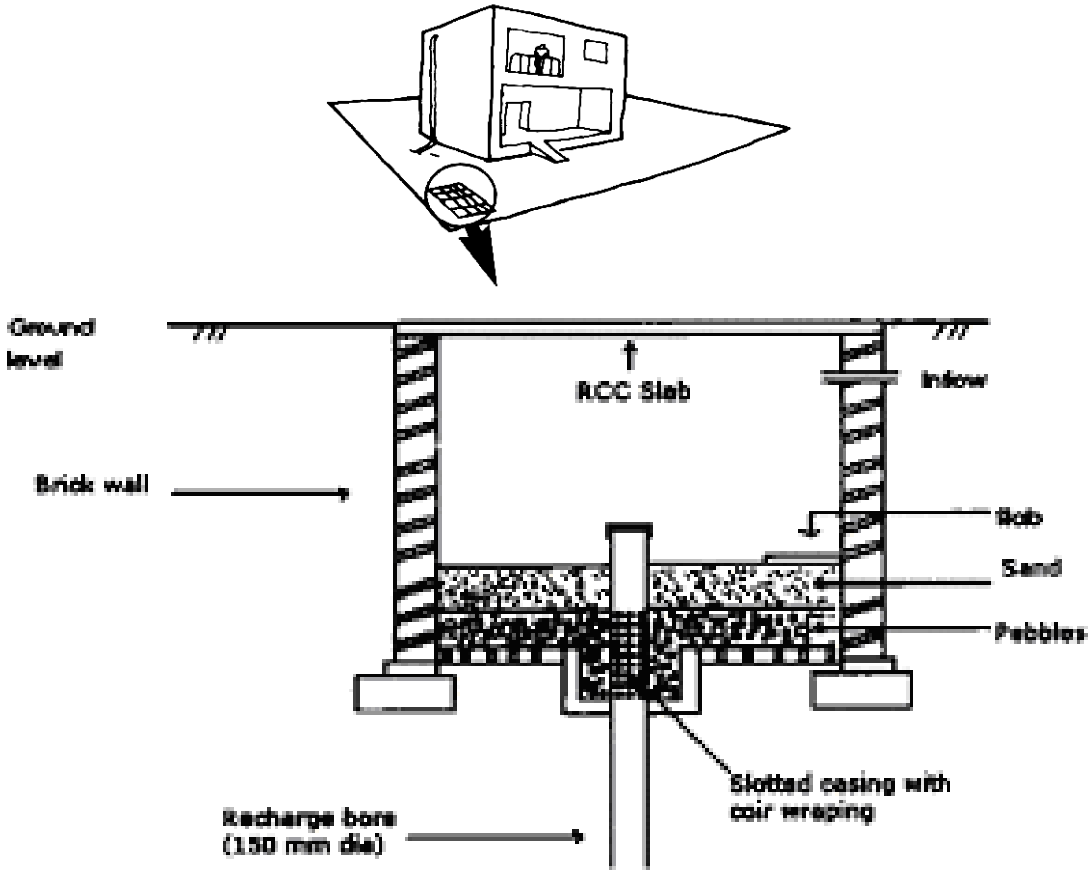
This *sub-surface technique* is used where permeable sandy strata exists within 3 to 5 meter below ground level and up to the water level under unconfined conditions, and when the large quantity of runoff water is available within a short period of heavy rainfall for recharge. In this technique, sump i.e. pit/trough is used to store the runoff water in the filter media for subsequent recharge to ground water through a specially constructed boreholes i.e. soakaways.

A soakaway is a bored hole of up to 30 cm diameter drilled in the ground to a depth of 3 to 10 metres depending upon the nature of soil. If the soil is clayey, the bore should dugged to a depth till a reasonably sandy strata is reached. The depth of the bore is kept at least 3 to 5 meters above/below the water level as required.

The borehole can be left unlined if a stable soil formation like clay is present. In unstable formations like sand, the soakaway should be lined with a perforated PVC/MS pipe to prevent collapse of the vertical sides. In both the cases, *the soakaway are filled up with a filter media like brickbats*.

Depending upon the size of catchment area and quantity of runoff sump provided at the top of soakaway can be either a small pit or a trough and accordingly recharging technique are known as *recharge pit with soakaway* or *recharge trough with soakaway*.

- ***Recharge pit with soakaway***



Recharge pit with soakaway

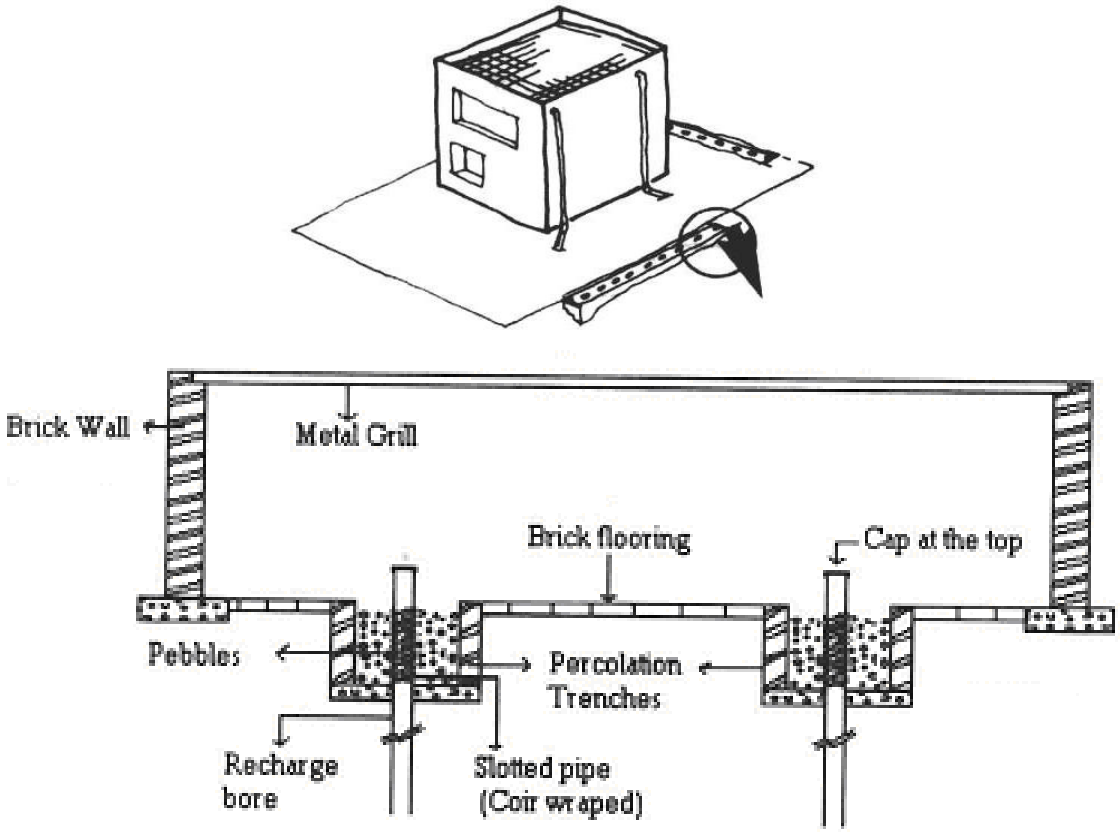
- It consists of 1 to 2 m wide and 2 to 3 m deep pit on the top of soakaway.
- The excavated pit is lined with the brick/stone masonry.
- Top of the pit may be covered with the perforated cover.
- For recharging silty water, bottom of the pit is refilled with boulders and pebbles at the bottom followed by gravel and then sand at the top to act as an inverted filter.
- The water collected from the rooftop is diverted to the pit through a drainpipe.
- Water is filtered through the inverted filter provided in the pit.

- The sand layer in the pit should be removed and replaced every year after rainy season.
- Recharge pit may be of any shape i.e. circular, square or rectangular.

It is suitable for small buildings having the roof top area upto ***100 sq. m****.*

The design of a recharge pit is similar to that for a settlement tank.

- ***Recharge trough with soakaway***



Details of recharge trough with soakaway

To collect the runoff from paved or unpaved areas draining out of a compound, recharge troughs are commonly placed at the entrance of a residential/institutional complex. These structures are similar to recharge trenches except for the fact that the excavated portion is not completely refilled except provision of inverted filter at the bottom. In order to facilitate speedy recharge, soakaways are provided at regular intervals in this trench.

The salient features of recharge trough are similar to that of recharge pit with soakaway except the length of the pit and number of soakaways provided in it.

The method for designing a recharge trough is similar to that for a settlement tank.

In this technique a sump provided at the top of the soakaway acts as a buffer. For removing suspended impurities inverted filter is provided at the bottom of a sump.

3.4.5 Recharge tube well (injection well)

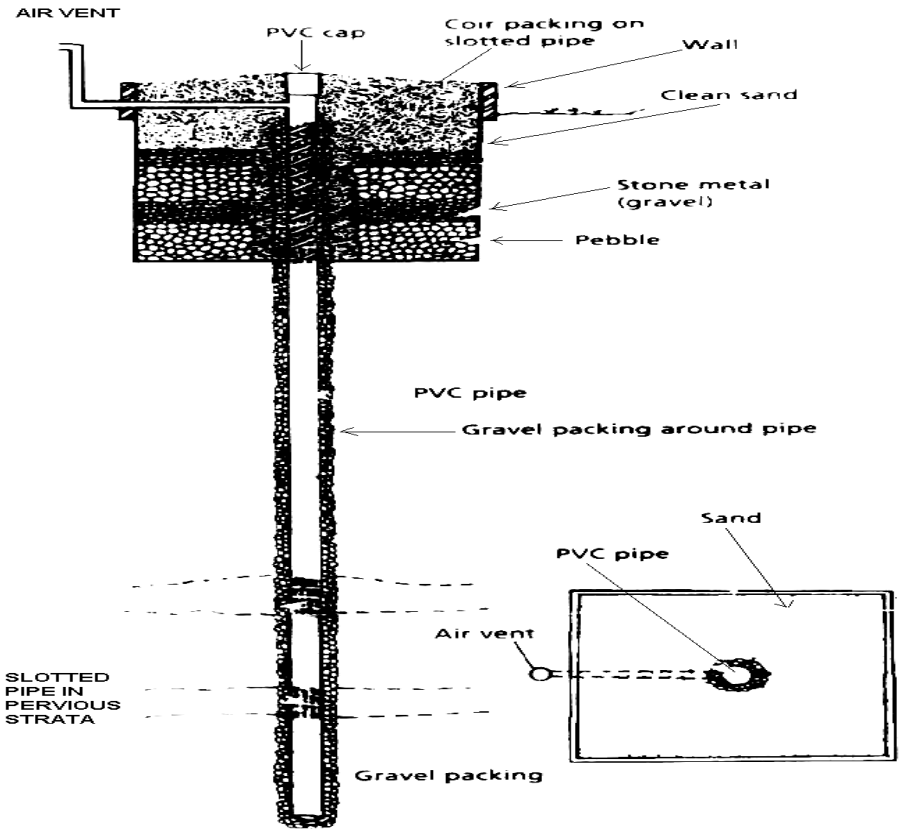
This *sub-surface technique* is used in the area where *aquifer is very deep* i.e. more than 20 meters and/or when a impervious layer is present in the zone of aeration or where confined aquifer is to be recharged.

In this method collected rainwater is diverted to a recharge well for recharging the ground water source directly under gravity flow. Due to direct charging of surface water, the recharge is fast and the absorption and transit losses are less.

For injection well, a tubewell of *50 cm* diameter is drilled, to the depth about 5-15 m below the water table in the area. A 20 cm dia perforated/slotted casing is provided against the aquifers in the tubewell. The annular space between the tubewell and the casing pipe is filled with the good gravel and developed with a compressor till it gives clear water. To provide adequate percolation time and to stop the suspended solids from entering recharge tube well, a chamber with filter mechanism is provided at the top as under.

- A chamber equivalent to settlement tank capacity is constructed with the tube well at the centre.
- This chamber is fitted with small, rounded boulders, stone chips and sand in layers with boulders at the bottom and sand at the top.
- The top 1 m of the casing assembly in this chamber is filled with the sand. The top of the casing pipe is provided with a cap, which is kept about 600 mm below in the sand bed to prevent suspended material from entering the well.

A typical arrangement of recharge well method is as under:



Recharge tube well (injection well)

In order to release the air present in the casing assembly during the percolation process, the air vent is provided through a 50-75mm diameter pipe connected to the recharging tubewell within the top 600mm through a reducer Tee. The air-releasing pipe is extended above the ground.

When rainwater filters through the sand, most of the suspended material is filtered out. The second sand filter surrounding the slotted section of the well and at the top prevents the remaining suspended material entering the well. Beyond this, there is coir wrapping as a final protective filter before water enters the well. The recharge rate gradually decreases due to settling of silt at the top. Every year, after the rainy season, about 1 m of the sand of the filter bed shall be replaced, and the well is developed with a compressor.

The chamber is designed similar to settlement tank with taking into account, porosity of filter material.

3.5 HOW TO DECIDE THE APPROPRIATE RECHARGE TECHNIQUE?

For deciding the appropriate recharge technique/method, the following points should be taken in to consideration:

(i) *Hydrogeology of the area* – nature and extent of aquifer, soil cover, topography, depth of water level and the chemical quality of ground water.

(ii) Quality and quantity of water available for recharge i.e.*;*

- *Catchment characteristics* – Area of catchment, land use patterns i.e. industrial, residential, green belt, paved area or the roof top area etc.

- *Hydrometerological factors* – Rain fall duration, pattern and the intensity of rainfall.

(iii) How readily will the aquifer accept the recharge water and how readily can it be extracted?

- The details of the ground water aquifer i.e. depth and quality of water, can be obtained from the water level of the wells in nearby locality or it can be obtained from the hydro- geological department. The details of the soil cover and the formations below ground level can be ascertained from the data collected from nearby boring sites, existing wells or from hydro-geological department.

- Rechargeable water quality and quantity can be worked out by knowing the catchment area, type of catchment surface and the rainfall intensity, its duration and pattern, as explained in chapter 2. Rainfall details can be obtained from the meteorological department.

- The aquifer recharge acceptance rate can be established by observing the rate of percolation through a test pit or bore/tubewell for few days, till percolation stabilises and attains fairly steady rate.

Based on the above data the appropriate recharge technique can be formulated as enumerated in following examples :

1. *Dwarka area of Delhi* : In this area clay and kankar formation exists in the top 4 meters below ground level. This clay layer is followed by a kankar and silt layer up to a depth of 68 meter bgl. The depth of water table is 5 to 10 metres bgl. Fresh water is available up to a depth of 18 metres bgl below that of saline or brackish water occurs.

   In this area the more appropriate method for recharging ground water is *pit/trough with soakaway*. The depth of the soakaway shall be kept 12 to 15 metres.

2. *Alipur area of Delhi :* In this area a sand formation exists up to a depth of 12 metres bgl, followed by a layer of kankar and silt up to a depth of 16 metres bgl followed by a clay and kankar layer from 16 to 20 metres bgl. This clay layer is further followed by a kankar and silt up to 50 metres depth. The depth of water table in area is 5 to 10 metres bgl. Fresh water is available up to a depth of 50 metres, below which saline or brackish water occurs.

   In this area recharge of ground water can be carried out either through a *recharge pit/trench or dugwell/borewell or by pit/trough with soakaways*.

3. *Rajendra Nagar area of Delhi* : In this area the top layer of clay and kankar extends to a depth of 4 metres bgl, followed by fractured and jointed formation of quartzite. The depth of water table is 20 to 30 metres bgl. In this area fresh water is available at all depth.

   In this area recharge of ground water can be carried out either through *defunct/functional borewell or pit/trough with soakaways*. The depth of soakaways shall be kept 15 to 20 metres below ground level (bgl).

3.6 QUALITY CONTROL PRECAUTIONS

Whether the harvested water is used for direct storage or for recharging the groundwater, it is of utmost importance to ensure that the rainwater collected is free of any pollutants that might be added to rainwater from the atmosphere or the catchment. While polluted water directly used for consumption would have a immediate impact on health, polluted water recharged into the ground-water would cause long-term problems of aquifer pollution. Damage done to aquifers by recharging polluted water is irreversible.

Important precautions for ensuring rainwater quality are summarised as under:

1. At the catchment level

- Keeping the catchment clean
- Using gratings to trap debris at the catchment itself
- Paving the catchment with ceramic tiles, stone tiles or other such non-erosive materials

2. At the conduit level

- Provision of first-flush to drain runoff from initial spell of rain

3. Before recharging

- Allowing for sedimentation of the water
- Filtering the water

In establishments like industries, it is very necessary to ensure that the catchment surfaces are free of chemical wastes, fuels, lubricants etc. While physical and biological impurities in water can be easily removed by sedimentation and filtration, it is difficult to remove chemical impurities.

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CHAPTER – 4

FILTERS

Filters are used in rainwater harvesting system when the water is stored in tanks for direct consumption, to remove suspended pollutants from collected rainwater. Filtration and disinfection of water are necessary before human consumption.

A filter unit is a chamber **filled** with filtering media such as fibre, coarse sand, gravel layers. Charcoal can be added for additional filtration. It consists of three parts:

- *Container*: Made of concrete, brick masonry, PVC, galvanised iron sheet or ferro-cement etc.

- *Perforated plate*: Made from a non-corroding material i.e. steel, PVC etc., with 1 cm diameter holes.

- *Filter Media*: It normally comprises of following layers :

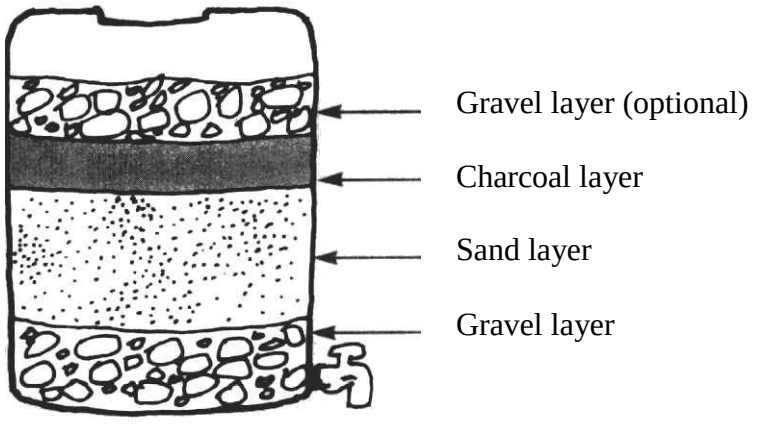
  Layer 1 :.Layer of sand-fine to medium
  Layer 2 : Layer of gravel (4 to l6 mm)
  Layer 3 : Layer of gravel/pebbles bed (16 to 50 mm)

4.1 Type of filters

Depending upon the filter media used and its arrangements, filters commonly used in rain water harvesting system are as under:

(i) Charcoal water filter

A simple charcoal filter can be made in a drum or an earthen pot. The filter media comprises of gravel, sand and charcoal.



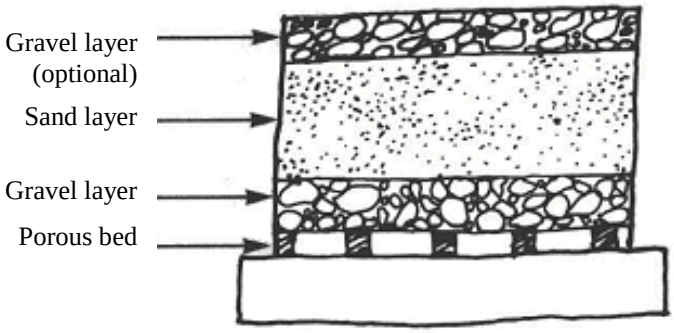
Composition of a charcoal filter

This filter is more suitable for roof top rainwater harvesting system for direct storage from individual houses.

(ii) Sand filters

In these filters commonly available sand is used as filter media. Sand filters are easy and less expensive to construct. These filters are quite effective for removal of micro-organisms and turbidity (suspended particles like silt and clay).

In these filter, filter media are placed as shown in figure below:



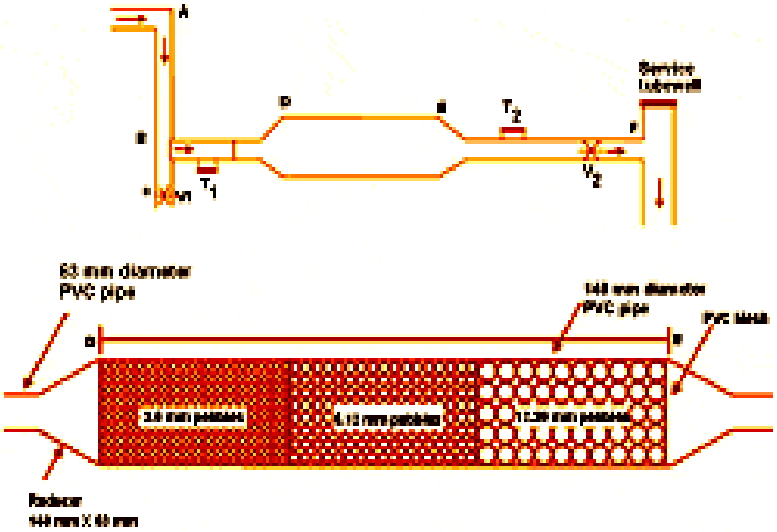
Sand filter

The container of sand filters can be either PVC, concrete, ferro-cement tanks or it can be provided underground in a pit lined with masonry. *The design of filter bed and the specification of gravel and sand has been explained in para 4.2.*

These filters are commonly used for recharging ground water. Sand filters are also used for removing silt from the harvested water for recharging functional tubewell/hand pump/ dugwell.

(iii) Dewas filters

These are the filters design and widely used for filtering roof top rain water in the Dewas area of Madhya Pradesh for recharging service wells.



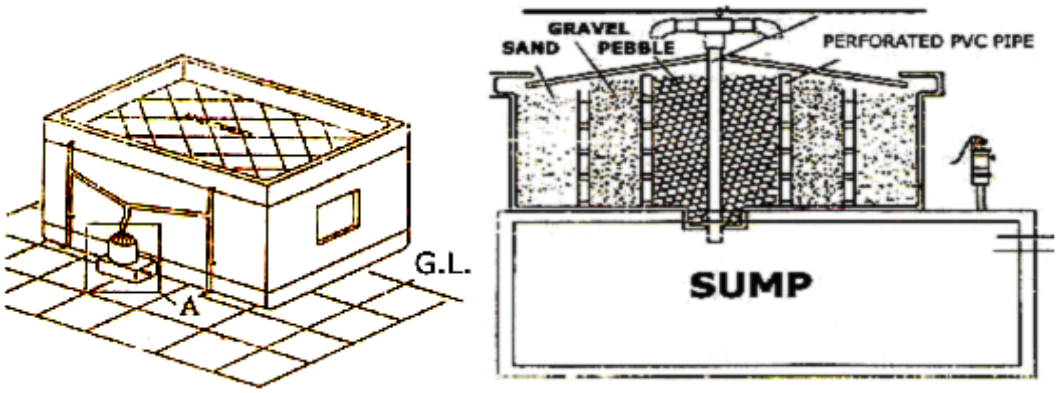
Dewas filter

The filter consists of a PVC pipe 140 mm dia and 1.2 m long. There are three chambers, the 1st purification chamber has pebbles varying between 2 to 6 mm, the second chamber has slightly larger pebbles between 6 to 12 mm, and the third chamber has the largest 12 to 20 mm pebbles. There is a mesh at the out flow site through which clean water flows out after passing through the three chambers.

These filters are the suitable for recharging ground water through functional borewell /hand pump in the roof top rainwater harvesting systems, where the quantity of harvested water is limited.

(iv) Filter for large rooftops

When the rainwater is harvested from a large rooftop area for direct storage, filtering unit with high filtration rate is required particularly for high intensity rainfall. A system is designed with three concentric circular chambers in which the outer chamber is filled with sand, the middle one with coarse aggregate the inner-most layer with pebbles. This way the area of filtration is increased for sand, in relation to coarse aggregate and pebbles to achieve overall higher rate of filtration. Rainwater reaches the centre core and is collected in the storage tank/sump.



Details of filter for large rooftops

These filters are mainly used in the roof top rainwater harvesting systems with direct storage, where the roof area is large with heavy intensity rainfall of short duration.

4.2 Filter media specification for sand filters

The filter media of inverted sand filter basically consists of a gravel bed overlain by a sand layer. The specifications for gravel bed and the sand layer are as under:

(i) Gravel bed

- It consists of 4 to 5 layers of gravel of various size as below:

Layer number from top	Size of gravel (mm)	Thickness of layer (cms)
1	2 – 5	7.5 – 10.0
2	5 – 12	7.5 – 10.0
3	15 – 20	10.0
4	20 – 38	10.0
5	38 – 65	10.0

➢ **Characteristics of gravel :**

- Gravel shall be non flaky free from clay, organic impurities, shells etc.
- Naturally available rounded gravels are more preferred.
- Specific gravity shall be more than 2.5.

(ii) Sand layer

Over a gravel bed a coarse sand layer of 50 to 75 cms thick is provided.

➢ **Characteristics of sand :**

- Sand should be hard free from clay, dust, roots, organic materials etc.
- Effective size = 0.45 to 0.70 mm
- Silica content > 90%
- Lime content < 2%
- Specific gravity – 2.55 to 2.65

4.3 Design of sand filter

(i) Filter bed area

Area of sand filter bed is designed to cater the critical runoff flow rate. Normally the rate of filtration of filter bed is considered 4 to 5 m^3/m^2/hour. The typical design of filter is enumerated as under:

Suppose filter is to be designed for a catchment area of 200 sq.m. Peak rainfall intensity of area is 80 mm/hour. Runoff coefficient of the catchment is 1.0.

First calculate the peak runoff rate from the catchment

Peak runoff rate = peak intensity of rain fall x catchment area x runoff coefficient
Therefore, Peak runoff rate = 200 x 0.08 x 1.0 = 16 m^3/hour
Assuming, Rate of filtration = 5 m^3/hour

Area of filter bed required = Peak runoff ÷ Rate of filtration
= 16 ÷ 5 = 3.2 m^2
Provide filter bed of 2 m x 1.6 m size

Normally, ratio of length to width of filter bed is kept as 1.25.

(ii) Height/Depth of filter unit

The depth of the container is normally kept at least one feet above the top of the filter media to provide the required hydro-static head for filtration.

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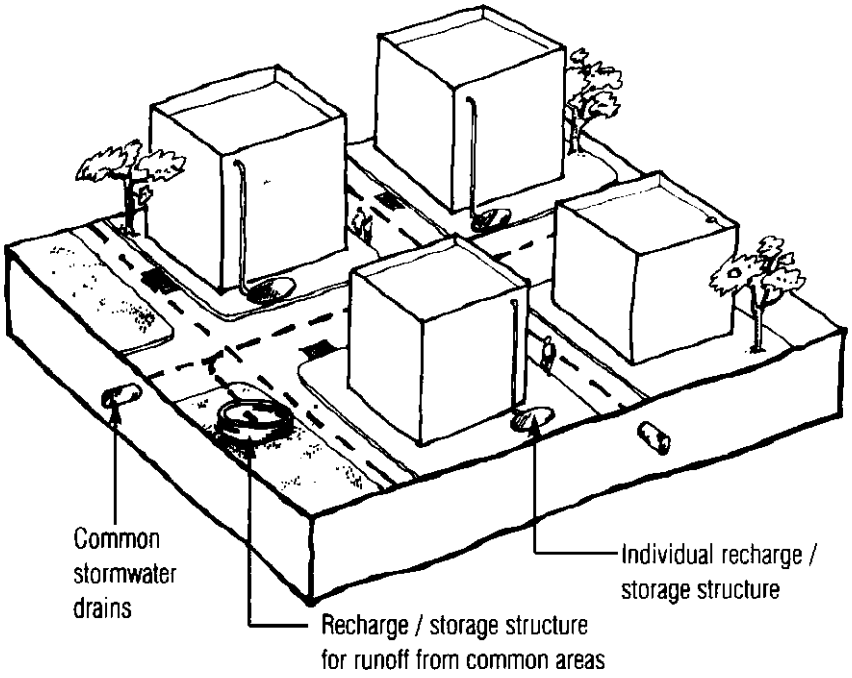
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CHAPTER - 5

SCHEMES OF RAIN WATER HARVESTING

Most methods explained in previous chapters are applicable at a singular building or establishment level. However, the same principles can be applied for implementing water harvesting at a larger scale, say, a residential colony or an institutional cluster. The type of structures and design parameters remain the same but physical scale and number of structures may vary corresponding to the size of catchment.

To control the total amount of runoff received by a large-scale system, the catchment can be subdivided into smaller parts. A community level water harvesting schemes illustrated in figure below, shows how the runoff from individual houses can be dealt with at the building-level itself, while remaining runoff from the storm water drain (which drains water from roads and open areas) can be harvested by constructing recharge structures in common areas.



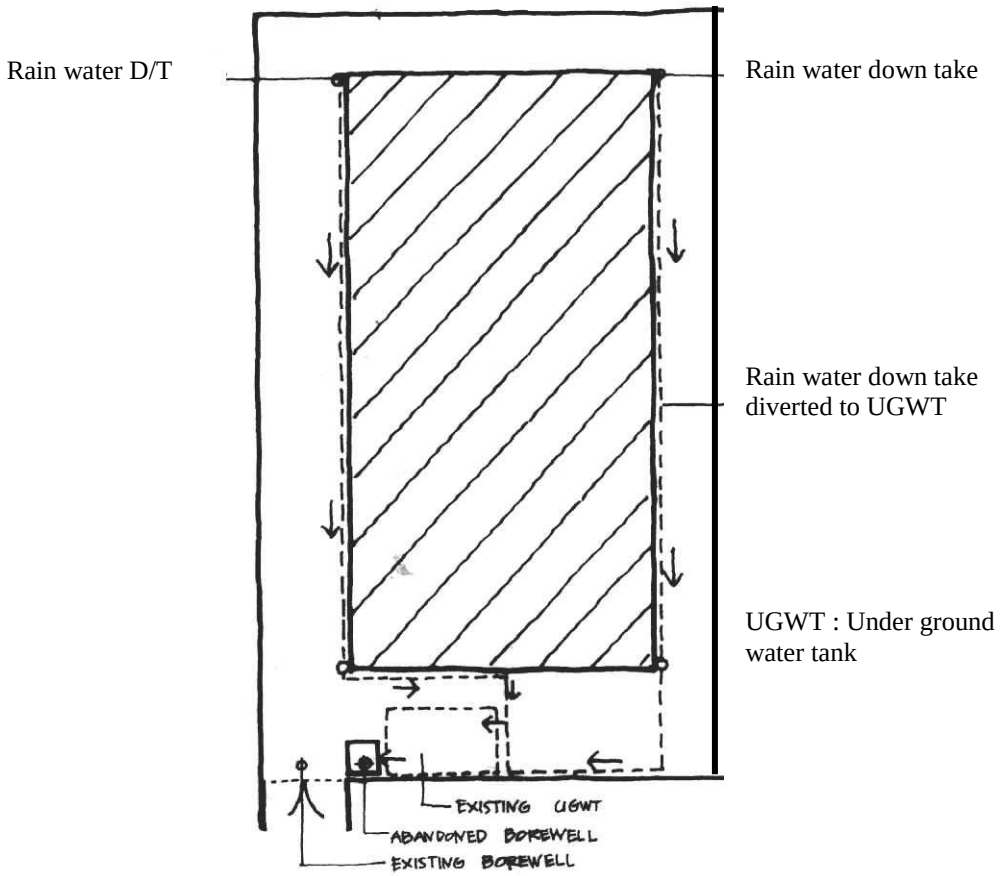
Community level harvesting scheme

Examples for large scale water harvesting

(A) RAIN WATER HARVESTING IN A RESIDENCE

Case background

The area of the property is about 500 sq.m. with a roof top area of 300 sq. m. A private borewell in the building is the only source of water to the house. The building also has an 45 m deep abandoned borewell in its area, which had run dry few years back. A new 100 m deep borewell was established adjacent to the old one.



Scheme for water harvesting

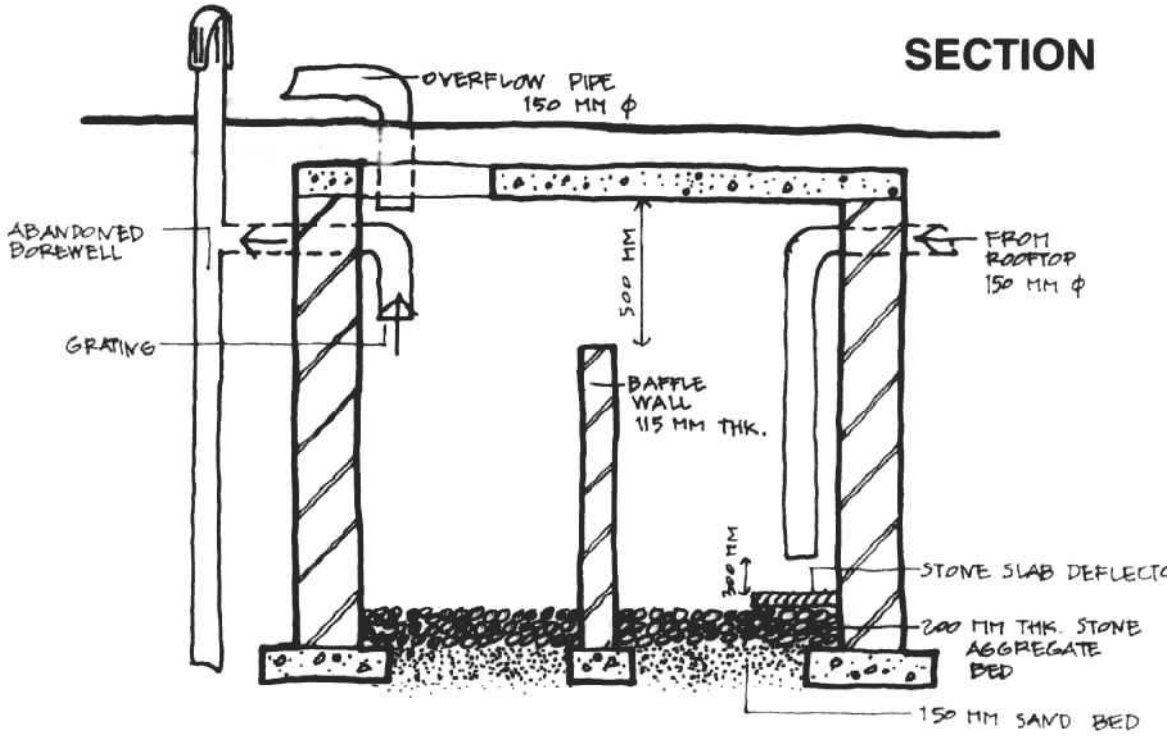
Measures taken for water harvesting :

The dry borewell present in the building provides an excellent opportunity for recharging the groundwater. Annual water harvesting potential from the rooftop is 109,000 litres.

Recharging of abandoned borewell

Runoff from the rooftop is discharged into the dry borewell. To ensure that suspended impurities in the water do not enter the borewell, the water is passed through a settlement tank.

An unused underground tank located near the borewell has been modified to be used as a settlement tank. All the rainwater drainpipes leading from the terrace are connected to the underground settlement tank. The bottom of the tank has been left unpaved and lined with a bed of brick-bats to allow the percolation of standing water in the tank.



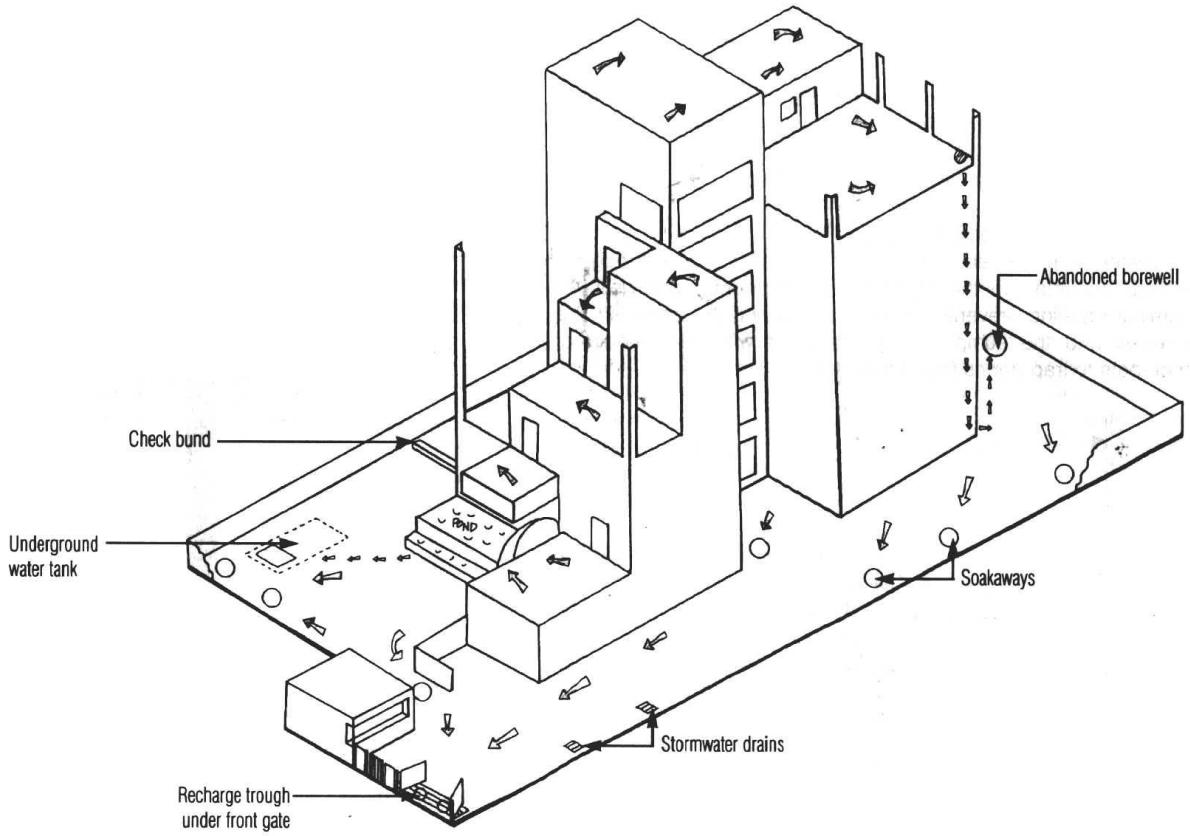
Details of recharge borewell and settlement tank

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(B) RAIN WATER HARVESTING OF THE OFFICE BUILDING

Case background

The total area of the office building is 1000 sq. m. The office gets most of its water supply from ground water through its borewell.

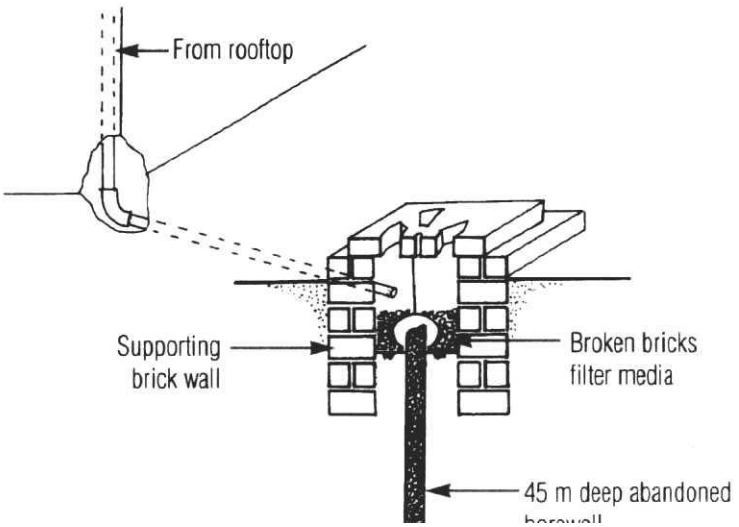


Measures taken for water harvesting :

A major portion of the rainwater is recharged into the groundwater aquifers. A small amount is stored in an underground tank for low-quality uses. Annual water harvesting potential of office building is 366,600 litres. A combination of methods used for harvesting the rainwater ensure that most of the rain water falling over the building area is recharged or stored.

Recharging of abandoned borewell

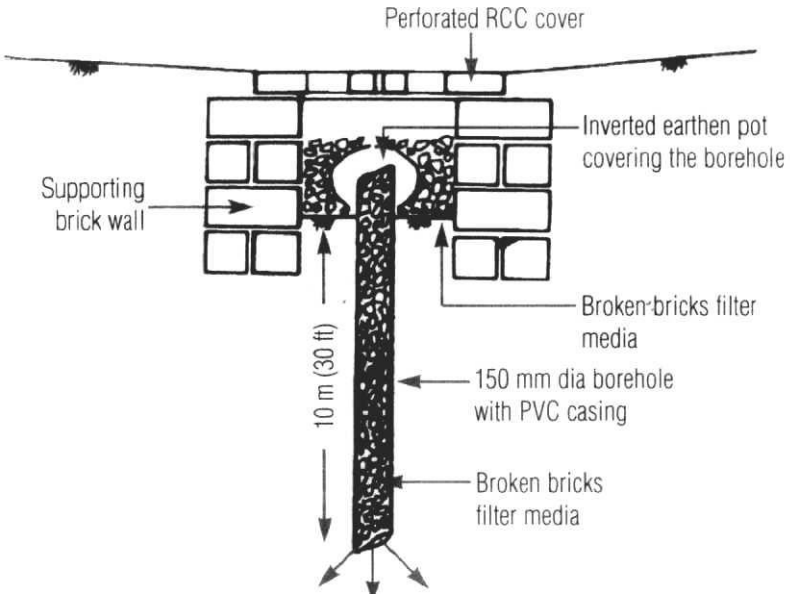
Rainwater from the rear portion of the terrace is led through a vertical drainpipe to the 45 m deep abandoned borewell. An aluminium grating prevents debris from entering the borewell. Borewell and the sump on top are filled with filter media of brick-bats to trap debris.



Detail of abandoned borewell recharging.

Soakaway

Thirteen soakaway have been constructed around the building. The mouth of the shaft is covered with an inverted earthen pot with a small hole to prevent the entry of debris in to the shaft. A small sump is constructed around the top of the shaft, which is filled with a filter media of brickbats to prevent entry of debris. A perforated RCC cover is placed on top of sump to allow the entry of rain fall runoff.



Detail of soakaway

Rain water storage tank :

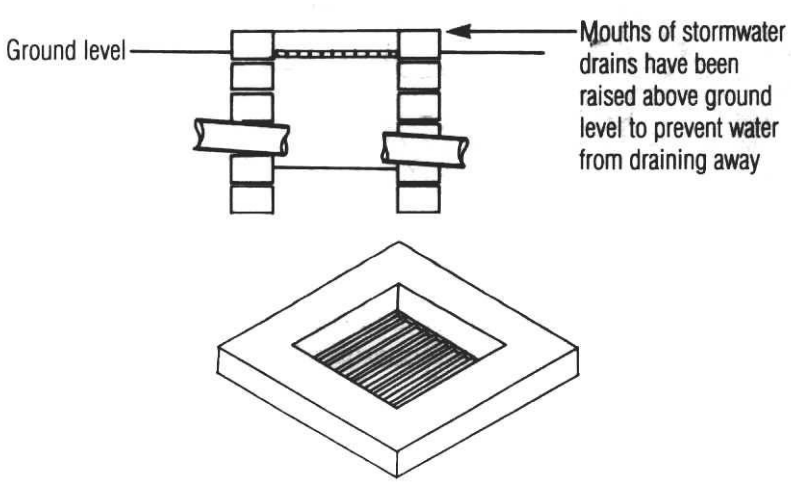
The front façade of the building has terraces projecting out at various floors. The rain water drainpipes from all terraces are connected in series so that the runoff from these terraces falls into the pond in the front of the building. When this pond overflows, water flows to the underground tank of 8,500 litre capacity. Water from this rainwater storage tank is used for low quality uses like gardening.

Recharge trough

Three soakaways have been constructed in the trough under entrance gate, which is covered with an iron grill. The runoff flowing out through the entrance is collected in this trough and gets recharged through the soakaways.

Raising of storm water drains

Openings of the municipal storm water drains within the campus area have been raised slightly above the ground level, so that rainwater does not drain away.



Details of storm water drains

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(C) RAIN HARVESTING OF A COLLEGE CAMPUS

Case background

The area of the college campus is about 32170 sq.m. The water requirement for the college is met through two borewell located inside the premises.

Measures taken for water harvesting :

Annual water harvesting potential from rooftop, paved and unpaved areas is approx. 70,70,000 litres.

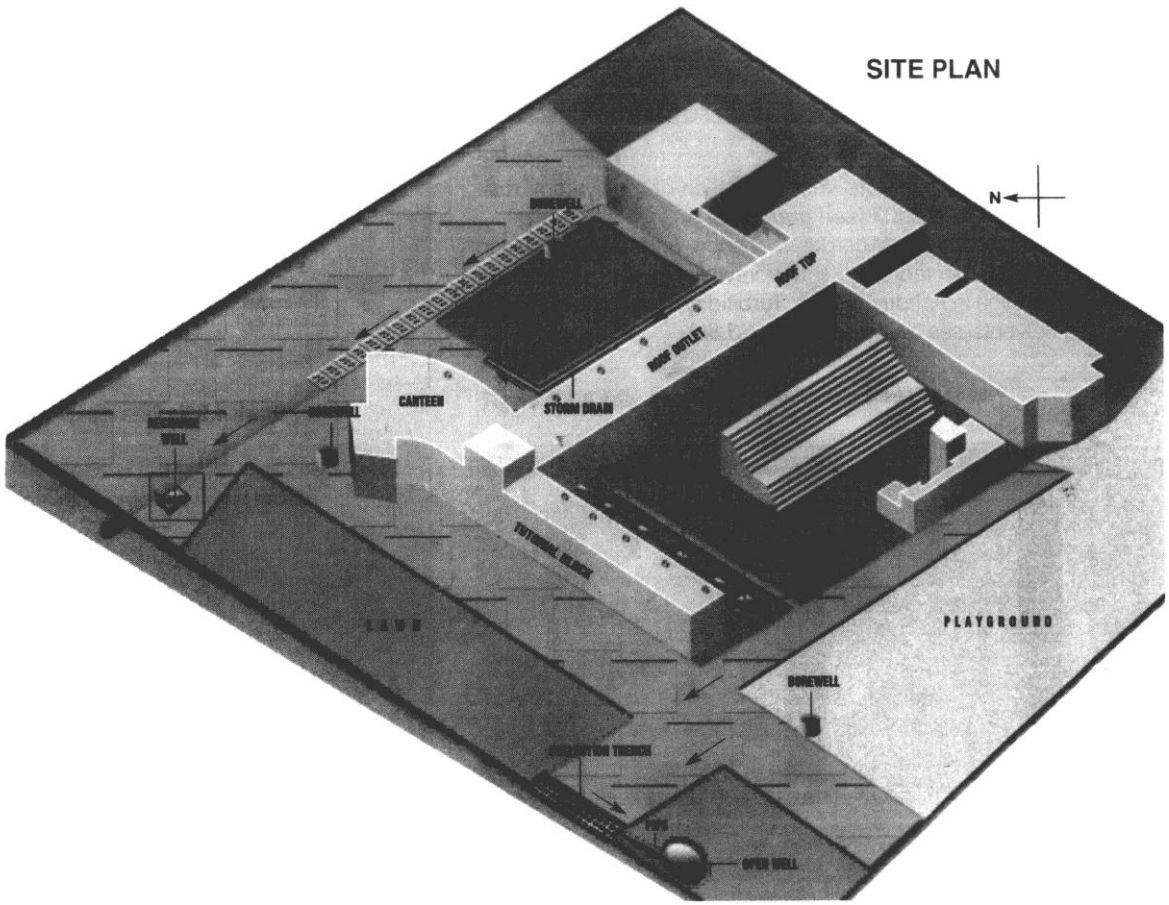


Figure : Scheme of water harvesting

(i) Rooftop water harvesting system

The runoff from the terrace is channelled into three recharge pit with soakaway measuring 1 m x 1 m x 2 m each, located on three different drainage lines. All rooftop rainwater outlets except those in the Tutorial block lead to storm-water drains from where the water goes into the recharge structures. In Tutorial Block the rooftop rainwater outlets are linked to a recharge structure through a network of pipes and collection chambers.

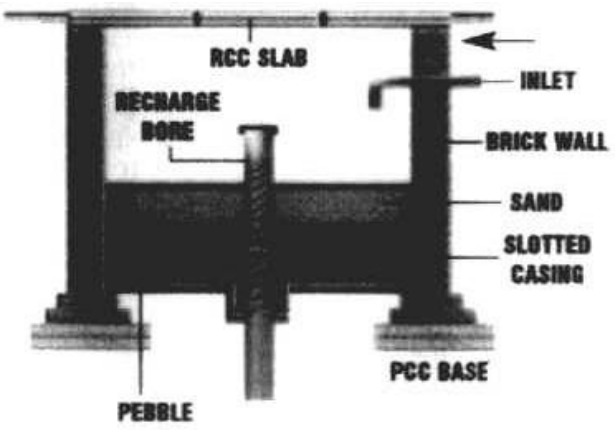


Figure : Recharge pit with soakaway

(ii) Surface runoff water harvesting

The runoff from the unpaved areas is intercepted at the main entrance by a collection trench, which eventually drains into an abandoned open-well as shown in figure of scheme of water harvesting.

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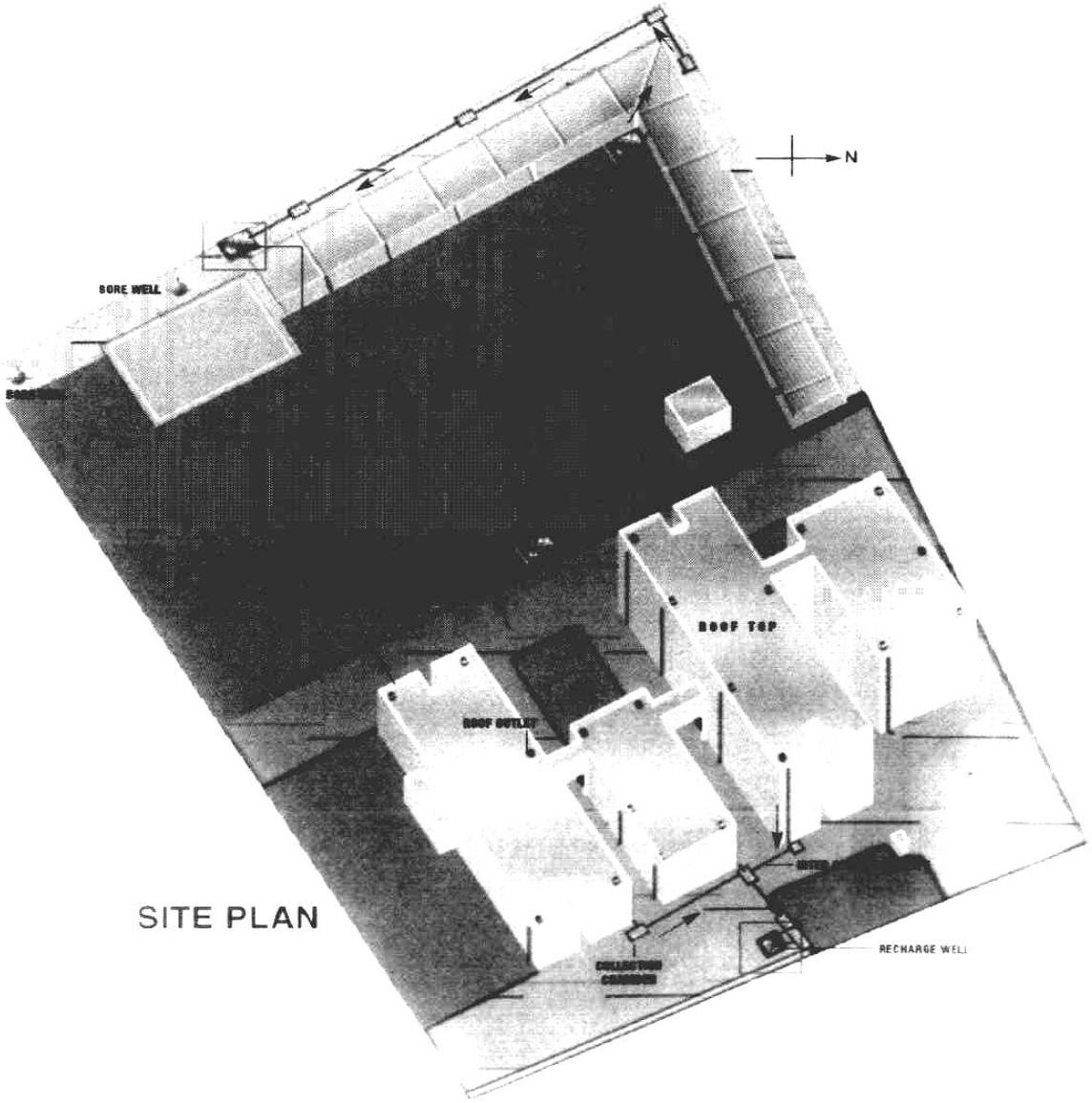
(D) RAIN WATER HARVESTING OF A SCHOOL CAMPUS

Case background

The area of the school campus is about 16,200 sq.m. The non-potable water requirement is met by two borewell located within the school. The drinking water requirement is fulfilled by the municipal supply, which is around one lakh litre per month.

Measures taken for water harvesting :

Annual water harvesting potential from the rooftop, paved and unpaved areas is 44,66,000 litres.



Rainwater harvesting system

(i) Western side of the building

A part of the rooftop runoff along with the surface runoff from the paved area near the play ground is intercepted in a drain, before entering a pit of size 1m x 1m x 1m. To facilitate recharge, a borewell/soakaway of 100 mm diameter and 15 m depth is provided inside the recharge pit. Layers of pebbles and sand filling the recharge pit act as an filtering medium, for the runoff that is being recharged.

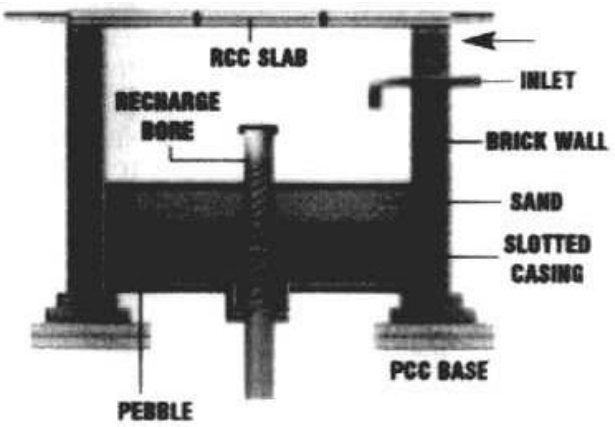


Figure : Recharge pit with soakaway

(ii) Eastern side of the building

Rooftop rain water and surface runoff in the eastern side of the building are channelled through a storm water drain to a recharge pit measuring 2 m x 2 m x 3 m. To facilitate recharge a borewell of 100 mm diameter and 8 m in depth is provided inside the recharge pit.

(iii) The football ground :

The runoff from the play ground is captured in the north western corner of the playground in a recharge pit of 1.5 m x 1.5 m x1.5 m in dimension by means of a trench filled with pebbles surrounding this pit (see figure of scheme of water harvesting). The 14 m deep borewell is provided inside the pit to facilitate recharging of the aquifer.

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References

1	Rain water-harvesting techniques to augment ground water ministry of water resources, Central Ground Water Board, Faridabad.
2	A water harvesting manual for urban areas – Centre for Science and Environment.
3	Rain water harvesting – Rotary club, Nagpur.
4	Manual on Rainwater harvesting – Shri K.R.Shivaraman & Shri Thillaigovindarajan.
5	Engineering Hydrology – Shri K.Subramanium.
6	Rain water harvesting and Recharging of Ground water technological options by Dr. D.Chakraborty, Central Ground Water Board.

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NOTES

OUR OBJECTIVE

To upgrade Maintenance
Technologies and Methodologies
and achieve improvement in
productivity and performance
of all Railway assets and manpower
which inter-alia would cover
Reliability, Availability,
and Utilisation.

If you have any suggestion & comments on content of handbook, please write to us :

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