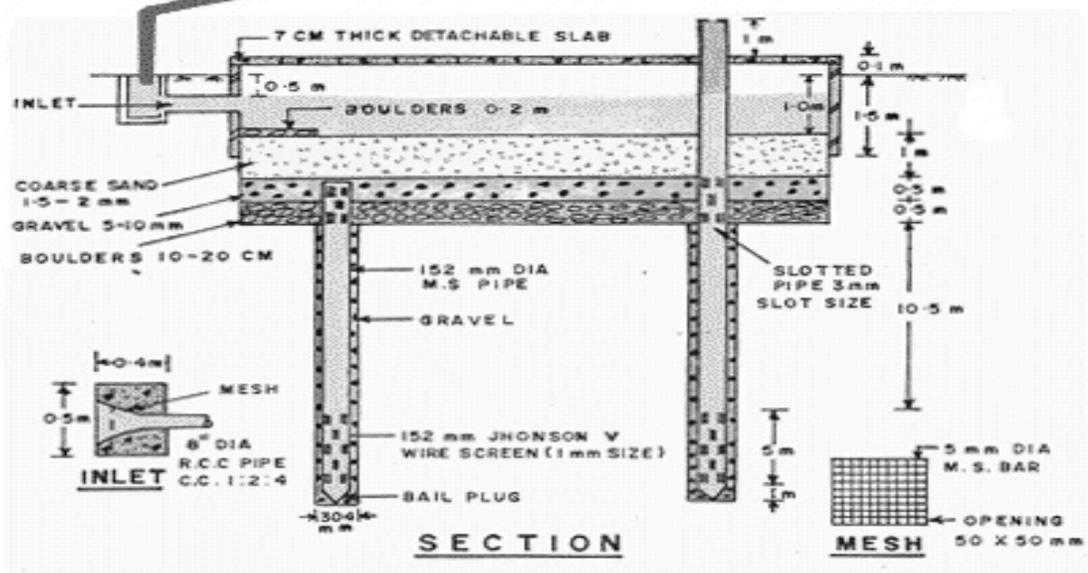


# Harvesting Rainwater: Catch Water Where it Falls!

Arjun Bhattacharya & O'Neil Rane

## ROOFTOP RAIN WATER RECHARGE



## Introduction

The famous water-diamond paradox may finally turn out not to be so. The use value of water was never undermined, but its about time that even its exchange value is given due importance. Fresh water today is a scarce resource, and it is being felt the world over.

The reality of water crisis cannot be ignored. India has been notorious of being poor in its management of water resources. The demand for water is already outstripping the supply. Majority of the population in the cities today are groundwater dependent. In spite of the municipal water supply, it is not surprising to find people using private tube wells to supplement their daily water needs. As a result, the groundwater table is falling at an alarming rate.

Extraction of groundwater is being done unplanned and uncontrolled. This has resulted in:

1. Hydrological imbalance
2. Deterioration in water quality
3. Rise in energy requirements for pumping

Uncontrolled disposal of industrial effluents and sewage of cities into rivers and other water bodies has also resulted in contamination of groundwater. Hence, immediate remedial actions need to be undertaken to avoid a national water crisis.

Rain Water Harvesting, is an age-old system of collection of rainwater for future use. But systematic collection and recharging of ground water, is a recent development and is gaining importance as one of the most feasible and easy to implement remedy to restore the hydrological imbalance and prevent a crisis.

Our focus is on the National Capital Territory (NCT) of Delhi, which is currently facing acute water shortage and drastic drop in the groundwater table over the last few decades.

Technically speaking, water harvesting means capturing the rain where it falls. Experts suggest various ways of harvesting water:

- Capturing run-off from rooftops
- Capturing run-off from local catchments
- Capturing seasonal flood water from local streams
- Conserving water through watershed management

Local water harvesting systems developed by local communities and households can reduce the pressure on the state to provide all the financial resources needed for water supply. In addition, involving people will give them a sense of ownership and reduce the burden on government funds.

More than 2000 million people would live under conditions of high water stress by the year 2050, according to the UNEP (United Nations Environment Programme), which warns water could prove to be a limiting factor for development in a number of regions in the world. About one-fifth of the world's population lacks access to safe drinking water and with the present consumption patterns, two out of every three persons on the earth would live in water-stressed conditions by 2025. Around one-third of the world population now lives in countries with moderate to high water stress—where water consumption is more than 10% of the renewable fresh water supply, said the GEO (Global Environment Outlook) 2000, the UNEP's millennium report. Pollution and scarcity of water resources and climate change would be the major emerging issues in the next century, said the report. These issues would be followed by problems of desertification and deforestation, poor governance at the national and global levels, the loss of biodiversity, and population growth, said the report  
(*The Observer of Business and Politics*, 12 October 1999).

## Need for Water Harvesting

The scarcity of water is a well-known fact. In spite of higher average annual rainfall in India (1,170 mm, 46 inches) as compared to the global average (800 mm, 32 inches) it does not have sufficient water. Most of the rain falling on the surface tends to flow away rapidly, leaving very little for the recharge of groundwater. As a result, most parts of India experience lack of water even for domestic uses.

Surface water sources fail to meet the rising demands of water supply in urban areas, groundwater reserves are being tapped and over-exploited resulting into decline in groundwater levels and deterioration of groundwater quality. This precarious situation needs to be rectified by immediately recharging the depleted aquifers.

Hence, the need for implementation of measures to ensure that rain falling over a region is tapped as fully as possible through water harvesting, either by recharging it into the groundwater aquifers or storing it for direct use.

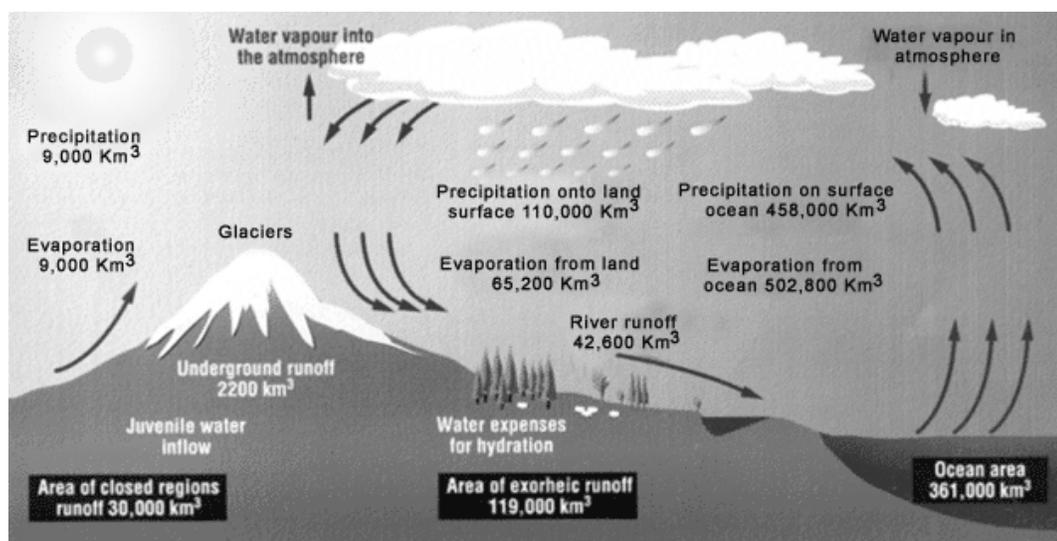
## Science of Water Harvesting<sup>1</sup>

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 inventions, aimed at conservation and efficient utilization of the limited water endowment of physiographic unit such as a watershed.

Rain is a primary source of water for all of us. There are two main techniques of rainwater harvesting:

- a) Storage of rainwater on surface for future use.
- b) Recharge to groundwater.

Directly collected rainwater can be stored for direct use or can be recharged into the groundwater. All the secondary sources of water like rivers, lakes and groundwater are entirely dependent on rain as a primary source.



Hydrological Cycle

The term "water harvesting" is understood to encompass a wide range of concerns, including rainwater collection with both rooftop and surface runoff catchment, rainwater storage in small tanks and large-scale artificial reservoirs, groundwater recharge, and also protection of water sources against pollution.

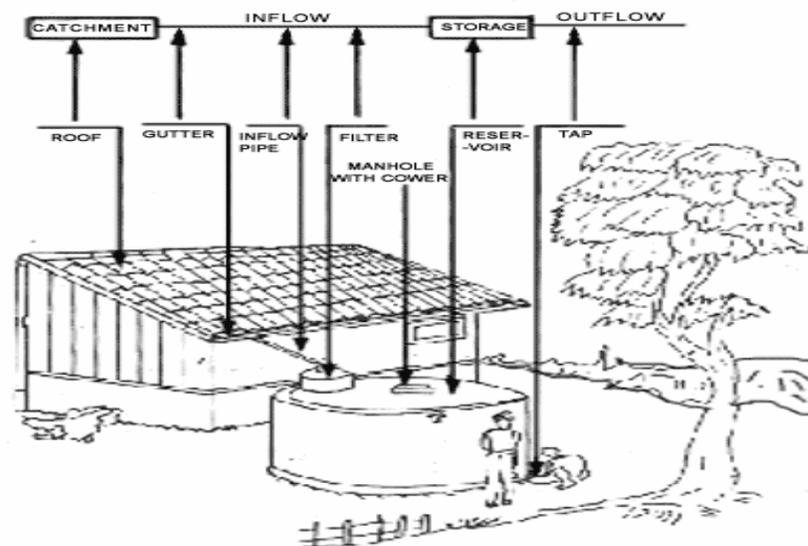
<sup>1</sup> A) A Water Harvesting Manual, Centre for Science and Environment

B) <http://www.cgwaindia.com/suo/home.htm>

The objective of water harvesting in India differs between urban and rural areas. In urban areas, emphasis is put on increasing groundwater recharge and managing storm water. On the other hand, in rural areas securing water is more crucial. There the aim is to provide water for drinking and farming, especially for life-saving irrigation, and to increase groundwater recharge.

## Rooftop / Runoff Rainwater Harvesting for Artificial Recharge to Ground Water

Water harvesting is the deliberate collection and storage of rainwater that runs off on natural or manmade catchment areas. Catchment includes rooftops, compounds, rocky surface or hill slopes or artificially prepared impervious/ semi-pervious land surface. The amount of water harvested depends on the frequency and intensity of rainfall, catchment characteristics, water demands and how much runoff occurs and how quickly or how easy it is for the water to infiltrate through the subsoil and percolate down to recharge the aquifers. Moreover, in urban areas, adequate space for surface storage is not available, water levels are deep enough to accommodate additional rainwater to recharge the aquifers, rooftop and runoff rainwater harvesting is ideal solution to solve the water supply problems.



**Rain Water Collection From Roof In Single Slope**

Harvested rainwater can be stored in sub-surface ground water reservoir by adopting artificial recharge techniques to meet the household needs through storage in tanks.

The Main Objective of such rainwater harvesting is to make water available for future use. Capturing and storing rainwater for use is particularly important in dryland, hilly, urban and coastal areas. In alluvial areas, energy saving for 1m rise in ground water level is around 0.40 kilo watt per hour.

## Advantages of Rainwater Harvesting

1. To meet the ever increasing demand for water. Water harvesting to recharge the groundwater enhances the availability of groundwater at specific place and time and thus assures a continuous and reliable access to groundwater.
2. To reduce the runoff which chokes storm drains and to avoid flooding of roads.
3. To reduce groundwater pollution and to improve the quality of groundwater through dilution when recharged to groundwater thereby providing high quality water, soft and low in minerals.
4. Provides self-sufficiency to your water supply and to supplement domestic water requirement during summer and drought conditions.
5. It reduces the rate of power consumption for pumping of groundwater. For every 1 m rise in water level, there is a saving of 0.4 KWH of electricity.

6. Reduces soil erosion in urban areas
7. The rooftop rainwater harvesting is less expensive, easy to construct, operate and maintain.
8. In saline or coastal areas, rainwater provides good quality water and when recharged to ground water, it reduces salinity and helps in maintaining balance between the fresh-saline water interface.
9. In Islands, due to limited extent of fresh water aquifers, rainwater harvesting is the most preferred source of water for domestic use.
10. In desert, where rainfall is low, rainwater harvesting has been providing relief to people.

### Design Considerations

Three most important components, which need to be evaluated for designing the rainwater harvesting structure, are:

1. Hydrogeology of the area including nature and extent of aquifer, soil cover, topography, depth to water levels and chemical quality of ground water
2. Area contributing for runoff i.e. how much area and land use pattern, whether industrial, residential or green belts and general built up pattern of the area
3. Hydro-meteorological characters like rainfall duration, general pattern and intensity of rainfall.

### Design Criteria of Recharge Structures

Recharge structures should be designed based on availability of space, availability of runoff, depth to water table & lithology of the area.

### Assessment of Runoff

The runoff should be assessed accurately for designing the recharge structure and may be assessed by following formula.

$$\text{Runoff} = \text{Catchment area} * \text{Runoff Coefficient} * \text{Rainfall}$$

### Runoff Coefficients

Runoff coefficient plays an important role in assessing the runoff availability and it depends upon catchment characteristics. It is the factor that accounts for the fact that not all rainfall falling on a catchment can be collected. Some rainfall will be lost from the catchment by evaporation and retention on the surface itself.

General values are tabulated below which may be utilised for assessing the runoff availability.

Type of catchment	Runoff coefficient
Roof Catchments	
▪ 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 catchments	
▪ Soil on slopes less than 10 percent	0.0 - 0.3
▪ Rocky natural catchments	0.2 - 0.5
▪ Green area	0.05 - 0.10

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

## How much water can be harvested?

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*.

$$\text{Water Harvesting potential} = \text{Rainfall (mm)} \times \text{Collection efficiency}$$

### An example of potential for rainwater harvesting<sup>2</sup>:

Consider a building with a flat terrace area of 100m<sup>2</sup>. The average annual rainfall in Delhi is approximately 600 mm (24 inches). In simple terms, this means if the terrace floor is assumed impermeable, and all the rain that falls on it is retained without evaporation, then, in one year, there will be rainwater on the terrace floor to a height of 600 mm.

Area of the plot	= 100 m <sup>2</sup>
Height of annual rainfall	= 0.6 m (600 mm or 24 inches)
Volume of rainfall over the plot = Area of plot X Height of rainfall	
	= 100 m <sup>2</sup> X 0.6 m
	= 60 m <sup>3</sup> (60,000 litres)

Assuming that only 60 percent of the total rainfall is effectively harvested,  
 Volume of water harvested = 36,000 litres

This volume is about twice the annual drinking water requirement of a 5-member family. The average daily drinking water requirement per person is 10 litres<sup>3</sup>.

## Quality of Stored Water

Rainwater collected from rooftops is free of mineral pollutants like fluoride and calcium salts that are generally found in groundwater. But, it is likely that to be contaminated with these types of pollutants:

1. Air Pollutants
2. Surface contamination (e.g., silt, dust)

Such contaminations can be prevented to a large extent by flushing off the first rainfall. A grill at the terrace outlet for rainwater can arrest leaves, plastic bags and paper pieces carried by water. Other contamination can be removed by sedimentation and filtration. Disinfectants can remove biological contamination.

## Cost Analysis

1. Cost of a Rainwater harvesting system designed as an integrated component of a new construction project is generally low.
2. Designing a system onto an existing building is costlier because many of the shared costs (roof and gutters) can be designed to optimise system.
3. In general, maximising storage capacity and minimising water use through conservation and reuse are important rules to keep in mind.
4. With careful planning and design, the cost of a rainwater system can be reduced considerably.

## Cost of installation

<sup>2</sup> A Water Harvesting Manual, Centre for Science and Environment

<sup>3</sup> IS 1172: Indian Standard Code of Basic Requirements for Water Supply, Drainage and Sanitation

### Estimated average cost of installing a Water Harvesting System for<sup>4</sup>:

1. **An individual house** of average area of 300-500 m<sup>2</sup>, the average cost will be around Rs. 20,000-25,000. A recharge well will be constructed near the existing borewell. The roofwater through PVC pipe will be diverted to recharge well.
2. **An apartment building**, the cost will be less since the many people will share the cost. More over in apartments there are separate storm water drains, which join the MCD drains in the main road. Here along with recharge well, recharge trench and percolation pits can be constructed. The cost will be around 60 to 70 thousand.
3. **A colony**, the cost will be much less. For instance, in Panchsheel Park colony, around 36 recharge wells were installed at the cost of 8 lakh, which is around Rs 500-600 per house. In many colonies in Delhi, storm water drains are present but it is difficult to isolate them from sewage drains because there has been violation of the drainage master plan. Also, these drains are not properly maintained. Hence, care needs to be taken while using storm water for water harvesting. Rooftop harvesting is preferred because the silt load is less. In storm water drain the silt load is high and generally the municipality does not maintain the storm drains properly.
4. **An institution** with campus, the cost was around 4 lac. Here two recharge wells and three trenches cum percolation pits were constructed.

**Average annual maintenance cost** would be around Rs 200-300 for two labourers once in a year to remove the pebbles and replace the sand from trenches.

## Rain Water Harvesting Structures in Urban Environment

A typical Roof top Rainwater Harvesting System comprises of

- a) Roof catchment
- b) Gutters
- c) Downpipes
- d) Rain water/Storm water drains
- e) Filter chamber
- f) Ground water recharge structures like pit, trench, tubewell or combination of above structures.

## Methods of Ground Water Recharge

### 1. Storage tanks

For harvesting the roof top rainwater, the storage tanks may be used. These tanks may be constructed on the surface as well as under ground by utilising local material. The size of tank depends upon availability of runoff and water demand. After proper chlorination, the stored water may be used for drinking purpose.

### 2. Recharge Pits

Recharge pits are constructed for recharging the shallow aquifers. These are constructed 1 to 2 m. wide and 2 to 3 m. deep which are back filled with boulders, gravels & coarse sand.

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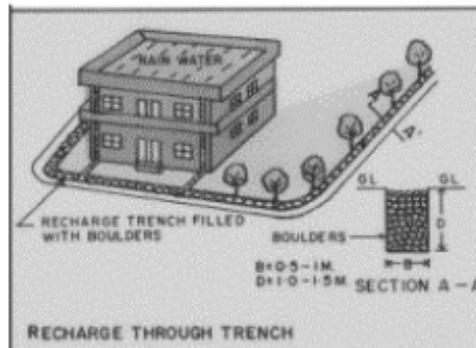
<sup>4</sup> Srinivasan, Expert, Water Harvesting Systems, Centre for Science and Environment (CSE)

## Recharge pit constructed in Lodhi Garden



### 3. Trenches

These are constructed when the permeable strata is available at shallow depths. Trench may be 0.5 to 1 m. wide, 1 to 1.5 m. deep and 10 to 20 m. long depending upon availability of water. These are back filled with filter materials. In case of clay layer encountered at shallow depth, the number of auger holes may be constructed and back filled with fine gravels.

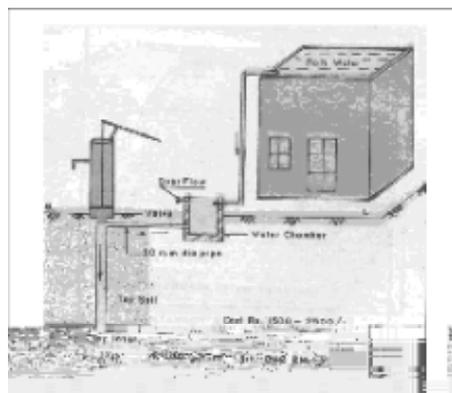


### 4. Abandoned Dug wells

Existing abandoned dug wells may be utilised as recharge structure after cleaning and desilting the same. For removing the silt contents, the runoff water should either pass through a desilting chamber or filter chamber.

### 5. Abandoned Hand pumps

The existing abandoned hand pumps may be used for recharging the shallow / deep aquifers, if the availability of water is limited. Water should pass through filter media before diverting it into hand pumps.



**6. Abandoned tube well**

Abandoned tubewell may be used for recharging the shallow / deep aquifers. These tube wells should be redeveloped before use as recharge structure. Water should pass through filter media before diverting it into recharge tube well

**7. Recharge wells**

Recharge wells of 100 to 300 mm. diameter are generally constructed for recharging the deeper aquifers and roof top rain water is diverted to recharge well for recharge to ground water. The runoff water may be passed through filter media to avoid choking of recharge wells.

**8. Vertical Recharge Shafts**

For recharging the shallow aquifers which are located below clayey surface at a depth of about 10 to 15 m, recharge shafts of 0.5 to 3 m. diameter and 10 to 15 m. deep are constructed depending upon availability of runoff. These are back filled with boulders, gravels and coarse sand.

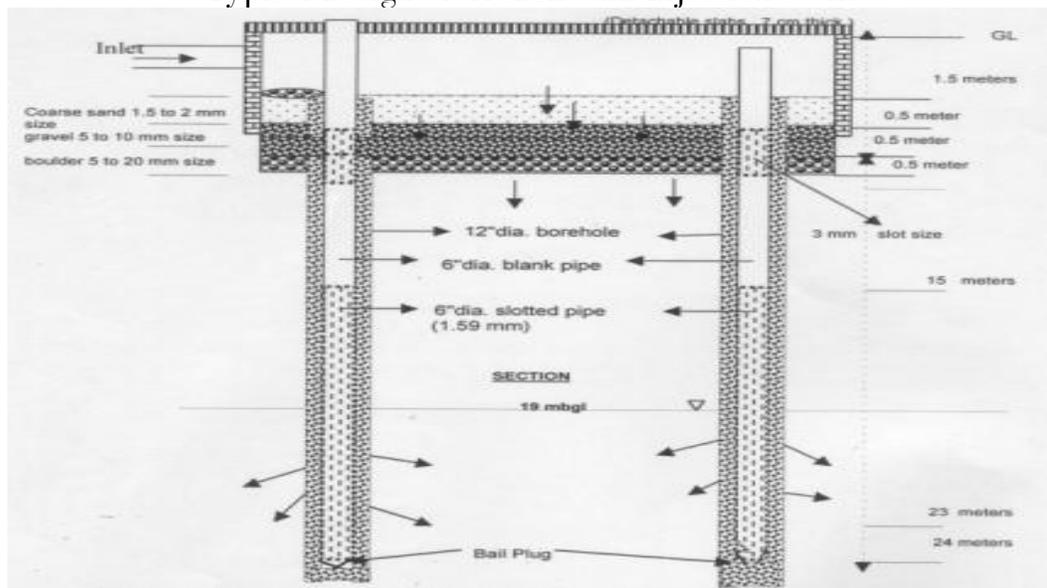
**9. Shaft with recharge well**

If the aquifer is available at greater depth say 20 or 30 m, in that case a shallow shaft of 2 to 5 m diameter and 5 to 6 m deep may be constructed depending upon availability of runoff. Inside the shaft, a recharge well of 100 to 300 mm diameter is constructed for recharging the available water to deeper aquifer. At the bottom of the shaft, a filter media is provided to avoid choking of the recharge well.

**10. Lateral trench with bore wells**

For recharging the upper as well as deeper aquifers, lateral trench of 1.5 to 3 m. wide and 10 to 30 m. long depending upon availability of water with one or more bore wells may be constructed. The lateral trench is back filled with boulders, gravels and coarse sand.

Typical Design of Trench cum Injection Wells



Above design is specific to location. Size of storage cum filter tank varies from place to place and depending upon the available runoff water from the catchment. Depth of the tubewell also varies from place to place and is normally taken down to the first granular saturated sandy formation.

Recharge trench with tube well under construction. After the construction trench can be covered with detachable slabs. Vehicles can move over it and children can play without fear or lawn can be grown over after putting soil over the slabs leaving provision for periodical cleaning.

## Cost of Recharge Structures

The cost of each recharge structure varies from place to place. The approximate cost of the following structures is as under:

S.No.	Recharge Structure	Approximate cost (Rs.)
1.	Recharge pit	2,500 – 5,000
2.	Recharge Trench	5,000 – 10,000
3.	Recharge through hand pump	1,500 – 2,500
4.	Recharge through dug well	5,000 – 8,000
5.	Recharge well	50,000 – 80,000
6.	Recharge shaft	60,000 – 85,000
7.	Lateral Shaft with Bore well	Shaft per m. 2,000 – 3,000 Bore well 25,000 – 35,000

(Source: [www.cgwaindia.com](http://www.cgwaindia.com))

## Success Parameters:

1. Level of Water Table: Increase in the level of groundwater is an obvious and visible parameter for success of rainwater harvesting systems.
2. Quality of Water: Rainwater is available as the purest form of natural water. The very process of dilution that occurs as rainwater mixes with the groundwater leads to an improvement in the quality of groundwater. Decrease in the following factors are taken into consideration to assess the groundwater quality before and after rainwater harvesting:
  - a. Salinity
  - b. Fluoride concentration
  - c. Nitrate concentration
  - d. Bacteriological and heavy metal concentration

## Agencies actively involved in Rainwater Harvesting

### 1. Central Ground Water Board (CGWB)

Established in 1954, the Central Ground Water Board (CGWB), a National apex organisation, functions under the Ministry of Water Resources. The Central Ground Water Board has been entrusted with the responsibilities to carry out scientific research, surveys, exploration, monitoring of development, management and regulation of country's vast ground water resources for irrigation, drinking, domestic and industrial needs.

The Central Ground Water Authority (CGWA) was set up in 1997 under sub-section (3) of Section 3 of the Environment (Protection) Act, 1986 (Act of 1986) and has been given the mandate for the "Regulation and Control of Ground Water Development and Management" in the country.

### 2. Centre for Science and Environment (CSE)

The Centre for Science and Environment is a public interest research and advocacy organisation, which promotes environmentally sound and equitable development strategies. CSE has been involved in raising awareness about the need of community based water management for a number of years. A water crisis that has come about because rain, as a source of water has been ignored. As a technological solution CSE is therefore promoting the concept of community and household based water harvesting as this decentralised technology can be adopted by all concerned and also promote a participatory paradigm of water management.

## The Case of Delhi

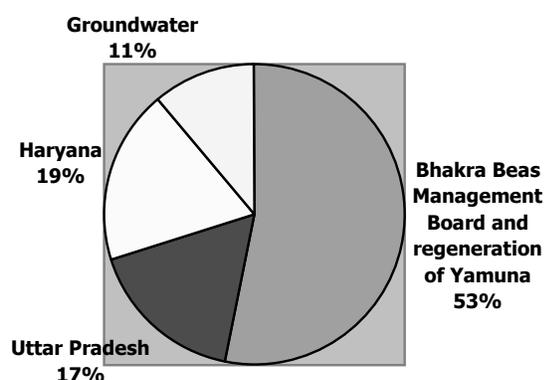
The National Capital Territory (NCT) of Delhi is facing a water crisis and is even likely to face a water famine. Rapid urbanization coupled with population explosion is attributed as the major cause. The situation becomes grimmer during dry seasons and large numbers of residents have to depend on

groundwater to augment the municipal water supply. In South and Southwest districts of Delhi, the situation is explosive and water levels are declining at alarming rates. The Central Ground Water Authority has notified South and Southwest districts of Delhi in August 2000 for regulation of ground water development. Proper water management strategy is the need of the hour. A number of measures are also being promoted to arrest the falling groundwater levels. One of the foremost and essential measure is rainwater harvesting followed by artificial recharge of groundwater.

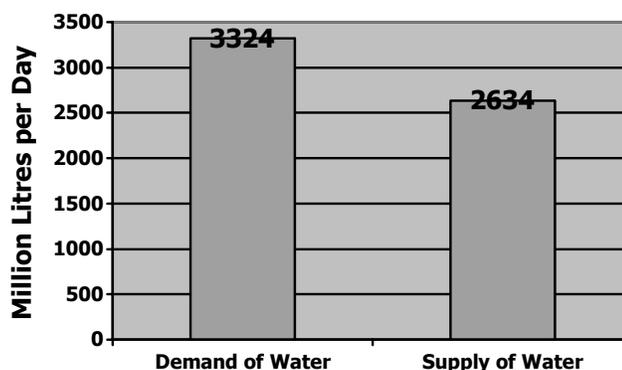
Delhi has a population of roughly 14 million. Against the present requirement of about 3,324 million litres per day (MLD), the installed capacity is only 2,634 MLD.<sup>5</sup> There has been a widespread drop in the groundwater table in Delhi, especially in the south and southwestern localities of Delhi. Lack of regulation related to private and individual extraction of groundwater aggravates this situation.

Delhi has an annual average rainfall of 611.8 mm. Due to poor recharge and heavy extraction of groundwater, groundwater levels in Delhi have declined by as much as 8 metres in the past decade.

### Source of Delhi's Water Supply



### Status of Water Supply in Delhi



Sources: *Water Harvesting Manual*, CSE

## Hydrogeology of Delhi and Surrounding Areas

The groundwater availability in NCT, Delhi is controlled by the hydrogeological situation characterized by occurrence of alluvial formation and quartzitic hard rocks. The following distinct physiographic units further influence the groundwater occurrence.

<sup>5</sup> Serah, Marie-Helen 2000, *Water – Unreliable supply in Delhi*, Manohar Publishers and Distributors, New Delhi, p64

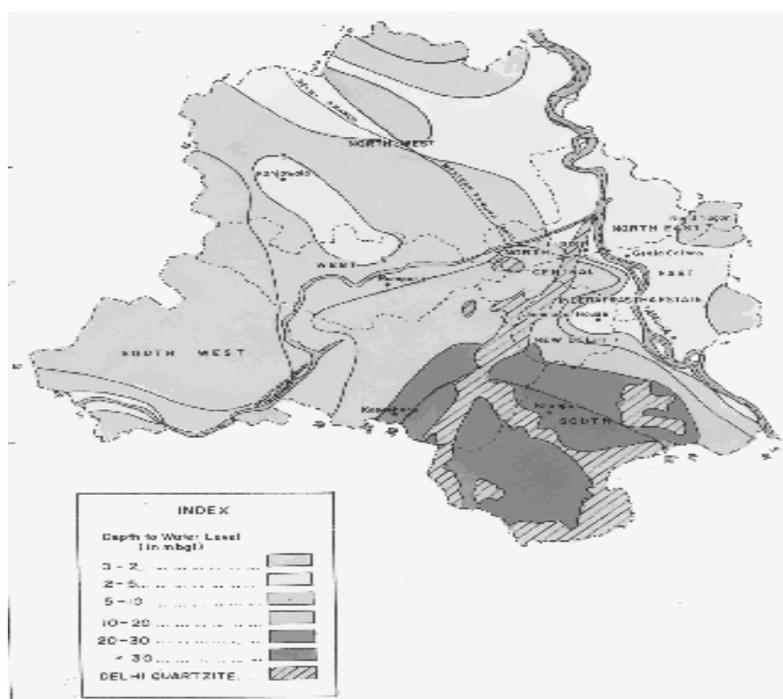
## Physiographic Units and Ground Water Potential

The Four physiographic units that influence and control the groundwater occurrence and movement are:

- Alluvial plain on eastern and western sides of the ridge (low to moderate yield prospects 25-30 m<sup>3</sup>/hr.)
- Yamuna flood plain deposits (large yield prospects 50-100 m<sup>3</sup>/hr.)
- Isolated and nearly closed Chattarpur alluvial basin (low yield prospects 10-15 m<sup>3</sup>/hr.)
- NNE-SSW trending Quartzitic Ridge (limited yield prospects 5-10 m<sup>3</sup>/hr.)

## Depth to water Levels

The periodic monitoring of groundwater levels indicates deeper water levels in the range of 20 to 45 m below ground level (bgl) in southern parts of Delhi extending from Rajokri in the west to Kalkaji-Okhla industrial area including Chattarpur basin in the south. In the central part of southwest district, water levels are in the range of 12 to 16 m bgl. Shallow water levels within 5 m bgl are mainly in the flood plains of Yamuna falling in east and northeast districts. Most areas of north, central, New Delhi and northwest districts are having water levels in-between 5 to 10m bgl.



## Decline in water levels

A comparison of water levels from 1960 to 2001 shows that water levels in major part of Delhi are steadily declining because of over-exploitation. During 1960, the groundwater level was by and large within 4 to 5 meters and even in some parts water logged conditions existed. During 1960-2001, water levels have declined by 2- 6 m. in most part of the alluvial areas. Decline of 8-20 m. has been recorded in south-west district and in south district the decline has been 8-30 m. Areas registering significant decline fall mainly in south and south-west districts and have been identified as priority areas for taking up artificial recharge to groundwater by roof top rain water harvesting.

## Ground Water Quality

Chemical quality of groundwater in NCT Delhi varies with depth and space. In alluvial formations, the quality of groundwater deteriorates with depth, which is variable in different areas. Brackish groundwater mainly exists at shallow depths in northwest, west and southwest districts with minor

patches in north and central districts. Groundwater is fresh at all depths in the areas around the ridge in the central, New Delhi, south and southwest districts. In the areas west of the ridge, in general, the thickness of fresh water aquifers decreases towards northwest. In the flood plains of Yamuna, fresh water aquifers exist down to 30-45 m. In other parts of NCT, Delhi areas falling under central, New Delhi, east and north-east districts ground water is fresh and potable at shallow depths except in a few pockets around Nizamuddin and Connaught Place where ground water is marginally brackish to saline.

### A Model for South and Southwest Delhi:

Total aerial extent of the district	= 670 km <sup>2</sup>
Total population	= 40.07 Lac (Census 2001)
Yield Potential of fracture zones	= 100-200 lpd
Groundwater level varies from	= 5m-50m below ground level
Rate of decline of groundwater level	= 1-4m per annum

(Source: Rainwater Harvesting: A necessity in south and southwest districts of NCT, Delhi, Central Ground Water Board, Ministry of Water Resources, GOI)

South and southwest districts of Delhi are comparatively at a disadvantage situation in terms of providing piped water supply, as the water treatment plants are located in northern part of Delhi. Though the government is supplying 148 lpcd (litres per capita per day), the demand and supply gap in these two districts is high because of being posh and economically developed nature. To meet this demand supply gap there has been an explosion of tubewells in this area leading to rapid depletion of groundwater table.

Any man-made scheme or facility that adds water to an aquifer system may be considered to be an artificial recharge to groundwater. Artificial recharge to groundwater in south and southwest Delhi needs to be given top priority so as to make the groundwater resources sustainable and improve the quality, which is deteriorating because of over-exploitation.

The thickness of unsaturated zones (potential unsaturated aquifer system for recharge) in these areas varies from 12-50 m.

The success rate of Water Harvesting Systems in south Delhi is high compared to other parts of Delhi due to deeper water levels. The intake capacity of the recharge well is good. Where as in Yamuna flood plain and in north Delhi where the water level is very shallow, the intake capacity is low. Water harvesting structures work effectively when the water is more than 15 m below ground level. Hence, south Delhi is ideal for water harvesting.

### Groundwater Recharge from Rainfall

Recharge from high intensity rainfall is not a rapid process, but occurs through stagnant pools that are left in low lying areas after significant amount of surface runoff from surrounding areas and farm lands. Thus, rainfall recharge being depression focussed, certain parts of groundwater recharge zones may never receive direct infiltration to the water table. Hence, there is a need to conserve this large amount of water which can be utilised for artificial recharge of groundwater. The annual precipitation over NCT of Delhi in volumetric terms comes out to be 910 MCM (Million Cubic Metres)<sup>6</sup>. The amount of runoff generated out of this is about 193 MCM. Thus, it is essential to conserve each and every drop of water falling on the territory so as to solve the problem of water supply through augmentation of groundwater resources in suitable areas of the territory.

Nuclear Research Laboratory, IARI has estimated that direct groundwater recharge from rainfall infiltration has wide range of spatial and temporal variation, with most parts receiving less

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<sup>6</sup> Ground Water in Delhi: Improving the sustainability through Rain Water Harvesting. March 2003, CGWB, GOI.

than 8 percent recharge from rainfall. But on an average only 10 percent<sup>7</sup> of the annual rainfall is considered as potential recharge without any artificial effort.

For south and southwest districts of Delhi, which roughly measures 670 km<sup>2</sup> (670,000,000 m<sup>2</sup>) in terms of area, annual natural recharge of groundwater is

$$\begin{aligned}
 (\text{Area} \times \text{Annual Rainfall}) &= (670,000,000 \text{ m}^2 \times 0.6 \text{ m}) \\
 \text{Total rainwater} &= 402,000,000 \text{ m}^3 \\
 10 \text{ percent of the above} &= 40,200,000 \text{ m}^3 \\
 &= 40,200,000,000 \text{ litres (1m}^3=1000 \text{ litres)} \\
 \text{Total water recharged naturally} &= 40,200 \text{ Million Litres per Year}
 \end{aligned}$$

Now consider 65 percent of 670 km<sup>2</sup> area<sup>8</sup>, i.e. 435.5 km<sup>2</sup> (435,500,000 m<sup>2</sup>) as being built up as one huge structure with a continuous roof.

$$\begin{aligned}
 (\text{Area} \times \text{Annual Rainfall} \times \text{Runoff coefficient for rooftop}) & \\
 &= (435,500,000 \text{ m}^2 \times 0.6 \text{ m} \times 0.85) \\
 &= 222,105,000 \text{ m}^3 \\
 &= 222,105,000,000 \text{ litres (1m}^3=1000 \text{ litres)} \\
 \text{Total water recharged by harvesting} &= 222,105 \text{ Million Litres per Year} \\
 &= \text{Approx 5.525 times more}
 \end{aligned}$$

Now the question arises, how many buildings with two average 2-Bedroom Hall Kitchen (BHK) flats per floor can be constructed in the given available land in south and southwest Delhi.

If these are the specifications of an average 2-BHK:

- One Bedroom (12 ft X 14 ft) X 2 = 336 ft<sup>2</sup>
- Kitchen (10 ft X 6 ft) = 60 ft<sup>2</sup>
- Living Room (20 ft X 14 ft) = 280 ft<sup>2</sup>
- Total for one flat = 676 ft<sup>2</sup>
- Total area for two flats = 1,352 ft<sup>2</sup>
- Staircase = 80 ft<sup>2</sup>
- Total area per level = 1,432 ft<sup>2</sup>
- Total built-up area of a building = Approx. 1,500 ft<sup>2</sup>  
= Approx. 135 m<sup>2</sup>  
(Approx. 11.11 ft<sup>2</sup> = 1 m<sup>2</sup>)
- Total number of buildings of 135 m<sup>2</sup> that  
can be built in an area of 435,500,000 m<sup>2</sup> = 3,225,926  
Hence, cost of installing Rooftop WHS for 3,225,926 buildings at Rs 70,000 per building would be  
= Rs. 225,814,820,000

### Role of the Government Through the Eyes of the Media

To tackle the problem of drought that rocked the country, the Ministry of Water Resources has drawn up a programme for rainwater harvesting and recharge. A Rs 45-crore plan has been earmarked for rainwater harvesting and recharge in the Ninth Plan. The ministry has sanctioned Rs 25 crore for the Central Ground Water Board programme, which involves states and user agencies in rural and inaccessible areas. The Central Ground Water Authority is also issuing directives to the states and municipal bodies to undertake rooftop rainwater harvesting and its recharge to groundwater mandatory for every dwelling unit by amending city by laws.

<sup>7</sup> Central Ground Water Board uses this estimate for its calculations.

<sup>8</sup> Delhi Development Authority and Municipal Corporation of Delhi requires 35-40percent of plot area to be left as free space.

At the state level, sensing the need to conserve water, the Delhi Development Authority has proposed amendments to building by-laws making it mandatory for city buildings to have in-built provisions for water conservation, rainwater harvesting, and energy conservation. The proposals, if accepted, would necessitate build-ups over 250 m<sup>2</sup> to have provision for rainwater harvesting, dual water supply system, limiting flushing equipment capacity to 5 litres, installation of waste water recycling plants and conservation of energy through passive climate control.

Coimbatore has joined the select group of cities in the country which have made rainwater harvesting mandatory to reduce groundwater exploitation. Plans for all new structures within the corporation limit would be approved only if they satisfy the newly drafted guidelines of the corporation. The corporation council has approved the resolution, which necessitates residential buildings, commercial and industrial structures to have proper rainwater harvesting systems. Over the years, the groundwater level has been depleting in the city and surroundings following large-scale exploitation. It is estimated that the level could be down to 200 to 350 feet in most of the areas. Moreover, increasing encroachments at 17 of the 28 tanks have aggravated the situation (*The Financial Express*, 26 June 2000).

Experts point out that the scope of water harvesting is tremendous. An improvement in water conservation can also provide the foundation for a multitude of other problems. However, they opine that there needs to be a change in the governance of water systems—a decentralized system of water management is required.

### Arguments Against Water Harvesting

Despite the growing awareness about the benefits of water harvesting, there is another school of thought that argues that roof water harvesting systems (RWHS) are not alternative to public systems in urban and rural areas of regions receiving low rainfall. It says that very little empirical work has been done to assess the impact of roof water harvesting on urban and rural water supply situation. Two important factors seem to be missed out. First, there is significant variation in rainfall in many arid and semi-arid regions and it can pose serious limitations on the amount of water that could be captured. Second: the roof area per capita that is available for capturing rainwater is quite limited and this again could pose a constraint on the amount of water that can be captured. Therefore, the estimates currently available over-emphasise the scope of this technique. Further, there has been no systematic inquiry into the technical feasibility of storing water captured from rooftop in the urban areas. The hydrological opportunities for roof water harvesting would vary significantly from year to year, as well as from location to location, and variation likely to be more in low rainfall areas.

The physical feasibility of RWHS in urban and rural areas is of great importance. To analyse this, M Dinesh Kumar studied the city of Ahmedabad, which falls within the semi-arid tropic of India. He showed that there could be major variations in the volume of water that could be stored across different housing stocks. In case of large individual bungalows (600 sq. m roof area), it can vary from 72 m<sup>3</sup> to 21 m<sup>3</sup>. Assuming the per capita requirement for the upper class family as 500 litres per day, the water stored would be sufficient to meet the domestic water requirement for 5 months in a good year to one and a half months in a bad year. For a small bungalow (200 sq. m roof area), the amount of water that could be stored varies from 24 m<sup>3</sup> in a good year to 7 m<sup>3</sup> in a bad year. Assuming the per capita water requirement to be 300 litres per day, the stored water would be sufficient to meet the requirements for 80 days in a good year to 23 days in a bad year. In the case of a 3-storeyed middle-income housing stock, the volume varies from a maximum of 7.5 m<sup>3</sup> to a minimum of 2.7 m<sup>3</sup>. For the lower income groups (320 sq. m roof area), it can vary from 4 m<sup>3</sup> to 1.2 m<sup>3</sup>. Assuming the per capita water requirement of the middle income group as 200 litres per day, stored water would be sufficient to meet the requirements for 5 weeks in a good year to 2 weeks in a bad year. Similarly for the lower income group, assuming a per capita water requirement of 150 litres per day, the stored water would be sufficient for just four weeks in a good year to just one week in a bad year. In the case of multi-storeyed apartments for the high-income groups, the volume of water per capita varies from a maximum of 5.3 m<sup>3</sup> to a minimum of 1.5 m<sup>3</sup>. Similarly for the middle-income groups it can vary from 2.4 m<sup>3</sup> to 0.70 m<sup>3</sup>. Taking the per capita water requirement for the high

income group as 200 litres per day, the stored water would be sufficient to meet the requirements for less than 4 weeks in a good year and one week in a bad year. Taking the water requirement of middle-income groups as 150 litres per day, the stored water would be sufficient to meet the requirements for 16 days in a good year to 5 days in a bad year. RWHS require underground storage tanks. For an apartment with roof area of 320 sq. m, the maximum volume of water that can be stored is 416 m<sup>3</sup> to 112 m<sup>3</sup> for rainfalls of magnitude 1200 mm and 350 mm respectively. The capacity of existing storage tanks in a typical 10-storeyed apartment will be 30-40 m<sup>3</sup>. Most urban housing stocks do not provide the kind of land area required for building such large tanks, which is necessary for storing the water for lean seasons.

The actual size of a new storage tank would depend on the time duration between two large rain spells, given the magnitude of rainfall. If there is good number of non-rainy days between two large wet spells, the capacity requirement would come down, provided water from the new storage tank is used up during this period. For this, two things are required. First: when rainwater is available, the public system will have to cut down its supplies, which means that both the systems have to be synchronised. Second: rainwater stored in the new tank will have to be lifted and put in the old storage tanks as and when it gets empty space. This would pose complex management problem in case of large housing stocks with several users under one roof.

The analysis shows that roof water harvesting is beneficial for those who are living in bungalows and flat systems, provided the available per capita roof area is quite significant, that is more than 6 sq. m. Hence, roof water harvesting systems are best suited to higher and middle-income groups. As such, it is not a substitute for urban public water utilities. RWHS is only one among many strategies for countering the growing urban water crisis.

### Concluding Remarks

It is no denying that sustaining and recharging the groundwater along with judicious use of the limited fresh water resources is the need of the hour. If sufficient measures are not taken up immediately, we will face a crisis which will be detrimental to the very survival of mankind. Efficient management of water resources and education about judicious utilisation of water resources along with measures of harnessing, recharging and maintaining the quality of water and water bodies has to be taken up on war footing.

One of the most logical steps towards this goal would be acknowledging the importance of rainwater harvesting. This should not only encompass rooftop rainwater harvesting but also stormwater harvesting systems. Stormwater harvesting is yet to be acknowledged as a better alternative over rooftop water harvesting. One of the major hurdles in stormwater harvesting is the poor state of stormwater drain systems in India. A planned approach is hence needed in order to fully utilise the potential of rainwater to adequately meet our water requirements. Hence, an equal and positive thrust is needed in developing and encouraging both the types of water harvesting systems. We have to catch water in every possible way and every possible place it falls.

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## Appendix I

### URBAN RAINWATER HARVESTING: SOME EXPERIENCES

#### Centre for Science and Environment, New Delhi

**Introduction:** Centre for Science and Environment (CSE), a New Delhi based non-governmental organisation, through its “Peoples’ management of water” campaign promotes the paradigm of community- based rainwater harvesting with the objective of ‘Making Water Everybody’s Business’. Rainwater harvesting is a potential solution to address the water crisis in both rural and urban areas.

**The model projects:** CSE is constantly deluged with queries, opinions and ideas from people who are concerned about the prevailing water crisis and are keen to play an active role in managing water. As a part of its initiative to spread awareness about community – based rainwater harvesting techniques, (CSE) has identified five model projects in Delhi, from among those that have been designed by it. These act as effective tools to establish the fact that rainwater harvesting can be taken up and implemented successfully in urban centres. This paper is a discussion on the rainwater harvesting systems adopted in these five model projects which are situated at distinct geographical and geological areas. These sites include Jamia Hamdard University, Tughlakhabad; Panchsheel Park colony, Panchsheel park; The Shri Ram School, Vasant Vihar; Janki Devi Memorial College, Rajendra Nagar and Mira Model School, Janakpuri. They feature different forms of rainwater harvesting – rooftop harvesting and surface water harvesting. CSE have been monitoring these projects since its implementation to assess the impact of rainwater harvesting on the quality and quantity. Improvement of both quantity and quality at all these project areas has been remarkable.

**Quantity:** Measurement of water levels in the tubewells in project area is indicative of a positive trend. The details of the Pre monsoon, Monsoon, and Post monsoon water levels are as follows:  
(Note: All readings in metres)

Name of the site	Pre-monsoon	Monsoon	Post-monsoon
Jamia Hamdard University	45	38	40
Janki Devi Memorial College	35.8	22.1	27
The Shri Ram School	40	35.1	36.2
Mira Model School	7.6	5.2	7.1
Panchsheel Park Colony	28.6	26.7	27.1

**Quality:** It has been found that after rain water harvesting the quality of groundwater in general has improved. The following is the highlights of the water tests conducted by the Pollution Monitoring Lab (PML) of CSE. The average impact on different physicochemical parameters are as follows:

- In all the samples pH (Hydrogen ion concentration) has improved and has moved towards neutral.

- In 72 per cent and 82 per cent of the samples there is decline in Total Dissolved Solvents (TDS) and Total Solids (TS) values respectively, and the maximum improvement in value of TDS is up to 80 per cent in the sample from Panchsheel Club.
- In 91 per cent of the samples alkalinity increased within prescribed limit and acidity declined after the monsoons.
- Calcium (Ca), Magnesium (Mg) and hardness, these parameters are showing mixed results. In around 50 per cent of the samples, there is an increase in hardness after monsoon. In 50 percent there is decrease in hardness value after monsoon. Samples from the Mira Model School have shown a drop in the concentration of Calcium (Ca). While 64 per cent post monsoon samples show a declining trend in Ca content, the remaining 36 per cent follow the reverse trend. Again, sample from Mira Model School is shows 63 per cent decrease in Mg concentration. In general, around 55 per cent of the samples are showing a decrease in the Mg content after the monsoons.
- In 100 per cent samples there is decline in the values of oil and grease, turbidity and chromium content.
- Nitrate concentration has shown a declining trend in all the post monsoon samples.
- Nitrite was detected in two samples and mercury was detected in one sample pre monsoons, but post monsoon the traces of these two compounds were not detected in any of the samples.

**Conclusion:** It can be concluded from above findings that rainwater, if conserved and utilised using the rainwater harvesting technology, can be an effective tool of replenishing ground water resources