"Rain Drop - a Heritage to Preserve"

Karnataka

Rain Water Harvesting

- Users' Manual

KUIDFC

Working towards better urban living

Karnataka Urban Infrastructure Development and Finance Corporation

This Report has been prepared by KUIDFC through CMAK

The Report has been finalised by
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"Suvarna Karnataka"

RAMESHWAR THAKUR
HIS EXCELLENCY
GOVERNOR OF KARNATAKA

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MESSAGE

It is, indeed, a pleasure to know that Karnataka Urban Infrastructure Development and Finance Corporation (KUIDFC) is bringing out the second edition of the Manual on Rainwater Harvesting meant for the Users.

KUIDFC had brought out the first edition of the Manual on Rainwater Harvesting for the Trainers, covering all the technical aspects of harvesting rainwater. It was intended to serve as a guide for training of district level officials and Nirmiti Kendras on the real-time implementation of rainwater harvesting systems.

The present Users' Manual is intended to create awareness among the general public about the importance of harvesting rainwater and giving them basic technical inputs.

Capturing rainwater can empower us to become self-reliant and live in a sustainable environment. The KUIDFC has since been working to make this vision a reality by developing a strategy to implement rainwater harvesting in all urban areas. I strongly believe that the Manual will enable the users to effectively implement Rainwater Harvesting in their available space.

I convey my best wishes to KUIDFC and urge them to continue such endeavors for the conservation of water and help to mitigate the water scarcity issue in the urban sector.

RAMESHWAR THAKUR

"Suvarna Karnataka"

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MESSAGE

Urban Centres are facing an increasing water shortage leading to excessive and indiscriminate exploitation of ground water. As a consequence, the ground water table in many parts of the state has gone down alarmingly. Ironically the water deficient areas are often flooded during the monsoons.

No single initiative is adequate to solve the problem of drinking water. But, the one idea that stands out for its simplicity, efficacy and affordability is the Rainwater Harvesting. Capture rain water, store it and use it. If simple techniques illustrated in this Users' Manual are developed, one can provide decentralized, local level solutions that can considerably meet the drinking water needs of our urban population.

The Karnataka Urban Infrastructure Development and Finance Corporation (KUIDFC) has since been working to make this vision a reality by developing a strategy to implement rainwater harvesting in all urban areas. I strongly believe that the Manual developed by KUIDFC will enable the users to effectively implement Rainwater Harvesting in their available space. I appreciate the efforts undertaken by KUIDFC internal team and CMAK in successfully bringing out this Manual.

Chairperson
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"Suvarna Karnataka"

GOVERNMENT OF KARNATAKA

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FOREWORD

Water is the basis of life, it is a precious natural resource which needs to be managed wisely. The former President of India Dr. A.P.J. Abdul Kalam, while charting the 11-mission roadmap for the development of Karnataka, has emphasized the implementation of Rainwater Harvesting in the state as one of the important elements of the Roadmap.

Capturing rainwater can empower us to become self-reliant and live in a sustainable manner. The Karnataka Urban Infrastructure Development and Finance Corporation, has since been working to make this vision a reality by developing a strategy to implement rainwater harvesting in all urban areas. A policy has been drawn to mandate rainwater harvesting in all residential, commercial and industrial complexes, as well as public areas such as parks. As a first step KUIDFC has come out with the Trainers' Manual on rainwater harvesting and now venturing for bringing out the Users' Manual which would not only create awareness among the general public about the importance of rainwater harvesting, but also help in implementing the same. I hope and trust that this Manual will prove to be an extremely meaningful and purposeful document that will address the water scarcity in Karnataka by harvesting this precious bounty of nature and enable the users to effectively implement Rainwater Harvesting in their available space.

Principal Secretary
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PREFACE

Water is one of the most basic human needs. It underlies human health and impacts all other aspects of sustainable development. Karnataka is only second to Rajasthan in being the drought-prone state. With rapid urbanization and the population growing at a phenomenal rate, the demand for water has been on the rise. The supply of adequate quantity of potable water on one hand and managing the flooding of streets during monsoon on the other hand have become Herculean tasks that ULBs have to face. Urban areas are becoming increasingly dependent on ground water as surface water supply is inadequate and unable to cater to the needs of entire urban population. This has resulted in rampant and un-hindered extraction of ground water leading to depletion of ground water resources. It is estimated that about 27% of the urban population depends on bore wells.

Rainfall is the only source to replenish the ground water. Most of the rainwater goes as runoff, only a small percentage infiltrates into the aquifer. As open spaces in the cities are being increasingly covered by metalled roads, buildings etc., infiltration is getting reduced day by day. Therefore, there is an urgent need to address the issue of dwindling ground water resources in urban areas.

The former President of India Dr. A.P.J. Abdul Kalam while charting the 11 mission roadmap for the development of Karnataka has emphasized the implementation of Rainwater Harvesting in the state as one of the important elements of the roadmap.

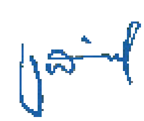
The Government of Karnataka has taken an initiative to advocate rainwater harvesting across urban Karnataka. State Policy on rainwater harvesting is being formulated to mandate rainwater harvesting for residences, commercial buildings, industrial complexes, public buildings and parks etc.,. An Advisory Committee at the State Level has been constituted with Principal Secretary UDD as its Chairman to look into the issues of Policy / Guidelines, implementation strategy and monitor overall implementation of rainwater harvesting.

A Technical Committee has been constituted by the Government of Karnataka with Managing Director, KUIDFC as its chairman for preparing the Guidelines, Normative Standards and furnish technical inputs on rainwater harvesting. As a first step KUIDFC has already come out with Trainers' Manual on rainwater harvesting and now this Users Manual for creating awareness among the general public about the importance of rainwater harvesting.

Although a simple concept, it is important that the general public understands the various elements of rainwater harvesting. I strongly believe that the Manual will provide the necessary expertise required for implementation and enable the users to effectively implement Rainwater Harvesting in their available spaces.

The contributions made by the members of the Technical Committee on Rainwater Harvesting under my chairmanship, in the overall development, review and editing of the Manual and their valuable suggestions are highly commendable. I extend my gratitude to Sri. A. R Shivkumar, Scientist, Karnataka State Council for Science and Technology (KSCST), Dr. Chandankeri Expert, Technology Infrastructure Development Endeavor (TIDE), Sri. A.S Ravikumar, Reader in Civil Engineering, Bangalore University and Smt. Rashmi Gopal, Research Associate, TERI. I thank them for their unstinting support in the development of the Manual.

I would like to take this opportunity to thank Sri. Vishwanath, Technical Committee member & Expert, Rain Water Club and Sri. Gopal Roa, Research Associate, CMAK (City Managers Association of Karnataka), who have put their best in preparing this Manual. Last but not the least, I thank and commend the internal team of Environment and Energy Cell (E&EC) of KUIDFC headed by Sri. Ashok Jain, Genereral Manager (Urban Affairs) and its members Smt. Shambavi Kamath, Assistant General Manager and Sri. Syed Parveez Ahmed, Environmental Engineer who served as the editorial team of which I was a part, for reviewing and finalizing this manual.



(JAWAID AKTHAR)
Chairman, Technical Committee on
Rainwater Harvesting and
Managing Director, KUIDFC

CONTENTS

CHAPTER – I

"Where there is no water, there is no life."

INTRODUCTION

Water is a precious natural resource that needs to be managed and used wisely. We need to do so because the total amount of rainfall in India remains the same, while the increase in population and the growing economic prosperity has created a huge demand for water which has increased the pressure on its availability. Agriculture continues to remain the single largest consumer of water and industrial demand is also growing at a rapid pace.

In urban areas, the demand for water is more concentrated which means that Urban Local Bodies have to pump it from sources that are located at greater distances from the city limits. For example, the city of Bangalore pumps water from the river Cauvery nearly 100 kilometers away and about 300 meters below the city level. Pumping water from such a distance involves huge expenditure for the government and the agencies involved. The average production cost of water, for ULBs in Karnataka and excluding Bangalore, which covers pumping, treatment and distribution is estimated at Rs. 14/- for 1000 litres (as per 2006 estimates). In respect of Bangalore city it is Rs. 19/- for 1000 litres. This figure is just the delivery cost of water to our doorstep and does not include the cost of waste water treatment.

On the other hand, many households also depend on groundwater to meet their requirements. The town of Doddaballapura meets its entire requirement from deep bore-wells, as a result of which, the water level in the region has sunk as far as 1,000 feet deep. In addition to that, the groundwater aquifers are fast depleting and many bore-wells are running dry. There are also many problems being reported with the groundwater quality. For example, the presence of nitrates, fluoride, iron and salts are on the rise.

Paradoxically, when it rains many parts of the city gets flooded. This is because rainwater is not managed carefully. Increasing paved areas increases runoff and reduces percolation and the recharge of ground water. Valleys and tanks are being encroached and the smooth flow of rainwater is being disturbed. Hence, incorporating rainwater harvesting techniques while planning cities will not only prevent urban flooding but also recharge groundwater.

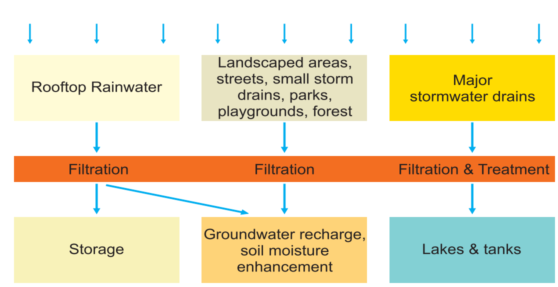
Depletion of groundwater and flooding during the monsoon are signals that tell us that urban areas have to be careful with their water use. Water can no longer be wasted and citizens should participate in the process of finding a solution to the problem of water scarcity and contribute their mite to help.

Understanding Rain

The first thing that you need to understand about water is that the primary source of water is rain. Water evaporating from both the sea and land, falls back as precipitation and runs off as streams and rivers, settles in lakes and tanks, seeps through the soil and reaches the underground aquifer. This water then becomes available to be taken out as well water or bore-well water, but in all cases, the primary source of this water is rain. Rainfall is measured in millimeters using specified rain gauges set up throughout the country. The rainfall for a particular place is averaged over 30 years and reported as normal rainfall for a place. The normal rainfall for all the taluks of Karnataka is given in Annexure I.

Based on the actual average rainfall for a city, the theoretical model to be followed for a city level rainwater harvesting system would involve:

- The capturing of rooftop rainwater
- Collecting water runoff from open areas
- Collecting the city level runoff



Schematic representation of a RWH system in an urban area.

The role of tanks in rainwater harvesting

Narasipura Lake in Bangalore

Lakes and tanks are the ultimate water harvesting structures. Tanks are man-made water retaining structures built with a careful understanding of location, confined catchments and percolation possibilities. Rainwater is carefully collected in them and the groundwater gets recharged from these tanks, at rates varying between 5 mm to 12 mm every day. Regular annual desilting of the tanks ensures rapid percolation. The zone of influence of the groundwater recharge runs into kilometers and it results in open wells being full and being used for withdrawal of water. According to the N. Laxmana Rao Committee's report, there were 262 tanks in Bangalore in the year 1960, which have now been reduced to 81. Water sensitive urban design and water harvesting can only be achieved when these tanks and lakes are restored to be repositories of clean storm water without any pollutants or sewage.

IMPORTANCE OF RAINWATER HARVESTING

Why harvest rainwater?

There are many reasons why rainwater needs to be harvested. Some of them are given below:

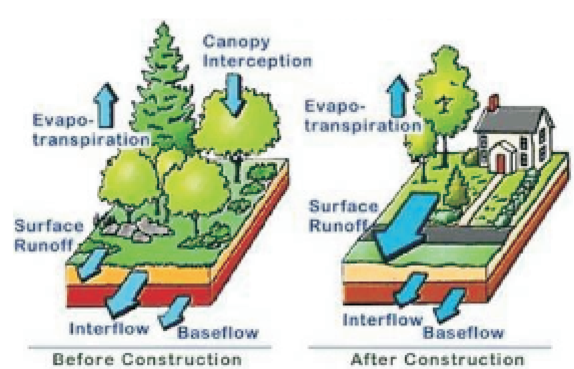
- Water is a scarce natural resource and hence it should not be wasted.
- It can supplement our domestic, industrial and other water needs.
- If rainwater harvesting is incorporated at the design stage of any construction project, the investment is low and the water collection is large.
- Centralized systems of water supply are under stress to cope with huge water supply demand of cities.
- Ground water is constantly getting depleted or polluted in large areas.
- Water is not only becoming scarce but expensive as well.
- The link with the hydrologic cycle is re-established leading to efficient and effective use of water .
- It can be an individual's contribution to reduce the 'ecological water footprint' i.e. the distance water has to travel to reach a house.
- It will reduce electricity consumption and the cost required to pump water from sources that are a long distance away.
- It will mitigate and to a certain extent prevent urban flooding.

Consider the example of a house being built on a new housing site. The site would have been naturally vegetated land or agricultural land prior to the construction. The local hydrologic cycle would change dramatically after the construction. The figure and the chart below will show surface runoff increasing from 10 to 55% and infiltration decreasing from 50 to 15% due to this activity.

One of the aims of rainwater harvesting is to restore the original hydrologic cycle by storing the increased runoff and by using some of it for recharging.

The restoration of the natural hydrologic cycle is the key aim of rainwater harvesting. This is true even for small housing sites, as it is, for the entire city.

LOCAL HYDROLOGIC CYCLE



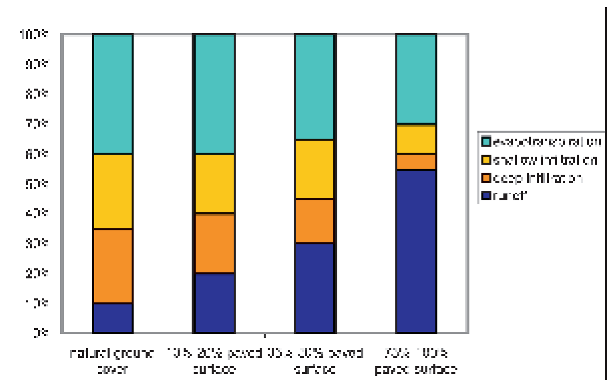
Hydrological cycle

Source: KSCST

Change in water flows with increasing paved surface

	Runoff	Deep Infiltration	Shallow infiltration	Evapotranspiration
Natural ground cover	10	25	25	40
10%-20% paved surface	20	20	20	40
35%-50% paved surface	30	15	20	35
75%-100% paved surface	55	5	10	30

The decrease in infiltration (green bar) and the increase of surface runoff (blue bar) is evident as paved area increases.



Change in water flows with increasing paved surface

- Infiltration is the process through which rainwater enters the soil.
- Percolation is the process through which it proceeds to the aquifer below.
- Evaporation is the process by which rainwater goes back to the atmosphere as water vapour.
- Transpiration is the process through which plants breathe out water vapour.
- Evapotranspiration is the combination of evaporation and transpiration.

What is rainwater harvesting?

Collecting and storing of rain water for productive use in the future is called rainwater harvesting.

There are certain other terms which need to be understood when you speak of rainwater harvesting, such as,

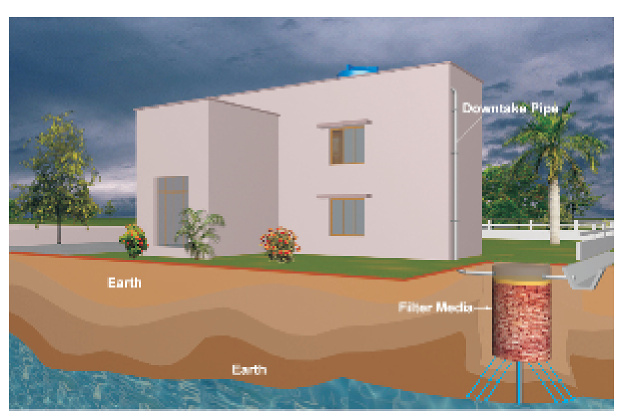
- rooftop rainwater harvesting which is collection of rainwater from rooftops.
- storm-water harvesting which is collection of rain from paved and unpaved areas and also from storm-water drains.

Rooftop Rainwater harvesting

Different ways of using Harvested Rainwater is shown in the sketches below.

Reuse of harvested rainwater

Water can be collected either from rooftops or from the ground or a combination of both. It may involve the simple collection of rainwater from the rooftop of a house, for use in gardening or collection from a large industrial campus for reuse in industrial processes or for recharging into the ground as shown.



Recharge of harvested rainwater

Who can harvest rainwater?

In short, the answer is, everybody.

- It is ideal for people planning to construct or in the process of constructing any building. It could be a home, a school, a factory or a shed.
- Already built structures can be retrofitted or refitted for rainwater harvesting.
- Industries and institutions with large roof areas have a good potential for rainwater harvesting.
- Apartments and multistoried buildings too, can harvest rainwater.
- Paved and unpaved ground also provides a potential catchment for rainwater harvesting.
- In rural areas, where water needs to be brought from a source that is at a long distance away or where the groundwater is contaminated with fluoride, nitrates, arsenic etc.
- In low income areas, where water is to be stored in small containers and is available infrequently.
- Parks and open spaces can harvest rain to increase soil moisture and groundwater levels for meeting their water requirements.
- Cities and towns can harvest rainwater in lakes and tanks to supplement their water requirement.

Case Study:
House

Prithvi and Purushottam, twin brothers, bought their 30 x 50 feet site in Sahakarnagar, off Bellary road in North Bangalore. They were keen on incorporating rainwater harvesting in their house design, right from the beginning and insisted that the architect incorporate it into the plan.

The first rain separator with an end cap used as a by- pass when cleaning the roof

The roof area of the house was 650 square feet or approximately 65 square meters. The roof was given a slope, appropriately, during the course of water proofing to bring all the rainwater to one point. The rainwater was brought down through a 90 mm diameter down-take pipe to the first rain water separator.

The first rain water separator is a multi-purpose device and can be opened when the terrace is being cleaned so that the dirty water flows into the garden.

After cleaning, the cap of the first rain water separator is replaced and it collects the first 1.50 mm of rain falling on the terrace every time it rains. The maximum amount of silt and dust on the roof is picked up in this vertical pipe i.e. the first rain separator, leaving cleaner rainwater to be filtered and stored for use.

After this process of separation, the rainwater is filtered. Purushottam designed the rain filter using a 90 litre blue coloured HDPE drum. Rainwater enters from below the drum and passes through two layers of sponge and sand placed in alternate layers. The water is then collected at the top and flows into the sump tank which has a capacity of 6000 litres.

Rainwater enters the filter from the lower pipe to the left and is collected at the top with a pipe before flowing into the sump. The brown cover of the sump is seen at the back.

During heavy rains, if the sump tank fills up, the overflow of the rainwater is let into an open well on the premises. The well water has considerably improved both in quantity and quality, over time. Whenever well water is available, it is used for all purposes.

The house has a 'zero runoff.' All the rainwater falling on the plot or the roof is either collected or allowed to recharge the open well. In fact, the side setback area is left unpaved to allow infiltration of rainwater. It is estimated that the house harvests around 50,000 litres in the sump tank and recharges around 30,000 litres into the well, annually, from overflows and from the paved area.

There is a great sense of ownership for the rainwater harvesting system, in the family. The filter is prominently placed in front of the house, so that the owners can explain the mechanism and its benefits to curious relatives and friends. The system works well only when all the members of the family take interest in the project and participate in it.

Water harvested:
Total water stored: 52280 litres
Total recharge water: 30000 litres
Days serviced in a year: 174

Water is precious, preserve it!

CHAPTER – 2

Water is a mystically powerful element which being connected with God in some way, can cleanse sins, inner and outer defilement and regenerate the human body

WATER USAGE

How much water does a person use?

It is a good idea to install a water meter and measure monthly consumption of water, whether it is from the city pipelines or from your own well or bore-well. A good water meter should be Bureau of Indian Standards (BIS) certified and bear the BIS certification mark. Measuring consumption is the first step to managing and conserving water usage. However, the consumption pattern as suggested by the Central Public Health and Environmental Engineering Organisation (CPHEEO) standards is given below:

Consumption pattern

Type of Use	Litres per person and per day
Drinking	3
Cooking	4
Bathing	20
Flushing	40
Washing clothes	25
Washing utensils	20
Gardening	23
TOTAL	135

Source: CPHEEO norms.

If you examine the water bill from your service provider, it should give you a fair idea of your water use. Consumption can range from 50 liters to 300 liters per person per day. At many times, you will find that cheap and subsidized water results in inefficient use and high consumption.

In Bangalore, for example, the production cost of water is Rs. 19 a kilolitre (the average for the rest of Karnataka, as per Karnataka Urban Water Sector Improvement Project KUWASIP studies is Rs. 14 per 1000 litres). On the other hand, the average supply cost to the domestic sector in the first slab is about Rs. 6.00 a kilolitre. Since it is the financially well off who are more likely to have piped supply to their house from Bangalore Water Supply and Sewerage Board (BWSSB), they get (BWSSB), they get the subsidy. The poorer sections of society manage with the public taps and bore-well water.

How much water does a person need?

If you use water efficient taps, flushes and showers and are careful and conservative with water use, 90 to 100 litres per capita per day should be adequate. Therefore, assuming a demand of 450 litres of water for a family of 5, harvested rainwater in Bangalore should suffice for 173 to 192 days on an average in a year. This is nearly 50% of yearly requirement.

How much water can a person get from the rain?

It would depend upon where you are located and how much rain falls there. Details for the average normal rainfall for all Taluks in Karnataka are given in Annexure II.

In Bangalore, for example, over the last 17 years it has rained as follows:

Year	Rainfall (mm)	Rainy days	Possible collection (Litres for 100 m2 roof area)
1990	528	42	47520
1991	1328	65	119556
1992	958.3	56	86247
1993	1176.6	65	105894
1994	736.6	45	66294
1995	657	61	59130
1996	886	64	79740
1997	1196.7	52	107703
1998	1184.6	68	106614
1999	1091.2	52	98208
2000	1232.3	96	110907
2001	1000.5	87	90045
2002	628	48	56520
2003	649.7	52	58473
2004	998.4	66	89856
2005	1358.2	62	122238
2006	743.8	53	66942

Calculation made with a runoff of 0.9 source: GKVK (Bangalore)

What purpose can harvested rainwater be used for?

It can be used:

- For non-potable purposes like gardening, flushing and washing clothes.
- For all purposes, but you can do this only after confirming the potable qualities of harvested rainwater.
- For only potable purposes after ensuring the quality of the water, where there is no alternative source or the source is contaminated. This is typical in many habitations.

Case Study:

Urban apartment complex

Cristal Jade is located on the Outer Ring Road, Bangalore.

The rooftop rainwater is collected in down-take pipes placed on each side of the building. On one side, the water flows in an open drain, on the other, it is sent in an underground pipe as shown in the pictures:

As the roof area is about 2,000 m^2 and the normal annual rainfall is 870 mm in this area, with a runoff coefficient of 0.9, water available for recharge every year =2000x0.87x0.9=15 lakh litres.

The water is filtered in an underground chamber and sent into two recharge wells. After one or two rainy seasons, the level of groundwater is expected to increase. Once there is some water remaining in the wells for at least part of the year, the apartment plans to use one of them as an open well for the water requirement of the apartment dwellers. The second well will remain as a recharge well to keep the level of water high in the withdrawal well.

The filter chamber (to the right) and the 2 wells are shown on the picture:

CHAPTER – 3

Receive shower with folded hands.
It is a blessing to our mother earth...

HARVESTING RAIN

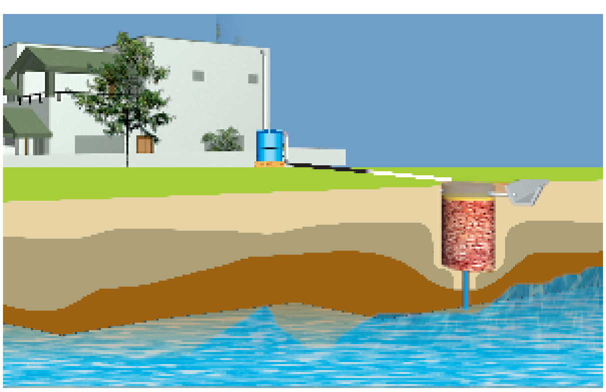
How does a person harvest rooftop rainwater?

It is a very simple process and requires at the most, the assistance of a good plumber.

You need to:

- •Make provisions for a roof that is as clean as possible, so that it can be used as a collector of rainfall.
- •Draw rainwater down through pipes or gutters as necessary.
- •Separate a little water from the first rain that will contain leaves and dust and filter the rest.
- •Store the harvested rain water in a sump tank or lined pond for later use and / or
- •Charge the groundwater through percolation pits, open wells or bore-wells.

Storage of harvested rainwater for immediate use and the overflow from the storage as ground water recharge should also be possible as is shown in the Fig below.



Storage and recharge of rainwater.

The System and the Design

Design your roof keeping in mind the rainwater harvesting requirements. If the roof is flat, slope the roof in the direction of gutter or the down-take pipe. Sloping roofs should have adequate 'gutters' or down-take pipes to handle the entire rainfall falling on the roof. Down-take pipes should preferably be made of PVC, and resistant to UV rays. The National Building Code says that if the intensity of rain in a place is 50 mm per hour, then one 75 mm down pipe will serve an 85m^2 roof area. Usually, two 100mm diameter pipes are good enough for a 100m^2 roof area. Provide a simple first rain separator and filter the rain water before storage or recharge. Use a small container, like a drum with gravel and sand, as a filter.

Roofs

Rainwater can be harvested from sloping roofs as well as flat roofs, as is shown in the picture below, using PVC or GI gutters ana pipes

Sloping roof & Flat Roof

Calculate your rainwater collection

To calculate the amount of rainwater that can be harvested from your roof, you need to first find out the average rainfall in your area using the taluk level data.

Check the row with your roof area (column A) then check the column with the amount of rainfall in your city (top row). The box corresponding to the column and the row you have selected, gives you the figure, in litres, of THE RAINWATER YOU CAN COLLECT FROM YOUR ROOF.

Example: Rooftop area: 100 M^2, annual rainfall 600 mm > 48000 litres collected

Roof area (m^2)	Annual Rainfall in mm												
	300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500
10	2400	3200	4000	4800	5600	6400	7200	8000	8800	9600	10400	11200	12000
20	4800	6400	8000	9600	11200	12800	14400	16000	17600	19200	20800	22400	24000
30	7200	9600	12000	14400	16800	19200	21600	24000	26400	28800	31200	33600	36000
40	9600	12800	16000	19200	22400	25600	28800	32000	35200	38400	41600	44800	48000
50	12000	16000	20000	24000	28000	32000	36000	40000	44000	48000	52000	56000	60000
60	14400	19200	24000	28800	33600	38400	43200	48000	52800	57600	62400	67200	72000
70	16800	22400	28000	33600	39200	44800	50400	56000	61600	67200	72800	78400	84000
80	19200	25600	32000	38400	44800	51200	57600	64000	70400	76800	83200	89600	96000
90	21600	28800	36000	43200	50400	57600	64800	72000	79200	86400	93600	100800	108000
100	24000	32000	40000	48000	56000	64000	72000	80000	88000	96000	104000	112000	120000
110	26400	35200	44000	52800	61600	70400	79200	88000	96800	105600	114400	123200	132000
120	28800	38400	48000	57600	67200	76800	86400	96000	105600	115200	124800	134400	144000
130	31200	41600	52000	62400	72800	83200	93600	104000	114400	124800	135200	145600	156000
140	33200	44800	56000	67200	78400	89600	100800	112000	123200	134400	145600	156800	168000
150	33600	48000	60000	72000	84000	96000	108000	120000	132000	144000	156000	168000	180000
160	36000	51200	64000	76800	89600	102400	115200	128000	140800	153600	166400	179200	192000
170	38400	54400	68000	81600	95200	108800	122400	136000	149600	163200	176800	190400	204000
180	40800	57600	72000	86400	100800	115200	129600	144000	158400	172800	187200	201600	216000
190	43200	60800	76000	91200	106400	121600	136800	152000	167200	182400	197600	212800	228000
200	45600	64000	80000	96000	112000	128000	144000	160000	176000	192000	208000	224000	240000
210	48000	67200	84000	100800	117600	134400	151200	168000	184800	201600	218400	235200	252000
220	50400	70400	88000	105600	123200	140800	158400	176000	193600	211200	228800	246400	264000
230	52800	73600	92000	110400	128800	147200	165600	184000	202400	220800	239200	257600	276000
240	55200	76800	96000	115200	134400	153600	172800	192000	211200	230400	249600	268800	288000
250	57600	80000	100000	120000	140000	160000	180000	200000	220000	240000	260000	280000	300000
260	60000	83200	104000	124800	145600	166400	187200	208000	228800	249600	270400	291200	312000
270	62400	86400	108000	129600	151200	172800	194400	216000	237600	259200	280800	302400	324000
280	64800	89600	112000	134400	156800	179200	201600	224000	246400	268800	291200	313600	336000
290	67200	92800	116000	139200	162400	185600	208800	232000	255200	278400	301600	324800	348000
300	69600	96000	120000	144000	168000	192000	216000	240000	264000	288000	312000	336000	360000

Rainwater collected in litres

Piping System

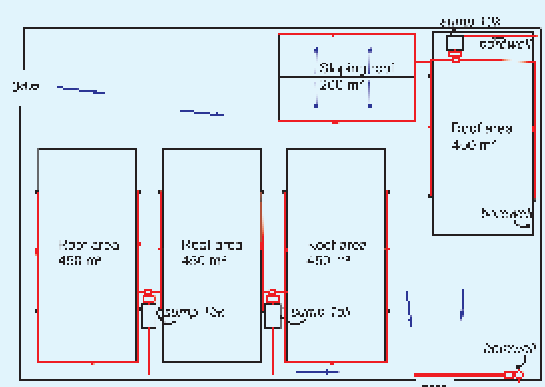
In case of a sloping roof, a gutter (viz, a horizontal pipe) running along the edges of the roof is necessary. You can use clamps to fix it to the edges of the roof. The gutter can be connected to the down-pipe using an elbow junction. Seal the other end of the gutter using the end cap. The PVC pipe used for the gutter should be UV resistant and of good quality. Four inch diameter pipes are generally used, however, six inch pipes are preferable.

Elbow Junction & Tee Junction

Case study

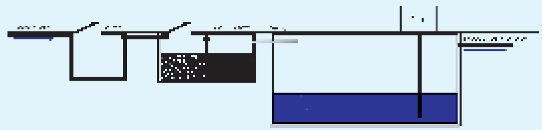
Apartment in JP Nagar, Bangalore

The GSBF apartment complex has four buildings, housing 68 individual units. The water supply is currently provided by two bore-wells going to a depth of 400 feet. The groundwater table is steadily decreasing one of their three initial bore-wells is already dry, and both the others keep yielding less. The apartment complex buys 2 water tankers, approximately 12,000 litres a day to respond fully to the water demand. This means an expenditure of Rs. 400 daily. The committee members have decided to harvest rainwater and thus have a more sustainable water management plan. An investigation suggested that the harvested rainwater can be used for two different purposes in the apartments. The rooftop rainwater can be collected from the down-take pipes, filtered and stored in the three existing sump tanks for direct use. The excess water from the sumps and the storm-water from the paved areas can be sent into the ground to recharge the bore-wells. A plan of the system is shown in below:



The total roof area is around 2,060 m² and the normal annual rainfall in South Bangalore is 970 mm. With a runoff coefficient of 0.9, 2060x0.970x0.9=18 lakh litres of rainwater can be stored for direct use in the apartments. With an average demand of 500 litres per family, the harvested rainwater can be used as the only source of water for more than two months, in a year.

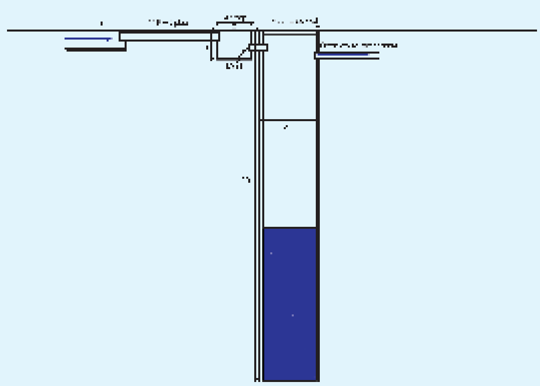
The rainwater is collected using 6" PVC pipes and connected to a silt trap with the dimensions of 3'x3'x3' and a filter chamber with the dimensions of 9'x6'x3', filled with sand and jelly.



This entire storage system costs around Rs. 90,000/-. The annual savings in the water billed at Rs. 33.33/- a kilolitre (the price paid for tanker water) will be 1,800x33.33=Rs. 59,999/-. The entire amount of money, invested on rainwater harvesting, can be recovered in less than 2 years.

Excess water from one sump tank and water falling on the paved areas can be sent into recharge wells dug beside the bore-wells.

The recharge well is 3'in diameter, 20' deep made with RCC rings. The hydrostatic pressure of the water entering the well allows it to percolate efficiently into the ground. The water will then reach the same aquifer as the bore-well and increase the level of the groundwater table in the area. As the land there has a natural gradient leading the runoff water through the gate, the water is caught in a trench (1' wide, 1' deep) covered with a grill for recharging the bore-well.



Around 19 lakh litres of water can be sent to the recharge well. This system costs around Rs. 23,000/- (cost as of 2006)

Siting a rainwater harvesting structure

Every town has a building bye-law which identifies the front, rear and side setbacks. The table below gives the details of the setbacks, for Bangalore. It is clear that this is based on the depth of the site. The drawings below indicate the building footprint on the site. If the bye-laws are followed, it is very easy to locate either a storage structure or a recharge structure. Possible locations for these are also indicated in the drawing. By minimizing the number of down pipes and giving the roof a slope keeping in mind the rainwater harvesting structure, the cost of the rainwater harvesting structure can be reduced.

Sizing of rainwater pipes for roof drainage

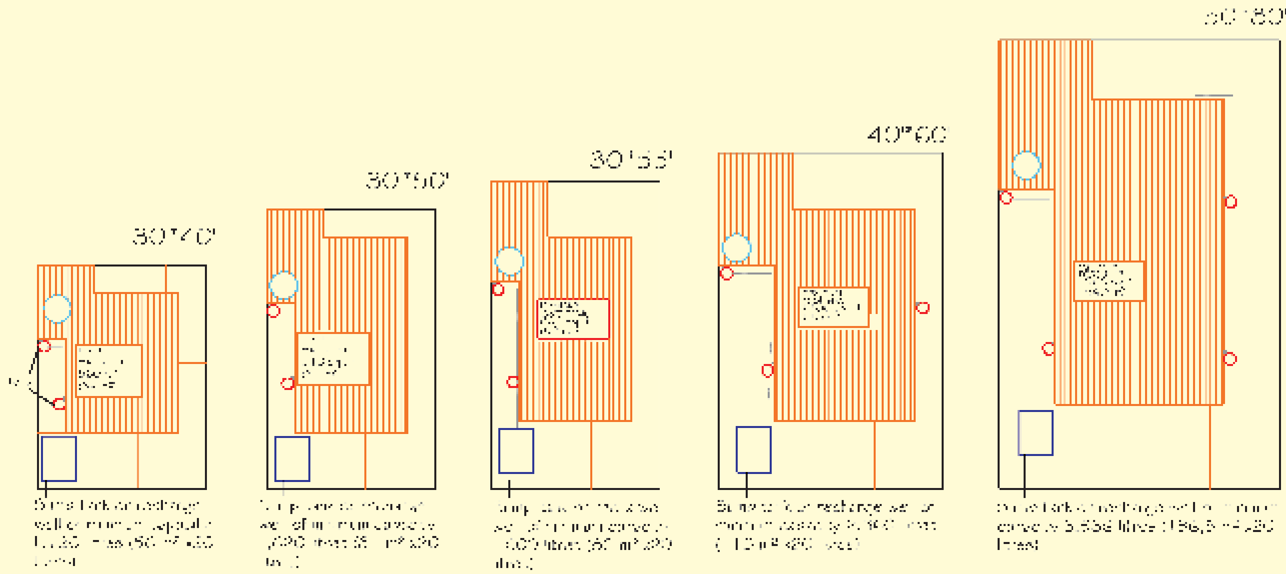
All buildings with a flat roof have rainwater down-take pipes to bring the rainwater down from the terrace to the ground. The sizing and placing of the pipes depends on the intensity of rainfall at the place. Using the chart provided in the national building code of India, appropriate and optimal dimension of the pipes can be calculated.

For example, in a place with maximum intensity of 75 mm per hour of rainfall, if we choose a 100 mm diameter down-take pipe, then a roof area of 57 m^2 can be drained by this down-take pipe.

Of course, the practical sloping of the roof will also determine the number of down-take pipes.

	Average rate of rainfall (mm/h)					
	50	75	100	125	150	200
Dia of pipe (mm)	Roof area (m^2)					
50	13.4	8.9	6.6	5.3	4.4	3.3
65	24.1	16	12	9.6	8	6
75	40.8	27	20.4	16.3	13.6	10.2
100	85.4	57	42.7	34.2	28.5	21.3
125	-	-	80.5	64.3	53.5	40
150	-	-	-	-	83.6	62.7

Source: National building code of India, 1983



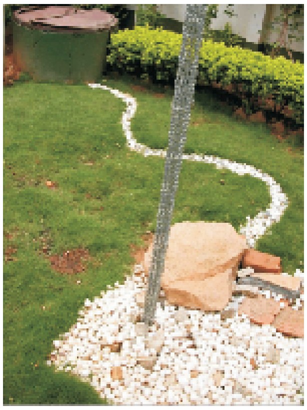
Depth of site (meters)	Residential		Commercial		T&T and PUB Public and Semi-Public		Width of site (meters)	Residential		Comercial		T&T and PUB Public and Semi Public	
	Front	Rear	Front	Rear	Front	Rear		Left	Right	Left	Right	Left	Right
Upto 6	1	-	1	-	1.5	-	Upto 6	-	1	-	-	-	1.5
Over 6 upto 9	1	1	1.5	-	1.5	1.5	Over 6 upto 9	1	1	-	1.5	1.5	1.5
Over 9 upto 12	1.5	1.5	1.5	1.5	3	1.5	Over 9 upto 12	1.5	1.5	1.5	1.5	1.75	1.5
Over 12 upto 18	3	1.5	3	1.5	3	1.5	Over 12 upto 18	1.5	3	1.5	3	2	3
Over 18 upto 24	4	3	3.5	3	4.5	2	Over 18 upto 24	2.5	3.5	2.5	4	3	3
Over 24	5	3.5	4.5	3	6	3	Over 24	3	4	3	4.5	3.5	4.5

T&T and PUB means Traffic & Transportation and Public Utility Buildings

Below is the table of the prices of PVC pipes for 6mts length

Diameter (mm)	Price (Rs.)
150	1000 - 1500
100	400 - 600
75	500 - 700

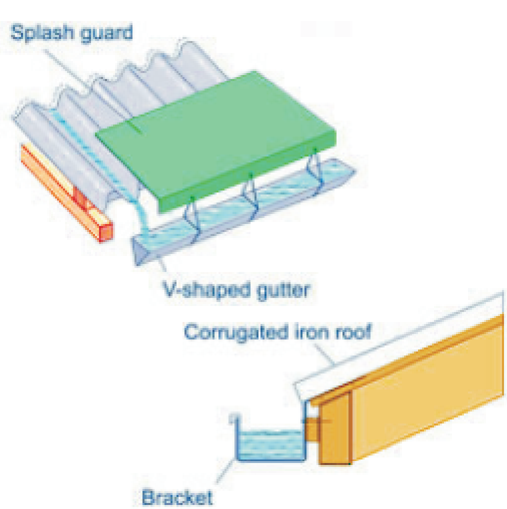
Rainwater down-take pipes can be replaced by chains to give an aesthetic effect to the building.



Chains leading the water to a recharge well

Gutter/chains connection details

In the case of sloping roofs, rainwater will have to be picked up in "gutters". The gutters can be made of PVC, GI, Aluminium, Copper or even Stainless Steel. The rule of the thumb is one cm^2 of gutters to one m^2 of roof area to harvest the maximum possible rain. Sometimes, a splash guard is used to direct the water into the gutter. Providing a slope of anywhere between 1/100 to 3/100 is recommended.



V-shaped and rectangular gutters

Source: GOULD and NISSEN-PETERSEN

Case study:
Integrated water management in a house

Rainwater harvesting and water re-use systems can be cost effective and well integrated when designed with the house. Here is an example of an eco-friendly house in Bangalore.

The rainwater is harvested on the terrace and brought down using iron chains instead of PVC pipes and a ferro-cement filter is placed at the entrance. Hence, the sight of the rainwater running down the chains pleases every visitor. The rainwater is let into a sump tank, noticeable only through a small door. This minimal system allows the house to harvest more than 60000 litres of rainwater every year.

At the back of the house, a 250 litre tank has been built at the first floor level, on the external wall. This tank has been connected with the exit pipe of the washing machine placed on the same floor and the grey water from the washing machine will run by gravity to flush the ground level toilet.

Chains leading the roof water to the filter

Filter and sump tank integrated at the entrance

Storage

The storage tank size is dependent mainly on two things:

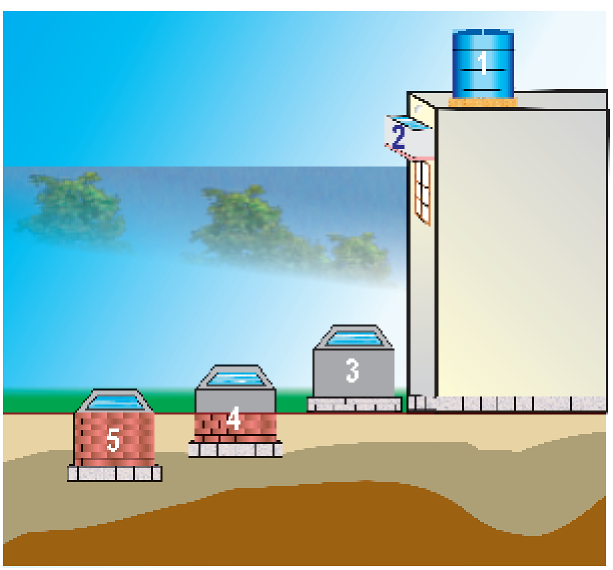
- the extent of the scarcity of water
- the conventional construction practice

If the conventional building practice is to build a sump, the same sump can be used for harvesting rainwater. In Bangalore, for example, construction of a sump is a common building practice. Collecting rainwater after filtration in the sump would be the most cost effective plan. The thumb rule in Bangalore is building a 6000 litres sump for a 100 m^2 area.

If a well or a bore-well is present in the premises, then rainwater can be used to recharge the groundwater after filtration.

Storage system can be located at the following places:

1. On the roof itself
2. Just below the roof level
3. On the ground
4. Partially above and partially below the ground
5. Below the ground



Storage System

Locating the storage system on the roof or just below the roof is good because water can be drawn by gravity and is therefore, the most energy efficient. However, some engineering skill is required to design such a system.

On the ground storage systems are the easiest to maintain. However, it may restrict movement on small housing sites as the storage system occupies space.

Below the ground sumps are the cheapest and do not obstruct movement. However, water needs to be pumped up and cleaning the sump is a chore. Typically, sumps are the most favoured solution as a water storage device.

Sometimes, breeding mosquitoes can prove to be a problem in tanks, sumps or lined ponds. To control this problem, guppy or molly fish, which eat mosquito larvae and grow only about 2 inches in size, can be bred in the tank. Neem oil can also be applied as a layer on water to prevent mosquito breeding. The cost of a sump tank varies between Rs. 2 to Rs. 6 per litre.

Some forms of storage are shown below:


Ferro cement tank


Above ground masonry tank


HDPE tank

Case study:
Rainwater Harvesting in MABL School, Dodballapura

The rooftop rainwater is collected through 6 down-take pipes at the back of the building. The roof area is around 450 m². At the end of the down-take pipes, cylindrical ferro-cement filters allow the rainwater to pass through layers of sand and jelly.

The filter and sump tank

Then the water is allowed to flow into a 50,000 litre capacity sump tank located on the front of the building. The total cost of the system is around Rs. 95,000/-.

The rainwater harvesting system is also an educative tool in the school. Every rainy season, the students calculate how much water is actually collected and write it down on the wall of the playground.

Sri MB Gurudev of the Management Committee has been the key driving force behind the initiative.

Calculating the size of your tank

While designing a rainwater harvesting system, you need to first calculate the appropriate size for the storage tank. Different methods can be used to calculate the optimum size.

Runoff coefficient

All calculations relating to the performance of rainwater harvesting systems involve the use of a runoff coefficient to account for losses due to spillage, leakage, infiltration, catchment surface wetting and evaporation, all of which contribute to a reduction of the amount of rainwater that actually enters the storage reservoir. The runoff coefficient is defined as the ratio of the volume of water that runs off a surface to the volume of rainfall on to the surface.

Roof Type	Runoff coefficient
RCC	0.8 to 0.9
Tiled roof	0.7 to 0.8
AC sheet roof	0.7 to 0.8
GI roof	0.8 to0.9

Therefore, if a roof area is 100 m², the rainfall is 600 mm annually and the roof is a GI sheet roof, the total volume of rainwater available for collection annually would be : 100x600x0.8=48,000 litres

Simple method or graphical method

This method will generate the optimal size according to your water consumption. Let's take an example: a family of five people with a daily consumption of 50 litres per person. In Bangalore, the longest dry period has duration of four months (120 days). During this period, for a family of five people, the volume of water required is: Volume = 50x120x5 = 30,000 litres. This gives you the size of the tank that needs to be built.

However, this method assumes that a sufficient amount of rainfall will be available and that there is a sufficient catchment area.

Note: Both graphical method and computer method are given in the CD enclosed

Computer based method

This method will give you the optimal size including both the previous approaches. The way it works is shown below, with the example of Hubli:

Actual tank size	9000
Harvested water	62370
Water harvested	57261
Overflow	5109
Days serviced	229

Location	Area (m^2)	Runoff coeff
Roof	100	0.9

The green coloured squares have to be filled up by the user: roof surface area, runoff coefficient, size of the tank, daily water demand. Using this information the computer will calculate the total harvestable water, the water collected in the tank, total water for recharge and the number of days serviced in the year, on a monthly basis. To optimize the size of your tank, you have to test for different values until you are able to match the resulting number with the maximum number of days serviced in the year.

This calculation sheet (in excel format) is available on www.rainwaterclub.org.

The Rain Barrel

A very simple way for people to start harvesting rainwater is by placing a Rain Barrel in their homes. A Rain Barrel is a simple rainwater storage device, usually a HDPE tank. By placing this rain barrel along with a first rain separator and a filter, substantial quantity and quality of rainwater can be harvested at a household level.

In Bangalore, a 500 litre Rain Barrel collecting rainwater from a 50 m² roof area can generate nearly 23,000 litre of water in a year, if the rainwater stored is used immediately after collection.Similarly, a 1000 litre Rain Barrel can generate nearly 36,000 litres of water in a year.

	RAINFALL (MM)	NO. OF RAINY DAYS	HARVESTABLE WATER (litres)	OPENING WATER VOLUME (litres)	DAILY WATER DEMAND (litres)	MONTHLY WATER DEMAND (litres)	EFFECTIVE TANK SIZE (litres)
JAN	1.1	0.2	99	0	250	7500	9050
FEB	1.2	0.5	108	0	250	7500	9125
MAR	6.8	0.4	612	0	250	7500	9100
APR	40.6	3	3654	0	250	7500	9750
MAY	77.5	7	6975	0	250	7500	10750
JUN	85.8	6.4	7722	0	250	7500	10600
JUL	120.4	8.3	10836	222	250	7500	11075
AUG	84.3	10	7587	3558	250	7500	11500
SEP	106.3	9.3	9567	3645	250	7500	11325
OCT	118.3	9	10647	3825	250	7500	11250
NOV	40	4	3600	3750	250	7500	10000
DEC	10.7	1.7	963	0	250	7500	9425
TOTAL	**693**	**59.8**	**62370**			**90000**	**54000**

Given the average cost considerations and a space of 4 feet x 4 feet, installing a rain barrel will cost about Rs. 4,000/-. The figure for a 1000 litre Rain Barrel will be Rs. 5,300/- (cost as of 2006)

It is also important to note that the water from the rain barrel can be used to recharge open wells or bore-wells easily, using a hose and a Zero-B type water filter.

Rain Barrels can be installed in individual houses, apartments, institutions and industries. Rain Barrels also can be installed in phases depending on budget availability.

Rainwater harvesting through rain barrels generates water for productive use which otherwise would have been wasted. It also helps mitigate urban flooding and reduces the pressure on city level water supplies.

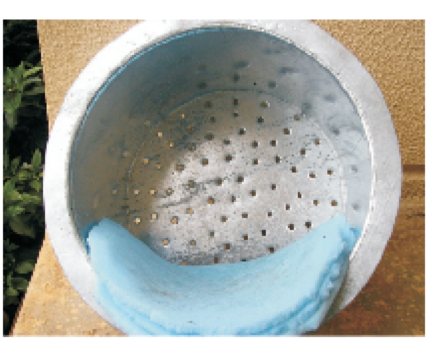
Components of a rain barrel:

1) Drum
2) Filte
3) Tap

The Rain Barrel productivity in Bangalore is shown below:

Year	No of days with rainfall	Amount of rainfall (mm)	Volume of rainfall on $50m^2$ roof (litres)	Volume of rain collected in a 500lt tank (litres)	Overflow (litres)	Volume of rain collected in a 1000lt tank (litres)	Overflow (litres)
1992	77	870.3	43515	22695	20820	32090	11425
1993	82	1176.2	58830	23725	35105	36190	22640
1994	95	731.5	36575	21395	15180	27480	9095
1995	81	657.5	32865	20750	12115	28385	14480
1996	96	887	44350	25235	19115	33725	10625
1997	93	1196	59810	23425	36385	31925	27885
1998	84	1135	57515	23425	34090	37150	20365
1999	82	1004.3	50215	24395	25870	36725	13540
2000	96	1092.2	54610	26625	27985	36350	18260
2001	87	1116.4	55820	24955	30865	36290	19530

An aluminium perforated basket with a sponge can act as rainwater filter, as shown below:



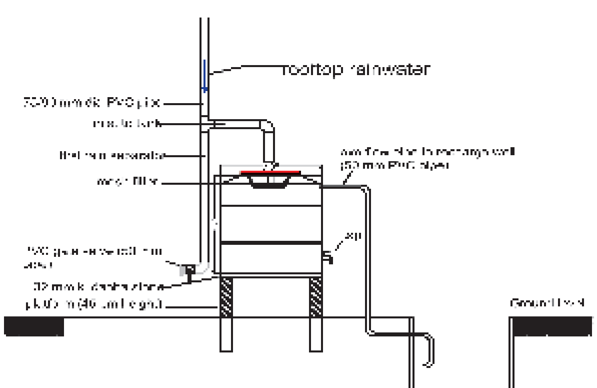
In conventional households or in low income areas, rain barrels can be very helpful. The harvested water can be used for many applications from drinking to gardening. The rain barrel works as a multipurpose storage tank for storing water from other sources during the months when no rainfalls. The additional storage is especially useful for the low income households.

Rain Barrels at Work:

On the first floor of a house

In a low income area

Details of a Rain Barrels:



Open wells and recharge wells

Open wells have a major role to play in the artificial recharge of groundwater. Rooftop rainwater and surface water flowing in storm water drains can be filtered, the silt removed and the filtered water can then be allowed to recharge the open wells. If you are building on a new housing site, do not forget to consider digging an open well. It can be made of RCC rings, only a meter in diameter and about six meters deep. A recharge well will lead water into the aquifer, for later withdrawal through an open well or a bore well. Therefore, this water has to be clean, to avoid ground water contamination. It can be water from a rooftop, from a clean paved area or from a grassed area.

Concrete ring-wells of diameter ranging from 2 feet to 6 feet and a depth of 20 feet to 30 feet store large volumes of rainwater and recharge the groundwater under good hydrostatic pressure. About 70% of the water will percolate vertically, the other 30% horizontally through the holes provided in the rings. The soil profile of the site helps to determine the depth of the well. Its bottom should reach a critical level of the weathered zone, where the water can easily percolate. For large quantities of water (industries, layouts…etc), a percolation test should be done with the first well, to see how fast the water enters into the ground. This will help you calculate the number of wells that are necessary. Water should also be allowed to flow into the well gently from the sides or as a spray so as to not churn up silt and cause air bubbles to block the natural pores in the soil. Maintenance is essential for these wells and if it is done regularly, recharge wells are excellent for recharging bore-wells. Rooftop rainwater is ideal for such recharging as it is easy to keep roofs clean. A three feet diameter and 20 feet deep well can recharge groundwater from nearly 1000m² which in a normal year of rainfall (900 mm) means about 1 million litres of water.

Groundwater contamination

Groundwater contamination has been reported from many parts of India. Two major sources of groundwater contamination are industrial effluents and domestic sewage. In the rural areas, groundwater contamination occurs mainly from fertilizers and pesticides.

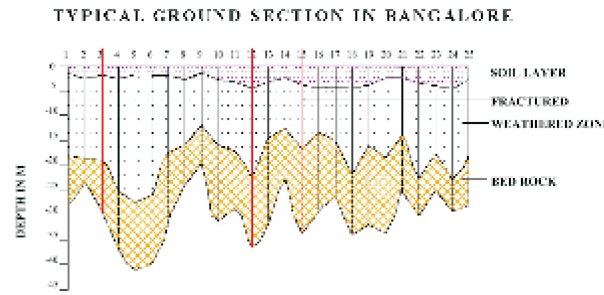
In order to avoid contamination of groundwater through rainwater harvesting and artificial recharge, a clear catchment management strategy should be in place.

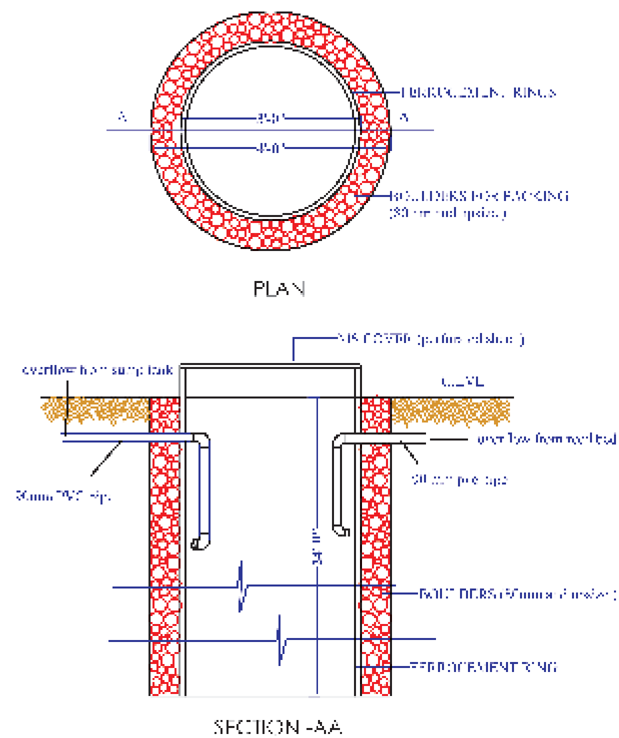
In no case should chemicals, oil, grease, petrol, solid-waste be stored in the catchment area. Especially, when water is picked up from lawns, it should be fertilizer and pesticide free. The golden rule for recharge is 'put in only what you can take out and drink'. Groundwater contamination, once if occurred, is very difficult to clean up and therefore should be avoided at all costs.

The making of a recharge well

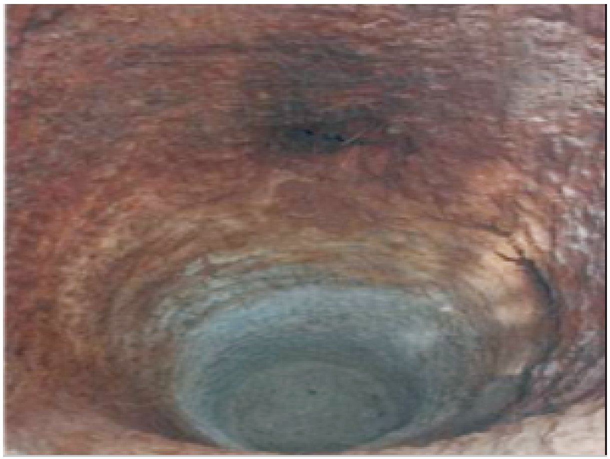
Understanding the ground profile is important before digging a recharge well. Look around the housing site and check if there are any open wells nearby. You need to also check the depth of the water in the well in the summer and in the rainy season. This will give you clues as to the dimensions of the recharge well that you need to construct. A professional hydro-geologist could also give you advice on how to construct a recharge well. Remember that a recharge well has an entirely different function from an open well. The recharge well seeks to take surface water and put it back into the ground.

Look at the figure below, which is a ground section of a part of Bangalore. Here, your recharge well will go into the weathered rock section as close to the bed rock as possible. It is then lined with RCC rings to hold the earth back. A strong perforated RCC cover is then placed on top of the well for safety. Rainwater from the rooftop is allowed to flow into the well through pipes.





Plan and Section of a recharge well



Excavation

RCC Rings

RCC rings being placed

RCC perforated cover

Steel grill cover

Rainwater being sent for recharge

Percolation test

A percolation test will give you the correct rate of percolation of the recharge well on your housing site.

Typical percolation rates in the red soil weathered zone of South Karnataka are 2,500 litres to 5,000 litres per day. This is approximately 200 to 400 litres per hour for a recharge well of 6 meters depth.

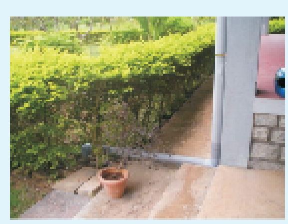
For instance, if you have a roof area of 100 m^2 and assume a rainfall of 60 mm spread over three hours has occurred. If this rainfall is let into a recharge well of 1 meter diameter and 6 meters depth, this is what will happen. The full volume of rain entering the well is 100x60x0.9=5,400 litres and the capacity of the well is 5,000 litres. Assuming a recharge rate of 200 litres per hour, the total capacity of the well to hold and recharge is 5,600 litres which is more than 5,400 litres falling into the well as rain. In 27 hours, the well would have completely sent the rainwater into the aquifer.

Case Study:

Recharging the surface aquifer with rooftop rainwater

The Shah's house has a 500m^2 roof. The rainfall near Dodballarpura is around 850 mm. With a coefficient of collection 0.9, the total harvestable rainwater on the rooftop in an average year of rain is 500x850x0.9=3,82,500 litres

The rainwater comes down from the roof through PVC pipes. It is then filtered in an RCC box filter and then flows into two recharge wells. The rate of recharge in the wells is low and it takes two days for the water to completely percolate if the wells are full. As a result of this, they sometimes overflow. However, they normally recharge close to 200 thousand litres of water. This has positively impacted the bore-well which supplies the Shah's with water. The Shah's are considering installing two more recharge wells.

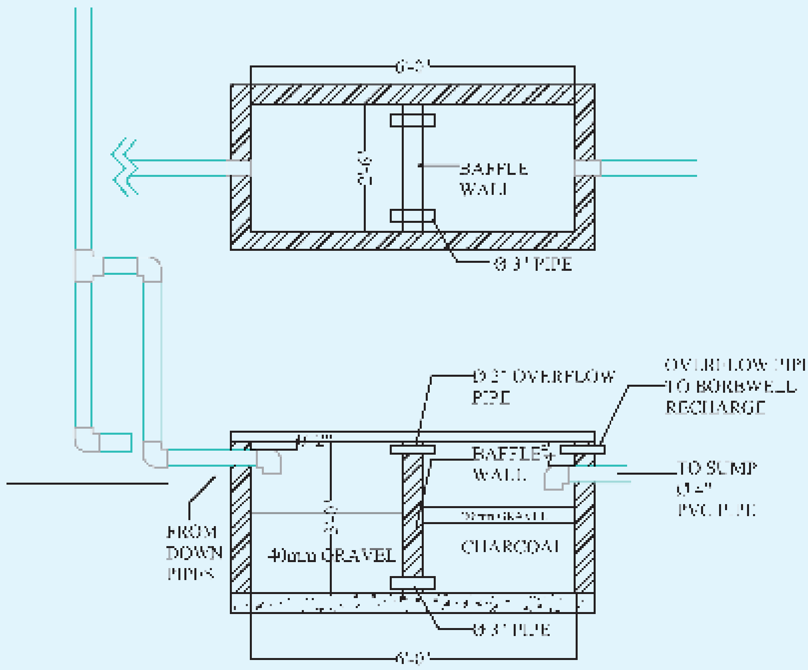


PVC down-take pipe

Subsurface filter

Recharge well

Plan & Section of the filter chamber



Recharging Bore-wells

Bore-wells in hard rock terrain have reached depths of 400 meters in some places in Karnataka. Many of them are going dry because the fossil water has been mined. There is a concerted attempt to recharge these bore-wells and bring them back to life.

There are two major methods of recharging bore-wells.

Surface spread techniques in which water is stored in surface water bodies like small farm ponds close to the bore-well which recharge the bore-wells.

Injection techniques by which water is either recharged directly through the casing of the bore-wells or allowed to penetrate the shallow aquifer close-by through recharge wells.

The recharging of bore-wells should always be approached cautiously and indirect methods are preferred to direct recharge methods.

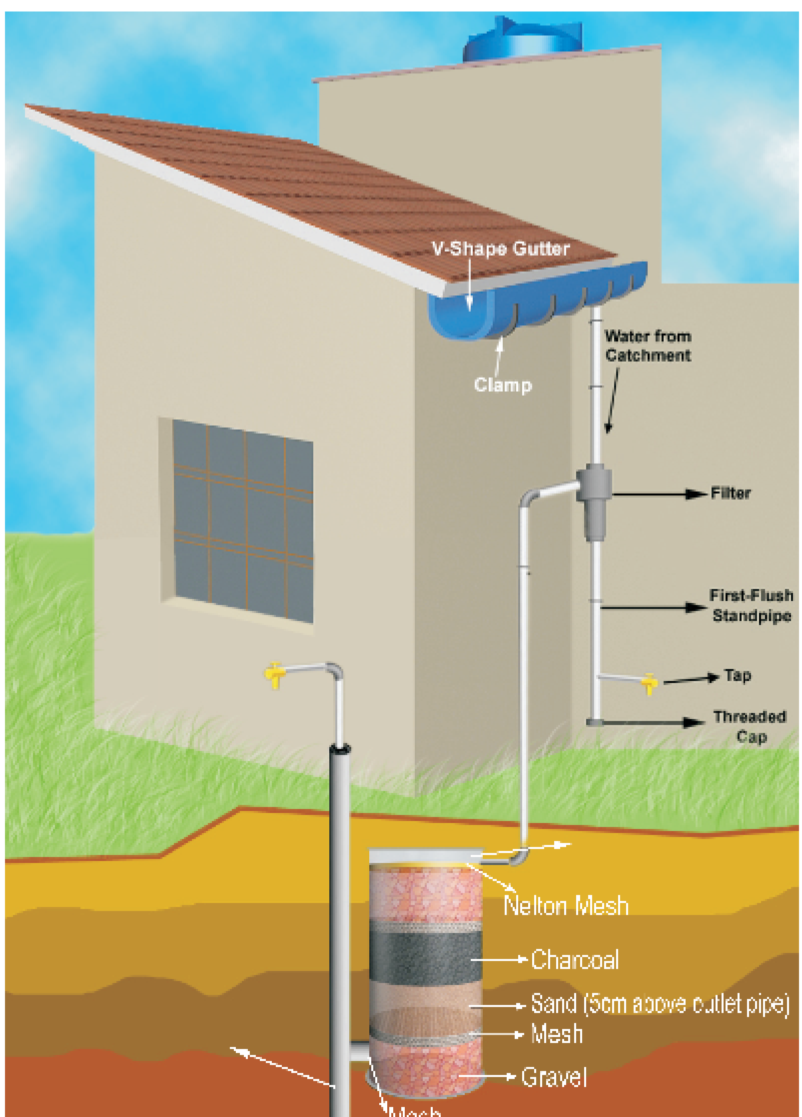
A bore-well which has yielded copious water and is now no longer yielding is ideal. Provided that the casing pipe has been installed properly, rainwater from the rooftops can be collected, filtered through an appropriate sand filter to remove silt and organic material and sent in directly through the casing. It is to be remembered that some bore-wells can absorb a huge quantity of water and some can absorb water only in small quantities. Therefore, provision needs to be made for excess water to overflow from the bore-well. From a $100m^2$ roof area in Bangalore 90,000 litres of rainwater will be available for recharge of bore-wells, annually. Two precautions are essential in the recharge technique. The first is that only clean, good quality rainwater should be allowed into the bore-well. The second is that a by-pass arrangement should be in place in case of any problem, either with the water quality or with the bore-well itself in terms of silting. In an ideal situation, judicious use of water and recharge of bore-well with rainwater would ensure that the city and the state never run out of water.

Recharge well
around bore-well

Recharge pit
around bore-well

Perforated casing

Recharging a bore-well through rainwater harvesting:



The making of a recharge pit

A recharge pit is made to create a porous space for rainwater to easily infiltrate and percolate into the ground. Usually, surface ground cover is affected by a phenomenon called crusting. This is the hardening of the top one inch of the earth's surface which prevents rainwater from easily entering the earth. In agriculture, the fields are ploughed to break up the crust. But with all other kinds of land, some provision should be made to facilitate the percolation of water. A percolation pit is a large hole in the ground, filled systematically with large stones at the bottom, smaller stones above it and finally sand. It is dug in the low lying portion of any given land area with sufficient catchment to collect rainwater. The rainwater then filters through the sand and stone and percolates into the ground.

The sand layer at the top of the recharge pit needs to be raked and cleaned regularly to ensure infiltration of water. The catchment area should also be covered with grass, shrubs and trees to prevent soil erosion and runoff.

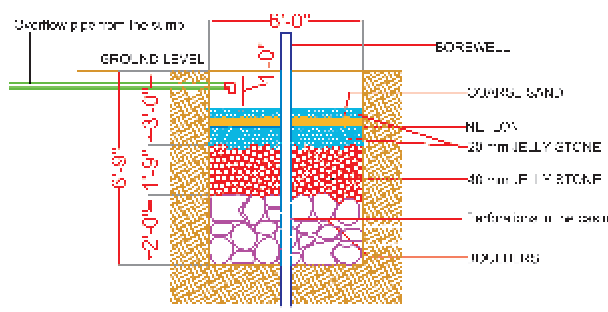
Excavation

Filling with jelly

Sand at the top

Recharge pits can cost anywhere between Rs.10,000 to 20,000 (cost as of 2006)

Details of a recharge pit (around borewell)



Case study:

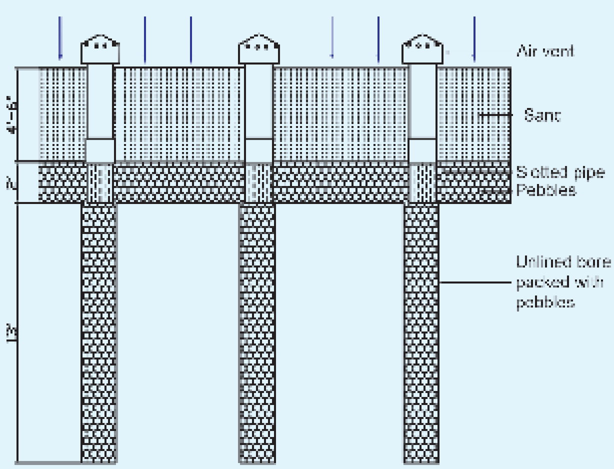
Rooftop rainwater harvesting in Tamilnadu Water and Drainage Board

The failure of the monsoon for the past two years has lead to the scarcity of drinking water supply in Tamilnadu. The extensive utilization of groundwater by the public has lead to the decline in groundwater level. The Tamilnadu State Government has taken steps to harvest the rainfall falling on the roofs of government buildings.

Rainwater harvesting structures in the TWAD Board building

Recharge trench: The TWAD Board building has 2000 m^2 of roof area. There are about 12 drain pipes through which roof water is *drained to 3 recharge trenches and one recharge well. The dimensions of the trench are as follows: length 33 feet; width 3 1/4 feet; depth 6 ½ feet.*

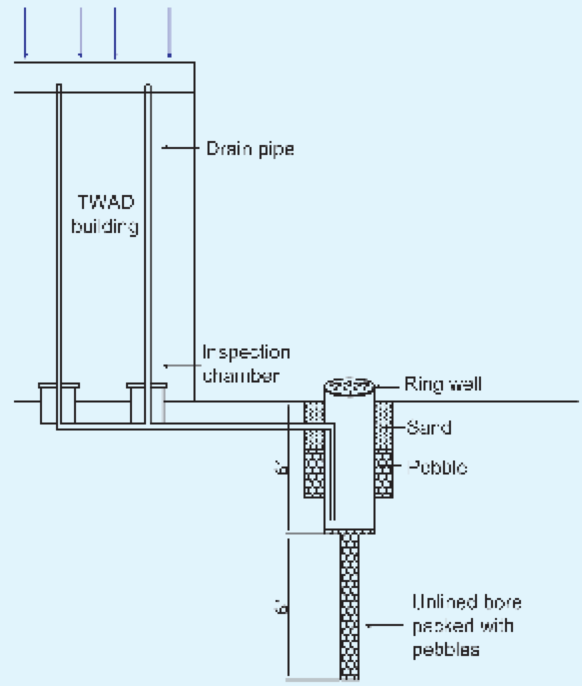
The bottom of the trench is filled with 2 feet of pebbles followed by coarse sand up to 4 ½ feet. Three unlined bore-wells are drilled inside the trench each to a depth of 13 feet with 6 inches diameter. The bore-wells are filled up with pebbles. Three drain pipes are connected to each trench. Diagrammatic representation of the system is given below



Rainwater harvesting structure (roof water collecting trench)

Recharge well:

The recharge well is located very near the existing bore-well that is being utilised by the TWAD Board. The recharge well is round in shape and has the following dimensions: depth 6 ½ feet; diameter 3 feet. Three bore-wells are drilled inside the recharge well. Three drain pipes are connected to this recharge well. The diagrammatic representation is shown beside the figure.



Estimation of rain harvested: The average rainfall in Chennai is 1,200 mm and the amount of rainfall collectable is 60%. The total harvestable water is thus 2000 x 1.2 x 0.6 = 14.4 lakhs liters per year. This arrangement will reduce the salinity of groundwater.

There are 800 employees working in TWAD Board and about 200 persons are expected to be visiting per day. The 14.4 lakhs litres of rainwater that is expected to be harvested through the rainwater harvesting structure will serve the water supply of these people for 144 days.

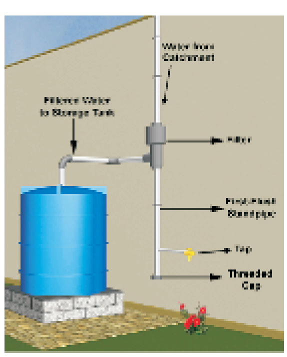
Estimated cost: The total expenditure for the construction of the structure shown above was Rs. 1.35 lakhs and the work was completed in 20 days.

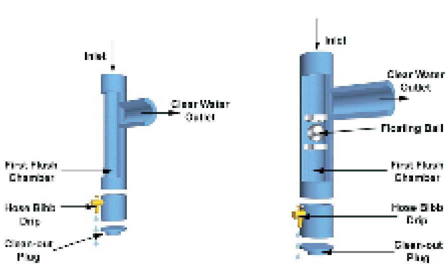
Source: TWAD Board technical newsletter, Sept.2001

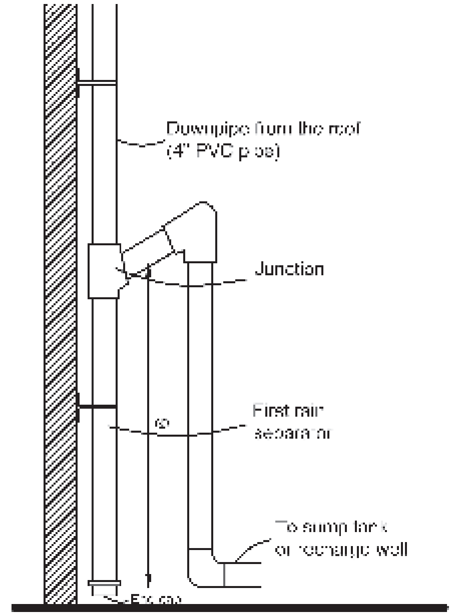
First rain separator

Water from the first showers of rain will carry a lot of dust, leaves and debris and therefore, should not be harvested. Similarly, when the roof is being cleaned, the dirty water that results, should be left out of the rainwater harvesting system. A first rain separator is a device which does just that. It can be a simple vertical pipe with an end cap or a valve. When the cap or valve is open, the dirty rainwater from the rooftop flows away from the system.

When it is closed, the vertical pipe or container fills up and the rainwater moves through the elbow into the filter. The first rain separator is a very important component of the rooftop rainwater harvesting system. Using a T-junction at the end of down pipe, connect one end of theT-junction to the first rain separator and the other end to the inlet of the storage unit. A first rain separator can cost anywhere between Rs. 150 to 400 (cost as of 2006).







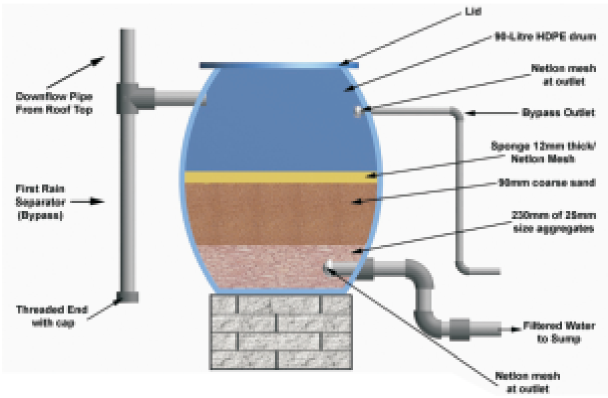
Filtering the rainwater

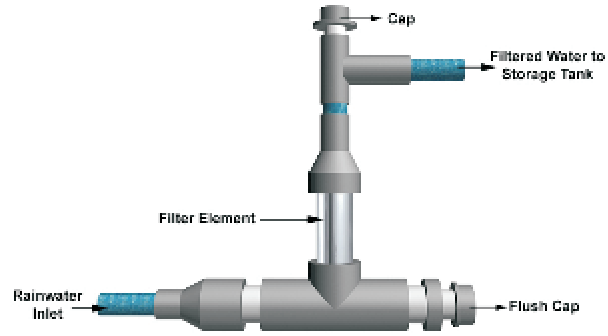
Rainwater is amongst the purest forms of water that one can get. However, in a rainwater harvesting system, the rain comes in contact with several surfaces, such as the roof or gutters. It is possible that during its flow along these surfaces, it gets mixed with leaves or dust. Apart from keeping these surfaces clean and using a first rain separator, we can filter the water before storage to get water fit for consumption at the end of the harvesting process. Usually, the filter is placed below the vertical down-take pipe. A sand filter can cost between Rs. 1,000 to 1,800 (cost as of 2006).

Drum filters

PVC drums are light weight, easy to transport and easy to install. It is also the cheapest filter but it cannot be kept outside, under the sun as this will affect the longevity of the drum. A drum of 90 litres can filter the water of a roof area up to 100 m^2.

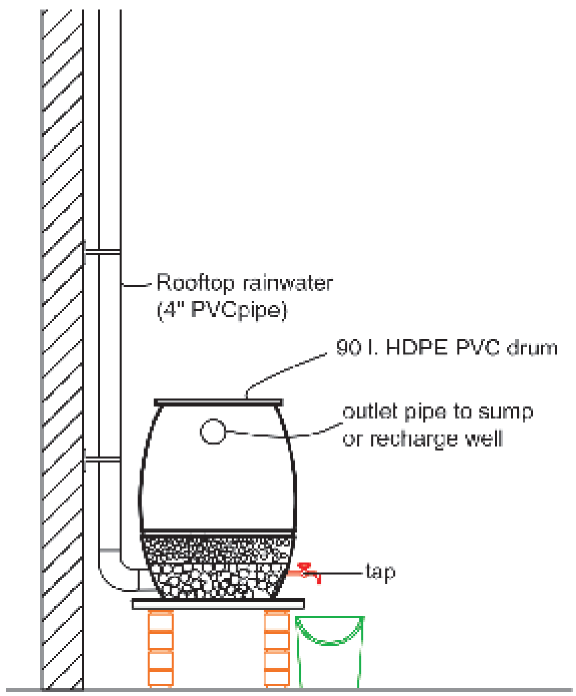
Down-flow filter:





Structure of a Pop-up Filter

Providing a tap on the filter drum can make it a storage unit:

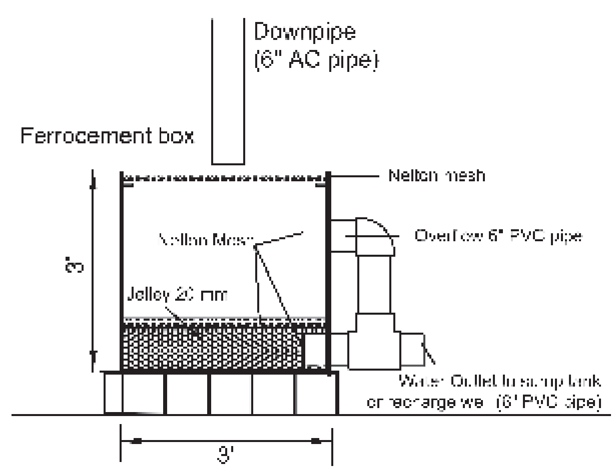


The pop-up filter

Designed by rainwater harvesting expert A.R. Shivakumar of Karnataka State Council for Science and Technology (KSCST), this filter can be used for small scale projects. The first rainwater which cleans the roof and pipes will be flushed out. After some time, an end-cap is placed and this allows the rainwater to pass through a vertical mesh filter before following its path to the storage or recharge unit. The filter element has to be cleaned regularly during the rainy season.

Ferro-cement filter

Its size can be made to suit the requirements of the location. It can also be designed as an outdoor seating area where the family can relax or as an area where flower pots are kept.



Taking care of the system

Some simple steps help to maintain the quality of rainwater harvested.

These include:

- Keeping the roof clean of leaves and dust by regularly sweeping it.
- Keeping the rainwater gutters clean by removing material collected in them.
- Washing the first rainwater separator and cleaning the end cap or valve at frequent intervals.
- Ensuring that the filter is kept clean by removing the mesh at the top and washing it at regular intervals, if necessary removing the top 2” of filtering material and washing it .
- Keeping the sump clean by removing accumulated silt, if any and cleaning it with bleaching powder once in a year.
- Desilting the recharge well, if necessary, usually once in a year.

These simple common sense precautions, usually after the first rain, keeps the system functional and does not cause problems like blockage of pipes or bad smell in the water

Maintenance of the roof is simple and crucial

CHAPTER – 4

"Water a symbol of life, cleanliness and purity as well as coolness and humility."

Rainwater Quality

Rainwater Analysis

Many questions arise in people's minds when the issue of rainwater quality comes up. Is it potable? Is the water the result of acid rain? Will it 'spoil' if it is kept in storage for a few days? Will it contain worms and other organisms? Will it be too soft without minerals? Will you get a cold if you drink rainwater?

Drinking water has to meet requirements of the Indian Standards' 10500 for physical, chemical and biological parameters. Certified government and private laboratories can check the water sample to ensure that it is potable. In Karnataka, the Department of Mines and Geology and the Karnataka State Pollution Control Board provide water testing facilities in many towns. In all cases, check rainwater to make sure that it is potable before drinking.

Simple methods to preserve water quality

Remember that for most of the time you are not going to store water for use in summer. What we suggest is that when it rains, harvest rainwater and use it first. If it replaces groundwater, you have saved groundwater for a rainy (sunny) day. If it replaces piped water, energy cost in pumping the water has been saved. However, if indeed, you are storing water for a sunny day, here is what could happen.

Water needs three conditions to go bad: air, sunlight and organic matter within it.

1. By excluding organic matter through proper filtration and by storing water in a closed container without access to sunlight and air, water will remain good for a long time.
2. Treating water with a solution of 30 gms of alum, dissolved in 3 liters of water and added to 250 liters reduces turbidity of water.
3. Bleaching powder: Make a solution by adding one large spoon in two litres of water and this solution has to be added to about 1000 litres of water as an effective treatment for bacterial contamination.

Water should always be treated well before it is drunk and wherever possible, boiled or sterilized.

INDIAN STANDARDS FOR DRINKING WATER BIS 10500

Sl. No.	Substance or Characteristic	Requirement (Desirable Limit)	Permissible Limit in the absence of alternate source
Essential Characteristics			
1.	Colour (Hazen units, Max)	5	25
2.	Odour	Unobjectionable	Unobjectionable
3.	Taste	Agreeable	Agreeable
4.	Turbidity (NTU, Max)	5	10
5.	Ph Value	6.5 to 8.5	No relaxation
6.	Total hardness (as CaCo3) mg/lit	300	600
7.	Iron (as Fe) mg/lit. Max	0.3	1.0
8.	Chlorides (as CI) mg/lit. Max	250	1000
9.	Residual, fee chlorine, mg/lit. Min	0.2	--
Desirable characteristics			
10.	Dissolved solids mg/lit. Max	500	2000
11.	Calcium (as Ca) mg/lit. Max	75	200
12.	Copper (as Cu) mg/lit/Max	0.05	1.5
13.	Manganese (as Mn) mg/lit. Max	0.10	0.3
14.	Sulfate (asSO4) mg/lit. Max	200	400
15.	Nitrate (as NO4) m/lit. max	45	100
16.	Fluoride (as F) mg/lit. Max	1.9	1.5
17.	Phenolic Compounds (as C6 H5OH)mg/lit. Max	0.001	0.002
18.	Mercury (as Hg) mg/lit. Max	0.001	No relaxation
19.	Cadmium (as Cd) mg/lit. Max	0.01	No relaxation
20.	Selenium (as Se) mg/lit. Max	0.01	No relaxation
21.	Arsenic (as As) mg/lit. Max	0.05	No relaxation
22.	Cyanide (as CN) mg/lit. Max	0.05	No relaxation
23.	Lead (as Pb) mg/lit. Max	0.05	No relaxation
24.	Zinc (as Zn) mg/lit. Max	5	15
25.	Anionic detergents (as MBAS) mg/lit.Max	0.2	1.0
26.	Chromium (as Cr6+) mg/lit. Max	0.05	No relaxation
27.	Polynuclear aromatic hydro carbons (as PAH) g/lit. Max	--	--
28.	Mineral Oil mg/lit. Max	0.01	0.03
29.	Pesticides mg/lit. Max	Absent	0.001
30.	Radioactive Materials		
	i. Alpha emitters Bq/lit. Max	--	0.1
	ii. Beta emitters pci/lit. Max	--	1.0
31.	Alkalinity mg/lit. Max	200	600
32.	Aluminium (as AI) mg/lit. Max	0.03	0.2
33.	Boron mg/lit. Max	1	5

Source BIS: 10500 - 1991, The Indian Standard

CHAPTER – 5

Making water everybody's concern is our motto...

Rainwater harvesting in larger contexts

Rainwater harvesting in a manufacturing industry unit

The factory is located in South Bangalore on a plot of 4 acres and the objective was 0% runoff. Three different kinds of rainwater harvesting systems have been implemented. Four rain barrels collect the water from the roof of the factory and this water is directly used for gardening. The storm water flowing on the paved areas is directed through open drains to a 22,000 litre sump tank and this water is also used for gardening. The water from the land is allowed to percolate into the ground through recharge wells. The recharge wells have a depth of 25 feet and they allow the rainwater to recharge the aquifer. The factory is thus storing more than 12 lakhs litres of rainwater every year, for gardening and sending about 5 lakh litres to the aquifer. The design of swales in the open land provides an increase of soil moisture by retaining rainwater and allowing infiltration.

Rain barrels collecting rooftop rainwater

Recharge well with filtering material around (jelly)

The pictures below are clear indicators of the enhanced greenery due to increased soil moisture:

Swale directing the rainwater falling on the land to a recharge well

The open drains shown below lead the rainwater into the sump tank (right side) of 50,000 litres capacity:

Open drains collecting the rainwater

Sump tank converted into rainwater storage tank

The sump tank below has been converted to be used as a percolation tank. The plastered bottom has been removed and a recharge well (on the right side) is dug inside.

Sump tank converted in percolation tank

Recharge well inside the sump

Rainwater harvesting in a liquor manufacturing industry unit

The factory uses 1 lakh litres of water daily – the water is used mainly for gardening, processing and for manufacturing the product itself.

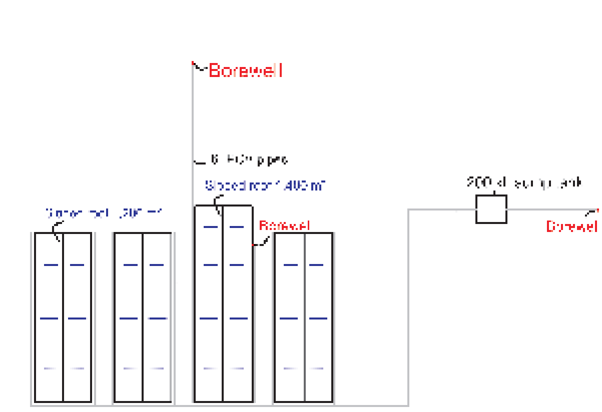
Four bore-wells have been dug. One goes to the depth of 400 feet and is contaminated. It is used for gardening. One bore-well ran dry a few months back and the remaining two bore-wells are used by the factory for the industrial processes. These wells have been sunk to a depth of 480 feet.

Rainwater harvesting in the industry can serve two purposes:

1. The rooftop rainwater can be collected in closed pipes, filtered and stored for direct use.
2. Excess water from the sump tank and part of the rooftops can be sent into the ground to recharge the bore-wells.

The normal annual rainfall in South Bangalore is 970 mm and the total roof area from the four factory buildings is around 5,000 m^2. With a runoff coefficient of 0.95000x0.970x0.9=44 lakh litres of water can be harvested.

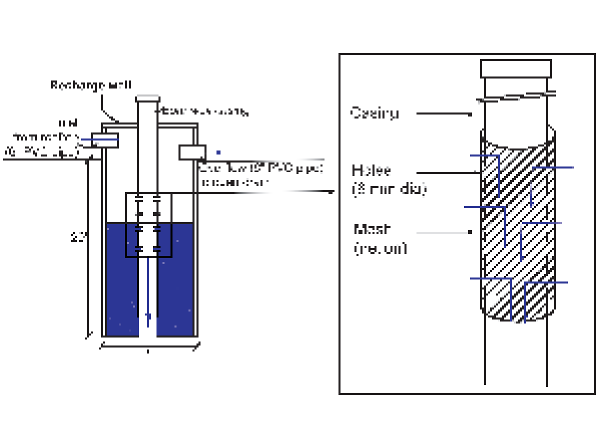
The system is shown in the plan below



Before being stored or sent into the ground the rainwater needs to undergo a natural filtration process to remove dust and silt. For that purpose, rainwater has to pass through a layer of gravel. Ferro-cement filter boxes have been placed under every down take pipe from the roof.

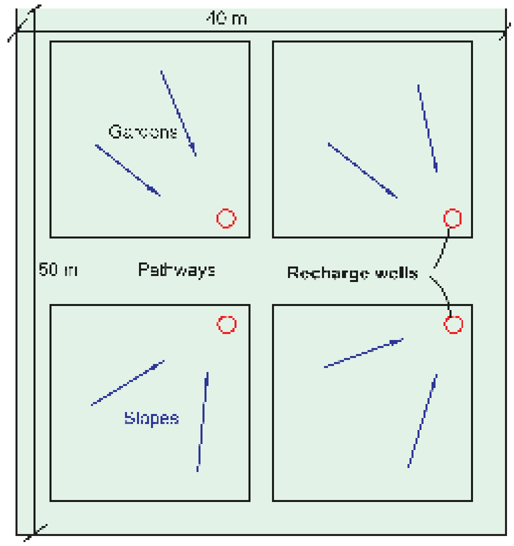
These filters are easy to maintain and make the rainwater harvesting system visible. The fact that it is visible will create awareness amongst visitors and employees regarding the value of water and green practices of the factory.

Excess water from one sump tank and water falling on largest building can be used to recharge the three bore-wells. Recharge wells has been dug beside the bore-wells that are being used. In the case of the bore-well that has run dry, the recharge can be direct. A recharge well is dug around the bore-well and if holes are provided in the casing, the water will directly reach the bottom of the bore-well and help to increase the groundwater table as shown in the section below:



Thanks to the rainwater harvesting system, the factory uses only rainwater one month every year and sends more than 12 lakh litres of water for recharge.

Rainwater harvesting in a park



Garden city: Thanks to the efforts of the Bruhat Bangalore Mahanagara Palike and the Horticulture Department of the Government of Karnataka, parks have seen a magnificent revival and Bangalore is well and truly on the way to being Garden City, again. Parks demand water right through the year and especially in summer. About 10 litres of water per square meter is the norm used to calculate water demand. Many parks however, do not have adequate water to meet this demand. Though some parks get water from the BWSSB and some have their own bore-wells, many parks, including the park that is the subject of this case study, need to have water brought in tankers for their use. A possible solution was to harvest rainwater to meet the water requirement of the park at least, partially. Let us take the case of one park, in particular the park in question has a 2,500 m^2 area. The landscaped or planted area is about 2,000 m^2. The water demand is therefore about 10,000 litres per day. In a year, the water requirement is about 3,000 kilolitres considering water requirement for 300 non-rainy days.

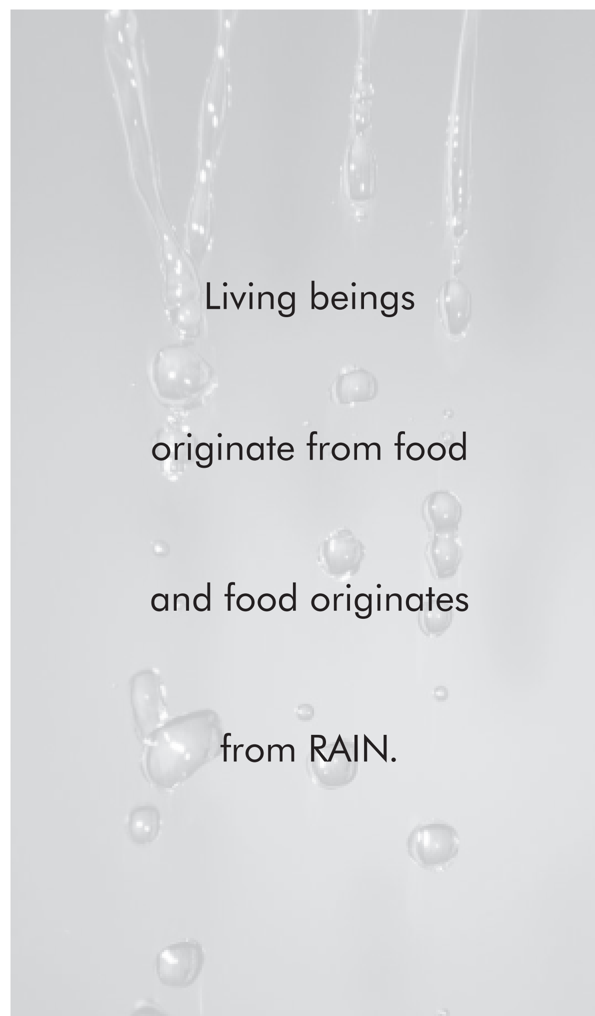
Rainwater harvesting is simply the process of collecting and storing water for productive use, later. There are two basic ways of rain harvesting. Storage of rainwater and its recharge into the ground. Storage may be limited option in open ponds because of the large evaporation losses and the possibility of mosquitoes breeding in open water bodies. With an average rainfall of 970 mm, rainwater falling on the park in a year is about 2,425 kilolitres, of which about 60 percent can be harvested.

This means that 1,455 kilolitres or about 50 percent of the yearly requirement for watering the park can be met through rainwater harvesting. The harvesting in this particular case was done through four recharge and withdrawal wells based on the infiltration capacity during a heavy down pour of 50 mm per hour. For each quadrant of the park a 3 feet diameter and 22 feet deep well was dug and lined with concrete rings.

Recharge wells of Garden city:

Water was struck at the depth of 12 feet in the month of January and the well was deepened further by about 10 feet. The well will be observed for its behaviour in the summer months and if need be, deepened. Rainwater from quadrant of about 25x25 meters will be let into this well through swales and a silt trap, in the rains, to recharge and replenish the aquifer. The well water will be drawn during the non-rainy days through a portable half-HP pump with a mist sprayer for watering. It is expected that in an open well water will be sufficient for the park right through the year. Surprising as it may sound in many places in the city, water tables are actually rising. Thanks to the BWSSB, which gives piped water to each house and therefore makes sure that there is no withdrawal of water from wells. It also helps that 40 percent of this piped water leaks and recharges the groundwater. Well diggers who have been out of a job for some time are back in business, this time digging recharge wells for rainwater harvesting. Parks will become sustainable for this water requirement only if the landscaping changes to less water intensive ones.

Further requirements would be the installation of drip irrigation systems and a switch from water intensive grass based parks to more a shrub, bush and tree based model with xeri-scaping. Efficient ways to water plants without water wastage and evaporation losses will need to be found.



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Rainwater catchment systems for domestic supply,
John GOULD and Erik NISSEN – PETERSEN

Self reliance in water, Indukanth S. RAGADE

Rainwater harvesting for Drylands, Brad LANCASTER
A complete and well illustrated manual, presented through the own experiences of its author in Tucson, USA.

The rainwater technology handbook, Rainwater harvesting in buildings, Klaus W.KONIG

A busca da agua no sertao, joao GNADLINGER
A manual made for people living in the setao, semi-arid region of Brazil, pertinent and simple explanations are available on the climate, rain patterns and tools needed to take care of the rain.

WEBSITES

www.rainwaterclub.org
Where you can download one more version of this manual and distribute it to others around you! You will also find lot more information on rainwater harvesting

www.rainwaterharvesting.org

www.bwssb.com

www.twadboard.com

www.agwt.org

www.rainwater-toolkit.net

www.urbanrainwater.com

www.unep.or.jp/ietc/Publications/Urban/UrbanEnv-2/index.asp

www.twdb.state.tx.us/publications/reports/RainwaterHarvestingManual_3rdedition.pdf

www.kscst.iisc.ernet.in/rwh.html

ANNEXURE

Rainwater harvesting by-law for Bangalore schedule XII (by-law 32)

Rainwater Harvesting

Rainwater harvesting in a building site includes storage or recharging into ground of rainwater falling on the terrace or on any paved or unpaved surface within the building site.

1. The following systems may be adopted for harvesting the rainwater drawn from terrace and the paved surface.

   Open well of a minimum of 1.00 meter diameter and 6 meter in depth into which rain water may be channeled and allowed to run into, after filtration for removing silt and floating material. The well shall be provided with ventilating covers. The water from the open well may be used for non-potable domestic purposes such as washing, flushing and for watering the garden etc.

   Rainwater harvesting for recharge of ground water may be done through a bore-well around which a pit of one meter width may be excavated up to a depth of at least 3.00 meters and refilled with stone aggregate and sand. The filtered rainwater may be channeled to the refilled pit for recharging the bore-well

   An impervious storage tank of required capacity may be constructed in the setback or other space and the rainwater may be channeled to the storage tank. The storage tank may be raised to a convenient height above the surface of the ground and shall always be provided with ventilating covers and shall have draw–off taps suitably placed so that the rain water may be drawn off for domestic, washing, gardening and such other purposes. The storage tanks shall be provided with an overflow mechanism.

The surplus rainwater after storage may be recharged into ground through percolation pits or trenches or combination of pits and trenches. Depending on the geomorphologic and topographical condition, the pits may be of the size of 1.20 m width 1.20 m width x 1.20 m length x 2.00 m to 2.50 metre depth. The trenches can be or 0. 60 m. width x 2.00 to 6.00 meter length x 1.50 to 2.00 meter depth. Rainwater from the terrace of the building shall be channeled to pits or trenches. Such pits or trenches shall be backfilled with filter media comprising the following materials:

a. 40 mm stone aggregate as a bottom layer up to 50% of the depth;

b. 20 mm stone aggregate as a lower middle layer up to 20% of the depth;

c. Coarse sand as an upper middle layer up to 20% of the depth;

d. A thin layer of fine sand as the top layer;

e. The top 10% of the pits/trenches will be empty and a splash guard is to be provided in this portion in such a way that roof top water falls on the splash pad

f. A brick masonry wall is to be constructed on the exposed surface of pits/trenches and the cement mortar plastered.The depth of wall below ground shall be such that the wall prevents loose soil from entering into pits / trenches. The projection of the wall above ground shall be, at least 15 cms;

g. Perforated concrete slabs shall be provided to cover the pits / trenches

h. If the open space surrounding the building is not paved, the top layer of soil shall be removed up to a sufficient depth and refilled with course sand to allow percolation of rainwater into ground.

2. The terrace of the building shall be connected to the open well / bore-well / storage tank / recharge pit / trench by means of HDPE/PVC pipes through filter media. A valve system shall be provided to enable the first rain water washing from roof or terrace catchment to be separated from the rest of the water, as they would contain undesirable dirt. The mouths of all pipes and opening shall be covered with mosquito (insect) proof wire net. For the efficient discharge of rain water, there shall be at least two rainwater pipes of 100 mm diameter for a roof area of 100 sq metres.

3. Rainwater harvesting structures shall be sited so as not to endanger the stability of the building or earthwork. The structures shall be designed such that no dampness is caused in any part of the walls of foundation of the building or those of an adjacent building.

Monthly normal rainfall in Karnataka (in mm) – District wise detail

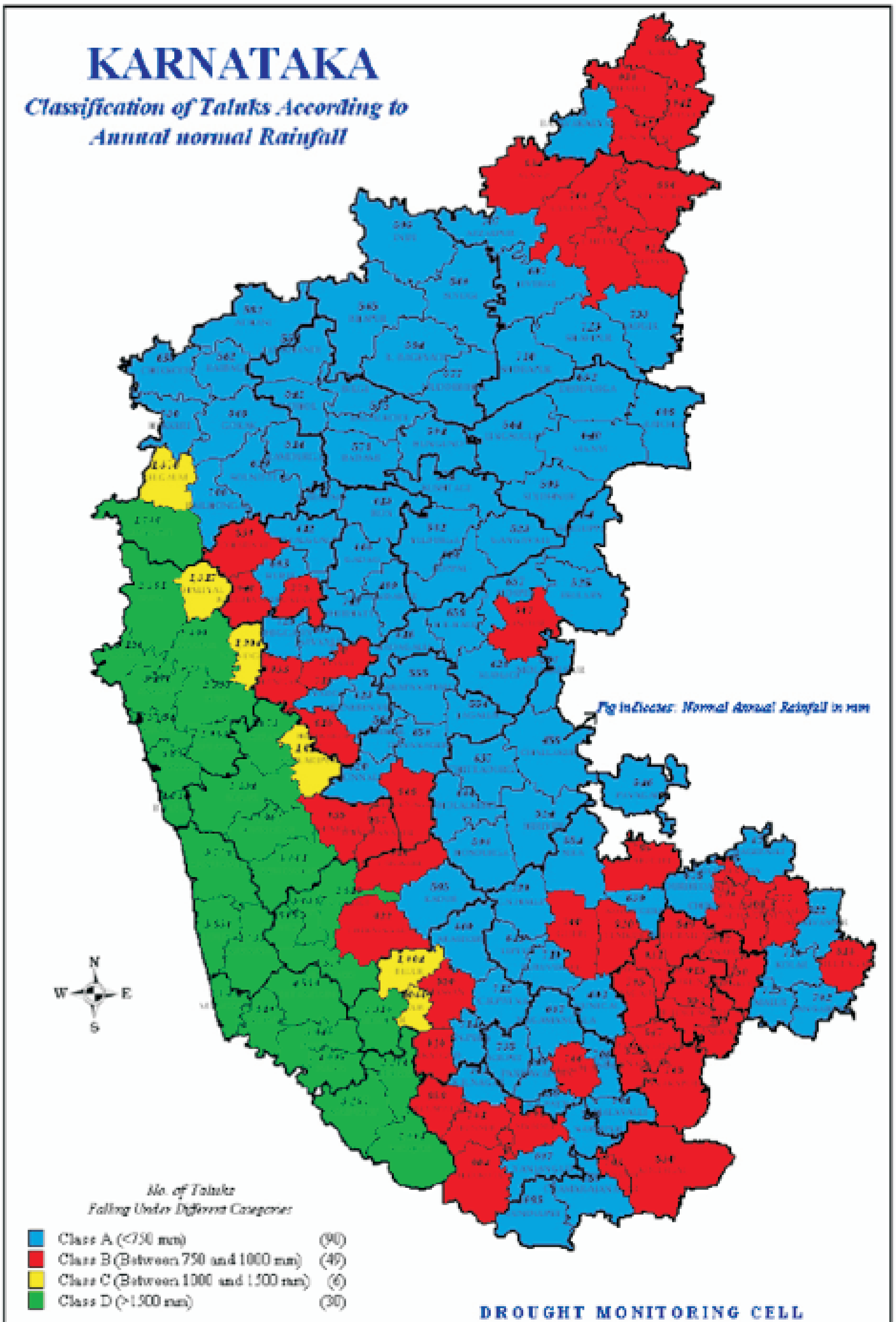
DISTRICT	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
Bangalore (U)	5	8	8	42	116	69	99	123	149	168	64	47	867
Bangalore (R)	4	6	8	42	107	68	84	112	151	158	63	13	817
Kolar	7	6	9	33	80	61	81	100	145	136	69	17	744
Tumkur	3	4	6	34	91	61	69	85	128	142	56	10	688
Shimoga	1	2	8	44	87	307	681	352	130	146	44	10	1813
Chitradurga	3	4	5	25	76	49	63	68	99	124	46	12	573
Davanagere	2	3	8	35	78	66	96	80	102	120	42	10	644
Mysore	3	6	13	66	139	65	100	76	89	152	61	13	782
Chamrajanagara	4	5	11	66	140	47	53	68	100	163	76	19	751
Mandya	3	5	8	50	123	44	45	64	112	169	62	15	700
Kodagu	5	6	15	74	147	486	938	529	219	202	80	19	2718
Hassan	3	4	8	69	109	118	250	139	98	161	65	15	1031
Chickmagalur	3	4	9	55	102	300	672	382	160	164	59	16	1925
Dakshinakannada	5	2	10	47	172	940	1301	806	321	257	94	19	3975
Udupi	4	2	5	37	170	1055	1342	800	383	224	78	19	4119
Dharwad	1	3	7	45	85	95	152	100	112	120	42	10	772
Gadag	2	2	4	35	71	70	68	70	128	116	337	9	612
Haveri	2	2	5	40	77	96	172	103	85	122	39	11	753
Uttarakannada	1	1	4	28	103	680	1006	554	248	148	49	12	2835
Belgaum	2	2	8	33	65	104	205	122	110	111	38	9	808
Bijapura	3	4	6	19	35	78	79	77	157	84	28	8	578
Bagalkote	2	3	55	24	48	65	73	67	141	93	44	8	621
Raichur	1	2	5	17	34	76	108	113	152	84	22	7	572
Koppal	1	0	2	23	50	60	82	91	136	100	21	7	572
Bellary	2	3	4	28	64	66	85	95	142	105	33	9	636
Gulbarga	3	4	10	19	33	108	161	144	193	81	16	5	777
Bidar	4	6	11	21	23	131	190	180	192	65	19	6	847
State average	3	4	7	37	87	182	285	190	150	134	49	12	1139

Maximum rainfall intensity - Guideline value only

While it is necessary to obtain the correct rainfall intensity from the nearest meteorological station, broad guideline figures are given for quicker reference below:

Coastal districts	: 90 mm per hour
Malnad area	: 80 mm per hour
Bayaluseeme (plains) area	: 60 mm per hour

Map of Annual Normal Rainfall in Karnataka



Annual Normal Rainfall in Karnataka (in mm) - Taluk Wise Detail

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
Afzalpur	1.6	4.1	10.3	22.1	37.9	102.2	130.2	128.6	179.5	79.9	7.7	3.7	707.8
Alanad	2.9	3.9	6.1	20.7	40.3	104.6	182.3	157.5	210.6	88.7	11.5	4.9	834.0
Alur	3.1	4.8	6.5	72.9	107.9	121.4	253.4	159.3	85.9	162.6	67.2	15.4	1,060.4
Anekal	5.3	6.3	8.8	42.2	118.6	60.7	91.3	116.7	140.8	156	65.4	15.9	828.0
Ankola	0.5	1	0.2	13.4	114.5	1001.	1172.	601.5	290.1	144.6	54.4	11.5	3,405.8
Arasikere	4.9	3.7	6.8	36.4	101.6	50.7	66	68.7	102.6	146.8	65.6	14.7	668.5
Arkalgud	2.4	5.8	5.8	61.1	111	95.4	207	121.7	116	142.2	75.2	18.1	961.7
Athani	3.6	1.1	5.5	24.1	52.8	73.2	81.4	69.6	134.4	95.8	30.7	9.4	581.6
Aurad	3.7	3.4	3.8	13.4	26.5	121.6	162.3	185.8	171.7	70.3	19.1	2.3	783.9
Badami	0.7	2.5	3.9	23	52.9	64.8	71.1	73.3	144.2	94.9	39.2	7.9	578.4
Bagalkot	0.8	3.9	4.6	22	47.9	69.8	78.7	64.9	145	95.2	32.3	9.2	574.3
Bagevadi	1.8	4.7	7.7	18.9	41	75.6	72.2	73.9	152.5	94.6	29	12.4	584.3
Bailonghal	1.2	1.5	7.7	35.2	71.2	93.6	138.7	85.6	105.9	120.7	38.4	7.7	707.4
Bangalore North	3.6	9.9	4.9	37.1	116.5	70.8	95.3	112.3	140.3	184.4	64.9	17	857.0
Bangalore South	5.2	7	8.8	46.5	112.5	75.1	111.5	139	165	164.3	62.6	17.8	915.3
Bangarpet	7.3	5.4	9.8	35.9	92	49.6	63.3	92.4	129.8	133.4	66.5	16.5	701.9
Bantwal	5.2	1	6.7	35.6	155.3	976.2	1241.	740.6	314.6	240.7	78.8	22.8	3,818.6
Basavalayan	0.9	5.8	10.3	21.4	20.9	166.9	193.5	191.7	191.3	78.2	16.7	8.3	905.9
Begepalli	4	3.6	7	30.2	65.3	57.1	85.1	92.9	147	122.2	52.1	11.4	677.9
Belgaum	2.9	2.2	10.8	44.9	84	188.8	484.9	263.1	117.2	130	35.8	11	1,375.6
Bellary	2.8	4.7	4.3	23.3	50.9	47.3	48.1	66.4	124.6	102.1	41.9	9	525.4
Beltangadi	4.1	1.6	11.6	54.3	169	960.5	1579.	978	401.5	3919	-3511	20.2	4,588.0
Belur	4.6	4	7.6	65	120.8	122.2	254.2	107.4	82.6	146.8	69.2	19.1	1,003.5
Bhadravathi	1.1	2.9	9.7	49.8	101.7	99.6	257.3	154.3	87.9	146.6	46.7	8	965.6
Bhalki	5.1	4.4	16.9	29.6	27.9	151.3	198.8	203.2	227.6	53.9	12.7	7.8	939.2
Bhatkal	3.3	0.6	1.9	21.3	143.8	1086.	1309.	798.1	395.4	184.4	57.6	13.1	4,015.7
Bidar	4.7	8.1	13.5	26.5	25.9	137.6	222	176	230	67.3	24.9	4.2	940.7
Bijapur	4.1	2.9	6.3	22.1	36	77.3	75.2	73.8	145.8	86.6	28.2	7.1	565.4
Bilgi	2	3.2	6.8	22.3	43.9	60.3	65.9	62.6	137	89.8	29.4	6.7	529.9
Bydagi	0.5	0	3.7	40.9	77.8	89.4	146.6	94.2	90.8	125.9	34.9	7.9	712.6
Challakere	2.4	4.5	3.8	19.6	63.6	33.2	33.9	54.1	87.5	112.9	33.3	9	457.8
Chamarajanagar	4.2	3.8	8.8	55	136.8	35.4	39	65.5	87.1	160.3	74.3	18.3	688.5
Channa Patna	2.4	6.6	8.7	47.5	128.1	67.3	76.3	108.8	146.9	162	57.7	13	825.3
Channagiri	3.6	2.7	33	35.7	83.3	76.2	160.9	114	105.3	128	55.1	10.9	808.7
Channarayapatna	3.4	2.5	8.6	52.2	114.5	51.4	71.3	61.6	104.6	162.4	65	14.9	712.4
Chikkaballapura	7.2	6.5	9	33.2	73	77.2	102.3	121.8	148.5	142.9	61.3	11.9	794.8
Chikkamangalur	4.5	5.8	12.4	60.1	121.4	103.6	192.3	96.1	82.5	155.8	67.9	19.7	922.1
Chikkanayakanahalli	4	4	8.6	40.3	101.9	60.3	70.5	80.2	123	160.7	63.1	11.9	728.5
Chikkodi	1.7	0.9	6.5	31.8	57.7	71.8	135.5	86.1	89.9	106.1	37.9	9.5	635.4
Chincholi	1	3.8	8.5	12.4	25.3	126.1	208.4	173.1	225.7	78.1	12.5	5.1	880.0
Chinthamani	8.1	5.7	10.4	35.7	76.9	61.5	77.5	92.2	142.6	156	88.3	22.5	777.4
Chitradurga	4.7	3.9	4.5	26.4	80.4	59.2	76.8	81.9	100.1	132.2	51.8	15.3	637.2
Chittapur	2.3	2.6	16.3	16.5	34.6	118.4	172.6	155.1	190.8	68.1	13.8	3.1	794.2
Davannagere	2	3.1	3	33.6	81.2	75.9	91	74.9	111.5	131	40.2	11.5	658.9
Deodurga	0	0.2	1.6	24.8	48.6	70.9	73.1	103	149.1	90.5	24.3	7.1	593.2
Devanahalli	6.4	5.6	8.5	37	83.9	71	88.7	100.4	142.7	133.7	76.4	12.6	766.9
Dharwad	1.4	1.3	7.1	48.6	81.9	102.5	183.8	118.6	107.5	129.9	44.9	11	838.5
Doddaballapura	8.3	7.4	4.8	34.5	88	75.1	100.5	126.4	159.9	164.9	65.5	14.1	849.4
Gadag	2.8	1.9	5.7	39	80.9	72.7	70.5	83.4	132.7	126.9	38.8	10.4	665.7
Gangavathi	0	0	1.5	19.8	41.2	50.6	74.8	84.1	113.8	102.8	28.4	6.3	523.3
Gokak	2.5	1	7	32	66.1	61.5	79	60.1	96.3	112.7	40.7	8.7	567.6
Gouribidanur	3.6	4.4	5	28.9	70.6	62.3	83.9	89.6	151.9	118.2	52.1	7.7	678.2
Gubbi	2.3	4.9	6.2	37.4	97.4	71.2	84.8	102.9	138.6	152.5	50.3	8.3	756.8
Gudibanda	4.4	5.2	8.9	31.7	69.3	78.4	108.1	114.5	181.8	131.3	57.7	12.5	803.8
Gulbarga	6.3	6.2	9.3	19	35.6	107.7	146	136.5	198.6	69.8	26.1	5.3	766.4
Gundlupet	5.5	5.6	15.1	73.5	134.1	39.3	52.6	43.7	68.1	159	76.1	20.1	692.7
Hadagali	3.4	2.7	3.7	31.5	66.9	66.9	80.8	82.5	123.3	106.8	35.4	11.6	615.5
Hagari Bommanahali	0	0.2	1.3	21	70.5	56.1	63.7	64.9	166.7	75.6	21.2	1.3	542.5
Haliyal	1.4	2.8	12.1	49.5	92.7	197.4	410.5	240.4	116.6	137.3	43.5	12.9	1,317.1
Hanagal	1.9	1.1	5.8	38.6	70.2	142	283.2	151.7	73.1	117.5	37.5	10.8	933.4
Harapanahalli	0.9	2.8	5.2	35.4	71.7	77.8	98.6	88.6	115.8	114.9	35.4	9.7	656.8
Harihara	3	2.2	2.4	32.8	72.8	58.3	74.1	64.7	0	111.5	41.3	10.5	473.6
Hassan	3.6	6.7	12.4	55.9	113.6	83	164.5	90.1	96	170	65.2	15	876.0

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
Haveri	3.1	2.3	7.7	44.5	82.4	93.8	164.9	98.3	90.7	126.5	42.6	13.3	770.1
Heggadadevancote	3.5	7.7	15.1	72.7	140.8	87.4	185	99.1	77.3	135.2	64.6	15.1	903.5
Hirayur	2.7	3.5	3.9	24.8	83.3	38.6	48.2	55.3	96.8	117.7	45.2	8	528.0
Hirekerur	1.7	3.3	3	37.7	73	100.6	211.6	113.2	86.9	124.9	42.6	12	810.5
Holakere	4.8	4.5	6.2	34.7	84.4	58	93.4	84.5	100	134.4	46	14.6	665.5
Holenarasipura	3.8	3.9	8.5	57.5	110.6	56.9	99.7	65.4	77.8	155.4	61.8	12.7	714.0
Honalli	1.9	4.7	4.1	43.3	88.1	58.3	94.4	61.8	81.6	131.2	41.6	9.4	620.4
Honnavar	1.7	0.1	1	17.6	162.2	1018.	1141.	717	375.3	174.2	58.8	17.6	3,685.5
Hosadurga	2.4	4.4	5.2	0	0	51.9	73.6	58.2	89.4	132.4	58.1	13.	488.6
Hosakote	4.3	5.6	11.5	39.1	94.2	67.5	77.3	97.3	136.1	146.2	59.1	11.7	749.9
Hosanagara	2.1	1.5	5.9	43.4	98.3	608.6	1231.	564.9	203	151.3	43.7	8.2	2,962.3
Hospet	1.9	3.3	3.8	25.4	62.1	68.6	82.4	106.2	149.6	108.1	38.2	8.4	658.0
Hubli	1.1	1.2	6.8	40.6	77.5	85.8	120.4	84.3	106.3	118.3	40	10.7	693.0
Hukkeri	1.3	2.3	9.7	38	82.4	83.5	149	86.4	102.3	122.6	44.6	11.2	733.3
Humnabad	1	5.8	10.3	21.4	20.9	166.9	193.5	191.7	191.3	78.2	16.7	8.3	906.0
Hungund	2.8	3.5	4.8	26.9	48.2	65.1	80.4	80.8	148.9	89.9	34.4	7.8	593.5
Hunsur	2	3.5	10.6	63.2	137.7	68.9	108.7	71	76.9	150.6	55	12.9	761.0
Indi	2.1	4.7	6.5	17.1	26.1	82.9	84.4	81.2	176.4	76.7	30.3	6.5	594.9
Jagalur	3.1	5.2	2.9	27.2	70.8	48.7	65.9	75.1	105.8	102.8	40.6	8.1	556.2
Jamkhandi	4.3	1.6	5.4	25.4	44.3	66.6	72.2	58.1	139.3	99.2	27.6	7.4	551.4
Jevargi	0	3.8	8.2	20	34.9	98.2	120.8	128	182.7	80.1	14.5	5.3	696.5
Kadur	2.9	3	6.3	32	86.6	56	79.5	46.7	72.1	136.5	57.1	16	594.7
Kalghatagi	0.6	1.1	7.5	44.4	83.5	133.5	245.6	153.7	99.5	119.6	41.2	9.5	939.7
Kanakapura	3	4.2	11.1	46.7	122.6	53.1	69.6	92.6	138.5	155.9	56.6	14.2	768.1
Karkala	6.8	1.2	8.1	49.4	179.5	1091.	1549.	977	423.1	310.9	111.2	24.6	4,732.7
Karwar	0.5	0.7	0.5	16.9	118.1	962.5	1023.	526.2	294.8	137.6	48.9	12.2	3,142.5
Khanapur	0.9	0.8	5.2	30.2	60	288.8	746.4	371.2	122.7	119.9	33.6	8	1,787.7
Kolar	7.8	5.4	9.2	35.8	88.5	49.2	66.6	97.2	136	125.4	76.5	18.7	716.3
Kollegal	4.3	4.9	11.7	68.4	131.3	58.8	66	88.7	128.4	172.3	76.6	18.8	830.2
Koppa	3.5	3.8	7.2	61.9	102.9	481.5	1195.	709.4	245.2	175.4	59.5	13	3,058.9
Koppala	3.4	0	1	21.6	58.1	74	89.6	86.6	135.6	105.5	9.8	4.5	589.7
Kortagere	3.7	3.7	3.7	27.1	82.3	60.2	72.7	78.2	118.8	124.3	55.4	9	639.1
Krishnarajapet	2.6	4.3	7.1	53.6	137.8	55.6	67.8	59.6	102.1	168	65.8	10.9	735.2
Krishnarajnagar	4.1	4	12.8	53.7	143.9	55.8	71.6	59.5	88.3	169.4	64.1	13.8	741.0
Kudligi	1.9	2.6	3.9	28.2	69.4	62.7	83.6	105.7	132.7	96.7	32.9	8	628.3
Kumta	1.1	1.9	2	16.3	129.2	1058.	1247	705.6	389	163.8	52.6	14	3,780.6
Kundapur	1.2	1.9	4.3	26.3	158	1040.	1236.	708	358.2	161.5	60.6	16.9	3,774.2
Kundgol	0	9.7	7.9	58.7	108.5	89.1	135.7	75.6	118.1	114.6	52.5	7.5	777.9
Kunigal	1.7	3	6.9	42.5	109.2	69.2	74.6	105.5	147.1	160.6	53.4	11.4	785.1
Kushtagi	0	1.3	3.4	25.4	53.1	51	92.7	77.4	141.5	102.1	15.2	8.3	571.4
Lingsugur	0.1	0.8	10.5	12.4	28.9	79.8	119	122.3	161.5	76.5	12.9	7.1	631.8
Maddur	1.7	4.5	5.4	53.8	100.3	44.3	45.6	78.4	136.4	167.8	52.2	15.7	706.1
Madhugiri	3.7	4.4	6.3	29.7	74.5	63.8	73.8	82.4	142.6	141.5	57.8	10	690.5
Madikeri	5	6.2	17	75.9	149.5	588.8	1149.	696.1	295.3	205.5	78.7	19.3	3,287.2
Magadi	3.9	3.7	4.8	39.5	103.1	63.1	75.2	121.1	154.1	159.3	56	11.6	795.4
Malavalli	2.1	8.1	8	53	122.2	44.1	47.6	73.8	110.2	157.3	61.1	16.3	703.8
Malur	6.6	6.9	10.3	39.6	99.6	52.3	69.2	94.1	133.4	132.8	63.3	15.1	723.2
Mandya	0	1.2	10.1	40.5	91.6	38.3	47	60.6	150.7	128.4	57.3	6	631.7
Mangalore	3.1	3	7	36.1	200.1	944.6	1038	609.7	285.2	206.5	74.9	18.9	3,427.1
Manvi	1.4	1.1	7.8	19	39.9	62.5	80.2	96.6	141.4	77.6	30.3	6.2	564.0
Molakaramuru	2	3.8	4.2	22.5	64.4	50.1	51.2	71.4	122.7	113.8	40.3	10.5	556.9
Muddebihal	2.1	3.7	4.6	20.8	43.2	72.3	78.9	76.4	159.1	82.4	27	6	576.5
Mudhol	2	1.6	5.3	23.8	51	63.8	66.9	64.7	130	87.9	38	7.3	542.3
Mudigere	3	4.1	12.7	75.7	124.2	429.8	849.6	403.1	198.8	199.8	63.5	14.6	2,378.9
Mulabagilu	13.2	7.4	10.4	32.7	85.1	65.2	76	109.7	140.5	152.9	91.1	33.7	817.9
Mundargi	1.8	1.8	2.3	26.8	58.9	53	41.3	54.9	104.8	100.1	34.2	9.1	489.0
Mundgod	1.2	0.8	6.1	49.7	86.3	191.7	396.1	230.2	129.5	144.4	46.4	13.9	1,296.3
Mysore	3.9	6.2	11.9	61.9	148.6	62.1	71.5	79.4	111.2	161.6	67.1	12.8	798.2
Nagamangala	3.7	5	6.9	47.1	118.2	37.9	33	55.8	124.6	166.6	72.3	15.4	686.5
Nanjanagud	4.8	6.9	11.4	71.2	136.5	43.6	67.5	62	78.4	139.4	62.6	12.4	696.7
Naragund	1.9	3.1	3.6	27.6	65.1	58.3	69.9	55.4	124.4	93.5	33.4	8.8	545.0
Narasimarajpura	2	2.9	10.1	57.4	96	256.8	665.8	371.2	145.1	149.9	47.2	13.4	1,817.8
Navalgund	0.9	2.5	5.7	33.5	72.5	65	73.6	66.6	129.9	115.8	32.3	10.3	608.6
Nelamangala	3.8	7.9	6.4	45.7	108	76.1	101.5	141.7	168.9	182.1	70.7	17.7	930.5
Pandvapura	2	3.4	9.3	51.3	111	33.3	38.3	48.1	97.7	181.9	54.6	15	645.9
Pavagada	3.2	3.3	4.4	20.5	71.2	51.6	50.9	71.5	105.6	108.6	46.7	8.9	546.4
Periyapatna	2.6	3.8	16.4	79.3	136.3	89.5	144.1	85.8	80.4	153.9	52.9	12.6	857.6
Puttur	4.4	2.1	9.6	45.2	171.7	919.6	1279.	789.7	317.2	283.5	103.9	19.4	3,945.8
Raibagh	1.8	0.7	7	27.9	47.8	55.5	83.9	52.6	95.5	103.7	31.5	6.5	514.4

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
Raichur	1.2	0	3.3	17.9	33.8	74.6	135	107	156.7	95.6	8.9	6.2	640.2
Ramadurga	2.1	2.2	9.3	31	56	66	73.1	66.7	115.1	90.3	41.6	8.9	562.3
Ramangara	2.2	6.6	8.9	46.6	131.6	72.4	82.6	107.1	162.3	155.7	58.9	12	846.9
Ranebennur	2	1.9	5.6	37.5	77.5	69.4	98.8	71.1	86	119.6	40.5	13.4	623.3
Ron	1	2.7	4.1	23.3	53.2	82.6	66.6	79.9	154	104.4	31.7	9.6	613.1
Sagara	1.7	2.5	9.9	43.4	75.1	386.4	828.6	437.2	148.1	146.1	45.6	9.5	2,134.1
Sakaleshpura	4.2	4.2	10.2	59.4	115.9	375.7	855.1	449.5	165.6	185	73.3	17.8	2,315.9
Sandur	0.5	3	4.6	40.4	85.6	90.4	124.8	124.6	143.4	138.7	35.9	14.9	806.8
Savanur	2	1.9	5.6	37.5	77.5	69.4	98.8	71.1	86	119.6	40.5	13.4	623.3
Sedam	3.9	4.5	13.7	25.6	43.9	117	226.8	181.6	204.8	81.4	13.2	4.2	920.6
Shahapur	4.7	2.5	10.7	16.1	29.6	99.4	141.6	116.5	191.7	89.7	12.8	8.1	723.4
Shiggaon	1.7	1.1	3.6	38.8	70.4	90.8	168.9	106.2	81.1	119.1	36.3	9.9	727.9
Shikaripura	1	2.1	8.8	50.2	86.5	137.4	295	155.2	85.4	145.2	44.2	15.6	1,026.6
Shimoga	1.4	0.5	10	49	105.5	116.8	275.7	137.5	82.1	152.2	45.7	6.5	982.9
Shorapur	0.3	2.9	5.6	12.6	22.3	107.8	121.4	137.1	172.1	93.6	25.4	8.6	709.7
Shrirahatti	0.5	2.7	4.8	57.1	99.1	81.3	93.9	75.4	125.2	156.8	45.2	6.9	748.9
Siddapur	1.7	1.3	3.7	25.2	75.5	557.8	1263.	644.5	208.7	144	46.9	10	2,982.5
Sidlaghatta	6.6	5.3	9.7	33.6	83.9	61.3	85.8	104.6	151	140.2	70.2	16.4	768.6
Sindgi	4.6	4.2	5.5	14.5	32.5	88.9	87.6	85.7	179.9	78.2	36.5	8.6	626.7
Sindhanur	2.5	5.8	4.5	18.5	28.8	93.4	128.9	125.2	165.8	85.9	22.8	5.5	687.6
Sira	5.1	2.5	5	23.2	73.5	49.5	47.9	66.2	114.6	116.7	41.5	7.8	553.5
Sirsi	0.9	1.3	5	31.2	68.2	512.7	1019.	520.3	184.6	137.5	45.1	8.5	2,534.6
Siruggupa	1.8	6.2	4.5	21.8	47	67.6	98.5	116.3	172.4	98.2	24.1	5.4	663.8
Somwarpet	5.2	4.8	12.5	69.5	119.3	322.6	760.1	462.9	170	182.3	77.4	19.5	2,206.1
Soraba	1.9	0.9	6.8	36.7	68.4	281.7	646.1	315	120.1	140	44.4	11.1	1,673.1
Soundatti	2.1	2.8	7.4	37.2	72.1	63.5	89.6	72.8	110.9	117.1	46.2	7.4	629.1
Srinegeri	3.3	1.3	10.9	58.4	98.9	686.1	1488.	904.9	287.2	187.6	63.4	17.6	3,808.2
Srinivasapura	7.6	7.8	8.7	28.8	77.4	58.4	73.5	91.4	139.4	139	71.4	15.6	719.0
Srirangapatna	3.4	5	9.2	45.3	131.3	41.6	38.9	59	87.7	159.7	61.6	13.1	655.8
Sulya	4.4	2.0	9.6	45.2	171.7	916.6	1279	789.7	317.2	283.5	103.9	19.4	3945.8
Supa	0.9	1.3	5	31.2	68.2	512.7	1019.	520.3	184.6	137.5	45.1	8.5	2,534.6
T Narasipura	3.3	6.6	9.6	59.2	127.4	49	48.4	75.5	110.3	151.7	62	14.7	717.7
Tarikere	2.5	3.8	4.6	42.5	83.7	89.5	242.6	143.6	88	142.6	57.5	15.5	916.4
Tiptur	2.5	3.1	5.6	0	0	48.8	52.2	64.7	103.5	144.7	65.5	12.3	502.9
Tirthahalli	2	1.8	6.1	35.2	86.1	543.1	1270.	703.9	213.6	157.7	45.1	11.9	3,077.3
Tumkur	3.1	8.3	7.4	38.5	92.5	79	101.1	117.4	155	152.9	56.7	7.9	819.8
Turuvekere	1.8	3.7	7.1	36.3	106.9	52.7	60.5	80.6	128.4	157.3	69.6	14	718.9
Udupi	2.5	2.2	3	35.3	171.7	1032.	1239.	716.3	368.4	199.9	63.1	16.1	3,850.1
Virajpet	4.7	5.9	14.6	75.1	171.3	546.7	905	429	191.5	217.2	83	17.2	2,661.2
Yadgir	4.3	4.7	7.6	20.9	25.1	101.2	161.7	134.1	167.5	79.1	23.1	3.5	732.8
Yelandur	3.4	3.8	9	67.4	156.9	56.4	53.5	72.6	115	159.7	75.6	19.3	792.6
Yelburga	0	0.9	1.5	18.3	40.4	67.3	77.1	112.7	135	84.4	35.6	8.5	581.7
Yellapur	0.6	0.6	5.9	29.7	74.1	500.6	1104.	599	198.1	136.8	39.6	9.4	2,698.7

Karnataka Urban Infrastructure Development & Finance Corpn.

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