RAINWATER HARVESTING (B22EDO601) OPEN Elective- Semester-VI

School of Civil Engineering

<table>
<tr><td>Course Title</td><td colspan="4">Rainwater Harvesting</td><td colspan="2">Course Type</td><td colspan="2">OE</td></tr>
<tr><td>Course Code</td><td>B22EDO601</td><td>Credits</td><td colspan="2">3</td><td colspan="2">Class</td><td colspan="2">Semester-VI</td></tr>
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Course Overview

The course provides an understanding of traditional and modern RWH methods, emphasizing the design, implementation, and maintenance of RWH systems.

Course Outcomes

- Recognize the importance and benefits of rainwater harvesting and water conservation techniques.
- Understand the design and components of RWH systems for urban and rural applications.
- Analyze water conservation and recycling techniques for sustainable water management.
- Evaluate the effectiveness of RWH systems through case studies and practical applications.
- Apply advanced RWH technologies such as IoT-based monitoring and smart systems.
- Interpret government policies, guidelines, and case studies to develop sustainable RWH solutions.

Course Content

Unit -1

Global and Indian Scenario for Water Resources: Surface Water and Groundwater Global and Indian Scenario-Quality of water resources. Usable water resources by continent and Country-Water footprint.

Water use and Sustainable Reuse Methods.

Unit -2

Introduction: Concept and Necessity of Rainwater Harvesting, Benefits of Rainwater Harvesting (Social, Environmental, and Economic), Rainwater Harvesting in ancient India and worldwide.

Introduction: Advantages of Rainwater Harvesting, Natural Water Resources.

Agricultural Practices, integrated farming, Soil erosion and conservation techniques.

Concept of Arid and Semiarid Regions. Drought Management- introduction, Drought assessment and classification, drought mitigation planning, Concept of watershed, introduction to watershed management.

Unit -3

Rainwater Harvesting: Types of Rainwater Harvesting, Components of domestic Rainwater Harvesting system, Principles of design of roof top Rainwater Harvesting System. Conveyance Systems- Material selection and installation.

Water Conservation and Recycling: Perspective on recycle and reuse, Wastewater reclamation, Rainwater Harvesting Techniques- in Urban areas and Rural areas, a case study of both techniques, maintenance and monitoring of Rainwater Harvesting Structures.

Unit -4

Advancement and Policies of RWH: Government policies and schemes for RWH in India, guidelines and regulations (e.g., building codes, municipal policies), Incentives and subsidies for RWH.

Smart RWH systems, Integration with IOT for monitoring and management. Role of RWH in achieving water sustainability, Case Studies in Urban and Industrial.

Textbooks

Rainwater Harvesting for Drylands and Beyond, Volume 1: Guiding Principles to Welcome Rain into Your Life and Landscape by Brad Lancaster, Rainsource Press, 2019.

Rainwater Harvesting: Principles and Practices by H.S. Ramesh, New India Publishing Agency, New Delhi, India, 2020.

Rainwater Harvesting and Utilisation: Blue Drop Series, United Nations Environment Programme, UNEP and IETC, 2009.

Water is the most common or major substance on earth, covering more than 70% of the planets surface. All living things consist mostly of water. For example, the human body is about two third water.

It is said that If third world war take places it will be on water.

Already so many water disputes are going on in our country between neighboring states for sharing river water.

Water Metrics

Same situation of sharing river water also exists with neighboring countries like Pakistan, China, Nepal and Bangladesh.

The basic reason of all these disputes is

- Scarcity of potable water
- Increasing requirement for human consumption
- Industrialization.

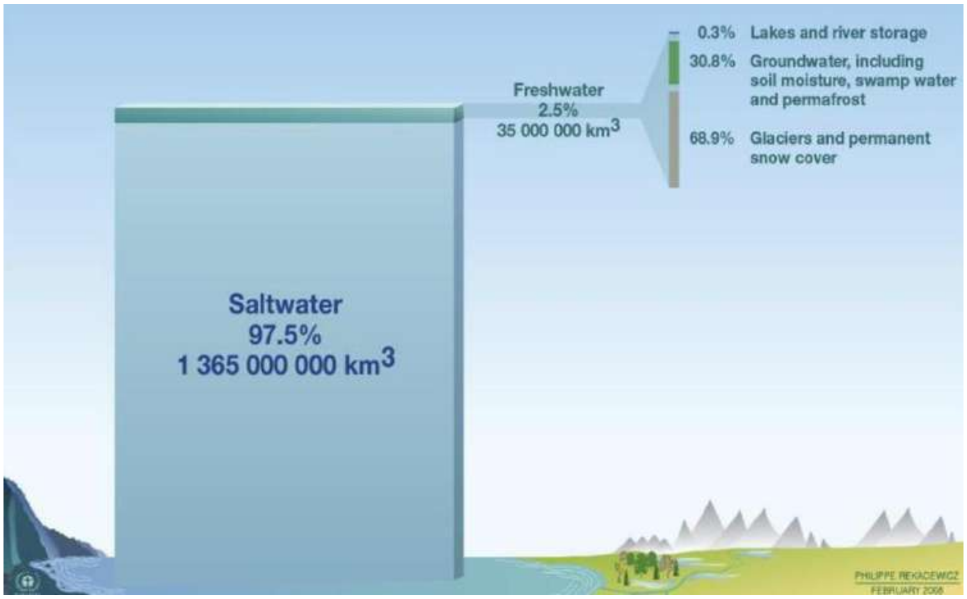
Water Metrics

Few basic facts we should know:

Only 3% of water on earth is available for human use.

Only 10% rainwater is harvested currently. This can be enhanced to 50% if adopted as habit or movement. This can solve water problems of major part of country.

On an average rains, occur only for about 100 hours every year.



Water Stress in India

Per Capita Water Availability in India

Year	Population (Million)	Per capita water availability (m^3/year)	Remarks
1951	361	5178	
1955	395	4732	
1991	846	2210	
2001	1027	1820	
2011	1211	1651	water stressed#
2015	1326*	1508[$]	water stressed#
2021	1345[a]	1486[$]	water stressed#
2031	1463[a]	1367[$]	water stressed#
2041	1560[a]	1282[$]	water stressed#
2051	1628[a]	1228[$]	water stressed#

Source: Government of India, 2009 (NCIWRD Report, 1999), *projected from 2011 census

Area of the country as % of world area	2.4%
Population as % of world population (Census, 2011)	17.1%
Water as % of world water	4%
Average annual rainfall (India Meteorological Dept.)	1160 mm (world average 1110 mm)
Range of distribution	150-11690 mm
Range Rainy days	5-150 days

Source: Water Resources Information System of India

Categories of Water

Category of water	Source	Potential for use in agriculture or remarks
Blue water	Sea, lakes, rivers, canals, etc.	Extensively used for irrigation. Its availability is likely to decrease with increasing competition from other sectors.
Green water	Soil moisture and water in plants	Mostly used by plants and agricultural crops particularly forest, grass lands and rain fed agriculture.
Fossil water	Groundwater	Used for domestic and agricultural uses. Its availability to agriculture would decrease with time as a result of competitive demand from other sectors.

Grey water	Wastewater from bathroom, kitchen and washbasins.	Potential for use in crop production. Suitable for kitchen gardening and irrigating lawns.
Black water	Domestic sewage/Industrial waste	Potential for use in crop production. 21st century water resource for agriculture. Cleaner technologies required to avoid heavy metals/pathogens entering human chain.
Virtual water	Water used in producing grains/animal product	Export-import of food grains/animal product indirectly results in export-import of water. One kg of rice or wheat export means export of 2000 litres of water for rice and 800 litres of water for wheat. It is going to assume importance in export-import during the next few decades.

Water use and Sustainable Reuse Methods

Water recycling is reusing treated wastewater for beneficial purposes such as agricultural and landscape irrigation, industrial processes, toilet flushing, and replenishing a ground water basin.

Environmental Benefits of Water Recycling: In addition to providing a dependable, locally-controlled water supply, water recycling provides tremendous environmental benefits. By providing an additional source of water, water recycling can help us find ways to decrease the diversion of water from sensitive ecosystems.

Water use and Sustainable Reuse Methods

- Agriculture
- Landscape
- Public parks
- Golf course irrigation
- Cooling water for power plants and oil refineries
- Processing water for mills, plants
- Toilet flushing
- Dust control
- Construction activities
- Concrete mixing
- Artificial lakes (Power generation)

Uses of recycled water

Secondary Treatment: Biological Oxidation, and Disinfection

- Surface irrigation of orchards and vineyards
- Non-food crop irrigation
- Restricted landscape impoundments
- Groundwater recharge of non-potable aquifer
- Wetlands, wildlife habitat, stream augmentation
- Industrial cooling processes

Tertiary and advance treatment

- Landscape and golf course irrigation
- Toilet flushing
- Vehicle washing
- Food crop irrigation
- Unrestricted recreational impoundment
- Indirect potable reuse- Groundwater recharge of potable aquifer and surface water reservoir augmentation

Water Footprint

The water footprint of a commodity is the total volume of freshwater used to produce the commodity throughout the various steps of the production chain.

It is an indicator that looks at both direct and indirect water use.

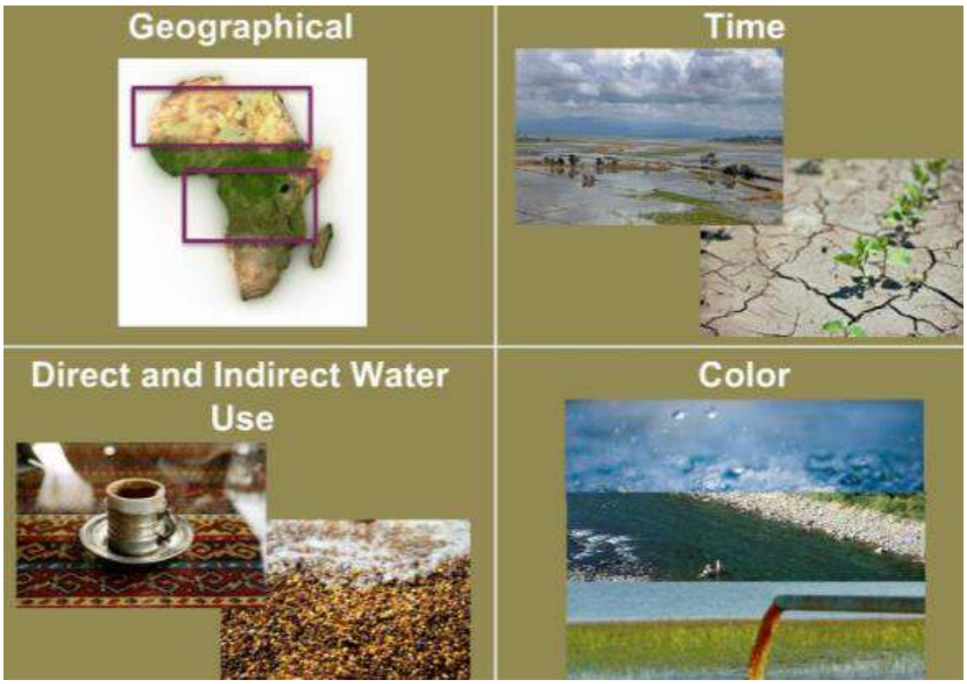
Water Footprint refer to an individual, a commodity, a business or a nation.

The water footprint of a consumer is defined as the total volume of freshwater that is used to produce the goods and services consumed by the person over a period of time.

Dimensions of a water footprint

The water footprint is a multi dimensional indicator of water use.



First, it has a geographical dimension. It contains information on both the use of water in volume and the location of that use.

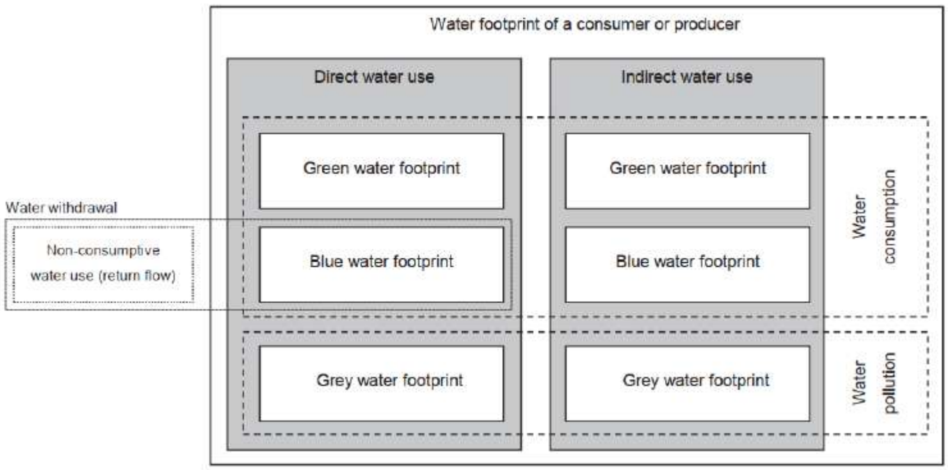
Geographical information is important because consuming one cubic meter of water in a water abundant area has a different significance than consuming the same volume in a water-scarce area.

Second, it has a time dimension. Consuming water from a product that is produced in a wet season has a different implication than a product that is produced in a dry season.

These geographical and time dimensions of water footprints of a product are not always obvious at a first glance, as water use data is often presented in total volume or in average volume. However, if you dig deeper, you will find the data details comprising these dimensions.

Third, water footprint can reveal both the direct and indirect water use of producing a commodity, or by a consumer or a producer.

Another dimension of water footprint is its colour: Green water footprint refers to the use of rainwater in the production of a commodity; Blue water footprint refers to the use of fresh water from rivers or groundwater aquifers; and Grey water footprint refers to the volume of water needed to assimilate the pollutants that enter rivers or groundwater as a result of the production of a commodity.



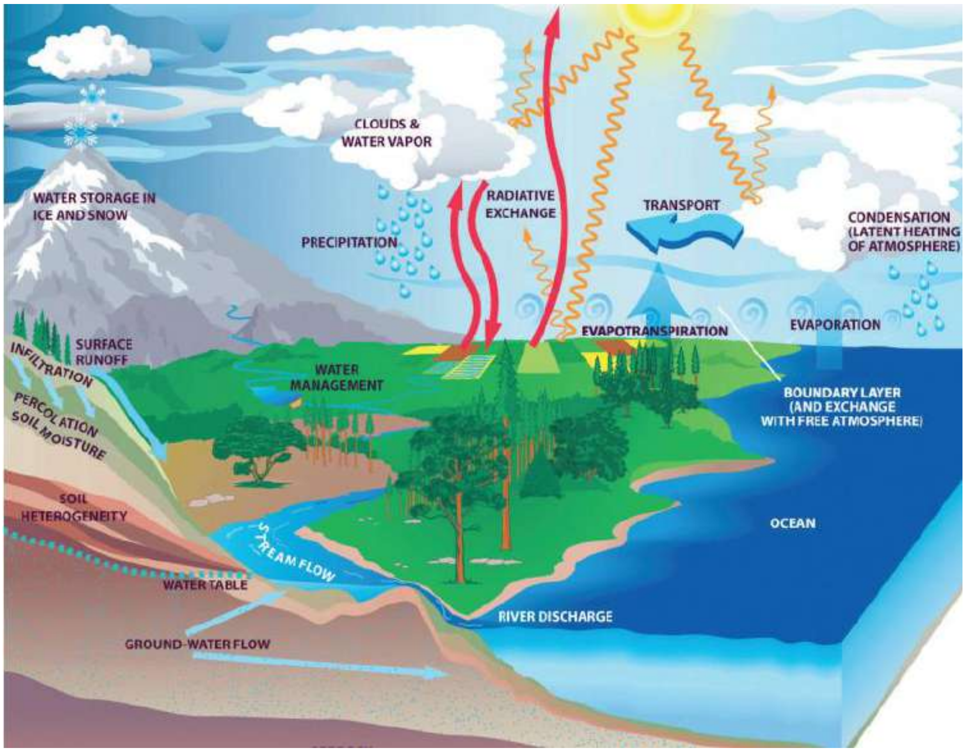

180
litres
1 kg of
tomatoes

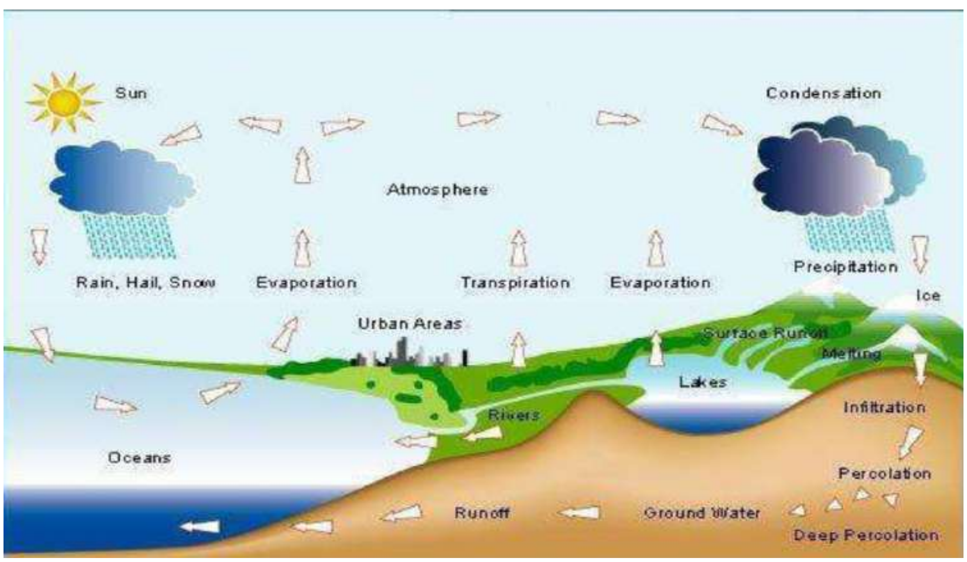

2,400
litres
1 hamburger

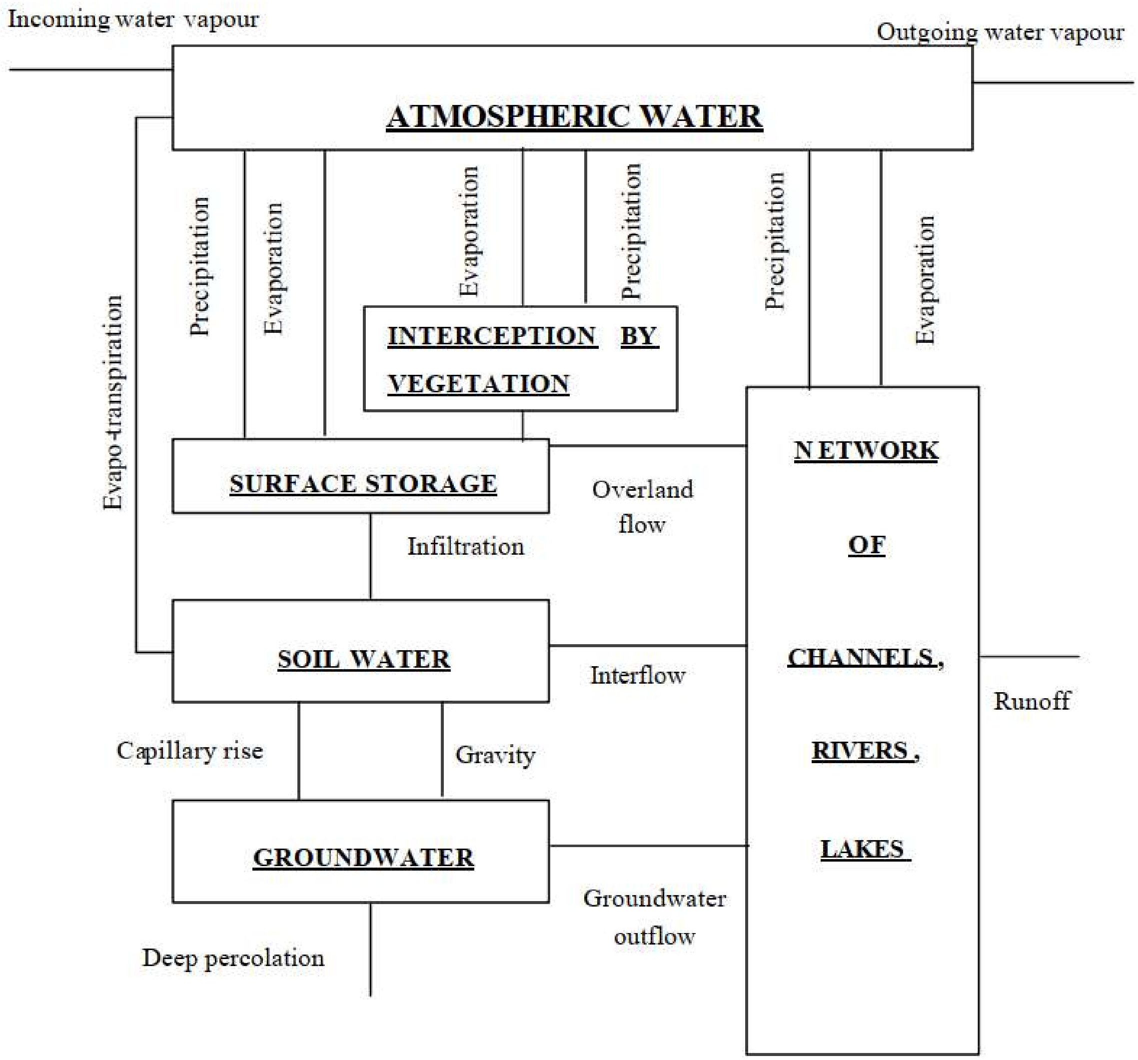

16,600
litres
1 kg
of leather

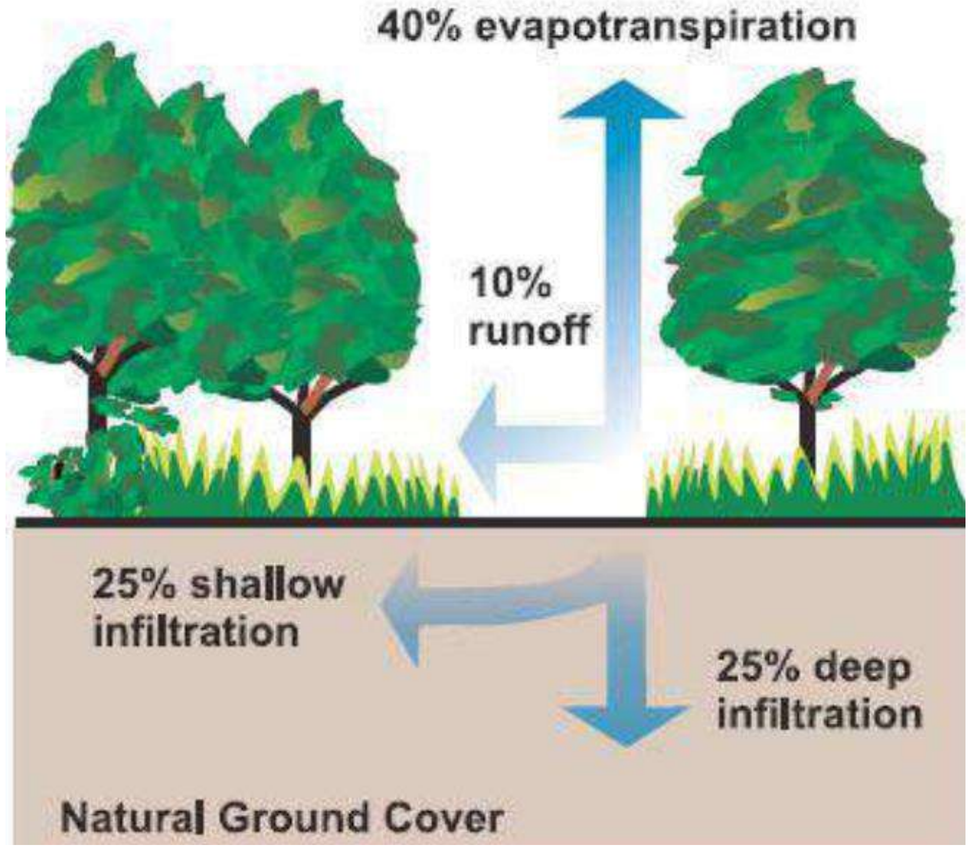

10
litres
1 sheet of
A4 paper

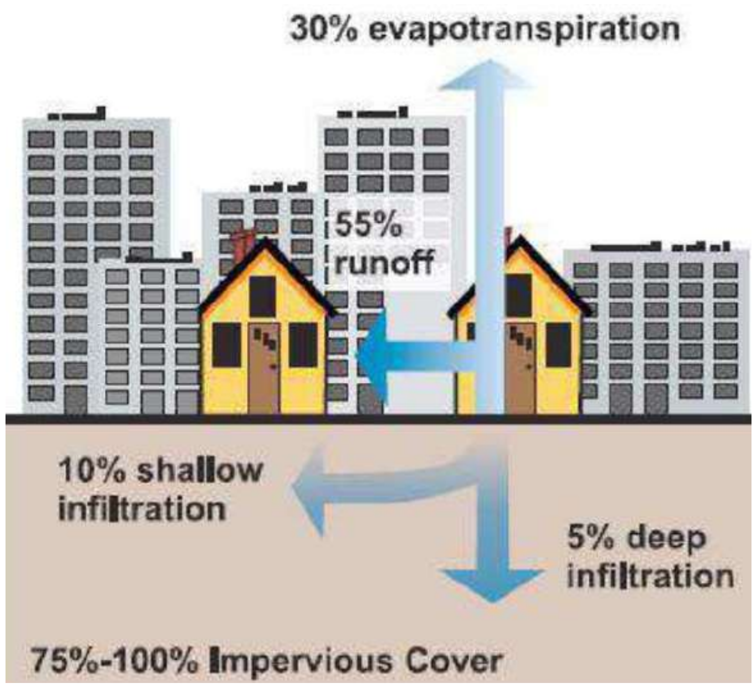
Water (Hydrological) Cycle


CLOUDS &
WATER VAPOR
WATER STORAGE IN
ICE AND SNOW
RADIATIVE
EXCHANGE
TRANSPORT
CONDENSATION
(LATENT HEATING
OF ATMOSPHERE)
PRECIPITATION
SURFACE
RUNOFF
INFILTRATION
EVAPOTRANSPIRATION
EVAPORATION
WATER
MANAGEMENT
PERCOLATION
SOIL MOISTURE
BOUNDARY LAYER
(AND EXCHANGE
WITH FREE ATMOSPHERE)
SOIL
HETEROGENEITY
OCEAN
STREAM FLOW
WATER TABLE
RIVER DISCHARGE
GROUND-WATER FLOW


Sun
Condensation
Atmosphere
Rain, Hail, Snow
Evaporation
Transpiration
Evaporation
Precipitation
Ice
Urban Areas
Surface Runoff
Melting
Lakes
Rivers
Infiltration
Oceans
Percolation
Runoff
Ground Water
Deep Percolation


Incoming water vapour
Outgoing water vapour
ATMOSPHERIC WATER
Evapo-transpiration
Precipitation
Evaporation
Evaporation
Precipitation
Precipitation
Evaporation
INTERCEPTION BY VEGETATION
SURFACE STORAGE
Overland flow
Infiltration
NETWORK OF CHANNELS, RIVERS, LAKES
SOIL WATER
Interflow
Runoff
Capillary rise
Gravity
GROUNDWATER
Groundwater outflow
Deep percolation


40% evapotranspiration
10%
runoff
25% shallow
infiltration
25% deep
infiltration
Natural Ground Cover


30% evapotranspiration
55%
runoff
10% shallow
infiltration
5% deep
infiltration
75%-100% Impervious Cover

Stages in Hydrological Cycle

Evaporation- Water from soil surface, ponds, lakes, rivers and oceans gets transferred as moisture. The factors which affect evaporation are: temperature, relative humidity, wind velocity, amount of rainfall or snowfall, quality of water, surface area of the water source, sunshine etc.

Transpiration- Transpiration refers to loss of water in vapour form from plant leaves. The water taken into the roots of the plants from the soil replaces the transpired water. In a way, transpiration is like the action of a pump absorbing water from the soil and leaving the vapour into the atmosphere.

Interception is the retention of precipitation by thick vegetation (of trees and plants) or by shrubs that is evaporated back to atmosphere.

Precipitation Water returns to the land and sea from the atmosphere by means of condensation and deposition. Precipitation signifies rainfall and snowfall.

Condensation is the process of conversion of water vapour into liquid state (in the form of dew droplets).

Deposition is the process by which water vapour changes into ice crystals. In the atmosphere, tiny droplets of water and ice crystals form clouds.

Run off-Some of the rainfall is soaked into the soil as ground water. The excess water flows over the land surface along the natural slope of the area and is known as run off.

Rainwater Harvesting

Rainwater harvesting is the technique of collection & storage of rainwater at surface or in subsurface aquifers.

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

Need for Rainwater Harvesting

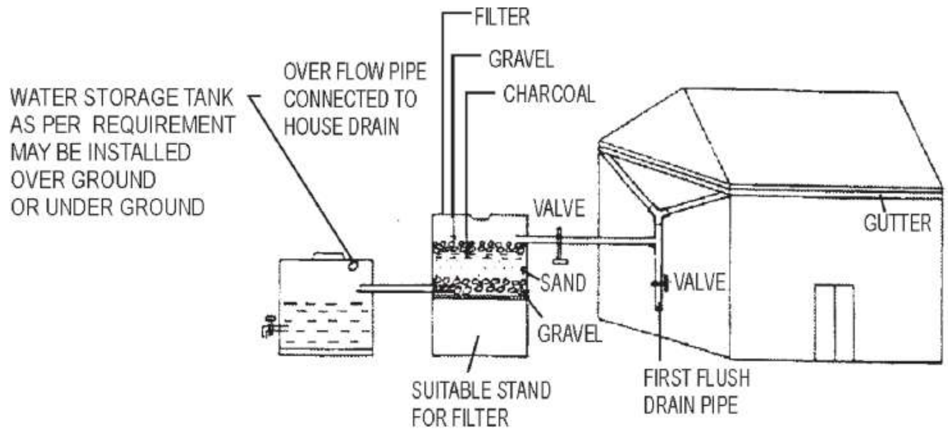
- To meet the ever-increasing demand for water.
- To reduce the runoff which chokes storm water drains.
- To avoid flooding of roads.
- To augment ground water storage.
- To reduce the soil erosion.
- To supplement domestic water requirement during crisis.

Rainwater harvesting is in two ways:

Direct Use: The process of collecting and storing the rainwater by construction of sump through filters for future productive use.

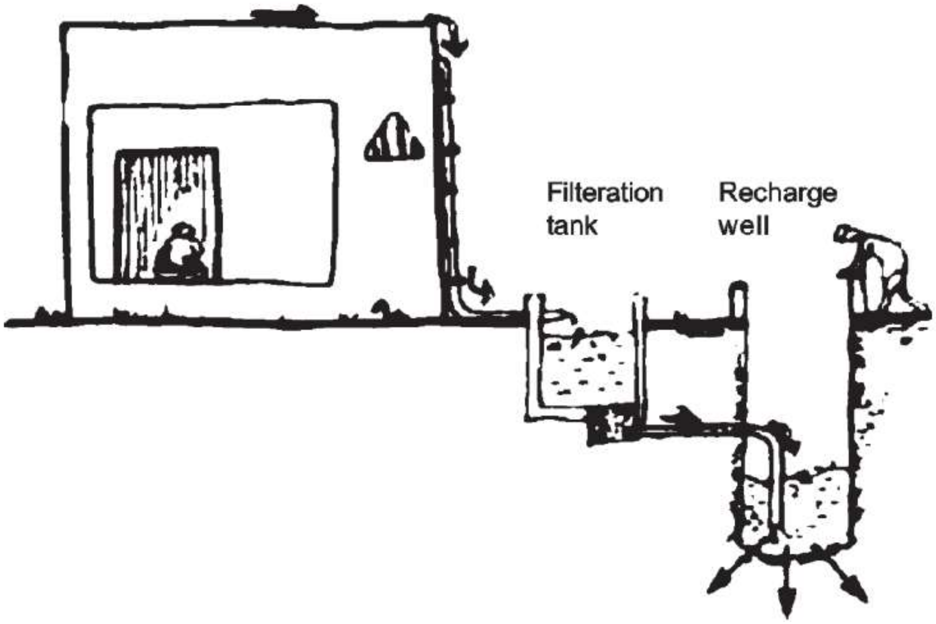
Artificial recharge to groundwater: Recharge the rainwater in a scientifically planned way by construction of rain / roof top water harvesting structures to augment the groundwater.

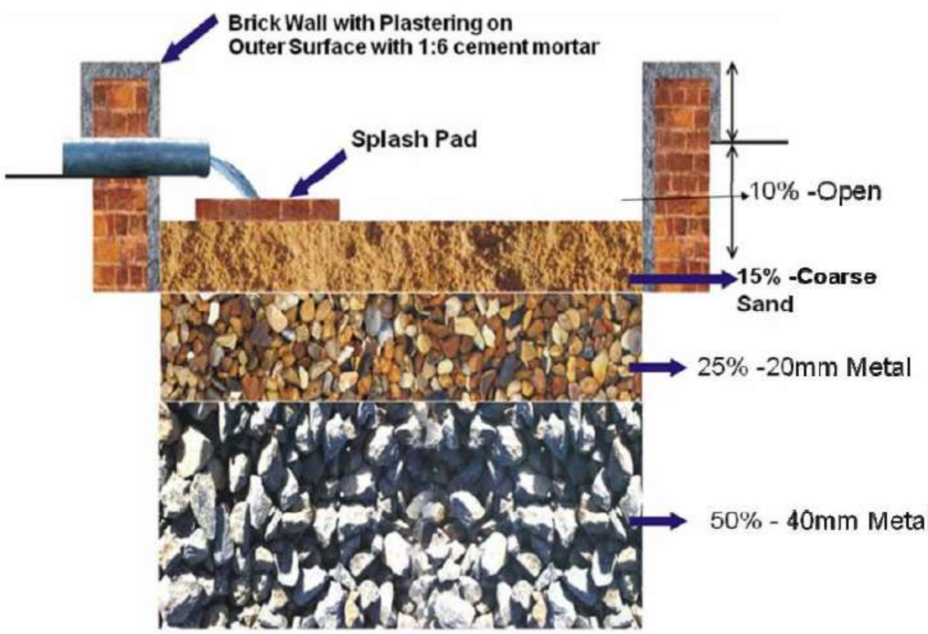
Rainwater Harvesting-Direct Use



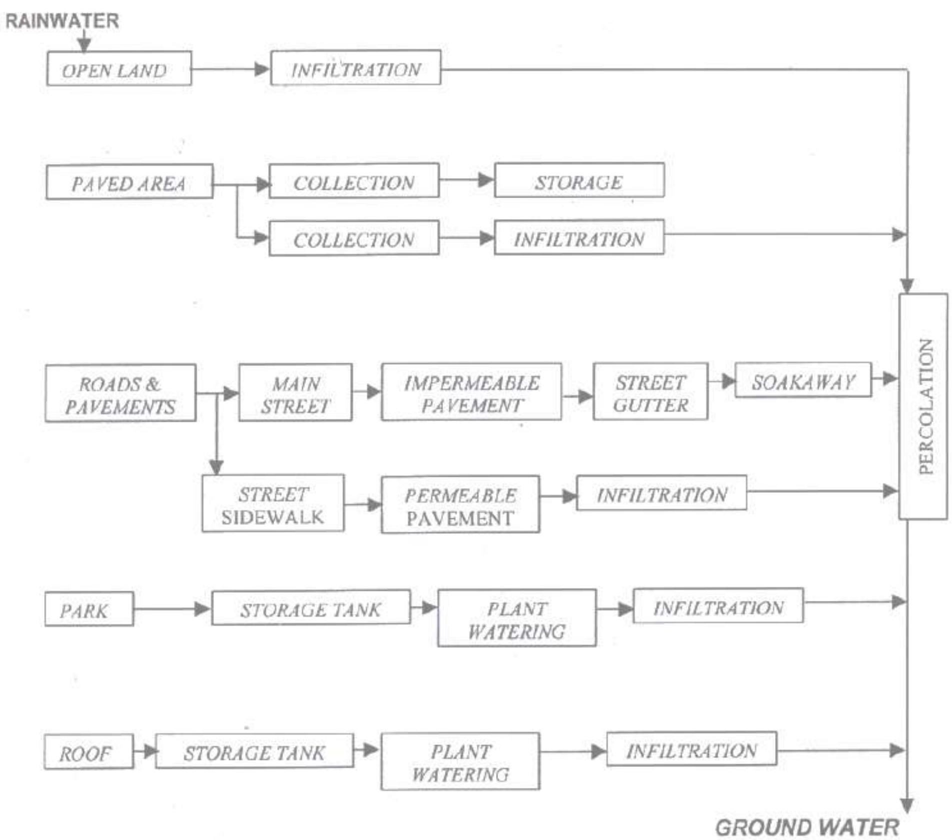

Kaveri

Rainwater Harvesting-Artificial recharge

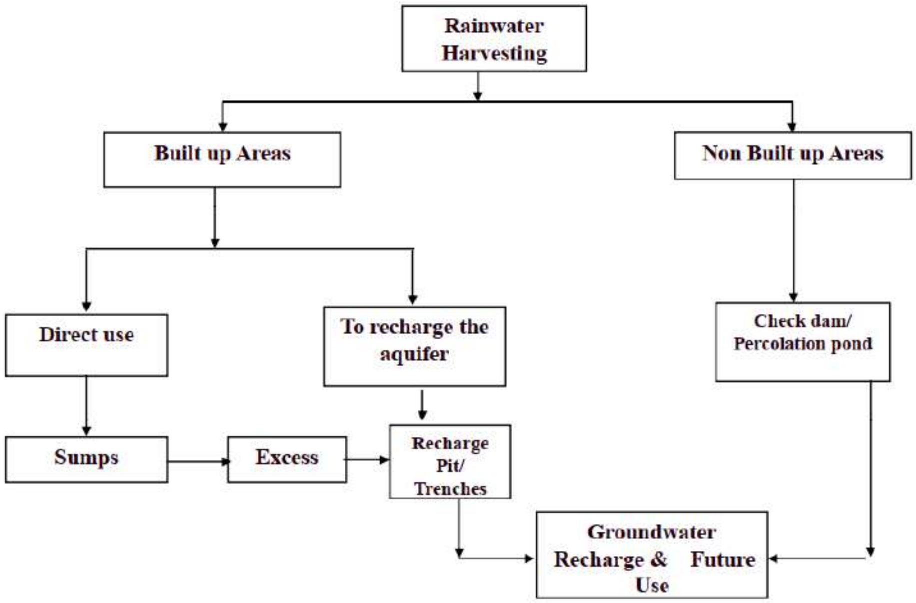




Systems of Rainwater Harvesting



Integrated Rainwater Harvesting System



Advantages of Rainwater Harvesting

- Promotes adequacy of underground water.
- Mitigates the effect of drought.
- Reduces soil erosion as surface run-off is reduced.
- Decreases load on storm water disposal system.
- Reduces flood hazards.
- Improves ground water quality / decreases salinity (by dilution).
- Prevents ingress of sea water in subsurface aquifers in coastal areas.
- Improves ground water table, thus saving energy (to lift water).
- The cost of recharging subsurface aquifer is lower than surface reservoirs.
- The subsurface aquifer also serves as storage and distribution system. No land is wasted for storage purpose and no population displacement is involved.
- Rainwater is bacteriological pure, free from organic matter and soft in nature.
- Rainwater can be harnessed at place of need & time of need.
- Recharged aquifers also serve as distribution system & water can be harnessed by just putting a hand pump at convenient location.
- The infrastructure required for rainwater harvesting are simple & economical.

Legislation on Rainwater Harvesting in India

Under the Section 15 of Environment (protection) Act 1986, central ground water authority (ministry of water resources) has made mandatory to adopt rainwater harvesting system for certain types of buildings/ institutions.

RWH is mandatory since June 2001 if roof area = 100 sqm or plot area = 1000sqm.

Rainwater Harvesting in ancient India

- Tanka
- Khadins/Dhora
- Bandharas
- Ahars
- Johads
- Saza Kuva
- Kund/Kundi
- Kuis/Beris
- Baoris/Bers
- Kere
- Surangam

Rainwater Harvesting in ancient India-Tanka

Traditional underground tanks known as tankas (little tanks) are most Bikaner homes in Rajasthan. These can be erected in the courtyard or the main home.

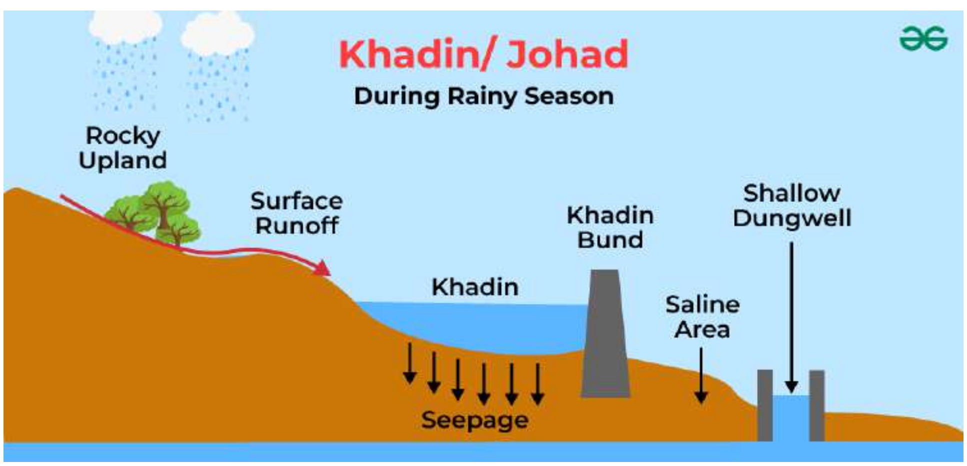
Rainwater was collected in the ground in circular holes lined with finely polished lime.

Tiles were frequently used to embellish tankas, which assisted to retain the water cool.

Rainwater Harvesting in ancient India- Khadins/Dhora

Khadins/Dhora is constructions that gather surface runoff water for agricultural use particularly in very low rainfall areas of Jaisalmer district of Rajasthan.

A long (100300 m) earthen ridge constructed beneath gravelly uplands that spans the lower hill slopes is the areas most recognizable feature.



Rainwater Harvesting in ancient India- Bandharas

Check dams, also known as diversion weirs, are built across rivers. Rivers rise in level as a result of their existence, leading them to flow into channels according to a traditional Maharashtra system.

These can also be used to hold water and create a large reservoir.

Rainwater Harvesting in ancient India- Ahar-Pynes

Traditional irrigation systems in South Bihar, known as Ahars and Pynes, were developed nearly 5000 years ago during the reign of the Magadh dynasty and are still widely used in the Gaya district.

Wherein 3m high earthen bunds are constructed with 1:2 ratio of upstream and downstream slope. Runoff water is collected behind the bund. Gates are also provided to drain out water from the bund in sufficient quantity for pre sowing irrigation.

Rainwater Harvesting in ancient India- Johads

Johads generally used in Rajasthan are small earthen check dams used to capture/conserve rainwater and improve ground water recharge resulting in rise in ground water level and increase in the forest covers.

Rainwater Harvesting in ancient India- Saza Kuva

Saza Kuva, an open well with multiple owners (saza = partner) is the most important source of irrigation in the Aravalli hills of Mewar in eastern Rajasthan.

Rainwater Harvesting in ancient India- Kund

These structures harvest rainwater in Gujarat from a saucer-shaped catchment area gently sloping towards the well.

The harvested rainwater is generally used for drinking purposes.

Rainwater Harvesting in ancient India- Kuis/Beris

Kuis/Beris are 10-12 m deep pits dug near tanks to collect the seepage and harvest rainwater in areas with meager rainfall.

The entrance of the pit is typically built narrow; as a result, the water does not evaporate. As the crater sinks deeper into the earth, it spreads, allowing water to seep onto a sizable surface.

Rainwater Harvesting in ancient India- Baoris/Bers

Baoris, also known as bers/Vav/Vavdi/Baoli/Bavadi, are community wells which are primarily used for drinking water purposes.

The majority of the Baoris were very ancient and constructed for the drinking water needs of banjaras (mobile trading communities). Because water evaporation is nearly non-existent, they can clutch water for an extended time.

Rainwater Harvesting in ancient India- Kere

In the Central Karnataka Plateau, tanks were the most common traditional irrigation method. These are known as Keres in Kannada.

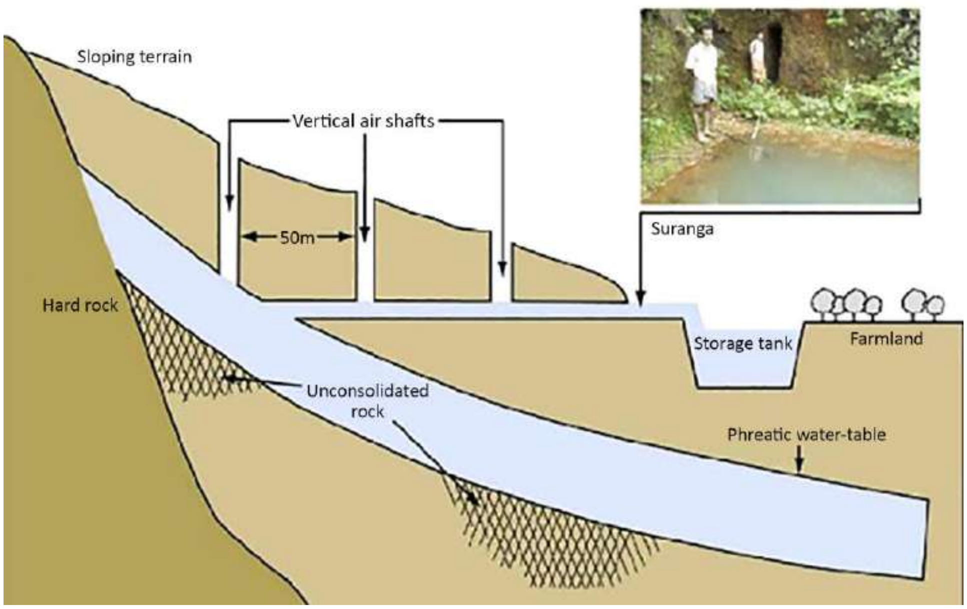
They were irrigated either by rivers in valleys or by channels that branched out from check dams constructed across streams.

The tanks were frequently constructed in succession and a few kilometers apart; excess flow from one tank fed the next. This ensured that discharge from a higher-ranking tank was collected in the lower-ranking tank and that no water was wasted due to overflow.

Rainwater Harvesting in ancient India- Surangam

In Kerala, northern Malabar area, the Kasaragod district is a site where surface water is scarce. Because of the terrain, rivers have during the monsoon, there is a high discharge, while during the dry months, and there is a low discharge.

The word surangam means tunnel. Surangams measure roughly 0.450.70 m in width and 1.82.0 m in height. The length ranges from 3 to 300 m.


Sloping terrain
Vertical air shafts
50m
Suranga
Hard rock
Storage tank
Farmland
Unconsolidated rock
Phreatic water-table

Rainwater Harvesting in ancient India

Eco-zone	Traditional water harvesting system	Salient feature	Location
1. Trans-Himalayan region	Zing	Tanks that use melted ice to collect water	Ladakh
2. Western Himalayas	Kul	Waterways in mountainous regions	Jammu, Himachal Pradesh
	Naula	Small pond	Uttaranchal
	Kuhl	To redirect water from a natural stream for irrigation, build a headwall across a ravine	Himachal Pradesh
	Khatri	Carved water storage chambers in hard rock	Himachal Pradesh

Eco-zone	Traditional water harvesting system	Salient feature	Location
3. E. Himalayas	Apatani	Interconnected by inlet and outlet channels are terraced parcels	Arunachal Pradesh
4. NE hill ranges	Zabo	Impounding runoff	Nagaland
	Cheo-oziihi	Channels from rivers	Nagaland
	Bamboo drip irrigation	Drip irrigation is used to bring water from streams in the highlands to the plains through bamboo pipes	Meghalaya
5. Brahmaputra valley	Dongs	Pond	Assam

Eco-zone	Traditional water harvesting system	Salient feature	Location
	Dungs/Jampois	Small irrigation canals linking rice fields and a stream	W. Bengal
6. Indo-Gangetic plain	Ahar-pynes	Embanked catchment basin and channel	S. Bihar
	Bengal's inundation channels	Inundation canal	W. Bengal
	Dighis	Canals from rivers feed a small square or circular reservoir	Delhi
	Baolis	Stepwell	Delhi
7. Thar desert	Kunds/Kundis	Underground storage	W. Rajasthan
	Kuis/Beris	Deep pits near tanks	W. Rajasthan

Eco-zone	Traditional water harvesting system	Salient feature	Location
	Baoris/Bers	Community well	Rajasthan
	Jhalaras	Tank	Rajasthan, Gujarat
	Nadi	Village pond	Jodhpur, Rajasthan
	Tankas	Underground tank	Bikaner, Rajasthan
	Khadins	Embankment across lower hill slopes	Jaisalmer, W. Rajasthan
	Vav/Vavdi/Baoli/ Bavadi	Step well	Gujarat, Rajasthan

Eco-zone	Traditional water harvesting system	Salient feature	Location
	Virdas	Shallow well	Rann of Kutch, Gujarat
	Paar	Area where water has percolated, accessed by kuis	–
8. Central highlands	Talab/Bandhis	Reservoir	Bundelkhand, Madhya Pradesh
	Saza Kuva	Open well	Mewar, E. Rajasthan
	Johad	Earthen check dam	Alwar district, Rajasthan
	Naada/bandh	Stone check dam	Mewar, Thar desert
	Pat	Diversion bund across stream	Jhabua district, Madhya Pradesh

Eco-zone	Traditional water harvesting system	Salient feature	Location
	Rapat	Percolation tank	Rajasthan
	Chandela tank	Tank	Rajasthan
	Bundela tank	Tank	Rajasthan
9. Eastern highlands	Katas/Mundas/ Bandhas	Earthen embankments across drainage lines	Orissa and Madhya Pradesh
10. Deccan plateau	Cheruvu	Reservoir to store runoff	Chitoor, Cuddapah districts, Andhra Pradesh
	Kohli tank	Tank	Maharashtra

Eco-zone	Traditional water harvesting system	Salient feature	Location
	Bhandara	Check dam	Maharashtra
	Phad	Check dam and canal	NW Maharashtra
	Kere	Series of tanks	Central Karnataka
	Ramtek Model	Surface and underground canals connect a complex network of groundwater and surface waterbodies	Ramtek, Maharashtra
11. Western Ghats	Surangam	Horizontal well	Kasaragod, Kerala
12. Western coastal plains	Virda	Shallow well	Rann of Kutch, Gujarat

Eco-zone	Traditional water harvesting system	Salient feature	Location
13. Eastern Ghats	Korambu	Temporary wall of brushwood, grass and mud laid across channels to raise the level of water	Kerala
14. Eastern coastal plains	Yeri	Tank	Tamilnadu
	Ooranis	Pond	Tamilnadu
15. The Islands	Jack wells	Bamboo pipes are used to lead water into shallow pits	Great Nicobar Island