6 Hydrogeology

Introduction :

Hydrogeology, is a branch of geology dealing with the study of groundwater, its occurrence and movement. It is therefore often referred to as groundwater hydrology, geohydrology or hydrogeology.

Groundwater is extremely important for the existence of humans, as it is the major source of drinking water. It is also an important source for the agricultural and industrial sector all around the globe. About 50% of water required for drinking as well as domestic, agricultural and industrial purposes comes from groundwater. Groundwater is an integral part of hydrological cycle and its availability depends on the rainfall and recharge conditions. Although industrialization and urban growth have started contaminating groundwater, it is still considered a dependable source of potable water.

Groundwater makes up about only 1% of the total water on the Earth. It occurs beneath the Earth's surface, but is usually restricted to depths less than about 750 meters. This water occurs in the pore spaces and fractures of rocks and sediments. It originates as rainfall or snow, and then moves down the soil into the groundwater system, and eventually makes its way back to the surface in the form of springs or streams.

Sources of Groundwater :

a) **Meteoric Water :** The main source of groundwater, which originates in the atmosphere and is received in the form of rain or snow. The downward entry of the water into the soils and rock surface is called infiltration. The flow of water through soil and porous or fractured rocks is known as percolation. Groundwater can also be derived directly from atmospheric moisture by condensation of water vapour from air circulating through the pores and interstices. This is also known as 'condensational water' and is known to replenish the water table in arid and semi-arid areas.

b) **Connate Water :** It is another important source of groundwater that is contained in pores and cavities of sedimentary rocks. It is entrapped in the interstices of sedimentary rocks at the time of deposition. Generally it is highly mineralized and salty and does not mix readily with meteoric groundwater.

c) **Magmatic Water :** Hot magma contains considerable amount of gases and water vapours. The water vapours on condensation are converted into groundwater called magmatic water. It is also called juvenile water. Such water is considered to have been generated in the interior of the Earth.

Vertical distribution of Groundwater :

Water occurs underground in two zones separated by water table. The level beneath which all the pore spaces in the rocks are filled with water is known as water table (fig. 6.1). The zone extending from the water table to an impermeable layer is called saturated zone, wherein all voids are completely filled with water. In this zone, water is held at a pressure greater than the atmospheric pressure, and hence it moves in a direction based on the continuous hydraulic situation. The zone between the ground surface and the top of capillary fringe is called unsaturated zone (zone of aeration) which consists of voids (pores or interstices) partially filled with water and partially with air. Water is held at a pressure less than the atmospheric pressure in the unsaturated zone. Zone between bottom of the unsaturated zone and top of the water table is called capillary zone, wherein most voids are filled with water but the water is held at a pressure less than the atmospheric pressure.

The unsaturated zone can be further sub-divided into 'soil-water zone' and 'intermediate zone' (fig. 6.1). This zone between the ground surface and the top of water table is known as the vadose zone and is part of the unsaturated zone and capillary zone (also known as 'capillary fringe'). Water present in the vadose zone is called vadose water, and is held at a pressure less than the atmospheric pressure. The term vadose zone is technically more appropriate than the conventional term of unsaturated zone because portions of the vadose zone may actually be saturated, even though the pressure of water is below the atmospheric pressure.

Broadly speaking, the water stored in the zone of saturation is called as groundwater. However, not all underground water is groundwater, rather only free water or gravitational water (the water that moves freely under the force of gravity into wells) constitutes the groundwater. Therefore, a practical explanation of groundwater as given by Bouwer in 1978 is: "Groundwater is that portion of the water beneath the Earth's surface, which can be collected through wells, tunnels, or drainage galleries, or which flows naturally to the Earth's surface via seeps or springs".

Inter-granular spaces vary widely in terms of size. Minute voids between the component particles of clay, shale and slate may feature on one end, while large spaces between the pebbles of well-sorted and unconsolidated valley gravel may feature on the other end of the spectrum. Massive spaces are those that occur between large blocks of rocks such as fractures, joints and bedding planes sometimes enlarged by the process of solution.

Capillary interstices or spaces are those that are small enough to hold surface tension forces (fig. 6.1). They can be further classified into two types; namely super capillary and sub-capillary. The former is large and may sometimes be as large as a limestone cave. The latter is very small and water is held in them mainly by molecular forces.

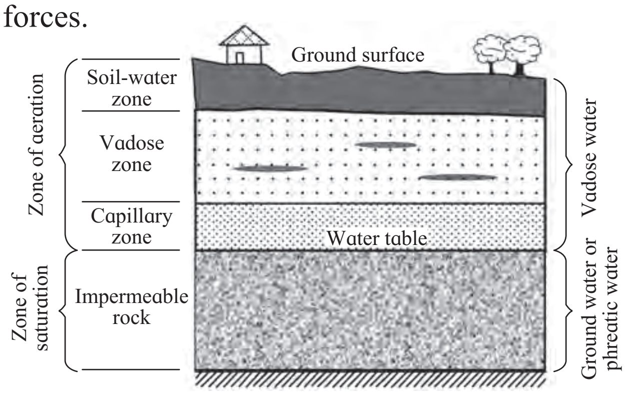


Fig. 6.1 : Vertical distribution of groundwater

Hydrological properties of rocks :

a) Porosity :

Porosity of a rock is its property to possess open spaces or interstices (fig. 6.2. a) like voids, fractures, cracks, joints, crevices etc. Porosity is the ratio of the volume of void space to the total volume of the rock or Earth material. It is the voids or openings of the rock or soil and is sometimes expressed as a percentage. Effective porosity is the void volume that contributes to water movement and is roughly equivalent to specific yield. Specific yield is the ratio of volume of the water that a saturated rock as soil will yield by gravity to the total volume of the rock or soil. It is usually expressed in percentage. Porosity is an indication of the amount of water in the subsurface, but does not equate to the volume that can be released from storage.

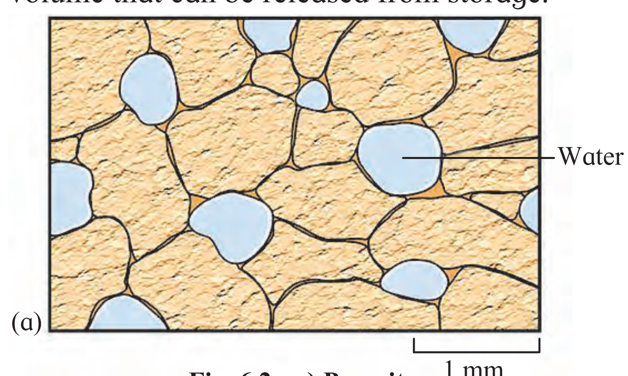


Fig. 6.2 : a) Porasity

When the pores are formed during the formation of rocks, like pore spaces produced by the process of sedimentation, it is called as primary porosity (e.g. porosity in sandstone). When the pores or fractures are formed due to external Earth processes, after the formation of the rocks it is called as secondary porosity (e.g. vesicles in basalts).

b) Permeability :

The capacity of water bearing formation to transmit water is called permeability (fig. 6.2. b). Thus it is the ease with which a fluid can pass through a porous medium. It is the volume of fluid discharged from a unit area of an aquifer under unit hydraulic gradient in unit time.

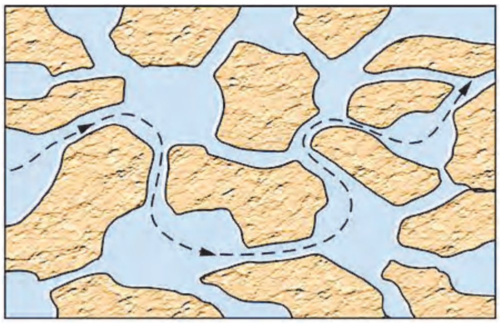


Fig. 6.2 : b) Permeability

Aquifers :

An aquifer is a rock formation of porous material. It has considerable porosity and permeability with sufficient volume to yield appreciable quantities of water.

Characteristics of Aquifers :

An aquiclude, is a rock formation which is porous enough to hold sufficient quantity of water, but does not allow an easy and quick flow through it (e.g. clay). An aquifuge is an impermeable rock formation through which there is no possibility of storage or movement of water (e.g. compact granite). An aquitard is a rock formation which permits the flow of water but does not yield sufficient quantity of water when compared to an aquifer (e.g. sandy clay). Aquifers can be classified into four kinds :

a) Unconfined Aquifer : An aquifer which has an impermeable layer at its base is called an unconfined aquifer (fig. 6.3). It is necessarily exposed to the atmosphere and its upper portion is partly saturated with water. The upper surface of saturation is called water table which is under atmospheric pressure. Therefore this aquifer is also called phreatic aquifer.

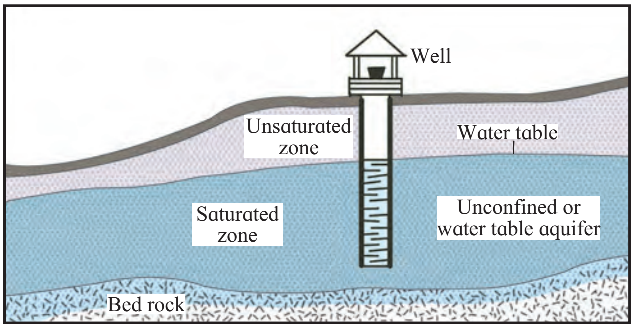


Fig. 6.3 : Unconfined Aquifer

b) Perched Aquifer : It is a special case of an unconfined aquifer. This type of aquifer occurs when an impermeable or relatively impermeable layer of limited area in the form of a lens is located in the water bearing unconfined aquifer. As shown in following (fig. 6.4) the water storage created above the lens is perched aquifer and its top layer is called perched water table.

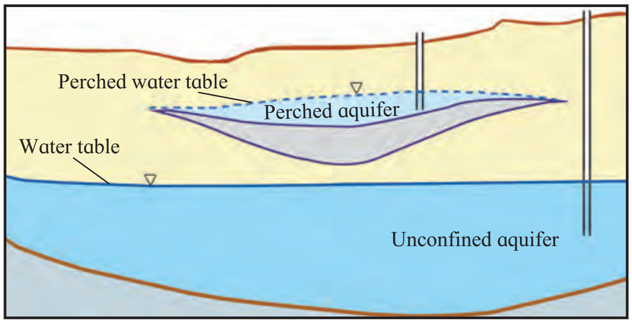


Fig. 6.4 : Perched Aquifer

c) Confined Aquifer : It is also called an artesian aquifer. It is overlain as well as underlain by confining layers. The water within the aquifer is therefore, held under pressure greater than atmospheric pressure. A well intersecting such an aquifer will yield water without pumping. The imaginary level up to which the water will rise is called piezometric surface (fig. 6.5).

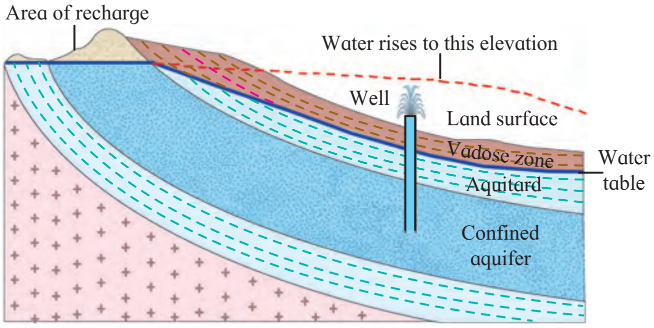


Fig. 6.5 : Confined Aquifer

d) Leaky Aquifer : An aquifer which is overlain or underlain by semi-pervious layer through which leakage of water takes place is called as leaky aquifer.

Do you know?

Artesian is a term originally applied to boreholes in Artois in France from which a constant supply of water was obtained because groundwater spontaneously discharged from them. It is suspected that the term was then applied to confined aquifers into which a number of artesian boreholes had been sunk. The term artesian aquifer is probably a misnomer and the term confined aquifer should rather be used.

Conservation and Management of Groundwater :

Water conservation includes all the policies, strategies and activities to sustainably manage the natural resources of fresh water, to meet the current and future human demand. Water conservation is the practice of using water efficiently to reduce unnecessary water usage. It is important because fresh clean water is a limited resource.

Groundwater management should include objectives of renewability (replenishment, recharge) of the resources, practical exploitation and rational consumption. Rainwater harvesting is one easy and affordable method of groundwater replenishment and recharge.

Methods of Rainwater Harvesting :

Broadly there are two ways of harvesting rainwater.

A) Rooftop Rainwater Harvesting : It is the technique through which rainwater is collected from the roof of the house or building. The collected water can either be stored in a tank or diverted to artificial recharge system. This method is less expensive and very effective in augmenting the groundwater level of the area. The augmented resource can be harvested at the time of need.

Methods of Roof Top Rain Water harvesting:

i) Recharge pit : A recharge pit is the most popular method for artificially recharging of aquifers. This technique is favourable for recharging shallow aquifers and where permeable strata permits infiltration of water. The pitcan be of any shape and size but generally it is 1 to 2m wide and 2 to 3 m deep. The excavated recharge pit is backfilled with boulders of 5-20 cm size at bottom, gravels of 5-10 mm size in between and coarse sand of 1.5-2 mm size at the top (fig. 6.6).

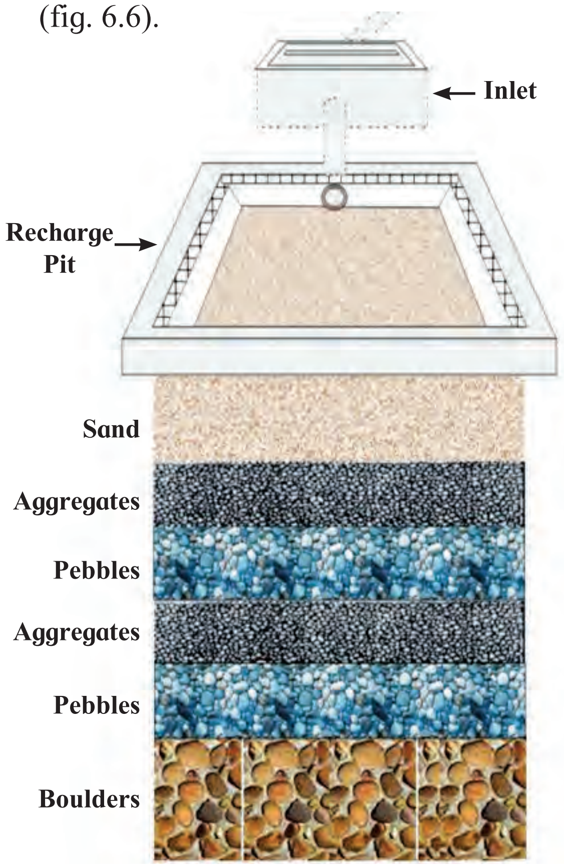


Fig. 6.6 : Recharge pit

A mesh must be provided on the top of the pit to prevent the solid material from entering it. Another mesh should be provided between the sand and gravel layer to avoid the sand from escaping towards the bottom. Periodically the sand layer must be cleaned for maintaining the rate of recharge.

ii) Recharge trench : A recharge trench is excavated on the ground for harvesting runoff water. this may vary in size depending upon the amount of runoff water. Generally it is 0.5 to 1 m wide, 1 to 1.5 m deep and 10 to 20 m long. It is then filled with boulders of 5 - 20 cm size at the bottom, gravels of 5 - 10 mm size in between and coarse sand of 1.5 – 2 mm size at the top. A bore well can be provided inside the trench to enhance the percolation of water (fig. 6.7).

Solid material must be prevented from entering the pit. This can be done by using a mesh on the top. Another mesh should be placed in between the sand and gravel layer in order to prevent the sand from escaping towards the bottom. Rate of recharge can be maintained by periodically cleaning the sand layer. First one or two showers are diverted from entering the recharge pit.

ii) Recharge Tube wells : This recharge method is applicable to existing tube wells which tap less amount of water. Roof water is collected with the help of PVC pipes

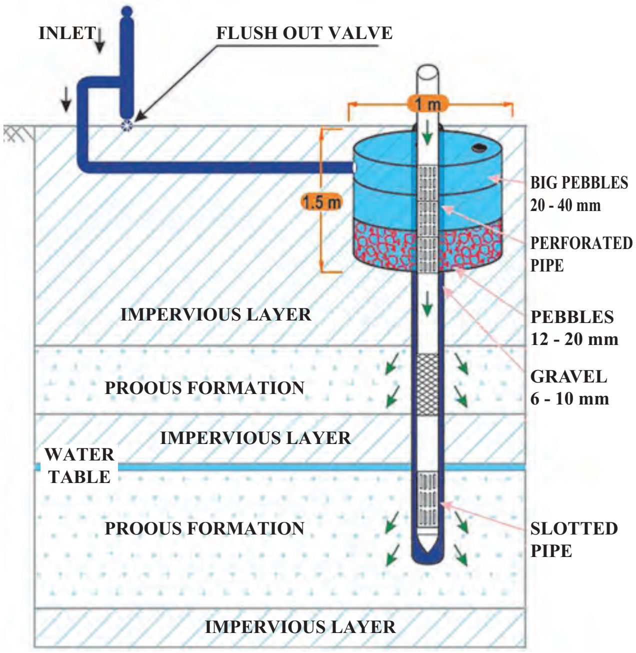
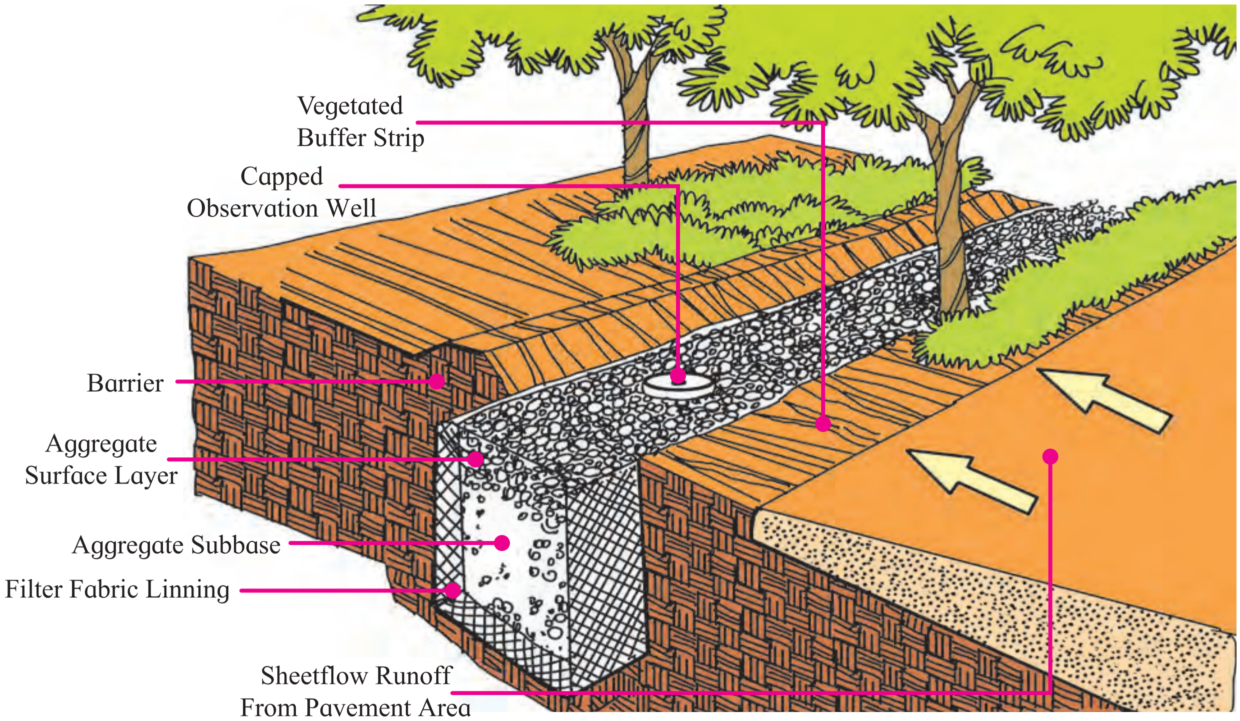


Fig. 6.8 : Recharge Tube Well



Credit and Source: https://www.buildinggreen.com/feature/stormwater-management-environmentally-sound-approaches

Fig. 6.7 : Recharge Trench

Diameter of the filter may vary depending on the roof area. The filter is divided into three chambers. First chamber is filled with gravel of 6 – 10 mm size, middle chamber with pebbles of 12 – 20 mm size and last chamber with bigger pebbles of 20 – 40 mm size (fig. 6.8).

B) Surface runoff harvesting : Surface runoff water harvesting is the collection, accumulation, treatment or purification, and storing of storm water for its eventual reuse. It can also include other catchment areas from manmade surfaces, such as roads, or other urban environments such as parks, gardens and playing fields. Surface runoff (also known as overland flow) is the flow of water that occurs when excess storm water, meltwater, or other sources flow over the Earth's surface. This can occur when the soil is saturated to full capacity, and additional precipitation is greater than the soil absorption capacity. Surface runoff often occurs because impervious areas (such as roofs and pavement) do not allow water to soak into the ground. It is the primary agent of soil erosion by water. The land area producing runoff that drains to a common point is called a drainage basin.

Surface runoff in urban areas is a primary cause of urban flooding, which can result in property damage and street flooding. In urban areas rainwater flows away as surface runoff. This runoff may be used for recharging aquifers by adopting appropriate methods.

Methods of Surface Rain Water Harvesting :

i) Gully Plug : They are built across small gullies. They are built with stones and soil. Gully plugs lowers the speed of water flow, prevents soil erosion and keeps soil moisture. It passes water through it but stops soil flowing through it (fig. 6.9).

Fig. 6.9 : Gully plug

ii) Contour Bund : It is constructed on land with moderate slopes. A line of stones is placed along the contour. This helps in reducing the runoff. The spacing between two contour bunds depend on the slope of the area. Contour bund also reduces soil erosion (fig. 6.10).

Fig. 6.10 : Stone contour bunding

iii) Check Dam : They are constructed across small streams having gentle slope. The purpose is to retain water upstream. Series of such check dams can be constructed to have recharge on regional scale (fig. 6.11).

Fig. 6.11 : Loose rock check dam

iv) Gabion Structure : This structure is a mesh of steel wires filled with rocks and anchored to the stream bank. This is constructed on small streams with width less than 10 m. The height of such structure is less than a meter (fig. 6.12).

Fig. 6.12 : Gabion dam on stream

v) Percolation Tank : Percolation tanks is a shallow tank which allows the excess waters to flow freely. The subsurface rock strata in the submergence area should be permeable to allow percolation with minimum evaporation losses. These are earthen dams and pitching with stones for the upstream wall reduces the damage of the tank wall (fig. 6.13). The purpose of the percolation tanks is to conserve the surface runoff and recharge the aquifers.

Fig.6.13 : Percolation tank

iv) Dugwell Recharge : The runoff water in the existing and abandoned dug wells is discharged through pipes. To avoid the sediments or silt from entering the dug wells, a desilting chamber or filter chamber is provided before the water discharge point. The desilting chamber or filter chamber is filled with pebbles, gravels and coarse sand. These chambers are periodically cleaned to maintain the efficiency (fig. 6.14).

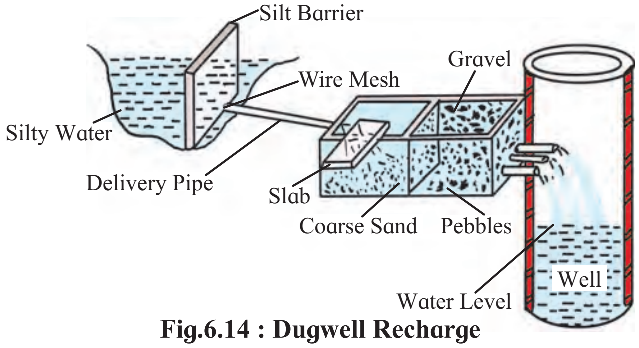


Fig.6.14 : Dugwell Recharge

Activity :

Calculating the quantity of water available from rooftop rainwater harvesting.

The quantity of the Rain water harvested (Q) can be calculated using the following formula :

Q = A X C X P

A = Area in Sq. meter

C = Is the Runoff Coefficient (decide the runoff coefficient according to the type of Roof from the Table 1)

P = Mean annual Rainfall in mm

Table 1. Runoff Coefficient for various types of catchments.

Sr. No.	Type of Catchment	Runoff Coefficient
	Roof Catchment	
1	Galvanised Iron Sheet	0.90
2	Asbestos Sheet	0.80
3	Tiled Roof	0.75
4	Concrete Roof	0.70
5	Organic (Thatched Roof	0.20
	Ground Surface Coverings	
6	Concrete, Asphalt	0.6 – 0.8
7	Brick Pavement	0.5 – 0.6
8	Hard Flat ground without Vegetation	0.25 – 0.75
9	Hard Flat ground with Vegetation	0.15 – 0.60

Example :

For a building with a concrete roof of size 10 m X 12 m (120 sq. meter) in a city with average annual rainfall of 900 mm, the quantity of rainwater that can be harvested in a year is

Q = 120 sq. meter X 900 mm X 0.70 = 75600 litres/year

Watershed management :

Watershed management is the study of the relevant characteristics of a watershed aimed at the sustainable distribution of its resources. It involves the processes of creating and implementing plans, programs, and projects to sustain and enhance watershed functions that affect the plant, animal, and human communities.

Watershed is a geo-hydrological unit draining to a common point by a system of natural drains. It is an area of land and water bound by a drainage divide within which the surface runoff collects and flows out of the watershed through a single outlet into a larger river or lake.

A) Types of Watershed :

Watersheds is classified depending upon the size, drainage, shape and land use pattern.

- Macro watershed (> 50,000 Hectare)
- Sub-watershed (10,000 to 50,000 Hectare)
- Milli-watershed (1000 to10000 Hectare)
- Micro watershed (100 to 1000 Hectare)
- Mini watershed (1-100 Hectare)

B) Objectives of watershed management :

The different objectives of watershed management programmes are :

1) Enhance the groundwater recharge, wherever applicable.
2) Check soil erosion and reduce the effect of sediment loss in the watershed.
3) Control excessive runoff and degradation thereby conserving soil and water.
4) Manage and utilize runoff water for useful purposes.
5) Conserve and improve watershed land for more efficient and sustained production.
6) Rehabilitate the deteriorating lands.
7) Moderate floods in downstream areas.
8) Increase infiltration of rainwater.

Do you know?

Water Audit

A water audit is an accounting procedure that monitors where and how much water enters and leaves a water system. This allows the assessment of current usage, provides data needed to reduce water and revenue losses, and allows forecasts of future water needs. The principal purpose of a water audit is to accurately determine the amount of un-accounted water in a water system, which includes water loss through leakages, etc.

Conducting a Household Water Audit :

A household water audit is an assessment of how much water is used and how much water can be saved in a household. Conducting a water audit involves calculating water use for different activities and identifying simple ways for saving water in a household.

Benefits of conducting a Water Audit :

Conducting a water audit can help you protect your water supply and the community's aquifer. Conducting a water audit will make you aware of how you use your water and help to identify ways you can minimize water use by implementing certain conservation measures. It is possible to cut your water usage by as much as 20 to 40 percent by implementing simple conservation measures and without drastically modifying your lifestyle.

Summary :

A basic knowledge of hydrogeology is essential for the geologist or civil engineer engaged in the development, utilization and management of water resources. It helps assessing the quantity of water available for domestic consumption, industrial usage, agriculture, hydro-electricity generation and other developmental works. Knowledge of hydrogeology is also required for the design of large and small water storage/ percolation structures such as dams and weirs.

In a world that today consumes more water than what is sustainable, the role of water conservation and management assumes utmost importance.

A watershed, affects the people in every sphere of life. The sustained productivity of food, fuel, forage, fibre, fruit and water by the management of vital resources of water, soil and vegetation and phenomena like floods and droughts are determined by the nature of watershed functioning.

EXERCISE

Q. 1. Choose the correct alternative :

1) Hydrogeology is often referred to as groundwater hydrology, geohydrology or hydrogeology
   a) groundwater hydrology, geohydrology or hydraulics
   b) groundwater hydrology, geohydrology or hydrogeology
   c) underground water hydraulics, groundwater hydrology or geohydrology
   d) groundwater hydraulics, geohydrology or hydrogeology

2) .... is the main source of groundwater, which originates in the atmosphere and is received in the form of rain or snow.
   a) Volcanic water b) Magmatic water
   c) Meteoric water d) Artesian water

3) The zone between the ground surface and the top of capillary fringe is called
   a) saturated zone b) zone of aeration
   c) supersaturated zone d) 'o' zone

4) Porosity is the ratio of the
   a) volume of solid soil to the total volume of the rock forming the soil material.
   b) volume of void space to the total volume of the soil or organic material in the aquifer.
   c) volume of void space to the total volume of the rock or Earth material.
   d) volume of solid space to the total density of the rock or Earth material.

5) The capacity of water bearing formation to transmit water is called
   a) Porosity b) Hydraulic constant
   c) Permeability d) Aquaclude

6) An unconfined aquifer is also called a
   a) Phreatic aquifer b) Artesian aquifer
   c) Compact aquifer d) Perched aquifer

7) Is not a method of rooftop rainwater harvesting
   a) Recharge pit b) Recharge trench
   c) Recharge tubewell d) Recharge gabion

8) They are constructed across small streams having gentle slope, for surface rain water harvesting:
   a) Gabions b) Contour trenches
   c) Percolation trenches d) Check dams

9) Gully plug
   a) Allows the passage of water through it but stops soil flowing through it.
   b) Allows the passage of soil through it but stops water flowing through it
   c) Allows the passage of soil through it but stops silt passing through it
   d) Stops the passage of water through it but allows to flow soil through it

10) A roof top rain water recharge pit is filled from bottom to top in this sequence:

   a) 40 mm gravel, 20mm pebbles, Coarse sand

   b) Coarse Sand, 20mm pebbles, 40mm gravel

   c) 20mm pebbles, 40mm gravel, 60mm large cobbles

   d) Fine sand, 40mm pebbles, 60mm large gravel

Q. 2. Very Short Answers :

1) Explain the term 'Aquifer'
2) Define the term 'Aquitard'
3) What constitutes an 'Aquifuge'
4) Explain the term 'Aquiclude'

Q. 3. Short Answers :

1) What is meteoric water?
2) What are the characteristics of a good aquifer?
3) What are the characteristics of the vadose zone?

Q. 4. Short Answers :

1) Explain the terms Porosity and Permeability.
2) 'Generally, a sandstone is more porous than basalt'- Explain.
3) 'A porous rock is not always a good aquifer' – Explain.

Q. 5. Long Answers :

1) Explain with illustrations the various methods of roof-top rainwater harvesting.
2) What is a 'Watershed'? What are the objectives of watershed management?
3) Why is watershed management the need of the hour? Explain in context to the present day drought scenario in central Maharashtra.
4) What is the need of surface runoff harvesting? Why is it important to implement it in our rural areas?
5) What are the rainwater harvesting methods you would recommend in an urban area where most of the land area is under built-up land.