Components of Rainwater harvesting

Rainwater Harvesting

Water has been harvested since antiquity, with our ancestors perfecting the art of water management. To address the challenges of water security in the new millenium, a mixture of traditional wisdom and new techniques must be employed. Various methods of rainwater harvesting are described in this section.

1. Surface runoff harvesting

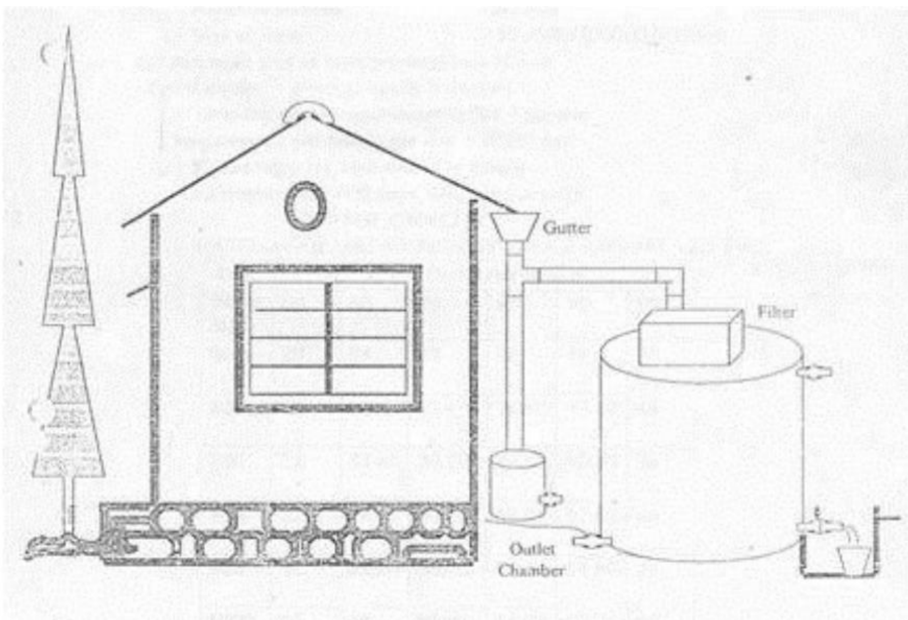
In urban area rainwater flows away as surface runoff. This runoff could be caught and used for recharging aquifers by adopting appropriate methods.

2. Roof Top rainwater harvesting

It is a system of catching rainwater where it falls. In rooftop harvesting, the roof becomes the catchments, and the rainwater is collected from the roof of the house/building. It can either be stored in a tank or diverted to artificial recharge system. This method is less expensive and very effective and if implemented properly helps in augmenting the ground water level of the area.

2.1 Components of the roof top rainwater harvesting

The illustrative design of the basic components of roof top rainwater harvesting system is given in the typical schematic diagram shown in Fig.



Components of Rainwater harvesting

The system mainly constitutes of following sub components:

i)Catchments ii) Transportation iii) First flush iv) Filter

Catchments

The surface that receives rainfall directly is the catchment of rainwater harvesting system. It may be terrace, courtyard, or paved or unpaved open ground. The terrace may be flat RCC/stone roof or sloping roof. Therefore the catchment is the area, which actually contributes rainwater to the harvesting system.

Transportation

Rainwater from rooftop should be carried through down take water pipes or drains to storage/harvesting system. Water pipes should be UV resistant (ISI HDPE/PVC pipes) of required capacity. Water from sloping roofs could be caught through gutters and down take pipe. At terraces, mouth of the each drain should have wire mesh to restrict floating material.

First Flush

First flush is a device used to flush off the water received in first shower. The first shower of rains needs to be flushed-off to avoid contaminating storable/rechargeable water by the probable contaminants of the atmosphere and the catchment roof. It will also help in cleaning of silt and other material deposited on roof during dry seasons Provisions of first rain separator should be made at outlet of each drainpipe.

Filter

There is always some skepticism regarding Roof Top Rainwater Harvesting since doubts are raised that rainwater may contaminate groundwater. There is remote possibility of this fear coming true if proper filter mechanism is not adopted. Secondly all care must be taken to see that underground sewer drains are not punctured and no leakage is taking place in close vicinity. Filters are used fro treatment of water to effectively remove turbidity, colour and microorganisms. After first flushing of rainfall, water should pass through filters. A gravel, sand and 'netlon' mesh filter is designed and placed on top of the storage tank. This filter is very important in keeping the rainwater in the storage tank clean. It removes silt, dust, leaves and other organic matter from entering the storage tank. The filter media should be cleaned daily after every rainfall event. Clogged filters prevent rainwater from easily entering the storage tank and the filter may overflow. The sand or gravel media should be taken out and washed before it is replaced in the filter.

Photograph of typical filter

There are different types of filters in practice, but basic function is to purify water. Different types of filters are described in this section.

a) Sand Gravel Filter

These are commonly used filters, constructed by brick masonry and filleted by pebbles, gravel, and sand as shown in the figure. Each layer should be separated by wire mesh. A typical figure of Sand Gravel Filter is shown in Fig.

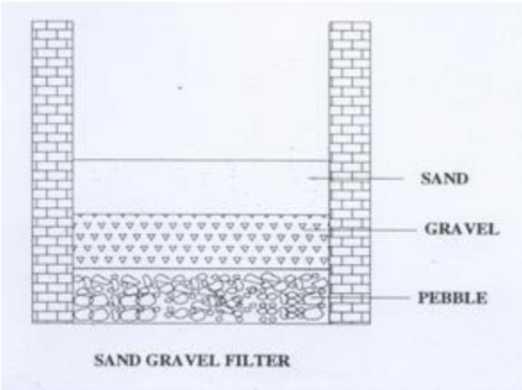


Fig. Sand Gravel Filter

Charcoal Filter

Charcoal filter can be made in-situ or in a drum. Pebbles, gravel, sand and charcoal as shown in the figure should fill the drum or chamber. Each layer should be separated by wire mesh. Thin layer of charcoal is used to absorb odor if any. A schematic diagram of Charcoal filter is indicated in Fig .

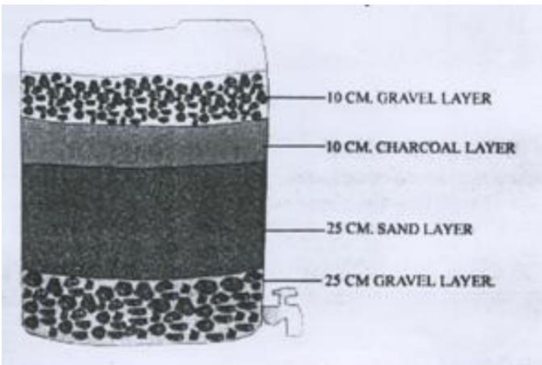


Fig Charcoal Filter

PVC –Pipe filter

This filter can be made by PVC pipe of 1 to 1.20 m length; Diameter of pipe depends on the area of roof. Six inches dia. pipe is enough for a 1500 Sq. Ft. roof and 8 inches dia. pipe should be used for roofs more then 1500 Sq. Ft. Pipe is divided into three compartments by wire mesh. Each component should be filled with gravel and sand alternatively as shown in the figure. A layer of charcoal could also be inserted between two layers. Both ends of filter should have reduce of required size to connect inlet and outlet. This filter could be placed horizontally or vertically in the system. A schematic pipe filter is shown in Fig .

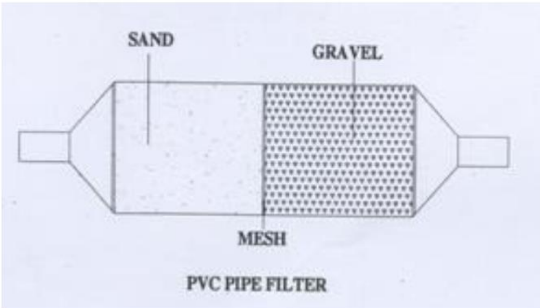


Fig : PVC-Pipe filter

Sponge Filter

It is a simple filter made from PVC drum having a layer of sponge in the middle of drum. It is the easiest and cheapest form filter, suitable for residential units. A typical figure of sponge filter is shown in Fig .

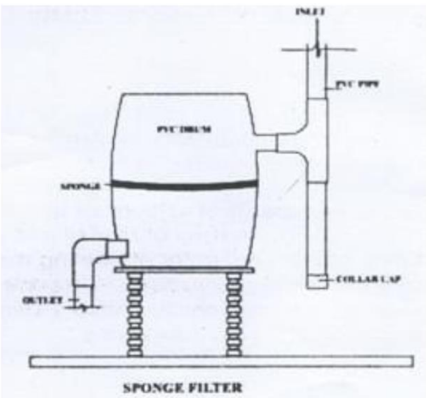


Fig : Sponge Filter

Methods of roof top rainwater harvesting

Various methods of using roof top rainwater harvesting are illustrated in this section.

a) Storage of Direct Use

In this method rain water collected from the roof of the building is diverted to a storage tank. The storage tank has to be designed according to the water requirements, rainfall and catchment availability. Each drainpipe should have mesh filter at mouth and first flush device followed by filtration system before connecting to the storage tank. It is advisable that each tank should have excess water over flow system.

Excess water could be diverted to recharge system. Water from storage tank can be used for secondary purposes such as washing and gardening etc. This is the most cost effective way of rainwater harvesting. The main advantage of collecting and using the rainwater during rainy season is not only to save water from conventional sources, but also to save energy incurred on transportation and distribution of water at the doorstep. This also conserves groundwater, if it is being extracted to meet the demand when rains are on.

b) Recharging ground water aquifers

Ground water aquifers can be recharged by various kinds of structures to ensure percolation of rainwater in the ground instead of draining away from the surface. Commonly used recharging methods are:-

a) Recharging of bore wells

b) Recharging of dug wells.

c) Recharge pits

d) Recharge Trenches

e) Soak ways or Recharge Shafts

f) Percolation Tanks

Recharging of bore wells

Rainwater collected from rooftop of the building is diverted through drainpipes to settlement or filtration tank. After settlement filtered water is diverted to bore wells to recharge deep aquifers. Abandoned bore wells can also be used for recharge.

Optimum capacity of settlement tank/filtration tank can be designed on the basis of area of catchement, intensity of rainfall and recharge rate. While recharging, entry of floating matter and silt should be restricted because it may clog the recharge structure. First one or two shower should be flushed out through rain separator to avoid contamination. A schematic diagram of filtration tank recharging to bore well is indicated in Fig .

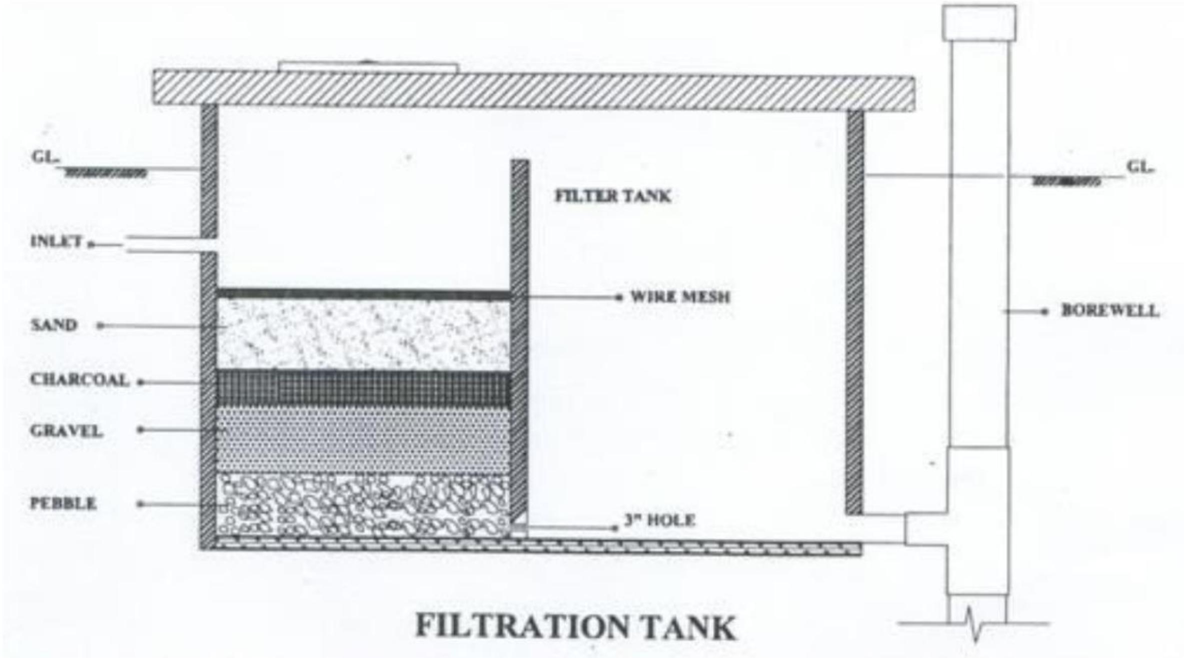


Fig :Filtration tank recharging to bore well

d)Recharge pits

Recharge pits are small pits of any shape rectangular, square or circular, contracted with brick or stone masonry wall with weep hole at regular intervals. Top of pit can be covered with perforated covers. Bottom of pit should be filled with filter media.

The capacity of the pit can be designed on the basis of catchment area, rainfall intensity and recharge rate of soil. Usually the dimensions of the pit may be of 1 to 2 m width and 2 to 3 m deep depending on the depth of pervious strata. These pits are suitable for recharging of shallow aquifers, and small houses. A schematic diagram of recharge pit is shown in Fig .

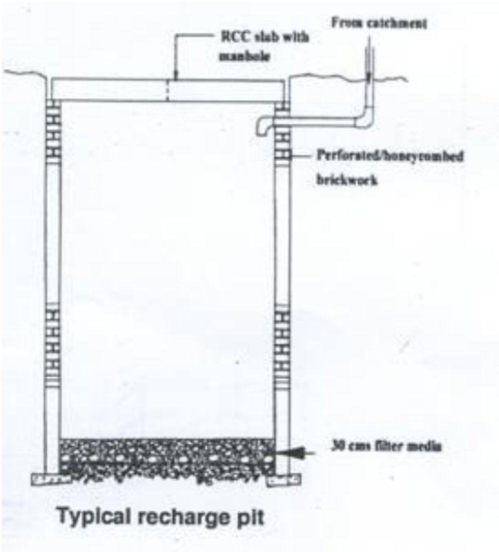


Fig: Recharge pit

e) Soak way or Recharge shafts

Soak away or recharge shafts are provided where upper layer of soil is alluvial or less pervious. These are bored hole of 30 cm dia. up to 10 to 15 m deep, depending on depth of pervious layer. Bore should be lined with slotted/perforated PVC/MS pipe to prevent collapse of the vertical sides. At the top of soak away required size sump is constructed to retain runoff before the filters through soak away. Sump should be filled with filter media. A schematic diagram of recharge shaft is shown in Fig .

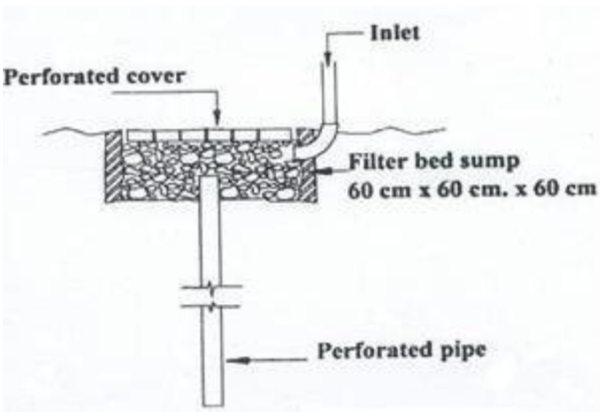


Fig : Schematic Diagram of Recharge shaft

f) Recharging of dug wells

Dug well can be used as recharge structure. Rainwater from the rooftop is diverted to dug wells after passing it through filtration bed. Cleaning and desalting of dug well should be done regularly to enhance the recharge rate. The filtration method suggested for bore well recharging could be used. A schematic diagram of recharging into dug well is indicated in Fig 11shown below.

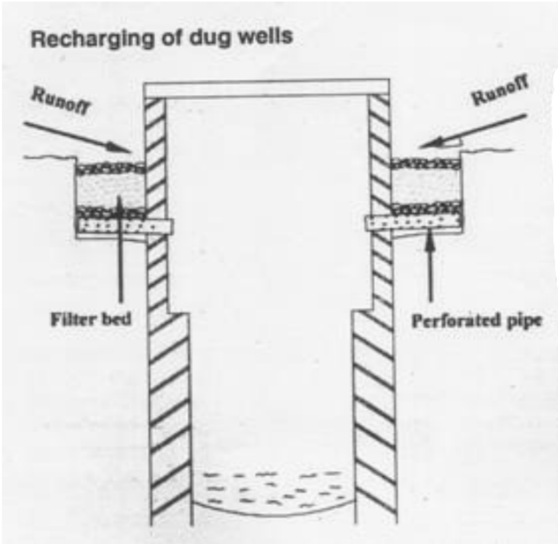


Fig : Schematic diagram of recharging to dug well

g)Recharge trenches

Recharge trench in provided where upper impervious layer of soil is shallow. It is a trench excavated on the ground and refilled with porous media like pebbles, boulder or brickbats. it is usually made for harvesting the surface runoff. Bore wells can also be provided inside the trench as recharge shafts to enhance percolation. The length of the trench is decided as per the amount of runoff expected. This method is suitable for small houses, playgrounds, parks and roadside drains. The recharge trench can be of size

0.50 to 1.0 m wide and 1.0 to 1.5 m deep. A schematic diagram of recharging to trenches is shown in Fig below .

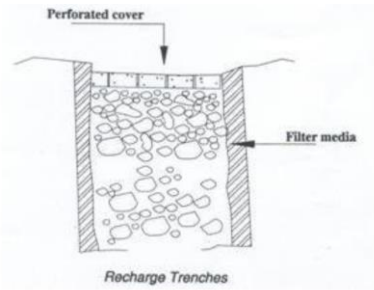


Fig : Recharging to trenches

h) Percolation tank

Percolation tanks are artificially created surface water bodies, submerging a land area with adequate permeability to facilitate sufficient percolation to recharge the ground water. These can be built in big campuses where land is available and topography is suitable.

Surface run-off and roof top water can be diverted to this tank. Water accumulating in the tank percolates in the solid to augment the ground water. The stored water can be used directly for gardening and raw use. Percolation tanks should be built in gardens, open spaces and roadside green belts of urban area.

WELL DESIGN

Wells may be dug, bored, driven, jetted or drilled. The drilled types are commonly referred to as boreholes. A well design involves selection of dimensions (depth/length, diameter) and type of the well (mode of construction), casing, screens (material) and of completion methods. The choice of water well and method of design depends upon topography, availability of space, hydrogeology, depth of groundwater table, rainfall, climate, quantity of water required and available funds.

Diameter

- ✓ significantly affects cost
- ✓ large enough to accommodate the proposed pump
- ✓ Well yield is not proportional to well diameter as can be seen from Theim's equation.

Depth

- o usually to the bottom of the aquifer
- o Because 'hard rock is intersected is not necessarily any reason to stop, as water fissures can be encountered after hard rock.
- o Poor quality aquifers encountered can be sealed to prevent contamination of good quality water.

Screen

- ✓ 70 – 80% of aquifer thickness is screened
- ✓ slot size is taken as 40 – 70% of the size of aquifer material 15

✓ material selected depends on quality of groundwater, strength requirement.

The screen material should be resistant to incrustation and corrosion and should have strength to withstand the column load and collapse pressure. Principal indicators of corrosive groundwater are low pH, presence of dissolved oxygen, CO2>50 ppm, Cl>500 ppm. Principal indicators of incrusting groundwater are total hardness > 330 ppm, iron content > 2 ppm, pH > 8. Mineral and slime deposits can be removed by chlorine and acid.

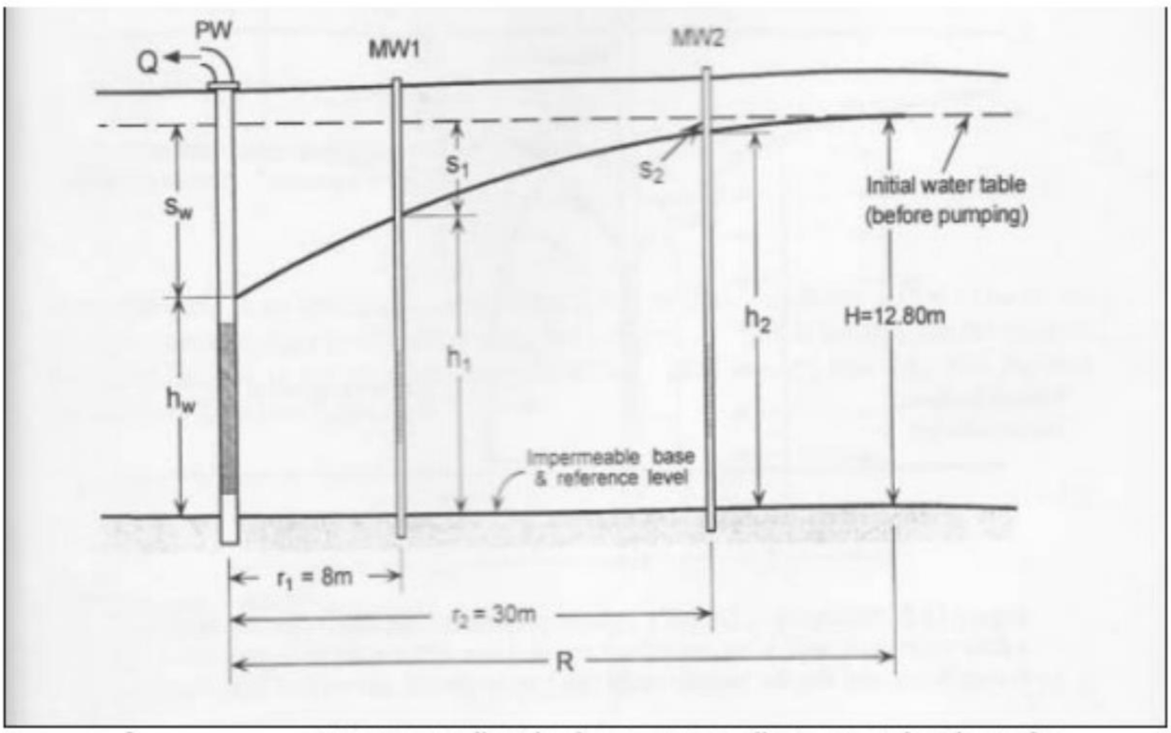
6. **Measurement of yield**

Pumping test

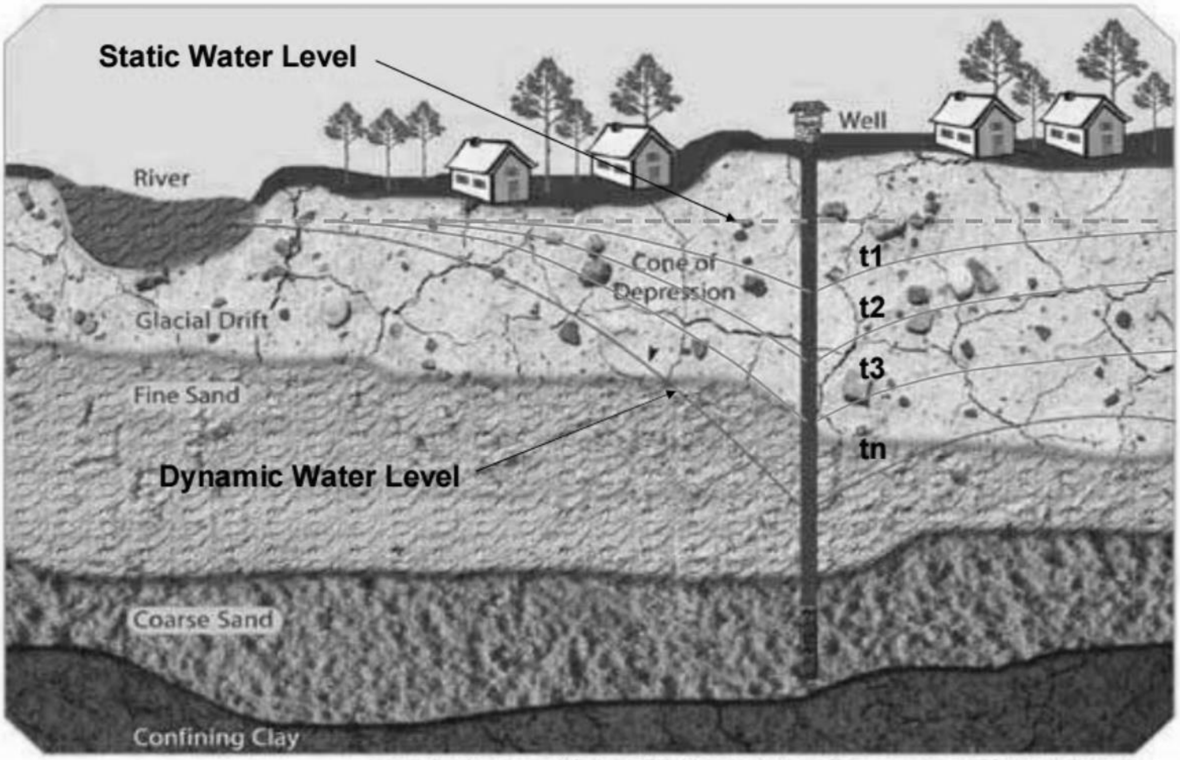
Pumping Test is the examination of aquifer response, under controlled conditions, to the abstraction of water. Pumping test can be well test (determine well yield and well efficiency), aquifer test(determine aquifer parameters and examine water chemistry). Hydrogeologists try to determine the most reliable values for the hydraulic characteristics of the geological formations.

The objectives of the pumping test are:

1. Determine well yield,
2. Determine well efficiency,
3. Determine aquifer parameters
4. Examine water chemistry

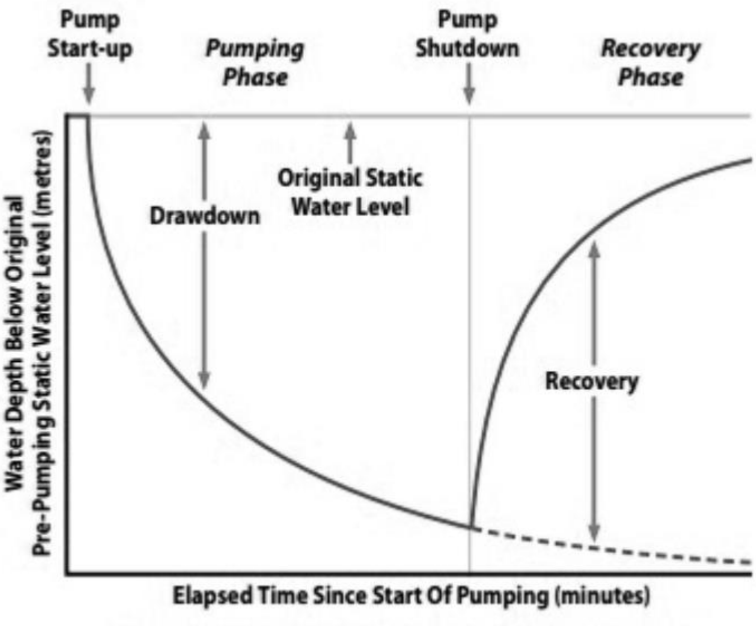


Pumping well with observation wells in unconfined aquifer



General notes about pumping test:

1. Pump testing is major investigative tool-but expensive.
2. Proper planning, observations, interpretation essential!
3. It is cheaper (much) if existing wells can be used.
4. Pump testing also carried out in newly constructed wells, as a well test.



Graph showing the different phases of a constant rate pumping test – the pumping phase and the recovery phase.

The principle of a pumping test involves applying a stress to an aquifer by extracting groundwater from a pumping well and measuring the aquifer response to that stress by monitoring drawdown as a function of time.

$$V = (\pi D^2/4) \times d$$

Rate of seepage in to the well = $(Qt - V)/t$
V = Volume of water stored in the well
D= Diameter of the well
d= Depth of water column
Q= Pumping rate

Pumping tests are carried out to determine:

1. How much groundwater can be extracted from a well based on long-term yield, and well efficiency?
2. The hydraulic properties of an aquifer or aquifers.
3. Spatial effects of pumping on the aquifer.
4. Determine the suitable depth of pump.
5. Information on water quality and its variability with time.

The methods of measurement are:

1 Water level

Dippers

Water Level Records

Data Loggers

2 Discharge

Orifice Plate

“V” Notch Weir

Flow Meter

Tank

Orifice Bucket

Recuperation test

Though constant level of pumping gives an accurate value of safe yield of an open well, it is sometimes very difficult to regulate the pump in such a way that constant level is maintained in the well. In such circumstance, a recuperation test can be performed to assess the aquifer parameters. In the recuperation test, water level is depressed to any level below the normal level h_1 and the pumping is stopped. The time taken (t) for the water to recuperate to the normal level h_2 is noted.

$C = (2.303/t)\log_{10}(h_1/h_2)$

$Q = CAH$

C = Specific yield of the well per unit cross sectional area per unit depression head

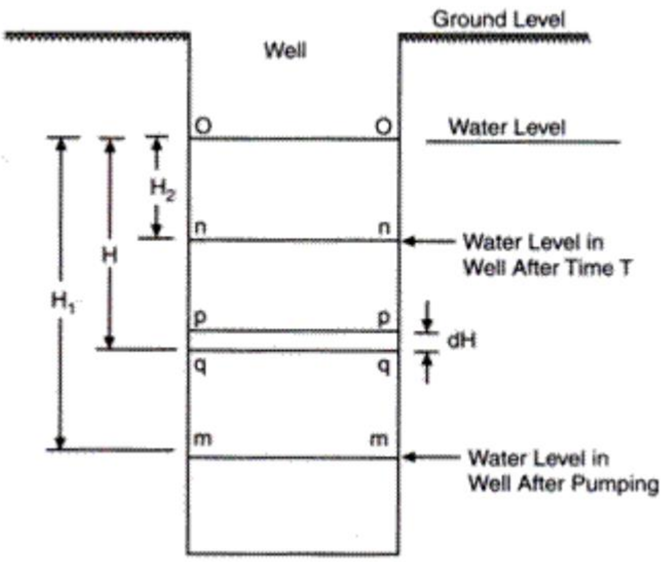
h_1 = water level after pumping stopped

h_2 = water level after time t

A= Cross sectional area of the well

H= Safe working depression head

Q= Pumping rate



O – O represents normal or original water level in the well.

m — m represents the water level in the well after pumping.

n – n represents the water level in the well at time T after stoppage of pumping.

q – q represents the water level in the well at any time t after stoppage of pumping.

p – p represents the water level in well at time t + dt after stoppage of pumping.

Tube wells and open wells

Borewells and Tubewells are very very similar.

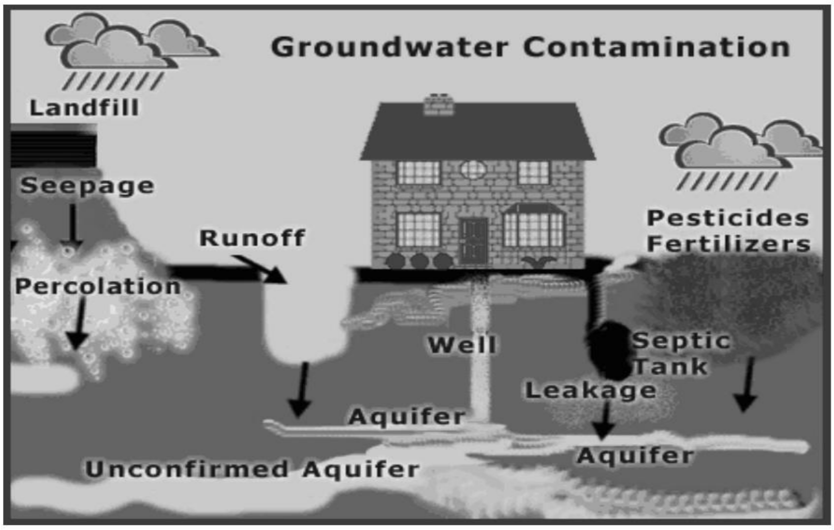
There are three basic difference between borewell and tube well :

- ✓ Casing: In case of bore well the casing is of PVC; in case of tube well casing is of Galvanized Iron.
- ✓ Bore well is usually used where there is a non collapsiblehardrock; tubewell is used where there is a collapsible soft rock or alluvial soil.
- ✓ Though tubewells and borewells both go deep; usually the tubewell casing goes far deeper; whereas borewell casing does not go completely into the bore hole and goes only until hardrock.

A bore well is drilled with casing pipe put only up to the soil-rock boundary and this is done normally for shallow depths in hard rock or in crystalline rock. But in a tube well, the casing pipes are put up to the bottom of the bore wells, with perforation in the pipes in some level. Normally the Tube wells are drilled in sand and gravel where the availability of water is much below the ground level.

Groundwater Pollution

GROUNDWATER POLLUTION May be defined as the artificially induced degradation of natural groundwater quality. Most pollution stems from disposal of wastes on or into the ground and the pollutants may be of organic (e.g. chlorinated phenoxy acid herbicides), inorganic (e.g. nitrate), biological (e.g. coliform bacteria), physical (colour) and radiological (e.g. barium) types.]



Methods of disposal of wastes include discharge in to the sea and streams, placement in percolation ponds, on the ground surface, (spreading or irrigation), in landfills, into disposal wells and into injection wells. Waste can be defined to be all undesirable or superfluous by-products, emissions, residues or remainders of any process or activity, whether gaseous, liquid or solid, or a combination of these. For practical reasons, material is taken to become waste when it is committed to storage (to last three months or longer) or leaves the site or enters the environment.

The principal sources of pollution include Municipal – sewer leakages, liquid and solid wastes Industrial – Mining activities, tank and pipeline leakage, oil field brines, liquid wastes Agriculture – Irrigation return flows, fertilizers, pesticides, animal wastes Miscellaneous – saline water intrusion, septic tank and cesspools, roadway deicing, interchange through wells. The sources can be point (singular location), line (with a liner alignment) or diffuse (occupying extensive areas) sources.

The aims of groundwater pollution investigation are varied, but may include

• Determination of the extent of pollution by quantifying the amount of pollutants

• Determination of the sources of possible pollutants to the groundwater regime

• Quantification of the contribution from different sources

• The study of the migration rate of the pollutants through the aquifers

• Model the local and regional movement of pollutants through the aquifer and predict future water qualities

• Suggestion of management strategies whereby the influence of disposal can be minimized. Remedial measures which can be used to prevent or reduce aquifer contamination include

• Surface water control increases runoff, reduces infiltration

• Groundwater control seals off lateral flow in shallow aquifers

• Plume management lower water table below contaminant scavenger wells to extract leachate injection to create hydraulic barrier

• Excavation physical removal of contaminant to safe site. The choice of which remedial measure is most appropriate or cost effective depends on :• extent of contamination

• Type of contaminant – is the contaminant “toxic or hazardous” material or a convectional pollutant.

•Whether the material is organic or inorganic

• How tightly bound the contaminant is to the soil.

•Hydrological setting The generator of hazardous waste should be liable for damage resulting from the disposal of hazardous waste.

REFERENCES AND FURTHER READING FOR STUDENTS

1. Chhandogya upanishad (the philosophical reflections of the vegas)
   Quote from - https://www.ancient.eu/article/1567/upanishads-summary--commentary/

2. Global water partnership (gwp) 2000

https://www.gwp.org/globalassets/global/toolbox/references/towards-water-security.-a-framework-for-action.-executive-summary-gwp-2000.pdf

3. United Nations Water Conference 1977

the report can be found here - https://digitallibrary.un.org/record/724642?ln=en

4. Engineering Hydrology – June 20, 2013 by Subramanya K

5. The relation of hydrographs of runoff to size and character of drainage-basins

LeRoy K. Sherman

6. Lohman, D. F. (1979). Spatial ability: A review and re-analysis of the correlational literature (Technical Report No. 8). Stanford, CA: Aptitudes Research Project, School of Education, Stanford University.

7. D. K. Todd 1980. Groundwater Hydrology

8. World Metrological Organization recomendations

https://public.wmo.int/en/resources/bulletin/guidelines