Urban Utilities Planning: Water Supply, Sanitation and Drainage
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Module - 12
Drainage and Recharge
Lecture - 57
Ground Water Recharge Part II

In lecture 57, Ground Water Recharge Part 2 will be covered.

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The different concepts that will be covered includes

- Artificial recharge techniques
- Surface spreading techniques
- Subsurface techniques
- Groundwater conservation techniques
- Rooftop rainwater collection and recharge of groundwater.

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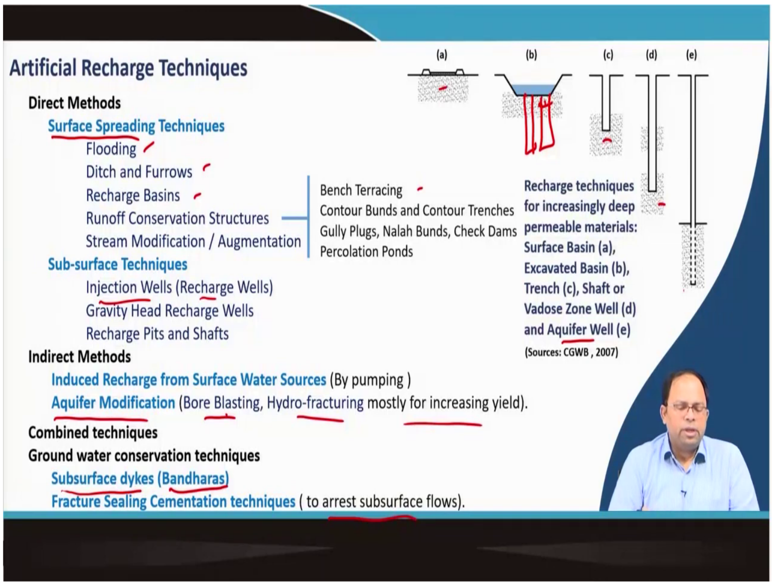
ARTIFICIAL RECHARGE TECHNIQUES



Artificial recharge techniques consists of direct methods and indirect methods.

Direct methods: involve techniques such as surface spreading techniques and sub surface techniques.

Surface spreading techniques: involves methods where water is spread on the surface. The techniques include flooding, ditch and furrows, recharge basins, runoff conservation structures and stream modification or augmentation. Bench terracing, contour bonds, gully plugs, nalah bunds, check dams percolation ponds etc. constitutes the various runoff conservation structures.

Subsurface techniques: involves processes where water is put in underground wells. It consists of structures such as Injection wells (Recharge wells), Gravity head recharge wells, Recharge pits and shafts. The different recharge techniques for increasingly deep permeable materials involves

- The surface basin which involves surface spreading
- Excavated basin

- Trenches
- Shafts or vadose zone well which is deeper and
- Aquifer well – which takes the recharge water at a lower level to reach the level of aquifers.

Indirect methods: Direct methods involve increasing the amount of water at a particular location whereas, in indirect methods, water is drawn from other locations by creating a hydraulic gradient by pumping. If water is pumped from an area continuously, a hydraulic gradient will get created and induce water to flow from surrounding areas through the soil pores. This method is called *Induced recharge* from surface water sources by pumping. There are other indirect methods such as *Aquifer modification* bore blasting or hydrofracturing is employed such that multiple aquifers are connected and water can be transferred from one to another. Yield is increased in this method.

Combined techniques: involves the use of both the surface spreading technique as well as the subsurface techniques. Example – Trench in an excavated basin

Groundwater conservation techniques: groundwater is retained with different structures such as subsurface dykes (similar to dams). Such underground structures are known as bandharas. Another groundwater conservation technique involves the fracture sealing cementation techniques which involve the sealing of fractures and preventing subsurface flows.

Surface Spreading Techniques

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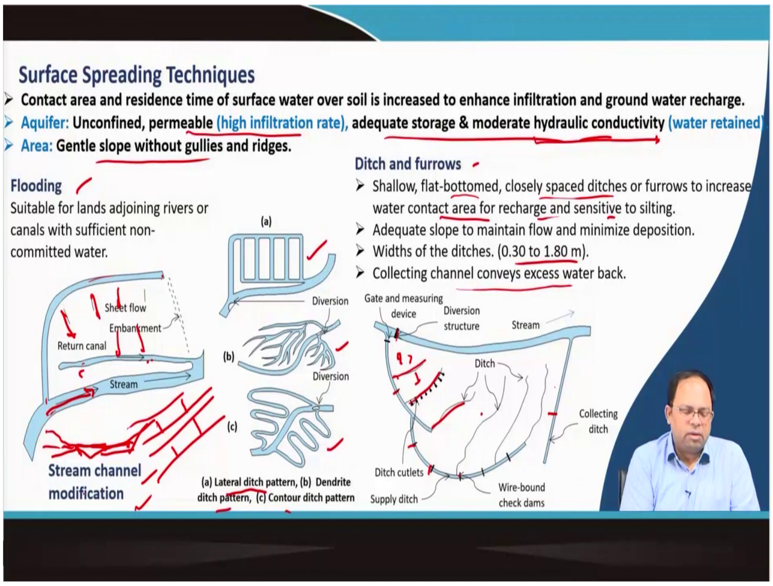

The contact area and residence time of the surface water over the soil are increased to enhance infiltration and groundwater recharge. When rainfall happens, only some amount of water percolates and most of the water will flow off the ground due to the less amount of time for which water stays in contact with the ground surface. Depressions created on the ground helps to store the rainwater and allow more time for percolation and increase filtration. Unconfined aquifers are suitable for surface spreading so that water can percolate directly into aquifers as it is permeable. Soil should have a high infiltration rate to allow adequate storage; and moderate hydraulic conductivity so that water doesn't pass quickly. Gentle slope is preferred.

The different techniques involved are:

- Flooding
- Ditch and furrows
- Stream channel modification.

The flooding technique is suitable for lands beside rivers or canals with sufficient water.

Stream channel modification - the mainstream channel and the subchannel is shown in the figure. The water from the surrounding areas is allowed to flow as a sheet of water on that land. Besides the natural channels, a ditch is dug to act as a return canal which can collect excess water from the runoff and facilitate more percolation.

The ***ditch and furrow system*** is similar to streamline modification however is more structured. It employs shallow flat bottomed closely spaced ditches or furrows to increase water contact area for a recharge which is also sensitive to silting. Because water is taken from a river it includes silt. The different structures involved are a large diversion structure (similar to a dam), supply ditches, ditch cutlets, wire-bound check dams and the collecting ditch. Supply ditches are constructed connecting the mainstream and smaller check dams are constructed to control the flow of water into the constructed ditches. Water flows through the ditches from where the water can spread to both directions instead of flowing on top of the land surface. A collecting ditch is constructed to collect any excess water and convey it to the mainstream. Adequate slope has to be maintained for flow and to minimize deposition in ditches. The width of ditches is given around 0.3 to 1.8 meters. There are different designs under the ditch and furrows system such as the lateral ditch pattern, the dendrite ditch pattern and the contour ditch pattern.

In addition to the above-mentioned methods, the stream channel can be modified (widened) by excavating the adjacent areas etc for water recharge as drawn in the above figure.

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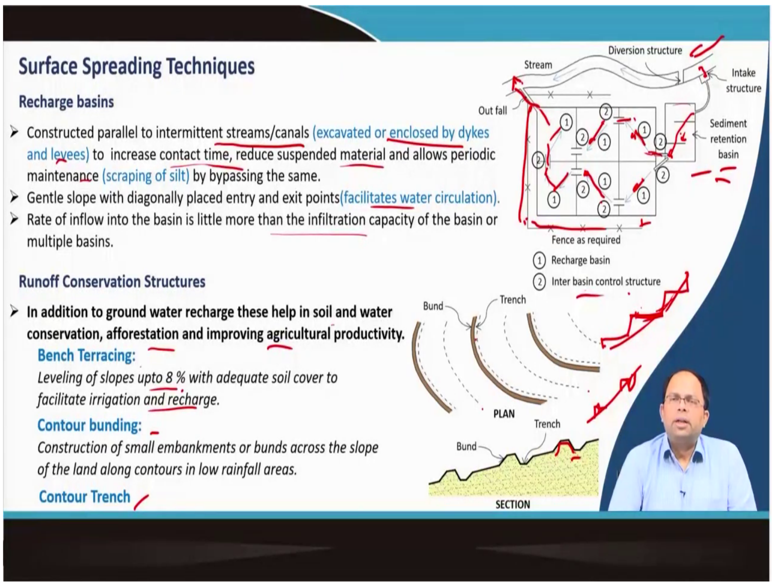

Recharge basins - These are constructed parallel to intermediate streams/canals and are excavated or enclosed by dykes and levees to prevent the flow of water out of the recharge basin. The system increases the contact time, reduce suspended material and allows periodic maintenance by scraping of silt by bypassing the same. The water from the stream is first conveyed to the sediment retention basin through a channel from the intake structure as shown in the figure. The sediment retention basins area has to consider the deposition rate. A diagonal movement pattern is allowed within the recharge basin. Inter-basin control structures are employed to allow water from one basin to another. This allows for easy maintenance as well as there is a requirement to remove deposits. The water movement pattern is marked in the above figure. A gentle slope with diagonally placed entry and exit points facilitates water circulation. The rate of inflow into the basin is little more than the infiltration capacity of the basin or multiple basins.

Runoff conservation structures – This involves some amount of surface spreading. This also helps in soil conservation apart from recharge as it prevents erosion. It helps in afforestation and is useful for agricultural productivity. This is employed particularly for hilly areas water as water holding is difficult because of the natural contours. It involves various methods such as Bench Terracing, Contour bunding and Contour trench.

- *Bench terracing* – involves levelling of slopes up to 8% with adequate soil cover to facilitate irrigation and recharge with benches created on hilly terrain.
- *Contour bunding* – at certain intervals on a hill, trenches are created so that the water gets trapped.
- *Contour trench* – a trench is created at specific intervals and are usually given along with contour bunds. This allows more water to get retained

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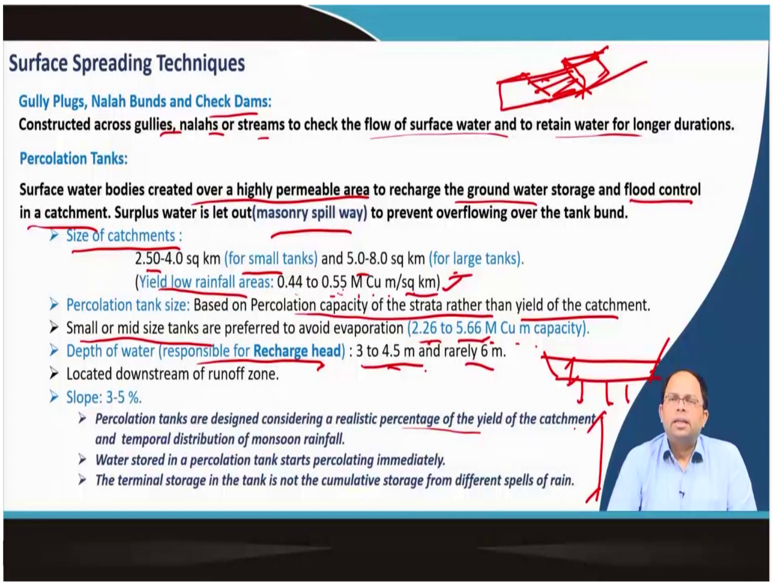

– *Gully plugs, nalah bunds and check dams* – These are constructed across streams to check the flow of surface water and to retain water for a longer duration. Raised structures along with the stream capture retains water for some time.

– *Percolation tanks* – Most of the surface spreading techniques are designed such that continuous flow of water is allowed whereas percolation tanks are designed to retain water in trenches etc. Surface water bodies are created over a highly permeable area to recharge the groundwater storage and also help in flood control in a particular catchment. When the Percolation tanks water level gets filled, the surplus water moves via masonry spillways to prevent overflowing around the tank. The excess water can be diverted to a drainage channel.

  - Size of catchments: 2.50-4.0 sq km (for small tanks) and 5.0-8.0 sq km (for large tanks)
  - Approximated Yield for low rainfall areas can be considered as 0.44 to 0.55 M Cu m/sq km
  - Percolation tank size: Based on the Percolation capacity of the strata rather than the yield of the catchment. (Because all the water is not

conveyed to the percolation tank some amount gets percolated and only the rest gets collected in the percolation tank)

- Small or mid-size tanks are preferred to avoid evaporation (2.26 to 5.66 M Cu m capacity).
- Depth of water (responsible for Recharge head): 3 to 4.5 m and rarely 6 m. It is represented in the above figure. The depth of water creates pressure and allows the water to move down faster.
- Located downstream of a runoff zone.
- Slope: 3-5 % is provided.
- Percolation tanks are designed considering a realistic percentage of the yield of the catchment and temporal distribution of monsoon rainfall.
- Water stored in a percolation tank starts percolating immediately.
- The terminal storage in the tank is not the cumulative storage from different spells of rain.

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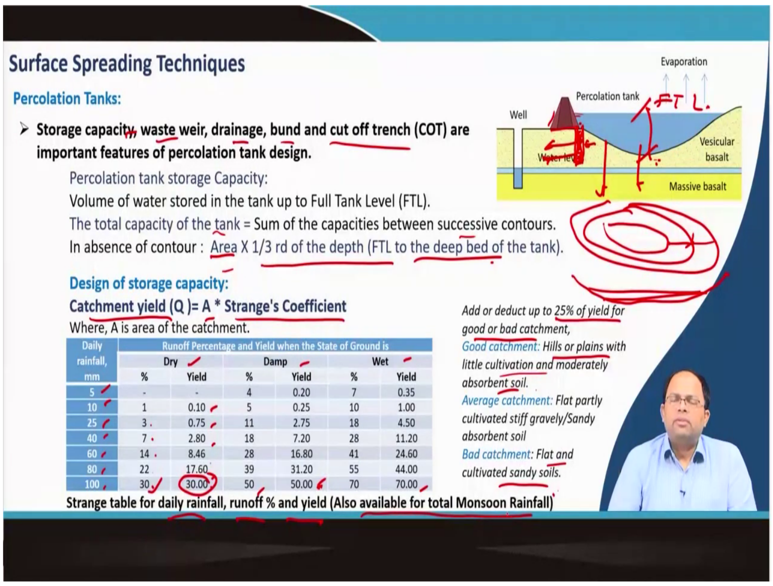

– *Percolation tanks (continued)* - Storage capacity of the tank, waste weir, drainage, bund and cut off trench are important features of the percolation tank design. The bund is shown in the figure. A cutoff trench is created next to the bund as represented in the above figure and is filled with clayey soil (doesn't allow water to pass through easily) to prevent the flow of water to the nearby areas. Percolation tanks storage capacity is the volume of water stored in the tank up to the full tank level. The total capacity of the tank is the sum of capacities between successive contours. The area enclosed between different contour lines and the depth of the region enclosed can be multiplied to determine the volume of water getting stored. In the absence of the contour details, it can be assumed that the area is equal to the surface area into one-third of the depth (FTL to the deep bed of the tank).

The catchment yield can be attained by multiplying the area of the catchment and the Stranges coefficient. The table gives the runoff % and yield values for different soil conditions such as dry, damp, and wet based on the daily rainfall. The soil conditions are important as the area with antecedent moisture conditions will have an increased amount of runoff (as discussed in the earlier lecture) In addition, addition or deduction of 25% yield can be done based on good or bad catchments. Good catchment (addition of yield) involves hills or plains with little cultivation and moderately absorbent soil. Bad catchment involves flat and cultivated sandy soils and for which yield can be reduced. The stranges coefficient is available for total monsoon rainfall in the Indian context.

Sub surface techniques

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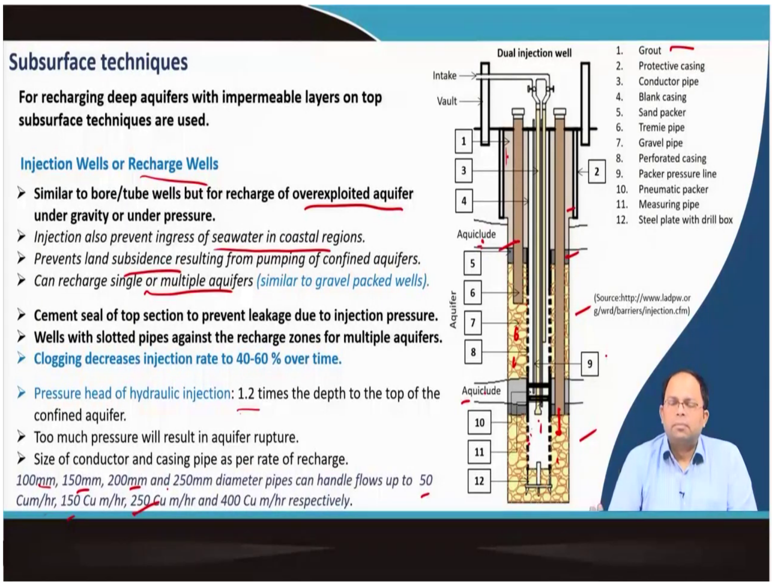

These are utilized for recharging deep aquifers which consists of impermeable layers on top (surface spreading techniques cannot be employed)

Injection well or a recharge well – These are similar to bore wells or tube wells in construction, but are used for recharging water in case of overexploited aquifers under gravity or under pressure instead of extracting water. The structure of a recharge well is shown in the above figure. Multiple aquifer layers and the hard stratum, the aquiclude which prevents the transfer of water between the aquifers can be noted. A conductor pipe within the casing pipe (shown as dotted) is used for recharge. The water moves to the aquifer through the casing pipe (surrounded by gravels as shown in the figure). In addition, tremie pipes are given through which concrete or these gravels are filled; These are utilized for putting such materials for the top two levels of an aquifer. Seals are provided in the aquifer such that water cannot travel in between. Water can be recharged via pressure via pump or via gravity. Injection prevents the ingress of seawater in coastal regions. It also prevents land subsidence resulting from the pumping of confined aquifers. (Subsidence may get caused because of the collapse of the gaps between soil layers because of overexploitation of aquifers). This can be employed to recharge single or multiple aquifers. A cement seal is put on the top to prevent leakage due to injection pressure and prevents the movement of water upwards. Wells with slotted pipes against the recharge zone for multiple aquifers is used (as in the case of a deep tube well). Clogging decreases the injection rate to 40 to 60 percent over time. So, the pumping rates and the pressure has to be adjusted otherwise eventually the pours would be clogged. The pressure head of hydraulic injection is 1.2 times the depth of the total confined aquifer. An increased pressure than the stated values may break the casing, gravel structure and also aquifer structure. The size of the conductor and casing pipe is determined based on the amount of recharge that is to be done for the particular aquifers. 100mm, 150mm, 200mm and 250mm diameter pipes can handle flows up to 50 Cu m/hr, 150 Cu m/hr, 250 Cu m/hr and 400 Cu m/hr respectively.

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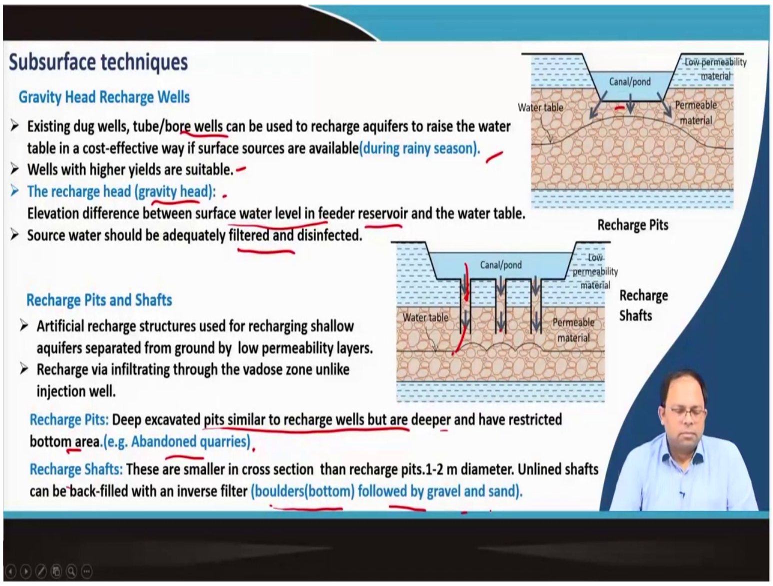

Gravity head recharge wells - Existing dug wells, tube/bore wells can be used to recharge aquifers to raise the water table cost-effectively if surface sources are available (during the rainy season). Wells with higher yields are suitable because more recharge can be done. The water can be recharged using the recharge head or gravity head; the elevated reservoir creates a gravity head allowing water to be filled in the well. So, the elevation difference between the surface water level in the feeder reservoir and the water table results in the gravity head, (should be around 1.2 times the depth of the recharge well). Source water should be adequately filtered and disinfected.

Recharge pits and shafts – are used for recharging shallow aquifers separated from the ground by low permeability layers and recharge by infiltration through the vadose zone, unlike injection wells. Recharge Pits are Deep excavated pits similar to recharge wells but are deeper and have restricted bottom area (e.g. abandoned quarries). Recharge Shafts are smaller in cross-section than recharge pits.1-2 m diameter. Unlined shafts can be back-filled with an inverse filter (boulders (bottom) followed by gravel and sand).

Ground water conservation techniques

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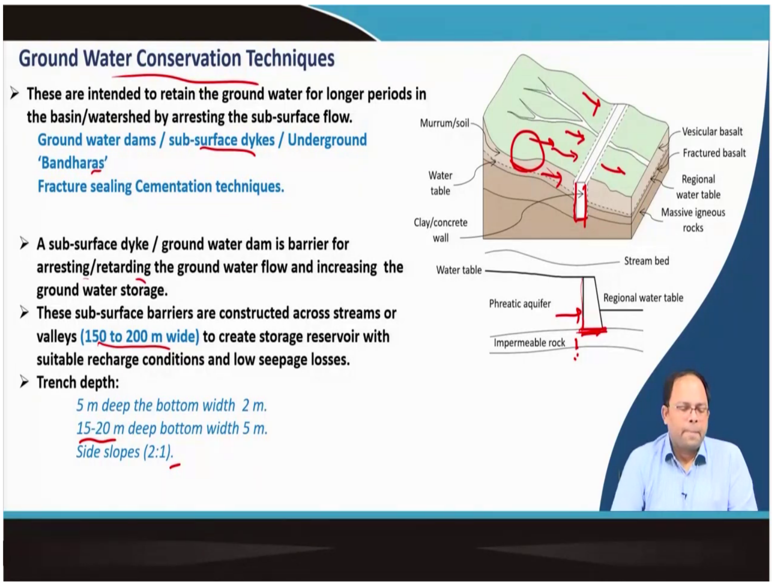

These are designed such that the groundwater is retained for longer periods in a particular basin or a watershed by arresting the subsurface flow. Some of such traditional structures include groundwater dams or subsurface dykes or underground bandharas. Fracture sealing cementation techniques can also be employed.

The figure shows the concrete wall constructed to prevent the flow from the upper areas toward the stream to allow for percolation. Subsurface dyke or groundwater dam acts as a barrier and arrests or retards the groundwater flow and helps in increasing the groundwater storage in this particular area. These structures can be constructed particularly across streams or valleys of 150 to 200 meters wide and to create storage reservoirs with suitable recharge conditions and low seepage losses. The wall has to be constructed such that its bottom connects to the impermeable rock so that water does not leak through below.

Trench depth:

- *5 m deep the bottom width 2 m.*
- *15-20 m deep bottom width 5 m.*
- *Side slopes (2:1).*

Roof top rainwater collection and recharge of ground water

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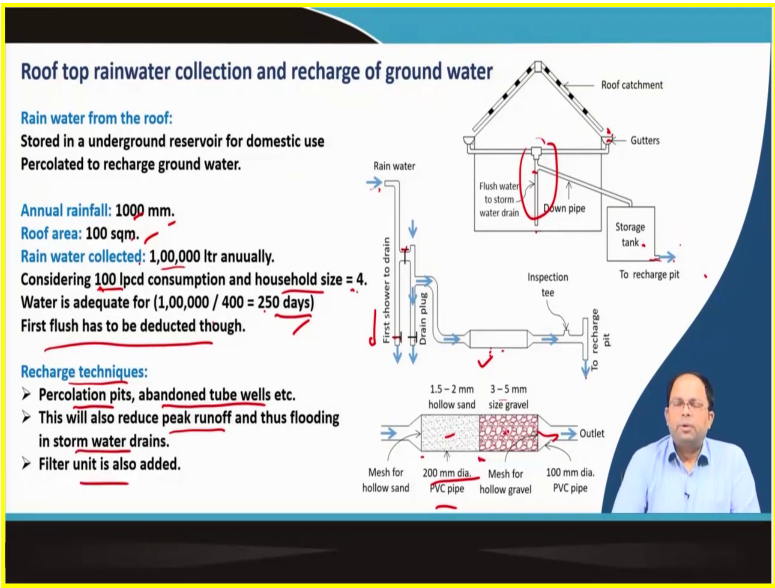

This slide will discuss recharge in urban areas. The strategies that have been discussed before, some of those could be constructed in urban areas, but many of those are not suitable for urban areas and it is for a much larger scale. But when rainwater harvesting or rooftop rainwater collection and recharge of groundwater is considered, then urban areas or urban catchments are discussed.

Usually, the rainwater that falls on the roof can be stored and used for either domestic use or one can use the water to percolate and then recharge the groundwater. The image shows the roof catchment in which the water comes down to the gutter and this is being captured and comes down.

The first flush could be let out. Once the first rainfall event happens then we can close it and the water is directly taken to a storage tank from, where the water can be used or the water can go to a recharge pit from where the water can be percolating inside the ground.

One can also do some amount of treatment of water. If excess water is coming in, some amount of water could be drained, but most of the water has to be taken through the filter. Then, one can take it either to recharge or to storage. This filter helps to perform some amount of basic treatment. There is a chamber that has sand and gravel. The water is allowed to pass through both sand and gravel. So, most of the solids are trapped over here and clean water is obtained which could be stored. The structure is shown in the image. The 200-millimeter dia. PVC pipe is used in which the 1.5 to 2 mm dia. sand and 3 to 5 mm dia. Gravel is used. Using this, the rainwater can be cleaned and then used for storage or recharge.

Let us perform the basic calculation. Let us assume that the annual rainfall is 1000 millimeter for a particular area. Though it is a high value, can be assumed for this problem. Let the roof area be 100 square meters. Then, the total rainwater that could be collected would be calculated by multiplying these two values and that comes to around 1,00,000 litres annually.

If we consider a 100 lpcd litres per capita per day consumption and the household size of about 4 people, the water is adequate for around (1,00,000/(100 * 4)), i.e., 250 days. Though one can get rid of the first flush, this would be adequate for around 250 days of a year. This is a huge amount of water that is captured from rain.

This water can be useful for recharge or can be used directly for certain purposes. That is why rainwater collection is very important.

In addition, to recharging the groundwater, additional techniques can be used such as percolation pits, abundant tube wells, etc. If this is done locally, then it will reduce the peak run-off and thus flooding in stormwater drains would also reduce. Filter units can also be added.

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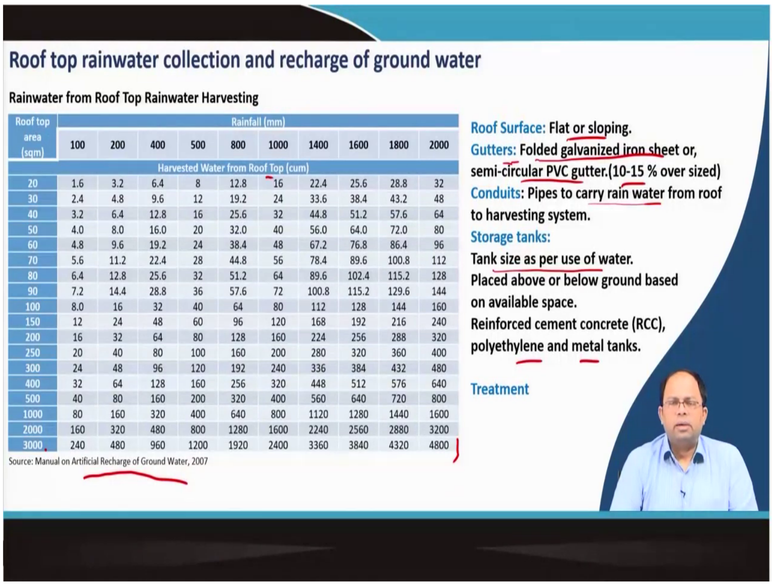

This table provides a rough estimate to determine the quantity of water from the roof tops. This table is available from the Manual of Artificial Recharge of Groundwater. The table shows the different sizes of roof area and different amounts of rainfall in millimeter. Based on these values, one can determine the total quantum of harvested rainwater from roof.

Using this table, one can easily determine what amount of water could be retained at the building level and then be used for recharge or consumption. This will also reduce the amount of stormwater that comes to the municipal sewer network or to the municipal open drains.

In the case of rooftop rainwater collection, the roof may be either flat or sloping. Accordingly, a decision needs to be taken. Gutters can be used which are folded galvanized iron sheets or semi-circular PVC gutters. These are oversized to 10 to 15 percent to collect the rainfall. The pipes are used to carry water from the roof to the harvesting system as shown in the previous figures. The storage tank depends on the tank size is as per the use of water.

If one wants to use 20 percent of this water, one can create a tank of 20 percent capacity. These are placed above or below ground based on available space. Reinforced cement concrete, polyethylene material tanks can be designed similar to any kind of standard reservoir that are used in houses. Water can be treated using one of the systems that were discussed when recharge needs to be done.

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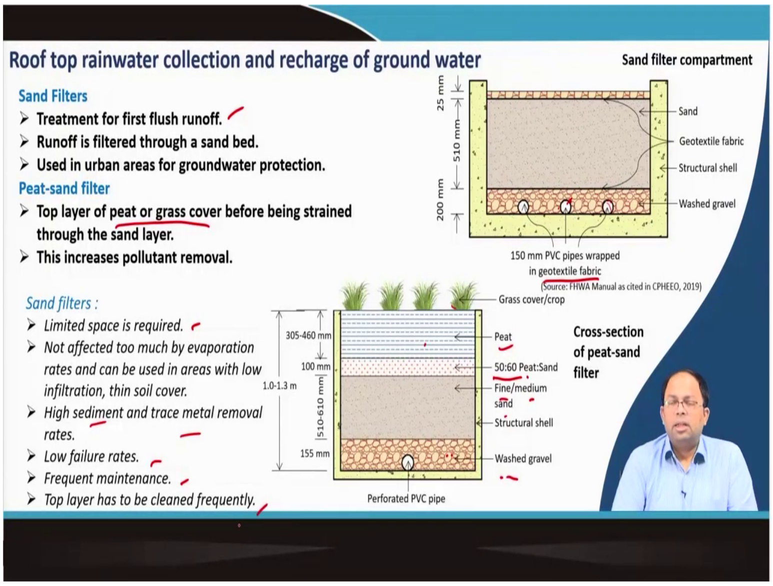

When rain water is used for recharge, it needs to be treated upto a certain extent. For this purpose, sand filters can be used to treat the first flush run-off before it can be used for recharge. It is a concrete structure and the runoff is filtered through a sand bed. The topmost and bottom layer is gravel. The under water drainage pipes are put in from which water could be drained out. The water could then be taken for storage or could be taken for recharge. The drainage PVC pipes are wrapped in geo textile fabric to prevent entry of sand or gravel inside those pipelines to prevent clogging of the pipelines. So, these are usually used in urban areas for groundwater protection.

Similarly, peat sand filter can be designed. The top layer of peat or grass cover is laid on the top of sand layer. So, instead of just using sand, we can have a top layer of peat or grass cover. Peat is a mixture of vegetation or which has been collected from the surroundings. Grass cover (loose vegetation material) is put on the top and the peat layer is put beneath it. The proportions of peat:sand is 50:60. Then, there is a layer of fine or medium sand layer and then washed gravel beneath. The purpose of this kind of filter is to clean the water before it is being recharged and this requires limited space.

It is not affected by evaporation rates and could be used in areas with low infiltration and thin soil cover. It can also remove lot of sediment and trace metals. These are quite robust and work well. They do not fail too much, but they require frequent maintenance. One have to clean the sand to remove all the dirt that is captured and particularly the top layer has to be cleaned frequently.

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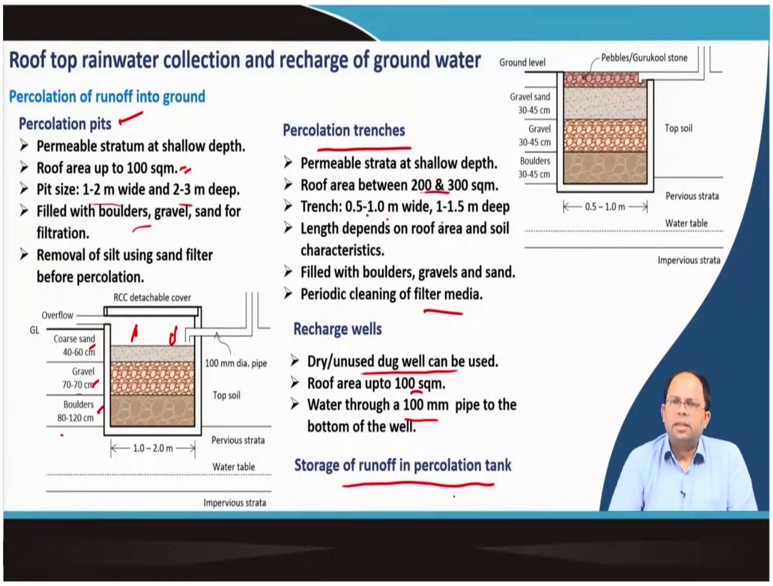

Similarly, there are percolation pits that allow ground water to percolate into the ground. These pits also have filter layers. As shown in the image, there are boulders (80 to 120 centimeter) at the bottom, then gravel (70 centimeter), then coarse sand (40 to 60 centimeter).

The water comes via inlet pipe, falls on filter layers and then gradually goes down and then percolates into the ground. So for roof area of around 100 square meter, pits sizes of 1 to 2 meter wide and 2 to 3 meter deep can be designed. These are filled with boulder, gravel and sand for filtration. There is a need to remove the silt using sand filter before percolation. In case the roof size exceeds by 100 square meters, for example, 200-300 square meters; larger areas for percolation is required. Then, the percolation trench is designed.

It is relatively wider, and the trench section is 0.5 to 1 meter wide and it is 1 to 1.5 meter deep. The length depends on the roof area the soil characteristics. So, the length of the trench would be as per requirement. These are filled with boulders, gravel and sand similar to percolation pit. The filter media also needs to be cleaned at certain period intervals.

Similarly, recharge wells can be used. Dry unused drug wells can be used for roof area around 100 square meter. Water is brought down through 100 millimeter pipe to the bottom of the well and then from there it automatically gets recharged. Storage of run-off in a percolation tank is also possible, but if in a open tank, some amount of water is lost due to evaporation.

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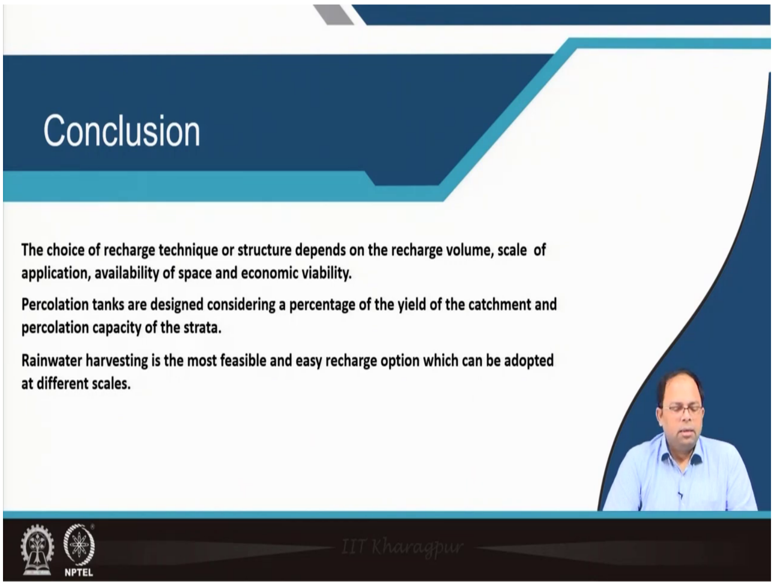

Conclusion

To conclude, the choice of recharge technique or structure depends on the recharge volume, scale of application and availability of space and economic viability. Then, percolation tanks are designed considering a percentage of the yield of the catchment and percolation capacity of the strata. Finally, rainwater harvesting is the most feasible and easy recharge option, which can be adopted at different scales.

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References

The references that can be used are provided.