



Research Paper

The Need of Artificial Recharge Techniques for Sustainable Development of Ground Water Resources

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Water is an essential element for life. Clean and safe water for daily use is the basic need of human beings. Some areas contain plenty of water but some areas doesn't contain plenty of water. The main reason for this condition is unavailability of ground water with in the required depth. The technique is to store the water within the aquifer without escaping from it by regulating the runoff and infiltration of water. Hence, various artificial recharge methods to improving the ground water table. Consequently enhance human survival and the quality of irrigation sector.

Keywords: Ground water, Infiltration, Runoff, Aquifer, Porosity and Permeability, etc.

Introduction

Water is the most essential fuel of life; clean and safe water for daily use is the basic need of human beings. Even after decade of hard work and struggle by the govt. bodies & other organization to supply ample amount of potable water to each & every human being in every corner of the world, is not yet achieved. Increasing demand for water, particularly in arid and semi-arid regions of the world, has shown that the extended groundwater reservoirs formed by aquifers are invaluable for water supply and storage. Natural replenishment of this vast supply

of groundwater is very slow. Therefore, exploiting groundwater at a rate greater than it can be replenished causes groundwater tables to decline and, if not corrected, eventually leads to mining of groundwater. Artificial recharge as a means to boost the natural supply of groundwater aquifers is becoming increasingly important in groundwater management. Groundwater can have a wide range of beneficial uses. For example, it can be used for irrigation of parks or agricultural land, industrial application, or to provide a potable water supply (i.e. one that is suitable for drinking).

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Literature Review

The term artificial recharge has different connotations for various practitioners. Artificial recharge to ground water is defined as the recharge that occurs when the Natural pattern of recharge is deliberately modified to increase recharge (ASCE, 2001). The process of recharge itself is not artificial. The same physical laws govern recharge, whether it occurs under natural or artificial conditions. What is artificial is the availability of water supply at a particular location and a particular time. In the Broadest sense one can define artificial recharge as “any procedure, which introduces Water in a previous stratum”. The term artificial recharge refers to transfer of surface water to the aquifer by human Interference. The natural process of recharging the aquifers is accelerated through Percolation of stored or flowing surface water, which otherwise does not percolate into the aquifers. Artificial recharge is also defined as the process by which ground Water is augmented at a rate exceeding that under natural condition of replenishment. Therefore, any man-made facility that adds water to an aquifer may be considered as Artificial recharge (CGWB, 1994).

Need for Artificial Recharge

Occurrence of rainfall in India is mostly limited to about three months in a year. The natural recharge to ground water reservoir is restricted to this period only in a major part of the country. Artificial recharge techniques aim at extending the recharge period in the post-monsoon season for about three or more months, resulting in enhanced sustainability of ground water sources during the lean season. In arid regions of the country, rainfall varies between 150 and 600 mm/year with less than 10 rainy days. A major part of

the precipitation is received in 3 to 5 major storms lasting only a few hours. The rates of potential evapotranspiration (PET) are exceptionally high in these areas, often ranging from 300 to 1300 mm. In such cases, the average annual PET is much higher than the rainfall and the annual water resource planning should be done by conserving the rainfall, by storing the available water either in surface or in sub-surface reservoirs.

Identification of Areas for Recharge

The first step in planning a recharge scheme is to demarcate the area of recharge. Such an area should, as far as possible, be a micro-watershed (2,000-4,000 ha) or a mini-watershed (40-50 ha). However, localized schemes can also be taken up for the benefit of a single hamlet or a village. In either case the demarcation of area should be based on the following Broad criteria:

- Where ground water levels are declining due to over-exploitation
- Where substantial part of the aquifer has already been desaturated
- Where availability of water from wells and hand pumps is inadequate during the lean months
- Where ground water quality is poor and there is no alternative source of water.
- Where the area is high runoff
- Where the area filled with sedimentation

Advantages of Artificial Recharge

Artificial recharge is becoming increasingly necessary to ensure sustainable ground water supplies to satisfy the needs of a growing population. The benefits of artificial recharge can be both tangible and intangible. The important advantages of artificial recharges are

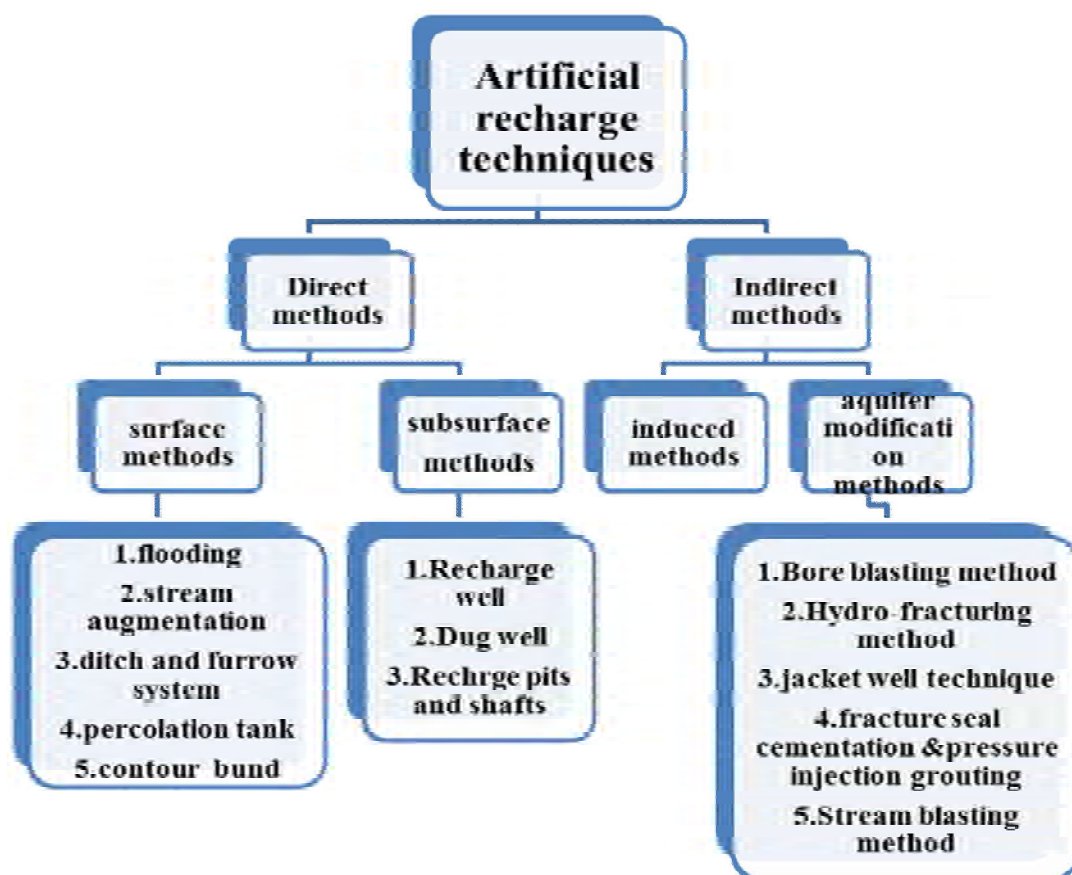
1. Subsurface storage space is available free of cost and inundation is avoided
2. Evaporation losses are negligible
3. Quality improvement by infiltration through the permeable media
4. Biological purity is very high
5. It has no adverse social impacts such as displacement of population, loss of scarce agricultural land etc.
6. Temperature variations are minimum
7. It is environment friendly, controls soil erosion and flood and provides sufficient soil moisture even during summer months
8. Water stored underground is relatively immune to natural and man-made catastrophes
9. It provides a natural distribution system between recharge and discharge points
10. Results in energy saving due to reduction in suction and delivery head as a result of rise in water levels

Results and Discussion

Techniques of Artificial Recharge

Techniques used for artificial recharge to ground water broadly fall under the following categories (Figure 1).

Figure 1: Techniques of Artificial Recharge



I. Direct Methods

1. Surface Spreading Techniques: Important considerations in the selection of sites for artificial recharge through surface spreading techniques include

- i) The area should have gently sloping land without gullies or ridges.
- ii) The aquifer being recharged should be unconfined, permeable and sufficiently thick to provide storage space.
- iii) The surface soil should be permeable and have high infiltration rate.
- iv) Vadose zone should be permeable and free from clay lenses.

- v) Ground water levels in the phreatic zone should be deep enough to

The most common surface spreading techniques used for artificial recharge to ground water are flooding, ditch and furrows and recharge basins (Figure 2).

1A. Flooding

Flooding method helps reduce the evaporation losses from the surface water system, is the least expensive of all artificial recharge methods available and has very low maintenance costs (Figures 3 and 3.1).

1B. Ditch and Furrows Method

This method involves construction of shallow, flat-bottomed and closely spaced ditches or furrows

Figure 2: Surface Spreading Techniques

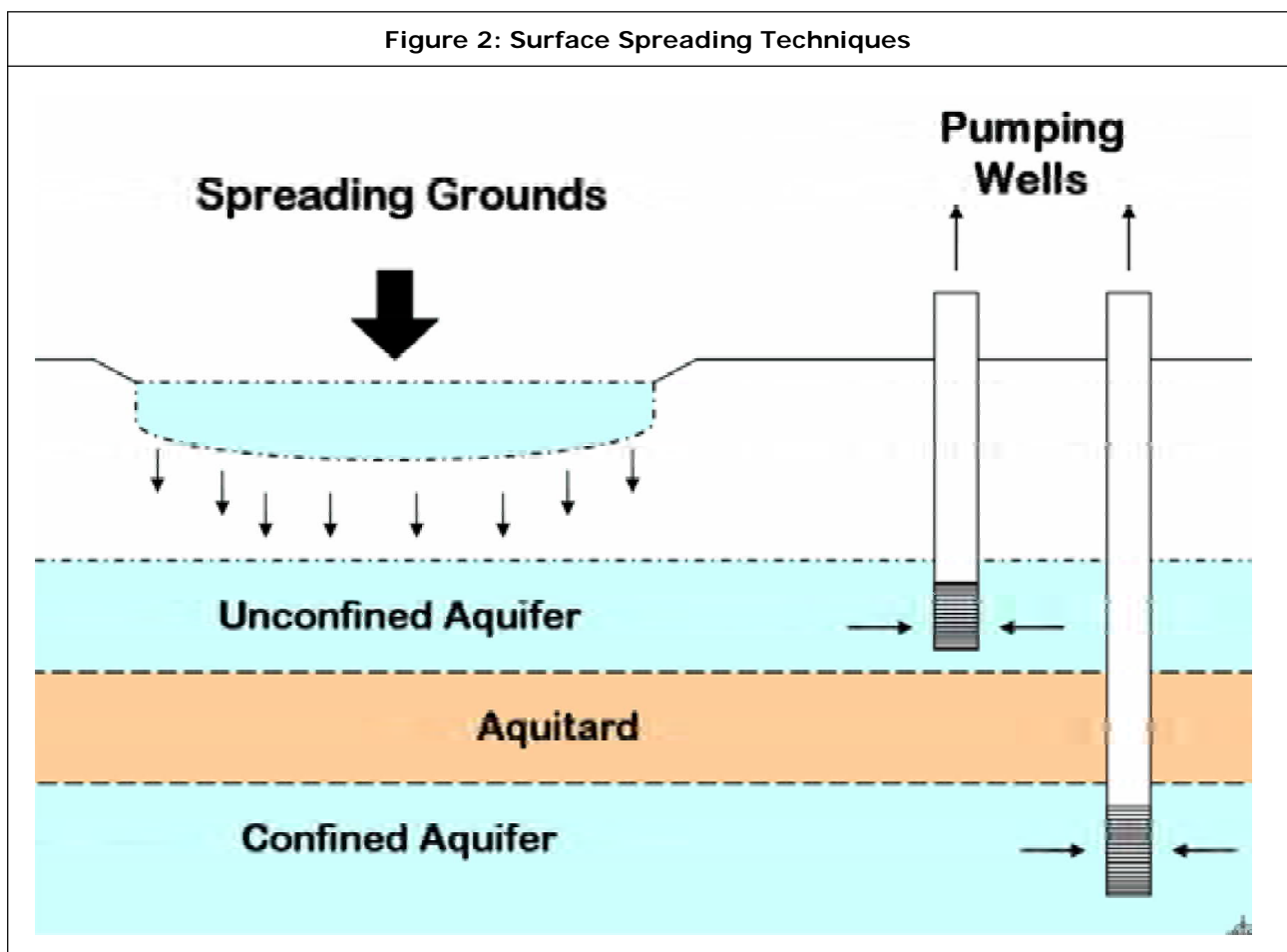
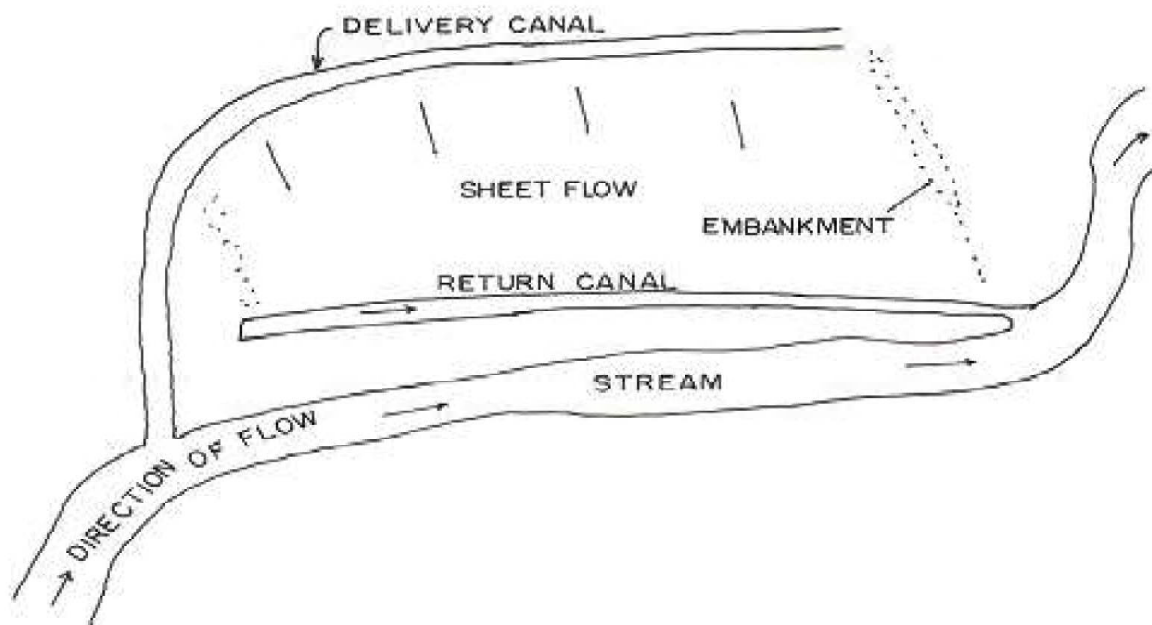


Figure 3: Flooding Method



Figure 3.1: Schematic Flooding Recharge Method



to maximum water contact area for recharge from source stream or canal. The ditches should have adequate slope to maintain flow velocity and minimum deposition of sediments. The widths of the ditches are typically in the range of 0.30 to 1.80 m. A collecting channel to convey the excess water back to the source stream or canal should also be provided. A typical system and three common patterns viz. lateral ditch pattern, dendritic pattern and contour pattern are shown in below figure (Figure 4).

1C. Recharge Basins

Artificial recharge basins are commonly constructed parallel to ephemeral or intermittent stream channels and are either excavated or are enclosed by dykes and levees. They can also be constructed parallel to canals or surface water sources. In alluvial areas, multiple recharge basins can be constructed parallel to the streams with a view to

- Increase the water contact time,
- Reduce suspended material as water flows from one basin to another and
- To facilitate periodic maintenance such as scraping of silt etc. to restore the infiltration rates by bypassing the basin under restoration (Figure 5).

1D. Runoff Conservation Structures

These are normally multi-purpose measures, mutually complementary and conducive to soil and water conservation, increased agricultural productivity. They are suitable in areas receiving low to moderate rainfall mostly during a single monsoon season and having little or no scope for transfer of water from other areas. Different measures applicable to runoff zone, recharge zone and discharge zone are available. The structures commonly used are bench terracing, contour bunds, gully, nalahbunds, check dams and percolation ponds.

Figure 4: Ditch and Furrows Method

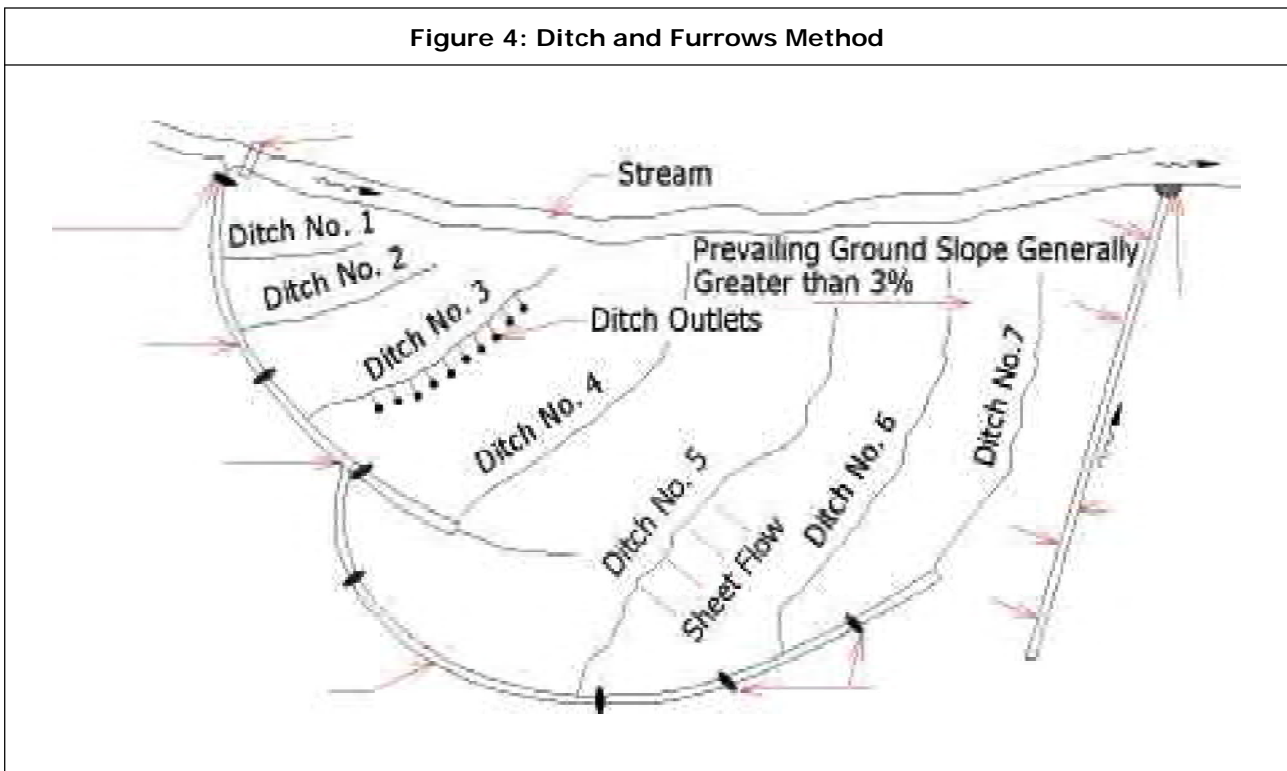
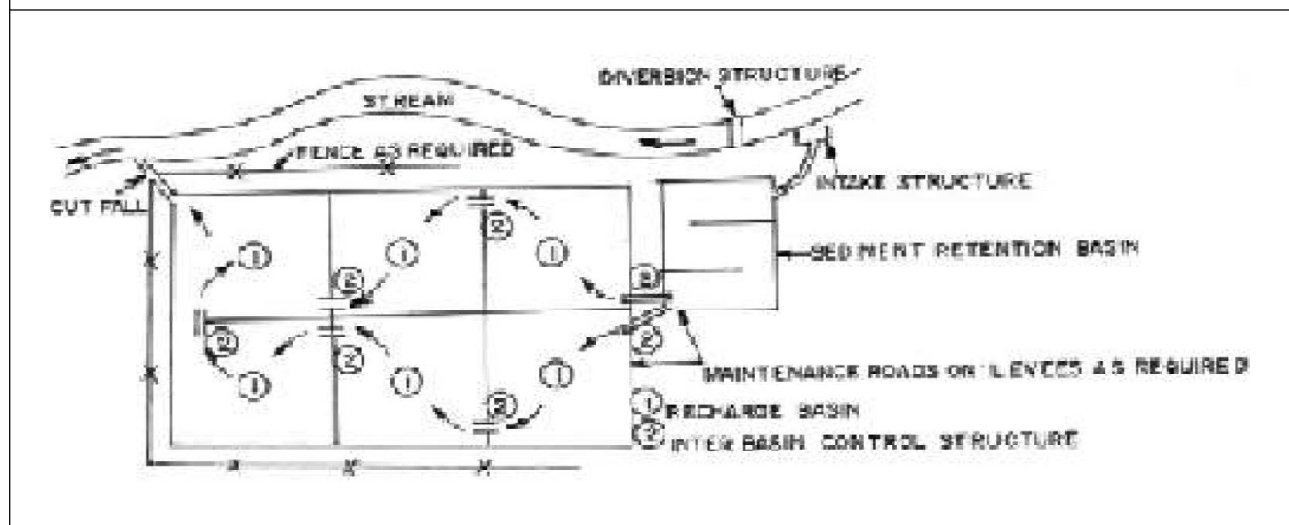


Figure 5: Recharge Basins Method



1D.1. Bench Terracing

Bench terracing involves levelling of sloping lands with surface gradients up to 8 percent and having adequate soil cover for bringing them under irrigation. It helps in soil conservation and holding runoff water on the terraced area for longer durations, leading to increased infiltration and ground water recharge. For implementing terracing, a map of the watershed should be prepared by level surveying and suitable benchmarks fixed. A contour map of 0.3 m contour interval is then prepared. Depending on

the land slope, the width of individual terrace should be determined, which, in no case, should be less than 12 m. The upland slope between two terraces should not be more than 1:10 and the terraces should be levelled. The vertical elevation difference and width of terraces are controlled by the land slope (Tables 1, 2 and 3).

1D.2. Contour Bunds

Contour bunding, which is a watershed management practice aimed at building up Soil moisture storage involve construction of small

Table 1: Soil and Weathered Rock Thickness, Vertical Elevation Difference and the Distance Between the Bunds of Two Terraces for Different Slope Categories

Land Slope (%)	Required Thickness of Soil and Weathered Rock (m)	Vertical Separation (m)	Distance Between Bunds of Two Terraces (m)
1	0.30	0.30	30
2	0.375	0.45	22
3	0.450	0.60	20
4	0.525	0.75	18.75
5	0.600	0.90	18
6	0.750	1.05	17.5
7	0.750	1.20	17
8	0.750	1.20	15

Table 2: Dimensions Output Channels for Different Watershed Areas

Area of watershed (ha)	Channel Dimensions (m)		
	Base Width	Top width	Depth
< 4	0.30	0.90	0.60
4 to 6	0.60	1.20	0.60
6 to 8	0.90	1.50	0.60
8 to 10	1.20	1.80	0.60
10 to 12	1.50	2.10	0.60

Table 3: Dimensions of Terraces in Different Soil Types

Type of Soil	Soil Thickness (cm)	Base Width (m)	Top Width (m)	Height (m)	Side slope
Light	7.50 to 22.50	1.50	0.30	0.60	1:1
Medium	22.50 to 45.00	1.80	0.45	0.65	1:1
Medium Deep	45.00 to 90.00	2.25	0.45	0.75	1:1
Deep	> 90.00	2.50	0.50	0.80	1:1

embankments or bunds across the slope of the land. They derive their names from the construction of bunds along contours of equal land elevation. This technique is generally adopted in low rainfall areas (normally less than 800 mm)

where gently sloping agricultural lands with very long slope lengths are available and the soils are permeable. They are not recommended for soils with poor internal drainage e.g., clayey soils. Schematic of a typical system of contour bunds is shown in Figure 6.

Figure 6: Contour Bunds



1D.3. Contour Trenches

Contour trenches are rainwater harvesting structures, which can be constructed on hill slopes as well as on degraded and barren waste lands in both high- and low- rainfall areas. Cross section of a typical contour trench is shown below Figure 7.

1D.4. Gully Plugs, Nalahbunds and Check Dams

These structures are constructed across gullies, nalahs or streams to check the flow of surface water in the stream channel and to retain water for longer durations in the pervious soil or rock surface. As compared to gully plugs, which are normally constructed across 1 order streams, nalahbunds and check dams are constructed across bigger streams and in areas having gentler slopes. These may be temporary structures such as brush wood dams, loose / dry stone masonry check dams.

1D.5. Percolation Tanks

Percolation tanks, which are based on principles similar to those of nalahbunds, are among the most common runoff harvesting structures in India. A percolation tank can be defined as an

artificially created surface water body submerging a highly permeable land area so that the surface runoff is made to percolate and recharge the ground water storage. They differ from nalahbunds in having larger reservoir areas. They are not provided with sluices or outlets for discharging water from the tank for irrigation or other purposes. They may, however, be provided with arrangements for spilling away the surplus water that may enter the tank so as to avoid over-topping of the tank bund. It is possible to have more than one percolation tank in a catchment if sufficient surplus runoff is available and the site characteristics favour artificial recharge through such structures. In such situations, each tank of the group takes a share in the yield of the whole catchment above it, which can be classified as

- (i) 'free catchment', which is the catchment area that only drains into the tank under consideration and
- (ii) 'combined catchment', which is the area of the whole catchment above the tank (Figure 8).

1E. Stream Channel Modification / Augmentation

In areas where streams zigzag through wide

Figure 7: Contour Trenches

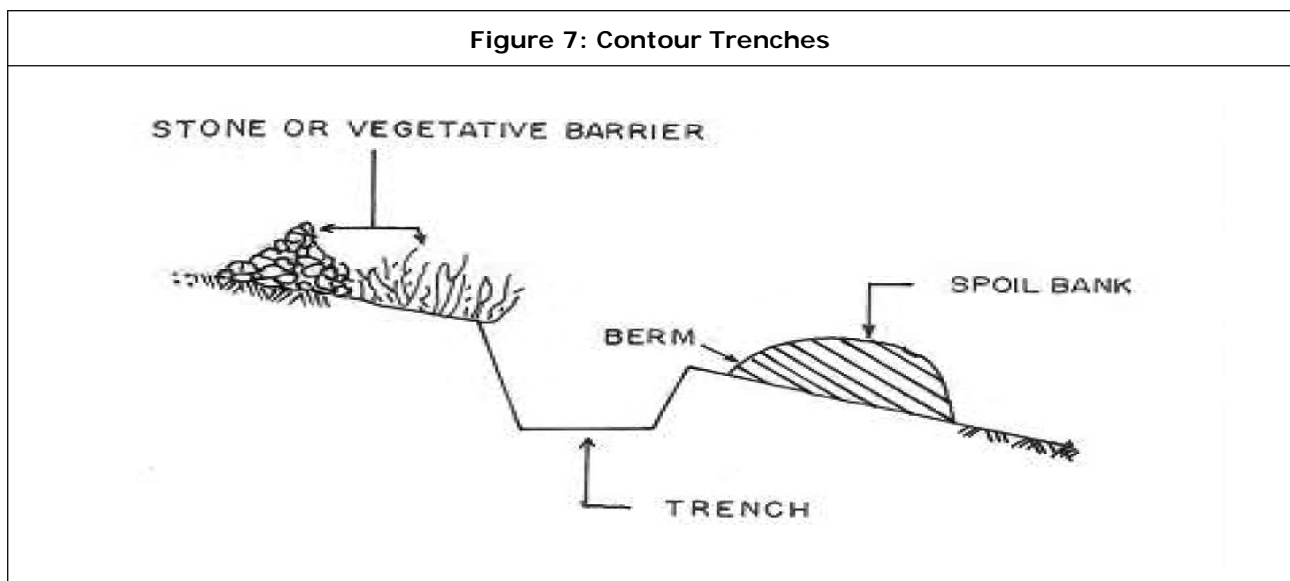
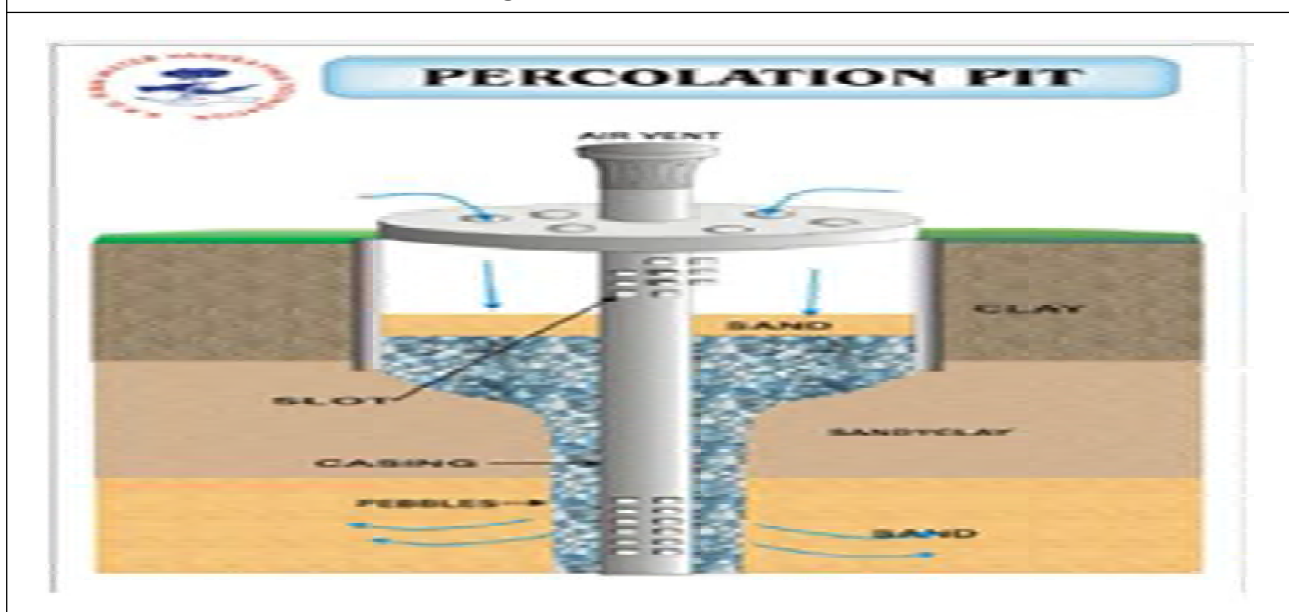


Figure 8: Percolation tank



valleys occupying only a small part of the valley, the natural drainage channel can be modified with a view to increase the infiltration by detaining stream flow and increasing the streambed area in contact with water. For this, the channel is so modified that the flow gets spread over a wider area, resulting in increased contact with the streambed. The methods commonly used include

- Widening, levelling, scarifying or construction of ditches in the stream channel,
- Construction of L – shaped finger levees or hook levees in the river bed at the end of high stream flow season and
- Low head check dams which allow flood waters to pass over them safely.

Subsurface Techniques

Subsurface techniques aim at recharging deeper aquifers that are overlain by impermeable layers, preventing the infiltration from surface sources to recharge them under natural conditions. The

most common methods used for recharging such deeper aquifers are

- Injection wells or recharge wells/ Dug well recharge
- Recharge pits and shafts,

A. Injection Wells or Recharge Wells

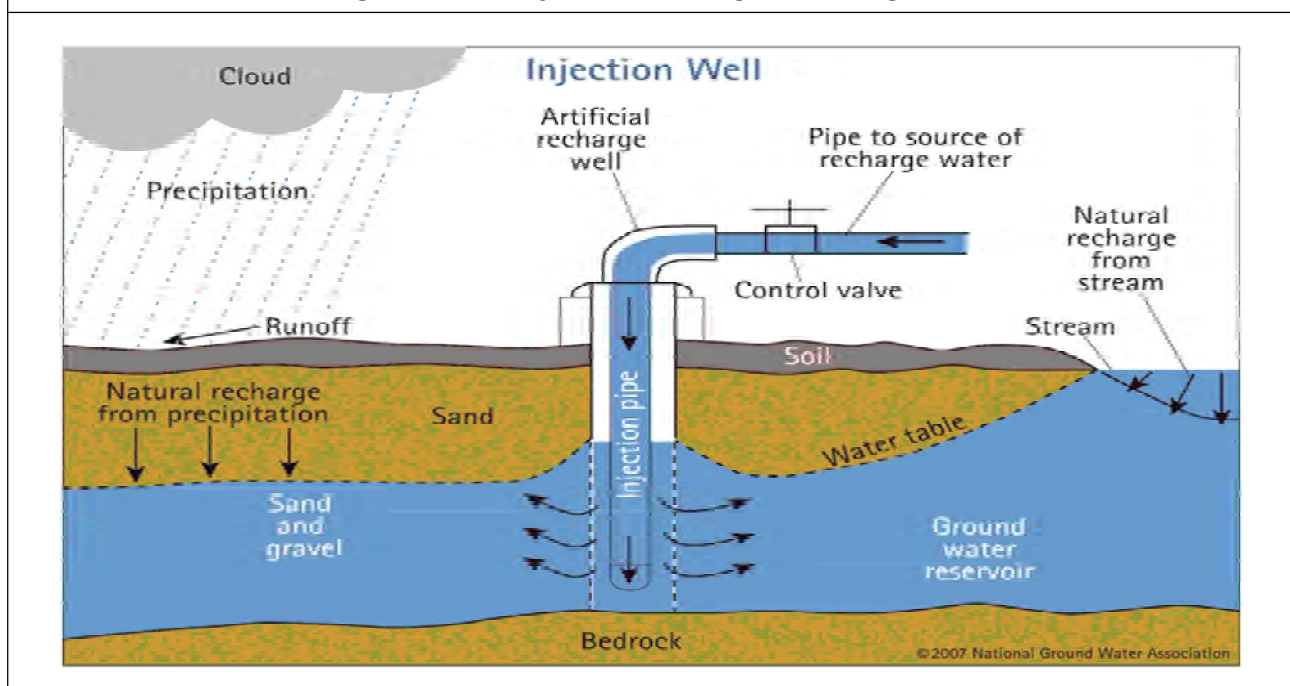
Injection wells or recharge wells are structures similar to bore/tube wells but constructed for augmenting the ground water storage in deeper aquifers through supply of water either under gravity or under pressure. The aquifer to be replenished is generally one with considerable desaturation due to overexploitation of ground water. Artificial recharge of aquifers by injection wells can also be done in coastal regions to arrest the ingress of seawater and to combat problems of land subsidence in areas where confined aquifers are heavily pumped (Figure 9).

B. Recharge Pits and Shaft

Recharge Pits of Variable Dimensions

Most of the time, especially in case of agricultural

Figure 9: Gravity Head Recharge Well/Dug Well



field, a layer of less permeable soil exists. So, the surface flooding methods of recharge do not show satisfactory performance so, recharge pit can be excavated which are sufficiently deep to penetrate the less permeable strata.

Recharge shaft is similar to the recharge pits, but the cross-sectional size of the recharge shaft is much lesser than the recharge pits.

II. Indirect Methods

Indirect methods for artificial recharge to ground water does not involve direct supply of water for recharging aquifers, but aim at recharging aquifers through indirect means. The most common methods in this category are induced recharge from surface water sources and aquifer modification techniques.

1. Induced Recharge from Surface Water

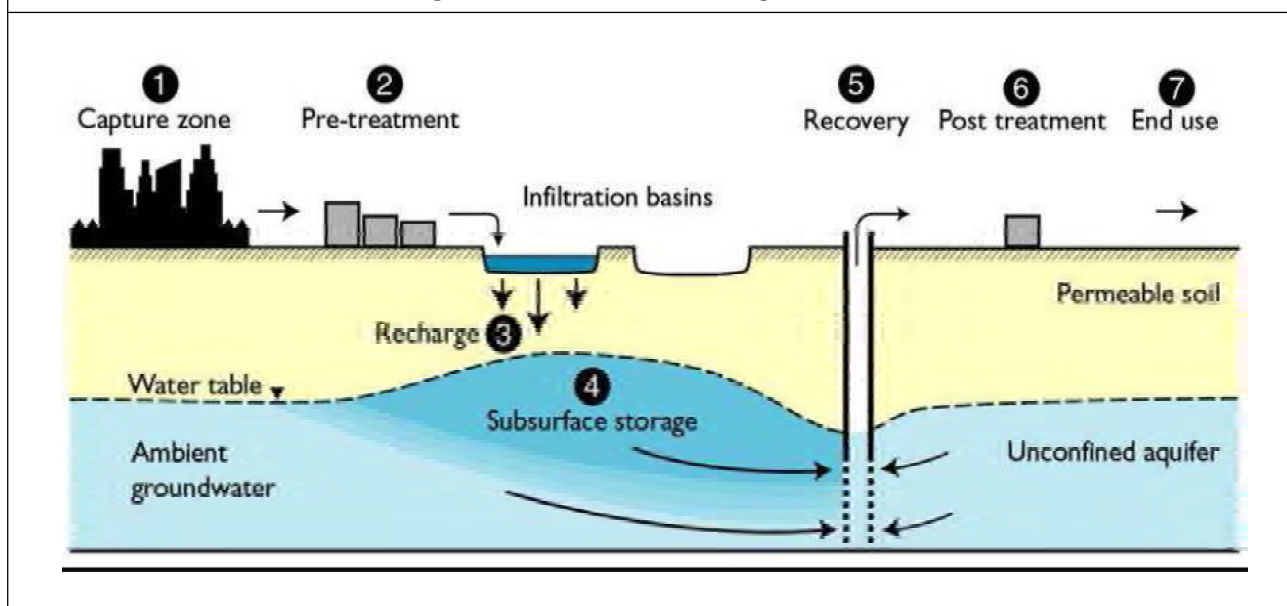
Induced recharge involves pumping water from an aquifer, which is hydraulically connected with surface water to induce recharge to the ground

water reservoir. Once hydraulic connection gets established by the interception of the cone of depression and the river recharge boundary, the surface water sources starts providing part of the pumping yield (Figures 6.17). Induced recharge, under favourable hydrogeological conditions, can be used for improving the quality of surface water resources due to its passage through the aquifer material. Collector wells and infiltration galleries, used for obtaining very large water supplies from riverbeds, lakebeds and water logged areas also function on the principle of induced recharge (Figure 10).

2. Aquifer Modification Techniques

These techniques modify the aquifer characteristics to increase its capacity to store and transmit water through artificial means. The most important techniques under this category are bore blasting techniques and hydro fracturing techniques. Though they are yield augmentation techniques rather than artificial recharge structures, they are also, being considered as

Figure 10: Induced Recharge Method



artificial recharge structures owing to the resultant increase in the storage of ground water in the aquifers.

Techniques

- A. Bore blasting method
- B. Hydro fracturing method
- C. Jacket well method
- D. Fracture seal cementation and pressure injection grouting

A. Bore blasting methods: This method is used to increase the fracture porosity of an aquifer. Shallow bore wells are drilled in the area where fracture porosity of the aquifer is planned to increase.

These bore holes are blasted with the help of explosive which creates fracture porosity in the aquifer (Figure 11).

B. Hydro fracturing method: Hydro-fracturing is used to improve the yield of a bore well.

In this technique, water is injected at a very

high pressure to widening the existing fracture of the rock.

The high-pressure injection of water also helps in removing of clogging, creates interconnection between the fractures, and extends the existing length of the old fracture.

The high-pressure injection also creates new fracture in the rock strata. As a result of these, the water storing and transmitting capacity of the strata increases

C. Jacket well technique: Jacket well technique is used to increase the yield of a dug well.

In this method, the effective diameter of the well is increased by drilling small diameter bores around the well in a circular pattern (Figure 12).

D. Fracture seal cementation and pressure injection grouting: This technique is used to control the outflow from an aquifer.

Cement slurry is injected into the aquifer using mechanical means or manually near to the aquifer outlet like spring, etc.

Figure 11: Bore Blasting Method



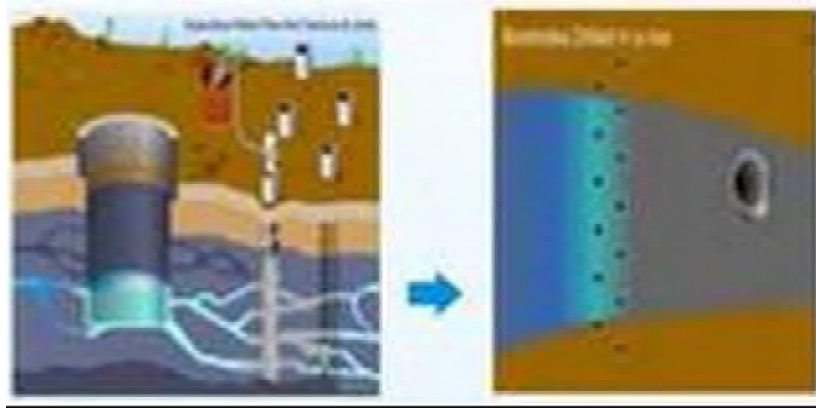
Figure 12: Jacket Well Technique



The injection of cement slurry helps in reducing the fracture porosity of the aquifer near the outlet

which will eventually reduce the outflow from the aquifer (Figure 13).

Figure 13: Fracture Seal Cementation and Pressure Injection Grouting



Conclusion

1. Stream or river with less percolation capacity won't increase ground water level, in this case improving of ground water level takes place near the stream not exactly under the stream, by either flooding, or recharge well, dug well if any present.
2. If soil of the river or stream is very porous and pervious, in that situation one can opt either stream augmenting or check dams.
3. Now in case of draught areas where water availability is low and period of rain fall is less in that situations water from rain fall and secondary treated water is used to recharge through recharge wells along with rain water harvesting, collecting water and pump it into ground through recharge well or dug well.
4. Villages in which people totally depends on irrigation in those areas water availability for summer is so hard, so they follow recharge pits and recharge shafts methods which increase water table level.
5. In urban areas where the entire locality will be concrete jungle in those areas there is no chance of permeability, here rain water harvesting is best method not only for increase water table but also to decrease floods.
6. If stream soil has high percolation capacity, so check dams, stream augmentation methods give best results in improve ground water.
7. In case one area having maximum capacity of percolation but no ground water available in that area, it shows that underground streams, which leads to problem of ground water level under ground dykes and dams which control under ground flow, best suited method.
8. If the aquifers in a locality are not capable of store and percolate water, in that situation aquifer modification is best method.
9. If available surface water is some salty or ionic content water, to reduce that effect induced recharge technique is the best suited and low cost method.
10. Hill areas with full gradients leads to loss of water to bottom of hill, in such cases the water storage and ground water improvement is difficult so contour bunds and contour trenches show us better answer.

The present techniques are easy, cost-effective and sustainable in the long term. Many of these can be adopted by the individuals, rural and urban communities with locally available materials and manpower. Though ground water recharge scheme either naturally or artificially may not be the final answer, but they do call for the community effort and create the spirit of cooperation needed to subsequently manage sustainably ground water as a community resource.

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References

1. Sai Prasad K S *et al.* (2016), "A Research Paper on Hydrometeorological Study of Kuthaleru River Basin, Anantapur District, Andhra Pradesh, India", *IJGES Journal*, ISSN 2395- 647X, Vol. 2, No. 4.
2. Sivanatha Reddy *et al.* (2017), A Project Report on "Planning and Design of Augmentation Structures of Water Resources" – A Case Study of JNTUA College of Engineering Pulivendula.
3. Manisha *et al.* (2017), A Project Report on Quality of Ground Water Case Study, Anantapur District, Andhra Pradesh.
4. Sasi Kumar *et al.* (2018), Academic Project Report on "Augmenting Ground Water Resources" Submitted to JNTUA College of Engineering, Pulivendula, Kadapa Dist., Andhra Pradesh.