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Groundwater Recharges Technology for Water Resource Management: A Case Study

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Abstract

The irregularity in monsoon has severely affected the water availability at surface and sub-surface systems. Diminishing surface and sub-surface availability has not only decreased the water availability, but it additionally affected the ecosystem and increased disastrous situations like floods and droughts, resulting problems of stress on groundwater recharge. Groundwater recharge is a technique by which infiltrated water passes through the unsaturated region of groundwater and joins the water table. It is based upon soil type, land use land cover, geomorphology, geophysical and climate (viz. rainfall, temperature, humidity etc.) characteristics of a region. Over the years, due to variations in weather pattern and overexploitation of aquifers groundwater recharge has decreased and groundwater level has reduced in the most parts of the country. This has led to severe water deficit problems in several parts of the country. This can be solved by different direct and indirect methods of groundwater recharge technology. This technology can reduce the wastage of water and enhance groundwater availability for uses in different sector like irrigation, domestic and industrial uses.

Keywords: groundwater recharge technology, groundwater, rainfall, water harvesting

1. Introduction

Groundwater is the foremost supply of freshwater that caters to the demand of household, agricultural and industrial sectors. It has become an essential for domestic uses especially for drinking water and food security for billions of population of the country. Approximately 70 percent water use in rural regions and approximately 50 percentage of water used in urban and commercial region are fulfilled by the sources of groundwater [1]. The average annual per capita water availability has been steadily falling since 1991 (2300 m³) to 2015 (1720 m³) in the country and these are projected to reduce to 1400 m³ and 1190 m³ for the years 2025 and 2050, respectively [2]. In last three decades an exponential growth in number of ground water structures has been observed, leads to enormous withdrawal of groundwater for various uses in different sectors. However, speedy urbanization and land use adjustments has resulted in decreased natural

infiltration/recharge of aquifers. This has result in various issues related to quantity and quality of groundwater, the decline in water table levels and depletion of groundwater resources [3].

Slow natural replenishment of groundwater reservoir is not able to keep pace with the excessive persisted exploitation of groundwater assets in numerous parts of the country. In order to increase the natural supply of groundwater, artificial recharge to groundwater has emerged as a vital and frontal management approach [4]. So, the recharge of groundwater is performed by using various direct and indirect recharge technologies. The adoption of this technology depends on hydrology, geology and other factors of a region [5]. Thus artificial recharging of aquifer is one of the best options, in order to improve groundwater crises which are sustainable in the long term.

2. Need to recharge groundwater

Artificial recharge is the process by which the ground water recharge is augmented at the rate much higher than those under natural condition of percolation.

According to [1] groundwater recharge meets the demand as

- By 2050 the demand for ground would reach to 1180 billion cubic meters.
- Water will be available to 1 person out of 3 and no food to 1/3rd population

In the country, either in pre- monsoon or post-monsoon or both the annual groundwater yields exceeds the annual groundwater recharge, resulting a significant fall in long term groundwater levels has been observed.

3. Problems associated with groundwater overexploitation

3.1 Lowering of the ground water level

The most critical effect of over-pumping of groundwater is that the water table may be lowered. For water to be withdrawn from the aquifers, water should be pumped from a well that reaches beneath the water table. If groundwater levels reduce too far, then the well owner may have to deepen the well, drill a new well, or, at least, lower the pump below the water table available. Also, as water levels fall down, the rate of water the well can yield might also reduce.

3.2 Increased costs for the user

As the depth of groundwater increases, the water must be lifted from the depth of groundwater to the ground surface. If water pumps are used to lift the water, more electrical energy is required to operate the water pump. Under this situation, using the well can become costly to users.

3.3 Reduction of water availability in water bodies

There may be more of an interaction between the water in water bodies such as ponds, lakes, rivers and streams, and groundwater than the most of the people

think. A proportion of water flowing in rivers contributed from seepage from the streambed to groundwater. Groundwater contribution mainly depends upon on the parameters of physiographic, region's topography, soil, geology and climate.

3.4 Land subsidence

The primarily cause of land subsidence is a lack of support underneath ground surface. Sometimes, when groundwater is over-exploited, the soil collapses, compacts, and sinks. This depends on various factors, such as the type of soil, soil compressibility, physical attributes of the aquifer, water table levels and earth geology. It is most often caused by anthropogenic activities, mainly from the excess removal of subsurface water.

3.5 Deterioration of water quality

Saltwater intrusion is the major cause and threat to contamination of fresh groundwater supplies. Available volume of water in the aquifers is not fresh water; much of the very deep groundwater and water below seas is saline. Under natural conditions the boundary between the freshwater and saltwater tends to be relatively stable while under excessive pumping conditions it may result saltwater to migrate inland and rising upward and it leads to contamination of the water supply.

4. Benefits of groundwater recharge

There are following advantages of artificial recharging of groundwater aquifers:

- Subsurface storage space is available free of cost and inundation is avoided
- Evaporation losses are negligible and temperature variations are minimum
- Quality improvement by infiltration through the permeable media
- It has no adverse social impacts such as displacement of population, loss of scarce agricultural land etc.
- It is a environment friendly technology that controls soil erosion and flood like situations, and provides sufficient soil moisture during dry spell or water deficit conditions.
- Water stored in soil profile is relatively immune to natural and man-made catastrophes.

5. Artificial groundwater recharge technology

The artificial groundwater recharge technology can be broadly categorized as follows [6].

Direct technology			Indirect Technology
Surface	Sub-surface	Combination surface and sub-surface	
<ul style="list-style-type: none"> • Flooding/ Water spreading • Basins or percolation tanks • Stream augmentation • Ditch and furrow system • Over irrigation 	<ul style="list-style-type: none"> • Injection wells or recharges wells • Recharge pits and shafts • Dug well recharge • Bore hole flooding • Natural openings, cavity fillings. 	<ul style="list-style-type: none"> • Basin or percolation tanks with pit shaft or wells. 	<ul style="list-style-type: none"> • Induced recharge from surface water source • Aquifer modification

Except above, water conservation structures like dams, sub-surface dykes (or locally termed as Bandharas) are entirely prevalent to capture sub-surface flows. Similarly, in hard surface areas rock fracturing strategies such as sectional blasting of boreholes with suitable techniques has been operated to inter-connect the fractures and gear up the groundwater recharge. Cement sealing of fractures, through specially built borewell has been utilized in the state of Maharashtra to preserve sub-surface flow and increase borewell yield [7].

6. Direct surface techniques

This method of groundwater recharge is very simple and most widely used. Under this method stored surface water is directly conveys into an aquifer without infiltration and water percolates naturally through the unsaturated zones of soil profile and join the groundwater table.

6.1 Flooding/water spreading

This is a very common method of groundwater recharge (**Figure 1**) [8]. This is

- This method is suitable for relatively flat topography
- Water is spread as a thin sheet
- Higher rate of vertical infiltration is obtained
- Potential area for this method is alluvial region of country

6.2 Percolation tank/basin

- A percolation tank can be defined as an artificially created surface water body in a highly permeable land submerged area so that the surface runoff is made to percolate and recharge the groundwater storage (**Figure 2**) [9].
- It is the most prevalent structures in India because it is used to measure the recharge the groundwater reservoir in highly permeable land areas.



Figure 1.
Water spreading technique.



Figure 2.
Percolation tank for water storage.

- It is applicable in both alluvial as well as hard rock formations regions.
- Its efficacy and feasibility is more in hard rock formation regions than alluvial regions.
- Suitable in the States of Himachal Pradesh, Jammu & Kashmir, Uttrakhand, Sikkim, North Eastern States, Punjab, Haryana, Uttar Pradesh, Bihar, West Bengal, Madhya Pradesh, Maharashtra, Karnataka, Tamil Nadu, Andhra Pradesh, Kerala

6.3 Stream augmentation (Check dams/Nala bund/ gabions)

- It is feasible to construct across small streams having gentle slope (less than 6 percent) [6].
- It is applicable in both hard rock as well as alluvial formation region.
- It is mainly confined to stream course and its height is normally very less (less than 2 m).
- To harness the maximum run off in the stream, series of such check dams can be constructed (**Figure 3**).
- A nala bund acts like a mini percolation tank.
- These are popular and feasible in Bhabar, Kandi and talus scree areas of Uttar Pradesh, Punjab, and Maharashtra.



Figure 3.
Check dam for surface water harvesting.

6.4 Ditch and furrow technology

This technology is mainly suitable in areas of irregular topography, shallow and flat bottomed and closely spaced furrows or ditches that provide more surface area under groundwater recharge through canal, river, stream and so on. This requires fewer earthworks and also less sensitive to siltation.

7. Direct sub-surface techniques

7.1 Dug well recharge

- It is suitable in alluvial as well as hard rock areas having depth upto 50 meters (**Figure 4**) [10].
- The ground water reservoir, storm water, tank water, canal water etc. can be diverted into these structures to directly recharge the dried aquifer.
- Ordinary dug wells, borewell and tube wells can be used for recharging of gw recharge takes place by gravity flow.
- Suitable in Madhya Pradesh, Maharashtra, Karnataka, Tamil Nadu, Andhra Pradesh, Kerala.

7.2 Recharge pit and shaft

- These are the most efficient and cost effective structures to recharge the aquifer directly (**Figure 5**) [6].
- In area where impervious layer is encountered at shallow depth.
- Where phreatic aquifer is not hydraulically in connection with surface water.
- The diameter of shaft should be more than 2 m for recharging rate 7–14 lps.



Figure 4.
Dug well groundwater recharge structure.

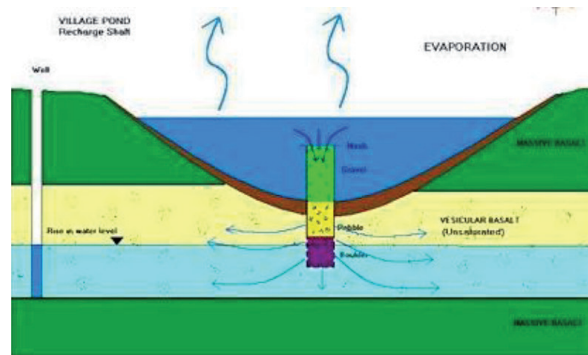


Figure 5.
Recharge pit for groundwater recharge.

- These structures are common in the states of Maharashtra, Madhya Pradesh, Andhra Pradesh, Bihar, Gujarat, Himachal Pradesh, Jammu & Kashmir.

7.3 Injection wells

Injection well is generally recommended in urban areas (**Figure 6**). It is operational in certain hydrogeological setting for groundwater recharge where the aquifers do not get the natural recharge because of the confining layers of low permeability [11]. There are following advantages for installation of the injection well:

- It is made with the purpose of augmenting the ground water storage of a confined aquifer by pumping-in treated surface water under pressure.
- The aquifer to be replenished is generally over-exploited.
- It is suitable in coastal regions to capture sea water and also to withstand the land subsidence problems in the regions where confined aquifers are over-pumped.

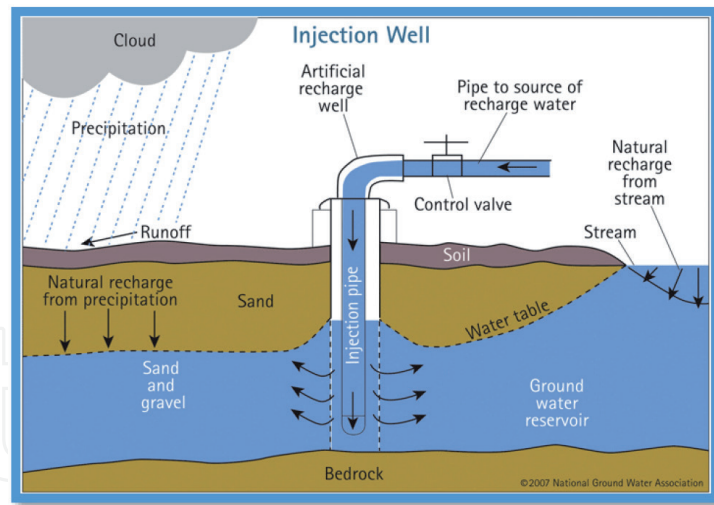


Figure 6.
Injection well for groundwater recharge.

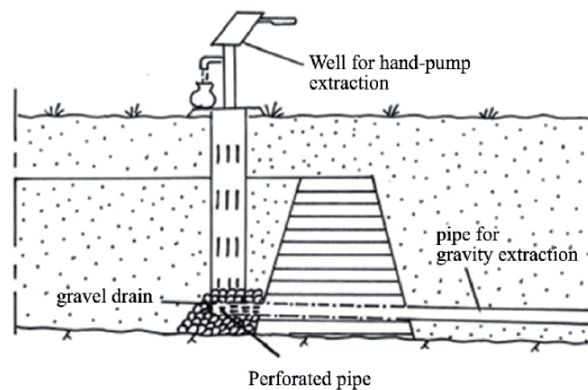


Figure 7.
Subsurface dyke for surface water harvesting.

- Water available for groundwater recharging is to be fairly treated for elimination of suspended material, chemical stabilization and bacterial manipulation.

7.4 Subsurface dykes

- It is a sub-surface barrier across a stream which slows down the natural sub-surface /groundwater flow of the system and capture water beneath ground surface to meet the water demand (**Figure 7**) [12].
- The main cause of groundwater dam is to capture the flow of groundwater out of the sub-basin and increase the storage capacity of the aquifer.
- Suitable in hard rocks or alluvium forested area.

8. Case study

Direct and indirect method of groundwater recharge technology was adopted in different locations of India.

Artificial groundwater recharge system at Shram Shakti Bhawan, New Delhi.

Shram Shakti Bhavan having catchment area of about 11,965 km². Roof top rainwater harvesting may annually recharge about 2900 m³ water this is going as waste. Over the years, depth to water level has fallen by 2 to 3 m in the catchment area. Artificial groundwater recharge is proposed via recharge trenches with two injection wells in each at selected locations in catchment area [10].

8.1 Salient features

- Rainwater runoff: 3325 cubic meter
- Area of 11,965 sq.km
- Recharge Structures Trench & recharge wells: 3
- Year of construction: 2001
- Average recharge: 3000 m³/Year
- Rise in water levels Aug 2007: 1.68–3.33 m
- Cost: Rs 4.10 Lakh

9. Artificial groundwater recharge system at President's Estate, New Delhi

President's Estate having catchment area of about 1.20 km² is located on the Northern flank of Delhi ridge. Extravagant groundwater development has resulted in annually groundwater fallen by 6 to 13 m. Four metre thick aquifer has become de-saturated over an area of 0.7 km². The artificial groundwater recharge in the catchment area is being done through two dried dug wells, one vertical recharge shaft, one injection well, two recharge trenches with injection wells and so on [10].

Annually approximately 28,170 m³ rainfall-runoff water collected and used to recharge groundwater (**Figure 8**).



Figure 8.
Artificial groundwater recharge structure at President's estate.

9.1 Salient features

- Campus area: 1.3 Sq.km
- Source of water: Rainwater & Swimming pool water
- Av annual rainfall:712.2 mm
- Depth of water table: 6–12 m. Bgl
- Year of construction: 2000
- Recharge structures:
 - Two existing dug wells
 - One recharge well
 - One recharge shaft
 - Two trench with recharge well

Rise in water level during 2003: Upto 4 m.

9.2 Artificial Recharge Structures (Sub surface Dykes) in Rajgarh district, M.P.

- District: Raigarh, M. P.
- Normal Rainfall: 950 mm
- Location: Barwa Kalan, Ajnar subbasin, Rajgarh district
- Type of Structure: Subsurface Dykes
- Cost: Rs. 2.0 lakhs
- Implementing Agency: Public Health Engineering Department, Govt. of M.P.
- Geology: Alluvium and basalt
- Year of completion: 2004–2005
- Study year: 2009–2010

Description: To capture the over groundwater flow to the river Ajnar, in the form of base flow, subsurface dykes were constructed near Barwa Kalan village (**Figure 9**) [10].

9.3 Impact

- Water level in the nearby dug wells recorded a rise in the range of 0.80 to 3.80 m.
- In the hand pumps, the water level rise in the range of 6.0 to 12.0 m.



Figure 9.
Artificial groundwater recharge structure at Rajgarh district in MP.

- During the period the cultivated areas under *rabi* crop has increased from 97 to 121 ha.
- The number of irrigation wells increased up to 102 from initially 38.

10. Conclusions

Artificial groundwater recharge technology is very impressive technology to increase water table and groundwater availability. It plays an important role in the reduction of surface runoff, increase availability of water for irrigation, domestic and industrial sector, improve the drainage, revival of springs and improvement of groundwater quality and so on. It is also considered to mitigate the impacts of variability in rainfall patterns under varying climatic conditions. Additionally, it is primarily important to meet the demand of spatial water productivity and availability at regional and global scale.

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