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Capacity of Water Harvesting Techniques for Water Management

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Abstract : Water is essential to all life on earth. The water that future generations will inherit will have to be the one in which ground water plays its full developmental, productive and environmental role. Regions with high population density, intensive agriculture and insufficient surface water availability shows decline in ground water. The problem of ground water decline is a fundamental threat to the wellbeing of humans, so it is necessary to conserve it. To control the ground water decline, rainwater harvesting techniques like ground water recharge and rainwater storage are adopted. Recharging of ground water table is the process by which water percolates down the soil and reaches the water table, either by natural or artificial methods. Storage on the surface or in the ground water reservoirs by suitable recharge techniques is useful for reducing over-draft, conserving surface runoff and increasing available ground water supplies. It is therefore essential to have a good idea of the different recharge and storage mechanisms and their importance in the study area. Choice of methods should be guided by the objectives of the study, available on infiltration capacity of soil, hydro-meteorological, hydrological, hydro-geological data. Economy too is an important factor. In this paper, various water harvesting techniques are outlined and reviewed for enhancing ground water recharge.

INTRODUCTION

The rainfall occurrence in India is limited to about three months period ranging from around 10 to 100 days. The natural recharge to ground water reservoir is restricted to this period only and during this period limited recharge occurs. In order to increase ground water recharge the artificial recharge techniques are used to increase the recharge period in the post-monsoon season for about 3 more months providing additional recharge. This results in providing sustainability to ground water development during the lean season. In most low rainfall areas of the country, the availability of utilizable surface water is so low that people have to depend largely on ground water for agriculture and domestic use. Excessive ground water pumping in these areas, especially in drought prone areas has resulted in alarming lowering of the ground water levels. The problem has been further compounded due to large-scale urbanization and growth of mega cities, which has drastically reduced open lands for natural recharge. In hard rock areas there are large variations in ground water availability even from village to village. In order to improve the ground water situation it is necessary to artificially recharge the depleted ground water aquifers and surface storage by water harvesting techniques. The available techniques are easy, cost-effective and sustainable in the long term. Many of these can be adopted by the individuals and village communities with locally available materials and manpower.

Remote sensing and GIS technologies give fast and economical, complex database to study groundwater resource and design suitable exploration plan of artificial recharge. Moreover, remotely sensed data serve as vital tool in identifying land features, drainage pattern and geomorphic indicators for location of recharge area. In hard rock terrain availability of groundwater is limited. Occurrences of groundwater in such rocky area are essentially confined to fractured and weathered area. In India, 65 percent of the total geographical area is covered by hard rock formation. Therefore, efficient management and planning of groundwater recharge in these areas is necessary (Saraf and Choudhury, 1998). The groundwater recharge is the entry of water from unsaturated zone into saturated zone below the surface. There are many factors that affect the groundwater recharge like topography, litho-logy, structure, weathering grade, fracture extent, permeability, slope, drainage pattern, land cover and climate. The present paper discusses various water harvesting techniques for storage on surface or recharging ground water reservoir along with their suitability for enhancing ground water recharge.

WATER HARVESTING TECHNIQUES

Water harvesting techniques comprises of surface storage and recharging ground water. The recharge may occur naturally and can be enhanced by artificial means as discussed below.

Natural Methods

Groundwater is recharged naturally by rain and snow melt and to a smaller extent by surface water. Rainfall and snow melt is the principal source for replenishment of moisture in the soil water system and recharge of ground water. Other sources include recharge from rivers, streams, irrigation water etc. Moisture movement in the unsaturated zone is controlled by suction pressure, moisture content and hydraulic conductivity relationships. The amount of moisture that will eventually reach the water table is defined as natural ground water recharge, which depends on the rate and duration of rainfall, the subsequent conditions at the upper boundary, the antecedent soil moisture conditions, the water table depth and the soil type. But, recharging by natural method is very slow and is unable to keep pace with the excessive continued exploitation of ground water resources in various parts of the country. This has resulted in declining ground water levels in some areas of the country.

Artificial Methods

As the natural recharge rate is very slow, so there is need to recharge the ground water by engineering intervention artificially. The artificial recharge methods are basically augmentation of natural movement of surface water into ground water reservoir through suitable manmade structures. The artificial recharge techniques interrelate and integrate the source water to ground water reservoir and are dependent on the hydro-geological situation of the area. The artificial recharge techniques can be broadly categorized as direct and indirect recharge techniques. Direct recharge techniques are both direct surface or subsurface technique and the combination of both. In indirect technique induced recharge from surface water source is done. Various water harvesting techniques for recharging ground water artificially are discussed below.

Rooftop/Runoff rain water harvesting

Rooftop/Runoff rain water harvesting is the collection and storage of rainwater that runs off on natural or manmade catchment areas. Catchment includes rooftops, compounds, rocky surface or hill slopes, flat land or artificially prepared impervious/semi-pervious land surface. The amount of water harvested depends on the frequency, duration and intensity of rainfall, catchment characteristics like slope, shape, area etc, soil characteristics like its permeability, depth of soil, depth of water table etc. The Main Objective of rainwater harvesting is to make water available for future use. Capturing and storing rainwater for use is particularly important in dry land, hilly, urban and coastal areas. The ground water recharge results in raising the ground water table which will result in lesser use of energy for pumping of water. It is estimated that energy saving for 1m rise in ground water level is around 0.40 kilo watt per hour (Bhattacharya & Rane, 2003). Rain water harvesting reduces the runoff which chokes storm drains and to avoid flooding of roads. As a result the maintenance cost of the roads and urban infrastructure reduces. It helps in reducing groundwater pollution and to improve the quality of groundwater through dilution. It reduces soil erosion in urban areas and in coastal areas; rainwater reduces salinity from ground water. A typical roof top rainwater harvesting system comprises of roof catchment, gutters, downpipes, rain water drains, filter chamber etc. The harvested rainwater may be reused without sending it to the underground reservoir or can be recharged to the ground water aquifer. For recharging ground water recharge structures like pit, trench, tube-well or combination of these structures as shown in figure 1 is used. Whereas the reuse of harvested water surface or subsurface storage structure as shown in figure 2 can be used.

Percolation tanks and spreading basins

Percolation tanks and spreading basins are the most prevalent surface recharge structures in India as a measure to recharge the ground water reservoir both in alluvial as well as hard rock formations (figure 3). The feasibility of these structures is more in hard rock formation where the rocks are highly fractured and weathered. In the States of Maharashtra, Andhra Pradesh, Madhya Pradesh, Karnataka and Gujarat, the percolation tanks have been constructed in plenty in basaltic lava flows and crystalline rocks. The purpose of percolation tank is to conserve the surface run off and to divert the maximum possible surface water to the ground water storage. Thus the water accumulated in the tank after monsoon should percolate at the earliest, without much evaporation losses. Normally a percolation tank should not retain water beyond February.

Stream augmentation and Channel spreading

Seepage from natural streams or rivers is one of the most important sources of recharge of the ground water reservoir. When total water supply available in a stream exceeds the rate of infiltration, the excess is lost as run off. This run off can be arrested through check bunds or widening the steam beds thus larger area is available to spread the river water increasing the infiltration. The site selected for check dam should have sufficient

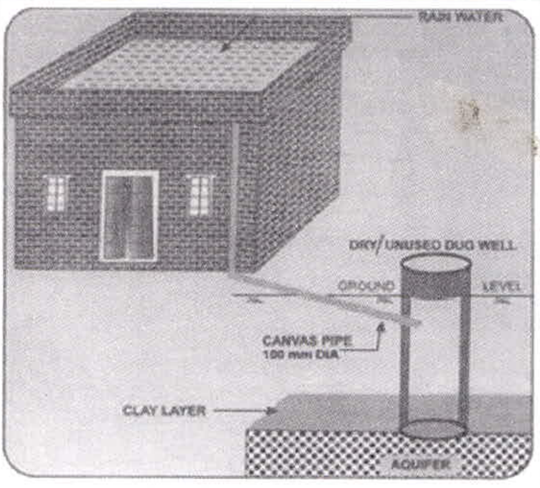

Fig. 1. Rooftop rain water harvesting for ground water recharge

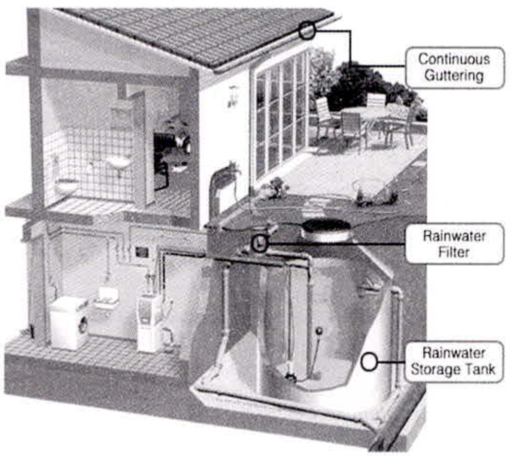

Fig. 2. Rooftop rain water harvesting for domestic use

thickness of permeable bed or weathered formation to facilitate recharge of stored water within short span of time. The water stored in these structures is mostly confined to stream course and height is normally less than 2 m. To harness maximum run off, a series of such check dam may be constructed. Whereas, channel spreading involves constructing small 'L' shaped bunds within a stream channel so that water moves along a longer path thereby improving natural recharge (figure 4). This method is useful where a small flowing channel flows through a relatively wide valley. However this is not useful where rivers are prone to flash floods due to which the bunds may be destroyed.

Check Dams or nala bunds

Check dams are constructed across small streams having gentle slope and are feasible both in hard rock as well as alluvial formation. The site selected for check dam should have sufficient thickness of permeable bed or weathered formation to facilitate recharge of stored water within short span. The water stored in these structures is mostly confined to stream course and the height is normally less than 2 m. These are designed based on stream width and excess water is allowed to flow over the wall as shown in figure 5. In order to avoid scouring from excess run off, water cushions are provided at down streamside. A series of small bunds or weirs are made across selected nala sections such that the flow of surface water in the stream channel is impeded and water is retained on pervious soil surface for longer time. Water percolates through the channel bed and recharges the ground water. Nala bunds are constructed across bigger nalas of second order streams in areas having gentler slopes. A nala bund acts like a mini percolation tank.

Ditch and furrow method

In areas with irregular topography, shallow, flat-bottomed and closely spaced ditches or Furrows provide maximum water contact area for recharge

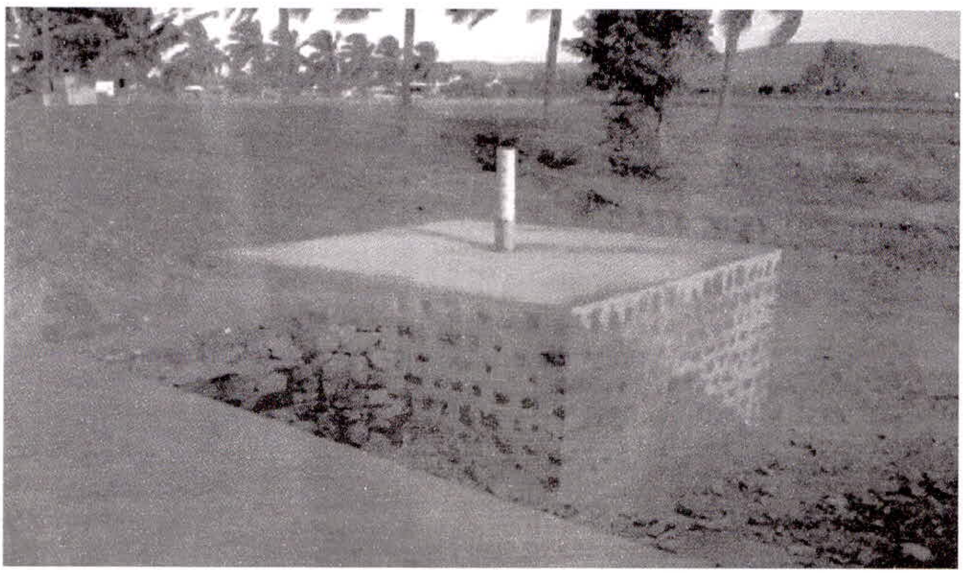

Fig. 3. Percolation tank for ground water recharge

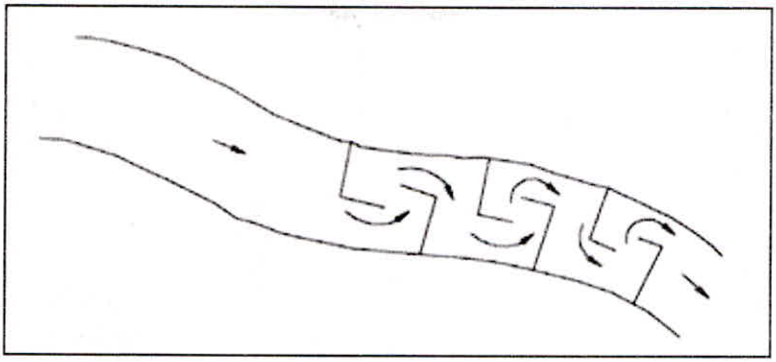

Fig. 4. Ground water recharge by channel spreading

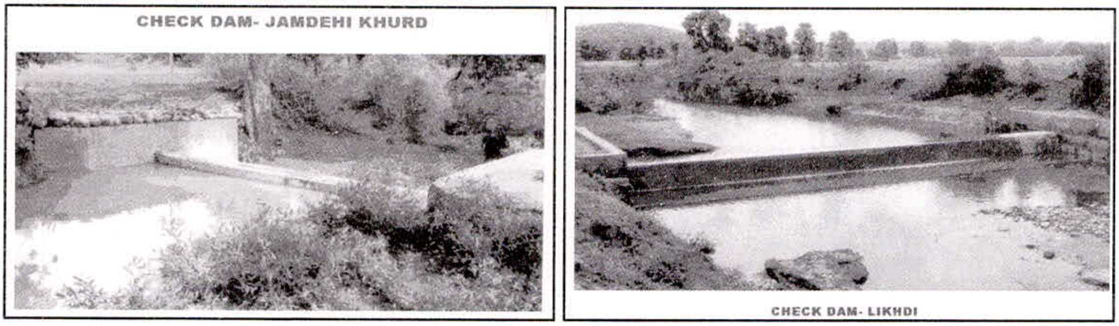

Fig. 5. Recharge by check dam

water from source stream or canal. This technique requires less soil preparation than the recharge basins and is less sensitive to silting. Generally three patterns of ditch and furrow system are adopted. In lateral ditch pattern the water from stream is diverted to the feeder canal from which smaller ditches are made at right angles (Figure 6). The rate of flow of water from the feeder canal to these ditches is controlled by gate valves. The furrow depth is kept according to the topography and also with the aim that maximum wetted surface is available and uniform velocity can be maintained. The excess water is routed to the main stream through a return canal along with residual silt. In dendritic pattern the water from stream is diverted from the main canal to a series of small ditches spread in a dendritic pattern (Figure 7). The bifurcation of ditches continues until practically all the water is infiltrated in the ground. In contour pattern ditches are excavated following the ground surface contour of the area (Figure 8). When the ditch comes closer to the stream a switchback is made and thus the ditch is made to meander back and forth repeatedly. At a lowest point downstream, the ditch joins the main stream, thus returning the excess water to it.

Injection wells or recharge wells

Direct sub-surface recharge technique or injection wells are used where permeable soils and sufficient land area for surface infiltration are not available. These structures are similar to a tube well but with the purpose of augmenting the ground water storage of a confined aquifer by pumping in treated

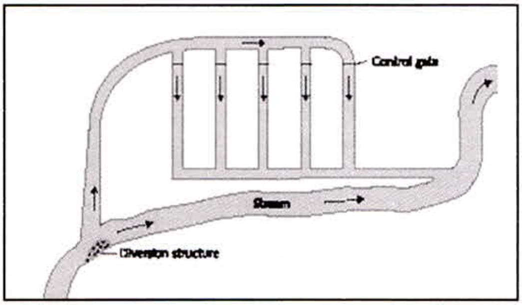

Fig. 6. Recharge by using lateral ditch pattern

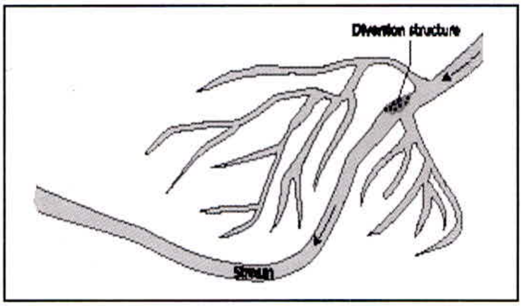

Fig. 7. Recharge by suing dendritic ditch pattern

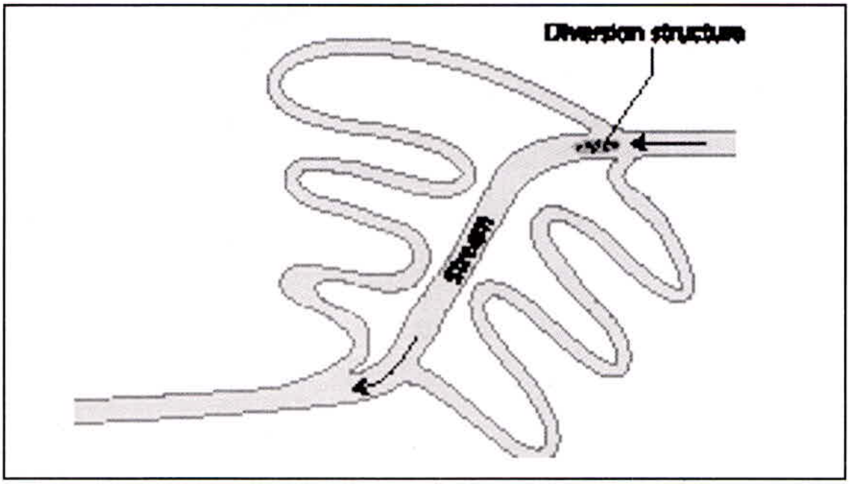

Fig. 8. Recharge by using contour ditch pattern

surface water under pressure. In vadose zone vertical infiltration systems, such as trenches or wells are used to recharge ground water. Recharge trenches are dug with a backhoe and are typically less than about 1 m wide and up to about 5 m deep. They are backfilled with coarse sand or fine gravel. Vadose-zone wells are normally about 1 m in diameter and as much as 60 m deep as shown in figure 9. The wells are also backfilled with coarse sand or fine gravel. Water is normally applied through a perforated or screened pipe in the center. The main advantage of recharge trenches or wells in the vadose zone is that they are relatively inexpensive. The disadvantage is that eventually they clog up at their infiltrating surface because of accumulation of suspended soils.

Dug wells

In alluvial as well as hard rock areas, there are thousands of dug wells which have either gone dry or the water levels have declined considerably.

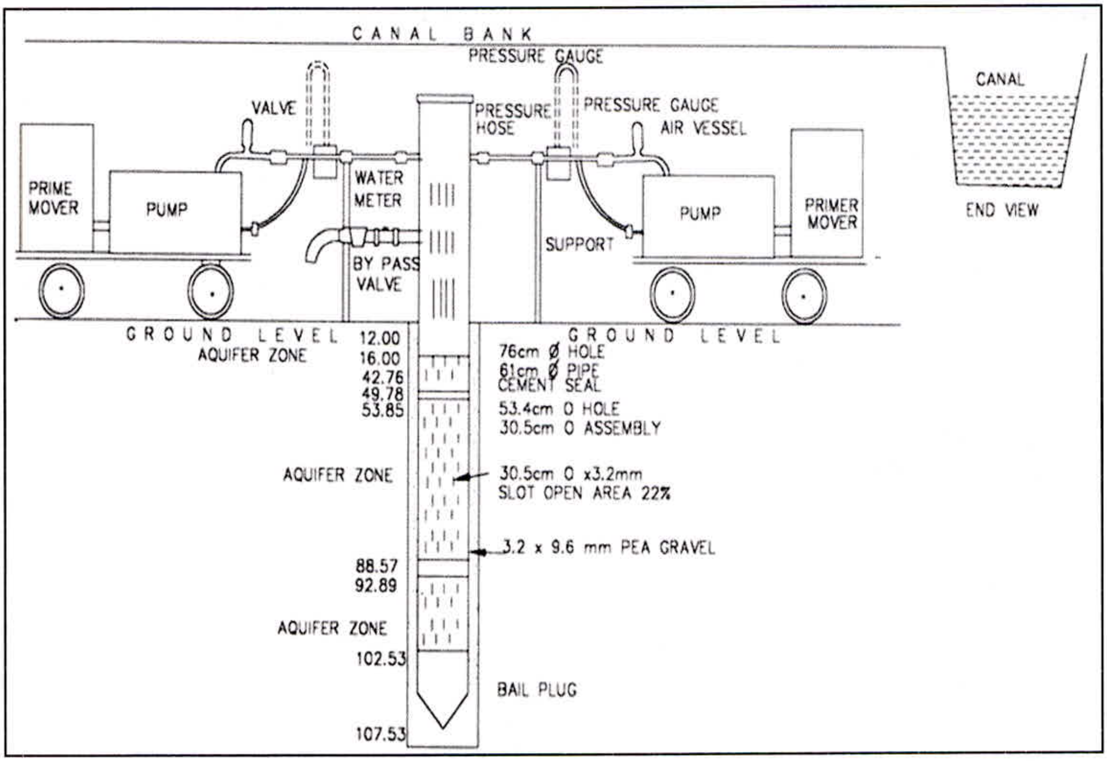

Fig. 9. Injections well used for recharge

These dug wells can be used as structures to recharge. The ground water reservoir, rain water, tank water, canal water etc as shown in (Figure 1) can be diverted into these structures to directly recharge the dried aquifer. By doing so the soil moisture losses during the normal process of artificial recharge, are reduced. The recharge water is guided through a pipe to the bottom of well, below the water level to avoid scoring of bottom and entrapment of air bubbles in the aquifer. The quality of source water including the silt content should be such that the quality of ground water reservoir is not deteriorated.

Recharge Shafts

Recharge Shafts are the most efficient and cost effective structures to recharge the aquifer directly. In the areas where source of water is available either for some time or perennially e.g. base flow, springs etc. the recharge shaft can be constructed. The recharge shafts can be constructed in two different ways viz. vertical and lateral. The vertical recharge shaft can be provided without or with injection well at the bottom of the shaft. Vertical recharge shaft without injection well (figure 10) are ideally suited for deep water levels (up to 15 m) where presence of clay is encountered within 15 m. Vertical recharge shafts with injection well (figure 11) ideally suitable for very deep water level (more than 15 m) where aquifer is overlain by impervious thick clay beds . Lateral recharge shafts (figure 12) are ideally suited for areas where permeable sandy horizon is within 3 m below ground level and continues up-to the water level

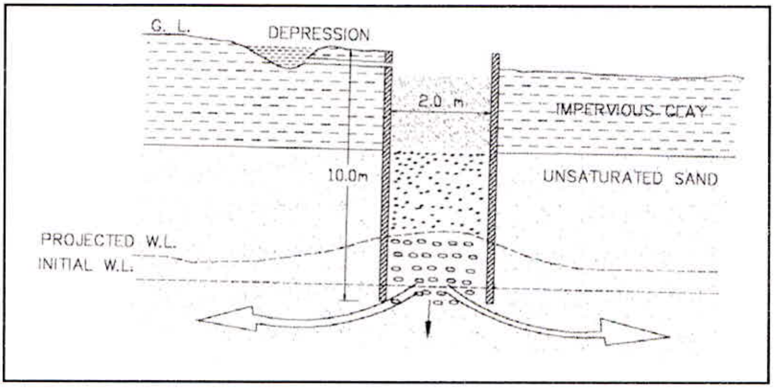

Fig. 10. Vertical recharge shafts without injection well

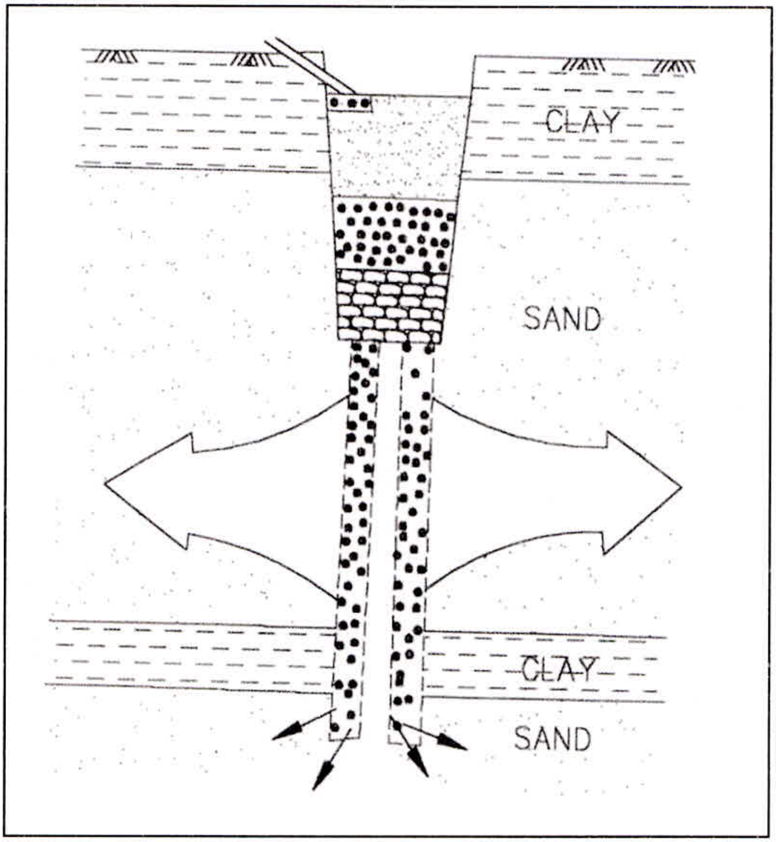

Fig. 11. Vertical recharge shafts with injection well

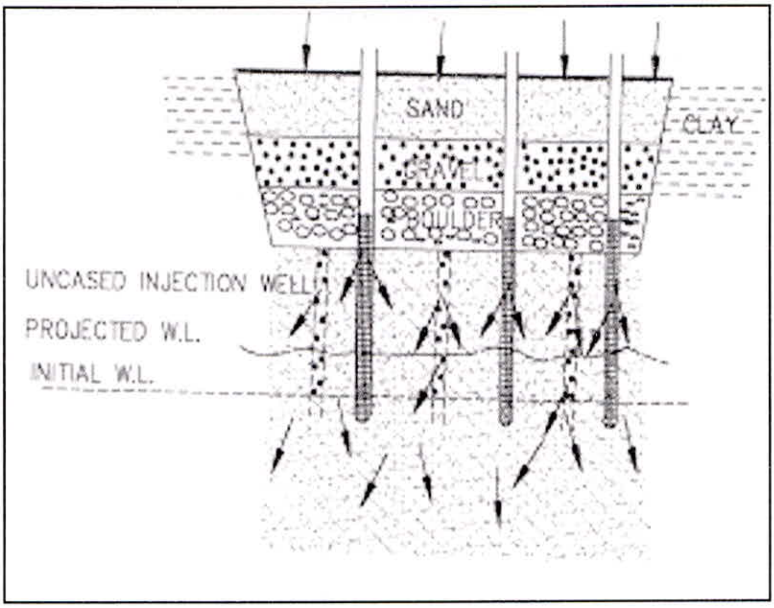

Fig. 12. Lateral recharge shafts

under unconfined conditions. Silt water can be easily recharged. 2 to 3 m wide and 2 to 3 m deep trench is excavated, length of which depends on the volume of water to be handled.

Ground water dams or sub-surface dykes

These are basically ground water conservation structures and are effective in providing sustainability to ground water structures by arresting sub-surface flow. A ground water dam is a sub-surface barrier across stream, which retards the natural ground water flow of the system, and stores water below ground surface to meet the demands during the period of need (Figure 13). The main purpose of ground water dam is to arrest the flow of ground water out of the sub-basin and increase the storage within the aquifer.

Induced recharge

Indirect method of artificial recharge involves pumping from aquifer which is hydraulically connected with surface water, to induce recharge to the ground water reservoir (Figure 14). When the cone of depression intercepts river recharge boundary a hydraulic connection gets established with surface source, which starts providing part of the pump-age yield. In such methods, there is actually no artificial build up of ground water storage but only passage of surface water to the pump through an aquifer. In hard rock areas the abandoned channels often provide good sites for induced recharge. Check weir in stream channel, at location up stream of the channel bifurcation, can help in high infiltration from surface reservoir to the abandoned channel when heavy pumping is carried out in wells located in the buried channel (Fig 15). The greatest advantage of this method is that under favorable hydro-geological situations the quality of surface water generally improves due to its path through the aquifer material before it is discharged from the pumping well. In areas where the phreatic aquifer adjacent to the river is of limited thickness, horizontal wells may be more

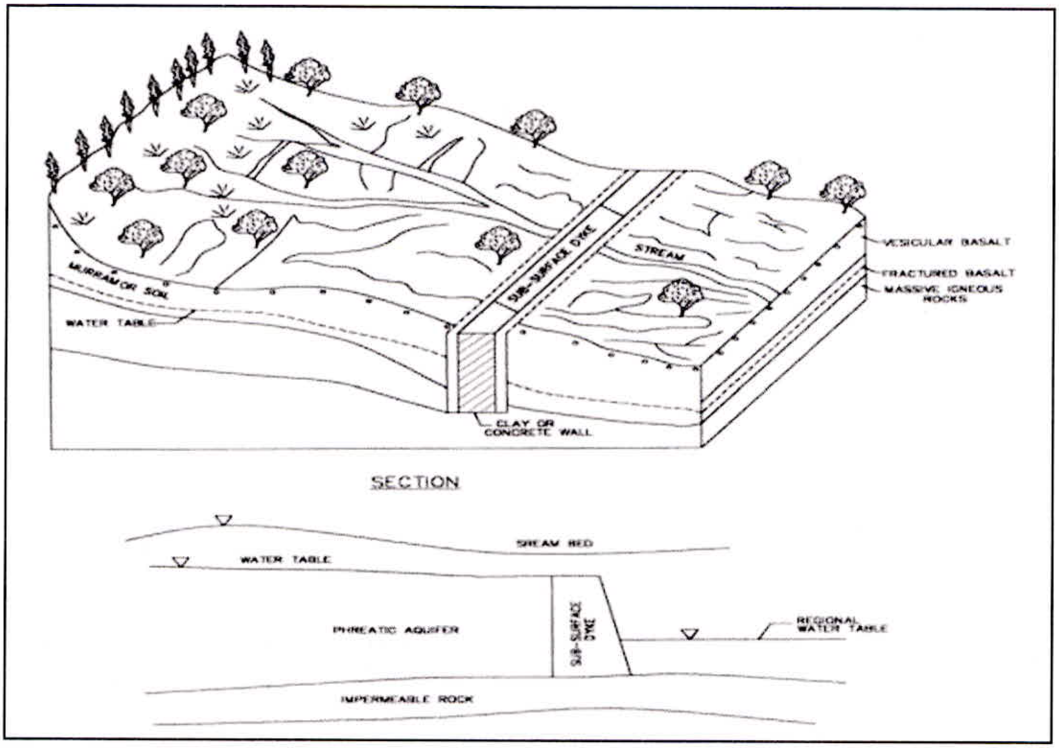

Fig. 13. Ground water dams or sub-surface dykes used for recharging

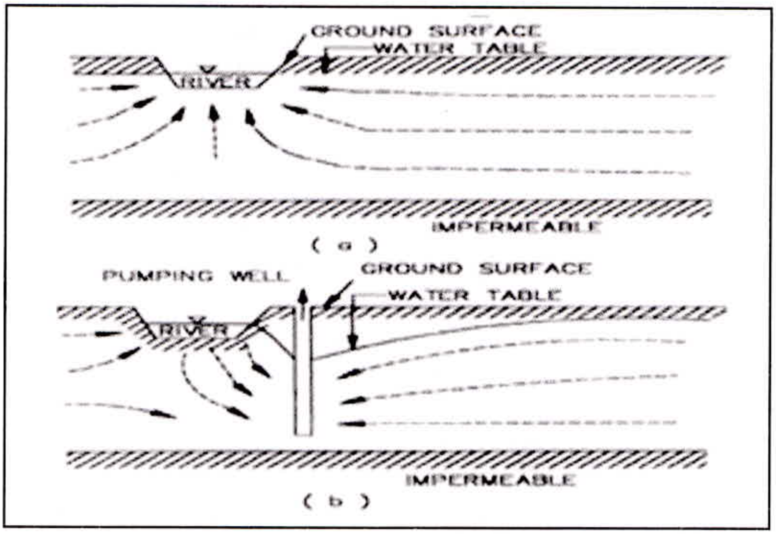

Fig. 14. Induced recharge resulting from a well pumping near a river

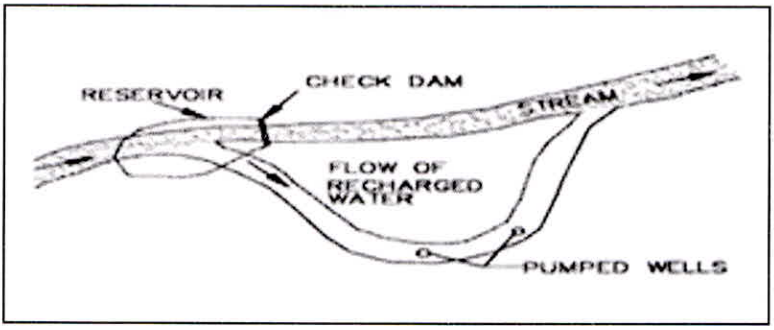

Fig. 15. Induced artificial recharge of buried channel

appropriate than vertical wells. Collector well with horizontal laterals and infiltration galleries can get more induced recharge from the stream collector wells. Constructed in seasonal nala beds these can be effective as induced recharge structures for short periods only.

CONCLUSIONS

Different rain water harvesting and recharge techniques are available for utilization/reuse of rain water. These techniques should be used for efficient reuse of rain water and for water management to save water for future. The most logical step toward this goal is to store harvested water on surface for reuse as it will save energy that is used for extracting water from aquifer by pumping. The excess surface water after storing on the surface for reuse should be recharged to ground water for increasing the capacity of ground water reservoir. The choice of techniques used for recharging ground water depend on rainfall, hydrological characteristics, geology of the area, slopes, and nature of the soil. The techniques selected must be easy, cost-effective and sustainable in the long term with locally available material and man power. Therefore a planned approach is needed in order to fully utilize the harvested water to adequately meet our water requirements. Hence, an effective and positive thrust is needed in developing and encouraging water harvesting techniques, for both surface storage and recharging the aquifer.

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