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Planned Recharge of Aquifer- A Review

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***Abstract* - Planned recharge of aquifers also called Artificial Recharge of ground water using treated wastewater, rainfall, surface water etc., is becoming important as the scarcity of water is increasing due to high consumption of water by pumping. This review paper is the compilation of various artificial recharge methods of groundwater in order to satisfy the demand of water. In this paper, direct surface, direct subsurface, combination of surface and subsurface and indirect recharge techniques are explained in detail. This paper helps people to choose appropriate technique with availability and cost.**

***Keywords*-- Artificial recharge, Direct surface methods, Direct subsurface methods, Indirect methods.**

I. Introduction

Groundwater recharge is increasing in popularity as groundwater resources are being depleted and as saltwater intrusion is becoming a greater threat to coastal communities [1]. These are done by either naturally or artificially. Natural recharge can be well explained by Hydrological process. In areas where groundwater is an important component of the water supply, and rainfall variability does not allow for a sufficient level of aquifer recharge by natural means, artificial enhancement of the natural recharge by different techniques are adopted. Planned recharge is a process by which excess surface water is directed into the ground either by spreading on the surface, by using recharge wells, or by altering natural conditions to increase infiltration to replenish an aquifer [2]. [3], [4] define as the practice of increasing the amount of water reaching a subterranean reservoir by artificial means.

The following factors are to be considered in selecting the proper location of sites for recharge [5]:

(1) Water (availability, source, turbidity, quality, etc)

(2) Surface soils

(3) Depth to aquifer

(4) Geologic structure and capacity of the ground-water reservoir

(5) The presence of aquicludes

(6) Movement of ground water

(7) Location of withdrawal area

(8) Pattern of pumping draft.

Planned recharge has applications in waste disposal, waste treatment, secondary oil recovery and land subsidence prevention, freshwater storage in saline aquifers, crop development, and stream flow augmentation [5], [6]. It may also be used to mitigate or control saltwater intrusion into coastal aquifers.

II. Planned Recharge Of Aquifer

Planned recharge is done in two basis - one on short term basis and other on long term basis. Planned recharge system are high systematic engineered plans which moves the surface water into the aquifers for augment ground water resources.

Planned recharge of aquifers contains the following steps:

- Pre-treatment (treating waste effluents before passing to recharge)
- Soil-aquifer processes (changes that occur when water moves through the soil and aquifer)
- Post-treatment (treatment after withdrawal for use from aquifers)

A. Pretreatment process

The effluents reclaimed waste water contains low concentrations of stable organics and heavy metals, pathogenic organisms which of high hazards nature which has to be treated before augmenting soil aquifers. The pre-treatment process contains the following methods

- P S = Primary sedimentation
- T F = Trickling filter
- A S = Activated sludge
- A L = Aerated lagoons
- CF C = Coagulation , flocculation , clarification
- S P = Storage ponds
- F = Filtration
- Ae r = Air stripping/Aeration
- GA C = Granular activated carbon
- R O = Reverse osmosis
- Di s = Disinfection

B. Soil Aquifer process

An aquifer is defined as soil or fractured rock that holds water in its voids. Soil aquifers are large reservoirs of water.

Soil aquifer process define the various scientific methodology of percolation of water through voids to aquifer for storage. Fig. 1 represents the aquifer recharge process.

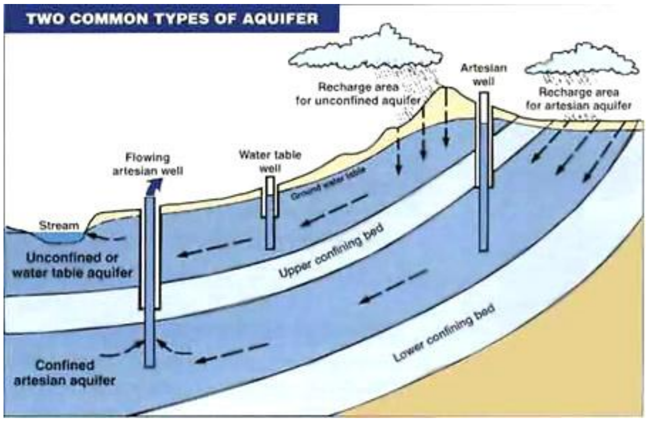

Fig. 1: Aquifer recharge process.

TABLE 1
Factors Affecting Soil Aquifer Process [7]

PROCESS	CONSEQUENCES	PROBLEMS
Accumulation of sludge in basins	• Stagnation of infiltration process • Eutrophication of surface water • Increase of chemical clogging of recovery system • More denitrifcation • More removal of (sub)oxic OMPs • Less leaching of aquifer below sludge	None, because: • Easy to remove • Quality now already very good • Accretion rate slow • prognosis = in future even cleaner
Accumulation of pollutants in aquifer	• Stagnation of infiltration process • Worsening of quality recovered water • Ecological threatening of impacted flow-through lakes in surroundings • Improved removal of pathogens	Hardly, because: • To a very limited extent only (low contents) • over a small area (proximal zone) • self purifying capacity of soil high • prognosis = inf.water becomes cleaner and flushes out ancient pollutants
Leaching of aquifer materials	• Loss of capacity to buffer acids and oxidants, and to sorb pollutants • Increase of NO_3 and (sub)ox. OMPs# • Decrease of Fe, Mn, NH_4 (less sludge) • Decrease of clogging of partly aerobic recovery systems • Possibly an increase of clogging of currently totally anoxic recovery systems	Not of serious concern, because: • Expected to decrease in consequence of EU-Water Framework Directive; • Raised SI-calcite and better quality of infiltration water already reduced CaCO3 leaching • Compensation by positive consequences: lower Fe and Mn concentrations of recovered water lead to reduced sludge production in post treatment • Although leaching in AR systems is relatively rapid, in absolute terms it is very slow • Loss of acid buffering capacity does not lead to acidification thanks to basic character of infiltration water

C. Post treatment process

Post treatment process contains the quality monitoring techniques. The aquifer water is tested for its accessibility, metal ion concentration, microbial concentration, pH and toxicity.

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TABLE 2.
Major Characteristics of Aquifer Recharge Methods

arameter	Recharge Basin	Vadose Zone Injection Wells	Direct Injection Wells
Aquifer type	Unconfined	Unconfined	Confined / Unconfined
Pre-Treatment Requirements	Low technology	Removal of Solids	High Technology
Capacity	1000 – 20,000 m^3/ha/day	1000-3000 m^3/well/day	2000-6000 m^3/well/day

Wa with standards of drinking water quality is utilized for human needs [8]. Infiltration capacity of soil is an important factor that governs the rate of saturation of the vadose zone and thereby the efficacy. This depends mainly on storage coefficient, availability of storage space and permeability [9]. Table 2 explains the major characteristics of Aquifer Recharge Methods.

Estimated water table:

To maintain the regional water balance and to assure optimal use of available water, knowledge of the water-table fluctuation scheme is essential. In Indian context, the availability of ground water level for human usage is given in Table 3. The estimated water table states the need for planned recharge or artificial recharge to maintain the water table for near future [10].

TABLE 3:
G.L. for Human Usage

YEAR	WATER LEVEL
1970	10 m below G.L.
1999	30 m – 60 m below G.L.
2050	80 m – 200 m below G.L. If not recharged now

III. TECHNIQUES OF ARTIFICIAL RECHARGE

The specific methods of percolation are listed below [9-20]

1. Direct surface techniques

- Flooding
- Ditch and furrow systems
- Basins
- Stream-channel modification
- Stream augmentation
- Over-irrigation

2. Direct subsurface techniques

- Natural openings
- Pits and shafts
- Reverse drainage
- Wells

3. Combination surface-subsurface techniques

- Subsurface drainage (collectors with wells)
- Basins with pits, shafts, or wells

4. Indirect techniques

- Induced recharge from surface-water sources
- Aquifer modification

A. Direct surface techniques

In direct-surface techniques water moves from land surface to the aquifer by percolating through the soil. In direct aquifers the percolation of water depends on certain factors like area of recharge [21], length of time, size of the aquifers [22] and nature of soil aquifer materials [19]. Direct-surface methods are here grouped into several categories, including flooding, ditch and furrow, basins, stream channel modifications, stream augmentation, and over irrigation.

i. Flooding

Recharge by flooding can be done in places with slope to facilitate the spread of water over a large area that travels slowly downhill without disturbing the soil. The water is spread over the land surface from several distribution points. Embankments or ditches are to localize infiltration. Excess water are collected in the system's topographic low point for disposal.

ii. Ditches and furrow systems

Ditches and furrows are well engineered closely spaced, shallow, flat-bottomed recharge aquifers.

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Most ditch and furrow systems have one of three patterns: lateral, dendritic, or contour [16,23]. *Lateral system* have one or more main supply canals from which smaller ditches protrude at right angles (Fig 2 a)). *Dendritic systems* divert flow from a main canal to a series of successively smaller ditches (Fig 2 b)). *Contour system* spread water through a ditch or ditches that follow the contour of the land (Fig 2 c)).

iii. Basins

Basins are excavated or enclosed by dikes or levees. Basin geometry is flexible construction adapted to the terrain. Basins are constructed individually, such as in small drainage areas to collect urban run-off, or in series for infiltration of stream or storm water [Fig.3]. Use of multiple basins for infiltration of stream water provides several advantages: the storage capability allows a longer time for recharge; the up-stream basins act as clarifiers for those below, and the ability to bypass the basins permits periodic maintenance (such as scraping, disking etc.) to restore infiltration rates [17]. Higher infiltration rates will be observed in case the basin is regularly cleaned and if the basin contains deeper gullies for the settlement of fine particles [24].

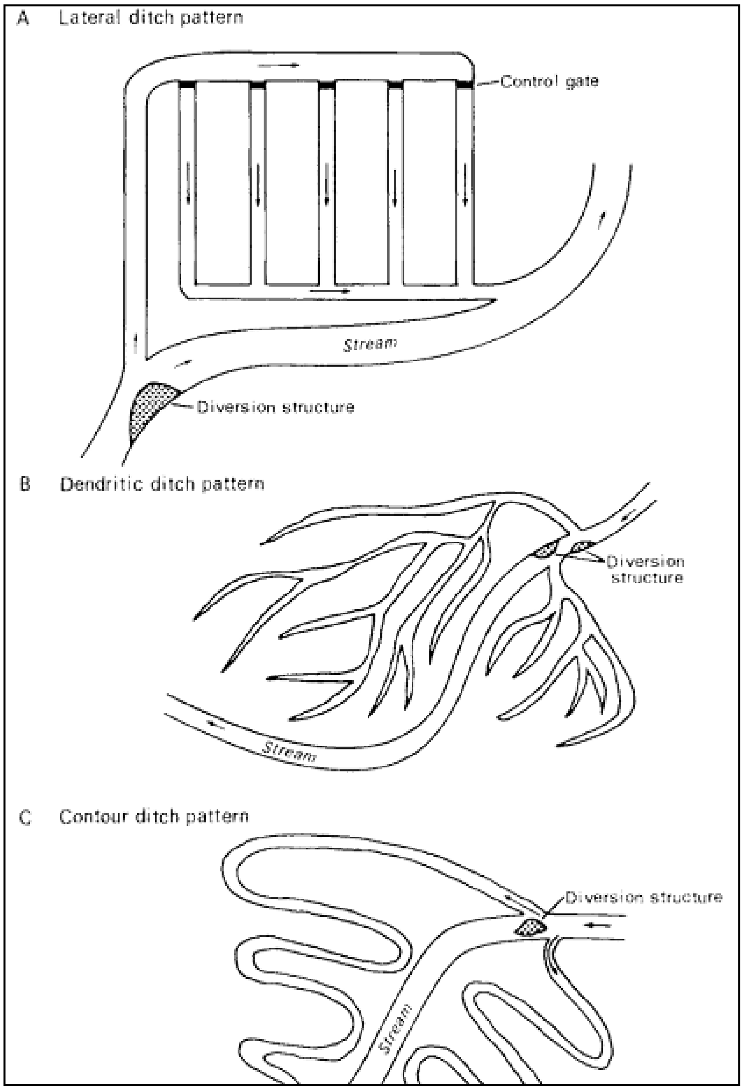

Fig. 2: Schematic diagram of a) Lateral ditch b) Dentric ditch c) Contour ditch

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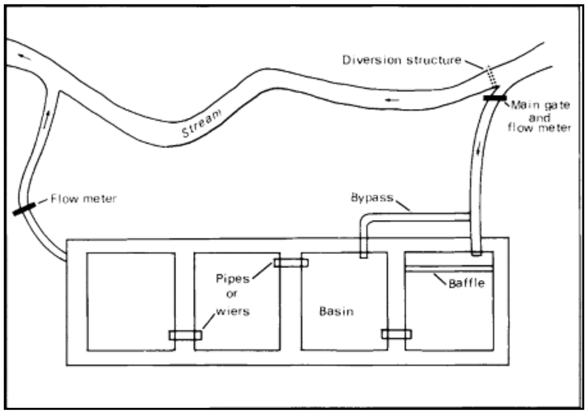

Fig 3: Schematic picture of Basins

iv. Stream channel modification

Stream channel modification is altering a natural drainage channel to increase infiltration by detaining stream flow and increasing the stream bed area exposed to water. Stream channel modification can be done in association with the flooding, ditch-and-furrow, and basin methods mentioned previously (Fig 4), or through dredging, leveling, and widening.

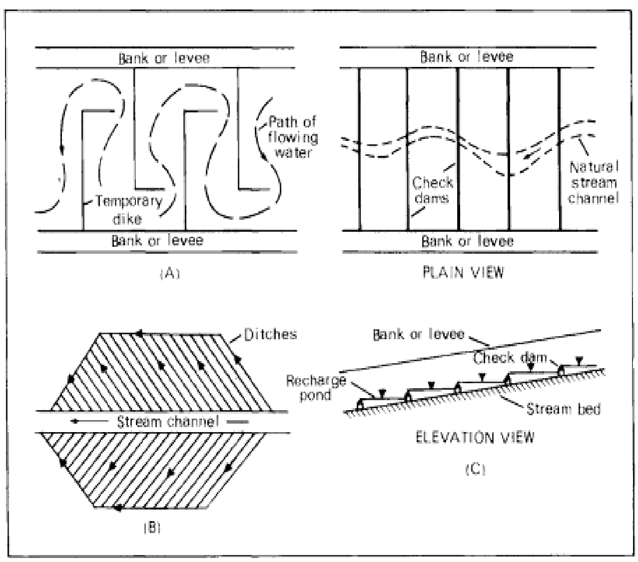

Fig 4: Stream Channel Modification

B. Direct subsurface technique

Direct-subsurface recharge is achieved when water is conveyed and replaced directly into an aquifer. Techniques of direct-sub-surface recharge include injection of water into (1) natural openings in the aquifer, (2) pits or shafts, (3) wells, and (4) drainage pipe networks.

i. Natural openings

Natural openings are formed by fracturing or solution in cavernous limestone or other soluble rocks that drains body of water or as the extension of a pipeline delivering water to it. .

ii. Pits and shafts

When a semi pervious confining layer is at or near land surface, the aquifers will be recharged through deep pits or shafts penetrating that layer [25].

iii. Vadose Zone Infiltration

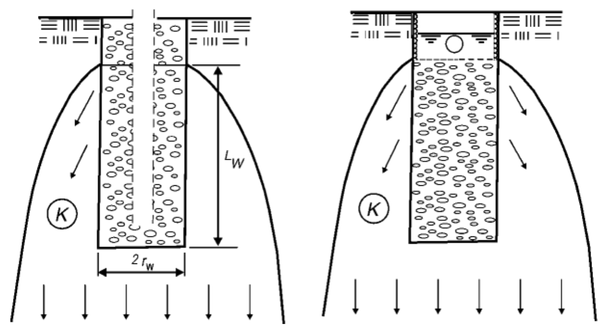

Fig.5: Shows the vadose layer of recharge well

Vadose zone which is with sufficiently permeable soils and/or sufficient land areas for surface infiltration groundwater recharge be achieved with vertical infiltration systems, such as trenches or wells in the vadose zone. Recharge trenches are dug with a backhoe. They are backfilled with coarse sand or fine gravel. Water normally is applied through a perforated pipeline on the surface of the backfill, and the trench is covered to blend in with the surroundings. For example, a layer of topsoil for grass or other plantings is placed on top of the backfill to blend in with landscaping, or concrete slabs or other paving are added where the area is paved. Sand-filled ditches have been tested in agricultural areas in Jordan to intercept surface runoff for deeper infiltration into the vadose zone.

iv. Recharge wells

Planned recharge wells are constructed near to the river so as to achieve maximum infiltration to increase augment ground water source. The river water is "pulled" into the aquifer as water tables near the streams are lowered by pumping the wells and thus "bank filtration" systems is a main source of pretreatment of the river water as it moves through the river-bottom materials. Bank filtration is used particularly where river water is contaminated or where the public prefers groundwater over surface water [20].

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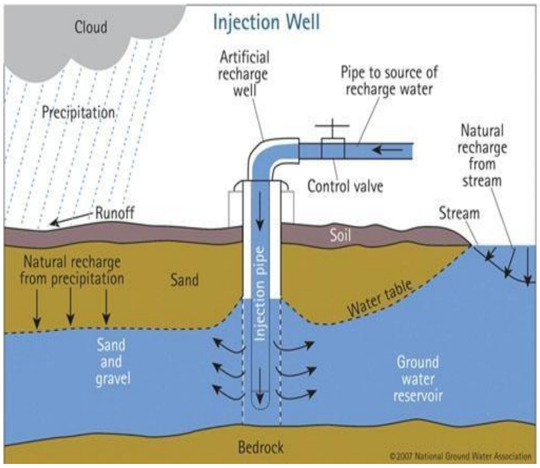

Fig 6: Artificial recharge using Injection Well

Injection wells are installed the upper section of the well is cased and the screen is placed directly in the aquifer or surrounded by an artificial gravel pack to enhance the water percolation for planned recharge. Fig 6 shows the artificial recharge process by injection well.

C. Combination surface-subsurface recharge

Combination of direct surface technology with sub surface technology can extent the storage of water up to 90% efficacy by planned recharge.

i. Subsurface drainage collectors with wells

The recharge potential of wells are greatly increased by under laying thick zone of low permeability materials that can increase the subsurface drainage collection used in conjunction with wells. In such systems, recharge water within the basin percolates into the ground and collected by horizontal drains between the basin and the zone of low permeability. The drains carry the water to wells that penetrate the zone of low permeability, to replenish an aquifer at depth [24] (Fig 7).

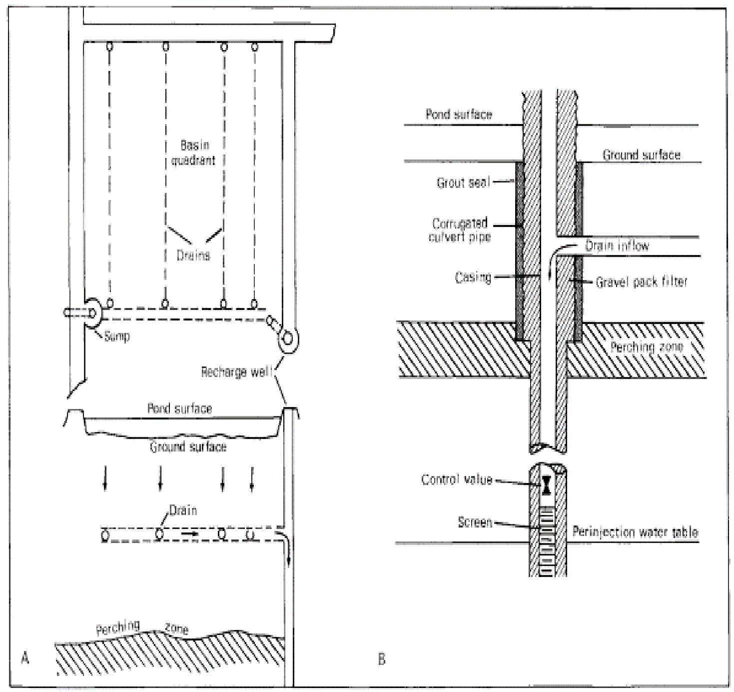

Fig 7: Subsurface drainage collectors with wells

ii. Basins with pits, shafts, or wells

A combination of basins with pits, shafts, or wells rely on the basins to store water and to dispense water rapidly to more permeable zones beneath the recharge site. Such systems may incorporate large-diameter precast perforated concrete cylinders installed below a less permeable zone (Fig 8).

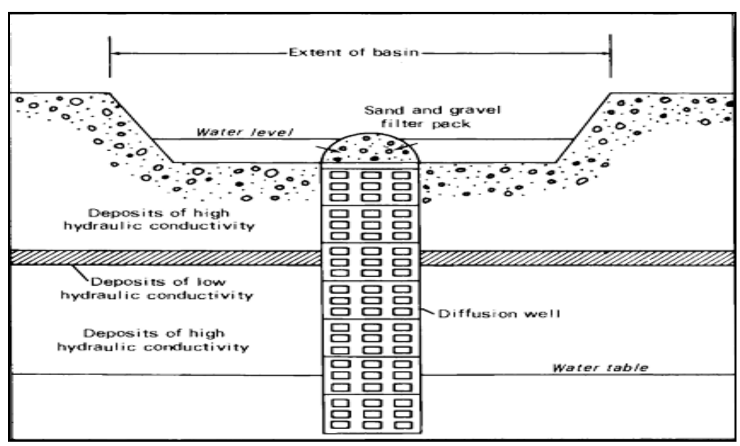

Fig 8: Basins with pits, shafts

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For example, Onlong Island, New York, in 1969, 5 to 10 percent of the 2,124 storm water recharge basins were equipped with "diffusion wells" in which the concrete casing is backfilled with coarse sand and gravel [25].

D. Indirect techniques

i. Induced recharge from surface-water sources:

Induced surface water recharge systems are installed near perennial streams that are hydraulically connected to an aquifer through the permeable, unconsolidated deposits that form the stream channel. The quantity of surface water that can be induced to recharge the aquifer varies with amount and proximity of surface water, the hydraulic conductivity and transmissivity of the aquifer, the area and permeability of the stream bed (or lake bottom), and the hydraulic gradient created by pumping [26]. (Fig 9).

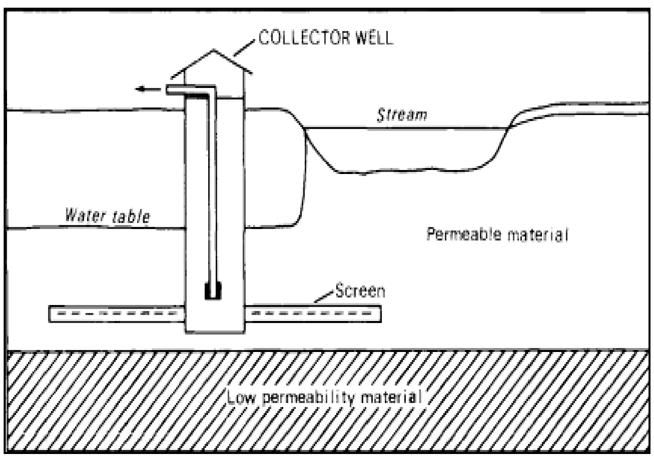

Fig 9: Induced surface water recharge system

One example of induced surface water recharge is in Kalamazoo, Michigan, where water from the portage river is diverted into recharge channels that surround the pumping field [26].

ii. Aquifer modification

Aquifers are modified structures that impede outflow or by techniques to create additional storage capacity. Groundwater barriers have been built in many places to obstruct and detain groundwater flow [27]. For example, in India, such structures are built across the channels of intermittent rivers beneath the river bed deposits [28] (Fig 10).

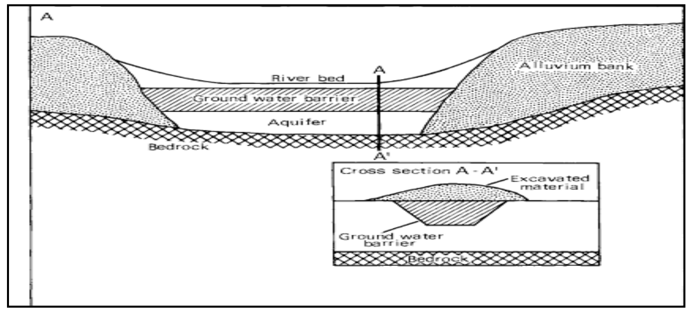

Fig 3.9: Aquifer modification

A trench is dug across the river bed and backfilled with relatively impermeable material obtained locally to increase percolation. The barrier extends only partly through the alluvial deposits above the bedrock to create a regulated "back-water" effect, which sustains elevated groundwater levels resulting from monsoon rains.

IV. CONCLUSION

Surface, subsurface, indirect, and combination methods of artificial recharge modelling provides available alternatives in predicting aquifer recharge to conserve water. Water quality and water level monitoring philosophies includes emphasize on the necessity of protecting and conserving our groundwater reservoir. Water use demands will only increase the technological advancement of planned recharge or artificial recharge to meet the future needs of urbanization and industrialization. Appropriate method are chosen depending upon situations and availability.

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