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Artificial Recharge Techniques and the Experience of Prince Sultan Research Center for Environment, Water and Desert, Saudi Arabia[1]

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Abstract: In recent years, arid regions like the Kingdom of Saudi Arabia are facing increasing challenges and escalating demand for water supplies. Water authorities are trying to face this situation by adopting all possible techniques and procedures for water conservation and rational use of both surface and groundwater supplies. Artificial recharge of groundwater is one of these tools for water conservation. This is a process by which surface water is directed into the ground to augment groundwater supplies. Artificial recharge techniques include some direct and some indirect methods. Direct methods are those of water spreading basins, recharge pits and shafts, ditches and recharge wells. Indirect methods include induced infiltration and conjunctive wells. These techniques were first applied in Europe in the 19Century and in the United States of America by the beginning of the 20century. Other countries like India, Pakistan, Syria, Egypt and Tunisia have gone through different experiences of water harvesting and artificial recharge. Recently, Prince Sultan Research Center for Environment, Water and Desert is applying these techniques to augment groundwater supplies in the Central of Saudi Arabia. This paper is aiming to give a comprehensive review on artificial recharge techniques, factors to consider for artificial recharge and, shed some light on the Saudi experience.

Key words: Artificial recharge • Recharge wells • Water harvesting • Saudi Arabia

INTRODUCTION

Arid regions are facing increasing challenges and escalating demand for water supplies. Water authorities are trying to face this situation by adopting all possible techniques and procedures, ancient and modern ones, for water conservation and rational use of both surface and groundwater supplies. Artificial recharge of groundwater is one of these tools of water conservation. Artificial recharge is defined as a process by which excess surface water is directed into the ground to replenish an aquifer. It is used also to store treated sewage effluent. It thus refers to the movement of water through manmade systems from the surface of the earth to the underground waterbearing strata. Artificial recharge is a technique that has been applied in early civilizations of the Mesopotamia and China. In recent history it was applied in Europe in the 19century, the and in the United States of America by the beginning of the 20century. Other countries like India, Pakistan, Syria and Tunisia have gone through different experiences of water harvesting and artificial recharge. A number of published works has advocated the use of artificial recharge of groundwater. Of these works we mention those of [1-8]. Since two years, Prince Sultan Research Center for Environment, Water and Desert Studies (PSRCEWD) is applying these techniques to augment groundwater supplies in Central Saudi Arabia. This paper is aimed to give a comprehensive review on artificial recharge techniques, factors to consider for artificial recharge and , shed some light on the Saudi experience.

Artificial Recharge Techniques: Artificial recharge techniques are classified in two main methods. These are direct and indirect recharge methods. Direct methods include: spreading basins, recharge pits and shafts, ditches and recharge wells. Indirect methods include: induced infiltration and conjunctive wells.

In spreading basins the amount of water entering the aquifer depends on the infiltration rate, percolation rate and the capacity for horizontal water movement. The common problem of water spreading is clogging of

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Table 1: Representative Spreading Basin Recharge Rates [2]

Location	Rate, m 3 / day
Santa Cruz River, Ariz.	0.31.2
Los Angeles County, Calif.	0.71.9
Madera, Calif.	0.31.2
San Gabriel River, Calif.	0.61.6
San Joaquin Valley, Calif.	0.10.5
Santa Ana River, Calif.	0.52.9
Santa Clara Valley, Calif.	0.42.2
Tulare County, Calif.	0.1
Ventura County, Calif.	0.40.5
Des Moines, Iowa	0.5
Newton, Mass.	1.3
East Orange, N.J.	0.1
Princeton, N.J.	<0.1
Long Island, N.Y.	0.20.9
Richland, Wash.	2.3

Table 2: Average Well Recharge Rates [2]

Location	Rate, m 3 / day
Santa Cruz River, Ariz.	0.31.2
Los Angeles County, Calif.	0.71.9
Madera, Calif.	0.31.2
San Gabriel River, Calif.	0.61.6
San Joaquin Valley, Calif.	0.10.5
Santa Ana River, Calif.	0.52.9
Santa Clara Valley, Calif.	0.42.2
Tulare County, Calif.	0.1
Ventura County, Calif.	0.40.5
Des Moines, Iowa	0.5
Newton, Mass.	1.3
East Orange, N.J.	0.1
Princeton, N.J.	<0.1
Long Island, N.Y.	0.20.9
Richland, Wash.	2.3

Fig. 1: Tujunga Artificial Recharge Facility, USA

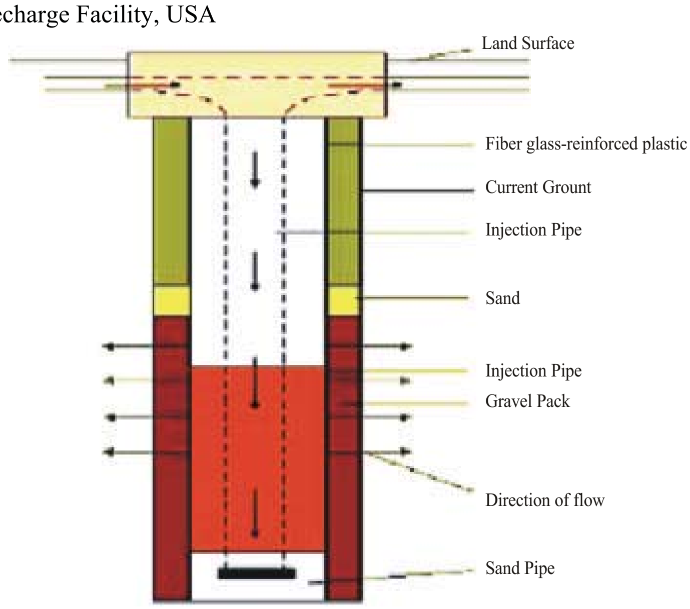

Fig. 2: Recharge or Induction Well

the surface material by suspended sediment in the recharge water or microbial growth. Spreading basins are effective where no impending layers between the surface and the aquifer exist. Spreading basin recharge rates in the United States of America range from < 0.1-2.3 m/day (Figure 1, Table 1).

Playas in general are suitable depressions for this artificial recharge method. Artificial recharge using pits and shafts could be effective when these structures penetrate a less permeablestrata in order to access the dewatered aquifer. Unfiltered runoff waters may leave thin film f sediments on the sides and bottom of the pits which require cleaning in order to sustain high and effective recharge rates. Recharge rate increase as the slope of the pitch increases. Shafts may have different shapes: circular, rectangular, or square crosssection. It may be backfilled with porous material. In both, pits and shafts recharge rate decrease with time. Other structures for direct recharge methods are ditches. A ditch is a long narrow trench with its bottom width less than its depth. It can be designed to suit topographic and geologic conditions at a given site. A series of ditches can layout and form an effective recharge site for groundwater.

A recharge well is used directly to get water into deep waterbearing horizons or zones. Its flow pattern is the reverse of the pumping well pattern. Hence, the equation, of radial flow, can be applied to estimate the recharge rate. Steady state recharge rate under unconfined condition can be expressed with the following equation:

$$Q = \bullet\ K (h1-h2) / \ln (r2/r1)$$

Where Q is the recharge, m /day; K, the hydraulic conductivity m/day; h1 and h2, the heads at the observation wells, m; and r1 and r2 is the distances of the respective observation wells from the recharge well, m (Figure 2).

Average well recharge rates range between 200 and 51, 000 m /day (Table 2) Recharge wells are particularly advantageous in areas where land is scarce or very limited.

Prince Sultan Research Center (PSRCEWD) Experience: PSRCEWD experience is based on the idea of both rainwater harvesting and artificial recharge of groundwater. The idea was to get maximum benefit from water collected upstream of dam sites in Central Saudi Arabia. The experience started with Dhurma Dam. Dhurma Dam lies to the NE of Dhurma town, at some 100 km west of Riyadh. It is an earth dam of 1450 m long and 6 m in height. Its basin can store up to 1, 500, 000 cubic meters of water (One and half million cubic meters). The dam has been erected in the year 1403 H for the purpose of recharging subsurface strata of the Jurassic Dhurma Formation in the area. Groundwater recharge has faced the problem of siltation and clogging. Surface runoff waters carry a lot of load and silt that hindered the effectiveness of the recharge process. In turn, the collected water was subject to high evaporation rates that characterize the region in general and , water loss was great. To face this situation PSRCEWD launched a program for artificial recharge in a number of dams in Central Saudi Arabia. The program included the construction of water harvesting structure or Ghadir Dhurma and a series of recharge wells upstream of Dhurma, Amariya, Dariyah, Huraimalla and Hareeq dams (Figures 3 to 8). The program was executed in four steps:

- A detailed topographic survey for the upstream area of the dam.
- A geophysical survey using geoelectrical techniques highlighted on the distribution of subsurface strata, choice of recharge wells sites, expected depths and designs.
- Wells drilling phase: the drilled wells were equipped with valves at appropriate levels with the expected runoff water for each area.
- Groundwater levels monitoring in observation wells nearby of each of the selected areas.

These results show the effectiveness of recharge wells in Dhurma area with recharge rate that ranges between 0.7 to 1.1 meters per day during the availability of surface water in the Wadi.

Table 3: Results of PSRCEWD experience

Day	Date	Faqeeh Farm	AlIssa Farm	AlOsman Farm	AlAjaji Farm	Remarks
Tuesday	29/1/1427H	24.4 m	23.22 m	30.87		Drilling 3 wells
Saturday	11/2/1427H	24.4 m	24.23 m	31.34 m		
Sunday	26/2/1427H	25.38 m	23.95 m	31.44 m		
Saturday	10/3/1427H	23.30 m	20.65 m	31.59	24.50 m	
Monday		23.30 m	21.05 m	31.80 m	21.35 m	
Wednesday	14/3/1427H	23.28 m	21.40 m	***	21.80 m	
Saturday	17/3/1427H	23.40 m	21.85 m	***	22.15 m	
Tuesday	21/3/1427H	23.70 m	22.45 m	***	22.50 m	
Wednesday	28/3/1427H	24.20 m	23.36 m	***	23.18 m	

Fig. 3 :Ghadir Dhurma

Fig. 4: Dhurma Site

Fig. 5: Amariya Site

Fig. 6: Dariyah Site

Fig. 7: Huraimalla Site

Fig. 8: Hareeq Site

CONCLUSIONS

Artificial recharge techniques can be used to store excess storm water runoff and treated sewage effluent. It serves twin purposes of improving declining groundwater levels and deteriorating water quality. But there are a number of factors to be considered when these techniques are applied. These factors are summarized as:

- Availability of surface water.
- Quantity of source water available.
- Quality of source water available.
- Reactions with native water and aquifer material.
- Clogging potential.
- Underground storage space available.
- Depth to underground storage space.
- Transmission characteristics.
- Topography.
- Legal/ Constitutional constraints. and costs.

The experience of PSRCEWD seems to be a successful one and in our point of view is to be encouraged in other upstream sites of dams in Central Saudi Arabia and may be elsewhere in the Arabian Peninsula.

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