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Low Cost Groundwater Recharge Structures for Semi-arid Regions

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Abstract: The community based different groundwater recharging structures have potential to increase the water table of the wells. To respond the primary need of the people, recharging of aquifers through rainwater harvesting and indigenous recharging techniques has become essential to check the declining rate of water table in the wells. In semi arid regions of Rajasthan, India farmers have evolved different indigenous groundwater recharging structures over the generations. These structures are simple, cost effective and easy to implement. Their unscientific design and construction have resulted in the failure of these indigenous structures in most cases. In view of the growing demand for these structures, the present study was undertaken to design low cost groundwater recharging structures and also to evaluate their cost economics. Three different groundwater recharge structures viz dry stone masonry pond, recharge of well through filtration pit and Naal bandhana-subsurface well recharging structure were designed considering the rainfall and topography of the area. The cost of dry stone masonry pond, recharge through filtration pit and Naal bandhana were estimated to be Rs. 32000, Rs. 3814 and Rs. 7739 respectively. These recharge structures were designed based on participatory approach. The ideas of local beneficiaries and all the technical details were taken into consideration.

Key words: Dry stone masonry pond • Naal bandhana • Subsurface well recharging structure • water harvesting structure

INTRODUCTION

India which has 16 per cent of the world's population, 2.45 per cent of the world's land area and 4 per cent of the world's water resources already has a grave drinking water crisis. Estimates of the Central Ground Water Board are that the reservoir of underground water will dry up entirely by 2025 in as many as fifteen states in India if the present level of exploitation and misuse of underground water continues. By 2025 when more than 50 per cent of the Indian population is expected to shift to the cities, fresh drinking water is expected to get very scarce [1]. The exploitation of groundwater is more as almost 90 per cent of drinking water supplies in rural areas and 40 per cent of the total irrigation potential are to be met from groundwater. At the same time, groundwater is generally widespread and easily available without any restrictions on its use. This has resulted in a rapid expansion in the development of the potential and also exploitation of groundwater in the country. This over exploitation of groundwater has led to decline of 2 to 4 meters of groundwater levels in many places.

Rajasthan is the largest state of the country in terms of geographical area. It is well endowed with land and sunshine but is less fortunate in available water resources. Due to scarcity of surface water, Rajasthan has to depend on groundwater resources to a great extent. But due to over exploitation of groundwater for drinking, irrigation and industrial use coupled with inadequate recharge, the water table is continuously depleting at an alarming rate of 1.0m to 1.5m per year, posing a serious threat [2].

In order to respond the primary need of the people, recharging of aquifers through community based indigenous rainwater harvesting and recharging techniques has become essential to check the declining rate of water table in the wells. Intensive efforts are required to be made for collecting detailed information on indigenous technology of groundwater recharging from all over the country and their documentation to serve as the basis for future research as well as for the programme planners to give due importance for such techniques during the planning. To see the magnitude of the problem an effort has been made to design some indigenous

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groundwater recharging techniques. These techniques will serve as a model indigenous technology for the semi arid areas having similar topography.

MATERIALS AND METHODS

The community based different groundwater recharging techniques have evolved by the farmers depending on rainfall and soil type in the semi arid regions of Rajasthan. Dry Stone Masonry Pond, Sunken Pond, Naal Bandhna and Recharge Pits are indigenously constructed by the farmers. During the last century scientist/engineers have only refined and structured them in a scientific manner, whereas these structures have been developed by the farmers. These indigenous low cost techniques that have evolved are designed on local knowledge and materials which are cost effective, simple and easy to maintain.

Overview of Study Area: The Dhariyawad Tehsil of Udaipur district of Rajasthan, India was selected as a study area for the present study. The Udaipur district has moderate climate with average annual rainfall of 580 mm of which June to September (monsoon months) accounts for about 98 per cent. Distribution of rainfall is very uneven, erratic and varies from year to year. The rural people of the district are dependent on agriculture, forestry and on livestock rearing for their livelihood. For drinking water and irrigation purposes most of the community is mainly dependent on open dug wells as surface water resources are very limited.

Design Criteria for Indigenous Groundwater Recharge Structures: For design of indigenous groundwater recharge structures the first step is to decide the location of site and size of the trench/pit, which is function of runoff yields and peak rate of runoff. These structures can be constructed manually by the village community at appropriate locations. In the present study, three types of indigenous recharge structures viz., recharge through filtration pit, dry stone masonry pond and Naal bandhana-subsurface well recharging structure are proposed and their scientific design parameters are presented for their better performance.

Design Considerations:

- The aquifer to be recharged should be permeable and unconfined.
- Adequate surface infiltration for the water to be absorbed so that it can move below the surface.
- There should not be any impervious stratum between the ground surface and water table.
- The water level in the well should be deep enough to accommodate the rise in water table.
- The well selected for recharging through filtration pit should have a micro catchment of 0.5 to 1.0 ha.
- The site selected for subsurface recharging should have considerable deposit of sand cushion up to the depth of 1-2 m.

Recharge of Well Through Filtration Pit: Recharge of well through filtration pit is a indigenous cost effective method of well recharging in semi arid regions of Rajasthan. In this method surface runoff is used to replenish the water table. The replenishment is possible by diverting some amount of surface runoff into the well from a limited catchment area, depending on the topographical features. On the basis of local experience [3], the recharge pit of 1.5 to 2.0 m depth suitable for the catchment area of 0.5 to 1.0 ha were designed.

Calculation of Peak Rate of Runoff and Runoff Yield: In the design of recharge structure first step is to compute the peak rate of runoff and runoff yield from the catchment area. The peak rate of runoff was computed by rational formula which is given below.

$$Q = CIA/36$$

Where,

Q = Peak rate of runoff (m^3/sec)

C = Runoff coefficient

I = Rainfall intensity (cm/hr) for design recurrence interval and for duration equal to the time of concentration of the watershed.

A = Catchment area (ha)

The runoff yield was estimated by Stranges Table.

Dry Stone Masonry Pond: For design of dry stone masonry pond type well recharging structure, the height of the structure is decided first on the basis of peak rate of runoff and runoff yields. On the basis of local experience the dry stone masonry pond of maximum 2.5 m height suitable for catchment area of less than 50 ha were designed. In the designed height of 2.5 m, free board of 0.5 m is provided for safe disposal of excess runoff. It can be constructed manually by the village community at appropriate locations. The site of ponds should be selected looking to the consideration that at downstream side of the pond sufficient numbers of open wells are already existing so that these wells could get the benefit of recharging through dry stone masonry ponds.

The upstream and downstream walls are made up of dry stone masonry and murrum/soil is filled in between two walls. The structure should not be constructed for more than 2.5 m height, which may cause overturning of structure [3]. A provision of emergency spillway is must for the safe disposal of excess runoff from the structure which is not being provided by the farmers at the time of construction.

Naal Bandhana-Sub Surface Well Recharge Structure: It is a very old and indigenous practice of recharging of wells situated on the banks of non perennial streams, small rivers or rivulets with enough depth of sand (sediments) deposits. This method is widely used in the rainfed river basins of semi arid regions of Rajasthan, India. In most such areas, open dug wells of shallow depth generally exist on the banks of seasonal small rivers and streams. The sub surface well recharging structure is installed across the river bed to carry the subsurface stored water of sand deposits in the link well. On the basis of local experience the sub surface well recharging structure are designed considering the depth of 1 to 2 m below the surface of river bed depending on the sand deposits.

RESULTS AND DISCUSSION

Harvesting of rainwater through indigenous practices for groundwater recharging is an age old concept in India. Uneven and erratic distribution of rainfall caused the use of water harvesting structure traditionally as a means of groundwater recharging. Anicuts (Masonry Water Harvesting Structure) which is usually constructed as major water harvesting structure in semi arid regions of Rajasthan, India for irrigation and recharging purposes are much costlier and require high initial investment. On the other hand, regional farmers have evolved different indigenous groundwater recharging structures over the generations.

Design of Indigenous Groundwater Recharge Structures: In the present study three different type of indigenous groundwater recharge structure viz. recharge of well through filtration pit, dry stone masonry pond and Naal bandhana–subsurface well recharging structure were designed.

Design of Dry Stone Masonry Pond: The design parameters of the proposed dry stone masonry pond alongwith the schematic diagram are shown in Figure 1. The recommended design parameter for the structure at 1 m, 2 m and 2.5 m height are presented in Table 1. The foundation depth of the structure of 1m height is kept as 0.5 m, whereas for 2 m and 2.5m height it is kept as 1.0 m. The length of dry stone masonry pond for groundwater recharging is considered 20 m as per the requirement of the site. It is also recommended to use locally available construction material so as to minimize the cost of construction. The cost estimation of dry stone masonry pond for groundwater recharging is shown in Table 2.

Design of Recharge of Well Through Filtration Pit: In this method a pit is constructed (1.5 m deep, 2 m length and 1.5 m width) at a reasonably higher elevation. This serves the purpose of a silt or sediment trap. It is filled with different layers of filtering

Table 1: Recommended design parameters of the dry stone masonry pond

	Height of dry stone masonry pond		
Design parameters	1 m	2 m	2.5 m
W1	0.5	0.5	0.5
W2	1.0	2.0	2.5
W3	0.5	0.5	0.5
W4	0.8	1.0	1.2
W5	0.8	1.0	1.2
L1	0.3	0.5	0.7
L2	1.0	2.0	2.5
L3	0.5	1.0	1.0

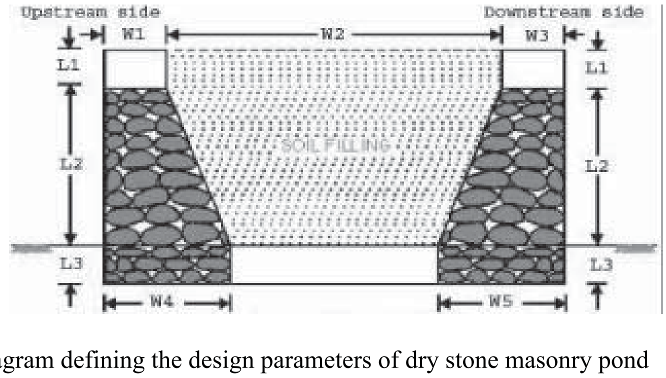

Fig. 1: Schematic diagram defining the design parameters of dry stone masonry pond

Fig. 2: Recharge of well through filtration pit

Table 2: Cost estimation of dry stone masonry pond

S. No.	Details of work	No	Measurements (m) L	B	H.D.T.	Quantity (m^3)	Rate (Rs.)	Per	Amount (Rs.)
1.	Excavation of foundation in hard soil	2	20	1.2	1.0	48	44	m^3	2112
2.	Dry stone masonry for foundation	2	20	1.2	1.0	48	178	m^3	8544
3.	Dry stone masonry for superstructure	2	20	2.125 m^2		85	185	m^3	15725
4.	Filling of murrum/soil in between two dry stone masonry walls		20	4.5 m^2	90	60	m^3	5400	
								Total	31781
								Say Rs.	32000

materials for protection against silt intrusion. In the bottom of the pit bigger sized pebbles or stones are filled upto a depth of 50 cm, smaller sized pebbles in the middle layer of 30 cm depth and at the top, there is a layer of 20 cm of coarse sand. The pit is kept unfilled about 0.50 m from ground level to hold water. This filtration pit is connected through a pipe of 14 cm diameter (0.30 m above the bottom) to a masonry tank. Runoff from the upper reaches having micro catchment of 0.5 to 1.0 ha is diverted to the well through masonry tank. This water helps to raise the water level of the well and also helps to recharge groundwater. This technique have been found very successful in semi arid regions of Rajasthan, India. The recharge of well through filtration pit is shown in Figure 2 and the cost of well recharging through filtration pit is shown in Table 3.

Design of Naal Bandhana-Subsurface Well Recharge Structure: In this method a 60 cm wide and 1.5 m high loose stone masonry channel with a very gentle slope towards the link well is constructed at 2.0 to 2.5 m below the surface of river bed, depending on the sand deposits (Figure 3). The end of the channel is directly joined with the well. Sometimes in wide streams the channel are constructed to cover only half or three-forth of the total width of the stream depending on the one time investment capacity of the farmer or group of farmers.

A trench of 2.0 m wide is dug across the river bed, reaching down to bed rock or some other solid impervious layer. A very gentle slope is maintained in the bed to direct the flow towards link well. Dry stone masonry walls of 60 cm width are constructed 60-80 cm apart to retain the sand. The height of the wall is generally kept 1.5 m. The top of the channel is always kept at least 1 m below the surface of the river bed in order to bear the human activities on the riverbed. The top of the channel is covered with rough stone slab or wooden logs to prevent sediments from entering the channel. Generally, the logs of the Dhak (*Butea Monosperma*) tree are used. The rainwater retained by sand (about 30-45% by volume of sand deposits) in the upward side of the river slope seeps through the loose stone wall/subsurface channel and clean water flows towards the link well. It maintains a continuous supply of water in the well. The design parameters of naal bandhana are shown in Figure 3. Recharging of well through Naal bandhana is shown in Figure 4 whereas the cost estimation is shown in Table 4.

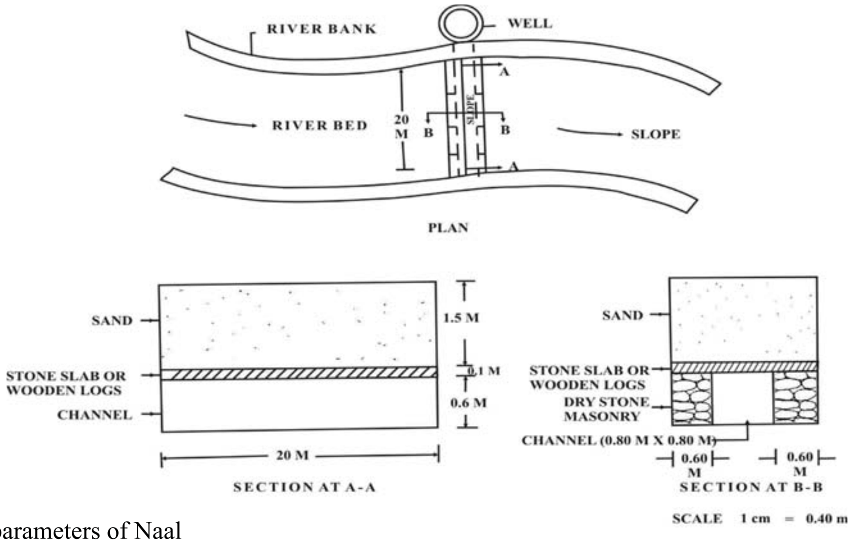

Fig. 3: Design parameters of Naal

Fig. 4: Recharging through Naal bandhana - subsurface well recharging structure

Table 3: Cost estimation of well recharging through filtration pit

							Total Amount	
Sr. No.	Details of Work	Length (m)	Width (m)	Depth (m)	Qty. (Cum)	Unit	Rate (Rs.)	Amount (Rs.)
1	Excavation of pit in hard soil and soft morrum							
a	Pit	2.00	1.70	1.50	5.10	Cum		
b	Trench	6.00	0.50	1.25	3.75	Cum		
	@50% in hard soil				4.43	Cum	45.00	199.13
	@25% in hard morum				2.21	Cum	70.00	154.88
	@25% in soft rock				2.21	Cum	93.60	207.09
2	Cost of PVC pipe dia 14 cm (4.00kg/cm^2)	6.00			6.00	m	160.00	960.00
3	Cost of Half bricks honey comb (1:6), (112 mm) for three side wall	1.50	2* 1.5		4.50	Sqm	83.00	373.50
4	Cost of gravel required for refilling(bigger andsmall size)	2.00	1.50	0.80	2.40	Cum	240.00	576.00
5	Cost of sand required for refilling	2.00	1.50	0.20	0.90	Cum	370.00	333.00
6	Cost of half bricks masonry (1:6), 112 mm for the side wall	2.00	1.5		3.00	Sqm	166.00	498.00
7	CC of 1:4:8 with 40 mm gravel	2.00	1.50	0.10	0.30	Cum	840.00	252.00
8	Labour charges for refilling of trench and pit						LS	260.00
		Total cost of one well recharging structure					Rs.	3813.60
					Say		Rs.	3814.00

Table 4: Cost estimation of Naal bandhana-Subsurface well recharging structure

S. No.	Details of work	No.	Measurements (m) L	W	H.D.T.	Quantity	Rate (Rs.)	Per	Amount (Rs.)
1.	Excavation of trench across the river/stream below the soil surface	1	20	2.0	2.5	100 m^3	36	m^3	3600
2.	Dry stone masonry wall on both the sides of the trench	2	20	0.60	0.60	14.4 m^3	178	m^3	2563
3.	Rough stone slab to cover the dry stone wall from top (1.0 m x 0.80 m)	1				20 Nos.	50	No.	1000
4.	Filling of sand on top of stone slab		20	0.80	1.0	16 m^3	36	m^3	576
								Total	7739

Cost of Groundwater Recharge Structures: The cost of different indigenous groundwater recharge structures were estimated on the basis of the recommended design dimensions. Dry stone masonry pond, recharge of well through filtration pit and Naal bandhana-subsurface well recharge structure were estimated to be Rs. 32000, Rs. 3814 and Rs. 7739 respectively (Table–2 to 4). It is clear that highest cost of construction is involved in dry stone masonry pond but it is quite less in comparison to the masonry water harvesting structure commonly used for groundwater recharging. The cost of recharging through filtration pit and Naal bandhana is quite less and it is within the reach of investment capacity of farmers. Hence, the proposed structures are cost effective in terms of construction cost and also suitable for the region.

CONCLUSIONS

The present study was carried out in the semi arid region of Rajasthan, India with the objective to design three different low cost indigenous groundwater recharge structures and also to evaluate the cost economics of these structures. Three different groundwater recharge structures i.e. recharge of well through filtration pit, dry stone masonry pond and naal bandhana-subsurface well recharging structure were designed considering the rainfall and topography of the area. The cost analysis of these structure revealed that the cost of dry stone masonry pond, filtration pit and Naal bandhana - subsurface well recharging structure is Rs. 32000, Rs. 3814 and Rs. 7739 respectively which is much lower than the masonry structure. As the proposed groundwater recharging structures integrate the indigenous technical knowledge with the scientific knowledge, the adoption and success of such cost effective recharging structures in practice is very high as revealed by the overwhelming response of the farmers in the study area. Therefore, in place of cost intensive masonry structure such cost effective groundwater recharge structures can be implemented in other semi arid regions having similar climate, topography and socio-economic conditions.

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