Innovative Artificial Ground Water Recharging using Canal Water as a Sustainable Techno-Economic Methodological Solution to Depleting Ground Water in Punjab State (India)

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Abstract

This study is primarily done to harness the potential of artificial ground water recharging schemes through canal waters. The capacity of the injection wells for various aquifer conditions is practically calculated after study of 30 such schemes installed for the purpose at various locations of the Punjab State. Based upon the results a recharging scheme has been proposed along the canals by application of such scheme to Sherpur block of Sangrur district of Punjab State. The scheme is not only technically feasible but give immense economic benefits with benefit cost ratio of more than 12. This scheme will provide a sustainable and practical solution to fast depleting ground water in Punjab state. Apart from this the scheme generates other social benefits of the sustainable development of the area as a whole.

Keywords - *Artificial Ground Water recharging, Distributary, Minor, Injection Wells, Aquifer, Filtration Chamber, Reference Distance (RD), Hectare Metre, Agricultural Potential generation, Benefit Cost ratio.*

I. INTRODUCTION

Punjab, a state in India, is predominantly an agrarian State having nearly 83% of the State's geographical area is under cultivation[1]. Out of the total irrigation, about 70% of irrigation is done by groundwater through tube wells and the remaining 30% by canal system. Dependence on ground water for agriculture has increased enormously resulting in decline of water table in 85% of the area of the State where ground water quality is mostly fresh and fit for irrigation[2]. With the falling of water table, the farmers are forced to deepen the tube wells. As the shallow tube wells already installed are becoming dry or discharge is becoming low, it forces the farmers to replace centrifugal pumps with submersible pumps resulting in high initial investment and additional recurring expenditure for more power consumption and maintenance. Thus, the economy of the state and wellb eing of farmers and their socio-economic development depends to a larger extent on the availability of sufficient water. Water is the only natural resource available in the state and it is devoid of any other mineral or natural resource. The water table in the state is fast depleting with groundwater being overexploited in 105 of the 138 blocks in the state. Only 26 blocks are in the safe zone[3]. Official data reveals that about 34.88 billion cubic metres (BCM) water was pumped out of the ground in a year, while replenishment was around 20.32 BCM. The average decline of subsoil water has been 20 cm per annum from 1980 to 1990 and 25 cm in the next decade. The decline has been 45 cm from 2008 to 2013. Of the 1,056 sites selected for monitoring the water table, the fall in water table was recorded at 749 sites from October 2013 to October 2014[4].

Keeping in view the state's economy and farmers' interest in view, there is an urgent need to adopt suitable strategies and take adequate steps so that the declining trend of ground water resources can be arrested to sustain agriculture production. Out of the various techniques available for artificial ground water recharging[5], the recharging though Injection wells are structures similar to a tube well but with the purpose of augmenting the groundwater storage of a confined aquifer by "pumping in" treated surface water under pressure. The aquifer to be replenished is generally one that is already over exploited by tube well pumping and the declining trend of water levels in the aquifer has set in[6].

Central Ground Water Authority (CGWA), as nodal agency to Ground water resources in India, has time and again issued directions for adoption of rainwater harvesting/artificial recharge to ground water. In view of above consideration, the proposals for recharging ground water in these blocks are being taken up in conservation and judicious use of ground water. Various advantages like negligible losses, no adverse effects of

inundation of large areas[7], enhance dependable yield of wells and hand pumps[8], no contamination effect on canal water supply and hence no specialized treatments required[9], and targeted aquifer replenishment lead to selecting artificial recharge through injection wells using canal water. Now as Punjab State has well spread network of canals with canals spread over major culturable cultivated areas. It is worth mentioning that substantial quantum of water is available for recharging as compared to roof top rainwater harvesting technicques[14]. On the basis of above, small standalone artificial recharge schemes through canal water have been executed at 30 locations in Punjab state from 2012 to 2015 (refer Figure I) and proper monitoring of the data and recharge capacity estimation for each of this scheme is carried out. Based upon the data so compiled, a pilot scheme has been proposed as a pilot project and techno-economic viability along with the social benefits envisaged through the same are brought out. On the practical success of this pilot scheme, it can be replicated in other blocks of the state. Therefore in this paper, based upon the result of 30 number trial schemes, the methodology for data compilation and subsequent structures proposed for carrying out the artificial recharge through canal water along with benefits and consequent benefit cost ratio is brought out.

II. METHODOLOGY AND DATA

With view to check the feasibility of the Injection wells in recharging the Aquifers, the Trial/test schemes for Artificial recharge using Canal water during Monsoon and low demand periods have been installed at discreet distributed places of Punjab along the canals. These pilot schemes have been installed at the places under 11districts of Punjab State which have most critical ground water situation out of total 22 districts. The 30 number such pilot test/trial schemes have been installed at districts of Patiala, Sangrur, Tarn Taran, Moga, Fatehgarh Sahib, Faridkot, Ludhiana, Amritsar, Gurdaspur, Jalandhar and Mansa.

A. Components of Pilot Trial/Test Schemes

The pilot trial/test schemes have been initially planned for the running period of 100 days in a year and has been funded by National Bank for Agriculture and Rural Development (NABARD) through loan to the State Government. This includes those times when water is not required for agricultural purposes or there is no water demand such as during monsoon period. The supply from canal supply is taken through 200 mm diameter PVC pipe. Then the water goes to Distribution/Sedimentation Chamber of size 5.0 metre diameter and 3.5metre height circular water tank (1.0 metre above Natural Surface Level (NSL)), where three number baffle walls of suitable height have been provided to reduce the silt load, then the water is further supplied to 3 no. filtration chamber [having proper inverted filter consisting of bottom layer of gravel size 6 to 50 mm (0.4 m thick), middle layer of gravel size 2 to 6 mm (0.4 m thick) and top layer of coarse sand (0.25m thick) has been provided.] of size 2.0 metre diameter and 3.5 metre height (1.0 metre above NSL) through 200 mm RCC pipe for filtration, and finally recharging to ground water through 2 No. injection wells (Refer Figure II) of 200 mm diameter PVC pipe with PVC Strainer Confirming to IS: 12818 installed with each filtration chamber as per Typical design approved by Central Ground Water Board to replenish the Aquifer (up to 60m depth) . In addition to above, one number Clearing cum filtration chamber of 2mtr diameter and 3.5 metre height(1.0 metre above NSL) has been provided with 1 No. Injection Well of the 200 mm diameter constructed to empty the distribution chamber's stand still water to avoid breeding of mosquitoes and weed growth when canal is not running. The distribution chamber is connected to different filtration chambers through 200mm diameter RCC Pipes and injection well are further connected to the filtration chamber through 200mm diameter PVC Pipe. The Filtration Cum Clearing Chamber connected with Distribution Chamber through 100mm diameter PVC Pipes. The top level of all chambers has been kept equal to the bank level of the canals. A typical schematic sketch of the trial schemes is at Figure III.

B. Data Acquisition and Discussion:

These 30 No. schemes installed have been monitored on monthly basis apart from the periodic tests for calculating the water in-take capacity of the injection wells installed. The following observations have been made:

a. The intake capacity of recharging canal water for the individual injection wells varies from 2.5 Litres/Second to 15 Litres/Second. The average intake capacity of each injection well for all the schemes comes out to be 7-7.5 Litres per second.

b. The intake capacity varies with following factors :-

- Type of the aquifer: the screens installed in coarse sand aquifer when encountered (strata logs for each bore plotted while installing the injection wells) give better capacity to in- take.
- Head of Water: The canals running full results in better head to the water being rechargedand consequently better capacity of in-take than the canals running in low capacity.
- Maintenance: The proper maintained injection wells which have been provided with periodic cleaning and development gave substantially better results in capacity of water intake.
- Silt load in canal: The schemes installed on Lined canals or clear water canals such as Bhakra Main line gave better capacity of intake than the other as the filter in filtration chambers gets choked early for silt loaded canals.

III. PROJECT ON BASIS OF PILOT STUDIES

As Punjab irrigation department has land width year marked to it all along the existing canals under the control of the state Government, so it is proposed to construct Artificial Recharge structures along the canal near existing outlets consisting of two or four injection wells each depending upon the available land width and the outlet capacity.

In pursuance of this, one over exploited block, that is, Sherpur has been selected to carry out the pilot project. A proposal for Artificial Recharge structures for Sherpur Block has been prepared to arrest the declining trend of ground water resources. This has been proposed as a pilot project and on success, will be replicated in other blocks of the state.

Block Sherpur is a part of District Sangrur and is being fed for agriculture purposes by various Distributaries and minors as enumerated in Table I along with the reference distance (RD) (It is to be noted that the RD mentioned are linear distance in feet from the head of the particular distributary or minor). In this Block, Water Resources and Environment Directorate has Five Ground Water Observatories at villages Panchgaraya, Rurgarh, Ghnouri Kalan, Kila Hakima and Sherpur. As per field survey and the data available from existing Piezometer tubes in the block, the ground water level goes up to around 35 metres below ground level[10].

During field survey and as per canal office record, it has been found that no Government land is available beyond the tail in any of the above mentioned canals. It is proposed that recharge structures will be constructed along the canal. A typical structure consists of one Filtration chamber and four number injection wells (Typical Sketch attached as Figure IV). A pipe outlet of 150mm Diameter PVC pipe which will be laid over 0.6 m wide and 0.15 metre thick PCC (1:4:8) is proposed to be constructed and will be connected to Filtration Chamber. This chamber is made of brick masonry and is divided into three parts through baffle walls (1.5m x 1.5m Haudi in the centre, 1.5m x 1.5m Filtration chambers on both sides). The top of this chamber has been kept equal to the top of lining/top of bank, whichever is higher. The internal walls of the Filtration chamber have been lined using tiles. Also, for inspection and maintenance purpose steel rugs have been proposed in all the three compartments. This Filtration chamber will be covered by Steel grating. Water from pipe outlet will enter into the central part of chamber i.e.haudi where silt is allowed to settle so that clearer water enters the Filtration tank by crossing the baffle walls whose height has been kept 0.5 m below FSL (Full Supply Level) of respective distributary or minor. In case water in the canal runs 0.5 m below FSL and in order to keep this scheme functional, 100mm Diameter PVC pipe has been proposed along the baffle wall height from bottom to top and its top level will be kept equal to the bottom of the proposed outlet from the canal. In each of the Filtration chambers, inverted filter consisting of bottom layer of gravel size 6 to 50 mm (0.4 m thick), middle layer of gravel size 2 to 6 mm (0.4 m thick) and top layer of coarse sand (0.25m thick) has been provided. Each Filtration chamber is connected to two injection wells (Typical sketch of injection well attached at Figure IV) at 6 metres and 12 metres distance (one injection well only per filtration chamber in case of less land availability) through horizontal 8" diameter PVC pipe which will be laid over 0.6 m wide and 0.15 metre thick PCC (1:4:8). A 50 metre deep injection well of 200 mm diameter PVC pipe is proposed and consists of 2 filters of 6 metre each. However, the actual depth of the injection well and location and size of filters will depend upon the site conditions and strata encountered during the execution of the work. It is further mentioned that the filters for the injection wells will be so placed as to have maximum benefit of recharging.

Based on above design, the number of such structures for each Distributary/ minor is enlisted in the Table I. The purpose of constructing these schemes close to the existing outlet is that the farmers will be made active participants and will be co-opted for the operation of the scheme. It is pertinent to mention here that the awareness will have to be generated among the farmers regarding the benefits of the scheme as the participation of the farmers is necessary for the success of the scheme. As sufficient government land is not available at some points along the canal, some part of the scheme is to be constructed in the private land of farmers. However, considering the benefits that are going to accrue to the farmers it is likely that they will be willing to give the required portion of land for its construction. Furthermore, it is worth mentioning here that these schemes will be operated only during the lean/ rainy season when the demand for water from the farmers is less. In this project, it has been assumed that canal water will be made available for 50 days in a year for the operation of the schemes.

A. Cost of the Scheme:

From the on-site experience of the 30 No. pilot observation schemes, it has been observed that for proper functioning of these schemes, proper maintenance and re-optimization of the entire scheme is required three times a year (Annual Maintenance Cost (AMC) so incurred is also enlisted is Table 1). This includes Removing and refilling of 2-6mm gravel from the filtration chambers after replacing the old gravel once in two years; Removing and refilling of 6-50mm gravel from the filtration chambers after washing once in two years; Removing the silted coarse sand thrice a year and Refilling coarse sand once a year; Refilling of

cavities created in ground called 'Gharas' is local language (around the chambers; Painting of one coat of readymade paint with metallic surfaces on old steel grating (with ordinary quality paints); Making dewatering arrangement by pumping set 4"x4" tractor 24 HP driven (rate per Hour). The rates for daily wages of Semi-skilled and unskilled labour is taken from the latest Punjab Government notification letter no. 2015/8232-8377 dated 24/04/2015. Roding of pipe from outlet to chamber and vertical pipes and development of all the bores once in two years for ascertaining their proper working to achieve the intended purpose. In order to draw maximum benefit of these schemes to replenish the ground water, Maintenance period of four years has been proposed in the project.

A cost of Artificial Recharge structures for Sherpur Block amounting to Rs 86.9 Million, has been prepared on the basis of latest "Common Schedule of Rates" (CSR) of Punjab State as issued by the Government, except for some non-schedule items for which the rates have been taken from estimate previously approved by Chief Engineer, Water Resources, Water Resources Bhawan, Sector 68, SAS Nagar to arrest the declining trend of ground water resources. This has been proposed as a pilot project and on success, will be replicated in other blocks of the state.

The Scheme details Abstract of cost for the scheme is at Table I

Table I : The Scheme Details with Abstract of Cost.

S.No.	Description	No. of Locations	Rate per Unit (Rs.)	Amount (Rs.)
A	CANAL BASED SCHEMES			
Barnala Distributary (RD 25786 To RD 74600)				
1	For Structures Near Outlets	18	1145281	20615058
2	Cost of Outlet Construction @ Rs. 35000/-	18	35000	630000
Handiaya Minor Of Barnala Distributary (RD 0 To RD 30950)				
1	For Structures Near Outlets	12	1145281	13743372
2	Cost of Outlet Construction @ Rs. 35000/-	12	35000	420000
Uppli Distributary (RD 0 To RD 19240)				
1	For Structures Near Outlets	4	1145281	4581124
2	Cost of Outlet Construction @ Rs. 35000/-	4	35000	140000
Sub- Minor No. 1 Of Handiaya Minor (RD 0 To RD 12180)				
1	For Structures Near Outlets	5	1092894	5464470
2	Cost of Outlet Construction @ Rs. 35000/-	5	35000	175000
Sub- Minor No. 2 Of Handiaya Minor (RD 6695 To RD 24600)				
1	For Structures Near Outlets	9	1092894	9836046
2	Cost of Outlet Construction @ Rs. 35000/-	9	35000	315000
Sub- Minor No. 3 Of Handiaya Minor (RD 0 To RD 17081)				
1	For Structures Near Outlets	6	1092894	6557364
2	Cost of Outlet Construction @ Rs. 35000/-	6	35000	210000
Sub- Minor No. 4 Of Handiaya Minor (RD 1883 To RD 17967)				
1	For Structures Near Outlets	5	1092894	5464470
2	Cost of Outlet Construction @ Rs. 35000/-	5	35000	175000
Sub- Minor No. 1 Of Barnala Distributary (RD 0 To RD 12228)				
1	For Structures Near Outlets	4	1092894	4371576
2	Cost of Outlet Construction @ Rs. 35000/-	4	35000	140000
Sub- Minor No. 2 Of Barnala Distributary (RD 0 To RD 26000)				
1	For Structures Near Outlets	6	1092894	6557364
2	Cost of Outlet Construction @ Rs. 35000/-	6	35000	210000
	TOTAL OF (A)			79605844
B	Amc Of Canal Based Schemes For 4 Years			
	For Recharge Structures with 4 Injection Wells Per Structure	69	106680	7360920
	TOTAL of (B)			7360920
	GRAND TOTAL (A) + (B)		**Rs.**	**86066764/-**
Rupees Eighty Six Million Nine Hundred Sixty Six Thousand Sven Hundred And Sixty Four Only				

Table II: Expected Benefits from Proposed Project

For Sherpur Block			
Ground Water Recharge schemes using canal water			
Total no. of injection wells along canal(200mm diameter)		276	Numbers
Av. Recharge capacity of each injection well		7	litre/sec
No. of Days taken in a year for recharge		50	days
Quantum of recharge during the year (276x7x50x24x60x60)/(1000X10000)		834.62	Hectare metre
Total Recharge Capacity of the scheme		69	cusecs
Total recharge from canal water in a year		834.62	Hectare metre
PRE IMPACT ASSESSMENT			
AS per dynamic ground water resource draft report 2013			
Net ground water available		13059	Hectare Metre
Draft for all uses		31380	Hectare metre
Thus, stage of development of Sharper block		240%	
After implantation of proposed schemes,			
Net ground water available	13059+834.62	13893.62	Hectare Meter
Draft for all uses		31380	Hectare Meter
Thus, stage of development of Sherpur block		226%	
The overall improvement in the stage of development of Sherpur Block		14%	
ADDITIONAL AGGRICULTURE POTENTIAL GENERATION			
Requirement of water per Paddy crop (Source: Agriculture Department Punjab.)		1400	mm
Requirement of water per Wheat crop		400	mm
Total Annual requirement of water for Paddy and Wheat	1400+400 = 1800mm	1.8	Metre
Total annual recharge from canal water		834.62	Hectare
Therefore additional area that can be brought under cultivation by the implementation of this project	834.62 /1.8	**463.68**	**Hectare**
The Average Yield of Rice in Sangrur District (As per Statistical Abstract of Punjab 2014, Economic Advisor, Government of Punjab)		47.24	Quintal / Hectare
The Average Yield of Wheat in Sangrur District		54.98	Quintal / Hectare
Therefore, Annual Increase in Yield of Rice in Khamanon Block	47.24x463.68	21904.24	Quintal
Annual Increase in Yield of wheat in Khamanon Block	54.98x463.68	25493.13	Quintal
Latest Minimum Support Price of Rice		1410	Rs
Latest Minimum Support Price of Wheat		1525	Rs.
Therefore total additional Revenue Generated Annually (21904.24x1410+25493.13x1525)		**69.8**	**Million**
Assuming Design period for the Project as 15 Years			
The total benefits accrued in the design period of the project (**15x69.8)**		**1047**	**Million**
Benefit Cost Ratio for the Project	**=1047/86.9**	**12.05**	

IV. BENEFITS OF THE SCHEME- DISCUSSION

As per Dynamic Ground Water Resources Report 2013, the Net annual ground water available for the Block Sherpur is 13059 hectare metre whereas the annual draft from all uses is 31380 hectare metre resulting in extremely high Stage of Development for Sherpur Block i.e. 240%. On implementation of the proposed schemes, the net annual ground water available will increase to 13893.62 hectare metre thereby improving the stage of development for Sherpur Block by 14 % to 226 %.

As per Agriculture Department, Punjab the requirement of Water for Paddy and Wheat Crops is 1400mm and 400mm respectively[11]. Total Annual Recharge by implementing the project in Sherpur Block is 834.62 Hectare Metre thereby resulting in additional area that can be brought under cultivation to 463.68 Hectare. As per statistical abstract of Punjab 2014, Economic Advisor, Government of Punjab[12] the average lead of Rice and Wheat in District Sangrur are 47.24 Quintal / Hectare and 54.98 Quintal / Hectare respectively. The additional area that will be brought under cultivation will thereby increase the yield of rice and wheat by 21904.24 and 25493.13 Quintals respectively. Taking the Latest Minimum Support Price (M.S.P. as issued by Government) of Rice as Rs.1410/- and Wheat as Rs.1525/-. The total Annual Additional Revenue of Rs.69.8 Million will be generated by the implementation of this Project. Assuming the life of the project to be 15 years, the total additional revenue generated will be Rs 1047.0 Million thereby, giving a Benefit-Cost ratio of 12.05. The detail calculations are attached as Table II. It is also pertinent to mention here that this amount of recharge will also result in saving of fuel and electricity as any improvement in the ground water level of the area will lead to lesser use of energy for Irrigation Purpose.

Apart from these Implementation of this scheme of Artificial Recharge Structures of Sherpur Block will go a long way in not only checking the declining trend of ground water table in over exploited areas, but will also help in various other benefits and achievement of following objectives :

1. To arrest the declining trend of Ground Water table in the area to sustain agriculture production.
2. To utilize surplus water available in distributaries and minors during monsoon and lean period for recharge in these distributaries/minors.
3. To monitor the impact and rate of ground water recharge.
4. To train the state government personnel in operation of Artificial Recharge schemes and Rain harvesting schemes.
5. To create awareness among the farmers about protection and proper management of ground water sources.
6. To improve the socio- economic conditions of the farmers.
7. Reduction in flood intensity.
8. More discharge to the farmers from tube wells at lesser cost and resulting in low energy consumption, thereby saving power.
9. Improvement of environment.
10. Reduction of canal water stress during Irrigation period.
11. More use of centrifugal pumps, thus decreasing financial burden of installing submersible pumps to the farmers.
12. Enhancement of cultivation command area.
13. To sustain agriculture production.
14. Conservation and storage of water for future requirements.
15. Avoiding wastage of valuable resources (water) that is FREE.
16. This will help to comply with directions issued from time to time by Government of India/ Ministry of Water Resources and Central Ground Water Board.
17. This may help in changing the category of block from over-exploited to critical /semi critical and further in de-notifying the block.
18. Sherpur Block having a substantial Schedule Caste (SC) population, the project will benefit the SC population in the overall economic and social development.

V. CONCLUSION

1. The artificial recharge of ground water through canal based schemes is a very beneficial project with benefit cost ratio of more than 12.0. This scheme is therefore economically very viable scheme.
2. Apart from tremendous economic benefits, the said scheme is having a great social impact and results in sustainable development of the area.
3. The scheme results in overall 14% improvement in stage of development of Sherpur block.
4. This scheme should be practically implemented and replicated in all the blocks where the canal system is available for irrigation purposes.

ACKNOWLEDGEMENTS

The authors express their sincere gratitude to all the officials and employees of Water Resources Organisation of Department of Irrigation,Punjab who had been providing the useful inputs and guidance in carrying out the above study.

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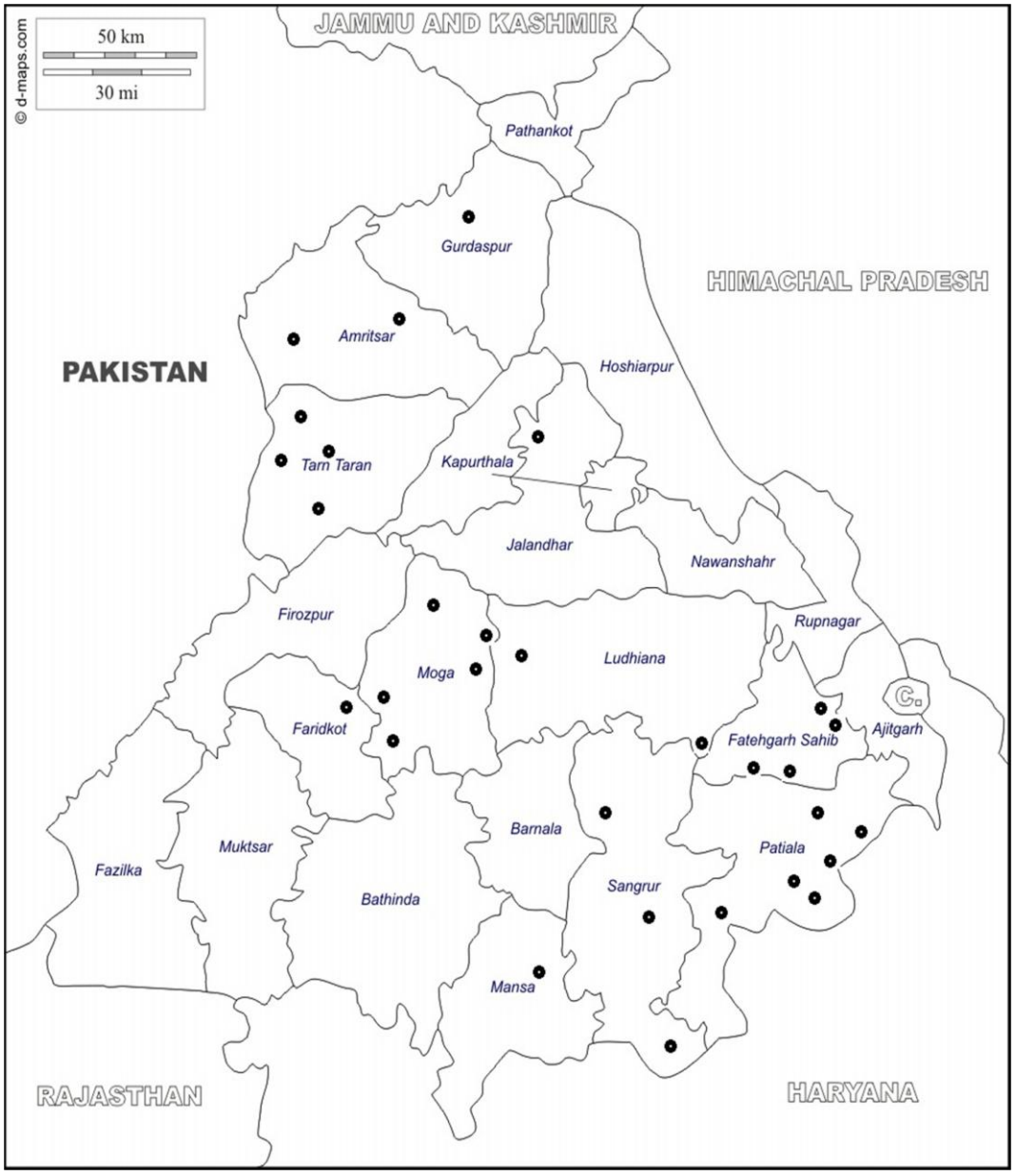

Figure I: Location Detail of 30 Number Trial Schemes in Punjab State to Monitor Ground Water Recharge Potential from Canal Water.

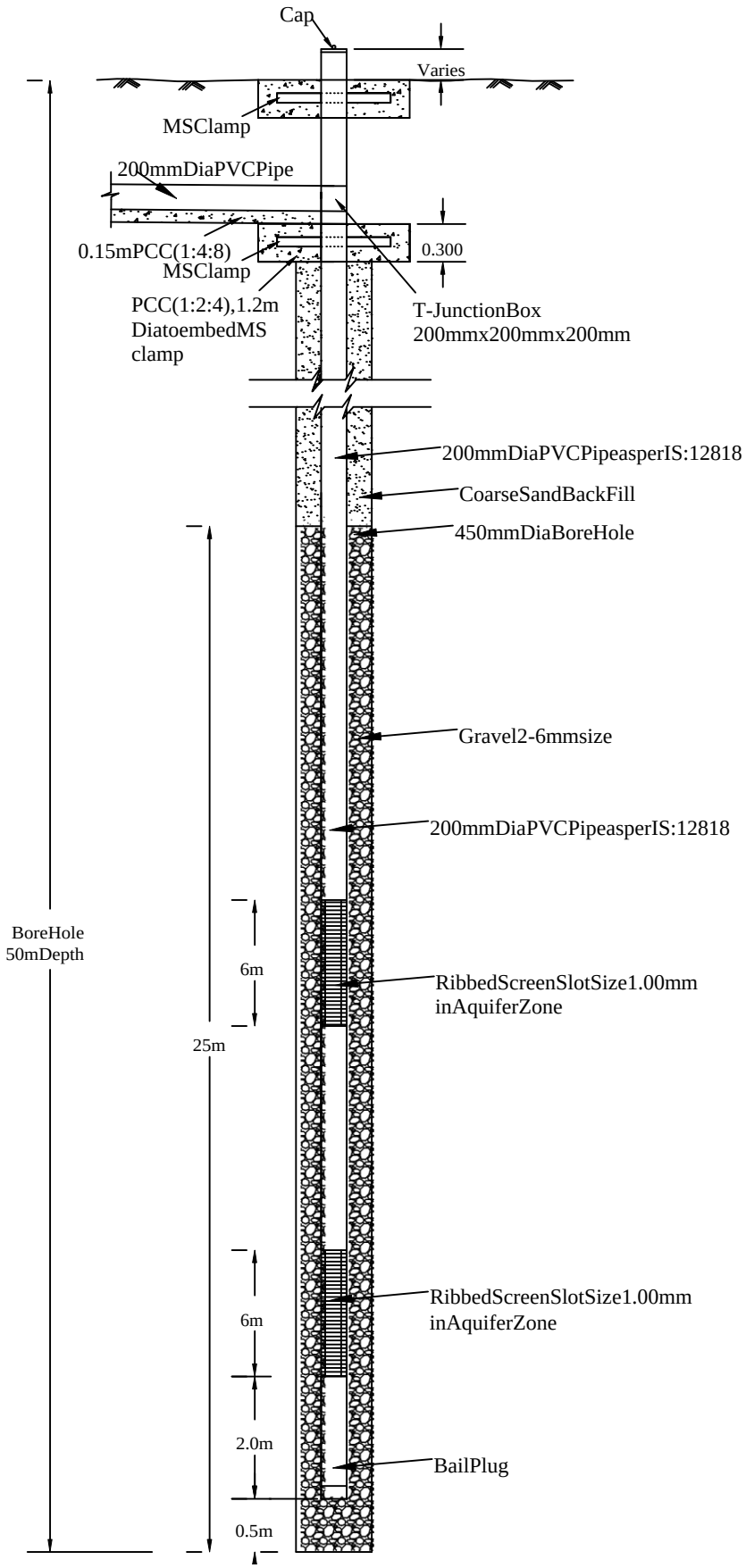

Figure II: Typical Sketch of An Injection Well

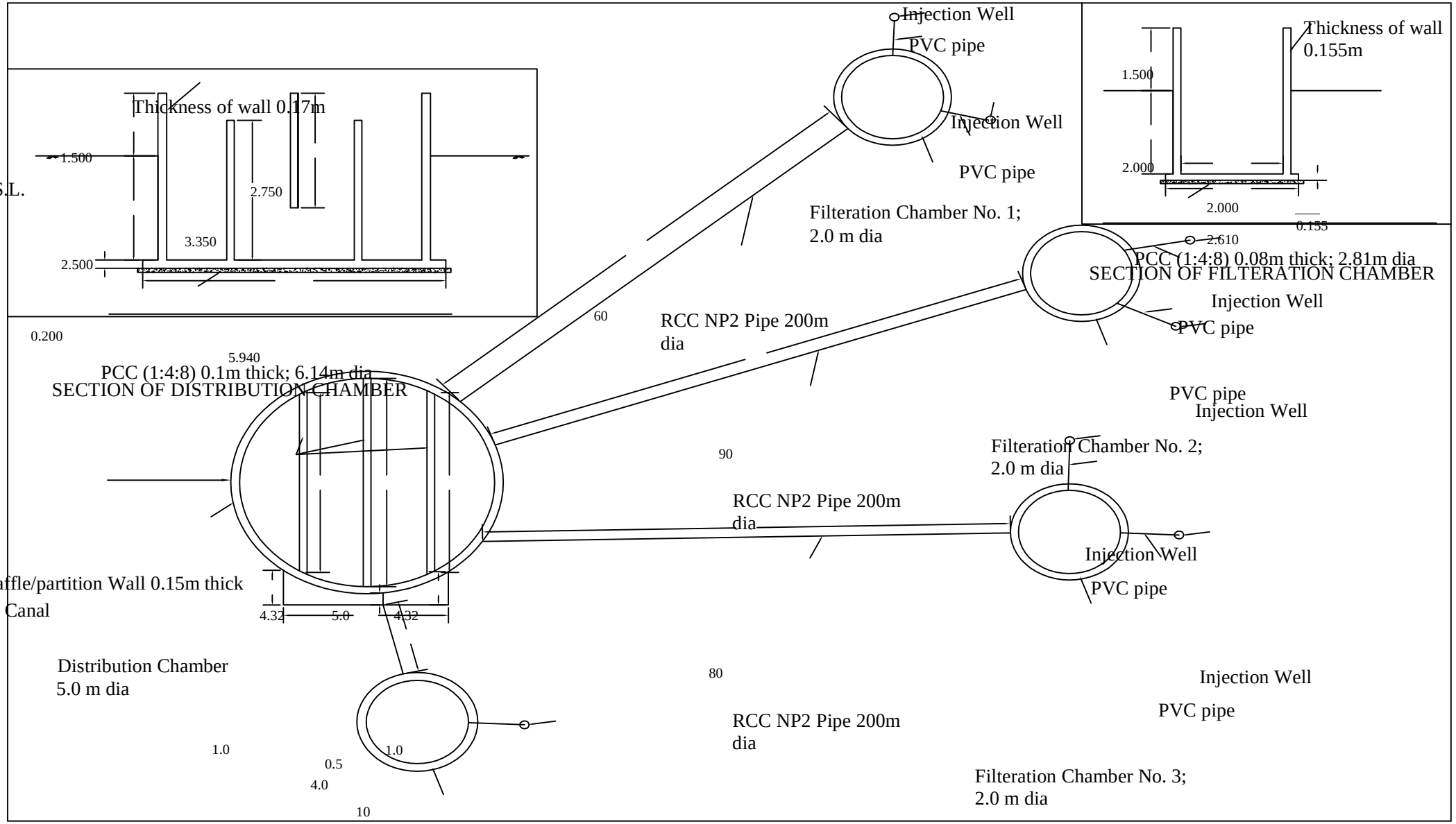

Figure III: Schematic Sketch To Show The Placement Of Test/Trial Schemes

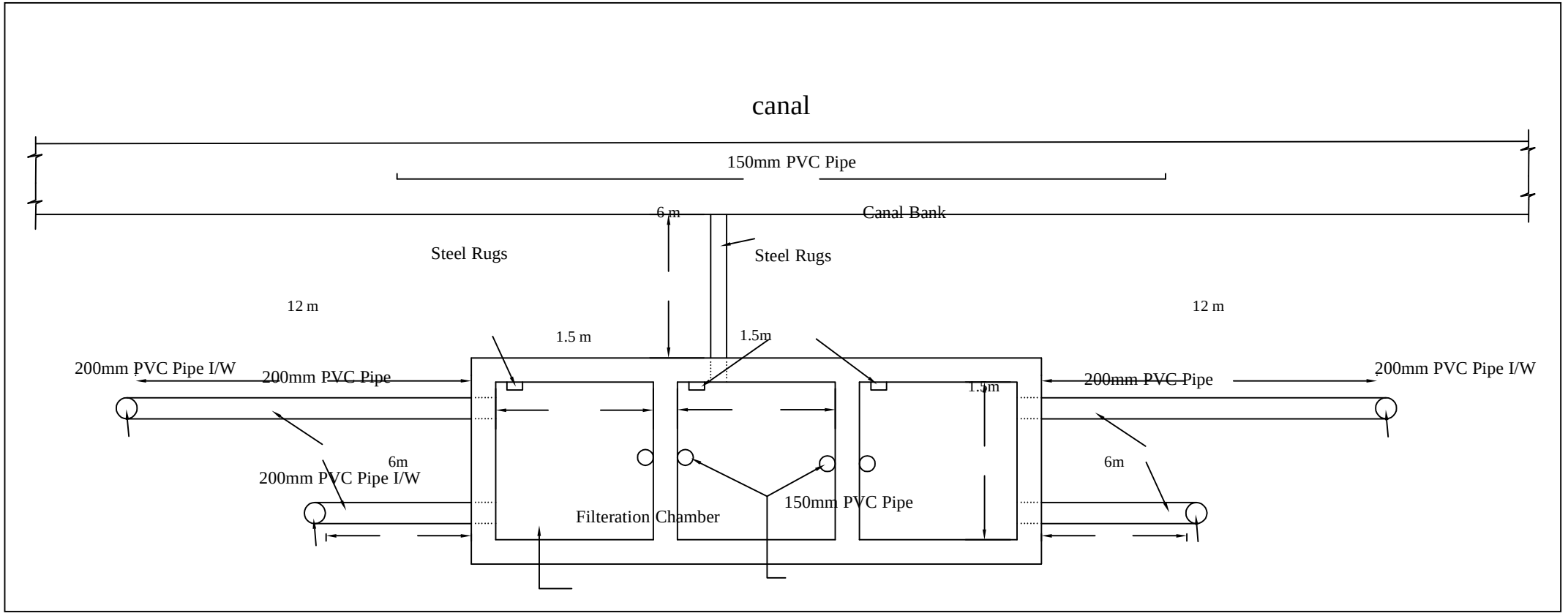

Figure IV: Typical Layout Plan of the Scheme Along The Canal
(For 4 Number Injection Wells)