Assessment of the Artificial Ground Water Recharging Potential with Innovative Artificial Ground Water Recharging Techniques using Canal Water in Moga and Fatehgarh Districts of Punjab State (India)

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Abstract *- In Punjab state, due to over-exploitation of ground water, there is a decline in ground water levels resulting in shortage of supply of ground water and thereby necessitating the need for artificial recharge of ground water using available canal water which is primarily available during lean periods/monsoons. Artificial recharge of Ground water using canal water through Injection wells has been studied for over a period of more than three years. The capacity of the injection wells for various aquifer conditions is practically calculated after study of 9 such schemes installed as pilot project for the purpose in Moga and Fatehgarh Sahib district of Punjab State. It has been found that the capacity of the injection wells to recharge the ground water through canal water depends upon several factors which include the aquifer class, the time for which the scheme is running without any maintenance/restoration of injection wells and the head of water available at the entry.*

Keywords - *Artificial Ground Water recharging, Distributary, Minor, Injection Wells, Aquifer, Distribution chamber, Filtration Chamber, Development of Injection wells.*

1.0 INTRODUCTION

Punjab state in India, having nearly 83% of the State's geographical area is under cultivation[1] is predominantly an agrarian state. Out of the total irrigation, about 30% of irrigation is done by canal water and the other predominant 70% part by ground water through tube wells. 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 wellbeing 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 147 blocks in the state. Out of the total 162 blocks notified for control and regulation of ground water by CGWB in the entire country, 45 are in Punjab State only[3]. 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[4,5].

For sustaining the state's economy and farmers' interest, 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[6], the recharging through Injection wells, 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, is investigated due to continuous supply and quantum of water available through canal network. 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[7]. It has been reported through various researches that storage of water in sub surface reservoirs through managed aquifer recharge is economically viable option in comparison to other storage techniques[8].

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 L osses, no adverse effects of inundation of large areas[9], enhance dependable yield of wells and hand pumps[10], no contamination effect on canal water supply and hence no specialized treatments required[11], 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[12]. In lines of this, the small stand-alone artificial recharge schemes have been executed as a pilot projects in various places of Punjab as Punjab State has well spread network of canals with canals spread over major culturable cultivated areas. In this study the total of 9 standalone recharge schemes installed in districts of Moga and Fatehgarh Sahib have been studied to assess the potential of the injection wells proposed for artificial recharging in carrying out the recharging through Canal water. These schemes have been installed since 2012 (refer Figure 1) and proper monitoring of the data and recharge capacity estimation for each of this scheme is carried out. The factors affecting the recharging potential of the injection wells installed in these schemes have been ascertained and discussed. Based upon the information gathered from these pilot schemes, other schemes based upon injection wells can be prepared/ replicated on various canal systems passing through other blocks of the state. This information is of paramount importance in designing various Ground water recharging schemes through Canal water after proper Techno-economic analysis[13].

2.0 METHODOLOGY

The recharge capacity apart from other factors depend majorly on the aquifer[8,14]. With view to check the feasibility of the Injection wells in recharging the Aquifers, the Pilot/Test schemes for Artificial recharge using Canal water during Monsoon and low demand periods have been installed at discreet distributed places in Moga and Fatehgarh Sahib districts of Punjab state along the canals. It is worth mentioning that out of 45 notified blocks by CGWB, total 6 blocks fall in districts of Moga and Fatehgarh Sahib. Thus these pilot schemes have been installed at the places under 2 districts of Punjab State which have most critical ground water situation out of total.

22 districts.

2.1 *Components of Pilot /Test Schemes:*

The pilot trial/test schemes have been initially planned for the running period of 100 days in a year and have 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 (the height is guided by the height of banks of the nearby canal but is generally 2.5 meter below NSL and minimum 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 Pebbles 50-100mm (0.4m thick), middle layer of gravel size 6 to 50 mm (0.4 m thick) and top layer of gravel size 2 to 6 mm (0.4 m thick) has been provided.] of size 2.0 metre diameter and 3.0 metre height (2.0 m below NSL and minimum 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, with the strainer provided at the places where an aquifer band has been encountered, installed with each filtration chamber as per Typical design approved by Central Ground Water Board to replenish the Aquifer (up to 50-60m depth) . In addition to above, one number Clearing cum filtration chamber of 2mtr diameter and 3.5 metre height (2.5 meter below NSL and minimum 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.

3.0 RESULTS AND DISCUSSION

The bore holes made are of 450mm diameter and while carrying out the boring using direct rotary rigs the soil samples are collected for every one meter depth of the bore. The lithology log of the subsurface soil profile is plotted and based upon the soil profile available and the water beneath the surface of the earth, the assembly for the bore hole is designed. The strainers are provided where there is sufficient thickness of sandy strata band available. The aquifer classification based upon the sub soil available is done as shown is Table I.

Table I
Aquifer Classification

S.No.	Description of Aquifer	Aquifer Class
1	Coarse to very Coarse sand and with substantially thick band width	A
2	Medium Coarse Sand and with reasonably thick band width	B
3	Fine sand with reasonably thick band width	C
4	Fine to Medium Sand but with less band thickness and with intervening bands of clays	D
5	Clay to Fine Sand with no well-defined aquifer bands	E

Based upon these lithology logs the aquifer classification for various site for Moga and Fatehgarh Sahib districts have been done and these sites, the time since when the scheme has already been running (since commissioning after installation/ last maintenance of injection wells) at the time of making the observations and the aquifer class available for these schemes is enumerated in Table II.

Table II
Aquifer Class for Recharge Scheme Sites at Moga and Fatehgarh Sahib Districts.

S. No.	Site Name/ Village name	District	Scheme working since	Aquifer Class
1	Kokri	Moga	36 Months	C
2	Dhangerian	Fatehgarh Sahib	33 Months	B
3	Pola	Fatehgarh Sahib	33 Months	C
4	Samalsar	Moga	10 Months	A
5	Cheeda	Moga	10 Months	B
6	Noorpur Hakima	Moga	11 Months	B
7	Dhala	Moga	10 Months	D
8	Amloh	Fatehgarh Sahib	11 Months	B
9	Allowal	Fatehgarh Sahib	10 Months	C

In the distribution tanks the push down gates are provided to contain the flow of water from distribution chamber to the clearing chamber (Refer Figure IV). For each of these sites, in order to assess the water intake capacity of the injection wells, the push down gates are closed and the inflow to the distribution chamber is opened. The distribution chamber is filled up to the level 0.75 m above the 3 No. baffle wall (Refer Figure III) and while doing so the flow of water from distribution chamber to filtration chamber have been stopped on temporary basis using plastic bags filled with sand. The head of 0.75 m is created on the top the No. 3 baffle wall and the inlet to the distribution chamber is plugged using plastic bags filled with sand, the temporary plugging of the outlet from distribution chamber to filtration chambers removed and the stop watch started. The water flowing from distribution chamber to the

filtration chambers cause the loss in the head, the residual head have been measured after every 30 seconds. The volume of water intake by each injection well is calculated using the following formula:

$$\text{Volume (L/s)} = \frac{A \times HL \times 1000}{T \times 6}$$

Where A = Area of distribution chamber corrected for deduction in area due to central baffle wall No. 2 in Square meter.
HL= Head Loss in Meters after time interval of 30 seconds
T = Time is seconds (30 seconds).

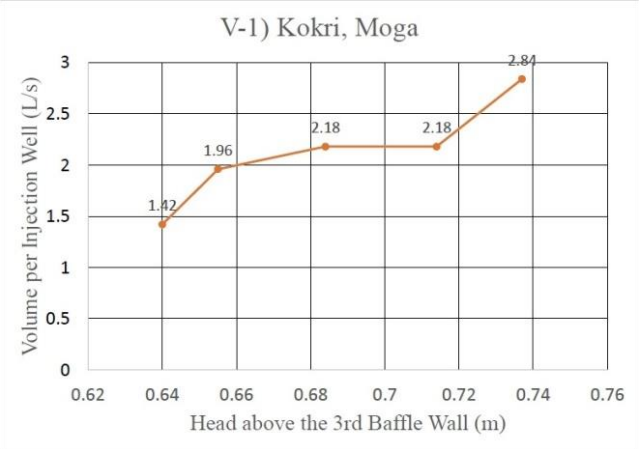
The intake characteristics of the injection wells for all the 9 sites is plotted against the head of water and shown in Figure V (V-1 to V-9). The results revealed that

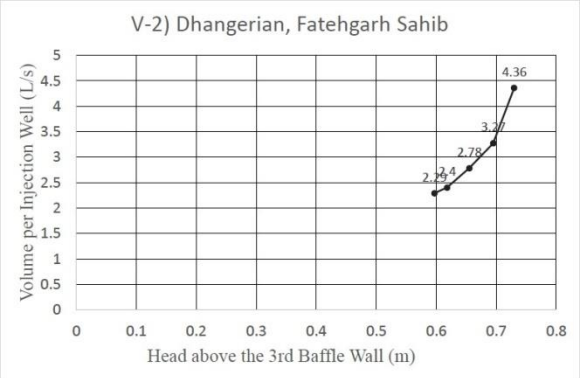
a) The intake capacity individual injection well to recharge canal water varies from 1.42 Liters/Second to 15.27 Liters/Second. The intake capacity of the injection wells installed in Aquifer Class A was maximum followed by Class B and then by Class C and lastly by Class D. Thus the sub surface strata with Coarse to very Coarse sand and with substantially thick strata widths are best suited for recharge purposes and as the grain size decreases and cohesive nature of the sub surface strata increases, its capacity to intake water decreases for same head of water at intake conditions as well as overall intake capacity.

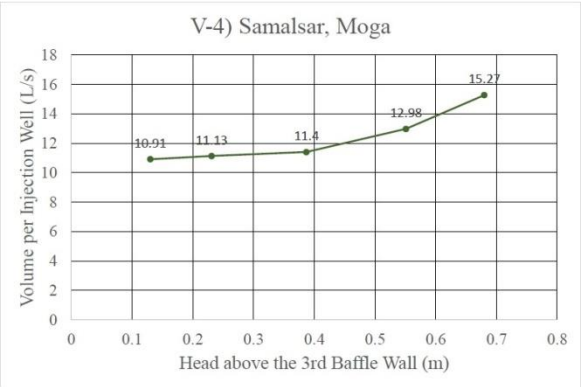
b) The injection wells which have been in use for substantial time (from commissioning after installation/ restoration of capacity of injection wells by development through air compressor) to inject water from canal based schemes show lesser performance/capacity to in-take water as compared to relatively new schemes for the same head of water conditions as well as overall intake of water capacity. This may be attributed to the fact that the canal water is a silt loaded water and even after sedimentation carried out in distribution chamber and subsequent filtration in filtration chambers, the smaller size particles tend to pass to the injection wells and with time tend to clog the strainer and the filter media. Further as injecting water is a relatively slow process so the silt loaded water remaining stagnant in the injection well and surrounding filter media beneath the sub soil surface level for longer intervals of time lead to the clogging of the filter media and the strainer pipes. Therefore it is recommended that apart from usual periodic cleaning and de-silting of the distribution chamber, cleaning and de-silting of the filter media in filter chambers and over all general cleaning of distribution pipes which should be carried out bi-annually, a proper development of the injection wells using air compressor of the relevant capacity be carried out once a year for getting optimum outcome form the scheme as it will substantially increase the in-take water capacity of the injection wells and will give maximum benefit for the intended purpose. It is assessed that when the head at the inlet is more there is substantial increase in the in-take capacity of the injection wells. As the water level in the distribution chamber will be more or less at the same level as the canal water level, so more is the head available or in other words, higher the canal than the Natural Surface Level (NSL) or when the canals are running full, better will be the performance of these artificial recharge schemes. More the head in the inlet, it will create more pressure/ water head for injecting water into the sub surface aquifer.

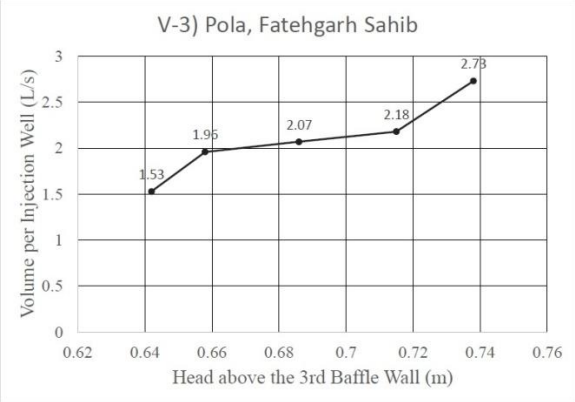
c) Further it can be inferred that the schemes installed on Lined canals such as Bhakra Main line, which have relatively lesser silt loads, give better capacity of intake than the others as the filter in filtration chambers get choked up early for silt loaded canals.

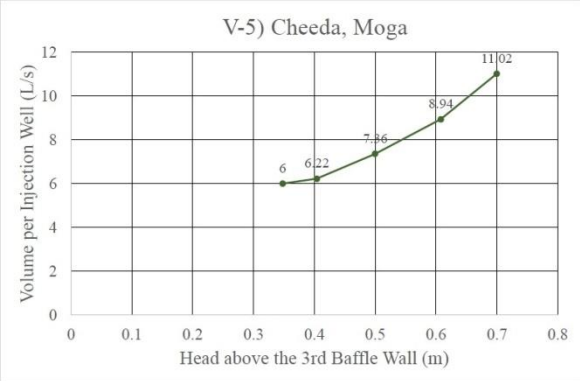
FIGURE V
Variation of the Intake Capacity of the Injection Wells with the Head of Water on the inltet (Head above the Baffle Wall No. 3 refer Figure III)

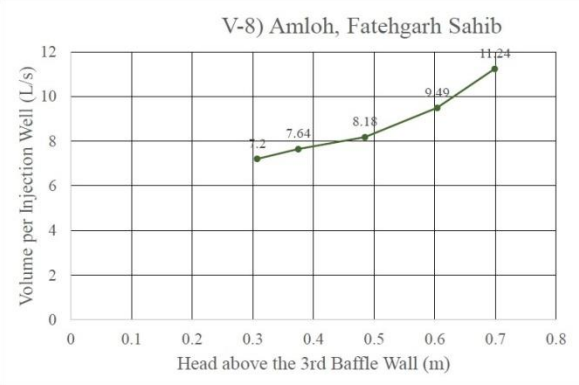


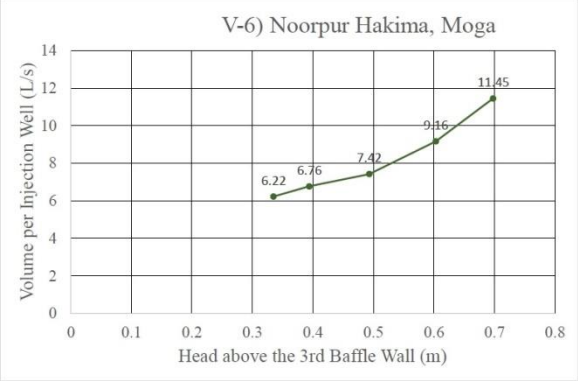

V-2) Dhangerian, Fatehgarh Sahib
Volume per Injection Well (L/s)
Head above the 3rd Baffle Wall (m)
4.36
3.27
2.78
2.4
2.23

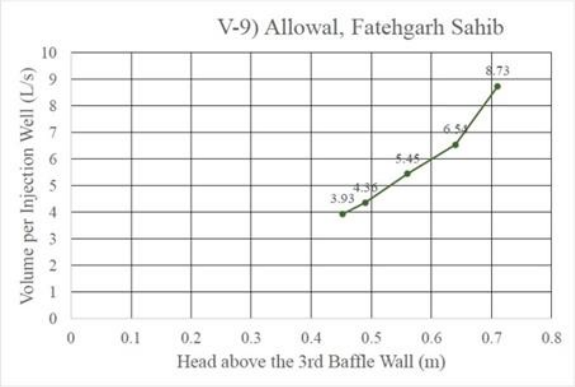

V-4) Samalsar, Moga
Volume per Injection Well (L/s)
Head above the 3rd Baffle Wall (m)
15.27
12.98
11.4
11.13
10.91


V-3) Pola, Fatehgarh Sahib
Volume per Injection Well (L/s)
Head above the 3rd Baffle Wall (m)
2.73
2.18
2.07
1.96
1.53


V-5) Cheeda, Moga
Volume per Injection Well (L/s)
Head above the 3rd Baffle Wall (m)
11.02
8.94
7.36
6.22
6


V-8) Amloh, Fatehgarh Sahib
Volume per Injection Well (L/s)
Head above the 3rd Baffle Wall (m)
11.24
9.49
8.18
7.64
7.2


V-6) Noorpur Hakima, Moga
Volume per Injection Well (L/s)
Head above the 3rd Baffle Wall (m)
11.45
9.16
7.42
6.76
6.22



The parameters assessed in this study not only provides a working ground in preparation of artificial ground water recharging schemes in Punjab State which when extensively applied will ultimately be instrumental in devising a sustainable technology for dealing with declining ground water trends in Punjab state. The schemes so prepared on basis of this study will not only help in 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.

2. To utilize surplus water available in distributaries and minors during monsoon and lean period for recharge in these distributaries/minors.

1. To monitor the impact and rate of ground water recharge.
2. To train the state government personnel in operation of Artificial Recharge schemes and Rain harvesting schemes.
3. To improve the socio- economic conditions of the farmers.
4. Reduction in flood intensity as the water available in lean period will be directly injected into the ground instead of flooding of the area especially tail reaches of the canals.
5. More discharge to the farmers from tube wells at lesser cost and resulting in low energy consumption, thereby saving power.
6. Improvement of environment.
7. Reduction of canal water stress during Irrigation period.
8. More use of centrifugal pumps, thus decreasing financial burden of installing submersible pumps to the farmers.
9. Conservation and storage of water for future requirements.
10. Avoiding wastage of valuable resources (water) that is FREE.
11. This may help in changing the category of block from over-exploited to critical /semi critical and further in de-notifying the block.

4.0 CONCLUSION

1. The intake capacity of recharging canal water for the individual injection wells varies from
   1.42 Liters/Second to 15.27 Liters/Second. The average intake capacity of each injection well, irrespective of the subsoil strata, head of water at intake and other factors, for all the schemes comes out to be 7-7.5 Liters per second.
2. 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 and those at higher elevation results in better head to the water being recharged and consequently better capacity of in-take than the canals running in low capacity or those in cutting.
   - 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 such as Bhakra Main line gave better capacity of intake than the other unlined silt loaded canals as the filter in filtration chambers gets choked early due to the silt load in water flowing through unlined canals.

5.0 ACKNOWLEDGEMENTS

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FIGURE I: Plan showing the Location of 9 sites for Pilot/ Test Artificial Recharge Schemes in Moga and Fatehgarh Sahib Districts of Punjab State.

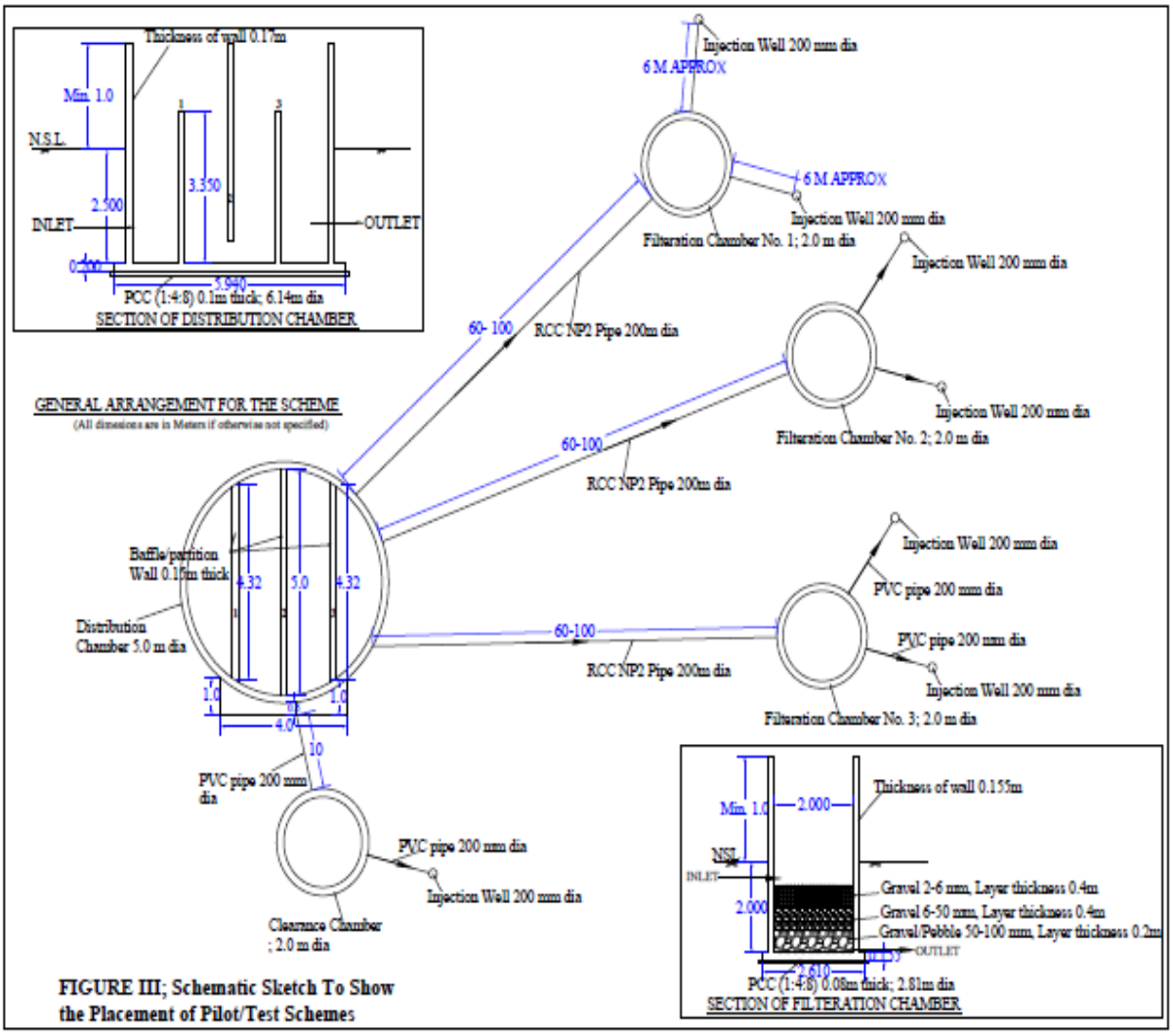

FIGURE III; Schematic Sketch To Show the Placement of Pilot/Test Schemes

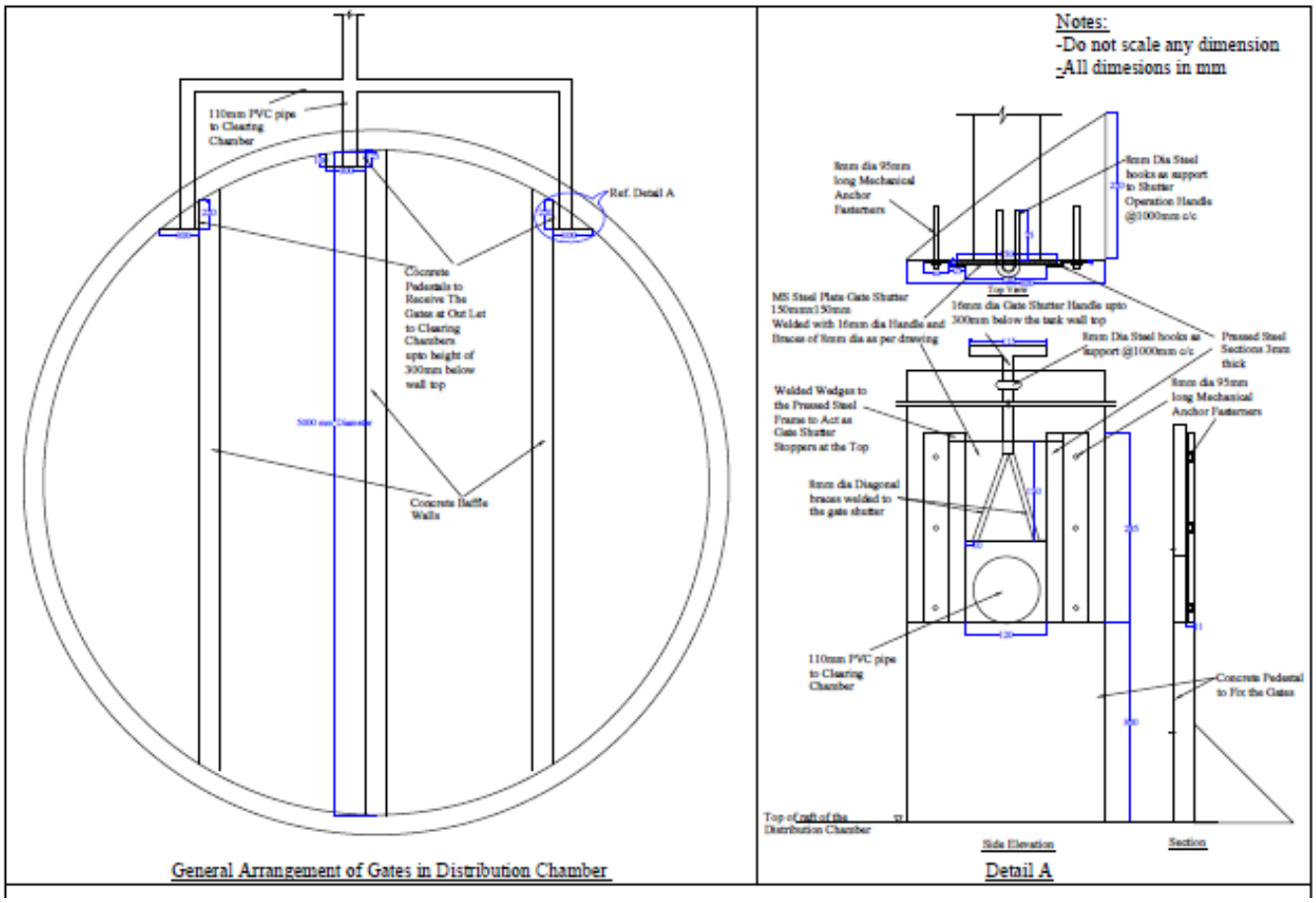

FIGURE IV : General Arrangement of Gates and the Design of the Gates