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SUSTAINABLE ENVIRONMENTAL SANITATION AND WATER SERVICES

Artificial recharge of groundwater by injection well

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THE LAND AREA of the Kathmandu valley is 600 square kilometers (sq. km) in which about 400 sq. km. is the valley floor towards the center, the remaining 200 sq. km. area being the surrounding hills. The hills and the basement beneath the floor are composed of intensely folded, faulted and fractured igneous and metasedimentary rock. Upon this basement complex rests unconsolidated to partly consolidated sediments which range from thin deposits along the valley floor margins to over 600 meters thick in the central portion forming the principal groundwater reservoir of the valley. The average annual rainfall in the valley is about 1580 mm, 80 per cent of which takes place during the monsoon, Jun-Sep. All the surface flow of the valley join the river Bagmati which drains out of the valley in the south at Chobhar. The maximum average monthly flow of Bagmati at Chobhar is 53.43 m3/sec in Aug and the minimum is 1.55 m3/sec during March.

With the use of most of the available surface sources of the valley, the development of deep groundwater began since the early eighties. About 50 million liters of water per day is being withdrawn from the deep aquifer of the valley. This is above the safe yield, as there have been lowering of deep water level by about 20 meters and reduction in the well discharge by about half.

With the utilization of all the surface sources and over exploitation of groundwater, Melamchi Water Supply Project is being implemented through which 510 million liters water per day will be diverted to the Kathmandu Valley in three phases from the adjoining Indrawati river basin. Along with the implementation of this new project it has also become imperative to protect and wisely use the groundwater of Kathmandu Valley, it would at least be needed during emergency time and the peak of the dry months when the Melamchi sources may not be able to meet the demand of Kathmandu valley as some water will need to be released downstream in the river to meet the river's ecological needs. As such monitoring the level and quality of the groundwater has been started, and a program on registration and licensing of groundwater use is being developed.

Along with these program on management of groundwater it was put forward to launch a program entitled *artificial groundwater recharge pilot project* with the objectives of injecting the deep aquifer with the surplus surface water available during the monsoon in order to improve the water supply condition and recover the depleted groundwater level. In the injection method of recharge water is allowed to pass directly into the deep aquifer through the screens provided in the well due to the pressure caused by rise in water level in the well due to injection of water into it. This method has been chosen because the aquifers to be charged are deep and confined and their recharge area is not known precisely. However given the high sophistication and cost of such a program the government wanted to drop the program, but later it was scaled down to a capacity of 10 lps only and to testing the feasibility at a more preliminary level with very limited cost as described below.

The recharge set up

A schematic diagram of the recharge test set up is given here as figure-1. The source of water is the Manohara stream. A five-meter deep dug well with a diameter of two-meter

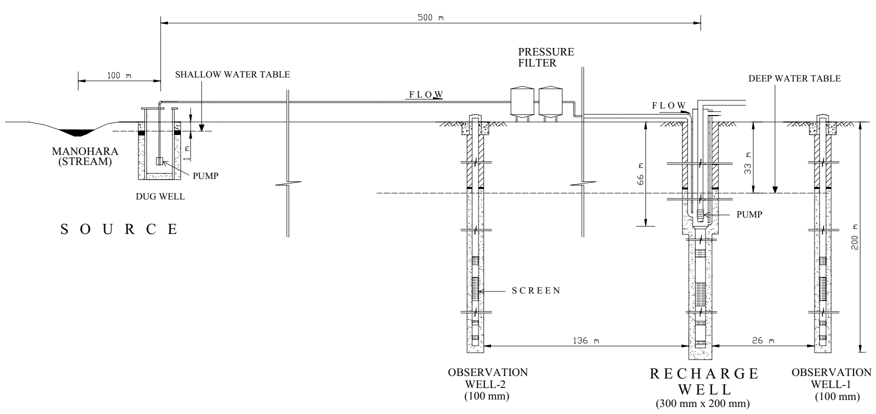

Fig 1. Schematic diagram of the recharge test set up

Table 1. Results of recharge test

Item		Duration		Water injected (m3)	Injection rate (l/s)	Water level build up (m)	Specific recharge capacity (m3/hr/m)
Stage-1	Step-1	48	hr	883	5.11	12.04	1.53
	Step-2	48	hr	1111	6.43	14.51	1.60
	Step-3	32	hr	1051	9.12	26.81	1.23
Stage-2		15	day	8188	6.32	29.44	0.77
Stage-3		21	day	8514	4.69	26.94	0.63

constructed at a distance of 100 meters from the Manohara stream collects the shallow water which is at a depth of about 1 meter below the ground level. The dug well water is pumped by a submersible pump through 100 mm diameter galvanized iron pipe to the pressure filter water treatment plant installed in the premises of the recharge well at a distance of 500 meters from the dug well. The treated water from the pressure filter is injected in to the adjacent recharge well.

The recharge well is 200 meter deep. The upper 66 meter is of diameter 300 mm and the rest of 200 mm with four stainless steel continuous screens totaling 30 meter below 123 m depth covering the deep confined aquifer intercepted by the well. The static water level in the recharge well is 33 meter below the GL. In order to avoid free fall and splashing of the recharge water while it enters in to the recharge well, the inlet pipe is joined to the recharge well below the static water level at a depth of 50 meter below the GL. A submersible pump is installed in the recharge well which is used for the purpose of back washing the well and carrying out pumping test for calculating the well and aquifer characteristics that indicate the efficiency of the well at different times during course of the recharge test – a decrease in the well efficiency indicating decline in recharge capacity of the well.

Two observation wells at 26 and 136 meters from the recharge well have been installed for monitoring the changes in water level and quality. The observation wells are of diameter 100 mm and depth 200 meters with the screens at locations similar to that of the recharge well.

The deposits in the recharge area are composed of unconsolidated permeable materials consisting of micaceous quartz, sand, gravel, clay, silt and silty clay. The deposits are alternate layers of permeable and impermeable deposits and their intercalation. The permeability is low.

Recharge test

The injection of water into the well was carried out in three stages of duration five, fifteen and twenty-one days respectively–the duration of the following stages being longer that the preceding ones and the recharge rates for the second and the third stages chosen on the performance of the well in the preceding stages. The recharge test results are presented here in table-1 and briefly discussed below.

The **first stage** was a step recharge test at rates 5.11, 6.43 and 9.12 liters per second for 48, 48 and 32 hours respectively carried out to guide the fixing of recharge rate for the second stage (continuous) recharge test. The maximum build-up (rise) of water level in the recharge well were 12.04, 14.51, and 26.81 meters respectively corresponding to the three recharge rates. The specific (recharge) capacity of the well in these three steps were 1.53, 1.60 and 1.23 m3/hr/m respectively. Total water injected in this stage of recharge was 3045 m3.

In the **second stage** 8188 m3 of water was injected for 15 days at an average rate of 6.32 l/sec. The maximum build up of water level was 29.44 m. The specific capacity was 0.77 m3/hr/m. Water level build up in the observation wells 1 and 2 were 1.28 m and 0.60 m respectively.

In the **third stage** 8514 m3 of water was injected in 21 days at an average recharge rate of 4.69 l/s. The maximum build up of water level was 26.44 m. The specific capacity was 0.77 m3/hr/m. The water level build up in the observation wells 1 and 2 were 0.48 m and 0.20 m respectively.

Table 2. Results of pumping test

Item		Duration		Discharge rate (l/s)	Draw-down (m)	Specific capacity (m3/hr/m)	Permeability (m/day)	Average transmissibility (m3/day/m)
Preliminary (before stage-1 recharge)	Step-1	140	min	6.40	11.26	2.05		
	Step-2	160	min	7.35	21.94	1.21		
	Continuous	72	hrs	6.25	21.06	1.07	76	1.9
After 1st stage recharge		8	hrs	8.00	20.67	1.39	27	0.7
Follow up (after 3rd stage recharge)		72	hrs	5.00	23.76	0.76	31	0.8

Table 3. Typical water quality report showing some parameters

	Parameter & Unit	Dug well*	Injection water*	Recharge well#	Observation well#
1	Temperature	17.7	17.3	17.7	19.8
2	pH	7.8	7.6	6.92	10.23
3	EC μS/cm	90	90	115	410
4	Dissolved Oxygen mg/L	6.5	3.7	4	3
5	BOD mg/L	6	< 1	1.6	16.8
6	Tot. coliform col/100 ml	nil*	nil*	nil	nil
7	Faecal coliform col/100 ml	nil	nil	nil	nil
8	Turbidity NTU	3	2	10	125
9	Ammonia mg/L as N	0.42	0.34	0.88	10.50
10	Nitrate mg/L as N	1.20	1.1	2.50	35.00
11	Nitrite mg/L as N	< 0.001	< 0.001	0.011	0.182
12	T. Iron mg/L	0.22	< 0.1	5.42	11.2
13	Manganese mg/L	0.15	< 0.1	0.25	0.61
14	Calcium mg/L	10	10	11	28
15	Magnesium mg/L	11	10	6	1
16	Total Hardness mg/L as CaCO3	71	65	53	78
17	Non-carb, Hardness mg/L as CaCO3	27	21	nil	nil

*During first stage recharge; #During well development after 1st stage recharge

Pumping test

A preliminary pumping test was carried out before the first stage recharge to determine condition of the well before the recharge. This comprised of three-step draw down tests followed by continuous pumping test of 72 hours and recovery test. The third step draw down test carried out at 10 l/s could not be continued beyond 30 minutes due to the lowering of the water level below the pump chamber. The recovery rate was very fast in the first 10 minutes but a residual of 0.17m still remained to be recovered at 24 hours of recovery. The pumping test results are given here in table-2.

The first and the second recharge tests were followed by eight hours continuous pumping test. The third stage recharge test was followed by a follow up pumping test in order to determine the effect of the recharge on the capacity of the well by comparing the well characteristics with that during the preliminary pumping test. This comprised of step draw down test followed by 72 hours of pumping test and subsequent recovery test. The step draw down test was carried out at 5 l/s discharge but the aquifer was clogged in such a way that the pumping could not be continued beyond 150 minutes due to heavy draw down. The well was then cleaned for further test. Water level in the observation wells were also measured during the pumping tests. Relatively large amounts of sediments were contained in the water pumped during most of these pumping tests.

After completion of the third stage recharge and before the follow up pumping test, the recharge well was surged with chemicals and air compressor was run to clean the well. But some turbidity still remained in the recharge well water on completion of the prescribed cleaning process.

Water quality

The physical, chemical and bacteriological quality of water (a) from the dug well, (b) before injection, (c) after injection, and (d) from the observation wells were monitored regularly throughout the test. In total up to 36 quality parameters from150 samples were analyzed. Typical water quality reports showing some of the quality parameters are given here in table-3.

Although there were some changes in some of the quality parameter of the dug well water during the course of the test, all the parameters were within the WHO guideline values for drinking water. It was not even necessary to add lime and alum in the treatment plant. The positive effect of the treatment on the water quality was a decrease in the concentration of ammonia, nitrite, total iron and BOD. Similarly there was increase in the concentration of silicate (because of new filter media) and decrease in the value of pH as the negative effect of the treatment process. The quality of the water pumped out of the recharge well after each of the three stages of recharge resembled that of the injected water, indicating that the water being pumped out was the water injected. The comparison of the observation well water with that from the dug well show a double in the value of EC, and higher turbidity, iron and manganese in the former, the rest of the parameters in the former being within the WHO drinking water guidelines values.

Discussion and conclusion

The capacity of an aquifer (soil strata in which the soil grain sizes are relatively large, are saturated with water, and can readily yield the water to the wells) to transmit water is measured by its *permeability* which is basically the velocity with which water in the aquifer can flow (under unit hydraulic gradient). Similarly the *specific capacity* of an aquifer or well with respect to delivery of water from the well or recharge into it is another parameter that indicates the efficiency of the well with respect to abstraction or recharge. The specific capacity is the flow coming out of the well or that going into divided by the corresponding values of lowering or rise of water level, as the case may be.

In the case of the recharge test under consideration, the specific capacity of the well at completion of the test has been reduced to 60% of the value that existed during the start of the test (table-1). Similarly the transmissibility (related to permeability) and the permeability values of the well have been reduced to less than half of the initial values (table-2).

Besides the aquifer material being of low to poor permeability, there has also been clogging of the screen and its vicinity which could be due to both the physical disturbances taking place in the aquifer and due chemical reaction of the recharge and native water of the well. Say, the surface water rich in dissolved oxygen mixed with the native groundwater with higher iron content have some potential for deteriorating the chemical quality of the water, for example by forming ferric hydroxide flocks. There could also be bubbles of air coming out of solution.

The exact diagnosis of the reasons behind the clogging and reduction in the recharge efficiency of the well is beyond the provision made in the recharge test and probable also beyond the expertise currently available with in the nation.

The recharge test does not seem to be feasible at this stage. However a further endeavour to diagnose the situation in more detail would seem to be a logical step to be taken in the future. One of the other possible practical alternatives could be to carry out the test with more efficient methods of cleaning the well.

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