Operational Constraints in Conventional Managed Aquifer Recharge in Barind Area at North-Western Region of Bangladesh

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Abstract

Barind area located in the north-west region of Bangladesh is a drought prone water stressed area. Due to the gradual increasing demand of groundwater withdrawal for irrigation as well as domestic use, huge number of deep tube-wells have been installed in this region. As a consequence, groundwater table is depleting in the Barind tract. Moreover, storm water cannot percolate during the monsoon due to the clay layer more than 40 ft depth from the ground surface. Therefore, the negligible natural recharge of groundwater indicates Managed Aquifer Recharge (MAR) is needed through artificial Recharge Well (RW). Conventional MAR system like recharge well and shaft were installed in the canal and performance was evaluated in the field. The quality of canal water was also determined. During the study it was observed that recharge rate was gradually decreasing and finally recharge was stopped. This is due to the siltation and clogging of top layer of recharge unit. A 40 mm to 80 mm thick muddy silt layer was observed on the top surface of recharge unit and canal bed when canal was completely dried up. Therefore, more research and modification of conventional recharge unit is necessary for the continuous operation of the unit.

Keywords: *Managed aquifer recharge, recharge well, groundwater, siltation, clogging.*

1 Introduction

The term Managed Aquifer Recharge (MAR), previously known as artificial recharge (Dillon, 2005), is the purposeful recharge of water to aquifers for reuse and/or environmental benefit (Bouwer, 2002), (Dillon, 2005), (Sprenger, C. et al., 2017), (Stefan, C. et al., 2017). The basic purpose of artificial recharge of ground water is to restore supplies from aquifers depleted due to excessive ground water development (CGWB, India, Guide 2000). The intensive exploitation of aquifers is in today's international context considered to be one of the most relevant issues regarding water resources management with direct negative consequences on both agricultural and urban water demands which, in turn, are the main causes for the state of exploitation observed in certain hydrogeological formations (aquifers) nowadays (Konikow. et al., and Kendy, 2005), (Gleeson et al.,2010) the irrigation water demand is the parameter that determines to a greater extent the recharge of aquifers, as they are exploited by agriculture especially in summer (Jaafar, 2014). Managed aquifer recharge (MAR) is being successfully implemented worldwide for various purposes: to increase groundwater storage, improve water quality, restore groundwater levels, prevent salt water intrusion, manage water distribution systems, and enhance ecological benefits (Stefan, C. et al., 2017). There are a large number and growing variety of methods used for MAR internationally (Stefan, C. et al., 2017). Managed recharge—through purpose-built recharge structures, such as injection wells and infiltration basins, for subsequent recovery and use or for storage to provide environmental benefit to the aquifer, e.g.,aquifer storage and recovery (ASR) in Australia (Pavelic, P. et al (2007) bank filtration in Germany (Greskowiak, J., 2006) and Norway (Kvitsand, H.M.L. et al, 2017) dune infiltration in Belgium (Van Houtte, E. et al., 2012) soil aquifer treatment in the USA (Bouwer,H, 2002).

The Rajshahi Barind Tract situated in the North-West region of Bangladesh is a drought prone water stressed area. Groundwater is the main source of irrigation and drinking water as the surface water sources are very limited. Rainfall is very less compared to the other parts of the country. The annual rainfall varies from minimum 1250 mm to a maximum 2000 mm and the average annual rainfall is 1418 mm (IWM 2012) where as the country average is 2500 mm. Almost 80% of the rainfall occurs during June to October. High temperature prevails in this area during dry period, which goes above 35^0C. Due to high elevation of Barind, it is located in flood free zone. So, only source of groundwater recharging in this area is rainfall, but lowest amount of rainfall occur in northwestern part of Bangladesh and it is also a very severely drought prone area (Rahaman and Mahbub, 2012).

Crop cultivation in this area is dependent on groundwater. More than 15000 Deep Tubewells (DTWs) have been installed to withdraw groundwater for irrigation (BMDA 2018). Some of the DTWs located near the villages are also used for providing drinking water to the rural people along side irrigation. The withdrawing rates of groundwater for irrigation and drinking purpose are being increased gradually whereas no significant recharge facilities have been developed in this area. Moreover, top layer of the area is almost clay soil and because of which the percolation rate is low and that is why natural recharge rate of rainfall is also low. Continuous and excessive withdrawals of groundwater cause declining of water table in some places. Such situation demands MAR of groundwater in the area. Considering the description mentioned above a Recharge Well (RW) was installed at the Sarmangla (Paromanondopur) canal of Godagari and a Recharge Shaft was installed at the Rasulpur canal of Niamatpur Upazilla as conventional groundwater recharge techniques. The aim of this study is to determine whether any operational constrains for conventional methods of groundwater recharge in Barind tract.

2 Approach and Methodology

The study area is located in High Barind area of Rajshahi and Naogaon districts. The study sites are Rasulpur Khari (canal) under Niamatpur upazila and Sharmangla Khari (canal) of Paromanondopur Mauza under Godagari upazila. Topography of the area varies from 10.5 m PWD to 44.3 m PWD. To select the location of Recharge well and shaft sites bore logs data were collected from the Barind Multipurpose Development Authority (BMDA) office and analyzed. Groundwater level records and rainfall data were also collected from the BMDA office and analyzed. It is found from the records in both the Upazillas that more than 40 ft of upper layer is clay soil. Maximum water level occurs in the month of March-April and minimum water level occurs in the month of August-September. If it is considered the last 20 years records, gradual declining of water level is observed for both the Upazillas. Figure 1 shows the declining trend of Godagari upazila.

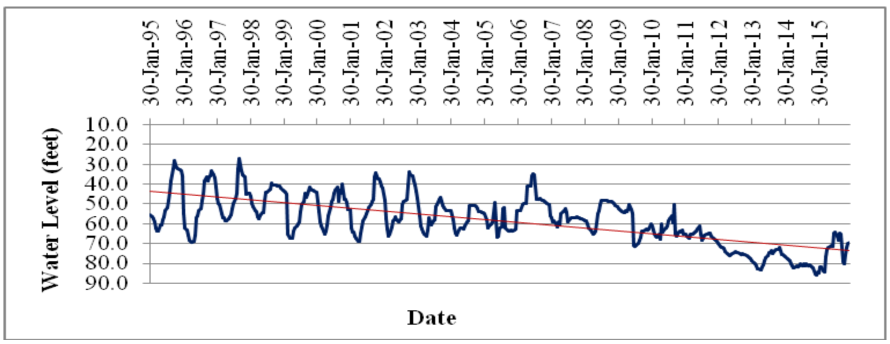

Figure 1. Trend of water level fluctuation at Paramanondopur Deep Tubewell, JL-180, Plot-482

Water remains in the Rasulpur canal for about 7 months (June-December) and in Sarmangla canal for about 6 months. Now river water is also conserved in the Sarmangla canal for irrigation. Practically to know about the aquifer condition, two bores were also made at two sites. The bore log data are shown as Figure 2(a) and Figure 2 (b).

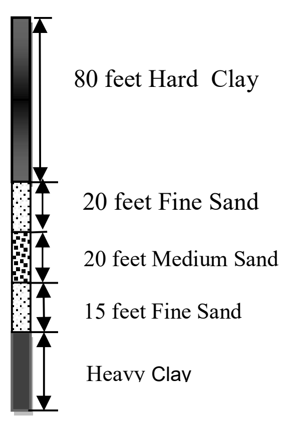

Figure 2(a). Bore log at Sarmangla Khari, Paramanondopur, Godari

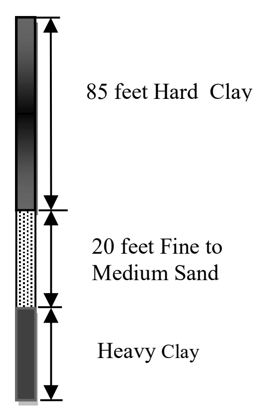

Figure 2 (b). Bore log at Rasulpur Khari, Rasulpur, Niamatpur.

Bore log samples were collected and tested in the laboratory of Institute of Water Modelling (IWM), Dhaka for grain size distribution. Grain size distribution curve of Paromanodopru site is shown in the Figure 3.

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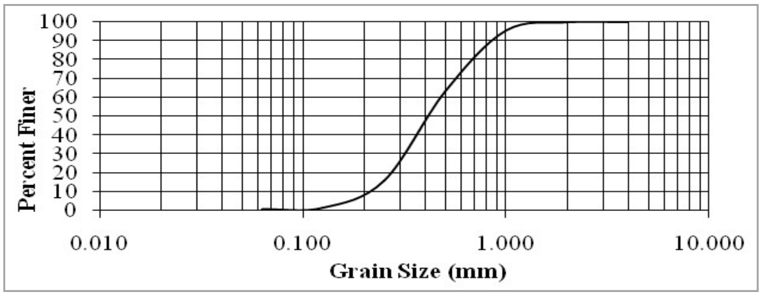

Figure 3. Grain size distribution curve of Paromanandopur (110' to 120') site

Lithology and grain size distribution curves are analyzed and the Recharge well (RW) and recharge shaft are designed as Figure 4(a) and 4(b) and installed them at canal bed of Sarmangla Khari and Rasulpur Khari.

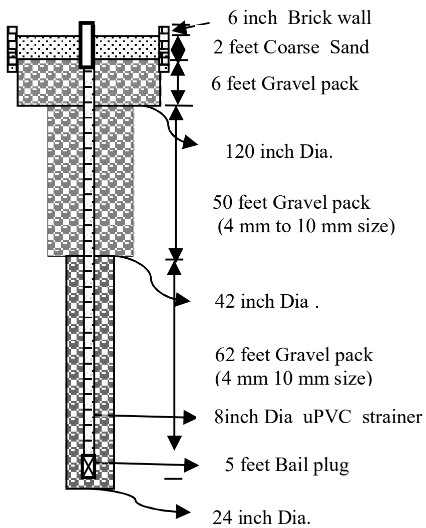

Figure 4(a). Recharge well at Sarmangla Khari, Paramanondopur, Godagari

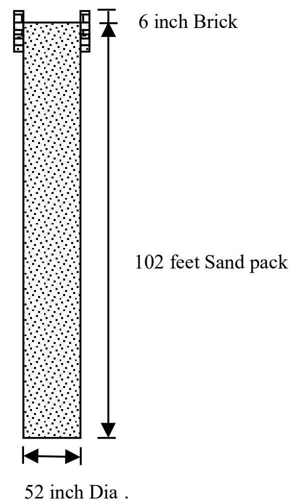

Figure 4 (b). Recharge Shaft at Rasulpur Khari, Rasulpur, Niamatpur

The Recharge Shaft was installed in March 2012 at the bed of Rasulpur canal by digging the soil up to 120 ft below the ground surface and the well was filled with coarse sand. Later on in 2013 a Recharge Well was installed at the bed of Sarmangla canal. The bore hole was made by using Rig machine. To filter the water 10′ diameter and 10′ depth filter pit was constructed top of the recharge well. Coarse sand and gravel were used to fill the filter pit. uPVC blind pipe and strainer were used as recharge tube. To monitor fluctuation of water level one observation well was installed at the canal side near the recharge unit for each case. After installation of unit, water was poured into the unit, measured the quantity of water and counted the time to recharge and thus calculated the recharge capacity of the well in terms of liter per minute (Figure 5). After drying up the canal, thickness of the deposited silt on the upper layer and the canal bed was measured and the upper clogged layer of sand was replaced by clean sand and quantity of recharge water was measured in the same way.

Figure 5. Measuring recharge capacity of recharge well and taking water level record

After installation of the recharge units, the water quality of groundwater was also tested before submergence and after submergence of recharge units and water level records of the observation wells were taken in different time. Canal water was also tested in the laboratory.

3 Observation

3.1 Paramanondopur Recharge Well

Recharge rate

Before inundating the recharge unit and after drying up the canal as well as the recharge unit, the water was poured into the recharge well. Quantity of water and recharging time were counted and thus recharge rate was calculated. The calculated recharge rates are shown in the following Table 1.

Table 1: Recharge rate (using volumetric method) of the Recharge Well.

Date of Measurement	Average recharge rate (lit/min)	Comments
23 May, 2013	48.0	Water recharge was measured after construction and before inundation of the recharge unit as well as canal.
22 March, 2014	2.5	After drying up the canal a muddy silt layer (about 55 mm thick) was observed on the top surface of recharge unit. Water recharge was measured without scraping or replacing the silt layer.
30 March, 2014	39.75	Water recharge was measured after replacing the silt layer by sand layer
20 March, 2015	1.50	Water recharge was measured after drying up the canal. Due to thick (about 75 mm thick) muddy layer no recharge was found.
25 March, 2015	28.64	Water recharge was measured after replacing the silt layer by sand layer

Due to the clogging of top sand layer by the muddy silt layer recharge rate decreased and at one stage it was stopped totally due to thick muddy layer deposited on the top of the sand layer (Figure 6). Furthermore, gradually recharge rate was decreasing though the top layer sand is replaced by new sand layer. It is might be due to the penetration of silt at the deep layer of sand bed that was not replaced.

Figure 6. Clogged Recharge well at Paramanondopur

Water level record

Water level fluctuation records were taken from the observation wells for the Rcharge Well which is shown in Figure 7.

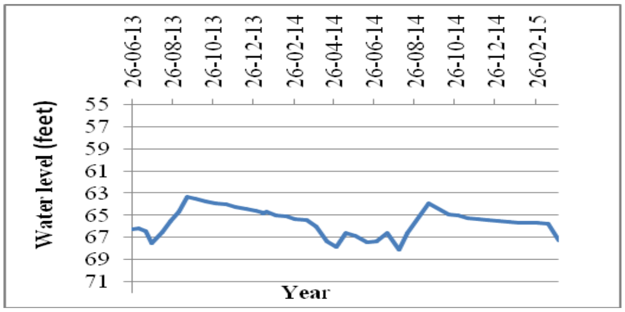

Figure 7. Water Level records of the observation well of Paramanondopur RW

It is found from the curve that after submergence of the RW, water level rises for some days and then start decreasing gradually due to clogging of the top layer of the recharge unit.

3.2 Rasulpur Recharge Shaft

Rcharge rate

Similar experiment was carried out for Rasulpur recharge shaft. The observation is presented in Table 2.

Table 2: Recharge rate (using volumetric method) of the Recharge Shaft.

Date of Measurement	Average recharge rate (lit/min)	Comments
6 March, 2012	41.0	Water recharge was measured after construction and before inundation of the recharge unit as well as canal.
14 March, 2013	5.0	After drying up the canal a muddy silt layer (about 52 mm thick) was observed on the top surface of recharge unit. Water recharge was measured without scraping or replacing the silt layer.
25 March, 2013	37.0	Water recharge was measured after replacing the silt layer by sand layer.
17 March, 2014	3.5	Water recharge was measured after drying up the canal. Due to thick (about 65 mm thick) muddy layer there was hardly any recharge.
20 March, 2014	28.5	Water recharge was measured after replacing the silt layer by sand layer.

Due to the clogging of top sand layer by the muddy silt layer recharge rate got decreased and at one stage it was found there was no recharge so to say. The muddy silt start depositing on the top of the sand layer of the recharge shaft and gradually it increases and make a thick layer and thus infiltration of water reduces. A 40 to 80 mm thick silt layer was observed on both of the canal of the Rasulpur and Sarmangla.

Water level record

Water level fluctuation records were taken from the observation well for the Rcharge Shaft which are shown in Table 3 and the curve is shown in the Figure 8.

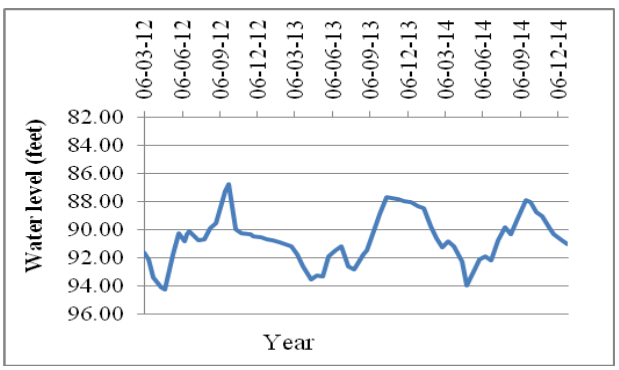

Figure 8. Water Level records of the observation well of Rasulpur Recharge unit.

It is found from the curve that when water is available in the canal due to recharge, water level rises for some days and then start decreasing gradually due to clogging of the top layer of the recharge unit

Water quality

After installation of the Recharge unit, groundwater sample was collected before inundation of the Recharge unit and tested it in water testing laboratory. Again water sample was collected when the canal was full with water and Recharge unit was under the water. The collected water samples were tested accordingly in the same laboratory. The tested results are shown in the Table 3.

Table 3: Water quality test result.

Sl. no	Location of Recharge unit	Testing Date	Water quality parameter							
			As ppm	Ca ppm	Mg ppm	Fe ppm	Cl ppm	Total Hardness ppm	P^H	EC µS/cm
1	Paramnandopur	30.05.13	0	51.28	8.31	0.38	56.95	181	7.4	510
		23.08.13	0	50.51	4.98	0.31	43.5	174	7.22	425
2	Rasulpur	20.04.12	0	66.87	9.49	0.017	49.0	202	7.49	615
		25.06.12	0	65.74	9.25	0.011	47.25	189	7.49	609

It is found from the above table, the values of different parameters reduced due to dilution when groundwater was recharged without clogging. The values are also within the allowable limit.

4 Conclusions

Based on the study findings, conclusions are summarized below:

- More than 40 ft from the ground surface towards bottom is clay layer and decrease in groundwater table indicate Managed Aquifer Recharge technique is needed for increasing groundwater recharge.
- Due to recharge, water level rises for some days and then start decreasing gradually due to clogging of the top layer of the MAR unit.
- More research and modification of conventional recharge unit is necessary for the continuous operation.

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