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Revitalization of tubewells yielding saline water in Delhi - a case study

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Abstract
The National Capital Territory of Delhi is besieged with the problem of acute shortage of good quality drinking water. The problem is further aggravated by the fact that the contribution of groundwater to the drinking water supplies of Delhi is only about 15% due to limited resources. This is more so because of occurrence of brackish to saline water at shallow depths in almost entire Delhi. The top fresh water aquifer is not separated with the underlying brackish/saline aquifer by an aquiclude. This results in the up-coning of the fresh-saline water interface due to heavy pumping being resorted to in several areas. This in turn leads to pumping of saline water and the tubewell being abandoned and precious investment going waste. One such case of up-coning of the fresh-saline water interface and pumping of saline water as well use of remedial measures successfully were taken up and the results are presented in this paper.

Quaternary Alluvium underlain by Alwar Quartzites of the Delhi System occupies the NCT of Delhi. The Fruit and Vegetable Project of National Dairy Development Board located in western part of Delhi depends on groundwater for running it's plants. However, two tubewells constructed in the campus started yielding saline water soon after being commissioned. The electrical conductivity values were in the range of 9400 micro mhos/cm. at 25^0 C. The tubewells were only 29.5 and 30.5 meters deep and the saline-fresh water interface was at 39 meters below ground level (mbgl). But due to continuous pumping at discharges of about 45 m^3 / hour, the pumped water became highly saline due to up-coning of the interface. A safe discharge was worked out based on an equation to work out the position of the moving fresh-saline water interface in response to withdrawal of fresh water by shallow wells penetrating a short distance above the interface. The depth of one tubewell was also reduced by sealing the bottom three meters with cement slurry. The safe discharge, base on the equation, was calculated to be 18 $m^{3/}$day. The well was pumped continuously at this discharge for 480 minutes and the electrical conductivity of pumped water at the beginning of pumping was 3182 micro mhos/cm. at 25^0 C and at the end of 480 minutes it was 3084 micro mhos/cm. at 25^0 C.

The experiment, based on scientific basis, thus proved to be successful in revitalisation of a tubewell which was otherwise yielding highly saline water. The same technique can be used to revitalise thousands of other tubewells lying defunct all over Delhi.

INTRODUCTION

Ground water plays a very important role in supplies of fresh water for domestic, industrial and irrigation purposes. This is especially so since ground water is free of pathogens, colour, turbidity and can be developed in close proximity to where water is required, thus avoiding the need for heavy expenditure involved in large scale storage, treatment and distribution systems.

However, in the National Capital Territory of Delhi, ground water is contributing only about 15 % of the total water supply for domestic purposes. This is not only because of inadequate ground water resources but also due to saline water underlying the fresh ground water. In almost entire Delhi, except Chhatarpur closed basin in Mehrauli block and parts of south Delhi in City block, brackish to saline ground water occurs, in general, below depths of 40 meter below ground level. The aquifers below 40 meters, though productive, cannot be developed due to saline ground water occurrence in them. Even the tubewells constructed in the fresh water aquifers occurring at shallow depths start yielding brackish to saline water after sustained pumping due to up-coning of fresh-saline water interface. Due to this problem even the fresh water layer floating over the saline water is not developed to its maximum availability, thus creating further shortages in water supply to Delhi metropolitan area. The expenditure incurred on the construction of tubewells and creating their infrastructure becomes infructuous due to water becoming saline. This drain on the exchequers' money can be checked by a simple methodology discussed in this paper.

During the course of detailed hydrogeological investigations as a part of normal activities of Central Ground Water Board (CGWB) in Delhi area during the year 1988, the author was assigned to assess whether the tubewells that were operating in the campus of Fruit and Vegetable Project (F & V Project) of the National Dairy Development Board (NDDB) Mongolpuri and had started yielding saline water could be revitalized so that the project did not face any water scarcity as also the expenditure incurred on the asset created was not wasted . This paper discusses the case study in detail as well as measures that could prevent occurrence/recurrence of this phenomenon in other areas of Delhi.

AREA, EXTENT AND LOCATION

The Fruit and Vegetable Project area of the National Dairy Development Board falls in the western part of the National Capital Territory of Delhi. It is located just west of the Outer ring road and about 300 meters south of Mongolpuri Resettlement Colony (Figure 1). The plant is spread over an area of about nine hectares and falls in Survey of India topographical sheet number 53 H/2 on 1:50.000 scale.

NATURE OF THE PROBLEM

The F & V Project requires about 1000 m^3/day of water when fully commissioned. During 1988, the project in its initial stages was using about 400 m^3/day of water for its plant. To meet this requirement the NDDB had got two tubewells constructed in the project campus in the year 1986 (Figure 2). Both the tubewells shortly after being commissioned started yielding saline water. The matter was referred to CGWB with a view to study the feasibility of revitalizing these two tubewells so that good quality water could be obtained.

HYDROGEOLOGY

The project area is occupied by Quaternary Alluvium underlain by Alwar Quartzites of the Delhi system. Outcrops of Delhi quartzites do not occur in the vicinity of the area.

However, based on the exploratory drilling taken up by CGWB in Delhi, it is expected that the thickness of alluvium in the study area would be more than 200 meters. The alluvium is composed of fine-grained sand; silt, clay and "Kankar" admixed in varying proportions. The entire alluvial deposits behave as a single unconfined aquifer system. The exploratory drilling has also established that the ground water in the alluvial aquifer of Delhi and its vicinity, except in the closed basin of Chhatarpur in Mehrauli block and some areas in South Delhi, is brackish to saline at depths greater than 40 meters in general with the degree of salinity increasing at deeper levels. An exploratory tubewell was drilled by CGWB at Rithala ($28^0 43' 10'' : 77^0 06' 23''$) located about 3.5 kms. north of the study area. The depth of drilling was 201.10 meters and the quartzite basement had not been reached. The entire alluvial thickness was composed of fine to medium grained sand, silt, clay and "Kankar". Saline -fresh water interface was encountered at 39 meters below ground level (m.b.g.l.). Based on the Aquifer Performance Test, the Transmissivity value was estimated to be 133 m^2/day.

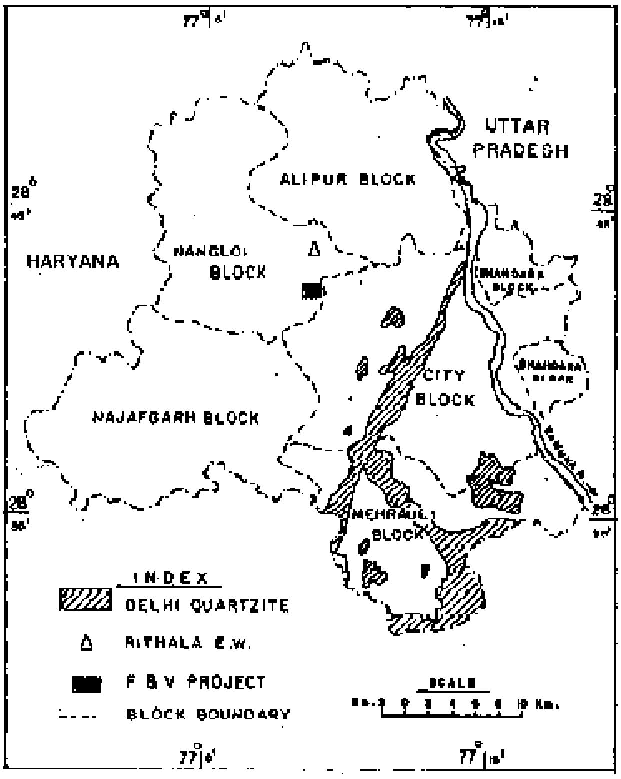

Figure 1. Location of Fruit and Vegetable Project area of the National Dairy Development Board, Delhi.

DETAILS OF THE TUBEWELLS IN THE PROJECT AREA

Two tubewells, TW I and TW II (Figure 2) were constructed in the project campus in the year 1986.The total depth of drilling for TW I was 113.60 m.b.g.l. and that of TW II was

107.35 m.b.g.l. The formation encountered was fine sand from ground level to 30 m.b.g.l. and silt, clay and "Kankar" below that upto the drilled depth. On the basis of electrical logging, it was deciphered that the formation water is saline after 38.5 m.b.g.l... The depth of TW I was restricted to 29.5 meters while tapping the zones from 16.5 to 22.5 and 24.0 to 27.0 m.b.g.l. (Figure 3). The depth of TW II was kept as 30.5 meters and only one zone between the depth of 17.5 to 27.8 m.b.g.l. was screened. Both the tubewells had a discharge of about 50 m^3/hour. The tubewells were being pumped at about 45 m^3/hour for use of water in the plant. As indicated by the project personnel, the tubewells started yielding saline water shortly after being commissioned.

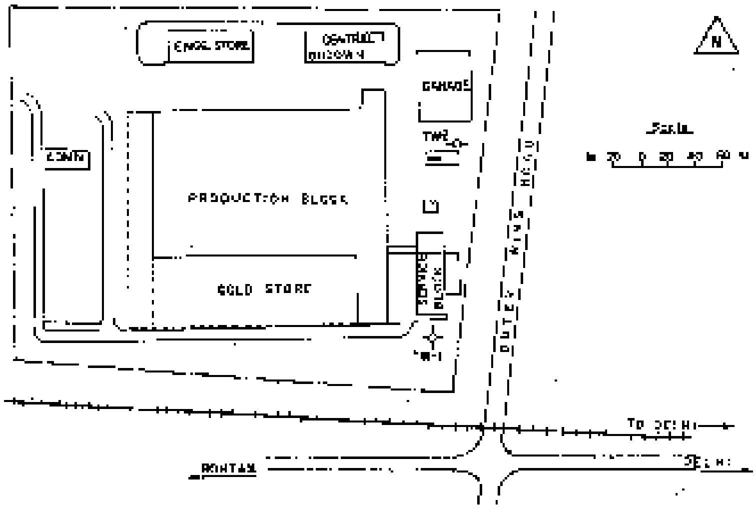

Figure 2. Details of the tubewells in the project area.

REVITALIZATION

During the course of this investigation it was considered appropriate to take up revitalization of TW I to start with. Accordingly during preliminary investigations all the data as described above was collected as well as water samples from both the tubewells. The electrical conductivity (EC) value of the sample from TW I was found to be 9400 micro mhos/cm. at 25^0C (μ mhos/cm) and that of TW II was 2250 μ mhos/cm. At the time of collection of the water samples TW I was being pumped continuously for use of water in the plant and TW II was shut down.

After careful study of the lithology, electric log, assembly design and the EC values it was deciphered that the aquifer tapped is immediately underlain by aquifer having saline formation water without any aquiclude in between. It was also deduced that the problem is being caused by up-coning of the saline-fresh water interface due to pumping at high discharges. This was also corroborated by the fact that the sample collected from TW II did not have high salinity at the time of sample collection since it had been shut down since quite some time and the interface had again reached an equilibrium condition. It was thus decided to work out a safe discharge so that the fresh-saline water interface which rises in the form of a cone, inverse to the cone of depression, does not rise upto the screened section of the well and turn the water saline. If the pumping rates are kept low, a new equilibrium could be established with the interface occupying an intermediate position between the original level and the screen.

Dagan and Bear (1968) have given an equation to work out the position of the moving saline- fresh water interface in response to withdrawal of fresh water by shallow wells penetrating a short distance above the interface. This equation was for coastal aquifers but was used in the present study also because of similarity in the situation. Accordingly, the height of the cone 'z' below the center of the well is given by the equation:

$$Zt = \frac{\rho_f \times Q}{2\pi(\rho_s - \rho_f)K_x \times d}\left[1 - \frac{2\rho_f \times \theta \times h_w}{2\rho_f \times \theta \times d + (\rho_s - \rho_f)K_z \times t}\right] \tag{1}$$

Where,

Zt =rise of apex of cone of saline water at time 't' in meters;

Q =discharge of well in m^3/day;

d =depth of interface below the bottom of the well, before commencement of pumping in meters;

K_x =Hydraulic conductivity in horizontal direction in meters/day;

K_z =Hydraulic conductivity in vertical direction in meters/day;

θ = porosity;

t = time since start of pumping;

ρ_s =density of saline water;

ρ_f = density of fresh water.

For t = α, the equilibrium height Z_α of the cone of impression of saline water is given by

$$Z\alpha = \frac{\rho_f \times Q}{2\pi(\rho_s - \rho_f)K_x \times d} \tag{2}$$

Equation (2) can also be written as:

$$Q = \frac{2\pi(\rho_s - \rho_f)K_x \times d \times Z\alpha}{\rho_f} \tag{3}$$

The above equation (3) was made use of in the present study to obtain optimum discharge of TW I so that the saline -fresh interface does not rise above a certain level and enter the screened portion of the tubewell. To increase the depth of interface, d, below the bottom of the well, before commencement of pumping it was thought that the screened portion lying between 24 to 27 mbgl could be closed by cement filling (Figure 3). This would reduce the total depth of the well. Because of the similarity in the aquifer material and hydrogeological set-up of the study area and the exploratory well site at Rithala, the same transmissivity value of 133 m^2/day was considered valid for present study. The hydraulic conductivity worked out to be 22 m/day since the thickness of aquifer tapped would now be six meters (16.5 to 22.5 m.b.g.l.) only. It was also considered appropriate that the apex of the cone of saline water be maintained at about three meters below the bottom of the well during pumping of the well.

Various components to work out the discharge as per EQ (3) were as follows:

ρ_s = 1.015
ρ_f = 1.00
K_x = 22 m/day
d = 16 m.
Z_α = 13 m.

Inserting the values in EQ. 3, the proposed optimum discharge was calculated to be 431 m^3/day (18 m^3/hour).

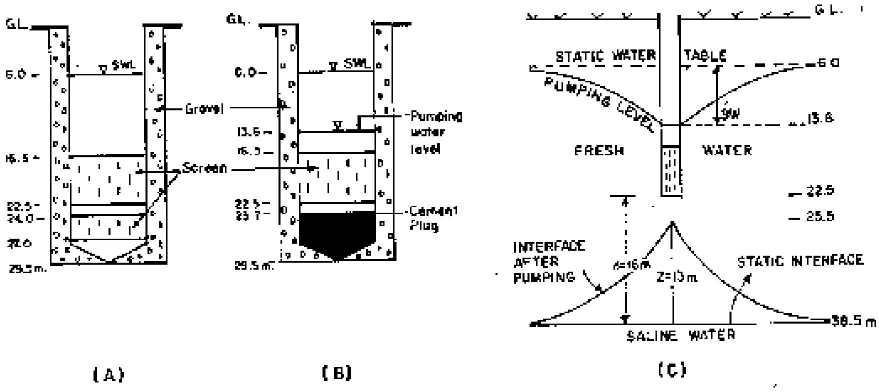

Figure 3. A & B- Tubewell assembly before and after cement plugging, C- Shhematic diagram of saline-fresh water interface.

OPERATIONAL PART

TW I was filled with cement slurry from bottom till 23.7 m. b. g. l. and adequate time was given for the cement to set properly. The well was subsequently pumped at a discharge of 431 m^3/day (18 m^3/hour) continuously for 480 minutes .The static water level was 6.12 mbgl and the pumping water level just before the stoppage of pumping was 12.60 mbgl, thus creating a drawdown of 6.48 m. The water quality was monitored regularly during the pumping .The electrical conductivity values obtained were as follows:

The above test thus clearly brought out that the calculation of the discharge to be kept at about 18 m^3/hour by using the equation given by Dagan And Bear (1968) was successful in revitalization of the tubewell which was otherwise yielding saline water. It was also recommended that the tubewell should not be pumped continuously for more than 8 hours. It was suggested that the tubewell be pumped in the cycle of 8 hours viz. rest for 8 hours after every 8 hours of pumping. This intermittent pumping would also act as a hindrance for the saline-fresh water interface to rise further.

Table 1. Salinity variation with pumping

Time Since Pumping Started (In Minutes)	Electrical Conductivity (in micro mhos/cm at 25^0C)
60	3182
120	3202
240	3229
360	3220
480	3084
During April 1988 at discharge of 45 m^3/hour	9400

DISCUSSION

The National Capital Territory of Delhi is besieged with the twin problems of inadequate ground water resources coupled with occurrence of saline water at shallow depths. This problem is further aggravated due to the fact that tubewells constructed in the alluvial aquifer start yielding saline water after some time. This phenomenon renders the structure i.e. the tubewell, useless and also pollutes the shallow occurring fresh water. One such case was studied and remedial measure as discussed above was implemented successfully to revitalize the defunct tubewell. Similar practice can be adopted in other areas of Delhi too.

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