

Well Losses by Step Drawdown Test – A Hantush Bierschenk Approach

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1.0 Introduction

DWASA (Dhaka Water and Sewerage Authority) is currently operating about 220 deep tubewells with a total production of water equal to 800 million liters/day, which met the 93% water demand of this city. It has long been suspected that the annual abstraction of groundwater is much higher than its annual recharge. Several studies (Bhuiyan 1995; DWASA 1991; Serajuddin 1990 b; Dhar 1995 etc) indicated its annual static water level declination at the rate of 0.5 m to 1.5m, depending on the area considered due to huge pumping. Hence, the aquifer system of the city exhibits its restricted capability to supply water to the existing wells.

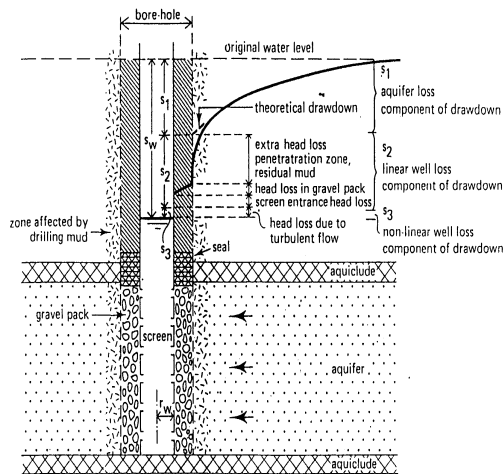


Fig. 1. Various head losses in well (Kruseman and Ridder, 1990)

2.0 Methodology

Well flow equations derived from Darcy's law and the equation of continuity are the effective tools to understand the flow of water towards the well. Based on Theis (1935) formula, Jacob developed a method (Cooper and Jacob 1946) to calculate the aquifer drawdown at any distance from the well.

$$s = \frac{2.3Q}{4\pi KD} \log \frac{2.25KDt}{r^2 S} \quad (1)$$

2.1 Step Drawdown Test

Step drawdown test is a single well test (first performed by Jacob in 1947) in which the well is pumped at a low constant discharge rate until the drawdown within the well stabilizes. The pumping rate is then increased to a higher constant discharge rate and the well is pumped until the drawdown stabilizes once more. This process is repeated through at least three steps, which should all be of equal duration say, from 30 minutes to 2 hours each. Referring from the Jacob's formula, the drawdown in a fully penetrated well (neglecting the well loss components) can be expressed as

$$s_w = B(r_{ew}, t)Q + CQ^2 \quad (2)$$

Rorabaugh (1953) therefore suggested that Jacob's equation should be:

$$s_w = BQ + CQ^p \quad (3)$$

p is the exponent due to turbulence, where p has the values of 1.5 to 3.5, depending on the value of Q . But the value of p is 2, as proposed by Jacob is still accepted (Ramey 1982; Skinner 1988).

Again, $B(r_{ew}, t) = B_1(r_{ew}, t) + B_2$, $B_1(r_{ew}, t)$ and B_2 = linear aquifer and well loss coefficients respectively, C = non-linear well loss coefficient, $B(r_{ew}, t)Q$ = Laminar Loss, $B_1(r_{ew}, t)Q$ = Aquifer Loss, B_2Q = Linear Well Loss, Turbulent loss (non-linear well loss) = CQ^2 , Total well loss = Linear well loss + Non-linear well loss = $B_2Q + CQ^2$. In this study, Hantush-Bierschenk method is used to determine the co-efficient of losses.

2.2 Hantush-Bierschenk's Method:

Applying the principle of superposition to Jacob's equation, Hantush (1964) expressed the drawdown $s_{w(n)}$ in a well during the n -th step of a step-drawdown test as:

$$s_{w(n)} = \sum_{i=1}^n \Delta Q_i B(r_{ew}, t - t_i) + CQ_n^2 \quad (4)$$

where, $\Delta Q_i = Q_i - Q_{i-1}$ = discharge increment beginning at time t_i ; Q_i = constant discharge during the i -th step of that preceding the n -th step. The sum of increments of drawdown

$$\sum_{i=1}^n \Delta s_w(i) = s_{w(n)} = B(r_{ew}, \Delta t)Q_n + CQ_n^2 \quad (5)$$

$$\frac{s_w(n)}{Q_n} = B(r_{ew}, \Delta t) + CQ_n \quad (6)$$

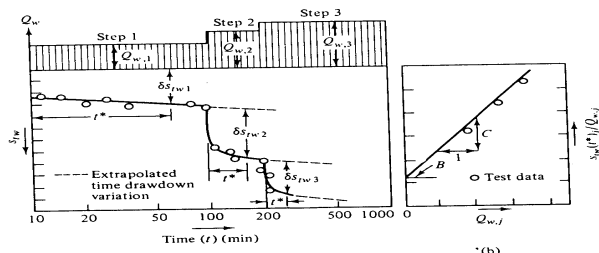


Fig.2: The Hantush-Bierschenk Method

3.0 Results and Discussion

DWASA has divided the whole city into six zones to administer its operation of potable water supply and safe sewerage disposal. Through this step drawdown test well losses in different zone are determined and table 1 shows the losses in zone 2 at an operating discharge $4897 \text{ m}^3/\text{day}$. Co-efficient B and C are calculated from the s/Q versus Q curves (Fig. 3). B values are varying from 1.42×10^{-3} to 3.5×10^{-3} , mostly between the range of 1.72×10^{-3} to 2.65×10^{-3}

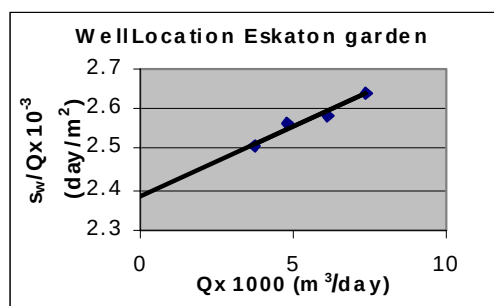


Fig.3: The Hantush-Bierschenk Method: Determination of B and C

and C values found from 1.0×10^{-8} to 9.0×10^{-8} , mostly between the range of 2.0×10^{-8} to 4.0×10^{-8} . These values can then be used to obtain the relationship between drawdown and discharge to choose, empirically, an optimum yield for the well, or to obtain information on the condition or efficiency of the well.

Aquifer losses are the head losses that occur in the aquifer where the flow is laminar. They are time dependent and vary linearly with the well discharge. Aquifer losses are independent of the well itself and depend on various aquifer characteristics. The highest aquifer loss found in Kallyanpur well (20.91 m) of zone 4 and the lowest was found in Rajnarayan Dhar Road well (8.21 m) of Zone 2.

Total well losses are divided into linear and non-linear well losses. Linear well losses are caused by damaging of the aquifer during drilling and completion of the well, i.e., head losses due to plugging of the aquifer

with drilling mud which reduces the permeability near the bore-hole, head losses in the gravel pack and head

Table 1. Diff. Types of Losses in Zone 1 at an Operating Discharge $4897 \text{ m}^3/\text{sec}$ (2 cusec)

Location of well	Laminar Loss (m)	Turbulent Loss (m)	Aquifer Loss (m)	T. Well Loss (m)
Jurain	12.34	2.16	12.01	2.49
Mughdapara	12.36	0.92	10.39	2.89
Gopibagh	11.58	1.38	11.03	1.93
Jatrabari	15.65	0.54	13.61	2.39
Bangababan	17.14	0.35	15.03	2.46
Saidabad	12.98	0.78	12.34	1.42
Paterbagh	13.17	1.14	9.78	4.53
Laxmibazar	10.94	1.49	10.21	2.22

losses in the screen. The non-linear well losses are the friction losses that occur inside the well screen and in the suction pipe where the flow is turbulent. All these well losses are responsible for the drawdown inside the well being much greater than one would expect on theoretical ground. The total well losses are found to vary in Dhaka city between 2.14 m and 14.73 m. Zone 2, 3 and 6 tubewells shows less total well compared to others zones. In fact, these losses are much higher because of the poor construction and development operations.

Laminar losses are the sum of the aquifer losses and the linear well losses of the well and can vary linearly with the well discharge and also depends on the aquifer properties. In this study the laminar well losses are found to vary between 10.4 m and 25.7 m and the non linear loss (turbulent loss) varies with some power of discharge. Turbulent losses that are found for all the wells tested vary between 0.59 m and 7.83 m.

4.0 Conclusion

Well losses of Dhaka city is very high showed in the study. This is due to the poor construction and development operation and use of non modernized equipment.

5.0 References

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