Position and Fluctuations of Water Level in Wells Perforated in More Than One Aquifer

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Abstract. The water level in a nonpumping well perforated in more than one artesian aquifer is shown to be affected by each aquifer in proportion to the transmissibility of that aquifer. The ratio of the water-level fluctuation in a well to the potentiometric-surface fluctuation in an aquifer perforated by that well is equal to the ratio of transmissibility of the aquifer in which the fluctuation occurs to the total transmissibilities of all aquifers perforated by the well.

Derivation. The water level in a well perforated in more than one aquifer, each with a separate potentiometric surface, does not coincide with any of the potentiometric surfaces. An example of a well perforated opposite two aquifers is shown in Figure 1. Water flows into the well from aquifer 1, which has a potentiometric surface higher than the water level in the well; a cone of depression is formed in aquifer 1 in response to this flow. Water flows from the well into aquifer 2, which has a potentiometric surface lower than the water level in the well; a cone, which is the inverse of the cone of depression, is formed in aquifer 2. In the general case, several aquifers may have potentiometric surfaces higher than the water level in the well and several aquifers may have potentiometric surfaces lower than the water level.

Assuming that head losses caused by flow between the well and aquifers are negligible, we can derive the position of the water level in a well that penetrates a multiaquifer system from an equation developed by G. Thiem. The Thiem equation in common notation [*Todd*, 1960, p. 32] is

$$Q = \frac{2\pi K b(h - h_w)}{\ln (r/r_w)} \tag{1}$$

where Q = flow rate, K = hydraulic conductivity, b = thickness of aquifer, h = height of potentiometric surface at distance r, and h_w = height of water level in discharging well of radius r_w.

Substituting transmissibility (T) for the product of hydraulic conductivity (K) and saturated thickness of the aquifer (b), we get

$$Q = \frac{2\pi T(h - h_w)}{\ln (r/r_w)} \tag{2}$$

In a well perforated in aquifers 1, 2, . . . , n, during periods when no water is pumped from the well or recharged to the well at the land surface,

$$Q_1 + Q_2 + \cdots + Q_n = 0 \tag{3}$$

Taking $r_1 = r_2 = \cdots = r_n = r_0$ at a distance sufficiently far from the well so that the potentiometric surfaces are not affected by flow into or from the well and substituting (2) into (3) for each aquifer leads to

$$\frac{2\pi T_1(h_1 - h_w)}{\ln (r_0/r_w)} + \frac{2\pi T_2(h_2 - h_w)}{\ln (r_0/r_w)} + \cdots + \frac{2\pi T_n(h_n - h_w)}{\ln (r_0/r_w)} = 0 \tag{4}$$

$$T_1(h_1 - h_w) + T_2(h_2 - h_w) + \cdots + T_n(h_n - h_w) = 0 \tag{5}$$

$$h_w = \frac{T_1 h_1 + T_2 h_2 + \cdots + T_n h_n}{T_1 + T_2 + \cdots + T_n} \tag{6}$$

which demonstrates that the water level in a well perforated in more than one aquifer is affected by each aquifer in proportion to the transmissibility of that aquifer.

The magnitude of a water-level fluctuation (Δh_n) in a well penetrating a multiaquifer system resulting from fluctuation (Δh_1) of the

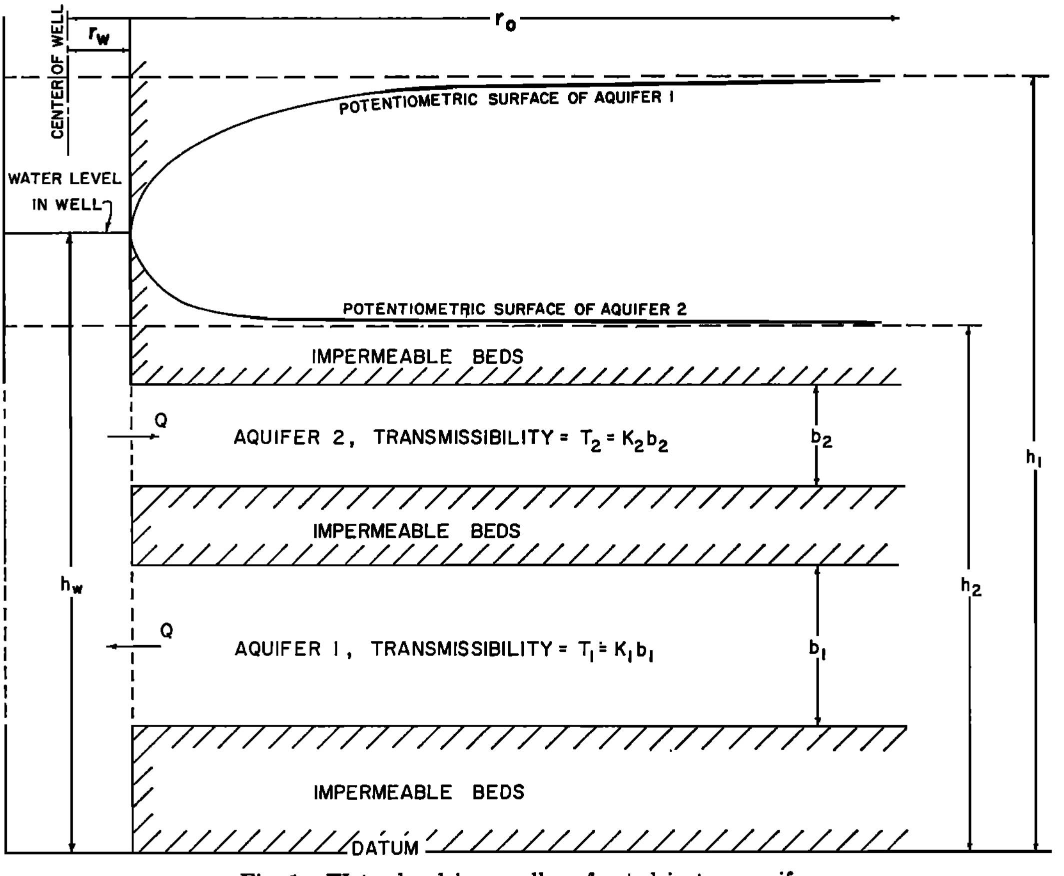

Fig. 1. Water level in a well perforated in two aquifers.

potentiometric surface in a single aquifer can be derived as follows:

$$h_w + \Delta h_w = \frac{T_1(h_1 + \Delta h_1) + T_2 h_2 + \cdots + T_n h_n}{T_1 + T_2 + \cdots + T_n} \quad (7)$$

If the value of h_w in (6) is substituted for h_w in (7) and terms are reduced,

$$\Delta h_w = \frac{T_1 \, \Delta h_1}{T_1 + T_2 + \cdots + T_n} \quad (8)$$

Thus it can be seen that the effect of the change in potentiometric surface of any aquifer imposes a smaller fluctuation on the water level. The ratio of the water-level fluctuation in a well to the potentiometric-surface fluctuation in an aquifer is equal to the ratio of transmissibility of the affected aquifer to the total transmissibilities of all aquifers perforated by the given well.

The limitations imposed in the foregoing analysis are:

1. All aquifers are confined and have artesian head; the saturated thickness is constant and transmissibility does not vary with change of potentiometric surface.

2. The effective radius of the well is assumed to be the same for all aquifers: r_w in equations 1, 2, and 4 is effective radius of the well; it is not necessarily the radius of the casing.

Reference

Todd, D. K., *Ground Water Hydrology,* 336 pp., John Wiley & Sons, New York, 1959.

(Manuscript received October 13, 1962; revised November 27, 1962.)

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