Steady-State Flow Applications

a) Thiem Equation

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Steady flow in a confined aquifer. The equation describing steady confined aquifer flow was first presented by Dupuit in 1863 and subsequently extended by Theim in 1906.[23] It may be written as follows (refer to Figure 2-27 for an explanation of the notation):

$$Q = \frac{2\pi T(h_2 - h_1)}{\ln(r_2/r_1)} \tag{2-11}$$

where

$T = KD$ = transmissibility, m^2/s
D = thickness of artesian aquifer, m
h_1, h_2 = height of piezometric surface above confining layer, m
r_1, r_2 = radius from pumping well, m
ln = logarithm to base e.

Example 2-9

An artesian aquifer 10.0 m thick with a piezometric surface 40.0 m above the bottom confining layer is being pumped by a fully penetrating well. The aquifer is a medium sand with a permeability of 1.50×10^{-4} m/s. Steady state drawdowns of 5.00 m and 1.00 m are observed at two nonpumping wells located 20.0 m and 200.0 m, respectively, from the pumped well. Determine the discharge at the pumped well.

First we determine h_1 and h_2

$$h_1 = 40.0 - 5.00 = 35.0 \text{ m}$$
$$h_2 = 40.0 - 1.00 = 39.0 \text{ m}$$

so

$$Q = \frac{(2\pi)(1.50 \times 10^{-4})(10.0)(39.0 - 35.0)}{\ln \frac{200.0}{20.0}}$$

$$Q = 0.0164 \text{ or } 0.016 \text{ m}^3/\text{s}$$

b) Dupuit Equation

Steady flow in an unconfined aquifer. For unconfined aquifers the factor D in Equation 2-11 is replaced by the height of the water table above the lower boundary of the aquifer. The equation then becomes

$$Q = \frac{\pi K(h_2^2 - h_1^2)}{\ln(r_2/r_1)} \tag{2-12}$$

Example 2-10

A 0.50 m diameter well fully penetrates an unconfined aquifer which is 30.0 m thick. The drawdown at the pumped well is 10.0 m and the permeability of the gravel aquifer is 6.4×10^{-3} m/s. If the flow is steady and the discharge is 0.014 m^3/s, determine the drawdown at a site 100.0 m from the well.

First we calculate h_1

$$h_1 = 30.0 - 10.0 = 20.0 \text{ m}$$

Then we apply Equation 2-12 and solve for h_2. Note that $r_1 = 0.50 \text{ m}/2 = 0.25$ m.

$$0.014 = \frac{\pi(6.4 \times 10^{-3})(h_2^2 - (20.0)^2)}{\ln \frac{100}{.25}}$$

$$h_2^2 - 400.0 = \frac{(0.014)(5.99)}{(\pi)(6.4 \times 10^{-3})}$$

$$h_2 = (4.17 + 400.0)^{1/2}$$

$$h_2 = 20.10 \text{ m}$$

The drawdown is then

$$30.0 - 20.10 = 9.90 \text{ m}$$

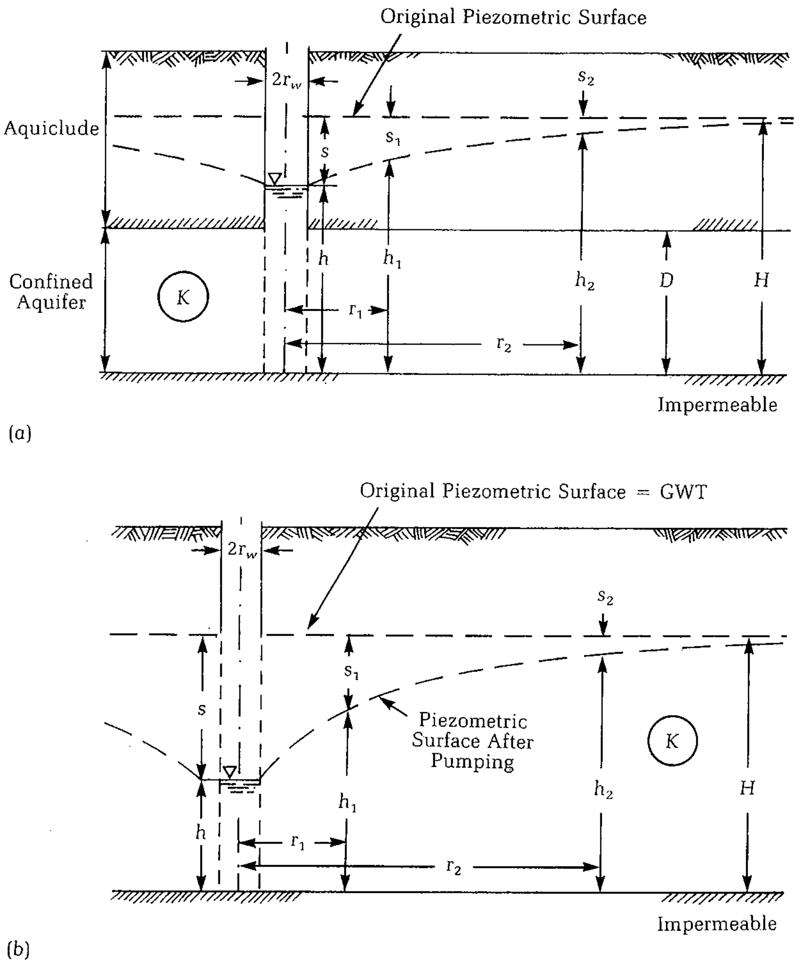

Figure 2-27 Geometry and symbols for a pumped well in (*a*) confined aquifer and (*b*) unconfined aquifer
(*Source:* H. Bouwer, *Groundwater Hydrology*. New York: McGraw-Hill, 1978. Reprinted by permission.)

SOURCE: Davis, M.L. & D.A. Cornwell
Introduction to Environmental Engineering
PWS Engineering, 1985