Important Unconfined Flow Formulas PDF

Formulas
Examples
with Units

List of 27
Important Unconfined Flow Formulas

1) Coefficient of Permeability when Equilibrium Equation for Well in Unconfined Aquifer Formula

Evaluate Formula

Formula

$$K = \frac{Q_u}{\pi \cdot \frac{H_2^{\ 2} - H_1^{\ 2}}{\ln\left(\frac{r_2}{r_1}\right)}}$$

Example with Units

$$8.1485\,\mathrm{cm/s} = \frac{65\,\mathrm{m^3/s}}{3.1416 \cdot \frac{45\,\mathrm{m}^{\ 2} - 43\,\mathrm{m}^{\ 2}}{\ln\left(\frac{10.0\,\mathrm{m}}{5.0\,\mathrm{m}}\right)}}$$

2) Depth of Water in Pumping Well when Steady Flow in Unconfined Aquifer is Considered Formula

Evaluate Formula

Formula

$$h_w = \sqrt{(H)^2 - \left(\frac{Q_u \cdot \ln\left(\frac{r}{R_w}\right)}{\pi \cdot K}\right)}$$

Example with Units

$$29.9486\,\mathrm{m} = \sqrt{(35\,\mathrm{m})^2 - \left(\frac{65\,\mathrm{m^3/s} \cdot \ln\left(\frac{25\,\mathrm{m}}{6\,\mathrm{m}}\right)}{3.1416 \cdot 9\,\mathrm{cm/s}}\right)}$$

3) Discharge at Edge of Zone of Influence Formula

Evaluate Formula

Formula

$$Q_u = \pi \cdot K \cdot \frac{H^2 - h_w^{\ 2}}{\ln\left(\frac{r}{R_w}\right)}$$

Example with Units

$$64.3897\,\mathrm{m^3/s} = 3.1416 \cdot 9\,\mathrm{cm/s} \cdot \frac{35\,\mathrm{m}^{\ 2} - 30\,\mathrm{m}^{\ 2}}{\ln\left(\frac{25\,\mathrm{m}}{6\,\mathrm{m}}\right)}$$

4) Equilibrium Equation for Well in Unconfined Aquifer Formula

Evaluate Formula

Formula

$$Q_u = \pi \cdot K \cdot \frac{H_2^{\ 2} - H_1^{\ 2}}{\ln\left(\frac{r_2}{r_1}\right)}$$

Example with Units

$$71.7926\,\mathrm{m^3/s} = 3.1416 \cdot 9\,\mathrm{cm/s} \cdot \frac{45\,\mathrm{m}^{\ 2} - 43\,\mathrm{m}^{\ 2}}{\ln\left(\frac{10.0\,\mathrm{m}}{5.0\,\mathrm{m}}\right)}$$

5) Saturated Thickness of Aquifer when Steady Flow of Unconfined Aquifer is Considered Formula

Evaluate Formula

Formula

$$H = \sqrt{\frac{Q_u \cdot \ln\left(\frac{r}{R_w}\right)}{\pi \cdot K} + h_w^{\ 2}}$$

Example with Units

$$35.044\,\text{m} = \sqrt{\frac{65\,\text{m}^3/\text{s} \cdot \ln\left(\frac{25\,\text{m}}{6\,\text{m}}\right)}{3.1416 \cdot 9\,\text{cm/s}} + 30\,\text{m}^{\ 2}}$$

6) Approximate Equations Formulas

6.1) Discharge when Drawdown at Pumping Well is Considered Formula

Evaluate Formula

Formula

$$Q_u = 2 \cdot \pi \cdot T \cdot \frac{s_w}{\ln\left(\frac{r}{R_w}\right)}$$

Example with Units

$$64.9973\,\text{m}^3/\text{s} = 2 \cdot 3.1416 \cdot 0.703\,\text{m}^2/\text{s} \cdot \frac{21\,\text{m}}{\ln\left(\frac{25\,\text{m}}{6\,\text{m}}\right)}$$

6.2) Drawdown at Pumping Well Formula

Evaluate Formula

Formula

$$s_w = \left(H - h_w\right)$$

Example with Units

$$5\,\text{m} = \left(35\,\text{m} - 30\,\text{m}\right)$$

6.3) Drawdown when Steady Flow of Unconfined Aquifer Formula

Evaluate Formula

Formula

$$s_w = \frac{Q_u \cdot \ln\left(\frac{r}{R_w}\right)}{2 \cdot \pi \cdot T}$$

Example with Units

$$21.0009\,\text{m} = \frac{65\,\text{m}^3/\text{s} \cdot \ln\left(\frac{25\,\text{m}}{6\,\text{m}}\right)}{2 \cdot 3.1416 \cdot 0.703\,\text{m}^2/\text{s}}$$

6.4) Transmissivity when Discharge at Drawdown is Considered Formula

Evaluate Formula

Formula

$$T = \frac{Q_u \cdot \ln\left(\frac{r}{R_w}\right)}{2 \cdot \pi \cdot s_w}$$

Example with Units

$$0.703\,\text{m}^2/\text{s} = \frac{65\,\text{m}^3/\text{s} \cdot \ln\left(\frac{25\,\text{m}}{6\,\text{m}}\right)}{2 \cdot 3.1416 \cdot 21\,\text{m}}$$

7) Unconfined Flow by Dupit's Assumption Formulas

7.1) Change in Drawdown given Discharge Formula

Evaluate Formula

Formula

$$s = Q \cdot \frac{\ln\left(\frac{r_2}{r_1}\right)}{2} \cdot \pi \cdot T$$

Example with Units

$$0.995\,\text{m} = 1.3\,\text{m}^3/\text{s} \cdot \frac{\ln\left(\frac{10.0\,\text{m}}{5.0\,\text{m}}\right)}{2} \cdot 3.1416 \cdot 0.703\,\text{m}^2/\text{s}$$

7.2) Discharge per Unit Width of Aquifer considering Permeability Formula

Evaluate Formula

Formula

$$Q = \frac{\left(h_o^2 - h_1^2 \right) \cdot K}{2 \cdot L_{stream}}$$

Example with Units

$$1.3093\,\mathrm{m^3/s} = \frac{\left(12\,\mathrm{m}^2 - 5\,\mathrm{m}^2 \right) \cdot 9\,\mathrm{cm/s}}{2 \cdot 4.09\,\mathrm{m}}$$

7.3) Length about Discharge per Unit Width of Aquifer Formula

Evaluate Formula

Formula

$$L_{stream} = \left(h_o^2 - h_1^2 \right) \cdot \frac{K}{2 \cdot Q}$$

Example with Units

$$4.1192\,\mathrm{m} = \left(12\,\mathrm{m}^2 - 5\,\mathrm{m}^2 \right) \cdot \frac{9\,\mathrm{cm/s}}{2 \cdot 1.3\,\mathrm{m^3/s}}$$

7.4) Length when Discharge entering per Unit Length of Drain is Considered Formula

Evaluate Formula

Formula

$$L = \frac{Q}{R}$$

Example with Units

$$0.0812\,\mathrm{m} = \frac{1.3\,\mathrm{m^3/s}}{16\,\mathrm{m^3/s}}$$

7.5) Length when Maximum Height of Water Table is Considered Formula

Evaluate Formula

Formula

$$L = 2 \cdot \frac{h_m}{\sqrt{\frac{R}{K}}}$$

Example with Units

$$6\,\mathrm{m} = 2 \cdot \frac{40\,\mathrm{m}}{\sqrt{\frac{16\,\mathrm{m^3/s}}{9\,\mathrm{cm/s}}}}$$

7.6) Mass Flux Entering Element Formula

Evaluate Formula

Formula

$$M_{x1} = \rho_{water} \cdot V_x \cdot H_w \cdot \Delta y$$

Example with Units

$$255000 = 1000\,\mathrm{kg/m^3} \cdot 10 \cdot 2.55\,\mathrm{m} \cdot 10$$

7.7) Maximum Height of Water Table Formula

Evaluate Formula

Formula

$$h_m = \left(\frac{L}{2} \right) \cdot \sqrt{\frac{R}{K}}$$

Example with Units

$$40\,\mathrm{m} = \left(\frac{6\,\mathrm{m}}{2} \right) \cdot \sqrt{\frac{16\,\mathrm{m^3/s}}{9\,\mathrm{cm/s}}}$$

7.8) Natural Recharge given Total Head Formula

Evaluate Formula

Formula

$$R = \frac{h^2 \cdot K}{(L - x) \cdot x}$$

Example with Units

$$18\,\mathrm{m^3/s} = \frac{4\,\mathrm{m}^2 \cdot 9\,\mathrm{cm/s}}{\left(6\,\mathrm{m} - 2.0\,\mathrm{m^3/s} \right) \cdot 2.0\,\mathrm{m^3/s}}$$

7.9) Recharge when Maximum Height of Water Table Formula

Evaluate Formula

Formula

$$R = \left(\frac{h_m}{\frac{L}{2}}\right)^2 \cdot K$$

Example with Units

$$16\,\mathrm{m^3/s} = \left(\frac{40\,\mathrm{m}}{\frac{6\,\mathrm{m}}{2}}\right)^2 \cdot 9\,\mathrm{cm/s}$$

7.10) Water Table Profile Neglecting Depths of Water in Drains Formula

Evaluate Formula

Formula

$$h = \sqrt{\left(\frac{R}{K}\right) \cdot (L - x) \cdot x}$$

Example with Units

$$3.7712\,\mathrm{m} = \sqrt{\left(\frac{16\,\mathrm{m^3/s}}{9\,\mathrm{cm/s}}\right) \cdot (6\,\mathrm{m} - 2.0\,\mathrm{m^3/s}) \cdot 2.0\,\mathrm{m^3/s}}$$

7.11) One Dimensional Dupit's Flow with Recharge Formulas

7.11.1) Coefficient of Aquifer Permeability considering Discharge per Unit Width of Aquifer Formula

Evaluate Formula

Formula

$$K = \frac{Q \cdot 2 \cdot L_{stream}}{\left(h_o^2\right) - \left(h_1^2\right)}$$

Example with Units

$$8.9361\,\mathrm{cm/s} = \frac{1.3\,\mathrm{m^3/s} \cdot 2 \cdot 4.09\,\mathrm{m}}{\left(12\,\mathrm{m}^2\right) - \left(5\,\mathrm{m}^2\right)}$$

7.11.2) Coefficient of Aquifer Permeability given Maximum Height of Water Table Formula

Evaluate Formula

Formula

$$K = \frac{R \cdot L^2}{\left(2 \cdot h_m\right)^2}$$

Example with Units

$$9\,\mathrm{cm/s} = \frac{16\,\mathrm{m^3/s} \cdot 6\,\mathrm{m}^2}{\left(2 \cdot 40\,\mathrm{m}\right)^2}$$

7.11.3) Coefficient of Aquifer Permeability given Water Table Profile Formula

Evaluate Formula

Formula

$$K = \left(\left(\frac{R}{h^2}\right) \cdot (L - x) \cdot x\right)$$

Example with Units

$$8\,\mathrm{cm/s} = \left(\left(\frac{16\,\mathrm{m^3/s}}{4\,\mathrm{m}^2}\right) \cdot (6\,\mathrm{m} - 2.0\,\mathrm{m^3/s}) \cdot 2.0\,\mathrm{m^3/s}\right)$$

7.11.4) Discharge at Downstream Water Body of Catchment Formula

Evaluate Formula

Formula

$$q_1 = \left(\frac{R \cdot L_{stream}}{2}\right) + \left(\left(\frac{K}{2 \cdot L_{stream}}\right) \cdot \left(h_o^2 - h_1^2\right)\right)$$

Example with Units

$$34.0293\,\mathrm{m^3/s} = \left(\frac{16\,\mathrm{m^3/s} \cdot 4.09\,\mathrm{m}}{2}\right) + \left(\left(\frac{9\,\mathrm{cm/s}}{2 \cdot 4.09\,\mathrm{m}}\right) \cdot \left(12\,\mathrm{m}^2 - 5\,\mathrm{m}^2\right)\right)$$

7.11.5) Discharge Entering Drain per Unit Length of Drain Formula

Evaluate Formula

Formula

$$q_d = 2 \cdot \left(R \cdot \left(\frac{L}{2} \right) \right)$$

Example with Units

$$96\,\mathrm{m^3/s} = 2 \cdot \left(16\,\mathrm{m^3/s} \cdot \left(\frac{6\,\mathrm{m}}{2} \right) \right)$$

7.11.6) Discharge per Unit Width of Aquifer at any Location x Formula

Evaluate Formula

Formula

$$q_x = R \cdot \left(x - \left(\frac{L_{stream}}{2} \right) \right) + \left(\frac{K}{2} \cdot L_{stream} \right) \cdot \left(h_o^{\ 2} - h_1^{\ 2} \right)$$

Example with Units

$$21.182\,\mathrm{m^3/s} = 16\,\mathrm{m^3/s} \cdot \left(2.0\,\mathrm{m^3/s} - \left(\frac{4.09\,\mathrm{m}}{2} \right) \right) + \left(\frac{9\,\mathrm{cm/s}}{2} \cdot 4.09\,\mathrm{m} \right) \cdot \left(12\,\mathrm{m}^{\ 2} - 5\,\mathrm{m}^{\ 2} \right)$$

7.11.7) Equation for Water Divide Formula

Evaluate Formula

Formula

$$a = \left(\frac{L_{stream}}{2} \right) - \left(\frac{K}{R} \right) \cdot \left(\frac{h_o^{\ 2} - h_1^{\ 2}}{2} \cdot L_{stream} \right)$$

Example with Units

$$0.6761 = \left(\frac{4.09\,\mathrm{m}}{2} \right) - \left(\frac{9\,\mathrm{cm/s}}{16\,\mathrm{m^3/s}} \right) \cdot \left(\frac{12\,\mathrm{m}^{\ 2} - 5\,\mathrm{m}^{\ 2}}{2} \cdot 4.09\,\mathrm{m} \right)$$

7.11.8) Equation of Head for Unconfined Aquifer on Horizontal Impervious Base Formula

Evaluate Formula

Formula

$$h = \sqrt{\left(\frac{-R \cdot x^2}{K} \right) - \left(\left(\frac{h_o^{\ 2} - h_1^{\ 2} - \left(\frac{R \cdot L_{stream}^{\ 2}}{K} \right)}{L_{stream}} \right) \cdot x \right) + h_o^{\ 2}}$$

Example with Units

$$28.791\,\mathrm{m} = \sqrt{\left(\frac{-16\,\mathrm{m^3/s} \cdot 2.0\,\mathrm{m^3/s}^{\ 2}}{9\,\mathrm{cm/s}} \right) - \left(\left(\frac{12\,\mathrm{m}^{\ 2} - 5\,\mathrm{m}^{\ 2} - \left(\frac{16\,\mathrm{m^3/s} \cdot 4.09\,\mathrm{m}^{\ 2}}{9\,\mathrm{cm/s}} \right)}{4.09\,\mathrm{m}} \right) \cdot 2.0\,\mathrm{m^3/s} \right) + 12\,\mathrm{m}^{\ 2}}$$

Variables used in list of Unconfined Flow Formulas above

- **a** Water Divide
- **h** Water Table Profile *(Meter)*
- **H** Saturated Thickness of the Aquifer *(Meter)*
- h_1 Piezometric Head at Downstream End *(Meter)*
- H_1 Water Table Depth *(Meter)*
- H_2 Water Table Depth 2 *(Meter)*
- h_m Maximum Height of Water Table *(Meter)*
- h_o Piezometric Head at Upstream End *(Meter)*
- h_w Depth of Water in the Pumping Well *(Meter)*
- H_w Head *(Meter)*
- **K** Coefficient of Permeability *(Centimeter per Second)*
- **L** Length between Tile Drain *(Meter)*
- L_{stream} Length between Upstream and Downstream *(Meter)*
- M_{x1} Mass Flux Entering the Element
- **Q** Discharge *(Cubic Meter per Second)*
- q_1 Discharge at Downstream Side *(Cubic Meter per Second)*
- q_d Discharge per unit Length of the Drain *(Cubic Meter per Second)*
- Q_u Steady Flow of an Unconfined Aquifer *(Cubic Meter per Second)*
- q_x Discharge of Aquifer at any Location x *(Cubic Meter per Second)*
- **r** Radius at the Edge of Zone of Influence *(Meter)*
- **R** Natural Recharge *(Cubic Meter per Second)*
- r_1 Radial Distance at Observation Well 1 *(Meter)*
- r_2 Radial Distance at Observation Well 2 *(Meter)*
- R_w Radius of the Pumping Well *(Meter)*
- **s** Change in Drawdown *(Meter)*
- s_w Drawdown at the Pumping Well *(Meter)*
- **T** Transmissivity of an Unconfined Aquifer *(Square Meter per Second)*

Constants, Functions, Measurements used in list of Unconfined Flow Formulas above

- constant(s): **pi**, 3.14159265358979323846264338327950288
  Archimedes' constant
- Functions: **ln**, ln(Number)
  The natural logarithm, also known as the logarithm to the base e, is the inverse function of the natural exponential function.
- Functions: **sqrt**, sqrt(Number)
  A square root function is a function that takes a non-negative number as an input and returns the square root of the given input number.
- Measurement: **Length** in Meter (m)
  Length Unit Conversion
- Measurement: **Speed** in Centimeter per Second (cm/s)
  Speed Unit Conversion
- Measurement: **Volumetric Flow Rate** in Cubic Meter per Second (m^3/s)
  Volumetric Flow Rate Unit Conversion
- Measurement: **Kinematic Viscosity** in Square Meter per Second (m^2/s)
  Kinematic Viscosity Unit Conversion
- Measurement: **Density** in Kilogram per Cubic Meter (kg/m^3)
  Density Unit Conversion

- V_x Gross Velocity of Groundwater
- x Flow in 'x' Direction *(Cubic Meter per Second)*
- Δy Change in 'y' Direction
- ρ_{water} Water Density *(Kilogram per Cubic Meter)*

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