Groundwater

EOSC316 Engineering Geoscience

Subsurface water

- Aeration zone
  - Soil belt
  - Intermediate belt
  - Capillary fringe (up to 5m in clays)
- Saturation zone

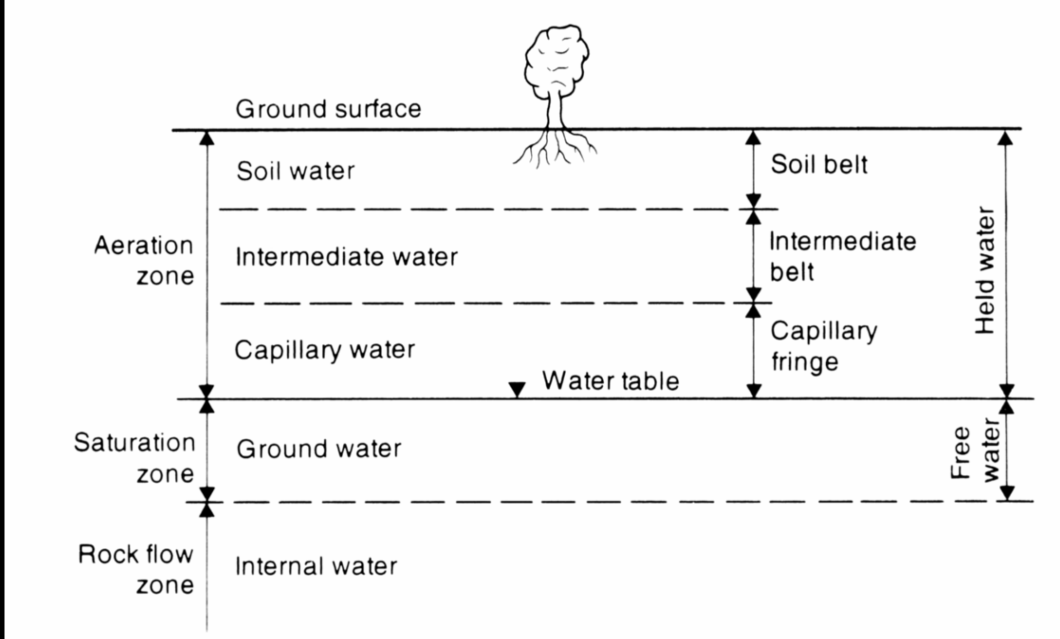
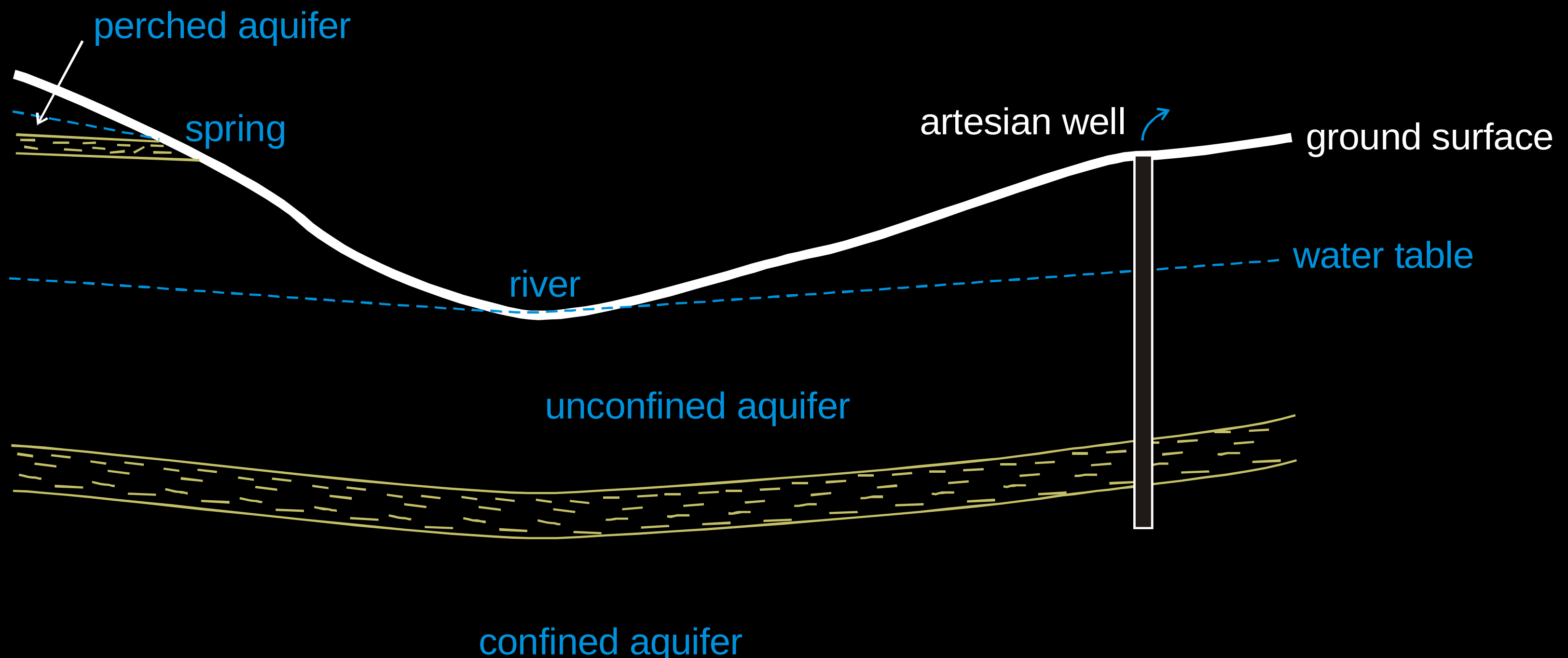


Fig. 2.2 Diagram illustrating types of subsurface water.

Types of aquifer

- Perched aquifer
- Unconfined aquifer
- Confined aquifer



Darcy's law (1856)

$$Q = AKi$$

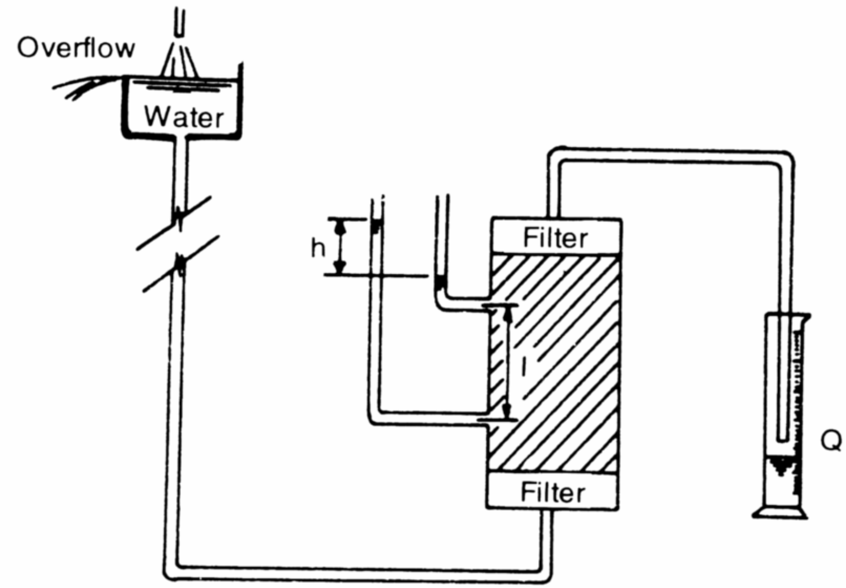


Fig. 2.3 The constant head permeameter.

where Q = volume of fluid per unit time ($m^3\ s^{-1}$)
A = cross-sectional area (m^2)
K = hydraulic conductivity (m/s)
i = hydraulic gradient, no units

[General] Darcy's law

$$Q = \frac{Ak}{\eta}\frac{dP}{dx}$$

where Q = volume of fluid per unit time ($m^3\ s^{-1}$)
A = cross-sectional area (m^2)
k = permeability (m^2)
η = viscosity (Pa s)
dP/dx = pressure gradient ($MPa\ m^{-1}$)

What is permeability?

- *effective* cross-sectional area for flow (m^2)

- Often expressed using the *Darcy*
  - 1 Darcy = 10^{-12} m^2

Difference between hydraulic conductivity, K and permeability, k

- Hydraulic conductivity, K (m s^{-1}) is a flow rate, and assumes the permeant is water at more or less atmospheric conditions

- Permeability, k (m^2) is an intrinsic material property, *independent* of the properties of the permeant.

Methods of measuring hydraulic conductivity: Field techniques

The 'pumping out' test

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

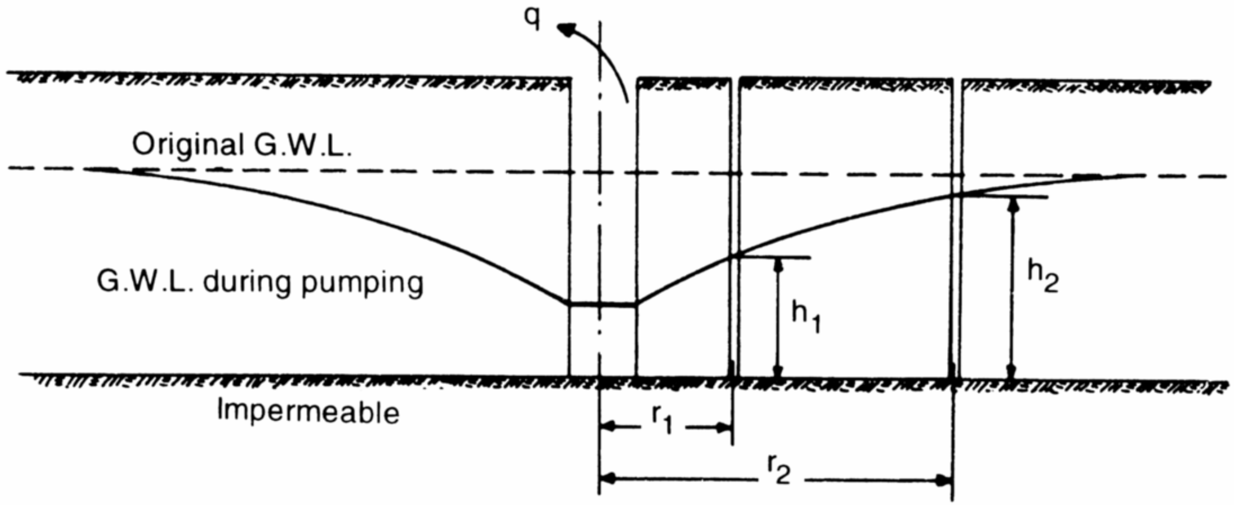
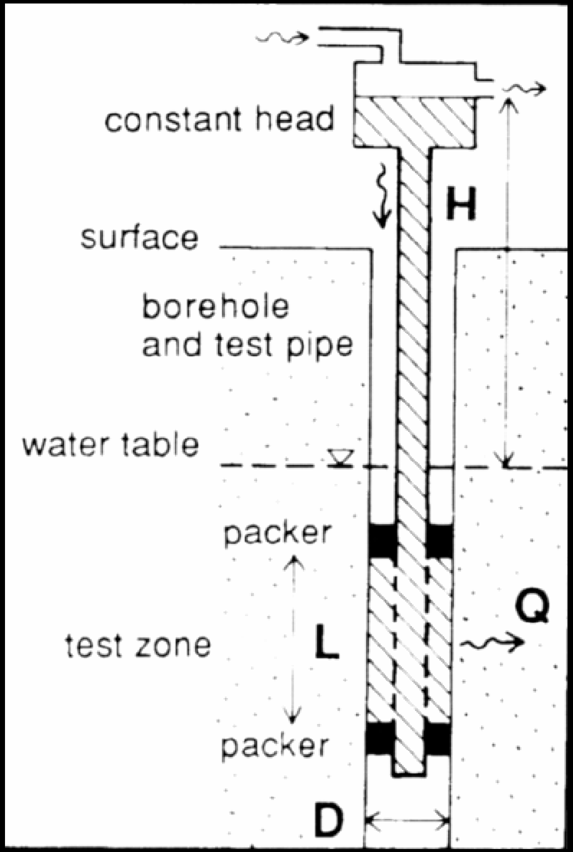


Fig. 2.5 The pumping out test.

Methods of measuring hydraulic conductivity: Field techniques

The borehole ‘packer’ test

$$K = \frac{Q \ln(2L / D)}{2\pi LH}$$



Methods of measuring hydraulic conductivity: Laboratory techniques

- Constant head method

$$K = \frac{Q}{Ai}$$

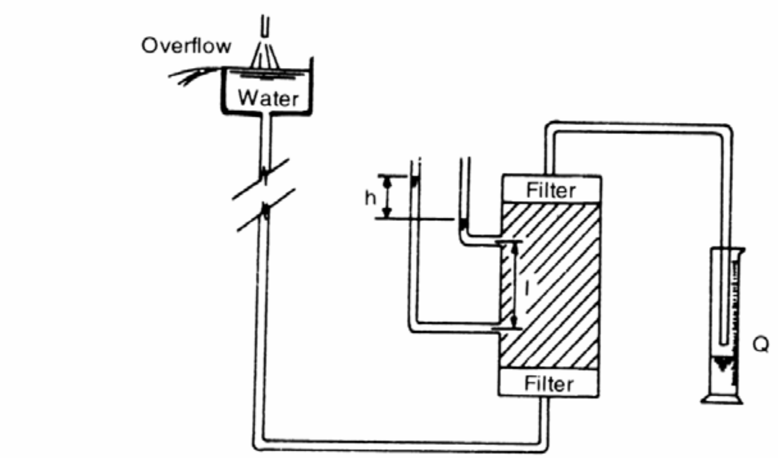


Fig. 2.3 The constant head permeameter.

Methods of measuring hydraulic conductivity: Laboratory techniques

- Falling head method

$$K = \frac{al}{At} \ln \frac{h_1}{h_2}$$

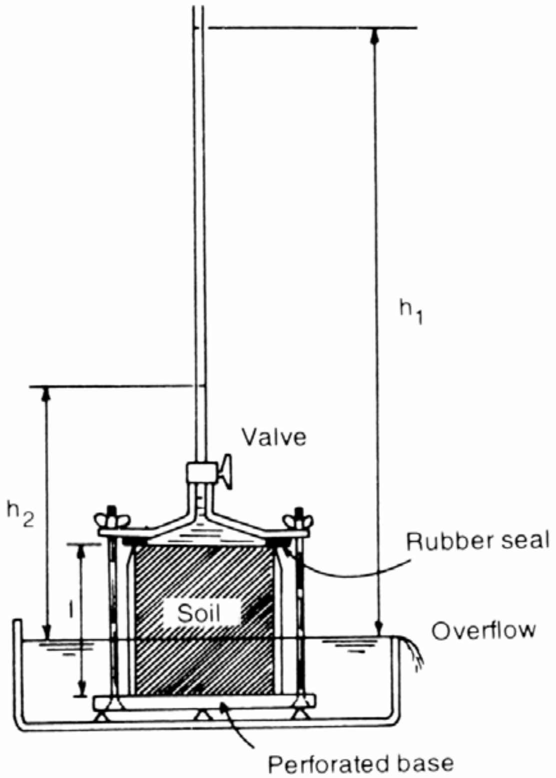


Fig. 2.4 The falling head permeameter.

Methods of measuring permeability: Laboratory techniques

- For ultralow permeability:
  - *pulse transient method* – where the decay of a pressure transient introduced on one side of the sample is observed
  - *pore pressure oscillation* – where the attenuation and phase retardation of a sinusoidal pressure wave on one side of the sample is observed

- These are all solutions of the *general* equation for fluid flow through porous media:

$$\frac{\partial P}{\partial t} = \frac{k}{\eta \beta_c} \frac{\partial^2 P}{\partial x^2}$$

β_c = storage capacity of the rock (Pa^{-1})

Typical values for permeability

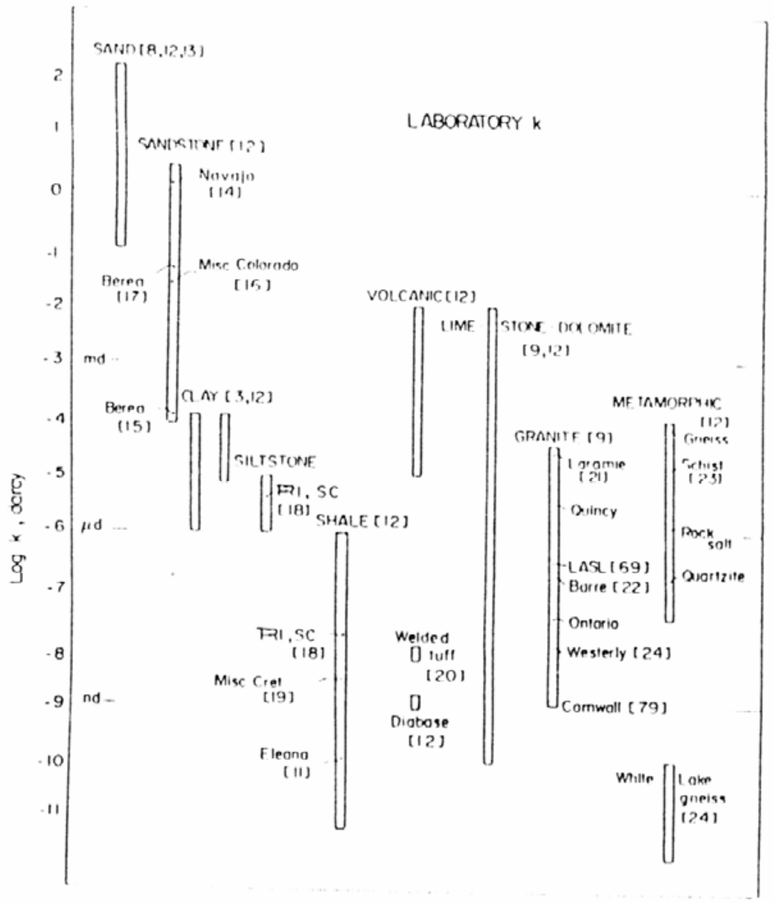


Fig. 1 Laboratory measurement of permeability of intact specimens. Boxes show range of measured values. Bracketed numbers are references. Pressure was hydrostatic and less than 10 MPa and temperature about 25 C

After Brace, 1980

Flow nets

- Uses two orthogonal sets of curves:
  - Flow lines: path of water molecule
  - Equipotential line: line of equal pressure

- Rules:
  - Equipotential lines must intersect flow lines at right angles
  - Flow elements formed are approximately square

Flow nets

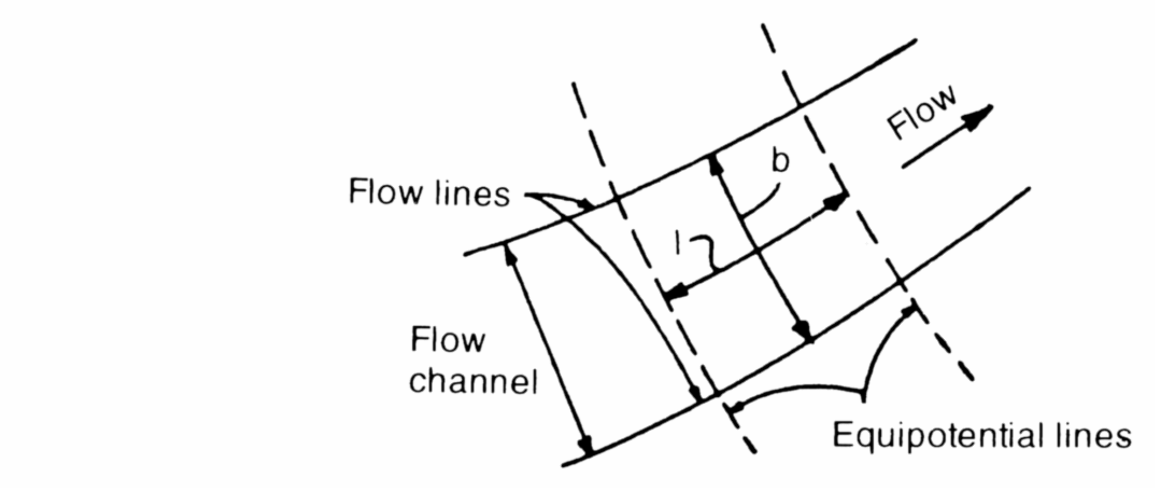


Fig. 2.8 Section of a flow net.

Rules:

1. Equipotential lines must intersect flow lines at right angles
2. Flow elements formed are approximately square

Flow nets

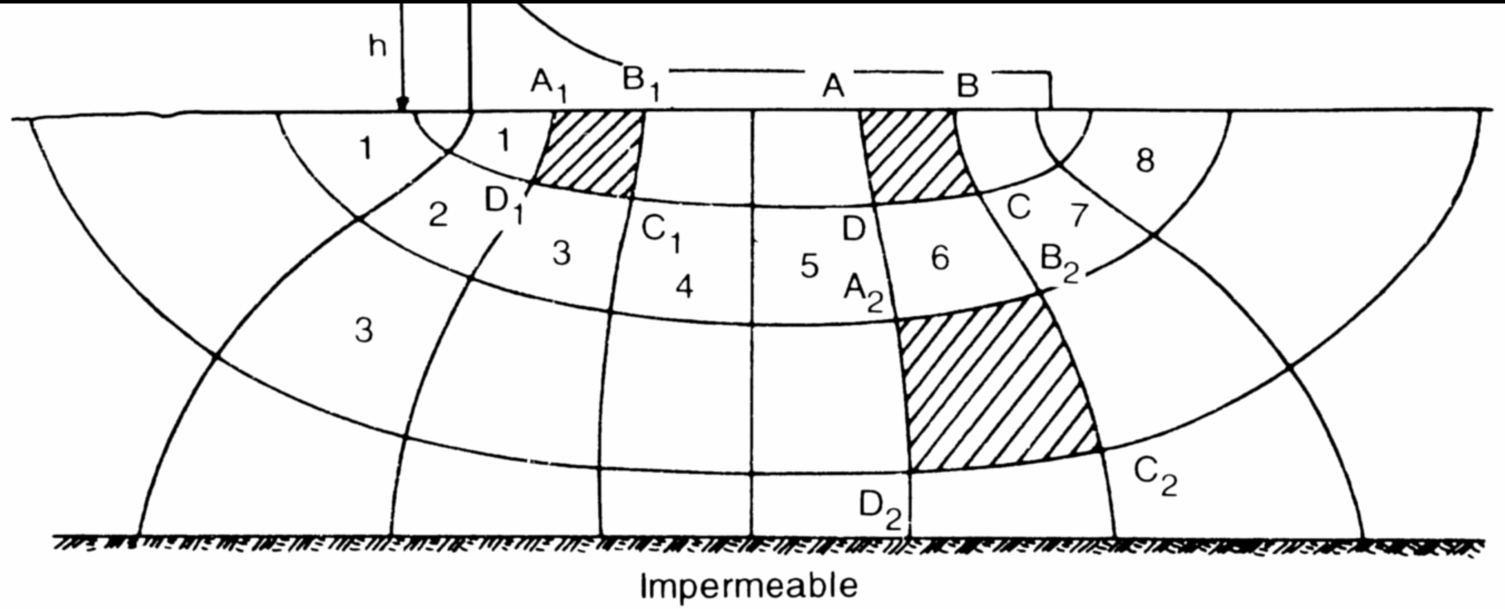
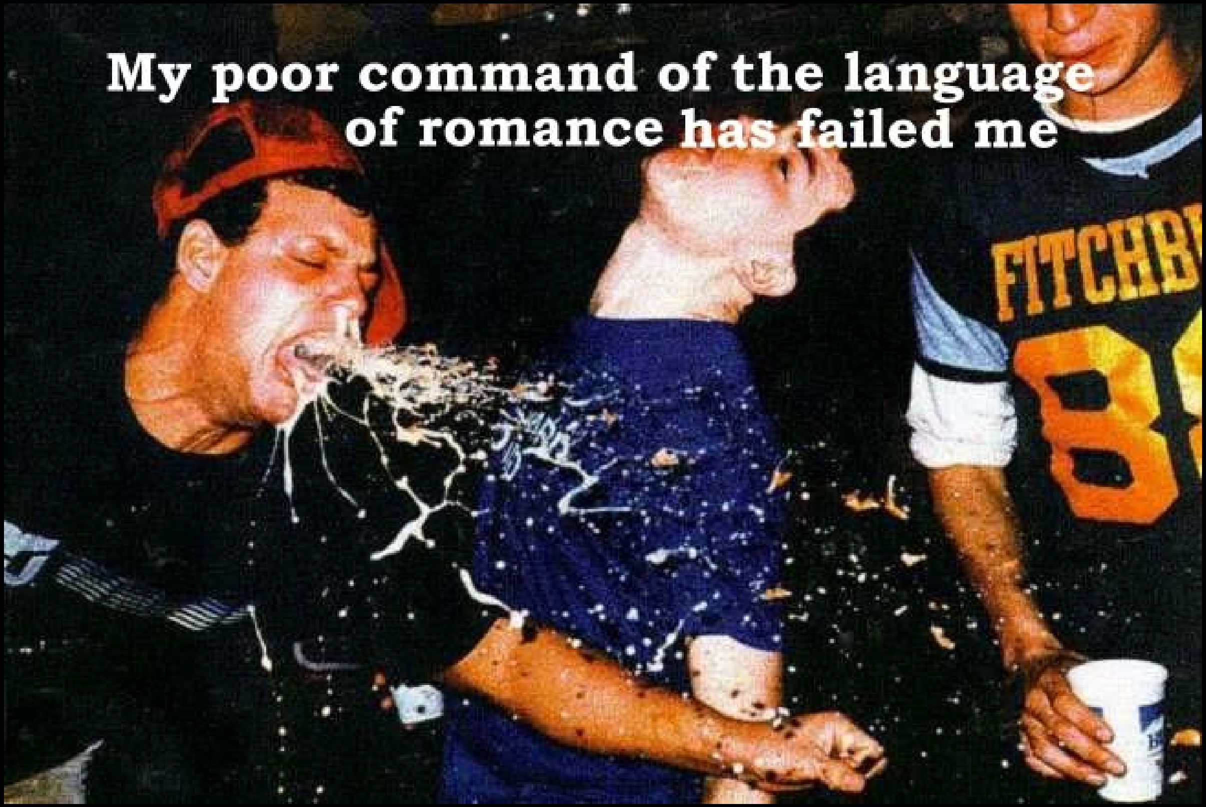


Fig. 2.7 Flow net for seepage beneath a dam.

Rules:

1. Equipotential lines must intersect flow lines at right angles
2. Flow elements formed are approximately square

Critical hydraulic gradient or 'heaving'



- Where the downward force equals the upward force

Critical hydraulic gradient or ‘heaving’

- In sands/silts:
  - produces ‘quicksand’ – not a type of soil, but a flow condition within the soil

- In fine silts/clays
  - cohesive forces hold particles together – heave of large mass of soil