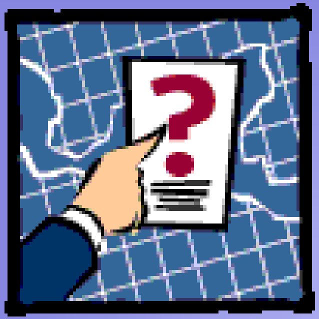
Topic 2:
Groundwater Movement



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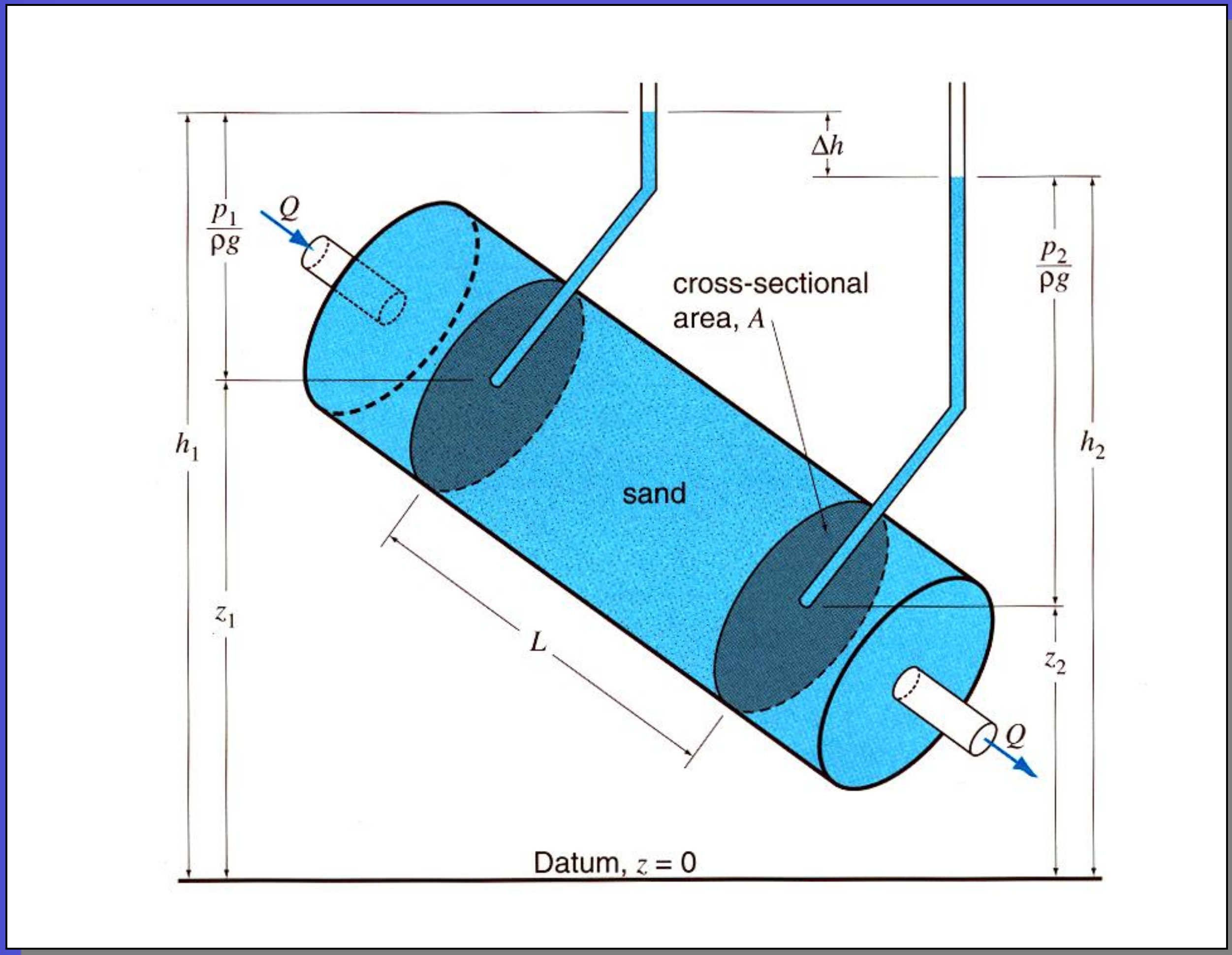
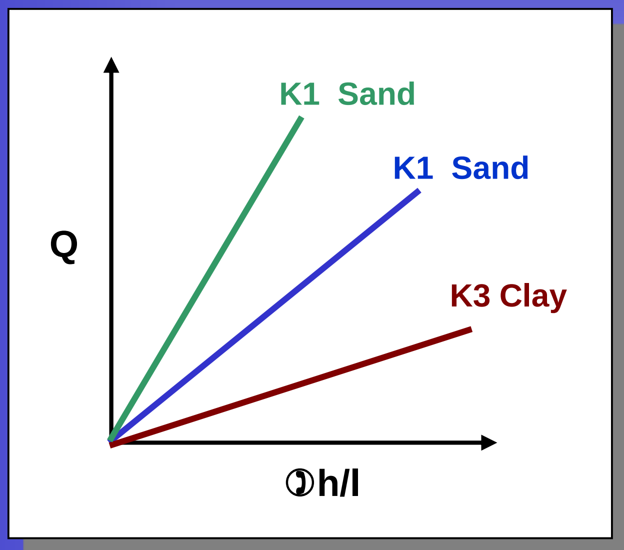
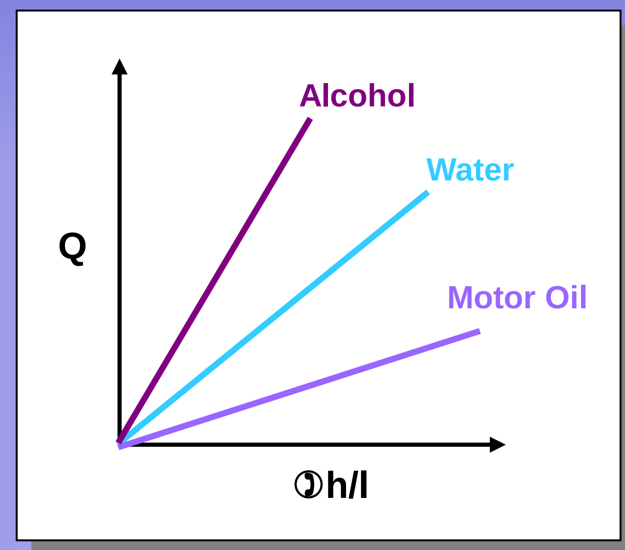
Groundwater movement – Darcy's Law



Groundwater movement – Darcy's Law





The Darcy Equation

$q = K\, dh/dl$

where:

q is the volumetric flux (Darcy Velocity) in Length/Time ($m\ s^{-1}$)

or Volume/Area/Time ($m^3\ m^{-2}\ s^{-1}$)

K is the Hydraulic Conductivity in Length/Time ($m\ s^{-1}$)

dh/dl is the Hydraulic Gradient in Length/Length (unitless)

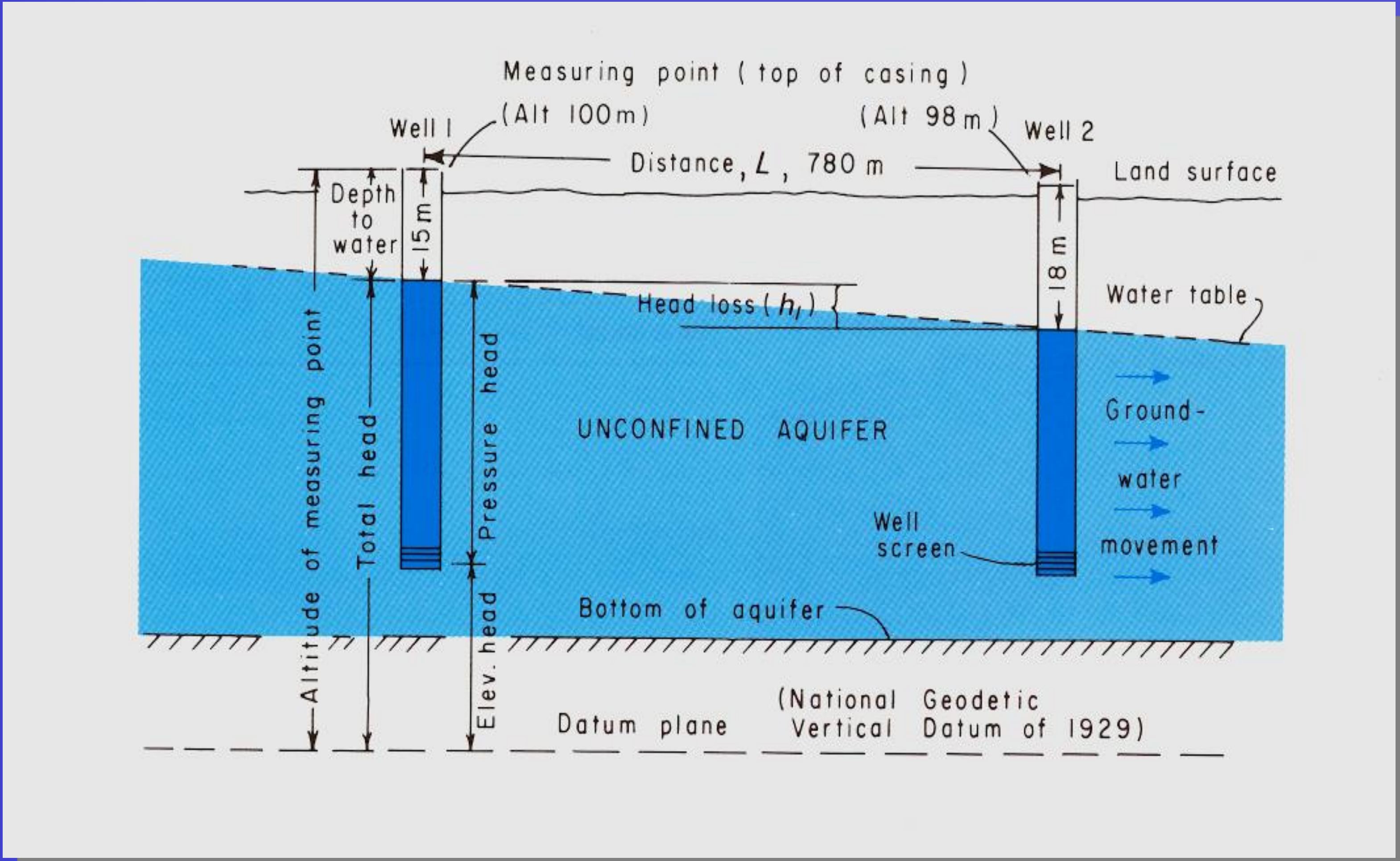
Alternatively: $Q = K\, A\, dh/dl$

Where:

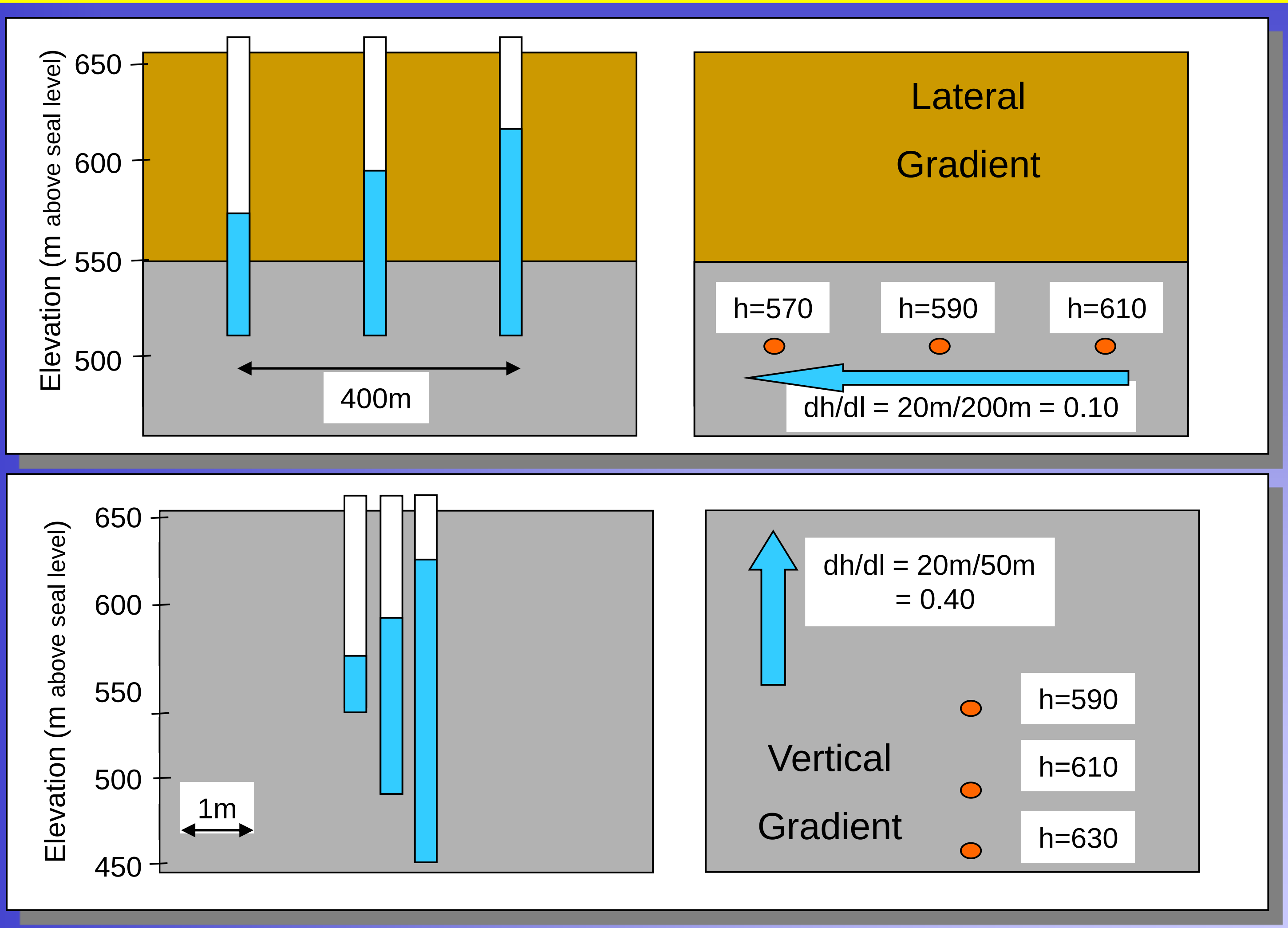
Q is the Flow Rate in Volume/Time ($m^3\ s^{-1}$)

A is the Area perpendicular to the Flow direction (m^2)

Hydraulic Gradient – The Driving Force



Lateral vs. Vertical Gradients



Hydraulic Conductivity

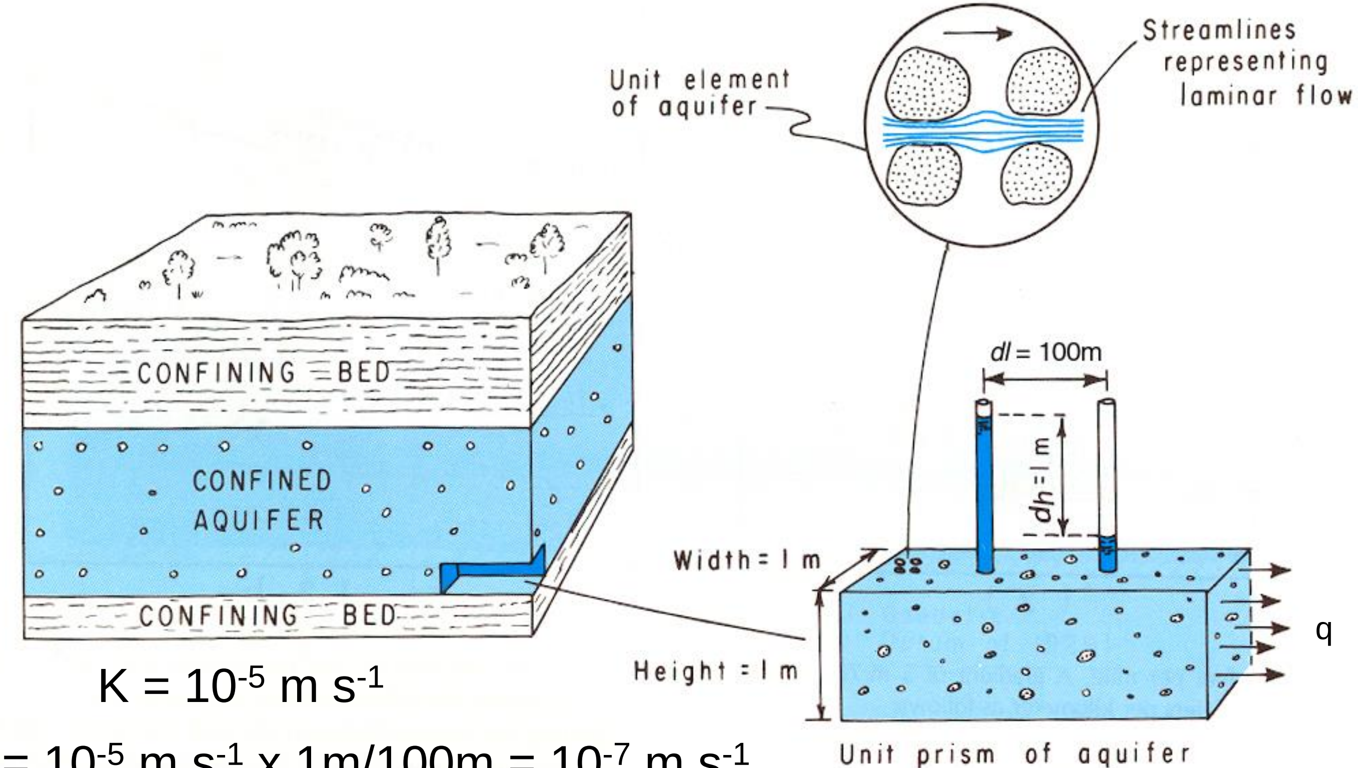
- K based on water flow
- Ease with which **water** moves through a geologic medium for a unit gradient
- A proportionality constant in Darcy's Law;

$q = K\,dh/dl$

Permeability

- k – function of geologic material only
- k – a function of grain size and fracture opening
- $k = C \times d^2$ where C is a proportionality constant and d is the representative grain size diameter
- k related to hydraulic conductivity where; $K = k$ □ g/μ *(□is fluid density; g is the gravitational constant; μ* is viscosity)

Hydraulic Conductivity (con't)



$K = 10^{-5}\ m\ s^{-1}$

$q = 10^{-5}\ m\ s^{-1} \times 1m/100m = 10^{-7}\ m\ s^{-1}$

Estimating Groundwater Movement

- If Q is the flow rate (m^3a^{-1}) and A is the cross-sectional area (m^2) the Q/A=q is the specific discharge (volumetric flux). So that q=K dh/dl

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Example: If $K=1*10^{-5}ms^{-1} = 3.2X10^2\ ma^{-1}$ and

$dh/dl = 1m/100m = 0.01$

Then

$q=3.2*10^2ma^{-1} * 0.01 = 3.2\ ma^{-1}$

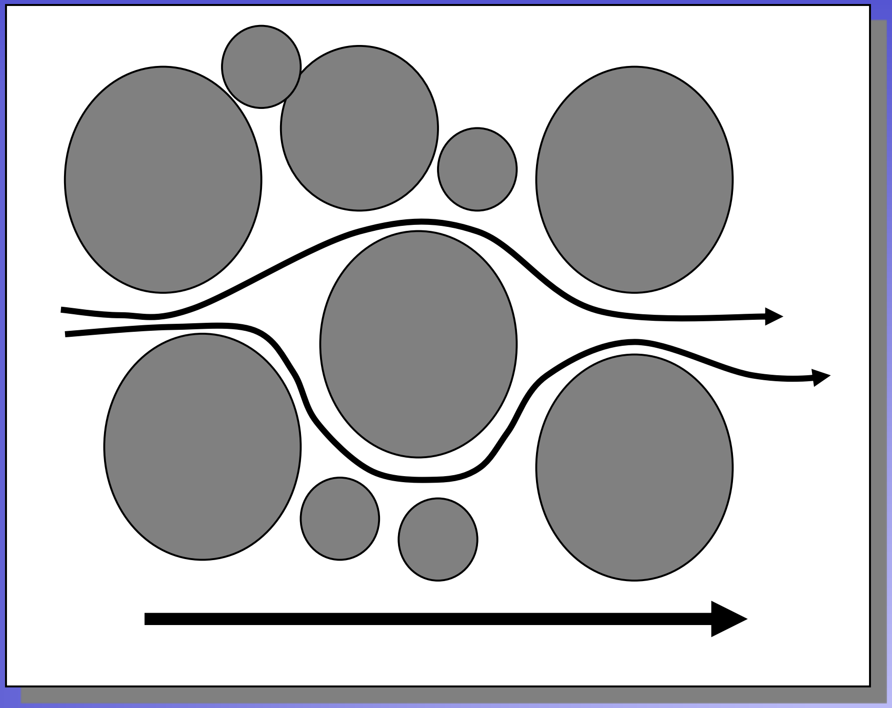
Is this a velocity ?

Specific Discharge vs. Velocity

q = volumetric flux (volume of water passing a unit area per unit time or $m^3 m^{-2} a^{-1}$ ==> $m\ a^{-1}$)

v = average linear velocity

Specific Discharge vs. Velocity



$V = q/n = k/n \; dh/dl$

Average velocity

Example of Average Velocity

- From previous; q= 3.2 $m^3m^{-1}a^{-1}$ (typical of sand) with n=0.35 (good approximation)
- v=q/n = 3.2 $m^3m^{-1}a^{-1}$ /0.35

  = 9.1 ma^{-1}
- Average linear velocities are always greater than specific discharge (or Darcy's Velocities) because porosities are less than 1

Estimating Flow Direction in the Field

THEORY

1. Determine water levels
2. Plot or contour surface
3. Select slope perpendicular to equipotentials
4. Plot flow directions

Estimating Flow Direction in the Field

PRACTICE

1. Only a few points are generally available (minimum of three required)
2. Interpolate water levels using wells, surface countours, streams, lakes etc
3. Plot flow directions / measure gradients

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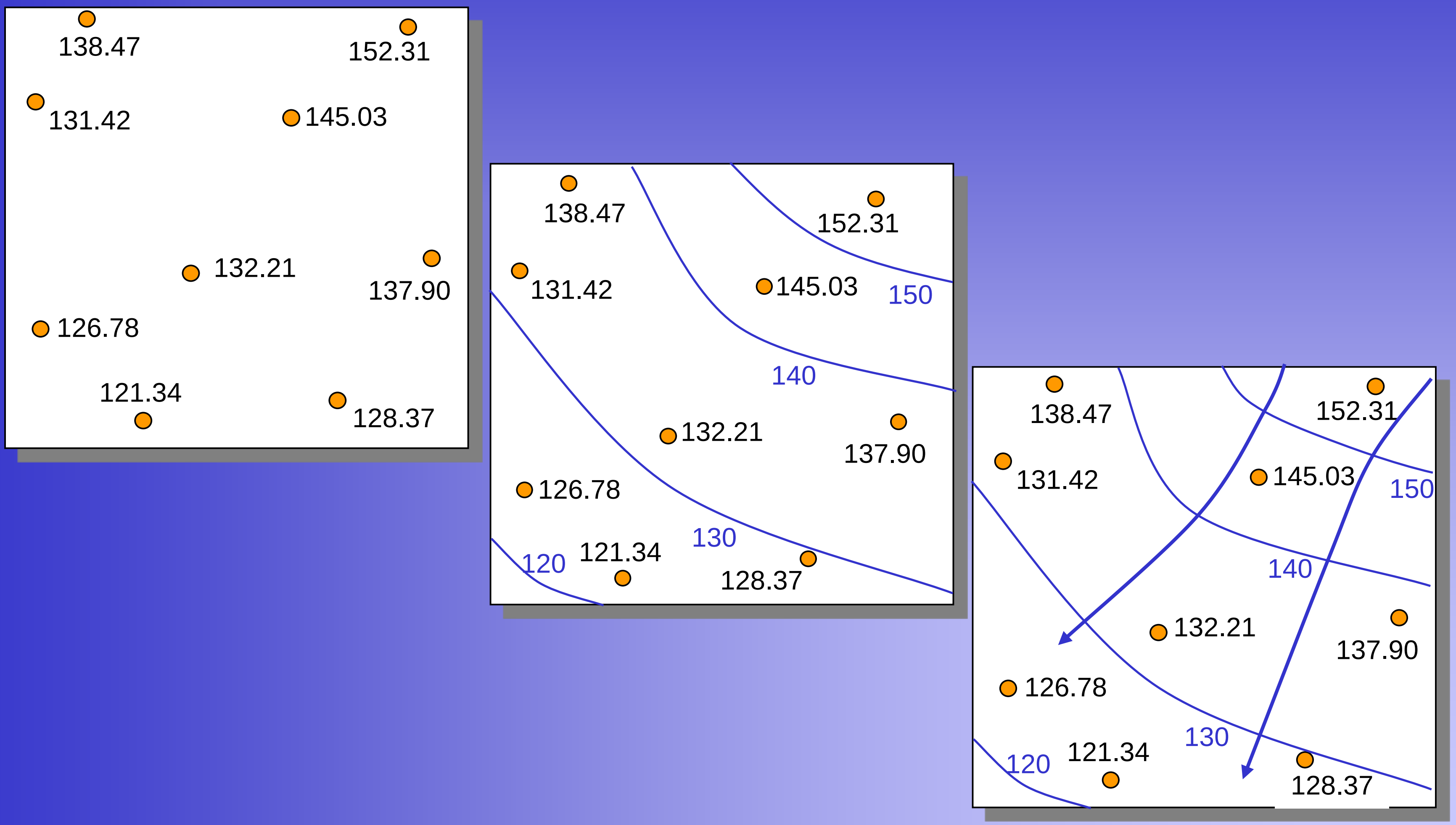
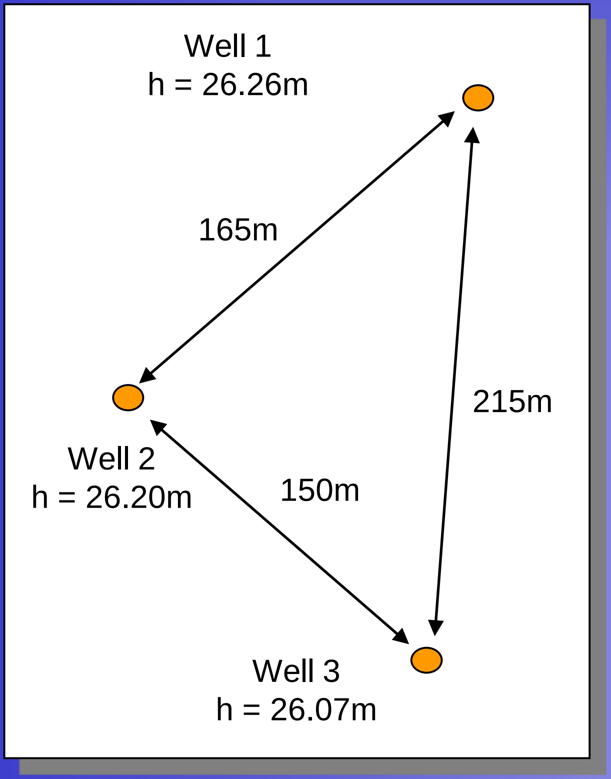
Estimating Flow Direction in the Field



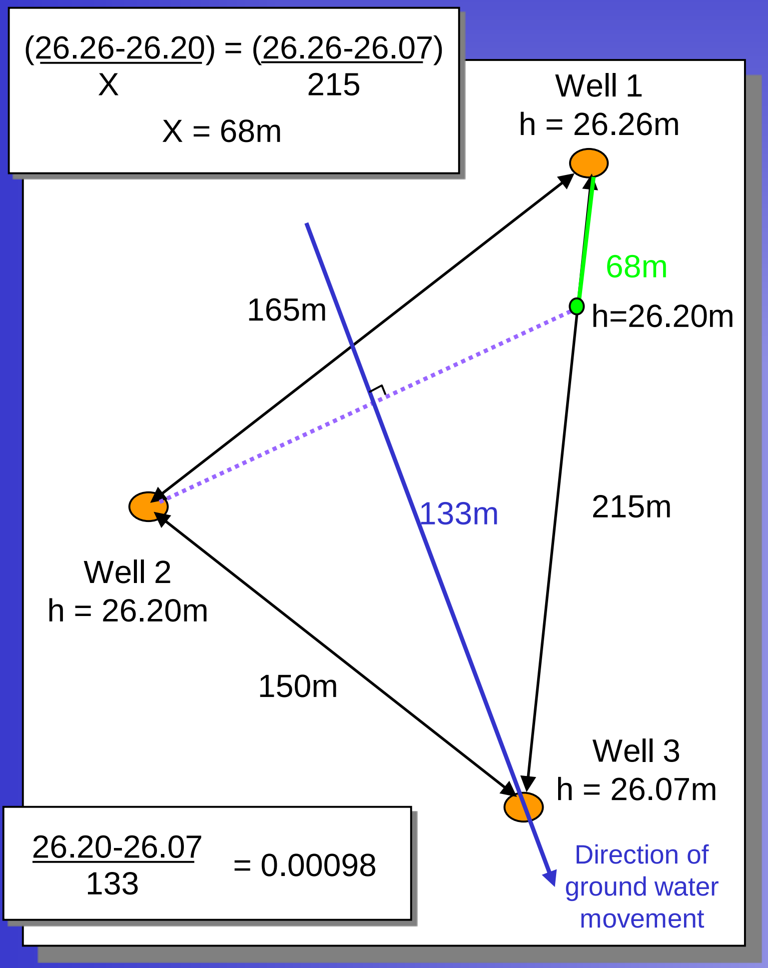
Estimating Flow Direction in the Field



Both the direction of groundwater movement and the hydraulic gradient can be determined if the following data are available

- The relative position of three wells
- The distance between each well
- The total head at each well

Estimating Flow Direction in the Field



1) Identify the well with the intermediate water level. Well 2: h=26.20

2) Calculate the position between well 1 and well 3 where the water level is the same as well 2. X = 68m

3) Draw a line between the intermediate well and the point identified in step 2. The head along this line is 26.20m

4) Draw a perpendicular line through the well with the lowest (or highest) head

5) Divide the difference between the head of the well and that of the contour by the distance between the well and the contour. This is the hydraulic gradient. = 0.00098