TD 603
Water Resources

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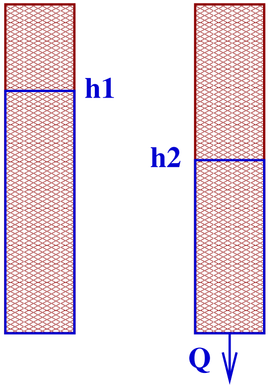
Lecture 4: Groundwater

Porosity and Specific Yield

- Porosity: The volume fraction of void to solid in dried sample.
- Saturation: When these voids are fully filled with water.

Specific Yield S_y: the ration of the colume of water that drains from a rock owing to gravity, to the total rock volumne.



- h_1, h_2 resp., are the heights of the saturated layer.
- Q is the volume of the water discharged to reach h_2 from h_1.
- $S_y = \frac{Q}{(h_1 - h_2)A}$

Caution: rock above h_i is wet, but unsaturated.
Lab. setup: Takes a lot of time for water to drip.

Specific Yield

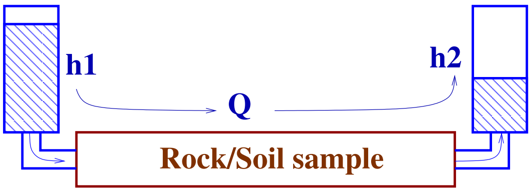
- Importance: This is actually the fraction which is accessible.
- Note 1: In accessible voids are NOT counted in porosity.
- Note 2: To access full n-fraction, oven heating was required.
- Clearly $S_y \leq n$, the porosity and

$$S_r = n - S_y$$

  S_r is called the Specific Retentivity.
- S_r is largely due to the adhesion of water molecules to the rock layer.
- Specific Yield of a well : to be done later.

Some Specific Yields			
Clay	2	Sandy Clay	7
Silt	18	Fine Sand	21
Medium Sand	26	Fine Gravel	25

Hydraulic Conductivity



- h_1 and h_2 are the heights of the water column.
- Q is in cu.m./sec, is the rate of flow.

Darcy's law

There is a constant K (depending just on the material) so that

$$Q = KA(h_1 - h_2)/L$$

- Q is in cu.m/s
- L is the length of the pipe and A its cross-section area.

Darcy' law

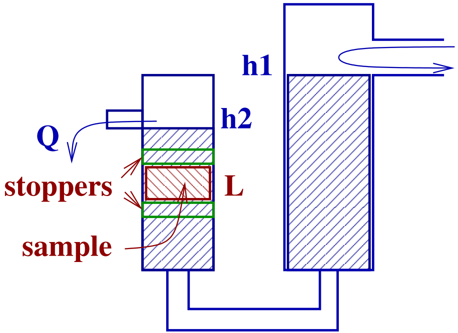
- The first law to relate the motion of ground-water
- Conductivity K: is an attribute of the substance.
- Dimension of K: is meter/second.

Material	K in cm/s
Clay	$10^{-9} - 10^{-6}$
Silts	$10^{-6} - 10^{-4}$
Fine Sands	$10^{-5} - 10^{-3}$
Gravels	$10^{-2} - 1$

source: Fetter

- Note that Darcy's law *almost* gives us *water particle velocities*.
- WARNING: Only saturated and slow moving flows.
- Typical velocities: few cm a day to few meters a day.
- K actually depends ob both the rock/soil and the fluid (e.g., water, oil) which is moving.
- This leads to a fluid independent constant called *intrinsic permeability* measured in *darcys*, which we skip.

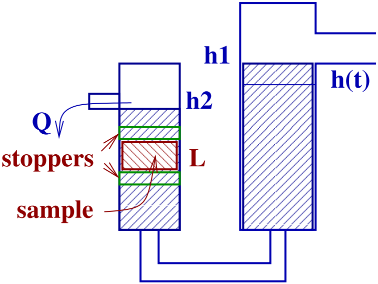
Measuring K: fixed heads



- The head difference is maintained at $h_1 - h_2$.
- The sample is held by two permeeable stoppers.
- The sample thickness is L and cross-section A.
- The system is at steady state and the outflow Q is measured.

$$K = \frac{QL}{A \cdot (h_1 - h_2)}$$

Measuring K: varying heads



- Start with height $h(0) = h_1$ and stop after time T and at height $h(T)$.
- Let cross-section of both tubes be A.
- Let Q be the total water discharged.

- We have $Q = KA(h(t) - h_2)/L$, whence we have:

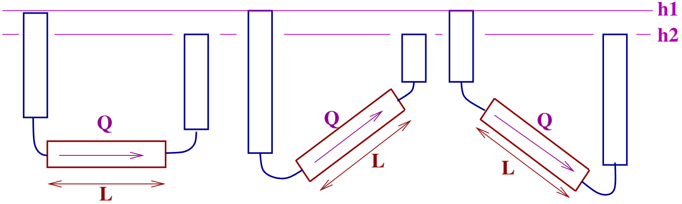
$$dh/dt = -K(h(t) - h_2)/L \qquad h(0) = h_1$$

- $h(t) = (h_1 - h_2)e^{-Kt/L} + h_2$ whence we have:
- $K = L \log[(h_1 - h_2)/(h(T) - h_2)]/T$

The General Darcy

Darcy's observation is that the flow *does not change* even if we vary the angle of inclination provided:

- The length of the rock-sample is not changed.
- The difference in the heads at the ends remains the same.



- This is remarkable in its similarity to ordinary fluid flow.
- It will also lead us to the gradient form of the ground-water differential equation.

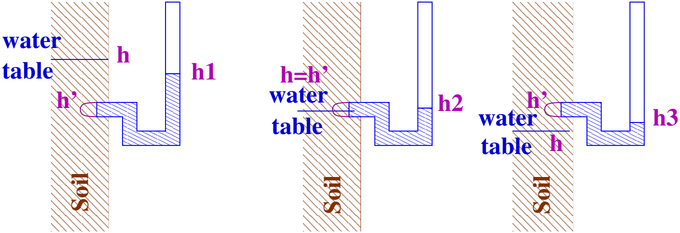
General Head

- The Piezometer: is a water column with a porous end, and is iused to measure the *piezometric head* at any point in the soil.
- Let h=ht. of water table and h' be the point at which the piezometer is inserted. Let h_i be the readings.

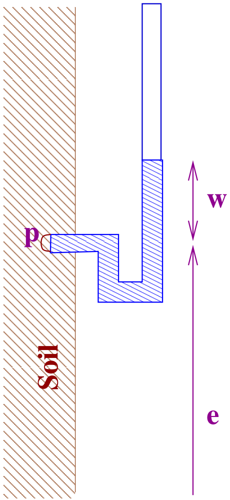
(i) If $h' < h$ then $h' < h1$.

(ii) If $h' = h$ then $h' = h2$.

(iii) If $h' > h$ then $h' > h3$.



Total Head



- The total head $h(p)$ is the sum of the hydrological head $w(p)$ and the elevation $e(p)$.

$$h(p) = e(p) + w(p)$$

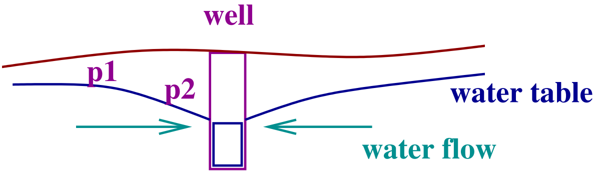
- $w(p) > 0$ iff the point p is saturated.
- $w(p) = 0$ iff p is on the water table.
- $w(p) < 0$ iff p is unsaturated.

Darcy's Law

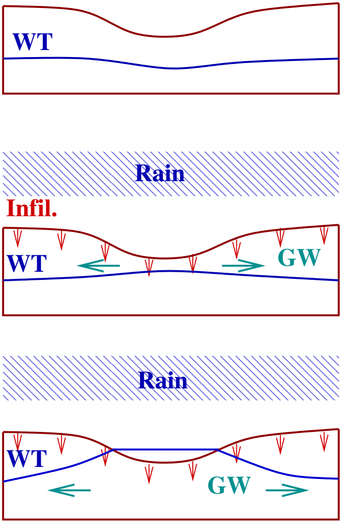
Water moves from higher total head to lower total head.

Well Recharge

- Let p_1 and p_2 be points on the water table.
- Clearly $h(p_i) = e(p_i)$ since $w(p_i) = 0$.
- Thus $h(p_1) > h(p_2)$ and groundwater flows from p_1 to p_2.
- A well from which water is drawn causes a *dip* in the water table, called the *draw-down cone*.
- This cone causes the well to recharge. The strength of the recharge is given by the angle of attack.
- If the water-table falls below the well-bottom then recahrge stops.



Groundwater and Rains

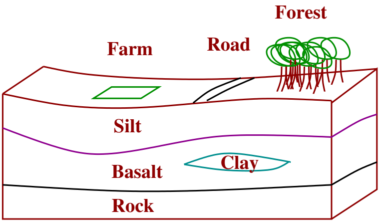


- A typical terrain with a depression. Water Table following the topography.
- Rains cause infiltration. Since in the depression, the thickness is small, WT rises faster here. A significant Groundwater flows away from the depression.
- Still more rains causes the water-table to touch the surface and this creates a pond.
- Eventually scenario (i) returns.

Larger Picture

In general, we would like to

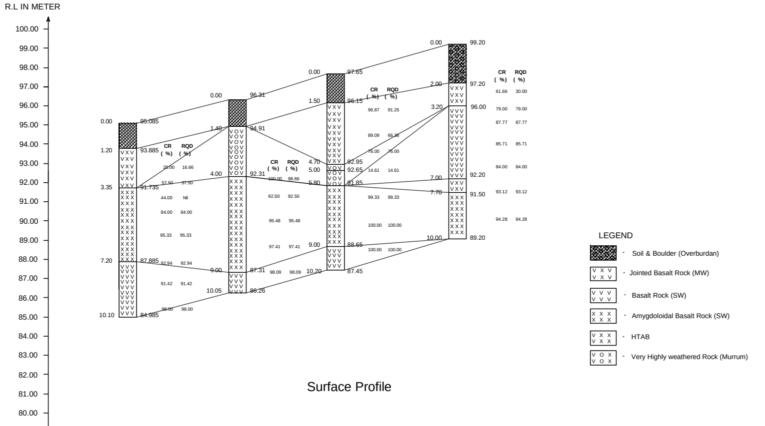
- analyse groundwater and surface water
- prescribe corrective measures
- understand sustainable use



A real-life scenario

- Various surface features such as farmslands, forests, built-up areas, which affect infiltration.
- Similar soils appearing as layers, and their geological properties, such as porosity, conductivity etc.
- climactic data such as rainfall, evaporation, etc.
- Water requirements and usage, such as for irrigation, domestic use, and so on.

Bore-logs



BH. NO	BH -1	BH- 2	BH -3	BH- 4
Depth	10.10 m	10.05 m	10.20 m	10.00 m
RL. M.	95.085 m	96.31 m	97.65 m	99.20 m
Chainage	15.00 m	35.00 m	55.00m	75.00 m

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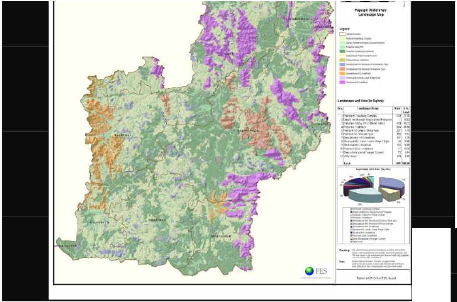
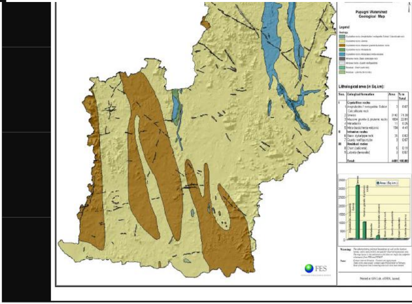
Project :- Soil Investigation at Gudvanwadi Check Dam.

Subject :- Surface Profile

DATE : 11 / 05 / 2009 | DRN. BY : Ulhas | APPROVED BY:

Papagni Again





Discussion

1. Draw a possible graph relating moisture content with head.
2. Would porosity measurement change due to handling of the sample? And conductivity?
3. What care would you take in the lab set-ups discussed in the class?
4. Why should Darcy's law break down for high velocity flows?
5. When would you use fixed head vs. varying head set-ups?
6. Study the Papagni data carefully and comment on it.
7. Compare and contrast the definition of electrical conductance.