Specific Capacity = discharge rate/max drawdown

after pumping at a constant, known rate for a time until apparent equilibrium is reached (i.e., minimal change in drawdown with time)

**Theis et al, 1963 - Theory - USGS Water Supply Paper 1536**
**Bradbury & Rothschild, 1985 - Computer Application - Ground Water, v23, n2 240-245.**
**Czarnecki & Craig, 1985 - Hand Calculator Application - Ground Water, v23, n5, p. 667-672.**

**Rearrange Theis (Jacob simplification) Equation to estimate T from Specific Capacity:**

$$T = \frac{Q}{4\pi s}\left(-0.5772 - \ln\left(\frac{r^2 S}{4Tt}\right)\right)$$

must assume an S

Note T on both sides

$$f(T) = T - \frac{Q}{4\pi s}\left(-0.5772 - \ln\left(\frac{r^2 S}{4Tt}\right)\right)$$

Rearrange and find a T value such that f(T) approaches zero

assume an S

correct for well losses ($s=s_w$)

correct for partial penetration (Bradbury)

***** IN THE PUMPING WELL**

What is specific capacity?

Where do we get specific capacity?

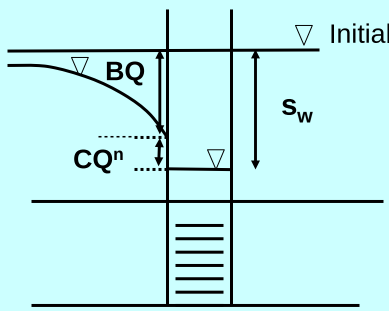
Why do we want to calculate Transmissivity from specific capcaity?

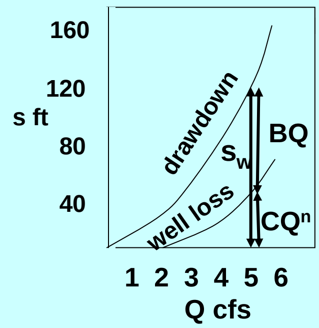
**Beware** - using water level in **pumped well** in analyses
**Beware** - using well hydraulics equation's to predict w.l. in **pumped well** for design purposes

**Drawdown is partially due to flow through aquifer, but head loss is also caused by flow through screen and well bore to the pump**

**Energy is dissipated in turbulent flow and reflected as lower head in well**
**Magnitude of well loss depends on discharge velocity, minimize loss by keeping V low at Steady State described as:**

$$s_{well} = \frac{Q}{2\pi T}\ln\frac{r_2}{r_1} + CQ^n$$



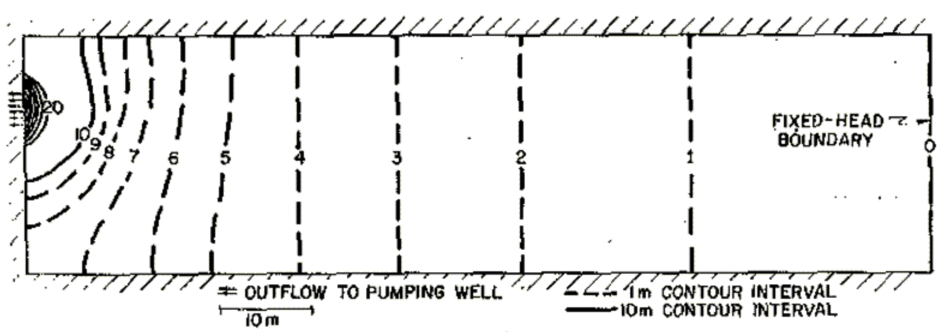




Partial Penetration

Full Penetration Equations are OK for:

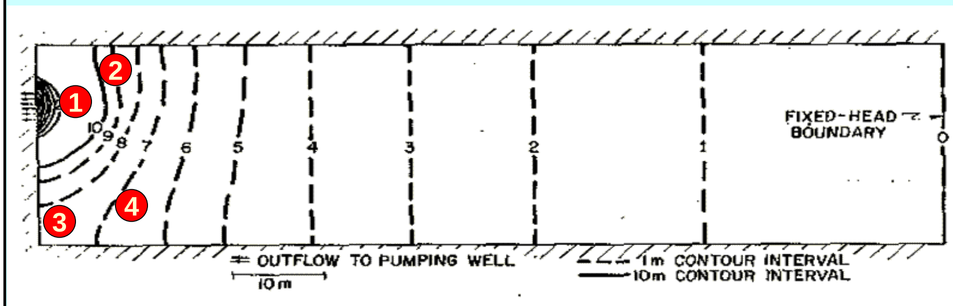
$$r > 1.5b\sqrt{K_H/K_V}$$

beyond this r the equipotential lines are vertical and equivalent to the values that would be obtained from a full penetrating well



If $K_H = 4$  $K_V = 1$  b=200 ft
How far must I be from the well to avoid affects of partial penetration?

$$r > 1.5b\sqrt{K_H / K_V}$$



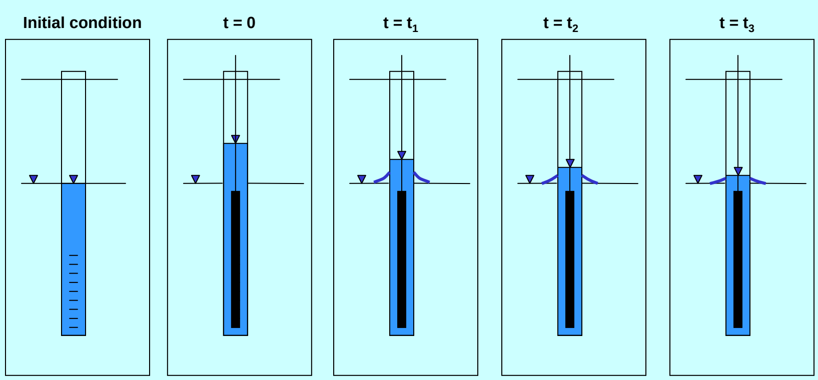

## Slug Testing

Slug tests are conducted by "instantaneously" raising or lowering the water level in a well and monitoring the recovery of the water level

Often accomplished by dropping a long object into the well to displace the water

Preferable to adding a slug of water to the well which influences the chemistry

Sometimes a slug is removed, or water is bailed, from the well, decreasing the water level



## Slug Testing

Cooper - Bredehoeft - Papadopulos

- offer a solution for a slug test in a confined aquifer via curve matching
- BEWARE! Storage coefficient estimated from this approach is not reliable
- we will not go into these in this class … curve matching, same as before

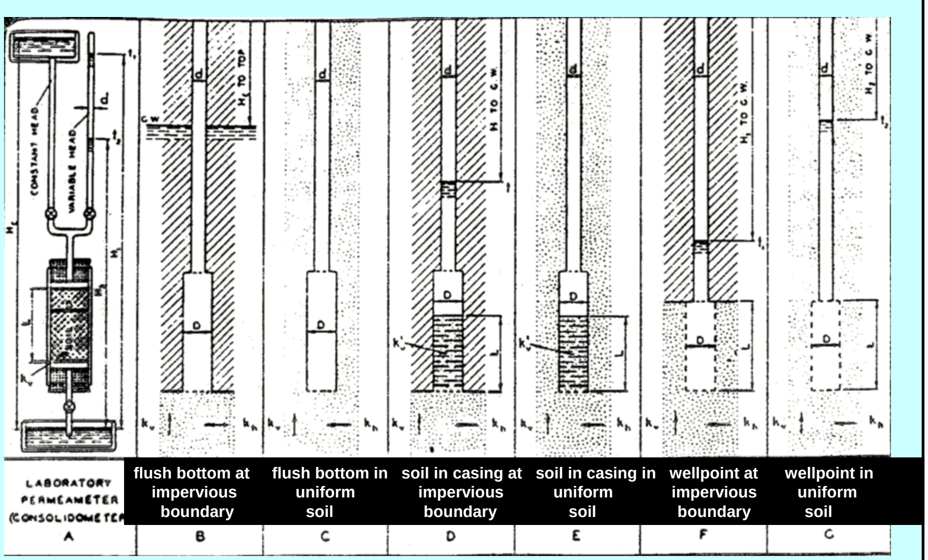
Hvorslev

- assumes water level change in the aquifer can be ignored
- offered many solutions for both confined and unconfined, see his:
  Waterway Experiment Station - Army Corps of Engineers
  Bulletin No. 36 - April 1951
  Time Lag and Soil Permeability

Bouwer & Rice

- assume water level change in the aquifer can be ignored with the exception of its affect on geometry via the effective radius of influence
- also offer a solution for unconfined aquifers using some empirically developed coefficients

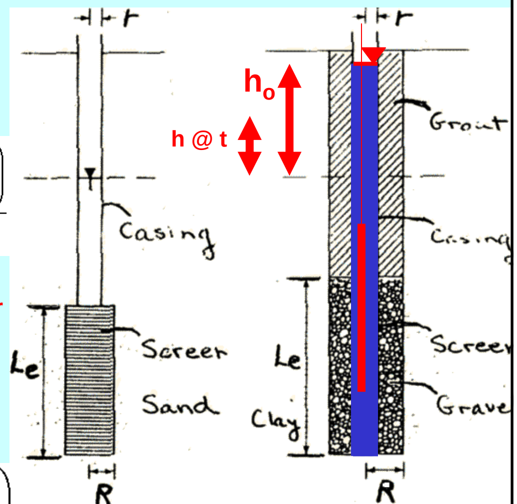
Hvorslev developed relationships for many configurations
a few examples:



As an example of one of **Hvorslev's** relationships, take $L_e$ / R > 8:

plot $h/h_o$ vs. time on semi-log paper,
the slope is $\ln(h_1/h_2) / (t_1 - t_2)$
then for consistent units where:
r - casing radius
$L_e$ - effective well screen length
R - effective well screen radius

$$K = \frac{r^2 \ln\left(\frac{L_e}{R}\right) \ln\left(\frac{h_1}{h_2}\right)}{2\, L_e\, (t_2 - t_1)}$$




We can simplify to use $T_o = (t_1 - t_2) =$
time to reach 37% remaining to recover
take $h_1 = h_o$ @ $t_1 = 0$
and $h_2 = 0.37\ h_o$ @ $t_2$ = when 37% remains to recover
then $\ln(h_1/h_2) = \ln(h_o / 0.37 h_o)$
$= \ln 2.7 = 1.0$
so slope is $1/T_o$

$$K = \frac{r^2 \ln\left(\frac{L_e}{R}\right)}{2\, L_e\, T_o}$$

Bouwer and Rice offer:

$$K = \frac{r_c^2 \ln\left(\frac{R_e}{R}\right)}{2\, L_e} \frac{1}{t} \ln\left(\frac{H_o}{H_t}\right)$$

**Hvorslev**

$$K = \frac{r^2 \ln\left(\frac{L_e}{R}\right) \ln\left(\frac{h_1}{h_2}\right)}{2\, L_e\, (t_2 - t_1)}$$

rate of change of h with time

$$\text{think of } \frac{1}{t} \ln \frac{H_o}{H_t} \text{ as } \frac{1}{t_2 - t_1} \ln \frac{H_1}{H_2}$$

consistent units
$r_c$ - casing radius
R - effective well screen radius
$R_e$ - effective radius of head dissipation
$L_e$ - effective well screen length
$H_o$ - drawdown at time = 0
$H_t$ - drawdown at time = t

$R_e$ is difficult to determine …………………

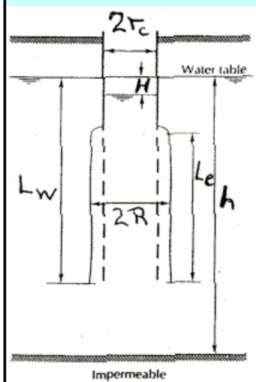
$$K = \frac{r_c^2 \ln\left(\frac{R_e}{R}\right)}{2\,L_e} \frac{1}{t} \ln\left(\frac{H_o}{H_t}\right)$$

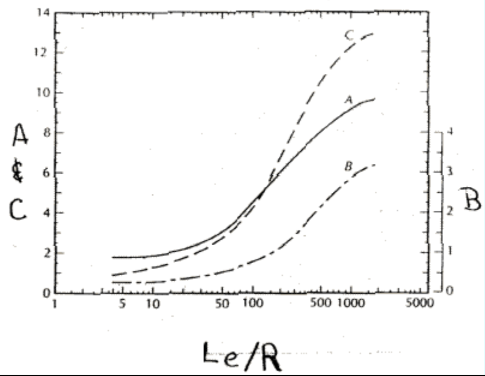
**$R_e$ is difficult to determine ………**

**Bouwer and Rice undertook lab experiments in sand tanks to establish** **ln($R_e$/R) ……**

$$for\ L_w < h \quad \ln\left(\frac{R_e}{R}\right) = \left[\frac{1.1}{\ln\left(\frac{L_w}{R}\right)} + \frac{A + B\ln\left(\frac{(h-L_w)}{R}\right)}{\frac{L_e}{R}}\right]^{-1}$$

$$for\ L_w = h \quad \ln\left(\frac{R_e}{R}\right) = \left[\frac{1.1}{\ln\left(\frac{L_w}{R}\right)} + \frac{C}{\frac{L_e}{R}}\right]^{-1}$$




**Gather data from the sand tank**

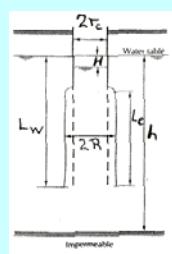
**Work with a partner to estimate K via Hvorslev AND Bouwer and Rice Methods**

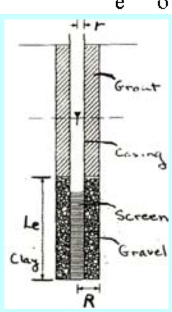
**How do the K values compare? And for the pump test we did earlier in the semester?**

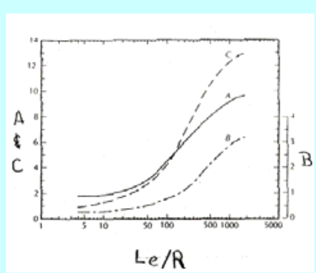
**How does the tank fit the assumptions of the methods?**

$$K = \frac{r^2 \ln\left(\frac{L_e}{R}\right)}{2\,L_e\,T_o}$$

$$K = \frac{r_c^2 \ln\left(\frac{R_e}{R}\right)}{2\,L_e} \frac{1}{t} \ln\left(\frac{H_o}{H_t}\right)$$




$$for\ L_w < h \quad \ln\left(\frac{R_e}{R}\right) = \left[\frac{1.1}{\ln\left(\frac{L_w}{R}\right)} + \frac{A + B\ln\left(\frac{(h-L_w)}{R}\right)}{\frac{L_e}{R}}\right]^{-1}$$

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