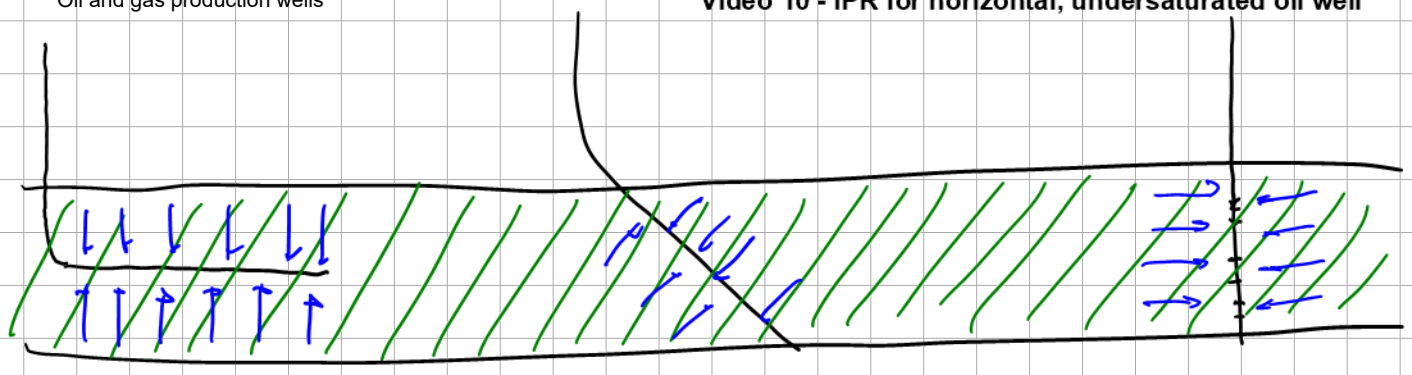
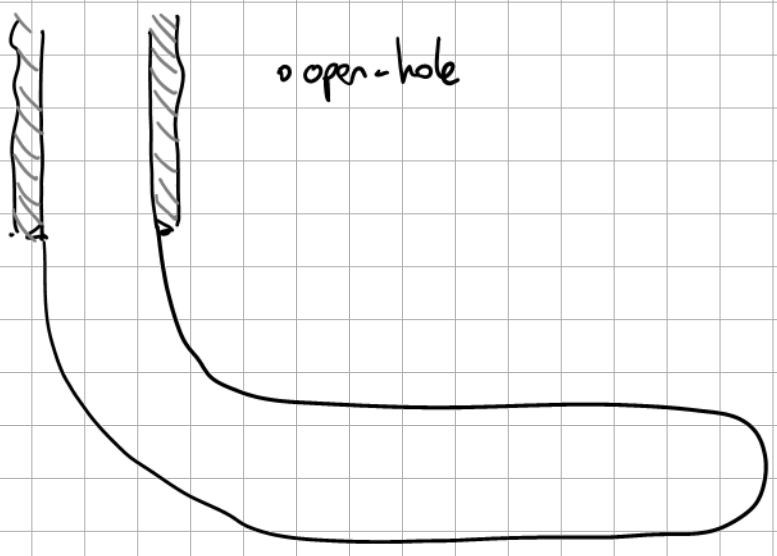


permeability anisotropy

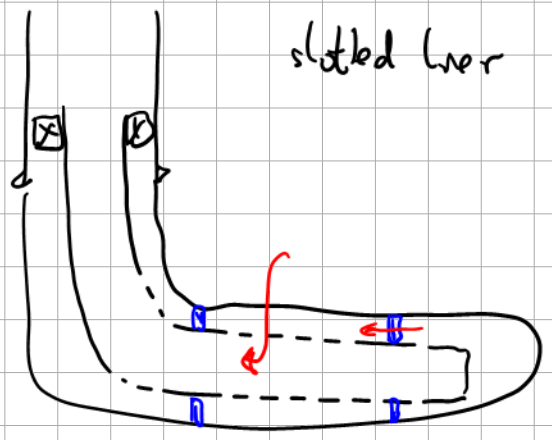
k_v

k_H

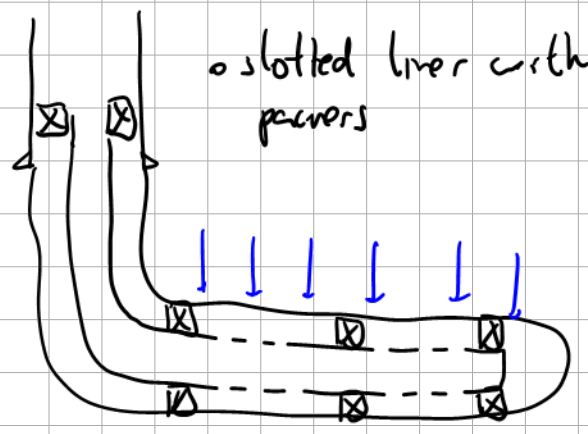
$\frac{k_H}{k_v} >> 1$ e.g. 10



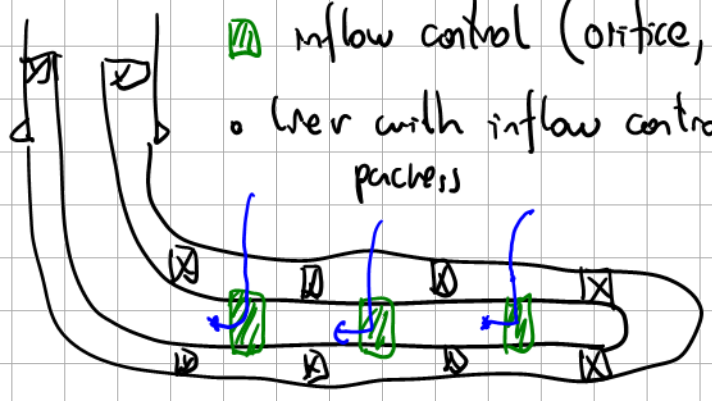
o open-hole



slotted liner



o slotted liner with packers



inflow control (orifice, control valve)

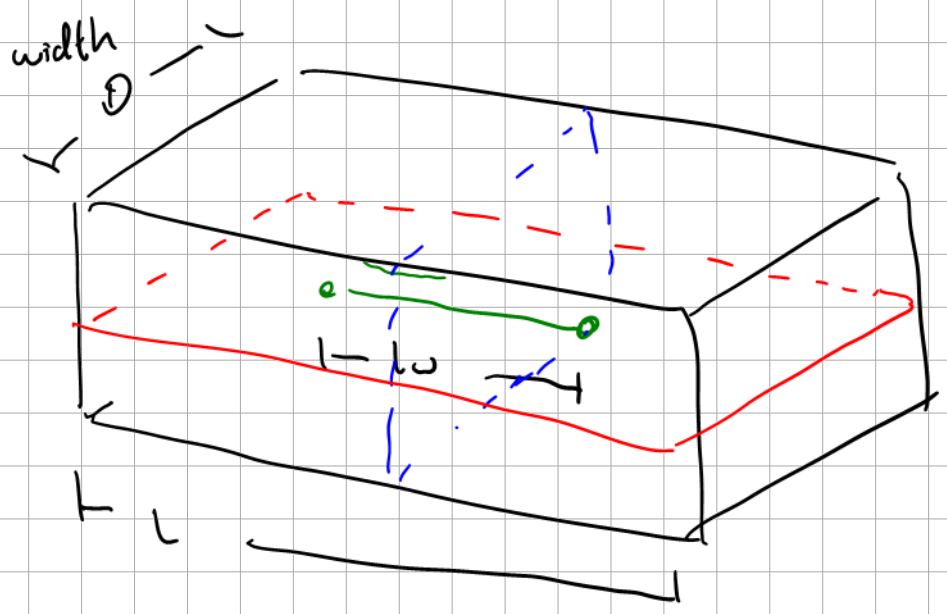
o liner with inflow control and packers

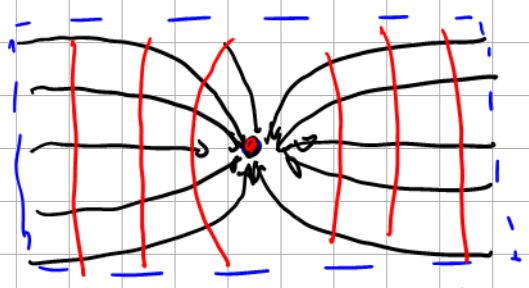
cemented and perforated liner

1937 - Muskat (1937) (Gulf oil)
1958 - Merkulov
1964 - Borisov
1974 - Gringarten (Imperial College), Ramey (Stanford)
1983 - Giger (IFP)
1988 - Joshi
1989 - Babuh, Odeh (Mobil)
1991 - Renard, Dupuy (IFP)
1994 - Buttler
Harald Asheim (NTNU)

Morris

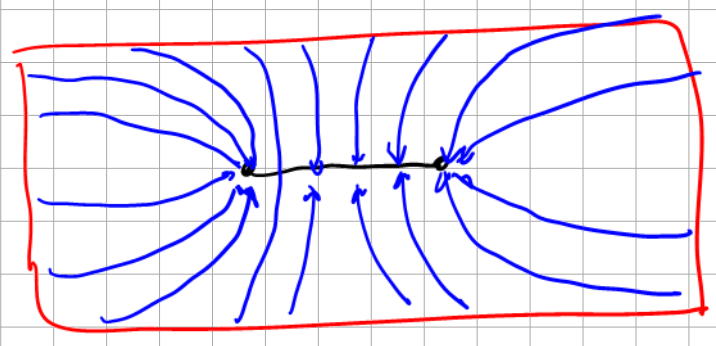
http://www.ipt.ntnu.no/~asheim/prodbr.html





iso pressure

$P = f(x)$

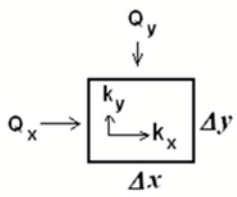


$\sim P = f(x)$

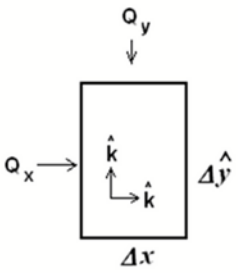
Superposition

Strategy to deal with permeability anisotropy

- Actual reservoir element



- Homogenous equivalent:



Permeability scaling: $\hat{k} = \sqrt{k_x k_y}$

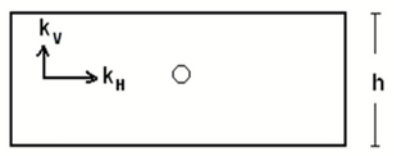
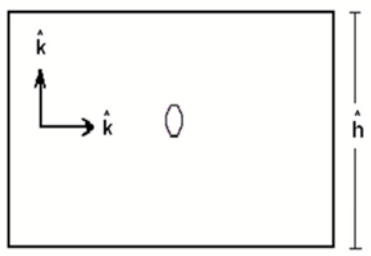


Figure 3.10 Anisotropic reservoir

$$k_H \frac{\partial^2 p}{\partial x^2} + k_V \frac{\partial^2 p}{\partial y^2} = \varphi \mu c \frac{\partial p}{\partial t}$$

$$\frac{\partial^2 p}{\partial x^2} + \frac{\partial^2 p}{\partial \left(\sqrt{k_H / k_V}\, y\right)^2} = \frac{\varphi \mu c}{k_H} \frac{\partial p}{\partial t}$$



$$\frac{\partial^2 p}{\partial x^2} + \frac{\partial^2 p}{\partial \hat{y}^2} = 0$$

$$\hat{y} = \left(k_H / k_V\right)^{0.5} y$$

Height scaling: $\hat{h} = \left(k_H / k_V\right)^{0.5} h$

Harald Asheim's IPR equation

- undersaturated oil
- horizontal well
- pss
- scaling due to anisotropy

$$q_o = \frac{k_H \cdot h}{6.22 \cdot (\mu_o \cdot B_o)_{@p_{av}} \cdot \left[\frac{\pi \cdot D \cdot \hat{f}_a}{2 \cdot \bar{L}_w} + \frac{3 \cdot h \cdot \beta}{\hat{L}_w} \cdot \left(\ln\left(\frac{h \cdot \beta}{2 \cdot \pi \cdot \hat{r}_w}\right) + s_b\right)\right]} [p_R - p_{wf}]$$

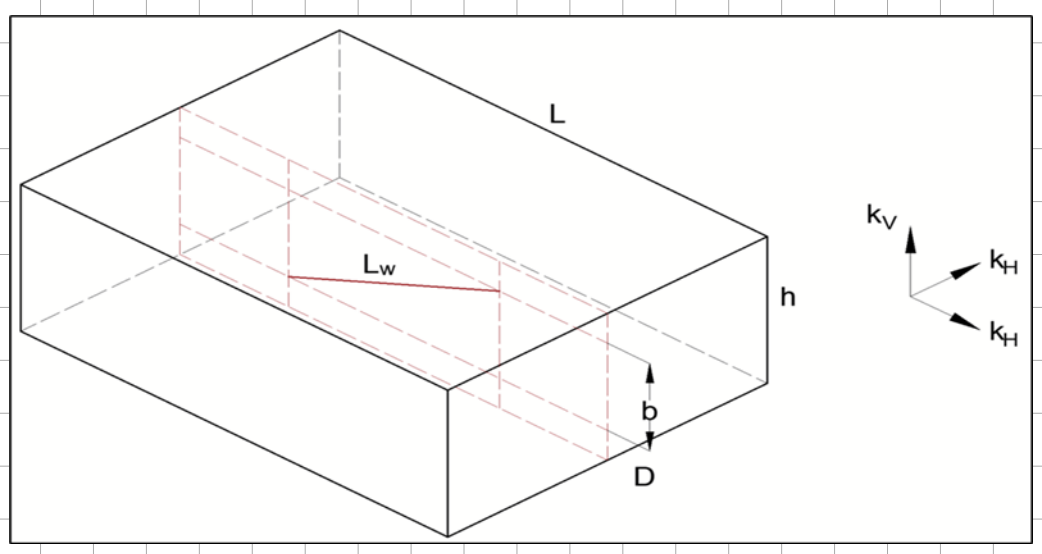
geometry related

function of PVT, fluid properties

$$\beta = \sqrt{\frac{k_H}{k_V}}$$

$$\hat{L}_w = L_w \cdot \sqrt{1 - \left(\frac{b}{L_w}\right)^2 \cdot (\beta^2 - 1)}$$

$$\bar{L}_w = L_w \cdot \sqrt{1 - \left(\frac{b}{L_w}\right)^2}$$



$$\hat{r}_w = r_w \cdot \frac{1 + \sqrt{1 + (\beta^2 - 1) \cdot \left(\frac{\bar{L}_w}{L_w}\right)^2}}{2}$$

$$\hat{f}_a = \frac{\bar{L}_w}{L} \cdot \left[1 + \left(0.53 \cdot \left(\frac{L}{D}\right)^2 + 1.15 \cdot \left(\frac{L}{D}\right) + 0.164\right) \cdot \left(\frac{1 - \left(\frac{\bar{L}_w}{L}\right)}{0.45 + \left(\frac{\bar{L}_w}{L}\right)}\right)\right]$$

~ well completed partially in the interval

$$\hat{s}_b = \begin{Bmatrix} 0.69 \ \ if \ \ O(b) = O(h) \\ 0 \ \ if \ \ b = 0 \end{Bmatrix}$$

~ skin factor, "shielding" effect from top and bottom walls