DEVELOPMENT OF A SMEAR-PROOF HORIZONTAL AND VERTICAL PERMEABILITY PROBE

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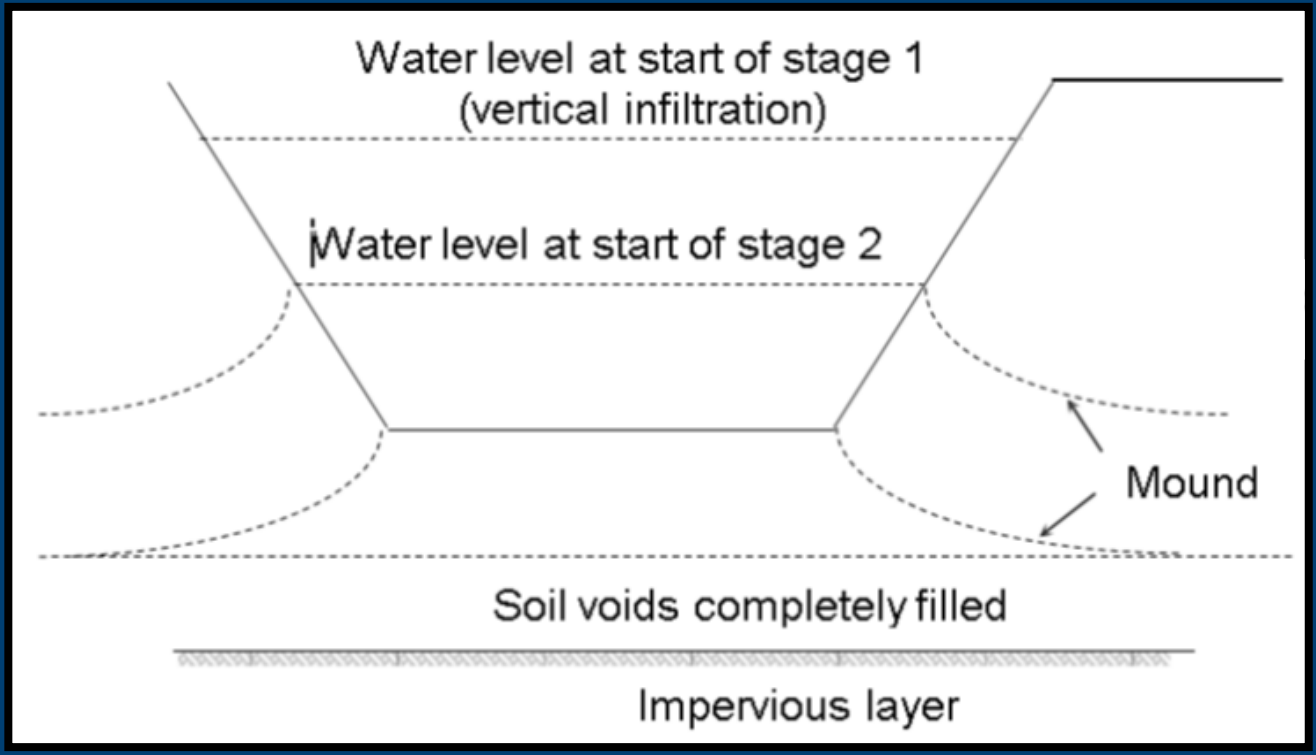
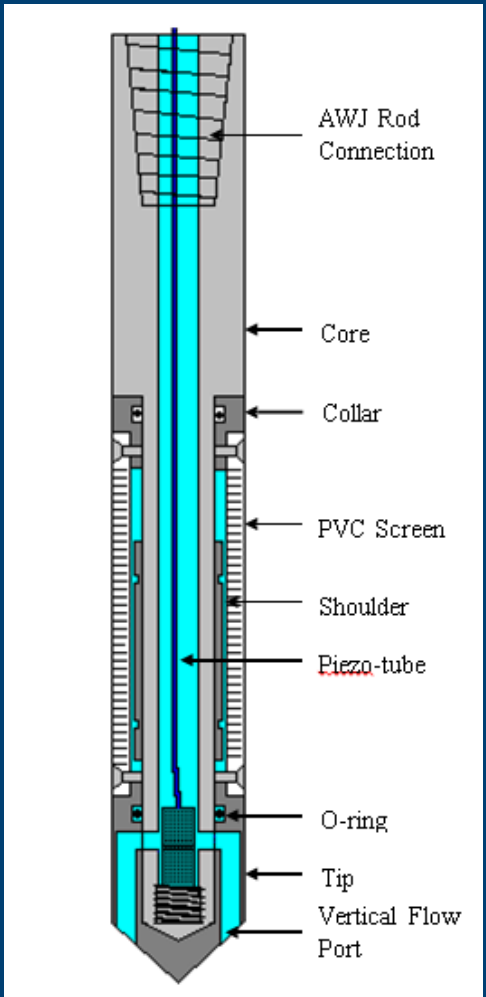
Anisotropic Permeability and Retention Ponds



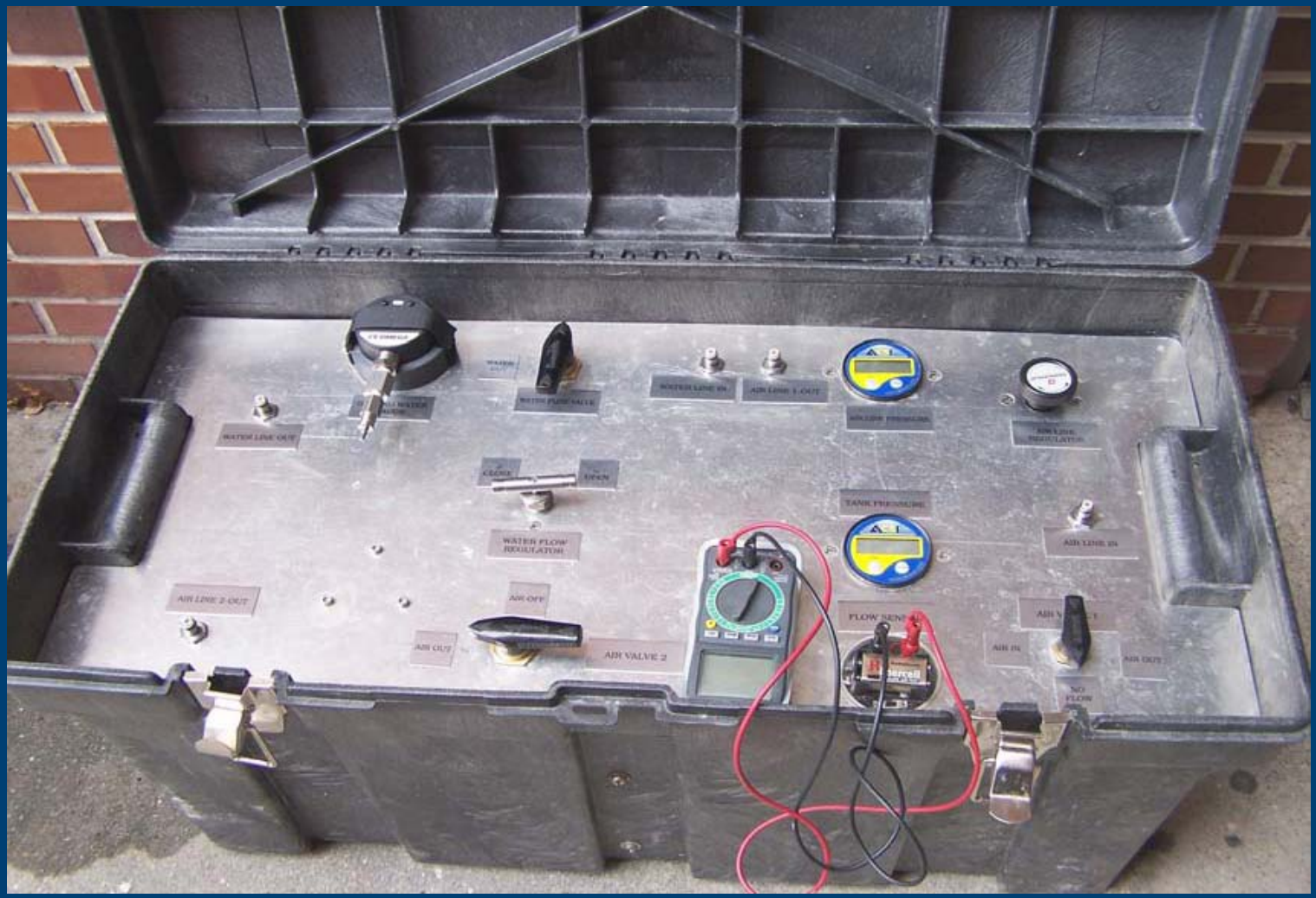
Retention Pond Drainage Schematic

- Vertical flow is function of vertical permeability coefficient (k_v)
- Horizontal flow is a function of horizontal permeability coefficient (k_h)

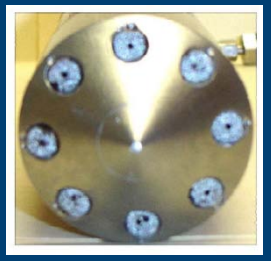
First-Generation VAHIP (2004)



First-Generation Flow System



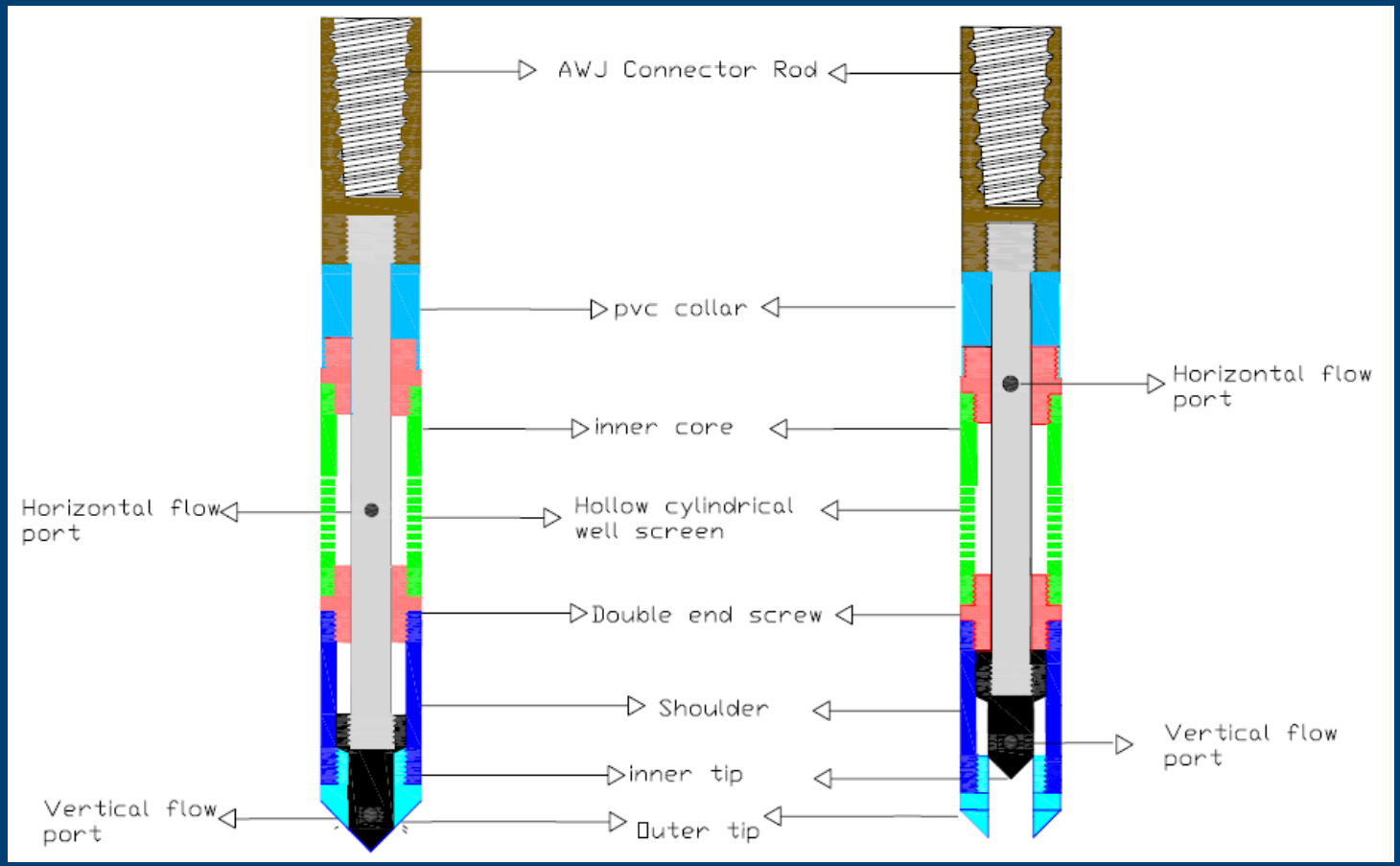
First-Generation VAHIP Updated (2005)



Second-Generation VAHIP Probe

Vertical Sediment Intrusion

Second-Generation VAHIP (2007)



Second-Generation VAHIP Schematic

Second-Generation VAHIP (2007)

Vertical Flow Position

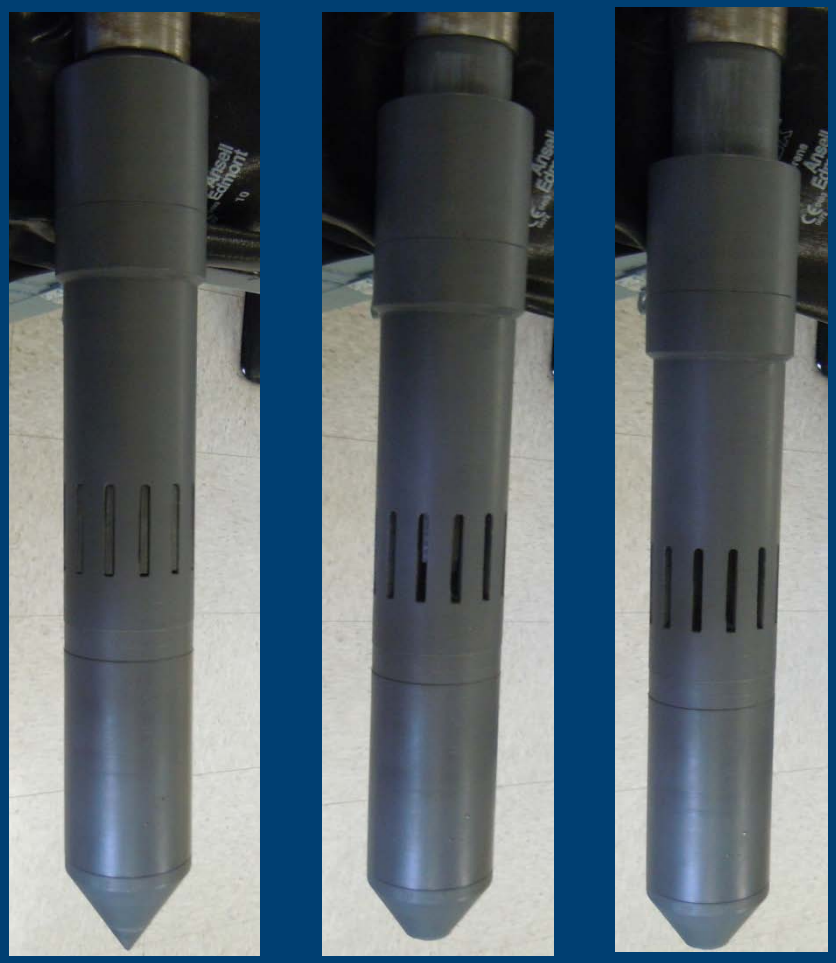
Horizontal Flow Position

Smearing and Sediment Intrusion

Second-Generation Flow System

Very Simple Falling Head Vessel

Third-Generation VAHIP (2012)



Third Generation VAHIP PVC Prototype

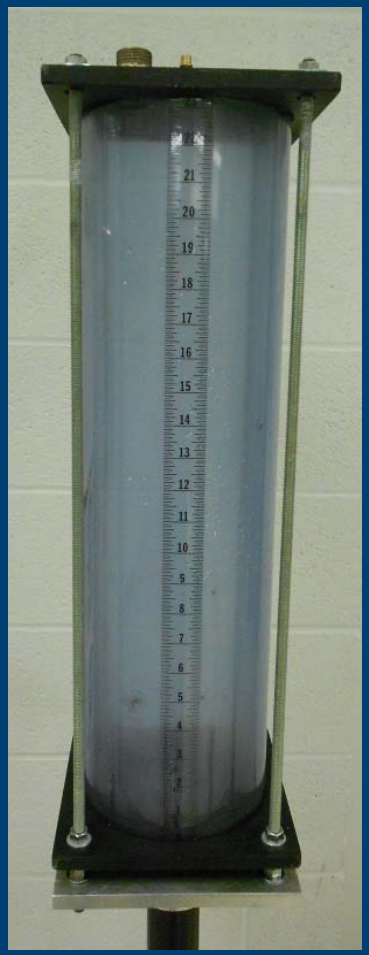
Third-Generation VAHIP and VIP (2012)

Third Generation VAHIP Probe

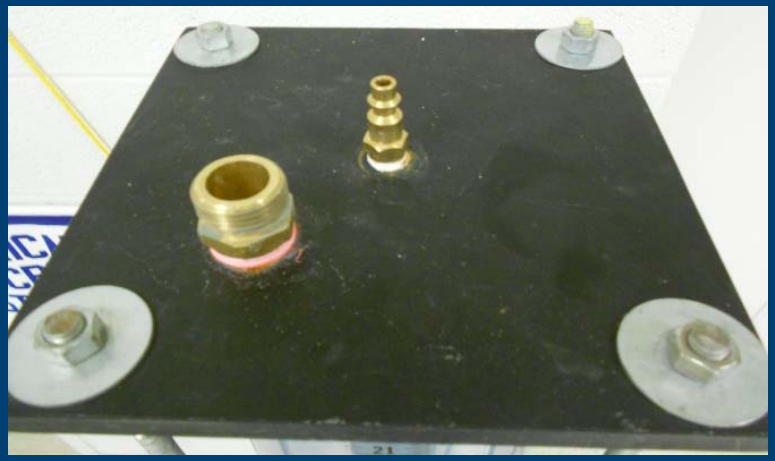
Vertical Insitu Permeability (VIP) Probe

Third-Generation Flow System

Final Falling Head Vessel



Zoomed Falling Head Tank



Top of Falling Head Tank

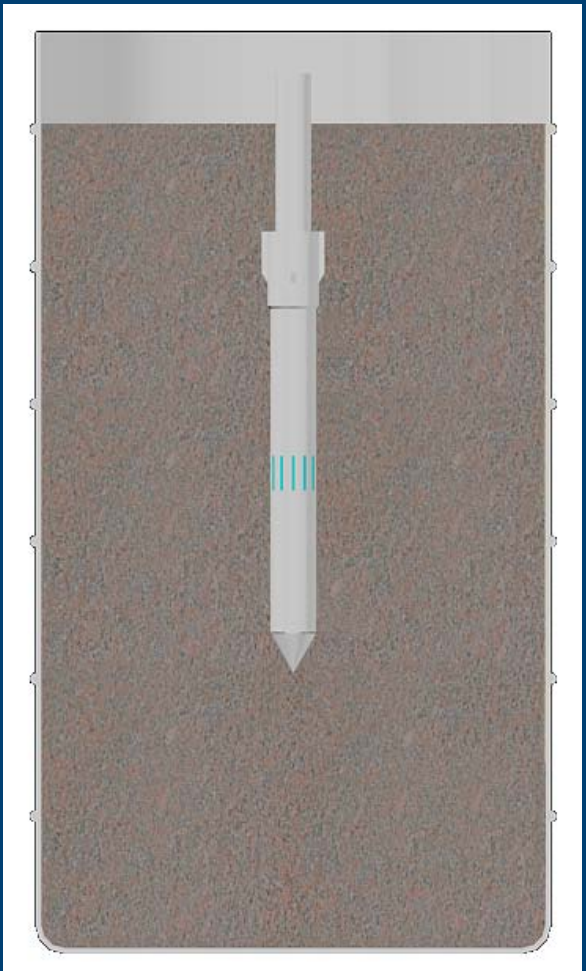
Third Generation Data Collection

VAHIP in Sand Barrel

Side View of Sand Barrel

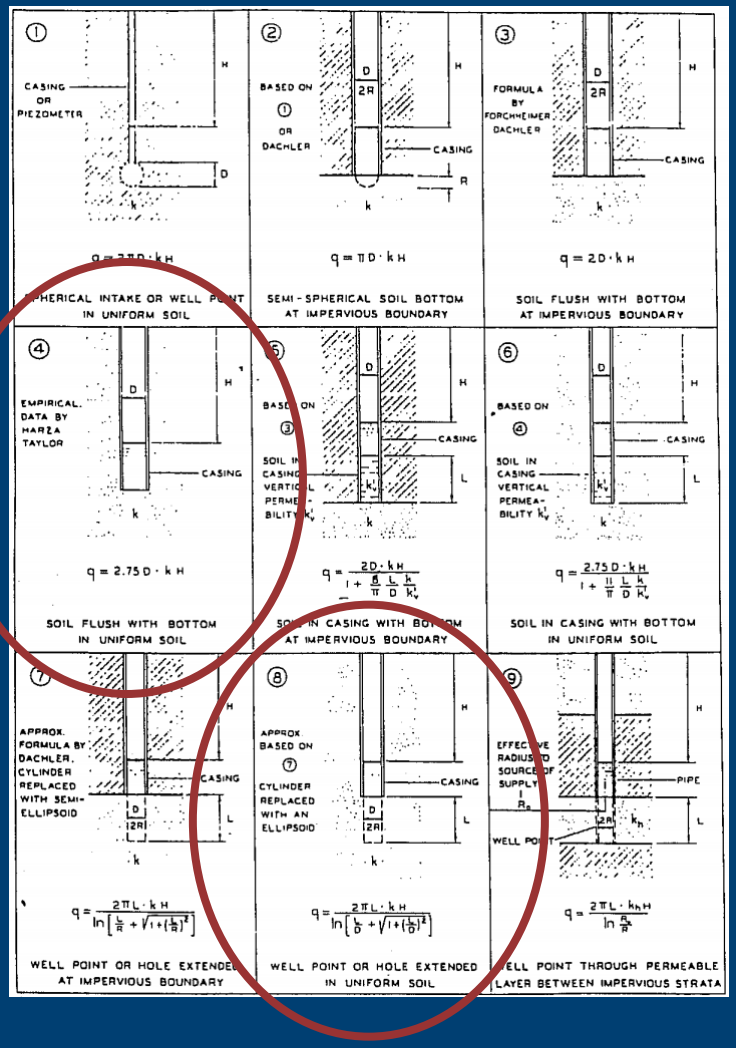
Sand Barrel Testing Soil (From Left to Right: 8/30, 20/30, and A-2-4)

VAHIP Analysis



- As W.R. Wood of Loadtest pointed out at GRIP 2011 – we can't "tell" water where to go!
- How then to ensure that "vertical" and "horizontal" flow translate to "vertical" and "horizontal" permeability coefficients?

VAHIP Analysis (Original)



$$q = kFH = \frac{\pi D_{tank}^2}{4}\left(\frac{dh}{dt}\right) \rightarrow k = \frac{\pi D_{tank}^2}{4F\Delta t}\ln\left(\frac{H_1}{H_2}\right)$$

Case 4: $F = 2.75D_{probe}$

Case 8: $$F = \frac{2\pi L}{\ln\left(\frac{L}{D_{probe}} + \sqrt{1+\left(\frac{L}{D_{probe}}\right)^2}\right)}$$

Assumptions:

1. Flow from vertical port means k in Eq. 1 can be replaced with k_V when Case 4 is used.
2. Flow from horizontal slit means k in Eq. 1 can be replaced with k_h when Case 8 is used

VAHIP Analysis Issues

- Original probes always relied on simultaneous flow for one test.
- Case 8 is for a probe with *uniform* slits *all directions*.
- Orientation-dependent flow does not necessarily correspond to orientation-dependent permeability.
- Therefore, questionable whether or not previous analysis produced accurate results.

VAHIP Reanalysis

$$F_{case8} = \frac{2\pi L}{\ln\left(\frac{mL}{D}+\sqrt{1+\left(\frac{mL}{D}\right)^2}\right)}$$

$$F_{case4} = 2.75D$$

$$F_{VAHIP_h} = \frac{2\pi L}{\ln\left(\frac{mL}{D_h}+\sqrt{1+\left(\frac{mL}{D_h}\right)^2}\right)} - \frac{2.75D_h}{m}$$

$$F_{VAHIP_v} = 2.75D_v m$$

$$q_{case8} = F_{case8} k_h H$$

$$q_{case4} = F_{case4} k_m H$$

$$q_{VAHIP_h} = F_{VAHIP_h} k_h H \rightarrow k_h = \frac{\pi D_{tank}^2}{4F_{VAHIP_h}\Delta t} \ln\left(\frac{H_{1h}}{H_{2h}}\right)$$

$$q_{VAHIP_v} = F_{VAHIP_v} k_v H \rightarrow k_v = \frac{\pi D_{tank}^2}{4F_{VAHIP_v}\Delta t} \ln\left(\frac{H_{1v}}{H_{2v}}\right)$$

$$k_m = \sqrt{k_v k_h} = m k_v = k_h / m$$

VAHIP Reanalysis

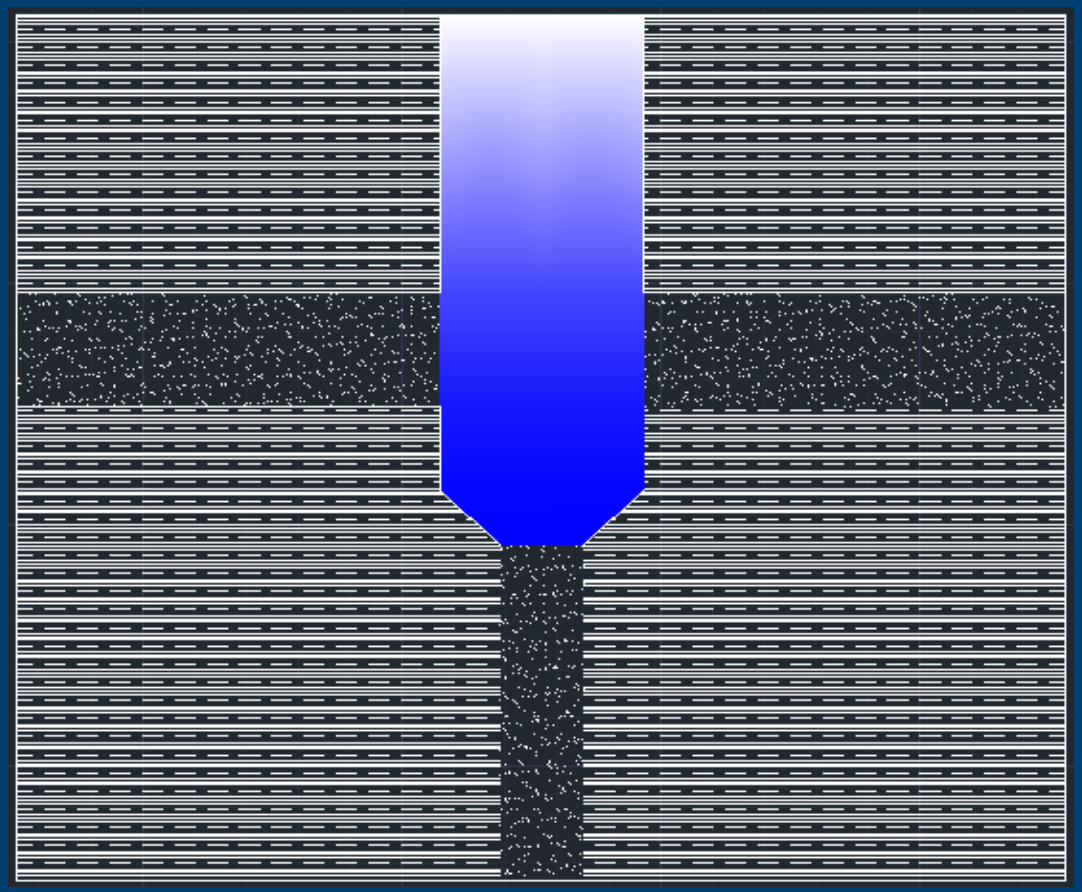
- Data Failed to Converge!

- Explanations:
  - Vertical shape factor (i.e. 2.75) is empirical.
  - Horizontal shape factor for large *L/D.*
  - Horizontal shape factor developed for approximately infinite horizontal slits.

Conclusions

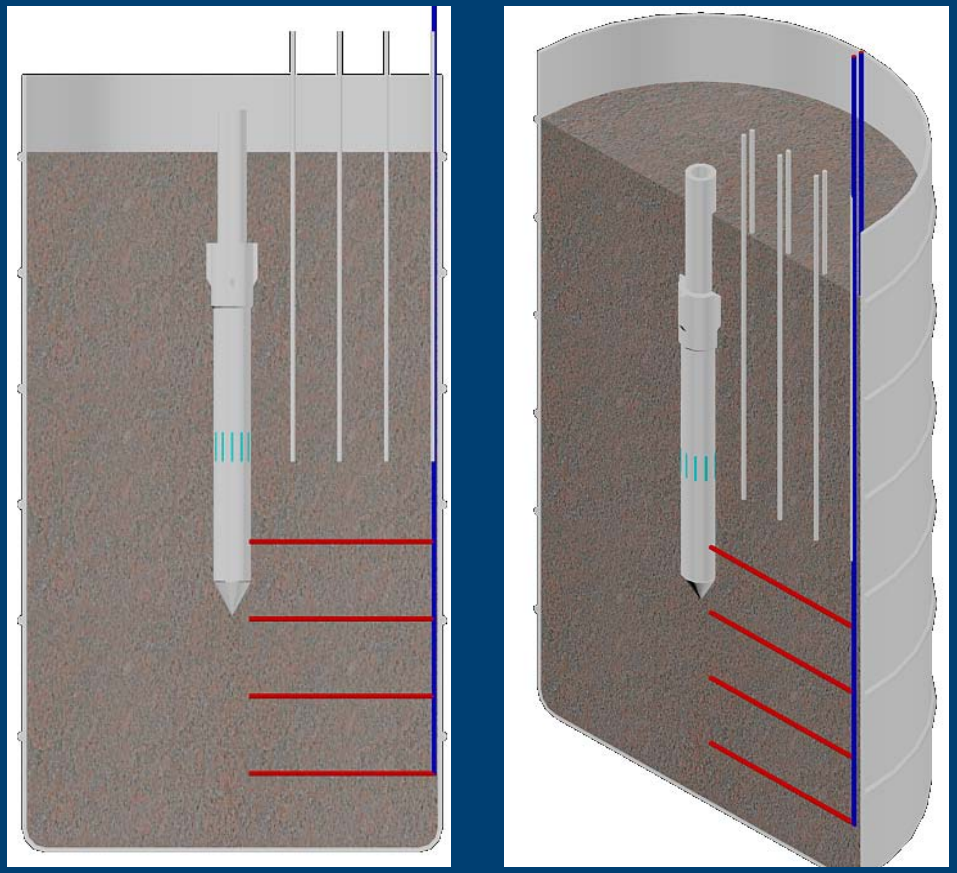
- Mechanics of VAHIP appear to function as designed.
- More research must be conducted to ensure proper orientation-dependent analysis.
- VIP-style device should suffice in the interim since this is both “smear-proof” and capable of giving average permeability.

VAHIP Reanalysis – Flow-Limiting Approach



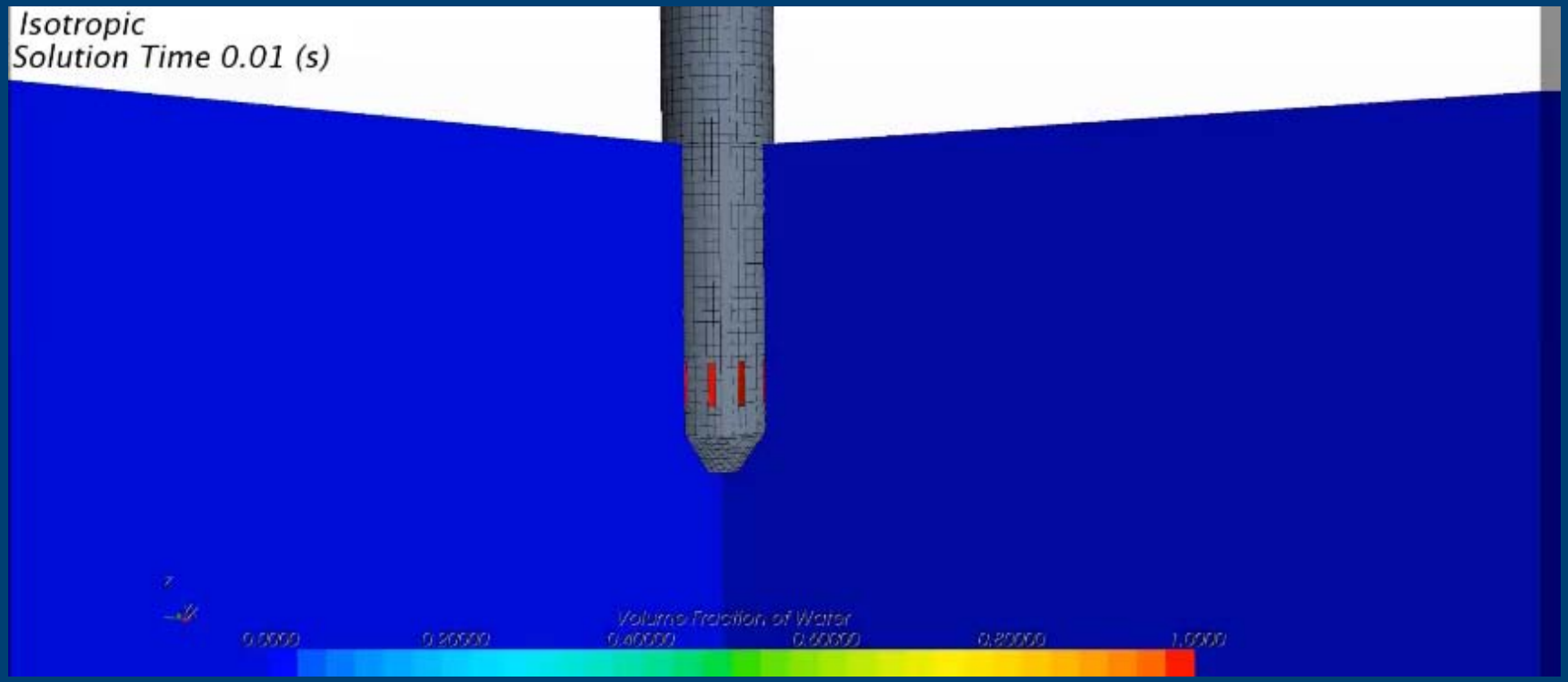
VAHIP Flow-Limiting Schematic

VAHIP Reanalysis – Flow-Tracking Approach

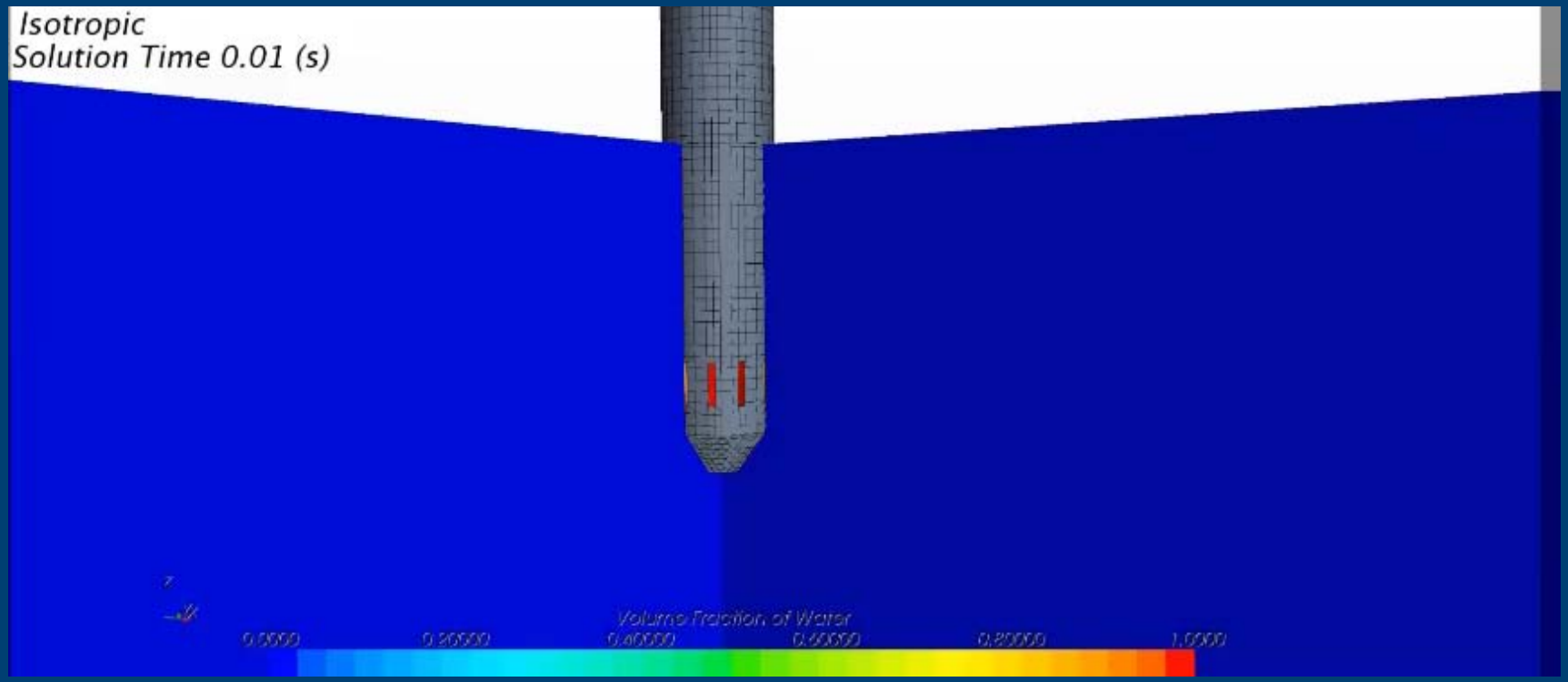


VAHIP Flow-Tracking Schematic

VAHIP Reanalysis – CFD Approach



VAHIP Reanalysis – CFD Approach



Questions?