

# DEVELOPMENT OF A SMEAR-PROOF HORIZONTAL AND VERTICAL PERMEABILITY PROBE

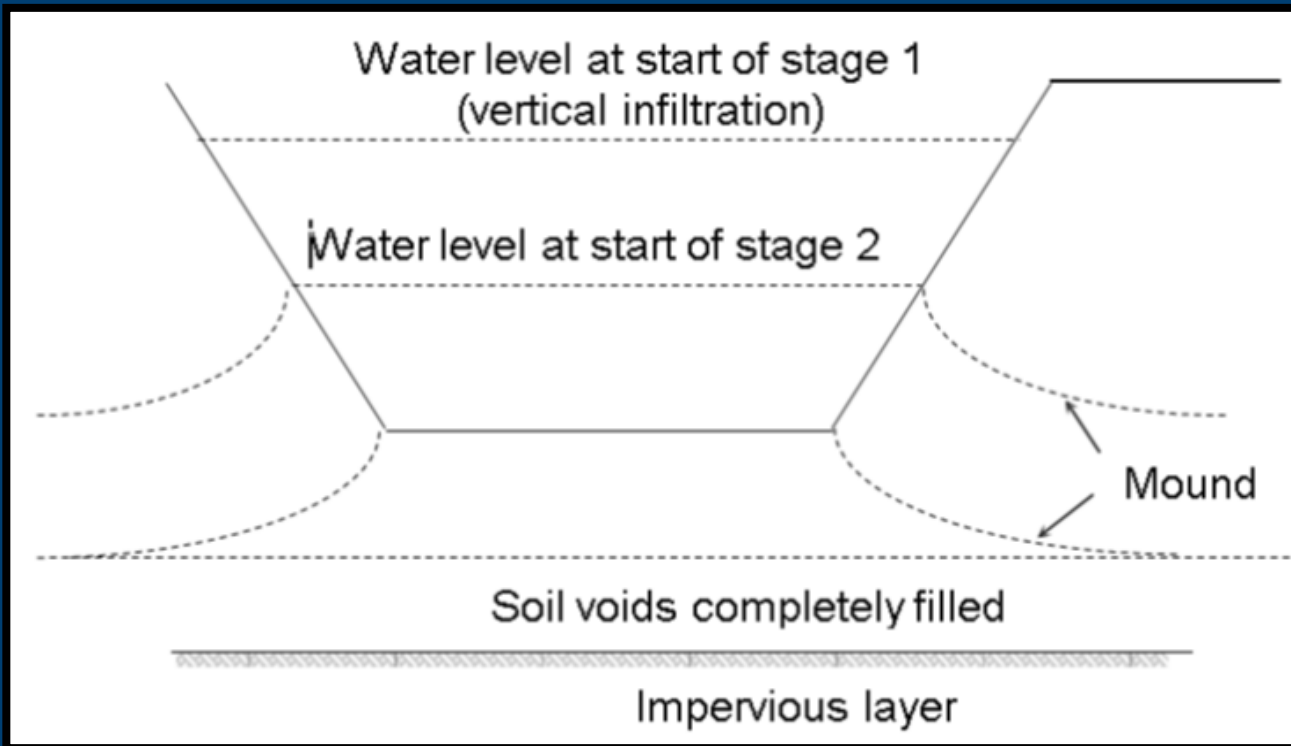
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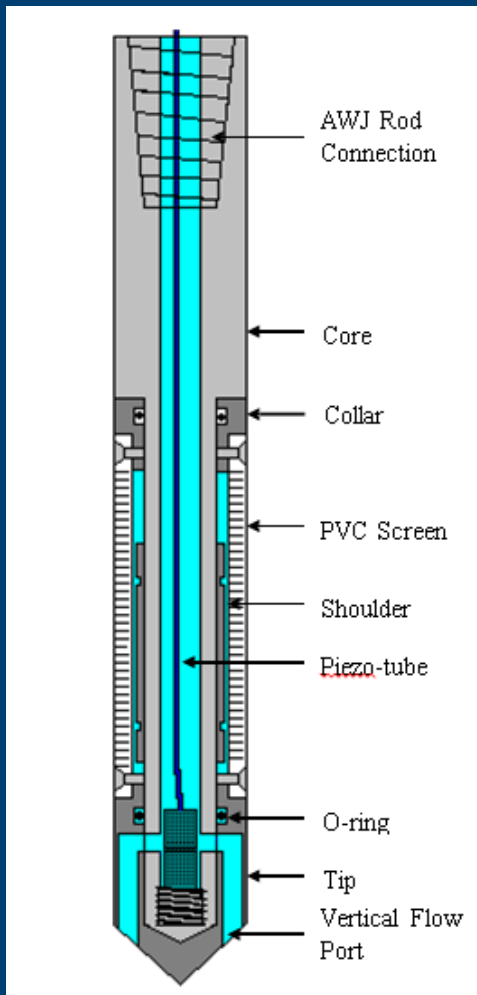
# Anisotropic Permeability and Retention Ponds



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 VAHIP Updated (2005)

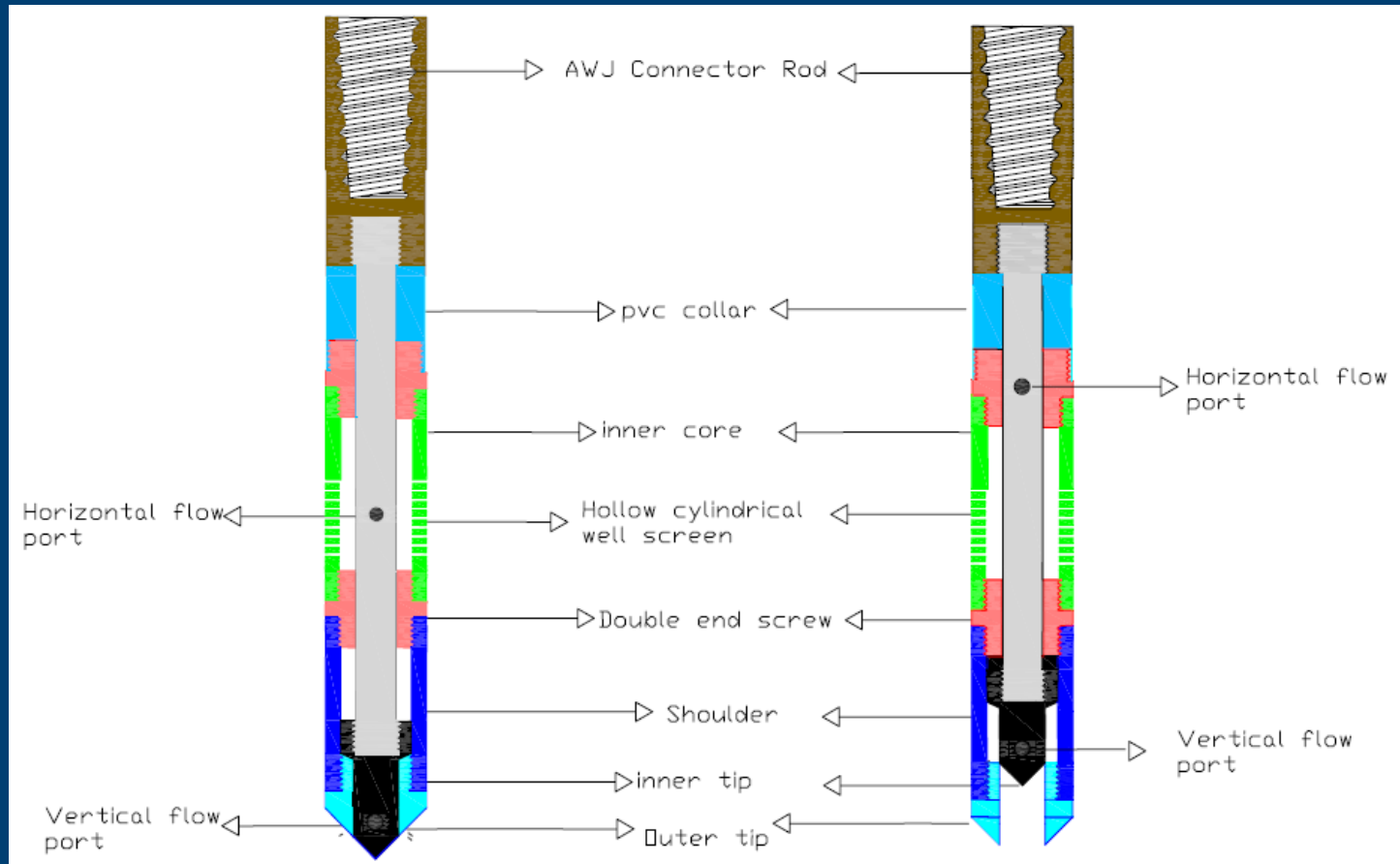


Second-Generation VAHIP Probe



Vertical Sediment Intrusion

# Second-Generation VAHIP (2007)



Second-Generation VAHIP Schematic

# Second-Generation VAHIP (2007)



**Vertical Flow  
Position**



**Horizontal  
Flow Position**



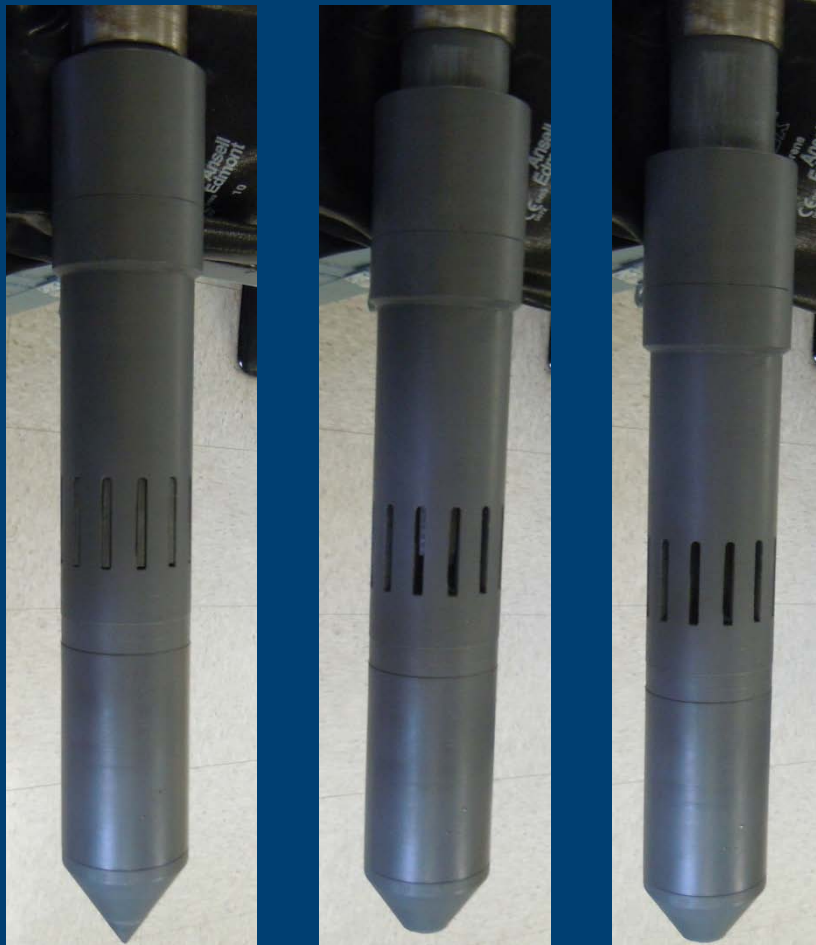
**Smearing and  
Sediment  
Intrusion**

# 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**

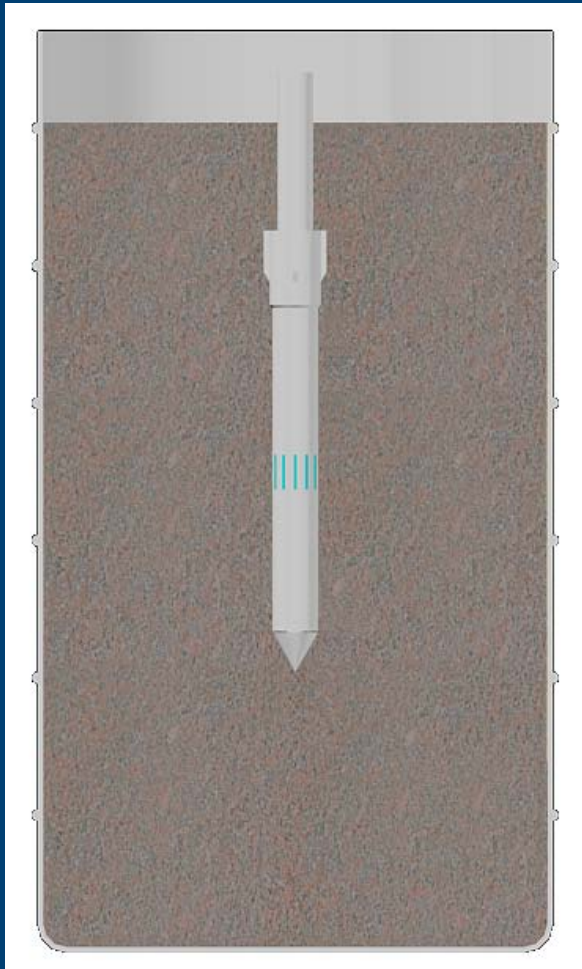


**Side View of Sand Barrel**



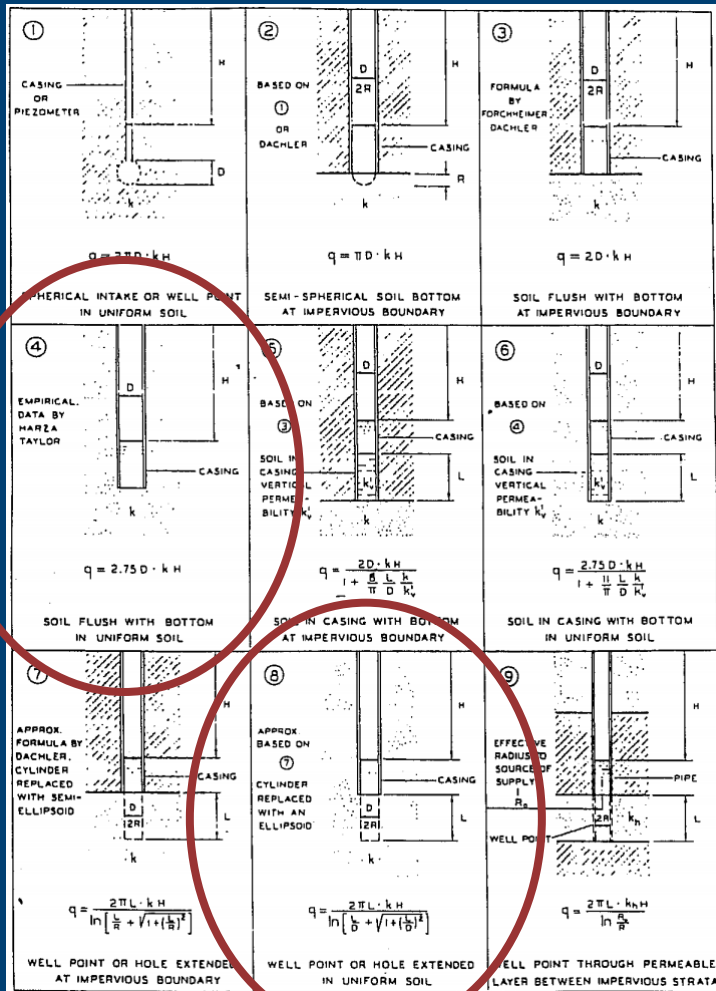
**Sand Barrel Testing Soil (From Left to Right: 8/30, 20/30, and A-2-4)**

# 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

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

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

$$F_{case4} = 2.75D$$

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

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

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

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

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

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

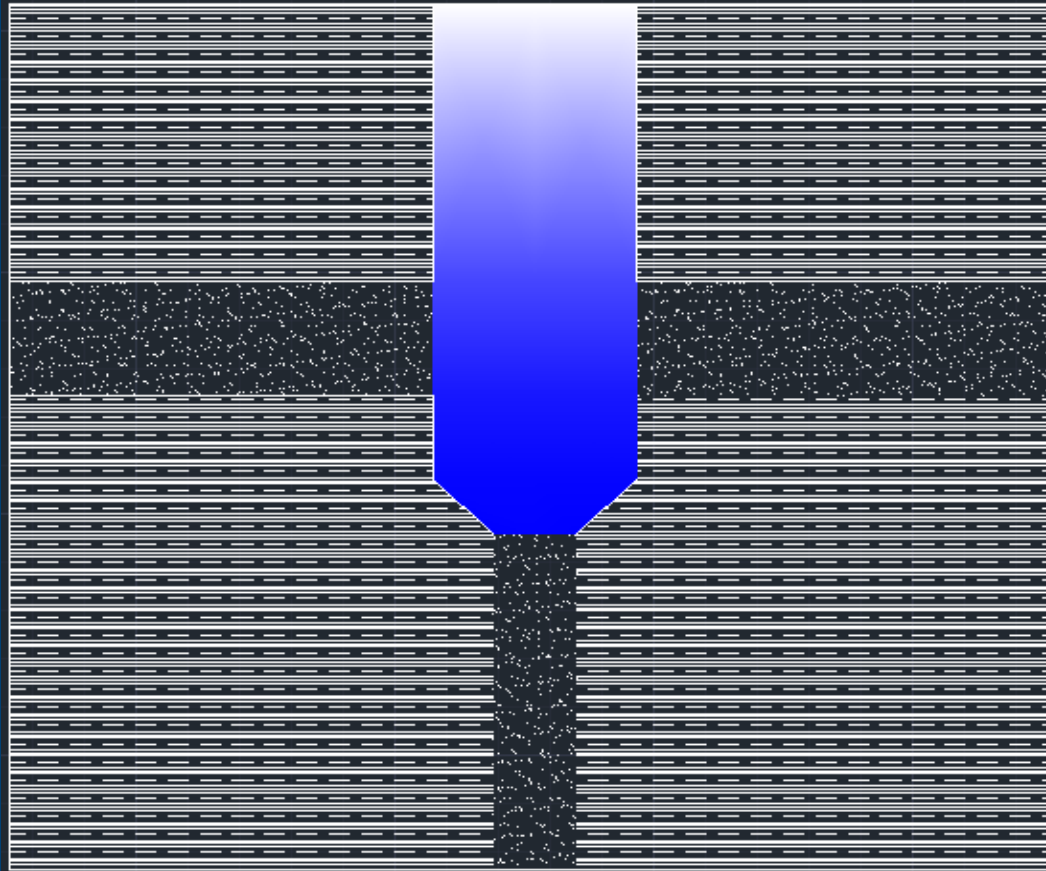
# VAHIP Reanalysis

- 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

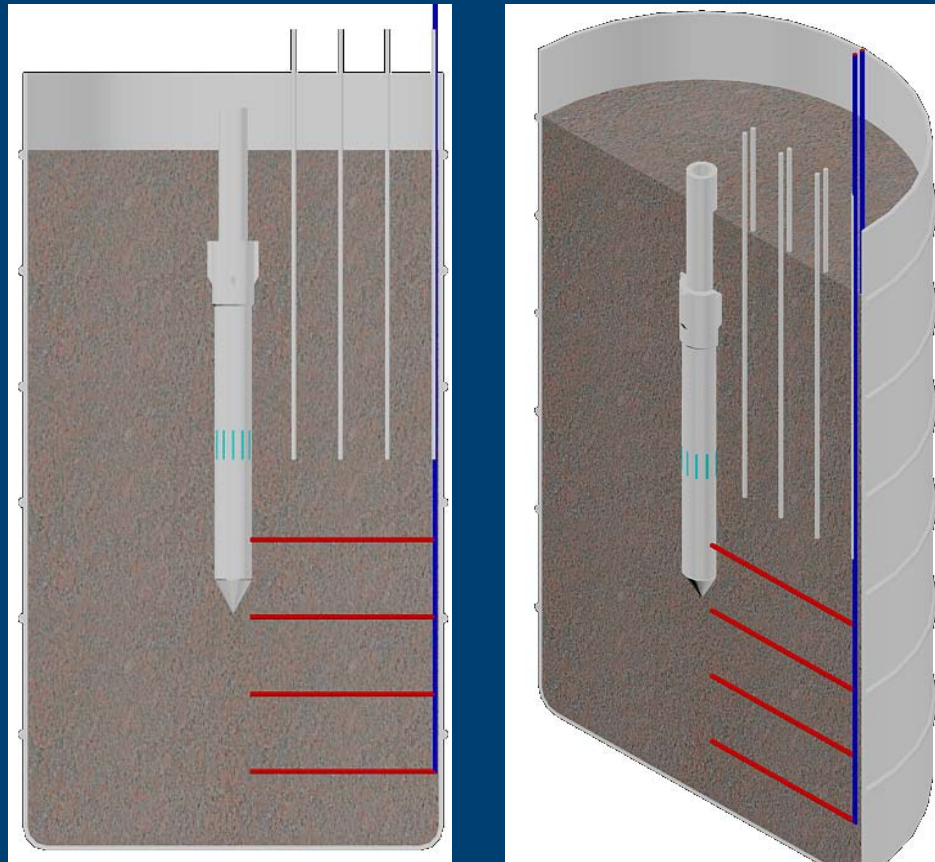
- Mechanics of VAHIP appear to function as designed.
- More research must be conducted to ensure proper orientation-dependent analysis.
- VIP-style device should suffice in the interim since this is both “smear-proof” and capable of giving average permeability.

# VAHIP Reanalysis – Flow-Limiting Approach



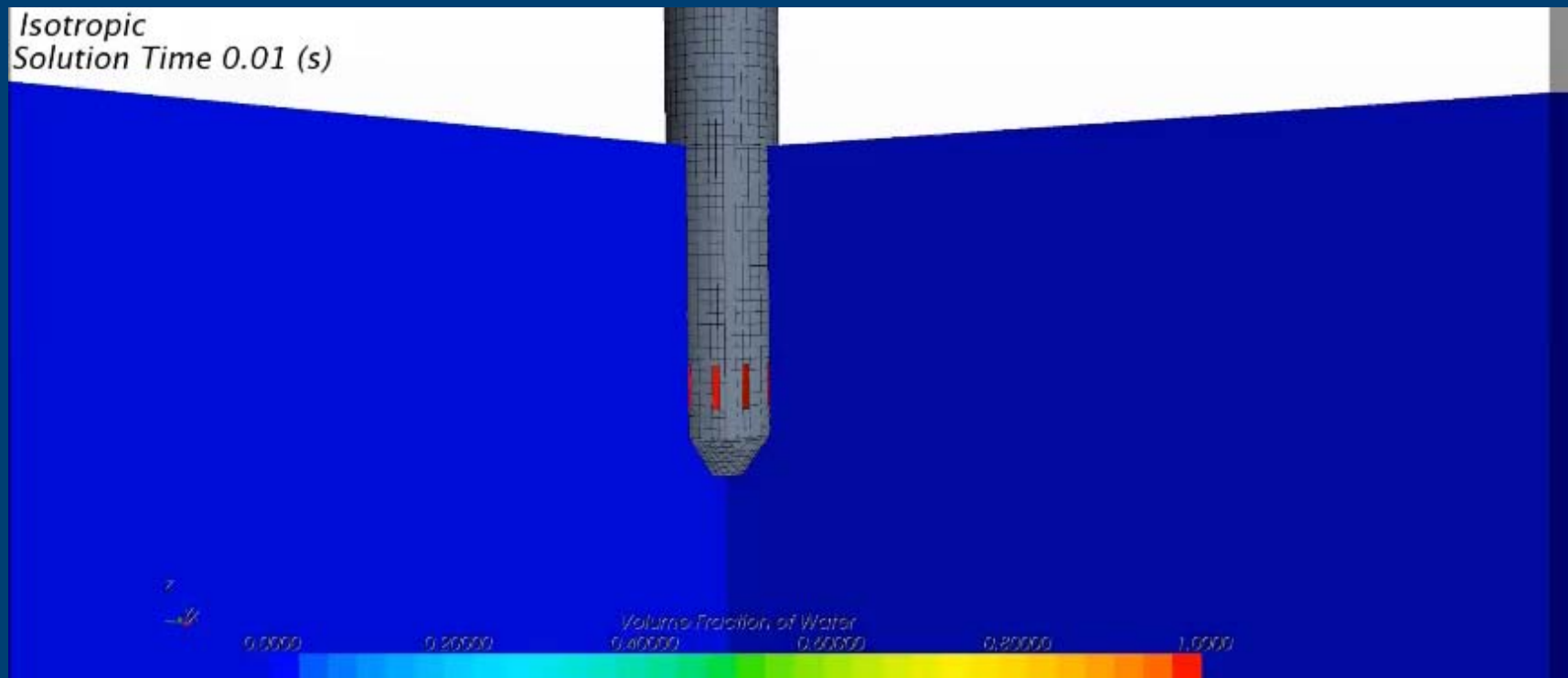
VAHIP Flow-Limiting Schematic

# VAHIP Reanalysis – Flow-Tracking Approach

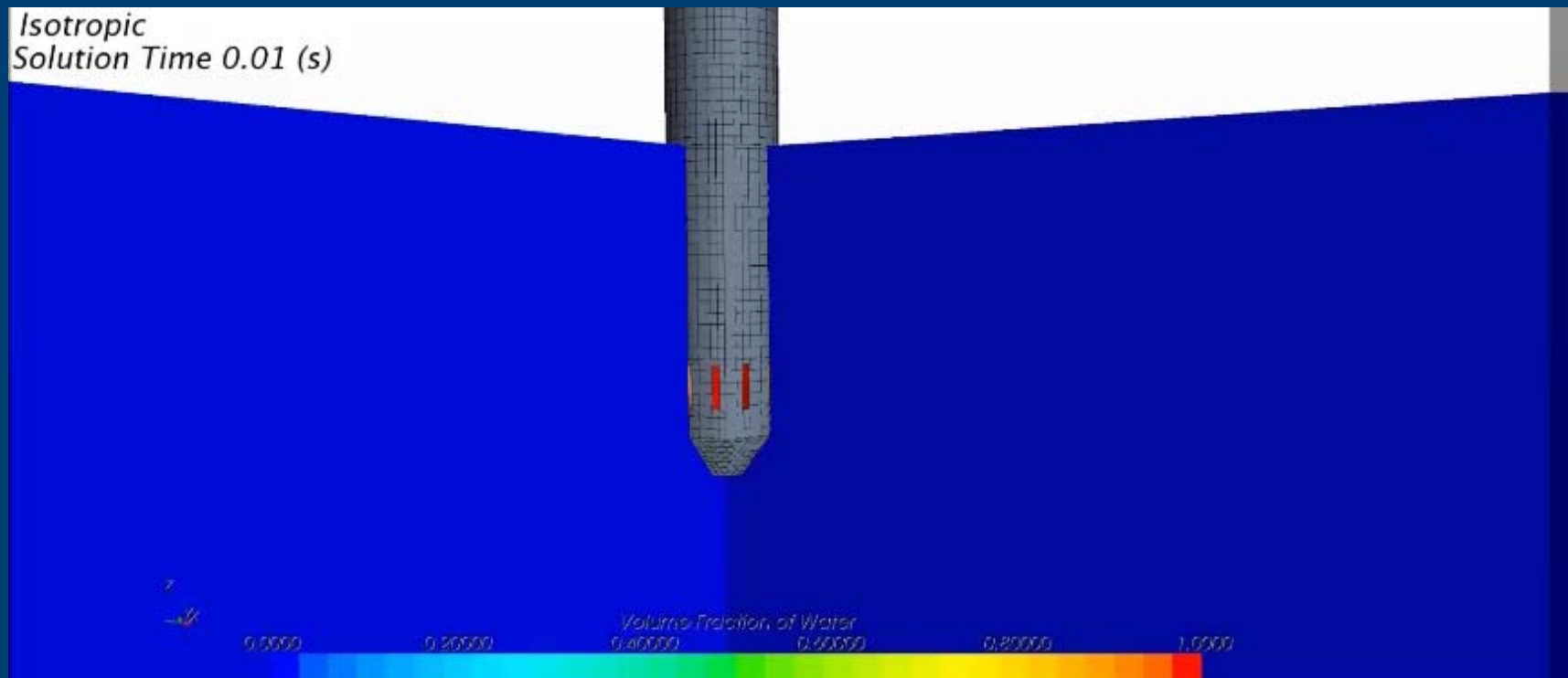


VAHIP Flow-Tracking Schematic

# VAHIP Reanalysis – CFD Approach



# VAHIP Reanalysis – CFD Approach



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Questions?

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