FIELD TESTING AND CALIBRATION OF THE VERTICAL INSITU PERMEAMETER (VIP)

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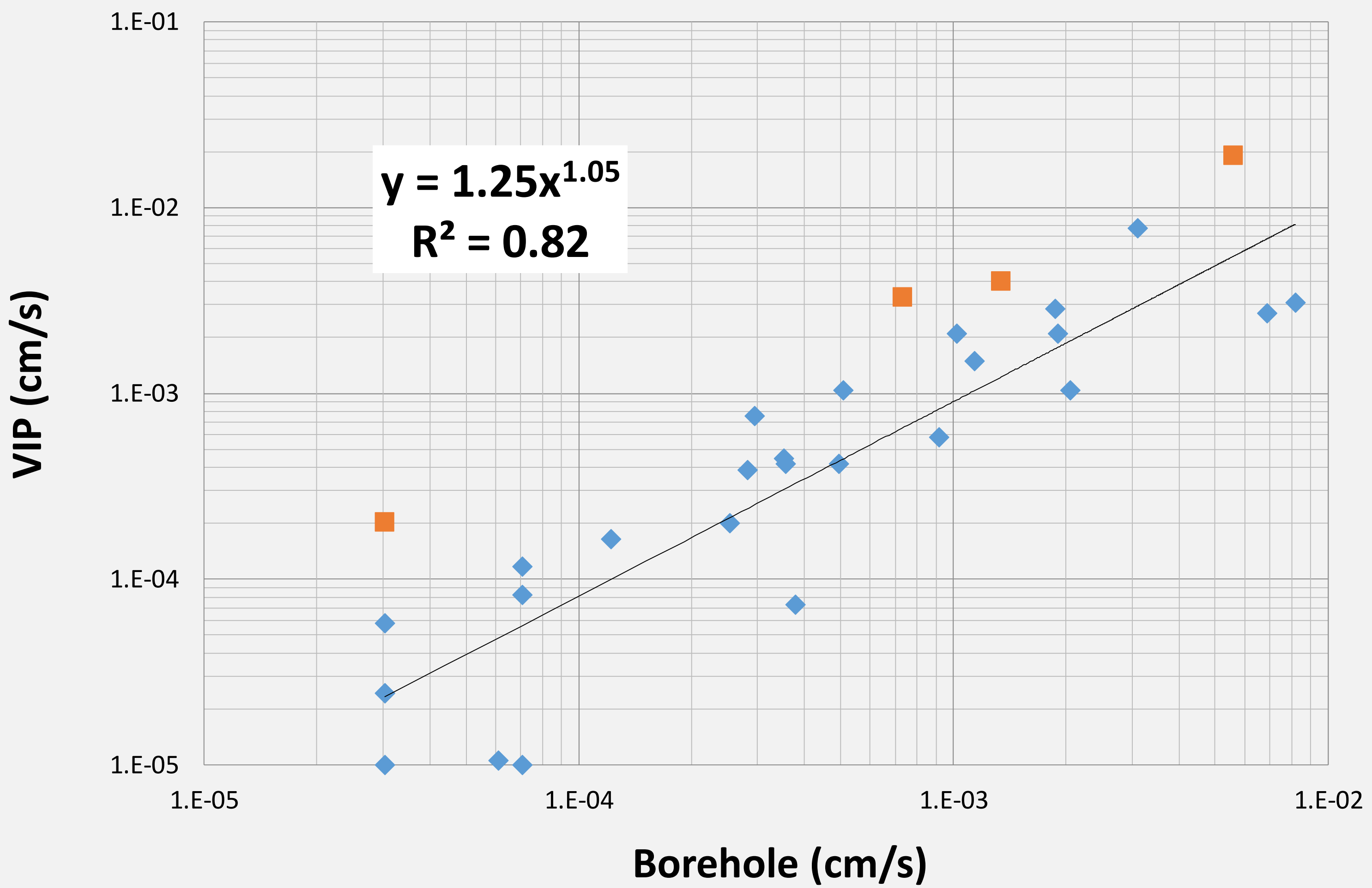
VIP PROJECT OBJECTIVE

- Implement a simple field procedure for **measuring hydraulic conductivity**
- Develop simple and theoretically consistent equations for VIP data interpretation
- Conduct **field testing of VIP** at multiple sites for validation
- Perform empirical data analyses comparing VIP data with **independent field permeability data**
- Performed tasks:
  - Literature review
  - Site identification
  - VIP testing
  - Data analyses and validation against independent borehole measurements

SUMMARY OF DATA

- VIP measurements
  - 4 sites, 104 tests, 72 depths
  - Permeability range: 1×10^{-5} – 2×10^{-2} cm/s
- Consultant/FDOT measurements
  - Various field methods
    - Uncased/cased & constant/falling head
  - Multiple equations
- Comparison
  - 47 comparisons by depth/soil type
    - 17 outside an order of magnitude
      - 9 no flow conditions
      - 4 in Panama City
      - Remaining 4 attributed to spatial variability in soil

COMPARISON OF VIP & BOREHOLE PERMEABILITY DATA



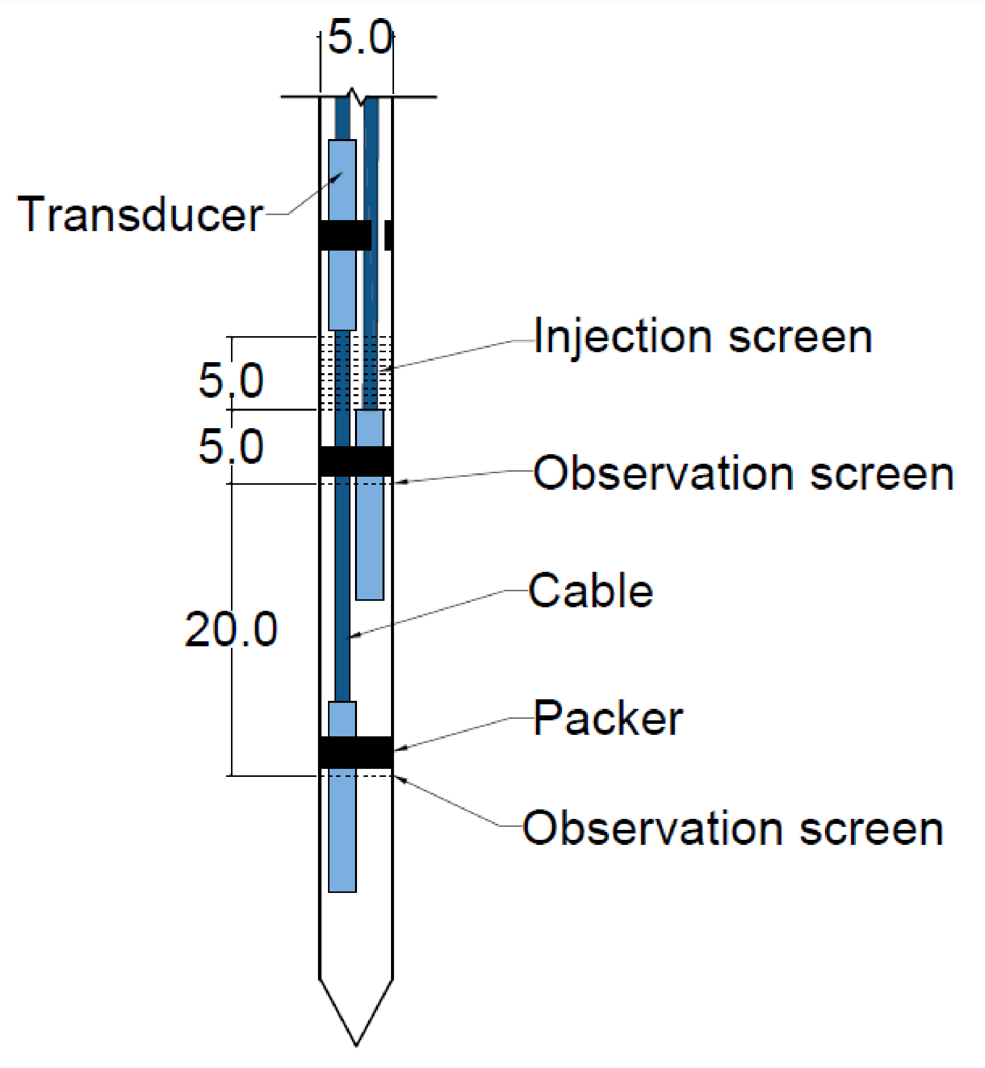
CONCLUSOINS FROM VIP FIELD TESTING

- Delivers some **"average" conductivity** $k_m = (k_h k_v)^{1/2}$
  - $k_m = \frac{\pi d^2}{4F(t_f - t_i)} ln \frac{H_i}{H_f}$
  - Based on falling head test
- Results were found to be **comparable to independent borehole measurements**, which are more time-consuming
- **Ready for field application**
- Possibilities to simplify design (eliminating probe rotation)
- Possibilities to increase efficiency (flexible saturation period)

MOVING FORWARD – VAHIP 2.0

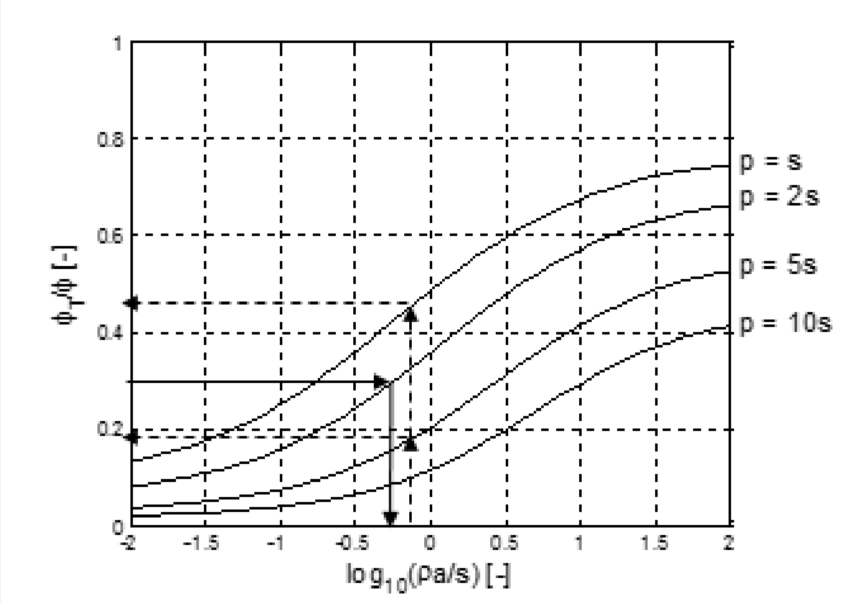
- Advances in flow theory provide potential for **estimating vertical and horizontal permeabilities k_v and k_h under saturated conditions**
- **Simple** mechanical design (no more moving parts)
- **Automated** data acquisition using pressure transducers (no hand readings)
- Potentially capable of reaching **greater depths** (no lateral wings)
- Potentially **insensitive to smearing and compaction** near probe surface
- Test interpretation above the water table (unsaturated zone) remains as before

PROBE DESIGN



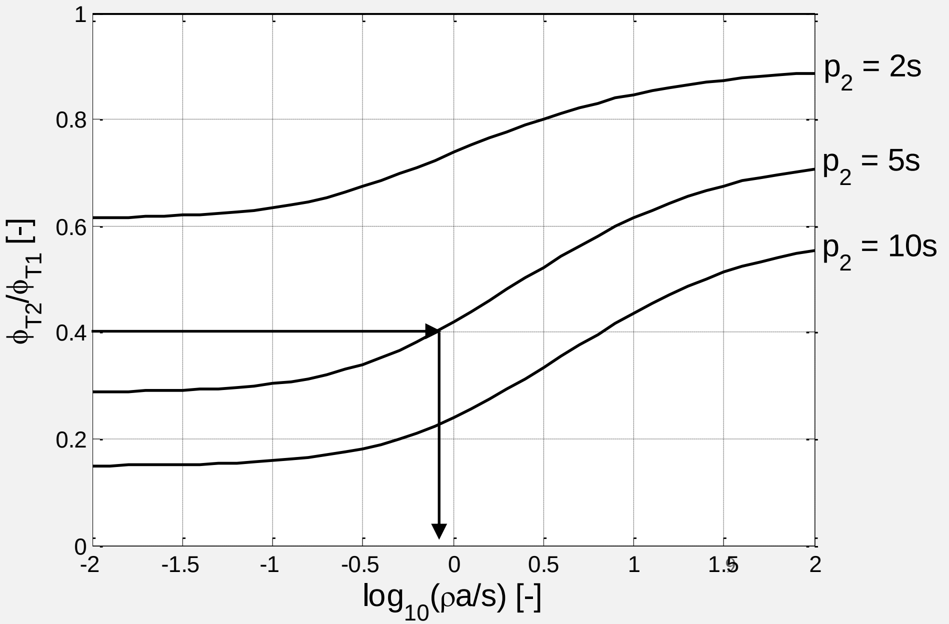
FUNDAMENTAL IDEA

- **Two independent pieces of information** are needed to estimate two parameters k_h and k_v
- Previous VAHIP designs used subsequent injections through lateral screen and probe tip
- Here we use single **injection through lateral screen with head observation along the probe**
- The ratio of observation head and injection head only depends on the anisotropy ratio k_v/k_h
- Knowing k_v/k_h, injection flow rate and injection head are used to estimate k_h and subsequently k_v



ADDITIONAL HEAD OBSERVATION

- The ratio of two head observations along the probe only depends on k_v/k_h and is **independent of possible clogging at the injection screen**
- Possible (partial) **clogging of observations screens should not matter**, because flow through them is zero
- Observation heads and k_v/k_h can be used to estimate effective injection head (after screen losses)
- As before, knowing k_v/k_h, injection flow rate and effective injection head are used to estimate k_h and subsequently k_v



PRESSURE TRANSDUCERS

- RST Instruments (vibrating wire technology)
- Range 3.5 bar (35 m water column)
- Accuracy 0.1 %
- Diameter 19 mm, length 130 mm, weight 115 g
- Material stainless steel
- Price ~ 500 $ (including 13 m of armored cable)

DATA LOGGER

- Logs all transducers simultaneously (cable connection through rods)
- No more hand readings (injection head can be below ground surface)
- Battery powered
- Optional wireless antenna
- Comes with Windows software
- Robust weather resistant
- Sampling every 10 seconds (or more)
- Price ~ 1200 $

REAL-TIME VISUALIZATION & DATA INTERPRETATION

- Data transmission by cable or wireless:
  - Directly to laptop, or
  - Ultra Rugged Field PC^2 (~ 1850 $)
- Real-time visualization
  - Location of water table
  - Identify mal-functioning /anomalies
  - Indicates end of test by showing when injection slug has dissipated or when steady-state injection is reached
- Convenient data interpretation using pre-programmed Excel templates, for example

DATA TRANSMISSION TO SURFACE

(Foto from Geoprobe)

- Armored cable containing all wires runs through a number of rods predetermined for VAHIP testing
- Need some kind of removable end piece on driving rods to allow for cable during driving

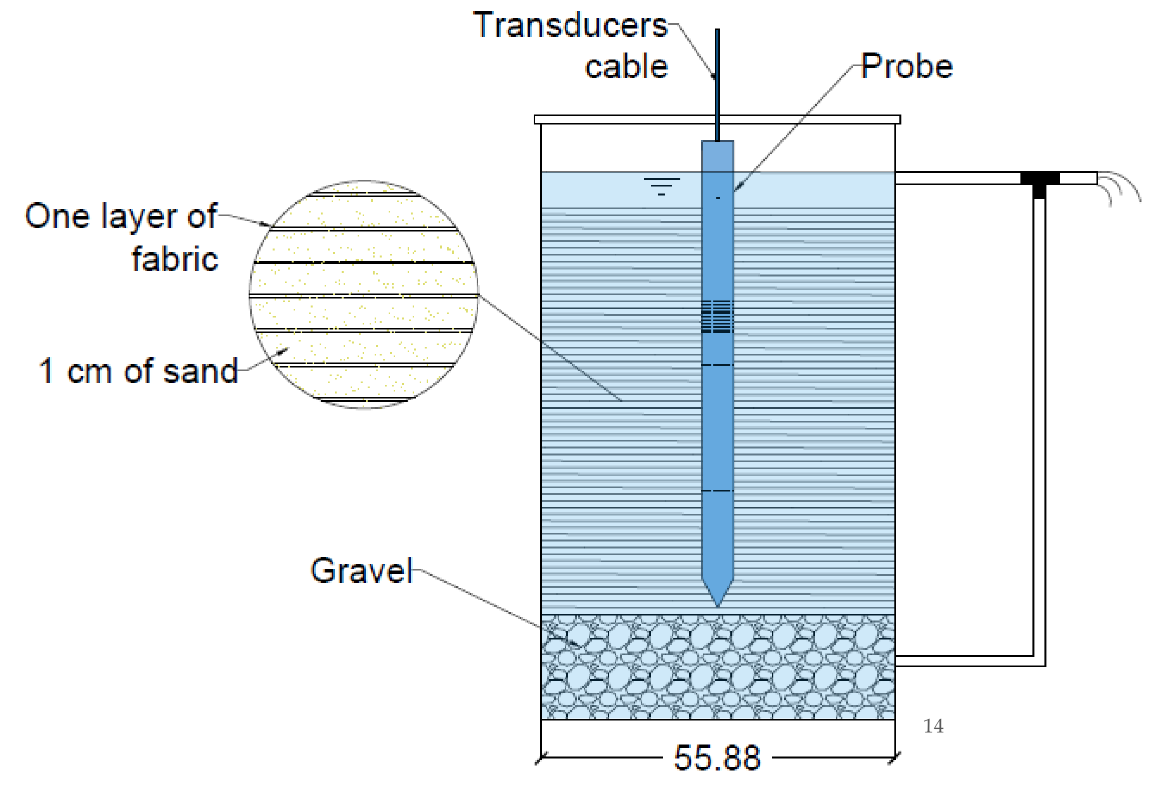
LABORATORY TESTING

- Laboratory tests in a **layered sand barrel** will be conducted to verify the functionality of the data acquisition system under **controlled saturated conditions**

$$k_h = \frac{d_{sand} k_{sand} + d_{farbic} k_{fabric}}{d_{sand} + d_{farbic}}$$

$$k_v = \frac{d_{sand} + d_{farbic}}{\frac{d_{sand}}{k_{sand}} + \frac{d_{farbic}}{k_{fabric}}}$$

$$k_h \geq k_v$$



UPCOMING TASKS

- Create **construction plans of probe**
- **Manufacture PVC prototype** and adjust injection mechanism according to conclusions from laboratory testing (constant flow, constant head, or falling head)
- **Test PVC prototype** and injection mechanism in DOT test pit using layers of high and low conductivity sand to emulate anisotropic conductivity
- **Manufacture steel probe**
- **Test steel probe** in DOT test pit

SUMMARY

- **VIP has been successfully field demonstrated** and validated at four DOT sites
- **New VAHIP design** is under development having potential to
  - Separately measure horizontal and vertical conductivities under saturated conditions
  - Reduce mechanical complexity of probe
  - Advance to larger depths
  - Be largely insensitive to smearing and compaction
  - Provide fully automatic data acquisition
- New crucial probe components for recording pressures have been selected and preliminary laboratory testing is about to start
- Prototype PVC and final steel probes will be designed, manufactured and tested at DOT test pit