

Liners and Packers: similarities and differences

By

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At

NGWA/EPA Fractured Rock Conference
Portland, Maine
September, 2007

More explicitly:

A comparison of the flexible liner method and the straddle packer method of hydraulic conductivity measurement.

A comparison of the concept and theory rather than an extensive comparison of the results

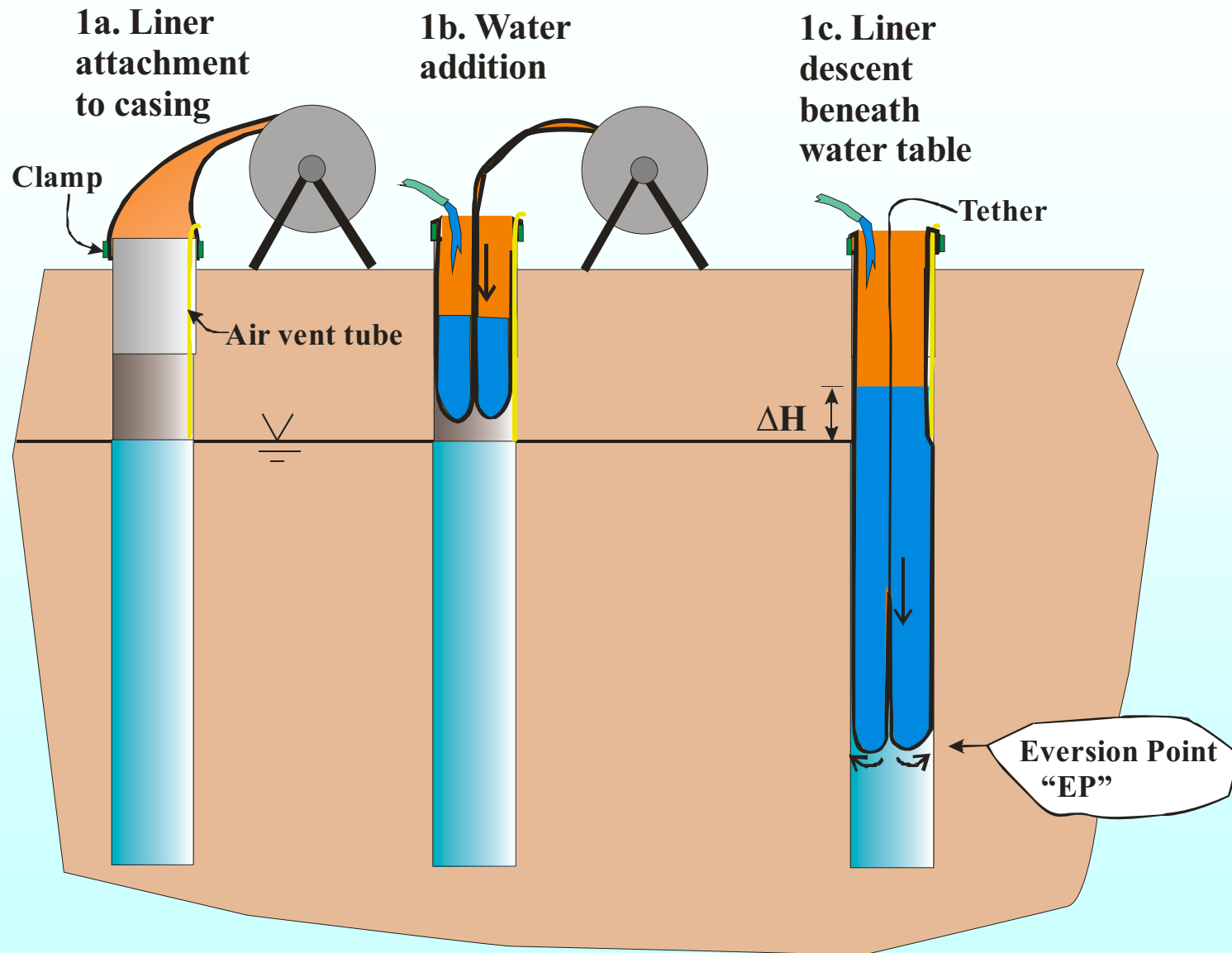
Topics

- Hydraulic conductivity profiling objectives
- The liner approach
- The straddle packer approach
- Method similarities
- Method differences
- Comparison of results
- Conclusion

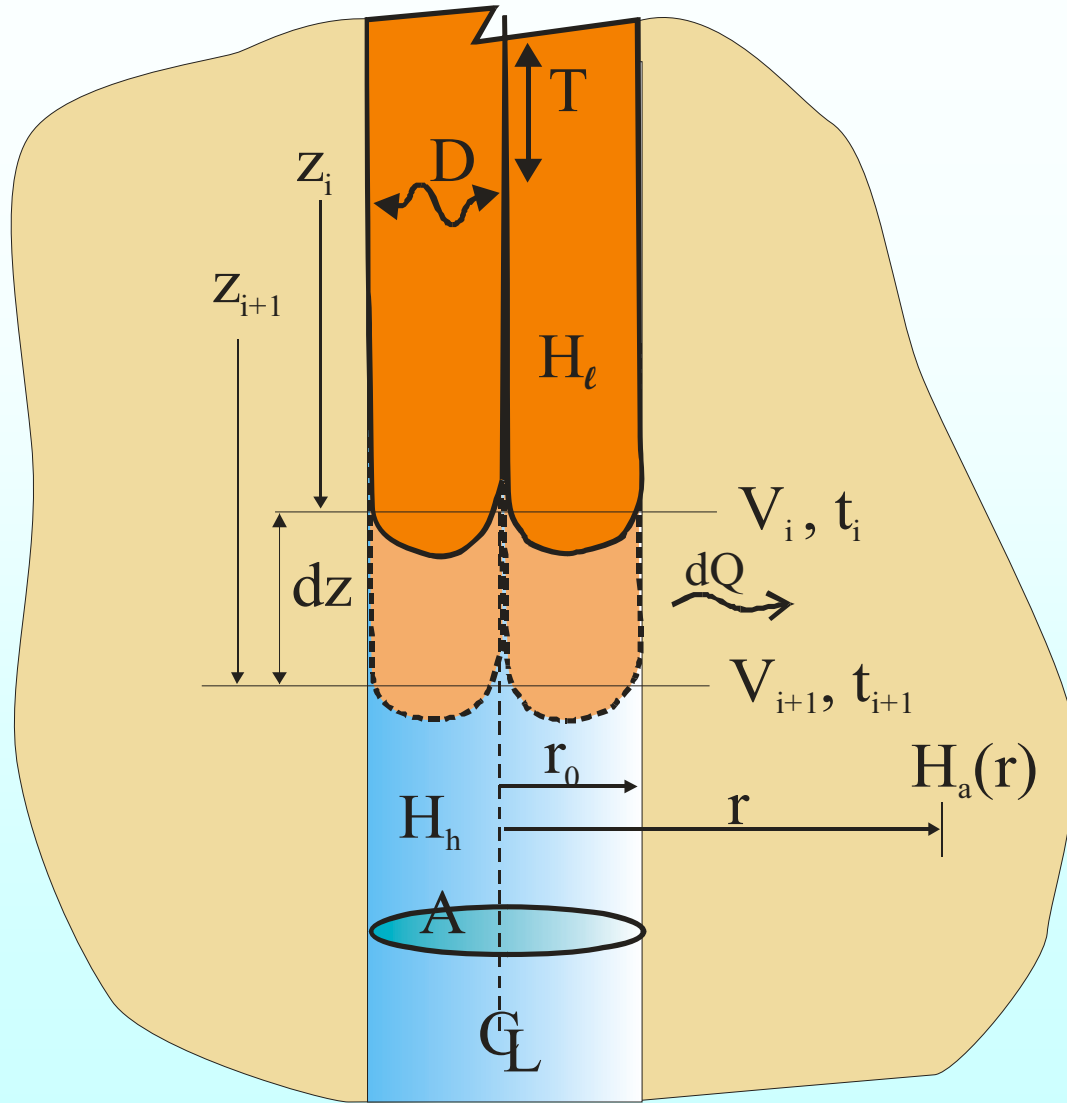
The objective of the measurements

- Primary objective: map the flow paths in both location and flow capacity as they intersect the borehole and are relevant to the local transport of water and contaminants
- A second objective of some packer testing is mapping of contaminant distribution

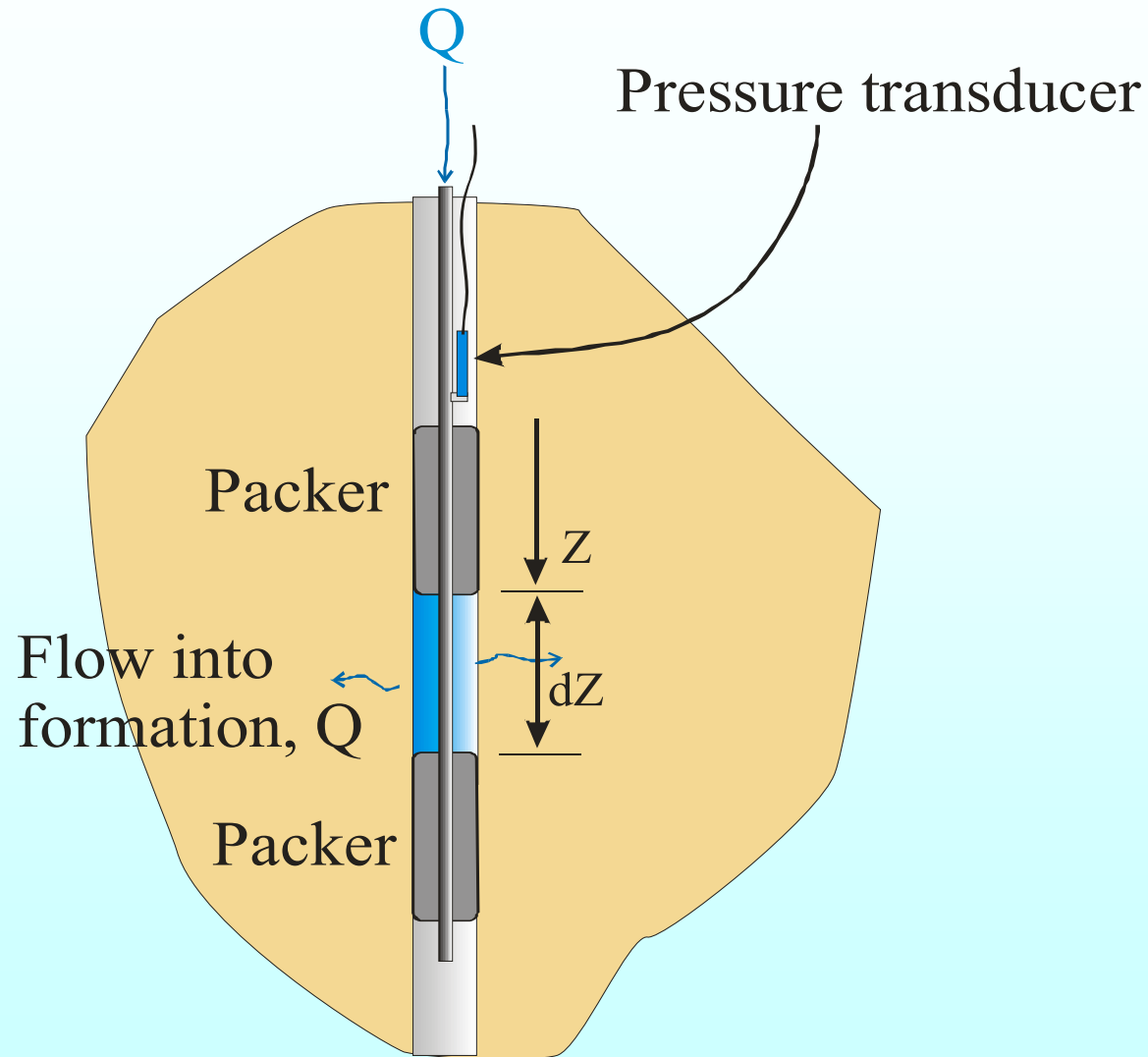
How the liner works



Liner terminology



How the straddle packer works



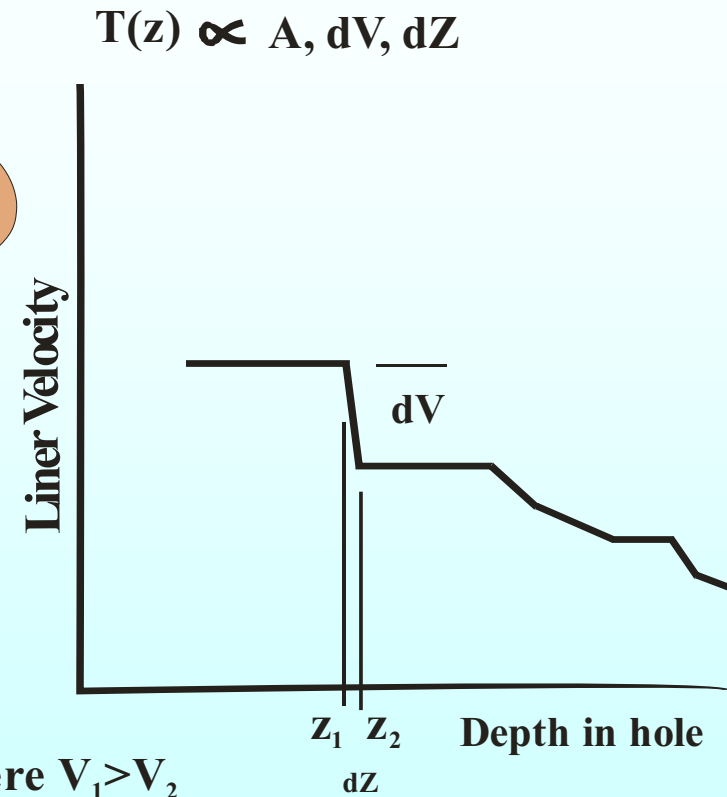
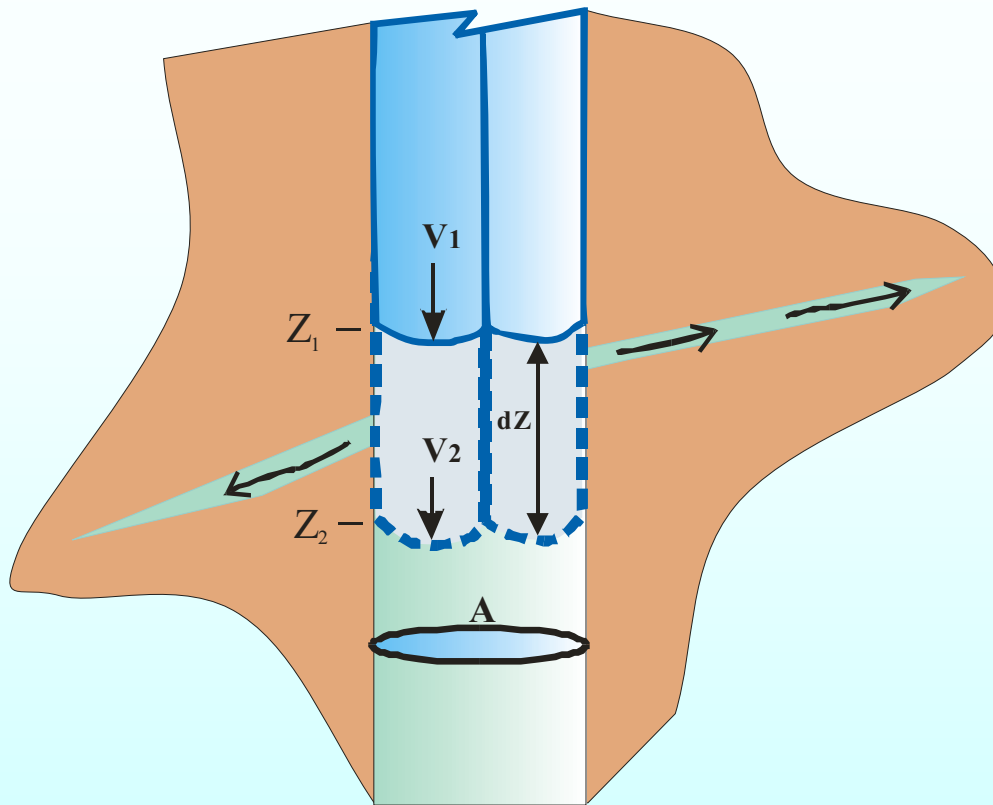
Calculation of conductivity/transmissivity is exactly the same for both methods

$$\begin{aligned} \text{Transmissivity} &= dZ \times \text{Conductivity} \\ &= Q \ln(r/r_o)/(2 \pi) \end{aligned}$$

But, for packers, Q = measured flow rate at surface, and dZ is the packer spacing.

For the liner, $Q = dQ_i = dV_i \times \text{Area of hole}$, and $dZ = dZ_i$ is the distance traveled by the liner in one time step. $dV_i = V_i - V_{i+1}$

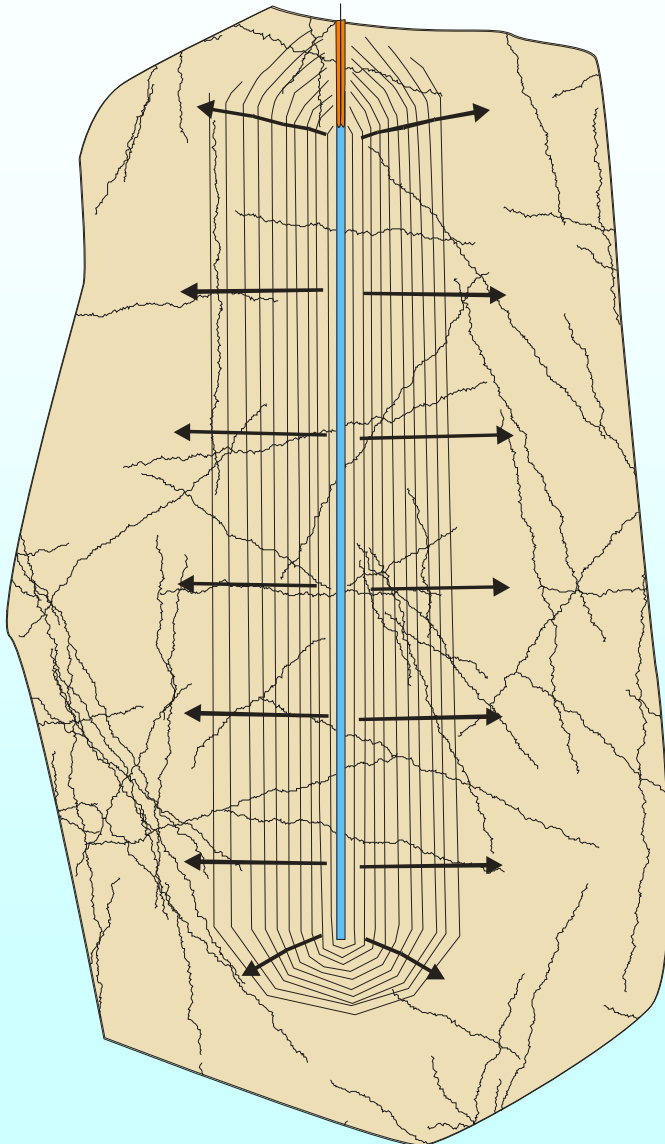
How is the flow, $Q=dQ$, defined for a liner measurement?



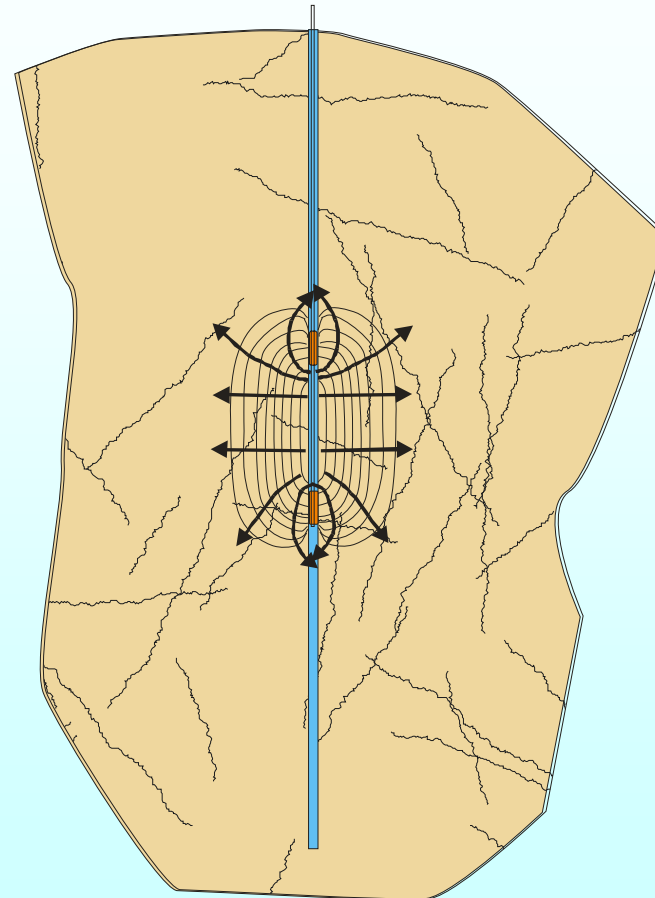
Flow rate into the fracture, $dQ = A(V_1 - V_2)$, where $V_1 > V_2$

The flow fields of the two methods

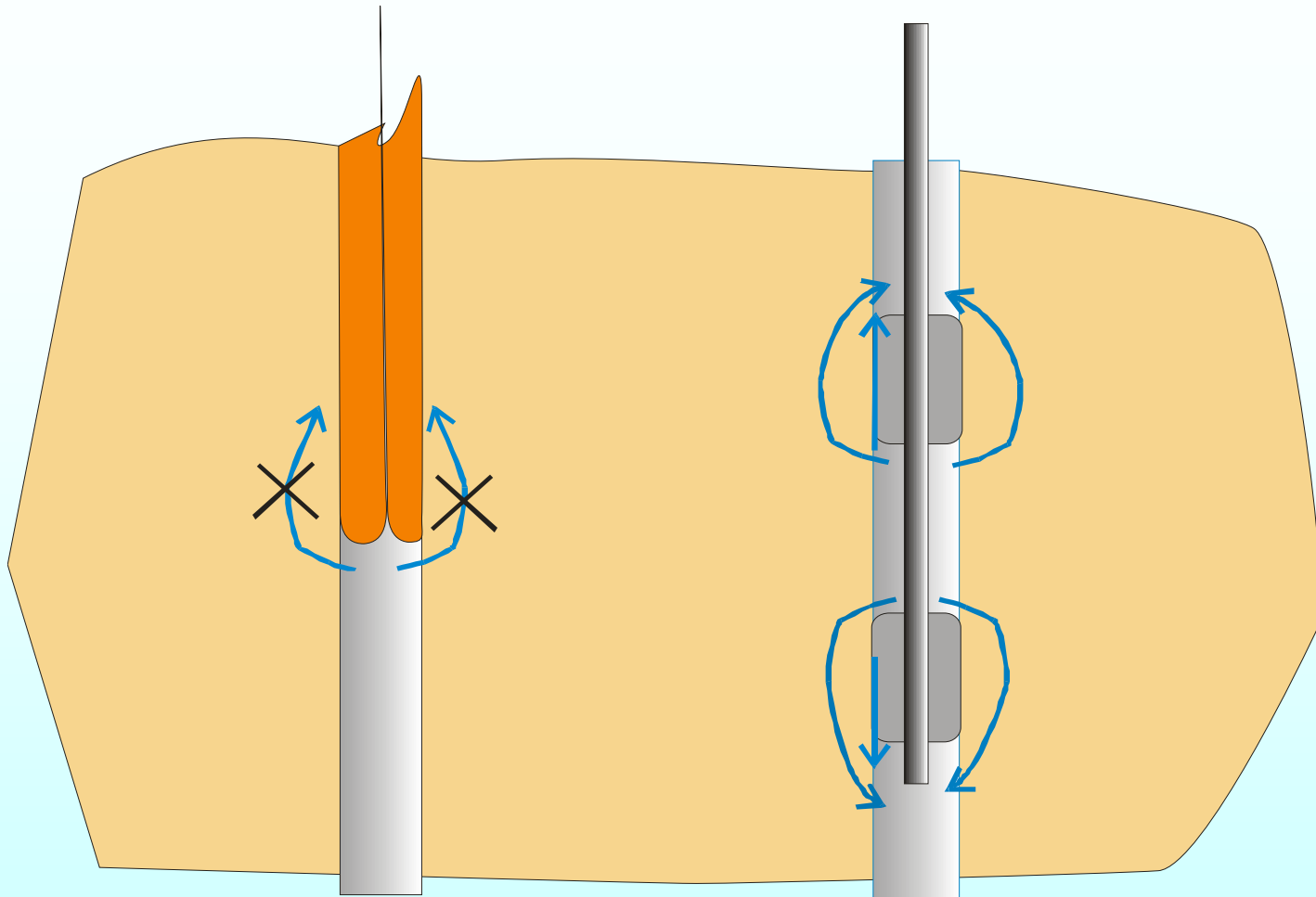
The liner flow field



Packer Flow Field



The liner has no bypass leakage

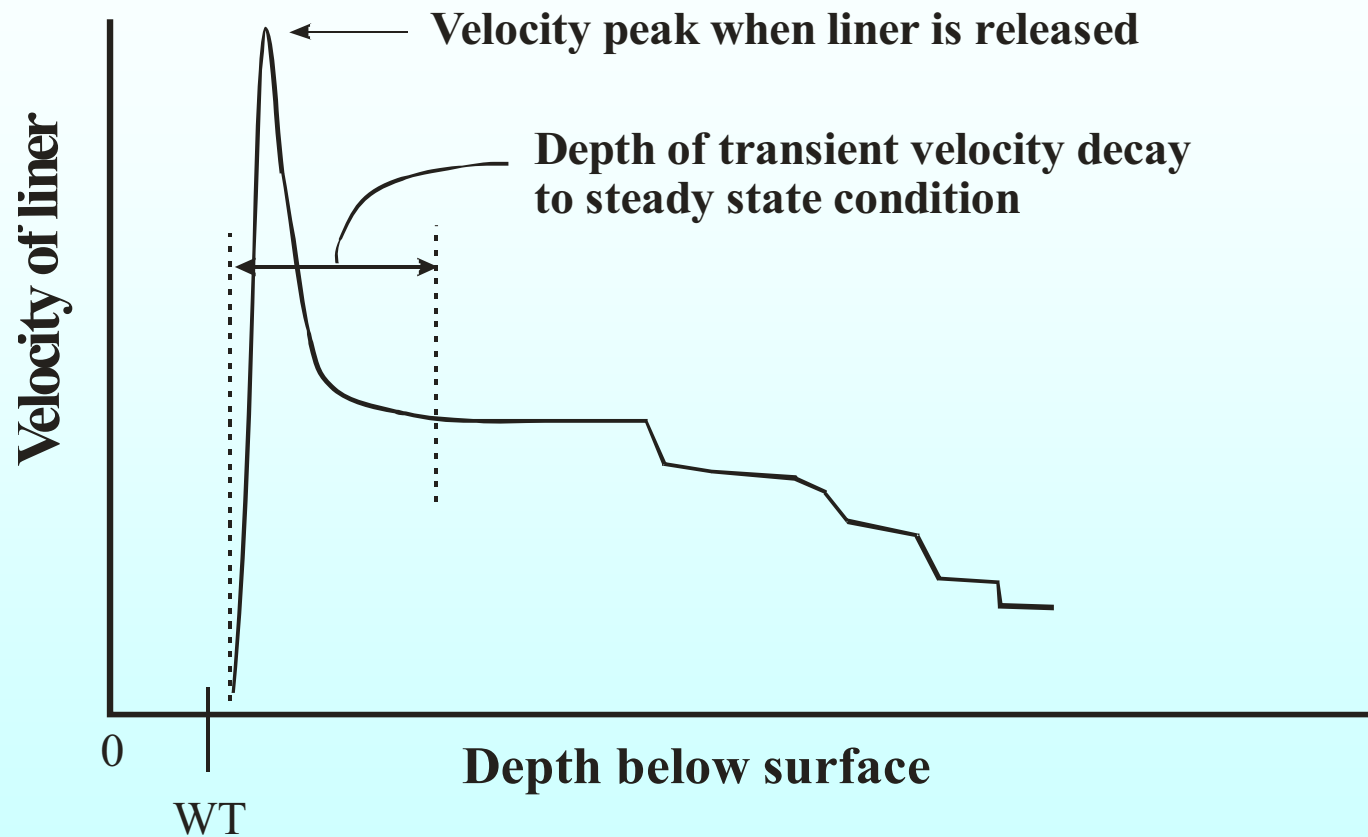


The packers have several potential leakage paths into the open borehole

Spatial resolution:

- The packer resolution is that of the packer spacing.
- The liner spatial resolution is that of the distance traveled in 2 seconds. That is ~1.0-.05 ft. typically.

The liner transient to steady state can prevent the measurement of a short part of the hole



Transmissivity resolution:

- Packers have potentially much better resolution of very low transmissivity
- Liner resolution is about 0.1-1% of the borehole transmissivity below the liner

Head measurements

- Packers can be used to measure the head distribution.
- Liners are not normally used to measure head. (That is left to the flexible liner multi level measurement system.)
- Liners have been used to measure head profiles, but only where large head differences exist in a borehole.

Sampling capability

- Straddle packers can be used to collect ground water samples (But, still susceptible to leakage effects and open borehole effects)
- Profiling liners can not collect a ground water sample.

How long is the hole open to cross connecting flow?

- Liner installations leave the borehole open to potential cross connection for 1-4 hrs.
- Packer testing of a 300 ft hole in 5 ft increments may leave the hole open for 2-4 days.

Entrapment risk

- Slough of the hole wall onto the top of the packer assembly can entrap the packer system in the hole. This hazard prevents use of the packer system in potentially unstable holes.
- No profiling liner has ever been entrapped in an unstable hole (123 measurements to date). The liner eversion and inversion process with the liner under pressure tends to stabilize the hole wall.

Cost (labor and equipment)

- The liner equipment weighs far less than a packer system and the time to measure a typical hole is 2-3 hrs.
- The packer testing of a 300 ft hole takes about 10-15 times as long as a liner run and uses heavier equipment.

Liner equipment

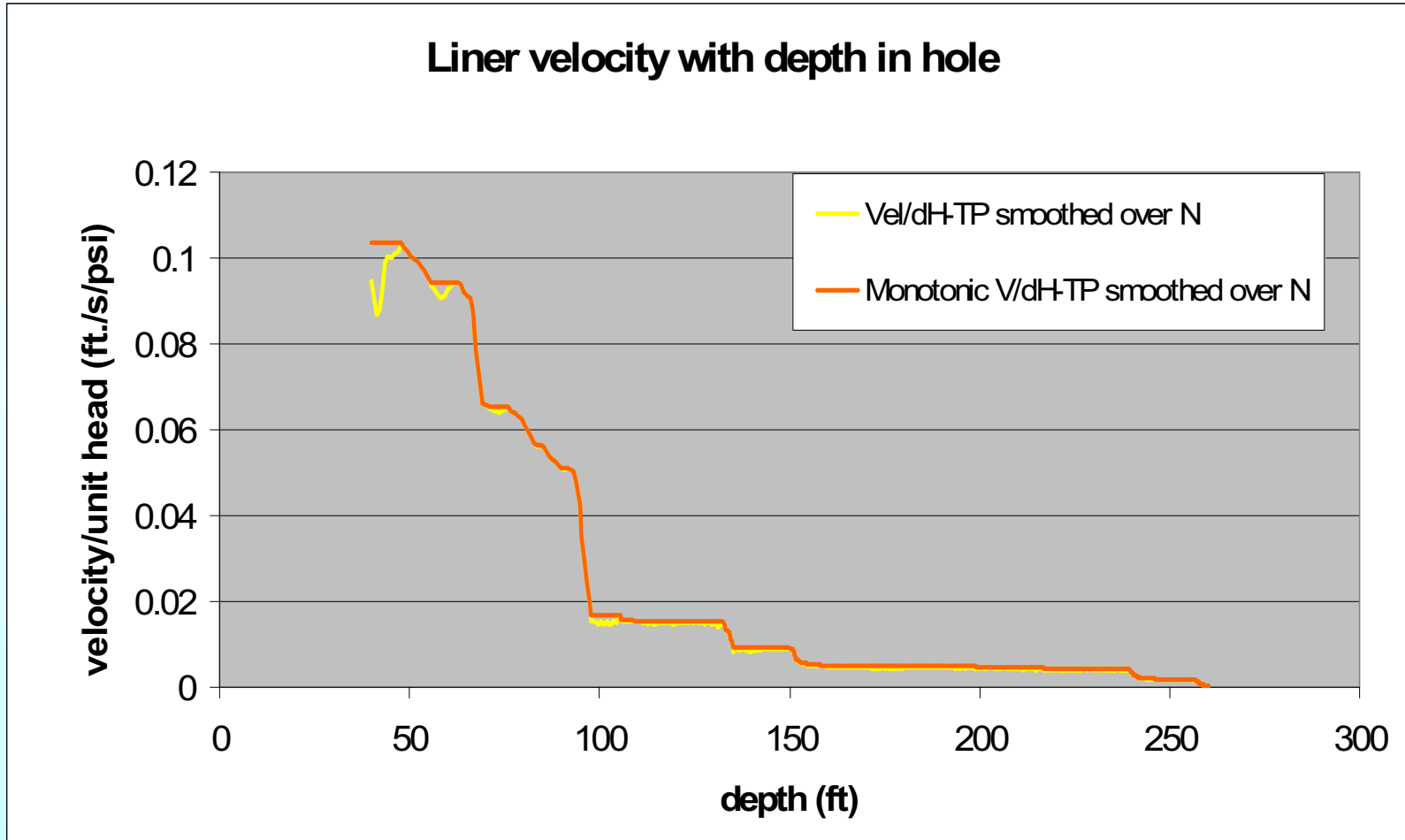


Packer equipment

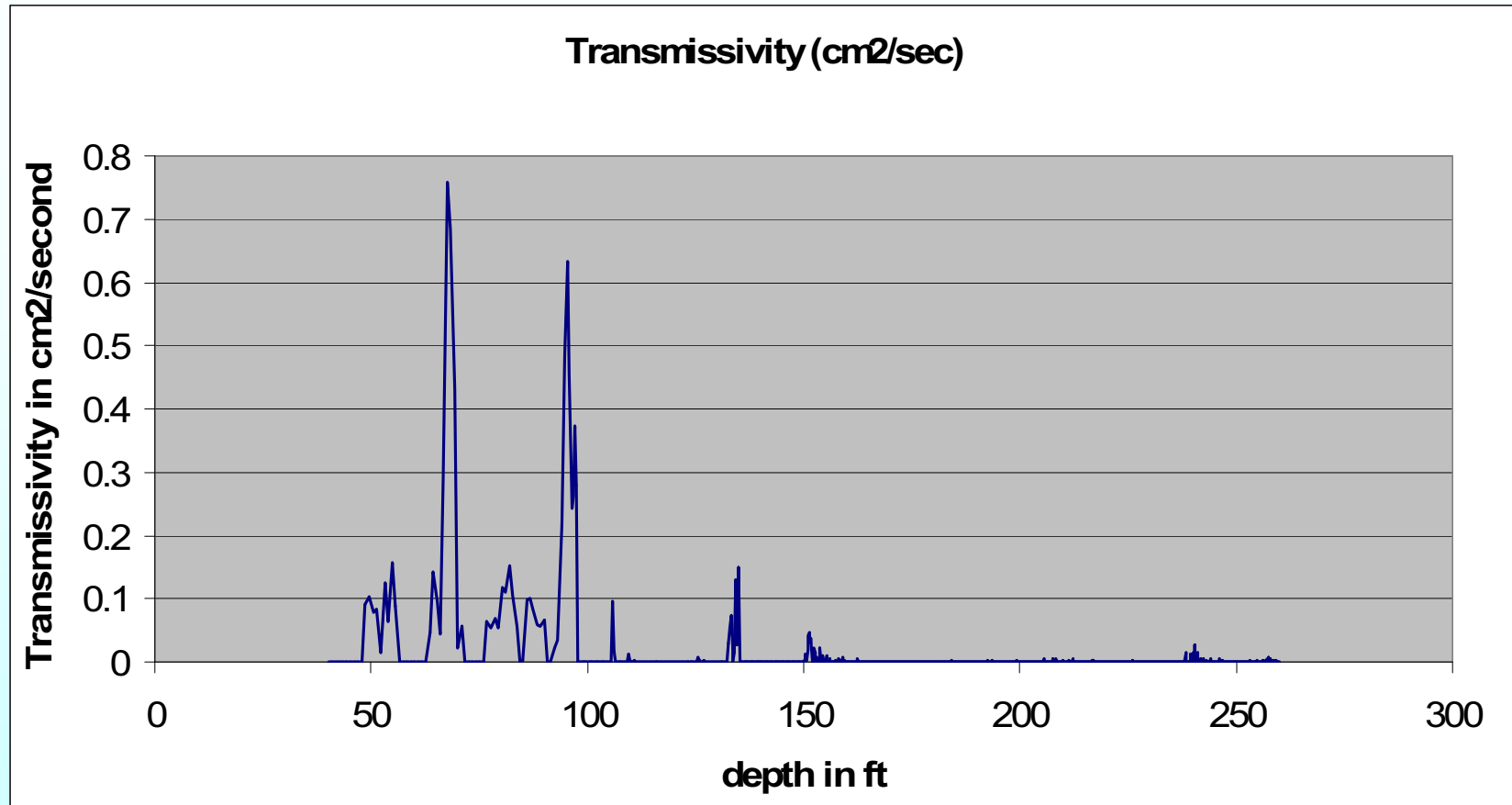


Both use a water source and an electrical source

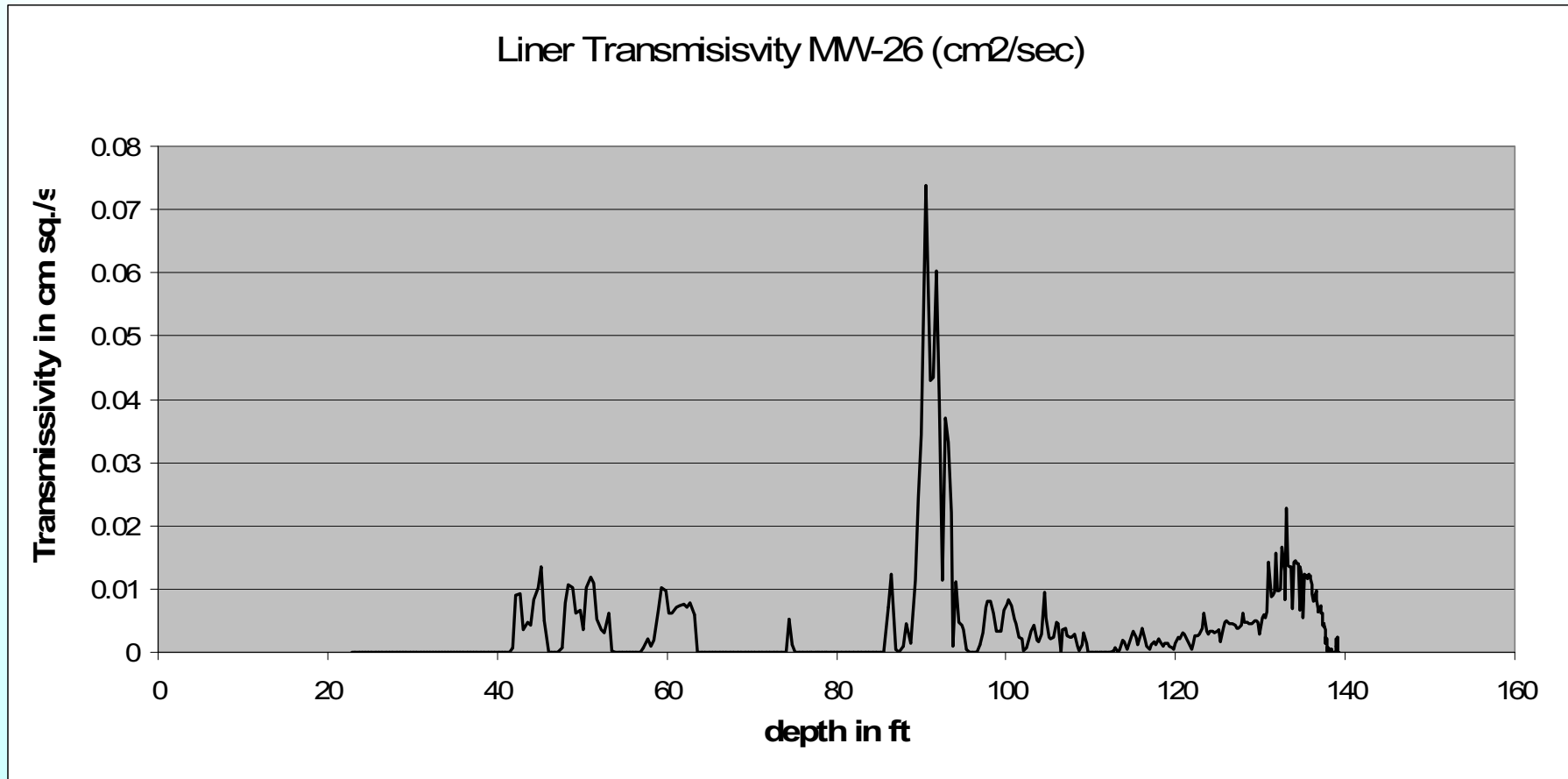
Typical liner result



The resulting liner profile

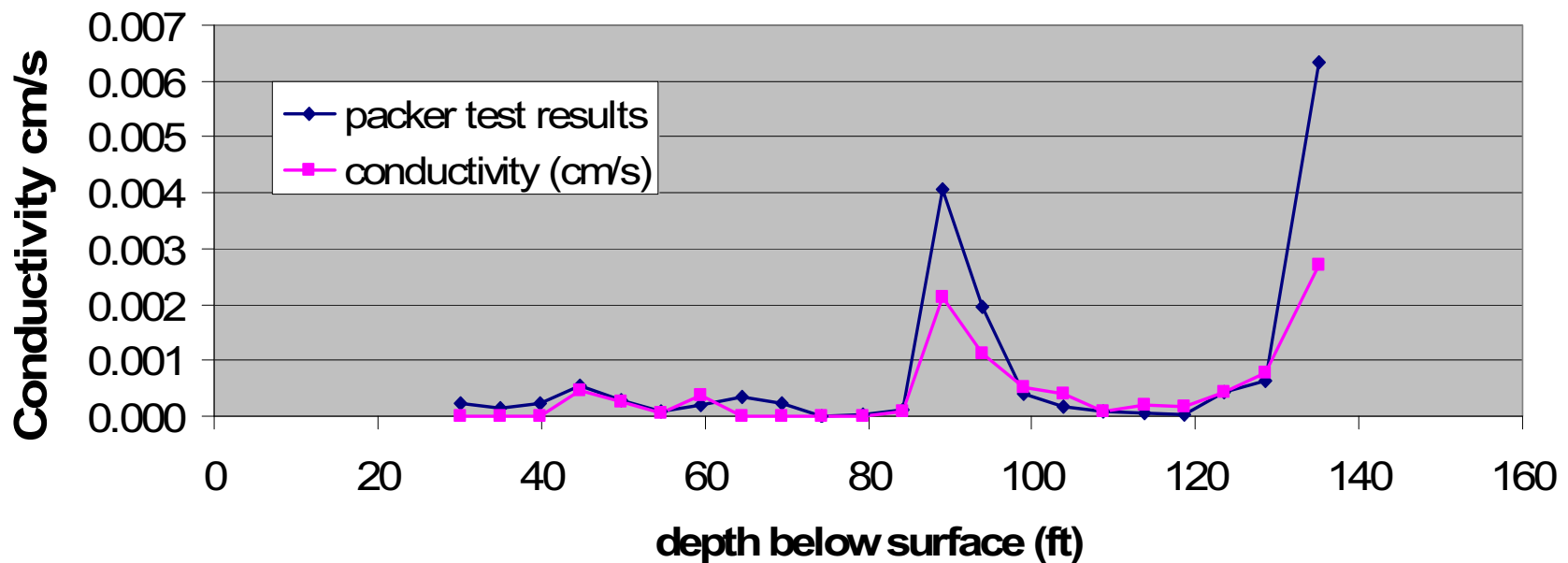


Another liner transmissivity profile



packer results compared to liner results

comparison of FLUTE liner to packer results at MW-26



<u>Parameter</u>	<u>K Profiling liner</u>	<u>Straddle Packers</u>
<i>Spatial resolution</i>	1 inch to 1 ft. (velocity dependent)	5 ft typically smaller spacing adds time
<i>Time for measurement</i>	2-4 hours (relatively independent of hole depth)	2-6 days (directly dependent on hole depth)
<i>Range of measurement</i>	4.0e-07m/s to 1.0e-03m/s	4.5e-08m/s to 2.0 e-04m/s or less with good seal

parameter

liner

packers

parameter	liner	packers
<i>Borehole size limits</i>	Any size above 3.5"	Depends upon packer availability
<i>Seal bypass potential</i>	None	Significant concern
<i>Time hole is open for cross connection</i>	2-4 hrs.	2-6 days
<i>Seal of borehole afterwards</i>	Sealing liner left in place	None, to intermittent seal if packer is left in place.

parameter

liner

packers

<i>Meets Their assumptions</i>	Uncertain to good	Uncertain to good
<i>Head measure. capability</i>	None	yes
<i>Sampling capability</i>	None	possible
<i>Cost per hole. (typically 10% of packer testing for liner profile)</i>	\$12/ft +(\$850+\$1500 per day) Several holes often done in one day.	Equip. rental + 4-8 man days?

Conclusion

- Both methods use the Theim model for data reduction
- The liner measurement has higher spatial resolution and costs less than packer testing.
- The liner does not measure head or collect samples.
- The packer has lower transmissivity resolution if it does not leak.
- The packer system does allow head measurement and sample collection.
- Entrapment of the packer system is a greater risk than for the liner system.
- The liner is left to seal the entire hole, and has much less cross connection risk.

Thanks to:

- Pat Quinn, U of Waterloo grad. student; the packer data collection and assistance with the profiling.
- Prof. John Cherry, Univ. of Waterloo
- Prof. Beth Parker, Univ. of Guelph