# How to Locate, and Flow Test, every Major Fracture in a Borehole in One Hour

by

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(*FLUTe*™)

at

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## The Challenge:

Locate every significant flow path in the borehole, and measure the flow rate in each flow path as quickly as possible.

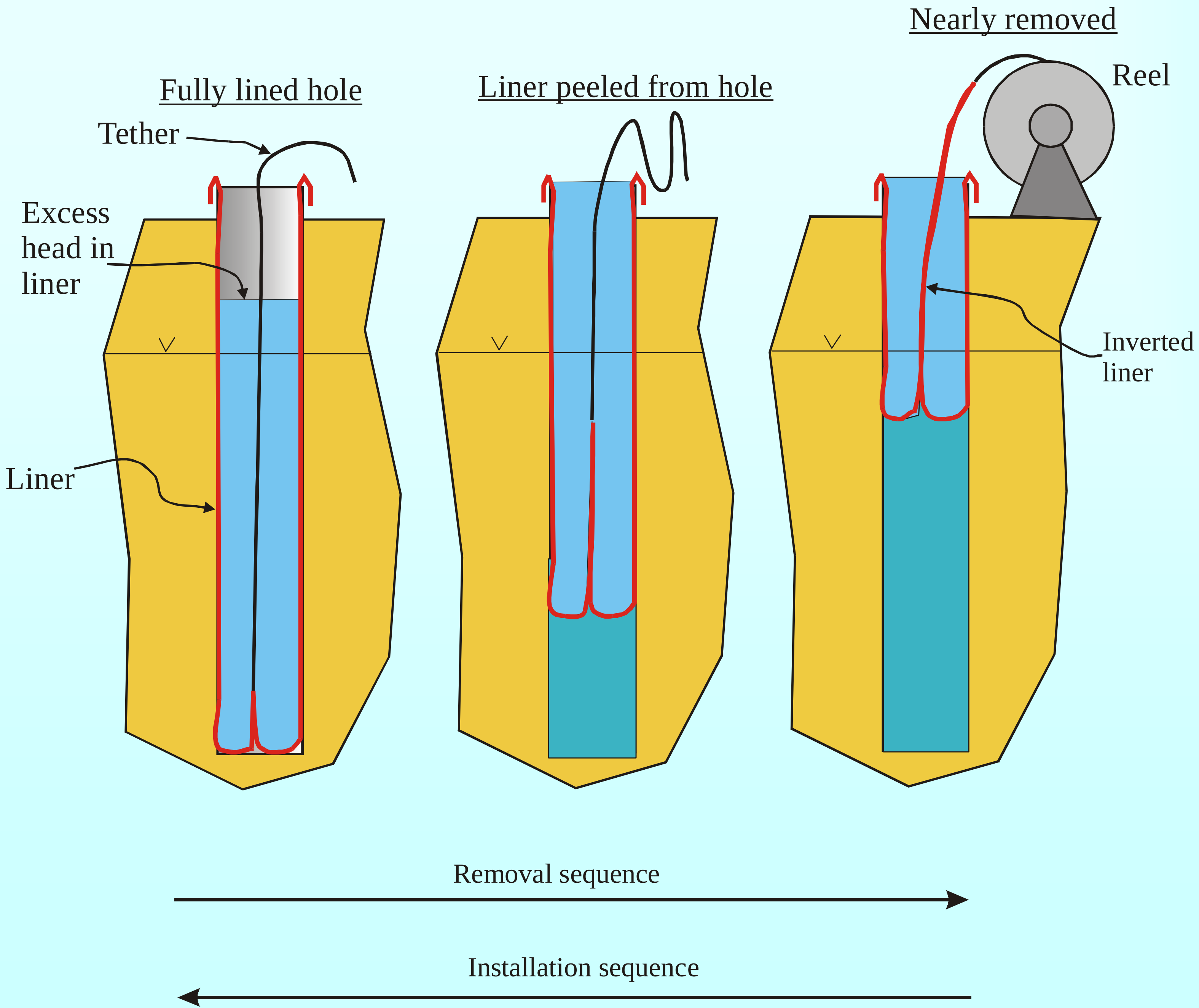
## The Result:

All significant flow paths identified and their flow rates measured in ½ hour to 4 hours in boreholes 150 – 600 ft deep.

# Topics to be addressed

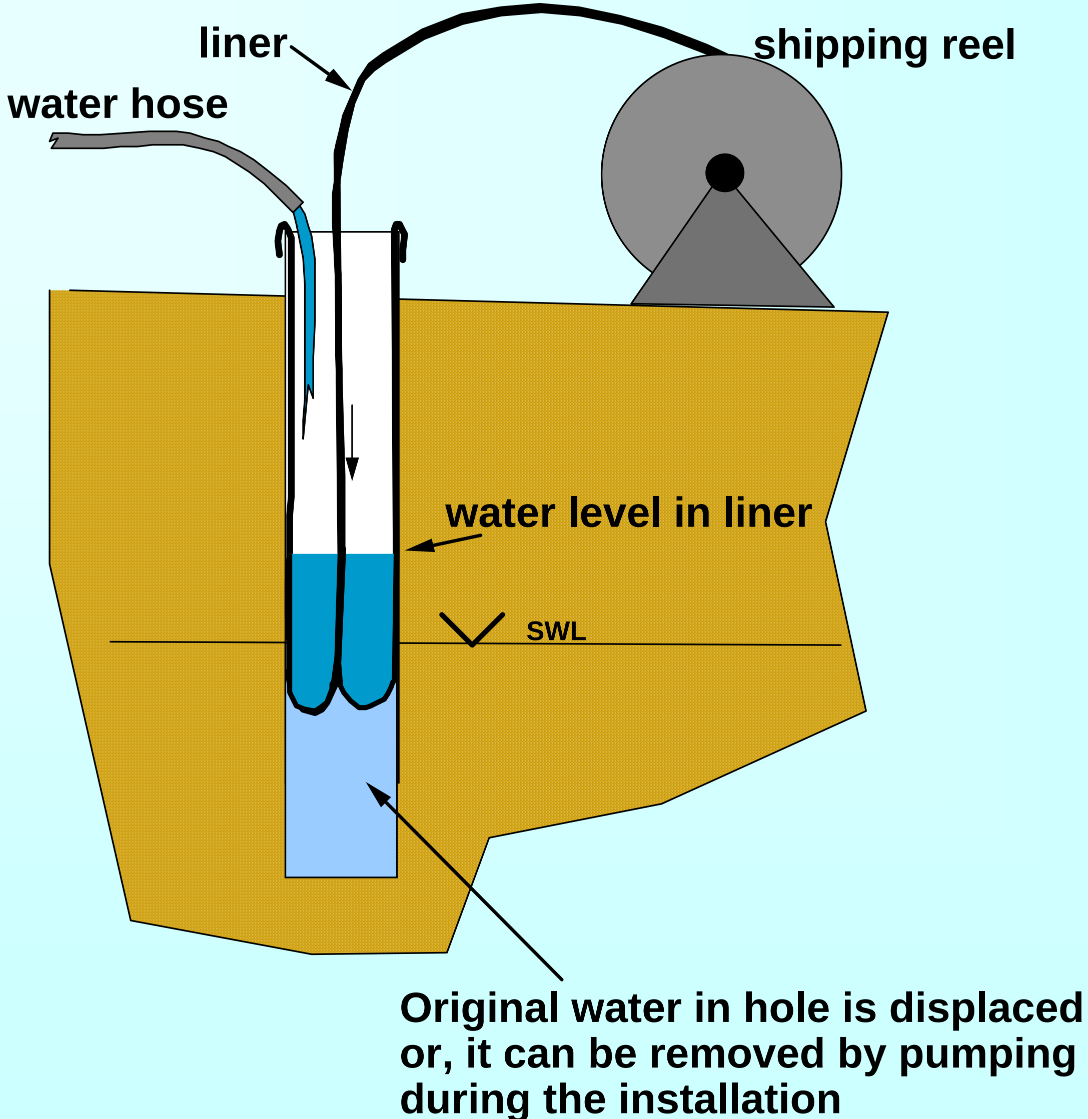
- How a blank flexible liner is installed
- What controls the installation rate
- How the installation is measured to obtain the required data for flow path mapping
- How the data is analyzed
- Results of measurements
- Comparisons with other measurements

# The blank liner installation seals the hole

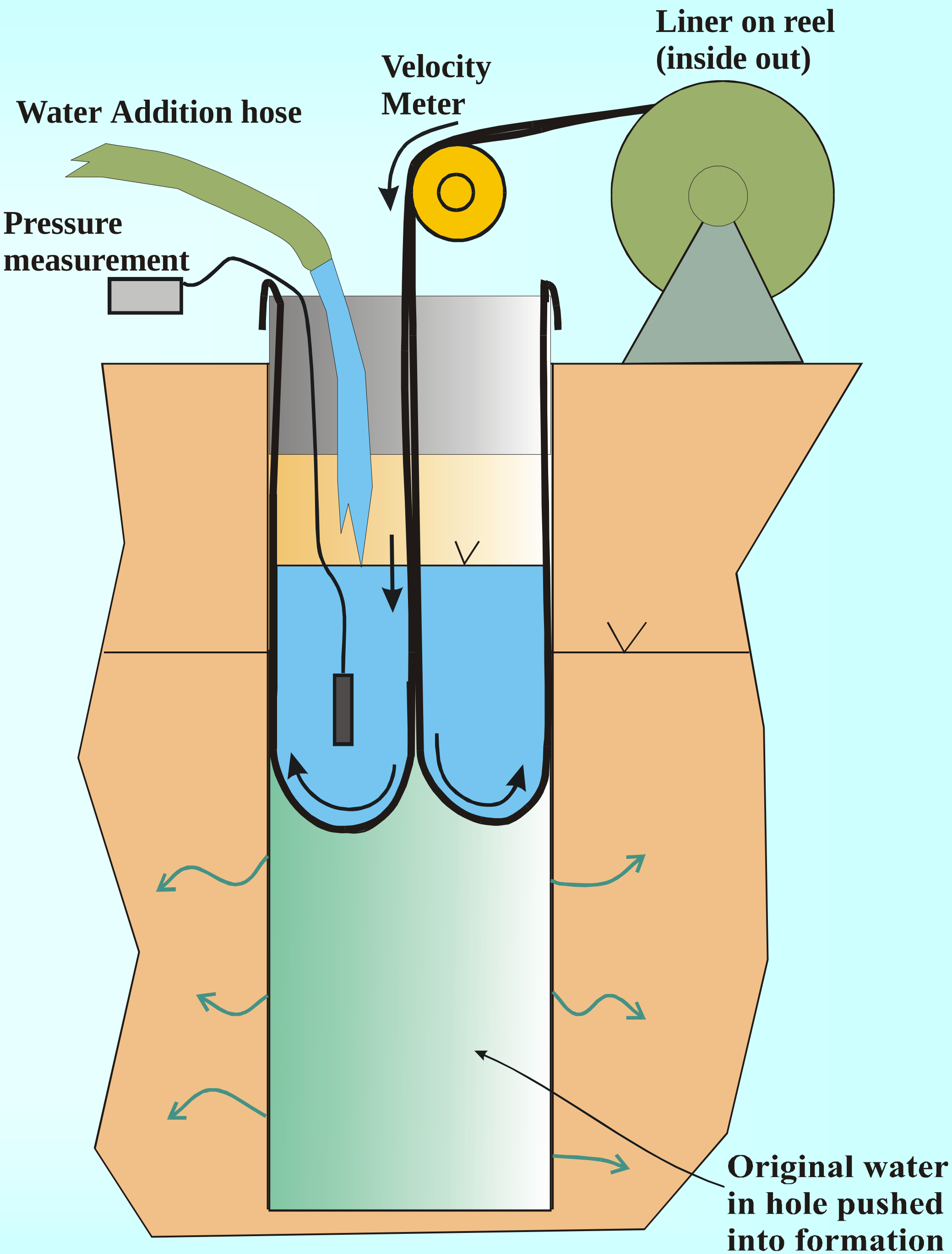


To install a blank sealing liner,

# ***Just Add Water!***

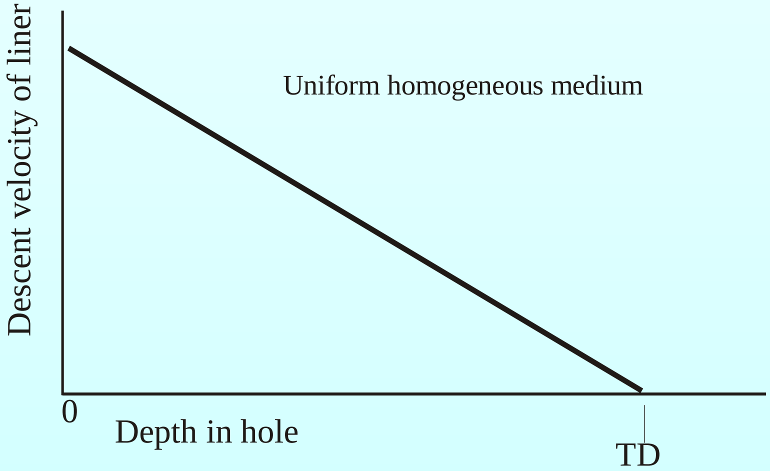


# Measuring the installation rate and head yields a transmissivity profile

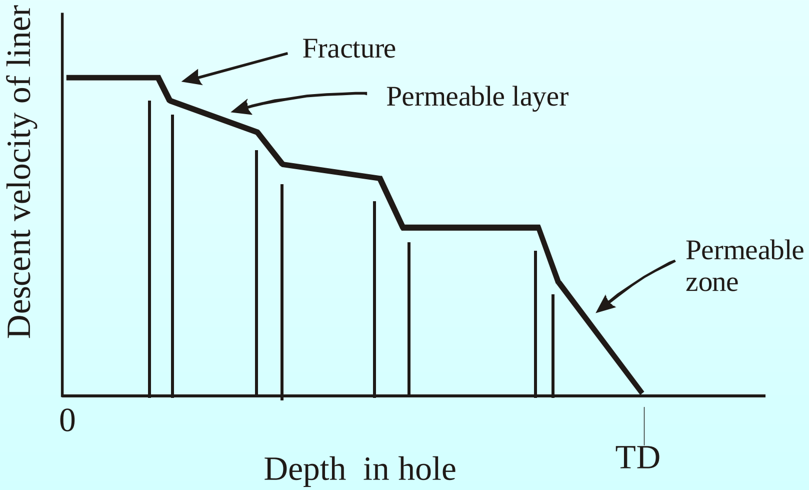


# The liner descent velocity is controlled by the flow paths

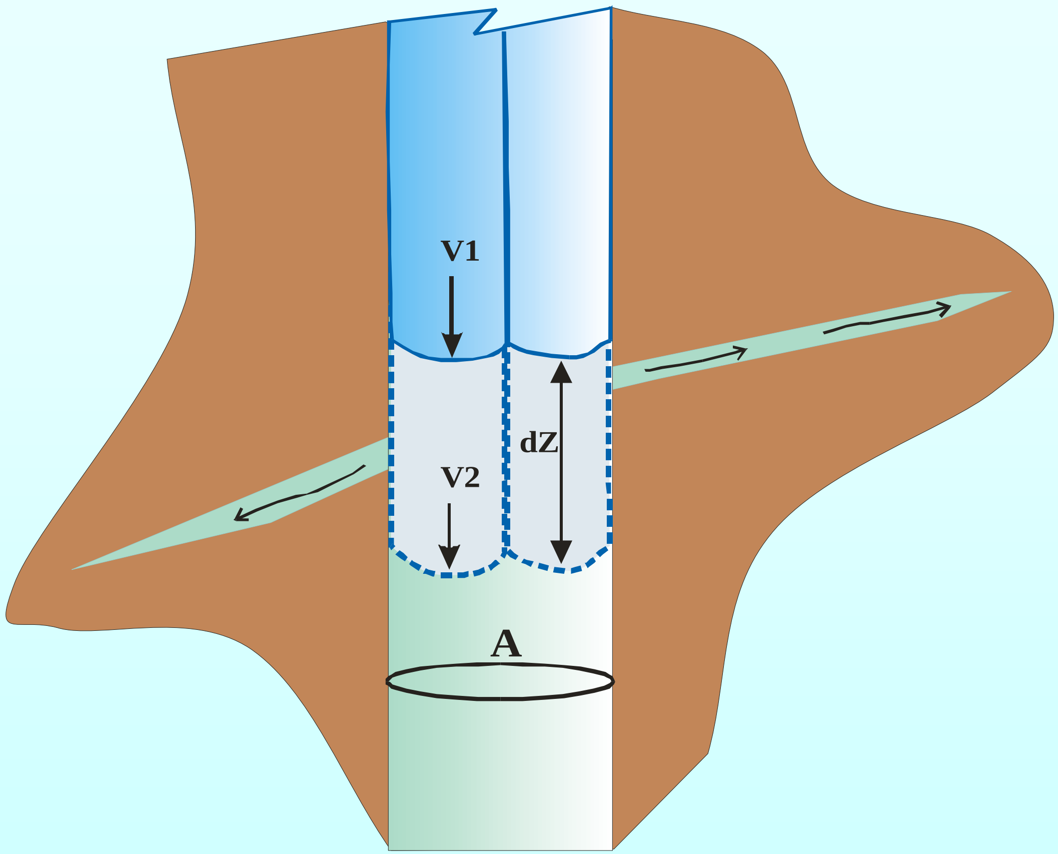
Velocity of liner in uniform medium




Possible velocity profile in fractured medium



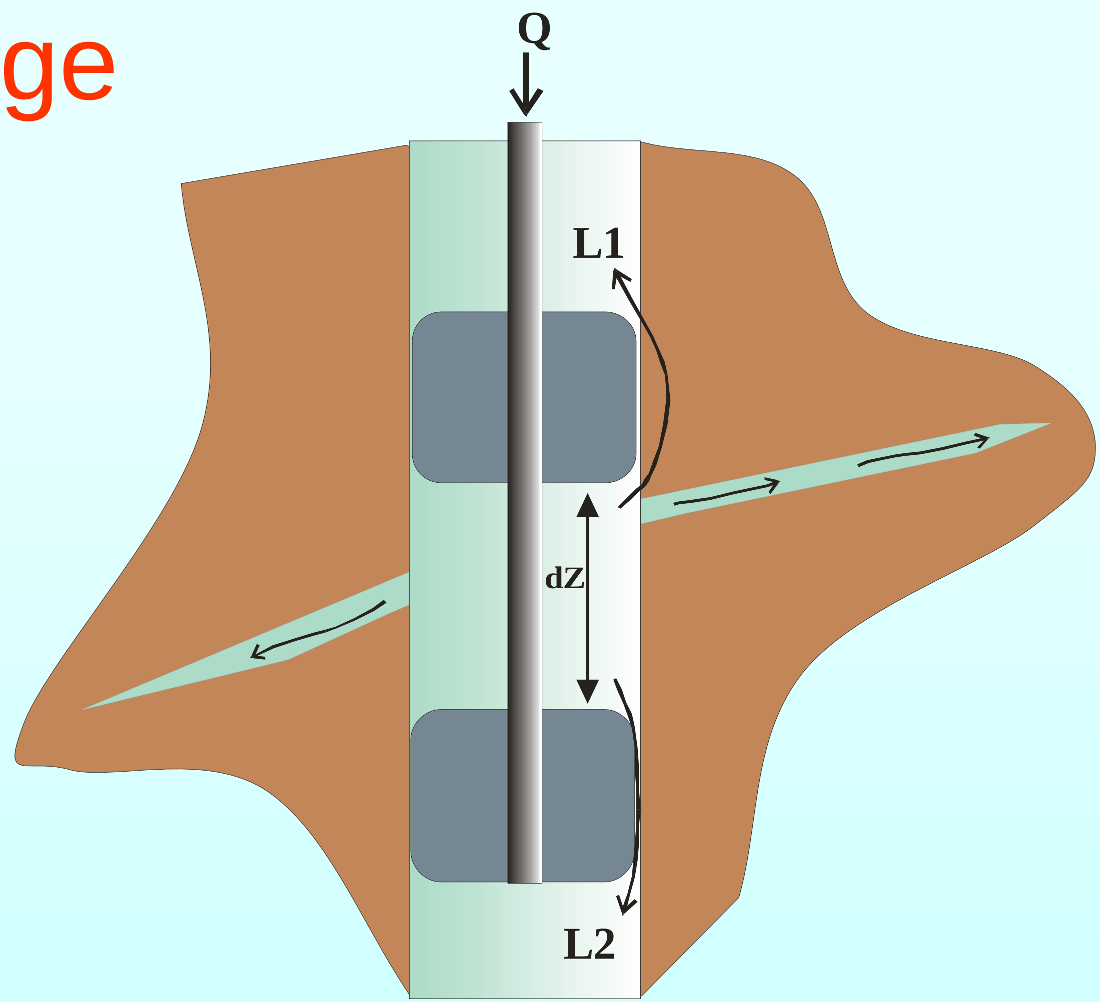
# The liner velocity drops when each fracture is sealed




**Flow rate into the fracture, Q, is A(V1-V2) , where V1>V2**

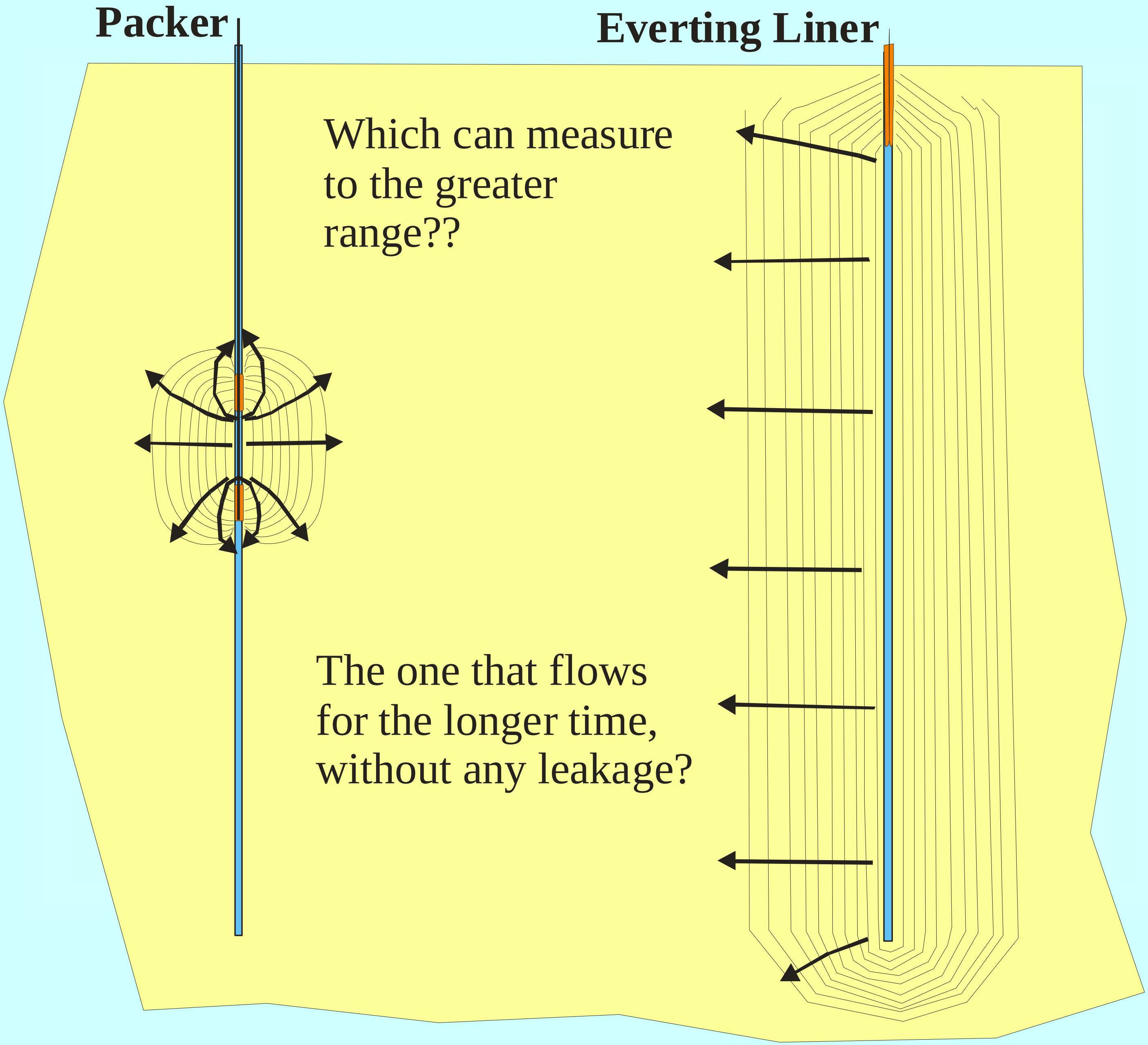
**Average flow rate into the hole wall over the interval dZ is:**
**$Q/(dZ\ \pi\ D) = fctn(C,dP, D,..)$**

# Straddle packers have more or less leakage




**Flow rate into the fracture is Q-L1-L2.**
**Average flow rate into the hole wall over the interval dZ is:**
**(Q-L1-L2)/(dZ π D) = fctn(C,dP, D, L,..)**

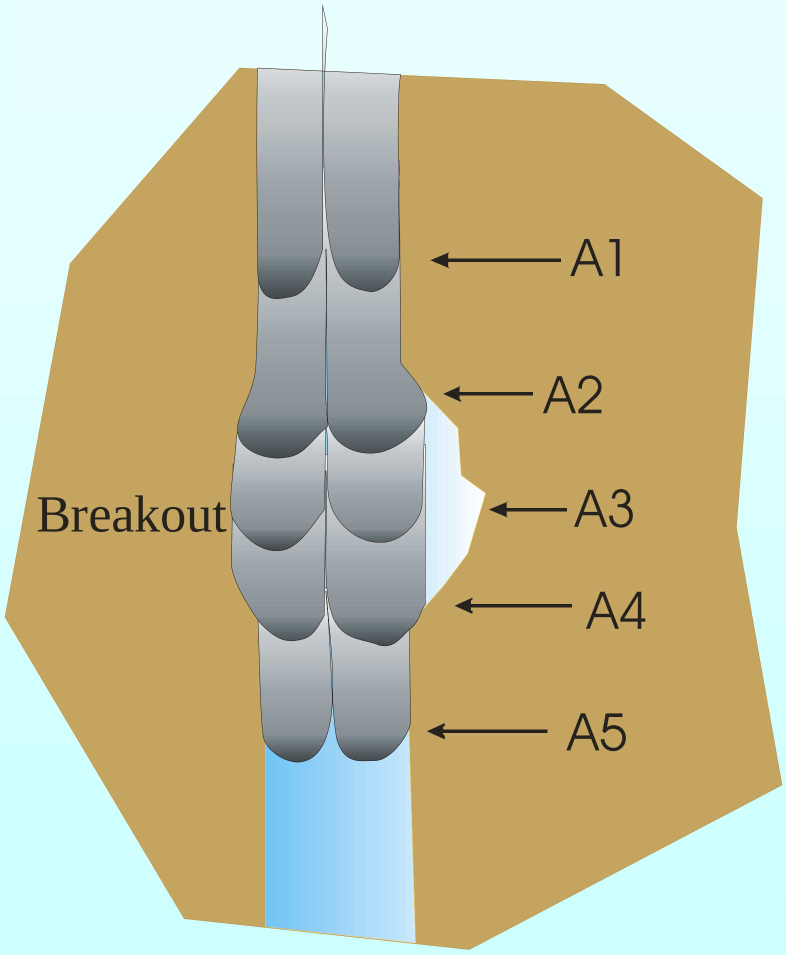
# Comparison of flow fields




Which can measure to the greater range??

The one that flows for the longer time, without any leakage?

# In a breakout, a liner slows and then accelerates as it exits




$$V_i = Q/A_i$$

Hence, only a breakout with flow paths causes a persistent drop in the velocity

# How well does the liner seal the hole?

- The following photo was taken inside a 6” diameter 328 ft hole at Cambridge, Ontario by Peter Pemhe.
- The liner is a 400denier urethane coated Nylon fabric.  The liner is about 6.5 inches in diameter with about 40 ft of excess head.
- In the lower left hand corner is a 1” wide welded seam tape.  This is the typical blank liner.

# This machine collects the data to a laptop and controls the tension (8” hole)

# Data collected every 1-2 seconds:

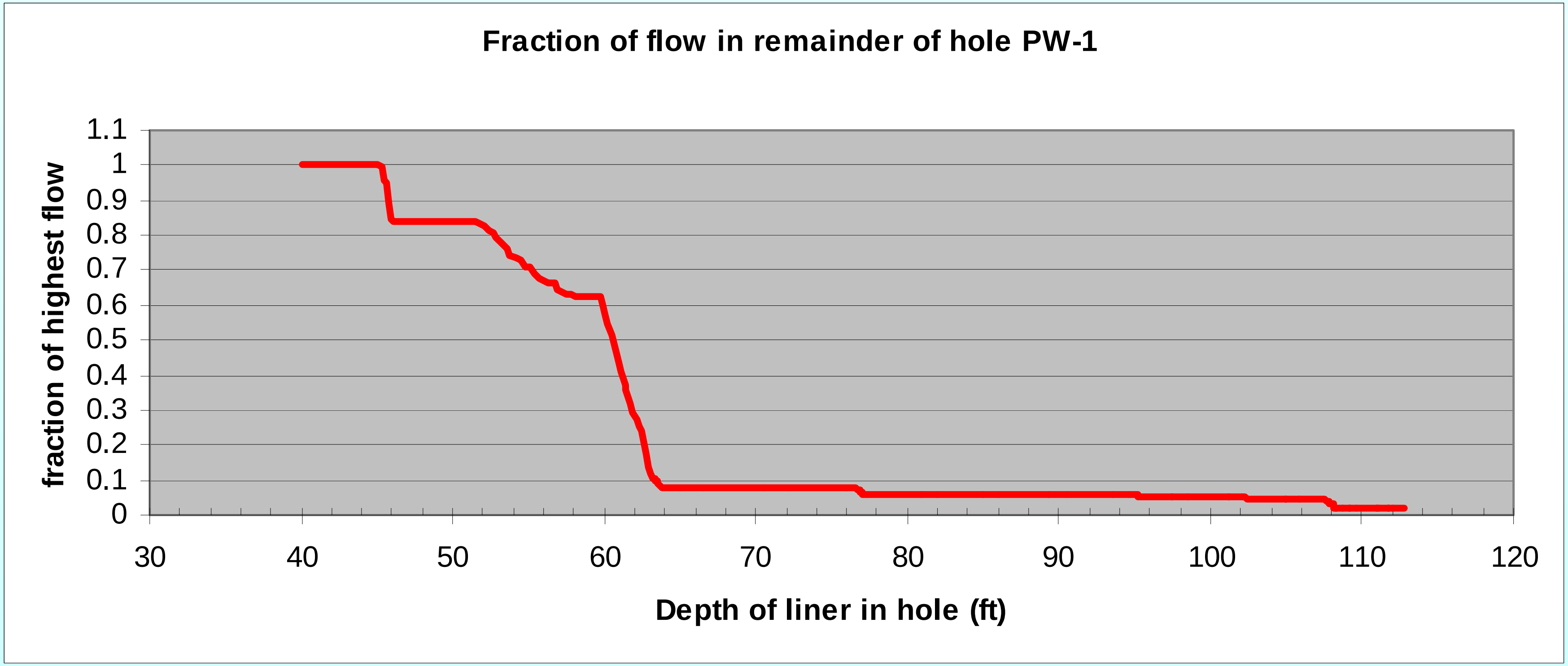
- Position
- Time
- Head inside the liner
- Tension on the liner

And, the tension on the liner is controlled at an essentially constant value.

# The calculations are:

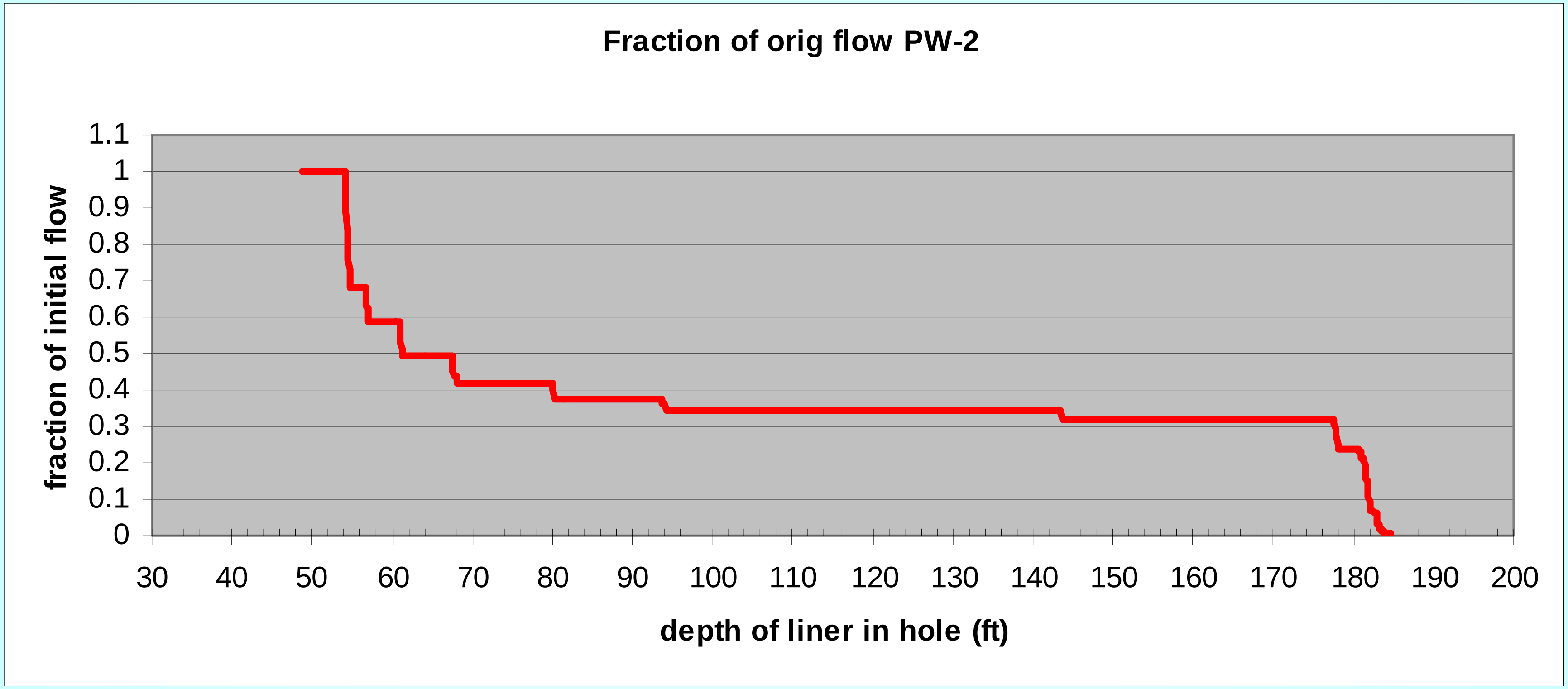
- Velocity of the liner descent
- The position of the liner in the hole
- The change in velocity between each time step
- The persistent change in velocity with depth
- The transmissivity of the hole with depth
- The conductivity of each increment in depth

# The results: amazing detail



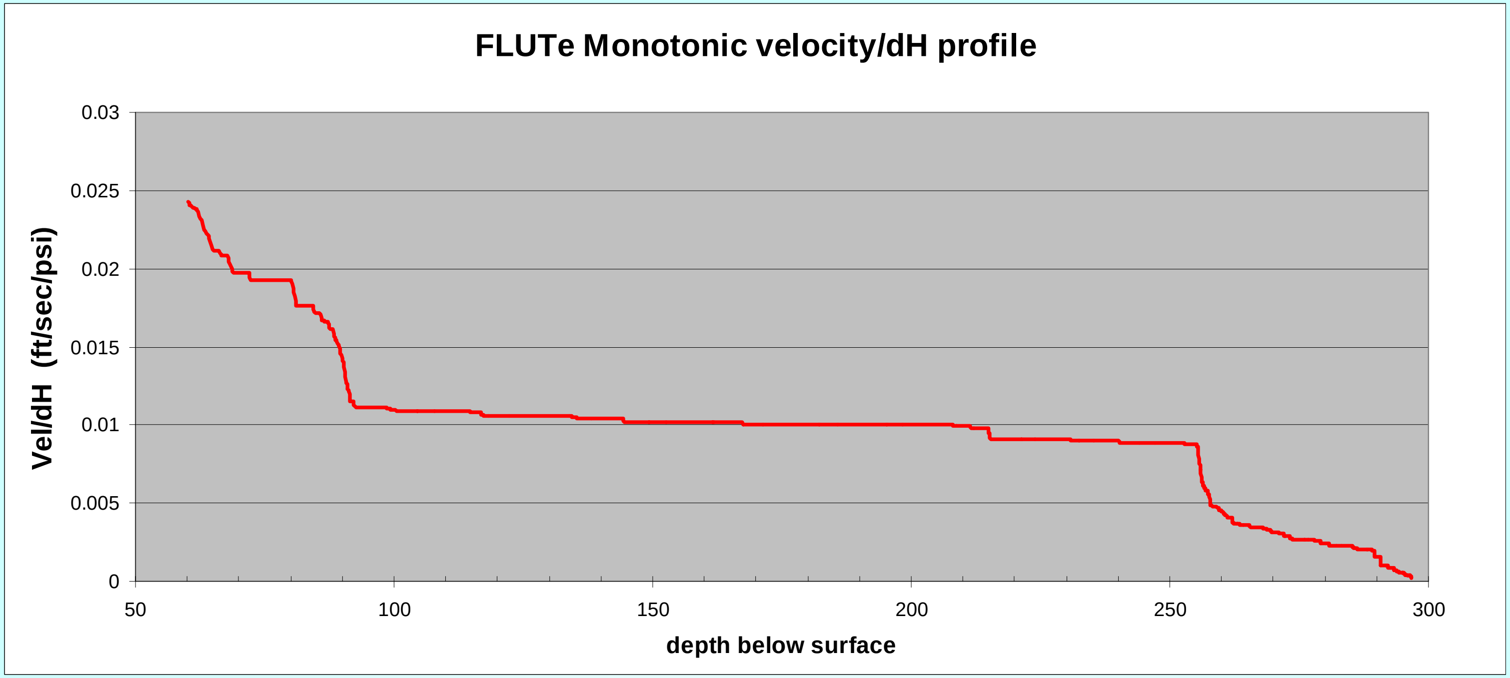

By 64 ft, the flow rate is down to only 8% of the initial flow

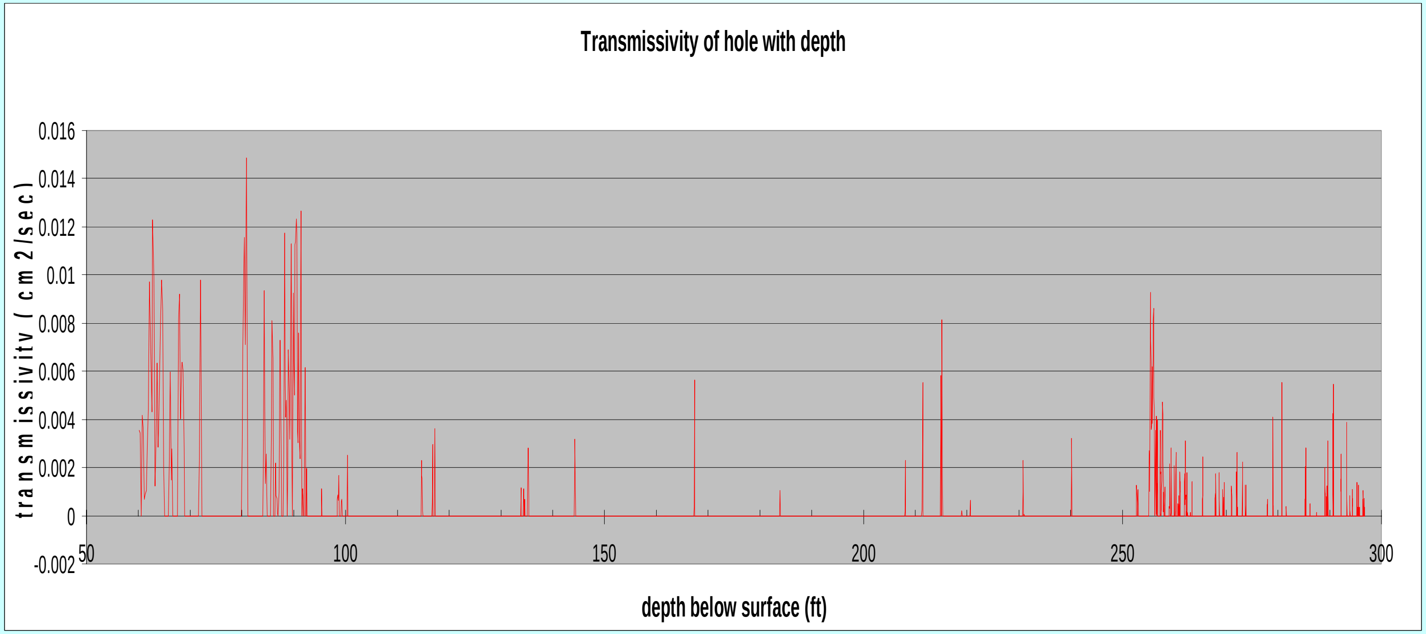
# 35% of the flow is out the last two fractures



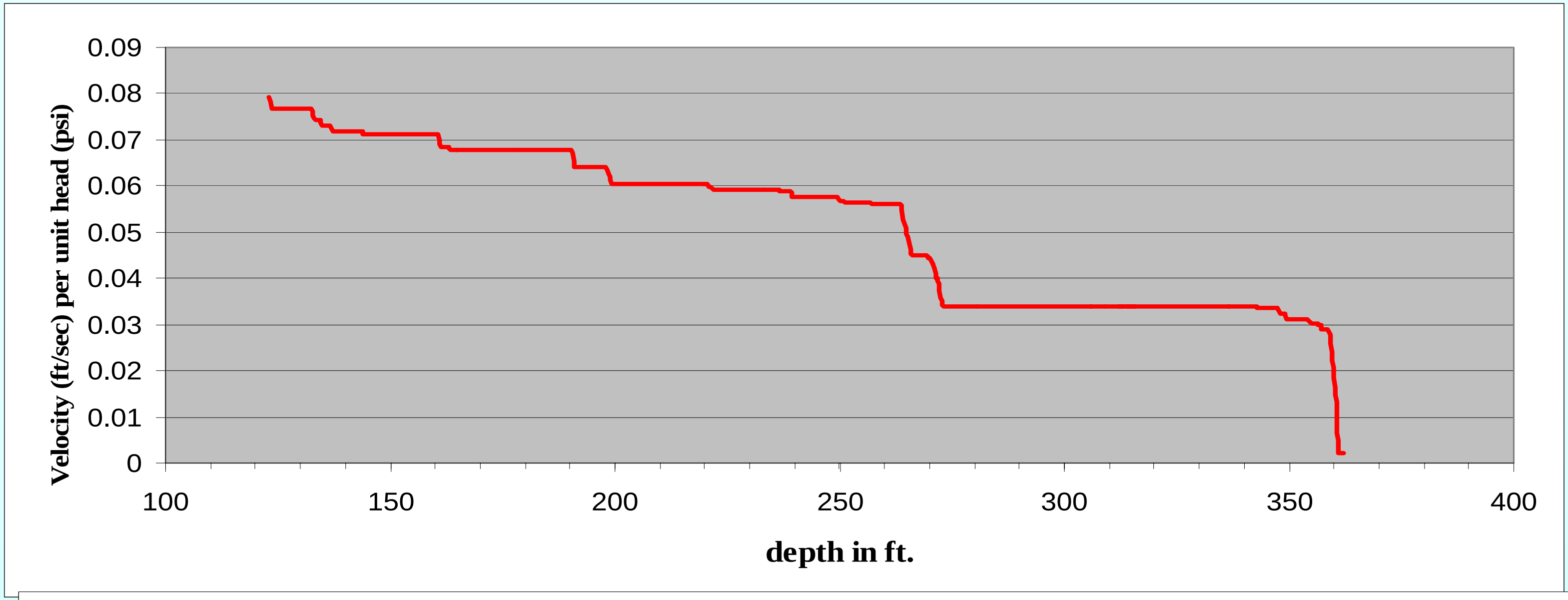

Approximately a 30 minute data collection time.

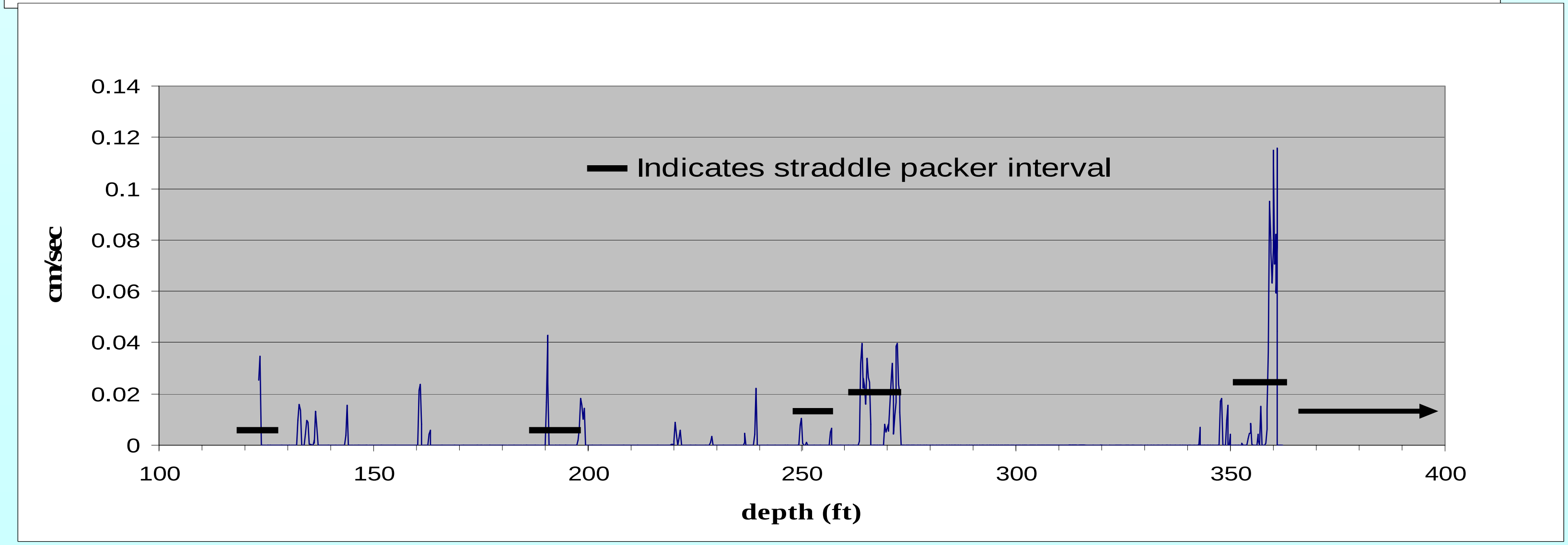
# 4” diam. x 408’ borehole in shale, we took about 4 hrs of data



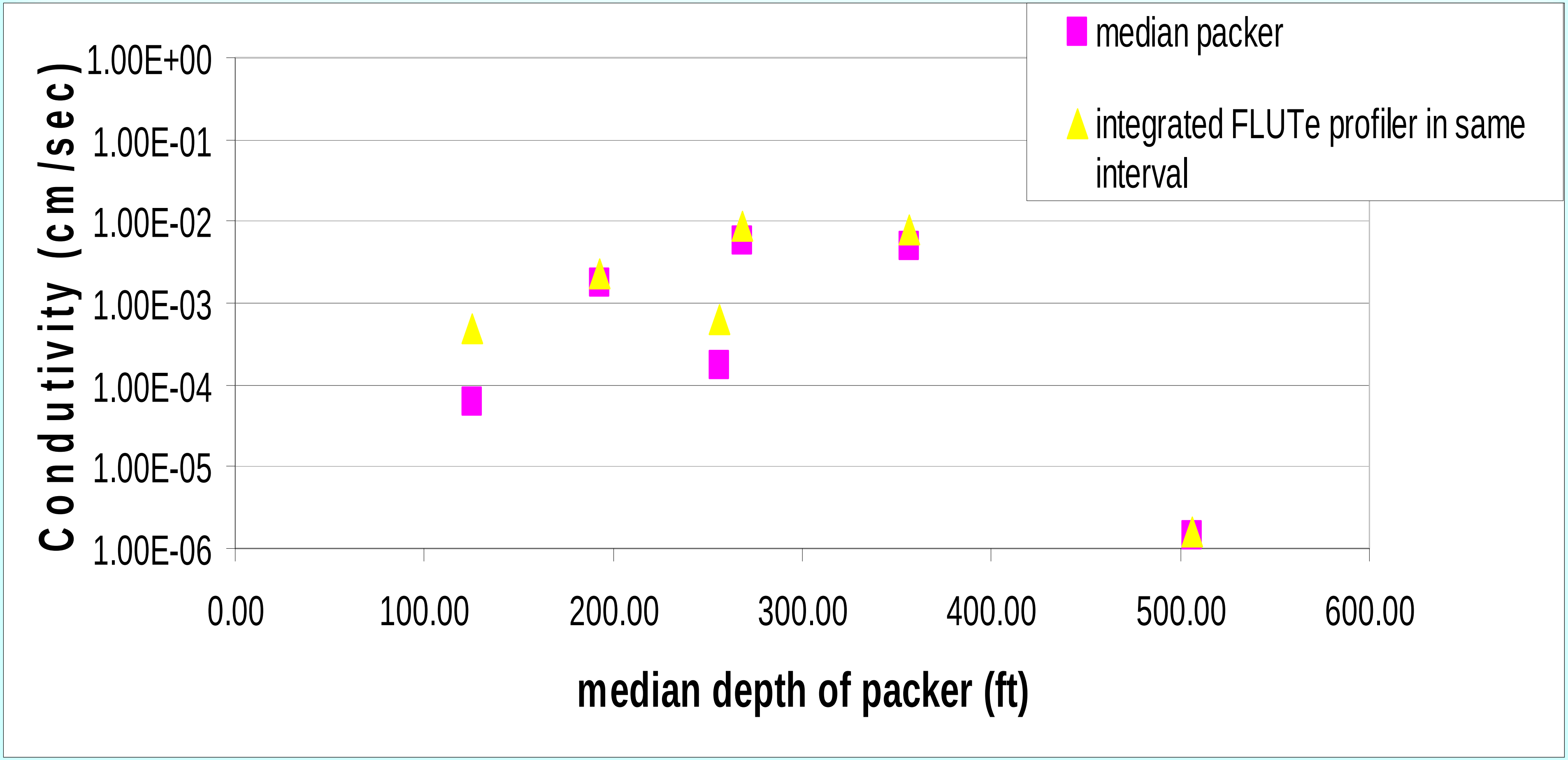



# This was taken in an 8” hole and compared to straddle packer tests



# Integrating the Profiler results over the same interval as the packer tests produces very good agreement



# Limitations?

- Primarily related to adhesion of the

liner to itself above the water level in the liner

- Hence the following combination is the most difficult:
  - Deep water table (long wet film possible)
  - With high transmissivity (limited excess head)
  - Small diameter hole (high velocity and low towing force to overcome any drag effects)
- These have been overcome in most cases.
- Easy to identify data quality in the data plots

# Definition of the FLUTe Trio

1. A sealing ***Blank Liner*** to prevent cross contamination in a borehole
2. The ***Hydraulic Conductivity Profiling*** of a hole while installing a blank liner
3. The installation of a multi level sampling liner, called a ***Water FLUTe***, for the head profile and water quality measurements

# Conclusions

- The flow path resolution of this profiling technique is far greater than packer testing can provide.
- The time to obtain these results is 5-15% of the time for a complete suite of packer tests of the entire hole.
- The profiling blank liner is often installed for the purpose of sealing the hole, so the additional cost is low.
- There is no significant leakage with this method, it conserves the entire hole volume flow.

# Conclusion (cont.)

- Preliminary data sets show better resolution than expected and excellent comparison with video, packer tests, and geophysical logs.
- The equipment and procedures are still being refined to even higher levels of resolution.
- The *Trio* produces a nice groundwater measurement medley

# Thanks for your attention

- More information is available at our web site: www.flut.com
- And at our booth at this conference.
- And in the paper in the proceedings.