Site Characterization Methods with a Flexible Borehole Liner

by

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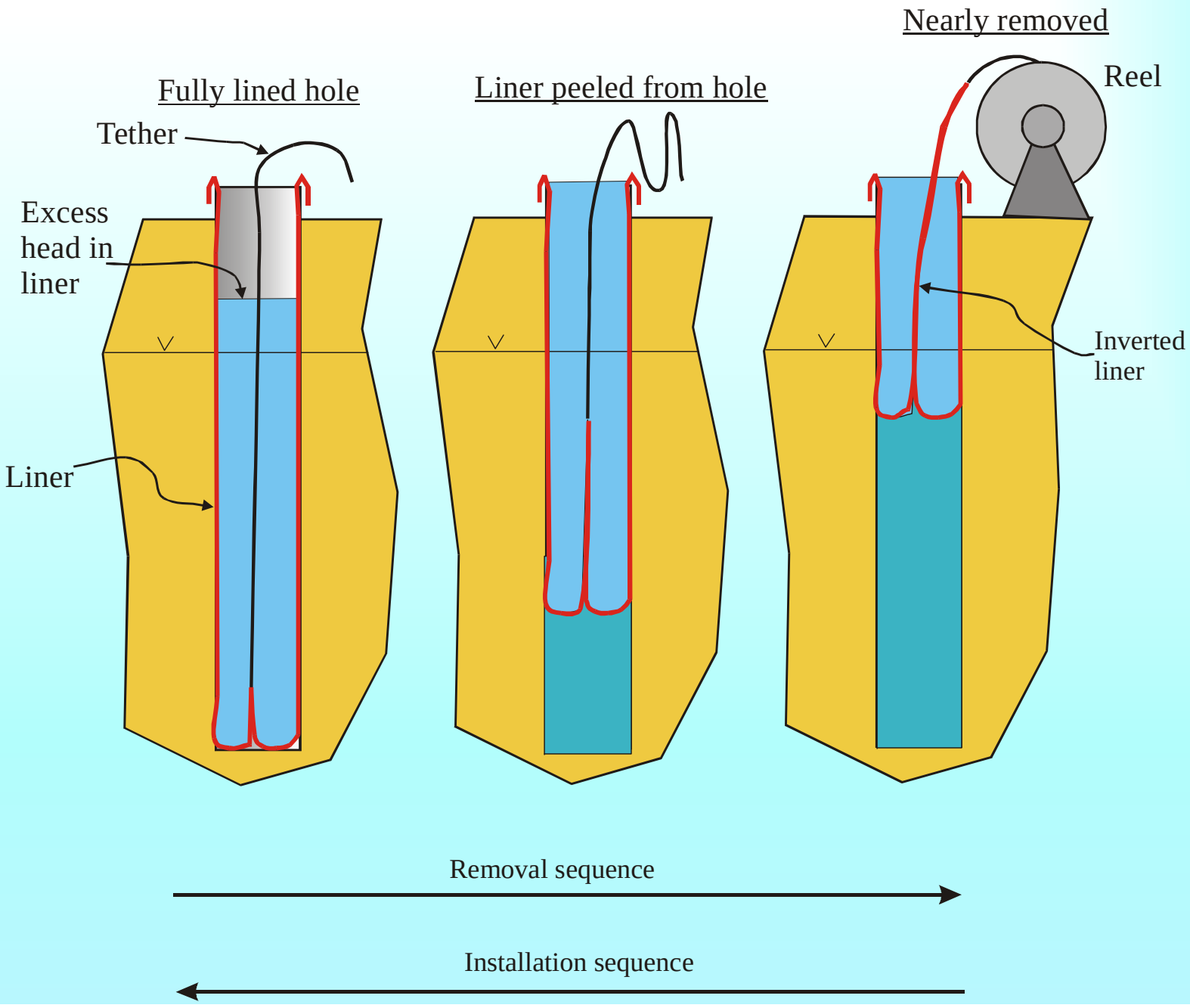
Topics

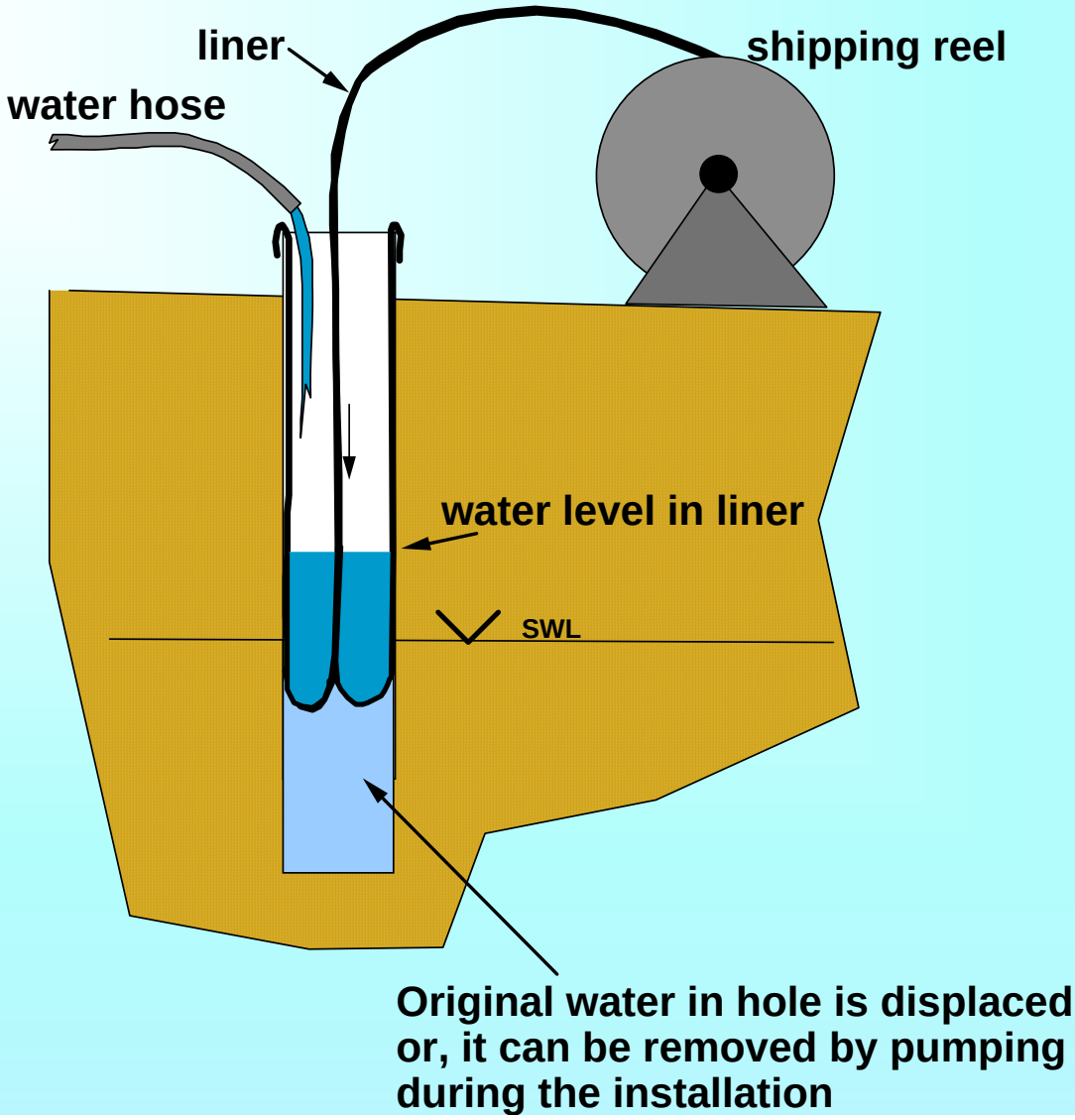
- How a blank liner is installed
- The transmissivity profiling technique
- Transmissivity results
- Highest head measurement
- Measurement of a head profile
- Multi-level sampling and head measurement

The blank liner installation seals the hole



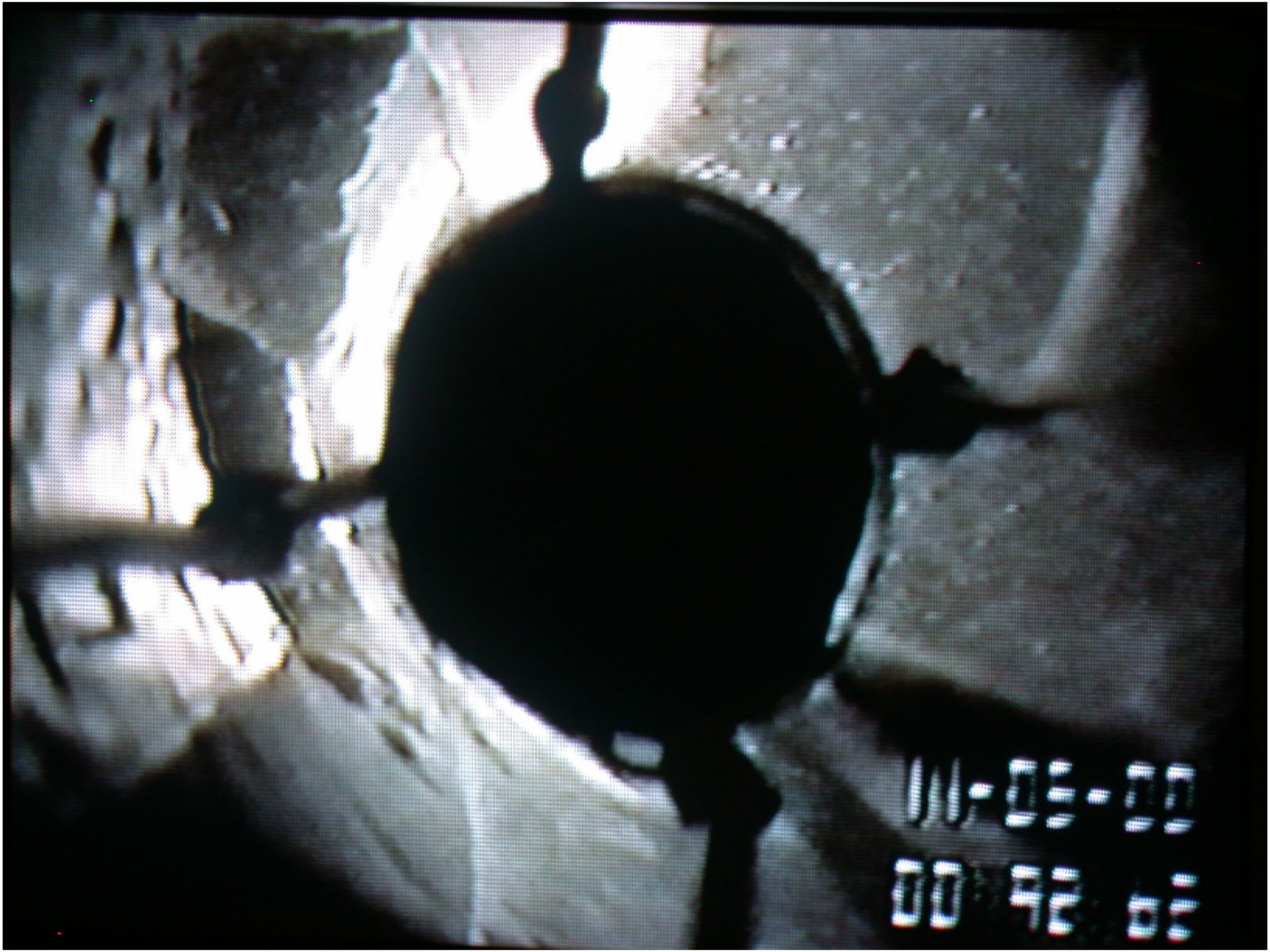
To install a blank sealing liner,

Just Add Water!

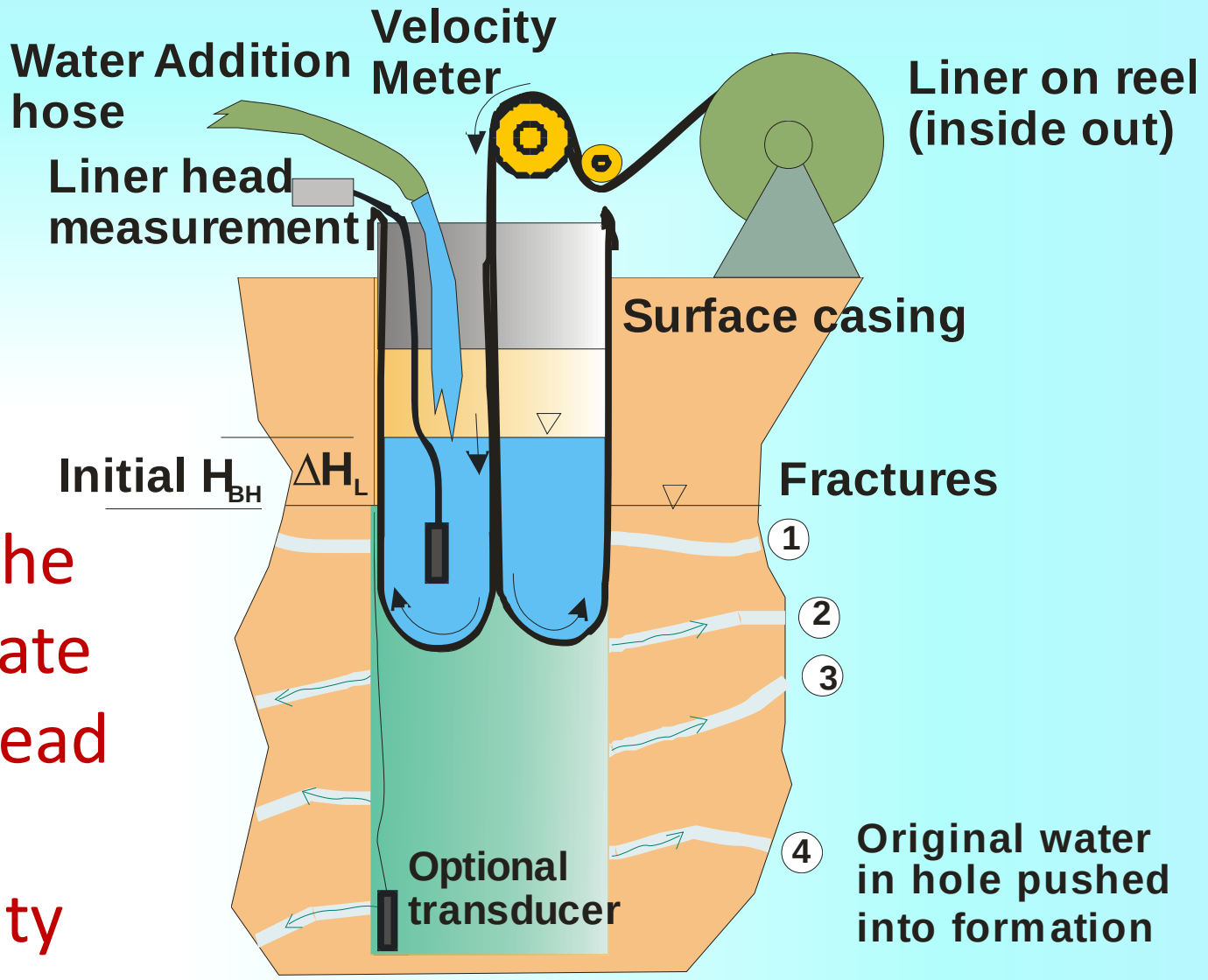


How well does the liner seal the hole?

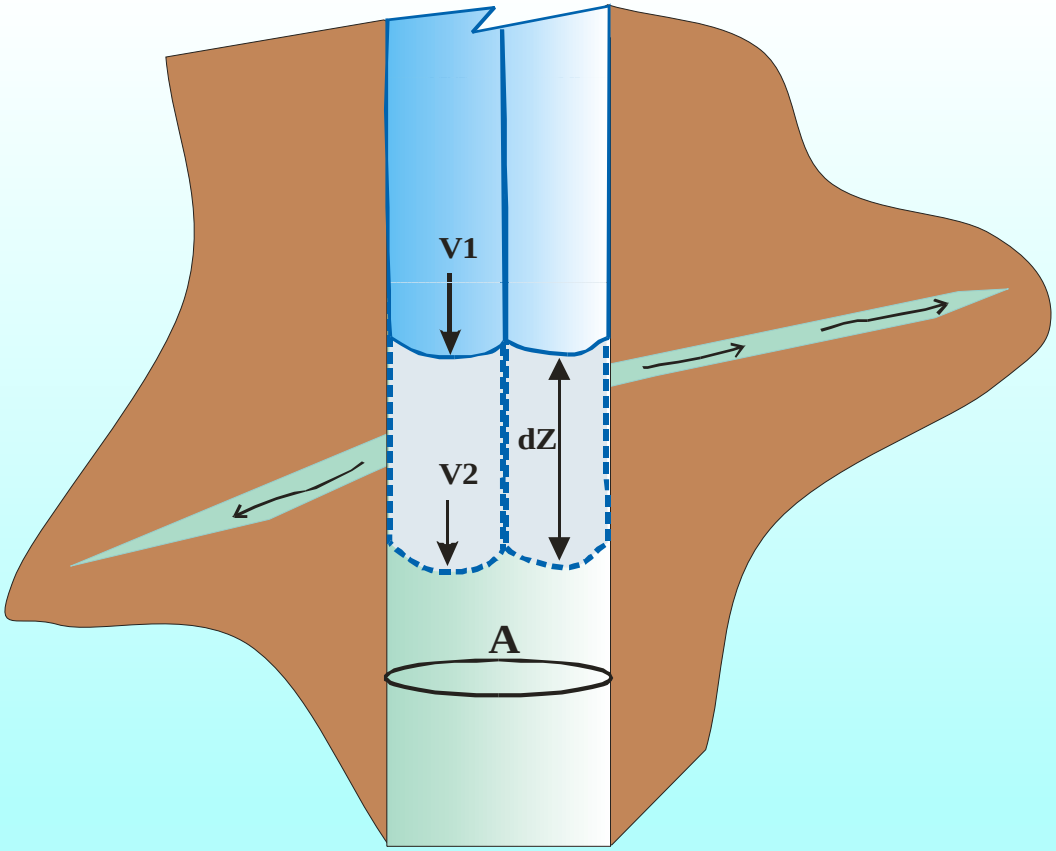
- The following photo was taken inside a 6” diameter 328 ft hole at Cambridge, Ontario by Peter Pemhe.
- The liner is a 400denier urethane coated Nylon fabric. The liner is about 6.5 inches in diameter with about 40 ft of excess head.
- In the lower left hand corner is a 1” wide welded seam tape. This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



Measuring the installation rate and driving head yields a transmissivity profile



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,..)

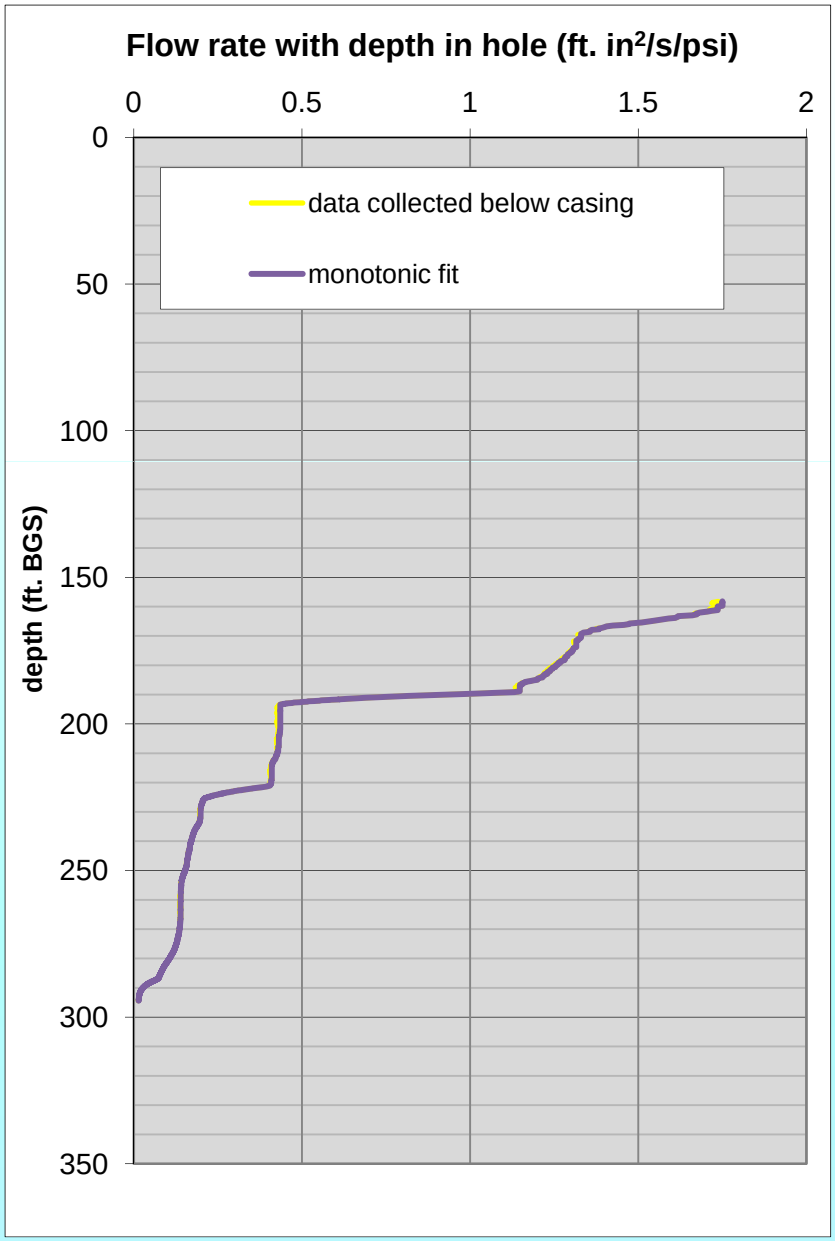
This machine collects the data to a laptop and controls the tension (8” hole)

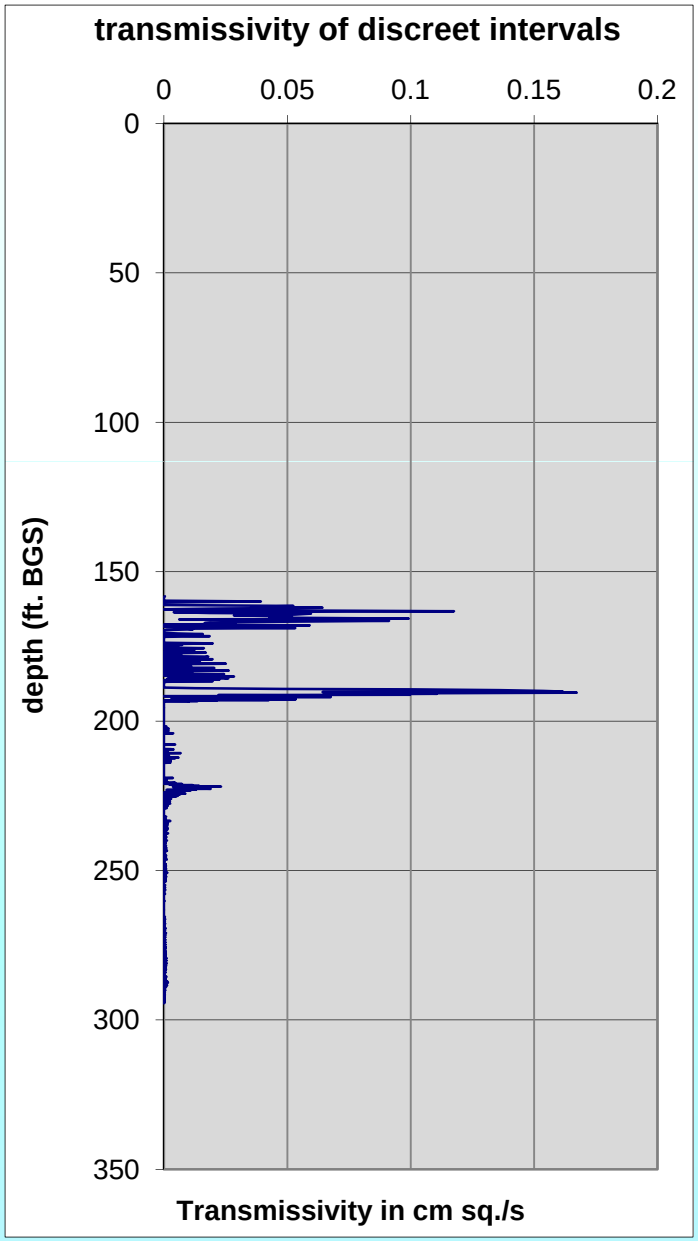
Data are collected every 0.5-1 second:

- Position
- Time
- Head inside the liner
- Tension on the liner
- Borehole pressure beneath the liner (usually)

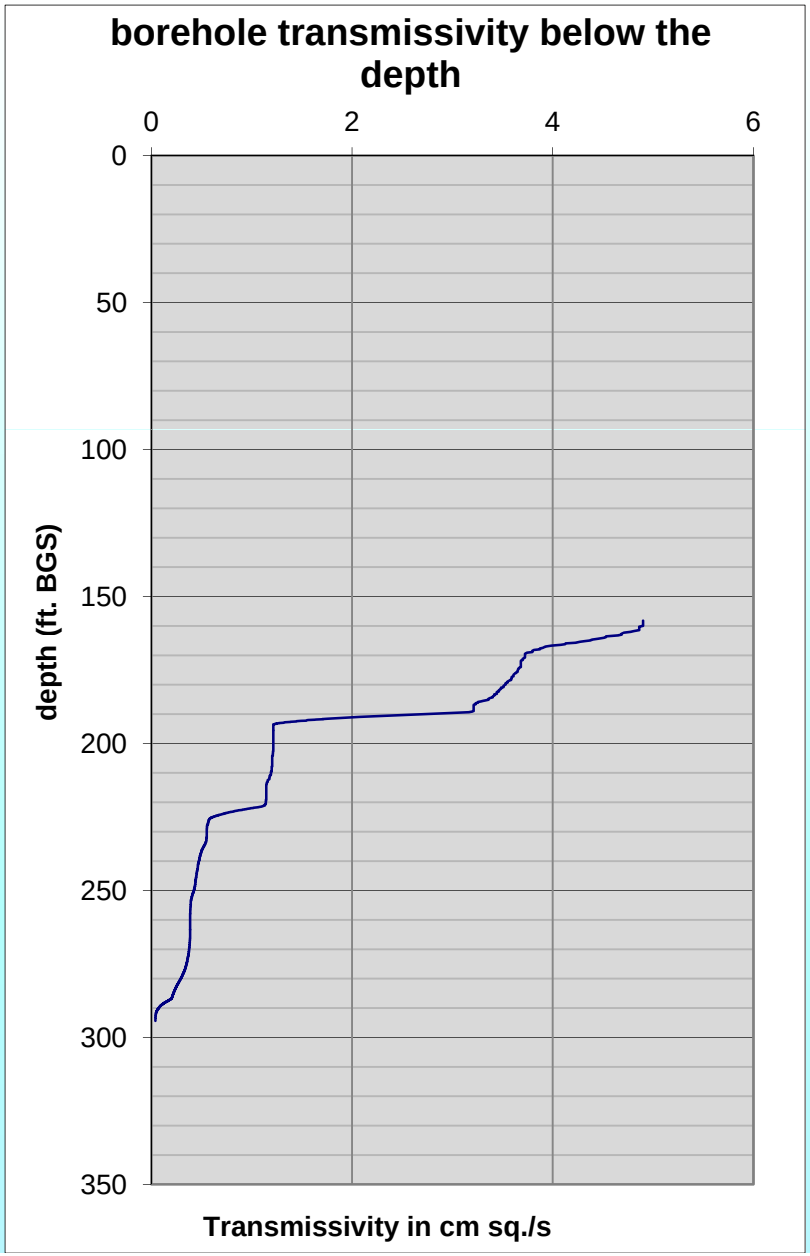
And, the tension on the liner is controlled at an essentially constant value.

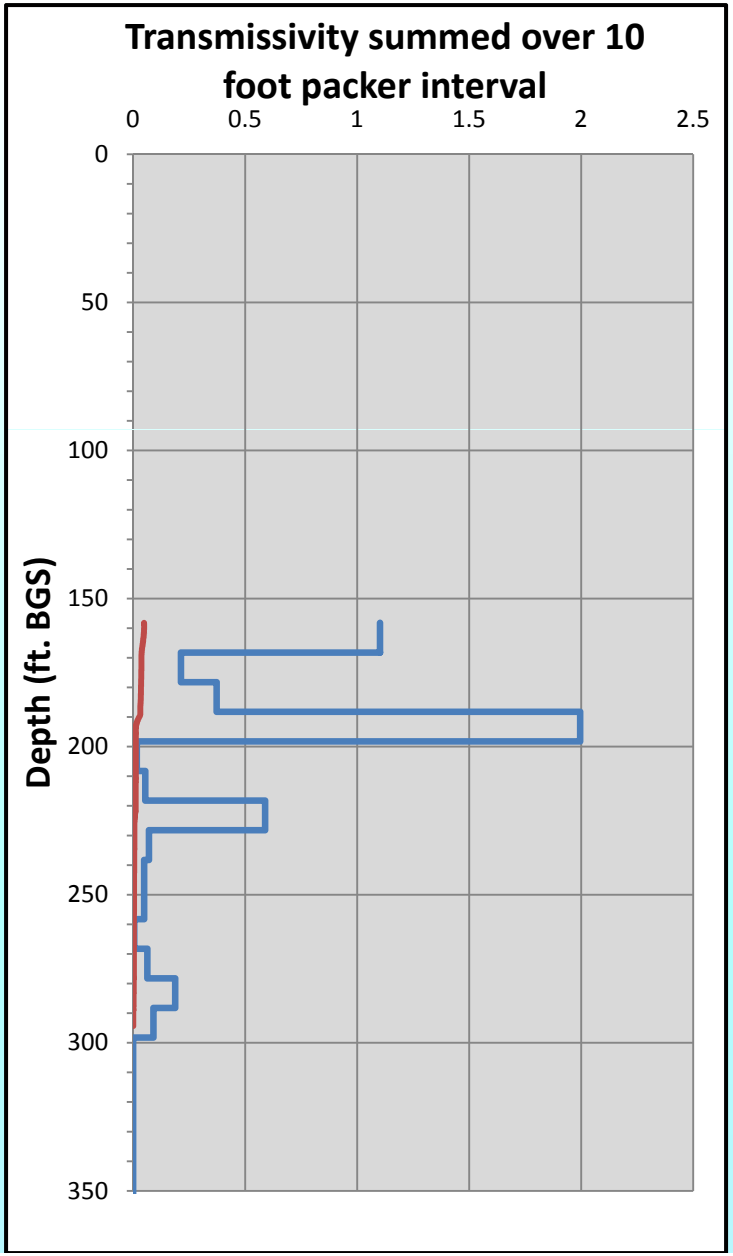
A typical result (performed in 1.5 hr.)





Integrating the transmissivity yields:

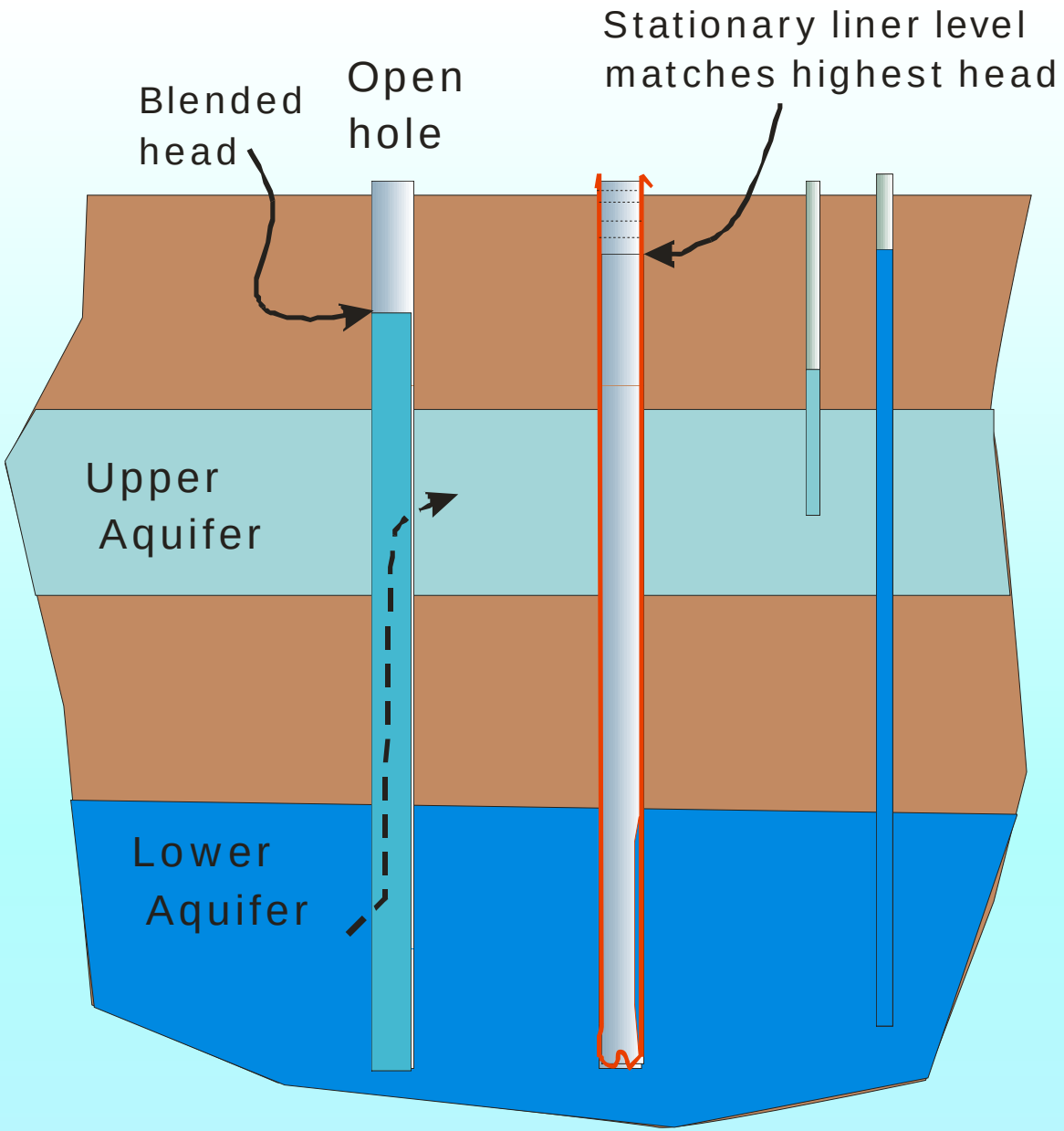




How do we obtain the highest head in the formation?

- Once the liner is installed as far as it will go, and filled with water, the hole is sealed. The tether is tied to prevent further descent.
- The water level in the liner is intentionally above the highest head in the formation in order to assure the seal.
- We lower the liner water level in incremental steps, by pumping water from the liner.
- The water level drops until the water level does not drop with the removal of more water.
- At that point, the water level in the liner is the highest head in the formation intersected by the borehole.

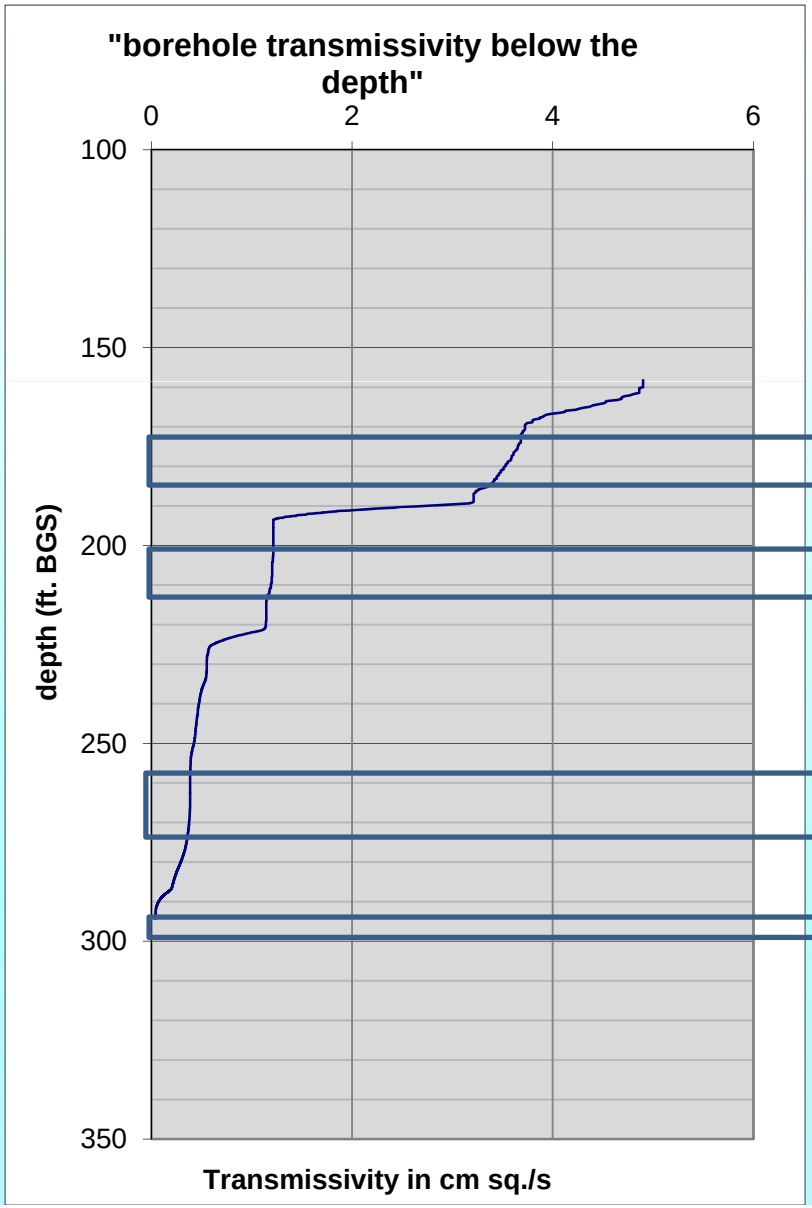
Liner measurement of highest head in formation



Next, how to gain a formation head profile

- The following method requires a continuous transmissivity profile.
- It also requires a liner which can be inverted from the hole in a stepwise manner. It can not be done reliably with a packer.
- The method can be performed by measuring the tension on the liner, but is easier using the transducer located in the bottom end of the hole. That is the assumption hereafter.
- Generally, the method is most easily performed after a transmissivity profile has been completed and the liner is still in place in the borehole.

Which of the low flow zones is an aquitard and what are the heads above and below the aquitards?



Interval numbers

8

7

6

5

4

3

2

1

We know the transmissivity of each interval, $\Delta T_i = (T_i - T_{i-1})$

We now know enough to calculate the head in each interval:

The head in the borehole interval no. 1 is the transducer measurement of the blended head in the borehole, BH_1.
This is also the head in the formation, H_1, for interval no. 1.

We know the transmissivity in each interval $= \Delta T_i = Tr_i$

If we raise the liner to uncover the intervals 1 and 2, and let the new blended head equilibrate for open intervals 1 and 2 at HB_2, we can write the sum of the flow in/out of both intervals as equal to zero:

$$Q_1 + Q2 = Tr_1 (BH_2 - H_1)\, 2\pi/\ln (R) + Tr_2 (BH_2 - H_2)\, 2\pi/\ln (R) = 0$$

More simply, $Tr_1 (BH_2 - H_1) + Tr_2 (BH_2 - H_2) = 0$

or, $\mathbf{H_2 = (Tr_1 (BH_2 - H_1) + Tr_2\, BH_2)/Tr_2}$, ***the formation head in interval 2!***

Hence we can determine the head in each interval:

$$H_i = [\ Tr_1\ (BH_i - H_1) + Tr_2\ (BH_i - H_2) + \ldots\ldots + Tr_i\ BH_i\ ]/Tr_i$$

Where BH_i is the equilibrium borehole pressure determined from the transducer in the bottom of the hole after each incremental rise of the liner.

Tr_i is obtained from the continuous transmissivity profile.

The continuation of this logic is very amenable to calculation in a spreadsheet and requires only the selection of intervals of interest.

Note, the least reliable head values are those results where Tr_i is near zero and therefore poorly measured with a liner. However, the product of H_i and Tr_i for that interval is also small for determination of other formation heads.

Additional methods available:

- Color reactive cover on a liner for mapping NAPL in fractures or permeable beds, “NAPL FLUTe”
- Activated carbon felt strip on the NAPL FLUTe called a “FACT” which wicks up a replica of the dissolved phase contaminant in the formation.
- Installations of NAPL FLUTe and FACT systems through direct push rods

These are described on our web site www.flut.com

The FLUTe “linear capstan” removing a liner

The blank liner is then swapped for the multi level sampling system:

1. First, the sampling intervals are defined by the customer

2. Then, the multi level “Water FLUTe” system is fabricated and shipped to the site on a reel.

3. The blank liner is removed.

4. The “Water FLUTe®” liner is installed

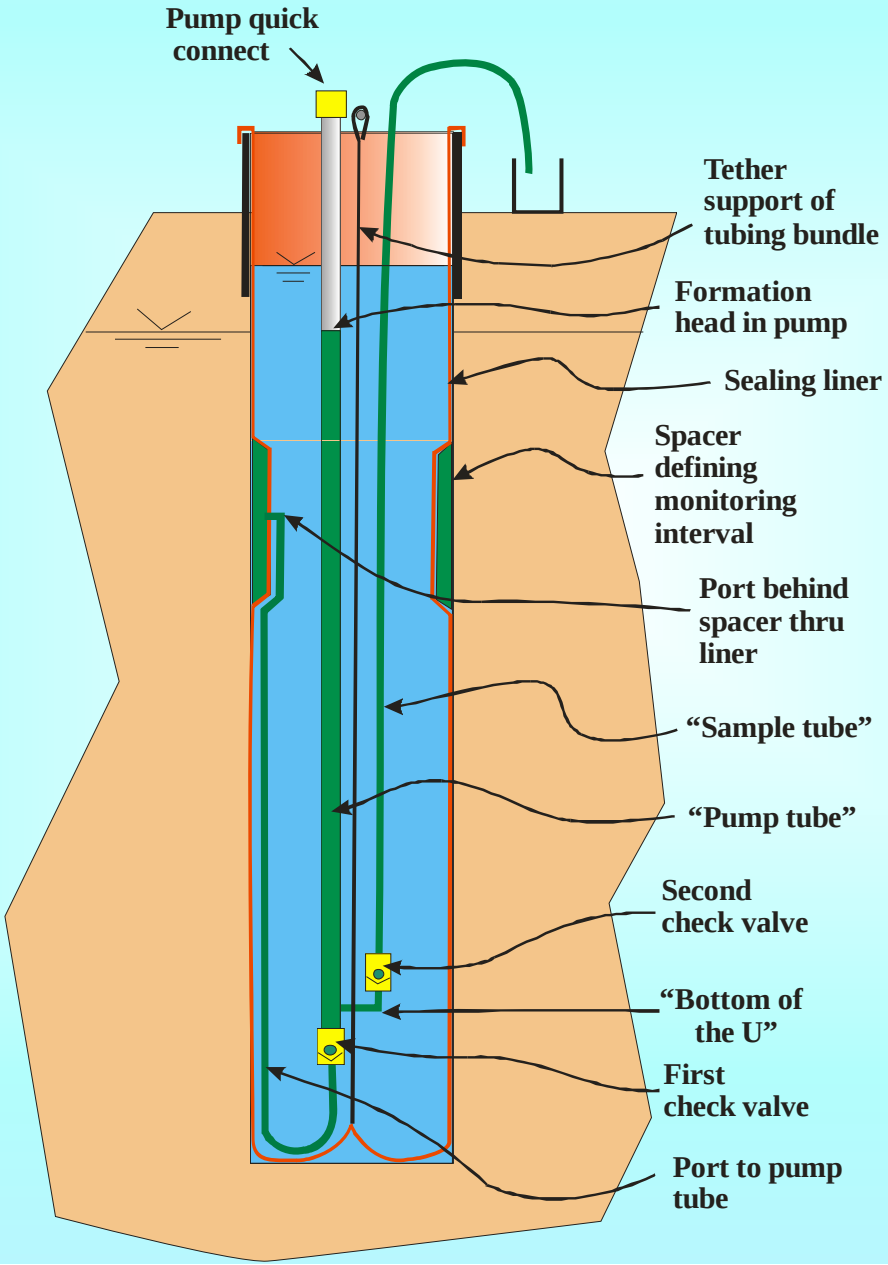
The Water FLUTe Installation

15 Ports
installed
to 328 ft
in 2 hrs

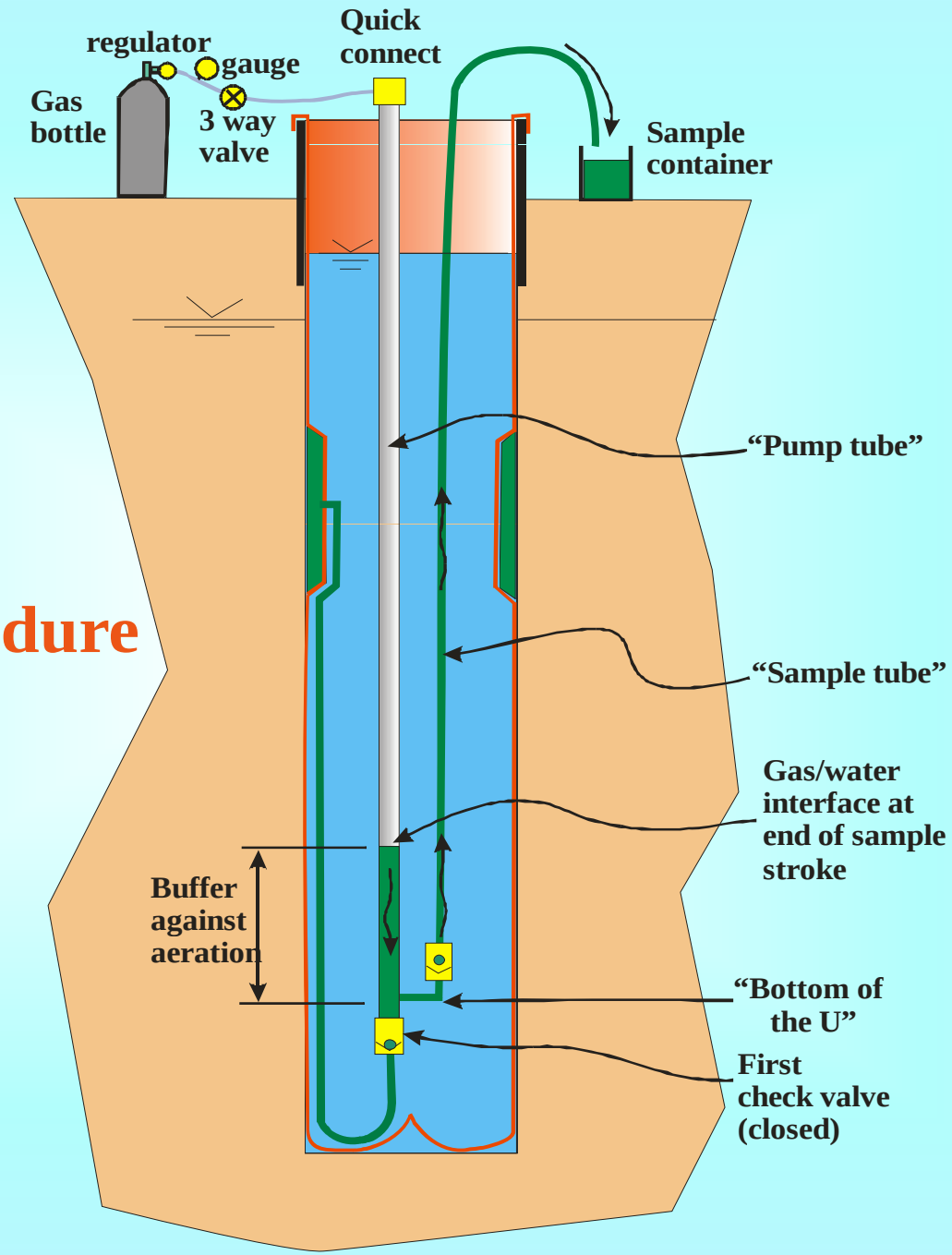
(Cambridge, Ontario, 2001)

Water FLUTe liner system in place

(Single port system shown for clarity)



Pumping Procedure



Additional Features of a Water FLUTe:

- Seals the entire hole except at spacers, no bypass possible.
- Draws samples directly from the formation
- All PVDF tubing system to minimize sample interaction.
- Purge and sample all ports simultaneously
- 6-15 ports in 4-6 inch holes, respectively.
- Add transducers to record head histories
- Completely removable
- Well suited for tracer measurements

In Summary

- A single flexible liner can be used to:
  - Seal a borehole
  - Map the transmissivity
  - Measure the head distribution
- The multi-level Water FLUTe can:
  - Obtain discrete water samples
  - Measure the head at each interval
  - Perform tracer tests

Thanks for your attention

Questions?

You can see more of our systems at our web site
www.flut.com

Note, FLUTe has patents in place or pending on all of these methods.