



# The Full Use of FLUTE Liner Technology in Fractured Rock Boreholes

BY

CARL KELLER

# Objectives?

Map the contaminant distribution

1. Two dimensional assessment of NAPL
2. Map the dissolved phase distribution of contamination
3. Sample the ground water at many elevations for analysis

Determine where it is going

1. Measure the conductivity distribution in the formation
2. Map the head distribution that is driving the flow

Or,

Map the flow paths and head distribution near mines

Or,

Map the water quality and availability for municipal water supplies

# Drill the hole quickly to avoid cross connection

Fastest drilling methods?

- Air rotary, preferably 6 inch diam.
  - Time per hundred ft ~ half day?
  - Cost per foot ~ \$26-30/ft
- HQ core drilling
  - Time ~4 times longer than air rotary
  - Cost per foot ~\$75/ft
- Sonic drilling
  - Time and cost ???

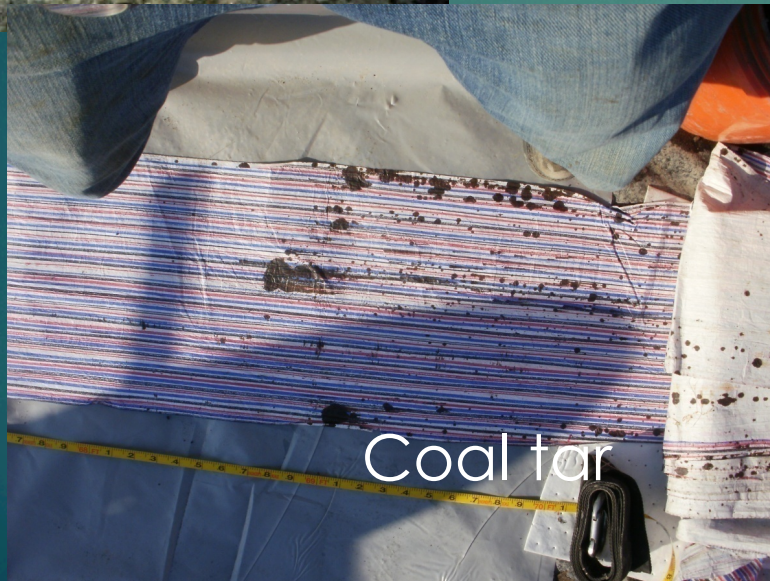
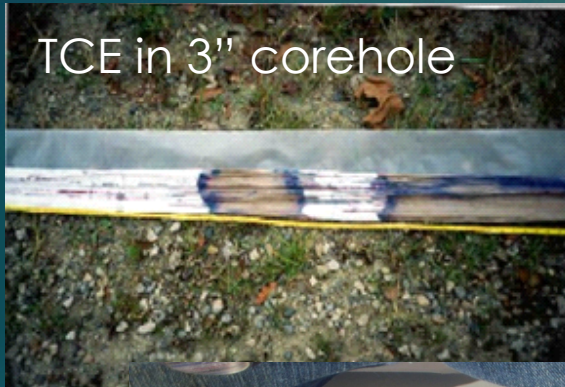
# Install a blank liner with NAPL/FACT systems (usually done by driller)

- ▶ Minimize time the hole is left open for cross connection
- ▶ NAPL Cover reacts to many free products and carries the FACT activated carbon strip
- ▶ FACT strip wicks by diffusion the dissolved contaminants from the pore/fracture space for a replica of the contaminant distribution.

# Removal of the liner enhances removal of cuttings from fractures

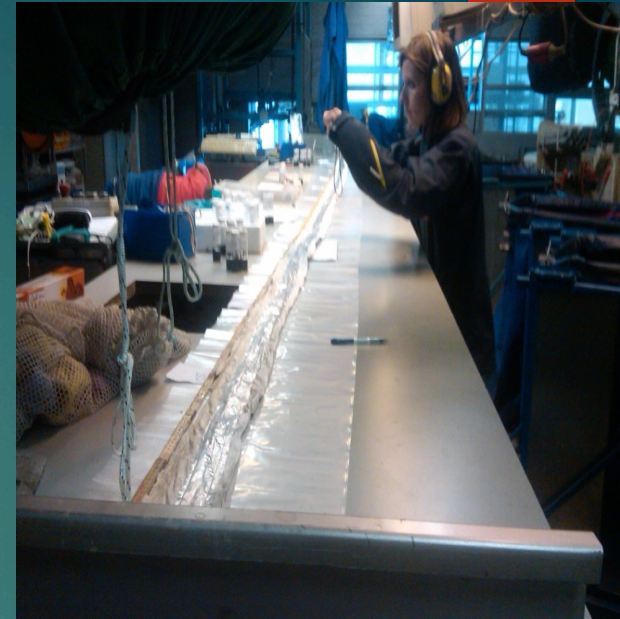
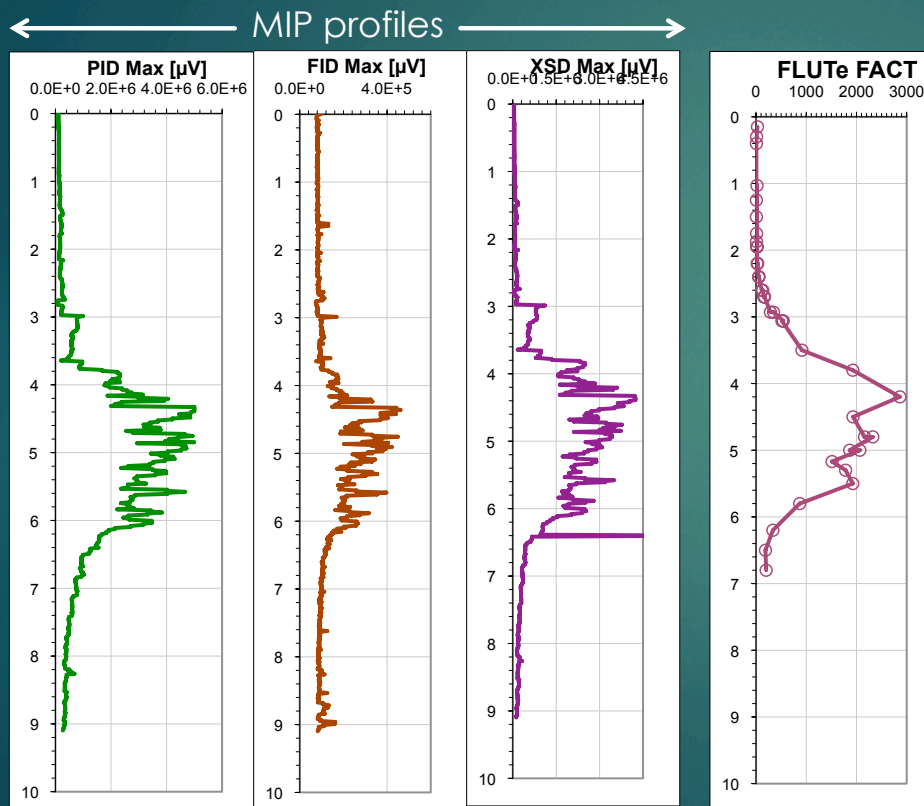
- ▶ Large drawdown beneath the liner in most cases
- ▶ Abrupt application of the drawdown head
- ▶ Effect has been demonstrated with measurements of transmissivity before and after.

# The NAPL FLUTE results



Stains locate DNAPLs

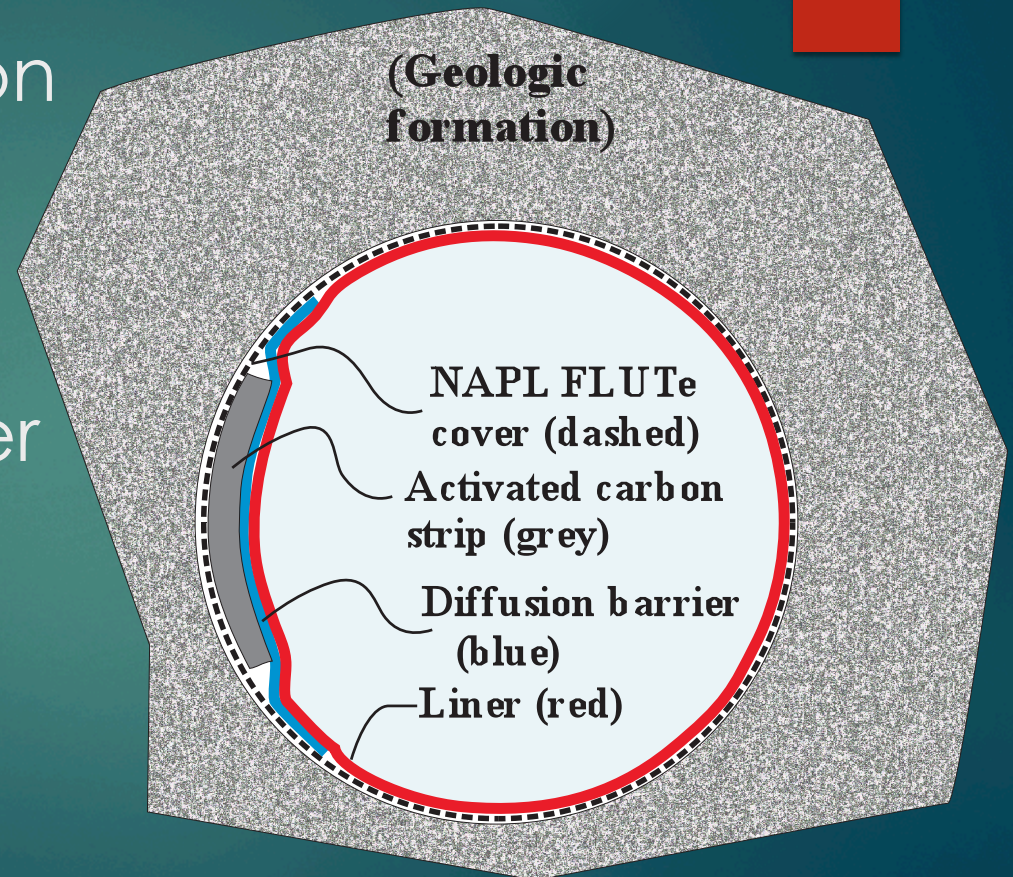
# Tests in Denmark confirm FACT maps dissolved phase



Inverted cover showing  
silver diffusion barrier

Circumstances of FACT:  
Direct push installation to 8 M  
in clay till in Denmark.  
Left in place one day.  
Mass spectrometer assessment  
of carbon felt.

The FACT outer NAPL cover and the diffusion barrier prevent undesirable carbon interaction with borehole water or liner

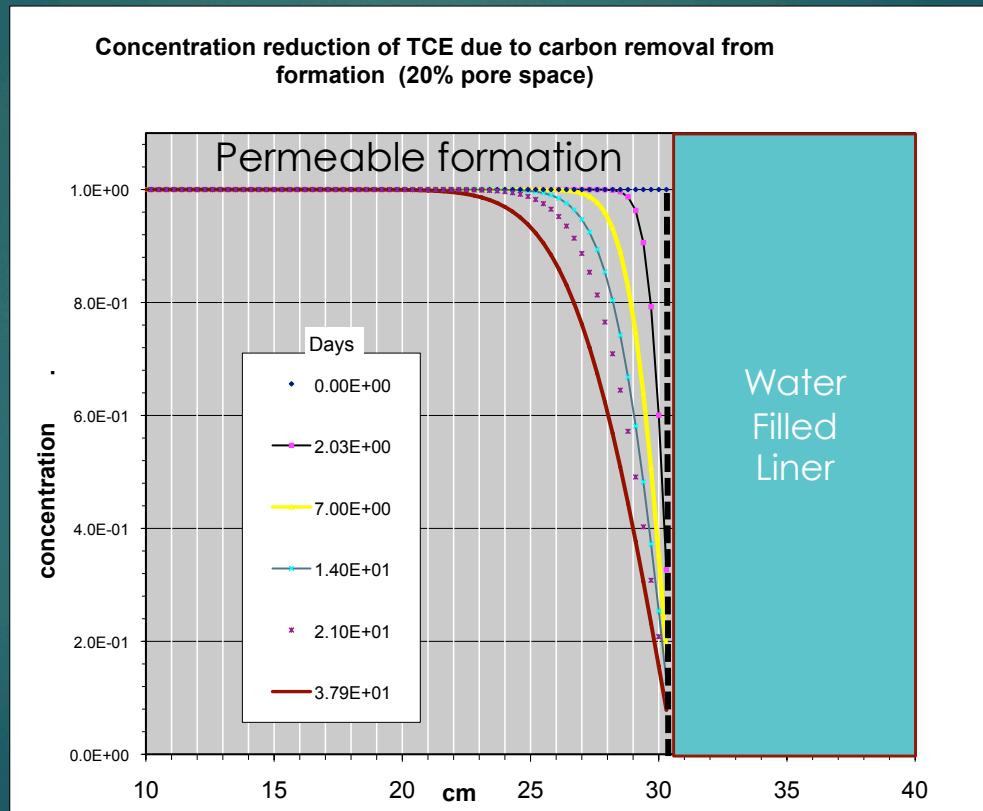




# How does the FACT work?

- ▶ The liner with the FACT is everted into place in a borehole and left for ~2 weeks.
- ▶ The liner is then inverted from the borehole and the NAPL cover is photographed for NAPL stains.
- ▶ The FACT is removed from the cover, rolled and shipped to the lab for explicit measurement of the contaminant species and relative abundance. Use the transmissivity profile (described hereafter) for selection of FACT intervals to be sampled, thereby reducing the analysis cost.

# The FACT wicks to a significant depth

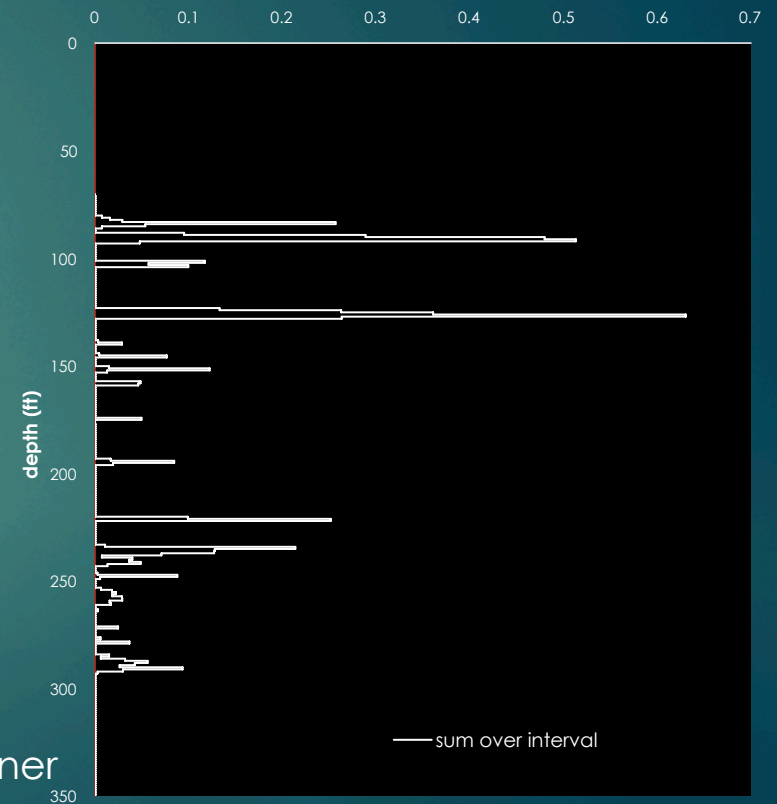


# Perform the Transmissivity Profile using the NAPL FLUTE/FACT carrier liner




- ▶ Plus, measure head at bottom of borehole
- ▶ Determine the highest head in hole (artesian?)
- ▶ Perform a head profile with stepwise removal of the liner

Transmissivity profile over 1 ft intervals ( $\text{cm}^2/\text{s}$ )



## Other useful measurements to be combined with Liner measurements:

- ▶ Borehole flow meter under natural head (i.e., un-pumped)
- ▶ Caliper log for correlation with the transmissivity velocity profile and confirmation of the depths of significant features.
- ▶ Video log for correlation with flow zones identified and formation information.



Define the sampling elevations for head and water quality measurements for construction of the Water FLUTe multi-level system for long term measurements.

- ▶ Guided by the profile results
- ▶ Guided by the FACT and NAPL FLUTe results
- ▶ Guided by any geophysical results available

# Install the Water FLUTE system in one day:

1. Pull the blank liner
2. Install the Water FLUTE system (with or without recording transducers)
3. Test the individual ports by purging individually
4. Thoroughly purge all ports simultaneously with the manifold
5. Sample all ports simultaneously with the manifold.

# Other useful options

- ▶ Monitor the arrival of Potassium permanganate with a transparent liner and white covering.
- ▶ Short stroke the Water FLUTe multi-level pumping system to detect the arrival of the injected remediation fluids or tracers with minimal water extraction.
- ▶ Hybrid options for both multi-level water sampling and vadose pore gas and pressure measurements in the same borehole.

# The new multi-level Water FLUTe system!

- ▶ Called the “Shallow Water FLUTe” system.
- ▶ The least expensive multi-level system for water tables less than 25 ft.
- ▶ Full liner seal of the borehole
- ▶ Sampling with a peristaltic pump
- ▶ Head measurement with a FLUTe air coupled water level meter.
- ▶ Continuous head monitoring with the FLUTe ACT (air coupled transducer) technique with all the transducers conveniently located at the surface.
- ▶ Shipped and installed like a blank liner

If you doubt the least expensive claim, or peristaltic pumping is not allowed, call us at 505-930-1154.



# Measurements that may not be needed:

- ▶ Electric log?
- ▶ Gamma log?
- ▶ Acoustic log (unless borehole water too cloudy for optical video)?
- ▶ Core assessment and related drilling costs?
- ▶ Packer tests? Because:
  - ▶ FACT identifies the extent of contamination confirmed with Water FLUTE measurements without the borehole being open for cross connection.
  - ▶ Head profile is available with blank liner and with the Water FLUTE.
  - ▶ Flow zones are identified with higher spatial resolution with the transmissivity profile unless there is a high flow zone at the bottom of the hole. In that case, packer testing is useful for identification of lower permeability flow zones.
  - ▶ Water quality and head measurements are made over long time periods with the Water FLUTE in a sealed hole, not just once in an open hole.
- ▶ Others? Food for thought. Ultimately the customer's choice.


# Summary:

1. Liners provide a rapid seal of the entire borehole
2. Liner measurements locate LNAPL and DNAPL sources
3. Liner measurements provide a dissolved contaminant distribution
4. Liner removal is an effective well development procedure
5. Liner measurements provide high resolution transmissivity information
6. Liner measurements provide long term water quality history
7. Liner measurements provide head distribution history
8. No sealing materials such as grout or bentonite are required
9. Liners are easily removed for other borehole use or abandonment
10. Liner measurements minimize the time the borehole is cross connecting

# Conclusion



- ▶ The ability to seal the entire borehole after drilling reduces the confusion of contaminant distribution due to cross connection.
- ▶ The mapping of NAPL and dissolved contaminants while the borehole is sealed has obvious advantages.
- ▶ The transmissivity profiling technique allows high resolution of formation flow paths in minimum time and for minimum cost.
- ▶ The flexible liner multi-level systems allow high resolution monitoring of water quality and head.
- ▶ The several liners' seal of the entire borehole reduces the confusion of contaminant distribution due to bypass of packer systems. The continuous seal also eliminates the cost of grouting and sand packs.
- ▶ The ability to remove the liner allows a practical warranty of the system.



For more information on liner methods, prices, and installation procedures:

- ▶ info@flut.com
- ▶ Web site [www.flut.com](http://www.flut.com)
- ▶ Call 1-505-852-0128 or 1-888-333-2433