Applications of the new Geoprobe® OIP system for NAPL and tracer detection

Anders G. Christensen
Expertise Manager, NIRAS Denmark

Acknowledgements

Søren Dyreborg, NIRAS (DK)
Peter Tyge, NIRAS (DK)
Markus Reicher, NIRAS (DK)
Wesley McCall, Geoprobe (US)
Fabian De Weirdt , Geoprobe Env. Tech. (BE)
Laura Stocco, NIRAS Intern (CH)

Outline of the talk

01 Introduction – what is the OIP system?

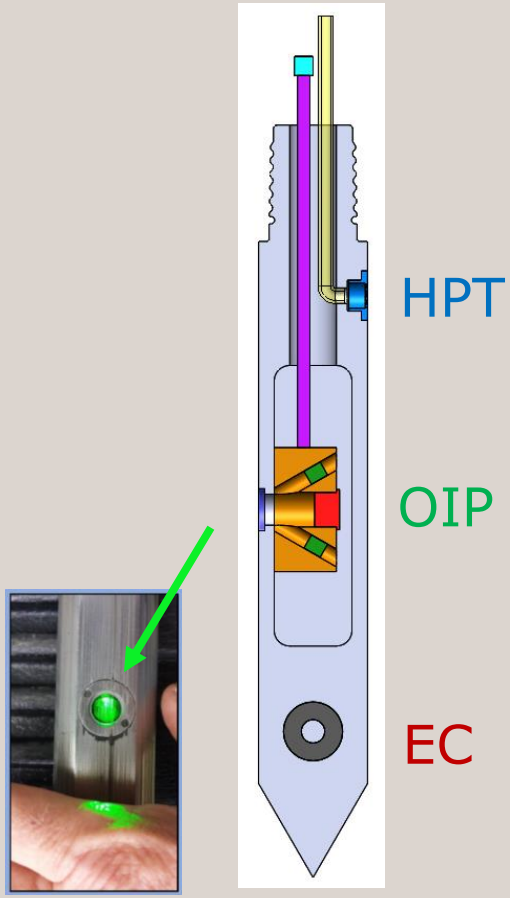
02 Case studies

- A Creosote DNAPL delineation with OIP-G
- B Delineation of old diesel NAPL spill
- C Detection of fluorescent dyes as part of injection test/pilot test
- D Estimating soil properties using OIP-VIS

03 Conclusion

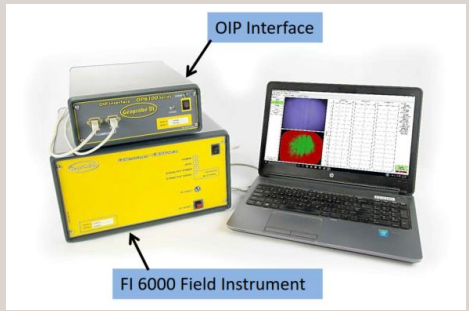
Geoprobe direct image®

Optical profiling tool (OIP)



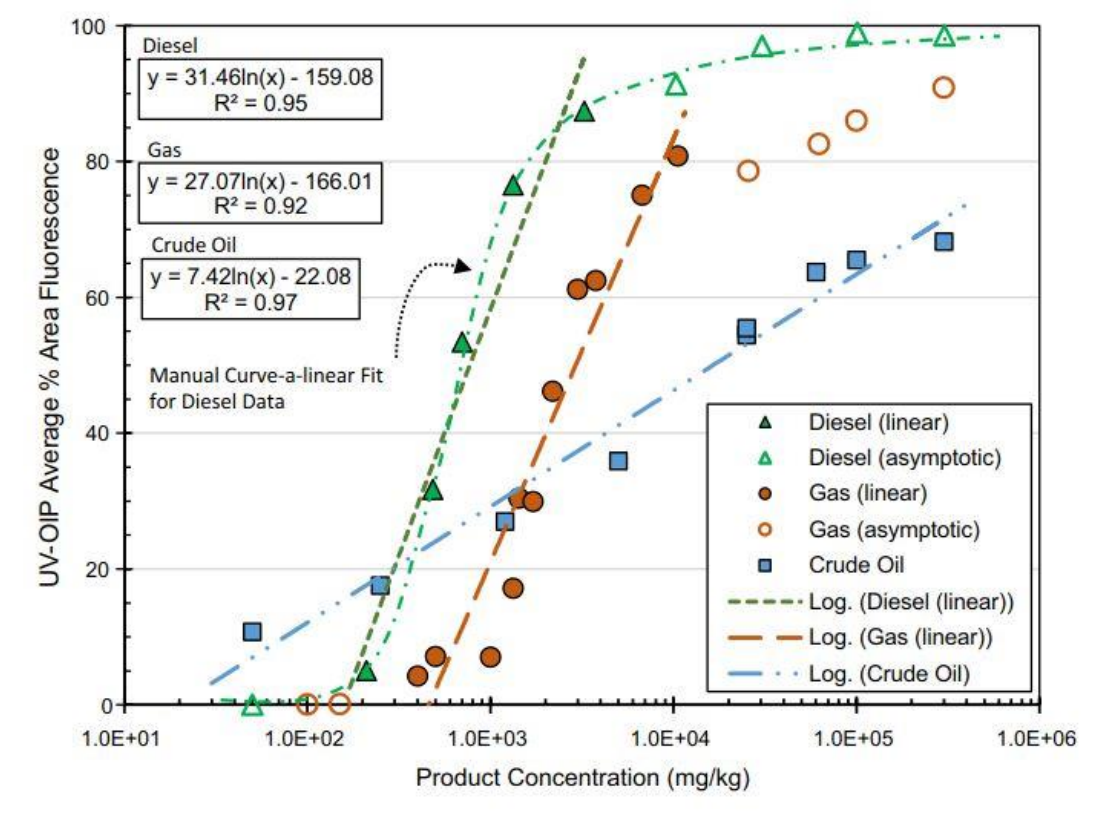
- Light directed through sapphire window, induces fluorescence
- Onboard camera captures 30 images per second analyzed as probe is advanced. Real time results.
- Still images using both visible and fluorescent light can be taken at desired depths
- Are integrated with the HPT system and named OIHPT

→ Logs EC, K and fluorescence of image



Fluorescence of fuels

PAH compounds



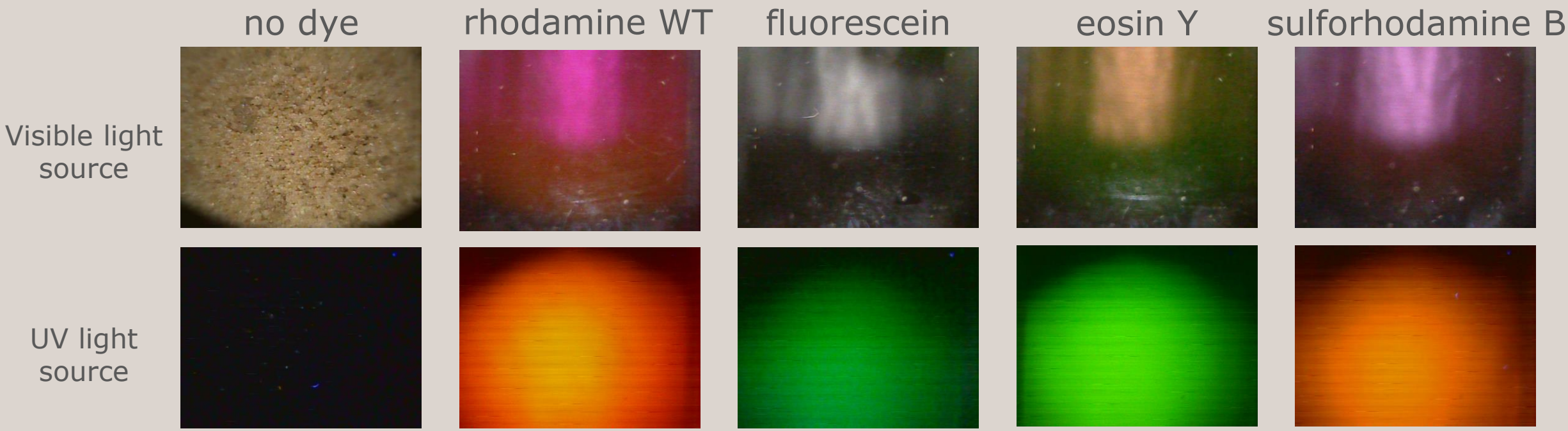
McCall et al., 2018. Evaluation and application of the optical image profiler (OIP) a direct push probe for photo-logging UV-induced fluorescence of petroleum hydrocarbons.

- Short chained PAH´s emit fluorescent light when irradiated with UV
- Longer chained PAH's respond better when irradiated with green light
- Approximate log-linear correlation of oil saturation and fluorescence over one to two orders of magnitude (product specific)

→ Signal can be used to give a semi-quantitative measure of fuel saturation (%area)

Lab testing OIP using fluorescent tracers

Image raw data, UV/VIS

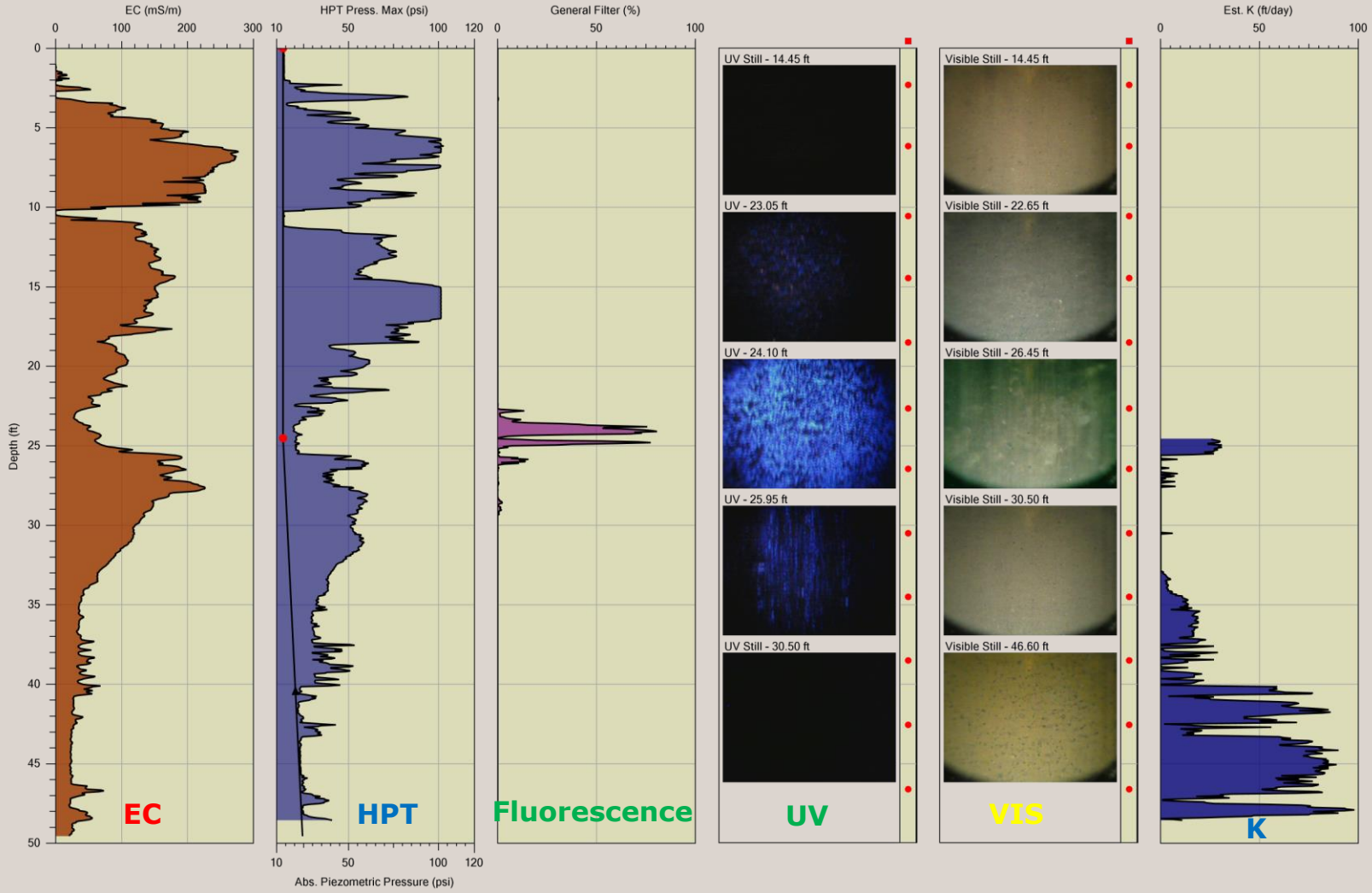


- All tracers are detectable using UV light source- but differ in their response (under publication*)

**Picture courtesy of Markus Reicher, PhD student at NIRAS/ University of Copenhagen*

Geoprobe OIP®

Typical log using the OIHPT system - combining both OIP and HPT



Geoprobe OIP®

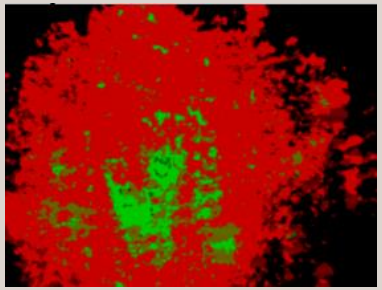
Response using UV – be careful!

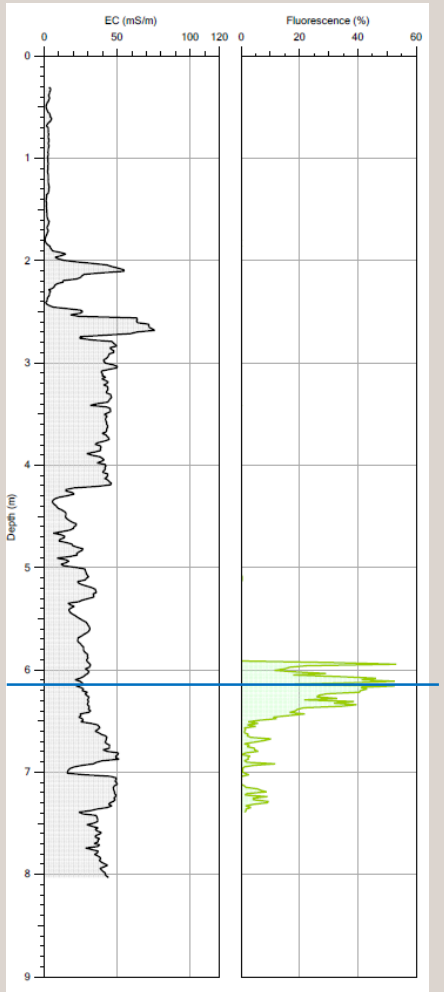
Positive

Visible light

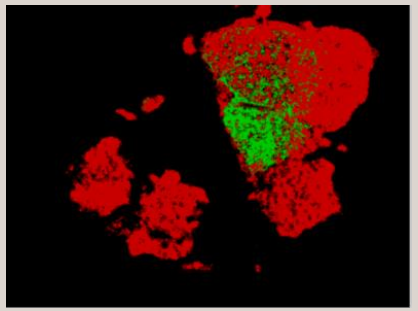
UV light

Analysed





False positive



Astarte Elliptica

Shells of calcite, limestone, pieces of reflective metals…

Case study A: Creosote DNAPL

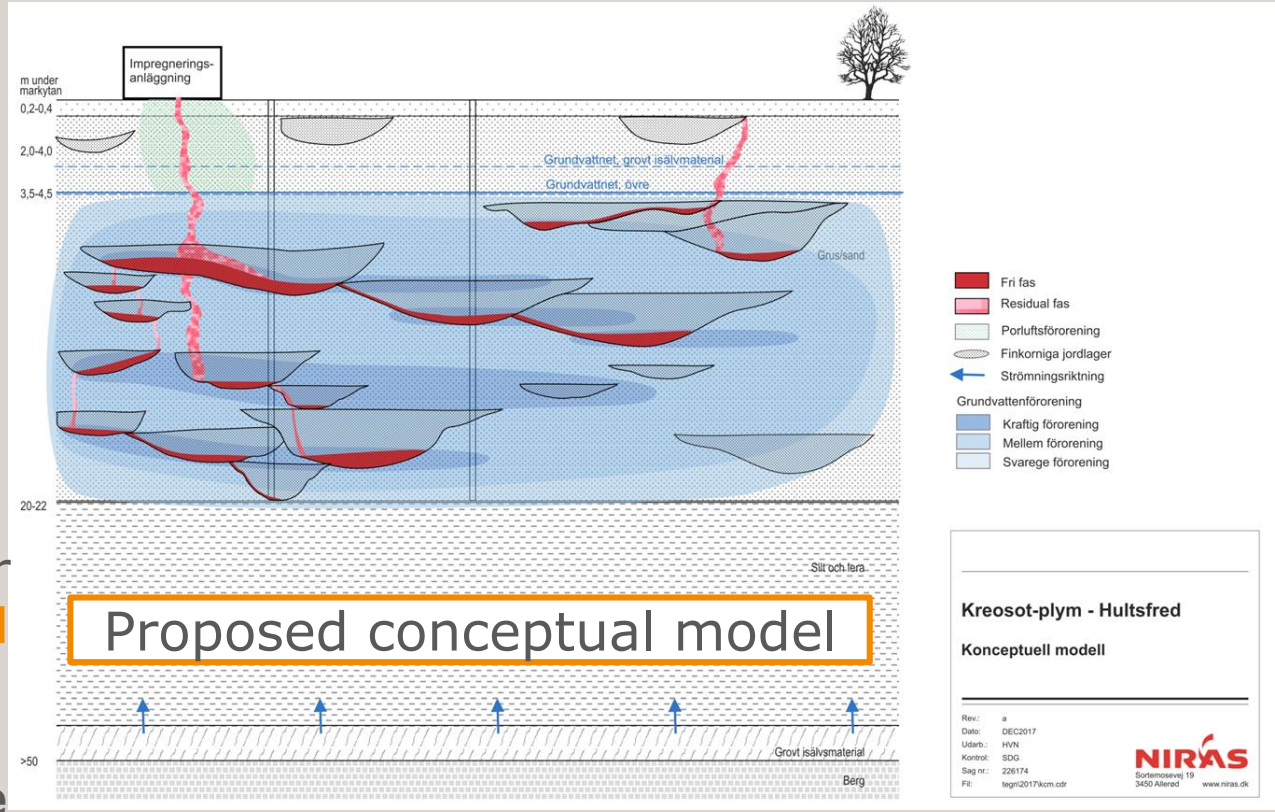
Delineation using OIP-G

- Former **creosote** impregnation during 1943-1989
- Multiple investigations performed using standard drilling techniques

→ Geology described as an **homogeneous** meltwater deposit

→ **Sporadic indication of DNAPL**, yet no clear understanding and **weak conceptual model**

New proposed conceptual model suggests very discrete DNAPL lenses and much more complex geology including through cross bedding

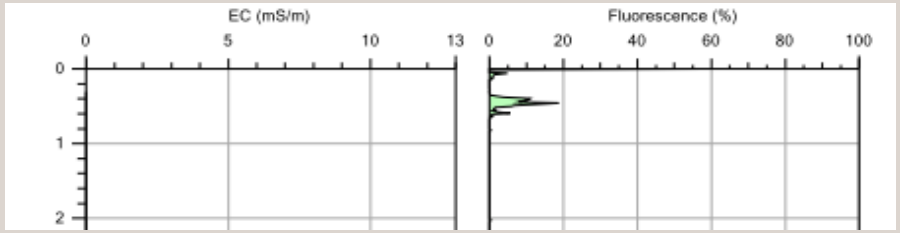


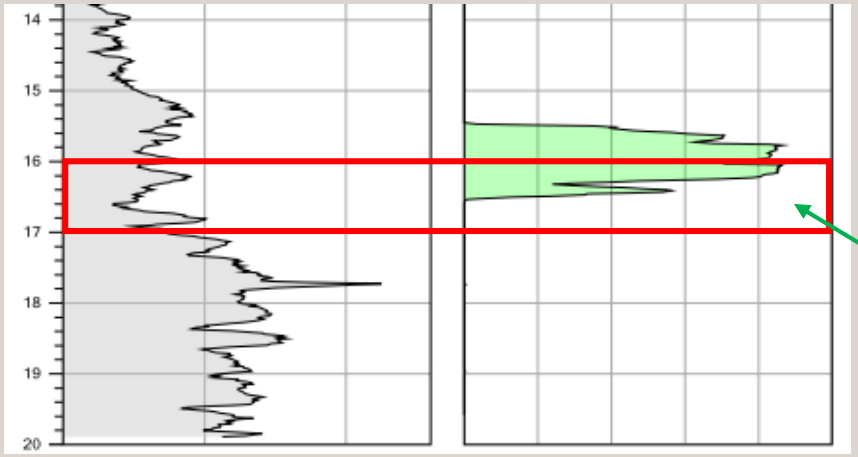
Proposed conceptual model

Need for **high resolution NAPL delineation** to test this hypothesis. **OIP-G** used for this purpose.

Case study A

Core sample with DNAPL and fine cm-scale geological features





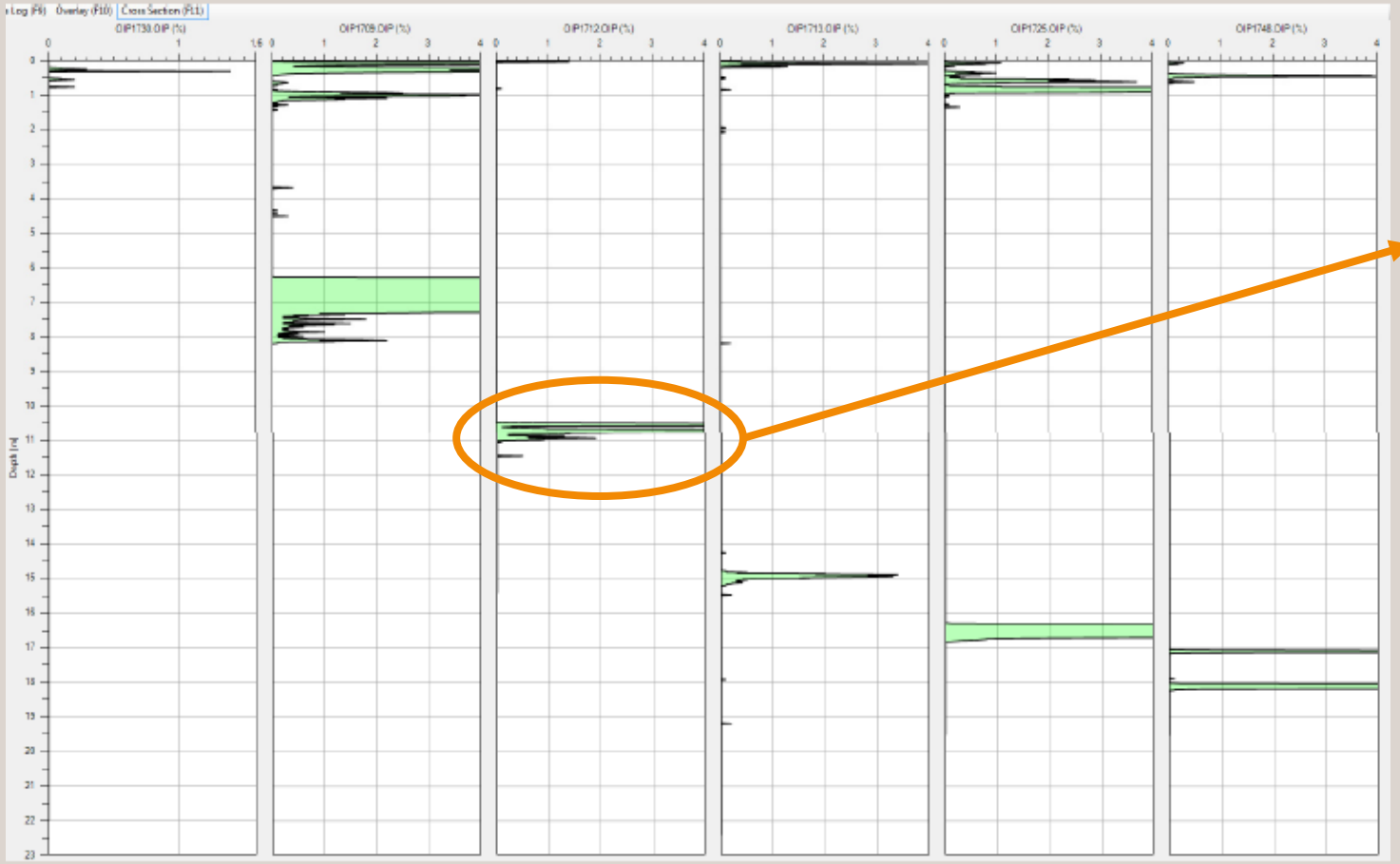
Fining upward sequences

Free phase creosote

16-17m depth

Case study A

OIP-G creosote profile shows very discrete DNAPL lenses across the site



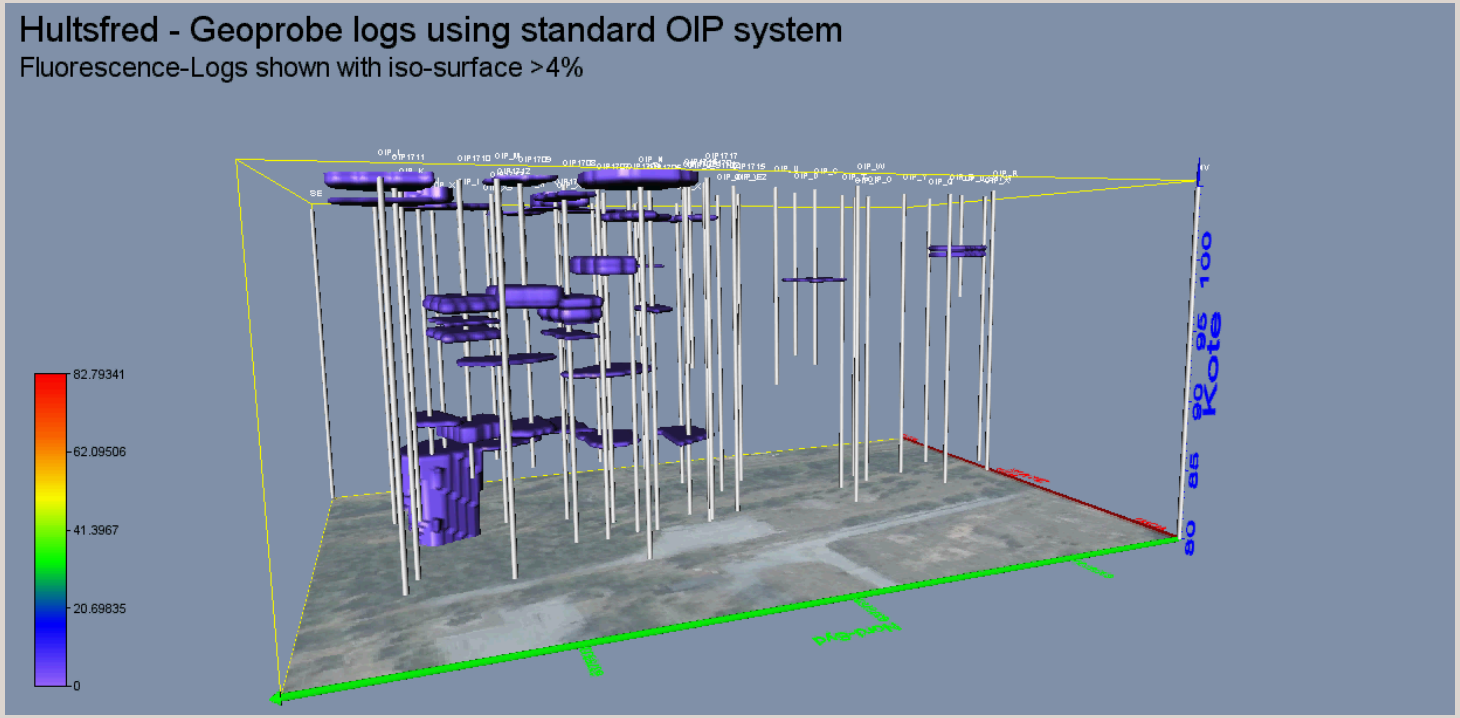
- Detection of DNAPL creosote by 30 data points, each separated by 1.5 cm (≈45 cm)
- Statistics for this profile indicate that NAPL is occupying only approx. 2% of the targeted 20m depth

Confirms the conceptual model and illustrates the need for high resolution data

Case study A

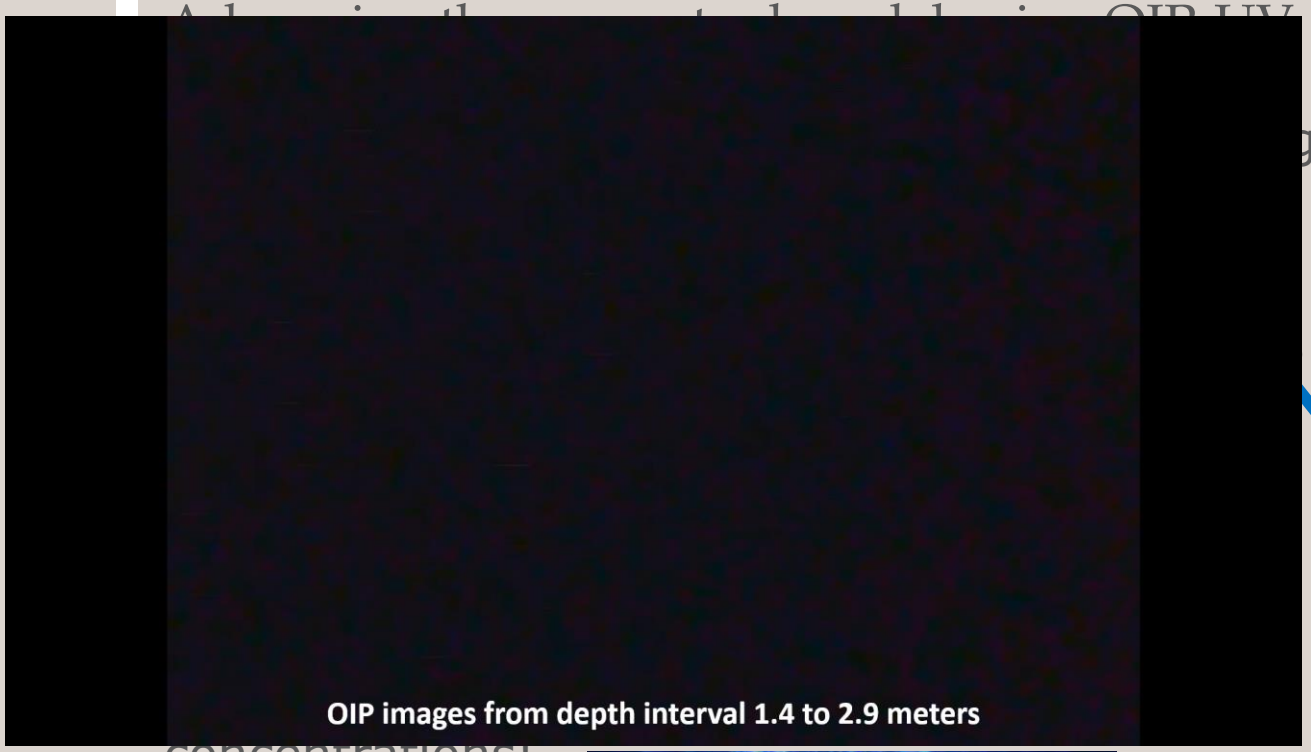
3D visualization of DNAPL distribution using OIP-G data

- Total of 71 measuring points to approx 20m depth have been completed with OIP-G
  - > 95’000 data points
  - equivalent to >1,4 km
  - 3 weeks of field work
  - ≈150’000 EUR
- Data imported in VOXLER to develop 3D visualization
- NAPL creosote volume estimated to be 60 m^3

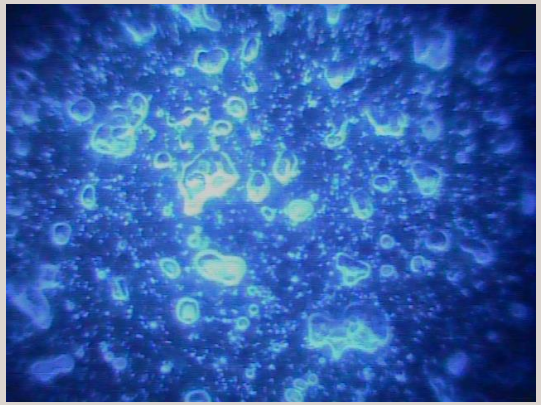


Greatly helps understanding the **complexity** of NAPL **distribution** due to **geological heterogeneity**

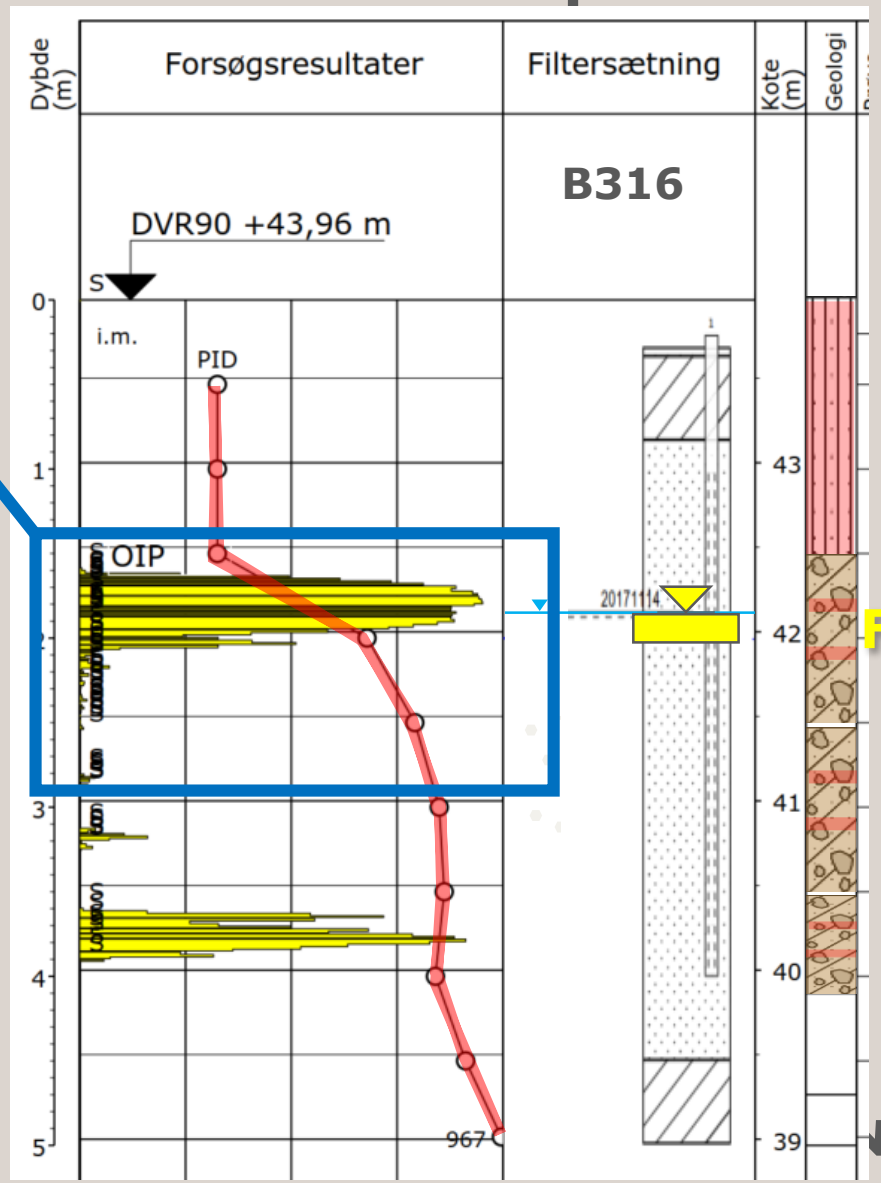
Case study B: Old diesel NAPL spill



concentrations!

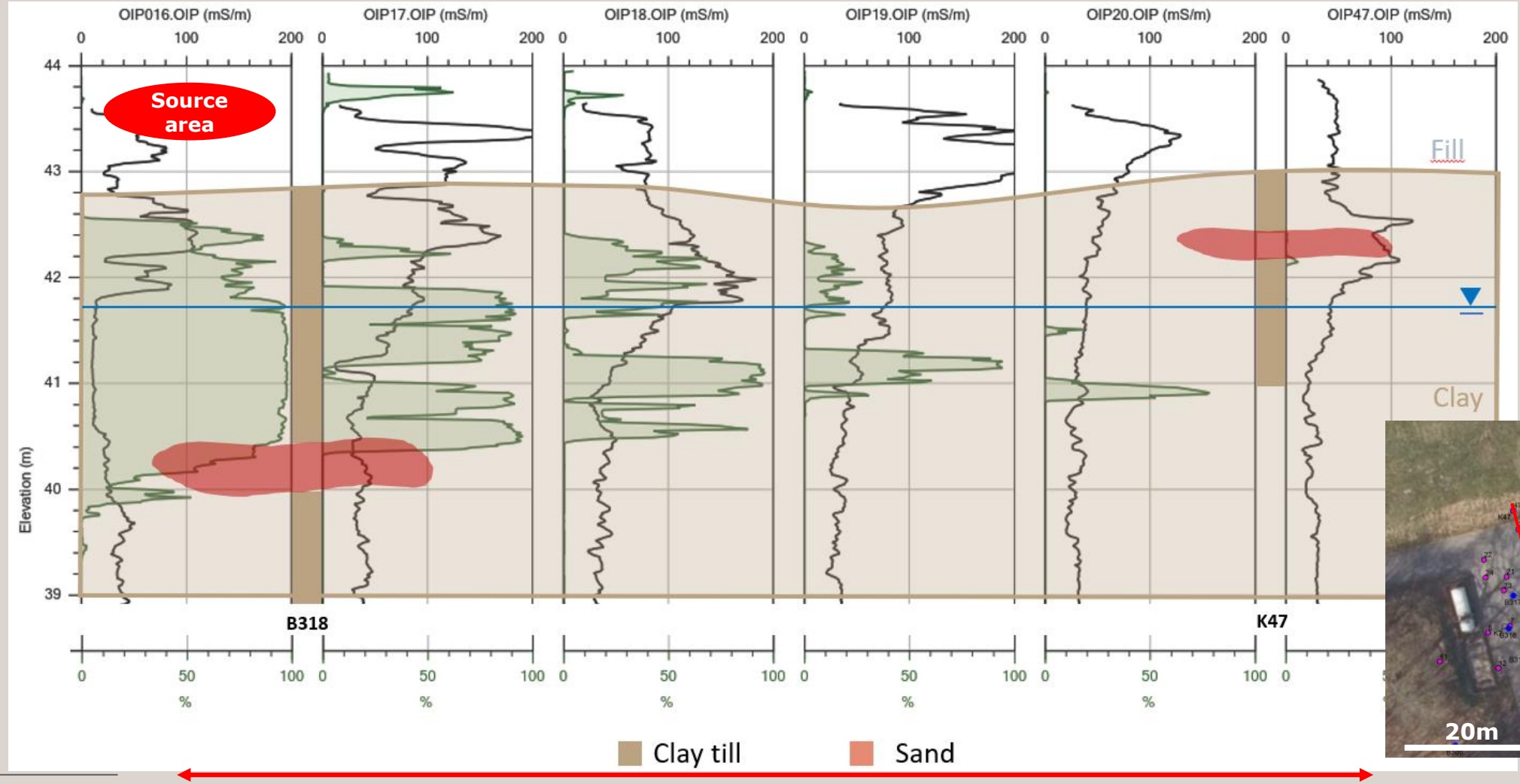


OIP-UV picture of tiny NAPL globules



Case study B: Old diesel NAPL spill

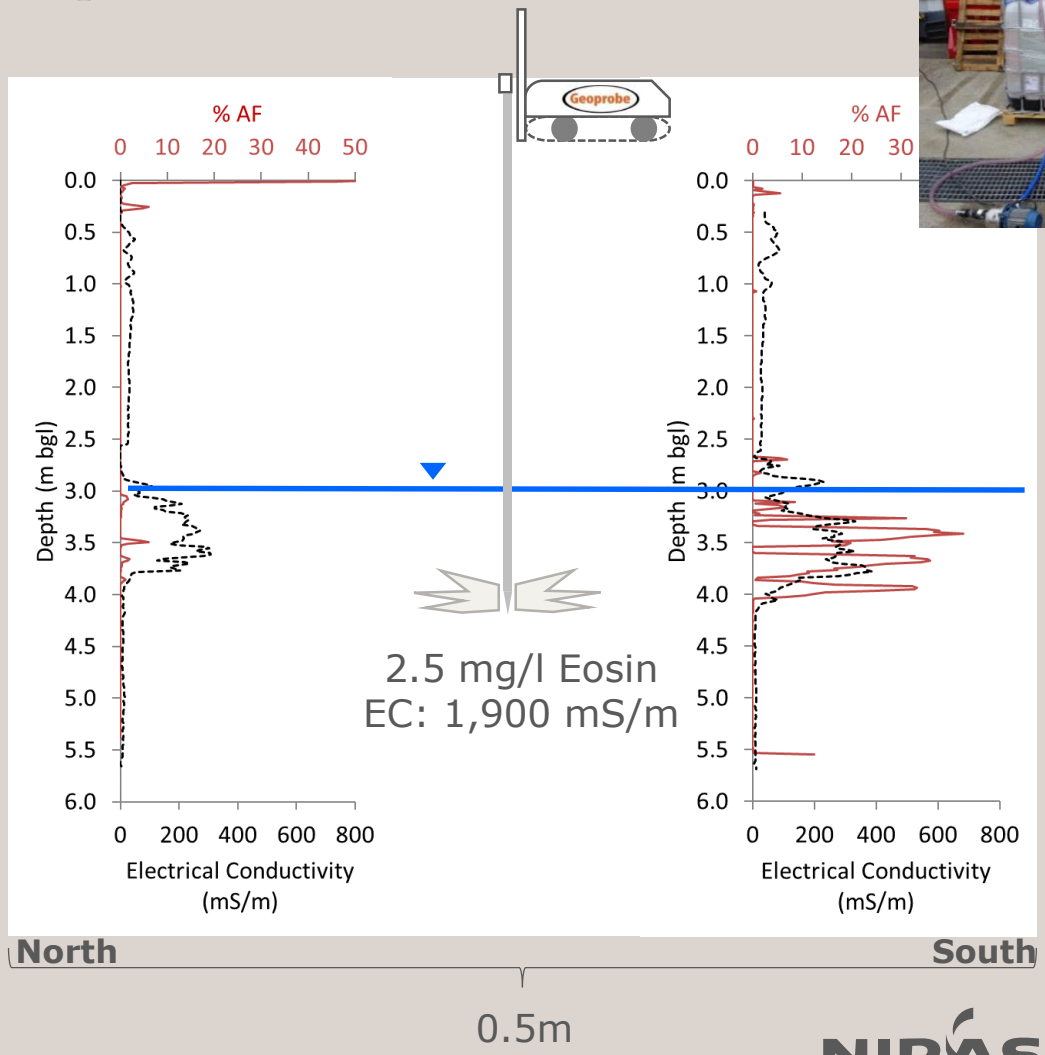
Final cross section oriented from source are towards east. EC and Fluorescent data.



Case study C: Detection of fluorescent dyes

OIP-G system for tracer detection during injection tests/pilot tests

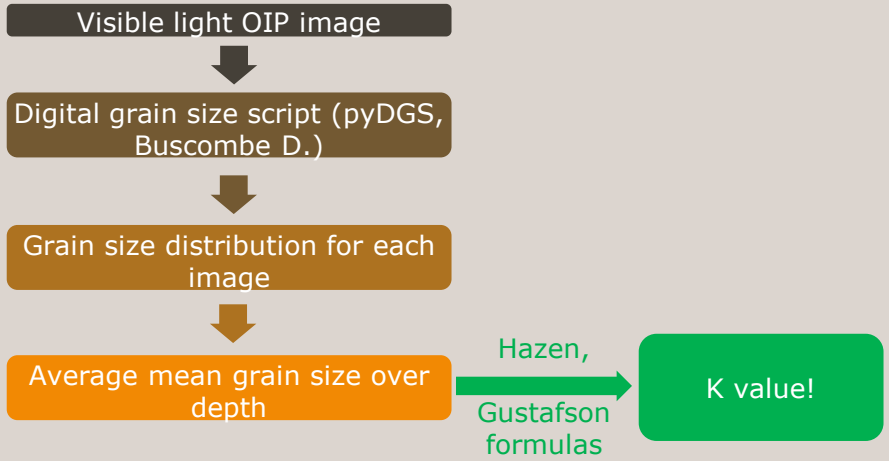
- Dual tracer test using both EC and OIP sensors by detecting dipotassium phosphate (K_2HPO_4) and eosine
- Injection of 1m^3 of highly conductive fluid (1900 mS/m) containg eosine (2,5 mg/l) and OIP-logging conducted around injection point (3-4 m bgl)
- Overall similar detection – but OIP shows finer vertical resolution, reflecting the difference in sensor designs.
- Use of tracers allows for rapid determination of injection performance prior to initiating in-site remedies.
- Tracers can also be used for describing advective flow paths



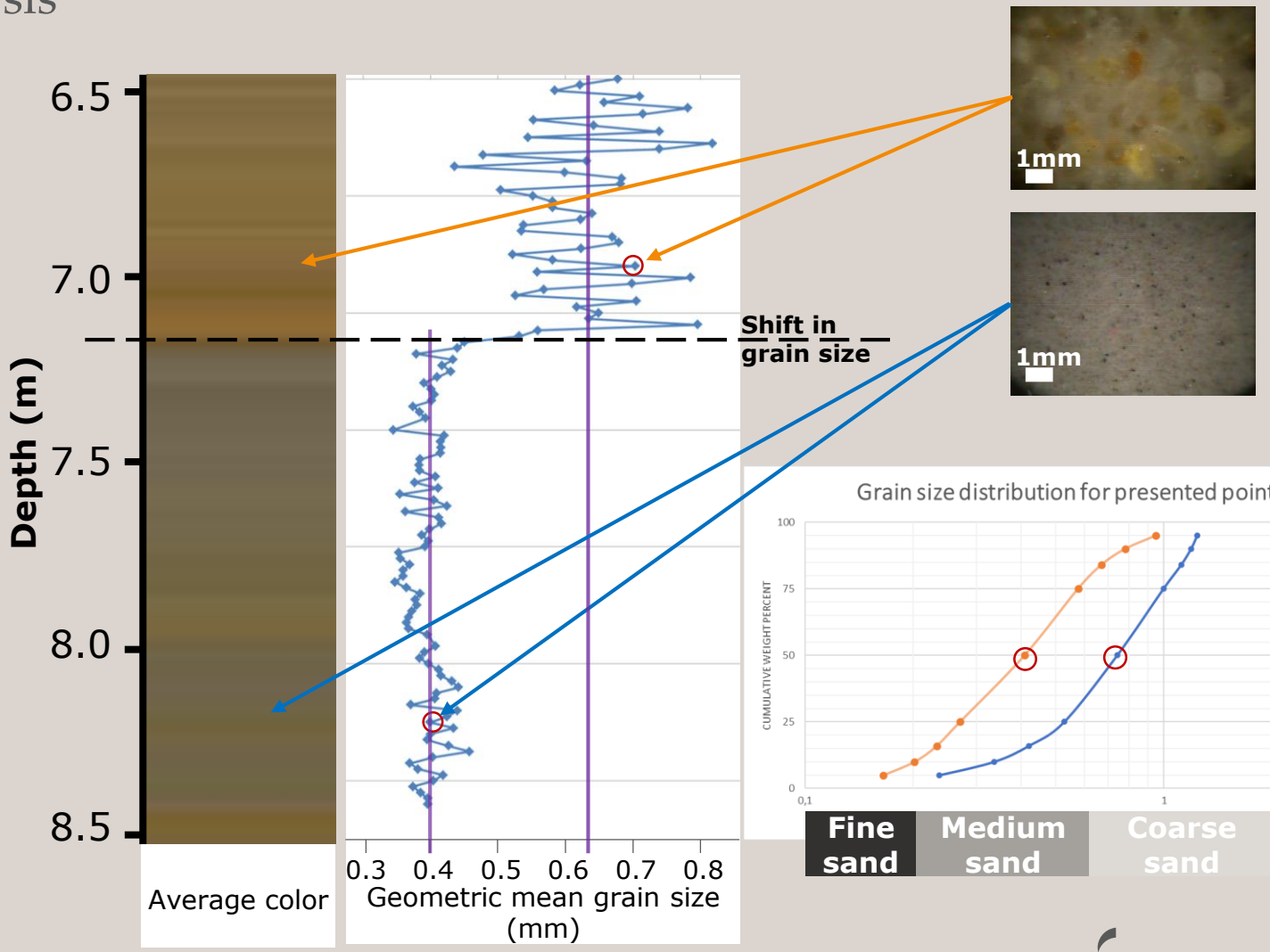
Case study D: Estimating soil properties

Grain size estimation using image analysis

- OIP system can be operated in VIS mode capturing RGB pictures every 1.5 cm
- Calculation of grain size distribution with python script, which allows for hydraulic conductivity determination



- Grain size detection limited by sensors resolution and picture quality



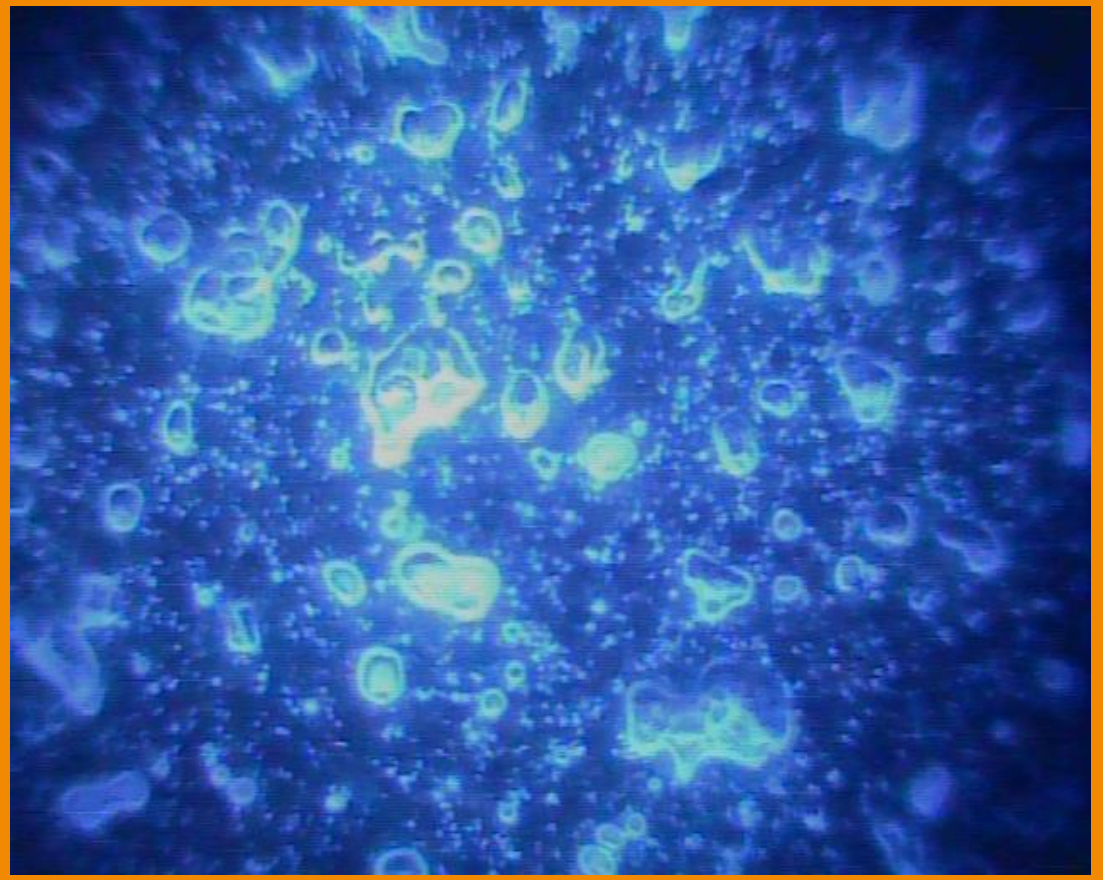
Buscombe, D. (2013) Transferable Wavelet Method for Grain-Size Distribution from Images of Sediment Surfaces and Thin Sections, and Other Natural Granular Patterns. Sedimentology 60, 1709-1732

Conclusion

- Relatively simple and robust system. Production rates of +100 m/day are possible.
- The OIP system is a very rapid and cost-effective way of delineating a broad range of NAPLs like gasoline, diesel and some DNAPLs like creosote and coal tar.
- When using the combined OIHPT probe the soil properties controlling the NAPL distribution can be established with very fine resolution.
- Real-time continuous results while in the field allow for dynamic planning and investigation. Possibility to assess the need for more sampling points or different focus zones.
- Powerful tool for detecting fluorescent dyes used in hydrogeological studies, and shows promise for generating other qualititative data (grain size, color, etc…).
- Conceptual models are often drastically improved/changed by using these types of high-resolution tools.
- Remediation efforts are likely to be more successful when the conceptual models are based on high resolution data.

NIRAS

Questions ?



Anders G. Christensen
Specialist Manager
M.Sc., Environmental engineer

.....

NIRAS
Sortemosevej 19, DK-3450 Allerød, Denmark
www.niras.dk
Phone +45 4810 4200, Fax +45 4810 4300
Direct +45 4810 4405, Mobile +45 2141 8330
agc@niras.dk