Multi-Disciplinary Characterization of Chloroethene Subsurface Contamination in Sedimentary Bedrock

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North Atlantic Ocean
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IRELAND
Irish Sea
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NETH.
Oder
POLAND
Elbe
Dnieper
Celtic Sea
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ROMANIA
Bay of Biscay
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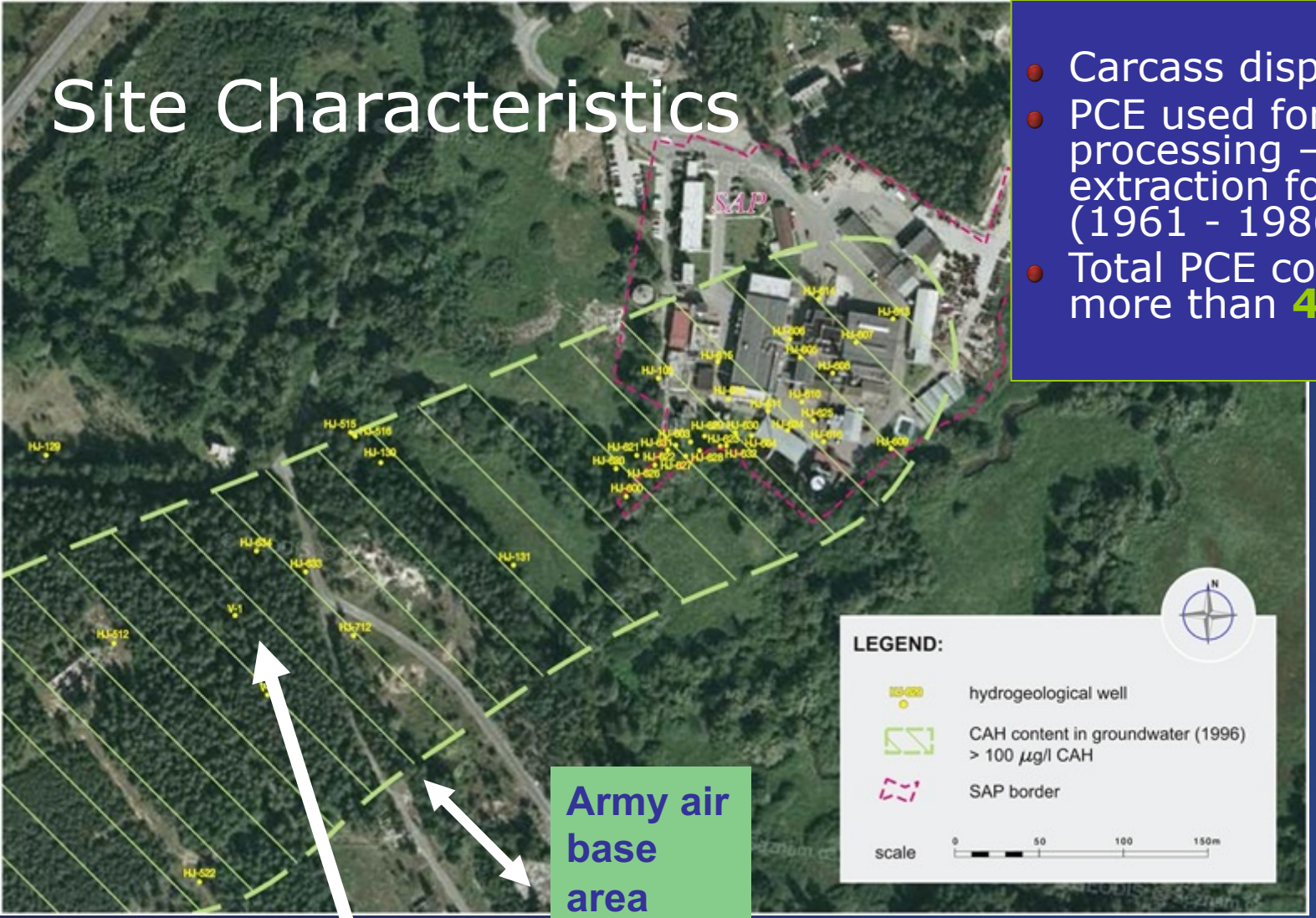
SLOVENIA
CROATIA
Black Sea
Po
Danube
BOSNIA AND HERZEGOVINA
SAN MARINO
SERBIA AND MONTENEGRO
BULGARIA
MONACO
Ligurian Sea
ITALY
Adriatic Sea
PORTUGAL
SPAIN
ANDORRA
F.Y.R.O.M.
40
ALB.
GREECE
TURKEY
Balearic Sea
Tyrrhenian Sea
SAP Mimoň
0
300 Kilometers
0
300 Miles

Site Characteristics

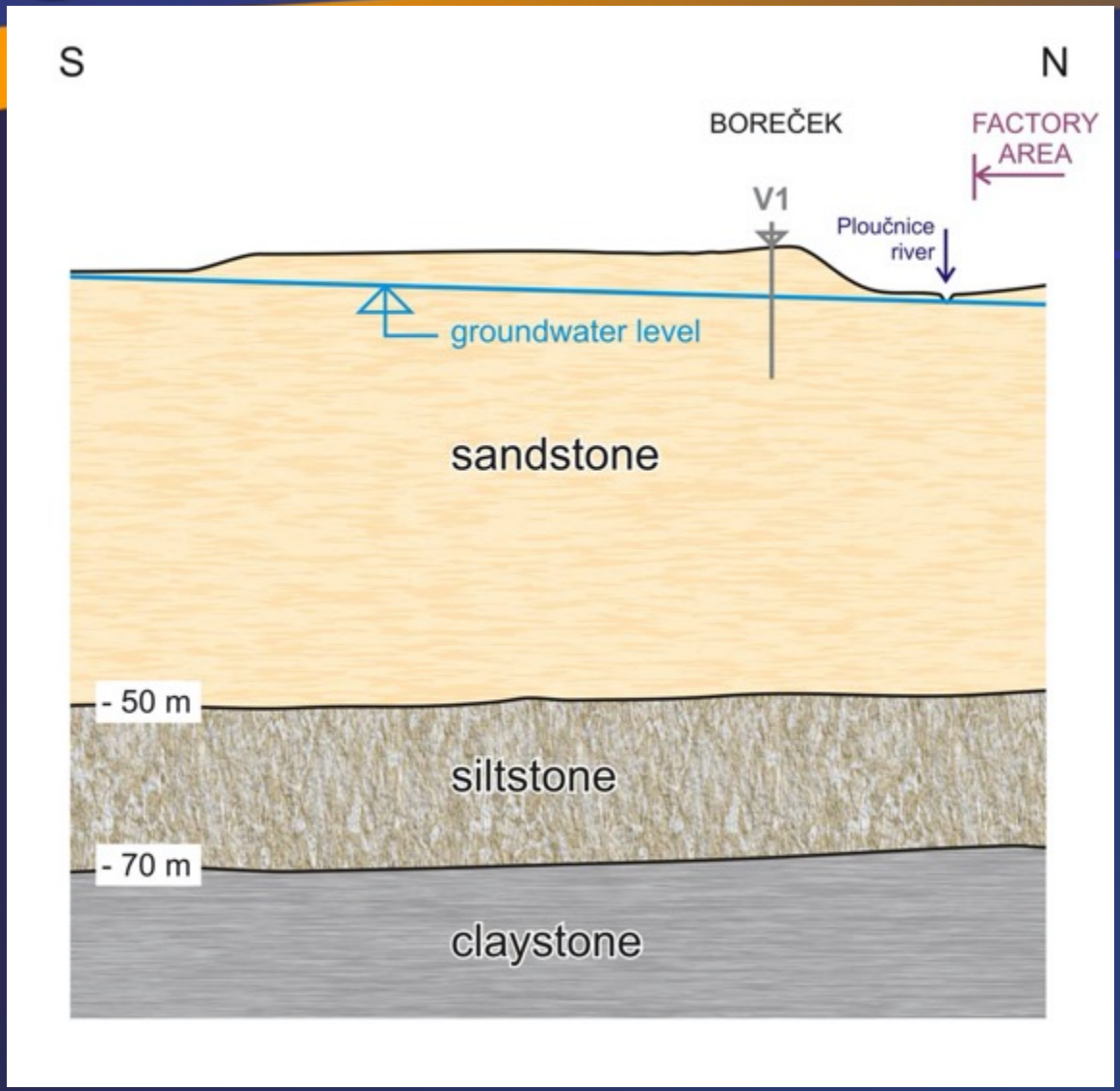
- Carcass disposal plant
- PCE used for material processing – fat extraction for 25 years (1961 - 1986)
- Total PCE consumption more than **4 000 tons**



Waterworks –
wells pumped until 1986 (5 L/s) when contamination with chloroethenes (60 mg/L) detected

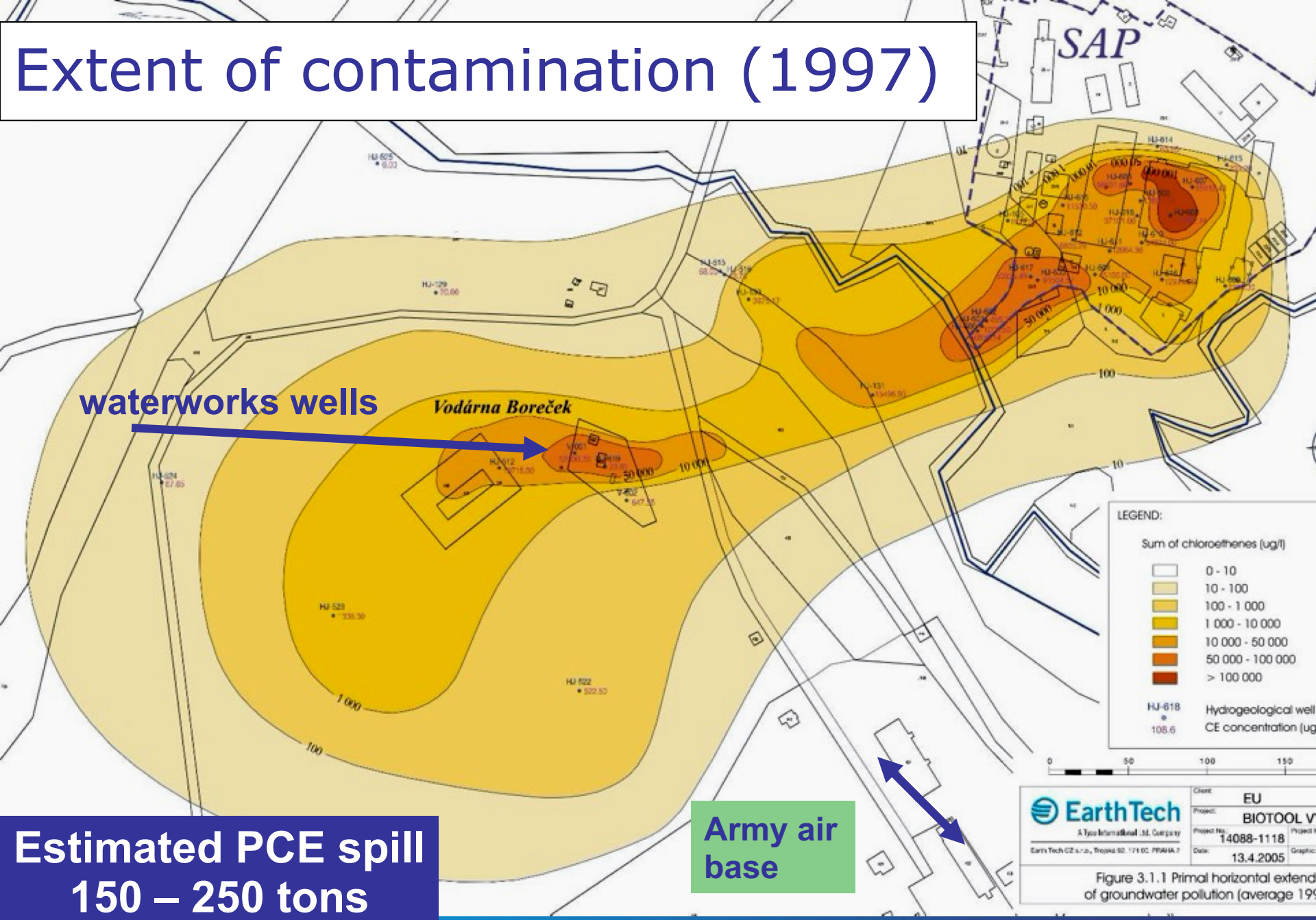
Until 1993
the source at the plant was unidentified

Site Geology



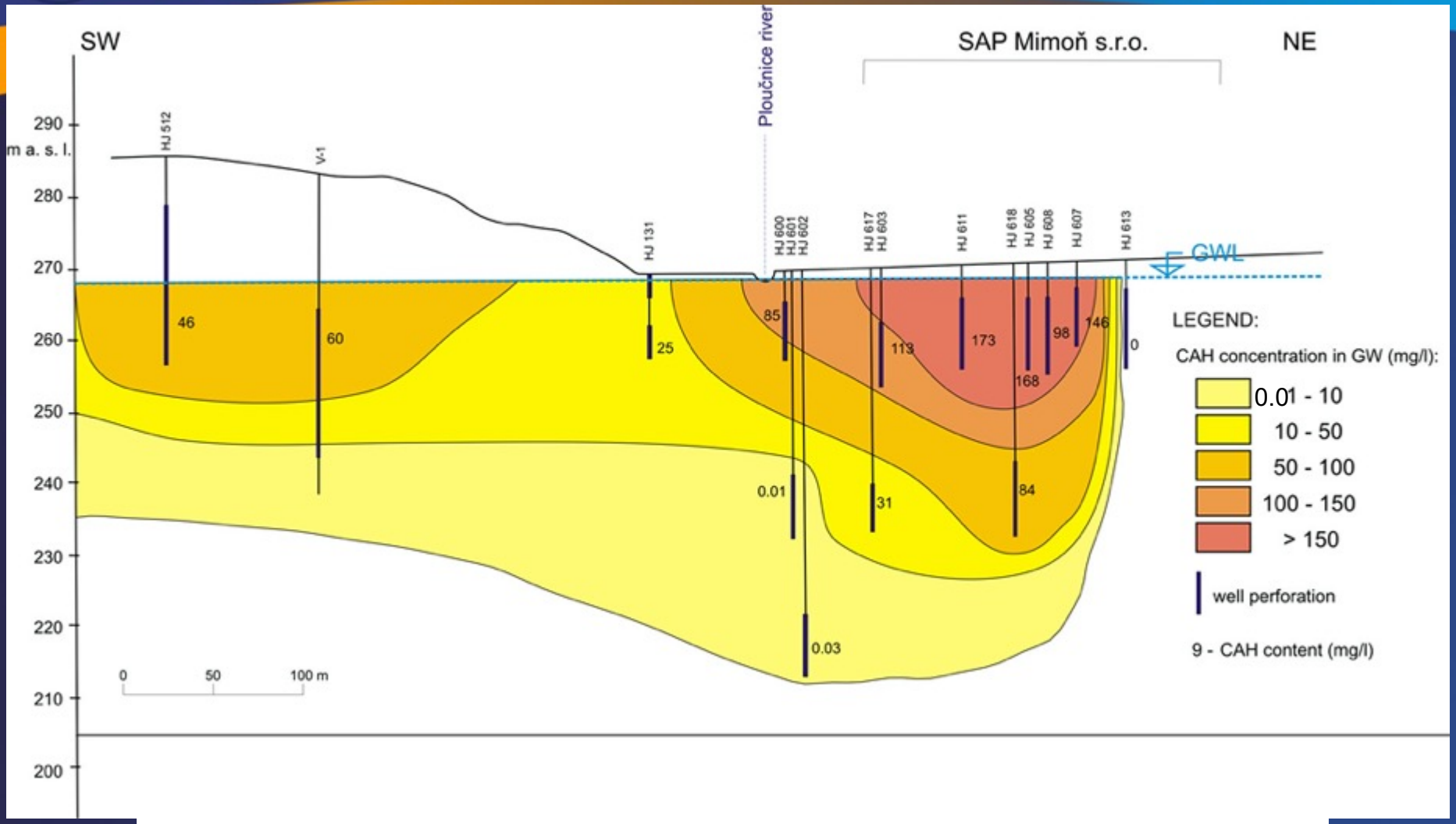
- Sedimentary complex of the Bohemian Cretaceous Basin
- In the factory area sandstone overlaid with Quaternary river terrace (4 m)
- DTW 1- 6 m bgs

Extent of contamination (1997)



Estimated PCE spill
150 – 250 tons
(95 % certainty)

Vertical Cross–section in 1997



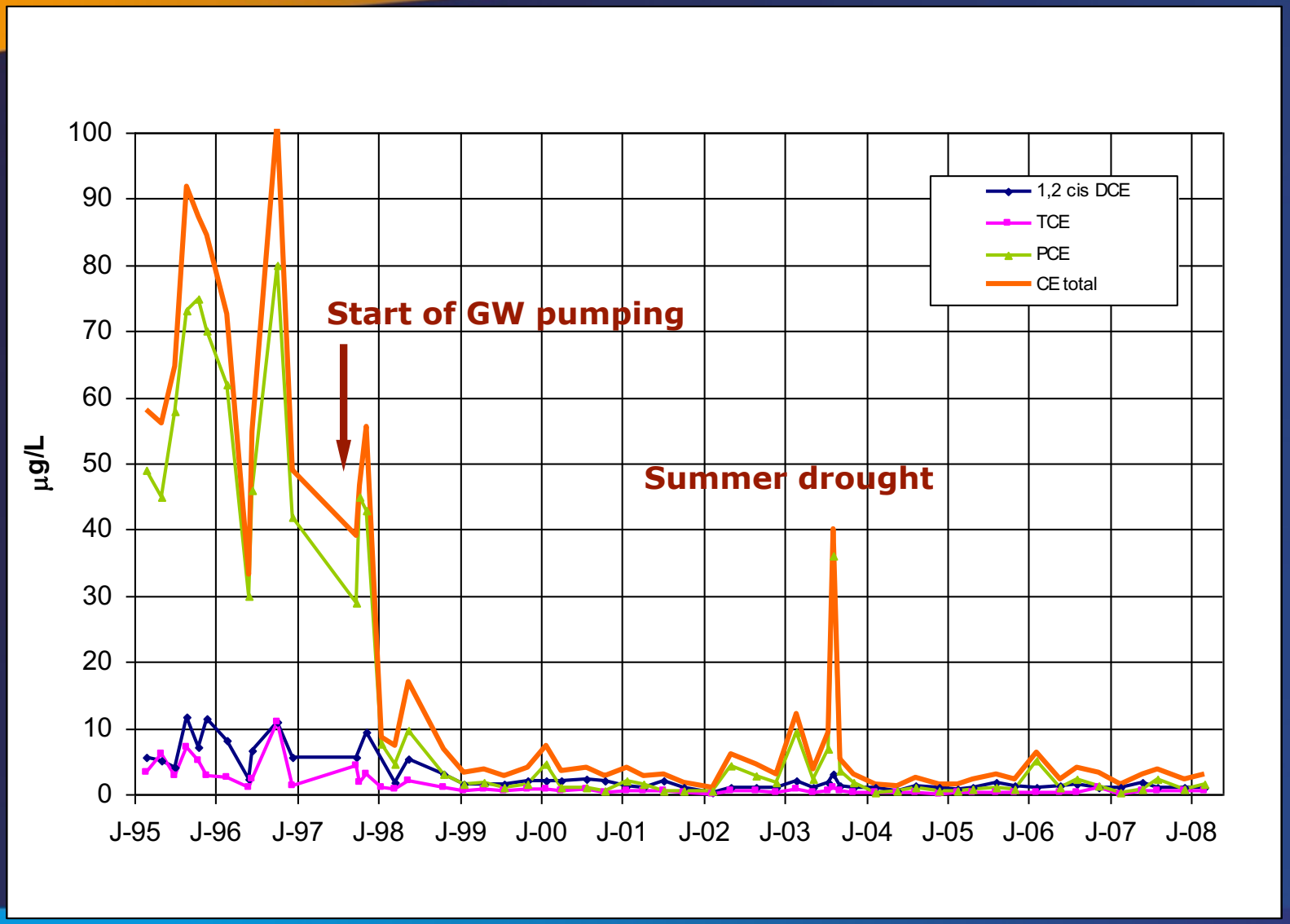
General assumption: migration under riverbed was induced by waterworks pumping and driven mainly by tectonic fractures in sandstone, verified by surface geophysics

Clean-up

- Intensive pump-and-treat (19 L/s plant, 4.5 L/s waterworks) started in 1997, venting + air sparging in the factory area
- Main goal – to protect surface water
- 15 kg of PCE discharged daily to the river prior to pumping

- Clean-up target 3 600 µg/L (plant)
  720 µg/L (waterworks)
- Clean-up removed 135 tons of PCE by the end of 2007

Concentrations of CE in the Ploučnice River



2005 – experimental site for BIOTOOL project

Tree core sampling – August 2005

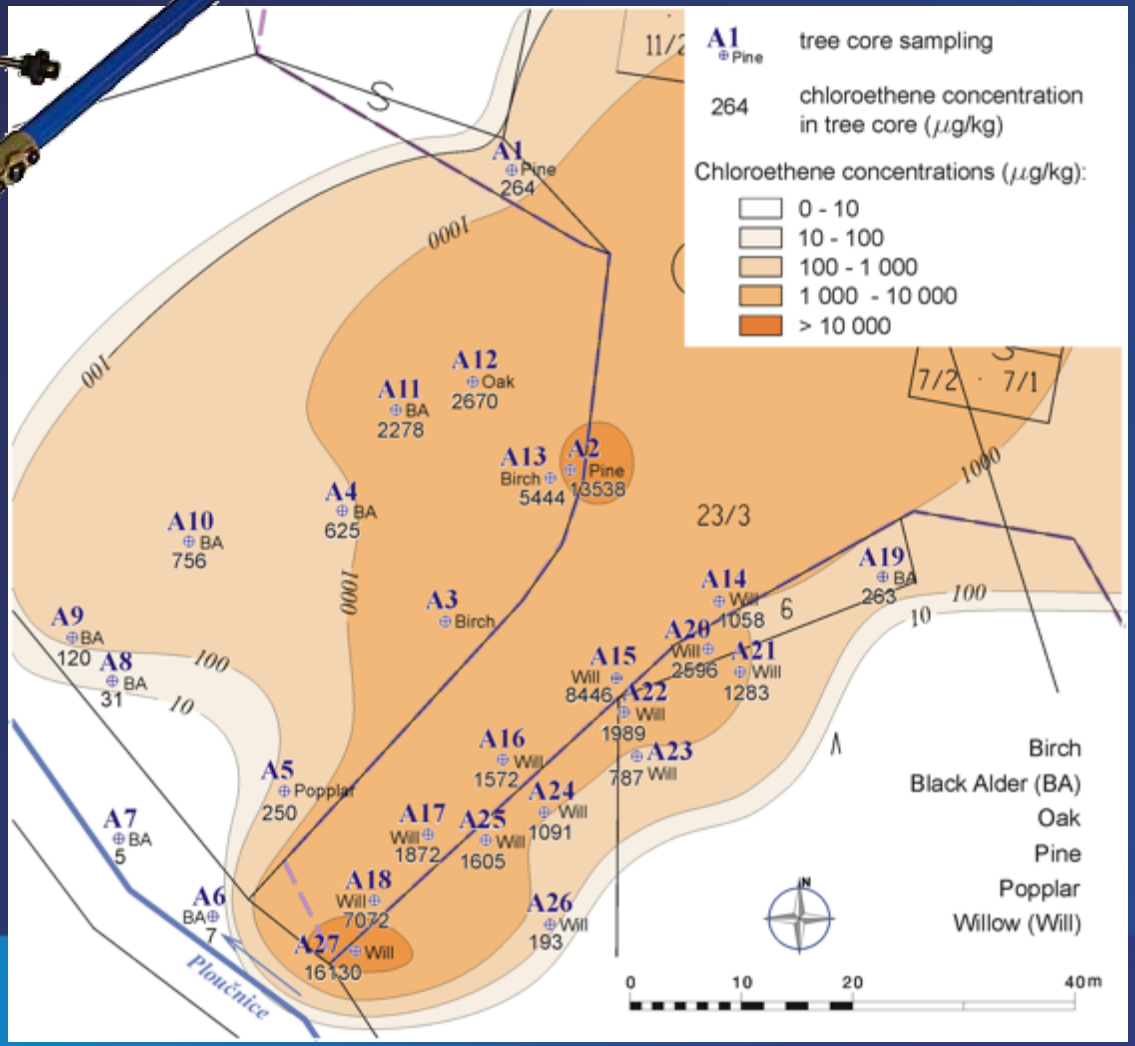
MIP (membrane interface probe)– April 2006

"Biological procedures for diagnosing the status and predicting evolution of polluted environments"

An EC-funded project (STREP) under the Sixth Framework Programme Priority [6] Sustainable Development, Global Change and Ecosystems

Tree core sampling

Tree core sampler used in forestry – tree age and health



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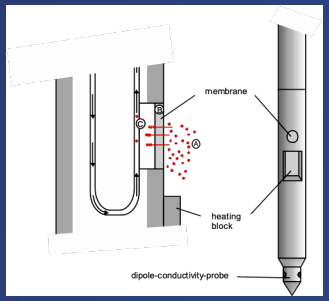
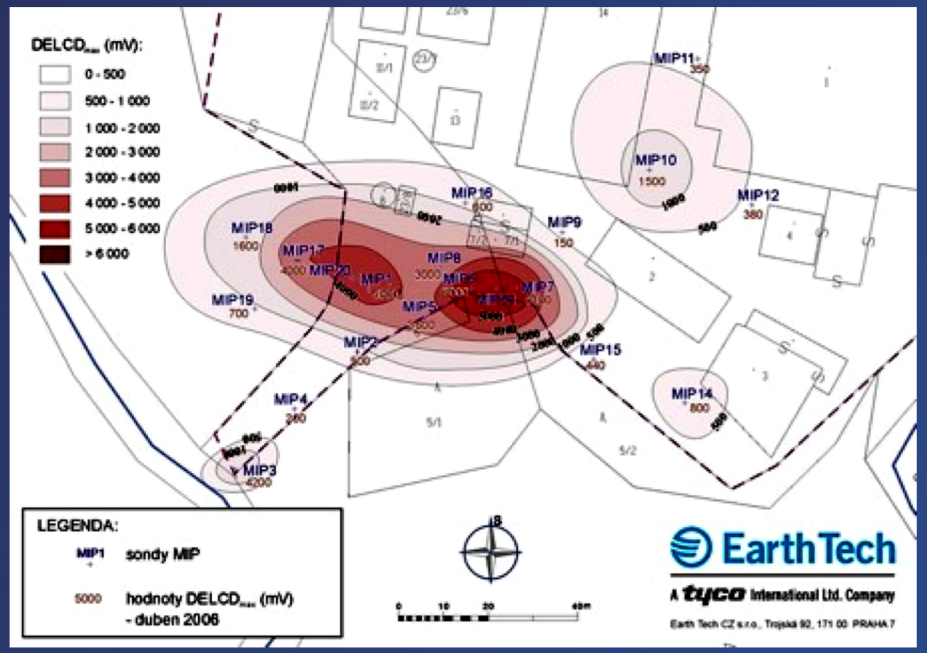
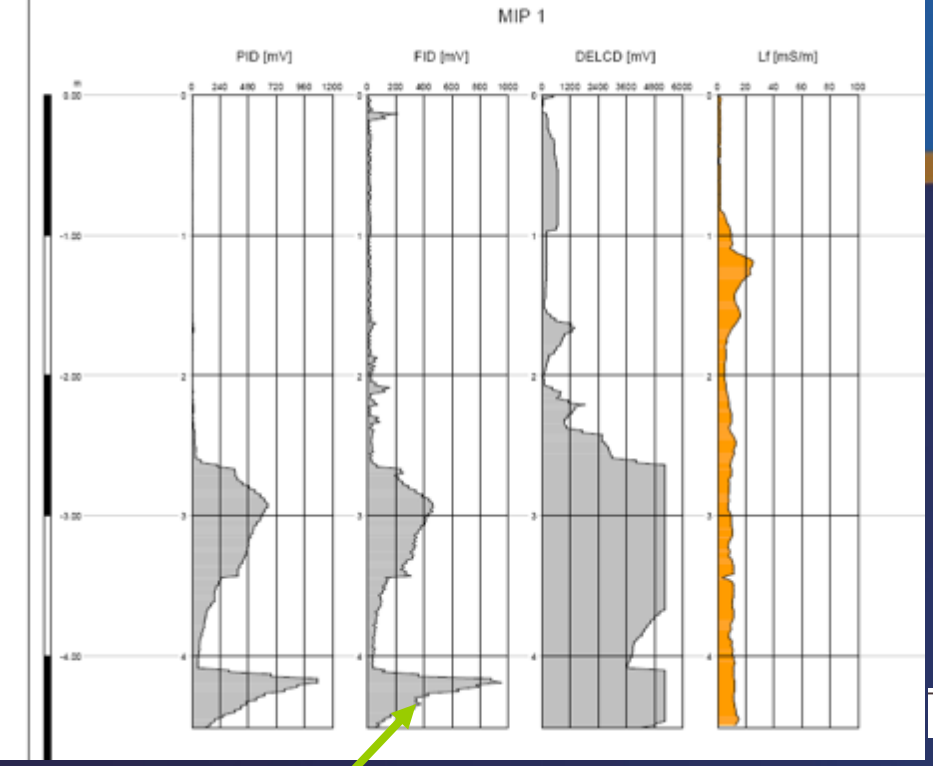
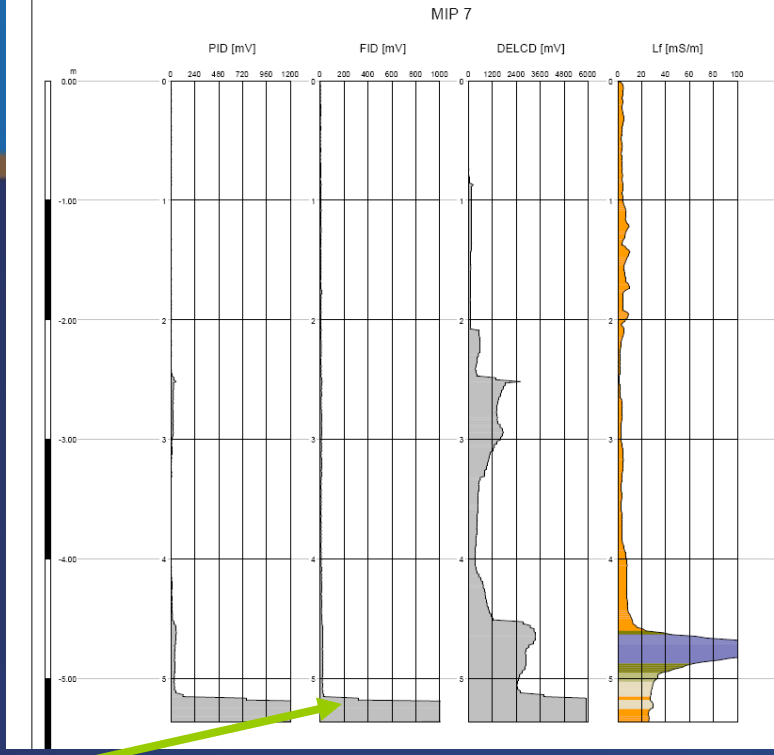
Membrane Interface Probing

- Direct-push probe with heating block (110-130 °C), thermal desorption of volatile organic compounds from soils
- Multiple detectors to identify CEs or fuel-related compounds
- Due to drilling limitations, MIP probe blocked in 4 -6 m bgs by consolidated bedrock

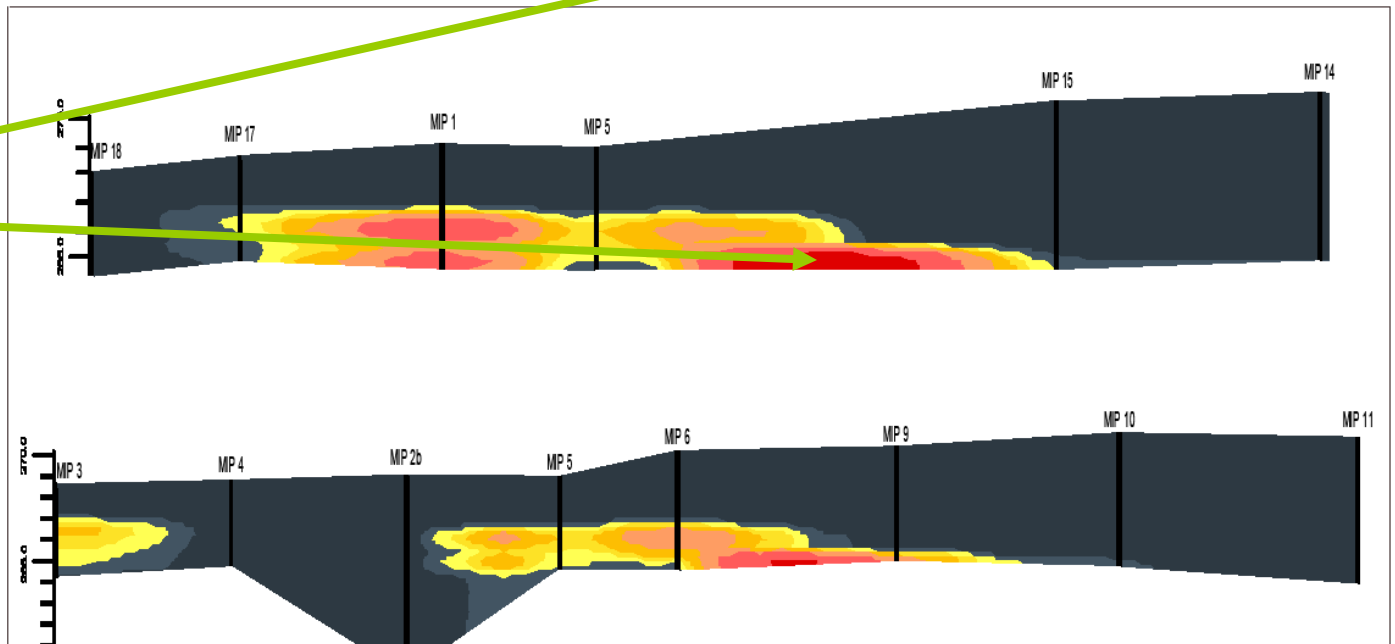








geo-log



Indication of DNAPL presence at depth

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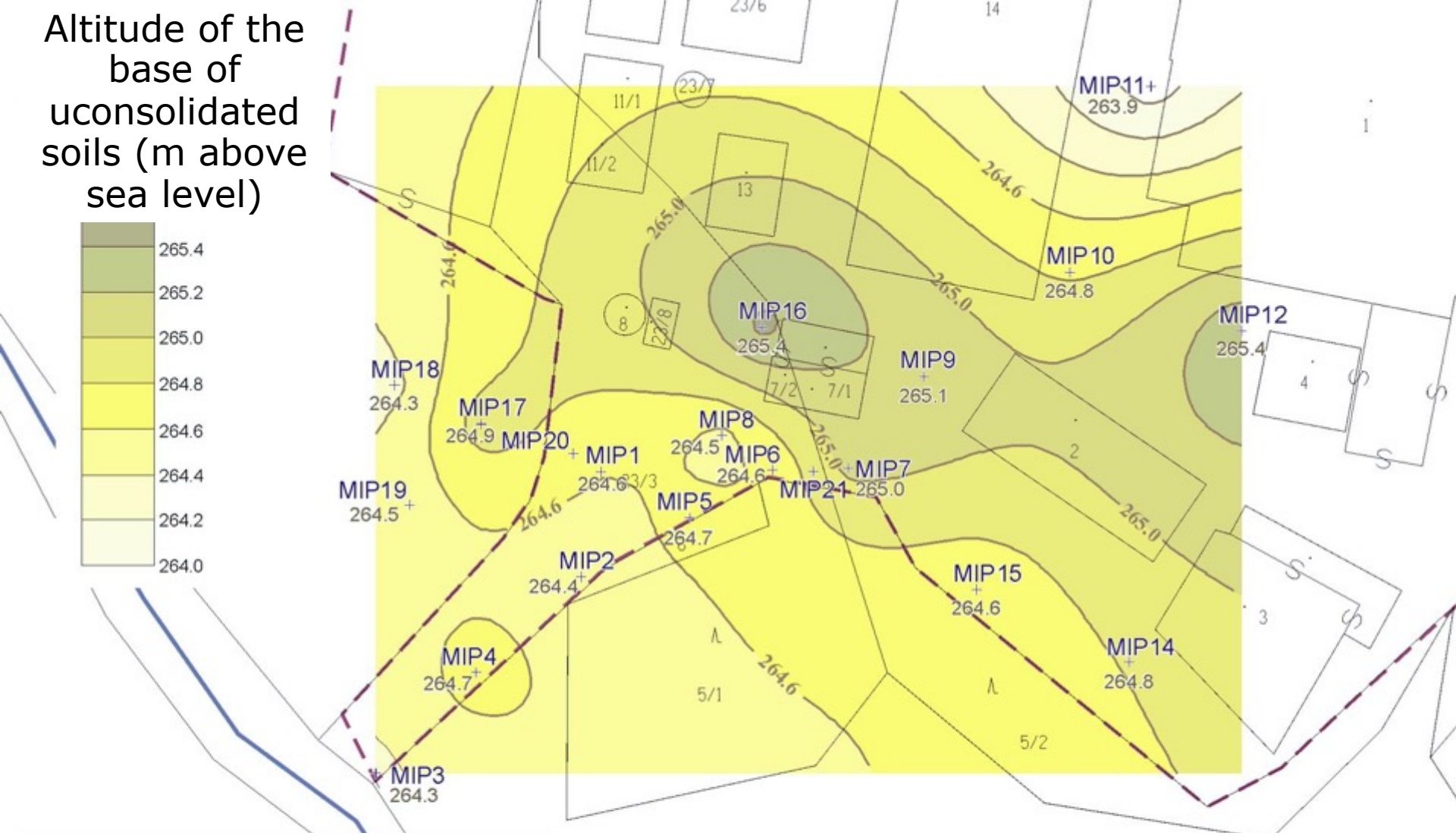
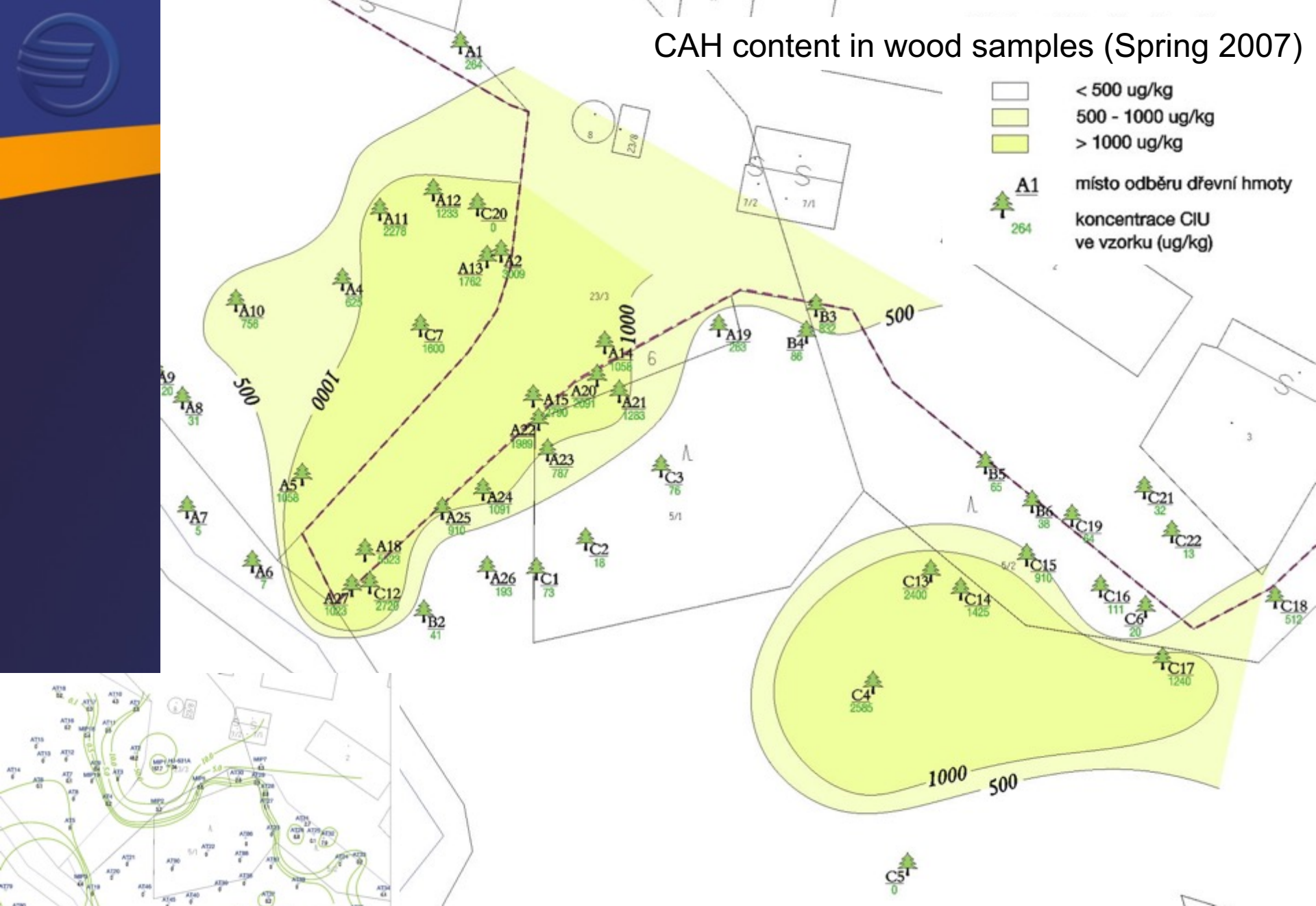


Additional result of MIP – relatively flat base of unconsolidated sediments, impenetrable for direct-push drilling, DNAPL had accumulated at the base

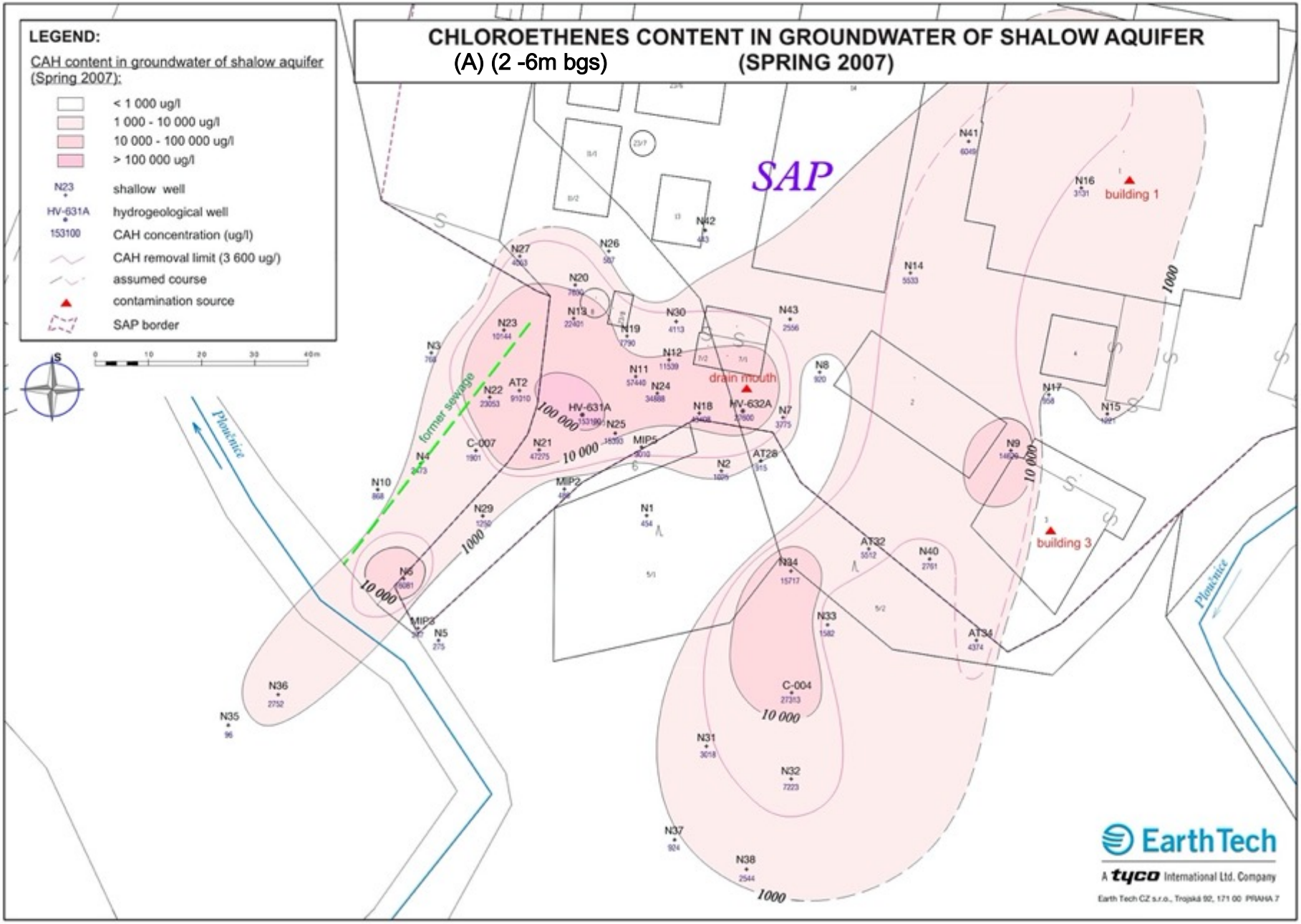
Detailed investigation, based on new findings

- Atmogeochemical survey
- Tree core sampling
- Groundwater Investigation
  - Shallow wells (Direct Well® Eikelkamp) – Quaternary aquifer
  - Depth-specific wells with max. 1m screen - deeper, consolidated sandstones strata
- Borehole geophysical logging (gamma + resistivity)

CAH content in wood samples (Spring 2007)



Atmogeochemical Survey (PID)



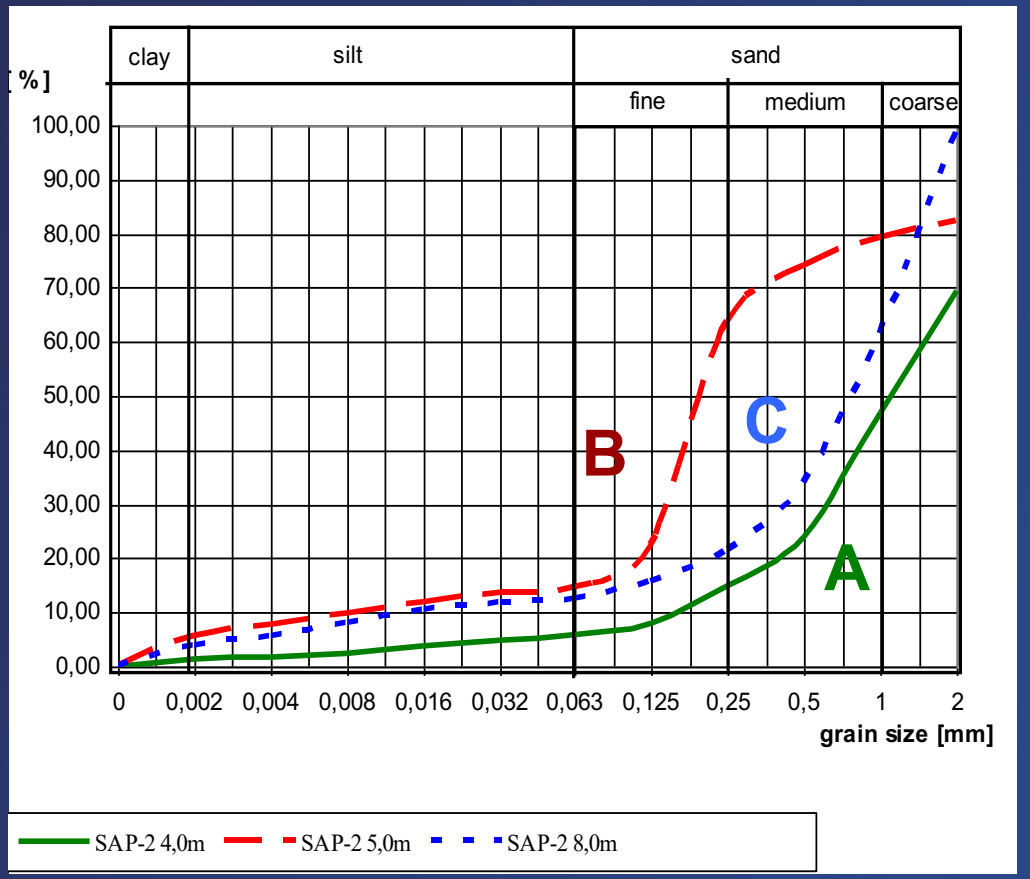
Maximum well depth limited by direct push drilling methods

Soil Core Records

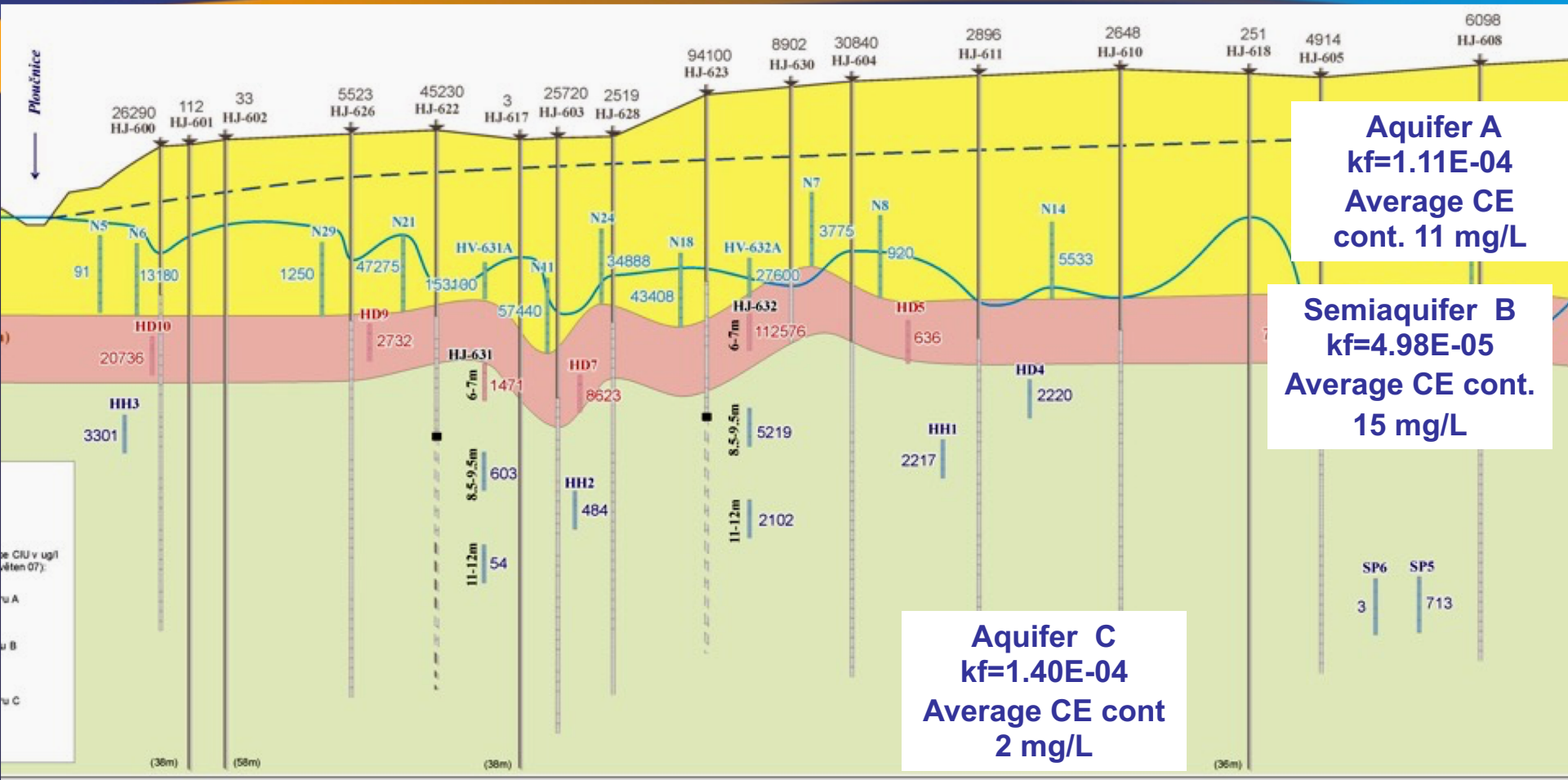
sample	depth of sample (m bgs.)	PCE soil content
		mg/kg dry w.
SAP-1	3 m	810
SAP-1	5 m	130
SAP-1	8 m	0,23
SAP-2	4 m	0,18
SAP-2	5 m	150
SAP-2	8 m	0,24

Soil Core Records

- Soil logs identified a layer of highly cemented sandstone with higher fine particle content (semi-aquifer B, 0.7 – 2 m thick), underlying unconsolidated river terrace deposit (Aquifer A) in the factory area
- Semi-aquifer B is underlain by Aquifer C – a layer of medium-grained, consolidated sandstone with high hydraulic conductivity and water content (changes to fluid sand, during drilling)



Vertical Cross-Section in Factory Area (2007)



Layers with slightly different hydraulic conductivity in sedimentary bedrock influenced stratification of residual contamination – pump-and-treat was focused on aquifer C

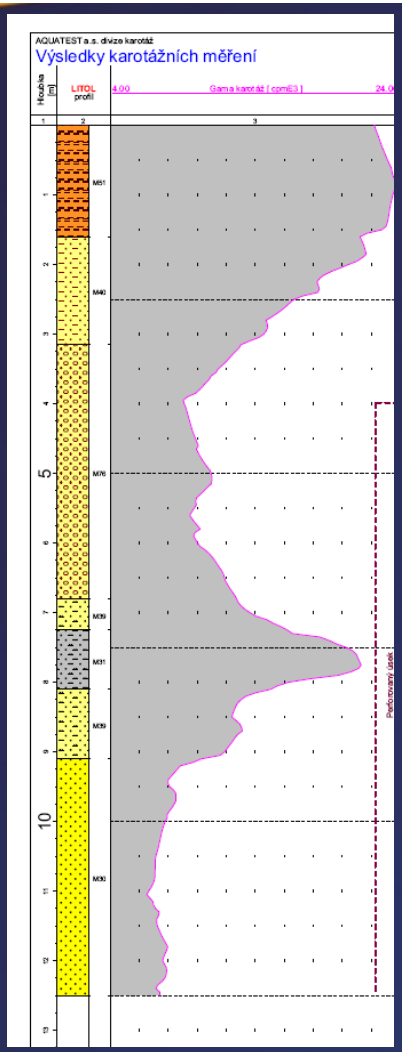
Borehole geophysical logging

- Soil core records revealed a layer of highly consolidated sandstone (semi-aquifer B 0,7 – 2 m thick), underbeding Quaternary aquifer A, semi-aquifer B is underlaid by aquifer C in the factory area
- Geological structure of deeper layers was investigated in detail by borehole geophysics (soil core samples could not be obtained from deeper strata)
- Geophysical logging was validated with soil core records and grain size analytical results
- Thickness of Aquifer C was confirmed (10 - 12 m)
- Semi-aquifer D (2 m), underlying Aquifer C, was identified in the factory area
- Similar geological structure verified on the opposite river bank by geophysics

→ NEW CONCEPTUAL MODEL OF THE SITE

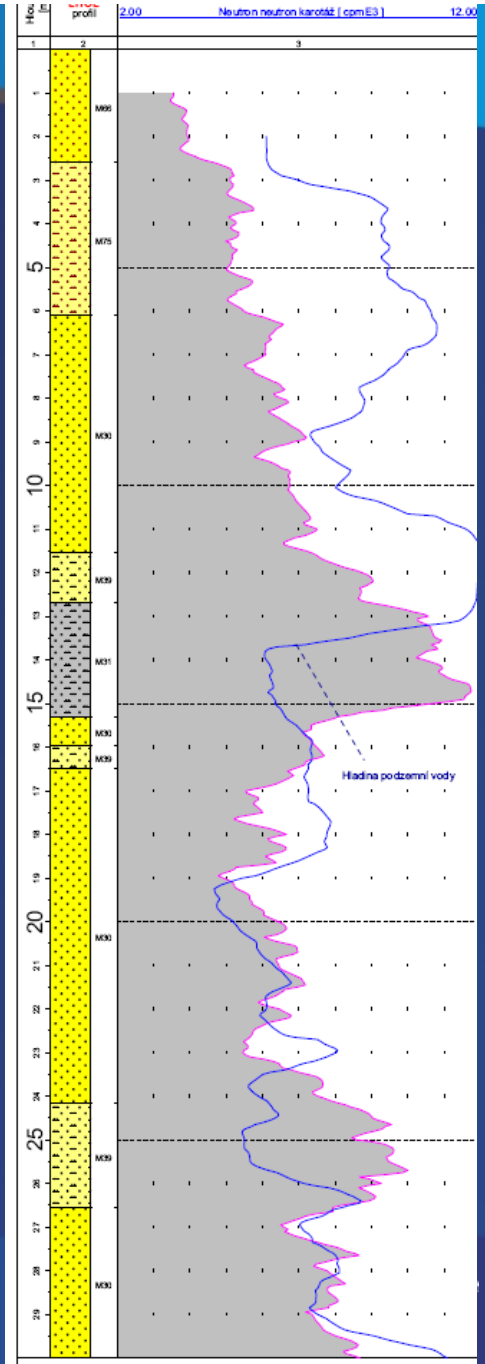
Gamma logging – lithologic profile

Factory area

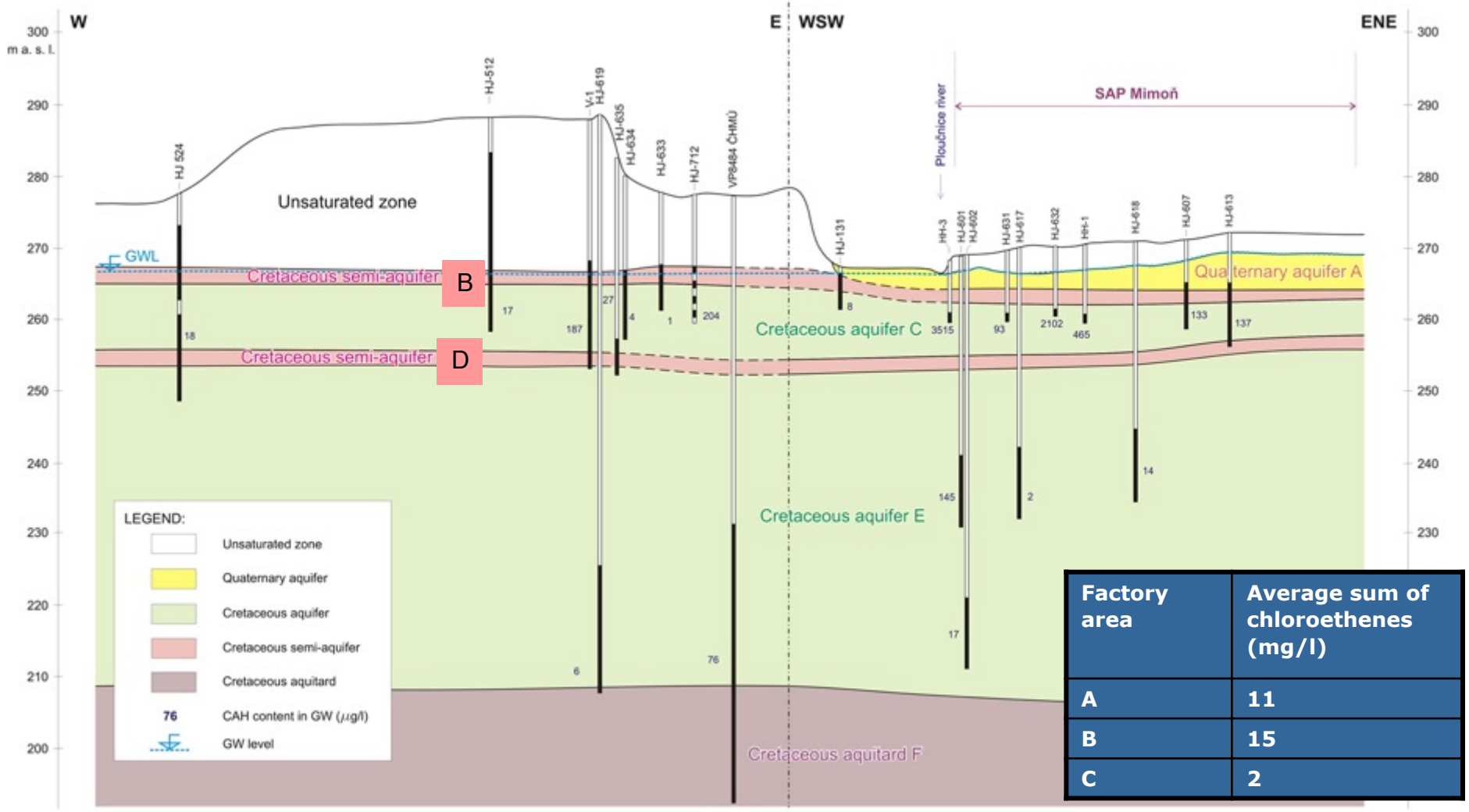


- Higher gamma logs indicate higher fraction of fine particles in soil because of higher content of radioactive potassium

Waterworks area



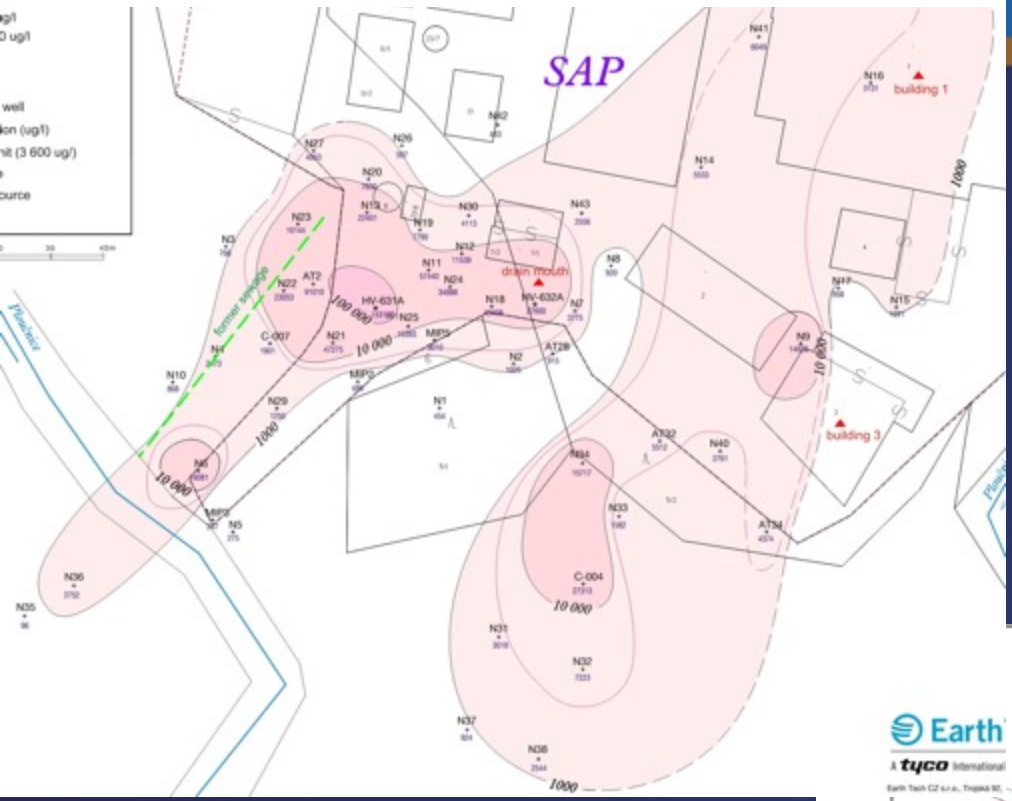
New Conceptual Model



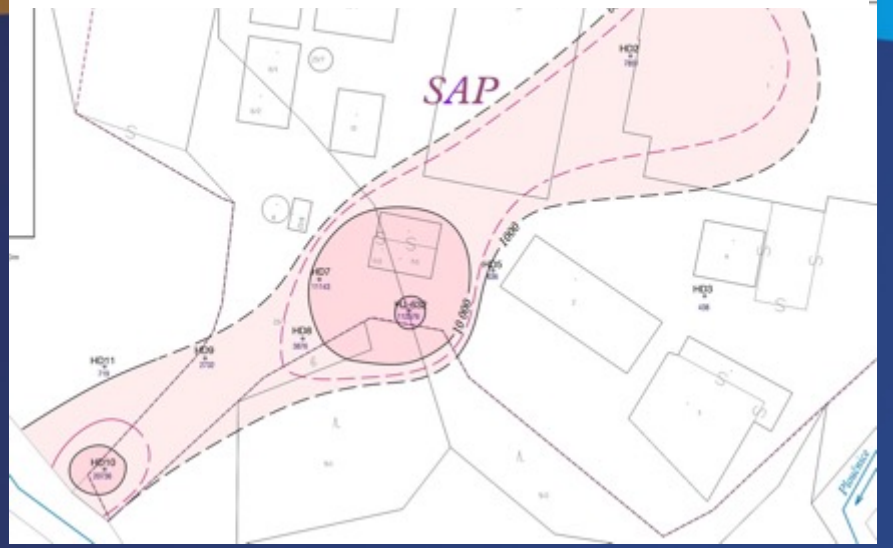
Factory area	Average sum of chloroethenes (mg/l)
A	11
B	15
C	2

Migration of contamination under riverbed driven mainly by high hydraulic conductivity of Aquifer C and pumping of waterworks well V-1, recent clean-up affected mainly the Cretaceous strata

CAH content in groundwater of Quaternary shallow aquifer (A) (2 -6m bgs)



CAH content in groundwater of Cretaceous semi – aquifer (B) (6 – 7 m bgs)



< 1 000 ug/l
1 000 - 10 000 ug/l
10 000 - 100 000 ug/l
> 100 000 ug/l

N23 shallow well
HV-631A hydrogeological well
153100 CAH concentration (ug/l)
CAH removal limit (3 600 ug/)

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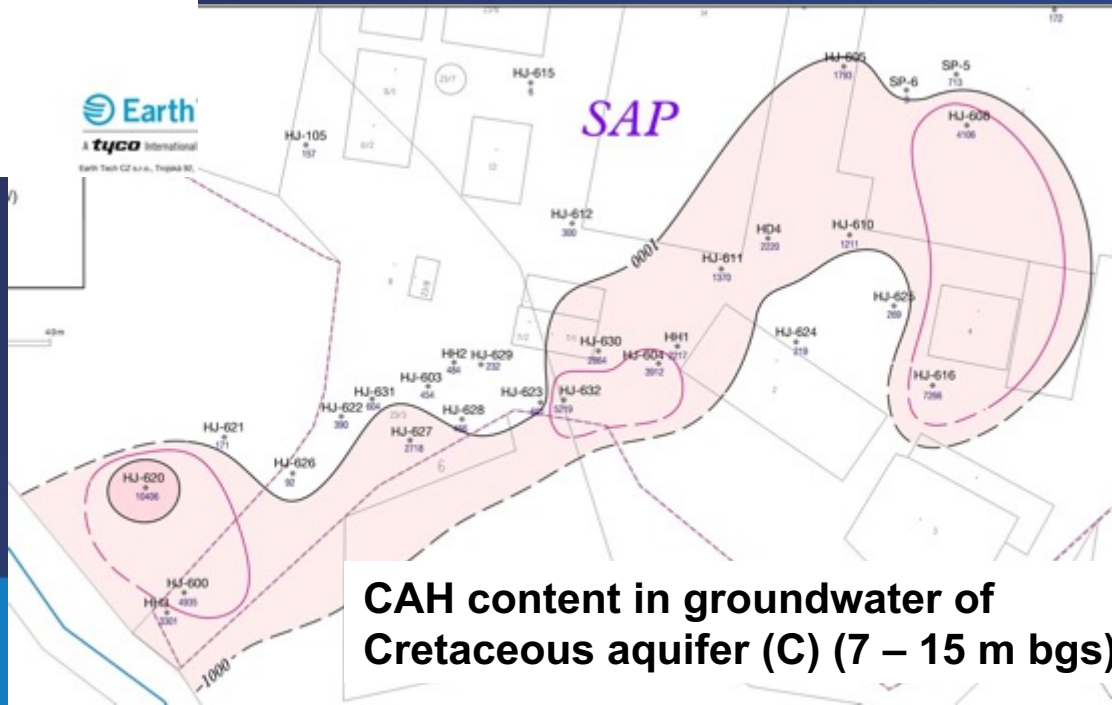

CAH content in groundwater of Cretaceous aquifer (C) (7 – 15 m bgs)

Conclusions

- Tree core sampling is a reliable and inexpensive alternative for delineating CE levels in shallow soil and groundwater
- Tree core CE content predicted GW contamination more accurately than atmogeochemistry, and was proven to be a cost-effective tool for preliminary evaluation of CAH contamination and defining optimal well locations
- MIP provided detailed information about contaminant distribution in soil profile and indicated that DNAPL had accumulated at the base of unconsolidated soils
- High MIP readings and DNAPL indication were verified by GW sampling (PCE conc. at max. solubility, 150 vs. 180 mg/L)
- Combination of traditional and innovative survey techniques deepened knowledge of the site
- Strata with only slight difference in hydraulic conductivity had a strong influence on distribution of CEs and has an impact on the efficiency of clean-up

Questions?