Life Cycle Assessment of ISTD and Improving the Sustainability of Source Removal

Ralph S. Baker (rbaker@terratherm.com) and Steffen Griepke Nielsen
(TerraTherm, Inc., Gardner, MA, USA)

Gitte Lemming
(Technical University of Denmark, Lyngby, Denmark)

Maiken Faurbye, Niels Ploug and Jesper Holm
(Krüger A/S, Søborg, Denmark)

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Overview

- Reerslev Site Description
- Life Cycle Assessment
- Remedy Selection
- ISTD Design and Implementation
- Results
- Conclusions

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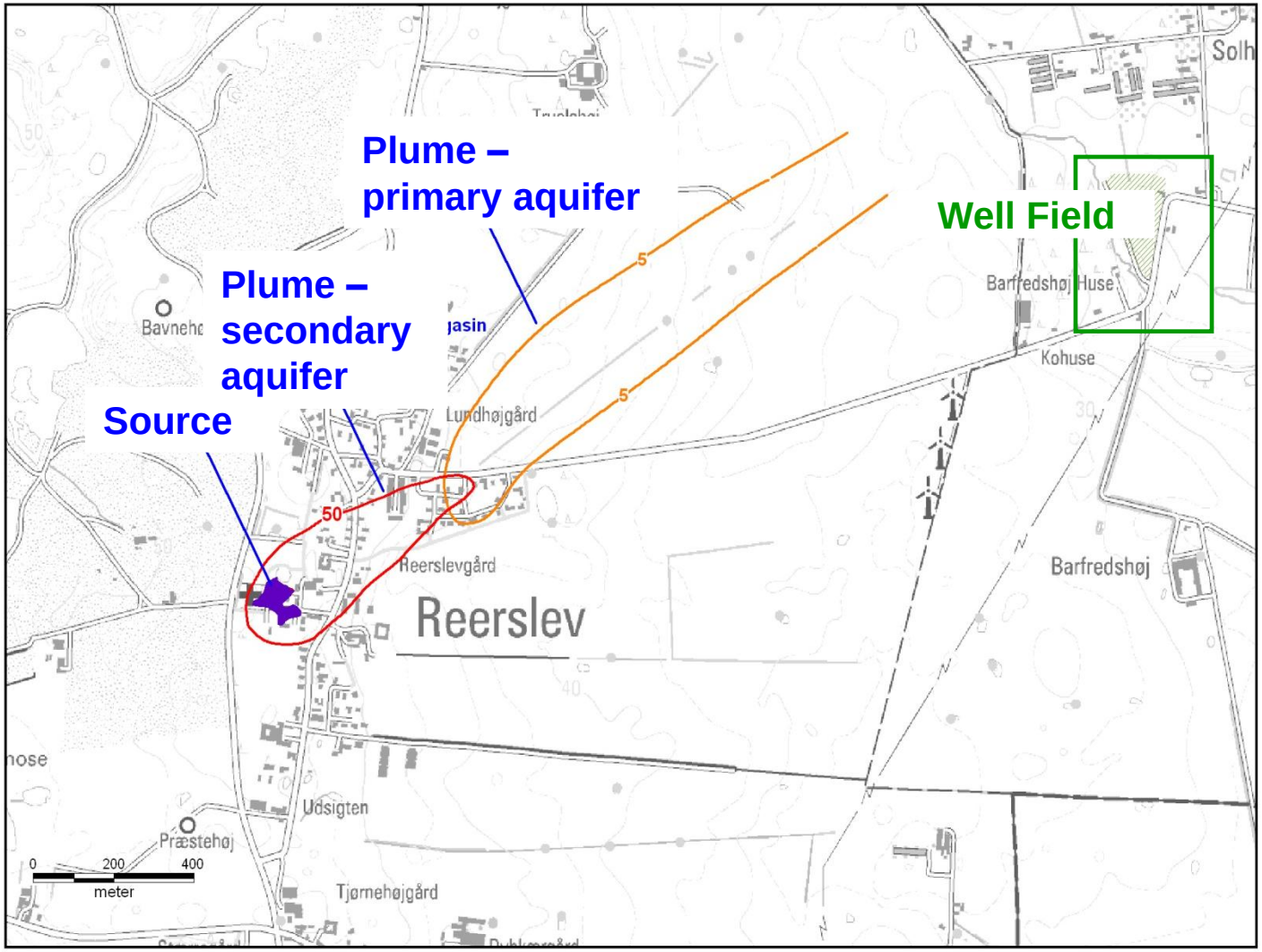
Reerslev – near Copenhagen, Denmark

Region Hovedstaden NIRAS KRÜGER TERRATHERM® ZACHO-LIND Entreprenørfirma

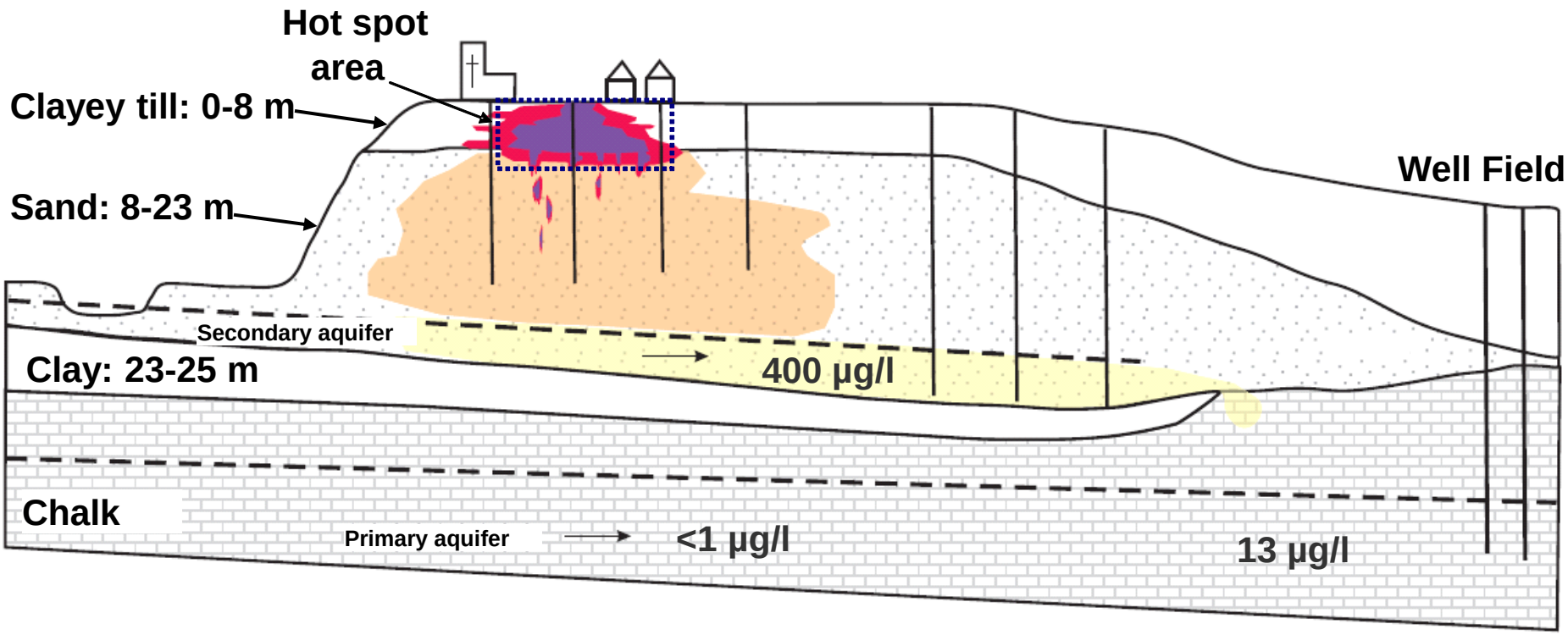
Reerslev – Locus



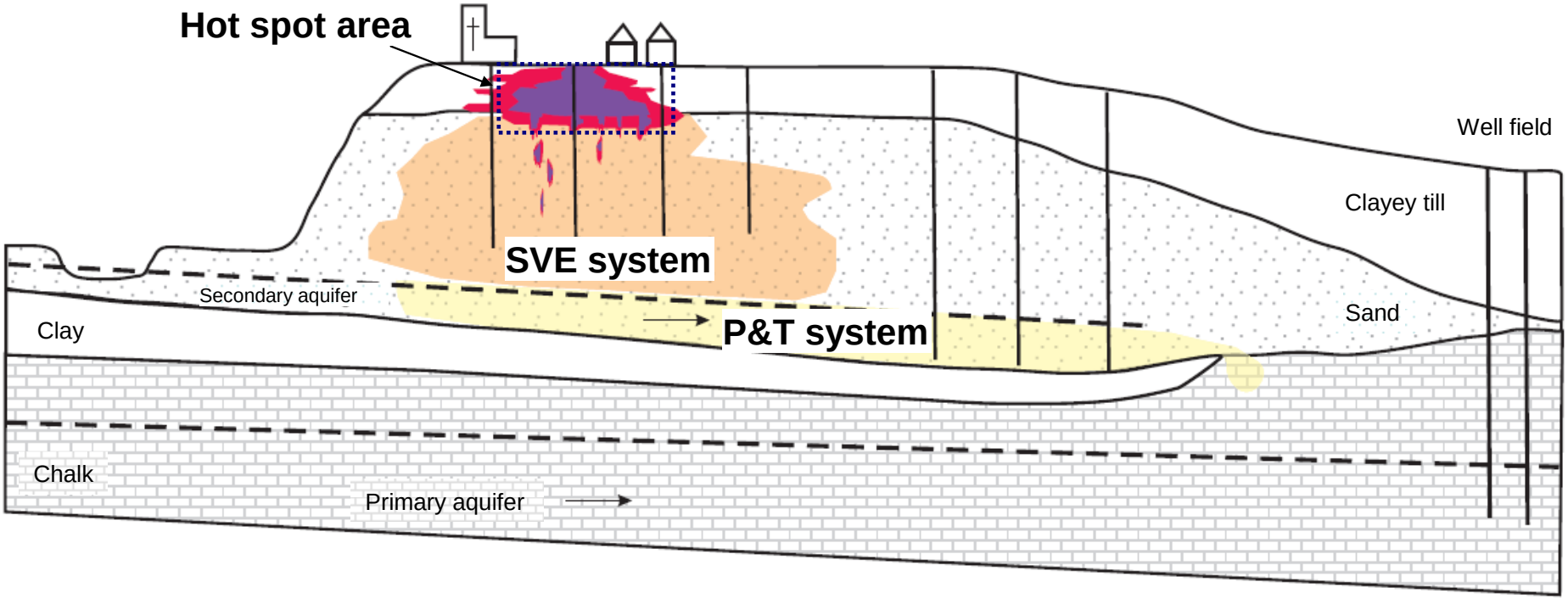
Solhøj Municipal Well Field

Supplied 50,000 homes

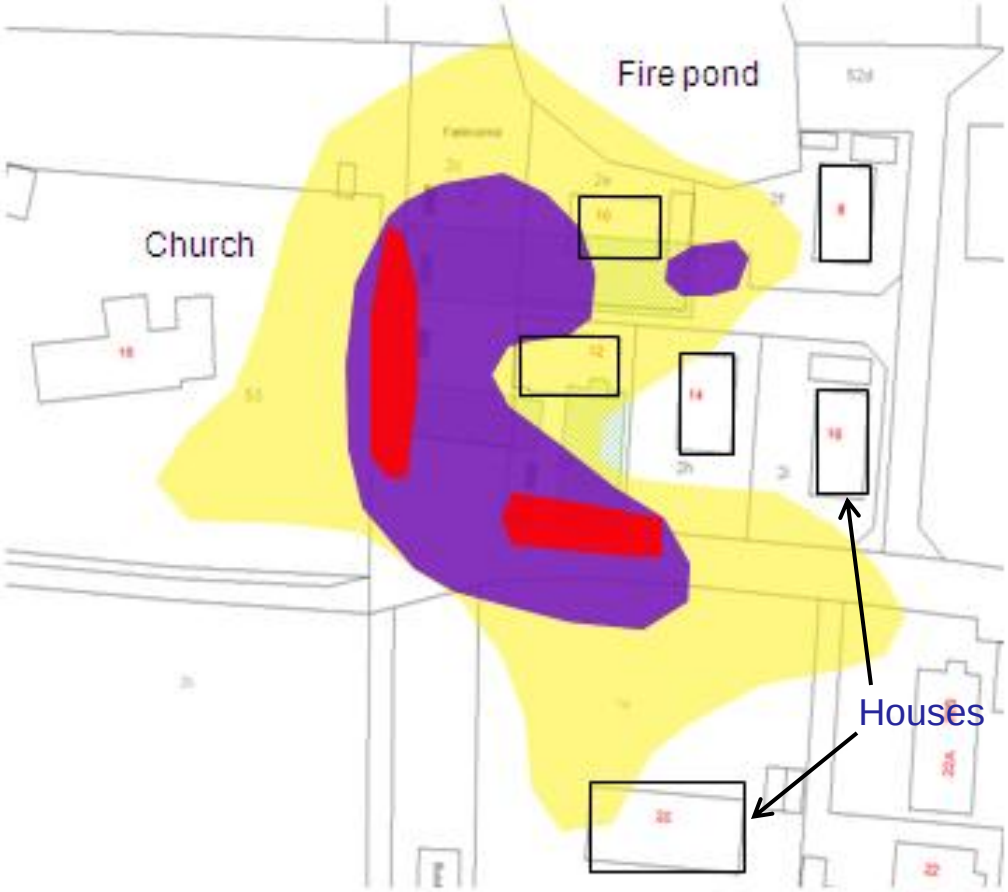
Conceptual Site Model



Initial Remedies



Reerslev – Site Description



Legend:

- Risk of DNAPL
- High soil concentrations
- Diffuse contamination - not to be treated

Technology Evaluation

- Excavation and off site treatment
- In Situ Thermal Desorption (ISTD)
- Cutting off hotspot by Soil Vapor Extraction (SVE)

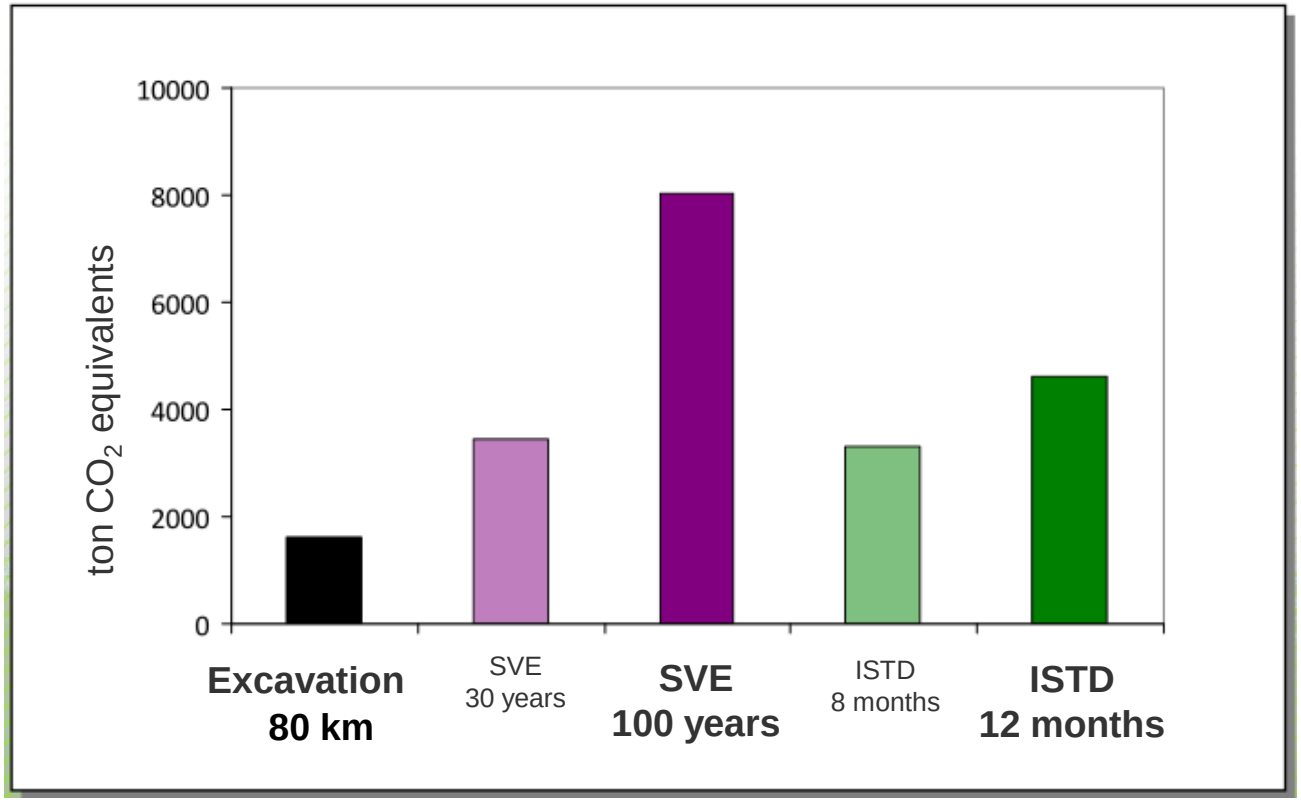
Life Cycle Assessment (LCA)
(Pfeilschifter et al. 2007)

Evaluation parameters

	Activities		Impacts		Effects
Setting-up	Transport Excavation Drilling Building equipment Commissioning	Consumables	Power Fuel/gas Plastic Concrete Iron/steel Activated carbon	Resources	Inadequate raw materials Metals Sand/gravel Water
Operation	Operation period Electrical effect Supervision Service	Emissions	CO_2, CO, NO_x, SO_4 VOC's Noise and vibrations Dust or odor	Environment	Global warming Acidification Toxicity Landfill Dangerous waste
Dismantling	Transport Waste	Exposure	Risk of fire or explosions Dangerous work Inconvenience/disturbance of neighbors	Human	Working environment Inconvenience/disturbance of neighbors

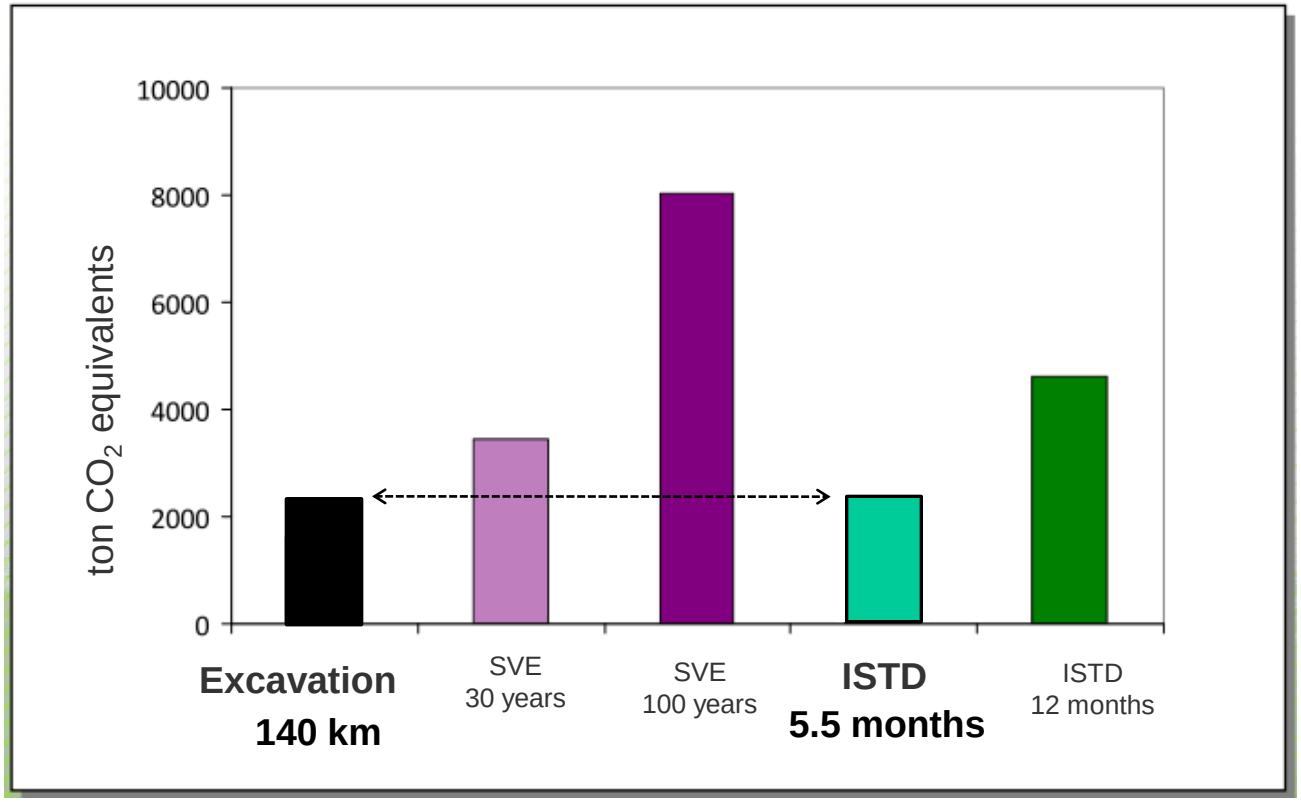
LCA, cont.
(Pfeilschifter et al. 2007)

Carbon footprint – ton CO_2 equivalents



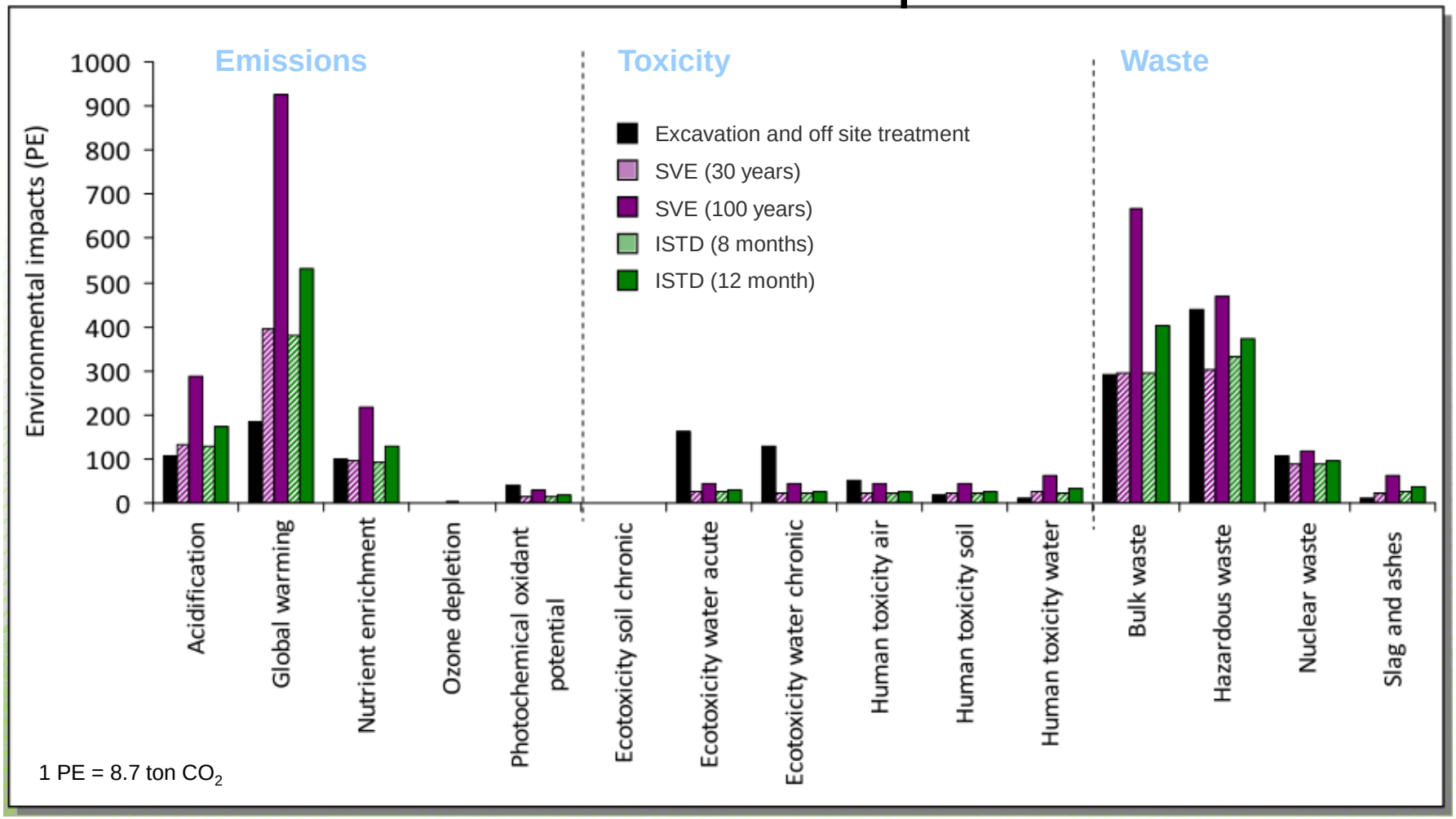
LCA, adjusted for:
Actual ISTD Duration; Transport Distance

Carbon footprint – ton CO_2 equivalents



LCA, cont. (Pfeilschifter et al. 2007)

Environmental Impacts



LCA, cont. (Pfeilschifter et al. 2007)

Comparison of Methods

"Most likely" scenarios are marked

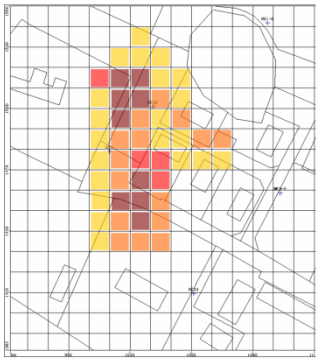
	Excavation		SVE		Heating	
	BC	WC	30y	100y	0.7 y	1 y
Impacts quantified in LCA						
Emissions (GW, AC, NE, OD, POP)	+		+	-		
Toxic effects		-	+			
Waste	+		+	-		
Resource consumption	+	+	-	-	-	-
Impacts described qualitatively						
Working environment						
Inconvenience	-	-				
Remediation efficiency	+	+	-	+	+	+

Green = best environmental performance
Red = worst performance
Yellow = intermediate environmental performance

Factoring in all considerations, heating was selected as the preferred remedy

Selection of Remedial Goals

Modelling objectives – size of area to be treated using ISTD and flux-reduction to be achieved



Concentration (mg-PCE/kg)	Area (m^2)	Flux (kg/y)
25	900	32.4
10	400	1.6
1	1500	0.5
0.1	2100	0.1

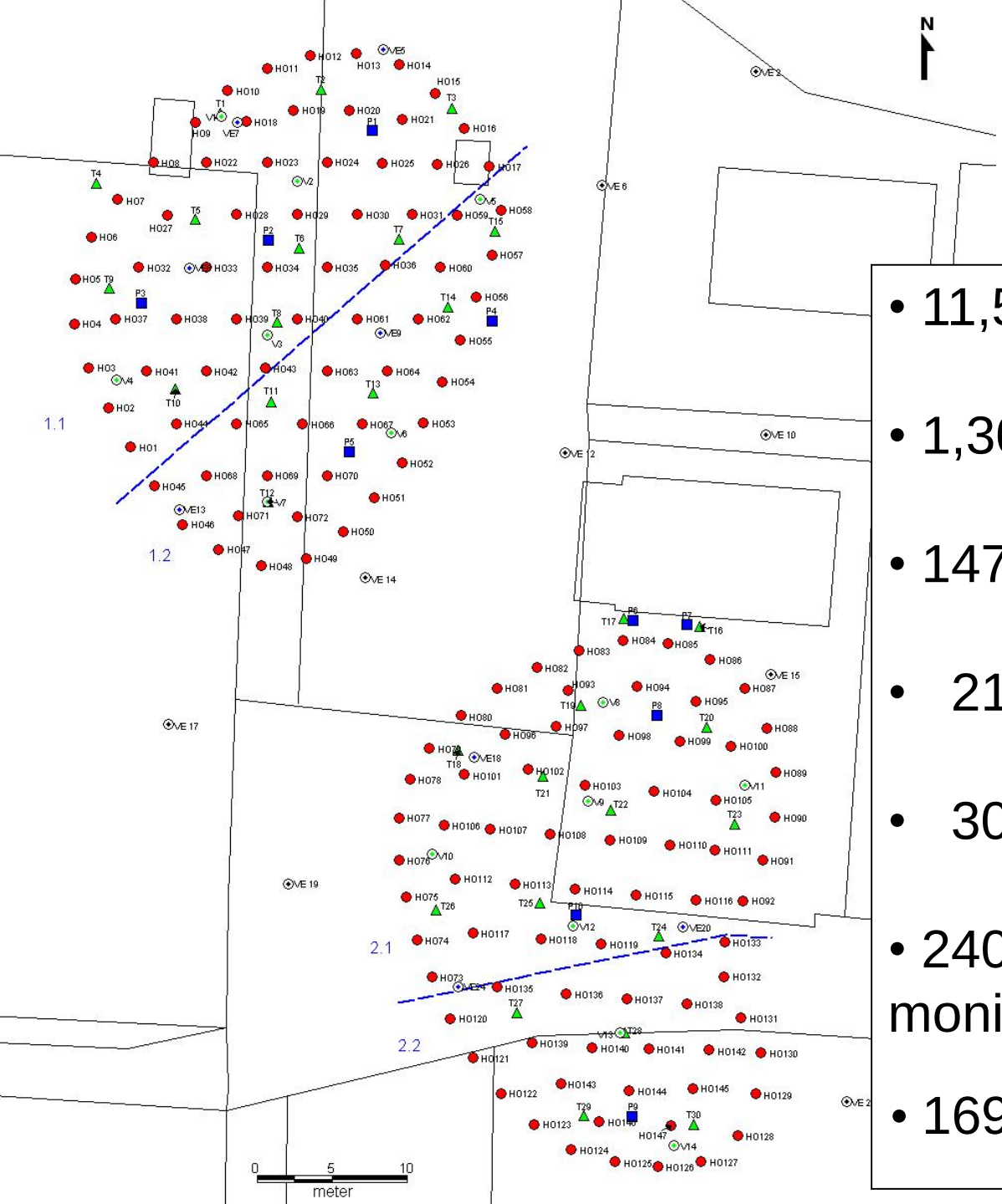
34.6 kg/y is the current flux of PCE into the vadose zone underlying the source area

Remediation scenarios considered:

- **Reduction to 10 mg/kg (900 m^2) → Flux 2.2 kg/y**
- **Reduction to 1 mg/kg (1300 m^2) → Flux 1.2 kg/y**

- **Reduction to 0.1 mg/kg (1300 m^2) → Flux 0.7 kg/y**
- **Reduction to 0.1 mg/kg (2800 m^2) → Flux 0.2 kg/y (original design)**
- **Reduction to 0.1 mg/kg (6000 m^2) → Flux 0.07 kg/y (complete remediation)**

⇒ Scenario should achieve < 1 µg-PCE /l at well field



ISTD Stats

- 11,500 m^3 soil treated
- 1,300 m^2
- 147 heater wells
- 21 extraction points
- 30 thermocouple wells
- 240 temperature monitoringpoints
- 169 days of heating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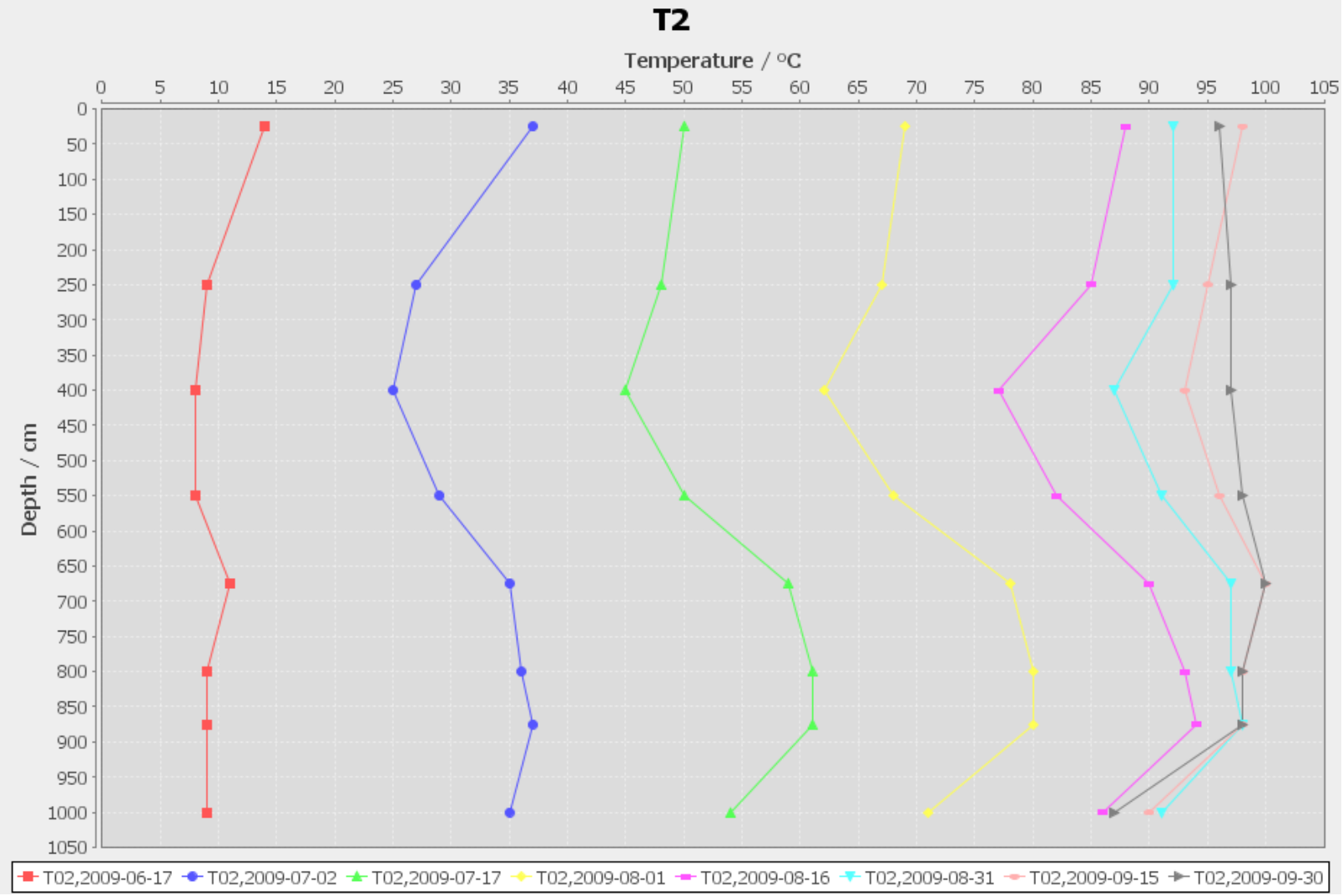
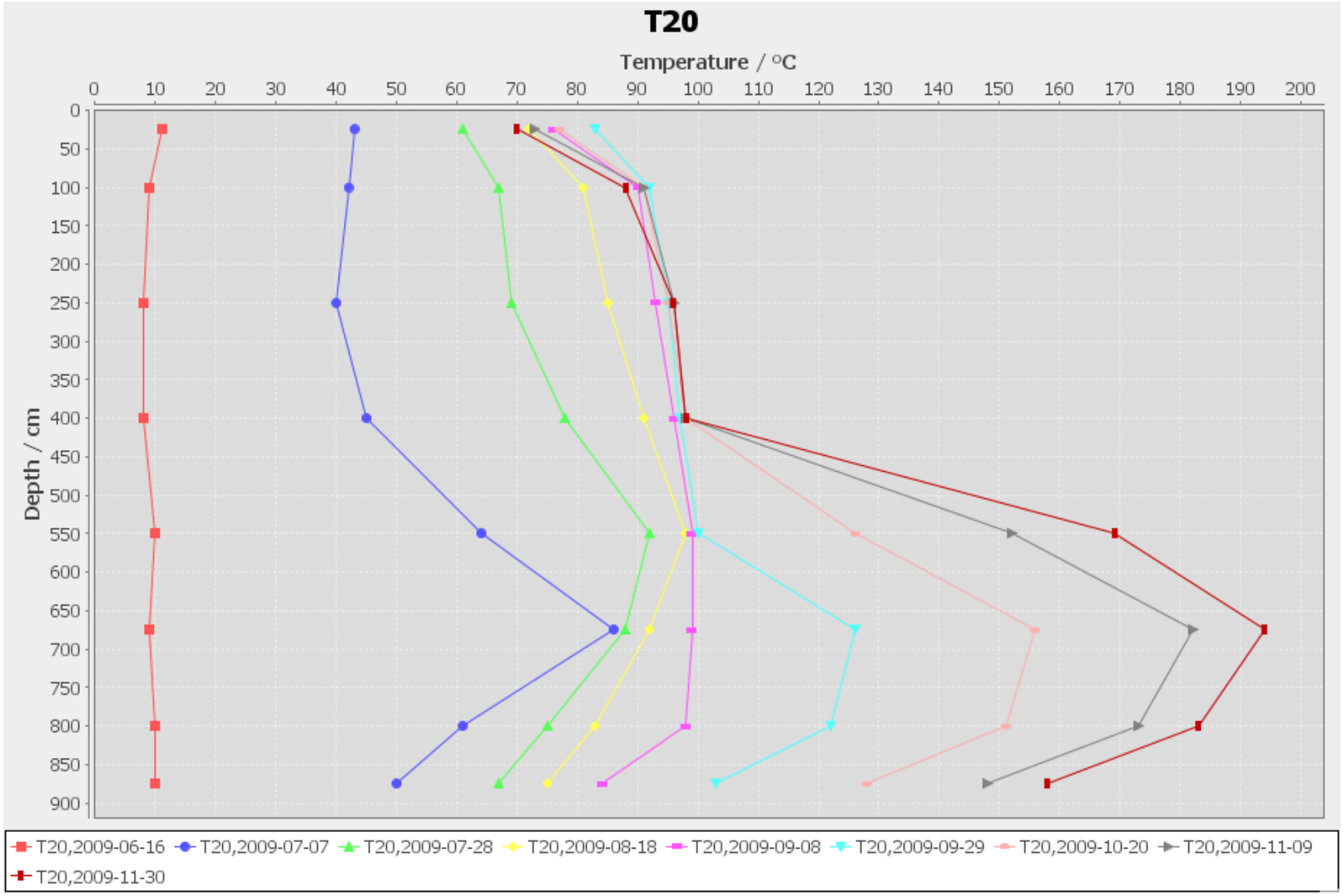
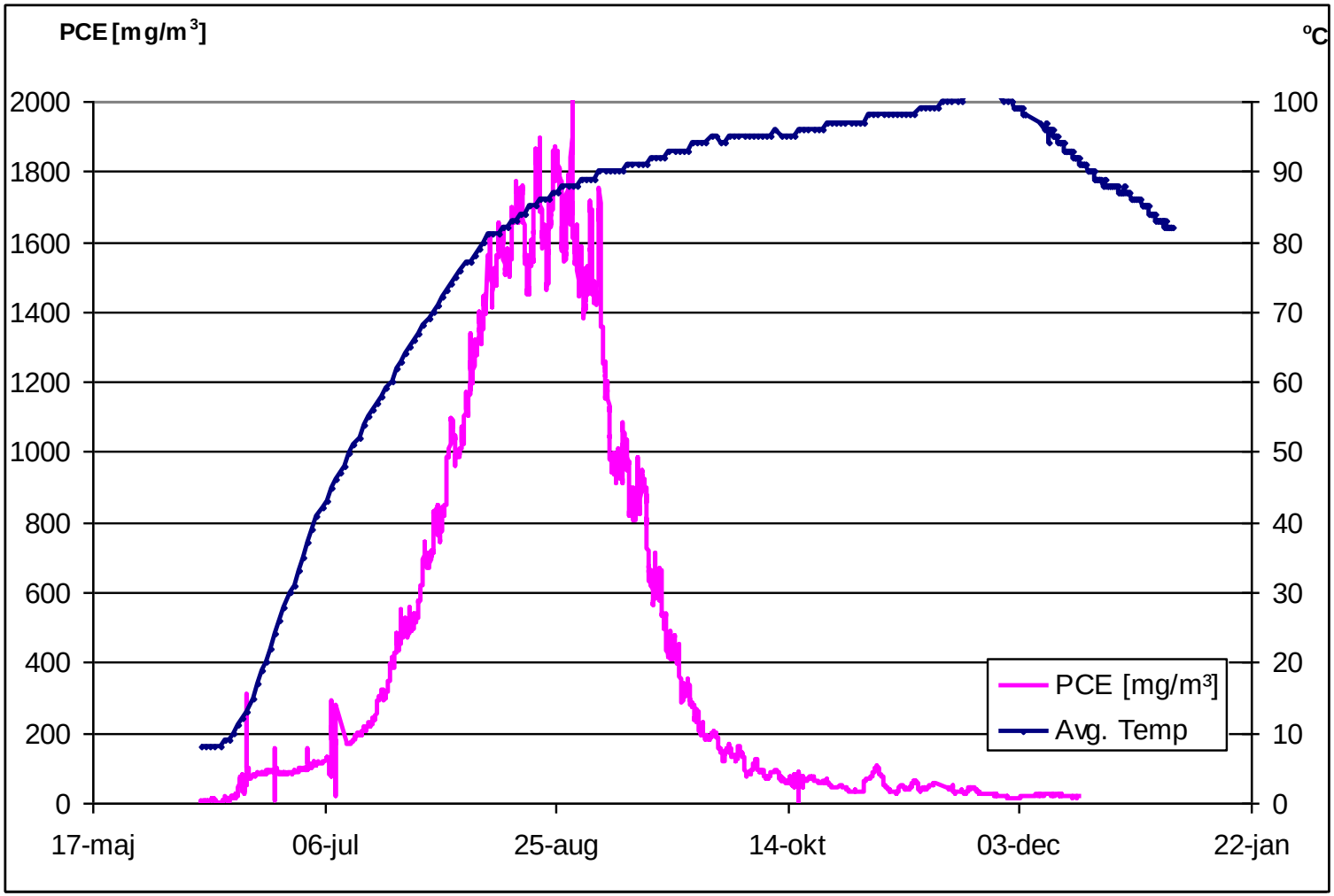
ISTD Temperature Progression



ISTD Temperature Progression, cont.



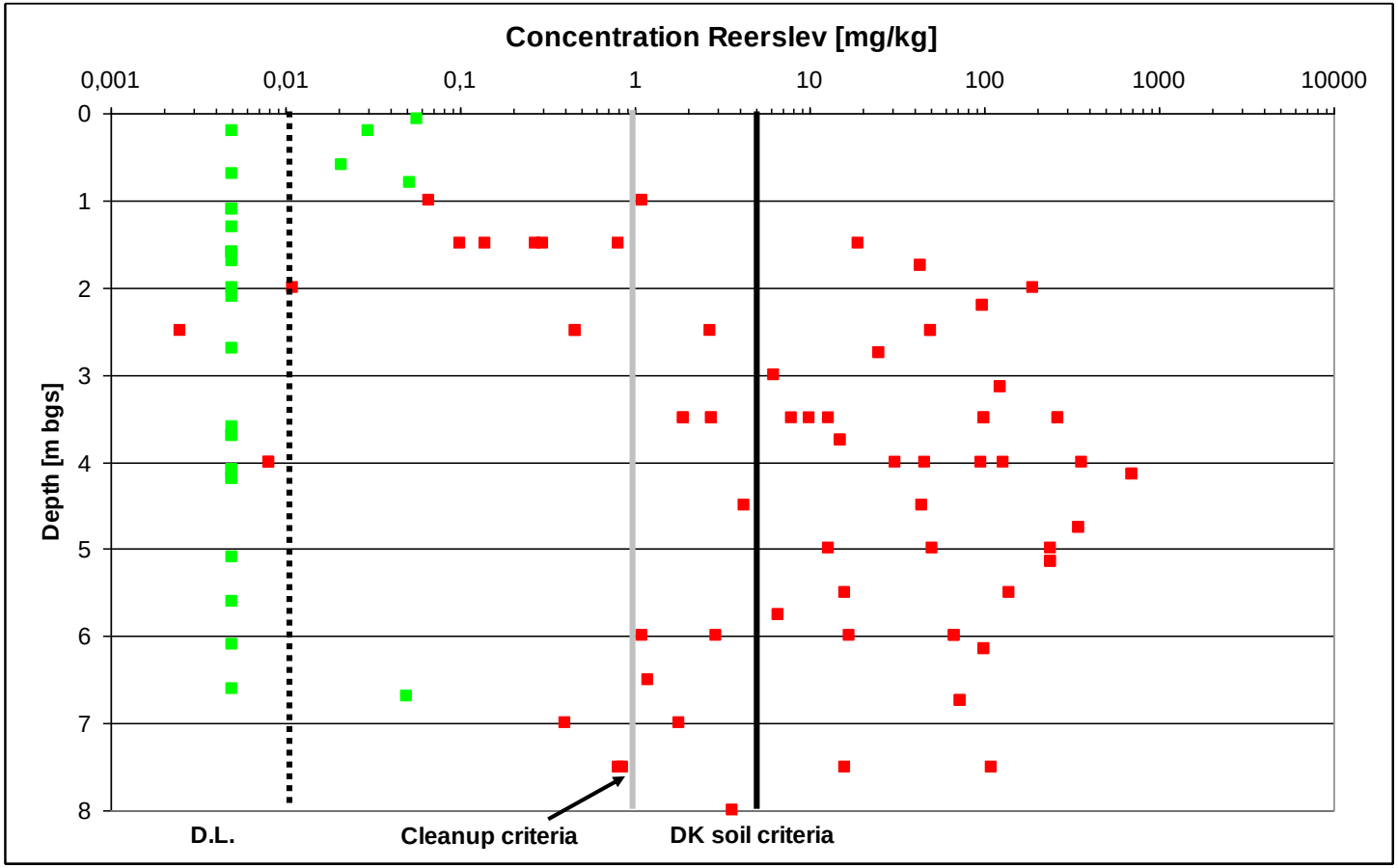
Extracted PCE during ISTD



2,500 kg of PCE removed

Results of ISTD Heating

Actual heating time: 5.5 months



Conclusions

- LCA selected ISTD over excavation and cold SVE
- Actual ISTD Heating Time = 5.5 months (46% of the LCA estimate of 1 year)
- Energy consumption ~ 340 kWh/m^3 (72% of the LCA estimate)
- PCE concentrations were reduced 17 times below cleanup criteria $\rightarrow$ 99.99%
- Total ISTD budget = $3.8M (88% of LCA est.)

Sustainability in Context of Source Removal

- The carbon footprint associated with electrically heating 1 m^3 of contaminated soil ≈ digging and hauling it 140 km (85 mi)
- Meanwhile, in-situ treatment has a lower neighborhood impact, and is environmentally friendly
- With In Situ Thermal Remediation (ISTR), liability is eliminated, not merely moved to another location

⇒ Certain outcome; short time-frame;
highly sustainable

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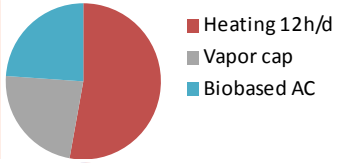
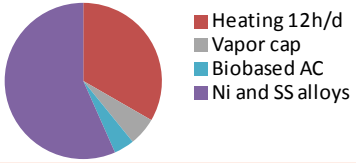
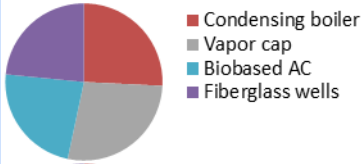
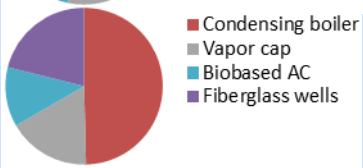
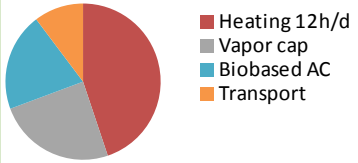
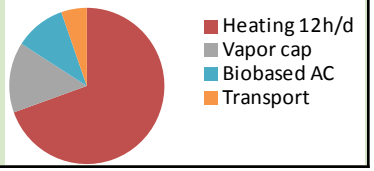
Summary of conclusions for ISTD, SEE and ET-DSP

	Hotspots	Improvement initiatives	Total reduction potential and division between initiatives
ISTD	Electricity use	• **Heating 12h/d**	**Environmental impacts:** 10% 
	Above grade materials	• **Vapor cap (concrete sandwich)** • **Biobased activated carbon**	**Resource depletion:** 20% 
	Well field materials	• **Substitution in nickel and stainless steel**	
SEE	Energy use	• **Change to condensing boiler**	**Environmental impacts:** 21% 
	Above grade materials	• **Vapor cap (concrete sandwich)** • **Biobased activated carbon**	**Resource depletion:** 9% 
	Well field materials	• **Change to fiberglass liners**	
ET-DSP	Electricity use	• **Heating 12h/d**	**Environmental impacts:** 13% 
	Above grade materials	• **Vapor cap (concrete sandwich)** • **Biobased activated carbon**	**Resource depletion:** 8% 
	Transportation	• **Use of experts and equipment from Denmark**	

ET-DSP: Electro-Thermal Dynamic Stripping Process

(Lemming et al. 2012)

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