Case studies (RADOIL project pilot sites)

Measurement of radon in soil gas as an indicator of contamination by petroleum substances

SS07010398

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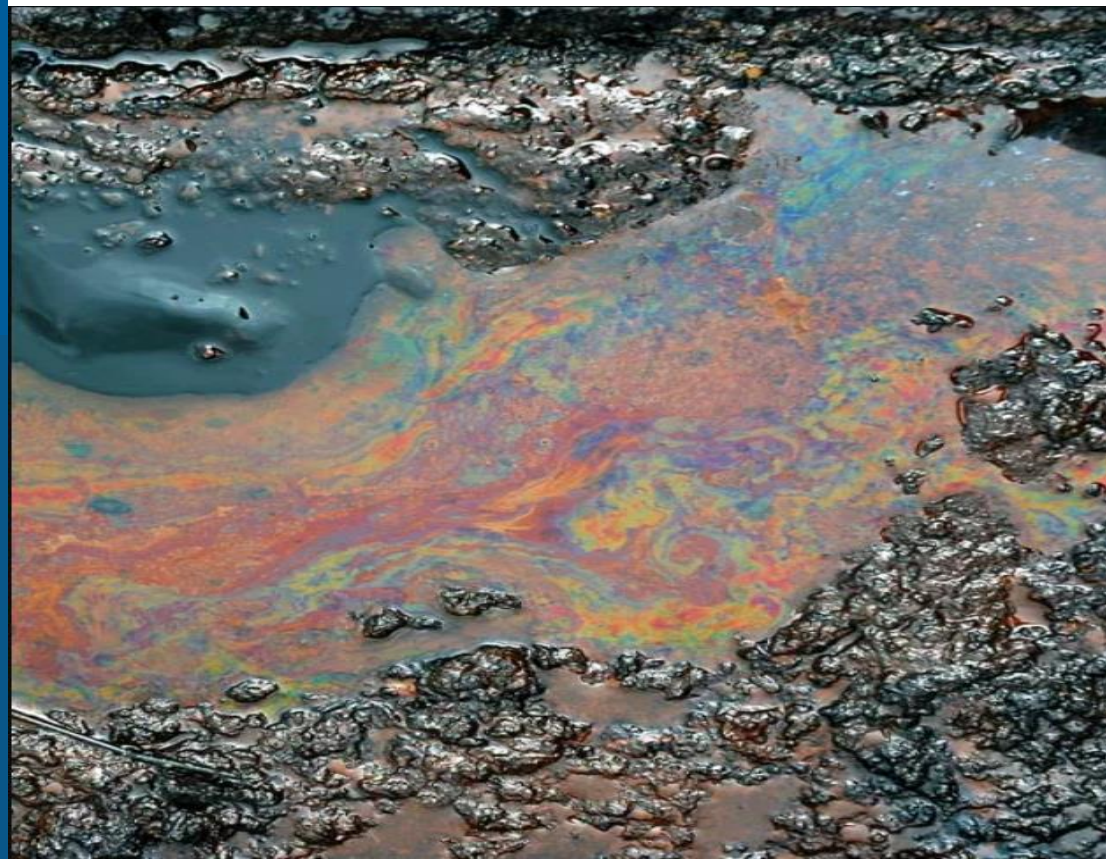
Česká zemědělská univerzita v Praze

Faculty of Environmental Sciences

T A

Č R

Program **Prostředí pro život**



The project:

RADOIL - Measurement of radon in soil gas as an indicator of contamination by petroleum substances

05/2024 - 06/2026

Support:

Technology Agency of the Czech Republic and the Ministry of the Environment of the Czech Republic

T A
Program **Prostředí pro život**
Č R

Ministerstvo životního prostředí
České republiky

Main Project Outcome:

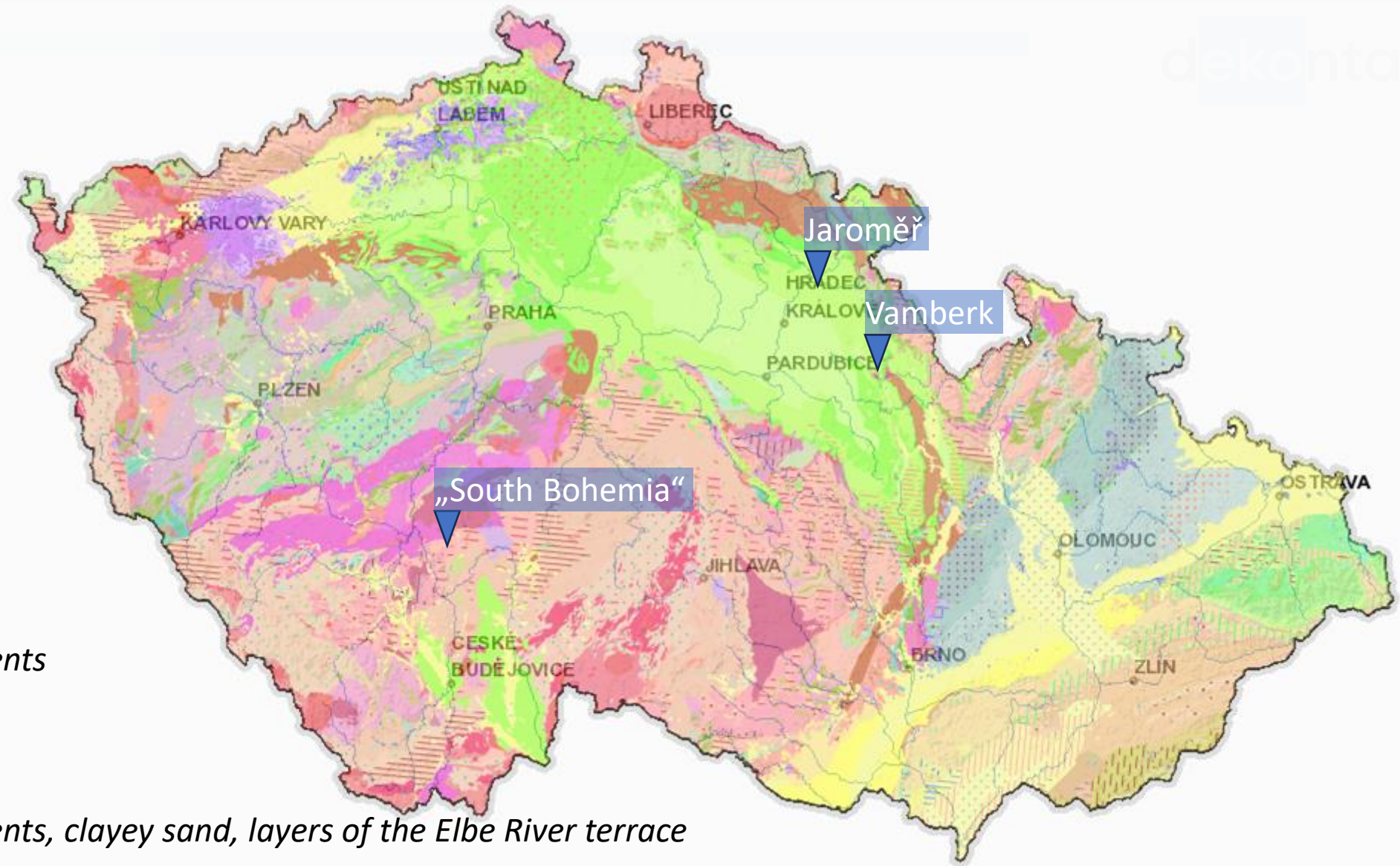
Methodology for indirect measurement of oil contamination using the natural tracer Rn

Pilot testing:
3 pilot sites

- Testing under different conditions (groundwater depth, geology, different measuring depths..)

- Sites with known geology
- Sites with known spatial distribution of contamination
- Different types of petroleum contamination

Geology



Vamberk

Bedrock: marlite

Quaternary: gravel-sand sediments

thickness: 1 - 3 m

Jaroměř

Bedrock: calcareous siltstone

Quaternary: gravel-sand sediments, clayey sand, layers of the Elbe River terrace

thickness: 2 - 3 m

„South Bohemia“ location

Bedrock: biotitic gneiss, strongly weathered in the upper parts

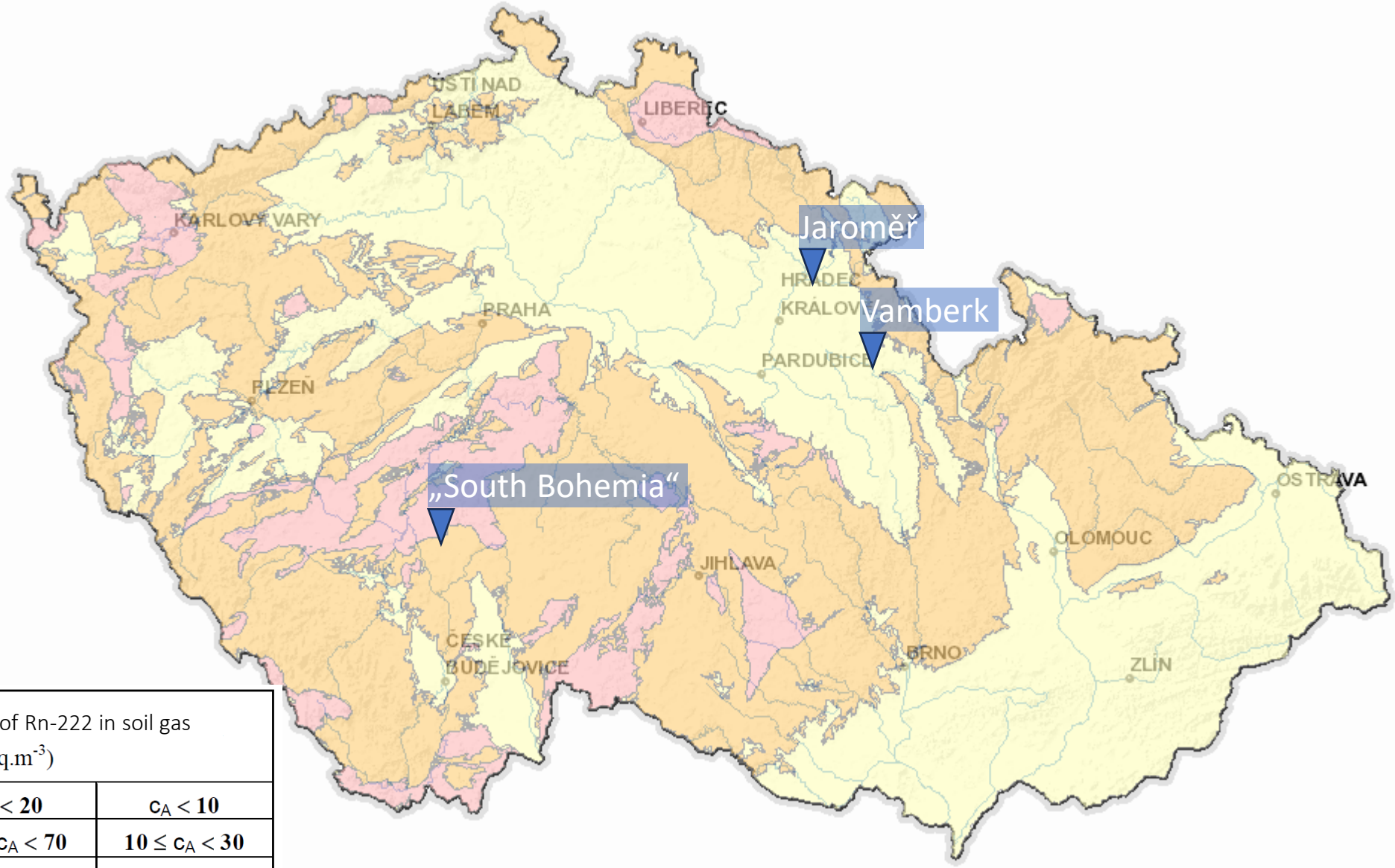
Quaternary: clay-sand sediments, sometimes represented by loess clay

thickness: 2.5 - 5 m

Radon situation

Radon index

- Low
- Medium
- High



Radon index	Volumetric activities of Rn-222 in soil gas ($kBq.m^{-3}$)		
Low	$c_A < 30$	$c_A < 20$	$c_A < 10$
Medium	$30 \leq c_A < 100$	$20 \leq c_A < 70$	$10 \leq c_A < 30$
High	$c_A \geq 100$	$c_A \geq 70$	$c_A \geq 30$
	Low	*Medium*	*High*
	$K<4.10^{-13}$ m^2		$K>4.10^{-12}$ m^2

Gas permeability of soils

Vamberk site

Area = 4 000 m2

Site background:

- Production of chains of various types and sizes
- Production site currently in operation
- Use of large quantities of cutting oils

Vamberk site

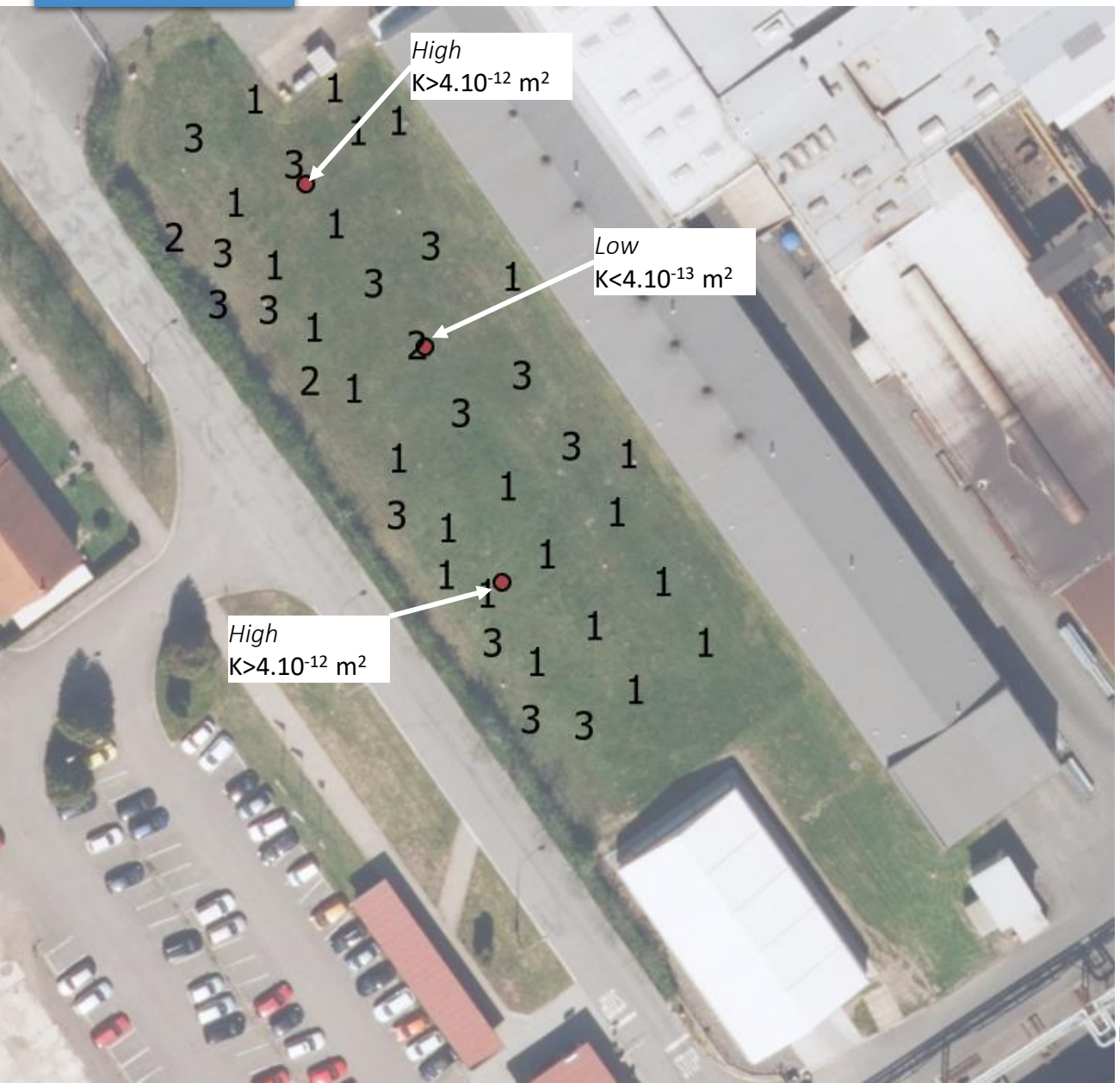
Bedrock: marlite

Hydrogeology:

- Groundwater depth: 2 – 3 m b.t.
- Shallow quaternary aquifer: K = 1 – 9.10^{-5} m/s

Source: Risk Assessment study, 2G geolog s.r.o., 2015

Vamberk site



Soil profile characterisation:

- Layer of soil of anthropogenic origin 0,5 – 2,9
- Sandy loam to loam, clay in spots, construction waste
- below anthropogenic layer: holocene fluvial deposits of clay and loam character
- Lowest part of quaternary: fluvial gravels

Dominant soil gas permeability:

- Subjectively during sampling (80 cm): High

3=Low $K<4.10^{-13}$ m² *2=Medium* *1=High* $K>4.10^{-12}$ m²

- Measured K by JOK apparatus: 3 points

Vamberk site

Contamination data:

- Source of contamination: Cutting oil warehouse (removed in 1987)

- Type of contamination:
  n-alkanes in the range C16-C35 with a maximum of C21-C30, corresponding to mineral oils, low solubility in water (C10-C40 0,1 – 0,5 mg/l)
  + light contamination of chlorinated ethenes in GW (TCE: 0,5 ug/l, PCE 4,2 ug/l)

- Max contamination in soil:
  C10-C40 52,5 g/kg, avg 10 g/kg in the plume area
  benzo(a)pyrene: 0,306 mg/kg

- measured phase thickness at the groundwater level:
  1 m at maximum

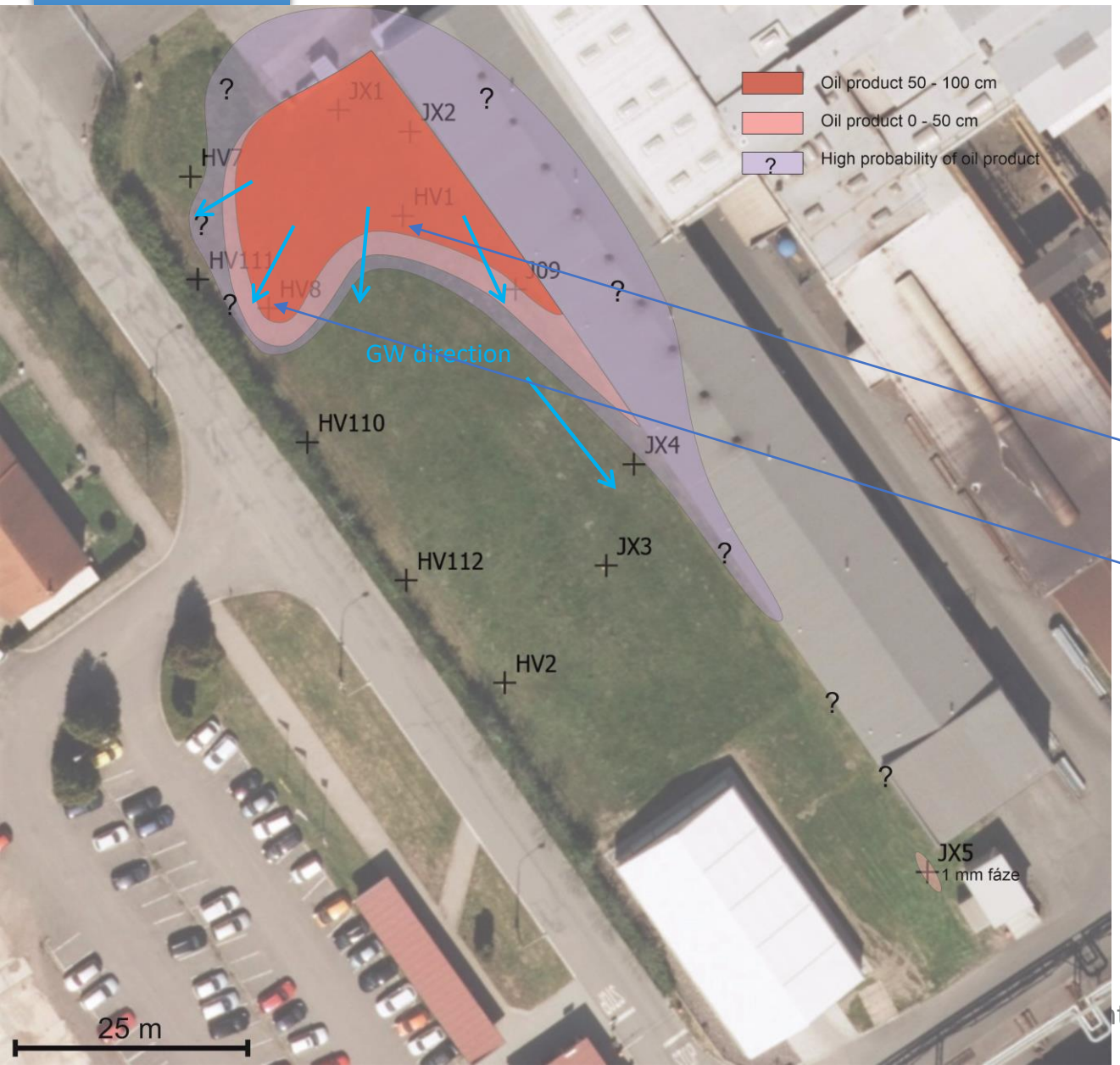
- **Estimated contaminated area: 850 m^2**
- **Estimated volume of oil product: 45 tonnes**
- **Estimated volume of contaminated soil: 2500 m^3**

- Extent and spread of contamination: in the direction of GW + preferred pathway along the building

- **Estimated velocity of oil product spread: cm/year**

Source: Risk Assessment study, 2G geolog s.r.o., 2015

Vamberk site



Source: Risk Assessment study, 2G geolog s.r.o., 2015

Vamberk site

Methodology of Radon measuring:

- 2 campaigns: 03/2025 and 05/2025
- Soil gas sampling in 80 cm and 50 cm depth
- Volumetric activity of Rn-222 (Bq/m3)
- RM-2 device with ionization chamber
- 40 sampling points, 10 x 10 m grid
- Outdoor temperature: 8°C and 15°C

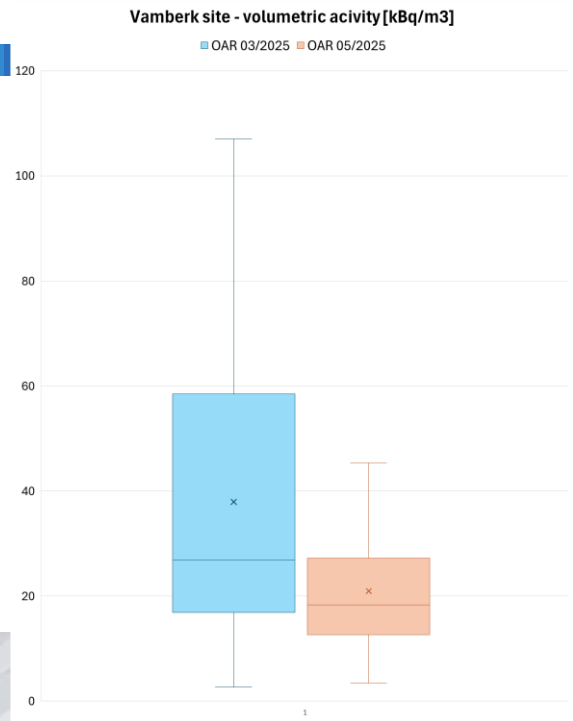
40 sampling points

Average activity

37,9 x 20,9 kBq/m3

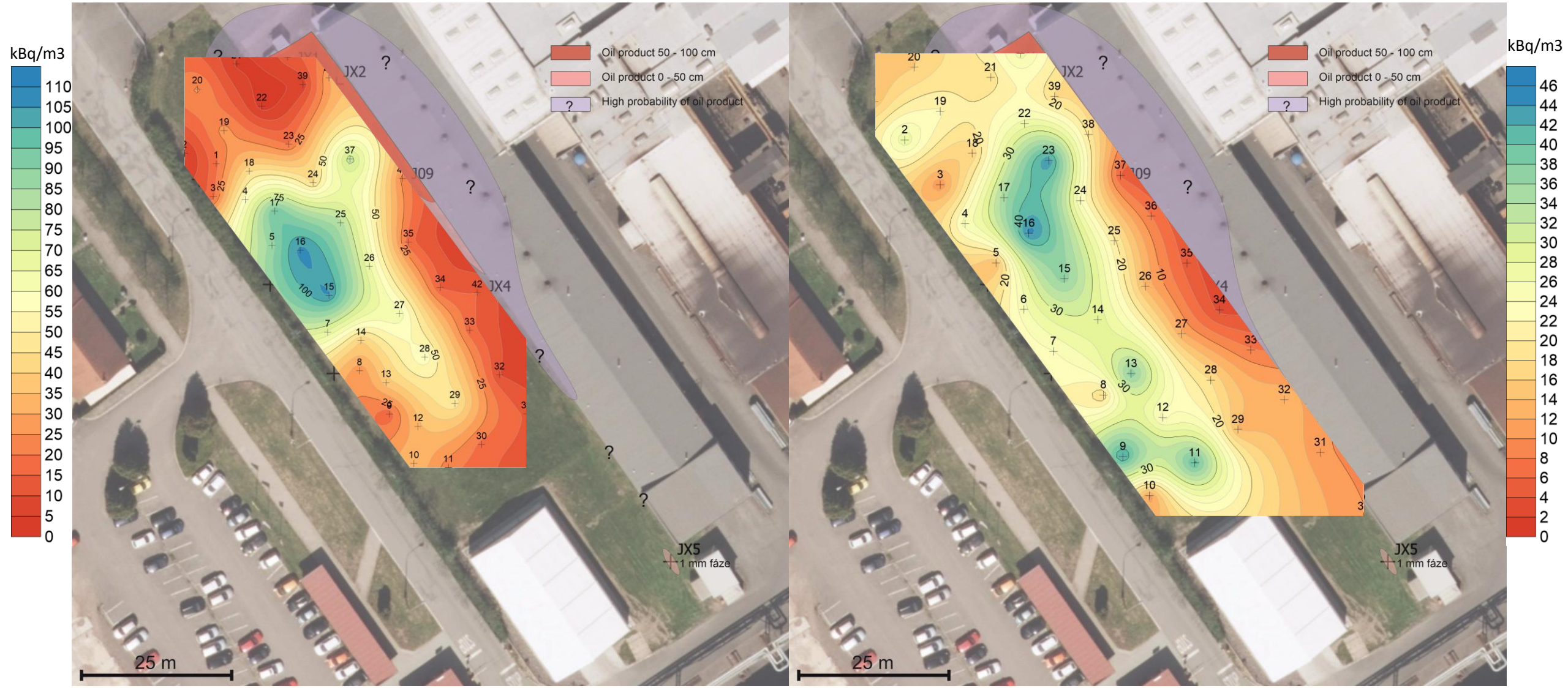
Coef. of variation

76% x 53%



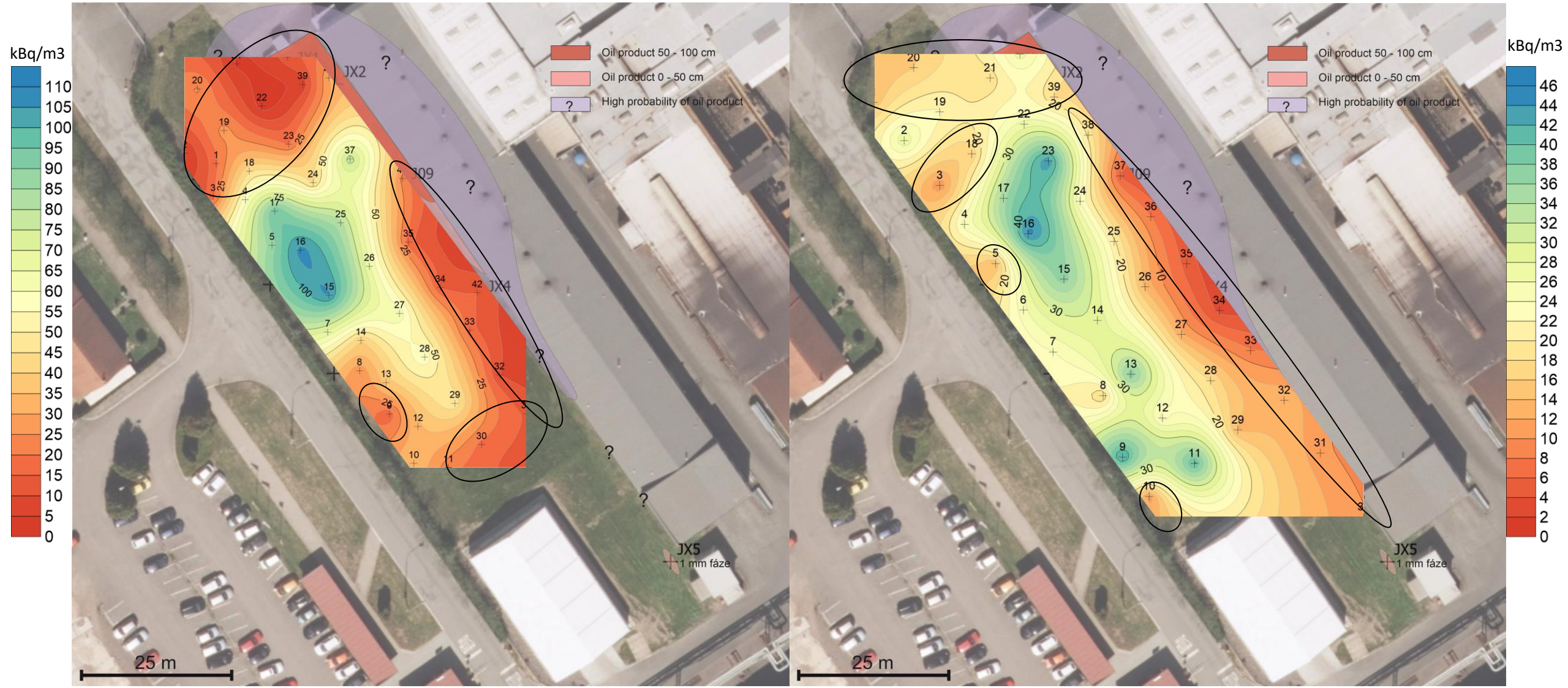
Vamberk site

Radon measuring - Results 03/2025 and 05/2025



Vamberk site

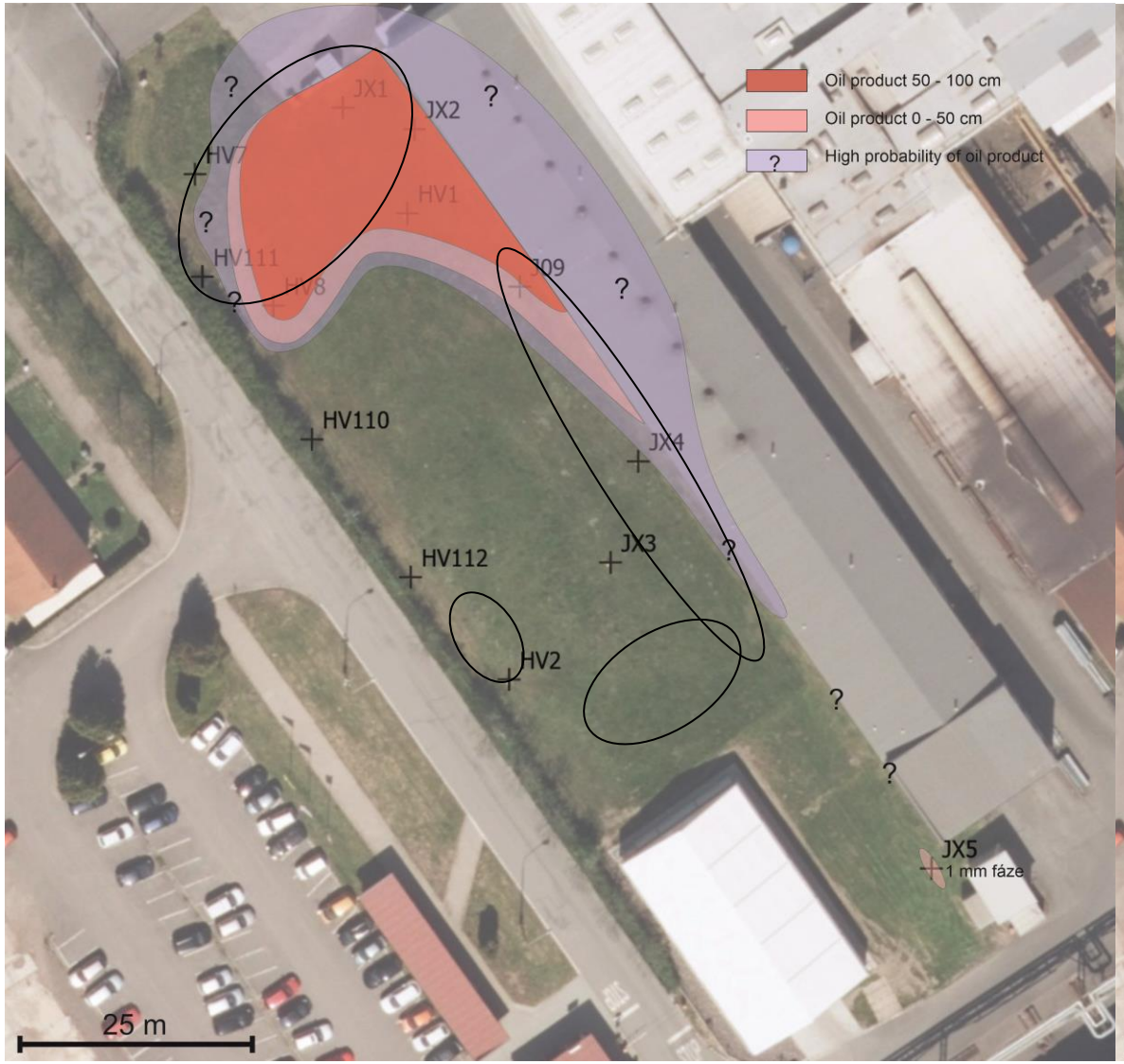
Radon measuring - Results 03/2025 and 05/2025

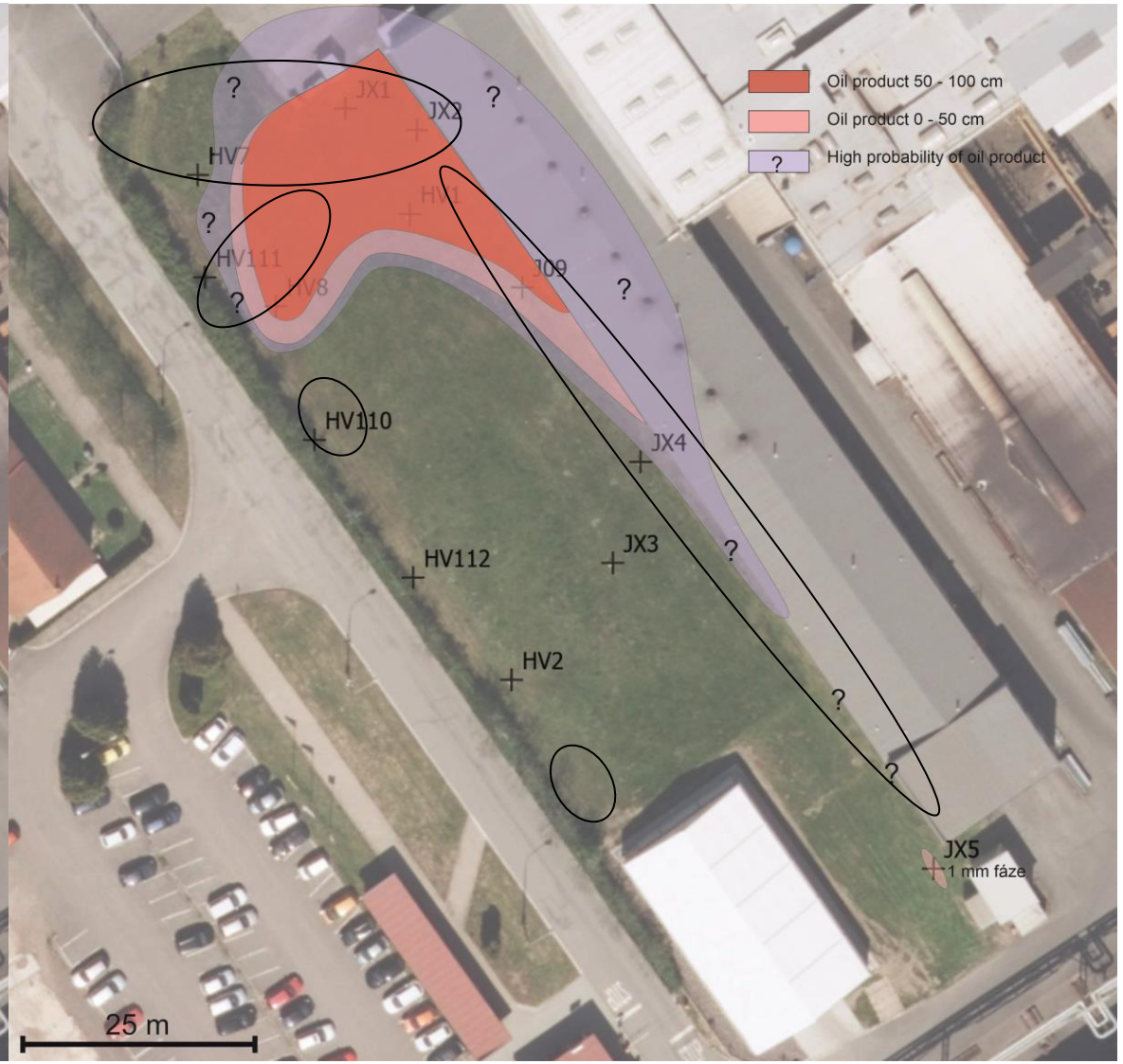


Vamberk site

Radon measuring - Results

03/2025 and 05/2025





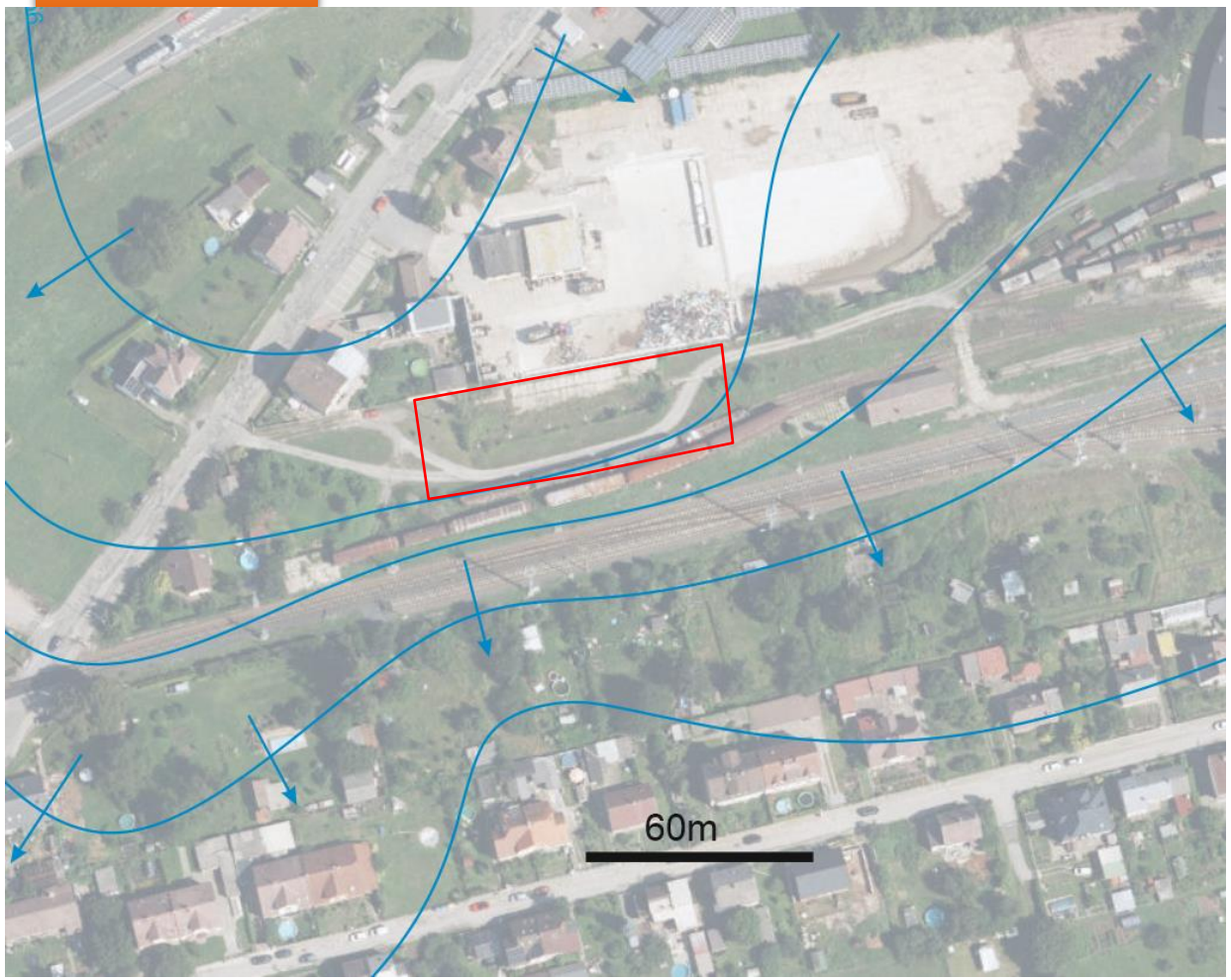
Jaroměř site

Area = 2 000 m2

Site background:

- The area of the railway siding and the neighbouring scrap metal depot (historically a fuel storage facility)
- The railway siding is no longer in operation, and the neighbouring site has already been remediated.

Jaroměř site

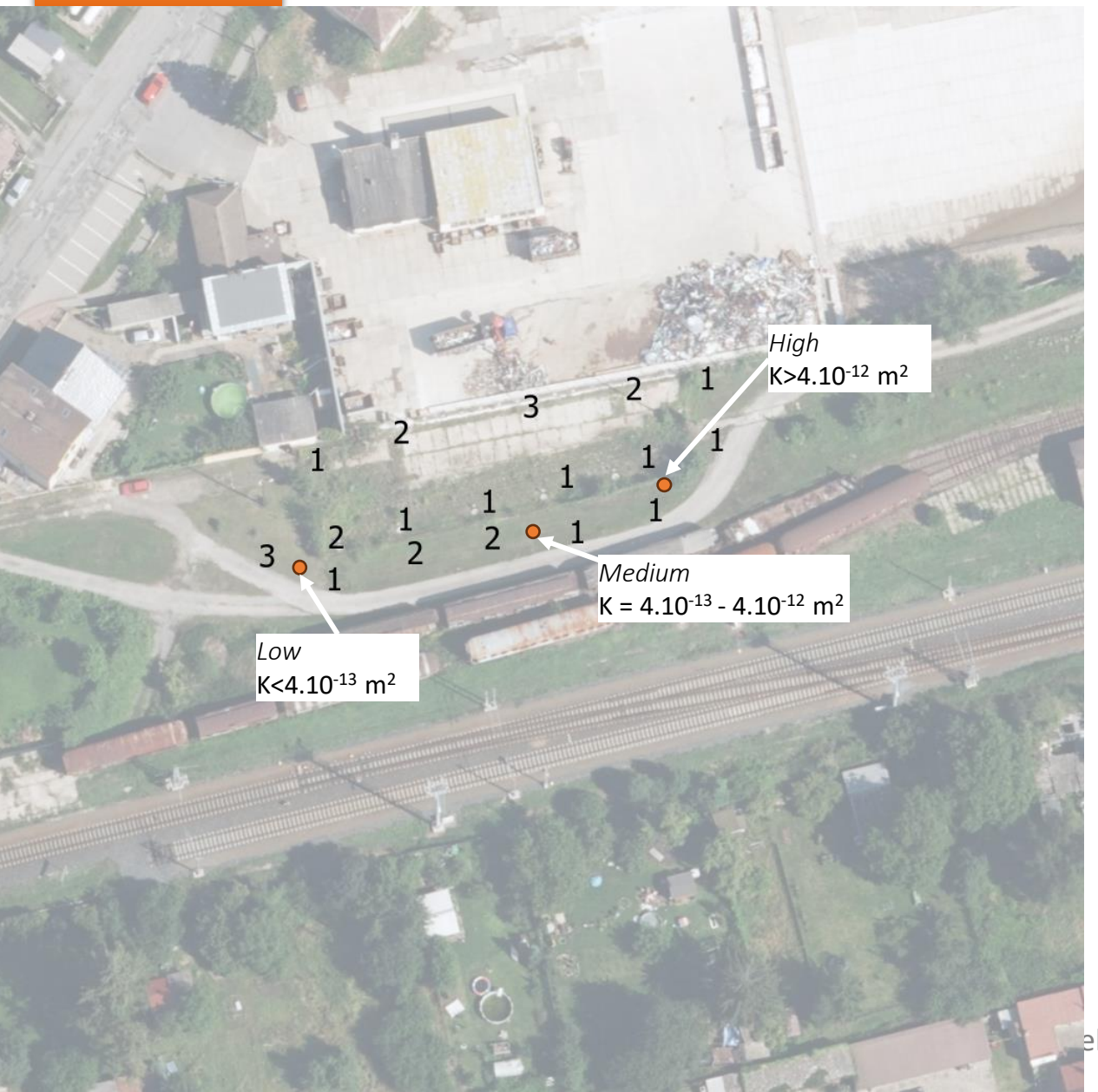


Bedrock: calcareous siltstone

Hydrogeology:

- Shallow aquifer: gravel-sand sediments of the Elbe terraces + weathered zone of the underlying Cretaceous siltstone
- Significant oscillation of GW during the year 2 – 6 m b.t.
- K = 3.10^{-7} - 3.10^{-3} m/s

Jaroměř site



Soil profile characterisation:

- Layer of soil of anthropogenic origin 0 – 0,7 m b.t.
- Gravel mixed with clay and sand
- Below anthropogenic layer: clay soil

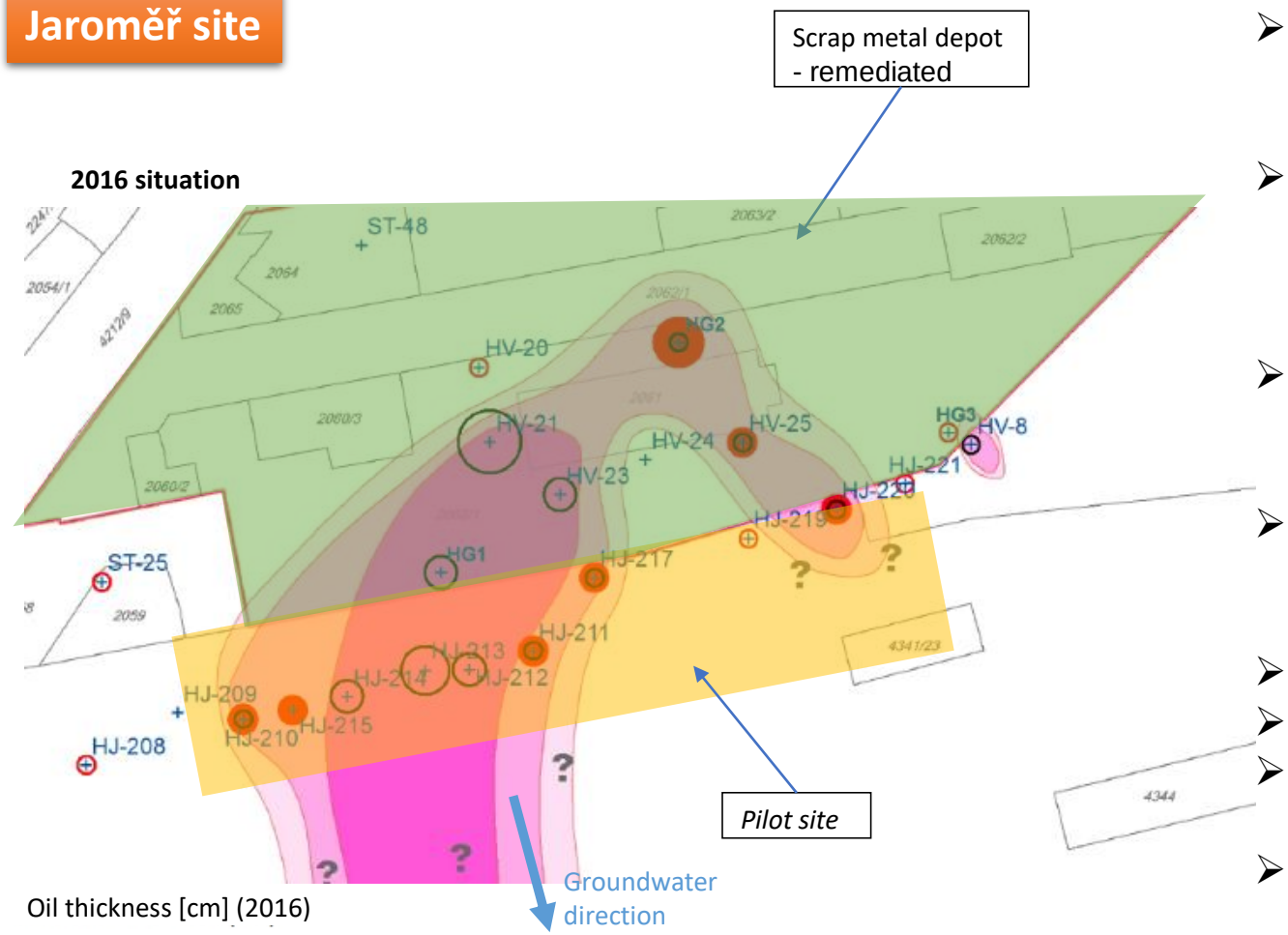
Dominant soil gas permeability:

- Subjectively during sampling (80 cm): High

3=Low $K<4.10^{-13}$ m² *2=Medium* *1=High* $K>4.10^{-12}$ m²

- Measured K by JOK apparatus: 3 points

Jaroměř site



2025:
Oil thickness max: 2 mm
C10-40 max: 386 mg/l

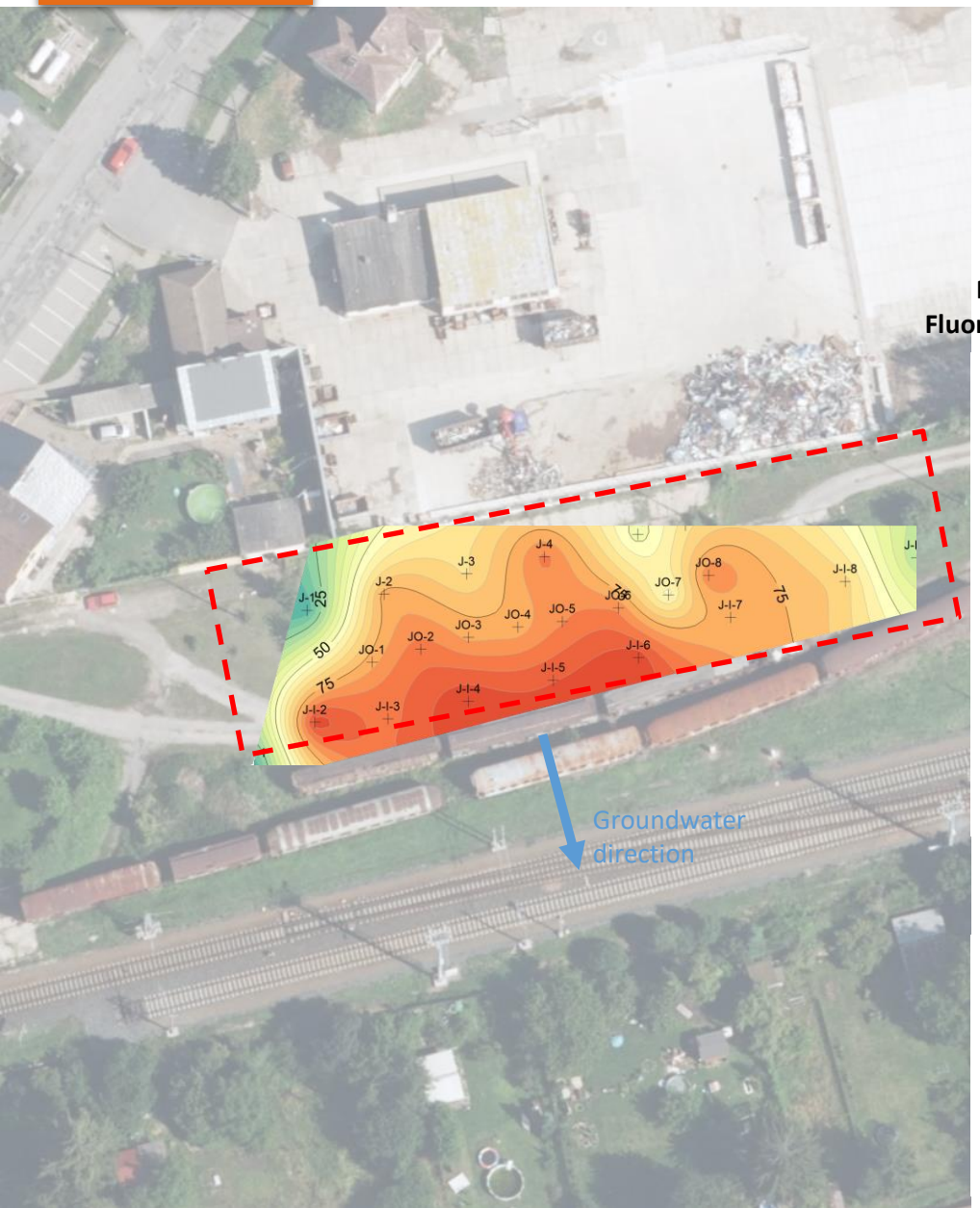
Contamination data:

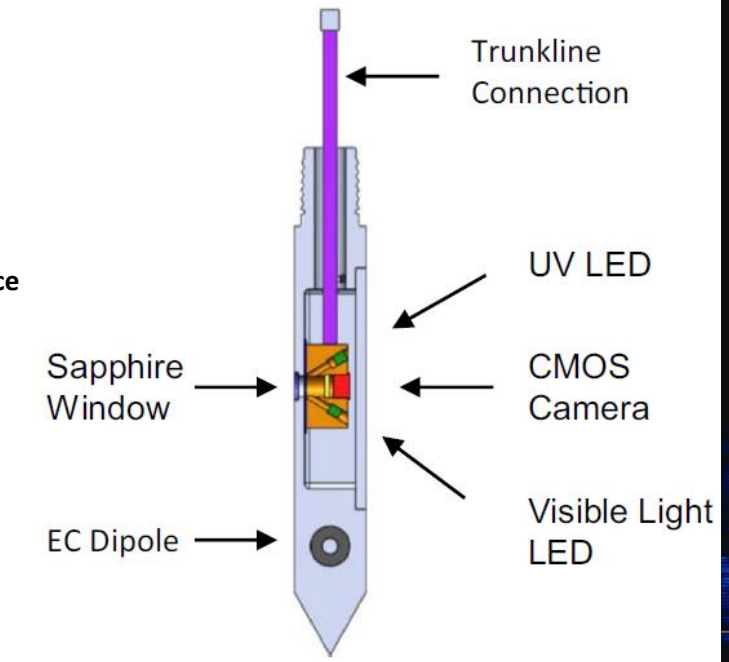
- Source of contamination: underground storage tanks (removed and site remediated 2022-2023)
- Type of contamination:
  n-alkanes in the range C12-C25 corresponding to the mixture of benzine and light heating oil (C10-C40 max. 386 mg/l in 2024)
- Max contamination in soil:
  C10-C40 1000 – 3000 mg/kg
- measured phase thickness at the groundwater level:
  2 mm at maximum (2025)
- **Estimated contaminated area: 500-700 m2**
- **Estimated volume of oil product: Not known**
- **Estimated volume of contaminated soil: Not known**
- Extent and spread of contamination:
  Oil product fixed to less permeable soil pockets and perched aquifers, gradually washed away by high oscillating groundwater in the direction of flow

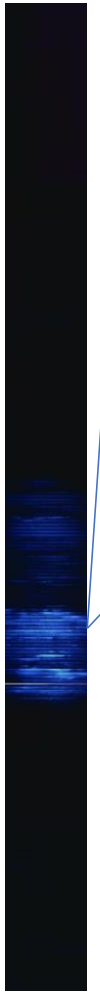
Jaroměř site

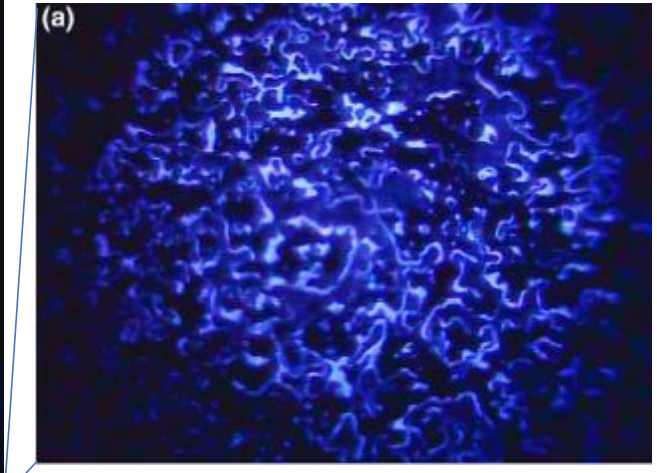
Contamination data:

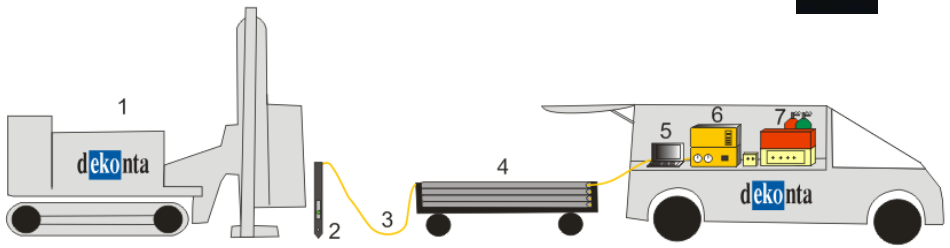
- Contamination survey using OIP (Optical Image Profiler)











Jaroměř site

Methodology of Radon measuring:

- 2 campaigns: 12/2024 and 06/2025
- Soil gas sampling in 80 cm and 50 cm depth
- Volumetric activity of Rn-222 (Bq/m3)
- RM-2 device with ionization chamber
- 17 and 20 sampling points, 10 x 10 m grid
- Outdoor temperature: 3°C and 28°C

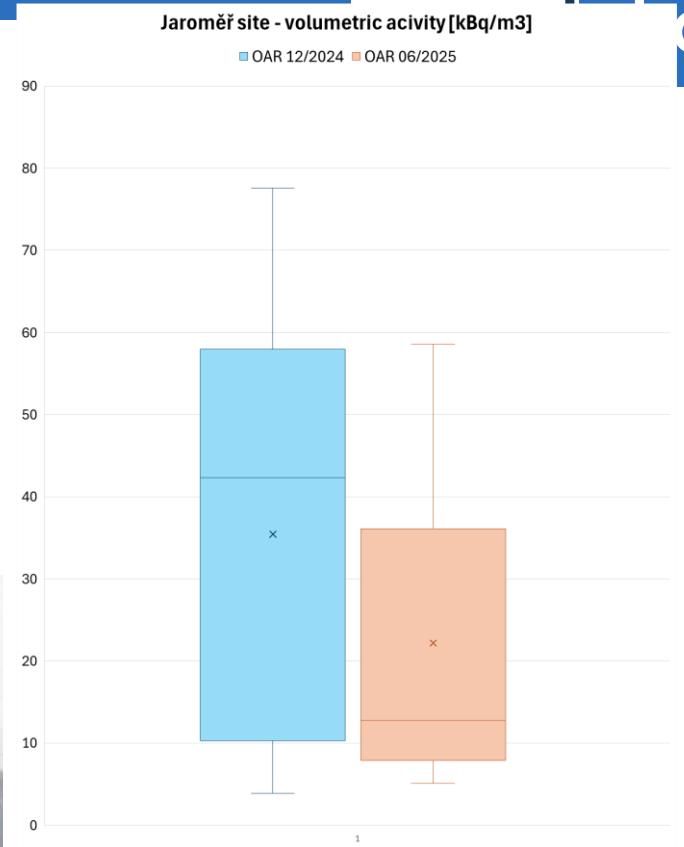
17/20 sampling points

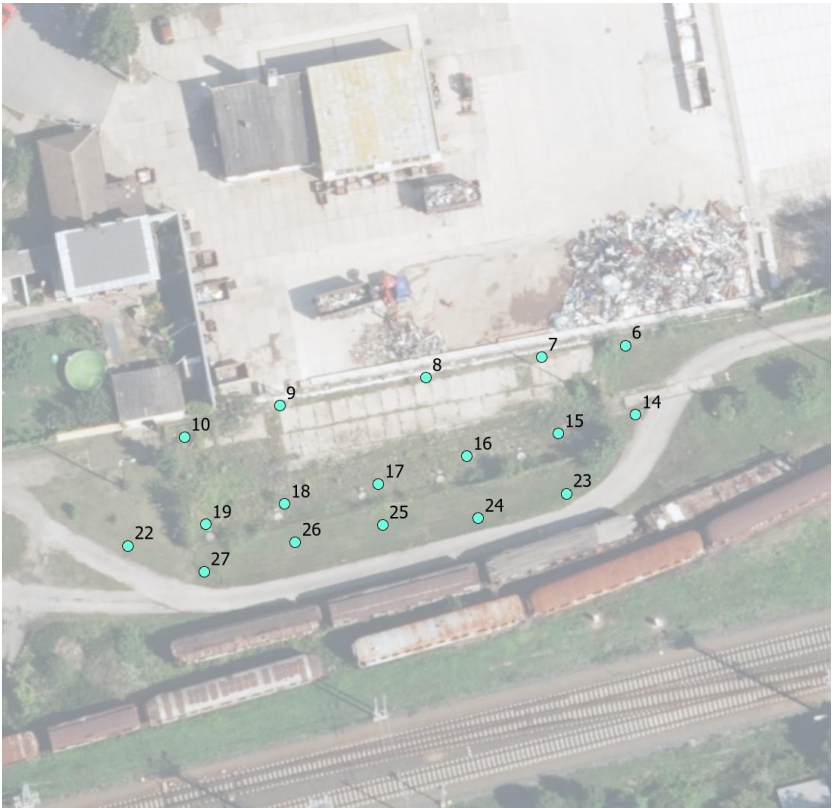
Average activity

35,4 x 22,2 kBq/m3

Coef. of variation

72% x 78%

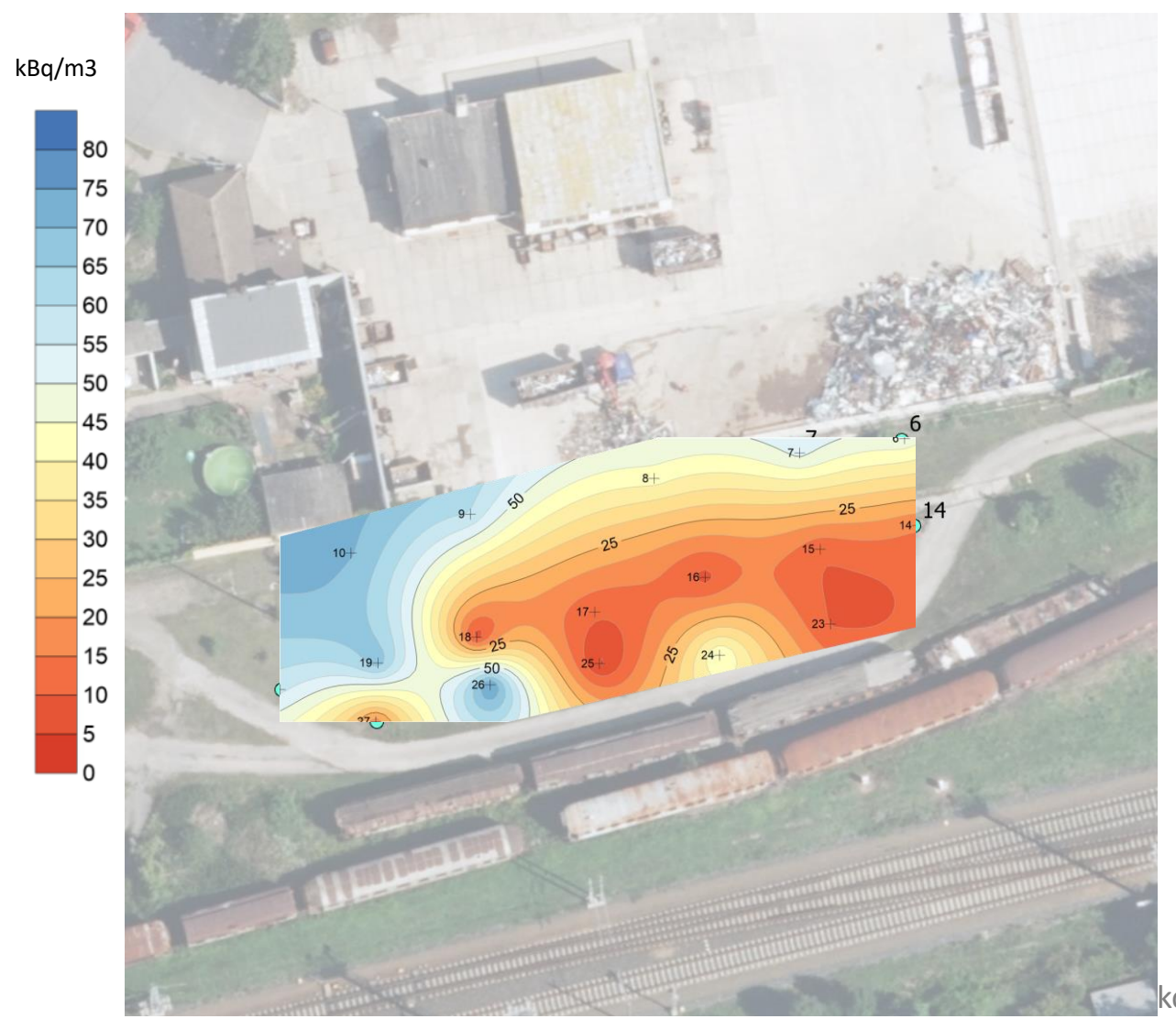


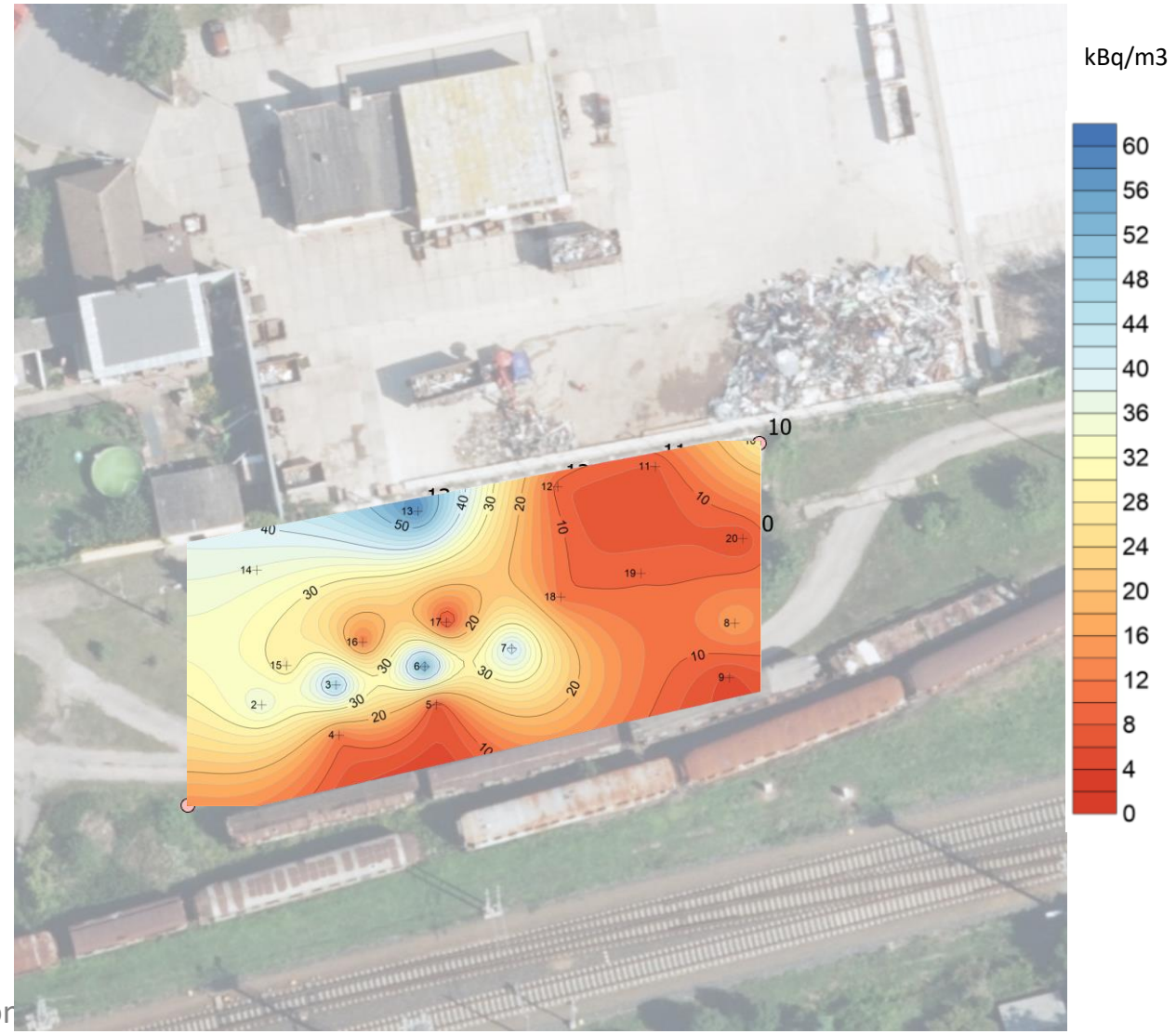


Jaroměř site

Radon measuring - Results

12/2024 and 06/2025

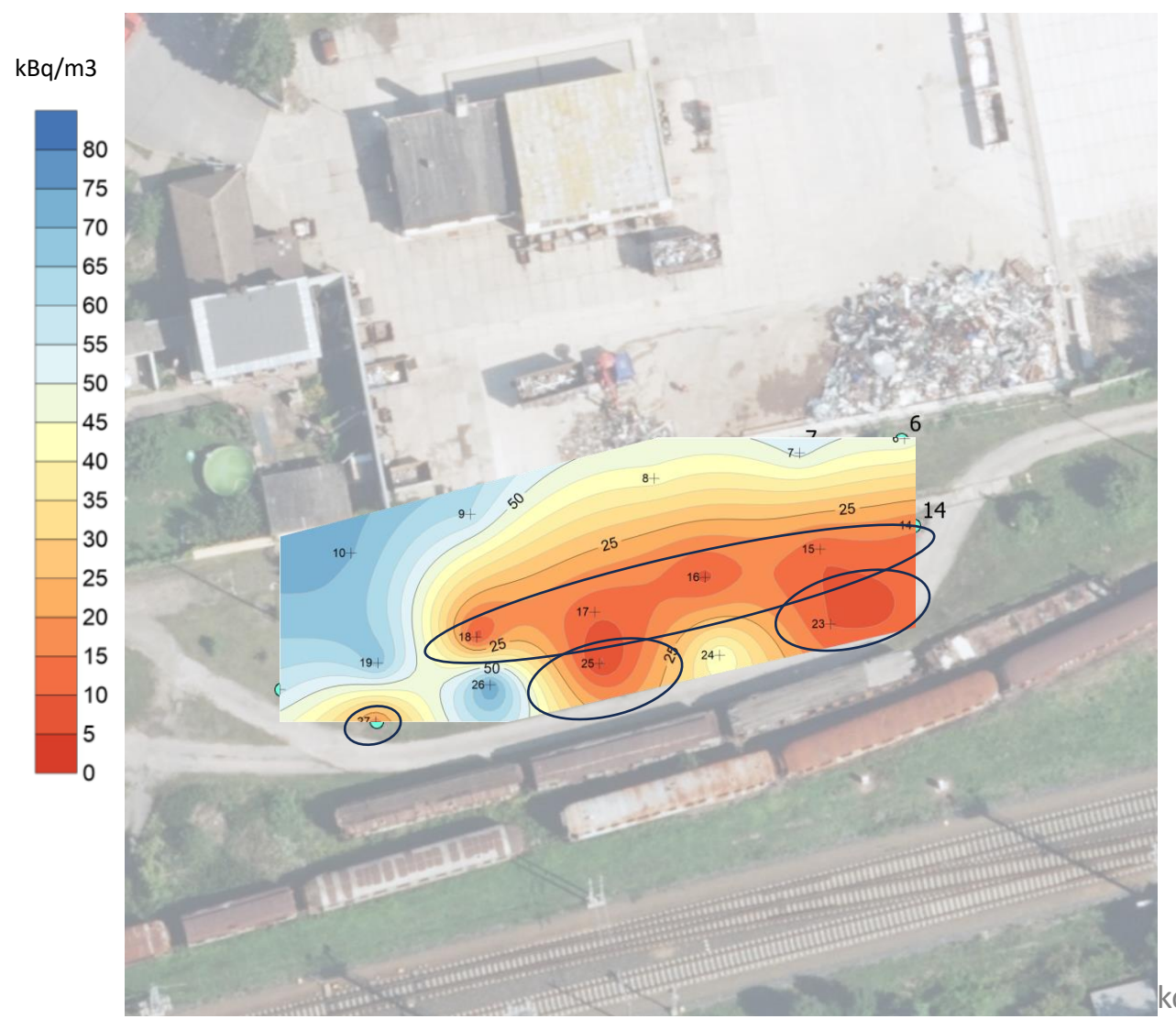


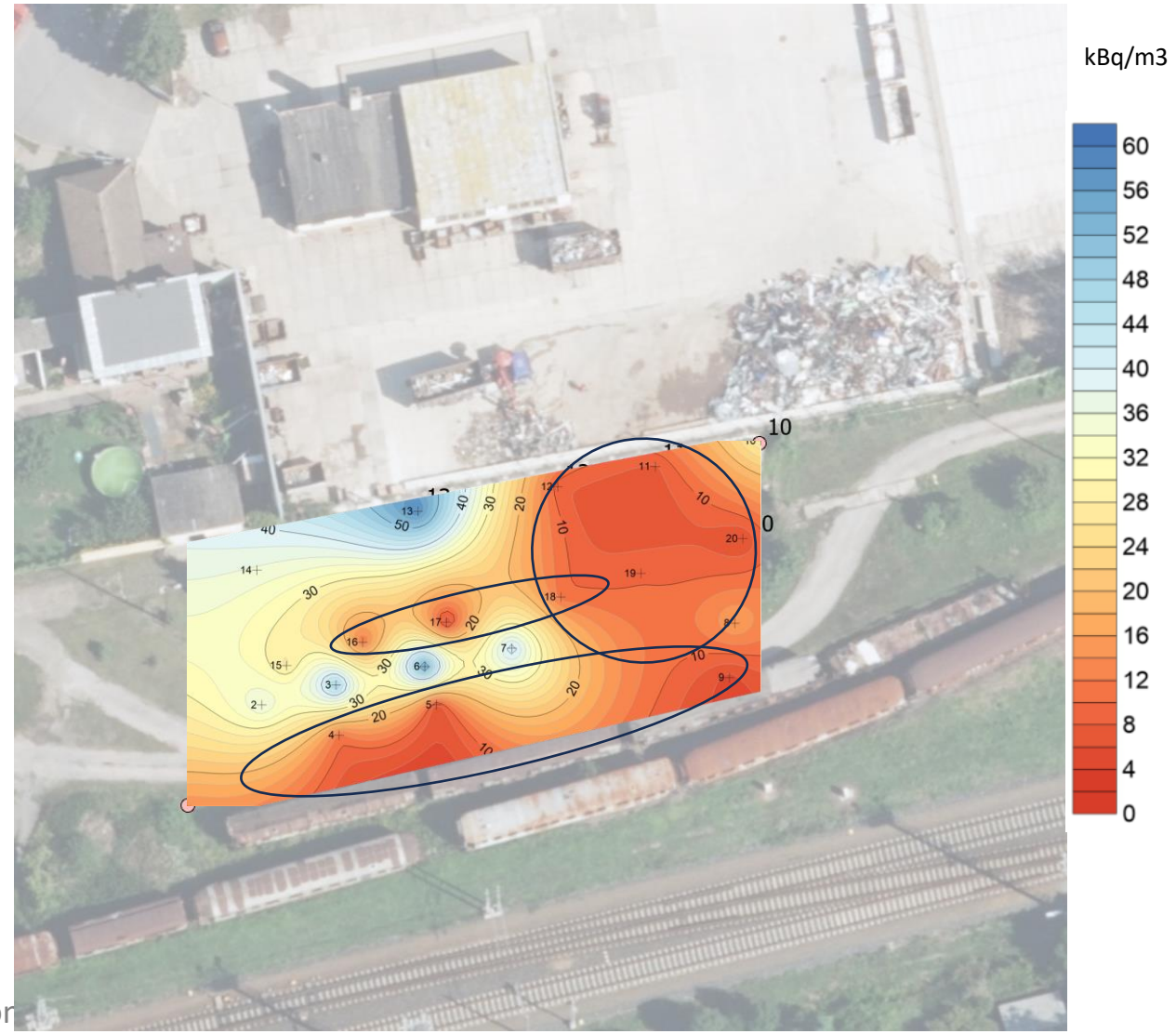


Jaroměř site

Radon measuring - Results

12/2024 and 06/2025

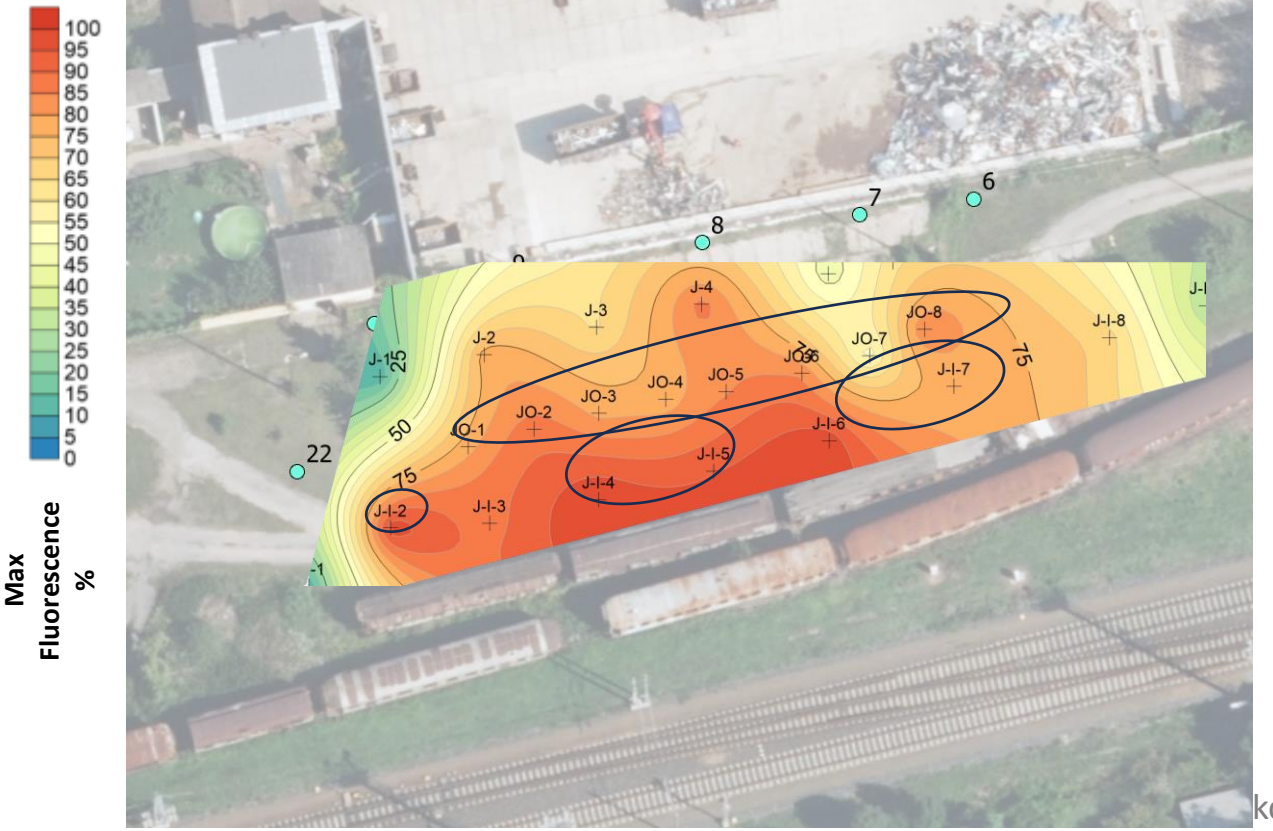


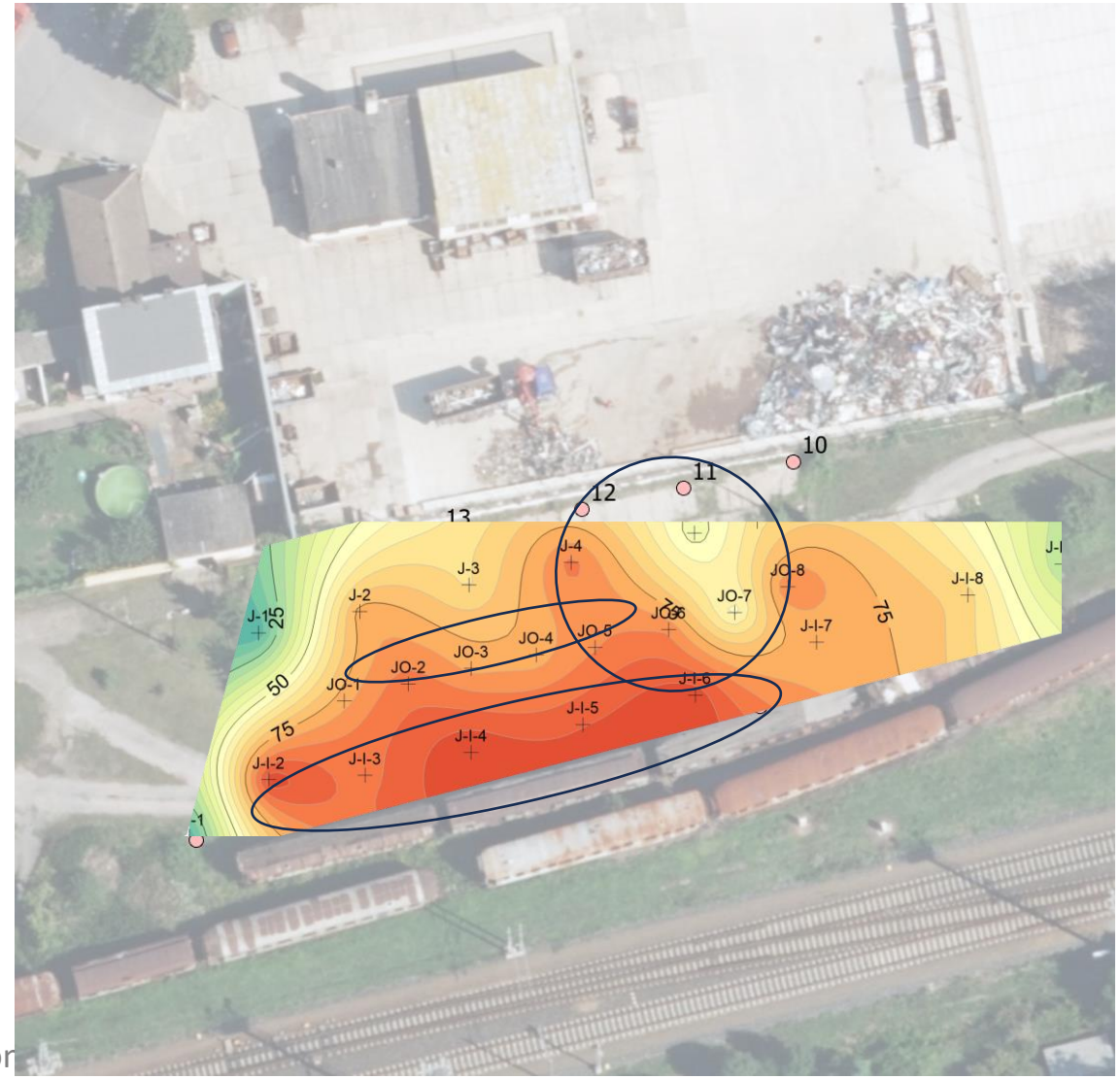


Jaroměř site

Radon measuring - Results

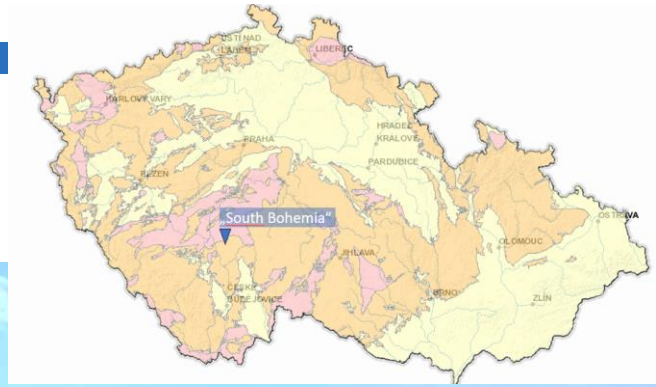
12/2024 and 06/2025





Location "South Bohemia"

Area = 8 000 m2



Site background:

- Agricultural land
- Underground pipeline at a depth of 1 m
- Historical accident on the pipeline before 1990 with fuel leakage (gasoline and diesel) into the subsoil

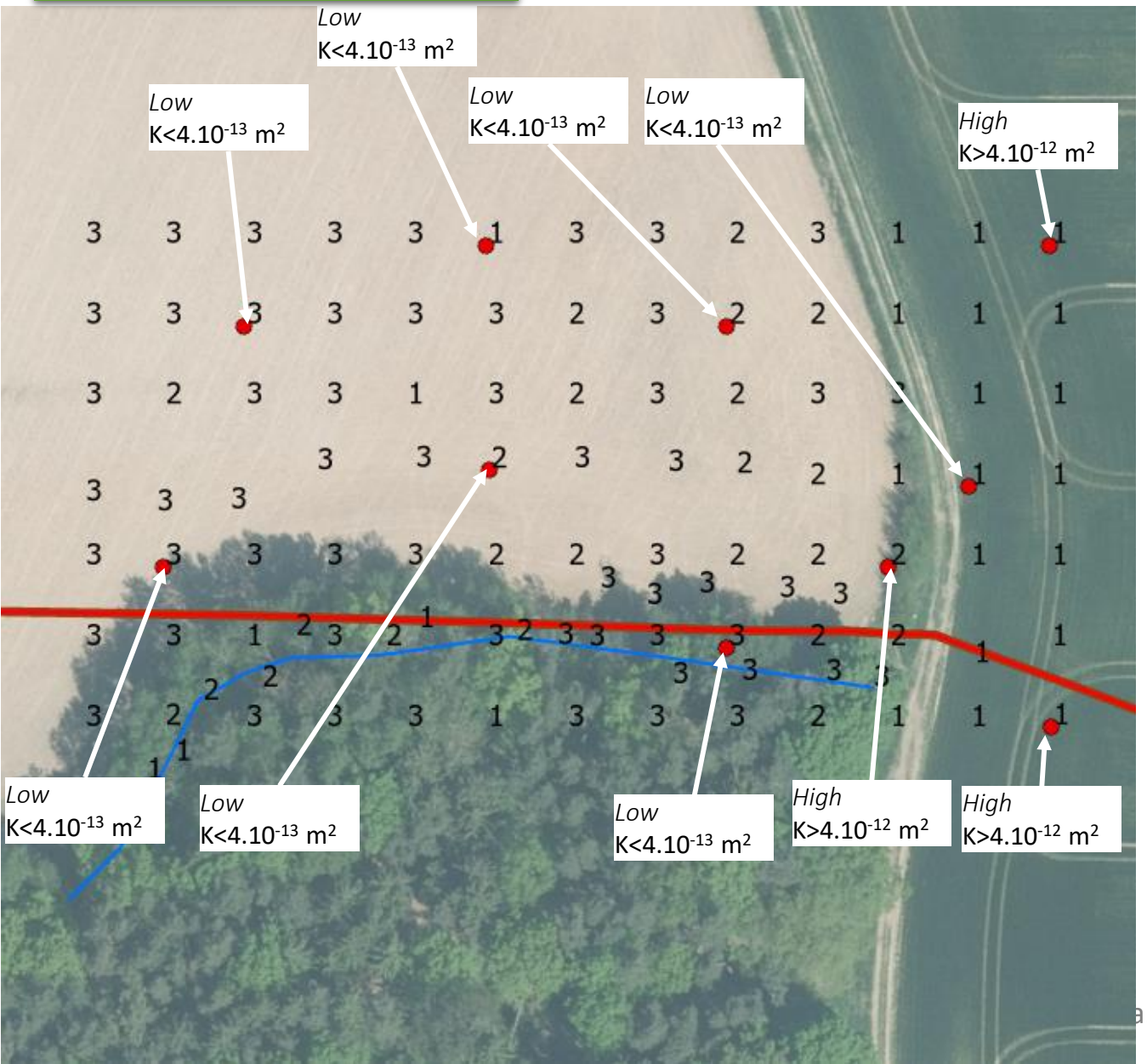
Location "South Bohemia"

Bedrock: biotitic gneiss, strongly weathered in the upper parts

Hydrogeology:

- Fracture aquifer of bedrock with groundwater depth approx. 30 m below ground level
- Quaternary cover represents an overlying insulator
- Local shallow and discontinuous subsurface aquifers with depth 2.6–0.7 m below ground level

Location "South Bohemia"



Soil profile characterisation:

- Agriculture soil
- 0 – 1 m sandy and clay loam

Dominant soil gas permeability:

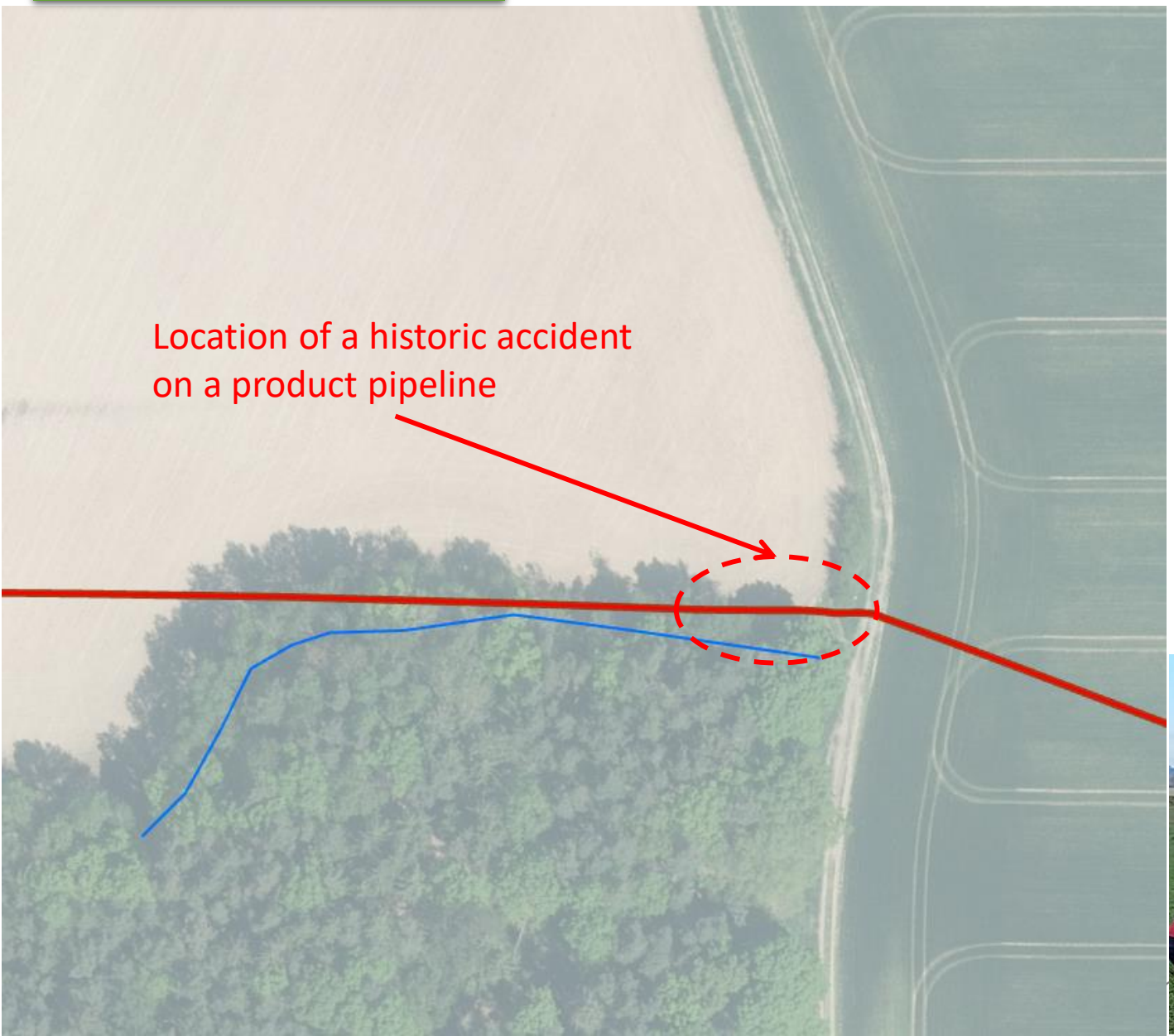
- Subjectively during sampling (80 cm): Low

3=Low $K<4.10^{-13}$ m² *2=Medium* *1=High* $K>4.10^{-12}$ m²

- Measured K by JOK apparatus:

10 points

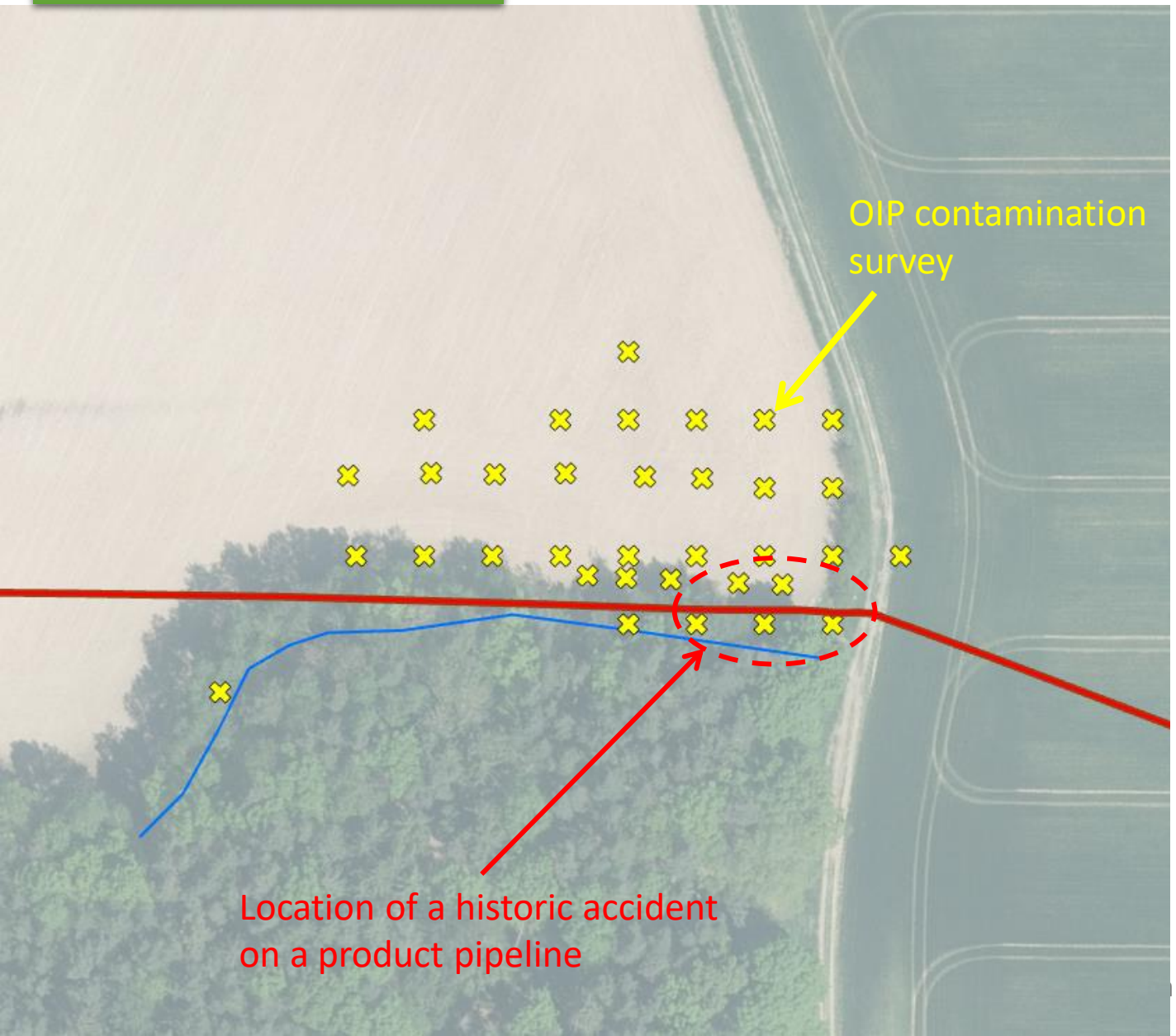
Location "South Bohemia"



Contamination data:

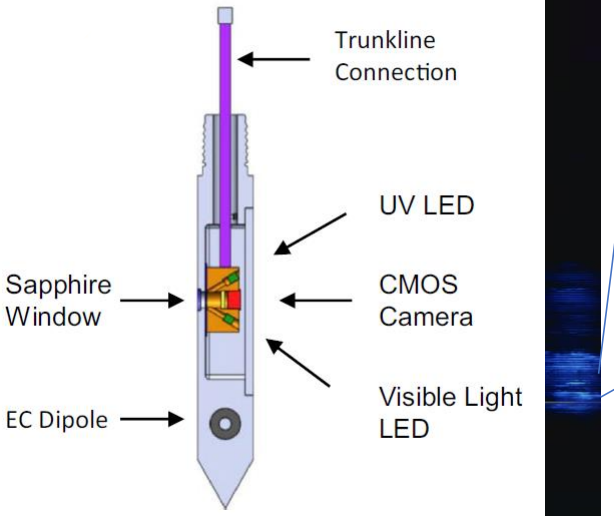
- Source of contamination: historical accident on the pipeline before 1990 with fuel leakage (gasoline and diesel) into the subsoil
- Type of contamination:
  n-alkanes in the range C10-C30, corresponding to Diesel
- Max contamination in soil: C10-C40 8000 mg/kg
- measured phase thickness at the groundwater level:
  just a thin layer of oil **(2025)**

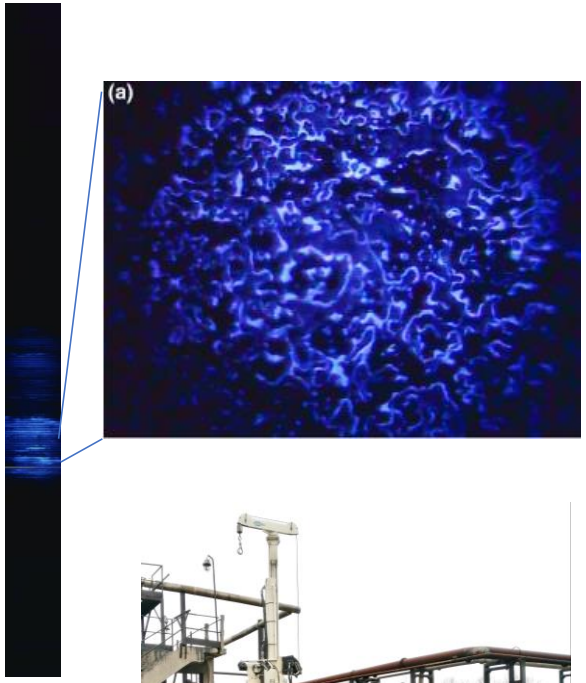
Location "South Bohemia"

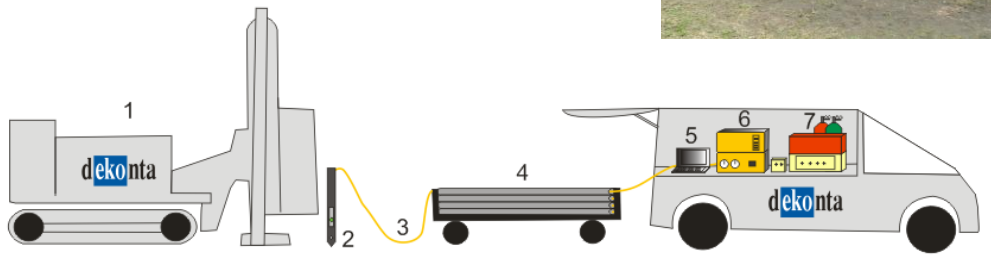


Contamination data:

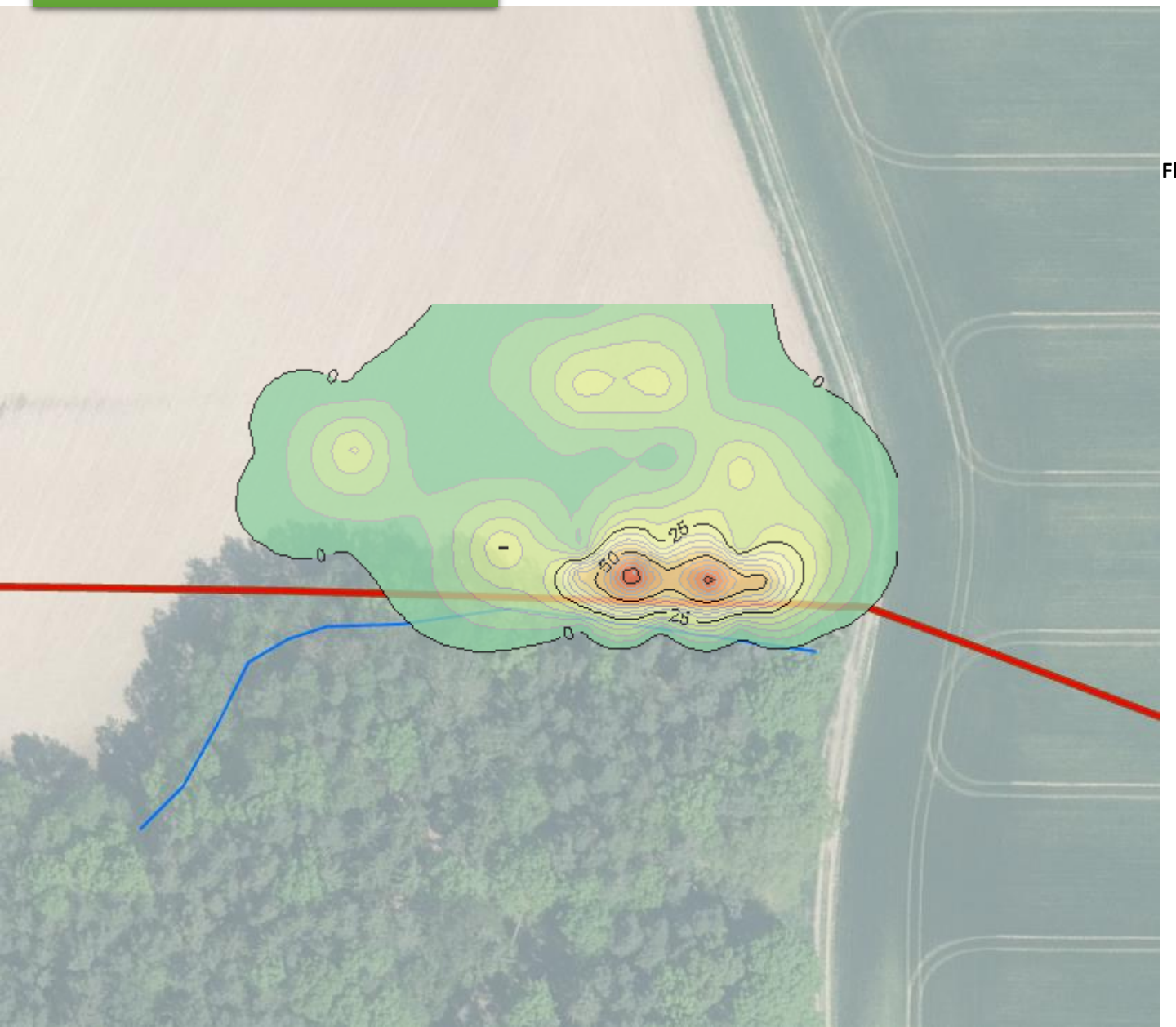
- Contamination survey using OIP (Optical Image Profiler)

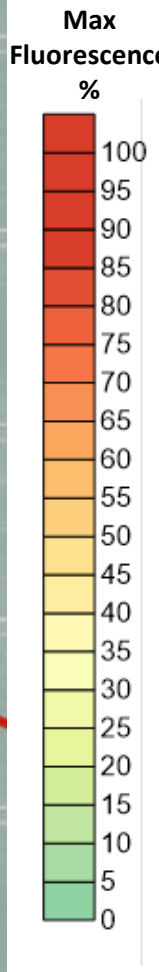






Location "South Bohemia"





Contamination data:

- Contamination survey using OIP (Optical Image Profiler)

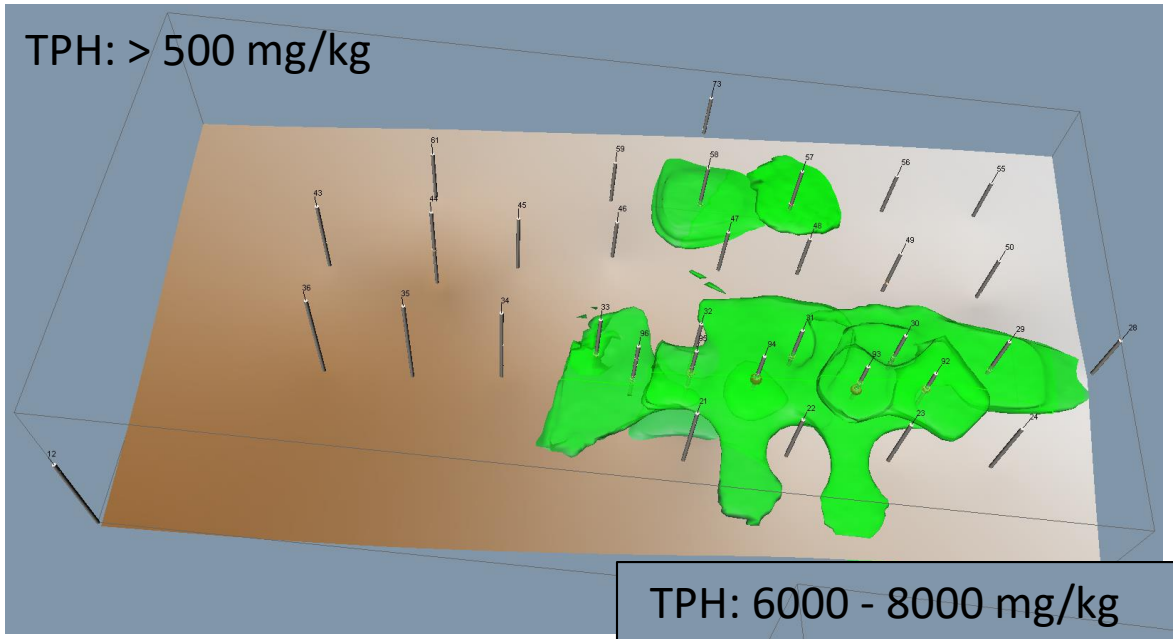
- **Estimated contaminated area: 400-800 m2**
- **Estimated volume of oil product: 400 - 1000 L (max)**
- **Estimated volume of contaminated soil: 800 m3 (max)**

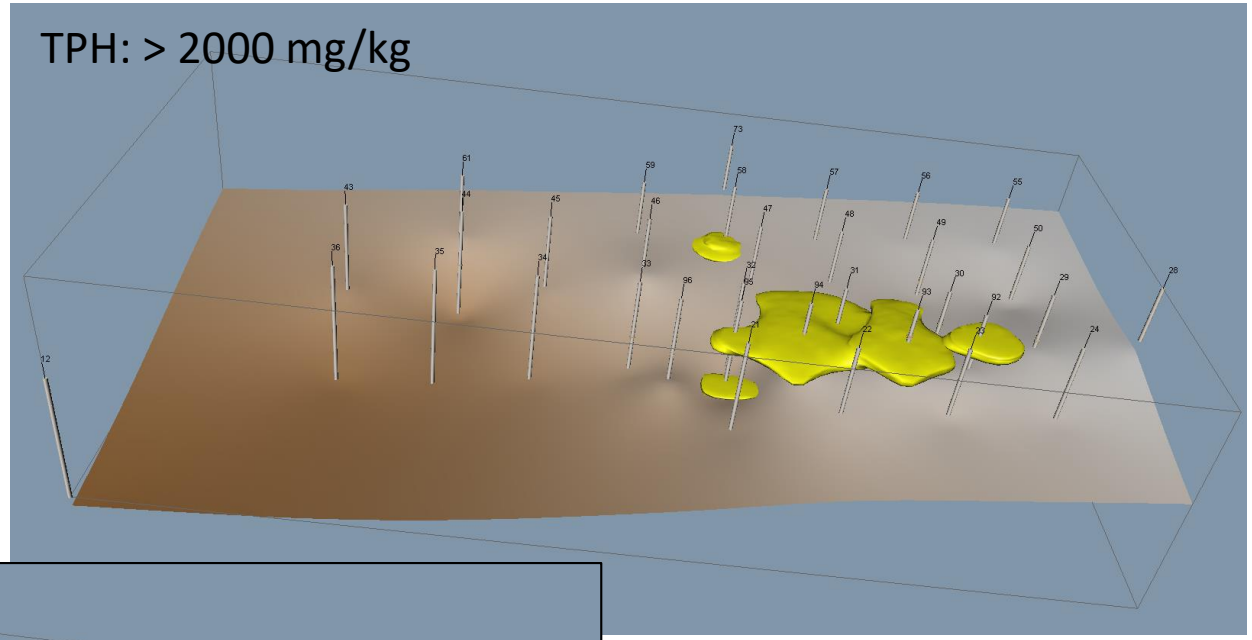
- Extent and spread of contamination:
  Oil product fixed to less permeable soil and local shallow aquifer, non-mobile

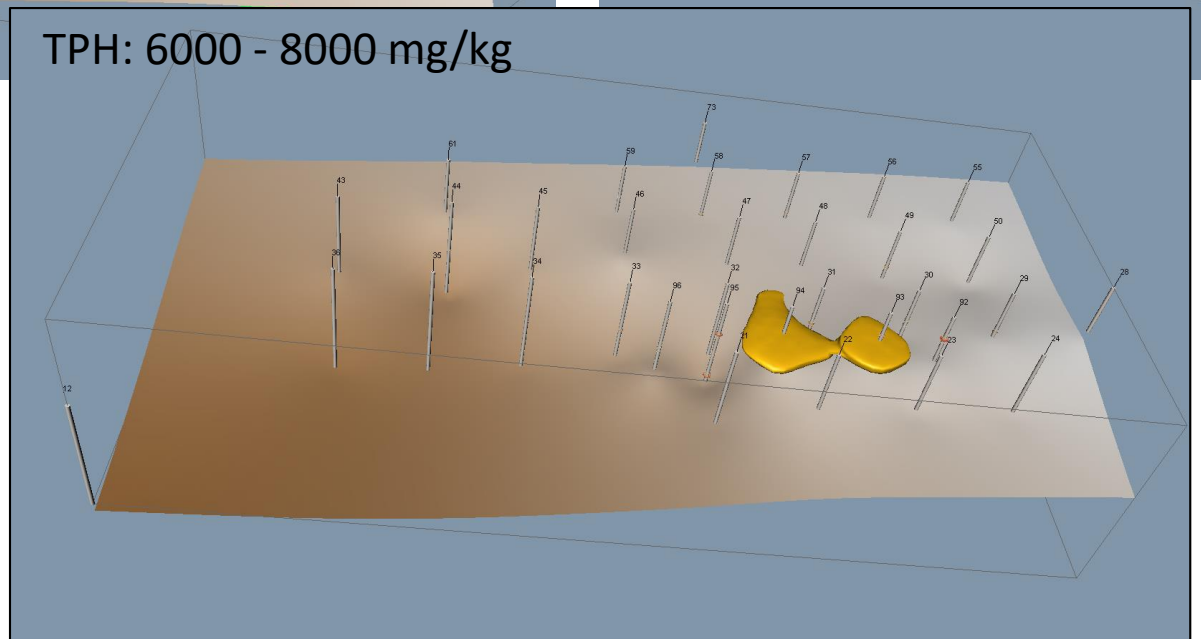
Location "South Bohemia"

Contamination data:

- Contamination survey using OIP (Optical Image Profiler)







Location "South Bohemia"

87/25 sampling points

Methodology of Radon measuring:

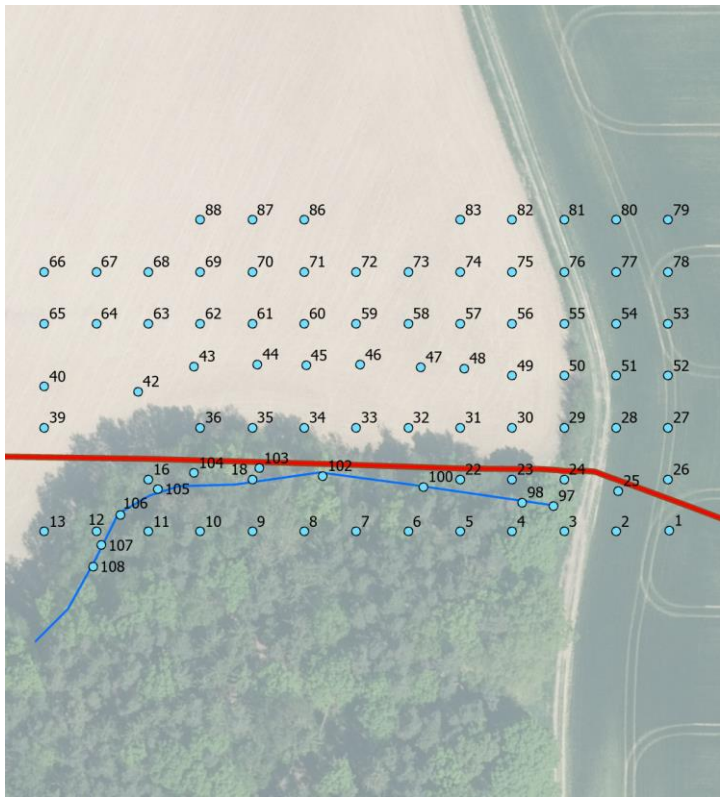
- 2 campaigns: 10/2024 and 11/2024
- Soil gas sampling in 50-80 cm and 30 cm depth
- Volumetric activity of Rn-222 (Bq/m3)
- RM-2 device with ionization chamber
- 87 and 25 sampling points, 10 x 10 m grid
- Outdoor temperature: 10°C and 5°C

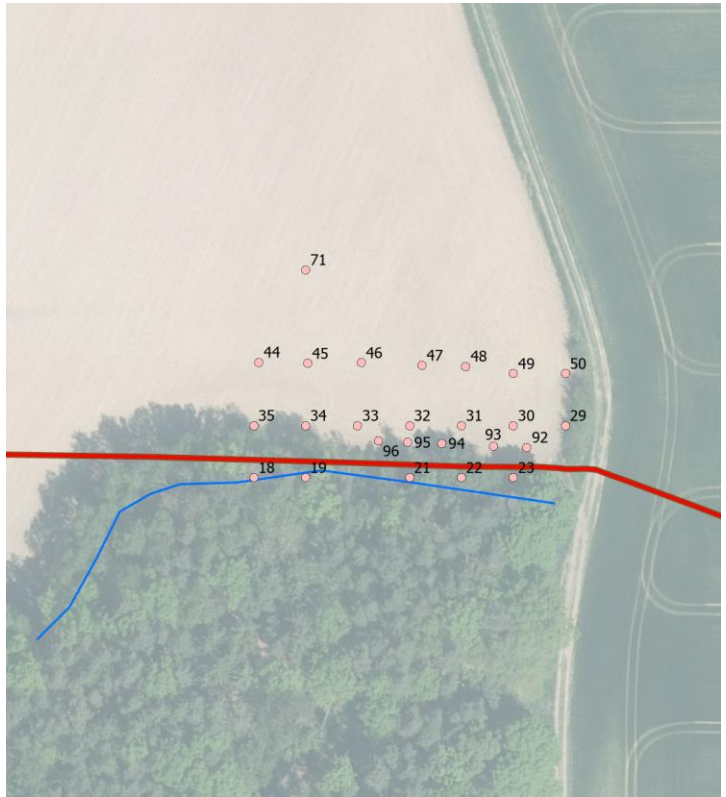
Average activity

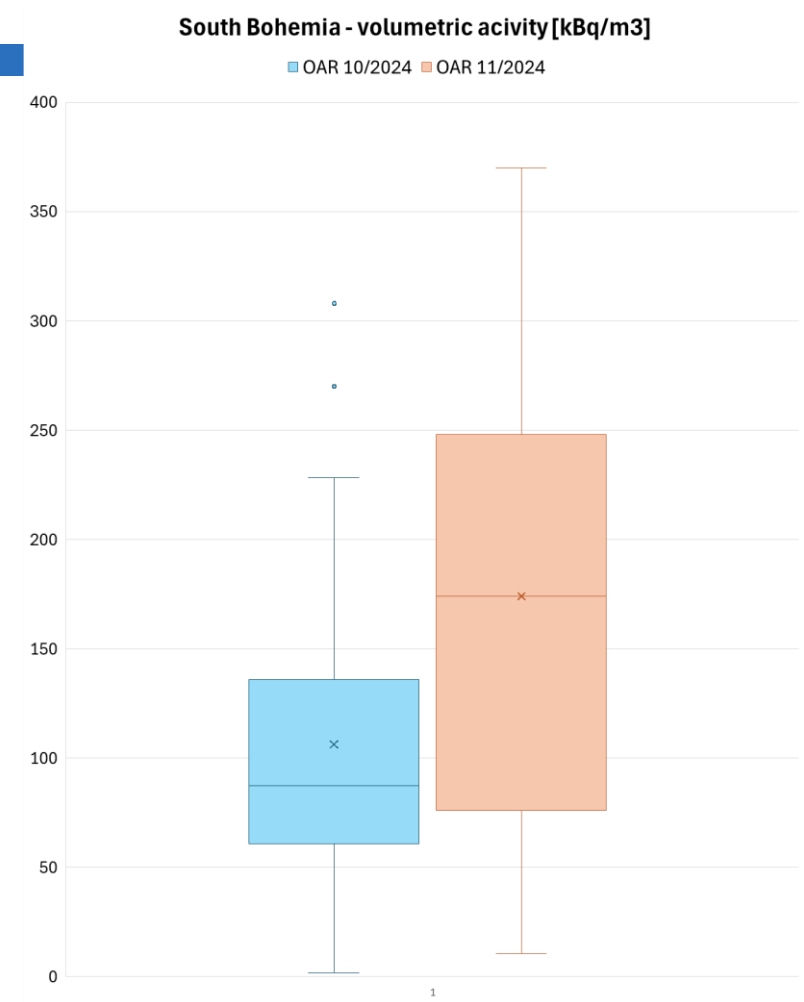
103 x 174 kBq/m3

Coef. of variation

63% x 60%



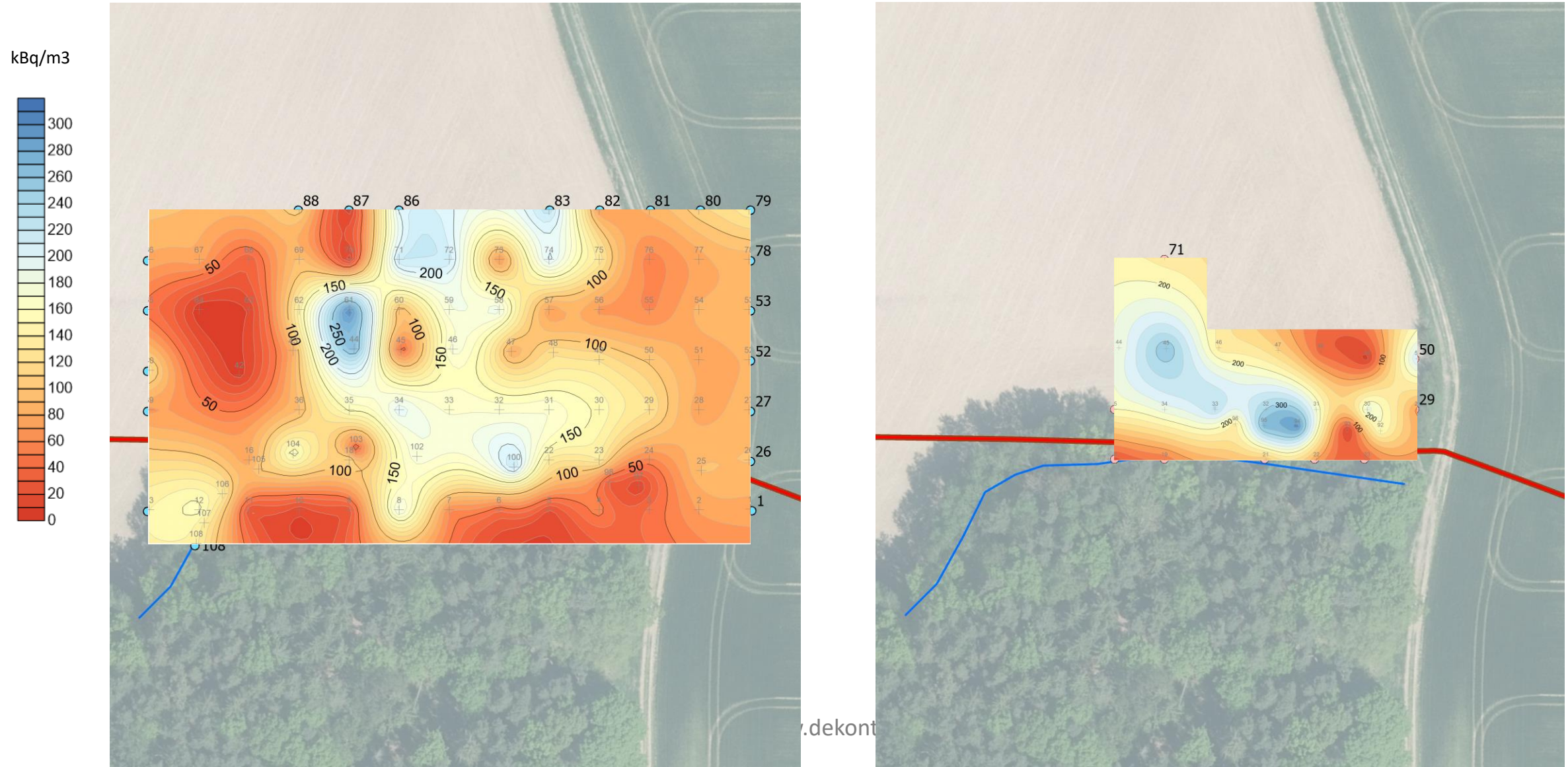




Location "South Bohemia"

Radon measuring - Results

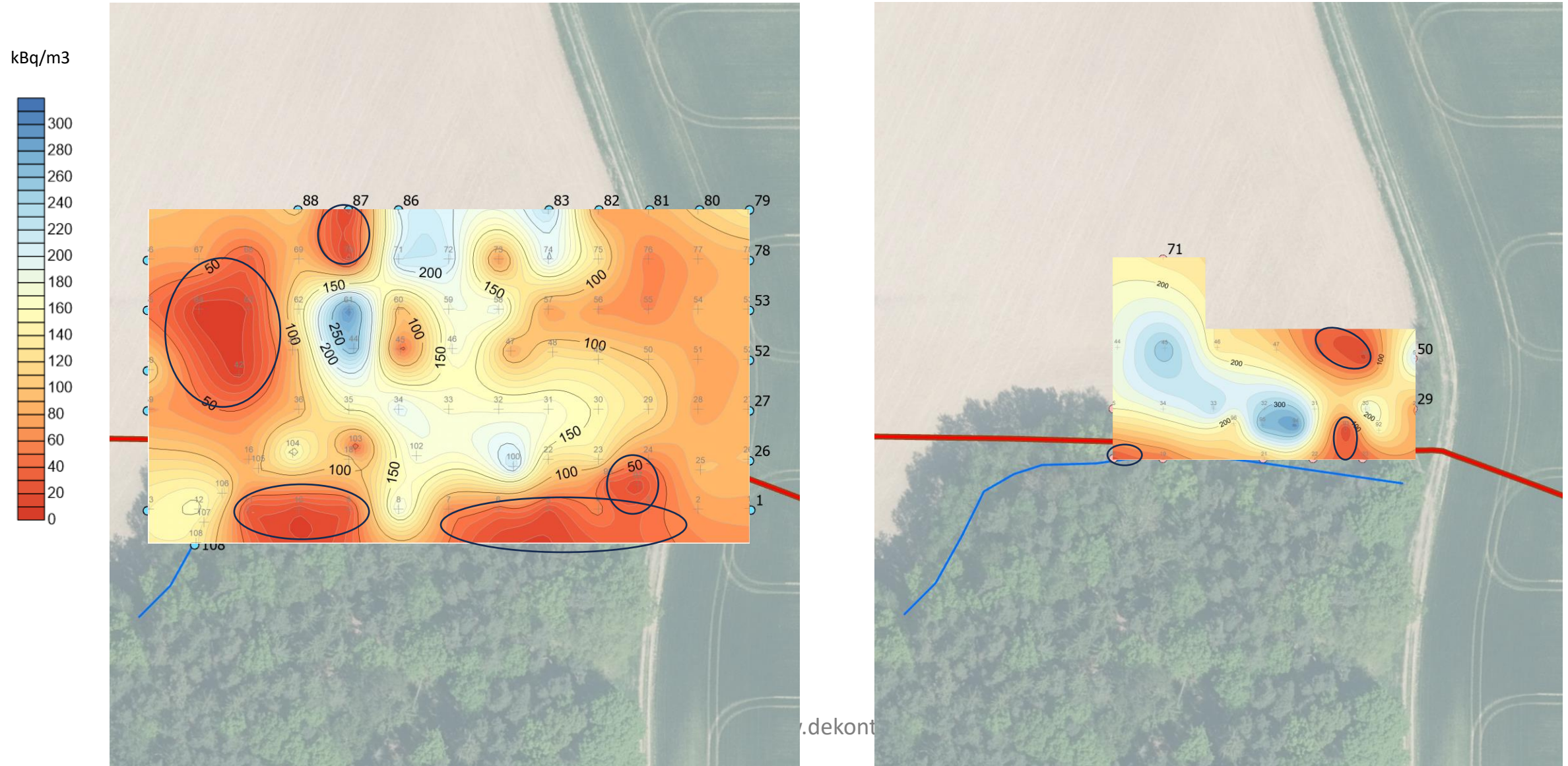
10/2024 and 11/2024



Location "South Bohemia"

Radon measuring - Results

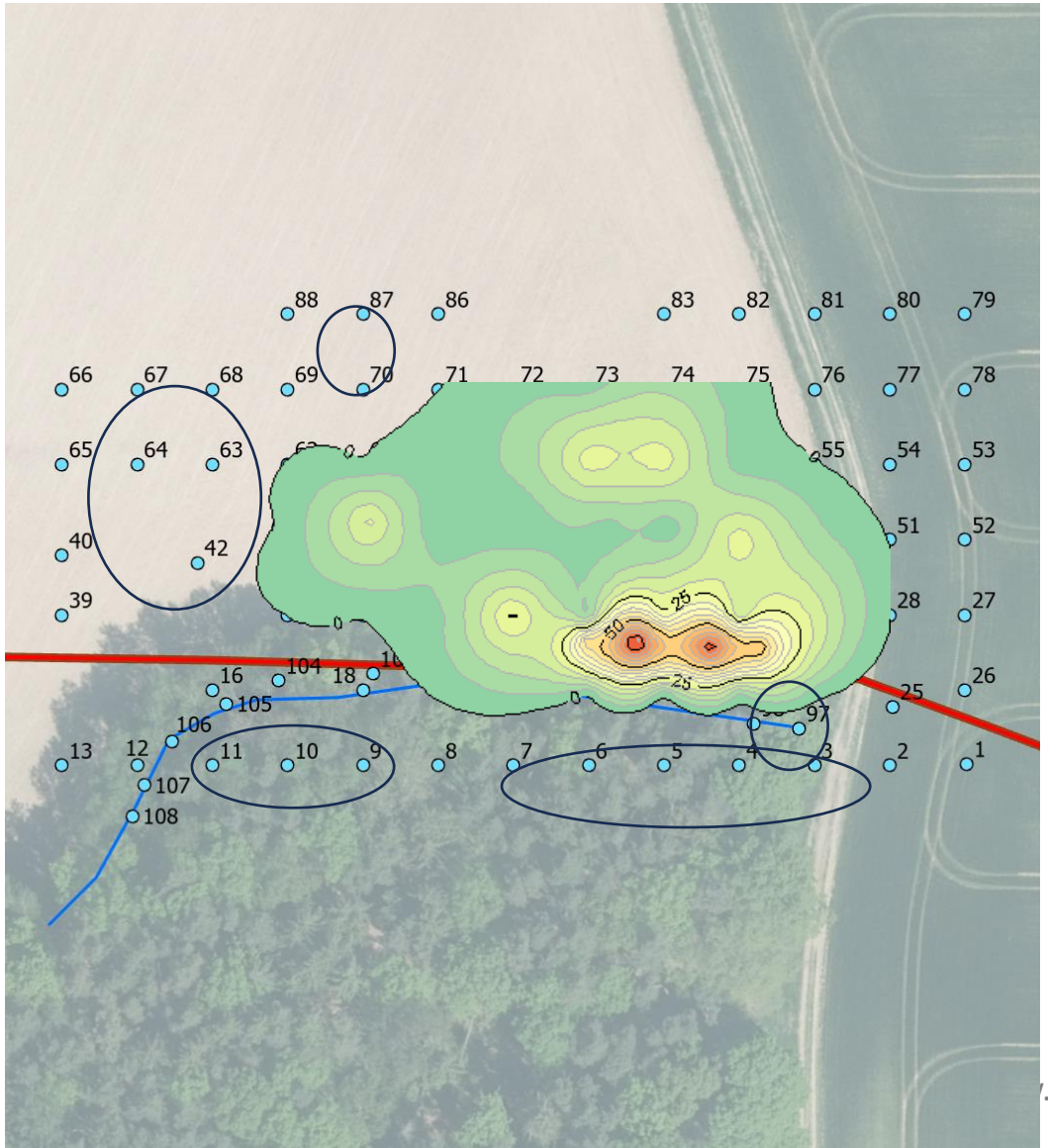
10/2024 and 11/2024

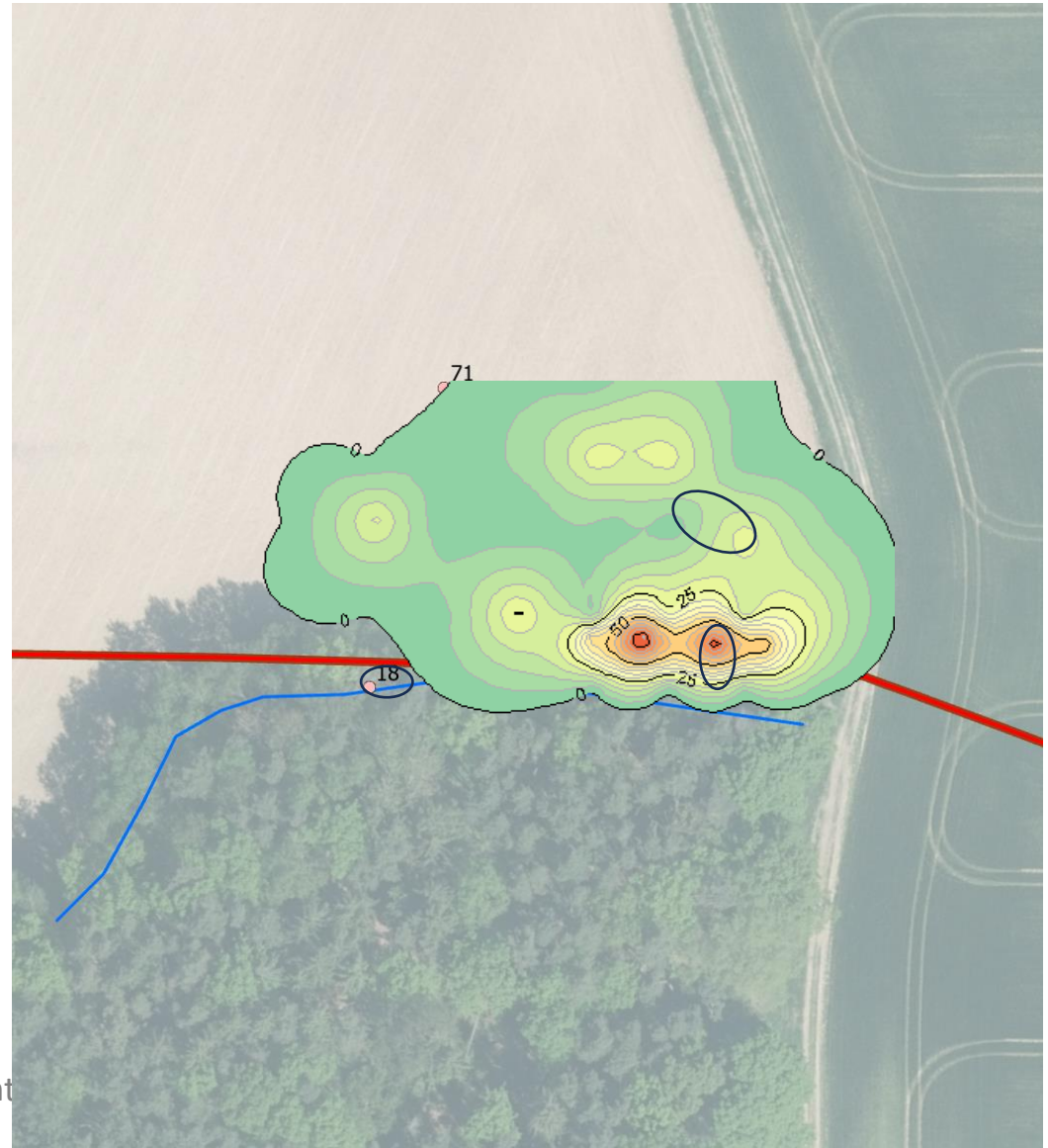


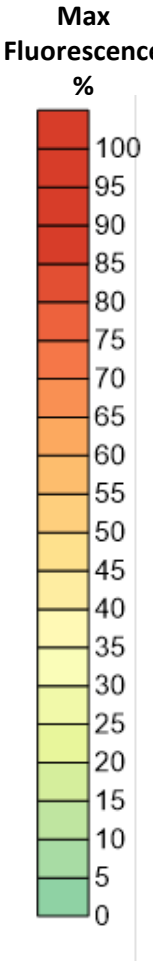
Location "South Bohemia"

Radon measuring - Results

10/2024 and 11/2024







Conclusion

Site	Radon index	No. of measured points	Average activity [kBq/m3]	Coef. of variation (%)	Quaternary thickness (m)	Bedrock	Dominant soil gas permeability	GW depth m b.t.	Radon measurement depth m b.t.	TPH type	Max. oil product thickness
Vamberk 03/2025	Low	40	37,9	76	1-3	marlite	High	2-3	0.8	Mineral oil	1 m
Vamberk 05/2025	Low	40	20,9	53	1-3	marlite	High	2-3	0.5	Mineral oil	1 m
Jaroměř 12/2024	Low	17	35,4	72	2-3	siltstone	High	2-6	0,8	Mixture of benzine and light heating oil	2 mm
Jaroměř 06/2025	Low	20	22,2	78	2-3	siltstone	High	2-6	0,5	Mixture of benzine and light heating oil	2 mm
South Bohemia 10/2024	Medium /High	87	103	63	2,5-5	biotitic gneiss	Low	0,7-2,6	0,5-0,8	Diesel type	Oil film limited in area
South Bohemia 11/2024	Medium /High	25	174	60	2,5-5	biotitic gneiss	Low	0,7-2,6	0,3	Diesel type	Oil film limited in area

Thank you for your attention!

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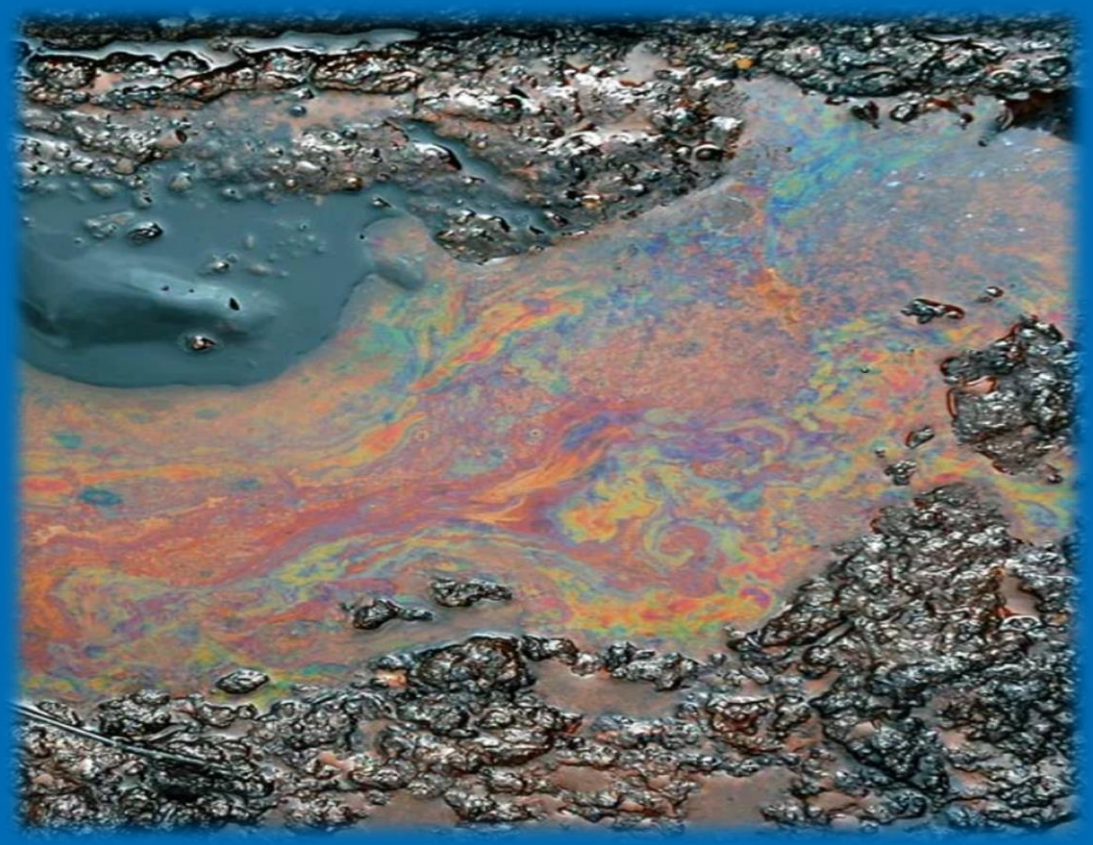

DEKONTA, a. s.
Volutová 2523
158 00 Prague 5
Czech Republic

www.dekonta.com

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