



***Innovative Soil Remediation Solutions
Appropriate remediation strategies***

**Beyond pump & treat: Aggressive in situ
remediation of a historical chlorinated solvent
source zone using Groundwater Circulation
Wells (GCWs) at Bussi sul Tirino, Italy**

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Barcelona, Spain** | **Innovative Soil
Remediation Solutions
& PFAS Challenges**

Formation :
Colloque reconnu
par le SPW ARNE
Wallonie
environnement
SPW



Technologies for Reliable and Innovative REMEdiation

Trireme is an innovative
environmental consulting
start-up specialized in
technologies and services
for the remediation of
contaminated sites



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CONSULTING SERVICES

- Site Characterization Plan
- 3D Conceptual Site Models
- Remediation Potential Assessment
- Screening of Remediation Strategies



REMEDIATION DESIGN

- Multidisciplinary Site Characterization
- Microcosm Studies
- Pilot-Scale and Full-Scale System Scale-Up



PROCESS & TECHNOLOGY DEVELOPMENT

- Integrated Physicochemical and Biological Processes
- Biostimulation
- Bioaugmentation



MONITORING & PERFORMANCE ASSESSMENT

- Chemical Analyses
- Biomolecular Analyses

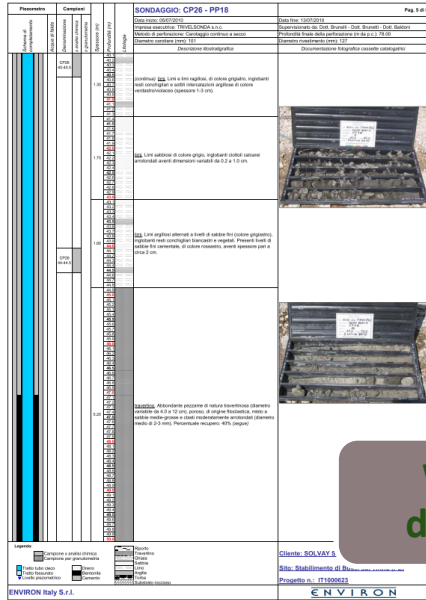
The case study (Bussi sul Tirino)



The case study

- **Bussi sul Tirino** (one of the 42 Italian National Priority Site)
- **Over 120 years of industrial history.** In 1902, Italy's first sodium chloride electrolysis plant began operating, producing caustic soda, sodium hypochlorite and hydrochloric acid.
- From **1905**, when carbon tetrachloride production began, until **2007**, the site produced various chlorinated solvents, including trichloroethylene, dichloroethane and chloromethanes.



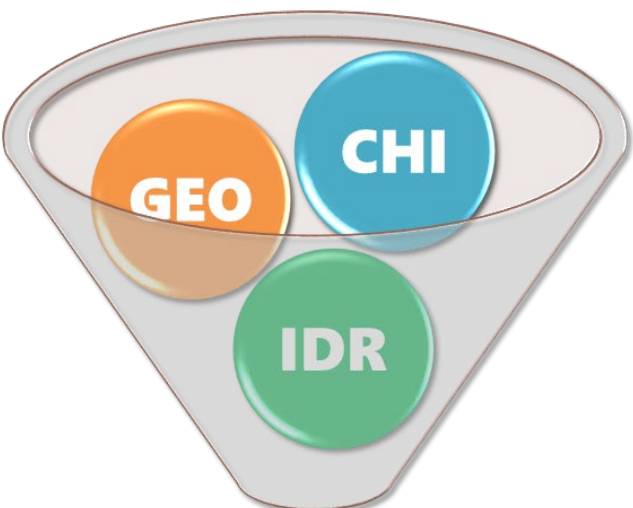


Geological boreholes

Piezometric levels

Piezometro	Qc [m s.l.m.]	Qc [m s.l.m.]	Soggezione da b.p. [m]	Livello piezometrico [m s.l.m.]	Troito fenestrato [m]	Complesso intercellato
A	239.05	239.27	4.29	234.98	40-60	DC-SC
A'	239.09	239.29	1.76	237.53	3-7	DF
B	240.30	240.45	5.49	234.96	24-80	DT-DC
B'	240.26	240.30	5.39	234.91	8-20	DT
C	237.04	237.34	5.73	231.61	51-61	DC
C'	237.17	237.18	3.44	233.74	6-12	DT
D	237.65	237.89	6.45	231.44	52-80	DC
D'	237.64	237.87	6.41	231.46	4.6-20	DT
E	237.85	238.10	0.22	237.88	39-60	DC
E'	237.80	237.93	0.97	236.96	3-12	DF-DP
F	237.45	237.77	4.97	232.80	49-60	DC
F'	237.45	237.52	3.95	233.57	6-20	DT
G	240.59	241.10	6.1	235.00	65-80	SC
			7.02	234.91	30-60	DT-DC-SC
			11.3	231.73	24-40	DT
			6.06	235.01	6-9	DF
			8.85	233.18	10-12	DP
			-	-	3-12	DP
			7.25	233.50	60-80	DC
			9.11	231.46	8-20	DT-DC
P	238.99	239.13	7.7	231.43	60-80	DC
P'	238.97	239.13	7.65	231.48	10-20	DT

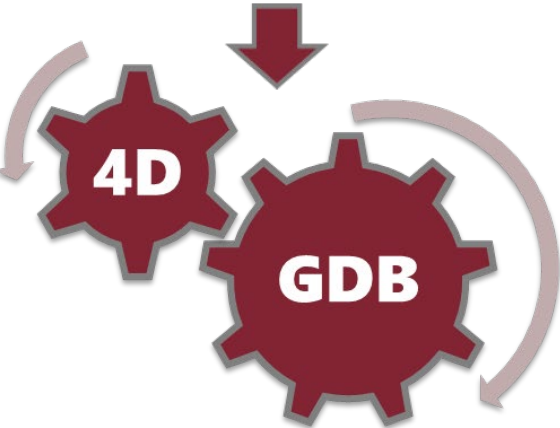
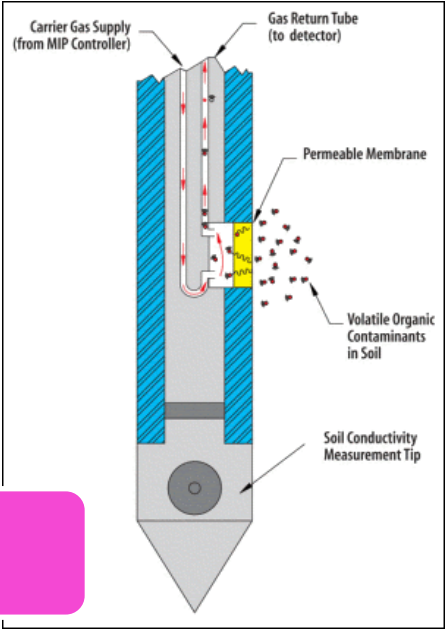
Well design



ID	Area	Data	Composto	Origine	Concentrazione	LL	LL	Eccedenza	1 - Conformità
2	P50	Est Sito - ex Area Medavox	01/03/19 pH in situ (U pH)	Ramboli	11.80 N.D.	N.D.			0
3	P73	Est Sito - ex Area Medavox	01/03/19 pH in situ (U pH)	Ramboli	10.26 N.D.	N.D.			0
4	P40	Barriera DX Tirino	01/03/19 pH in situ (U pH)	Ramboli	11.5 N.D.	N.D.			0
5	W06	Barriera DX Tirino	01/03/19 pH in situ (U pH)	Ramboli	10.48 N.D.	N.D.			0
6	W70	Barriera DX Tirino	01/03/19 pH in situ (U pH)	Ramboli	7.95 N.D.	N.D.			0
7	P74	Barriera DX Tirino	01/03/19 pH in situ (U pH)	Ramboli	7.38 N.D.	N.D.			0
8	E8	Barriera DX Tirino	01/03/19 pH in situ (U pH)	Ramboli	7.51 N.D.	N.D.			0
9	P62	Aree esterne	01/03/19 pH in situ (U pH)	Ramboli	7.63 N.D.	N.D.			0
10	P41	Aree esterne	01/03/19 pH in situ (U pH)	Ramboli	7.06 N.D.	N.D.			0
11	P23	Aree esterne	01/03/19 pH in situ (U pH)	Ramboli	7.53 N.D.	N.D.			0
12	P55	Barriera SX Tirino	01/03/19 pH in situ (U pH)	Ramboli	7.47 N.D.	N.D.			0
13	W71	Barriera SX Tirino	01/03/19 pH in situ (U pH)	Ramboli	7.68 N.D.	N.D.			0
14	W82	Barriera SX Tirino	01/03/19 pH in situ (U pH)	Ramboli	7.7 N.D.	N.D.			0
15	W83	Barriera SX Tirino	01/03/19 pH in situ (U pH)	Ramboli	7.21 N.D.	N.D.			0
16	P40	Est Sito - ex Area Medavox	01/03/19 Mercurio (µg/l) MAX=1	Ramboli	34.8	1	1		0
17	P73	Est Sito - ex Area Medavox	01/03/19 Mercurio (µg/l) MAX=1	Ramboli	0.67	1	1		0
18	P40	Barriera DX Tirino	01/03/19 Mercurio (µg/l) MAX=1	Ramboli	2.18	1	1		1
19	W06	Barriera DX Tirino	01/03/19 Mercurio (µg/l) MAX=1	Ramboli	1.3	1	1		0
20	W70	Barriera DX Tirino	01/03/19 Mercurio (µg/l) MAX=1	Ramboli	<0.2	1	1		0
21	P74	Barriera DX Tirino	01/03/19 Mercurio (µg/l) MAX=1	Ramboli	<0.2	1	1		0
22	E8	Barriera DX Tirino	01/03/19 Mercurio (µg/l) MAX=1	Ramboli	<0.2	1	1		0
23	P62	Aree esterne	01/03/19 Mercurio (µg/l) MAX=1	Ramboli	<0.2	1	1		0
24	P41	Aree esterne	01/03/19 Mercurio (µg/l) MAX=1	Ramboli	<0.2	1	1		0
25	P23	Aree esterne	01/03/19 Mercurio (µg/l) MAX=1	Ramboli	<0.2	1	1		0
37	P62	Aree esterne	01/03/19 Benzene (µg/l) MAX=1	Ramboli	<0.05	1	1		0
38	P41	Aree esterne	01/03/19 Benzene (µg/l) MAX=1	Ramboli	<0.05	1	1		0

Chemical analyses (2003 -2022)

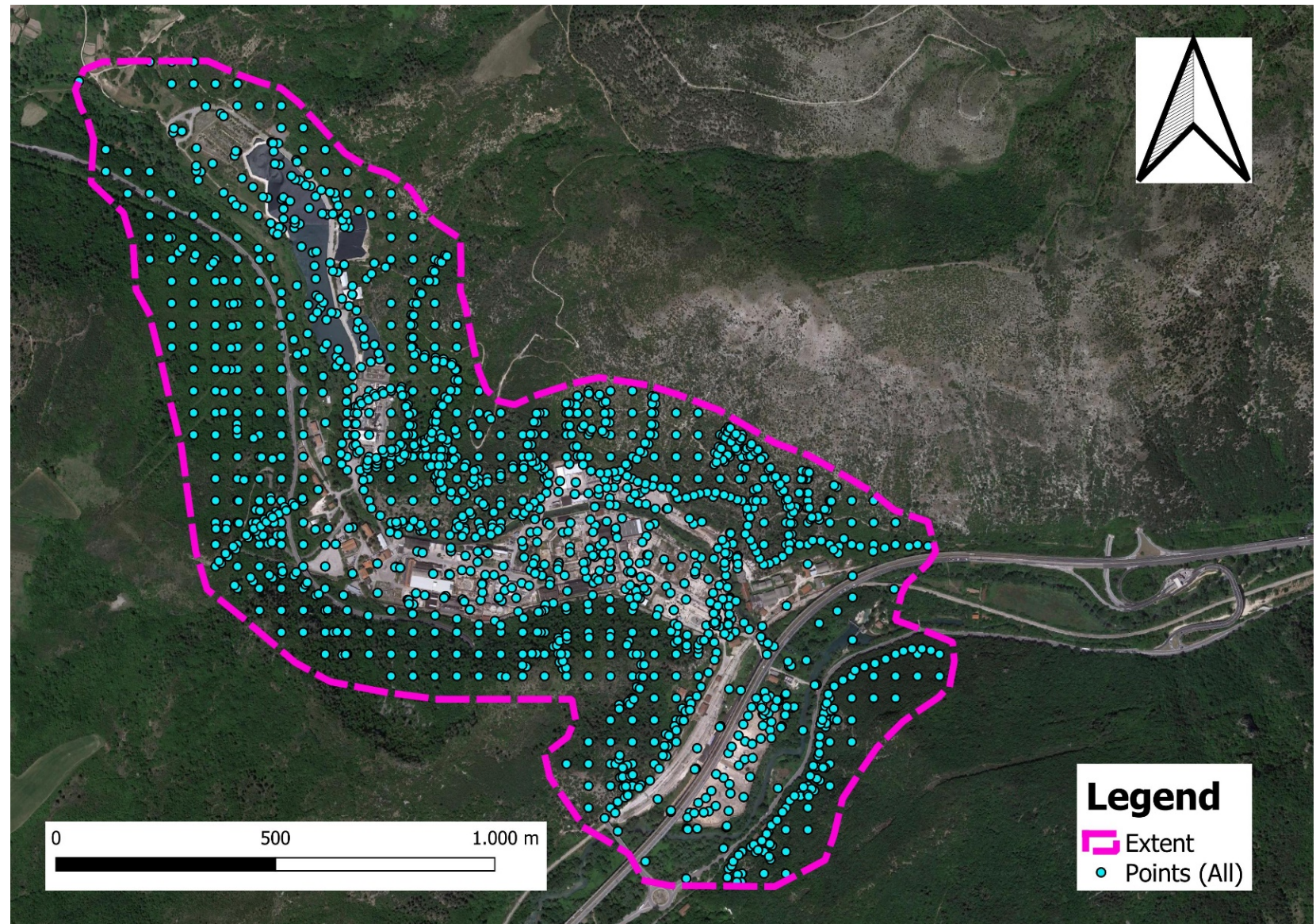
MIP



MULTI CRITERIA DECISION ANALYSIS TOOL

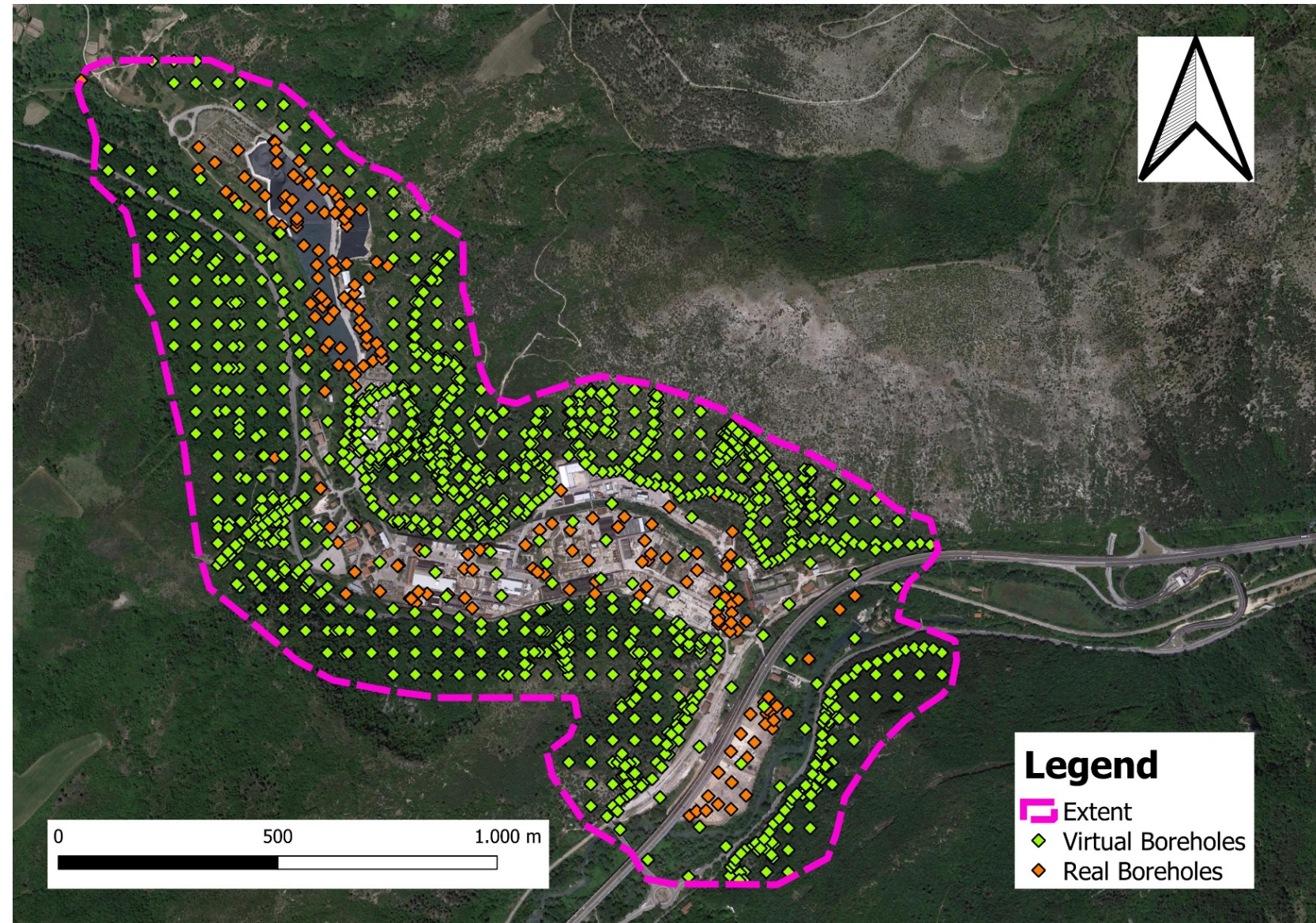
Total Area 1,77 km²

1578 Georeferenced points



186 Real Boreholes

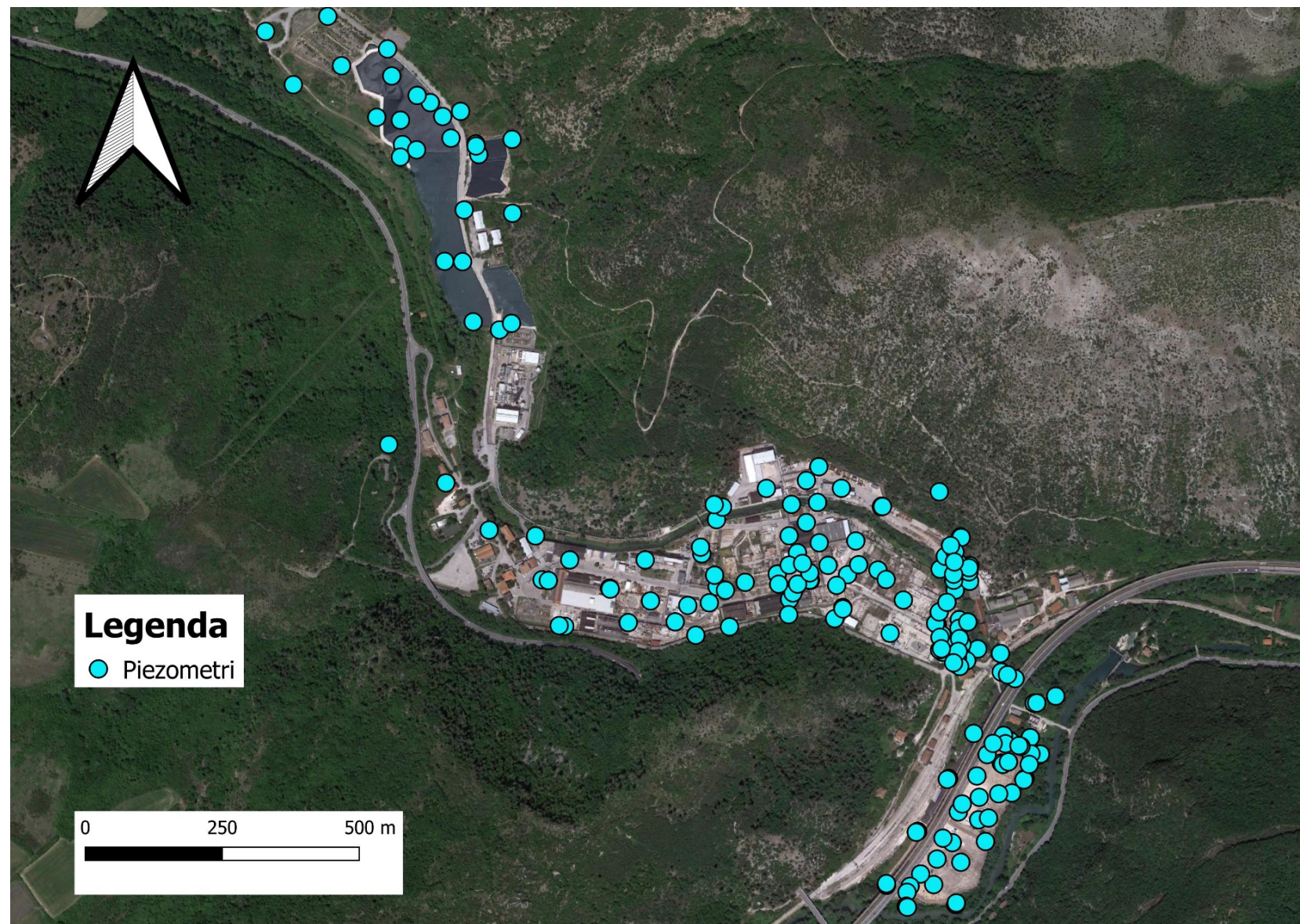
1277 Virtual Boreholes



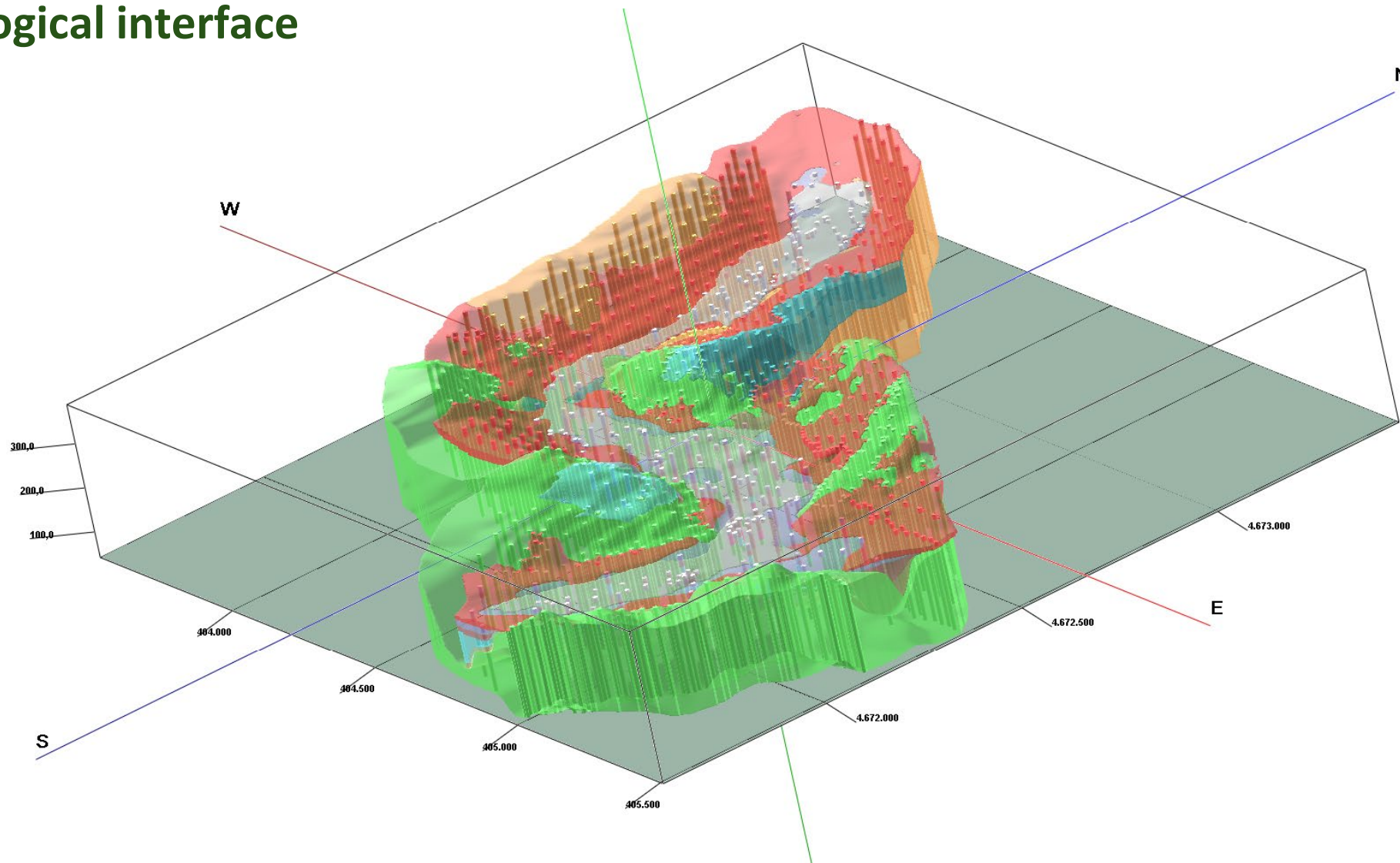
189 monitoring wells

chemistry OTT 03 – AGO 22

hydrology LUG 05 – DIC 21



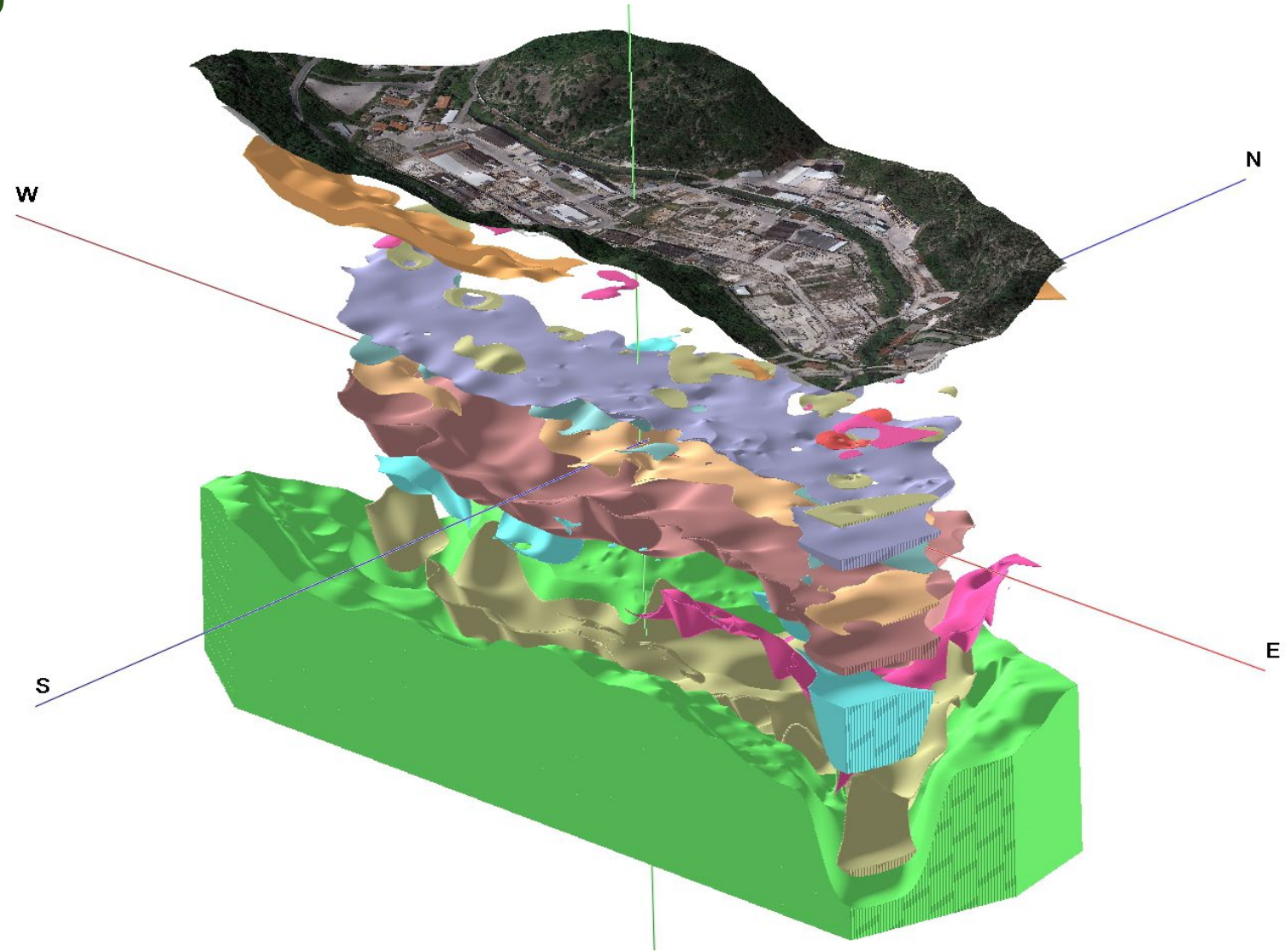
3D Full Scale Geological interface



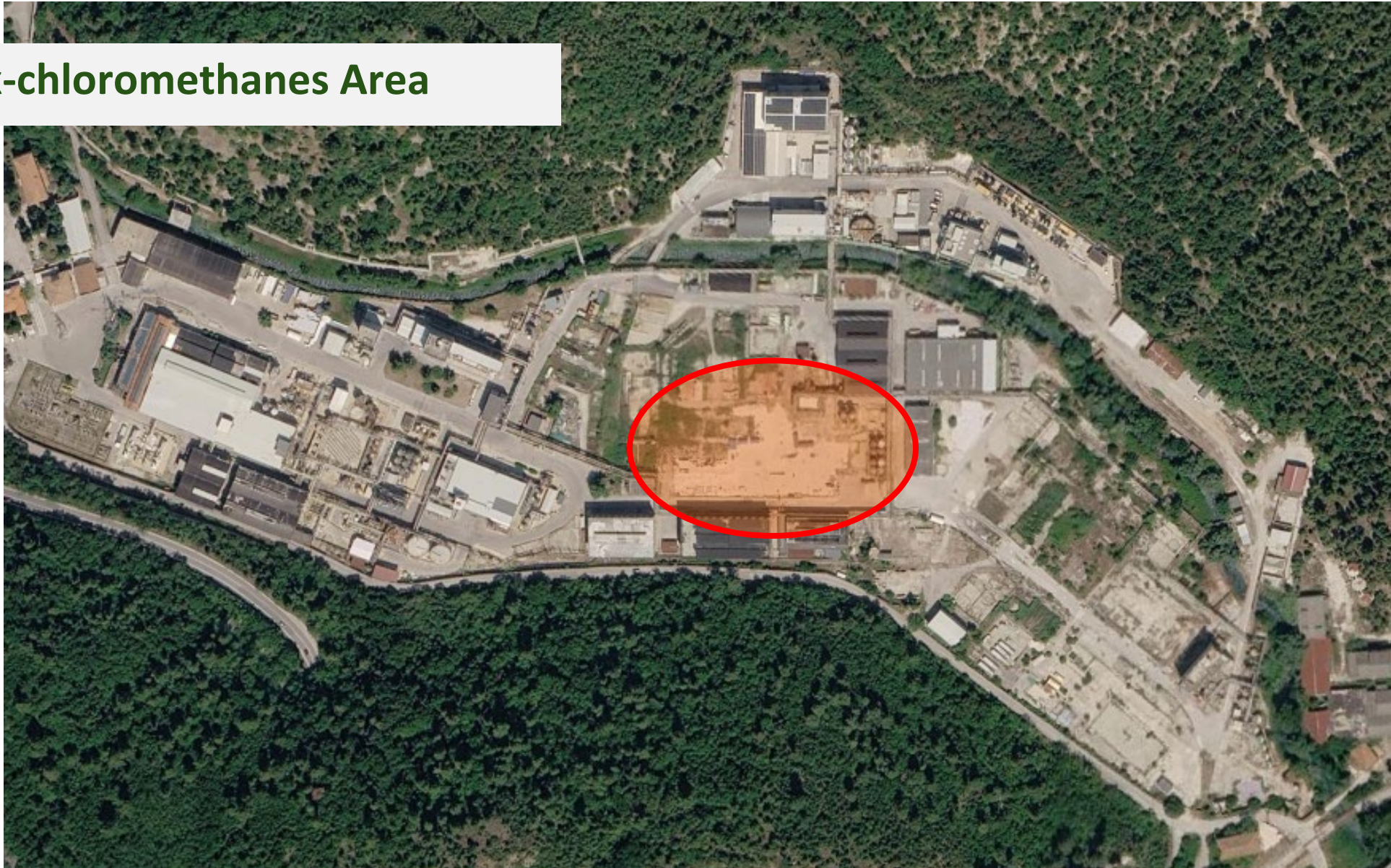
Post-Processing (geological CSM) 3D

Stratigraphy

-  Terreno Vegetale o Riporto
-  Materiale detritico recente
-  Rifiuto
-  Terre rosse
-  Limi con torbe
-  Alluvioni da grossolane a medio-fini
-  Limo argilloso
-  Sabbia limosa e limo sabbioso
-  Limi Bruni
-  Substrato roccioso Travertinoso
-  Detrito di Versante
-  Depositi alluvionali antichi medio-fini
-  Undefined alluvial deposits
-  Substrato roccioso calcareo

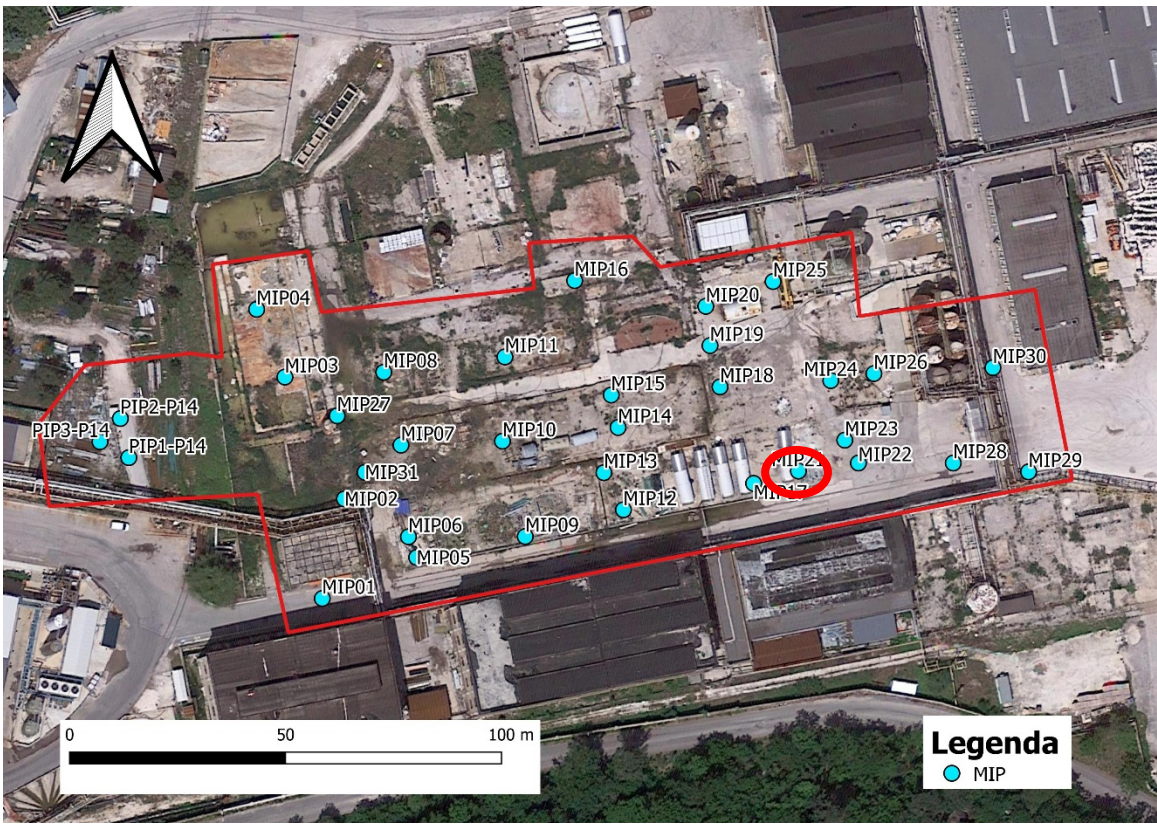


Ex-chloromethanes Area

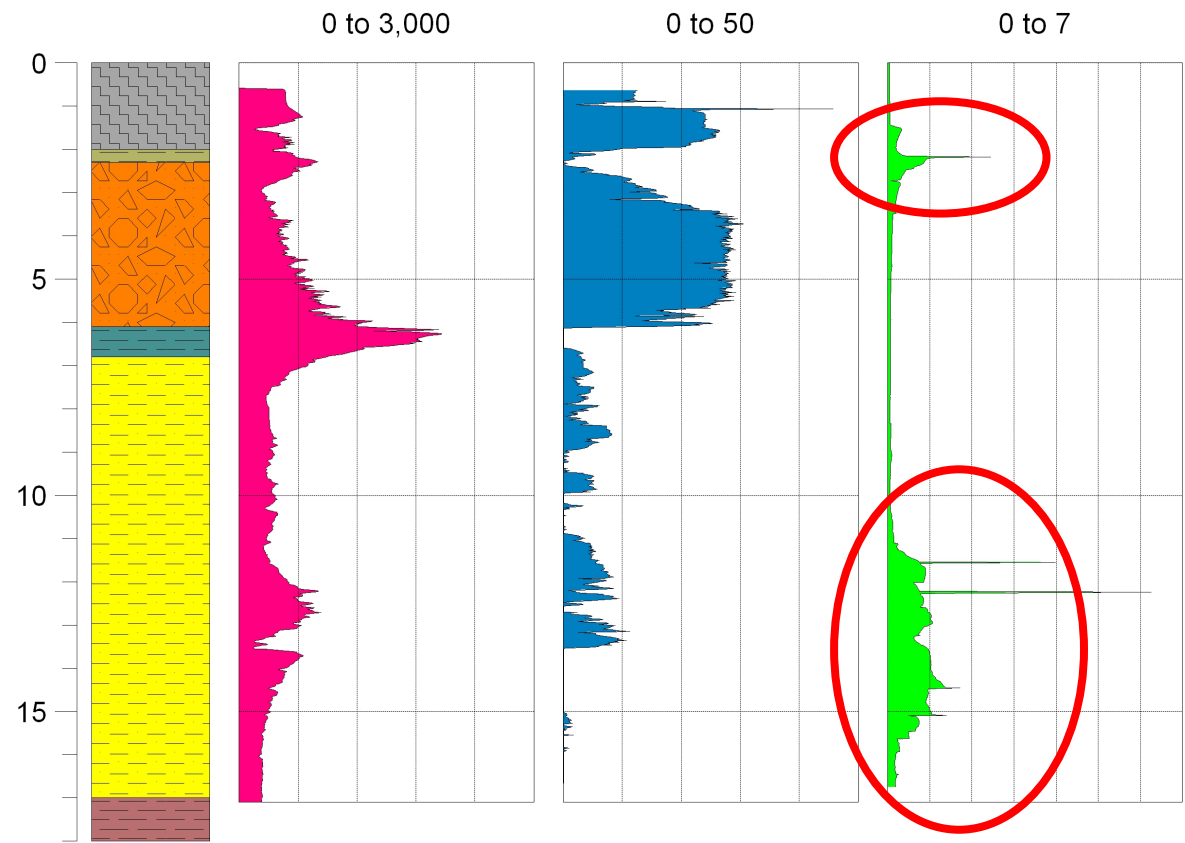




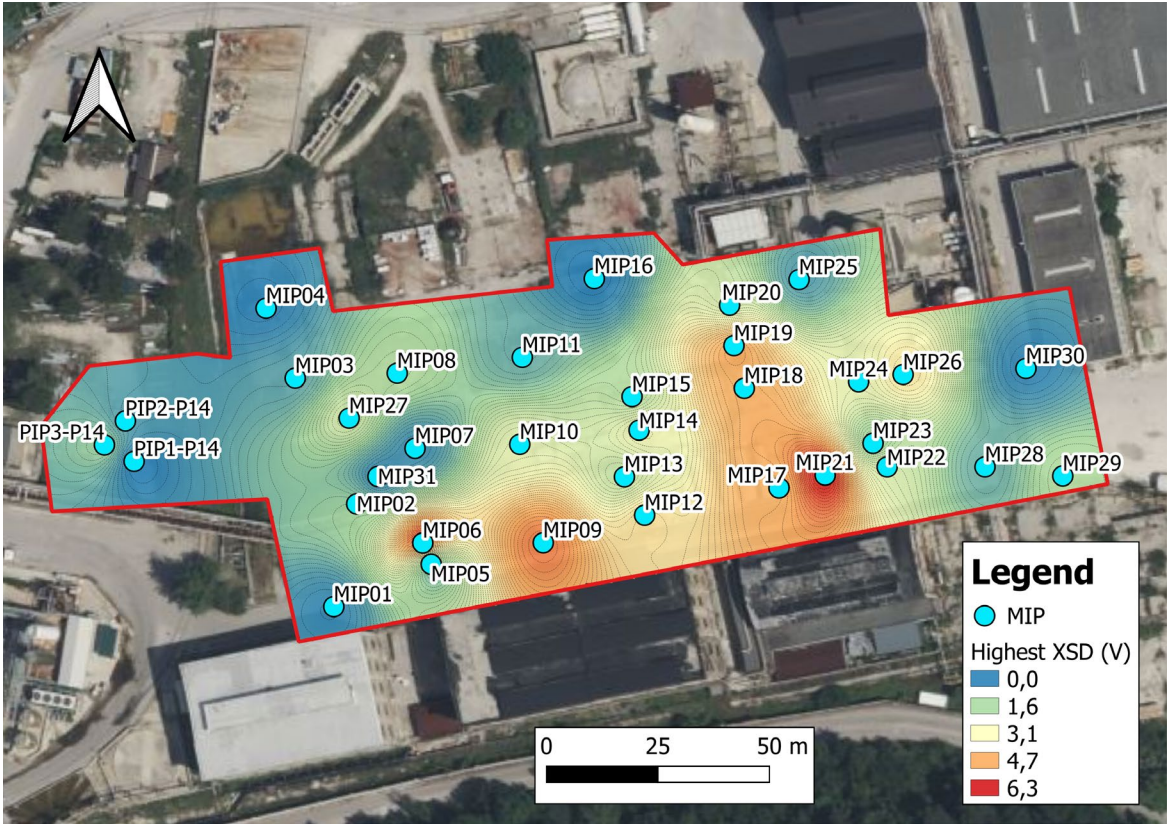
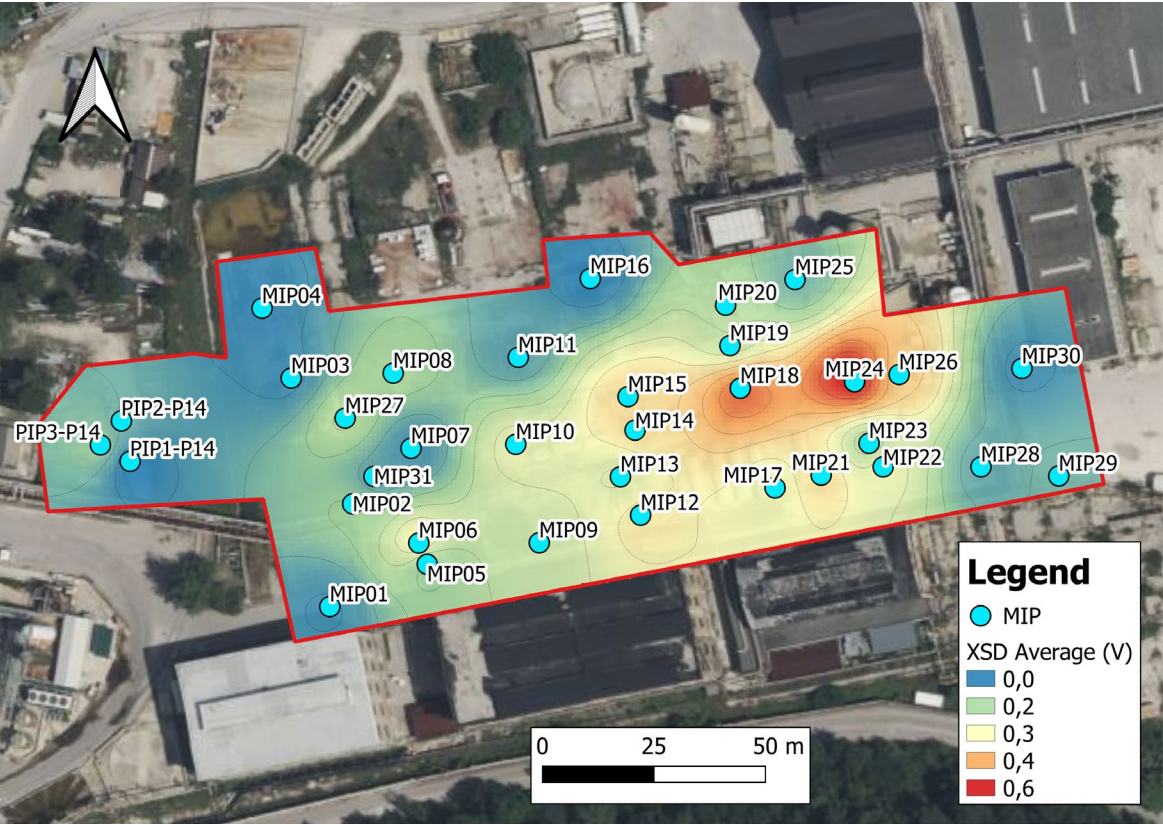
MIP Investigation (30 profiles)



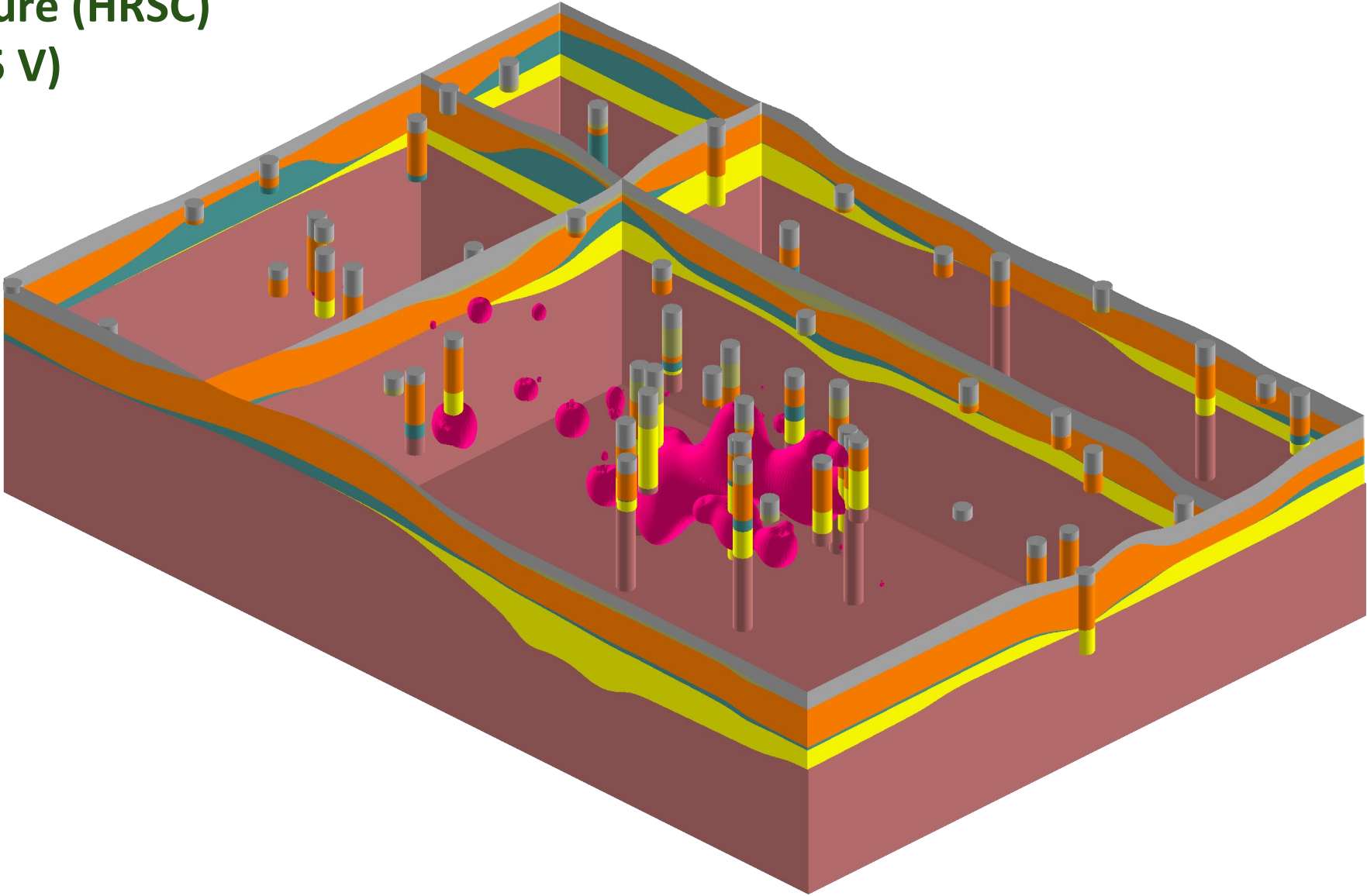
MIP21



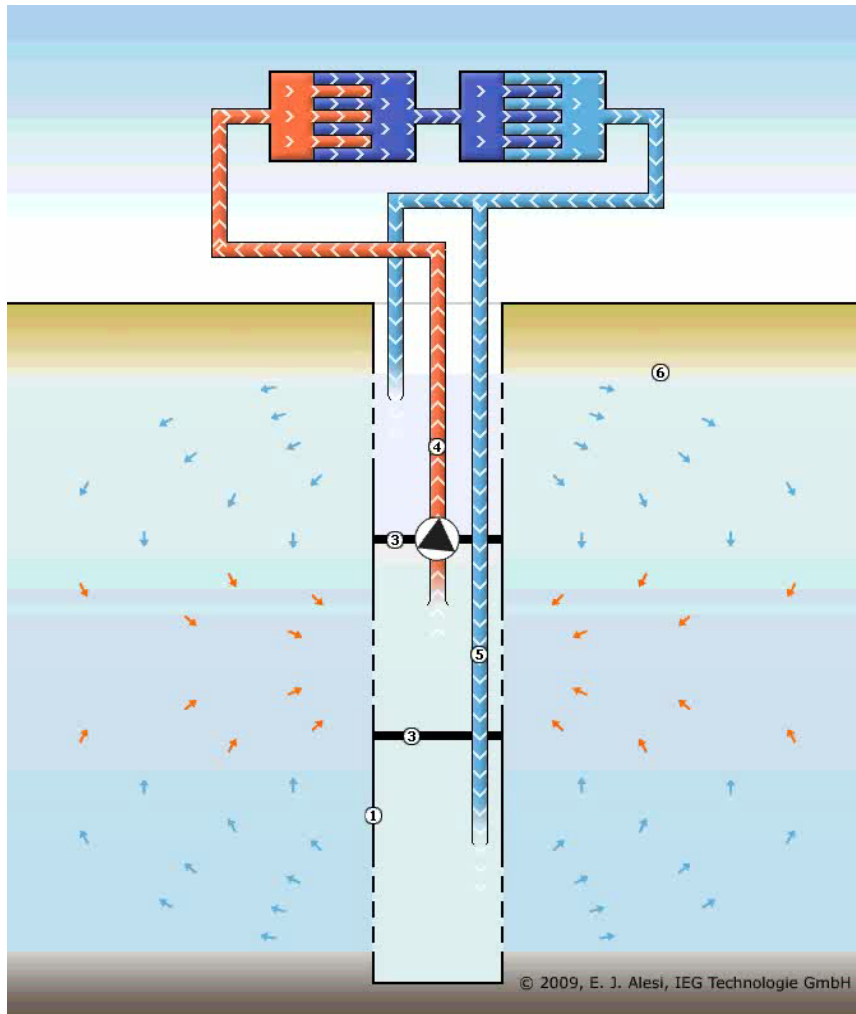
2D Source delimitation (HRSC)



3D Source architecture (HRSC)
(iso surface, XSD 0.5 V)



Groudwater Circulation Wells (GCW)



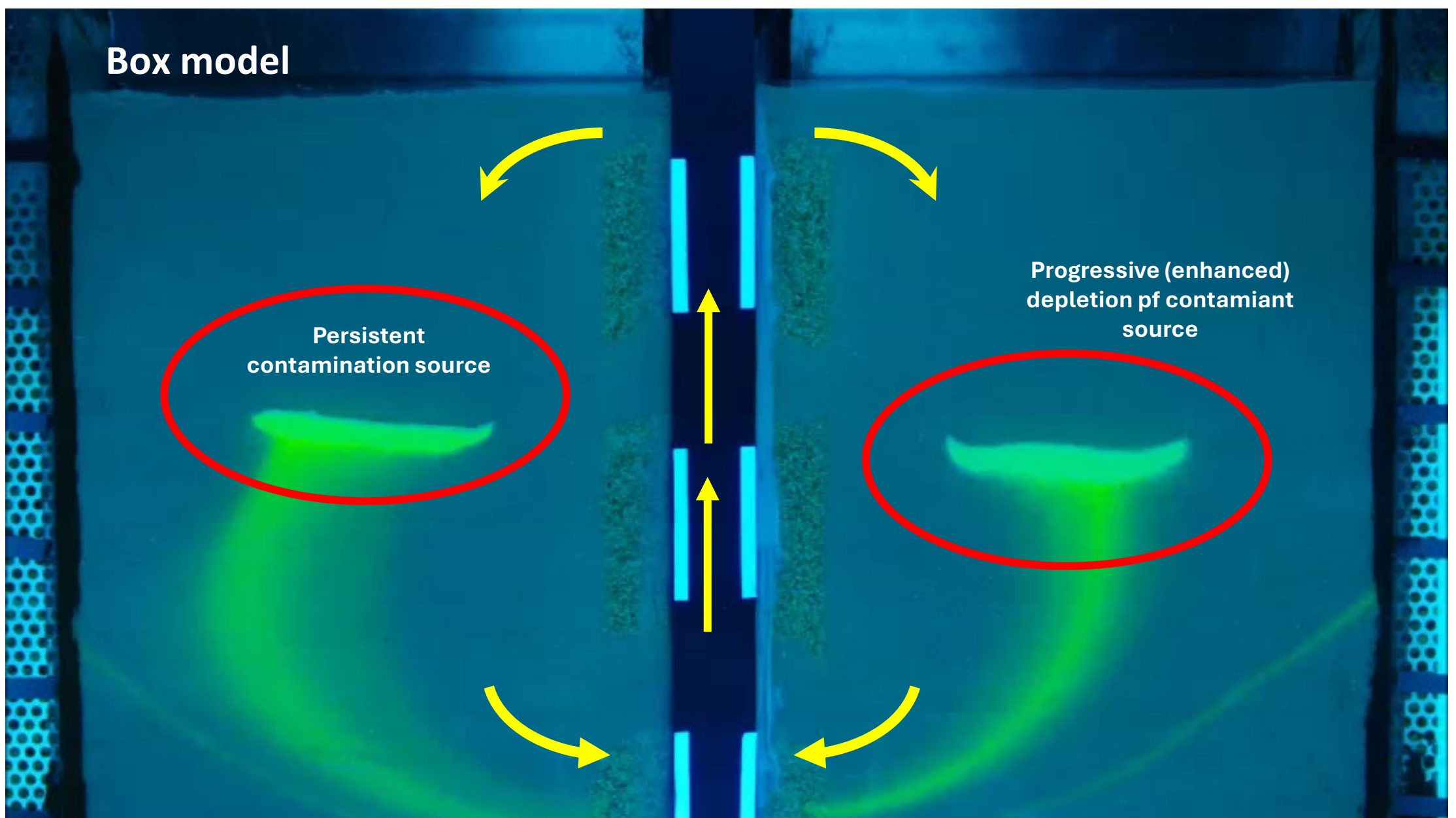
- Multi - screened wells designed to create in-situ ellipsoidal hydraulic circulation cells
- Generation of a "forced" vertical hydraulic gradient
- Mobilization of adsorbed contaminants on the solid matrix and residual NAPLs
- Configuration, sizing and design of the system based on site-specific hydrogeophysical peculiarities
- The pumped water is sent to a treatment plant before it is returned to the aquifer
- "Flexibility in operation"

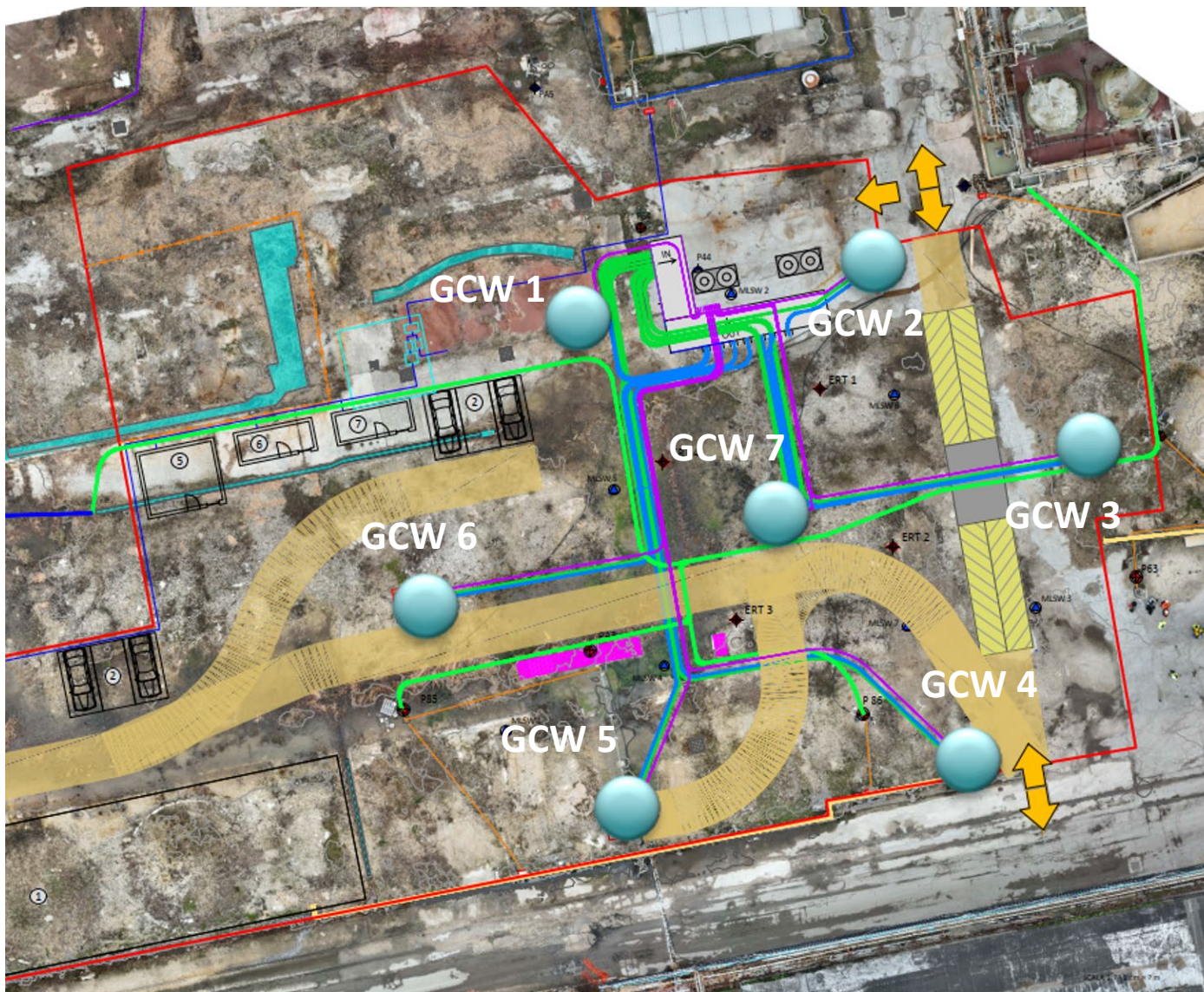
Box model

Re-Injection screen

Extraction screen

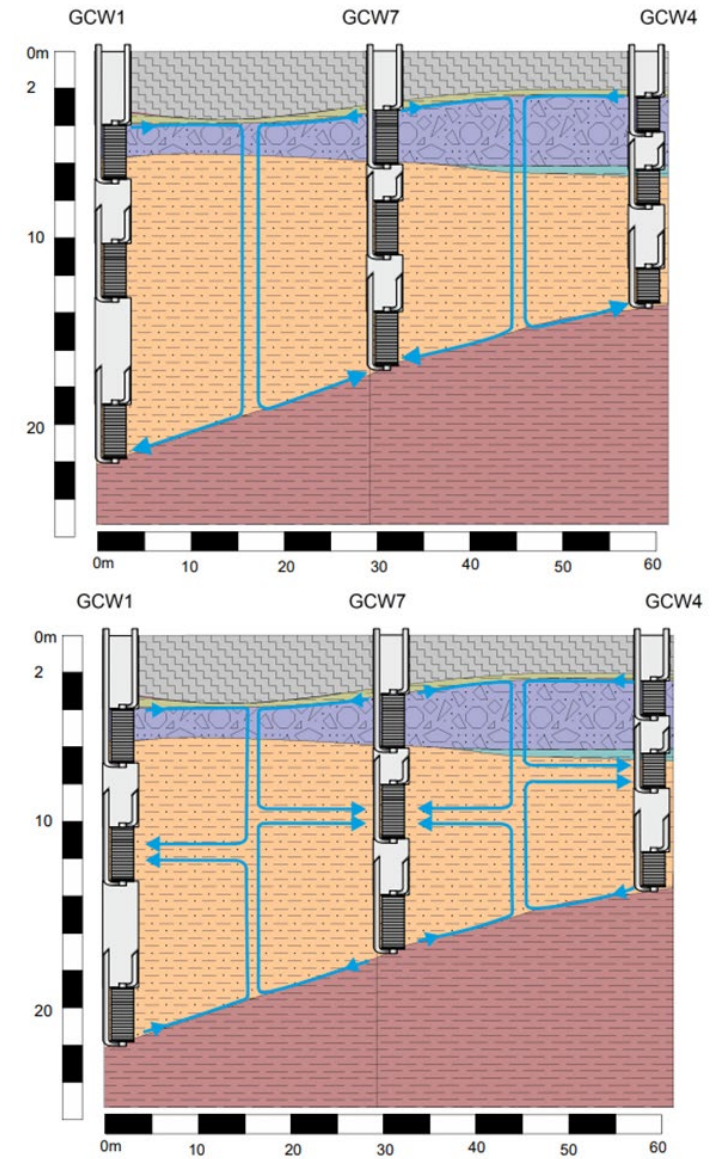
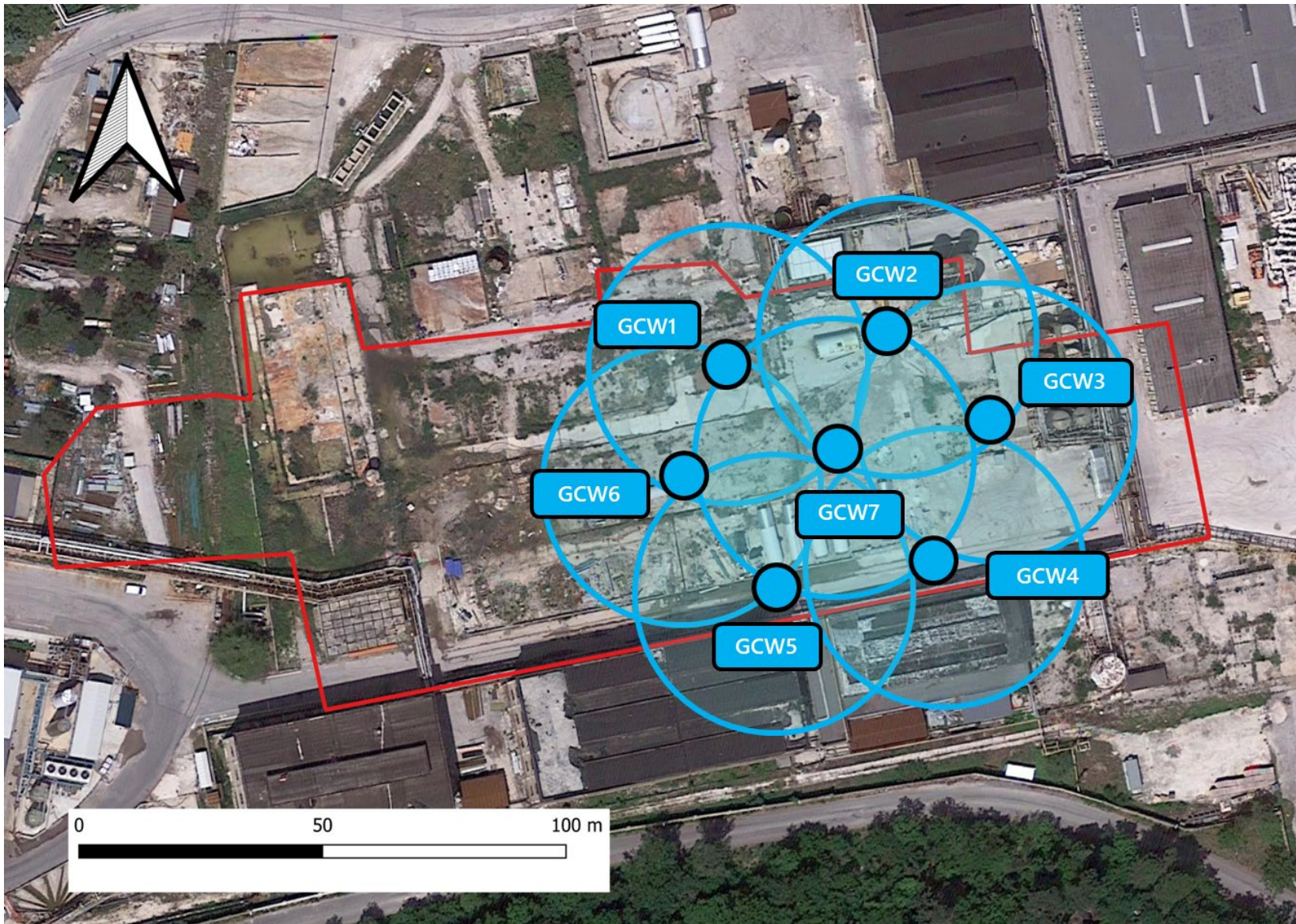
Box model





Plant configuration

- **7 GCW wells**
- 7 multilevel monitoring wells (MLWS)
- 4 wells (20 m deep) for 3D borehole Electrical Resistivity Tomography (ERT)
- Treatment system (compact air strippers and activated carbon adsorption, with optional UV polishing for vinyl chloride (VC) treatment)



Drone view



Drone view



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Drone view



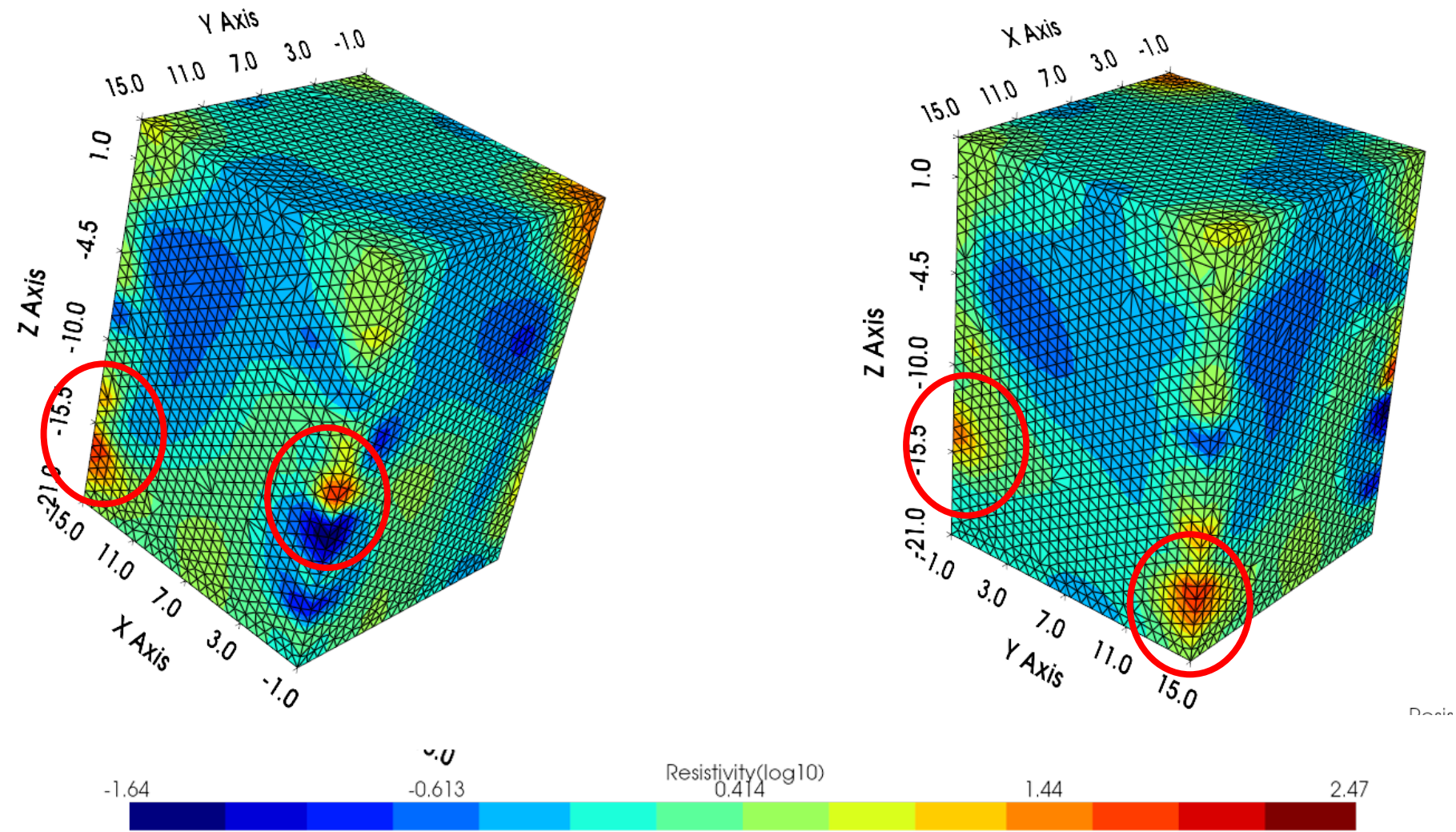
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Drone view



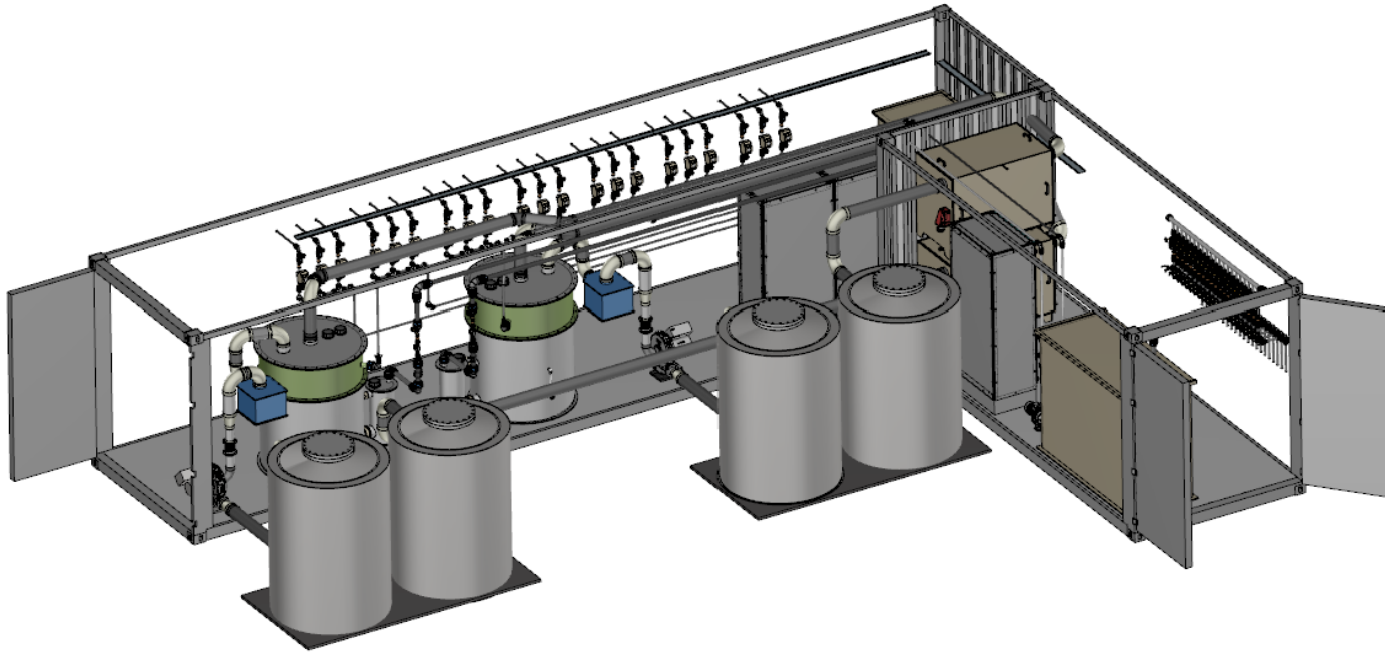
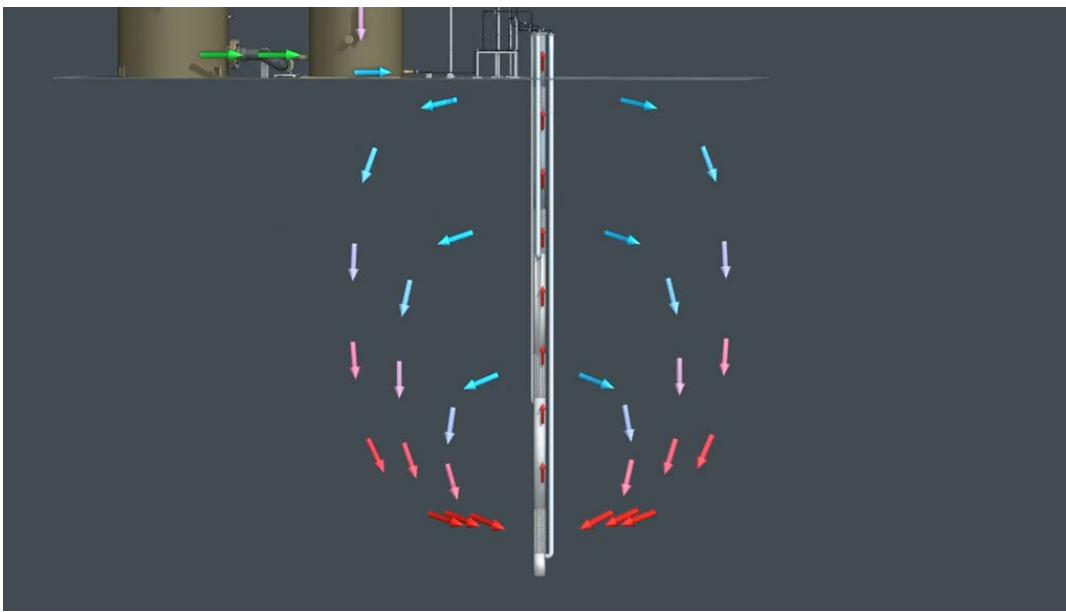
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Inverted Resistivity Model





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Thanks for your attention



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