

Ten Years of In Situ Treatment of a Former Sawmill Site: Methods, Performance and Lessons Learned

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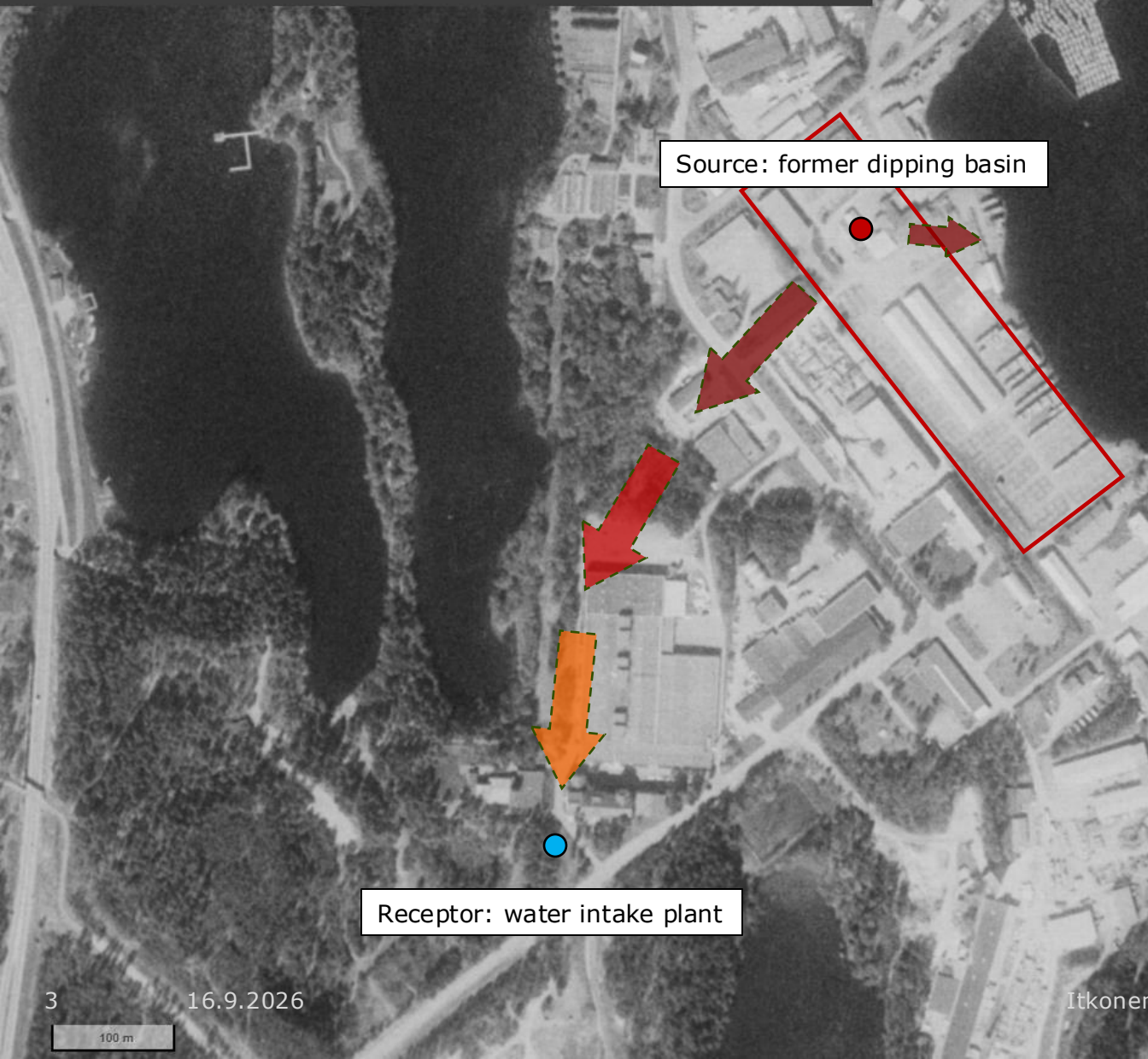


Beginning of the industrial activities

- The site is located in Mikkeli, Eastern Finland, adjacent to an esker system and situated between two lakes within an important groundwater area.
- Industrial operations started on the site in the early 1950s.
- The first sawmill operations started in 1954. The main property is shown as a red rectangular. Some storage and drying activities also took place in the surrounding areas.



1931 1940 1950 1960 1970 1980 1990 2000 2010 2020 2026

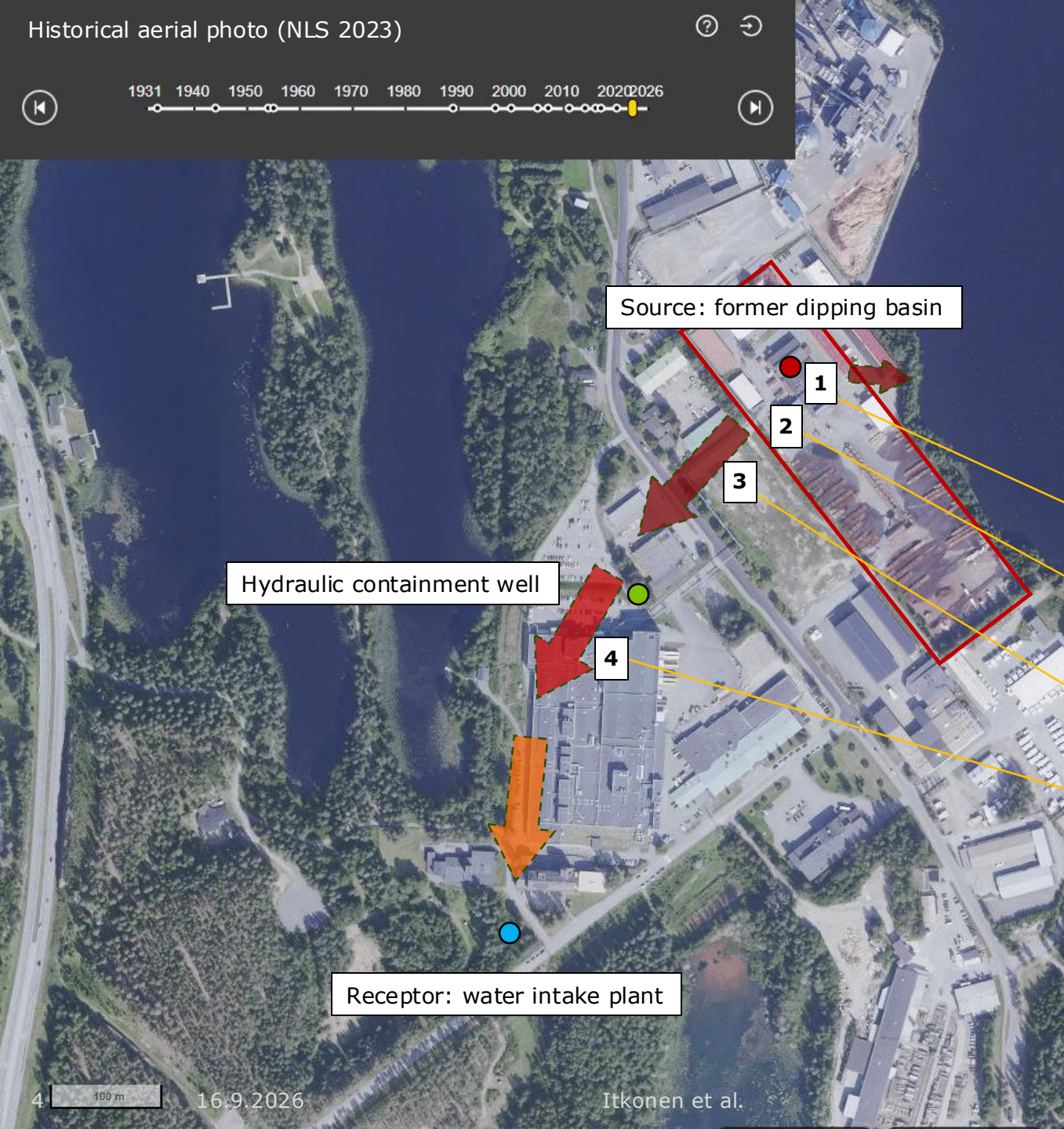


Source: former dipping basin

Receptor: water intake plant

Groundwater contamination

- KY-5 chemical was used on-site in 1954-1985 for anti-sapstain treatment.
- In particular, the dipping process resulted in chlorophenol releases to groundwater.
- First elevated concentrations were detected at the water intake plant in 2001.
- The saturated GW zone is relatively thick. It forms a small side stream of the total GW flow towards the intake plant.
- A minor fraction of the migrating chlorophenols reaches Lake Saimaa in the east.
- Only slightly elevated concentrations (CP, PCDD/F) in soil.



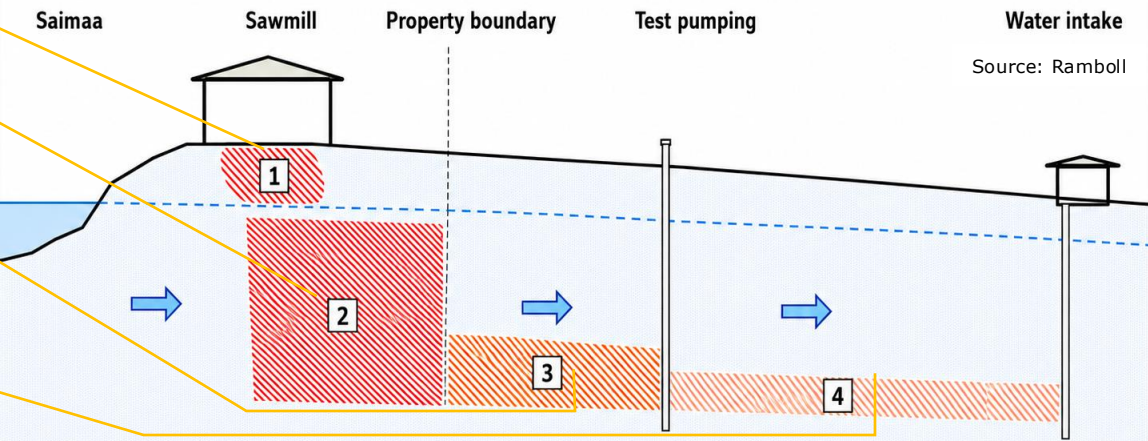
Source: former dipping basin

Hydraulic containment well

Receptor: water intake plant

Current situation and conceptual model

- The site is currently occupied by another operator. A new building has been constructed above the former dipping basin.
- Protective pumping was started in 2009. It currently controls the GW flow regime.
- In situ groundwater treatment was started in 2017. Pilot-scale remediation was conducted from 2016 to 2023, and full-scale remediation has been ongoing since then.
- A conceptual model has been developed for the site:

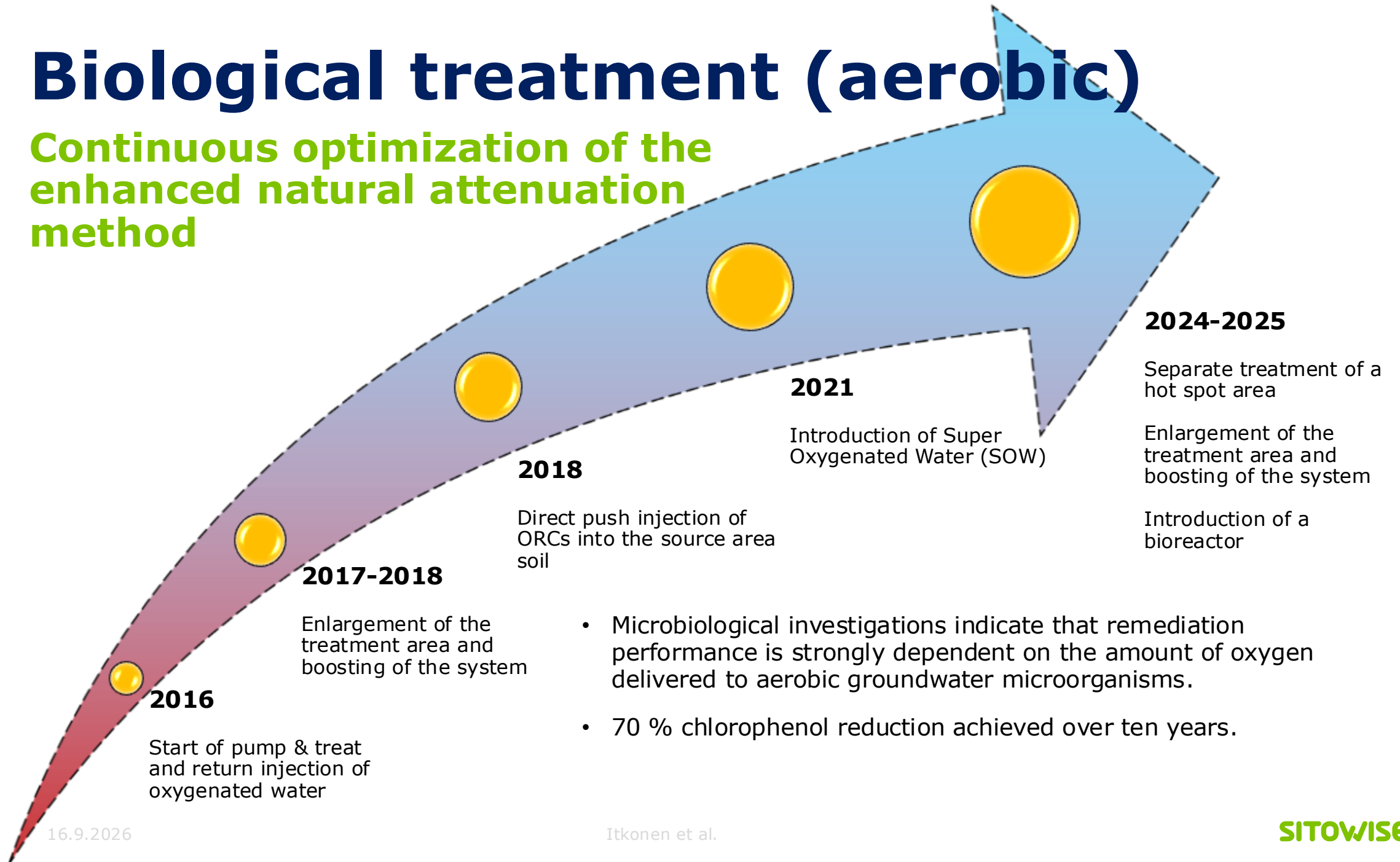


Area	Length	Width	Depth	Volume	Density/porosity	Mass	Cp concentration	Cp amount	Cp %
1	20 m	20 m	4 m	1 600 m3	1,8	2 880 t	20 mg/kg	58 kg	8
2	50 m	50 m	12 m	30 000 m3	0,3	9 000 t	55 000 ug/l	495 kg	72
3	200 m	50 m	5 m	50 000 m3	0,3	15 000 t	7 000 ug/l	105 kg	15
4	300 m	50 m	5 m	75 000 m3	0,3	22 500 t	1 500 ug/l	34 kg	5

Total	691 kg
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Biological treatment (aerobic)

Continuous optimization of the enhanced natural attenuation method



The current treatment system

-  Approximate migration route
-  In situ treatment container
-  Protection pumping container
-  Reserve protective pumping well
-  Remediation pumping well
-  Injection well
-  Water circulation and oxygenation

Hydraulic containment well

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Risk control

- Extensive monitoring as the primary risk control method.
- Protective pumping system.
- Traffic lights with action plans for elevated concentrations.
- A contingency plan for realization of the foreseen risks.
- Accumulation of oxygenated iron and manganese compounds to the treatment installations is a continuous problem. However, this has not affected the groundwater flow regime.
- Groundwater geochemistry has remained stable during the remediation, indicating that the applied measures have not caused adverse secondary impacts.
- No adverse degradation products have been identified despite repeated monitoring efforts.
- Changes to the treatment system always induce a temporary increase in chlorophenol migration. Concentrations typically return to their long-term declining trend within a few months to a couple of years.
- Chemical oxygenation, dig & dump etc. were rejected in the beginning due to risks.



Pumping - injection



250 m³



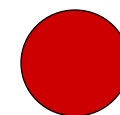
250 m³

Lake Saimaa
water level

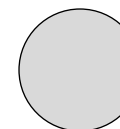


75,77 m
(N2000)

Example of a monthly report (June 2026)



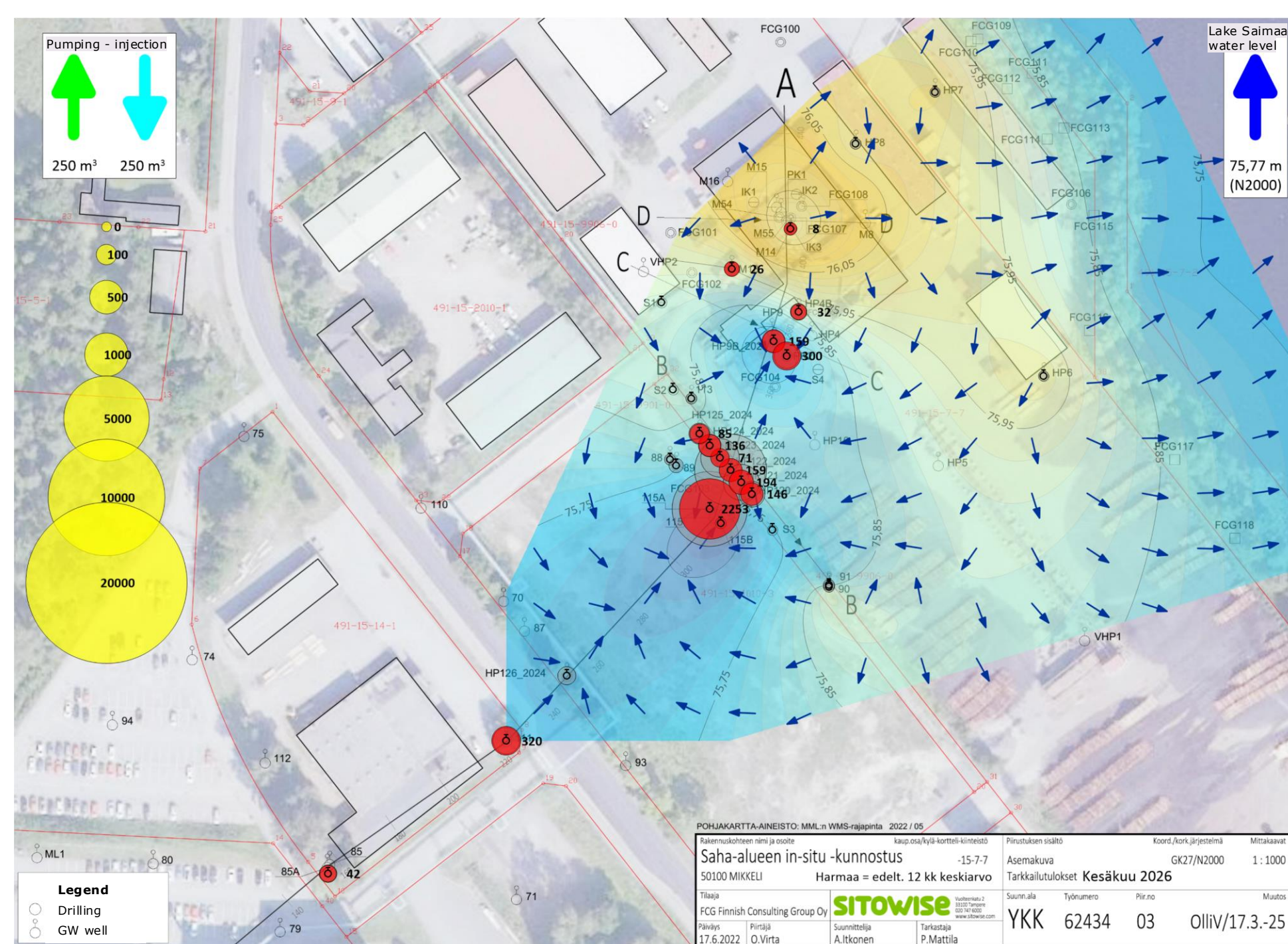
Concentration at the
monitoring time



Average concentration of
the preceding year



Groundwater level and
direction of the hydraulic
gradient



POHJAKARTTA-AINEISTO: MML:n WMS-rajapinta 2022 / 05

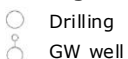
Rakennuskohteen nimi ja osoite kaup./osa/kylä-korttelikiteistö
Saha-alueen in-situ -kunnostus -15-7-7
50100 MIKKELI Harmaa = edelt. 12 kk keskiarvo

Piirustuksen sisältö
Asemakuva GK27/N2000 1:1000
Tarkkailutulokset Kesäkuu 2026

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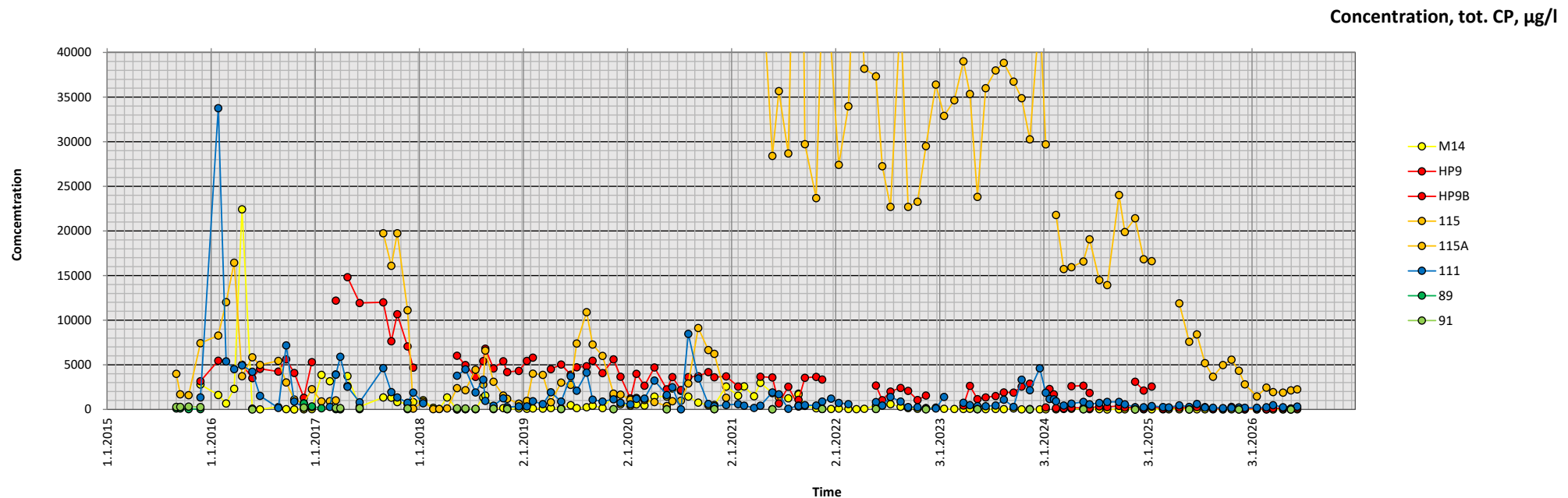
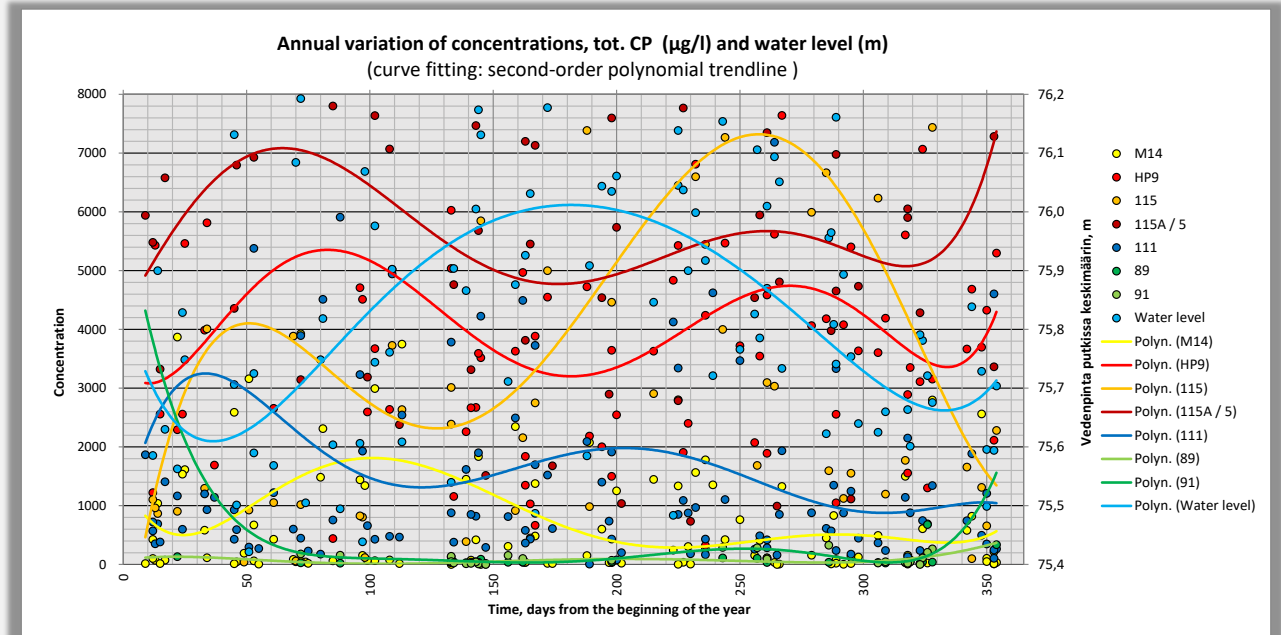
Legend



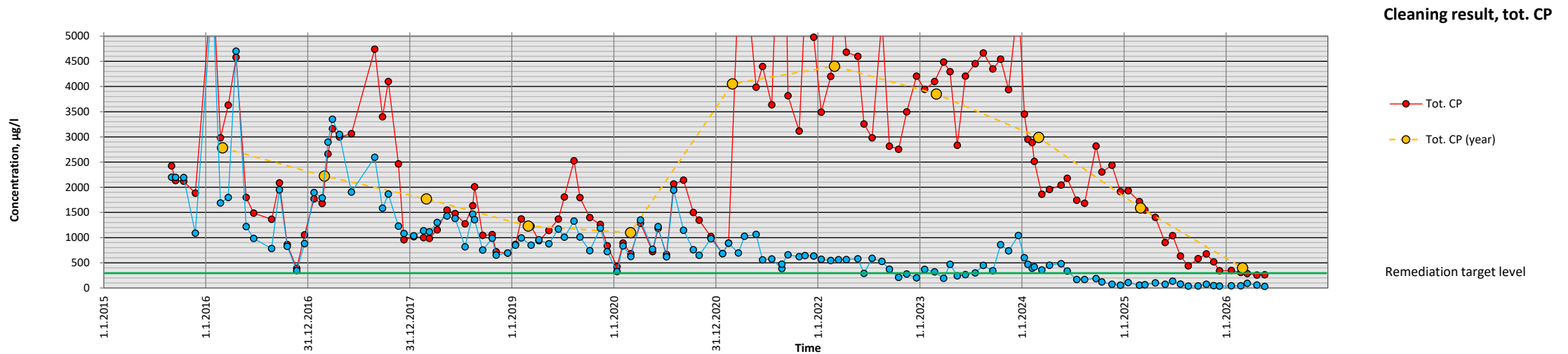
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Development of chlorophenol total concentrations

- In general, the concentrations have diminished and, in many wells, almost vanished.
- A strong double peaked annual variation in the concentrations.



Cleaning performance



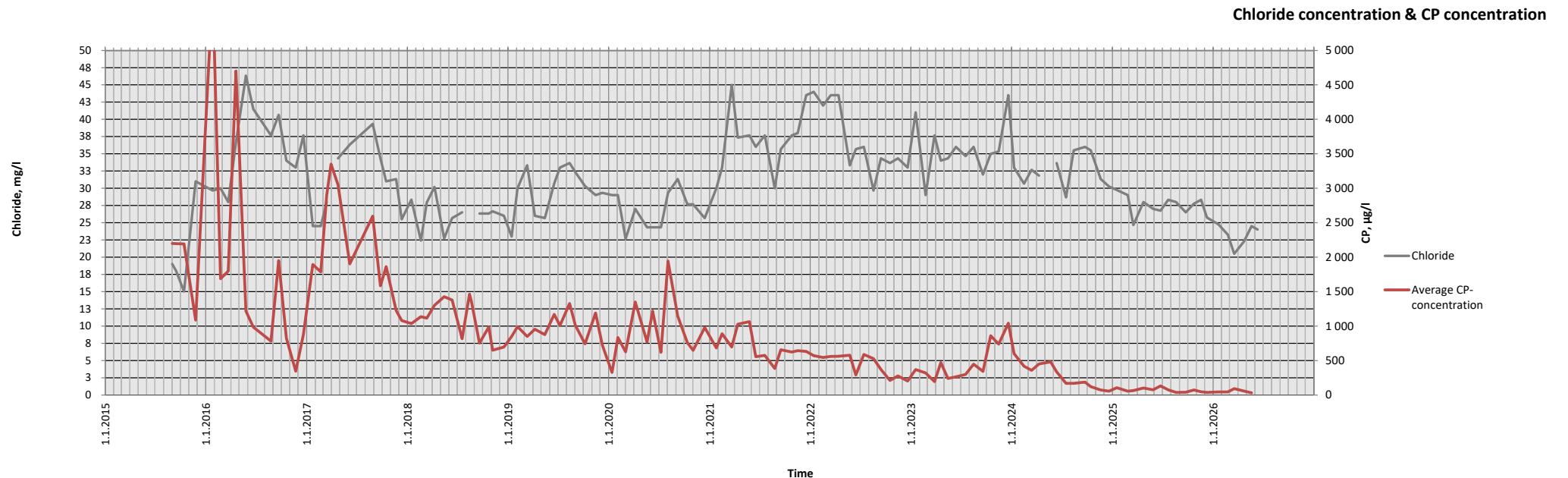
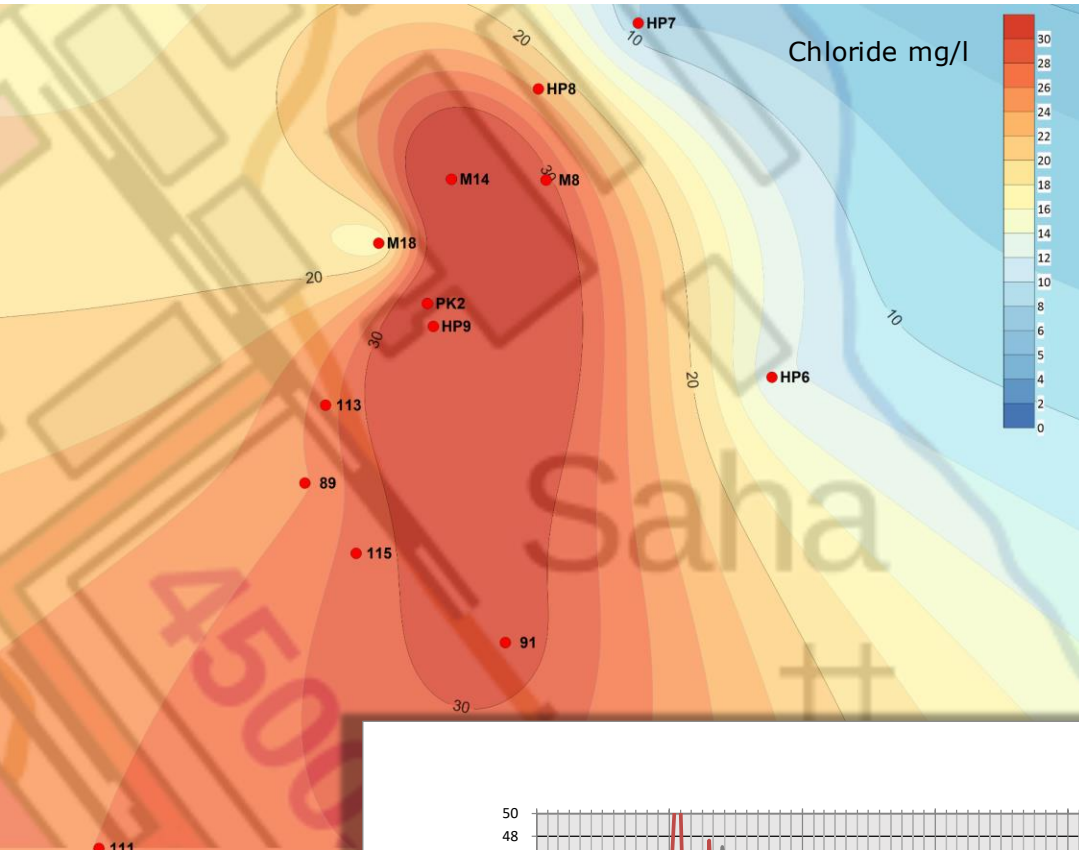
- Approximately 70% of the chlorophenols have been removed from the site.
- Approximately 50% has been removed through biodegradation, 20% through pump-and-treat, and 30% has migrated downstream.
- The migrated chlorophenol is almost completely removed by the protective pumping downstream.

Balance 1.9.-31.8.	Tot.-CP start balance	Tot.-CP migrated	Tot.-CP pump & treat	Chloride "extra"	TeCP biodegraded	TeCP biodegraded	Tot.-CP left
	kg	kg	kg	kg	mol	kg	kg
2015-2016 (start)	495,0	9,8	5,2	12,8	92,5	21,4	458,6
2016-2017	458,6	7,5	22,9	9,4	68,5	15,9	412,3
2017-2018	412,3	4,8	14,1	0,7	5,3	1,2	392,1
2018-2019	392,1	3,7	7,2	13,0	94,4	21,9	359,3
2019-2020	359,3	3,4	6,3	6,4	46,1	10,7	338,9
2020-2021	338,9	10,1	3,5	12,0	86,9	20,2	305,2
2021-2022	305,2	8,4	2,0	10,5	76,1	17,7	277,1
2022-2023	277,1	6,3	1,4	13,2	95,3	22,1	247,3
2023-2024	247,3	5,4	1,8	10,5	76,3	17,7	222,4
2024-2025	222,4	2,9	34,9	11,7	84,6	19,6	165,0
2025/9-2026/6	165,0	0,7	9,0	4,8	34,6	8,0	147,3

The entire project:	Start balance	Migrated	Pump & treat	Biodegradation	Left
	kg	kg	kg	kg	kg
	495	63	108	176	147

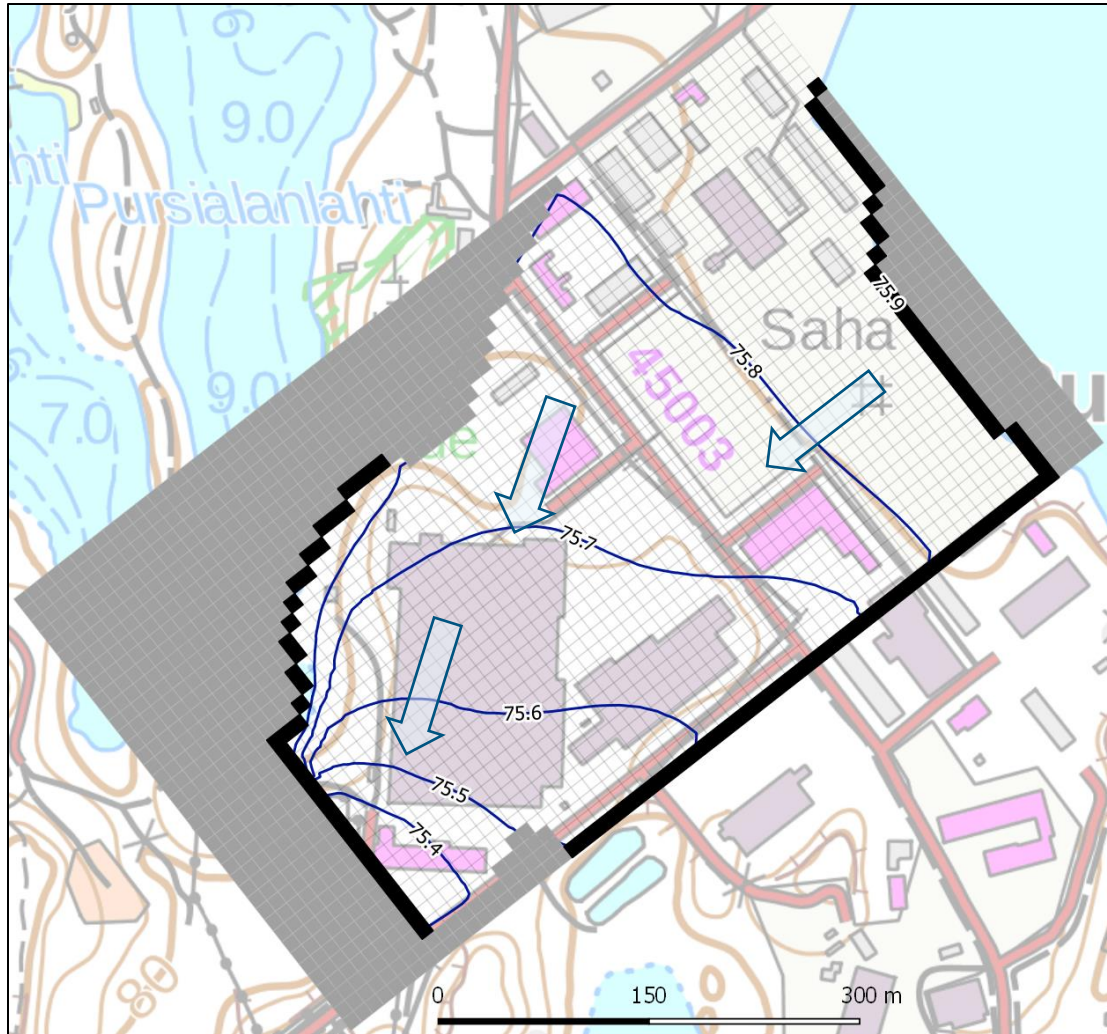
Chloride anomaly

- A pronounced chloride anomaly exists at the site. After correction for background concentrations (normally less than 5-10 mg/l), chloride can be used as a proxy indicator for chlorophenol biodegradation.
- This is actually the only way found since no metabolic gases or degradation products have been detected. The GW system is complicated and generally anoxic, so it is difficult to make conclusions from oxygen consumption, either.

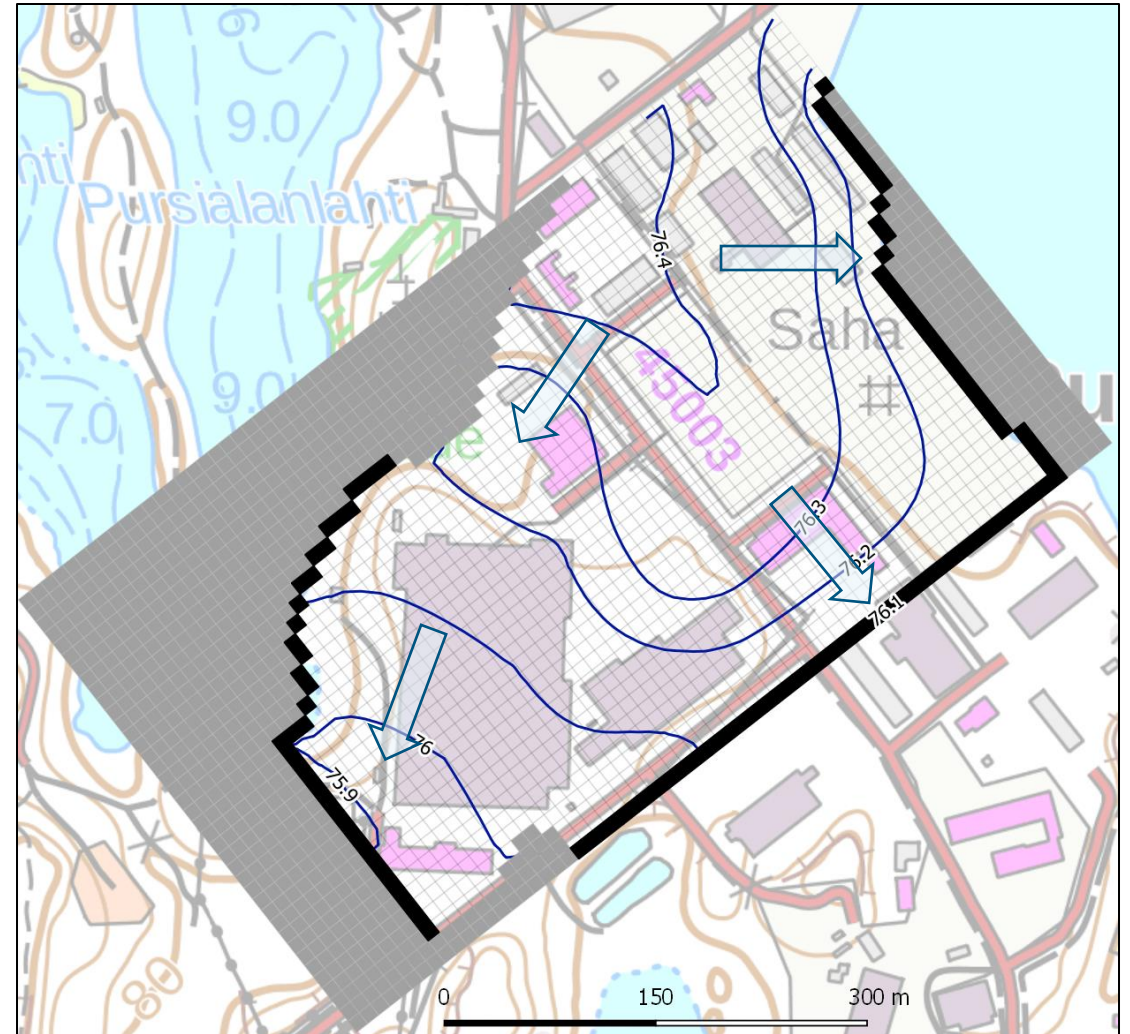


Two baseline scenarios for GW flow regime

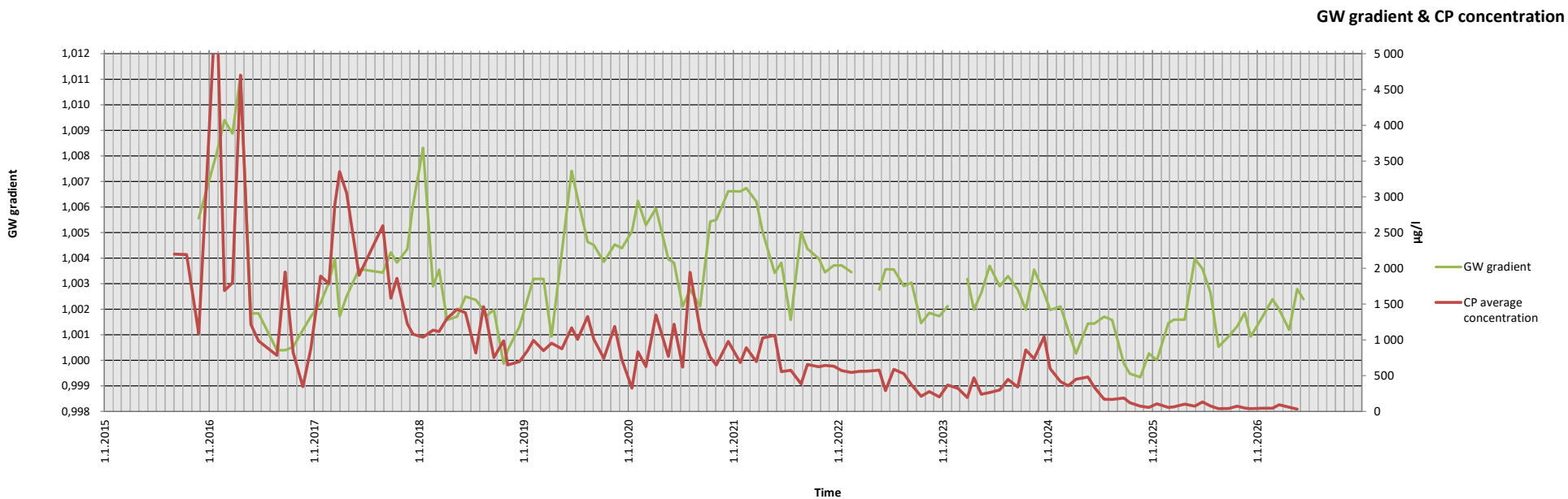
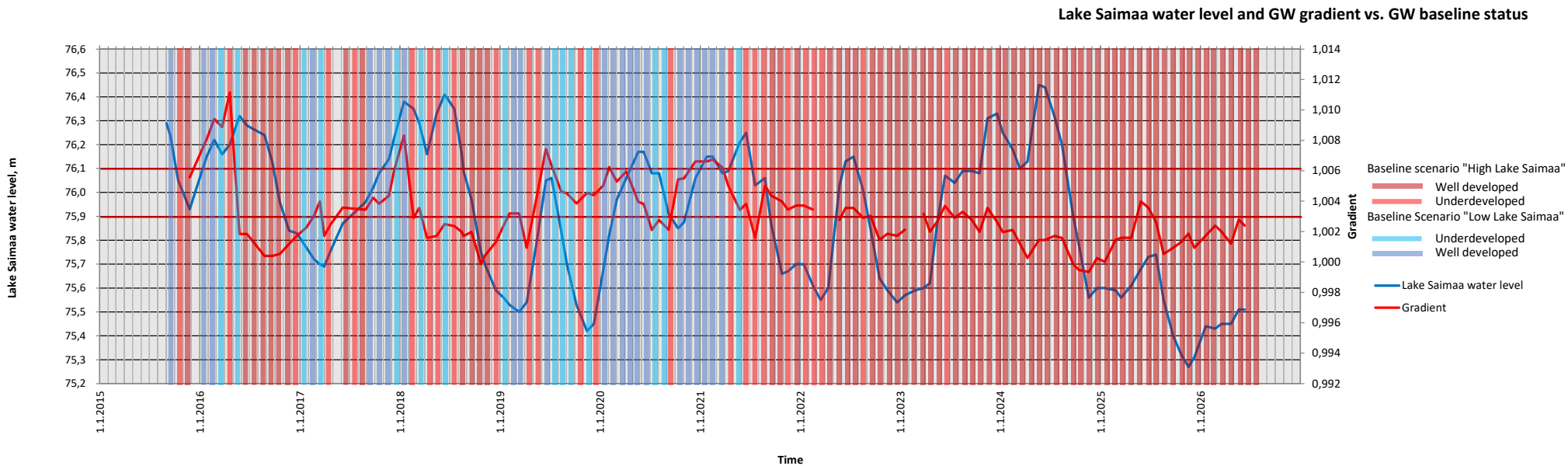
Low Lake Saimaa, no GW formation from precipitation,
ca. 4,9 m³/d



High Lake Saimaa, GW formation from precipitation,
ca. 0,58 m³/d



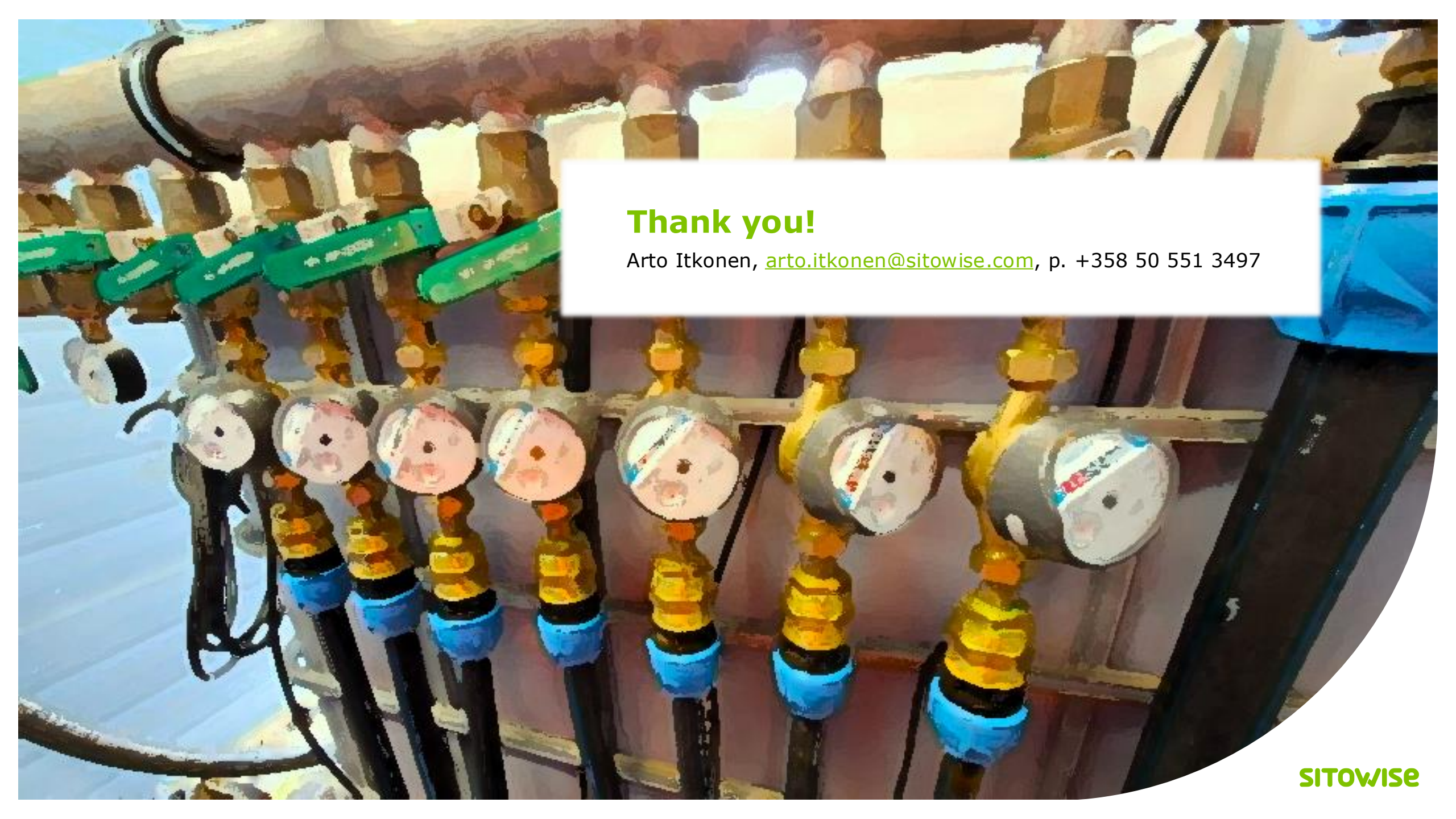
GW flow



Conclusions

- The project demonstrates that long-term, adaptive in situ remediation can be an effective and environmentally robust solution for persistent organic contaminants at complex groundwater sites.
- Key lessons in the Pursiala case include the importance of sustained oxygen delivery, iterative system optimization, and comprehensive monitoring to support risk-based decision-making and regulatory confidence.
- It is hard to deliver oxygen to microbes in a basically anoxic system, and it becomes more and more difficult when the concentrations drop. Several approaches have been tried with varying success.
- In enhanced natural attenuation projects, estimating the extent of biodegradation is essential but challenging. Reasonable results were got in this case with an annual balance model that is based on the amount of free chloride in the groundwater and justified estimates of groundwater flow.



The background image is a close-up photograph of a technical manifold, likely for a refrigeration or HVAC system. It features several vertical pipes with blue and yellow fittings. At the top of each pipe is a circular gauge with a white face and a red needle. The manifold is connected to various pipes and hoses, some of which are green. The overall scene is brightly lit, and the image has a slightly grainy, high-contrast appearance.

Thank you!

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