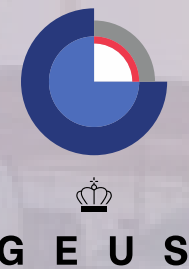


# GreenCat - A Sandbox Experiment for Evaluating the Degradation of Chlorinated Solvents with a Catalyst Made from Waste Materials in an artificial confined aquifer

AquaConSoil2023

- Anton Grønne Kühl  
- John Bastrup



## Agenda

- Introduction
- What was the plan when we started?
- What have we been doing?
- Preparing the injection
- Results – To be continued....

Funded by the  Innovation Fund Denmark

In collaboration with a consortium comprising

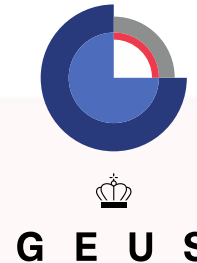
- The Capital Region of Denmark



- University of Copenhagen



- GEUS



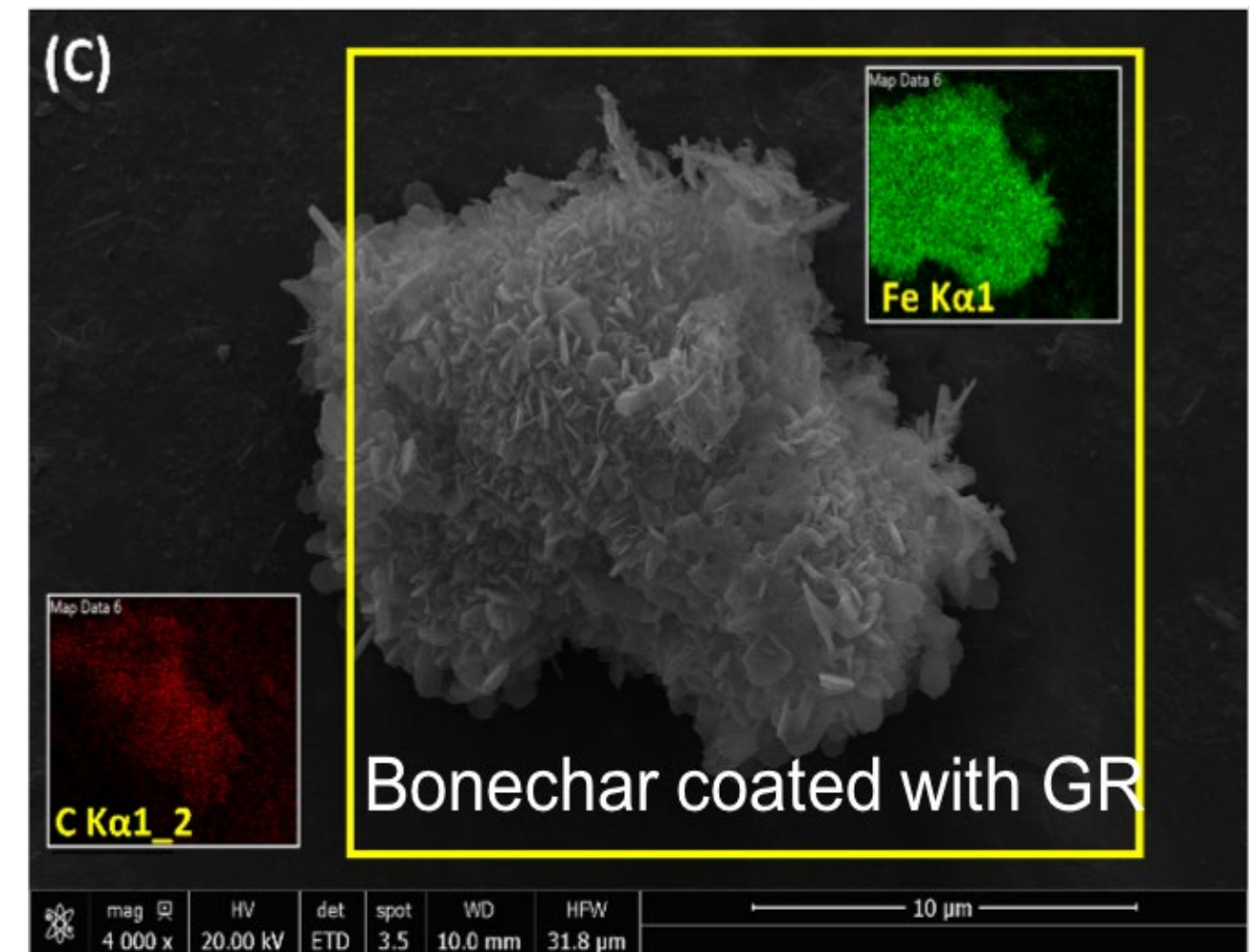
- Amphos21



- Alumichem



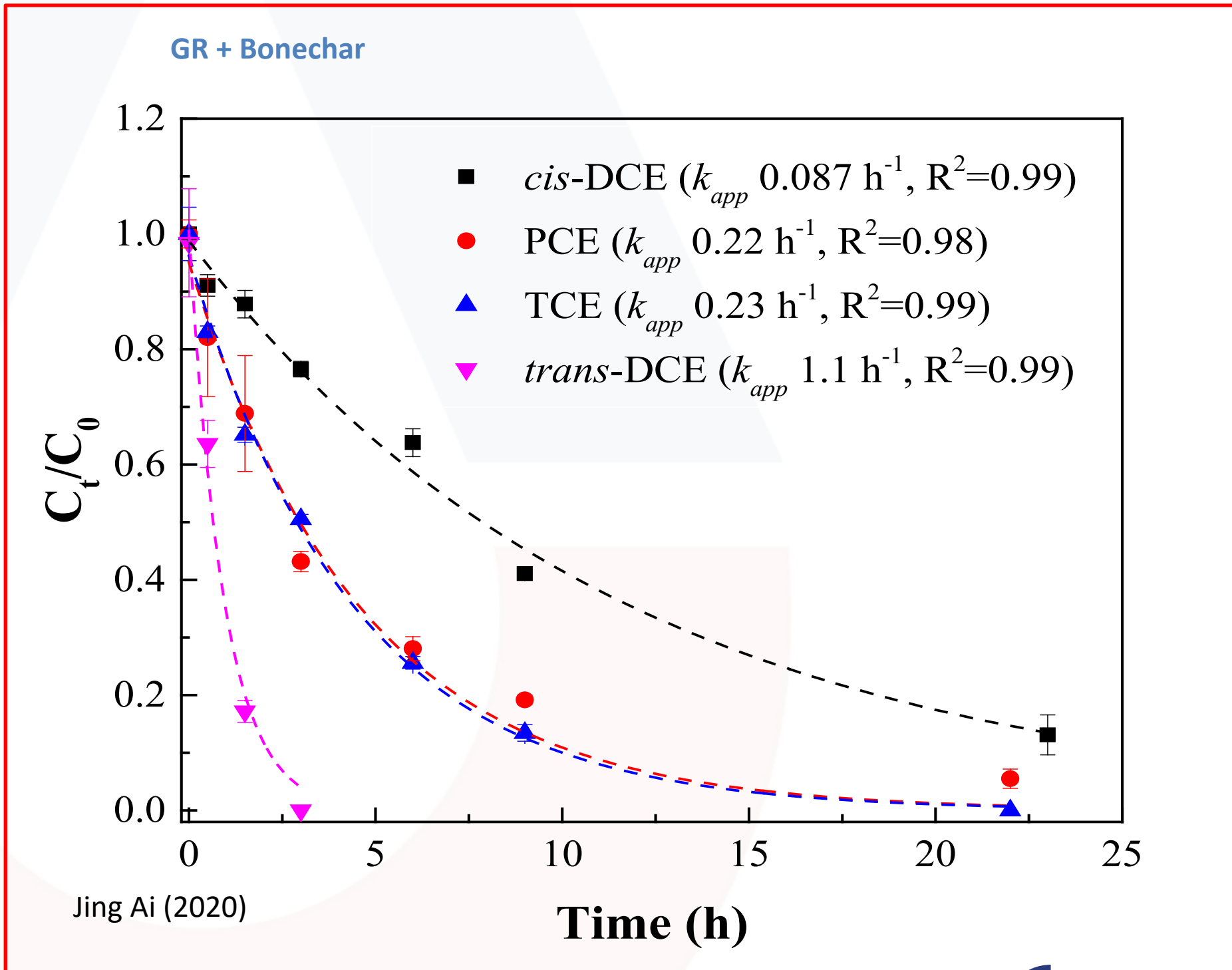
- Geo



**Green Catalyst → Greencat**

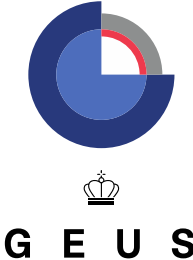


# 6 years ago in a lab far far away

- bonechar makes GreenRust super reactive

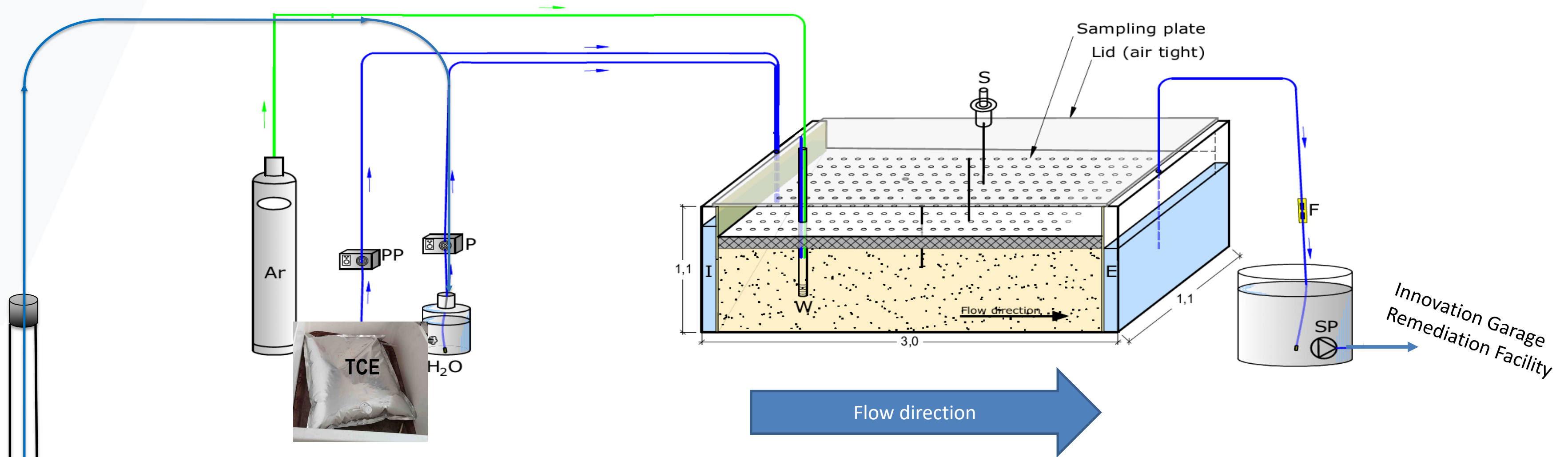


- Acetylene is the main product.
- Chlorinated ethylenes are fully dechlorinated.

# Why make an artificial aquifer?

- The GreenCat components have been thoroughly studied in labs at  and  UNIVERSITY OF COPENHAGEN
- A pilot project was too ambitious for the available funding, so we decided to conduct a large-scale, lab-like field-test in a tank
- The results from the tank should be modelled by Amphos 21 and used for later pilot-studies
- Thanks to The Capital region of Denmark  we can use the Innovation Garage and the groundwater from their remediation facilities in our tank

# Setup of Experimental Aquifer prior to GR+BC injection



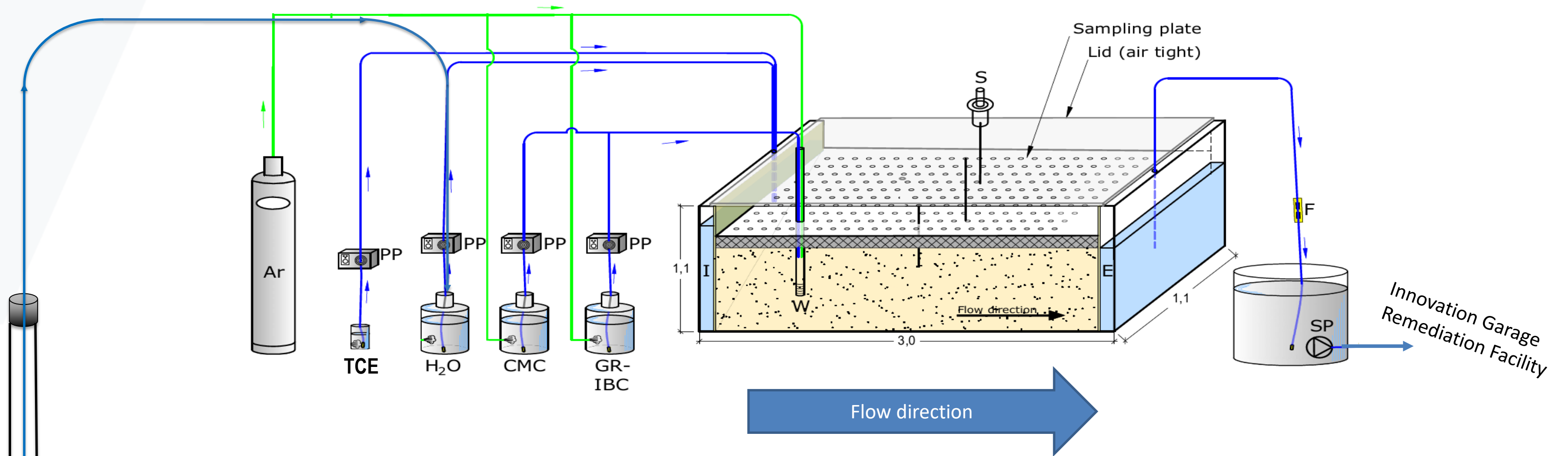
H<sub>2</sub>O: Water  
 CMC: Carboxy methyl cellulose  
 CE: Chlorinated ethens  
 I: Influent chamber  
 E: Effluent chamber  
 GR-IBC: Green Rust - Bone Char solution  
 F: Flow measurements  
 P: Pressure measurement  
 PP: Peristaltic pump  
 D: Drilling (Filters in 3 levels)  
 SP: Submersible Pump  
 S: Syringe, sampling needle  
 GAC: Carbon filter  
 W: Injection well

Sand (Saturated zone)  
 Bentonite  
 Drainage mat  
 Sparger

When we are sure that the tank, pumps, sensors etc is working we plan to inject the GR and BC components

Measuring Ph, EC, redox potential and O2 before and after the tank

# Setup of Experimental Aquifer



H<sub>2</sub>O: Water  
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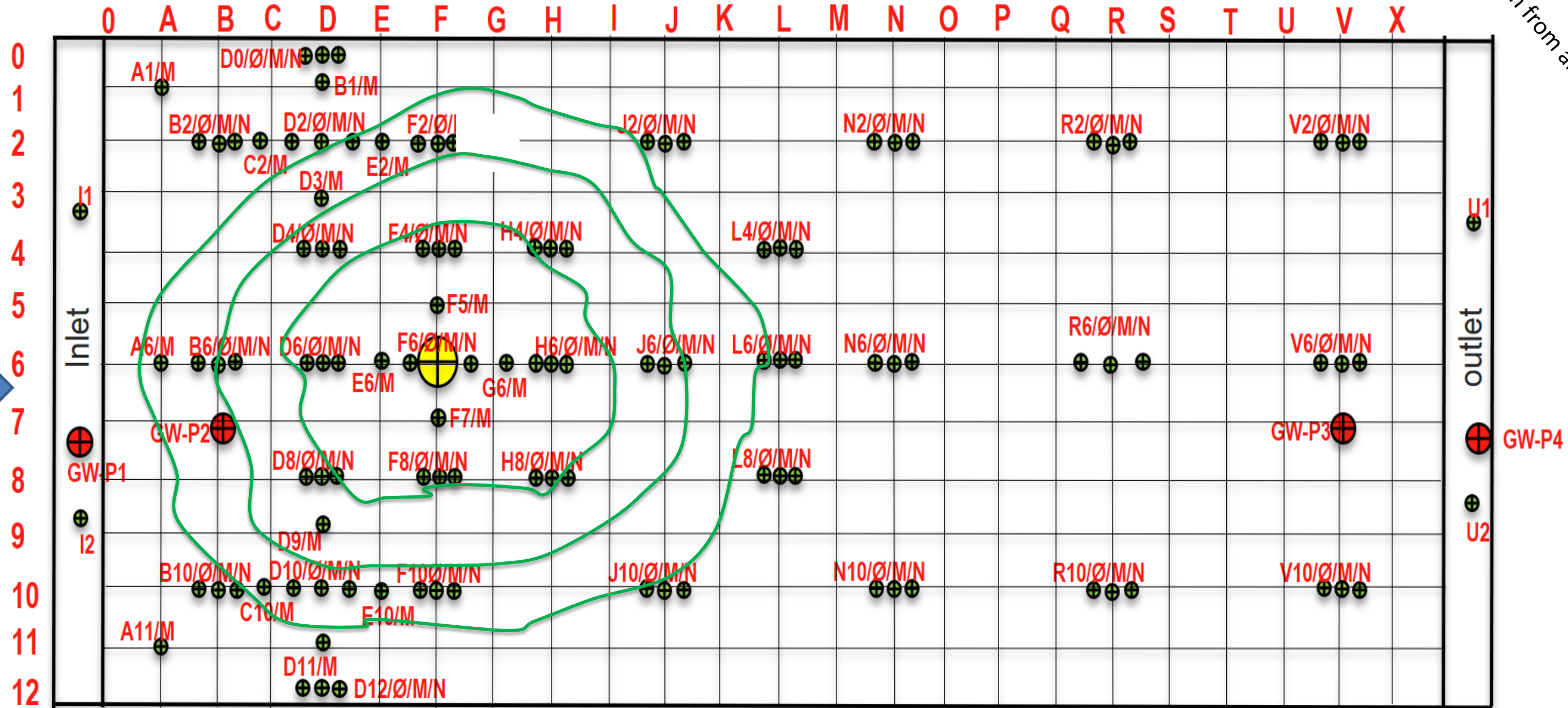
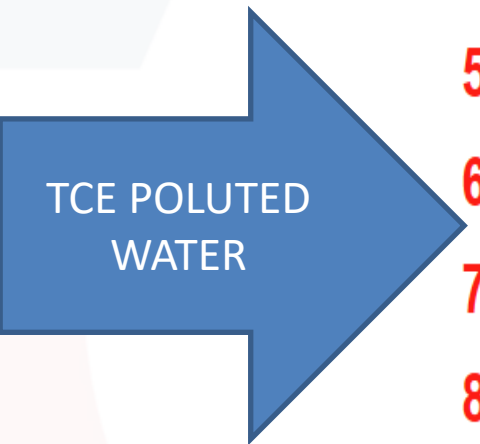
Sand (Saturated zone)  
 Bentonite  
 Drainage mat  
 Sparger

CMC is added to help disperse the GR and BC in the sand

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# An overview of the lid of the tank

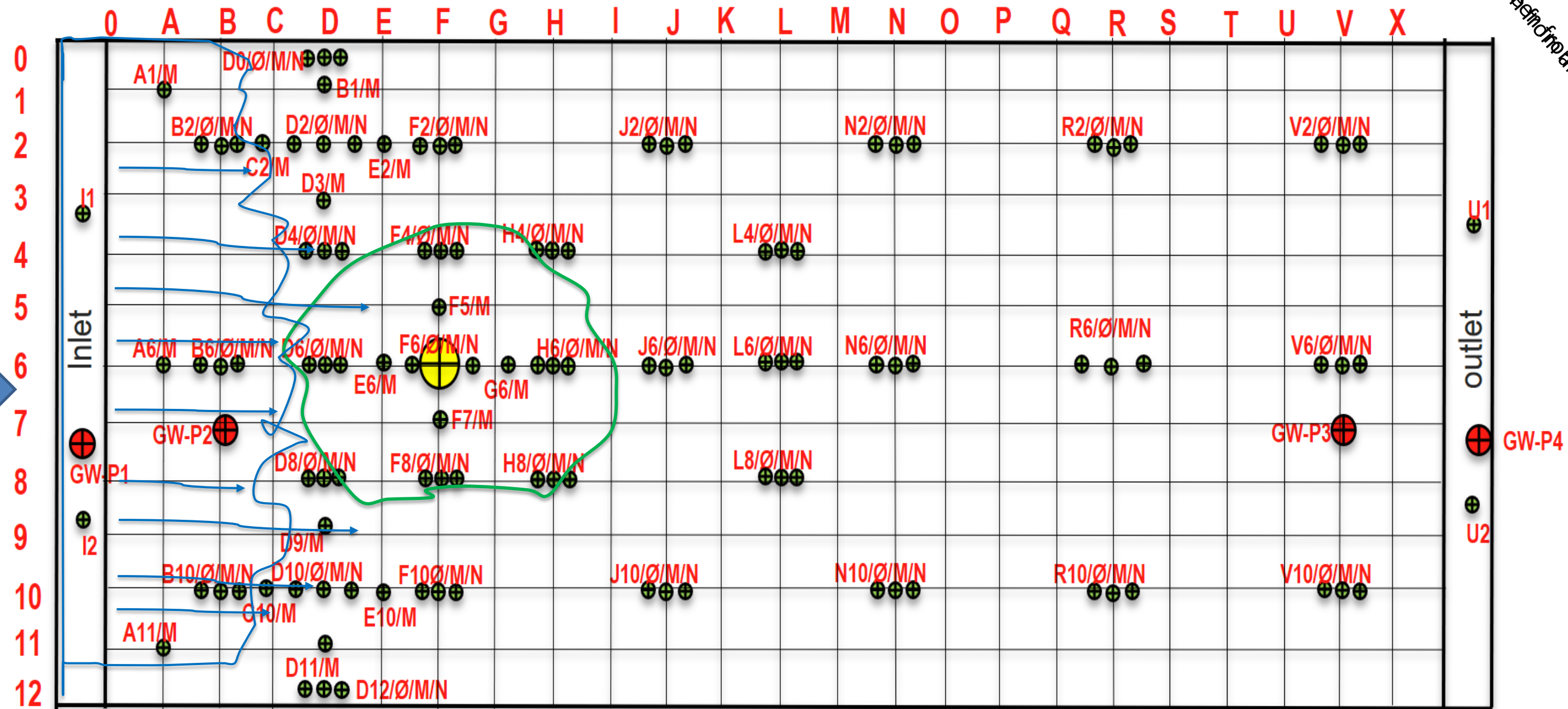
The tank seen from above



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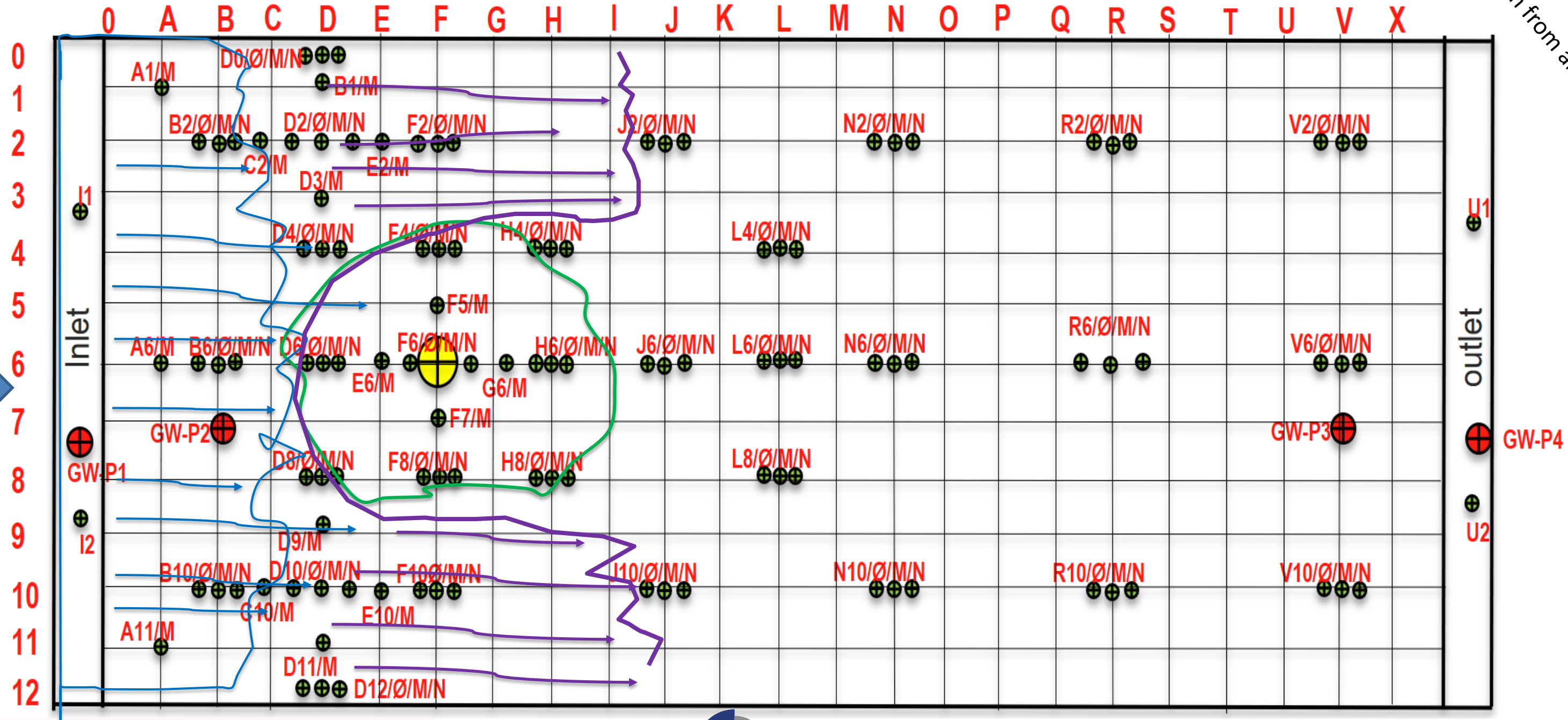
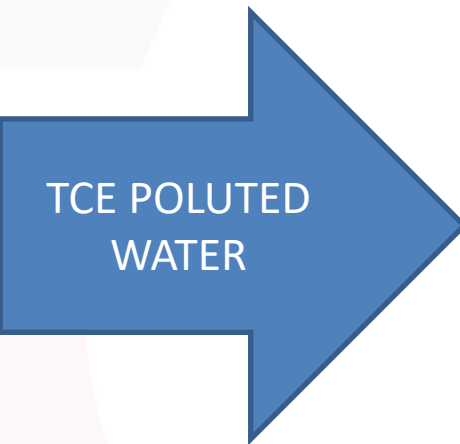
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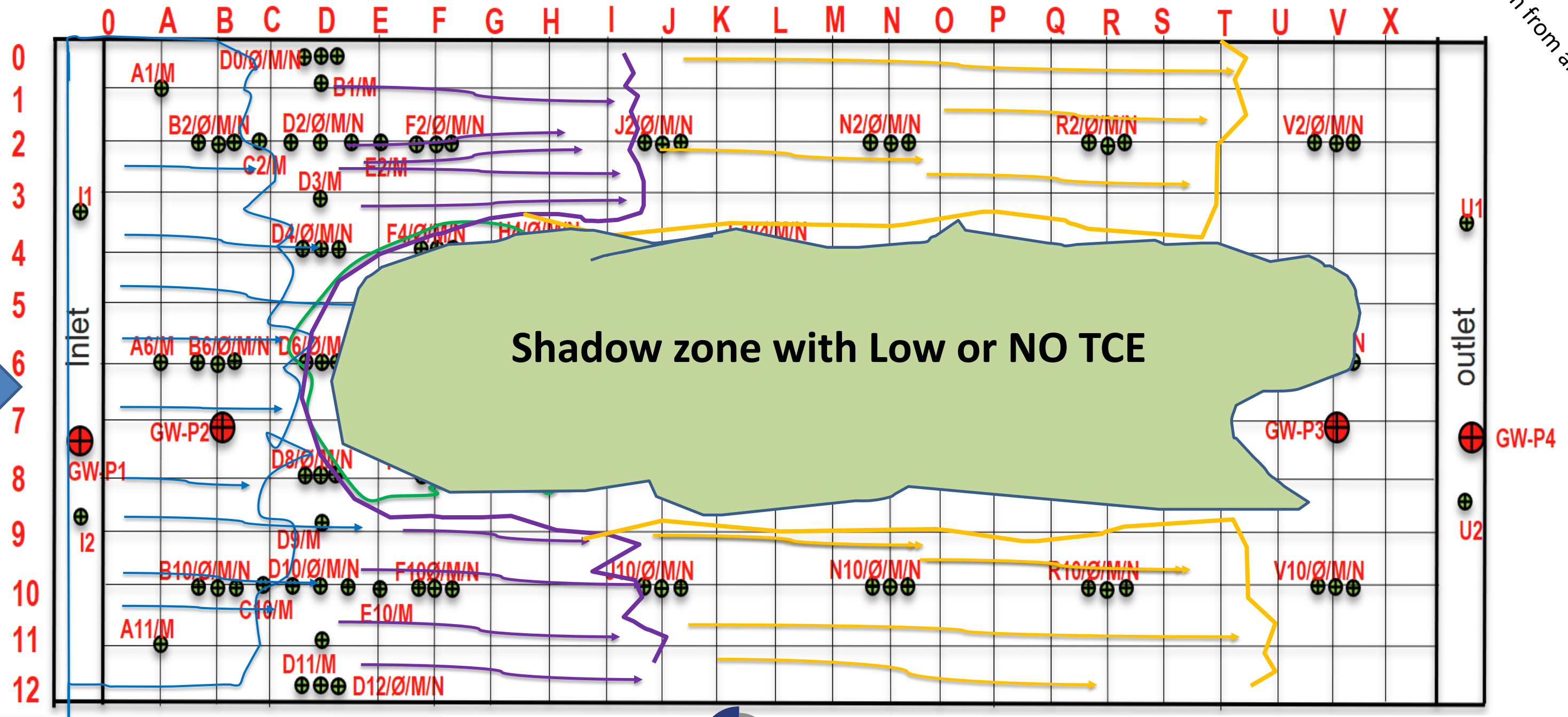
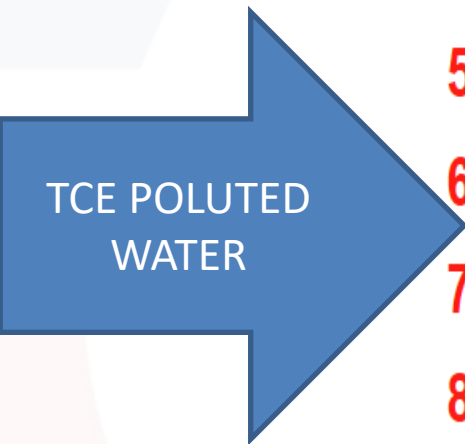
The tank seen from above



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# An overview of the lid of the tank

The tank seen from above

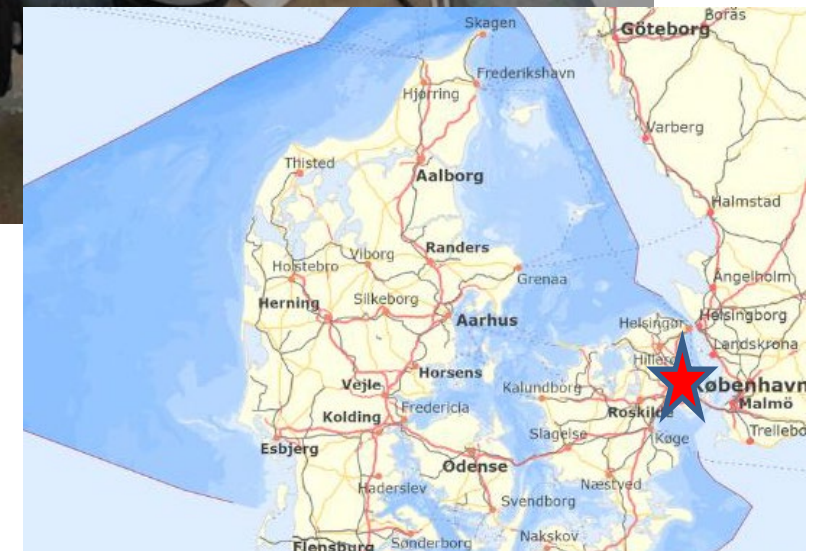


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The GreenCat tank was built at the Innovation Garage in Copenhagen next to a running remediation facility and we use anaerobic groundwater from there



Fotos from the room next to where the GreenCat tank are at the Innovation Garage. The polluted water comes into the facility through pipe A and the water to the greencat-project are taped from B, before the remediation-facility marked with a C,



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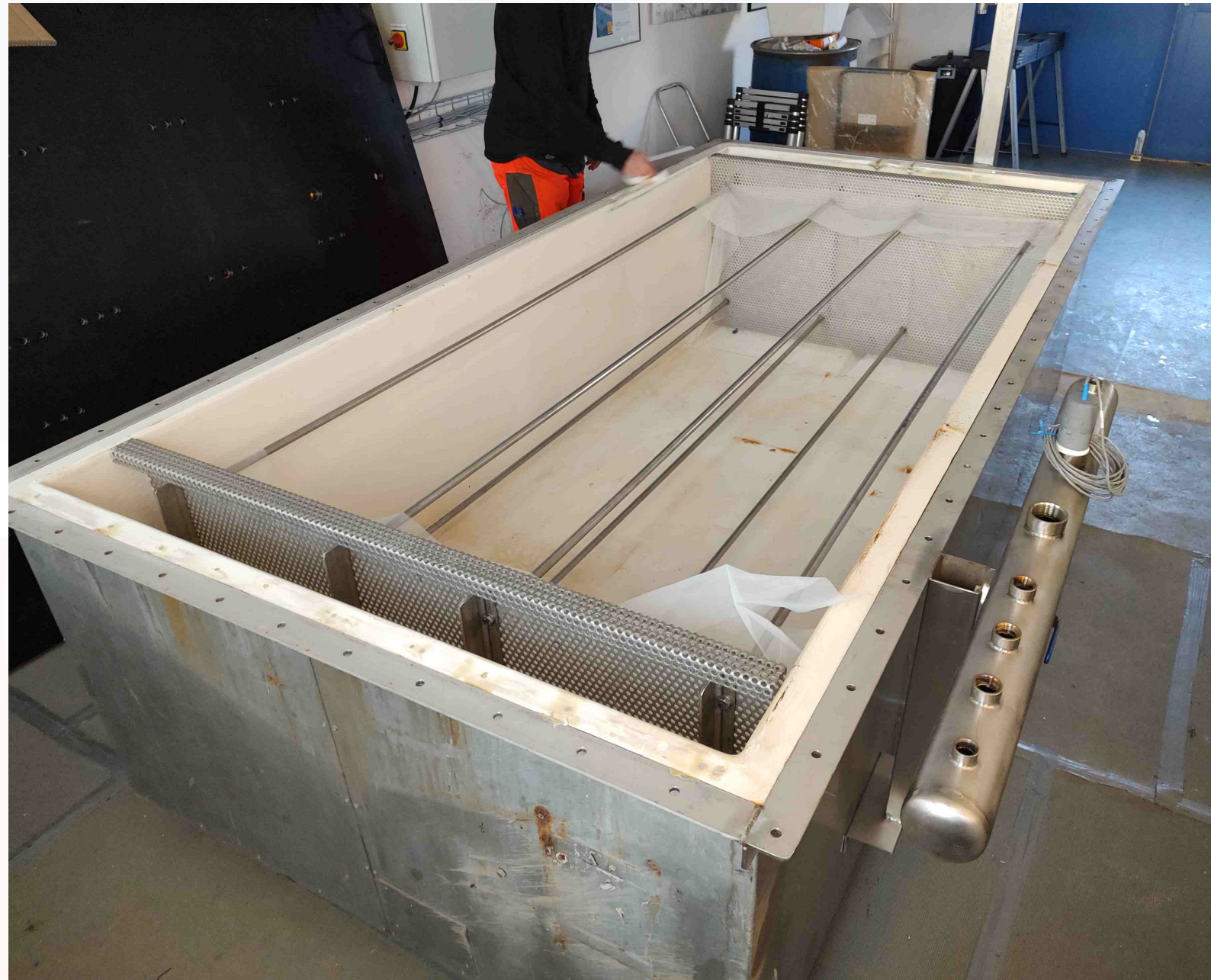
# Geo

SUBSURFACE EXPERTISE



# Filing the tank

We needed to move the steel rods out of the sandchamber



Very finegrained sand



# Installing the injection well – an actual hand dug well



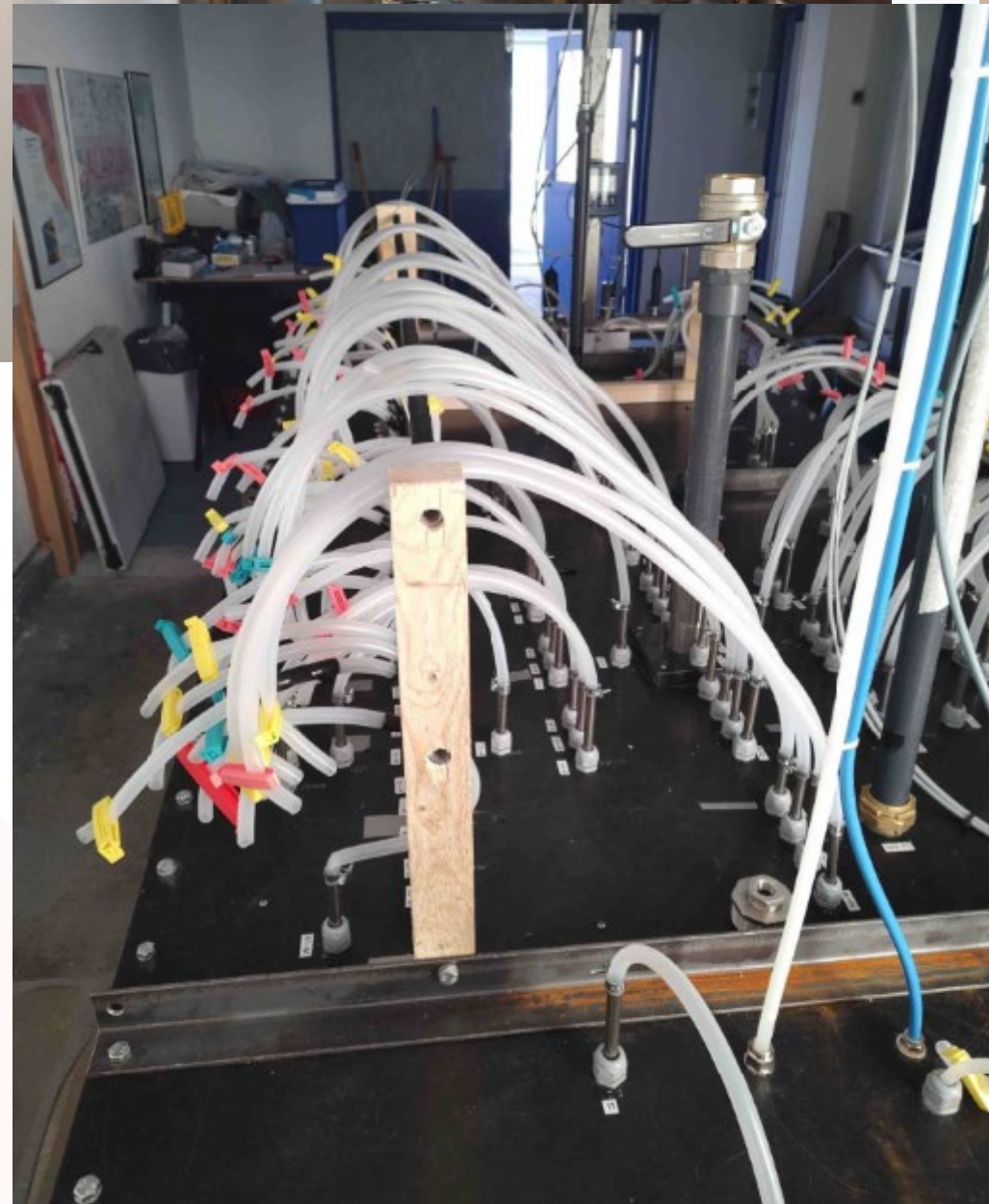
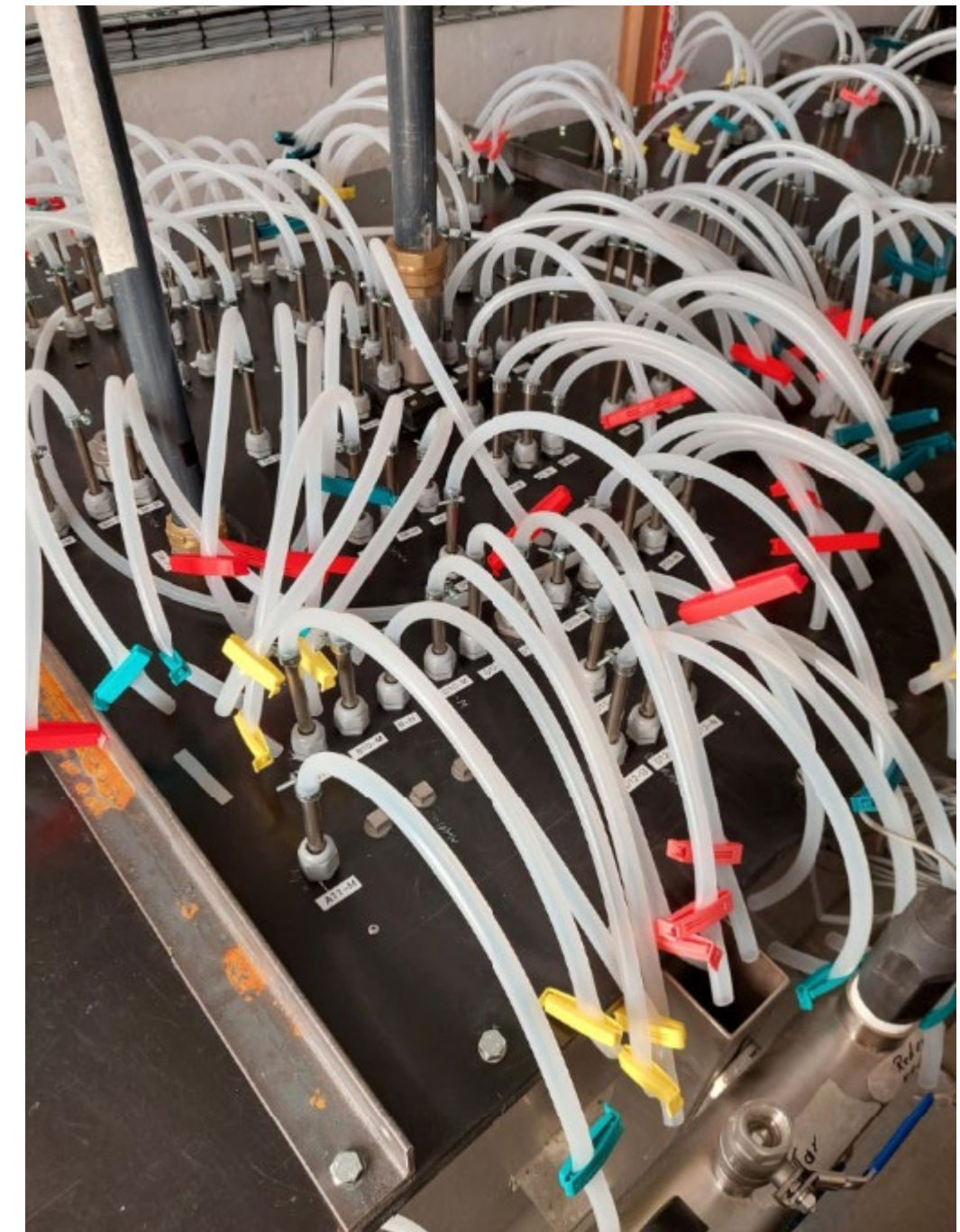
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# Sandbox Experiment - an artificial confined aquifer

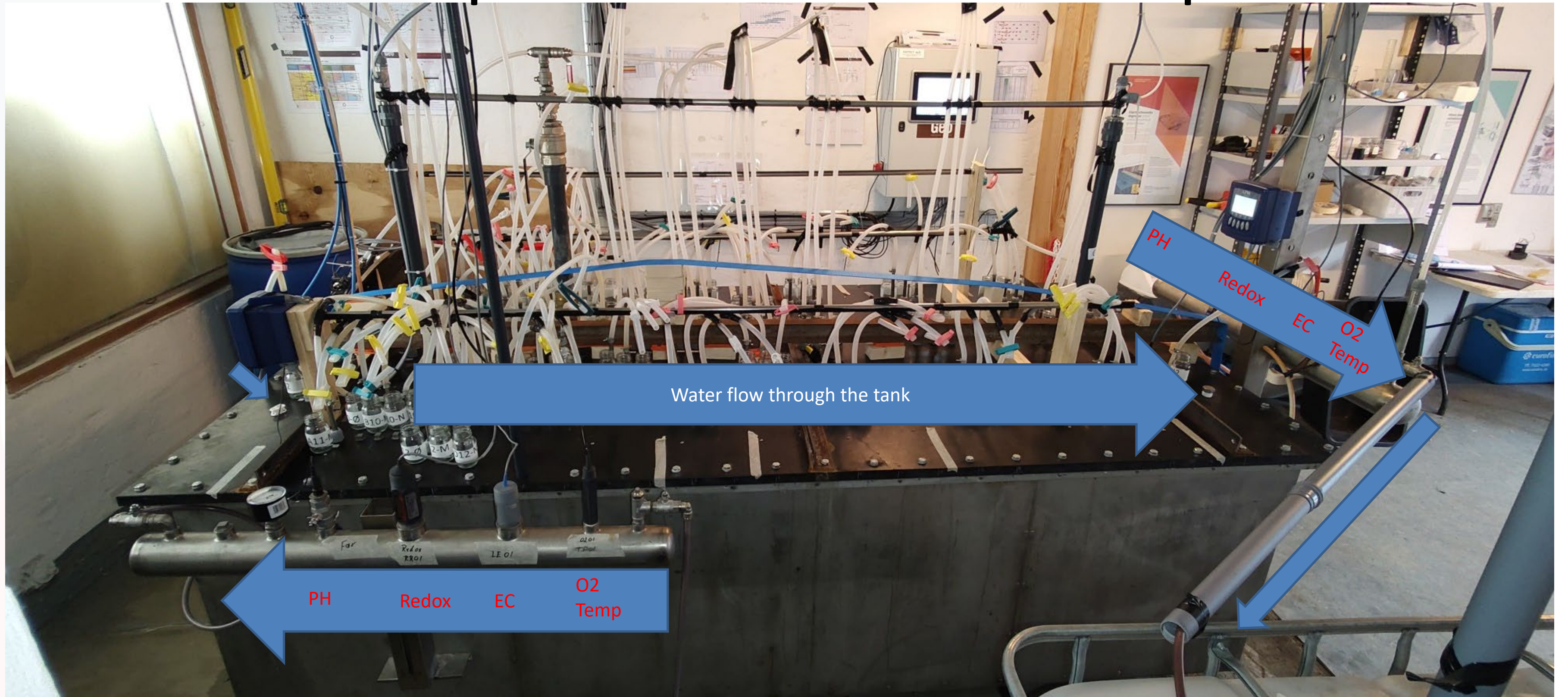




# Sandbox Experiment - an artificial confined aquifer



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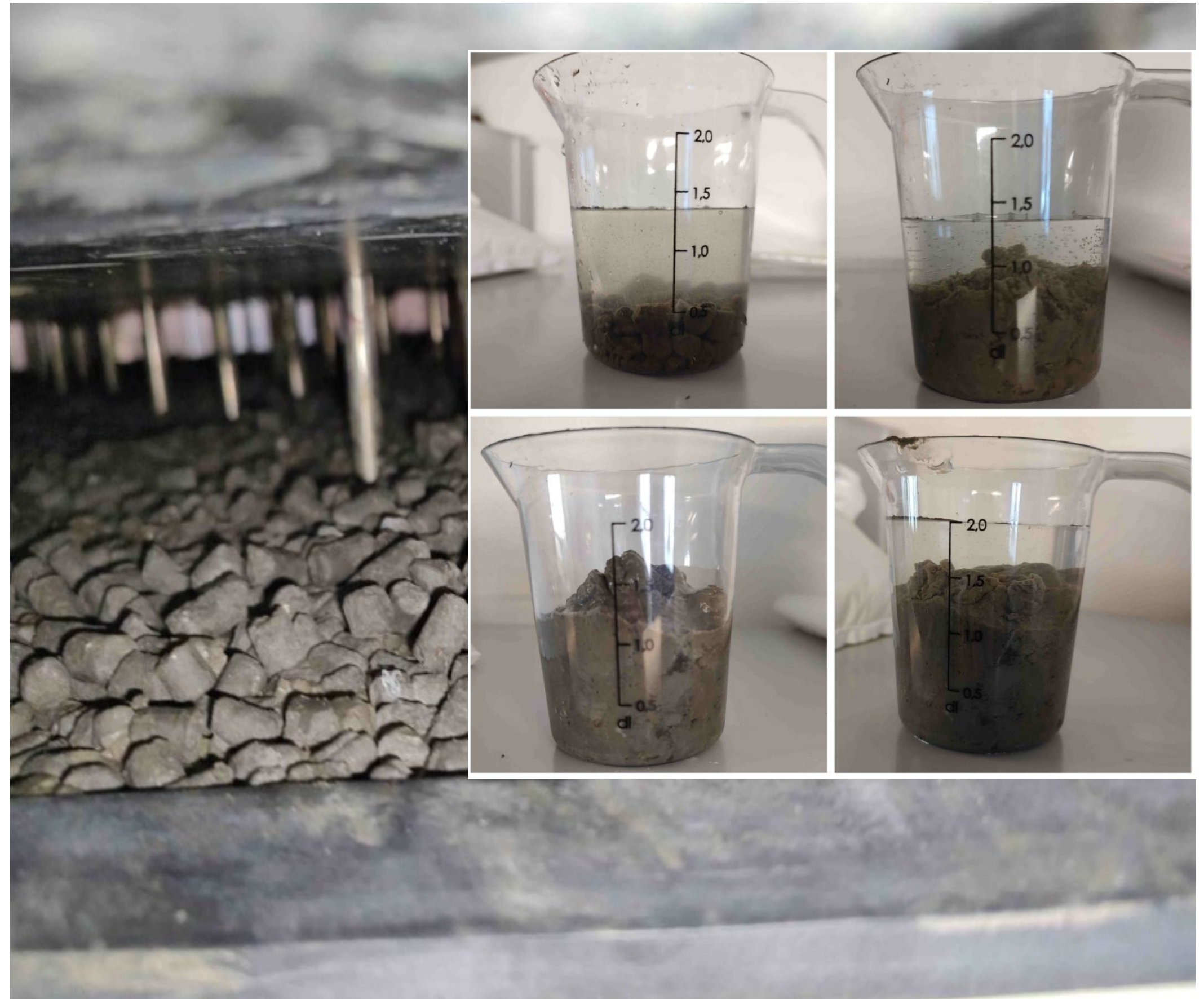


# Hydraulic tests 1.0

- Measuring the water columns across the tank
- **Hydraulic conductivity is much lower than the one predicted from grain size curves**
- Performing Spike tracer

Adding salt to the inlet chamber - **NO salt is entering the sand...** it shortcutting below the lid...

## Lifting the lid and adding bentonite below the lid



# Hydraulic tests 2.0

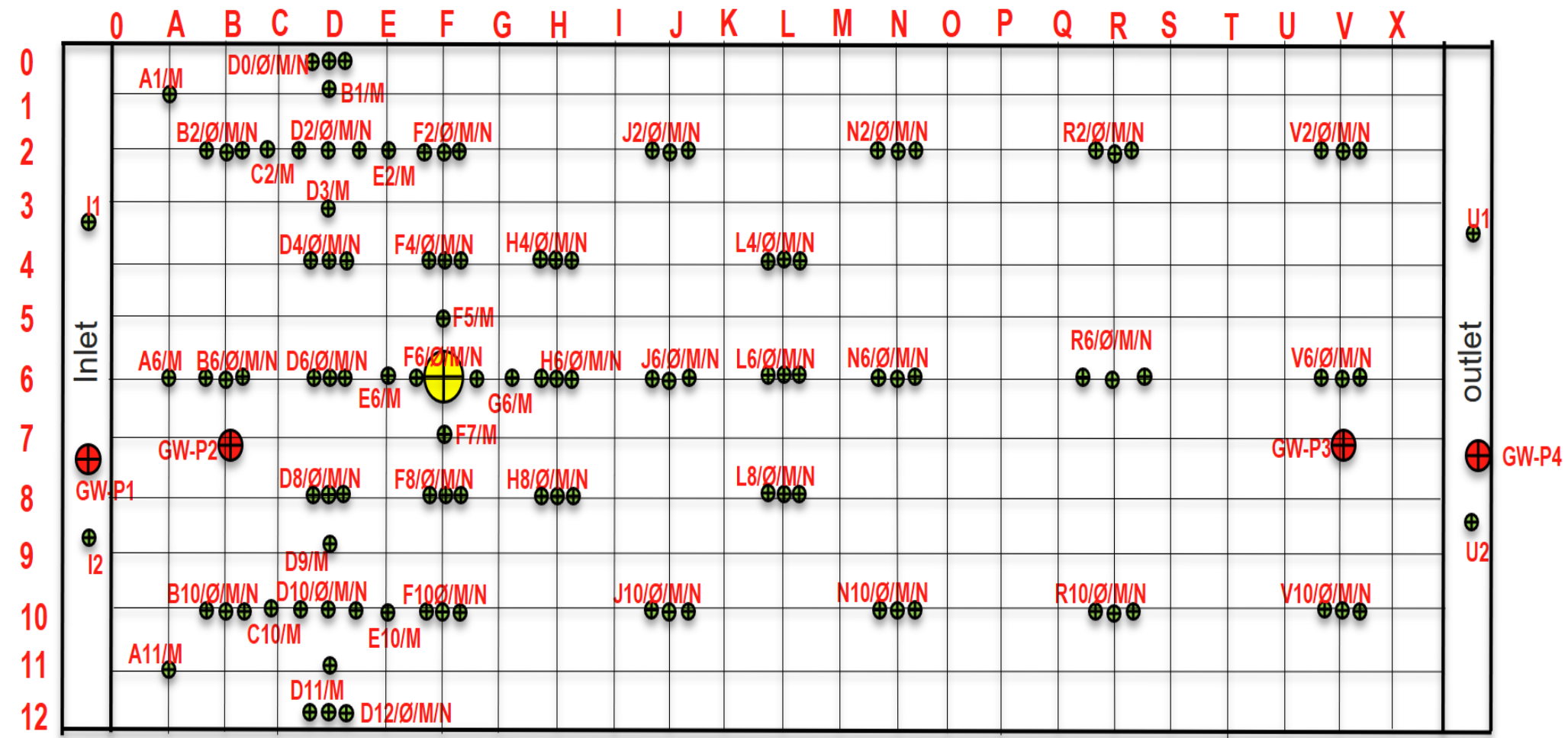
- Measured the water columns across the tank to determine the hydraulic conductivity
  - **Hydraulic conductivity perfectly matches the one predicted from grain size curves**
- Performed a piston spike tracer with NaCl to implement in modelling
  - Adding NaCl to the inlet and pushing it through the sand
  - The brine seems to flow a bit faster in the lower sections of the tank (not observed in the hydraulic tests and it is well fitted by the modelling)

# Modelling of the tank by AMPHOS<sup>21</sup>

SCIENTIFIC AND STRATEGIC ENVIRONMENTAL CONSULTING

The tank seen from above

- The following figures are the tank seen from above

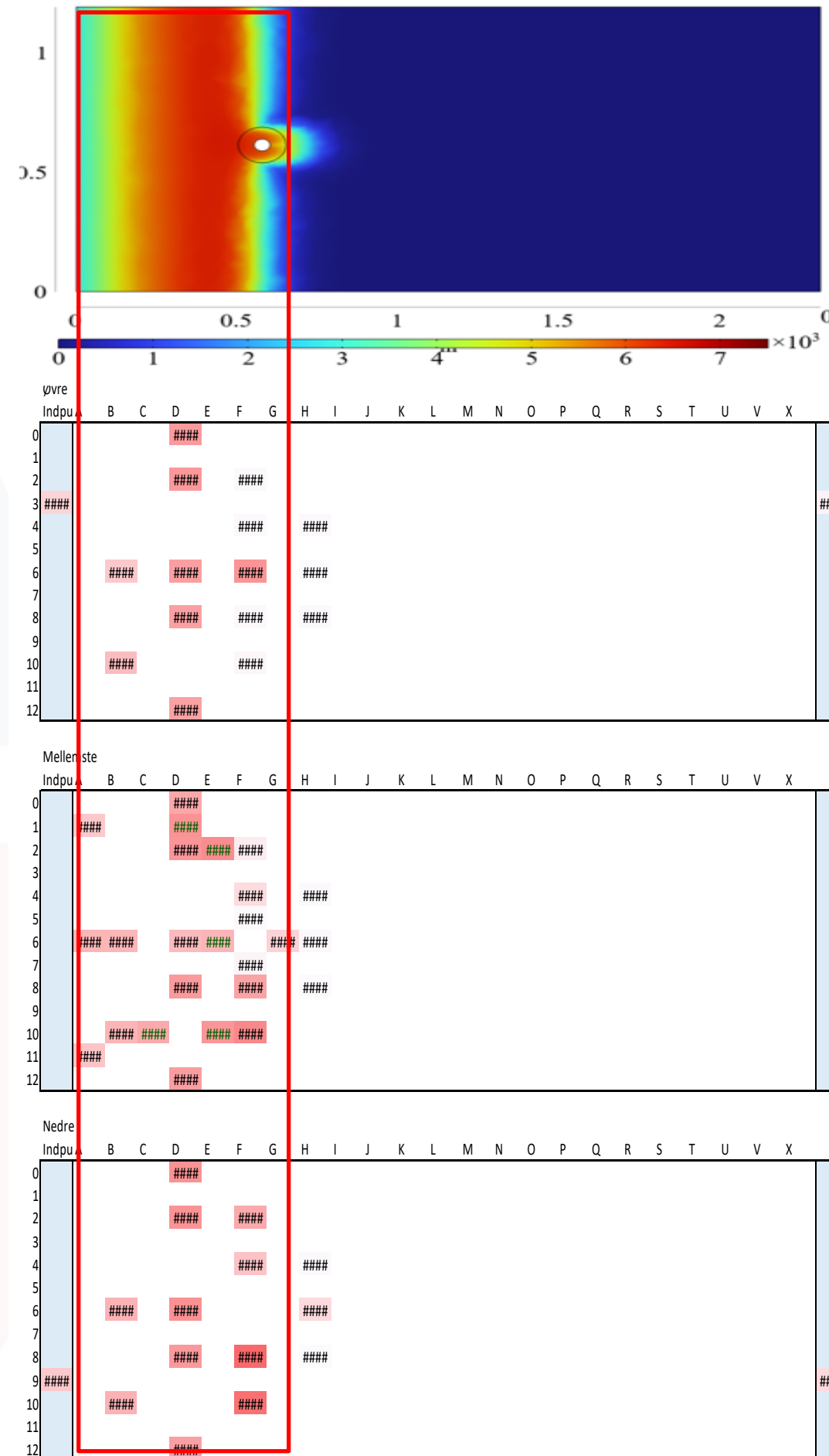


The tank seen from above

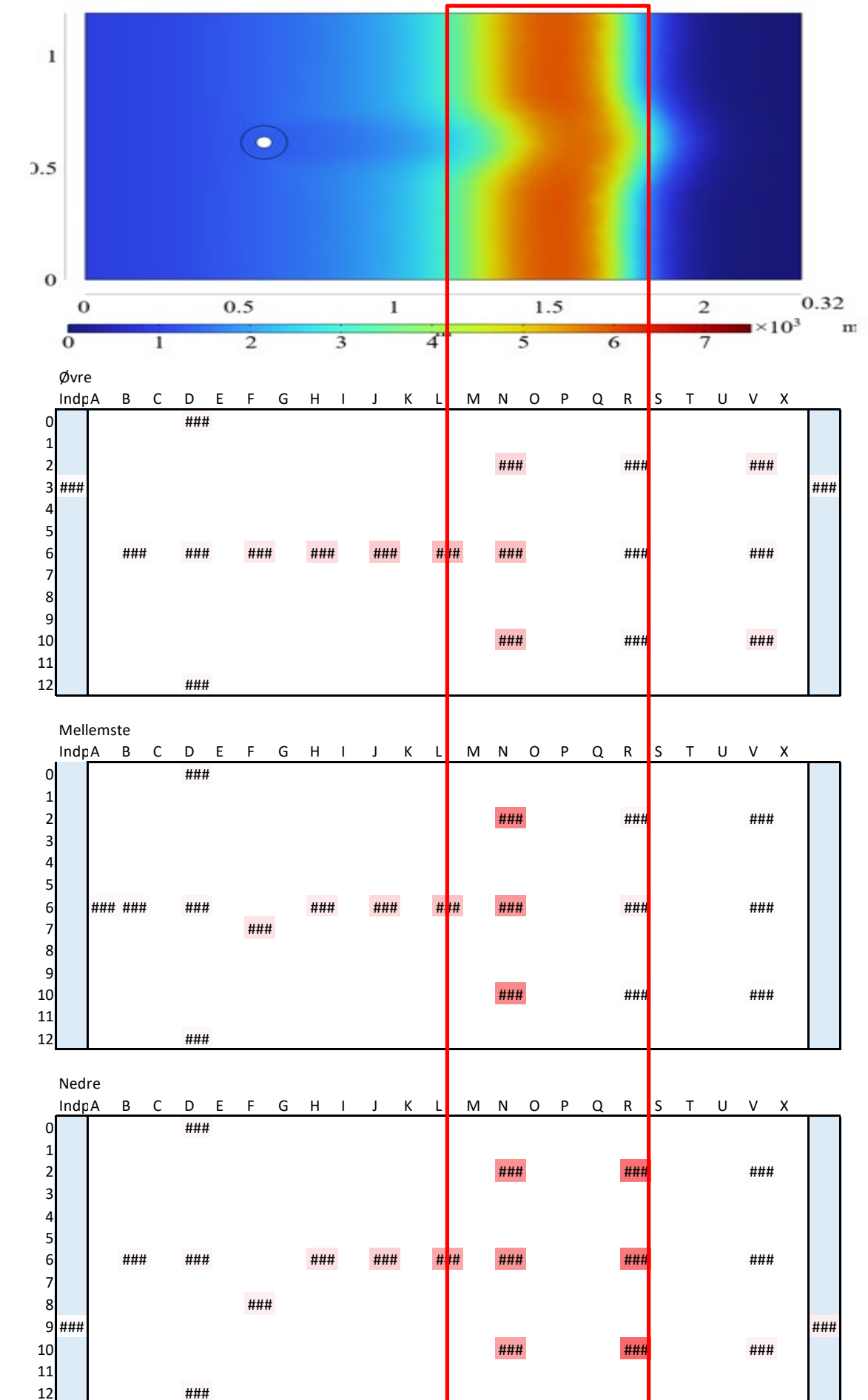
## Hydraulic tests 2.0

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2.5 hours: model comparison with experi



7.7 hours: model comparison with experiments

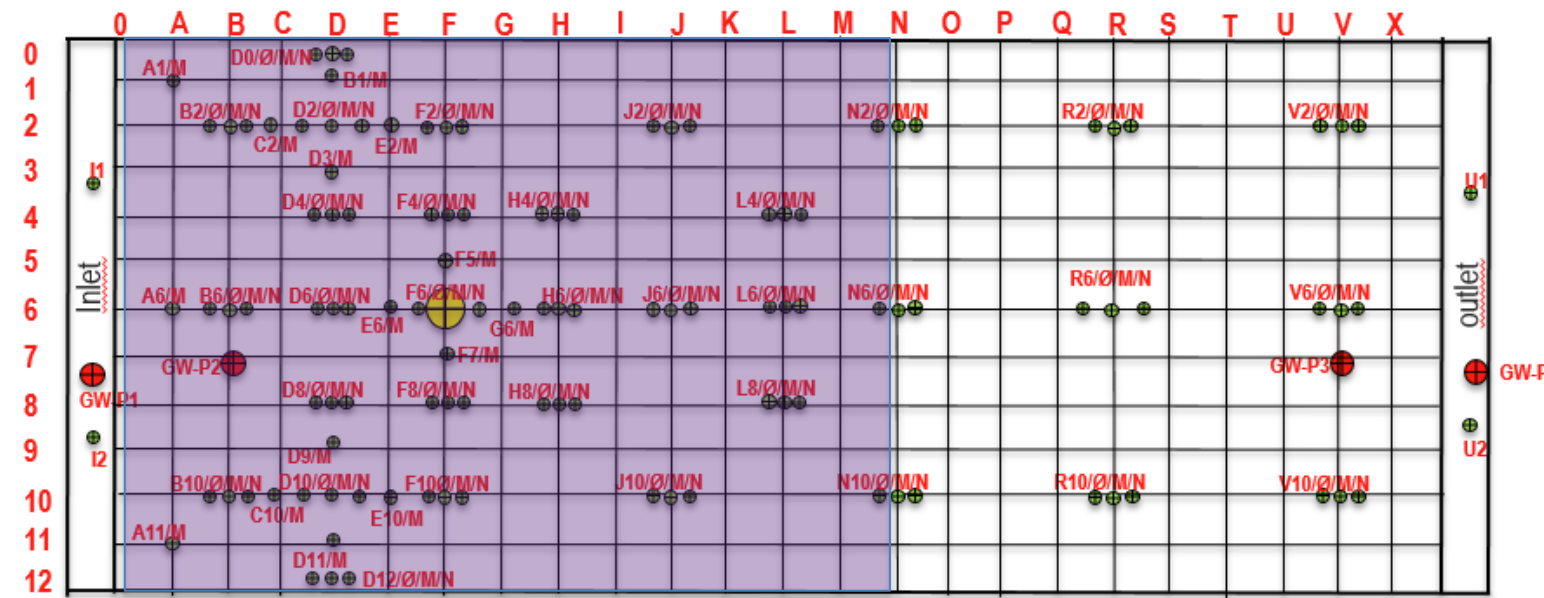


# And now the tank is ready

- We just needed to figure out if the iron will go through the tank or is it oxidised in the system?
- So we test if the sandbox was in equilibrium with the groundwater...



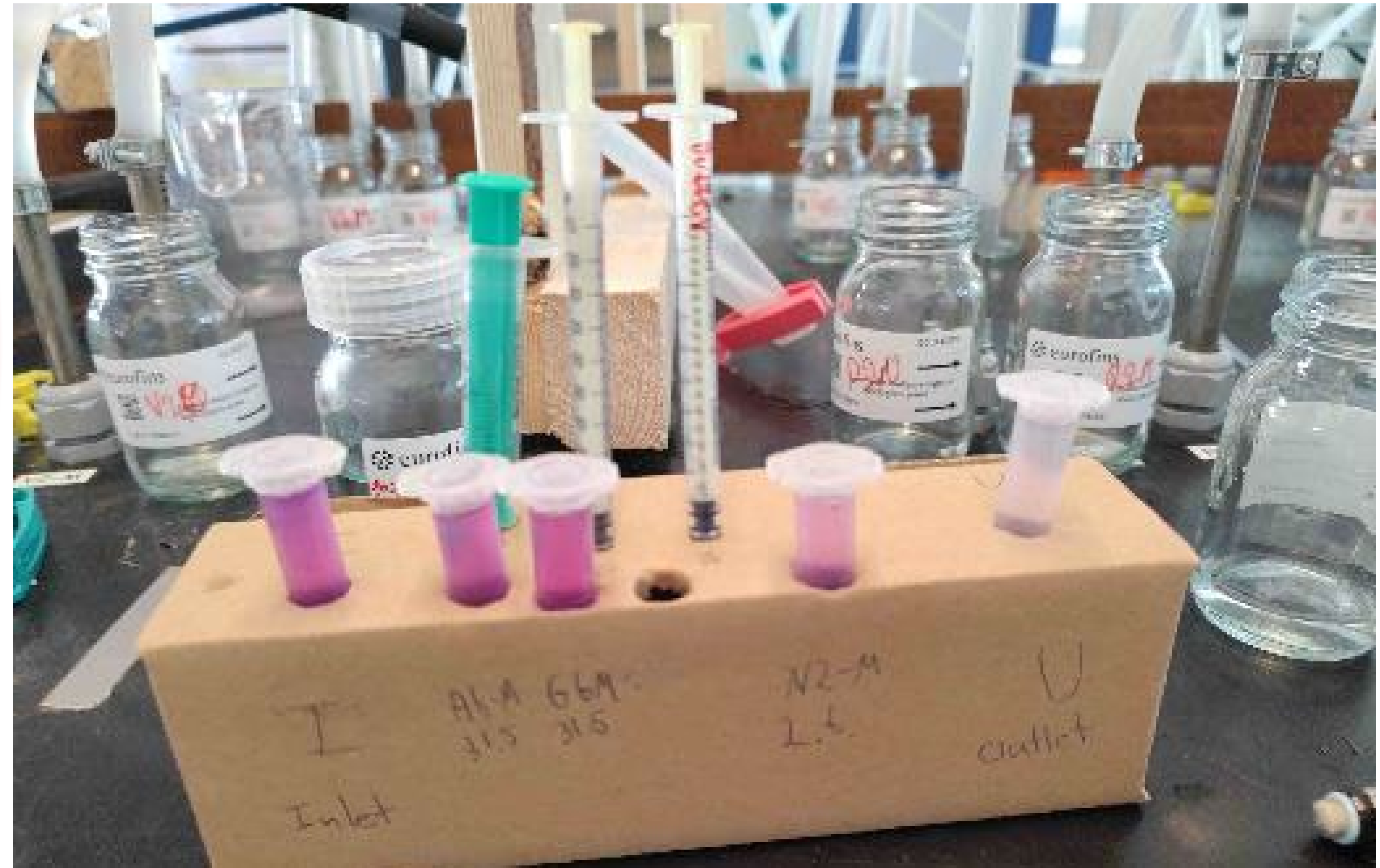
# Iron(ii) in the tank



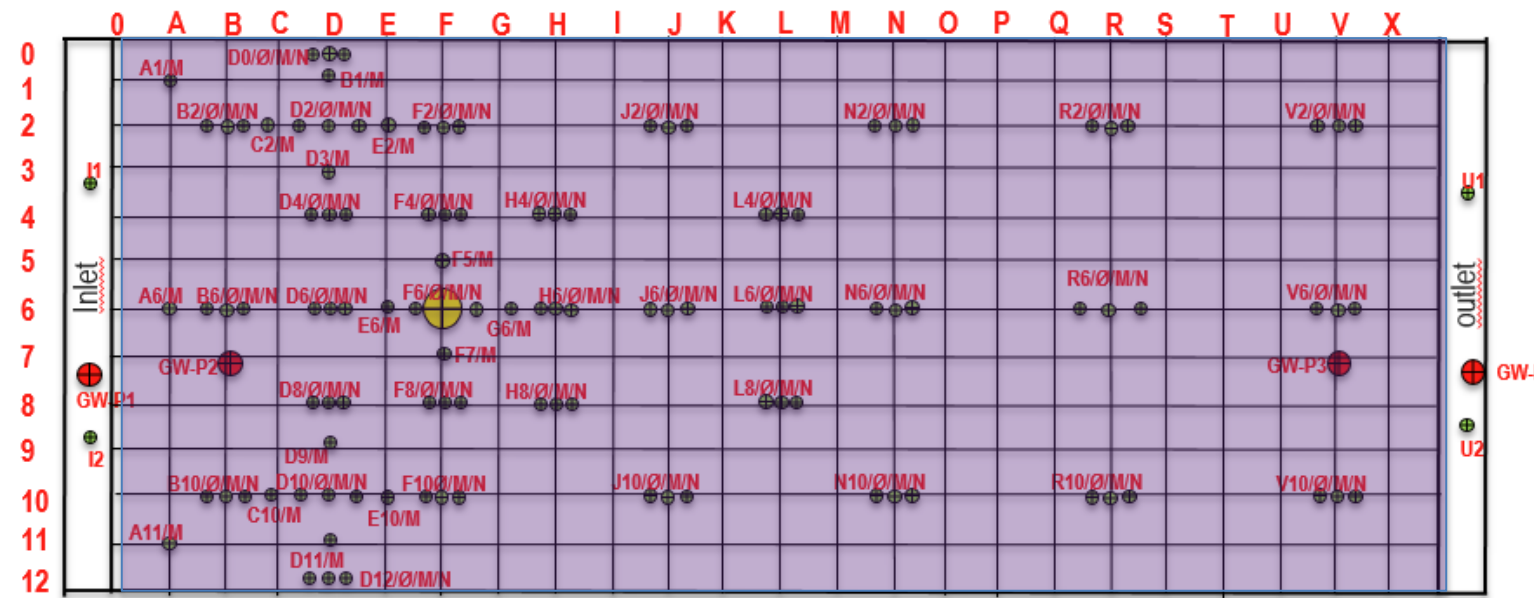
Iron(ii) status after  
Flushing the tank  
with 38 porevolumes

- Status is that the Iron concentrations are in redox equilibrium in the entire tank

June after 20 porevolumens



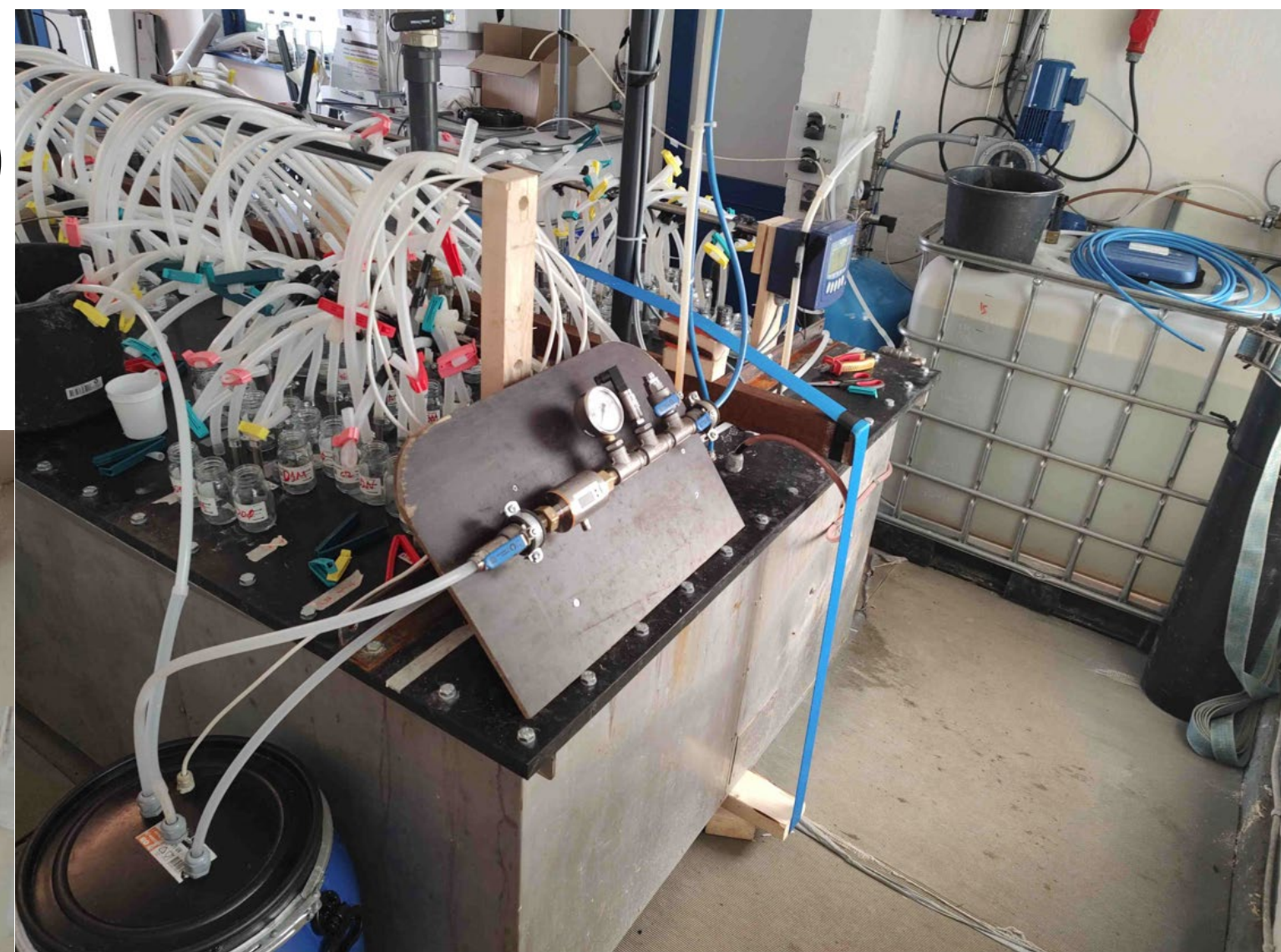
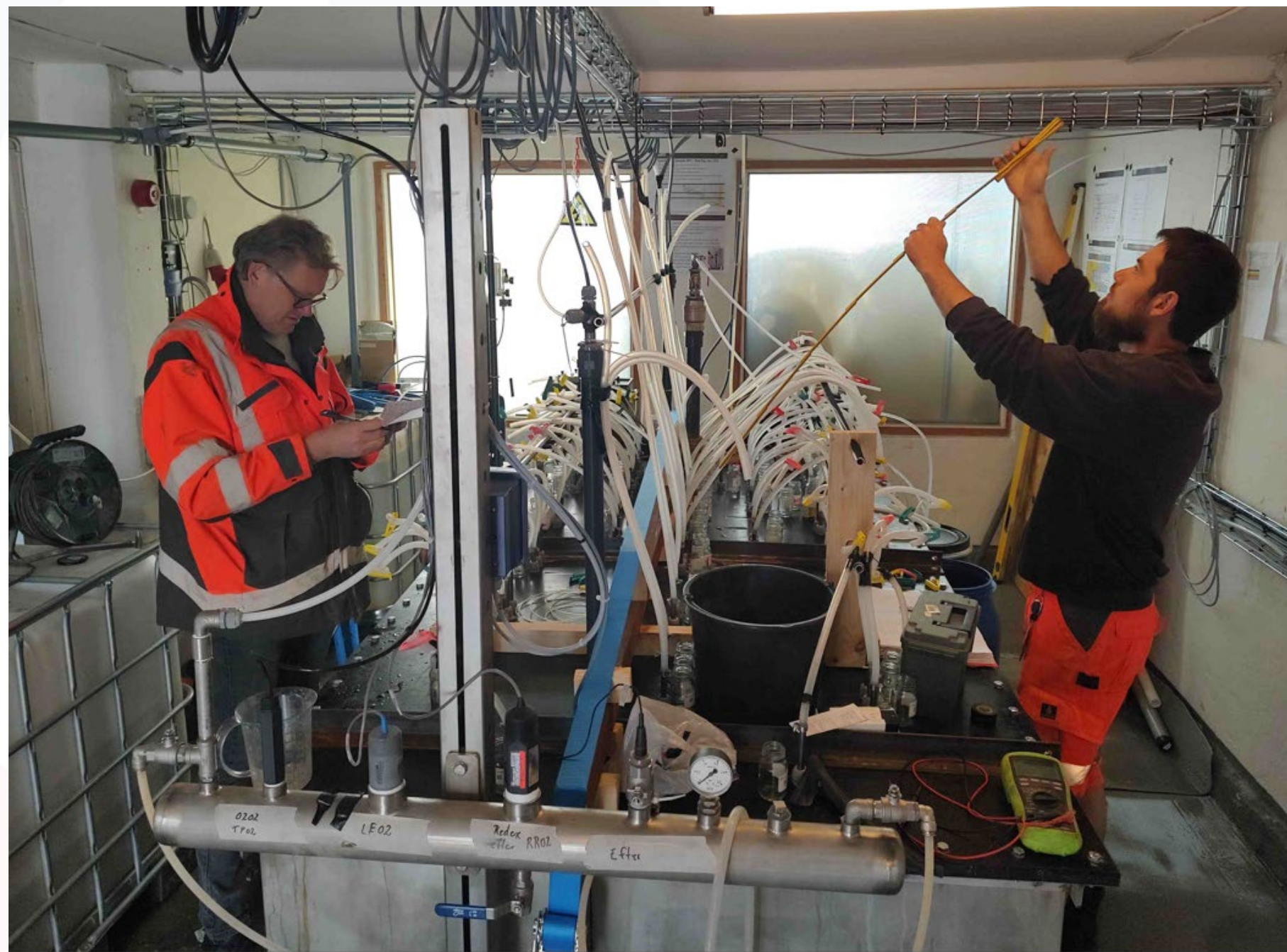
# Iron(ii) in the tank



Iron(ii) status after  
Flushing the tank  
with 65 porevolumes

- This gave another problem – as the Iron starts to precipitate when it passes our vacuum breaker after the outlet manifold our tubing started to clog...

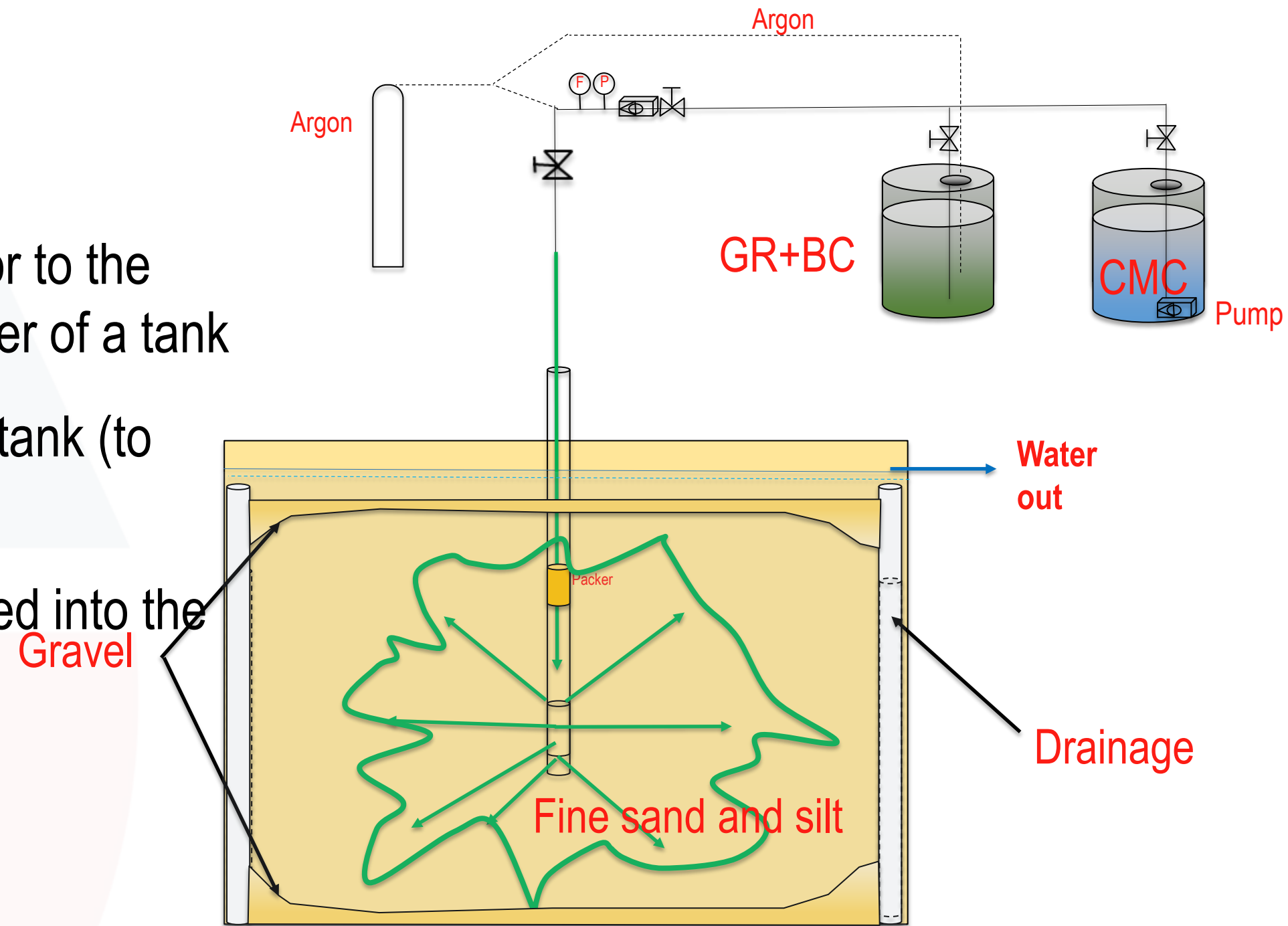
## Testing our injection setup In the tank





# Quick'n dirty Injection tests in Intermediate Bulk Container (IBC)

- Done to test the injectability prior to the actual injection in the big monster of a tank
- 130L CMC is preinjected to the tank (to ease the flow of GR+BC)
- 130L of GR+BC+CMC is injected into the tank



## 2. pre-injection test tank



# Status and Perspectives

- The tank is ready.
- The Green Rust in large scale quantities is ready thanks to  **ALUMICHEM**
- The BoneChar is soon ready thanks to  UNIVERSITY OF COPENHAGEN
- Planned test injection of GR+BC+CMC in end of september (two weeks time) into the IBC to quality check out injection setup
- Planned injection into the Greencat aquifer end November

-And a special thank to the great Greencat

# And a special thanks to the people in the GreenCat consortium

John Bastrup

Knud Dideriksen

Christian N. Albers

Shikhar Nilabh

Laura Ruiz

Dominique J. Toblerd

Hans Christian Bruun Hansen

Nina Tuxen

# Thank you for your attention

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Innovation Fund Denmark

