Møde i ATV Jord og Grundvand om PFAS i jord og grundvand - hvad har vi lært?

Monitering og modellering af PFAS skæbne i umættet zone
SCENARIOS

Knud Erik Klint[1], John Bastrup [1], Samuel Kolade[2], Ofer Dahan[2] Nadia Bali[3], Christos Tsakiroglou [3]

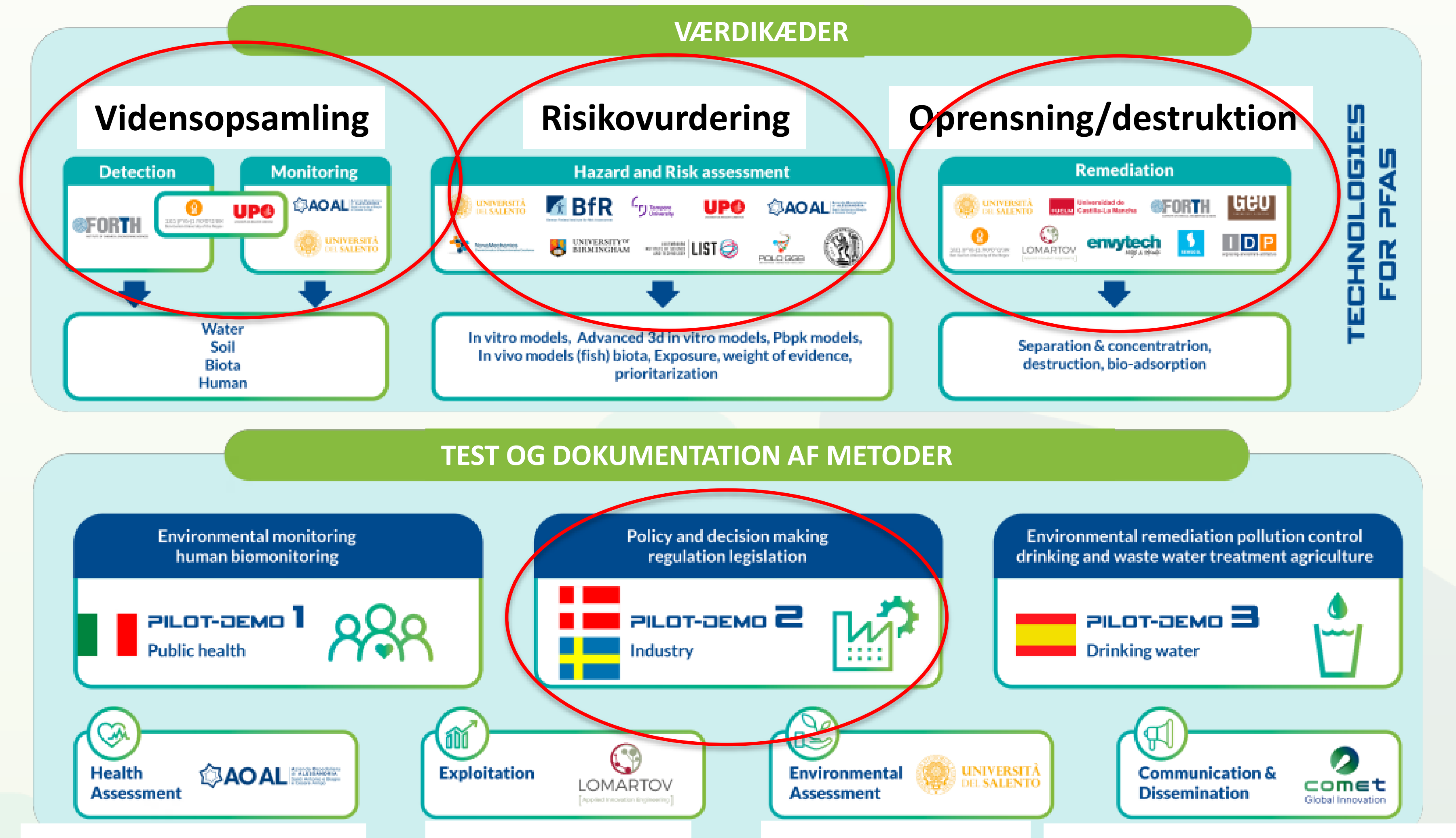
[1]GEO, Copenhagen, Denmark

[2]Zuckerberg Institute for Water Research, Ben-Gurion University of the Negev, Israel

[3]Foundation for Research and Technology Hellas, Institute of Chemical Engineering Sciences, 26504 Patras, Greece

This project has received funding from the H2020 programme under Grant Agreement No. 101037509

Baggrund: PFAS undersøgelser SCENARIOS Horizon 2020 projekt



VÆRDIKÆDER

Vidensopsamling

Risikovurdering

Oprensning/destruktion

Water
Soil
Biota
Human

In vitro models, Advanced 3d in vitro models, Pbpk models,
In vivo models (fish) biota, Exposure, weight of evidence,
prioritarization

Separation & concentratrion,
destruction, bio-adsorption

TEST OG DOKUMENTATION AF METODER

Environmental monitoring
human biomonitoring

PILOT-DEMO 1
Public health

Policy and decision making
regulation legislation

PILOT-DEMO 2
Industry

Environmental remediation pollution control
drinking and waste water treatment agriculture

PILOT-DEMO 3
Drinking water

Sundhedsvurdering

Markedsføring

Miljøvurdering

Vidensdeling/Implementering

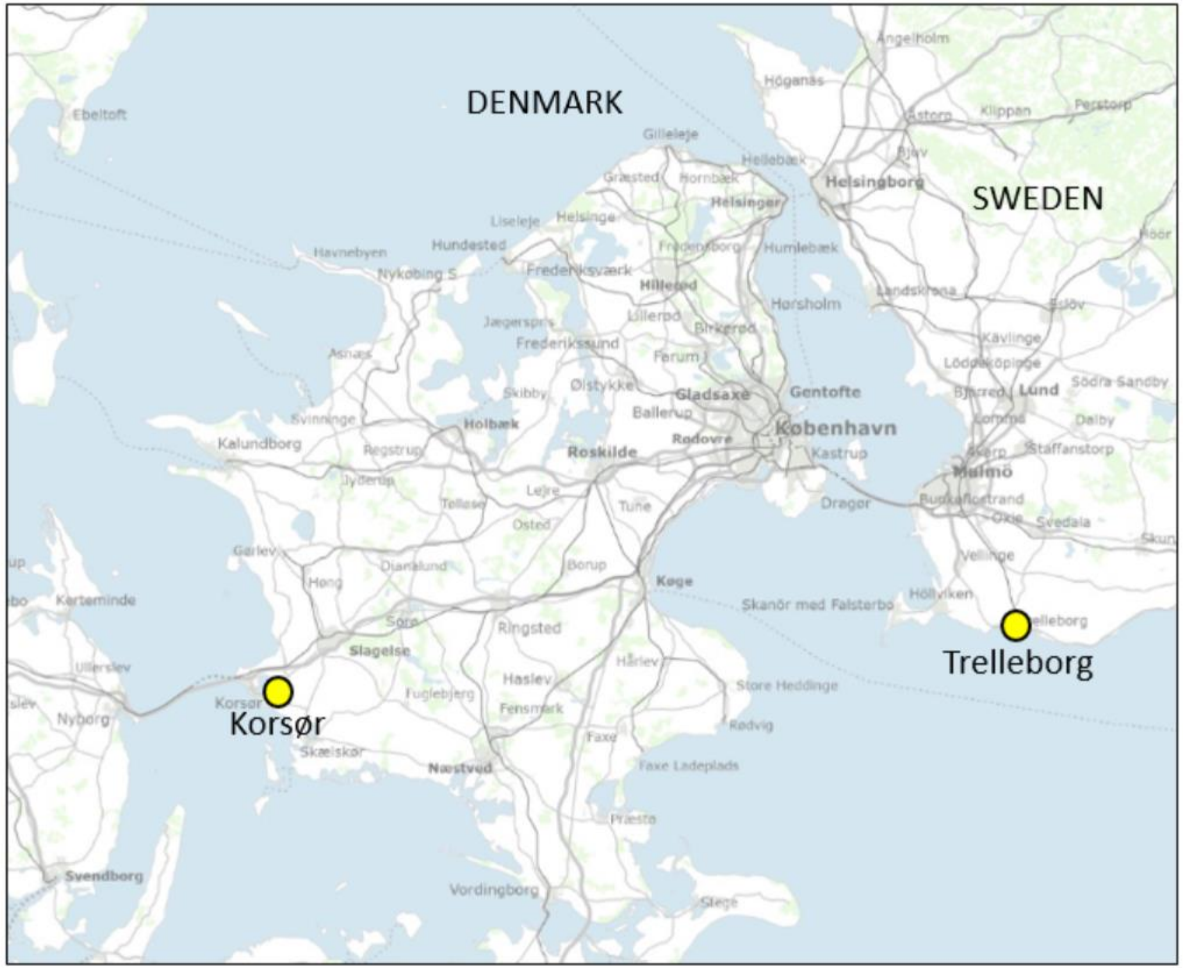
Scenarios pilotområder i Skandinavien

- **Korsør Rescue center (Danmark)**

smeltevandssand/silt/ler
morænesand, i issøbakke

- **Trelleborg brandøvelses plads (Sverige)**

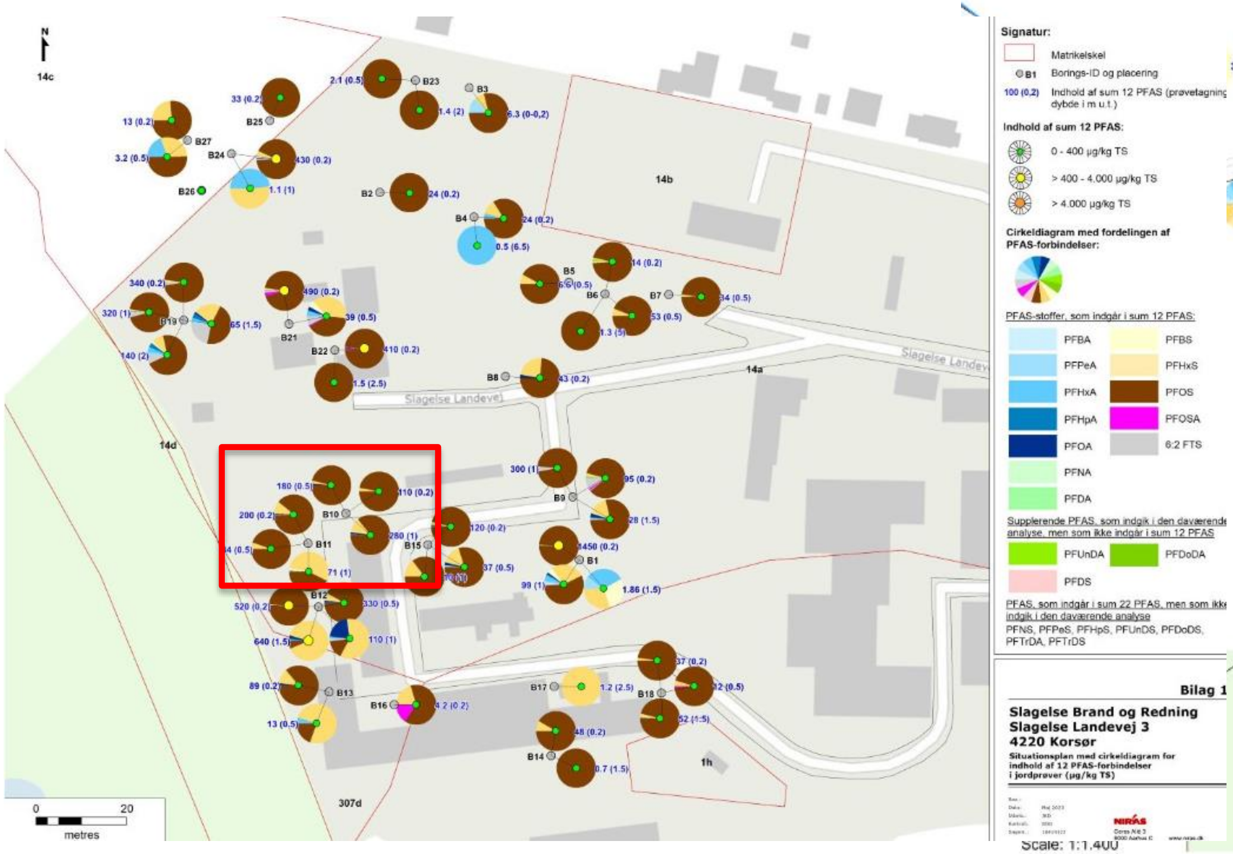
Losseplads på moræneler og smeltevandssand i ådal



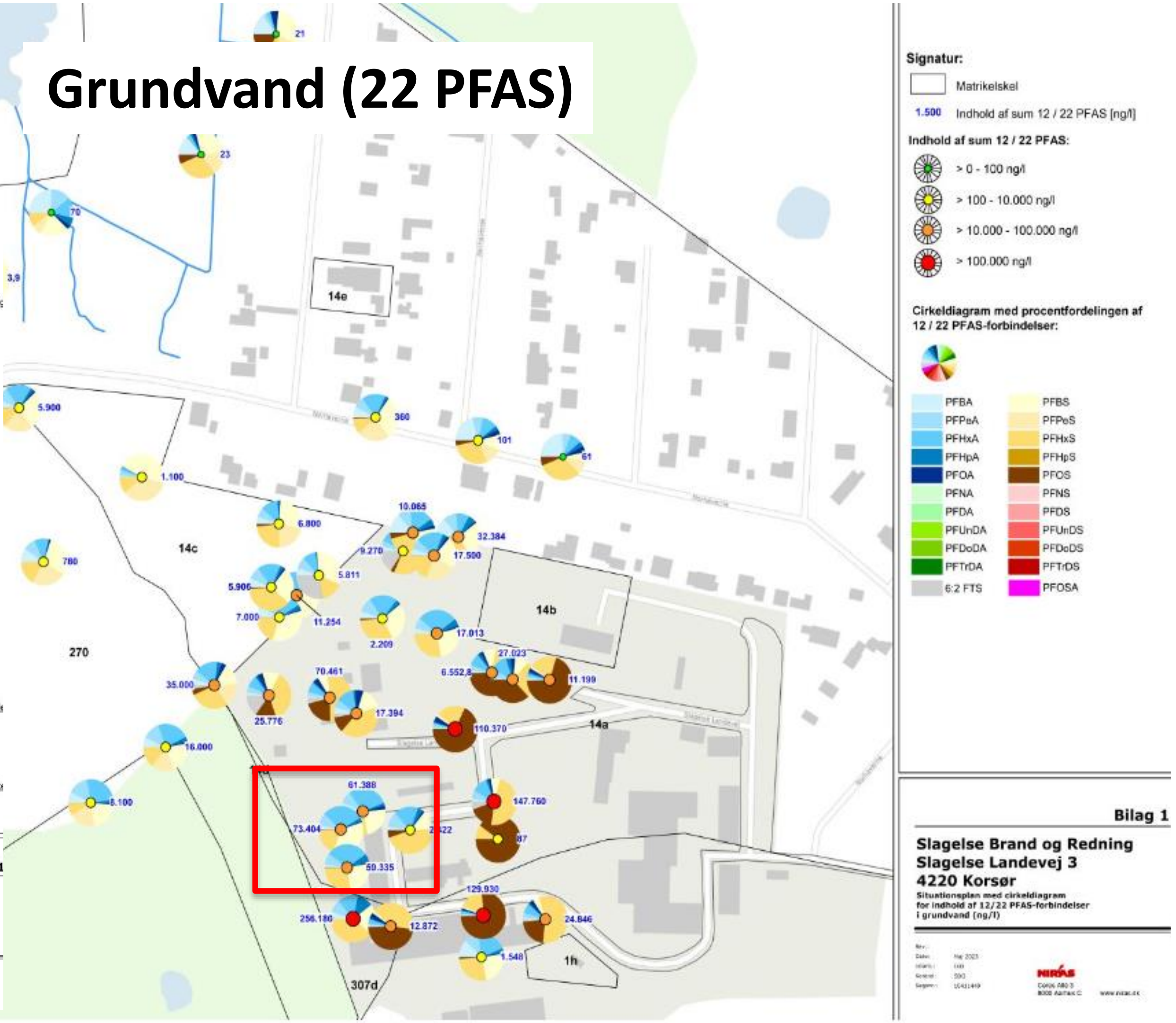
Pilot 2A RESC Korsør Sep 2022

Step 1 granskning af eksisterende data og udpegning af forsøgsområde

Jord (12 PFAS)



Grundvand (22 PFAS)



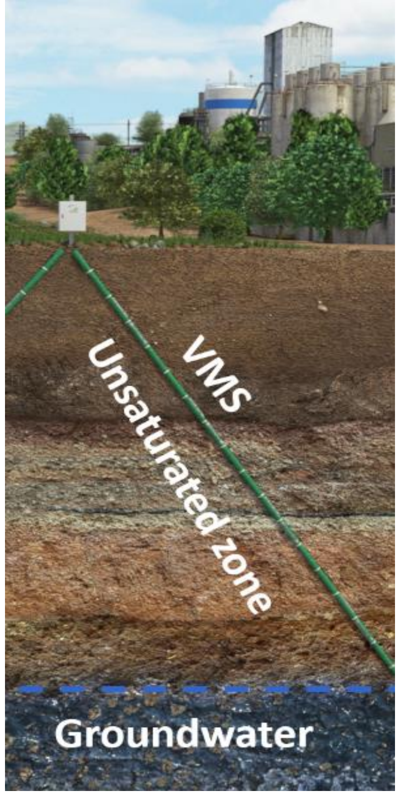
Ref https://www.danishsoil.org/media/test_sites/11/images/Fingerprints_PFAS_in_water_samples.jpg

Strategi for undersøgelser af PFAS spredning igennem den umættede zone på en forurenet grund

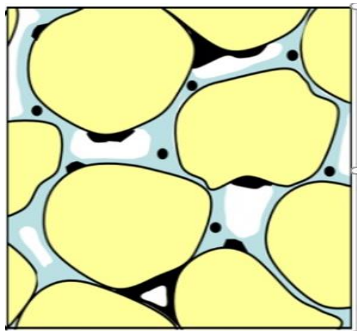
Pilot område:

Prøvetagning og Monitering

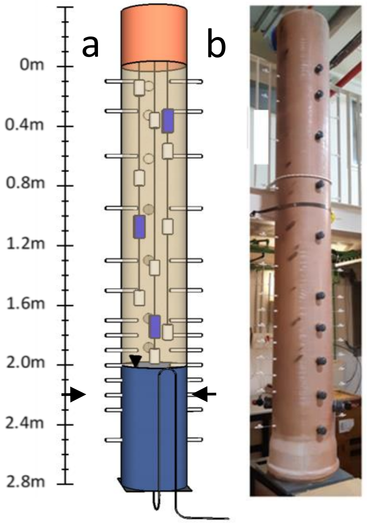
Tidsserier af nedbør, vand og jord data i 2 år



Pore scale study

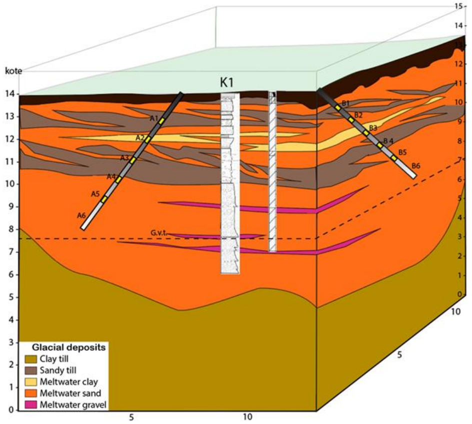


Lab scale study

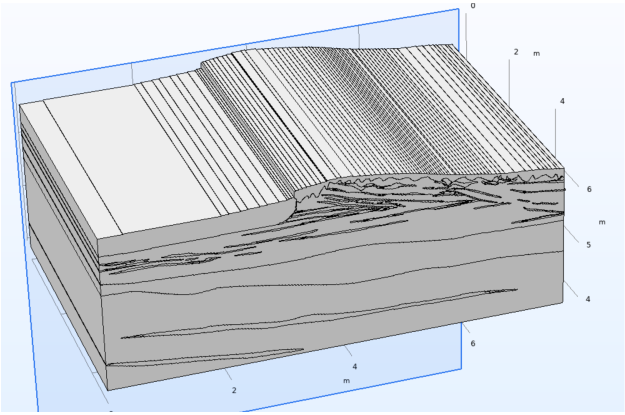


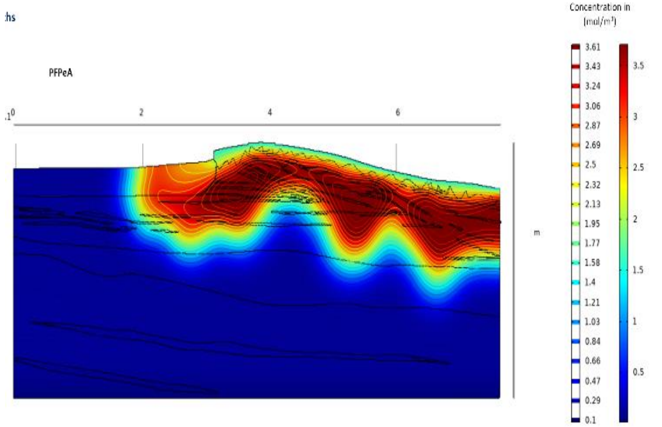
Parameterestimering

- Konceptuel model
- jordparametre
- Nedbør
- Infiltration
- PFAS koncentration
- Udvaskning/binding
- Transport i matrix og makropore



Modellering/Risikovurdering

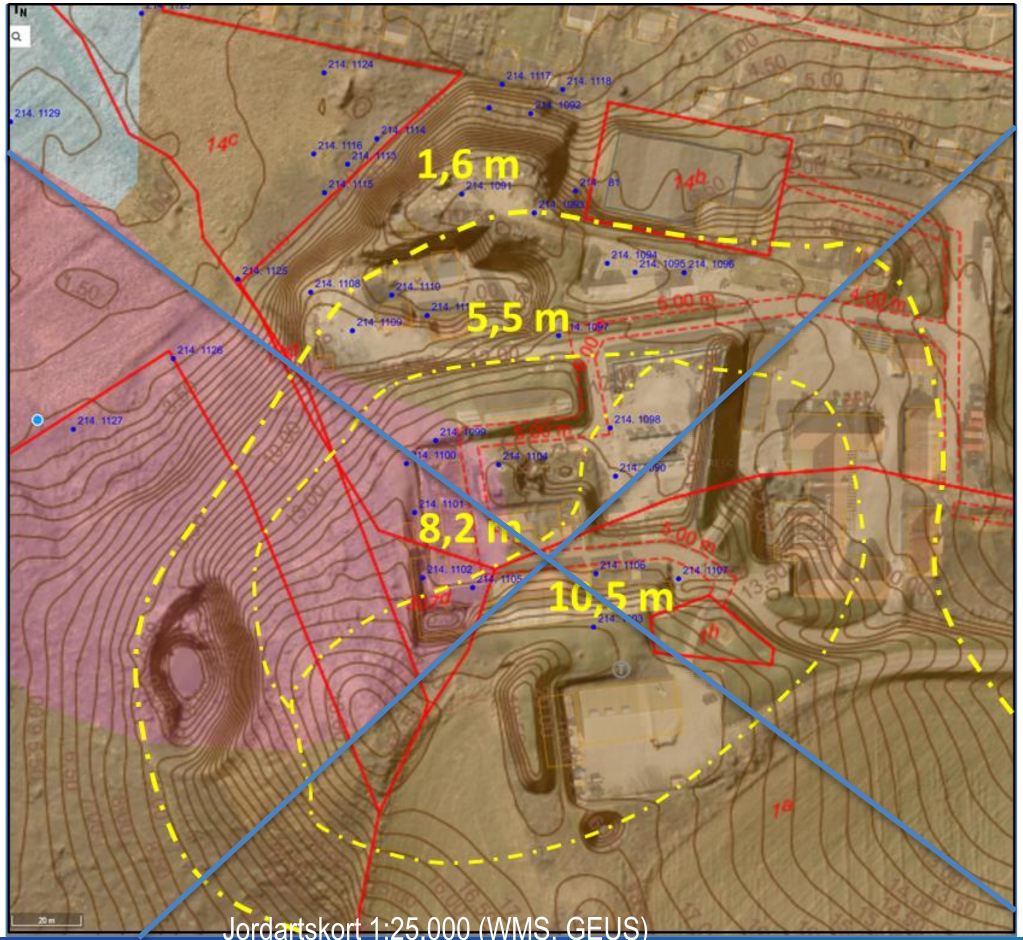




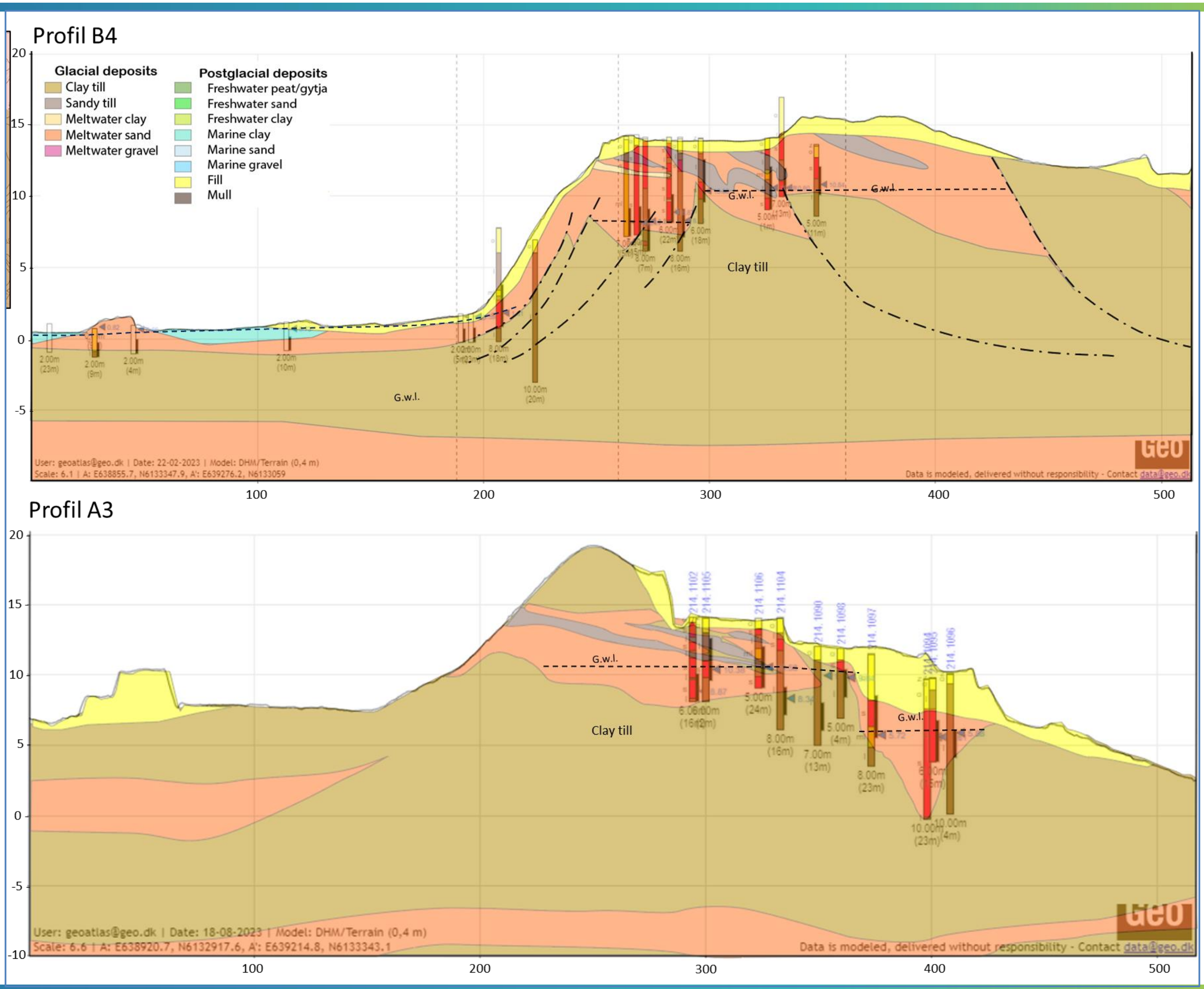
Multi skala 3-D geologisk modellering og monitering

Opstilling af Konceptuel ”site skala” geologisk forståelses model

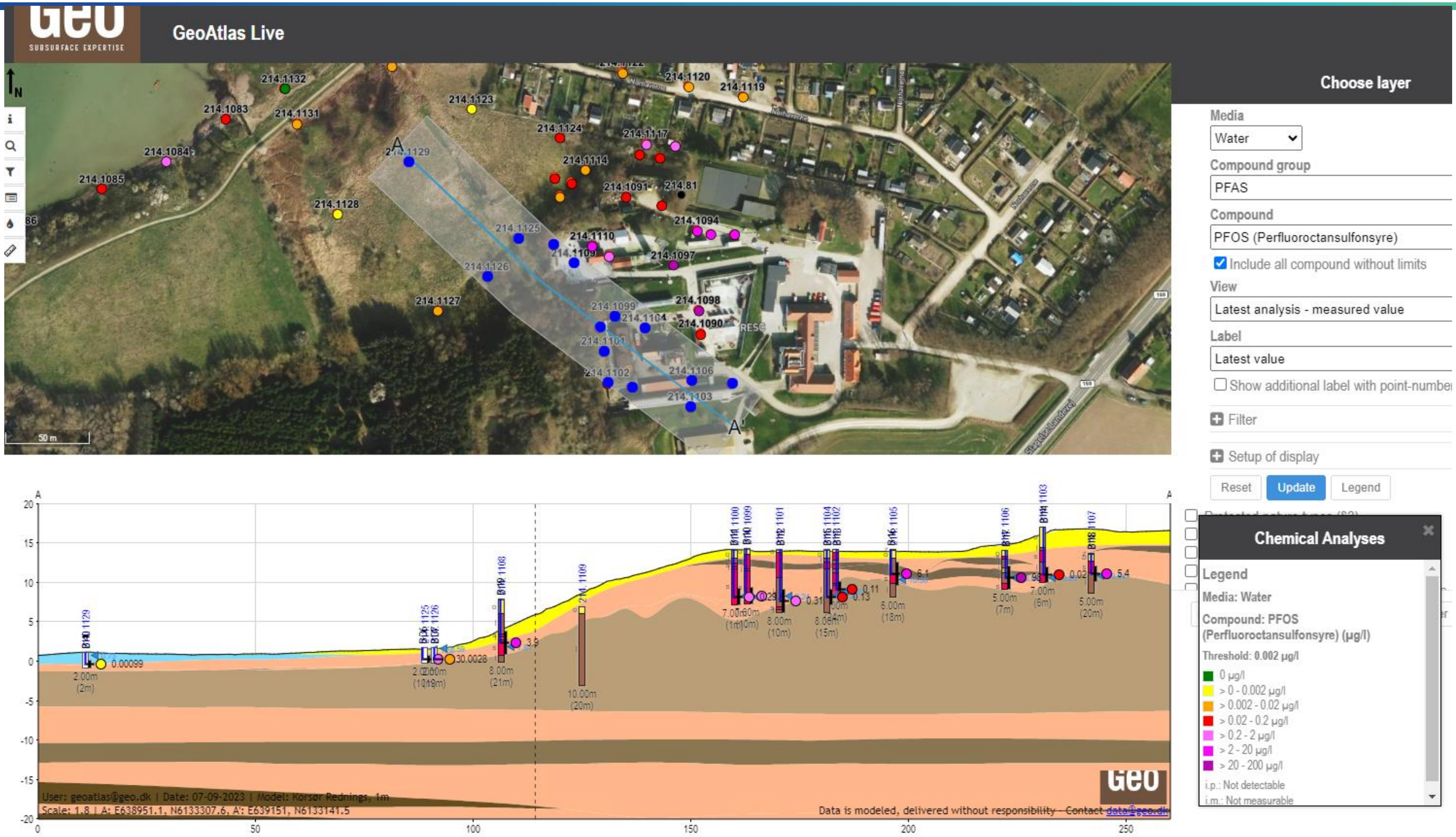
Flere separate grundvandsmagasiner med individuel gv.sp.



Jordartskort 1:25.000 (WMS, GEUS)



Dynamisk udstiling af PFAS data direkte i GeoAtlasLive



Choose layer

Media: Water

Compound group: PFAS

Compound: PFOS (Perfluoroctansulfonsyre)

☑ Include all compound without limits

View: Latest analysis - measured value

Label: Latest value

☐ Show additional label with point-numbe

Filter

Setup of display

Reset | Update | Legend

Chemical Analyses

Legend

Media: Water

Compound: PFOS (Perfluoroctansulfonsyre) (µg/l)

Threshold: 0.002 µg/l

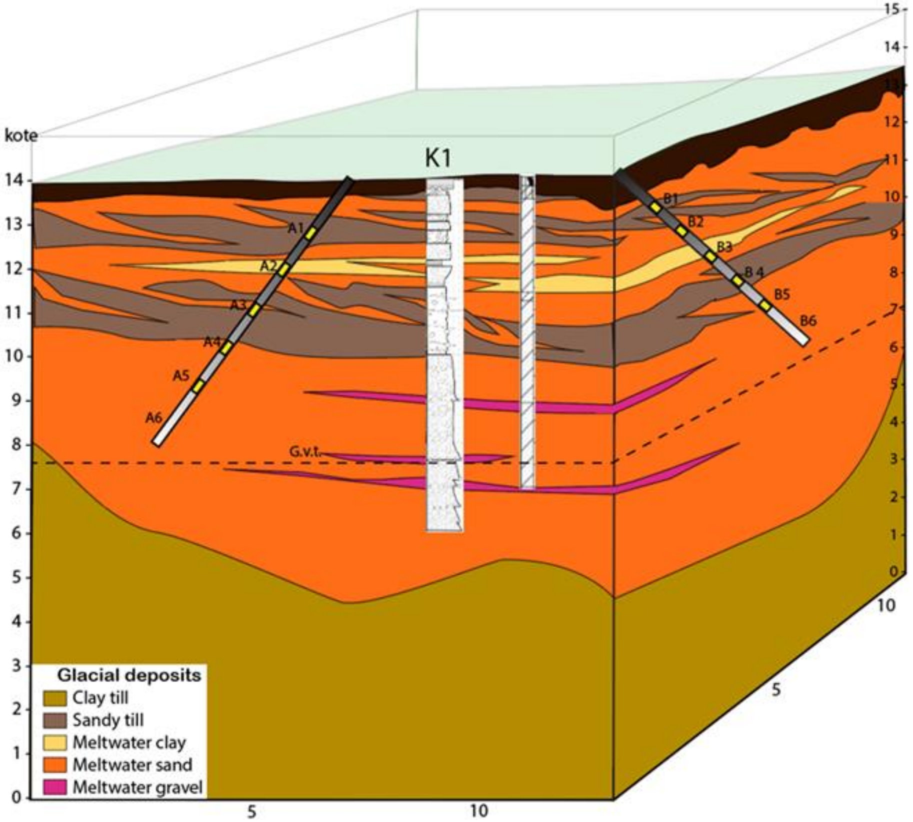
- 🟩 0 µg/l
- 🟨 > 0 - 0.002 µg/l
- 🟧 > 0.002 - 0.02 µg/l
- 🟥 > 0.02 - 0.2 µg/l
- 🟪 > 0.2 - 2 µg/l
- 🟪 > 2 - 20 µg/l
- 🟪 > 20 - 200 µg/l

i.p.: Not detectable
i.m.: Not measurable

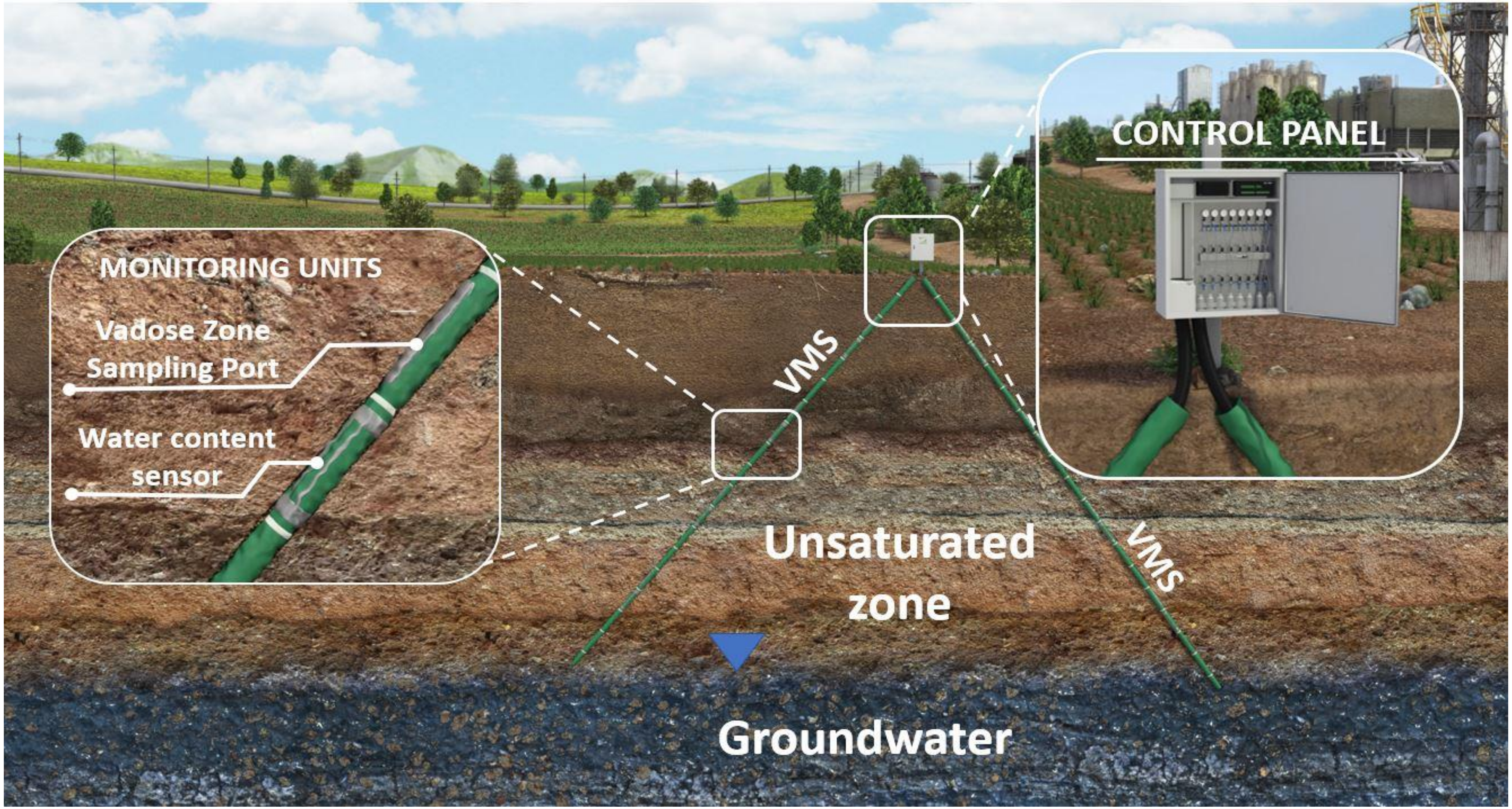
User: geoatlas@geo.dk | Date: 07-09-2023 | Model: Korsør Rednings, 1m
Scale: 1.8 | A: E638951.1, N6133307.6, A': E639151, N6133141.5

Data is modeled, delivered without responsibility - Contact data@geo.dk

Geologisk karakterisering af prøvetagnings-område og opstilling a lokal 3-D model



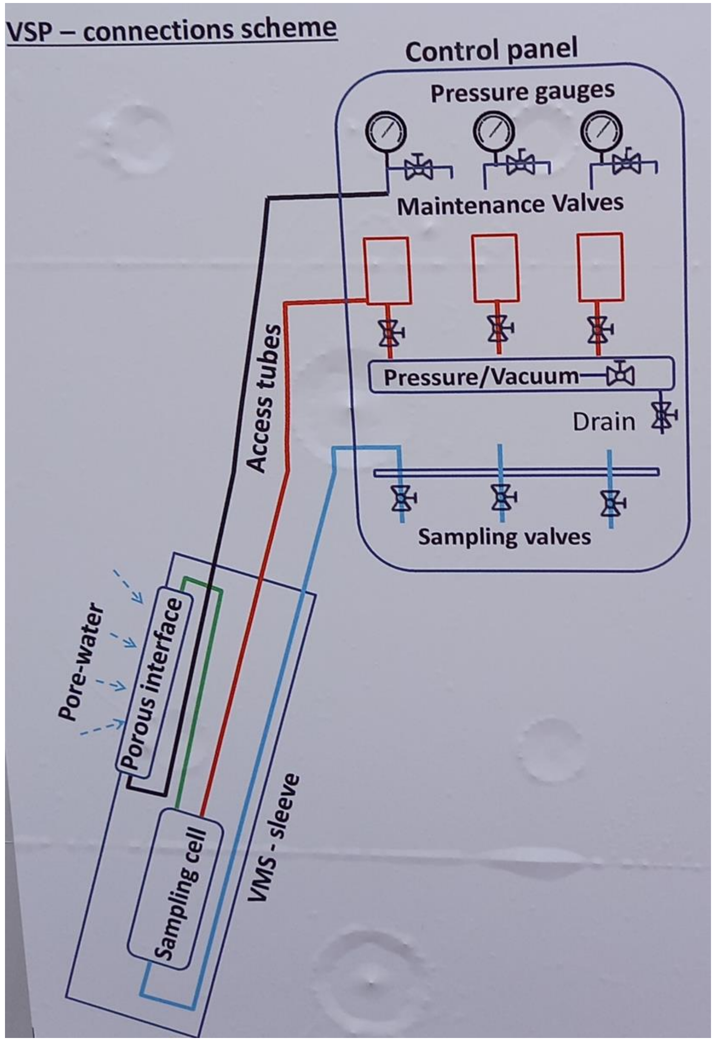
Installering af VMS-anlæg til at monitere tranport af vand og PFAS i den umættede zone.



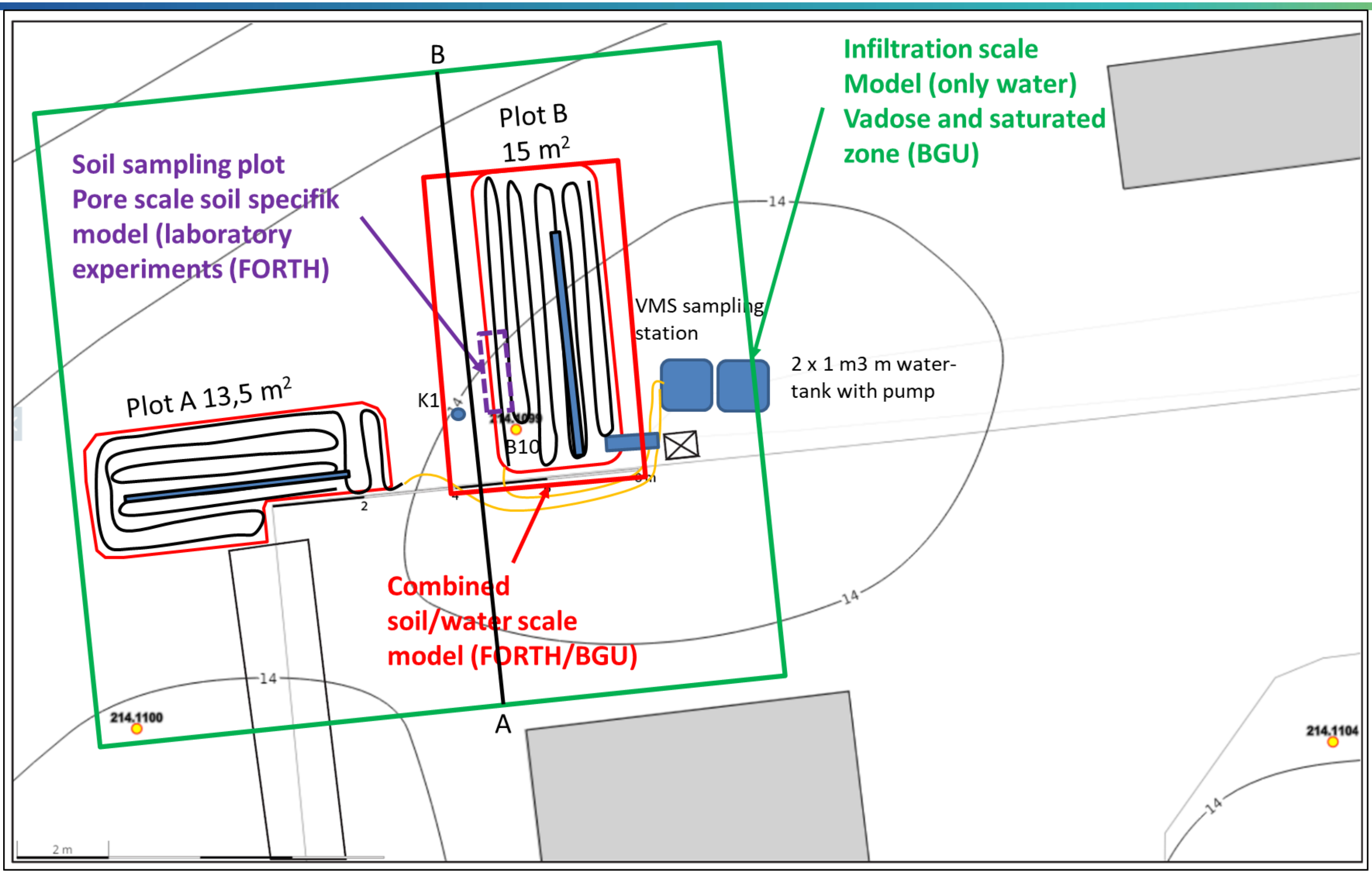
Forberedelse af ”Anakondaen” Moniteringsboring

Installering af ”Anakondaen”

”anakondaen” pumpes op (fyldes med cement) så den forsegler kontakten til indersiden af borehullet dernæst forbindes alle slanger og ledninger til prøvetagningspanelet



Infiltrations eksperiment og supplerende prøvetagning af jord



Soil sampling plot
Pore scale soil specifik model (laboratory experiments (FORTH)

Infiltration scale
Model (only water)
Vadose and saturated zone (BGU)

Combined soil/water scale model (FORTH/BGU)

Prøvetagning af jordprøver

0-1

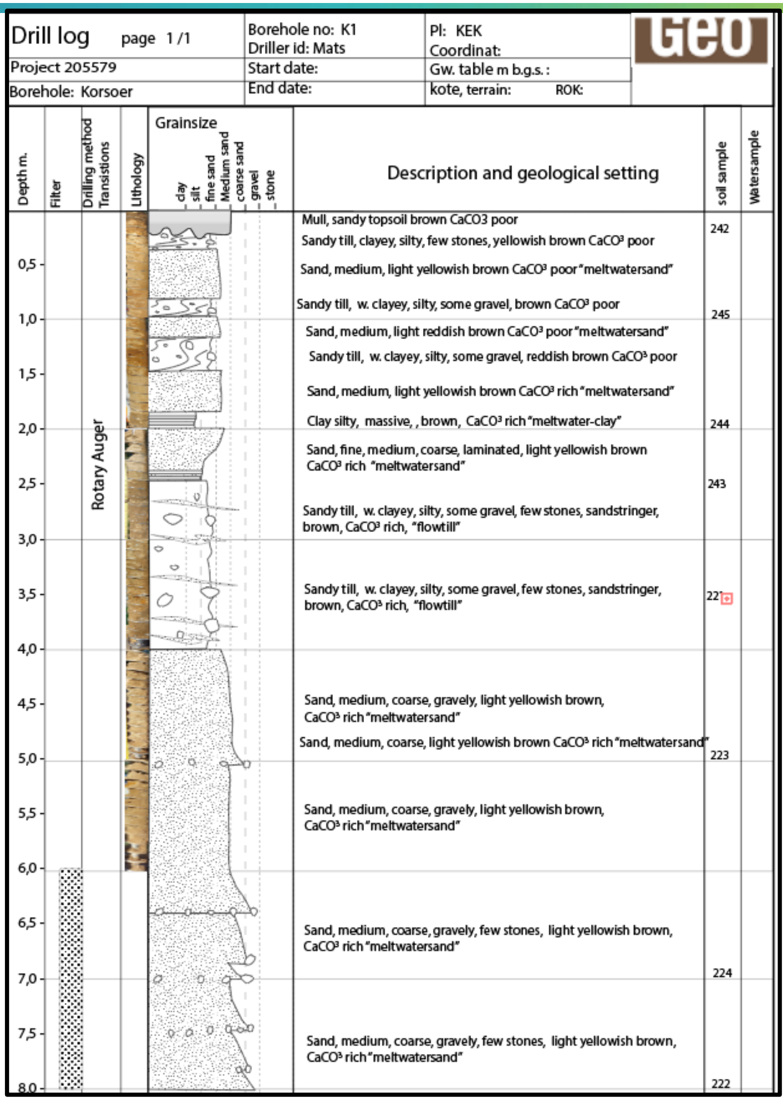
1-2

2-3

3-4

4-5

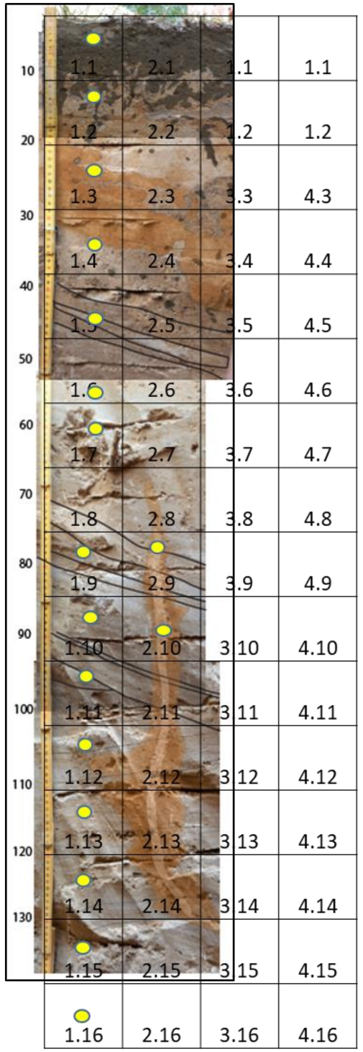
5-6



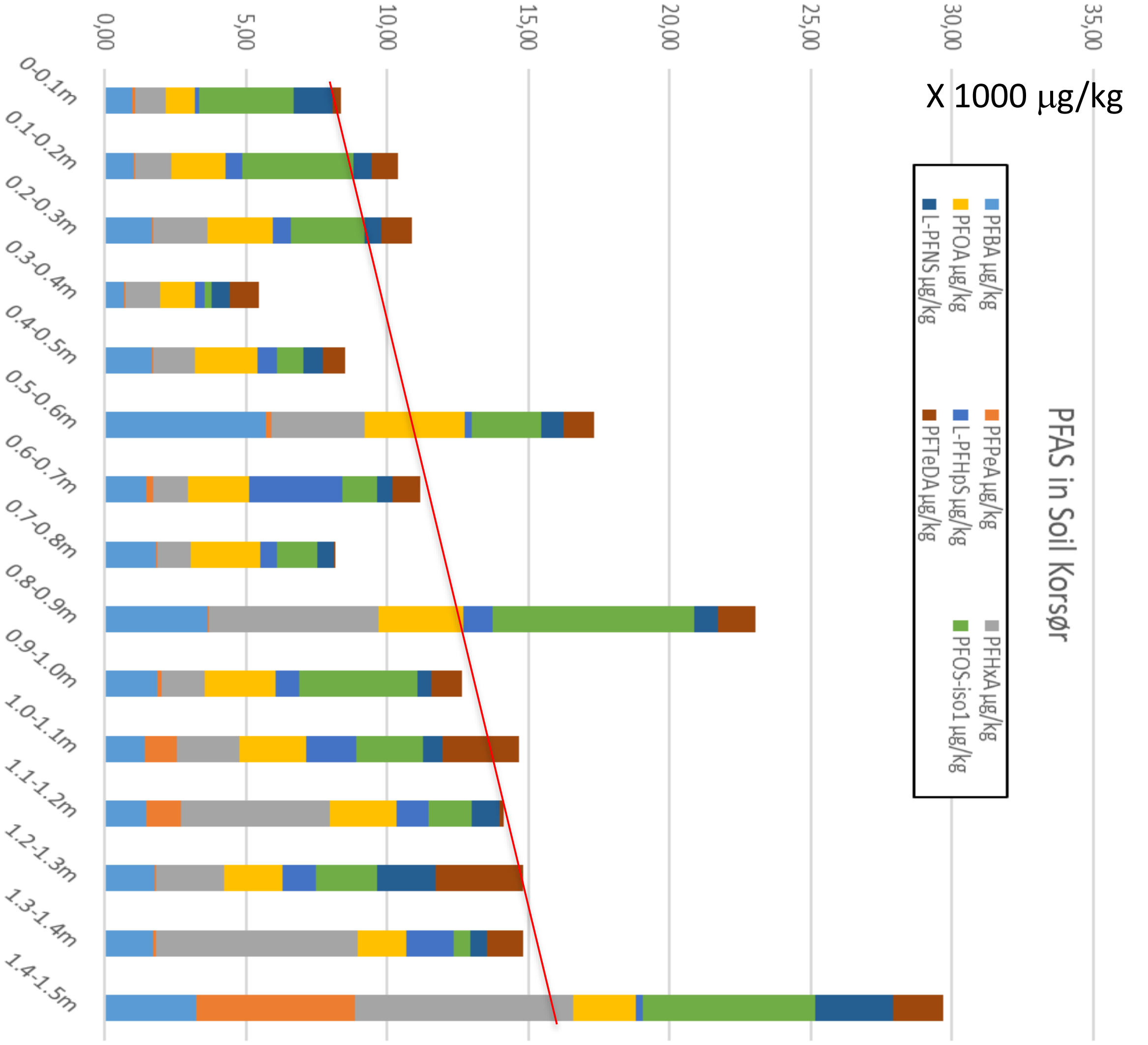
Drill log page 1 /1
Project 205579
Borehole: Korsoer
Borehole no: K1
Driller id: Mats
Start date:
End date:
Pl: KEK
Coordinat:
Gw. table m b.g.s. :
kote, terrain: ROK:

Depth m.	Drilling method Transistions	Description and geological setting	soil sample	Watersample
		Mull, sandy topsoil brown CaCO3 poor	242	
		Sandy till, clayey, silty, few stones, yellowish brown $CaCO^3$ poor		
0,5		Sand, medium, light yellowish brown $CaCO^3$ poor "meltwatersand"		
		Sandy till, w. clayey, silty, some gravel, brown $CaCO^3$ poor		
1,0			245	
		Sand, medium, light reddish brown $CaCO^3$ poor "meltwatersand"		
		Sandy till, w. clayey, silty, some gravel, reddish brown $CaCO^3$ poor		
1,5		Sand, medium, light yellowish brown $CaCO^3$ rich "meltwatersand"		
		Clay silty, massive, , brown, $CaCO^3$ rich "meltwater-clay"		
2,0			244	
	Rotary Auger	Sand, fine, medium, coarse, laminated, light yellowish brown $CaCO^3$ rich "meltwatersand"		
2,5			243	
		Sandy till, w. clayey, silty, some gravel, few stones, sandstringer, brown, $CaCO^3$ rich, "flowtill"		
3,0				
3,5		Sandy till, w. clayey, silty, some gravel, few stones, sandstringer, brown, $CaCO^3$ rich, "flowtill"	22	
4,0				
4,5		Sand, medium, coarse, gravely, light yellowish brown, $CaCO^3$ rich "meltwatersand"		
		Sand, medium, coarse, light yellowish brown $CaCO^3$ rich "meltwatersand"		
5,0			223	
5,5		Sand, medium, coarse, gravely, light yellowish brown, $CaCO^3$ rich "meltwatersand"		
6,0				
6,5		Sand, medium, coarse, gravely, few stones, light yellowish brown, $CaCO^3$ rich "meltwatersand"		
7,0			224	
7,5		Sand, medium, coarse, gravely, few stones, light yellowish brown, $CaCO^3$ rich "meltwatersand"		
8,0			222	

Detailstudie af PFAS koncentration i jord i de øverste 1,5 m



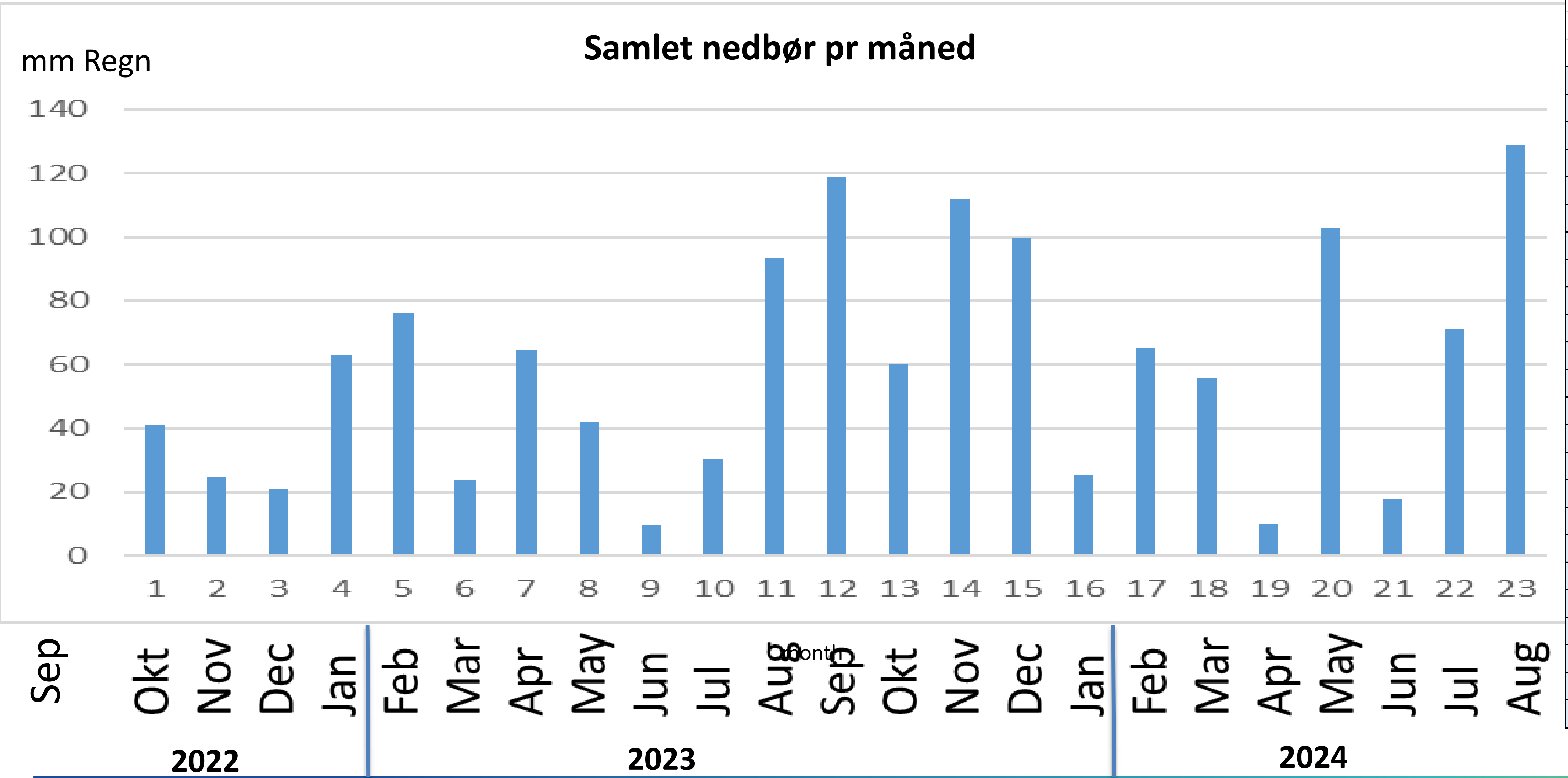
1.1	2.1	1.1	1.1
1.2	2.2	1.2	1.2
1.3	2.3	3.3	4.3
1.4	2.4	3.4	4.4
1.5	2.5	3.5	4.5
1.6	2.6	3.6	4.6
1.7	2.7	3.7	4.7
1.8	2.8	3.8	4.8
1.9	2.9	3.9	4.9
1.10	2.10	3.10	4.10
1.11	2.11	3.11	4.11
1.12	2.12	3.12	4.12
1.13	2.13	3.13	4.13
1.14	2.14	3.14	4.14
1.15	2.15	3.15	4.15
1.16	2.16	3.16	4.16



Resultater

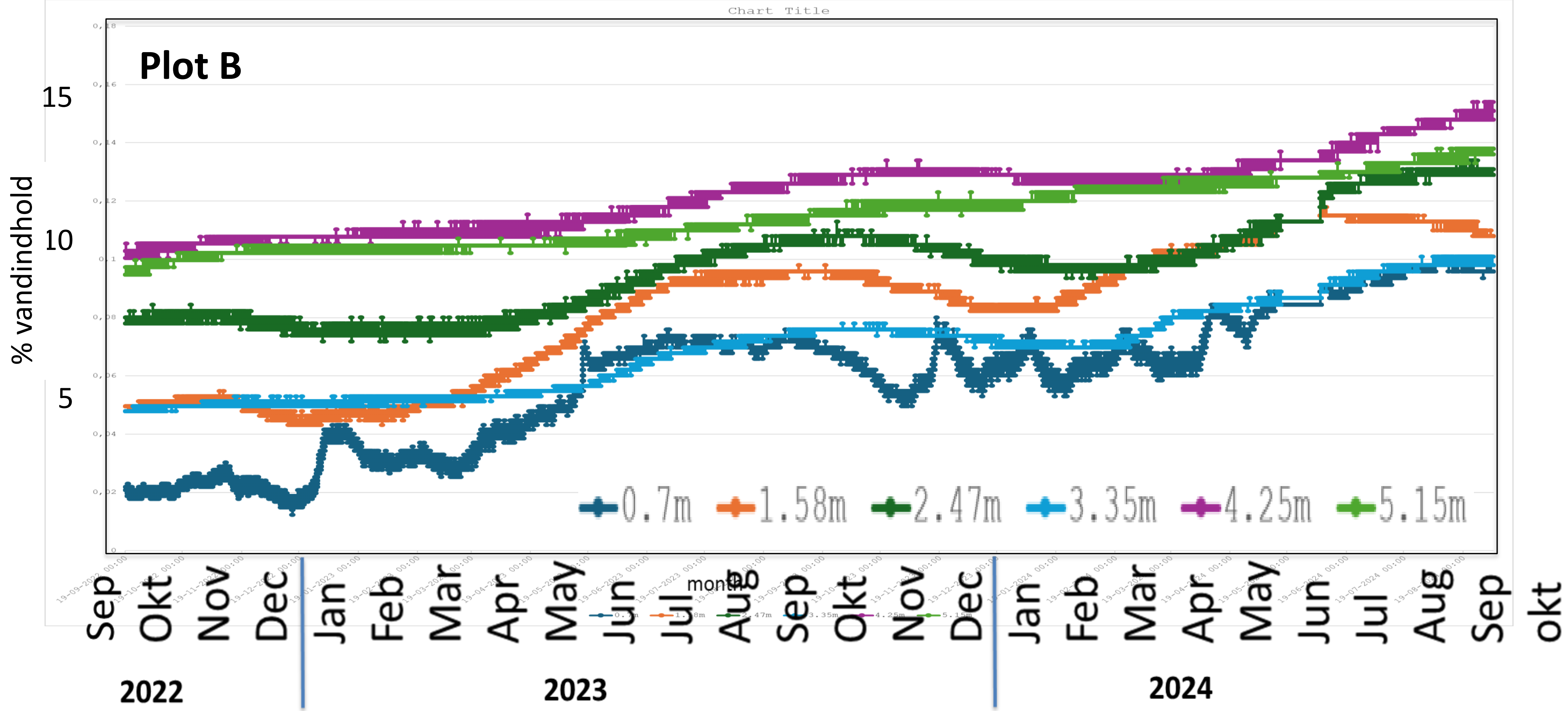
- Nedbør
- Nedsivning/vandindhold
- PFAS indhold i vandprøver

Nedbør 28 Sep 2022 til Aug 2024 i målt i ved RESC Korsør

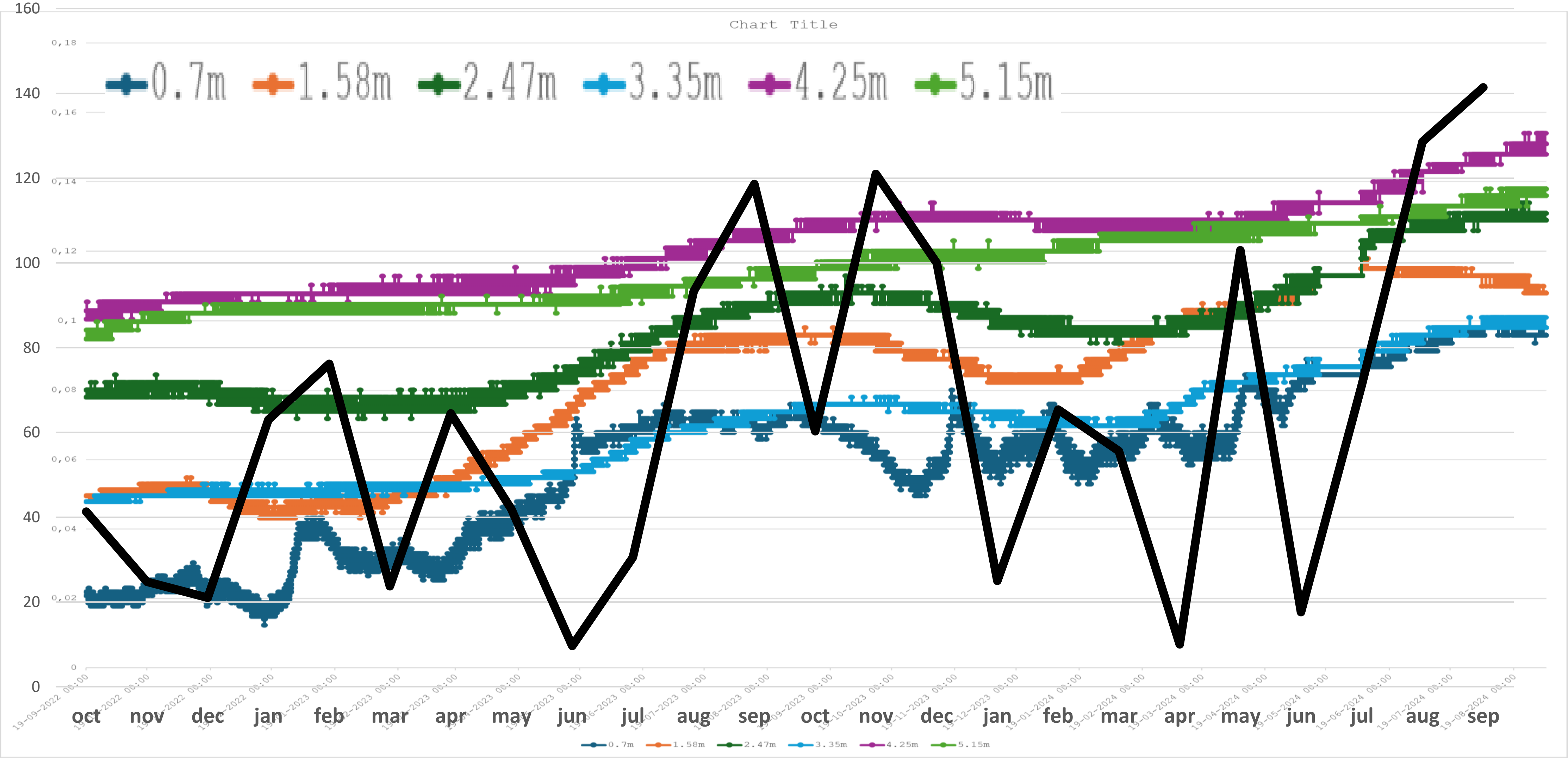


	Precipitation mm
	mm/month
10	41
11	25
12	21
1	63
2	76
3	24
4	65
5	42
6	10
7	31
8	93
9	119
10	60
11	112
12	100
1	25
2	65
3	56
4	10
5	103
6	18
7	71
8	129
9	141

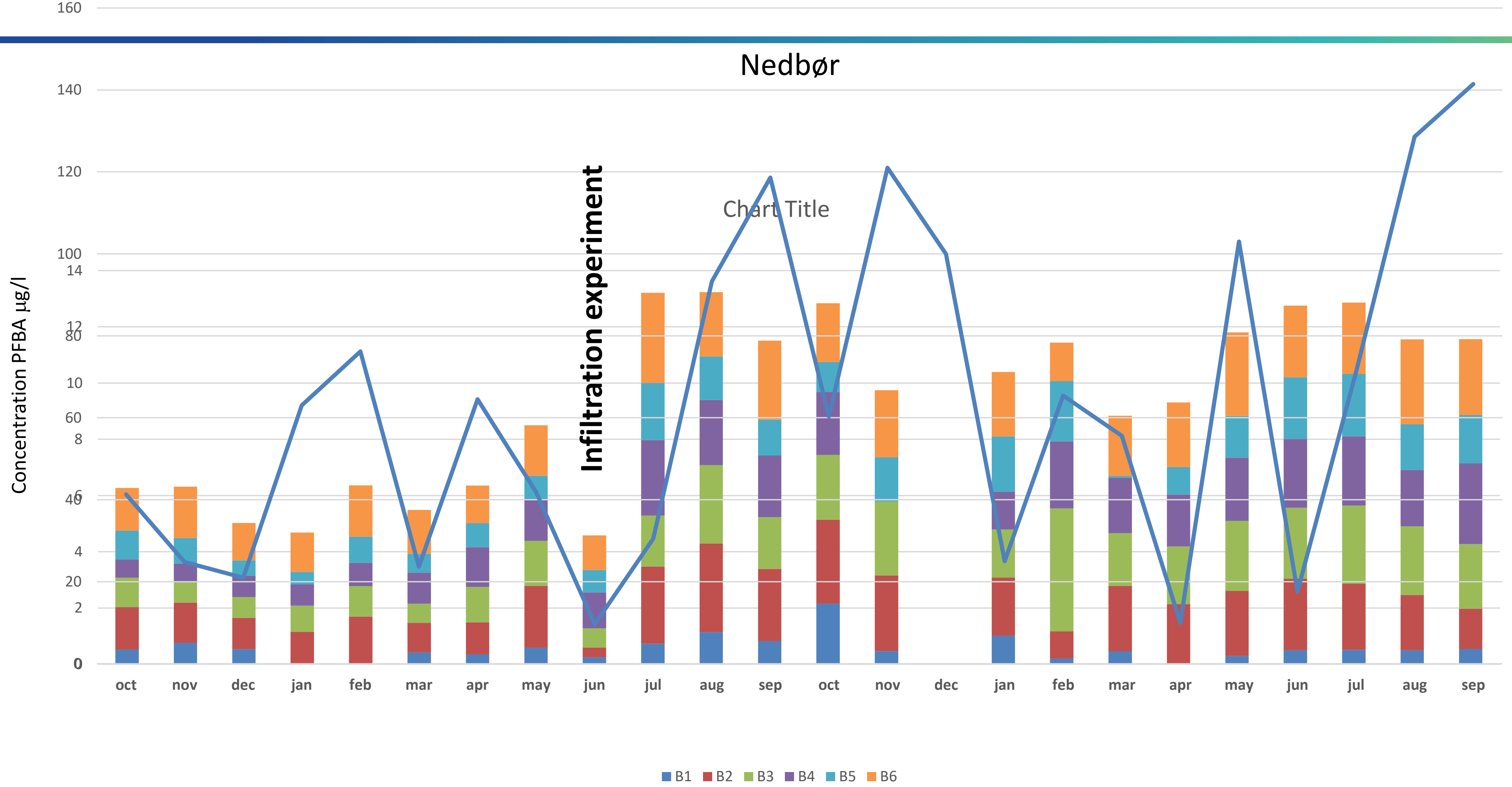
Vandindhold i 6 dybder
28 Sep 2022 til Aug 2024



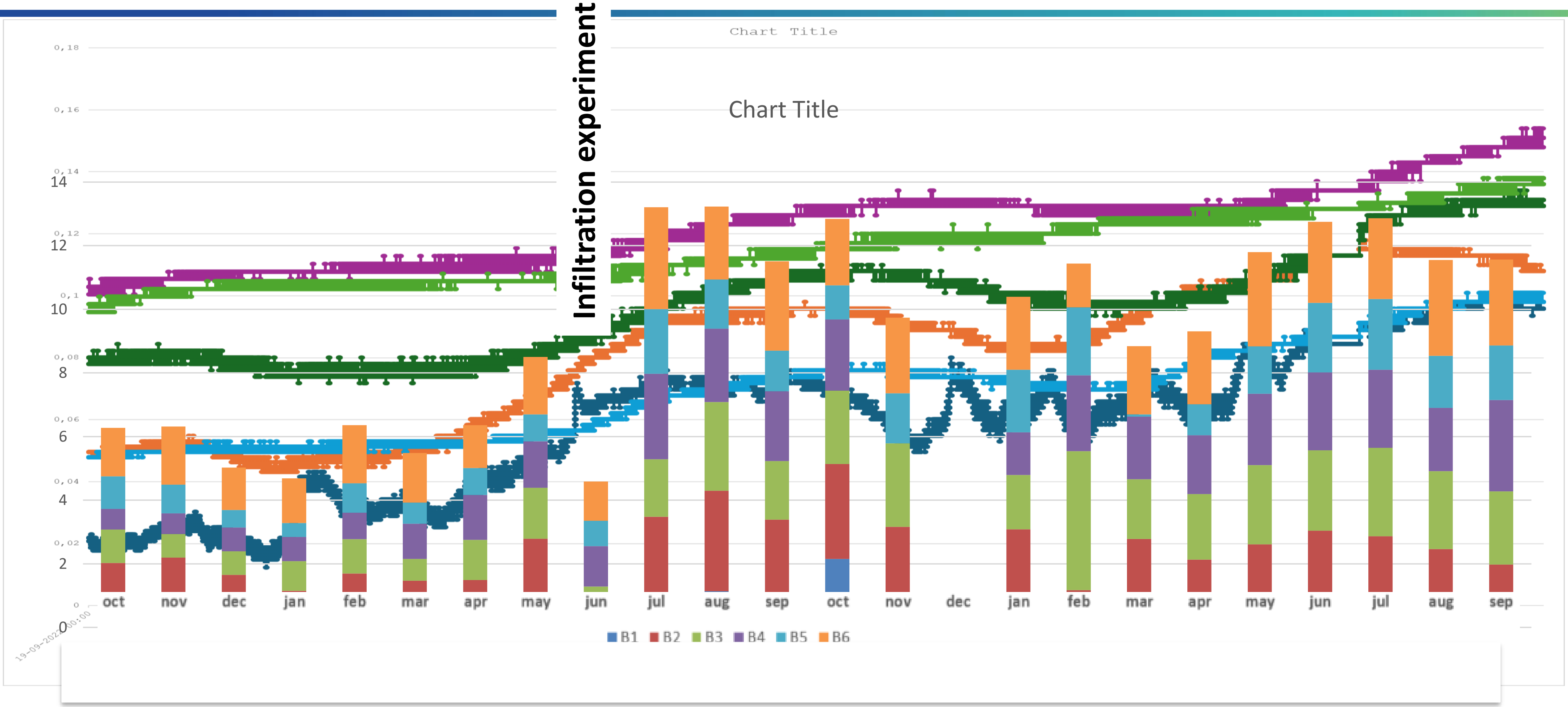
Vandmætning i 6 dybder i plot B over 2 år sammenlignet med nedbør



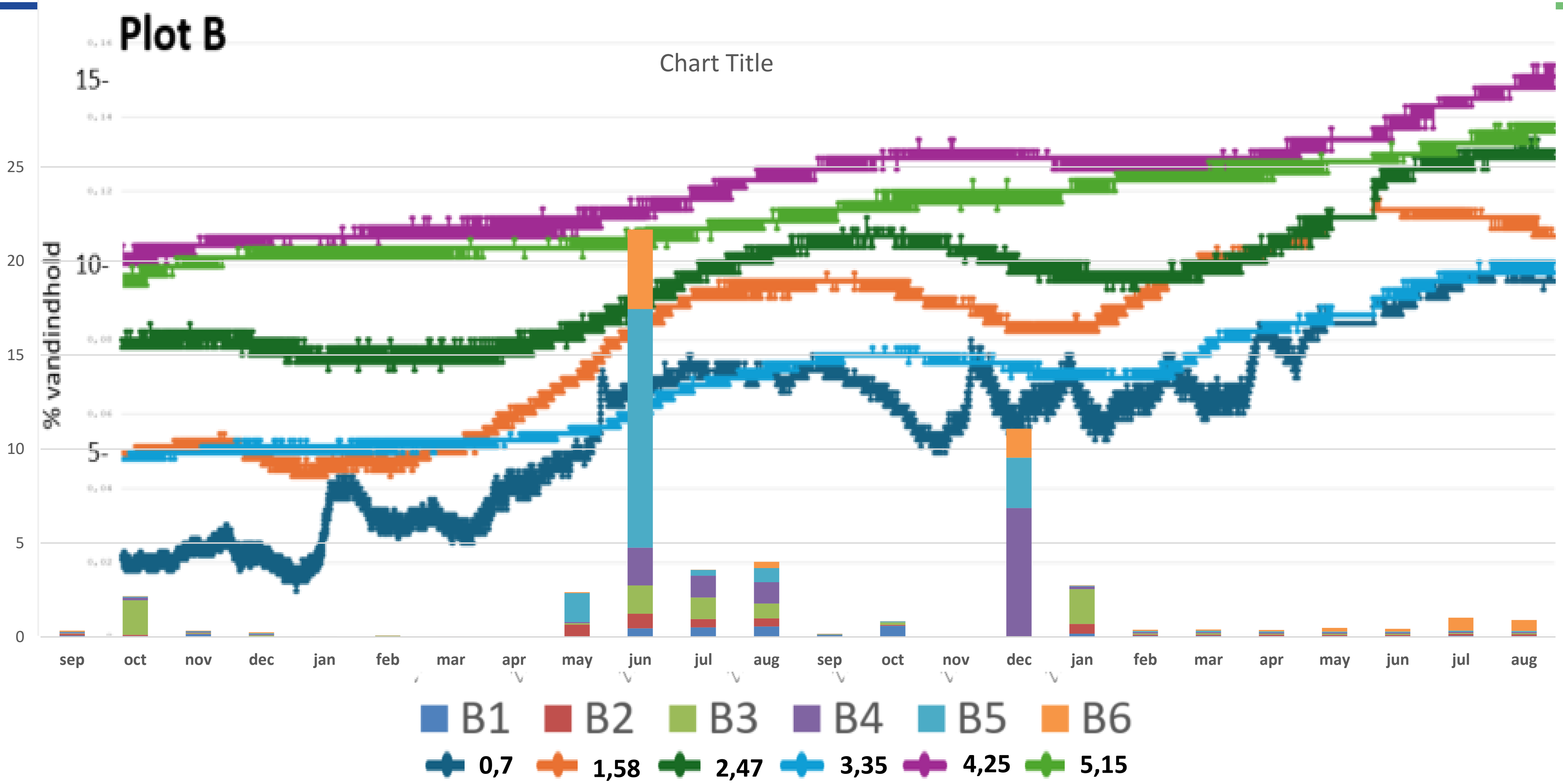
Koncentration af PFBA som funktion af nedbør



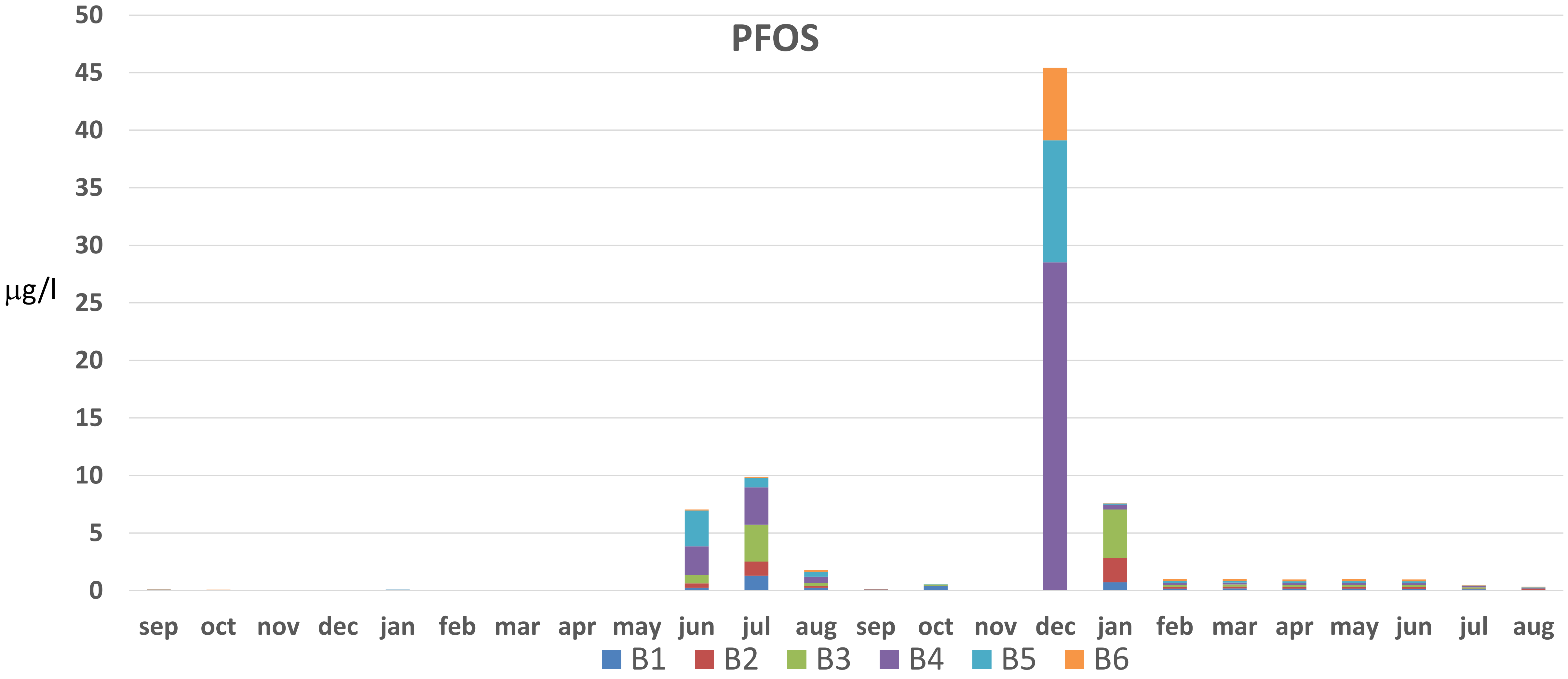
Koncentration af PFBA som funktion af vandmætning i jorden



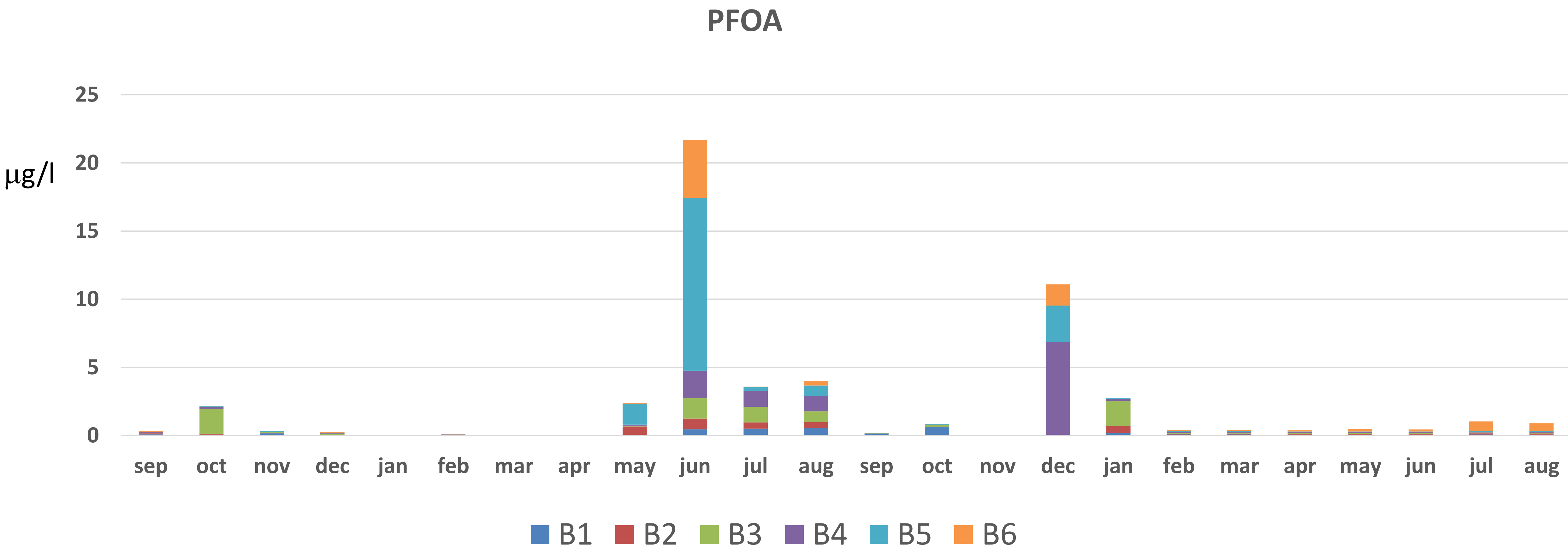
Koncentration af PFOA som funktion af vandmætning i jorden



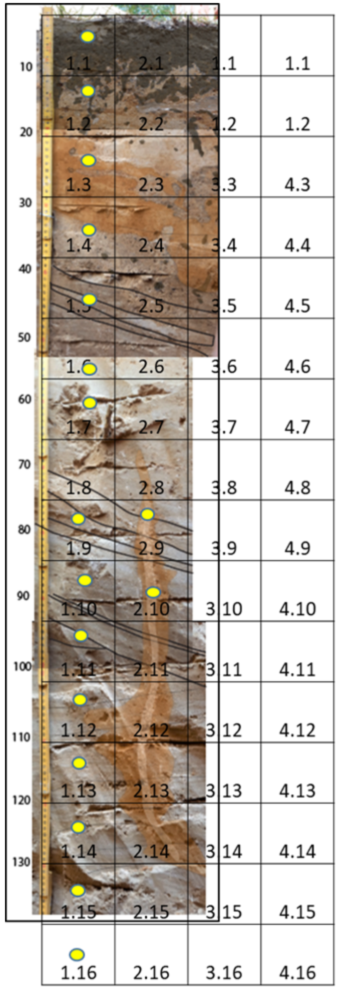
Udvaskning af PFOS og PFOA sker kun ved høj vandmætning

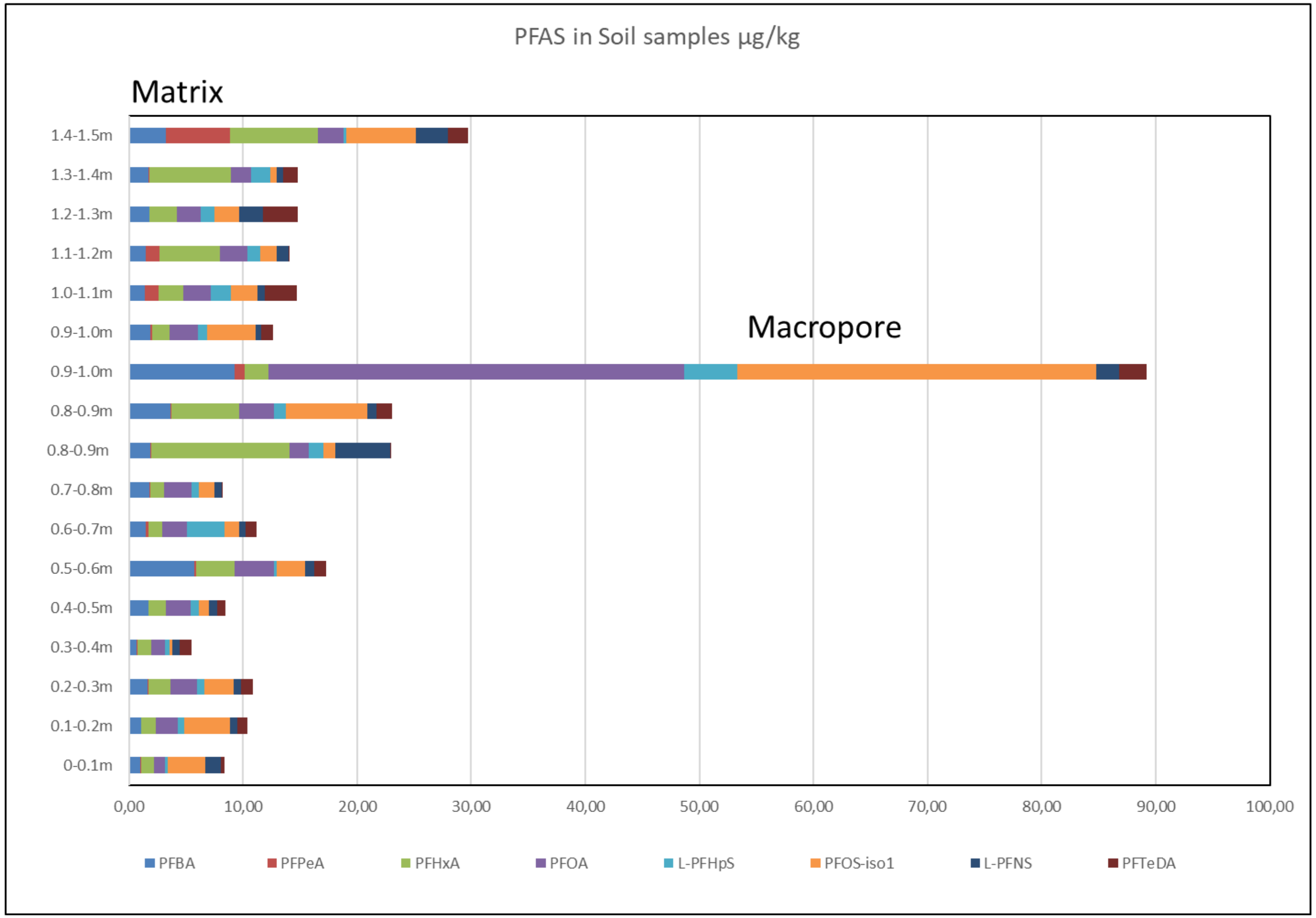


Nye spørgsmål: Hvorfor er koncentrationen af PFOA højest i B5 og B4 dybere nede?

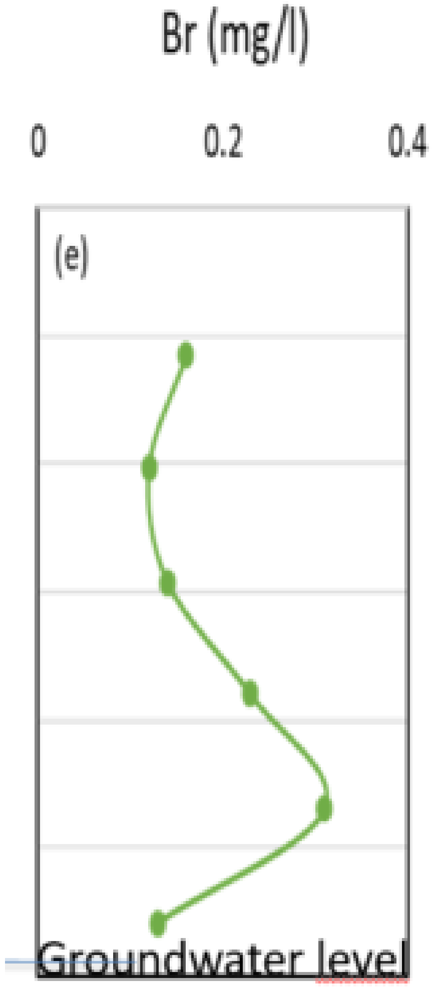


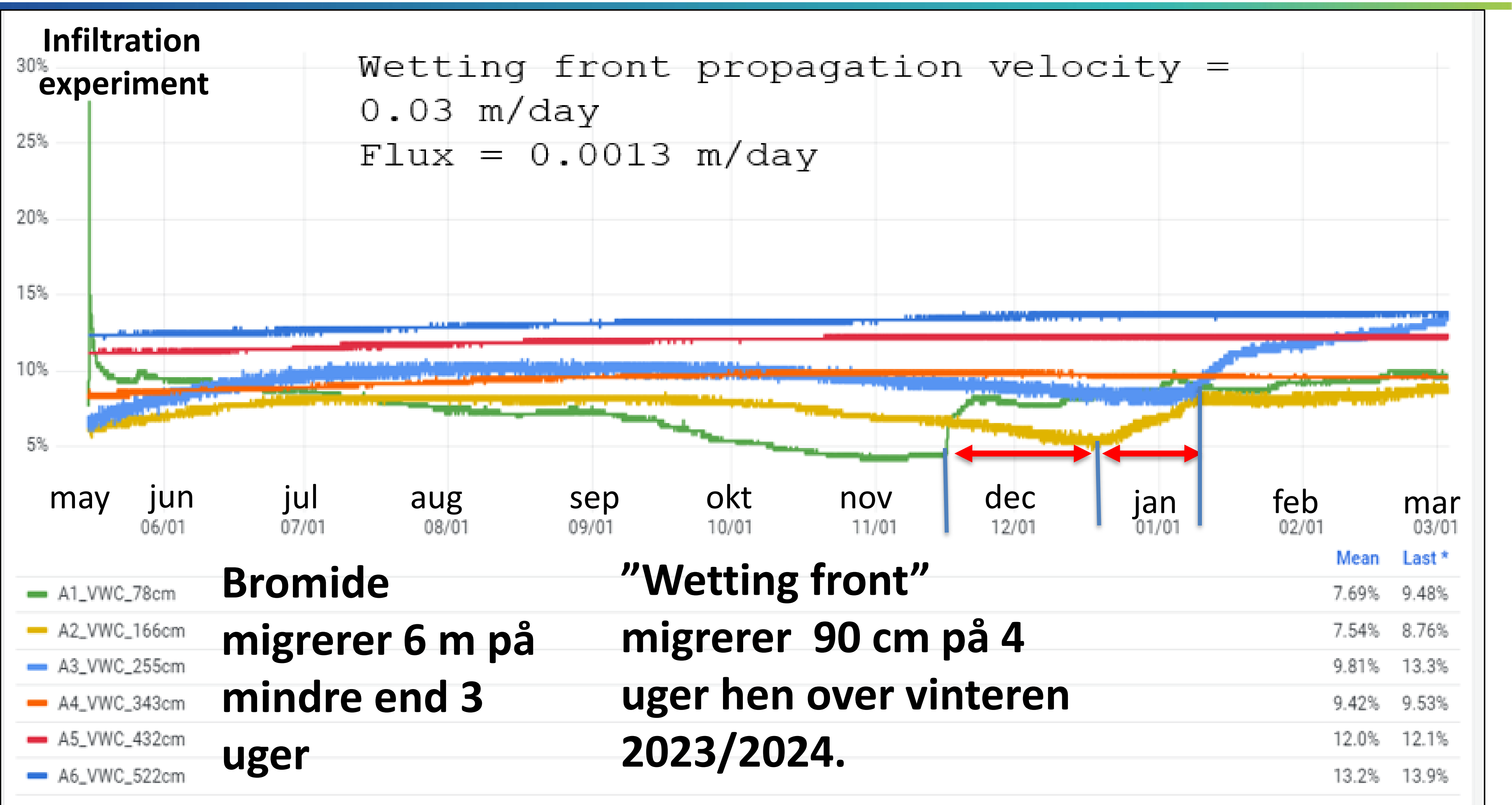
Preferentiel flow i makropore





Wetting front propagation og macroporeflow





Wetting front propagation velocity = 0.03 m/day

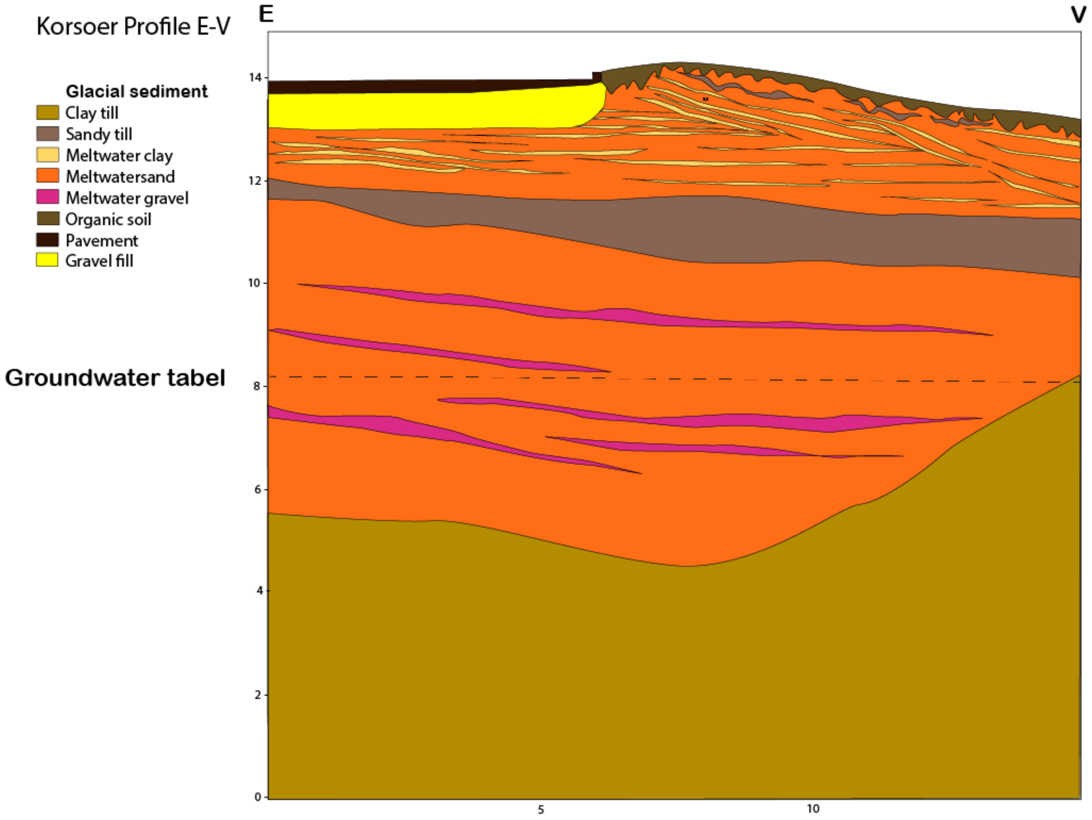
Flux = 0.0013 m/day

Bromide migrerer 6 m på mindre end 3 uger

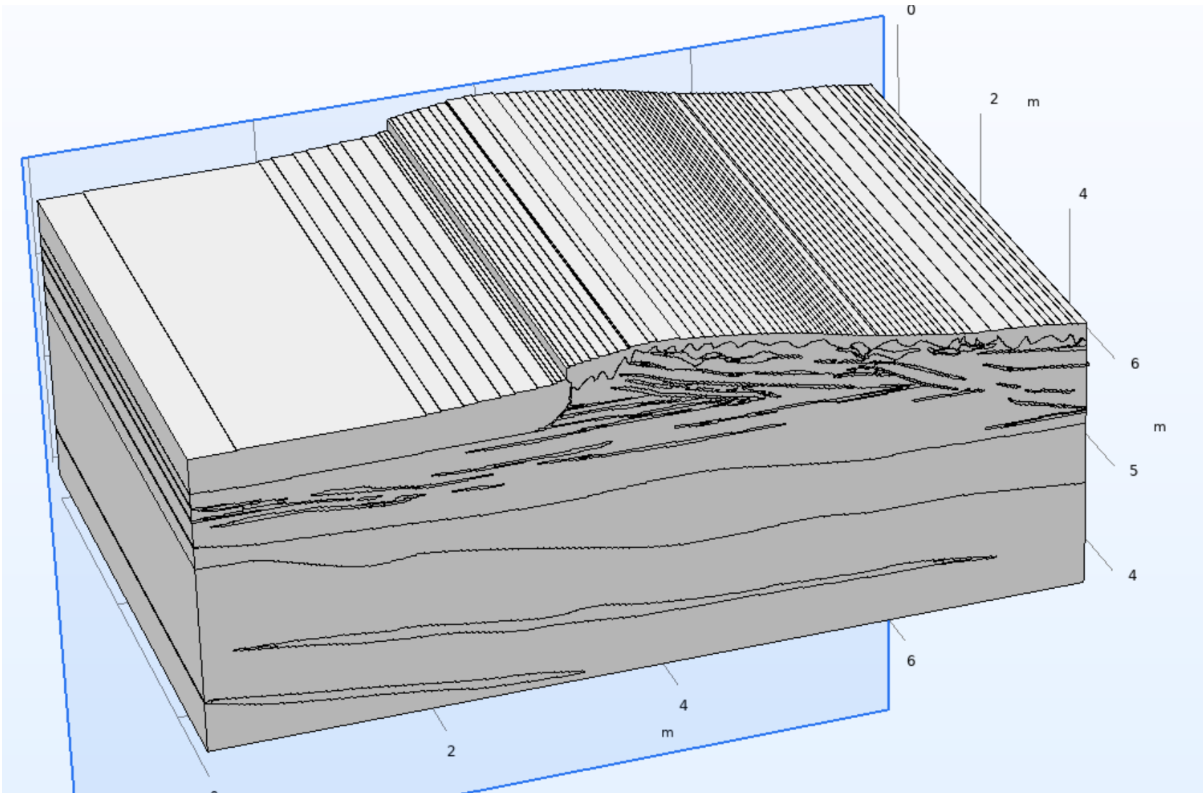
"Wetting front" migrerer 90 cm på 4 uger hen over vinteren 2023/2024.

Modellering

Geological conceptual model



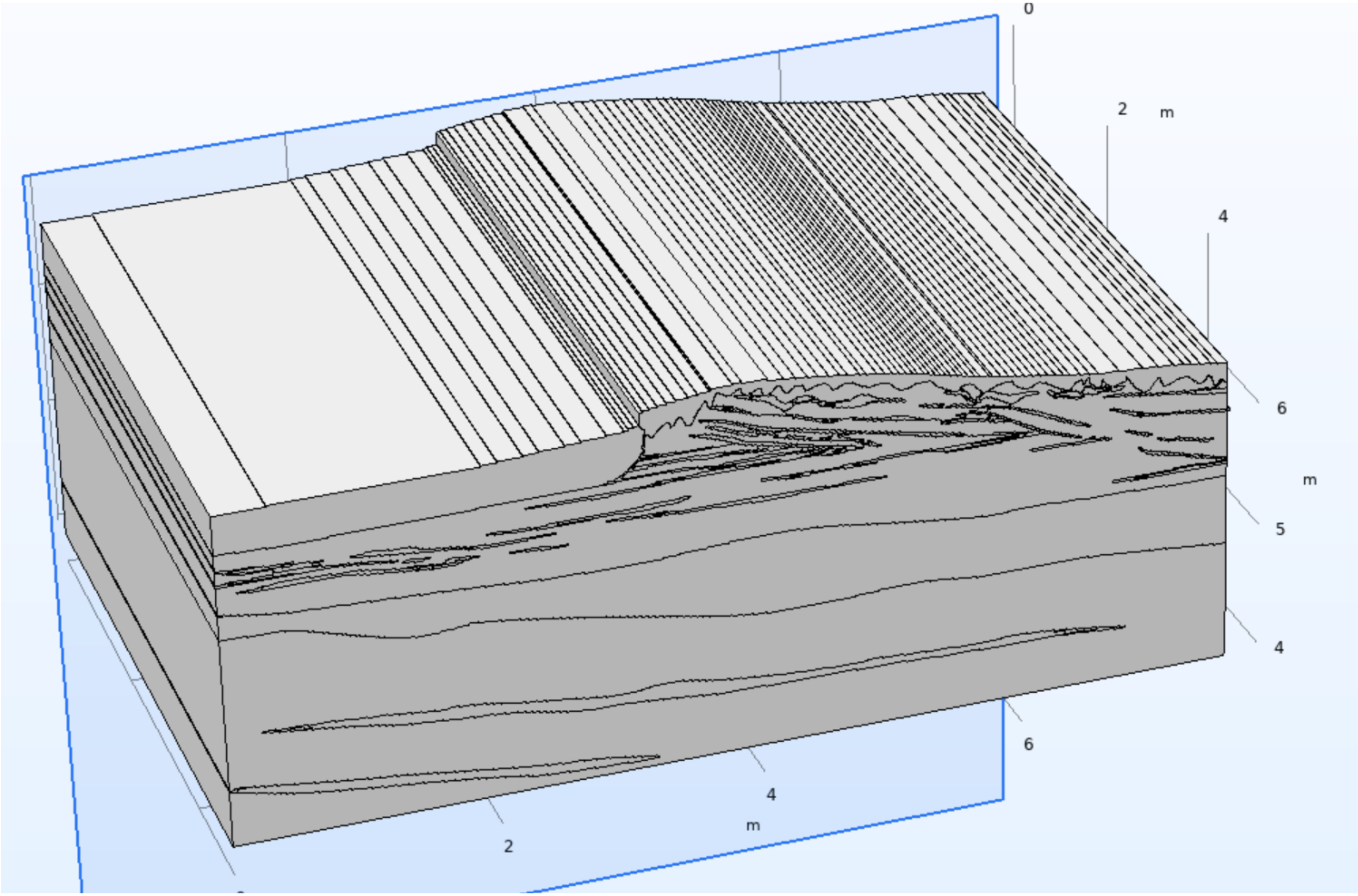
Reconstructed –simulation domain



Using Adobe Illustrator and an algorithm in python that transforms images to CAD geometry for further exploitation

Different soil layers take into account

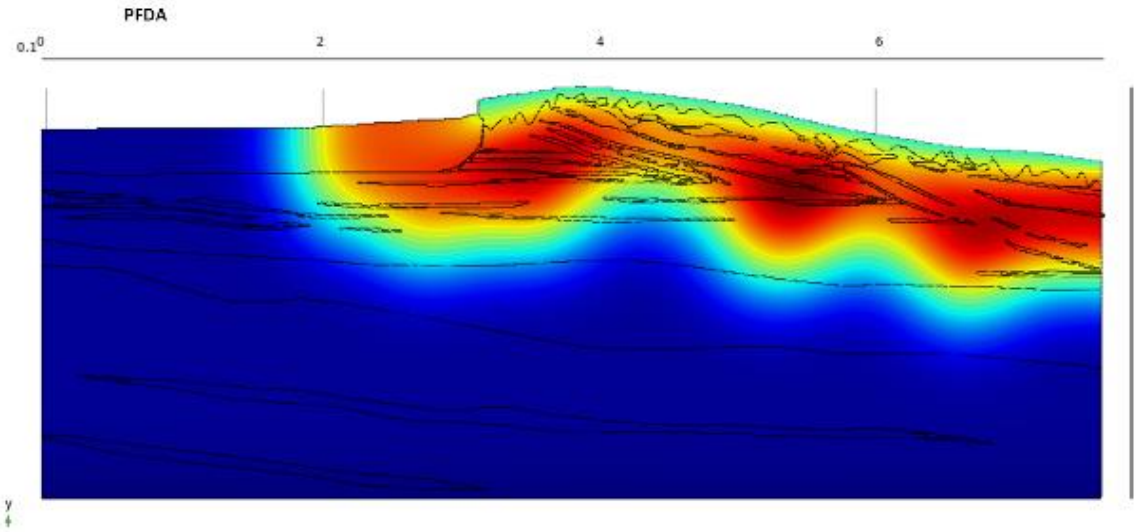
Parameter estimering



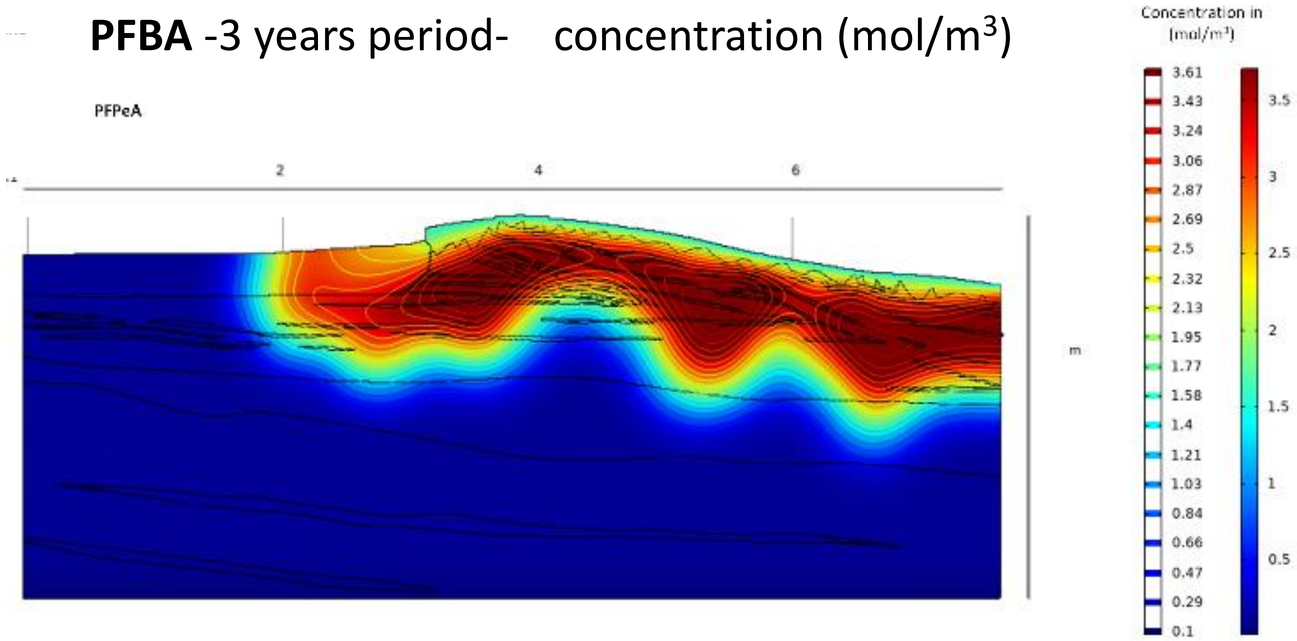
Soil type	Parameter	Value	Description
Clayey sandy till	ε	0.22	Porosity
	K	$4.8\ 10^{-13}\ m^2$	Absolute permeability
	α	$0.5\ m^{-1}$	Van Genuchten parameter
	n	1.09	Van Genuchten parameter
	θ_s	0.22	Water saturation = porosity
	θ_r	0.015	Water residual
Apply to all layers	aL	200 µm	Dispersivity (the default)
	D_{pfos}	$0.5\ 10^{-9}\ m^2/s$	Diffusion coefficient of PFOS
	D_{pfoa}	$3.5\ 10^{-9}\ m^2/s$	Diffusion coefficient of PFOA
	D_{pfda}	$2\ 10^{-9}\ m^2/s$	Diffusion coefficient of PFDA
	D_{pfba}	$8\ 10^{-9}\ m^2/s$	Diffusion coefficient of PFBA
	K_{dpfos}	$302.5\ 10^{-9}$ mol/kg	Freundlich constant PFOS
	K_{dpfoa}	$31.3\ 10^{-9}$ mol/kg	Freundlich constant PFOA
	K_{dpfda}	$386\ 10^{-9}$ mol/kg	Freundlich constant PFDA
	K_{dpfba}	$38.7\ 10^{-9}$ mol/kg	Freundlich constant PFBA
	n_{pfos}	0.63	Freundlich exponent PFOS
	n_{pfoa}	0.63	Freundlich exponent PFOA
	n_{pfda}	0.42	Freundlich exponent PFDA
	n_{pfba}	0.35	Freundlich exponent PFBA
Melt-water clay/silt	ε	0.28	Porosity
	K	$2.4\ 10^{-13}\ m^2$	Absolute permeability
	α	$0.8\ m^{-1}$	Van Genuchten parameter
	n	1.09	Van Genuchten parameter
	θ_s	0.28	Water saturation = porosity
	θ_r	0.015	Water residual
Melt-water Sand	ε	0.38	Porosity
	K	$7.2\ 10^{-12}\ m^2$	Absolute permeability
	α	$7.45\ m^{-1}$	Van Genuchten parameter
	n	1.89	Van Genuchten parameter
	θ_s	0.38	Water saturation = porosity
	θ_r	0.025	Water residual
Melt-water gravel/ sand	ε	0.45	Porosity
	K	$3.6\ 10^{-11}\ m^2$	Absolute permeability
	α	$14.5\ m^{-1}$	Van Genuchten parameter
	n	2.68	Van Genuchten parameter
	θ_s	0.45	Water saturation = porosity

Simulering af PFDA and PFBA transport

PFDA -3 years period- concentration (mol/m^3)



PFBA -3 years period- concentration (mol/m^3)



- High adsorption coefficient on soil grain for PFDA and on air/water interfaces (less concentration for transport downwards in the vadose zone)
- Differences in permeabilities (in particular in the region of clay formations) led to fingering transport

Sammenfatning?

Unikt datasæt med tidsserie data fra 24 måneder indeholdende:

- PFAS indhold i uforstyrret smeltevandssand/silt/ler og morænesand og macropore med
- Høj frekvens monitering af PFAS indhold i nedsivende vand
- On line ”real time” monitering af vandindhold i jorden i 6 forskellige dybder
- On line ”real time” monitering af nedbør

Disse data muliggør ret præcis beregning af ”Mass transfer” af forskellige PFAS typer til grundvandet

Hvad har vi lært?

- Koncentration af PFAS i nedsivende vand stiger med højere vandmætning.
- Udvaskning/mobilisering af ”kortkædede PFAS” sker med vandmætning over 5% men afhænger af vandindholdet
- Udvaskning/mobilisering af ”langkædede PFAS” sker kun ved markante ”Wetting front” passager (>10% vandindhold)
- Indhold af PFOS, PFOA er signifikant højere i makroporre end i matrix
- Flow sker som kombination af langsom matrixflow og hurtig makropore flow
- Mass transport af PFAS i den umættede zone bør altid kalibreres med vandindholdet i jorden, men jordspecifikke parametre som lerindhold, har også stor betydning.
- Selv homogene konfigurationer af geologiske modeller bør modelleres som dobbelt porøse medier, med både matrix og makropore flow.
- Måling af tidsserier er essentiel for forståelsen af den samlede udvaskning

Næste step og vigtige spørgsmål

- Betydning af ”udtørring/opmætnings” frekvenser
- Mere præcis estimering af betydning af andre parametre som organisk indhold, Ph, lerindhold på individuelle PFAS
- Betydningen af PFAS Cocktails. Nogle komponenter konkurrere om pladsen

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Thank you for your attention

SCENARIOS

Vil du vide mere så kontakt kek@geo.dk
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