



Impact of seasonal variations and transient colmation layer properties on bacteria and virus transport in bank filtration

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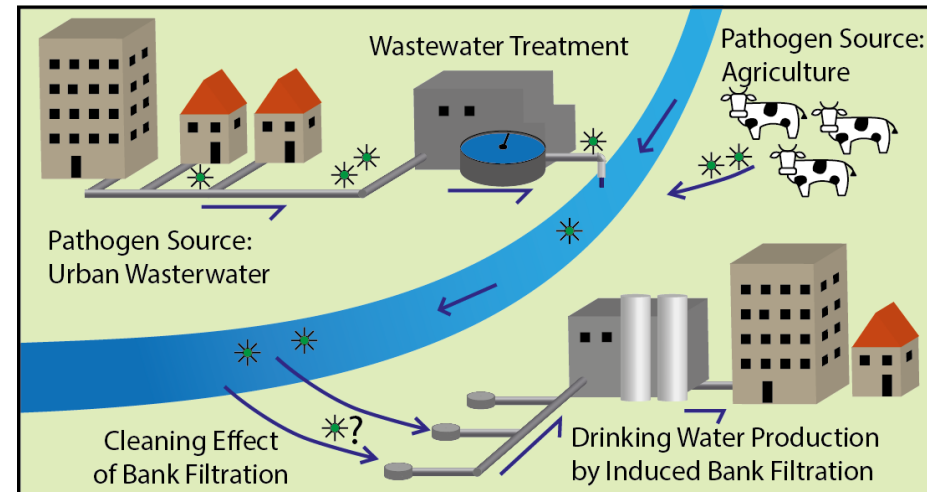


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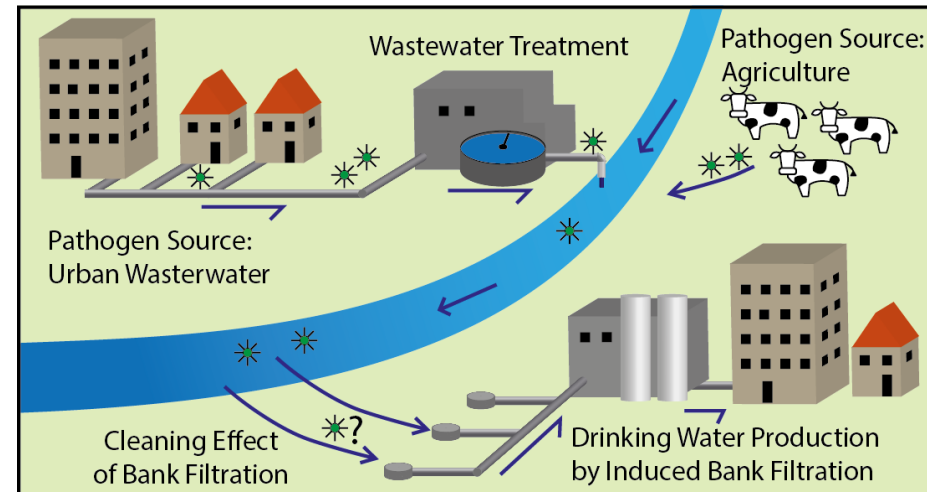
Induced Bank Filtration and Pathogens

- **drinking water** production by induced **bank filtration** applied in many especially **urban regions**
- potentially **threatened** by **surface water** contaminations with **pathogens** (viruses, bacteria, ...)
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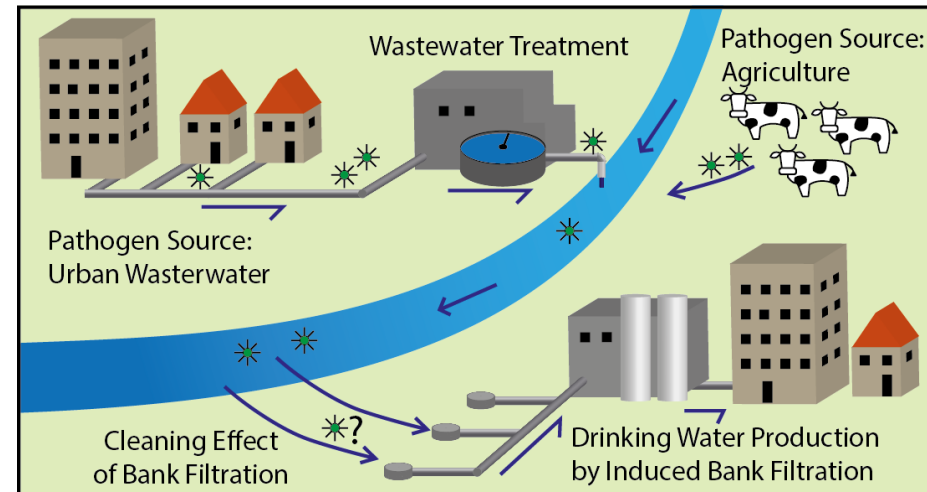
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- **Is the size of the cleaning effect constant? Does it change over time? Over a hydrological year?**
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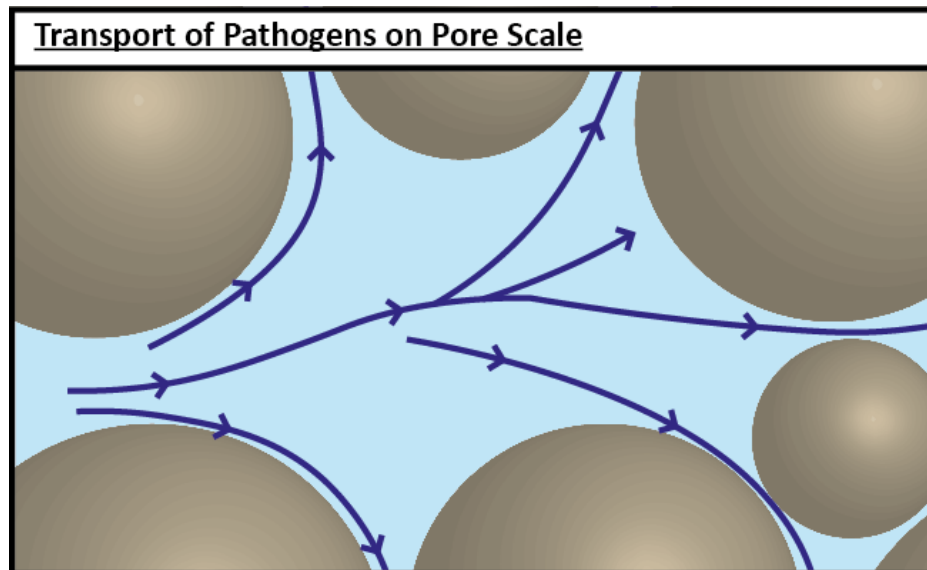
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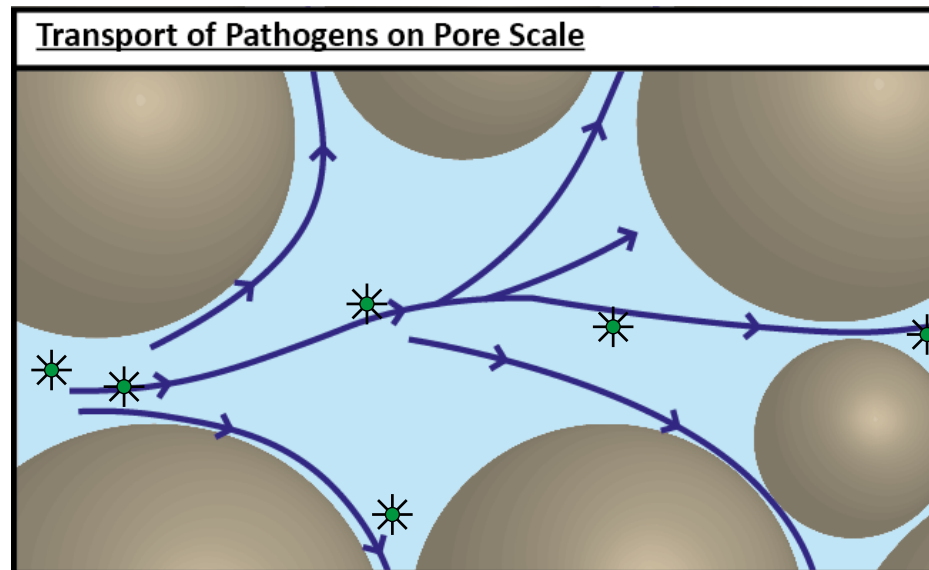
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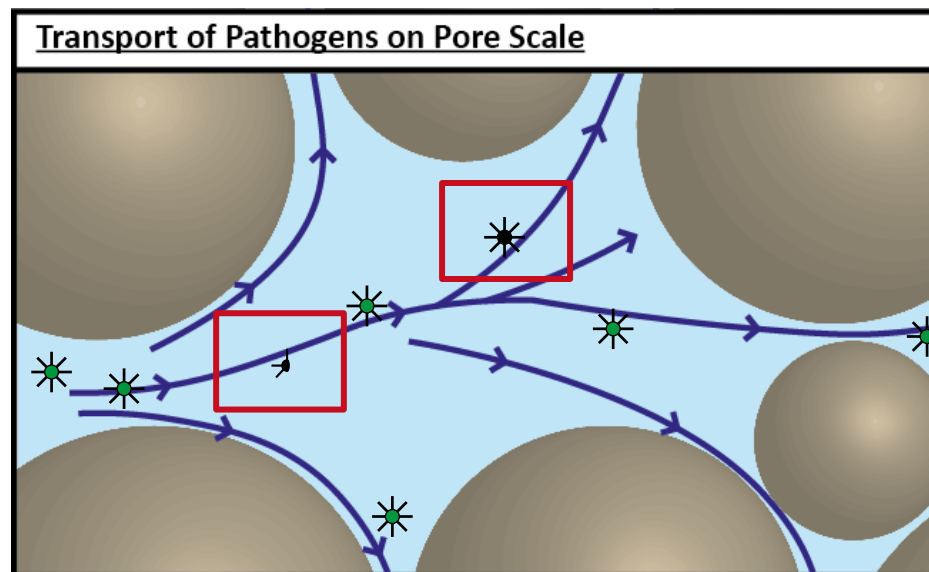
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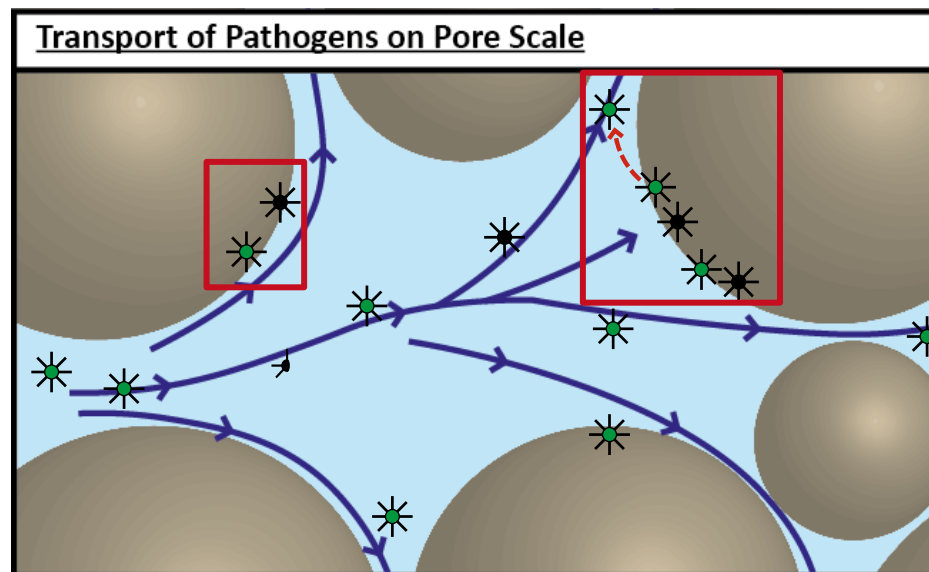
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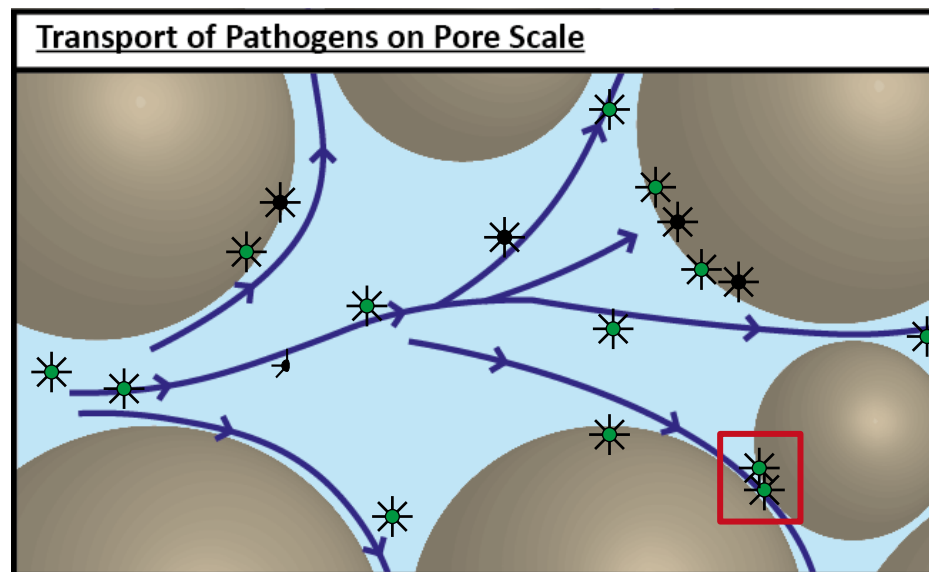
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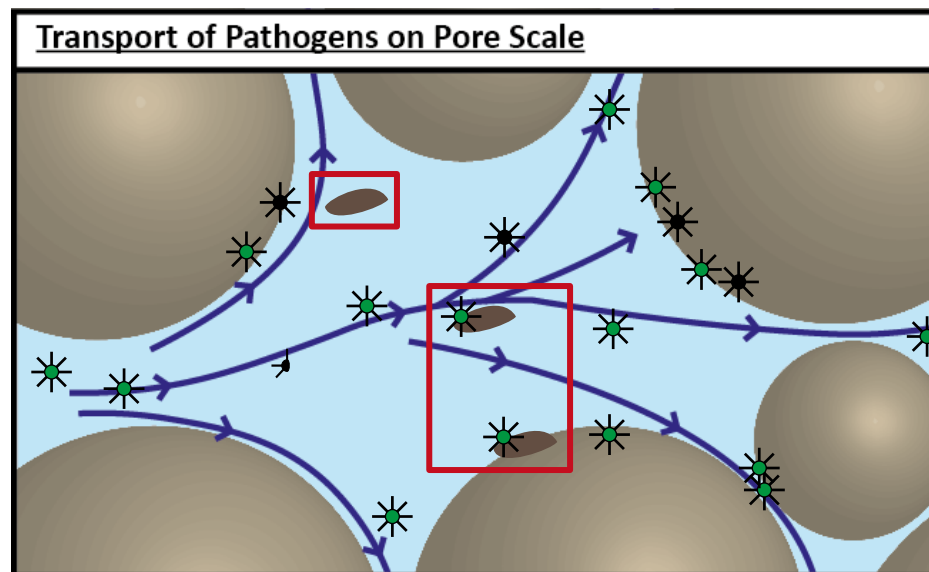
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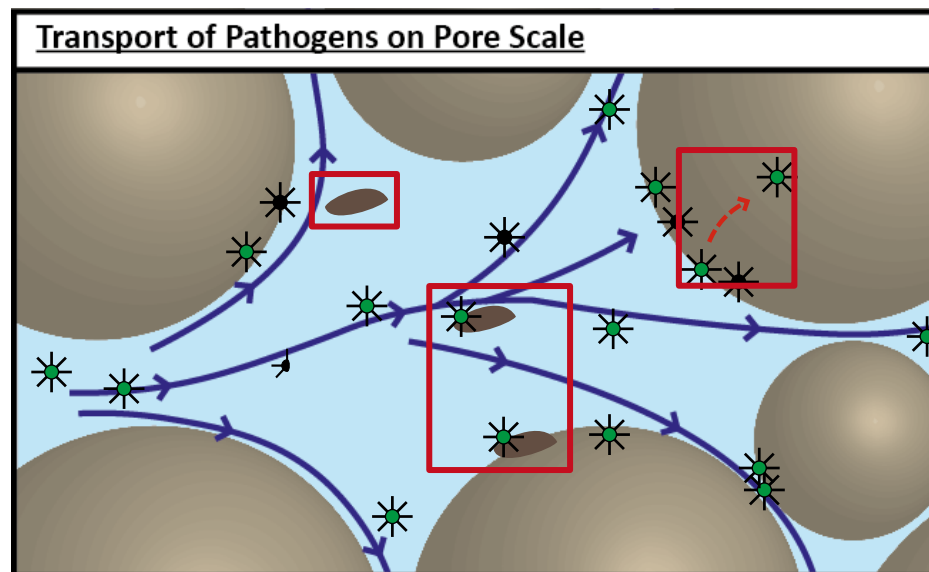
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concentration in the water phase (mobile phase) c_{Patho} :

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Change between mobile and immobile

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Colloid-Filtration-Theory

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**Inactivation
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Straining

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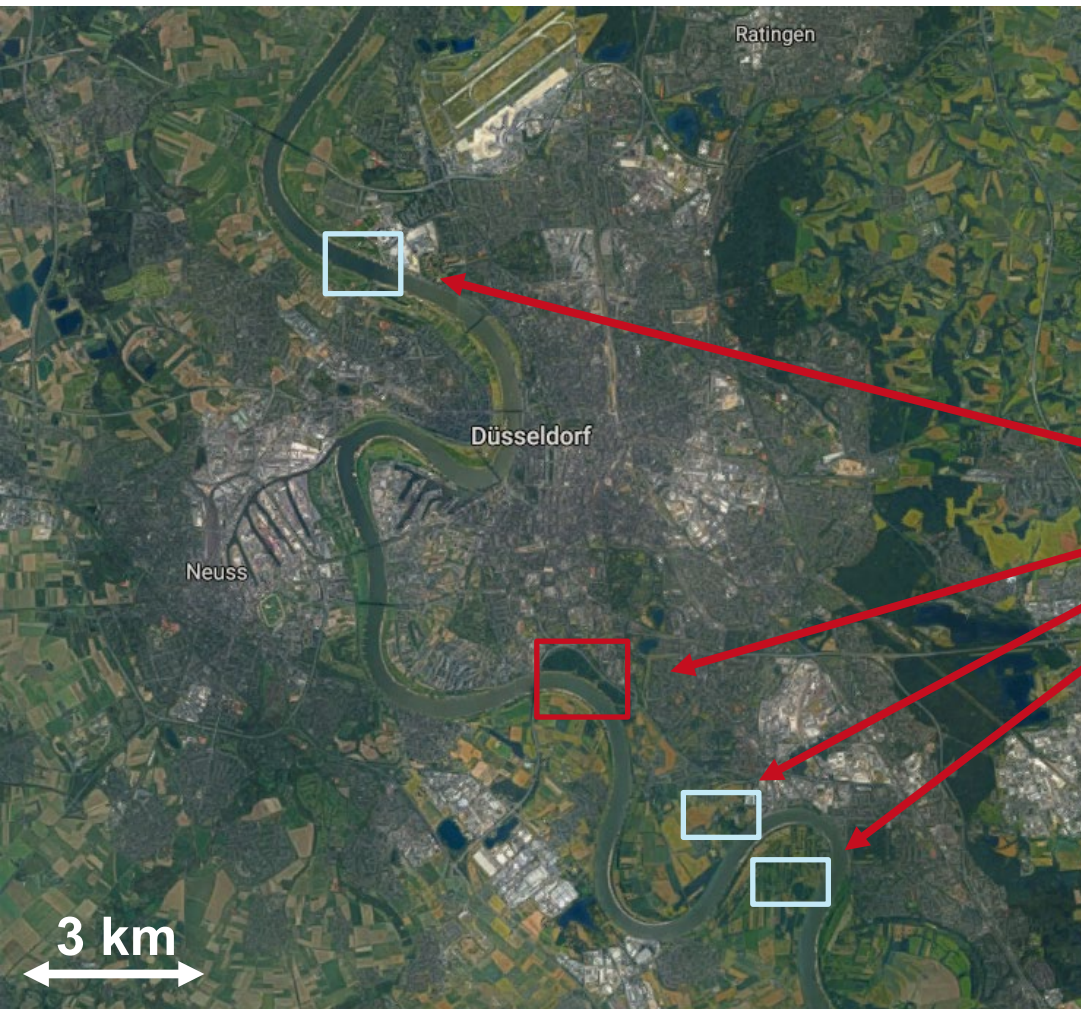
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1-year Monitoring at Induced Bank Filtration Site



Google Maps Image of the city of
Düsseldorf (600,000 inhabitants)

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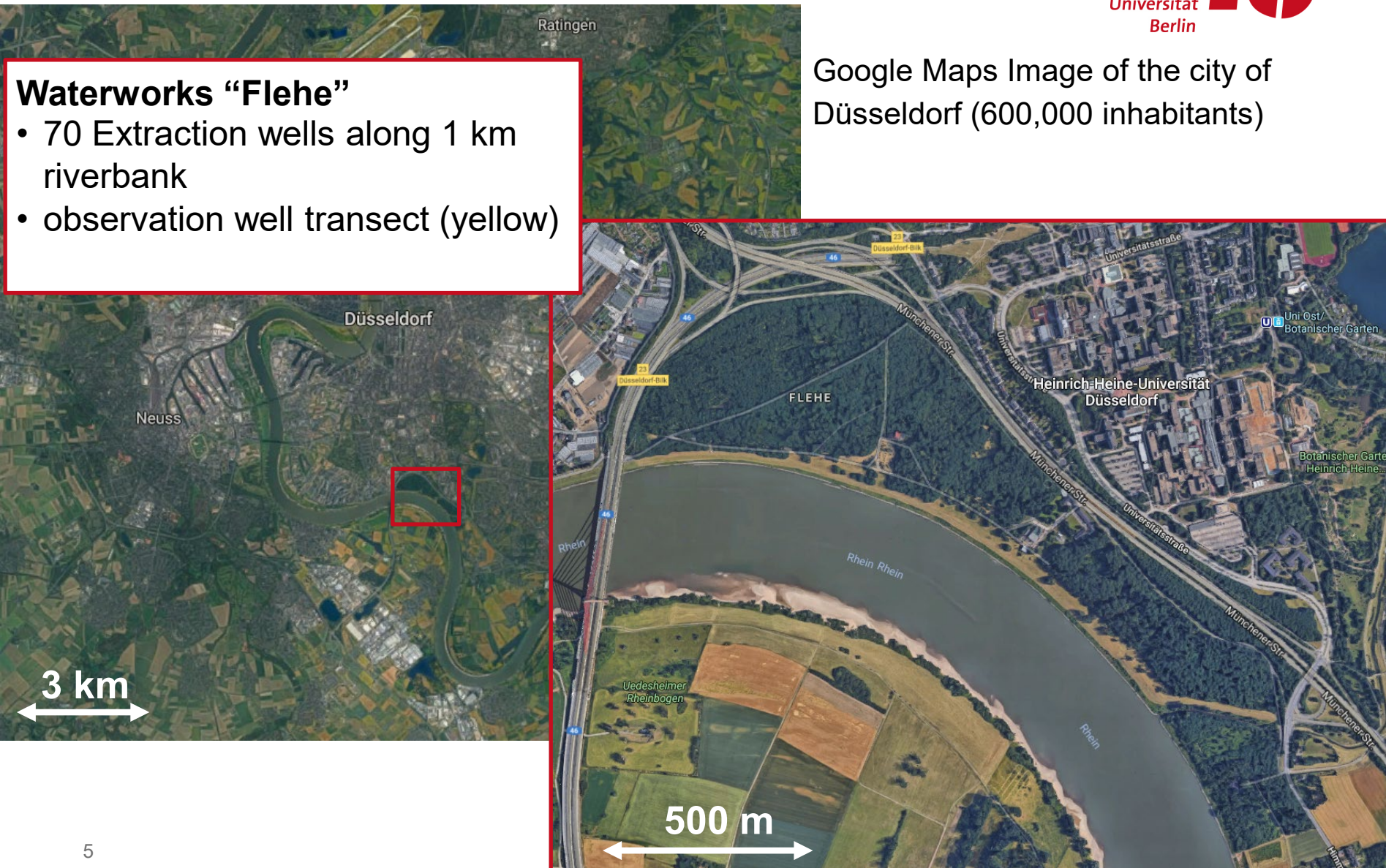
Drinking Water from 4
induced bank filtration
plants

1-year Monitoring at Induced Bank Filtration Site

Waterworks “Flehe”

- 70 Extraction wells along 1 km riverbank
- observation well transect (yellow)

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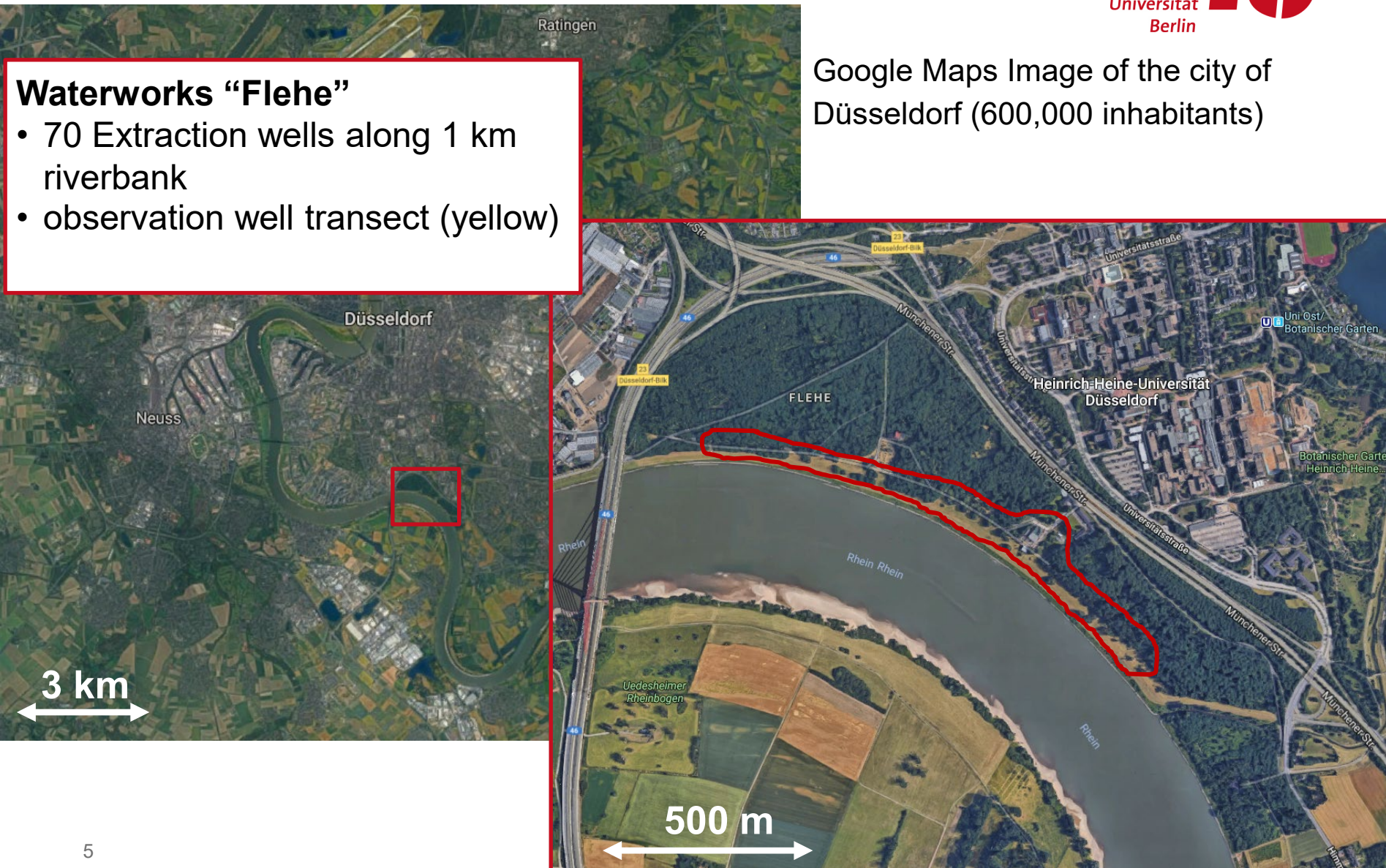


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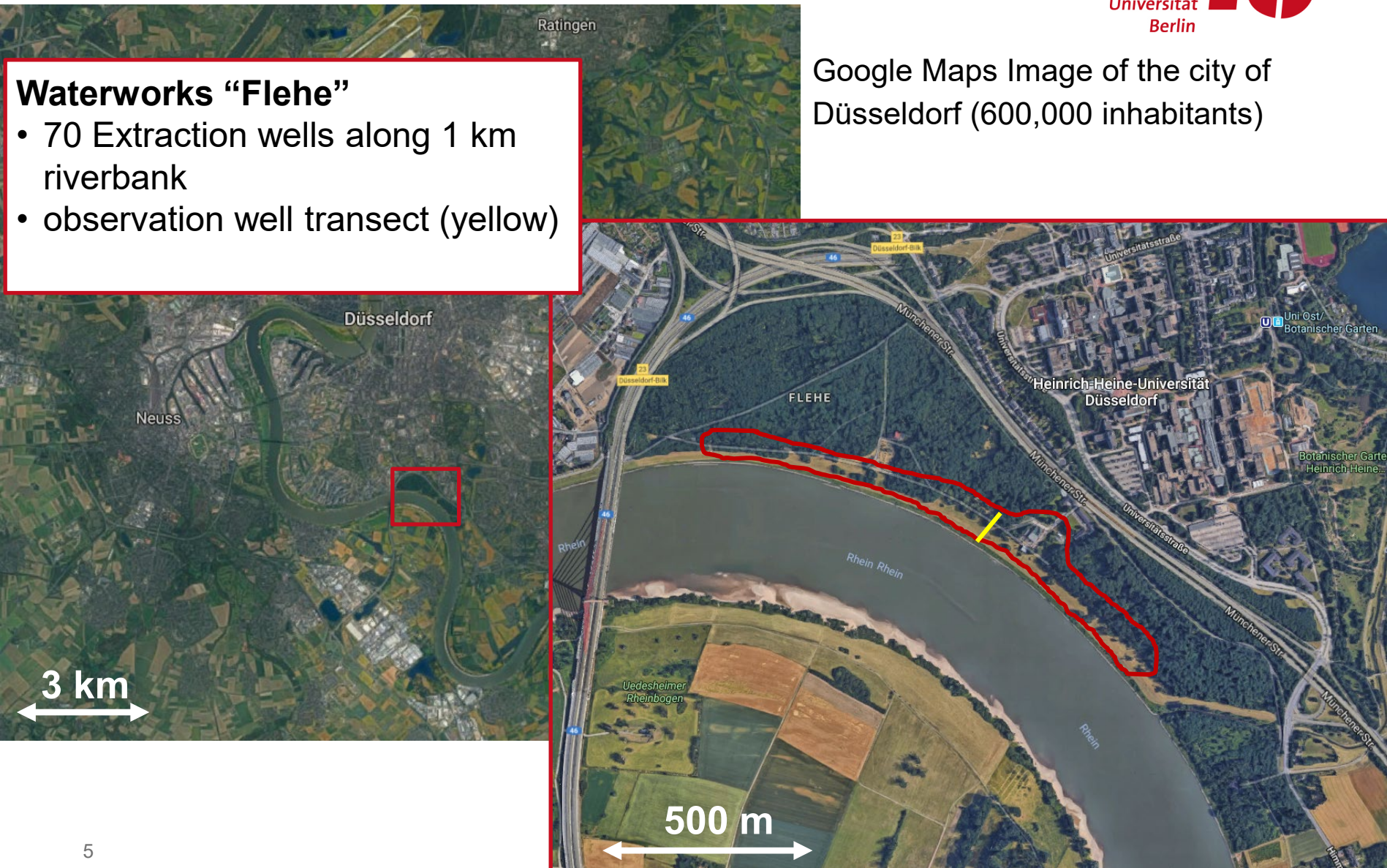


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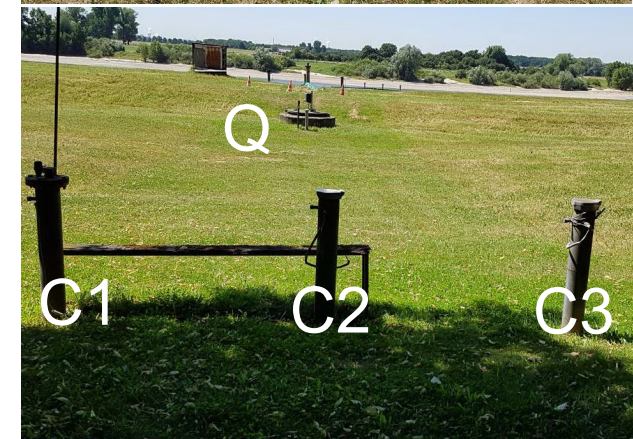
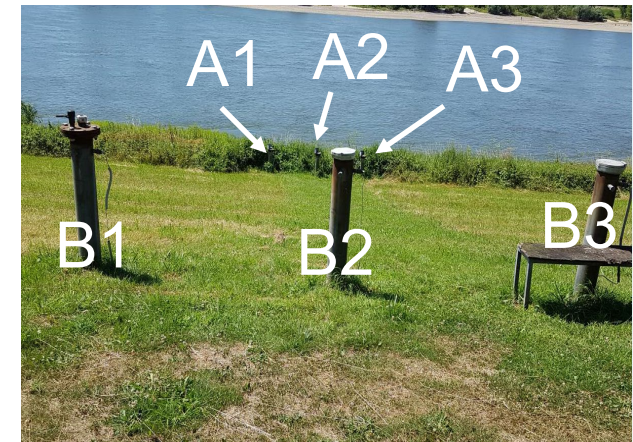
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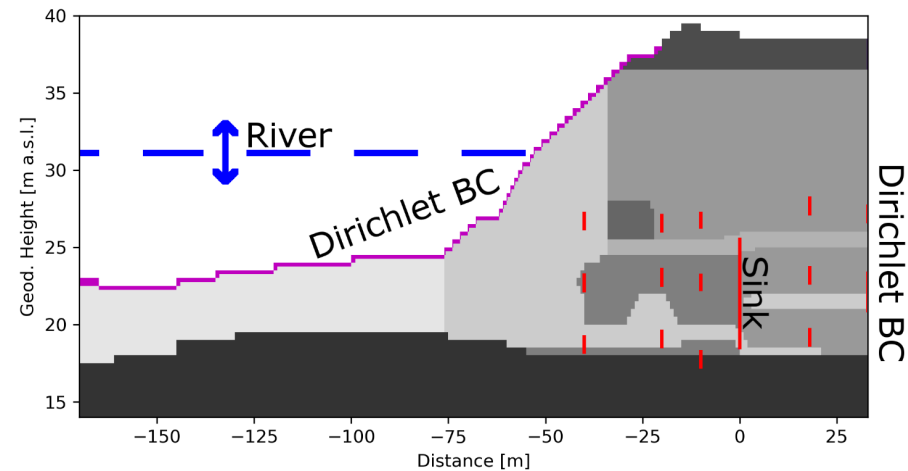
Numerical Model Setup

- numerical **2D-model** using **PFLOTRAN**
- simulating **flow, transport of heat**, dissolved species, **bacteria and viruses**
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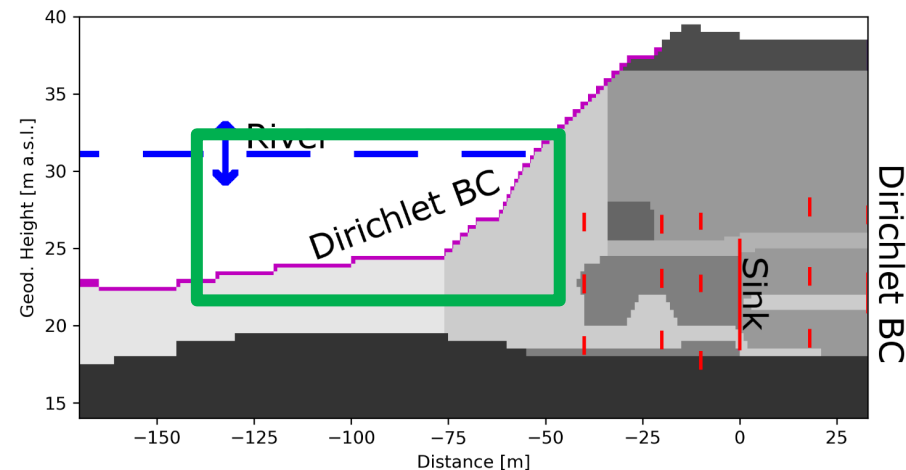
 Subsurface Zones
 Colmation Layer
 Well Screens



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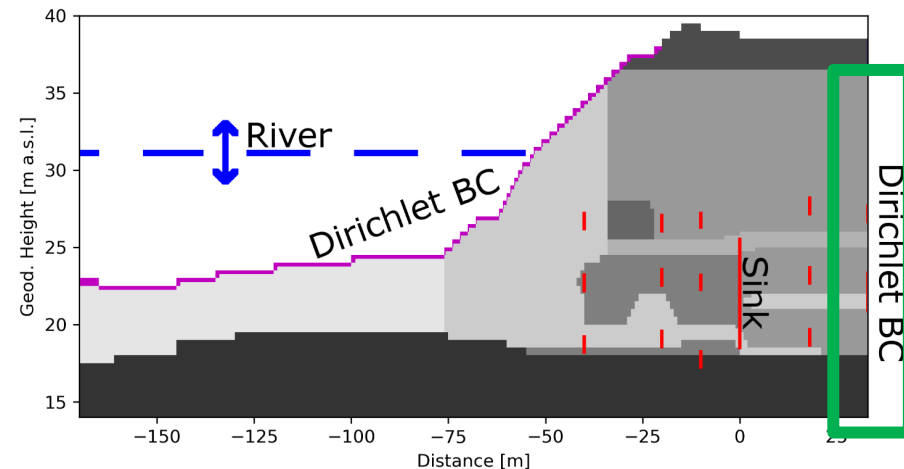
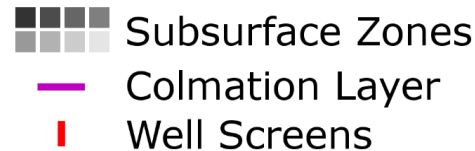


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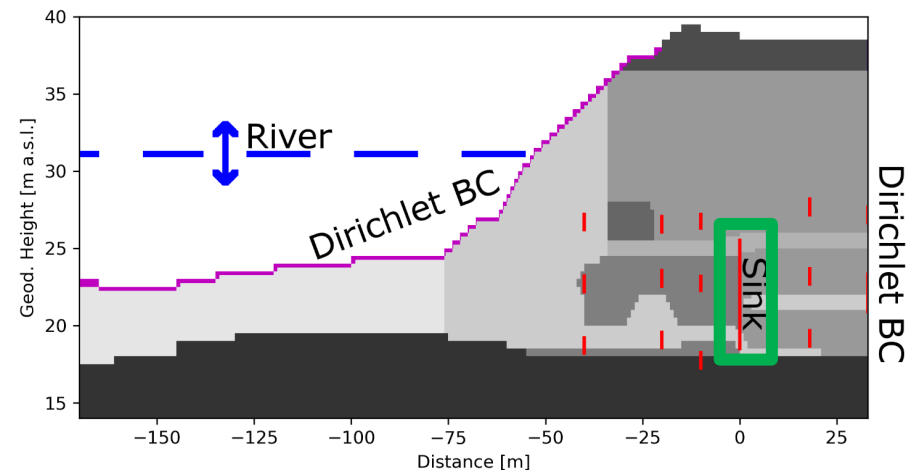
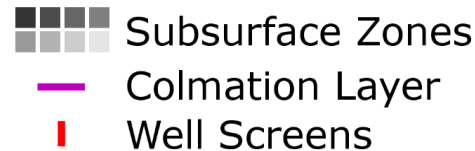


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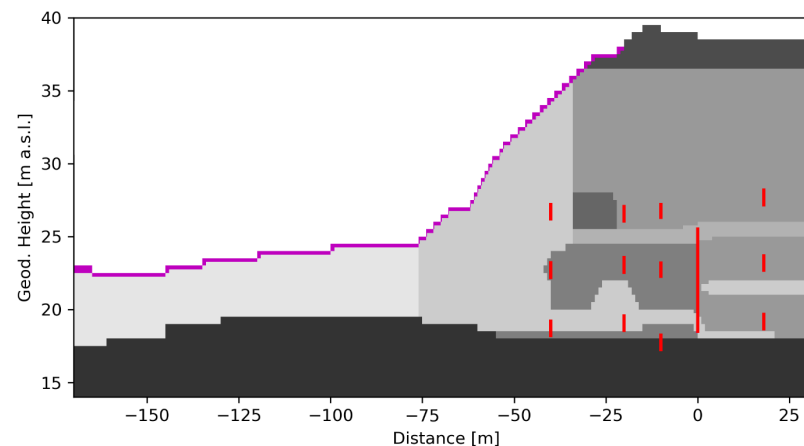


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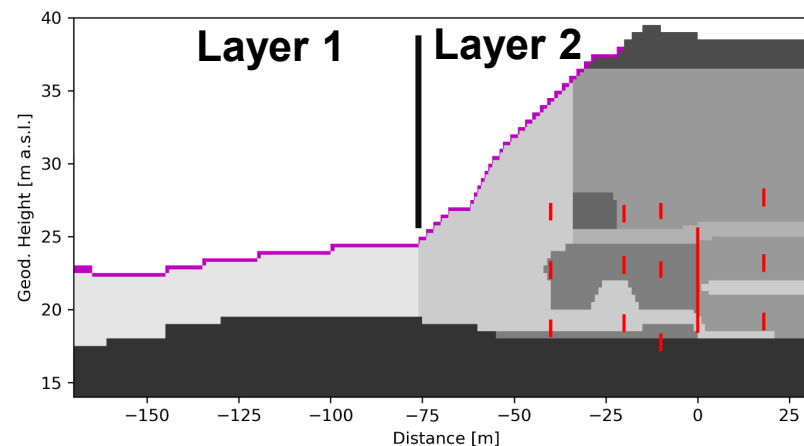
Colmation Layer Model

- **constant** forced **inflow** of surface water **clogs** the riverbed/colmation layer
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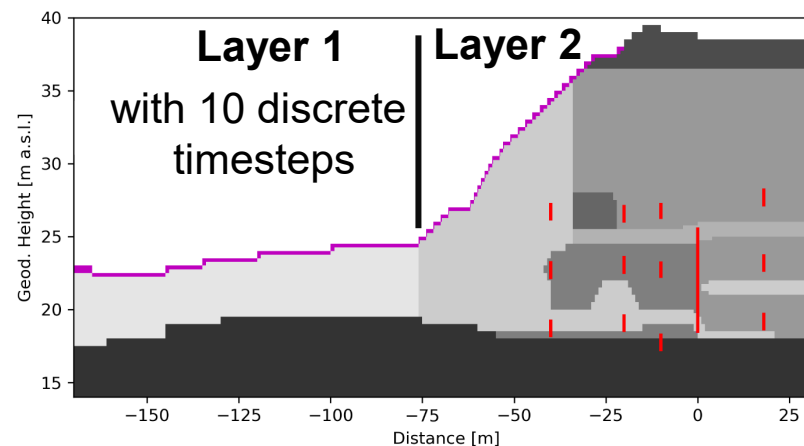
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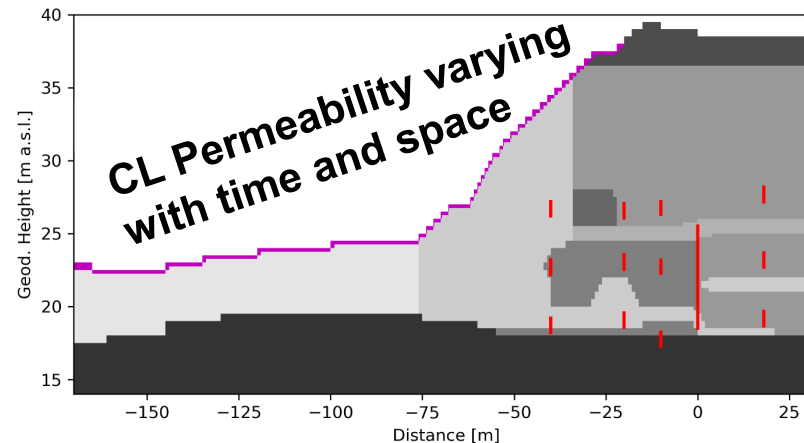
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Layer 2, with 3 timesteps



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 - **Clogging Model** (CM-CL) – permeability calculated based on clogging



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- working with **limited information**:

river level / discharge  erosion - unclogging

temperature  biological activity / bio-clogging

seepage flux  physical (un-)clogging

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$\searrow$
 $f_T = \exp\left(\beta \cdot T \cdot \left(1 - 0.5 \cdot \frac{T}{35}\right)\right)$

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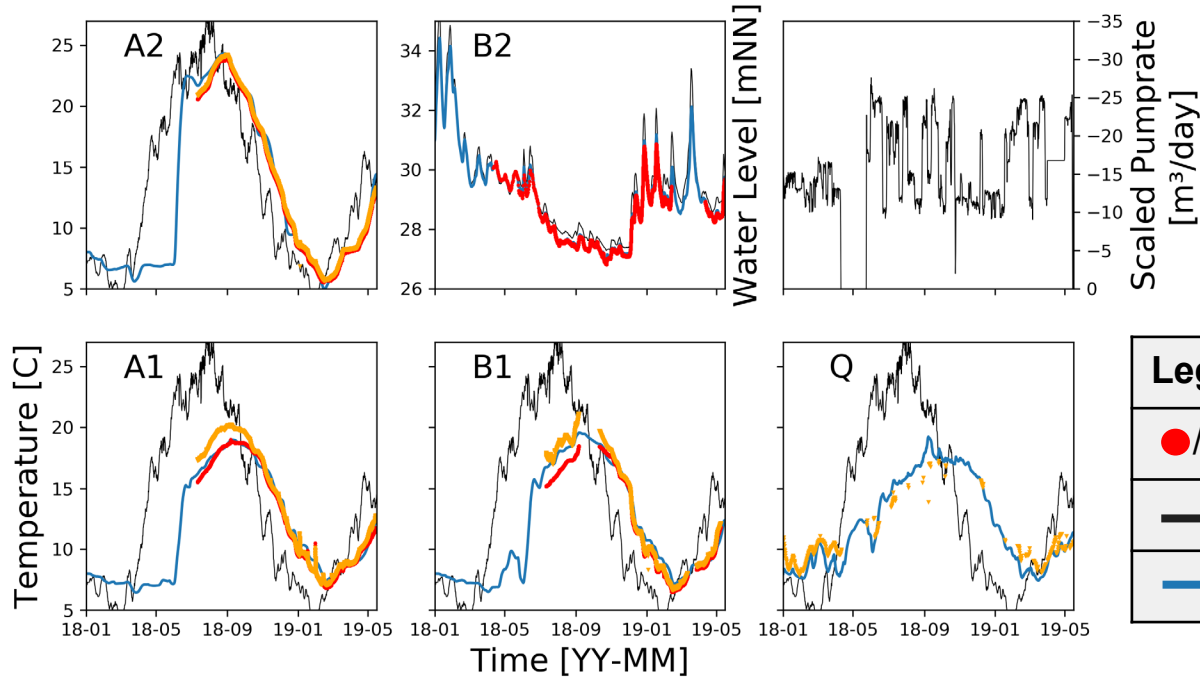
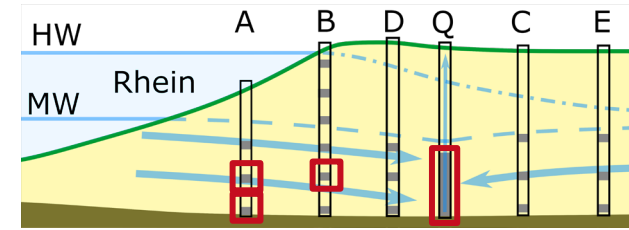
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- **porosity-permeability relation**:

$$K = K_0 \cdot \left(\frac{n - n_{ncrit}}{n_0 - n_{crit}} \right)^a, \text{ if } K < K_{min}, \text{ then } K = K_{min}$$

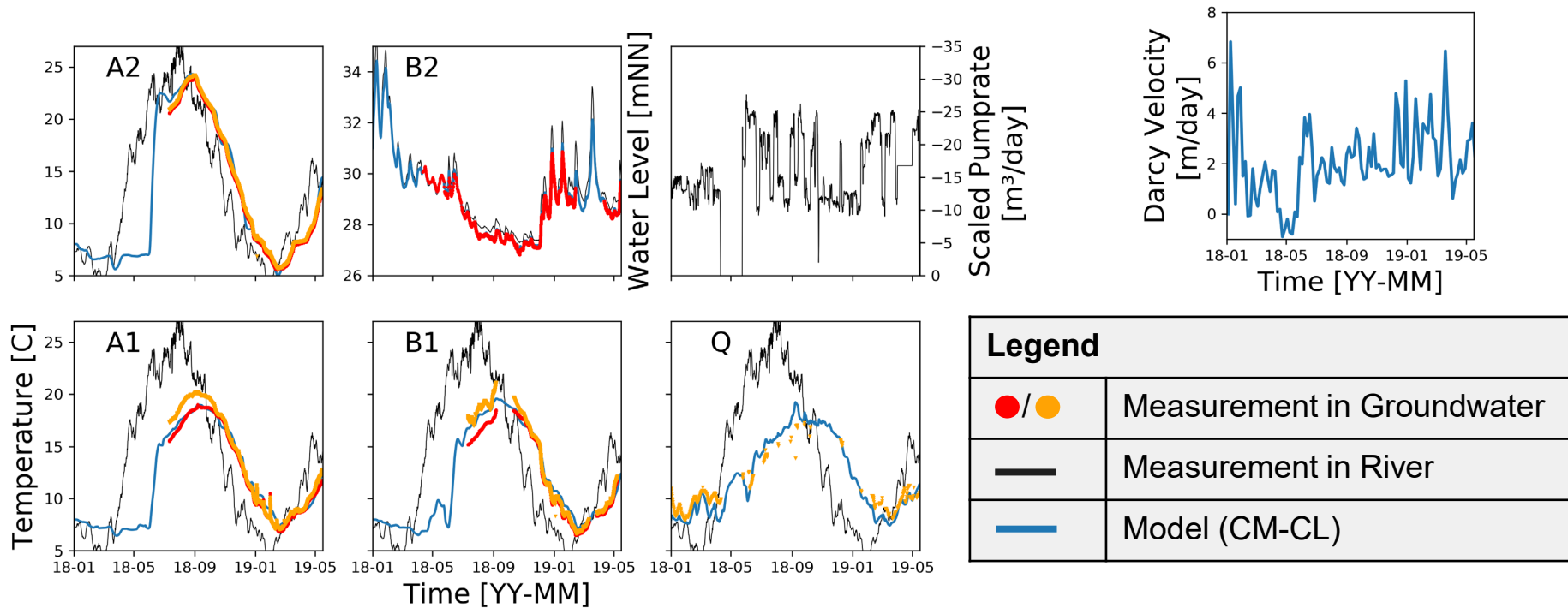
Hydraulics & Heat Transport – Overview –



- **typical seasonal variations** of temperature and river level
- **no pumping** for 40 days **April/May 2018** (waterworks maintenance)

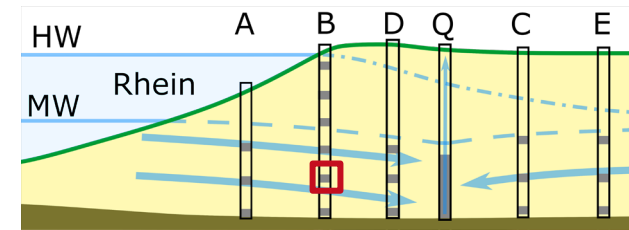
Hydraulics & Heat Transport

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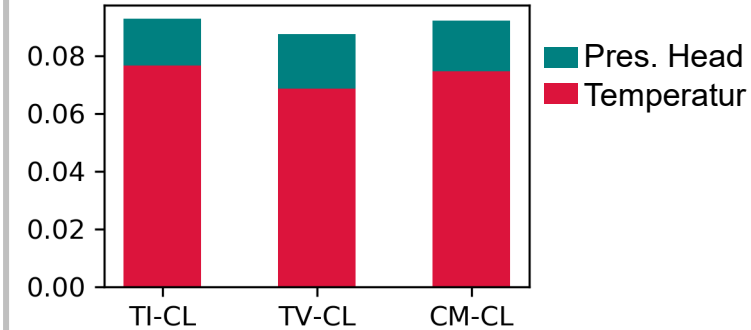


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Hydraulics & Heat Transport – Comparison –



Calibration Comparison

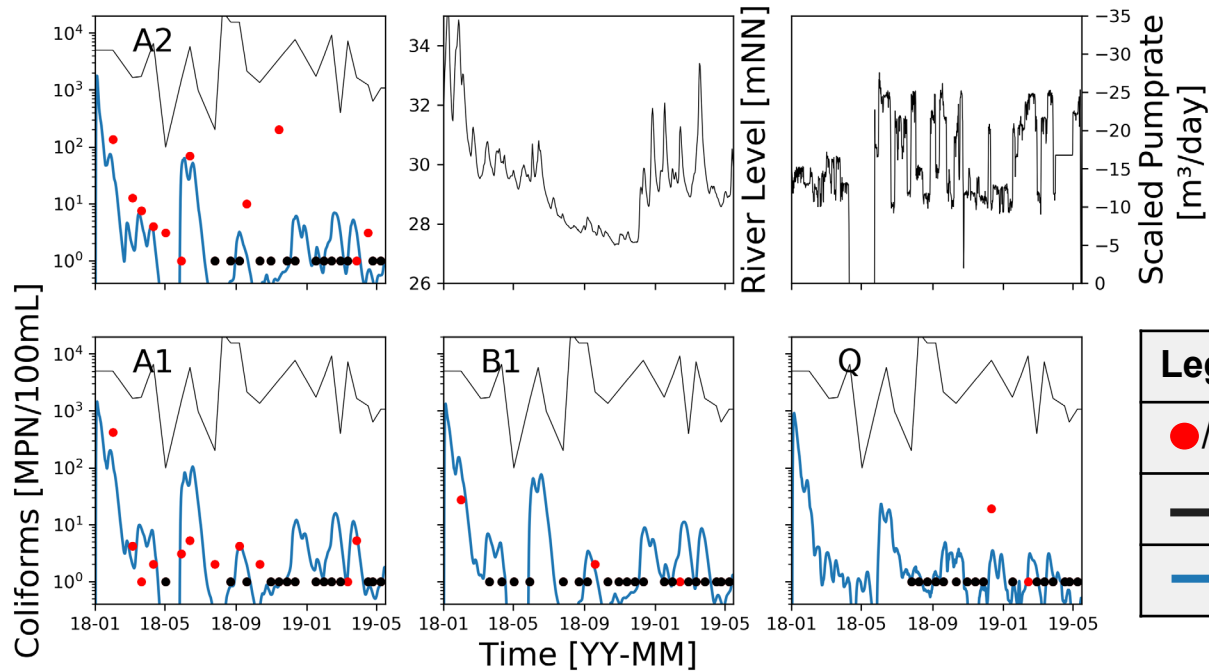
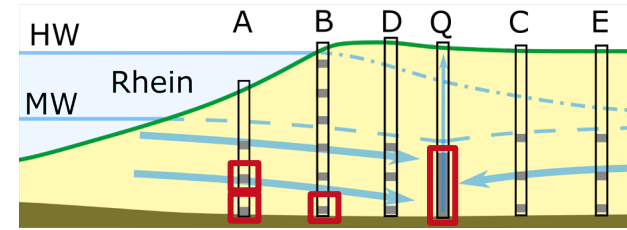


Legend	
● / ●	Measurement in Groundwater
—	Measurement in River
—	Model
— / - - -	Colmation Layer, close/distant

- **marginal differences in heat transport and hydraulics** for the models
- in TV-CL and CM-CL, colmation layer permeability the lowest in summer, and lower in the winter 18/19 than in winter 17/18

Coliforms

– Overview –



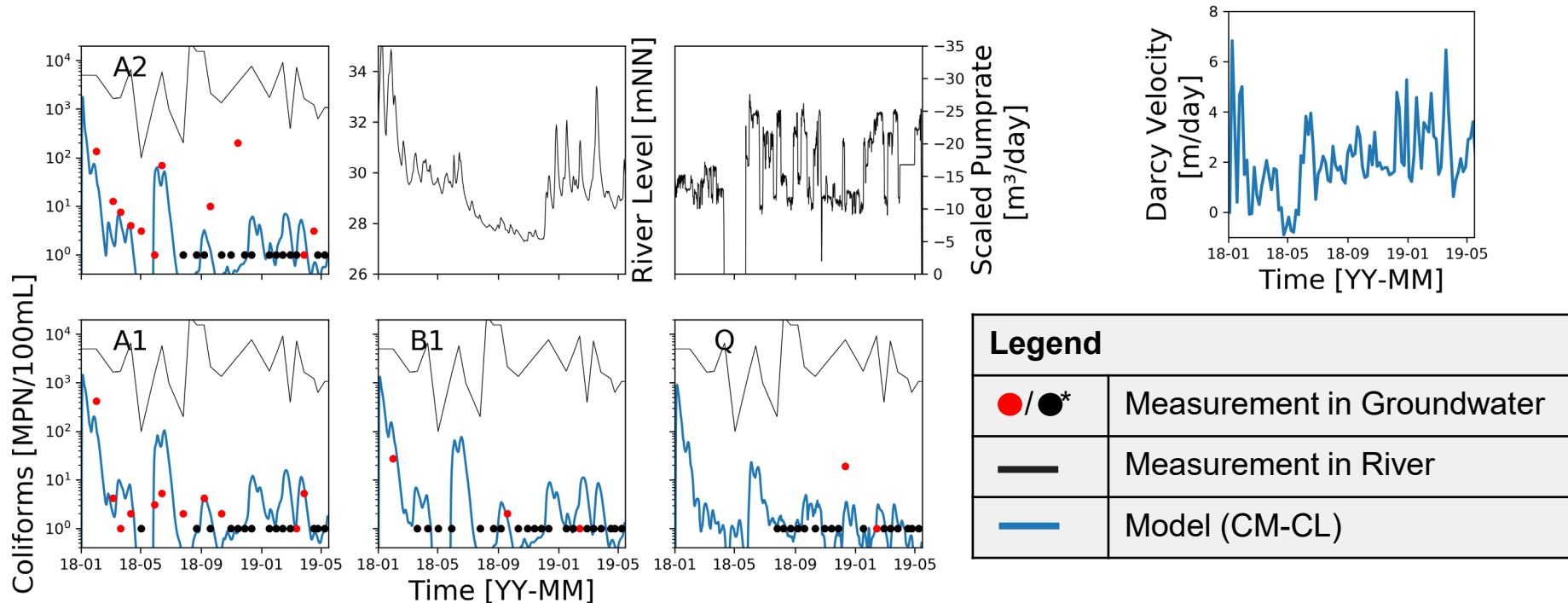
Legend	
●/●*	Measurement in Groundwater
—	Measurement in River
—	Model (CM-CL)

*Black Color = Below Detection Limit

- **high coliform concentration** following the initial **flood**, and after **pumping restarted** in May 2018
- **low concentrations** in the **second winter** (2018/19)

Coliforms

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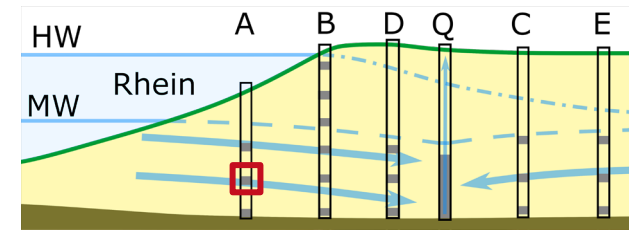
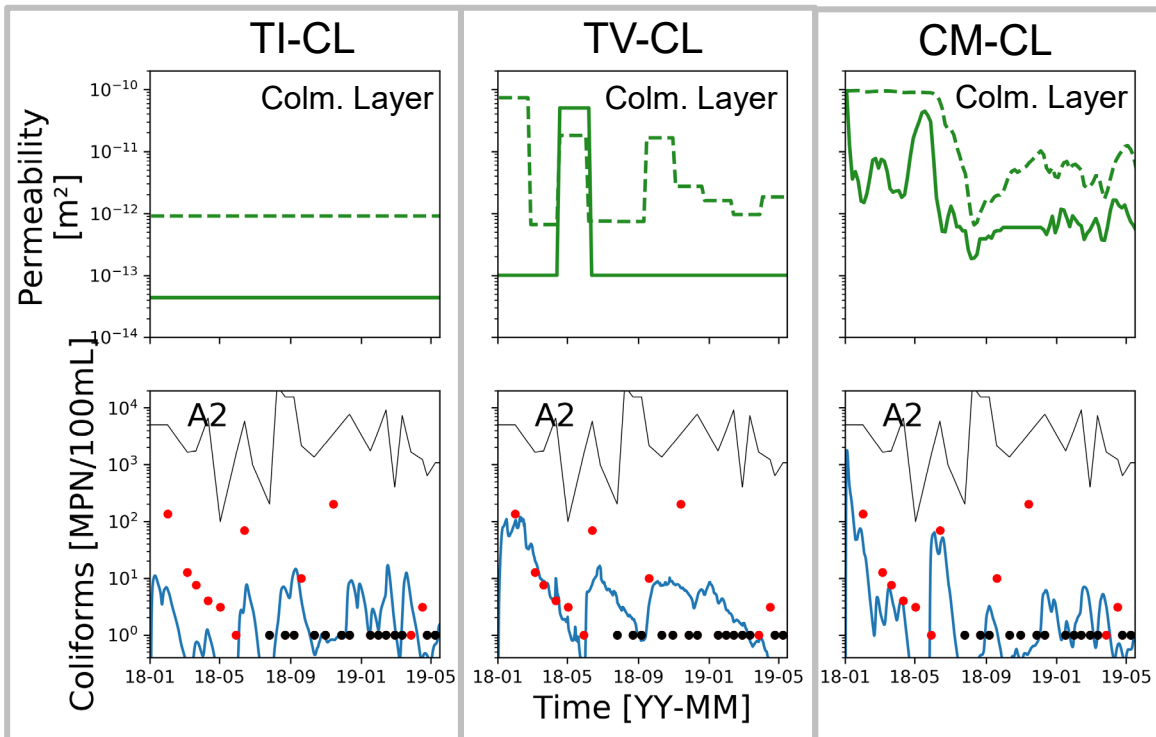


*Black Color = Below Detection Limit

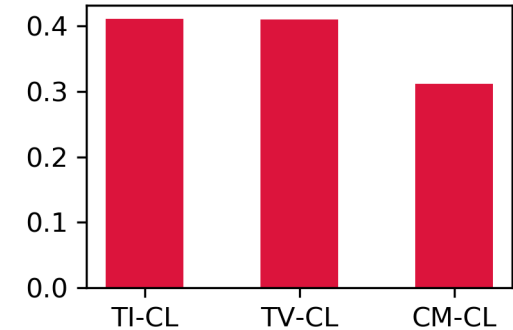
- **high coliform concentration** following the initial **flood**, and after **pumping restarted** in May 2018
- **low concentrations** in the **second winter** (2018/19)

Coliforms

– Comparison –



Calibration Comparison



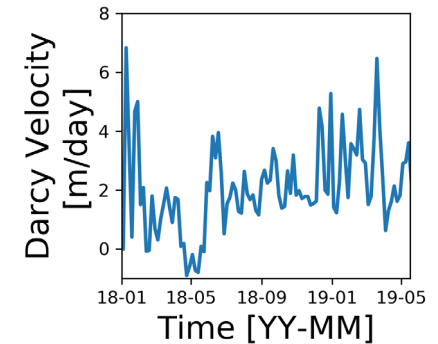
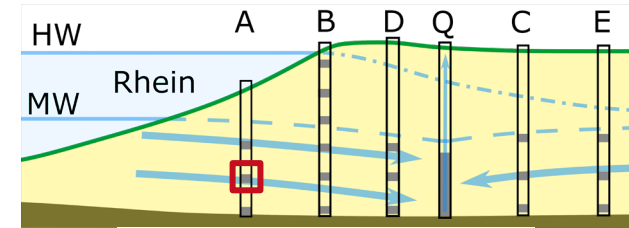
Legend	
●/●*	Measurement in Groundwater
—	Measurement in River
—	Model
—/—	Colmation Layer, close/distant

*Black Color = Below Detection Limit

- TI-CL model fails to display high concentrations in winter 17/18
- **low concentrations in the winter (2018/19), related to lower permeability and effective grain size of the colmation layer**

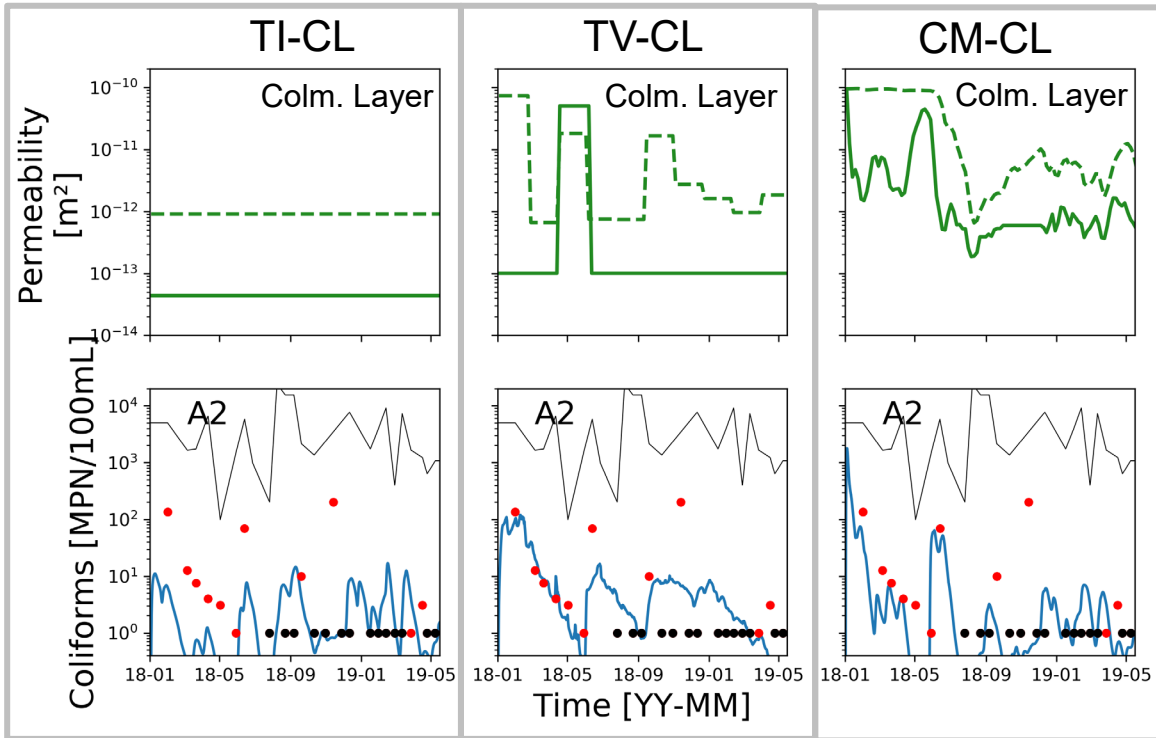
Coliforms

– Comparison –



Legend	
●/●*	Measurement in Groundwater
—	Measurement in River
—	Model
—/—	Colmatation Layer, close/distant

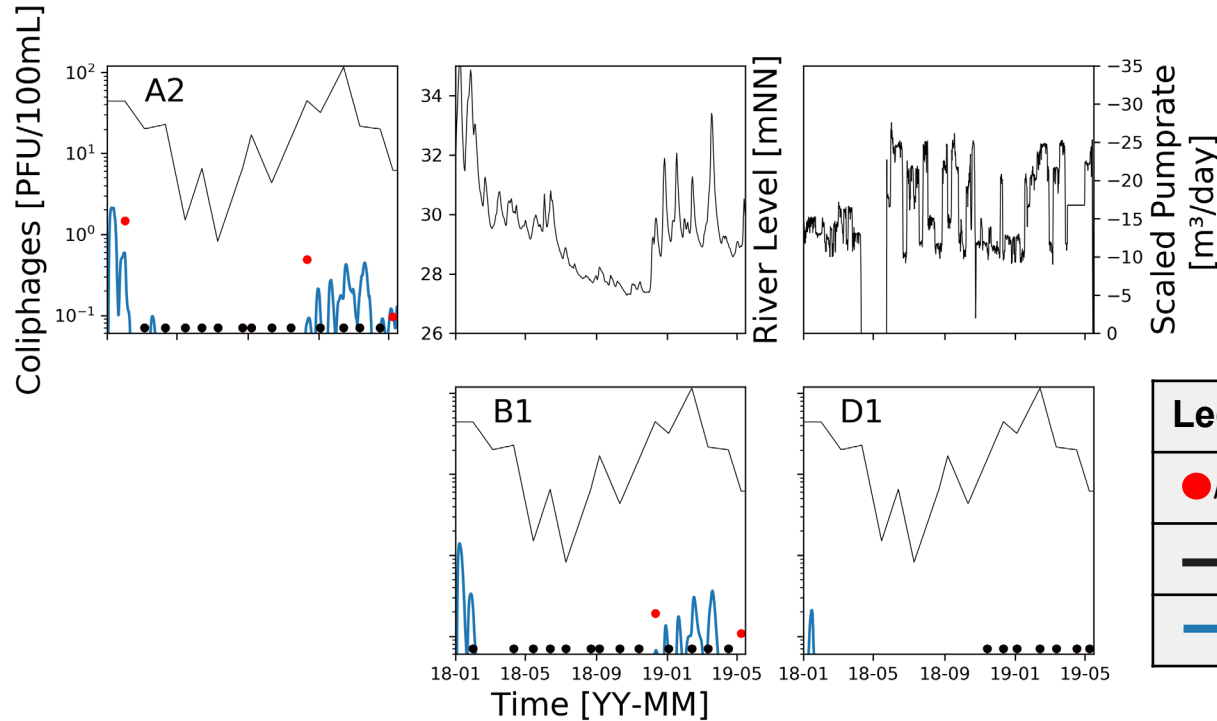
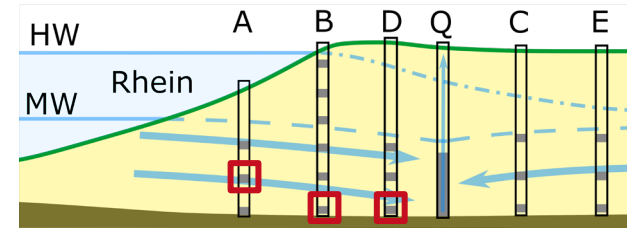
*Black Color = Below Detection Limit



- TI-CL model fails to display high concentrations in winter 17/18
- **low concentrations in the winter (2018/19), related to lower permeability and effective grain size of the colmatation layer**

Coliphages

– Overview –



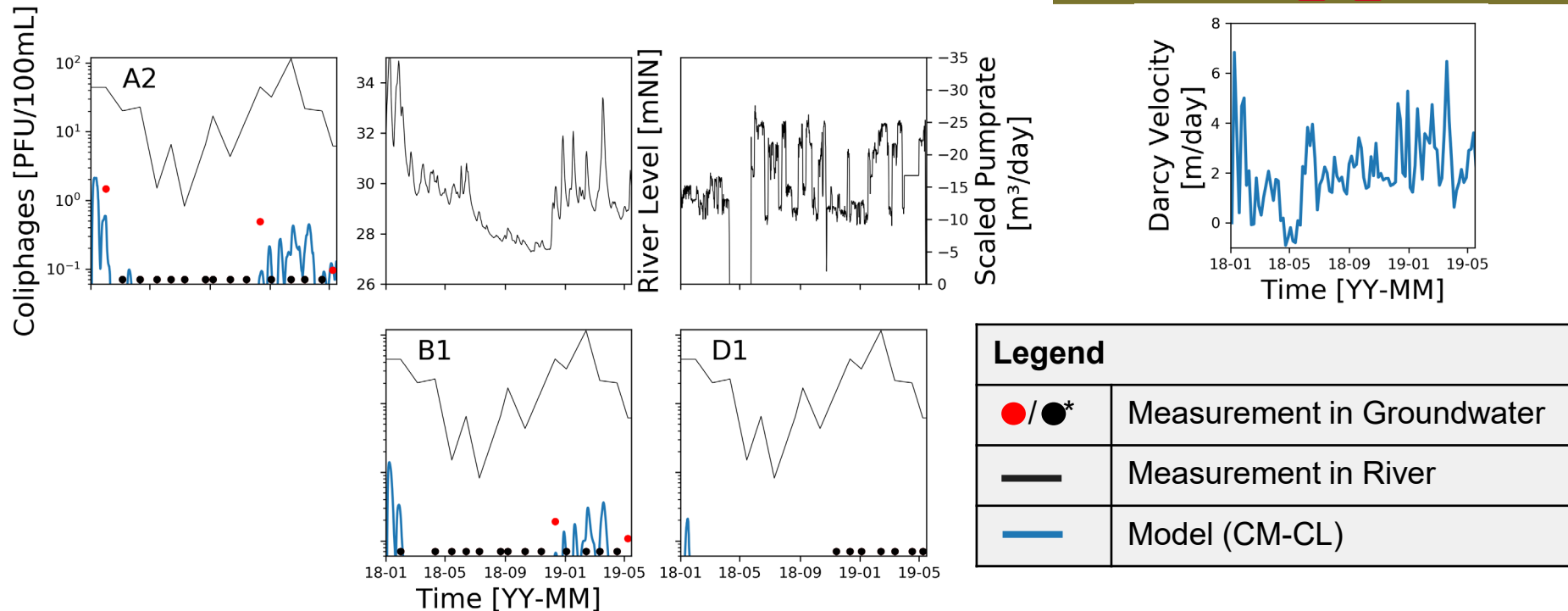
Legend	
●/●*	Measurement in Groundwater
—	Measurement in River
—	Model (CM-CL)

*Black Color = Below Detection Limit

- **Coliphages** only **detected** at **low residence times** (high groundwater velocities)
- model indicates that sampling frequency might have been too low to adequately detect all breakthroughs

Coliphages

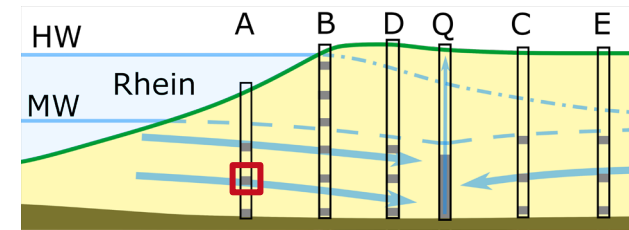
– Overview –



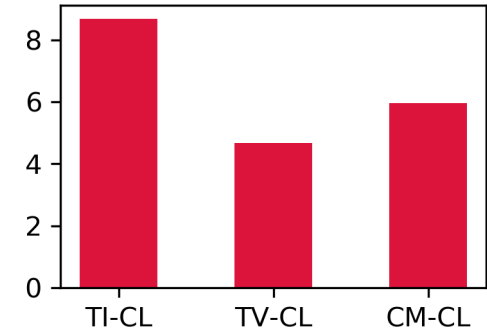
*Black Color = Below Detection Limit

- **Coliphages** only **detected** at **low residence times** (high groundwater velocities)
- model indicates that sampling frequency might have been too low to adequately detect all breakthroughs

Coliphages – Comparison –

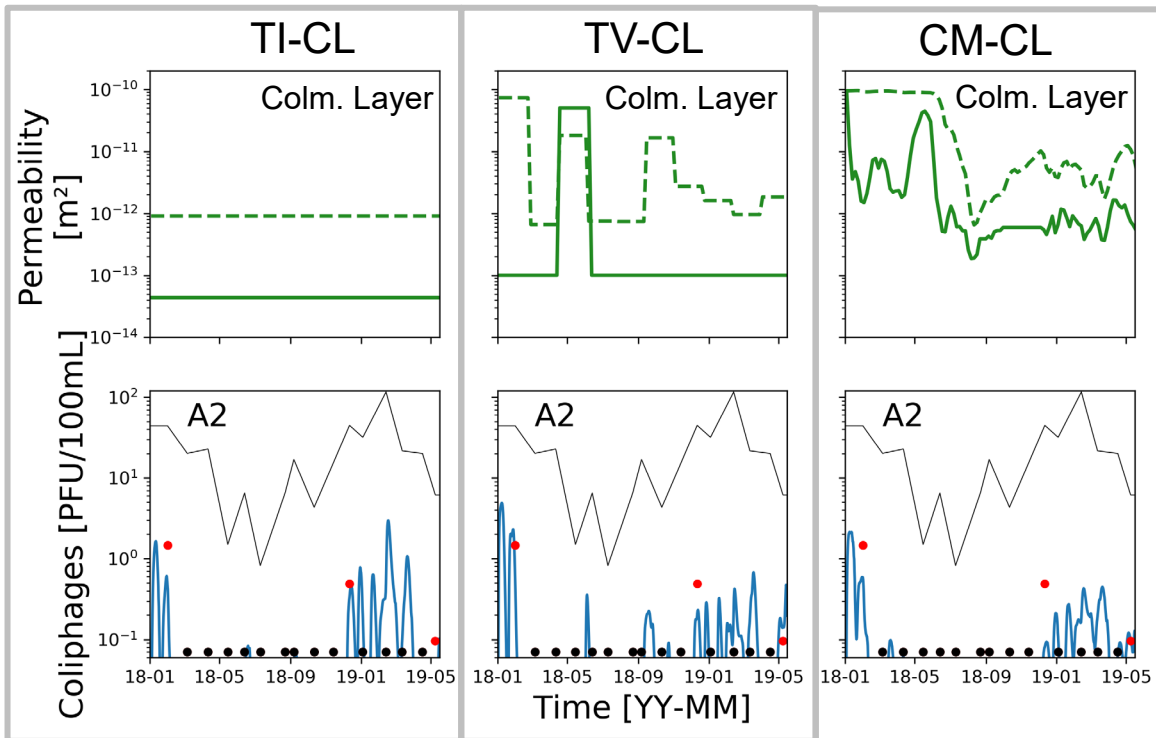


Calibration Comparison



Legend	
●/●*	Measurement in Groundwater
—	Measurement in River
—	Model
—/—	Colmation Layer, close/distant

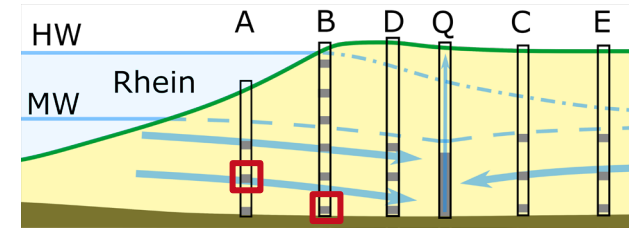
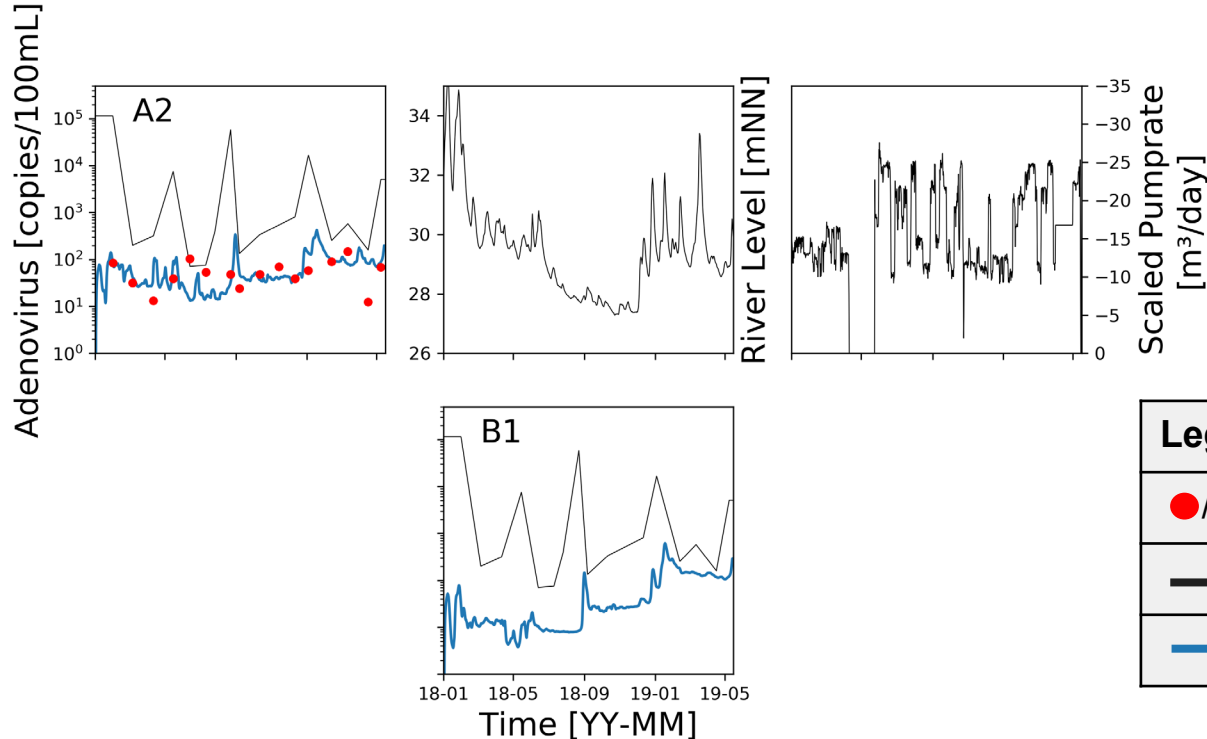
*Black Color = Below Detection Limit



- the TI-CL appears to overestimate concentrations in winter 2018/19
- but **low sampling frequency does not allow a clear conclusion**

Adenovirus

– Overview –

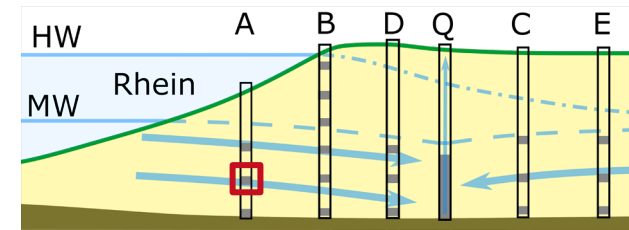
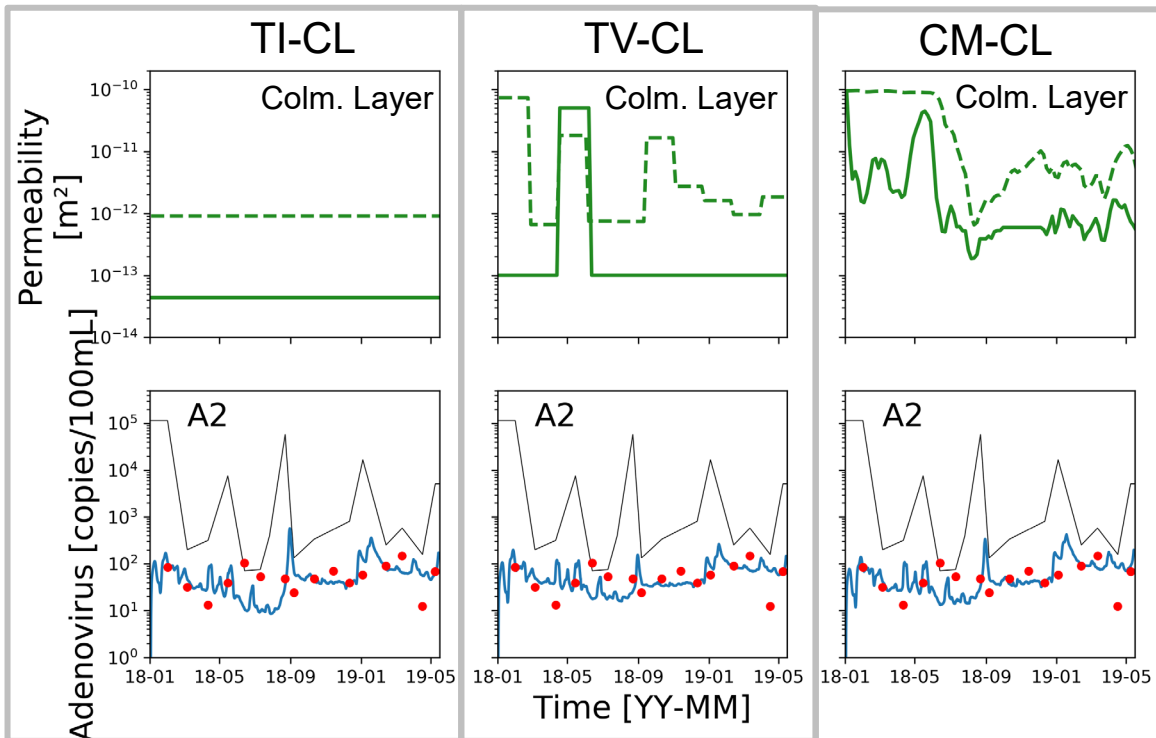


Legend	
●/●*	Measurement in Groundwater
—	Measurement in River
—	Model (CM-CL)

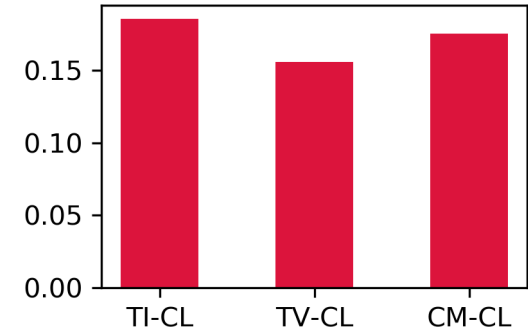
*Black Color = Below Detection Limit

- **high variability** of Adenovirus concentration **in river**, appears buffered in aquifer
- Adenovirus measured with ddPCR, data not directly comparable to plaque tests
data used for Coliphages measurements

Adenovirus – Comparison –



Calibration Comparison



Legend

●/●*	Measurement in Groundwater
—	Measurement in River
—	Model
—/—	Colmation Layer, close/distant

*Black Color = Below Detection Limit

- for Adenovirus data, **differences between the models are less distinct**

Conclusions

- at monitoring site, we found **lower retention of pathogen** (indicators) **in winter, especially during the flood** in winter 18/19, and **higher retention in summer**
- main **driving factors** for **change in retention behavior** appear to be **groundwater velocity** and **colmation layer permeability**
- **colmation layer** permeability **influenced** transport of **bacteria** (Coliforms) **stronger** than viruses
- **colmation layer permeability** was overall **higher in winter, lower in summer**, attributed to differences in river discharge and biological activity

Many Thanks

if you have questions/comments/etc., I'm happy to talk about them in the breakout text chat of the EGU Session (HS8.1.1, Tue, 27 Apr, 11:00–12:30 (CEST)) or later via Email: dustin.knabe@tu-berlin.de

