https://life-adsorb.eu/fr/site

Modelling hydraulics and fate of micropollutants in a variably saturated treatment wetland for urban stormwater

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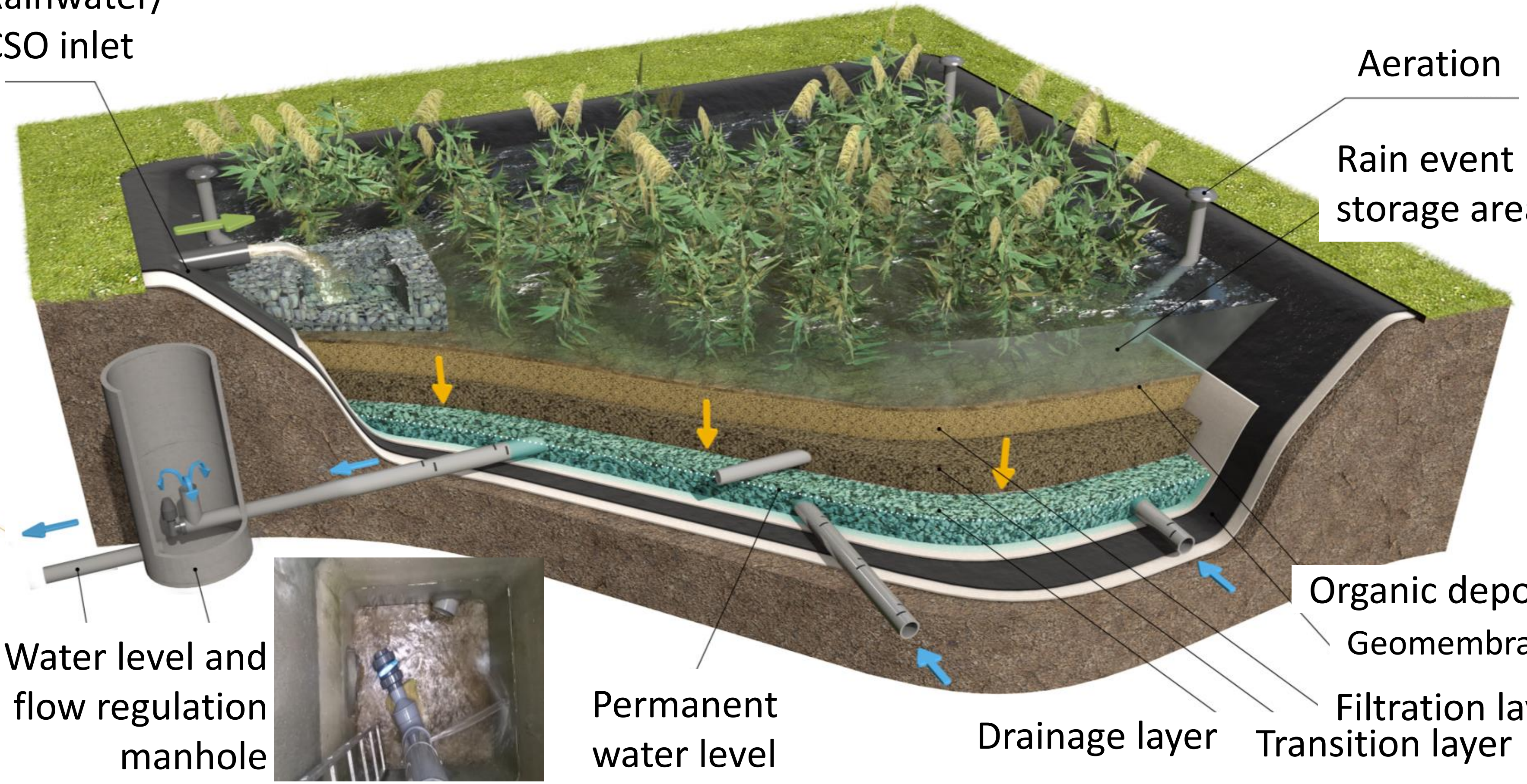
16th International Conference on Urban Drainage

The HYDR'EPUR® System
Nature-based solution for runoff and CSO



Outflow controlled by a throttle outflow

20 references in France

	Removal efficiency (%)	Concentration out (mg/L)
DCO	60	50
MES	90	20

https://ecobird.fr/

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The Life ADSORB project

https://life-adsorb.eu/fr/site

- Main objectives

  – Demonstrate the applicability of a treatment wetland to effectively reduce pollutant loads (TSS, metallic and organic micropollutants) from runoff water in a natural area

  – Better understanding and identification of mechanisms and parameters influencing water flow, transport and fate of micropollutants → optimize design and operational

- How can modelling contribute ?

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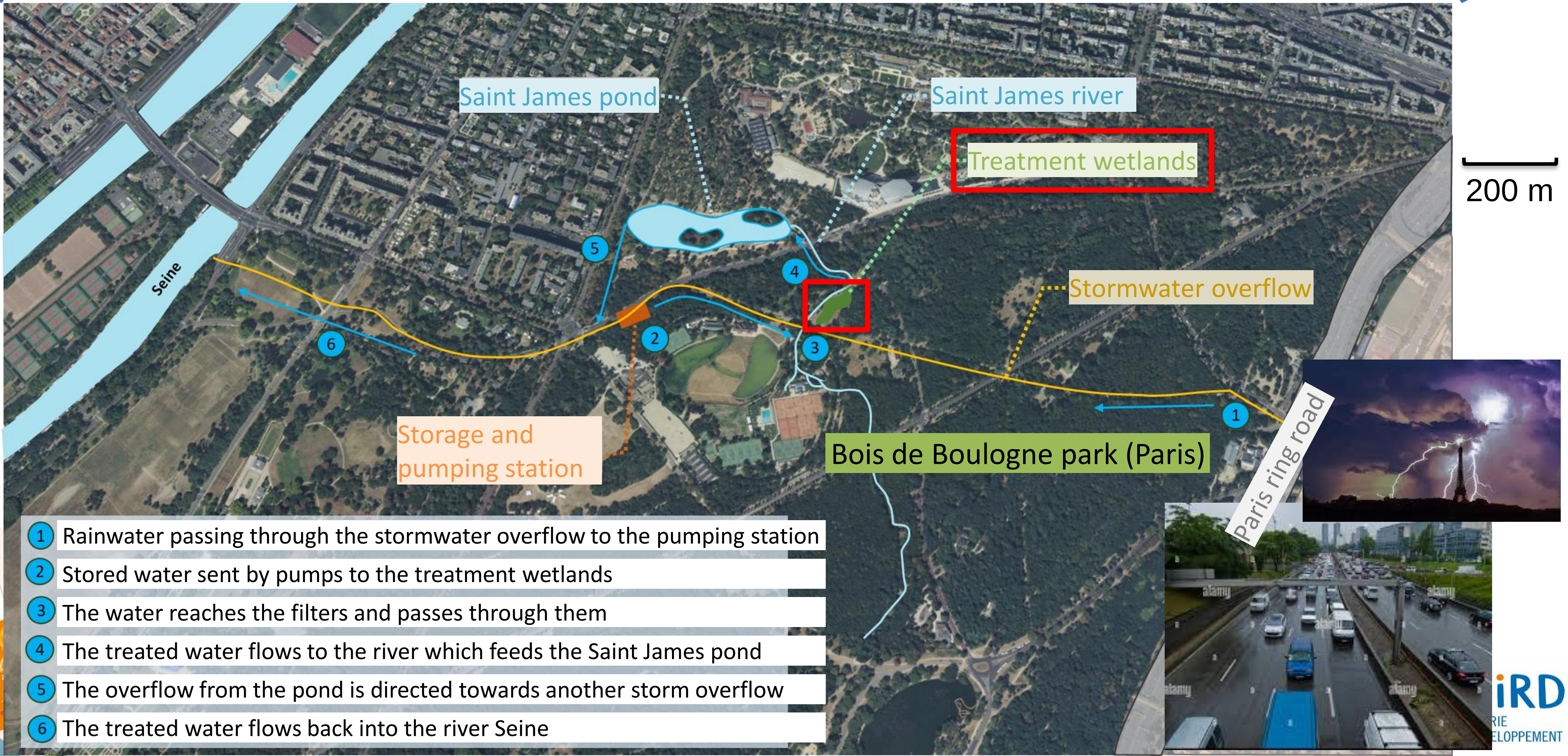
The Life ADSORB experimental site, in Paris



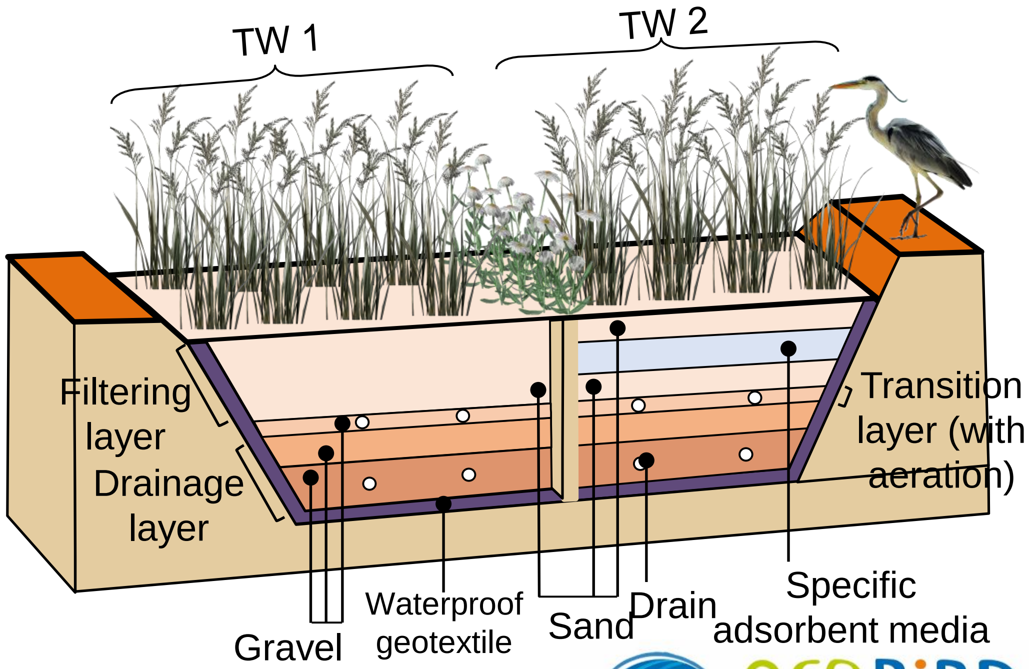
1. Rainwater passing through the stormwater overflow to the pumping station
2. Stored water sent by pumps to the treatment wetlands
3. The water reaches the filters and passes through them
4. The treated water flows to the river which feeds the Saint James pond
5. The overflow from the pond is directed towards another storm overflow
6. The treated water flows back into the river Seine

The treatment wetland pilots

- 2 pilot TWs of 600 m²
- Treatment of runoff water; Metallic and organic micropollutants
- Similar configuration (100 m long, 1 m deep) and operation
  Alternation every month
- Transition layer (10 cm) + drainage layer (50 cm)
- Single difference between the two pilots:
  composition of the filtering layer

TW1: only sand (40 cm)

TW2: layer of specific adsorbent material (micropollutants, Rainclean®, 20 cm) between two layers of sand (10 cm each)



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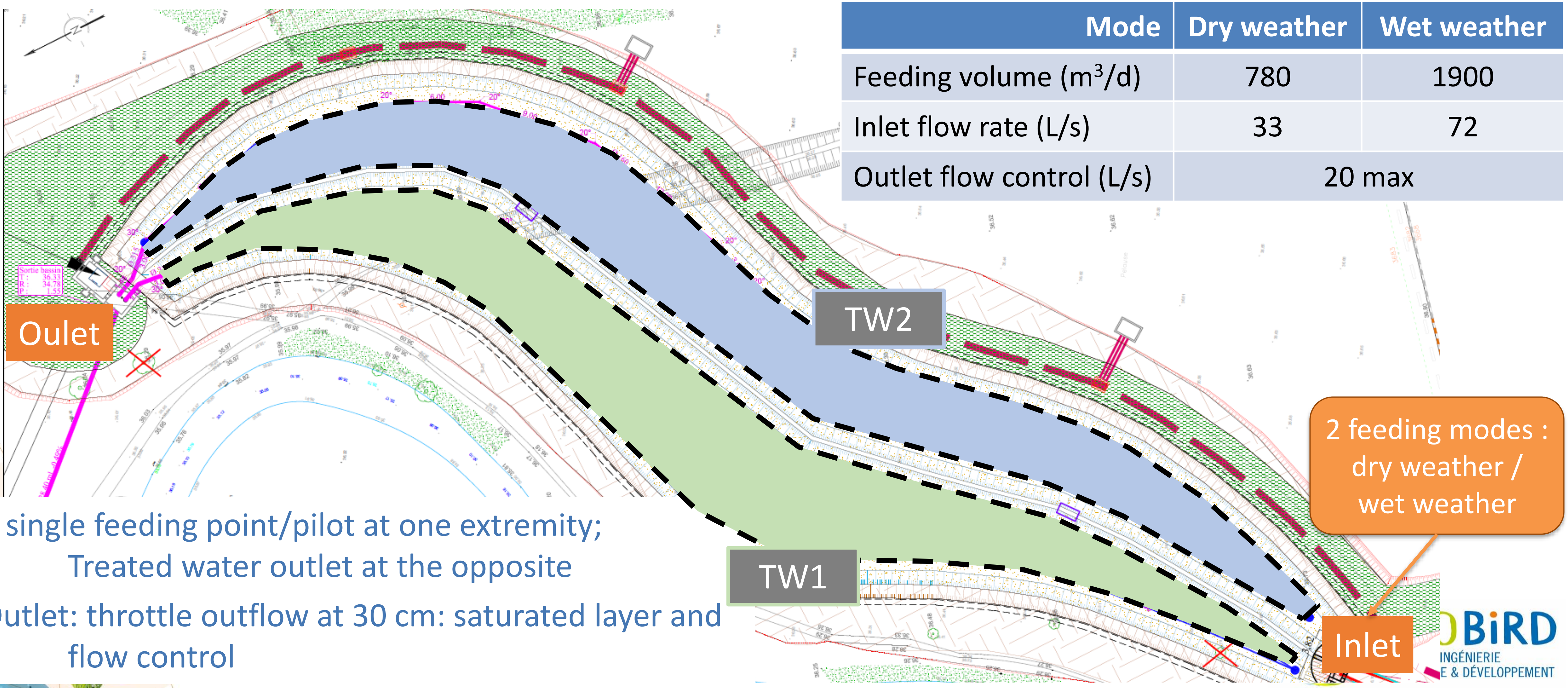
The treatment wetland pilots



Mode	Dry weather	Wet weather
Feeding volume (m^3/d)	780	1900
Inlet flow rate (L/s)	33	72
Outlet flow control (L/s)	20 max	

- 1 single feeding point/pilot at one extremity; Treated water outlet at the opposite
- Outlet: throttle outflow at 30 cm: saturated layer and flow control

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Objectives of the study

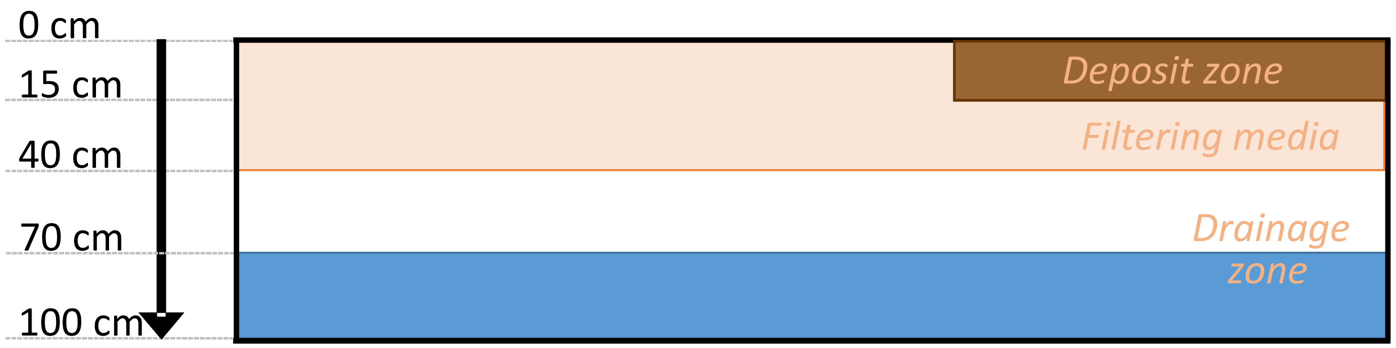
- Does the feeding and drainage specificities significantly influence the behaviour of the system ?

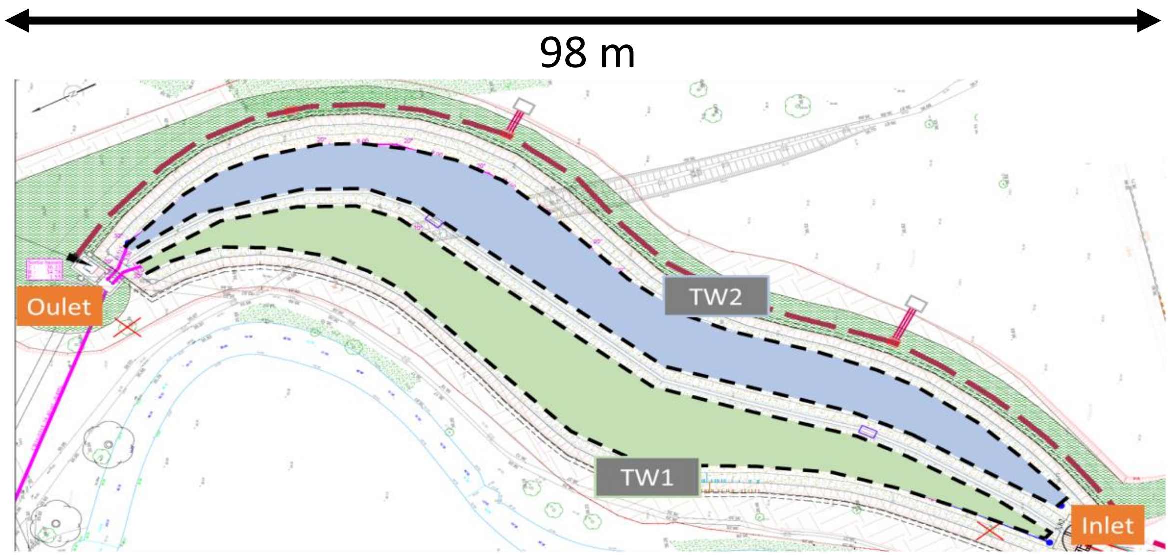
1. Mechanistic hydraulic modelling of a TW with a layer of specific adsorbent media for micropollutants

2. Determination of the adsorption parameters to be applied in the mechanistic model

1. Mechanistic hydraulic modelling

Conceptual model





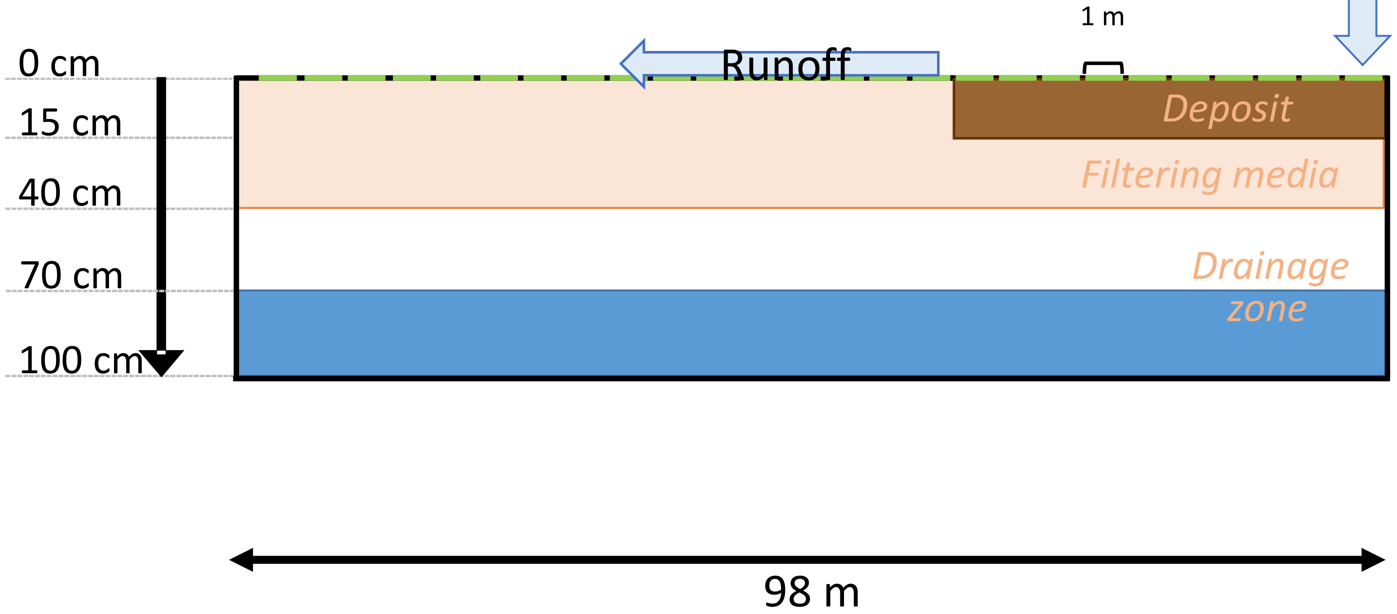
1. Mechanistic hydraulic modelling

Conceptual model

3 models

1. Surface flow (Matlab)

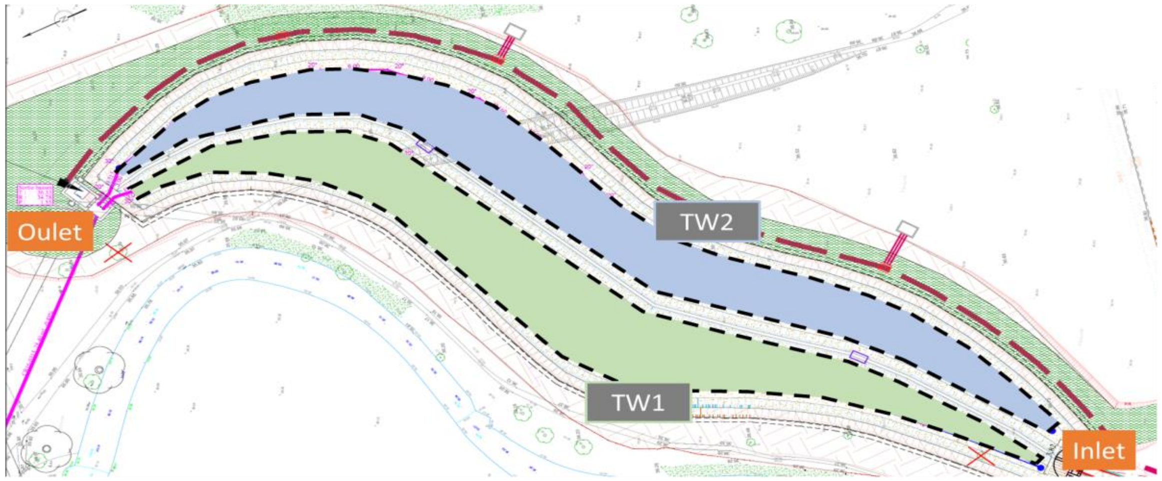
Inlet



* *Time-varying boundary condition*
- *"Pressure head" when water supply*
- *"No flow" when no water supply*

<u>Boundary conditions</u>

- No flux
- Pressure head
- Flux



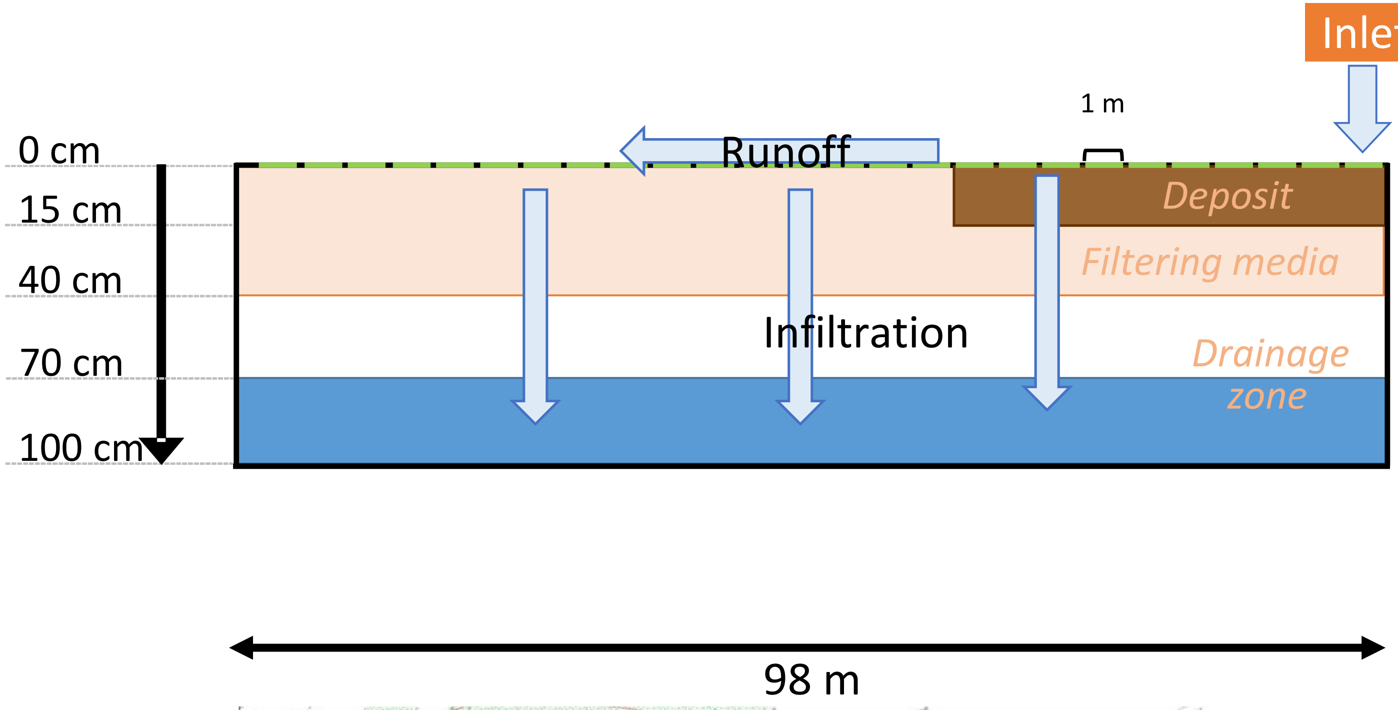
1. Mechanistic hydraulic modelling

Conceptual model

3 models

1. Surface flow (Matlab)

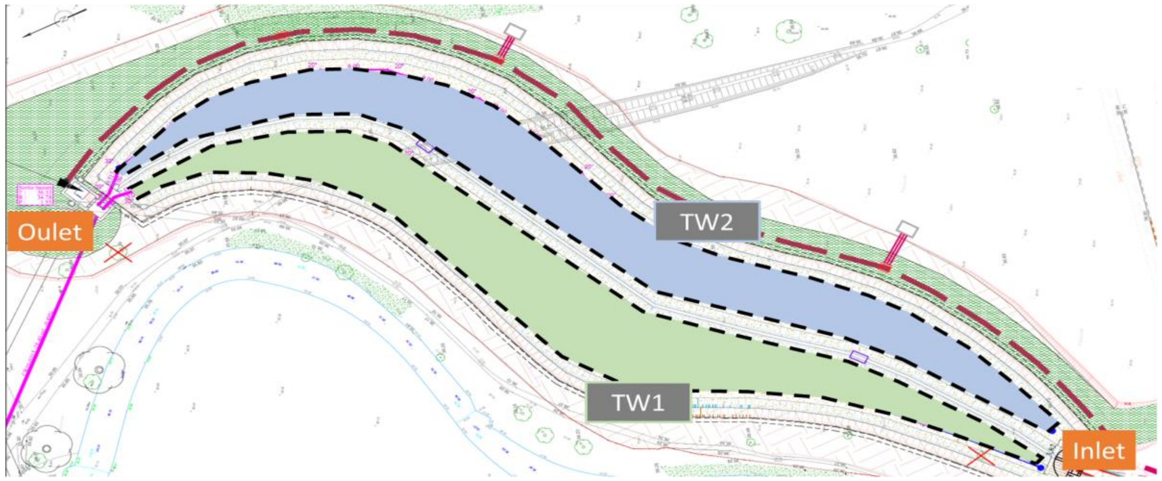
2. Water flow inside the filter (COMSOL)



* Time-varying boundary condition
- "Pressure head" when water supply
- "No flow" when no water supply

Boundary conditions

- No flux
- Pressure head
- Flux



1. Mechanistic hydraulic modelling

Conceptual model

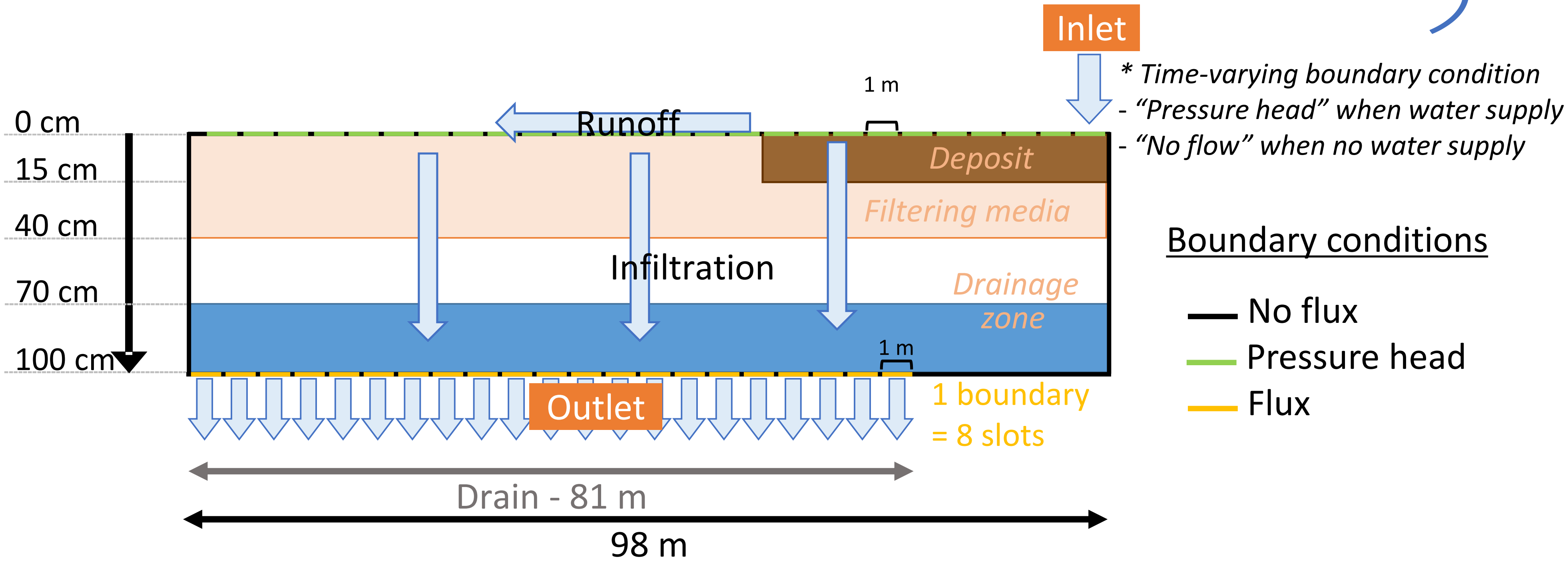
3 models

1. Surface flow (Matlab)

2. Water flow inside the filter (COMSOL)

3. Drain (Matlab)

Significant pressure head losses in the drain that cannot be ignored



1. Mechanistic hydraulic modelling

Conceptual model

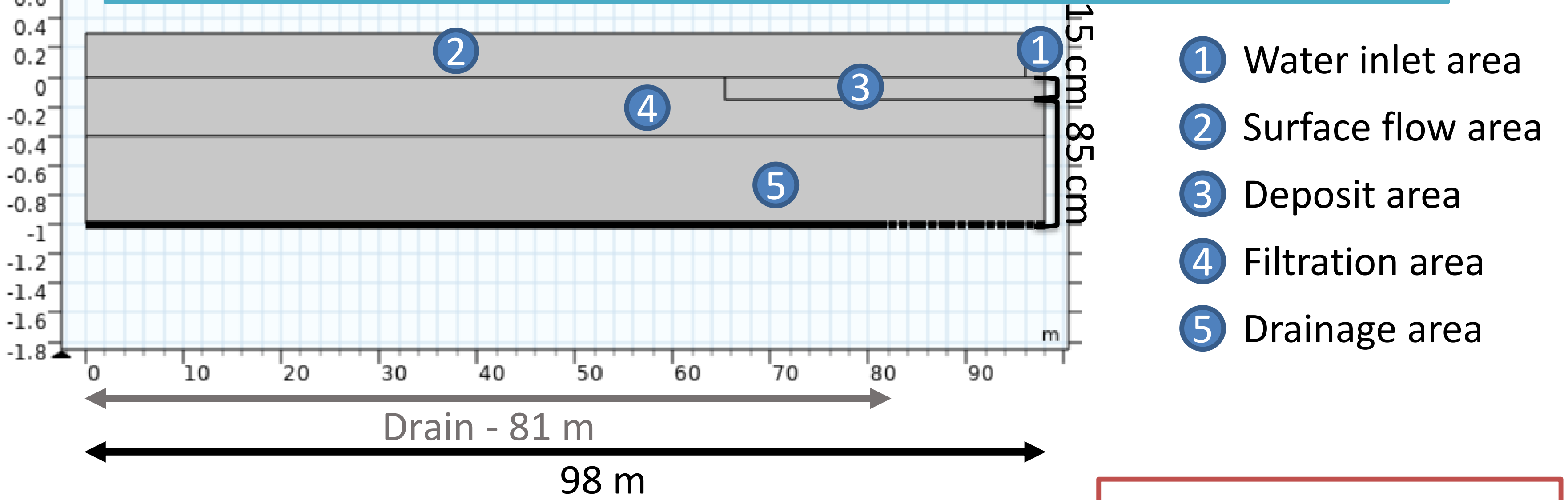
3 models

- 1. Surface flow (Matlab)
- 2. Water flow inside the filter (COMSOL)
- 3. Drain (Matlab)

COUPLING

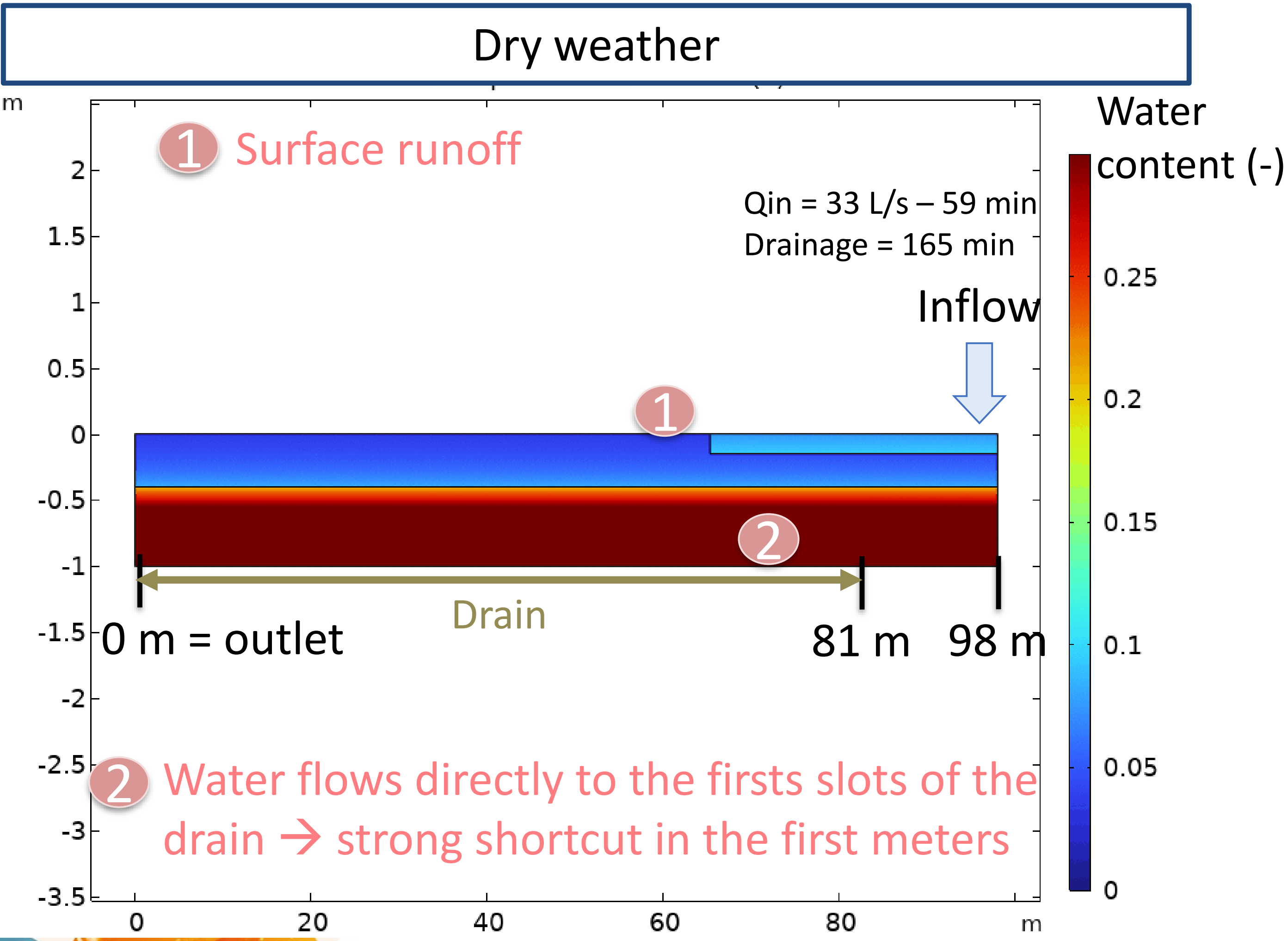
Significant pressure head losses in the drain that cannot be ignored

2D numerical model (COMSOL Multiphysics®/MATLAB® LivelinkTM) of TW2 (specific adsorbent)



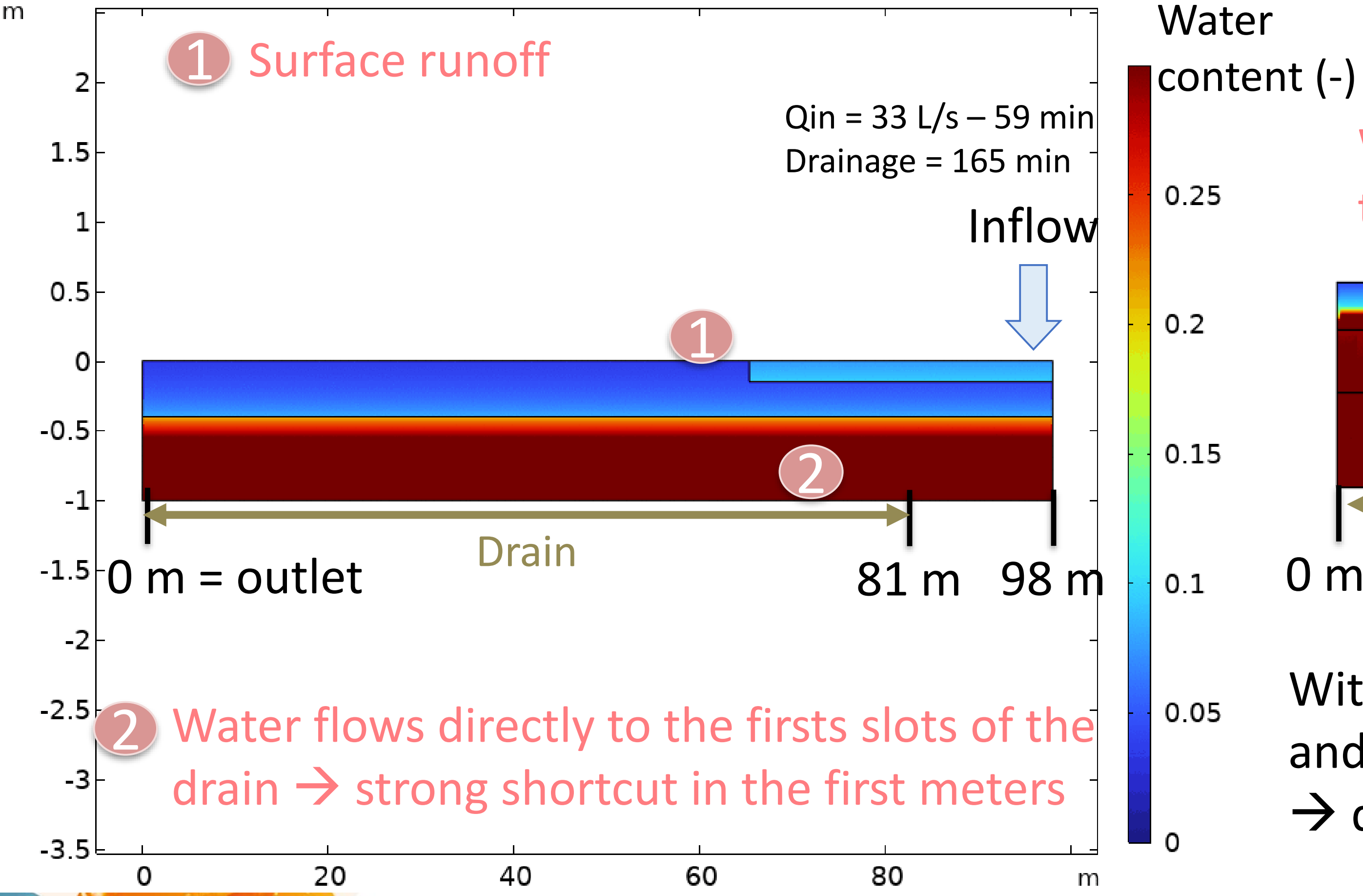
1. Dry weather
2. Drainage (Wet weather)

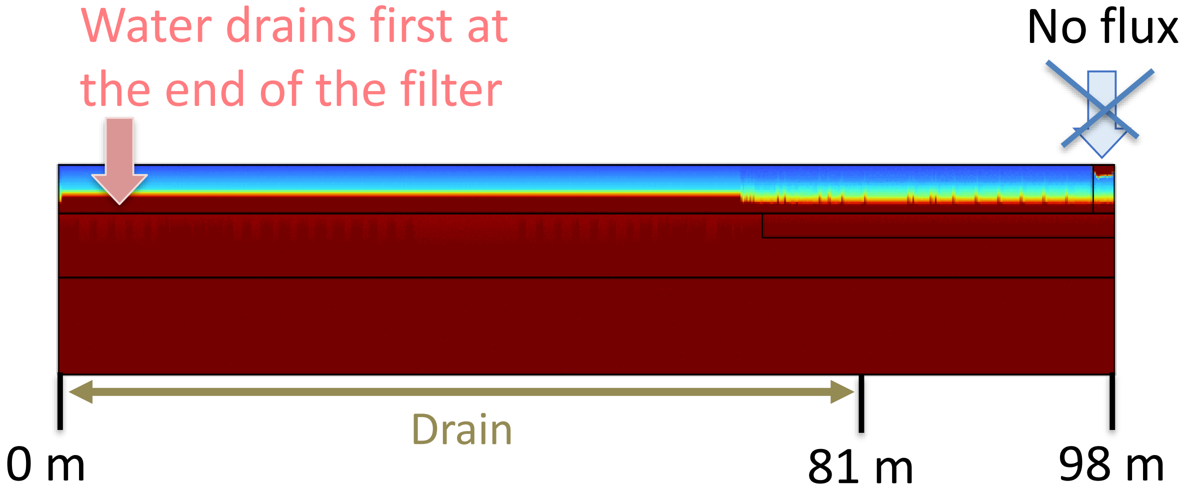
1. Mechanistic hydraulic modelling



1. Mechanistic hydraulic modelling

Dry weather	Drainage phase (Wet weather)





With higher water flow at the inlet → the filter fills up and the entire drain used until the filter completely full → drainage phase

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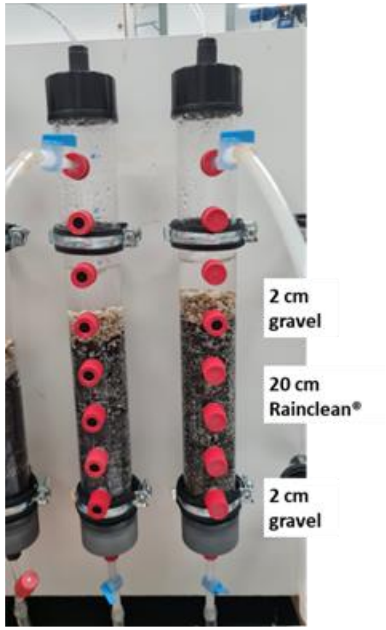
2. Adsorption parameters

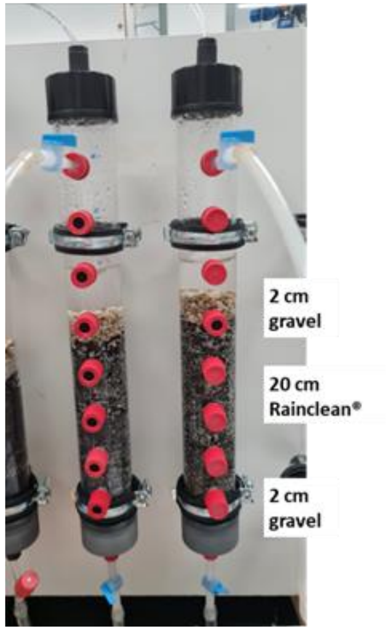
- Determination of the adsorption parameters to be applied in the mechanistic model
  - Batch experiments → Isotherm and kinetics coefficients
  - Columns experiments

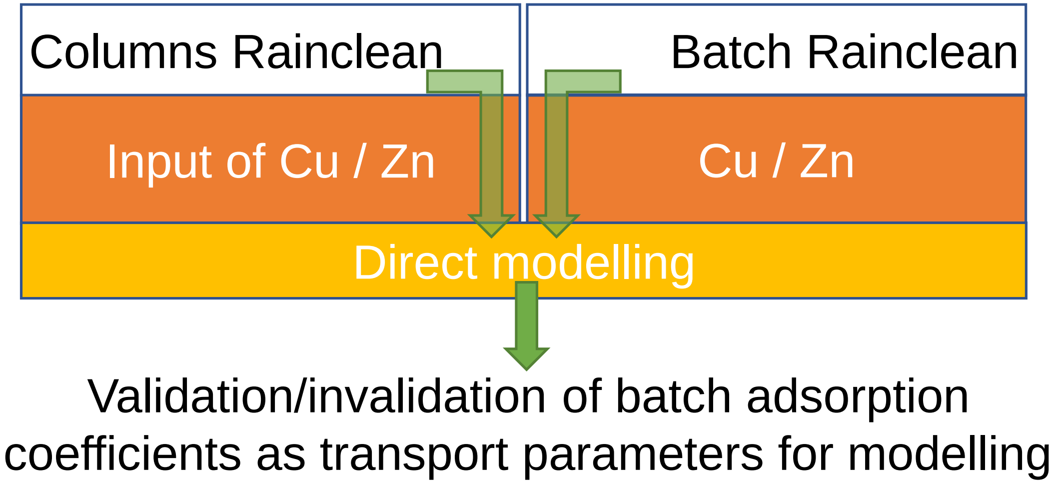


Columns Rainclean	Batch Rainclean
Input of Cu / Zn	Cu / Zn

2. Adsorption parameters

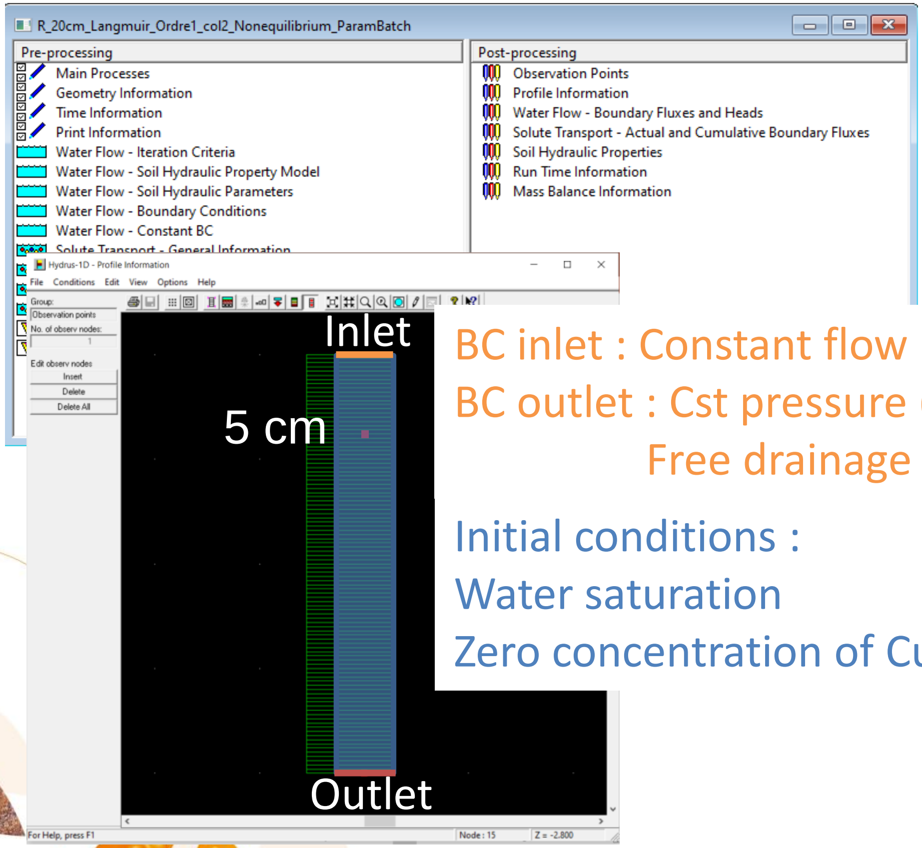
- Determination of the adsorption parameters to be applied in the mechanistic model
  - Batch experiments → Isotherm and kinetics coefficients
  - Columns experiments
- Are the results obtained in batch conditions representative of the behaviour of micropollutants in columns? Can batch values be used directly in the model?





2. Adsorption parameters

HYDRUS-1D model – <u>DIRECT MODELLING WITH BATCH VALUES</u>



BC inlet : Constant flow (water/Cu&Zn)
BC outlet : Cst pressure (water);
Free drainage (Cu&Zn)

Initial conditions :
Water saturation
Zero concentration of Cu&Zn

	Kinetic
	Pseudo-first order
	k_1 (mn^{-1})
Cu	2.03E-02
Zn	4.76E-03

	Isotherm	
	Langmuir	
	qm (mg/g)	K_L (L/mg)
Cu	1481	1.55E-02
Zn	835	2.93E-02

	Column 1	Column 2
Longitudinal dispersion (cm)	3.29	2.47
Interstitial flow rate (cm/min)	0.60	0.63
Water content at saturation θ_s (-)	0.56	
Applied Cu concentration (µg/L)	Variable (moy = 279.2)	
Applied Zn concentration (µg/L)	Variable (moy = 134.4)	

Application of pseudo-first-order kinetic/Langmuir isotherm

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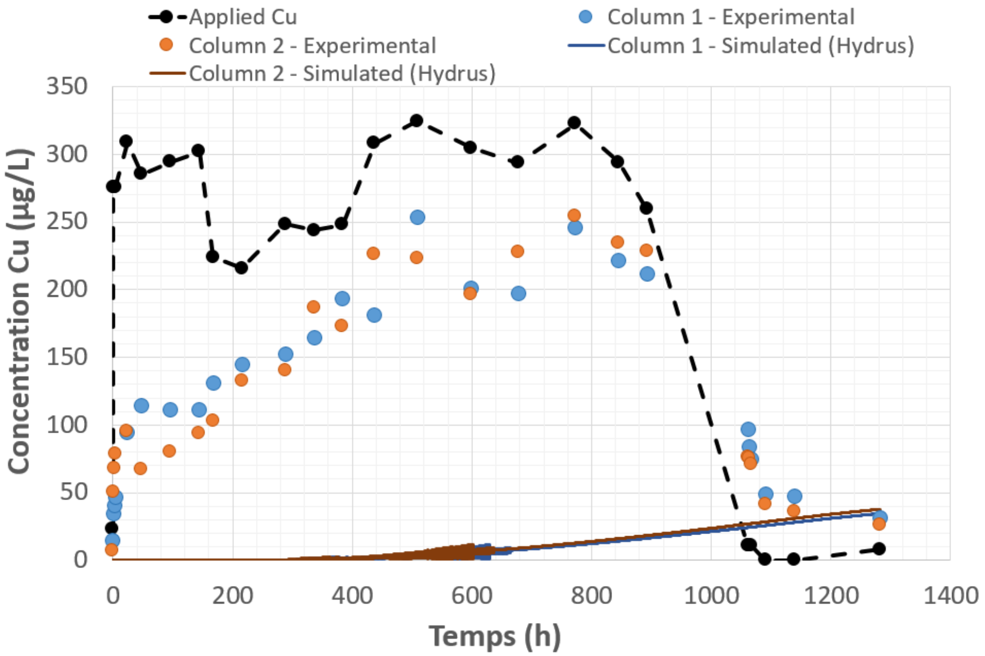
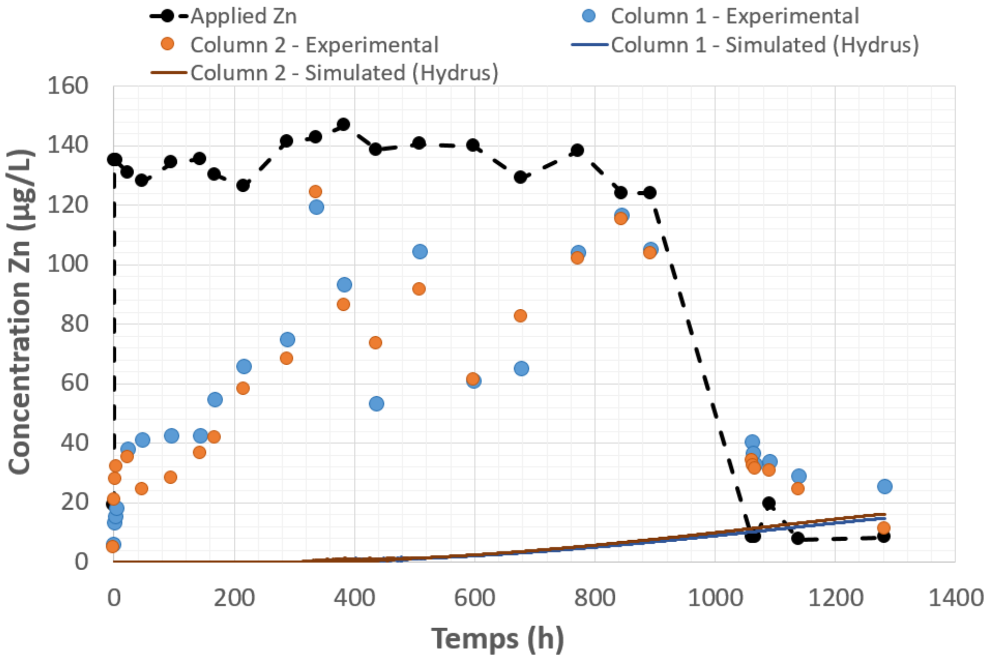
2. Adsorption parameters

Direct modelling – 5 cm Rainclean/Cu	Direct modelling – 5 cm Rainclean/Zn

Parameters estimated by BATCH





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2. Adsorption parameters

Direct modelling – 5 cm Rainclean/Cu	Direct modelling – 5 cm Rainclean/Zn

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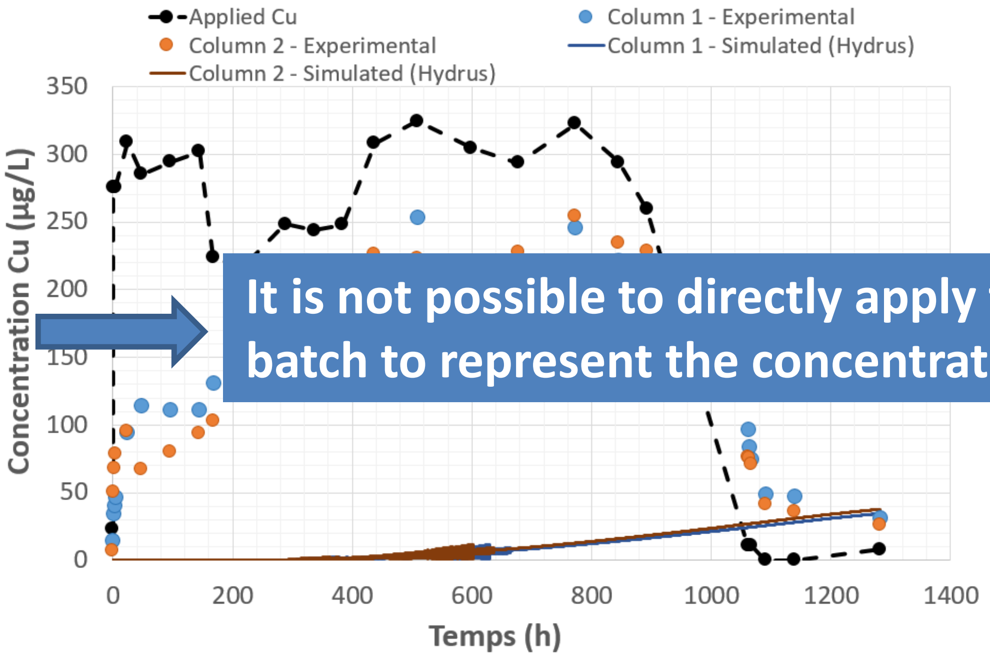

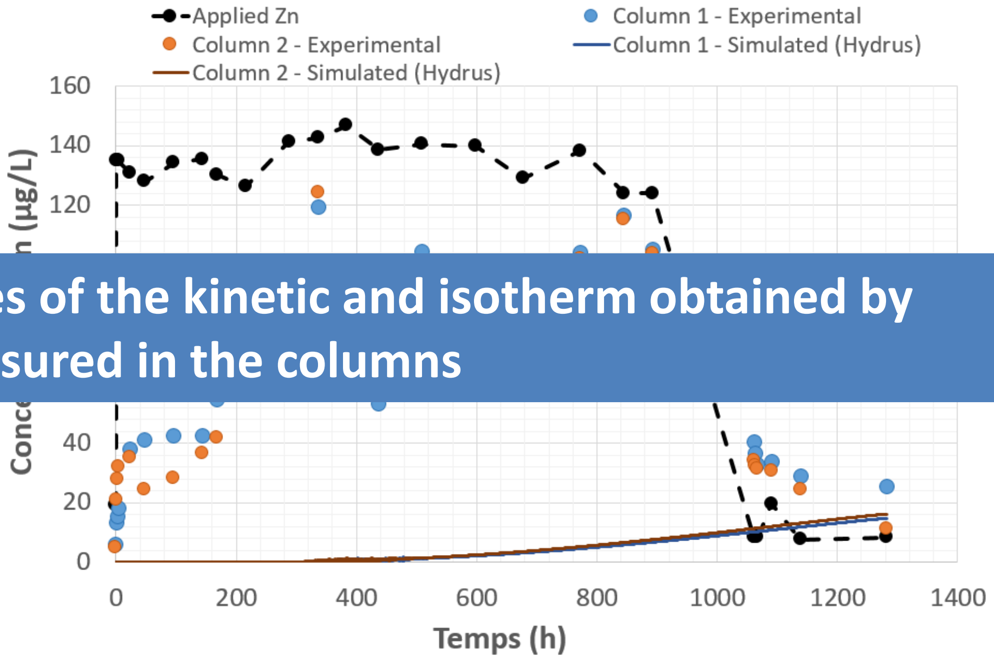

It is not possible to directly apply the values of the kinetic and isotherm obtained by batch to represent the concentrations measured in the columns

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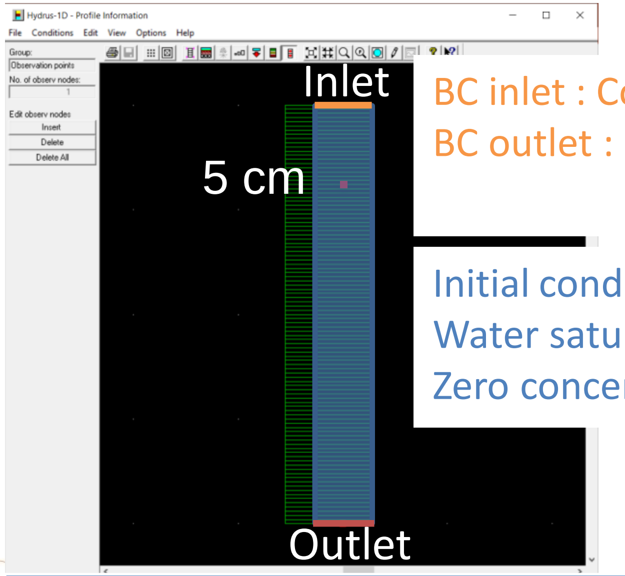
2. Adsorption parameters

HYDRUS-1D model – INVERSE MODELLING



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BC outlet : Cst pressure (water);
Free drainage (Cu&Zn)

Initial conditions :
Water saturation
Zero concentration of Cu&Zn

	Column 1	Column 2
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Interstitial flow rate (cm/min)	0.60	0.63
Water content at saturation θ_s (-)	0.56	
Applied Cu concentration (µg/L)	Variable (moy = 279.2)	
Applied Zn concentration (µg/L)	Variable (moy = 134.4)	

- Inversion of results obtained at a depth of 5 cm
- Initial values = values of kinetic and isotherm parameters obtained by batch

	Kinetic
	Pseudo-first order
	k_1 (mn^{-1})
Cu	2.03E-02
Zn	4.76E-03

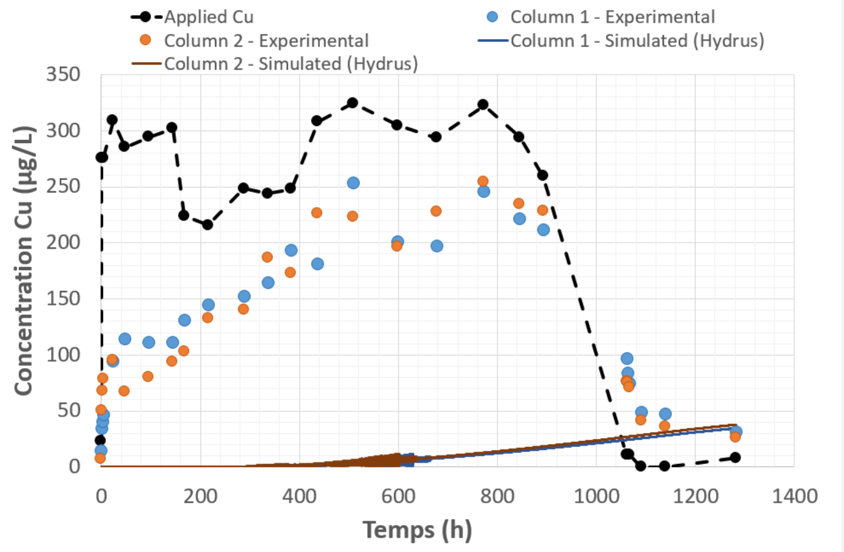
	Isotherm	
	Langmuir	
	qm (mg/g)	K_L (L/mg)
Cu	1481	1.55E-02
Zn	835	2.93E-02

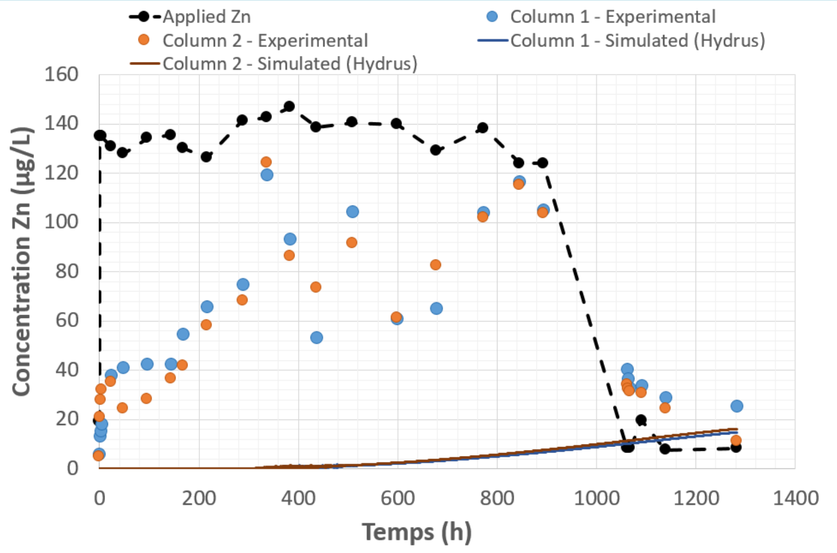
Simultaneous estimation of:
kinetic parameter: k_1,
Langmuir isotherm parameters: qm and K_L
For each column and each metal

5 cm Rainclean/Cu

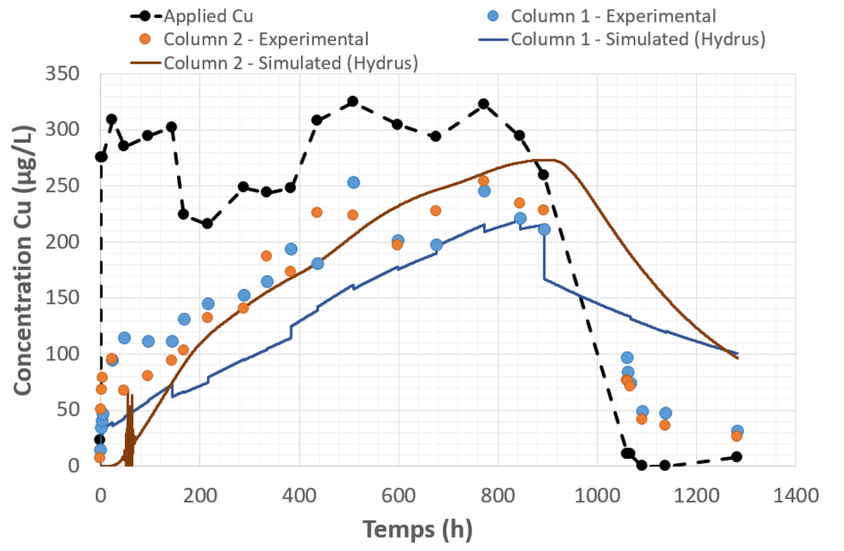
5 cm Rainclean/Zn

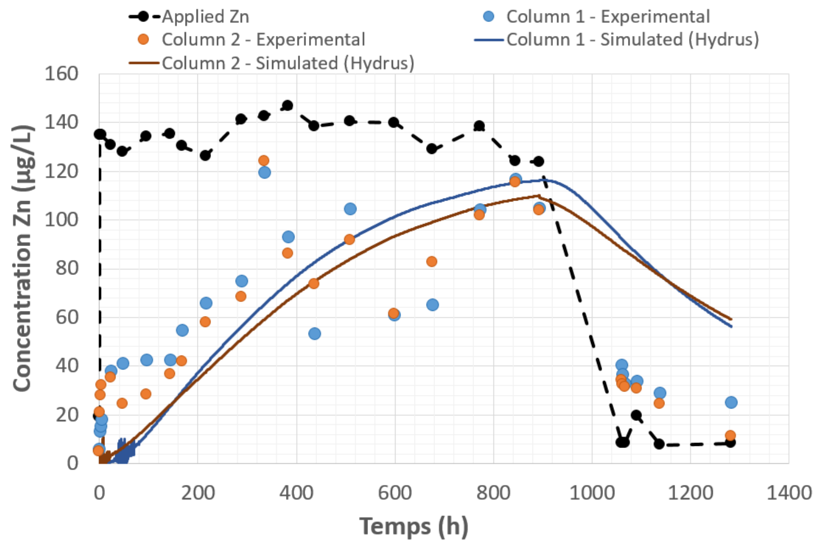
Parameters estimated by BATCH





Parameters estimated by INVERSE MODELLING





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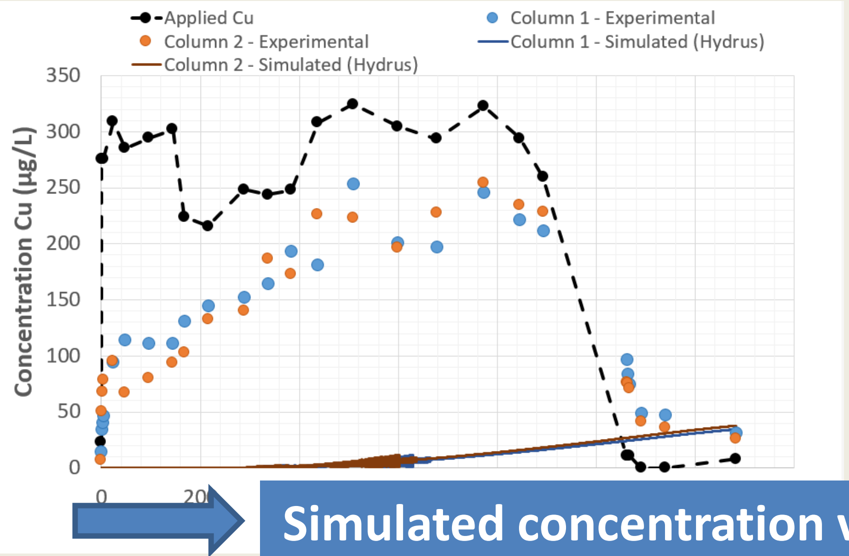
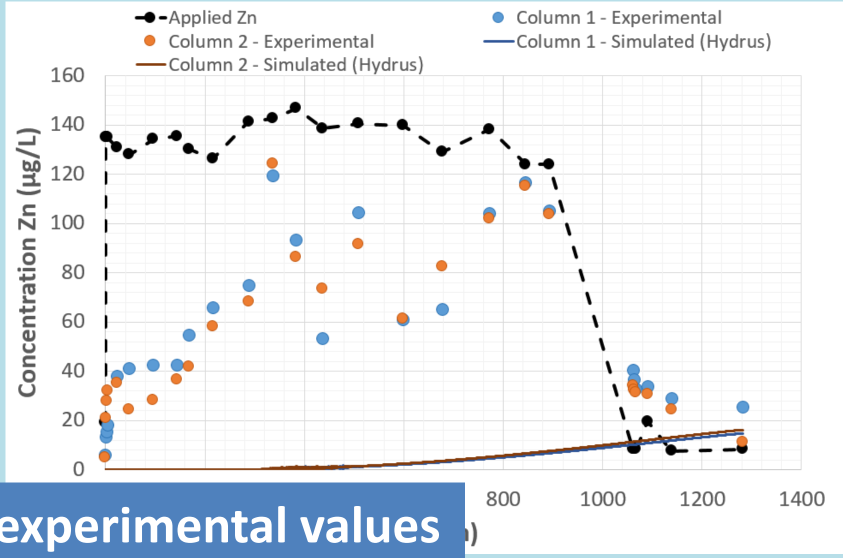
5 cm Rainclean/Cu

5 cm Rainclean/Zn

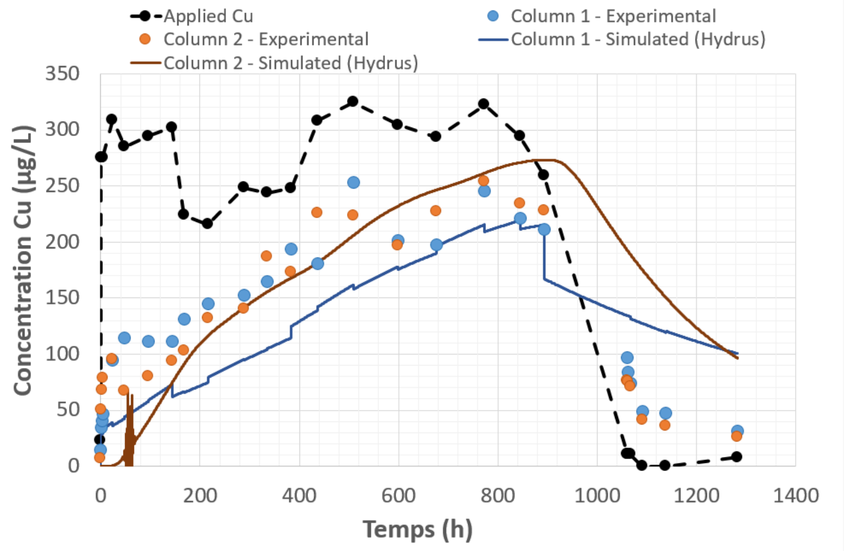
Parameters estimated by BATCH

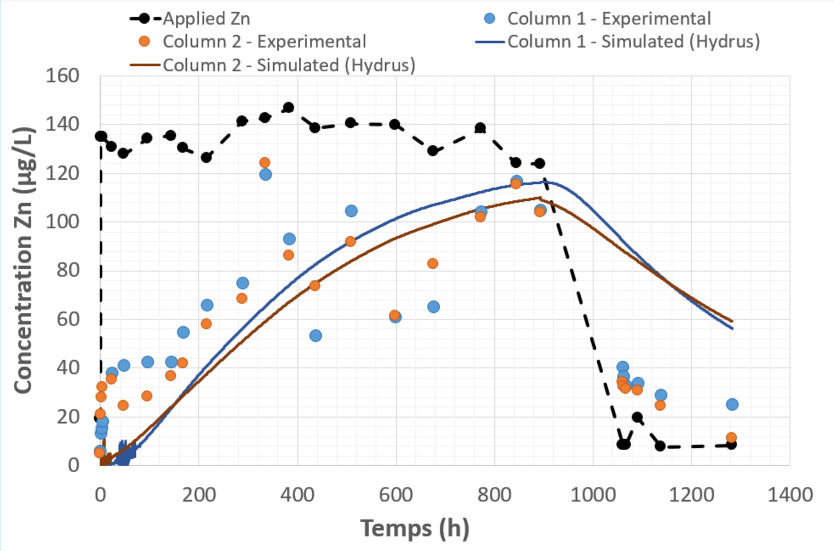




Simulated concentration values close to experimental values

Parameters estimated by INVERSE MODELLING





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Conclusions

- With the 2D model: we know which parts of the filter are solicited by the flow and therefore where the micropollutants will be retained
- The problem with this approach: a calculation code representative of the complexity of the system BUT costly in terms of calculation time (! Long term) → Surrogate model
- This approach will facilitate the design of TWs that treat the micropollutants contained in stormwater and CSO
- Batch adsorption values cannot be directly extrapolated to variably saturated porous media → need for experiments representing operating conditions closer to those found in TWs (columns)
- To be continued: modelling of the removal of micropollutants by adsorption and biodegradation


Thank you
for your attention