Building river networks in the lab

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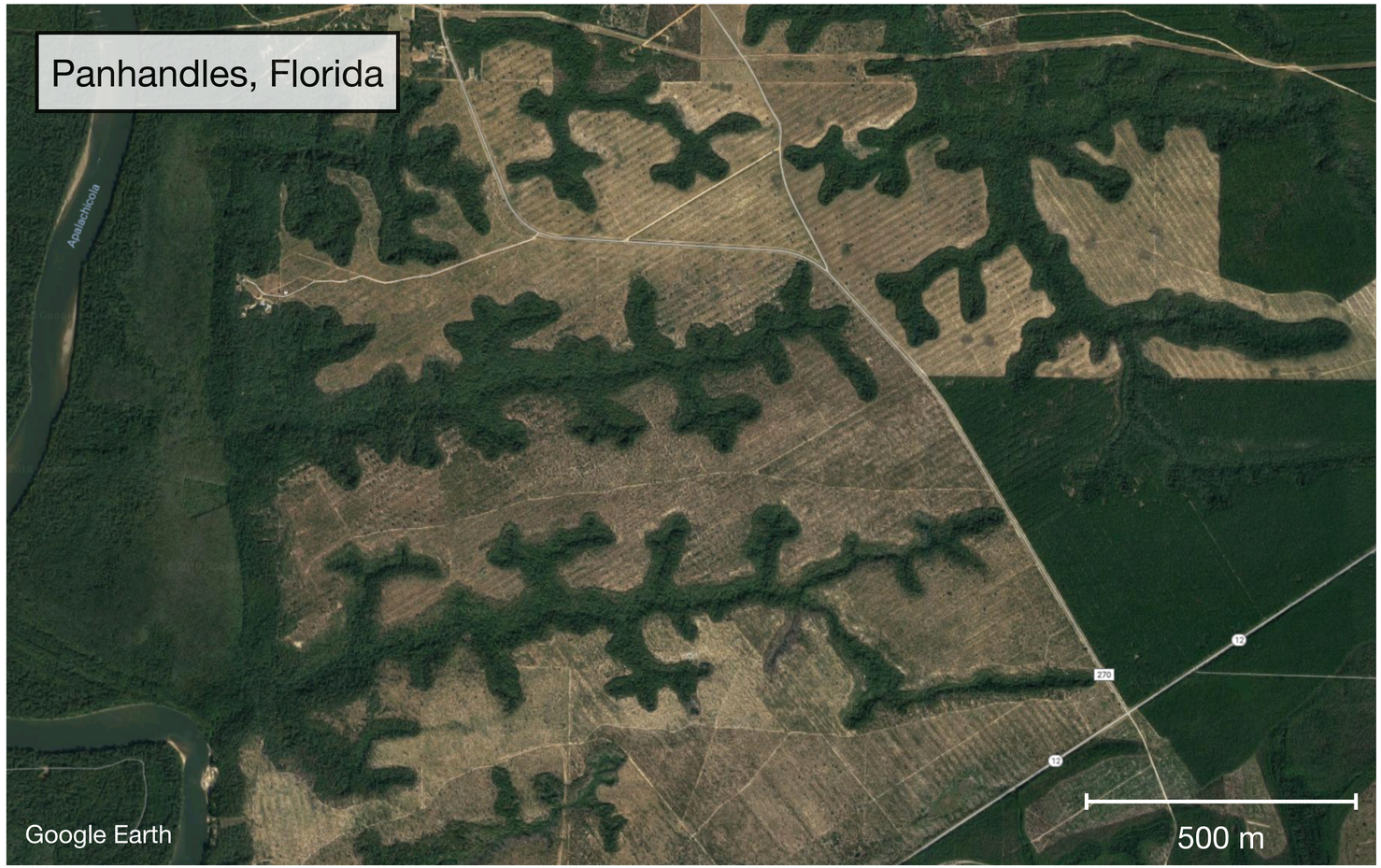
Eric Lajeunesse

CDD 2025

Université Paris Cité, Institut de Physique du Globe de Paris, Dep. of Geological Fluid Dynamics

Groundwater driven networks

Seepage erosion and growth



Petroff et al. (2011), Devauchelle et al. (2011)

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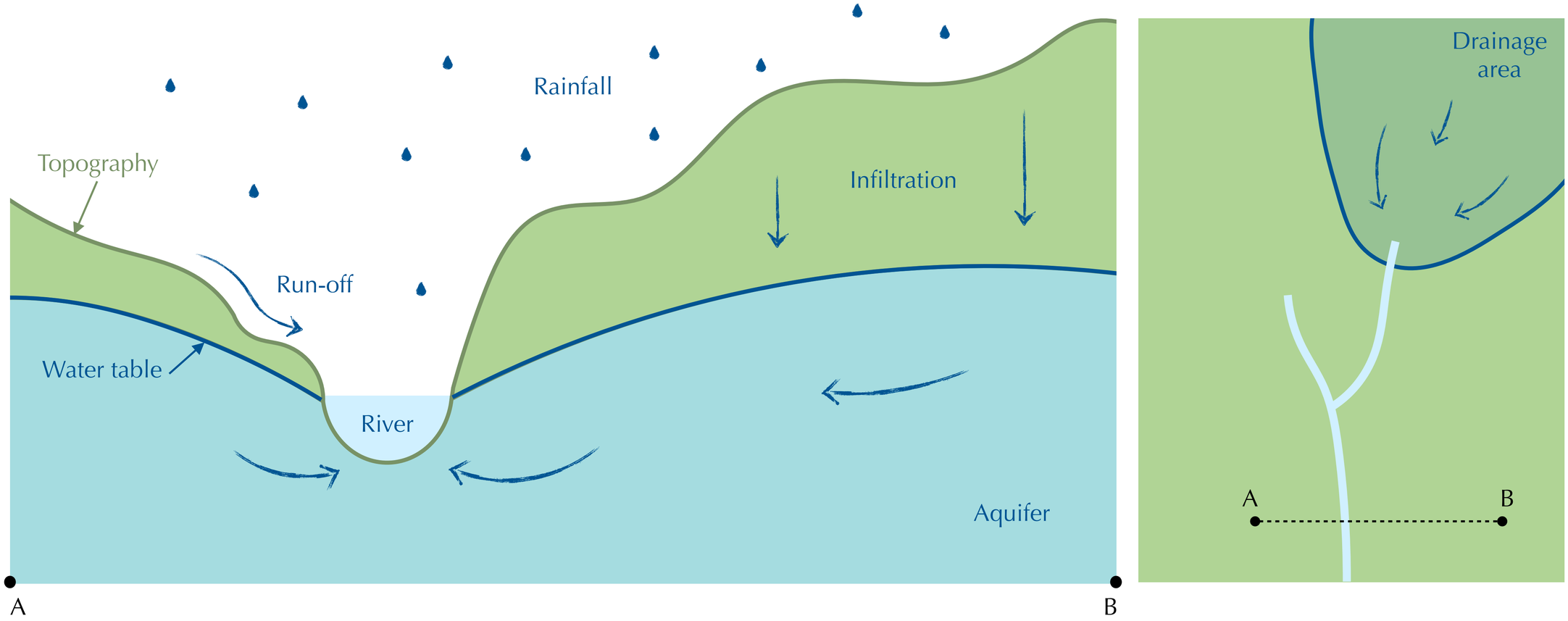

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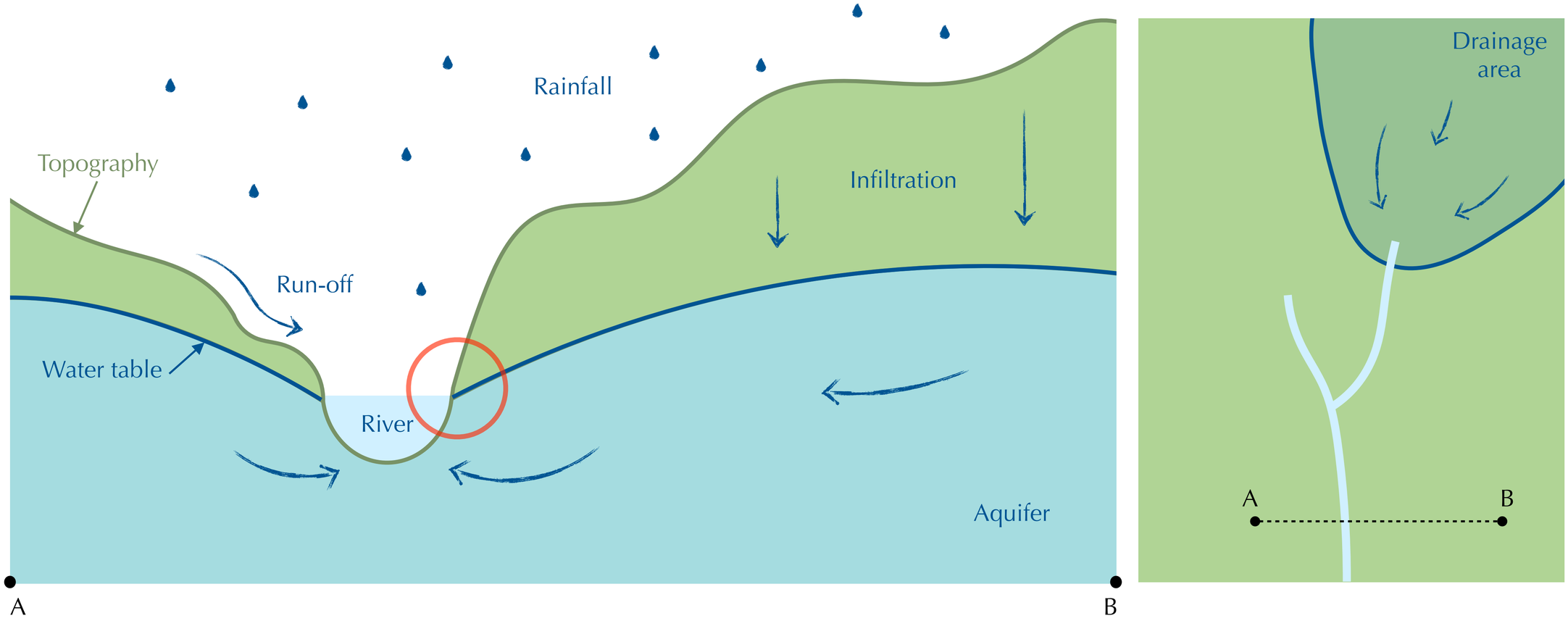

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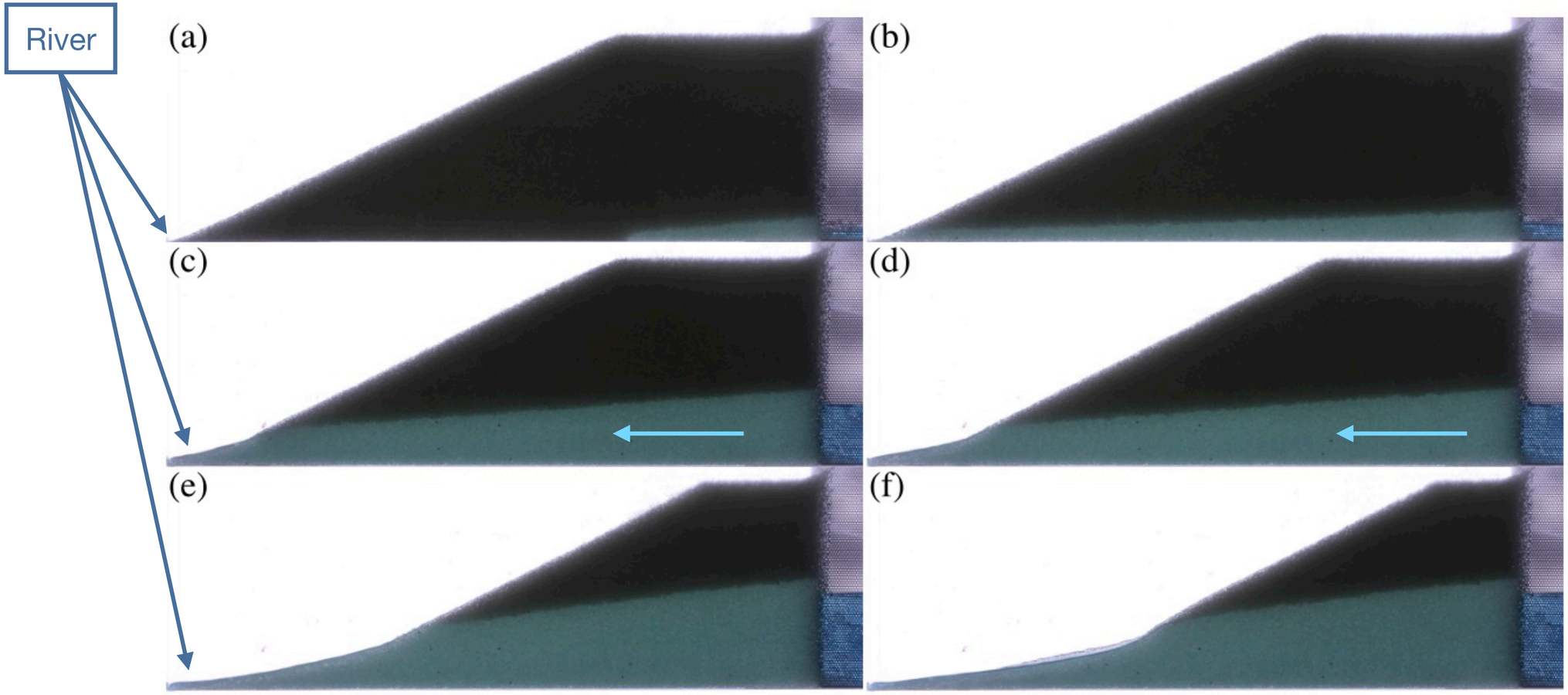

Vulliet , PhD 2023

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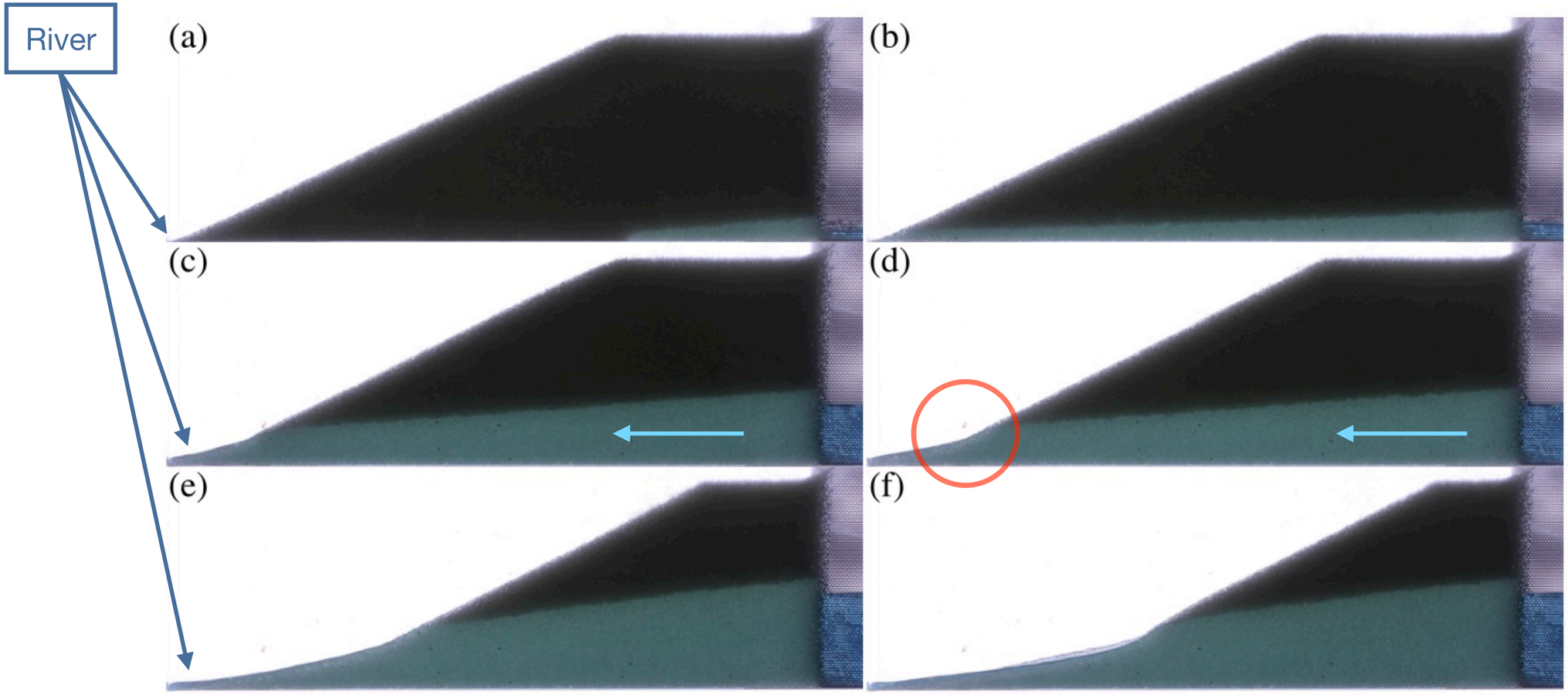

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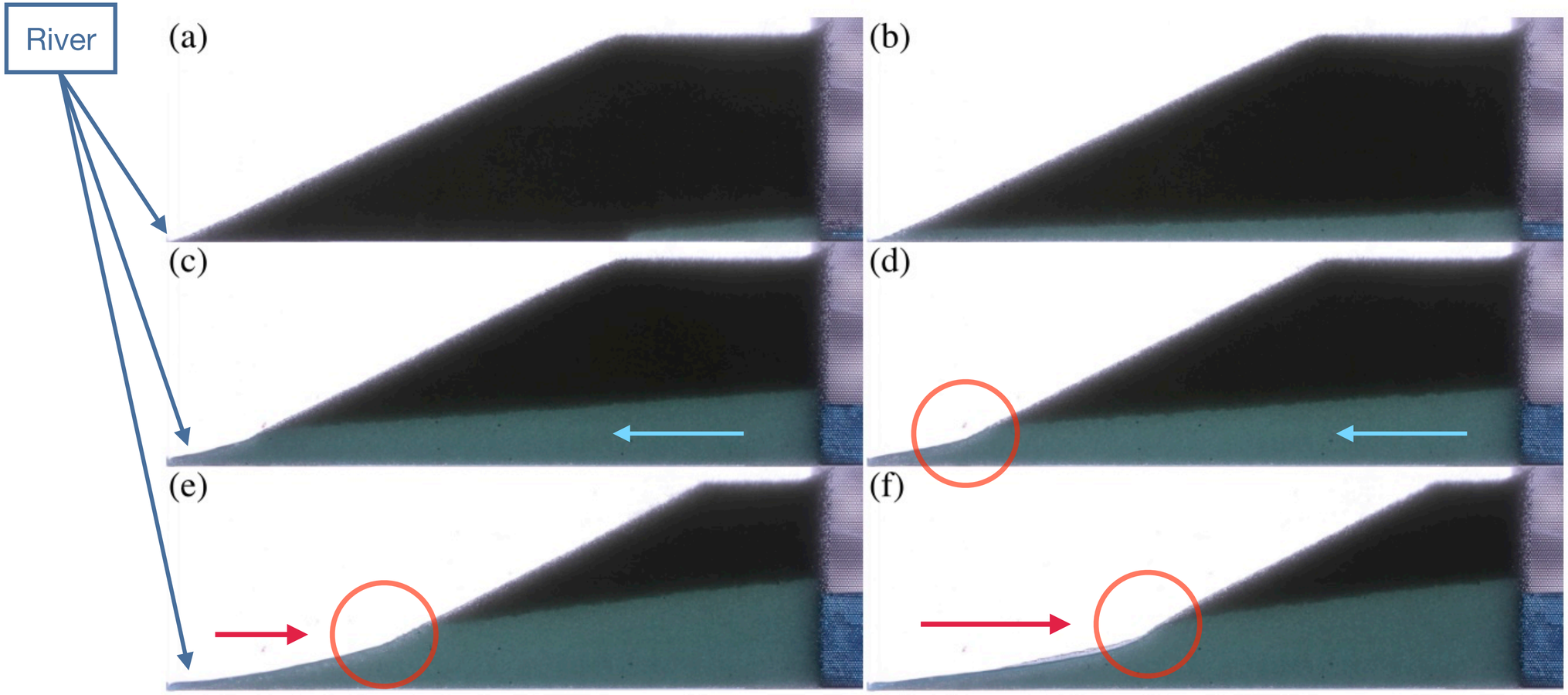

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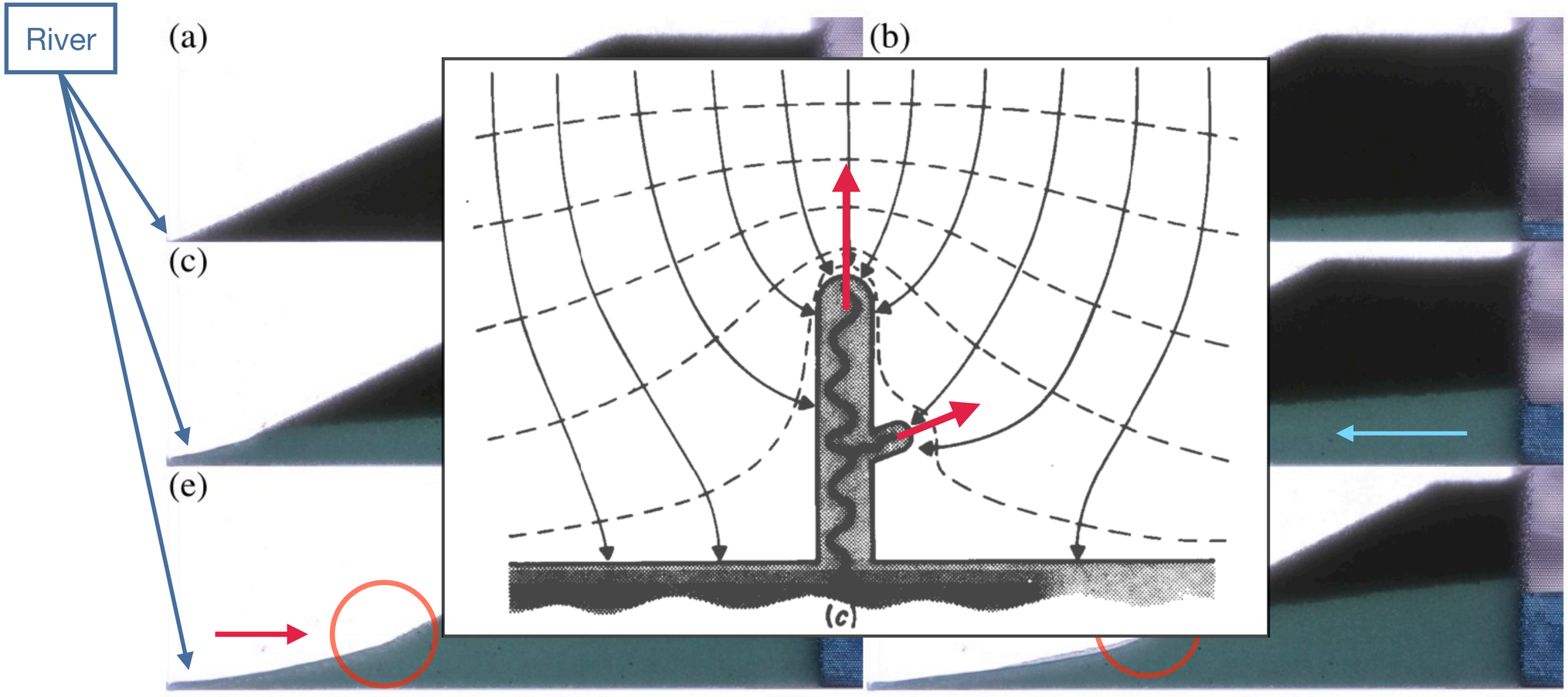
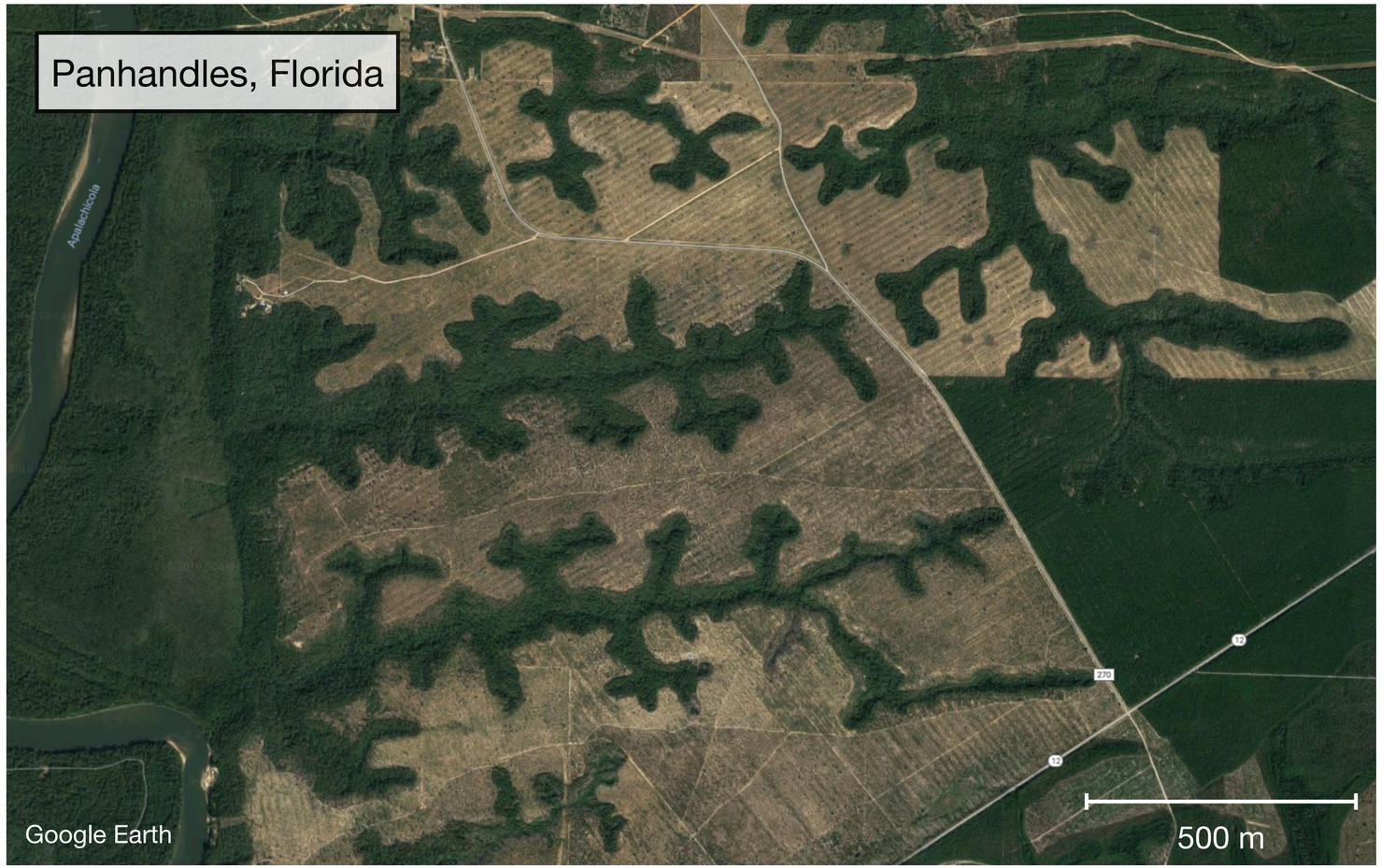


Vulliet , PhD 2023, Dunne (1980)

Network dynamics

From natural landscapes to laboratory experiments



Petroff et al. (2011), Devauchelle et al. (2011), Abrams et al. (2009)

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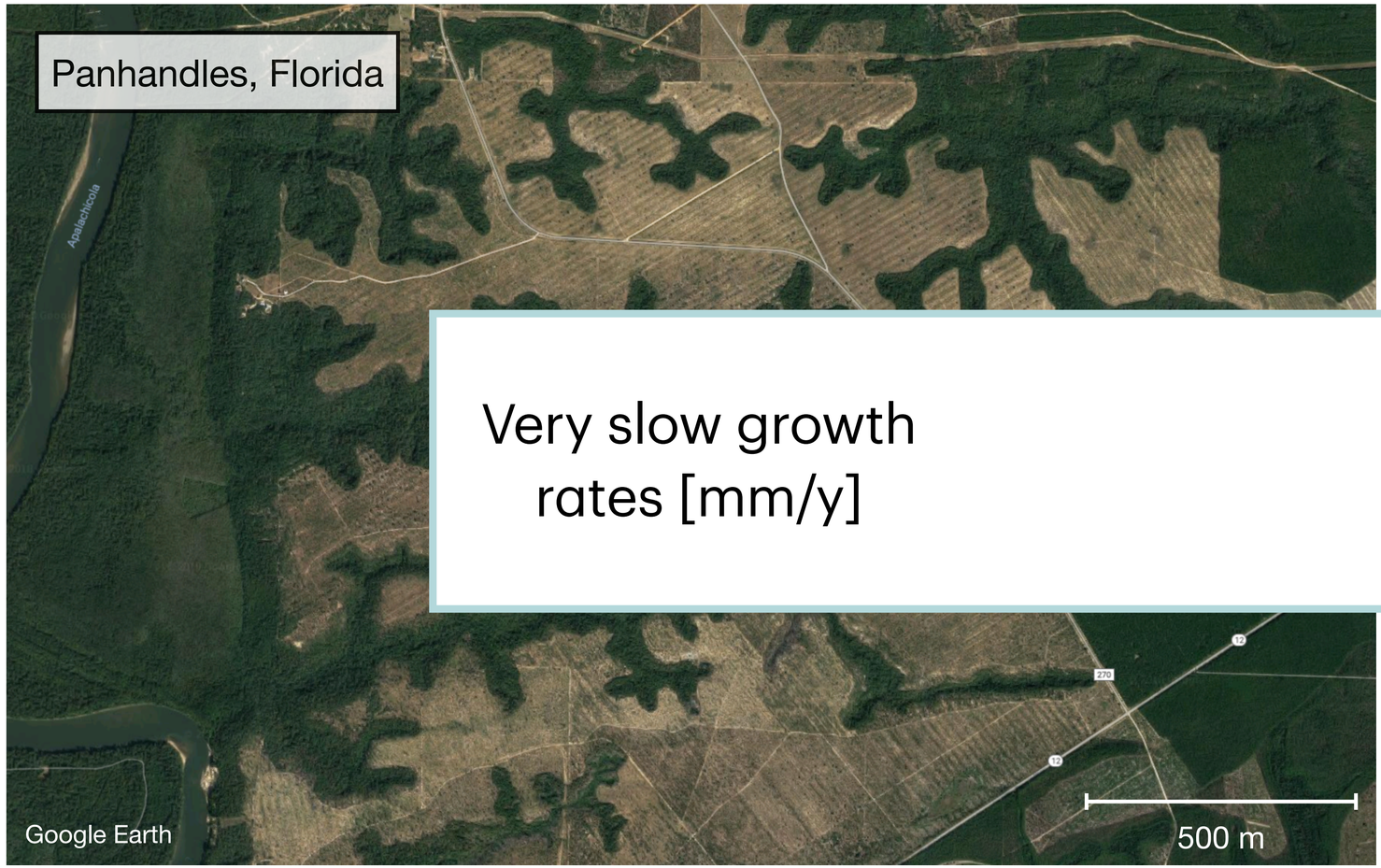

Very slow growth rates [mm/y]

Petroff et al. (2011), Devauchelle et al. (2011), Abrams et al. (2009)

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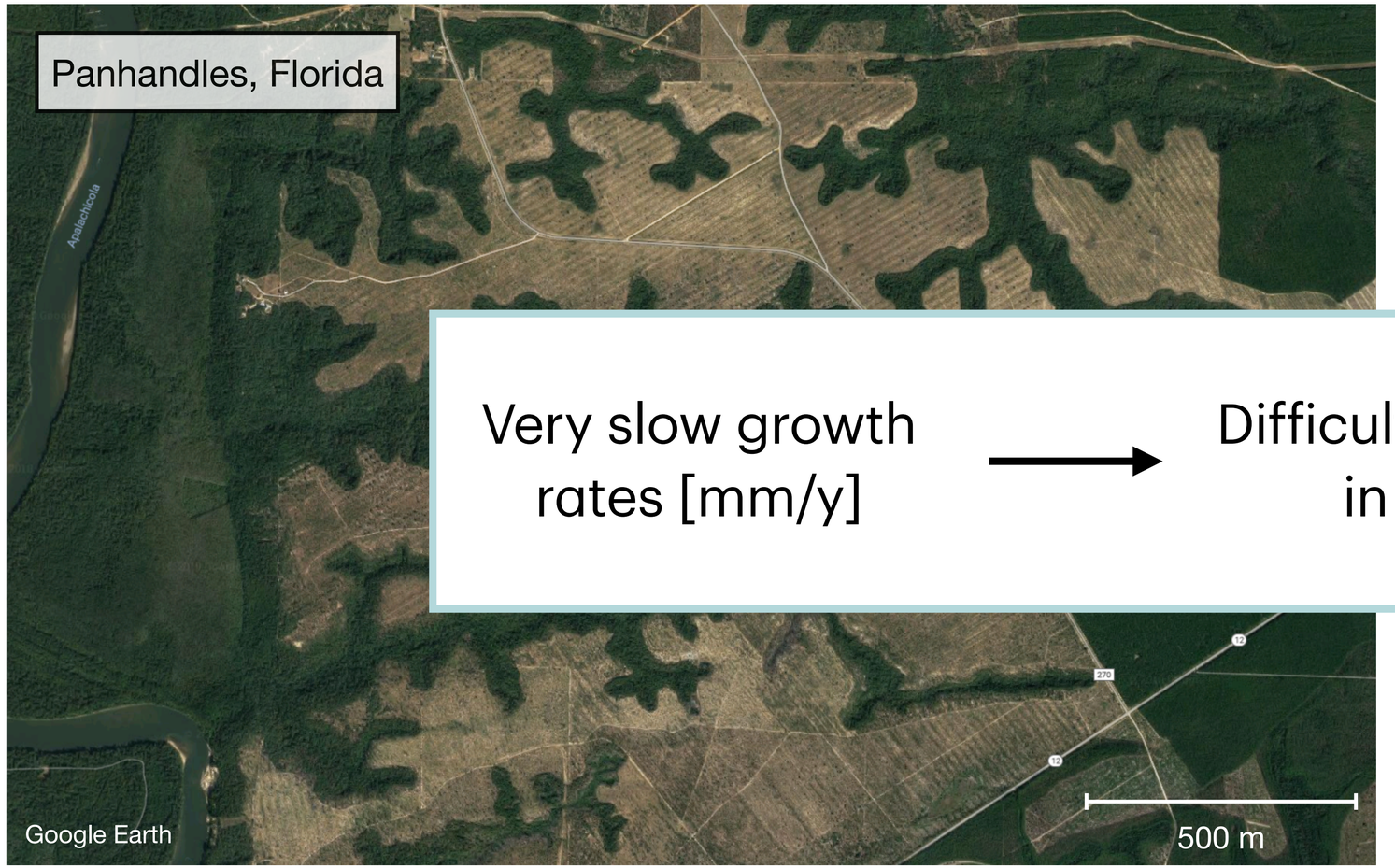
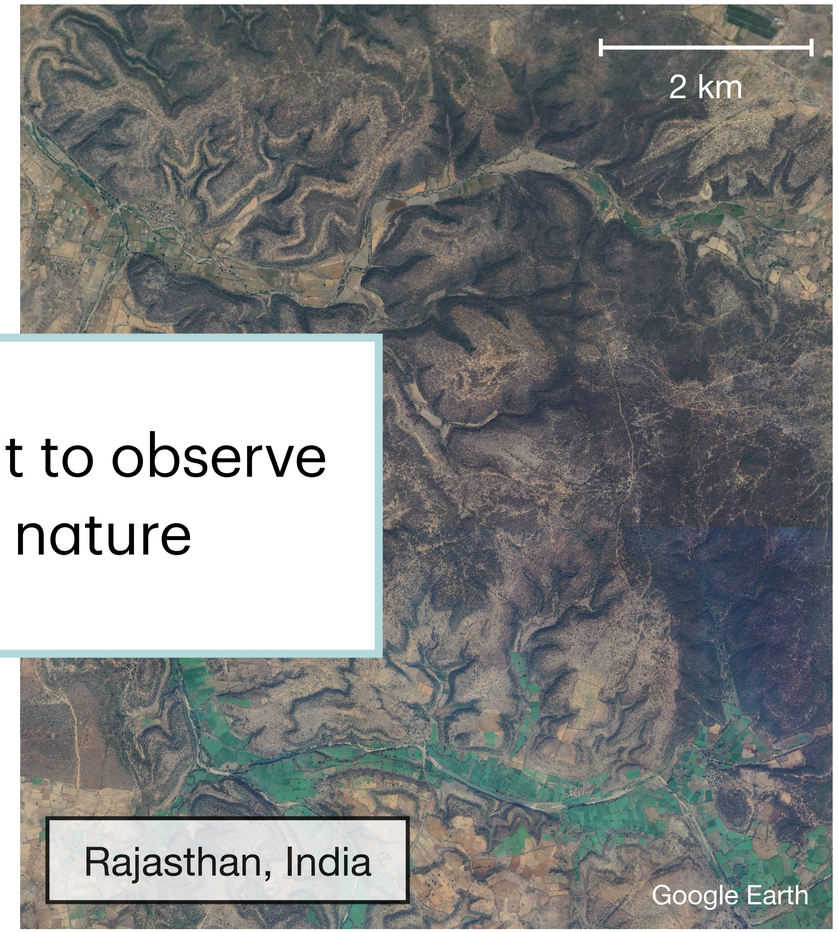


Very slow growth rates [mm/y] → Difficult to observe in nature



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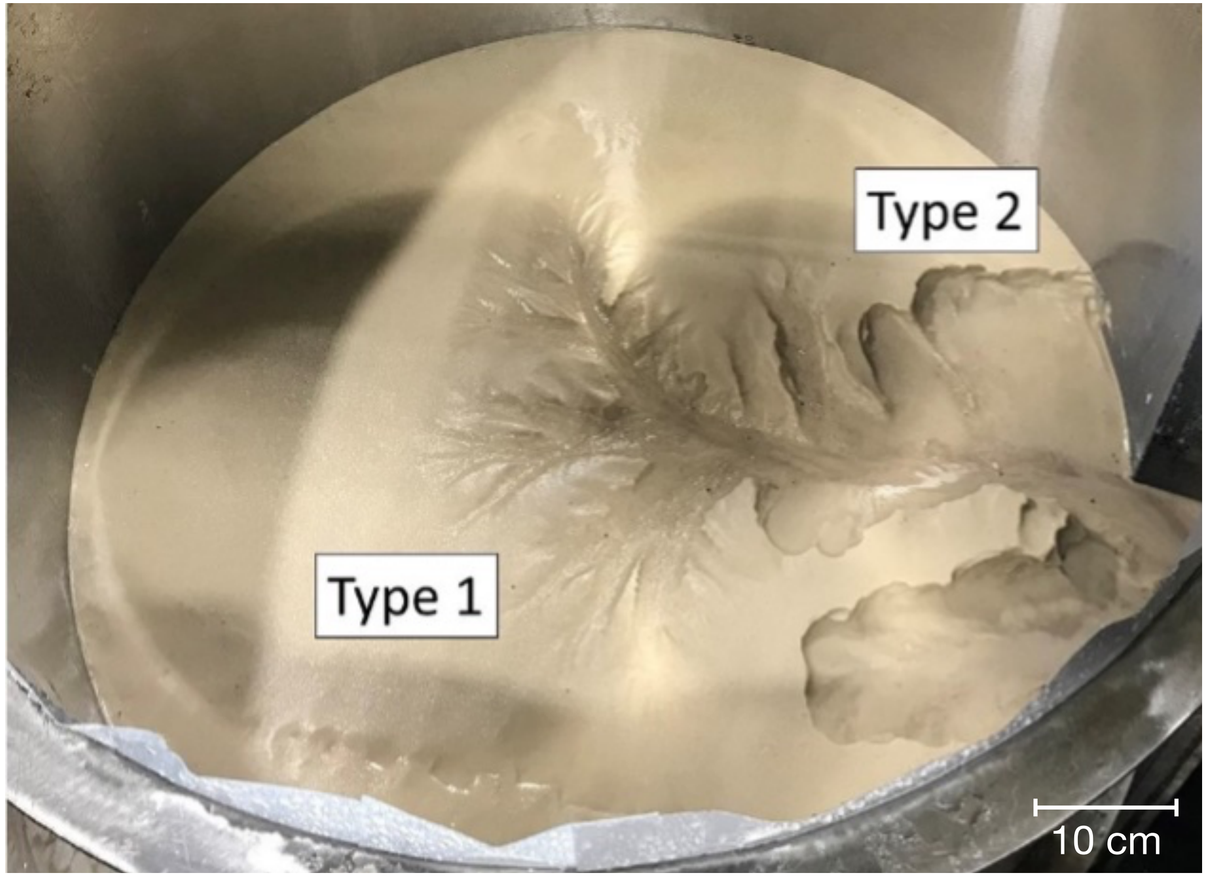
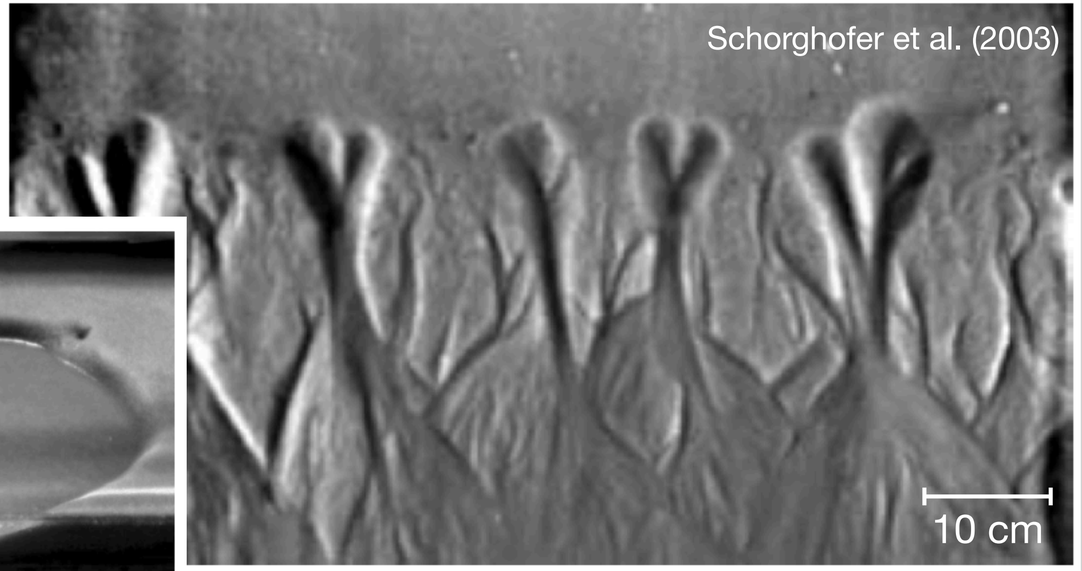


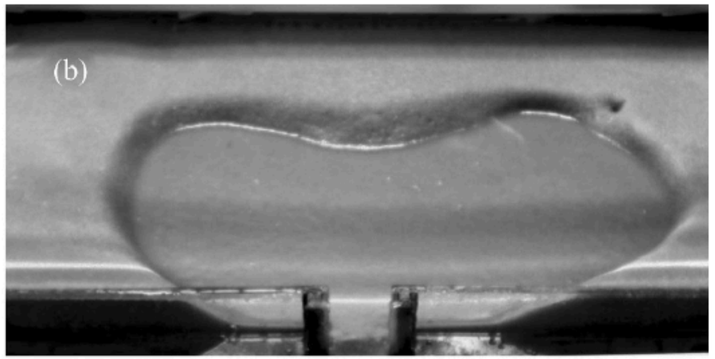
Sockness, B. G. and Gran, K. B (2022)

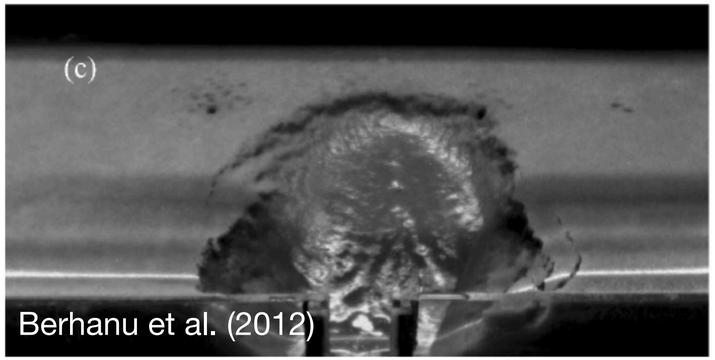
- Surface flows
- Saturated medium
- Channels :
  - Type 1 : surface erosion
  - Type 2 : seepage erosion

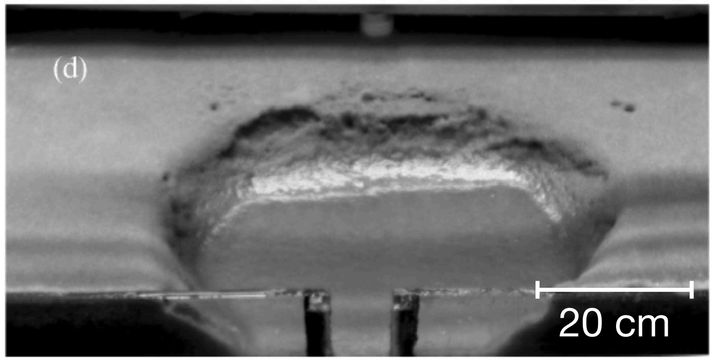
Network dynamics

From natural landscapes to laboratory experiments



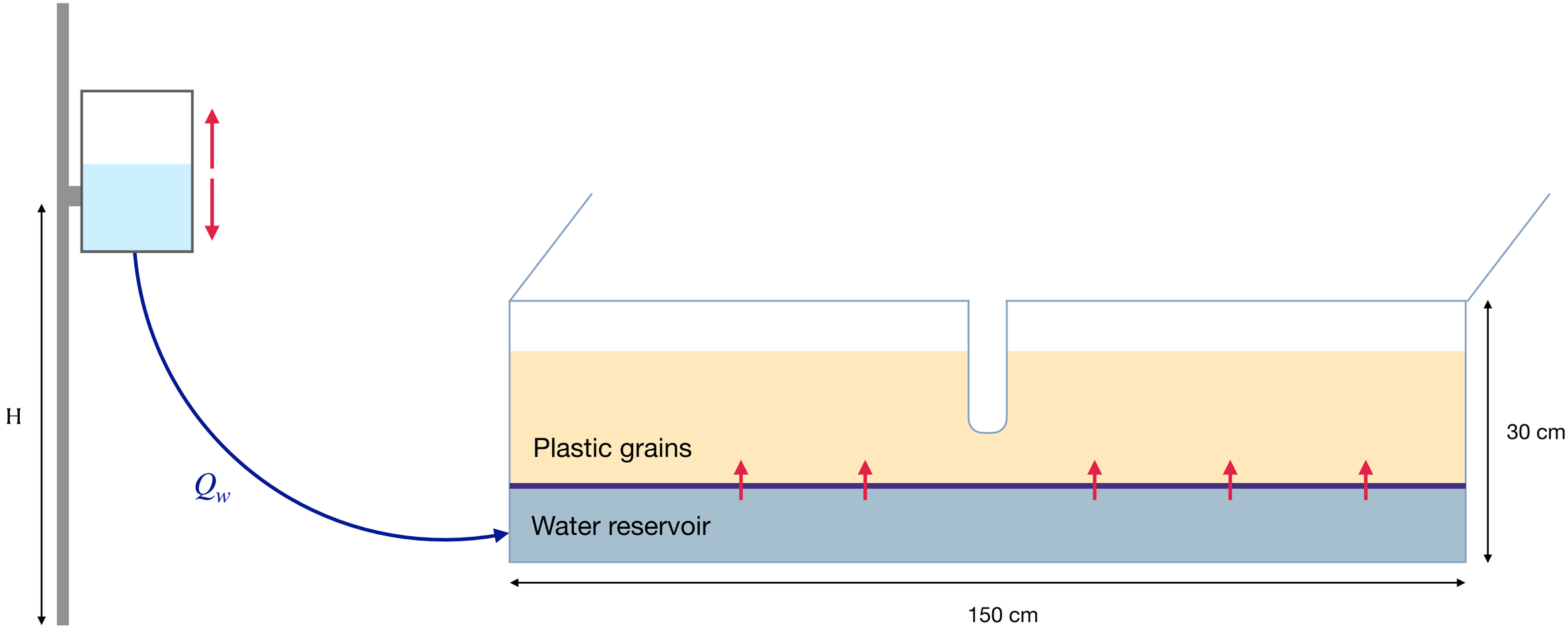






- Sub-surface flow
- Single channel

Experimental set-up



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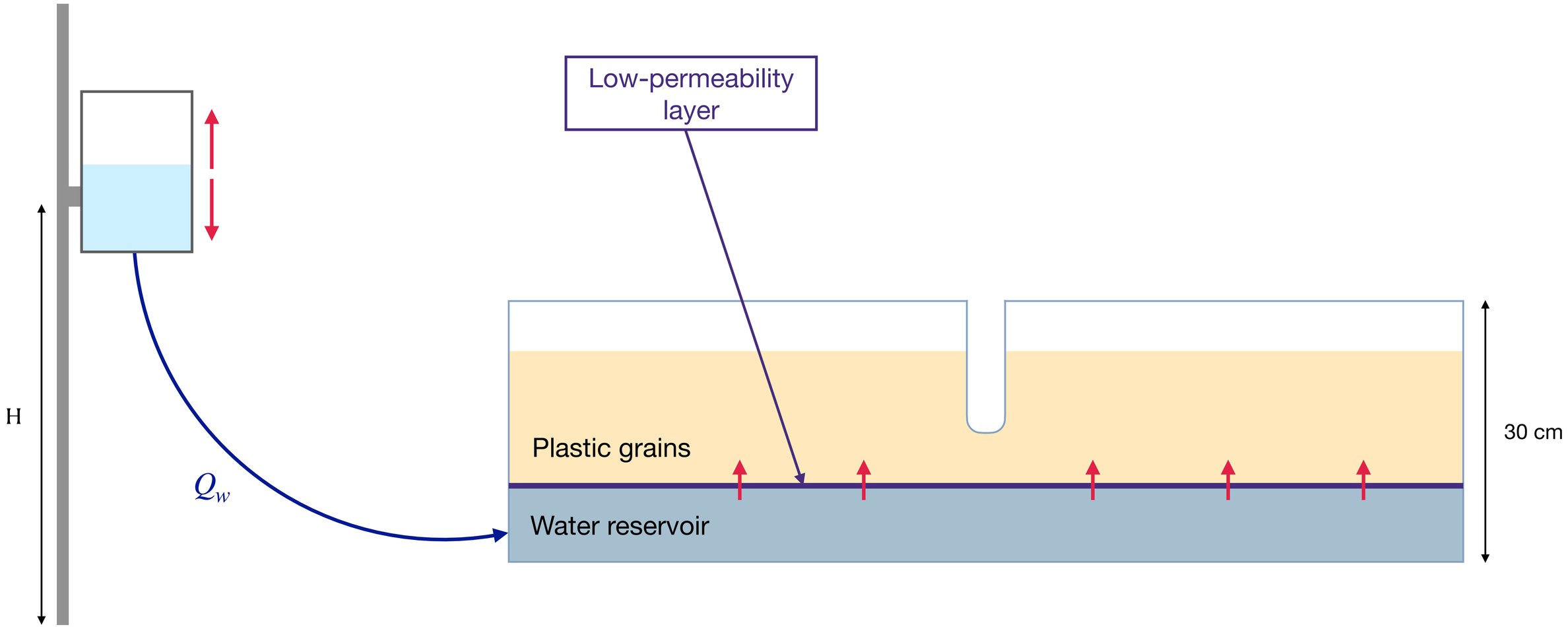

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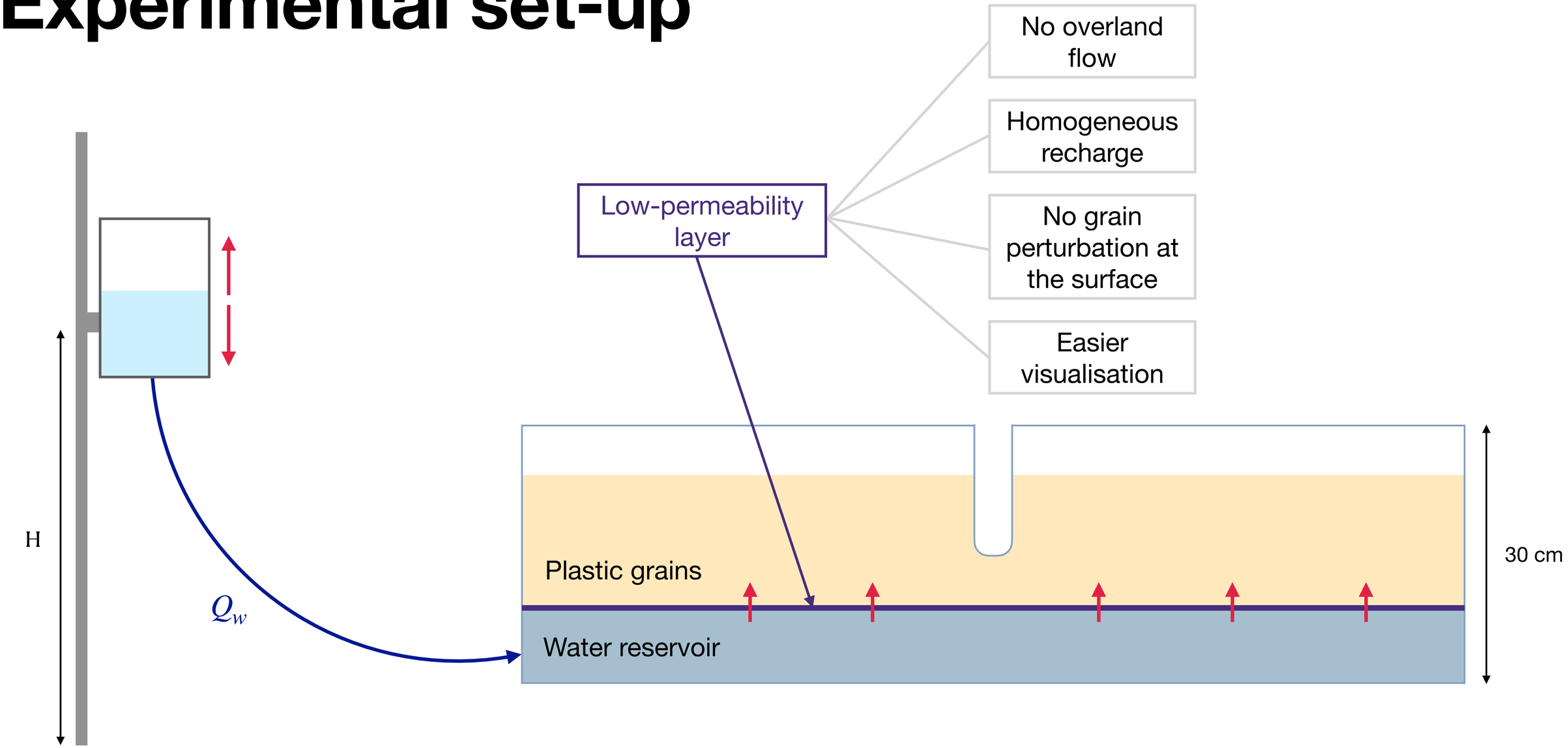

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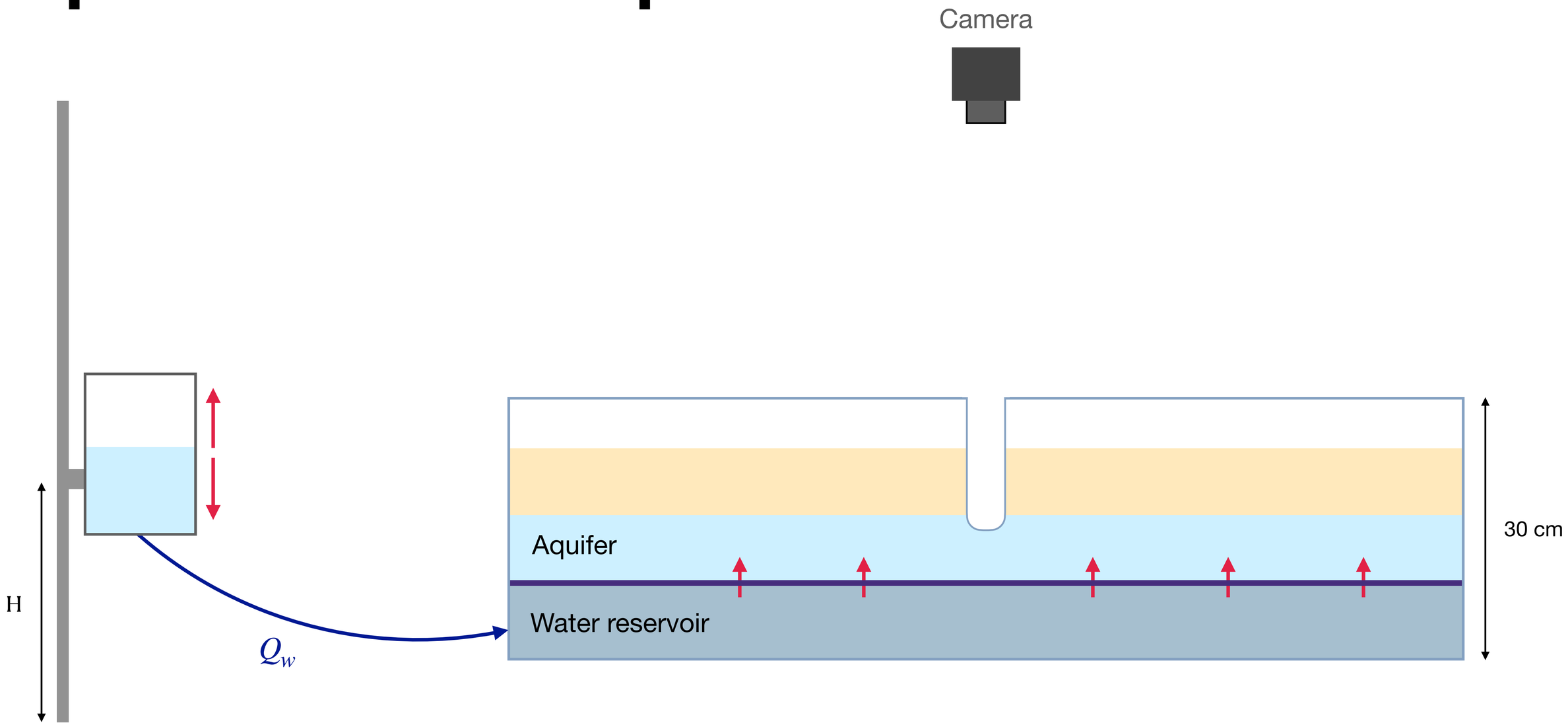

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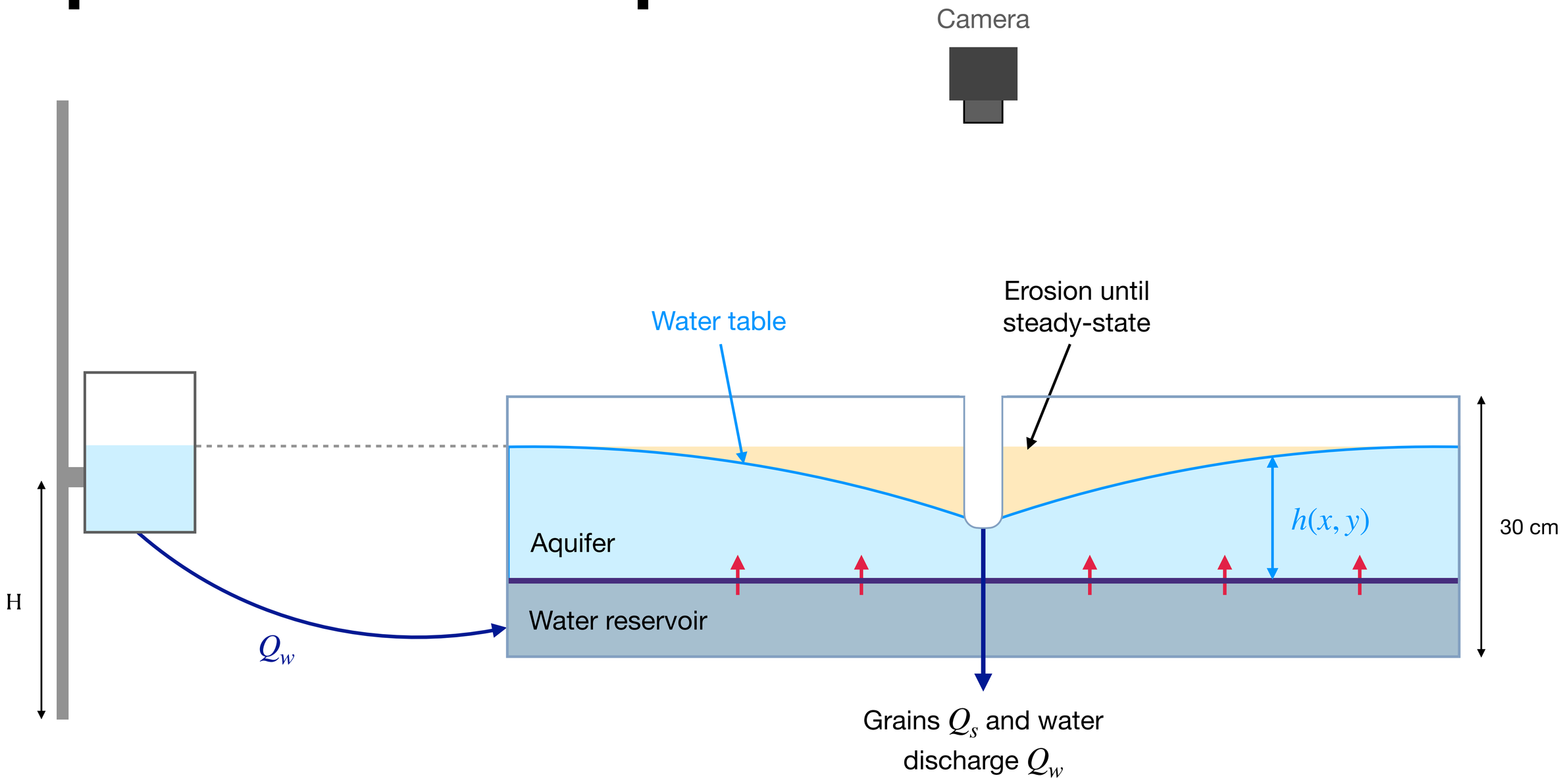

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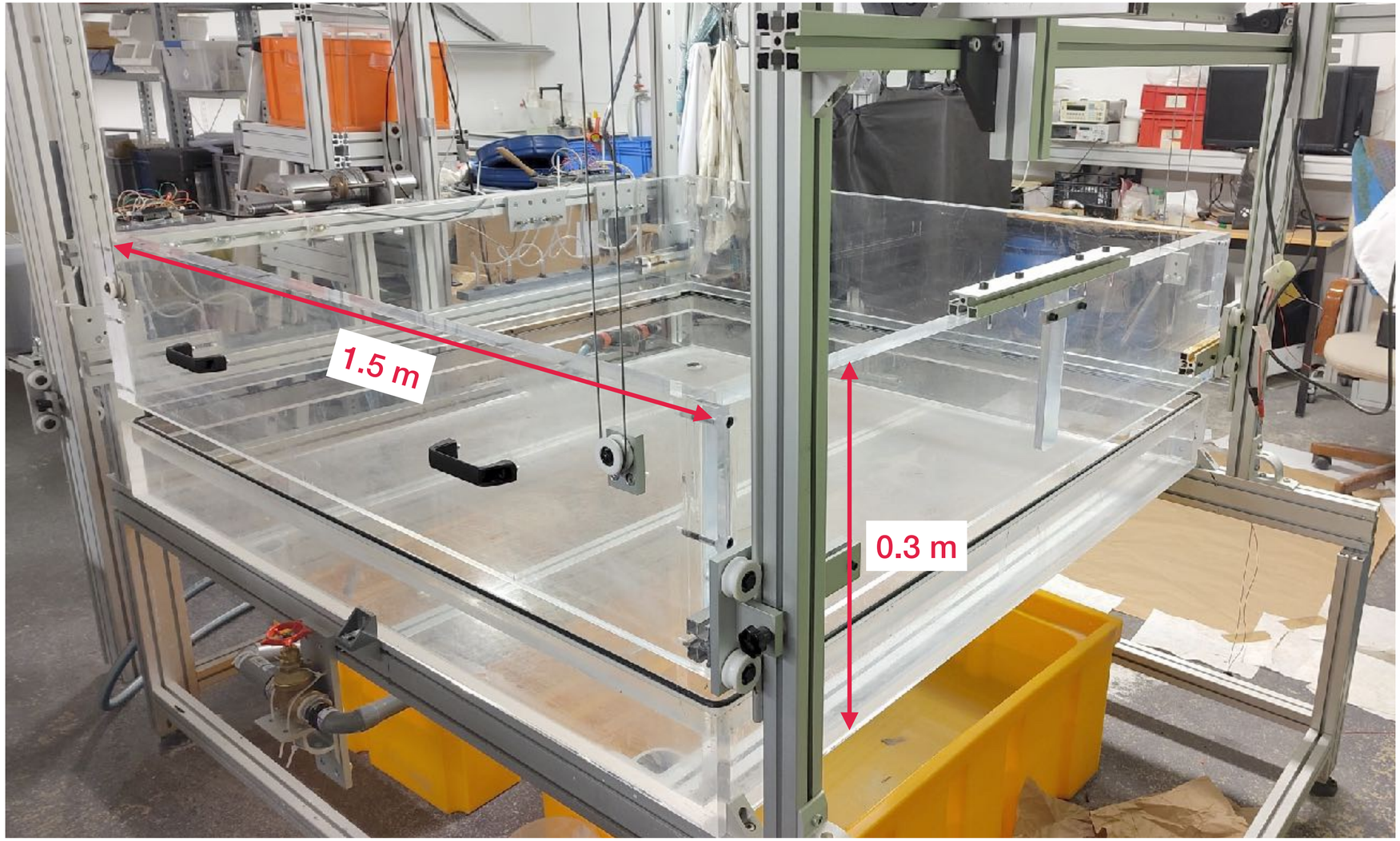

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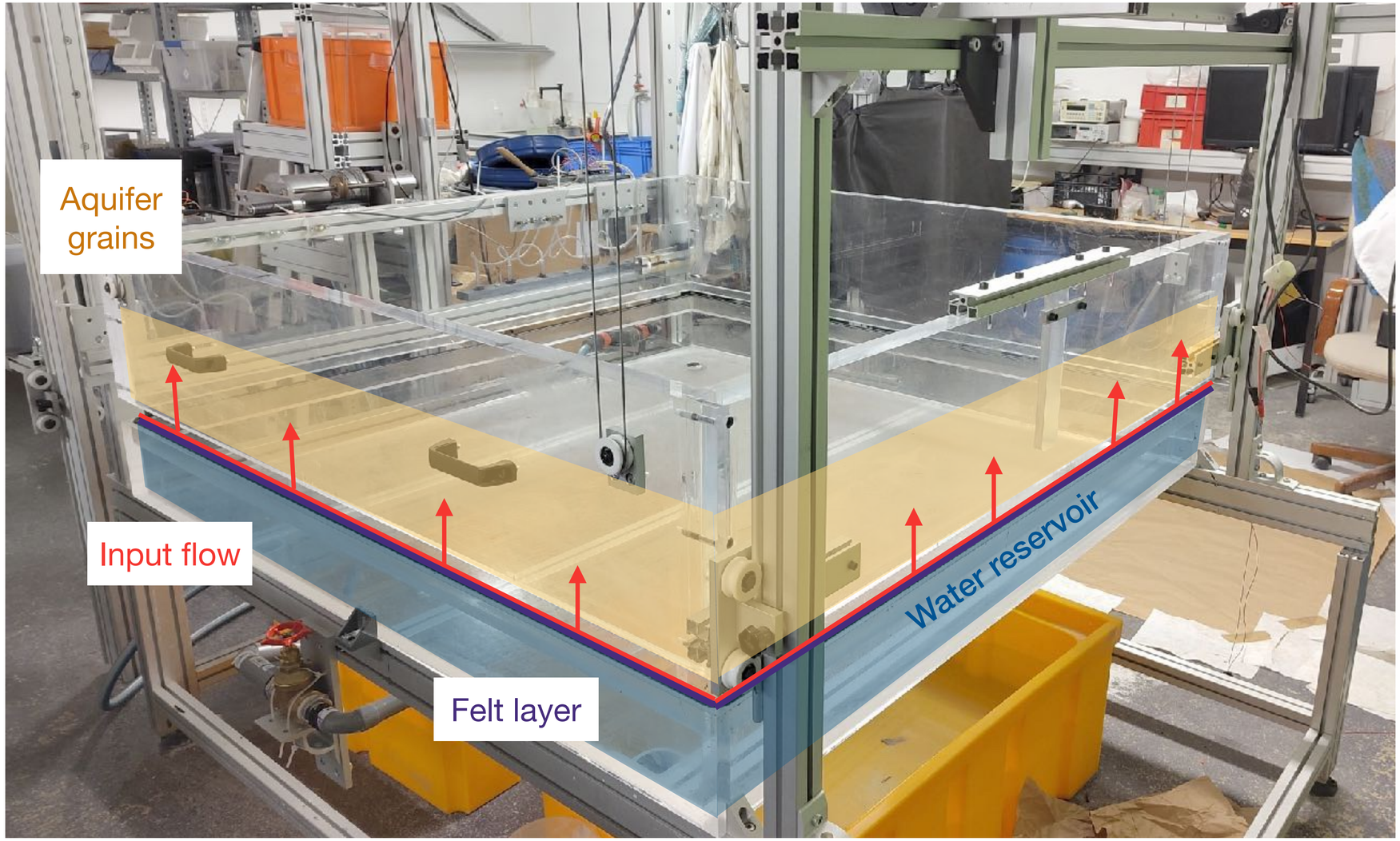

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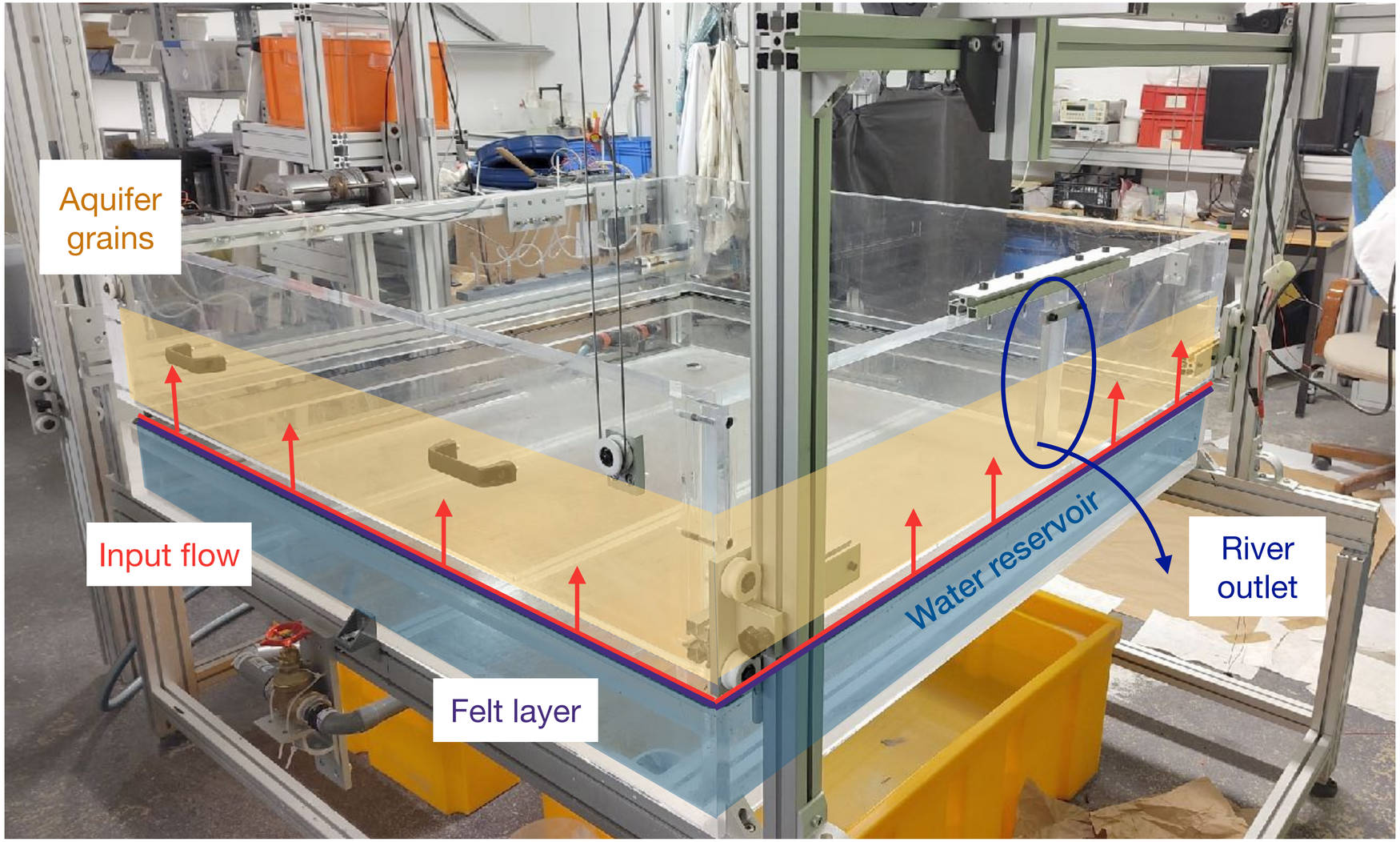
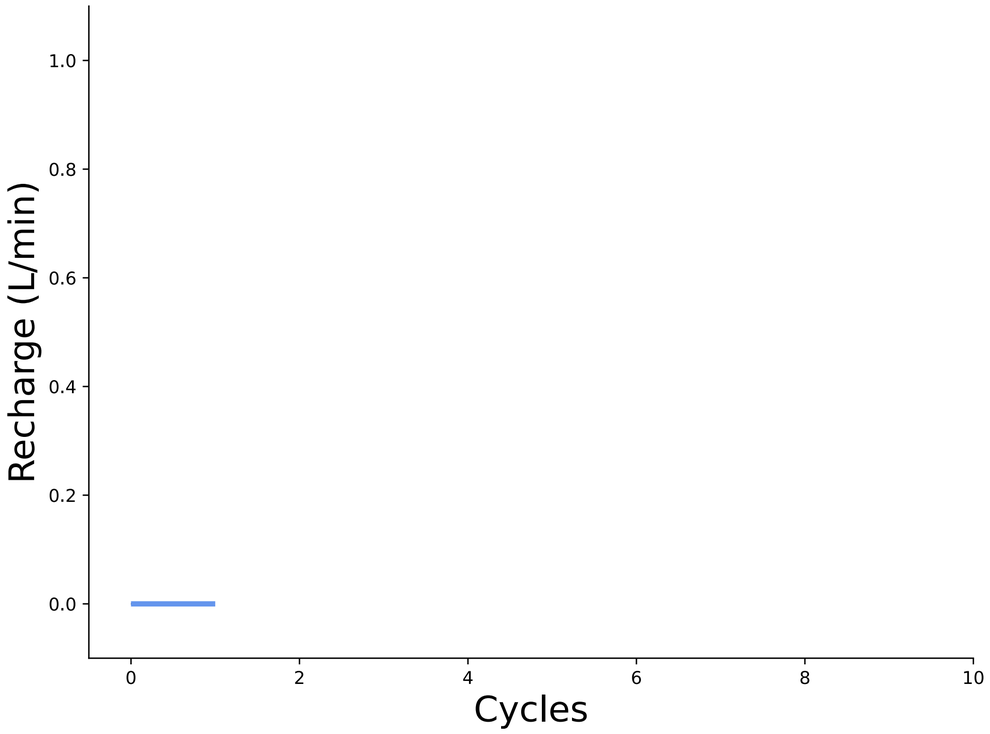
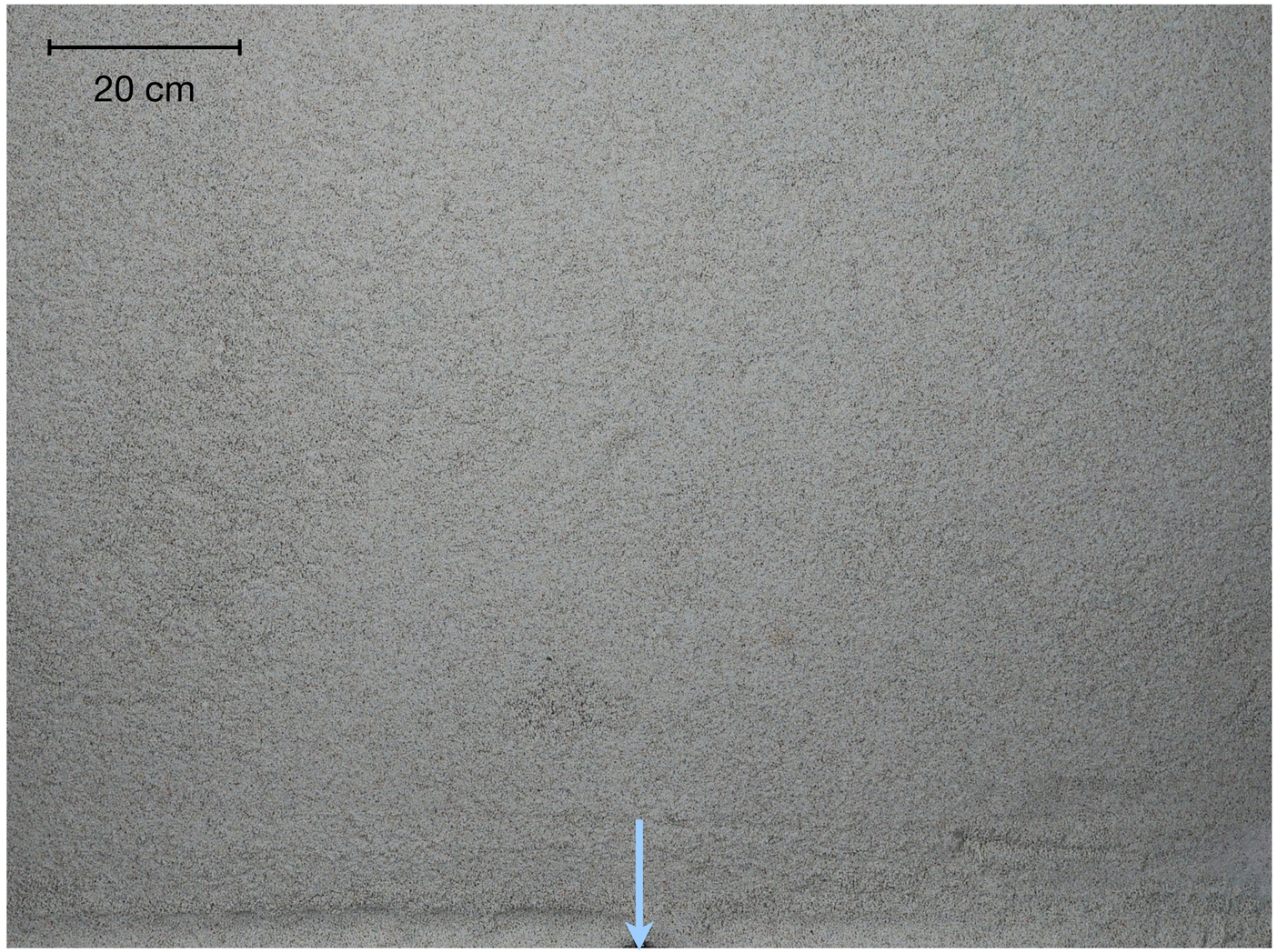


Network formation and evolution

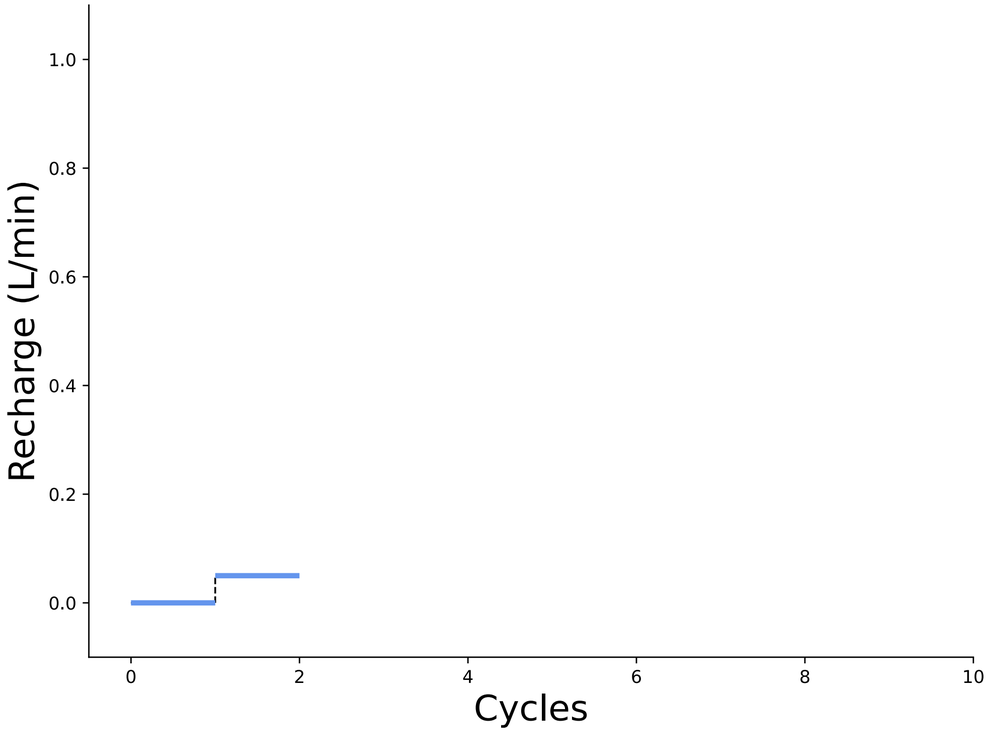
Initial aquifer :

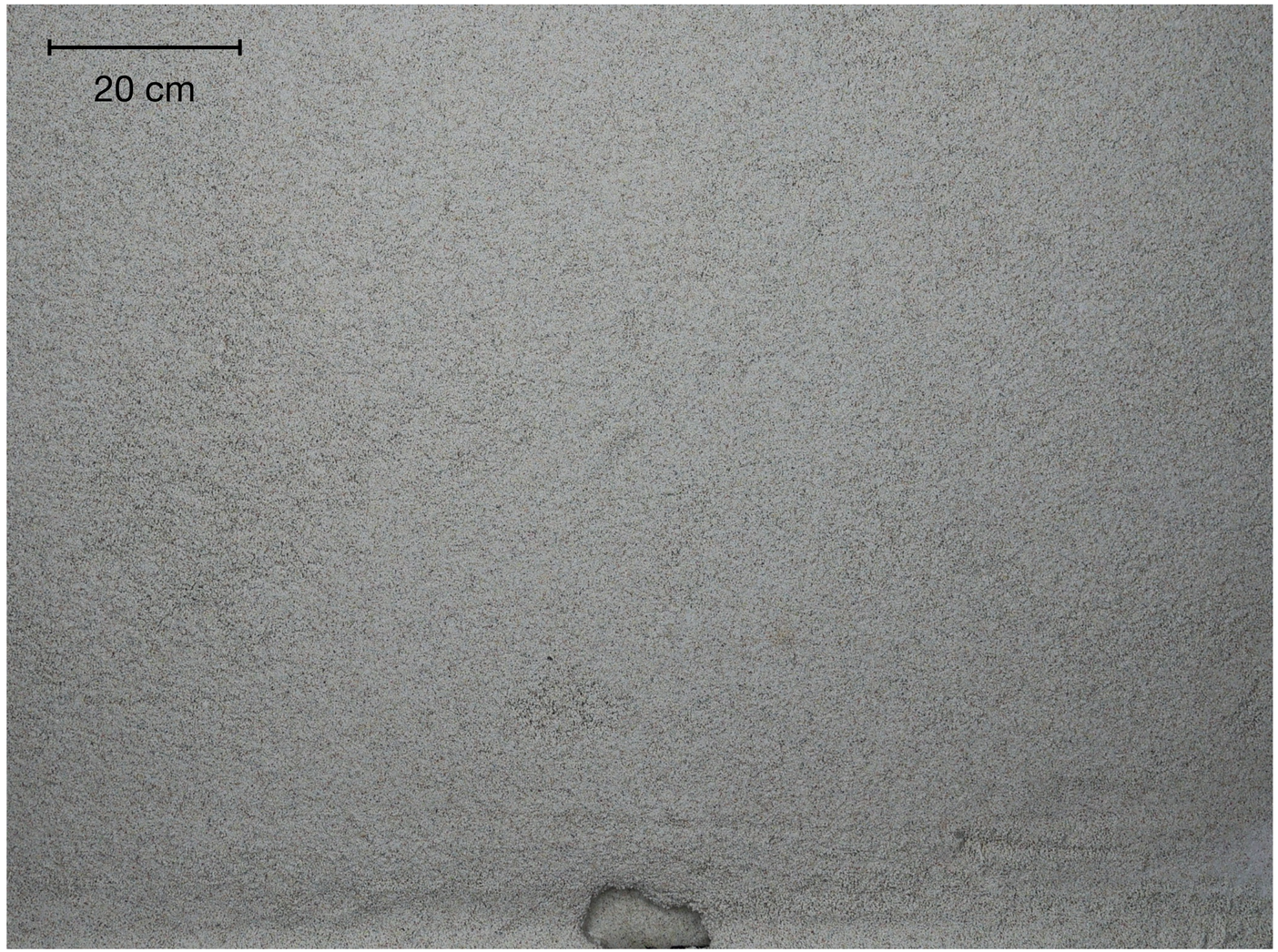




Network formation and evolution

Beginning of the erosion





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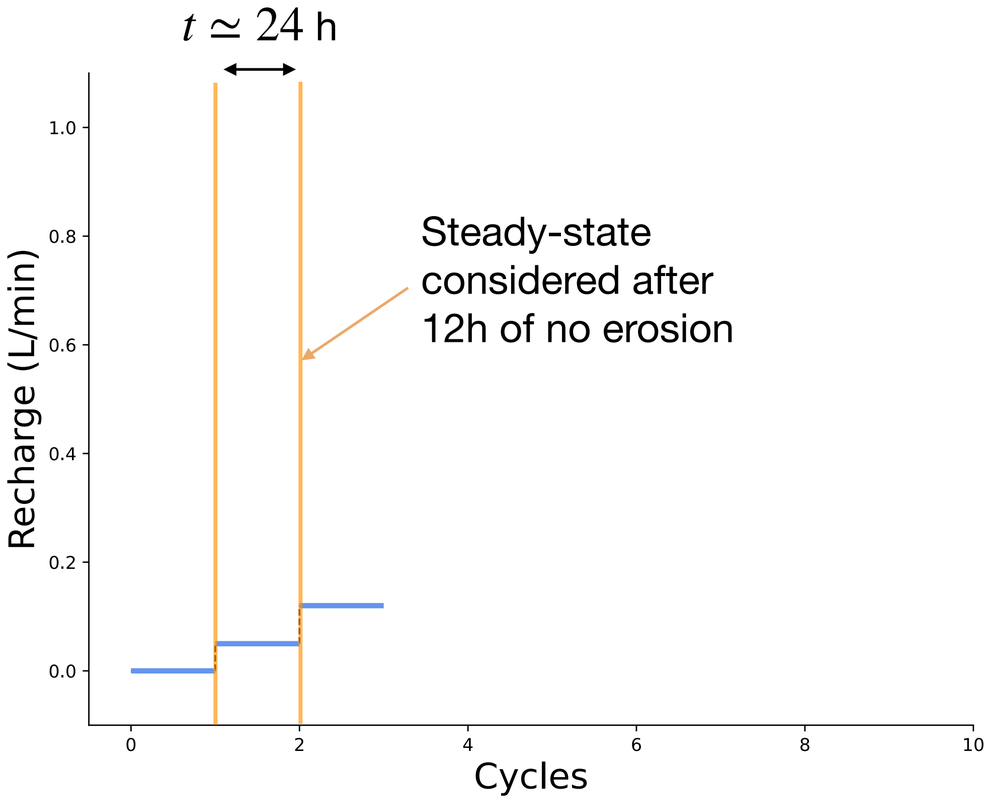
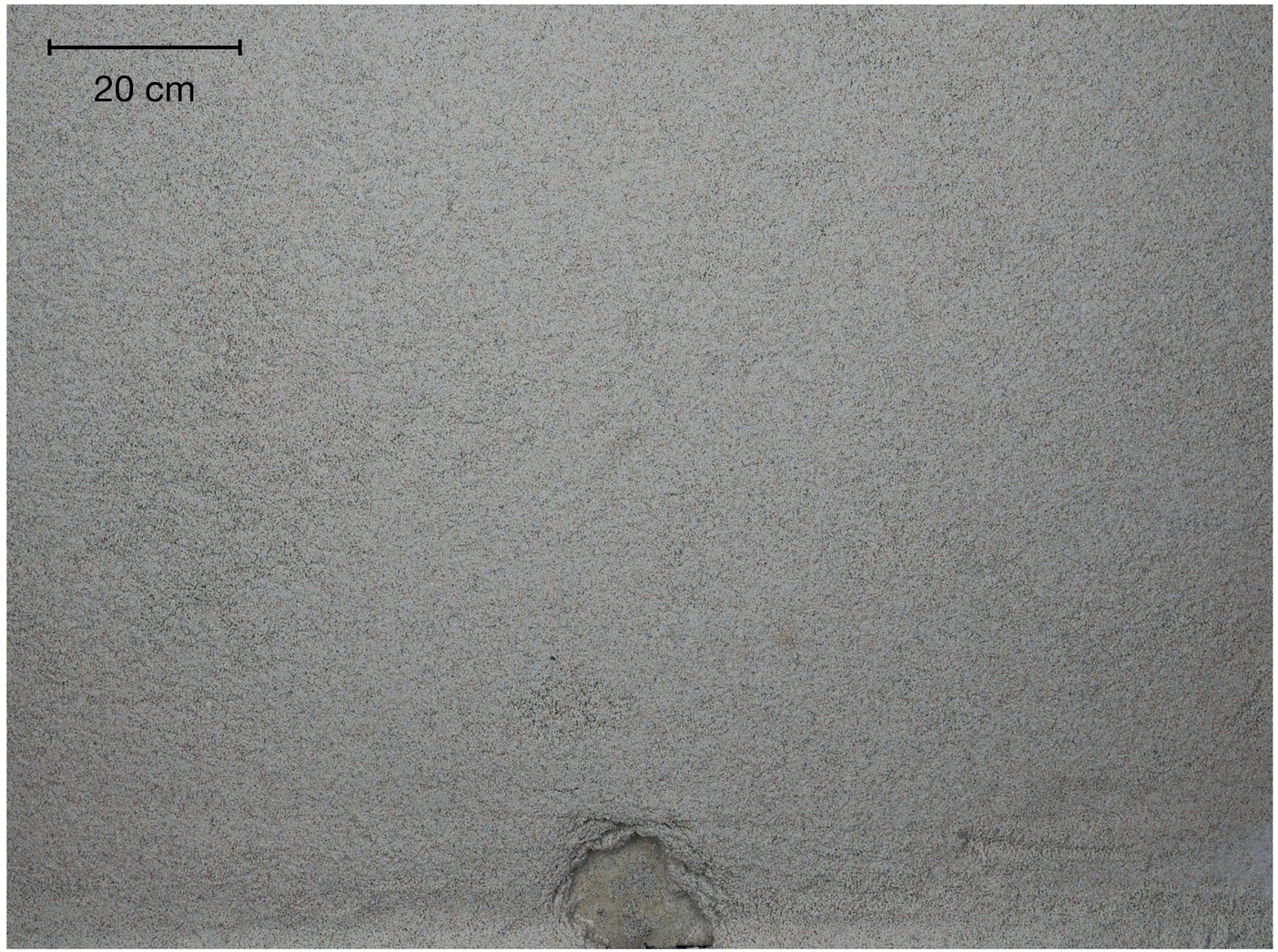
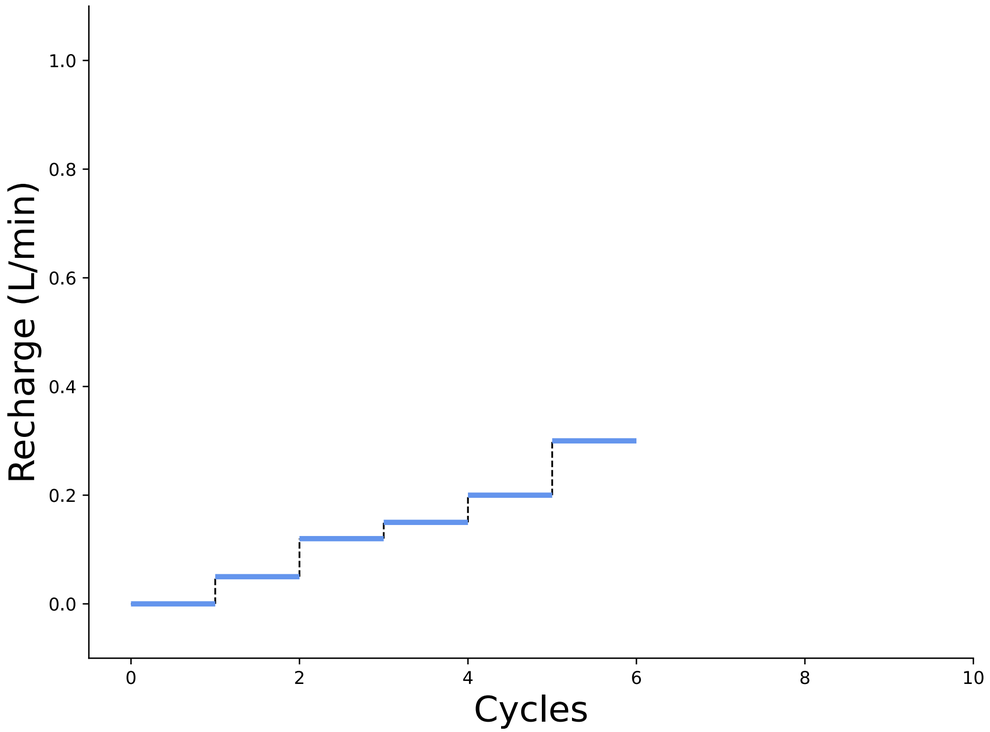




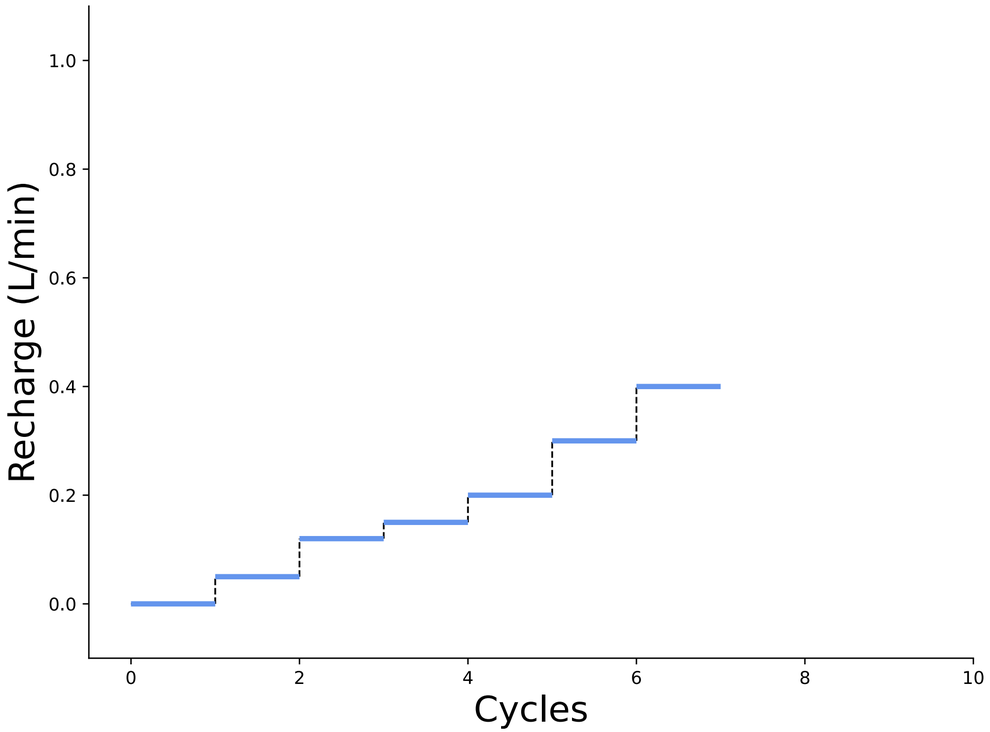
Network formation and evolution

Channels take form



Network formation and evolution

Channels grow



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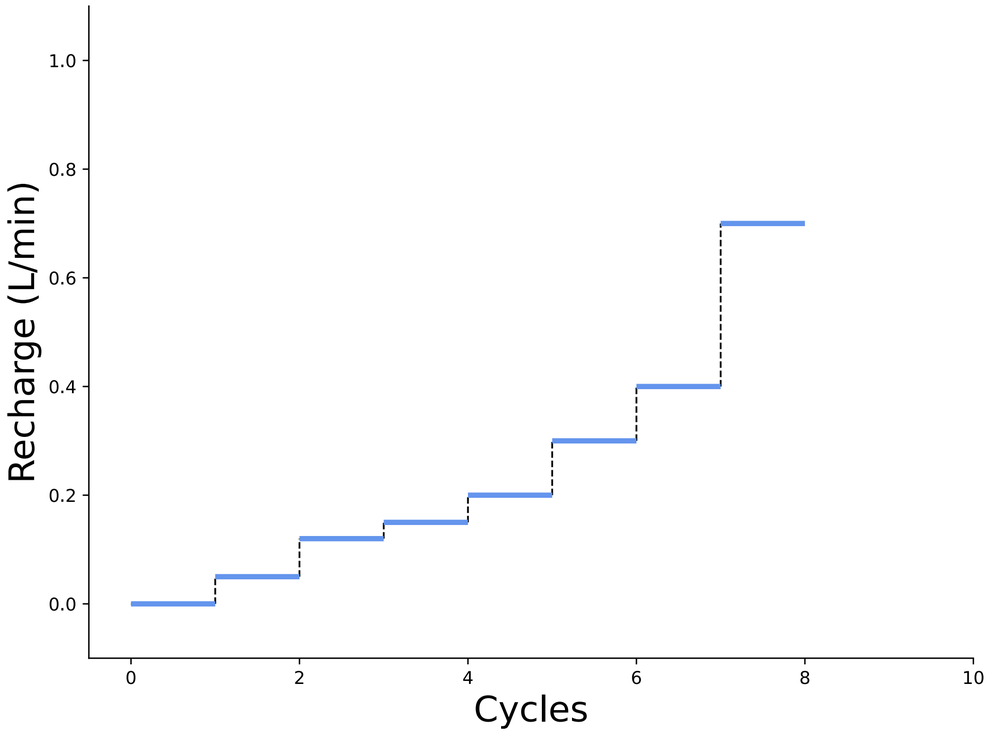

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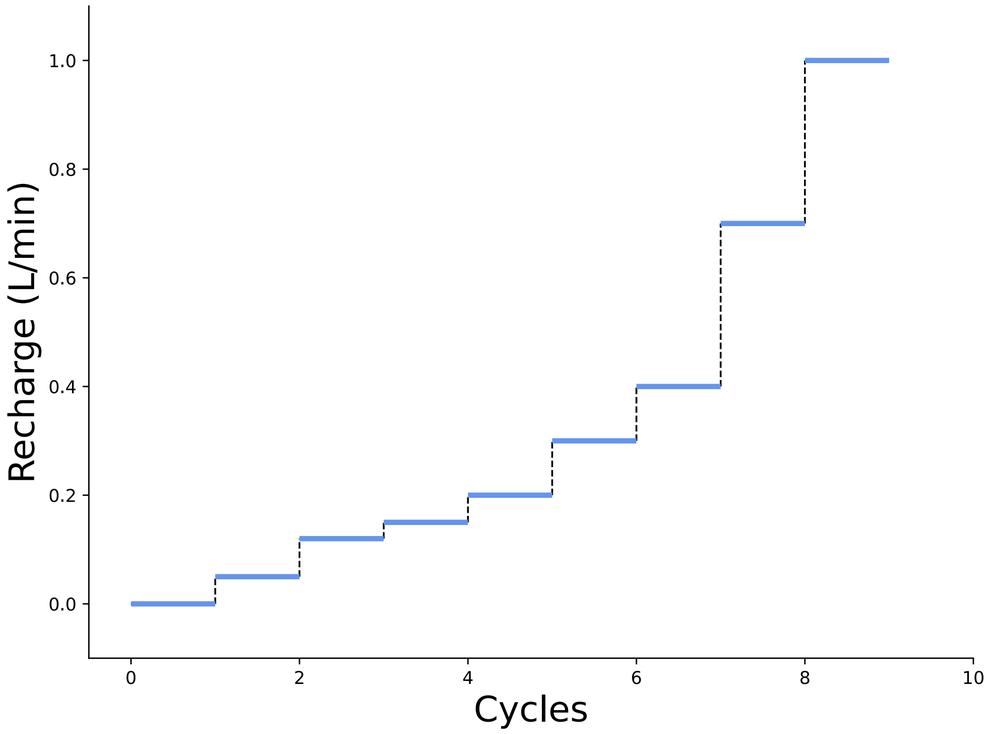
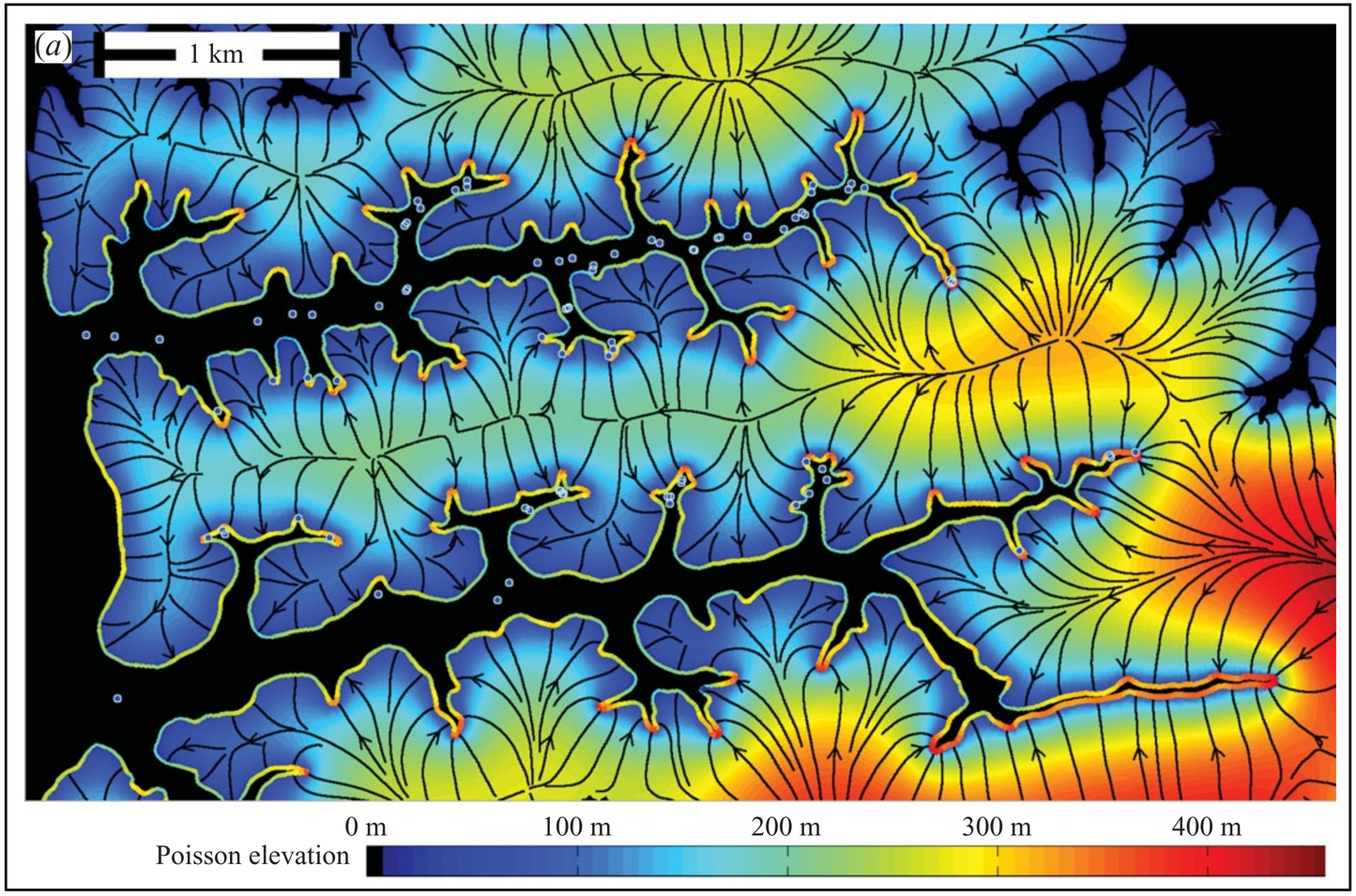


Groundwater fed network

As the river network changes, so does the groundwater distribution



Source : Petroff et al. (2011)

Groundwater fed network

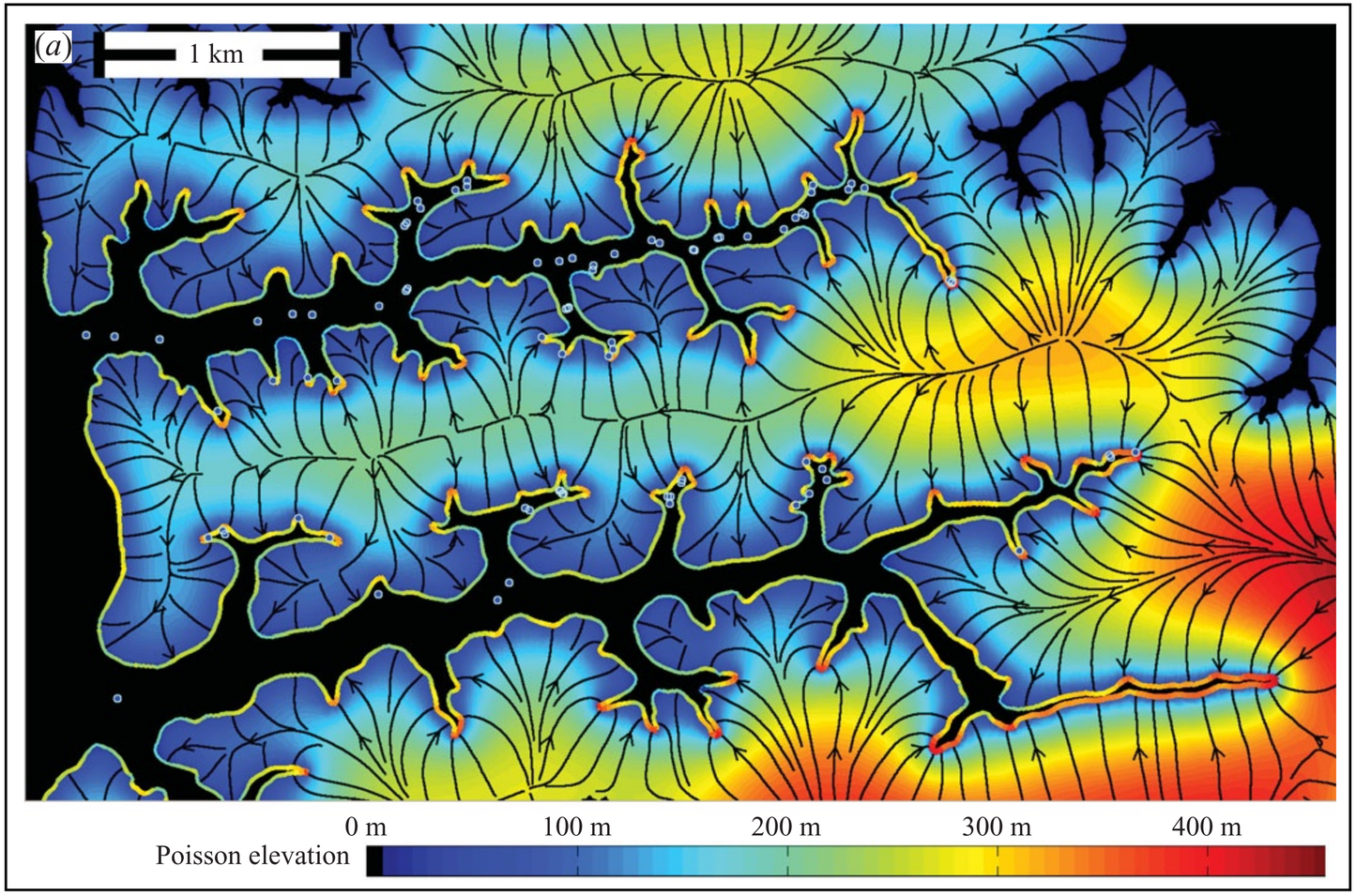
As the river network changes, so does the groundwater distribution

Poisson elevation / Water table height [m]

Recharge [m/s]

$$\nabla^2 h^2 = \frac{2R}{K}$$

Hydraulic conductivity [m/s]



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Groundwater fed network

Using Darcy's Law and the Dupuits-Boussinesq approximation

Poisson elevation / Water table height [m]

Recharge [m/s]

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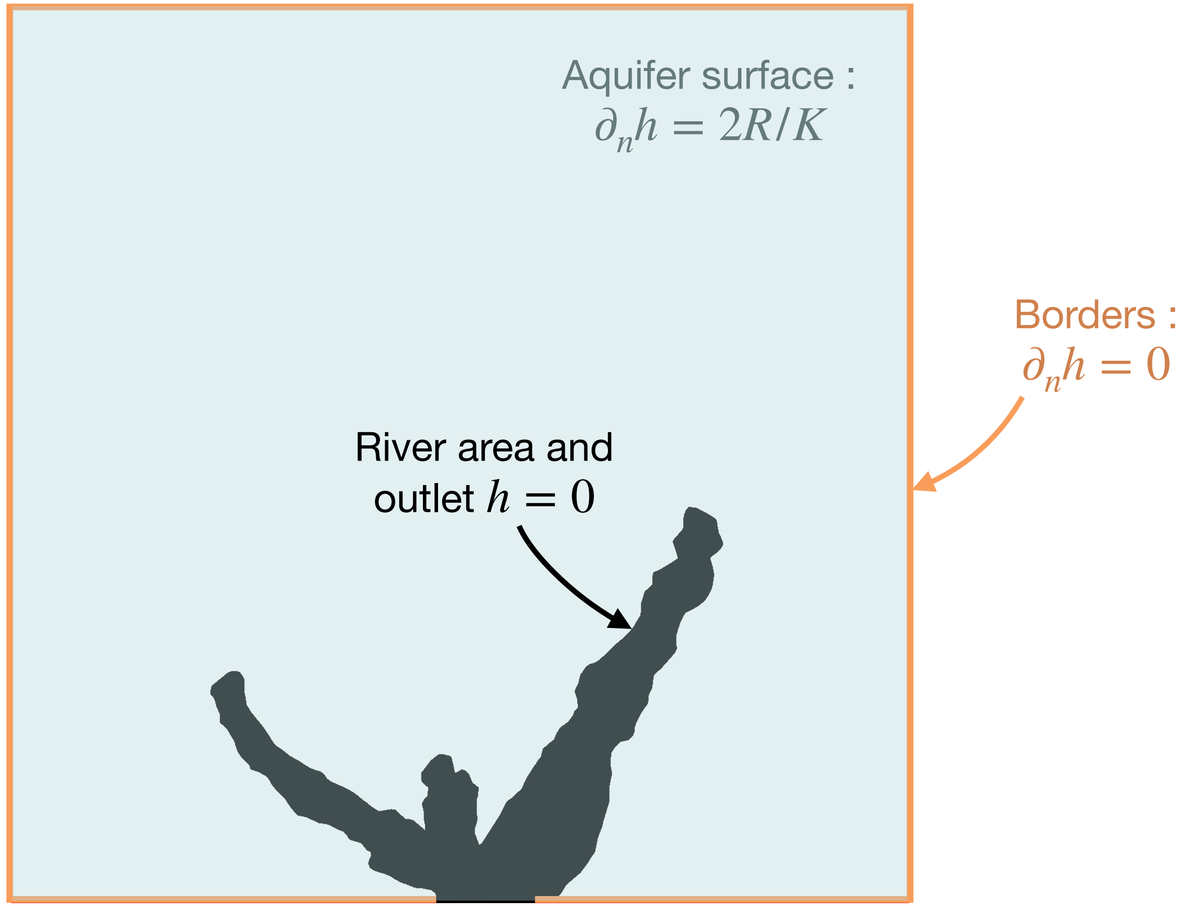
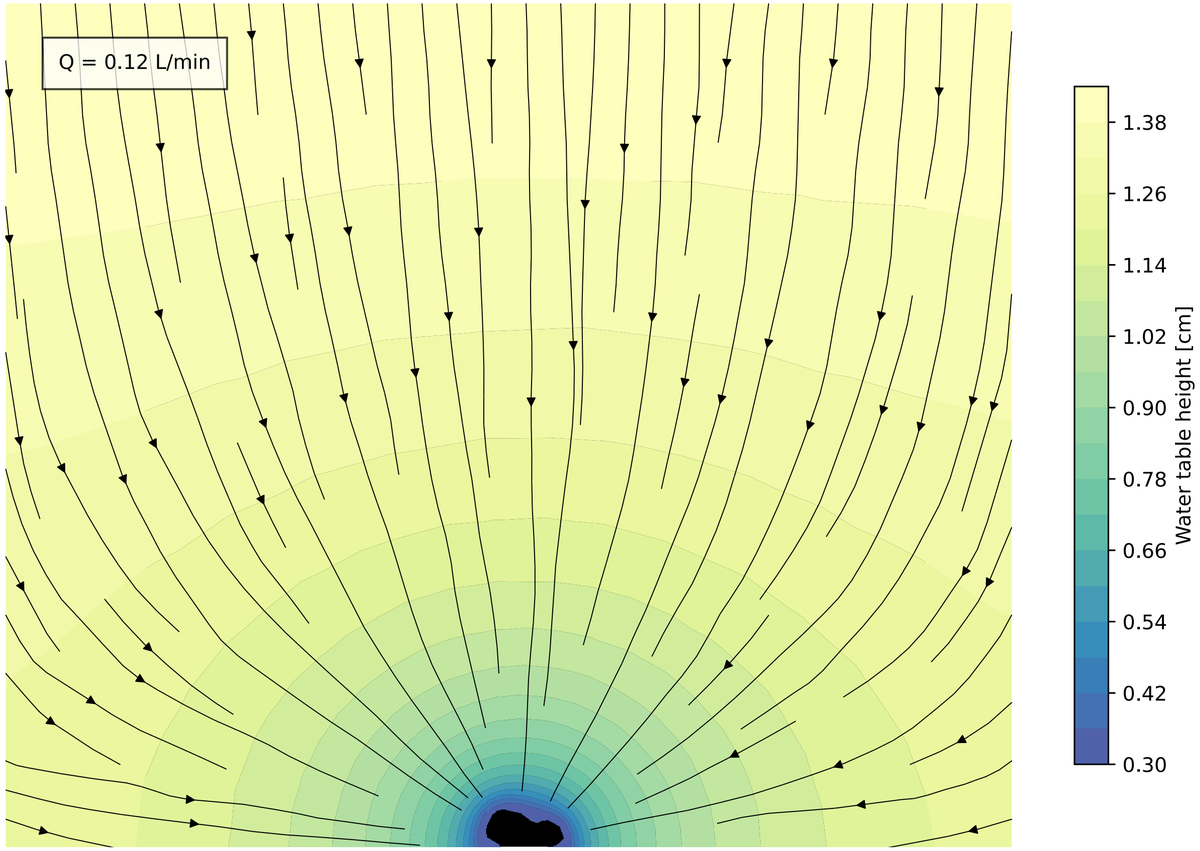
Hydraulic conductivity [m/s]



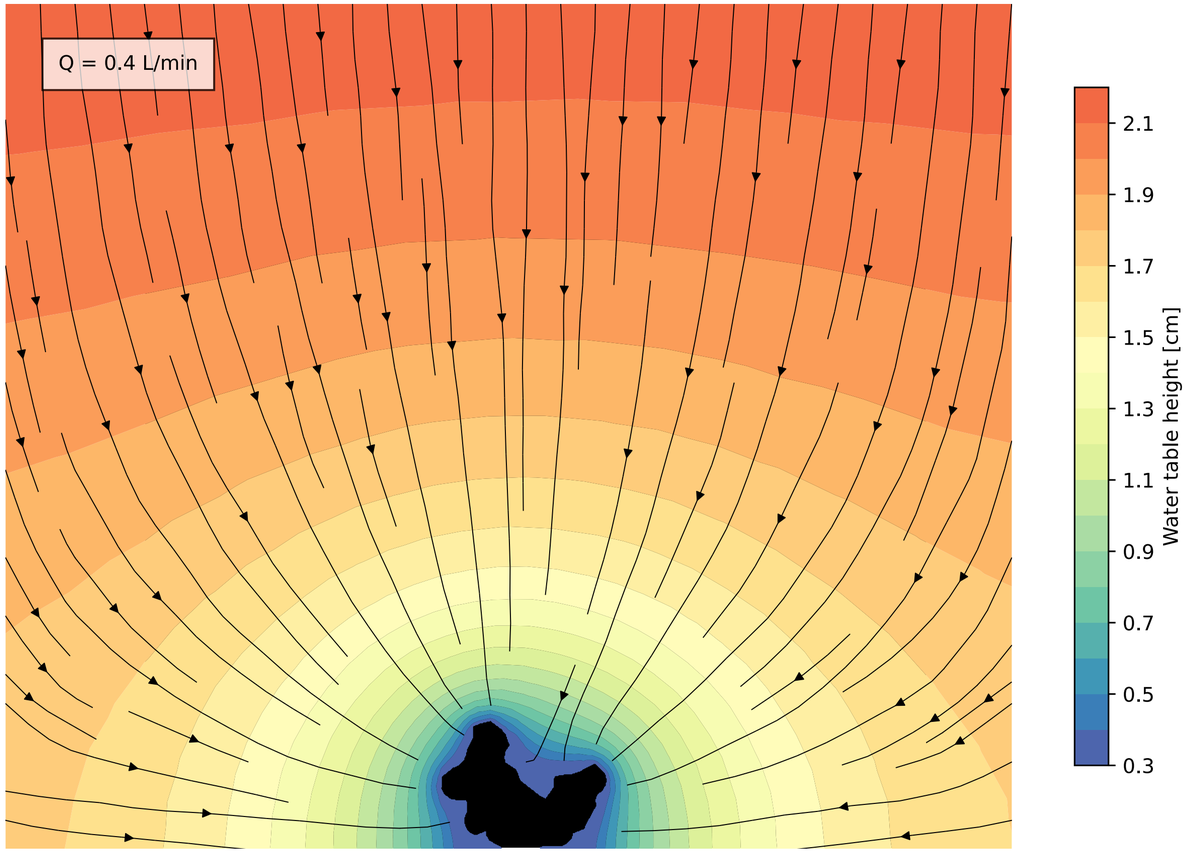
Network and Water table

All the groundwater flows towards the outlet



Network and Water table

Streamlines bend towards the network



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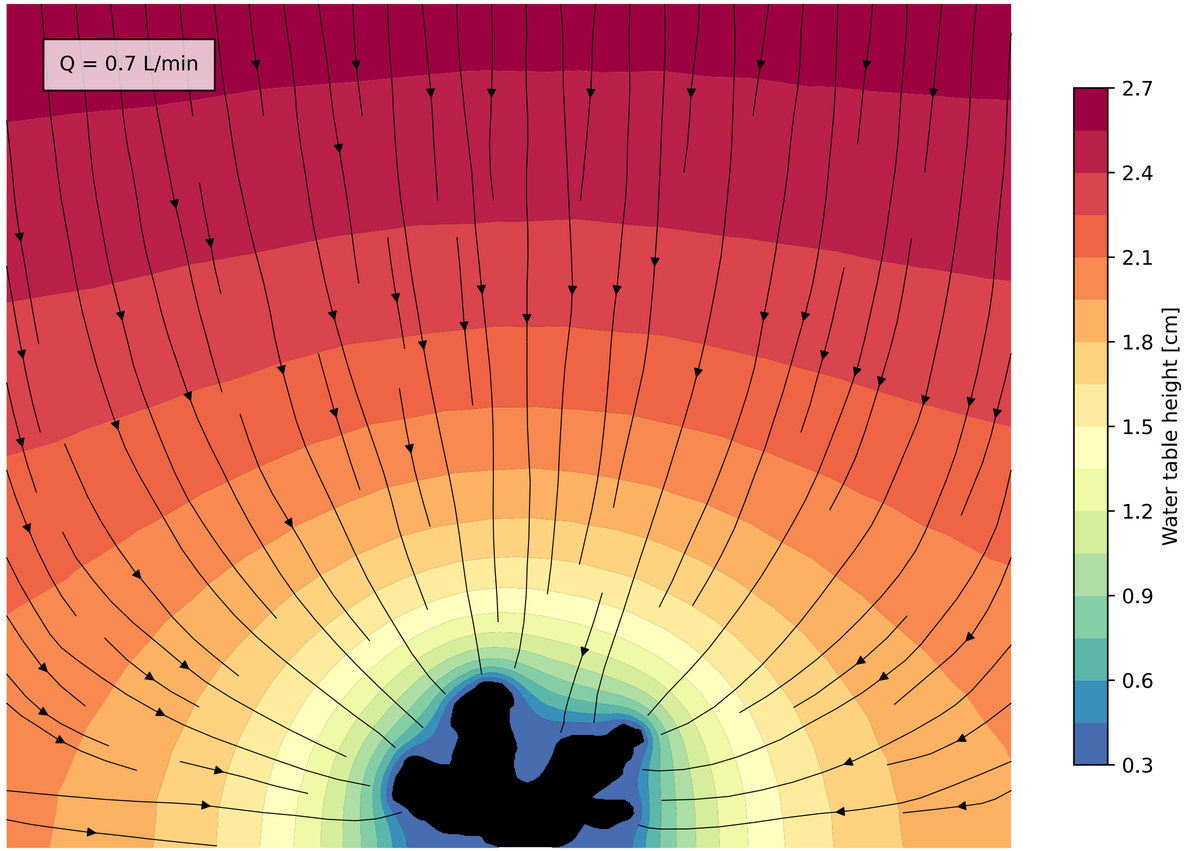
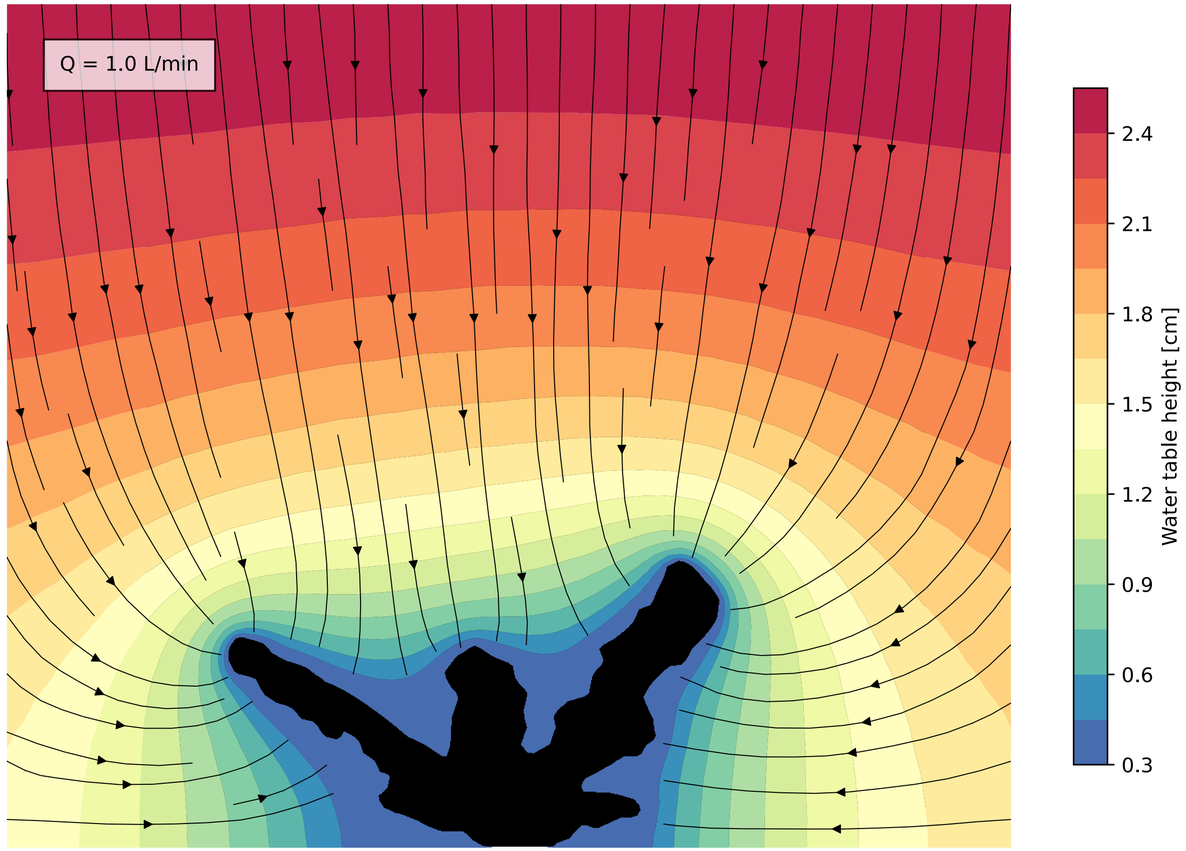


Network and Water table

The shape of the water table changes around the channels



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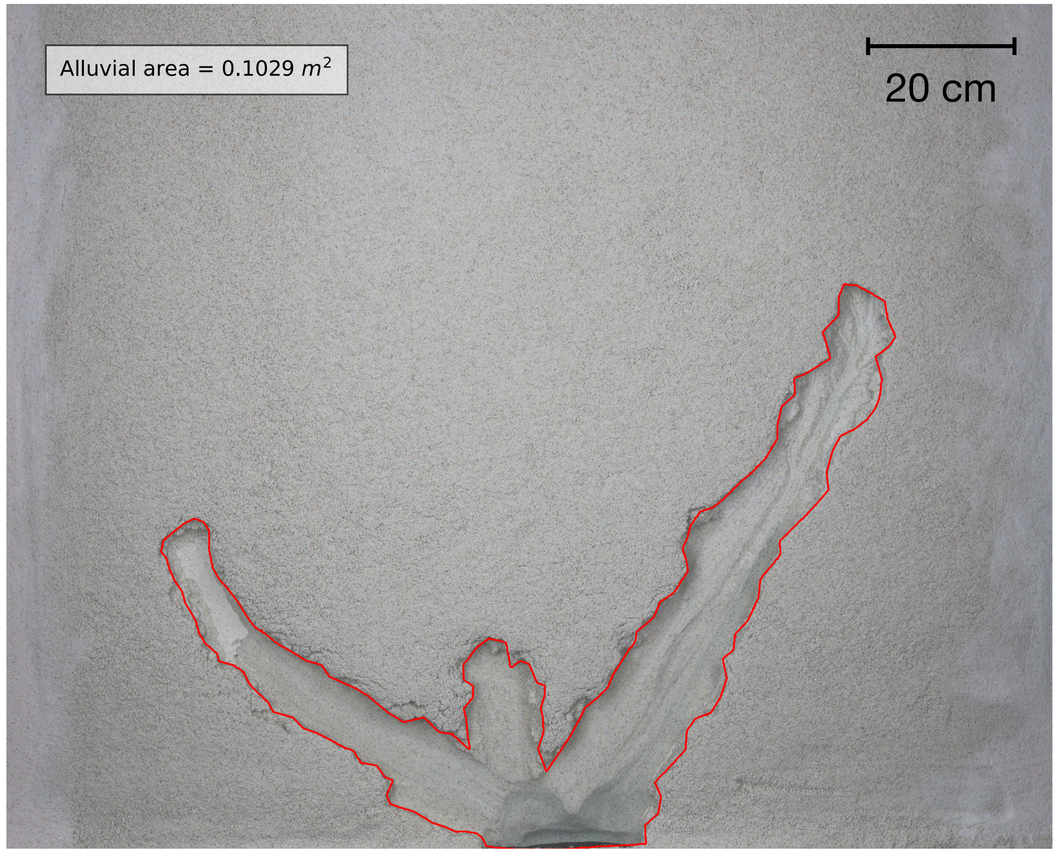
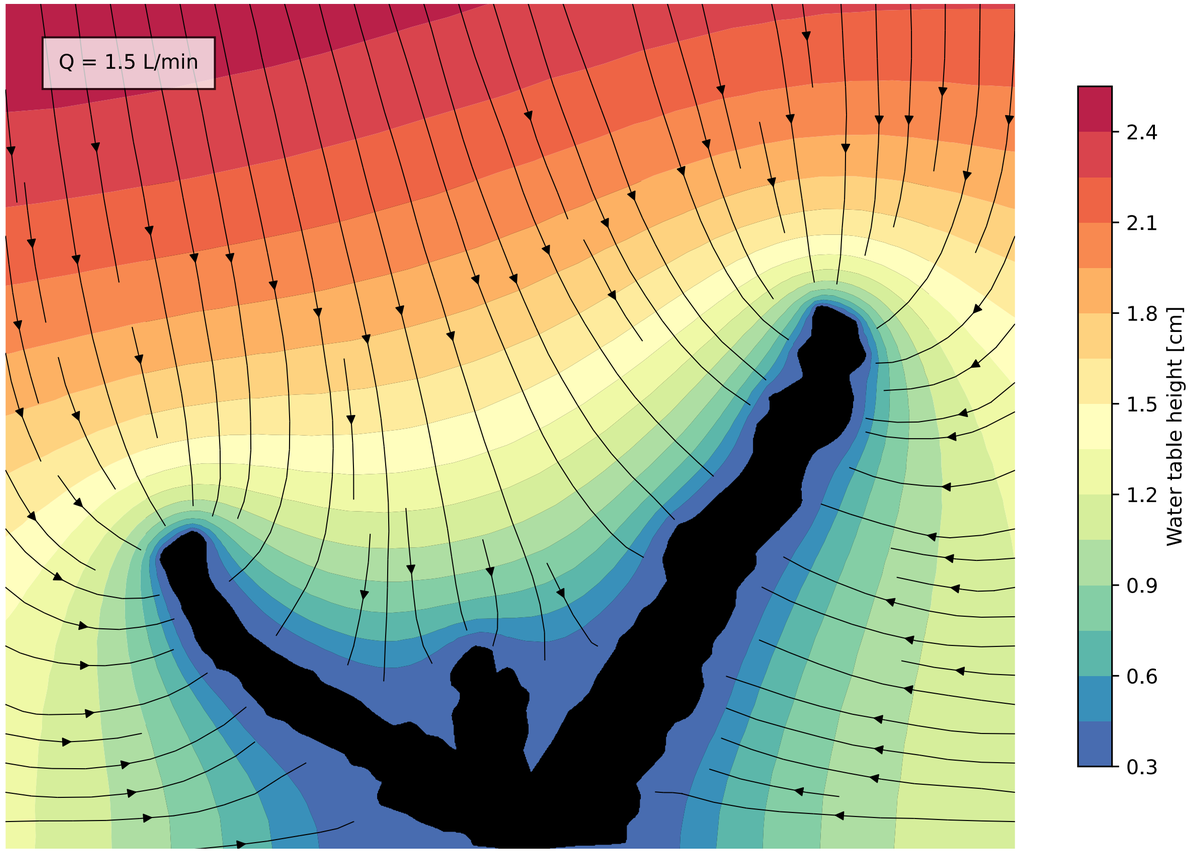
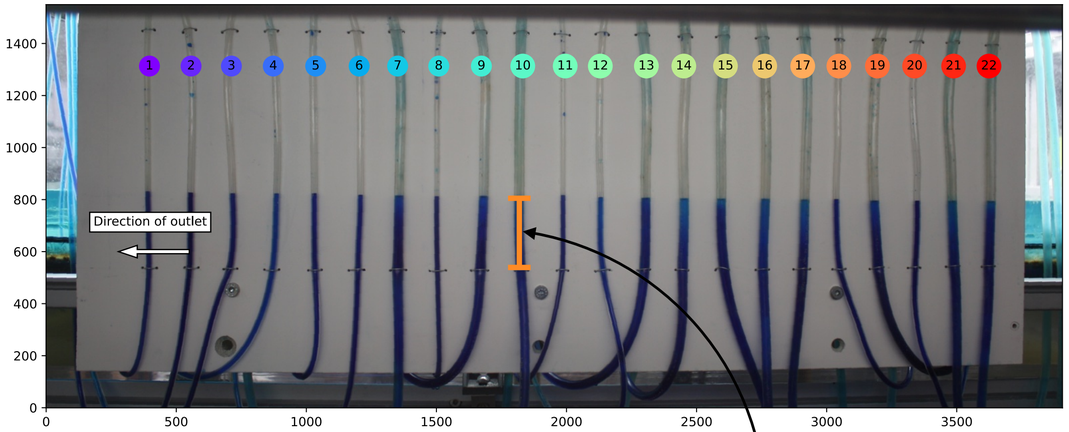
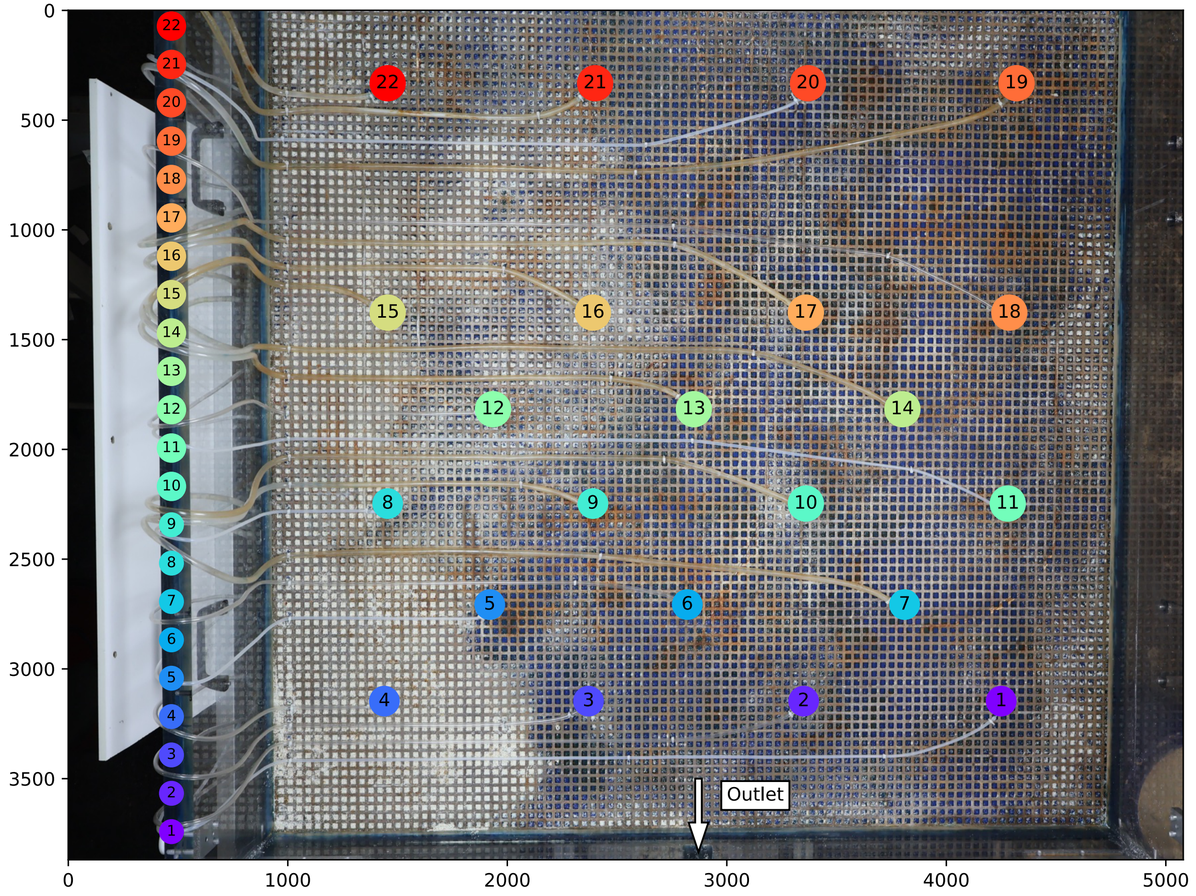




Data vs model

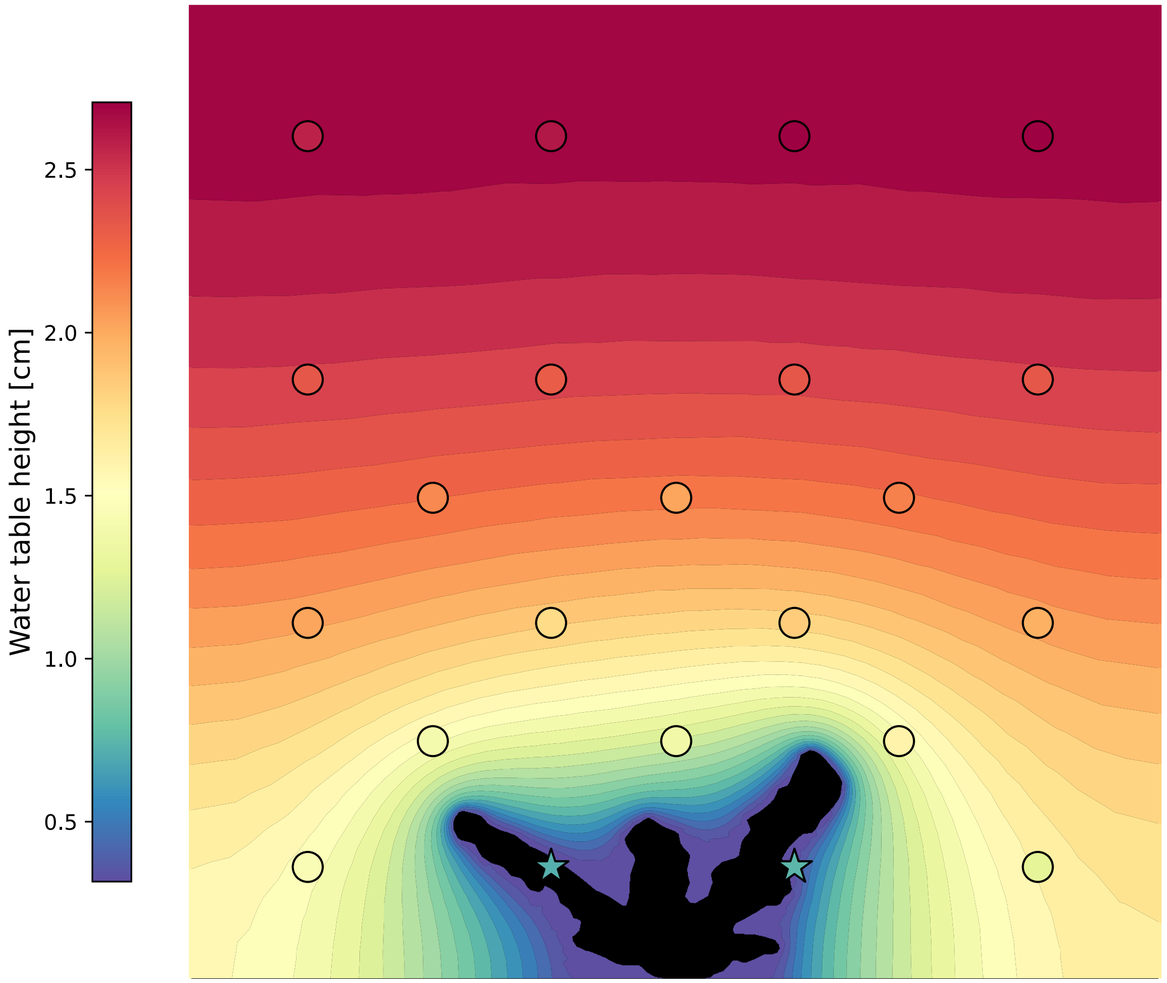
Piezometers :

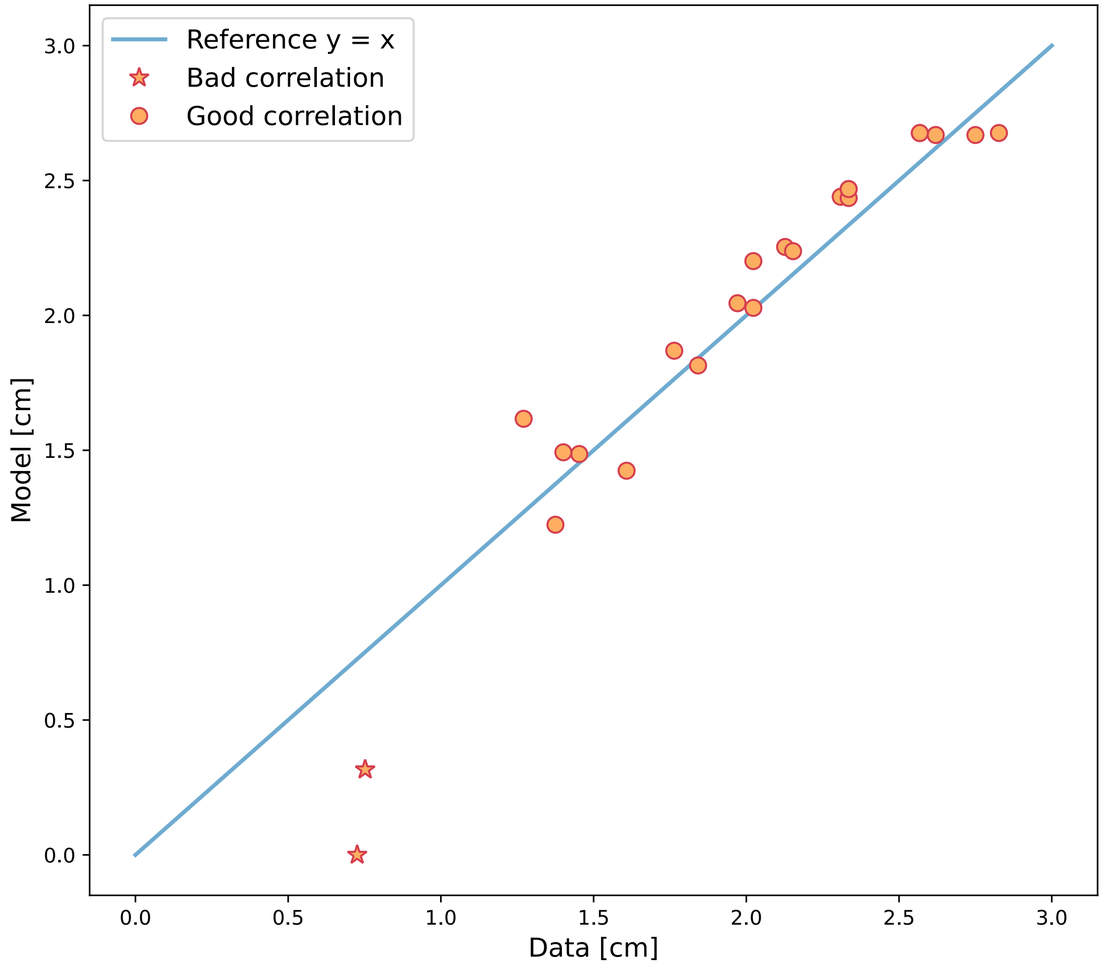




Data vs model

Best fit is for K = 0.0047 m/s





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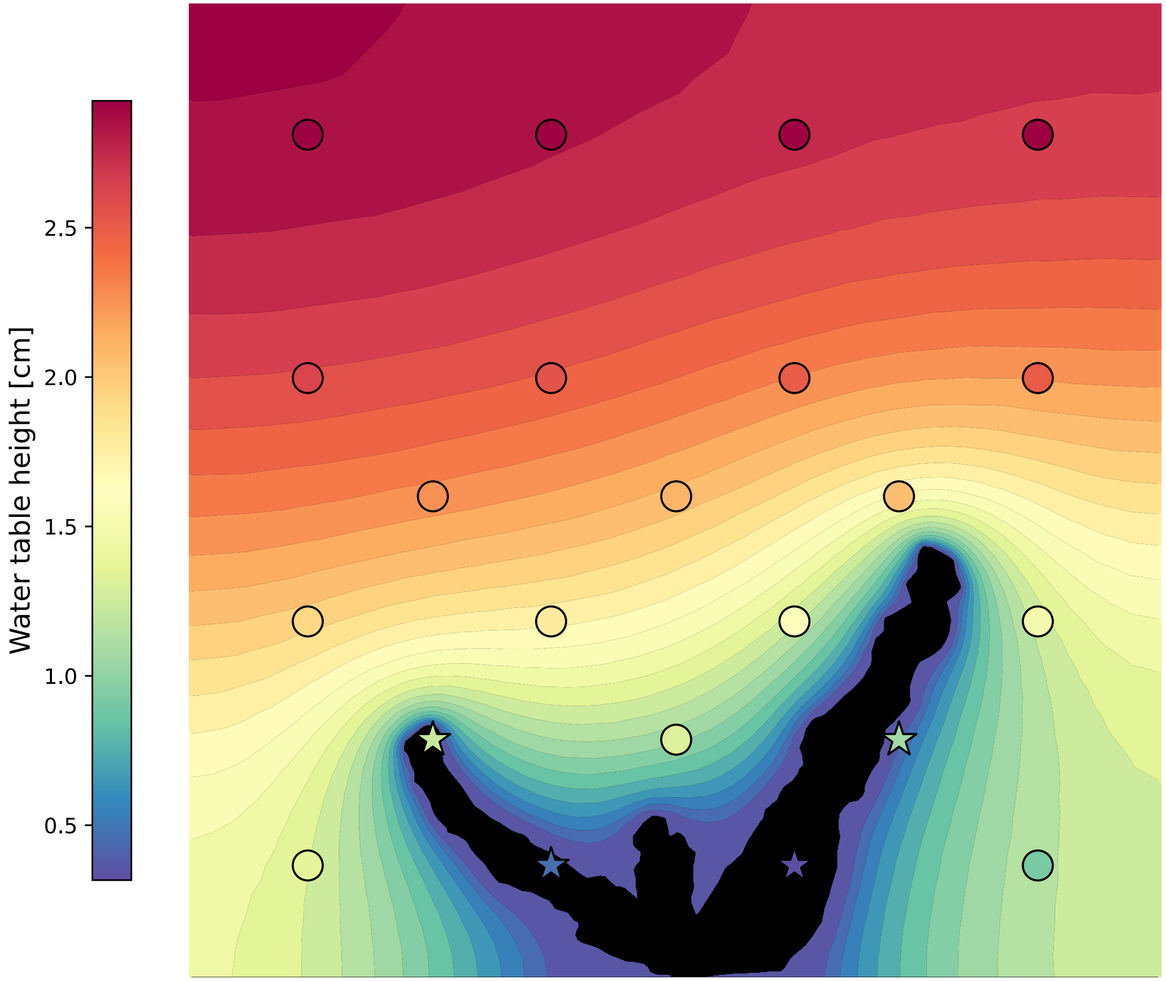
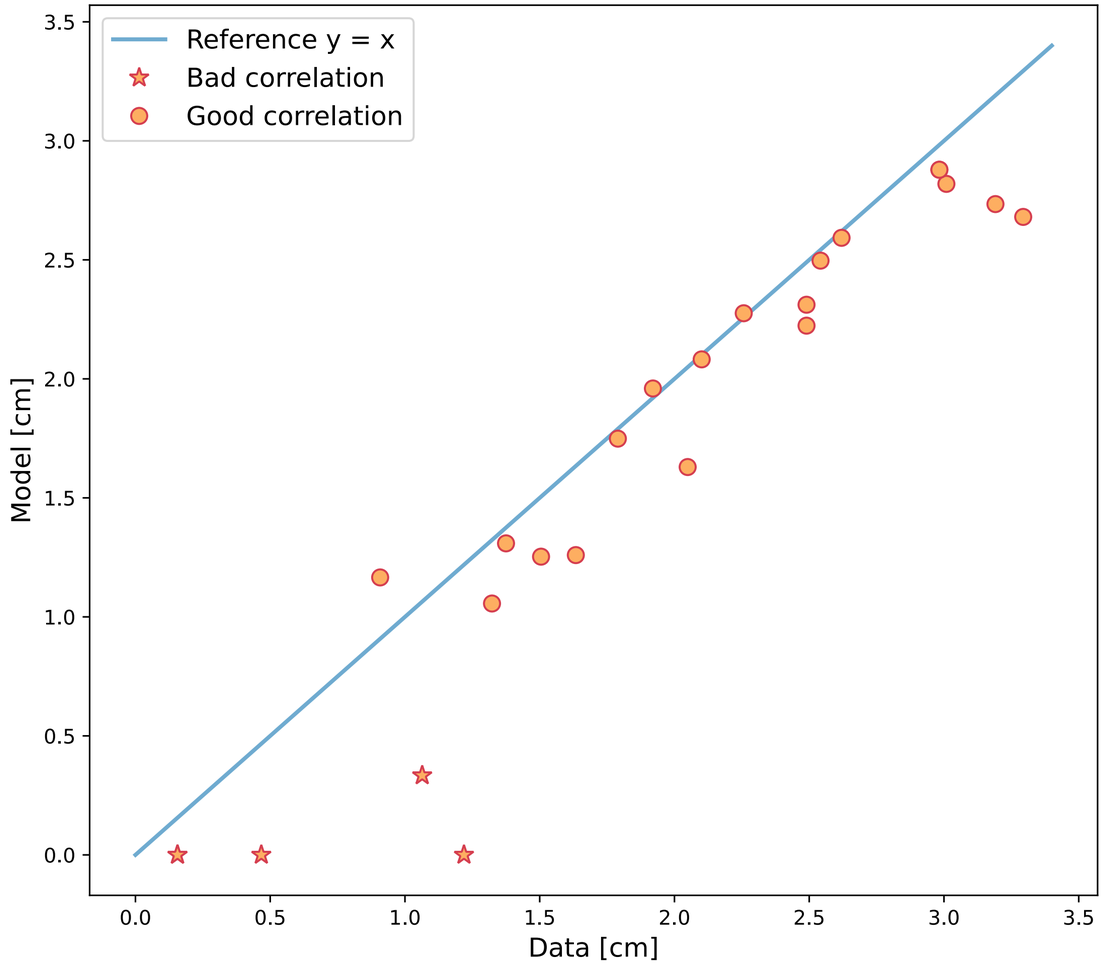




Take-home messages

We can create a network with seepage erosion

Take-home messages

We can create a network with seepage erosion

For a constant recharge, the network reaches a steady state

Take-home messages

We can create a network with seepage erosion

For a constant recharge, the network reaches a steady state

We can successfully model the shape of the water table around the network

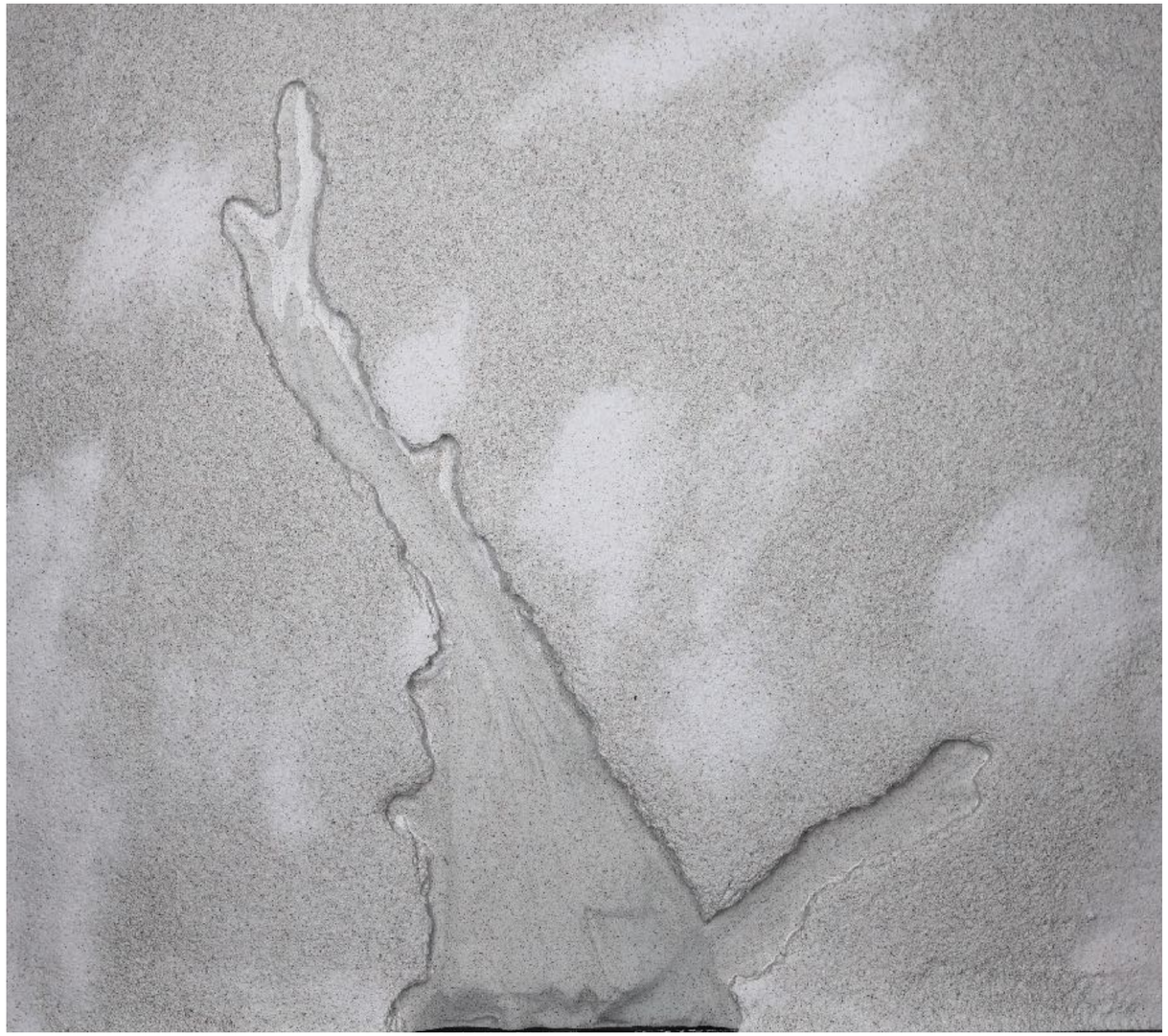
Take-home messages

We can create a network with seepage erosion

For a constant recharge, the network reaches a steady state

We can successfully model the shape of the water table around the network

The groundwater streamlines focus on the channel tips



Thank you for your attention !

Céleste Romon, at IPGP romon@ipgp.fr