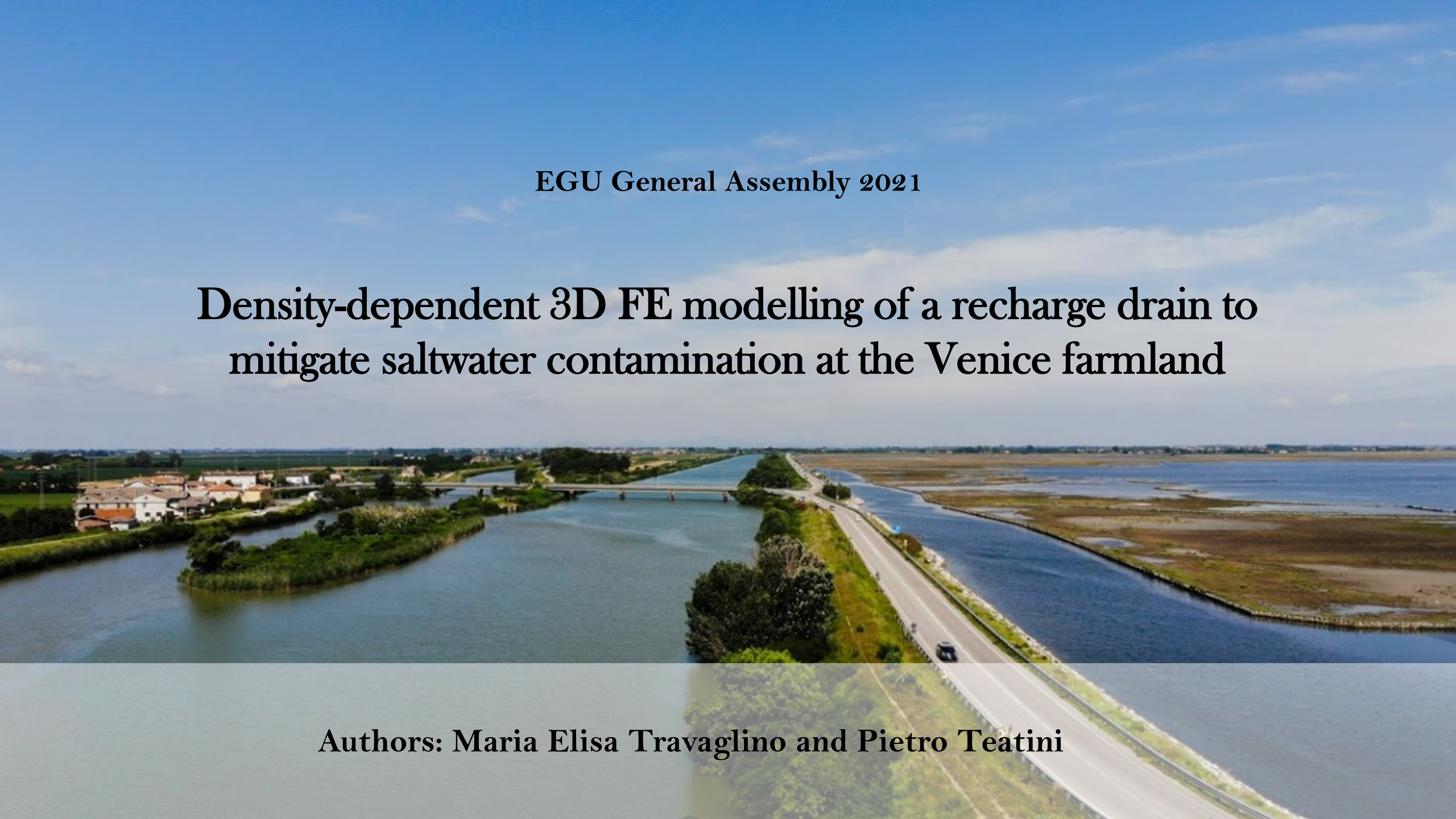


An aerial photograph of a coastal region. A multi-lane road runs diagonally from the bottom right towards the center. To the left of the road is a body of water, and to the right is a flat, marshy area. In the background, there are some buildings and more land under a blue sky with light clouds.

EGU General Assembly 2021

Density-dependent 3D FE modelling of a recharge drain to mitigate saltwater contamination at the Venice farmland

Authors: Maria Elisa Travaglino and Pietro Teatini

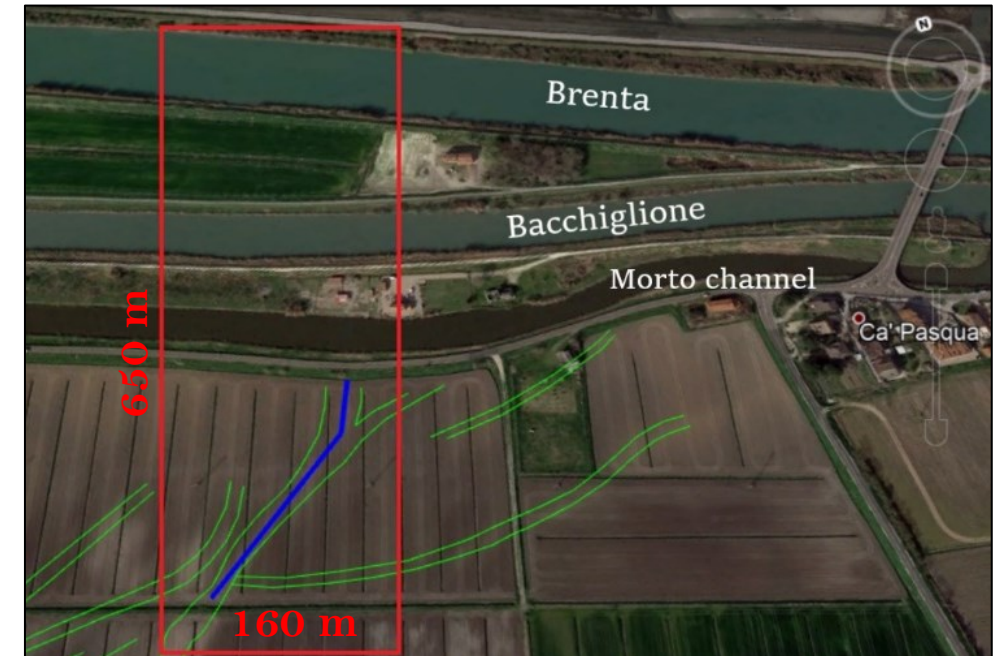
Introduction

Problem: saltwater intrusion in coastal aquifers

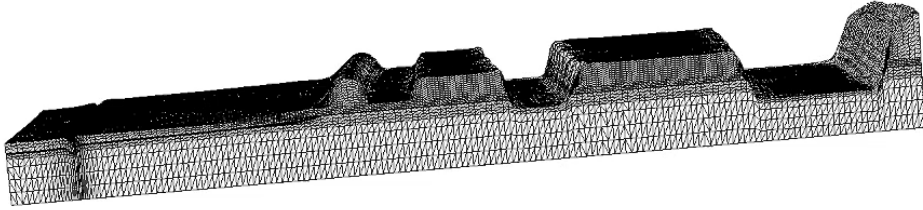
Possible mitigation strategies: subsurface barriers and recharge wells

Modelling study for a coastal farmland near Ca' Pasqua

Aim: assessment of the potential effects on salt concentration of a recharge drain recently established in the study area



The case study



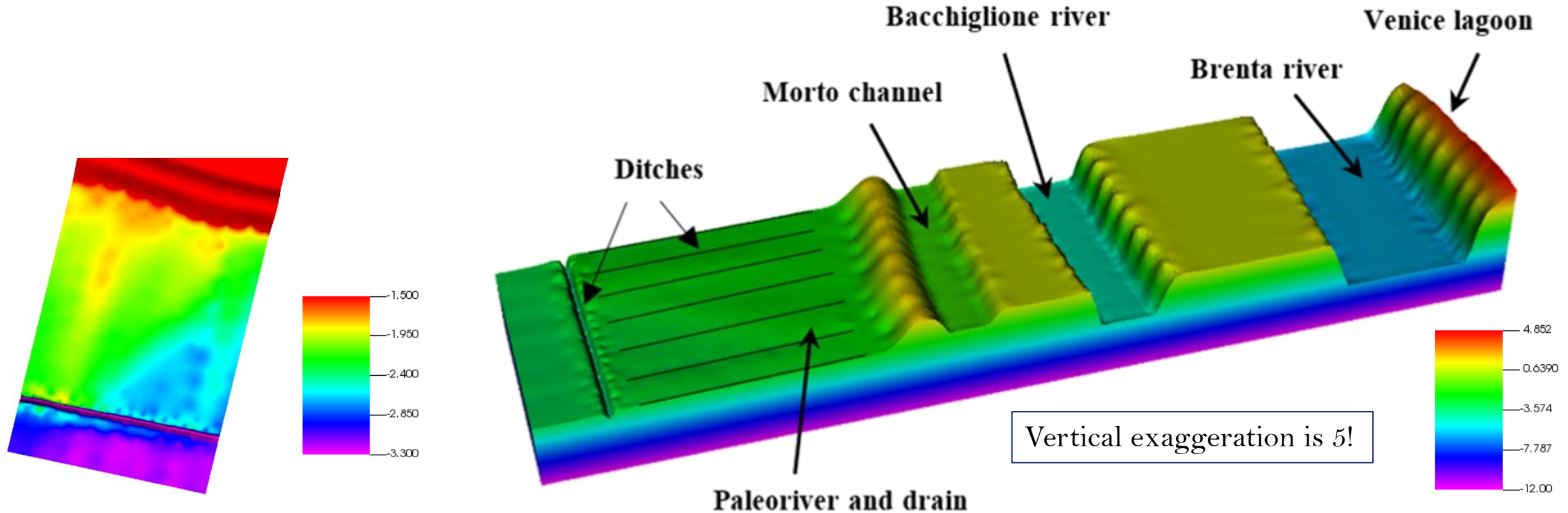
Mesh type: finite element (tetrahedra)

N° nodes: 500 000

N° elements: 3 000 000

Grid resolution: 0.25 m (drain and main ditch) and 4 m

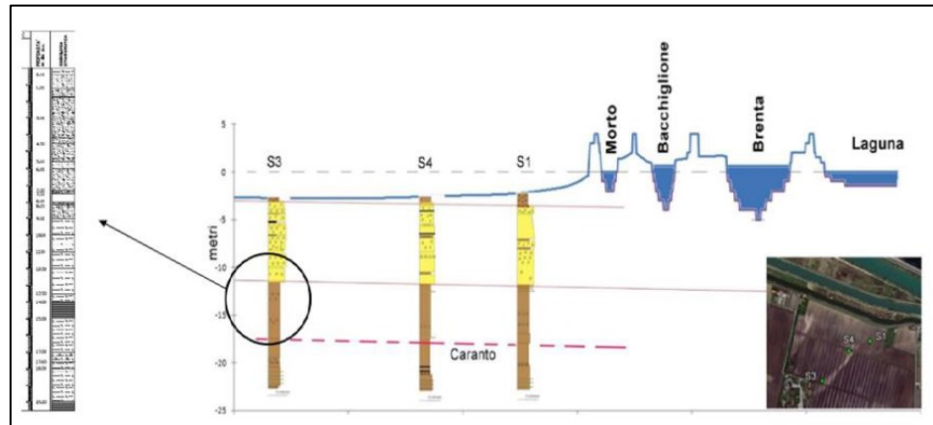
Vertical element dimension: 0.1 (close to the surface) - 2 m



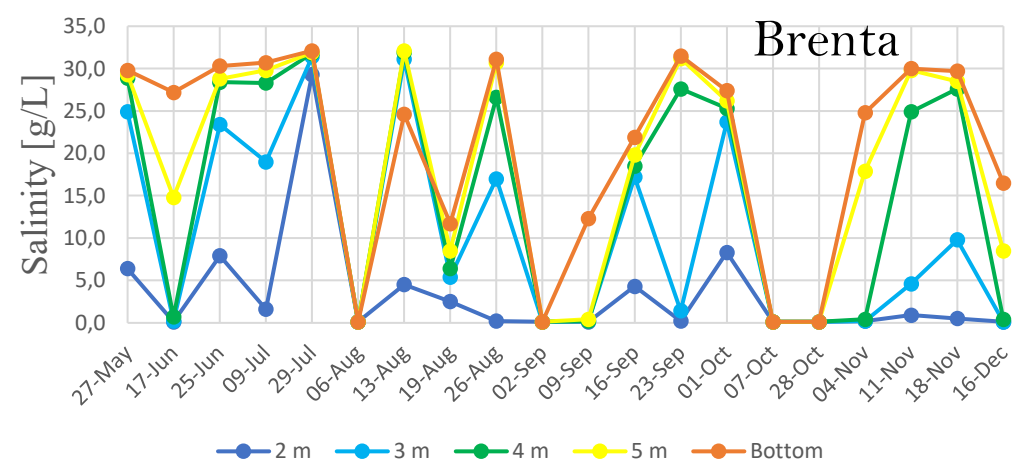
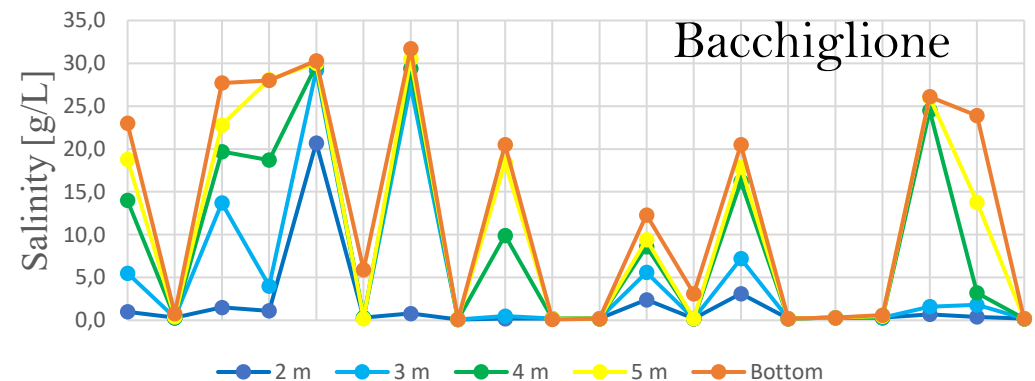
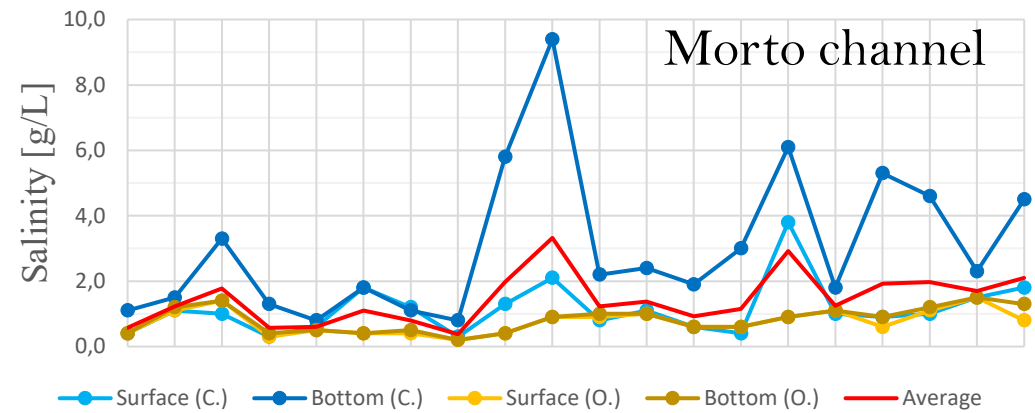
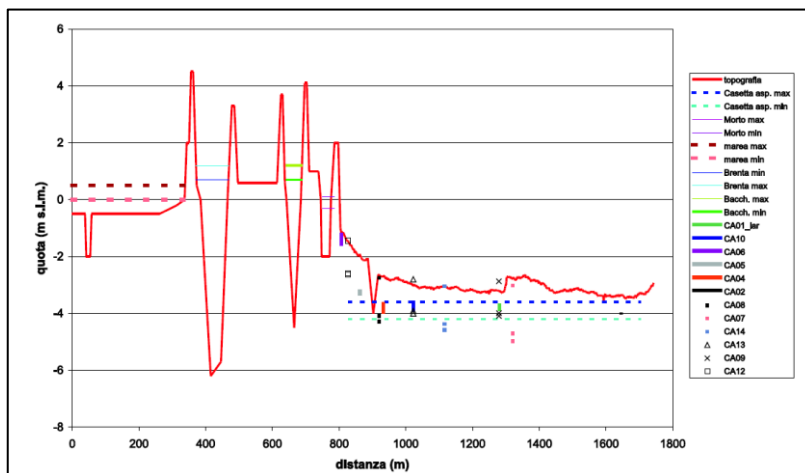
Available data

Soil stratigraphy

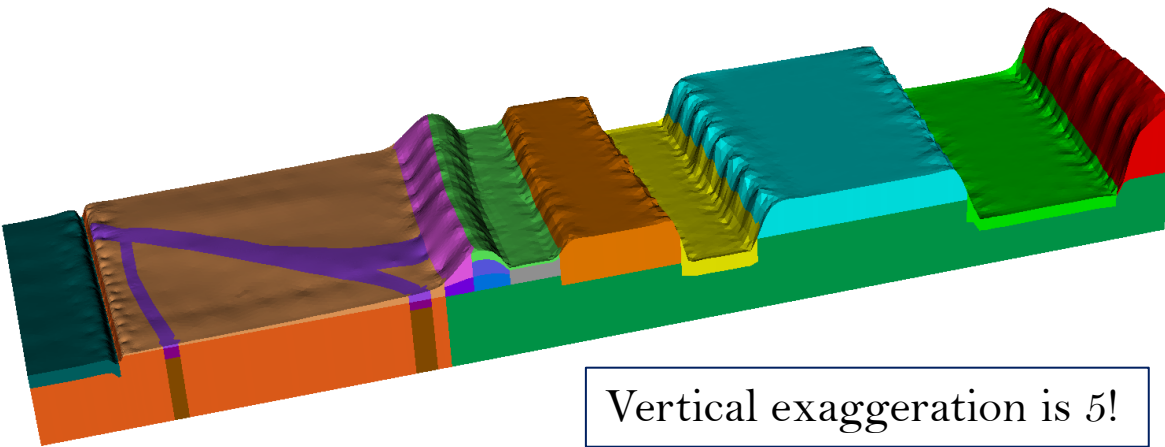
Salinity levels
in surface waters



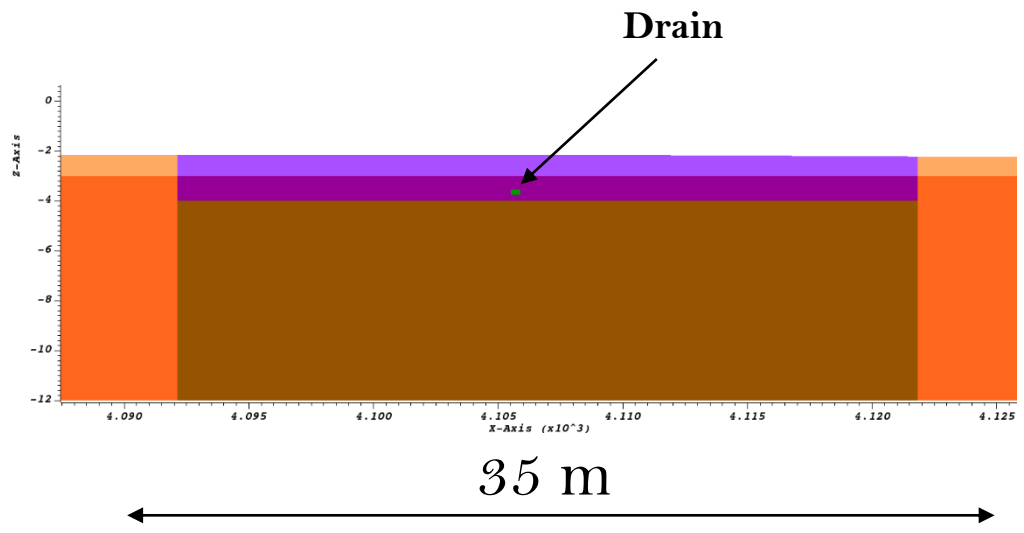
Surface and ground water levels



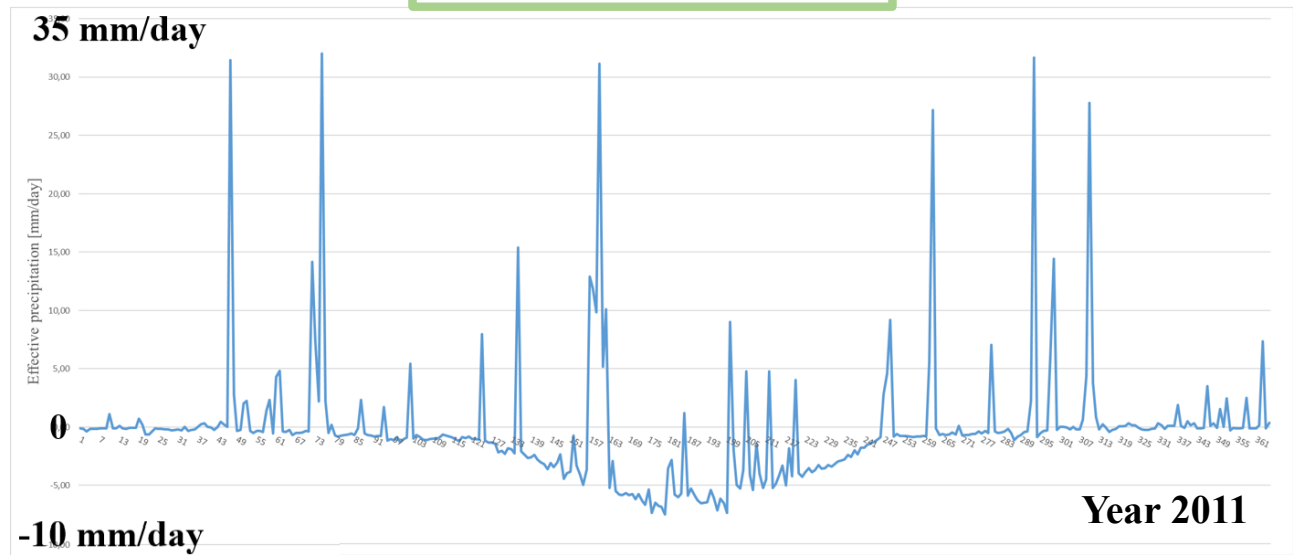
Model developement



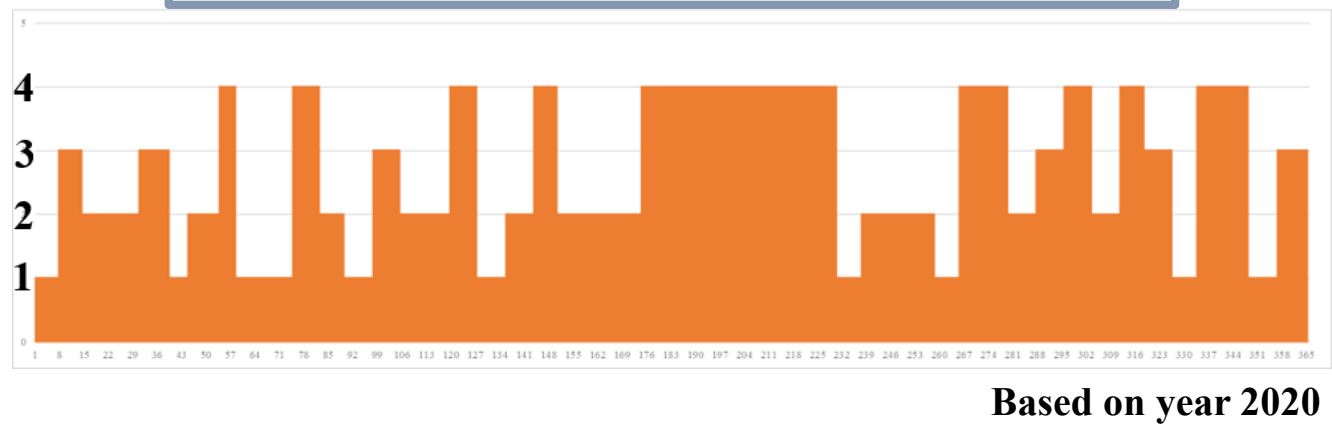
Vertical exaggeration is 5!



Effective precipitation



River dynamics: freshwater and saltwater periods



Model developement

Coupled density-dependent
flow and transport equations

$$\sigma \frac{\partial \psi}{\partial t} = \nabla \cdot \left[K_s \frac{1 + \epsilon \mathbf{c}}{1 + \epsilon' \mathbf{c}} K_r (\nabla \Psi + (1 + \epsilon \mathbf{c}) \eta_z) \right] - \phi S_w \epsilon \frac{\partial \mathbf{c}}{\partial t} + \frac{\varrho}{\rho_0} q \quad \text{Flow equation}$$

$$\mathbf{v} = -K_s \frac{1 + \epsilon \mathbf{c}}{1 + \epsilon' \mathbf{c}} K_r (\nabla \Psi + (1 + \epsilon \mathbf{c}) \eta_z)$$

$$\phi \frac{\partial S_w \mathbf{c}}{\partial t} = \nabla \cdot (\mathbf{D} \nabla \mathbf{c}) - \nabla \cdot (\mathbf{c} \mathbf{v}) + q \mathbf{c}^* + f \quad \text{Transport equation}$$

Van Genuchten relationships

$$S_e = \frac{\theta - \theta_r}{\theta_s - \theta_r} = (1 - (\alpha \psi)^n)^{-m}$$

$$K(\theta) = K_s S_e^{\frac{1}{2}} \left[1 - (1 - S_e^{1-m})^m \right]^2$$

Model application

Software: GroundWater Simulator (GWS)

- ❖ Application to a schematic case study
- ❖ Application to the Ca' Pasqua case study
 1. **Steady state simulations** for model initialization
 2. **Transient analysis** with natural forcings (i.e. effective precipitation and river dynamics), using the output of (1) as initial conditions
 3. Testing the **recharge drain** effects

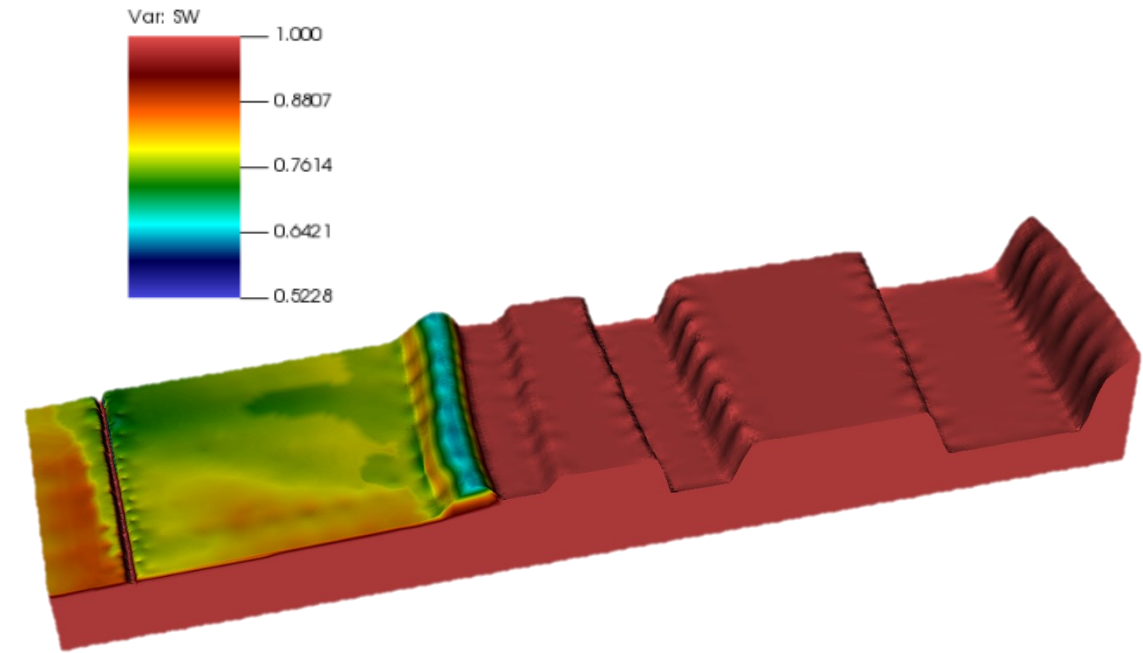
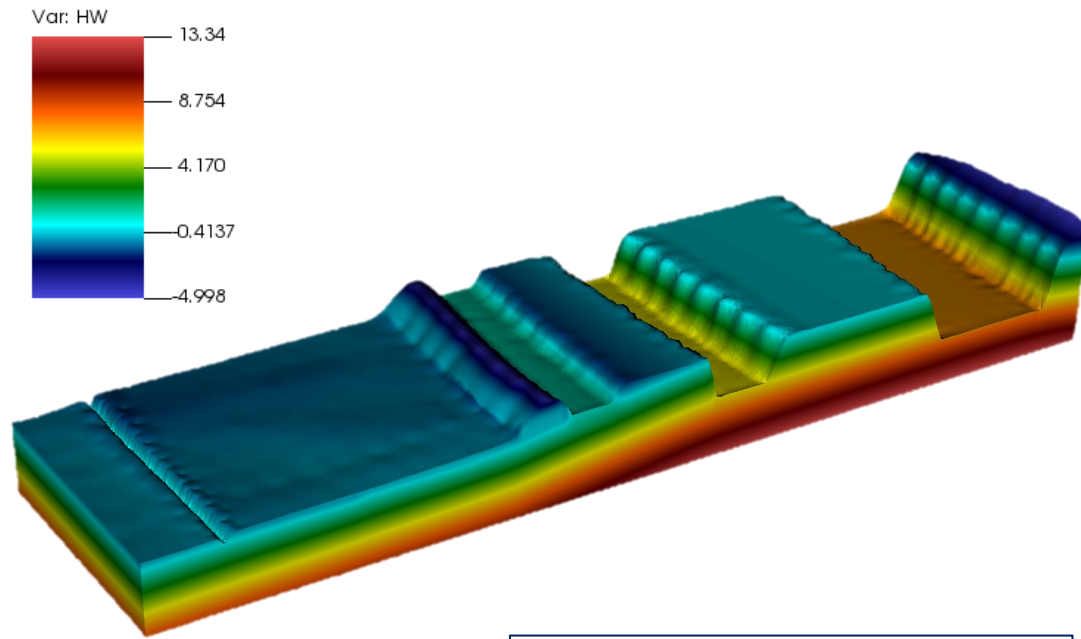
Sensitivity analysis for:

- Isotropic and anisotropic hydraulic conductivity
- Hydraulic conductivity for watercourse beds and embankments
- Transport parameters (diffusivity coefficients and molecular diffusion)

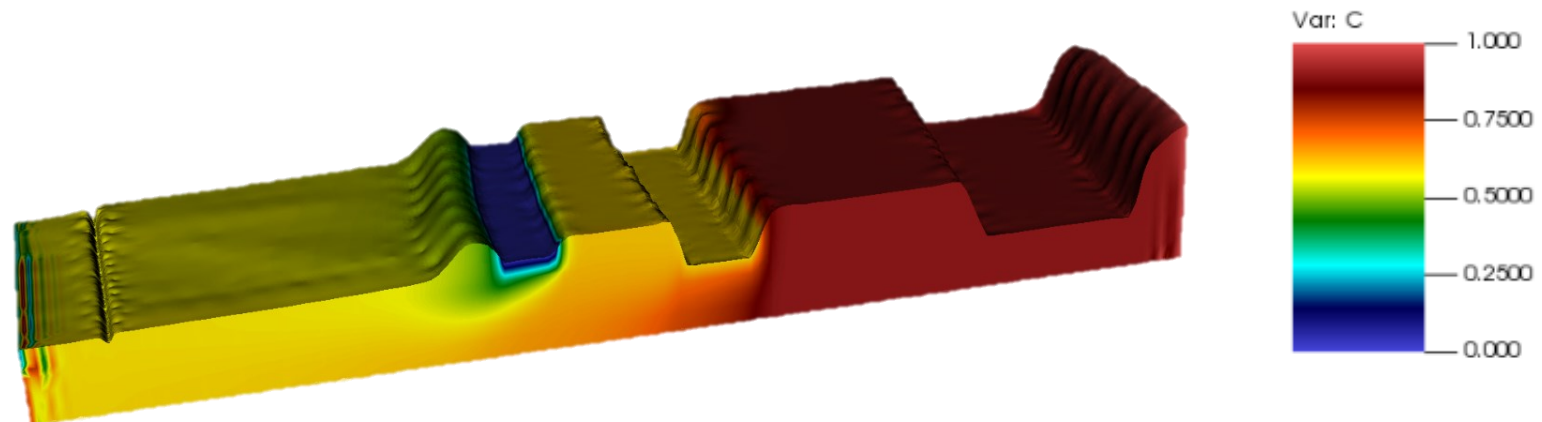
Material classification	K_s (m/day)
Levees	0.0001-0.004
Watercourse beds	0.0001-0.002
Farmland (outside the paleochannel)	0.05
Paleochannel	0.5
Aquifer	2-10
Drain	200

Transport parameters		Van Genuchten parameters	
		Sand	Silt/Clay
α_L (m)	0.1	θ_r	0.12
α_T (m)	0.01	θ_s	0.49
D_o	0.0001	α (1/m)	2
τ	200	n	1.75
		K_s (m/d)	0.56
		1	0.5

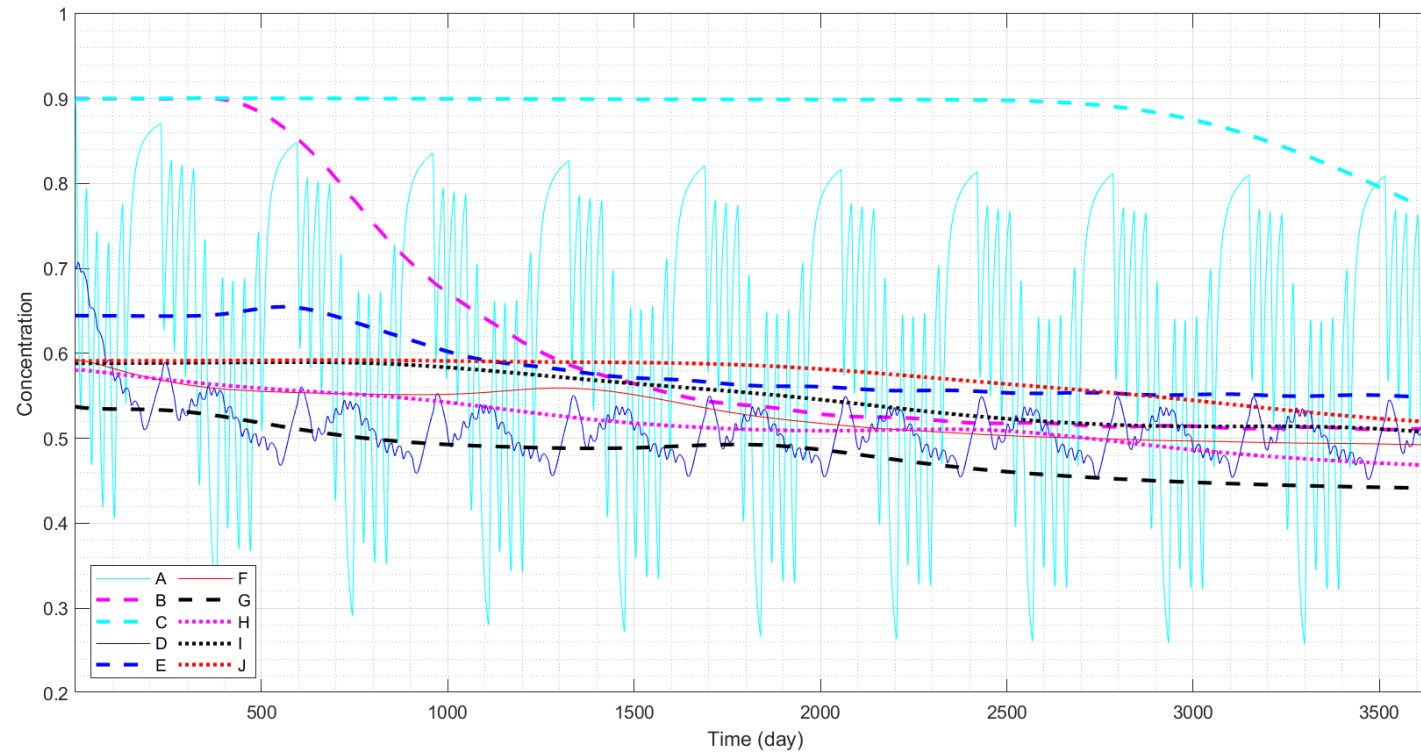
1. Steady state simulations



Vertical exaggeration is 5!



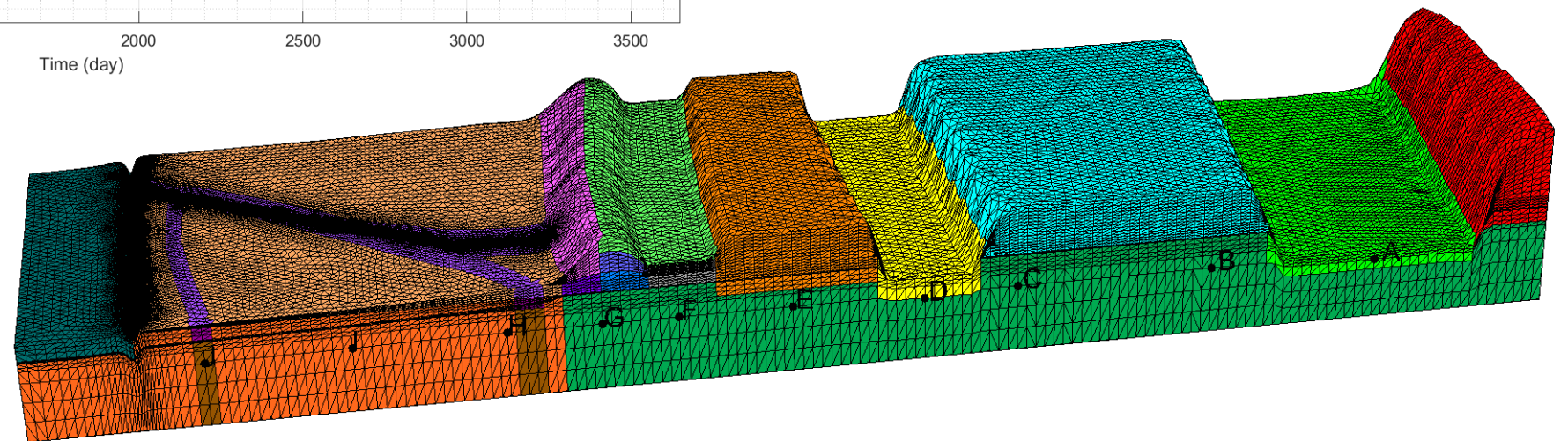
2. Transient analysis: river dynamics



10-year simulation

Isotropic conditions

10 selected nodes (A-J) at -6 m
below mean sea level



Vertical exaggeration is 5!

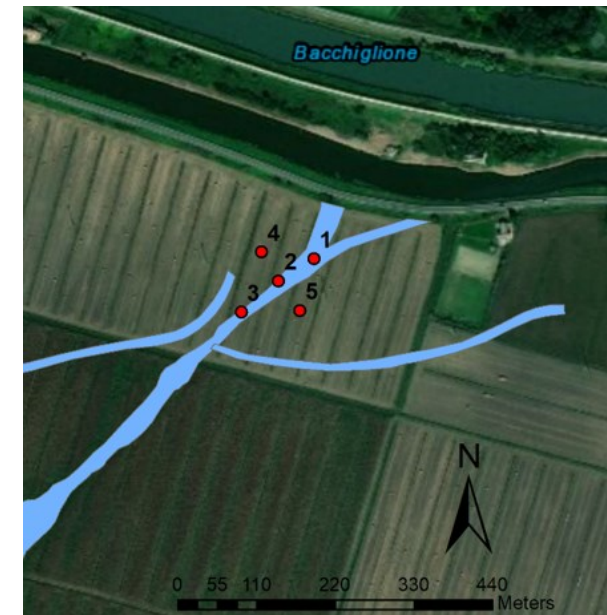
2. Transient analysis: effective precipitation



2-year simulation

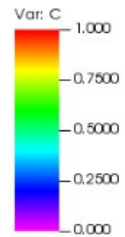
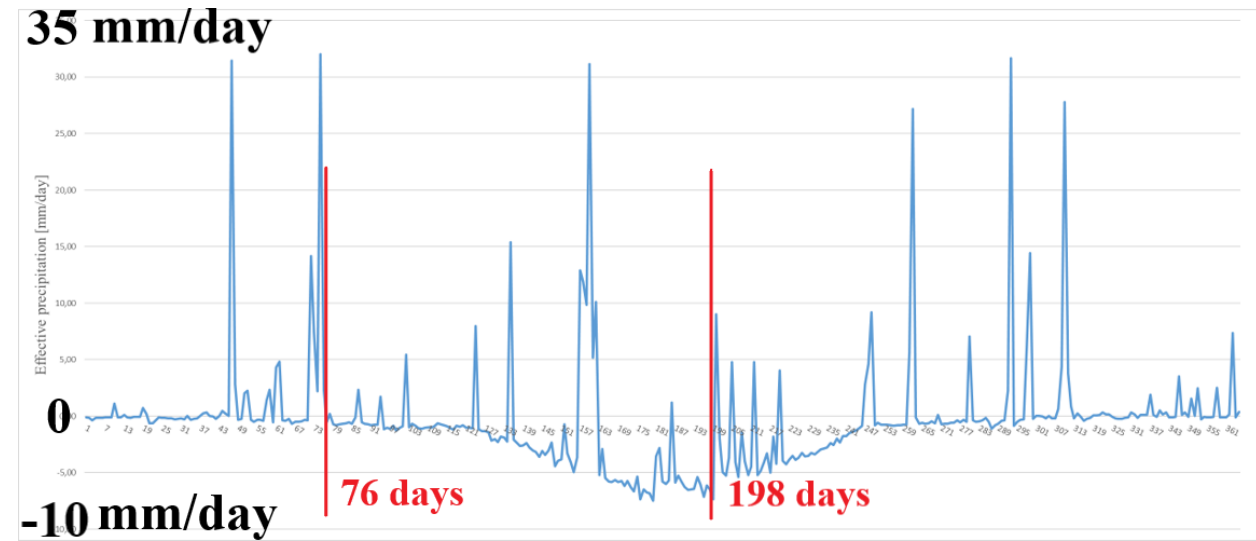
Anisotropic conditions

0.5 m below the ground level

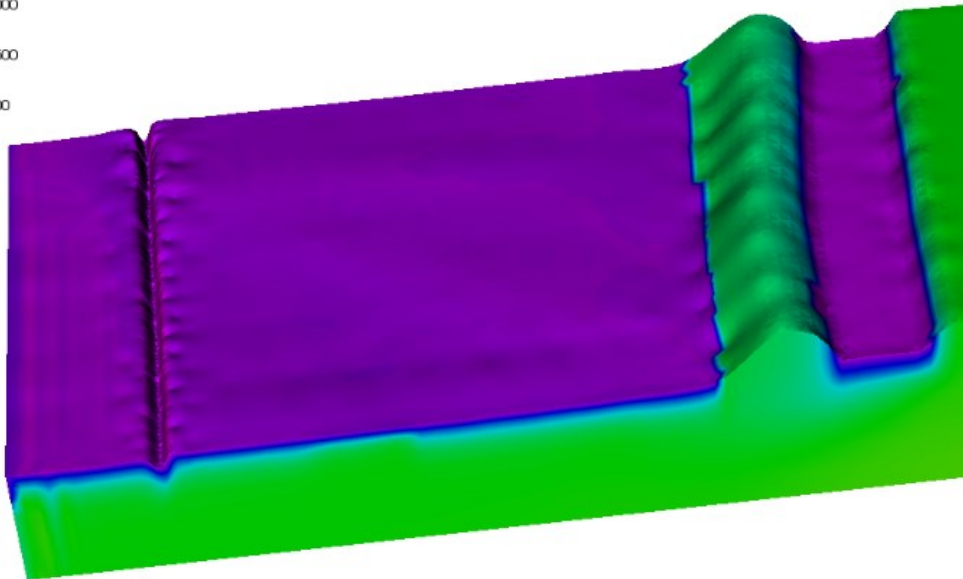


2. Transient analysis: effective precipitation

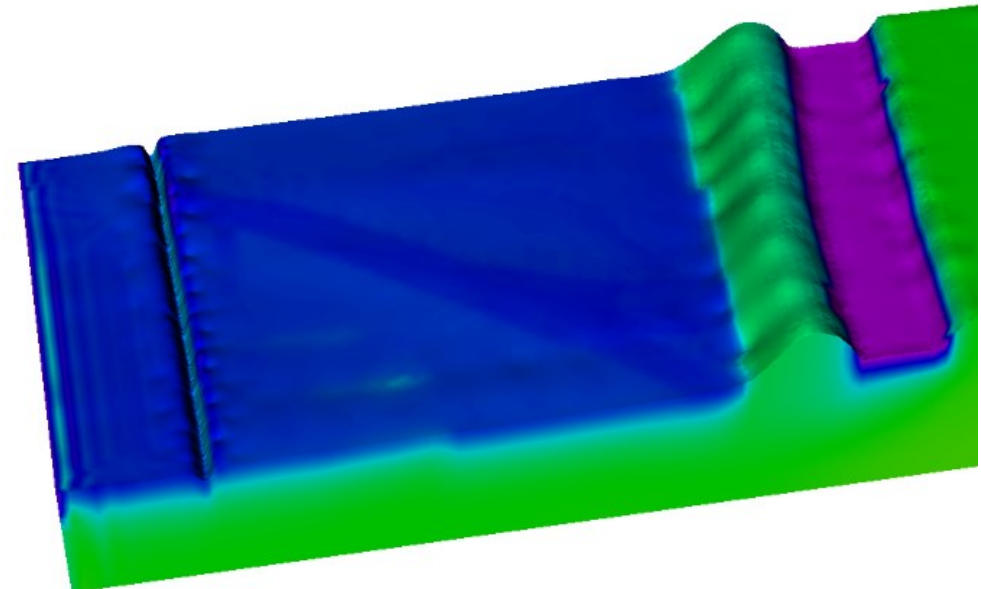
Vertical exaggeration is 5!



Time: 76



Time: 198

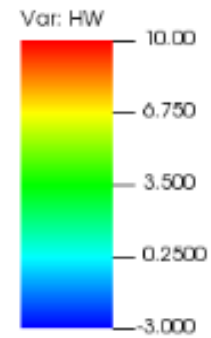


Testing the recharge drain effects

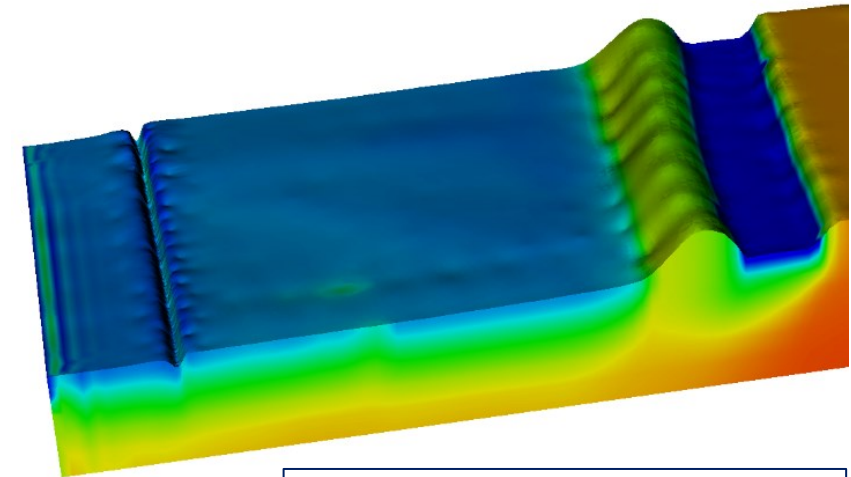
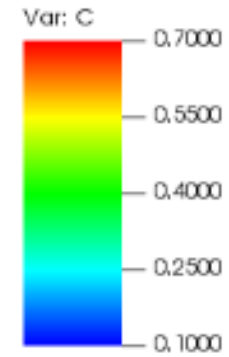
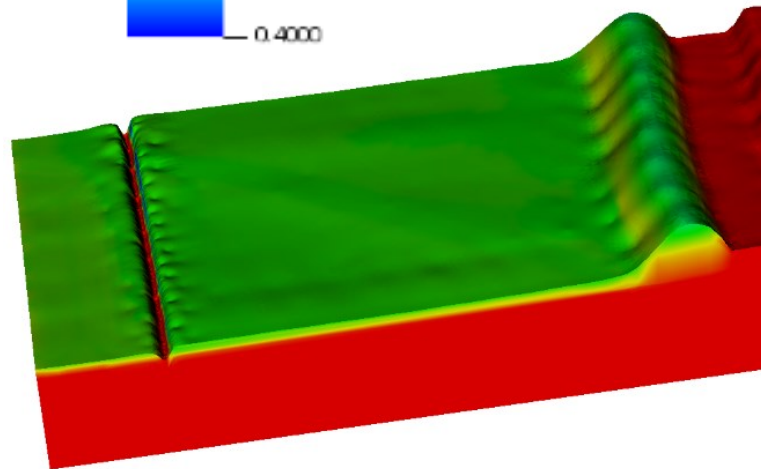
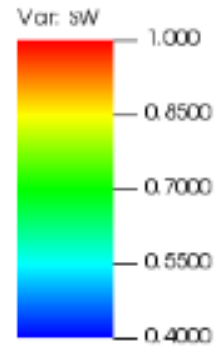
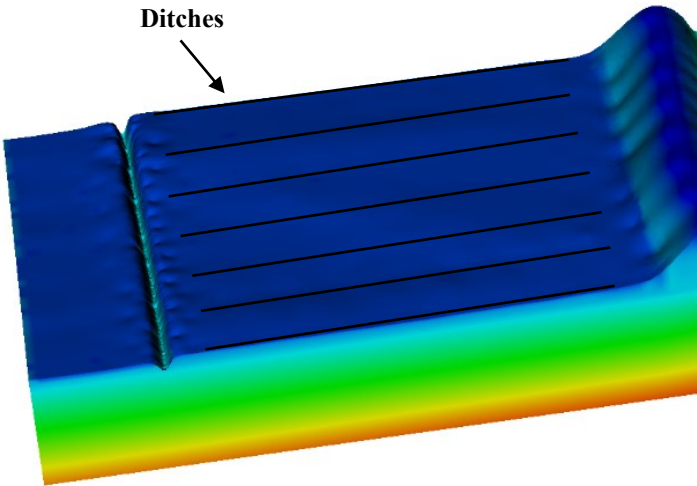
245-days simulation (starting from May)

Anisotropic conditions

Initial conditions: model outcomes at 500 days



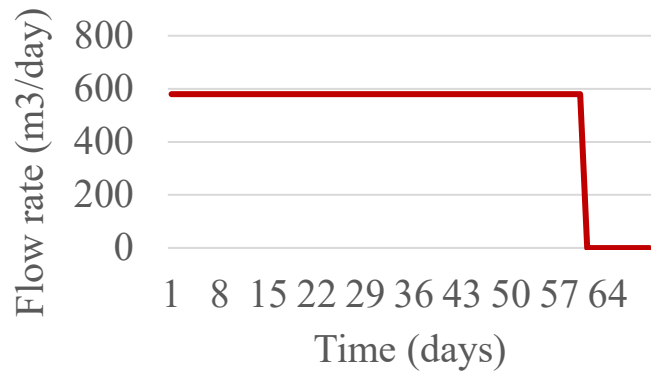
Ditches



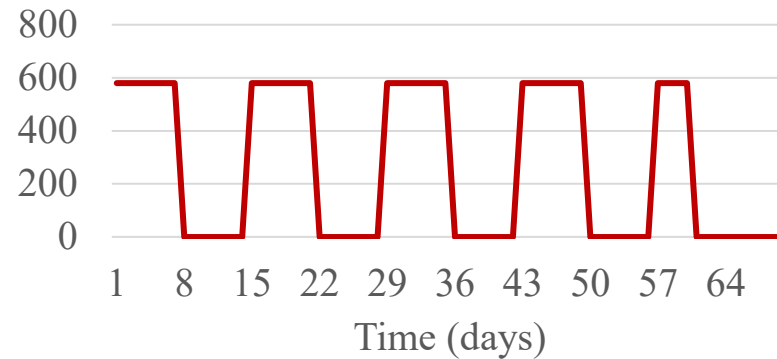
Vertical exaggeration is 5!

Testing the recharge drain effects

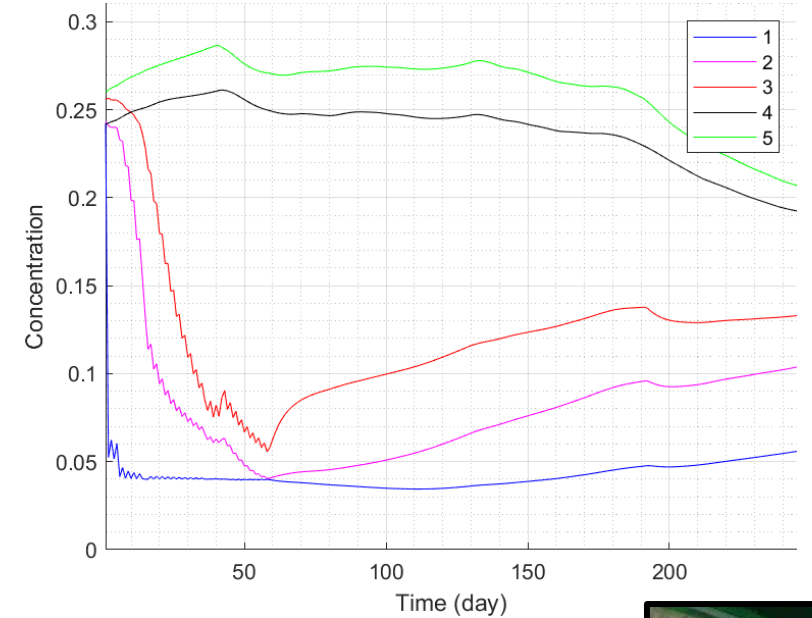
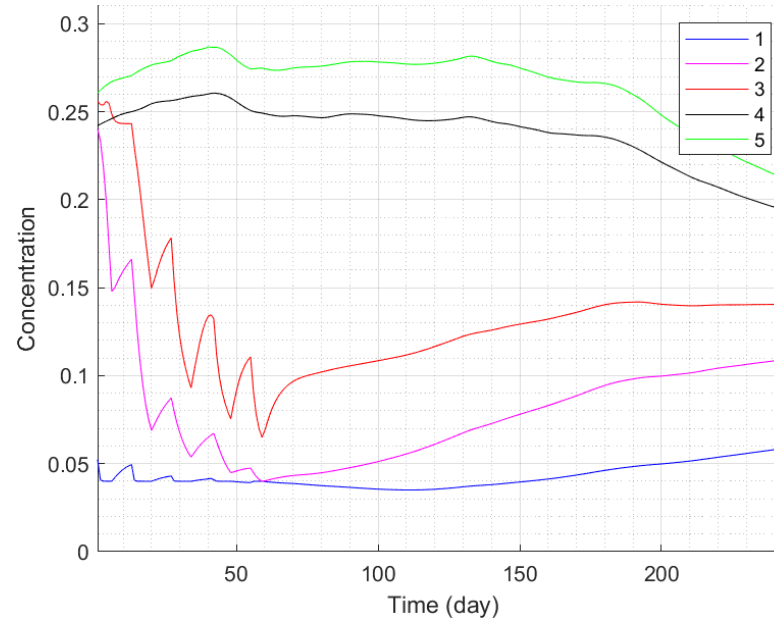
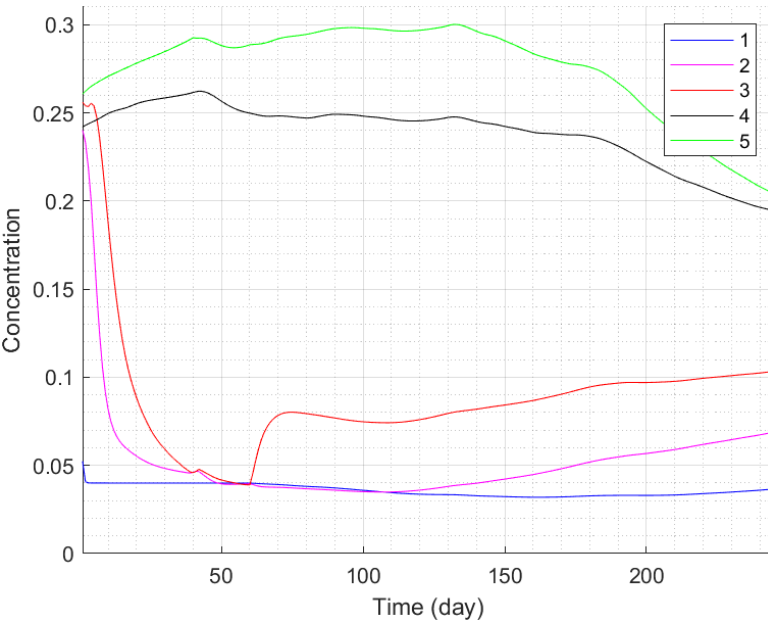
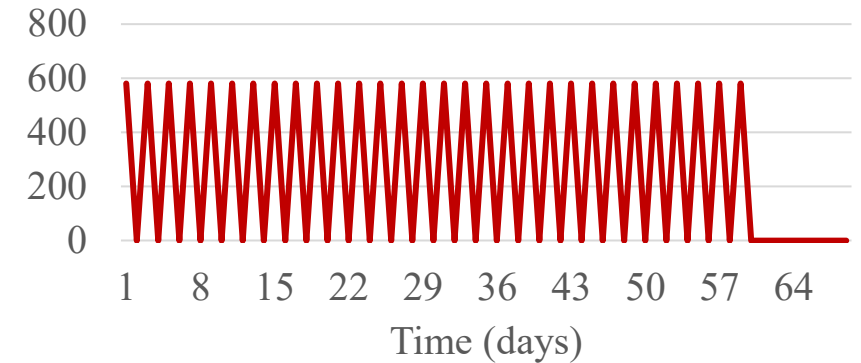
Continuous operation



Weekly intermittent operation



Daily intermittent operation

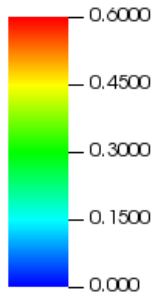


Period of drain activity: 60 days

1.5 m below the ground level



Testing the recharge drain effects



Time: 7 days

Isotropic conditions

Anisotropic conditions

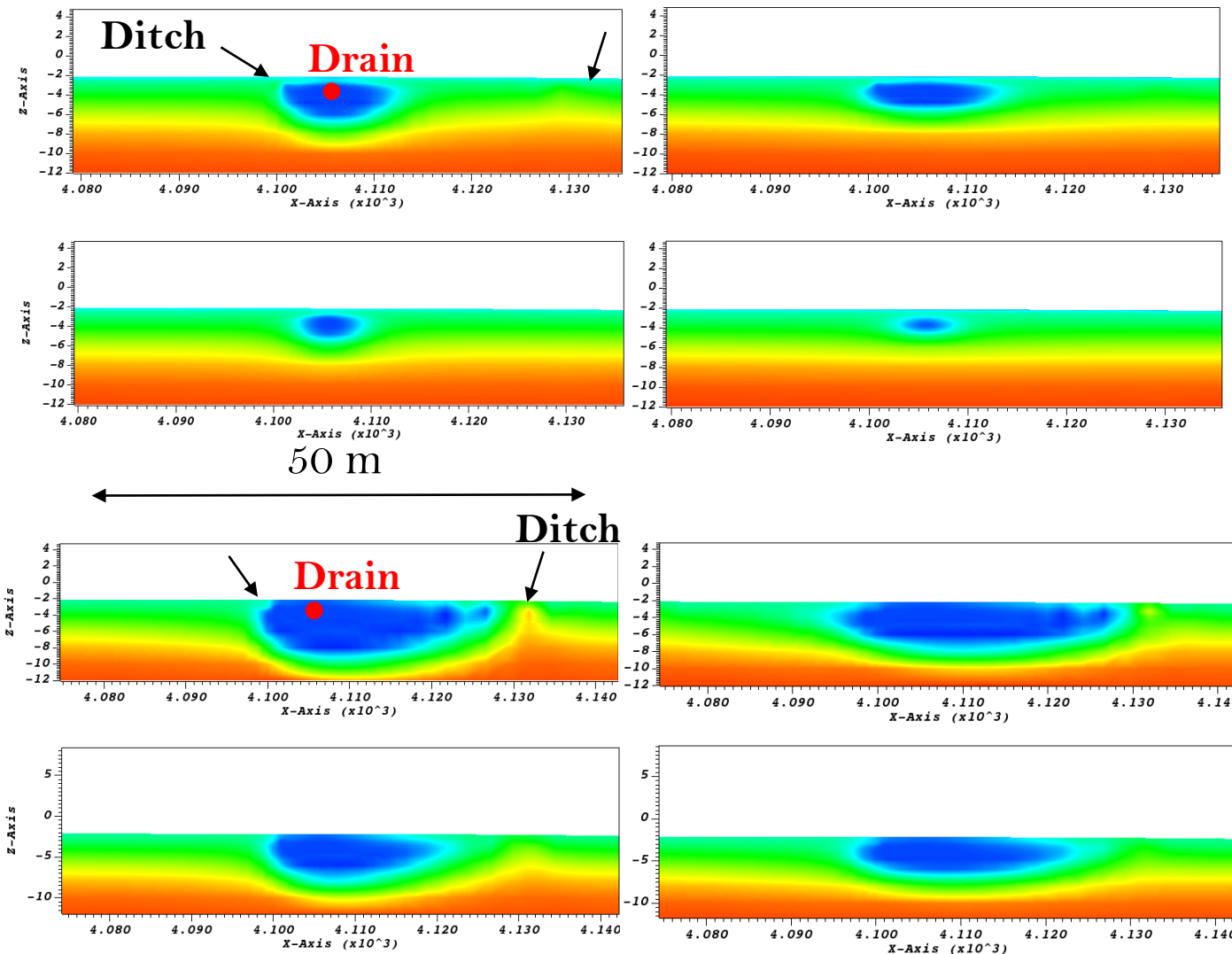
Continuous and weekly
intermittent operation

Daily intermittent
operation

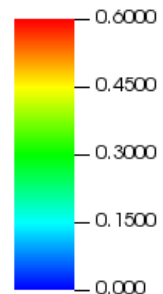
Time: 30 days

Continuous operation

Weekly intermittent
operation



Testing the recharge drain effects

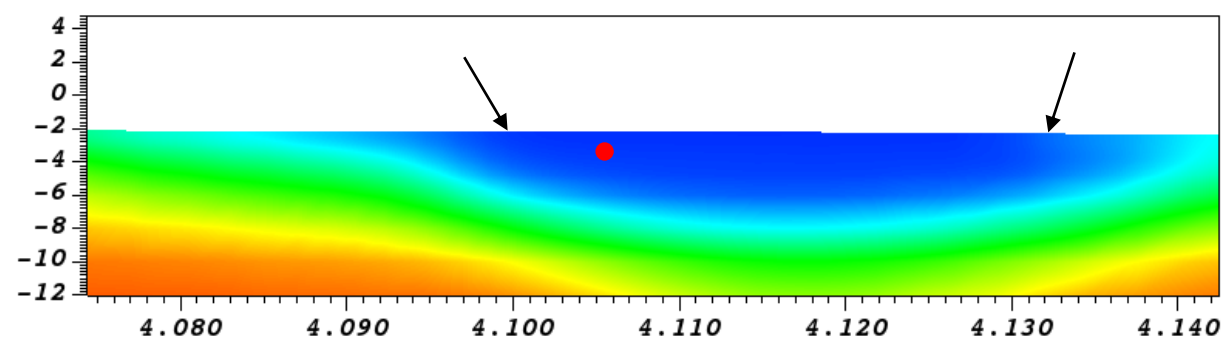
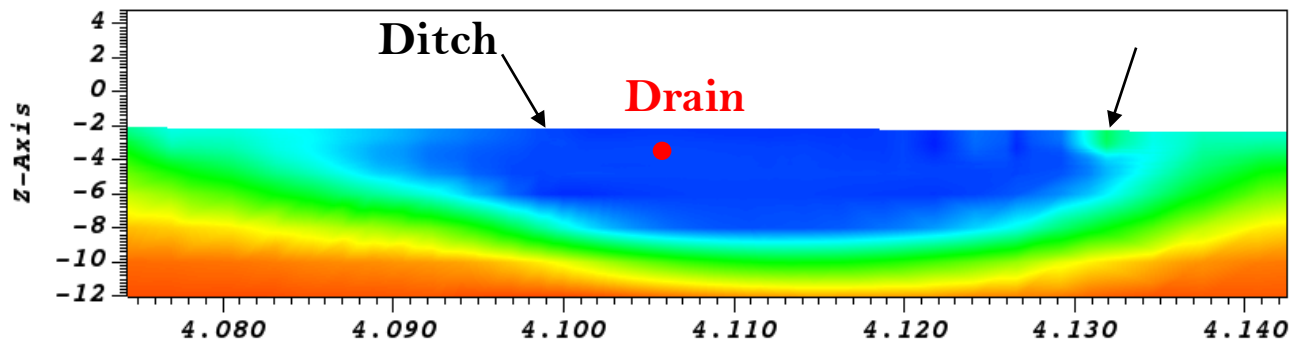


Anisotropic conditions

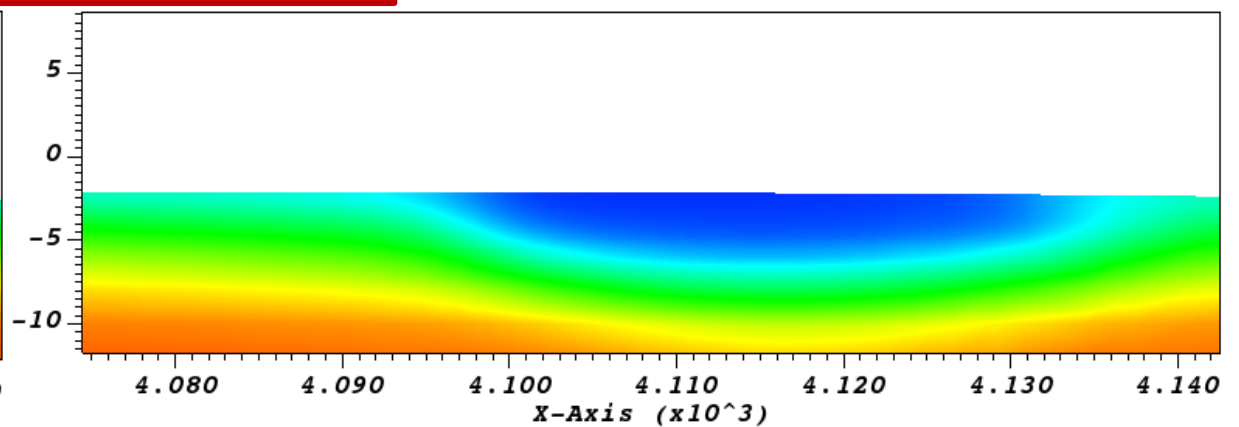
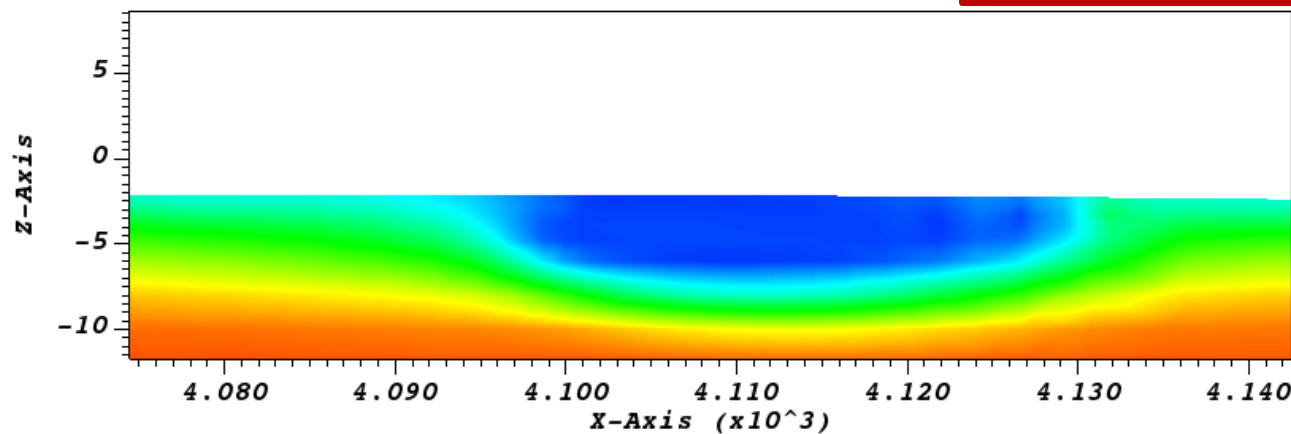
Time: 60 days

Continuous operation

Time: 120 days



Weekly intermittent operation

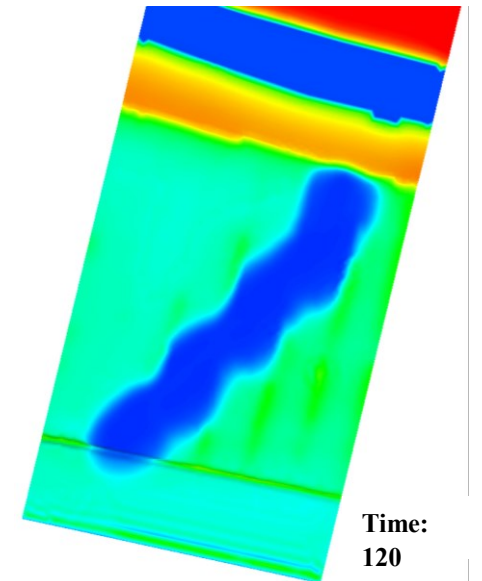
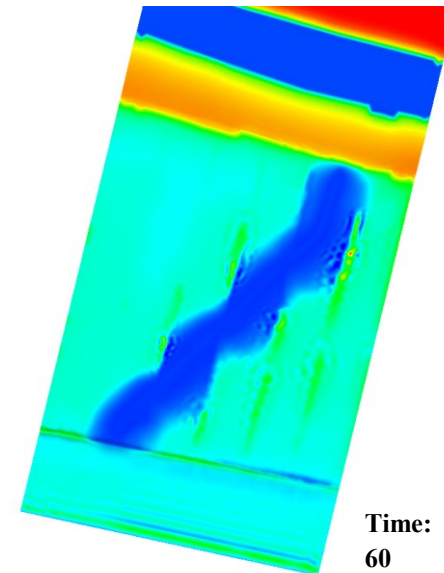
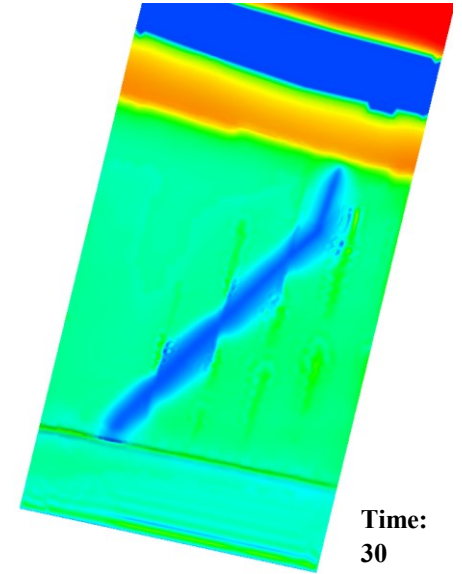
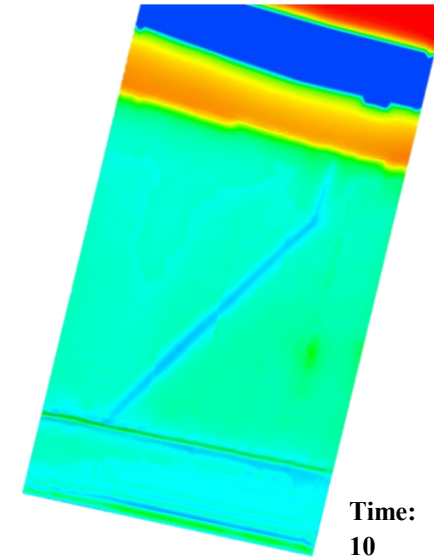
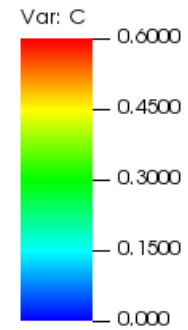


60 m

Testing the recharge drain effects

Anisotropic conditions

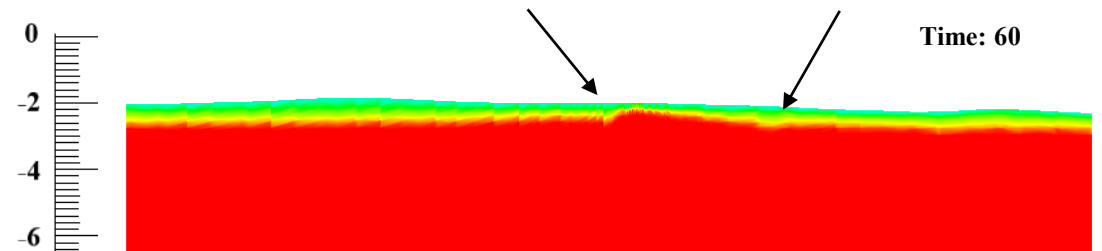
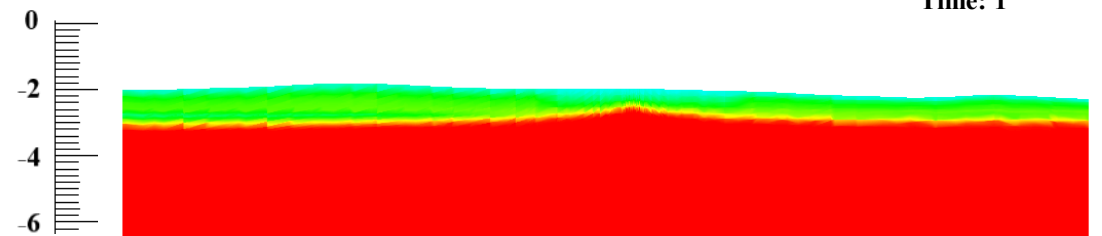
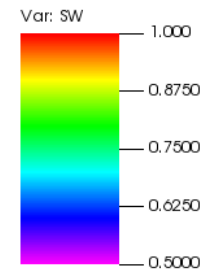
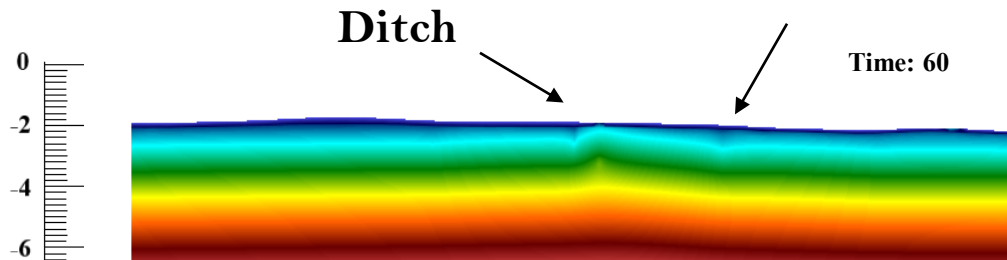
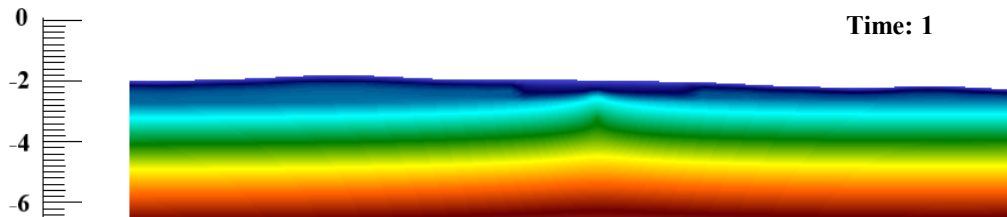
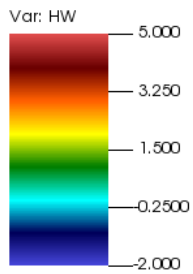
Continuous operation



Testing the recharge drain effects

Anisotropic conditions

Continuous operation



Vertical exaggeration is 5!

Conclusions

The recharge drain is an effective mitigation strategy against saltwater intrusion

Limitations:

Soil heterogeneity

Lack of experimental data  Uncertainties of flow and transport parameters

Further research:

Flow and transport parameter calibration (the drain activity is planned for spring 2021)

Cut-off wall implementation along a portion of the main ditch

Thank you for your time!

