Investigating an OpenMI coupling of FEFLOW and MIKE SHE

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Background and Motivations

Challenges involving the interaction between surface water and groundwater

- Water allocation
- Irrigation demands
- Nutrient transformation
- Wetland ecology
- Flooding dynamics
- Bio-geochemical

conditions in riparian areas

- Saltwater Intrusion

Background and Motivations

- Traditionally individual hydrological components have been managed separately.

- Mutual interactions between the different processes are important in complex water management problems

Needs for a more comprehensive modelling approach
To address more complex environmental problems

Background and Motivations

Water Framework Directive – WFD

Key objectives:

- to protect and enhance the status of ***aquatic ecosystems*** (and terrestrial ecosystems and ***wetlands*** directly dependent on aquatic ecosystems)
- to promote ***sustainable water use*** based on long-term protection of available water resources
- to provide for sufficient supply of ***good quality surface water and groundwater*** as need for sustainable, balanced and equitable water use
- to provide for enhanced ***protection and improvement of the aquatic environment*** by reducing / phasing out of discharges, emissions and losses of priority substances
- to contribute to mitigating the effects of ***floods*** and ***droughts***

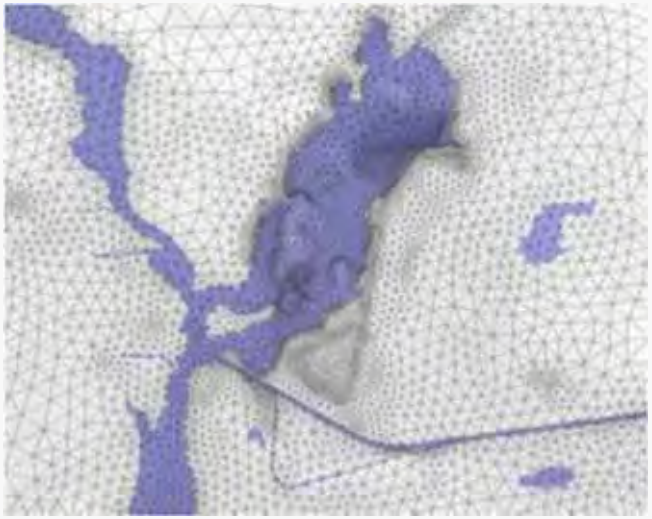
Background and Motivations

Interventions and land use change

Background and Motivations

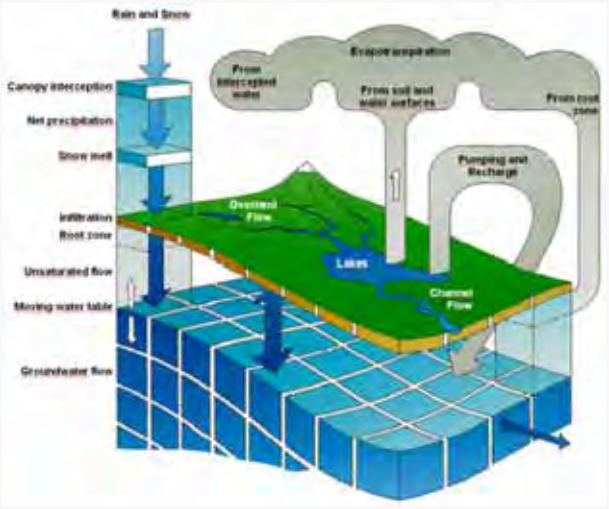
Combine the strengths of the existing models

- cost effective
- enhance the modelling capabilities



FEFLOW

Advanced subsurface water modelling system



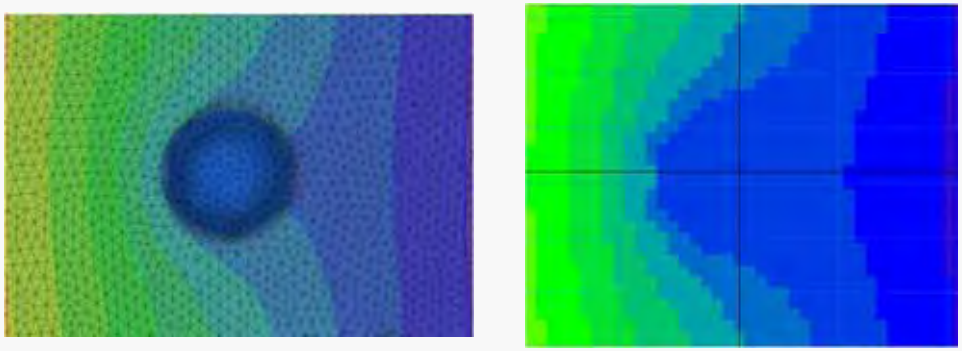
MIKE SHE

Fully distributed, process-based model, including evaportranspiration, overland flow, unsaturated flow, groundwater flow, and channel flow

Background and Motivations

Combine the strengths of the existing models
- enhance the modelling capabilities

Lake-Aquifer Interactions
Kacimov (2000)

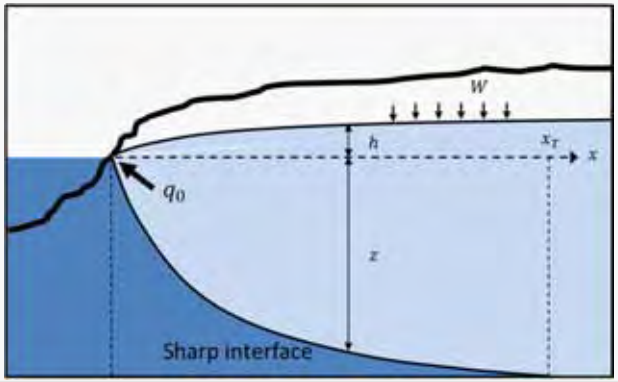


FEFLOW MIKE SHE

Strengths of FEFLOW

- Flexible mesh
  (Grid refinement)

- Saltwater Intrusion
  (New capabilities)



Background and Motivations

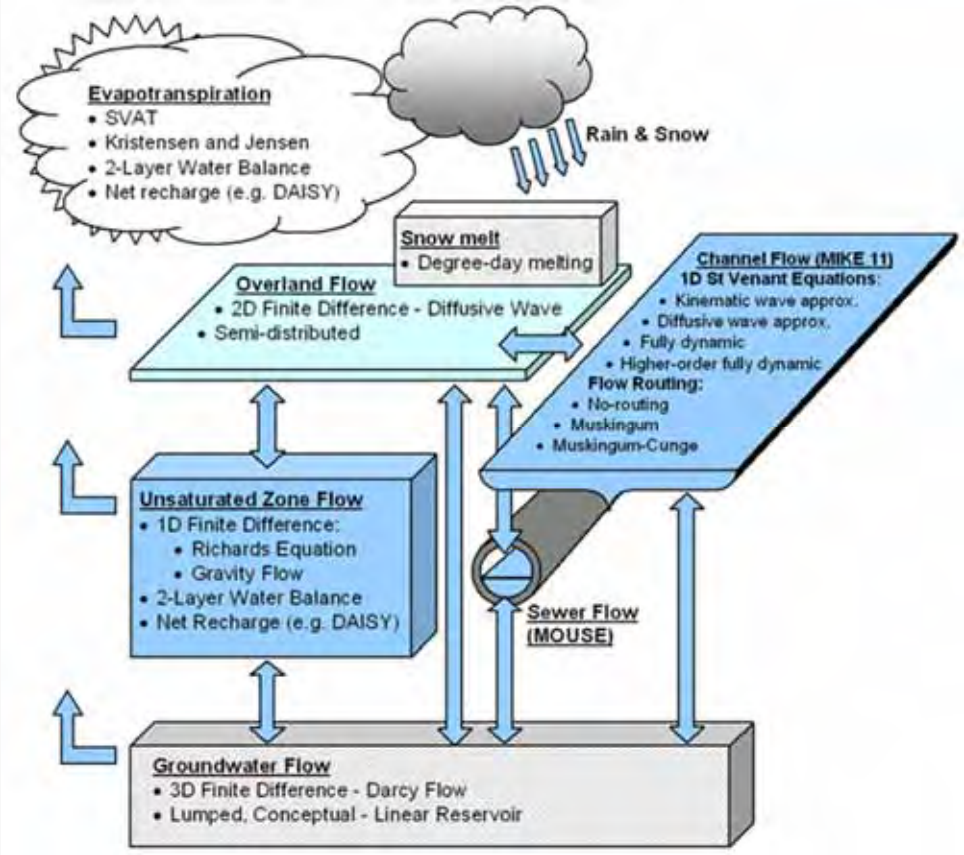
Combine the strengths of the existing models

- enhance the modelling capabilities

Strengths of MIKE SHE

Comprehensive, process-based modelling system:

- Dynamic recharge
- Drains
- Surface flows
  - River
  - Overland

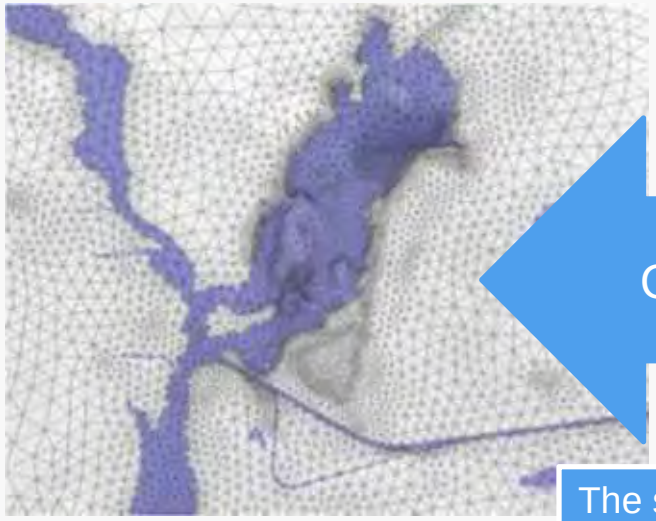


Background and Motivations

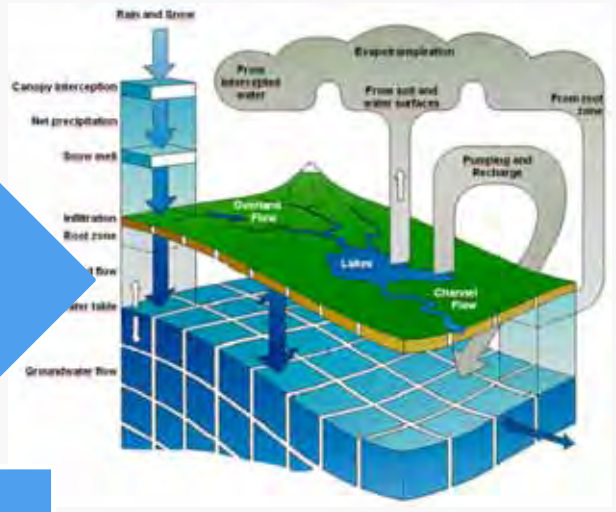
New technologies

Open MI 2.0 - more flexible and powerful mapping

FEFLOW kernel – replacing IFM



OpenMI coupling



The standard which allows different modelling tools to exchange data dynamically during the simulation

FEFLOW

- Advanced subsurface water mod system
- Transport of dissolved constituents, heat transport
- Density dependent flow.
- Flexible finite element model

MIKE SHE

y distributed, process-based model, uding evaportranspiration, overland flow, unsaturated flow, groundwater flow, and channel flow

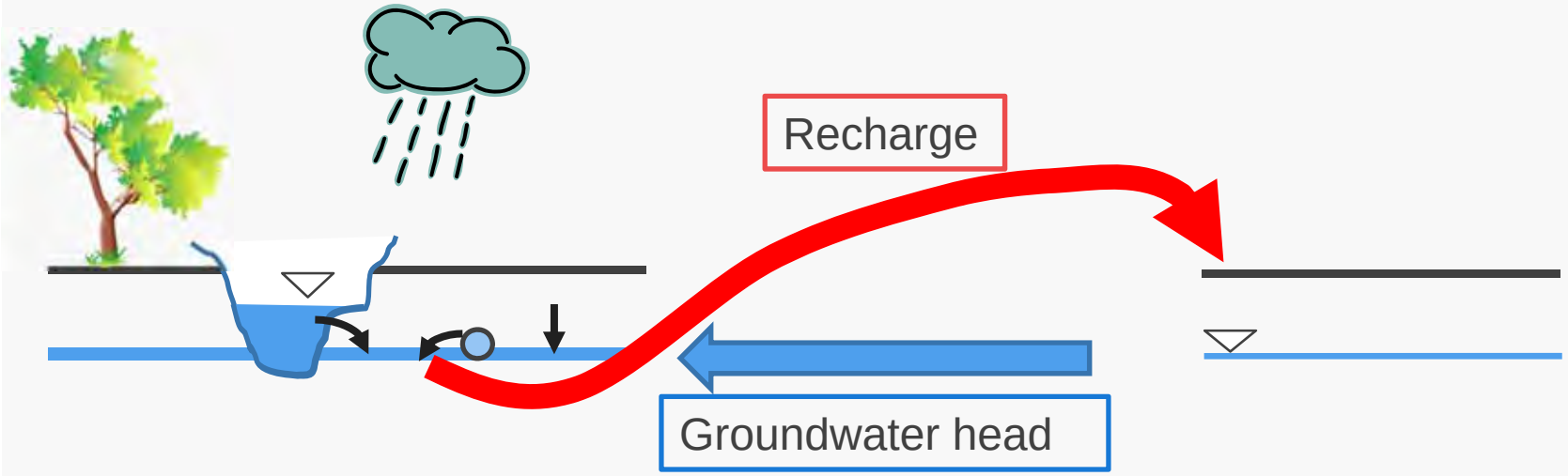
- Choice of process model
- Finite difference model.

Coupling Methodology

MIKE SHE

OpenMI

FEFLOW



Source/Sink
- Recharge
- Drain flow
- River exchanges

Mapping Adaptor
Time Buffering Adaptor

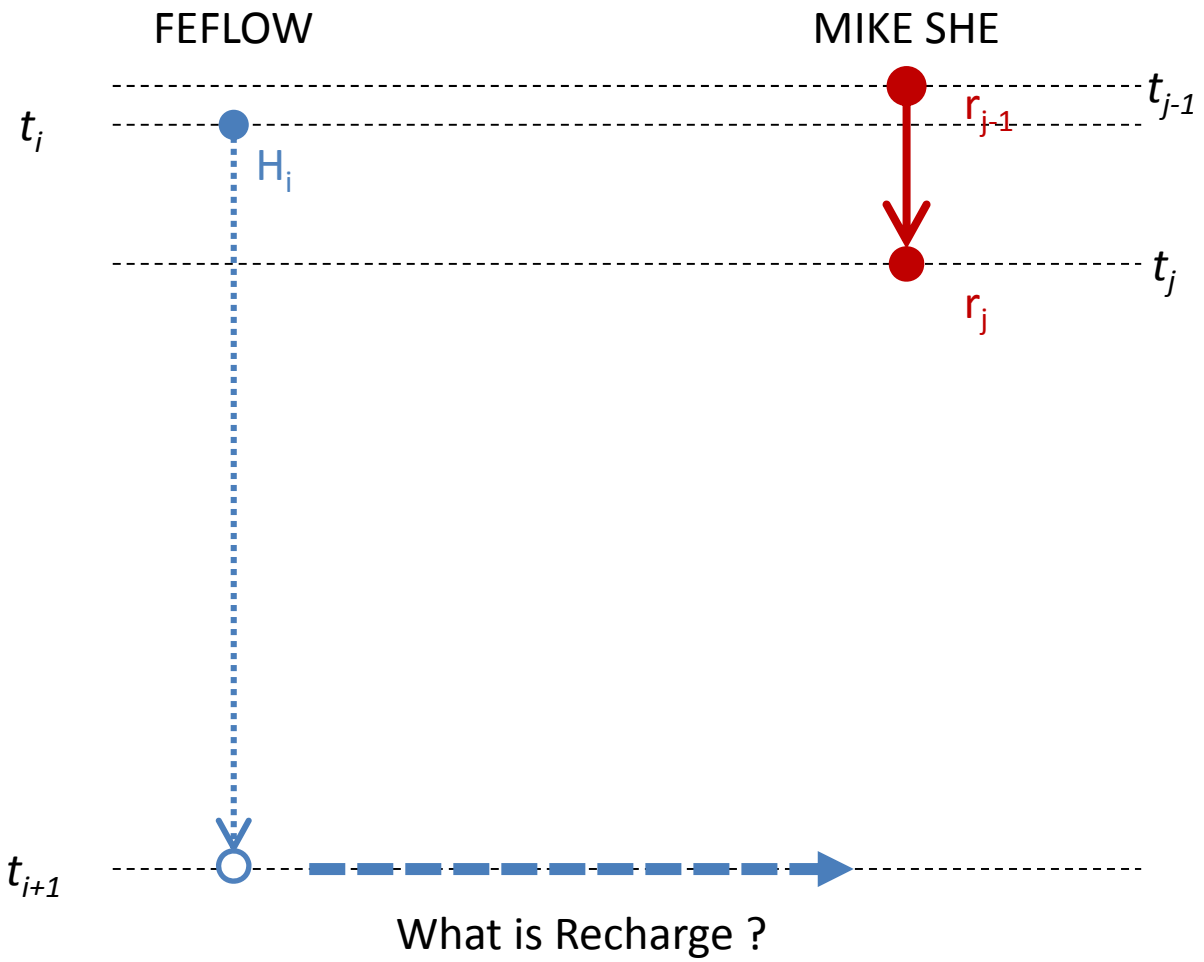
OpenMI:Time Adaptors

FEFLOW simulates one timestep

When FEFLOW is the trigger in coupling, FEFLOW tries to proceed simulation for one timestep.

FEFLOW requires recharge at this timestep from MIKE SHE to simulate t_{i+1},.

Then FEFLOW demands MIKE SHE to provide recharge value at t_{i+1}.

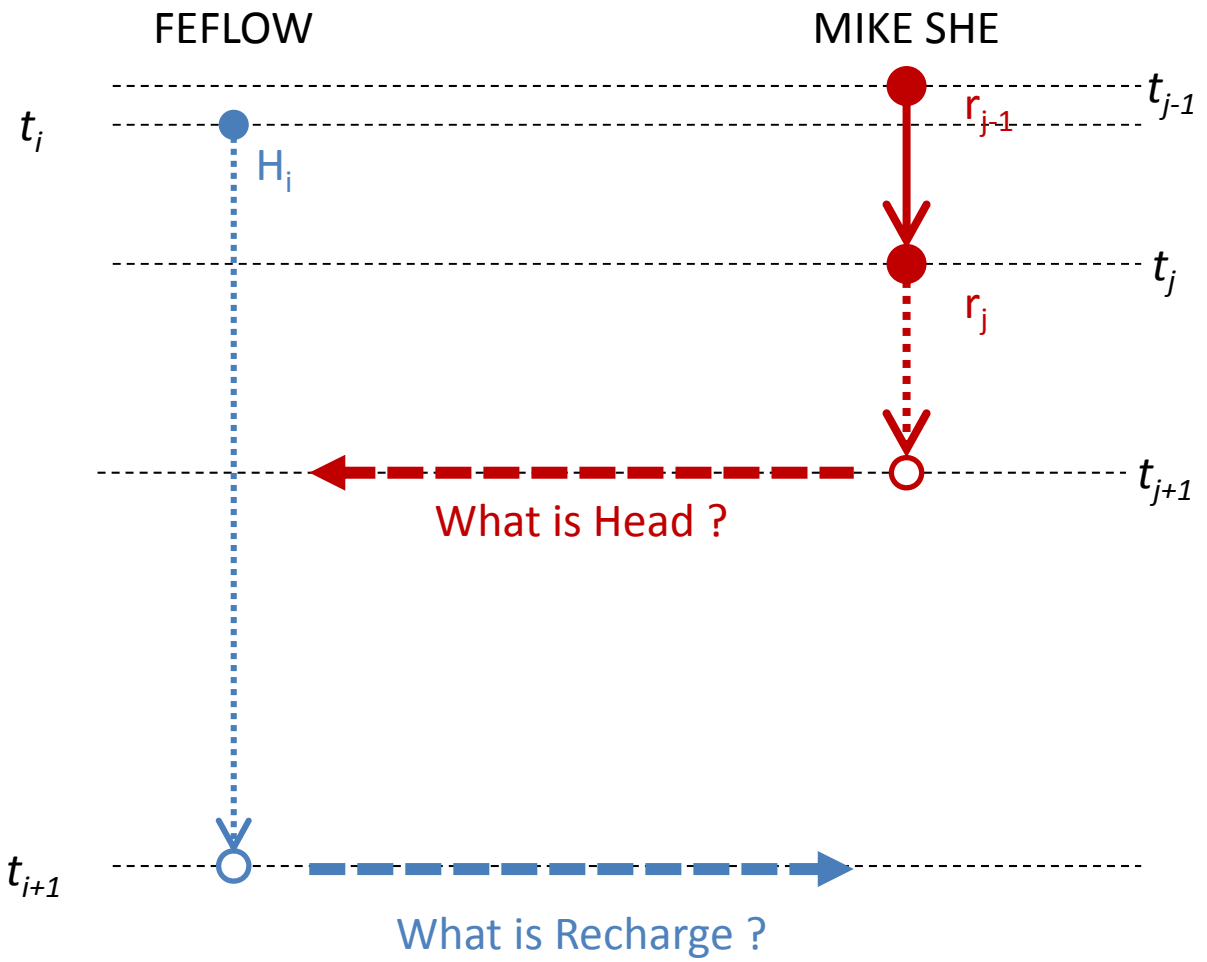


MIKE SHE simulates one timestep

MIKE SHE does not have recharge value at t_{i+1}yet.

Then MIKE SHE tries to proceed to the next timestep t_{j+1}.

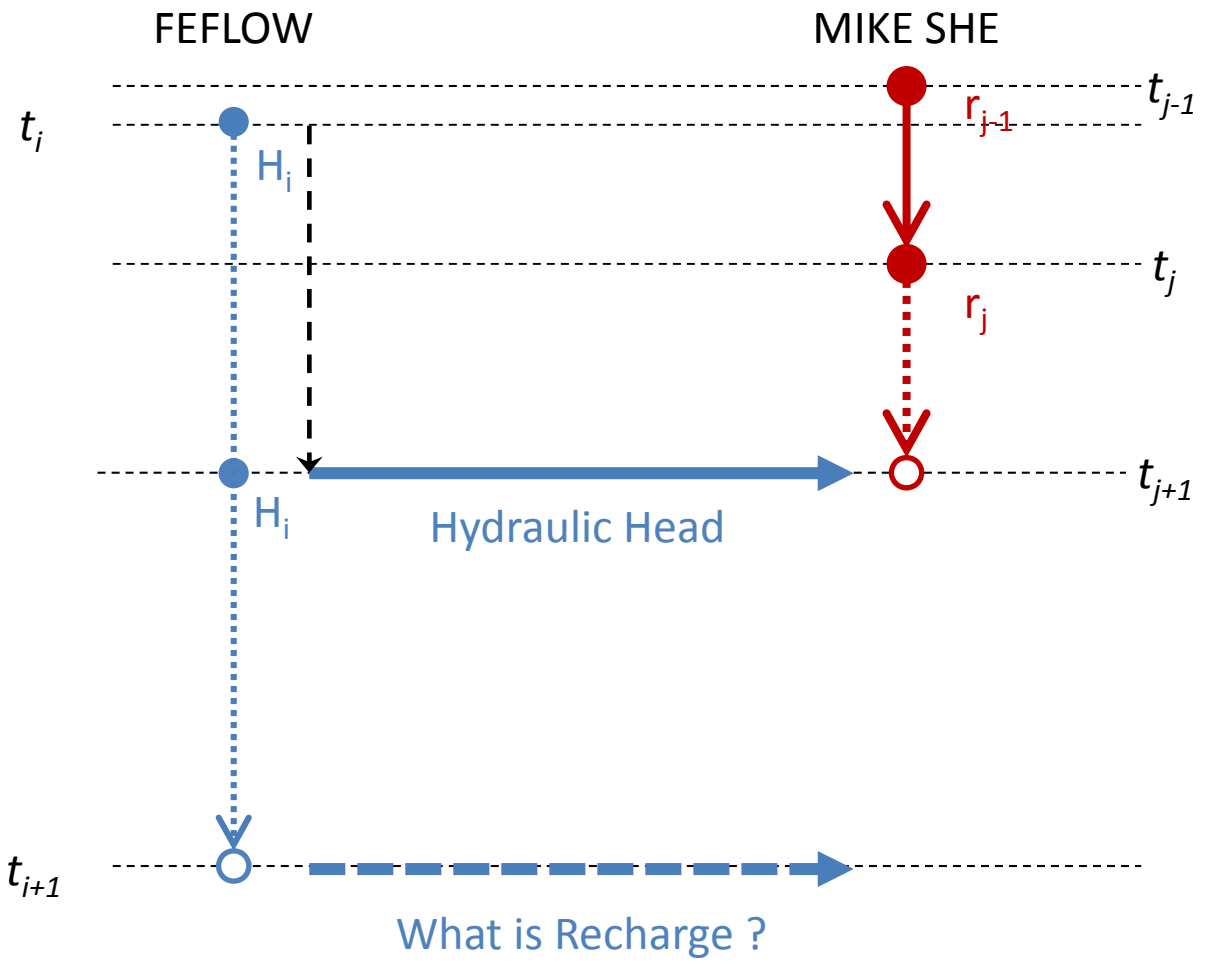
MIKE SHE requests FEFLOW to provide hydraulic head t_{j+1}.



MIKE SHE simulates one timestep

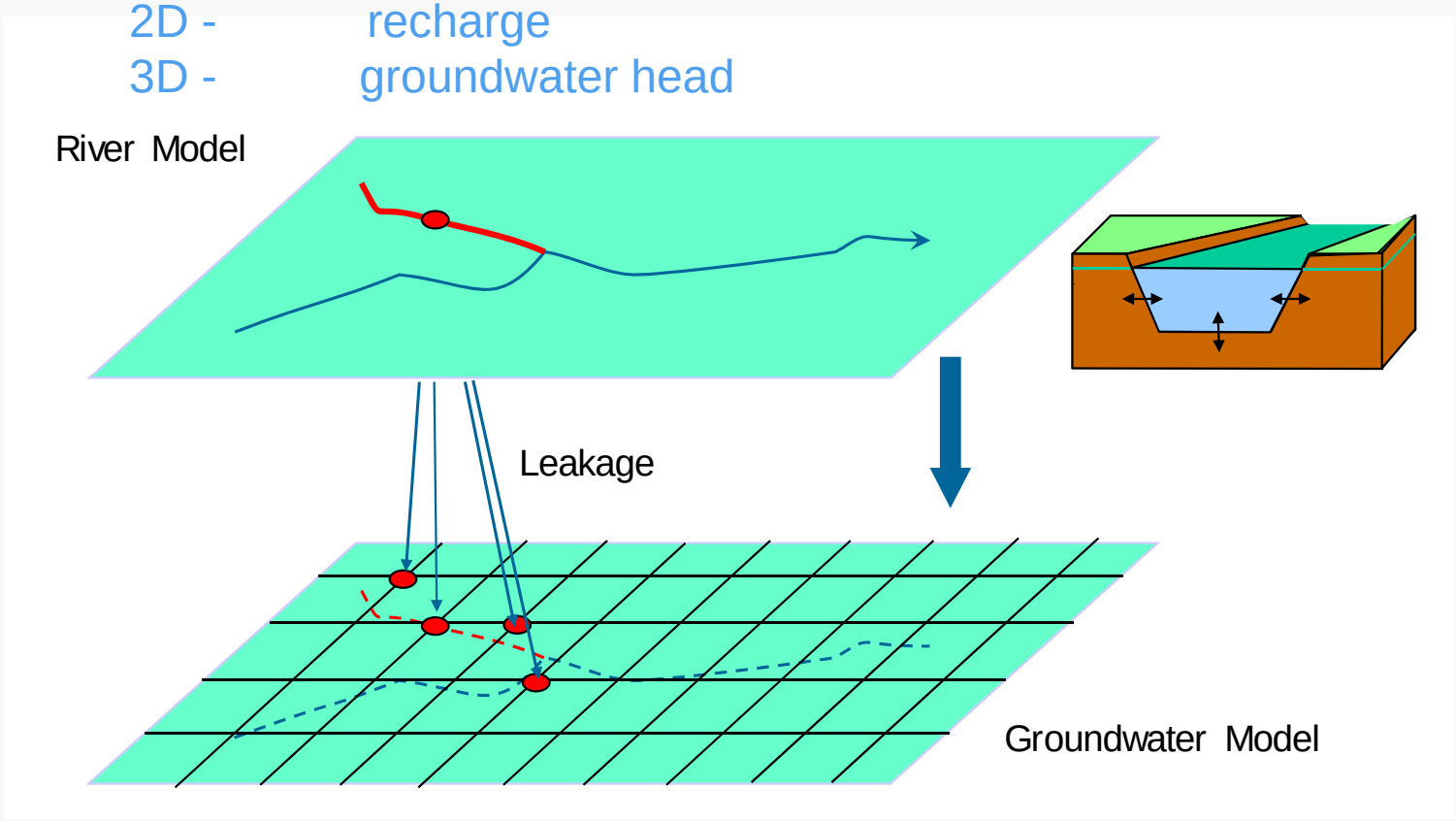
However, Hydraulic head in FEFLOW at t_{j+1} is not simulated yet.

Then the value from the previous FEFLOW time step t_i is applied as the simplest extrapolation method.



OpenMI: Spatial Adaptors

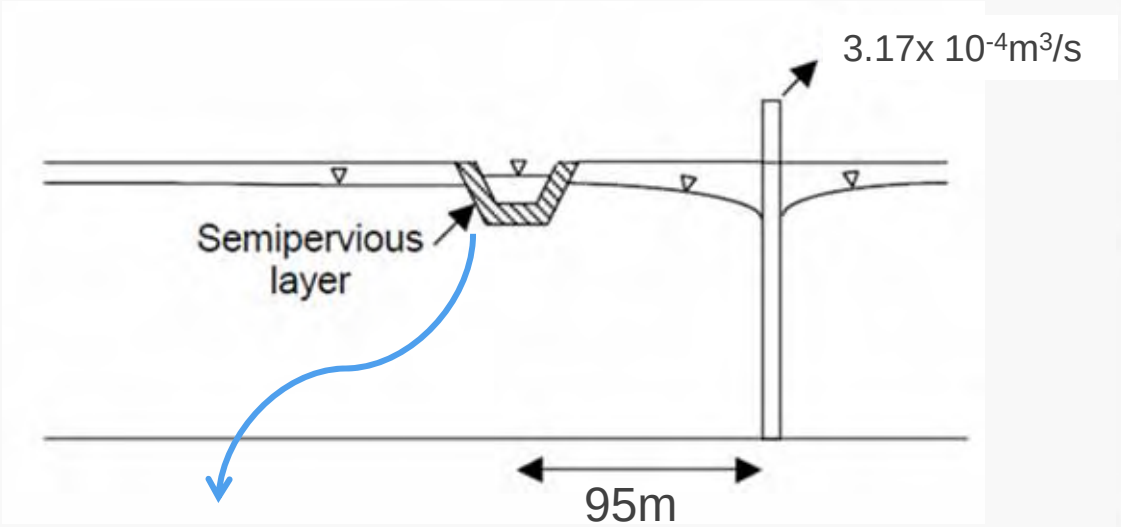
1D - river exchanges
2D - recharge
3D - groundwater head

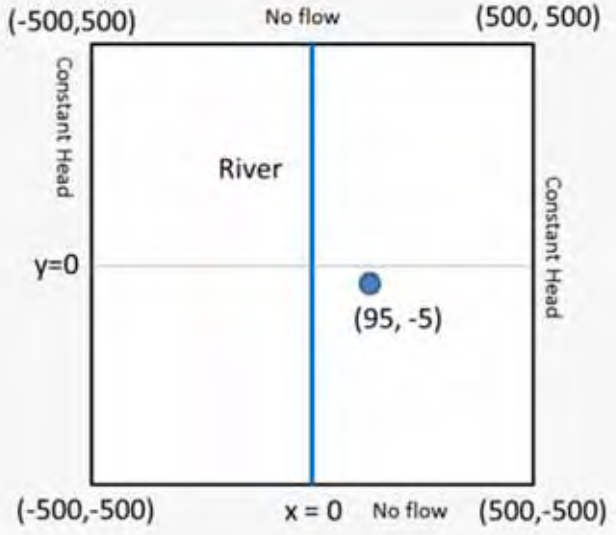


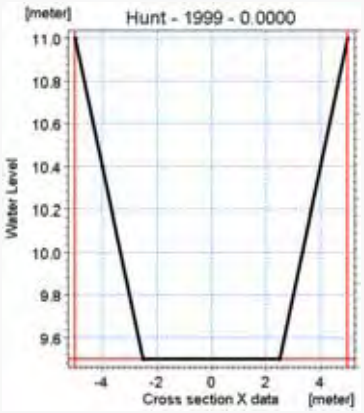
Finite element lattice centered layers
Finite difference block centred layers

Transient stream depletion

Analytical solution exists. (Hunt, 1999)

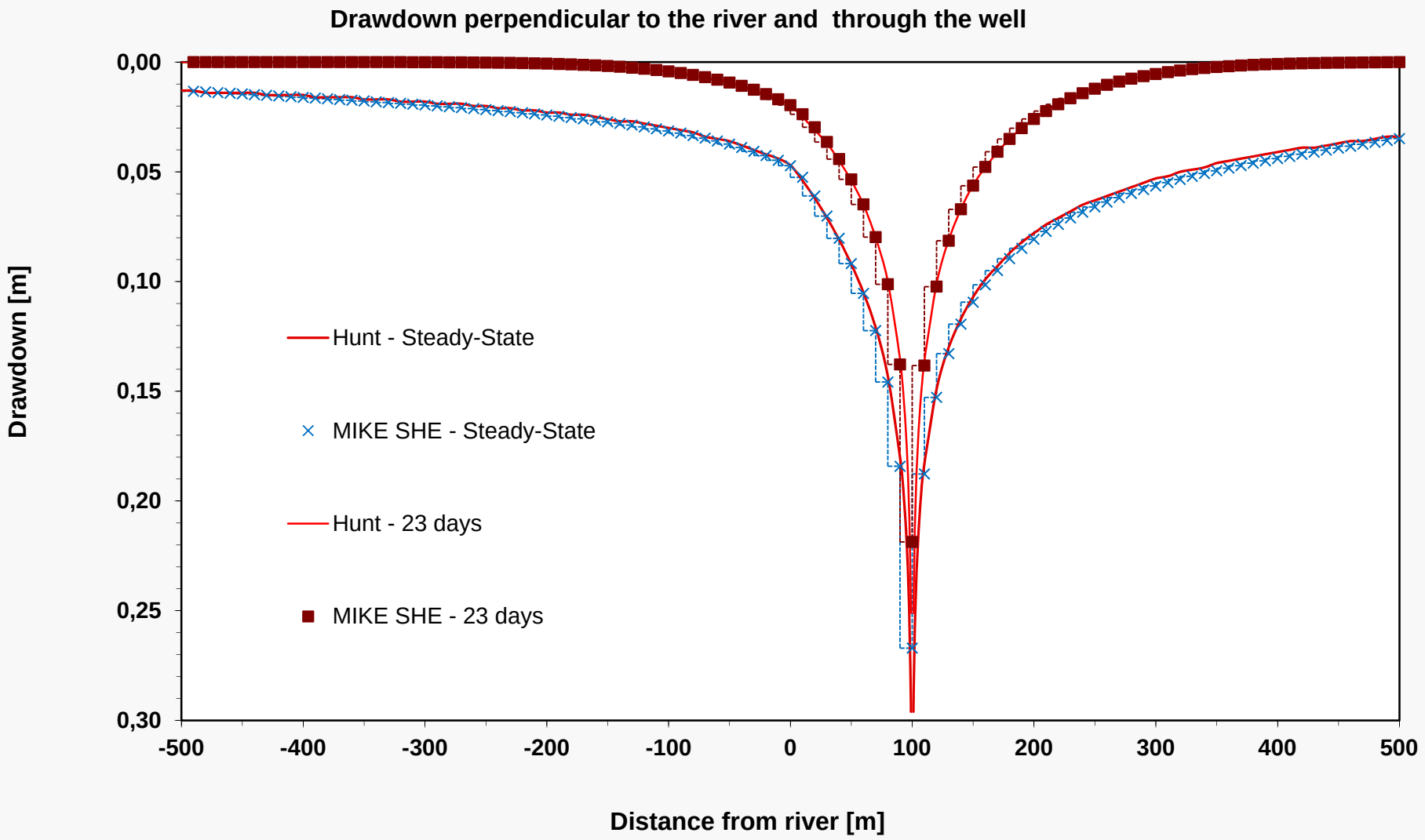






Shortest distance from the stream to the pumping well	**95 m**
Pumping rate	**3.17 x 10^{-4} m^3/s**
Thickness of the aquifer	**10 m**
Transmissibility of the aquifer	**0.001 m^2/s**
Storage coefficient of the aquifer	**0.2**
Stream bed leakage coefficient	**1 x 10^{-5} m/s**
Initial hydraulic head	**10 m**
Recharge	**0 m^3/s**

MIKE SHE simulations



Setting up models

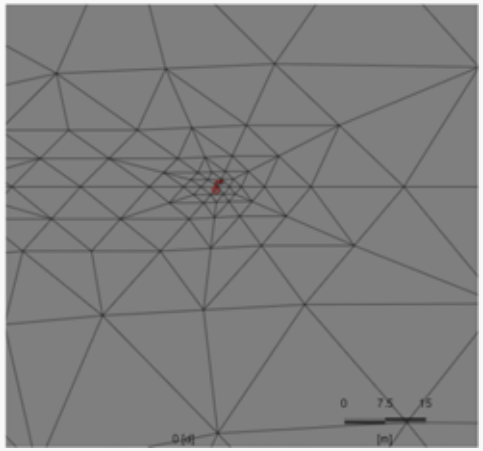
MIKE SHE

10m x10m grids
(10000 elements)

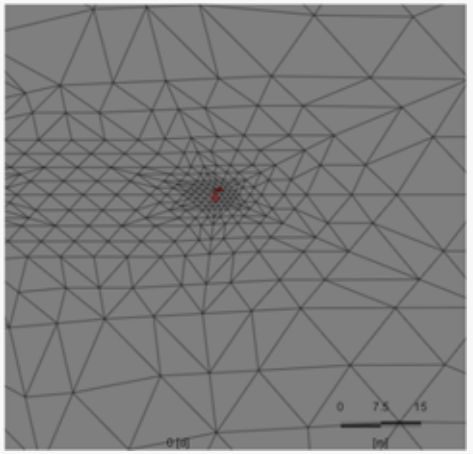
FEFLOW

2 models with different spatial resolutions

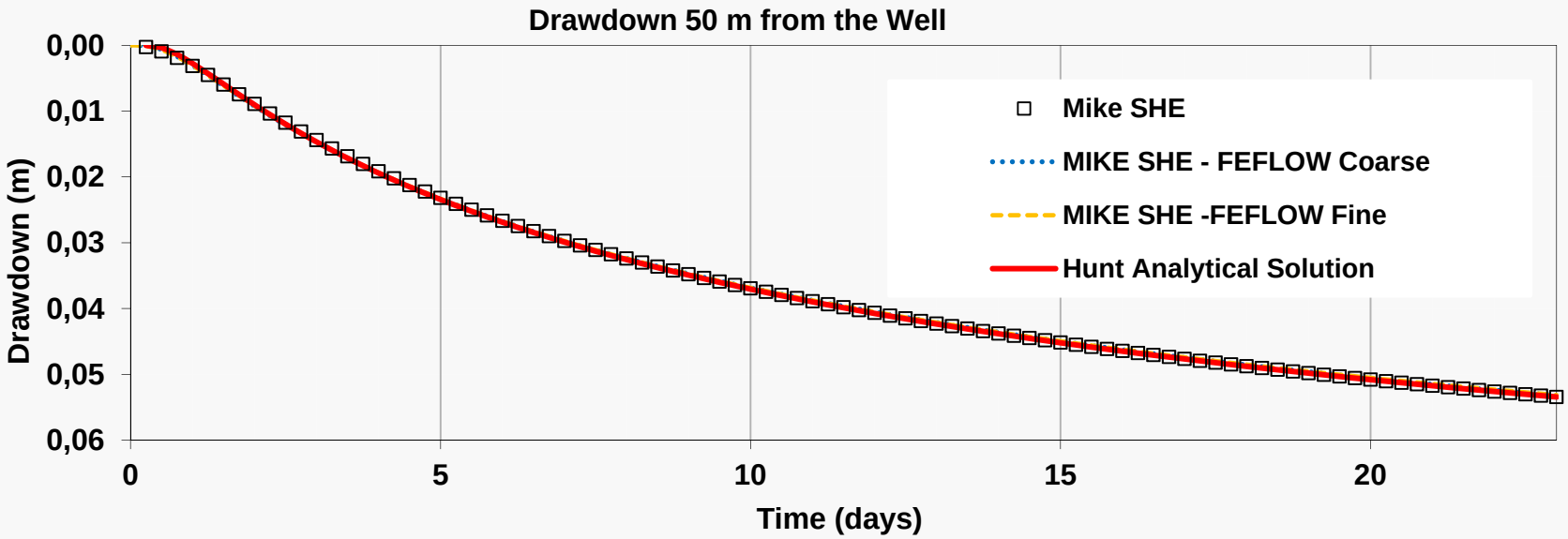
Coarse Mesh
(3263 elements)

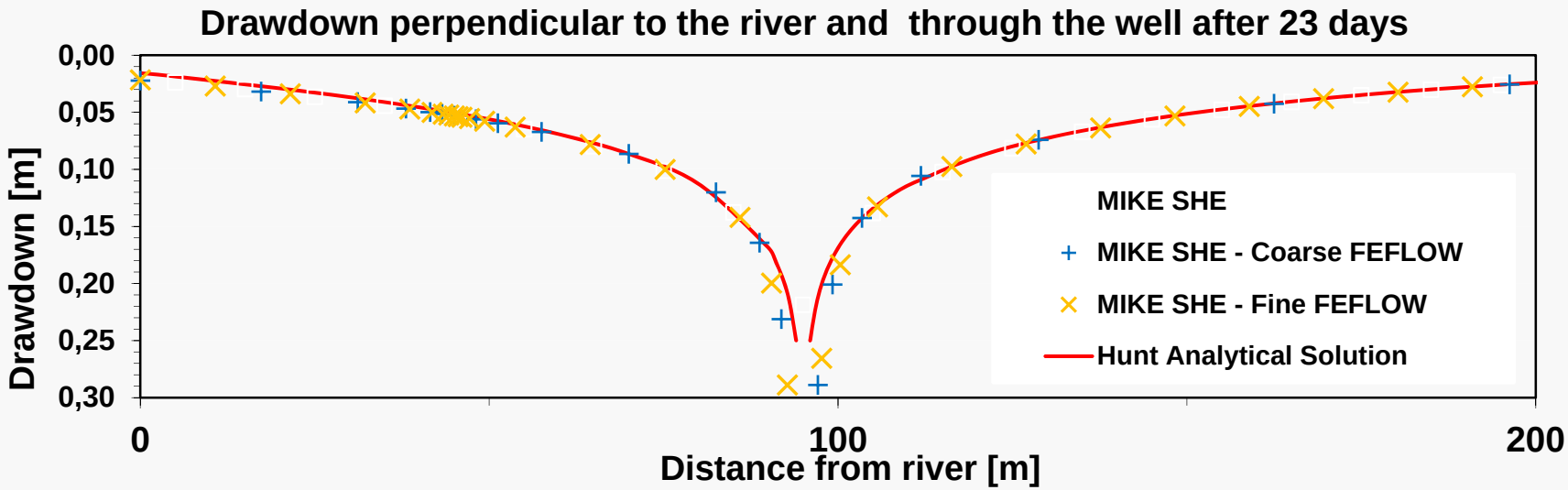


Fine Mesh
(29944 elements)



Simulation Results

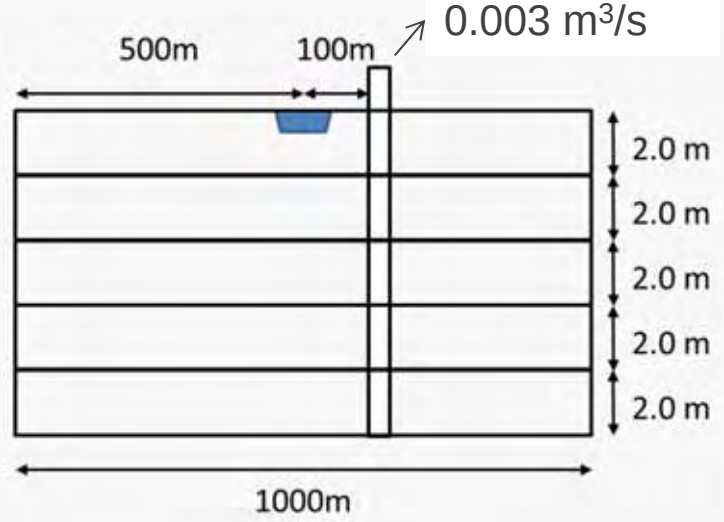




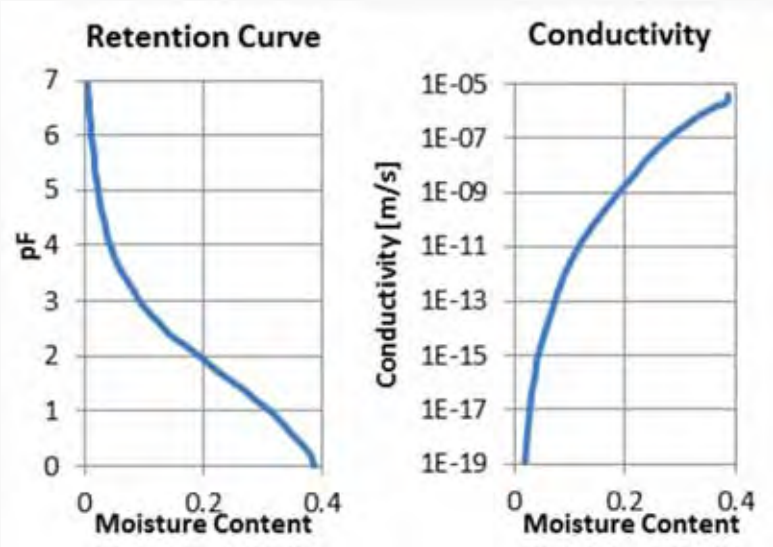
Transient stream depletion with unsaturated flow

Extended to verify the coupled model with multiple layers and unsaturated flow.

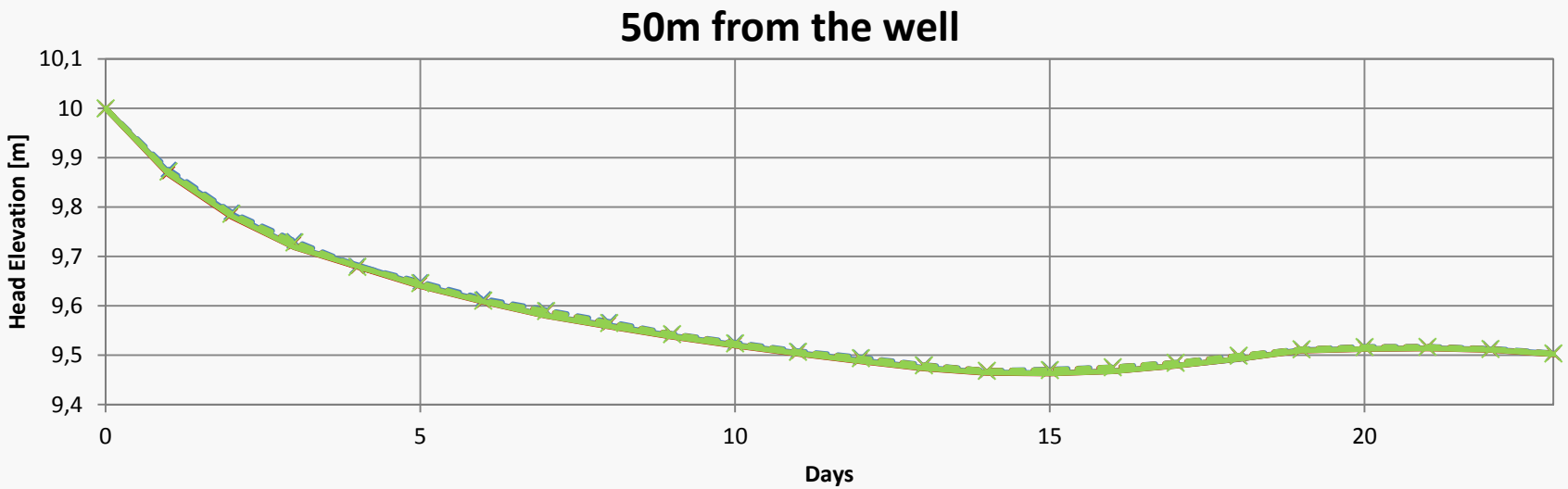
2.4 mm/day rain for 5days
after 13 days

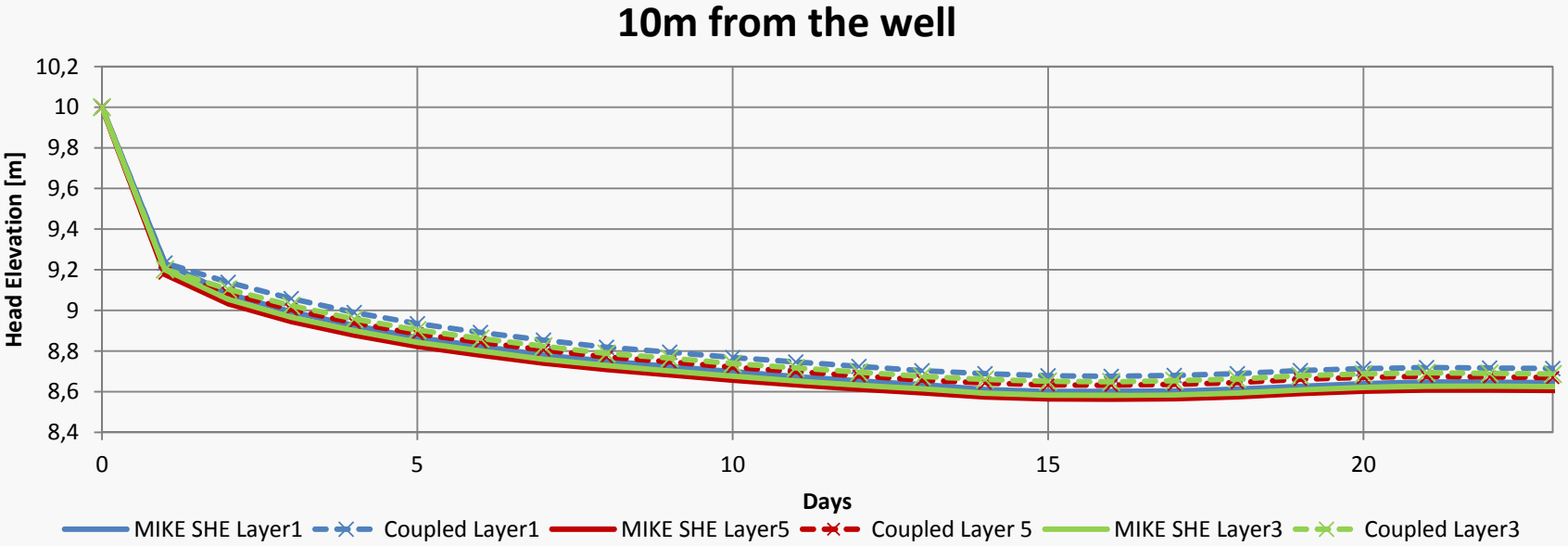


Parameters for unsaturated flow



Simulation Results





Conclusions and perspectives

- A dynamic coupling method of MIKE SHE and FEFLOW as an integrated modelling approach was developed, using OpenMI coupling.

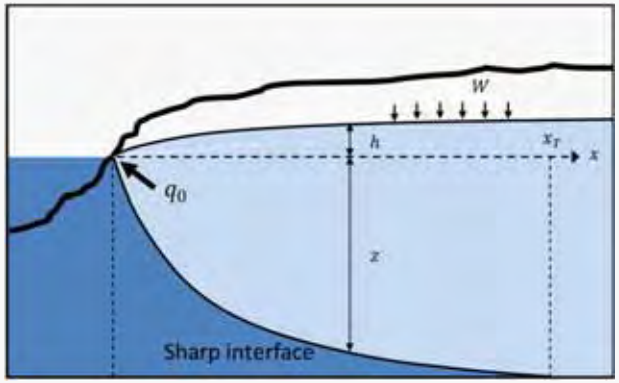
- The initial tests verified the capability of coupling of the models to represent the dynamic interaction between the surface water and groundwater systems.

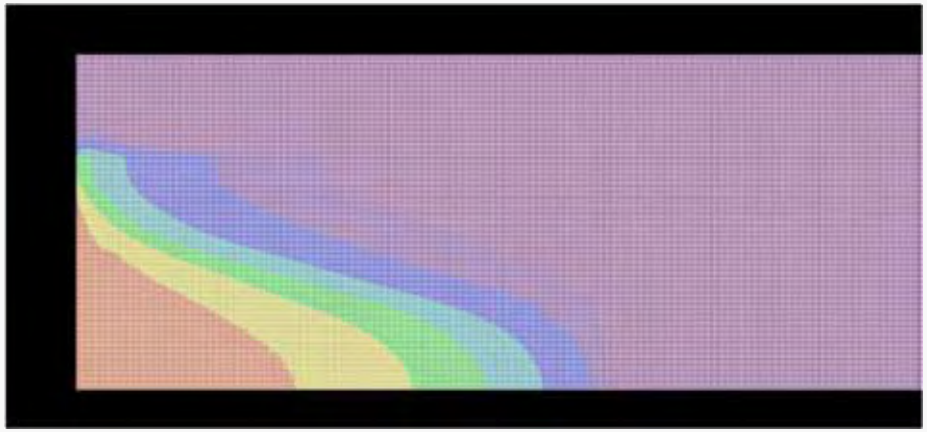
- Simple column
- Lake aquifer
- Steady state and transient streamflow depletion
- Numerical verification of coupling with the transient recharge

Perspectives

Saltwater Intrusion

Investigating the use with respect to saltwater intrusion problem in the coastal area, e.g. to assess the climate change impact on the coastal groundwater.





Perspectives

Catchment scale modelling

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