

# Regional scale flow and transport modelling for the management of groundwater and surface water bodies in the framework of the EU Water Directive

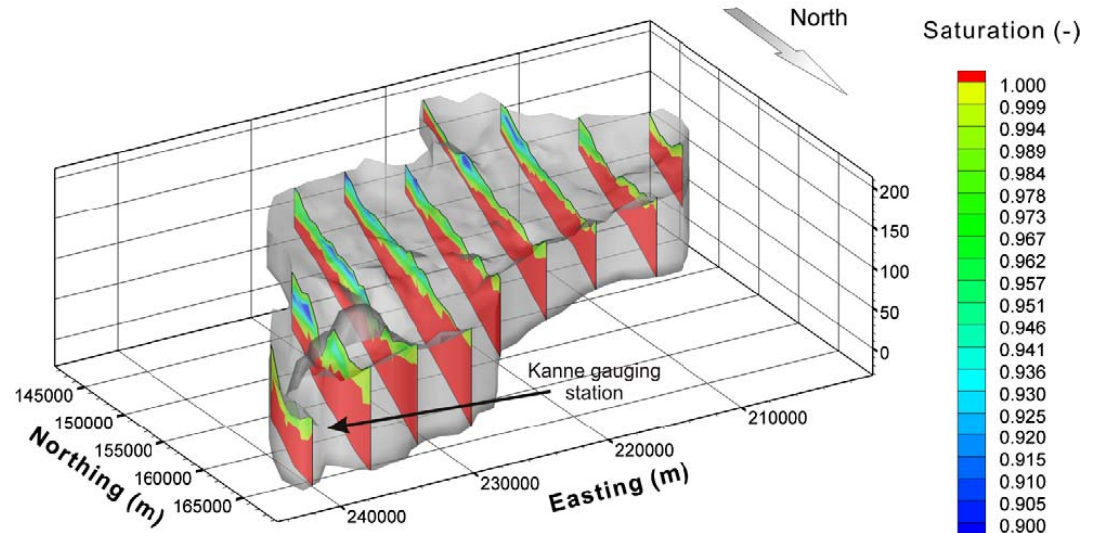
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**(...) river basin district (...) is  
identified as the main unit for  
management of river basins**

**(DIRECTIVE 2000/60/EC « Water Framework Directive »)**

An integrated management at regional scale requires characterization and modelling



(Goderniaux, 2010)

As managing tools in the framework of the EU Water Directive, regional scale models should provide:

- quantitatively
  - an estimation of the evolution of water balance terms (reserves), groundwater-surface water interactions (baseflow), and hydraulic head trends for several scenarios with regional impacts
- qualitatively
  - an estimation of the evolution of nitrate trends for several input scenarios

However, flow and transport models at regional scale face specific problems:

- complexity of geology and hydrogeology
- heterogeneity of level of knowledge
- representativity of measured parameters
- time-consuming simulations



How can we deal with these problems while meeting the manager needs?

The approach we developed is characterised by regional scale transient flow and transport models including no more complexity than needed or supported by the data. These models provide:

- quantitatively
  - an estimation of water balance, groundwater-surface water interactions, and hydraulic head trends
- qualitatively
  - an evaluation of nitrate trends

Presentation of the approach

Applications of the approach

Synclitorium of Dinant: **quantitative** results

Geer basin: **qualitative** results

# Presentation of the approach

## Applications of the approach

Synclinorium of Dinant: quantitative results

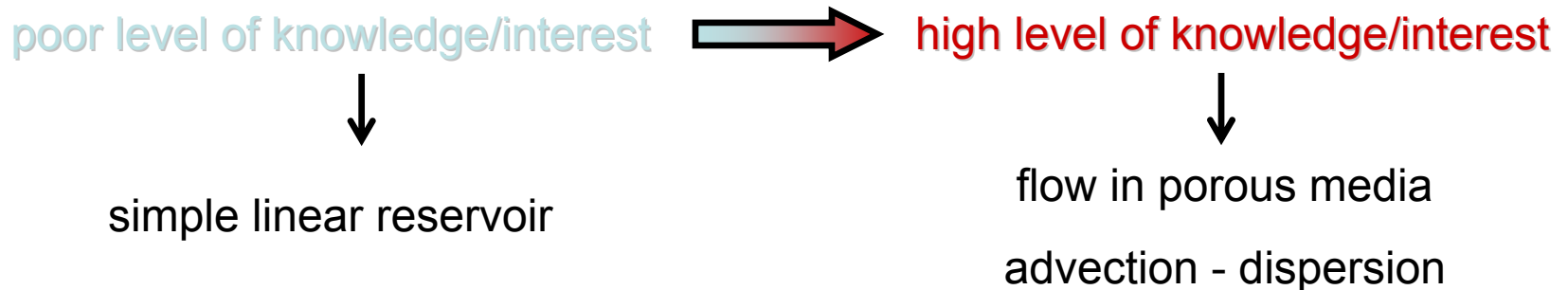
Geer basin: qualitative results



The **approach**, implemented in **SUFT3D**, consists in **three** steps:

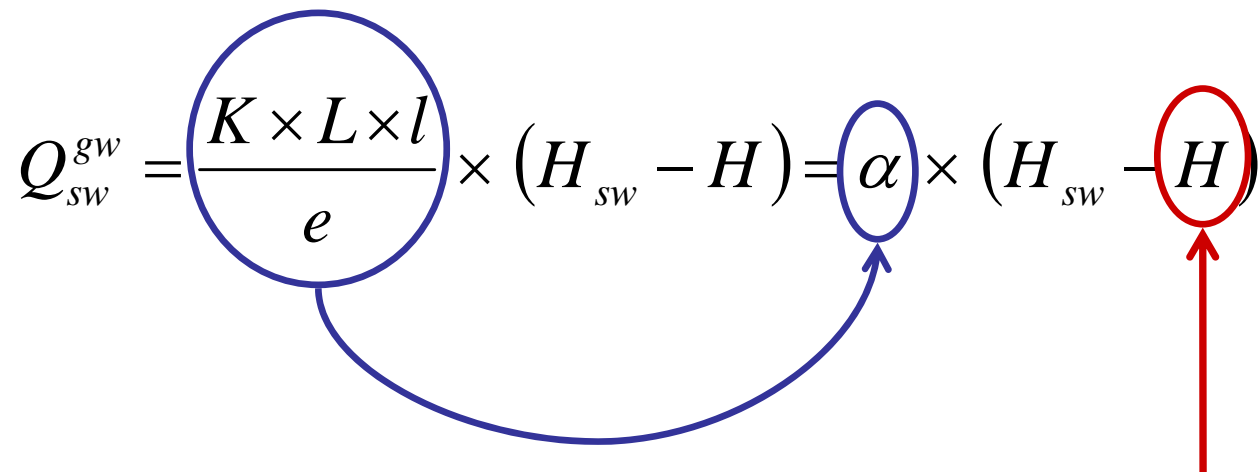
1. subdividing the zone of interest into **subdomains** corresponding to **independent hydrogeological units** or **variously characterised zones**

2. selecting the **equations** governing flow and transport into **each subdomain**



3. defining **internal boundary conditions** between subdomains: 1<sup>st</sup> type, 2<sup>nd</sup> type impervious or 3<sup>rd</sup> type

Groundwater-surface water interactions are taken into account through 3<sup>rd</sup> type boundary conditions

$$Q_{sw}^{gw} = \frac{K \times L \times l}{e} \times (H_{sw} - H) = \alpha \times (H_{sw} - H)$$


hydraulic head

=

unknown of the problem

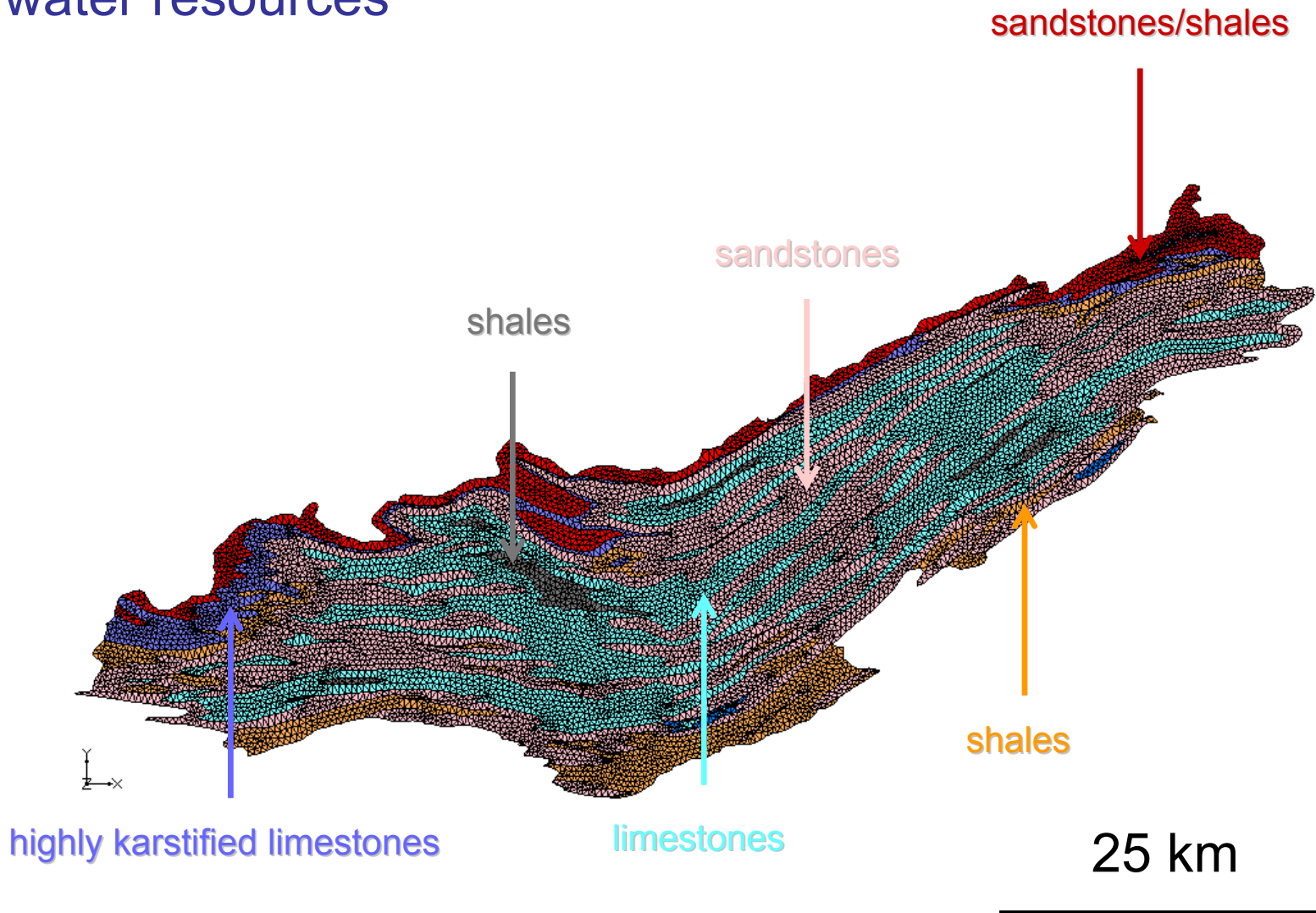
Presentation of the approach

**Applications** of the approach

Synclinorium of Dinant: **quantitative** results

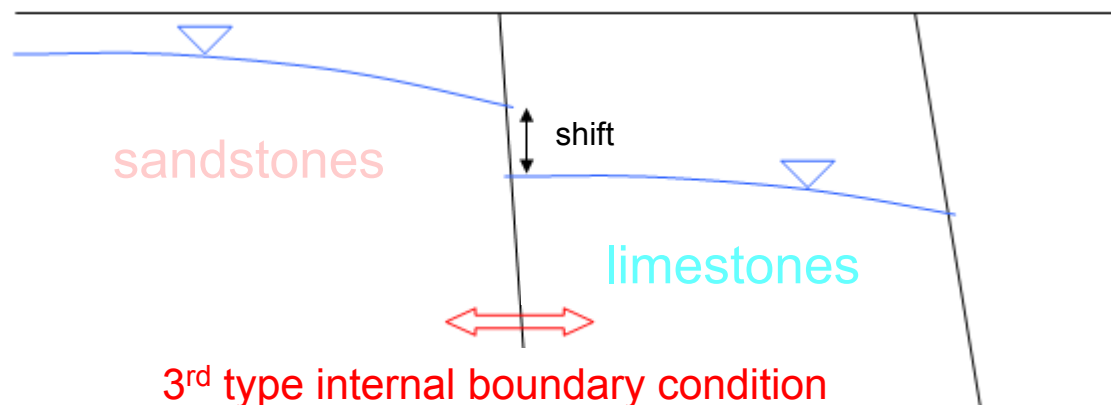
Geer basin: qualitative results

Three water bodies located in the Synclinorium of Dinant have been modelled for helping the management of their water resources



The subdomains and the internal boundary conditions have been defined based on the hydrogeological units and the hydrologic sub-basins for:

- considering the hydraulic head shift between sandstones and limestones units

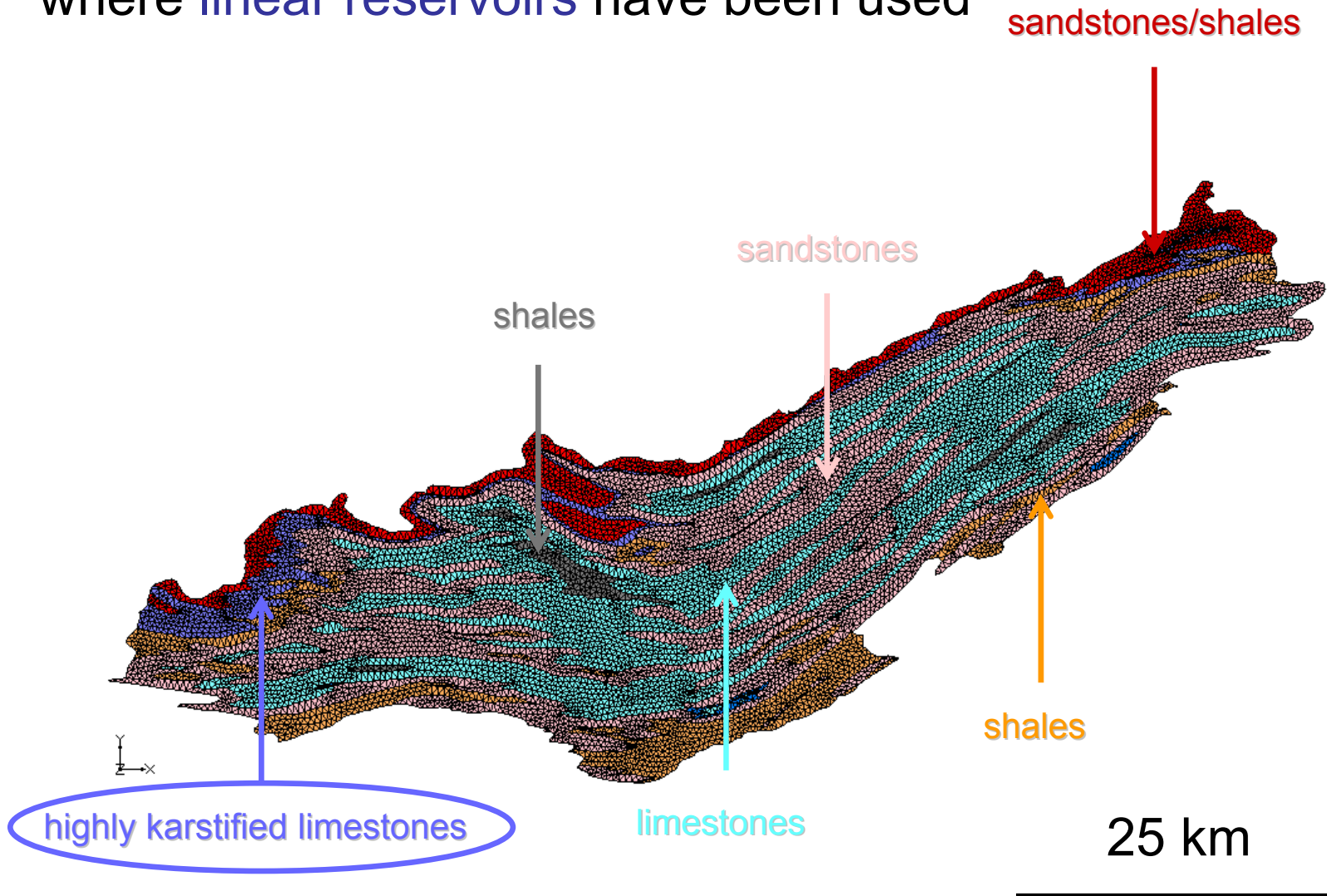


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efficient way to consider implicitly a  
thin low permeable shale unit

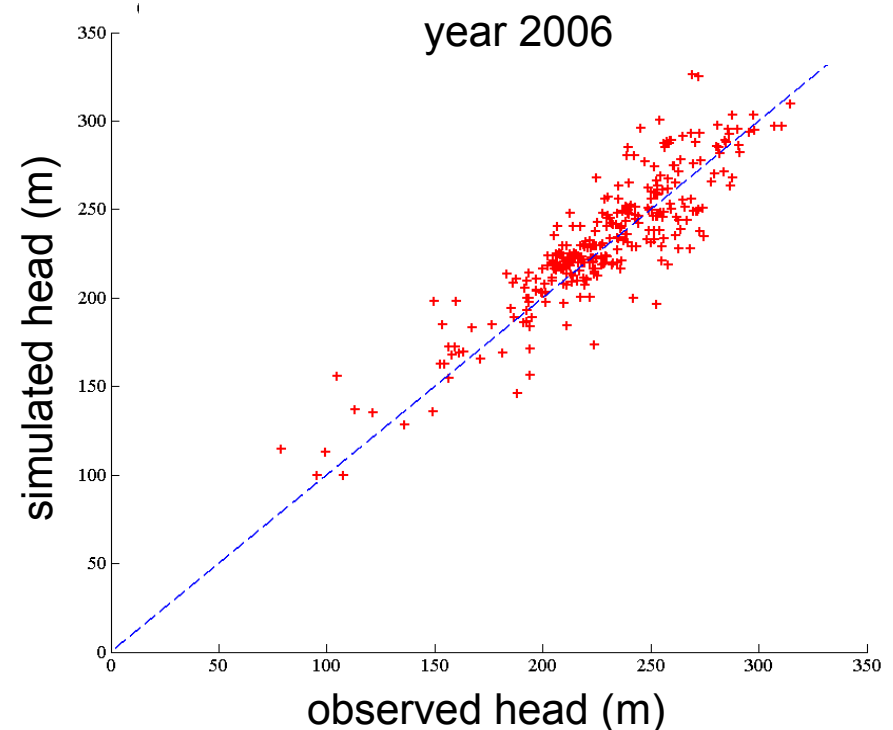
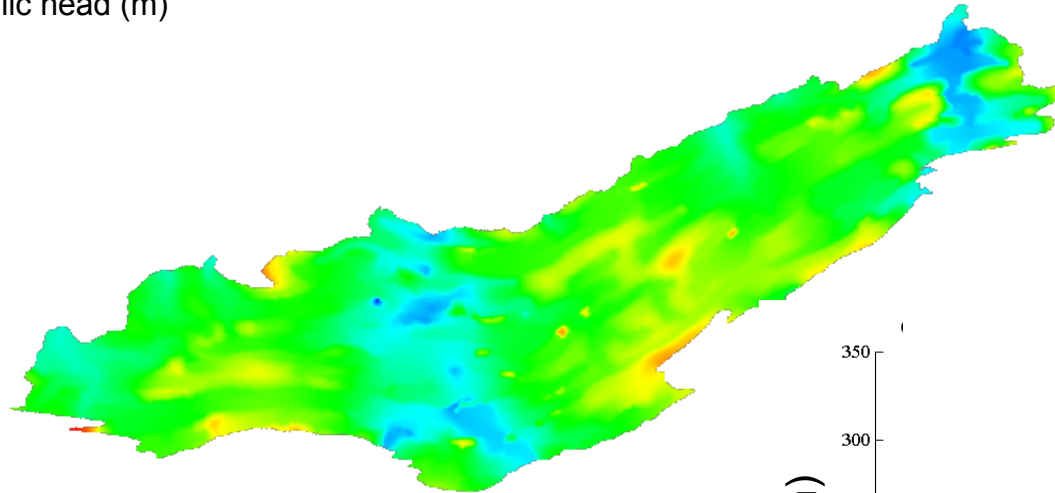
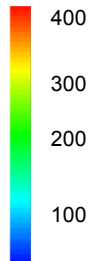
- evaluating groundwater flux exchanges between the main hydrologic sub-basins

Flow in porous media equations have been used in each subdomain except in the highly karstified limestones where linear reservoirs have been used

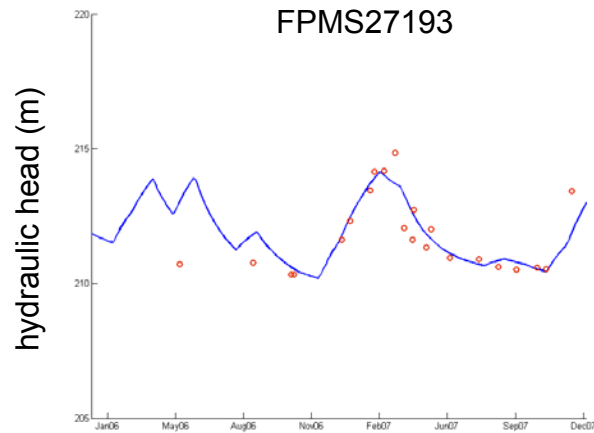


The calibration has been performed in steady-state (UCODE\_2005) using both hydraulic head and baseflow rate observations

Hydraulic head (m)

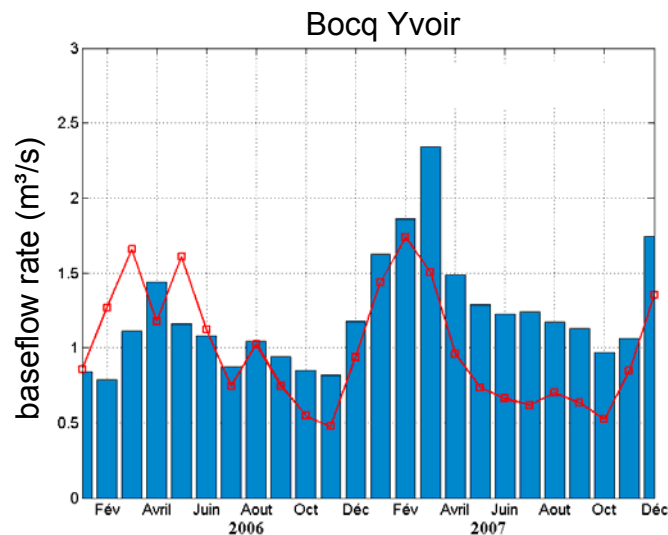
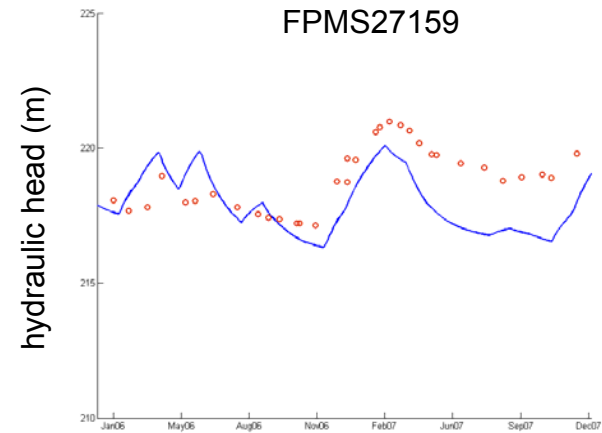


The groundwater flow calibration has then been performed in transient regime using both hydraulic head and baseflow rate observations



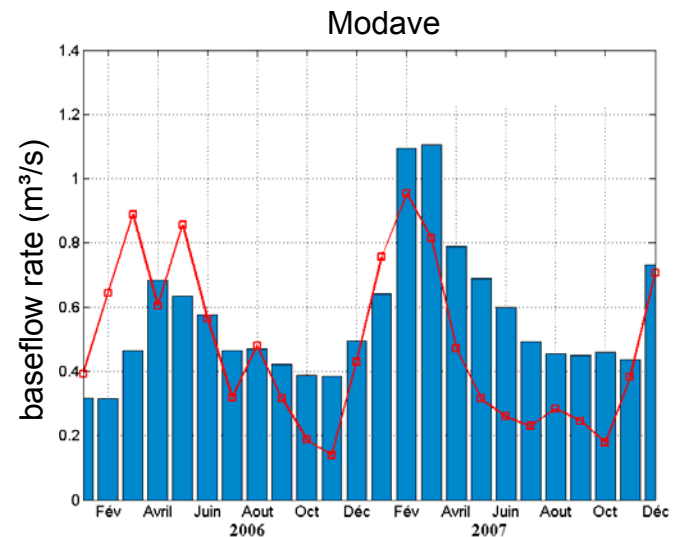
hydraulic head

~ simulated value  
○ observed value



baseflow rate

~ simulated value  
□ observed value

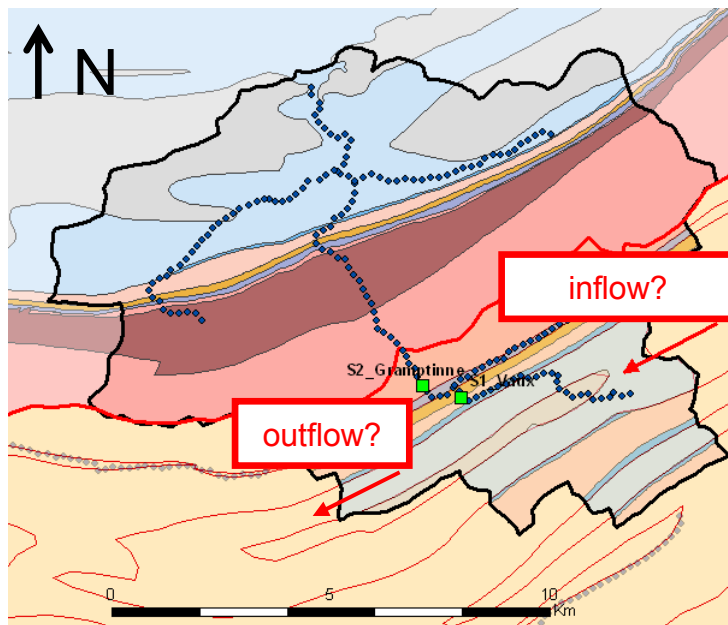




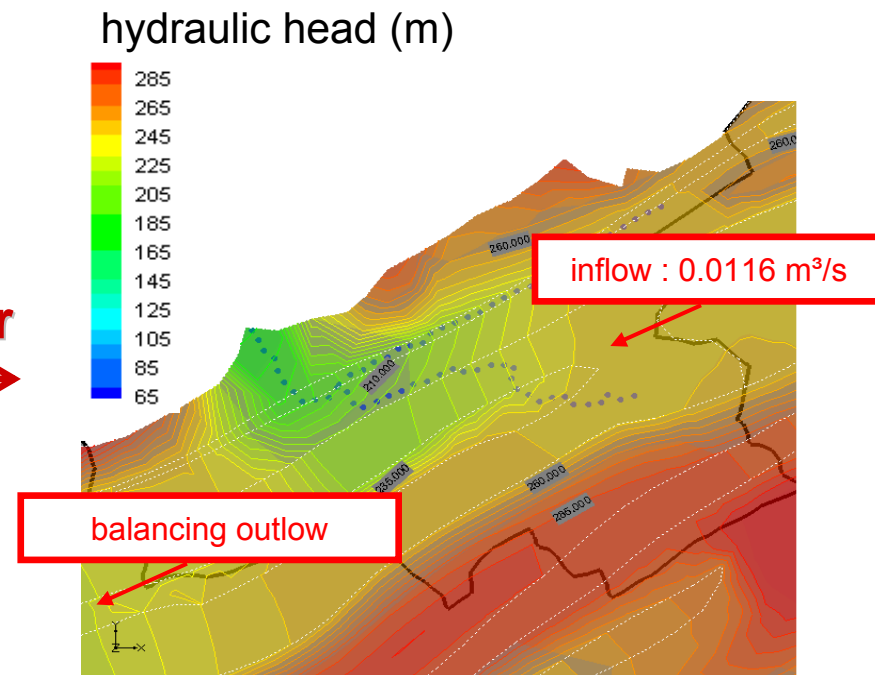
The calibrated model has been used for:

- obtaining additional information about the water balance of key sub-basins

What are the groundwater flux exchanges between sub-basins?



model  
answer



- obtaining boundary conditions for a local impact model linked to an open pit extension project

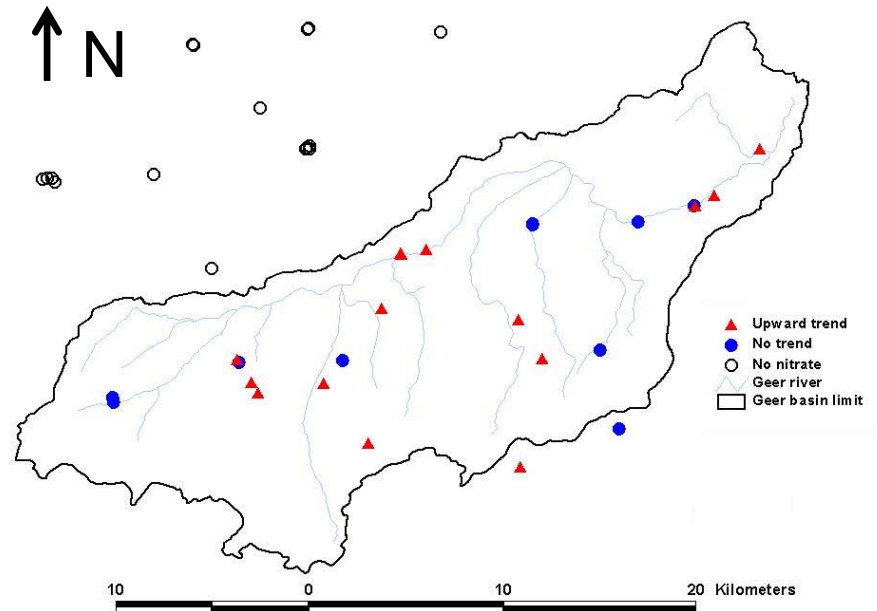
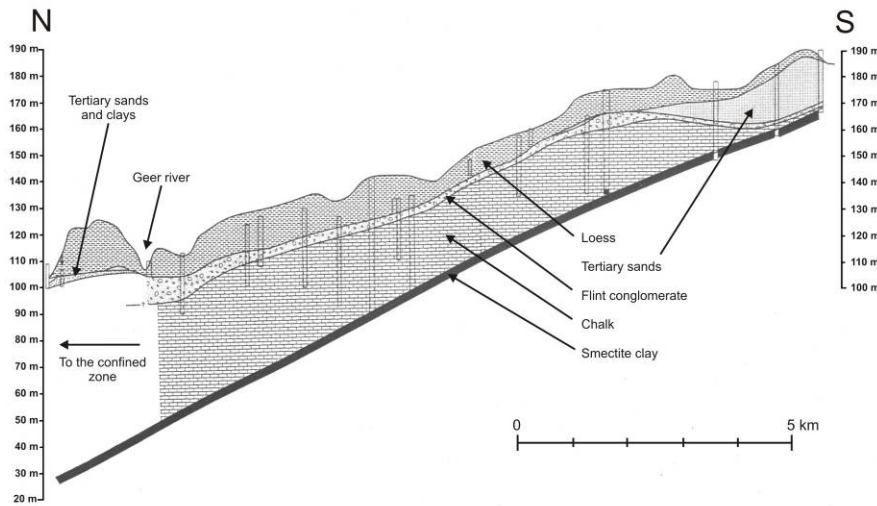
Presentation of the approach

**Applications** of the approach

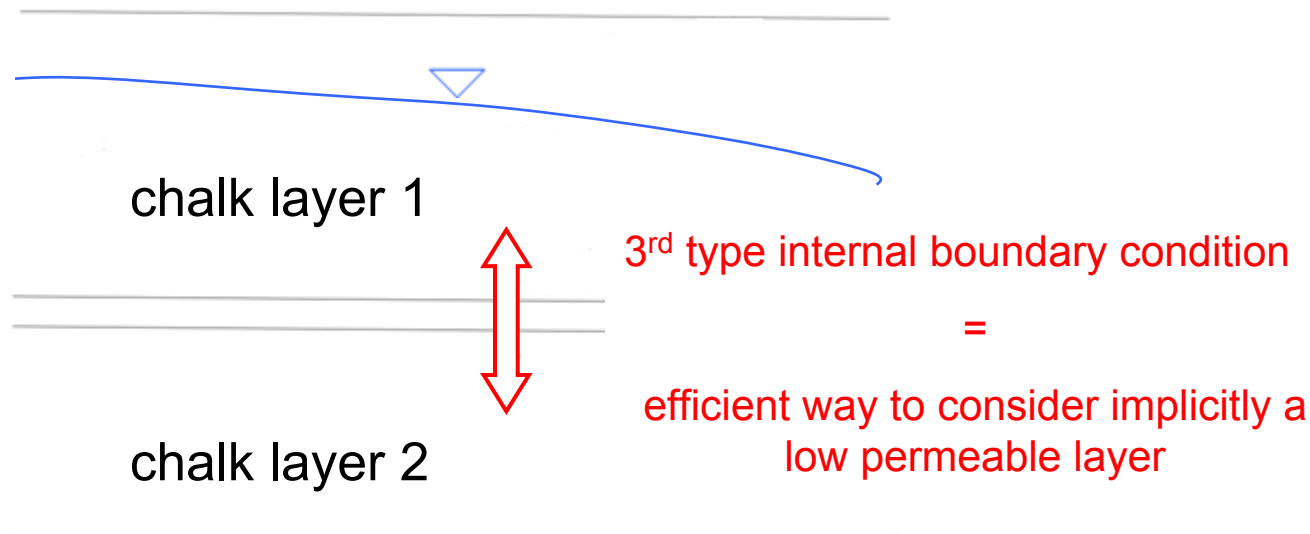
Synclinorium of Dinant: quantitative results

Geer basin: **qualitative** results

The chalk aquifer of the Geer basin constitutes important groundwater resources for the city of Liege but nitrate concentration in groundwater is increasing for 50 years

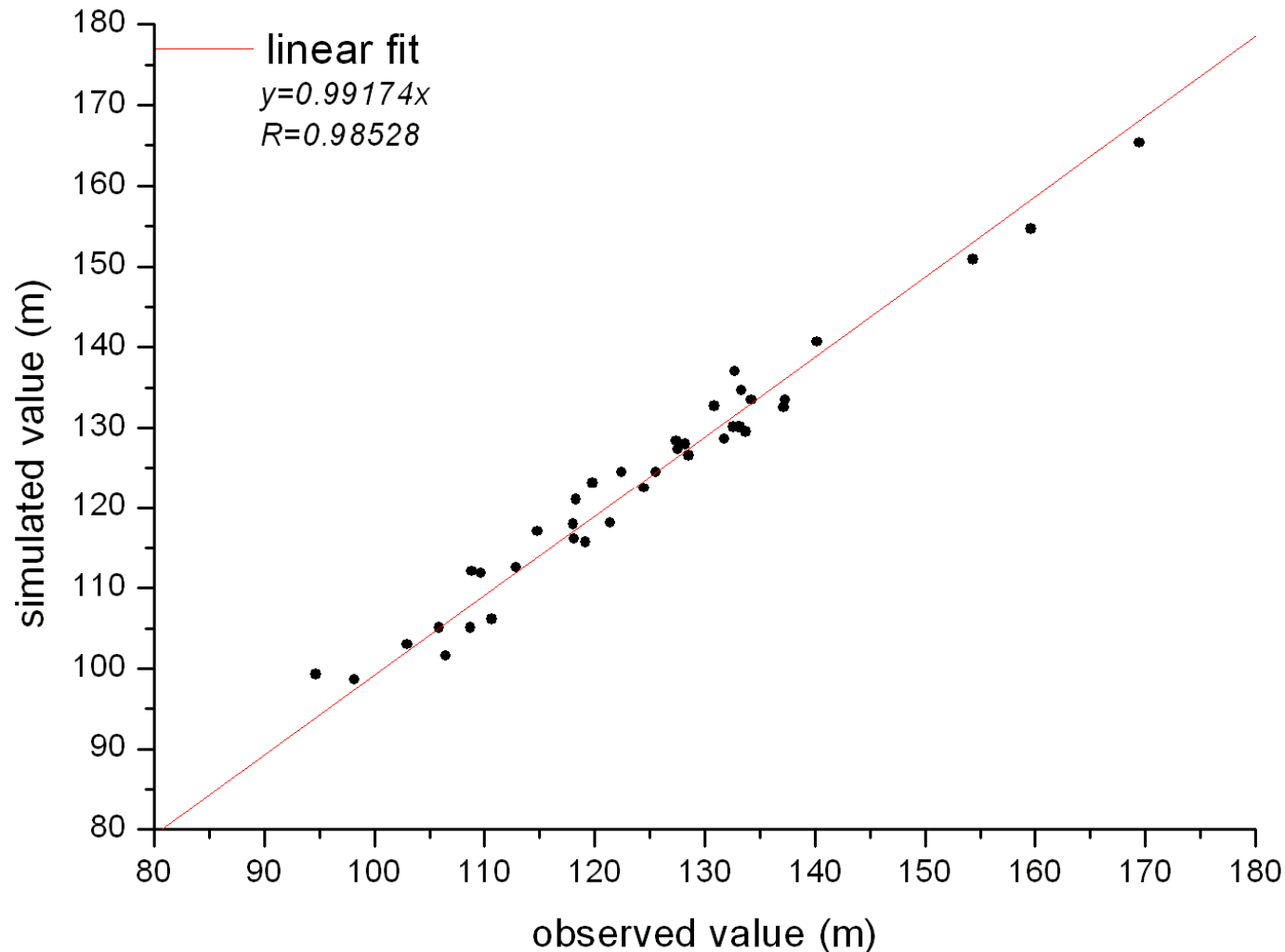


The zone of interest has been subdivided vertically into two subdomains interacting through a 3<sup>rd</sup> type internal boundary condition for taking implicitly into account a low permeable layer separating two permeable chalk layers

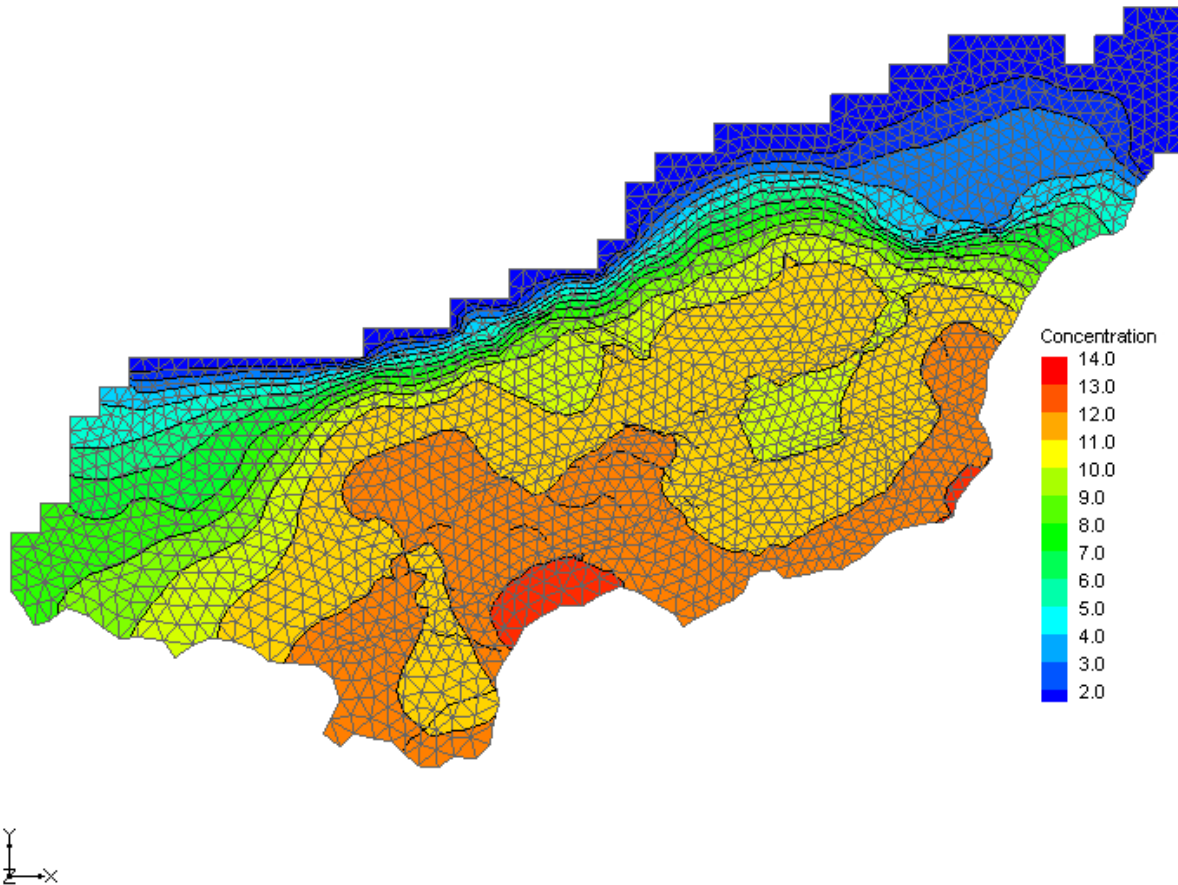


Flow in porous media equation and mixing cell for transport has been used in each subdomain

The groundwater flow calibration has been performed in steady-state (high and low groundwater level periods) using hydraulic head observations

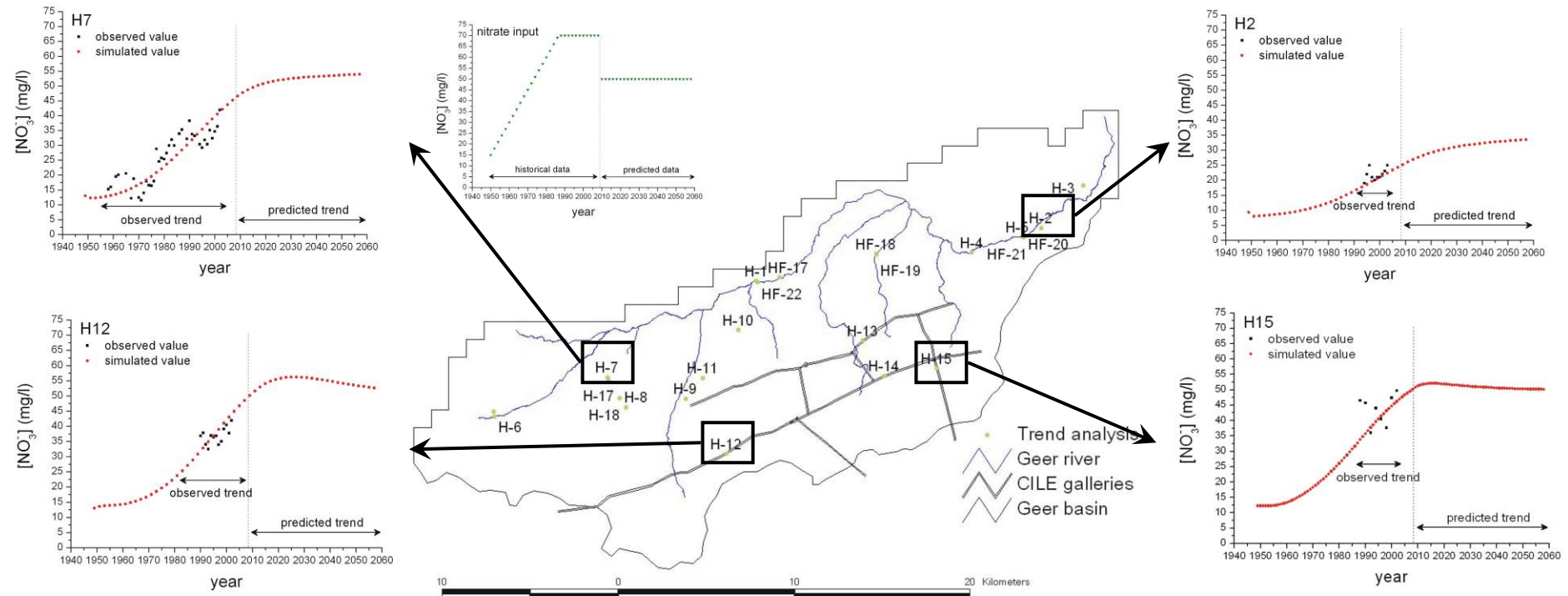


The calibration of transport has been performed on the calibrated steady-state flow field using tritium data and nitrate trends



The calibrated model has been used for evaluating the evolution of nitrate trends until 2060 using a simplified input scenario

Assuming a future nitrate input signal of 50 mg/L, will the increasing nitrate trends be inverted in the future?



The **model answer** is **yes** in the **southern** but **no** in the **northern** and **eastern** parts of the basin with thicker unsaturated zones

The approach proposed for regional scale groundwater flow and transport modelling has proved to meet the manager needs of Wallonia in the framework of the EU Water Directive. The models allow:

- quantitatively
  - obtaining additional information on water balance and particularly on inter-basin groundwater flux exchanges
  - simulating future hydraulic head trends and groundwater-surface water interactions based on transient calibration
- qualitatively
  - evaluating the evolution of nitrate trends in the future



**Although flow and transport model at regional scale face a lot of problems, this approach is promising for helping the integrated management of water resources as required by the EU WFD**

**Thanks for your attention!**