Assessment of nitrate trend in ground water using the regional scale HFEMC approach

Philippe ORBAN, Serge BROUYERE, Julie COUTURIER, Samuel WILDEMEERSCH, Pascal GODERNIAUX, Alain DASSARGUES, University of Liège, Belgium
Jordi BATLLE-AGUILAR, EPFL, Switzerland
Cécile HERIVAUX, BRGM

Groundwater Quality Conference – 13-18 June 2010

- Nitrate is the most common chemical contaminant in the world's groundwater - *ScienceDaily (Sep. 18, 2008)*

- Nitrate drinking water limit values are exceeded in around one-third of the groundwater bodies - *European Environment Agency*

EU Water Directive imposes new regulations

Good status by 2015

Inversion of damageable trends by 2015

⇒

Need to link changes in agricultural practices and groundwater trends

- Dependent on aquifers properties!
- Regional scale problem!

Need to evaluate the costs of measures and benefits for the society

- For policies optimization

Groundwater modelling is an efficient tool to reach these objectives

Main steps :

Understand groundwater flow and transport processes at the regional scale

Recharge vs discharge zones, mixing

Modelling flow and transport at the groundwater body scale

Calibration and prediction of trends

Coupling : Modelled trends ↔ socio-economic approach

Efficiency of measures in terms of :

- degradation mitigation
- costs

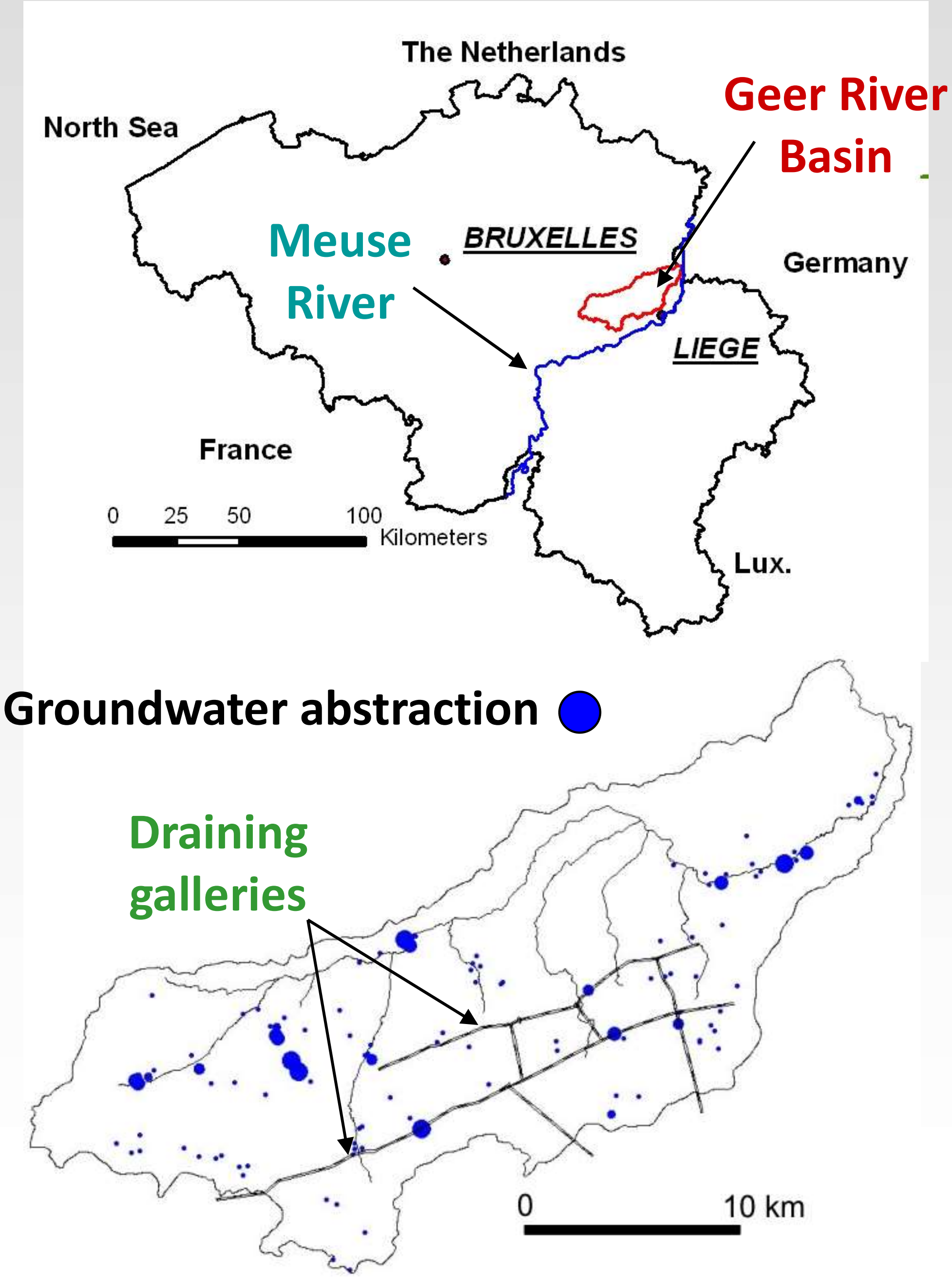
Methodology applied to the Geer basin case study (Belgium)

1. The Geer basin hydrogeology

2. Groundwater modelling

3. Costs – benefits analysis of mitigation measures

The Geer basin groundwater resources are strategic



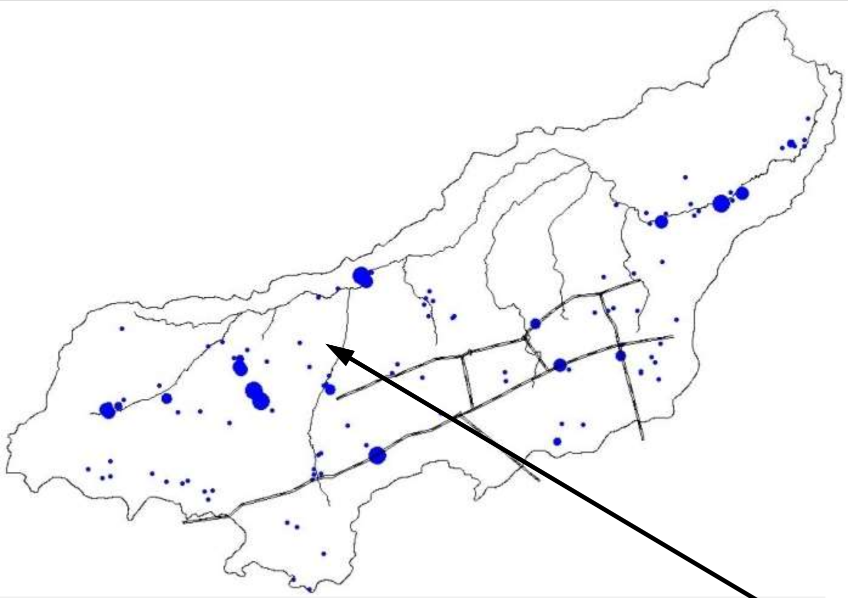
Area = 465 km²

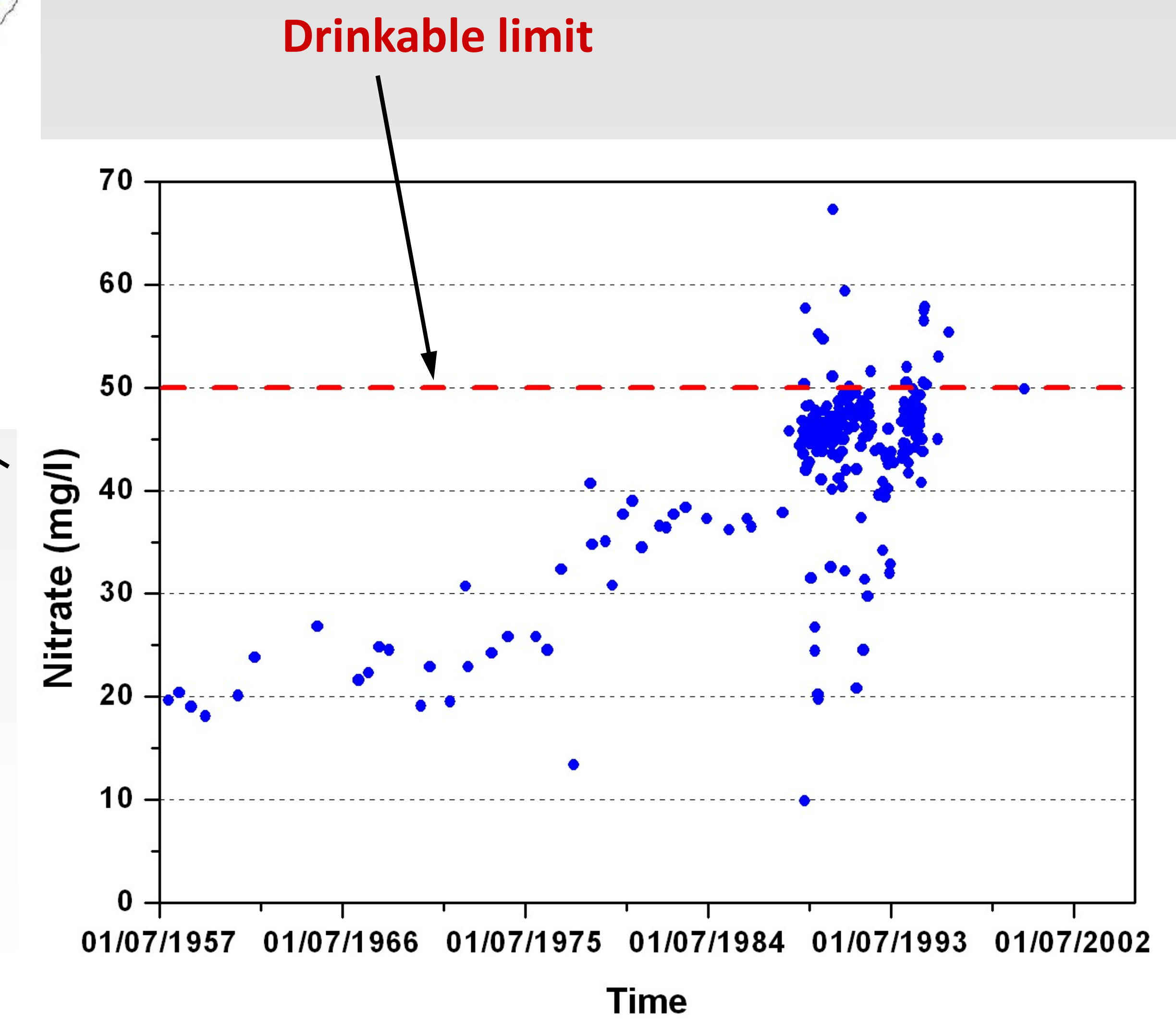
Sub-catchment of the Meuse River

Groundwater are intensively exploited in the Geer basin

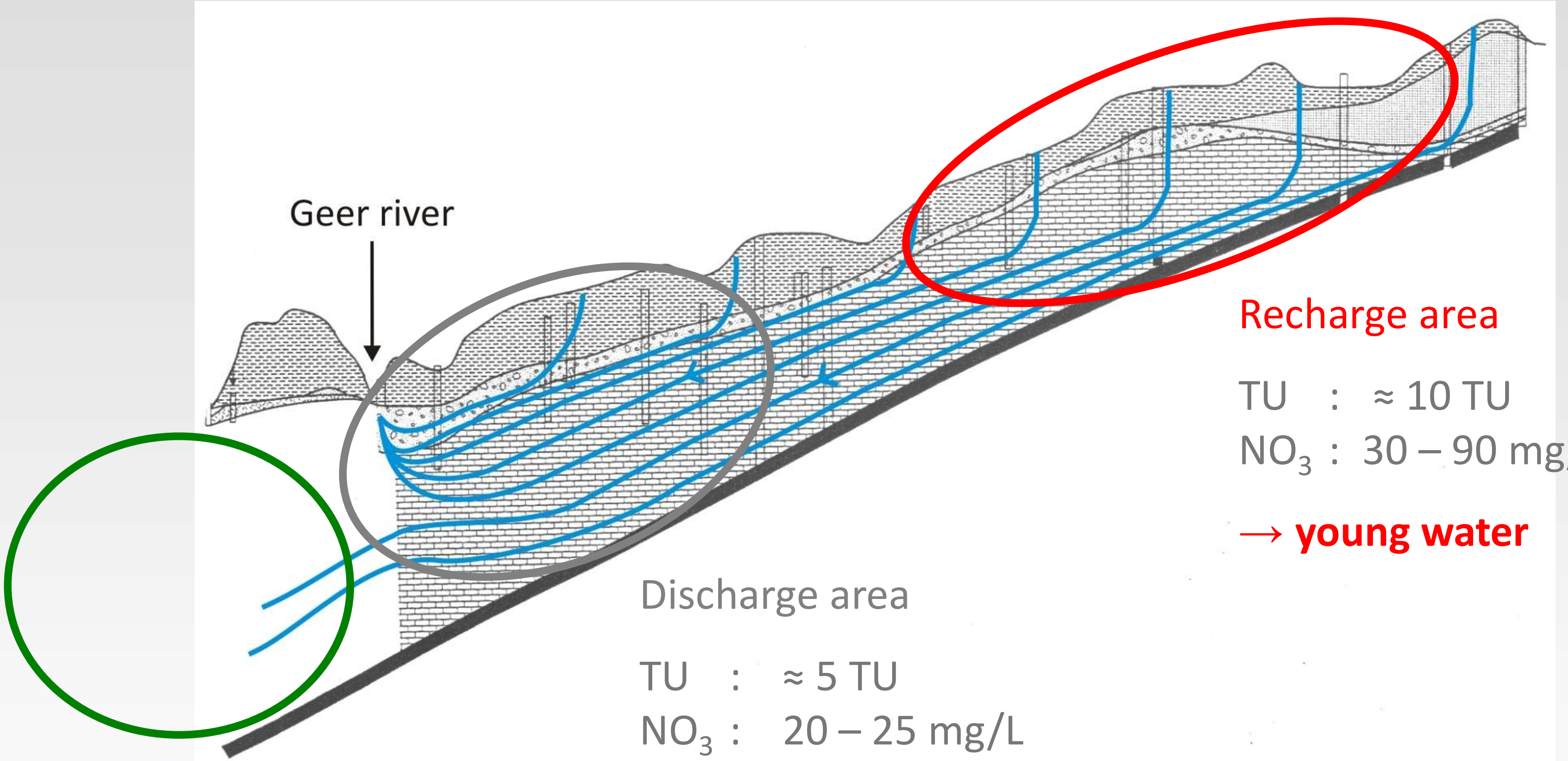
30 millions m³/year
for 600,000 people in Liège

Nitrate concentrations are increasing alarmingly





Nitrate concentrations are heterogeneous



Recharge area

TU : ≈ 10 TU
NO_3 : 30 – 90 mg/L

→ **young water**

Discharge area

TU : ≈ 5 TU
NO_3 : 20 – 25 mg/L

→ **mixing between old/young**

Confined area

TU : ≈ 1
NO_3 : ≈ 0 mg/L

→ **old water**

1. The Geer basin hydrogeology

2. Groundwater modelling

3. Costs – benefits analysis of mitigation measures

Modelling solute transport at the regional scale is challenging

Large areas
From a few 100 to several 1000 km^2

Very large computing times
From a few hours to a few weeks

Availability of representative data
Classical tracer tests are usually not usable

Numerical problems
Linked to solute dispersion and elements size

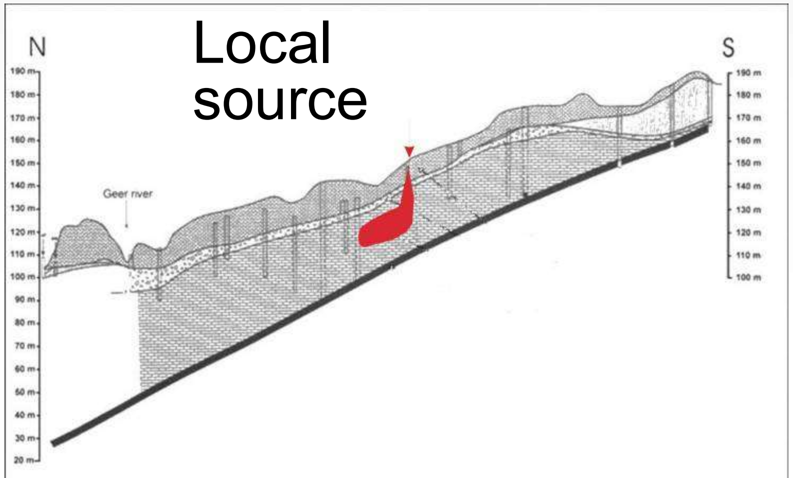
The Geer basin is modelled with the physically-based finite element SUFT3D code

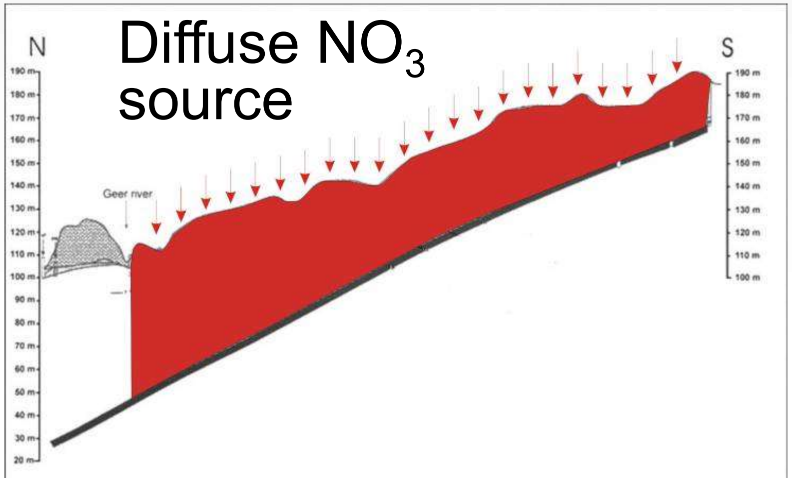
Groundwater flow

- Finite element solution in equivalent porous media
- Steady-state conditions
- Variably-saturated

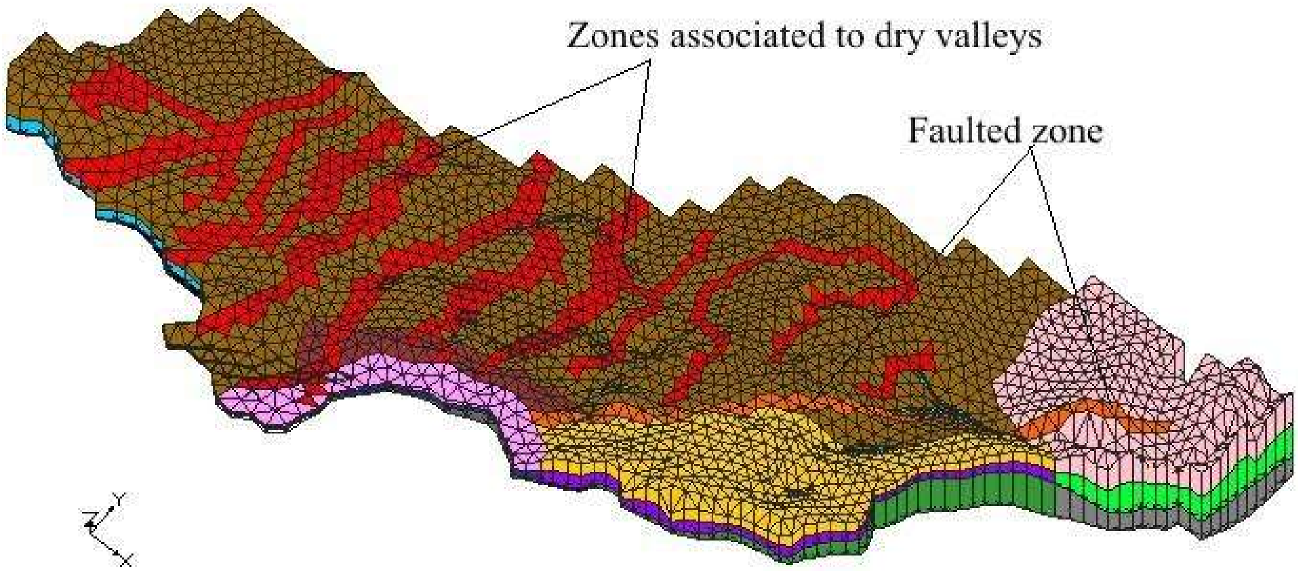
Groundwater transport

- Distributed mixing cells
- Dual-porosity model to represent fractures
- Transient conditions
- Simplified nitrate input
- Neglect dispersion (Spatial dispersion >> Physical dispersion)





The modelled domain is discretized with 5 layers of finite elements



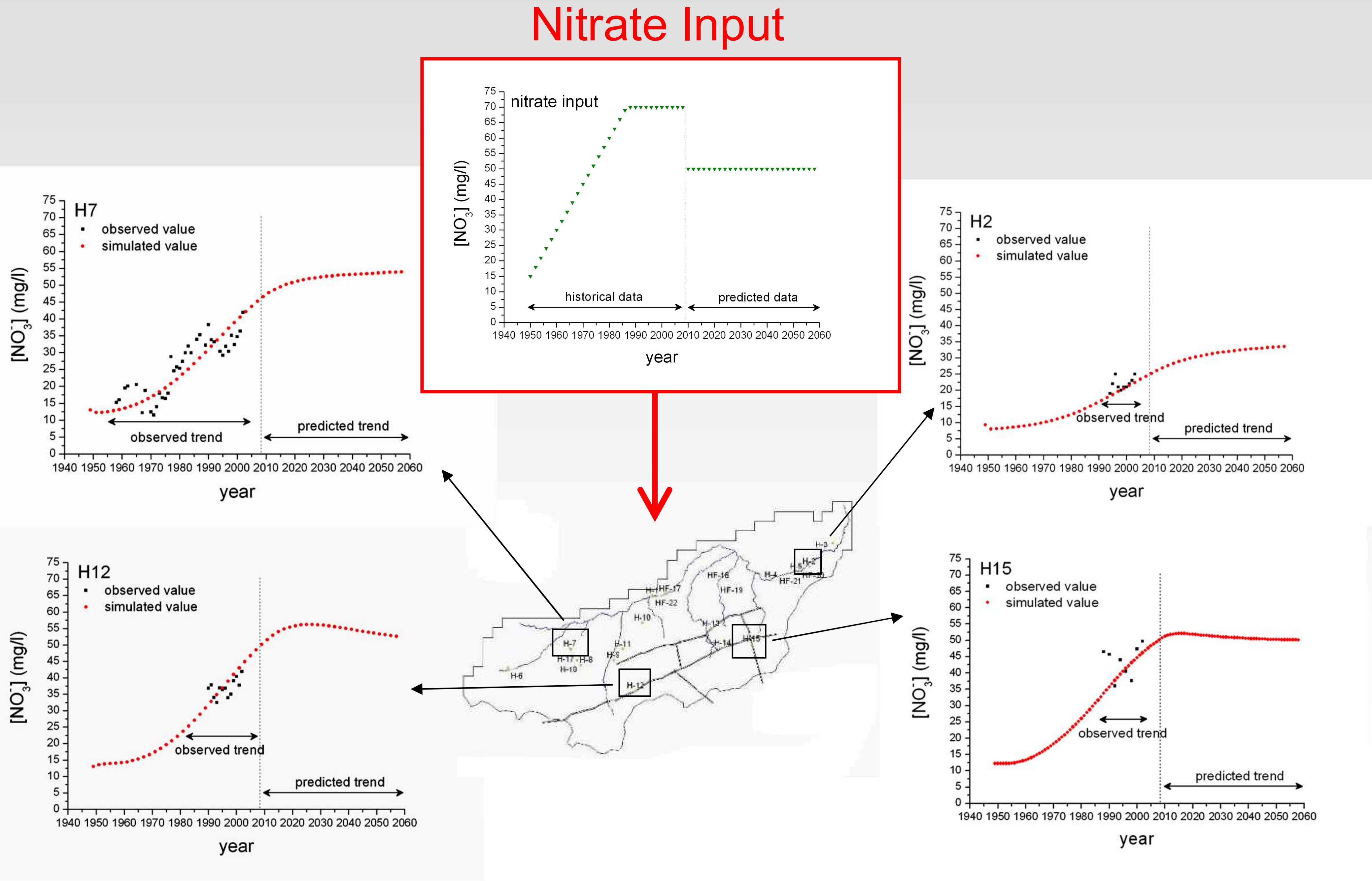
Limits of the model = hydrological limits of the basin

- No-flow boundary condition
- Fourier boundary condition

Different zonations

- for chalk heterogeneity

Modelled and observed nitrate trends are in accordance



1. The Geer basin hydrogeology

2. Groundwater modelling

3. Costs – benefits analysis of mitigation measures

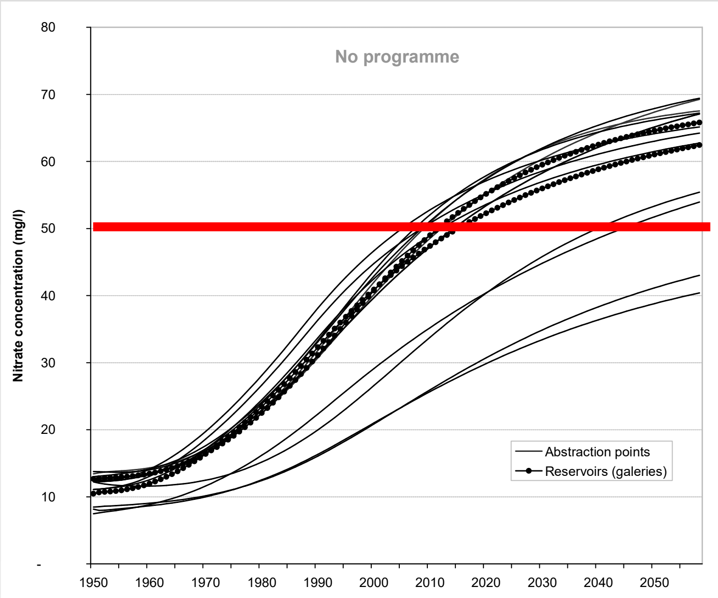
Coupling physical and socio-eco approaches allows comparing costs and benefits of measures

What happens if nothing is performed today?
- Damage?

What measures can be applied to prevent degradation?
- Efficiency?
- Time of efficiency?

Which measure to choose to maximize society welfare?
- Costs?
- Benefits?
- Comparison of costs and benefits

What happens if nothing is performed today?

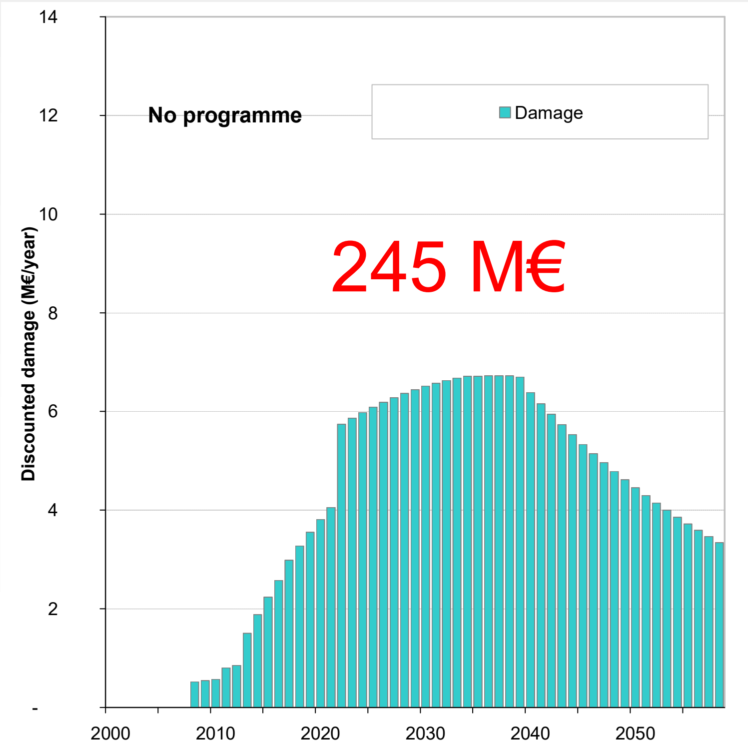


Nitrate concentrations are simulated

at each abstraction points

from 2010 to 2060

Drinkable limit is exceeded in 2015 for most locations



Estimated total damage for the 50-years horizon : 245 M€

Increase in treatment and dilution cost for water production

Increase in the water bill

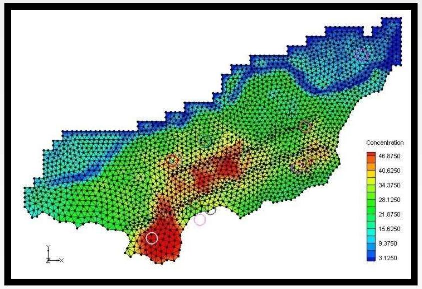
Increase in bottled water consumption

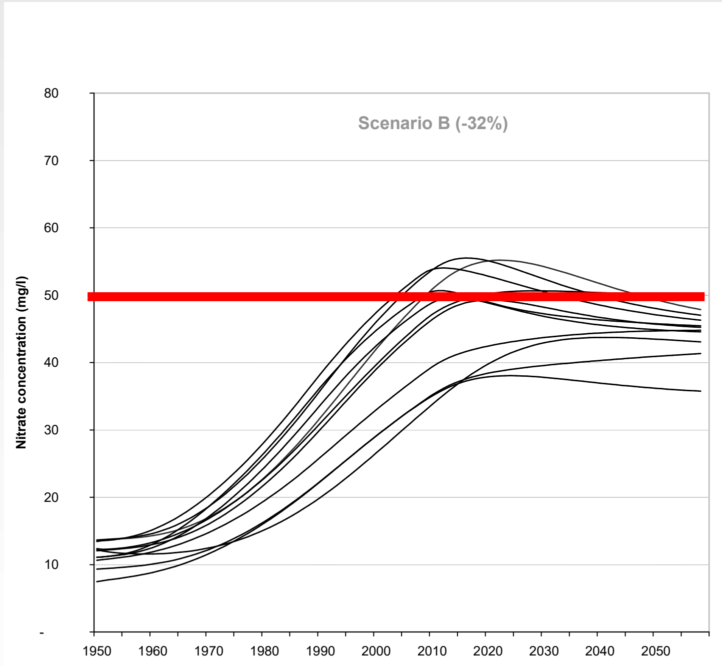
What measures can be applied to prevent degradation?

3 scenarios (set of agricultural measures) are tested with the groundwater model

reduction of nitrate inputs (-25% -32% -41%)

Scenario B -32%





Good status reached by 2040

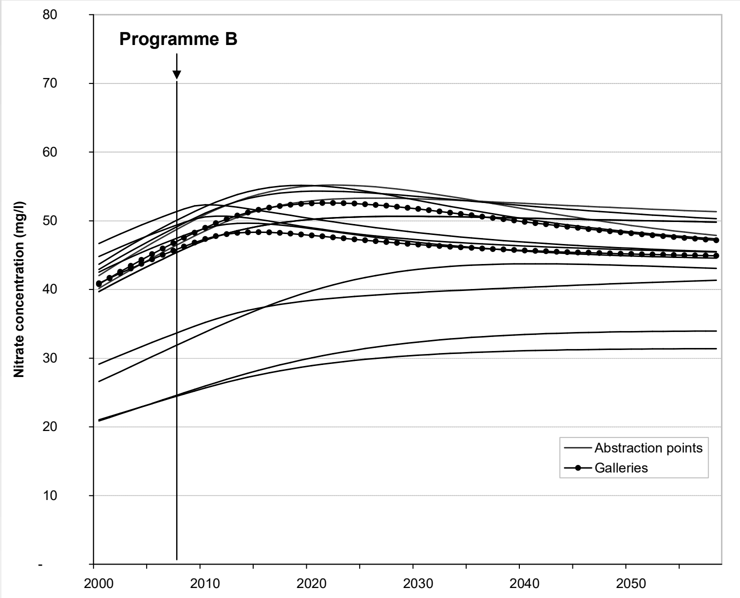
Which measure to choose to maximize society welfare?

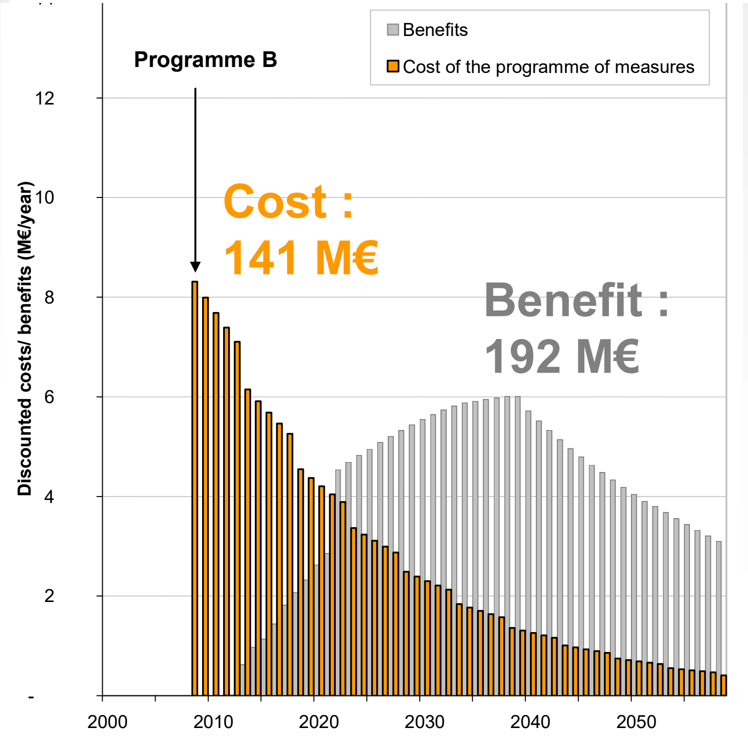
Costs (more expensive practice, compensation….)

Benefits are estimated as avoided damage

	Unit	No program	scenario B	scenario C
Damage	M€	244.5		
Benefit	M€		192.4	206.6
Cost	M€		141.0	220.6
Balance	M€		**51.4**	**-14.0**

→ Scenario B provides the highest net benefice : 51.4 M€





Conclusions

Large scale numerical model able to deal with real cases

Used for very practical groundwater management applications
(land use, climate change, …)

Strong added value of the coupled physical – socio-economic approach

Quantify the efficiency of complex scenarios in both practical and monetary terms

Good status of groundwater can not be reached before 2015 in the Geer basin

Important gap between measures setup and impact on groundwater

Acknowledgement

FP6 AquaTerra EC and partners

BRGM Team (C. Hérivaux)

Walloon Region, Groundwater division

Fonds National de la Recherche Scientifique of Belgium

Aquapôle University of Liège

Belgian Science Policy PAI Timothy