

# Games, Role-Playing, Tools and Models as a Learning Process to Simulate Groundwater Management Negotiation

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**FRANCE**

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***MODFLOW and More: Ground Water and Public Policy***  
***“Model application for decision making”***

**International Ground Water Modeling Center**  
**Colorado School of Mines**

# Groundwater: a vulnerable invisible resource

## Vulnerability : absence of natural protection

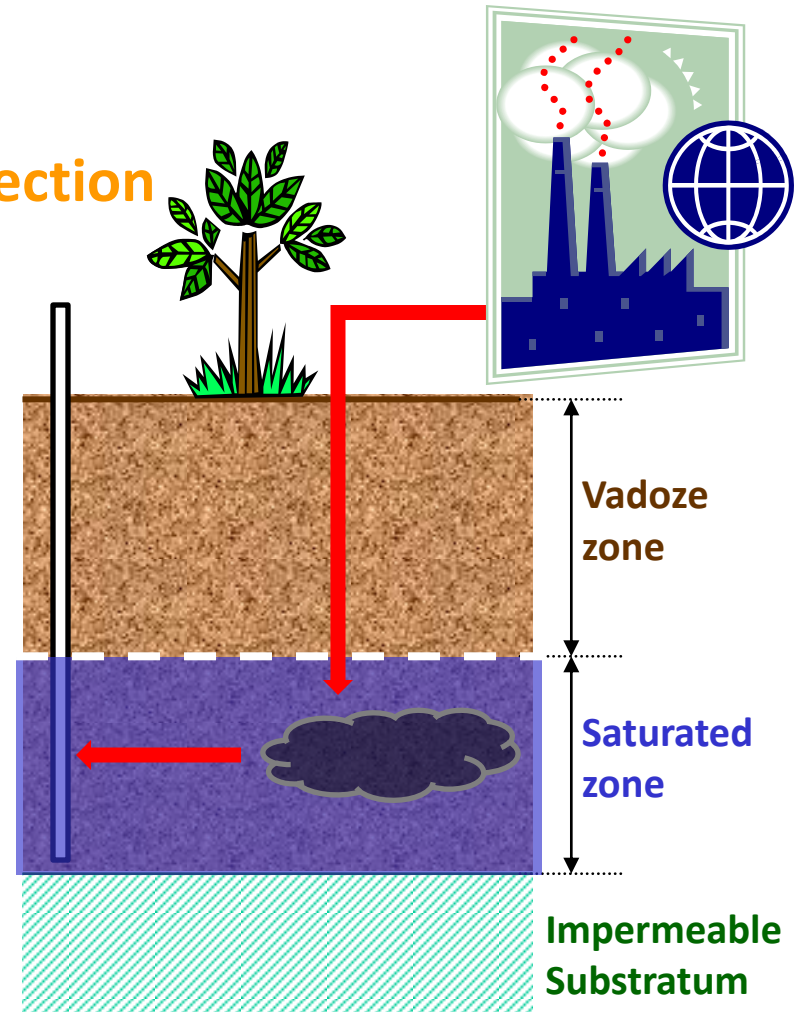
- Vertical infiltration
- Regeneration time of water quality

## Risk : an avoidable disaster

- Horizontal propagation

How to publicize and protect, this invisible but important resource ?

- human uses
- hydrosystem biodiversity



— Surface level  
- - - Piezometric level



## Objective

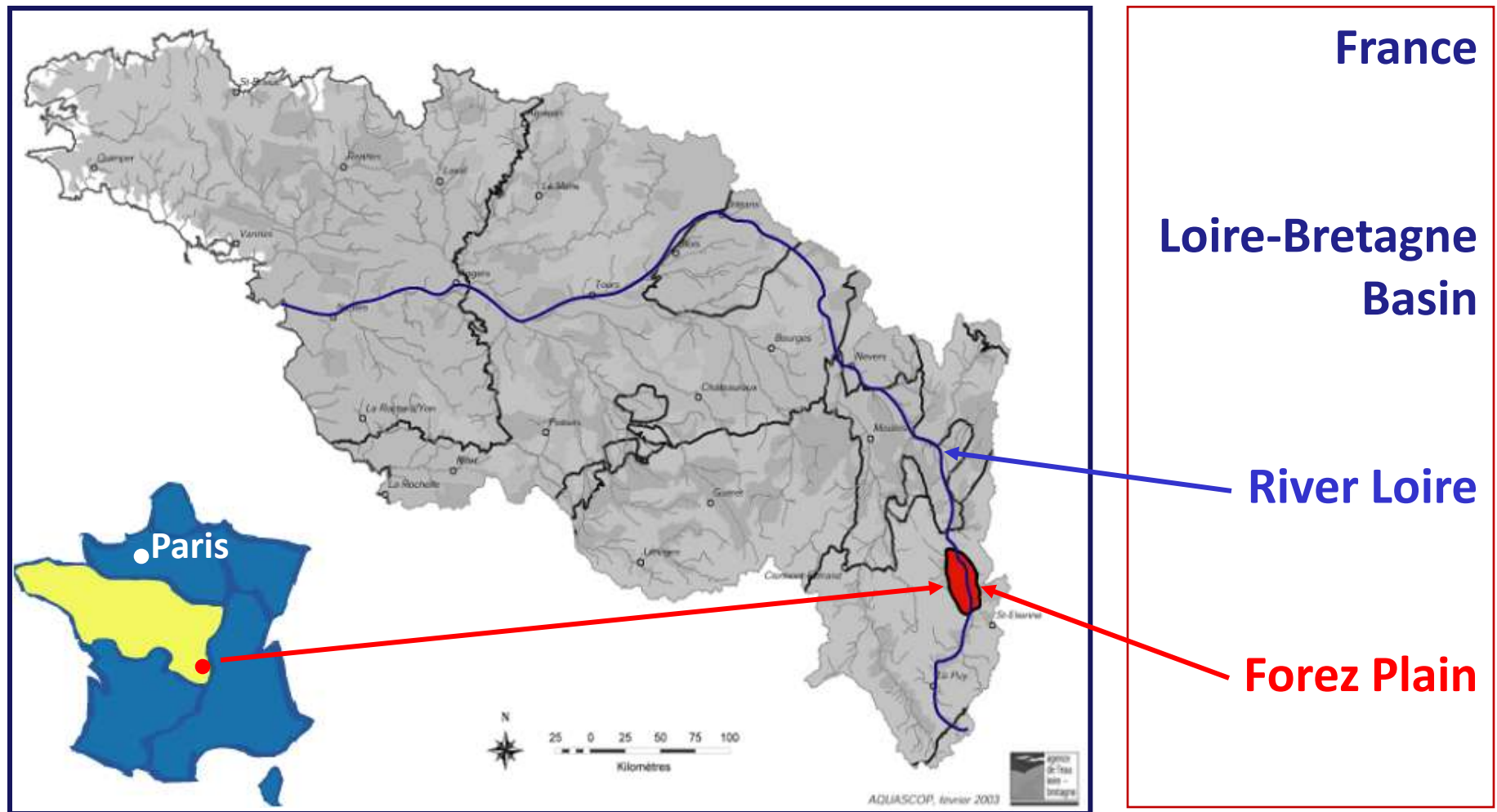
To simulate groundwater management negotiation, with a mediator and spatial argumentation, to reduce aquifer vulnerability using an example of gravel extraction in an alluvial aquifer

**How to make relevant decisions to preserve the quality of the hydrosystem and protect public health?**

Goals of this negotiation simulation are to design a cooperative solution where the participants must decide together :

- ➔ Where is the best new gravel pit location within a specified territory?
- ➔ What is the best method of rehabilitation after gravel extraction?
- ➔ Who is the most appropriate to manage the site after rehabilitation?

# Materials & methods 1: Industrial case (location)



Map and logo: Aquascop and Loire-Bretagne Water Agency (2003)

## Materials & methods 2: A future gravel pit site in the flood plain









Surface area : 10km<sup>2</sup>

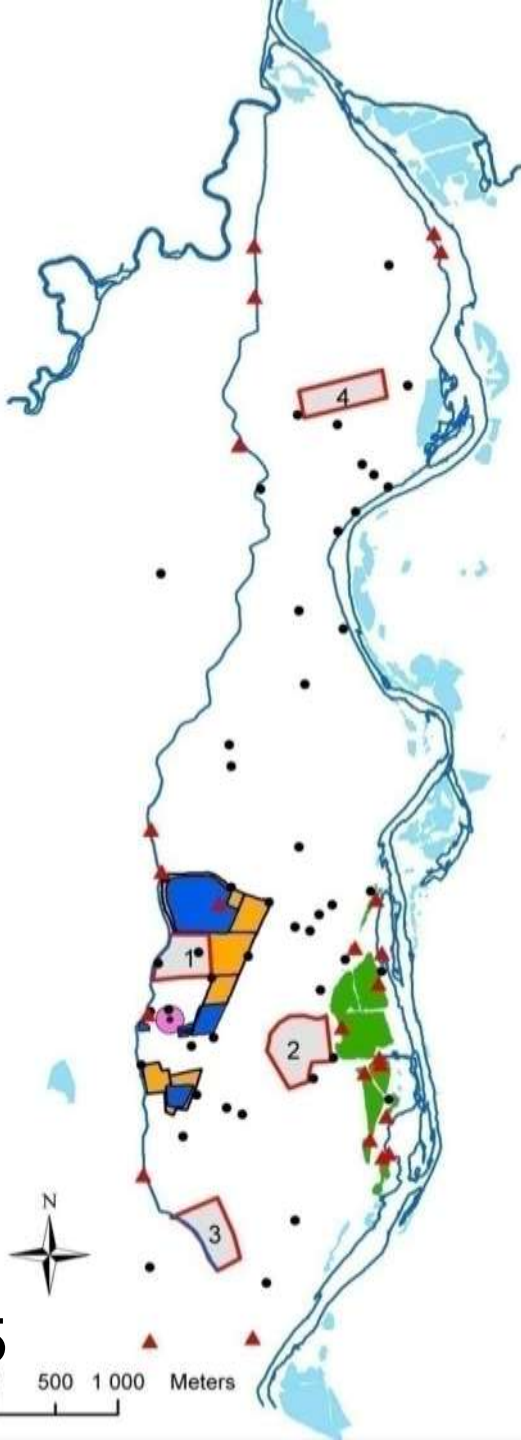
Aquifer volume : 18km<sup>3</sup>

Wells (48) and limnimeters (24)

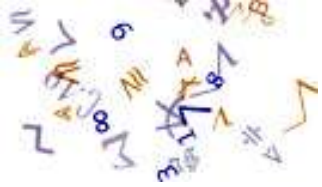
Human artefacts : dikes, gravel pits, embankments,  
agriculture fields

### Legend

- |   |  |   |                        |
|---|--|---|------------------------|
|    | Gravel pit (FRAPNA Loire)                    |    | Gravel processing site |
|   | Gravel pit (Morillon Corvol/Cemex)           |   | Limnimeters            |
|  | Embankment                                   |  | Wells                  |
|  | Future gravel pit location<br>(1, 2, 3 or 4) |  | Stream                 |
|   |  |  | Other lakes            |







# Materials & methods 3: Simulator home page

On line: <http://www.emse.fr/site/negotiation/index.html>

- web-site format
- html language
- Interactive links

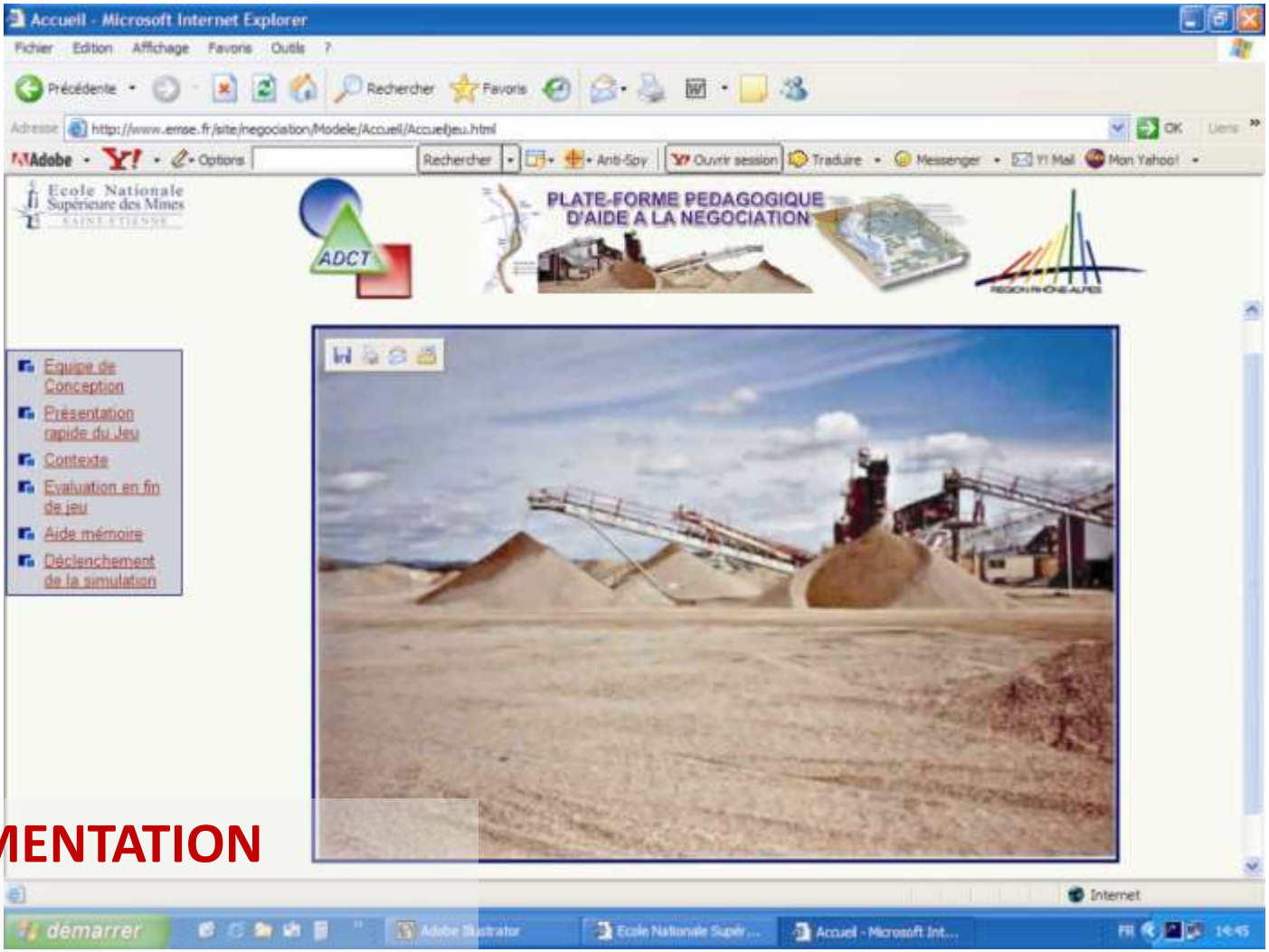


Information  
and design  
tools



**SPATIAL ARGUMENTATION**

**+ Role-Playing**



# Materials & methods 4: Simulator structure and role-playing game

## Simulator structure : information and knowledge acquisition

### Game context

Game description, glossary

Territorial context

Actors description (n=14)

Gravel pit sites description (n=4)

### Internet

Free access

Preselected links

### Tools

**GIS**

**Physical model**

Ecological model

Sociological model

## Role-playing : meeting and information exchange

### First declaration

Self presentation

Position

Making appointments

### Second declaration

**Argumentation (ex : map)**

Reaction

New meetings

### Third declaration

**New argumentation**

Reaction

New meetings

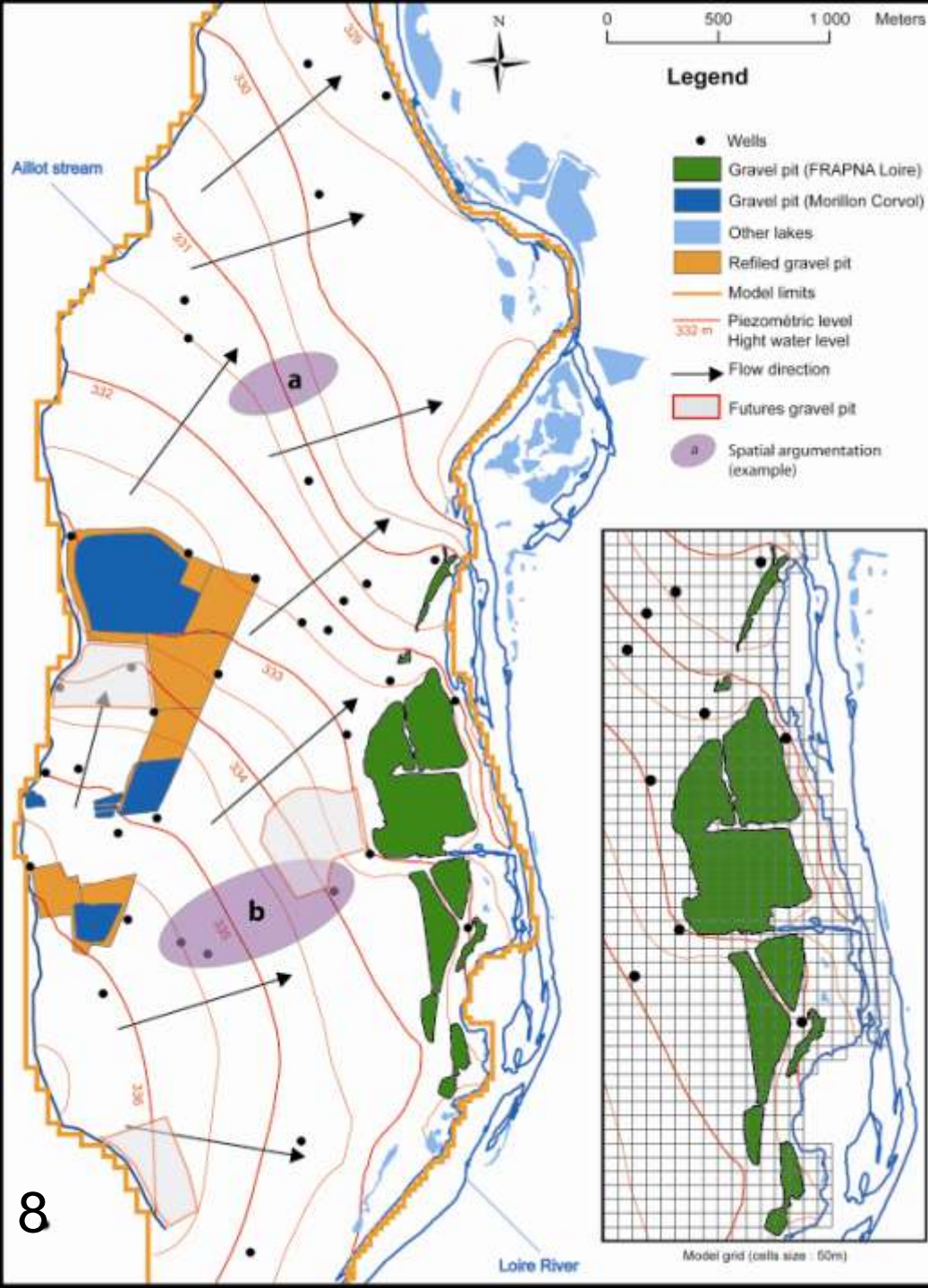
**Negotiation meeting**



**Agreement protocol**

**In parallel**

- Log book
- Teaching
- Debriefing



# Results 1: Physical model for spatial argumentation

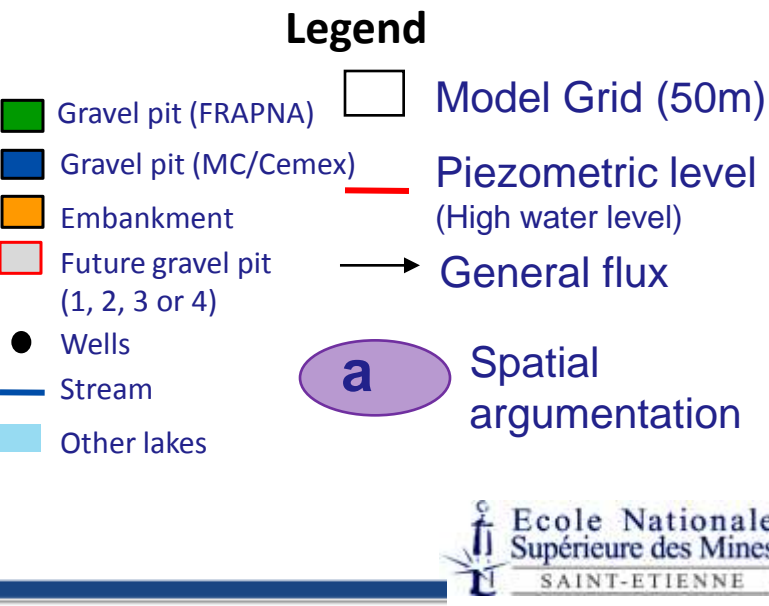
**Physical model : Modflow**  
*(Mimoun, 2004)*

**Boundaries condition**  
**General flux**  
**Model calibration**

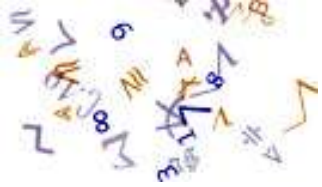
**GIS : ArcGIS 9.2.**

**Expert**

**Spatial argumentation**







# Results 2: Another physical spatial argumentation...

## ... built from physical groundwater model

- Permeability fields  $\longrightarrow$  Quarry potential
- Unsaturated zone thickness  $\longrightarrow$  Aquifer vulnerability
- Flow velocity and direction  $\longrightarrow$  Pollution risk

## ... constructed with other decision variables

- Water features  $\longrightarrow$  Location
- Topography  $\longrightarrow$  Landscape integration
- ...



## Discussion: Other argument to consider ?

### ... biological prospective

- Subterranean invertebrates, aquatic plants

### ... geochemical approach

- Classical physico-chemical elements, isotopic elements

### ... sociological model

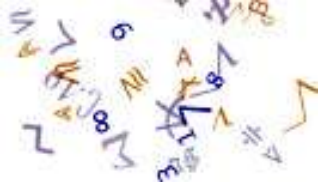
- Stakeholder representations, actor relationships

### ... other tools

- Territorial 3D views, movies, landscape diagrams...

### ... different physical model types

- Finite-differences groundwater flow with irregular grid
- Analytic elements model



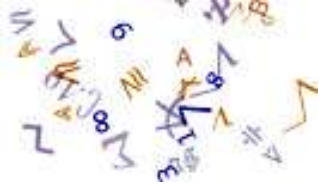
## Conclusion...

### ... negotiation and decision point of view

- use supplementary representations for spatial argumentation
- find representation in accordance with actor interests
- design argumentation together

### ... pedagogic point of view

- master scientific support tools and understand their relevance in negotiation
- learn first hand the complexity of territorial negotiation
- a professional initiation to the intricacy of territorial decision making










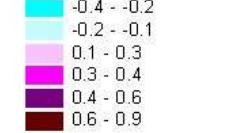
# Acknowledgements

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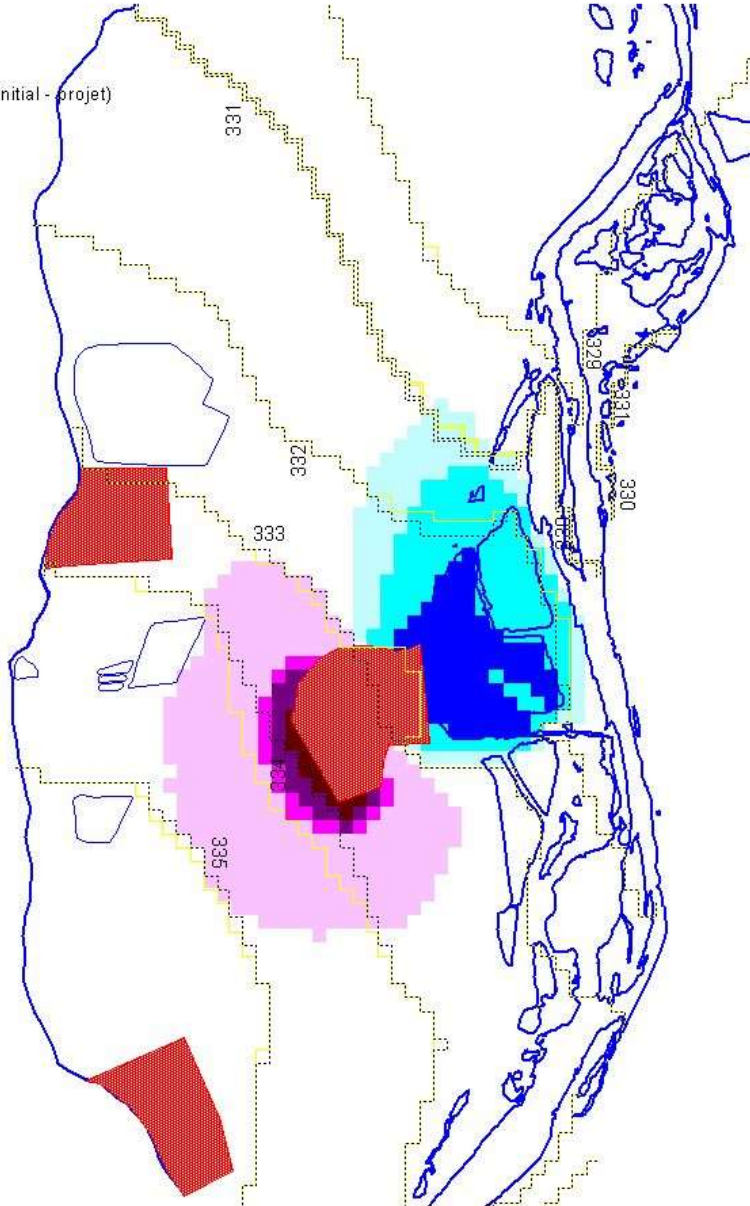
Special thanks to :

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- **Chris Yukna** for English advice and correction;
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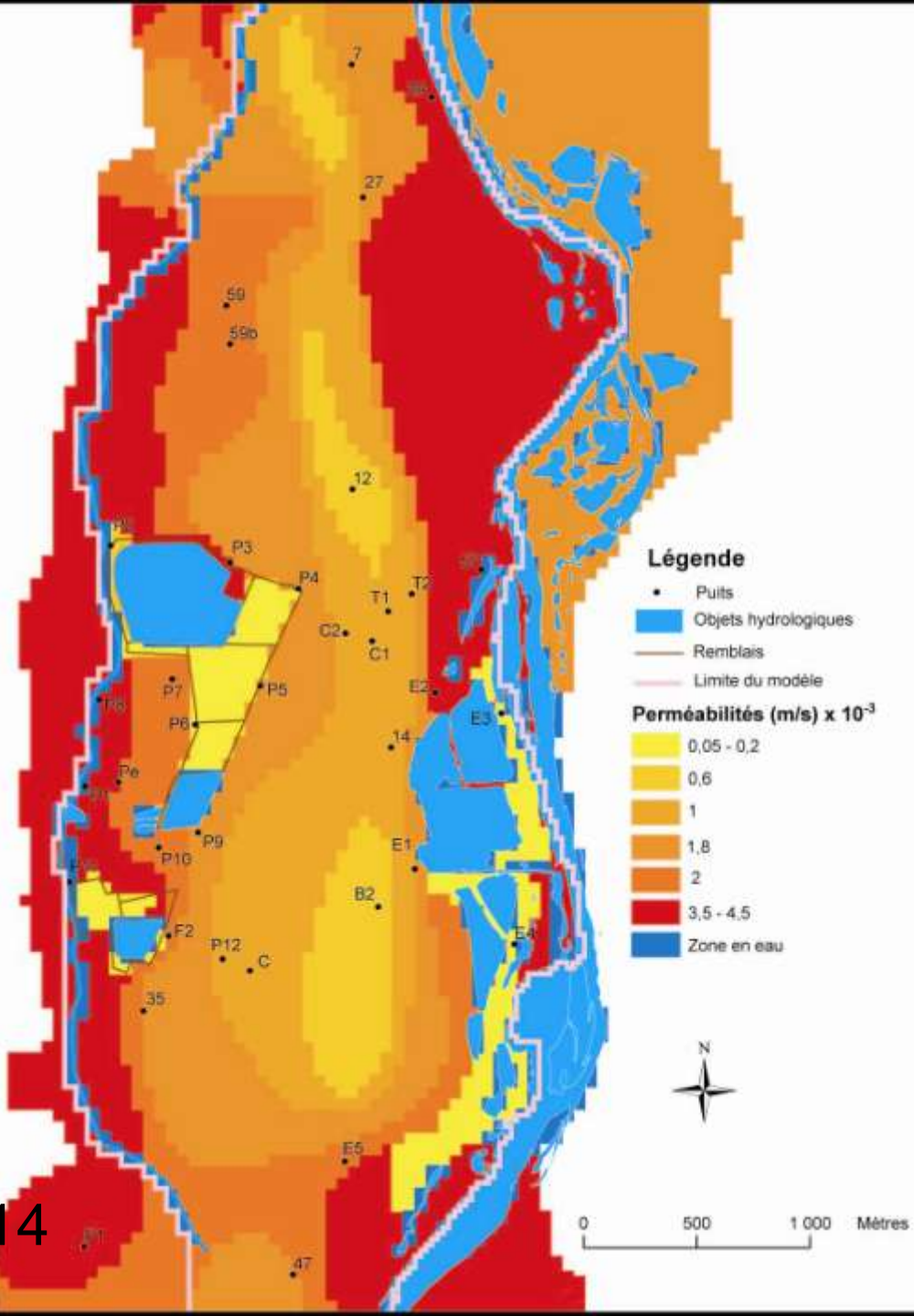


-  isopièze initial
-  isopièze gravières
-  Sites projet.shp
-  Gravière.shp
-  Bassin.shp
-  Aillot.shp
-  Loire.shp
-  rabattement de la nappe (initial - projet)

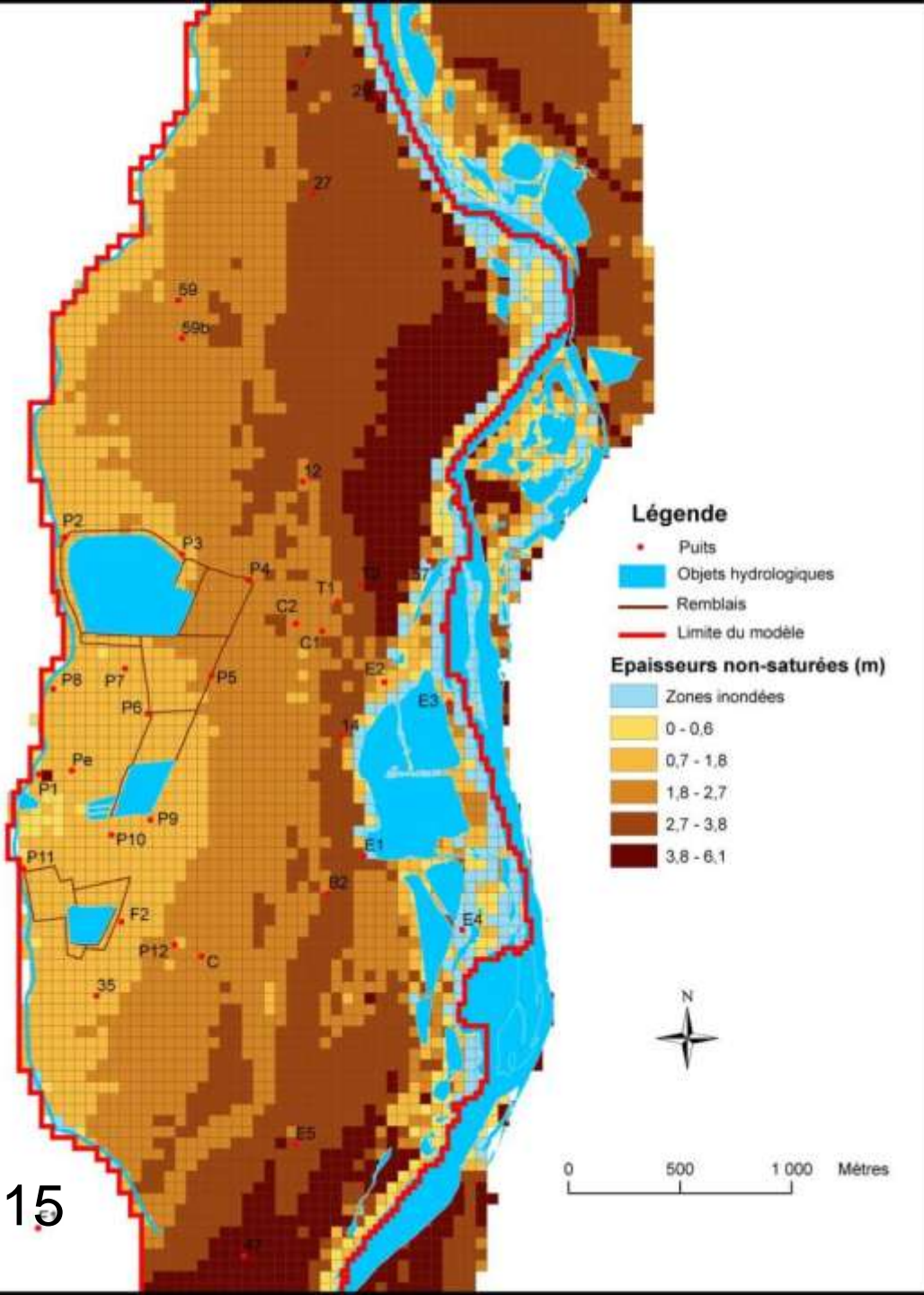
taille de la maille 50 m



## Gravel Pit Impacts on Groundwater: example



# Aquifer Permeability



# Vadoze thickness