Visegrad Fund

# Water Rennovation in Ukraine

University of Debrecen, Faculty of Agricultural and Food Sciences and Environmental Management, Debrecen, Hungary
National University of Water and Environmental Engineering, Rivne, Ukraine
Slovak University of Agriculture in Nitra, Faculty of Horticulture and Landscape Engineering, Slovakia
University of Agriculture in Krakow, Department of Water Engineering and Geotechnics, Poland
Mendel University in Brno, Faculty of Forestry and Wood Technology, Czech Republic

*The project is co-financed by the Governments of the Czechia, Hungary, Poland and Slovakia through Visegrad Grants from International Visegrad Fund. The mission of the fund is to advance ideas for sustainable regional cooperation in Central Europe.*

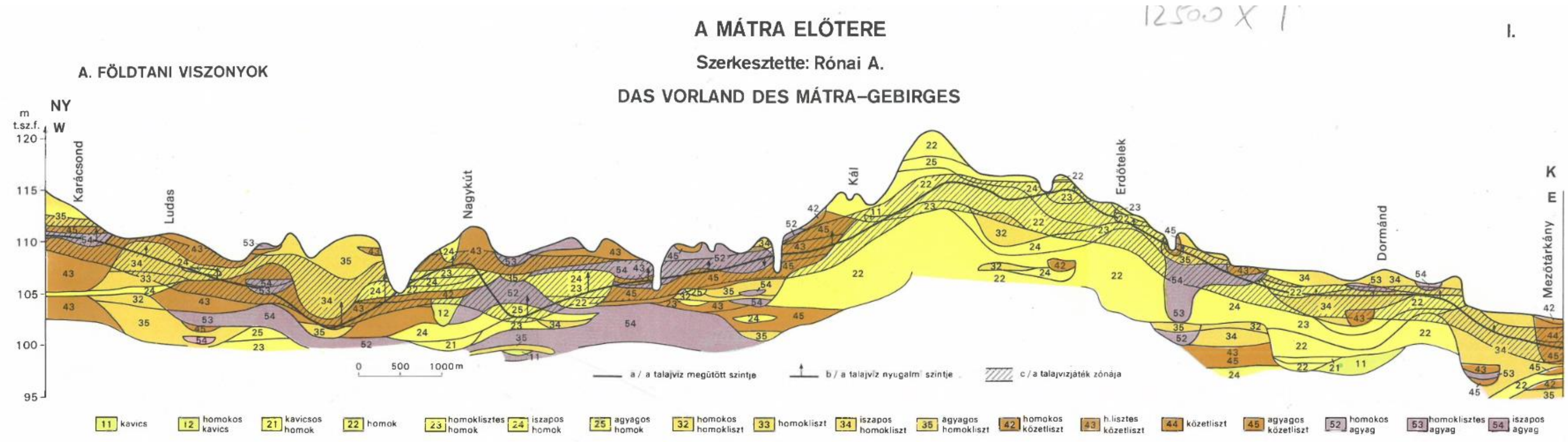
**Water Rennovation in Ukraine**
Project no. 22320101

# Hydrogeological Modeling

Kovács Elza, associate professor

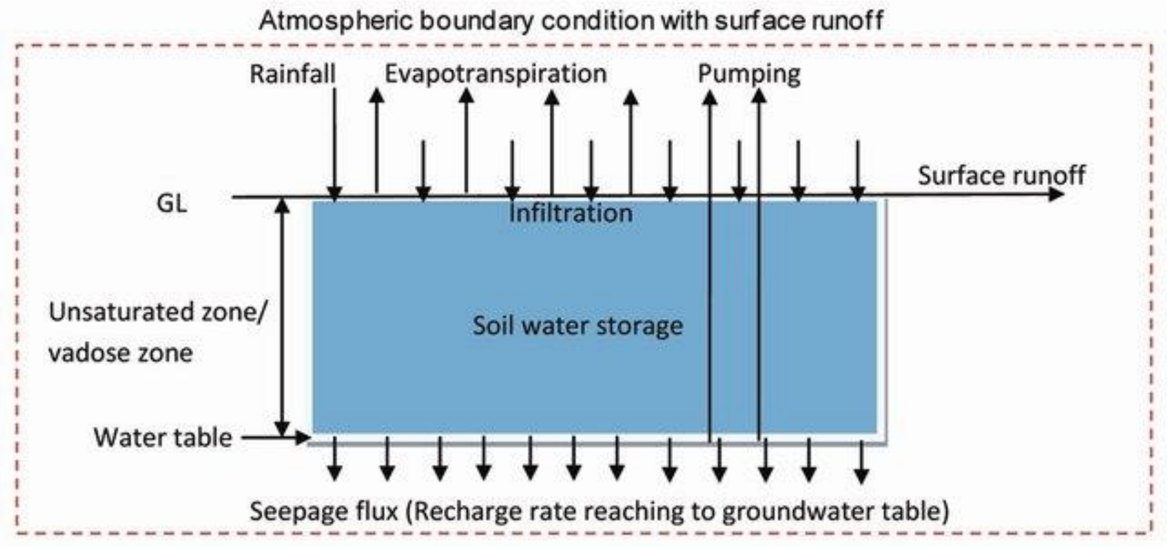
*The project is co-financed by the Governments of the Czechia, Hungary, Poland and Slovakia through Visegrad Grants from International Visegrad Fund. The mission of the fund is to advance ideas for sustainable regional cooperation in Central Europe.*

# Below your feet




| Soil type | Hydraulic conductivity (cm/sec) |
|---|---|
| Clean gravel | 100∼1 |
| Coarse sand | 1∼0.01 |
| Fine sand | 0.01∼0.001 |
| Silty sand | $10^{-3} \sim 10^{-5}$ |
| Clay | $< 10^{-6}$ |

# Below your feet

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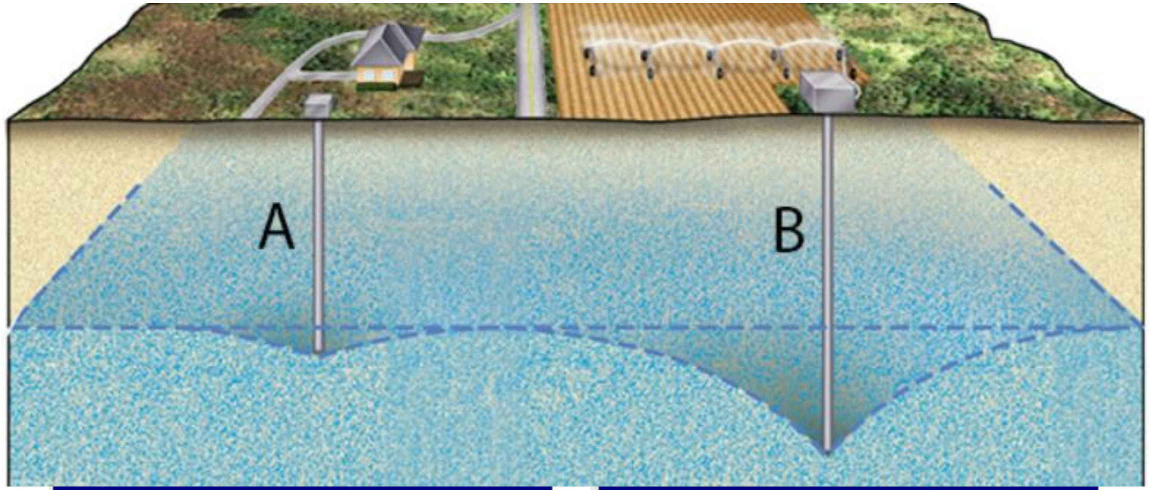


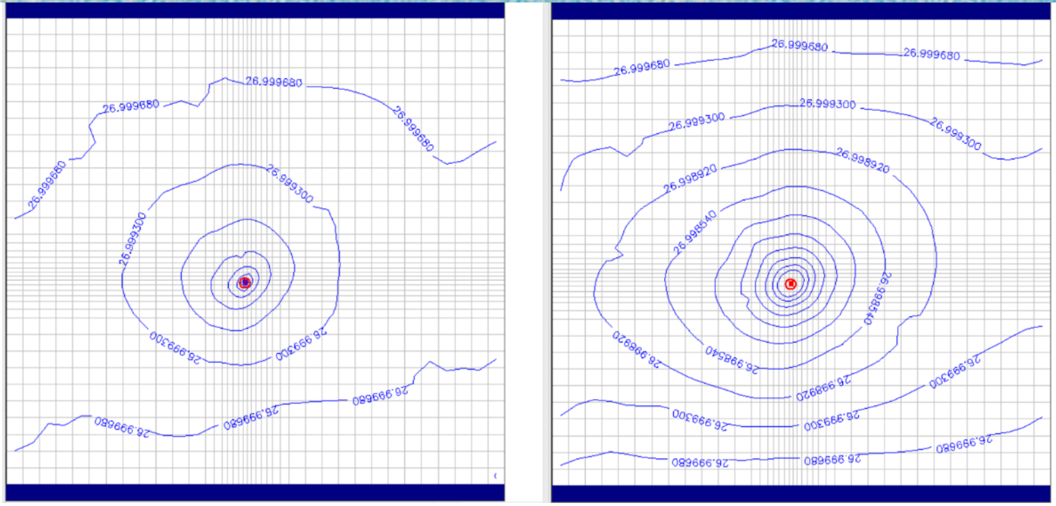

$k = 0.3$ cm $s^{-1}$ $k = 0.6$ cm $s^{-1}$

$n = 0.25$; $Q = -0.001$ $m^3$ $s^{-1}$

# Transport of contaminants underground

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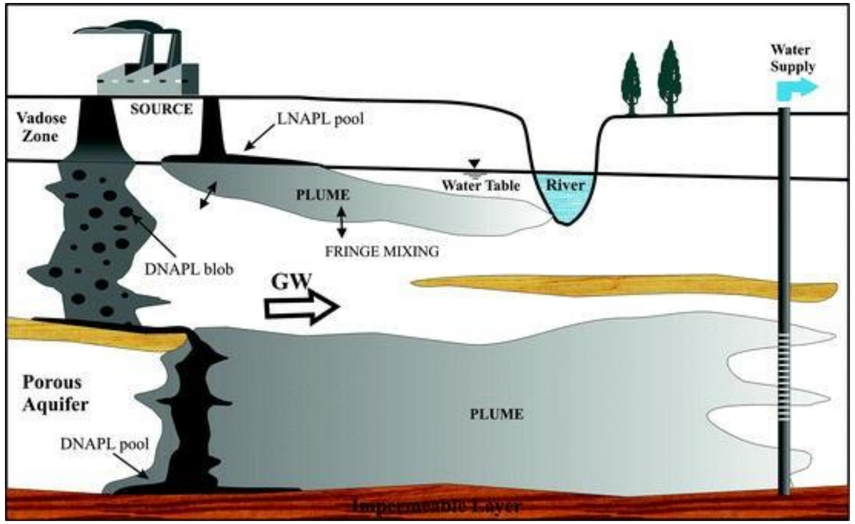
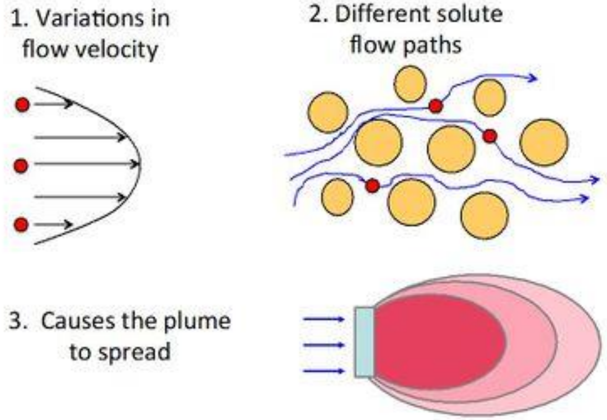
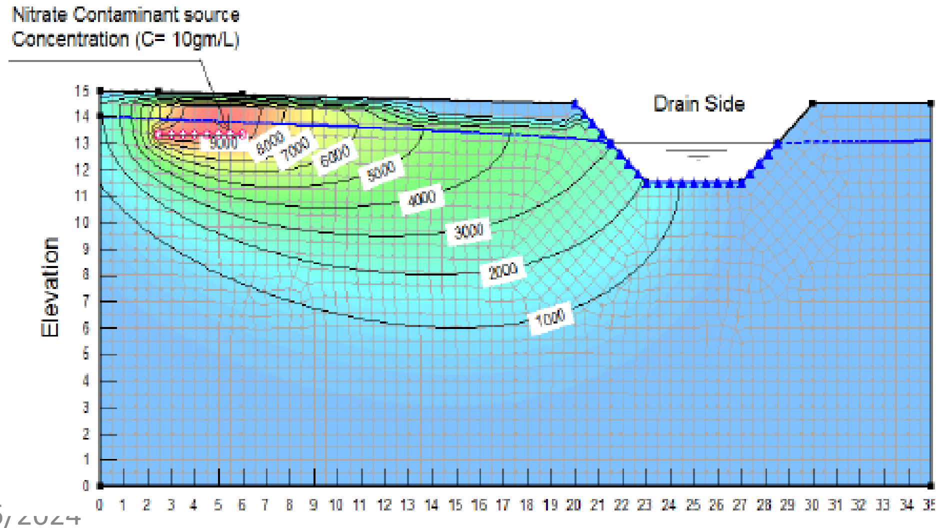
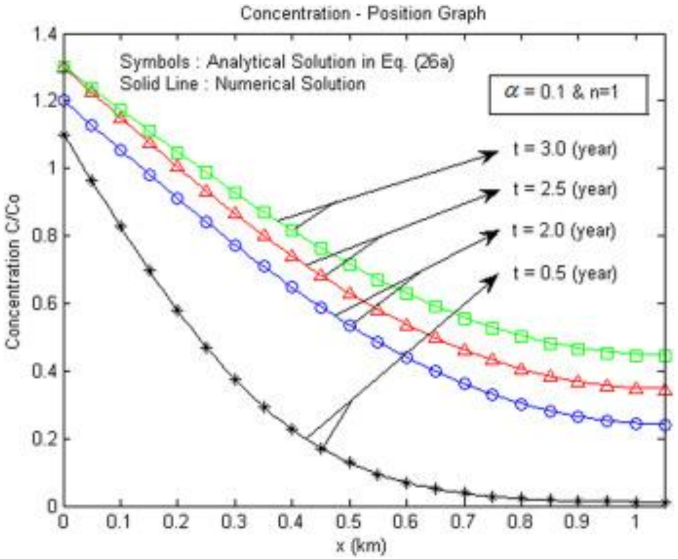
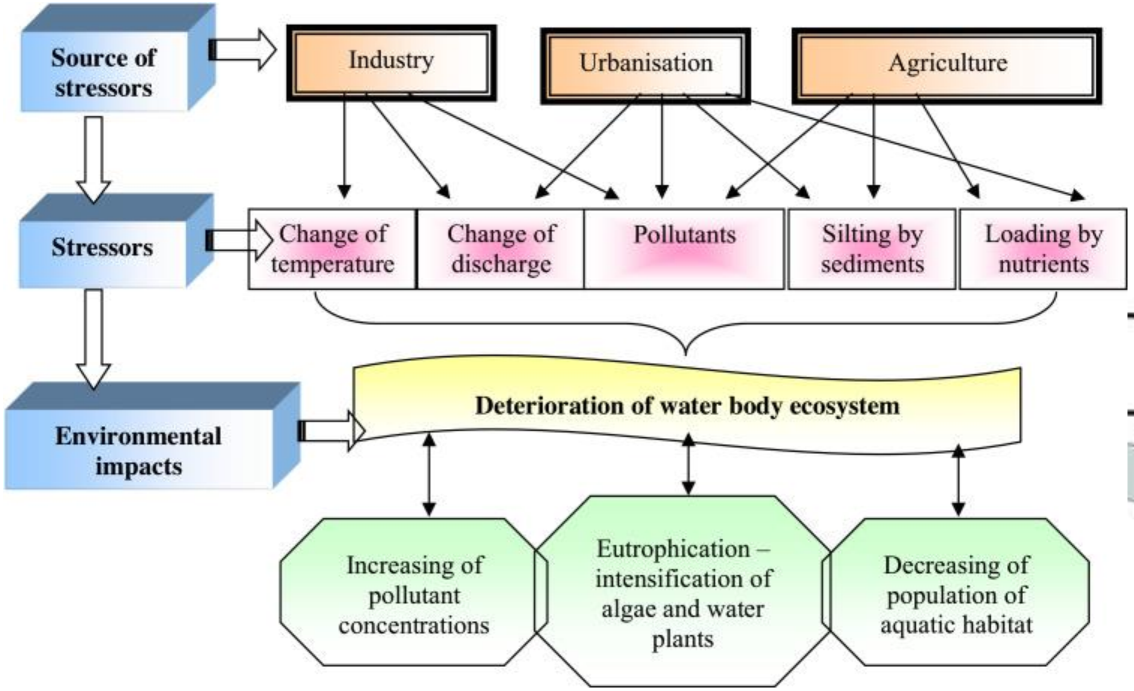


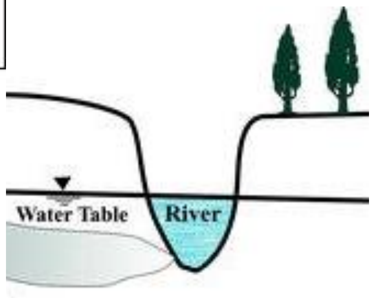



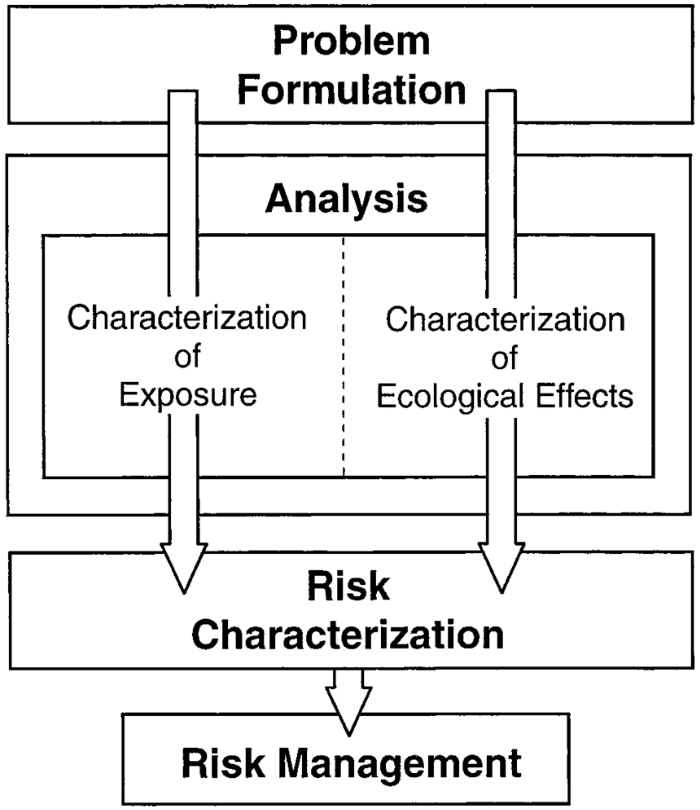



# Environmental risk assessment




| | Severity of Consequences | | |
|---|---|---|---|
| Probability | Low | Medium | High |
| High | Medium Risk | High Risk | High Risk |
| Medium | Low Risk | Medium Risk | High Risk |
| Low | Low Risk | Low Risk | Medium Risk |

| | Score |
|---|---|
| **High Risk** | 3 |
| **Medium Risk** | 2 |
| **Low Risk** | 1 |

# Risk quotient – need for management?

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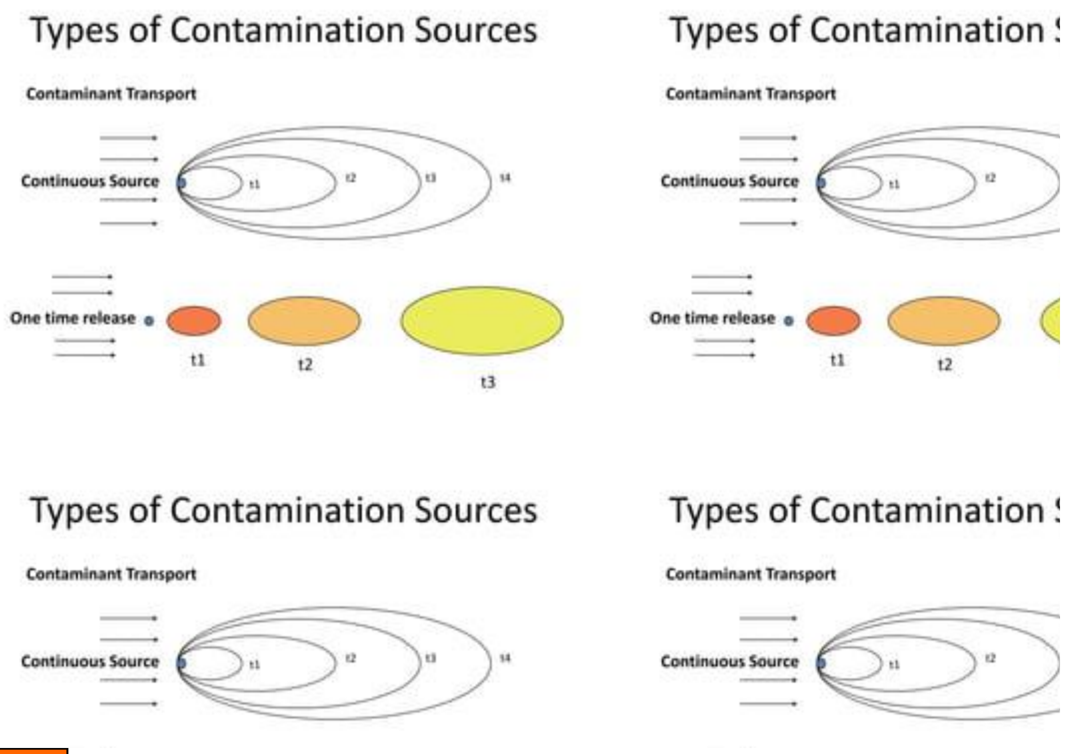
Components:

- ➢Contaminant source (effective factor)
- ➢Transport process
- ➢Receptor (exposed target)

Calculation:




emission → Modeling of distribution → Calculated env. concentration (x,y,z; t)

effect → extrapolation (test) → Predicted max. acceptable exposition

X/Y= risk quotient

# Fate and transport

X, Y: evaluated, modeled, extrapolated

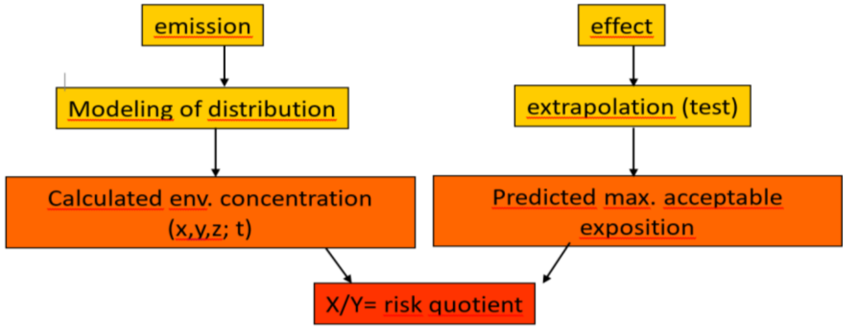
<u>Fate of contaminants:</u> transformation, degradation, adsorption, absorption, dilution, distribution between own forms

Modeling: algorithms, boundary conditions, neglected relationships (data requirement)

transport models (contaminant – medium interactions)

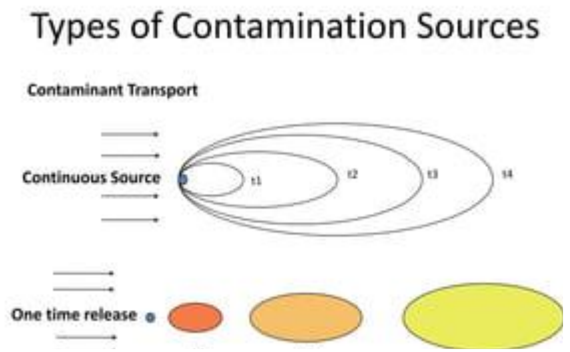
Y: „*max. acceptable*” NOAEL

- mobil, mobilizable
- bioavailable, potentially bioavailable

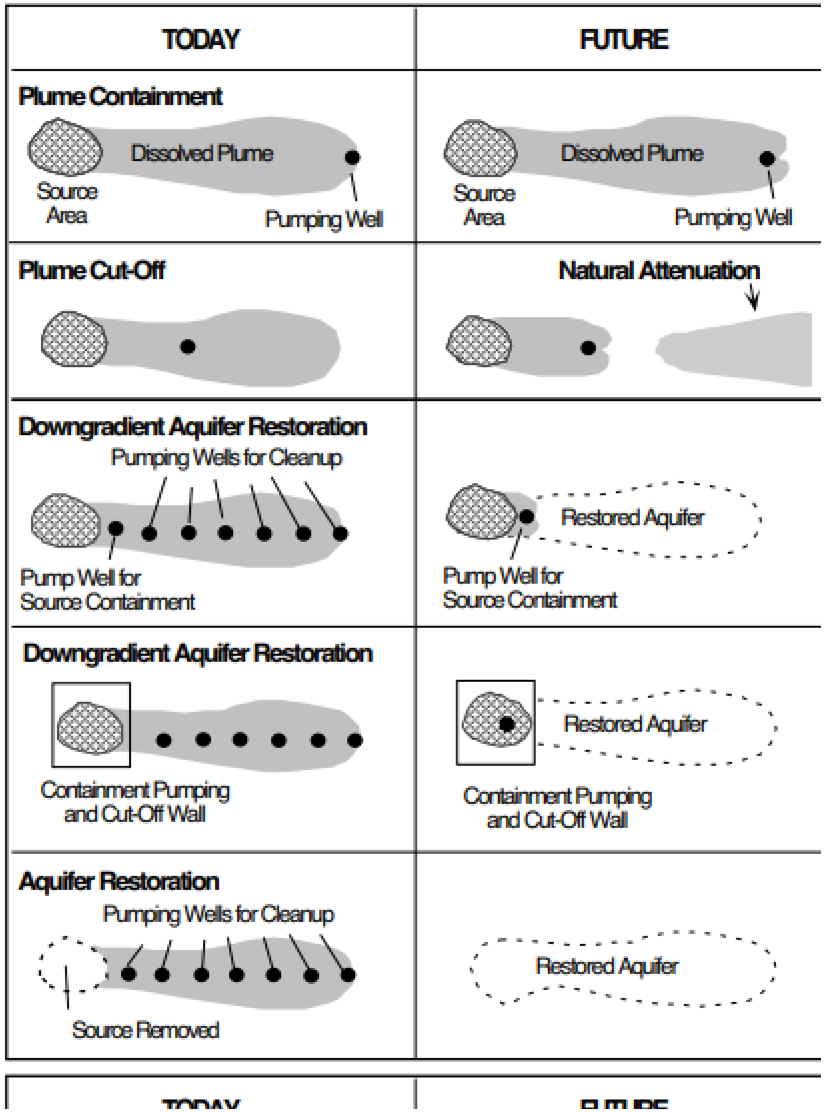



**<u>Calculation of X</u>:**

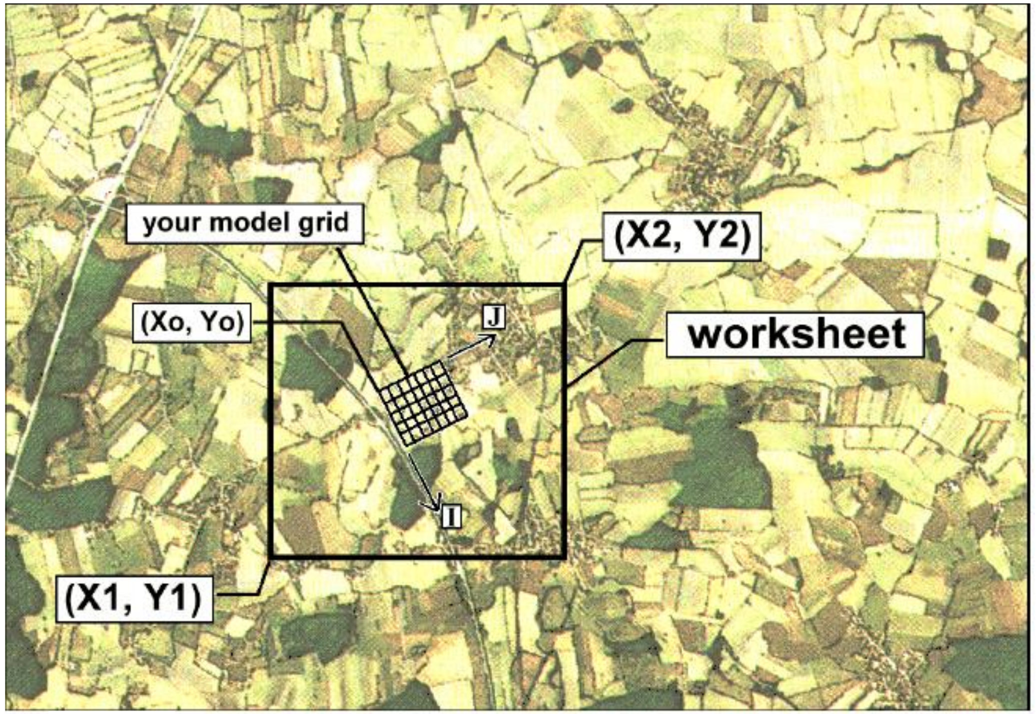
- Adequate and sufficiant data for distribution modeling (parametrization)
- Standard environment
- Secondary data (degradation, adsorption, etc.)
- Emission concentration (given, assessed)
- Modeling process (hydrogeological/hydrodinamical in soil, and groundwater)
- Calculation for x,y,z; t



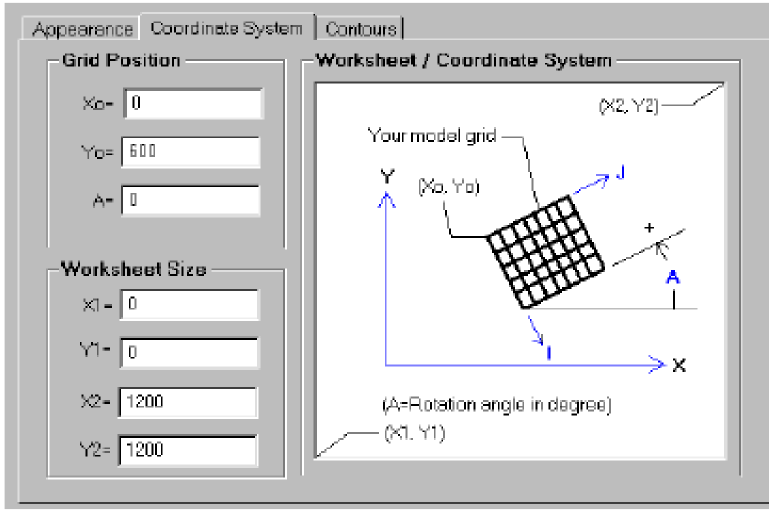
# Clean-up: pump and treat

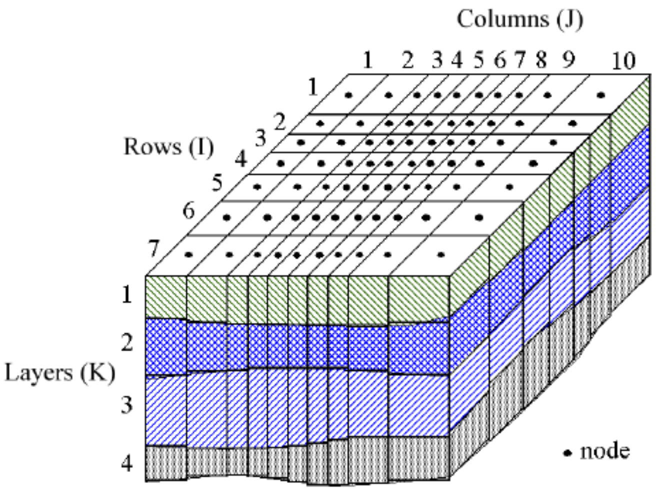


# Modeling




Defining the location and orientation of the worksheet and model grid



# 3D finite-difference grid

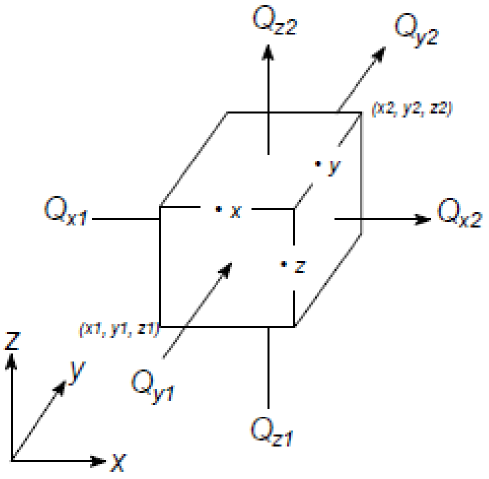
The grid is created using structured, rectangular cells.

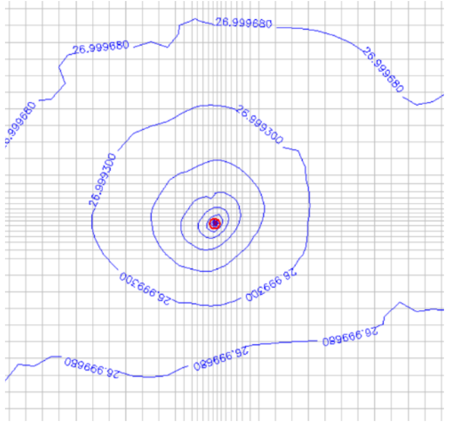
The finite difference solution is mass-conservative.

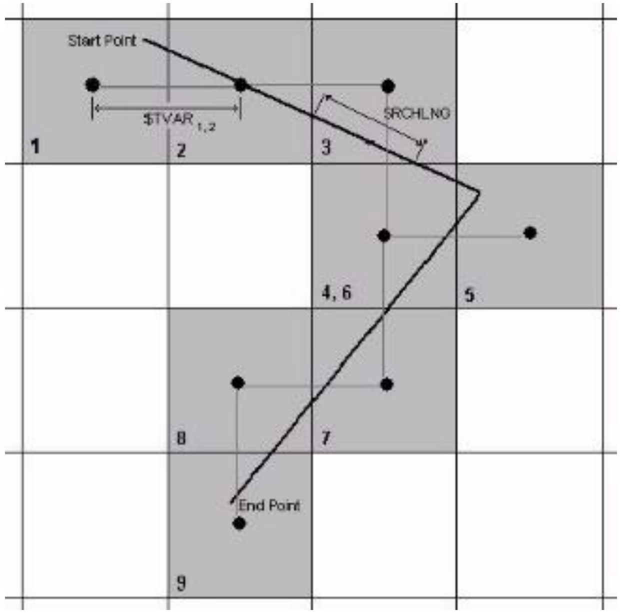
Grids are necessary to be refined around areas of interest, such as wells.

Discontinuous layers (complex geology), steep gradients in the stratigraphy are difficult to represent; this can result in disconnected cells which causes problems with running the model.

MODFLOW requires model layers to be continuous across the entire model domain.

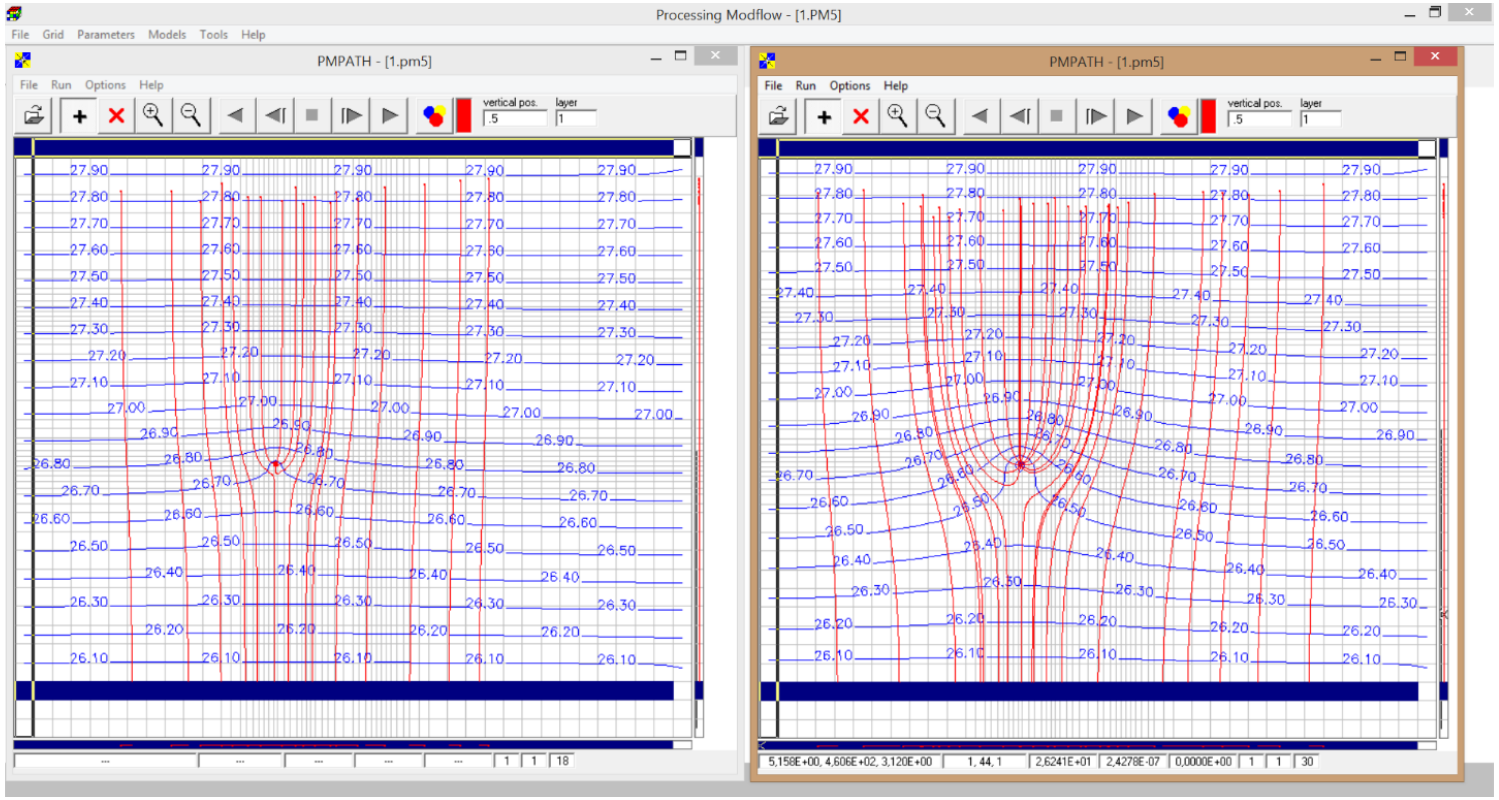


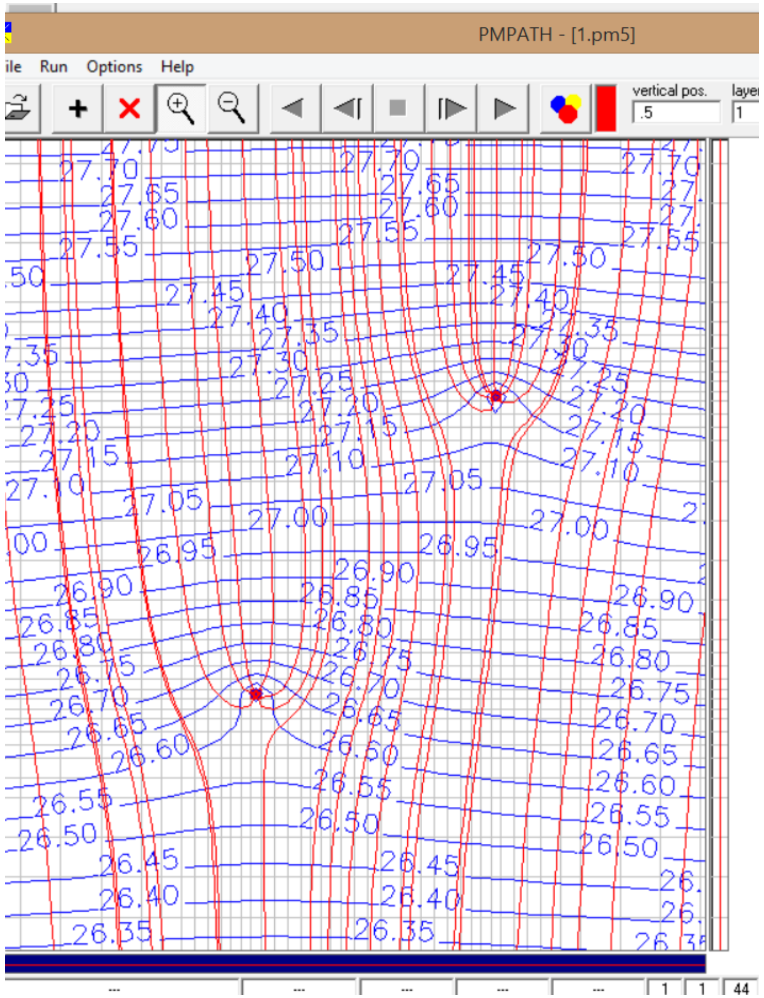



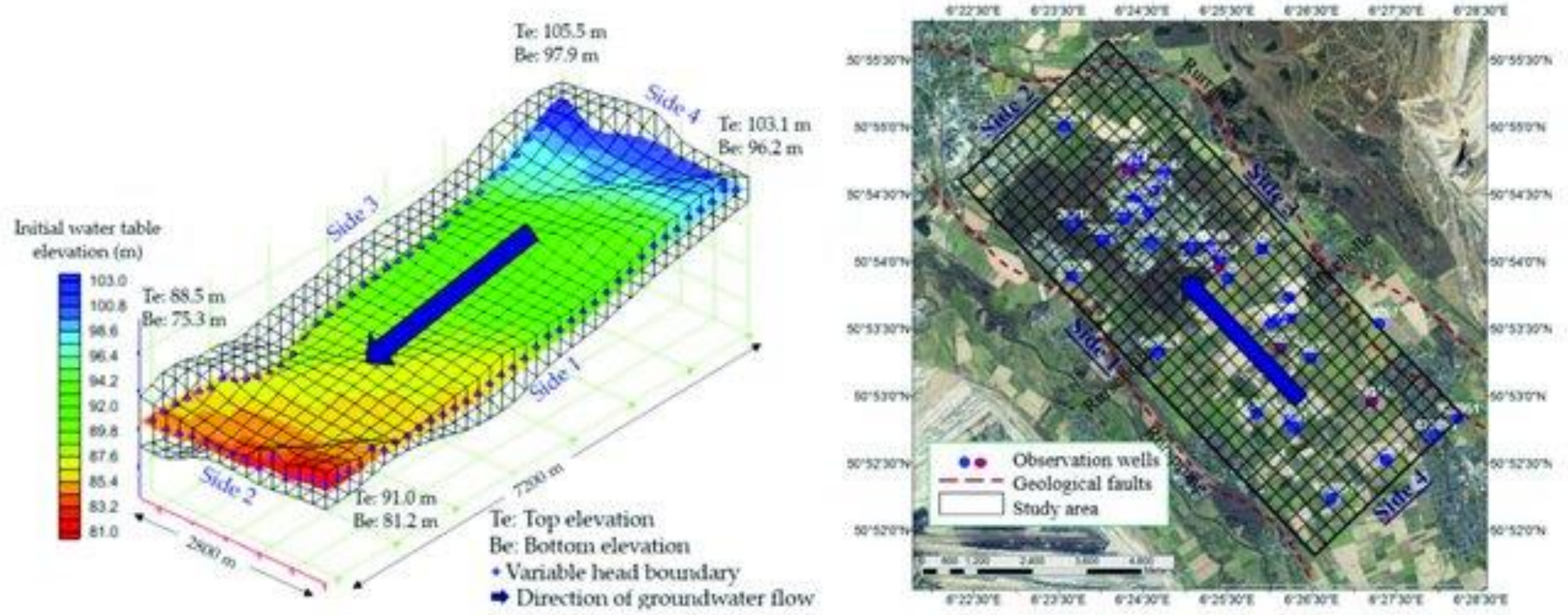
# Water „particles” flow direction Processing Modflow

- 1 well - different Qs, 2 wells



# Visualization




The initial water table elevation, MODFLOW grids, boundary condition, the general groundwater flow direction



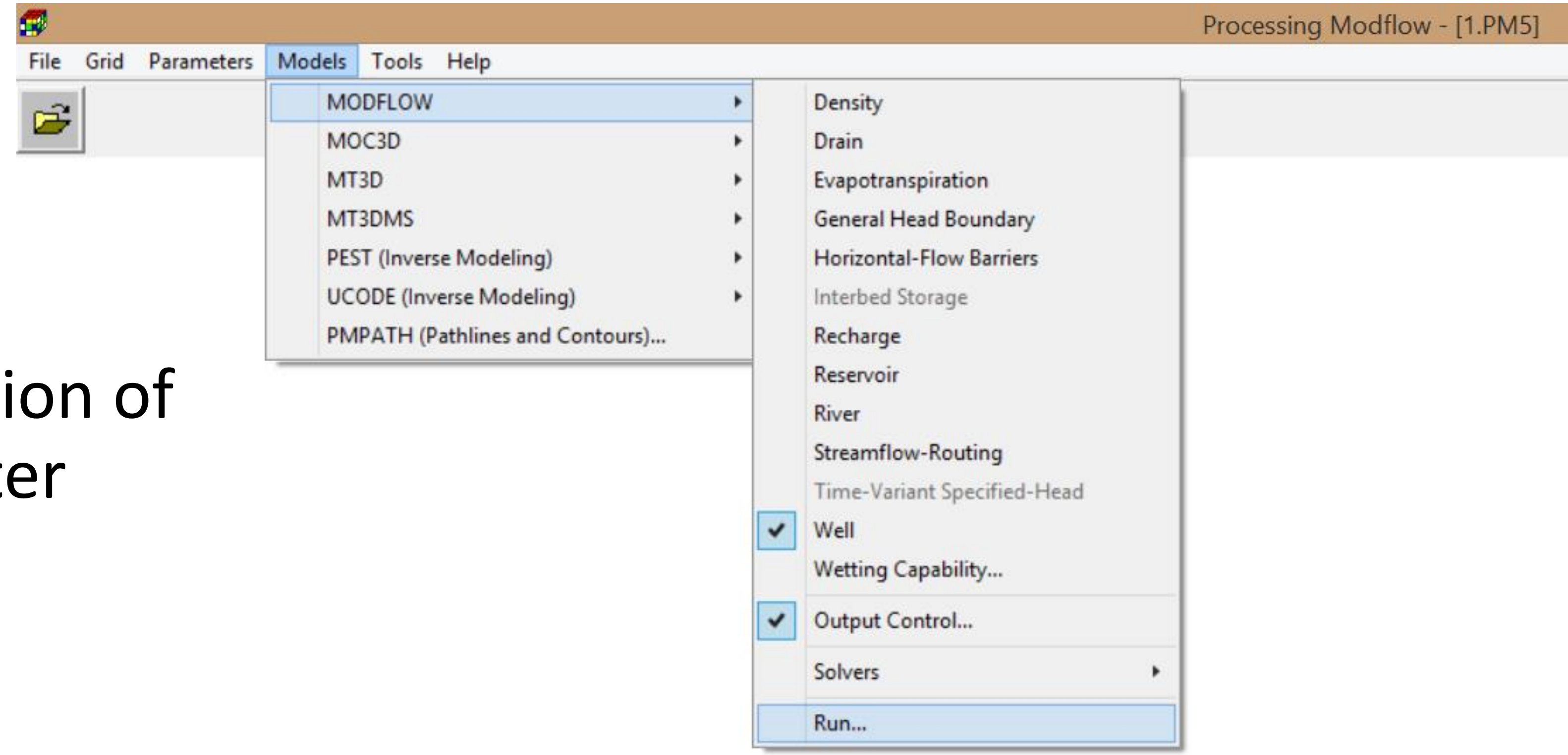
DOI: 10.3390/w12041019

# MODFLOW, a modular 3D groundwater model

by U. S. Geological Survey

for description and prediction of the behavior of groundwater systems.

MODFLOW can simulate…



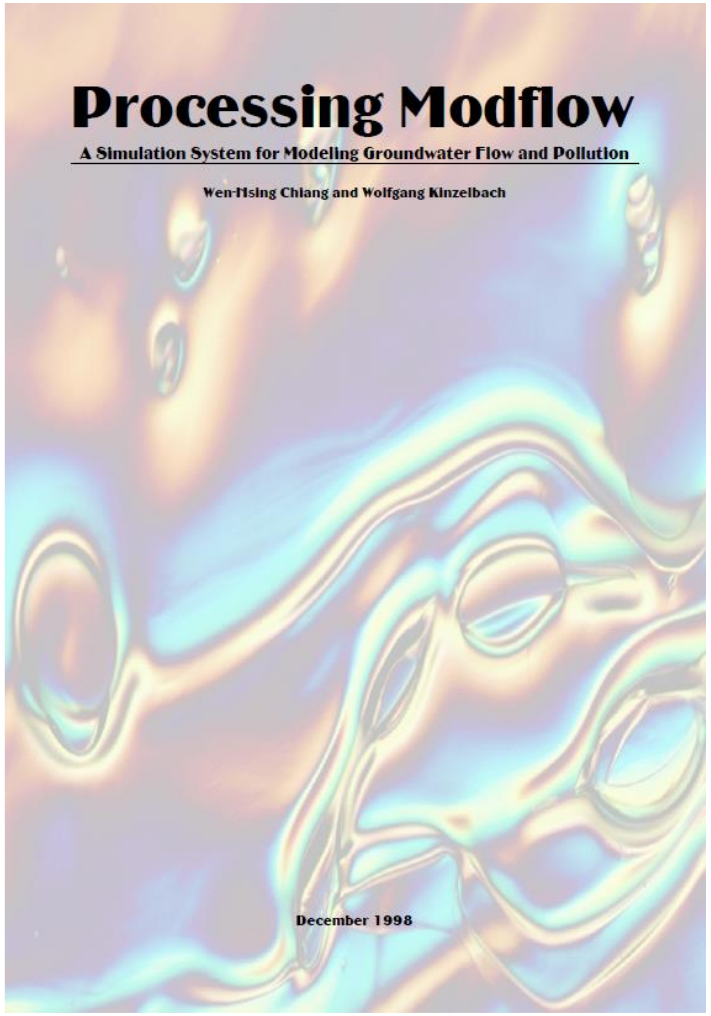

**https://www.pmwin.net/pmwin5.htm**

Wen-Hsing Chiang and Wolfgang Kinzelbach: Processing MODFLOW — a Simulation System for Modelling Groundwater Flow and Pollution, January 1998

# CASE STUDY

Tutorial 1

in Users' Guide of PROCESSING MODFLOW



# Unconfined Aquifer System with Recharge

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An unconfined aquifer is a coarse grained sand with a measured isotropic hydraulic conductivity of 160 m/day, the specific yield has been assessed as 0.06.

Recharge to the aquifer only occurs throughout the 4 month wet season at a rate of $7.5 \times 10^{-4}$ m/day, outside the wet season there is no recharge to the aquifer.

The elevations of the aquifer top and bottom are 25 m and 0 m, respectively.

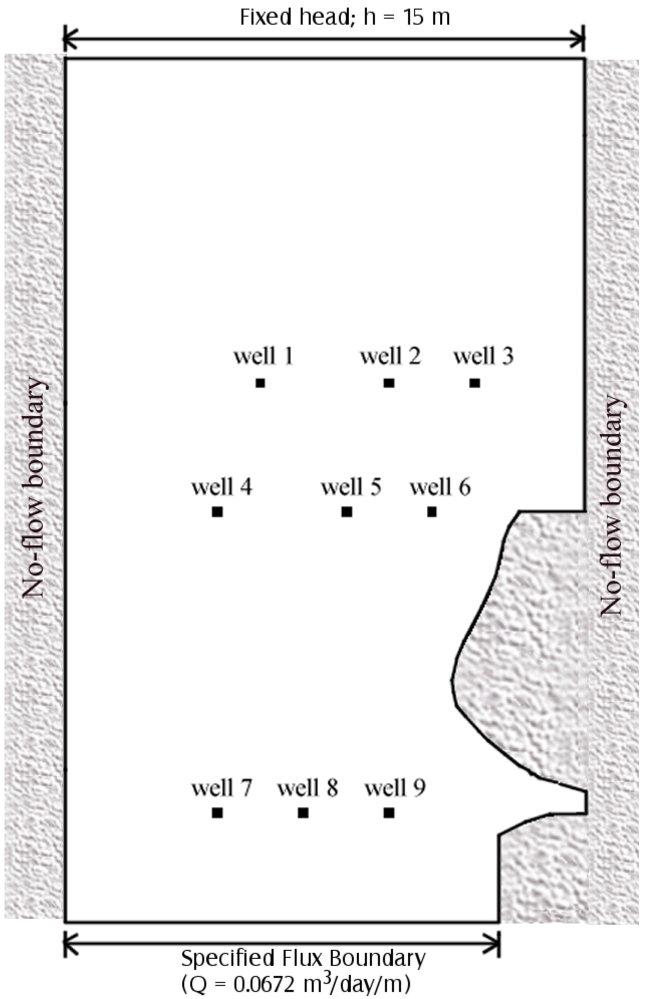
The area of interest is 10000 m long and 6000 m wide and is bounded by "no flow" zones to the east and west.

There is also a volcanic mountain in the south east corner of the model area.

To the north, an area of constant hydraulic head exist with a value of 15 m.

The southern boundary is a specified flux boundary with an inflow rate of 0.0672 $m^3$/day per meter.

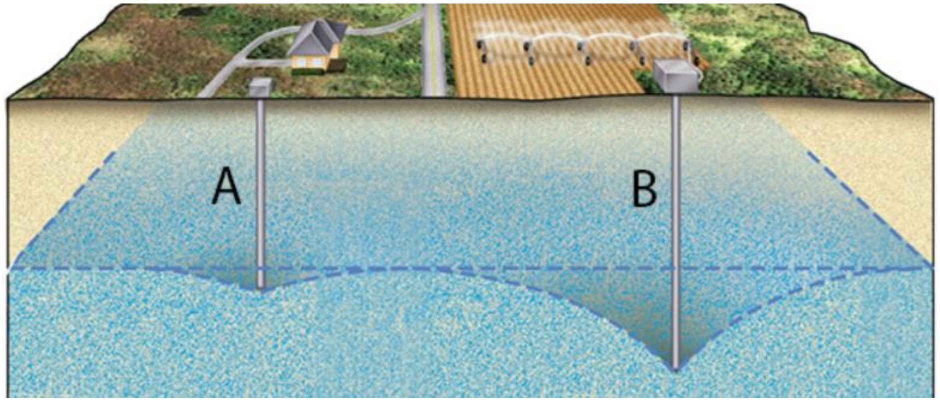
A total of nine wells in the area are pumped at 45 l/s (3888 $m^3$/d) each during the 8 month dry season to supply water for irrigation and domestic purposes.

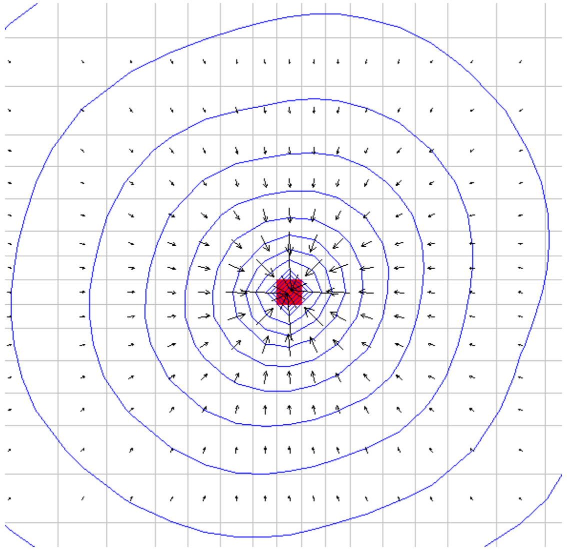


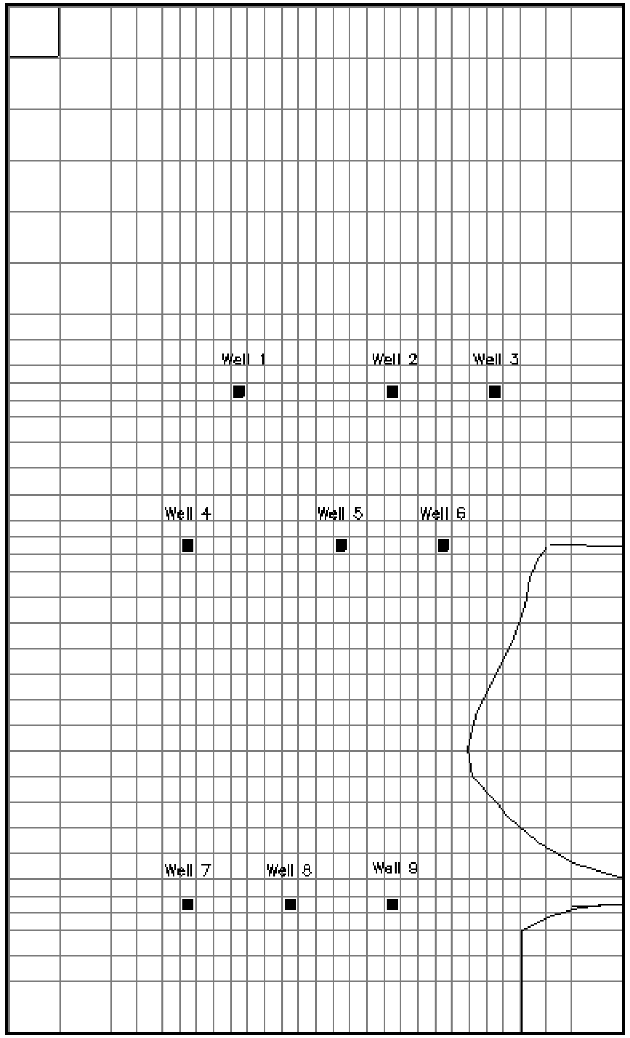
# Defining model size, model grid

| | | |
|---|---|---|
| Layers | Number | 1 |
| Columns | Number | 12 |
| | Size | 500 |
| Rows | Number | 20 |
| | Size | 500 |

**To refine the mesh around the pumping wells**



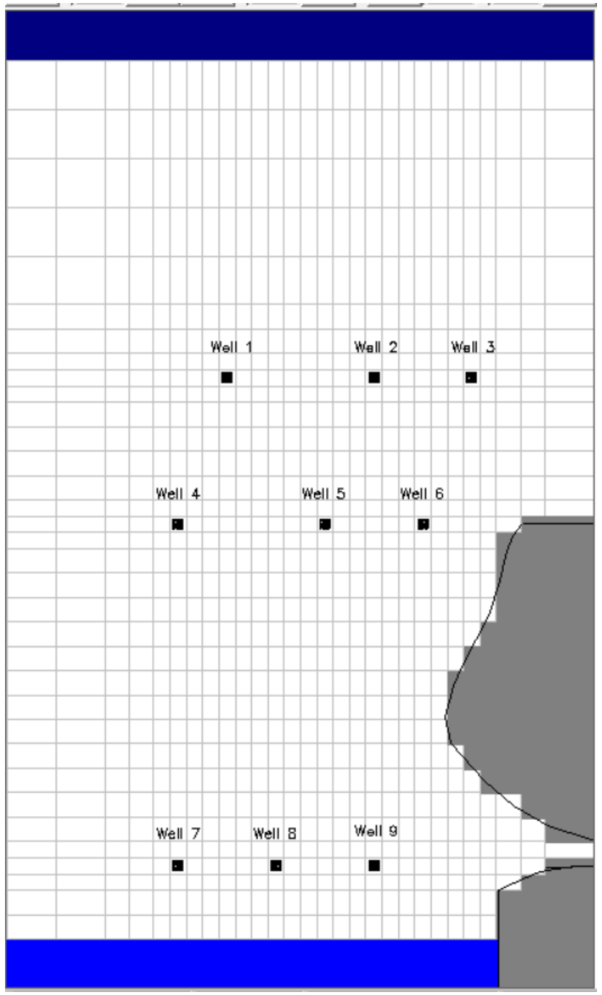





# Assign model data

- Aquifer type: unconfined
- Flow boundaries
- Aquifer geometry: top, bottom
- Aquifer parameters: horizontal hydraulic conductivity, specific yield – full matrix
- Initial conditions: initial hydraulic heads (North first row 16 m)
- Time parameters
- Recharge parameters: full matrix, mean of two seasons
- Specified flux boundary: south last row, calculated m$^3$/day per cell

| | | |
|---|---|---|
| active | = | 1 (or other positive integers) |
| inactive | = | 0 |
| fixed-head | = | -1 (or other negative integers) |



# Run flow simulation

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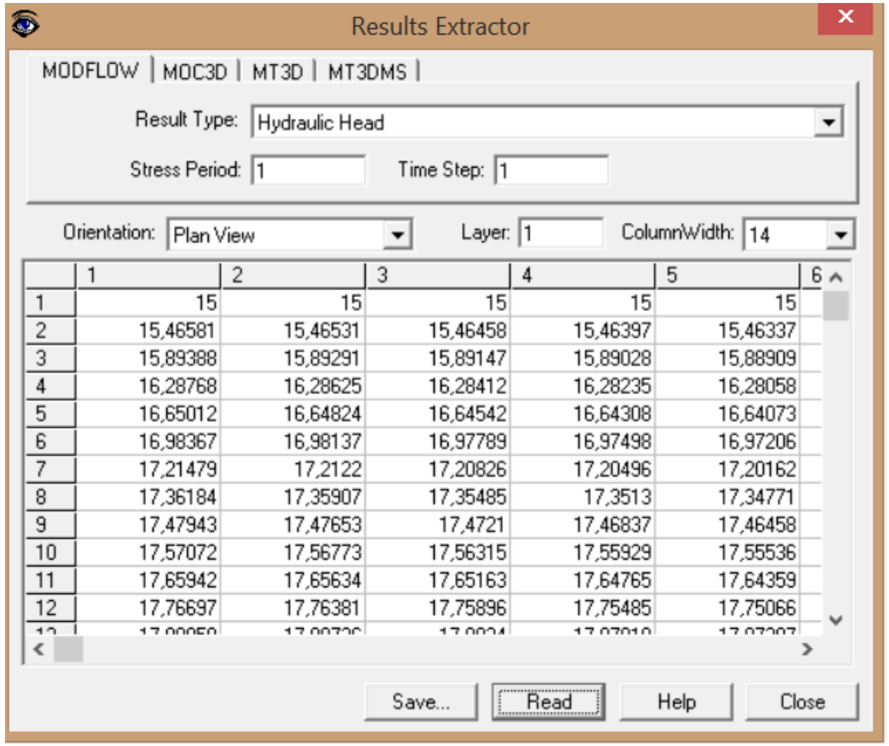
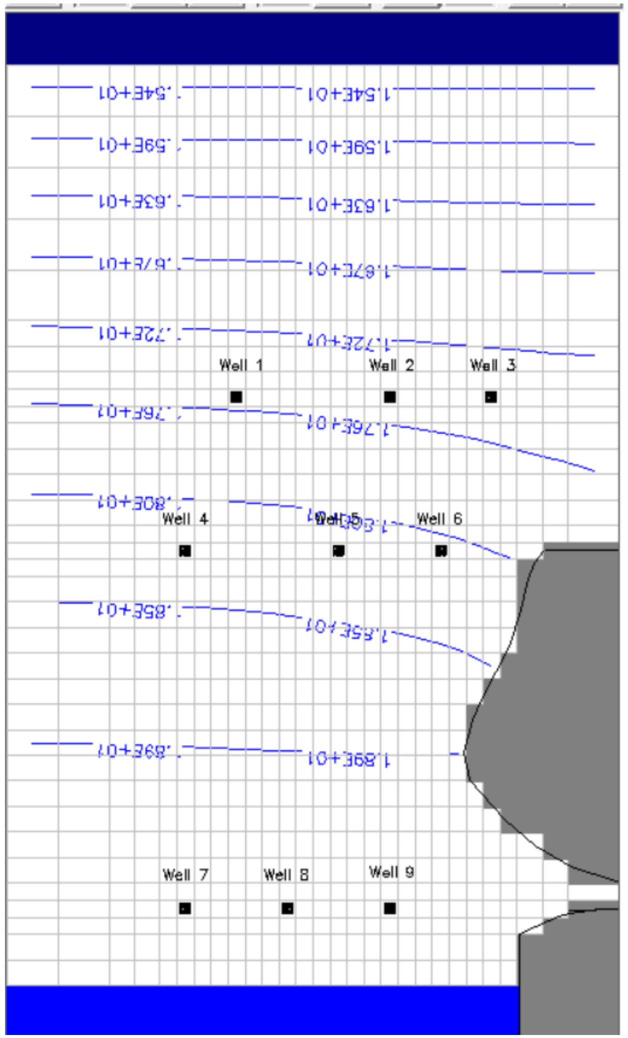
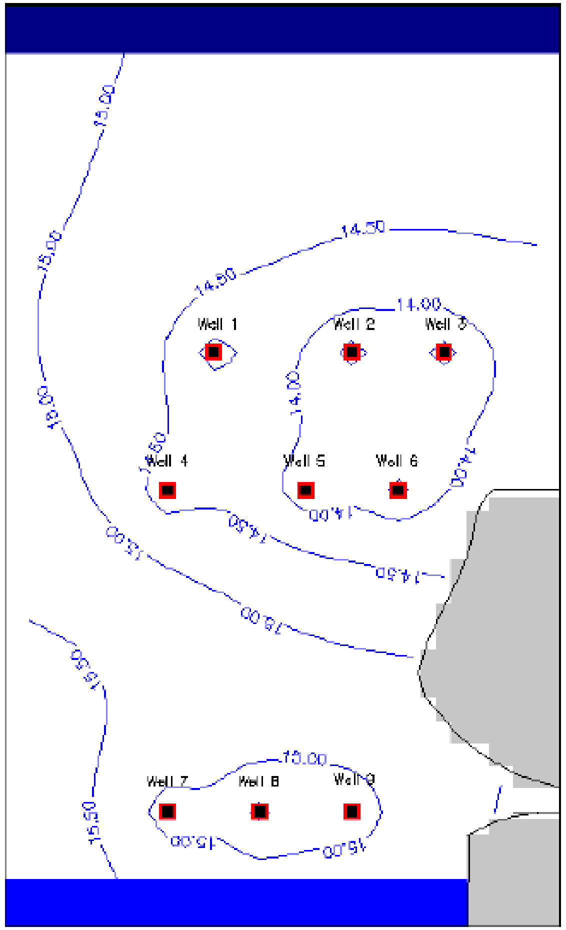
- Steady-state head distribution, wells are not in use



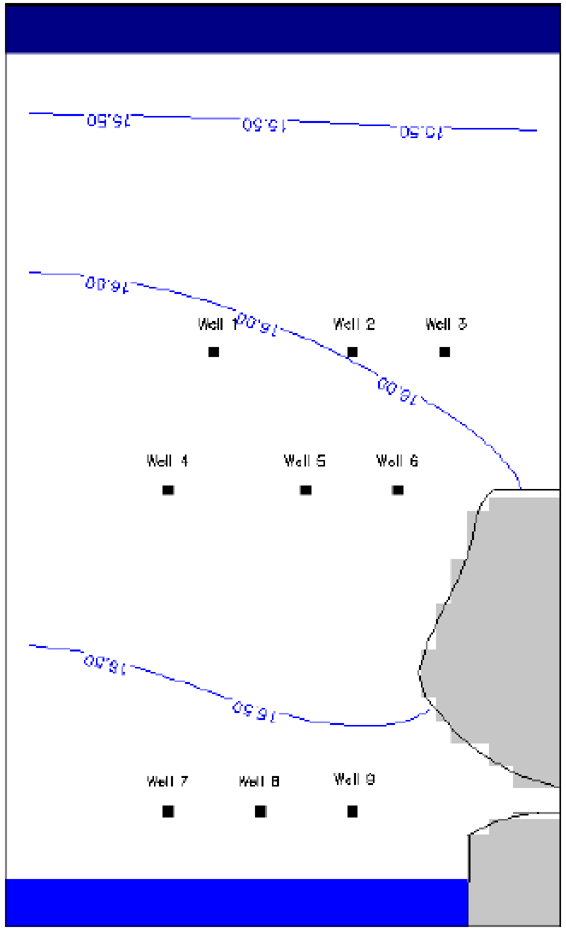



# Run flow simulation

- Transient flow simulation, wells are in use in dry seasons

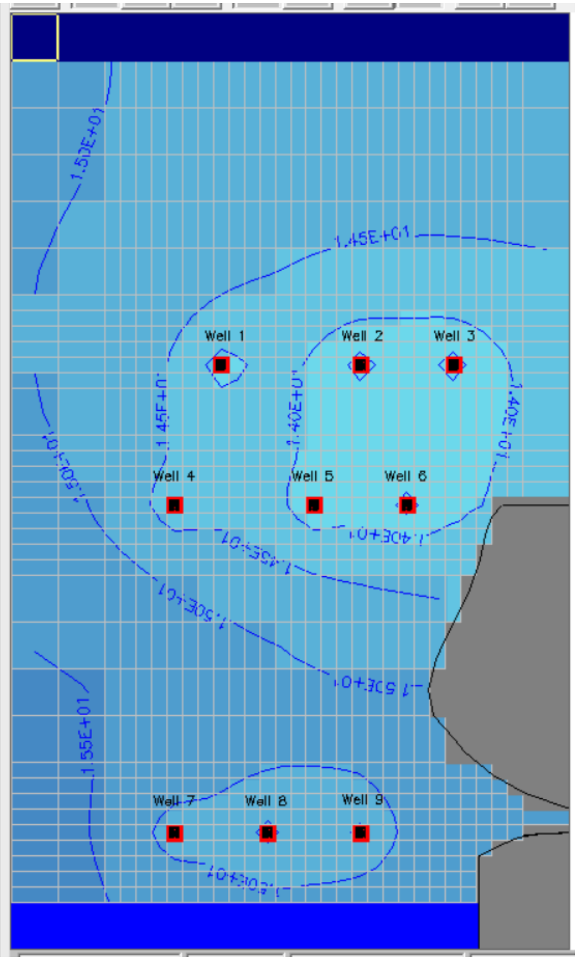


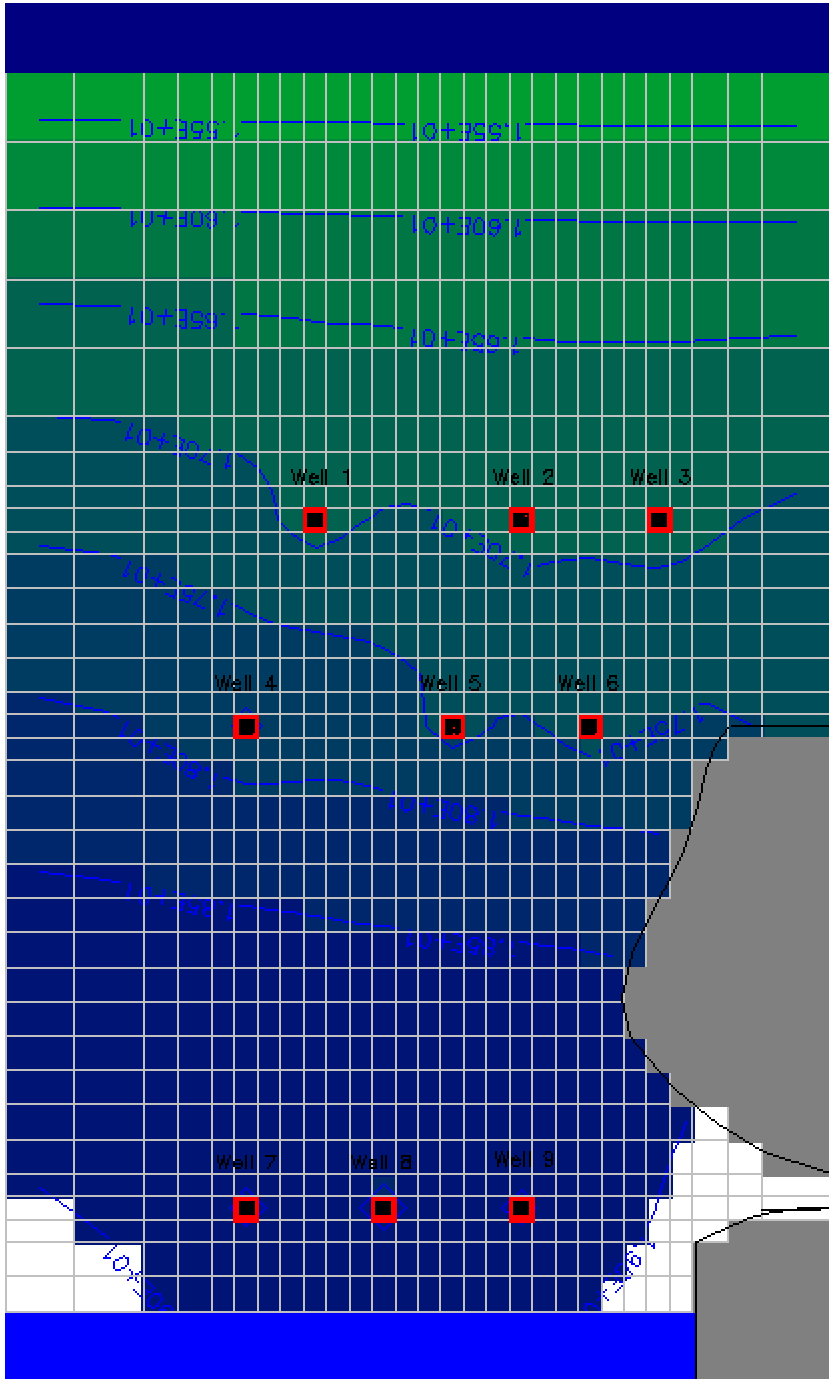

Head distribution after 240 days of pumping (period 1, time step 12)




Head distribution after 120 days of recharge (period 2, time step 6)

# Animation



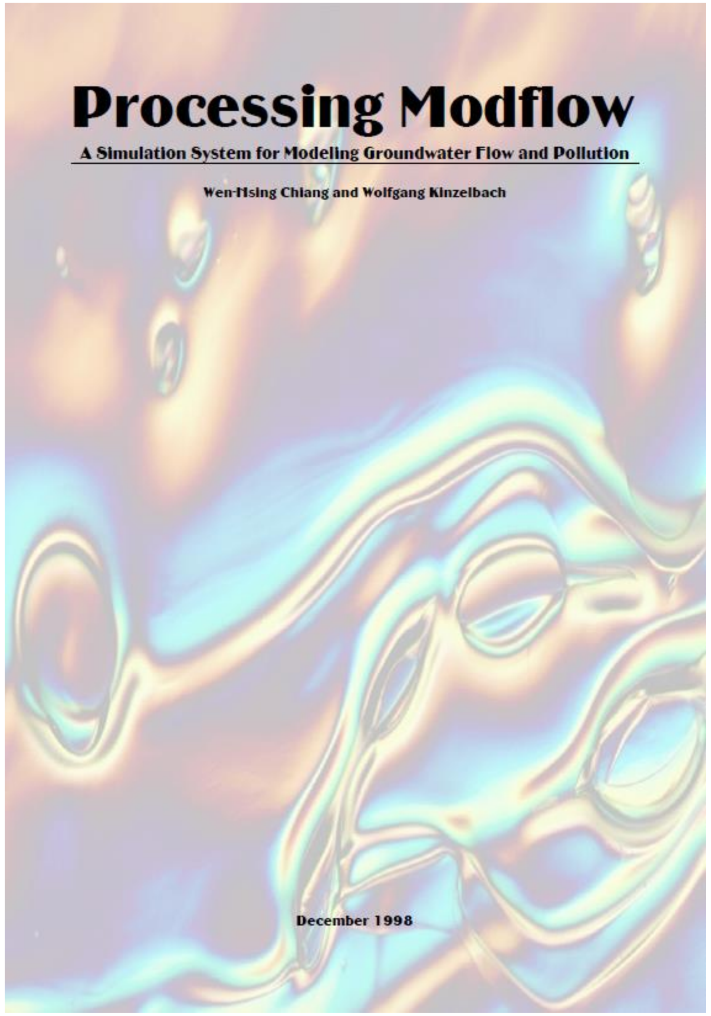




Visegrad Fund

# CASE STUDY

Tutorial 2

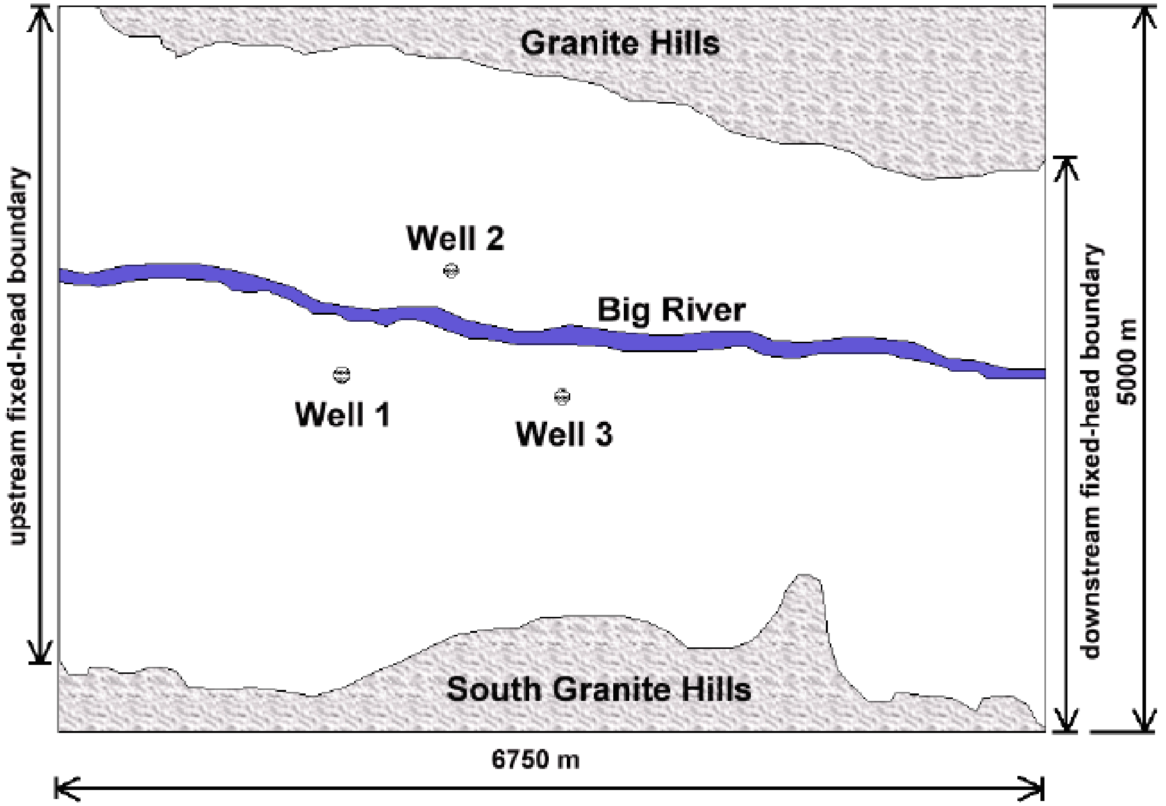
in Users' Guide of PROCESSING MODFLOW



# Confined and unconfined aquifer system with river

Visegrad Fund

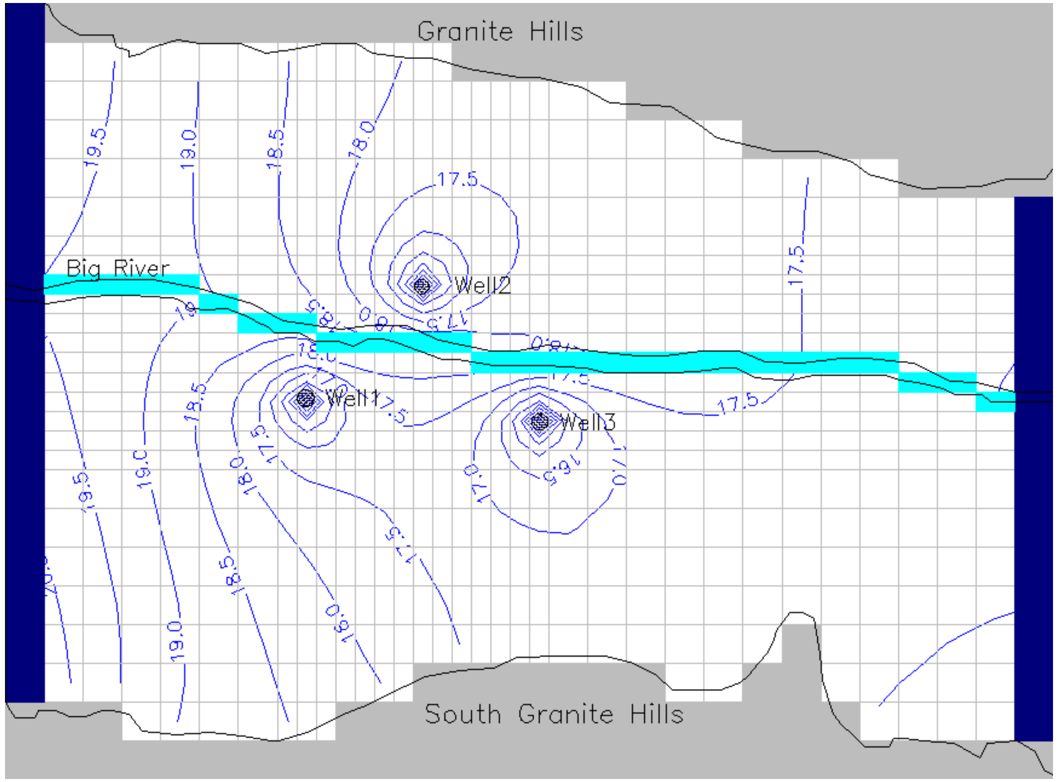
- A river flows through a valley bounded to the north and south by impermeable granitic intrusions.
- The hydraulic heads at the upstream and downstream are given as fixed-head boundaries.
- The river forms part of a permeable unconfined aquifer system ($K_h$ = 5 m/day, $K_v$ = 0.5 m/day, $n_e$= 0.2)
- which overlies a confined aquifer ($K_h$ = 2 m/day, $K_v$= 1 m/day, specific storage $S_s = 5 \times 10^{-5}$, $n_e$ = 0.25).
- A 2 m thick silty layer ($K_h$ = 0.5 m/day, Kv = 0.05 m/day, $n_e$ = 0.25) separates the two aquifers.
- Three pumping wells pumping at 500 $m^3$/day each abstract water from the confined aquifer.

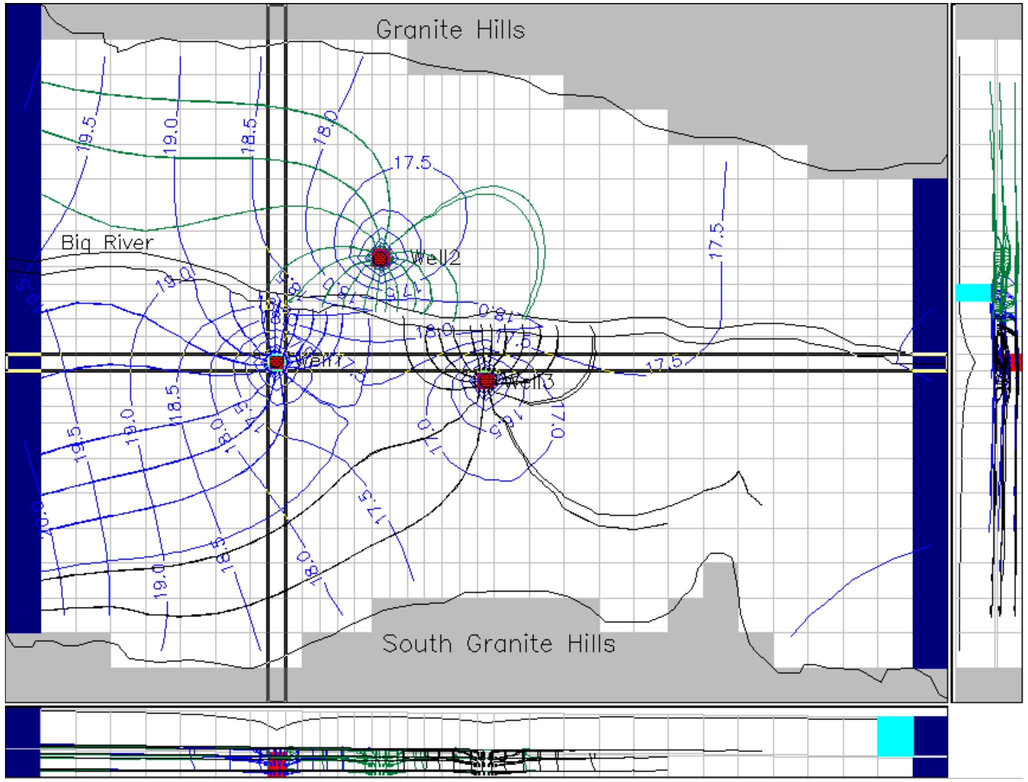


# Capture zone of the wells

Steady-state head distribution of the first layer (1)

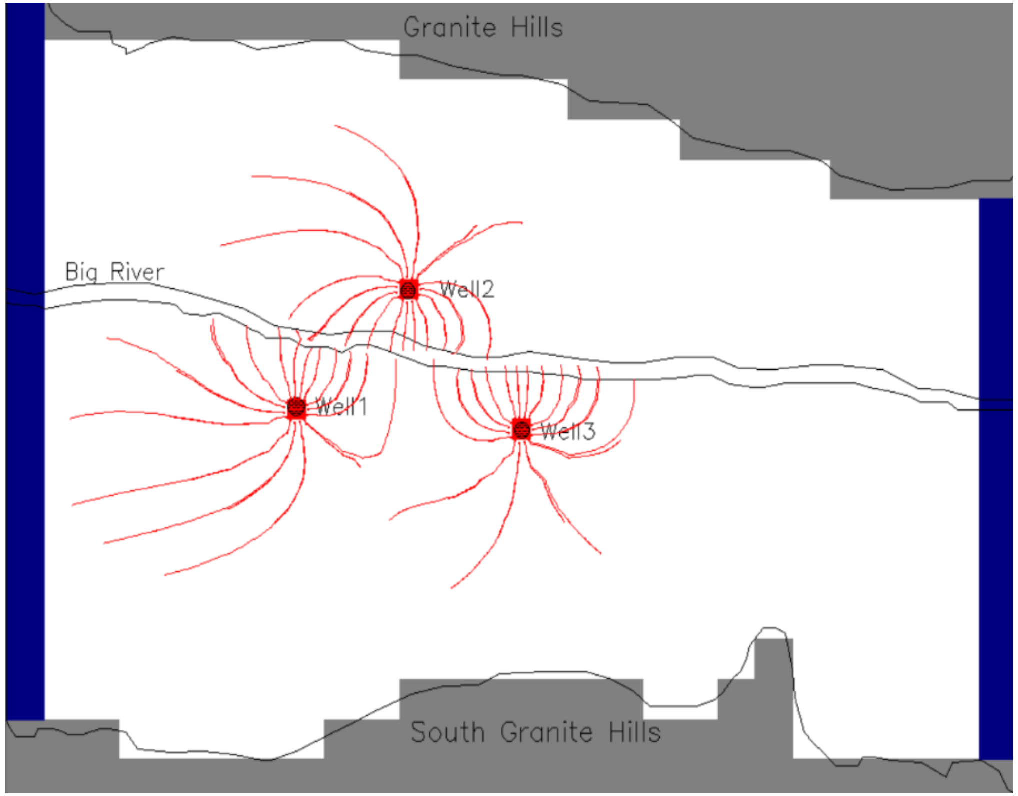
Steady-state head distribution in the third layer and capture zones of wells (2)



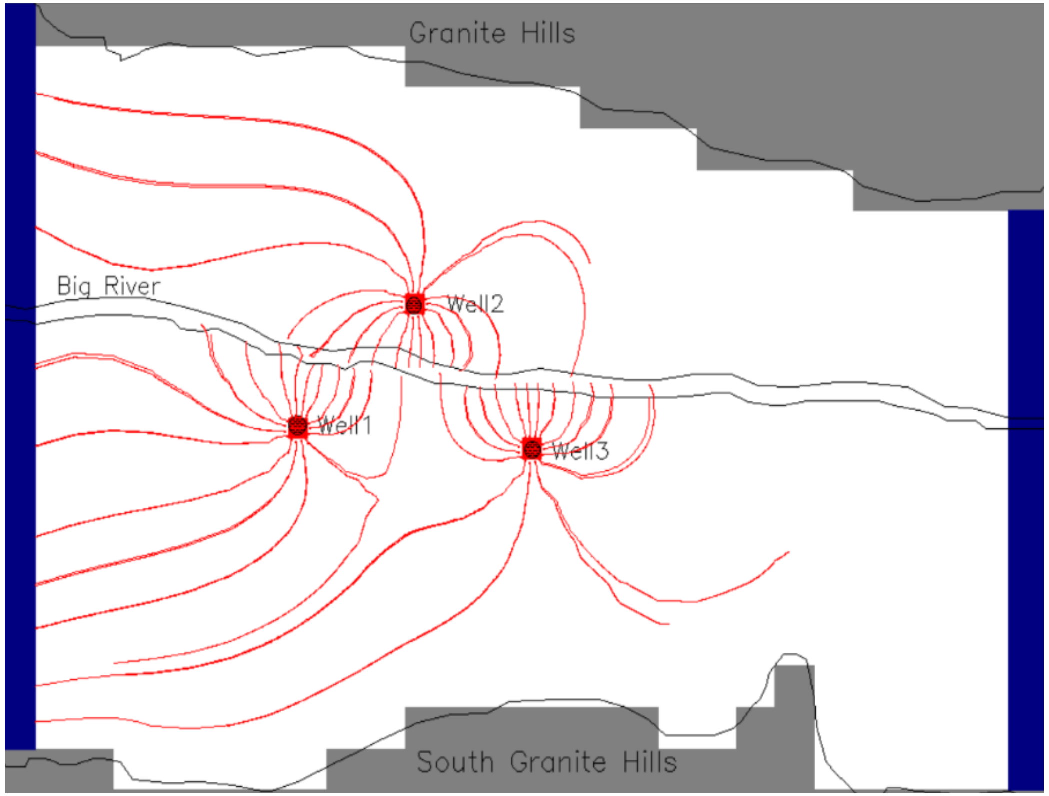



# Capture zone of the wells

1 year

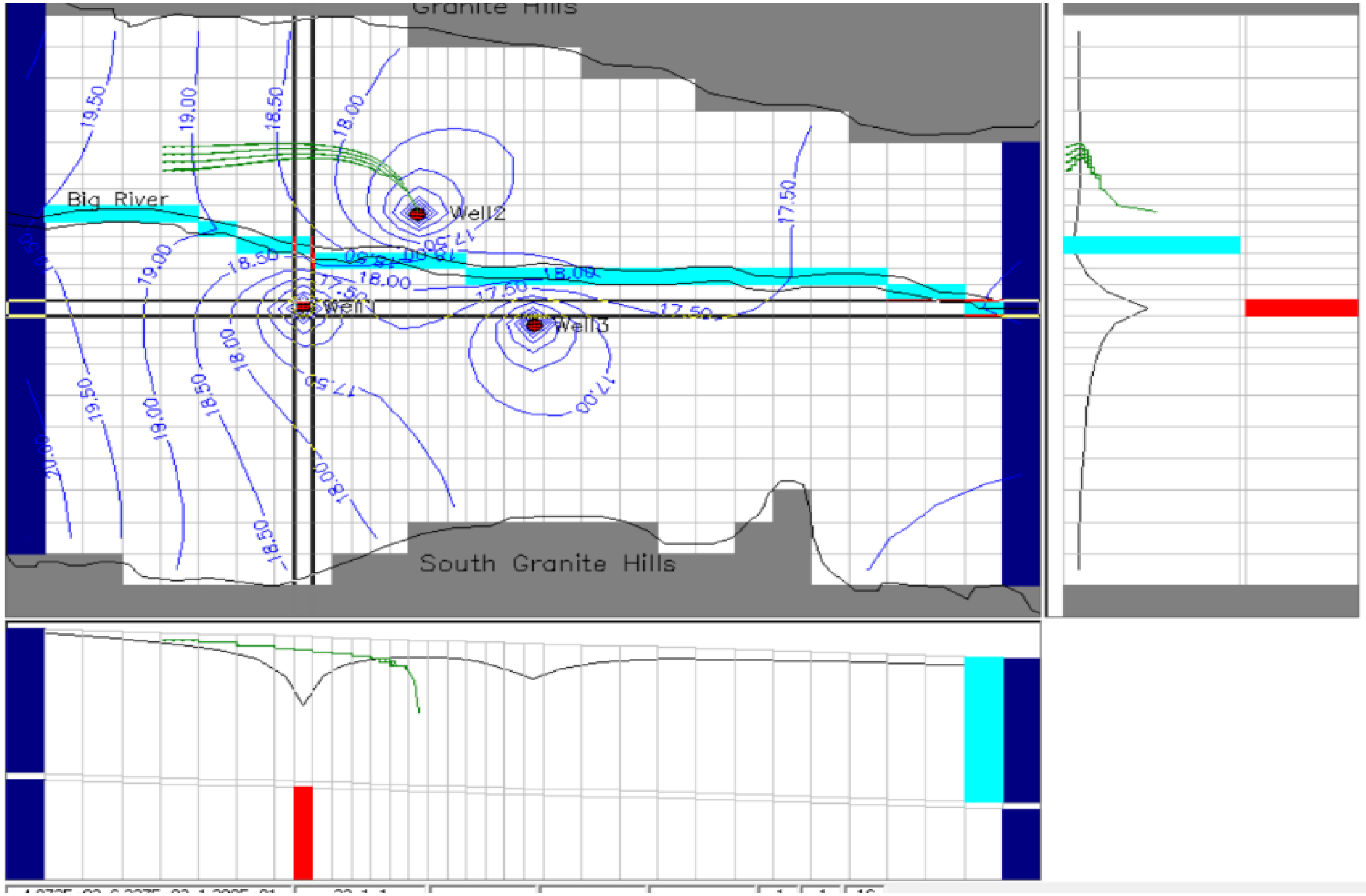



10 years



# Contaminant transport

See cross section of interest



# Let’s create a simple model!

## [https://www.pmwin.net/pmwin5.htm](https://www.pmwin.net/pmwin5.htm)

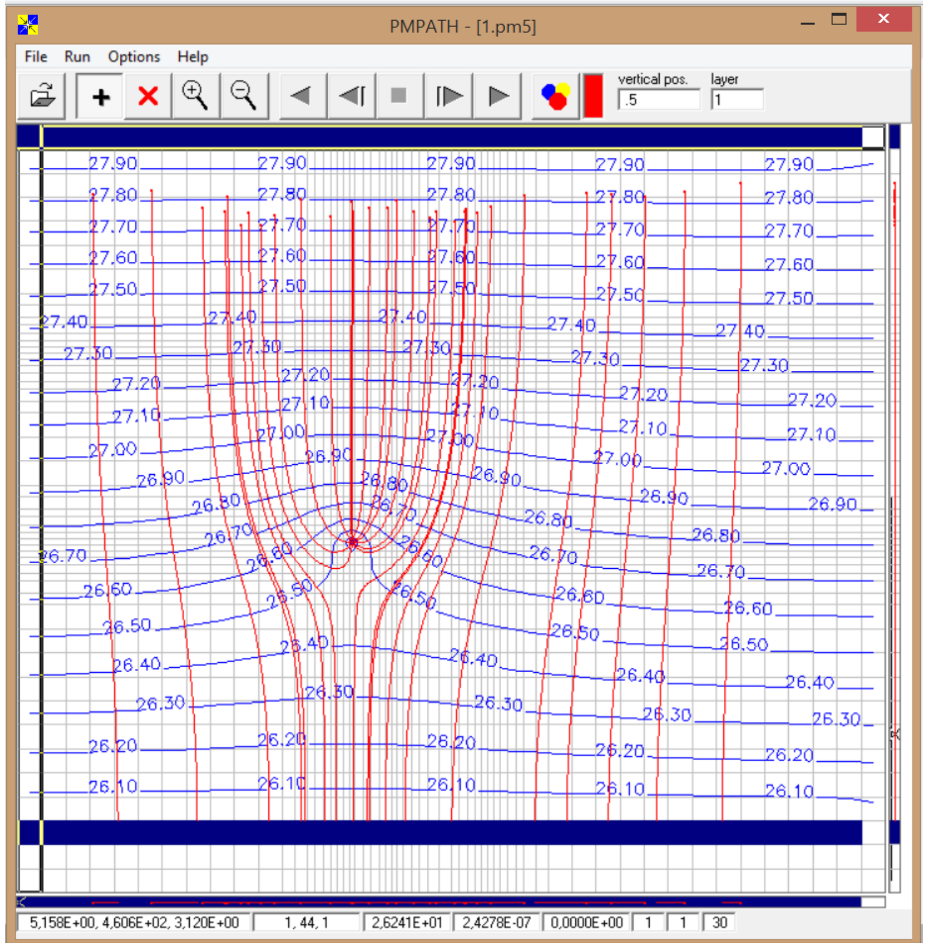
Visegrad Fund

NEW

2 **PMWIN 5.3.1 (Freeware):** Click to download this file and run it to install PMWIN 5.3.1. The installed Software can be found under Start > Programs > Simcore Software > Processing Modflow.

- 1 layer
- isotropic hydrogeological conditions
- 1 well

- 30x30 cells, cell size 100m x 100m
- unconfined layer; thinkness 50 m
- boundary conditions are defined in first and last rows, water table in first row 2m, last row 4m below feet
- hydraulic conductivity 0.0001 m/s; porosity 0.25
- well discharge rate 0.003 $m^3$/s




Risk zone for contaminant appearance from a given cell?

Time of appearance of a contaminant?

# Water Rennovation in Ukraine

University of Debrecen, Faculty of Agricultural and Food Sciences and Environmental Management, Debrecen, Hungary
National University of Water and Environmental Engineering, Rivne, Ukraine
Slovak University of Agriculture in Nitra, Faculty of Horticulture and Landscape Engineering, Slovakia
University of Agriculture in Krakow, Department of Water Engineering and Geotechnics, Poland
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