

# HYDRUS 2D – úvod a ilustrativní úloha



## Richards equation

$$\frac{\partial}{\partial x} \left( K_x(\theta) \frac{\partial h}{\partial x} \right) + \frac{\partial}{\partial y} \left( K_y(\theta) \frac{\partial h}{\partial y} \right) + \frac{\partial}{\partial z} \left( K_z(\theta) \frac{\partial h}{\partial z} \right) + \frac{\partial K_z}{\partial z} = \frac{\partial \theta}{\partial t} \quad \dots \text{in 3D}$$

$$\frac{\partial}{\partial z} \left( K(h) \frac{\partial h}{\partial z} + K(h) \right) - S = \frac{\partial \theta}{\partial t}$$

van Genuchten

$$\theta_e(h) = \begin{cases} \frac{1}{(1 + (-\alpha h)^n)^m} & h < 0 \\ 1 & h \geq 0 \end{cases}$$

Mualem

$$K_r(\theta_e) = \theta_e^{1/2} [1 - (1 - \theta_e^{1/m})^m]^2$$

# Opakování teorie



$$\frac{\partial \theta}{\partial t} = - \frac{\partial q}{\partial z} - s = \frac{\partial}{\partial z} \left[ K \left( \frac{\partial h}{\partial z} + 1 \right) \right] - s$$

Advekčně disperzní rovnice (jak je zavedena v HYDRUSu 1D):

$$\frac{\partial \theta c}{\partial t} + \frac{\partial \rho s}{\partial t} = \frac{\partial}{\partial z} \left( \theta D \frac{\partial c}{\partial z} \right) - \frac{\partial qc}{\partial z} - \underbrace{Sc_r}_{\text{Sink (flow)}} - \underbrace{\mu_w \theta c - \mu_s \rho s + \gamma_w \theta + \gamma_s \rho}_{\text{Reactions (decay/rozpad)}}$$

$c$  – solute concentration in liquid phase  
 $s$  – solute concentration on solid phase

Molecular diffusion coef.      Long. dispersivity (*input*)

$$D = D_w \tau + \lambda |v|$$

Dispersion coefficient      Tortuosity factor      Mean pore velocity

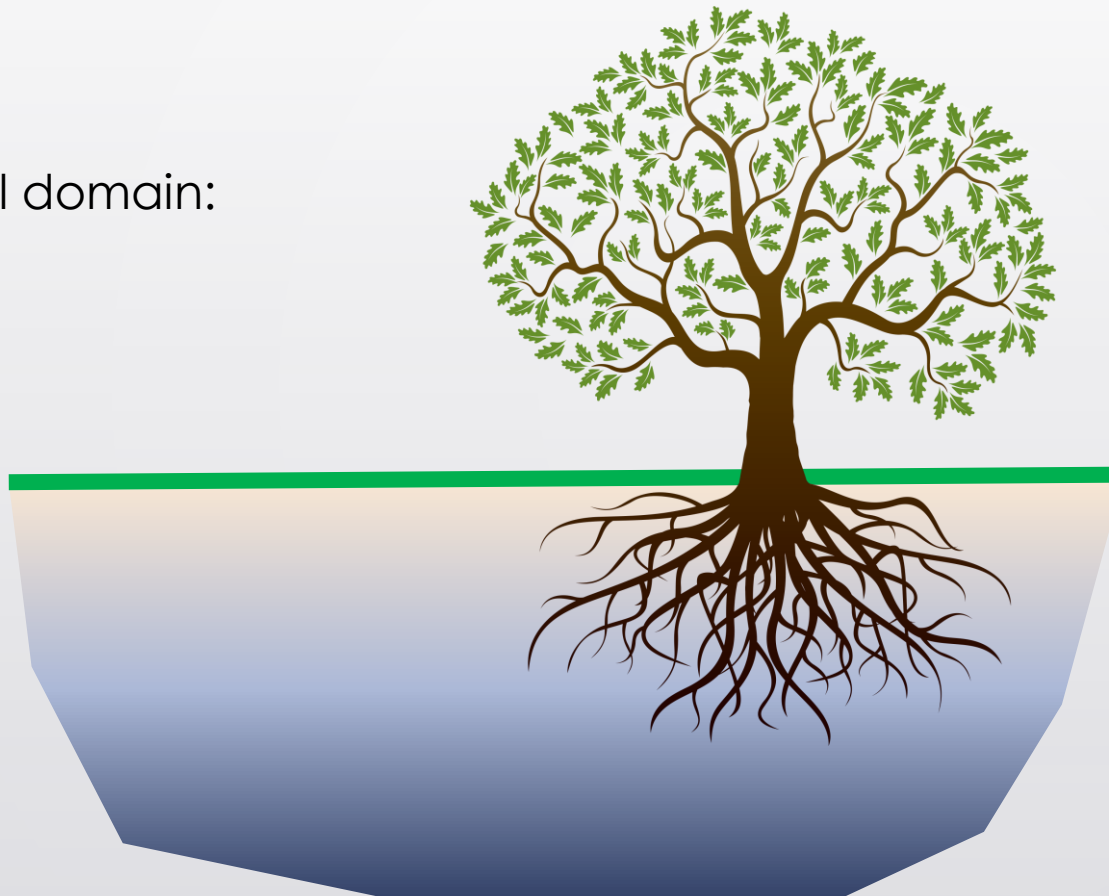
Equilibrium adsorption:

$$s = k_d c^\beta / (1 + \eta c^\beta)$$

Distribution coeff.

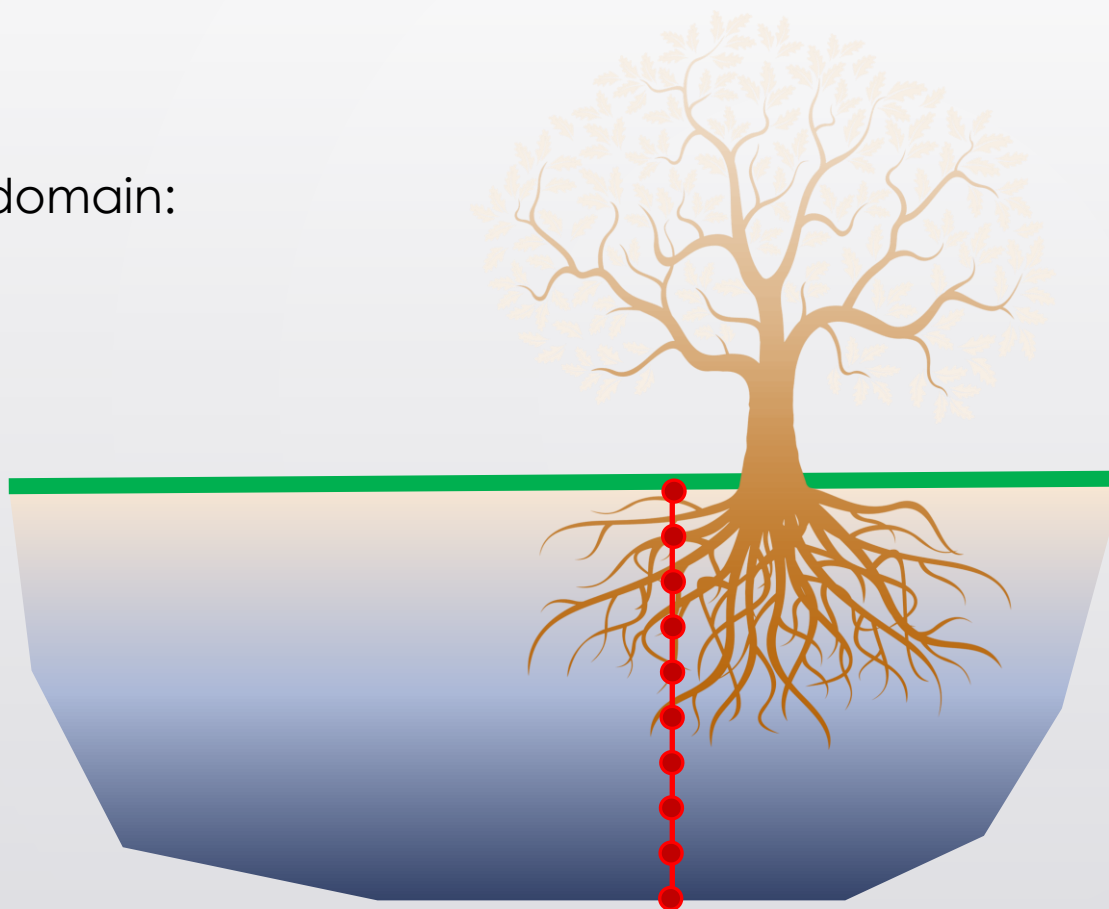
# Diskretizace domény v 1D

Real domain:



# Diskretizace domény v 1D

1D domain:



Top boundary node



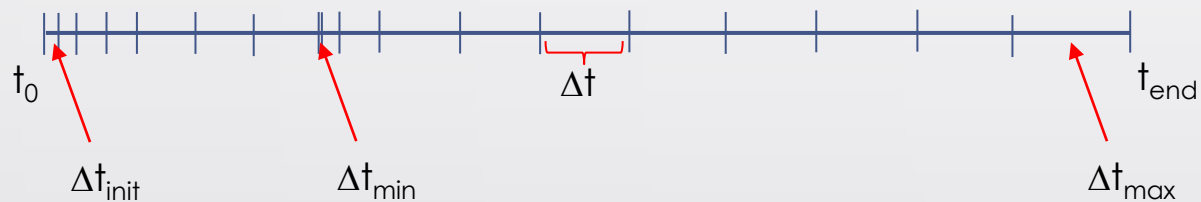
← Node / uzel

← Element

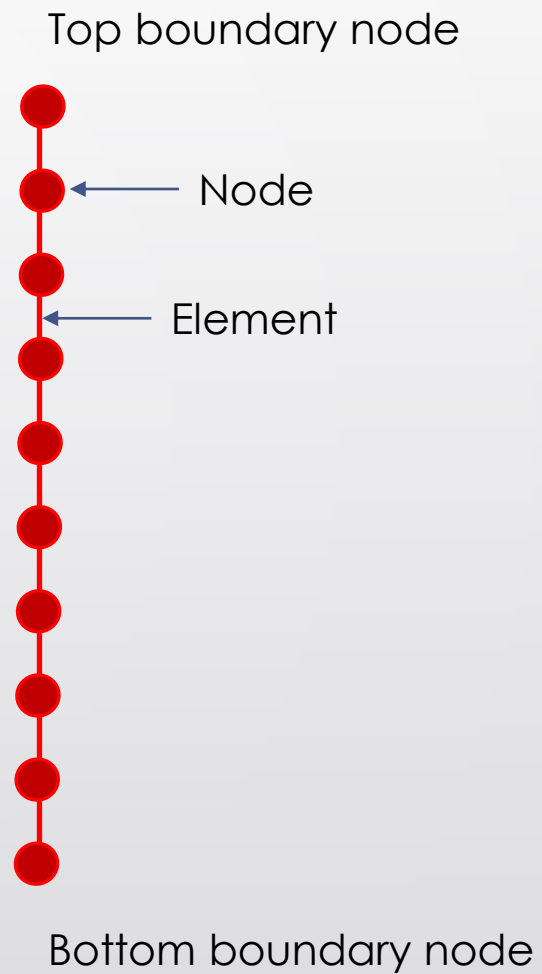
Bottom boundary node

# Diskretizace času

TIME:

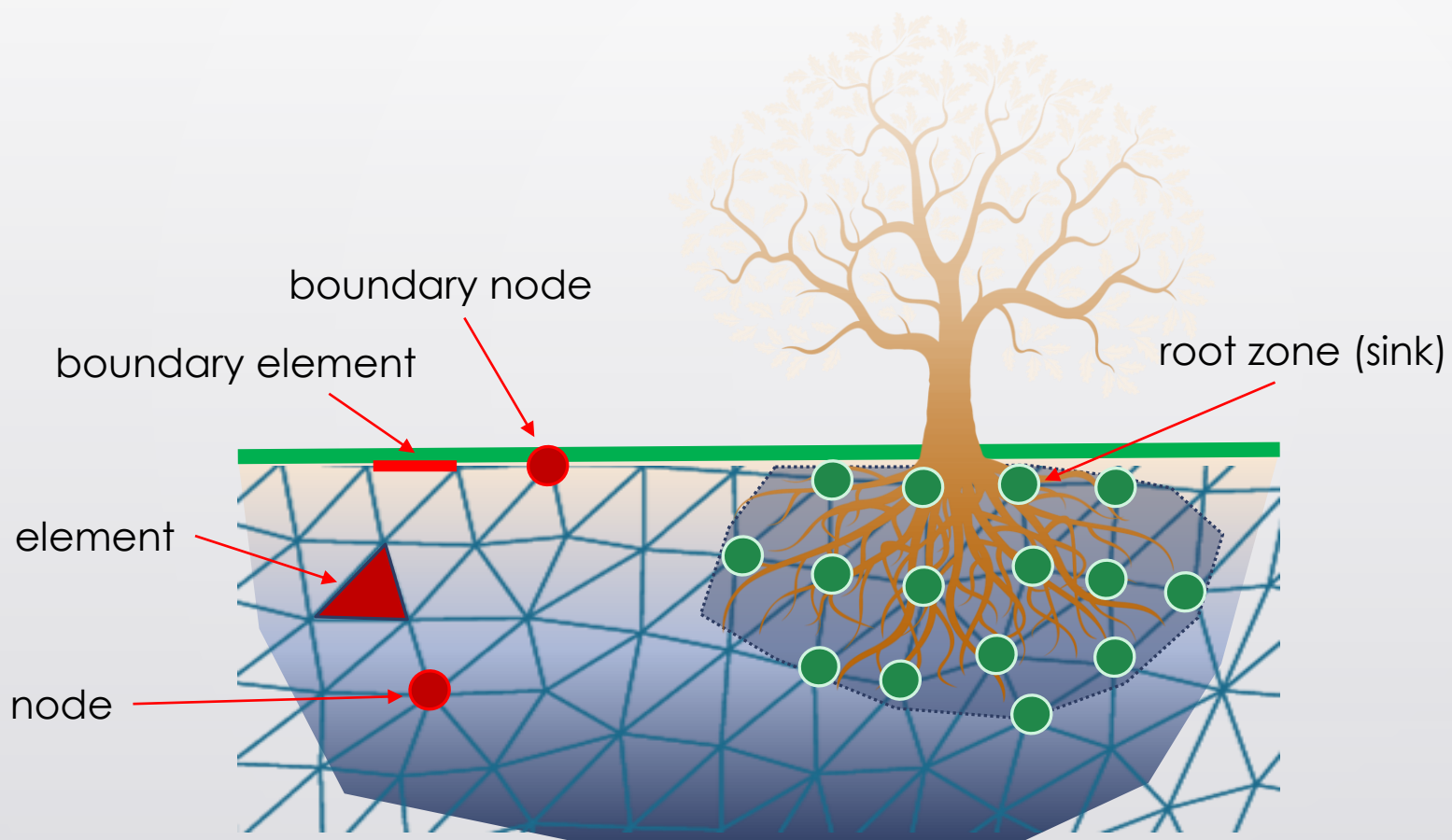


SPACE:





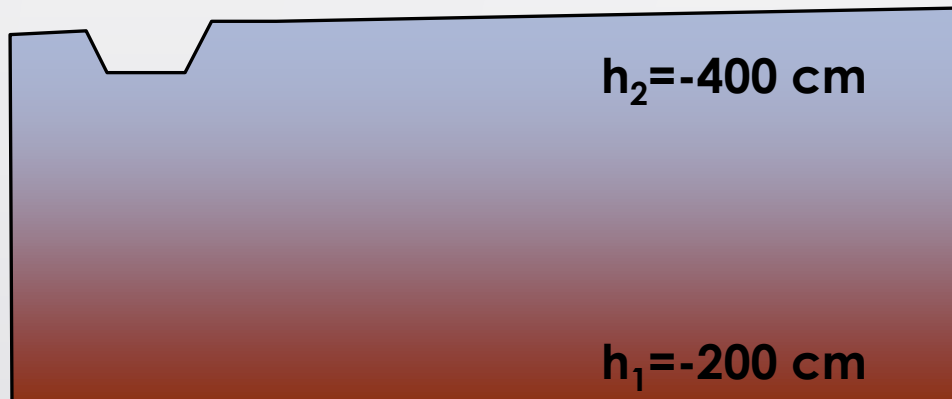
# Diskretizace v 2D



# Počáteční podmínky

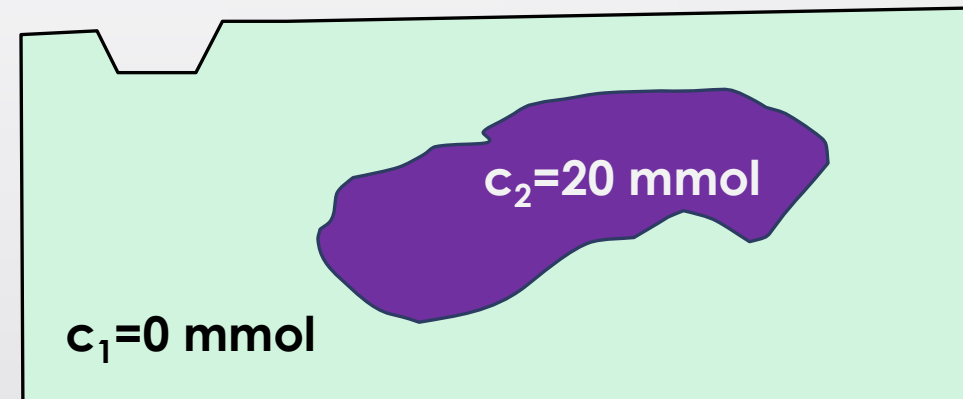
## Richards eq.:

Rozložení sacího tlaku / vlhkosti



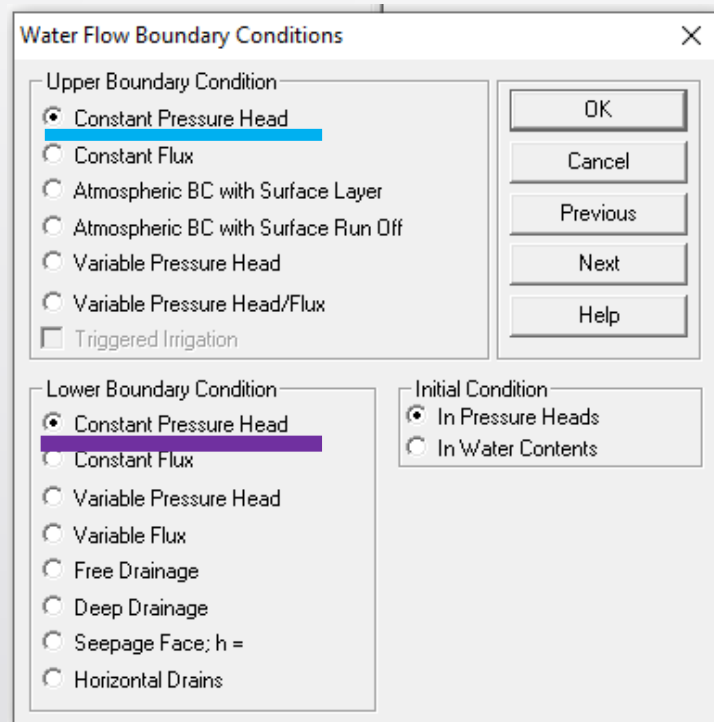
## ADE:

Počáteční rozložení koncentrace



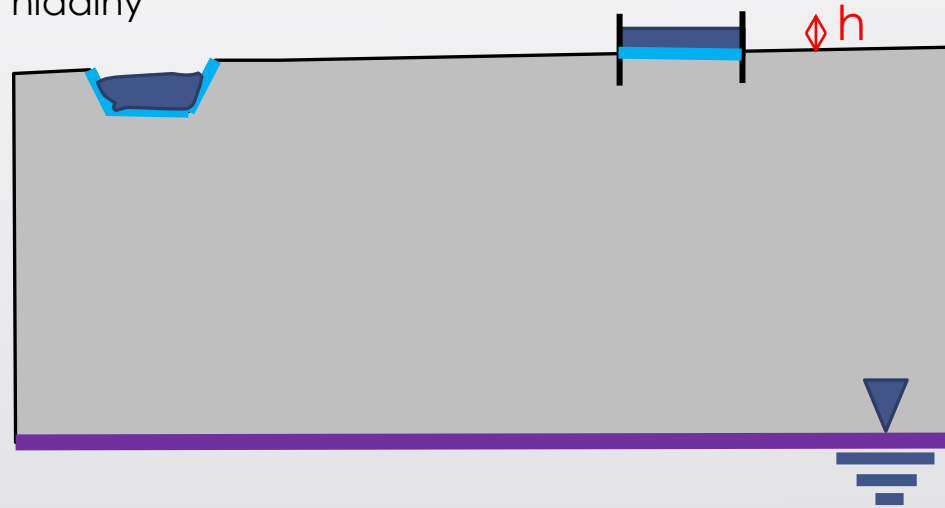


# Okrajové podmínky - opakování



Známa výška  
hladiny

Výtopová infiltrace



Hladina  
podzemní vody  
e.g.  $h = 0$  cm

# Boundary conditions

Water Flow Boundary Conditions

Upper Boundary Condition

- Constant Pressure Head
- Constant Flux
- Atmospheric BC with Surface Layer
- Atmospheric BC with Surface Run Off
- Variable Pressure Head
- Variable Pressure Head/Flux
- Triggered Irrigation

Lower Boundary Condition

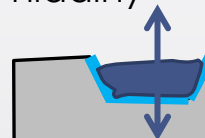
- Constant Pressure Head
- Constant Flux
- Variable Pressure Head
- Variable Flux
- Free Drainage
- Deep Drainage
- Seepage Face;  $h =$
- Horizontal Drains

Initial Condition

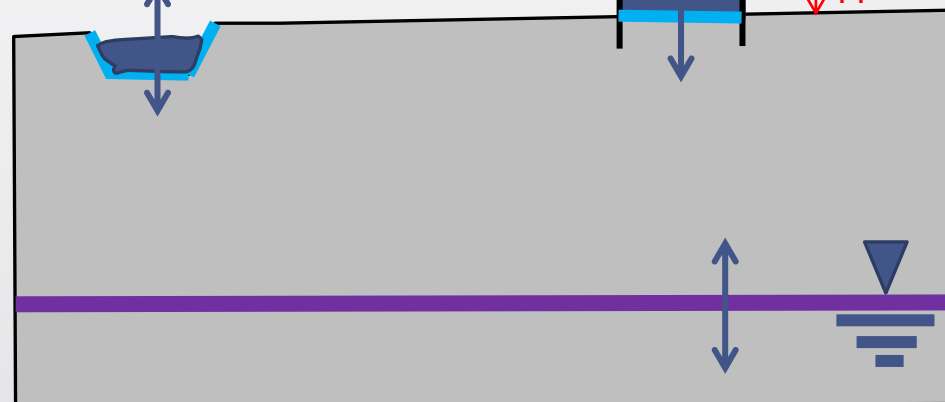
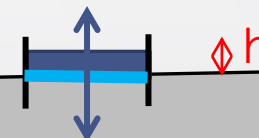
- In Pressure Heads
- In Water Contents

OK  
Cancel  
Previous  
Next  
Help

Známa výška hladiny

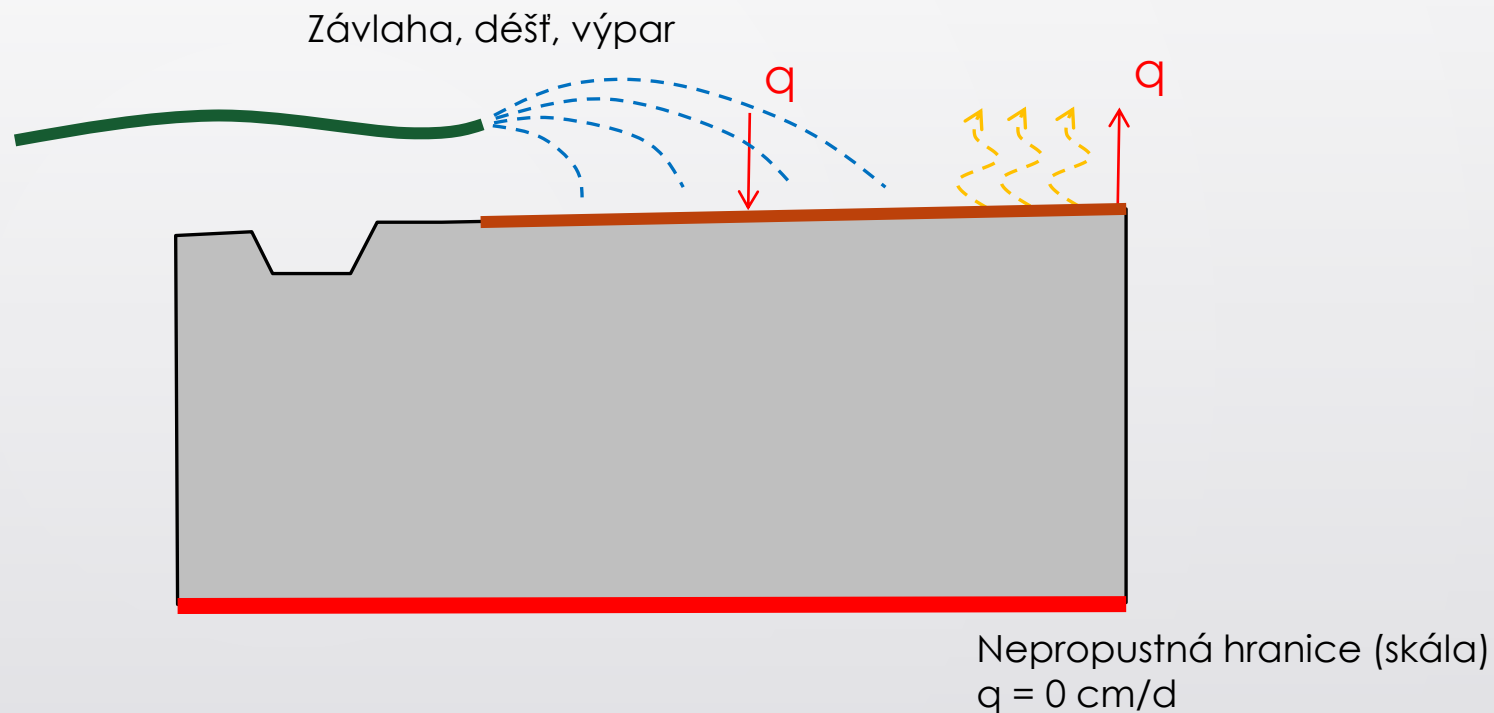
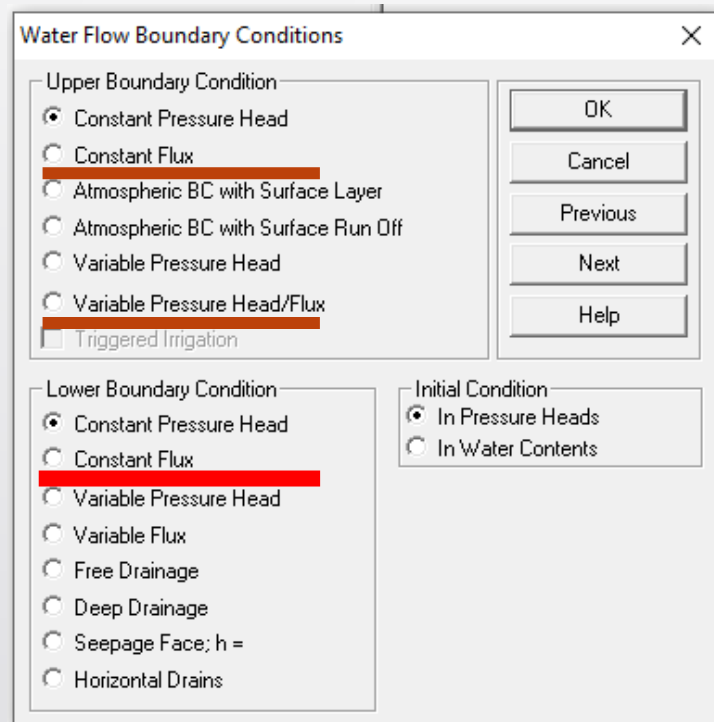


Výtopová infiltrace

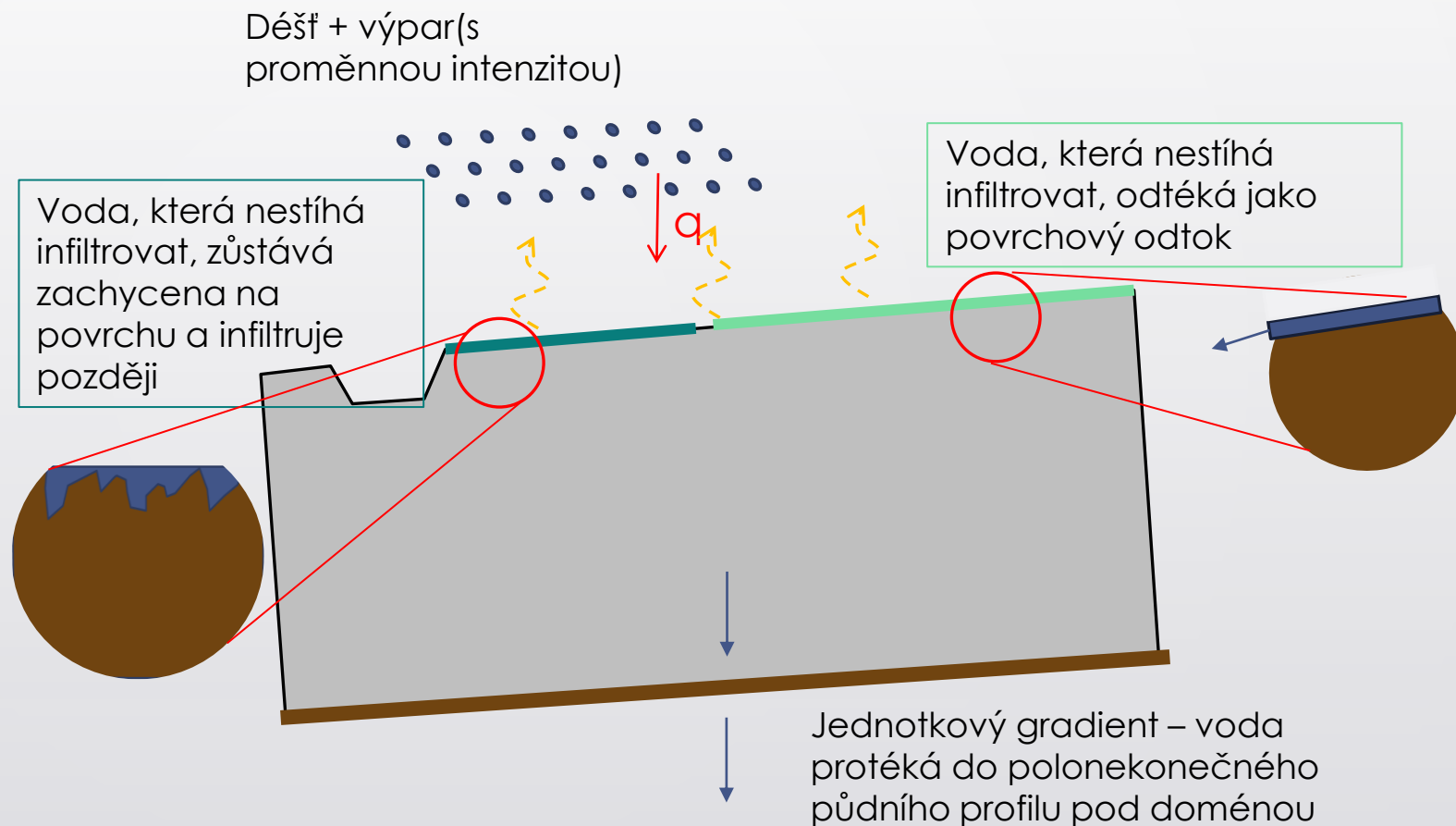
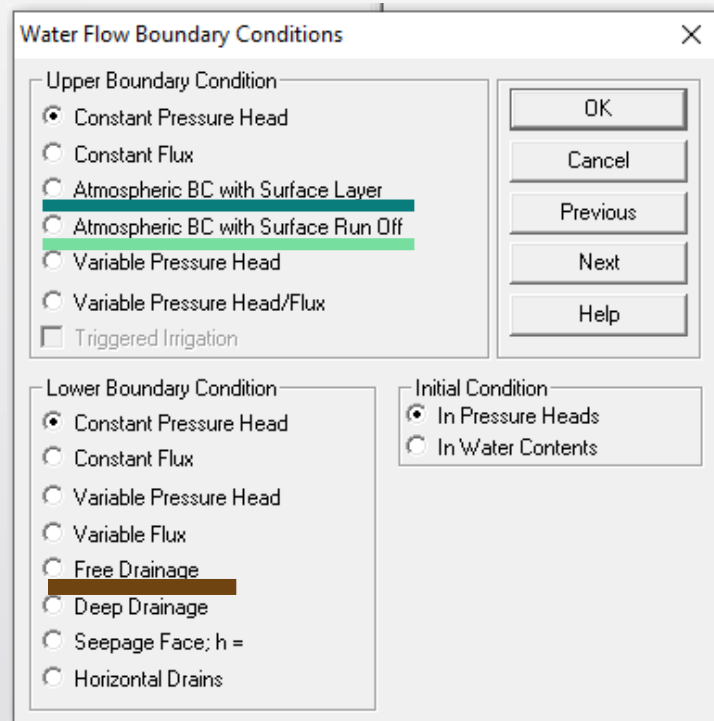


Hladina podzemní vody  
e.g.  $h = 0$  cm

# Boundary conditions



# Boundary conditions



# Boundary conditions

Water Flow Boundary Conditions

Upper Boundary Condition

- Constant Pressure Head
- Constant Flux
- Atmospheric BC with Surface Layer
- Atmospheric BC with Surface Run Off
- Variable Pressure Head
- Variable Pressure Head/Flux
- Triggered Irrigation

Lower Boundary Condition

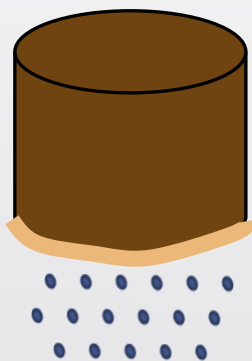
- Constant Pressure Head
- Constant Flux
- Variable Pressure Head
- Variable Flux
- Free Drainage
- Deep Drainage
- Seepage Face;  $h =$
- Horizontal Drains

Initial Condition

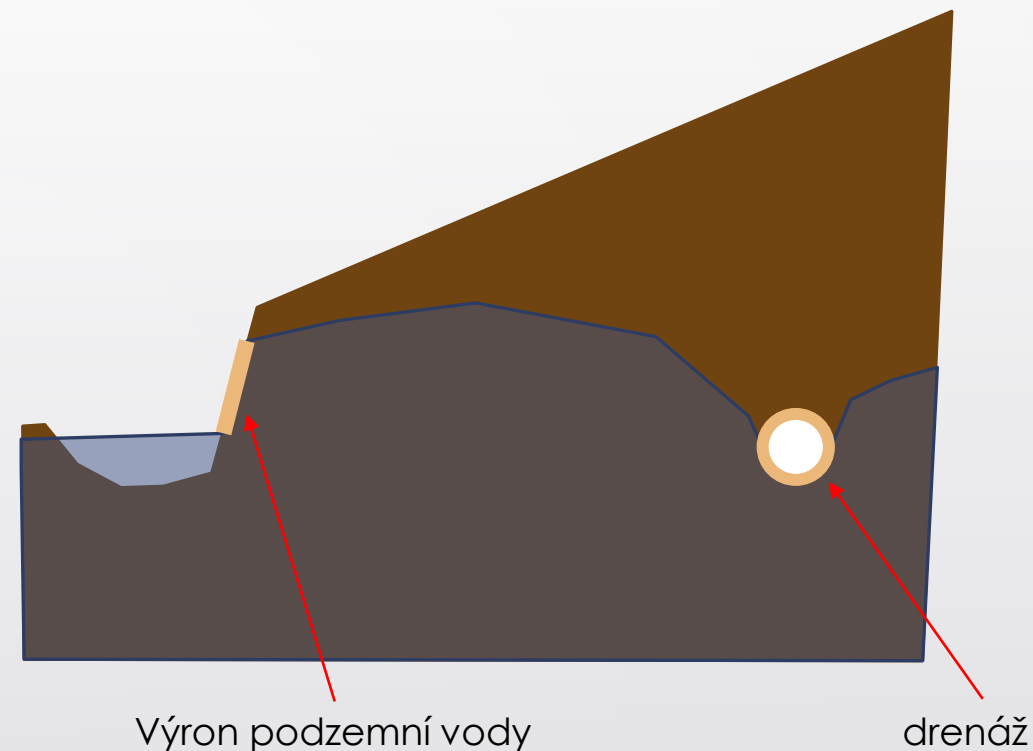
- In Pressure Heads
- In Water Contents

OK  
Cancel  
Previous  
Next  
Help

Rozhraní mezi půdou a atmosférou



Neporušený  
půdní vzorek

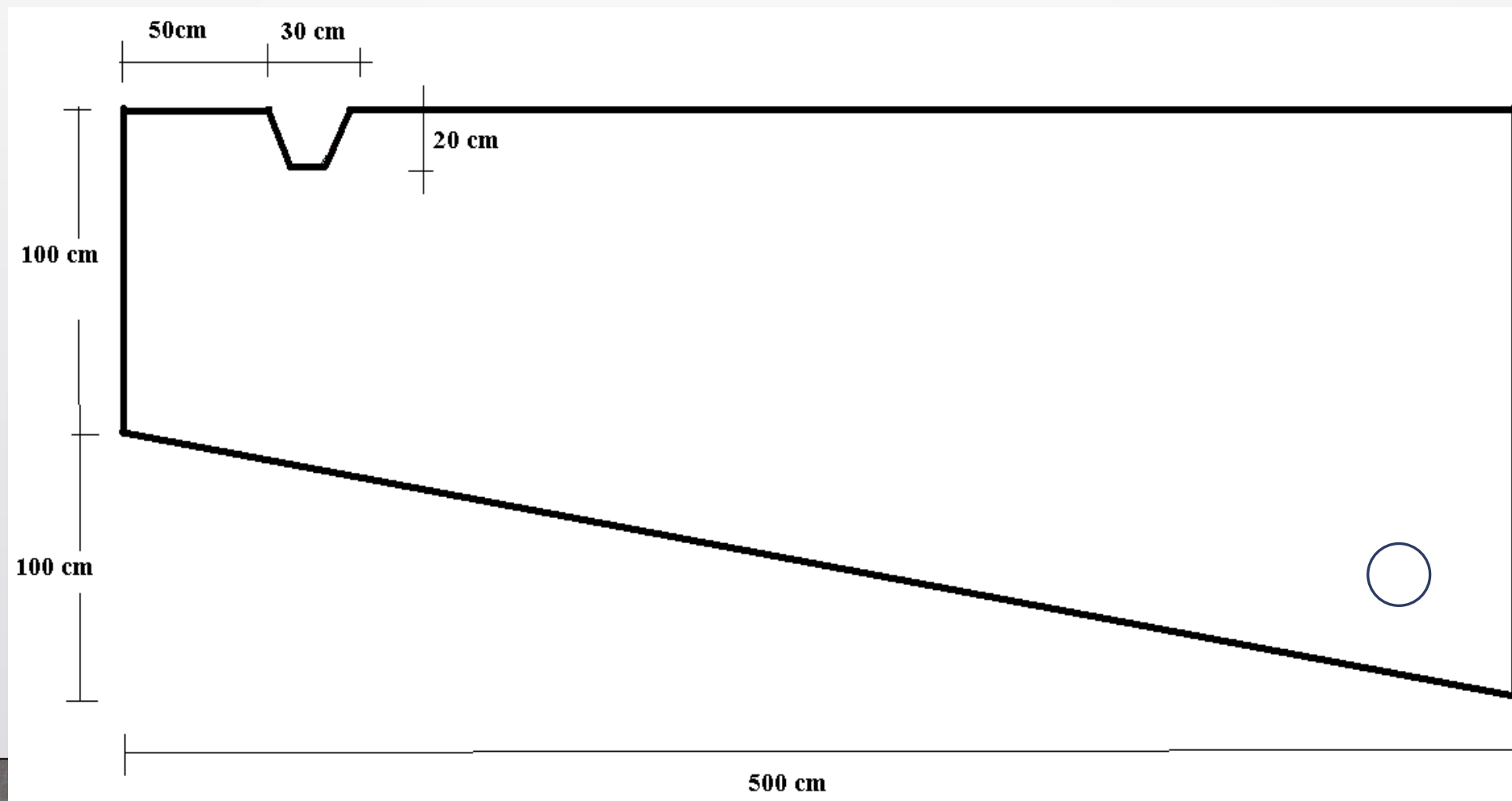


Výron podzemní vody

drenáž



# Infiltrace z příkopu do domény s nepropustným podožím



## Infiltrace z příkopu do domény s nepropustným podožím

Příkop byl naplněn vodou do výšky 8 cm.

*Initial conditions:* pressure 0 cm at the lowest point of the domain, the rest in equilibrium

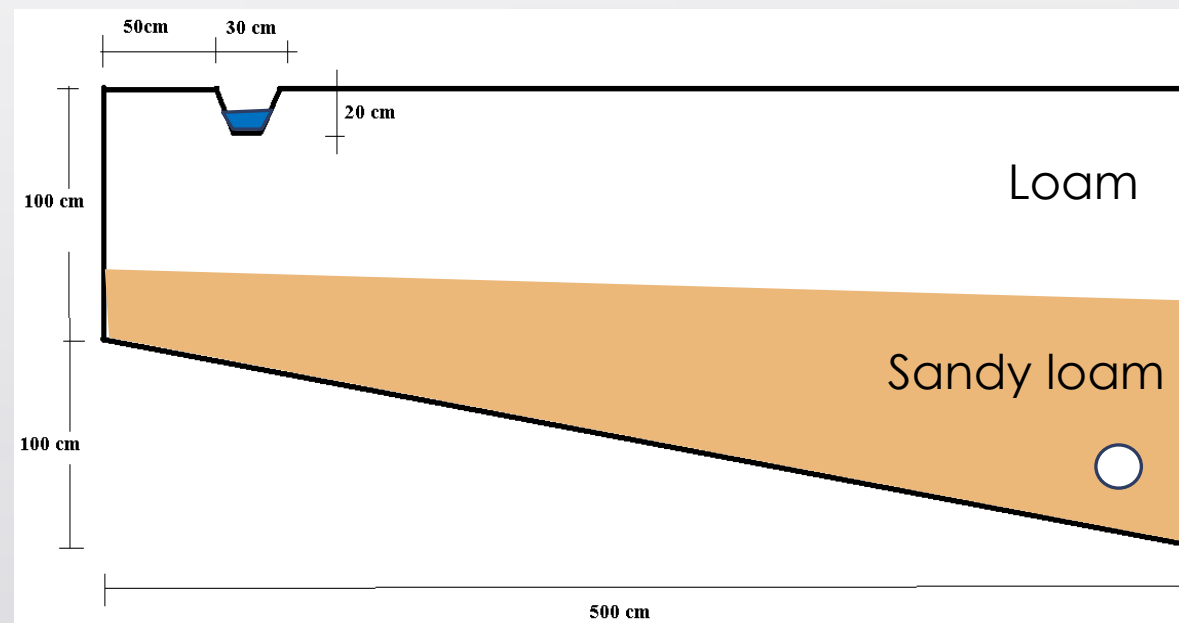
*Boundary conditions:* no flux – všude mimo příkop a drenáž

Duration: 50 days

Půda:

svrchní horizont: loam,

spodní vrstva: sandy loam



**Transport:**

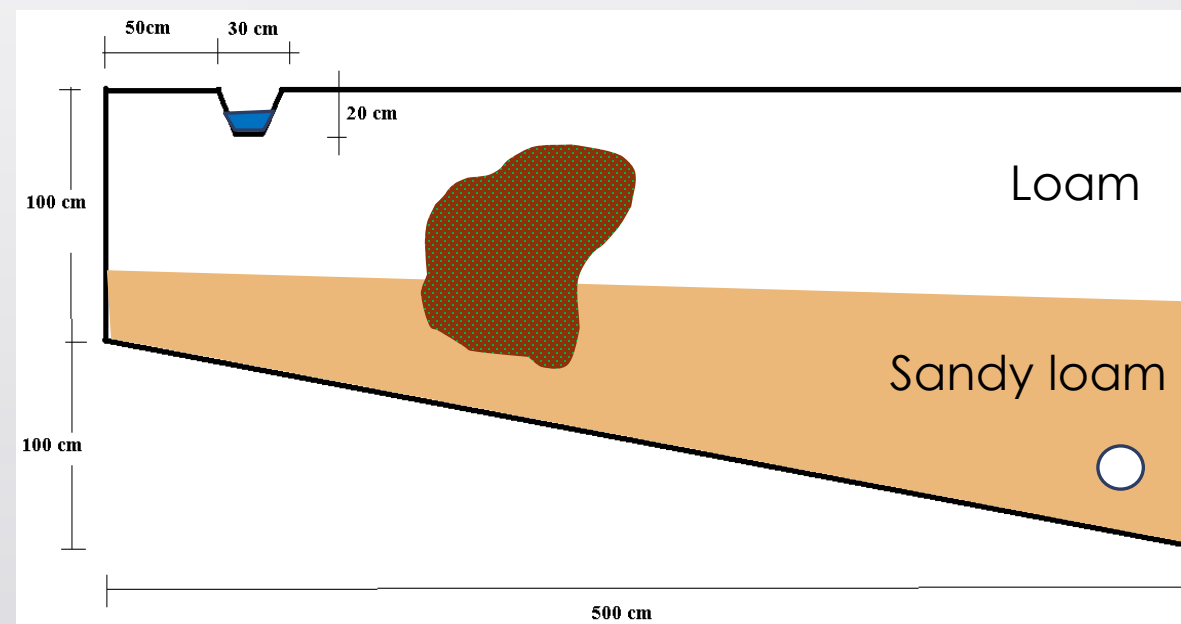
1. Simulujte šíření konzervativního traceru, rozpuštěného ve vodě v příkopu po dobu 1 dne a koncentraci  $5 \text{ mg/cm}^2$ .
2. Uvažujte látku B, která se nacházela v doméně (umístěte kontaminant libovolně mezi příkop a drenáž).  $K_d = 1.1$ , conc.  $10 \text{ mg/cm}^2$ .

Dispersivity (v onou směrech): 40 cm

Topsoil bulk density:  $1.28 \text{ g/cm}^3$ , bottom  $1.40 \text{ g/cm}^3$

Print information: vyberte 500 tiskových časů, s krokem 12 h

Flowing particles: vložte 5 – 15 částic (několik poblíž příkopu, zbytek libovolně)



# Otázky

- a/ Sledujte, jak probíhá plnění domény vodou a jak se pohybují obě znečišťující látky.
- b/ Identifikujte místa s nejvyšší rychlostí proudění.
- c/ Jaké množství vody a sledovaných látek se do domény infiltrovalo a doméno opustilo drénem po 10 a 50 dnech?
- d/ Kolik kontaminantu zůstalo v doméně na konci simulace?

