TECHNISCHE UNIVERSITÄT DRESDEN

Faculty of Forestry, Geo and Hydro Science, Institute of Waste Management and Contaminated Site Treatment

The simulation software

PCSiWaPro®

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DRESDEN concept
Exzellenz aus Wissenschaft und Kultur

Overview

1. Modelling in the unsaturated soil zone
2. The software PCSiWaPro®
3. The weather generator
4. Applications

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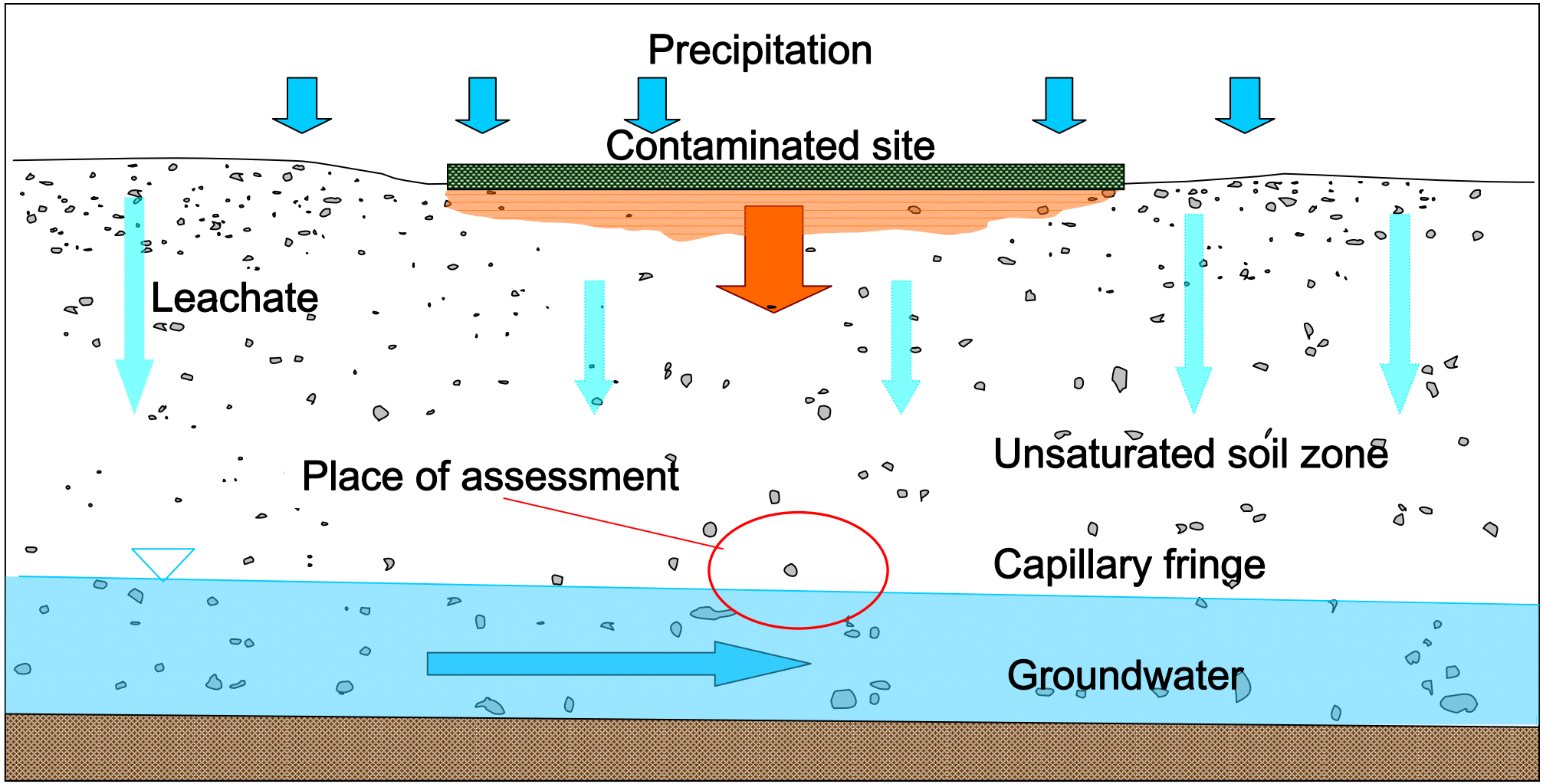
Precipitation
Contaminated site
Leachate
Unsaturated soil zone
Place of assessment
Capillary fringe
Groundwater

➔ Models described by **partial differential equations**:

→ **Flow**: RICHARDS-Equation, retention curve parameterization by VAN GENUCHTEN/LUCKNER

$$\frac{\partial \theta}{\partial t} = \frac{\partial}{\partial x_i}\left[K\left(K_{ij}^{A} \frac{\partial h}{\partial x_j} + K_{iz}^{A} \right)\right] - S$$

$$\theta = \theta_r + \frac{\phi - \theta_{r,w} - \theta_{r,l}}{\left[1 + (\alpha \cdot h_c)^n\right]^{1-\frac{1}{n}}}$$

θ	volumetric water content
t	time
x_i	(x_1=x, x_2=z), spatial coordinates
K	hydraulic conductivity
h	pressure head
S	sink/source term

ϕ	porosity
$\theta_{r,w}$	residual water content
$\theta_{r,l}$	residual air content
α	scaling factor (van Genuchten)
n	slope factor (van Genuchten)
h_c	capillary pressure head

➔ Models described by **partial differential equations**:

➔ **Transport**: Convection-Dispersion-Equation

$$\frac{\partial \theta c}{\partial t} + \frac{\partial \rho s}{\partial t} = \frac{\partial}{\partial x_i}\left(\theta D_{ij} \frac{\partial c}{\partial x_j}\right) - \frac{\partial q_i c}{\partial x_i} + \mu_w \theta c + \mu_s \rho s + \gamma_w \theta + \gamma_s \rho - S c_s$$

c	concentration	D_{ij}	tensor of dispersion coefficients
s	sorbed concentration	S	sink/source term
P	bulk density	C_s	concentration of sink/source term
t	time	γ_w, γ_s	parameters for 1st order processes
q_i	i-th component of flux	μ_w, μ_s	parameters for 0th order processes

➔ How to use these equations to **simulate** model behaviour

→ **input data**

→ **soil** parameters (conductivities, porosities, ...)

→ **contaminant** parameters (diffusion coefficient, half-life, ...)

→ **initial** conditions

→ steady-state or transient **boundary** conditions

→ mathematical equation **solving technique**

→ additional input data: **discretization** of the model area (space and time)

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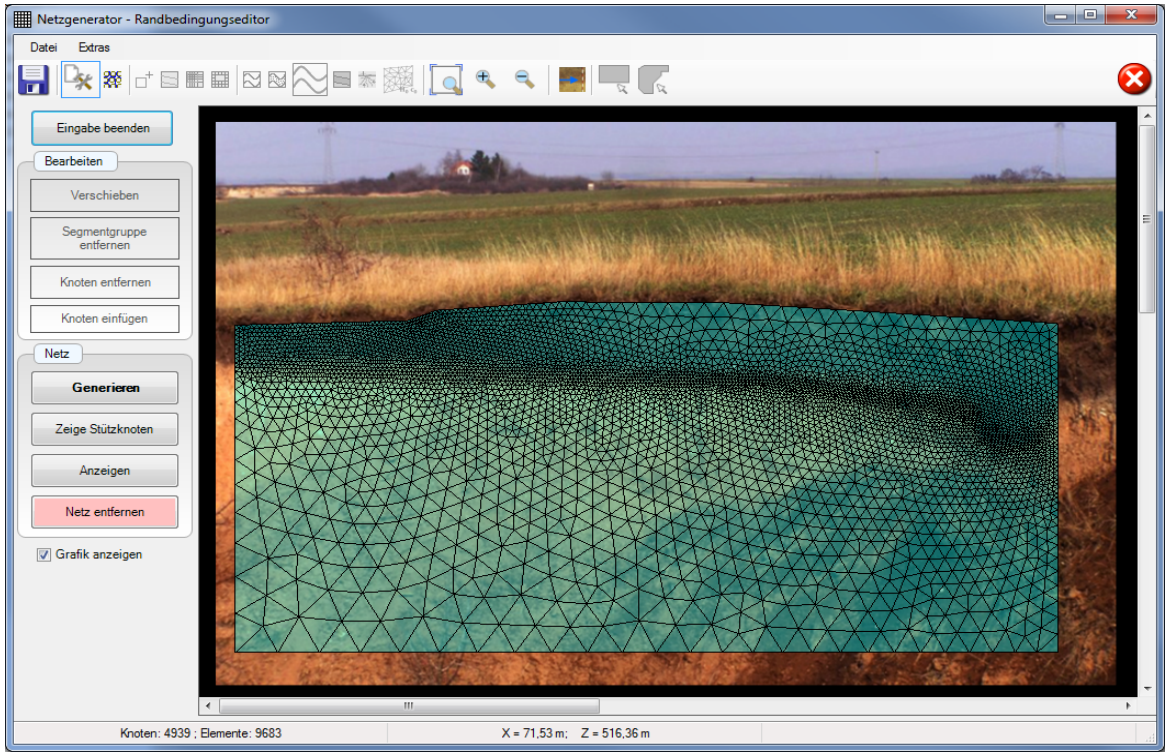
➔ **PCSiWaPro®**: a software to **simulate** flow and transport processes in the unsaturated soil zone

(1) model **generator**

(2) system **solver**

(3) result **viewer**



➔ How to use these equations to simulate model behaviour **with PCSiWaPro®**

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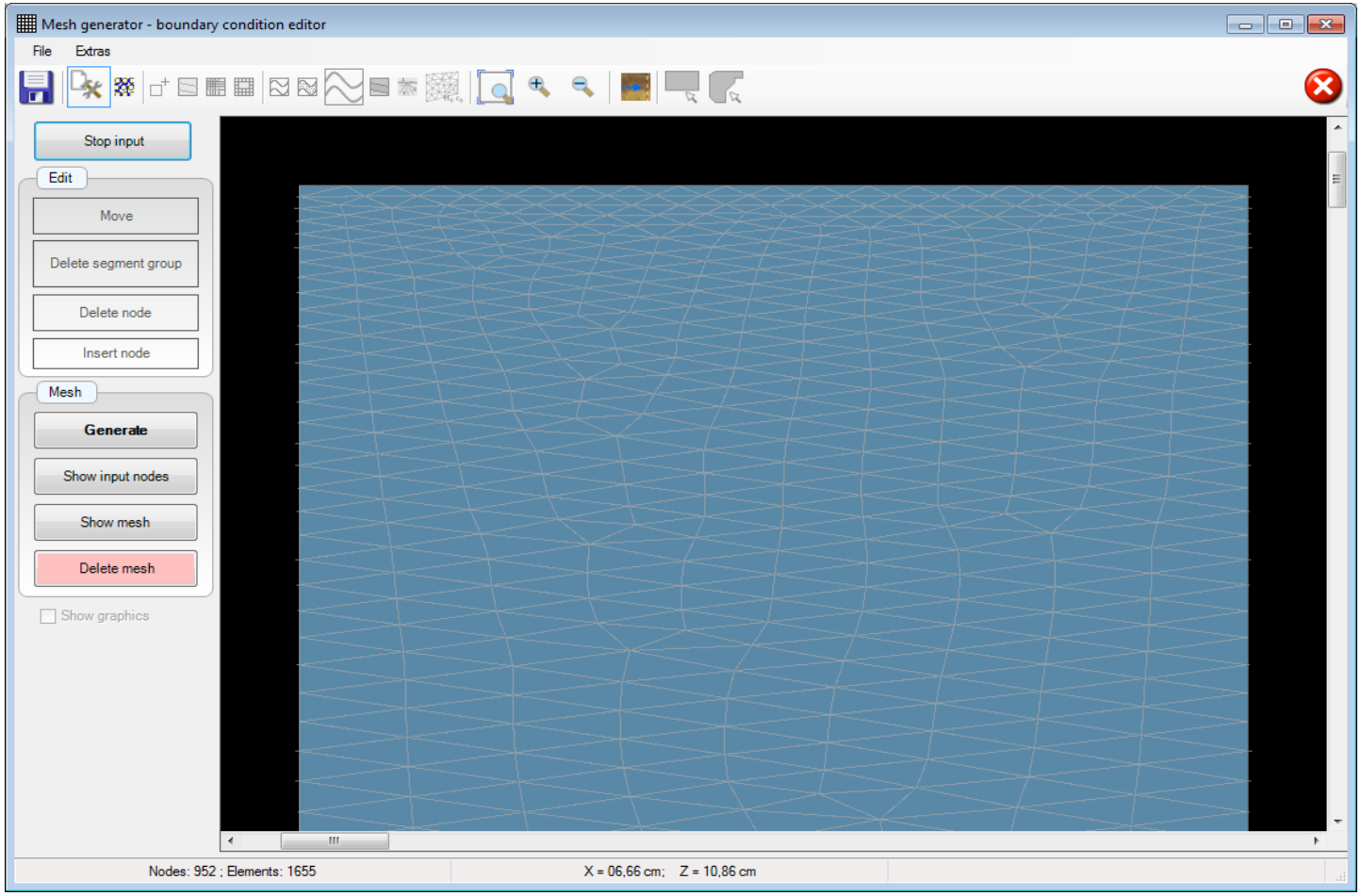
➔ Integrated 1D- or 2D-**mesh generator**



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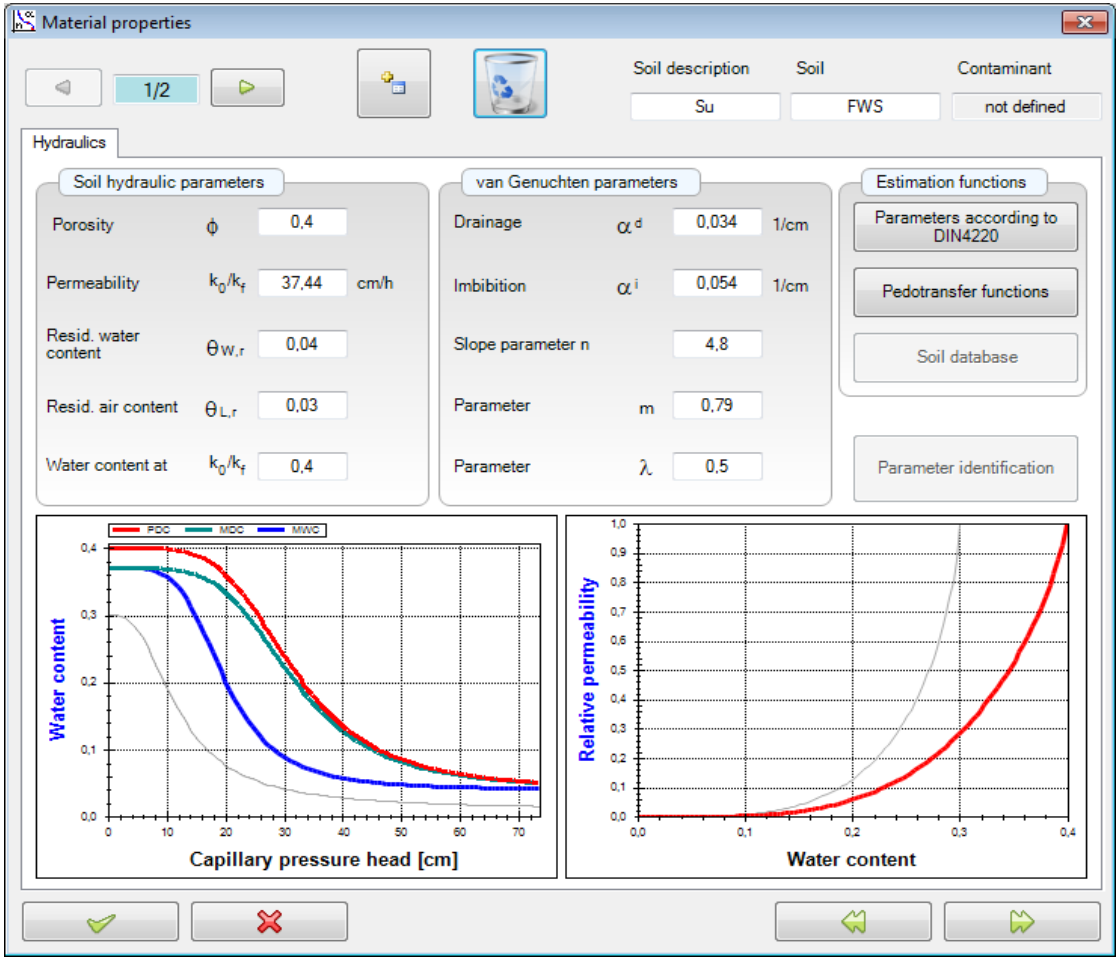
➔ Data input through user-friendly **GUI**



→ **input data** from:

(1) integrated databases

(2) pedotransfer functions

(3) measured data

→ selection of **model assumptions**

→ sorption isotherms

→ source term functions

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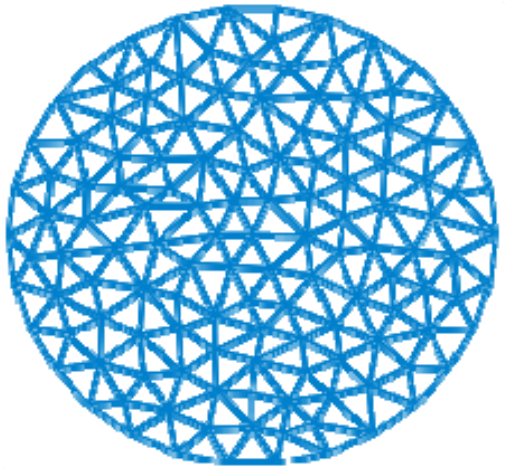
➔ Equations solved by:



→ **discretization**

→ space: **finite elements**

→ time: adjusted **finite intervals**

→ explicit, implicit, Crank-Nicholson

→ repeated solution of **linear equation system** for each timestep

→ **direct**: GAUSSian elimination

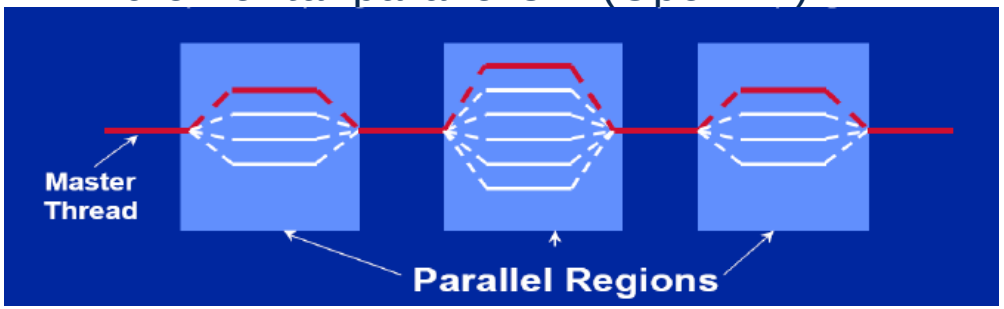
→ **iterative**: preconditioned conjugate gradient method

→ **Problem**: long simulation runtimes

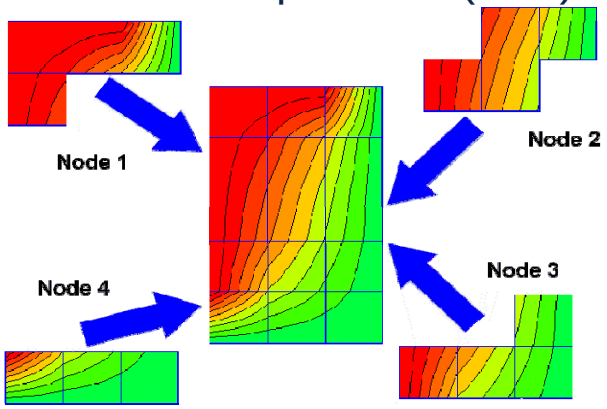
➔ Current research topic: source code **parallelization**

→ dividing work into **mutually independent** parts

Incremental parallelism (OpenMP)



domain decomposition (MPI)

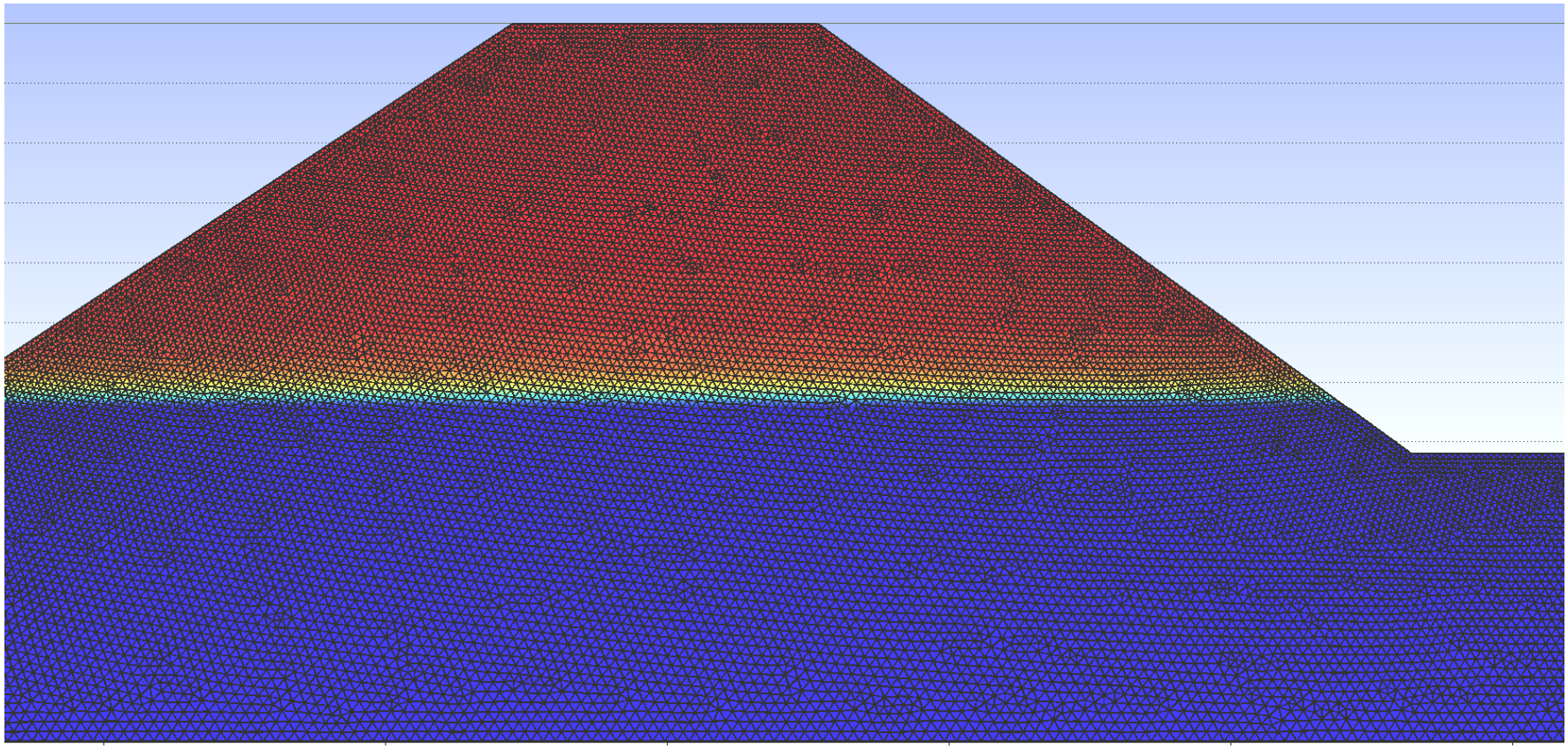


→ computationally most **expensive** tasks:

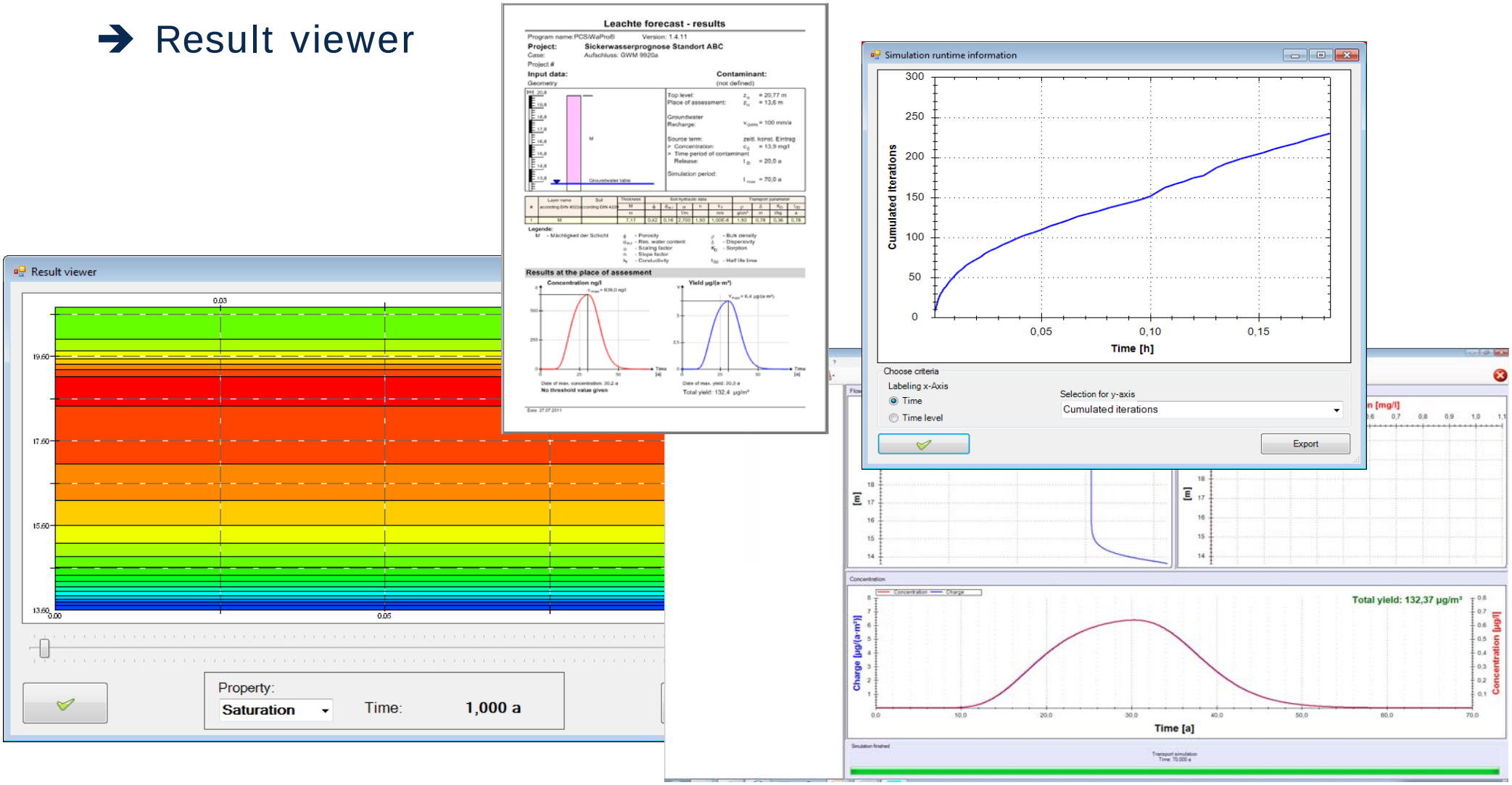
→ matrix assembly, system solver

→ integrating and testing of **parallel solver libraries**

➔ **Simulation** (dam seepage example)



➔ Result viewer



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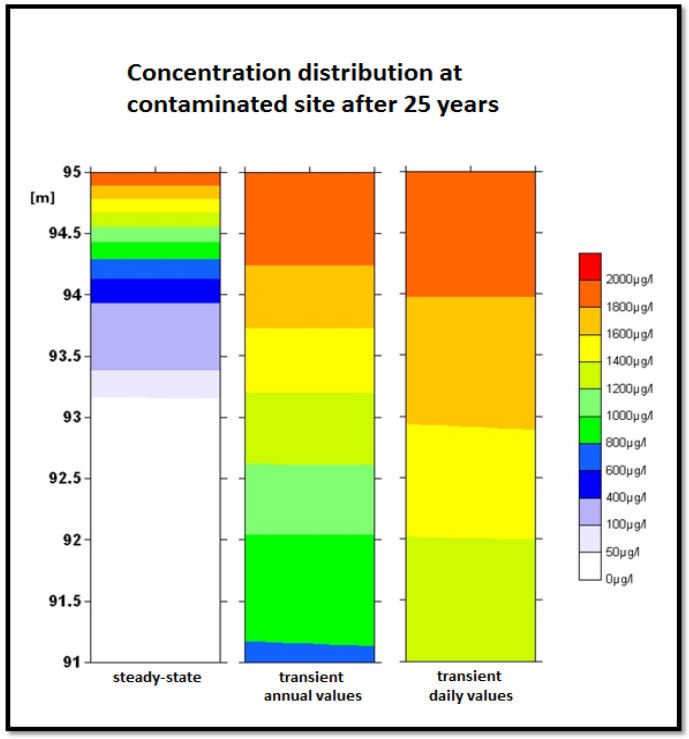
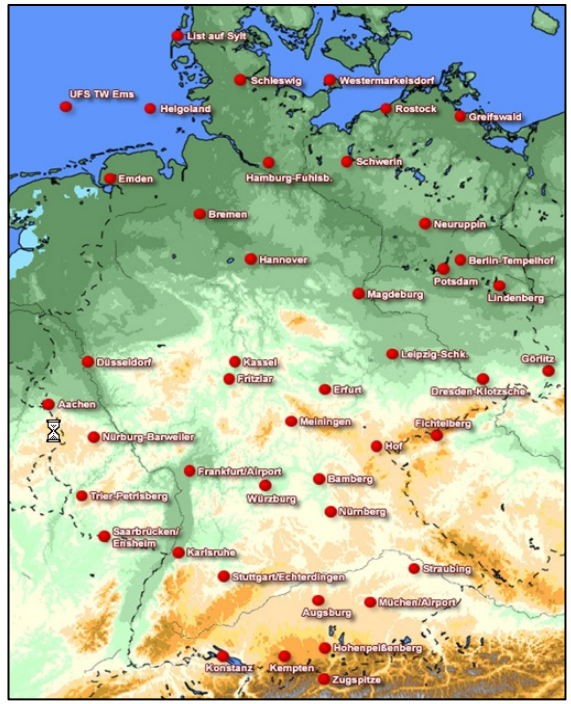
➔ Computation of upper boundary condition with the integrated **weather generator**



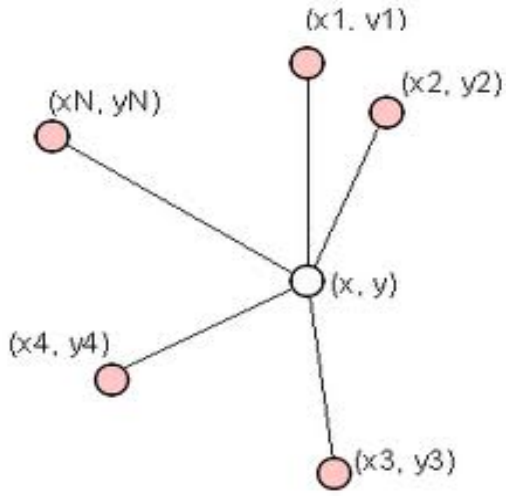
→ **input** data
- → precipitation
- → evapotranspiration
- → vegetation cover
- → slope
- → ...

→ output: <u>daily</u> values of precipitation

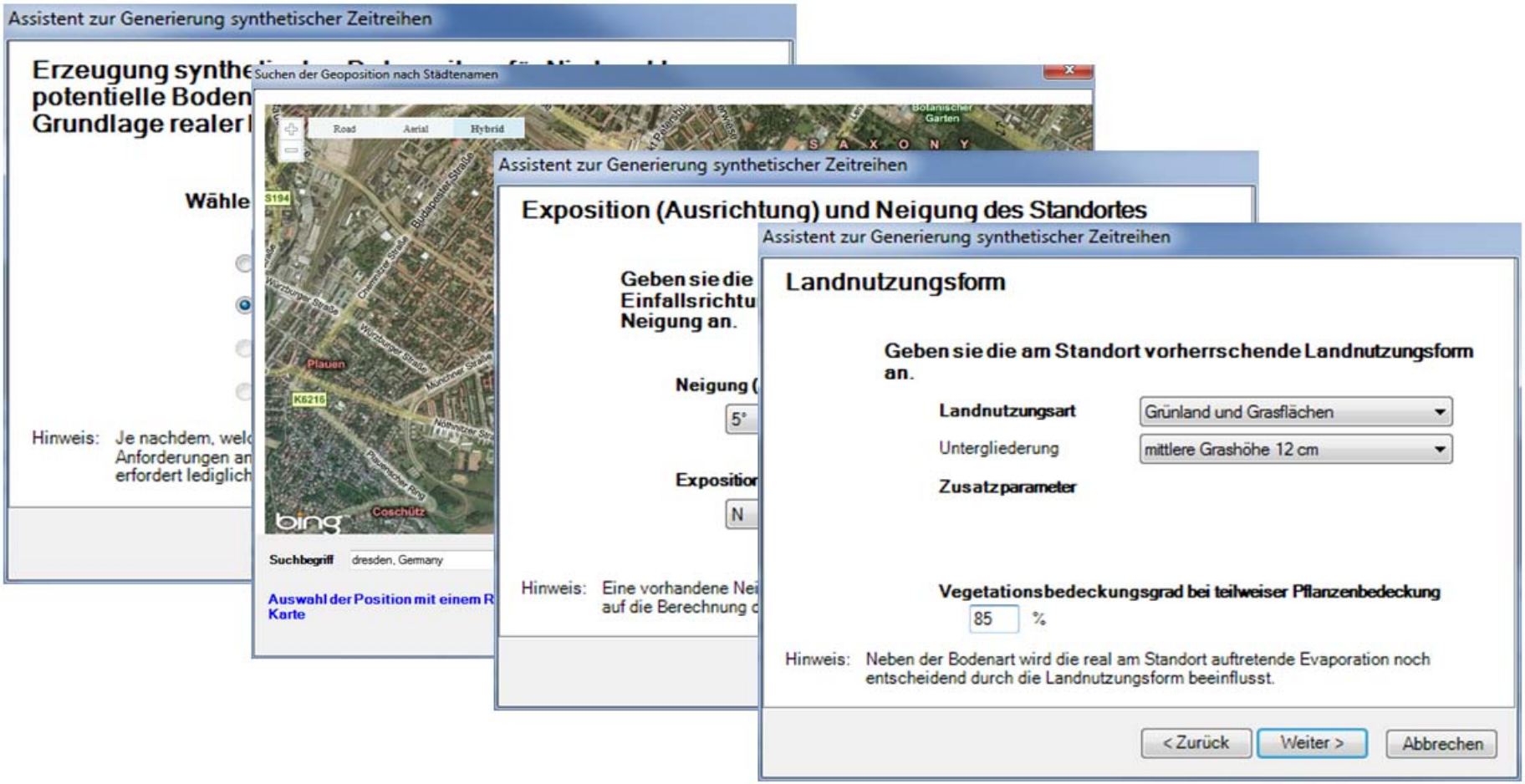


➔ **Time series generation** by:

(1) statistical **characterization** of input time series
(2) spatial **interpolation** of statistical parameters
(3) **sampling** of synthetical time series
→ past, present and **future**

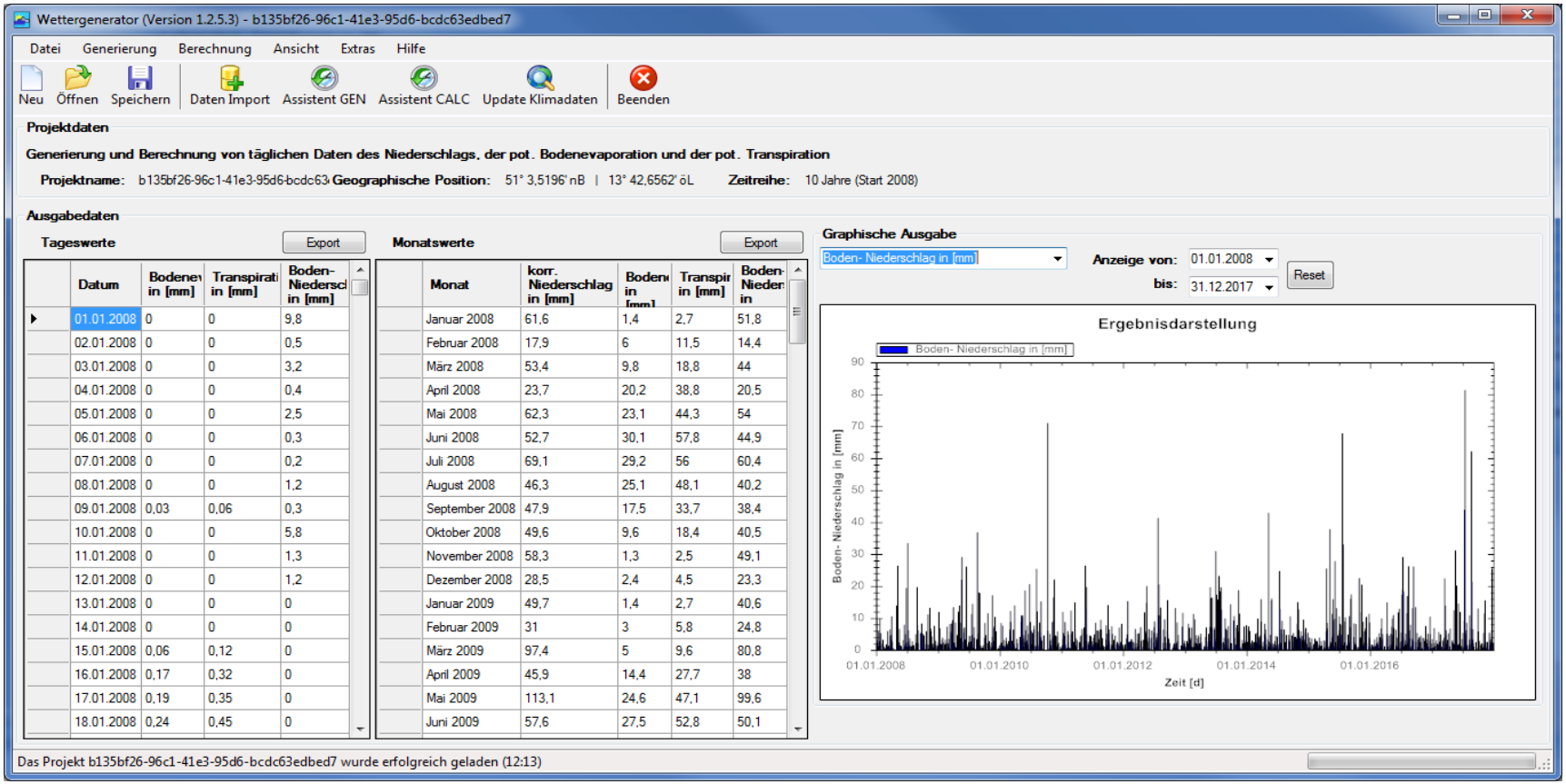


➔ Data input through **assistant**



➔ Graphical visualization of result **time series**

➔ **automatic transfer** to PCSiWaPro® model



Datum	Bodenev in [mm]	Transpirati in [mm]	Boden-Niederscl in [mm]
01.01.2008	0	0	9,8
02.01.2008	0	0	0,5
03.01.2008	0	0	3,2
04.01.2008	0	0	0,4
05.01.2008	0	0	2,5
06.01.2008	0	0	0,3
07.01.2008	0	0	0,2
08.01.2008	0	0	1,2
09.01.2008	0,03	0,06	0,3
10.01.2008	0	0	5,8
11.01.2008	0	0	1,3
12.01.2008	0	0	1,2
13.01.2008	0	0	0
14.01.2008	0	0	0
15.01.2008	0,06	0,12	0
16.01.2008	0,17	0,32	0
17.01.2008	0,19	0,35	0
18.01.2008	0,24	0,45	0

Monat	korr. Niederschlag in [mm]	Boden in [mm]	Transpir in [mm]	Boden-Nieder in
Januar 2008	61,6	1,4	2,7	51,8
Februar 2008	17,9	6	11,5	14,4
März 2008	53,4	9,8	18,8	44
April 2008	23,7	20,2	38,8	20,5
Mai 2008	62,3	23,1	44,3	54
Juni 2008	52,7	30,1	57,8	44,9
Juli 2008	69,1	29,2	56	60,4
August 2008	46,3	25,1	48,1	40,2
September 2008	47,9	17,5	33,7	38,4
Oktober 2008	49,6	9,6	18,4	40,5
November 2008	58,3	1,3	2,5	49,1
Dezember 2008	28,5	2,4	4,5	23,3
Januar 2009	49,7	1,4	2,7	40,6
Februar 2009	31	3	5,8	24,8
März 2009	97,4	5	9,6	80,8
April 2009	45,9	14,4	27,7	38
Mai 2009	113,1	24,6	47,1	99,6
Juni 2009	57,6	27,5	52,8	50,1

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➔ Applications of **PCSiWaPro®** in the following fields:

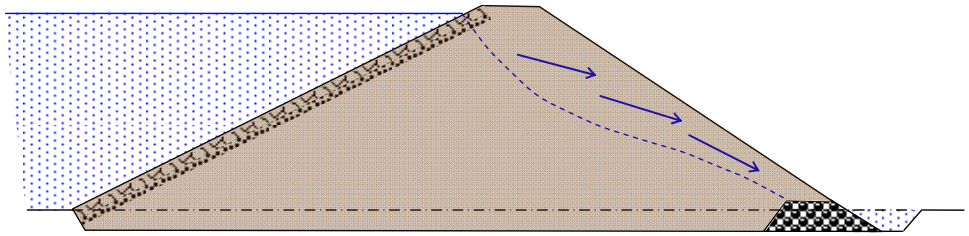
→ leachate forecast

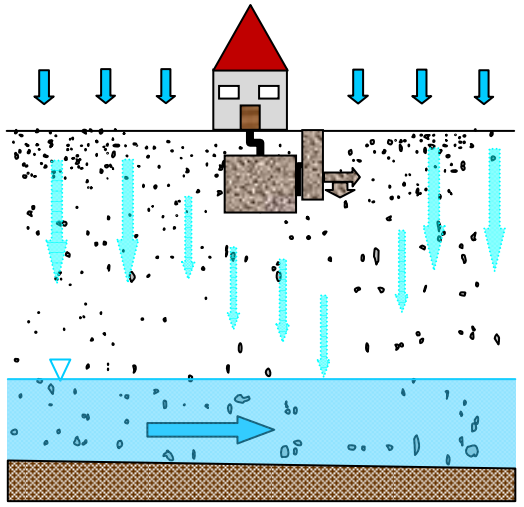
→ earth dams

→ capillary barriers

→ landfill coverage

→ small-scale sewage treatment plants



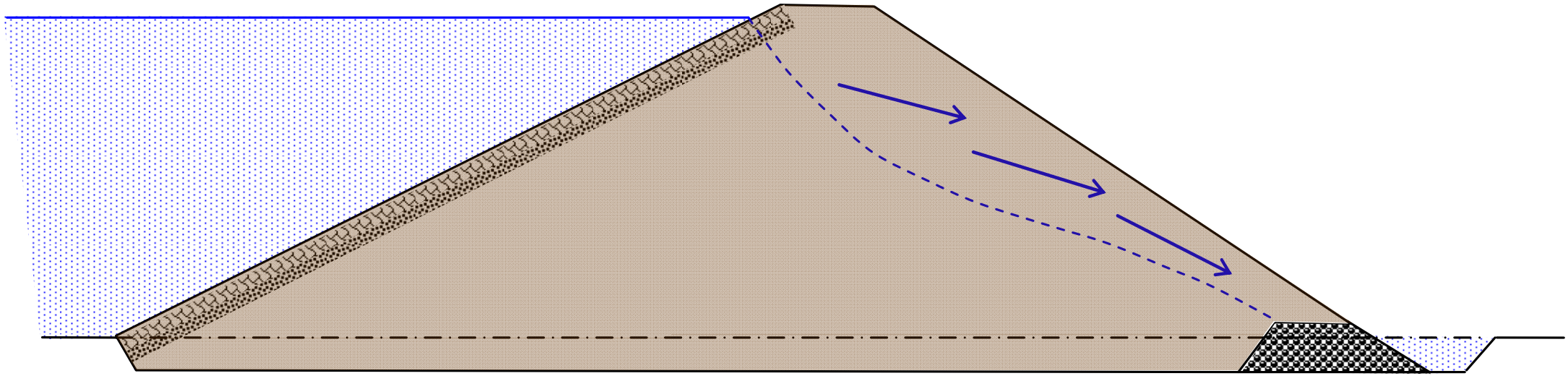


➔ Completed applications with **PCSiWaPro®**:

→ Seepage in an **earth dam**

How long / how far will the unsaturated zone be wetted until instabilities occur?

Influence of structural measures (drainage, blocking walls, …)

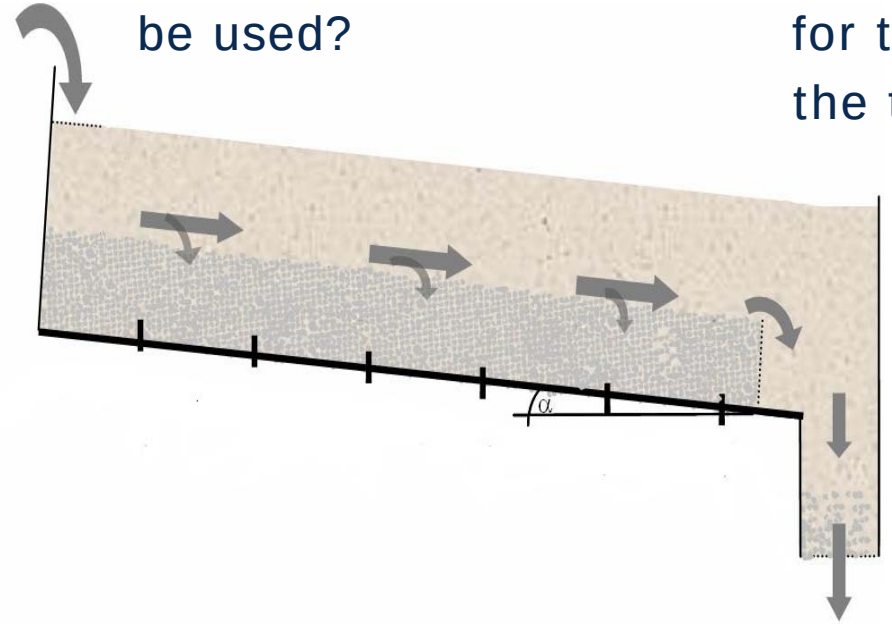


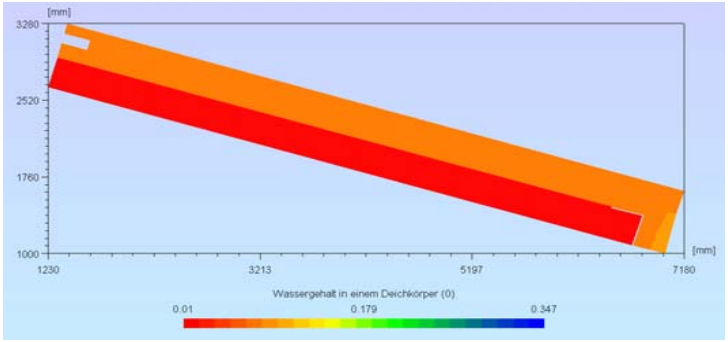
➔ Completed applications with **PCSiWaPro®**:

→ Simulation of a capillary barrier in a **tipping trough**

Which materials should be used?

What are requirements for the dimensioning of the tipping trough?





Thanks for your attention!