Modeling Subsurface Flow and Transport using **FEFLOW**

DHI
WASY

FEFLOW – More than Groundwater

More than „just" groundwater:

- Subsurface Flow and Transport

FEFLOW handles groundwater flow and related processes in one software environment and one simulation model:

o Variably saturated flow

o Contaminant transport

o Heat transport

o Density-affected flow

o Chemical reactions

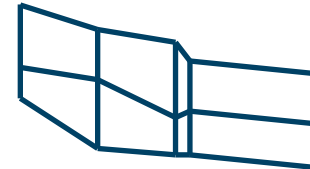o And more...
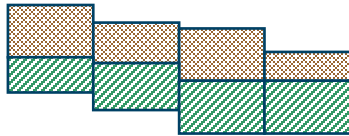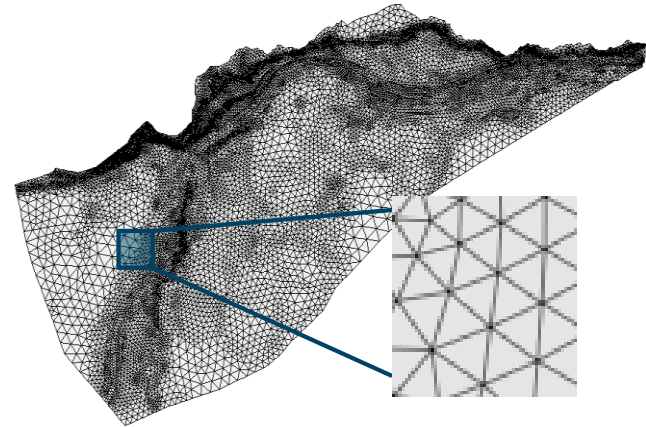
FEFLOW – More than Groundwater

The software must be ...

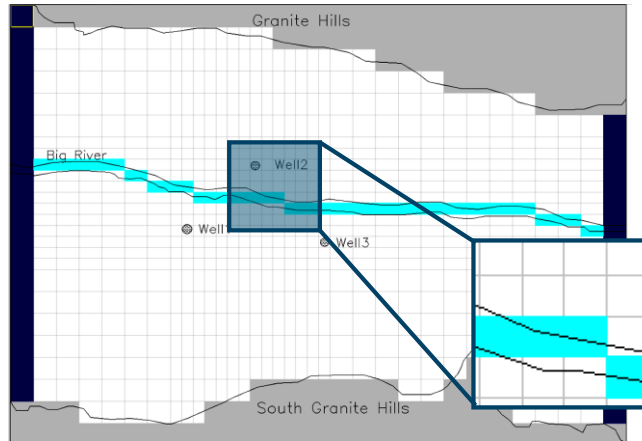- Easy-to-use and intuitive
  to quickly master everyday groundwater projects
- Powerful and comprehensive
  to model the complex subsurface processes
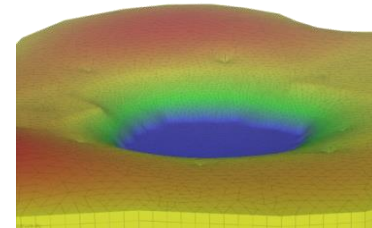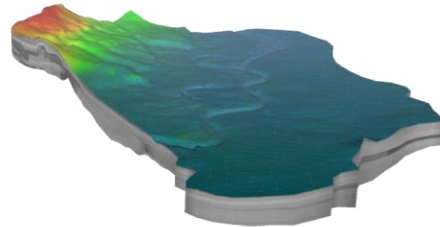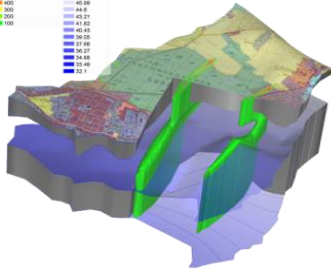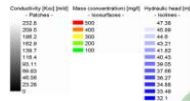
Flexible Meshes

- Finite Differences vs. Finite Elements

Flexible Meshing

- Triangular or quad elements (2D)

- Prisms or cuboids (3D)

- 3D or 2D horizontal / vertical / axisymmetric projection

- 1D and 2D for fracture / pipe / borehole flow
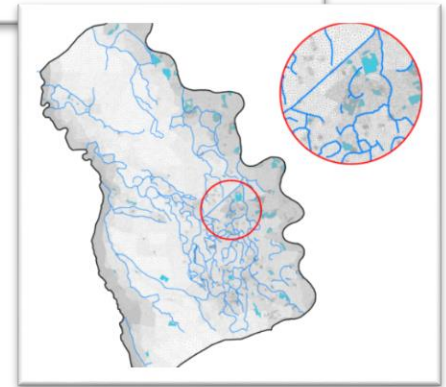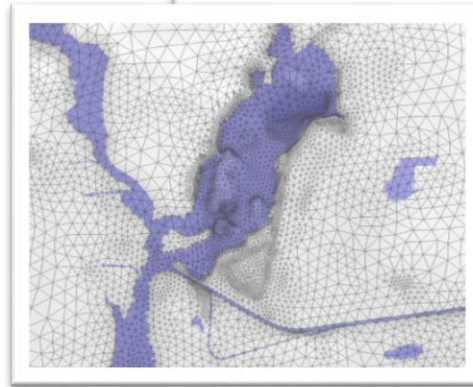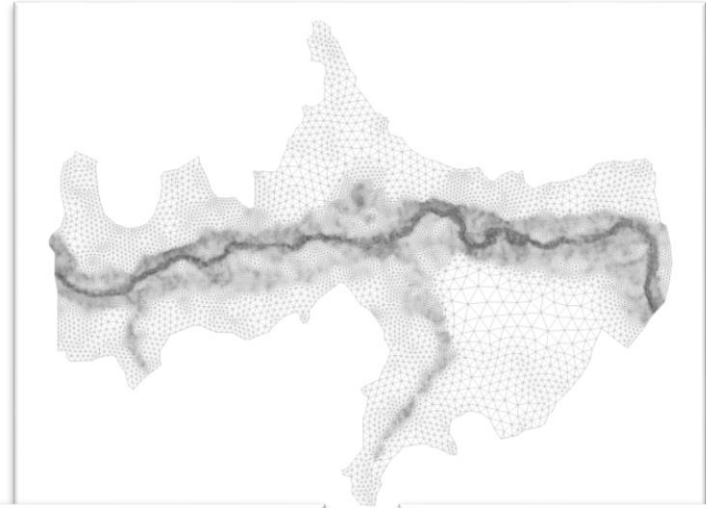
2D Model Projections
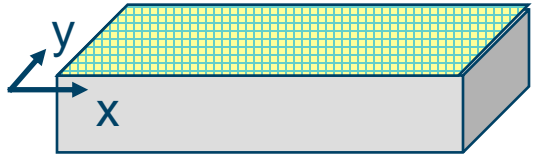
Horizontal projection
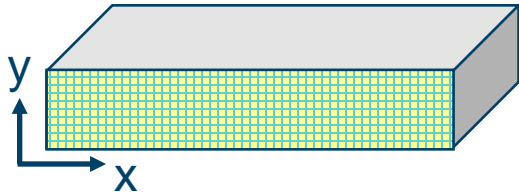
Vertical projection
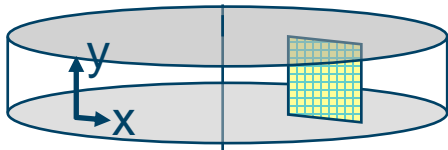
Axisymmetric projection

Flexible Meshing

3D Geometry

…allows detailed models of
complex geometrical structures
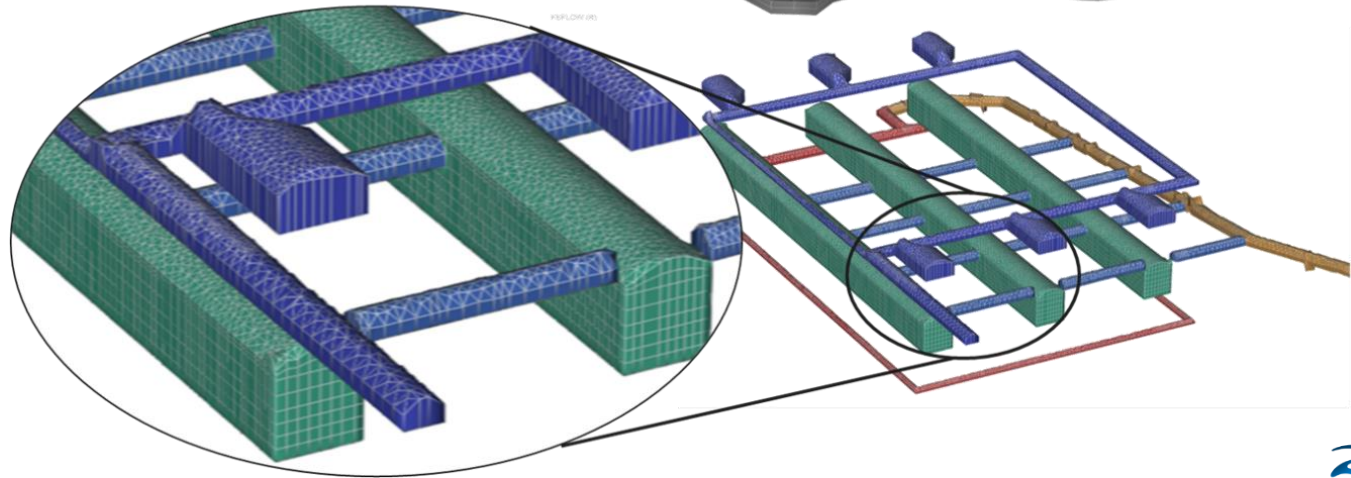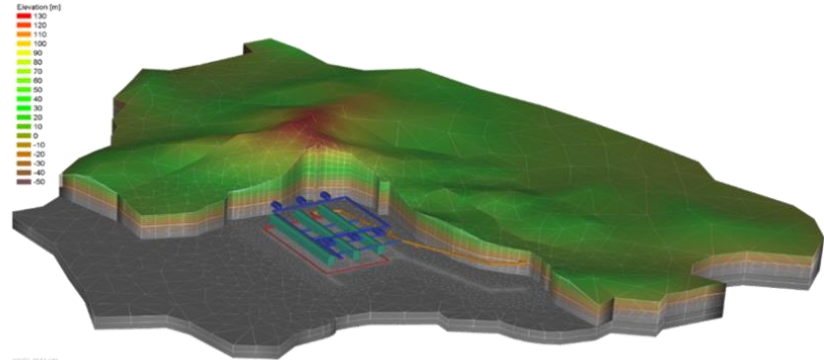
Physics

Groundwater and vadose-zone flow

o Saturated flow (Darcy law)

o Unconfined conditions (different approaches)

o Unsaturated / variably saturated flow (Richards equation)

o Fracture flow

o Density- and viscosity-dependent flow

Physics

Transport

- Heat transport (advection-conduction equation)
- Solute transport (advection-diffusion equation)
- Combined solute / heat transport
- Sorption, decay
- Multispecies simulation
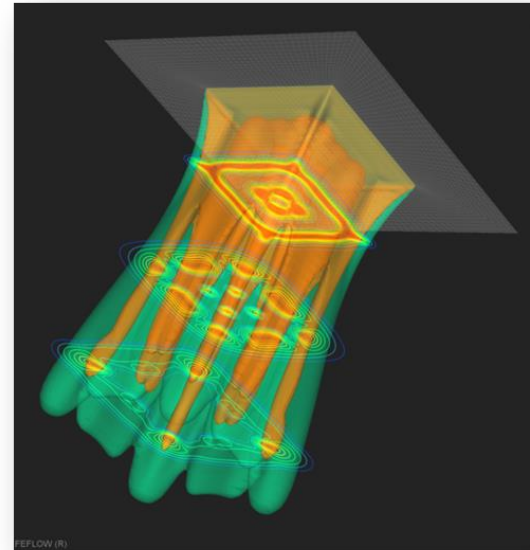- Kinetic reaction systems

FEFLOW Reaction Kinetics Editor

$f(x) =$ **Reaction Kinetics**   Ok   Cancel   Help

User defined   type kinetics, species 2 of 2.

C_1 Rate$_1$

(0) D$_0$ + − × √ sin cos abs ln e^0 [,] π

if = ≠ < ≤ > ≥ and or not

$f = 0.16667$ $g = \dfrac{1-f}{f}$ $K = Sorption_1$

$R_2 = Rate_2 \cdot SolidFrac_2 \cdot g \cdot K \cdot C_1 - SolidFrac_2 \cdot \left\langle Rate_2 + Rate_1 \right\rangle \cdot C_2$

Chemical species definition

Chemical species are associated with a phase:

FLUID PHASE   species dissolved in a mobile fluid phase subjected to dispersion and advection

SOLID PHASE   species of an immobile solid phase having no dispersion and no advection

	Name	Phase
1	PCE	fluid
2	TCE	fluid
3	DCE	fluid
4	VC	fluid
5	O2	fluid
6	NO3-	fluid
7	Cl-	fluid

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Ease of Use

- User interface for preprocessing, simulation, and postprocessing
- GIS/CAD/ASCII file interfaces for import and export
- 2D/3D map support
- Advanced computational methods
  - Powerful mesh generators
  - Automatic time-stepping scheme
  - Algebraic multigrid solver
  - Parallelization
- …

Visualization

- 2D top / cross-section / data-trace views

- 3D views

- 2D / 3D map support

- 3D clipping and carving

- Live, interactive visualization during simulation run

- Hardware acceleration via OpenGL

- 3D stereoscopic display/projector support


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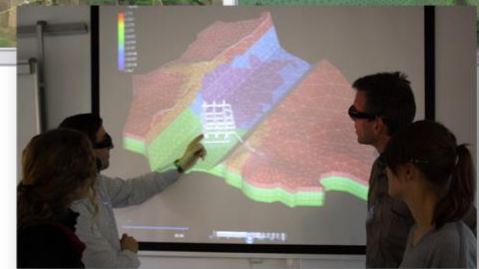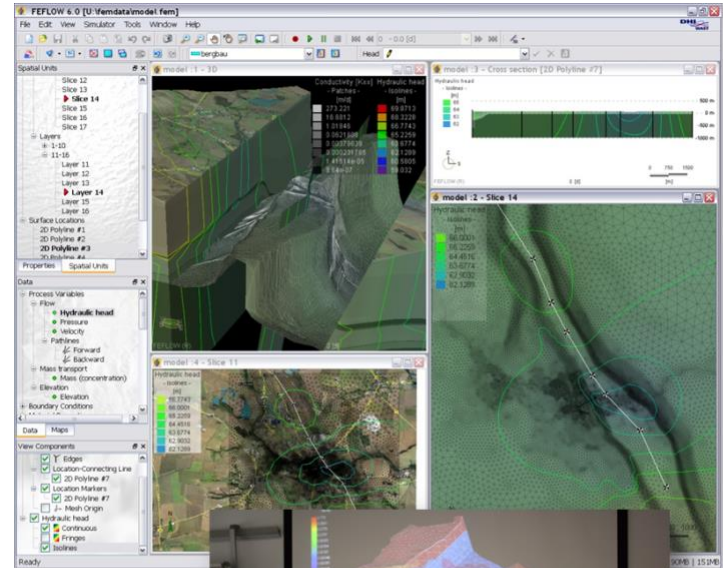
Temporal Element Deactivation

- Elements of the finite-element mesh can be temporally deactivated and reactivated.

- Simulation of time-varying model domain geometry (e.g. open-pit simulation projects, long-term morphological changes, etc.).

FePEST: Parameter Estimation with PEST

- Interface between FEFLOW and PEST

- Part of FEFLOW installation

- Calibration, optimisation, predictive analysis and sensitivity analysis

- Latest versions of PEST.exe and PLPROC.exe accessible

- Features:
  - Pilot-point method
  - Constant values within specified zones
  - 2D and 3D models
  - Steady state and transient models (version 6.2)
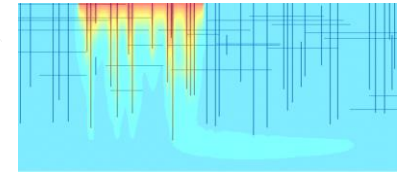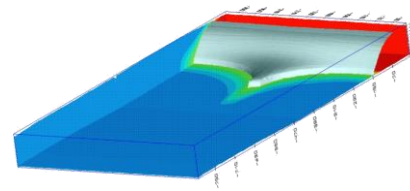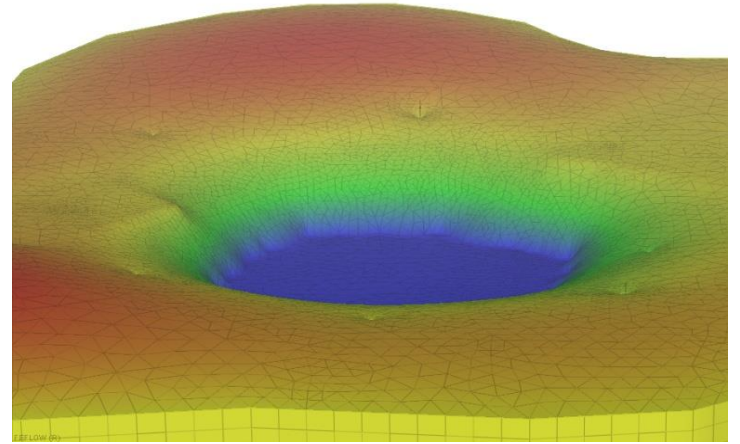 - Tikhonov regularization, SVD, SVD-Assist
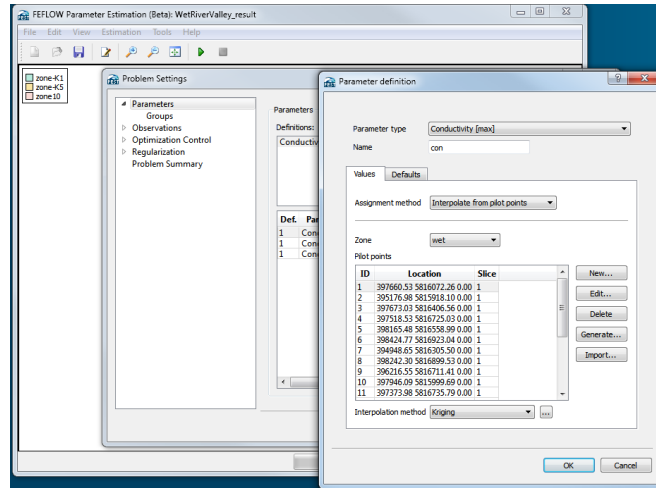
Extensibility

- Open programming interface
  - Documented API interface
  - User can develop plug-ins for
    - Additional functionality
    - Workflow automation

- Application Examples
  - Groundwater / surface-water coupling
  - Integration of technical installations in geothermal modeling
  - Import of model properties
  - Export of model results

- Development Services
  - Plug-in development as a consulting service

Fields of Application

- Regional groundwater management

- Mine-water management

- Groundwater management in construction and tunneling

- Geothermal energy (deep and near surface, both open-loop and closed-loop systems)

- Remediation / natural attenuation

- Seepage through dams and levees

- Groundwater – surface water interaction

- Capture-zone delineation

- Saltwater intrusion

- Industrial porous materials

- … and many more

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