Integrating geological structures into hydraulic-geothermal models to evaluate the productivity of alpine geological systems

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Interreg
Alpine Space
Greta
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Objectives Pilot Study Davos

The objective of the pilot study:

- Development of geological and hydrogeological models
- Understanding complex groundwater systems
- work out the use potential and productivity of shallow geothermal energy from an alpine aquifer, the „Arosa Dolomite“
- calculation of scenarios for geothermal use
- test the effects of changes of hydraulic regimes at different scales

Geothermal projects Davos

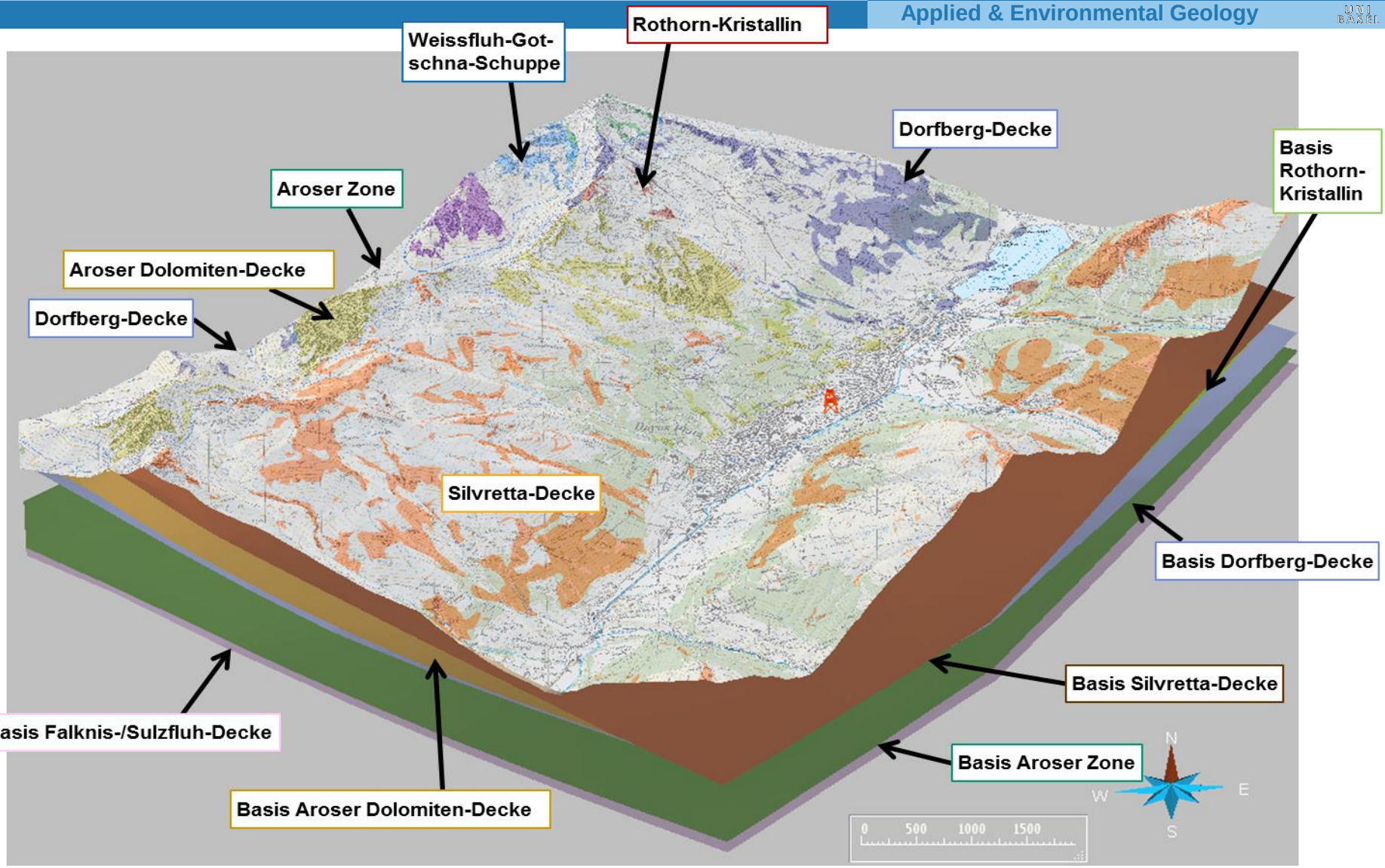
SFOE/ANU/Geotest		
1. Project phase	Seismic Additional hydrogeologic investigations	Basis for further investigations
2. Project phase	Drilling of exploration well Geophysical borehole measurement	Artesian outflow of 1200l/min
3. Project phase	Pumping test Aquifer parameters	GW decline 31m

GNAMA (Geothermal use of Alpine Aquifers)	Expansion of geothermal process knowledge for the aquifer of the Arosa Dolomites	
2014 Stages pumping test Bachelor Thesis 2015 (C. Eisenring)	3 GW observation wells 5 steps over 28d Isotope analysis	140-170 m Basis for model calibration 70-80% young groundwater

GRETA (Near-surface Geothermal Resources in the Territory of the Alpine Space)	3D Geologic model - hydraulic model

Davos Project Area: Geology

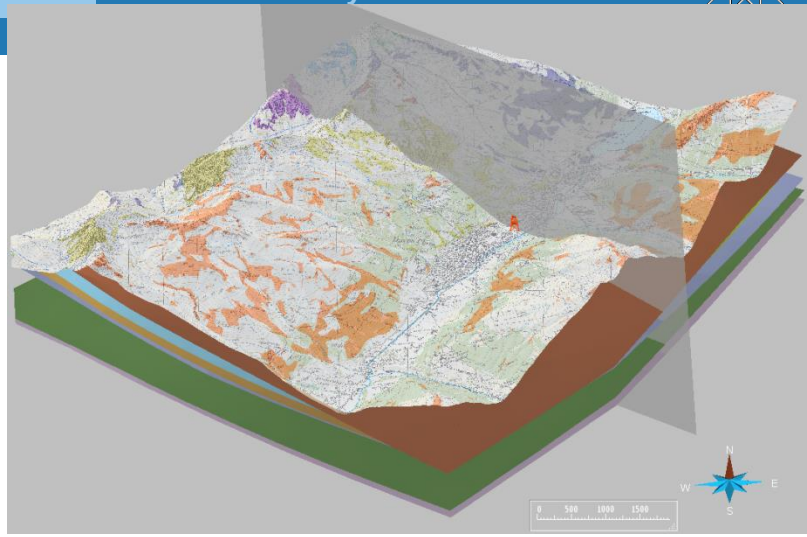
Department of Environmental Sciences
Basel University
Applied & Environmental Geology



Tectonic zones: from WMS server Canton Grisons

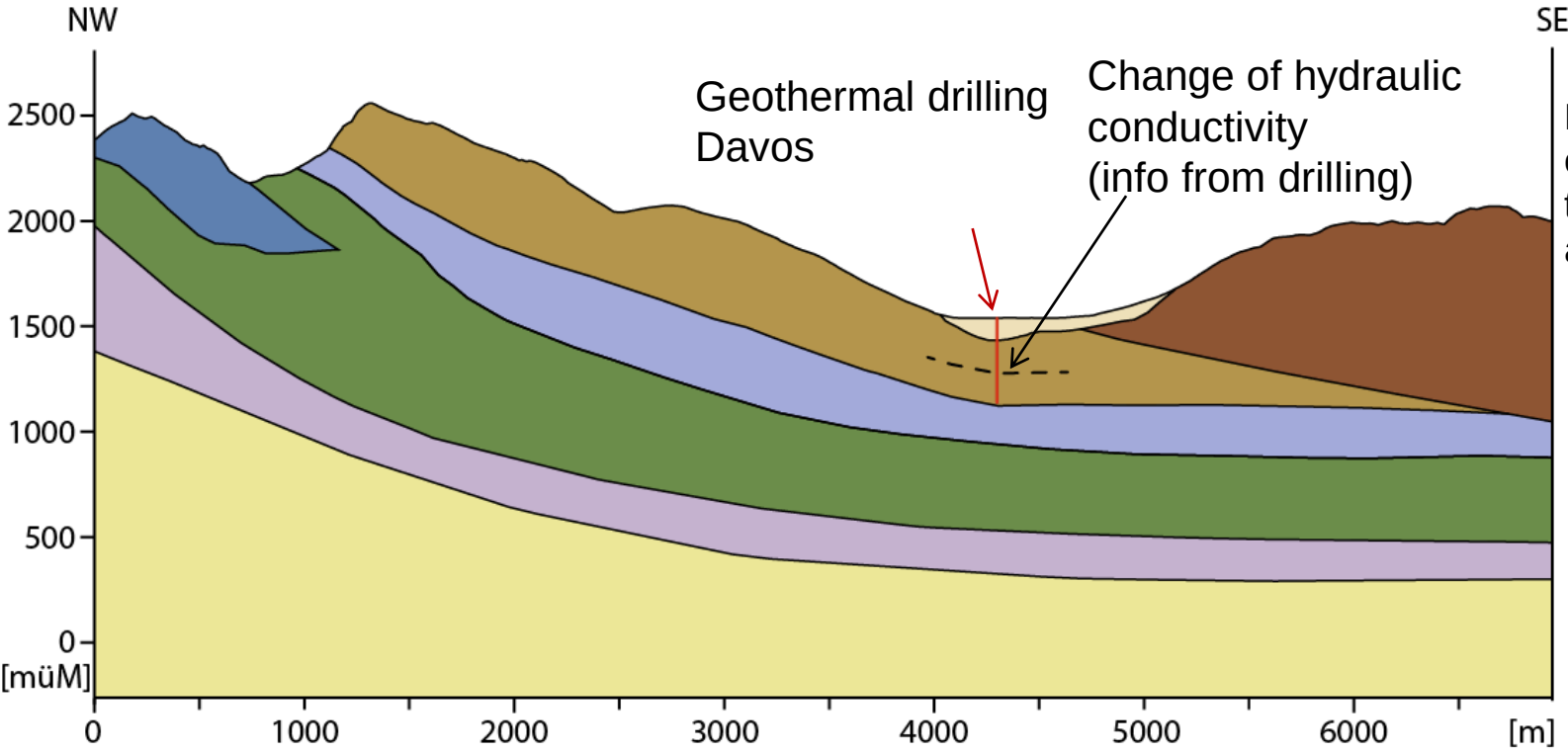
Geothermal Drilling Davos

Geological Profile



- Quartär
- Silvretta-Decke
- Aroser Dolomiten-Decke
- Dorfberg-Decke
- Aroser Zone
- Weissfluh-Gotschna-Schuppe
- Falknis-/Sulzfluh-Decke
- Prättigau Flysch Bündnerschiefer

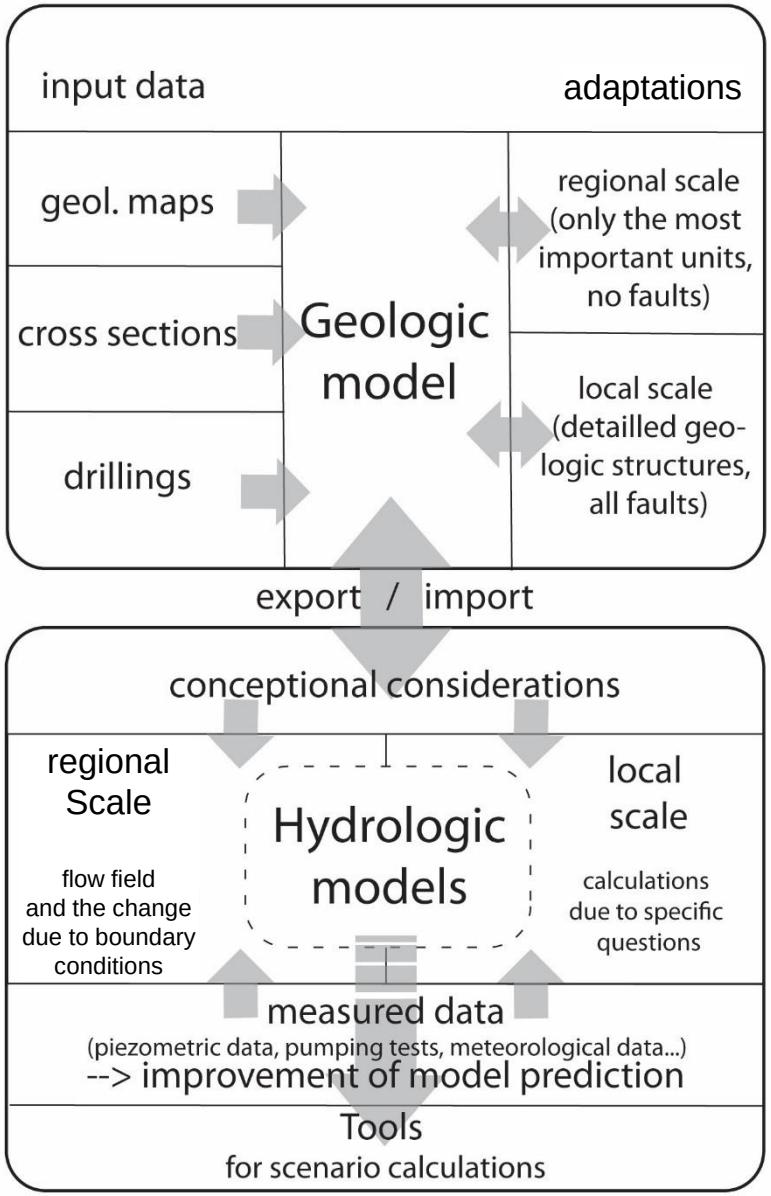
target formation



Projection distance of the borehole in the profile plane around 10 m

Daten Geothermiebohrung Davos: Regli et al. 2013

From geological to hydrogeological understanding



Hydrological Model

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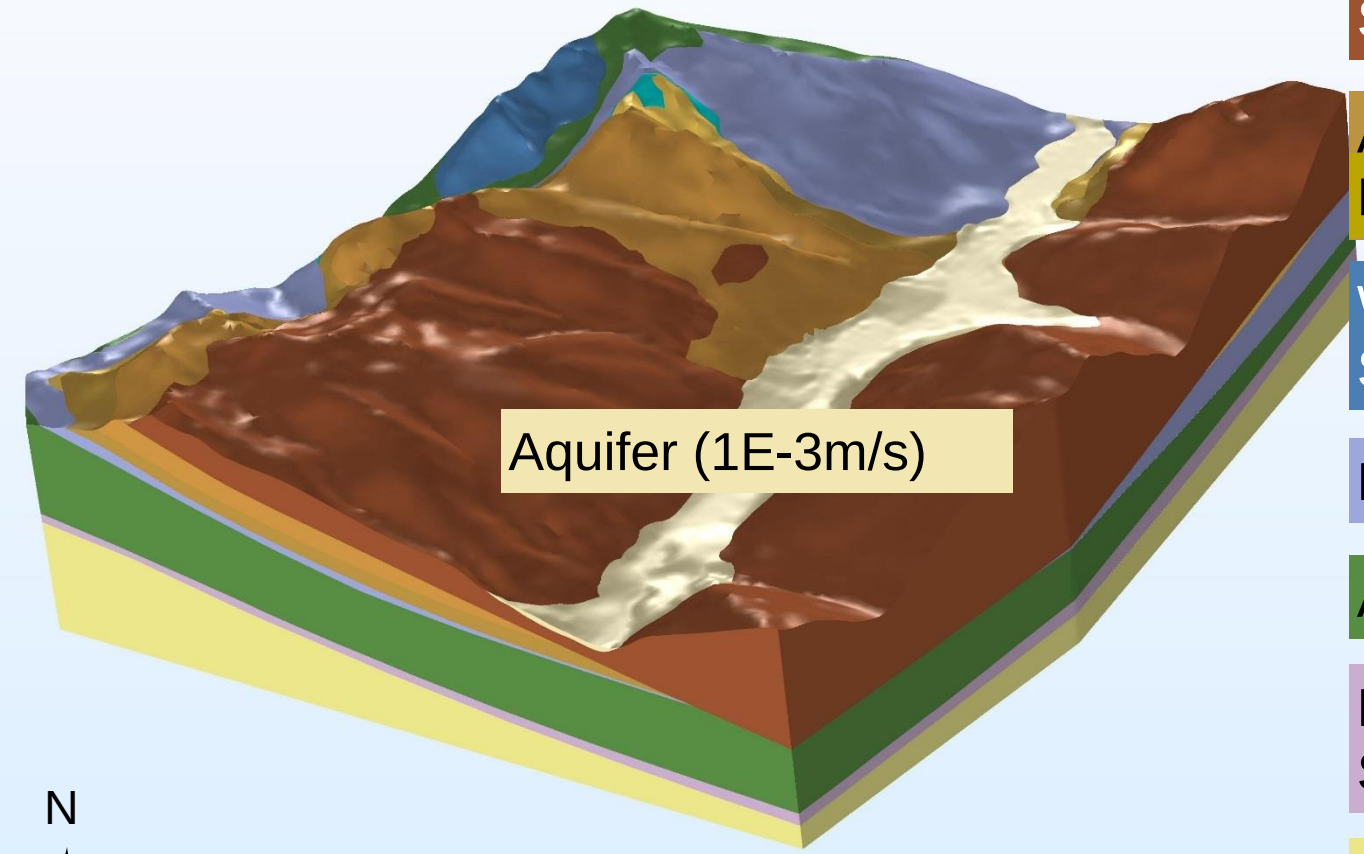


Quaternary

Silvretta Decke

Aroser Dolomiten

Rothorn Schuppe

Weissfluh- Gotschna Schuppe

Dorfberg Decke

Aroser Zone

Falknis-/ Sulzfluhdecke

Praettigau Flysch / Bündnerschiefer

Constructed mesh – basis for numerical calculation

Ca. 400'000 Tetrahedral Elements
Average Element Quality: 0.6

Continuity (mass balance):

$$div\, q = \frac{\partial q_x}{\partial x} + \frac{\partial q_y}{\partial y} + \frac{\partial q_z}{\partial z} = \nabla q$$

div = Divergenz
∇ = Nabla-operator
q = Vektor of Darcy velocity [L T-1]
qx, qy, qz = components of q in x, y und z - direction [L T-1]

Darcy's Law:

$$-K\left(\frac{\partial h}{\partial x}\hat{i} + \frac{\partial h}{\partial y}\hat{j} + \frac{\partial h}{\partial z}\hat{k}\right) = -K\nabla h$$

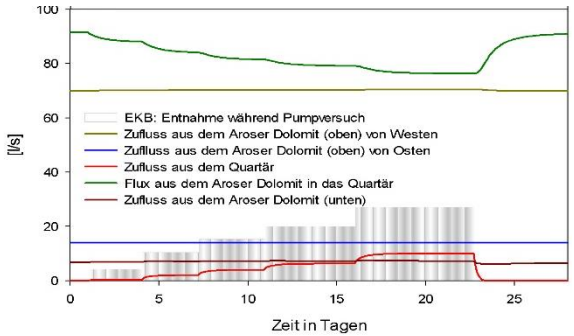
Groundwater flow equation:

$$\frac{\partial}{\partial x}\left(K_{xx}\frac{\partial h}{\partial x}\right) + \frac{\partial}{\partial y}\left(K_{yy}\frac{\partial h}{\partial y}\right) + \frac{\partial}{\partial z}\left(K_{zz}\frac{\partial h}{\partial z}\right) - W = S_s\frac{\partial h}{\partial t}$$

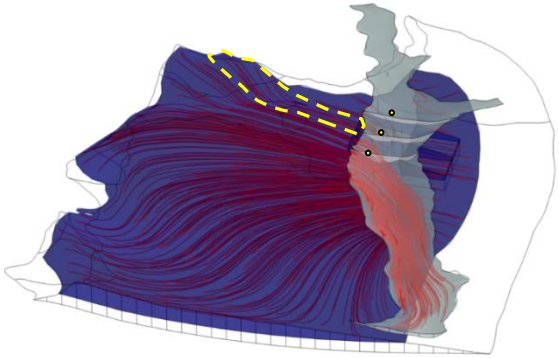
k, xx etc.: Components of permeability tensor [L T-1]
S = mS0: storage coefficient [-]
W = Sources and sinks [L T-1]

Ca. 2'250'000 Tetrahedral Elements
Average Element Quality: 0.68

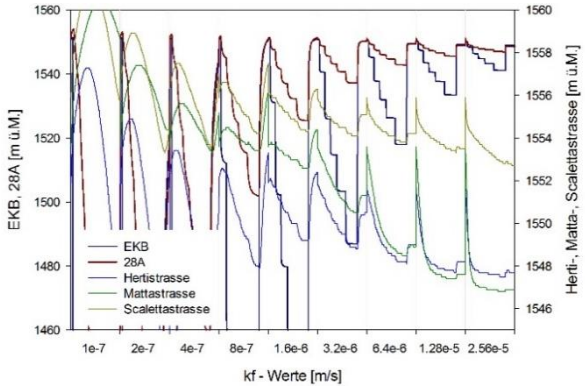
Some applications



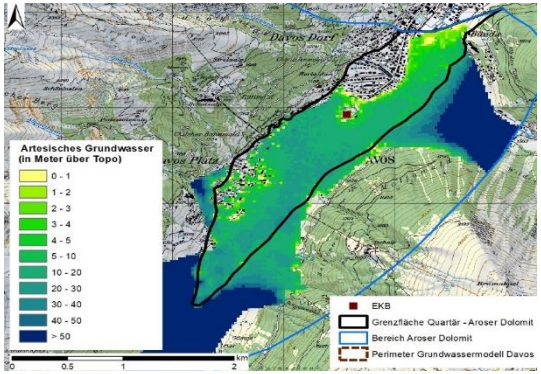
Groundwater budget



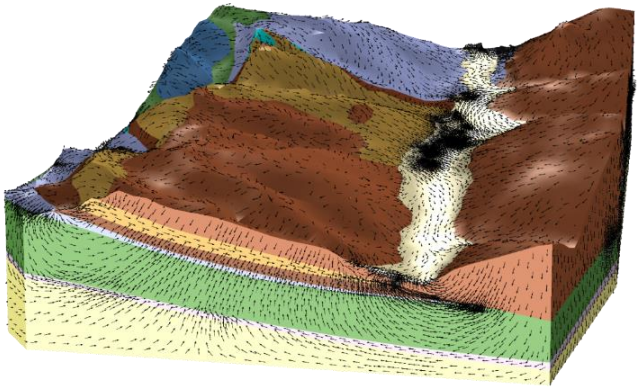
Capture zones



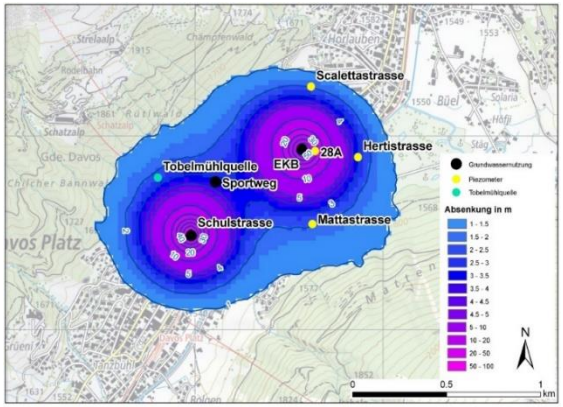
Sensitivities



Groundwater potential maps:
Here as map of artesian groundwater



Regional Groundwater-flowsystem



Influence of several uses

Conclusions

Model tool allows

- to calculate the head distribution in the Arosa Dolomite in dependence of groundwater discharge
- to simulate response of pumping tests
- to calcualte flow budgets from different boundaries
- to visualize the non-stationary capture zones of wells
- to calculate the changing contribution of the Quaternary deposits
- to use szenario techniques

Future

- **How much energy can be produced (Scenarios)**

→ **Potential**

- Coupling of flow and thermal processes

Projectpartners and extern experts

Urs Eichenberger – Institut Suisse de Spéléologie et de Karstologie (ISSKA)

Gian-Paul Calonder – Community Davos

Hansruedi Aebli – Office for nature and environment, Canton Grisons (ANU)

Sébastien Rieben – Federal Office for Spatial Development (ARE)

Gunter Siddiqi – Swiss Federal Office of Energy (SFOE)

Céline Weber – Swiss Federal Office of Energy (SFOE)

Christian Regli – Geotest AG

Stephan Boley – Geotest AG