

Case Studies

Project Data

Core piece of a new high capacity railway line which will link Styria with Carinthia. Length 32,8 km. Maximum overburden 1200 m

Tasks

Site investigation for the feasibility study and the preliminary design. Geotechnical assessment of the route corridor, route selection. Environmental impact assessment

Geology

Polymetamorphic basement consisting of gneiss, amphibolite, mica schist and marble. Development of complex fault systems, in particular at the boundaries to Tertiary basins

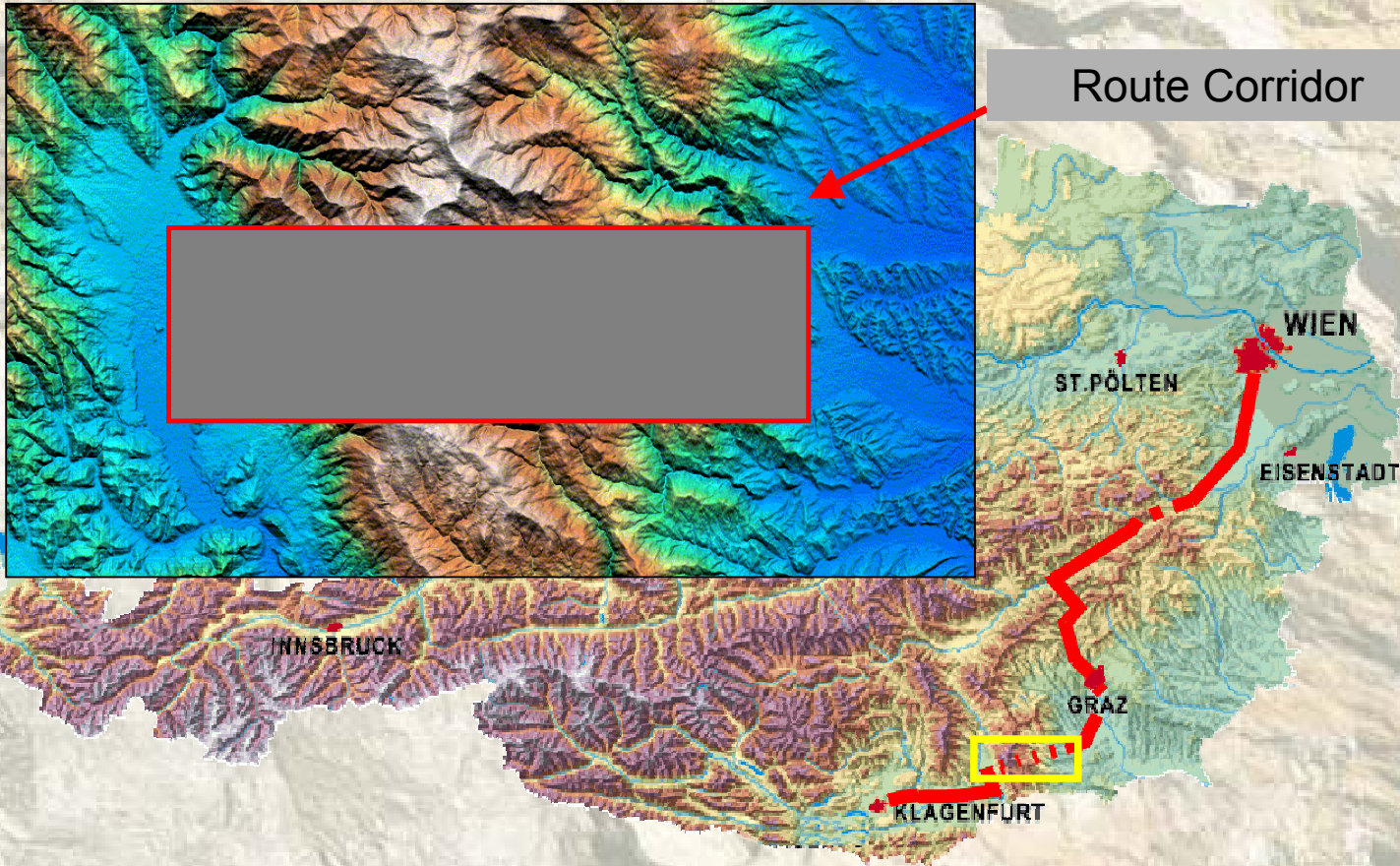
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Preliminary Corridor Assessment

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Case Studies

Location



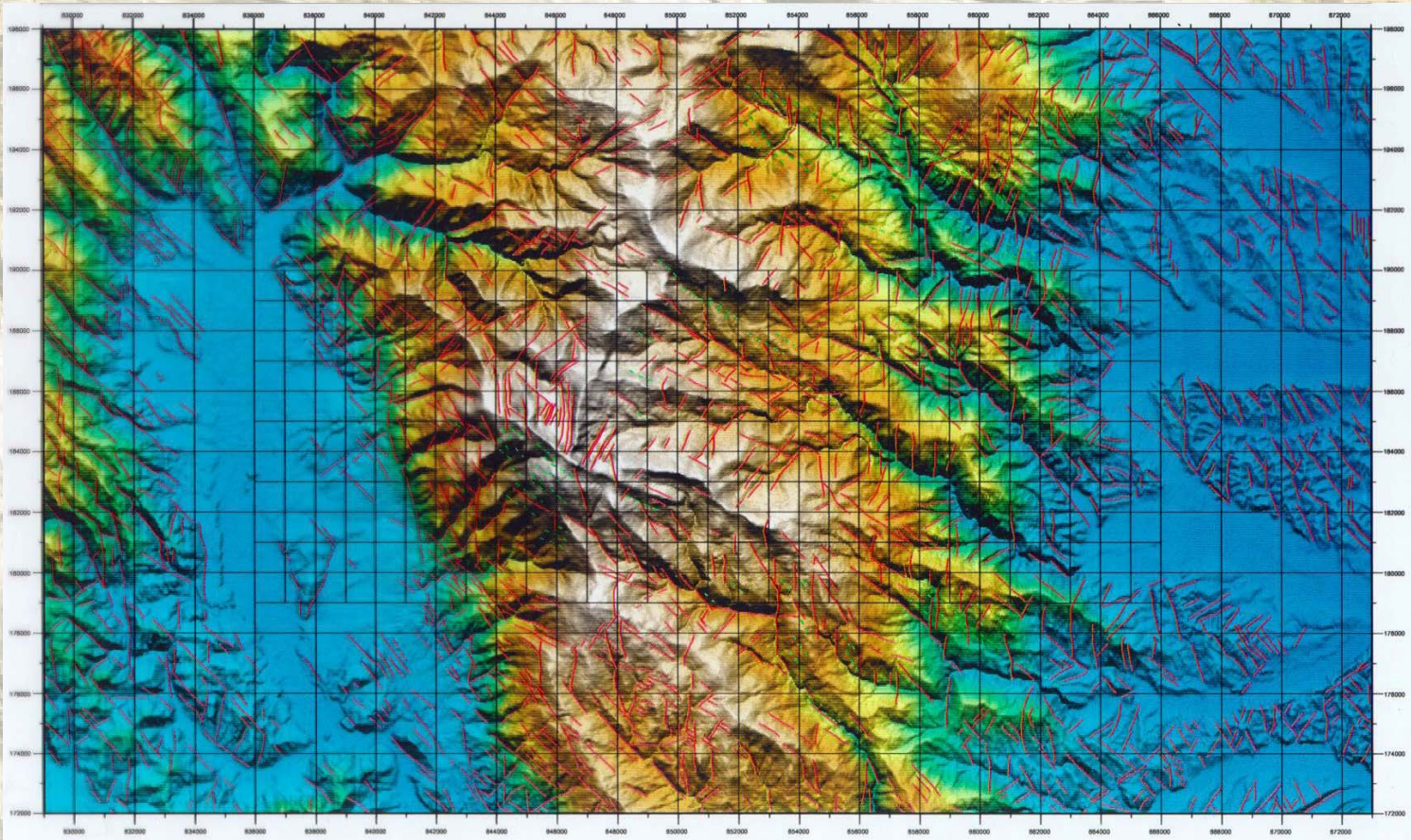
Route Corridor

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Corridor Assessment

Shaded digital elevation model overlain by fault pattern



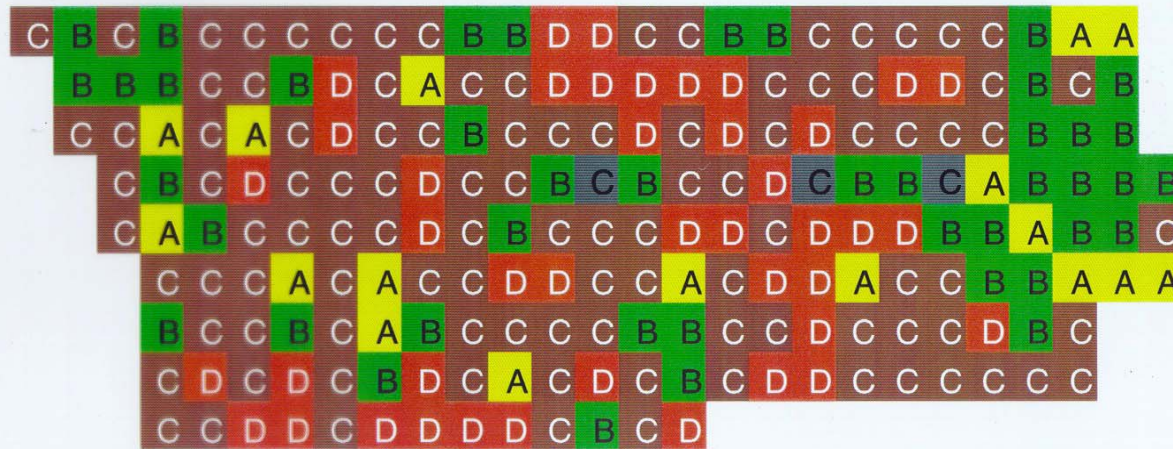
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Corridor Assessment

$$Rating = \frac{\sum_{i=1}^3 a_i}{b \cdot c} \cdot 10^4$$

- a_1 = overburden
- a_2 = lithology
- a_3 = orientation of schistosity
- b = faults
- c = groundwater

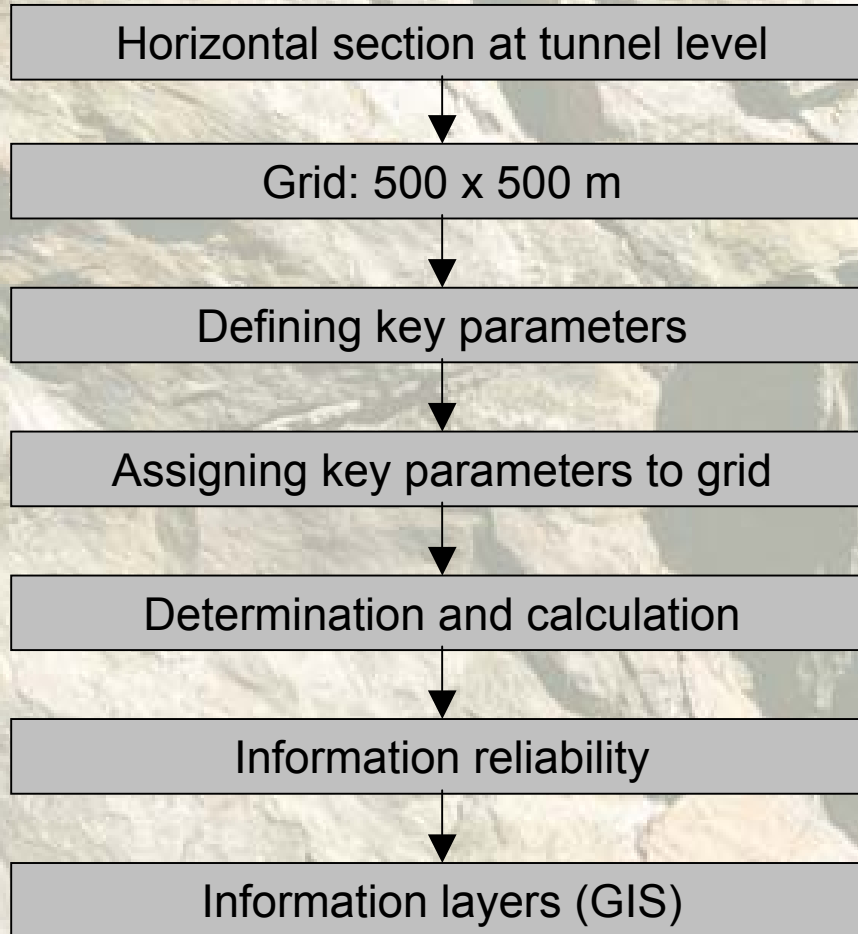


A low risk
 B moderate risk
 C high risk
 D very high risk

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Quantitative Route Selection



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Case Studies

Quantitative Route Selection

Input Data

Mechanical data:

Intact rock

UCS, m_i , E , ν , σ_t

Anisotropic behaviour

Abrasivity

Joints

ϕ , ϕ_{rest}

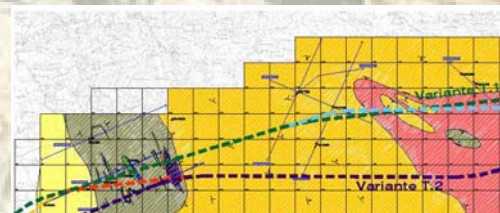
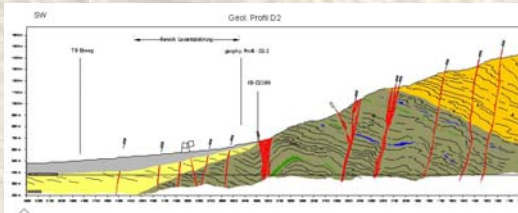
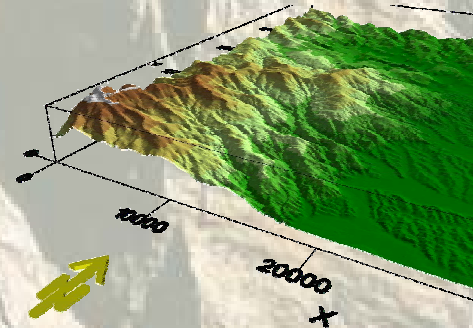
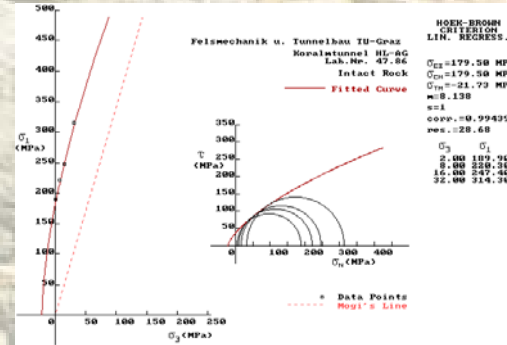
Geological data:

Overburden

Orientation of joint sets

Faults

Distribution of lithological units

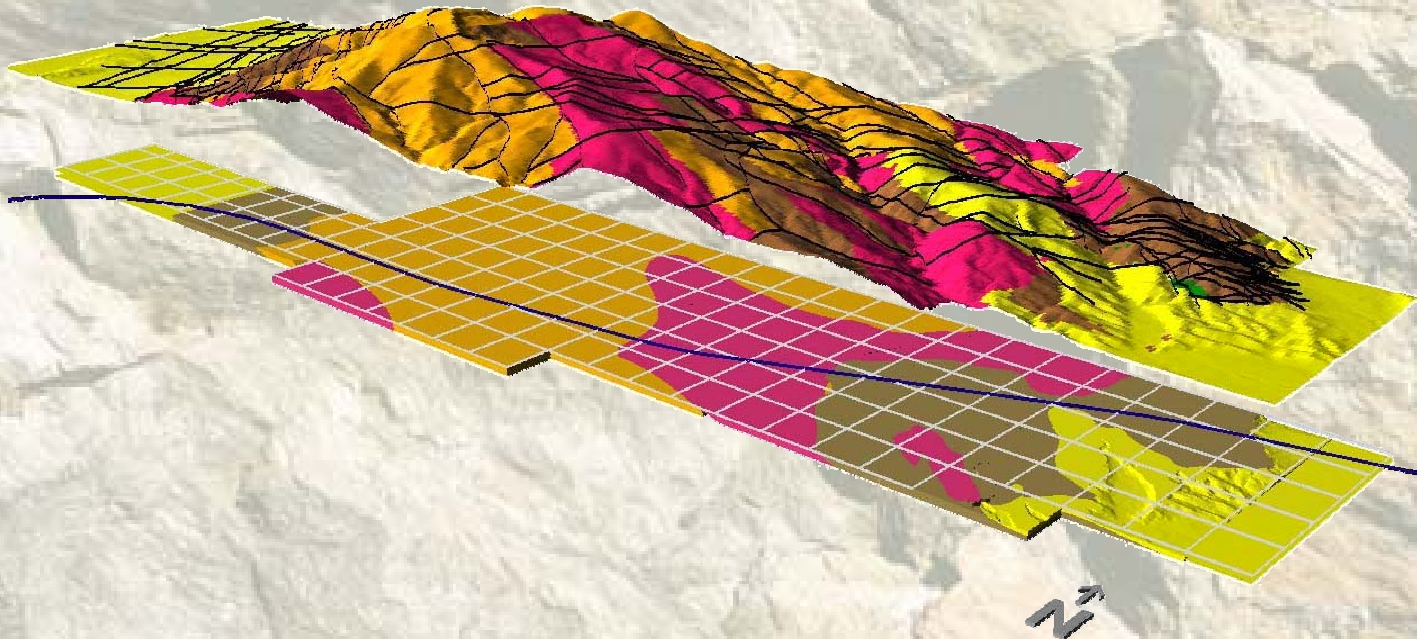


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Quantitative Route Selection

Input: Geological Architecture



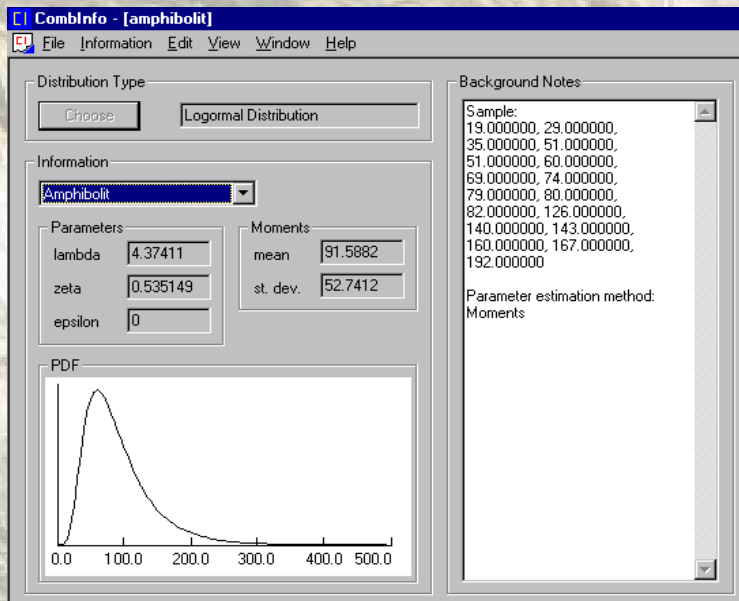
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Quantitative Route Selection

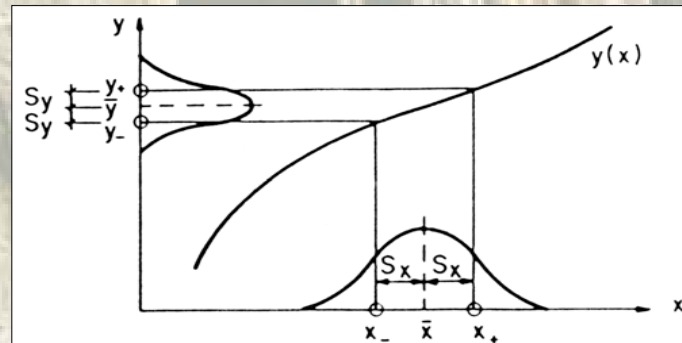
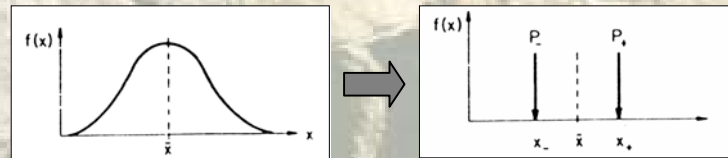
Input: Mechanical Data

Laboratory data



Probability Analysis

(Point Estimation Method, Rosenblueth)



Functions with several variables

Integration formulas

Permutations from $n+1$ to $2n^2+1$

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Quantitative Route Selection

Input: Fault Geometry

Geometrical conditions

$$L_{fault} = 3 * \left(\frac{D}{\tan \alpha} + \frac{1}{\sin \alpha} \right)$$

Probability of intersecting a fault

$$P(f) = \frac{L_{fault} * \sin \alpha}{500}$$

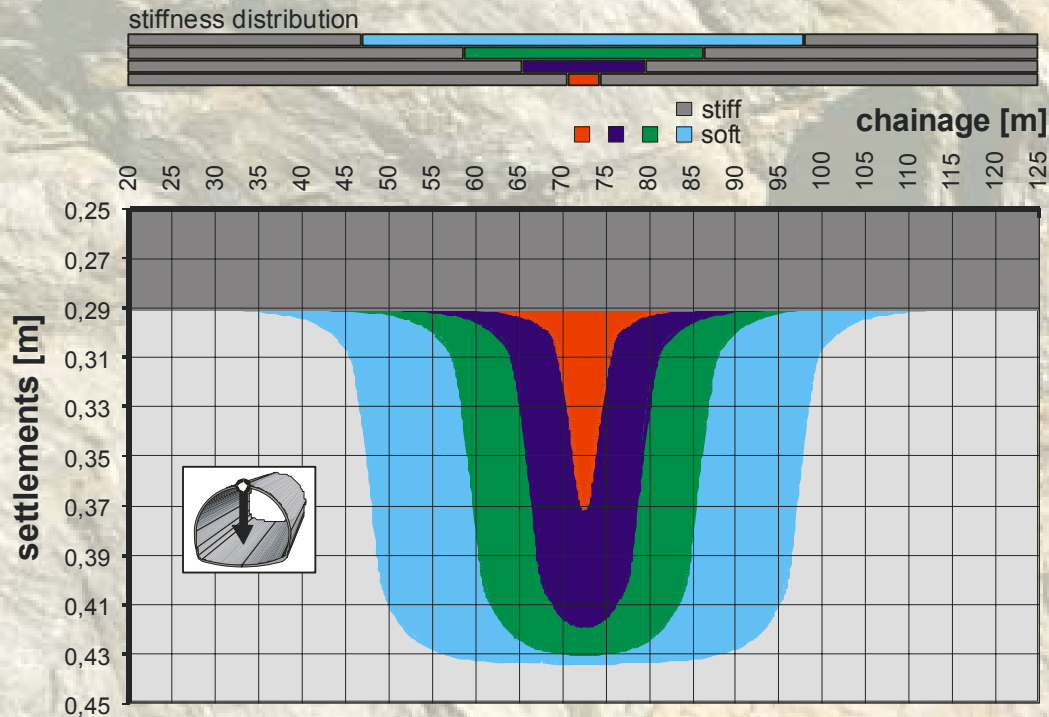
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Quantitative Route Selection

Calculation of Settlements (E. Hoek)

Undisturbed (stiff) and Faulted Rock Mass (soft)

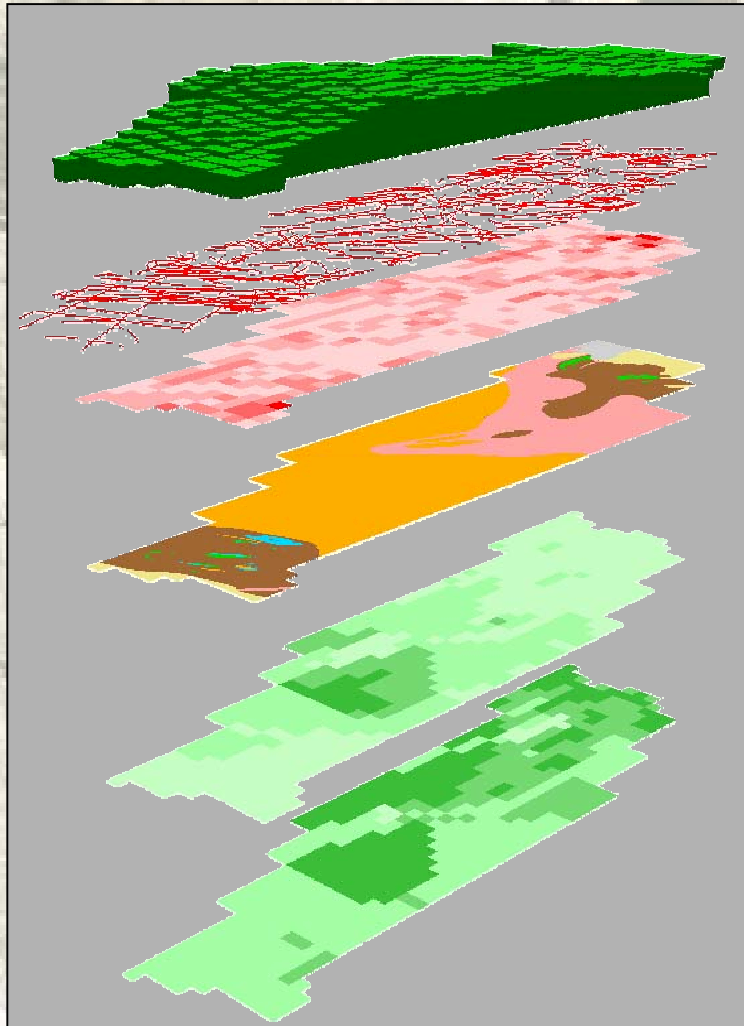


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Quantitative Route Selection

Input Layers for GIS Based Analysis of Radial Deformation



- ← Overburden
- ← Faults
- ← Fault Influenced Excavation Length
- ← Lithology
- ← Rock Mass Strength



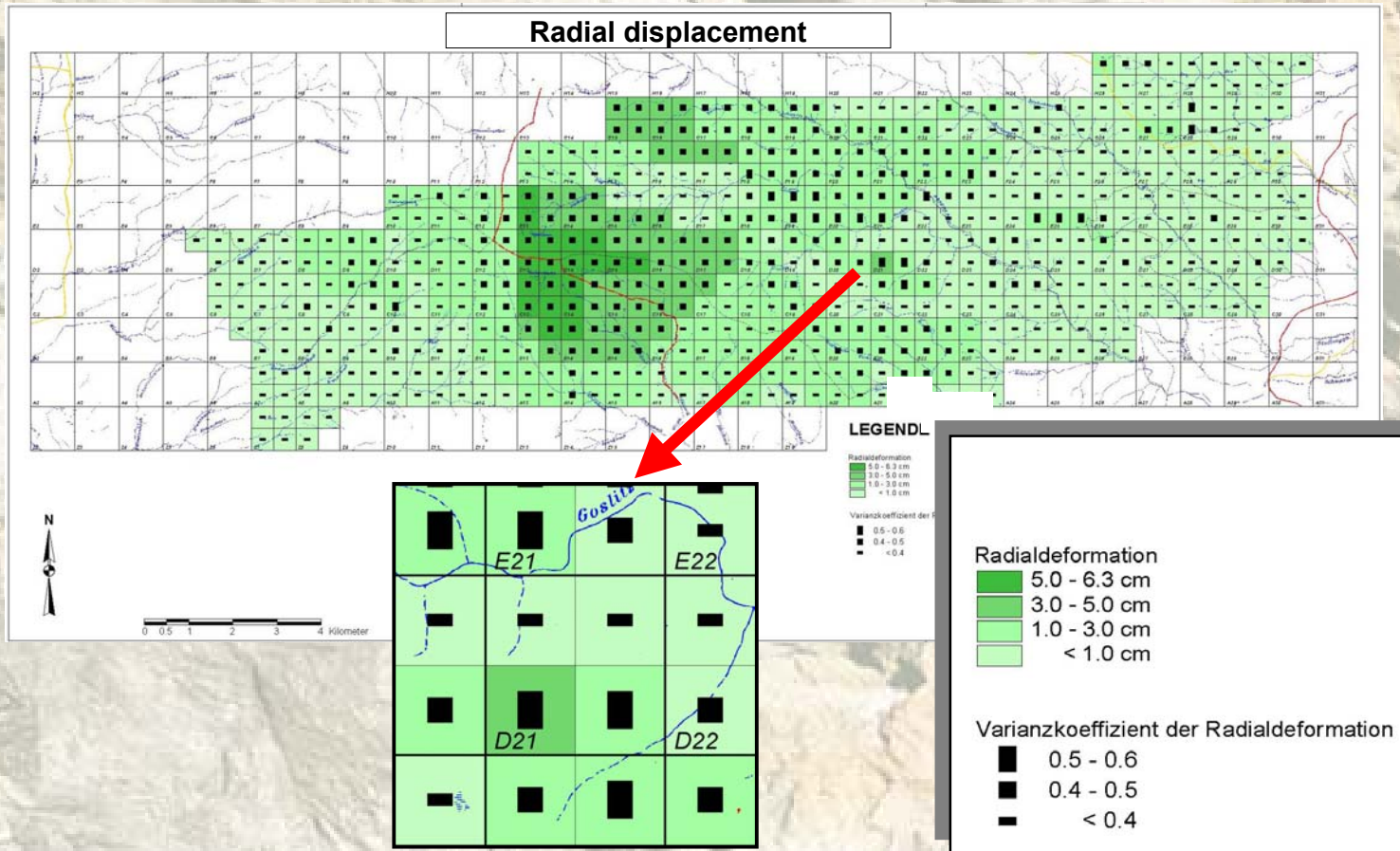
← **Radial Deformation**

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Quantitative Route Selection

Result Layer: Radial Deformation

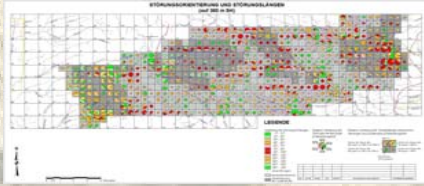


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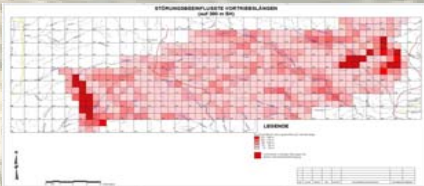
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Quantitative Route Selection

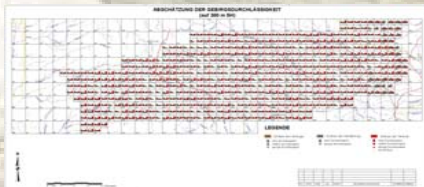
Input Layers



Faults, orientation, total lengths



Faults, excavation lengths

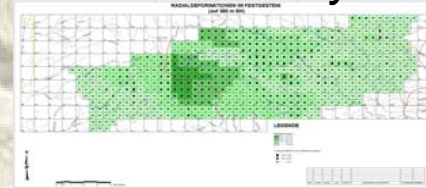


Permeability

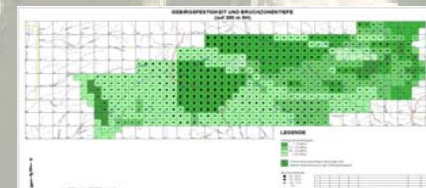


Information reliability

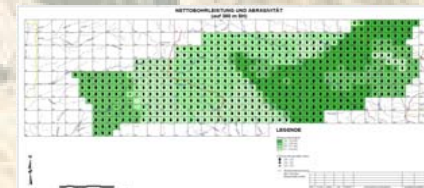
Result Layers



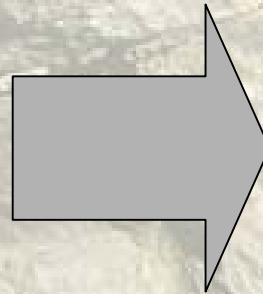
Depths of broken zone



Radial displacement



Penetration rate
(TBM and rock mass data)

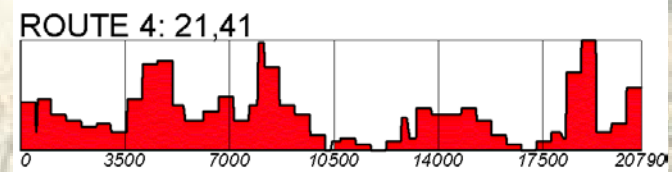
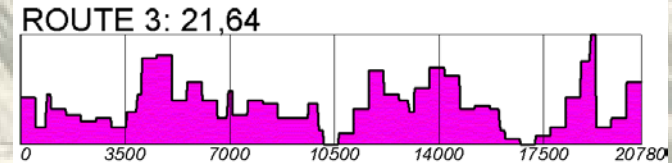
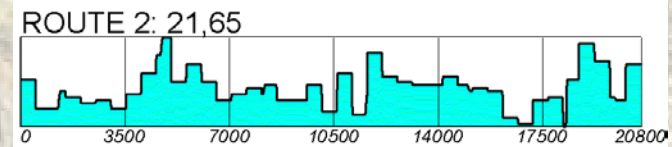
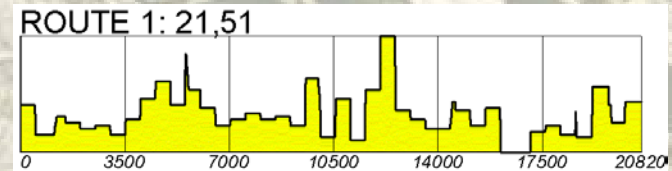
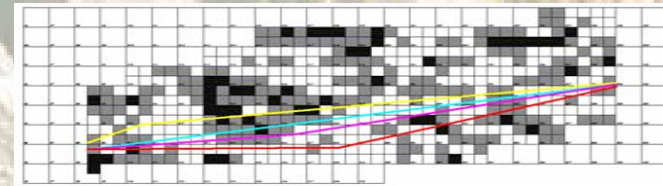
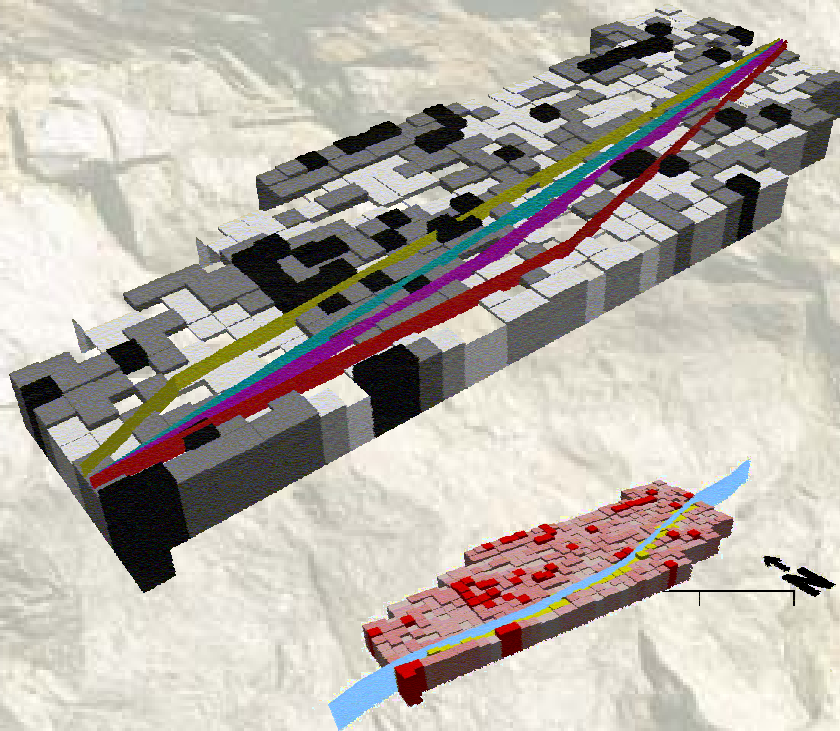


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Case Studies

Quantitative Route Selection

Results



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Case Studies

Preliminary Design

Geological 3D-Modelling

Objectives:

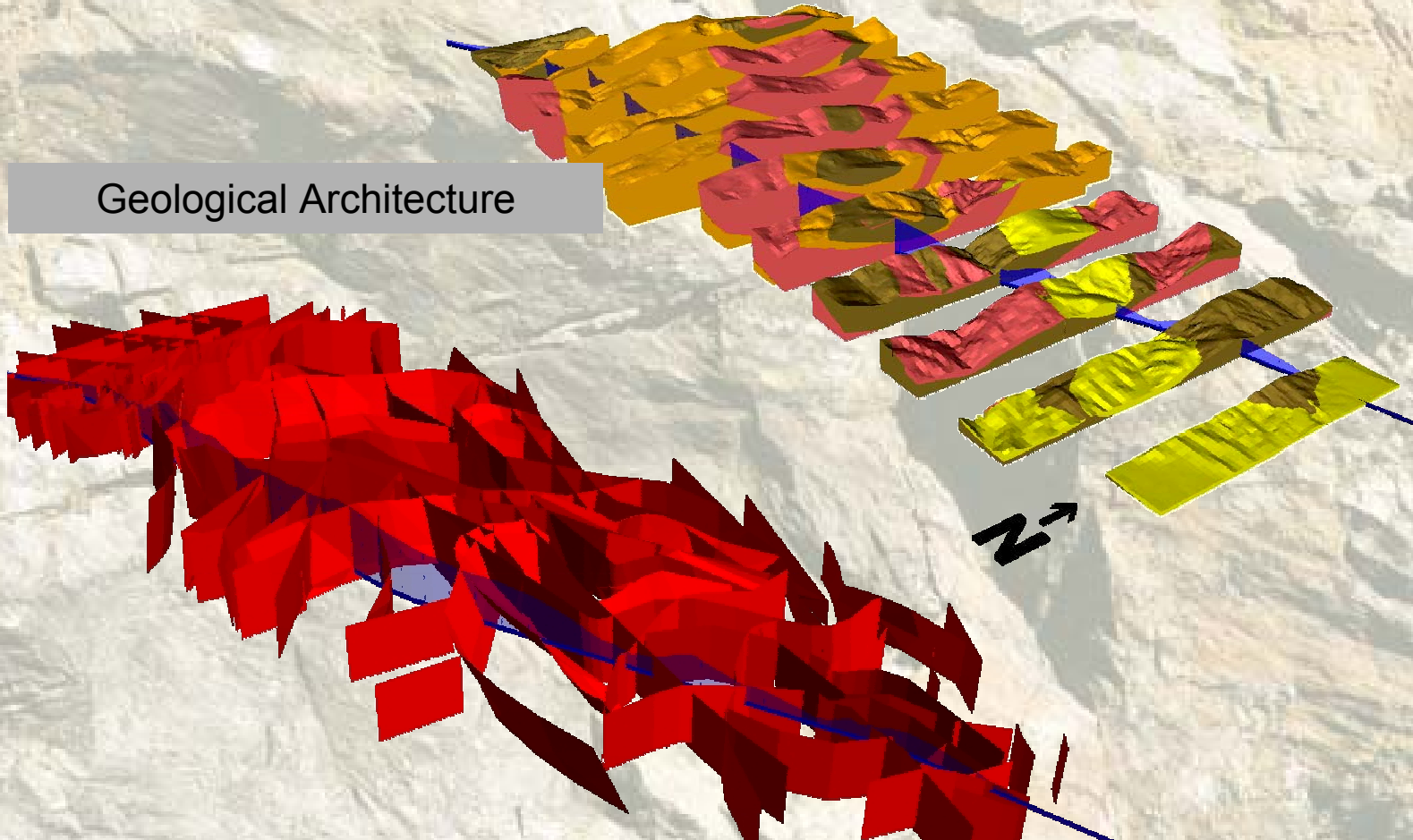
- Reliability of Geological Architecture
- Assessment of Groundwater Models
- Assessment of Tunnel-Groundwater Interactions
- Estimate of In-Situ Rock Temperatures
- Optimization of Further Site Investigations

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Case Studies

Preliminary Design

Geological Architecture

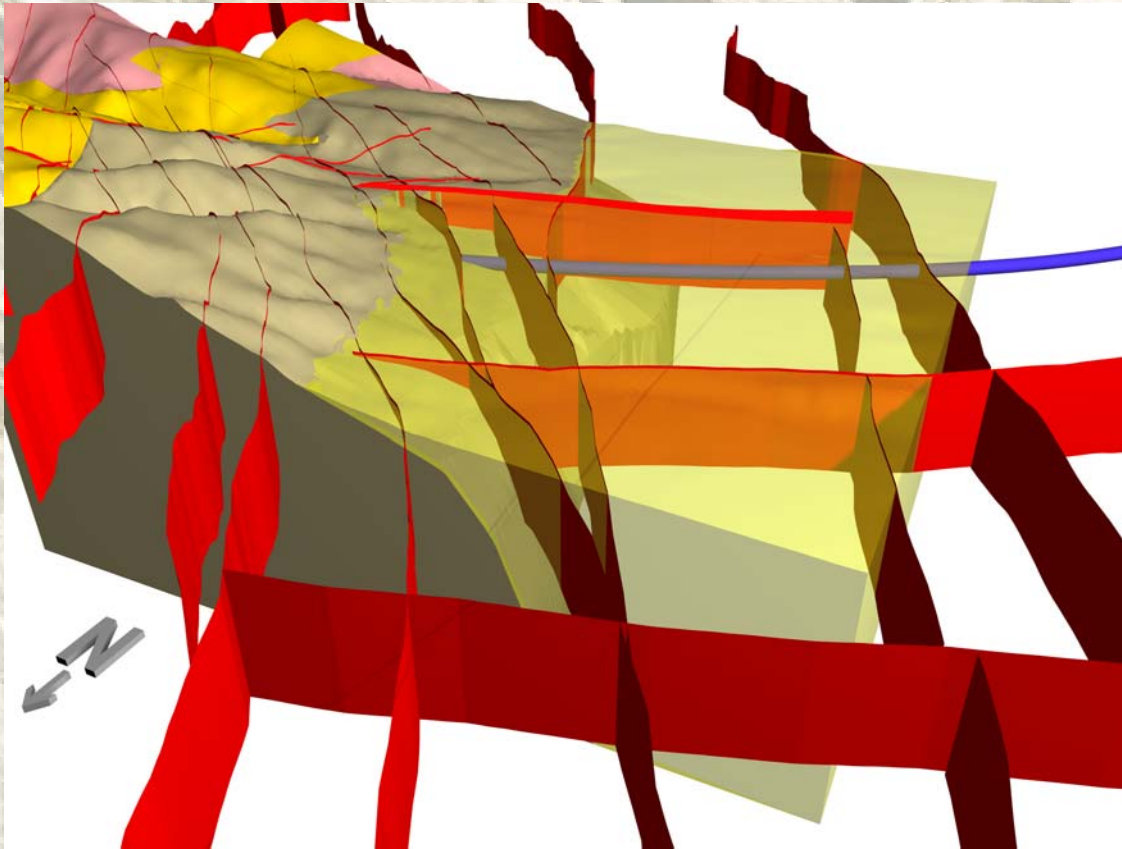


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Preliminary Design

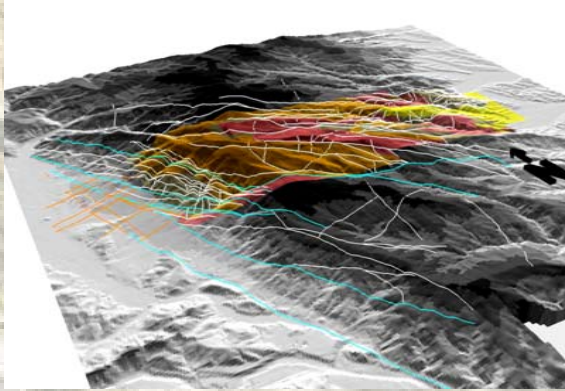
Geological 3D-Modelling



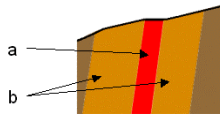
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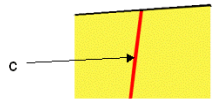
Preliminary Design



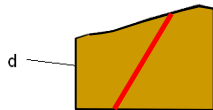
- Typ I – Lavanttalstörung



- Typ II – Lavanttalst. im Tertiär



- Typ III – "Standard" Störung



Hydraulic Fault Zone Definitions (modified after Caine et al. 1996)

Typ I, Major Strike-Slip Fault in Crystalline Basement

Well-developed Fault Core (predominantly M- and C- cataclasites) with low permeability) surrounded by high permeable Fracture Zone (G- and S-cataclasite) and Blocky Rock Mass

Typ II Major Strike-Slip Fault in Tertiary Clastic Sediments

Fault Core poorly developed. No Fracture Zones

Typ III Normal Fault in Crystalline Basement

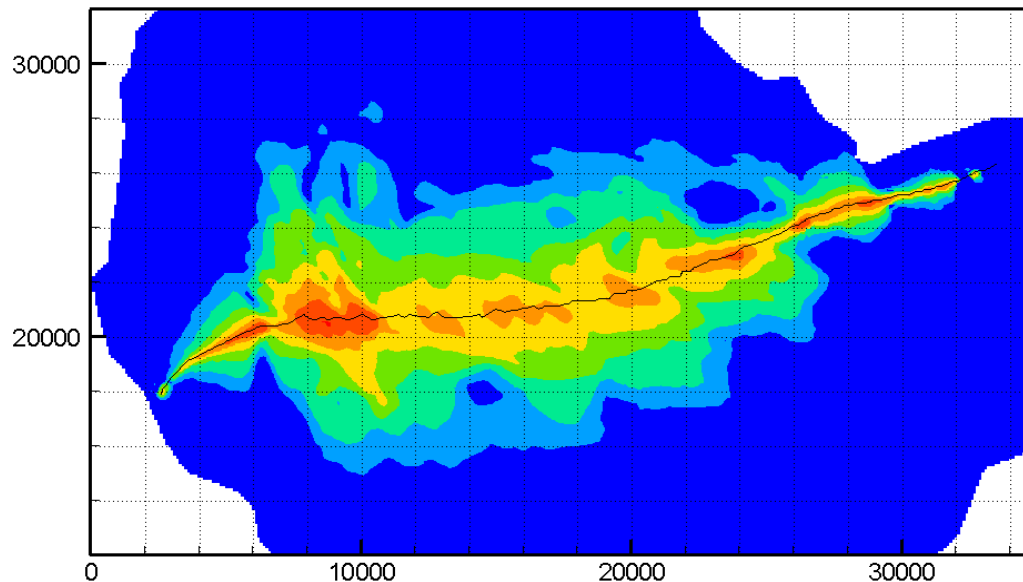
Fault Core poorly developed. Well-developed Fracture Zone associated with high permeable fracture network

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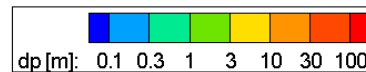
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Preliminary Design

Hydraulic Model, maximum possible lowering of the groundwater table



Modell M22



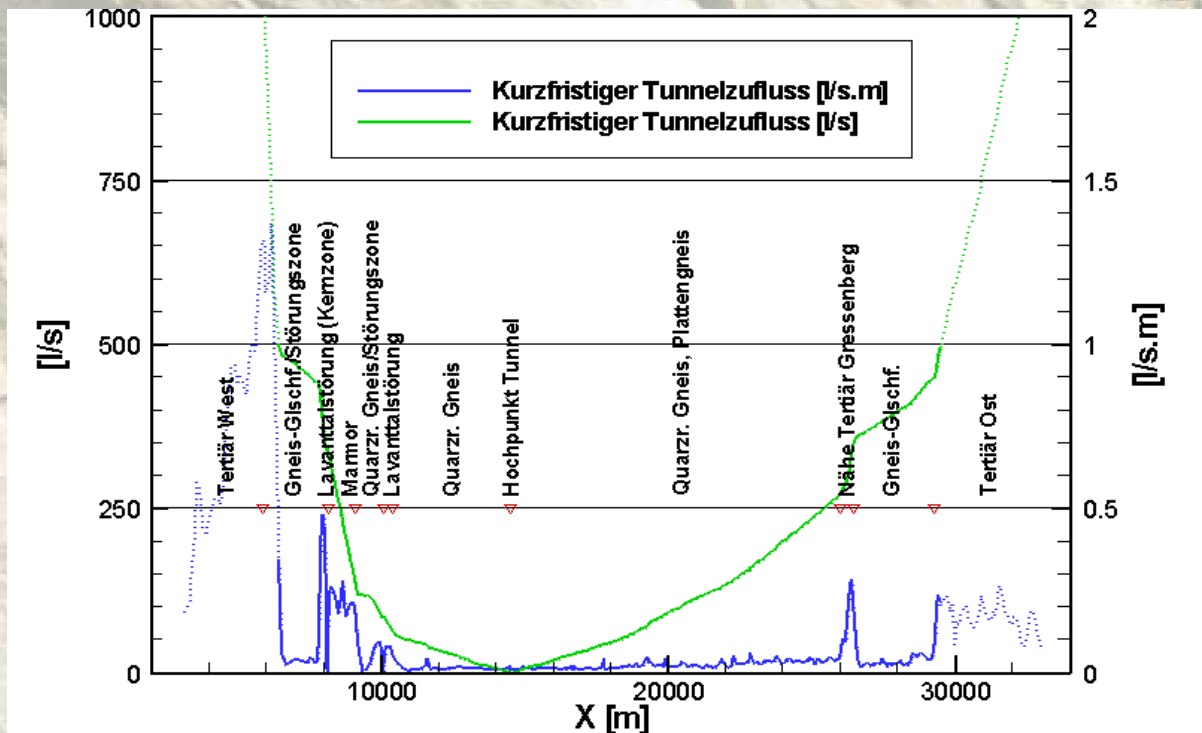
Conservative Model (1D Hydraulic Flow)

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Preliminary Design

Predicted Short-Term Inflows During Tunnel Excavation

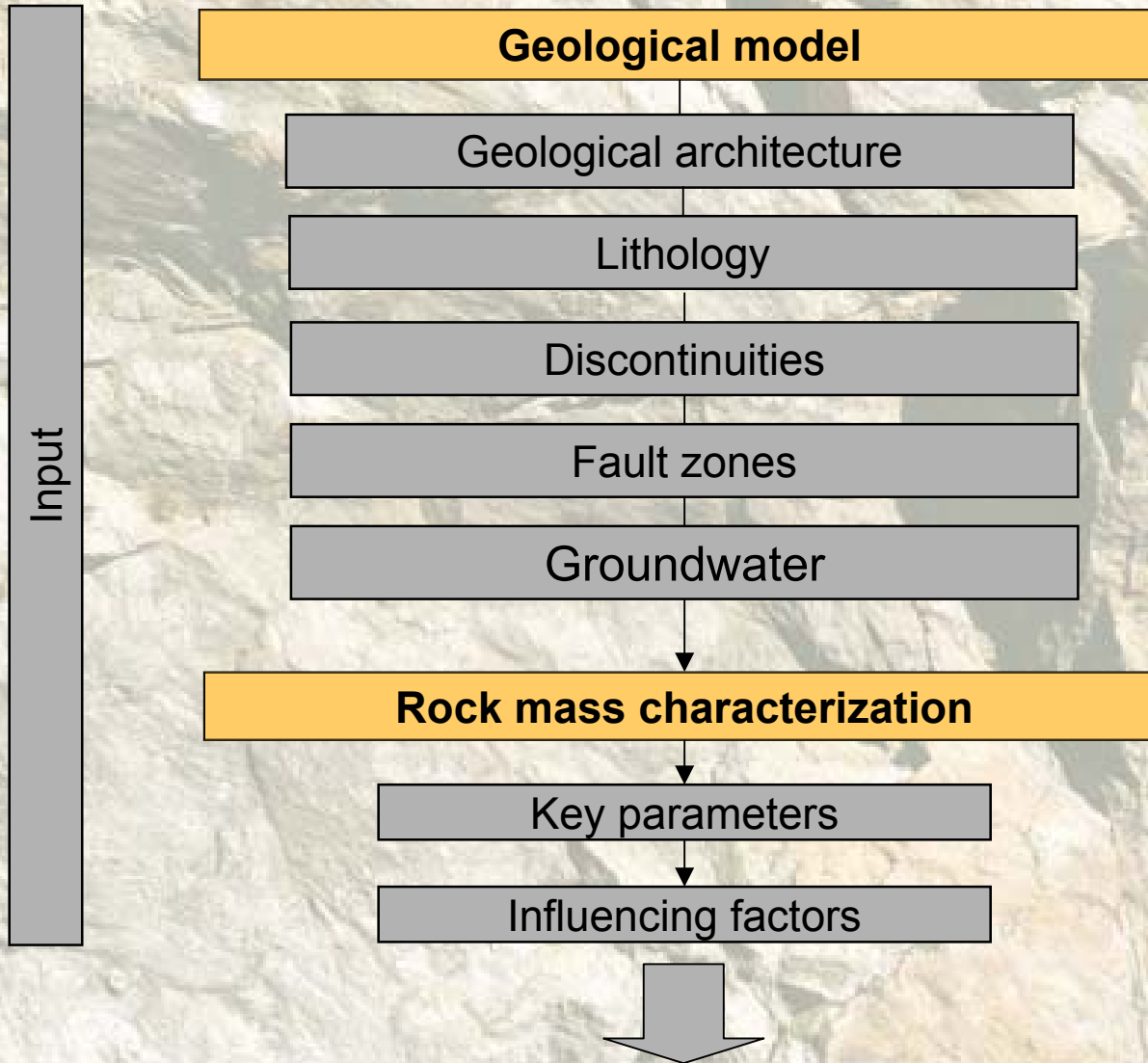


Boundary Conditions: (1) Groundwater at Surface (2) Recharge unlimited

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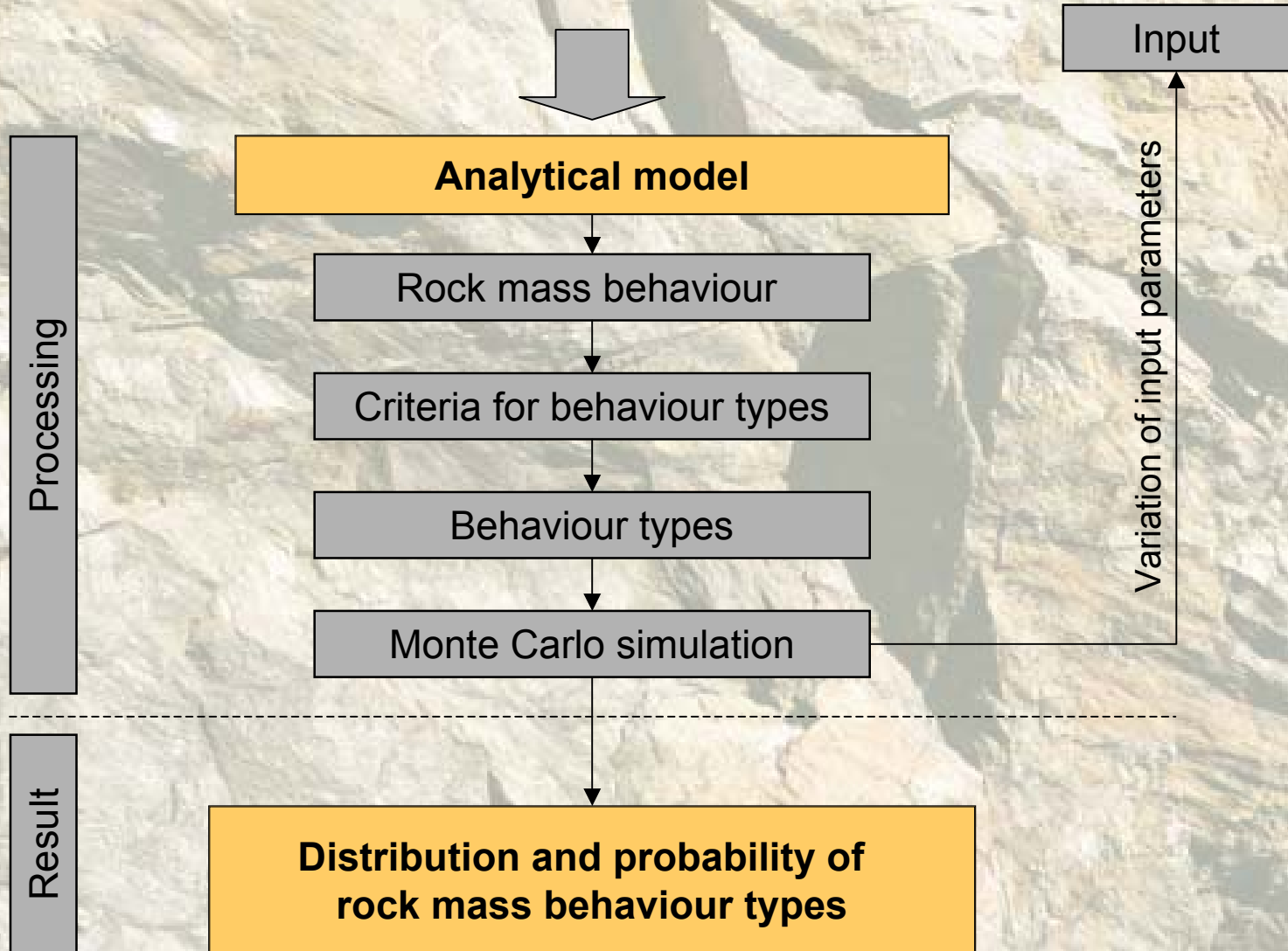
Case Studies

Assessment of Geotechnical Risk



Case Studies

Assessment of Geotechnical Risk



Assessment of Geotechnical Risk

Key parameters:

- Mechanical intact rock properties (UCS, E-Modulus, ...)
- Discontinuities properties (spacing, roughness, ...)
- Specific TBM parameters (abrasivity, penetration rate, ...)
- Rock mass properties

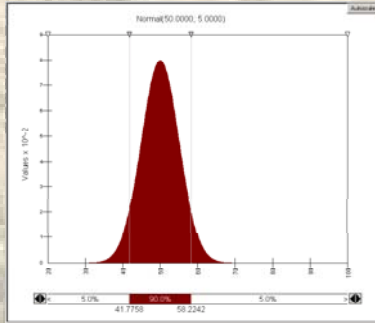
Influencing factors:

- Stresses
- excavation geometry
- Discontinuity orientation related to tunnel direction
- Groundwater

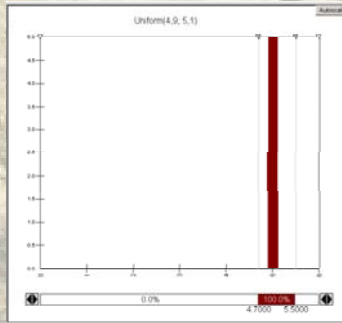
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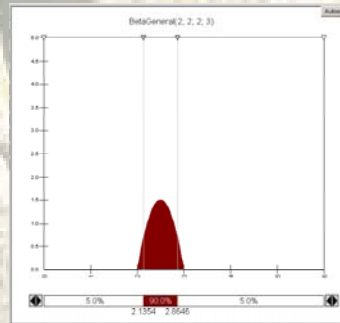
Assessment of Geotechnical Risk



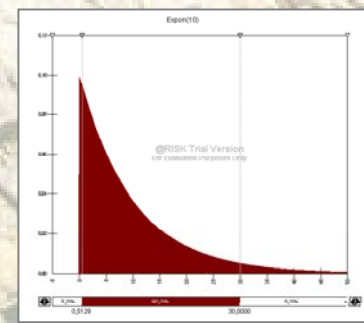
UCS



Tunnel diameter

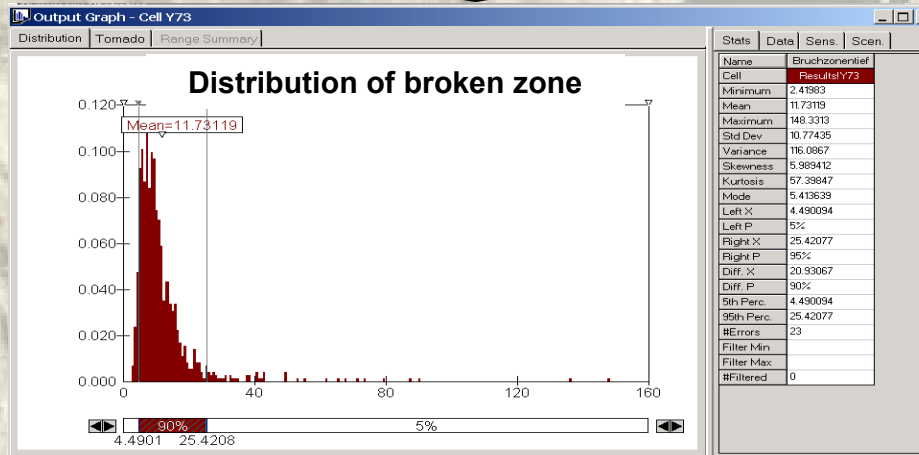


Principal stresses



Spacing

Input

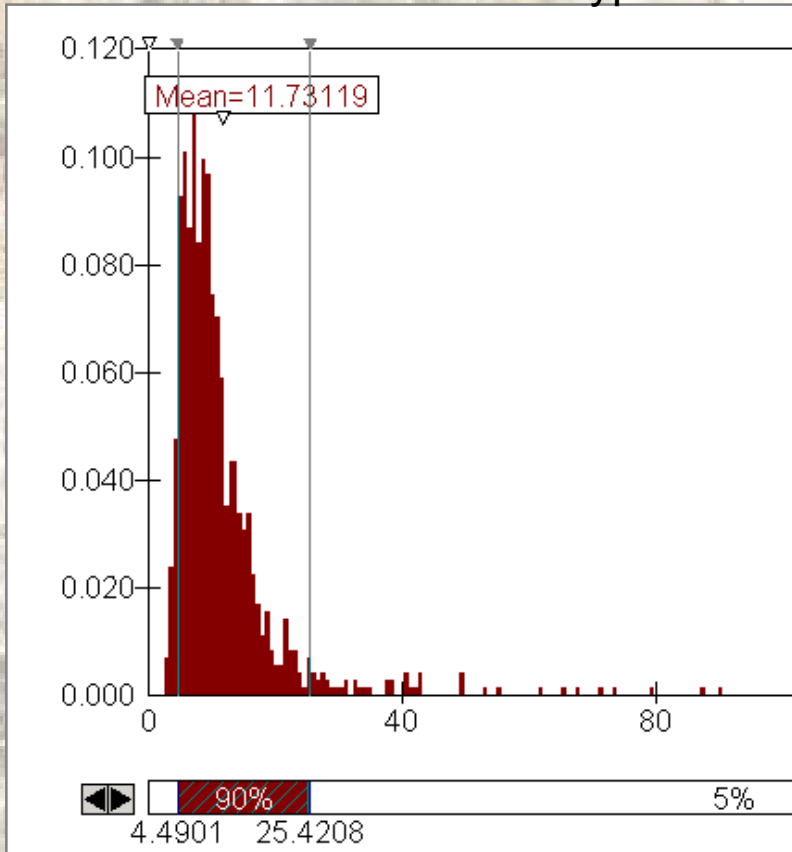


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Assessment of Geotechnical Risk

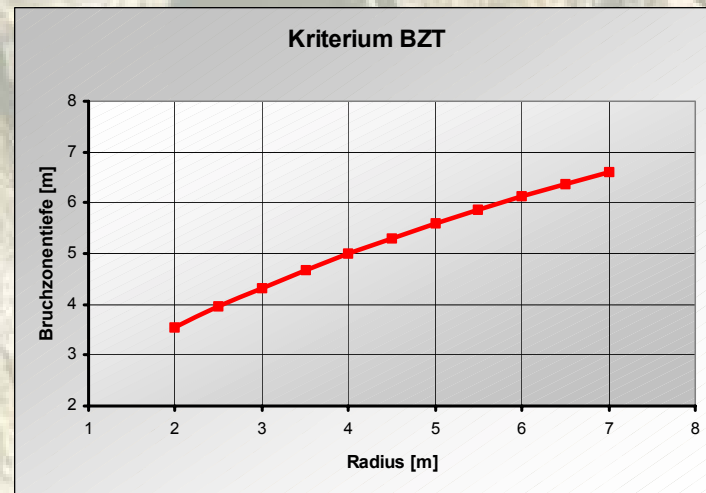
Criteria for the determination of rock mass behaviour types



$$DBZ = f(R)$$

Criteria

$$DBZ > D \times \left(\frac{2,5}{R^{0,5}} \times 0.5_{(inp)} \right)$$

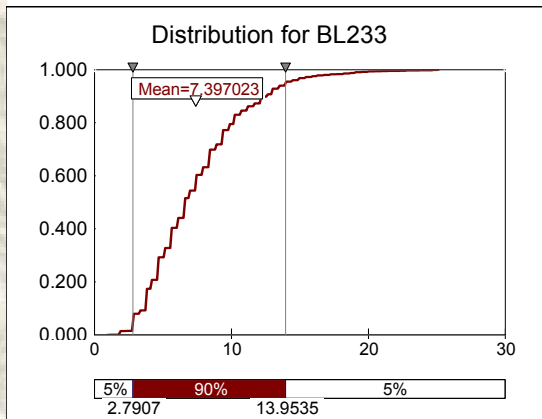
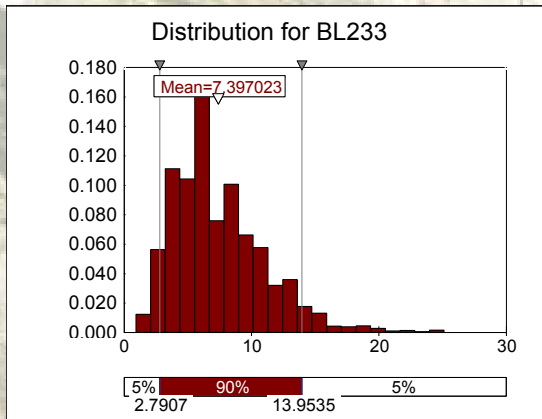


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Assessment of Geotechnical Risk

Distribution of a behaviour type calculated for a tunnel section



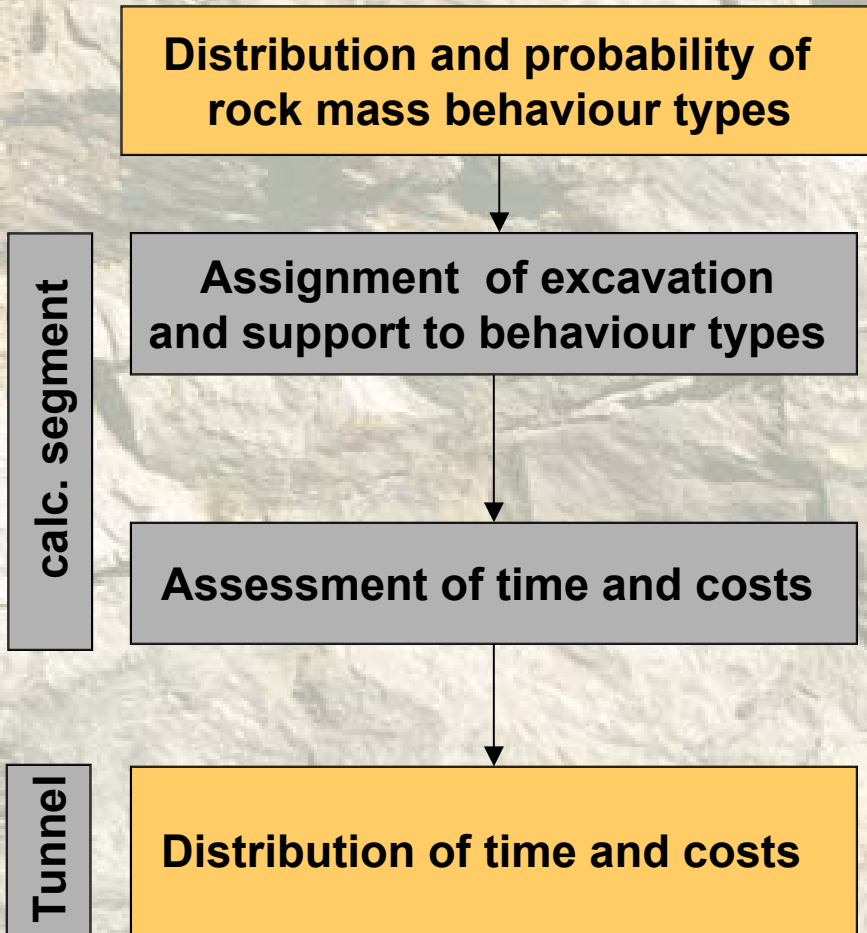
Summary Information	
Workbook Name	T-Pilotstollen-Risikoanaly
Number of Simulations	1
Number of Iterations	5000
Number of Inputs	175
Number of Outputs	38
Sampling Type	Latin Hypercube
Simulation Start Time	01.05.2002 14:34
Simulation Stop Time	01.05.2002 14:39
Simulation Duration	00:05:11
Random Seed	1808478211

Summary Statistics			
Statistic	Value	%tile	Value
Minimum	0,930232584	5%	2,790697575
Maximum	25,1162796	10%	3,720930338
Mean	7,39702322	15%	3,720930338
Std Dev	3,647360066	20%	4,1860466
Variance	13,30323545	25%	4,651162624
Skewness	1,148729854	30%	5,116279125
Kurtosis	4,876067642	35%	5,581395149
Median	6,511627674	40%	5,581395149
Mode	4,651162624	45%	6,511627674
Left X	2,790697575	50%	6,511627674
Left P	5%	55%	7,441860676
Right X	13,95348835	60%	7,441860676
Right P	95%	65%	8,372093201
Diff X	11,16279078	70%	8,837209702
Diff P	90%	75%	9,302325249
#Errors	0	80%	10,23255825
Filter Min		85%	11,1627903
Filter Max		90%	12,5581398
#Filtered	0	95%	13,95348835

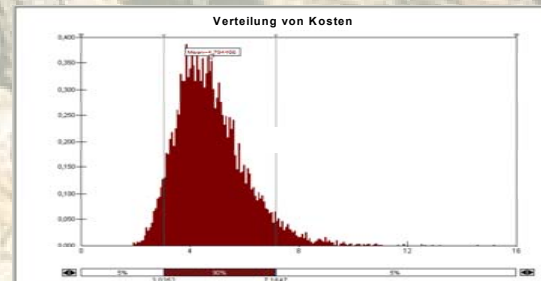
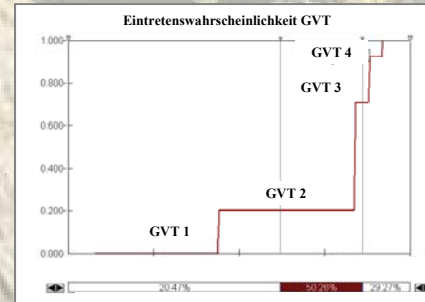
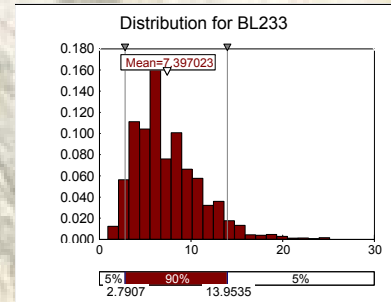
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Case Studies

Assessment of Geotechnical Risk



Time and costs



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