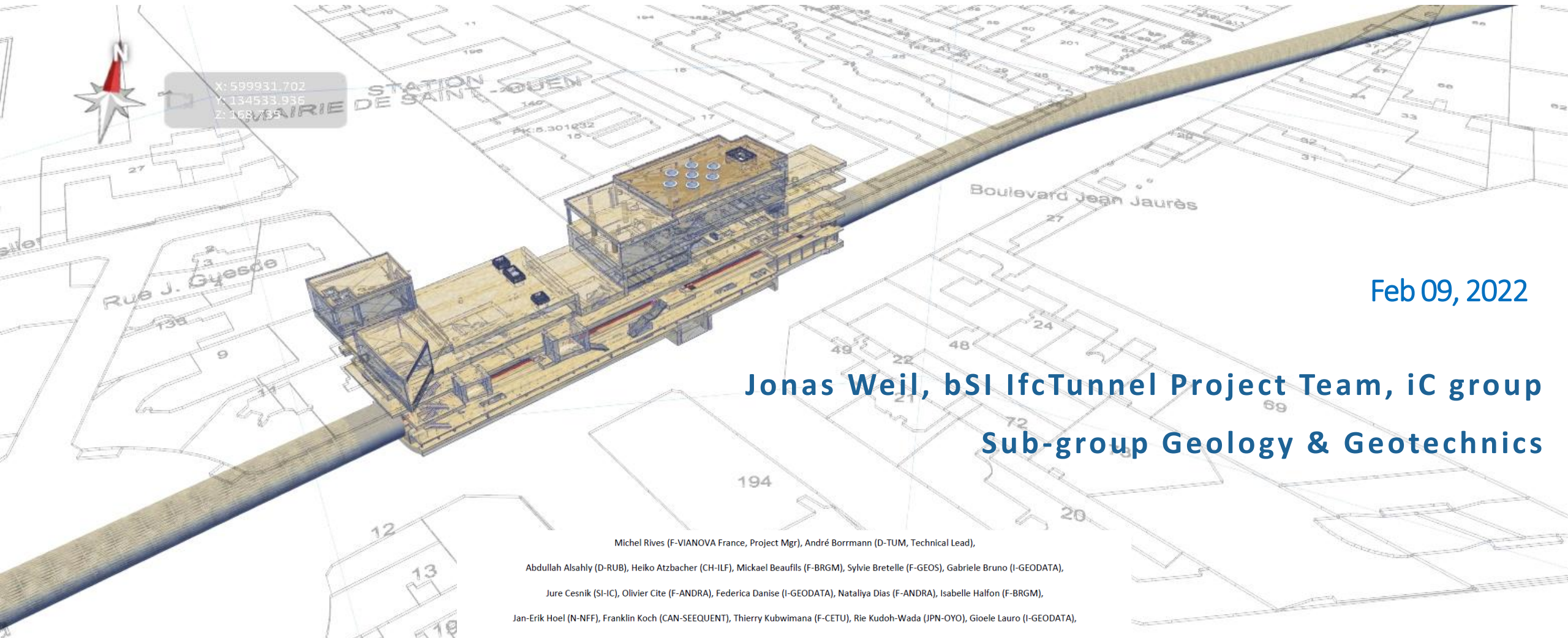




Digitization in Norwegian Tunneling

IfcTunnel – Ground models



Feb 09, 2022

**Jonas Weil, bSI IfcTunnel Project Team, iC group
Sub-group Geology & Geotechnics**

Michel Rives (F-VIANOVA France, Project Mgr), André Borrman (D-TUM, Technical Lead),

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Jan-Erik Hoel (N-NFF), Franklin Koch (CAN-SEEQUENT), Thierry Kubwimana (F-CETU), Rie Kudoh-Wada (JPN-OYO), Gioele Lauro (I-GEODATA),

Greta Lucibello (I-GEODATA), Pat McLarin (NZ-SEEQUENT), Sergej Muhič (D-SIEMENS), Syoichi Nisiyama (JPN-OYO), Andres Pena-Olarte (D-TUM),

Fabian Plaickner (CH-ILF), Benjamin Ruede (CH-ILF), Florent Robert (F-CETU), Federica Sandrone (CH-SBB), Benjamin Simonet (CH-ILF), Hiromasa Shima (JPN-OYO),

Jan Christian Thoren (S-TVK), Mirko Vendramini (I-GEODATA), Goetz Vollmann (D-RUB), André Vonthron (D-RUB), Jonas Weil (SI-IC), Lars Wikström (S-TRIONA)



IfcTunnel – Geology & Geotechnics

Overview current activities and status:

- Use case descriptions [\(as published in WP2\)](#)
- Taxonomy for conceptual model, UML-modeling ongoing
- Concept to link model of ground conditions to design
- Concepts to describe different kinds of uncertainty
- Geometrical representations: Requirement of voxel models

Input



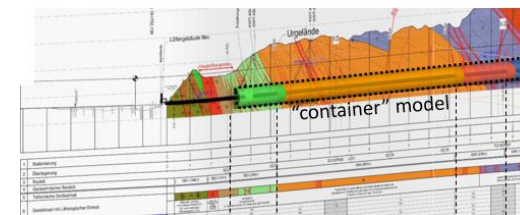
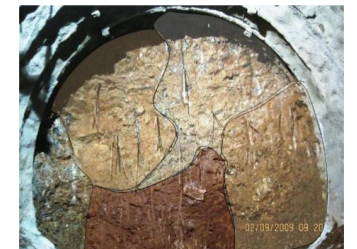
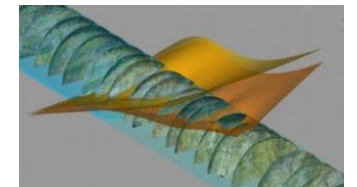
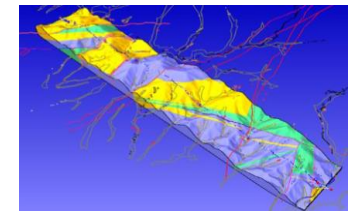
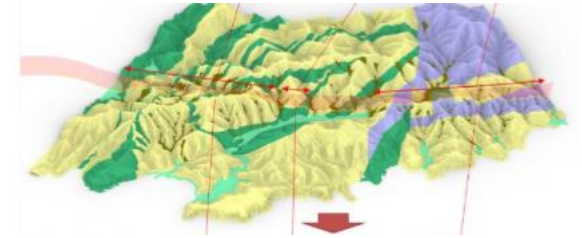
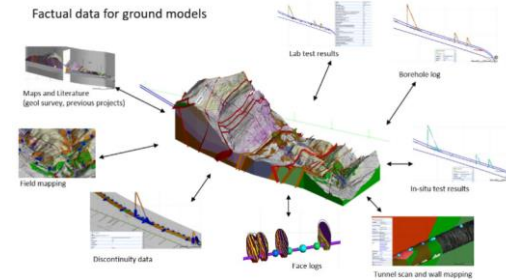
Etc.



IfcTunnel – Geology & Geotechnics

Use Cases (ground model related)

- 1b Geological factual data
- 2a Geological and geotechnical modelling for planning
- 2b Geotechnical modelling for design
- 2c geotechnical modelling for construction and maintenance
- 12b Geotechnical Model for tender, time and cost estimation
- 15b geological documentation



„GeotechSynthesisModel“

Book C: Tunnel Design

Tunnel Design Requirements

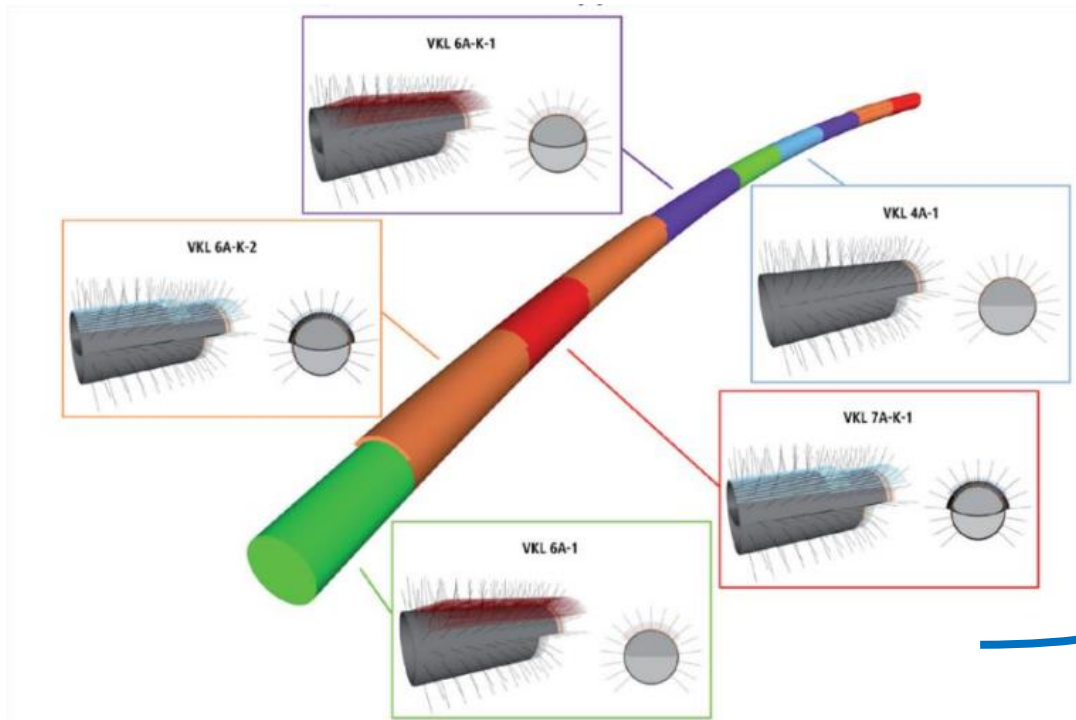
Construction methods and support measures depending on ground conditions

Design-related prognosis model of ground conditions:



Internal Space

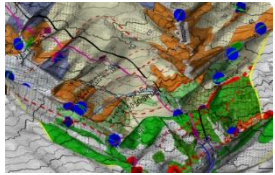
Requirements for internal space from project



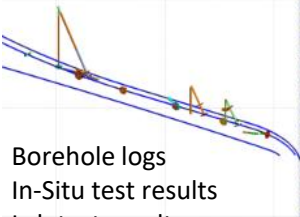
Prediction of expected conditions along the alignment required

„GeotechSynthesisModel“

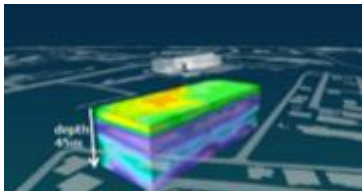
Book A Observations / Factual data



Field mapping



Borehole logs
In-Situ test results
Lab test results
Groundwater monitoring



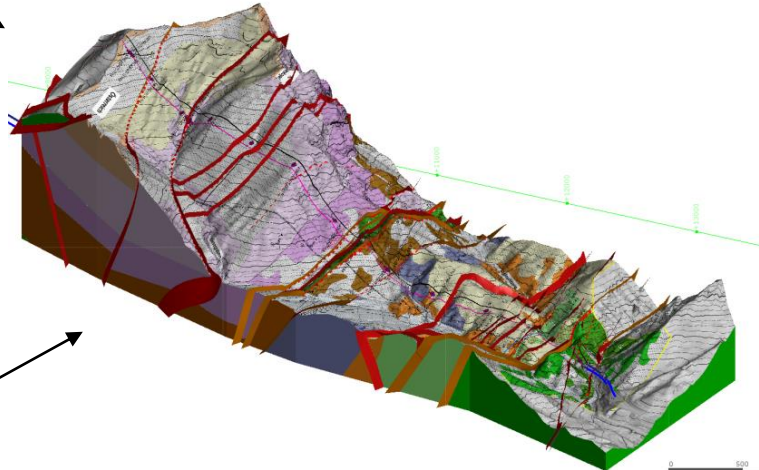
Geophysical Survey



Maps and Literature

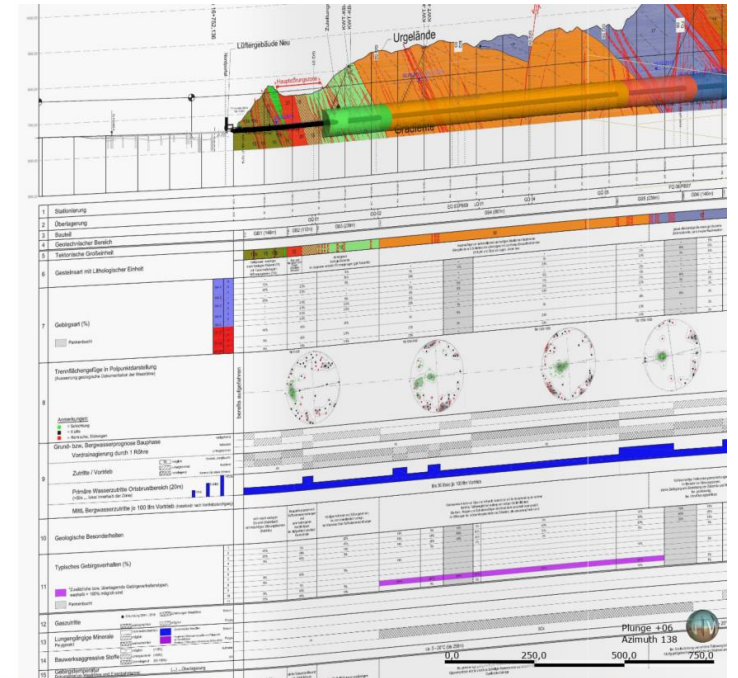
Book B Interpreted Models

Geological and Hydrogeological conditions
Geomechanical properties



Design-related prognosis model

- interpretation of conditions described in Book A and B with regard to the tunnel alignment
- Definition of intervals along the alignment with similar expected conditions, described by key-properties for tunnel design



Classical description in longitudinal section

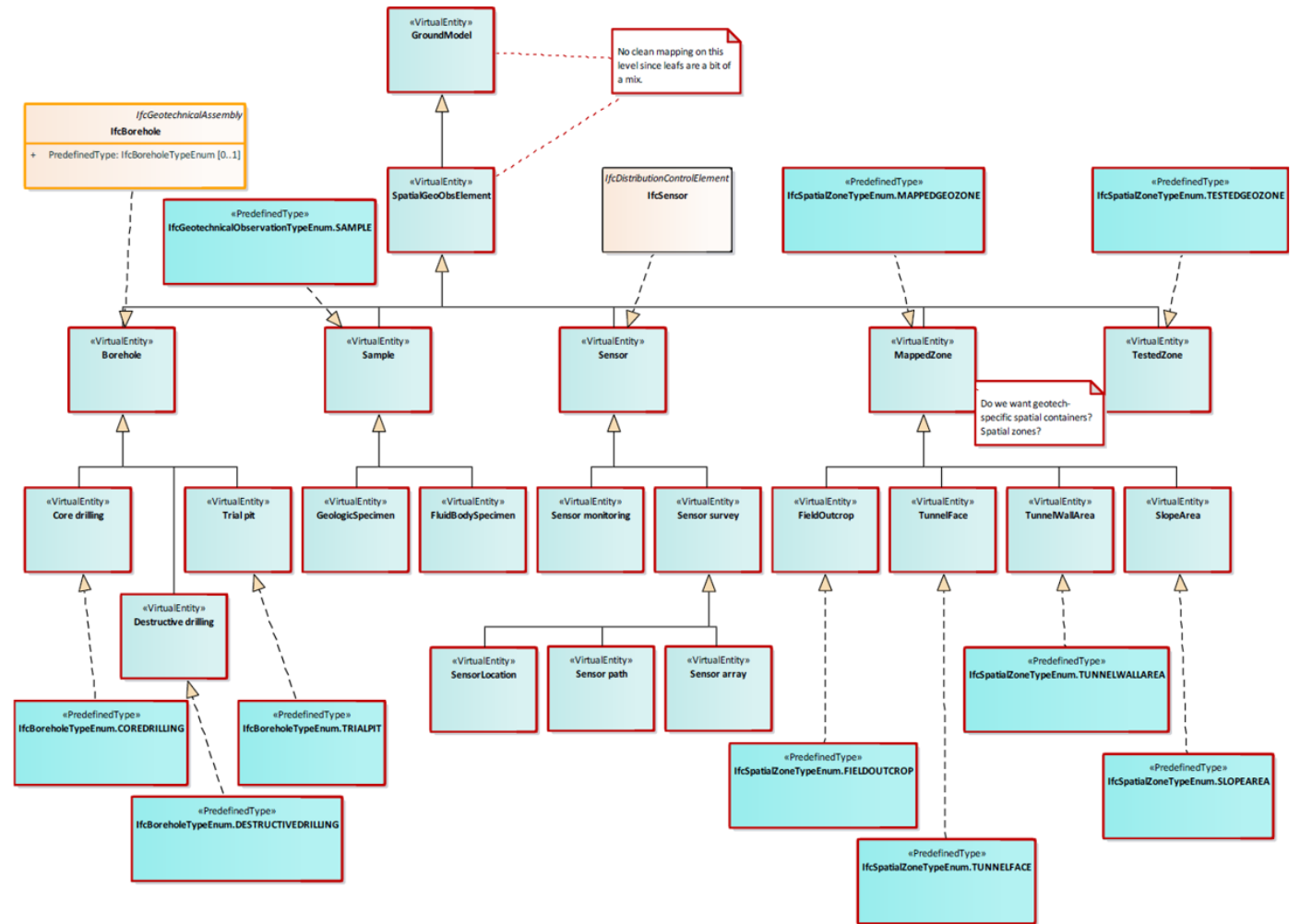


IfcTunnel – Geology & Geotechnics

Observations / Book A

- Domain-specific collection of typical data sets and classification of different types
- Objects with geometrical representation vs. semantic elements
- Link to external files for extensive datasets (e.g. borehole data, MWD or geophysical logs)

Example: geological tunnel documentation



Graphical visualization / UML drafts



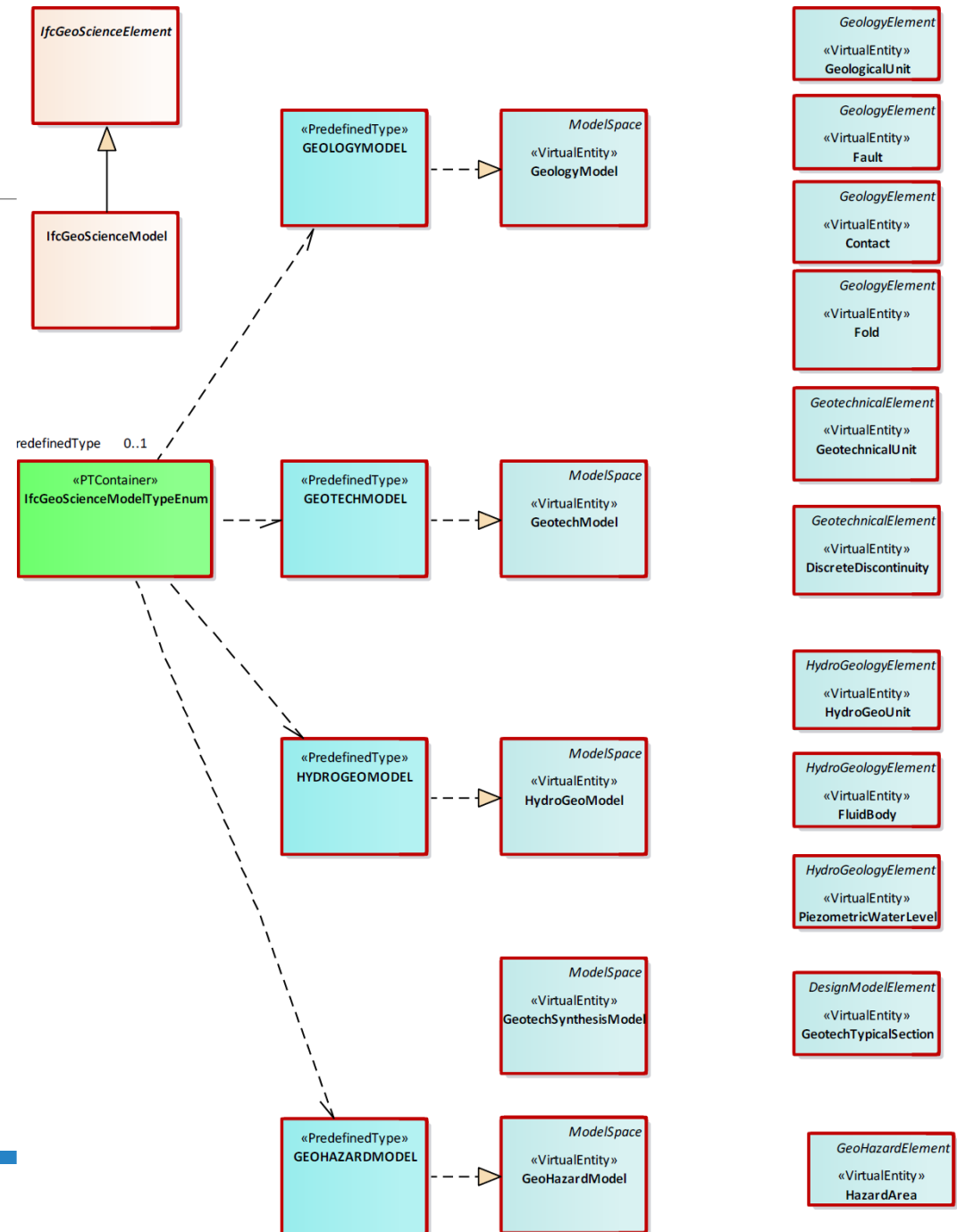
IfcTunnel – Geology &

Interpreted models / Book B

- Several models, representing specific classifications of the ground conditions as well as uncertainty and methodological info
- “GeotechSynthesisModel” as a link to building structure: e.g. representation of Geotechnical Baseline Report and Longitudinal Section

Example: Alternative approach for geotechnical models with different granularity

Graphical visualization / UML drafts





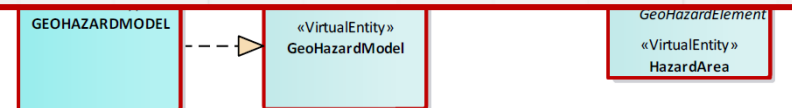
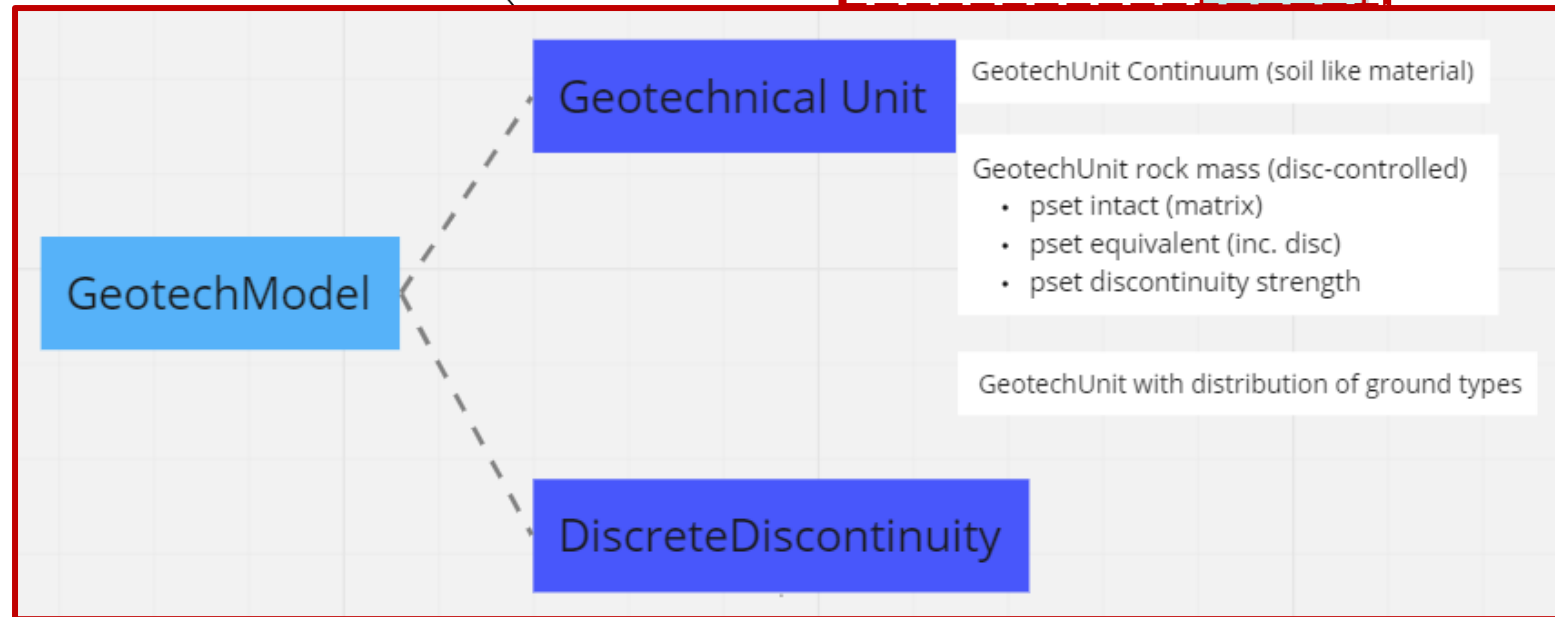
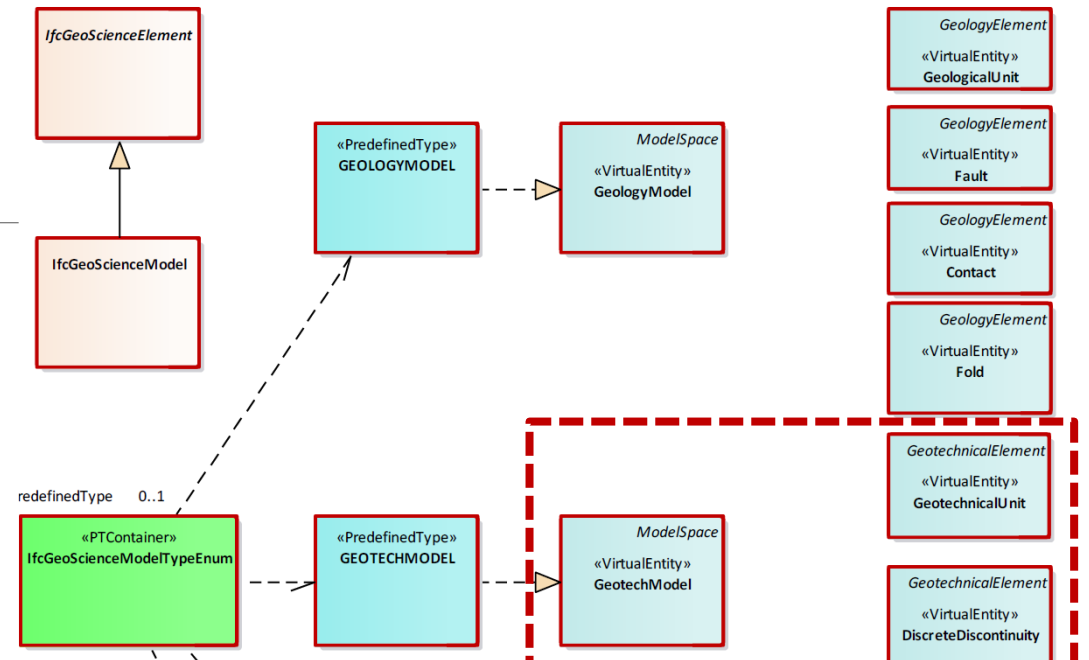
IfcTunnel – Geology &

Interpreted models / Book B

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Example: Alternative approach for geotechnical models with different granularity

Graphical visualization / UML drafts



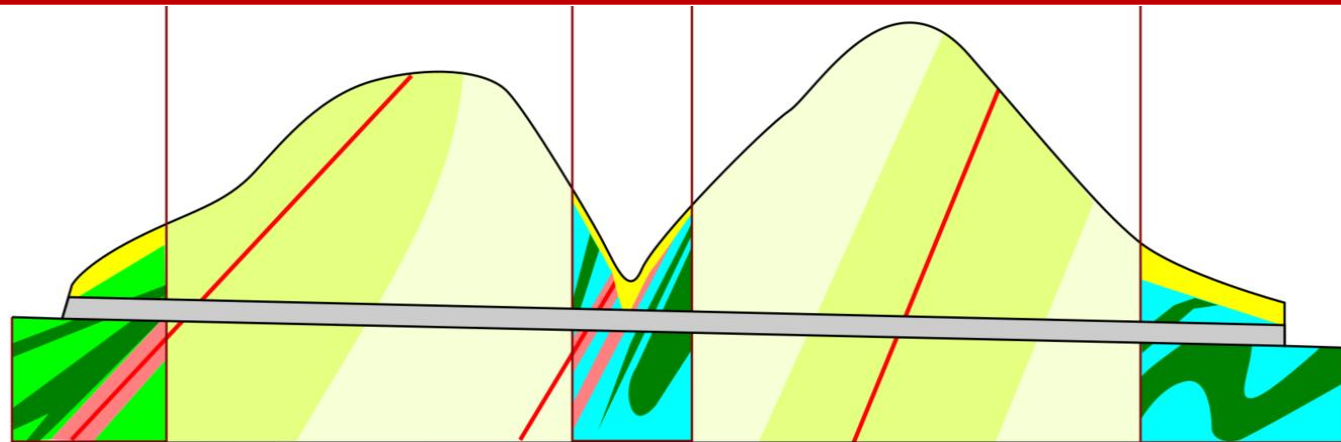


IfcTunnel – Geology & Geotechnics

Interpreted models / Book B

GS1
 □ A+B+S
 □ Q+B+C+S

GS2
 □ Q
 □ A
 □ B
 □ C
 □ S



GeotechUnit Continuum (soil like material)

GeotechUnit rock mass (disc-controlled)

- pset intact (matrix)
- pset equivalent (inc. disc)
- pset discontinuity strength

GeotechUnit with distribution of ground types

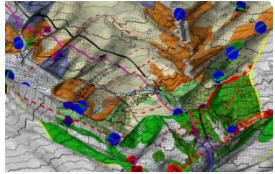
ty

Geology Model		One single model					
Knowledge / Site invest. Density		high	low		high	low	high
Geotechnical Model	Model approach *	2	1	2	1	2	
	Partial model (name)	Portal W	T1	T2	T3	Portal O	
	Resolution	3m	10m	3m	10m	3m	
	Allowed uncertainty	1m	5m	1m	5m	1m	

* 1: Enveloping geometry for similar units (materials) with expected %-distribution
 * 2: Explicitly modelled units

„GeotechSynthesisModel“

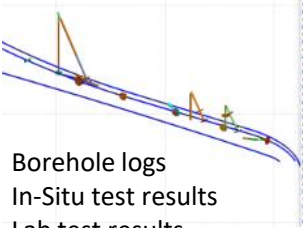
Book A Observations / Factual data



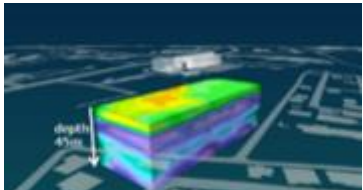
Field mapping



Maps and Literature



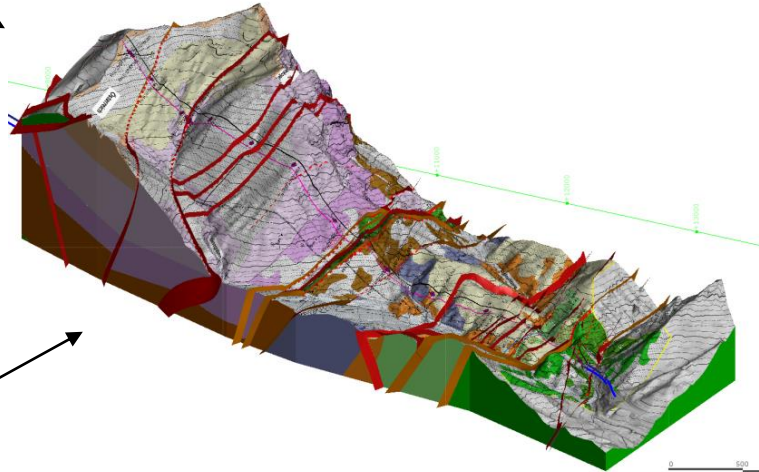
Borehole logs
In-Situ test results
Lab test results
Groundwater monitoring



Geophysical Survey

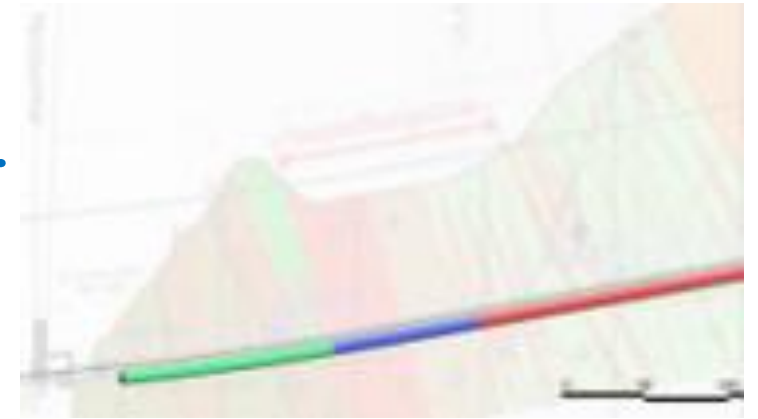
Book B Interpreted Models

Geological and Hydrogeological conditions
Geomechanical properties



Design-related prognosis model

- interpretation of conditions described in Book A and B with regard to the tunnel alignment
- Definition of intervals along the alignment with similar expected conditions, described by key-properties for tunnel design

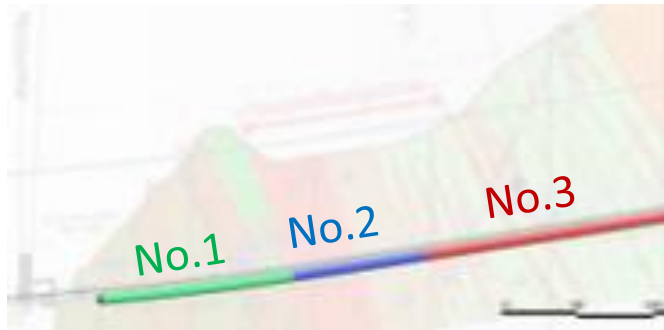


BIM-representation:
Alignment-based „Dummy Geometry“ with key-properties

→ GeotechTypicalSection

„GeotechSynthesisModel“

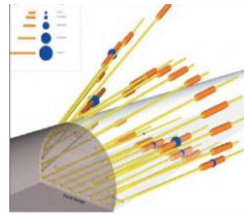
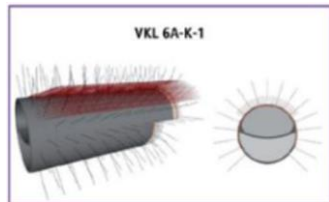
Geotechnical prognosis model



BIM-representation:
Alignment-based „Dummy Geometry“ with key-properties

Prognosis model of Tunnel Design

Design solution developed for the required tunnel space based on expected ground conditions



GeotechTypicalSection		No.1	No.2	No.3	No.4
Geotech key properties	Expected distribution of ground types	GT A: 70% GT B: 30%	GT B: 50% GT B: 50%	GT A: 70% GT B: 30%	GT A: 50% GT D: 50%
	Discontinuity setting	1	1+2	2+3	4
	Groundwater conditions	1	2	3	4
	Geogene hazards	1	1	1	1
	Contaminations	1	-	-	1
	...				

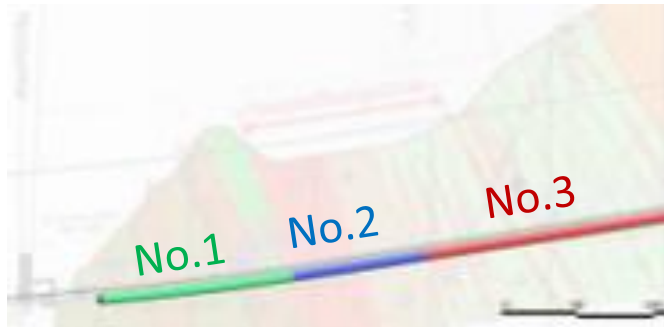


ExcavationModel		No.1	No.2	No.3	No.4
Design solution	Expected distribution of support types	ST 1: 40% ST 2: 30% ST 3: 30%	ST 3: 70% ST 4: 30%	ST 2: 30% ST 4: 30% ST 5: 30%	ST 1: 50% ST 4: 50%
	Excavation methods	A	A	A	B
	Injections	1	1	1	
	Health&safety measures				
	Material management	A	A	B	A
	...				



„GeotechSynthesisModel“

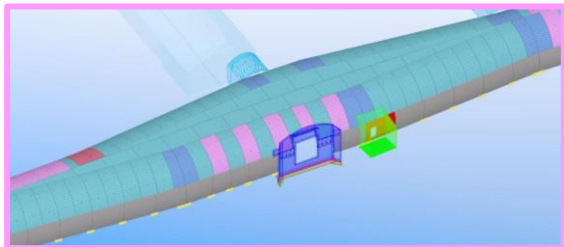
Geotechnical prognosis model



BIM-representation:
Alignment-based „Dummy Geometry“ with key-properties

Prognosis model of Tunnel Design

Additional requirements depending on building structure to be considered (e.g. cross passages, niches, ...)

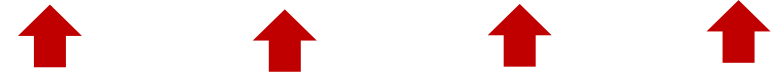


GeotechTypicalSection		No.1	No.2	No.3	No.4
Geotech key properties	Expected distribution of ground types	GT A: 70% GT B: 30%	GT B: 50% GT B: 50%	GT A: 70% GT B: 30%	GT A: 50% GT D: 50%
	Discontinuity setting	1	1+2	2+3	4
	Groundwater conditions	1	2	3	4
	Geogene hazards	1	1	1	1
	Contaminations	1	-	-	1
	...				

Similar ground conditions, but different tunnel geometry

ExcavationModel		No.1	No.2a	No.2b	No.3	No.4a	No.4b
Design solution	Expected distribution of support types	ST 1: 40% ST 2: 30% ST 3: 30%	ST 1: 70% ST 3: 30%	ST 3: 70% ST 4: 30%	ST 2: 30% ST 4: 30% ST 5: 30%	ST 1: 70% ST 3: 30%	ST 3: 70% ST 4: 30%
	Excavation methods	A	A	B	B	B	A
	Injections	1	1		1		
	Health&safety measures						
	Material management	A	A	A	B	A	A
	...						

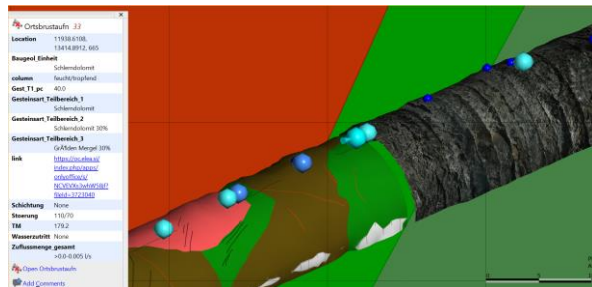
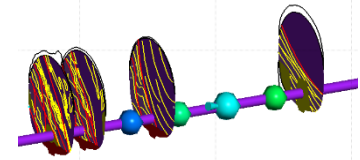
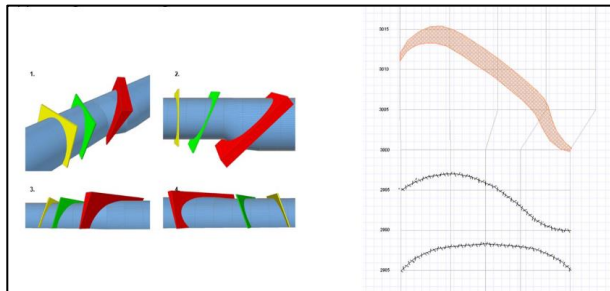
Building Structure						
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„GeotechSynthesisModel“

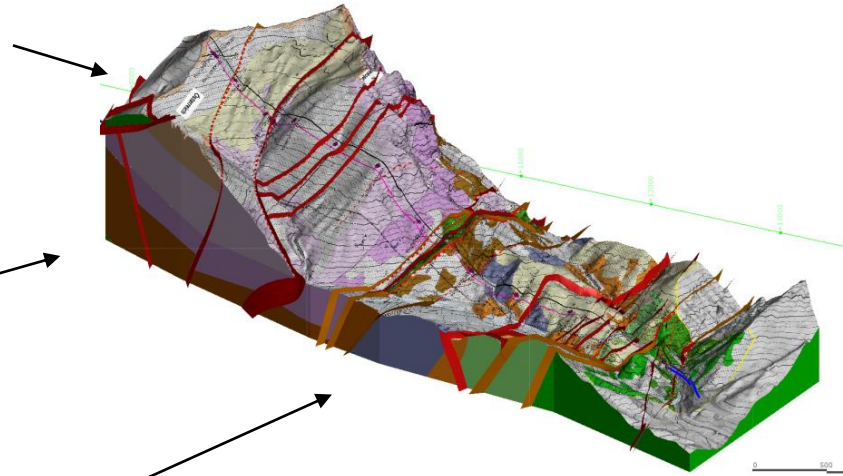
Book A Observations / Factual data

Geological documentation during construction



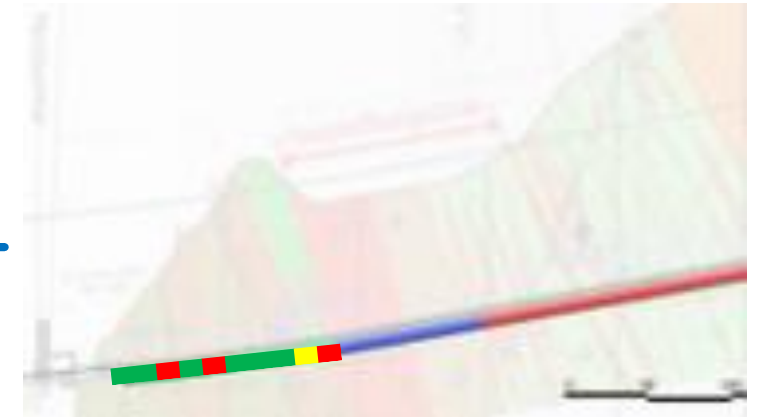
Book B Interpreted Models

Update of Interpreted Model



Geotech Synthesis Model

- Check of documented encountered conditions against prediction
- High granularity „As Built“ Model for comparison and accounting



BIM-representation:
Alignment-based „Dummy Geometry“ with key-properties

→ *GeotechTypicalSection*

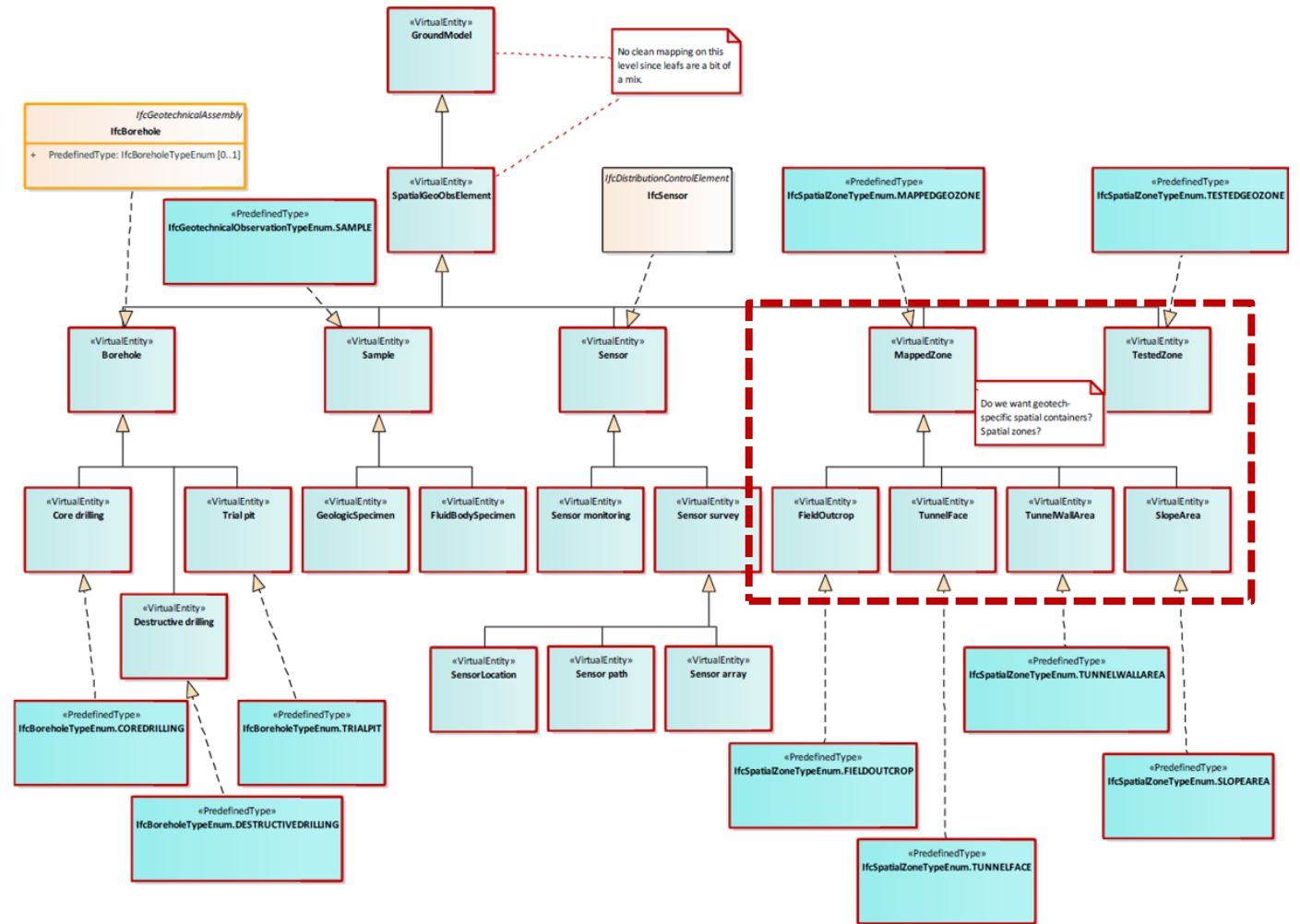


IfcTunnel – Geology & Geotechnics

Observations / Book A

- Domain-specific collection of typical data sets and classification of different types
- Objects with geometrical representation vs. semantic elements
- Link to external files for extensive datasets (e.g. borehole data, MWD or geophysical logs)

Example: geological tunnel documentation



Graphical visualization / UML drafts



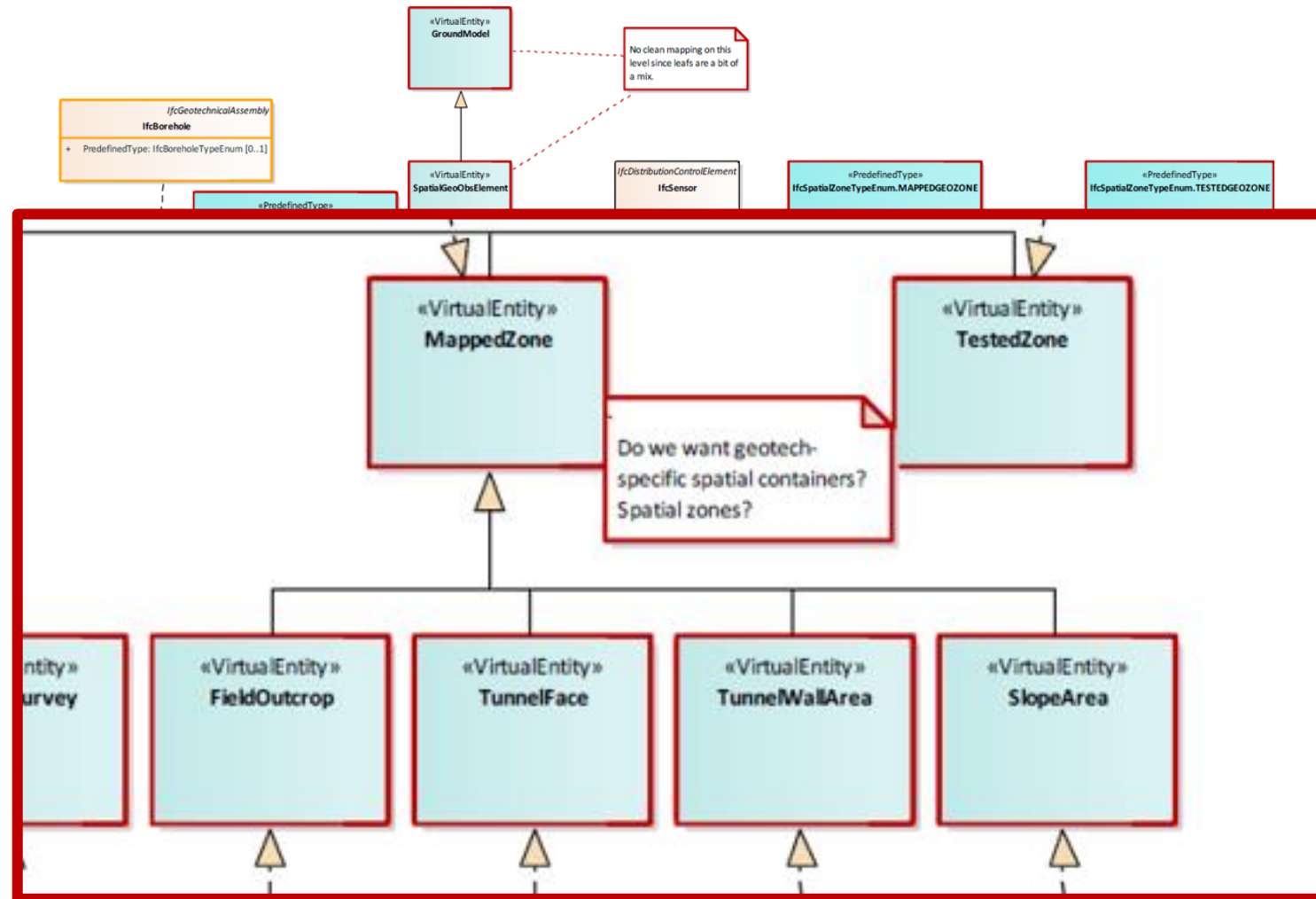
IfcTunnel – Geology & Geotechnics

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Graphical visualization / UML drafts

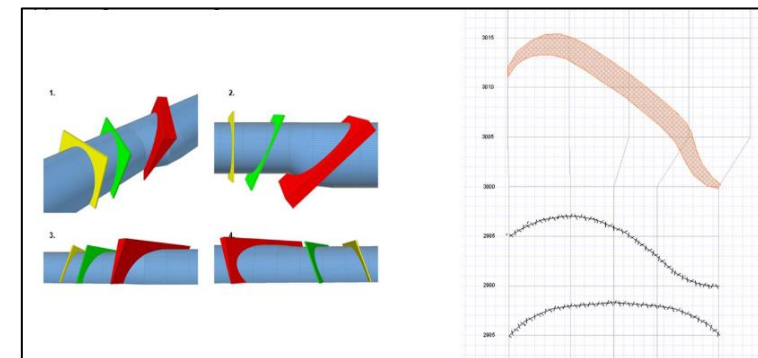
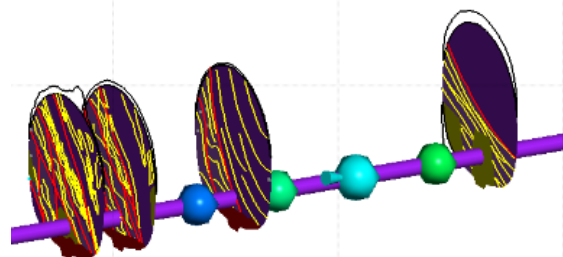




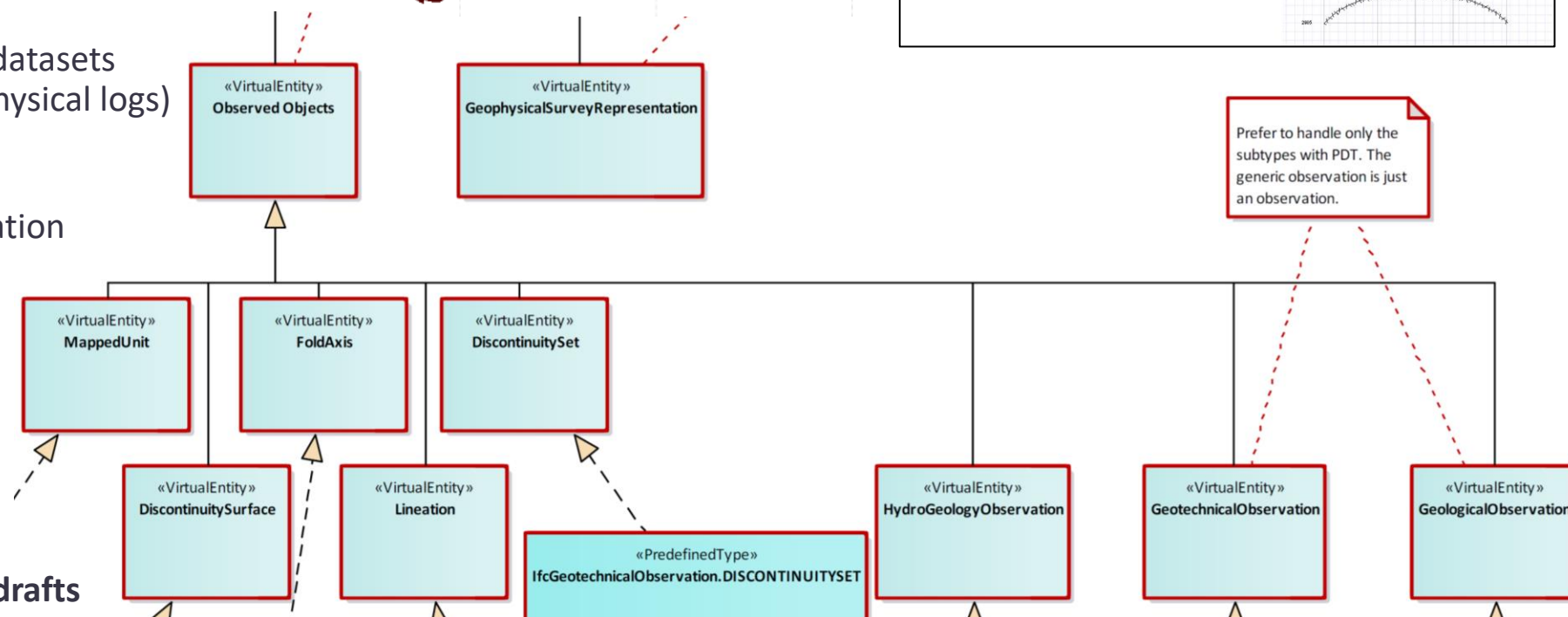
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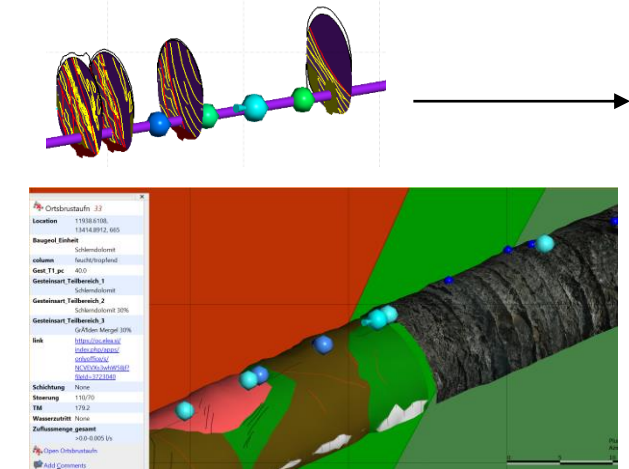
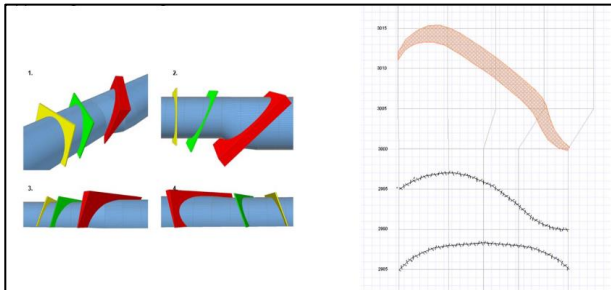


Graphical visualization / UML drafts

„GeotechSynthesisModel“

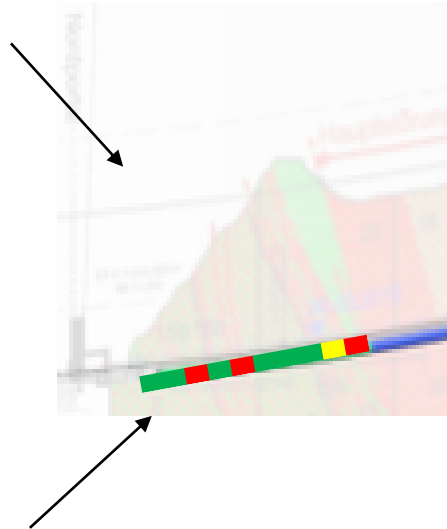
Book A Observations / Factual data

Geological documentation during construction



Book B Geotech Synthesis Model

- Check of documented encountered conditions against prediction
- High granularity „As Built“ Model for comparison and accounting

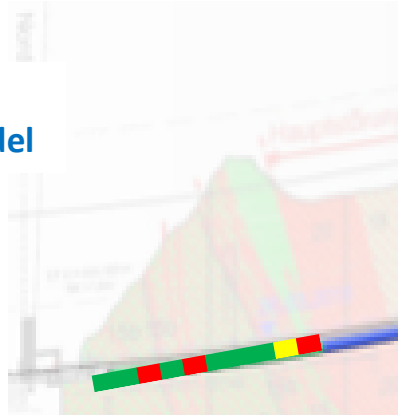


GeotechTypicalSection		No.1	No.2
PROGNOSIS Geotech key properties	Expected distribution of ground types	GT A: 70% GT B: 30%	GT B: 50% GT B: 50%
	Discontinuity setting	1	1+2
	Groundwater conditions	1	2
	Geogene hazards	1	1
	Contaminations	1	-
	...		

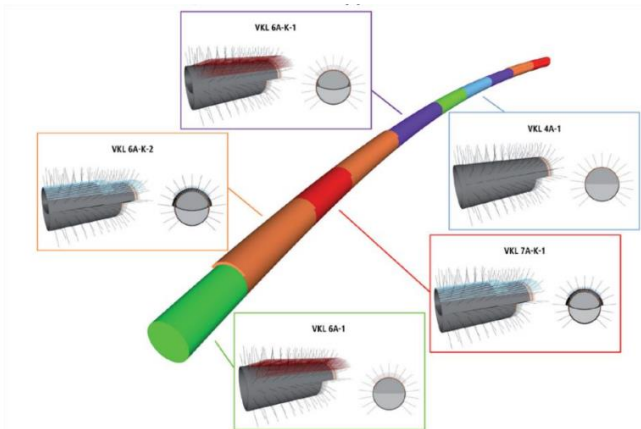
Chainage / Round No.		1	2	3	4	5	6	7	8	9	10	No.2
ENCOUNTERED Geotech key properties	Expected distribution of ground types	A	A	A+ B	B	A+ B	A	A	B	C	B	GT B: 50% GT B: 50%
	Discontinuity setting	1	1	1	1	1	2	1	1	1	1	1+2
	Groundwater conditions	1			1			1	1	1		2
	Geogene hazards	1	1	1			1	1	1			1
	Contaminations	1		1					1			-
	...											

„GeotechSynthesisModel“

Book B: High granularity „As Built“ Ground Model



Book C: „Active Design / As Built“ Design Model Construction and support measures executed as required from encountered ground conditions



Chainage / Round No.		1	2	3	4	5	6	7	8	9	10	No.2
ENCOUNTERED Geotech key properties	Expected distribution of ground types	A	A	A+ B	B	A+ B	A	A	B	C	B	GT B: 5 GT B: 5
	Discontinuity setting	1	1	1	1	1	2	1	1	1	1	1+2
	Groundwater conditions	1			1			1	1	1		2
	Geogene hazards	1	1	1			1	1	1			1
	Contaminations	1		1					1			-
	...											

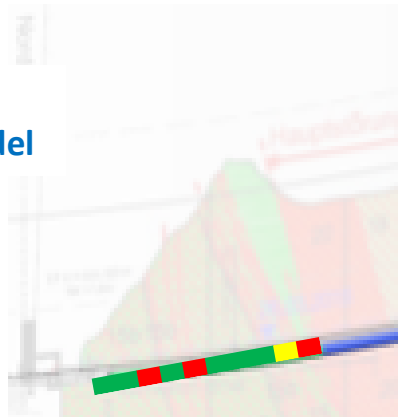


Chainage / Round No.		1	2	3	4	5	6	7	8	9	10	No.2a
APPLIED Design solution	Applied support types	ST3	ST3	ST2	ST2	ST2	ST1	ST1	ST1	ST5	ST5	ST 1: 70% S ST 3: 30% S
	Excavation methods	A	A	A	A	A	A	A	A	A	A	A
	Injections	1	1	1	1	1				1	1	1
	Health&safety measures									1	1	
	Material management	A	A	A	A	A	A	A	A	A	A	A
	...											



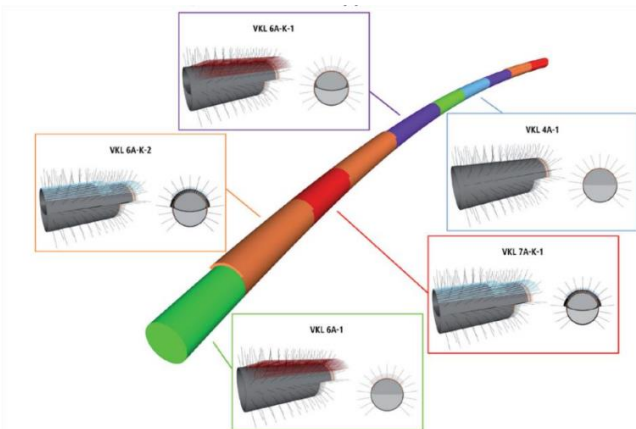
„GeotechSynthesisModel“

Book B: High granularity „As Built“ Ground Model



Book C: „Active Design / As Built“ Design Model

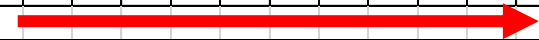
Construction and support measures executed as required from encountered ground conditions



GeotechTypicalSection		No.1	No.2
PROGNOSIS Geotech key properties	Expected distribution of ground types	GT A: 70% GT B: 30%	GT B: 5 GT B: 5
	Discontinuity setting	1	1+2
	Groundwater conditions	1	2
	Geogene hazards	1	1
	Contaminations	1	-
	...		

Chainage / Round No.		1	2	3	4	5	6	7	8	9	10	No.2
ENCOUNTERED Geotech key properties	Expected distribution of ground types	A	A	A+ B	B	A+ B	A	A	B	C	B	GT B: 5 GT B: 5
	Discontinuity setting	1	1	1	1	1	2	1	1	1	1	1+2
	Groundwater conditions	1			1			1	1	1		2
	Geogene hazards	1	1	1			1	1	1			1
	Contaminations	1		1					1			-
	...											

Excavation progress



Chainage / Round No.		1	2	3	4	5	6	7	8	9	10	No.2a
APPLIED Design solution	Applied support types	ST3	ST3	ST2	ST2	ST2	ST1	ST1	ST1	ST5	ST5	ST 1: 70% S ST 3: 30% S
	Excavation methods	A	A	A	A	A	A	A	A	A	A	A
	Injections	1	1	1	1	1				1	1	1
	Health&safety measures									1	1	
	Material management	A	A	A	A	A	A	A	A	A	A	A
	...											

ExcavationModel		No.1	No.2a
PROGNOSIS Design solution	Expected distribution of support types	ST 1: 40% ST 2: 30% ST 3: 30%	ST 1: 70% S ST 3: 30% S
	Excavation methods	A	A
	Injections	1	1
	Health&safety measures		
	Material management	A	A
	...		