FCC – PLACEMENT SCENARIO ASSESSMENT

CIVIL ENGINEERING / GEOLOGY ASPECTS

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JUNE 30TH 2021

FUTURE CIRCULAR COLLIDER

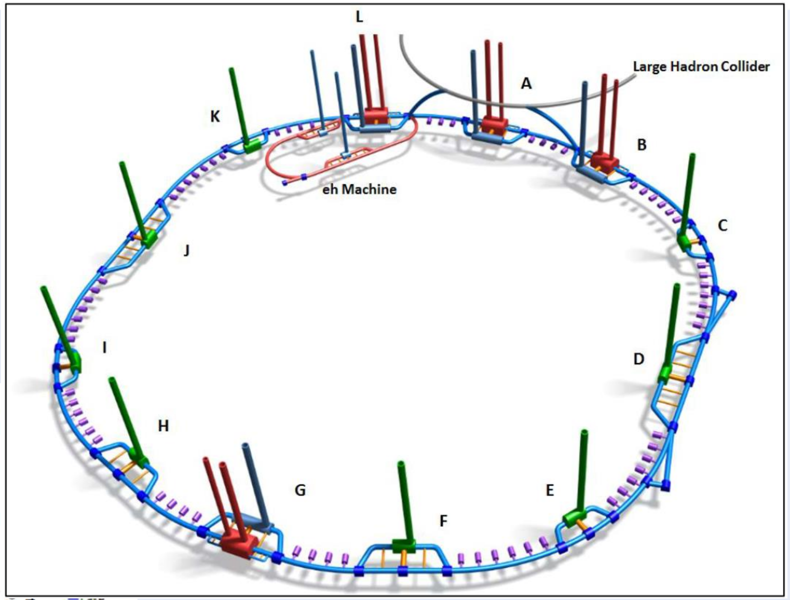
CONSULTING ENGINEERS

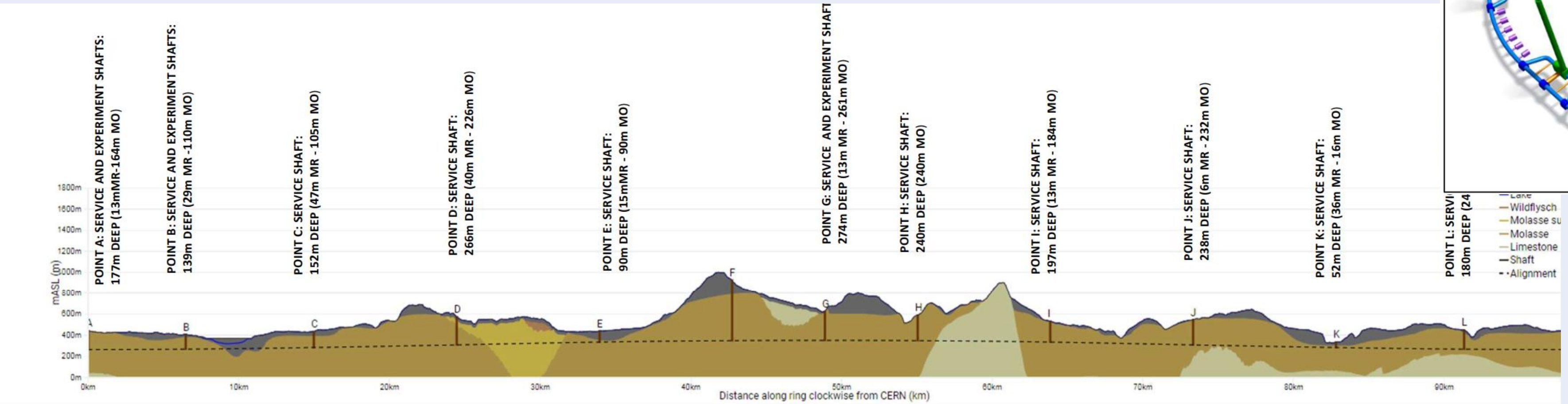
STATUS

- CONCEPTIONAL DESIGN REPORT
- ENVIRONMENTAL INVESTIGATIONS
- DEVELOPMENT OF SUITABLE ALIGNMENTS
- PREPARATION OF WORK PACKAGES FOR “HRA” SITE INVESTIGATION

OVERVIEW COST & SCHEDULE STUDY

- **Proposed Alignment**
- **Definition of elevation based on existing geological data - (GADZ SA Geologists)**
- **Suitable advance methods were evaluated and defined**





CHAINAGE																																																
0	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48	50	52	54	56	58	60	62	64	66	68	70	72	74	76	78	80	82	84	86	88	90	92	94	96

MATERIAL	MOLASSE	MR	MOLASSE	LIMESTONE	MOLASSE																
GROUND TYPE LENGTH (m)	GOOD ROCK 8,000	POOR R. AND SOFT G: 4,700	GOOD ROCK 20,000	POOR ROCK 5,000	GOOD ROCK 31,000	POOR R: 3,000	GOOD ROCK 9,000	POOR ROCK 13,000	GOOD ROCK 4,750												
WATER FLOW	LOW	HIGH	LOW	HIGH	LOW	LOW TO HIGH	LOW	HIGH	LOW	HIGH	LOW										
SUITABLE TBM OPTION	OPTION 1 DOUBLE SHIELD TBM	OPTION 3 MULTI MODE TBM	OPTION 1 DOUBLE SHIELD TBM	NOT APPLICABLE	OPTION 1 DOUBLE SHIELD TBM	OPTION 2 DOUBLE SHIELD TBM	OPTION 1 D. SHIELD TBM														
ASSUMED MACHINE TUNNEL CONSTRUCTION (m)	TBM 6,346	TBM 8,201	150 MT	150 MT	TBM 8,831.75	TBM 8,832	150 MT	150 MT	TBM 8,528	TBM 6,085	TBM 4,336	MIN. T 1,759	MINED 8,768	150 MT	TBM 7,732	MT 1,400	MT 1,400	TBM 7,732	150 MT	150 MT	TBM 8,201	TBM 6,346

OVERVIEW COST & SCHEDULE STUDY

- **Definition of construction lots for the optimization of the Construction schedule**

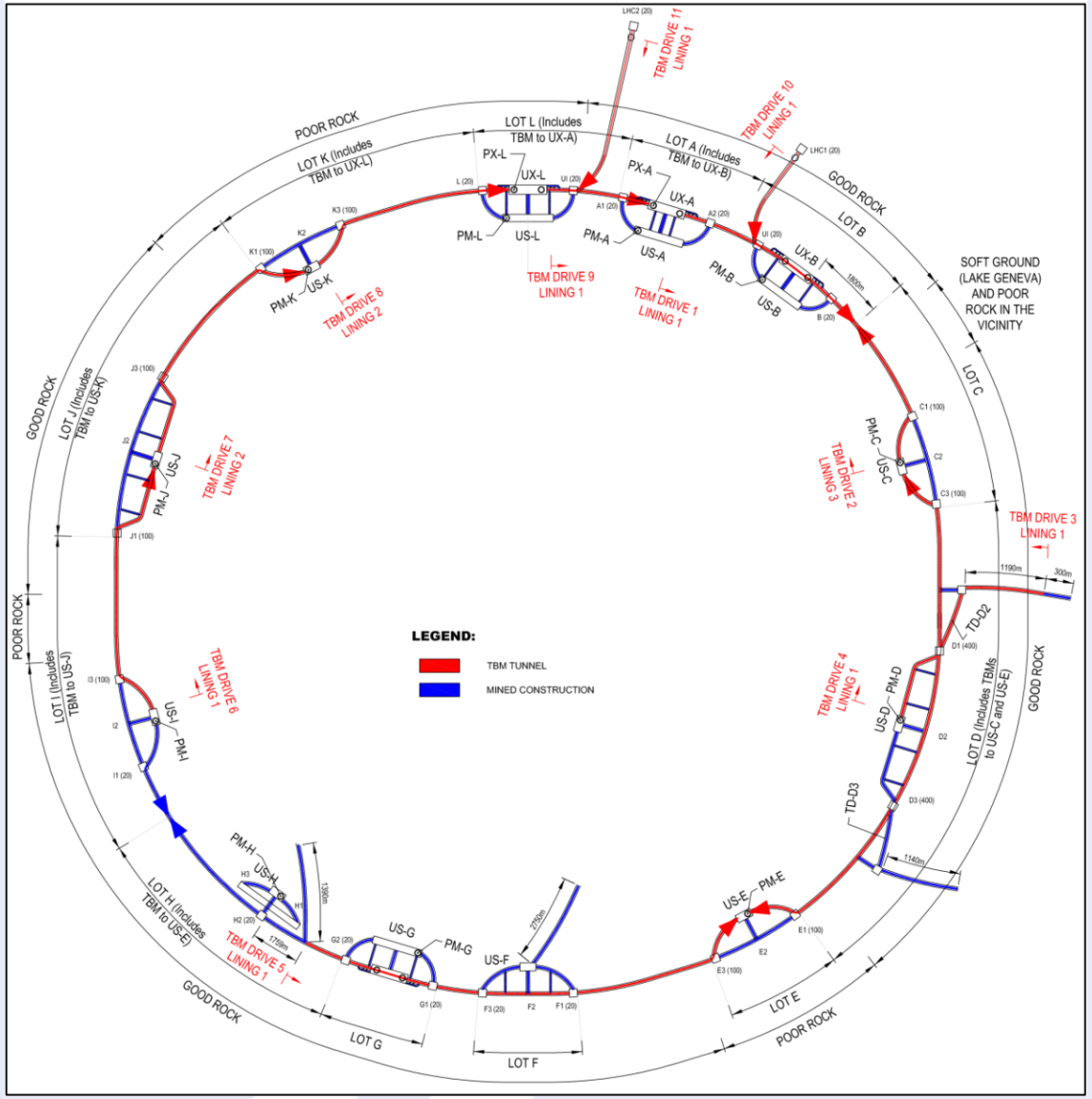
Considering

» Advance method

» Shaft Excavation

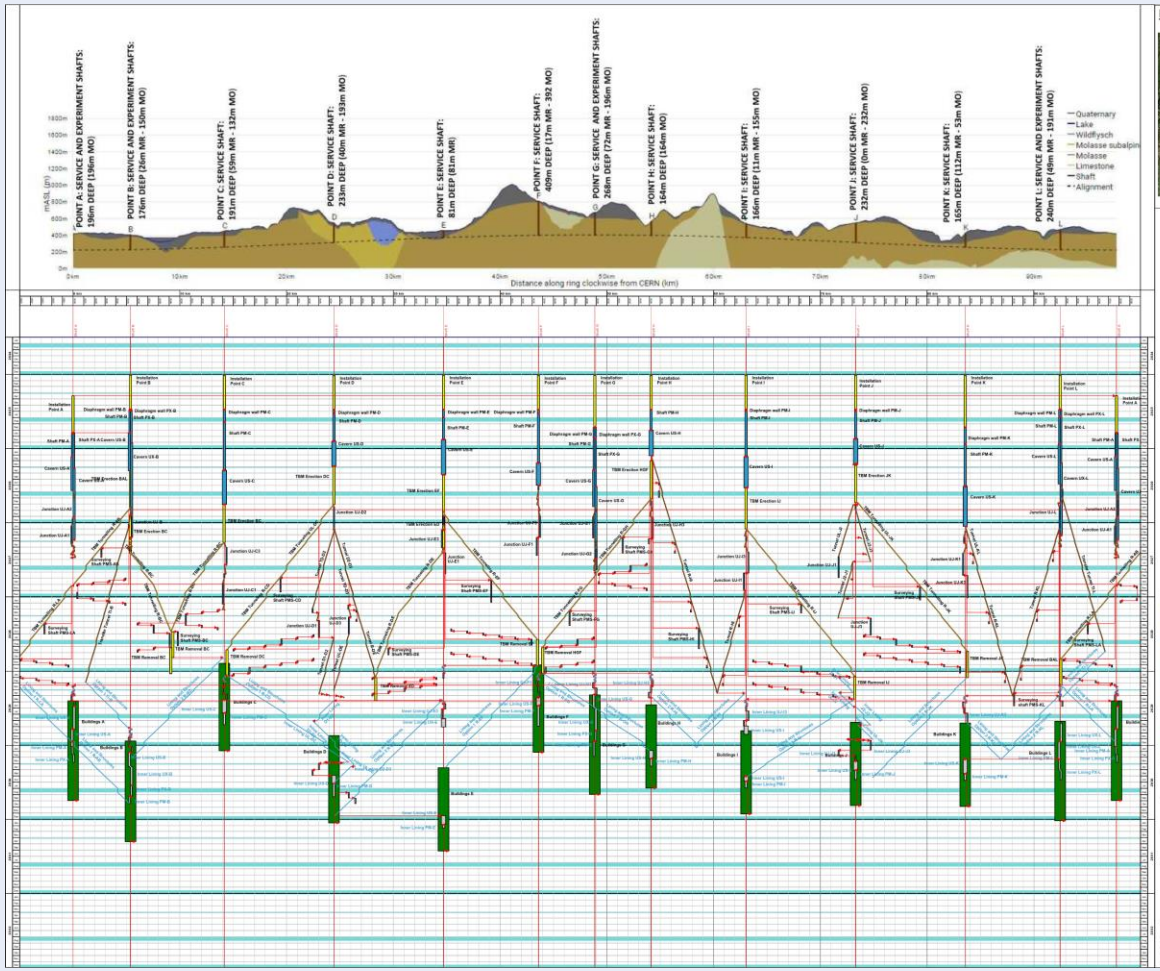
» Temporary Access Adits (sloped)

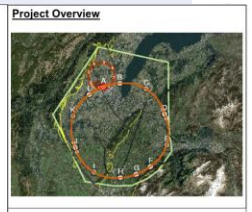
» Inner lining types

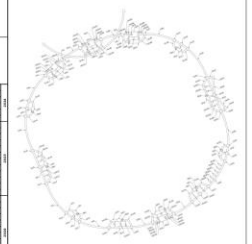


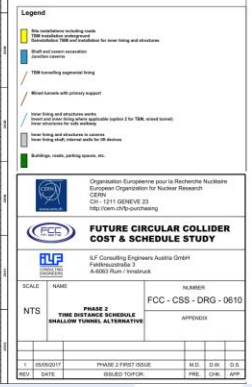
OVERVIEW COST & SCHEDULE STUDY

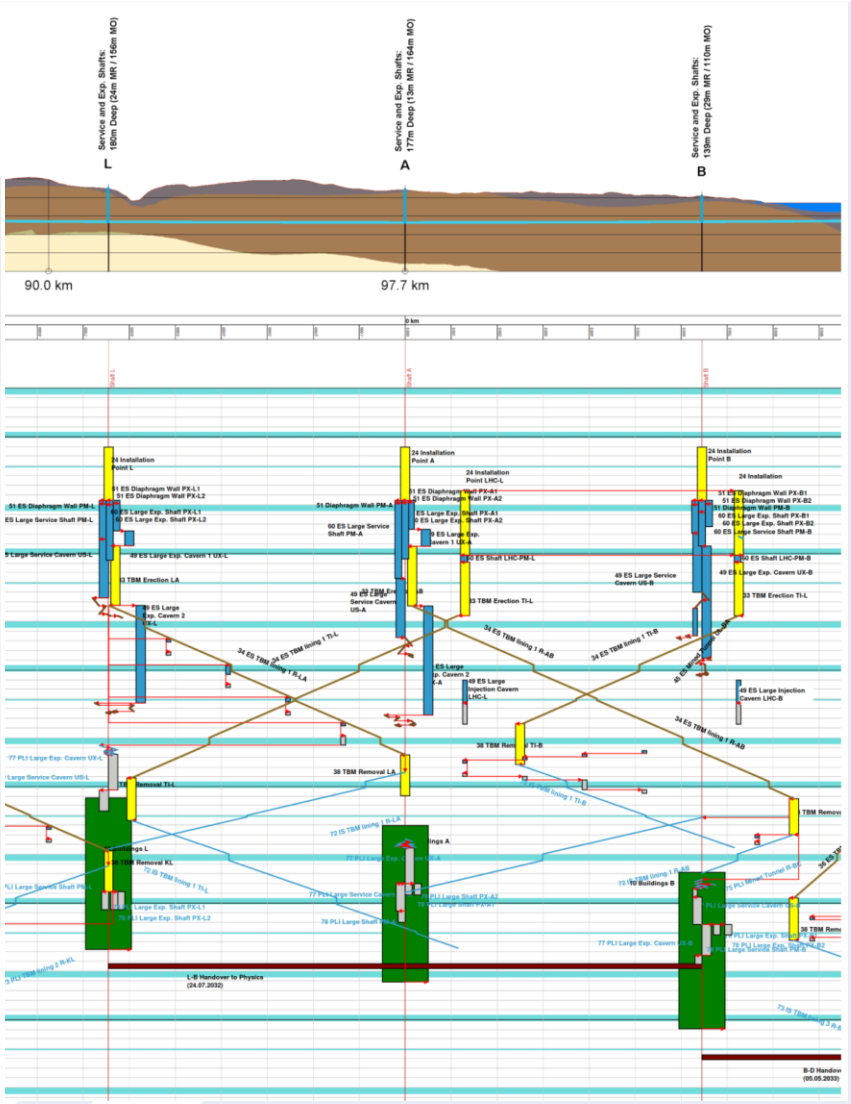
- and development of the Construction Schedule









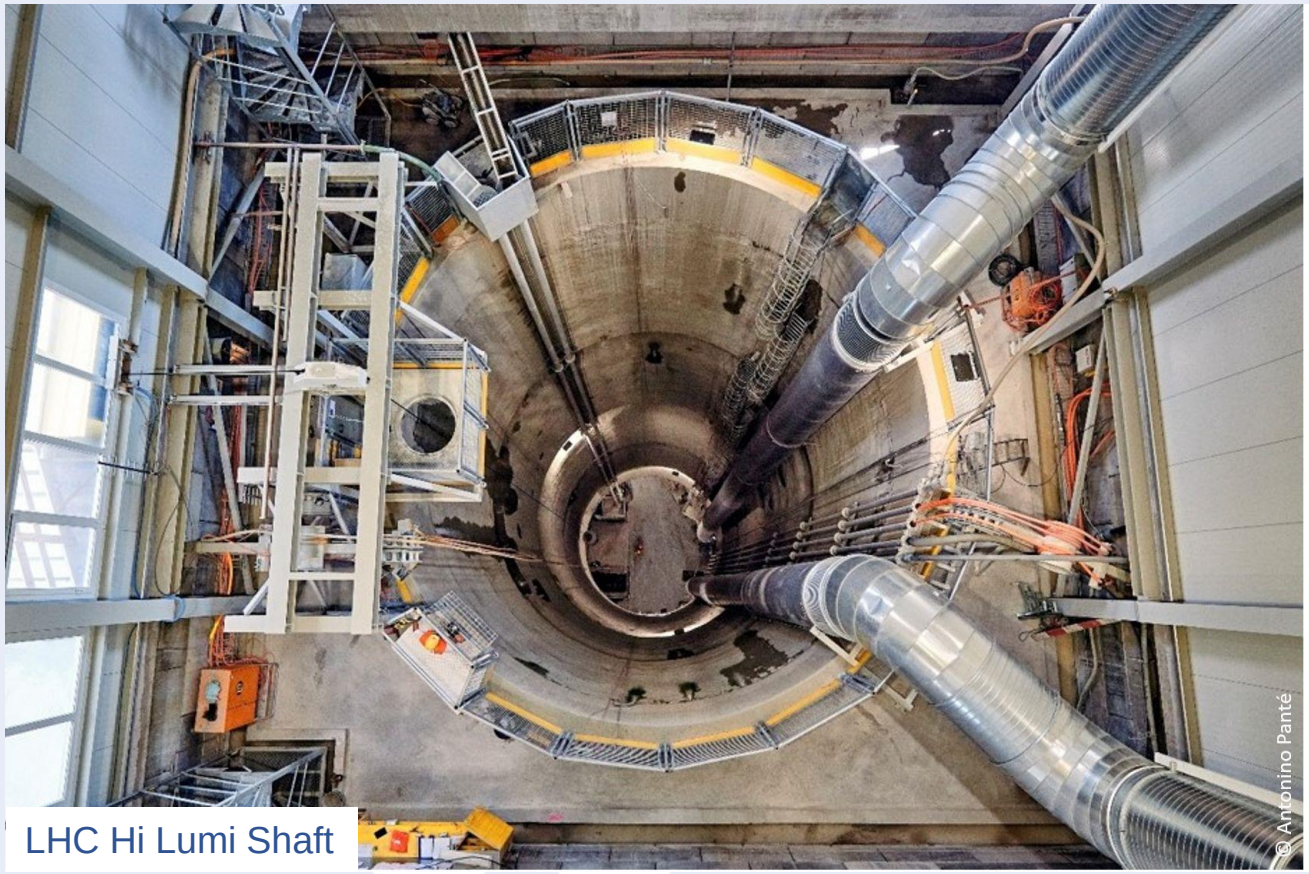


OVERVIEW COST & SCHEDULE STUDY

The calculation of the Construction Costs was performed based on the construction schedule,

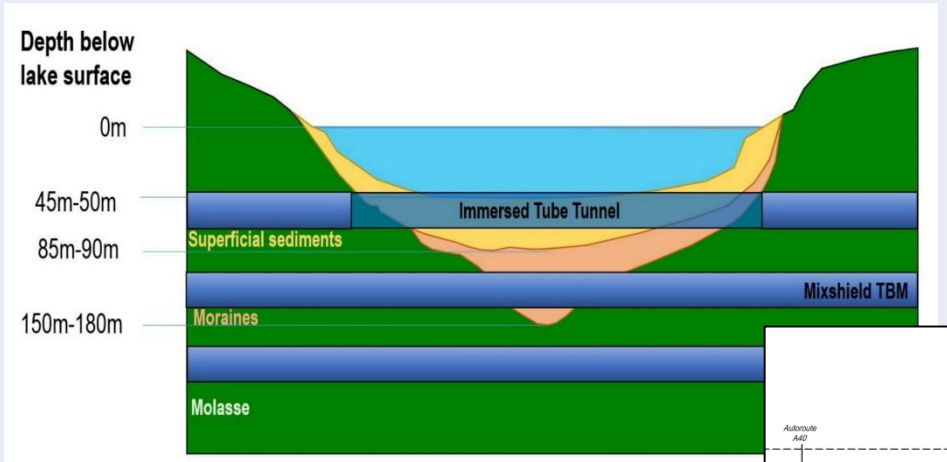
Split in the following parts

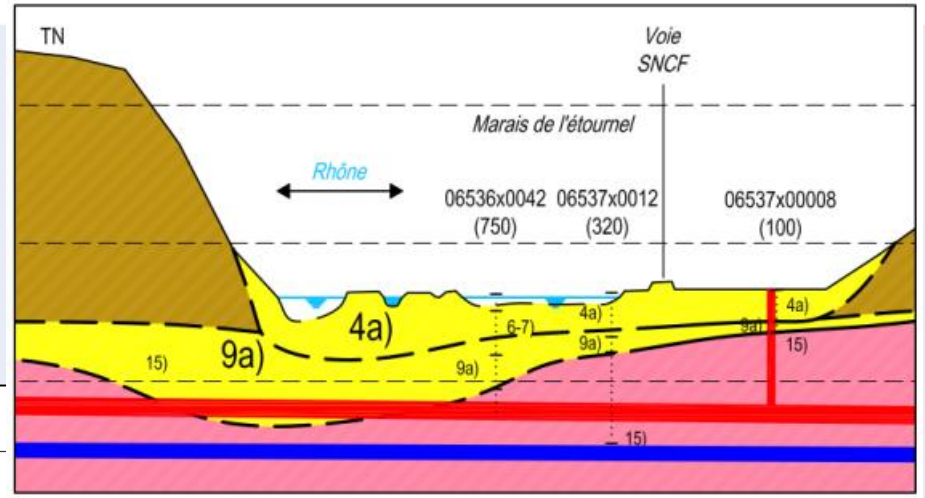
- Materials
- Labor costs (based on the schedule)
- Equipment – where necessary also based on the schedule
- Consumables

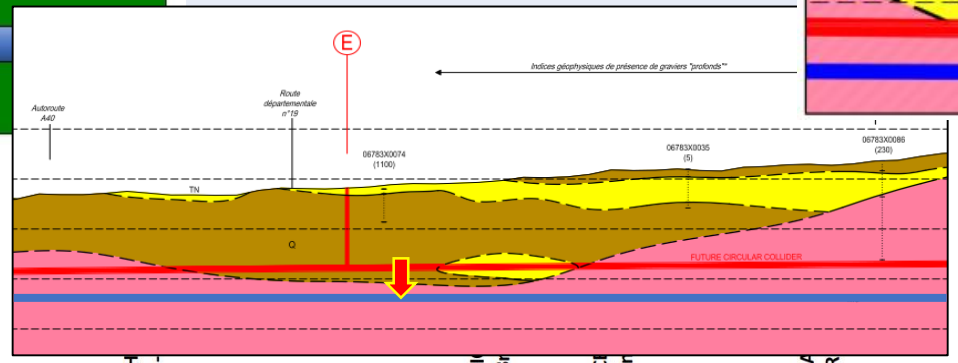


LHC Hi Lumi Shaft

HIGH RISK AREA'S - CDR



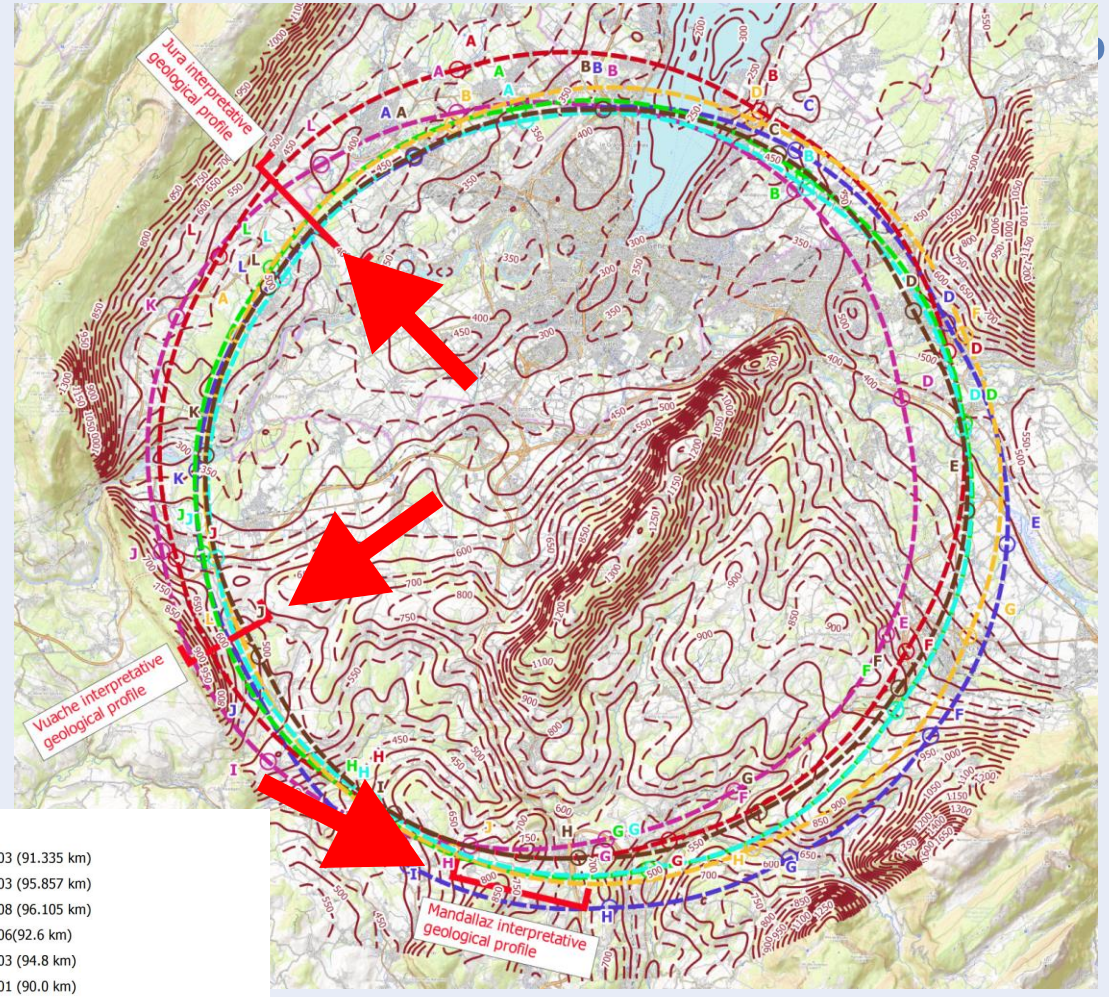


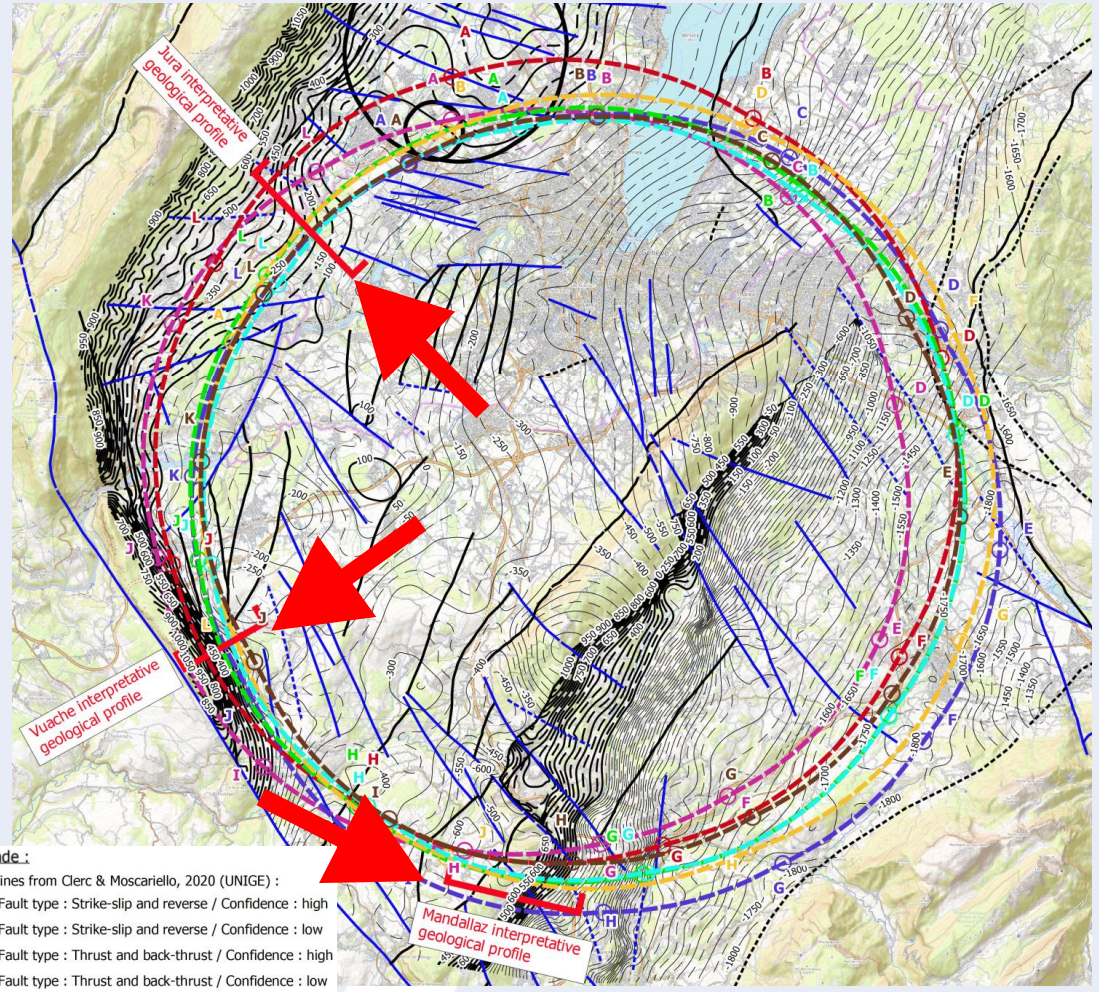


OVERVIEW GEOLOGY - STATUS

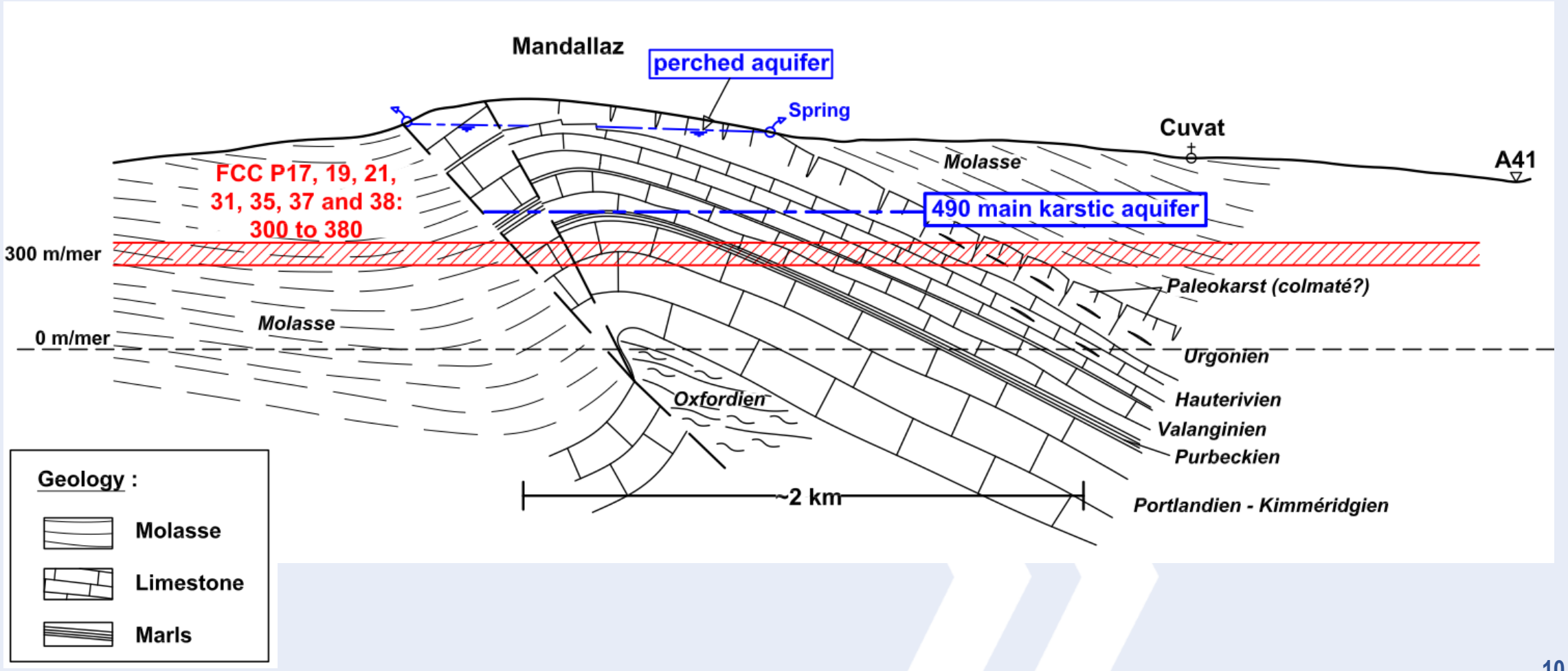
- **Existing geological data and processing**
  - » TOT with geological data GADZ 2014 and GGE (for Limestone rockhead contours)
  - » Geoprofiler (CERN tool in development - similar output as TOT) with geological data from UNIGE as well as GADZ
  - » CERN-UNIGE Cooperation project (started end 2020)
    - establishing a «GIS-based subsurface data set» in progress
    - define reliability of existing data
    - Reprocess existing geophysical data
  - » GADZ geological 3D modelling (Software GEOMENSURA) includes UNIGE actual data

OVERVIEW GEOLOGY

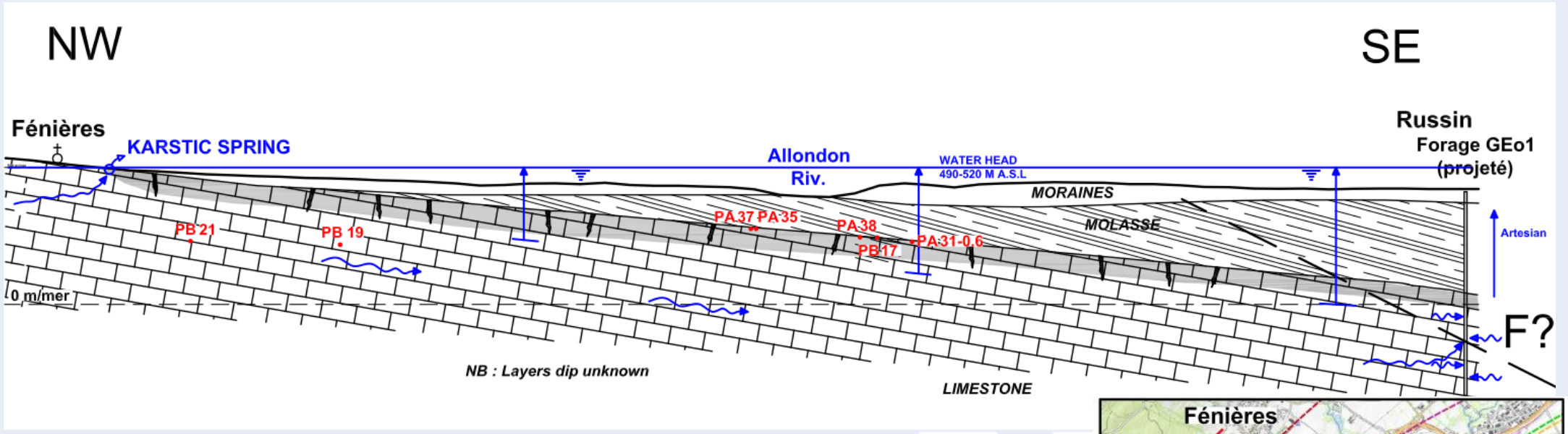




OVERVIEW GEOLOGY - MANDALLAZ

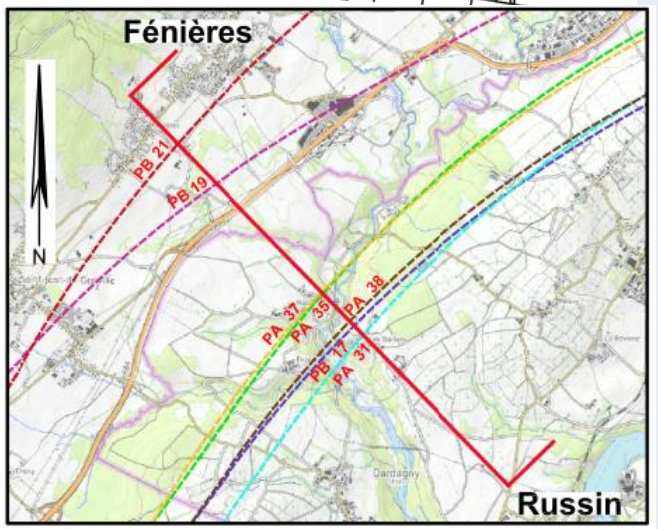


OVERVIEW GEOLOGY - JURA

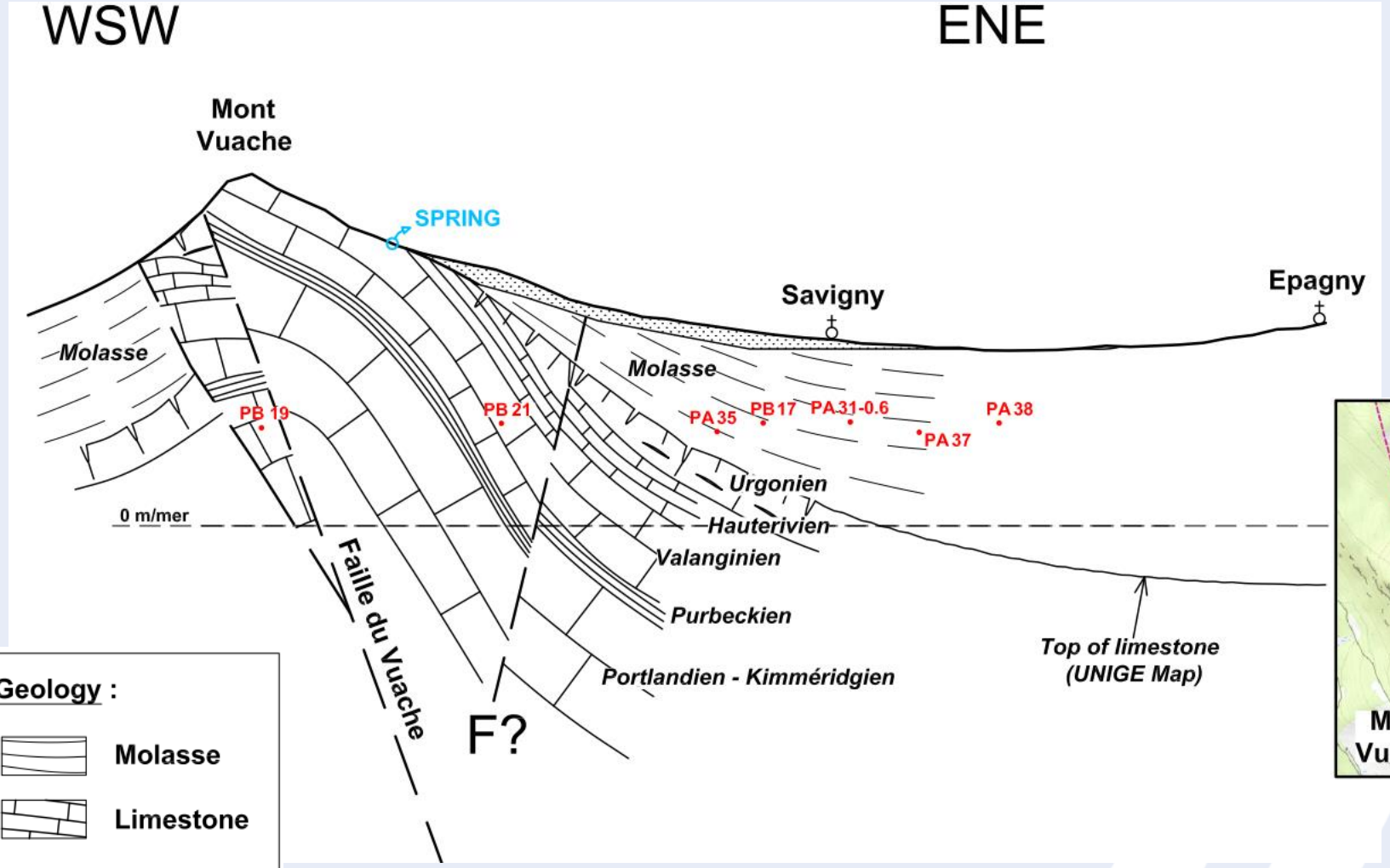


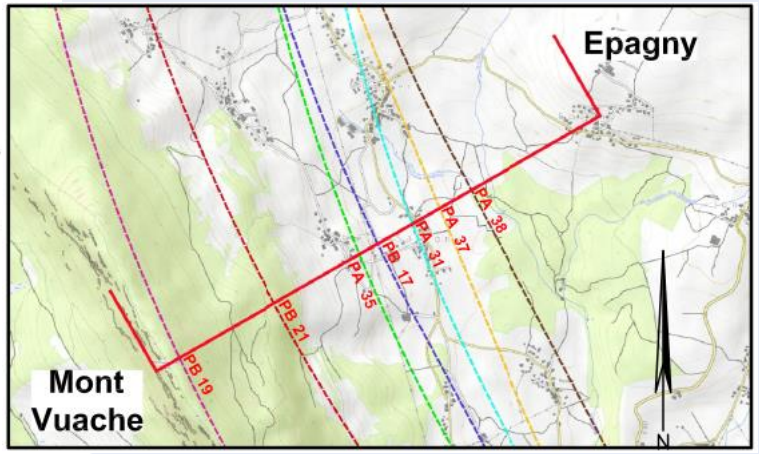
Geology :

- Molasse
- Limestone
- Upper zone with filled cracks and low permeability



OVERVIEW GEOLOGY - VUACHE



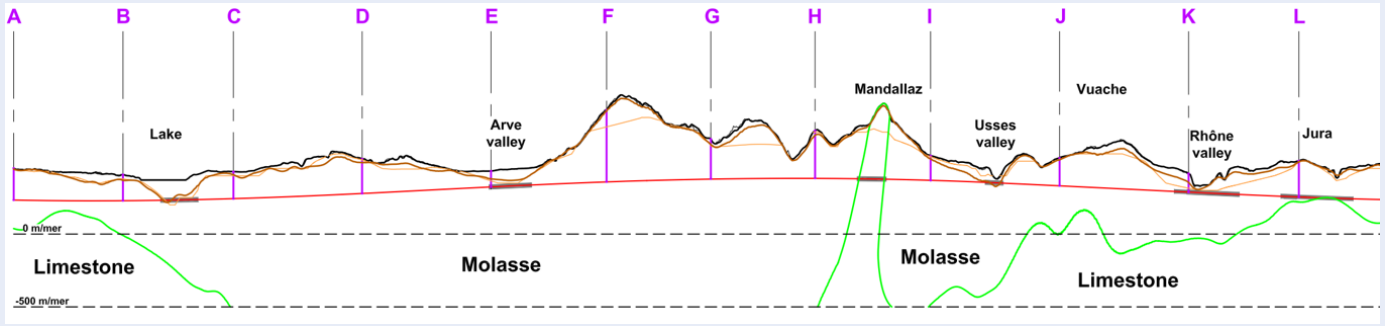


COMPARISON OF ALIGNMENTS

FCC – PLACEMENT STUDIES REVIEW WORKSHOP - TUNNELLING/GEOLOGY ASPECTS

Evaluation of «Uncertainties»

- **Theoretical Distance to Quarternary / Limestone:**
  - » **> 0** => Project in molasses
  - » **< 0** => Project in Limestone/ Quaternary
- **Geological uncertainty:**
  Assessment in progress (first estimate)
- **WATER HEAD**
  - » Minium value based on the river/lake level
  - » maximum based on the mountain spring level
- **N.R.: no repercussion**



GEOLOGICAL / HYDROGEOLOGICAL MODEL - UNCERTAINTIES

SECTOR	INTERFACE	TOP MOLASSE (UNIGE) [m a.S.L.]	TOP LIMESTONE (UNIGE) [m a.S.L.]	ALIGN. ELEV. [m a.S.L.]	**Theo. Dist. To Quat/Lim [m]**	**Current model uncertainty (m)**	WATER HEAD [m] MIN	MAX	**WATER PRESSURE [bar] MIN**	**MAX**
LAKE	Quat./molasse	216	N.R.	231	**-15**	**30**	372		**14**	**-**
ARVE	Quat./molasse	367	N.R.	322	**45**	**30**	445		**12**	**-**
MANDALLAZ	Molasse/Limestone	N.R.	896	376	**-520**	**100**	490	770	**11**	**39**
USSES	Quat./molasse	326	N.R.	349	**-23**	**30**	375		**3**	**-**
VUACHE	Molasse/Limestone	N.R.	167	310	**143**	**100**	350	650	**4**	**34**
RHONE	Quat./molasse	305	N.R.	271	**34**	**40**	328		**6**	**-**
JURA	Molasse/Limestone	N.R.	251	247	**-4**	**100**	490	520	**24**	**27**

COMPARISON OF ALIGNMENTS

FCC – PLACEMENT STUDIES REVIEW WORKSHOP - TUNNELLING/GEOLOGY ASPECTS

Evaluation of «Final Risk Index»

- **LOCAL OCCURRENCE INDEX:**
  Estimation based on UNIGE top of limestone and top of molasse map, taking into account current reliability of the model
- **PROB. INDEX : LOCAL OCCURRENCE INDEX x LENGTH**
- **IMPACT:**
  Impact on tunnel construction methods, schedule and costs
- **RISK ASSESSMENT QUALITY**:
  Estimation of the risk assessement after all site investigations
- **FINAL RISK INDEX : PROB. INDEX x IMPACT x RISK ASSESSMENT QUALITY**

FINAL RISK INDEX : PROB. INDEX x IMPACT x RISK ASSESSMENT QUALITY

SECTOR	RISK DESCRIPTION	LOCAL OCCURRENCE INDEX	LENGTH (km)	PROB. INDEX	IMPACT	RISK ASSESSMENT QUALITY	FINAL RISK INDEX
LAKE	Quaternary soft ground, water bearing	2	2.3	4.6	3	2	28
ARVE	Quaternary soft ground, water bearing	1	2.2	2.2	2	1	4
MANDALLAZ	Limestone, water bearing karsts	4	2.0	8	4	3	96
USSES	Quaternary soft ground, water bearing	3	1.2	3.6	2	1	7
VUACHE	Limestone, water bearing karsts	4	9.2	36.8	4	3	442
RHONE	Quaternary soft ground, water bearing	2	1.3	2.6	2	1	5
JURA	Limestone, water bearing karsts	4	14.0	56	4	3	672
						TOT	1254

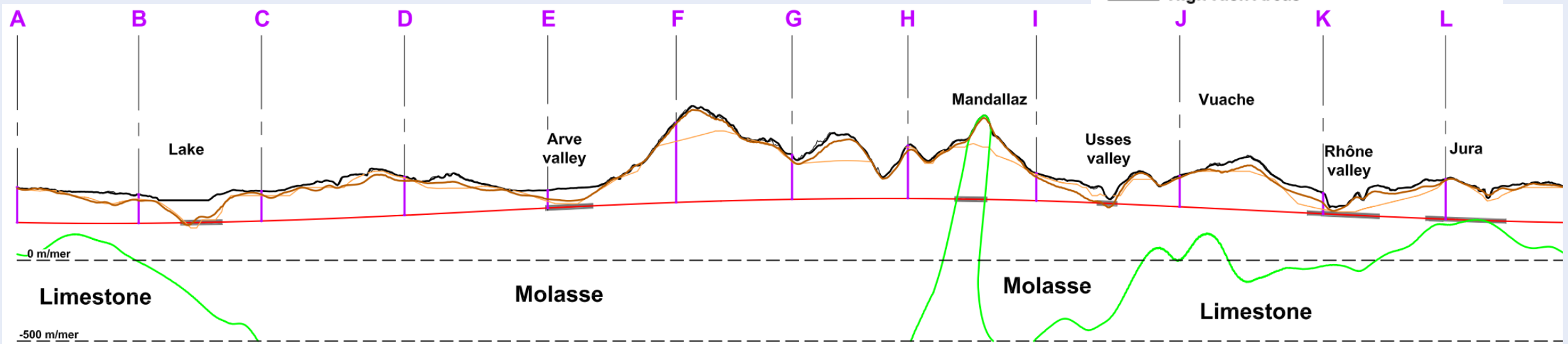
LOCAL OCCURENCE INDEX	
1	rare
2	possible
3	probable
4	certain

IMPACT	
1	low
2	medium
3	high
4	very high

RISK ASSESSEMENT QUALITIY	
1	good
2	medium
3	low

COMPARISON OF ALIGNMENTS

PB17-0.8 Length: 96.1 km, Tilt: x-x 0.6% / y-y 0.07%



Aligment 17-0.8

GEOLOGICAL / HYDROGEOLOGICAL MODEL - UNCERTAINTIES

SECTOR	INTERFACE	TOP MOLASSE (UNIGE)	TOP LIMESTONE (UNIGE)	ALIGN. ELEV.	Theo. Dist. To Quat/Lim.	WATER HEAD MIN	WATER HEAD MAX	WATER PRESSURE MIN	WATER PRESSURE MAX
LAKE	Quat./molasse	216	N.R.	231	-15	372		14	-
ARVE	Quat./molasse	367	N.R.	322	45	445		12	-
MANDALLAZ	Molasse/Limestone	N.R.	896	376	-520	490	770	11	39
USSES	Quat./molasse	326	N.R.	349	-23	375		3	-
VUACHE	Molasse/Limestone	N.R.	167	310	143	350	650	4	34
RHONE	Quat./molasse	305	N.R.	271	34	328		6	-
JURA	Molasse/Limestone	N.R.	251	247	-4	490	520	24	27

FINAL RISK INDEX : PROB. INDEX x IMPACT x RISK ASSESSMENT QUALITY

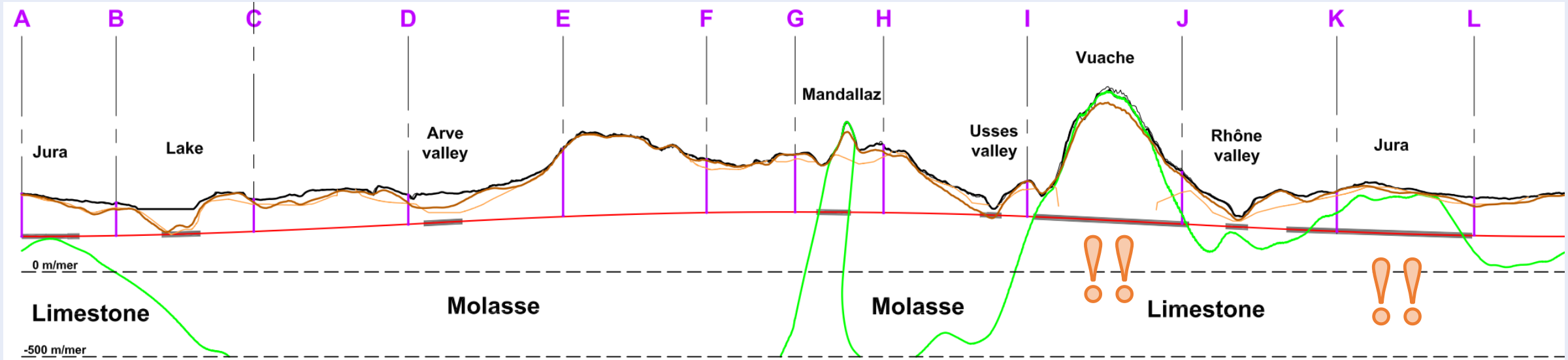
SECTOR	RISK DESCRIPTION	LOCAL OCCURRENCE INDEX	LENGTH (km)	PROB. INDEX	IMPACT	RISK ASSESSMENT QUALITY	FINAL RISK INDEX
LAKE	Quaternary soft ground, water bearing	3	2.6	7.8	3	2	47
ARVE	Quaternary soft ground, water bearing	2	3.0	6	2	1	12
MANDALLAZ	Limestone, water bearing karsts	4	2.0	8	4	3	96
USSES	Quaternary soft ground, water bearing	3	1.2	3.6	2	1	7
VUACHE	Limestone, water bearing karsts	2	1.5	3	4	2	24
RHONE	Quaternary soft ground, water bearing	2	4.5	9	2	1	18
JURA	Limestone, water bearing karsts	2.5	5.0	12.5	4	2	100
						TOT	304

COMPARISON OF ALIGNMENTS

PB19-0.3 Length: 91.3 km, Tilt: x-x 0.8% / y-y 0.1%

Geology :

- TN
- Top molasse (GADZ, may 2014)
- Top molasse (UNIGE, april 2021)
- Top cretaceous (UNIGE, january 2021)
- High Risk Areas



Aligment 19-0.3

GEOLOGICAL / HYDROGEOLOGICAL MODEL - UNCERTAINTIES

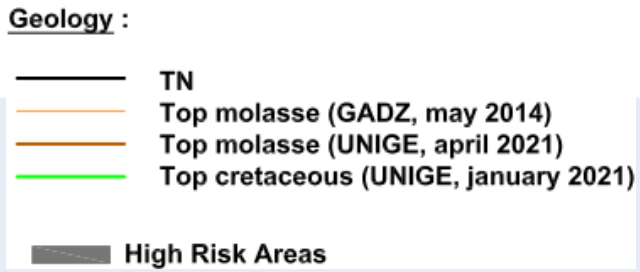
SECTOR	INTERFACE	TOP MOLASSE (UNIGE)	TOP LIMESTONE (UNIGE)	ALIGN. ELEV.	Theo. Dist. To Quat/Lim.	WATER HEAD		WATER PRESSURE MIN	WATER PRESSURE MAX
LAKE	Quat./molasse	234	N.R.	220	14	372		15	-
ARVE	Quat./molasse	376	N.R.	286	90	445		16	-
MANDALLAZ	Molasse/Limestone	N.R.	884	352	-532	490	770	14	42
USSES	Quat./molasse	316	N.R.	333	-17	375		4	-
VUACHE	Molasse/Limestone	N.R.	1066	280	-786	350	650	7	37
RHONE	Quat./molasse	306	N.R.	263	43	328		7	-
JURA	Molasse/Limestone	N.R.	453	215	-243	490	520	28	31

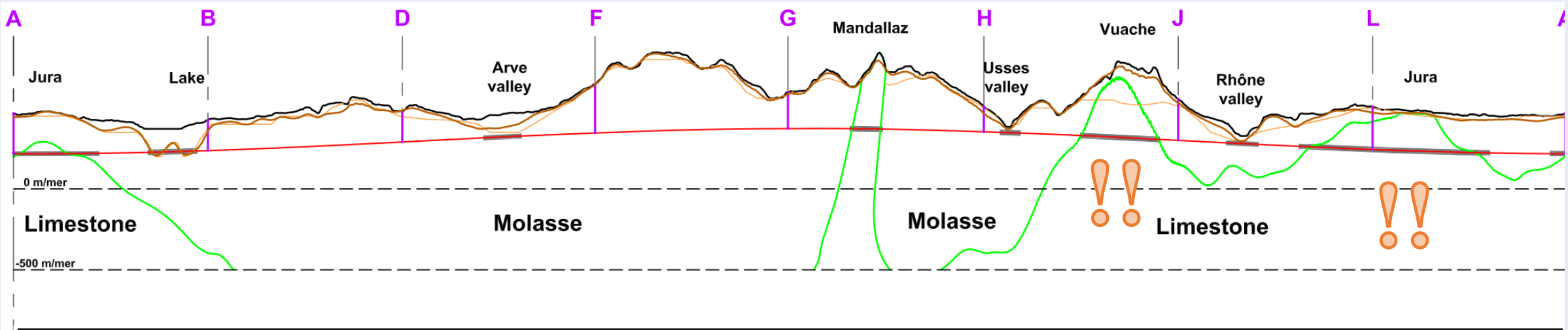
FINAL RISK INDEX : PROB. INDEX x IMPACT x RISK ASSESSMENT QUALITY

SECTOR	RISK DESCRIPTION	LOCAL OCCURRENCE INDEX	LENGTH (km)	PROB. INDEX	IMPACT	RISK ASSESSMENT QUALITY	FINAL RISK INDEX
LAKE	Quaternary soft ground, water bearing	2	2.3	4.6	3	2	28
ARVE	Quaternary soft ground, water bearing	1	2.2	2.2	2	1	4
MANDALLAZ	Limestone, water bearing karsts	4	2.0	8	4	3	96
USSES	Quaternary soft ground, water bearing	3	1.2	3.6	2	1	7
VUACHE	Limestone, water bearing karsts	4	9.2	36.8	4	3	442
RHONE	Quaternary soft ground, water bearing	2	1.3	2.6	2	1	5
JURA	Limestone, water bearing karsts	4	14.0	56	4	3	672
						TOT	1254

COMPARISON OF ALIGNMENTS

PA21-0.3 Length: 95.8 km, Tilt: x-x 0.5% / y-y 0.1%





Aligment 21-0.3

GEOLOGICAL / HYDROGEOLOGICAL MODEL - UNCERTAINTIES

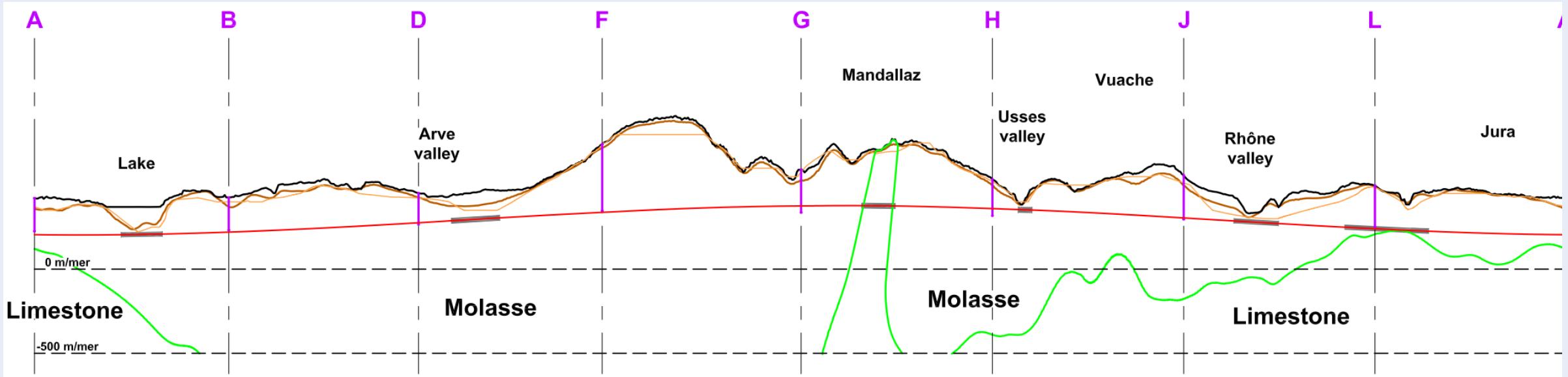
SECTOR	INTERFACE	TOP MOLASSE (UNIGE)	TOP LIMESTONE (UNIGE)	ALIGN. ELEV.	Theo. Dist. To Quat/Lim.	WATER HEAD		WATER PRESSURE MIN	WATER PRESSURE MAX
LAKE	Quat./molasse	205	N.R.	226	-21	372		15	-
ARVE	Quat./molasse	372	N.R.	315	57	445		13	-
MANDALLAZ	Molasse/Limestone	N.R.	842	370	-472	490	770	12	40
USSES	Quat./molasse	369	N.R.	345	24	375		3	-
VUACHE	Molasse/Limestone	N.R.	691	306	-385	350	650	4	34
RHONE	Quat./molasse	293	N.R.	275	18	328		5	-
JURA	Molasse/Limestone	N.R.	468	223	-245	490	520	27	30

FINAL RISK INDEX : PROB. INDEX x IMPACT x RISK ASSESSMENT QUALITY

SECTOR	RISK DESCRIPTION	LOCAL OCCURRENCE INDEX	LENGTH (km)	PROB. INDEX	IMPACT	RISK ASSESSMENT QUALITY	FINAL RISK INDEX
LAKE	Quaternary soft ground, water bearing	3	3.0	9	3	2	54
ARVE	Quaternary soft ground, water bearing	2	2.3	4.6	2	1	9
MANDALLAZ	Limestone, water bearing karsts	4	2.0	8	4	3	96
USSES	Quaternary soft ground, water bearing	2	1.2	2.4	2	1	5
VUACHE	Limestone, water bearing karsts	4	5.0	20	4	3	240
RHONE	Quaternary soft ground, water bearing	2	2.0	4	2	1	8
JURA	Limestone, water bearing karsts	4	18.0	72	4	3	864
						TOT	1276

COMPARISON OF ALIGNMENTS

PA31-0.4 Length: 90.9 km, Tilt: x-x 0.6%



Aligment 31-0.6

GEOLOGICAL / HYDROGEOLOGICAL MODEL - UNCERTAINTIES

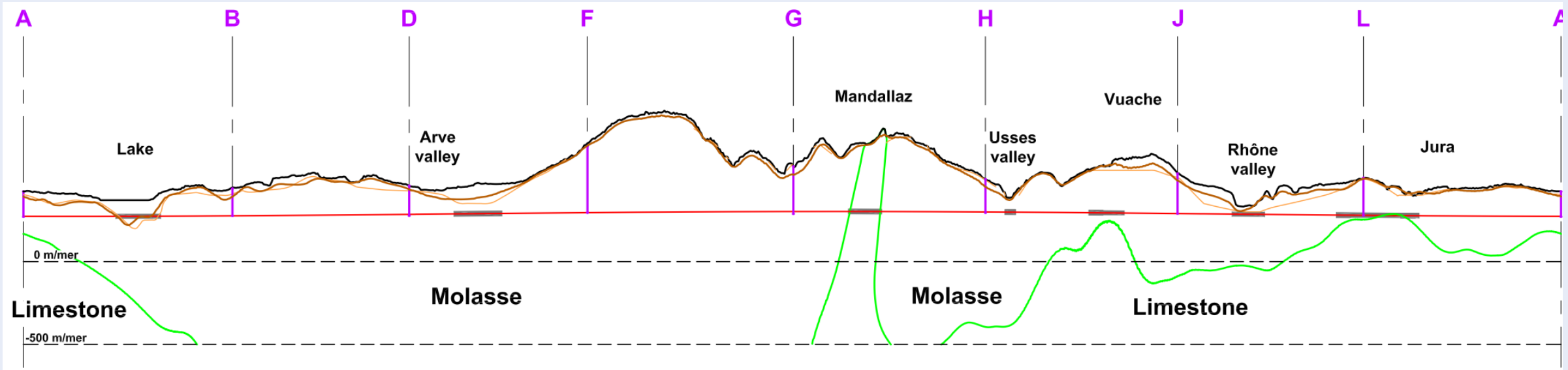
SECTOR	INTERFACE	TOP MOLASSE (LNIGE)	TOP LIMESTONE (UNIGE)	ALIGN. ELEV.	Theo. Dist. To Quat/Lim.	WATER HEAD*		WATER PRESSURE MIN	WATER PRESSURE MAX
LAKE	Quat./molasse	236	N.R.	204	**32**	372		**17**	-
ARVE	Quat./molasse	374	N.R.	287	**87**	445		**16**	-
MANDALLAZ	Molasse/Limestone	N.R.	770	375	**-395**	490	770	**12**	**40**
USSES	Quat./molasse	384	N.R.	351	**33**	375		**2**	-
VUACHE	Molasse/Limestone	N.R.	90	315	**225**	350	650	**4**	**34**
RHONE	Quat./molasse	309	N.R.	271	**38**	328		**6**	-
JURA	Molasse/Limestone	N.R.	231	232	**1**	490	520	**26**	**29**

FINAL RISK INDEX : PROB. INDEX x IMPACT x RISK ASSESSMENT QUALITY

SECTOR	RISK DESCRIPTION	LOCAL OCCURRENCE INDEX	LENGTH (km)	PROB. INDEX	IMPACT	RISK ASSESSMENT QUALITY	FINAL RISK INDEX
LAKE	Quaternary soft ground, water bearing	2	2.4	4.8	3	2	**29**
ARVE	Quaternary soft ground, water bearing	1	2.9	2.9	2	1	**6**
MANDALLAZ	Limestone, water bearing karsts	4	2.0	8	4	3	**96**
USSES	Quaternary soft ground, water bearing	2	0.8	1.6	2	1	**3**
VUACHE	Limestone, water bearing karsts	1	1.5	1.5	4	2	**12**
RHONE	Quaternary soft ground, water bearing	2	2.7	5.4	2	1	**11**
JURA	Limestone, water bearing karsts	2.5	5.0	12.5	4	2	**100**
						TOT	**257**

COMPARISON OF ALIGNMENTS

PA35-0.6 Length: 92.6 km, Tilt: x-x 0.1%



Aligment 35-0.6

GEOLOGICAL / HYDROGEOLOGICAL MODEL - UNCERTAINTIES

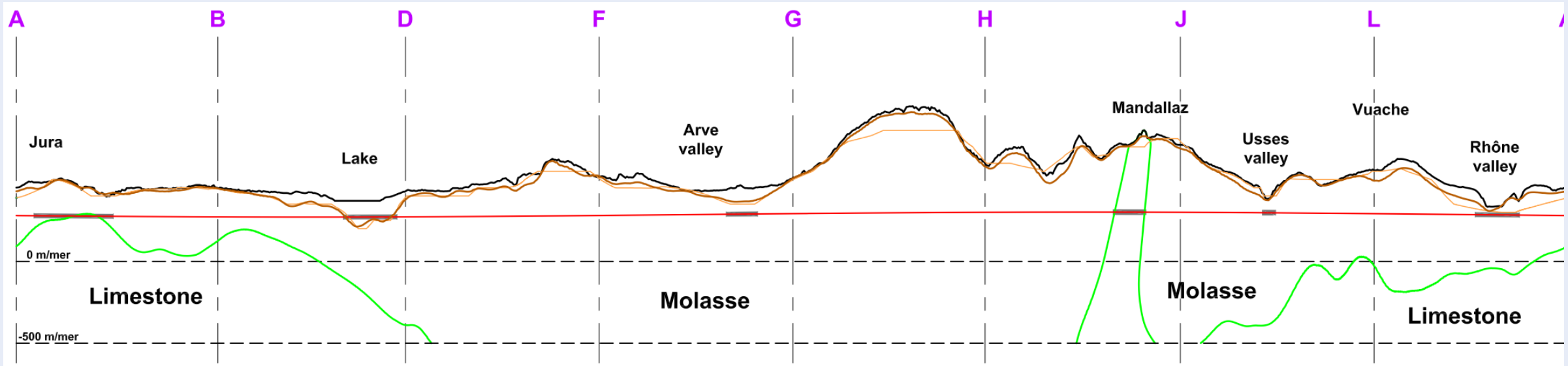
SECTOR	INTERFACE	TOP MOLASSE (UNIGE)	TOP LIMESTONE (UNIGE)	ALIGN. ELEV.	Theo. Dist. To Quat/Lm.	WATER HEAD		WATER PRESSURE MIN	WATER PRESSURE MAX
LAKE	Quat./molasse	220	N.R.	272	**-52**	372		**10**	-
ARVE	Quat./molasse	375	N.R.	287	**88**	445		**16**	-
MANDALLAZ	Molasse/Limestone	N.R.	802	302	**-500**	490	770	**19**	**47**
USSES	Quat./molasse	371	N.R.	298	**73**	375		**8**	-
VUACHE	Molasse/Limestone	N.R.	247	293	**46**	350	650	**6**	**36**
RHONE	Quat./molasse	304	N.R.	284	**20**	328		**4**	-
JURA	Molasse/Limestone	N.R.	287	277	**-10**	490	520	**21**	**24**

FINAL RISK INDEX : PROB. INDEX x IMPACT x RISK ASSESSMENT QUALITY

SECTOR	RISK DESCRIPTION	LOCAL OCCURRENCE INDEX	LENGTH (km)	PROB. INDEX	IMPACT	RISK ASSESSMENT QUALITY	FINAL RISK INDEX
LAKE	Quaternary soft ground, water bearing	4	2.7	10.8	3	2	65
ARVE	Quaternary soft ground, water bearing	1	2.9	2.9	2	1	6
MANDALLAZ	Limestone, water bearing karsts	4	2.0	8	4	3	96
USSES	Quaternary soft ground, water bearing	1	0.6	0.6	2	1	1
VUACHE	Limestone, water bearing karsts	2.5	2.5	6.25	4	2	50
RHONE	Quaternary soft ground, water bearing	2	2.0	4	2	1	8
JURA	Limestone, water bearing karsts	2.5	5.0	12.5	4	2	100
						TOT	326

COMPARISON OF ALIGNMENTS

PA37-0.3 Length: 94.8 km, Tilt: x-x 0.1%



Aligment 37-0.3

GEOLOGICAL / HYDROGEOLOGICAL MODEL - UNCERTAINTIES

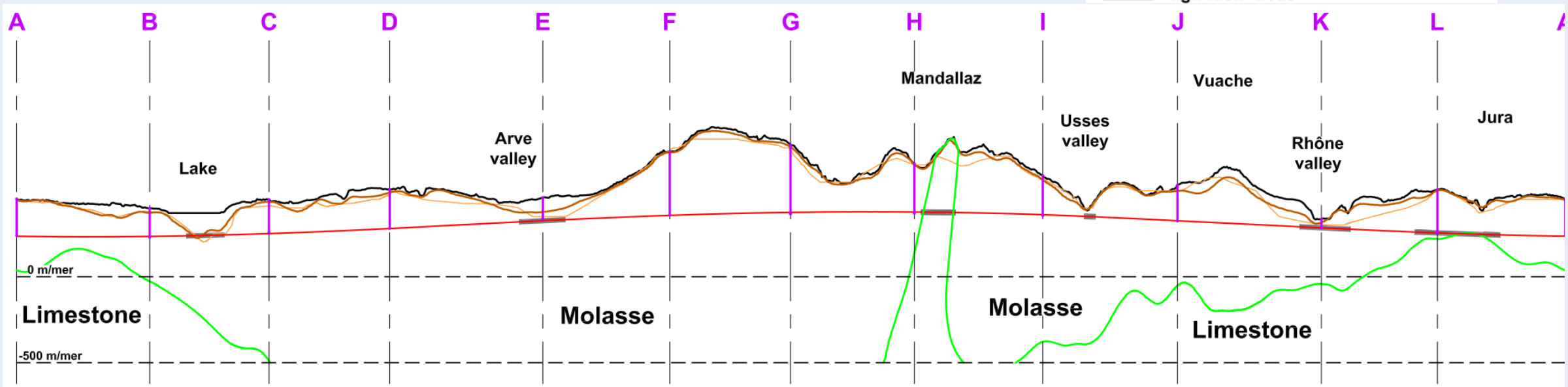
SECTOR	INTERFACE	TOP MOLASSE (UNIGE)	TOP LIMESTONE (UNIGE)	ALIGN. ELEV.	Theo. Dist. To Quat/Lim.	WATER HEAD		WATER PRESSURE MIN	WATER PRESSURE MAX
LAKE	Quat./molasse	212	N.R.	271	-59	372		10	-
ARVE	Quat./molasse	364	N.R.	288	76	445		16	-
MANDALLAZ	Molasse/Limestone	N.R.	801	300	-501	490	770	19	47
USSES	Quat./molasse	374	N.R.	297	77	375		8	-
VUACHE	Molasse/Limestone	N.R.	30	290	260	350	650	6	36
RHONE	Quat./molasse	308	N.R.	283	25	328		5	-
JURA	Molasse/Limestone	N.R.	292	276	-16	490	520	21	24

FINAL RISK INDEX : PROB. INDEX x IMPACT x RISK ASSESSMENT QUALITY

SECTOR	RISK DESCRIPTION	LOCAL OCCURRENCE INDEX	LENGTH (km)	PROB. INDEX	IMPACT	RISK ASSESSMENT QUALITY	FINAL RISK INDEX
LAKE	Quaternary soft ground, water bearing	4	3.3	13.2	3	2	79
ARVE	Quaternary soft ground, water bearing	1	1.9	1.9	2	1	4
MANDALLAZ	Limestone, water bearing karsts	4	2.0	8	4	3	96
USSES	Quaternary soft ground, water bearing	1	0.8	0.8	2	1	2
VUACHE	Limestone, water bearing karsts	1	1.5	1.5	4	2	12
RHONE	Quaternary soft ground, water bearing	2	2.7	5.4	2	1	11
JURA	Limestone, water bearing karsts	2.5	5.0	12.5	4	2	100
						TOT	303

COMPARISON OF ALIGNMENTS

PA38-0.1 Length: 90.0 km, Tilt: x-x 0.5% / y-y 0.1%



Aligment 38-0.1

GEOLOGICAL / HYDROGEOLOGICAL MODEL - UNCERTAINTIES

SECTOR	INTERFACE	TOP MOLASSE (UNIGE)	TOP LIMESTONE (UNIGE)	ALIGN. ELEV.	Theo. Dist. To Quat/Lim.	WATER HEAD		WATER PRESSURE MIN	WATER PRESSURE MAX
LAKE	Quat./molasse	224	N.R.	237	-13	372		14	-
ARVE	Quat./molasse	373	N.R.	318	55	445		13	-
MANDALLAZ	Molasse/Limestone	N.R.	802	373	-429	490	770	12	40
USSES	Quat./molasse	388	N.R.	348	40	375		3	-
VUACHE	Molasse/Limestone	N.R.	33	317	284	350	650	3	33
RHONE	Quat./molasse	308	N.R.	276	32	328		5	-
JURA	Molasse/Limestone	N.R.	255	248	-7	490	520	24	27

FINAL RISK INDEX : PROB. INDEX x IMPACT x RISK ASSESSMENT QUALITY

SECTOR	RISK DESCRIPTION	LOCAL OCCURRENCE INDEX	LENGTH (km)	PROB. INDEX	IMPACT	RISK ASSESSMENT QUALITY	FINAL RISK INDEX
LAKE	Quaternary soft ground, water bearing	3	2.2	6.6	3	2	40
ARVE	Quaternary soft ground, water bearing	1	2.7	2.7	2	1	5
MANDALLAZ	Limestone, water bearing karsts	4	2.0	8	4	3	96
USSES	Quaternary soft ground, water bearing	2	0.6	1.2	2	1	2
VUACHE	Limestone, water bearing karsts	1	1.5	1.5	4	2	12
RHONE	Quaternary soft ground, water bearing	2	2.9	5.8	2	1	12
JURA	Limestone, water bearing karsts	2.5	5.0	12.5	4	2	100
						TOT	267

COMPARISON OF ALIGNMENTS
SUMMARY TABLE

SECTOR	RISK	FINAL RISK INDEX							Std. Dev.*
		17-0.8	19-0.3	21-0.3	31-0.4	35-0.6	37-0.3	38-0.1	
LAKE	Quaternary soft ground, water bearing	47	28	54	29	65	79	40	20
ARVE	Quaternary soft ground, water bearing	12	4	9	6	6	4	5	3
MANDALLAZ	Limestone, water bearing karsts	96	96	96	96	96	96	96	0
USSES	Quaternary soft ground, water bearing	7	7	5	3	1	2	2	2
VUACHE	Limestone, water bearing karsts	24	442	240	12	50	12	12	16
RHONE	Quaternary soft ground, water bearing	18	5	8	11	8	11	12	4
JURA	Limestone, water bearing karsts	100	672	864	100	100	100	100	0
	TOTAL	304	1254	1276	257	326	303	267	29
	Std. Dev.* : witout P19-0.3 and P21-0.3	12	12	8	8	8	8	12	

COMPARISON OF ALIGNMENTS SUGGESTION GEOLOGIST/ENGINEER

- **Choice of the favourite alignment for HRASI**
  - » Alignments 19-0.3 and 21-0.3 should be **excluded**
  - » Based on data currently available, other alignments are conceivable, with a preference for the number 31-04 and 38-0.1.
  - » The order of preference estimated for alignments 17, 31, 35, 37 and 38 must be considered with caution regarding current model uncertainty.

COMPARISON OF ALIGNMENTS SUGGESTION GEOLOGIST/ENGINEER

- **The alignment feasibility must be clarified during HRA Site Investigations:**
  - » Mandallaz
    - Water pressure at the tunnel level
    - Karstification (detection difficult and uncertain)
  - » Jura, Vuache
    - Top of limestone
    - Karstification and filling-in at the level depth
    - Water pressure
  - » Lake, Rhône, Arve and Usses Valley
    - Top of the molasse
    - Quaternary soft grounds nature, water bearing layers and water pressure

MITIGATION MEASURES

Possible measures after HRA Site Investigation performed and results available:

- **Vertical Adjustment of Tunnel Elevation**
- **Horizontal Adjustment of Alignment (FCC ring position)**
- **Verify proposed Tunnel method (TBM open/close mode, conventional)**
- **Define further Site Investigation (Main SI)**
- **Where critical area can't be avoided (i.e. Mandallaz), define construction method, Construction site investigation**