Developments in the Underground Civil Engineering

FCC Feasibility Study

Liam Bromiley SCE-SAM-FS

Mid-Term Review 2023 Layout

8 sites

13 shafts

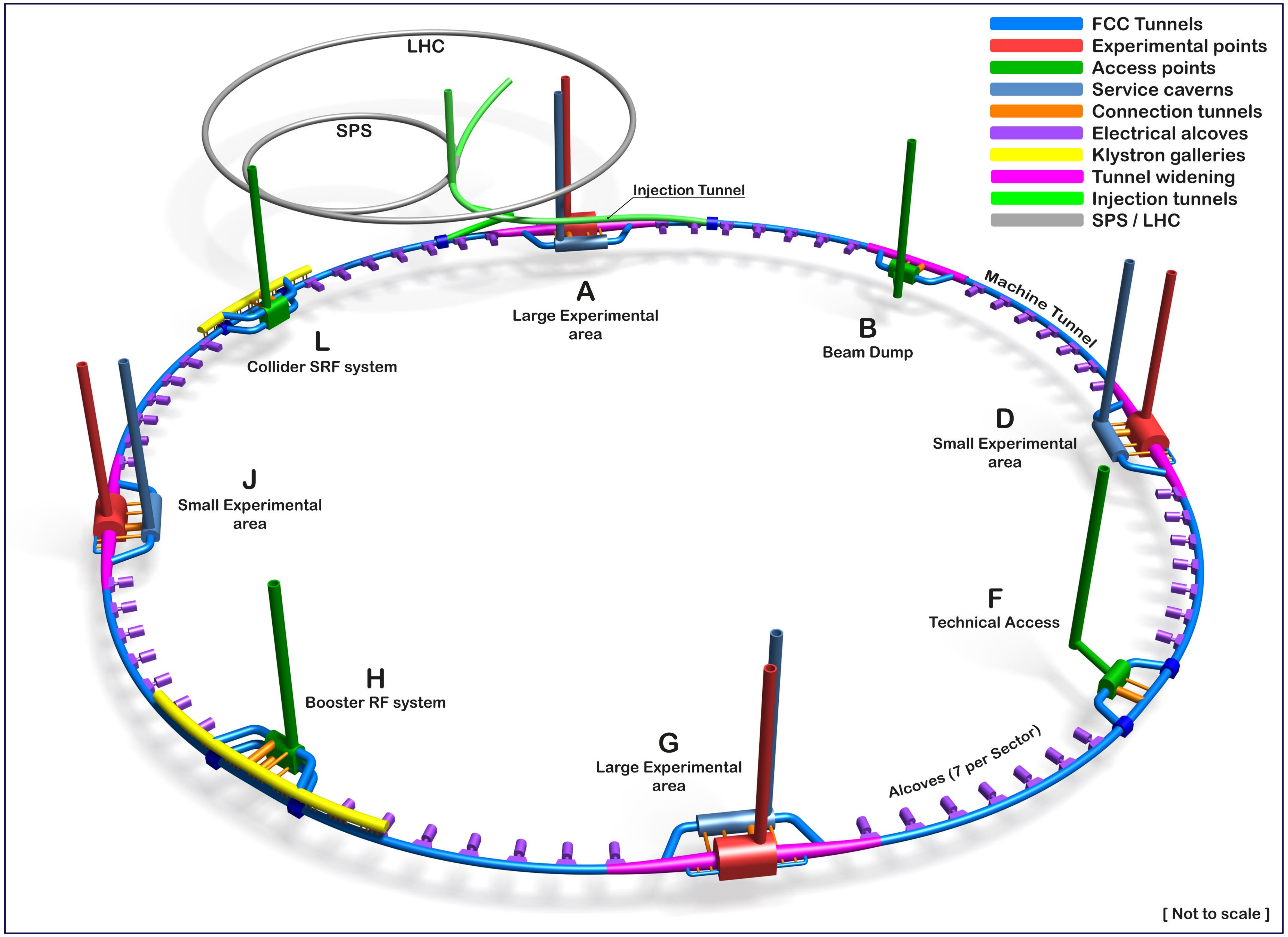
4 experiment caverns

8 service caverns

Beam dump

RF klystron galleries

SPS injection lines



Credit: Angel Navascues Cornago

Work In Progress 2024 Layout

8 surface sites

12 shafts

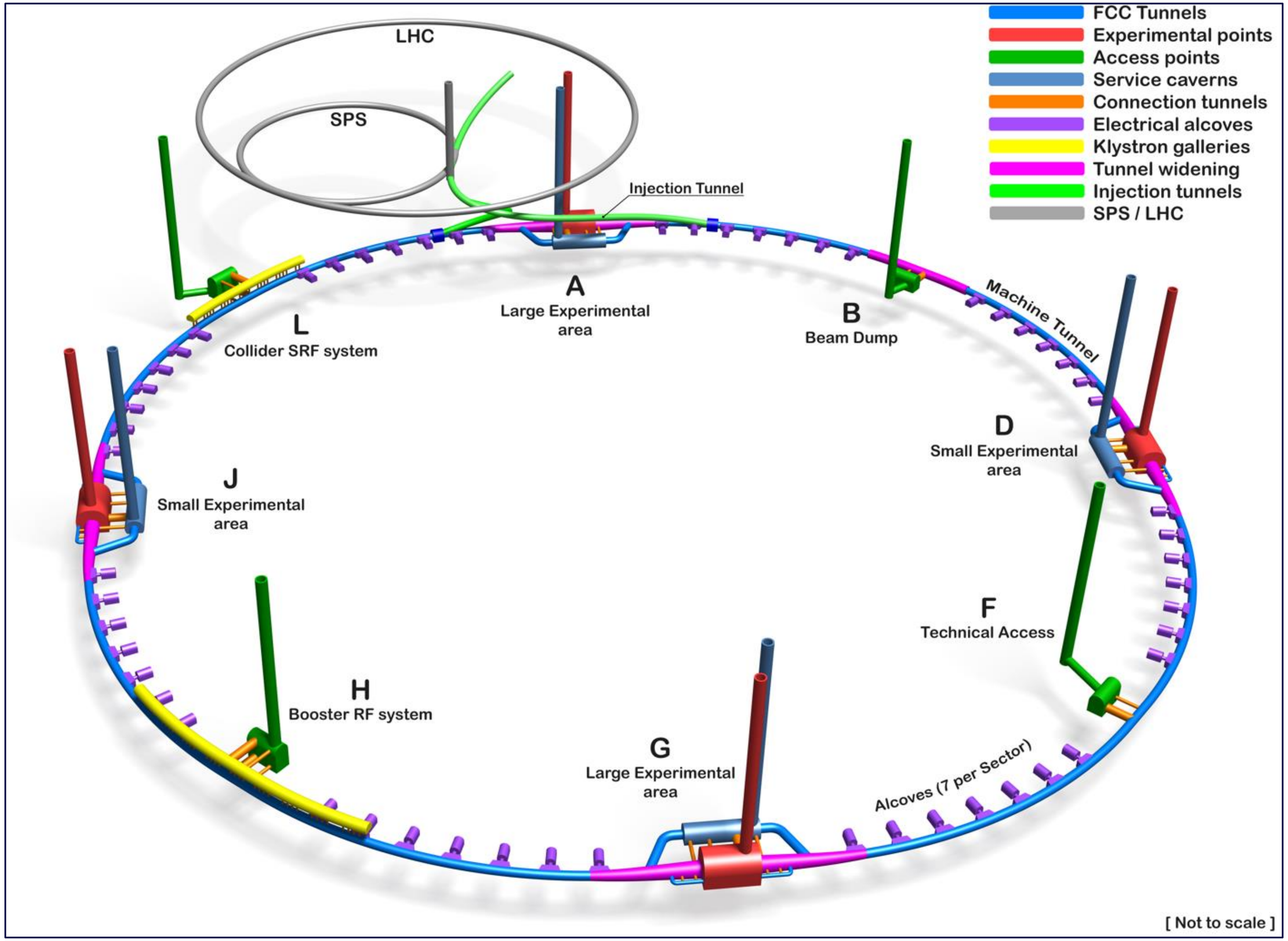
Use of existing shaft (PGCN81)

Removal of bypass tunnels (PB, PF, PH, PL)

Offset shaft at PL

Polarimeter galleries at PA

Increase in number of alcoves (10 per sector)



Credit: Angel Navascues Cornago

Mid-Term Review Feedback

- Conduct a review of molasse tunnelling projects.
- Gather lessons learned from experienced tunnelling consultants and contractors.
- Further investigate ground conditions, water tables, tunnel water tightness, rock squeezing and mitigation of such risks.
- Consider opportunities for improving the sustainability of FCC construction.
- Investigate the safety, logistics and ventilation of the 11 km single bore tunnel sectors.

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Amberg Safety, Ventilation & Logistics Study

- Small tunnel diameter (5.5 m), single bore of 11 km
- Ventilation requirements and design.
- Focused on TBM excavation phase of the tunnel construction.
- Considering French, Swiss, German and International standards.
- Also investigating the logistics of TBM servicing and spoil removal.

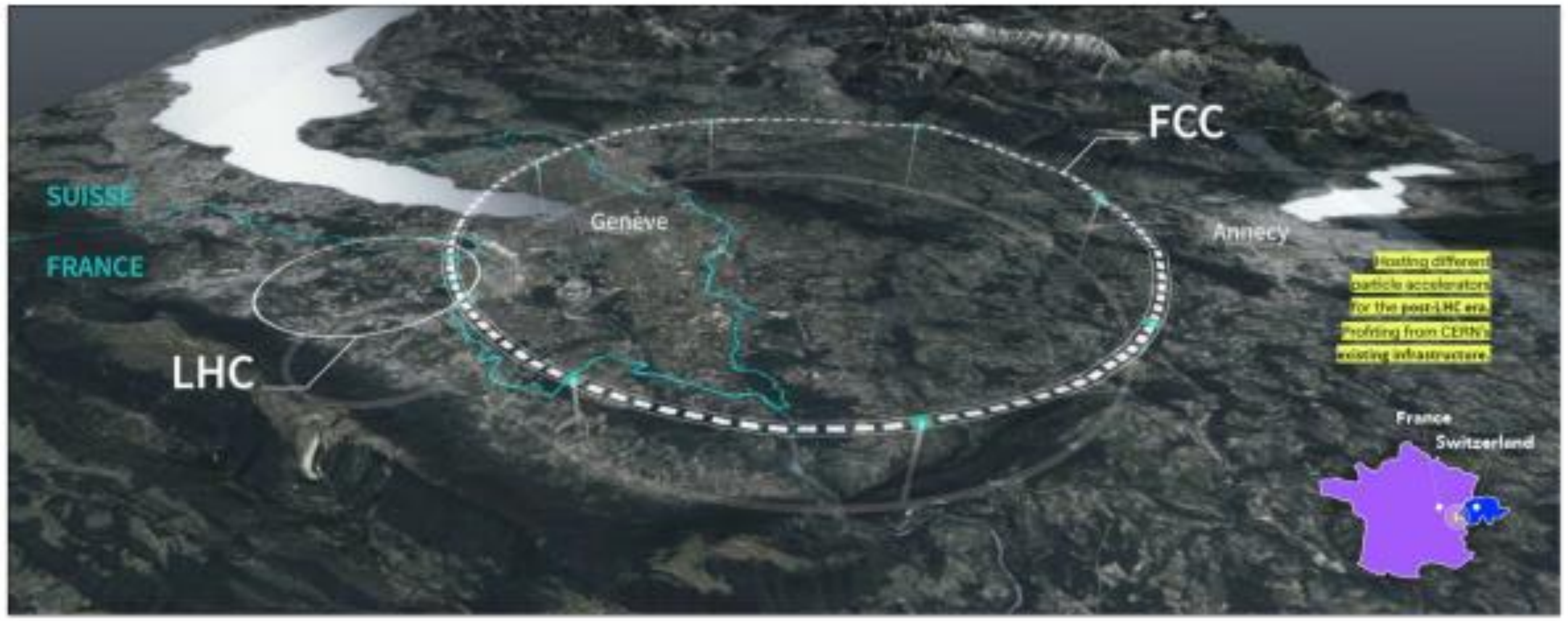
Feasibility study FCC

Safety, Ventilation and Logistics for the Future Circular Collider (FCC)

CA1102261

Report 10S00644-01

Nyon / Paris, 17 May 2024



Amberg Study – Multi-Service Vehicle

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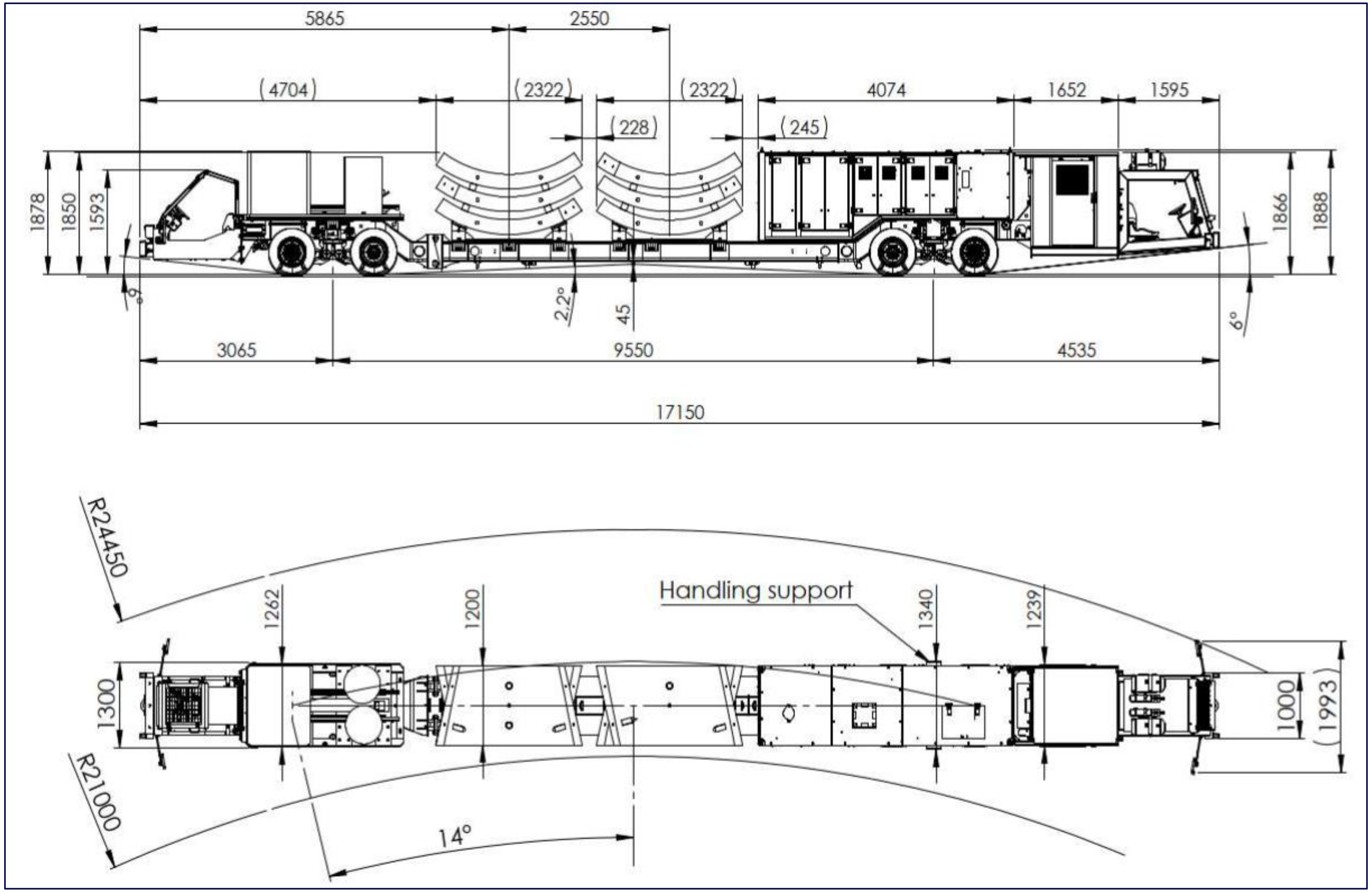
Capacity
20 tonnes

Speed
Loaded: 10 km/h
Unloaded: 24 km/h

Load
Precast concrete segments
Pipeline sections
Pea gravels
Other components and materials

Fuel
Diesel, not electric
- Size
- Fire risk
- Authorisation issues

Personnel
Separate vehicle, 10 to 15-person



TBM Logistics

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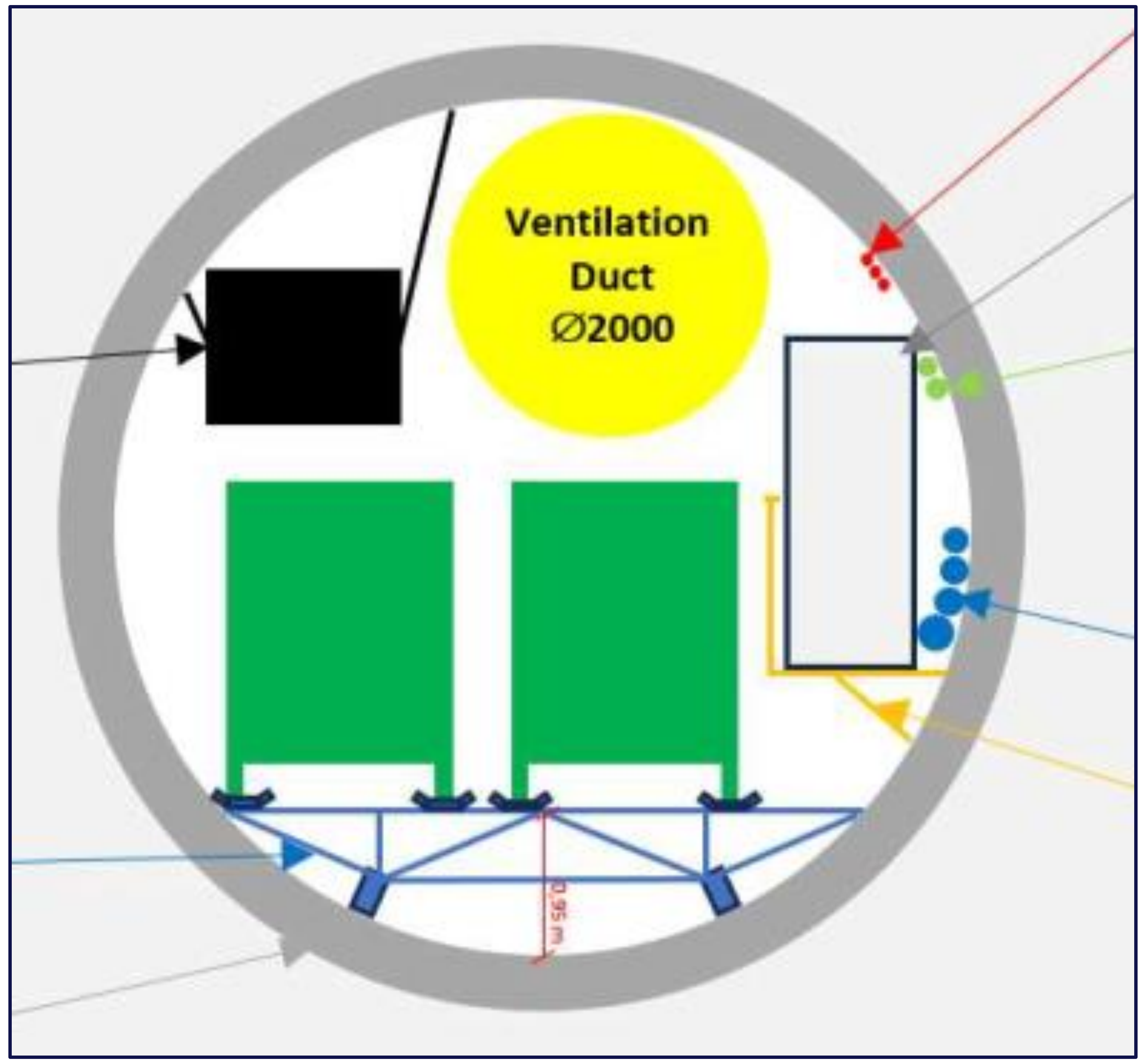
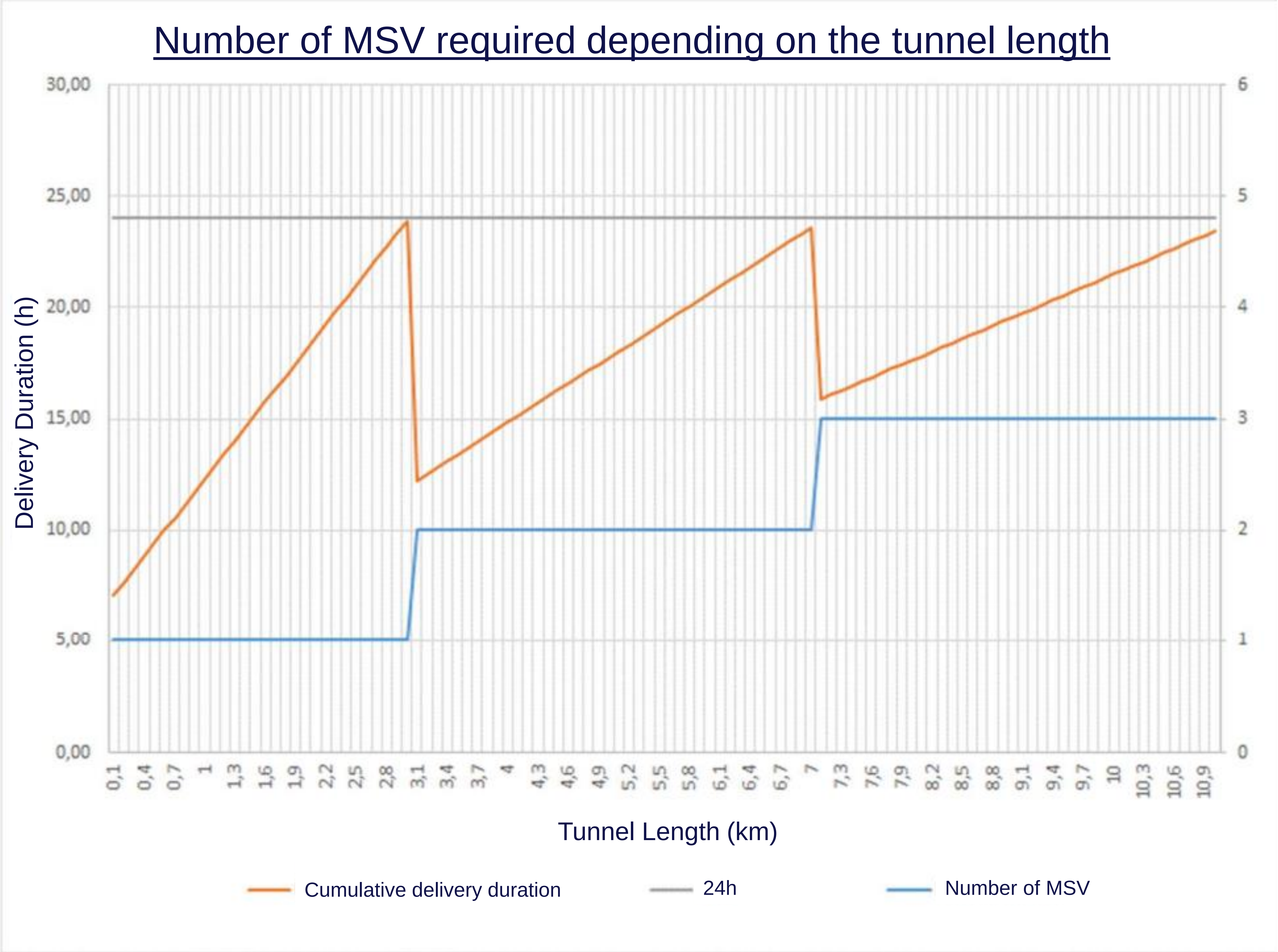
- TBM requires 39 Multi-Service Vehicle deliveries a day (24h).
- Peak excavation rate of 36 m day.
- 1 full tunnel ring delivered per MSV.
- Round trip (TBM and back) of 1.5 h.
- 4 MSVs needed at full 11km tunnel sector length.

MSV		
Distance to the front	11	km
Loading capacity	20	t
Loaded MSV speed	10	km/h
Unloaded MSV speed	24	km/h
Nb ring loaded	1	
Loading time	0	min
Unloading time	10	min
Trip duration to the TBM	66	min
Trip duration from the TBM	27,5	min
add-on factor - crossing	1,05	
Max load dimensions		
Height H	1,47	m
Width W	1,4	m
Length L	5,1	m
Volume capacity	10,5	m3

MSV Crossings

- 1 MSV needed for up to 3 km excavation.
- 2 MSV for up to 7 km.
- 3 MSV for up to 11 km (4th MSV being loaded at shaft).
- 4 crossing locations are required at the full 11 km length.





Conveyor Belt

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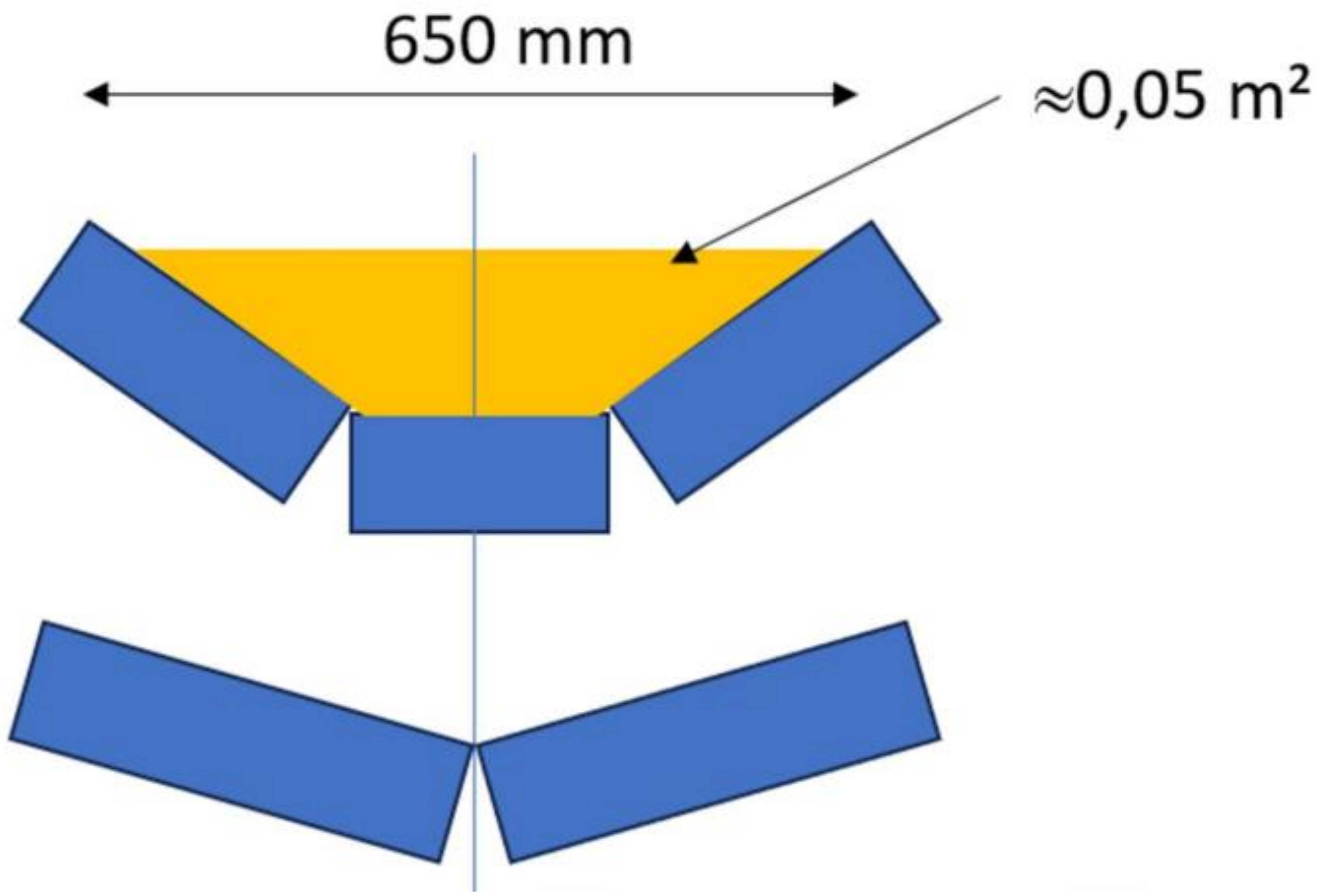
- Up to 50 m^3/h of spoil produced by the TBM.
- Excavation occurs 1/3 of time (accounting for segment placement and jacking activities).
- Conveyor required to transport at a rate of 150 m^3/h.
- 650 kW power.

Credit: Herrenknecht



$$V_{belt} = \frac{150}{0.05/_2 \times 3600} = 1.7\ m/s$$

Water

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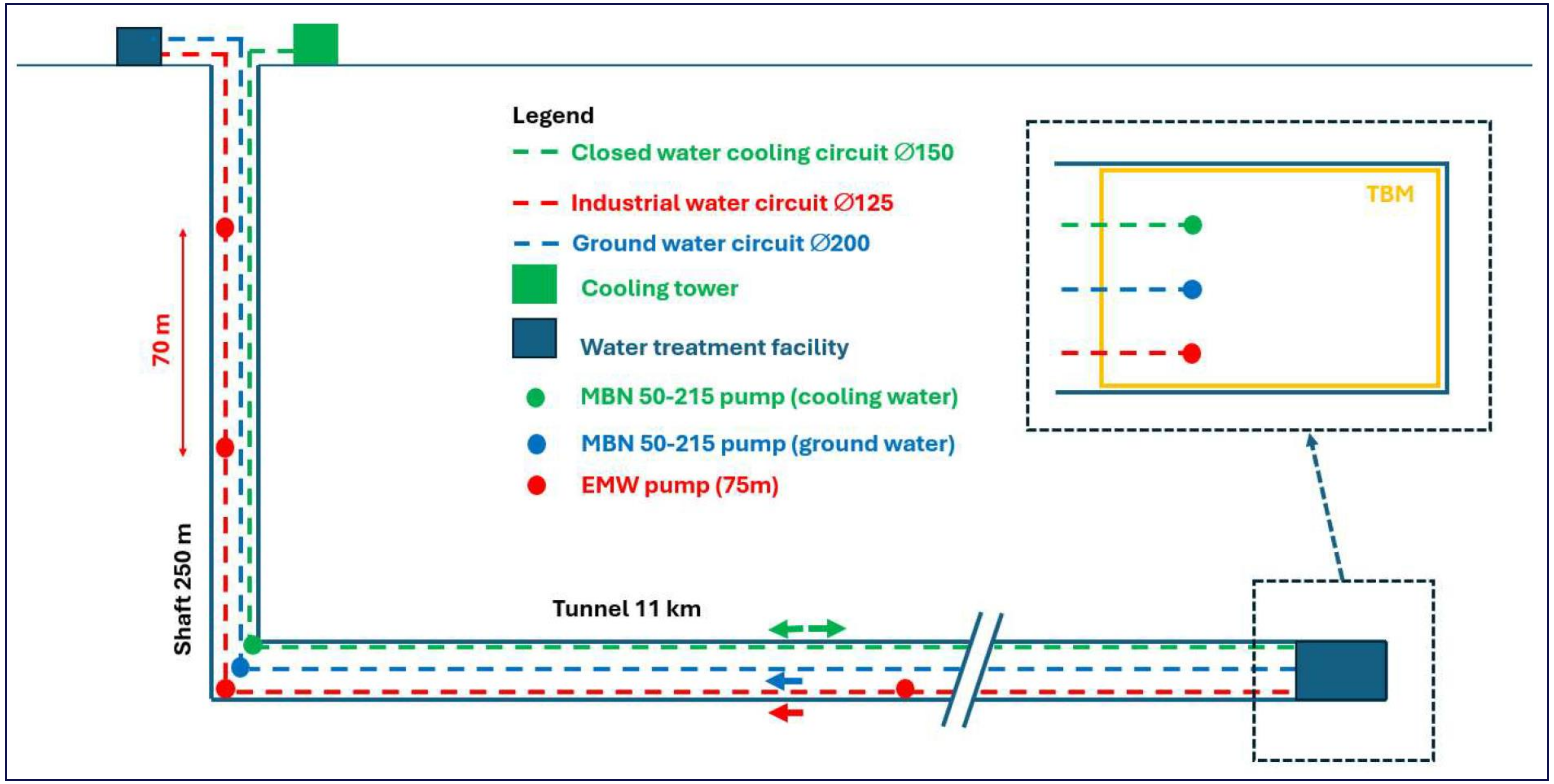
Cooling water
TBM equipment
100 m^3/h

Industrial water
TBM cleaning and dust suppression
30 m^3/h

Ground water
Allowance for inflow from surrounding rock



Ventilation Requirement

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- Fresh air of **11.88 m³/s** at the excavation front required.
    - Fresh air for personnel,
    - Dust extraction,
    - Diesel fumes,
    - Methane
- Minimum 2 m diameter ventilation duct.

Geometry			
D	5.5	m	Diameter
A	23.76	m2	Cross section
Persons in the tunnel			
Number	20	-	Number of persons
q_min_Person	0.09	m3/s,person	Fresh air per person
Q_min_Persons	**1.80**	m3/s	Minimum air velocity for persons
Dilution of dust			
u_min_Dust	0.5	m/s	Minimum air velocity for persons
Q_min_Dust	**11.88**	m3/s	Minimum airflow for dust dilution
Dilution of Diesel fumes			
P_Diesel	100	kW	Diesel power
q_min_Diesel	0.068	m3/s,kW	Fresh air per kW
Q_min_Diesel	6.80	m3/s	Minimum airflow for dilution of Diesel fumes
Minimum air velocity			
u_min	0.5	m/s	Minimum airflow in case of Methane
Q_min_Velocity	11.88	m3/s	Minimum airflow Methane
Methane			
Relevant?	0		Methane (0/1)
u_min	0.5	m/s	Minimum airflow in case of Methane
Q_min_Methane	0	m3/s	Minimum airflow Methane
Resulting fresh-air requirements			
Q_required	**11.88**	m3/s	Required airflow

Ventilation System

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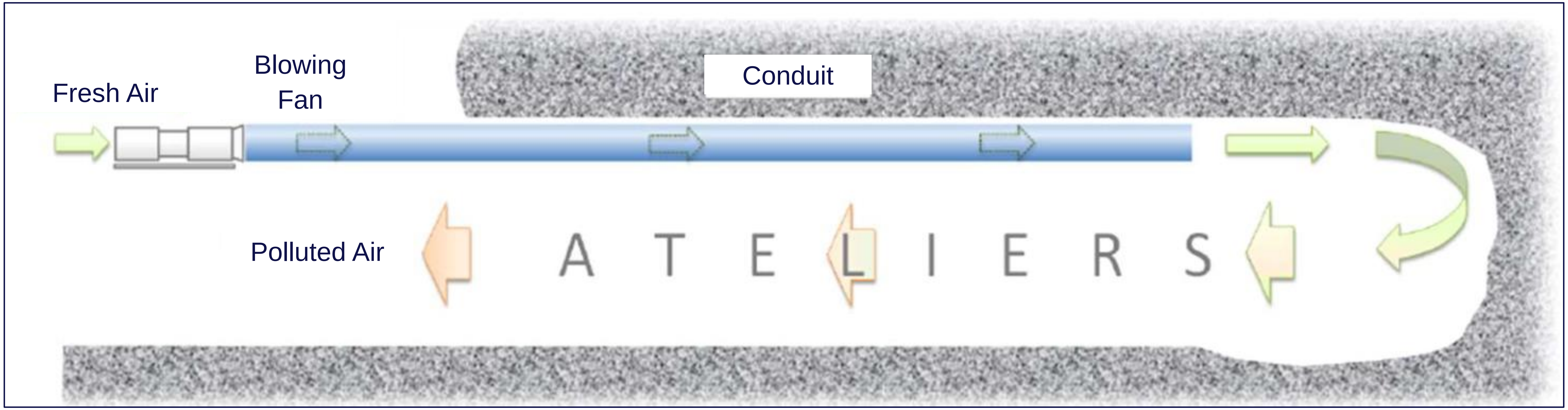
- Blowing ventilation system.
- Fans are installed away from the excavation front.
- Best air quality available directly at the excavation front.
- Rigid steel duct used for the shaft intake.
- Flexible duct for the tunnel section.



Ventilation System - TBM

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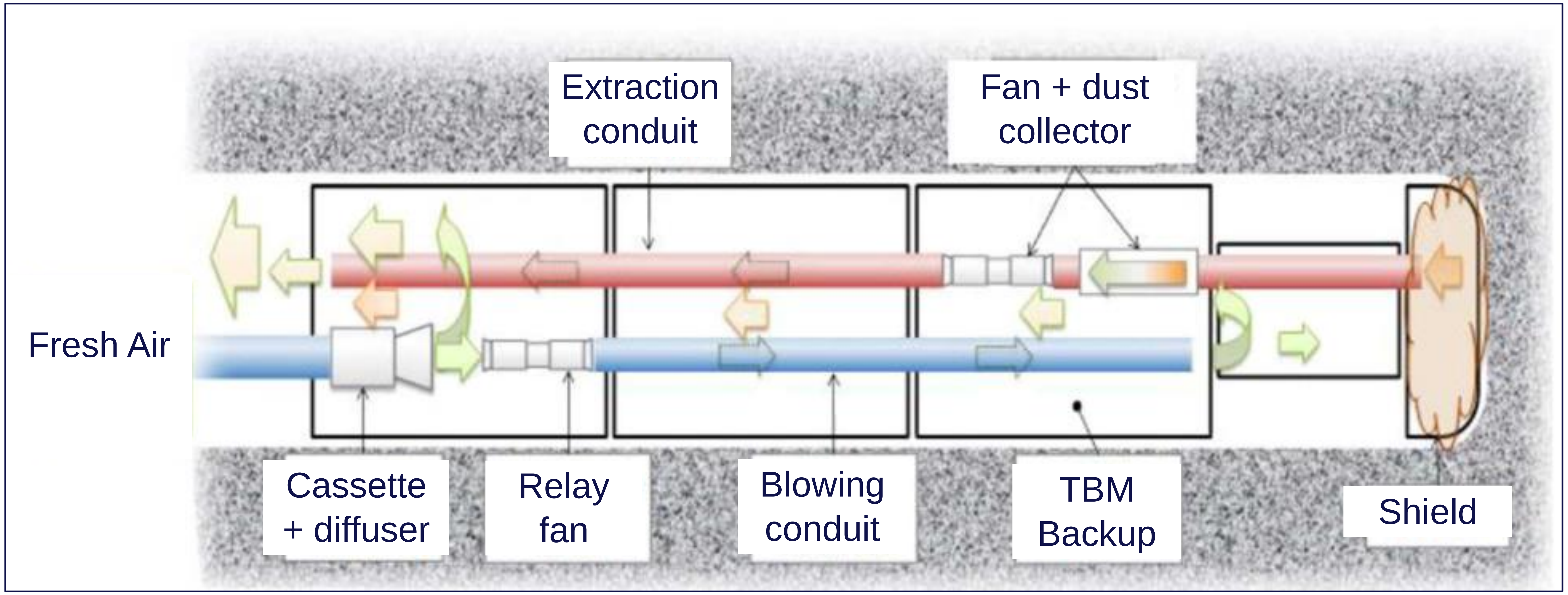
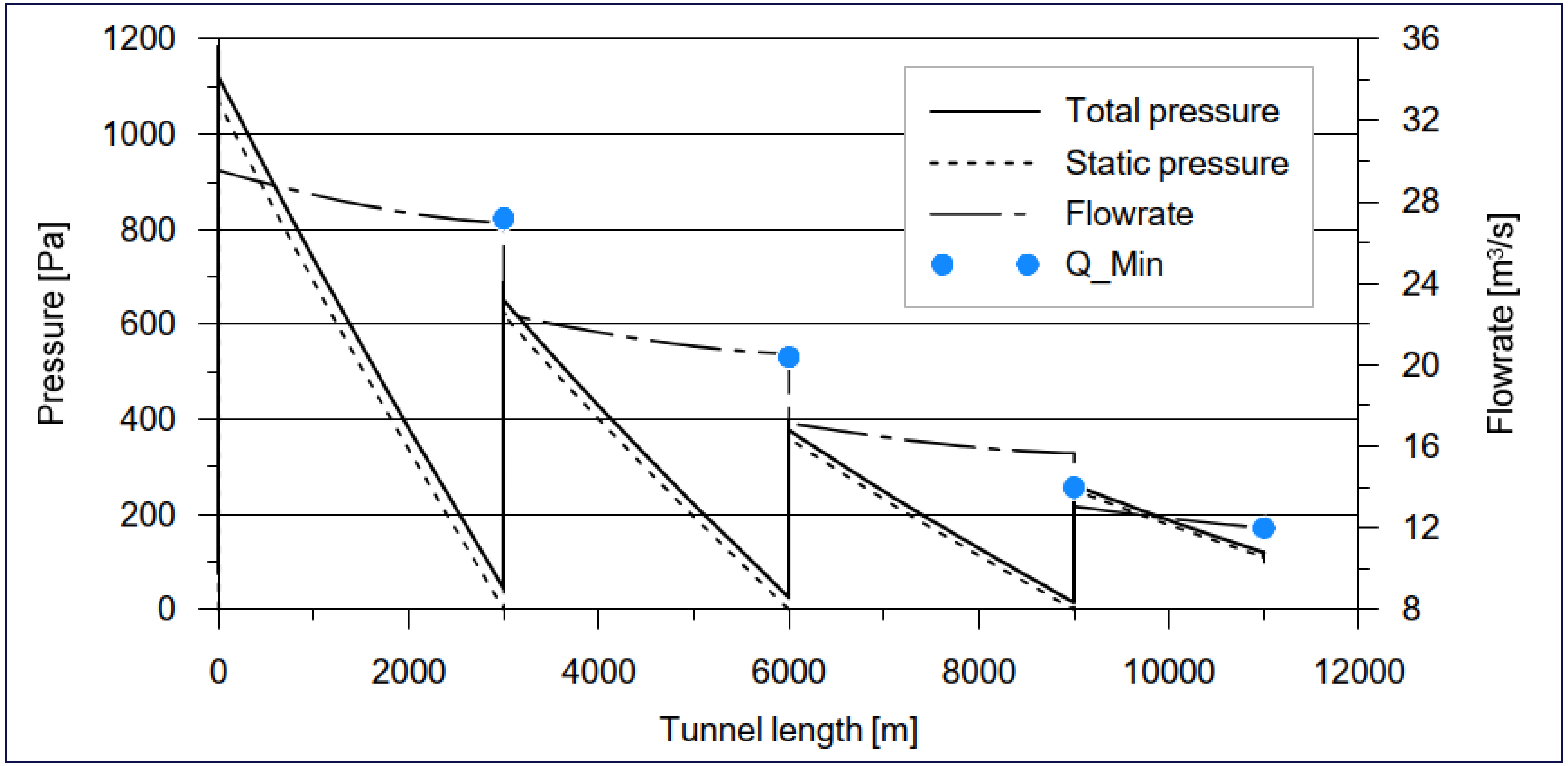
- Mixed system at TBM.
- Aspirating system to control the dust and other pollutants at the excavation front.
- Dust collection handled at TBM.



Ventilation - Pressure

- Class S (medium pressure) flexible duct.
- 2 m diameter.
- Fans every 3 km.
- Total fan power of 100 kW.
- Assumed efficiency of 70%.
- Achieves 12.0 m^3/s at the excavation front.



Shaft and Construction Logistics

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- Bucket conveyor for spoil removal.
- Use of intermediate levels necessary for 250 m height.
- Elevator for the transport of people.
- Material cranes
- Water pipes
- Grout pipes
- Steel ventilation duct
- Electrical cables

Credit: Steinhilber

Refuge Chambers

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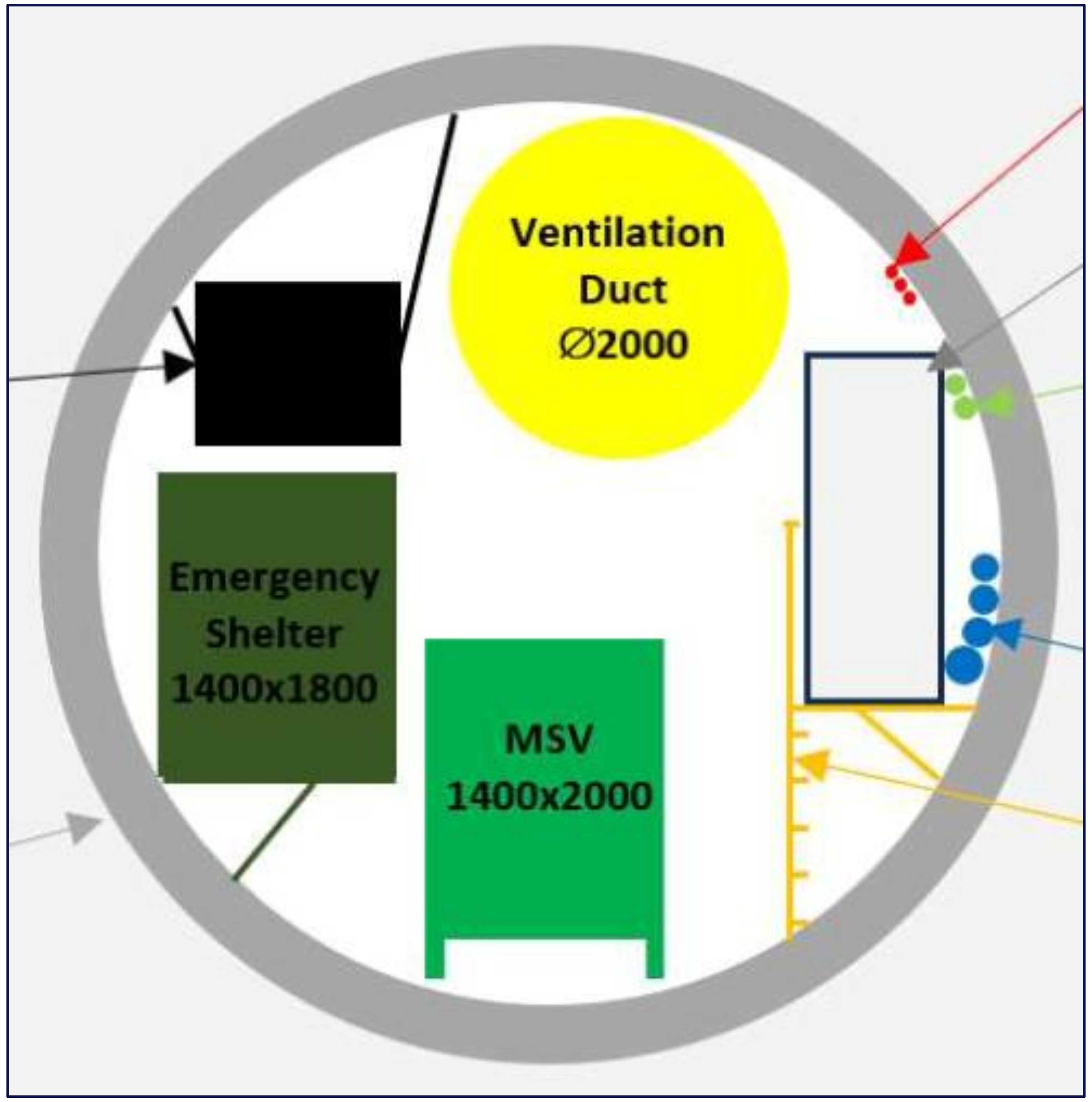
- 12-person capacity.
- Minimum 24h duration refuge.
- On the TBM, 500 m behind the TBM and at each crossing deck.



Typical Cross Section

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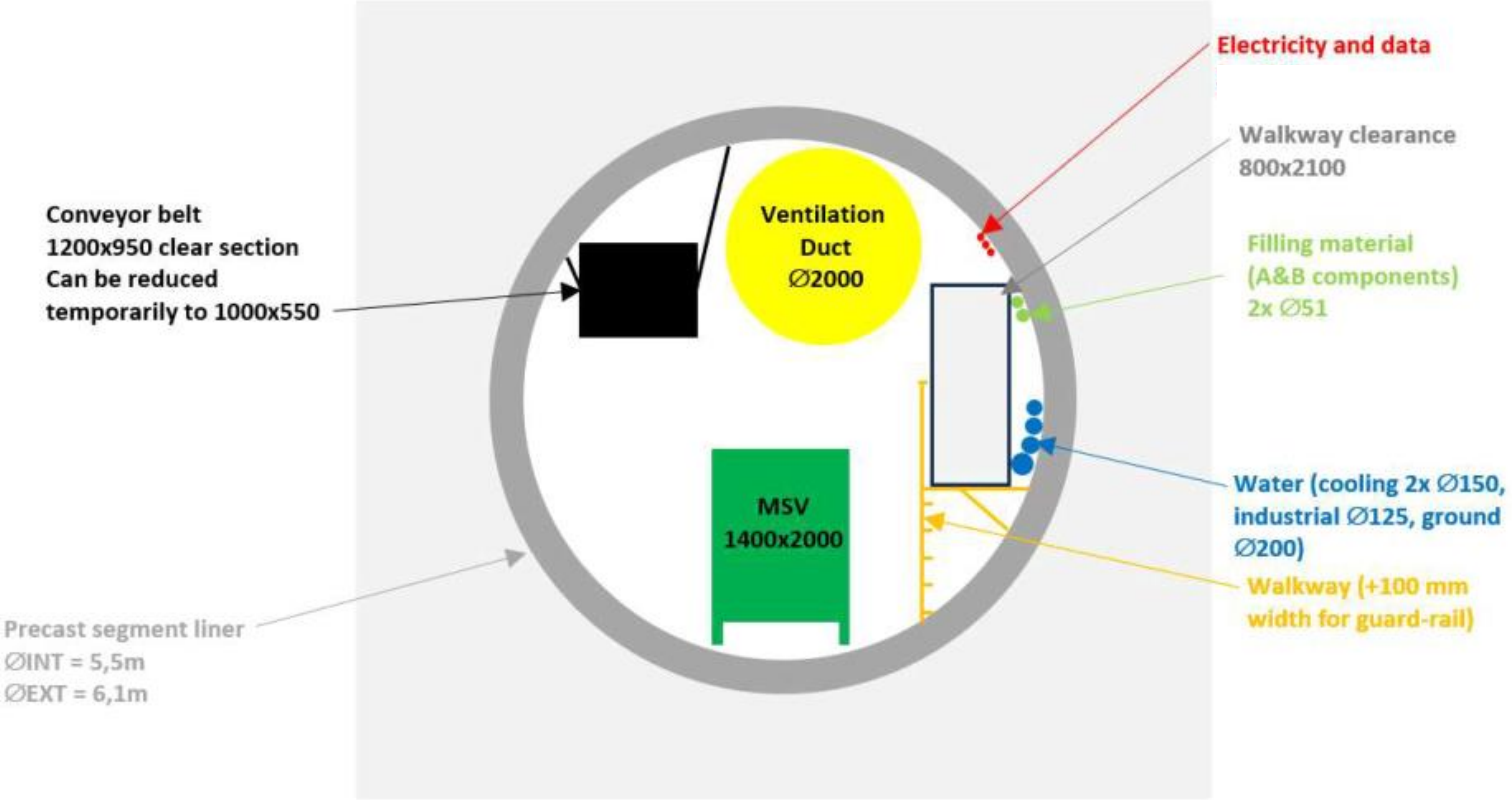


UMS Shafts – Proof of Concept Study

UMS METS INT
UNITED MINING SERVICES

- Experienced shaft contractor.
- Ultra deep shaft capabilities, up to 3000 m depth.
- Gotthard base tunnel experience (Sedrun shaft, 800 m).
- Conducting a study on the methodology and logistics of shaft construction.
- Experienced in groundwater control measures.
- Logistics of TBM spoil extraction and servicing.

Credit: UMS

Herrenknecht

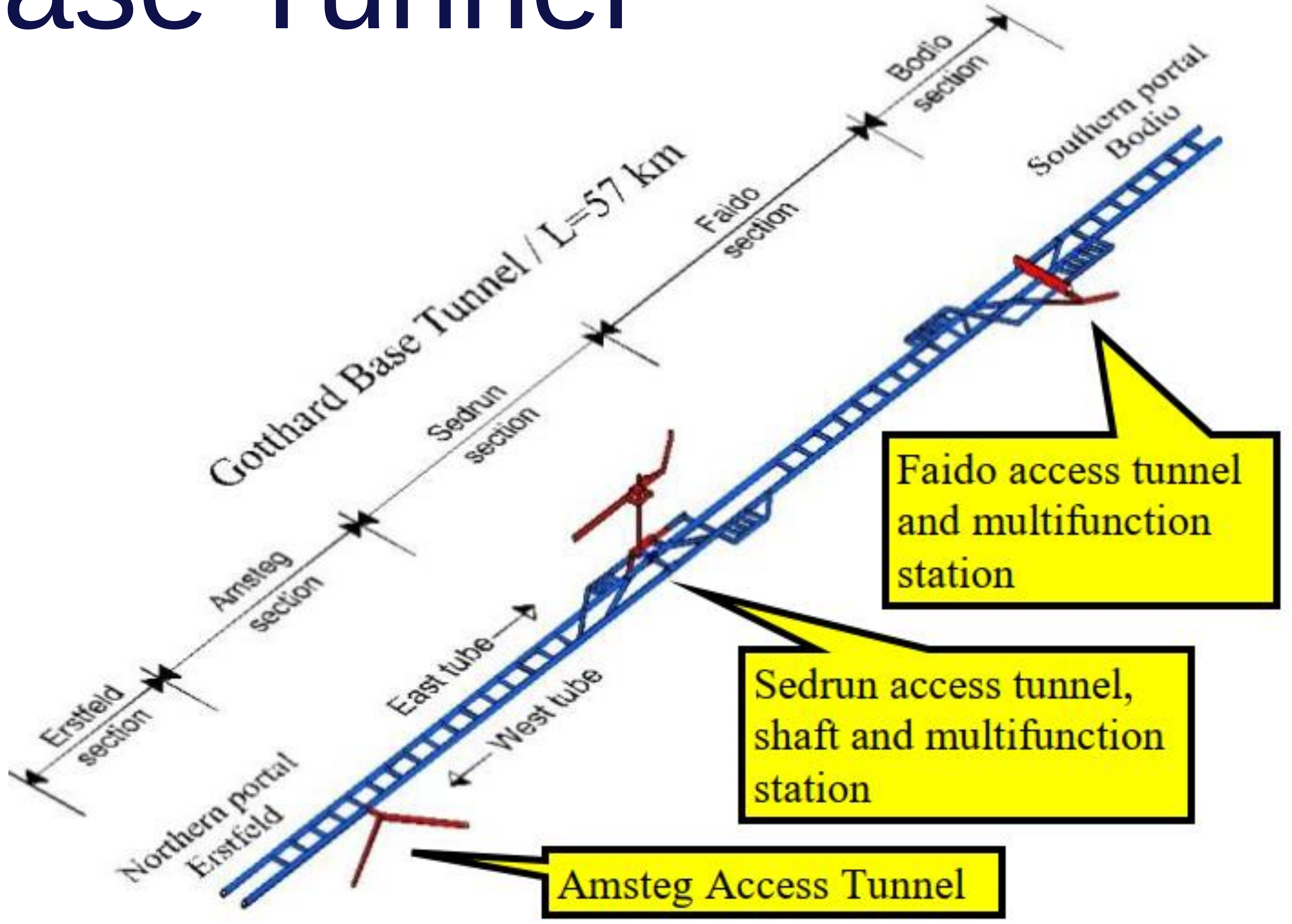
HERRENKNECHT Tunnelling Systems

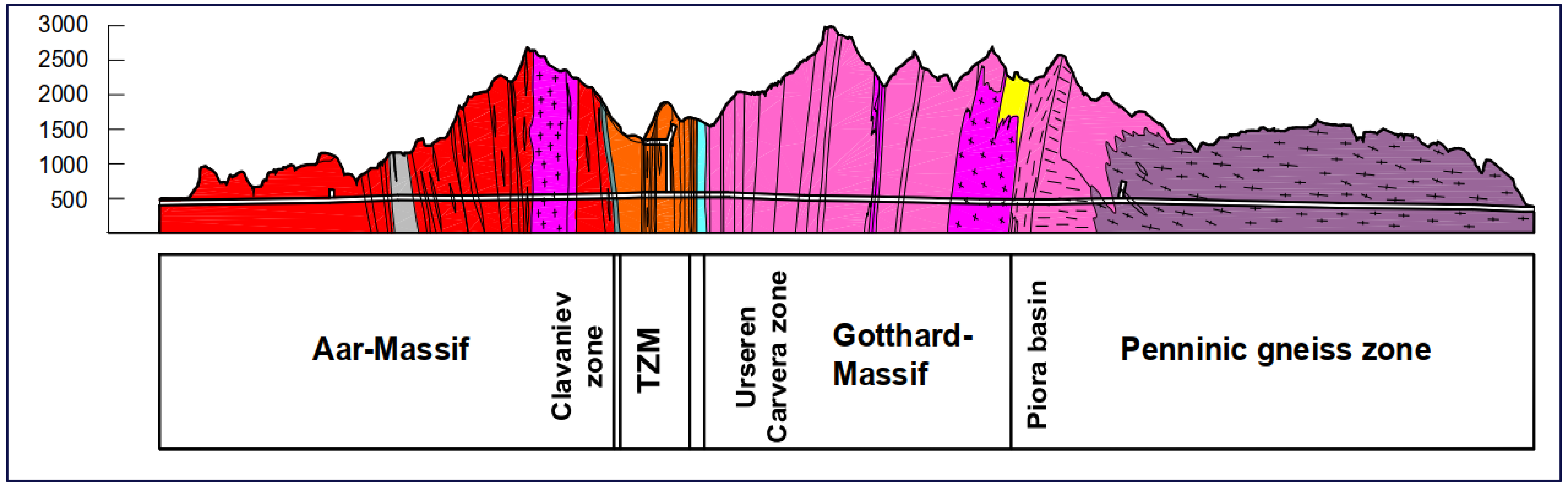
- Each tunnelling contractor is likely to have their own preference for the TBM specifications.
- The shaft logistics could pose the biggest risk to the construction schedule, due to bottleneck.
- The TBM advance rate may be dictated by the logistics at the shaft rather than the performance at the cutter head.
- Therefore, a single shield could be more cost effective than double shield machine.
- TBM can be specifically designed to account for rock squeezing and pore water pressure risk.

Credit: Herrenknecht

Case Studies – Gotthard Base Tunnel

- TBM intercepted a sub-horizontal fault zone of over 100 m.
- Loose material detached above the TBM and created cavities of 6 metres.
- Required filling with shotcrete and concrete.
- TBM advancement could not exceed 2.5 m day.
- Highly fractured geology in places also caused the TBM to jam and encounter delays of up to 10 days.
- FCC overburden (<550 m) is less significant, but risk of rock squeezing should be considered in design.





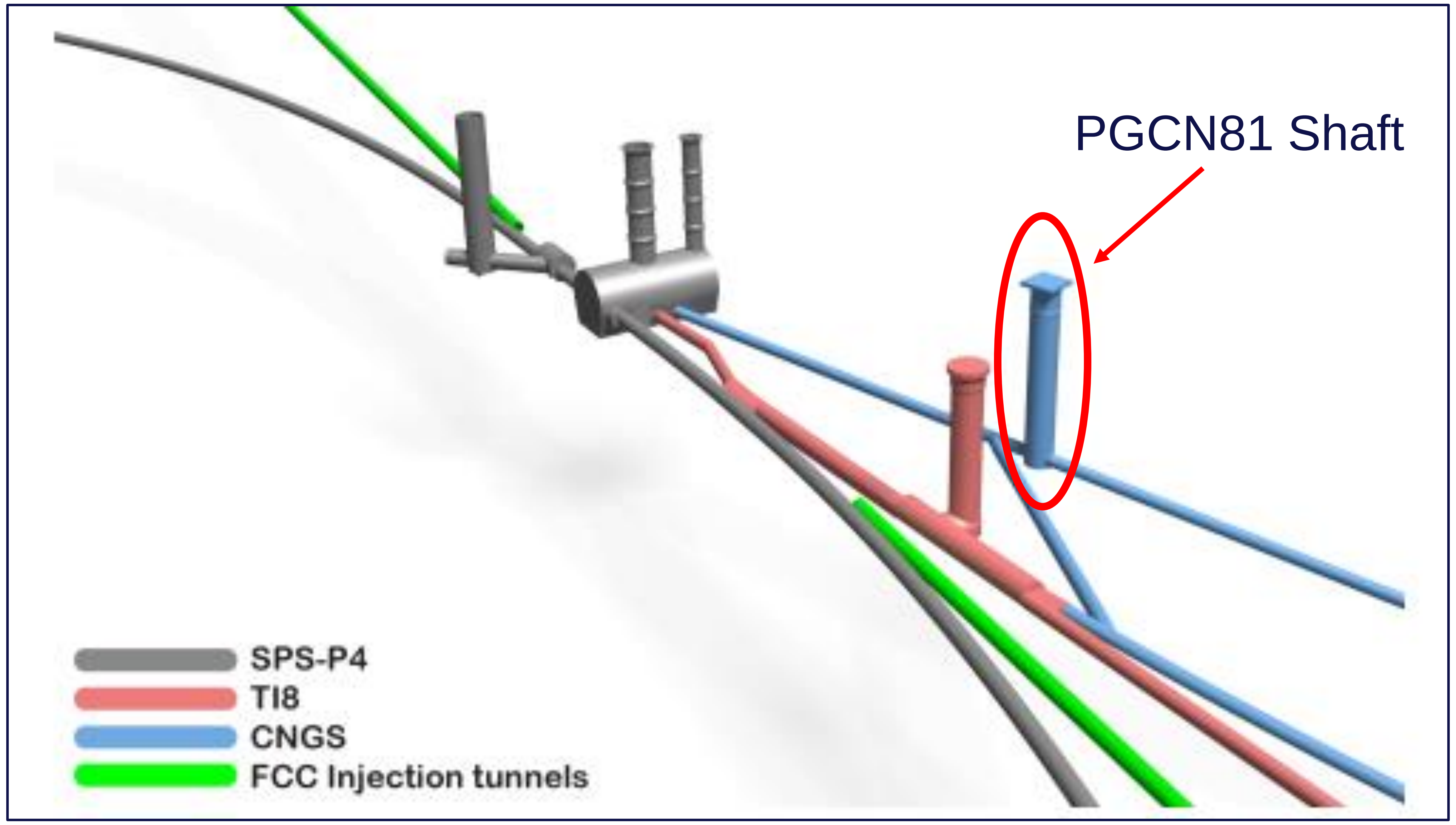
Case Studies – Moutier Tunnel

- Partially weathered molasse layers, some cases water bearing.
- Cave in at the face of the TBM and subsidence at the surface.
- Caused the TBM to be blocked for several months.
- Conventional tunnelling methods were used to extract the blocked TBM.
- Underlines the importance of geological site investigations.
- Contact will be made with Marti for further discussion.

Credit: Marti

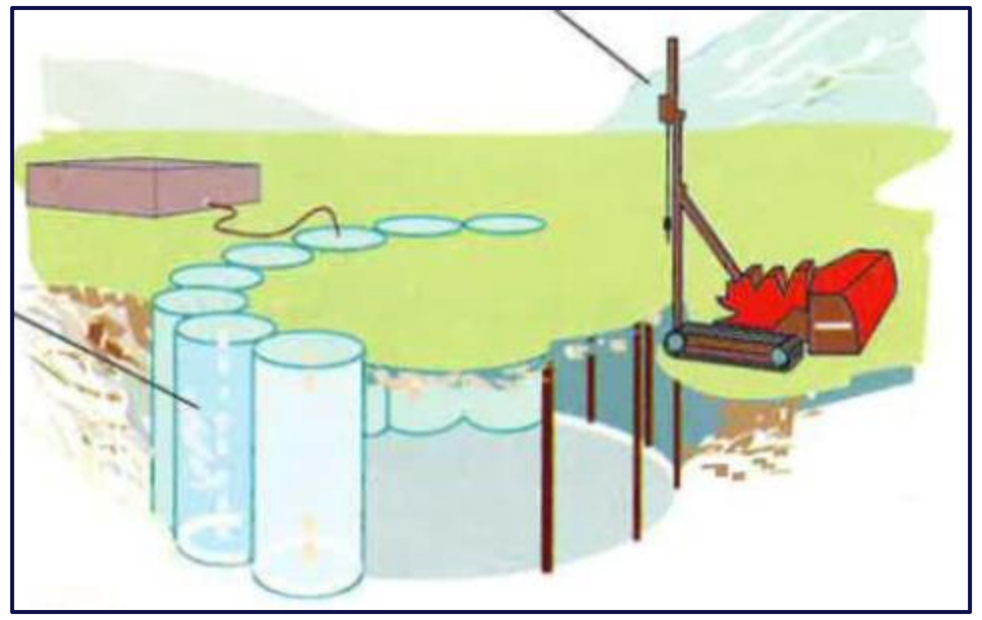
PGCN81 Shaft Reuse

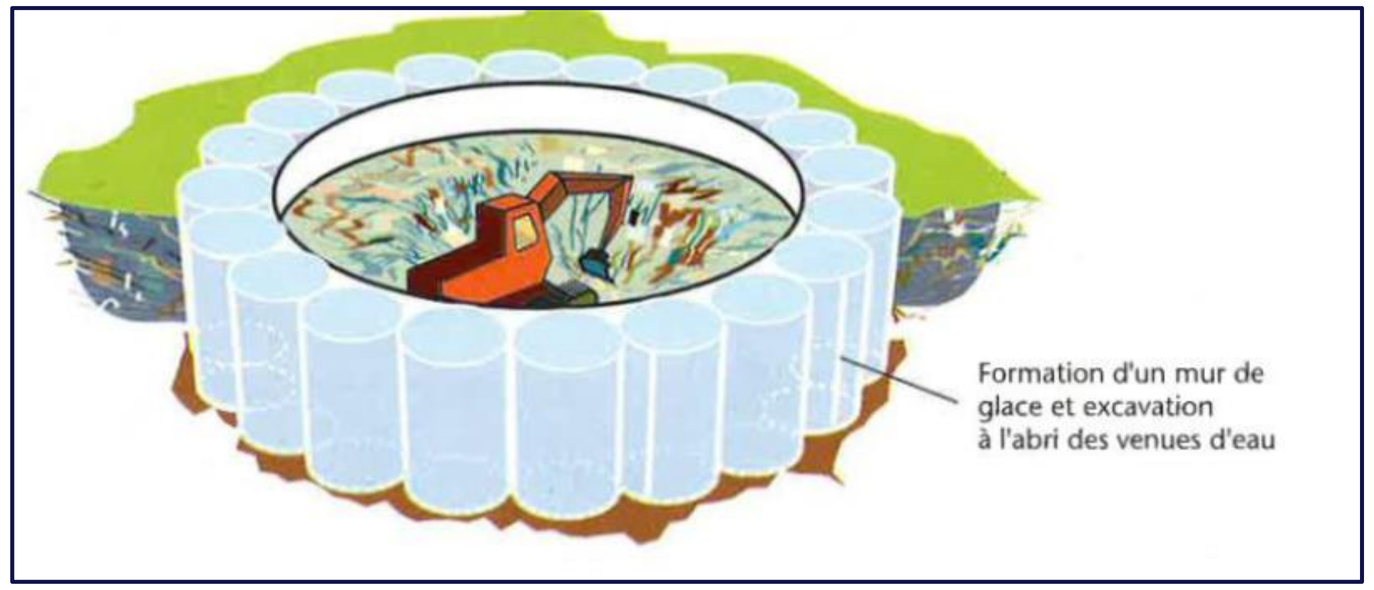
- Potential reuse of the existing shaft for the construction of the FCC-ee injection lines.
- Generally good condition.
- Patches of water ingress and hydrocarbons.



Shafts through Aquifers

- Concern raised by Swiss authorities about the risk of shaft excavation through aquifers.
- Shafts at LHC CMS were excavated through ground water using ground freezing.
- Avoids pollution of the aquifer and can be utilised to greater depth than diaphragm wall.
- Can be combined with diaphragm wall if necessary.

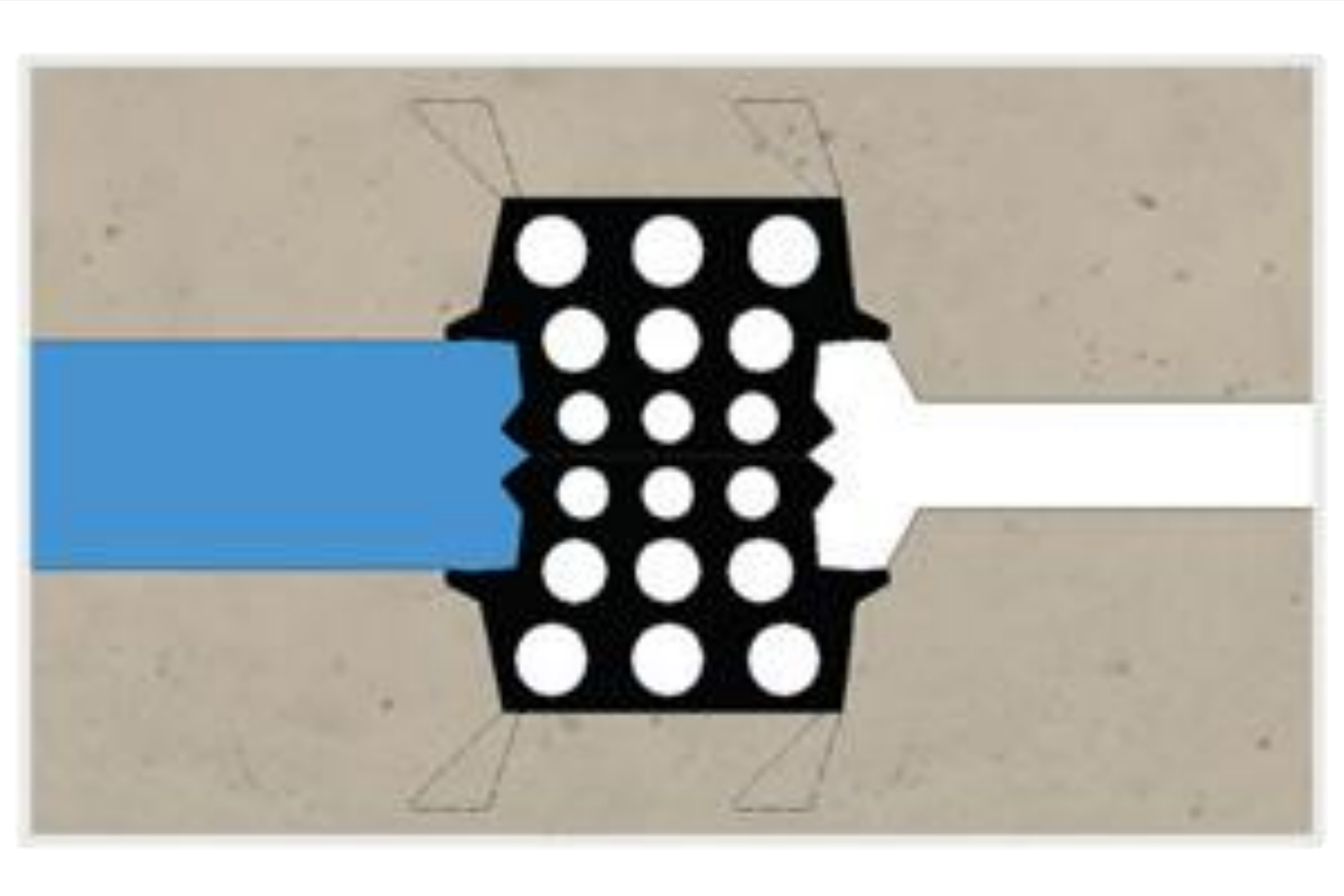




Point 5 -Excavation commencement of PM54 shaft - July 09, 1999 - CERN ST-CE

Technical Studies – LHC Water Inflow

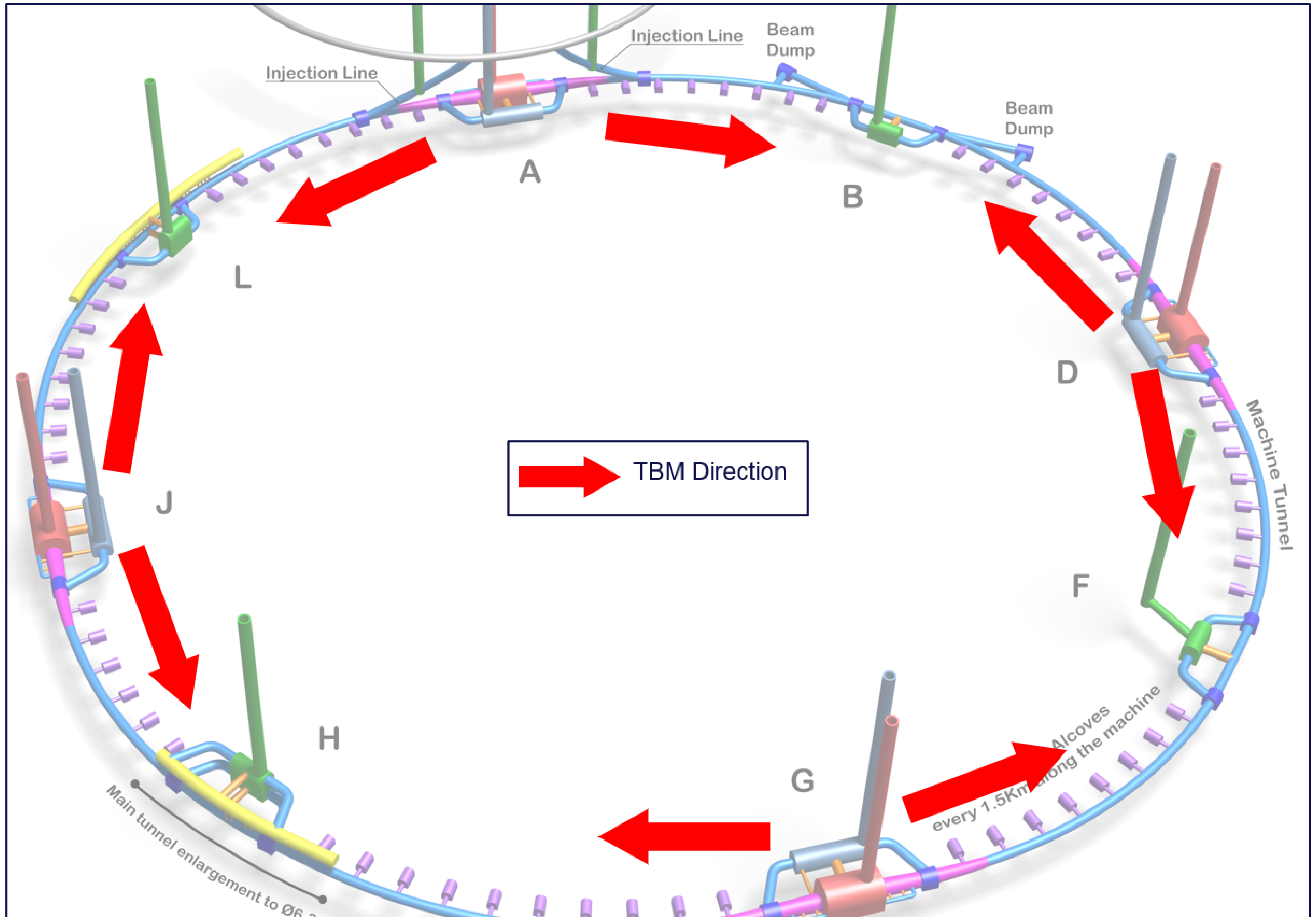
- Extrapolated estimate for FCC (molasse): **5.6 m³/h** per sector
- Estimate for limestone geology: **100 m³/h**
- Proposal for water-tight tunnel with precast segment gaskets.
- Capacity up to 25 bar of water pressure.



LHC Sump	Structure Drainage	Flow Rate (m³/h)
US15	Tunnel	0.67
UX15	Cavern	0.1
UX25	Tunnel	1.12
PM32	**Tunnel**	**70**
UX45	Tunnel	0.54
US54	Cavern	0.1
US56	Tunnel	0.24
UJ76	Tunnel	0.04
UX65	Tunnel	1.09

Cost and Schedule Update

- ILF to undertake an updated cost and construction schedule study.
- Rearrangement of the TBM layout from MTR.
- Sub-surface optimisations, layout changes and additions to be included.
- Delivery February 2025.



Credit: Angel Navascues Cornago

Conclusion

- Delivery of the feasibility study March 2025.
- Further meetings with contractors and consultants.
- Ongoing shaft logistics studies.
- Conclusions to the MTR feedback, with technical notes.
- Inputs required from integration by September 2024.