Implenia

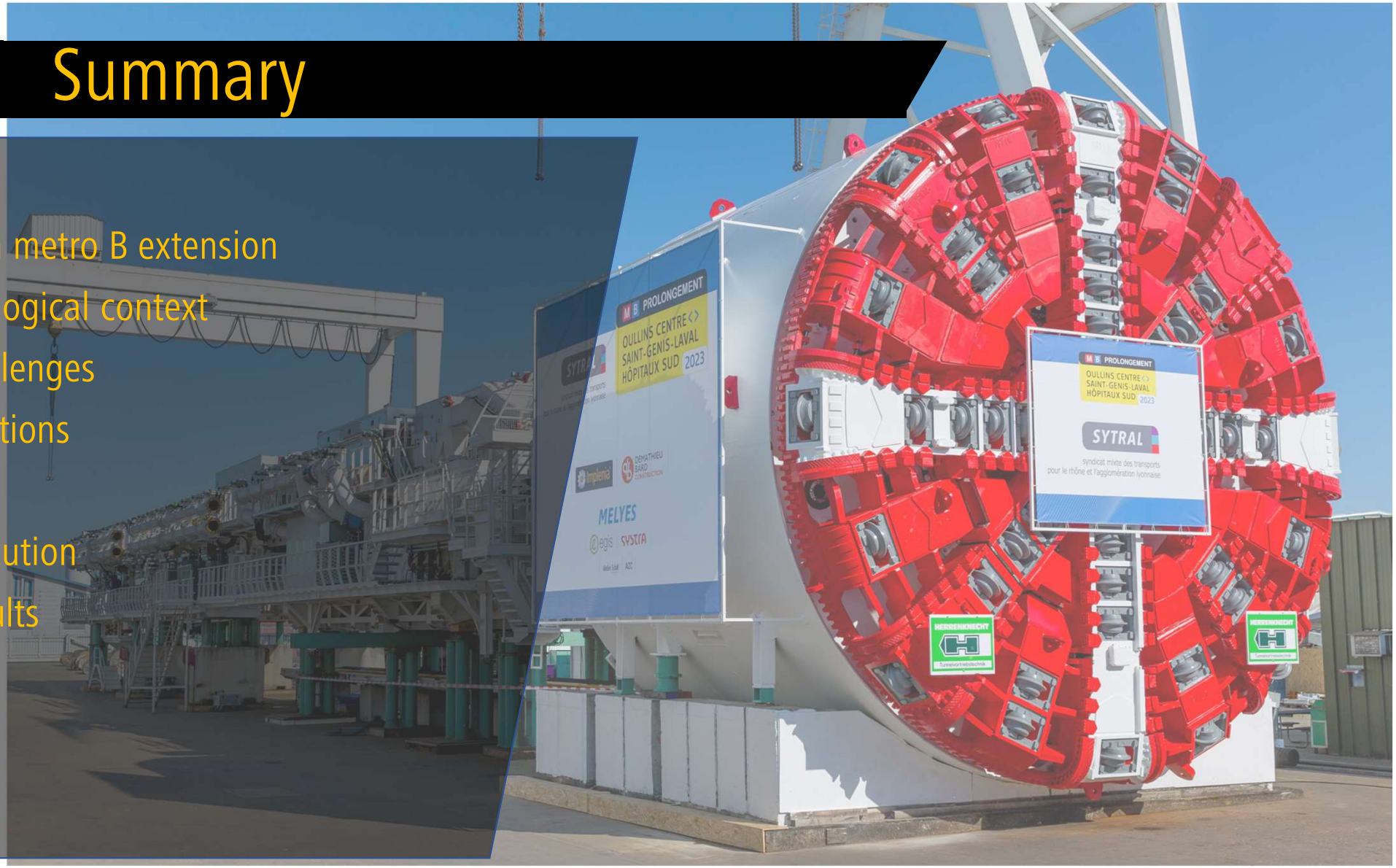
EXTENSION OF THE METRO B IN LYON, FRANCE

TBM EXCAVATION IN HIGHLY PERMEABLE GROUND CONDITIONS

2022

Denis VIALLE
ETH - Zürich,
May 19, 2022

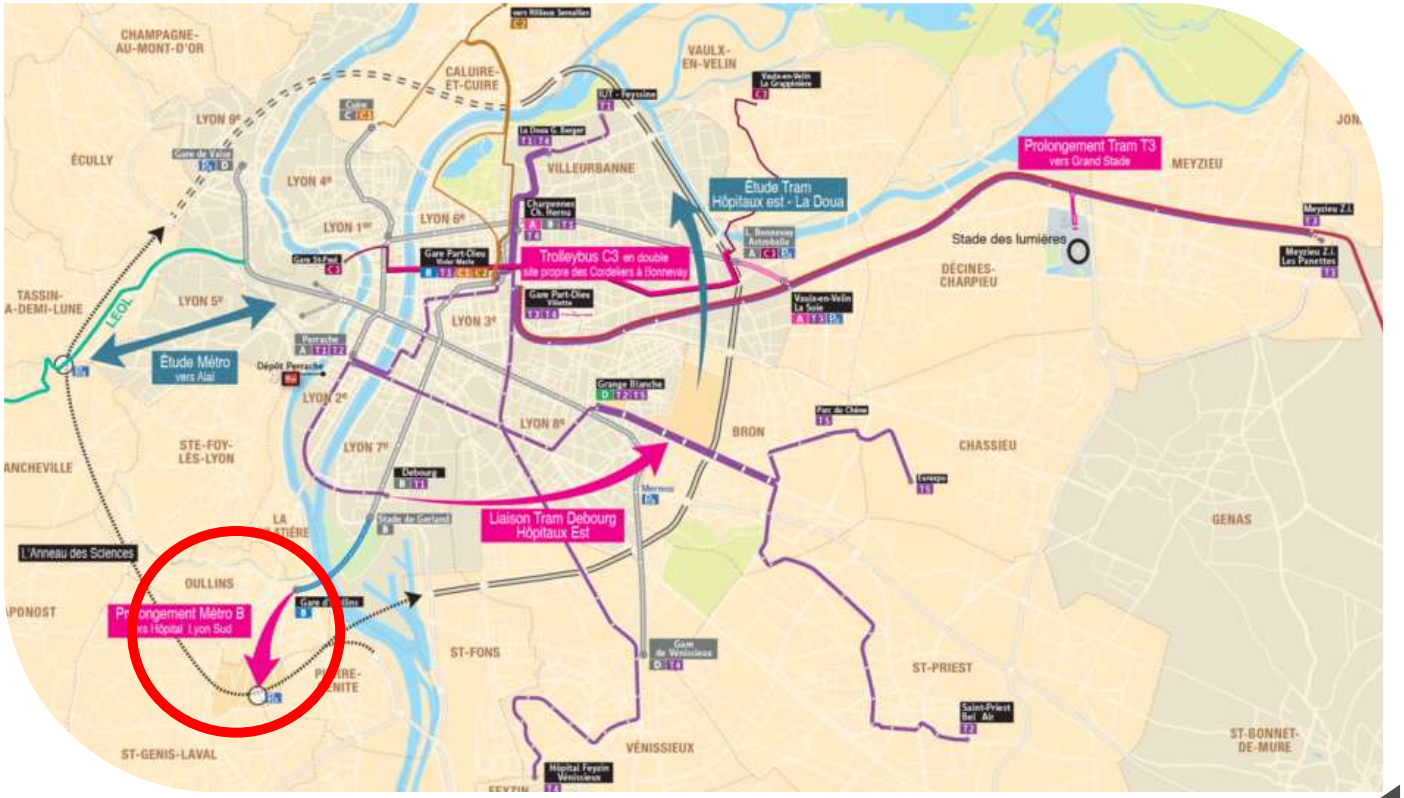
Summary



Lyon Metro B extension

The project: extension of the existing B line of the Lyon metro (South)

- 2,4 km of underground new line
- 2 new stations
- 1 service shaft
- 1 launching shaft
- Opening in 2023



Lyon Metro B extension

- Client: Sytral

MAITRISE D'OUVRAGE

SYTRAL

- Engineer: Melyes

MAITRISE D'OEUVRE

MELYES

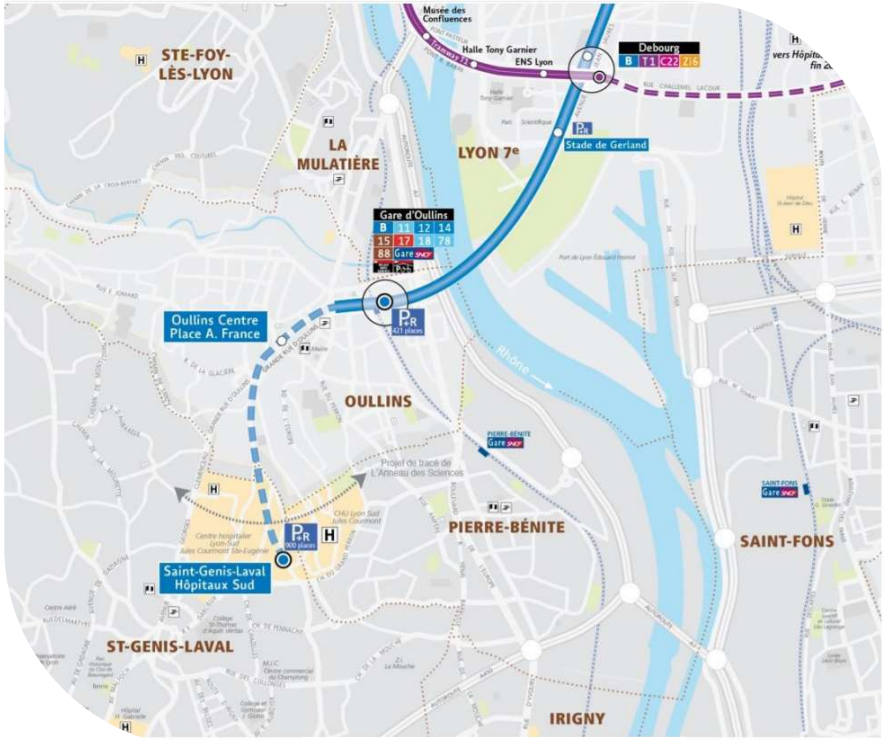
Atelier Schall ARCHITECTES DPLG

AZC

- Civil works main contract “GC01”:
  JV Implenia - Demathieu Bard

DEMATHIEU BARD CONSTRUCTION

Implenia



- Total contract amount: 138 M€
- Delay 54 months including 3 months of preparation works

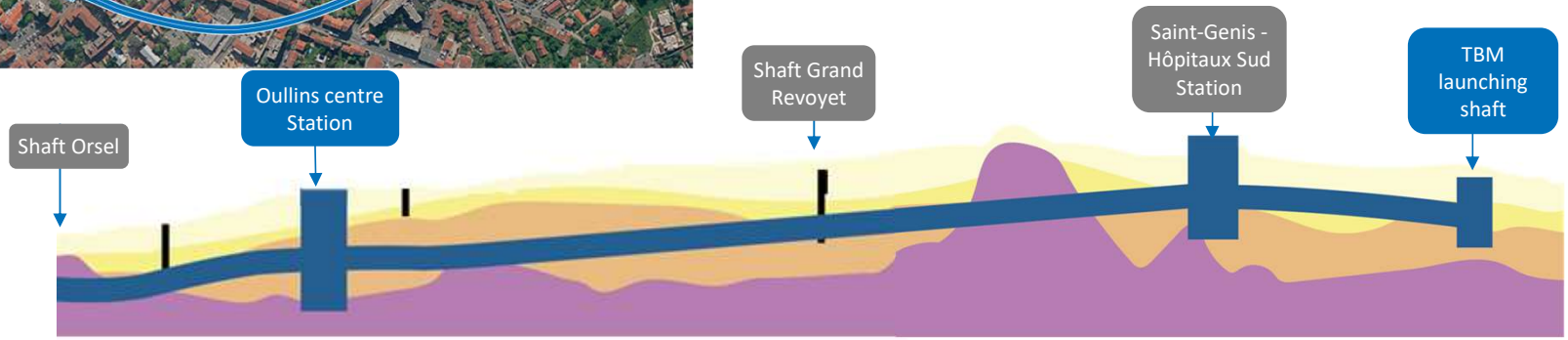
- 250 000 m³ of spoil (incl. 167 000 m³ for the TBM)
- 90 000 m³ of concrete (incl. 25 550 m³ for precast segments)
- Up to 250 persons (incl. subcontractors)

MBHLS

Prolongement du Métro B aux Hôpitaux Lyon Sud

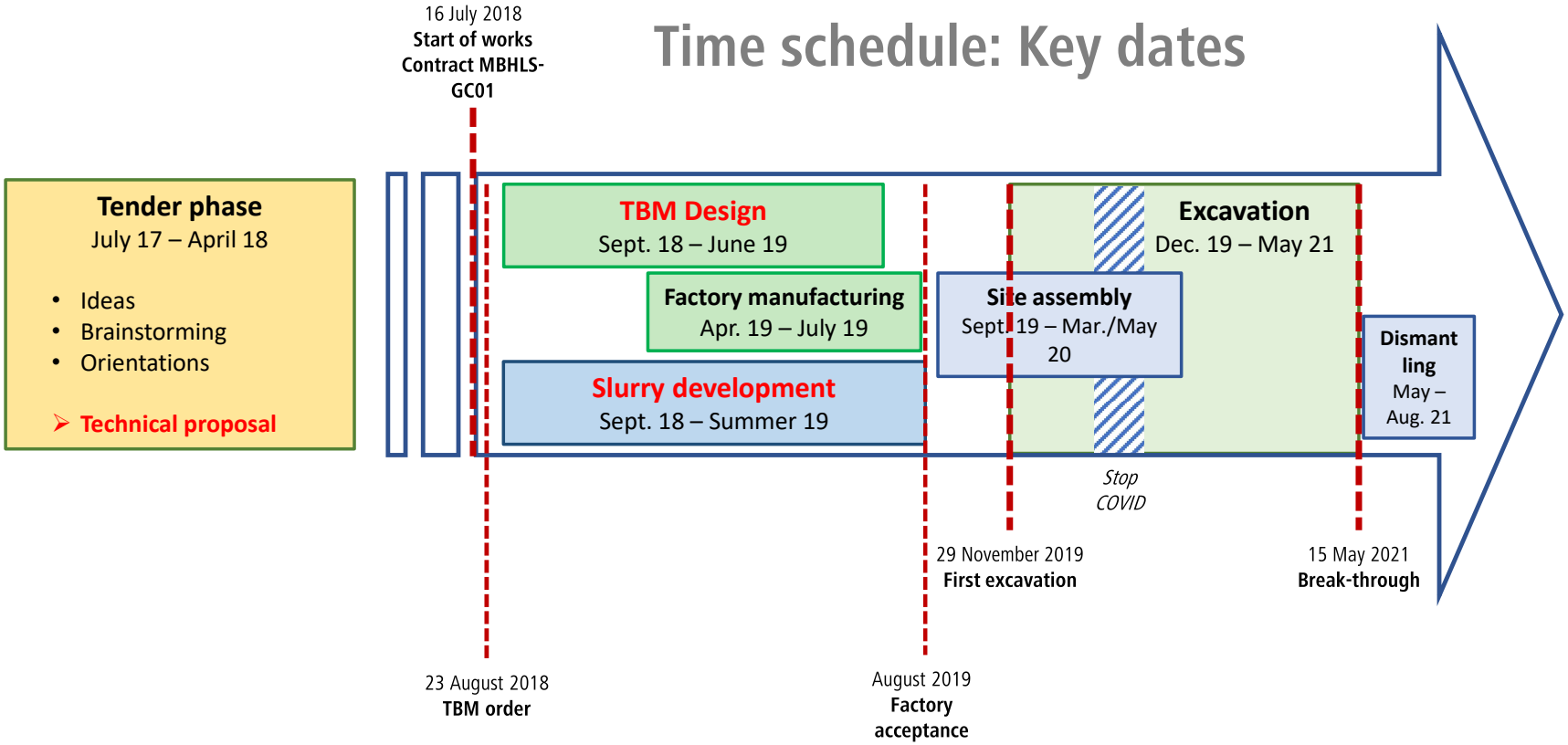
Lyon Metro B extension

- 2,4km single tube tunnel, excavation diameter 9,75m with TBM
- One launching shaft – PAHLS
- One station – OCE
- One cross-passage towards ventilation shaft – PGRE



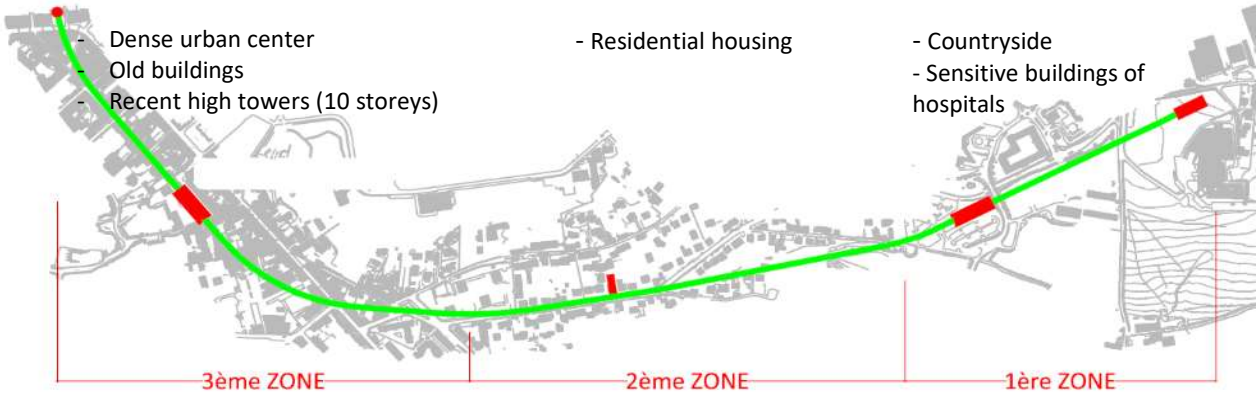
Lyon Metro B extension

Time schedule: Key dates

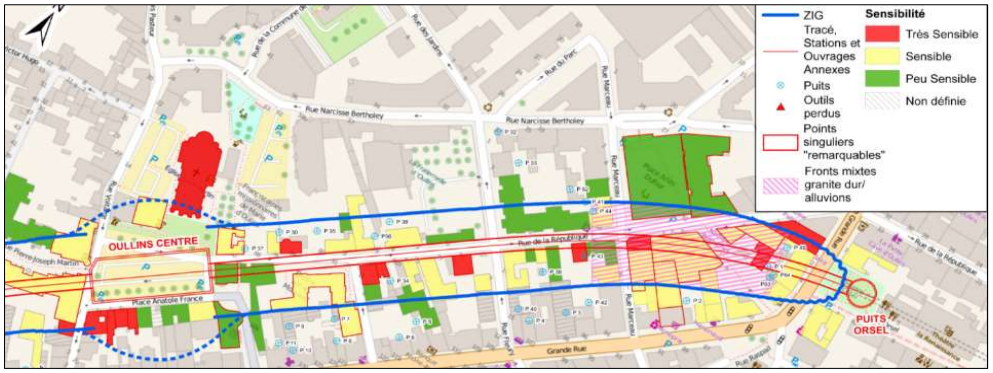


Urban context

Surface settlements : a major concern focused by the client



Special studies of sensitivity of buildings



Sensitive buildings

10 storeys

Cob houses

Geological context

- Glacial valley
- Alluvial filling
- Granitic substratum

Geological context

- Lack of fines in Fv ALLUVIUM
- Permeability up to 1.10-2 $m.s^{-1}$
- Tunnel alignment above water table
- Erratic blocs and boulders

Pressurized TBM principle

Soft ground / Unstable soil

needs

Stability of the face during excavation

needs

Pressurization of the excavation chamber while excavating

allows

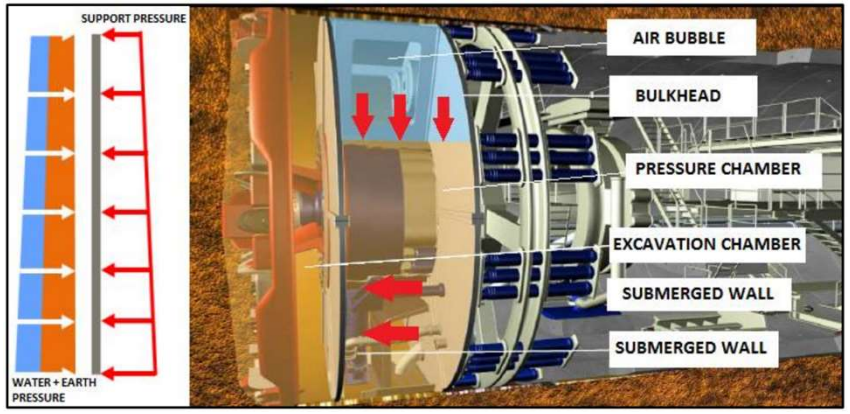
Control of surface settlements / Preservation of buildings

2 existing technics :

⇒ ***Earth Pressure Balance « EPB »***

or

⇒ ***Slurry Shield TBM***



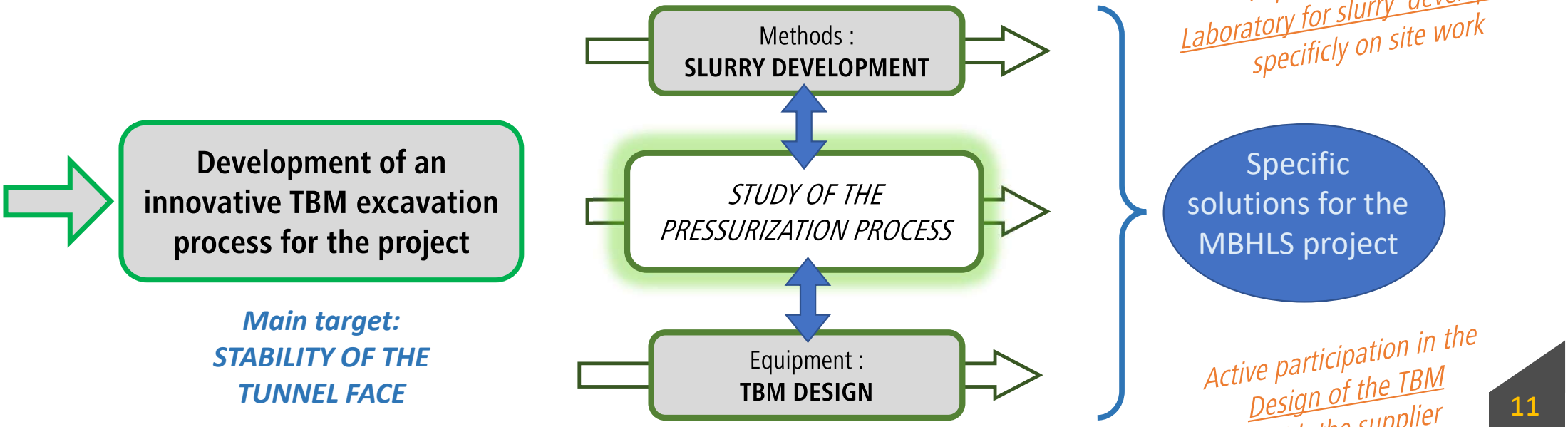
Example of a Slurry Shield TBM

Going beyond the limits

For MBHLS project, the 2 existing technics reach their limits in the « dry cobbles » :

- **EPB:** Lack of fines doesn't allow to create the EPB paste in the excavation chamber
- **Slurry:** the excessive porosity of the ground would cause a leak of mud into the ground

In the 2 cases, the stability of the tunnel face would not be ensured.



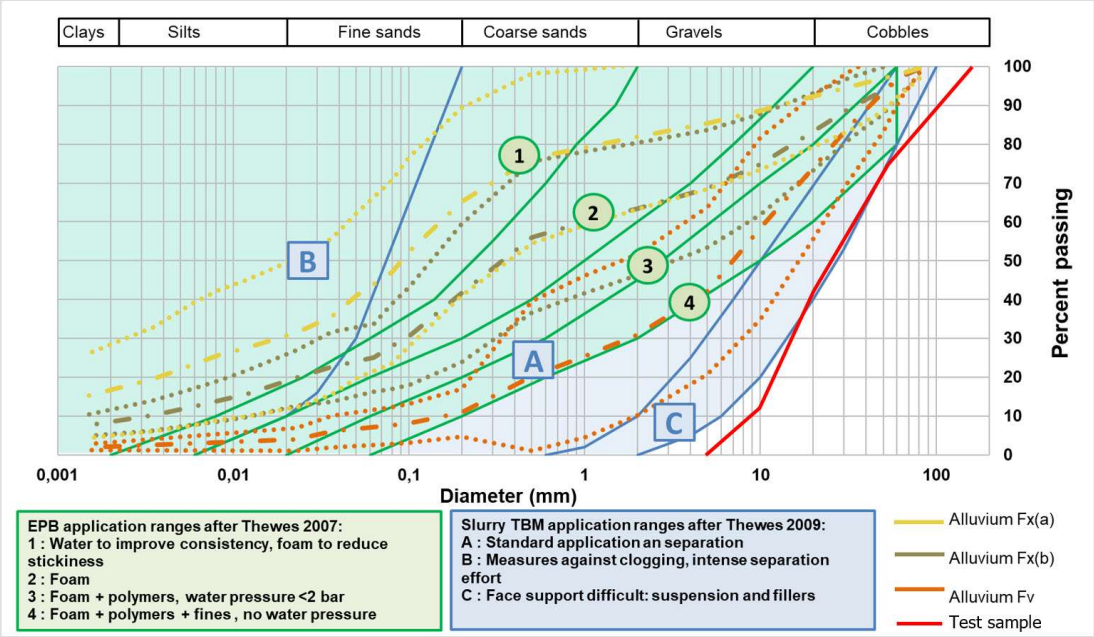
Slurry development Challenges

Risk of slurry loss

Challenging confinement pressure control

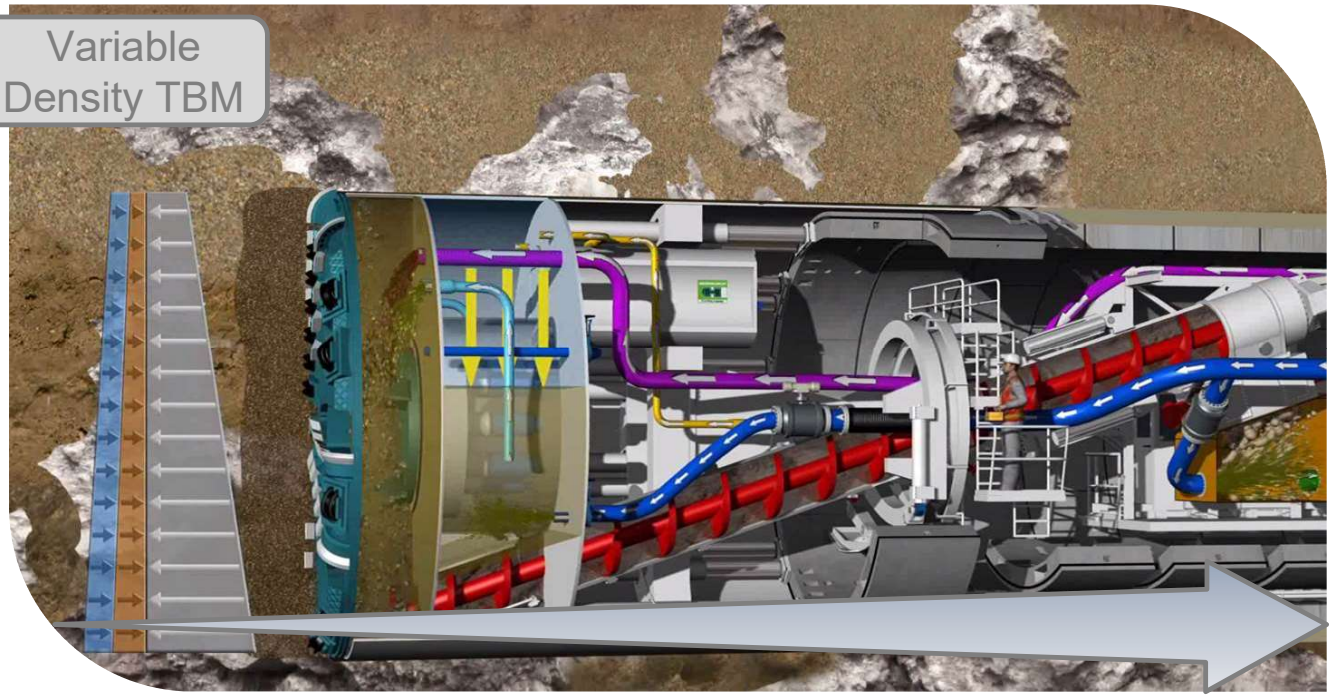
Risk of excess surface deformation

Alignment located in an area with sensitive buildings



Foreseen solutions

Variable Density TBM



Slurry pressure

High density slurry or other specific slurry

Earth pressure

Foreseen solutions

Slurry development program:

The slurry must stop the mud flow through the ground permeability without affecting:

- Yield
- Filtrate
- Viscosity
- Slurry treatment plant efficiency

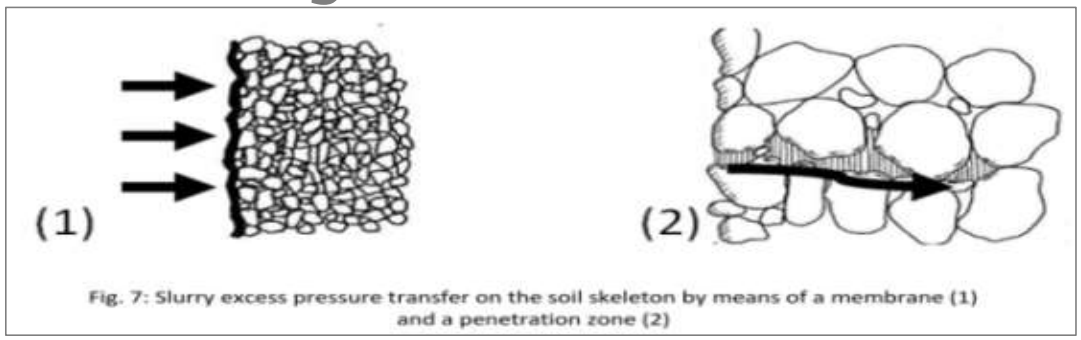


Fig. 7: Slurry excess pressure transfer on the soil skeleton by means of a membrane (1) and a penetration zone (2)

From DAUB

Clogging technical slurry

Slurry development – other topics

In addition to the Clogging technical slurry

- Condition an efficient EPB paste by the addition of fines
- Create an emergency mud acting like an airbag with a panic button

On-board storage

Slurry development - Plan

Phase 1:

Characterization of products after l'API :

- 9 Bentonites
- 17 Polymers
- 6 Minerals
- 4 Vegetal
- 5 « hardeners »

Over 400 tests…

Phase 2 :

Trials with « small permeameter » - 70 trials

Phase 3:

Validation with large permeameter

Set-up for industrial process

Slurry development

Characterization

- Increase number and type of tested products
- Based on official norms (API, AFTES, … rheology, filtrate, …)
- Improvement / degradation rate assessment
- Selection of products and bentonite for the next step to the permeameter

Slurry development

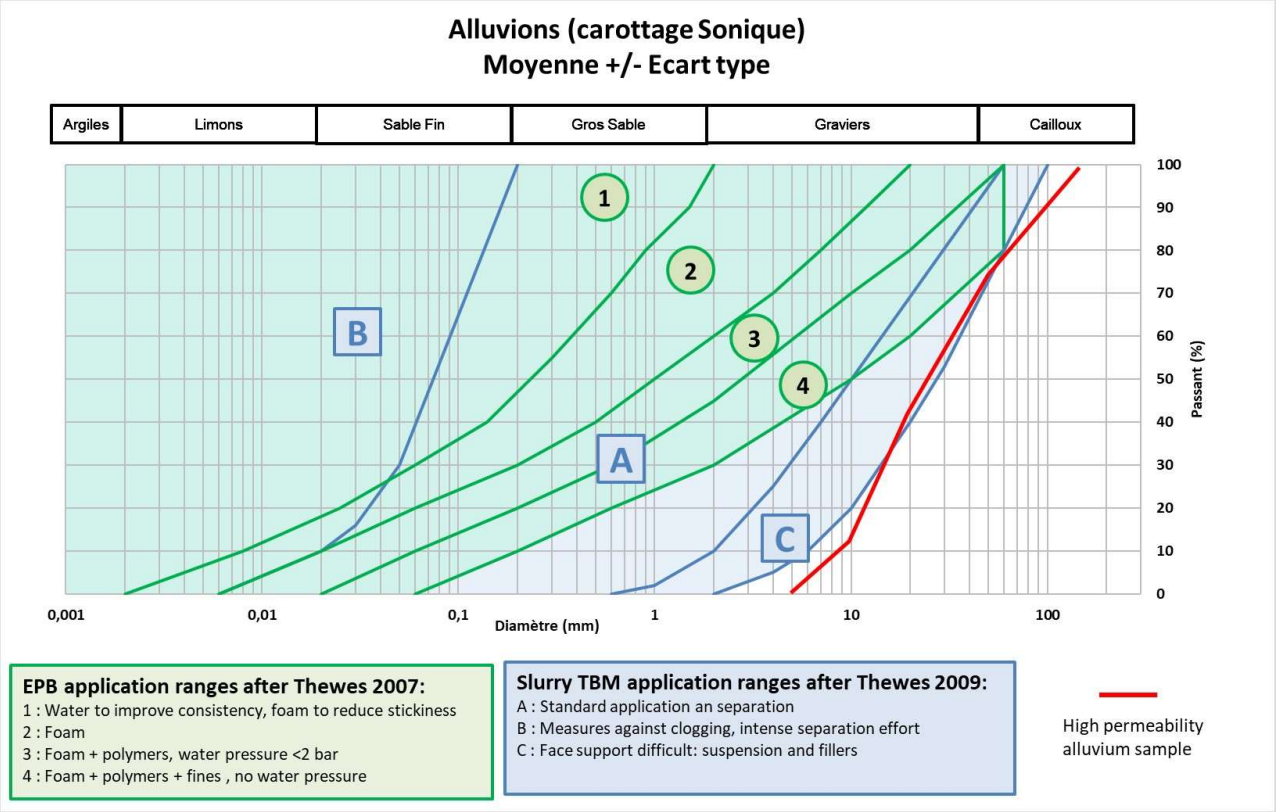
First results with “small” permeameter ∅ 300mm

- Target : 2,5 bars maintained with no counter pressure
- Limited improvement with polymers and minerals matters
- Mechanical clogging solution

Slurry development

Solution validation:

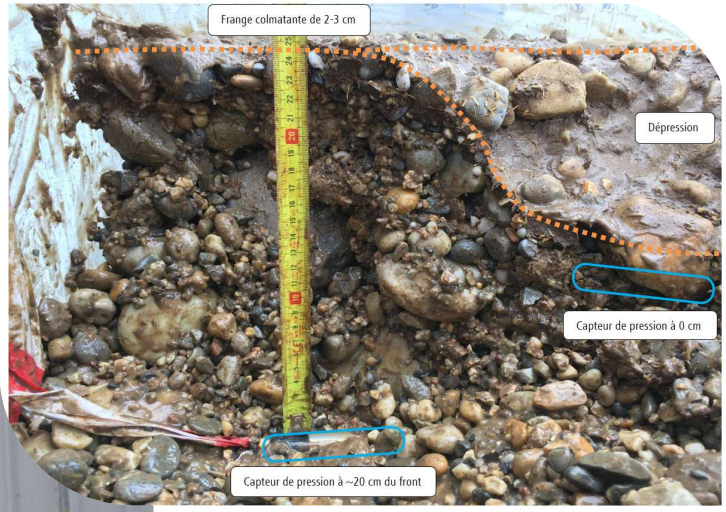
- Representative sample
- Repeatability et robustness
- STP trial
- Scale effect
- Financial optimization
- Set-up for “industrial” production

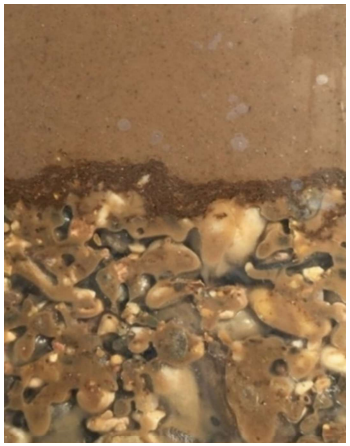


Slurry development

Taylor made permeameter : Slurry pressure

- Cobbles up to 200mm
- No grain <5mm
- Maintain pressure at 2,5 bar (without counter-pressure)
- Stops slurry losses immediately
- Membrane cake formation





Slurry development

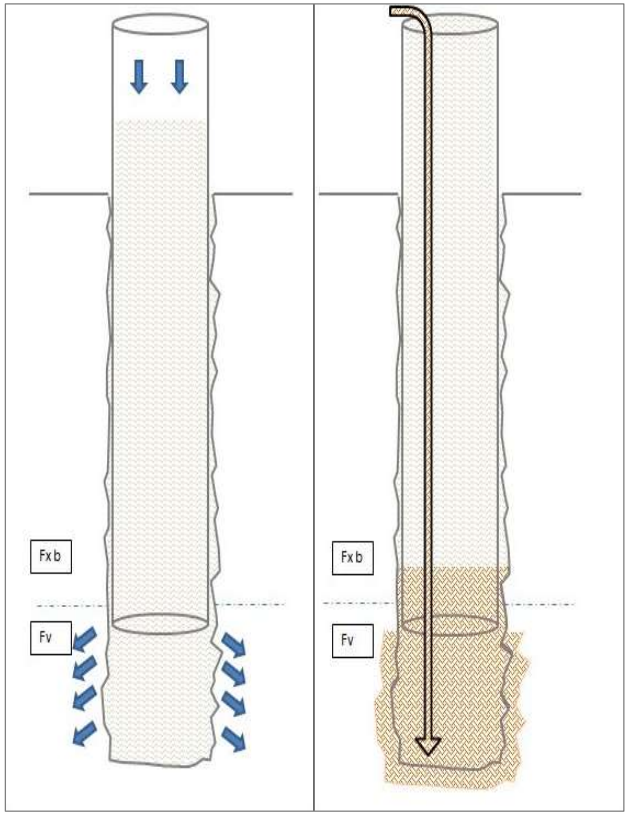
- Simulation of hyperbaric intervention
- Air loss management
- Maintain stable front face
- Desiccation proof
- Intervention time optimization

Slurry solution

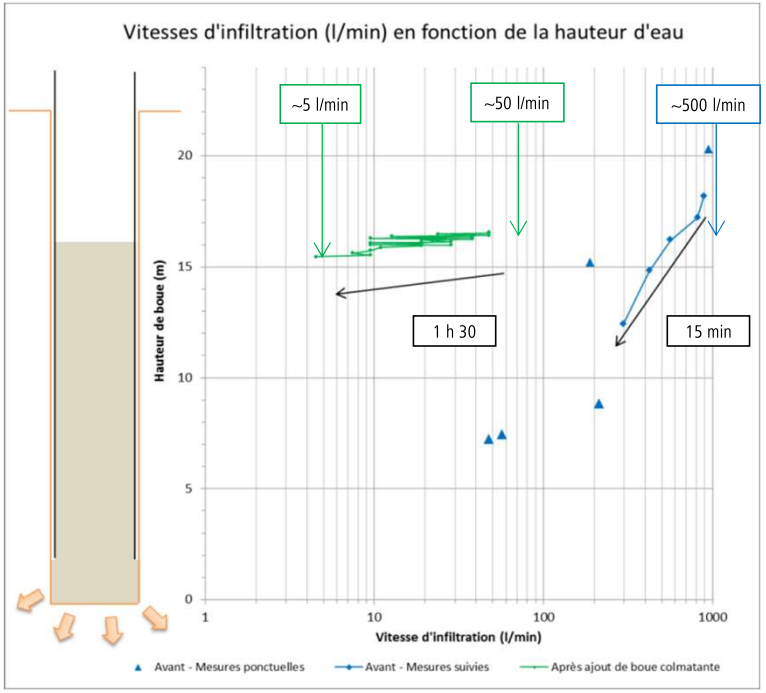
A « clogging » technical slurry mud based on natural products :

- Base : bentonite slurry
- Additional materials of vegetable origin: recycled, wood, straw …
- Quick clogging, Membrane cake, supporting pressure 2,5 bars
- Density, viscosity, STP separation are controlled

Execution



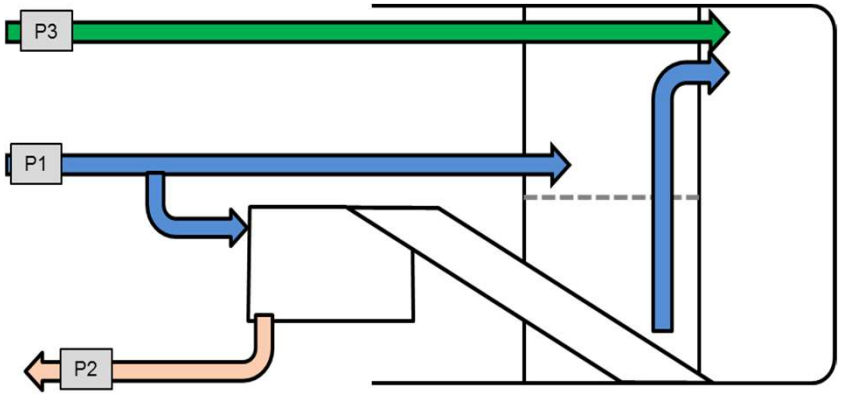
In situ test : first time in real ground during pile excavation at OCE station

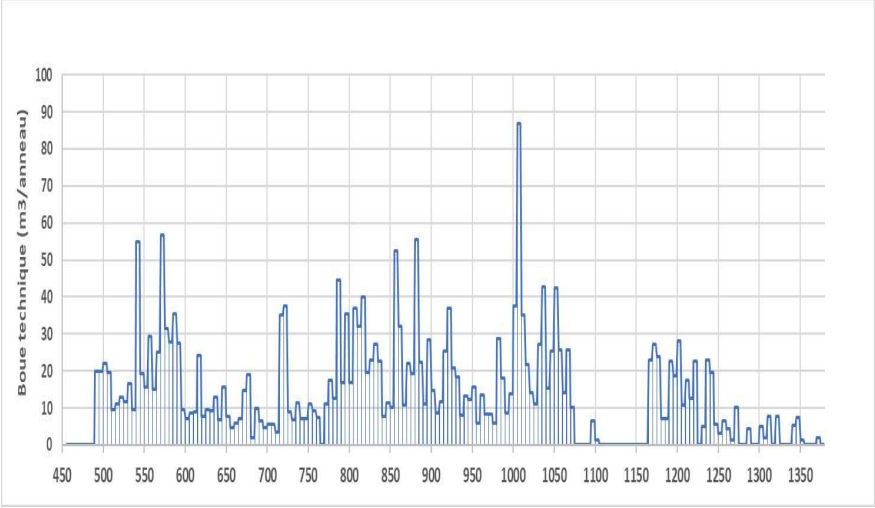


Execution

Process during execution phase:

Injection directly into the excavation chamber via the secondary network “HDSM”



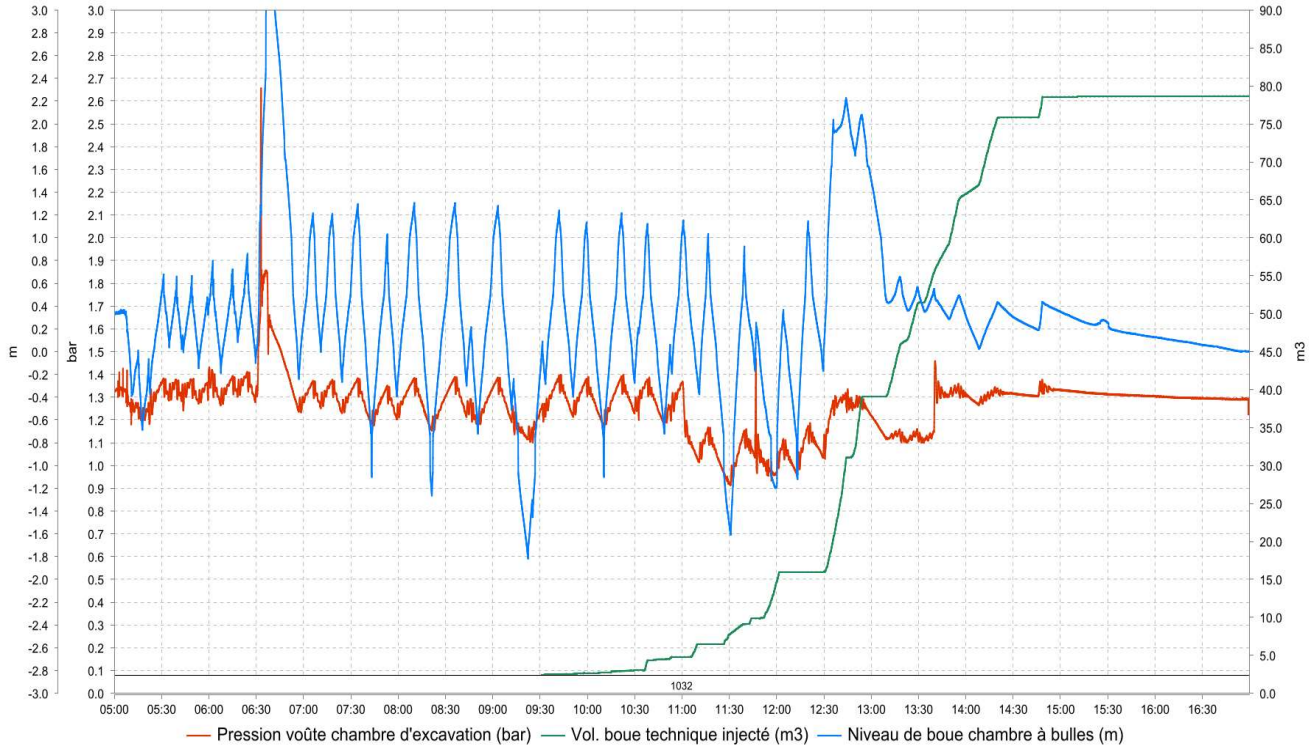


- Learning – fixed volumes
- Observation – fine tuning of instructions
- Appropriation – injection as required based upon pilot judgement / evaluation of losses

Results

One efficient example :

- Low slurry loss area
- Maintenance shift
- Obstructed HDSM
- Huge and continuous loss of standard slurry



1 000 m³ consumed in about 8 hours

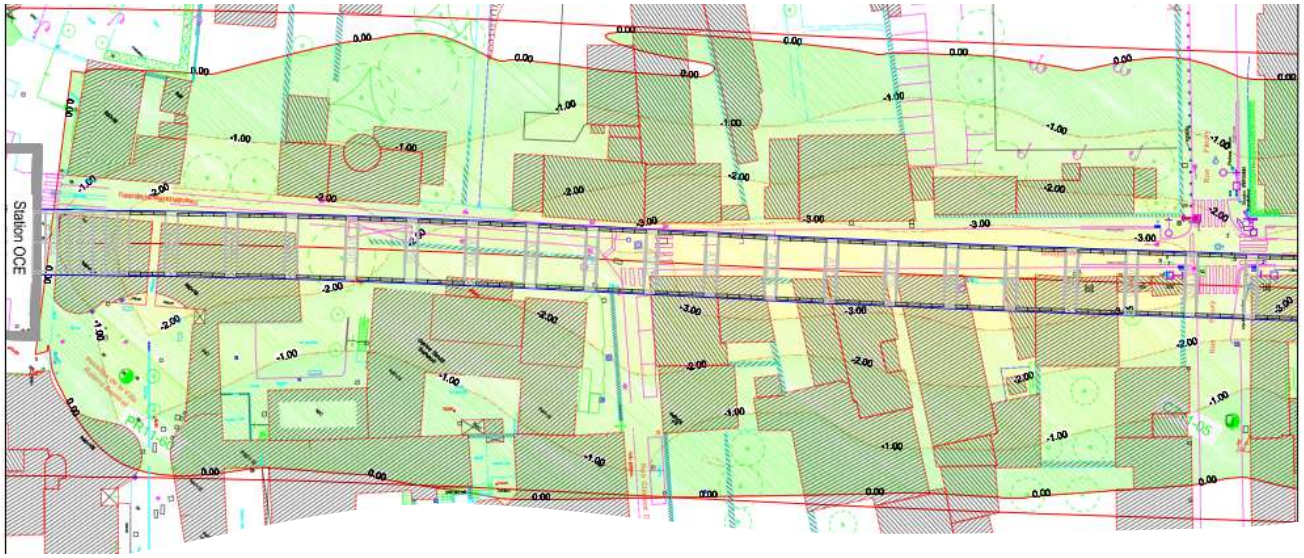
Rapid decrease of loss flow as soon as the rehab of the HDSM pipe

Results

Surface settlements:

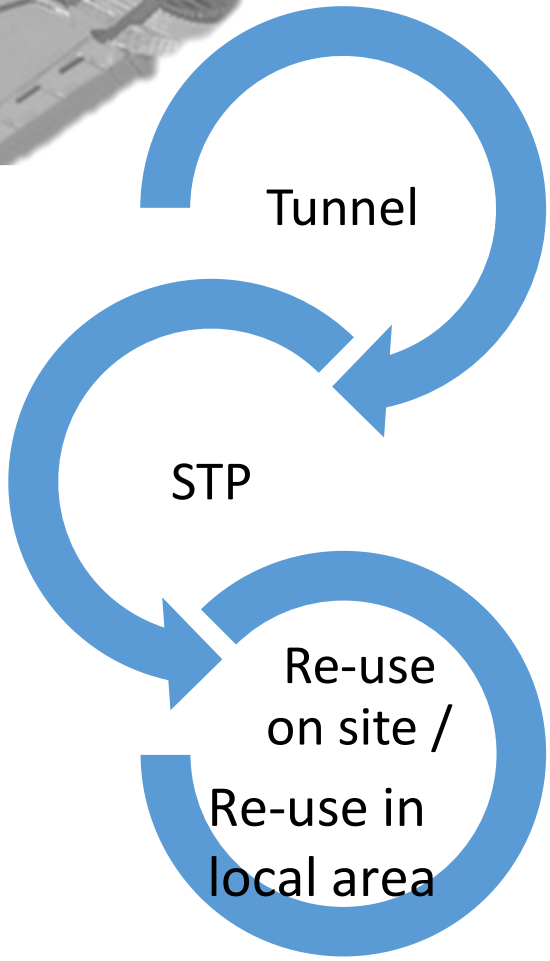
Isotassements range : **3 mm** in the Fv alluvium and underneath sensitive building

- Confinement pressure constantly fine tuned by observational method
- No limitation to overpressure due to slurry loss



Sustainability

Non-impacting solution….



Coming from excavated materials:

- 75% of backfilling material for the invert
- 50% of sand for annular void grouting

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THANK YOU