Fractured Rock Groundwater Conceptual Site Model

Diabase and Sandstone Contact in a Basin-Edge Context

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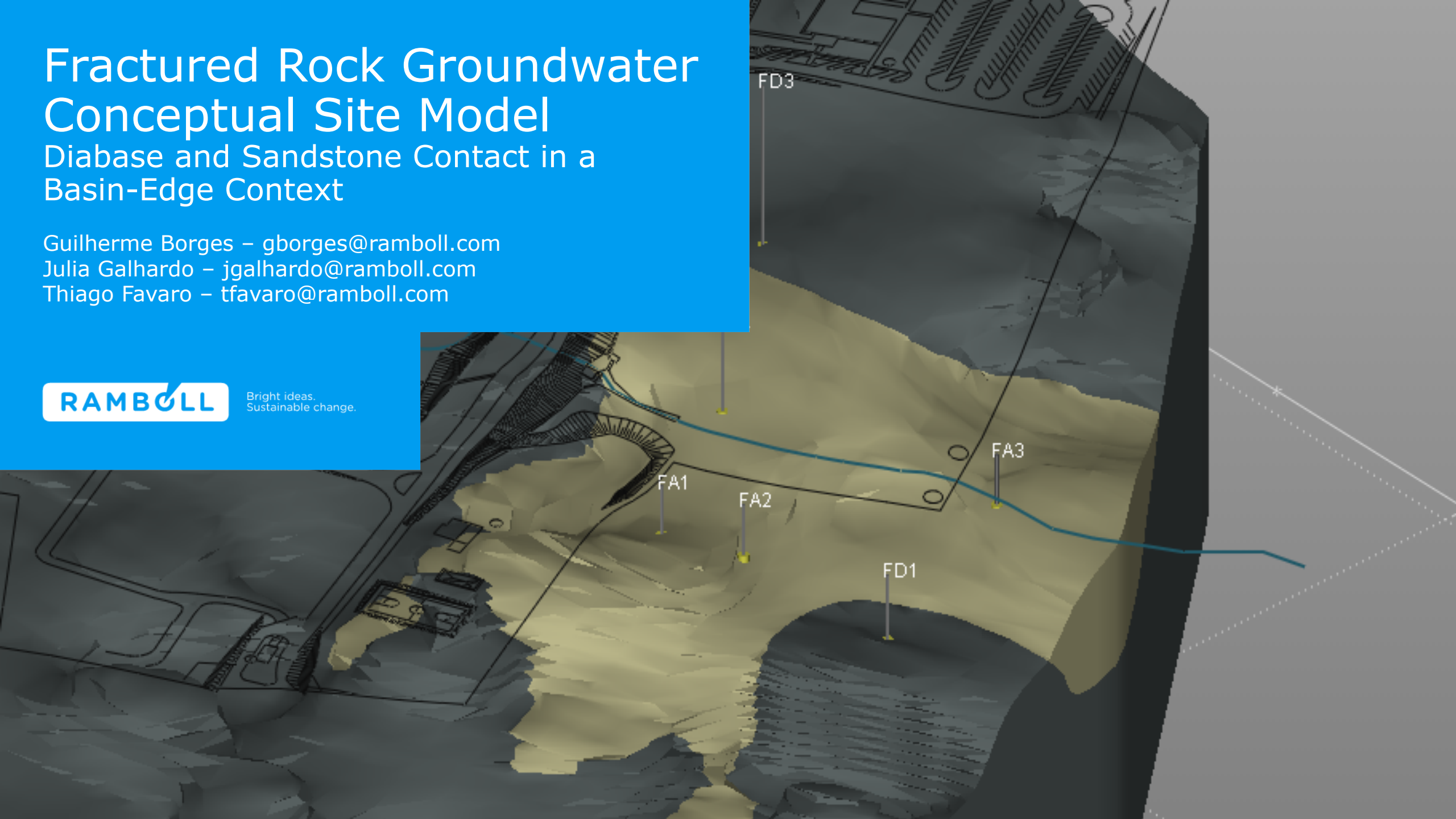
RAMBOLL

Bright ideas.
Sustainable change.

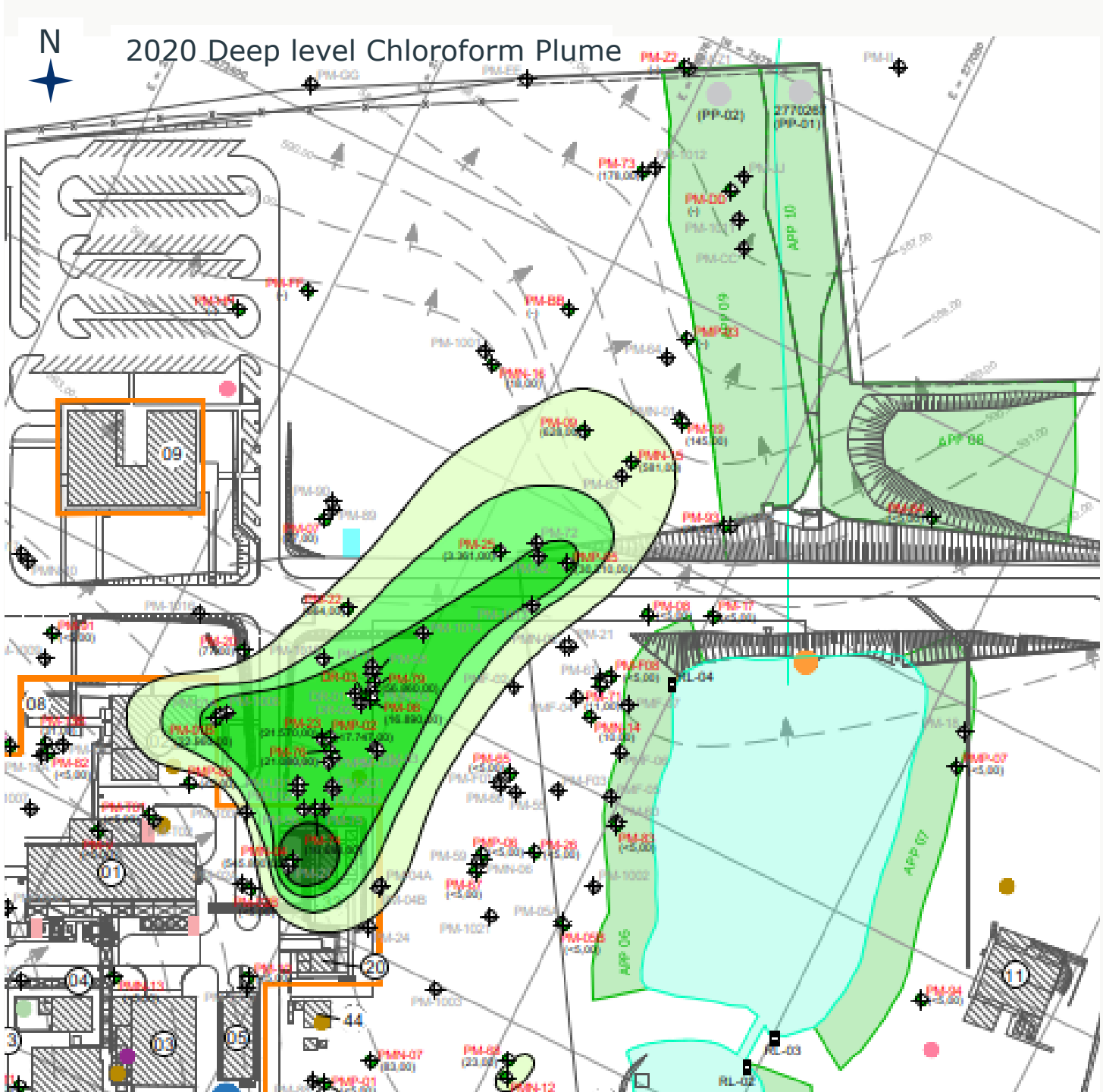


Agenda

1. Project Background and Motivation
2. Geological Context
3. Initial Fractured Aquifer Investigation
4. Geophysics Survey (ER)
5. Second Fractured Aquifer Investigation
6. Deep Penetrating Radar Survey
7. 3D Geological Model
8. Additional Fractured Aquifer Investigation
9. Conclusions
10. Lessons Learned and Next Steps

Project Background and Motivation

- Industrial site located in the Campinas Metropolitan Area;
- Ongoing site assessments and remediation since 1991;
- Main COC: Chloroform, Benzene and Chlorobenzene;
- Contamination plume mapped down to bedrock;
- State Environmental Agency requested fractured aquifer investigation in 2019.



Geological Context

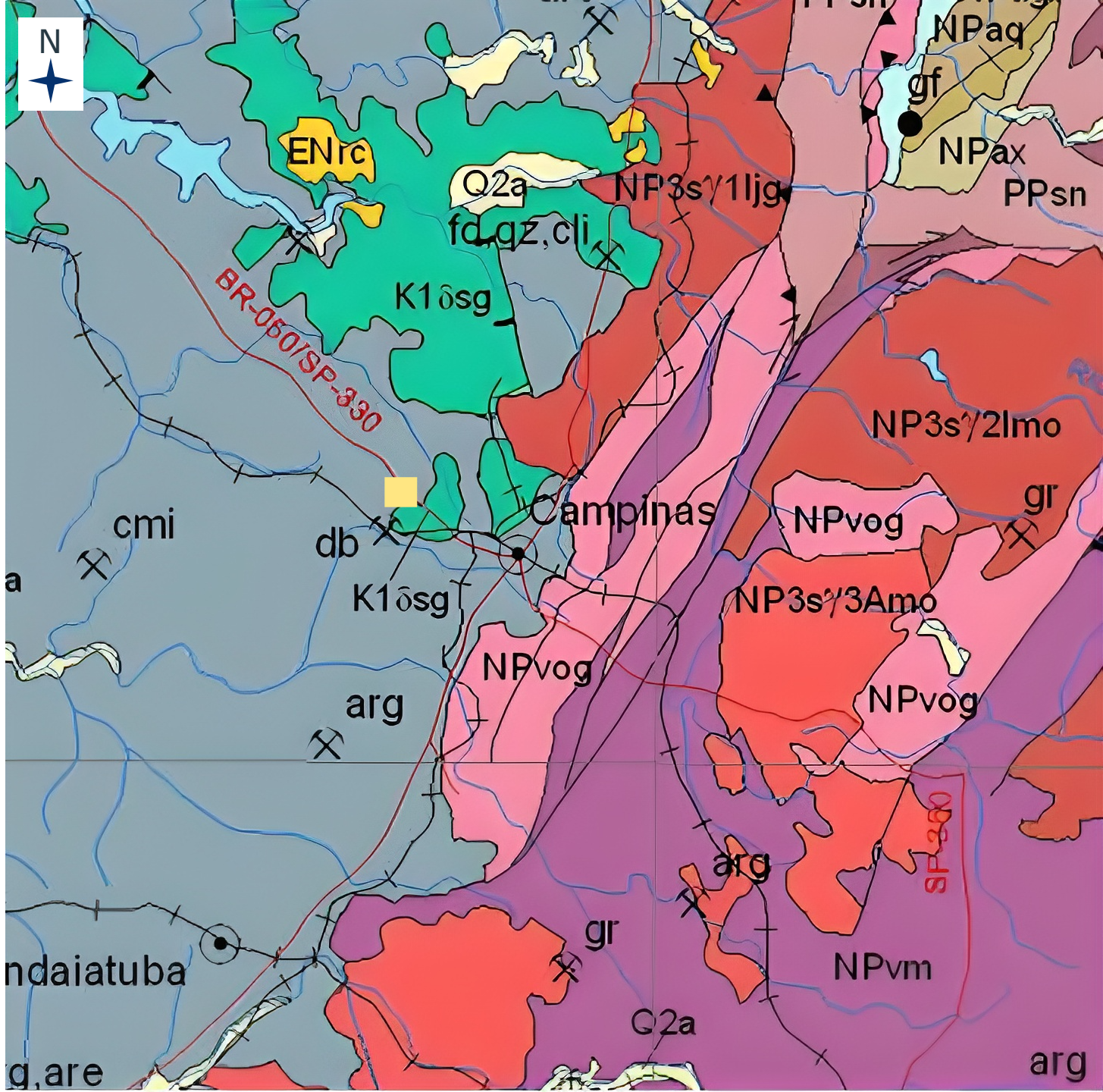
Site located in the Paraná Basin-Edge;

Igneous and metamorphic rocks to the East:

- Morungaba and Jaguariúna granitic suítes;
- Gneiss from Varginha Guaxupé Complex;

Sedimentary and igneous rocks from the Paraná Basin to the west:

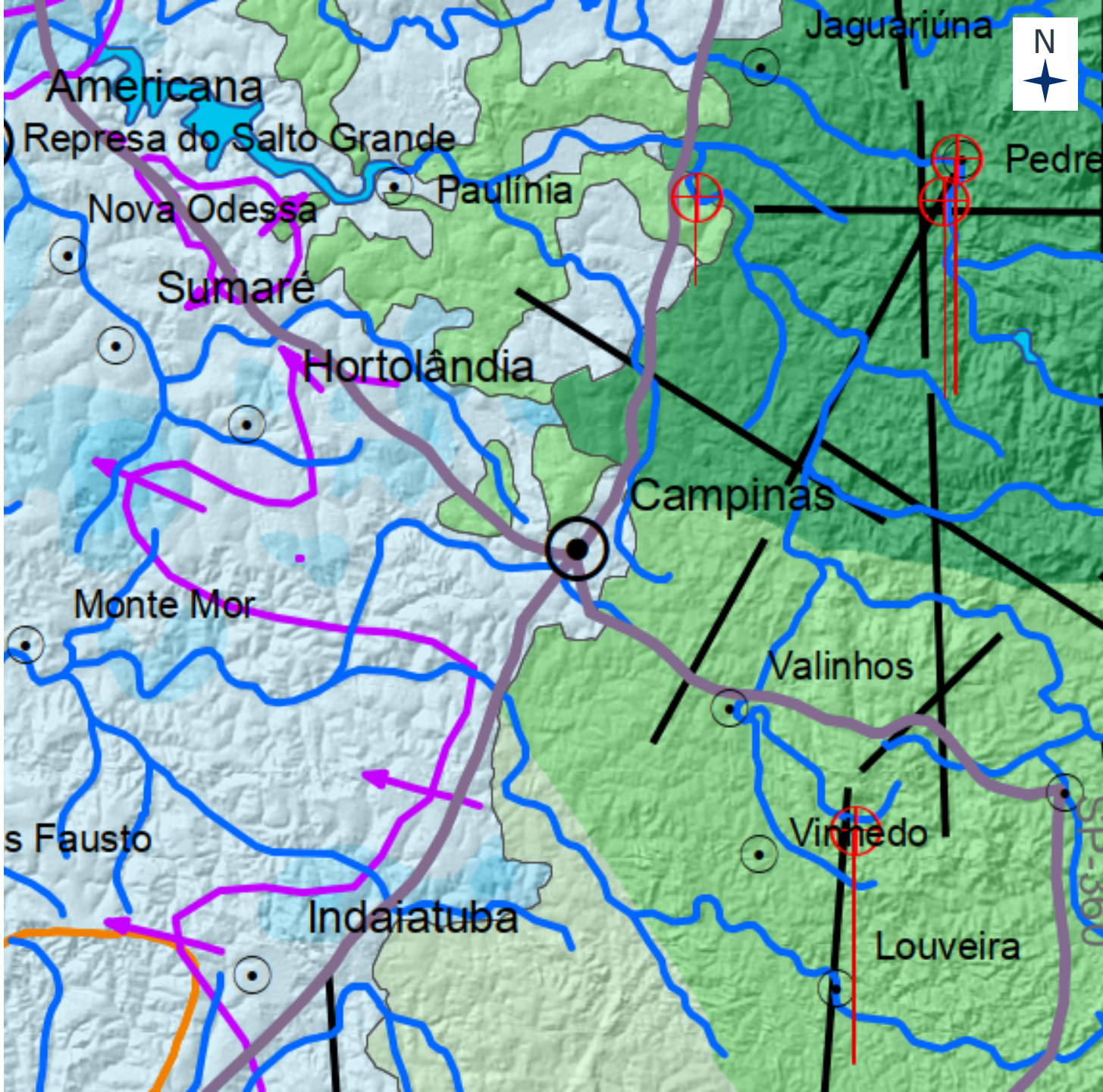
- Botucatu Formation Sandstones;
- Serra Geral Formation basalt and diabase;



Hydrogeology

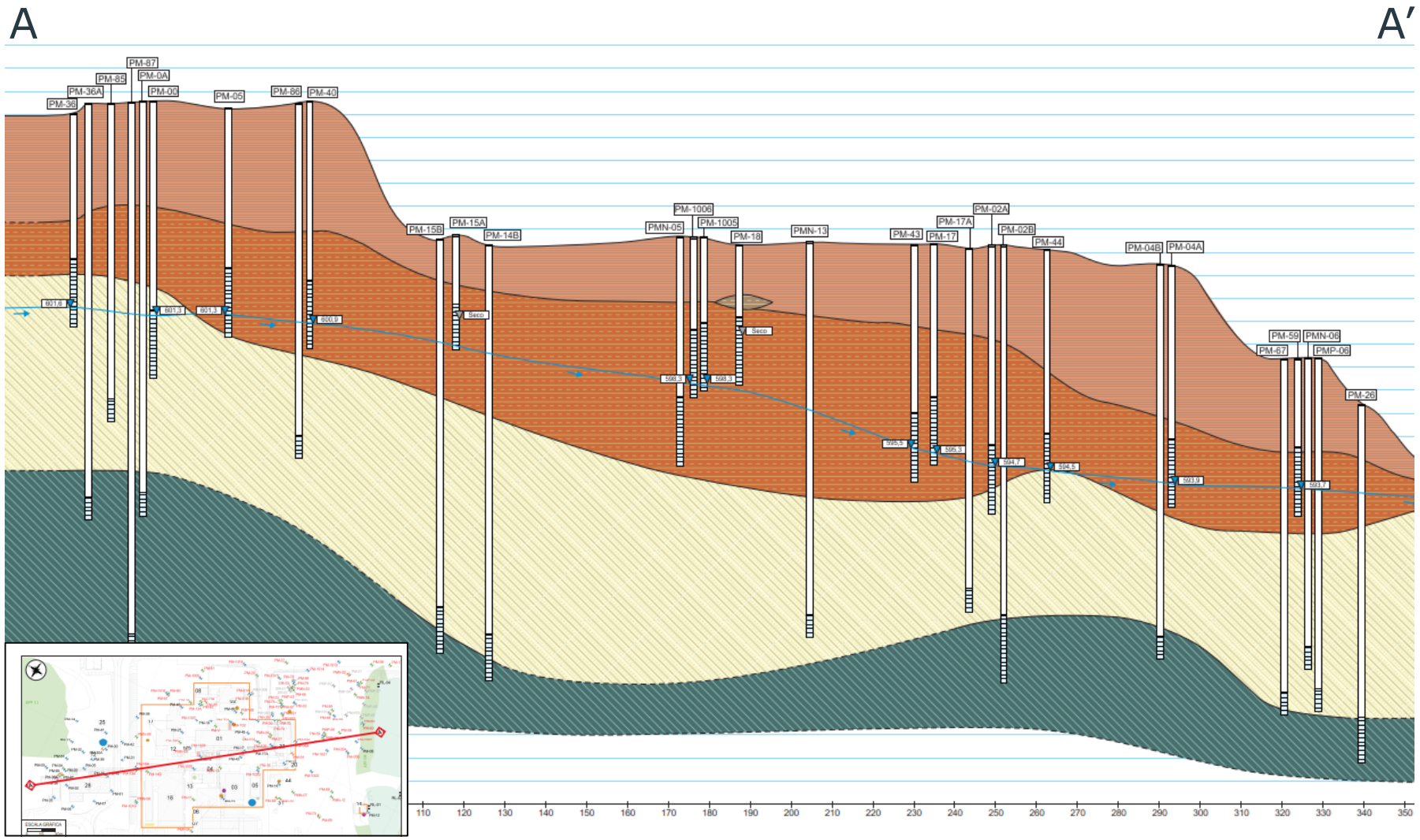
Can be divided in 2 main domains:

- Fractured to the east, associated with gneiss, granites, diabase and basalt
- Sedimentary (primary porosity) to the west associated with the Paraná Basin sedimentary rocks
- Main flow from SE-NW

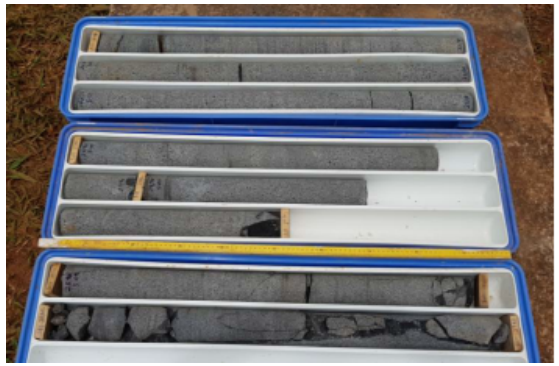


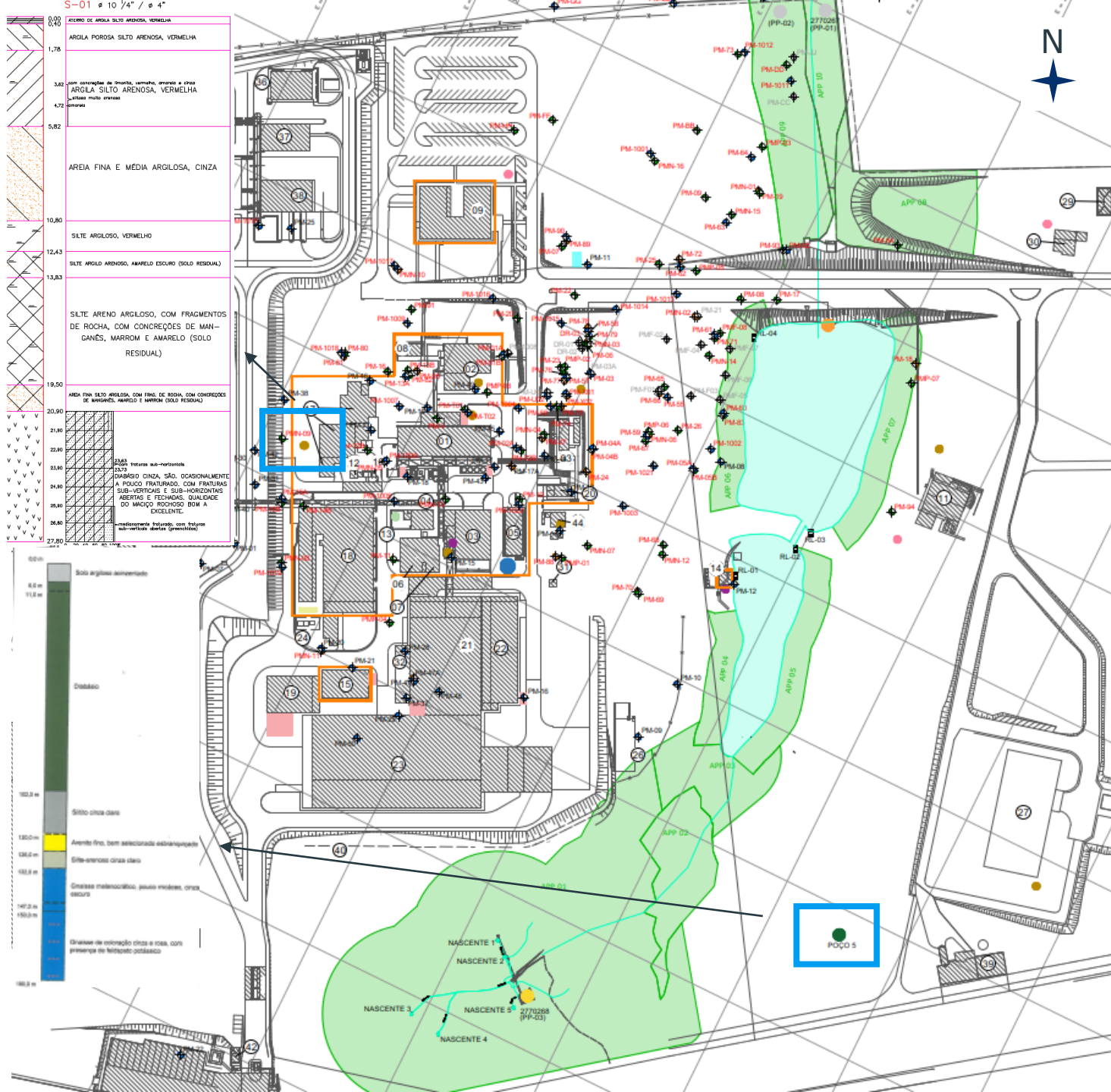
Local Geology

- Sandy clay composing first ~2m of soil;
- Silty clay (10^{-3} cm/s);
- Sandy silt (10^{-5} cm/s);
- Weathered diabase (10^{-6} cm/s);
- GW flow from W-E;
- GW level at~8 meters below ground levels (mbgl);



Local Geology





Abstraction well PP-05 indicated diabase from 6,0 to 102 mgbl;

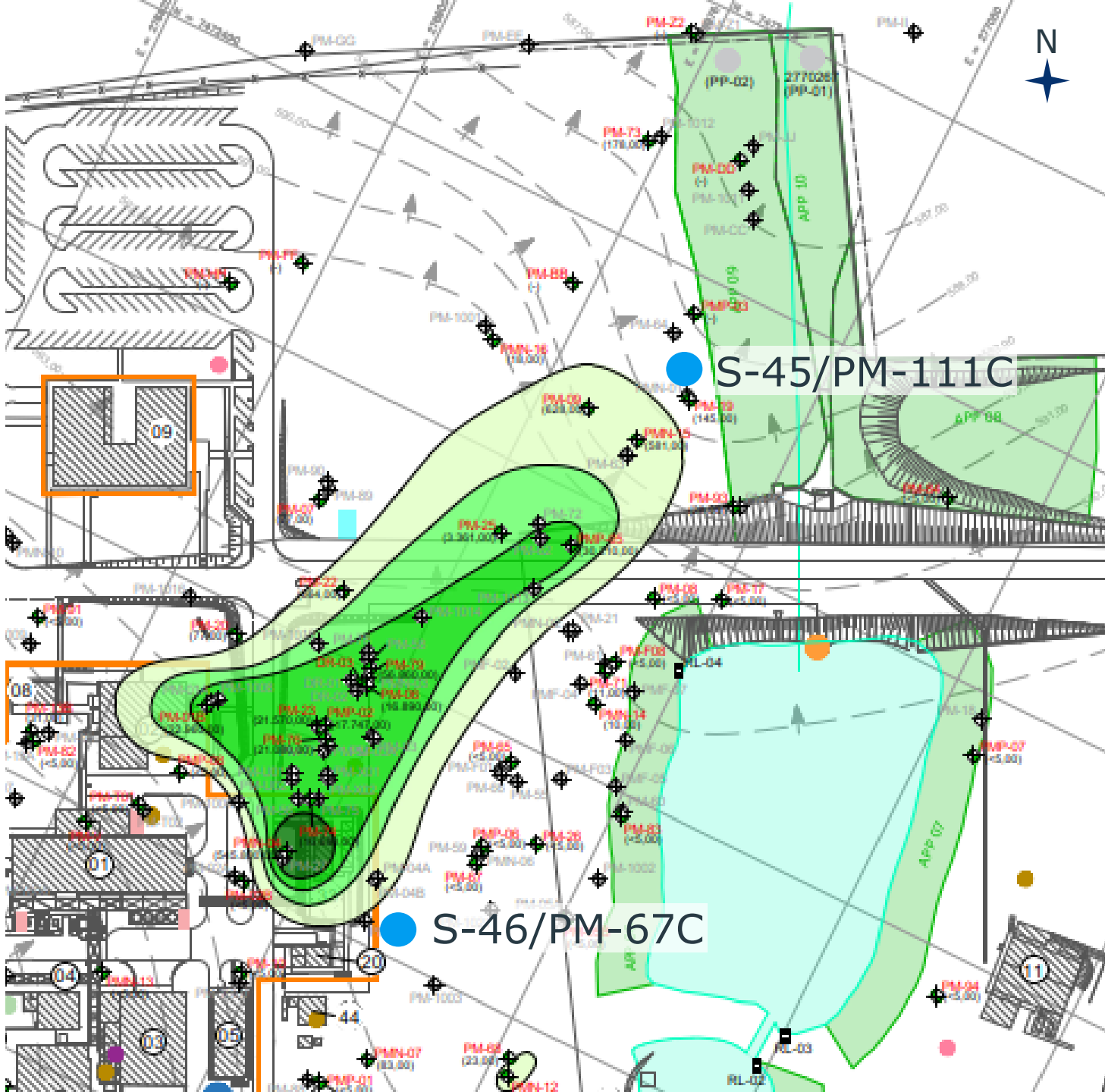
- Silt and sandstone from 102 to 132 mbgl;
- Gneiss from 132 to 180 mbgl;

Borehole S-01 indicated diabase from 20.9 to 27.7 mbgl (max depth).

Initial Fractured Aquifer Investigation

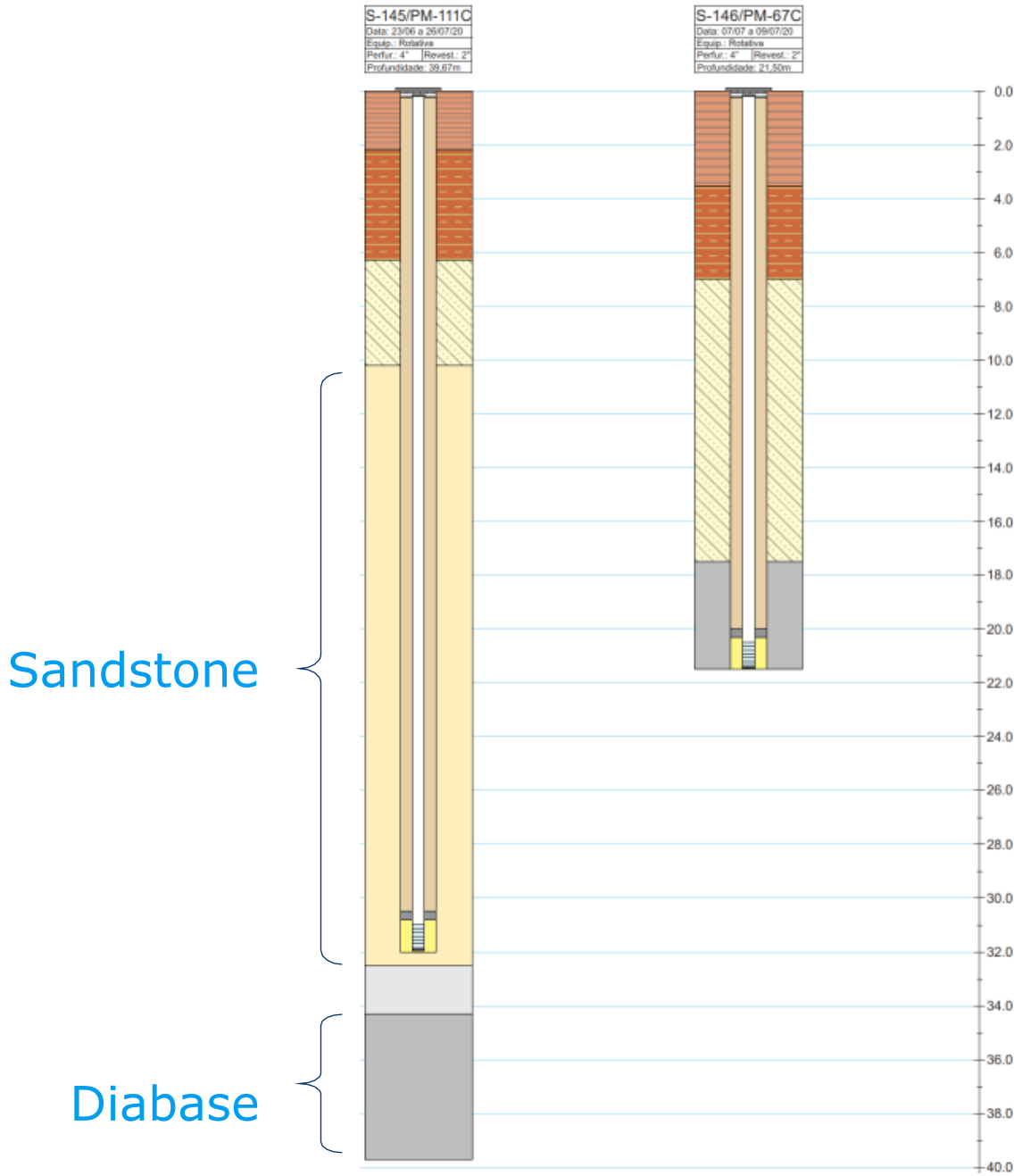
Installation of 2 groundwater monitoring wells

- Downgradient from the intermediate plume; and
- Closer to the center of mass.



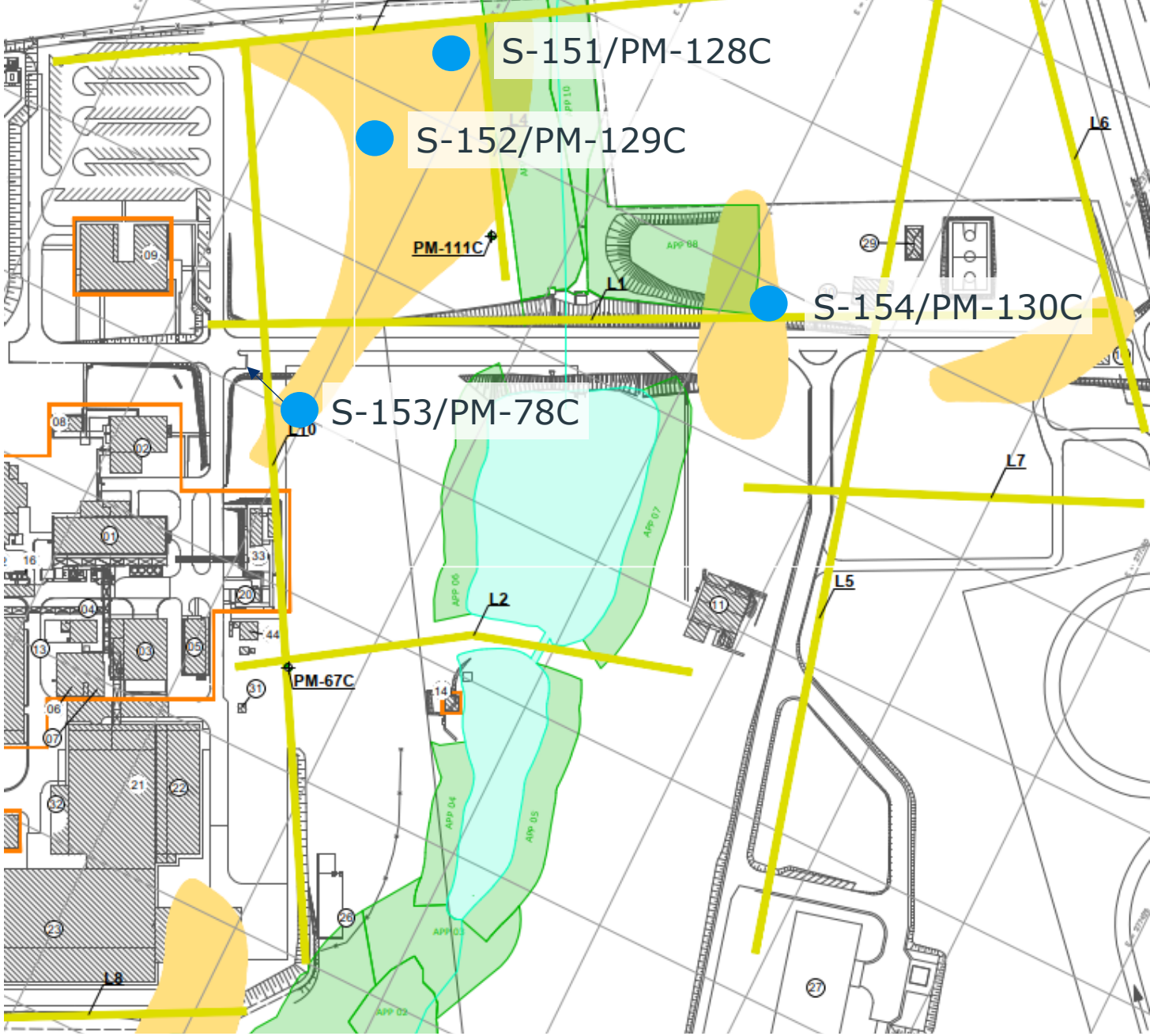
Initial Fractured Aquifer Investigation

- ~22m thick sandstone with centimetric lenses of silt and clay;
- High Porosity;
- Hydraulic conductivity: 3,62x10^{-4} cm/s;
- Contact metamorphism with diabase at ~32 mbgl;
- No open fractures observed;
- 100.000 µg/L of chloroform.



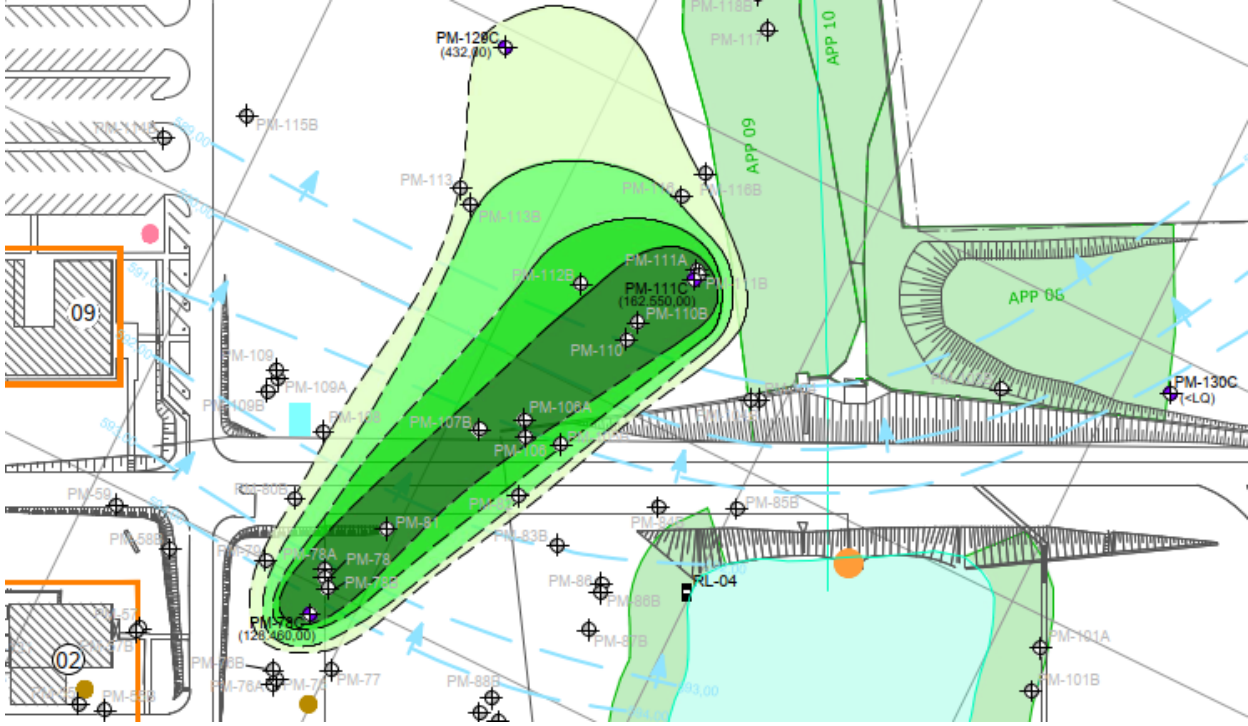
Geophysics Survey (ER)

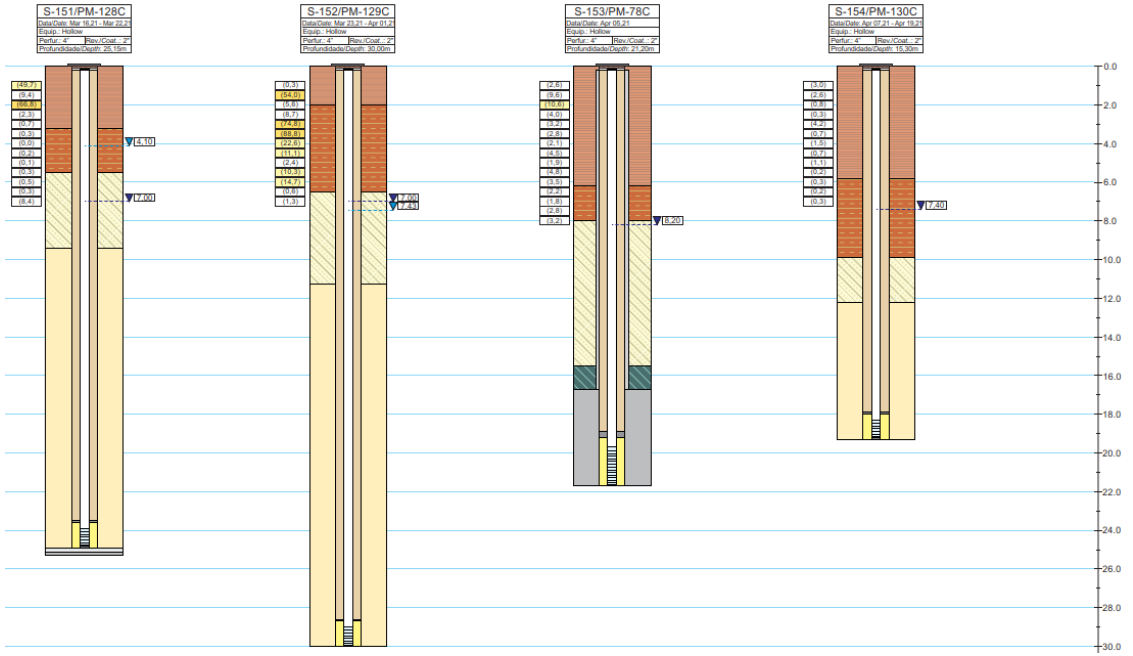
- Survey on 10 lines throughout the site;
- Main objective was to determine sandstone occurrences on site;
- Installation of 4 new monitoring wells;



Additional Investigation

- Sandstone confirmed on PM-128C, PM-129C and PM-130C
- Only diabase (fractured) was present in PM-78C;
- High COC concentrations on PM-78C and PM-111C;



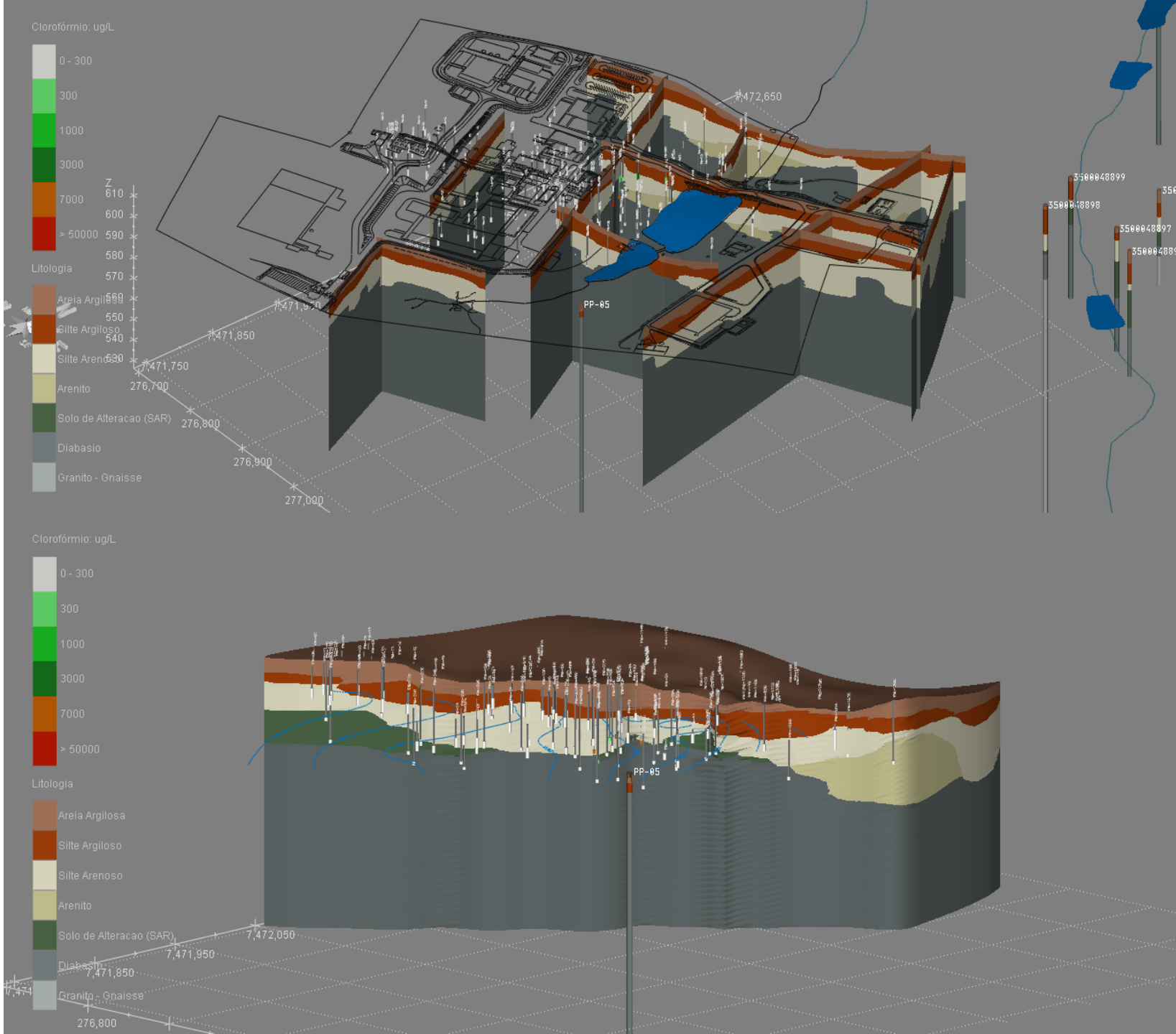


Deep Penetrating Radar (DPR) Survey

- Able to map down to 70mbgl in high definition;
- 25 MHz transmitter and 50 MHz receptor;
- Survey on 11 lines;
- 3D CSM development

3D Geological Model

- DPR cross sections manually inserted;
- Combined with borehole and abstraction well log data;
- Definition of new scope of work.



New Scope Of Work

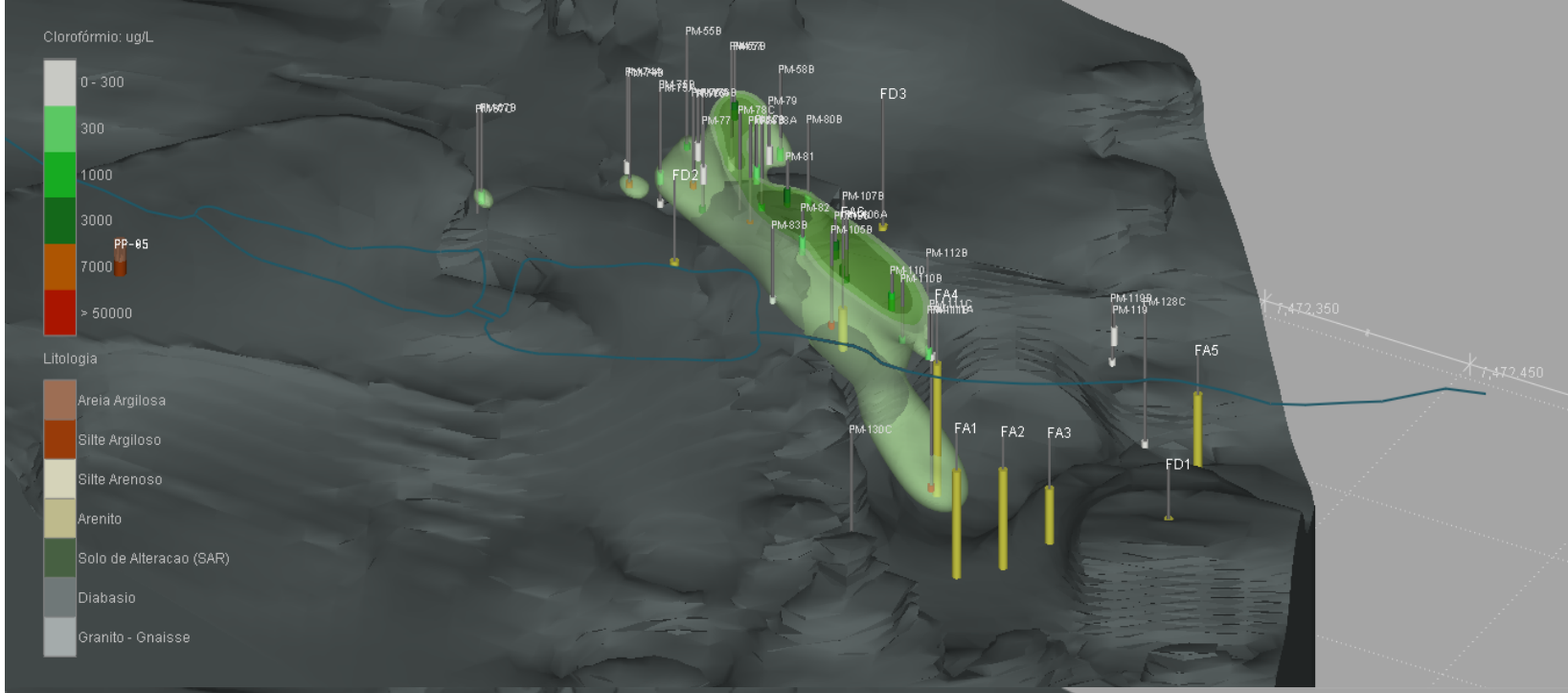
Installation of 4 new monitoring wells:

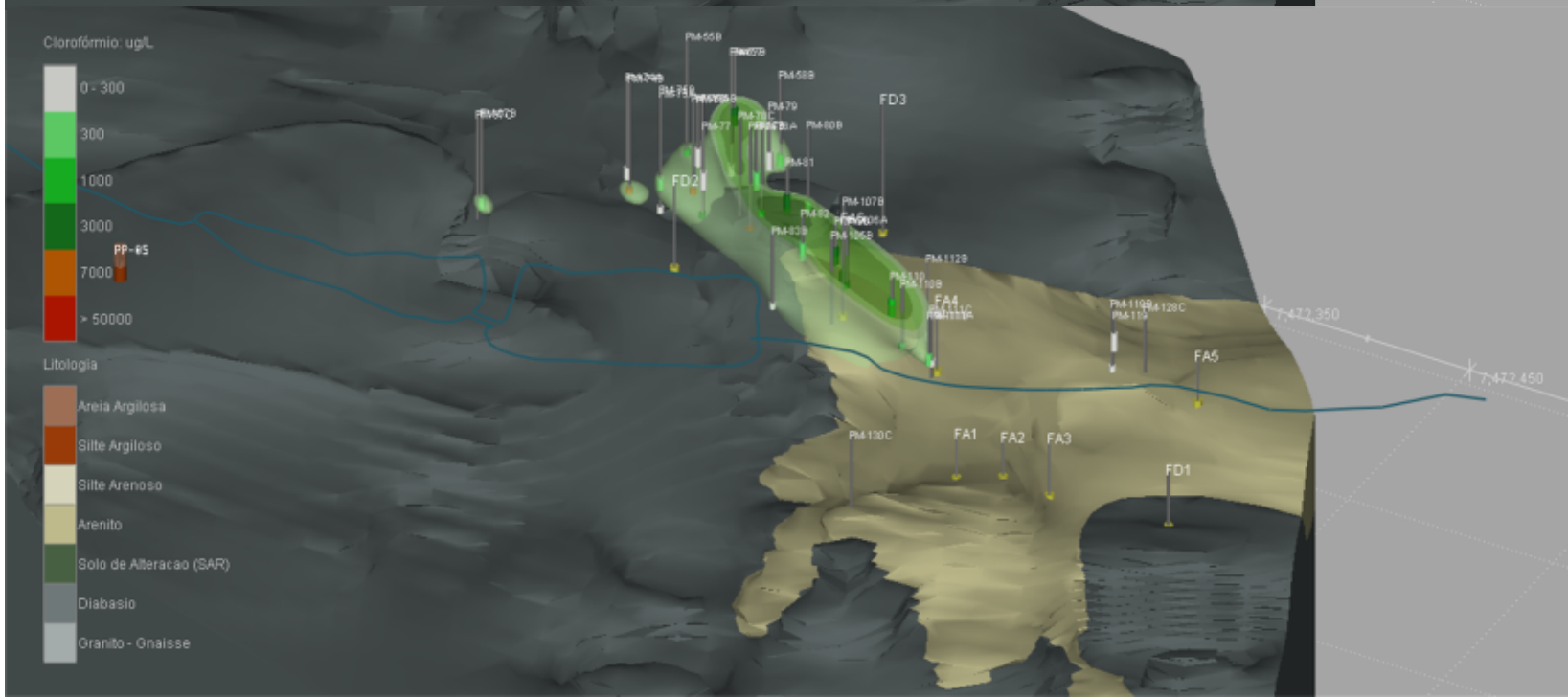
- 2 to investigate the diabase;
- 2 to investigate the sandstone;

Core sampling;

Downhole geophysics;

3 channel CMT wells.





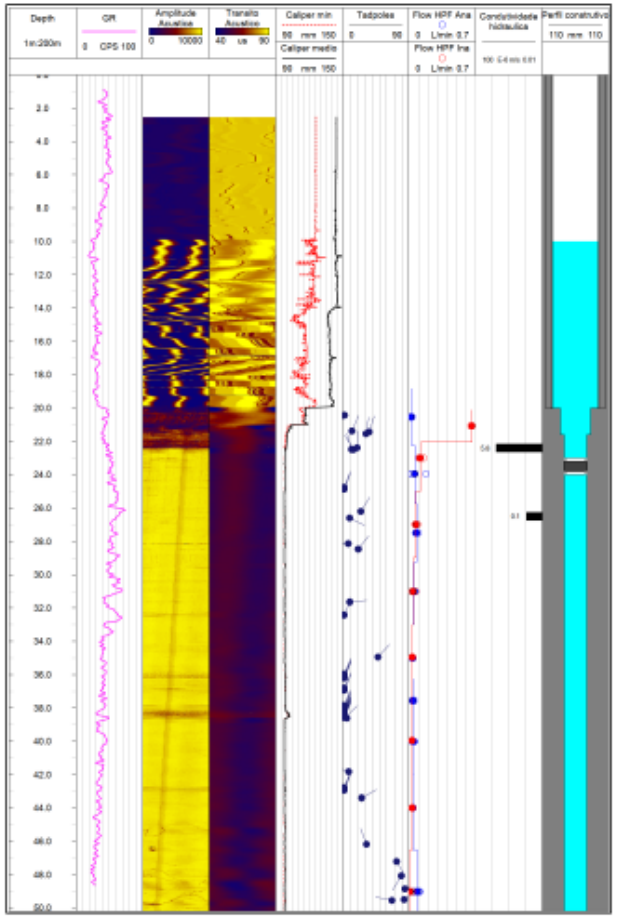
Borehole Drilling

Presence of diabase where sandstone was expected (FA5).

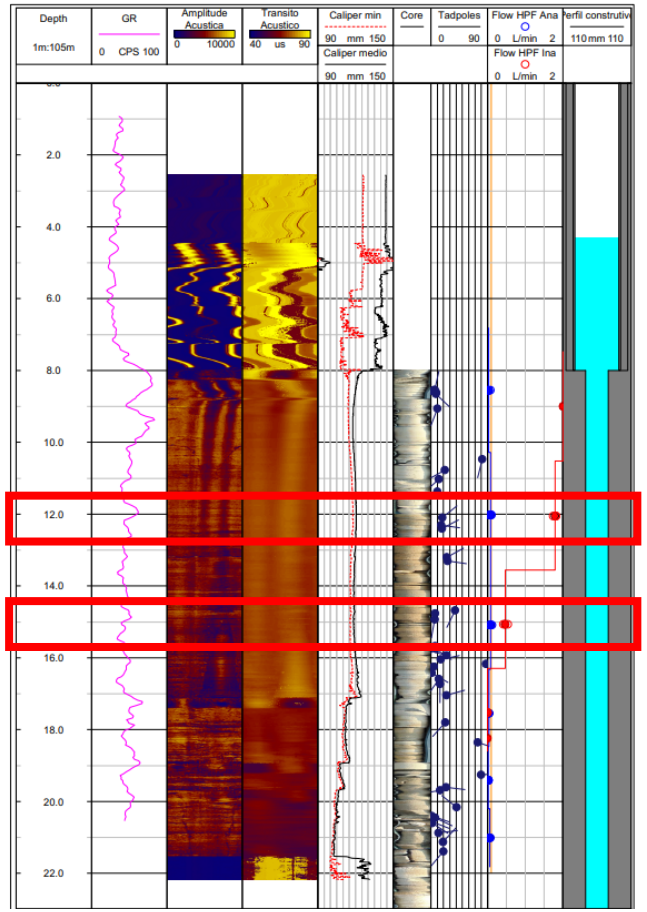
Downhole Geophysics

- Borehole filming;
- Acoustic profiling and natural gamma;
- Mapping flow conditions with the HPF Probe;
- Additional investigation in diabase: Hydraulic tests and discrete sampling;

FD3



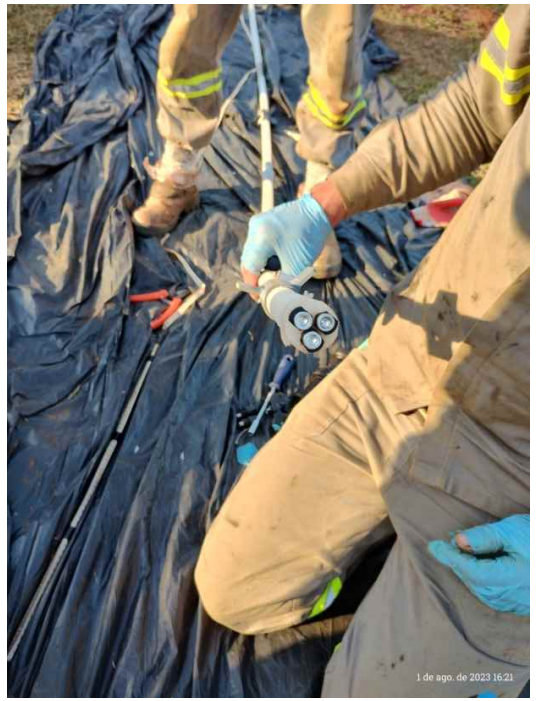
FA4



CMT® Monitoring Well Installation

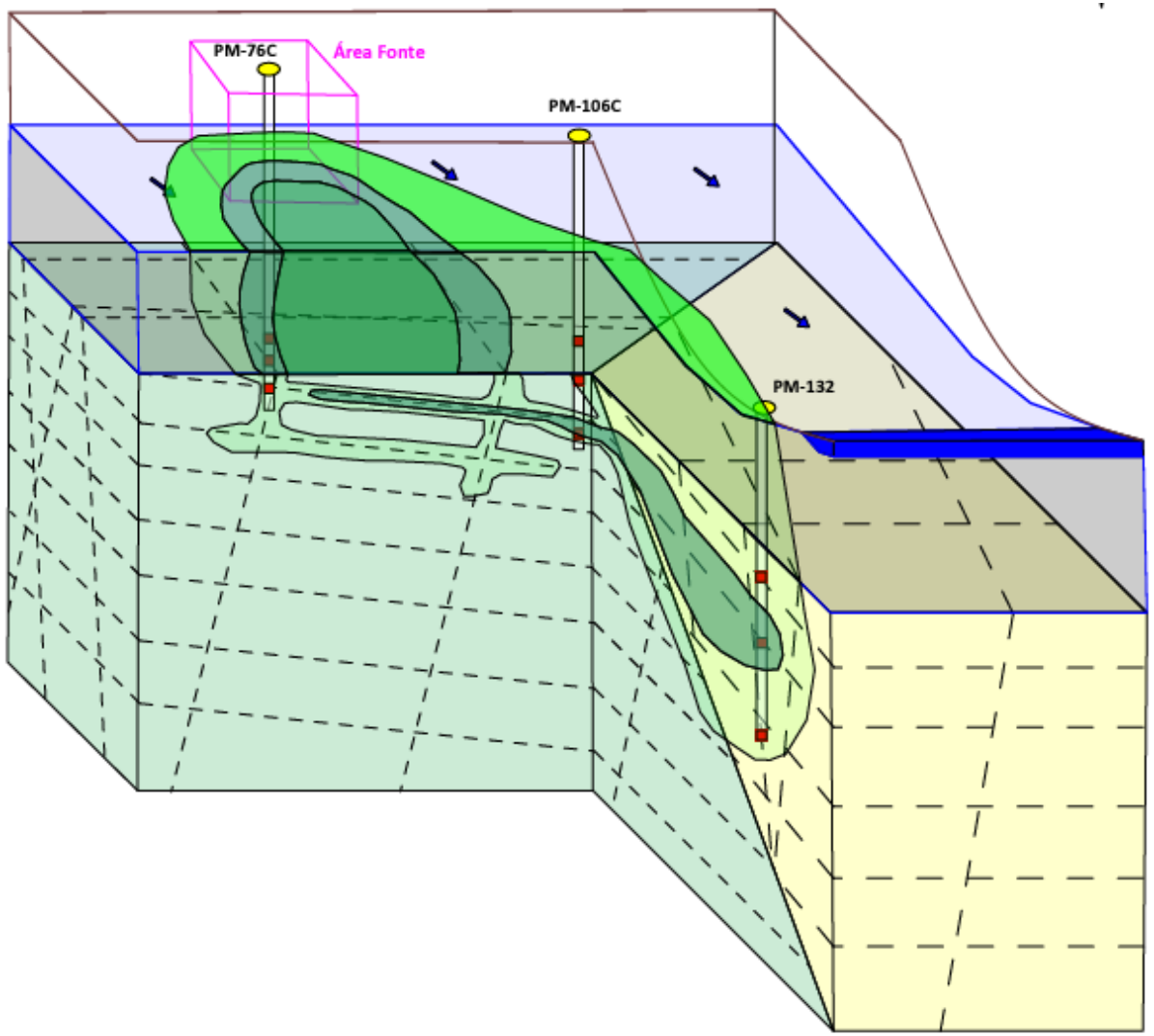
Monitoring Well	FD2	FD3	FA4	FA5
Channel 1 (m)	17,7	22,3	13,5	15,5
Channel 2 (m)	18,7	24,7	16,5	17,0
Channel 3 (m)	19,7	48,0	23,0	20,8





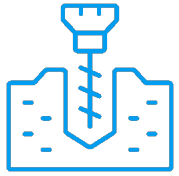
Results/Conclusions

- Open hole geophysics conducted in the Diabase have shown limited flux capacity in the intercepted fractures;
- Initial data suggests that contaminant transport in the Diabase is mainly related with shallow sub-horizontal fractures;
- Heat Pulse Flow Meter have shown important flux zones in the sandstone - related with highly fractured zones;
- Fractures in Sandstone have mainly E/NE sub-horizontal dip.
- Possible Diabase/Sandstone fault contact –groundwater plume dips in this region;
- Hydraulic head in the evaluated fractured aquifer shows that regional groundwater flux is similar to the granular aquifer – NE Direction – conditioned by terrain depression.

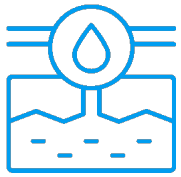


Lessons Learned and Next Steps

The assessment had limitations regarding vertical drilling bias – No near rock outcrop to conduct a scanline evaluation;

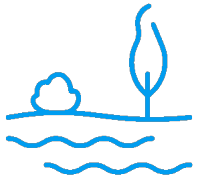


Difficulties with CMT deep wells installation – careful bentonite insertion must be conducted to secure well screen interval sealing;



Concentrations in the fractured aquifer have shown highly variability in CMT and "conventional" wells - methods under evaluation to assess the mechanism behind those variations;

The installation of one additional Sandstone well in June 2024 to refine the CSM;



Additional groundwater sampling campaigns to evaluate the concentration variations and to determine the best sampling method in CMT wells.

Thank You!

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