WaterJPI project

SMARTControl

Smart framework for real-time monitoring and control of subsurface processes in managed aquifer recharge (MAR) applications

Deliverable D5.5

Installation of real-time monitoring system pilot site at João Pessoa, Brazil

Experiment setup & sensors' installation for real-time monitoring

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Short summary

This report shows the information about the Managed Aquifer Recharge pilot site at João Pessoa, Brazil. In this report you can find detailed information about the whole pilot site setup: piezometers (7), pumping (1) and injection (2) wells drilling, storage tank, water level sensors installation and general facilities of this MAR site. This pilot site is located inside the Federal University of Paraíba (UFPB, in Portuguese) campus, close to the Hydraulics Laboratory. The system construction started in July 2019, during the BRAMAR project, an international cooperation between Brazil and Germany, which was finished from October to November 2020 with the support of the SMART-Control project. The whole system is monitored online, where it is possible, for instance, to remotely follow an injection test. This site is the first one built in South America. The first pumping and injection tests are also show in this report. Two annexes are presented consisting of a set of photos showing the building process and all detailed information about the wells and piezometer profiles.

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ABSTRACT

This report presents information about the João Pessoa Managed Aquifer Recharge (MAR) pilot site including a real-time and online monitoring system, build with the support of two international research and cooperation projects, i.e., the BRAMAR and the SMART-Control projects. The pilot-scale is made up of one pumping and injection well, one injection well, seven piezometers in the unconfined aquifer (the Barreiras formation), one piezometer in the confined aquifer (the Beberibe formation), one storage tank (15 m^3), and a set of installed accessories. A monitoring system provided by Ampeq company is used to monitor every part of the pilot site in a very high temporal resolution (sub-hourly time steps). This monitoring system is connected to the INOWAS platform which is important to understand the behavior of the pilot scale system. Due to the COVID-19 pandemic, some parts of the project were delayed. Thus, this report presents what was done during the last 2,5 years including the construction of the pilot site and extensive and detailed data containing lithological and constructive profiles of the wells and piezometers, as well as a photographic dossier.

CONTENT

FIGURES

1. INTRODUCTION

In Brazil, Managed Aquifer Recharge (MAR) is still a very incipient technology. Very few case studies were or are currently under development in the country. At the same time, the legal framework is also very incipient and superficial. Federal and State Laws have few information about how MAR should be carried out, what kind of qualitative and quantitative monitoring parameters should be used to measure the impact of MAR, etc. Although MAR is an alternative water management solution in different countries, in Brazil there is a long way until MAR can be considered as part of the Integrated Water Resources Management system. MAR, which is approved and feasable solution to improve groundwater quality, subsidence reduction, groundwater availability augmentation, etc., for instance, is under-used in Brazil mainly due the lack of knowledge. Then, this project was a proposal to improve and spread the MAR kwowledge in this country. In order to do this, we decided to build a pioneering MAR pilot system in João Pessoa, Paraíba, Brazil. This system was built in the uncofined aquifer, which is known as Barreira hydrogeological formation. The pilot system is made up of: 7 piezometer, 1 pumping & injection well, 1 injection well, 1 stotage tank (15 m^3), 2 dataloggers and communication system, and a set of pipelines to flow water from and into the aquifer. All of the piezometers and wells have on average 40 meters depth. A very detailed hydrological profile and aquifer cross sections could be built due to the sample collection, which was done every 2 meters. Every part of this pilot site is monitored online and in real-time, where a total of 12 sensors was installed: 10 water level sensors in the piezometers, storage tank and pumping and injection wells. A rain water harversting system should be built, but it was not possible due to COVID-19 issues. Furthermore, a piezometer in the confined aquifer (Beberibe system) was built to support a groundwater monitoring network. This pilot site will be used as a demostration site for MAR and with it we intend to spread knowledge about water management issues and solutions in Brazil.

2. PILOT SYSTEM DESCRIPTION

In this section we provide information about the João Pessoa pilot scale experiment. This section is divided into three parts, where first we present a background, second the pilot site description is exhibited, and third the monitoring system set up is shown.

2.1 BACKGROUND

The proposal of this pilot site (Figure 1) started in 2014 in the BRAMAR project scope (Almeida et al. 2018). In July 2019, part of this pilot system was built with support of the BRAMAR project: 2 wells (6" diameter) and 2 piezometers (2" diameter), both in the unconfined aquifer, the Barreiras formation. Due to the end of the BRAMAR project, there was no more financial resources to go on with the system. In that project, we also started studies regarding Managed Aquifer Recharge in this region of Brazil, but more focused on the legal framework at national scale. Then, in November 2017, we had the opportunity to join the SMART-Control proposal with a full-scale case study. In February 2019, the SMART-Control project started, however due to financial resources delay and the COVID-19 restrictions, we just could start to continue to build the pilot system in October 2020, finishing it in November 2020. After setup of the pilot system, groundwater level sensors were installed and, finally, in 2021 the whole system was ready to use. Unfortunately, due to the COVID-19 pandemic we were not able to build the rainwater harvesting system.

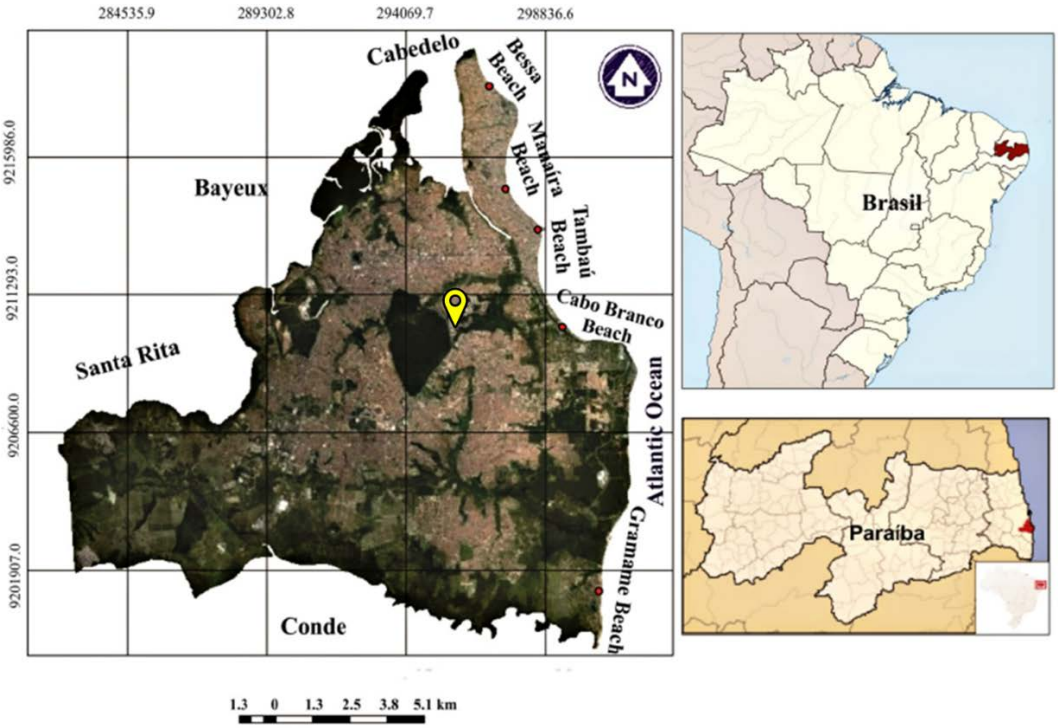

Figure 1. Pilot scale location – Brazil, Paraíba state and João Pessoa city (yellow mark is the location of the pilot system).

2.2 PILOT SYSTEM DESCRIPTION

The João Pessoa MAR pilot system is located inside the campus of the Federal University of Paraíba (UFPB, in Portuguese). The first part of the pilot system was built in July 2019: 2 wells (6" diameter) and 2 piezometers (2" diameter). The neighborhood of Hydraulics Laboratory was selected to install this pilot site, first because of the free area and second because it is close to where water resources researchers develop their research. The unconfined aquifer (Barreiras formation) was also selected as study zone and has an average thickness of 40 meters. In this area there are no other wells drilled in the unconfined aquifer. It was an important criterion to the

selection of the area, otherwise we could have influence of other wells on our pilot system. The pilot site was created following the schema presented in Figure 2.

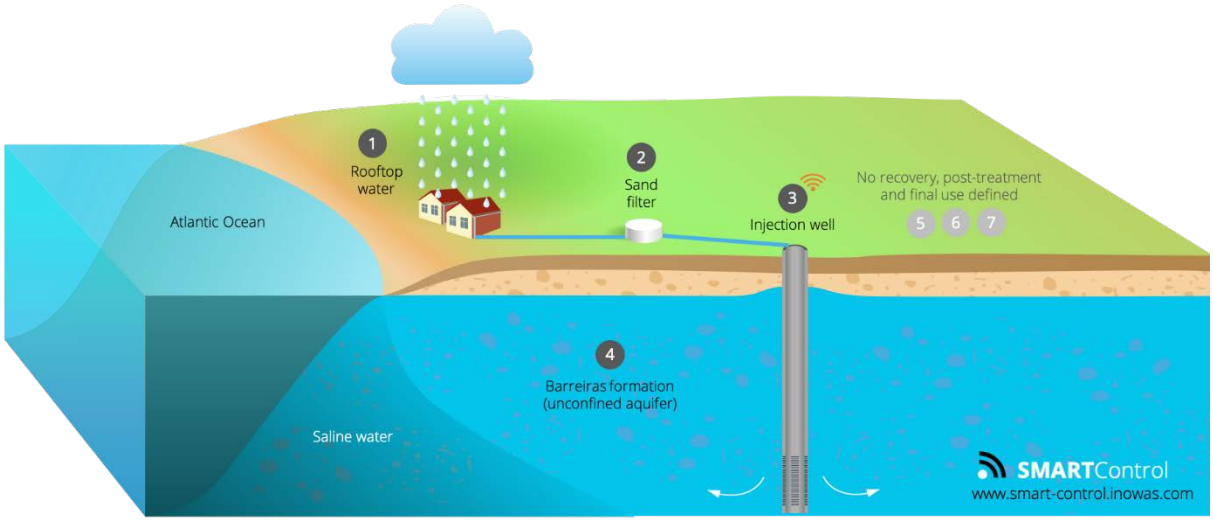

Figure 2. Schematic overview of MAR components at João Pessoa pilot scale system.

Currently, the pilot scale system is made up of the following items (Figure 3):

- **1 injection well (PT-01).** A ~ 40 meters and 6" diameter well located in the unconfined aquifer. Drilled by the BRAMAR project;
- **1 pumping/injection well (PT-02).** A ~ 40 meters and 6" diameter well located in the unconfined aquifer. Drilled by the BRAMAR project;
- **7 piezometers (PZ-01 to PZ-07).** Piezometer with ~ 40 meters and 2" diameter located in the unconfined aquifer. The two first were drilled in the BRAMAR project while the other five were drilled in the SMART-Control project;
- **1 extra piezometer (PZ-08).** A ~ 130 meters and 2" diameter piezometer drilled in the confined aquifer in the SMART-Control project;
- **1 storage tank.** A 15 m³ storage tank used to store water pumped from the PT-02 as well as to inject water in the wells PT-01 and PT-02;
- **1 Ampeq monitoring system.** System used to measure groundwater level, storage tank water level, discharge and send data to Ampeq and SMART-Control servers;
- **Accessories installation.** Set of pipelines, pump, valves, and other hydraulic items to pump groundwater, store and inject back in the uncofined aquifer (Obs. The pumping system is fully automated).

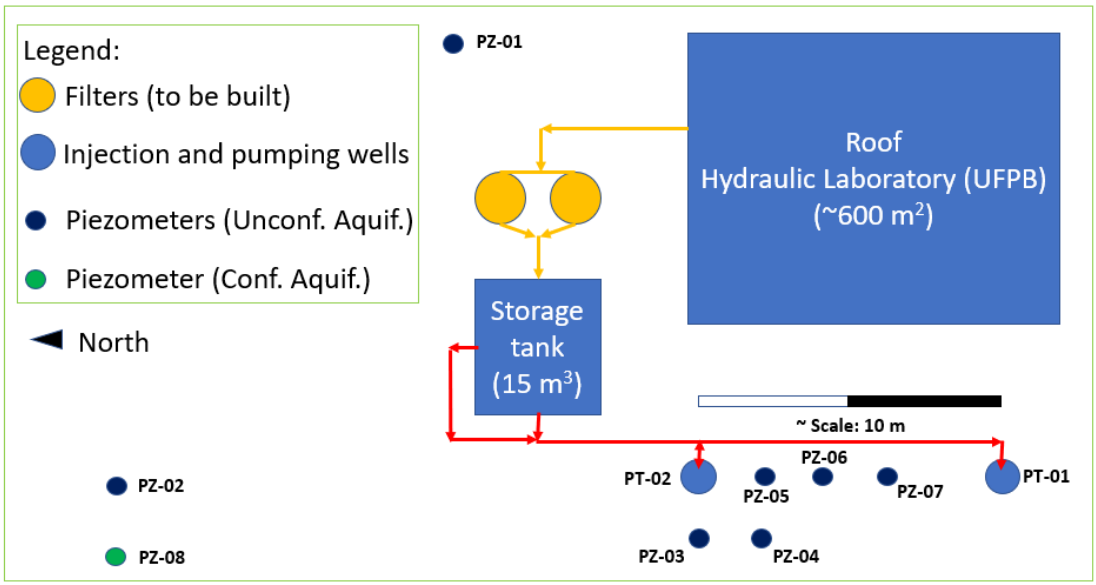

Figure 3. Layout of the pilot-scale MAR system in João Pessoa

In Figure 4 a schematic overview of the different formations (Barreiras, Gramame and Beberibe) can be seen, together with the information about the soil samples obtained every 2 meters during the drilling process. A detailed schematic cross section was built, as shown in Figure 5.

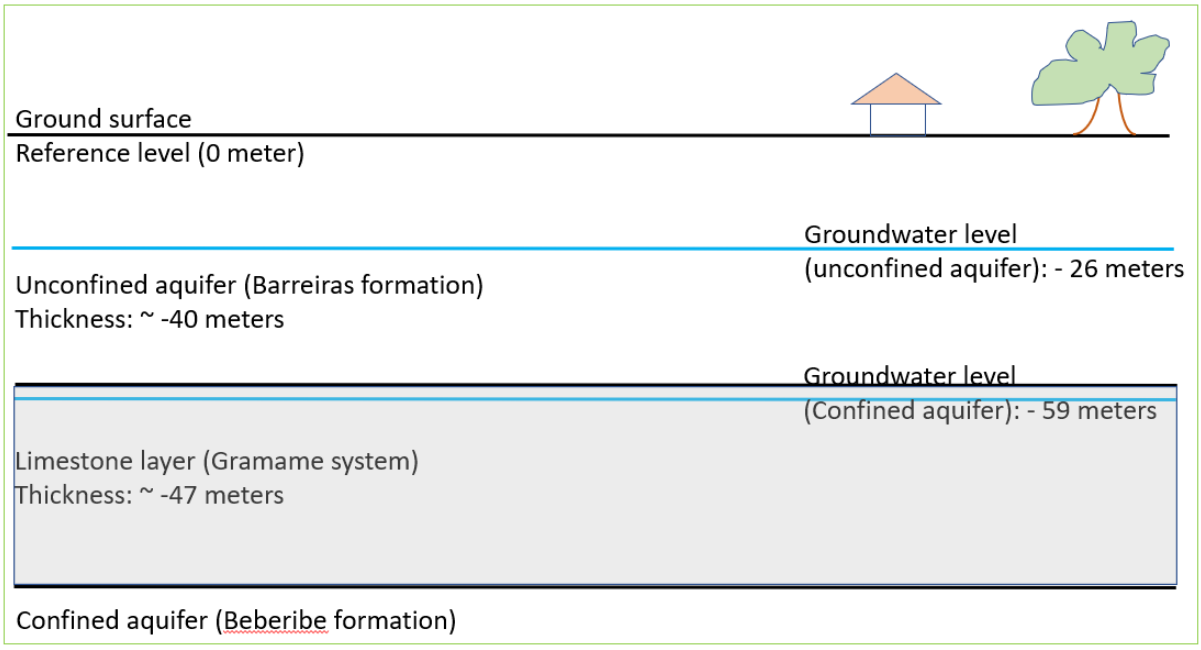

Figure 4. Schematic cross section of the João Pessoa pilot site.

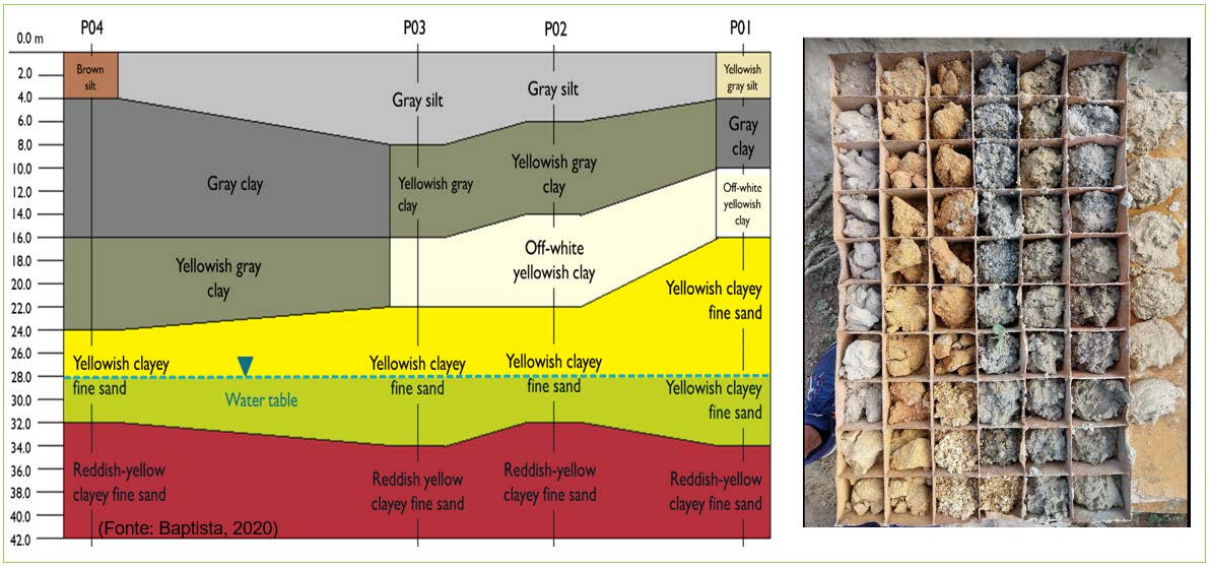

Figure 5. Detailed cross section (direction: North-South) of the João Pessoa pilot site and collected samples (every 2 meters).

2.3 MONITORING SYSTEM SETUP

The monitoring system was developed and installed by Ampeq (http://ampeq.ch/pt/), a company with more than 10 years of experience in water resources monitoring systems. The monitoring system was installed to obtain data from the groundwater level in the two wells (pumping and injection), the 7 piezometers, the pumping flow rate, the atmospheric pressure, and the storage tank water level. Every part of the pilot scale system has a probe for monitoring how the water flows from one point to other during the pumping and injection tests. These probes are connected to a central system that collects levels and flow rates, sending it to a database provided by Ampeq. The monitoring time step can be easily changed and set to one minute or other time steps before and/or after infiltration or pumping tests. The communication between the central system and database is based on a Wi-Fi connection. Ampeq provides a home page with information about the monitoring data that can be seen in real time. The first address is http://ampeq.net/graf/est_ufpb.php, where all data can be seen in just one chart. The second one is http://ampeq.net/graf/est_mini_ufpb.php, and every part of the system can be seen separately (Figure 6). Besides that, the data can be downloaded from the Ampeq home page. The João Pessoa pilot scale data was also included in the monitoring tool of the web-based INOWAS platform (www.inowas.com, Deliverable 4.2, see http://smart-control.inowas.com/wp-content/uploads/2020/06/SMART_Control_D4_2.pdf), which was implemented during the SMART-Control project (Figure 7).

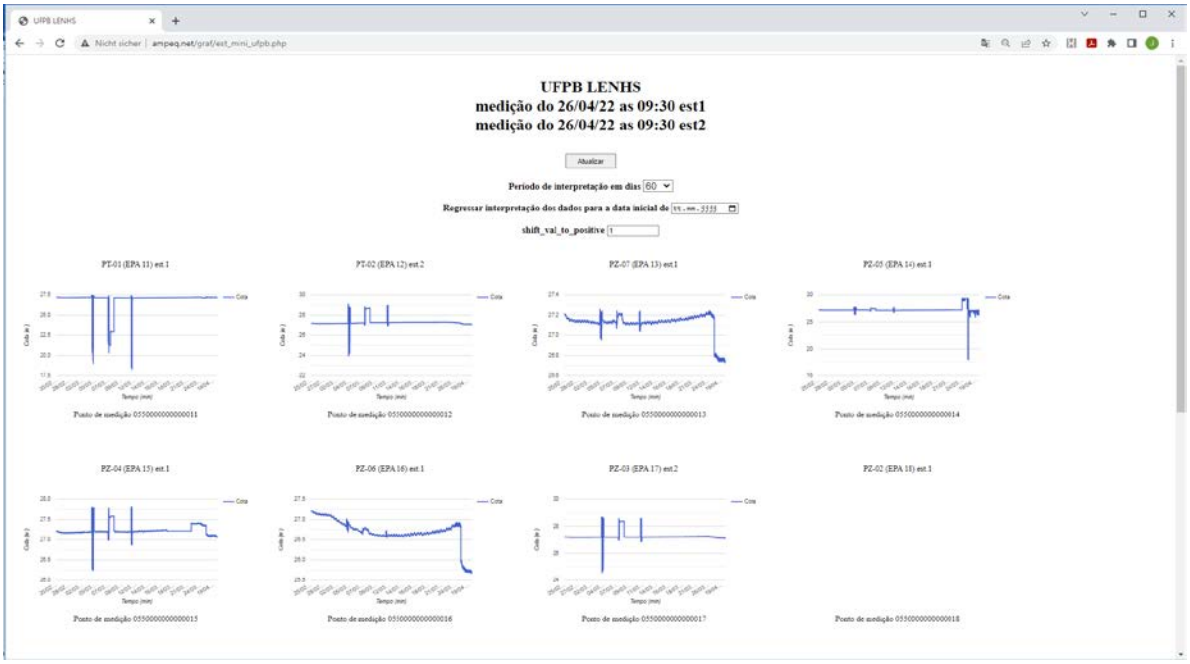

Figure 6. Screenshot of the AMPEQ web interface including monitoring data from the João Pessoa pilot site between the 25th February and 26th April 20222.

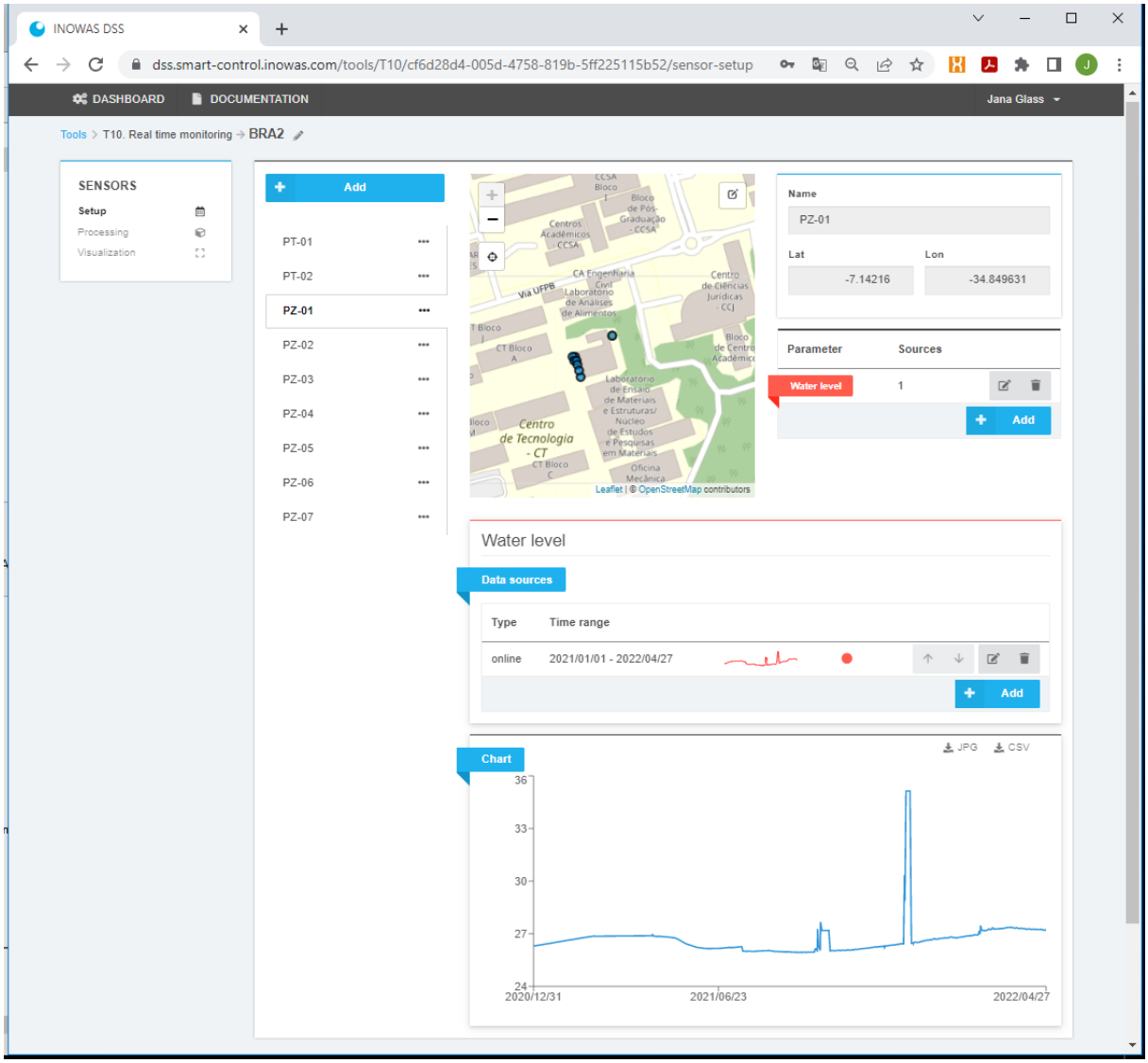

Figure 7. Screenshot of the web-based INOWAS platform showing monitoring well PZ-01 at the João Pessoa pilot site.

3. FIRST INJECTION AND PUMPING TEST

On 14th December 2020, the first injection and pumping tests were carried out. In order to avoid the influence of changes on the groundwater level, one day before the test, the storage tank was filled with groundwater from the pumping well PT-02. The first test was an injection of water into PT-02 and the flow control valve of the storage tank was fully opened in order to have the maximum flow rate. With this test, we found that 15 m³ could be injected in 60 minutes and, of course, the flow rate changes with the storage water level, but this flow rate and water level were not monitored in the first test. As can be seen in Figure 8, all the wells and piezometers presented head pressures changes. The monitoring time step during these tests was one minute.

After that, we waited just some few minutes until the complete groundwater level reestablished after the pumping test. After approximately 60 minutes, 15 m³ storage tank was filled.

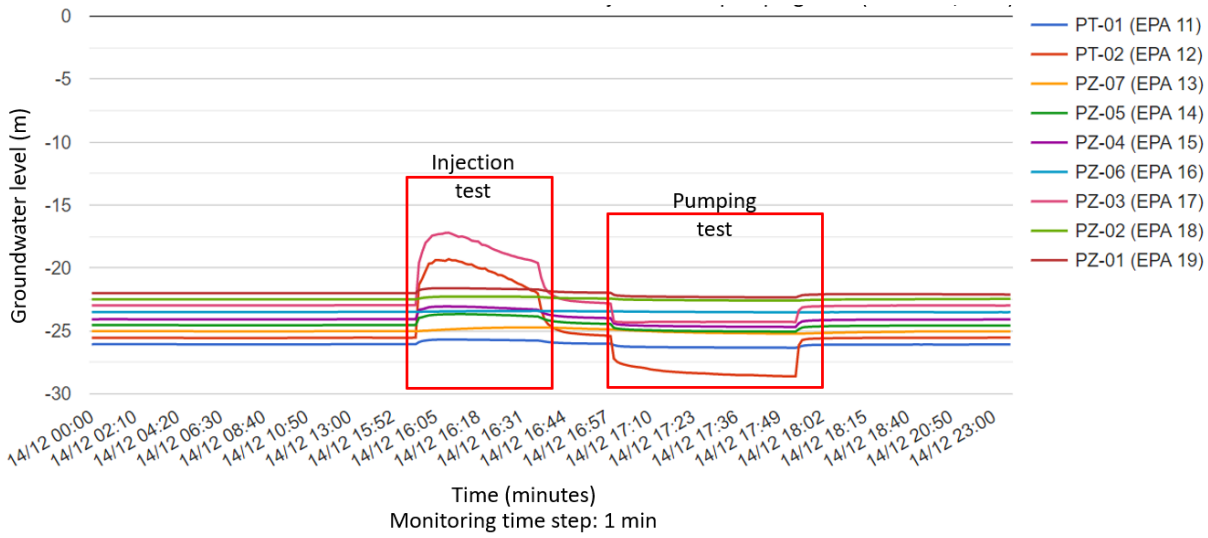

Figure 8. Groundwater level variation during the first injection & pumping tests carried out on 14th December 2020 (Note: groundwater levels were artificially shifted from 1 meter just for better visualization)

4. CONCLUSIONS

This report describes in detail the João Pessoa pilot scale system that was built with support of two research and cooperation projects, the BRAMAR and the SMART-Control projects. Finally, we have an inspiring real Managed Aquifer Recharge case study that can be used as a demonstration site. Sadly, due to the COVID-19, we could not build two parts of the pilot scale: i) the rainfall harvesting system & ii) the system to filter rainfall harvested from the rooftop of the Hydraulic Laboratory. The CODIV-19 pandemic also not allowed the group to carry out a more detailed study on the use of the pilot scale system, which was planned as an activity in the SMART-Control project. Nevertheless, during the SMART-Control project, the pilot MAR scheme was extended by various components such as piezometers and storage tank including an online monitoring system. The online monitoring system is connected to the INOWAS platform, allowing the visualization and processing of the monitoring data. In addition, the time series data can be used in the future in further web-based tools such as groundwater modelling or the heat transport tool.

The site is equipped with an online monitoring system that is connected in real-time with the SMART-Control / INOWAS platform. The report demonstrates the integration of small-scale, pilot MAR schemes into the web-based MAR modelling platform. Technical risks associated with the operation of the scheme can be thus addressed easily in the future once both unconfined and confined aquifers have been monitored since December 2020.

This pilot scale system plays an important role for the groundwater monitoring system of João Pessoa city and region. There is a lack of information on groundwater, mainly due to the lack of a monitoring network. With this pilot site, both unconfined and confined aquifers, will be monitored during the next years.

The report demonstrates the integration of a small-scale, pilot MAR schemes into the web-based MAR modelling platform. Technical risks associated with the operation of the MAR scheme can thus be addressed easily in the future. In addition, the pilot site can be used for demonstration and research purposes to improve the understanding and foster the application of MAR in the Latin American context.

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2. BAPTISTA, V. S. G. Performance of different configurations of rooftop rainwater harvesting used for managed aquifer recharge: a stormwater management approach in an urbanized area. 2020. Dissertação (Mestrado em ENGENHARIA CIVIL E AMBIENTAL) - Universidade Federal da Paraíba.

6. ANNEX I – WELLS AND PIEZOMETER PROFILES

In the next figures, detailed information about lithological and constructive profiles of wells and piezometers are presented.

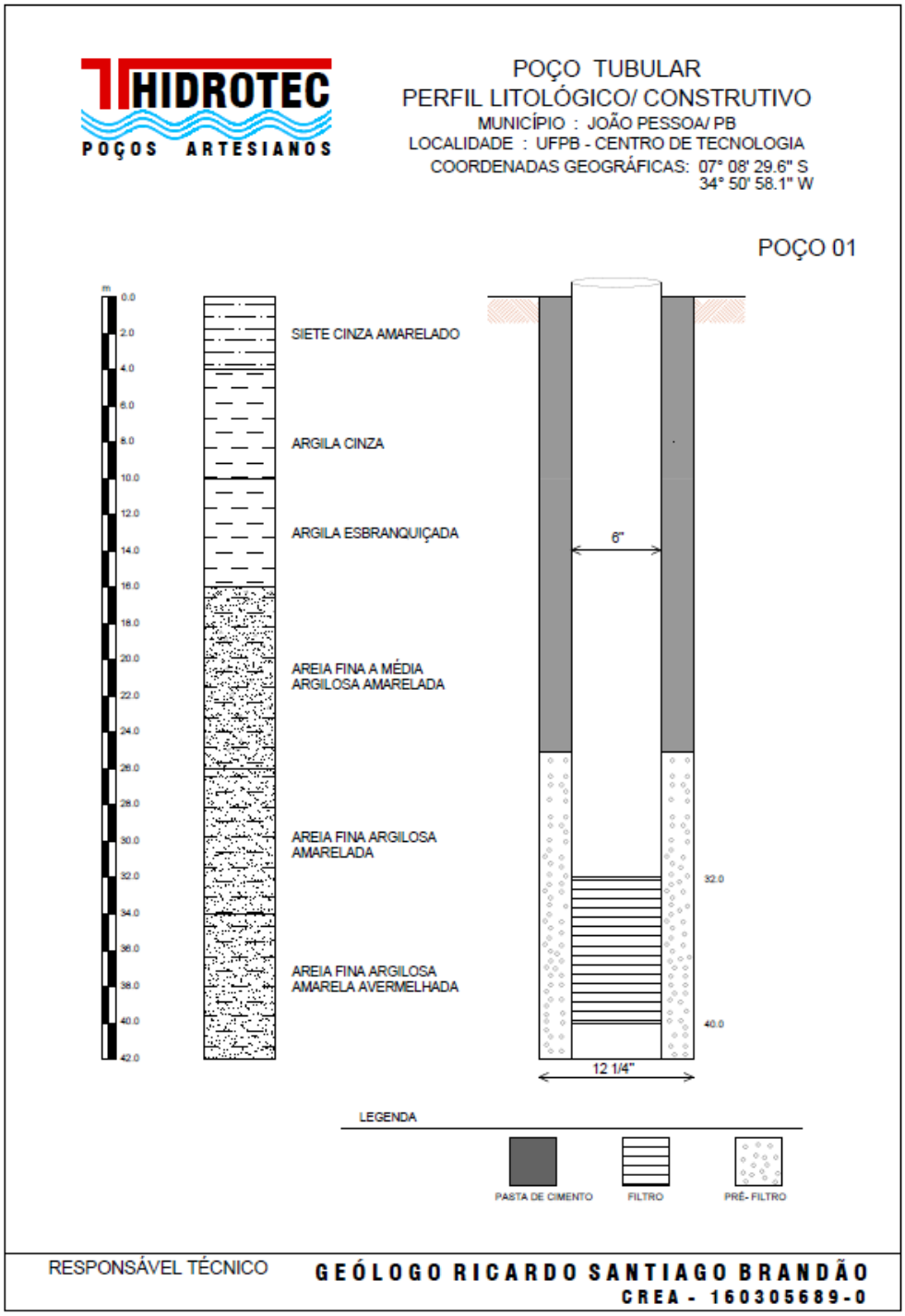

Figure 9. Lithological & construtive profiles – PT-01 (source: BRAMAR project).

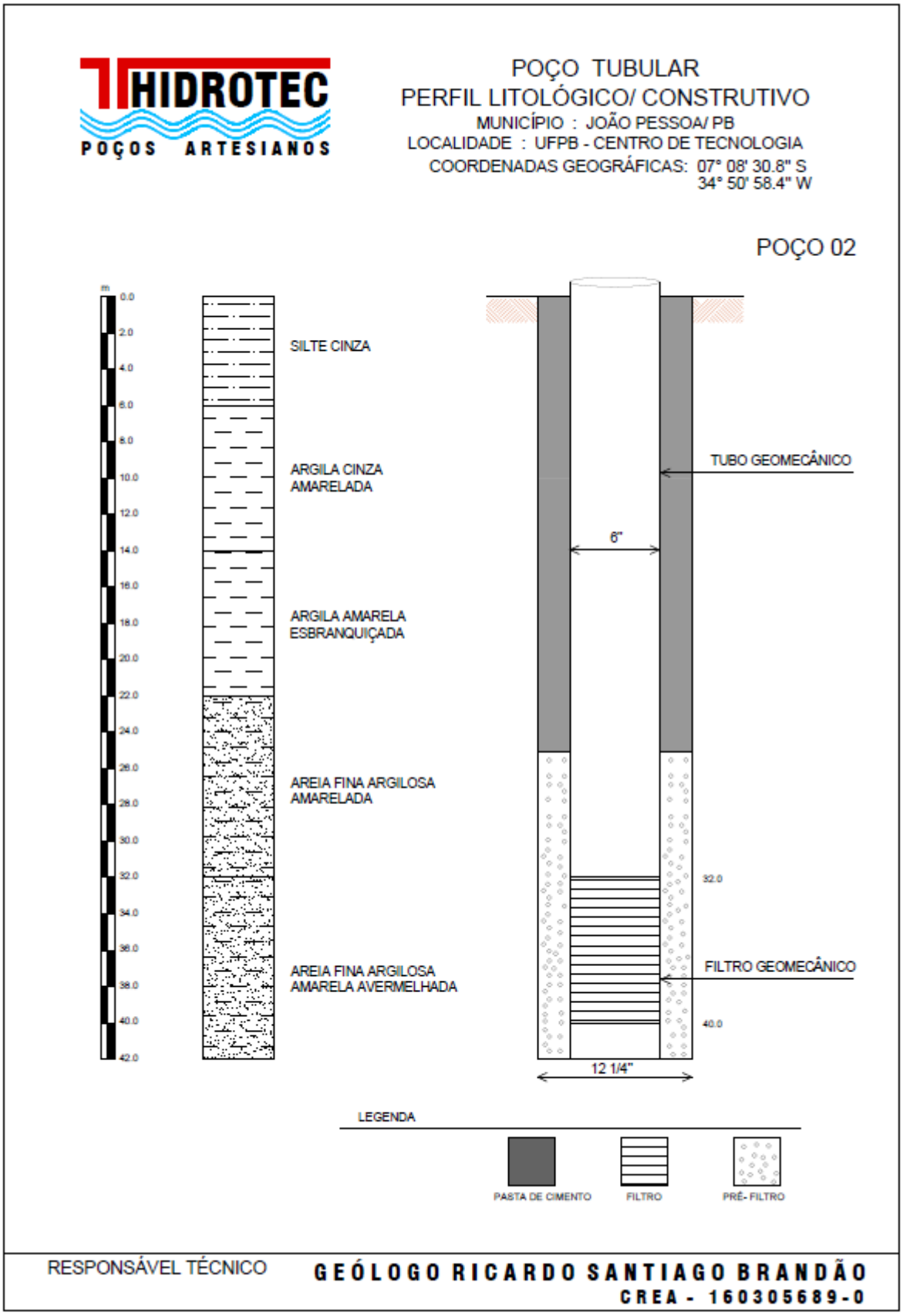

Figure 10. Lithological & construtive profiles – PT-02 (source: BRAMAR project).

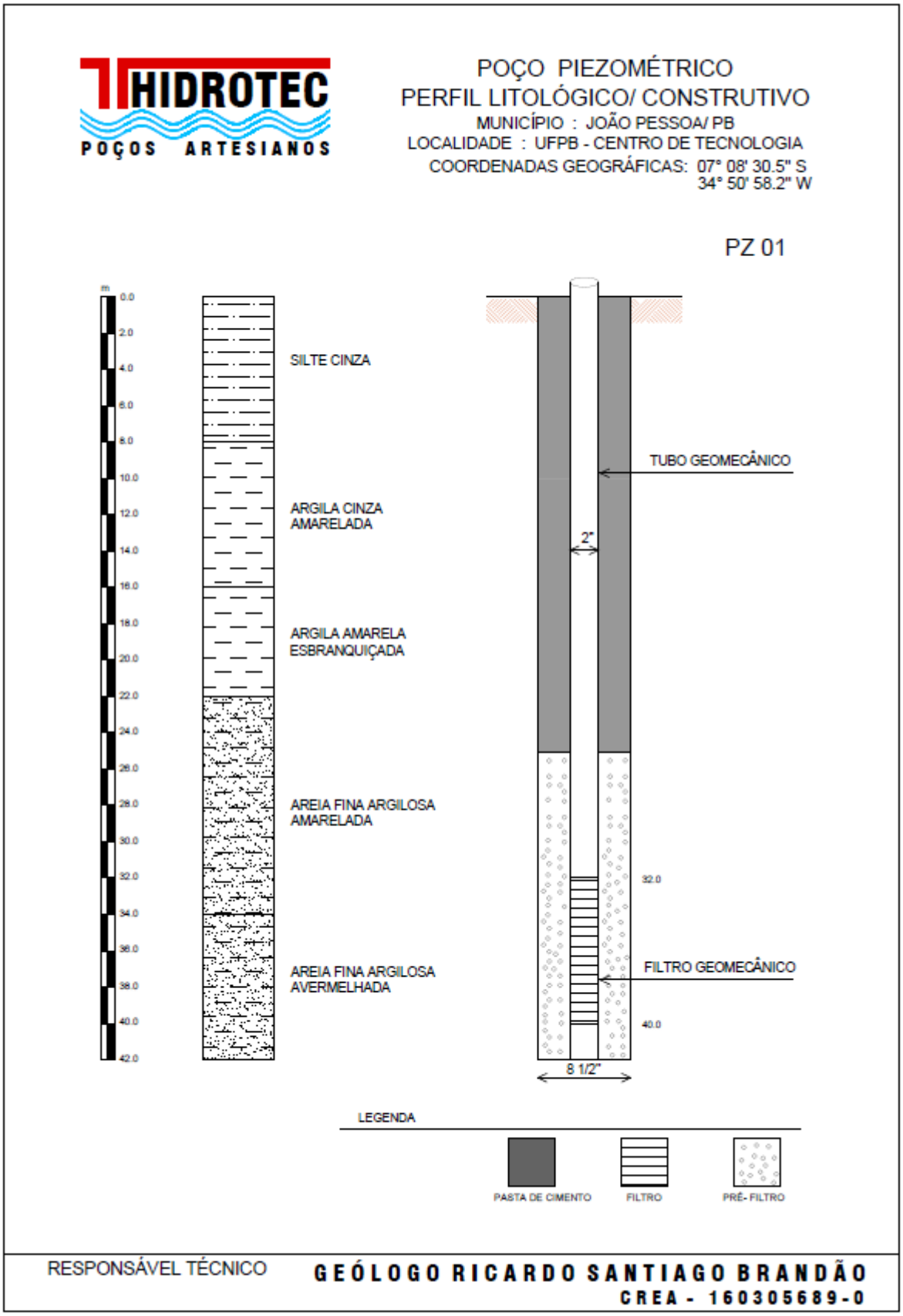

Figure 11. Lithological & construtive profiles – PZ-01 (source: BRAMAR project).

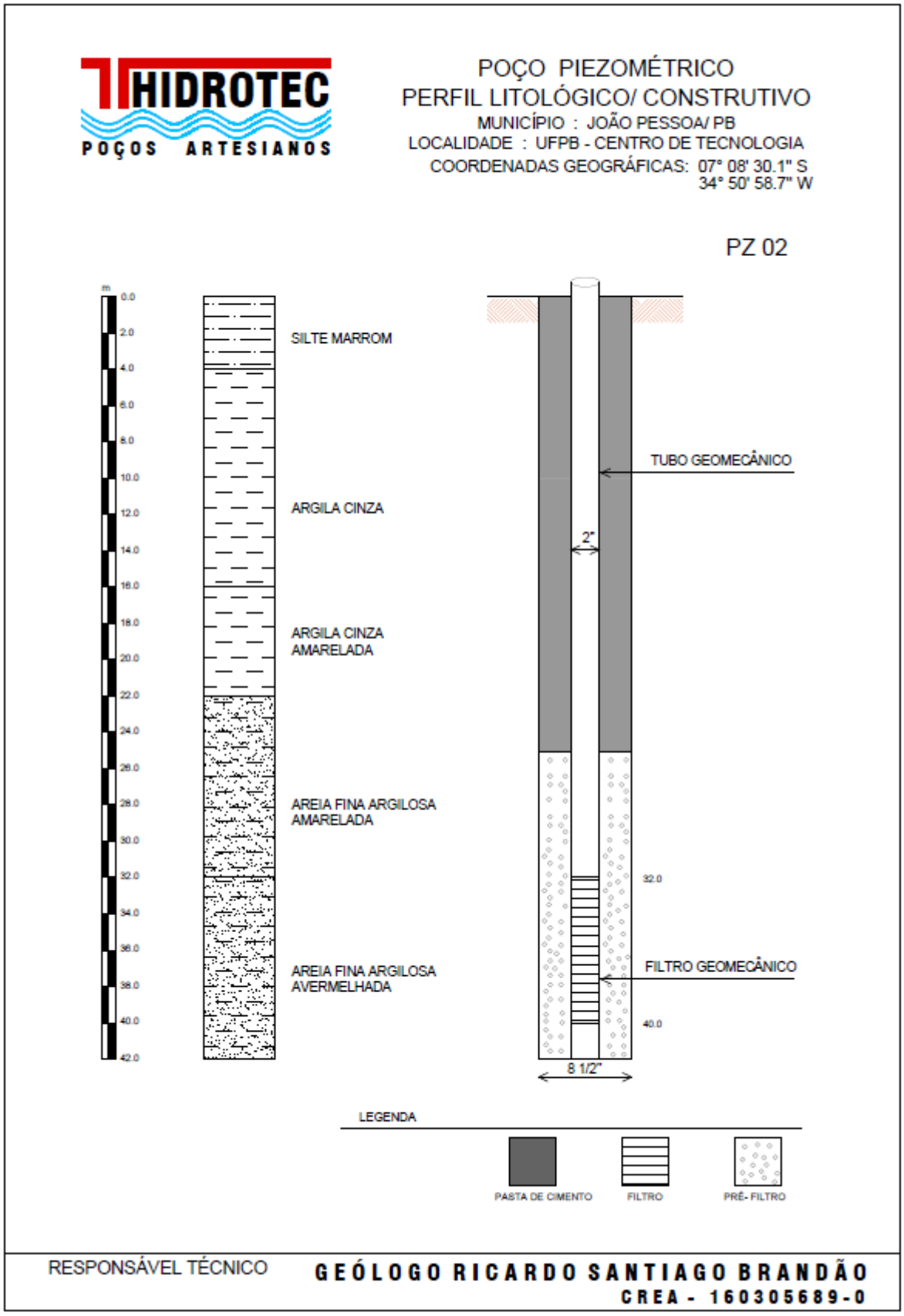

Figure 12. Lithological & construtive profiles – PZ-02 (source: BRAMAR project).

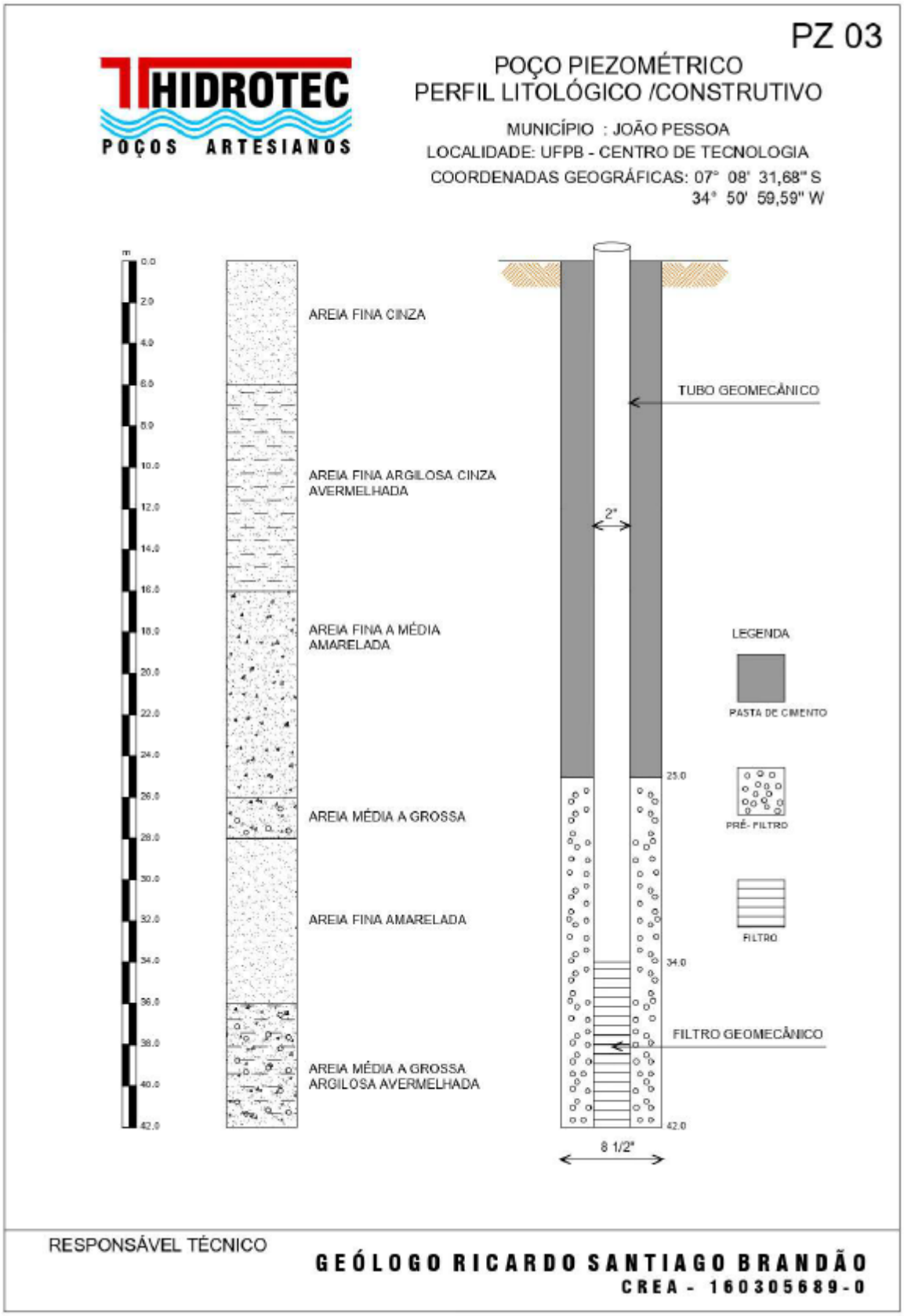

Figure 13. Lithological & construtive profiles – PZ-03 (source: SMART-Control project).

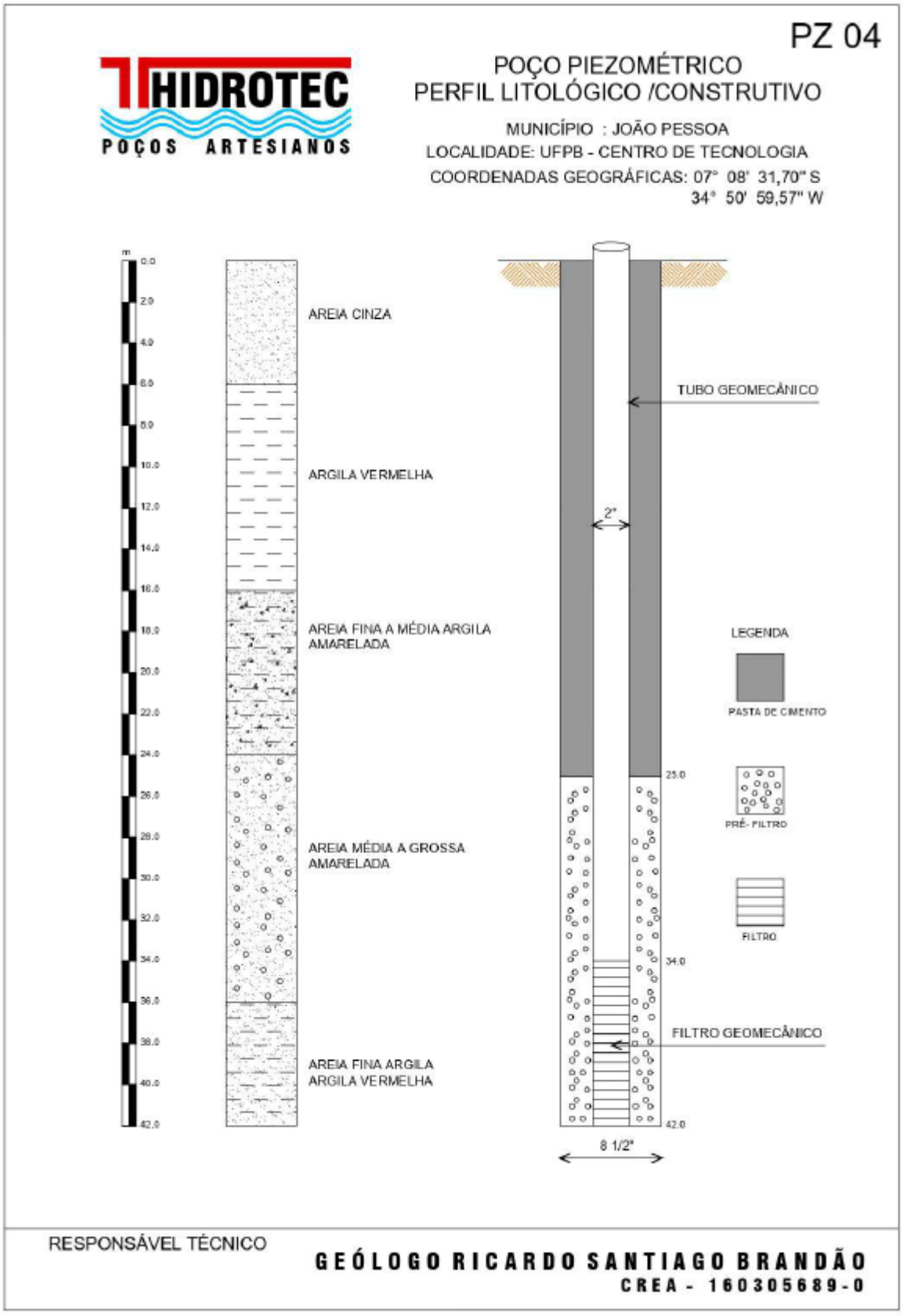

Figure 14. Lithological & construtive profiles – PZ-04 (source: SMART-Control project).

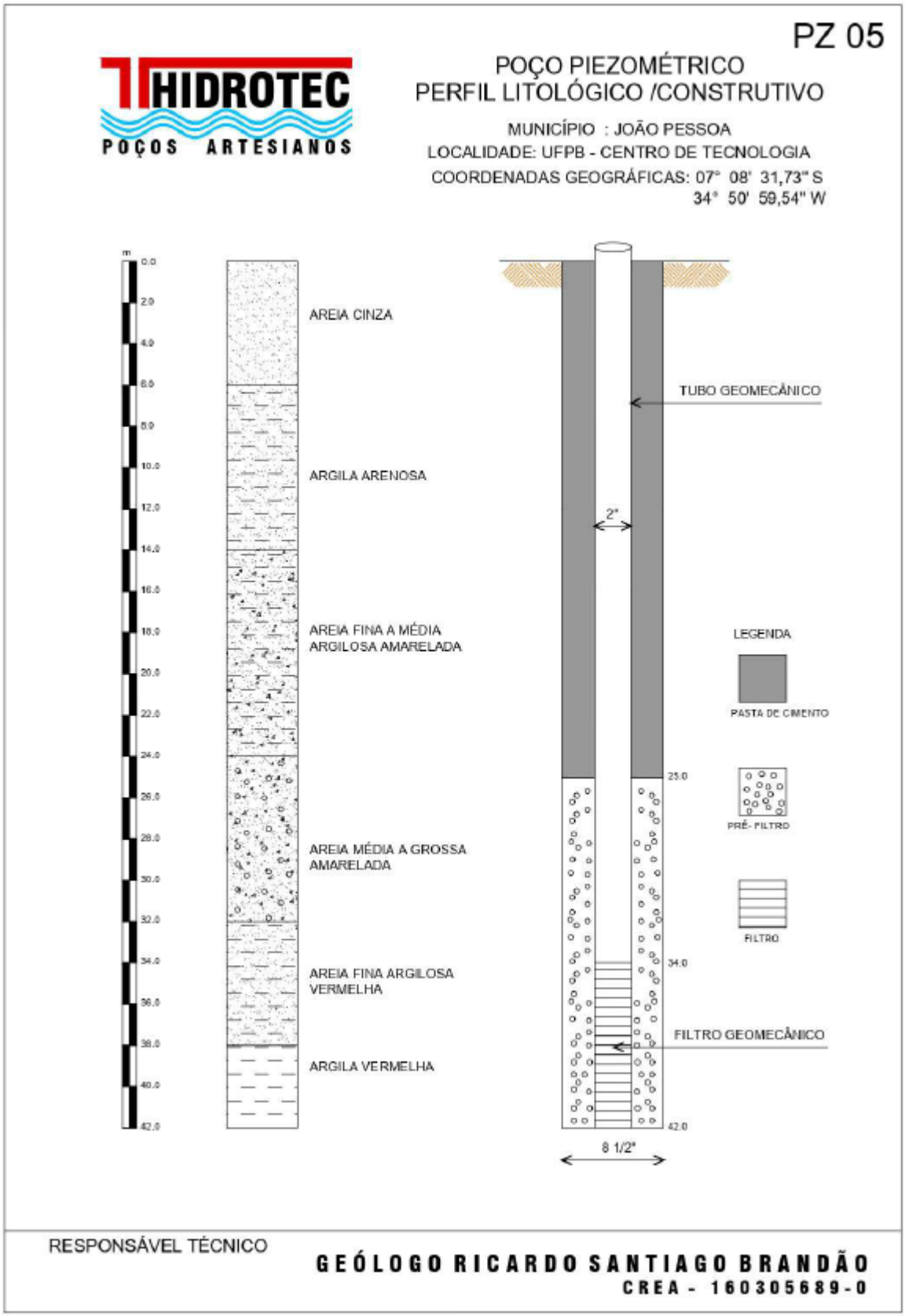

Figure 15. Lithological & construtive profiles – PZ-05 (source: SMART-Control project).

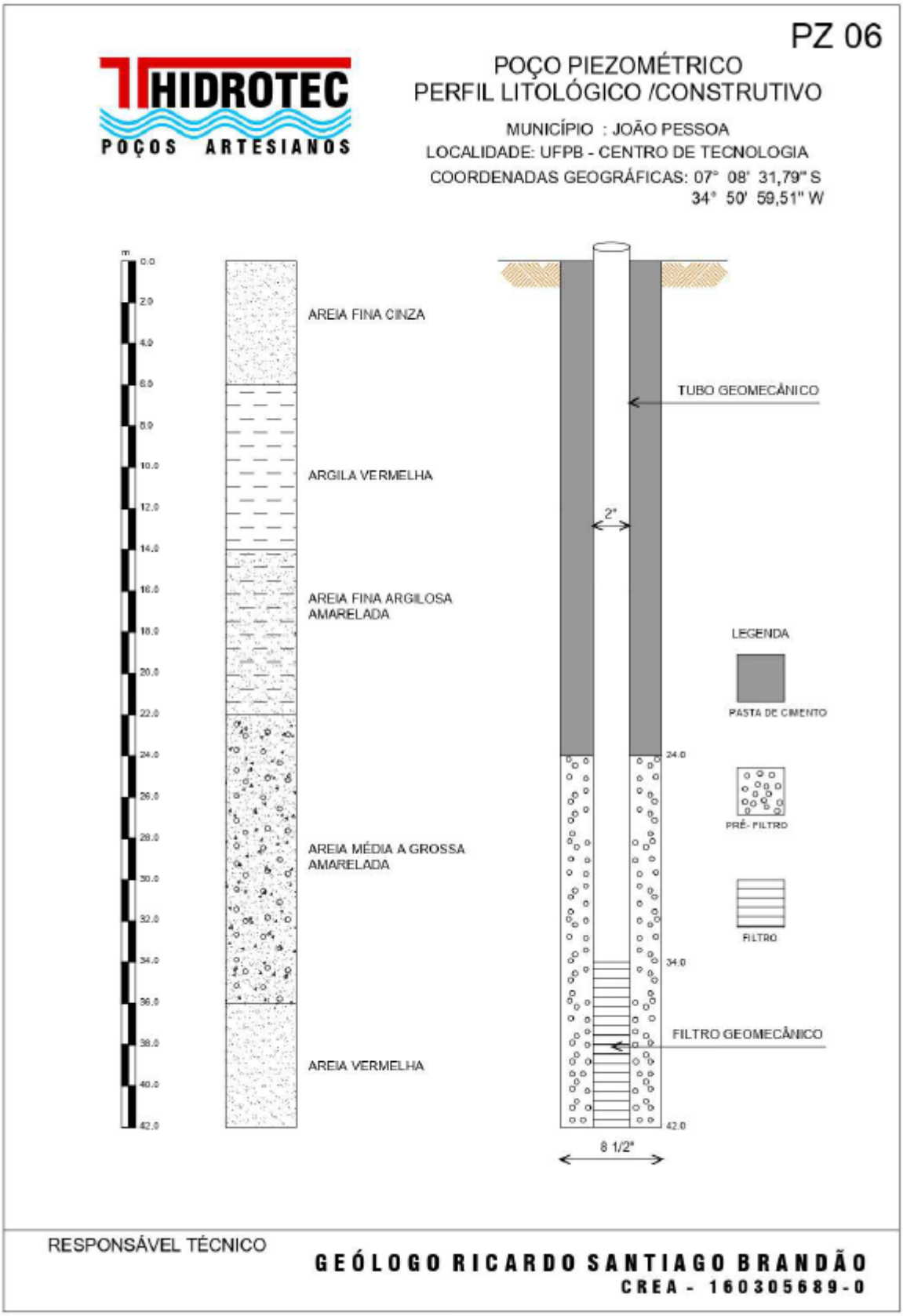

Figure 16. Lithological & construtive profiles – PZ-06 (source: SMART-Control project).

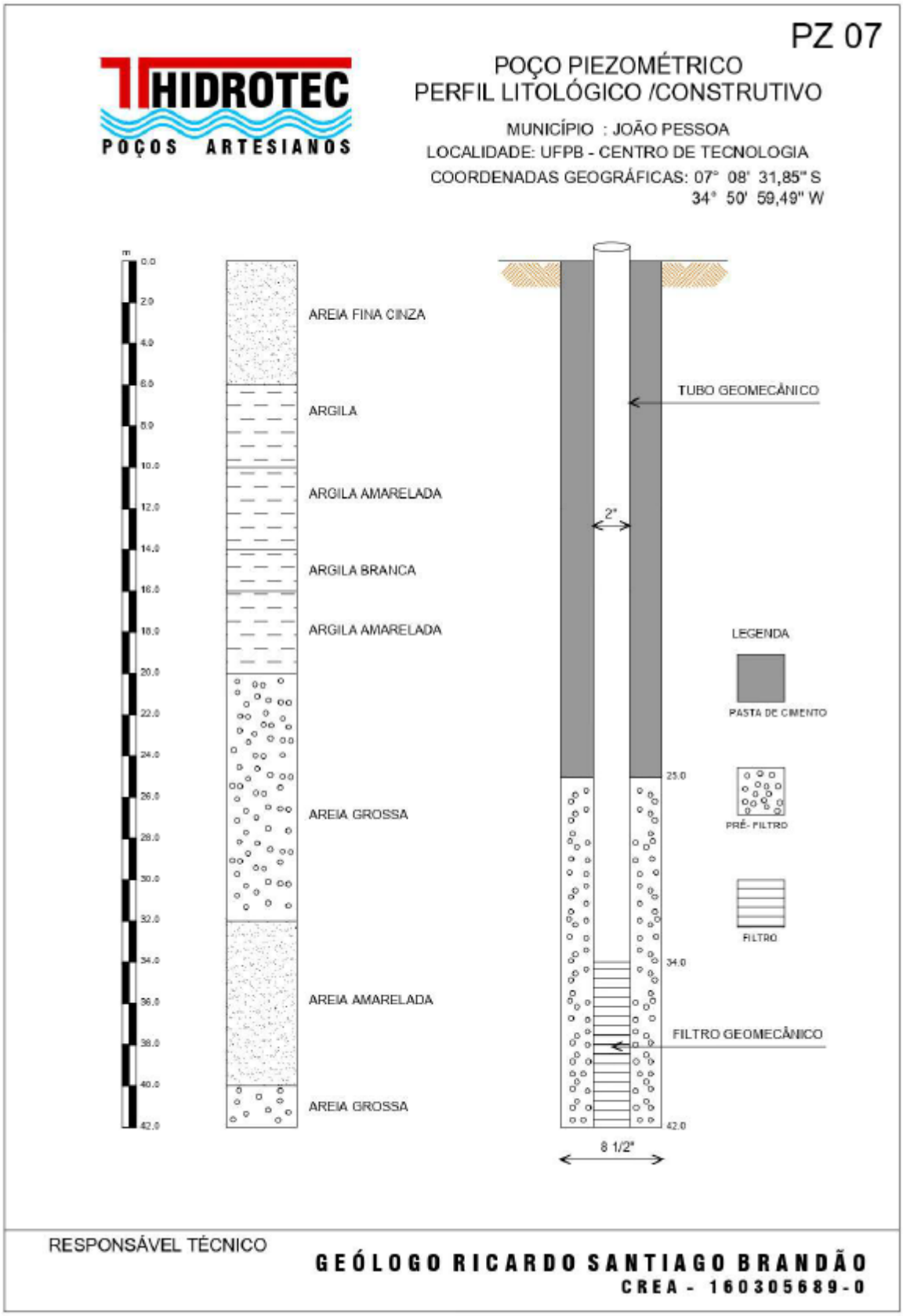

Figure 17. Lithological & construtive profiles – PZ-07 (source: SMART-Control project).

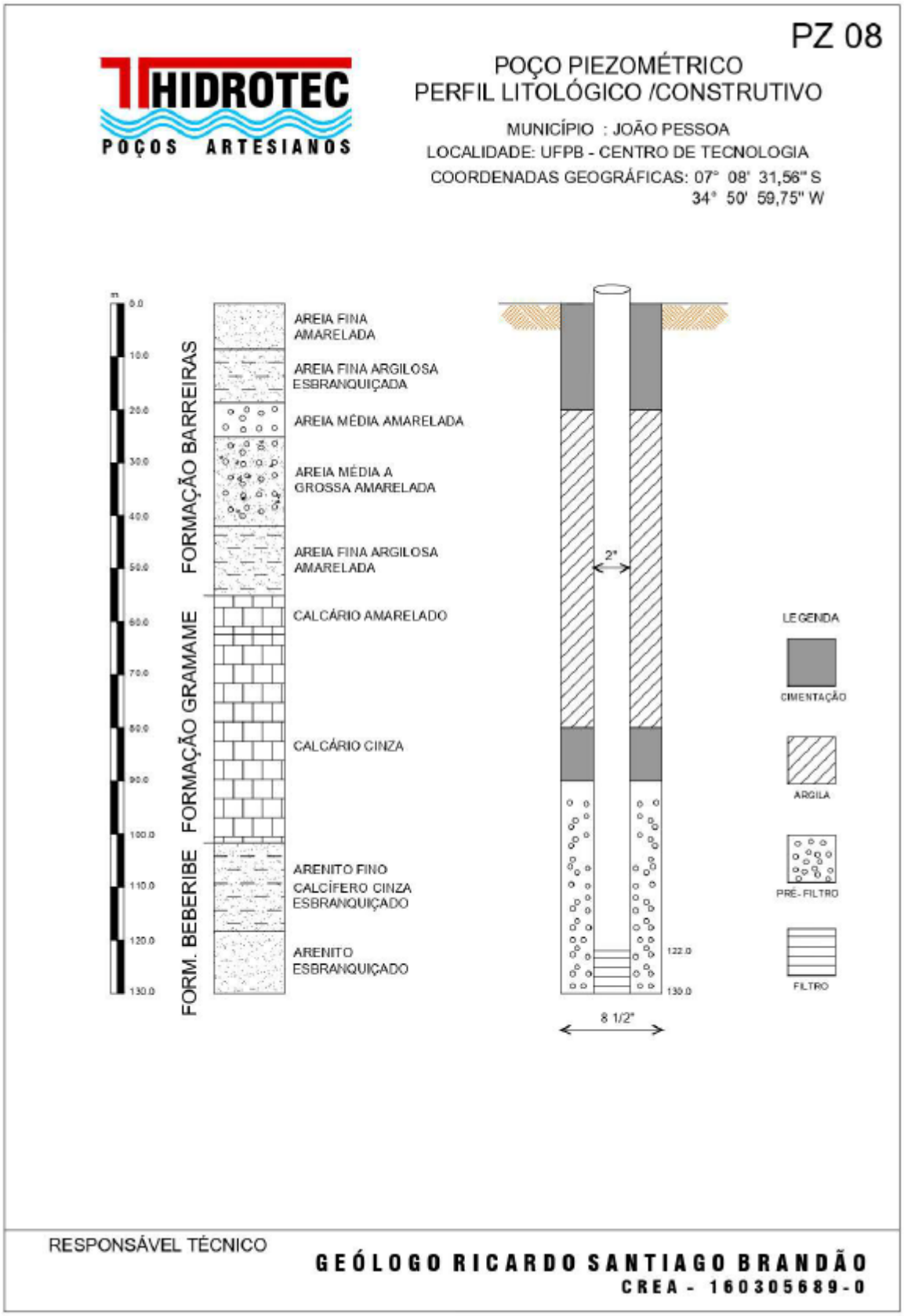

Figure 18. Lithological & construtive profiles – PZ-08 (source: SMART-Control project).

7. ANNEX II – PHOTOGRAPHIC DOSSIER

The whole building of João Pessoa MAR pilot scale system was documented and can be seen in the next photos.

Figure 19. Beginning of the drilling process PT-01 (source: BRAMAR project).

Figure 20. Beginning of the drilling process in the SMART-Control project and pre-existent injection well – PT-01 (source: BRAMAR project).

Figure 21. Drilling process – four new piezometers (source: SMART-Control project).

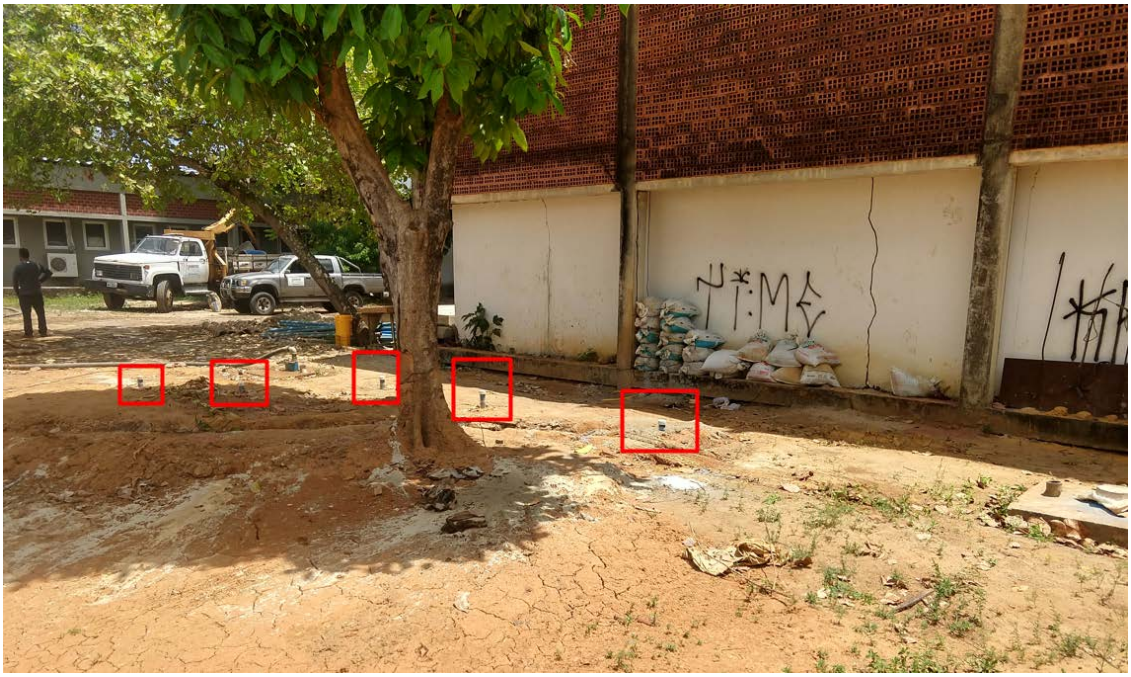

Figure 22. Drilling process – five new piezometers (source: SMART-Control project).

Figure 23. Drilling process – Soil samples and geomechanical tubes (source: SMART-Control project).

Figure 24. Drilling process – last two piezometers PZ-07 and PZ-08 (source: SMART-Control project).

Figure 25. Drilling process – Installation of hydraulic facilities including storage tank (source: SMART-Control project).

Figure 26. Drilling process – installation of pumping automation control & Ampeq monitoring system (source: SMART-Control project).

Figure 27. Drilling process – installation of tubes for Ampeq monitoring system (in red) and piezometers and well protection (source: SMART-Control project).

Figure 28. Drilling process – Pumping well and flow control valve (source: SMART-Control project).

Figure 29. Drilling process – Conclusion of pumping and injection wells and piezometers (source: SMART-Control project).

Figure 30. Drilling process – João Pessoa pilot scale overview after conclusion (source: SMART-Control project).