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MASTER DISSERTATION

GPR application for locating and mapping water conduits in Utinga State Park, Belém-PA.

HEVERLYN DYANNE TELES DE MIRANDA

Belém-PA
2019

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Advisor: Dr. Marcos Welby Correa Silva

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RESUMO

Este trabalho de pesquisa apresenta os resultados de um levantamento geofísico de GPR realizado para avaliar a existência de adutoras na área do Parque Estadual do Utinga. Requisitados pela Companhia de Saneamento do Pará (COSANPA), os dados utilizados neste estudo foram adquiridos durante seis dias de trabalho de campo e processados utilizando o software REFLEXW. Foram obtidos radargramas de alta resolução que apresentaram fortes reflexões hiperbólicas, o que resultou na identificação precisa das posições e profundidades das adutoras que foram encontradas. As interpretações resultantes deste trabalho foram corroboradas pela escavação posterior desses objetos mostrando a eficácia da aplicabilidade do GPR para esta área.

Palavras-chaves: GPR. Adutora. Utinga.

ABSTRACT

This research presents the results of a GPR geophysical survey carried out to evaluate the existence of water conduit in a Utinga State Parkthe area. Requested by the Pará Sanitation Company (COSANPA), the data used in this study were acquired during six days of field work and processed using the REFLEXW software. High resolution radargrams were obtained that presented strong hyperbolic reflections, which resulted in the precise identification of the water conduits positions and depths that were. The interpretations resulting from this work were corroborated by the posterior excavation of these objects, showing the GPR applicability efficacy to this area.

Keywords: GPR. Water conduit. Utinga.

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1 INTRODUÇÃO

O Radar de Penetração no Solo (Ground Penetrating Radar - GPR) é um método geofísico que faz uso de pulsos eletromagnéticos de alta frequência (de 50 a 1600 MHz) que são transmitidas ao solo, onde a velocidade de propagação depende das propriedades elétricas dos materiais em subsuperfície e suas variações fazem com que parte do sinal transmitido seja refletido, podendo ser detectado na superfície onde é amplificado, digitalizado e armazenado, para posteriormente ser processado e transformado em registro (radargrama), e por fim, fornecer informações em forma de imagens sobre a subsuperfície. Por ser um método de alta frequência, o GPR proporciona um imageamento com melhor resolução entre outros métodos geofísicos de superfície rasa.

O GPR foi utilizado neste trabalho por permitir a execução de perfis contínuos, de alta resolução, facilidade na aquisição de dados e por ser um método não invasivo, possibilitando sua aplicação inclusive em áreas urbanas, como foi o caso deste trabalho em que foi necessário realizar alguns dos perfis em uma área asfaltada.

O objetivo deste trabalho foi empregar o GPR para verificar a existência de adutoras a partir de um centro de distribuição de água chamado Bolonha para a Companhia de Saneamento do Pará (COSANPA), e se comprovada, mapeá-las até o ponto em que a empresa ainda possuía os registros das mesmas, já que uma parte da documentação foi perdida devido a uma troca de funcionários da parte administrativa da empresa.

Os levantamentos foram realizados em 6 dias de trabalho e resultaram em um total de 24 perfis, 5 deles realizados em uma área asfaltada do parque e o restante em uma área de mata fechada. Analisando os radargramas conseguimos mapear uma adutora até uma região que circundava uma grande caixa de concreto, desta caixa de concreto saía outra adutora e a partir de então ambas passam a seguir lado a lado mata adentro em direção a uma segunda caixa de concreto, onde a partir dalí a empresa possuía os registros das mesmas encerrando os levantamentos.

O capítulo 2 deste trabalho é composto pelo artigo produzido a partir dos dados coletados durante este trabalho de campo e o capítulo 3 pelas conclusões finais.

2 GPR APPLICATION FOR LOCATING AND MAPPING WATER CONDUITS IN THE UTINGA STATE PARK, BELÉM-PA.

2.1 ABSTRACT

This research work presents the results of a GPR geophysical survey performed to evaluate the existence of water conduits in the Utinga Natinal Park area. Demanded by the company COSANPA, the data used in this study was acquired during six days of field work and processed using the REFLEXW software. The resulting high-resolution radargrams presented strong hiperbolic reflections at the position and depth of the two found water conduits, which was corroborated by the posterior excavation of these objects showing the effectiveness of the GPR applicability for this area.

2.2 INTRODUCTION

The Ground Penetrating Radar (GPR) is a shallow geophysical method that uses the electromagnetic waves in the radio frequency band to image the subsurface. Changes in the electromagnetic properties of the medium, like the electrical permittivity, causes changes in the propagation velocity of the electromagnetic wave generating the reflections responsible for imaging the subsurface (Baker et al., 2007). As the frequency range of this method is high (15 - 2,500 MHz), it enables higher resolution imaging among other shallow subsurface geophysical methods, like electrical resistivity tomography and seismic refraction.

The GPR method has a variety of applications in different media including rock, soil, fresh water, ice, pavements and structures used extensively to investigate subsurface structures or buried objects in geology, archaeology, civil engineering and environment. It is a geophysical technique of great importance in cases of buried artifacts since this is a non-invasive, relatively inexpensive, precise and quick-viewing method. In addition to being an easy-to-use tool, it can be easily moved around the ground and it is also suitable for surveys in large areas (Sato and Yarovoy, 2008).

Several earlier studies show the GPR effectiveness on the detection of buried objects, for example, Graf (1990) showed a direct GPR identification of gas pipeline leaks, Powers and Olhoeft (1996) compared synthetic GPR signatures for leaking and nonleaking pipes with diverse configurations and Tong (1993) examined the use of GPR for pipe detection.

The main goal of this work was using the GPR method to find and map some water conduit of the Companhia de Saneamento do Pará - COSANPA, which is a water supply and sanitation company based at the Utinga Complex in Belém, the capital of Pará

(Brazil). Initially, we had no prior information on whether or not there was a water distribution network in that location due to the loss of documentation during one of the exchanges of employees in the company's administrative area. The first two profiles were performed covering a larger area in which the probability of finding the target was greater because, nearby, there is a water treatment and distribution station called Bolonha. After finding the first water conduit and its preferential direction, we followed this direction mapping and georeferencing each profile.

Although the site where the GPR surveys were carried out is very conductive, causing the signal to easily attenuate, the results are of great resolution. Because the conductor is made of iron the dielectric contrast between the water conduit and the surrounding medium is substantial which, in turn, causes the amplitude of the reflections from the iron pipe to be outstading. Therefore, accurately locating the position of the pipes became straightforward.

2.3 STUDY AREA

The surveys were performed in the interior of the Utinga State Park located in the northeast of the Pará State, in the municipalities of Belém and Ananindeua. The data were acquired specifically at 2 Lago Bolonha St., in Curió Utinga neighborhood. The main entrance gate of the park is located on João Paulo II Avenue, which can be accessed from Almirante Barroso Avenue. Figure 2.1 is showing the satellite image of the surveyed area.

Figure 2.1: A satellite image of the surveyed area. Source: Google Earth, 2019.

2.4 LOCAL GEOLOGY

The Utinga State Park and the surrounding region are composed of three geological facies: Holocene Alluvium; Coverage detritus from the Late Pleistocene; and Barreiras

Formation (Menezes et al., 2013). In the interior of the park, which corresponds to the area where the study was performed, the Pleistocenic Detrito-Lateritic Coverage predominates with an area of 1,335 hectares (95.7%), followed by the Barreiras Formation with 55 hectares (4.0%) and the Holocene alluvium with 4 hectares (0.3%). In the surroundings, approximately 73.5% of the area (1,583.46 hectares) comprises of Pleistocenic Detrito-Lateritic Coverage and the rest, an area of approximately 560 hectares, presents Holocene Alluvium and Barreiras Formation.

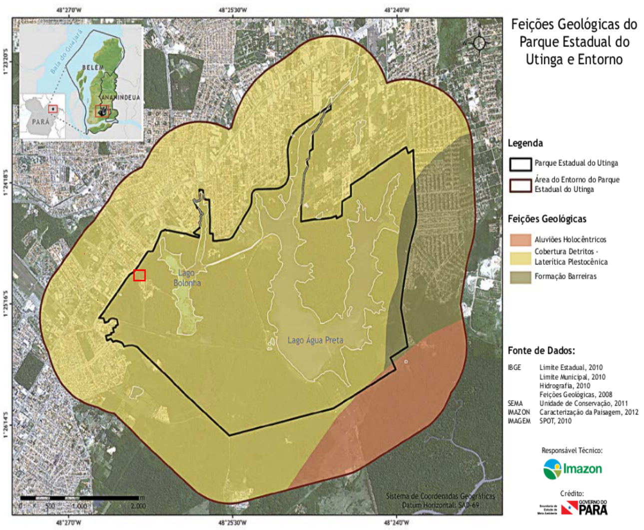

Figure 2.2: Local Geology. The red square corresponds to the especfic area where the study was performed, which corresponds to the Pleistocenic Detrito-Lateritic Coverage

2.5 METHODOLOGY

2.5.1 GPR

The GPR is a geophysical tool composed of two antennas, a transmiter and a receiver. The transmitting antenna is responsible for generating and releasing the electromagnetic wave that eventually will, in the subsurface, be reflected when finding an interface or scattered if a scattering point is reached due to the contrast of the electrical permittivity. The receiving antenna is responsible for recording the returning reflected or scattered energy that is amplified, digitized and stored by the CPU. The resulting signal is processed and transformed into a record called radargram.

Besides the electrical permittivity, there are two other properties that influence the signal recorded by the receiving antenna: the electrical conductivity and the magnetic permeability. These properties influence the propagation of the electromagnetic wave in the subsurface by altering its penetration power. For instance, high magnetic permeability and high electrical conductivity tend to decrease the penetration power of the electromagnetic wave in the subsurface and, consequently, produce poor data with a low penetration depth (Baker et al., 2007).

2.5.2 GPR Geophysical Survey

In this work, the dataset was acquired using the instrument GSSI-SIR 3000 shown in Figure 2.3. The surveys were performed with the 200 MHz antenna, which resulted in a investigation of more than 5 m depth with a great resolution. The acquisition parameters used were: "continuous" mode with a spacing of 20 cm and stacking of 64 times, the time windows were of 120 and 130 ns with a sampling frequency of 1024 MHz and the number of samples was 1024.

Figure 2.3: GSSI-SIR 3000 and antenna of 200 MHz.

The GPR data file was processed using the REFLEXW software (version 7.2.3) of Sandmeier Software aiming to improve the quality and the temporal resolution of the subsurface layers in order to facilitate visualization and interpretation of the data. As the data acquired was of excellent quality, a standart processing flow was applied. The sequence can be visualized in the flowchart below:

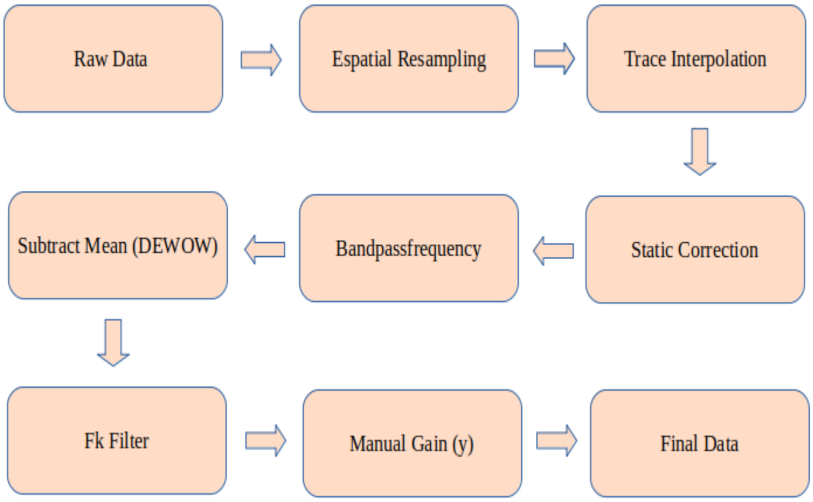

Figure 2.4: Flowchart of the processing sequence used in the data. Source: Author

Before processing the data, there are trhee steps that must be performed for data treatment: Spatial Resampling, Trace Interpolation and Static Correction. The Trace Editing is a time-correction performed to cut the trace intervals relative to data from the same point, that is, the data acquired while the antenna is not moving. After that spatial resampling the data is necessary to correct them to their real lengths (Souza, 2012). The Trace Interpolation aims to normalize the horizontal scale of the profile collected in time mode (Sandmaier, 1998). Finally, the Static Correction is applied on the data in order to remove the air wave effect adjusting the window interval to approximately the main pulse size. These four stages are included in the data preprocessing.

The data processing itself starts with the application of 1-D filters. In this stage two filters were used. First, the bandpass filter (bandpassfrequency) that is applied to attenuate incoherent noise in a given frequency band. To do this, it is necessary to enter cut-off frequency values that will eliminate all frequencies outside this band. Subsequently, the Dewow filter (subtract-mean) was applied to eliminate most of the low frequencies associated with electronic and static noise inherent to the system. An average value is calculated for each trace according to the chosen time window. For the data collected in the area, the used time window was from 8 to 10 ns (Souza, 2012).

After the applications of the 1D filters, 2-D filtering is initiated applying the f-k spectrum filter to attenuate noise from inclined reflectors. This filter performs the Fourier transform of the data from the time-space domain (t, x) to the frequency-wave number domain (f, k) to easily extract dipping events. Once these events are attenuated, the data is converted back into the time-space domain.

Inevitably, after applying all the necessary filters, the signal ends up losing a lot of information, including the ones related to the target of interest. To minimize this effect and to recover the dissipated energy, it is convenient to apply Gain to the signal. In this work, we used Manual Gain in the Time Axis (Manual Gain in Y). The gain in the signal gradually potentiates the contrasts, even those related to low frequency noises (Silva, 2018).

2.6 RESULTS AND DISCUSSIONS

In this section we show the processed and interpreted radargrams collected during the surveys in COSANPA located at Utinga State Park. The data were first collected in an asphalted part of the Park to have a broader view of the possible adductors. Furthermore, we also acquired data inside the forest already having an idea of the possible water conduit direction (information taken from the surveys carried out on the asphalted part). So the profiles are presented and named according to the order of acquisition, from the first to the last acquired profile, and grouped according to the direction of the found water conduits. Figure 2.5 shows an overview of how the profiles were arranged after organizing the data collected during the 6 days of surveying, which resulted in a total of 24 profiles: 5 of them acquired in the asphalted area and the remaining 19 performed in the forest. It is important to emphasize that the profiles made in the forest do not follow any pattern in size (there are profiles between 9 m and 21 m) due to trees, roots and other obstacles, like some small concrete boxes that we have found along the way, so most of the profiles had to be cleaned before the surveys so that roots and leaves could be removed and did not interfere in the final results. Figure 2.6 shows some of the profiles performed in the close forest.

Figure 2.5: A satellite image of the study area showing an overview of the profiles distribution. The profiles are indicated by the yellow straight lines.

Figure 2.6: One of the profiles opened and cleaned in the forest. We can observe the amount of trees and bush around, and therefore, the difficulty in maintaining the pattern in profiles sizes.

Since we had no prior information on whether or not there were water conduits on the study area, Profile 1 and Profile 2 were acquired to cover a larger area to guarantee no loss of important information about any possible buried objects. The two profiles were performed in the asphalted area, at Street Bolonha. The first is 40 m and the second is 30 m, as we can see in Figure 2.7. The correponding radargrams are shown in Figures 2.8 and 2.9.

Figure 2.7: A satellite image of the area where Profile 1 and Profile 2 were placed.

We can observe that the radargram of Profile 1 reveals a strong reflection characterized by the presence of a hyperbola. The reflection in focus may be an indication of the metallic structure that was supposed to be found by this work, the water conduit that belongs to the water and sanitation company COSANPA.

Profile 2 was acquired in a direction almost perpedicular to Profile 1. In this profile, the only important reflection present is the hyperbole's "tail" which corresponds to the same reflection of the water conduit found in Profile 1.

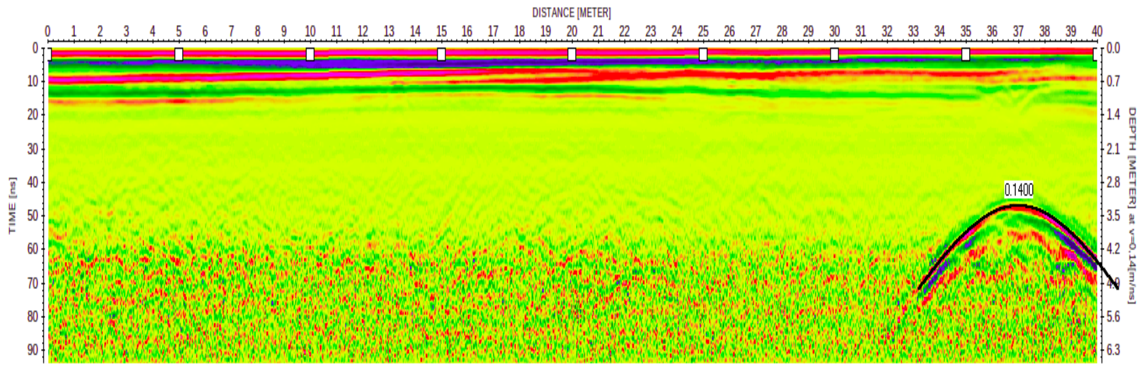

Figure 2.8: The radargram of Profile 1 of 40 m in length.

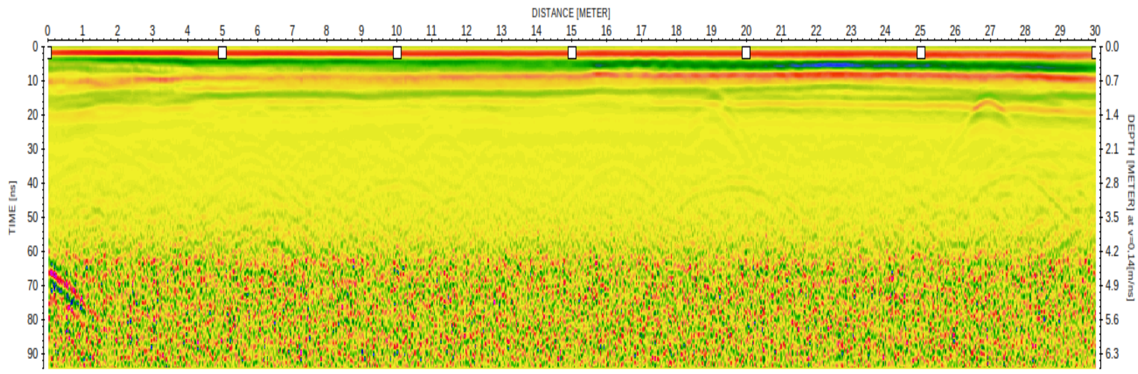

Figure 2.9: The radargram of Profile 2 of 30 m in length.

The next profiles and radargrams will be presented in groups, each group is composed of a certain number of profiles that have in common the direction in which the water conduit is. The first group of profiles is composed of four lines, Profiles 3, 4, 5 and 6. The fisrt three profiles were acquired in the asphalted area to indicate the direction of the water conduit extention and, based on it, to better conduct the rest of the survey within the forest. Figure 2.10 show the display of the three profiles used to find the water conduit direction.

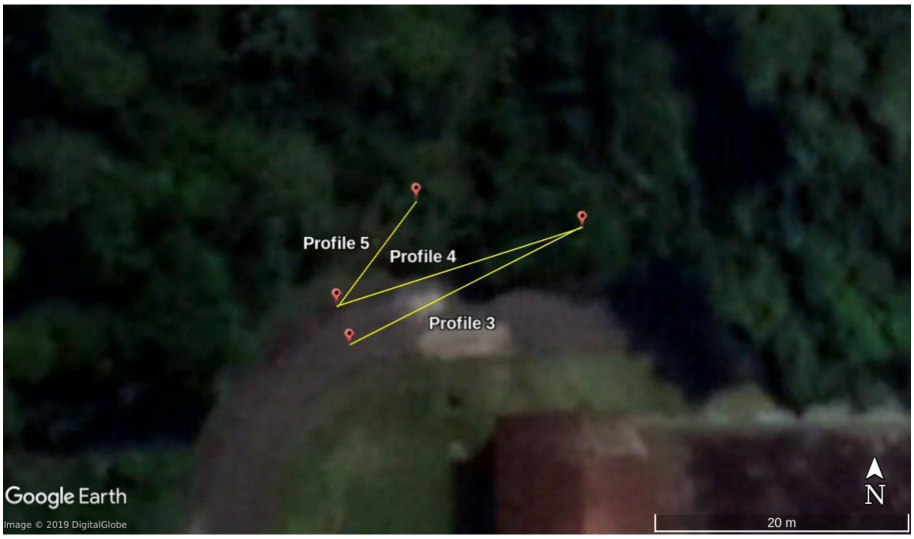

Figure 2.10: A satellite image of the area where Profile 1 and Profile 2 were performed.

The 3 radargrams performed in the asphalted area also reveal a strong reflection characterized by the presence of a hyperbola. To find the possible directions of the water conduit forest inside, we entered the coordinates of the Profiles in Google Earth, in this case, Profiles 3, 4 and 5, and analyzing the radargrams we obtained the distance between the beginning of the profiles and the position of the top of the hyperbola (which indicates the water conduit's center). Then, we highlighted the position of the hyperbola top of each profile using a green marker to finally connect them with a red straight line and better perform the surveys within the forest along this direction, that possibly is the water conduit preferential direction. Figures 2.11, 2.12, 2.13, show their respective radargrams and Figure 2.14 shows the configuration of the green markers and the read line mentioned.

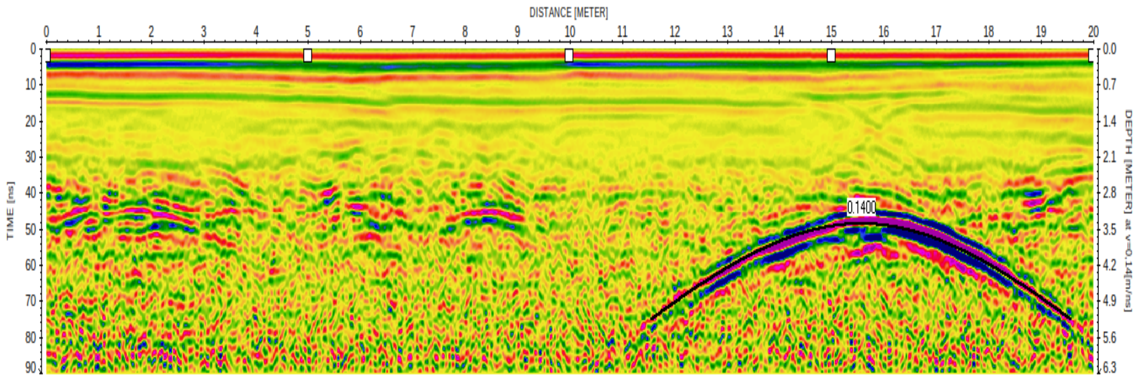

Figure 2.11: The radargram of Profile 3 of 20 m in length.

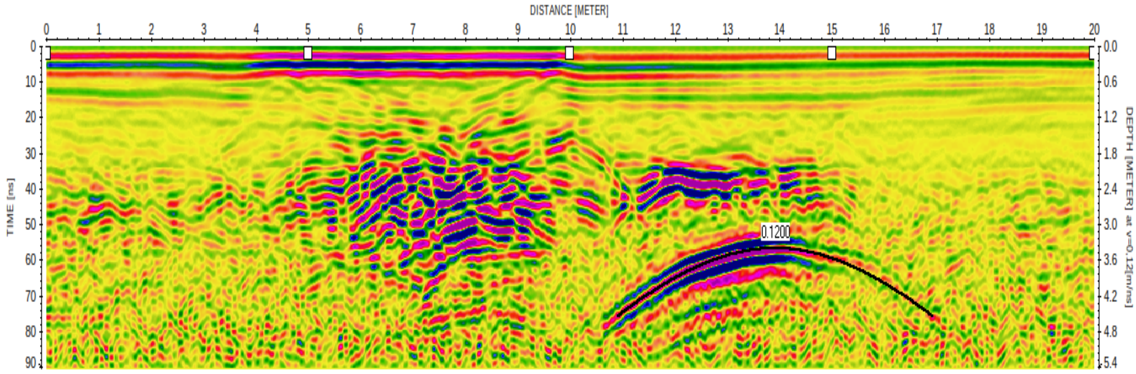

Figure 2.12: The radargram of Profile 4 of 20 m in length.

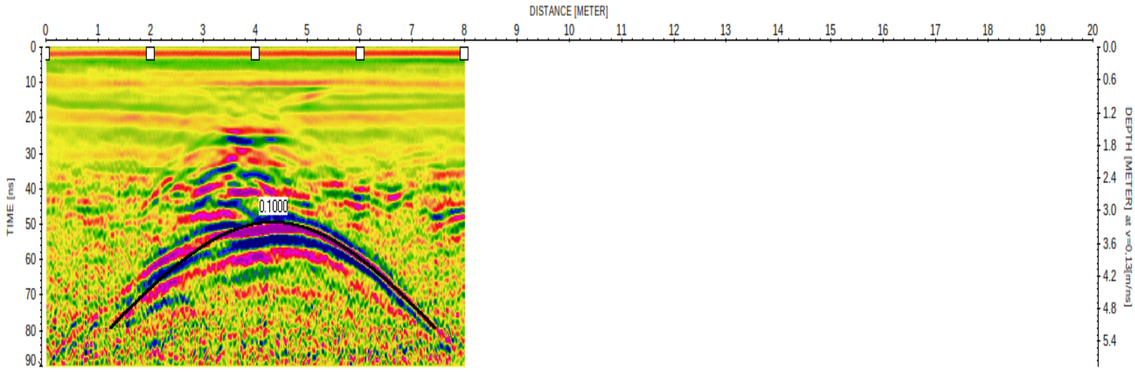

Figure 2.13: The radargram of Profile 5 of 8m in length.

Figure 2.14: A display of the possible direction of the water conduit forest inside (highlighted by the red line), the profiles location (represented by the yellow lines and the red markers) and the position of the top of the hyperbolas (indicated by the green markers).

After finding the water conduit preferential direction, Profile 6 was acquired in the forest, its radargram is shown in Figure 2.15. Notice that all profiles from the first group are presenting a strong reflection characterized by the presence of the hyperbola referring to the buried water conduit and that Profile 6 follows the same direction from Profiles 3, 4 and 5, as we show in Figure 2.16.

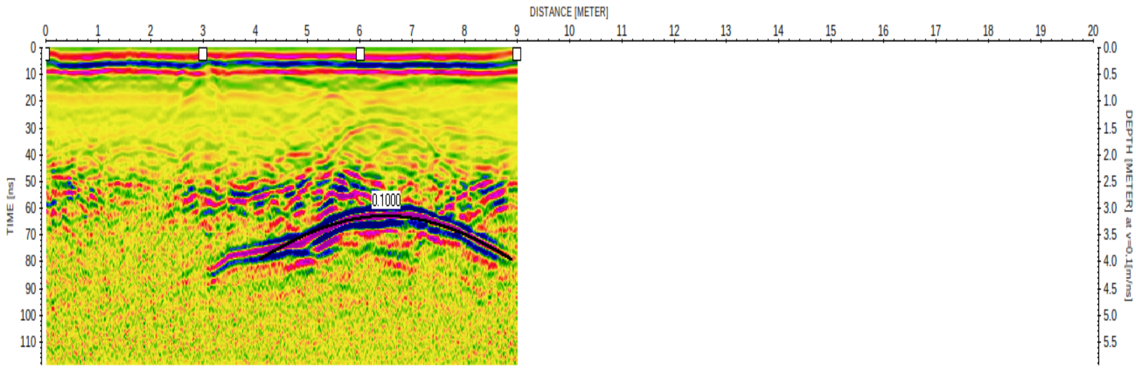

Figure 2.15: The radargram of Profile 6, acquired within the forest, whose length is 9 m.

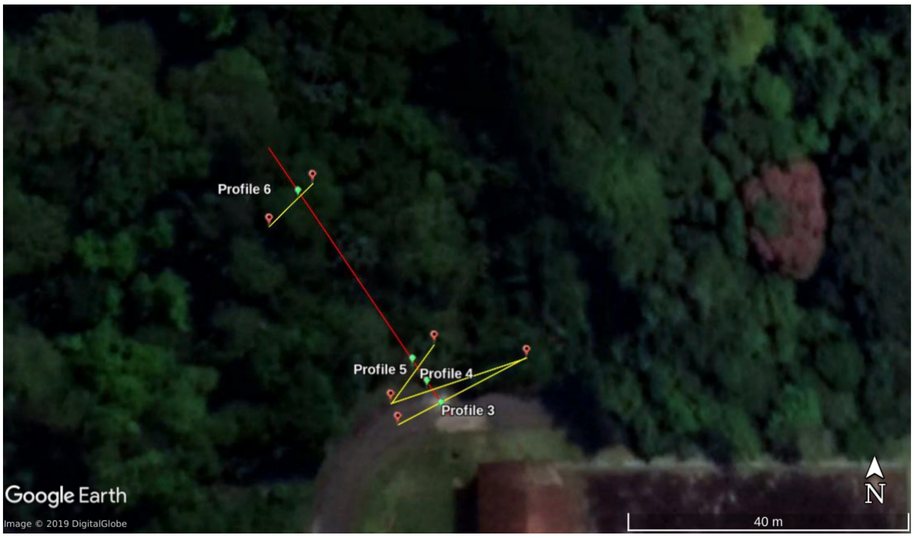

Figure 2.16: A display of the possible direction of the water conduit forest inside (highlighted by the red line), the profiles location (represented by the yellow lines and the red markers) and the position of the top of the hyperbolas (indicated by the green markers).

Besides the profiles presented here, some test profiles were acquired in order to find the new directions that the water conduit makes as we entered the forest. These test profiles are not presented in this work because they are not a relevant contribution to the study of the anomalies interpreted as associated with the water conduits. To each different direction emerges a new group of profiles, such as Group 2 that is composed of three profiles, Profiles 7, 8 and 9. The profiles' position in the forest are shown in Figure 2.17

Figure 2.17: A satellite image of the area where Profiles 7, 8 and 9 were performed. These profiles compose Group 2.

The radargram of Profile 7 of 10 m (Figure 2.18) shows a strong reflection regarding the water conduint as the previous profiles. The radargram of Profile 8 has two differentiated anomalies (Figure 2.19) due to the proximity of a concrete box that we find along the way, the two strong reflections present a hyperbolic shape. The first one (between 0 m and 5 m) is considered to be the influence of a small concrete box that was very close to the profile and the second one (between 5 m and 14 m) is probably referring to the same adductor that appeared in Profile 7. Profile 9 (Figure 2.20) we can observe another strong hyperbolic reflection that we can associate to the adductor, we imagine that the anomaly was presented a little smaller than the others due to the closed angle that the profile cuts the adductor, as we can observe in Figure 2.21 when we draw the new direction that the water conduit does in the forest.

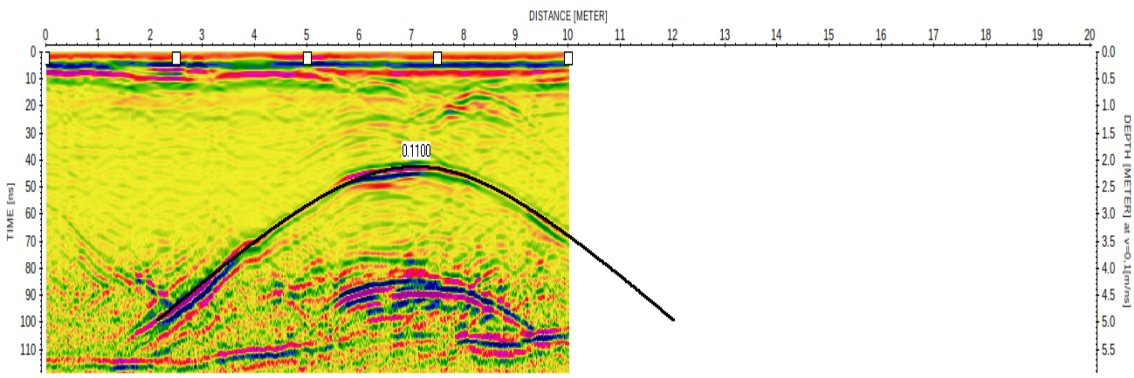

Figure 2.18: The radargram of Profile 7, acquired within the forest, whose length is 10 m.

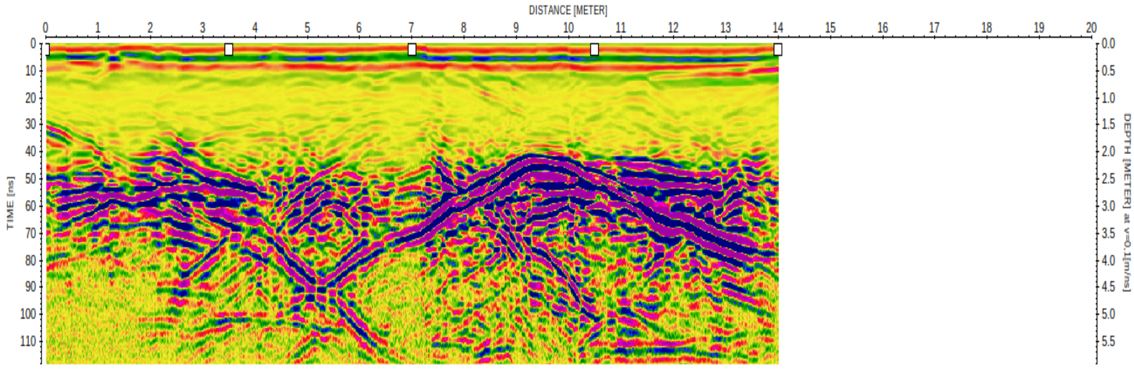

Figure 2.19: The radargram of Profile 8, acquired within the forest, whose length is 14 m.

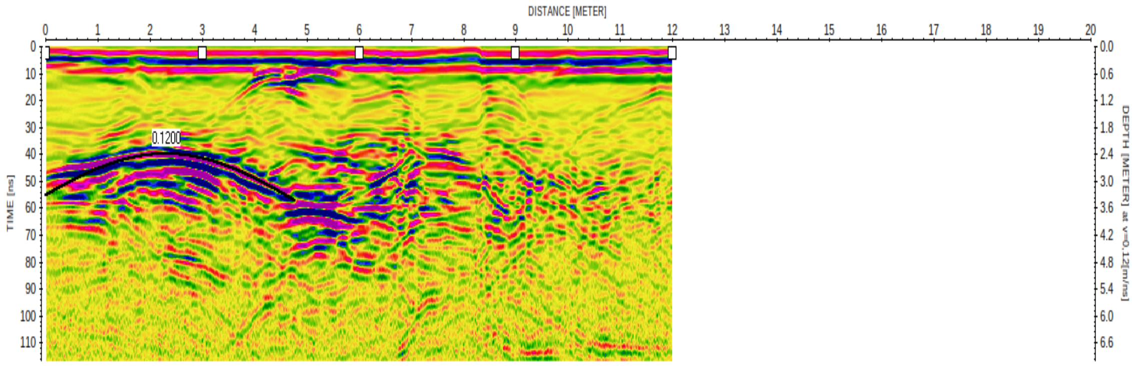

Figure 2.20: The radargram of Profile 9, acquired within the forest, whose length is 12 m.

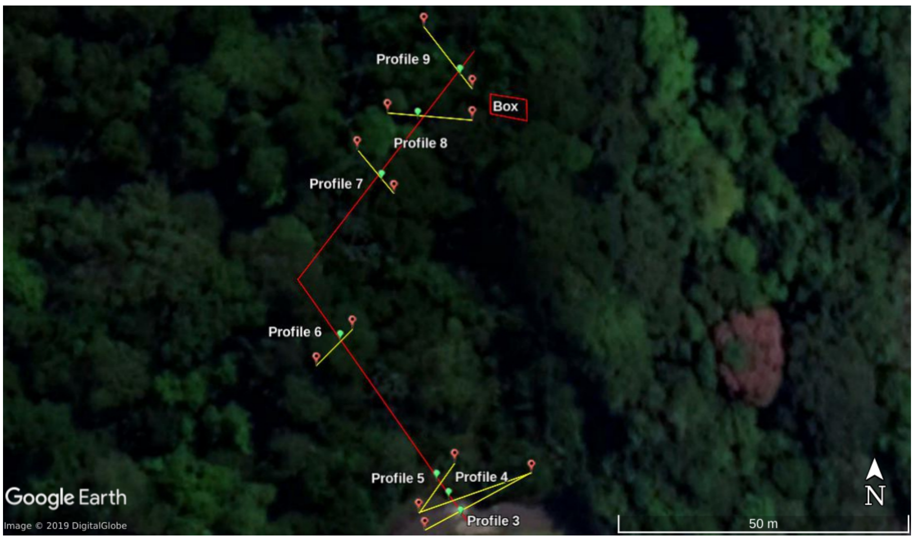

Figure 2.21: A satellite image of the surveyed area showing a change in the water conduit direction determined by the analysis of the profiles composing Group 2. The water conduit direction is indicated by the red straight line, the profiles highlighted by the yellow lines and the red markers, and the position of the top of the hyperbolas represented by the green markers.

Group 3 is composed of 12 profiles in total as shown in Figure 2.22. The radagrams corresponding to these 12 profiles are represented in Figures 2.23, 2.26, 2.28, 2.29, 2.30, 2.31 and 2.32.

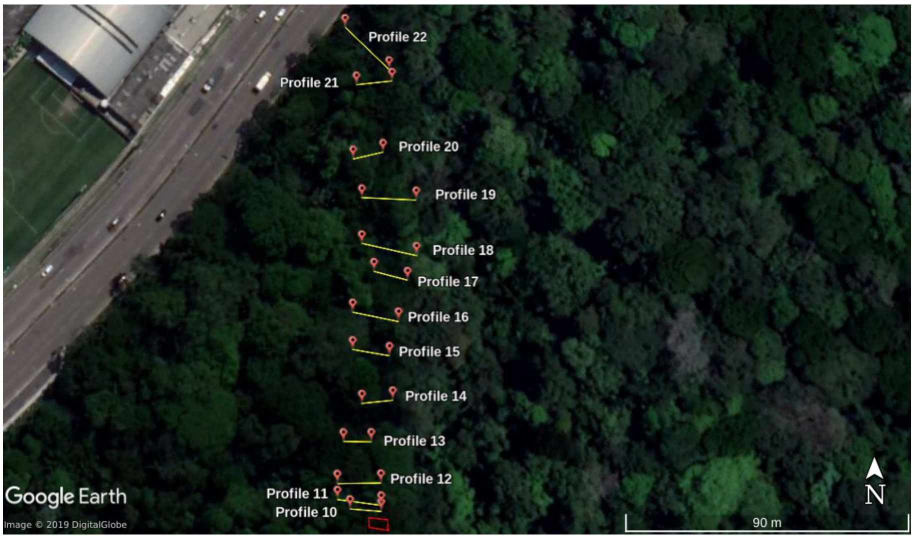

Figure 2.22: A satellite image of the area where Profiles 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21 and 22 were acquired. These profiles compose Group 3.

In radargram of Profile 10 (Figure 2.23), we can identify a strong hyperbolic reflection that also characterizes an anomaly referring to a water conduit. It is noticeable that this water conduct is different from the first found due to the position of the hyperbola when georeferenced. This new water conduit is probably leaving from the concrete box present in that region, besides the hyperbolic reflection, between 6.5 m and the end of the profile, we can observe an horizontal reflection, to which we associate the first water conduit, since the end of the Profile 10 ends almost on the direction that we assume to be from the first adductor, as we can see in Figure 2.24.

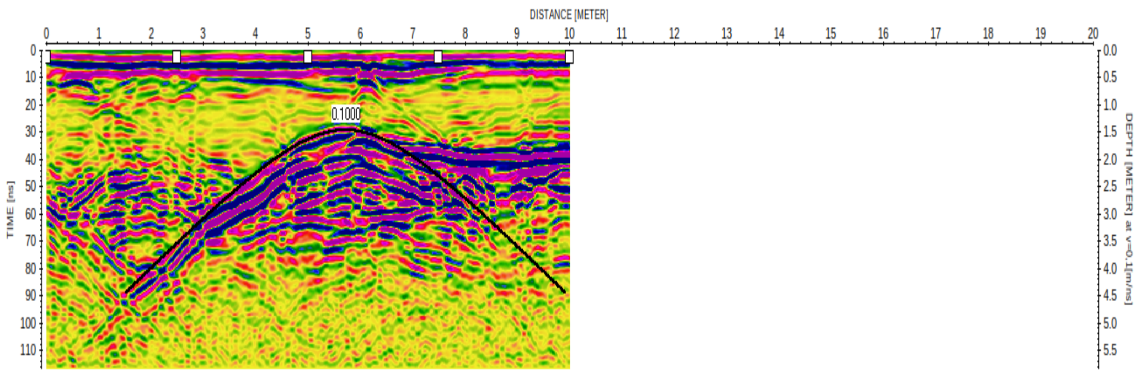

Figure 2.23: The radargram of Profile 10, acquired within the forest, whose length is 10 m.

Figure 2.24: The radargram of Profile 11, acquired within the forest, whose length is 14 m.

In Profile 11 (Figure 2.25), the presence of two strong reflections characterizing two hyperboles is another indication of the second conduit. These anomalies can be interpreted as an indication the two water conduits are approaching. This hypothesis is corroborated by the remaining profiles (from profile 12) of the group in which two hyperboles are presented side by side, as we can observe in Figure 2.27.

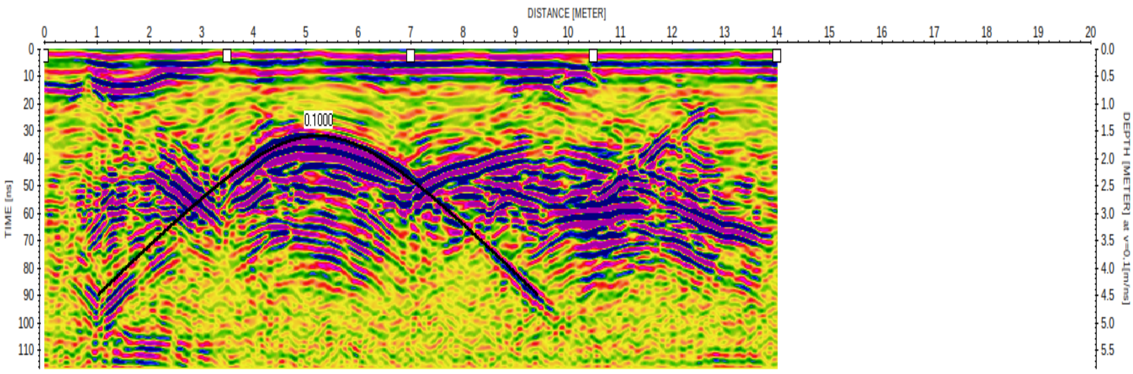

Figure 2.25: The radargram of Profile 11, acquired within the forest, whose length is 14 m.

The radargram of profile 12 is the first of Group 3 to present the two hyperbolic reflections closest to each other, which we associate with the fact that the two water conduits begin to walk together the rest of the survey as will be observed later.

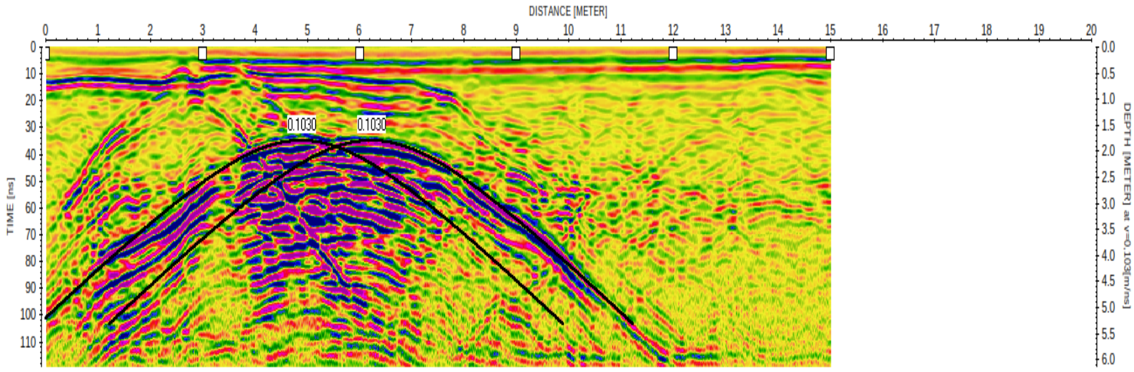

Figure 2.26: The radargram of Profile 12, acquired within the forest, whose length is 15 m.

Figure 2.27: A satellite image of the area where we can observe by analyzing the radargrams of Profiles 10, 11 and 12 that the water conduits approach. The red line represents the direction of the first water conduit and the green line the direction of the second water conduit.

From the radargram of Profile 13 onwards we did not see many significant changes in the direction or arrangement of the water conduits, but no less important than the previous ones, they served to map where the two mains followed in the forest until a next change in direction, which was observed for the profiles of Group 4. The direction of the two water conduits is shown in Figure 2.38, where the red line represents the direction of the first water conduit and the green line the direction of the second water conduit.

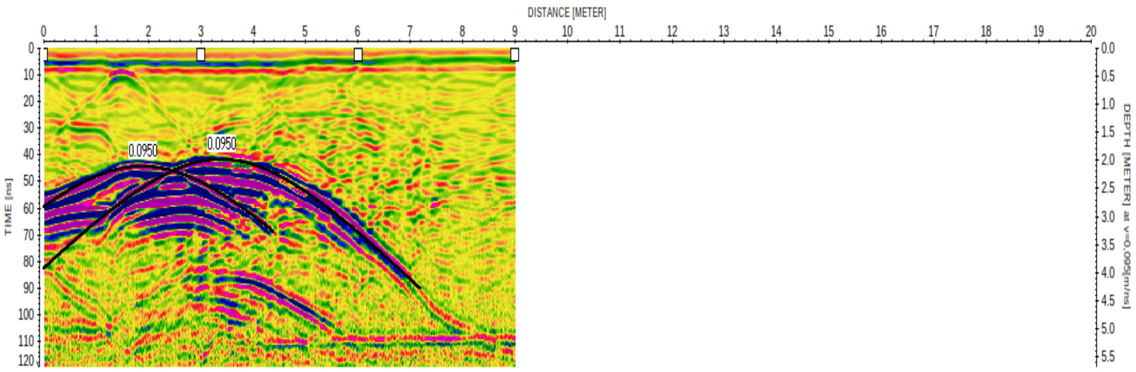

Figure 2.28: The radargram of Profile 13, acquired within the forest, whose length is 9 m.

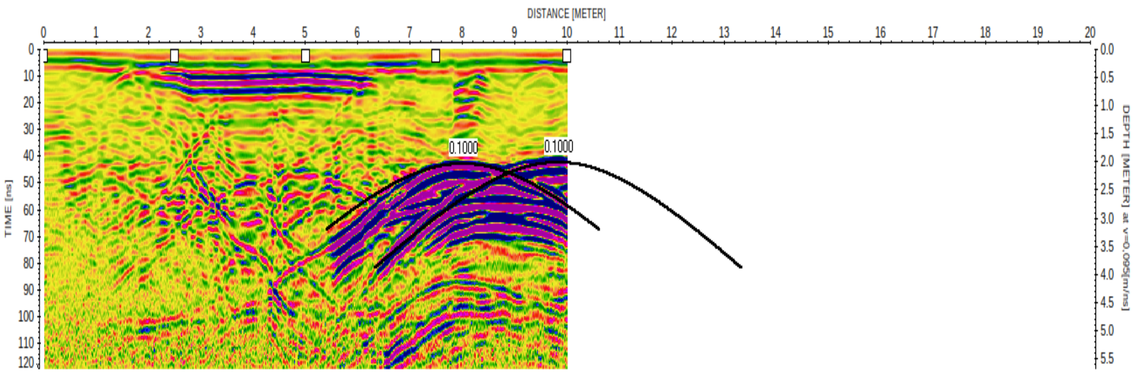

Figure 2.29: The radargram of Profile 14, acquired within the forest, whose length is 10 m.

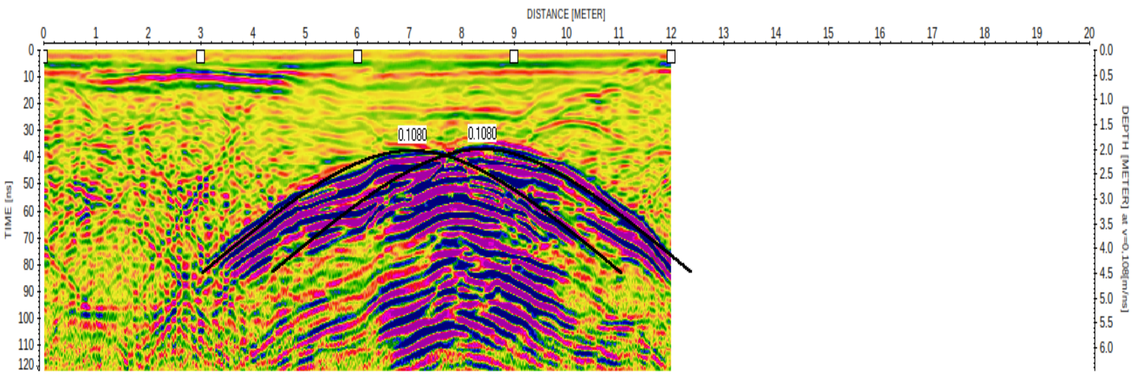

Figure 2.30: The radargram of Profile 15, acquired within the forest, whose length is 12 m.

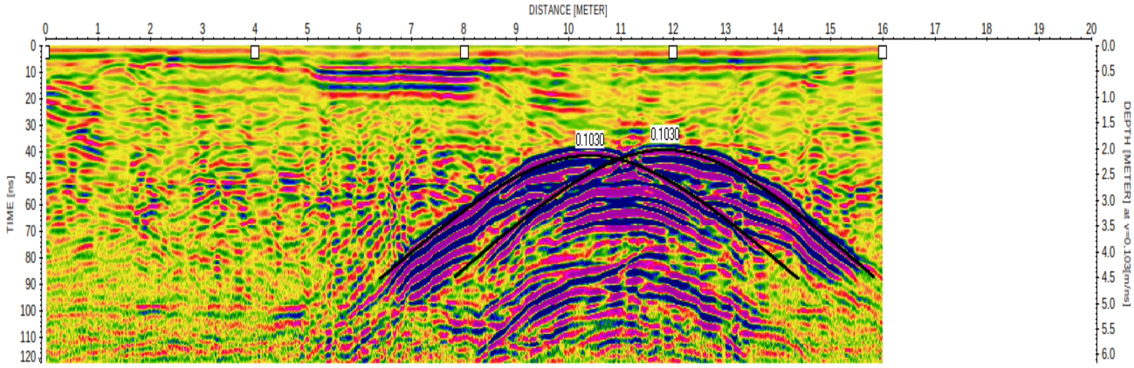

Figure 2.31: The radargram of Profile 16, acquired within the forest, whose length is 16 m.

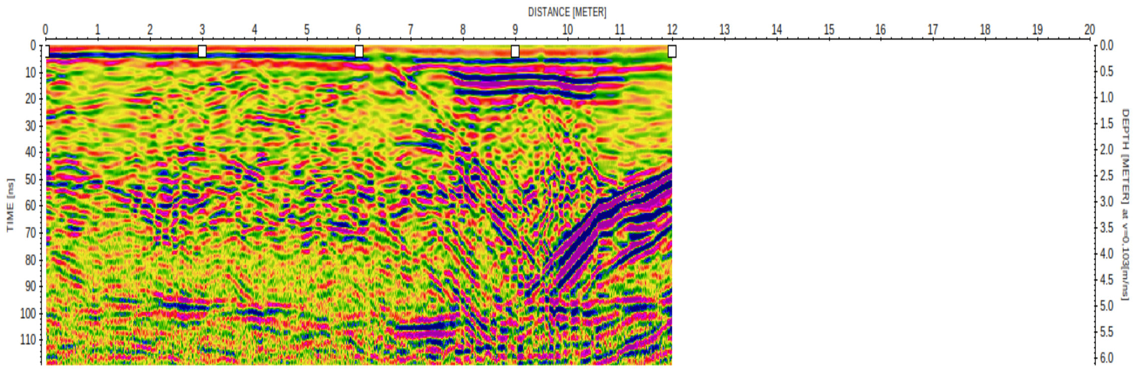

Figure 2.32: The radargram of Profile 17, acquired within the forest, whose length is 12 m.

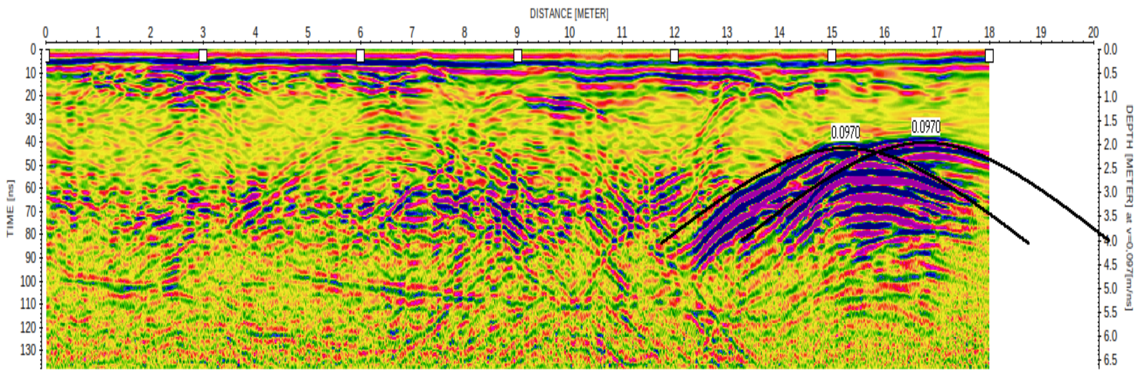

Figure 2.33: The radargram of Profile 18, acquired within the forest, whose length is 18 m.

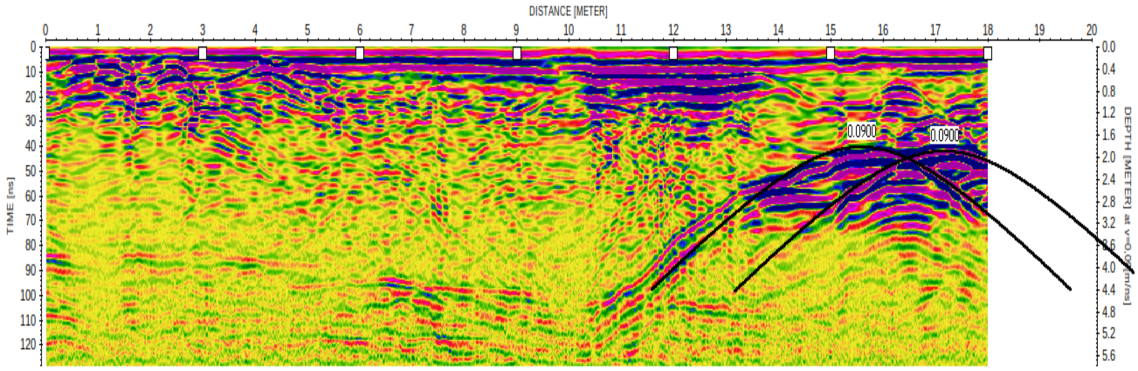

Figure 2.34: The radargram of Profile 19, acquired within the forest, whose length is 18 m.

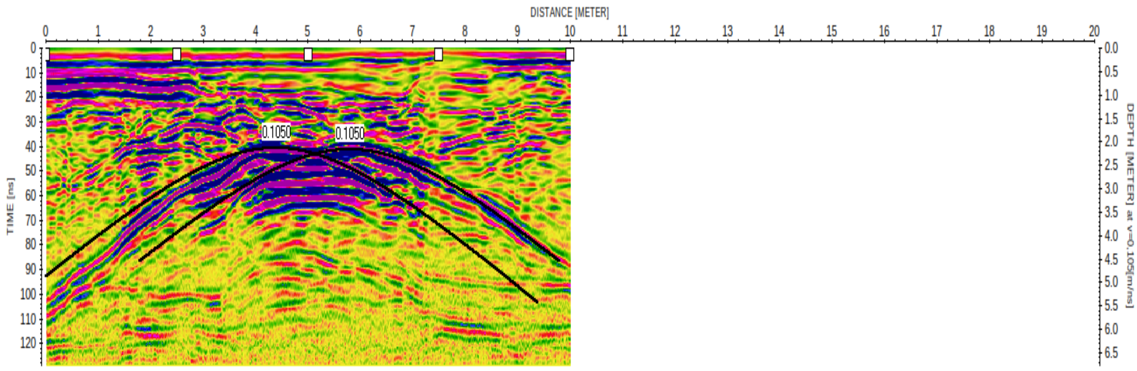

Figure 2.35: The radargram of Profile 20, acquired within the forest, whose length is 10 m.

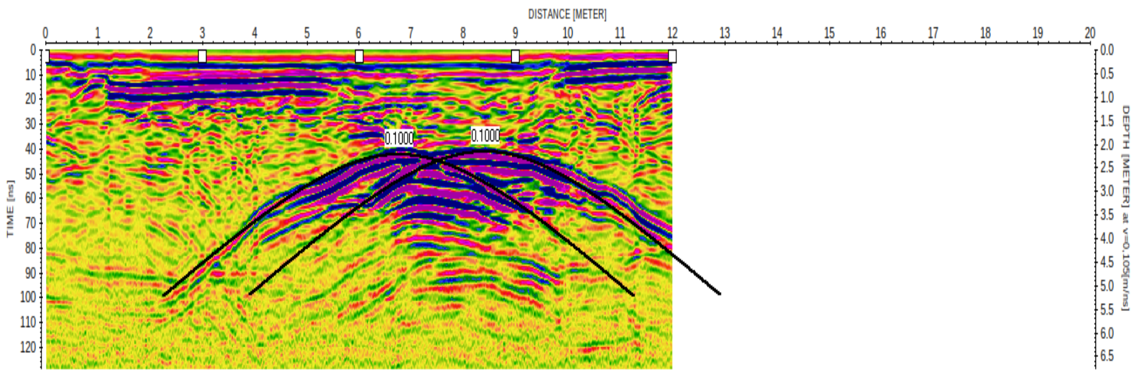

Figure 2.36: The radargram of Profile 21, acquired within the forest, whose length is 12 m.

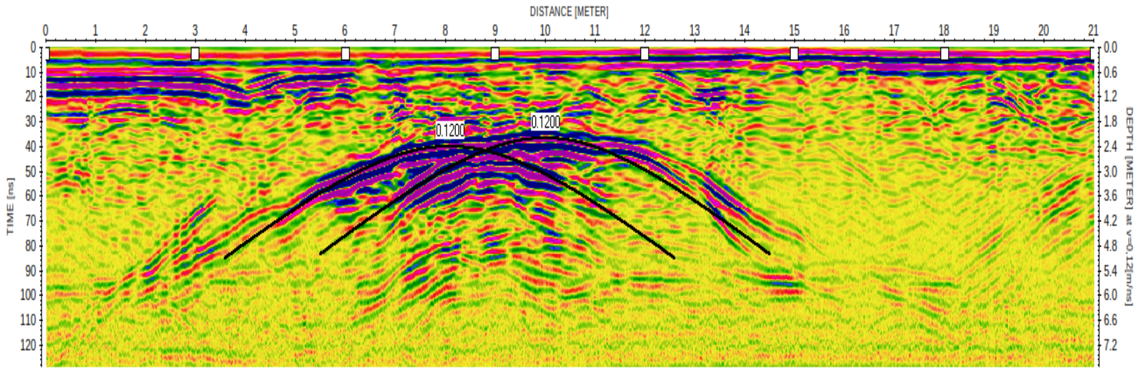

Figure 2.37: The radargram of Profile 22, acquired within the forest, whose length is 21 m.

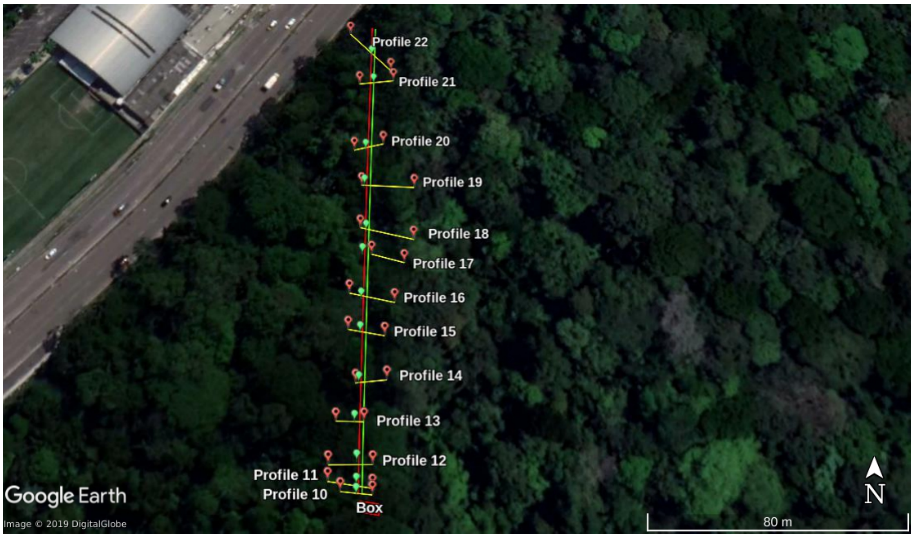

Figure 2.38: A satellite image of the area where the profiles from Group 3 were acquired highlighting the direction of both water conduits: the first one in red and the second one in green.

From Profile 23 and 24 we noticed a new change in the direction of the two water conduits, so they make up Group 4 and are shown in Figure 2.39.

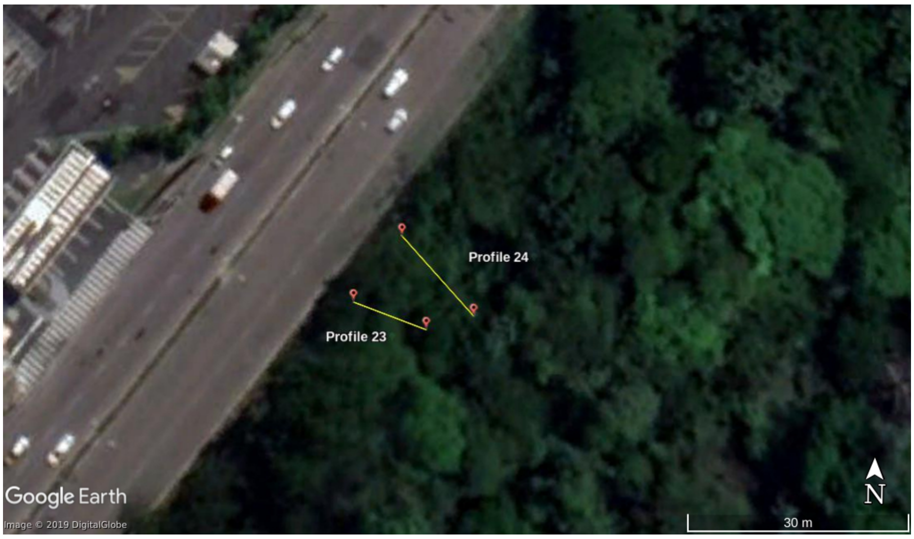

Figure 2.39: A satellite image of the area where Profiles 23 and 24 were performed. These profiles compose Group 4.

The radargramns of Profiles 23 and 24 show the same anomalies present on profiles from Group 3, two strong hyperbolic reflections which corresponds to both water conduits, but from them its perceptible a change in the direction as shown in Figure 2.42, where we can see that both water conduits are now parallel to João Paulo II Avenue towards a second concrete box.

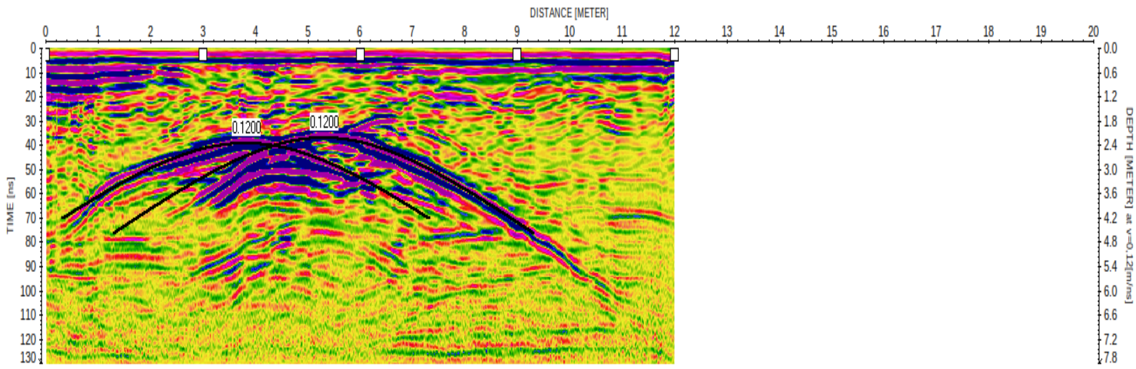

Figure 2.40: The radargram of Profile 23, acquired within the forest, whose length is 12 m.

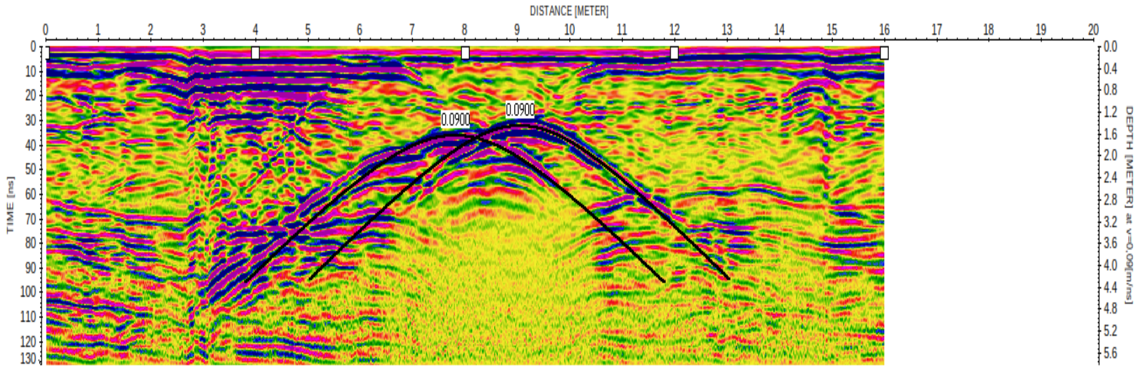

Figure 2.41: The radargram of Profile 24, acquired within the forest, whose length is 16 m.

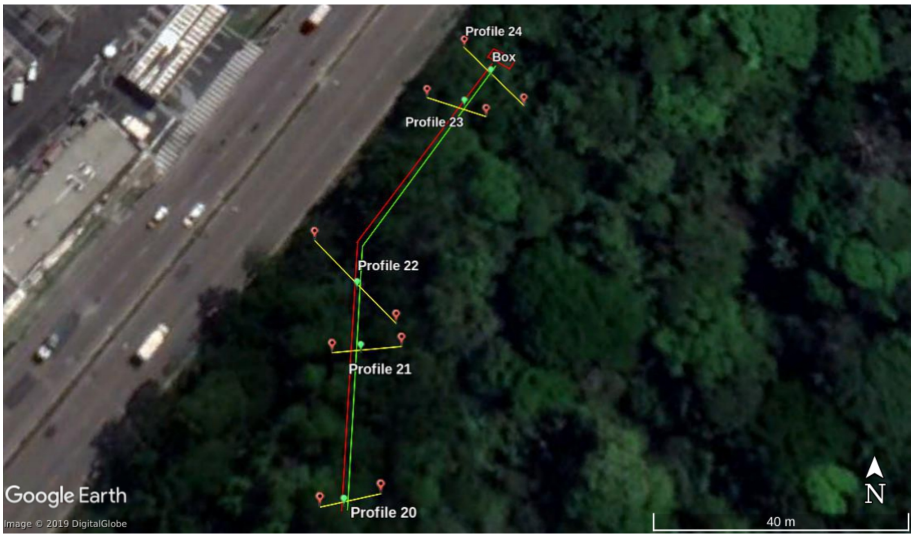

Figure 2.42: A satellite image of the area where the profiles from Group 4 were acquired highlighting the new direction of both water conduits (the first one in red and the second one in green) and the location of a concrete box (the red rectangle).

The final configuration of the mapping of the water conduits is shown in Figure 2.43. From the second concrete box onwards COSANPA already had the remaining of the mapping, so the surveys were finalized there.

Figure 2.43: Final result of the mapping

The interpretations listed above were corroborated by the posterior excavation of the water conduits in the location and depth indicated by the strong reflections of hyperbolic shape present in the radargrams. Therefore, the GPR method was effective not only on confirming the existance of the water conduits but also on distinguishing them from each other and indicating their preferential direction. Figure 2.44 shows an image of one of the excavations that were made in the course of the work. In it we can observe the two water conduits side by side as we had interpreted by the anomalies presented in some of the radargrams and in Figure 2.45 we can observe the excavation related to the radargram of Profile 11 (Figure 2.46), wich indicates the exactly location and depth where one of the water conduit was found.

Figure 2.44: The two water conduits side by side as the interpretation made by some of the resulting radargrams.

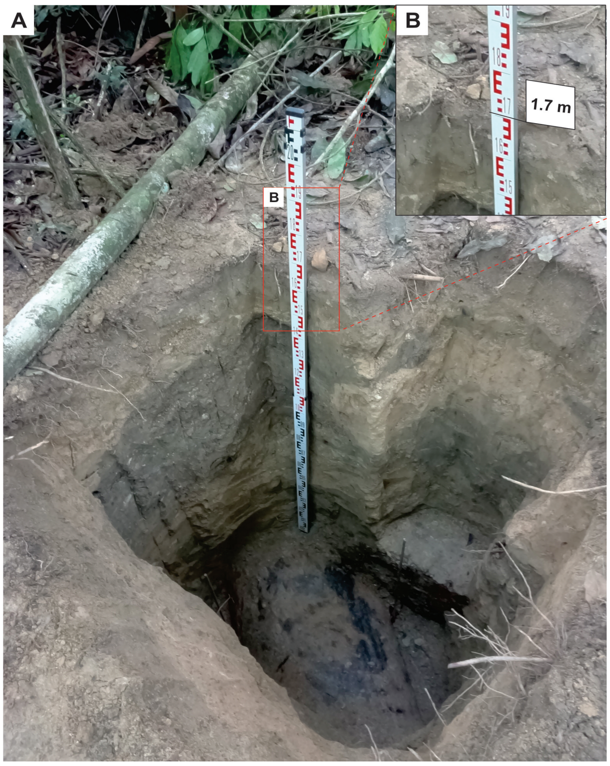

Figure 2.45: Excavation related to the radargram of Profile 11.

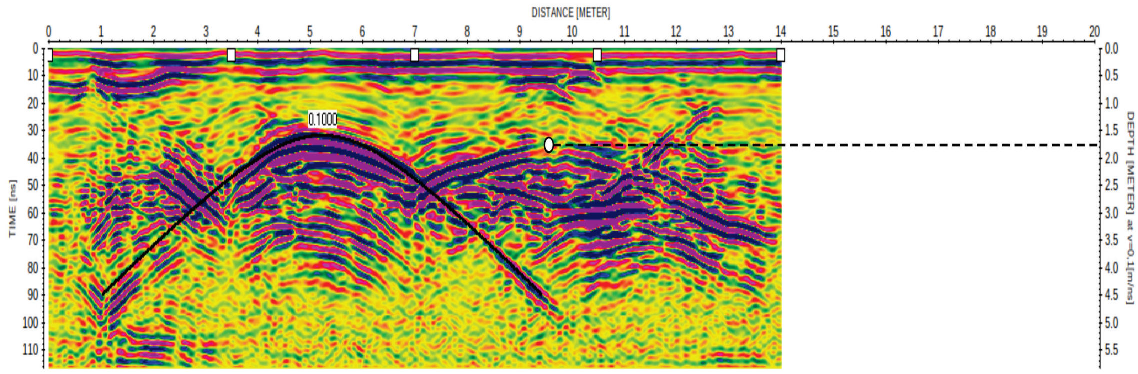

Figure 2.46: Profile 11 indicating that the depth of the second water conduit match exactly with the excavation.

2.7 CONCLUSION

In this work, 24 GPR profiles were acquired in order to study the existence and, if confirmed, the direction of any water conduits in the area of the Utinga National Park. The surveys were demanded by the water supply and sanitation company COSANPA and the data acquired was collected in six days of field work using the instrument GSSI-SIR 3000. The processed radargrams are of high resolution due to the great contrast between the buried metallic structure and the sunrounding medium, leading to the following interpretations:

- The first two performed profiles - Profiles 1 and 2 - confirmed the existence of the first found water conduit;
- The next four acquired profiles - Profiles 3, 4, 5 and 6 - indicated the direction of this fisrt water conduit;
- The following 12 profiles - Profiles 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21 and 22 - indicated a change in the direction of the first water conduit and the presence of a second water conduit that probably begins in a concrete box inside the forest.
- The last two acquired profiles - Profiles 23 and 24 - it is noticeable a new change in the direction of the two water conduits.

2.8 ACKNOWLEDGEMENTS

The authors would like to thank CAPES for the financial support, COSANPA for giving us the opportunity of accomplishing this research, the Postgraduate Program of Geophysics (CPGF) for providing the necessary geophysical instruments used on the field acquisition, the Federal University of Para for the space and structue provided to continue my education. Finally, but no less important, we would like to thank the Utinga National Park for receiving us during the days of surveying.

3 CONCLUSÃO

Os perfis realizados no Parque Estadual do Utinga utilizando o método GPR apresentaram radargramas com ótima resolução, devido ao grande contraste entre a estrutura metálica enterrada e o meio encaixante, exibindo feições anômalas hiperbólicas nos propusemos a procurar e mapear a serviço da empresa COSANPA.

Os dois primeiros perfis realizados - Perfis 1 e 2 - confirmaram a existência da primeira adutora; Os próximos quatro perfis adquiridos - Perfis 3, 4, 5 e 6 - indicaram sua direção; Os 12 perfis seguintes - Perfis 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21 e 22 - indicaram uma mudança na direção da primeira adutora e a presença de uma segunda que provavelmente começa em uma caixa de concreto dentro da mata fechada. Os dois últimos perfis adquiridos - Perfis 23 e 24 - é perceptível uma nova mudança na direção das adutoras que passaram a caminhar paralelas a Avenida João Paulo II e encontravam uma segunda caixa de concreto. Por fim, os levantamentos terminaram nesta segunda caixa de concreto dentro da mata pois a partir de então a empresa já possuía o restante das adutoras mapeadas.

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