ENVIRONMENTAL & SOCIAL IMPACT ASSESSMENT

Piauí Nickel Project

Volume II

Chapter 4 – Definition and Delimitation of Areas of Influence

Chapter 5 – Environmental & Social Diagnosis of the Areas of Influence

NOVEMBER 2017

Design & Consultancy for natural and built assets

Environmental & Social Impact Assessment

Volume II

Piaui Nickel Project

PIAUÍ NÍQUEL METAIS S.A

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4. Definition and Delimitation of Areas of Influence

Determining the areas of influence of a given project is one of the legal requirements (CONAMA Resolution 01/86) for assessing environmental and social impacts, being an important factor directing the environmental diagnosis.

The areas of influence of the project are the places that may suffer the greatest environmental, socioeconomic and cultural interference in the planning, implementation, operation and deactivation phases of the project. The characteristics of the enterprise and its interactions with the environment in which it is to be located also determine the limits of its area of influence.

In this study, the areas of influence were defined at three levels:

- Directly Affected Area (DAA): corresponds to the places where actions / interventions necessary for the implementation of the different elements of the enterprise will take place, and are common to the physical, biotic and socioeconomic environment. The DAA comprises the following structures: the mine area, the crusher area, the stockpile area, the leaching area, the acid solution ponds, the emergency pond, the precipitation plant, the spent ore and the solid residue storage area, the containment pond, the water pipeline, the transmission line, the explosives factory, the run-off water control structures and the access roads, including the internal ones between the structures that make up the project. It is the same area for all studied environments.
- Area of Direct Influence (ADI): is the geographical area surrounding the DAA, which is likely to be directly affected by the significant positive or negative impacts, directly resulting from the implementation, operation and deactivation of the project. The ADI of the Physical and Biotic environment is the same area but is different from the ADI delimited for the Socioeconomic environment.
- Area of Indirect Influence (AII): this area, which includes the ADI, is liable to suffer indirect impacts of the project's implementation and operation, whether positive or negative. The AII of the Socioeconomic and Cultural environment differs from the AII of the Physical and Biotic Resources.

4.1. Area of Influence, Physical and Biotic

4.1.1. Area of Direct Influence (ADI)

The Area of Direct Influence (ADI) of the physical and biotic environment is the area subject to propagation of the direct impacts resulting from the implementation and operation of the enterprise. The basic ADI delimitation unit was part of the Piauí River watershed, where the Piauí Nickel Project structures or components are to be located, regardless of whether the drainage network is perennial or intermittent.

For delimitation of the geographical area of the ADI, consideration was also given to the basin's physiographic characteristics, such as hill tops, which are potentially subject to the direct and indirect impacts caused by the implementation or operation of the structures that make up the enterprise, and included part of the microbasins close to the areas of the nickel and limestone mines (the Brejo Seco Mine and Umbuzeiro Quarry).

The ADI also includes the Jenipapo reservoir, located on the Piauí River, where water will be collected for the project. In the areas related to the pipeline, the transmission line and the access road to the limestone mine, the ADI considered was a 1 km strip around each structure (500 m on each side), prevailing over the basin's physiographic criteria.

Map 4.1-1 shows the delimitation of the ADI for the physical and biotic environment.

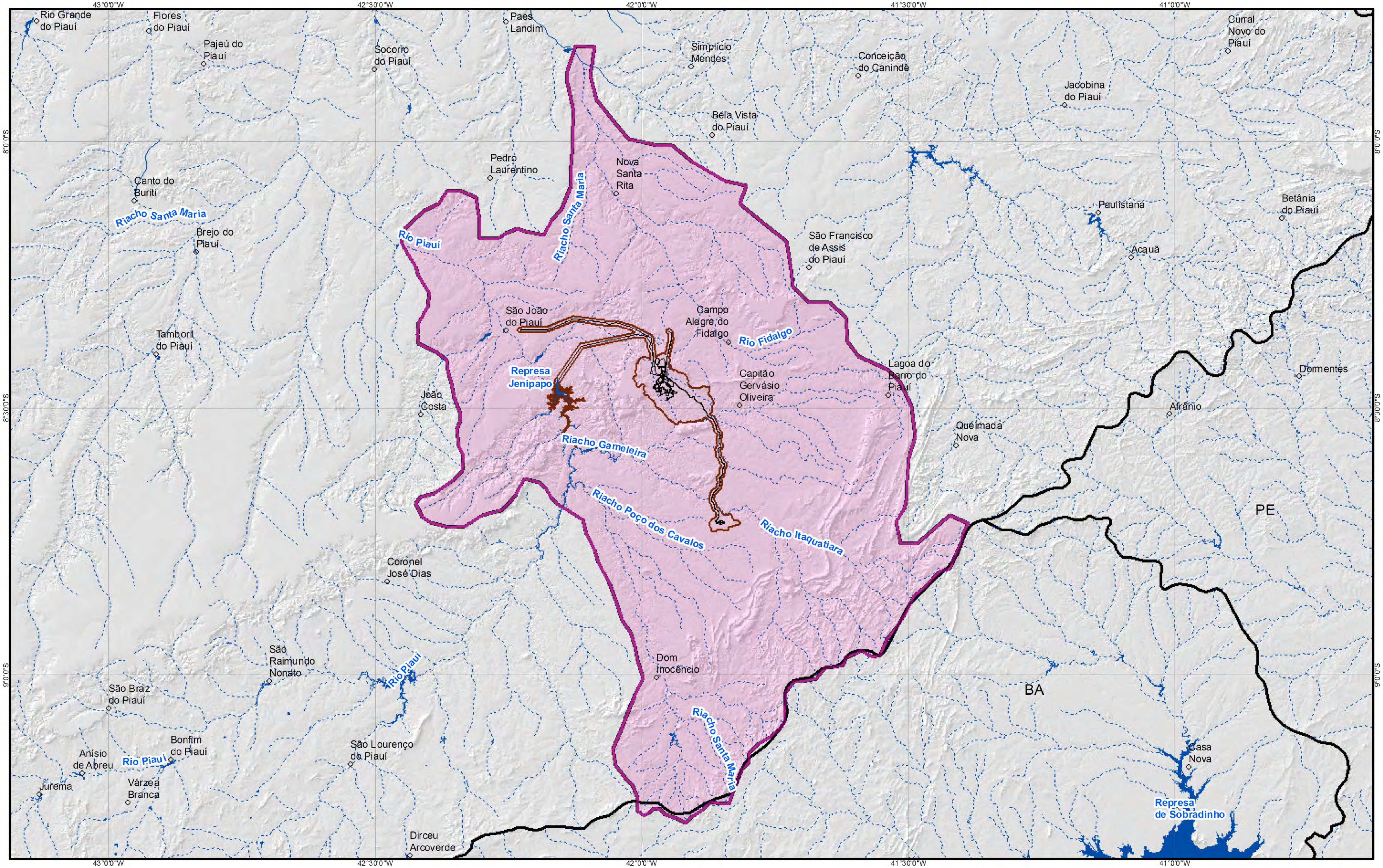
4.1.2. Area of Indirect Influence (AII)

The Area of Indirect Influence (AII) of the physical and biotic environments within an area subject to the propagation of indirect impacts resulting from the implementation and operation of the project in question.

The delimitation of the physical and biotic environment is based, in general, on physiographic criteria. Among these are the limits of the hydrographic basin (watersheds), which is considered a suitable unit for the assessment of ecological phenomena. In this case, the hydrographic basin used to determine the AII layout was part of the Piauí River basin. The AII is limited to the south by the Serra do Boqueirão, an important watershed in the sub-basins of the Piauí River. To the west, it is limited to a few tributaries on the left bank of the Piauí River and the sub-basin of the Poço dos Cavalos stream, which has its sources close to the limestone mine (Umbuzeiro Quarry). To the north, the limit is the sub-basin of the Fidalgo River and, to the east, the limit was defined by the Serra da Gameleira.

The conFiguretion of the AII for the physical and biotic environment is also shown in Map 4.1-1.

Map 4.1-1 – Physical and Biotic Areas of Influence for the Piaui Nickel Project.



LEGENDA

- Municipal Headquarter
- State Limits
- Perennial Drainage
- Intermittent Drainage
- Water Mass
- Area of Indirect Influence - All
- Area of Direct Influence - ADI
- Directly Affected Area - DAA

REFERÊNCIAS

IBGE, Brasil ao milionésimo, 2014;
PNM, Projeto, 2016.

ESCALA GRÁFICA
0 10 20 km
Sistema de Coordenadas: GCS SIRGAS 2000

MAPA DE LOCALIZAÇÃO

PIAUÍ NÍQUEL

ARCADIS Design & Consultancy for natural and built assets

EIA/RIMA – PROJETO PIAUÍ NÍQUEL

Map 4.1-1 – Areas of Influence of the Physical and Biotic Environments

EXECUTADO POR:	ESCALA:	NÚMERO:	DATA:
ARCADIS	1:750.000	Única	jan/2017

4.2. Socioeconomic Areas of Influence

4.2.1.1. Area of Direct Influence (ADI)

The Area of Direct Influence (ADI) of the socioeconomic environment, that is, the area subject to direct impacts related to the different phases of the project, includes the municipalities Campo Alegre do Fidalgo, Capitão Gervásio Oliveira, Dom Inocêncio, and São João do Piauí, in the state of Piauí, where the project under study will be located, if licensed.

The factors considered for the delimitation of the ADI were:

- The physical location of the project's structures; which determines the collection of local taxes from the installation works, in favor of the municipalities of Campo Alegre do Fidalgo, Capitão Gervásio Oliveira, Dom Inocêncio, and São João do Piauí;
- The probable effect upon the economies of the municipalities, considering hiring of workers, acquisition of inputs (low sophistication products and services), etc., and
- Adverse effects of the likely population attraction that introduction of the enterprise is expected to cause.

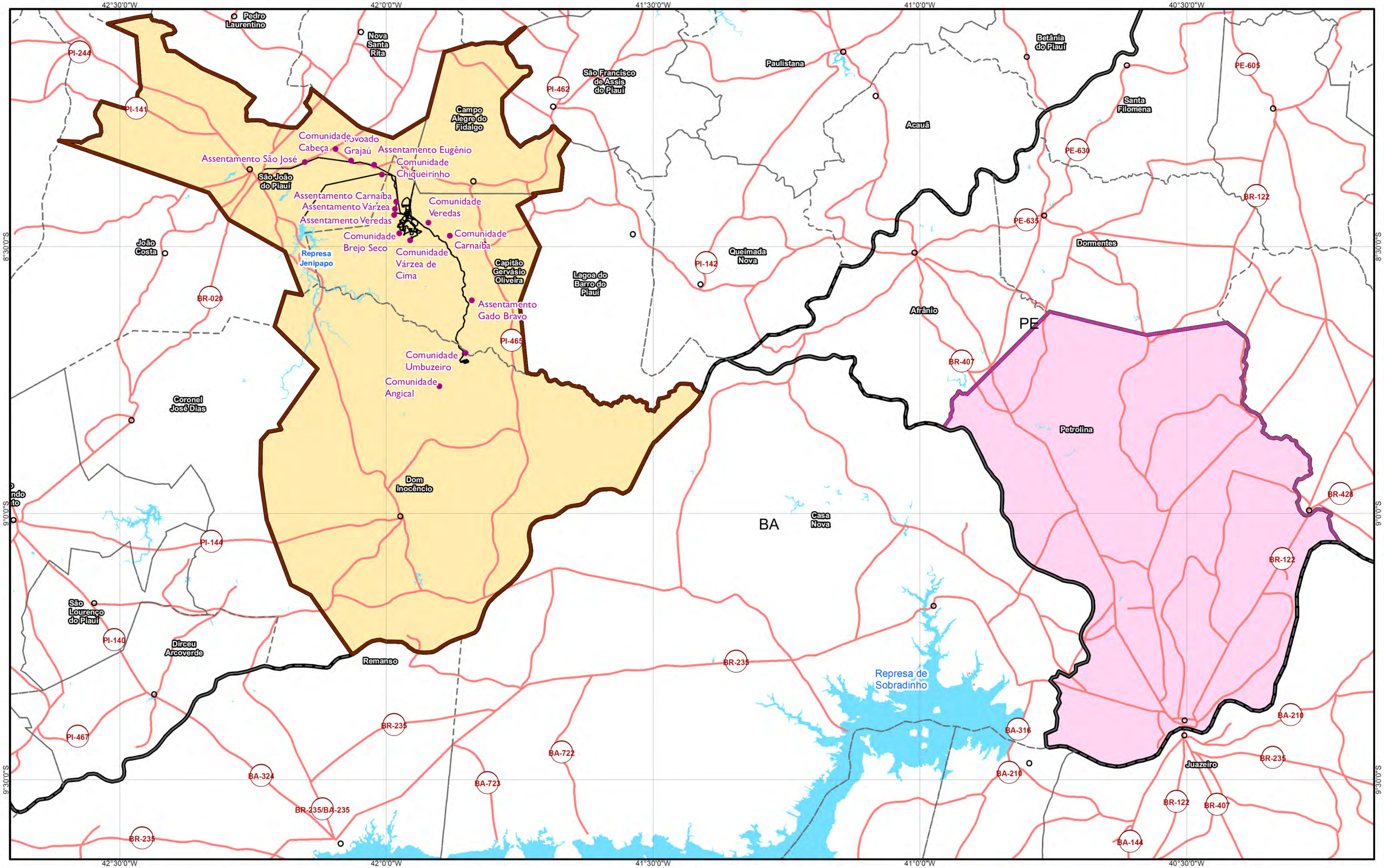
4.2.1.2. Area of Indirect Influence (AII)

The socioeconomic environment AII is an area subject to indirect impacts resulting from the implementation and operation of the project in question. In this way, the municipality of Petrolina, in the state of Pernambuco, was defined as within the AII.

The factors considered for the delimitation of the AII were related to the municipality's capacity, which is the most developed economic area close to the Piauí Nickel Project, to supply inputs (products and services) of higher sophistication that will be demanded by the enterprise, which in turn should generate indirect impacts on the economy of this location.

Map 4.2-1 shows the areas of influence for the socioeconomic environment.

Map 4.2-1– Socioeconomic Areas of Influence.



LEGENDA

- Surrounding Communities
- Municipal Headquarters
- Road System
- Municipal Limits
- State Limits
- Water Mass
- Area of Indirect Influence - AII
- Area of Direct Influence - ADI
- Directly Affected Area - DAA

REFERÊNCIAS

IBGE, Brasil ao milionésimo, 2014;
Projeto Piauí Níquel, 2016.

ESCALA GRÁFICA
0 10 20 km

Sistema de Coordenadas: GCS SIRGAS 2000

MAPA DE LOCALIZAÇÃO

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PIAUÍ NÍQUEL
ARCADIS

EIA/RIMA – PROJETO PIAUÍ NÍQUEL

Map 4.2-1 – Areas of Influence of the Socioeconomic Environment

EXECUTADO POR:	ESCALA:	NÚMERO:	DATA:
ARCADIS	1:750.000	Única	mai /2017

5. Environmental & Social Diagnosis of the Areas of Influence

5.1. Physical Environment

This section aims to conduct a regional characterization, by means of secondary data, of the physical environment framework of the planned area for the project, focusing mainly on the area of indirect influence of the previously defined physical and biotic environment.

In addition, its core purpose is to provide a synthesis of the main and most relevant topics of the physical environment for the area directly affected and the area of direct influence. For this purpose, secondary data, environmental studies from the environmental licensing of the Pilot Plant, as well as an Environmental Impact Study (Arcadis Tetraplan, 2008) were used.

Regarding the primary data, information contained in the Environmental Impact Study (Arcadis Tetraplan, 2008) was used, which was prepared for the licensing of the project developed by the company Vale S.A. but which was not made publicly available. It is important to note that although the survey of primary data took place in 2008, there were few anthropic changes in the area directly affected and the area of direct influence of the physical and biotic environment, with no changes in land use and occupation, conversion of native vegetation in other areas, forms of use, or new sources of pollution that may alter the environmental quality of the area where the enterprise is planned. In this way, the data obtained in 2008 are sufficient to technically support the impact assessment and the proposal of mitigating measures for the project in question. This understanding was confirmed by SEMAR and PNM in a meeting held in September 2016, later validated by the Term of Reference - TR issued by SEMAR for the present ESIA / RIMA.

In addition, a new field campaign was carried out to collect primary data between 20 and 31 October 2016, to carry out speleological prospecting (cave survey) in the entire area of the project and to verify the existence or not of natural underground cavities.

5.1.1. Climatology and Meteorology

5.1.1.1. Regional Climatic Context - Area of Indirect Influence (AII)

To determine the climatic conditions of the region, specific bibliographic references were used, such as technical books, theses and academic articles. The climatic units are described using the climatic classifications of Köppen-Geiger and the Brazilian Institute of Geography and Statistics (IBGE).

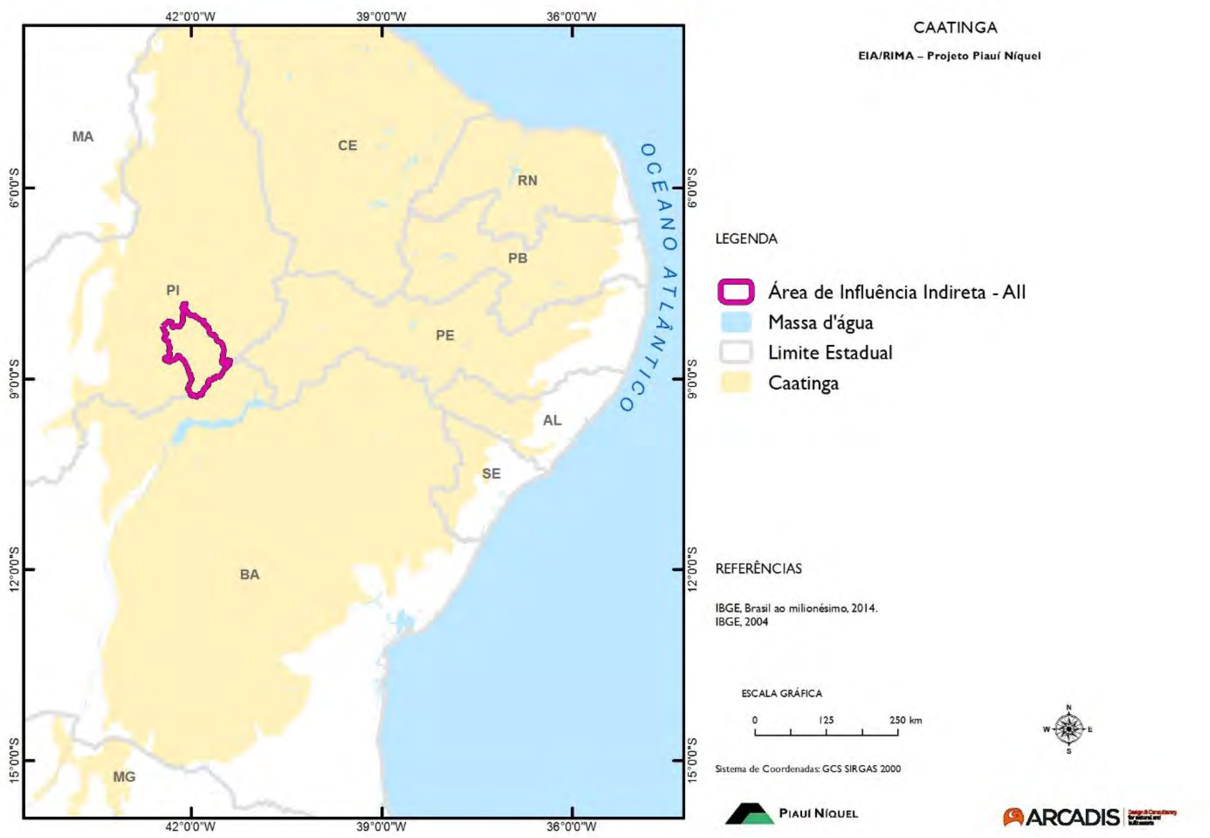
A) Climate Classification

The project's areas of influence are located in the south-eastern portion of the State of Piauí, within the boundaries of the semi-arid hot tropical climate, in the Caatinga biome. This biome has an area that extends over 935,000 km², (IBGE, 2004) and occupies 11% of the national territory of Brazil and 70% of the northeast region, covering the states of Bahia, Sergipe, Alagoas, Pernambuco, Paraíba, Rio Grande do Norte, Ceará and Piauí; Minas Gerais being the only state outside the Northeast to have areas within the Biome.

According to the Ministry of National Integration (2005), in its publication “New Delimitation of the Brazilian Semi-Arid Region”, the areas of influence of the enterprise are comprised of the ‘drought polygon’, characterized mainly by low annual precipitation and the high incidence of dry spells and drought.

Map 5.1-1 below shows the Areas of Indirect Influence of the Physical and Biotic Environment in relation to the limits of the Caatinga Biome.

Map 5.1-1 – Caatinga and the Area of Indirect Influence of the Physical and Biotic Environment.



Source: IBGE, 2004. Prepared by: Arcadis, 2017.

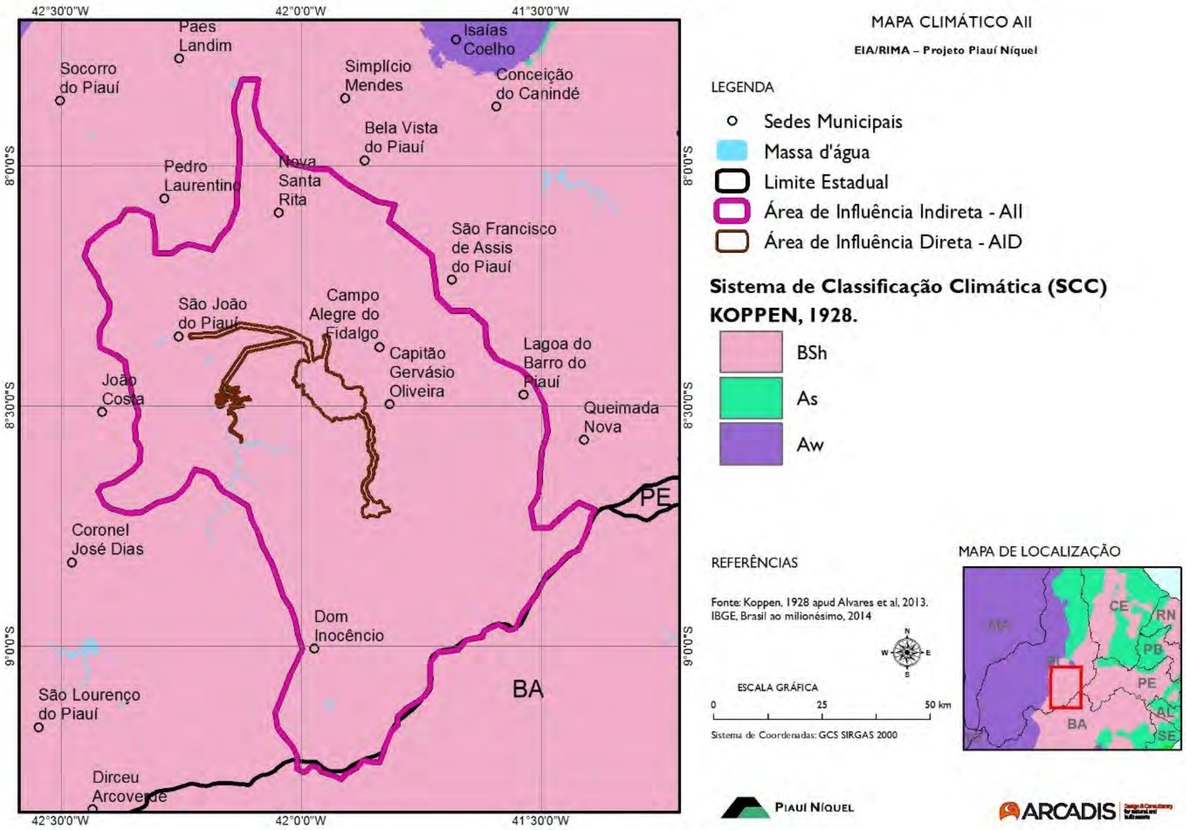
Climate classification systems (CCS) are of great importance for climatic characterization, since they analyze and define the climates of different regions taking into account different climatic elements synthesizing them into 'climatic units'.

In the specific bibliography, one of the most acclaimed CCSs is Köppen (1928). This classification system basically relates to seasonality and the average annual and monthly values for air temperature and precipitation. Each major climatic type is denoted by a code, consisting of uppercase and lowercase letters, whose combination denotes the types and subtypes considered, where the first letter denotes the general climate characteristic of a region, constituting the indicator of the climate group related to latitudes of the region; the second establishes the type of climate within the group, and denotes the particularities of the rainfall regime, that is, the amount and distribution of precipitation; and finally the third letter defines the monthly average air temperature of the hottest months or the annual average air temperature.

According to this CCS, modified by Alvares *et al* 2013, the AII is fully contained within the climate zone 'Bsh', described as a 'Warm Semi-Arid Climate' with a rainy season from January to May and a dry season that extends from May to December. The rainfall index varies around 600 mm per year; annual average temperature is 28ºC, with diurnal range reaching up to +/-10ºC, with an annual average of +/-5ºC.

The map below shows the AII Climate Classification for the Physical and Biotic Environment with the climatic zones according to Köppen's SCC (Map 5.1-2).

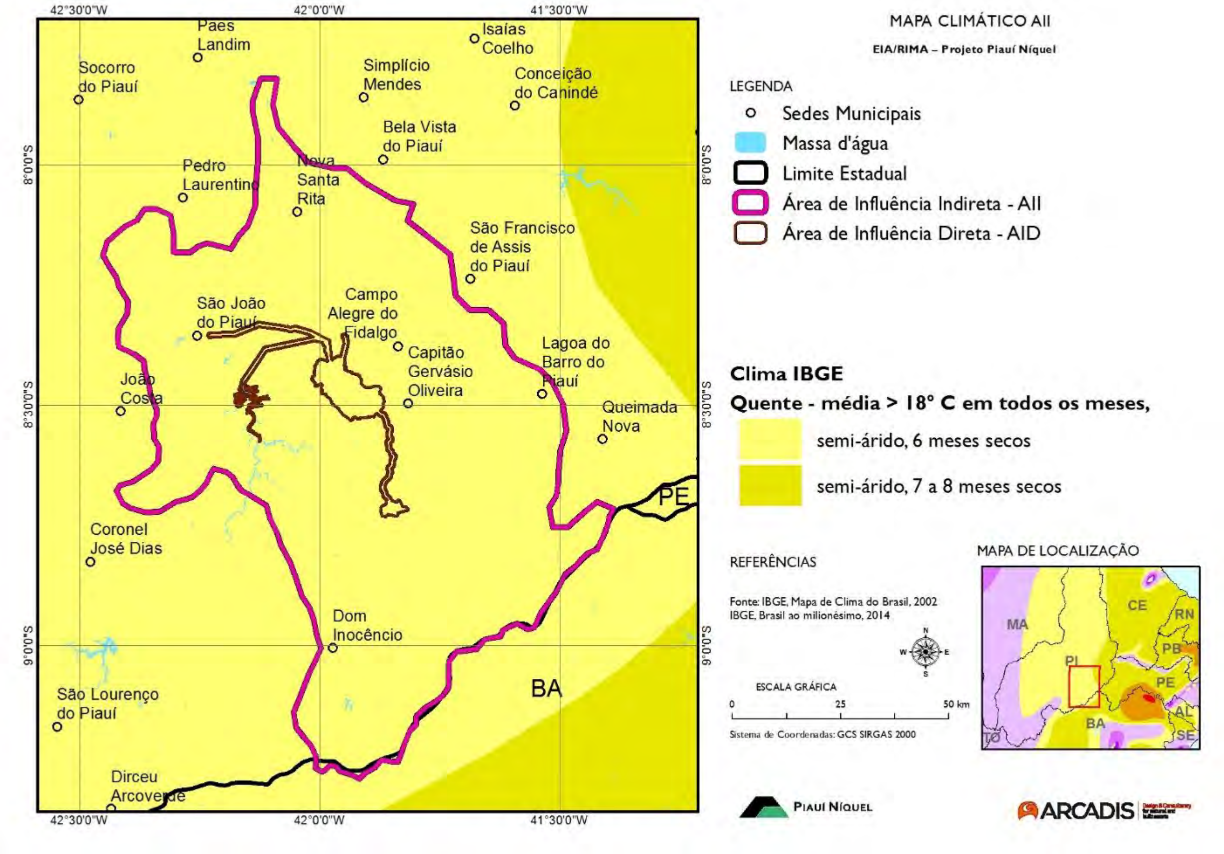
Map 5.1-2 – Climate Classification for the Physical and Biotic Environment AII - Köppen (1928).



Prepared by: Arcadis, 2017.

The 'Map of Climates of Brazil' by the Brazilian Institute of Geography and Statistics (2006) prepared from the combination of average temperature and rainfall, annual volume and seasonal distribution corroborates the Köppen climate classification (1928), and indicates the AII of the physical and biotic environment as a region with a hot semi-arid climate, with 6 dry months and an average temperature above 18ºC in all months.

Map 5.1-3 – Climate Classification – IBGE, 2011.

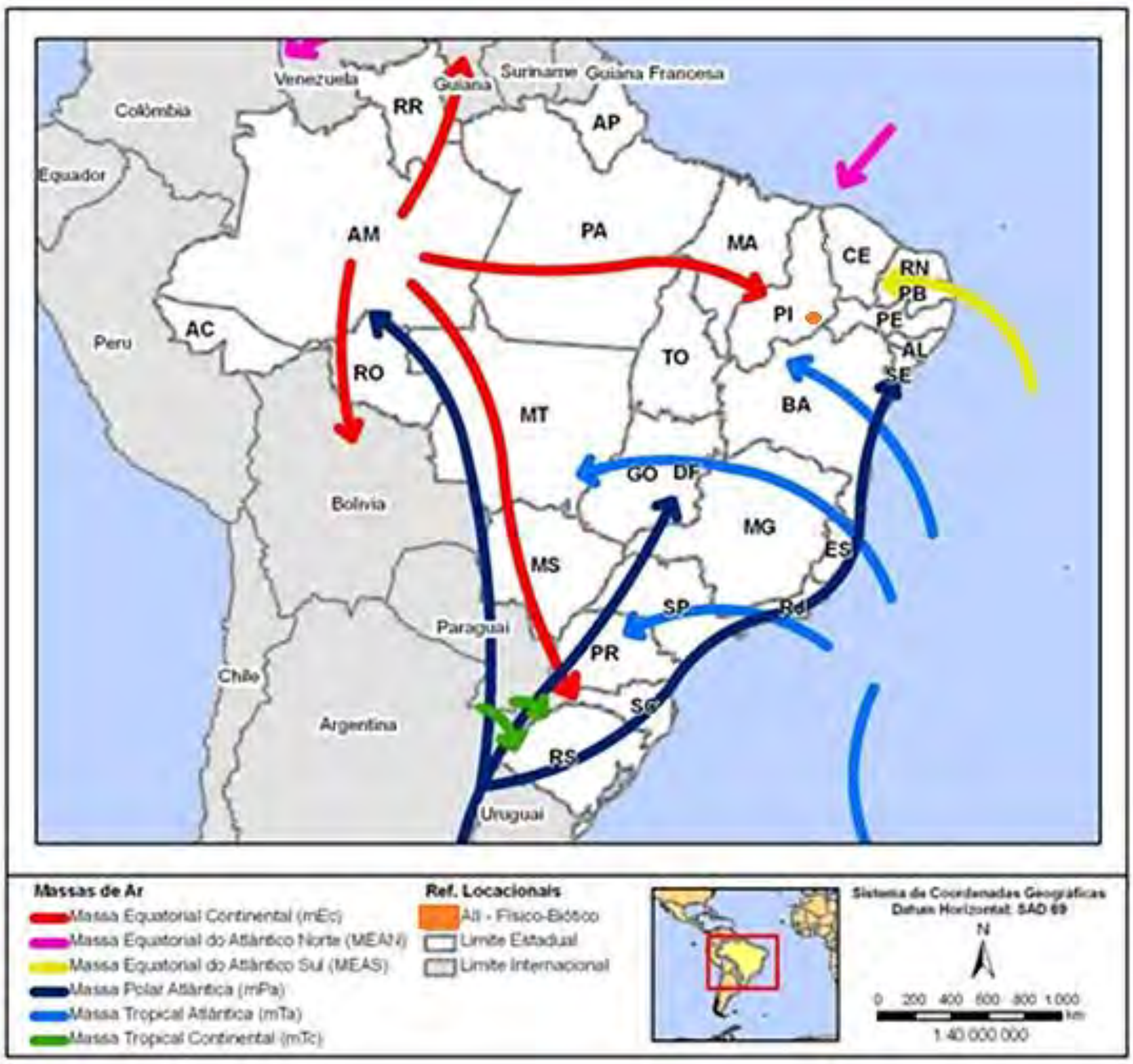


Prepared by: Arcadis, 2017.

B) Synthesis of Regional Climate Dynamics and Atmospheric Circulation

With regard to atmospheric circulation, the region in question is affected by the tropical Atlantic mass (tAm) and the continental Equatorial mass (cEm), both wet and hot air masses. The first, originating in the Atlantic Ocean, reaches the region through the central portions of the Northeast Region. The cEm, from the Amazon, reaches the region of the enterprise from the west, carrying moisture from the Amazon rainforest. There are also minor influences of the equatorial mass of the North Atlantic (EMNA) and the Equatorial Mass of the South Atlantic (EMSA), which reach the region via the coast. These aspects can be seen in Figure 5.1-1.

Figure 5.1-1 – Air Masses in Brazil.



Source: Mendonça and Oliveira-Danni, 2007. Prepared by: Arcadis, 2017.

According to Mendonça and Oliveira-Danni (2007), in the climate system of the Northeast region, two synoptic systems that generate precipitation are associated with seasonal variations, being the Intertropical Convergence Zone (ITCZ), which oscillates throughout the range of the tropics; and the Cyclonic Vorticity Center (CVC), which has a variable time within the rainy season. The Intertropical Convergence Zone (ITCZ) causes an increase in precipitation and humidity. This zone characterizes one of the most important atmospheric circulation systems in the globe and operates mainly close to equatorial regions, in which the project is located.

The climate of the Northeast is also influenced by the El Niño phenomenon, which is an oceanic phenomenon characterized by abnormal warming of the waters of the equatorial Pacific Ocean, close to the coast of South America. This condition, in many cases, contributes to the reduction of rainfall in the northern sector of Northeastern Brazil. La Niña, unlike El Niño, provides an abnormal cooling of the waters of the equatorial Pacific Ocean near the coast of South America. Normally, La Niña would tend to produce greater rain events in the Northeast region, including the state of Piauí.

The proximity of the Equator is another natural factor that has a marked influence on the climatic characteristics of the Northeast. The low latitudes condition the region to high temperatures (average of 26° C), and also a high number of hours of sunshine per year (estimated at about 3,000) and high levels of evapotranspiration, due to the perpendicular incidence of sunlight on the soil surface. (Mendonça and Oliveira-Danni, 2007).

5.1.1.2. Local Climate Characterization – Area of Direct Influence (ADI) and Directly Affected Area (DAA)

Meteorological elements are key parameters to estimate or measure any climatological behavior in any region, being of paramount importance for the composition of environmental impact studies.

For the structuring of the meteorological elements of the DAA and ADI of the Physical and Biotic Environment the following variables were used:

- Rainfall index;
- Temperature;
- Solar radiation;
- Cloudiness;
- Relative air humidity;
- Water balance; and
- Direction and speed of winds.

The climate is the synthesis of the weather in a certain place during a period of 30 to 35 years, according to J.O. Ayoade (1996), while the World Meteorological Organization (WMO) uses 30 years. Atmospheric time is the momentary state of the atmosphere at a given time and place. Atmosphere state is the set of attributes that characterize that moment, such as rainfall data, origin, wind speed and direction and local temperature, among others.

The ‘Climatological Norms’ are data obtained by calculating the averages of meteorological parameters, obeying WMO criteria. In this way, the so-called ‘Normal Climatologicals’ were adopted, relating to the period from 1961 to 1990 (INMET, 1992). For the present characterization, data from São João do Piauí Station (Latitude 08º21’S Longitude 42º15’W, altitude 235.3 meters) were used due to its proximity and greater availability of historical data. Data from the National Department for Works Against Drought (DNOCS) were also considered.

In addition, data from the Piauí Níquel Metais meteorological station, located at the development's DAA, were used. From this station, temperature (maximum and average) and precipitation (average) data were used, in addition to data from the wind regime (direction in degrees and average speed). It is worth mentioning that the referred station is not integrated, for comparative purposes, with the official and regional data. However, the available data, within ten years of the PNM station, proved to be satisfactory.

A) Temperature and Precipitation

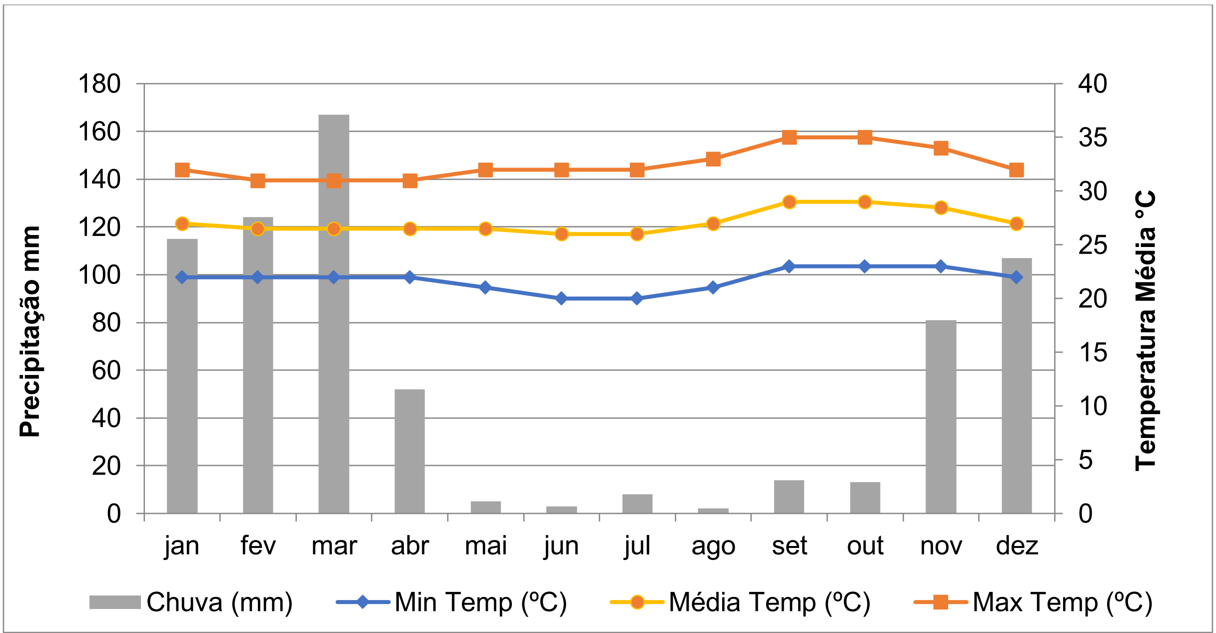
Two of the essential climatic factors for the climatic classification of an area are the amount of rainfall that occurs each year and the respective interannual variation associated with the average monthly temperature. Below, the 'climatogram' of the São João do Piauí weather station, relates the variation throughout the year of the monthly average precipitation and minimum, average and maximum average temperatures.

Data Table 5.1-1 – Norms for average precipitation (mm) and minimum, average and maximum temperatures, for the São João do Piauí weather station. Period 1961-1990

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	YEAR
Rainfall (mm)	115	124	167	52	5	3	8	2	14	13	81	107	691
Min Temp (ºC)	22	22	22	22	21	20	20	21	23	23	23	22	
Average Temp (ºC)	27	26.5	26.5	26.5	26.5	26	26	27	29	29	28.5	27	
Max Temp (ºC)	32	31	31	31	32	32	32	33	35	35	34	32	

Source: INMET, 1992. Prepared by: Arcadis, 2017.

Graph 5.1-1 – Climatogram (Precipitation - mm x Temperature - ° C) for São João do Piauí weather station. 1961-1990.



Source: INMET, 1992. Prepared: Arcadis, 2017.

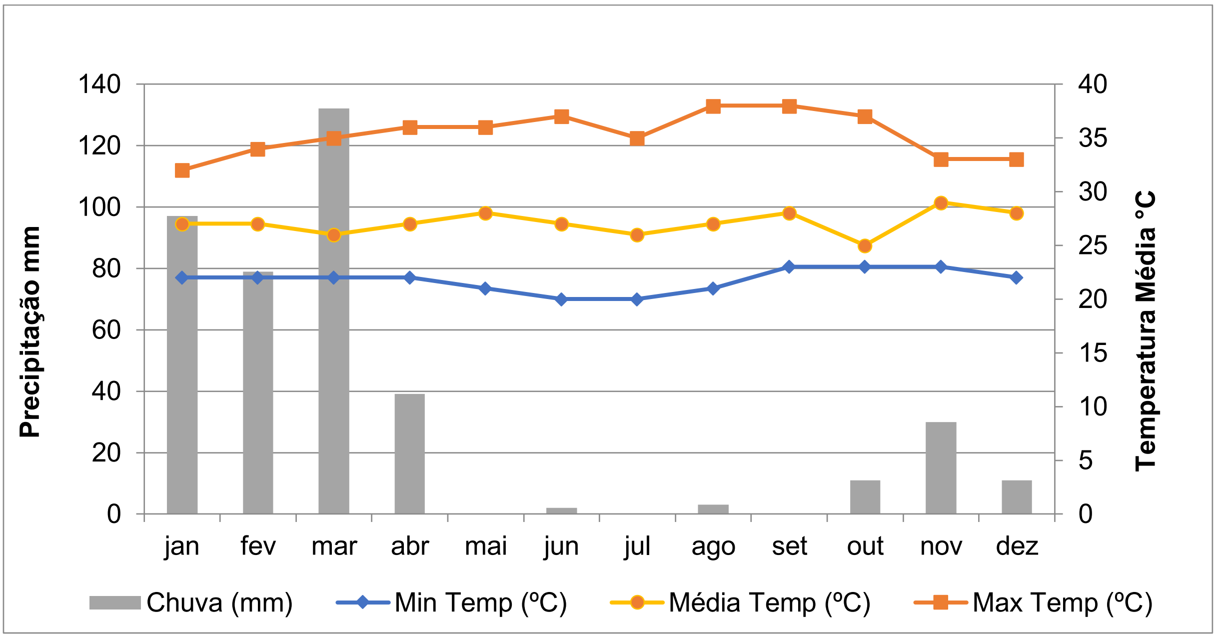
The PNM Meteorological Station recorded temperature and rainfall data between the years 2006 and 2010 and the results are presented below.

Data Table 5.1-2 – Average precipitation (mm) and minimum, average and maximum temperatures °C, for the Capitão Gervásio weather station. 2006-2010.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	YEAR
Rainfall (mm)	97	79	132	39	0	2	0	3	0	11	30	11	405
Min Temp (ºC)	22	22	22	22	21	20	20	21	23	23	23	22	
Average Temp (ºC)	27	27	26	27	28	27	26	27	28	25	29	28	
Max Temp (ºC)	32	34	35	36	36	37	35	38	38	37	33	33	

Source: Estação PNM, 2016. Prepared by: Arcadis, 2017.

Graph 5.1-2 – Climatogram (Precipitation - mm x Temperature - ° C) for Capitão Gervásio weather station. 2006-2010.



Source: Estação PNM, 2016. Prepared by: Arcadis, 2017.

Both graphs above show that ADI and DAA have a warm tropical climate, with two well-defined seasons: the rainiest between November and March, with March being the month of greatest rainfall, and the other between May and October characterized by a significant lower rainfall, with higher temperature levels, with temperature highs between August and October.

According to the Climatological Norms (INMET, 2009) the total annual rainfall is around 600/700 mm, while the historical record of the last ten years of the PNM Station indicates an annual total of rain around 400 mm. However, it is important to note the low annual rainfall for the AII, ADI and DAA.

There is a noticeable division of precipitation throughout the year: in the first half (January, February, March) the rainfall values are relatively high, and the rainy season is marked by a pattern of torrential rains. While in the second semester, whose driest months are between May and October, rainfall commonly declines until reaching levels close to zero, rising again in November and December.

B) Solar radiation, cloudiness, evaporation, relative humidity.

Solar radiation has the effect of heating the air and the Earth's surface, altering evaporation and evapotranspiration and consequently increasing or decreasing the relative humidity of the air, and its cloudiness.

For obtaining and treating solar radiation data from the ADI and DAA, SunData[1], a program of the Reference Center for Solar and Wind Energy Sérgio Brito (CRESESB, 2014), was used, which is intended to calculate solar radiation as a support tool for photovoltaic systems.

The SunData program is based on the database of Brazilian stations and in neighboring countries and provides the average solar radiation values of different locations in the country, containing daily solar radiation values and monthly averages.

Additionally, the following sources were consulted:

- Atlas Solarimétrico do Brasil (2000), developed through the FADE-UFPE / CEPEL agreement, is published and distributed by CRESESB.
- Atlas Brasileiro de Energia Solar (2006) published by INPE.
- Atlas Climatológico do Estado do Piauí, 2004, published by EMBRAPA.

Data Table 5.1-3 shows the location of the solarimetric stations used and the corresponding linear distance from the project.

Data Table 5.1-3 – Stations used for characterization of solar radiation.

Station	Latitude [°]	Longitude [°]	Distance [km] from DAA/ADI
São João do Piauí	8.3° S	42.250514° O	40.7
Paulistana	8.1° S	41.149722° O	98.2
Caracol	9.1° S	43.328611° O	166.3

Source: CRESESB, 2014. Prepared by: Arcadis, 2017.

[1] http://www.cresesb.cepel.br/index.php#data, serached in 2016.

The data in the following table shows the average monthly solar radiation (kWh / m².day) for all months of the year.

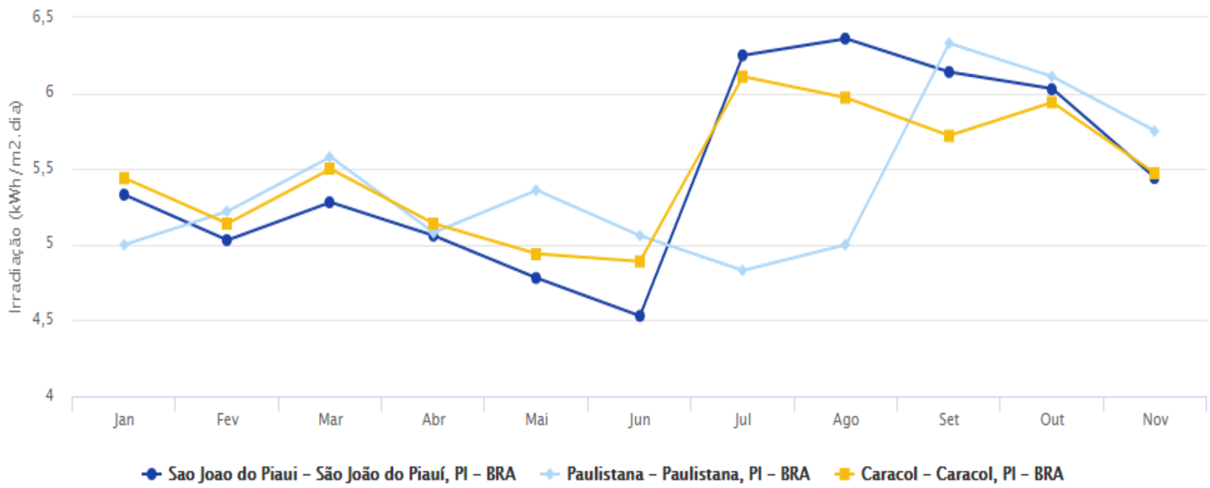
Data Table 5.1-4 – Monthly Average Solar Radiation (kWh/m².dia).

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average	Delta
São João do Piauí	5.33	5.03	5.28	5.06	4.78	4.53	5.36	6.25	6.36	6.14	6.03	5.44	5.47	1.83
Paulistana	5.00	5.22	5.58	5.08	5.36	5.06	5.50	4.83	5.00	6.33	6.11	5.75	5.40	1.50
Caracol	5.44	5.14	5.50	5.14	4.94	4.89	5.31	6.11	5.97	5.72	5.94	5.47	5.46	1.22

Source: CRESESB, 2014. Prepared by: Arcadis, 2017.

The graph of solar radiation in the horizontal plane for stations near the PNM project.

Graph 5.1-3 – Solar radiation (kWh/m².dia) in the Horizontal Plane.



Source: CRESESB, 2014.

The average solar radiation in the first semester, between the three seasons, is in the range between 5 and 5.5 kWh / m².day, with a drop to 4.5 kWh / m².day in June followed by a sharp increase in July to 6.25 kWh / m².day. Whereas in the second semester the variation is between 5.5 and 6.5 kWh / m².day.

Cloudiness is a climatological element that reflects the fraction of the celestial vault that is covered by clouds. INMET divides the sky into tenths and, based on the number of tenths covered by clouds, the cloudiness is divided into:

- Clear skies: no trace of clouds;
- Almost clear skies: at least one tenth covered by clouds;
- Lightly cloudy sky: at least three tenths of sky covered by clouds;

- Partly cloudy sky: at least five tenths, approximately half the sky, covered by clouds;
- Almost cloudy sky: at least eight tenths covered by clouds; and
- Cloudy sky: all tenths are covered by clouds.

According to interpolation of regional data made by EMBRAPA, 2004 (op. Cit.), in the region of the ADI and the DAA of the project, a clear to almost clear sky predominates. July and August are the months with the lowest average cloudiness, at 1.5 tenths. The other months of the year show a slightly higher average cloudiness, varying between 2.5 tenths covered by clouds, with emphasis on the months of May and October. With 4.5 tenths, December, January, February and March.

Table 5.1-1 represents the distribution of the data presented above.

Table 5.1-1 – Cloudiness in tenths.

Mês	Nebulosidade em décimos	Média Nebulosidade
jan	4 a 5	4,5
fev	4 a 5	4,5
mar	4 a 5	4,5
abr	3 a 4	3,5
mai	2 a 3	2,5
jun	4 a 5	4,5
jul	1 a 2	1,5
ago	1 a 2	1,5
set	4 a 5	4,5
out	2 a 3	2,5
nov	3 a 4	3,5
dez	4 a 5	4,5

Source: EMBRAPA, Andrade Júnior. [et al.]., 2004. Prepared by: Arcadis, 2017.

Table 5.1-2, shows an average annual variation of the relative humidity of the air, between 72.5% and 42.5%, however it should be noted that the less rainy months, which are common, show diminished relative humidity of the air, not infrequently reaching rates below 35% , as was the case in September 2012.

Table 5.1-2 – Air Relative Humidity.

Mês	Umidade relativa%	Média mensal %
jan	65-70	67,5
fev	55-60	57,5
mar	70-75	72,5
abr	70-75	72,5
mai	60-65	62,5
jun	50-55	52,5
jul	50-55	52,5
ago	40-45	42,5
set	40-45	42,5
out	45-50	47,5
nov	45-50	47,5
dez	55-60	57,5

Source: EMBRAPA, Andrade Júnior. [et al.]., 2004. Prepared by: Arcadis, 2017.

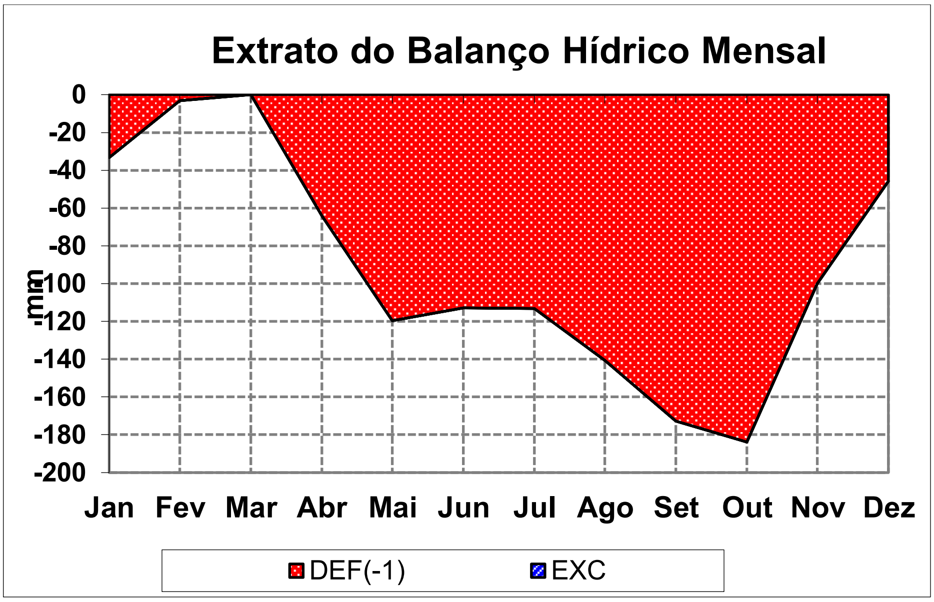
C) Hydraulic Balance

The climatological hydraulic, or water, balance, established by Thornthwaite & Mather (1955), aims to describe the variation of water content in the soil. By accounting for the natural supply of water to the soil, from rain (R), and for atmospheric demand, for potential evapotranspiration (PET), and with a maximum level of storage or available water capacity (AWC) appropriate to the study in question, the water balance provides estimates of real evapotranspiration (RET), water deficiency (DEF), water surplus (EXC) and soil water storage (SWS), which can be prepared on a daily to monthly scale (Camargo, 1971 ; Pereira et al., 1997).

The water balance data, collected from 1969 to 1990, was obtained through the Agroclimatic Monitoring Center (NURMA) of the Department of Exact Sciences at USP. Data were obtained from the São João do Piauí station and used in the equation spreadsheet provided by NURMA.

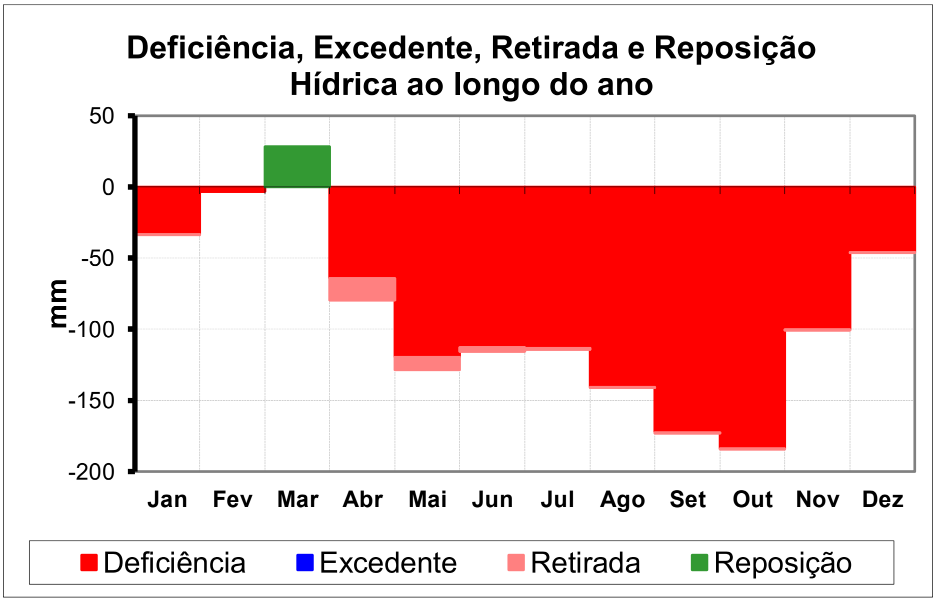
The following are the graphs of Extract from the Normal Monthly Water Balance (Deficits and Surpluses) (Graph 5.1-4) and deficiency, surplus, Withdrawal and Water Replacement throughout the year (Graph 5.1-5).

Graph 5.1-4 – Extract from the Normal Monthly Water Balance (Deficits and Surpluses)



Source: ESALQ/USP, 2009 (Nurma).

Graph 5.1-5 – Deficiency, Surplus, Withdrawal and Water Replacement throughout the year.



Fonte: ESALQ/USP, 2009 (Nurma).

Just as the precipitation and temperature indices show similarities in their temporal regularity, the water balance values follow the same pattern. That is, in the drought months there is a significant water deficit, while the rainy months show a small surplus. In short, practically the whole year is marked by water deficit, while only in March is there replacement. This situation characterizes a significantly negative water balance, typical of the Brazilian semi-arid region, whose actual evapotranspiration (RET[2]) and potential evapotranspiration (PET[3]) exceed rainfall.

D) Wind Direction and Intensity

In the region of the project, as well as throughout the Northeast of Brazil, the winds are directly influenced by the air masses coming from the Atlantic Ocean and the intertropical convergence zone, formed mainly by the confluence of the trade winds of the northern hemisphere with the trade winds of the southern hemisphere.

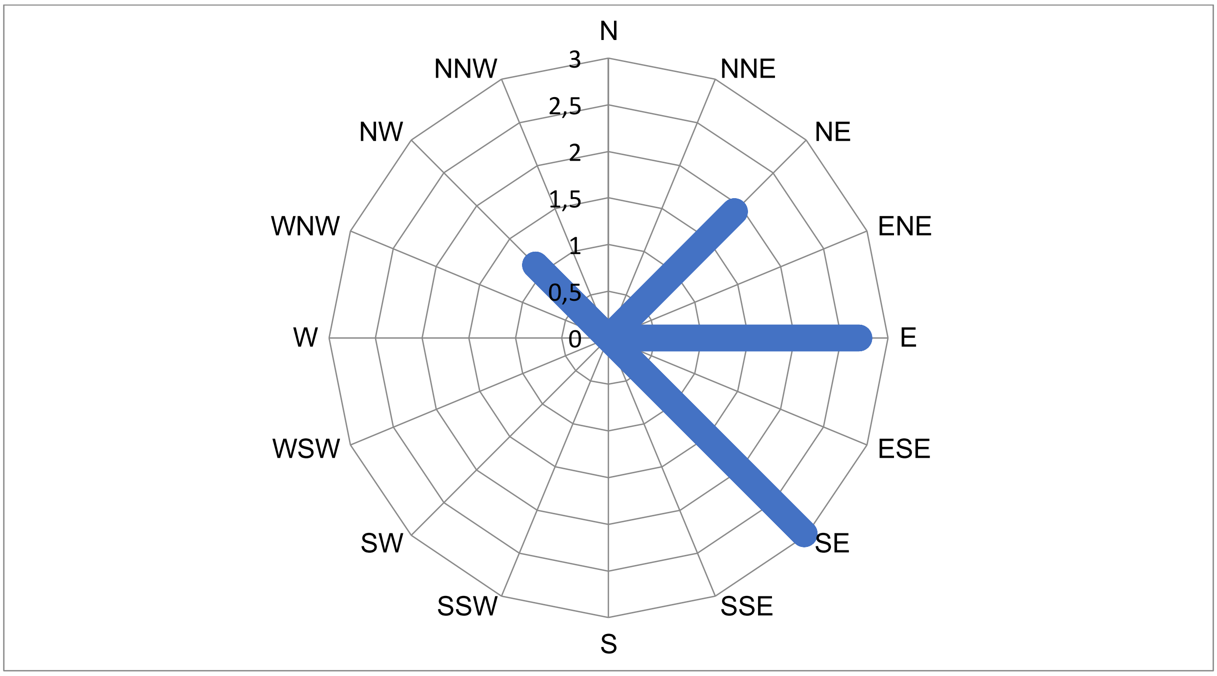
Wind data from the São João do Piauí[4] station, which started operating on 09/30/1975, show a predominance of winds from the southeast and east direction (Graph 5.1-6 e Graph 5.1-7).

[2] Real or effective evapotranspiration (RET): total vapor transfer to an atmosphere that is evaporated by the surface and transpired by the plants under the current conditions of atmospheric temperature, soil moisture and crop conditions. (CIIAGRO, 2011)

[3] Potential evapotranspiration (PET): Maximum water capacity capable of being lost as steam, in a given climatic condition, by a continuous medium of vegetation that covers the entire surface of the soil, whether at or above field capacity. In this way, it includes the evaporation of the soil and transpiration of a vegetation of a specific region in a given time interval. (CIIAGRO, 2011)

[4] http://www.inmet.gov.br/projetos/rede/pesquisa/, accessed in 2016.

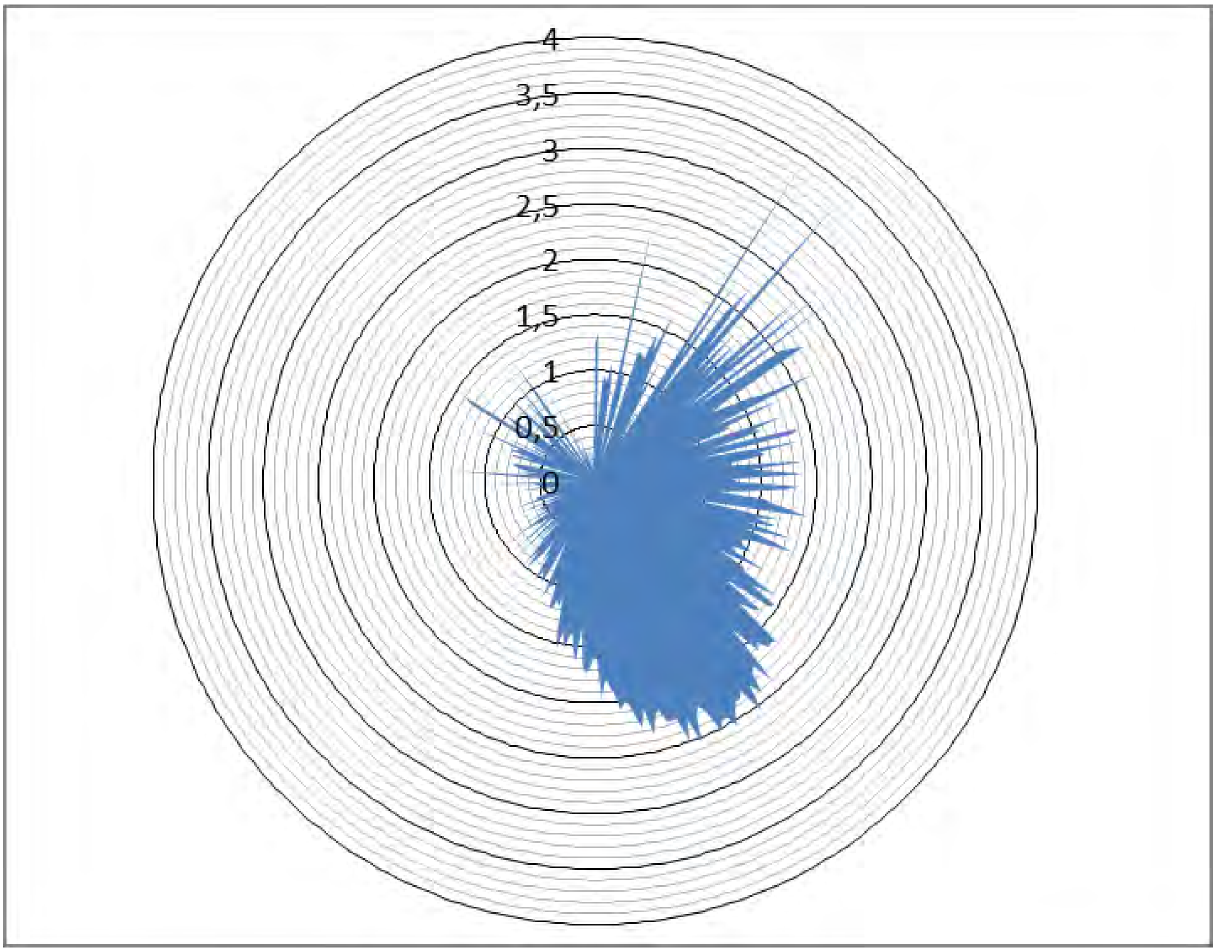
Graph 5.1-6 – Predominant direction and average wind speed (m / s) from the data between the years 1961-1990 at the São João do Piauí station.



Source: INMET, 1992. Prepared by: Arcadis, 2017.

The PNM Meteorological Station recorded the behavior of winds in the Directly Affected Area in the period between 2006 and 2016. It is clearly observed that the predominance of winds is from the southeast, the highest occurrence of winds in the 4^{th} quadrant of the graph. The average wind speed, recorded in the Climatological Norms, coincides with the winds recorded in the historical series of the last ten years of the PNM station.

Graph 5.1-7– Predominant direction (from 0º to 359º) and average wind speed (m / s) in the data from the years between 2006 and 2016 for the Piauí Níquel Metais station.



Source: Estação Piauí Niquel Mineração, 2016. Prepared by: Arcadis, 2017.

The local wind rose follows the regional trend with predominant winds coming from the southeast, east and northeast. Secondarily, there are northwest winds, recorded between the months of January and March. The local Wind Intensity Chart confirms the regional frequency of prevailing winds.

The average wind speed was 4m / s. and gusts were recorded in January (12 m / s) coming from the southeast.

5.1.2. Geology

5.1.2.1. Regional Geological Context - Area of Indirect Influence (AII)

In order to characterize the regional geological context and the distribution and characterization of lithostratigraphic units, a bibliographic survey was carried out to determine the main characteristics and evolution of geological knowledge of the region where the enterprise is located; principally the region of the AII of the physical and biotic environment for the project.

The mapping and respective explanatory notes of the Geological Map of the State of Piauí, prepared by CPRM, and the sheets, SC.24-VAI RIACHO QUEIMADAS ESCALA 1: 100.000 - CPRM, 2013 and SC-23-XB-VI BARRAGEM ESCALA 1, were consulted. : 100,000 - CPRM, 2011.

In addition, information from the ESIA / RIMA was used (Arcadis Tetraplan, 2008).

A) Geotectonic Context

The enterprise's AII comprises part of the domains of the structural provinces São Francisco, Borborema and Parnaíba, as shown in Figure 5.1-2, and is tectonically emplaced in the Riacho do Pontal Folding Strip (Brito Neves, 1975).

The Riacho do Pontal Strip, defined by Brito Neves (1975) consists of a passive margin basin, where it is represented by the Casa Nova Group, corresponding to the Casa Nova de Souza et al. (1979). This group is represented by the Mandacaru and Barra Bonita formations, and borders on the south with the Vitor Complex, migmatitic gneiss, granulite, of the São Francisco Craton; and to the west, its boundary is covered by Paleozoic sediments from the Parnaíba Province.

The province of São Francisco or *Cráton São Francisco* (Almeida et al. 1977), mainly covers the states of Bahia and Minas Gerais and is the most exposed and studied tectonic unit of the of the South American basement rocks. It is described as a component of the platform, the basis of which consists of an Archean block, which has not suffered the effect of the meso and neo-Proterozoic orogens. Sedimentary coverings are distributed as two large morphotectonic features, namely the São Francisco Basin and the Aulacógeno do Parnamirim

With regard to the Borborema province, which is present in most states in the northeast of Brazil, the area is limited to the north of Bahia and the southeast of Piauí. This province is bounded to the south by the São Francisco Craton and to the west by the Parnaíba province. It is an area of considerable lithostructural complexity, where the effects of crustal rework generated by tectonic, thermal and magmatic events of the Brazilian Cycle are evident (Santos and Brito neves, 1984).

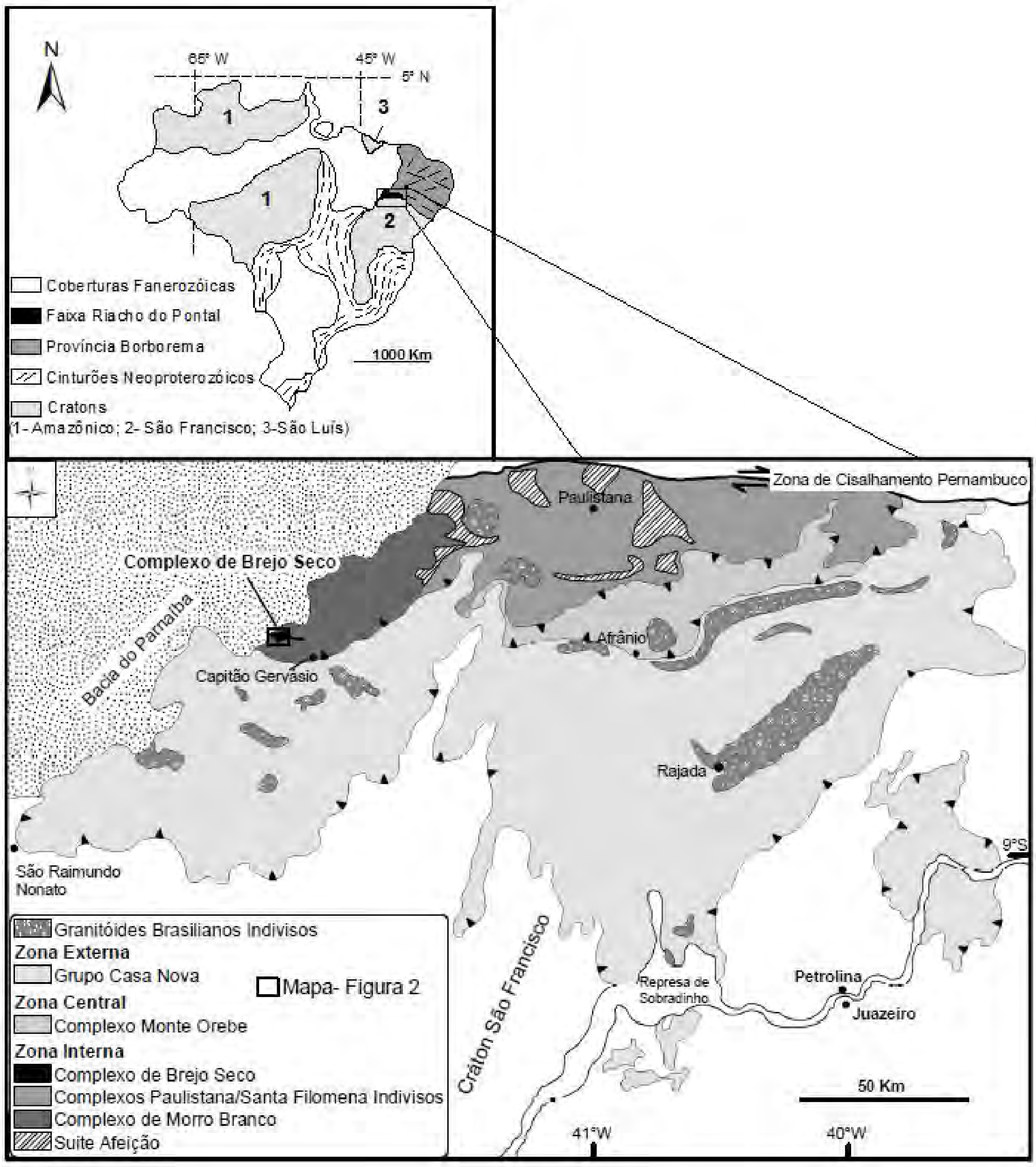
The Parnaíba Province, can be described as composed of four depositional sites: the Parnaíba Basin, the Espadrilles Basin, the Grajaú Basin and the Espigão-Mestre Basin. These are separated by discontinuities which coincide with those that limit the supersequences of Góes and Feijó (1994).

Góes (1995) when proving the difficulty of understanding the tectono-sedimentary picture, proposed the designation of Parnaíba Province, since, within the context of a single basin, it is verified that its polycyclic evolution is compartmentalized in basins with genesis, tectonic styles, sedimentary filling and different ages.

The Parnaíba Basin comprises the Silurian (Serra Grande Group), Devonian (Canindé Group) and Carboniferous-Triassic (Balsas Group) supersequences of Góes and Feijó (1994).

According to Góes and Feijó (1994), the Serra Grande Group can be interpreted as an environment of fluvial-glacial and glacial deposition, changing to transitional (neritic) and returning to continental conditions (interlaced fluvial). The Tianguá and Jaicós formations, respectively, would represent the maximum flood surface and the regressive interval of this sequence.

Figure 5.1-2 – Geological Map of the Riacho do Pontal Strip. Simplified by Caxito (2013).



Source: Salgado, 2014.

B) Geological Context of the AII

The Riacho do Pontal Strip (northern limit of the São Francisco Craton and southern portion of the Borborema Province), in the context of the project's AII, is represented by a Paleoproterozoic volcano-sedimentary sequence, with an approximately east-west trend, in which mafic-ultramafic intrusions are found, such as the Brejo Seco Complex, which is of potential economic interest, as it contains the lateritic nickel deposit. Imbricated in this sequence, forming tabular bodies, there are also metamorphic assemblies, such as granitic orthogneisses and those of granodioritic composition.

These ultramafic rocks are partially deformed, due to their own genesis, and are metamorphosed, with the development of mafic and ultramafic shale bands. The enclosing consist predominantly of fine (mica) and coarse (quartzite) metassediments.

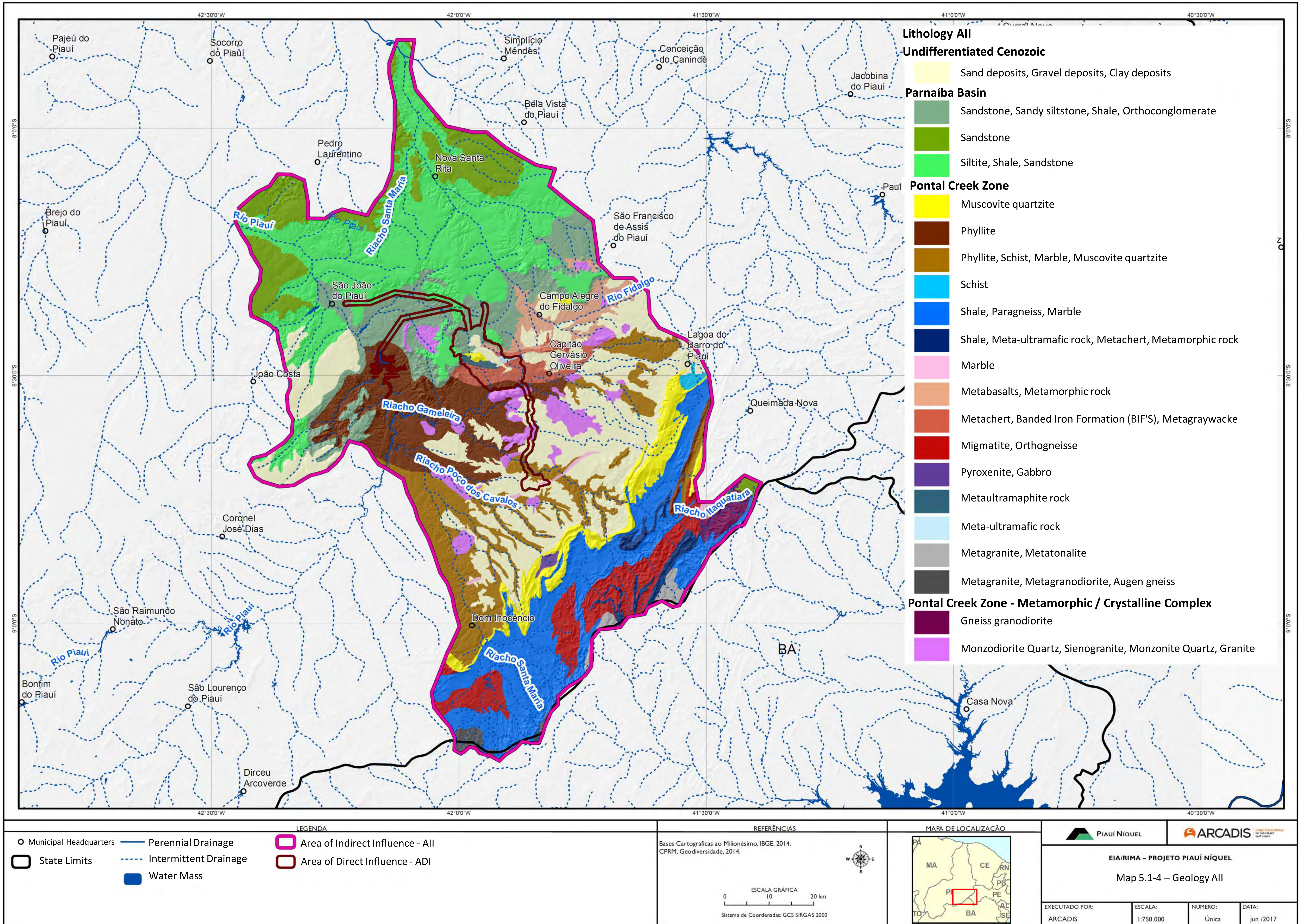
The most common rocks in the AII, within the context of the cratonic region, are represented by Gneisses-migmatitic complexes, formed by TTG-type orthogneisses, alternated with leukogranitic levels of tonalite / granodioritic composition, diverse migmatitic structures, encompassing varied supracrustal rocks of Paleoproterozoic age.

Numerous intrusive bodies of granitic and syenitic composition, of Neoproterozoic age of alkaline affinity, occur mainly south of the AII, being represented in the region by the massive formations of the mountains of Aldeia and Laurinda, south of Morro do Brejo.

As can be seen in Map 5.1-4, to the north of the AII, discreetly covering the Precambrian metamorphic and igneous rocks of the crystalline basement, outcrop sedimentary rocks of the Parnaíba intracratonic basin, which are of hydrogeological interest, and is a Paleozoic basin with Mesozoic sediments covering much of its area.

Shallow sea sediments accumulated in the basin, resulting from transgressive processes, with continental sediments deposited during the regression phases.

Map 5.1-4 – Geology – All.



Lithology AII
Undifferentiated Cenozoic
Sand deposits, Gravel deposits, Clay deposits
Parnaíba Basin
Sandstone, Sandy siltstone, Shale, Orthoconglomerate
Sandstone
Siltite, Shale, Sandstone
Pontal Creek Zone
Muscovite quartzite
Phyllite
Phyllite, Schist, Marble, Muscovite quartzite
Schist
Shale, Paragneiss, Marble
Shale, Meta-ultramafic rock, Metachert, Metamorphic rock
Marble
Metabasalts, Metamorphic rock
Metachert, Banded Iron Formation (BIF'S), Metagraywacke
Migmatite, Orthogneisse
Pyroxenite, Gabbro
Metaultramaphite rock
Meta-ultramafic rock
Metagranite, Metatonalite
Metagranite, Metagranodiorite, Augen gneiss
Pontal Creek Zone - Metamorphic / Crystalline Complex
Gneiss granodiorite
Monzodiorite Quartz, Sienogranite, Monzonite Quartz, Granite
42°30'0"W
42°0'0"W
41°30'0"W
41°0'0"W
40°30'0"W
8°0'0"S
8°30'0"S
9°0'0"S
Pajeú do Piauí
Socorro do Piauí
Simplício Mendes
Conceição do Canindé
Jacobina do Piauí
Bela Vista do Piauí
Pedro Laurentino
Nova Santa Rita
Paulistana
Brejo do Piauí
São Francisco de Assis do Piauí
São João do Piauí
Campo Alegre do Fidalgo
Capitão Gervásio Oliveira
Lagoa do Barro do Piauí
João Costa
Queimada Nova
Coronel José Dias
São Raimundo Nonato
Dom Inocêncio
Bonfim do Piauí
São Lourenço do Piauí
Dirceu Arcoverde
Casa Nova
BA
Rio Piauí
Riacho Santa Maria
Rio Fidalgo
Riacho Gameleira
Riacho Poço dos Cavalos
Riacho Itaquatiara
LEGENDA
Municipal Headquarters
Perennial Drainage
Intermittent Drainage
State Limits
Water Mass
Area of Indirect Influence - AII
Area of Direct Influence - ADI
REFERÊNCIAS
Bases Cartograficas ao Milionésimo, IBGE, 2014.
CPRM, Geodiversidade, 2014.
ESCALA GRÁFICA
0 10 20 km
Sistema de Coordenadas: GCS SIRGAS 2000
MAPA DE LOCALIZAÇÃO
PA
MA
CE
RN
PB
PI
PE
AL
SE
TO
BA
PIAUÍ NÍQUEL
ARCADIS
EIA/RIMA – PROJETO PIAUÍ NÍQUEL
Map 5.1-4 – Geology AII
EXECUTADO POR: ARCADIS
ESCALA: 1:750.000
NÚMERO: Única
DATA: jun /2017

The following lithological units, belonging to the Parnaíba Basin, are found in the area:

- Serra Grande Formation

According to SCHOBBENHAUS *et al* (1984), the Serra Grande Formation consists of conglomerates and conglomeratic sandstones in the basal portion, overlaid by well-sorted, fine to medium sandstones, with a fine clastic sequence until reaching a typically pelitic facies at the top of the unit. The conglomeratic levels have pebbles of quartz, feldspar, slate, graywacke and siltstone, which can reach up to 20.0 cm in diameter (CALDASSO et al 1973).

The thickness of the Serra Grande Formation varies spatially, from tens of meters, in the western portion, to approximately 1,000 meters, in the eastern and northeast borders.

The sedimentary deposition sequence of this unit is proposed as a passage from a continental environment (conglomerates), to a shallow marine environment (fine sandstones) and finally a deep marine environment (pelitic sequence), which occurred during the passage of the Silurian to the Devonian (SCHOBBENHAUS et al 1984).

In some regions of the Serra Grande Formation, when close to contact with the crystalline base, the sandstones are sometimes silicified and acquire the appearance of quartzites, with low porosity.

- Pimenteiras Formation

An important characteristic of this formation is the lateral and gradual variation between clastic and pelitic facies, with a predominance of fine clastics. The lower portion is marked by a predominance of fine, clayey and well-sorted sandstones, interspersed with shales and siltstones. In the upper section, there is a predominance of fine sandstones, alternating to conglomeratic and calcareous sandstones.

The thicknesses in the Pimentairas Formation vary from 20 to 200 meters, with values between 40 and 100 meters predominating. Its contact with the overlapping unit, the Cabeças Formation, is consistent and gradual, although discontinuities occur locally.

The sedimentation environment of this unit is described as infraneritic to coastal, with fluctuations in sea level that caused periods of exposure of elevated areas (SCHOBBENHAUS et al 1984). The Pimenteiras Formation is Devonian in age and usually forms rounded hills, with convex escarpments, and constitutes a dendritic drainage pattern (CALDASSO et al 1973).

- Cabeças Formation

This formation is constituted from the base to the top, by poorly sorted, coarse sandstones, siltstones with interspersed bands of shales and fine sandstones. Also mentioned is the presence of diamictites accompanied by pebbles of the crystalline basement of (mainly) the Pimenteiras Formation and of the Cabeças Formation itself. The main sedimentary structure found in the Cabeças Formation is planar cross-stratification (MDGEO, 2008).

The thickness of this unit varies from 40 to 300 meters, with the greatest thickness found in the eastern portion of the basin.

The sedimentation environment of this unit is interpreted as being coastal with deltaic contributions. Formation age is mid-Devonian. The relief is usually demarcated by flat and extensive plateaus, with escarpments forming plateaus, due to the sandy levels.

Also, in the area, with small extensions, there are mafic dykes (diabases), embedded in faults with predominant NNE direction, that cut the rocks locally. There is also another fault system, with a predominant NW direction, not always containing this intrusion. This lito-structural aspect is noticeable in the area of the nickel deposit.

Throughout the AII, there is significant presence of a thick detritus-lateritic cover, sometimes siliceous, of Tertiary-Quaternary age.

Currently, the Brejo Seco Complex, or Brejo Seco Mafic-Ultramafic Complex, is interpreted as an intrusion associated with crustal rifting (gravity failures) on the edge of the São Francisco Craton.

5.1.2.2. Local Geological Characterization - Area of Direct Influence (ADI) and the Directly Area Affected (DAA)

The characterization of the geological framework of the areas directly affected and of direct influence was supported by the Geological Map of the State of Piauí, prepared by CPRM, 2004 and in the sheets, SC.24-VAI RIACHO QUEIMADAS ESCALA 1: 100.000 - CPRM, 2013 and SC -23-XB-VI DAM SCALE 1: 100,000 - CPRM, 2011.

High-resolution satellite images, the SALGADO Master's Dissertation (2014) and information provided from the 2008 ESIA (Arcadis Tetraplan, 2008) were also used, and considered sufficient, to compose the diagnosis of the Directly Affected Area (DAA) and of the Area of Direct Influence (ADI) of the mining-industrial component of the Piauí Nickel Project.

From the ADI / DAA Map, prepared from CPRM data, the following lithological units have been verified locally, according to Data Table 5.1-5.

Data Table 5.1-5 – Lithological distribution in the ADI.

Lithologic Unit	Environment	Principal rock types	Area (km²)	%
Serra Grande	Parnaíba Basin	Sandstone, Sandy siltstone, Shale, Orthoconglomerate	72.73	29%
Brejo Seco Complex - Unit 3	Metamorphic, Sedimentary (or Sediments)	Metachert, Banded iron formation (BIF's), Metagraywacke	45.47	18%
Colluvium-eluvial deposits	Undifferentiated Cenozoic	Sand deposits, Gravel deposits, Clay deposits	40.16	16%
Barra Bonita Formation - Unit 2	Metamorphic	Phyllite	27.29	11%
Pimenteiras, Canindé Group	Parnaíba Basin	Siltite, Shale, Sandstone	20.82	8%

Lithologic Unit	Environment	Principal rock types	Area (km²)	%
Brejo Seco Complex-Brejo Seco Body-meta-ultramafic zone	Metamorphic	Meta-ultramafic rock	11.44	5%
Barra Bonita Formation - Unit 1	Metamorphic	Phyllite. Schist. Marble. Muscovite quartzite	8.94	4%
Complex Brejo Seco - Unit 2	Metamorphic	Muscovite quartzite	6.44	3%
Serra da Aldeia	Crystalline	Monzodiorite quartz. Sienogranite. Monzonite quartz. Granite	6.00	2%
Monte Orebe Complex - Unit 1	Metamorphic	Metabasalts. Metamorphic rock	4.48	2%
Paulistana Complex - meta-ultramafic body	Metamorphic	Meta-ultramafic rocks	4.19	2%
Barra Bonita Formation - Unit 1 - limestone	Metamorphic	Marble	1.40	1%
Total			**249.36**	**100%**

Fonte: Arcadis, 2017.

From the above, it appears that 38% of the area is characterized by sediments from the Parnaíba Basin, 25% by the Brejo Seco Complex, 19% by other metamorphic formations, 16% by undifferentiated deposits of the Cenozoic and 2% by the crystalline basement.

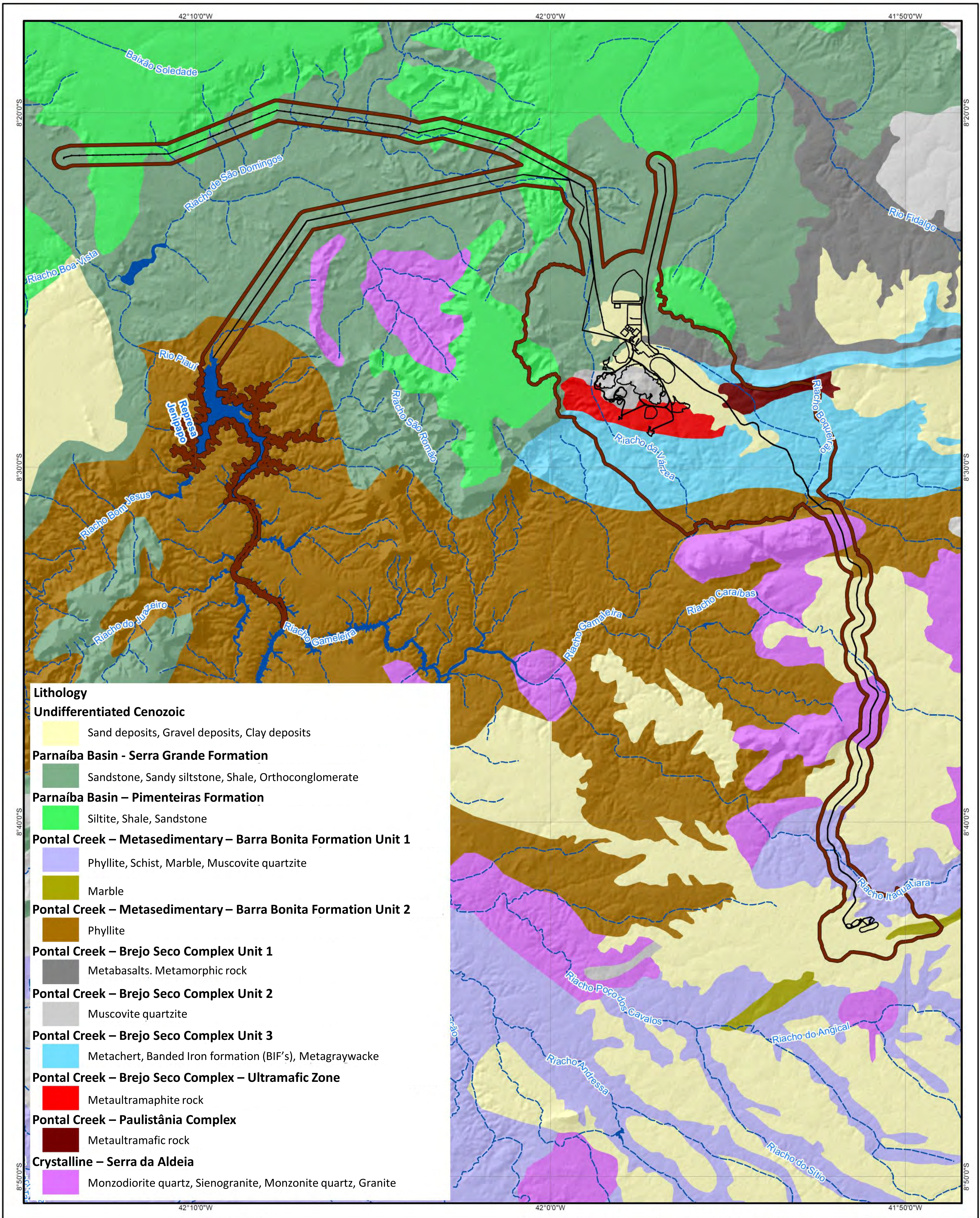
In the central area, lithology is described by the metamorphic formations, mainly by the Brejo Seco Complex, which is where the pilot plant and the mining area are inserted.

South of the ADI, in the Umbuzeiro area, where there will be quarrying of carbonate rocks, the lithology is described by metamorphic rocks represented by shales, phyllites and marbles.

Thus, the focus areas of this section are those where there will be greater intervention by the enterprise, and which take place over the central area (Brejo Seco Complex) where the nickel mine and the ADI will be installed in the south (Umbuzeiro) where limestone quarrying is planned. It is understood, therefore, that these two units should be the focus of detail for this section, since the description about the sedimentary unit is more than sufficient in the topic of the AII and will be covered, later, in the hydrogeological context of the area.

Map 5.1.5 shows the lithologies of the ADI and DAA of the project

Map 5.1-5 – Geology – ADI and DAA.



LEGENDA

- Intermittent Drainage
- Water Mass
- Area of Direct Influence - ADI
- Directly Affected Area - DAA

REFERÊNCIAS

CPRM, Geodiversidade Piauí, 2014.
SRTM/Topodata, consulta 2016.
Cartas SC23, SB23, SC24, SB24.
IBGE, Base contínua 1:250.000, 2015.

ESCALA GRÁFICA: 0 – 2,5 – 5 km

Sistema de Coordenadas: GCS SIRGAS 2000

LOCALIZAÇÃO

PA, MA, CE, RN, PB, PI, PE, TO, BA

Piauí Níquel | ARCADIS

EIA/RIMA – PROJETO PIAUÍ NÍQUEL

Map 5.1-5 – Geology
ADI and DAA

EXECUTADO POR:	ESCALA:	FORMATO:	FOLHA:	DATA:
ARCADIS	1:180.000	A3	ÚNICA	JUN /2017

A) Brejo Seco Mafic-Ultramafic Complex

The most evident geological feature in the area is the basic-ultrabasic intrusion of the Brejo Seco Complex into the rocks of the vulcanosedimentary sequence. The Brejo Seco Complex, also known as the Mafic-Ultramafic Complex, is interpreted as an intrusion associated with crustal rifting (gravity failures), on the edge of the São Francisco Craton.

This complex occurs in the central area of the ADI and is identified locally in the region of the pilot plant and area to be mined by the open pit.

The Brejo Seco complex covers an area of approximately 63 km² of the ADI, consisting of serpentinites (forming the Serra de Bacamarte), gabbros, diorites and troctolites, to which asbestos and garnieritic nickel mineralizations are related (SCHOBBENHAUS et al 1984). It is located to the north and has an accentuated topographic feature with elevations up to 470m, forming the Serra do Bacamarte.

Mixed drilling carried out by PROGEO in 2006 corroborate this scenario, where the rocks are mostly described as mafic to ultramafic rocks, characterized as serpentinites, normally gray in color, and can be phaneritic or aphanitic (Photo 5.1-1 e Photo 5.1-2). The main minerals, commonly observed, are described as plagioclases, pyroxene and olivine and some opaques (magnetite and chromite). In some points, subvertical to inclined mineral banding were also observed, with the occurrence of a portion of plagioclase as veinlets / veins and with chaotic millimeter venulations.

Photo 5.1-1 – Drill core, from the Brejo Seco area, of aphanitic textured rock, with serpentinized appearance.

Photo 5.1-2 – Drill core from the Brejo Seco area, of light gray rock, solid, subfaneritic, with inclined incipient foliation and possible silica and carbonate veinlets (mm).

Source: PROGEO, 2006.

From analysis of the thin laminations, a mesh texture consisting essentially of antigorite and chrysotile was identified. Common associations are chlorite, magnetite (martite), goethite, hematite and chromium spinel (picochromite).

From the modal analyzes performed, the following average composition was determined, according to Data Table 5.1-6.

Data Table 5.1-6 – Ultrabasic Zone: Average Composition of Modal Analises.

Mineral	Average (%)
Serpentine (antigorite, chrysotile and serpophyte)	78.0%
Chlorite (penite)	2.0%
Goethite	6.0%
Limonite	3.5%

Mineral	Average (%)
Magnetite (martite)	2.5%
Hematite	2.0%
Spinel (picochromite)	2.6%
Clays and other	3.4%

Source: Arcadis Tetraplan, 2008.

It was not possible to define the origin of the serpentinite, but its composition suggests a dunitic protolite.

The local fracturing observed and well demarcated in the area is encountered in the Ultra-mafic Zone to the north and the Mafic Zone to the south.

The basic rocks that occur to the south, form a semi-planed surface with levels of the order of 300 meters, comprising diorites, gabbros, peridotites and troctolites.

In the proximity of contact with the serpentinite, transitions between forms such as peridotites (olivine-plagioclase-pyroxene) and troctolites (olivine-plagioclase calcium-pyroxene) are common. These, close to the surface, in an advanced stage of alteration, show a dark red clayey saprolite with whitish spots and voids due to the alteration of the feldspars. At depth, the saprolite becomes lighter, with brown and light-yellow tones.

The incipiently altered rock has a “salt and pepper” texture and medium to coarse graining. The sublinear orientation of crystals is common, with mafic (pyroxene and / or olivine) and feldspar (plagioclase) in a ratio of 1: 1.

Under the microscope they show xenomorphic to granular hyponomorphic texture. Olivine commonly changes to serpentine + limonite + chlorite + dark minerals. Calcium plagioclase is saussuritized and pyroxene is of the diopside-augite variety.

These areas of contact of serpentinite with basic rocks, still in the south, are anastomosed and locally faulted, to the east and northeast, and a narrow strip of basic rocks surrounds the ultrabasic zone, presenting interdigitated contacts throughout its occurrence.

As a result of erosion action, colluvial capping is observed over almost the entire occurrence of the ultrabasic zone. Only in small areas, to the south and west, is it possible to observe outcrops of serpentinites.

The lateritic nickel mineralization occasioned, predominantly, by weathering, percolation of meteoric water and / or fluctuation of the water level of the free aquifer, causing the leaching of the olivine, is, therefore, restricted to the Ultramafic Zone (dunites). Thus, the nickel contained in the original olivine was released. Substitution of Mg by Ni and / or Fe occurs, generating nickeliferous serpentines. These silicates have also changed to a series of amorphous Si-Fe products rich in Ni.

The result of this alteration is the formation of a very oxidized (lateritic) horizon (soil), superimposed on the horizon consisting of the altered rock (dunite).

Fifteen lithological types of mining and environmental interest (pedological, geotechnical, hydrogeological) were characterized in the area of the Brejo Seco Mafic-Ultramafic Complex. This characterization was carried out by Vale, based on the interpretation of drilled profiles, tactile-visual identification of the materials and physical-chemical analises of the samples thereby collected and in the sampling pits, since there are practically no representative outcrops in terms of quantity and quality.

The deposit has strong structural anisotropy, being cut by several systems of faults / fractures and shear zones. The nature of the weathering process on rocks of different types, combined with structural anisotropy, creates a great difficulty in visual identification of the material.

The registered lithological types are as follows:

- Quaternary Sandy Cover

Sandy to sandy-silty, siliceous, unconsolidated, sterile material, with colors ranging from light yellow to red and brown. They come from the erosion of the Paleozoic sedimentary units adjacent to the Mafic-Ultramafic Complex. They cover the northeast and east portions of the surface of the plain, in the vicinity of the Mafic-Ultramafic Complex.

- Laterites

Sterile ferruginous coat, containing sub-angular to sub-rounded fragments of silica and soils from the alteration of the mafic and ultramafic rocks. They are generally consolidated and the fragments are surrounded by a ferruginous matrix (Figures 1.1-6 to 1.1-9). They occur at the level of the plain, and also in the vicinity of the Mafic-Ultramafic Complex.

- Undifferentiated cover

Allochthonous soils, rarely autochthonous, possibly with an interesting concentration of nickel, consisting predominantly of iron oxides and silica fragments and alterations of ultramafic soils. They are distributed mainly in the lower slope and at the foot of the mafic-ultramafic body.

- Colluvium

Allochthonous, sterile material, with a sandy matrix, rich in iron oxides, involving angular to sub-angular fragments, originating from mafic and ultramafic rocks, usually with strong silicification and sub-rounded fragments, coming from the adjacent Paleozoic sedimentary units.

- Silica

A type of amorphous silica, rich in iron, from red to dark brown, depending on the oxidation stage of the iron, sterile, high density, with a conchoidal fracture. This occurs mainly at the top of the weathering profile (plateau). SiO_2 levels are greater than 65%, reaching 97%, while Ni levels rarely reach 0.3%.

- Saprolite or Alteration Soil or Siliceous Residual Soil

Saprolite with siliceous network as boxwork and stockwork, of economic interest, varying amounts of iron oxides / hydroxides and silica, with some presence of nickel.

- Saprolite or Alteration Soil or Ferruginous Residual Soil

Red to brown saprolite, low density, of economic interest, consisting mainly of iron oxides and hydroxides (hematite / goethite). Locally it occurs as very massive levels and potential siliceous veinlets.

- Saprolite or Alteration Soil or Structured Ferruginous Residual Soil

Material occurring in structural discontinuities (areas of failure / fracturing), of economic interest, similar to ferruginous saprolite.

- Saprolite or Alteration Soil or Silicified Magnesian Residual Soil

Transition between the saprolites in the oxidized zone and the magnesian saprolite. It is usually generated from the weathering of a dunite / serpentinite, but it can include saprolites resulting from basic rock, as long as it has nickel contents above 0.5%.

Saprolite ranges from clayey to silicified, from green to greenish-brown in color. It is often found with a preserved cumulate texture, with silica-filled veinlets, eventually forming stockwork and boxwork structures. Mn oxide is observed filling fractures and widespread garnierites and smectites. Classified as ore.

- Saprolite or Alteration Soil or Magnesian Residual Soil

Saprolite with 25%> MgO ≥ 7%, with nickel contained in smectite and garnierite, of economic interest. It is a product of dunite / serpentinite weathering, but it can include saprolites resulting from basic rock, as long as it has nickel contents above 0.5%.

Saprolite has a green color, friable to compact, often with portions with intense silicification. Dissemination and possible concentrations of magnetite / chromite are observed, dissemination of garnierite / smectite and Mn oxide filling fractures.

- Saprolite or Alteration Soil or Aluminous Residual Soil

Saprolite generated from mafic bodies, with contents of Al2O3 ≥ 10% and MgO <7%, with potential economic interest. It shows a pale green to pink color, preserving the original rock texture. The granulation is coarse, with fine widespread phyllosilicates and whitish compact kaolinite fragments in the middle of a fine pale green matrix.

- Weathered serpentinite

Weathered serpentinized dunite, potentially mineralized and of economic interest. It has an MgO content of around 30%. The serpentinite is weathered, compact, green to yellow-green in color, medium grained. Crystals of magnetite / chromite are frequent and have chrysotile / asbestos in veinlets.

- Serpentinite

Serpentinized dunite, with MgO content ≥ 30%, without economic interest. It is an ultramelanocratic rock, of medium granulometry, green to gray-green in color, with olivine pseudomorphs, showing strong serpentinization. Disseminated chromite / magnetite and often microveinlets of silica and chrysotile / asbestos and disseminated chlorite (Figure 5.1-3).

- Mafics

These are gabbros, olivine-gabbros, troctolites and some anorthosites, without economic interest. They belong to the evolution of the Brejo Seco Mafic-Ultramafic Complex and have high levels of TiO_2 and CaO and low levels of Ni.

- Mafic Dikes and Sills

These materials, of no economic interest, differ from other mafics due to their lower Al_2O_3 contents and the higher TiO_2 contents.

Photo 5.1-3 – Laterite. Experimental nickel pit. Ore block with Ni/Co minerals.

Photo 5.1-4 – Blocks of lateritic rocks and asbestos.

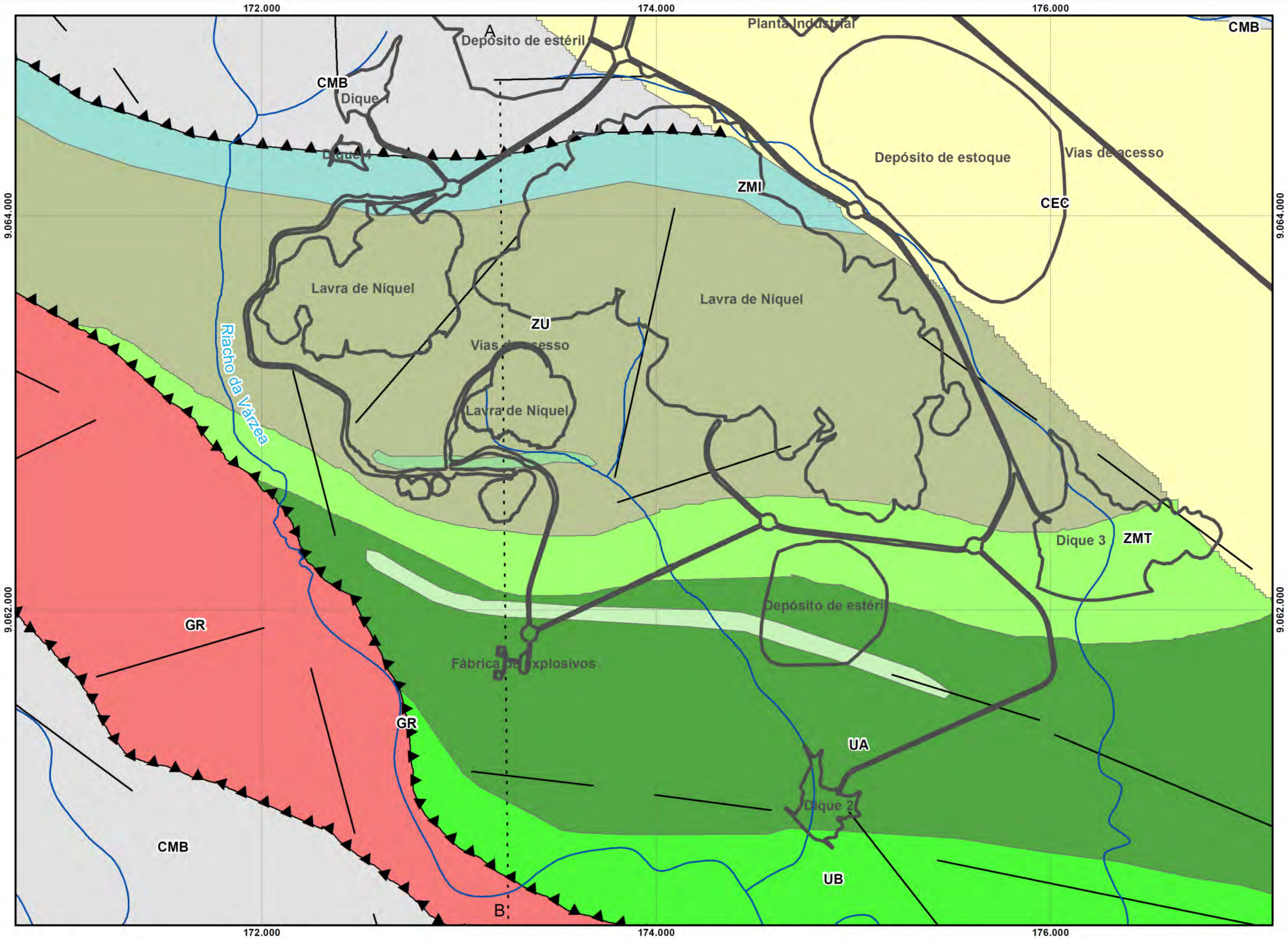
Photo 5.1-5 – Blocks of lateritic rocks and asbestos.

Photo 5.1-6 – Banded structure with fine asbestos veins. Rock colored green, black and purple.

Source: Arcadis, 2017.

Corroborating with the aforementioned, and deepening the level of detail of the information of the Brejo Seco complex, a geological map of the DAA (Map 5.1-6) was produced in greater detail (1: 25,000), in particular, of the area of the pilot plant and the mine. This map was made from the study of the metallogenetic potential of the Brejo Seco mafic-ultramafic complex, prepared by SALGADO (2014).

Map 5.1-6 – Geology of the DAA – 1:25.000.



Phanerozoic Cover
Colluvium-eluvial Cover – CEC

Neoproterozoic – Felsic Zone
Rajada Granite – GR

Neoproterozoic – Brejo Seco Complex – Superior Mafic Zone
Gabbro ilmenite-magnetite- UB

Gabbro and Dunite subordinate – UA

Dunite subordinate – UA

Neoproterozoic – Brejo Seco Complex – Transitional Mafic Zone
Troctolite – ZMT

Neoproterozoic – Brejo Seco Complex – Ultramafic Zone
Dunite and troctolite subordinate

Troctolite subordinate

Neoproterozoic – Brejo Seco Complex – Inferior Mafic Zone
Gabbro and troctolite subordinate

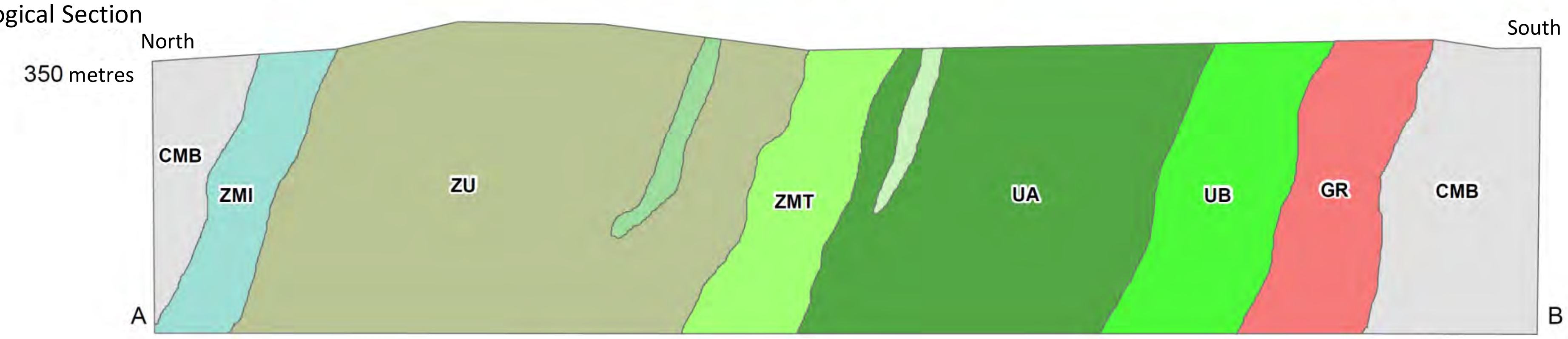
Embedding
Morro Branco Complex

Structural lines
Lineament

Geologic Section A – B

Compressional Shear Zone

Geological Section



LEGENDA

Drainage

Directly Affected Area - DAA

REFERÊNCIAS

IBGE, Base contínua 1:250.000, 2015
Projeto Piauí Níquel, 2016
Salgado, 2014

ESCALA GRÁFICA

0 0,25 0,5 km

Sistema de Coordenadas: SIRGAS 2000 UTM Zone 24S
Projeção: Transverse Mercator

MAPA DE LOCALIZAÇÃO

Piauí Níquel Mineração

ARCADIS

EIA/RIMA – PROJETO PIAUÍ NÍQUEL

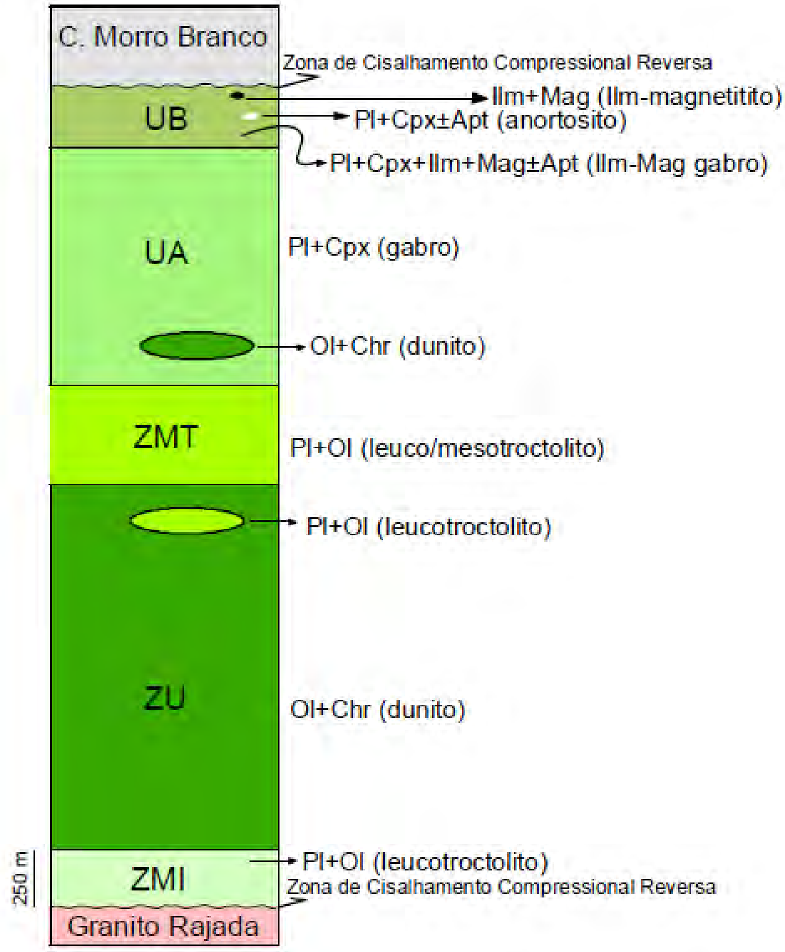
Map 5.1-6 – Geology of the DAA
Nickel Mine

EXECUTADO POR:	ESCALA:	NÚMERO:	DATA:
ARCADIS	1:25.000	Única	jun/2017

According to criteria suggested by Irvine (1982), the division of a tiered igneous complex must be carried out based on three main points: i) the association between the main cumulus phases; ii) the identification of units that may represent cyclical crystallization processes; iii) the representativeness of each lithology according to the mapping scale.

Thus, the Brejo Seco complex was divided into four main zones: Lower Mafic Zone, Ultramafic Zone, Transitional Mafic Zone and Upper Mafic Zone (according to the DAA geological map and Figure 5.1-3).

Figure 5.1-3 – Stratigraphy of the magmatic chamber of the Brejo Seco Complex with the representation of the main cumulus phases present throughout the different zones.



ZMI- Lower Mafic Zone; ZU- Ultrasound Zone; ZMT- Transitional Mafic Zone; UA- Unit A; UB- Unit B. Ol- Olivine; Chr- Chromite; Pl- Plagioclase; Cpx- Clinopyroxene; Ilm- Ilmenite; Mag-Magnetite; Apt- Apatite.

Source: Salgado, 2014.

According to SALGADO (2014), the concept of base and top applied to the nomenclature of the zones was established with the perspective of the base and the top of the magmatic chamber, but the stratigraphic relationships of top and base in the Brejo Seco Complex were tectonically inverted. The tectonic inversion of the magmatic bedding is evidenced by the general pattern of fractionation of the complex and also indicated by the polarity of the fractionation in several cyclic units exposed and / or intercepted in drill holes in the Ultramafic Zone. The Lower Mafic Zone is interpreted as a basal border group of the Brejo Seco Complex and, therefore, comparable with the basal zones of several layered complexes such as the Niquelândia complex (Ferreira Filho et al. 2010) and the Sonju Lake and Partridge River, at the Duluth Complex (United States; Miller & Ripley, 1996).

Lower Mafic Zone (ZMI) - This consists of a narrow strip, approximately 250 meters thick, positioned at the north end of the complex. It occurs in a broken area, with very sparse outcrops, so that its delimitation on map and petrographic characterization was based essentially on drilling data. In the basal contact with the Morro Branco Complex milonitized green shales occur, which show a compressional, reverse shear zone, with tectonic transport to the south. It consists of leukotroctolite (Cumulative Pl + Ol ± Chr; mineral abbreviations according to Whitney & Evans 2010, namely Ol- Olivine; Chr- Chromite; Pl- Plagioclase; Cpx Clinopyroxene; Ilm- Ilmenite; Mag- Magnetite; Apt- Apatite). The contact with the Ultrasound Zone cannot be precisely defined, but it is marked by the transition from cumulative Pl + Ol ± Chr to cumulative Ol + Chr (SALGADO, 2014).

Ultramafic Zone (ZU) - This comprises the Morro do Bacamarte, a plateau supported by silexites that cover the lateritic nickel deposit. The ZU is about 1,500 m thick, being formed predominantly by serpentinized dunite (Ol + Chr cumulates) and leukotroctolite intercalations (Pl + Ol ± Chr). The intercalations have a thickness that reach tens of meters and occur in all stratigraphy of the ZU, becoming, however, thicker and more frequent in its upper portions, thus showing a gradual contact with the Transitional Mafic Zone. In this contact, the presence of some sulfide mineralization stands out (SALGADO, 2014).

Transitional Mafic Zone (ZMT) - This is located between the Ultramafic Zone and the Upper Mafic Zone. It has a thickness of approximately 400 m in its western portion, but that increases towards the east. It is characterized by the predominance of cumulative Pl + Ol, consisting of leuco and mesotroctolite (Cumulative Pl + Ol ± Cpx ± Chr). The gradual decrease of olivine as a cumulus phase in the upper portions of the ZMT characterizes its contact with the Upper Mafic Zone (SALGADO, 2014).

Upper Mafic Zone (ZMS) – This is the one with the best exposure area of the complex, where it occurs continuously along the local drainages, from north to south. Its thickness is approximately 1,000 m and makes tectonic contact with the milonitized Granite Plateau to the south and west. This zone is subdivided into units A and B, which are distinguished, according to SALGADO, 2014, by the restricted presence of the cumulates of ilmenite-magnetite in Unit B.

Unit A (UA) is composed essentially of gabbro (Cumulative Pl + Cpx), with olivine-gabbro (Cumulative Pl + Cpx + Ol) and subordinate troctolite (Cumulative Pl + Ol + Cpx ± Chr). An adcumulative dunite lens, containing troctolite xenolites, emerges close to the contact between the UA and the ZMT. It is succeeded, over 150 m to the south, by troctolite and olivine-gabbro, until the return of gabbro as the predominant lithology (SALGADO, 2014).

Unit B (UB) is essentially formed by gabbro ilmenite-magnetite (Pl + Cpx + Ilm + Mag ± Ap cumulated), with slightly thick intercalations (<5 meters) of ilmenite-magnetite (Mgt + Ilm cumulated) and subordinate anorthosite (Pl + Cumulative Cpx + Apt) (SALGADO, 2014).

B) Umbuzeiro Limestone

In order to better select the alternative for supplying raw materials for the Piauí Nickel Project - PNP, and based on geological information collected from previous works of a regional nature, carried out in early 2004, field campaigns in the south-southwest region of Capitão Gervásio de Oliveira - PI were planned and executed by the PNP team, more specifically, in a restricted strip between the Itaquatiara and Angical rivers, covering areas of interest and, at the time, under exploration permits granted in the name of Vale.

In these campaigns, rocks that form a set with general direction N60-70E were mapped, with moderate to high average dip to the northwest. It was found that a striking feature of the Umbuzeiro Area is the smooth relief, with an average level between 327 and 358 m, with extensive quaternary sandy cover, where small or expressive outcrops of limestones and dolomites stand out or emerge.

In regional recognition, among the mapped and registered units, the dominant presence of calcitic limestone was emphasized, among other factors. This supported the choice and definition of the best area for the implementation of a topographic network to support exploration.

The geological mapping carried out in the area basically consists of observation and detailed description of the main structures and types of rocks present in the area, as follows:

- Tertiary-quaternary cover, consisting of residual in-situ or allochthone soil, sand and gravel, the latter as remnants of the destruction of the old Siluro-Devonian cover (Serra Grande and Pimenteiras Formations). It covers about 60% of the area.
- Pink to beige, marbled and fine to very fine-grained dolomites, massive to finely foliated and or laminated, the first having striking characteristics, namely: they are always severely broken, micro-fractured in both outcrops and cores from rotary diamond drilling machines.
- Light gray to medium colored limestones, also marbled, sometimes fine-grained, sometimes coarser, with laminated and / or foliated structure, sometimes striking, sometimes diffuse or even absent (Photo 5.1-7 e Photo 5.1-8). The laminated / banded structures being a major feature of the calcitic terms and the foliated / absent ones, of the magnesians. Infills and late carbonate veining, white, sometimes calcitic, sometimes dolomitic, occur in a random, sparse or, more rarely, dense form in metric intervals.
- Milky white quartz, in centimetric to decimetric fragments, sparsely loosened in the soil or filling fractures northeast - southeast, of a few centimeters thick, existing in the carbonate rocks or along the foliations and fractures in the embedding shales.
- Slightly green to medium grained mica shale, composed of sericite, chlorite and quartz, with a striking mylonitic foliated structure. Quartz forms lenticular aggregates, sometimes stretched sigmoidal or boudinated, sometimes broken lenticulars and fractures.
- Coarse-grained intrusive granitoids, foliated in shear zones. In the studied area, they are very restricted, appearing only in the middle of the embedding shales, 3 km to the northeast, before contact with the carbonate rocks.

Interpretatively, the local geology is marked by a general and dominant, anti-normal “M” structure, with a NE-trending dip and its inverted southwestern extension. The pink, massive and fractured dolomites border this structure, with the calcite limestones, magnesian limestones and foliate beige dolomites, in the inner portion of the package.

Photo 5.1-7 – Light gray to medium colored limestone, marbled.

Photo 5.1-8 – Limestone blocks, marbled.

Source: Arcadis, 2017.

Both in the outcrop and in the diamond core drilling samples, micro-fold relic structures in "Z", "S", "M" and "W" shapes are observed, surrounded by parallel structures of a lamination or foliation sometimes striking, indicating dextral and sinistral movements.

In short, the Umbuzeiro sequence is found with chevron-like folding, with marked banding, lamination and foliation trending N70E, with dominant vergence to the northwest, coinciding with the regional domain, as observed in the São Romão and Itaquatiara riverbeds, between Capitão Gervásio de Oliveira and the Umbuzeiro area.

As a result of this chevron folding, with the planar Sn structure folded into Sn + 1 milonitic, the Umbuzeiro rocks, dipping under the shales, reappear about 8 km south of this area, in the place called Vila Angical.

The Sn structure, generated by the first phase, is a penetrative milonitic foliation with recrystallization of grains. It is this foliation that marks the main microstructures (millimeter to centimeter) as banding of light / dark limestone, and the permanence of this pressure event later marked the drag folds, closed isoclinic folds and broken flanks.

The Sn + 1 structure, generated through the second phase of rework of the massif, is characterized by regional folding with axis located between N40E and N30E (NE-SW), seen only at the eastern end of the area. In this portion, from north to south, it is possible to observe what could be an anticline. The second phase does not form a surface, but only generates a bend in the rocks.

The western portion has thick ground cover and does not have enough outcrops, which makes it difficult to understand the surface geology.

5.1.3. Geomorphology

5.1.3.1. Regional Geomorphological Context and the Area of Indirect Influence (AII)

This section aims to contextualize the regional geomorphological situation, describing the morphological domain of the project, the main relief systems characterized from the morphostructures and morphosculptures existing in the area, in order to identify its genesis and main relief patterns found in the physical and biotic environment of the AII.

The characterization of the AII was made using secondary data, derived from interpretations of satellite images and regional geological maps. The geological map presented for the AII was prepared from the integration and refinement of the sheets SB23 and SB24 (Teresina / Jaguaribe), SC.23 and SC24 (Rio São Francisco / Aracajú), scale 1: 1.000.000 (PROJETO RADAMBRASIL, 1973) of the Map of Relief Units of Brazil, scale 1: 5,000,000 (IBGE, 2006).

The region is divided into two distinct morphostructural units, the first on the southeast side of the AII, the eastern domain of the Sertaneja Depression and the São Francisco River, whose unit is represented by the Neoproterozoic Mobile Belts and Neoproterozoic Cratons, and the second unit, at the northwestern strip of said area of influence, it is the Parnaíba Sedimentary Basin, represented by the Phanerozoic Sedimentary Basins and Coverings.

Sertaneja Depression

This morphostructure occupies the south center of the AII, bordering Piauí and Bahia, this limit also coincides with the drainage head of the Itaquatiara and Riacho do Poço, both tributaries of the Piauí River Basin. The Sertaneja Depression (Maia and Bezerra, 2014) is characterized by a relatively flat relief with a dissected, gently wavy surface. The unit is represented by a pediplane developed on Precambrian rocks with a strong influence of pediplanation and endogenous movements of the Cretaceous and Cenozoic.

In general, it shows relief predominantly constituted of low hills and hillocks, with a predominance of slopes below 15%. However, some isolated rocks and knobs, rise abruptly (inselbergs) and such shapes are arranged and aligned as folded ridges, standing out in the landscape, having slopes between 15 and 45%. Both the relics and the ridges form sets of small hills with elevations between 180 m and 650 m, they are lithological inheritances of the Cycle-Brazilian that emerged to the surface after the erosive cycles that occur up to the Cenozoic.

Parnaíba Basin

In the AII, the Parnaíba Basin is limited by the Sertaneja Depression through sandstone-based escarpments. To the interior of the Parnaíba Basin, from the center to the north of the AII, the reverse side of the escarpment drains into Piauí. The flat and wide tops of these plateaus are supported by the Cretaceous sediments, while the dissected sediments and escarpments are usually associated with the Paleozoic sediments (Ross, 1990).

The macroform of the Parnaíba Basin is conditioned by its intracratonic nature (Ab'Saber, 1969), limited by structural arches and high-grade moving bands, reworked during the Brazilian Cycle (± 600 Ma). Its lithology, as a result of depositional conditions, is represented only by Paleozoic rocks, corresponding to the Serra Grande, Canindé and Balsas groups, which represent the remaining portion of an extensive Afro-Brazilian sedimentation, involving three major transgressive-regressive cycles that occurred since the Silurian until the continentalization of the basin (Triassic). Therefore, this macroform has a tectonic and sedimentary development associated with basin basement subsidence within the evolutionary context of the Gondwana paleocontinent.

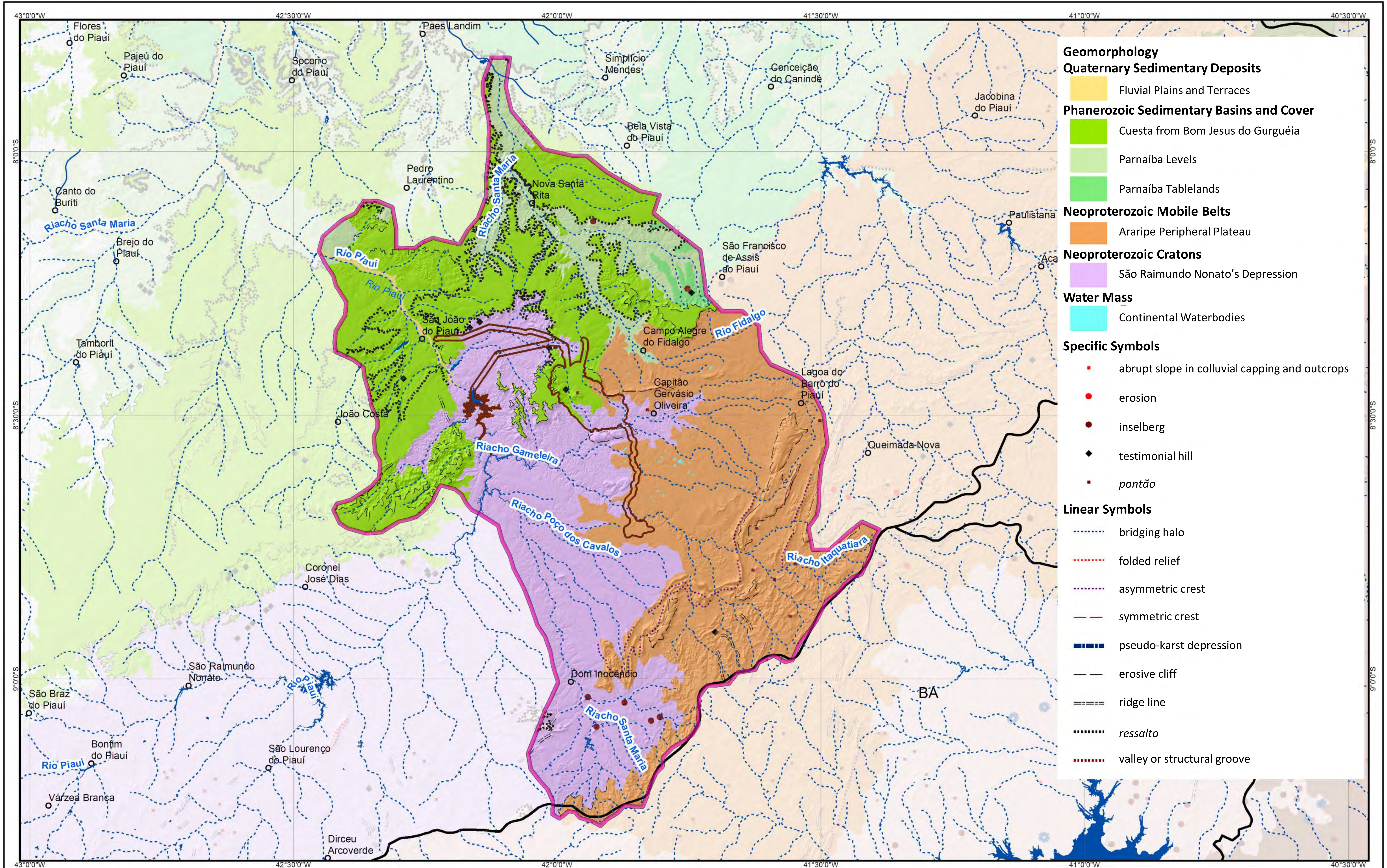
The biggest slopes of the AII are distributed between the Ibiapaba / Araripe Peripheral Plateau and the Cuestas, Patamares and Tabuleiros of the Parnaíba Basin. These slopes are associated with the features of asymmetrical ridges, edges of terraces and on erosive escarpments. These features are located mainly in the Neoproterozoic belt of the peripheral levels and in the formations of the phanerozoic sedimentary cover. A good part of the AII is between 0-12% of inclination, with special emphasis on the Depression of São Raimundo Nonato.

The highest altitudes are in the Neoproterozoic Mobile Belts and at the summits of the erosive escarpments of the Cuesta de Bom Jesus de Gurgéia, while the lowest altitudes are obviously downstream of the AII, in the domains of the Parnaíba levels.

The AII Geomorphological Map based on RADAM Brazil (1973) depicts the fluvial plains developed in the quaternary, in addition to the phanerozoic sedimentary coverings of the Morphostructure of the Parnaíba Basin, and, finally, the Neoproterozoic belts and cratons of the Sertaneja and São Francisco Depression.

It is noted that in the AII there are mapped inselbergs in the Depression of São Raimundo Nonato, while the prominent hills are more frequent near the edges of the sedimentary level of the Parnaíba basin. The forms of accumulation, such as river plains, are extremely restricted, since drainage is intermittent, even in the rainy season. The hydrographic pattern is predominantly dendritic, sometimes with parallel aspects, other latticed formed. The flow is from southeast to northwest in a fourth-order network according to the Straler method.

Map 5.1-7 – Geomorphology of the AII.



LEGENDA

- Municipal Headquarters
- State Limits
- Perennial Drainage
- Intermittent Drainage
- Water Mass
- Area of Indirect Influence - AII
- Area of Direct Influence - ADI

REFERÊNCIAS

Bases Cartograficas ao Milionésimo, IBGE, 2014.
Projeto RADAM - disponível em http://mapas.ibge.gov.br/bases-e-referenciais/bases-cartograficas/cartas.html
Cartas SC23, SB23, SC24, SB24.

ESCALA GRÁFICA
0 10 20 km
Sistema de Coordenadas: GCS SIRGAS 2000

MAPA DE LOCALIZAÇÃO
PA MA CE RN PB PE AL SE PI BA TO

PIAUÍ NÍQUEL
ARCADIS

EIA/RIMA – PROJETO PIAUÍ NÍQUEL

Map 5.1-7 – Geomorphology of the AII

EXECUTADO POR:	ESCALA:	NÚMERO:	DATA:
ARCADIS	1:750.000	Única	jun /2017

5.1.3.2. Local Geomorphological Characterization - Area of Direct Influence (ADI) and Directly Affected Area (DAA)

This section aims to describe the forms and dynamics of the relief of the Area of Direct Influence (ADI) and the Directly Area Affected (DAA). For this reason, the correlation between information obtained from basic cartographic products, fieldwork and secondary data, already mentioned in the diagnosis of the IIA, was used.

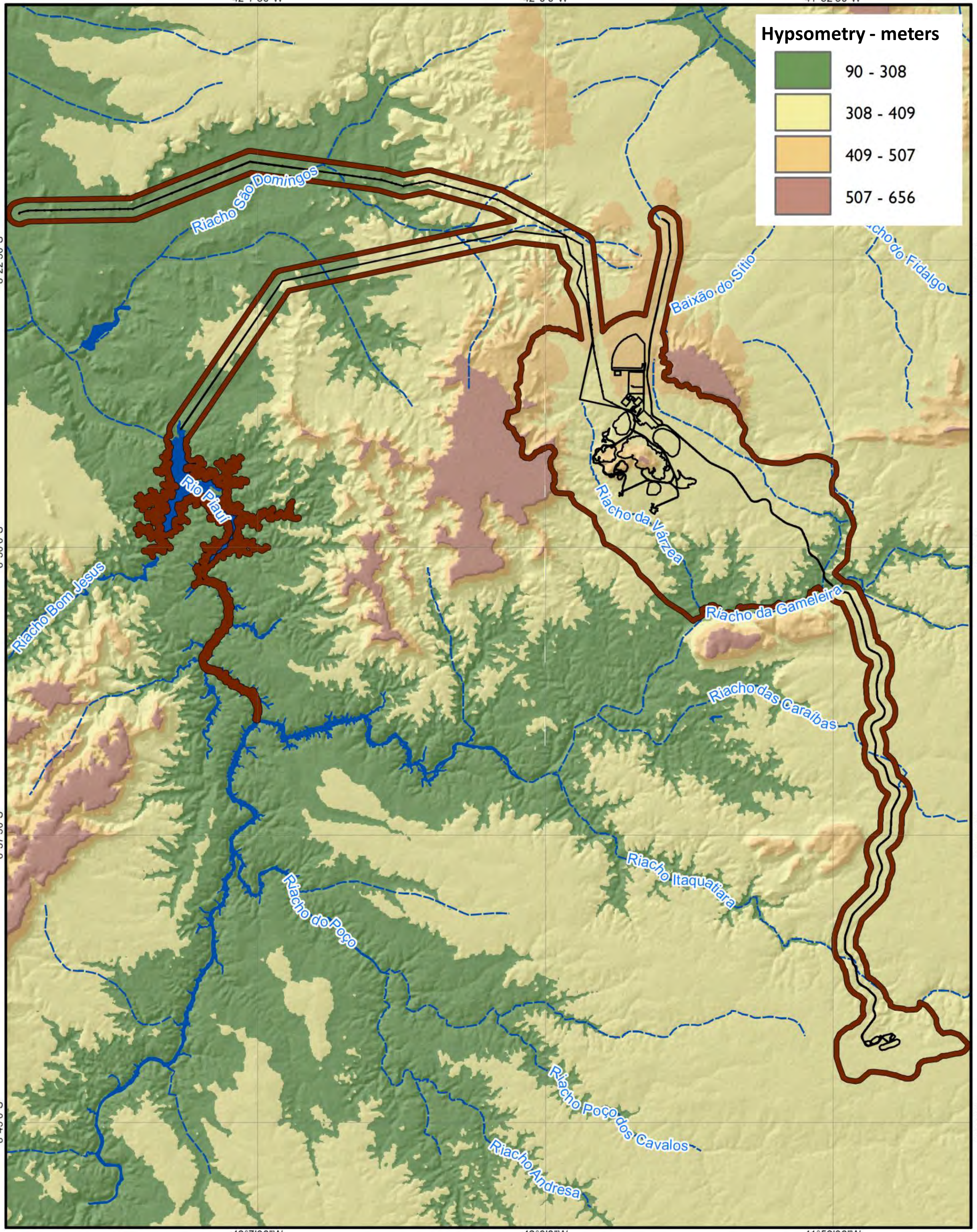
The geomorphological mapping of the aforementioned areas of influence was prepared from the interpretation of SRTM / Topodata radar images and the planialtimetric survey of the area of interest of the PNM project in the light of the mappings of CPRM (2010) and RADAM (1973). Thus, seven landforms were defined and mapped, namely: (1) Fluvial Plain, (2) Flat Top, (3) Smooth Slope, (4) Smooth Dissection Slope, (5) Dissected Slope, (6) Slope Very Dissected and (7) Abrupt.

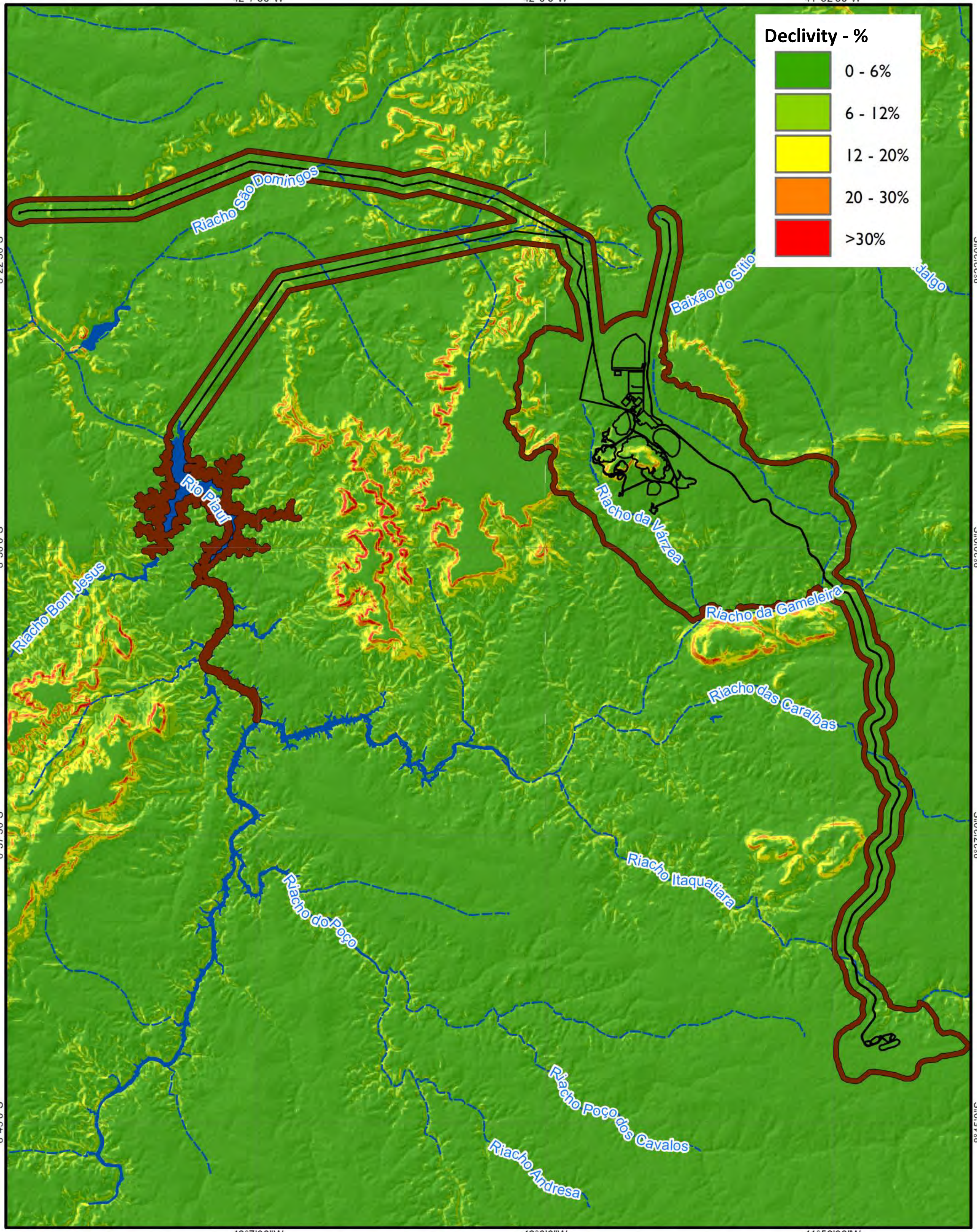
As an overview of the study area, the relief of ADI is predominantly composed of extensive flattened areas, both from the summit of the sandstones, as well as in the broken lands of the Sertaneja Depression. The flattening of the hinterland pediplane is recognized by the presence of residual hills. And the Cenozoic flattening of the Parnaíba summits in the ADI are close to the plateaus, such as the Chapada de São Francisco.

The planed surfaces have levels below 300 m in altitude and slope between 0 and 6%. The mountains and hills are pre-Cambrian structures folded and eroded (Morro do Brejo Seco), or structural ridges, which rarely exceed 500 m in altitude. The rugged cuestiform lines are limited by the high slope (scalloped) edges (above 30%). The forms of accumulation, such as river plains, are extremely restricted. The plateaus that surround the ADI, are tabular surfaces, with an altitude around 500m of altitude and very low slope.

The location of the toponyms mentioned, in addition to altitude and slope of the surface in the ADI and DAA, are expressed in the Clinographic and Hypsometric map of the ADI and DAA. In it, five classes of relief division are defined (according to Ross, 1994) and four classes of altimetry. Most of the ADI and DAA show very weak to weak dissection, between 0% to 6%, however in the surroundings of reliquaries and slopes the inclination reaches from strong to very strong, exceeding 30%. The altimetry mapped in the ADI and DAA show altimetries from 90 to 507 meters above sea level. The highest altimetry is related to the plateaus bordering the ADI, the lowest slopes go towards the interior of Piauí, showing the direction of the drainage flow.

Map 5.1-8 – ADI and DAA Hypsometric and Clinographic map.





LEGENDA

- Intermittent Drainage
- Water Mass
- Area of Direct Influence - ADI
- Directly Affected Area - DAA

REFERÊNCIAS

SRTM/Topodata, consulta 2016.
Cartas SC23, SB23, SC24, SB24.

ESCALA GRÁFICA
0 2,5 5 km

Sistema de Coordenadas: GCS WGS 1984

MAPA DE LOCALIZAÇÃO

PIAUÍ NÍQUEL | ARCADIS

EIA/RIMA – PROJETO PIAUÍ NÍQUEL

Map 5.1-8 – Hypsometry and Declivity – ADI and ADA

EXECUTADO POR:	ESCALA:	NÚMERO:	DATA:
ARCADIS	1:250.000	Única	jun /2017

Below is a description of the relief forms and respective morphodynamic processes in the ADI and the DAA.

Fluvial Plain

Comprising depressed and essentially flat land, with a low slope (0-6%). Agradacional in form, subject to silting and can be a route of contamination of groundwater due to the subterranean to outcropping water table. Furthermore, these lands are recharge areas for underlying aquifers, as well as providing storage for subsurface water.

The most expressive river plains are associated with the Gameleira, Itaquatiara (near Umbuzeiro Mine), Caraíbas and tributary streams of the São Domingos stream.

Photo 5.1-9 – Riverbed in the dry season, substrate surface with hydromorphy with agglutination and cracking due to the contraction effect of clays.

Source: Arcadis, 2017.

Flat tops/Plateaus

They are lands associated with summit plateaus, with an altitude close to 500m and slope between 0 and 6%. It is a degradational feature, but with a greater tendency to pedogenetic processes compared to sculptural processes.

Thus, they are terrains of morphodynamic stability where the rainwater infiltration process predominates in the face of runoff.

These are associated with the Chapada de São Francisco and the Chapada do Sítio, west and east of the ADI respectively.

Photo 5.1-10 – In the background, tabular features with flat top.

Source: Arcadis, 2017.

Smooth Slopes

These are lands with wide slopes, varying between concave, rectilinear and convex, with a slope between 6% and 12%, and altimetry around 300m, generally located in the sedimentary basin of Parnaíba.

They are degradational features, where the meteoric water inflation process is slightly less than that of surface runoff, in this sense they are areas of morphodynamic stability, with diffuse and slow exhaustion being suitable for occupation by buildings, accesses and others. The erosive potential of these lands is low and they are not susceptible to mass movements.

This unit occurs around the Morro do Brejo Seco and lands where project structures will be constructed; transmission line and water supply.

Photo 5.1-11 – Smooth slope features of the Parnaíba Basin domain.

Source: Arcadis, 2017.

Smooth Dissection Slopes

These are three-tiered terrains, varying between concave, rectilinear and convex, with a slope between 6% and 12%, and altimetry around 300m. They are in the Sertaneja Depression. They are degradational features, with the percolation flow slightly less than the surface flow. They are areas of great morphodynamic stability, suitable for occupation and buildings and use of machinery. They are mapped notably at the Umbuzeiro Mine and its access route to the Nickel Mine.

Photo 5.1-12 – Panoramic view from inselberg towards the plateaus.

Source: Arcadis, 2017.

Dissected slopes

These are terrains where medium to high declivity predominates, varying between 12 and 20% and with an altitude of around 350m. They are degradational features where runoff can vary from diffuse to concentrated with moderate to fast speed, being subject to linear and laminar erosive processes, in general grooves and ravines. As a rule, they are not susceptible to mass movements.

Despite the potential for the occurrence of erosive processes, they have a good support capacity if the correct rainwater management measures are taken.

In are associated with the sectors with the highest hydrographic densities of the ADI.

Photo 5.1-13 – Dissected slopes.

Photo 5.1-14 – Dissected slope, with laminar erosion and ravination

Source: Arcadis, 2017.

Very dissected slopes

They are areas of strong dissection, with a slope between 20 and 30% and with altitudes around 380-450m. They are degradational features, with energetic sculptural processes, where surface runoff can vary from diffuse to concentrated with expressive speed, being highly prone to linear and laminar erosive processes, where possible small mass movement processes depending on the occurrence incipient soils.

Thus, they are lands that are not very favorable to occupation. These occur notably around escarpments and relic hills, such as the Morro Brejo Seco and the Chapadas.

Photo 5.1-15 – Very dissected slope.

Photo 5.1-16 – Above, the escarpment front, below, a very dissected slope feature.

Source: Arcadis, 2017.

Abrupt slopes

These are terrains associated with features with a slope above 35% and the altimetric level varies between 400 to 500m. They comprise forms of cornice, escarpment, talus and orthoclinal depression. They can show profiles with a straight, scalloped or arched layout and have subsequent drainage advances in relation to the inclination of the lithological layers. These lands are also associated with steep slopes present in inselbergs or hills.

They are degradational forms, with a practically null pedogenetic process, where the condition of runoff is very intense. These areas are subject to mass movements such as falling blocks. Not suitable for building structures, accesses and other uses. This unit is associated with the edges of the Chapada de São Francisco and the Chapada do Sítio, west and east of the ADI, respectively and by the Morro do Brejo Seco in the DAA.

Photo 5.1-17 – Abrupt slope. Outcrop.

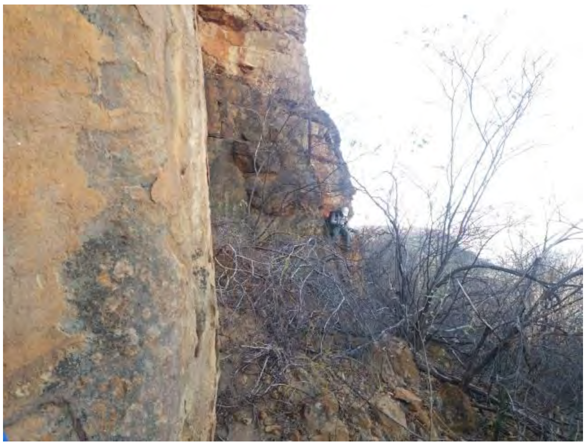


Photo 5.1-18 – Escarpment feature.

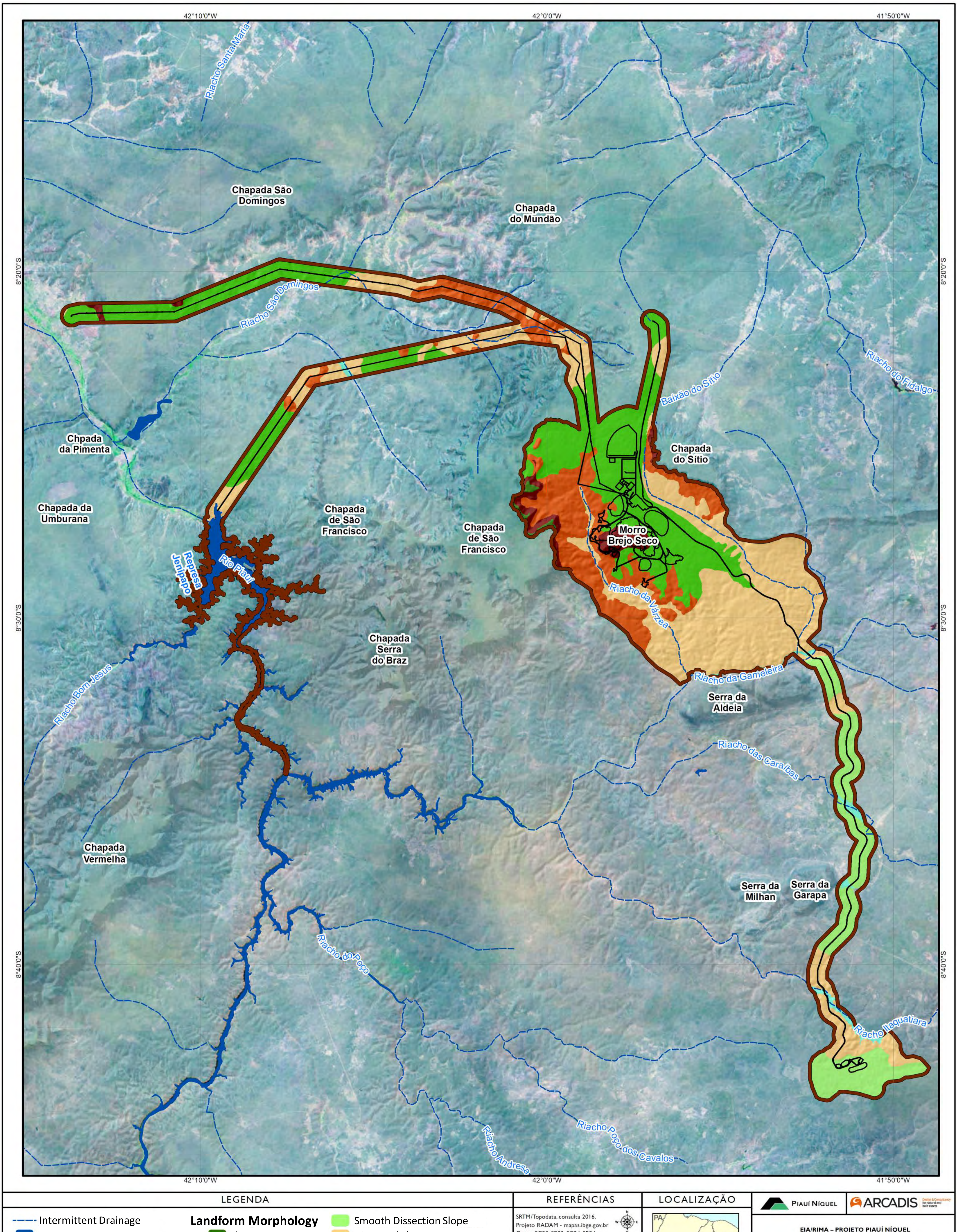
Photo 5.1-19 – Inselberg.

Photo 5.1-20 – Testimonial hill.

Source: Arcadis, 2017.

Below is the morphological map (Map 5.1-9) of the ADI and DAA with the locations of the forms described above.

Map 5.1-9 – Relief Morphology, ADI and DAA.



LEGENDA

- Intermittent Drainage
- Water Mass
- Area of Direct Influence - ADI
- Directly Affected Area - DAA

Landform Morphology

- Flat Top
- Fluvial Plain
- Smooth Slope
- Smooth Dissection Slope
- Dissected Slope
- Very Dissected Slope
- Abrupt Slope

REFERÊNCIAS

SRTM/Topodata, consulta 2016.
Projeto RADAM - mapas.ibge.gov.br
Cartas SC23, SB23, SC24, SB24.
Levantamento Topográfico Projeto PNM, 2016.
Bases Cartograficas ao Milionésimo, IBGE, 2014.

ESCALA GRÁFICA

0 2,5 5 km

Sistema de Coordenadas: GCS SIRGAS 2000

LOCALIZAÇÃO

PIAUÍ NÍQUEL ARCADIS Design & Consultancy for natural and built assets

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Map 5.1-9 – Relief Morphology ADI and DAA

EXECUTADO POR:	ESCALA	FORMATO:	FOLHA:	DATA:
ARCADIS	1:180.000	A3	ÚNICA	JUN /2017

5.1.4. Pedology

5.1.4.1. Regional Pedological Context - Area of Indirect Influence (AII)

This section aims to present the orders and suborders of the identified soils, their distribution and occurrence in the Area of Indirect Influence, for this, mapping prepared within the scope of the mapping project of RADAM Brasil (1973) was used.

The pedological units listed in the aforementioned mapping were included in the Brazilian Soil Classification System (EMBRAPA, 2006).

Below is the representation of the pedological classes identified for the level of detail of the Area of Indirect Influence AII, followed by the description of the respective pedological units. These descriptions are followed by the respective AII Pedological Map (Map 5.1-10) showing the disposition of pedological packages in the AII.

Red-Yellow Latosols (Oxisols)

These comprise medium texture soils, associated with spodosol. Soils made up of mineral material, with a L-latioilic horizon just below any of the types of superficial horizon, except hystic. They are soils in an advanced weathering stage, very evolved, as a result of energetic transformations of the constitutive material. They are virtually devoid of primary or secondary minerals that are less resistant to weathering and have the ability to exchange cations of the clay fraction, less than 17cmol / kg of clay without correction for carbon. The Red-Yellow Latosols are located in areas with smooth relief (slopes from 0 to 30%), have medium texture, are soils with high permeability, low water retention and low cohesion. They may experience greater water stress during periods of drought.

Litolic Neosols

Comprising litholic soils and rocky outcrops, sometimes associated with medium-yellow Oxisol with medium texture and or Quartzene Neossoil. These are shallow soils, such as horizons A or E histic less than 40 cm thick, sitting directly on the matrix rock or on horizon C or Cr. They are mineral soils formed above the rocky substrate, from which they can retain mineralogical and structural characteristics. In the AII these are predominantly in the Parnaíba Basin.

Quartzarenic Neossols

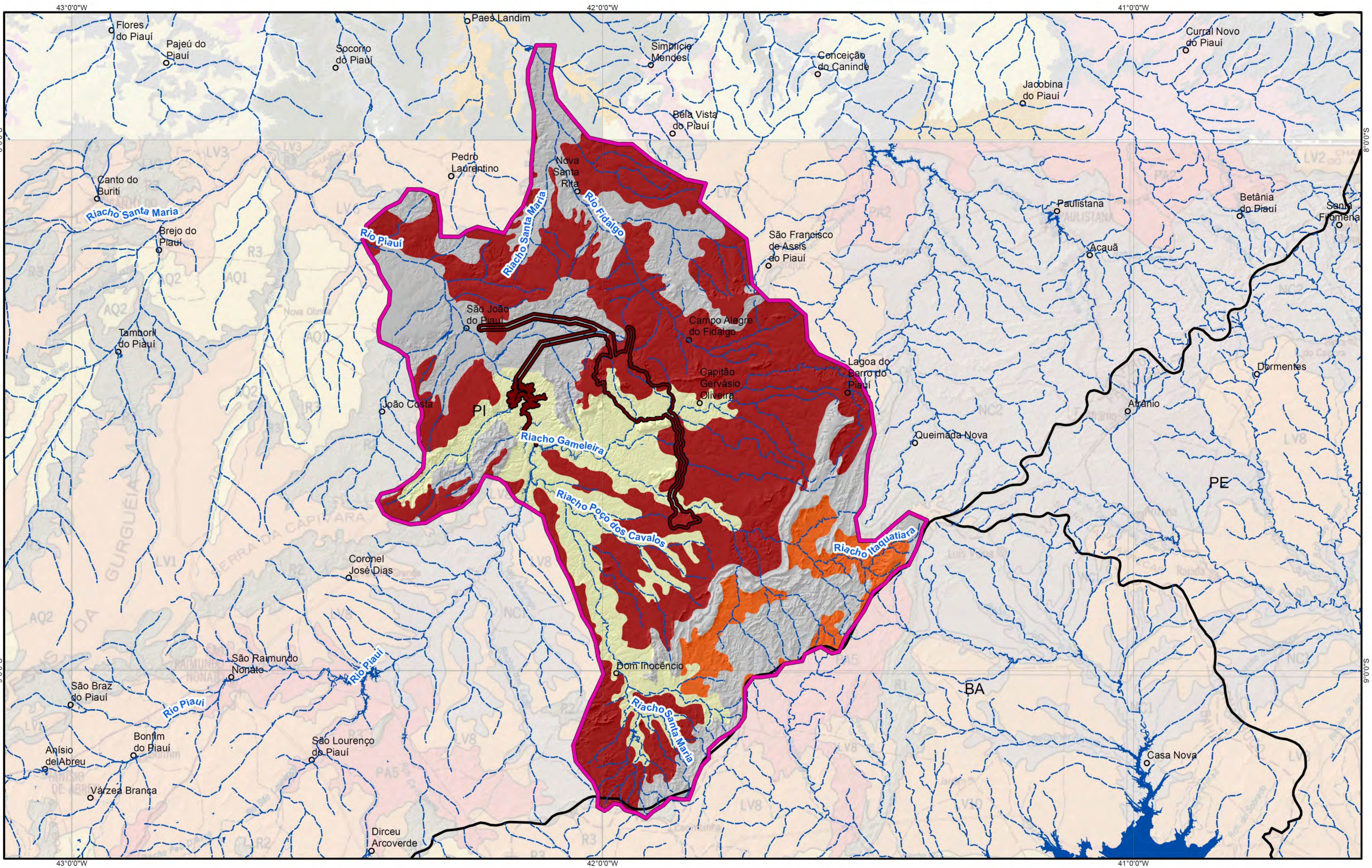
These are soils made up of mineral, non-hydromorphic or thin organic material, which does not show significant changes in relation to the original material due to the low intensity of the execution of the pedogenetic processes. These are poorly advanced soils that do not have a diagnostic B horizon. Developed over sandstones, the soil occurs in smooth or wavy relief, has a sandy texture in long profile and uniform yellowish color below the horizon A, which is slightly dark. To develop the relief of the occurrence, the erosion process is not high, however, erosion should be avoided due to the texture being sandy. Because they are deep, there is no physical limitation for the development of roots at depth, the levels of organic matter, phosphorus and micronutrients are very low. This condition, in association with its high permeability and very low water and nutrient retention, confers high fragility to Quartzarenic Neossols for the establishment of erosive processes. They are often found on the reverse sides of the sandstone cliffs at the edge of the Parnaíba Basin.

Red-Yellow Argisols

These are moderately deep to deep soils, moderately drained, with a textural B horizon, with red to yellow colors and a clay texture, below an A or E horizon of lighter colors and sandy or medium texture, with low levels of organic matter. They have low activity clay and high base saturation. In view of the high susceptibility to erosion, even in smooth wavy relief, soil conservation practices are recommended[5]. In the AII they are present in portions of the Sertaneja Depression.

[5] http://www.agencia.cnptia.embrapa.br/gestor/bioma_caatinga/arvore/CONT000g5twggzi02wx5ok01edq5sp172540.html, search in 12/21/2016

Map 5.1-10 – Pedology of the AII.



LEGENDA

- Municipal Headquarters
- State Limits
- Perennial Drainage
- Intermittent Drainage
- Water Mass
- Area of Indirect Influence - AII
- Area of Direct Influence - ADI

Soil

- Neossol
- Luvisol
- Argisol
- Oxisol

REFERÊNCIAS

EMBRAPA (Adaptação), Solos, 2006;
IBGE, Brasil ao milionésimo, 2014;
Projeto Piauí Níquel, 2016;
RADAM - disponível em http://mapas.ibge.gov.br/bases-e-referenciais/bases-cartograficas/cartas.html
Cartas SC24, SB24.

ESCALA GRÁFICA
0 10 20 km

Sistema de Coordenadas: GCS SIRGAS 2000

MAPA DE LOCALIZAÇÃO

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Map 5.1-10 – Pedology of AII (RADAM)

EXECUTADO POR:	ESCALA:	NÚMERO:	DATA:
ARCADIS	1:750.000	Única	jun /2017

5.1.4.2. Local Pedological Characterization - Area of Direct Influence (ADI) and Directly Area Affected (DAA)

The pedological characterization of the ADI and DAA was carried out by integrating the data obtained for the AII and the description of soil profiles from archaeological excavations, carried out in 2008 by the Museu do Homem Americano Foundation (FMHA, 2008).

Based on the text of EMBRAPA (2006)[6], the ADI / DAA pedological diagnosis considers the distribution of different types of soil across the study areas and presents the characteristics of each typology regarding its vulnerability to morphodynamic processes that can trigger socio-environmental impacts.

The low annual rainfall rates do not favor the performance of chemical weathering processes, so that even residual rock alteration soils are not very significant in the area. Thus, similarly, even in the few places where greater soil thickness occurs, there is no significant pedogenetic evolution.

Almost all terrain is marked by extensive occurrences of Litoss, Quartzarenic and Fluvic Neossols. When Neosols do not occur, non-calcium Luvisolo and Red Yellow Latosol occur.

Exclusively in the escarpments of the mountains and hills of the region, there are bands of rocky outcrops that have been mapped based on field surveys and satellite image interpretation.

The ADI Pedology map illustrates the compartmentalization of the different pedotypes, whose main characteristics are described below.

Fluvic Neossol

Deep soil derived from river sediments. Stratified soil with varying texture and depth of organic carbon content.

- Medium to high natural fertility, flat relief, which allows mechanization, and good potential for agriculture, there is a restriction due to environmental legislation.
- It has a high risk of periodic flooding, salinization, solonization and silting.
- Used as a substrate for irrigated agriculture, annual agricultural crops and pasture, extensive livestock and environmental preservation of riverbanks (riparian forest).
- Mapped on the beds of the Gameleira stream, Itaquatiara stream (near the Umbuzeiro Quarry), Caraíba stream and a tributary of São Domingos stream.
- Low susceptibility to settlement, null for erosion.

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[6] http://www.agencia.cnptia.embrapa.br/gestor/bioma_caatinga/arvore/CONT000g5twggzi02wx5ok01edq5sp172540.html, search in 12/21/2016

The photos below show a trench in the bed of Tercino stream. The profile is 80 cm thick, horizon "A" 30 cm thick, composed of sand and a high concentration of organic matter, including fragments of roots. Composed of medium to fine gray sand, massive structure.

Photo 5.1-21 – River surface Point: 0176403/ 9060934 24S.

Photo 5.1-22 – Neossol Profile - Fluvial.- Point: 0176403/ 9060934 24S.

Photo: FMHA, 2008.

Quartzarenic Neossols

Soils derived from rocks or sediments of an essentially quartzy nature. They have a sandy texture up to 1.5 m deep. They occur in smooth wavy relief and show little differentiation between horizons in the profile. Sequence of horizons of type: A-C.

- Great effective depth, strong to excessively drained, with low water retention capacity, very low natural fertility, low levels of organic matter and high risk of contamination of groundwater.
- Used as a substrate for irrigated agriculture (fruit growing), pasture, extensive livestock, environmental preservation and sand source for civil construction.
- Found in sedimentary lithology.
- High erodibility.

The photos below show two profiles, Photo 5.1-23 and Photo 5.1-24, Quartzarenic Neossol 40 cm deep, yellowed and with pebbles in the second layer, 155 cm deep trench. It shows superficial formation of fine sand, showing granules of quartz and iron oxide. At a depth of 120 cm there is a concentration of iron oxide granules.

Photo 5.1-23 – Quartzarenic Neossol – Point: 172437/ 9068025 24S.

Photo 5.1-24 – Quartzarenic Neossol – Point: 0172519/ 9064631 24S.

Photo: FMHA, 2008.

Litholic Neossol

Shallow and generally stony soil. It shows lytic contact within 50 cm of depth. It is formed from any type of rock, commonly associated with an active relief. Soil with a clear predominance of physical, chemical and mineralogical attributes inherited from the source material. Sequence of horizons of type: A - C - R or A - R.

- Formed in inclined relief.
- Small effective depth and small water storage capacity,
- Characteristic presence of stony and generalized rockiness and high susceptibility to erosion.
- Can be used as a material borrow area.
- Immature and unconsolidated soil.
- High erodibility.

Photo 5.1-25 shows a ravine that exposes the profile of a Litholic Neossol.

Photo 5.1-25 – Litholic Neossol.

Photo: Arcadis, 2017.

Plinthossol

Soil with a pliny, lithoplastic or concretionary horizon, with or without brightly colored mottles. It occurs in the lower thirds of slopes and at the edges of plateaus. Its formation is associated with the effects of alternating current or past wetting and drying cycles. Soils of variable texture and with clay, commonly of low activity.

- Formed in low-activity relief, it has a good water reserve when not concretionary, low water availability when concretionary.
- Can be used as a substrate for short cycle and pasture crops; extensive livestock and environmental preservation. It can be a source of material for civil construction.
- Representative of the DAA, Quartzarenic Neossols + Plinthossol association.
- Found around Brejo Seco hill.
- Low erodibility

The photo overleaf shows a 155 cm thick trench. It shows superficial formation of fine sand, showing granules of quartz and iron oxide. At a depth of 120 cm there is a concentration of iron oxide granules.

Photo 5.1-26 – Plinthossol - Point: 0172636/ 9064307 24S.

Photo: FMHA, 2008.

Red-Yellow Latossol

Well-developed, deep and well-drained soil with a latosol B horizon (Bw). Uniform morphological, physical, chemical and mineralogical characteristics in the profile. Displays red-yellow color. It commonly occurs in smooth wavy to flat relief. Its sequence of horizons is type A - Bw - C.

- It has good water storage capacity.
- It has low natural fertility and can be used for intensive agricultural production, pasture, forestry. It can also be used as a base for building highways, houses and landfills.
- Very low erodibility.

In the regions indicated by the regional mapping as Red-Yellow Latossol, south of the ADI (Map 5.1-11), the surface is covered by clasts (Photo 5.1-27), pebbles and mechanically weathered blocks, in addition to several rocky outcrops with weathered flank features, normal folds and vertical drop features of the hinge line. These outcrops contributed to the lithic surface above the pedological mantle.

Trench with 247 cm thick profile. The surface formation is composed of two distinct layers. The basal layer ranges from 0 to 50 cm, showing gravel supported by a fine sandy matrix, yellowish in color, with clasts, marble / limestone pebbles, sub-rounding to sub-angular, massive structure. The second layer between 50 and 247 cm is composed of fine, yellowish sand, there are granules dispersed throughout the layer, there is concentration of roots in the uppermost 20 cm.

Photo 5.1-27 – Surface with pebbles and outcrops

Photo 5.1-28 – Red-Yellow Latossol - Point: 0172636/ 9064307 24S.

Photo: FMHA, 2008.

Luvissol

Surface to shallow soil typical of the semiarid environment, rich in bases and with high activity clay. It shows clay accumulation in subsurface, characterized by the Bt horizon. It has a clear differentiation between horizons A and Bt according to color, texture and structure.

- High susceptibility to erosion, surface commonly stony, small effective depth, very hard consistency when dry, and very sticky when wet, and risk of salinization and solonization.
- Used for rainfed agriculture, pasture, extensive livestock and environmental preservation.

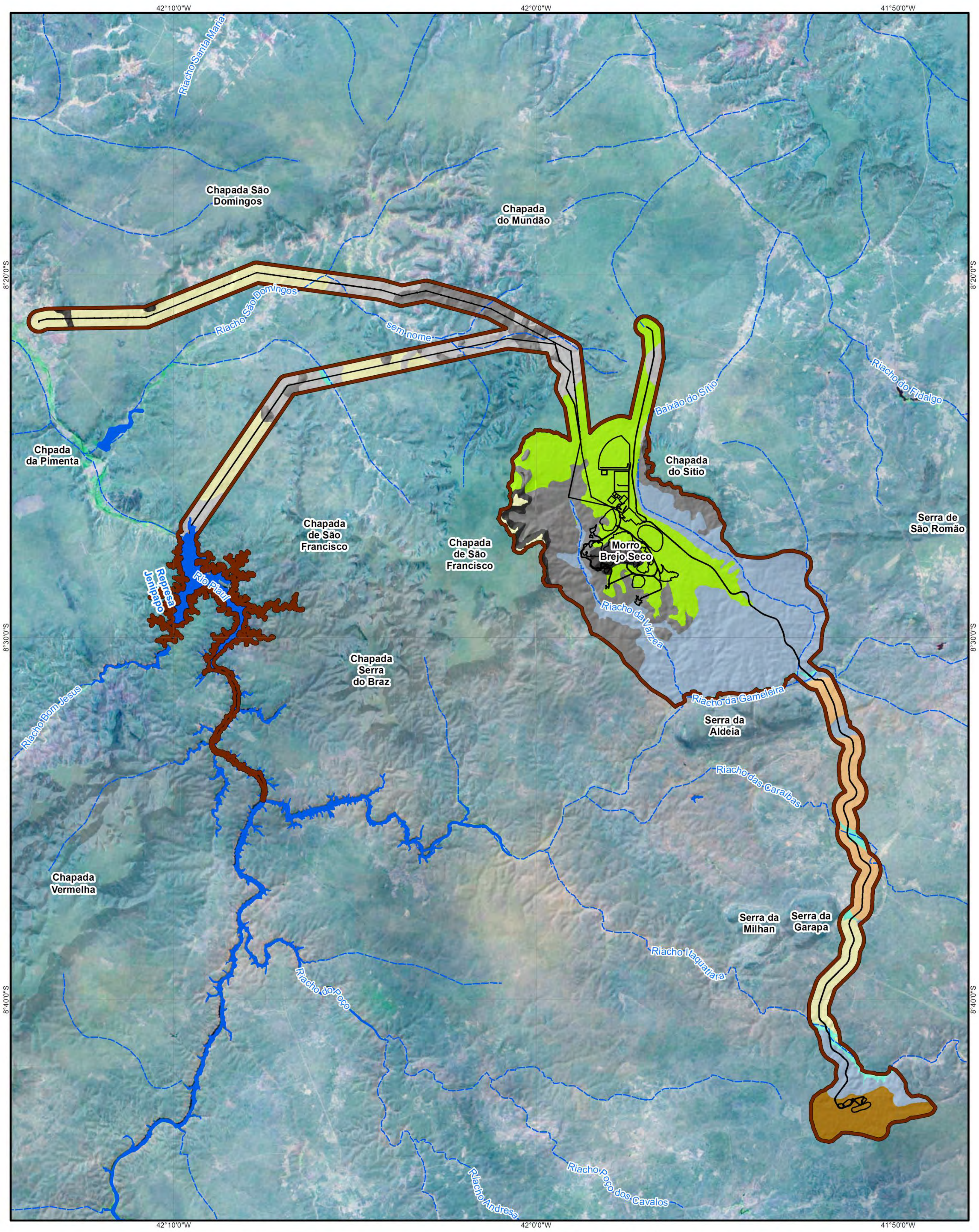
Photo 5.1-29 shows the environment where the trench was made. The trench (Photo 5.1-30) exposes a 45 cm thick layer developed in situ, with a clay texture with granules from the weathering of the parent rock.

Photo 5.1-29 –Luvissol Environment - Point 0176396/ 9060889 24S.

Photo 5.1-30 – Luvissol - Point 0176396/ 9060889 24S.

Photo: FMHA, 2008.

Map 5.1-11 – Pedology of the ADI and DAA.



LEGENDA

- Intermittent Drainage
- Water Mass
- Area of Direct Influence - ADI
- Directly Affected Area - DAA

Soil

- Fluvic Neossol
- Red-Yellow Latossol
- Red-Yellow Latossol + Exposed Rock
- Bruno Luvisol non calcic
- Quartzarenic Neossol + Plinthosol
- Quartzarenic Neossol
- Litolic Neossol
- Litolic Neossol + Quartzarenic + Exposed rock
- Exposed rock + Litolic Neossol

REFERÊNCIAS

IBGE, Brasil ao milionésimo, 2014;
Projeto Piauí Níquel, 2016.
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ESCALA GRÁFICA

0 2,5 5 km

Sistema de Coordenadas: GCS SIRGAS 2000

LOCALIZAÇÃO

Piauí Níquel | ARCADIS Design & Consultancy for natural and built assets

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Map 5.1-11 – Pedology
ADI and DAA

EXECUTADO POR:	ESCALA	FORMATO:	FOLHA:	DATA:
ARCADIS	1:180.000	A3	ÚNICA	JUN /2017

5.1.5. Potential Fragility of Land - Area of Direct Influence (ADI) and Directly Area Affected (DAA)

After the specific mappings, the DAA and ADI lands were assessed according to their Potential Fragility. This classification indicates the propensity of the land to harmful morphodynamic processes, such as erosion, silting, mass movement and subduction.

In the study of surface dynamic processes, it is assumed that the morphometry and morphology of the relief can be considered key variables of the process dynamics, which together with the other physical characteristics (climate, soil and lithology), creating conditions of greater or lesser susceptibility to erosive triggering.

With that said, five types of weaknesses in the ADI were mapped, the description of these sectors is shown in the table below. In this table, the types of potential weaknesses of the terrain are listed, associating the morphology and the earthy substrate. The indication of the procedural conditions and aptitudes of each sector of potential fragility also follows.

Thereafter follows Table 5.1-3 and Map 5.1-12 that illustrate the Potential Fragility of the ADI / DAA, according to the classes of forms mapped:

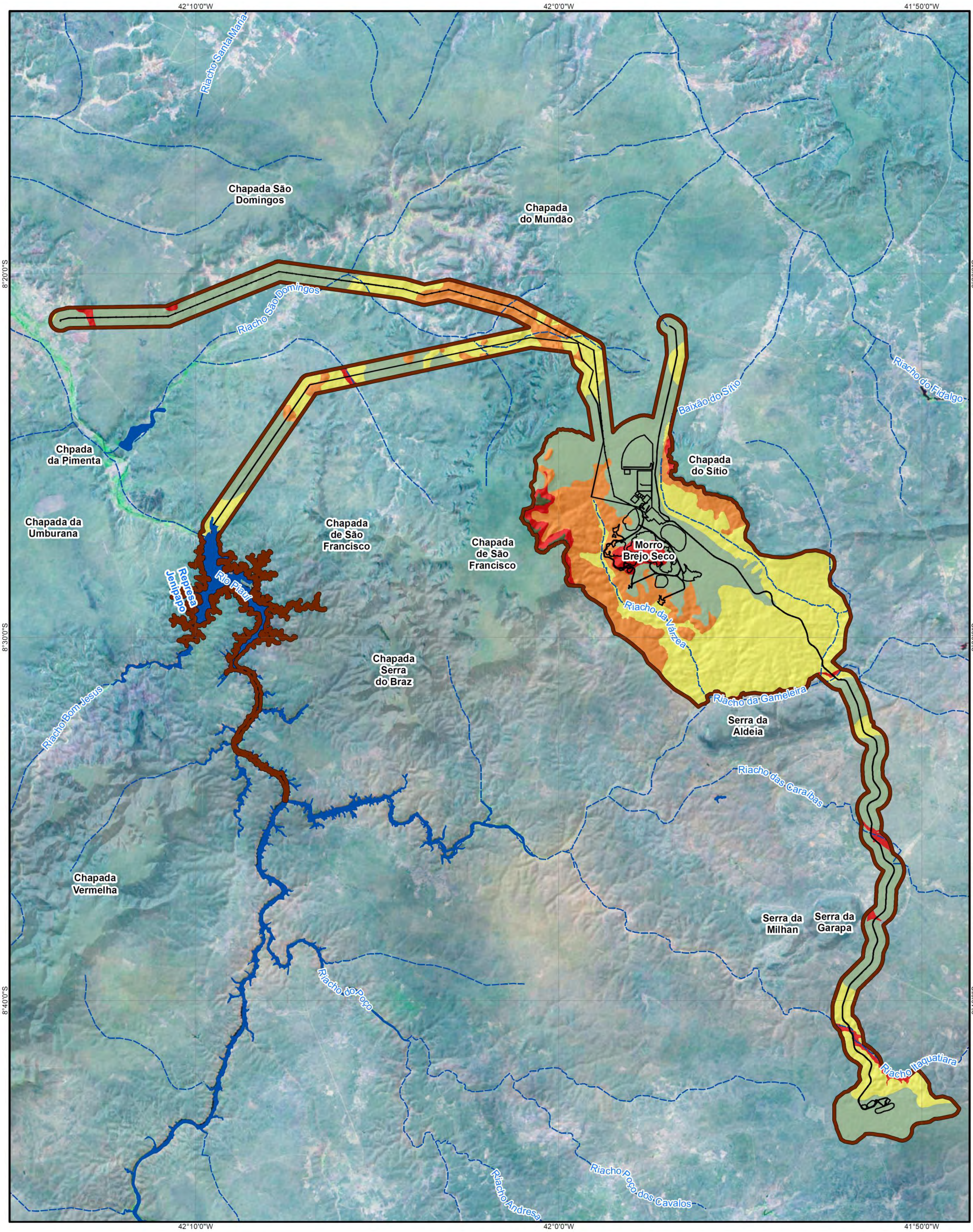
Table 5.1-3 – Potential fragility of relief, conditions and aptitudes.

Potential Fragility	Relief Form	Soil Types	Conditions/Aptitudes
Very Low	Plateau	Quartzarenic Neossol	Low slope High erodibility soil Low rainfall Has scenic beauty Recommended vegetation preservation.
Low	Smooth Slope	Quartzarenic Neossol Quartzarenic Neossol + Plinthossol	Low slope High erodibility soil Low rainfall Fit for occupation Indicated basic care and good practices for occupation
	Dissected Smooth Slope	Red-Yellow Latossol Red-Yellow Latossol + Exposed Rock Litholic Neossol	Low slope Low erodibility soil Low rainfall High support capacity for machine movement Suitable for occupation
Medium / High	Dissected slope	Luvissol non-calcitic Litholic Neossol	Average slope High erodibility soil Low rainfall Fit for occupation Adequate handling and good practices in occupation are necessary
High	Very dissected slope	Litholic Neossol+ Quartzarenic + Exposed Rock	High slope High erodibility soil Low rainfall Fit for occupation Essential to carry out special practices for the management and occupation of this type of land.

Potential Fragility	Relief Form	Soil Types	Conditions/Aptitudes
Very High	Fluvial Plain	Fluvial Neossol	Low slope Low erodibility soil Subject to silting up Possibility of land settlement Subject to contamination of groundwater Favorable to aquifer recharge and storage of subsurface water. Preservation or special care in handling and occupation recommended.
	Abrupt Slope	Exposed Rock + Litholic Neossol	High slope Areas subject to mass movements such as falling blocks Has scenic beauty Not suitable for conventional uses.

Prepared by: Arcadis, 2017.

Map 5.1-12 – Potential Fragility.



LEGENDA

- Intermittent Drainage
- Water Mass
- Area of Direct Influence - ADI
- Directly Affected Area - DAA

Fragility Potential

- Very Low
- Low
- Medium / High
- High
- Very High

REFERÊNCIAS

SRTM/Topodata, consulta 2016.
Projeto RADAM - mapas.ibge.gov.br
Cartas SC23, SB23, SC24, SB24.
Levantamento Topográfico Projeto PNM, 2016.

ESCALA GRÁFICA
0 2,5 5 km

Sistema de Coordenadas: GCS SIRGAS 2000

LOCALIZAÇÃO

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Map 5.1-12 – Potential Terrain Fragility - ADI

EXECUTADO POR:	ESCALA	FORMATO:	FOLHA:	DATA:
ARCADIS	1:180.000	A3	ÚNICA	JUN /2017

5.1.6. Mineral Licenses

This section aims to survey the various mineral license polygons of the National Department of Mineral Production (DNPM) overlapping the area of direct influence of the physical and biotic environment of this project. The survey was based on a consultation held on September 21, 2017 in the Mining Geographic Information System (SIGMINE) of DNPM (http://www.dnpm.gov.br/).

5.1.6.1. Mineral Licenses - Area of Direct Influence (ADI) and Directly Affected Area (DAA)

According to the research carried out, there are 35 DNPM polygonals either totally or partially located within the ADI of the Physical and Biotic Environment.

The targeted substances and the occurrence of existing polygons of each substance are summarized in the table below.

Table 5.1-4 – Occurrence of substances of interest in the mineral licenses of the Area of Direct Influence (ADI) and the Directly Affected Area (DAA).

Substance	Occurrences
Mineral Water	1
Clay	1
Limestone	7
Gravel	2
Data not registered	3
Granite	2
Marble	1
Iron ore	3
Manganese ore	3
Nickel ore	5
Gold	6
Nickel (mining concession)	1

Source: DNPM, 2017. Prepared by: Arcadis, 2017.

Of these 35 polygons, 21 occurrences are in the exploration authorization phase; 1 is a mining concession (whose holder is the proponent of this project); 6 are available; 2 in licensing application; and 5 in exploration license application (of which 3 are from the proponent of this project). Below is Table 5.1-5, which shows the surveyed polygons, the respective license numbers, year of entry of the process, licensing phases, intended substance and uses of these substances and which is in the DAA or only in the ADI. Thereafter, Map 5.1-13 illustrates the mining titles in question overlapping the area of direct influence of the physical and biotic environment.

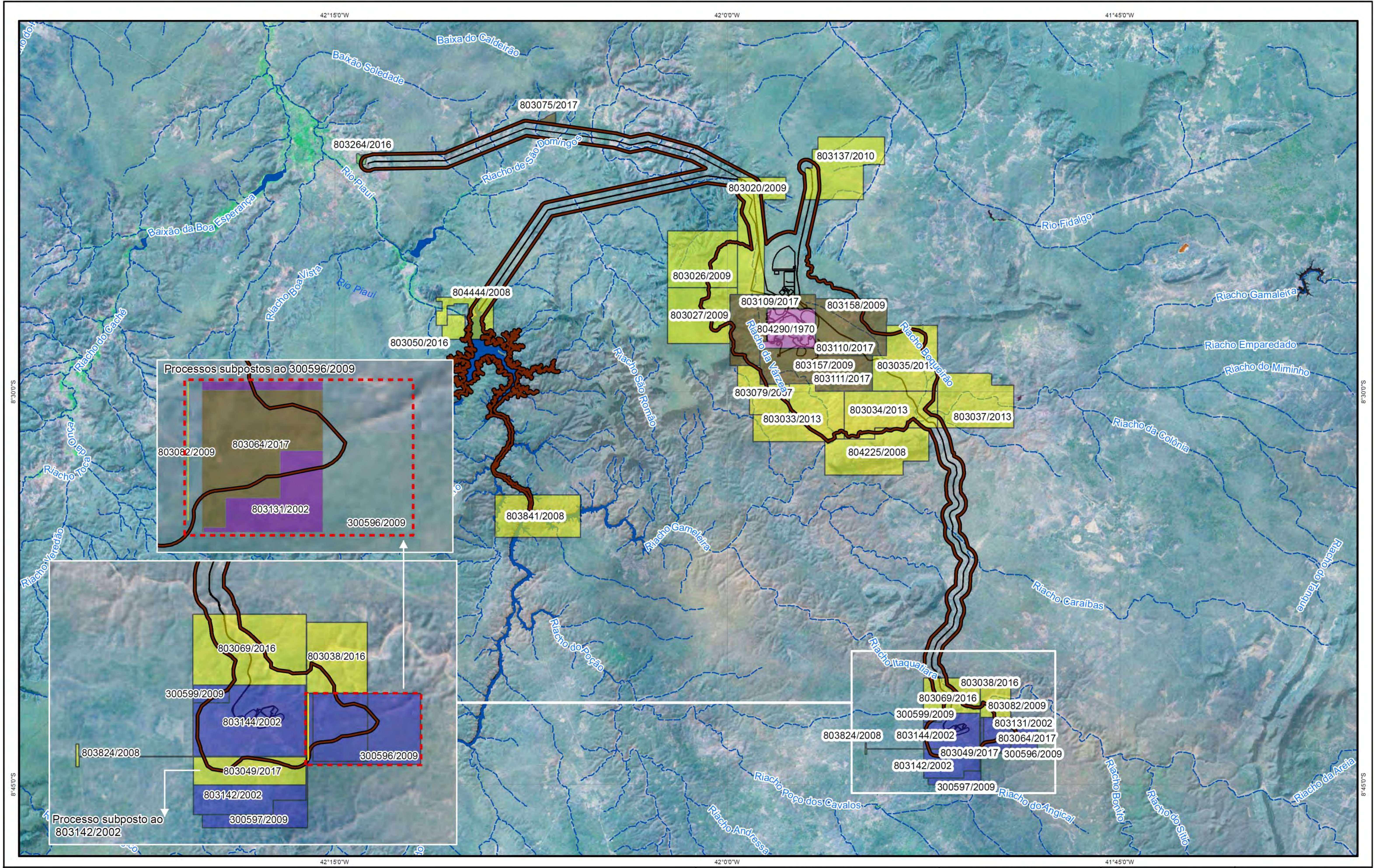
Table 5.1-5 – DNPM polygons overlapping the ADI and the DAA of the physical and biotic environment.

License	Phase	Holder	Substance	Use	Influence Area
803841/2008	Exploration License	José Alves de Mendonça Filho	Gold	Industrial	DAA
804444/2008	Exploration License	Construtora Jurema ltda	Granite	Civil covering	DAA
803020/2009	Exploration License	Bemisa Brasil Exploração Mineral SA	Manganese	Industrial	DAA
803158/2009	Exploration License	Piauí Níquel Metais SA	Nickel	Industrial	DAA
803156/2009	Exploration License	Piauí Níquel Metais SA	Nickel	Industrial	DAA
803157/2009	Exploration License	Piauí Níquel Metais SA	Nickel	Industrial	DAA
803137/2010	Exploration License	Gme4 do brasil participações e empreendimentos SA	Iron ore	Industrial	DAA
803034/2013	Exploration License	Sumitomo metal mining do brasil ltda.	Gold	Industrial	DAA
803035/2013	Exploration License	Sumitomo metal mining do brasil ltda.	Gold	Industrial	DAA
803050/2016	Exploration License	Agreste mineração indústria e comércio ltda	Granite	Civil covering	DAA
803069/2016	Exploration License	Votorantim cimentos SA	Clay	Industrial	DAA
804290/1970	Mining Concession	Piauí Níquel Metais SA	Nickel	Industrial	DAA
300599/2009	Available	Data not registered	Data not registered	Data not registered	DAA
803144/2002	Available	Vale SA	Limestone	Industrial	DAA
803079/2007	Exploration License	Ysao Munemassa	Gold	Industrial	ADI
804225/2008	Exploration License	Glicia Arcoverde Modesto Amorim	Iron ore	Industrial	ADI
803824/2008	Exploration License	Vale SA	Limestone	Cement manufacture	ADI
803026/2009	Exploration License	Bemisa Brasil Exploração Mineral SA	Manganese	Industrial	ADI
803027/2009	Exploration License	Bemisa brasil exploração mineral s a	Manganese	industrial	ADI

License	Phase	Holder	Substance	Use	Influence Area
803082/2009	Exploration License	Vale SA	Limestone	Cement manufacture	ADI
803033/2013	Exploration License	Sumitomo metal mining do brasil ltda.	Gold	Industrial	ADI
803037/2013	Exploration License	Sumitomo metal mining do brasil ltda.	Gold	Industrial	ADI
803075/2017	Exploration License	Cohiso Construção Hidrogeologia e Sondagem	Mineral water	Bottling	ADI
803038/2016	Exploration License	Renovae máquinas equipamentos e empreendimentos ltda. Epp	Limestone	Soil correction	ADI
300597/2009	Available	Data not registered	Data not registered	Data not registered	ADI
300596/2009	Available	Data not registered	Data not registered	Data not registered	ADI
803142/2002	Available	Vale SA	Limestone	Industrial	ADI
803131/2002	Available	Vale SA	Limestone	Industrial	ADI
803227/2016	Licensing application	Simplicio ferreira de carvalho neto me	Gravel	Civil construction	ADI
803264/2016	Licensing application	Simplicio Ferreira de Carvalho Neto Me	Gravel	Civil construction	ADI
803064/2017	Exploration application	Vulcano Export Mineração Exportação e Importação Ltda.	Marble	Civil covering	ADI
803049/2017	Exploration License	Mineracao Nordeste Ltda	Limestone	Soil correction	ADI
803110/2017	Exploration application	Piauí Níquel Metais S.A	Nickel	Industrial	ADI/DAA
803109/2017	Exploration application	Piauí Níquel Metais S.A	Nickel	Industrial	ADI/DAA
803111/2017	Exploration application	Piauí Níquel Metais S.A	Nickel	Industrial	ADI/DAA

Source: DNPM, 2016. Prepared by: Arcadis, 2017.

Map 5.1-13 – Mineral Licenses (DNPM).



LEGENDA

- Intermittent Drainage
- Water Mass
- Area of Direct Influence - ADI
- Directly Affected Area - DAA

Mining Processes

- Exploration License
- Mining Concession
- Availability
- Licensing Requirement
- Exploration Requirement

REFERÊNCIAS

IBGE, Base contínua 1:250.000, 2015.
Processos Minerários - DNPM - disponível em
http://sigmine.dnpm.gov.br/webmap/

ESCALA GRÁFICA
0 2,5 5 km

Sistema de Coordenadas: GCS SIRGAS 2000

MAPA DE LOCALIZAÇÃO

PA MA CE RN PB PE AL SE PI BA TO

PIAUÍ NÍQUEL | ARCADIS

EIA/RIMA – PROJETO PIAUÍ NÍQUEL

Map 5.1-13 – Mining Processes (DNPM)

EXECUTADO POR:	ESCALA:	NÚMERO:	DATA:
ARCADIS	1:250.000	Única	set /2017

5.1.7. Surface Water Resources

5.1.7.1. Regional Context of the Drainage Network - Area of Indirect Influence (AII)

A) Hydrography

The area corresponding to the Piauí Nickel Project's AII is in the Parnaíba Hydrographic Region (ANA, 2003), according to the National Hydrographic Division, established by CNRH Resolution No. 32, of October 15, 2003, which defines twelve hydrographic regions for Brazil.

This Hydrographic Region (RH), which drains almost all rivers in the State of Piauí (99% of the drainage network), occupies an area of 333,056 km², 75% of which covers the State of Piauí. The other 25% of the RH area drains rivers from the States of Maranhão and Ceará, being the second most important hydrographic region in the Northeast Region of the country (ANA, 2016). The map below shows the hydrographic regions of Brazil, established by the National Water Agency - ANA.

The Parnaíba Hydrographic Region covers 220 municipalities, of which the main urban centers in Piauí are Teresina, Parnaíba and Picos.

The Parnaíba River, the main one of this RH, has a length of approximately 1,400 km. It rises in Chapada das Mangabeiras under the name Água Quente, at an altitude of 800 m, and drains in a north / northeast direction, serving as a border between the States of Piauí and Maranhão. In the municipality of Guadalupe, the Parnaíba River is dammed, forming the Boa Esperança reservoir, with the purpose of generating electricity. Its main tributaries are the Balsas, Poti, Portinho, Gurguéia, Piauí, Canindé, Uruçui-Preto and Longa rivers, being supplied by groundwater and rainwater (ANA, 2016).

Parnaiba's HR, according to MMA (2006), is divided into three large sub-basins (level 1):

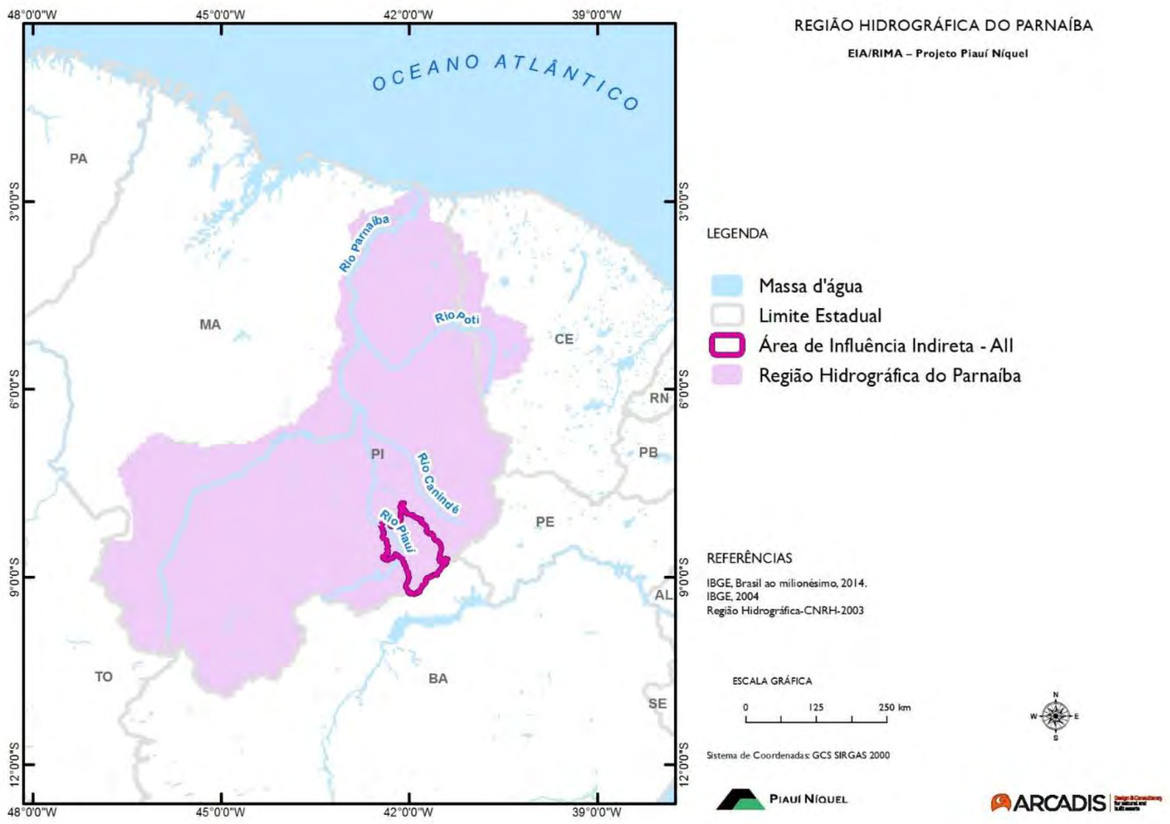
- **Upper Parnaíba**: of approximately 151,630.3 km ².
- **Mid Parnaíba**: of approximately 137,000.8 km².
- **Lower Parbaíba**: of approximately 42,810.4 km².

Each of these sub-basins is divided into smaller sub-basins (level 2), totaling seven sub-basins. These were delimited according to the importance of their main rivers and the pattern of the physical-biological aspects:

- **Upper Parnaíba**: Parnaíba 01 – Rio Balsas; Parnaíba 02 – Upper Parnaíba; Parnaíba 03 – Rio Gurguéia; Parnaíba 04 – Rio Itaueiras
- **Mid Parnaíba**: Parnaíba 05 – Piauí/Canindé; Parnaíba 06 – Poti/Parnaíba
- **Lower Parnaíba**: Parnaíba 07 – Longa Parnaíba.

In Map 5.1-14 it is possible to observe the Parnaíba RH in relation to the area of indirect influence (AII) of the project.

Map 5.1-14 – Area Indirect Influence (AII) of the Piauí Nickel Project in relation to the Parnaíba Hydrographic Region.



The project's AII corresponds to the **Mid Parnaíba**, sub-basin 05 Piauí / Canindé. The sub-basin of the Mid Parnaíba comprises the Poti, Canindé and Piauí rivers (MMA, 2006).

According to MMA (2006), this sub-basin has a high degree of complexity with regard to its water resources, mainly due to the difficulty of obtaining water in areas of crystalline rocks and the large number of rivers that have intermittent regimes, due to the irregularity and poor distribution of rainfall patterns. Important rivers in the area of the project, such as Fidalgo, Itaquatiara, Gameleiras and Piauí drain their waters into the Parnaíba River, through the Canindé River. It should be noted that the rivers Gameleiras, Itaquatiara and Fidalgo are intermittent.

The spatial outline of the AII defined for the physical and biotic environment, which includes surface water resources, covers the Piauí River basin to the mouth of the Peixe stream (a tributary of the Piauí River on its left bank). It comprises, to the north, the high course of the Fidalgo River, a tributary of the right bank of the Piauí River. To the south, the AII boundary coincides with the state boundary between Piauí and Bahia.

The Piauí River, the main river surrounding the Piauí Nickel Project area, rises along the border with the State of Bahia, in the municipality of Caracol. For most of its course, the drainage has a northwest orientation, passing through municipalities such as São Raimundo Nonato and São João do Piauí.

Throughout its course, it supplies some reservoirs such as Jenipapo, in the municipality of São João do Piauí (Photo 5.1-31), of great importance for the project. After covering 380 km, this river flows into the Canindé River, close to the municipality of Parnaíba. It is a torrential and dry river; its main tributaries are the rivers Itaquatiara, Fidalgo, São Lourenço, Cachê and Fundo. Specifically, in the project area, the tributaries of the Piauí river are the Itaquatiara and Fidalgo rivers.

The Fidalgo River rises in São João do Piauí, drains in a northwest direction and flows into the Piauí River, after covering approximately 150 km. The Itaquatiara River rises in the municipality of Lagoa do Barro do Piauí and flows into the Piauí River, on the border between the municipalities of Capitão Gervásio de Oliveira and Dom Inocêncio.

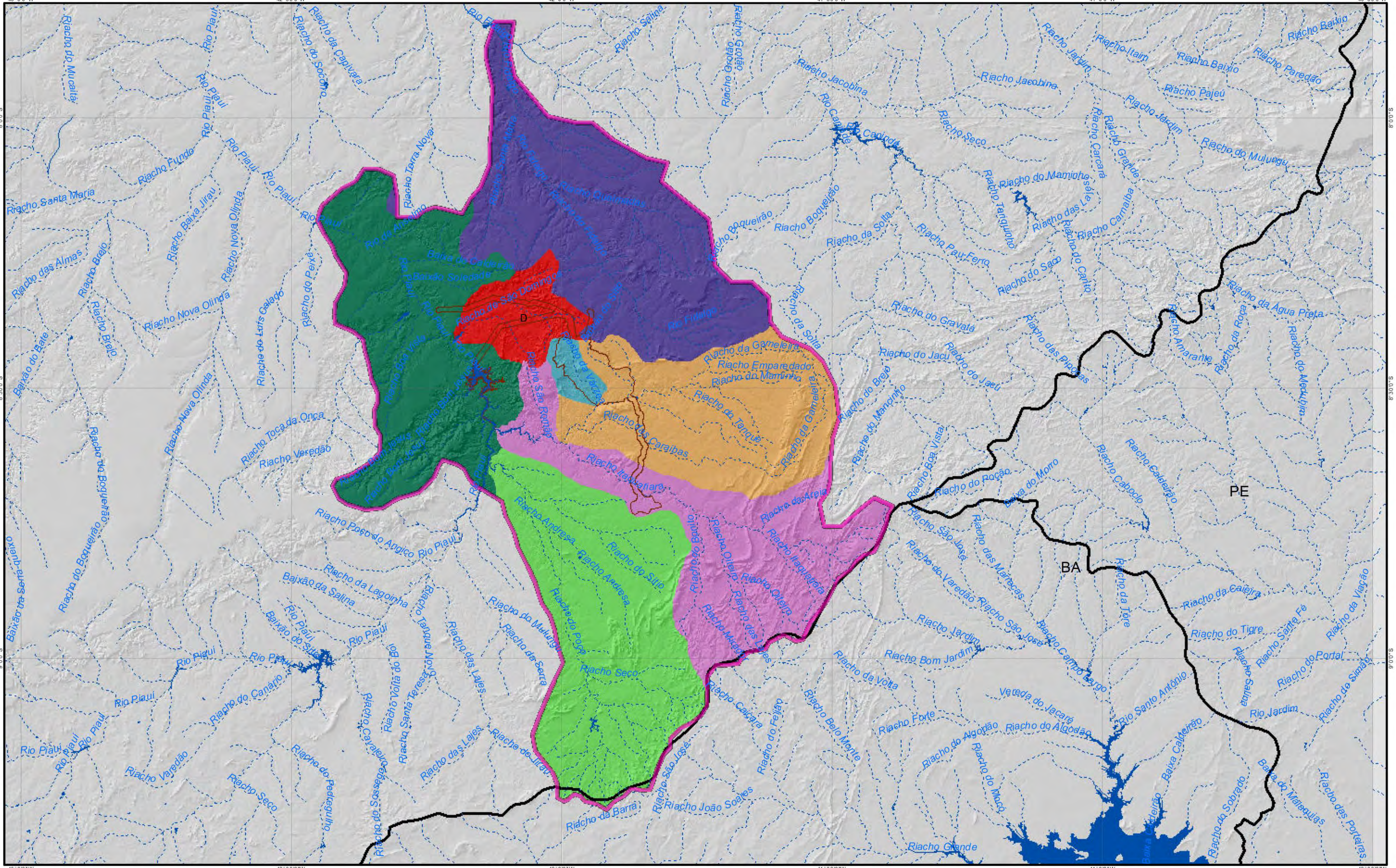
The Canindé River, on the other hand, rises in the municipality of Paulistana, on the border with Pernambuco. Its drainage has a northwest orientation and over its 350 km length, it crosses thirty-one municipalities. It is a torrential river, presenting in most of its course, an intermittent character in the months without rain.

Finally, the Poti River rises in the State of Ceará, and after draining initially in a northerly direction, it takes a westerly direction, entering the State of Piauí, specifically in the municipality of Castelo do Piauí. Its most important tributaries are the Sambito, Berlengas, São Nicolau, Cais, Capivara and Canudos rivers. Almost all of these tributaries rise in a semi-arid region and have characteristics similar to other rivers in the region, with an intermittent character due to the irregular distribution of rainfall, and torrentiality.

Photo 5.1-31 – Jenipapo Reservoir, in the municipality of São João do Piauí. In the background, the Chapada do São Francisco.

Source: ESIA/RIMA - Arcadis Tetraplan, 2008.

Map 5.1-15 –Hydrographic Network of the AII of the Piauí Nickel Project.



LEGENDA

- State Limits
- Perennial Drainage
- Intermittent Drainage
- Water Mass
- Area of Indirect Influence - AII
- Area of Direct Influence - ADI

Hydrographic Basins in AII

- Itaquatiara Stream
- Santa Maria Stream
- Gameleira Stream
- Várzea Stream
- São Domingos Stream
- Fidalgo River
- Piauí River

REFERÊNCIAS

Bases Cartograficas ao Milionésimo, IBGE, 2014.

ESCALA GRÁFICA

0 10 20 km

Sistema de Coordenadas: GCS SIRGAS 2000

MAPA DE LOCALIZAÇÃO

PIAUÍ NÍQUEL MINERAÇÃO

ARCADIS

EIA/RIMA – PROJETO PIAUÍ NÍQUEL

Map 5.1-15 – Hydrographic Network – AII

EXECUTADO POR:	ESCALA:	NÚMERO:	DATA:
ARCADIS	1:750.000	Única	mai /2017

B) Hydrology

a) Hydrometeorological data

According to the KÖPPEN (1931) classification, the climate of the Canindé / Piauí river basin region is classified as BSwh - dry, megathermic, formed under high pressure conditions originated by the movements of the atmosphere (FAHMA, 1999 *apud* BVP Engenharia, 2008).

Throughout the year, the wettest period is from January to April, peaking in March, and the least, from July to October, with September being the driest month. The monthly average temperature shows a small temporal variation, being governed, throughout the year, by the rainy season, with the highest averages from September to December, and the lowest from February to May. The average annual temperature is around 27ºC, with the month of October being the warmest, with an average of approximately 30ºC (FAHMA, 1999 *apud* BVP Engenharia, 2008).

Temperature has a great influence on water resources because heat, associated with low relative humidity, strong winds and high solar radiation, contributes decisively to evaporation and evapotranspiration losses (FAHMA, 1999 *apud* BVP Engenharia, 2008).

According to the National Water Agency - ANA *apud* BVP Engenharia (2008), the Piauí River basin has a total of seven pluviometric stations with consistent data.

Data Table 5.1-7 – Rain stations in the Piauí Nickel Project region.

Station Code	Station name	Municipality	Altitude (m)	Sponsor	Coordinates (Lat/Long)
841002	Fazenda Bugiu	São João do Piauí	250	SUDENE	-8:12:0 / -41:58:0
841013	Ouricuri	Casa Nova	500	SUDENE	-8:56:33 / -41:24:25
842004	Moreira	São Raimundo Nonato	480	SUDENE	-8:37:0 / -42:8:0
842009	Sítio Estação	São Raimundo Nonato	510	SUDENE	-8:47:0 / -42:44:0
941000	Curral Novo	São Raimundo Nonato	350	SUDENE	-9:1:0 / -41:58:0
942002	Cavalheiro	São Raimundo Nonato	380	SUDENE	-9:6:0 / -42:23:0
942003	Fartura do Piauí	São Raimundo Nonato	520	SUDENE	-9:22:0 / -42:47:0

Source: BVP Engenharia, 2008. Prepared by: Arcadis, 2017.

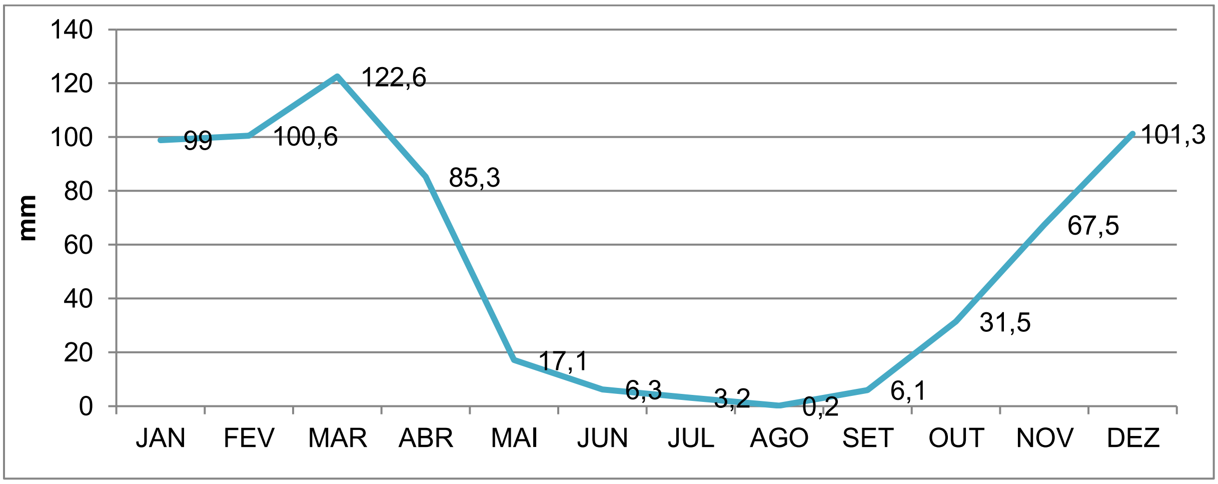
Although not all are within the AII, all can be considered representative of the region under study, especially Stations 842004 and 841002, which are closer to the Piauí Nickel Project's ADI. The average monthly results of these stations are presented below.

Data Table 5.1-8 – Average monthly rainfall (mm) and statistical parameters (mm) of the rain station at Station 842004– Moreira.

Year	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SET	OCT	NOV	DEC	ANNUAL TOTAL
Average	99.0	100.6	122.6	85.3	17.1	6.3	3.2	0.2	6.1	31.5	67.5	101.3	640.7
S.D.	62.2	74.9	70.4	64.9	28.5	20.4	8.9	0.7	11.3	44.0	32.9	61.3	189.3
Minimum	12.9	2.6	17.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	14.1	15.8	409.2
Maximum	218.4	276.6	245.0	212.4	91.2	73.8	31.4	2.6	29.4	157.2	116.2	208.8	1062.6

Legend: S.D.: sample standard deviation.
Source: BVP Engenharia, 2008. Prepared by: Arcadis, 2017.

Graph 5.1-8 – Monthly rainfall indexes registered at Moreira Station (code 842004).



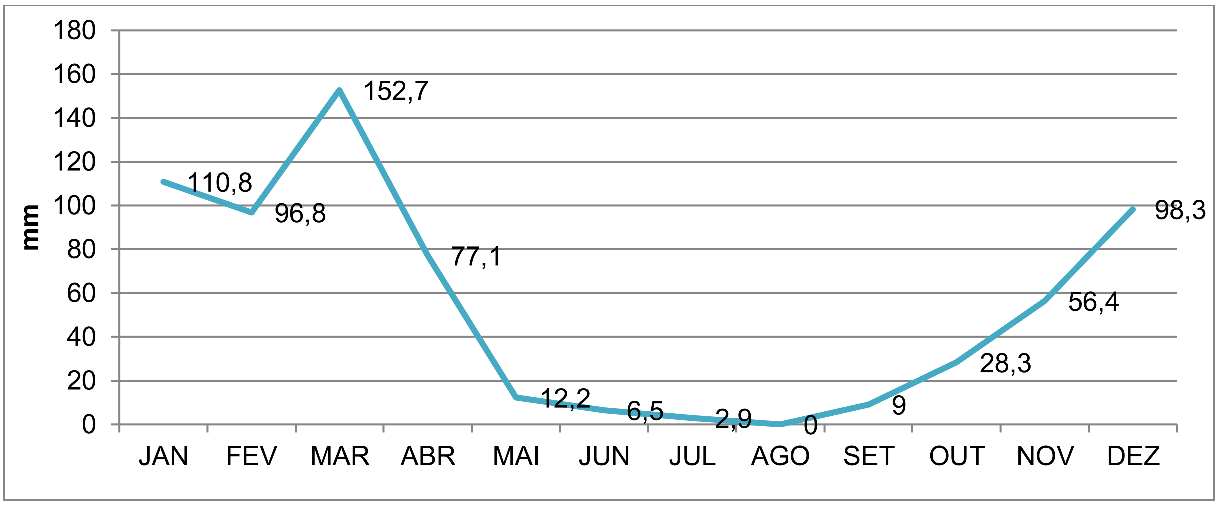
Source: BVP Engenharia, 2008. Prepared by: Arcadis, 2017.

Data Table 5.1-9 – Average monthly rainfall (mm) and statistical parameters (mm) of the rain station 841002 - Fazenda Bugiu.

Year	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SET	OCT	NOV	DEC	ANNUAL TOTAL
Average	110.8	96.8	152.7	77.1	12.2	6.5	2.9	0.0	9.0	28.3	56.4	98.3	650.9
S.D.	72.3	76.6	80.4	71.4	22.1	23.6	7.1	0.0	19.2	25.6	55.0	68.2	218.8
Minimum	6.2	18.8	10.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	24.5	308.8
Maximum	267.9	288.5	318.7	218.8	63.0	85.1	22.0	0.0	67.3	69.5	205.4	261.9	1132.3

Legend: S.D.: sample standard deviation.
Source: BVP Engenharia, 2008. Prepared by: Arcadis, 2017.

Graph 5.1-9 – Monthly rainfall indices recorded at Fazenda Bugiu station (code 841002).



Source: BVP Engenharia, 2008. Prepared by: Arcadis, 2017.

The data obtained in the rain stations named Moreira (code 842004) and Bugiu (code 841002), corroborate the regional rainfall characteristics, with the highest rainfall in March and the lowest in August.

According to the inventory of fluviometric stations published by ANA (BVP Engenharia, 2008), 4 stations were recorded in the vicinity of the Piauí Nickel Project.

Data Table 5.1-10 – Fluviometric stations in the Piauí Nickel Project region.

Code	Name	River	Municipality	Sponsor	Coordinates	Drainage Area (km²)
34410000	Pedra Redonda	Rio Canindé	Conceição do Canindé	ANA	-8:0:20 S / -41:29:52 O	4,760
34450000	Maria Preta	Rio Itaim	Patos do Piauí	ANA	-7:32:47 S/ -41:17:42 O	7,212
34480000	Fazenda Talhada	Rio Canindé	Rio Canindé	ANA	-6:58:24 S/ -42:6:22 O	28,700
34571000	São Francisco do Piauí	Rio Piauí	São Francisco do Piauí	ANA	-7:13:59 S/ -42:32:40 O	35,000

Source: BVP Engenharia, 2008. Prepared by: Arcadis, 2017.

Data Table 5.1-11 – Average monthly flow and statistical parameters of fluviometric stations.

Station 34410000 - Pedra Redonda													
Year	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SET	OCT	NOV	DEC	ANNUAL TOTAL
Average	1.6	3.5	6.9	7.9	1.6	0.0	0.0	0.0	0.0	0.0	0.1	0.4	22.1
S.D.	1.7	2.8	8.3	13.1	2.7	0.0	0.0	0.0	0.0	0.1	0.2	0.8	22.3
Minimum	0.0	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Maximum	4.2	7.6	20.5	31.1	6.3	0.0	0.0	0.0	0.0	0.1	0.5	1.8	60.8
Specific flow (l/s/km²)													0.387

Station 34450000 - Maria Preta													
Year	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SET	OCT	NOV	DEC	ANNUAL TOTAL
Average	6.1	2.2	13.4	8.5	1.1	0.1	0.0	0.0	0.0	0.0	0.1	3.8	35.3
S.D.	13.3	2.9	24.0	10.2	1.3	0.3	0.1	0.0	0.0	0.0	0.3	15.7	33.8
Minimum	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.3
Maximum	56.2	10.6	92.1	34.4	4.3	0.8	0.3	0.0	0.0	0.0	1.3	66.7	133.3
Specific flow (l/s/km²)													0.407

Estação 34571000 - São Franciso do Piauí													
Year	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SET	OCT	NOV	DEC	ANNUAL TOTAL
Average	9.1	14.2	16.3	20.1	5.1	1.0	0.2	0.0	0.0	0.0	0.8	3.7	64.9
S.D.	11.2	18.4	11.4	26.0	8.5	1.6	0.5	0.1	0.0	0.0	1.2	6.3	55.0
Minimum	0.0	2.4	2.2	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.5
Maximum	47.6	76.8	39.3	108.5	36.3	6.5	2.0	0.6	0.1	0.1	4.1	23.3	265.2
Specific flow (l/s/km²)													0.168

Estação 34480000 - Fazenda Talhada													
Year	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SET	OCT	NOV	DEC	ANNUAL TOTAL
Average	14.2	21.0	36.1	22.1	5.1	1.2	0.6	0.4	0.3	0.6	1.4	4.9	108.0
S.D.	8.5	15.8	27.0	34.8	4.5	0.8	0.5	0.3	0.2	1.7	1.8	3.8	70.2
Minimum	1.9	6.4	8.7	2.6	0.8	0.3	0.1	0.0	0.1	0.0	0.1	0.7	42.6
Maximum	27.0	57.0	85.1	114.1	15.4	2.8	1.4	1.0	0.7	5.5	5.5	11.7	263.7
Specific flow (l/s/km²)													0.314

Legend: S.D.: sample standard deviation.
Source: BVP Engenharia, 2008. Prepared by: Arcadis, 2017.

The marked seasonality between the least rainy and the most rainy period is reflected in the flows of the analyzed rainfall stations. The highest average flows occur between February and April and the lowest between July and October.

It appears that the average specific flow of the region is in the order of 0.3l / s / km², which is considered a low value when compared to the other regions of Brazil. The specific flows decrease from the source of the water courses to the mouth, since the highest values of specific flow occur in stations with less drainage area. The specific flow equal to 0.387 l / s / km² and 0.407 l / s / km², observed at stations 34410000 and 34450000, with drainage areas of 4,846 km² and 7,212 km², while at stations 34571000 and 34480000, specific flow equals 0.168 l / s / km² and 0.314 l / s / km², with a drainage area of 28,700 km² and 35,000 km² (BVP Engenharia, 2008).

b) Surface Water Availability and Demand

According to the study Availability and Demand for Water Resources in Brazil (ANA, 2005), the Parnaíba RH has an average flow of 763 m³ / s and 24.1 km³ / year, which is equivalent to 0.4% of the average flow of the country, the smallest recorded among all the Brazilian Hydrographic Regions. The drought flow (with a 95% guarantee) is 294 m³ / s. The table below shows the flow values for each sub-basin in the Parnaíba RH.

Data Table 5.1-12 – Flow rates in Parnaíba RH Sub-basins.

Sub-basin	P	Q	Q95%	q	q95%
Upper Parnaíba	590,536	529.9	237.3	13.06	5.74
Mid Parnaíba	2,343,393	177.8	43.2	2.58	0.63
Lower Parnaíba	1,053,171	55.4	13.7	1.29	0.32
Total	**3,987,100**	**763**	**294**	**17**	**38**

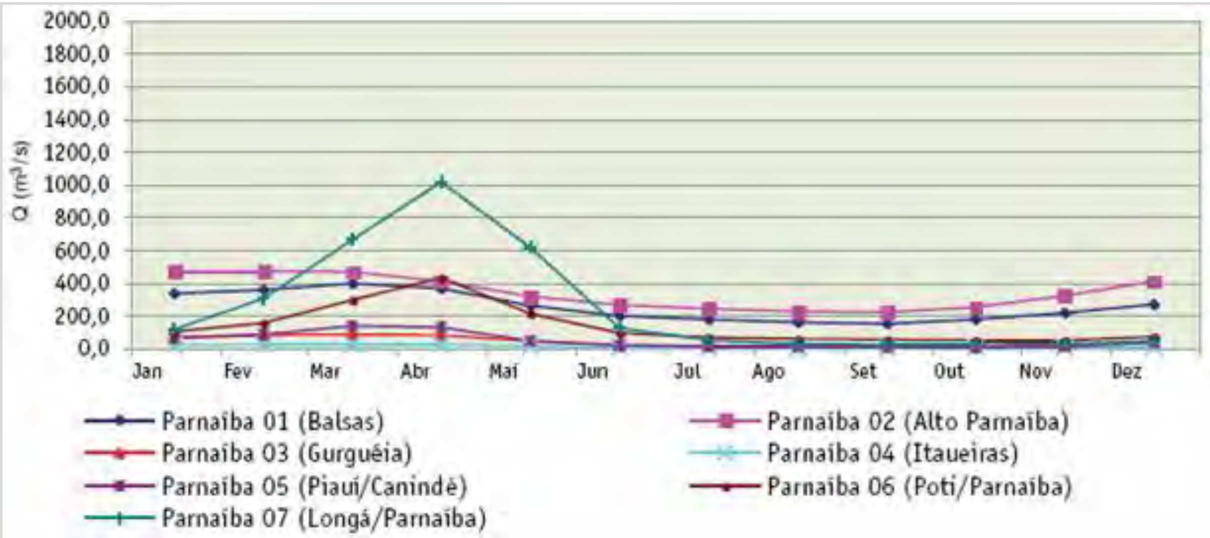
P: total Population (Demographic census IBGE, 2000); Q: long-term average flow (m³/s); Q95%: 95% guaranteed flow (m³/s); q: specific flow (l/s/km²); q95%: 95% guaranteed specific flow (l/s/km²).

Source: Bases do Plano Nacional de Recursos Hídricos (2005). Prepared by: Arcadis, 2017.

Based on the data presented above, it can be noted that the Sub-basin of the Middle Parnaíba, despite being the sub-basin with the largest population, is in second place within the RH of Parnaíba in terms of flows. This contrast is only one side of the problem of water scarcity, which does not supply the entire population of the region. In addition, the rainy season is intense on just a few days of the year, contributing to the intermittency of rivers.

In particular, the level 2 sub-basin Parnaíba 05 (Canindé / Piauí) has low average flow values, registering an increase in the period of March and April, and a decrease in May, reaching the lowest value in June, as illustrated by Figure 5.1-4.

Figure 5.1-4 – Average Monthly Flow for each Parnaíba Sub-basin.



Source: Caderno da RH Parnaíba (2006); Bases do PNRH (2005).

There are several dams and weirs built in the Parnaíba 05 sub-basin. Considering a usable volume of 10% of the total capacity of all of them, there is an availability of water resources of 106,505,980 m³ / year, which is equivalent to a flow of 3.38 m³ / s. The Jenipapo dam, located close to the project area, has a water availability of approximately 18,000,000 m³ / year, considering only a usable volume of 10%.

There is also a number of lagoons with relevant capacity, whose usable volume is 12,370,000 m³ / year, which is equivalent to a flow rate of 0.39 m³ / s. Adding the flow of the lagoons to that of the dams and weirs, there is a flow of 3.77 m³ / s.

The demand and surface water availability for each sub-basin in the Parnaíba hydrographic region are presented in the following tables.

Data Table 5.1-13 – Surface water availability for each sub-basin in the Parnaíba hydrographic region.

Sub-basin (level 1)	Sub-basin 2	Q95% (m³/s)	Regulated flow (m³/s)	Available in Lakes and Reservoirs (m³/s)	Total Availability (m³/s)
Upper Parnaíba	Parnaíba 1	65.29	-	-	65.29
	Parnaíba 2	150.61	-	-	150.61
	Parnaíba 3	16.68	-	0.52	17.20
	Parnaíba 4	4.70	301.0	0.36	306.06
Mid Parnaíba	Parnaíba 5	23.98	-	3.77	27.75
	Parnaíba 6	19.2	301.0	-	320.20
Lower Parnaíba	Parnaíba 7	13.66	301.0	-	314.66

Source: MMA, 2006. Prepared by: Arcadis, 2017.

Data Table 5.1-14 – Accumulated average demand / flow balance and demand / availability for each sub-basin in the Parnaíba hydrographic region.

Sub-basin (level 1)	Sub-basin 2	Total demand (m³/s)	Average annual flow (m³/s)	Accumulated average annual flow (m³/s)	Available flow (m³/s)	Total demand / Accumulated average annual flow (%) - criterion 1	Total demand / Water availability - criterion 2
Upper Parnaíba	Parnaíba 1	1.305	133.6	133.6	65.29	0.98	2.0
	Parnaíba 2	0.493	308.3	442.0	150.61	0.11	0.3
	Parnaíba 3	1.411	68.7	510.6	17.20	0.28	8.2
	Parnaíba 4	0.487	19.3	530.0	306.06	0.09	0.2

Sub-basin (level 1)	Sub-basin 2	Total demand (m^3/s)	Average annual flow (m^3/s)	Accumulated average annual flow (m^3/s)	Available flow (m^3/s)	Total demand / Accumulated average annual flow (%) - criterion 1	Total demand / Water availability - criterion 2
Mid Parnaíba	Parnaíba 5	2.527	98.7	98.7	27.75	2.56	9.1
	Parnaíba 6	7.600	79.1	707.8	320.20	1.07	2.4
Lower Parnaíba	Parnaíba 7	6.795	55.4	763.2	314.66	0.89	2.2
Parnaíba		20.617	109.01	763.2	1201.8	0.89	1.7

Source: MMA, 2006. Prepared by: Arcadis, 2017.

As described in MMA (2006), in order to analyze the demand / availability ratio in each sub-basin (Data Table 5.1-14) the methodology presented in ANA (2005) was followed. Two evaluation criteria were adopted:

- Relationship between withdrawal flow and average flow
- This relationship, according to ANA (2005), is adopted by the European Environment Agency and the United Nations with the following classifications:
  - <5% Excellent - Little or no management activity is necessary, water is considered a free asset;
  - 5 to 10% Comfortable - There may be a need for management to solve local supply problems;
  - 10 to 20% Concerning - Management activity is essential, requiring medium investments to be made;
  - 20 to 40% Critical - Requires intense management activity and large investments;
  - > 40% Very Critical.
- Relationship between withdrawal flow and water availability
- According to ANA (2005), it reflects the real situation of the use of water resources in the Hydrographic Basin. It considers the same variations listed in the previous criterion.

The table (Data Table 5.1-14) shows that all the Sub-basins are in the Excellent category, that is, they all have a balance between demand and the average accumulated flow below 5%, this means that there is no need for management activities and that water is a free good. However, the Parnaíba 05 (Piauí / Canindé) and Parnaíba 06 (Poti / Parnaíba) Sub-basins showed the highest values.

The second criterion (Data Table 5.1-13) it is more realistic and considers the water availability of the Sub-basins. In this case, the Sub-basins Parnaíba 03 (Gurguéia) and Parnaíba 05 (Piauí / Canindé) fit into the Comfortable situation, and there may be a need for management to solve local water supply problems. As previously mentioned, the future project is located in the Parnaíba 05 sub-basin, which is located in a semi-arid region, the rivers are intermittent and dry out in very dry years. However, it is the sub-basin that has the largest number of reservoirs built, increasing availability (MMA, 2006).

It is worth noting that in the first criterion the accumulated average flow was used, determined through data from fluviometric stations, without considering availability in lakes and reservoirs and regulated flows. The second criterion, on the other hand, considers the flow with a 95% guaranteed time plus the annual availability in lakes and reservoirs and regulated flows (MMA, 2006).

5.1.7.2. Local Characterization of the Drainage Network - Area of Direct Influence (ADI) and the Directly Area Affected (DAA)

A) Hydrography

The drainage network that covers the Piauí Nickel Project's ADI and DAA is typical of a semi-arid climate. Rivers and streams have an intermittent character, due to the low levels of precipitation and its irregularity. In the dry season, therefore, the water flow in most surface watercourses disappears.

Another fact that contributed to the intermittency of the ADI and DAA drainage network is the lithological structure, in particular the crystalline basement, which largely controls the paths of water courses. In areas with crystalline basement, the formation of aquifers is very restricted, with rivers becoming dependent on rainwater, which, as explained in section (5.1.1) 'Climate and Meteorology', are irregular, focusing in just a brief period of the year. Thus, the perennial character of these rivers is seen only when they cross domains of sedimentary rocks, in which they receive a contribution from groundwater.

In this way, the rivers in this climatic domain have periods of droughts and floods, two distinct hydrological extremes, which are the most important events, with regard to water resources, for the population of the area.

This situation requires strategies for water rationing, such as the construction of dams and cisterns. The latter have an important role in the accumulation of water, as they connect to gutters, located on the roofs of the houses, which direct the rainwater to a reservoir, as illustrated by Photo 5.1-32.

Photo 5.1-32 – View of residence with cistern.

Fonte: Arcadis Tetraplan, 2008.

All ADI watercourses belong to the Piauí River sub-basin on its right bank and are considered to belong to level 3 or lower basins.

The Várzea stream, located in the central portion of the ADI, close to the area of the project, is a tributary of the Gameleira stream on its right bank.

Gameleiras stream rises in the Serra da Gameleira (from its northern portion), about 40 km from the central portion of the ADI. From there, it passes through the town of Capitão Gervásio Oliveira and has its course predominantly in a southwest direction, crossing the ADI in the central portion, just 600 meters north of the Serra da Aldeia, to empty into the Itaquatiara Creek.

Also belonging to the ADI are, part of the São Domingos streams and its tributaries, part of the Caraíbas stream and the Itaquatiara stream, in addition to the Piauí river, including the Jenipapo dam.

The São Domingos stream has its source 8 km north of the ADI (in the area where the construction of the Water Transmission Line and Water Supply is planned) in the Chapada do Mundão, where the elevation level is about 400 meters. From there, it goes in a southwest direction and, after covering 31.5 km, it flows into the Piauí River.

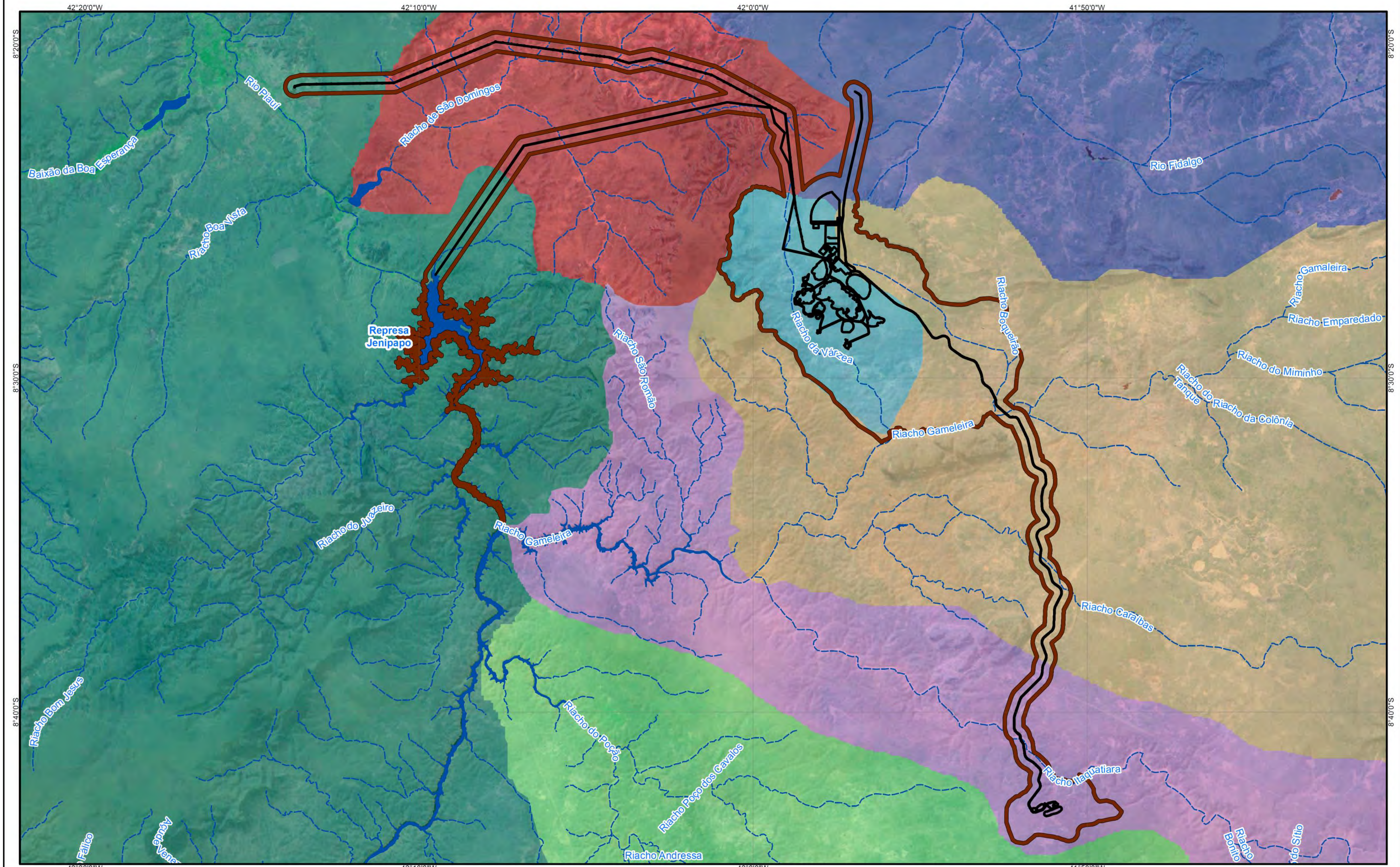
The Caraíbas stream rises in the Serra da Gameleira, located 25 km northeast of the projected limestone quarry, at an altitude of approximately 600 meters. Heading northwest, cross the ADI by the road that links the projected limestone quarry to the Piauí Nickel Project industrial area, passing about 1.5 km south of the Serra da Aldeia. It flows into the Gameleiras stream, after covering about 57 km.

The Itaquatiara stream begins southeast of the ADI, in the Serra do Boqueirão, with the name of Bonito stream, at an approximate height of 530 meters. It drains north towards the Barra do Bonito community, where it takes a westerly direction. In the vicinity of the projected limestone quarry, after covering a distance of approximately 32 km, the Bonito stream starts being called Itaquatiara stream, at an approximate altitude of 430 meters. From this point, it heads northwest until it flows into the Piauí River, in the backwater area of the Jenipapo dam. Next to the overflow structure of this dam, the water catchment point of the Piauí Nickel Project is planned, whose flow will be directed through a pipeline to the process plant area. The path of this pipeline will cross some tributary springs on the left bank of the São Domingos stream, also crossing some springs of the Várzea stream, in the vicinity of the project core area.

Finally, the Piauí River, the main watercourse in the area, receives contributions from the waters of all other streams in the region and has its source in the Piauí municipality of Caracol, located on the border with the State of Bahia. After covering more than 180 km, this river crosses the ADI, first in the western portion (Jenipapo dam) and then in the north / northwest portion (projected transmission line).

During its course, the Piauí River receives waters from several tributaries, originating mainly from the chapadas and chapadões that surround the Piauí River Valley. On its left bank, streams like Bom Jesus, Juazeiro and Onça flow. On the right bank, the Piauí River receives the waters of Poção stream, Grande stream, Mulungu stream, among others. All of these streams are intermittent. The map below shows the drainage network that makes up the Piauí Nickel Project's ADI.

Map 5.1-16 –Drainage network of Piauí Nickel Project's ADI.



LEGENDA

- Intermittent Drainage
- Water Mass
- Area of Direct Influence - ADI
- Directly Affected Area - DAA

Hydrographic Basins in ADI

- Itaquatiara Stream
- Santa Maria Stream
- Gameleira Stream
- Várzea Stream
- São Domingos Stream
- Fidalgo River
- Piauí River

REFERÊNCIAS

IBGE, Base contínua 1:250.000, 2015.

ESCALA GRÁFICA

0 5 10 km

Sistema de Coordenadas: GCS SIRGAS 2000

MAPA DE LOCALIZAÇÃO

MA CE RN PB PE PI AL TO BA SE

PIAUÍ NÍQUEL

ARCADIS

EIA/RIMA – PROJETO PIAUÍ NÍQUEL

Map 5.1-16 – Hydrographic Network – ADI

EXECUTADO POR:	ESCALA:	NÚMERO:	DATA:
ARCADIS	1:200.000	Única	jun /2017

In general terms, the ADI and the DAA reproduce the general pattern observed in the AII, being characterized by low drainage density, with intermittent water courses. The first order channels, in addition to being temporary, are short and are positioned on topographic levels close to 500 meters in relation to the mean sea level, reaching the base level in environments already quite flattened at topographic levels close to 330 meters.

In the mining area and in the topsoil disposal area for lateritic and overburden material, there are no surface drains. Along the road that joins the future mine to the site of the pilot plant, the existing route cuts temporary drains, of short length. In the area of the pilot plant, the existing drainage is oriented in the NE-SW direction and is partly filled with materials derived from a past asbestos mining activity that existed at the site.

The area of direct influence of the project is, to a large extent, characterized by the high erosive competence of the land, as demonstrated by the geometry of the excavated channel beds by flow exclusively during the rainy periods and by the size of the coarse material dragged and deposited along the dry beds, an aspect also observed in the AII.

B) Hydrology

According to information from the National Water Agency, there are no pluviometric and fluviometric stations in the Piauí Nickel Project's ADI.

In the ADI of the project, the presence of the Jenipapo reservoir, which has a drainage area of 14,600 km², should be highlighted. Its accumulation volume is 248 x 106 m³. The main information pertinent to this reservoir is summarized in the table below and in the figure thereafter.

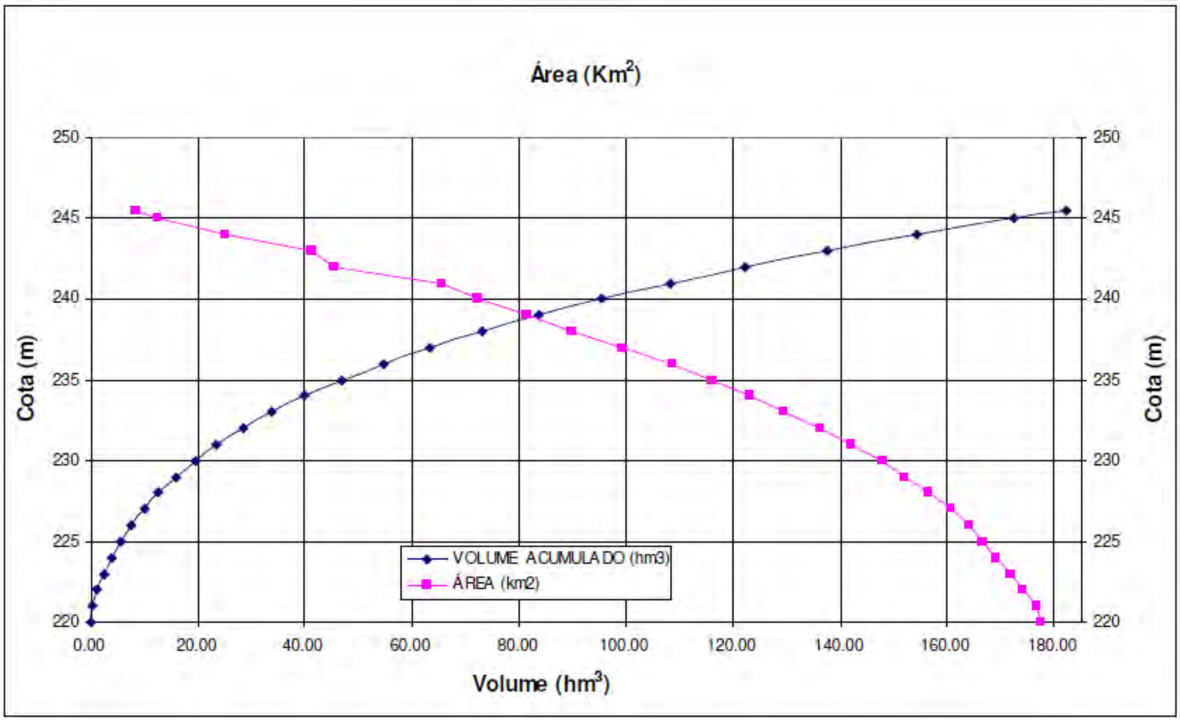
Data Table 5.1-15 – Data for the Jenipapo Reservoir.

Characteristics	Information
Name of dam	Jenipapo
River dammed	Rio Piauí
Crown Length (m)	174.00
Hydrographic Basin Area (km²)	14,602
Hydraulic Basin Area – Elevation 245.5 (m)	2,100
Locality	São João do Piauí
Accumulation Capacity (m³)	248,000,000
Spillway Elevation (m)	245.5
Crown Level (m)	254.0
Spillway Width (m)	200.00
Regulated Flow with 90% Guarantee - Qr	2.56 m³/s
Average Reservoir Volume - Va	$176x10^6$m³/yr (5.6 m³/s)

Characteristics	Information
Reservoir Average Annual Runoff - D	12.1 mm
Reservoir Storage Capacity / Average Annual Volume Reservoir - I	1.3

Source: DNOCS,1977 apud BVP Engenharia, 2008. Preparation by: Arcadis, 2017.

Figure 5.1-5 – Elevation curve x area x volume of the Jenipapo dam.



Source: DNOCS,1977 apud BVP Engenharia, 2008.

As already reported in the Project Description chapter, the operation of the Piauí Nickel Project will result in a demand of 460 m³ / h of water to be captured at the Jenipapo Dam. This water extraction, which already has a permit, will be used in the industrial process, for human consumption, sanitary use, the sulfuric acid factory and for the firefighting system.

Considering that the total volume of the Jenipapo dam is 248,000,000 m³, it can be said that the demand for water necessary for the operation of the project is insignificant compared to this volume.

5.1.7.3. Quality of Surface Waters

A) Regional Context of Surface Water Quality - Area of Indirect Influence (AII)

Preparation of the surface water quality diagnosis for the region where the project is located was based on secondary data available from public agencies, on specialized bibliography, from other sources of consultation, relevant to the theme, from which the following were described: the regional context of the Parnaíba basin, which contains the project AII, and a general characterization of water quality.

The water quality of the AII is strongly conditioned by climatic factors and the flow of water courses, which are irregular and do not maintain runoff throughout the year.

A large part of the tributaries of the Piauí River rise in the domains of crystalline basement and are perennial only when they reach the sedimentary basin, when they begin to receive underground contributions from the main aquifers, such as the Serra Grande and Cabeças, which maintain minimum residual flow in the riverbed.

Depending on the regional climatic characteristics, two distinct categories of water courses are observed:

(i) Intermittent: during the rainy seasons, the underground water table is preserved above the riverbed and feeds the watercourse together with the rainwater. In the dry season, the flow ceases, since the water table is below the bed.

(ii) Ephemeral: these exist only during or immediately following periods of precipitation and only carry surface runoff. As the water table remains below the riverbed, there is no possibility of draining underground water.

The low rainfall and the seasonal flow pattern have two associated effects that are reflected in the water quality - the accumulation of pollutant loads in the drainage basin over an extended period of time, tending to reach the water courses in greater concentration with the occurrence of the first rains, and the low capacity to assimilate polluting loads, due to the reduced flows of the rivers at the beginning of the rainy season.

The use of the riverbed during the dry season for productive activities, such as goat grazing, strongly contributes to the accumulation of fecal matter and mineral nutrients in the sediments, which are immediately incorporated into the water flow as soon as precipitation starts.

In municipalities within the AII, the population lives predominantly in rural areas, so that the main sources of pollution are of diffuse origins. Despite the improvement observed in recent years across the region, the basic sanitation infrastructure, including the disposal of sanitary sewage and solid waste, is precarious and affects water quality, favoring the transmission of waterborne diseases, such as hepatitis and worms.

The regional economy is predominantly focused on livestock, the production of honey and milk and some subsistence agriculture, activities that do not require intensive application of inputs such as fertilizers and agrochemicals, which minimizes the supply of contaminating compounds to water courses. It is quite common to use organic animal fertilizer for backyard crops, particularly for vegetables or small fruit orchards.

This regional pattern tends to be altered by the implementation of irrigation projects, such as a project in the AII by CODEVASF (São Francisco and Parnaíba Valleys Development Company) that will use the waters regulated by the Jenipapo dam on the Piauí River, for irrigation of fruit growing in the Marrecas Settlement, at a distance of 31 km from the headquarters of the municipality of São João do Piauí.

According to information from the MMA (2006, op.cit.), the implementation of water infrastructure projects in the Piauí / Canindé Sub-basin, comprising several pipelines and dams, both built and projected, and associated with low population density when compared to the rest of the basin the Parnaíba River, increases the availability of water in that region.

However, the intermittent characteristics of the rivers, combined with the dispersed distribution of the population in rural areas, lead to the exploitation of underground water resources, which overlap the use of surface water. Despite the abundance of underground water sources in the AII, there is an intensive use of these waters with techniques that are often inadequate. The quality of these sources, in general, is compromised by the construction of cesspits in the immediate vicinity, a factor that restricts the supply of drinking water to the inhabitants of the region.

Another environmental factor that conditions the availability of water from the AII is related to the high evaporation rate, which causes a high concentration of ions, such as chloride, promoting salinization processes of springs.

The surface watercourses of the AII have not yet been submitted to the framework process under the terms of CONAMA Resolution No. 357, of March 17, 2005. As established by this legislation, “As long as the respective frameworks have not been approved, fresh waters will be considered of class 2”. For groundwater, for the present study, the drinking standards governed by Ordinance No. 2914 of 2011 from the Ministry of Health and by CONAMA Resolution No. 396/2008, which provides for classification and environmental guidelines of these waters, are considered.

Information on water quality in the region is very scarce. According to the Panorama of Water Quality in Brazil (ANA, 2012), the Parnaíba Hydrographic Region has insufficient information on the quality of surface water.

According to the Water Resources Master Plan of the Canindé / Piauí Rivers Hydrographic Basin (SRH, 1999), in several rivers the considerable levels of concentration of organic pollutants are due much more to the low flows observed in drier seasons than the release of large organic loads in rivers.

However, the rivers that cross important urban centers, such as the Poti, Guaribas, Gurguéia and Paranaíba rivers, are affected by pollution originating from urban and hospital solid waste, subjecting the population to waterborne diseases. It should be noted that industrial pollution is not very significant in the region.

The main sources of pollution in the Parnaíba Hydrographic Region are shown in the following figure, where there is an indication that in the region where the project will be implemented, solid waste and domestic sewage are the main sources of pollution.

Figure 5.1-6 – Critical areas and their respective sources of pollution in the Parnaíba Hydrographic Region.

Source: ANA, 2012.

The National Water Agency (ANA) maintains a network of dissolved oxygen (DO) measurement stations in the Parnaíba Hydrographic Region, covering five points in Sub-basin 5 - Piauí / Canindé, downstream of the Piauí Nickel Project's area of influence (MMA, 2006, op.cit.), As shown below.

In some stations, mean OD values were found below the limit recommended by CONAMA Resolution 357/05 (5.0mg / l). These results are typical of intermittent rivers, due to the low flow that they have in times of drought, with limited capacity to assimilate organic loads, consuming much of the available oxygen.

The figure also shows the estimated organic load generated in Sub-basin 5, expressed in terms of Biochemical Oxygen Demand (BOD), which reaches approximately 14.83 t / day, resulting in an average concentration of 7.1 mg / l, above the limit recommended by legislation for class 2 waters.

Regarding the values of solid discharge in the Parnaíba Hydrographic Region, despite the high potential for soil erosion in the AII, it appears that the lowest values of sediment production occur in Sub-basin 5 - Piauí / Canindé, estimated at 3,9 t / year / km², well below the average of 29.2 t / year / km² of sediments produced in the Parnaíba region.

Data Table 5.1-16 – Organic Load Generated in the Sub-basins of the Parnaíba Hydrographic Region.

Sub-1	Sub 2	Area (Km²)	Population (2000)	Q 95 (m³/s)	Load (tDBO/day)	Load (mg/L)
Upper Parnaíba	Parnaíba 01	25,590	118,966	65.29	4.62	0.82
	Parnaíba 02	59,032	130,021	150.61	3.11	0.24
	Parnaíba 03	52,297	238,687	16.68	4.62	3.20
	Parnaíba 04	14,726	102,862	4.70	3.70	9.11
Mid Parnaíba	Parnaíba 05	75,193	627,517	23.98	14.83	7.10
	Parnaíba 06	62,143	1,715,876	19.20	72.54	43.70
Lower Parnaíba	Parnaíba 07	42,821	1,053,171	13.66	30.77	26.07

Source: Bases do PNRH (2005); Apud (MMA, 2006, op.cit.). Prepared by: Arcadis, 2017.

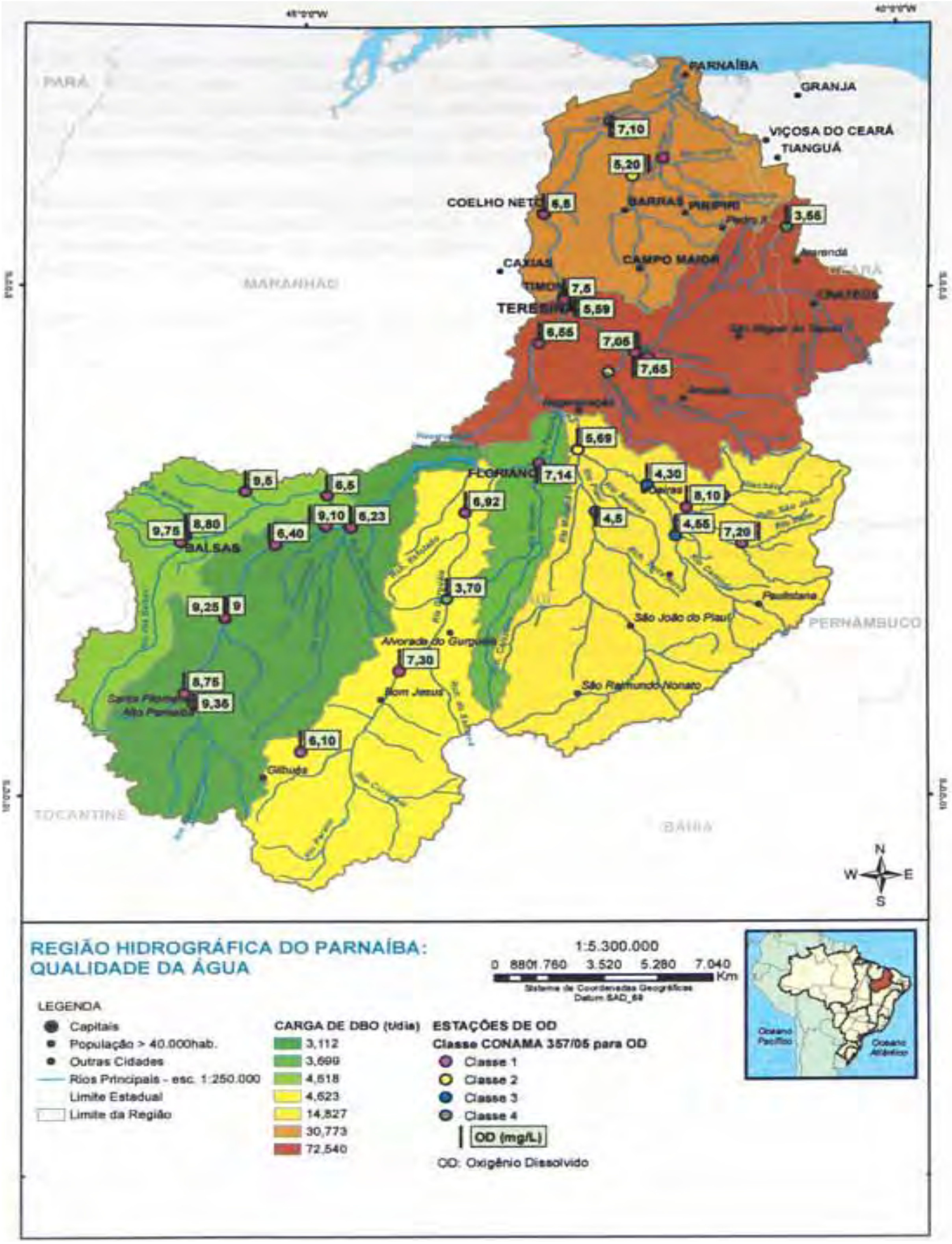
Data Table 5.1-17 – Estimated Sediment Load in the Sub-basins of the Parnaíba Hydrographic Region.

Code	Sub 2	River	Qss (10 6 t/year)	Q (m³/s)	Area (Km²)	Load t/yr/ km²
34060000	Parnaíba 02	Parnaíba	3.77	203	32,700	115.3
34090000	Parnaíba 02	Uruçui Preto	0.51	36	14,700	34.7
34170000	Parnaíba 01	Das Balsas	0.58	166	22,800	25.4
34270000	Parnaíba 03	Gurguéia	0.29	28	48,400	6.0

Code	Sub 2	River	Qss (10 6 t/year)	Q (m^3/s)	Area (Km^2)	Load t/yr/ km^2
34600000	Parnaíba 05	Canindé	0.29	39	73,900	3.9
34690000	Parnaíba 06	Parnaíba	3.40	516	270,000	12.6
34789000	Parnaíba 06	Poti	0.62	76	50,000	12.4
34879500	Parnaíba 06	Parnaíba	7.42	612	322,800	23.0

Source: Planap / Hidroweb (ANA) apud Arcadis Tetraplan, 2008. Prepared by: Arcadis, 2017.

Figure 5.1-7 – Regional Water Quality in the Context of the Parnaíba Hydrographic Region.



Source: Bases do PNRH (2005).

According to Hidroweb / ANA (2016), water quality monitoring is periodically carried out in the State of Piauí, aiming mainly to understand and evaluate the surface water quality conditions in the state and to provide subsidies for the planning of water resources.

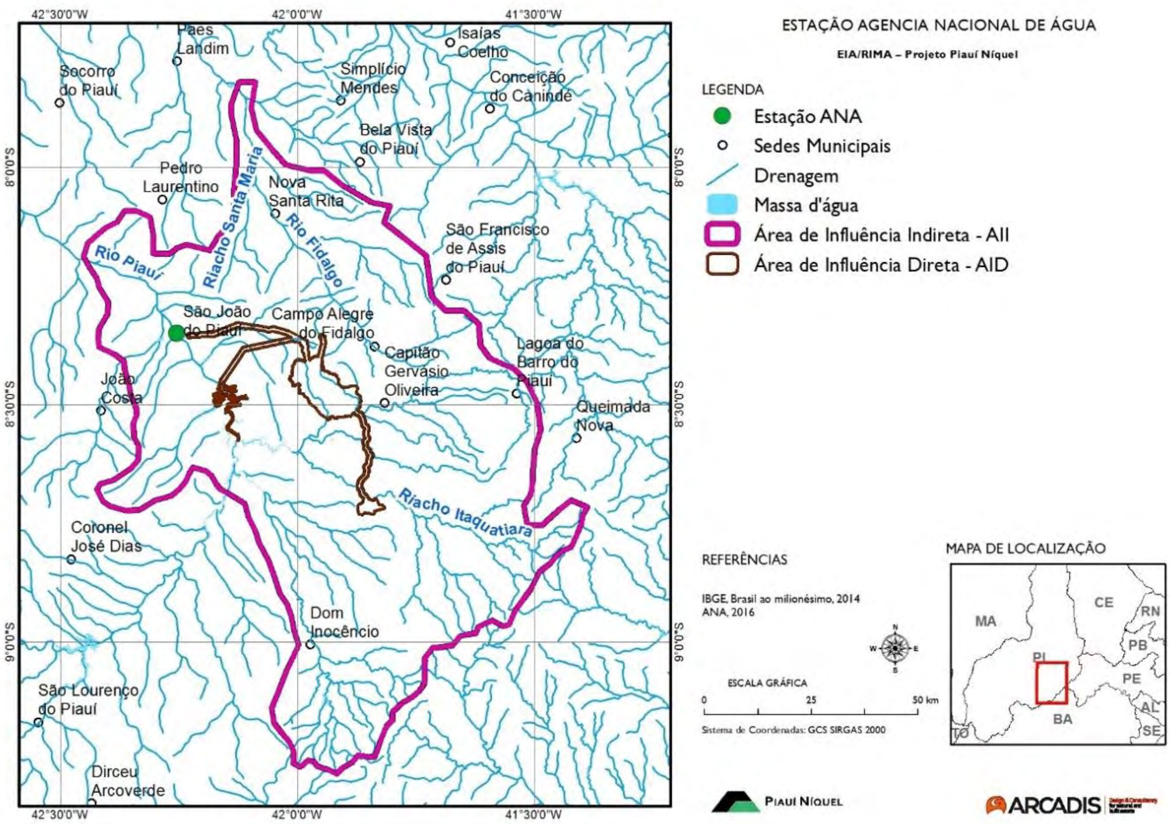
Among the monitored stations, only one is located within the AII of the project, in the Piauí River sub-basin, in the municipality of São João do Piauí, and its results will be presented shortly below.

Table 5.1-6 – Water quality monitoring station in the project's AII.

Station Code	Station Name	Lat/Long	Monitoring responsibility	Operator
34564000	São João do Piauí	-8:21:18 S/ -42:14:43 O	ANA	CPRM

Source: Hidroweb, 2016.

Map 5.1-17 – Location of the station monitored by ANA.



At the 34564000 station, surface water sampling was carried out between 2009 and 2016, when parameters such as pH, turbidity, conductivity and dissolved oxygen were analyzed. The results showed waters with low oxygenation (average 2.29 mg / l), large amounts of salts (average conductivity of 361 µS / cm), low amounts of suspended particulate matter (average turbidity of 9.13 FTU) and pH, in general, close to neutrality, with a variation from 6.1 (February 2010) to 9.38 (June 2011).

As will be seen in the subsequent section, specifically in 5.1.7.3 on ADI and DAA Surface Water Quality, the results obtained in this station monitored by ANA point to less oxygenated waters and with slightly higher conductivity than in point 8A, which was also sampled in the Piauí River sub-basin, however in the first half of 2008 and about 15 km upstream from the location where station 34564000 is located. The worst condition recorded at the station monitored by ANA may be a reflection of the contributions of anthropic origin from the municipality of São João do Piauí, since it is located near the municipal headquarters of this locality. Turbidity and pH showed similar values between the two sampling points.

It should be noted that by 2020 there is a forecast that a greater number of stations will be monitored in the state of Piauí by the National Water Agency, including at points very close to the area of the future development, such as in the Piauí River and the Gameleira Creek, which will contribute to a better assessment of the quality of the region's waters.

B) Local Characterization of Surface Water Quality - Area of Direct Influence (ADI) and Directly Area Affected (DAA)

For analysis of the ADI and DAA, the following section discusses the context of the drainage network where the main structures of the Piauí Nickel Project are located and the general characterization of the water quality in the sub-basins in the influence areas of the project.

a) Drainage Network Context

As previously mentioned, the main water courses that drain the ADI and DAA are located on the right bank of the Piauí River, with emphasis on the Várzea stream, Gameleiras stream, São Domingos stream, Itaquatiara stream and the Caraíbas stream.

In general, the streams are located on shallow and poorly permeable soils, which makes it difficult to store water in this region. The river runoff regime also leads the population to adopt specific procedures aimed at accumulating and retaining water, such as the construction of cisterns and small weirs, spread throughout the drainage network.

The cisterns, an alternative commonly used in homes, are masonry works that have the purpose of capturing rainwater from roofs, and can be supplied by water trucks during the dry season. The *cacimbas* (small boreholes or ponds dug artisenally to access underground water) found in the bed of intermittent watercourses, as in the Itaquatiara stream, are fed exclusively by groundwater during the dry period, serving as a source of supply to the surrounding villages.

The waters stored in dams and weirs are used for multiple purposes, such as human supply, domestic activities, bathing, recreation, fishing and animal drinking. Within the ADI, the Jenipapo dam stands out for its size. Built to divert the waters of the Piauí River for irrigation projects, this dam is currently used for fishing, irrigation of vegetables and fruits, animal drinking, and is used as a spa by the local population.

As noted in the AII section above, the main sources of pollution in the ADI and DAA are of diffuse origin, resulting mainly from animal herd excrement, especially goats, dispersed throughout the region. These animals tend to concentrate around weirs for drinking, compromising the sanitary quality of the water, in addition to enriching the environment with mineral salts, promoting the development of algae. The contribution of solids resulting from erosive processes also strongly interferes with the quality of surface water, especially in the rainy season, as will be discussed below.

In this sense, the factors that contribute to regional population health problems related to water-borne diseases are the low standards of basic sanitation that exist in most villages, which results in a concentration of waste of a differing natures around the bodies of water, and the direct use of this water for human consumption without previous treatment, generating poisonings, diarrhea and other gastrointestinal problems. This situation is mitigated by the large number of cisterns that exist throughout the region, which collect rainwater or are supplied by water trucks, meeting local demands. The presence of cyanobacteria in the waters should also be highlighted, but this will be discussed in item 5.2.5.2 on Hydrobiological Communities.

b) Surface Water Quality

As already mentioned, the diagnosis of water quality in the ADI and DAA was conducted based on secondary data and field surveys carried out over three campaigns in 2008.

It is important to note that although the survey of primary data took place in 2008, there was little change in land use in the region, suggesting that the current environmental characteristics are similar to those of 2008 and, therefore, the data obtained in 2008 are sufficient to technically support the assessment of impacts and the proposal of mitigating measures for the project in question. This understanding was corroborated by SEMAR and PNM in a meeting held in September 2016 and subsequently validated by Technical Opinion 7,975 / 16 issued by SEMAR in December of the same year.

The first campaign in 2008 took place from February 15 to 17, the second from March 14 to 19 and the third from May 1 to 5. In these campaigns, samples were taken for physical-chemical and bacteriological analyzes of surface waters, and collections were also carried out to characterize the hydrobiological communities (aquatic biota), thus allowing an integrated interpretation of the results obtained. The results of these campaigns, however, are presented in the chapter referring to the Biotic Environment.

It should be noted that these three collection periods were very opportune because they represent relevant hydrological events in the study of environmental impact related to water quality. According to the climatological data of 2007 and 2008, there was a considerable discrepancy in the amount of rainfall for the months of February and March. In February 2007, rainfall was approximately 220 mm, while in 2008, it was around 50 mm. In March 2007, rainfall was approximately 30 mm; in contrast, in 2008, it exceeded 300 mm (ARCADIS TETRAPLAN, 2008).

Thus, the first campaign coincided with the occurrence of still sparse rainfall in the region, being representative of the transition between the dry and rainy periods. A large part of the streams still had a completely dry bed, showing in some places the existence of *cacimbas*.

In this sense, the samples collected are indicative of a very unfavorable situation for surface water courses, since it combines two associated factors - a) the contribution of a high concentration of organic and mineral materials accumulated in the dry season and b) the reduced flow of the watercourses resulting in low potential for self-cleaning and dilution of the pollutant load. This situation tends to worsen in small dams and weirs, which start to act as nutrient reservoirs, favoring the proliferation of cyanobacteria, as in fact was observed in the limnological surveys carried out in the Jenipapo dam.

The second campaign was conducted under intense precipitation, capturing in the samples analyzed the reflection of the high potential for transporting solids to the receiving water bodies, with compromise of the aesthetic and sanitary aspects of the waters.

The third campaign, developed immediately after the end of the rainy season, showed, as will be presented later, a significant improvement in the water bodies due to the reduction in the flow of diffuse loads generated in the drainage basin combined with the greater dilution potential and for the purification of surface water resources.

In the subsequent sections, the adopted sampling network, the variables analyzed and the preliminary results obtained are presented.

c) Sampling Network

The ADI and DAA surface water quality sampling network was designed based on the location of the main structures of the project that could promote changes in the water system, in order to support the analysis of the impacts in the implementation and operation stages of the Piauí Nickel Project.

The collection sites were previously defined in dams and drains located around the facilities of the project, in the vicinity of the mining area, the pilot plant, the access roads, the limestone quarry, the water collection and supply structures and the power transmission line.

For a more comprehensive assessment, often considering points upstream and downstream of some structures, downstream of the confluence of some important contributors or close to villages or relevant sources of pollution, the location of some sampling points is not located within the ADI, although it is part of the water quality assessment of the same. Accessibility conditions and logistical support, among other factors, were also assessed.

With this guidance, the sampling network also included stretches of water courses located close to the ADI, making it possible to assess in an integrated manner the water quality where the project is located.

In total, 16 collection points were sampled, whose locations are indicated in Data Table 5.1-18 and in Table 5.1-7 shown below. The name of the points corresponds to the sequence of numbers 01 to 16 (except 14), with stations located upstream and downstream of the Jenipapo dam being identified as 8A and 8B, respectively. Also identified in these figures are the points located in water courses and in dams / weirs, as they represent lotic and lentic systems, respectively.

As mentioned above, in the first campaign (February / 2008), several points inspected had a bed that was still completely dry, making it impossible to collect water samples; two points defined in the Itaquatiara creek comprised *cacimbas* (water wells) fed only by the water table. In total, this campaign comprised 9 sampling points.

In the second collection campaign (March / 2008), the streams had developed runoff, with covering of *cacimbas*, allowing a larger number of samples to be taken. In total, this campaign covered 13 sampling points.

In the third campaign (May / 2008), the samples were concentrated mainly in the dams. Due to the heavy rains that occurred previously, it was possible to introduce new points in the basic network, such as two dams in the Várzea stream (Points 15 and 16), which were completely dry during the two previous campaigns. The reservoir in the city of Capitão Gervásio Oliveira, located outside the ADI, was also sampled, as it will be used to supply the municipality, and should suffer greater pressure from the use of water due to the increase in the number of people expected during the implementation and operation of the project.

In total, the third campaign comprised 11 sampling points, three of which (Points 01, 05 and 16) included only in situ measurements of some parameters.

For the purpose of assessing the waters under the influence of the project structures, the points of the sampling network were grouped into five main watersheds / sub-basins:

- (i) Itaquatiara stream, with a view to covering the limestone quarry and the respective access route (Points 01, 02, 03 and 09);
- (ii) Gameleira stream (Points 6, 10, 11, 12, 13);
- (iii) Várzea stream (Points 4, 5, 15 and 16), where the main operational structures of the project are concentrated, including the mining and ore processing area and local access roads;
- (iv) Piauí River, where the Jenipapo dam is located, planned to supply water to the mine (Points 8A and 8B); and
- (v) São Domingos stream, a tributary of the right bank of Piauí, which is near the proposed transmission line (Point 07).

In this sampling network, the five dams (Points 04, 07, 13, 15, 16) and the Jenipapo dam at Point 8A are considered lentic systems, while the other sampled points are lotic environments, with a perennial regime (Point 8B) or intermittent (Points 01 to 03, 05, 06, 09 to 12). The *cacimbas* identified in the first campaign (Points 01 and 03) represent an accumulation of groundwater.

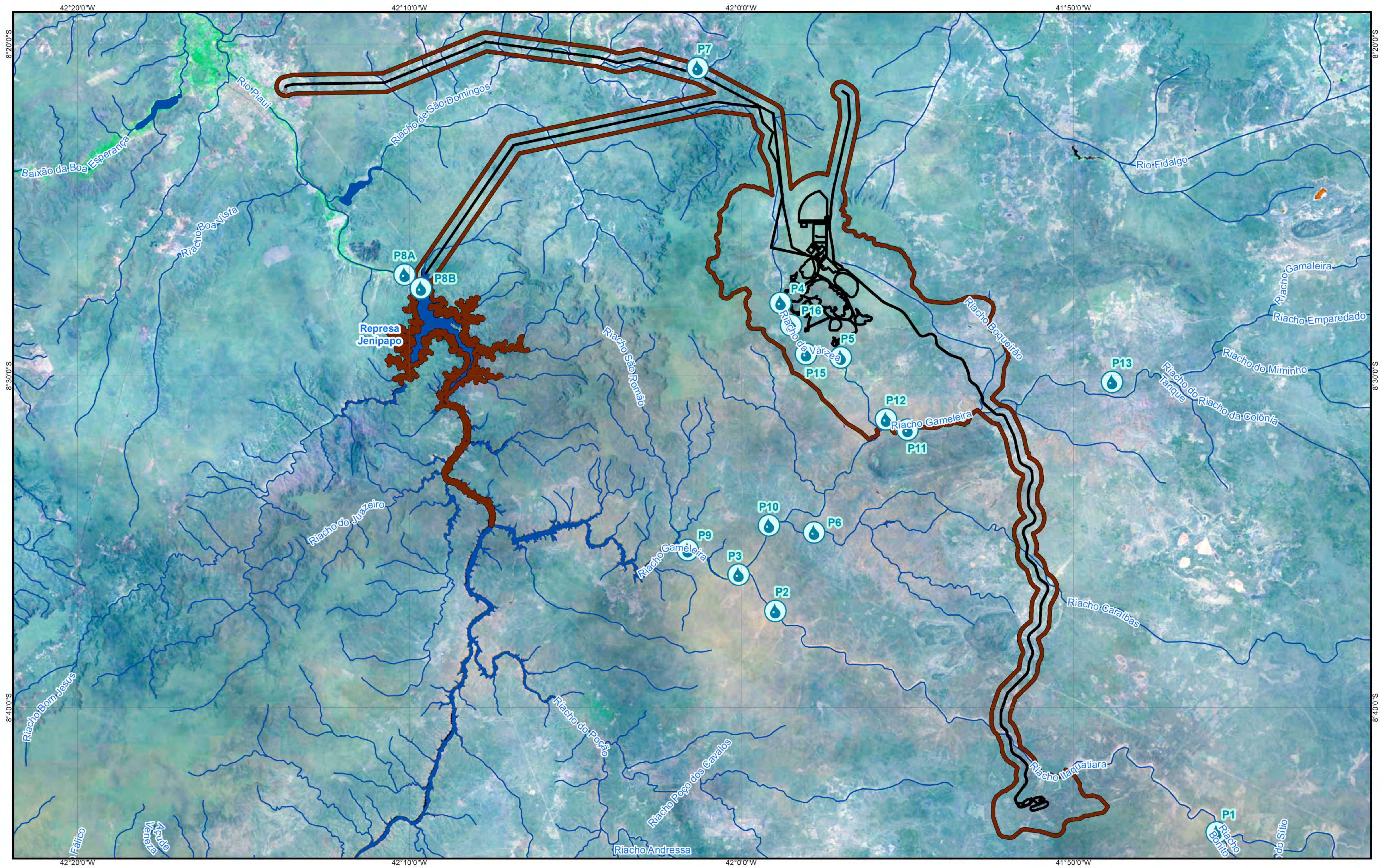
Data Table 5.1-18 – Surface Water Quality Sampling Network.

Points		Coordinates		Fuso	Water body	Location	Municipality
		North	East				
Itaquatiara	P1	9,033,980	196,155	24 L	Bonito stream	Upstream of the limestone quarry / Barra do Bonito	Between Dom Inocêncio/Capitão Gervásio Oliveira
Itaquatiara	P2	9,046,106	171,659	24 L	Itaquatiara stream	Downstream of the limestone quarry	Between Dom Inocêncio/Capitão Gervásio Oliveira
Itaquatiara	P3	9,048,108	830,080	23 L	Itaquatiara stream	Downstream from the mouth of the Gameleira	Between Dom Inocêncio/Capitão Gervásio
Itaquatiara	P9	9,049,502	827,271	23 L	Itaquatiara stream	Upstream from the mouth of the São Romão – Scale 2. Largos/Itaquatiara	Capitão Gervásio Oliveira
Gameleira	P6	9,050,488	173,767	24 L	Caraíbas stream	Upstream from the mouth of the Gameleira. Locally known as Veneza/Poços	Capitão Gervásio Oliveira
Gameleira	P10	9,050,849	171,256	24 L	Gameleira stream	Downstream from the Caraíbas - Scale 4	Capitão Gervásio Oliveira
Gameleira	P11	9,056,244	178,896	24 L	Gameleira stream	Downstream of the access road to the limestone mine - Scale 5	Capitão Gervásio Oliveira
Gameleira	P12	9,056,806	177,703	24 L	Gameleira affluent	Downstream from the pilot plant - Scale 6	Capitão Gervásio Oliveira
Gameleira	P13	9,058,970	190,179	24 L	Gameleira affluent / Weir	Capitão Gervásio Oliveira / Town	Capitão Gervásio Oliveira

Points		Coordinates		Fuso	Water body	Location	Municipality
		North	East				
Várzea	P4	9,063,236	171,801	24 L	Várzea stream / Weir	Upstream of the nickel mine area	Capitão Gervásio Oliveira
	P5	9,060,222	175,176	24 L	Várzea stream	Downstream of the nickel mine area	Capitão Gervásio Oliveira
	P15	9,060,387	173,237	24 L	Várzea stream / Weir	Downstream of the nickel mine area	Capitão Gervásio Oliveira
	P16	9,062,844	171,849	24 L	Várzea stream / Weir	Between Point 04 and 05	Capitão Gervásio Oliveira
São Domingos	P7	9,076,308	828,040	23 L	São Domingos stream/ Weir	Community of Eugênio (crossing point of the high-tension line)	São João do Piauí
Piauí	P8A	9,064,534	812,189	23 L	Jenipapo Reservoir	Jenipapo Reservoir- Water extraction point for the project	São João do Piauí
	P8B	9,064,548	812,631	23 L	Piauí River	Downstream from the Jenipapo Dam	São João do Piauí

Source: Arcadis Tetraplan, 2008 - ESIA/RIMA. Prepared by: Arcadis, 2017.

Map 5.1-18 – Surface Water Quality Sampling Network.



LEGENDA

- Drainage
- Water Mass
- Area of Direct Influence - ADI
- Directly Affected Area - DAA

Sampling Points

- Sampling Points

REFERÊNCIAS

IBGE, Base contínua 1:250.000, 2015.
ARCADIS Tetraplan, 2008.

ESCALA GRÁFICA

0 5 10 km

Sistema de Coordenadas: GCS SIRGAS 2000

MAPA DE LOCALIZAÇÃO

PIAUÍ NÍQUEL

ARCADIS Design & Consultancy for natural and built assets

EIA/RIMA – PROJETO PIAUÍ NÍQUEL

Map 5.1-18 – Sampling Points
Surface Water Quality

EXECUTADO POR:	ESCALA:	NÚMERO:	DATA:
ARCADIS	1:200.000	Única	jun /2017

During the field surveys, basic information was recorded, such as date and time of collection, air temperature, weather conditions and the occurrence of rain in the last 24 hours. In parallel, observations were made on the sampled watercourses and the prevailing conditions of the surroundings, with respective photographic record, in order to provide elements for the interpretation of the analytical results.

The table below shows a summary of the main field notes made during the two water quality campaigns, carried out in February, March and May 2008, respectively. In the following, the most relevant aspects of the selected points are presented.

Table 5.1-7 – Summary of Field Observations.

Point	Campaign		Water body	Location	Collection date	Time	Approximate depth (m)	Transparency (m)	Approximate width (m)	Rainfall in previous 24 h	Air temperature (°C)	Sample temperature (°C)
Itaquatiara Sub-basin	P1	1ª	Bonito stream (well)	Upstream from the limestone quarry / Barra do Bonito	15/02/08	8:17	0.2	-	1		32.5	28.1
		2ª	Bonito stream		17/03/08	6:10	0.3	-	10	X	24.6	27.1
		3ª			03/05/08	5:05	0.5	-	10			29.5
	P2	2ª	Itaquatiara stream	Downstream from the limestone quarry and upstream from the mouth of the Gameleira	17/03/08	10:10	0.4	-	3	X	30.2	27.1
	P3	1ª	Itaquatiara stream (well)	Next to the mouth of the Gameleira	15/02/08	10:49	0.2	-	1		28.7	26.9
		2ª	Itaquatiara stream		18/03/08	8:42	0.3	-	10	X	22.8	24.3
	P9	1ª	Itaquatiara stream	Downstream from the mouth of the Gameleira and	17/02/08	14:30	0.9	0.1	10		32.5	28.1

Point	Campaign		Water body	Location	Collection date	Time	Approximate depth (m)	Transparency (m)	Approximate width (m)	Rainfall in previous 24 h	Air temperature (°C)	Sample temperature (°C)
		2ª		upstream from the mouth of the São Romão. Scale 2 - Lagoon/Itaquatiara	17/03/08	17:00	1.3	0.1	10	X	34.8	27.6
Gameleira Sub-basin	P6	1ª	Caraíbas stream	Upstream from the mouth of the Gameleira. Locally known as Veneza/Poços	17/02/08	8:05	1.2	0.1	20		28.5	26.1
		2ª			17/03/08	11:10	1.5	0.1	4	X	32.6	26.4
	P10	2ª	Gameleira stream	Downstream of the Caraíbas stream- Scale 4	17/03/08	18:00	0.4	-	8	X	33.5	29.3
	P11	2ª	Gameleira stream	Downstream from the limestone quarry access road - Scale 5	17/03/08	15:25	0.5	0.1	20	X	36.8	31.9
	P12	2ª	Gameleira affluent	Downstream from the pilot plant - Scale 6	17/03/08	14:10	0.3	0.1	3	X	36.9	34.0

Point	Campaign		Water body	Location	Collection date	Time	Approximate depth (m)	Transparency (m)	Approximate width (m)	Rainfall in previous 24 h	Air temperature (°C)	Sample temperature (°C)
	P13	3ª	Gameleira affluent	Weir in Capitão Gervásio Oliveira / Town	03/05/08	17:05	0.3	-	>200		32.7	30.9
Várzea Sub-basin	P4	1ª	Várzea stream	Weir upstream of the nickel mine area	15/02/08	12:25	0.1	-	50		32.6	32.2
		2ª			18/03/08	6:35	0.1	-	50	X	24.3	22.8
		3ª			04/05/08	8:30	0.5	-	50		26.4	28.9
	P5	1ª	Várzea stream	Downstream of the nickel mine area	16/02/08	16:40	0.5	-	5	X	31.0	30.5
		2ª			18/03/08	7:40	1.2	-	3	X		23.1
		3ª			04/05/08	7:00	0.1	-	4			23.5
	P15	3ª	Várzea stream	Weir Downstream of the nickel mine area	04/05/08	7:00	>3	-	>200		27.4	27.6

Point	Campaign		Water body	Location	Collection date	Time	Approximate depth (m)	Transparency (m)	Approximate width (m)	Rainfall in previous 24 h	Air temperature (°C)	Sample temperature (°C)
	P16	3ª	Várzea stream	Weir (between Points 04 e 05)	04/05/08	10:05	>3	-	>30		*	29.1
São Domingos Sub-basin	P7	1ª	São Domingos stream	Weir Eugênio (crossing the high-tension line)	16/02/08	12:58	0.4	-	50-100	X	28.6	28.7
		2ª			16/03/08	15:10	0.4	-	50-100	X	29.8	30.8
		3ª			03/05/08	6:50	0.3		50-100		28.5	26.5
Piauí Sub-basin	P8A	1ª	Rio Piauí	Jenipapo Reservoir- Project water extraction point	16/02/08	8:13	1.0	0.7	>500m	X	26.3	28.5
		2ª			16/03/08	11:37	1.0	1.1	>500m	X	29.9	30.9
		3ª			03/05/08	9:05	0.3		>200m		31.2	29.2
	P8B	1ª	Rio Piauí	Downstream from the Jenipapo Reservoir dam	16/02/08	10:00	0.5	0.5	40	X	29.9	26.5
		2ª			16/03/08	12:45	0.5	0.5	40	X	27.8	31.2

Point	Campaign		Water body	Location	Collection date	Time	Approximate depth (m)	Transparency (m)	Approximate width (m)	Rainfall in previous 24 h	Air temperature (°C)	Sample temperature (°C)
		3ª			03/05/08	10:10	0.3	-	40		34.0	29.6

Source: Arcadis Tetraplan, 2008 - ESIA/RIMA. Prepared by: Arcadis, 2017.

The most relevant aspects verified *in loco* of the collection points previously presented are outlined below.

(i) Itaquatiara Sub-basin

In this sub-basin, four collection points were sampled, described below:

Point 01 – Bonito stream/ Upstream of the limestone quarry / Barra do Bonito

Point located in the Bonito stream, one of the tributaries of the Itaquatiara stream, upstream of the limestone quarry and downstream of the respective access road. It is located in the vicinity of a small town, which comprises a set of practically uninhabited residences.

In the first campaign (February / 2008), the bed of the Itaquatiara was completely dry, which is why a *cacimba* was sampled, whose water is used for consumption by the nearby houses. In the second campaign, the river had runoff that covered the *cacimba*, a situation maintained in the third campaign. The *cacimba* was approximately 1m wide and 20cm deep.

During the first two collections the presence of domestic animals (pigs, goats, chickens, dogs, donkeys) in this area was noted, resulting in a large amount of excrement and also garbage around the collection point. At the peak of the rains (March / 2008), the waters had a very muddy appearance, improving in the third campaign (May / 2008) after the end of the rainy season. During this flood period, the Bonito stream was approximately 10 m wide and 50 cm deep.

Because this last campaign was mainly aimed at reservoir sampling, only on site analyzes of the parameters conductivity, dissolved oxygen, temperature and pH were carried out at Point 01.

Photo 5.1-33 – Barra do Bonito - Cacimba (1st campaign).

Photo 5.1-34 – Community of Barra do Bonito (1st campaign).

Photo 5.1-35 – Barra do Bonito (2nd campaign).

Photo 5.1-36 – Barra do Bonito (3rd campaign).

Source: ESIA/RIMA (Arcadis Tetraplan, 2008).

Point 02 – Itaquatiara stream/ downstream of the limestone quarry

Point located downstream of the limestone quarry and the respective access road, within the limits of the municipalities of Dom Inocêncio and Capitão Gervásio Oliveira. In this section, the stream bed is dry for most of the year and is even used as a local access route. The riparian vegetation has a good composition on both banks. There was no anthropic and animal interference around the collection point.

As it was dry, it was not possible to take samples in the first campaign (February / 2008). In the following campaign (March / 2008), the bed was covered with shallow water and the margins occupied by grasses, being approximately 3 m wide and 40 cm deep. The waters contained a large amount of solids with high turbidity. The third campaign (May / 2008) did not include a survey at Point 02.

Photo 5.1-37 – Dry riverbed (1st campaign).

Photo 5.1-38 – Collection during the 2nd campaign.

Source: ESIA/RIMA (Arcadis Tetraplan, 2008).

Point 03 – Itaquatiara stream / downstream of the mouth of the Gameleira

Point located near the mouth of the Gameleira, located in the sub-basin of the Itaquatiara, on the limits of the municipalities of Dom Inocêncio and Capitão Gervásio Oliveira, in order to verify possible changes in the drainage of the Gameleira, the Várzea stream and the upstream Itaquatiara.

As in the other upstream points, in the first campaign of this stretch of Itaquatiara it was dry, and a sample was collected in a *cacimba*, whose water is used for consumption by the local population. The *cacimba* was about 1m wide and 20 cm deep, being fully covered in the rainy season.

Another reservoir was located, about 200m downstream from the confluence with the Gameleira stream, which is used only for animal drinking. Residents' reports indicate that since 2004 the Itaquatiara stream has not had runoff.

In the next collection, when the bed was covered with water, the stream was about 10 m wide and 30 cm deep, making it possible to take surface water samples. The landscape was totally altered, as shown in the following photo, which also highlights the mouth of the Gameleira stream. During the collection, the presence of animals and excrement was recorded along these water courses.

The third campaign (May / 2008) did not include sampling at Point 03.

Photo 5.1-39 – Cacimba analysis (1st campaign).

Photo 5.1-40 – View of the Itaquatiara (2nd campaign).

Source: ESIA/RIMA (Arcadis Tetraplan, 2008).

Point 09 – Itaquatiara stream

Point located in the Itaquatiara sub-basin, upstream of the São Romão stream and downstream of the Gameleira stream, in the municipality of Capitão Gervásio Oliveira. In this location, Scale 2 is installed to monitor the height of the water depth and previously corresponded to one of the alternatives for water abstraction for the project.

In the vicinity of Point 09, about 200 m from the bank of Itaquatiara and upstream of the collection point, a *cacimba* was located in the first campaign to supply the local population. In the rainy season, this *cacimba* was submerged, preventing good water being obtained for consumption, according to reports by local residents. There was also, on the banks of the Itaquatiara stream, a large amount of solid waste and animal excrement, which may reflect the existence of the village in this place. The stream is used for fishing, and in the rainy season some fishermen were observed using nets.

In the first campaign, intense water coloring, high turbidity and low flow were noted, which will be discussed in the presentation of the results. At the time of collection, the stream was 10 meters wide and 1 meter deep. These measures were maintained in the second campaign, when there was an improvement in the condition of the water. No water was collected at this point in the third campaign.

Photo 5.1-41 – Collection 1st campaign (murky water).

Photo 5.1-42 – General view (2nd campaign).

Source: ESIA/RIMA (Arcadis Tetraplan, 2008).

(ii) Gameleira Sub-basin

In this sub-basin, five sampling points were assessed, as described below.

Point 06 – Caraíbas stream/ Upstream from the mouth of the Gameleira

Point located in the Caraíbas stream, upstream from the mouth of Gameleira, in the municipality of Capitão Gervásio de Oliveira, in a location registered as Veneza and known as Poços.

This place is located in a valley, bordered by large rocks. Residences were observed about 200 m away from the sampling point, in addition to a large amount of animal excrement and garbage.

As shown in the photos below, muddy-looking waters, about 20 m wide and 1.2 m deep were observed in the first two campaigns. The stream bed remains full throughout the year.

In the second campaign, the rainy season, the road that crosses the river was flooded, with the presence of fishermen arriving at the site. There were no withdrawals at Point 06 during the third campaign.

Photo 5.1-43 – Caraíbas stream (1st campaign).

Photo 5.1-44 – Caraíbas stream (2nd campaign).

Source: ESIA/RIMA (Arcadis Tetraplan, 2008).

Point 10 – Gameleira stream / downstream from the Caraíbas stream/ Scale 4 - Vale

Point located on the Gameleira stream, in the municipality of Capitão Gervásio de Oliveira, where Scale 4 is located, identified for VALE's fluviometric monitoring, as shown in the photo below.

During the first campaign (February / 2008), the bed of this stream was completely dry, making it impossible to collect. In the following campaign (March / 2008), a sample was taken for analysis, under intense precipitation, from brown water. This section was about 8 m wide and 0.4 m deep. The presence of domestic animals was not observed along the banks of this stream, probably due to little interference due to the difficulty of access to the point. The nearest dwellings are located about 800 meters from the riverbed. There was no collection in the third campaign.

Photo 5.1-45 – Gameleira stream (2nd campaign).

Source: ESIA/RIMA (Arcadis Tetraplan, 2008).

Point 11 – Gameleira stream / downstream of the limestone quarry access road / Scale 5 – Vale

Point located on the Gameleira stream, in the municipality of Capitão Gervásio de Oliveira, at the position of VALE's fluviometric monitoring scale 5.

Similar to Point 10, this site was sampled only in the second campaign (March / 2008), in which there was high turbidity of the water due to the rains. This section was about 20 m wide and 0.5 m deep. There are residences in the immediate vicinity, but no solid waste or animal waste was observed. The bed remains dry for much of the year, filling only during periods of rain.

Photo 5.1-46 – General view (2nd campaign).

Source: ESIA/RIMA (Arcadis Tetraplan, 2008).

Point 12 – Tributary of the Gameleira stream / downstream from the pilot plant / Scale 6 - Vale

Point located in a tributary of the Gameleira stream, in the municipality of Capitão Gervásio de Oliveira, where VALE's fluviometric monitoring scale 6 is located.

Features similar to Point 11, located upstream. Similar to Points 10 and 11, this site was sampled only in the second campaign (March / 2008), in which there was high water turbidity due to the rains. The bed also remains empty for much of the year, partially filling only during periods of rain. At the time of collection, it was about 3 m wide and 30 cm deep. No homes or animals were observed in this location.

Photo 5.1-47 – General view (2nd campaign).

Source: ESIA/RIMA (Arcadis Tetraplan, 2008).

Point 13 – Gameleira stream / weir in Capitão Gervásio Oliveira / town

Reservoir located in the Gameleira sub-basin, in the municipality of Capitão Gervásio de Oliveira.

This weir was incorporated into the sampling network only in the third campaign (May / 2008), as its waters will be used to supply the city of Capitão Gervásio Oliveira. On that occasion, there were technicians installing the pump that will serve to pump water from the weir to the municipal headquarters. During the collection, a herd of goats was observed in the vicinity of the weir, clearly showing the contribution of excrement to the waters, deposited in all marginal areas of the reservoir.

Photo 5.1-48 – View of the weir (3rd campaign).

Photo 5.1-49 – Altered riparian forest (3rd campaign).

Source: ESIA/RIMA (Arcadis Tetraplan, 2008).

(iii) Várzea Sub-basin

In this sub-basin, four sampling points were assessed as described below.

Point 04 – Várzea stream/ weir upstream of the nickel mining area

Weir located in the sub-basin of the Várzea stream, a tributary of the Gameleira, in the municipality of Capitão Gervásio Oliveira. It is located upstream of the mining area, with interference from the Pilot Plant located a few meters away.

Its waters are used mainly for animal drinking, as highlighted in the photos below. The entire margin of the reservoir is altered, which favors sediment entry in the water which is evidenced by its strong brown color. In the surroundings there is a large presence of animal excrement.

Photo 5.1-50 – Watering animal (1st campaign).

Photo 5.1-51 – Water with elevated turbidity (2nd campaign).

Photo 5.1-52 – Overflowing weir (3rd campaign).

Fonte: ESIA/RIMA (Arcadis Tetraplan, 2008).

In the first campaign (February / 2008), there was high water turbidity and a large amount of excrement in the margins. The weir was about 50 m wide and 10 cm deep, characteristics that were maintained in the following campaign. In the last campaign (May / 2008), overflow of water was observed in the reservoir and massive development of algae.

Point 05 – Várzea stream / downstream of the nickel mine area

Point located downstream from the mining area, in the Várzea sub-basin, in the municipality of Capitão Gervásio Oliveira.

The Várzea stream has a predominantly rocky substrate, as highlighted in the photos below, being used mainly for animal drinking. In the field surveys, there was a large presence of animal excrement and domestic waste on the banks.

Photo 5.1-53 – Collection point (1st campaign).

Photo 5.1-54 – Water with elevated turbidity (2nd campaign).

Photo 5.1-55 – General view at point P5 (3rd campaign).

Source: ESIA/RIMA (Arcadis Tetraplan, 2008).

During the first collection, the waters were clearer, contrasting with the brown color and high content of solids observed in the second campaign. As it is not a reservoir, water collection from this location was not foreseen in the third campaign, analyzing *in situ* only the parameters conductivity, pH, DO and temperature.

Point 15 – Várzea stream / weir downstream of the nickel mining area

Reservoir located in the Várzea sub-basin, in the municipality of Capitão Gervásio, downstream from Vale's Pilot Plant.

Because it was dry in the first two campaigns, this weir was only sampled in the May 2008 collection. On that occasion, interviews with local residents revealed that the waters of this weir are used directly for human consumption, without treatment, and are also used for various household activities such as bathing and washing clothes, as well as animal drinking. The presence of cattle was noted at the time of collection.

Photo 5.1-56 – Dweller collecting water (3rd campaign).

Photo 5.1-57 – View of the Várzea weir (3rd campaign).

Photo 5.1-58 – Dweller washing clothes (3rd campaign).

Source: ESIA/RIMA (Arcadis Tetraplan, 2008).

Point 16 – Várzea stream / weir (between points 04 and 05)

Weir located downstream from the mouth of the Gameleira, with the objective of evaluating possible interference from the Pilot Plant and the operational structures of mining and ore processing.

As in Point 15, this reservoir was dry in the first two campaigns, being sampled only in the third campaign (May / 2008), after heavy rainfall. Due to the fact that collection was not scheduled at this point, it was decided to carry out in situ surveys, with pH, conductivity, dissolved oxygen and temperature readings, in order to obtain a background record of this area.

Photo 5.1-59 – Water quality analysis (3rd campaign).

Photo 5.1-60 – View of the weir (3rd campaign).

Source: ESIA/RIMA (Arcadis Tetraplan, 2008).

(iv) Piauí Sub-basin

In this sub-basin, two sampling points were assessed as described below.

Point 8A – Rio Piauí / Jenipapo Reservoir – planned project water extraction point

Point located in the Piauí sub-basin, municipality of São João do Piauí, at the Jenipapo dam. This is a dam to capture water and is characterized by being the selected alternative for capturing water from the pipeline to process ore from the Piauí Nickel Project.

The waters of this dam are used for different purposes, having been designed for irrigation. It serves locally for fishing, leisure and animal drinking, with a large amount of goats on the margins being noticed in the first campaign, as well as excrement and garbage in the vicinity.

Photo 5.1-61 –Jenipapo Reservoir (1st campaign).

Photo 5.1-62 – Taking water sample for analysis.

Photo 5.1-63 – General view of point P8A (3rd campaign).

Source: ESIA/RIMA (Arcadis Tetraplan, 2008).

In the second campaign (March / 2008), there were fishermen and a small amount of dead fish on the banks. Both collections were carried out after rainfall, with a very strong odor, probably due to decomposing materials in the sediments.

In the third campaign (May / 2008) a higher level of water was observed in this dam, covering part of the herbaceous vegetation. There was also a large amount of animal waste on the banks.

Point 08B – Rio Piauí / downstream of the Jenipapo Dam

Point located in the Piauí sub-basin, municipality of São João do Piauí, just downstream of the Jenipapo dam.

The presence of animals and fishermen was observed in this place, in addition to animal excrement and garbage on the banks of the river. The place also has a strong sulfide smell.

In the first campaign (February / 2008), animals were decomposing at the site, with a strong odor release from the sediments, also found in the second collection (March / 2008). In the following campaign (May / 2008), following the rainy period of March and April, the dam was overflowing, and no sulfide odor was detected.

Photo 5.1-64 – Taking of water sample.

Photo 5.1-65 – Below the Jenipapo Dam.

Photo 5.1-66 –Jenipapo Dam (3rd campaign).

Source: ESIA/RIMA (Arcadis Tetraplan, 2008).

(v) São Domingos Sub-basin

In this sub-basin, a single sampling point was analyzed, described below.

Point 07 – São Domingos stream/ Eugênio weir (Crossing - transmission line)

Weir located in the São Domingos sub-basin, municipality of São João do Piauí. The São Domingos stream is one of the tributaries on the right bank of the Piauí River. Point selected to provide a baseline for the works of the project's transmission line.

The Eugênio reservoir is located in the vicinity of the village of the same name and remains full throughout the year. It was opened in the early 1980s, aiming to supply this community, which today encompasses about 50 families. Since 2007, this village has been supplied with water through wells, which represents a benefit, given the improper quality of the reservoir.

The Eugênio settlement is located about 150 meters from this weir. The presence of garbage and a large amount of animal excrement on the banks of this reservoir is noted. This stream is used only for animal watering, mainly of goats and pigs.

Photo 5.1-67 – General view (1st campaign).

Photo 5.1-68 – General view (3rd campaign).

Photo 5.1-69 – Herd from the Eugênio community (3rd campaign).

Source: ESIA/RIMA (Arcadis Tetraplan, 2008).

In the first two campaigns, samples were taken after rainfall. The weir is about 50 to 100 m wide and 0.4 m deep. In the third campaign, the weir had a very high water level. In all collections, there was no presence of riparian forest, which intensifies the sediment input in the water and its brown color.

d) Sample Collection and Preservation Methodology

In order to characterize the quality of surface water in the areas of influence of the project, a set of physical, chemical and bacteriological variables, traditionally employed in a study of this nature, were selected. For this purpose, the list of parameters defined by CONAMA Resolution 357/05 for class 2 freshwater was used, and further analyzes were carried out that reflect probable sources of water pollution and the degree of salinity of this water system.

The collected samples were transferred to specific vials, being properly packaged and preserved according to standards established by the Standard Methods for the Examination of Water and Wastewater[7] 21st edition, according to Table 5.1-8, below. Sample collections and analyzes were under the charge of the TCA Laboratory, whose devices were certified by INMETRO.

It is worth mentioning that, due to the difficulty of access and logistics in this region, especially during the rainy season, the collections of coliforms, *Escherichia coli* and BOD exceeded the recommended limit of 24 hours for laboratory analysis, so that the results for these parameters may be underestimated. Even with this caveat, it was decided to include the values obtained in the interpretation of the analytical results, taking these data as a reference for assessing water quality.

Table 5.1-8– Selected Variables and Sample Preservation Procedures.

Variable	Preservation Procedure
Total Alkalinity	R
Dissolved aluminum	HNO3 - pH < 2,0 ; R
Arsenic	HNO3 - pH < 2,0 ; R
Cadmium	HNO3 - pH < 2,0 ; R
Calcium	HNO3 - pH < 2,0 ; R
Total Organic Carbon	H_2SO_4
Lead	HNO3 - pH < 2,0 ; R
Chloride	R
Chlorophyll-a	1.0 ml of 1% saturated solution of magnesium carbonate / liter of sample; R

[7] APHA et al. Standard Methods for the Examination of Water and Wastewater, 21ª ed., APHA, 2005.

Variable	Preservation Procedure
Cobalt	HNO_3 - pH < 2,0
Dissolved copper	HNO3 - pH < 2,0 ; R
Total Coliforms and Thermotolerants (faecal) and *Escherichia coli*	EDTA a 15 %
Conductivity	R
True color	R
Total Chrome	HNO3 - pH < 2,0 ; R
Biochemical Oxygen Demand (BOD)	R
Chemical Oxygen Demand (COD)	H2SO4 - pH < 2,0 ; R
Total Hardness	R
Phenol	R - H2SO4 - pH<2
Pheophytin -a	1.0 ml of 1% saturated solution of magnesium carbonate / liter of sample; R
Dissolved Iron	HNO3- pH < 2,0 ; R
Total Phosphorus	H2SO4 - pH < 2,0 ; R
Magnesium	HNO3 - pH < 2,0 ; R
Manganese	HNO3 - pH < 2,0 ; R
Mercury	HNO3 - pH <2; R;
Nickel	HNO3 - pH < 2,0 ; R
Nitrate	H2SO4 - pH < 2,0 ; R
Nitrite	H2SO4 - pH < 2,0 ; R
Total Ammoniacal Nitrogen	H2SO4 - pH < 2,0 ; R
Total Kjeldahl Nitrogen	H2SO4 - pH < 2,0 ; R
Oils and Greases	H2SO4 - pH<2; R
Field Dissolved Oxygen	-
pH in the field	-
Potassium	HNO3 - pH < 2,0 ; R
Salinity in the field	-
Sodium	HNO3 - pH < 2,0 ; R
Total Dissolved Solids	R
Total Suspended Solids	R
Sulfate	R
Sulfide	do not aerate; add 4 drops of 2N zinc acetate / 100 mL, add NaOH until pH> 9; R

Variable	Preservation Procedure
Anionic Surfactants	R
Field water temperature	-
Turbidity	R
Total Zinc	HNO_3 - pH < 2,0 ; R

Legend: R: Refrigeration at 4°C. Source: ESIA/RIMA (Arcadis Tetraplan, 2008).

e) Presentation of Results

Below are the results of the physical, chemical and bacteriological analyzes carried out in the three campaigns, summarized in Data Table 5.1-19, which indicates the maximum permissible standards for class 2 freshwater, according to CONAMA Resolution No. 357/05. Due to the fact that surface waters and *cacimbas* are usually used for direct consumption by the inhabitants of the region, especially by the most isolated residences without any level of treatment, this work has also chosen to take as a reference the drinking standards defined by Ordinance No. 2914 of 2011 from the Ministry of Health.

The data and dashes highlighted in red in the table and graphs below refer to concentrations that exceeded the limits of the Maximum Allowable Values - VMP of CONAMA Resolution No. 357/05 class 2 (fresh water), while the colors in blue indicate the parameters that exceeded the limits of Ordinance No. 2914/2011.

Data Table 5.1-19 – Surface Water Quality Results.

Variable	Units	M.P.V. (1)		Detection Limit	Itaquatiara Sub-basin								Gameleira Sub-basin					
					P1			P2	P3		P9		P6		P10	P11	P12	P13
		Fresh Water Class 2 (2)	Potability (3)		1st	2nd	3rd	2nd	1st	2nd	1st	2nd	1st	2nd	2nd	2nd	2nd	3rd
Bicarbonate Alkalinity	mg/L	_	_	2	119	47	NA	55	91	23	75	20	20	27	30	35	61	65
Carbonate Alkalinity	mg/L	_	_	_	ND	ND	NA	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Hydroxide Alkalinity	mg/L	_	_	_	ND	ND	NA	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Dissolved Aluminum	mg/L	0.1	_	0.1	ND	ND	NA	ND	ND	0.64	ND	ND	ND	ND	ND	ND	ND	ND
Arsenic	mg/L	0.01	0.01	0.017	ND	ND	NA	ND	ND	0.021	ND	0.023	ND	ND	0.019	0.018	0.018	ND
Total Cadmium	mg/L	0.001	0.005	0.001	ND	ND	NA	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Calcium	mg/L	_	_	0.8	31.2	17.6	NA	13.2	23.2	6.8	8	4	3.2	4.4	8.4	10	11.2	12
Total Organic Carbon	mg/L	_	_	0.00001	ND	3.2	NA	10.8	ND	16	0.02925	7.1	0.001	5	3.3	9.8	1.3	ND
Lead	mg/L	0.01	0.01	0.01	ND	ND	NA	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Chloride	mg/L	250	250	0.5	41.5	97.5	NA	32.5	12	11.5	62.5	25	6.5	14.5	6.5	13	7.5	14
Chlorophyll-a	□g/L	30	_	0.01	ND	ND	NA	0.842	ND	0.014	ND	ND	0.084	0.645	0.067	ND	ND	ND
Cobalt	mg/L	0.05	_	0.08	ND	ND	NA	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Dissolved Copper	mg/L	0.009	_	0.002	ND	ND	NA	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Thermotolerant Coliforms	NMP/100 mL	1,000	_	2.2	24,000	46,000	NA	9,300	23	9,300	24,000	24,000	43	210	15,000	240	28	Absent
Total Coliforms	NMP/100 mL	–	Absent /100mL	2.2	46,000	110,000	NA	110,000	150	46,000	110,000	110,000	1.100	1,100	46,000	1,100	1,100	240
Conductivity (field)	□S/cm	_	_	0.1	359	425	890	201	228	75.3	279	84.3	65.3	119.1	97.8	126.6	158.7	159.8
True Color	mg Pt/L	75	_	5	15	20	NA	50	5	30	500	20	50	60	20	50	30	50
Total Chrome	mg/L	0.05	0.05	0.002	ND	ND	NA	ND	ND	ND	ND	0.1	ND	ND	ND	ND	ND	ND
Biochemical Oxygen Demand - DBO	mg/L	Up to 5	_	1	ND	ND	NA	ND	ND	28	44	9	19	ND	ND	ND	ND	ND
Chemical Oxygen Demand - COD	mg/L	_	_	6	ND	ND	NA	ND	ND	100	151	72	65	ND	ND	ND	ND	ND
Total Hardness	mg/L	_	500	2	103	86	NA	49	104	22	64	21	37	19	32	44	59	42
Escherichia coli	NMP/100 mL	–	Absent /100mL	–	11,000	15,000	NA	900	10	2,300	11,000	9,300	24	150	4,300	43	9	Absent
Phenol	mg/L	0.003	_	0.001	ND	0.003	NA	0.003	ND	0.001	ND	0.002	ND	0.001	0.002	ND	0.002	0.005

Variable	Units	M.P.V. (1)		Detection Limit	Itaquatiara Sub-basin								Gameleira Sub-basin					
					P1			P2	P3		P9		P6		P10	P11	P12	P13
		Fresh Water Class 2 [2]	Potability [3]		1st	2nd	3rd	2nd	1st	2nd	1st	2nd	1st	2nd	2nd	2nd	2nd	3rd
Pheophytin -a	mg/L	_	_	0.00001	ND	ND	NA	ND	ND	0.00016	ND	ND	0.000107	0.00174	0.00265	ND	ND	ND
Dissolved Iron	mg/L	0.3	_	0.03	0.22	0.35	NA	0.68	ND	0.35	1.37	0.42	0.76	0.9	0.16	1.13	0.14	0.97
Total Phosphorus	mg/L	lentic = 0.030/ 0.1 lotics	_	0.003	0.07	0.2	NA	0.11	0.08	0.76	0.56	0.9	10	0.32	0.3	0.12	0.14	0.087
Magnesium	mg/L	_	_	_	6.1	10.2	NA	3.9	11.2	1.2	10.7	2.7	7.1	1.9	2.7	4.6	7.6	3
Manganese	mg/L	0.1	0.1	0.002	0.03	0.32	NA	0.29	ND	1.7	0.03	1.63	ND	0.23	0.42	0.03	0.08	0.05
Mercury	mg/L	0.0002	0.001	0.0002	ND	ND	NA	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Nickel	mg/L	0.025	0.07	0.002	ND	0.04	NA	ND	ND	0.1	ND	0.1	ND	ND	ND	ND	0.06	ND
Total Kjeldahl Nitrogen	mg/L	_	_	0.05	8.08	1.49	NA	0.34	0.6	0.31	13	1.86	4.05	3.09	1.62	1.46	2.63	25
Organic Nitrogen	mg/L	_	_	0.05	7.76	1.40	NA	0.22	0.16	0.19	12.33	0.42	3.65	2.88	1.39	1.35	2.45	24.95
Ammoniacal Nitrogen	mg/L	3.7 / 2.0 / 1.0 / 0.5 [4]	1.5	0.02	0.32	0.087	NA	0.12	0.44	0.12	0.67	1.44	0.4	0.21	0.23	0.11	0.18	ND
Nitrogen - Nitrate	mg/L	10	10	0.02	0.35	ND	NA	0.11	0.03	0.28	0.06	0.61	0.28	0.19	0.22	0.37	0.02	0.27
Nitrogen - Nitrite	mg/L	1	1	0.005	0.18	0.033	NA	0.03	0.129	0.015	0.341	0.035	0.338	0.032	0.022	0.026	0.018	0.222
Oils and Greases	mg/L	Virtually absent	_	2	ND	ND	NA	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Oxygen Consumed	mg/L	_	_	1	1	NA	NA	NA	3	N/A	5	NA	5	NA	NA	NA	NA	
Dissolved Oxygen (field)	mg/L	≥ 5.0	_	0.1	2.7	6.5	6.5	6	3.7	6.4	5.3	3.3	1.6	NA	5.2	5.8	6.4	6.5
pH (field)	UpH	6.0 - 9.0	6.0 a 9.5	0.01	7.01	7.04	7.74	6.75	6.54	7.28	6.99	6.45	7.08	6.66	6.36	6.74	7.06	7.58
Potassium	mg/L	_	_	0.01	5.35	7.08	NA	6.9	0.16	6.43	0.05	4.6	0.12	2.22	3.3	2.84	1.96	4.01
Salinity (field)	‰	≤0.5	_	_	0.2	0.2	NA	0.1	0.1	0	0.1	0	0	0.1	0	0.1	0.1	0.1
Sodium	mg/L	_	200	0.005	41.8	48.2	NA	15.6	0.22	8.15	0.1	5.74	0.07	9.99	8.52	8.66	9.02	27.2
Total Dissolved Solids	mg/L	500	1000	1	192	214	NA	102	156	42	138	54	94	64	52	72	86	96
Total Dissolved Solids (field)	mg/L	500	1000	_	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	75
Total Suspended Solids	mg/L	_	_	1	88	720	NA	510	52	1250	128	1290	380	430	750	220	410	52
Sulfate	mg/L	250	250	2	ND	12.2	NA	5.9	ND	7.6	7.4	5.2	ND	7.9	3.6	3.4	4.2	2.4
Sulfide	mg/L	0.002	_	0.8	ND	ND	NA	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Anionic Surfactants	mg/L	0.5	0.5	0.04	ND	ND	NA	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.08
Turbidity	FTU	100	5	0.02	3.5	360	NA	330	1.6	850	120	900	180	425	325	230	225	31

Variable	Units	M.P.V. (1)		Detection Limit	Itaquatiara Sub-basin								Gameleira Sub-basin					
					P1			P2	P3		P9		P6		P10	P11	P12	P13
		Fresh Water Class 2 (2)	Potability (3)		1st	2nd	3rd	2nd	1st	2nd	1st	2nd	1st	2nd	2nd	2nd	2nd	3rd
Zinc	mg/L	0.18	5	0.002	0.01	0.16	NA	0.26	ND	0.26	ND	0.26	ND	0.08	0.1	0.12	0.12	ND

Variables	Units	M.P.V. (1)		Detection Limits	Várzea Sub-basin								São Domingos Sub-basin			Piauí Sub-basin					
					P4			P5			P15	P16	P7			P8A			P8B		
		Fresh Water Class 2 (2)	Potability (3)		1st	2nd	3rd	1st	2nd	3rd	3rd	3rd	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd
Bicarbonate Alkalinity	mg/L	_	_	2	600	97	103	18.4	85	NA	41	NA	100	40	56	9.4	78	16	93	41	55
Carbonate Alkalinity	mg/L	_	_	_	ND	ND	8	4	ND	NA	ND	NA	ND	ND	ND	0.6	ND	ND	ND	ND	ND
Hydroxide Alkalinity	mg/L	_	_	_	ND	ND	ND	ND	ND	NA	ND	NA	ND	ND	ND	ND	ND	ND	ND	ND	ND
Dissolved Aluminum	mg/L	0.1	_	0.1	ND	ND	ND	ND	0.75	NA	ND	NA	ND	1	ND	ND	ND	ND	ND	0.82	ND
Arsenic	mg/L	0.01	0.01	0.017	ND	ND	ND	ND	0.017	NA	ND	NA	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total Cadmium	mg/L	0.001	0.005	0.001	ND	ND	ND	ND	ND	NA	ND	NA	ND	ND	ND	ND	ND	ND	ND	ND	ND
Calcium	mg/L	_	_	0.8	221.6	10.4	36	133.6	18.4	NA	10	NA	62.4	17.2	5.2	22.8	8.8	15.6	22	24.4	16
Total Organic Carbon	mg/L	_	_	0.00001	0.028	5.6	ND	0.0145	10	NA	ND	NA	0.0195	5.1	ND	ND	1.5	ND	ND	1.8	4
Lead	mg/L	0.01	0.01	0.01	ND	ND	ND	ND	ND	NA	ND	NA	ND	ND	ND	ND	ND	ND	ND	ND	ND
Chloride	mg/L	250	250	0.5	62.5	25.5	105	143	22.5	NA	1	NA	110	39.5	38.5	70.5	50.5	11	49	52	39
Chlorophyll-a	□g/L	30	_	0.01	ND	ND	ND	ND	ND	NA	ND	NA	ND	ND	0.029	ND	ND	ND	ND	ND	ND
Cobalt	mg/L	0.05	_	0.08	ND	ND	ND	ND	ND	NA	ND	NA	ND	ND	ND	ND	ND	ND	ND	ND	ND
Dissolved Copper	mg/L	0.009	_	0.002	ND	ND	ND	ND	ND	NA	ND	NA	ND	ND	0.01	ND	ND	ND	ND	ND	ND
Thermotolerant Coliforms	NMP/100 mL	Up to 1,000	_	2.2	4	240	7	93	3	NA	Absent	NA	9,300	Absent	Absent	Absent	Absent	Absent	15	28	7
Total Coliforms	NMP/100mL	_	Absent/100mL	2.2	75	1,100	1,100	150	1,100	NA	460	NA	24,000	Absent	460	21	93	75	43	1,100	460
Conductivity (field)	□S/cm	_	_	0.1	976	288	1022	847	251	984	81.7	116.4	544	265	78.4	284	318	227	306	336	235
True Color	mg Pt/L	Up to 75	_	5	40	30	35	40	50	NA	40	NA	150	30	10	10	10	25	15	10	25
Total Chrome	mg/L	0.05	0.05	0.002	ND	0.16	ND	ND	0.2	NA	ND	NA	ND	ND	ND	ND	ND	ND	ND	ND	ND
Biochemical Oxygen Demand - DBO	mg/L	Up to 5	_	1	32	ND	10	ND	11	NA	10	NA	35	ND	11	ND	ND	8	ND	ND	ND
Chemical Oxygen Demand - COD	mg/L	_	_	6	90	ND	34	ND	48	NA	30	NA	94	ND	46	ND	ND	26	ND	ND	ND
Total Hardness	mg/L	_	500	2	643	124	720	390	104	NA	43	NA	163	64	21	106	99	71	111	104	74

Variables	Units	M.P.V. (1)		Detection Limits	Várzea Sub-basin								São Domingos Sub-basin			Piauí Sub-basin					
					P4			P5			P15	P16	P7			P8A			P8B		
		Fresh Water Class 2 (2)	Potability (3)		1st	2nd	3rd	1st	2nd	3rd	3rd	3rd	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd
Escherichia coli	NMP/100mL	_	Absent/100mL	_	1	93	Absent	75	Absent	NA	Absent	NA	4.600	Absent	Absent	Absent	Absent	Absent	4	9	Absent
Phenol	mg/L	0,003		0.001	ND	0.004	ND	ND	0.003	NA	0.003	NA	ND	0.004	0.002	ND	0.005	0.004	ND	0.002	0.003
Pheophytin -a	mg/L	_	_	0.00001	ND	ND	ND	ND	ND	NA	ND	NA	ND	ND	0.0015	ND	ND	ND	ND	ND	ND
Dissolved Iron	mg/L	0.3	_	0.03	ND	0.16	0.15	0.15	0.22	NA	0.92	NA	ND	0.68	18	0.07	0.2	0.34	0.46	0.18	0.38
Total Phosphorus	mg/L	lentic = 0.030 / 0.1 lotics	_	0.003	0.18	0.14	0.11	0.028	0.41	NA	0.089	NA	0.1	0.52	0.25	0.003	0.033	0.052	0.024	0.084	0.073
Magnesium	mg/L	_	_	_	21.7	23.9	154	13.6	14.1	NA	4.4	NA	1.71	5.1	2	11.9	18.8	7.8	13.7	10.5	8.3
Manganese	mg/L	0.1	0.1	0.002	ND	0.18	0.11	ND	0.62	NA	0.13	NA	ND	0.49	0.22	ND	0.14	ND	ND	0.39	0.03
Mercury	mg/L	0.0002	0.001	0.0002	ND	ND	ND	ND	ND	NA	ND	NA	ND	ND	ND	ND	ND	ND	ND	ND	ND
Nickel	mg/L	0.025	0.07	0.002	ND	0.58	ND	ND	ND	NA	ND	NA	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total Kjeldahl Nitrogen	mg/L	_	_	0.05	8.18	0.64	8.29	1.44	2.81	NA	13	NA	2.71	0.74	19	6.86	1.53	7.96	6.06	3.86	12
Organic Nitrogen	mg/L	_	_	0.05	1.13	0.59	8.24	0.87	2.74	NA	12.87	NA	2.19	0.68	18.95	6.61	1.48	7.84	4.93	2.68	11.87
Ammoniacal Nitrogen	mg/L	3.7 / 2.0 / 1.0 / 0.5 (4)	1.5	0.02	7.05	0.053	ND	0.57	0.069	NA	0.13	NA	0.52	0.061	0.054	0.25	ND	0.12	1.13	1.18	0.13
Nitrogen - Nitrate	mg/L	10	10	0.02	0.18	0.14	0.68	0.34	ND	NA	0.12	NA	0.18	0.13	0.17	ND	ND	0.26	ND	ND	0.14
Nitrogen - Nitrite	mg/L	1	1	0.005	0.045	0.048	0.138	0.064	0.04	NA	ND	NA	ND	0.019	ND	ND	ND	0.01	ND	0.121	0.015
Oils and Greases	mg/L	Virtually absent	_	2	ND	ND	ND	ND	ND	NA	ND	NA	ND	ND	ND	ND	ND	ND	ND	ND	ND
Oxygen Consumed	mg/L	_	_	1	6	NA	NA	2	NA	NA	NA	NA	3	NA	NA	1	NA	NA	1	NA	NA
Dissolved Oxygen (field)	mg/L	≥5.0	_	0.1	5	4.9	9.7	0.9	6.5	6.4	2.8	7.4	3.8	4.4	4.6	6.6	7.6	5.9	7.1	6.4	6.1
pH (field)	UpH	6.0 – 9.0	6.0 to 9.5	0.01	8	6.45	8.08	8.5	6.7	7.84	6.68	7.5	8.15	6.99	6.84	7.74	8.12	7.14	7.18	7.34	7.34
Potassium	mg/L	_	_	0.01	0.08	4.08	2.55	0.07	2.81	NA	3.34	NA	0.1	30.9	7.75	8.89	7.14	4.84	7.85	6.99	5.21
Salinity (field)	‰	≤0.5	_	_	0.5	0.1	0.5	0.4	0.1	NA	0	NA	0.3	0.1	0	0.1	0.1	0.1	0.1	0.2	0.1
Sodium	mg/L	_	200	0.005	0.1	7.95	94.6	0.11	11	NA	4.47	NA	0.17	10.4	7.99	28.6	35.9	32.2	35.8	49.2	37.2
Total Dissolved Solids	mg/L	500	1000	1	360	148	724	372	136	NA	48	NA	297	134	46	198	154	122	188	162	128
Total Dissolved Solids (field)	mg/L	500	1000		NA	NA	491	NA	119	NA	38	NA	NA	NA	37	NA	NA	107	NA	NA	111

Variables	Units	M.P.V. (1)		Detection Limits	Várzea Sub-basin								São Domingos Sub-basin			Piauí Sub-basin					
					P4			P5			P15	P16	P7			P8A			P8B		
		Fresh Water Class 2 (2)	Potability (3)		1st	2nd	3rd	1st	2nd	3rd	3rd	3rd	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd
Total Suspended Solids	mg/L	_	_	1	118	410	328	182	920	NA	34	NA	235	1110	26	82	70	98	74	80	104
Sulfate	mg/L	250	250	2	ND	12.5	11.2	23.9	12	NA	ND	NA	ND	14.6	5.1	ND	ND	ND	ND	ND	ND
Sulfide	mg/L	0,002	_	0.8	ND	ND	ND	ND	ND	NA	ND	NA	ND	ND	ND	ND	ND	ND	ND	ND	ND
Anionic Surfactants	mg/L	0,5	0,5	0.04	ND	ND	0.21	ND	ND	NA	0.09	NA	ND	ND	ND	ND	ND	0.04	ND	ND	0.04
Turbidity	FTU	Up to 100	5	0.02	20	385	4	8.5	900	NA	12	NA	65	1,600	960	1.5	2	10	1.8	2.5	10
Zinc	mg/L	0,18	5	0.002	ND	0.08	ND	ND	0.11	NA	0.01	NA	ND	0.2	0.13	ND	ND	0.01	ND	ND	0.02

Legend:

M.P.V. – Maximum Permitted Value.

Resolution CONAMA nº 357/05 for waters of class 2.

Ordinance nº 2914/2011 Ministry of Health - Potability.

For class 2waters, the legislation defines the maximum of 3.7 mg / l of ammoniacal nitrogen (pH below 7.5); up to 2.0 mg / l (pH between 7.5 and 8.0); up to 1.0 mg / l (pH between 8.0 to 8.5) and 0.5 mg / l (pH greater than 8.5).

ND – Not Detected

NA – Not Applicable, no sample taken

Source: ESIA/RIMA (Arcadis Tetraplan, 2008). Prepared by: Arcadis, 2017.

Below are the results obtained for the Physical, Chemical and Bacteriological variables from the sampling network.

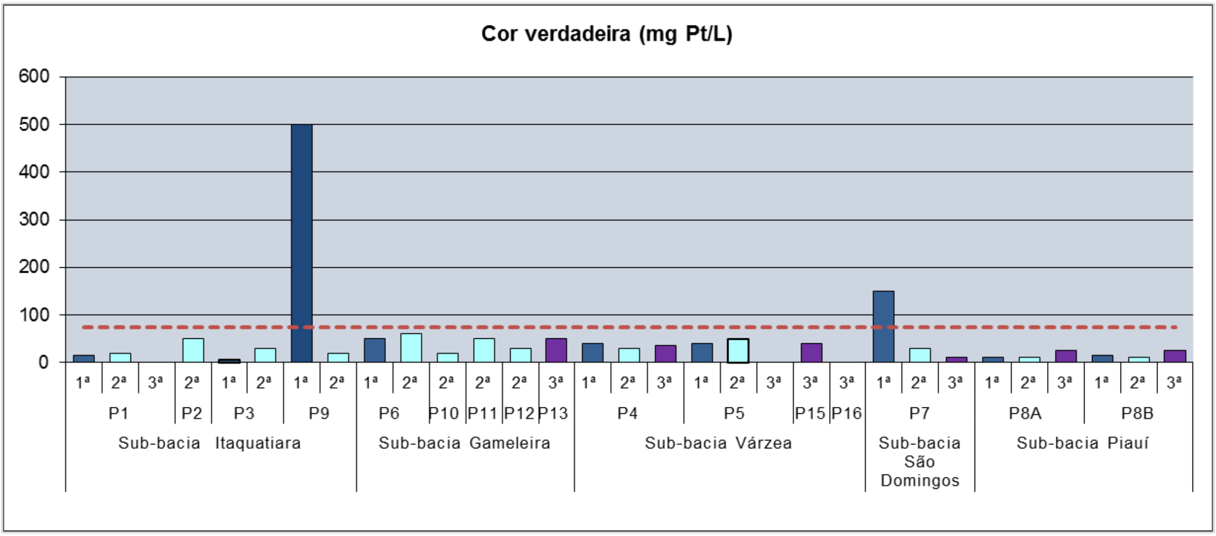
True Color

The true color of the water is a result of the presence of substances in solution, usually due to decomposition of plant remains, such as fulvic and humic acids, which give the water courses a yellowish to brown color, assuming a darker hue in the presence of compounds of iron. The introduction of solids from the drainage basin, the resuspension of sediments and the development of phytoplankton in general affect the optical properties of a body of water by increasing color and also turbidity.

Color is an aesthetic parameter, of special interest for water sources intended for public supply, as levels of intense color tend to cause rejection of water for human consumption. However, high levels of color may be associated with parameters of sanitary interest, such as algae bloom and the presence of metals and other contaminants that cause public health problems.

CONAMA Resolution No. 357/05 determines the maximum of 75 mg Pt / l of true color for class 2 freshwater. As already mentioned, during the collection the very high index obtained in the first campaign at Point 09 (Itaquatiara, downstream of the Gameleira - Scale 2), stands out reaching 500 mg Pt / l, a result attributed to the blooming of algae that occurred there. Another discrepant value in the sample network concerns the Eugênio reservoir (Point 07), during the first campaign that reached 150 mg Pt / l, due to the introduction of solids resulting from precipitation.

Graph 5.1-10 – Values for True Color (2008).



Turbidity

Water turbidity is a measure of its ability to disperse light as a function of suspended particles (silt, clay, microorganisms). High values of turbidity generally indicate the contribution of solids from the drainage area and can interfere with the photosynthetic activity of a body of water. When sedimented, the particles form banks of sludge that provoke anaerobic digestion, leading to the formation of gases.

Turbidity levels in water bodies at the ADI and DAA fluctuated between 1.5 FTU (Point 8A, Jenipapo Dam) in the first campaign, reaching a peak of 1,600 FTU in the Eugênio reservoir (Point 07) in the rainy season (March / 2008).

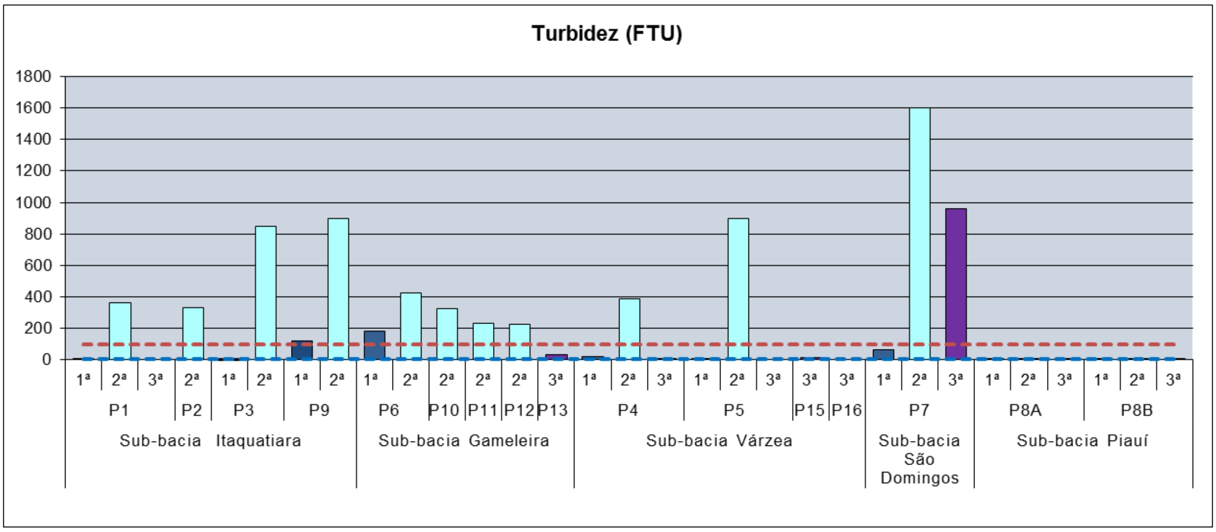
In the first campaign, only the Itaquatiara *cacimbas* (Points 01 and 03), and the Jenipapo dam, upstream and downstream of the dam (8A and 8B), met the drinking standards (5 FTU). Point 04 and 05 in the Várzea stream (upstream and downstream from the mining area) and the Eugênio weir (Point 07) were also the only ones that complied in this survey to the limits of class 2 (100 FTU).

As expected, in the second campaign, there was a strong increase in turbidity conditions due to rain in all water bodies, with emphasis on Points 03, 05 and 09, which had results above 850 FTU, in addition to Point 07 (1,600 FTU) mentioned above. At all points, the value defined by CONAMA Resolution 357/05 were exceeded, with the exception of points 8A and 8B (upstream and downstream) at the Jenipapo dam, which remained within acceptable drinking and class 2 standards, due to the likely sedimentation of solids occurred in the sectors upstream of the dam.

In the last campaign, Point 04 was the only one in the sampling network that maintained the standard defined by Ordinance 2914/2011, while the weirs of Points 13 (Capitão Gervásio), 15 (Várzea stream), and the Jenipapo dam, were in line with class 2 limits. Again, the Eugênio reservoir (Point 07) stands out as having the highest level of turbidity in this collection (960 FTU).

These results indicate that the supply of solids to the water network constitutes one of the main factors for altering the quality of surface water in the ADI and the DAA and deserves special attention during the implementation phase of the Piauí Nickel Project.

Graph 5.1-11 – Turbidity (2008).



Hydrogen Potential (pH)

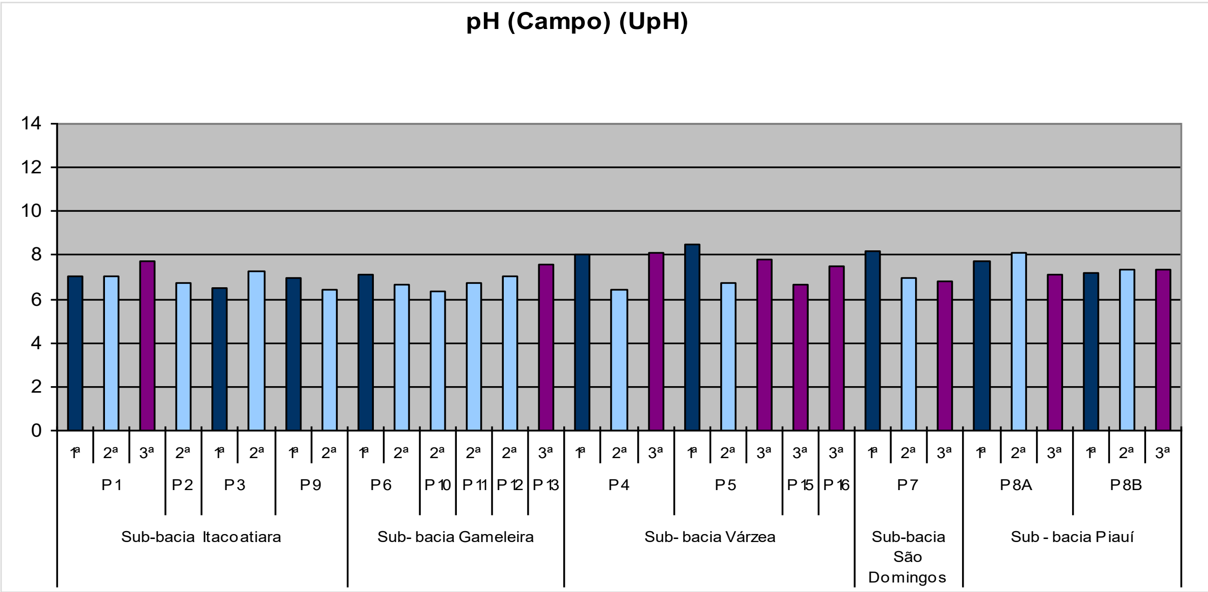
The pH defines the acidic, basic or neutral character of a sample. Its influence on natural aquatic ecosystems occurs directly on the physiological aspects of organisms or, indirectly, contributing to the precipitation of chemical elements and the toxicity of various compounds. In an acidic environment, heavy metals tend to have greater bioavailability, increasing their level of toxicity.

Natural waters generally have a pH between 4 and 9. The pH measured in the field in the three campaigns at the Piauí Nickel Project ranged from 6.36 in the Gameleira stream (Point 10/ Scale 4) to 8.5 in the Várzea stream (Point 05) , being compatible with CONAMA Resolution 357/2005 (pH between 6.0 and 9.0) and Ordinance 2914/2011 (6.0 to 9.5).

More pronounced pH variations, as observed in the Várzea stream (Points 04 and 05), the Eugênio reservoir (Point 07) and the Jenipapo dam (8A), may be due to precipitations that tend to make the waters in general more acidic. These results may also indicate the presence of a large amount of algae, whose photosynthesis process during the hours of greatest solar radiation raises the pH, also causing an increase in the level of dissolved oxygen (DO) in the waters.

In fact, a massive growth of phytoplankton, very high OD values (9.0 mg / L) and greater fluctuation in pH (8, 6.45 and 8.8) were observed during the third campaign in the Várzea stream reservoir (P04) over the three campaigns.

Graph 5.1-12 – pH values (2008).



Alkalinity

This is the total measure of the substances present in the water capable of neutralizing acids, acting as a buffer. The total alkalinity, expressed in mg / l of $CaCO_3$, is the sum of the alkalinity produced by all these ions present in the sample. Waters that drain limestone rocks generally have high alkalinity.

In the three campaigns at the Piauí Nickel Project, the alkalinity of bicarbonates stands out, which ranged from 9.4 mg / l at Point 8A (Jenipapo dam) to 600 mg / l at Point 4 (reservoir of the Várzea stream, upstream from the mining area), both in the first campaign. There are no limits established in the legislation for this variable.

Hardness

Total hardness is the concentration of all divalent cations in water, with calcium (Ca^{2+}) and magnesium (Mg^{2+}) being the most common cations in almost all freshwater systems.

Ordinance 2914/2011 defines the maximum limit as 500 mg / l, with no determination for this parameter by CONAMA Resolution 357/05. The results varied between 21 mg / l at Point 07 (Eugênio reservoir) and 720 mg / l at Point 04, both in the third campaign.

Salinity

Salinity is a measure of the concentration of salts dissolved in water, mainly sodium, calcium, magnesium and potassium cations and chloride, sulfate and bicarbonate anions. The spatial and temporal distribution of magnesium, sodium, potassium and chloride ions, does not particularly depend on the biological dynamics of the environment, due to their limited chemical reactivity and biological demand. On the other hand, the concentration of calcium, inorganic carbon and sulfate is strongly influenced by the metabolism of microorganisms.

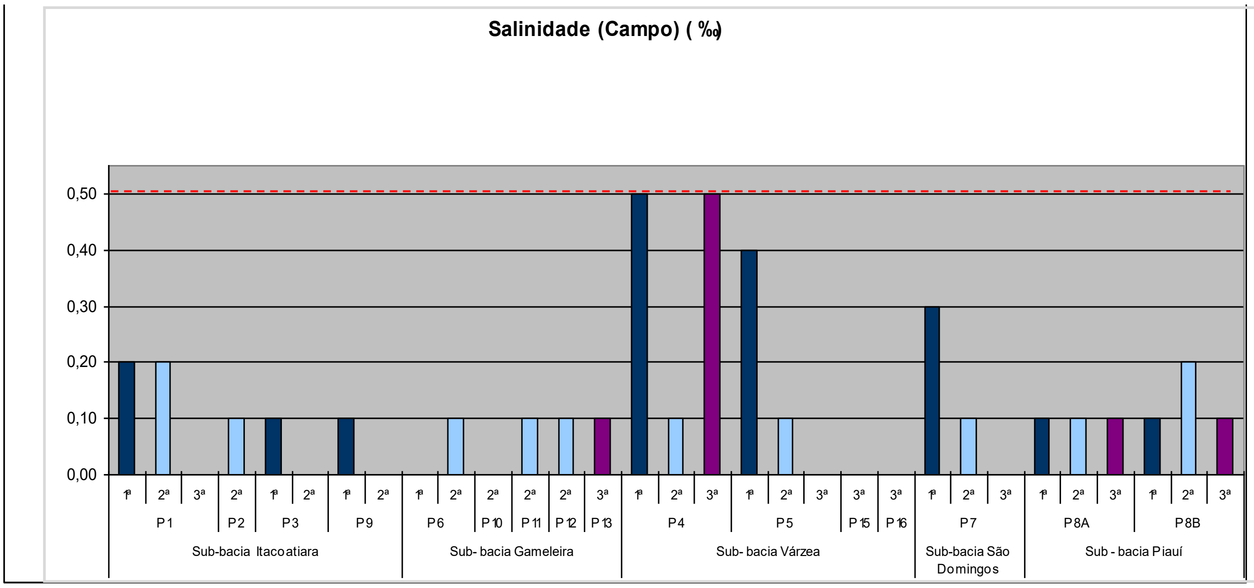
All natural waters have, to differing degrees, a set of salts in solution, with groundwater generally having higher levels than surface water, as they are intimately exposed to the soluble materials present in the soil and rocks.

In the Northeast of Brazil, excessive water salinization is a major problem. In areas with high rainfall, the constant recharge of the aquifers allows a greater dilution of the salts in solution. However, in semi-arid climates, low rainfall levels lead to salinization on the soil surface through the evaporation of water that rises through capillarity action. During the most intense rains, the most soluble salts are carried to the deepest parts of the aquifer, increasing its salinity.

CONAMA Resolution 357/05 determines a range of salinity for each type of environment; fresh water, salinity equal to or less than 0.5 ‰; brackish waters, salinity between 0.5 and 30 ‰; saline water, salinity equal to or greater than 30 ‰. There are no defined standards for salinity in Ordinance 2914/11.

The salinity measured in the sampling network at the Piauí Nickel Project, in all campaigns, characterizes the water system as fresh water, but Point 04, the reservoir upstream of the mining area, in the Várzea stream, is at the limit determined by legislation (0.5 ‰). This result is mainly due to the high levels of chloride, magnesium and bicarbonate ions detected in this sub-basin.

Graph 5.1-13 – Values for Salinity (2008).



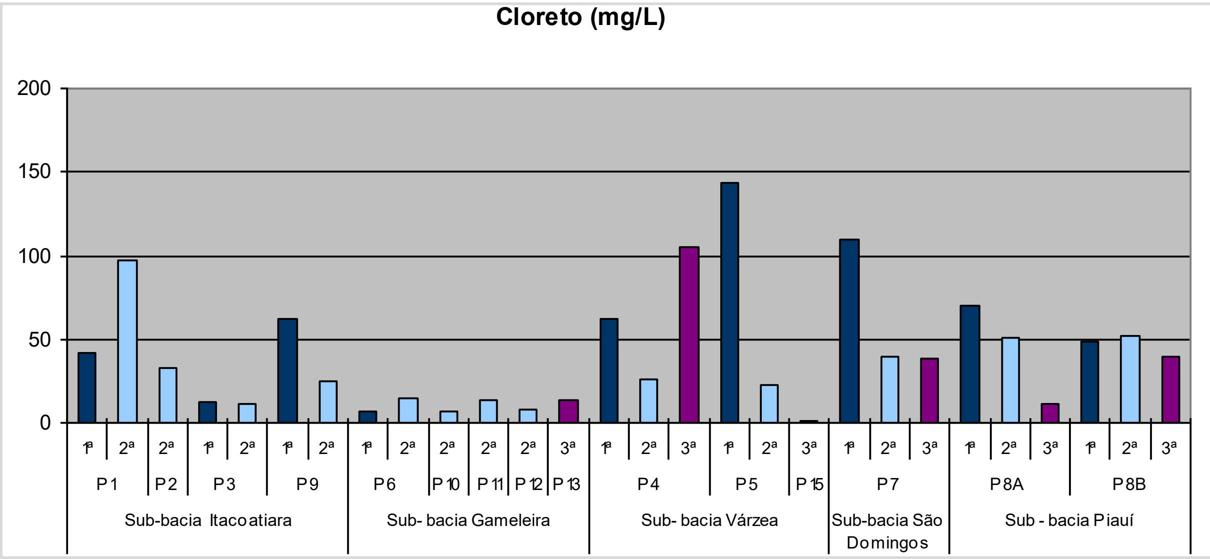
Chloride

Chloride is widely distributed in natural waters, generally with high concentrations in coastal areas and semi-arid regions, where evaporation levels are highest.

According to the graph below, the chloride concentrations recorded in all campaigns in the sampling network are compatible with the limit value of 250 mg / l defined by both CONAMA Resolution 357/05 (class 2) and Ordinance 2914/11.

The results obtained are consistent with the salinity ranges recorded at the sampling points, with higher values being obtained in the Várzea sub-basin (Points 04 and 05) and at Point 07 (Eugênio weir), which reached 105, 143 and 110 mg / l, respectively, however, all well below the rate determined by the legislation in force.

Graph 5.1-14 – Chloride Values (2008).

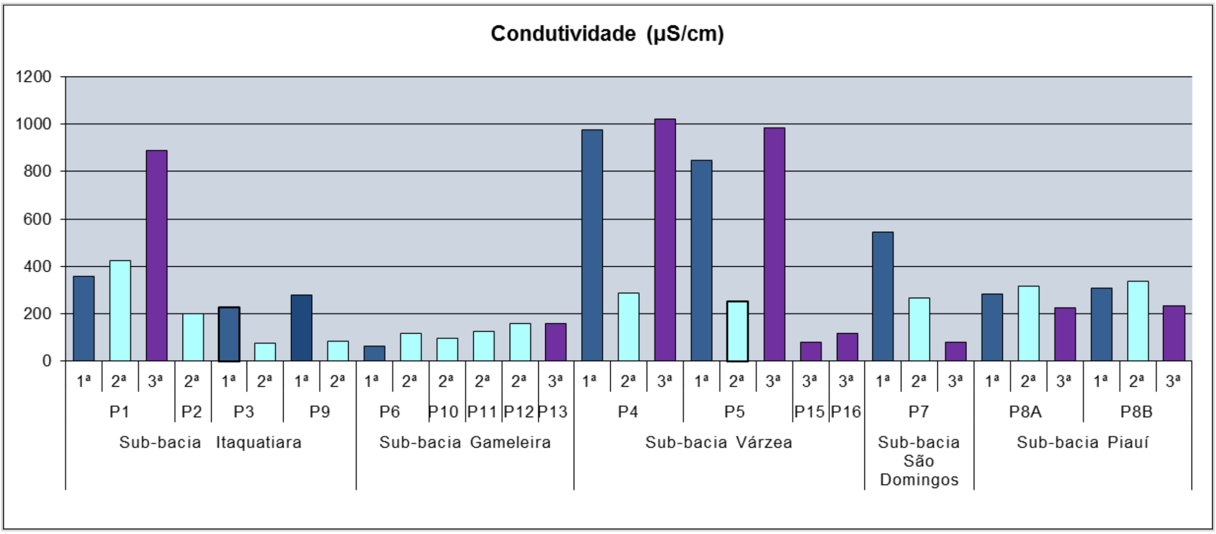


Conductivity

Conductivity is a numerical expression of the ability of the aquatic environment to conduct electrical current as a function of the concentration of ions present, such as chlorides, and is influenced by temperature and pH. There are no defined standards in the legislation for this variable.

During the collection campaigns, results were obtained between 65.3 µS / cm at Point 06, the Caraíbas stream (first campaign) and 1,022 µS / cm at Point 04, in the Várzea stream (third campaign). The sub-basin of the Várzea stream, therefore, tends to have a higher level of conductivity, corroborating the results of salinity and chlorides presented above, which indicate a higher concentration of salts in the same.

Graph 5.1-15 – Conductivity Values (2008).



Solids Series (residues)

In natural waters, solids can be present in different fractions. Total solids are the sum of the suspended and dissolved portions present in a given sample. These plots can be organic (volatile solids) or inorganic (fixed solids).

Total Suspended Solids

The suspended solids comprise inorganic particles (sand, silt, clay) as well as organic debris (algae, bacteria, decomposing leaves). Erosive processes in the drainage basin contribute greatly to the amount of suspended solids to the receiving water bodies, especially in the rainy season, interfering in the turbidity of the waters.

When present in large quantities, they can cause damage to aquatic life, as they can reduce the amount of light available for photosynthetic processes. They can also retain bacteria and organic residues in the particles, favoring anaerobic decomposition. There are no standards in federal law for suspended solids.

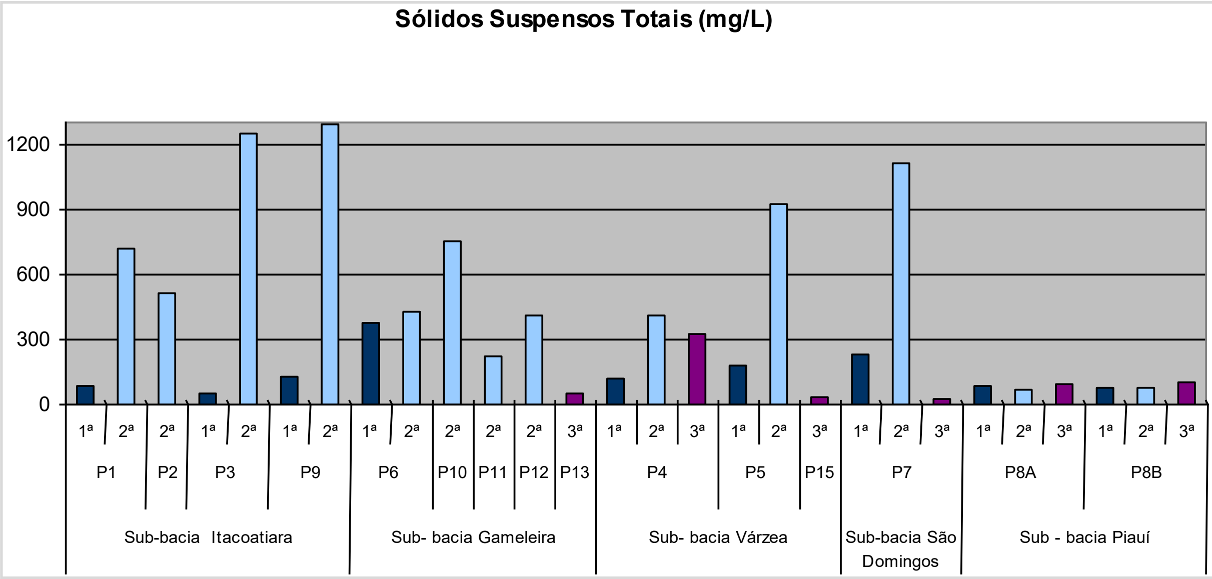
During the first campaign, the levels of total suspended solids ranged from 52 mg / l at Point 03 (*cacimba*) in the Itaquatiara to 380 mg / l at Point 6 – the Caraíbas stream.

In the following campaign, much higher results were obtained, due to the rainfall that contributed to the transport of solids to the water bodies, especially at Points 09 and 03, both located in the Itaquatiara stream, at 1,290 and 1,250 mg / l respectively. In contrast, the Jenipapo dam, both upstream and downstream of the dam (Points 8A and 8B), had the lowest levels in the sampling network, 70 and 80 mg / l respectively. These results are certainly favored by the fact that the Jenipapo dam is a lentic environment, where the calmer waters contribute to the deposition of solids and cause less sediment remobilization. It should be noted that although the point 8B is not a lentic environment, it receives contributions directly from one.

In the third and last campaign, conducted in May 2008, there was a general drop in the concentrations of suspended solids in the sampled weirs, with a maximum of 328 mg / l at Point

04. On the Piauí River (Jenipapo dam upstream and downstream of the dam), however, there was a slight increase compared to previous results, reaching 98 and 104 mg / L at Points 8A and 8B, respectively.

Graph 5.1-16 – Values for Total Suspended Solids (2008).



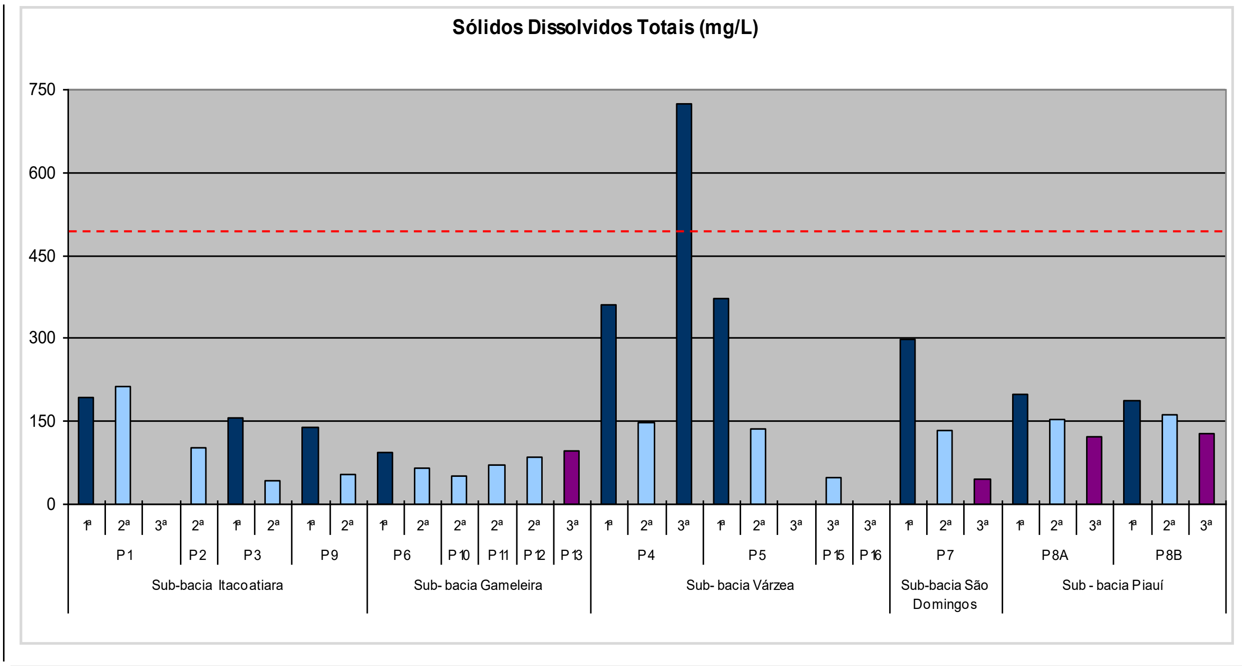
Total Dissolved Solids

Dissolved solids consist of carbonates, bicarbonates, chlorides, sulfates and phosphates, among others, reflecting the values of several parameters, such as salinity, conductivity and pH. In the ADI and DAA of the Piauí Nickel Project, the total dissolved solids contents remained within the potability standards defined by Ordinance 2914/2011 (1,000 mg / l) in all analyzed samples.

In the first campaign, the dissolved solids were measured at concentrations between 94 mg / l at Point 06 (the Caraíbas stream) and 372 mg / l at Point 05, the Várzea stream; concentrations also in accordance with the limit of 500 mg / l established by CONAMA Resolution nº 357/05. During the second campaign, the sampled points remained within the range recommended by this legislation, with a maximum of 214 mg / l at Point 01 (the Bonito stream, in the Itaquatiara stream watershed).

In the third campaign, Point 04 was the only one that showed a value above the standard established by CONAMA Resolution No. 357/05, at 724 mg / l, in line with the high recorded concentrations of salinity, conductivity, and the high concentration of bicarbonates, as attested by the results of alkalinity.

Graph 5.1-17 – Total Dissolved Solids (2008)



Dissolved Oxygen (DO)

The concentration of dissolved oxygen in water is of fundamental importance to aquatic biota, as it conditions the survival of aerobic beings, including fish.

Oxygen consumption in water systems generally occurs through the biological processes of organic matter decomposition. The introduction of these compounds in excess in the aquatic environment can generate anaerobic environments, especially in the deeper layers of rivers, dams and weirs, with concomitant production of methane and sulfides, among other products, that give a characteristic odor.

The high concentration of organic materials also leads to the formation of reducing environments in sediments, a process that makes heavy metals and phosphorus compounds more soluble and bioavailable in the environment.

In fresh water, the level of dissolved oxygen must be at least equal to 5 mg / l, as recommended by CONAMA Resolution No. 357/05 (class 2), with no specification of a standard by Decree 2914/2011.

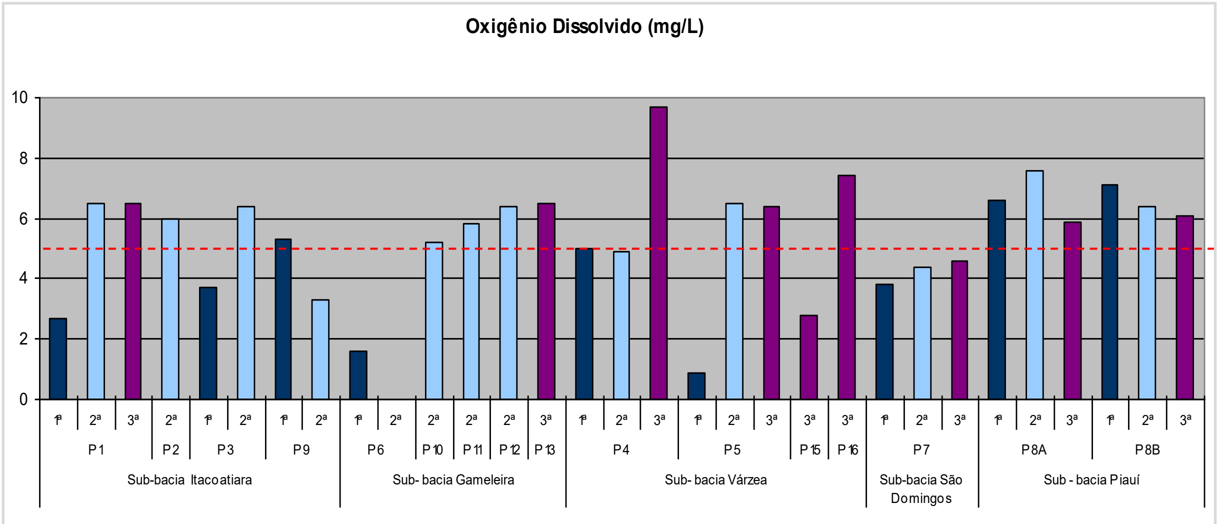
In the first campaign, carried out in the transition period between the dry and rainy seasons, with the occurrence of sparse rainfall, there was a preponderance of water bodies with little capacity for dilution and self-purification of organic materials, resulting in low DO levels at practically all the sampled points, below the limit defined by legislation. This condition was caused by the reduced flow of water systems and the introduction of a high concentration of organic waste, mainly in the form of animal excrement, associated with high temperatures typical of the region that favor intense biological decomposition activity.

In this sense, Points 05 (0.9 mg / l) and 06 (1.6 mg / l) stood out, located respectively in the Várzea stream and in the Gameleira stream. The only points that maintained dissolved oxygen above 5.0 mg / l were the Jenipapo dam (8A and 8B) and the Itaquatiara (Point 09), probably due to the photosynthetic processes resulting from the high density of phytoplankton found at these locations.

In the second campaign, there was an improvement in the general standards in terms of dissolved oxygen, due to the higher flow from the rainfall. However, Points 04 (Várzea stream reservoir), 07 (Eugênio reservoir) and 09 (Itaquatiara) showed DO deficits, with levels ranging from 3.3 to 4.9 mg / l.

Among the locations sampled in the third campaign, only Points 15 and 07, located at the Várzea and Eugênio weirs, resulted in concentrations below the legal limits for class 2, at 2.8 and 4.6 mg / l, respectively. In the rest of the sampling network, the DO levels were compatible with the legislation, implying environments conducive to the maintenance of aquatic biota.

Graph 5.1-18 – Dissolved Oxygen Values (2008).



Biochemical Oxygen Demand (BOD) and - Chemical Oxygen Demand (COD)

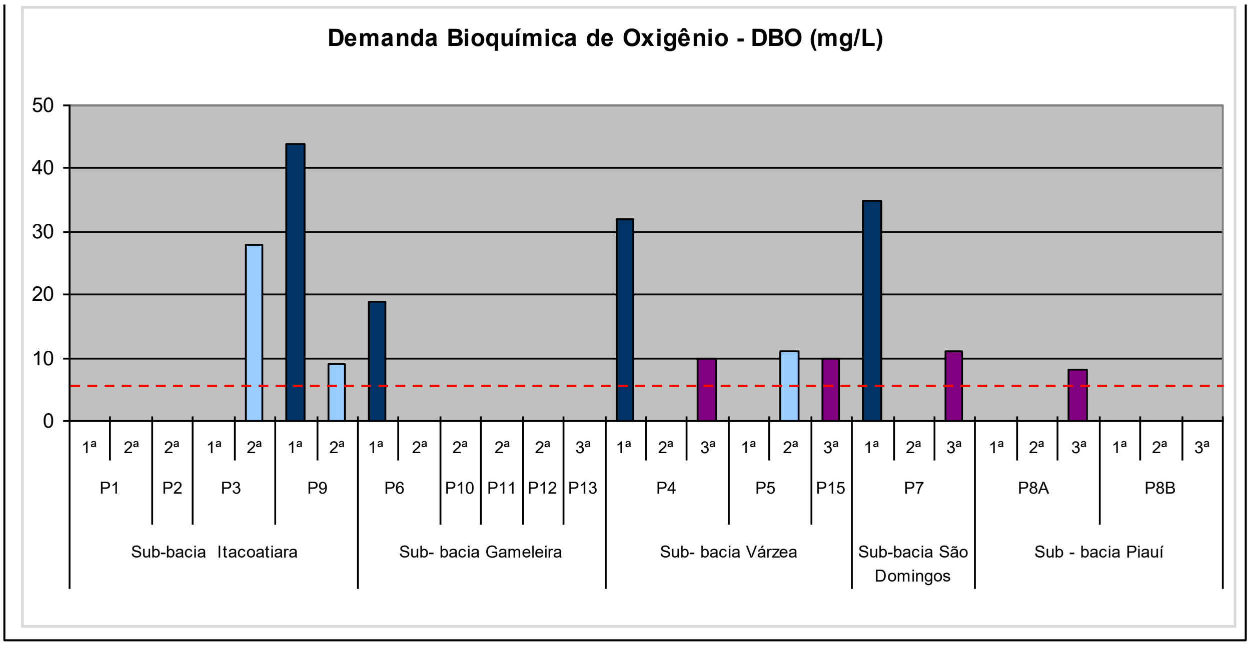
The BOD of a water sample is the amount of oxygen needed to oxidize organic matter through aerobic biological decomposition, forming by-products in stable inorganic form. The BOD, according to CONAMA Resolution No. 357/05 for freshwater class 2, should not be higher than 5 mg / l, with no standards determined by Ordinance 2914/11 of the Ministry of Health.

The highest BOD value in the first campaign occurred at Point 09 (44 mg / l), probably attributed to the excessive development of algae, and high concentrations of organic materials were also detected at Point 07 (Eugênio weir) and 04 (Várzea stream weir), with BOD reaching 35 and 32 mg / l, respectively.

In the second campaign, the high BOD value persisted at Point 09 (9 mg / l), as well as at Point 03 (28 mg / l) and 05 (11 mg / l), located at the Itaquatiara and the Várzea streams, with values above the class 2 standard.

During the third campaign, Points 04 (10 mg / l), 07 (11 mg / l), 8A (8 mg / l) and 15 (10 mg / l) were not in compliance with the legal limit of the CONAMA Resolution.

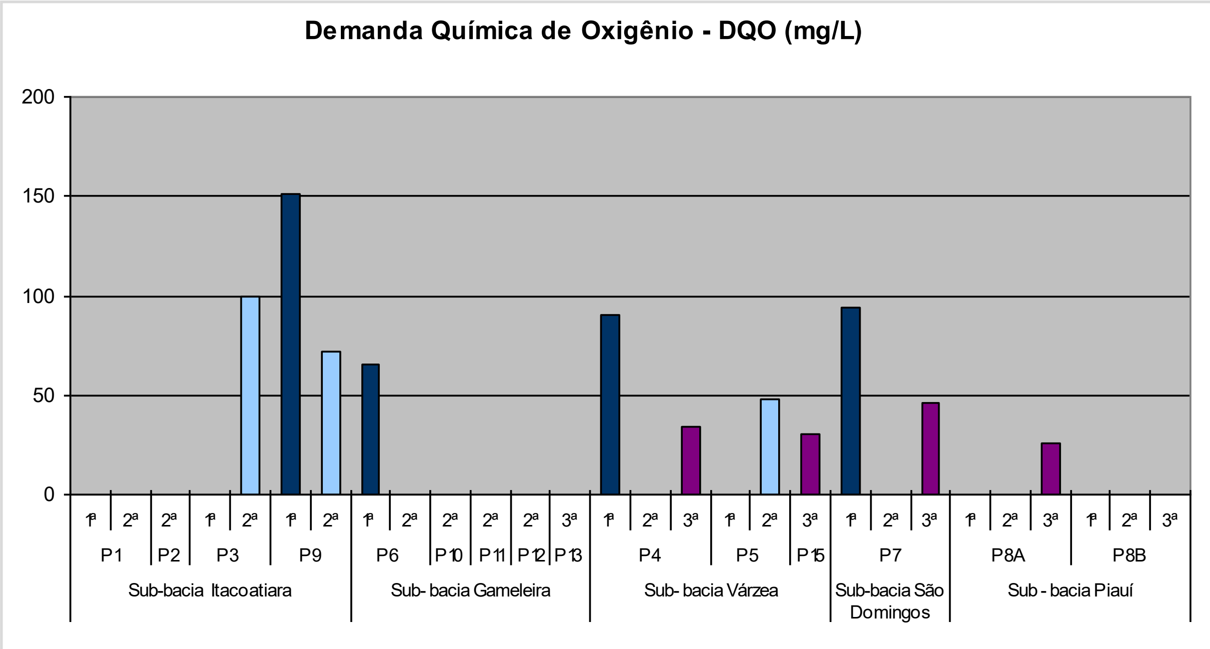
Graph 5.1-19 – BDO Values (2008).



COD is the amount of oxygen needed to oxidize organic matter by a chemical agent. As BOD measures only the biodegradable fraction, the closer this value approaches COD, the greater the potential for biological degradation of the compounds present in a given sample. There are no standards for this variable in CONAMA Resolution 357/05 and Ordinance 2914/11.

In the sampling network, COD values maintained the same pattern as BOD at the respective sampling points, ranging from 26 mg / l (Point 8A - Jenipapo dam in the third campaign) to 151 mg / l (Point 9 - sub-basin Itaquatiara, in the first campaign), as shown in the graph below.

Graph 5.1-20 – COD values (2008).



Total Organic Carbon (TOC)

The TOC has a direct relationship with the content of organic matter available in the aquatic environment.

Current legislation does not establish TOC standards for freshwater. The low concentrations detected suggest that much of the organic matter in the aquatic environment was concentrated at depth. In the samplings carried out in the three campaigns, at several points total organic carbon concentrations were not detected, reaching a maximum of 16 mg / l at Point 03 (Itaquatiara stream, downstream from the mouth of the Gameleira) in the second campaign.

Nitrogen compounds

Nitrogen participates in the formation of proteins in the metabolism of living beings, and can be found in the aquatic environment in organic (microorganisms, organic debris) and inorganic forms, especially as ammonia, nitrite and nitrate.

The biological decomposition processes lead to ammonification of the nitrogen present in organic compounds. In well-oxygenated environments, ammoniacal products are quickly converted to nitrites, which are extremely unstable in the environment and then to nitrates, stable elements easily assimilated by autotrophs (algae and vegetation in general).

There are two interchangeable forms of ammonia - ionized (the ammonium ion NH^{4+}) and non-ionized (free ammonia - NH_3). The higher the pH of the sample, the greater the proportion of free ammonia, which is more toxic, in relation to the ammonium ion.

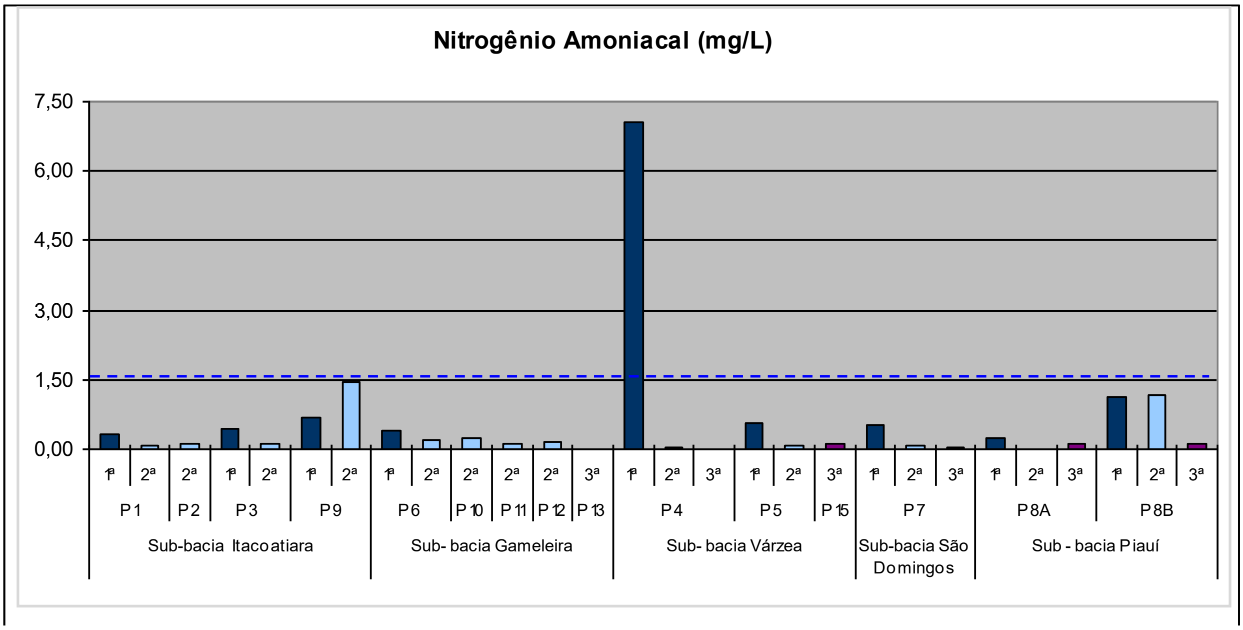
Ammoniacal nitrogen in fresh water is legislated by CONAMA Resolution 357/05 in ranges that vary according to pH. For class 2 waters, the legislation defines a maximum of 3.7 mg / l of ammoniacal nitrogen (pH below 7.5); up to 2.0 mg / l (pH between 7.5 and 8.0); up to 1.0 mg /

l (pH between 8.0 to 8.5) and 0.5 mg / l (pH greater than 8.5). Ordinance 2914/11 establishes a maximum value for drinking water of 1.5 mg / l.

Considering the results of ammoniacal nitrogen obtained in all campaigns, it is noted that the limits defined for class 2 were exceeded only at Point 04 (reservoir in the Várzea stream, upstream of the mining area) in the first collection (7.05 mg / l), a value considered very high for a pH equal to 8, allowing the release of toxic products to aquatic biota.

It is worth mentioning that Point 05, also located in the Várzea sub-basin, registered in this same campaign 0.57mg / l of ammoniacal nitrogen, at pH 8.5, which gives this system greater potential for toxicity.

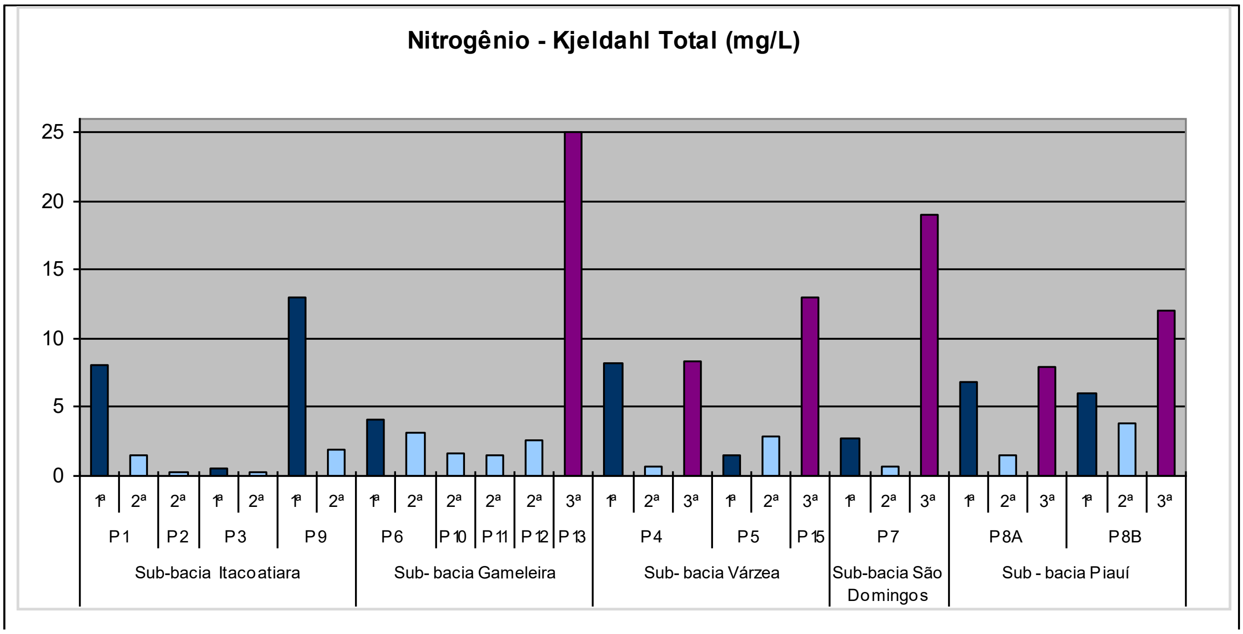
Graph 5.1-21 – Ammoniacal Nitrogen Values (2008).



The sum of the ammoniacal and organic nitrogen fractions is expressed as Kjeldahl nitrogen, a parameter not covered by the aforementioned legislation.

Kjeldahl nitrogen levels in the sampling network showed the predominance of organic nitrogen over the ammoniacal fraction; however, deficits of dissolved oxygen detected in the sampling network, especially in the first campaign, can cause accumulation of ammoniac compounds in the aquatic environment, restricting the conversion of these compounds to nitrite salts, which are very unstable, and later to nitrate.

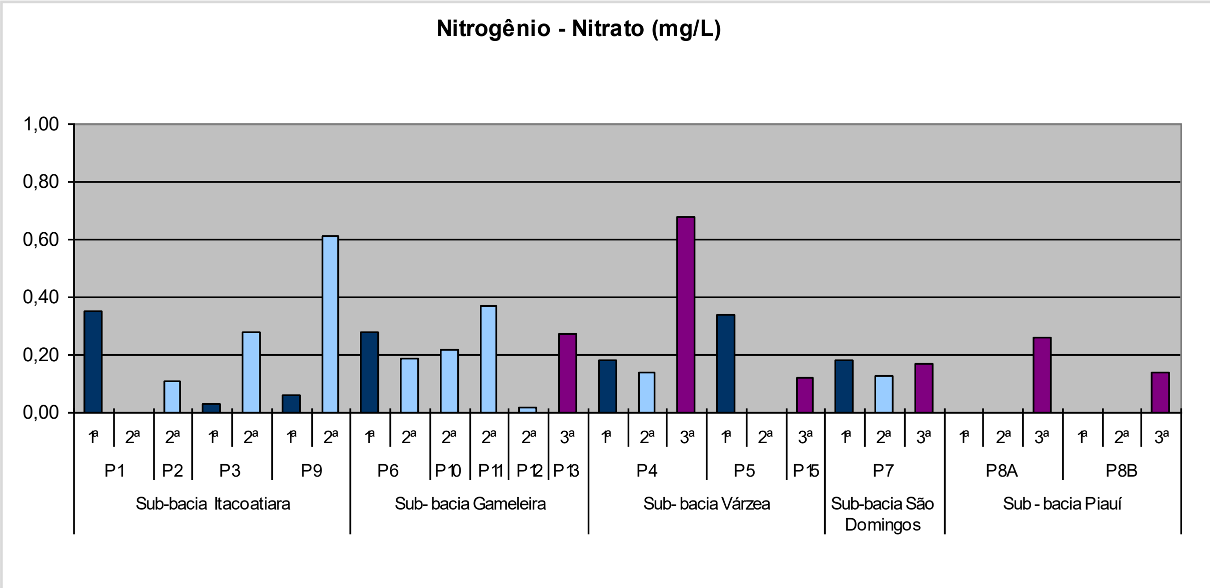
Graph 5.1-22 – Values for Total Kjeldahl Nitrogen (2008).



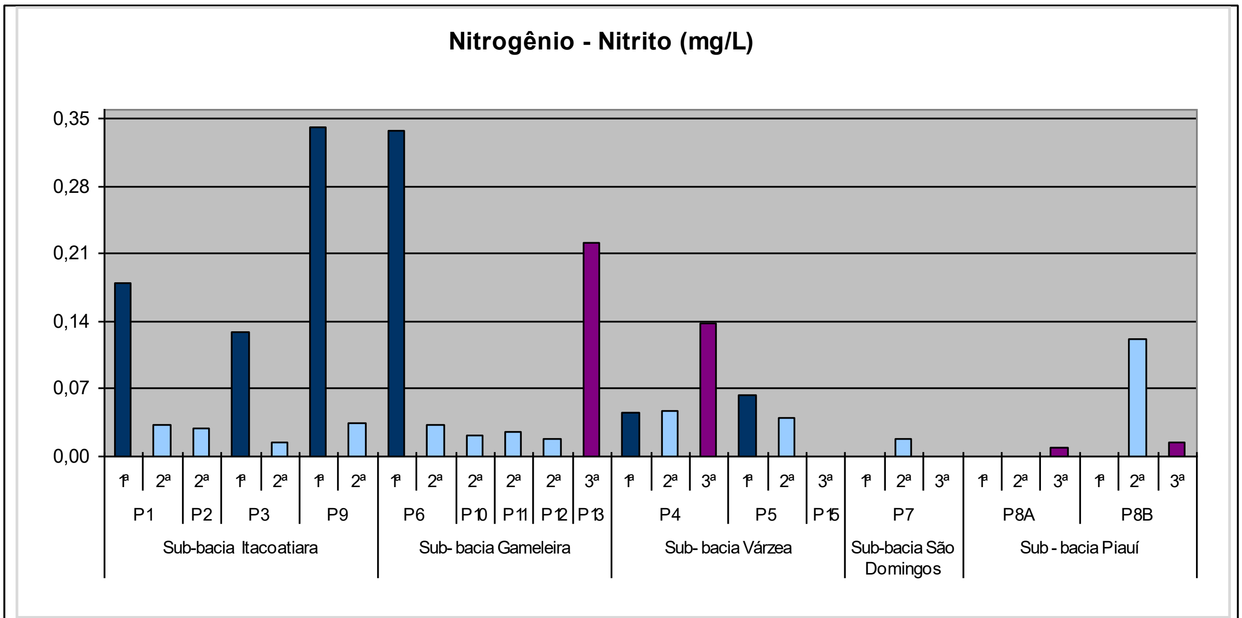
Nitrate is the most oxidized fraction in the nitrogen biogeochemical cycle and is present in water in a form readily assimilated by microorganisms, as it has a lower energy cost for absorption than ammonia. Nitrite is very unstable and represents an intermediate phase between ammonia (the lowest oxidized form) and nitrate (the most oxidized form) in the biogeochemical cycle of nitrogen.

According to CONAMA Resolution No. 357/05 for class 2 waters and Ministry of Health Ordinance No. 2914/2011, nitrate must have a maximum result of 10 mg / l and nitrite, 1 mg / l. The graphs below show that all values obtained for these two parameters in the campaigns carried out in 2008 were in compliance with the limits set by these laws.

Graph 5.1-23 – Nitrogen Values – Nitrate (2008).



Graph 5.1-24 – Nitrogen Values – Nitrite (2008).



Total Phosphorus

Phosphorus in water is mainly in the forms of orthophosphate, polyphosphate and organic phosphorus. Orthophosphates are bioavailable and, once assimilated, are converted into organic phosphate and condensed phosphates. After the death of an organism, the condensed phosphates are released into the water, being assimilated by algae after their conversion to orthophosphate, a process carried out by bacteria.

In comparison with other structural components of living beings, phosphorus is the least abundant and in general the main limiting factor to the productivity of water systems. Total phosphorus concentrations in lentic environments greater than 0.01 mg / l causes water eutrophication. Its release from sediments depends, above all, on the pH and the prevailing redox conditions.

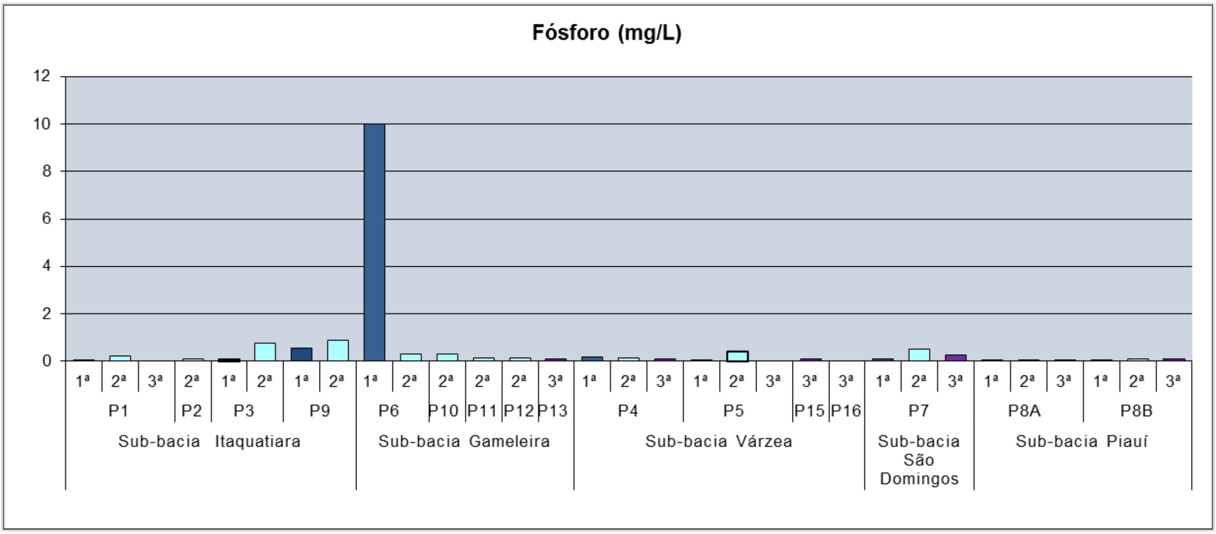
The main sources of phosphorus to the waters in the region are associated with diffuse loads generated primarily by animal husbandry, whose waste contribution occurs more intensely during the first rainfall, favoring the development of algae.

CONAMA Resolution 357/2005 defines for lotic and lentic environments the maximum limits of 0.1 and 0.030 mg / l, respectively. In the sampling network, the five weirs (Points 04, 07, 13, 15, 16) and the Jenipapo dam at Point 8A are considered lentic systems, while the other sampled points constitute lotic environments, with a perennial regime (Point 8B) or intermittent regime (Points 01 to 03, 05, 06, 09 to 12). There are no standards defined for this variable by Decree 2914/11.

The results of total phosphorus in the sampling network varied between 0.003 mg / l (Point 8A) in the first campaign and 10 mg / l at Point 06 (the Caraíbas stream) in that same campaign. Non-compliances were recorded at all collection points in at least one of the campaigns, with the exception of Point 8B, downstream from the Jenipapo dam, which had waters with a low concentration of total phosphorus in the first campaign (0.024 mg / l).

These results, obtained downstream from the lake, may reflect possible phosphorus precipitation processes in the sediments of the Jenipapo dam, a mechanism favored by the high dissolved oxygen levels recorded upstream of the dam, above 6.0 mg/l.

Graph 5.1-25 – Values for Total Phosphorous (2008).



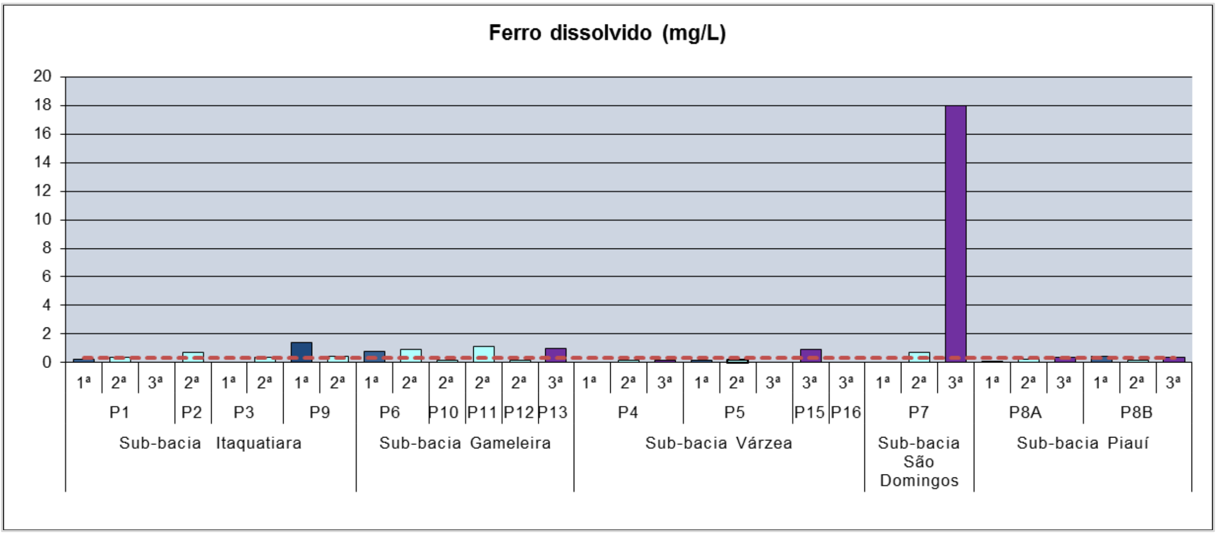
Dissolved Iron

In surface waters, the presence of iron is associated with regional geochemical characteristics, being almost always accompanied by manganese. Although not a toxic element, it can lead to the development of ferruginous bacteria and cause obstruction in pipes.

Iron is dissolved in water in the form of bicarbonate (soluble). In the presence of oxygen, it becomes ferric (insoluble) hydroxide, which precipitates in sediments, especially at alkaline pHs. When adsorbed by iron, phosphorus also tends to precipitate, being released again in the water column in anaerobic environments and at a pH below 7.

CONAMA Resolution 357/05 (class 2) defines a limit of 0.3 mg / l for dissolved iron and Ordinance 2914/11 a limit of 0.3 mg / l for its total portion, with no limit value for dissolved iron. Most of the points sampled at the Piauí Nickel Project showed values above the standards determined by the CONAMA Resolution, a result probably attributed to the characteristics of the local geology, whose contribution to watercourses is from erosion processes. In the sampling network, a maximum of 18 mg / l was obtained in the Eugênio reservoir during the third campaign.

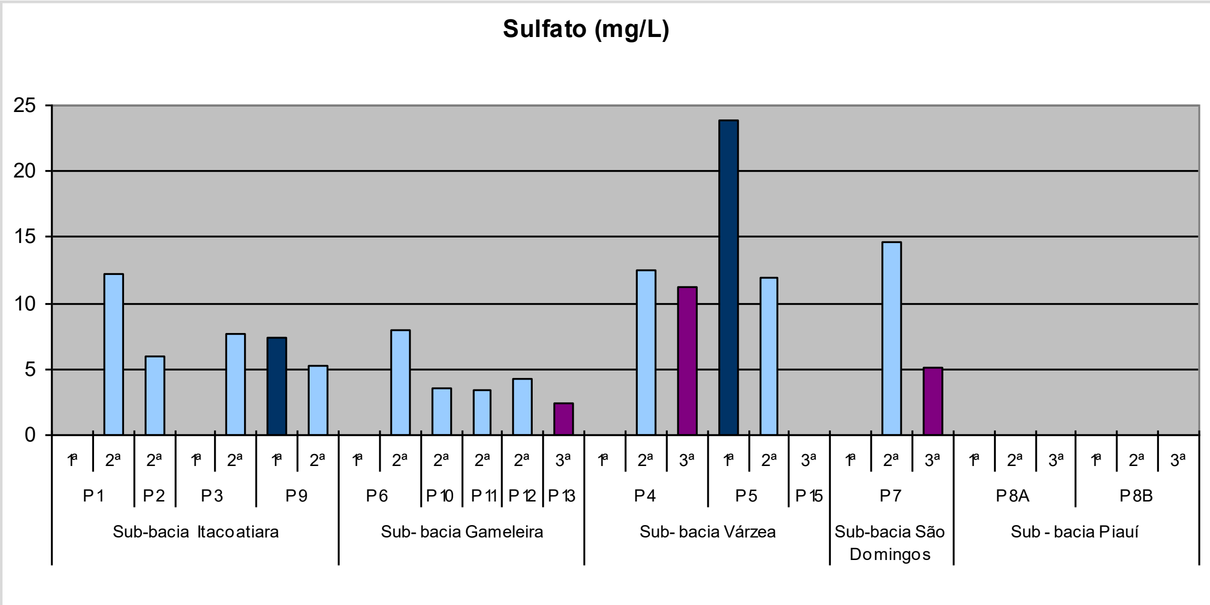
Graph 5.1-26 – Vales for Dissolved Iron (2008).



Sulfate

Sulfate concentration is strongly influenced by the metabolism of microorganisms. In places with an intense supply of organic matter and under anoxic conditions, sulfate is reduced to sulfides by the action of reducing bacteria. As shown in the graph below, the sulfate results in the sampling network remained within the standard established by CONAMA Resolution 357/05 and Ordinance 2914/11 (250 mg / l) in all campaigns, with results well below the limit set by the legislation.

Graph 5.1-27 –Sulfate Values (2008).



Sulfide

Hydrogen sulfide is a biologically active compound that is formed from the decomposition of organic matter and sulfate in the absence of oxygen through the action of bacteria. It is toxic to fish at a concentration of 1 to 6 mg / l. Some toxic heavy metals form insoluble sulfides and precipitate in sediments.

Being strongly reducing agents, most sulfides are also responsible for an immediate demand for oxygen, reducing its availability in the water body. In well-aerated water systems, hydrogen sulfide is oxidized to sulfate or biologically oxidized to elemental sulfur, minimizing the effects on the environment.

CONAMA Resolution No. 357/05 establishes a maximum concentration of 0.002 mg / l for sulfide. Although this compound was not detected in the sampling network in any of the campaigns, it is worth noting the characteristic odor release in the vicinity of Point 8B, located on the Piauí River downstream of the Jenipapo dam, in the first two collections.

Thermotolerant Coliforms and *Escherichia coli*

Thermotolerant (or faecal) coliforms are bacteria present in human and homeothermic animal feces, constituting an important indicator of the existence of pathogenic microorganisms, responsible for the transmission of waterborne diseases, such as typhoid fever, paratyphoid fever, bacillary dysentery and cholera.

The presence of faecal coliforms in waters throughout the region is a problem of great relevance to public health, especially in water sources intended for human consumption without prior treatment, as is the case of the vast majority of water bodies under study.

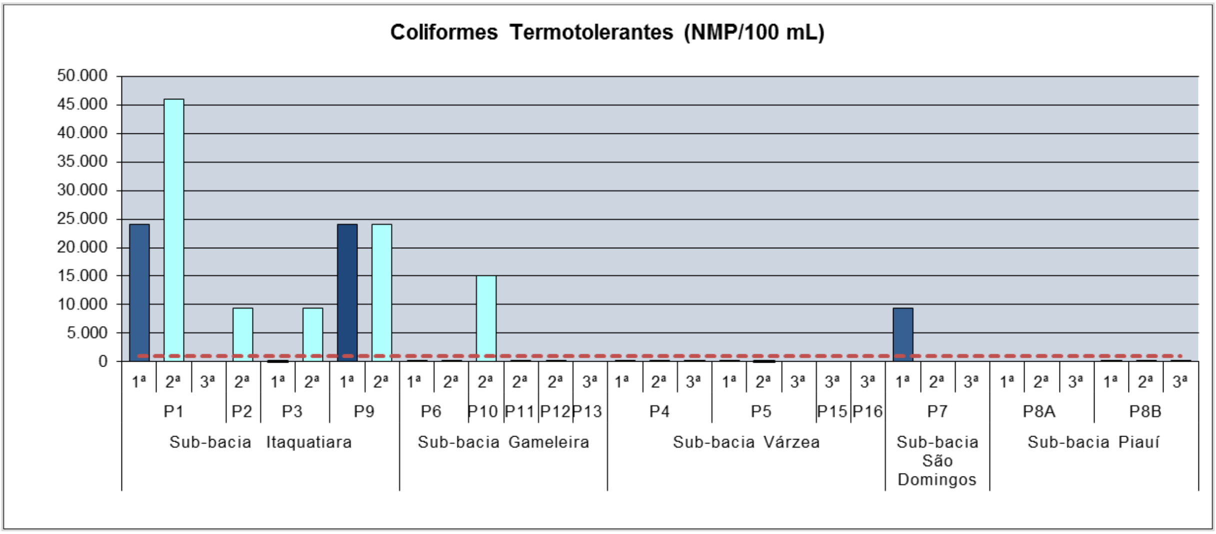
CONAMA Resolution No. 357/2005 establishes a maximum of 1,000 thermotolerant coliforms for class 2 waters, while Ordinance 2914/11 requires the absence of *Escherichia coli* in water intended for human consumption, the main representative of this group.

With the exception of the Jenipapo dam (Points 8A and 8B), the Eugênio reservoir (Point 07), the Várzea stream, downstream from the mining area (Point 15) and Capitão Gervásio (Point 13), where thermotolerant coliforms were not detected in at least one of the campaigns, the other points of the sampling network showed generally high *E. coli* values, reaching 46,000 organisms / 100 ml, at Point 01, the Bonito stream, in the second campaign, a time of intense precipitation.

The test results of *Escherichia coli* were positive for most of the samples, highlighting the points located in the sub-basin of the Itaquatiara stream, which demonstrates the incompatibility of these waters for human consumption without prior treatment.

However, it is worth mentioning that, due to logistical problems previously described, the values obtained for these parameters may be even higher than those recorded in the analyzes, especially in samples that showed results below the detection limit of the analytical method (ND), since the field inspections reported that practically all water bodies in the region have animal excrement on the banks.

Graph 5.1-28 – Index of Thermotolerant Coliforms (2008).

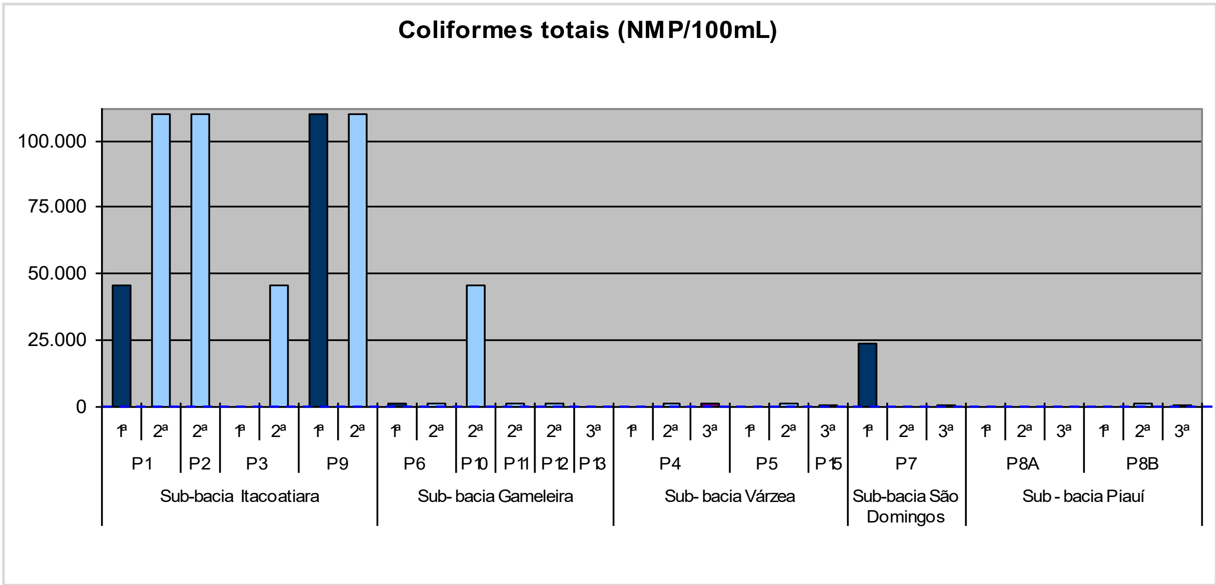


Total Coliforms

According to VON SPERLING (2005), total coliforms can be understood as "environmental" coliforms, as they can be found in non-contaminated waters, representing, therefore, free living and non-intestinal organisms. Ordinance 2914/11 defines the absence of these microorganisms in 100 ml of the sample as a standard for total coliforms. CONAMA Resolution 357/05 has no limits for this parameter.

The results obtained in the entire sampling network of the Piauí Nickel Project were very high in all campaigns, following the same pattern of the thermotolerant coliform indices, with maximum of 110,000 NMP / 100 ml detected in the Itaquatiara sub-basin (Points 01, 02 and 09), with emphasis on the second campaign, as illustrated in the graph below.

Graph 5.1-29 – Index of Total Coliforms (2008).



Chlorophyll-a and Pheophytin-a

Chlorophyll-a, common to all autotrophs, is the pigment responsible for the assimilation of light energy in the process of synthesis of organic matter. In aquatic systems, algae are the main organisms capable of performing photosynthesis, so that the increase in chlorophyll-a concentration indicates greater algae development in these environments. Pheophytin is the product resulting from the degradation of chlorophyll-a.

The CONAMA Resolution determines the maximum value of 30 µg / l for class 2 waters, without establishing limits for pheophytin. There are also no defined potability standards for these compounds. The results obtained in the three sampling campaigns indicate low levels of chlorophyll-a in all the sampled watercourses, compatible with the legislation in force, as well as for pheophytin, which had a maximum of 2.65 µg / l at Point 10, the Gameleira stream, downstream of the Caraíbas stream – at the Vale Scale 4.

Heavy Metals

On the Earth's surface, the concentration of metals is linked to the geological matrix in which they are associated. In the natural aquatic environment, metals are usually found in trace and sub-trace levels, and can occur in dissolved, colloidal and particulate (non-soluble) forms.

In the case of heavy metals, toxicity is high when they occur dissolved in water. However, the concentrations of the dissolved forms are generally very low, as soon as these elements enter the aquatic environment, as they tend to be quickly adsorbed in to suspended particles, especially by the finer ones, such as silt and clay, and then settle in the sediment (KENNISH, 1996).

In anoxic conditions, frequent in the bed of rivers rich in organic matter, some metals such as iron and manganese are mobilized from the sediments and remain dissolved in the water column, while other metals, such as cadmium, copper, zinc, chromium and nickel can be removed from the water column, by precipitation in the form of sulfides or by another type of reduction, becoming insoluble (CHAPMAN & WANG, 2001).

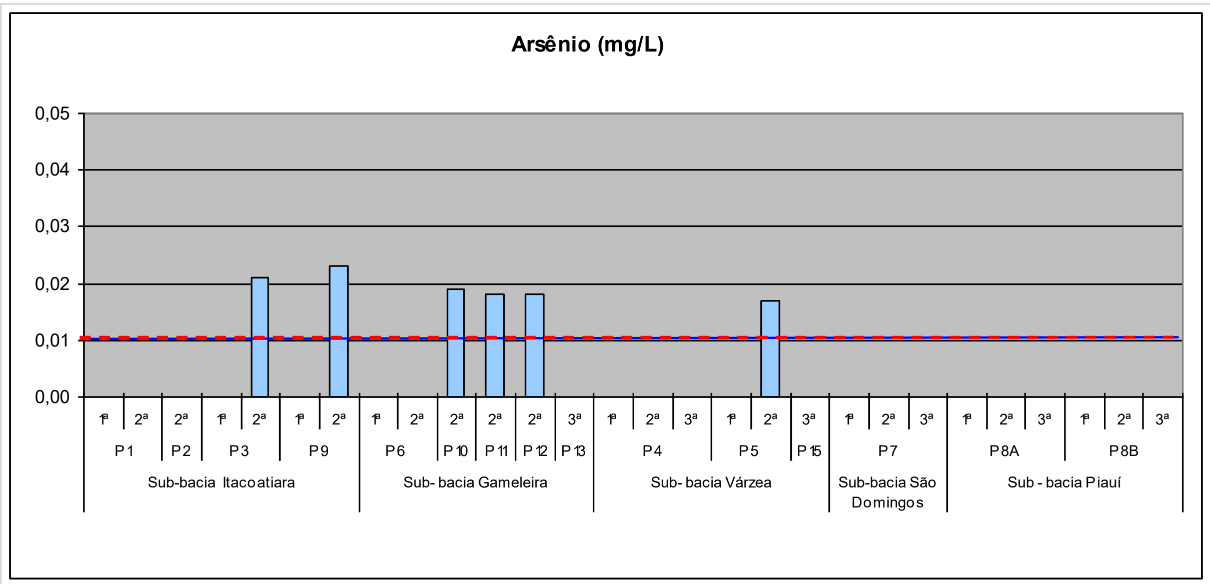
The following describes general aspects of the metals analyzed in the sampling network of the Piauí Nickel Project and the respective results. It should be noted that although some elements such as arsenic are not considered metals, they were also included in this item.

Total Arsenic

Arsenic is a metalloid with a wide distribution on the Earth's surface, generally associated with deposits of metallic minerals. It is used in the formulation of insecticides, herbicides, in the preservation of wood, being able to reach the aquatic system through diffuse sources or by leaching of effluent dumps. Given its characteristics, arsenic also produces toxic effects on aquatic biota.

CONAMA Resolution 357/2005 and Ordinance 2914/11 permit 0.01 mg / l of arsenic for fresh water. In the sampling network, this element was detected only in the rainy season, probably due to the effect of carrying particles from the soil to the waters, and it must be a characteristic element of the geological substrate of the region. In this campaign (March / 2008), concentrations above legal standards were obtained in the sub-basins of Itaquatiara (Points 03 and 09), Gameleira (Points 10, 11, 12) and Várzea (Point 05), in the range between 0.017 mg / l and 0.023 mg / l (Graph 5.1-30).

Graph 5.1-30 –Total Arsenic (2008).



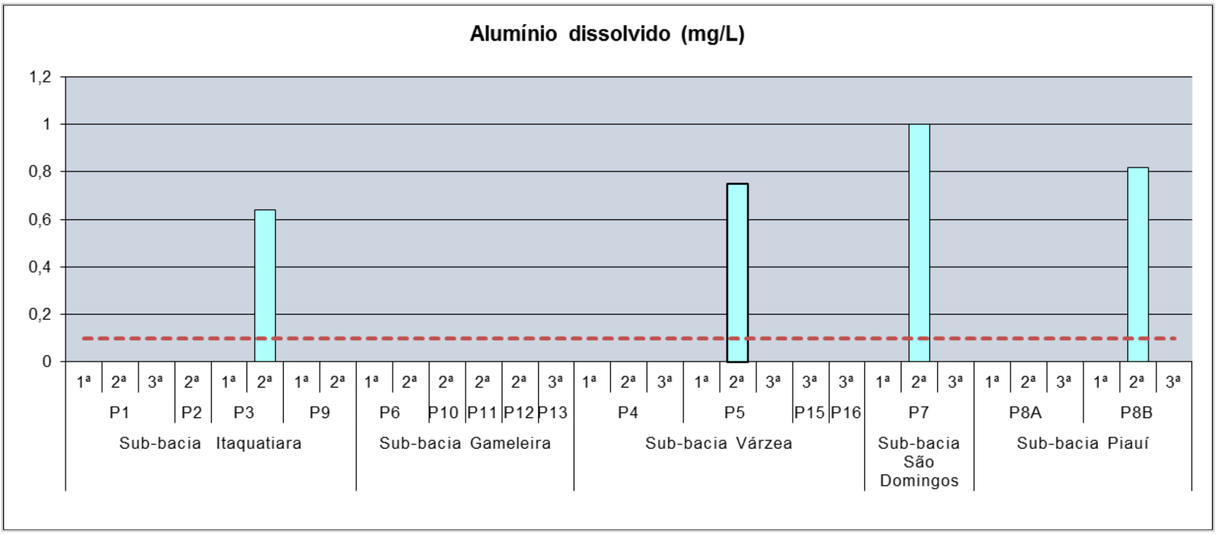
Dissolved Aluminum

Aluminum is found in mineral deposits in the form of bauxite. In water, aluminum forms complexes with other elements, such as phosphorus, being influenced by factors such as pH, temperature, presence of sulphates, organic matter and other binders. It is used as a flocculant in water treatment systems, serving to precipitate polluting compounds, such as phosphorus.

The increase in the concentration of aluminum in water bodies, in general, is due to the transport of solids from the drainage basin, especially in the rainy season, being associated with soil erosion processes. The limit established for dissolved aluminum by CONAMA Resolution 357/05 is 0.1 mg / l (class 2), while Ordinance 2914/11 does not establish a limit for the dissolved fraction of this parameter.

In the sampling network, aluminum was detected above legal standards only during the second campaign (rainy season), at Point 03 (Itaquatiara stream, downstream from the mouth of the Gameleira), Point 05 (Várzea stream, downstream from the mine), 07 (Eugênio reservoir) and 8B (downstream of the Jenipapo dam), with results ranging from 0.64 to 1.0 mg / l (Graph 5.1-31).

Graph 5.1-31 – Values for Dissolved Aluminum (2008).



Total Cadmium

This metal occurs naturally in the form of salts or sulfides, often associated with zinc, where it appears as an impurity. In natural waters, cadmium is found in minimal trace amounts. When introduced into the aquatic environment, it tends to be quickly adsorbed by particulate material, depositing in the sediment, whose mobility is now controlled by pH and redox potential. Cadmium has a high toxic potential, with a cumulative effect, and can be concentrated in fish tissues and other forms of aquatic life.

CONAMA Resolution 357/05 (class 2) and Ordinance 2914/11 provide for maximum limits of 0.001mg / l and 0.005 mg / l, respectively, for total cadmium. All samples collected in the three campaigns in the sampling network of the Piauí Nickel Project resulted in total cadmium levels below the detection limit of the analytical method, and are therefore consistent with the legislation in force.

Total Lead

In natural waters, lead is found only as a trace element. Its presence in higher concentration is associated with activities of mineral deposits or discharge of effluents. It has a toxic and cumulative effect, especially in ionic form. Chronic intoxication of this metal is called “saturnism” or, more commonly, lead poisoning, which can be frequent in workers exposed to the action of lead and its compounds.

The legal standard for fresh water and drinking water is 0.01 mg / l. In all campaigns carried out in 2008, the total lead results were below the detection limit of the analytical method.

Dissolved Copper

Copper is a widely distributed metal in the earth's crust. It is used, in the form of oxides and sulfates, in the manufacture of fungicides and algaecides, among other pesticides. Because it is a widely used metal, it is often found in wastewater and domestic and industrial sewage.

For man, copper is toxic when ingested in very high amounts. In water systems, it has a strong interaction with organic matter, which significantly reduces its bioavailability for aquatic organisms.

The results obtained at all points sampled in the three campaigns of the Piauí Nickel Project were below the detection limit of the analytical method, which does not allow establishing a direct correlation with the standard defined by the CONAMA Resolution (0.009 mg / l). Ordinance 2914/11 establishes a limit for this parameter only for its total portion.

Total Chromium

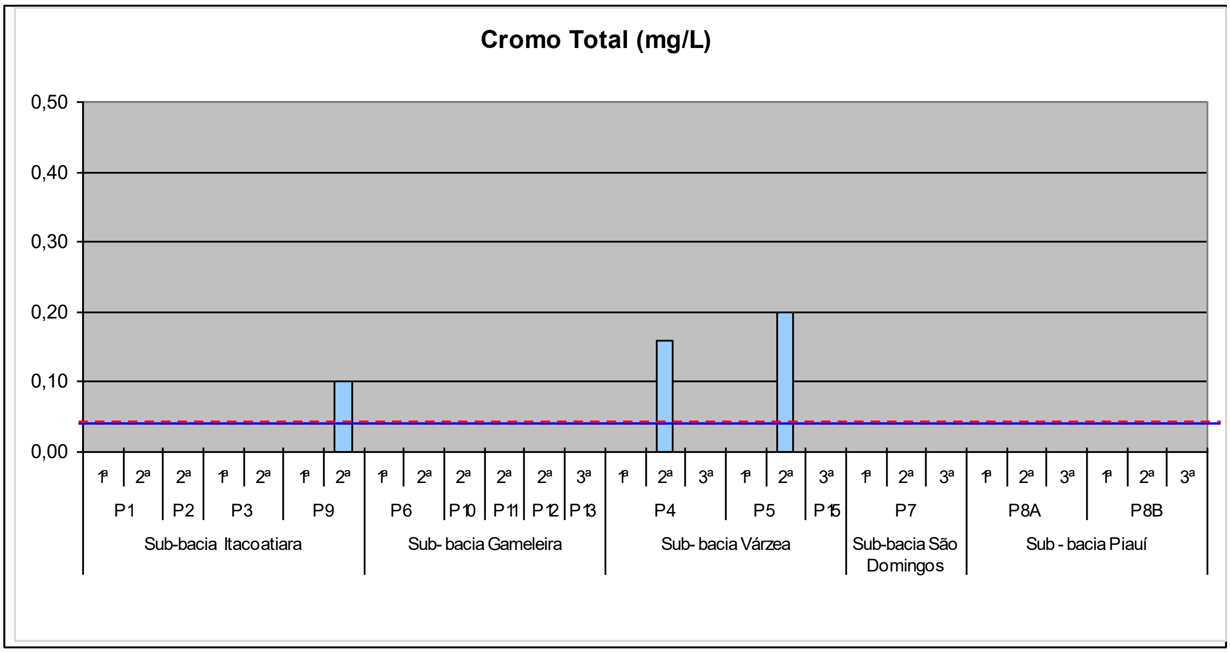
Chromium occurs naturally in several minerals, often associated with other metals. It is widely used in chroming (electroplating), and are also found in waters receiving untreated domestic sewage. This metal can accumulate in aquatic organisms, especially in filter feeders. The most stable forms are trivalent and hexavalent chromium, the latter considered carcinogenic to humans.

During the first campaign, the values found in most water samples were below the detection limit of the analytical method (0.01 mg / l), as well as the value established by CONAMA Resolution 357/05 and Ordinance 2914/11 (0.05 mg / l). The detectable result at Point 01, in the Itaquatiara stream (0.002 mg / l), is in line with current legislation.

In the second campaign, in the middle of the rainy season, Points 09 (Itaquatiara stream, R2-Lagoon), 04 (weir in the Várzea stream, upstream of the mining area) and Point 05 (Várzea stream, downstream of the mine area) showed values above the limit recommended by current legislation reaching 0.1 mg / l, 0.16 mg / l and 0.20 mg / l.

During the third campaign, the presence of total chromium was not detected in the samples, inferring that the occurrence of this metal is probably due to the geological characteristics of this region.

Graph 5.1-32 – Values for Total Chromium (2008).



Total Manganese

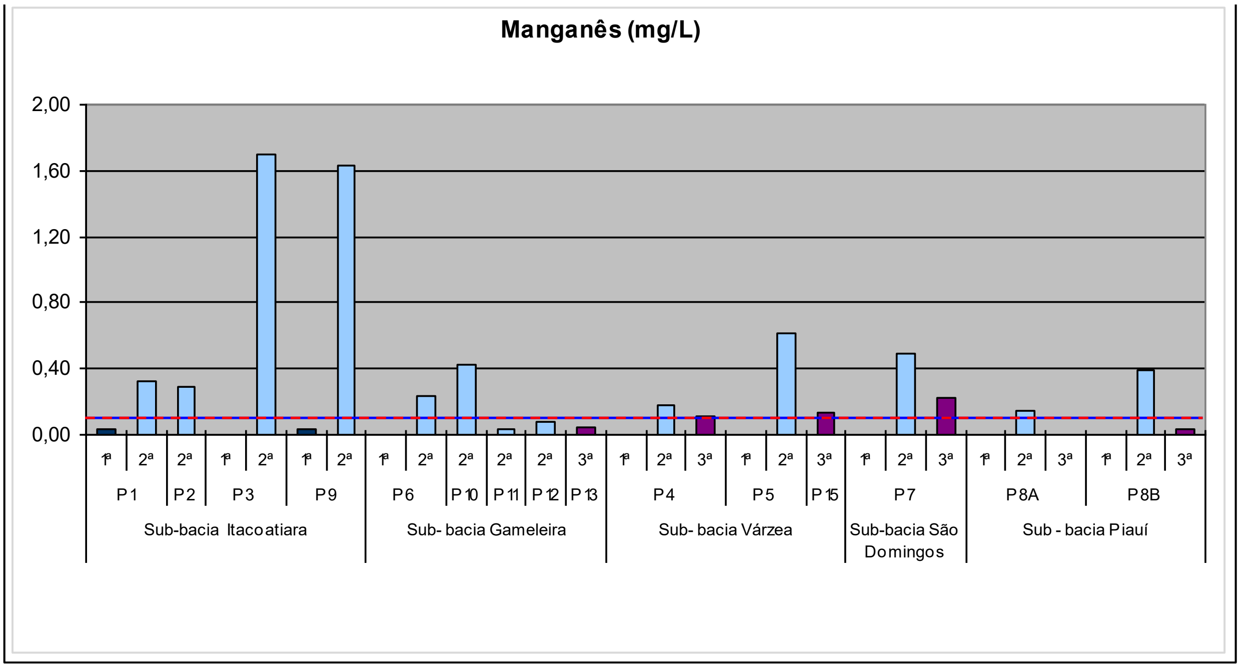
Manganese is an element found in most igneous rocks and is often associated with iron, with which it has a high degree of similarity in chemical behavior in the environment. High concentrations of these elements give taste and flavor to water.

No point belonging to the Piauí Nickel Project sampling network, during the first campaign, showed values above the limit established by CONAMA Resolution 357/05 (class 2) and by Decree 2914/11 (0.1 mg / l).

However, the occurrence of intense rainfall in the second campaign raised the level of total manganese in the samples in several sub-basins. Points 01, 02, 03 and 09 (Itaquatiara sub-basin) showed higher concentrations, between 0.3 and 1.7 mg / l. In the Gameleira and Várzea sub-basins, Points 05, 06 and 10 also showed manganese values not compatible with the legislation, between 0.25 and 0.60 mg / l. At Points 07 (the Eugênio reservoir) and 8B (downstream from the Jenipapo dam), results were obtained between 0.50 and 0.40 mg / l, respectively.

In the third campaign, only the weirs at Points 04, 15 (Várzea sub-basin) and 07 (Eugênio) showed values between 0.11 and 0.22 mg / l, incompatible with the potability and freshwater class 2 standards.

Graph 5.1-33 – Total Manganese (2008).



Total Mercury

Mercury is found in nature mainly in sedimentary rocks and clay sediments. When undergoing the process of methylation by living beings, this element changes to the organic form and can be accumulated by organisms in the food chain. It is a highly toxic element, both to man and aquatic organisms, occasioning very restrictive legal standards for its presence in the waters.

In all campaigns of the Piauí Nickel Project, the results of the collected samples were below the detection limit of the analytical method (0.0002 mg / l) and, therefore, were in accordance with the value determined by CONAMA Resolution 357/05 for fresh water class 2 (0.0002 mg / l) and Ordinance 2914/11 (0.001 mg / l).

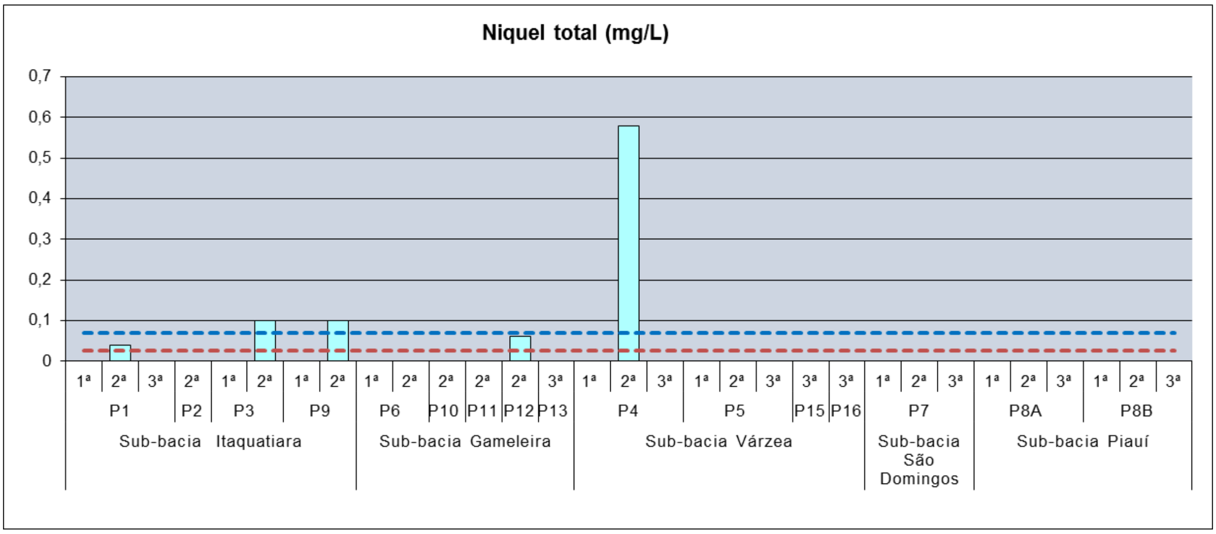
Total Nickel

Nickel is naturally present in the earth's crust, being explored by the project under analysis. The future mining and ore processing area of the Piauí Nickel Project is located in the sub-basin of the Várzea stream, which has a geological substrate enriched by this metal.

In the samples collected in the first and third campaigns, all nickel results were lower than the analytical detection method (0.002 mg / l), being in line with the legal limits established by CONAMA Resolution 357/05, which permits the maximum value of 0.025 mg / l as a standard for class 2 fresh water and with the limit of 0.07 mg / l established by Ordinance 2914/11 of the Ministry of Health.

In the second campaign, Points 01, 03, 09 (Itaquatiara sub-basin), 12 (Gameleira sub-basin) and 04 (Várzea sub-basin) showed nickel concentrations above the limits established by legislation, with values ranging from 0.04 mg / l and 0.58 mg / l, probably as a consequence of the contribution of solids from drainage basins.

Graph 5.1-34 – Values for Total Nickel (2008).



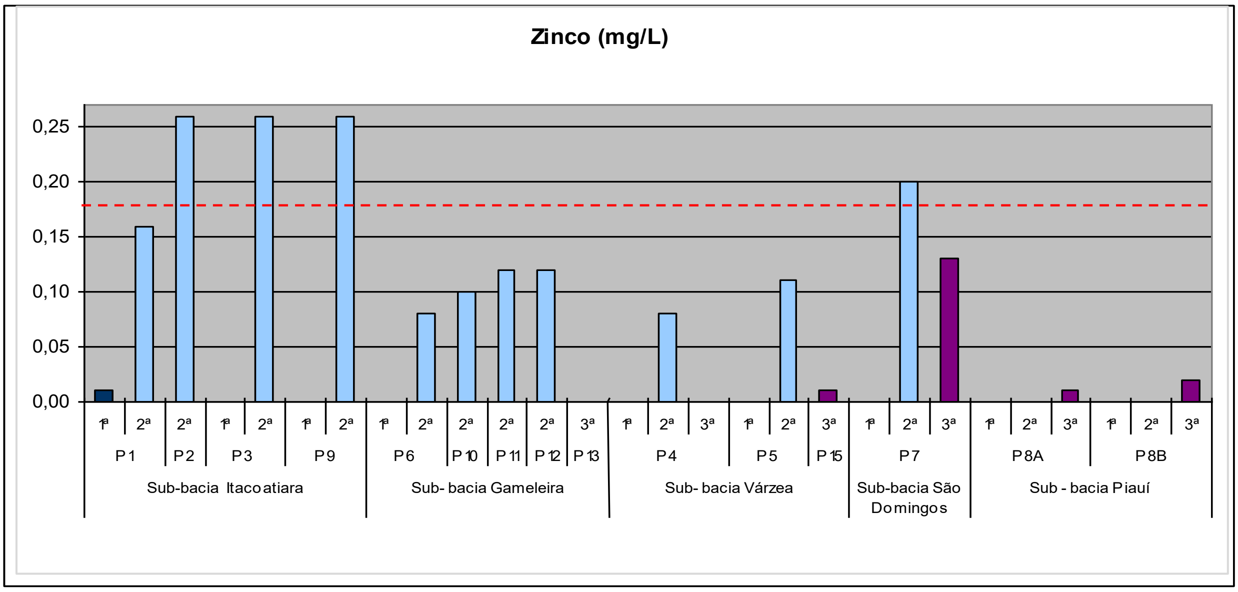
Zinc

Zinc is a metal widely distributed in nature, and its use in metal form or in metal salts is common, being present in homes (tiles, utensils) and in various products. This metal easily accumulates in filtering aquatic organisms and in fish.

For this element, CONAMA Resolution 357/05 defines the limit of 0.18 mg / l for class 2, while Ordinance 2914/11 establishes the value of 5 mg / l as a potability standard.

All points belonging to the sampling network of the first and third campaigns showed values lower than those defined by the current legislation. In the second campaign, Points 02, 03 and 09 (Itaquatiara sub-basin) and Point 07 (São Domingos sub-basin) showed a concentration of this metal higher than the limit set by CONAMA.

Graph 5.1-35 – Values for Total Zinc (2008).



Phenol

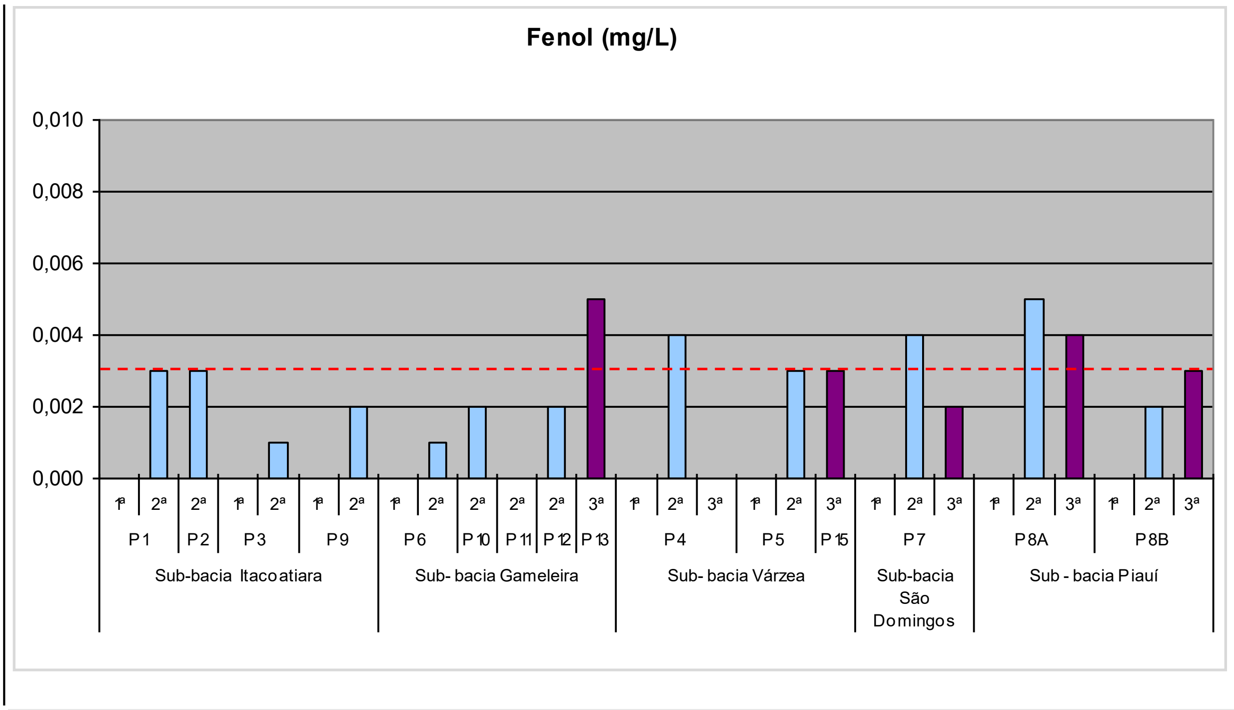
Phenolic compounds comprise a variety of organic substances, depending on the number of hydroxyl groups attached to the aromatic ring. Such products are derived from several sources, such as wood and coal processing, domestic sewage and pesticides in the biodegradation phase.

Phenolic compounds are toxic, affecting mainly aquatic fauna, in a concentration of 1 to 10 mg / l. The standard established by CONAMA Resolution 357/05 is 0.003 mg / l for freshwater class 2. This parameter is not considered by Ordinance 2914/11.

The results obtained in the samples of the first campaign were less than 0.001 mg / l, which corresponds to the detection limit of the analytical method adopted. In the second campaign, Points 04 (weir upstream from the mining area - Várzea sub-basin) and 07 (the Eugênio weir) showed concentrations above the limit determined by legislation (0.004 mg / l). At Point 8A (Jenipapo Dam), 0.005 mg / l was obtained.

During the third campaign, concentrations above the legal standard were obtained at Point 13 (Capitão Gervásio weir) and Point 8A (the Jenipapo dam), at 0.005 and 0.004 mg / l, respectively. Points 15 (the Várzea stream weir, downstream from the mining area) and 8B (downstream from the Jenipapo dam) showed values at the limit of this resolution (0.003 mg / l).

Graph 5.1-36 – Phenol Values (2008).



Anionic Surfactants

Analytically, detergents or surfactants are defined as compounds that react with methylene blue under certain specified conditions. These compounds are called "methylene blue active substances". They can have toxic effects on aquatic ecosystems and contribute to the acceleration of eutrophication.

The limit established by CONAMA Resolution 357/05 and Ordinance 2914/11 is 0.5 mg / l for freshwater class 2 and potability. All the results obtained, in the three campaigns of the Piauí Nickel Project, were below the limit recommended by legislation.

Oils and Greases

Oils and greases are organic substances of mineral, vegetable or animal origin, represented mainly by hydrocarbons, fats and esters. They are rarely found in natural waters. Its presence in water bodies is associated with the introduction of industrial dumps and waste, domestic sewage, effluents from mechanical workshops and gas stations and rainwater that drains roads and highways.

The layer of oils and greases that forms on the surface of the water can cause adherence in aquatic organisms. The low degree of solubility of these compounds reduces the contact area between the water surface and atmospheric air, restricting the transfer of oxygen in the aquatic environment.

CONAMA Resolution 357/05 establishes that oils and greases are virtually absent in fresh waters. Ordinance 2914/11 does not establish limits for this variable.

In the three campaigns analyzed, no detectable results of oils and greases were found, suggesting that there was no contamination by these compounds in the sampled waters.

5.1.7.4. Summary of Surface Water Quality

Based on the diagnosis of water quality and limnology, carried out in the area of influence of the Piauí Nickel Project, which was based on the results of three campaigns carried out in February, March and May 2008, it is possible to synthesize the most relevant aspects of ecosystem’s aquatic environments where the project is located.

The Parnaíba River behaves like the great watershed between rivers of different hydrological regimes. While on its left bank are located water courses with perennial characteristics, influenced by the tropical climate, on the right bank, where the Piauí Nickel Project's AII is located, the landscape of intermittent rivers begins.

Influenced by the semi-arid climate, these water courses have two distinct phases - the drought, which lasts most of the year, and the flood that normally occurs between January and March.

The AII and ADI are characterized by low drainage density and intermittent streams, such as the Gameleira and Várzea streams, in addition to stretches of the Itaquatiara, Caraíbas and São Domingos, contributors of the right bank of the Piauí River. These water courses are located on shallow and poorly permeable soils, which makes it difficult to store water in this region.

The river runoff regime also leads the population to adopt specific procedures aimed at accumulating and retaining water, such as the construction of cisterns and also small dams, spread along the drainage network.

The stored waters are used for different purposes, such as human supply, domestic activities, bathing, recreation, fishing and animal drinking. In the ADI, the Jenipapo dam stands out for its size. Built with the purpose of controlling the waters of the Piauí River, it is currently used for fishing, irrigation of vegetables, animal feed and is still used as a spa by the local population.

These regional climatic, hydrological and cultural characteristics are strongly reflected in aquatic ecosystems from both an ecological and public health standpoint.

Three factors contribute to the health problems of the regional population, related to water-borne diseases: low standards of basic sanitation in most villages, direct use of water for human consumption without previous treatment and a high level of water eutrophication, which provides development of cyanobacteria.

The following is a summary of the most relevant aspects of the sampled sub-basins from the point of view of water quality.

(i) Itaquatiara Sub-basin

Intermittent stream, with a dry bed at its largest extent during the dry season, except upstream of the confluence with the São Romão stream. In total, four points were sampled in the Itaquatiara (01, 02, 03 and 09), respectively from upstream to downstream, in order to monitor the activities of the future limestone quarry and access roads. As mentioned above, two of these points (01 and 03) constituted *cacimbas* in the first campaign, which were covered in the rainy season by surface runoff. No dams were observed in the sections inspected in the field.

In its natural condition, this stream maintains freshwater characteristics in the rainy season, although with higher levels of chlorides, and pH tending to alkalinity, due to the presence of limestone in this region, which also creates higher hardness.

From an ecological point of view, the Itaquatiara behaves as a collection channel for other drainages during the rainy season, with satisfactory dissolved oxygen levels, with the Jenipapo dam, downstream, the main water body receiving its waters.

When the rainy season ends, the remaining water collection structures, including *cacimbas*, tend to concentrate nutrients, favoring intense algal blooming, as observed in the Itaquatiara upstream from the São Romão stream, near the Jenipapo dam (Point 09). In this stretch, there is fishing activity, which consists of a source of protein for the villages dispersed in this region. During the drought, the available springs are used to supply communities directly and for animal watering.

The main sources of pollution in this sub-basin are of diffuse origin, due to the presence of residues and animal waste that alter the quality of the waters from a sanitary point of view. Erosive processes contribute to an increase in the color and turbidity of water, as well as metals, such as iron, manganese, chromium, nickel, zinc, aluminum and arsenic, which are characteristic of the regional geological substrate, compromising, during the rainy season, the pattern of potability.

(ii) Gameleira Sub-basin

An intermittent stream, with the longest dry bed during the dry season. The selected sampling points aim to control the mining area and access roads associated with the future development (Points 06, 10, 11, 12), in addition to the reservoir in the city of Capitão Gervásio Oliveira (Point 13), intended to supply the local population.

In its natural condition, this stream has freshwater characteristics in the rainy season. From an ecological point of view, the Gameleira behaves as a collection pathway for other drainages during the rains, with satisfactory dissolved oxygen levels, with the Itaquatiara stream being the main receiving body of its waters.

After the rainy season ends, the remaining water collections, particularly in more confined valleys, also tend to concentrate nutrients, with sparse fishing activity occurring, which consists of a source of protein for the villages dispersed in this region. During the drought, the available springs are used to supply communities directly and for animal watering.

The main sources of pollution in this sub-basin are of diffuse origin, due to the presence of residues and animal waste that alter the water quality from a sanitary point of view, as observed with greater evidence at Point 10 (downstream from the Caraíbas stream). Erosive processes contribute to the increase in color and the high levels of turbidity shown by the waters, especially at Point 06, reaching 425 UFT in the rainy season. During the rains, watercourses tend to retain a greater amount of metals, such as iron, manganese, arsenic and nickel, which are characteristic of the regional geological substrate, compromising potability.

Specifically, with regard to the Capitão Gervásio reservoir, high phosphorus levels and the presence of iron and phenols in the water at concentrations not compatible with class 2 standards are noted.

- **Várzea Sub-basin**

The Várzea stream, with an intermittent regime, maintains runoff in some stretches during the dry season, being intercepted by several weirs. On its left bank the Piauí Nickel Project pilot plant is located, currently in operation, as well as the main structures planned for the exploitation of the mine and the processing of the ore. In this sense, the Várzea stream will be one of the main water courses to potentially suffer the effects of the project's operation, and the analyzes carried out in these campaigns will serve as a reference for future monitoring.

In total, four points were sampled in this sub-basin, three weirs (Points 04, 15 and 16) and one point in the Várzea stream, where it has a permanent flow (Point 05).

Naturally, this stream contains high levels of mineral salts, especially calcium. The substrate characteristics give the waters alkaline pH, hardness and alkalinity expressed as bicarbonate, mainly in the weir at Point 04, where this last parameter reached a value of 600 mg / l of $CaCO_3$ during the drought. As a consequence, the Várzea sub-basin is the one with the highest levels of salinity throughout the sampling network, already being at the limit of the freshwater classification considered by CONAMA Resolution 357/05 (0.5 ‰).

From an ecological point of view, the Várzea stream provides support for the establishment of aquatic biota adapted to predominantly lentic environments, with a high concentration of phosphorus. The alkaline pH also favors the formation of toxic ammonia compounds. A concentration of phenols was also detected at this point, which represent a contaminant to the aquatic environment.

The waters of this sub-basin are used for direct consumption by sparse households, as well as for the watering of animals, especially at Point 05. The main potential factor of interference in water quality corresponds to the mineral exploration activity itself. Erosive processes in this region contribute to the increase in water color and turbidity, in addition to metals, such as iron, manganese, nickel, aluminum and arsenic, characteristic of the regional geological substrate, whose concentrations compromise the potability during the rainy season.

- **Piaui Sub-basin**

The Jenipapo dam represents the main body that receives water in the sampled water network, with the exception of Point 07, in the São Domingos stream, whose mouth is located downstream of this reservoir. The Jenipapo dam was sampled in the vicinity of the dam (Point 8A) and downstream of it (Point 8B). Its waters are destined for multiple purposes, including irrigation of vegetables, animal feed, fishing and recreation, and it is also considered as an option for capturing water for the Piauí Nickel Project.

Under its natural conditions, the Jenipapo dam has freshwater characteristics (maximum salinity of 0.2 ‰) and a pH of around 7.5.

From an ecological point of view, it has satisfactory oxygen levels in the surface layers, despite higher concentrations of organic materials detected in this environment. The sedimentation of particles along the dam reduces turbidity, increases the level of transparency of the waters, which, associated with high levels of phosphorus and high temperatures, favor the development of cyanobacteria, as will be presented in section 5.2.5.2 on Hydrobiological Communities. The concentration of phenolic compounds detected in the analyzed samples must be considered as an adverse factor to aquatic communities.

In general terms, the quality of this dam is at a higher level than the other sampled water systems, with low levels of coliforms, lower concentration of metals in the waters, however, the levels of iron and manganese are not in conformity with current legislation. Point 8B downstream has practically the same pattern observed in the dam, showing a reduction in phosphorus contents that, together with metals, must precipitate in the upstream sediments.

- **São Domingos Sub-basin**

This sub-basin was sampled only at the Eugênio reservoir (Point 07), aiming at controlling the implementation of the project's transmission line. This weir remains perennial during the dry season, and its waters are currently only destined for the watering of animals.

In its natural condition, it has a maximum salinity of 0.3 ‰ and pH tending to alkalinity, reaching 8.15 in the first campaign.

The main sources of pollution in this sub-basin are of diffuse origin, due to the presence of residues and animal waste that alter the quality of the waters from a sanitary point of view. Erosive processes contribute to an increase in color and turbidity. This point stands out in the entire sampling network due to the very high peak of turbidity in the rainy season (1,600 FTU), a period in which water courses tend to concentrate a greater amount of metals, such as iron and manganese, exceeding class 2 limits.

From an ecological point of view, high levels of solids and low values of dissolved oxygen limit the establishment of aquatic biota, even in the face of the highest concentration of phosphorus. It is also necessary to consider the adverse concentration of phenolic compounds that are contaminants in the aquatic environment.

5.1.8. Hydrogeology and Underground Water Resources

5.1.8.1. Regional Hydrogeological Context - Area of Indirect Influence (AII)

A bibliographic survey was carried out to characterize the regional hydrogeological context and the distribution and description of the local hydro-stratigraphic units, to document the main characteristics and evolution of the physical and biotic media that are present in the area where the project is located and especially in its AII.

The following studies were used to prepare this section:

- Mapping and analysis of Brazil’s Hydrogeological Map to the Millionth – CPRM (2014).
- Assessment of Underground Water Availability in the area of the Piauí Nickel Project - MDGEO (2008).
- Serra Grande Aquifer Diagnostic Report – Integrated Groundwater Monitoring Network (RIMAS) – CPRM (2012).
- Piauí State Water Resources Plan – SEMAR, 2010; and
- Diagnosis of the Capitão Gervásio de Oliveira Municipality – Registration of Groundwater Supply Sources Project – Piauí – CPRM (2004).

A) Conceptual Hydrogeological Model of the AII

Approximately 35% of the AII's surface is over the *Parnaíba* sedimentary basin, as shown in the AII's Map 5.1-19 and Data Table 5.1-20. The other 65% is divided into Crystalline, Metasedimentary / Metavolcanic domains, by undifferentiated Cenozoic formations and by carbonates-metacarbonates in a small area.

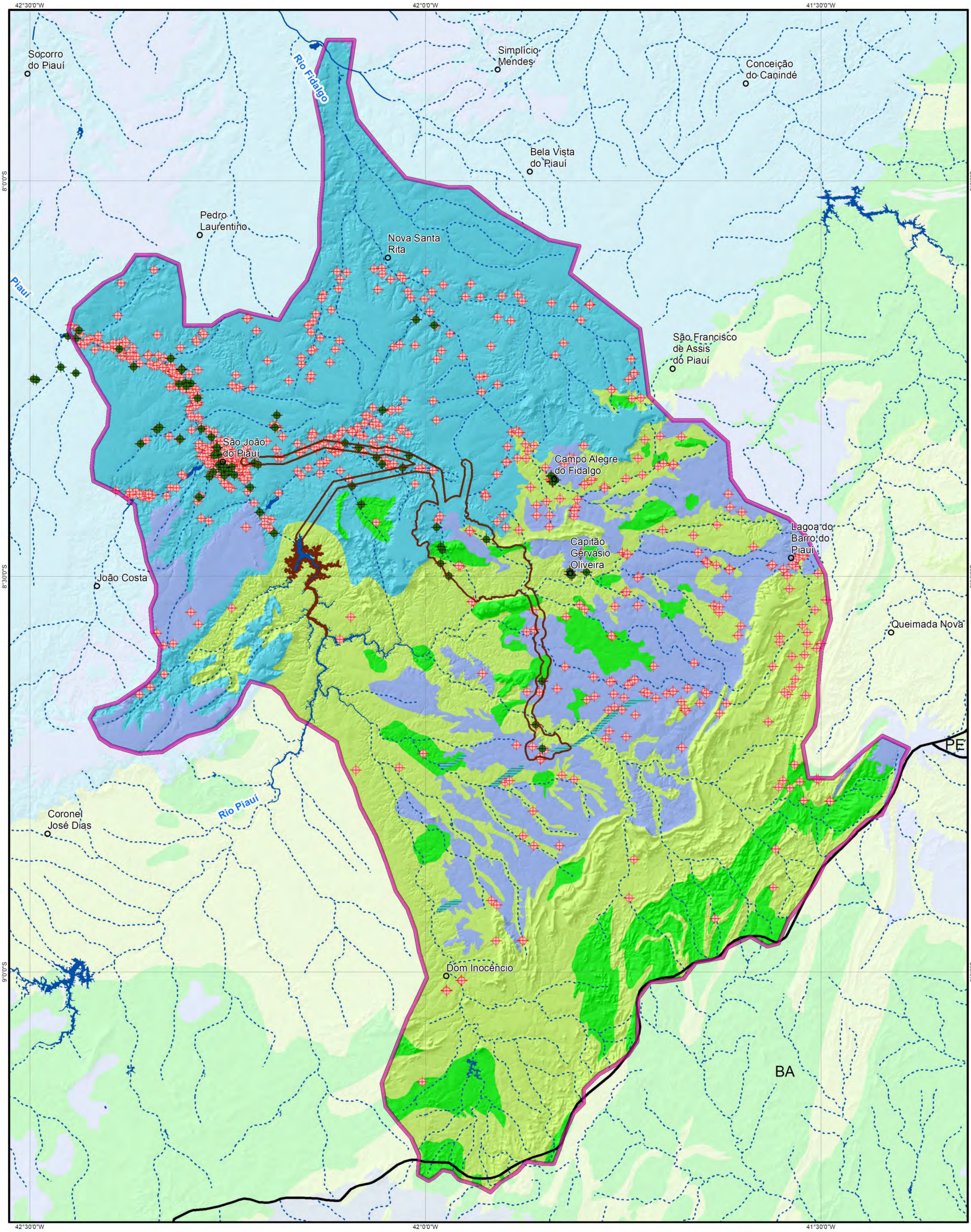
Crystalline domain aquifers are characterized by low to very low hydrogeological favorability, where their basic lithology is represented by *grantoids, gneisses, granulates, migmatites, basic* and *ultrabasic*. As the primary porosity of these rocks is practically nonexistent, the occurrence of groundwater is conditioned to secondary porosity represented by fractures and cracks, which gives its name as "*fissural aquifer*".

Data Table 5.1-20 – Quantification of AII Domains.

Domains	Km²	%
Parnaíba Basin	3,118.91	35%
Carbonates-Metacarbonates	19.41	>1%
Crystalline	863.74	10%
Cenozoic Formations	1,562.42	18%
Metasedimentar-Metavulcanics	3,260.50	37%
Total	**8,824.98**	**100%**

Source: CPRM, 2014. Prepared by: Arcadis, 2017.

Map 5.1-19 – Hydrogeological Domains – All.



LEGENDA

- Municipal Headquarter
- Perennial Drainage
- Intermittent Drainage
- Water Mass
- Area of Indirect Influence - AII
- Area of Direct Influence - ADI

Wells

- SIAGAS Well
- MDGEO Well

Domain – AII

- Parnaíba Basin
- Crystalline
- Undifferentiated Cenozoic Formation
- Metasedimentary - Metavolcanics

REFERÊNCIAS

Bases Cartograficas ao Milionésimo, IBGE, 2014.
Mapa de Domínios/Subdomínios Hidrogeológicos do Brasil, 1 :2.500.000. CPRM, 2005

ESCALA GRÁFICA
0 5 10 km

Sistema de Coordenadas: GCS SIRGAS 2000

LOCALIZAÇÃO

PIAUÍ NÍQUEL | ARCADIS Design & Consultancy for natural and built assets

EIA/RIMA – PROJETO PIAUÍ NÍQUEL

Map 5.1-19 – Hydrogeologic Domains AII

EXECUTADO POR:	ESCALA	FORMATO:	FOLHA:	DATA:
ARCADIS	1:500.000	A3	ÚNICA	JUN /2017

These underground reservoirs, due to their uniqueness water packing, are random, discontinuous, and small extensions. In general, the flows produced by wells installed in these areas are small and the water is salinized due to the lack of circulations and the type of hosting rocks.

Most of these lithotypes generally occur in the form of large and extensive massive bodies with infrequent discontinuities. These domains tend show the least chances for groundwater accumulation when comparing with those fissural aquifers.

The Metassedimentary/Metavolcanic aquifers are mainly represented by the lithotypes described as schist, phyllite, met arenite, metassiltites, amphibolite, quartzites, slates, metagraywacke and various metavolcanics. These aquifers are of the fissural type where the water packing is due to secondary porosity and shows low hydrogeological favorability. Due to these characteristics, the wells installed in these areas normally produce low flows and the water is also salinized.

However, although this domain has a similar behavior to the traditional Crystalline (Granites, migmatites, etc.), a separation between them is necessary considering that the rocks have different rheological behavior due to its different structure and competence (they react differently to the forces applied by cracks and fractures). Typically, these show greater hydrogeological favorability that the traditional Crystalline.

The aquifer of the *Parnaíba* sedimentary basin is the most important in the State of Piauí occupying about 75% of its surface, covering and area of 600,000 km². This basin formed in the Paleozoic can be divided into two classes when considering its hydrogeological favorability:

- Very high to medium: Represented by the main aquifer units in the basin (*Cabeças, Serra Grande, Poti, Grajaú, Itapecuru e Piauí*). Its hydrogeological favorability decreases at the edges of the basin. It is lithological represented by sandstones of different granulometries, siltstones, conglomerates supported by the matrix and siltstones and subordinate shales. Scarce levels of limestone are also noticeable. Generally, the water quality is good (not brackish, potable).
- Low: Includes the *Codó, Corda, Longá, Motuca, Pastos Bons, Pedra de Fogo, Pimenteiras e Sambaíba* formations where pelitic sediments of low permeability are predominant over *psamitos* and *psefitos*. The rocks present includes a variety of sandstones, clay stones, siltstones, shales and carbonates.

Undifferentiated Cenozoic Formations do not have a good hydrogeological favorability and are considered low. These formations include deposits of sand, silt, clay, gravel (lateritized or not), ferruginous laterites and undifferentiated colluvial and eluvial sediments. They are characterized by small thickness, short continuity and may have some hydrogeological importance as a recharge area or temporary stock for underlying aquifers.

Aquifers engendered by carbonate / metacarbonate formations have variable hydrogeological favorability. These aquifers are found in lands where limestone and dolomitic limestone predominate. Their main characteristic is the constant presence of forms of karst dissolution (chemical dissolution of limestone rocks) such as caves, sinks, sinkholes, dolinas and other erosive characteristics typical of these types of rocks.

Fractures and other forms of discontinuities are expanded by dissolution processes and provide this system with a secondary porosity that allows the accumulation of considerable volumes of water. However, this condition of underground water reservoir does not occur homogeneously throughout the entire area; on the contrary, they are localized which give high heterogeneity and anisotropy to the aquifer system. In general, the water is carbonated and with very high hardness.

B) Underground Water Potential

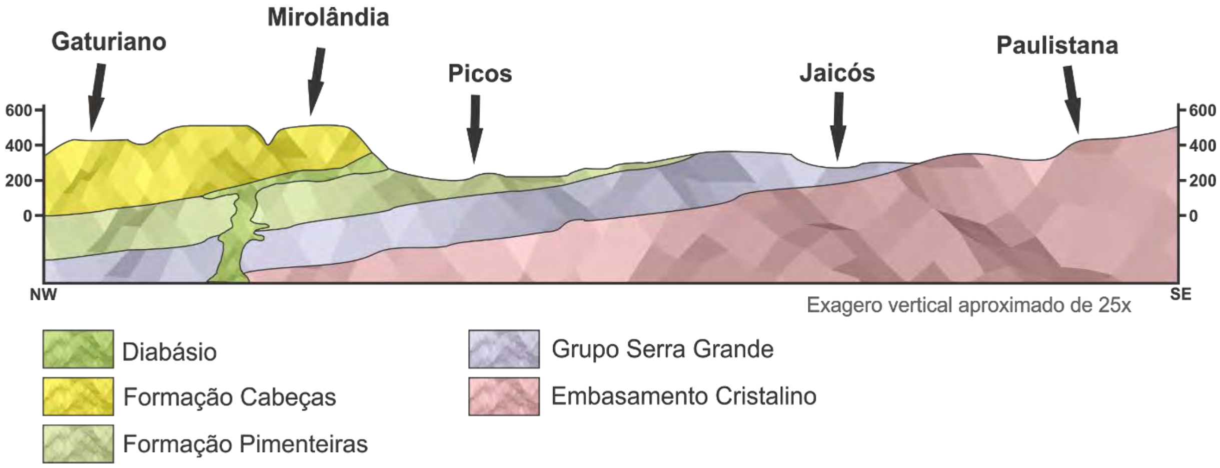
The assessment of the potential and availability of underground water in the Piauí State was developed based on studies made available by *Secretaria Estadual de Meio Ambiente e Recursos Hídricos* (SEMAR / PI, 2010) and by the *Serviço Geológico do Brasil* (CPRM, 2004, 2012, 2014), where wells distributed in the 11 aquifers of the *Parnaíba* Sedimentary Basin were analyzed subdivided into the following hydrogeological units: *Serra Grande, Pimenteiras, Cabeças, Longá, Poti/Piauí, Pedra de Fogo, Pastos Bons, Corda, Barreiras, Aluviões, Dunas and Fissural Cristalino*.

According to MDGEO (2008), the *Serra Grande, Pimenteiras* and *Cabeças* hydrogeological units are the only ones located in the AII, therefore only the results from these aquifer systems will be considered in this study.

The *Serra Grande* formation contains basal conglomerates, arcosean and conglomeratic sandstones, formed during the lower *Silurian/Devonian*. The *Pimenteiras* formation is classified as a lower *Devonian* unit and its basic lithology consists of fine sandstones with intercalations of siltstones and shales. The *Cabeças* formation was formed in the middle *Devonian*, and present medium to coarse grained sandstones, phyllites and rare shales.

From a stratigraphic point of view, the *Serra Grande* aquifer is confined by the shales of the *Pimentairas* formation, and sits directly on the crystalline basement rocks, as shown in Figure 5.1-8. The sedimentary package has a gentle drop to the east, towards the groundwater.

Figure 5.1-8 – Schematic Section of the Lithostratigraphic Units in the Parnaíba Basin (modified from CRUZ E FRANÇA, 1967)



Source: CPRM, 2012. Prepared by: Arcadis, 2017.

The assessment of reserves, potentialities, availability and exploitable resources was carried out by IBI Engenharia Consultiva S/S, based on the COSTA methodology (1998), with modifications subsequently introduced in COSTA (2005). The results of this study are presented in Data Table 5.1-21.

Data Table 5.1-21 – Assessment of the Aquifers and Aquitards Exploitable Resources of the *Parnaíba* Sedimentary Basin, in the project AII.

Hydrogeological Unit	Regulatory Reserves (hm³/year)	Potentiality (hm³/year)	Availability (hm³/year)	Usable Resources (hm³/year)
Cabeças	636.00	894.40	31.24	481.56
Pimenteiras	41.00	71.30	5.77	40.93
Serra Grande	487.50	1,512.40	27.12	1,192.78
Total	**537.50**	**1,605.10**	**37.58**	**1,245.02**

Source: SEMAR, 2010; Prepared by: Arcadis, 2017.

Where, the **permanent reserves** correspond to the accumulated water volumes that are independent of periodic or seasonal variations, while the **regulatory reserves** refer to the volume of renewable water at each annual or interannual period, corresponding to the aquifer recharge (Hydrogeological evaluation of the *Araripe* sedimentary basin, Recife, 1996, DNPM).

The **potentiality** refers to the amounts exploitable including a portion of the permanent reserves which can be used at a constant discharge during a certain period.

The effective **availability** represents the annual volume currently used by existing activities.

The **usable resources** are the maximum portion of the potential that can be used annually without causing a depletion in permanent reserves.

According to Data Table above, and as already mentioned in the geological context of the AII (Item 5.1.2.1.B), there is a significant hydrogeological potential and availability in the *Serra Grande* formation. The physical and chemical aspects of this formation need further analysis to determine the use of its groundwater. Santiago et al. (1982) verified that there is an increase in the salinization of the water as it moves away from the recharge zone towards the interior of the basin which may limit its use for some applications.

The Map of Hydro stratigraphic Units of the AII shows that the hydrogeological favorability is intrinsic to geological formations. In this case, it increases heading north towards the *Parnaíba Sedimentary* basin. This significant potential is also demonstrated by the high density of wells located in this sedimentary domain that are registered in SIAGAS/CPRM.

5.1.8.2. Local Hydrogeological Characterization - Area of Direct Influence (ADI) and Area Directly Affected (DAA)

In addition to the bibliography cited in the previous item, the following primary data were generated and analyzed from field works done in the project area:

- Underground Water Availability Assessment Report in the Piauí Nickel Project Area – MDGEO (2008).
- Deep Tubular Wells located in the Crystalline domain of the Piauí Nickel Project Area – MDGEO (2008).
- Geotechnical Survey, Pilot Plant, Piauí Nickel Project – PROGEO (2006); and
- Self-monitoring Reports of Groundwater and Liquid Effluents – Vale – Piauí - SGS GEOSOL Laboratórios LTDA (2010 a 2012).

A) Conceptual Hydrogeological Model of the DAA and ADI

In the ADI, according to the hydrogeological domains map of the ADI / DAA (Map 5.1-20), the largest domain found belong to the metamorphic units (metaigenic and metasedimentary), occupying 44% of the area. Further north, in the areas of the proposed water pipeline and power transmission line, the *Parnaíba* basin is located occupying 38% of the surface. The quantification of the domains and subdomains in the ADI is presented in Data Table 5.1-22.

Data Table 5.1-22 – ADI Domains Quantification.

Domains	Km²	%
Bacia do *Parnaíba*	93.54	38%
Cenozoic undifferentiated	40.17	16%
Crystalline	6.00	2%
Metamorphic	64.19	26%
Metasedimentary	45.49	18%
Total	**249.39**	**100%**

Source: CPRM, 2014. Prepared by: Arcadis, 2017.

The crystalline base in the southeastern portion of the state of Piauí consists of a volcano sedimentary sequence, intruded by mafic-ultramafic bodies, metamorphosed as the *Brejo Seco* basic-ultrabasic complex present mainly in the area of the pilot plant. These rocks are often lateritized and altered. Further south, in the area called *Umbuzeiro*, carbonate protolite rocks are observed, which characterizes the area as a karst hydrogeological domain.

As per described on item 5.1.2.1.B) – Geology, three formations are present in the *Parnaíba* basin domain:

- *Serra Grande* formation: Constituted by conglomerates and conglomeratic sandstones in the basal portion, overlaid by well selected sandstones, fine to medium, with a fine clastic sequence until reaching a typically pelitic facies at the top of the unit;
- *Pimenteiras* formation: Consisting of clastic and pelitic facies, with a predominance of fine clastic; and,
- *Cabeças* formation: Formed from the base to the top by poorly selected coarse sandstones, siltstones with interspersed levels of shales and fine sandstones.

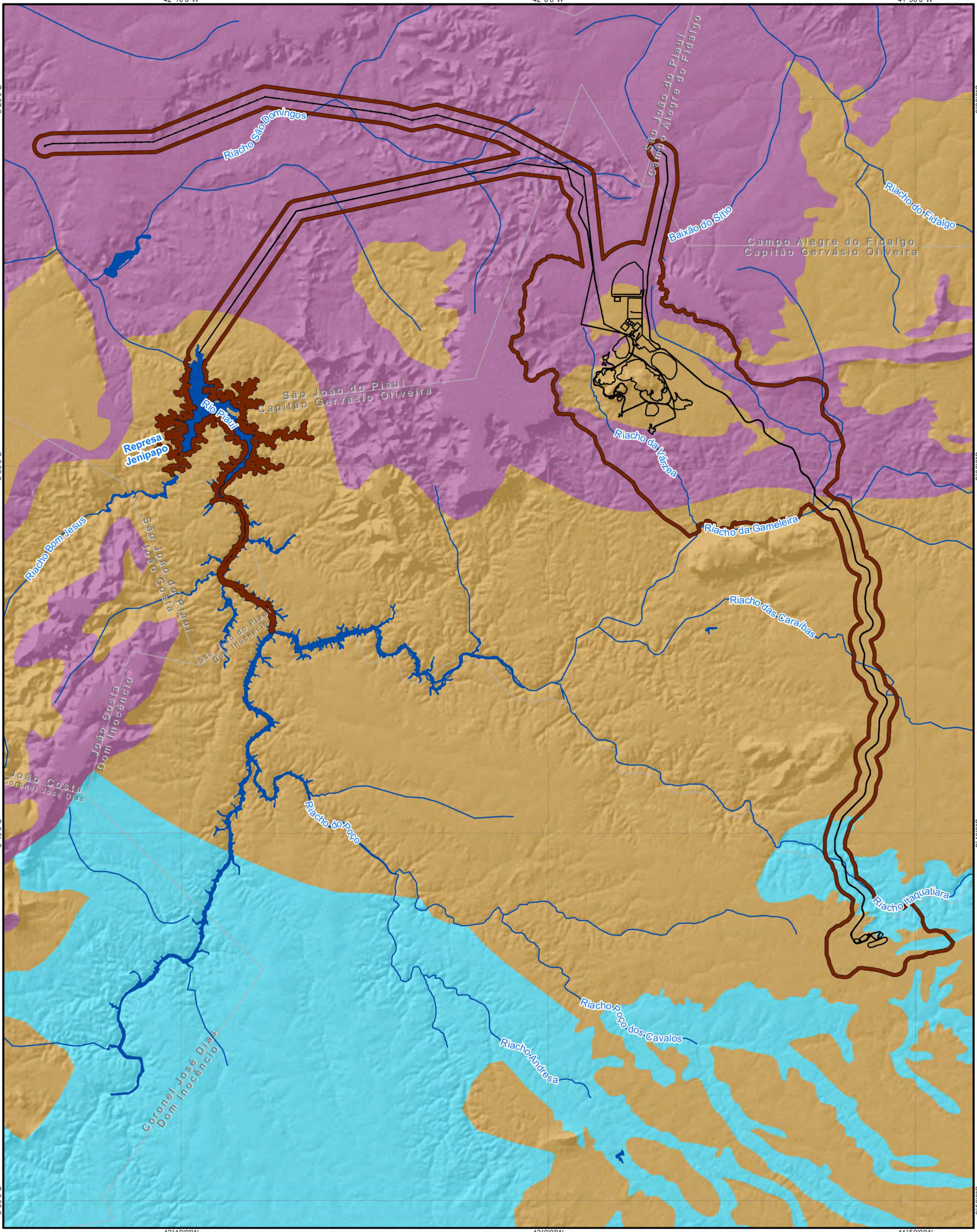
The area was divided into two distinct hydrogeological domains based on these lithostratigraphic properties:

- Crystalline Hydrogeological Domain (CHD): Precambrian crystalline basement rocks.
- Sedimentary Hydrogeological Domain (SHD): Sedimentary rocks of the *Parnaiba* basin composed by:
  - *Serra Grande* aquifer.
  - *Pimenteiras* aquitard.
  - *Cabeças* Aquifer.
  - Aquifuges on basement rocks.

The occurrence of basic intrusions of *Cretaceous* age also influence the hydrogeological behavior of these units.

The analysis of the hydrogeological domains characteristics in the area was carried out based on the work done by CPRM and also on the wells inventory carried out by MDGEO, which can be found in Figure I – Localization of Wells and Table I - Registered wells, in ANNEX IV (Volume IV).

Map 5.1-20 – Hydrogeological domains and subdomains – ADI / DAA.



Cartographic Convention

- Hydrography
- Water Mass
- Area of Direct Influence - ADI
- Directly Affected Area - DAA

Aquifer

- Karstic
- Fissural
- Granular / Fissural

REFERÊNCIAS

CPRM, Geodiversidade Piauí, 2014.
SRTM/Topodata, consulta 2016.
Projeto RADAM - mapas.ibge.gov.br
Cartas SC23, SB23, SC24, SB24.

ESCALA GRÁFICA
0 2,5 5 km

Sistema de Coordenadas: GCS SIRGAS 2000

LOCALIZAÇÃO

PA, MA, CE, RN, PB, PI, PE, TO, BA

Piauí Níquel
ARCADIS Design & Consultancy for natural and built assets

EIA/RIMA – PROJETO PIAUÍ NÍQUEL

Map 5.1-20 – Hydrogeologic Domains ADI and DAA

EXECUTADO POR:	ESCALA	FORMATO:	FOLHA:	DATA:
ARCADIS	1:180.000	A3	ÚNICA	JUN /2017

a) Crystalline Hydrogeological Domain – CHD

Crystalline rocks do not have primary porosity and the occurrence of groundwater is conditioned by secondary porosity (defects and fractures). This characteristic defines the so-called fissural aquifers as random, discontinuous and small basins (AGUIAR & GOMES 2004a).

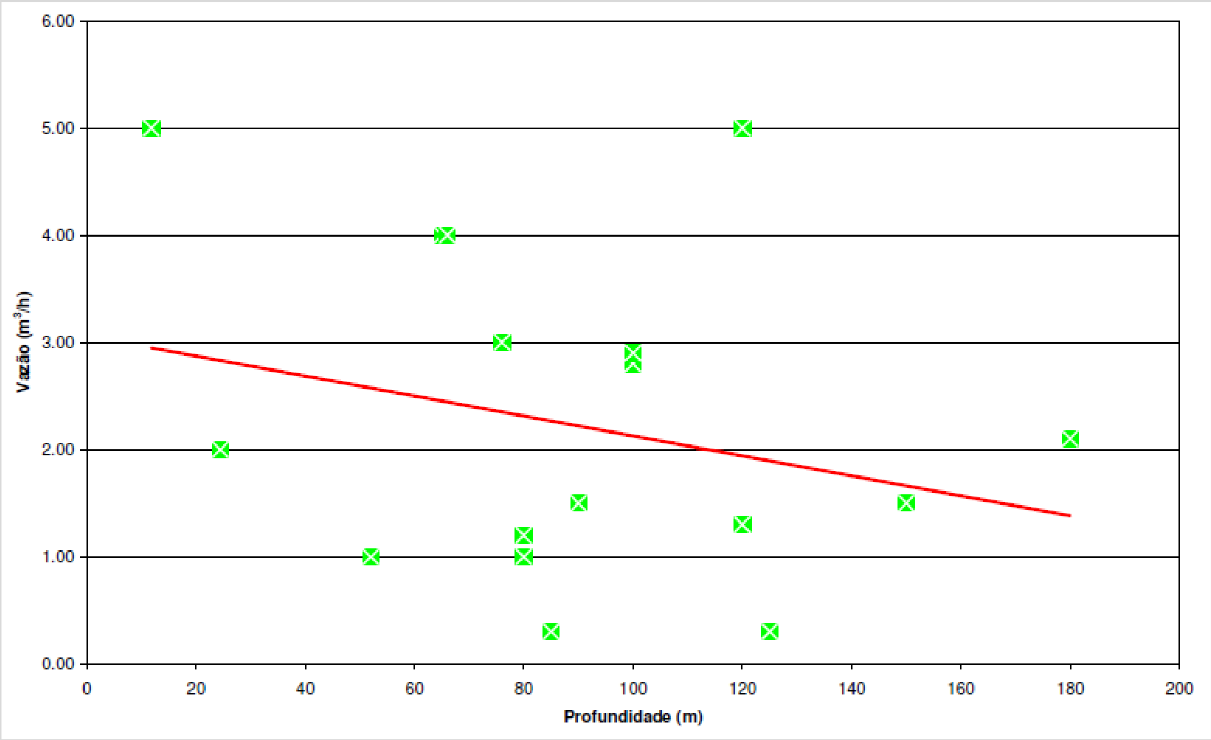
The underground water flow regime in the CHD rocks occurs through these defects and fractures in a downward direction with recharge occurring through the thin, and sometimes non-existent, layer of soil that covers the crystalline basement rocks (MDGEO, 2008).

Although the wells drilled in the CHD produce a low flow of (in most cases) salinized water, AGUIAR & GOMES (2004a) consider important to maintain the CHD as a strategic alternative reserve specially for regions with long periods of drought.

In the well inventory carried out by CPRM (AGUIAR & GOMES, 2004a; AGUIAR & GOMES, 2004c; CPRM, 2008), 139 tubular wells were documented in the municipalities of *Capitão Gervásio de Oliveira* and *Campo Alegre do Fidalgo*, where most of the territory is in a CHD. Among these, 107 had samples collected for chemical analysis with only 14 (13%) having fresh water (concentration of Total Dissolved Solids (TDS) less than 500 mg/l). The salinization of the waters in the crystalline rocks seems to have a direct relationship with the losses due to evapotranspiration that is significant in the region due to the long dry season (ANA & SEMAR, 2002).

To make better use of fractures and avoid brackish waters, the depths drilled for the installation of wells should not exceed 60 meters (ANA & SEMAR, 2002). Also, the wells registered in the *Capitão Gervásio de Oliveira* indicate a tendency to lose productivity as the depths increase.

Figure 5.1-9 – Relationship between depth and flow for wells registered in *Capitão Gervásio de Oliveira*.



Source: MDGEO, 2008.

CHD's low groundwater production potential is also confirmed when comparing the number of wells registered in *Capitão Gervásio de Oliveira* and *Campo Alegre do Fidalgo* with the number of wells in the municipality of *São João do Piauí* (386 tubular wells) (AGUIAR & GOMES, 2004b; CPRM, 2008) that is located in a SHD.

Among the wells registered by both CPRM and MDGEO, no wells were found on the CHD with flow rates greater than 5 m^3/h.

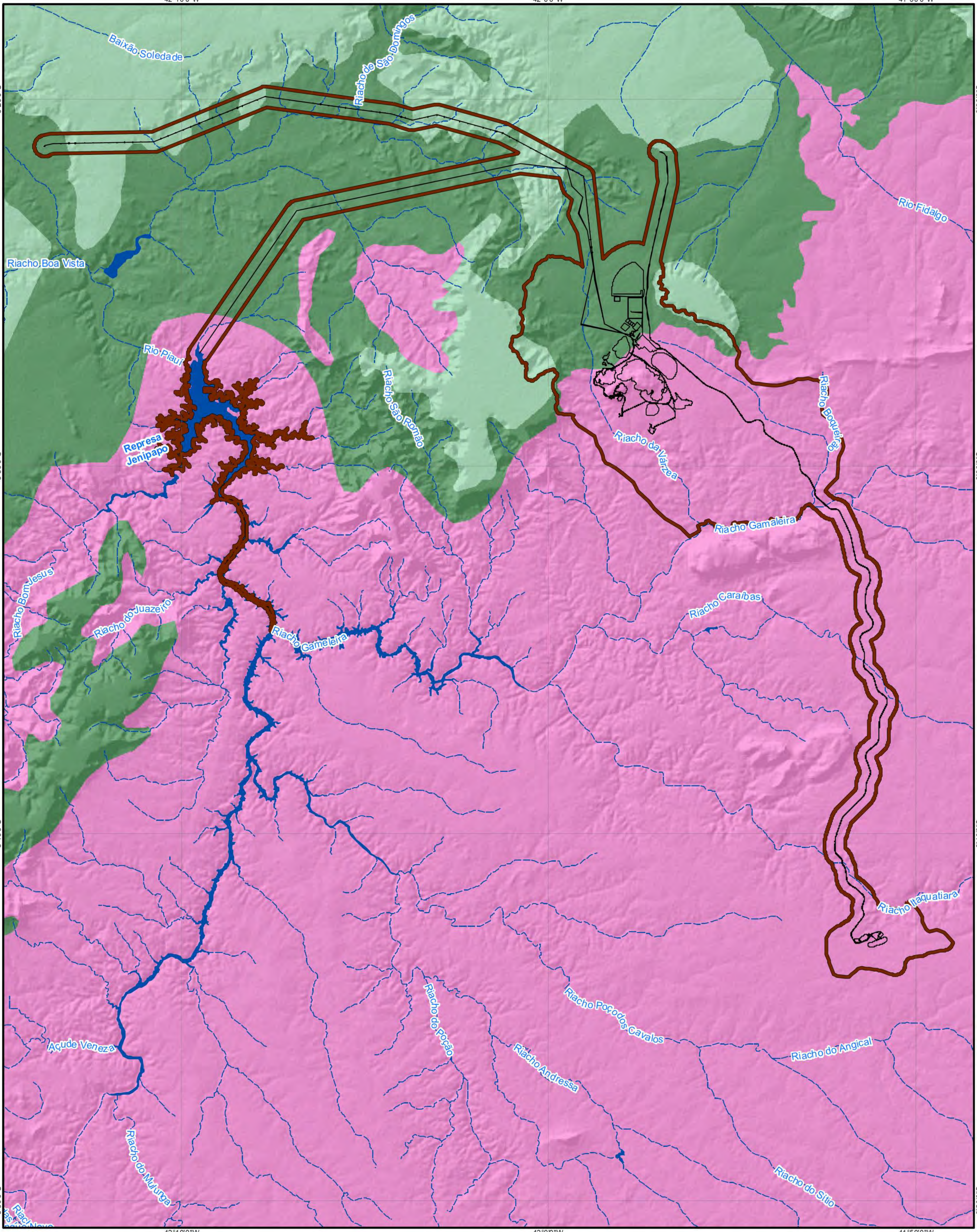
b) Sedimentary Hydrogeological Domain – SHD

As described in 5.1.2.2, the geological characterization of the *Parnaíba* sedimentary basin shows the predominance of clastic sedimentary rocks (described as sandstones) and conglomeratic sandstones that are excellent aquifers due to their high porosity and hydraulic conductivity.

There are 393 wells located in the SHD in the area studied by MDGEO in 2008, shown in Figure I - Well Location Map and Table I - Registered Wells, in ANNEX IV (Volume IV). Of these, 332 were sampled for chemical analysis, 206 (62%) of those categorized as fresh water (TDS less than 500 mg/l) satisfactory for domestic use.

The *Serra Grande* aquifer and the *Pimenteiras* aquifer are the most important due their proximity to the DAA (Map 5.1-21). However special attention must be also given to basement rock bodies presents in the area, which constitute important aquifuges (rocks lacking porosity and preventing the circulation of groundwater).

Map 5.1-21 – ADI Aquifers.



LEGENDA

- Intermittent Drainage
- Water Mass
- Area of Direct Influence - ADI
- Directly Affected Area - DAA

Aquifers

- Pimenteiras
- Serra Grande
- Semi-Arid Fractured

REFERÊNCIAS

Aquiferos - ANA - 2003
SRTM/Topodata, consulta 2016.
IBGE, Base contínua 1:250.000, 2015

ESCALA GRÁFICA
0 2,5 5 km

Sistema de Coordenadas: GCS SIRGAS 2000

LOCALIZAÇÃO

PA MA CE PI PB PE TO BA

PIAUÍ NÍQUEL | ARCADIS

EIA/RIMA – PROJETO PIAUÍ NÍQUEL

Map 5.1-21
Aquifers - ADI

EXECUTADO POR:	ESCALA:	FORMATO:	FOLHA:	DATA:
ARCADIS	1:180.000	A3	ÚNICA	JAN/2017

- *Serra Grande* Aquifer

According to MENTE et al. (1966), the *Serra Grande* aquifer (together with the *Cabeças* aquifer) is considered one of the most important and productive aquifers in the AII; it can be characterized as a confined aquifer (with 178,000 km²) or as a free aquifer (with 31,650 km²).

This aquifer possesses great attractiveness for water use considering its coarse-grained sedimentary rocks (sandstones), important conglomeratic levels, and an average thickness of roughly 550 meters. The average flow of registered wells is 20 m³/h with flows up to 200 m³/h. The average specific capacity of the wells is 5 m³/h/m (MDGEO, 2008).

The *Serra Grande* aquifer is explored predominantly in areas where it is confined by the *Pimenteiras* Aquitard, generally through tubular wells with “*artesianism*” (SEI 2003). The quality is very good classified as fresh water with an average TDS of 425 mg/l. (AGUIAR & GOMES, 2004b; CPRM, 2008).

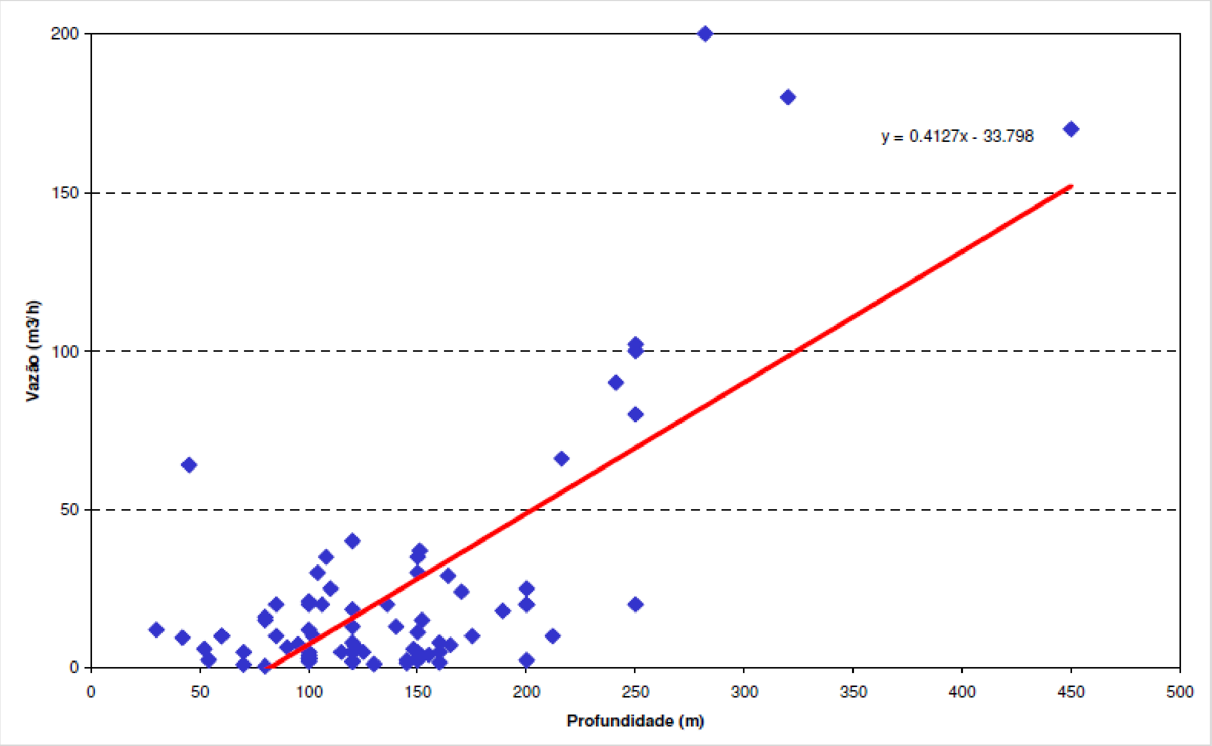
This aquifer is represented by a continuous outcrop strip in the southeast of the basin, around 40 km width to the north and 2 km to the southeast (ANA & SEMAR, 2004) and is mostly fed by water from pluviometric and fluvial infiltrations. Short-term torrential rains hinder infiltration and the intermittent nature of the region's watercourses results in a small recharge contribution. The areas of greatest exploitation of the *Serra Grande* aquifer and the *Pimenteiras* aquitard are located near the municipalities of *Simplício Mendes* and *Conceição do Canindé* and on an elongated strip in the municipality of *São João do Piauí* (CPRM, 2012).

The greatest losses are due to evapotranspiration in the recharge area (up to 90% of the average precipitation in the area) and by some natural sources in mountain escarpments (when in a free aquifer) and by the upward vertical movement of water ranging from the *Pimentairas* formation to the *Cabeças* aquifer (when confined) due to the greater hydraulic load of the *Serra Grande* aquifer (COBA & SEMAR, 2006).

The greatest losses are associated with evapotranspiration in the recharge area and the deposit shows an NNE-SSW direction and an elevation variation in the WNW direction, reaching 240 m. The underground flow of the Serra Grande aquifer is always towards the tail wigs of the existing rivers (CPRM, 2012).

There is a clear relationship between the depth and the flow of the wells installed in the *Serra Grande* aquifer. Figure 5.1-10 shows this comparison for wells documented by CPRM and MDGEO.

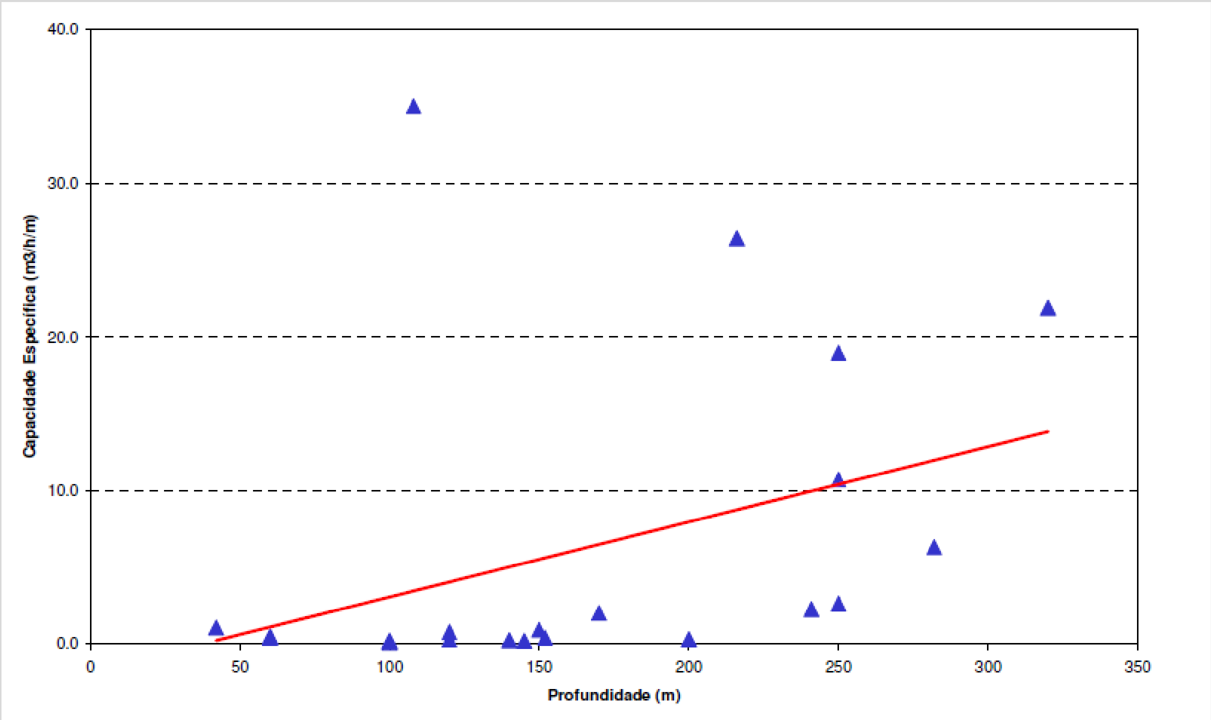
Figure 5.1-10 – Relationship between the depth and the flow of wells installed in the *Serra Grande* aquifer.



Source: MDGEO, 2008.

The same relationship is found when analyzing the specific capacity of the wells (Figure 5.1-11).

Figure 5.1-11 – Relationship between the specific capacity and the depth of wells installed in the *Serra Grande* aquifer.

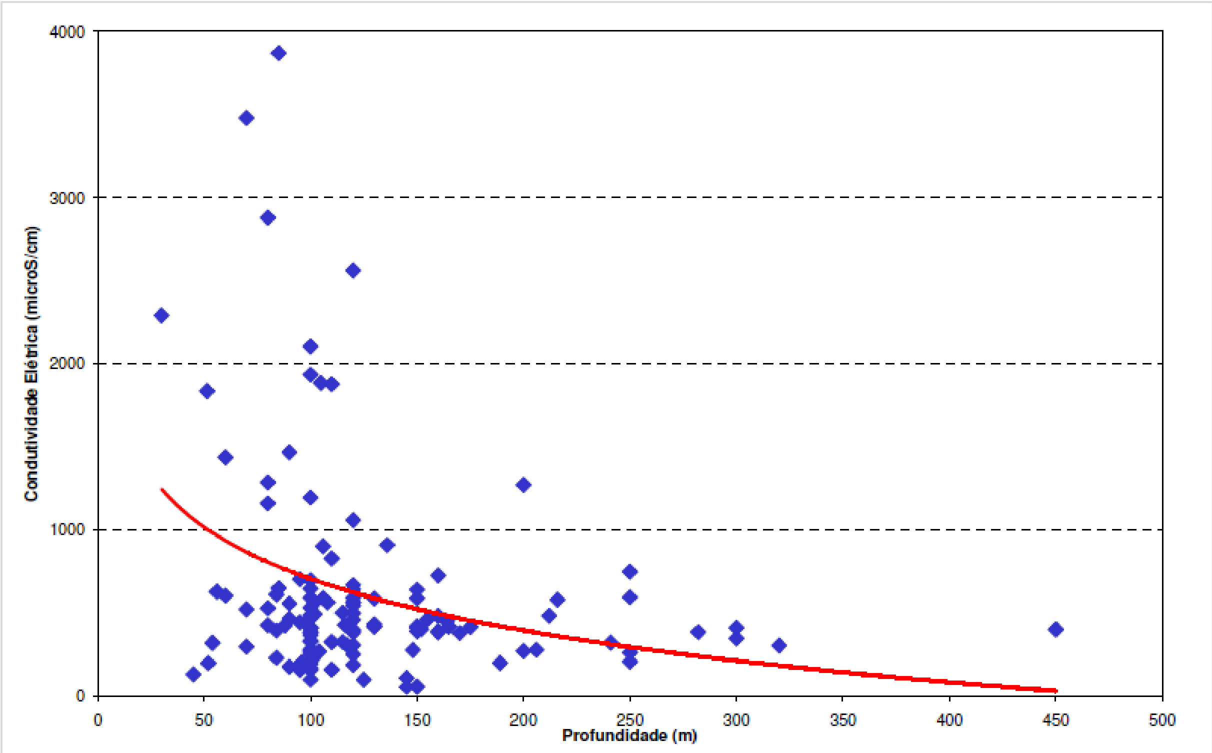


Source: MDGEO, 2008.

These figures show that the wells with low flow rates are shallow wells and that their performance improve when installed at deepest levels.

Wells over the *Serra Grande* aquifer still show a tendency to decrease electrical conductivity with increasing depth (Figure 5.1-12); this reinforces the need to install deeper tubular wells.

Figure 5.1-12 – Relationship between electrical conductivity and depth for wells over the *Serra Grande* aquifer.



Source: MDGEO, 2008.

The potential for groundwater exploitation in this unit increases proportionally with the penetration into the aquifer. This fact may reflect both the heterogeneity of the aquifer, as well as the presence of more permeable levels at the base.

- *Pimenteiras* Aquitard

The lateral and vertical variations of sandy and pelitic levels define the *Pimenteiras* aquitard as a heterogeneous and anisotropic unit that confines the *Serra Grande* aquifer creating conditions of "artesianism" in the wells that cross the *Pimentairas* aquitard and reach *Serra Grande* (MDGEO, 2008).

Despite confining the overlying unit, there are drainage areas that occur in the presence of the sandy levels in the *Pimenteiras* aquitard.

The wells drilled in this unit seek to reach, whenever possible, the *Serra Grande* aquifer, as the shallow levels in the *Pimenteiras* aquitard usually produce poor quality water (MENTE et al. 1966).

- *Cabeças* Aquifer

This is considered one of the best aquifers in the region due to its favorable development conditions (SEI 2003), despite that it is less thick than *Serra Grande*.

As well as the *Serra Grande* aquifer, the *Cabeças* aquifer also alternates areas where it is confined (136,600 km²) and areas where it is free (39,400 km²).

The recharge occurs mainly by infiltration of rainwater while the discharge occurs by evapotranspiration (free aquifer) and vertical infiltration to adjoining units (COBA & SEMAR, 2006).

The potential use of this unit is interfered by dikes and ridges of basement rocks originated by an intrusion event during the Cretaceous age. VIDAL (2003) refers to this situation in the municipality of *Picos* (north of the study area) where the circulation and quality of groundwater is hindered by these impermeable bodies that function as true underground hydraulic barriers. This author also mentions that the wells drilled near basement rock intrusions tend to be dry.

- Aquifuges in Basement Rocks

Although the geological literature associates the presence of basement rock bodies in the domain of the *Cabeças* aquifer, there are drilling reports of their presence in the *Serra Grande* aquifer, especially on the eastern edge of the basin.

The identification of these bodies in this area is extremely important because, in addition to the low hydrogeological performance, these intrusive rocks interfere in vertical electric drilling.

B) Vulnerability of Aquifers to Contamination

This section is based on secondary data and works developed by PROGEO (2006), where a series of environmental investigations were developed.

Since the structures with the greatest potential for interference with groundwater are the nickel and limestone pits, this item will focus only on the aquifer systems present in these locations.

a) Method GOD (Groundwater occurrence, Overall lithology of the unsaturated zone, Depth to the water table)

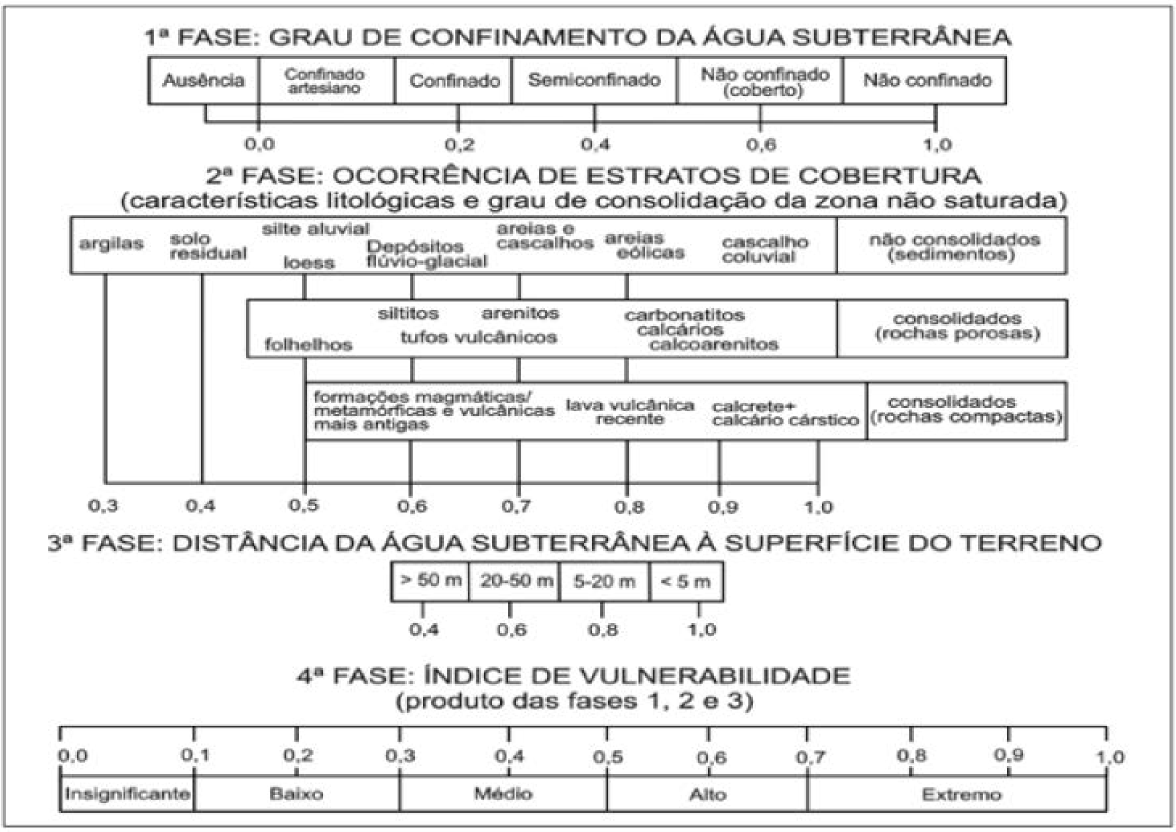
ASTM (American Society for Testing Materials) defines vulnerability in groundwater as the easiness with which a given contaminant can migrate to groundwater or to an aquifer of interest in certain land use situations, contaminant characteristics and area conditions. Therefore, the vulnerability depends on the characteristics of the aquifer (lithologies, porosity, etc.), the area (land use, topography, etc.) and the contaminant (mobility, density, etc.).

Traditional methodologies for calculating the vulnerability of aquifers require an abundance of data which is often not available. The information used to apply the GOD methodology for the aquifers in the area are:

1. Occurrence of the Water Table (free, confined, semi-confined)
2. Lithology of the unsaturated zone and adjoining layers
3. Depth of the Water Table (thickness of the padded area)

Figure 5.1-13 shows the GOD methodology components.

Figure 5.1-13 – Method GOD to assess the vulnerability of an aquifer to contamination



Source: Foster et al., 2006.

The GOD system assigns values between 0 and 1 to each of the variables mentioned. A value of 1 is given when the characteristics analyzed represents situations of greater vulnerability. A value of 0 (or close to 0) is given when the attributes under analysis represents a low vulnerability to the analyzed aquifer. The assigned values are multiplied with each other and result in the final classification ranging from extreme to low.

Data from the surveys carried out by PROGEO (2006) were used to evaluate the aquifer located in the Project area. The survey reports can be viewed in ANNEX V (Volume IV).

According to the Data Table 5.1-23, the confining layer of the aquifer usually consists of a light layer of soil/saprolite followed by metamorphic rock except where altered and fractured rocks are found from the top to the water level (N.A.); therefore the aquifer can be classified as semi-confined (0.4). The basement rocks are composed of volcanic/metamorphic lithology (0.7). Finally, the waterbodies are commonly found at a depth between 5-20m (0.8).

As per the GOD method, this aquifer has a low vulnerability to contamination.

Data Table 5.1-23 – Summary Description of PROGEO surveys.

ID	Water level N.A. (m)	Target Area	Lithology – Adjoining Layer (meterage)	Lithology - Aquifer (meterage)	Confining Rock Thickness
FG01-SM18	6.85	*Brejo Seco*	Sandy Silt (1.13), Base: (Serpentinite) (20.00)	Base: (Serpentinite) (20.00)	5.72
FG06-SM17	12.19	*Brejo Seco*	Sandy Silt (1.45), Base: (Serpentinite) (20.04)	Base: (Serpentinite) (20.04)	10.74
FG08-SM16	9.89	*Brejo Seco*	Sandy Silt (1.36), Base: (Serpentinite) (20.10)	Base: (Serpentinite) (20.10)	8.53
FG15-SM08	5.91	*Brejo Seco*	Silt Clay (0.40), Silt Clay (1.09), Base: (Serpentinite) (10.55)	Base: (Serpentinite) (10.55)	4.82
FG17-SM07	7.93	*Brejo Seco*	Silt Clay (1.12), Base: (Serpentinite) (10.15)	Base: (Serpentinite) (10.15)	6.81
FG21-SM06	6.4	*Brejo Seco*	Sandy Clay (0.40), Silt Clay (0.74). Base: (Serpentinite) (8.08)	Base: (Serpentinite) (8.08)	5.66

ID	Water level N.A. (m)	Target Area	Lithology – Adjoining Layer (meterage)	Lithology - Aquifer (meterage)	Confining Rock Thickness
FG24-SM04	10.55	*Brejo Seco*	Sandy Clay (0.30), Sandy Silt (1.36), Base: (Serpentinite) (16.04)	Base: (Serpentinite) (16.04)	9.19
FG28-SM05	18.24	*Brejo Seco*	Silt Clay (4.11), Altered Basement Rock Very Disintegrated (27.20)	Altered Basement Rock Very Fragmented (27.20)	-
FG31-SM11	7.75	*Brejo Seco*	Sand (0.80), Sandy Clay (3.00), Gravel (4.18), Rock Blocks (4.73). Base: (Serpentinite) (19.44)	Base: (Serpentinite) (19.44)	3.57
FG35-SM09	24.56	*Brejo Seco*	Sandy Clay (0.40), Silt Clay (4.20). Base: (Serpentinite) (25.90)	Base: (Serpentinite) (25.90)	20.36
FG37-SM03	26.56	*Brejo Seco*	Silt Clay (4.33), Disintegrated Rock (20.00), Silt Clay (21.50), Disintegrated Rock (31.90)	Fractured Rock (31.90)	-
FG56-SM01	10.57	*Brejo Seco*	Silt Clay (0.60), Sandy Clay (2.20), Disintegrated Rock (3.00), Silt Clay (3.21), Disintegrated Rock (4.00). Base: (Serpentinite) (14.35)	Base: (Serpentinite) (14.35)	6.57
FG57-SM02	22.6	*Brejo Seco*	Silt Clay (1.60), Base: (Serpentinite) (30.11)	Base: (Serpentinite) (30.11)	21

ID	Water level N.A. (m)	Target Area	Lithology – Adjoining Layer (meterage)	Lithology - Aquifer (meterage)	Confining Rock Thickness
FG83-SM28	13.48	*Brejo Seco*	Sandy Silt (0.48), Base: (Serpentinite) (20.02)	Base: (Serpentinite) (20.02)	13
FG84-SM20	13.14	*Brejo Seco*	Sandy Silt (1.28), Base: (Serpentinite) (20.07)	Base: (Serpentinite) (20.07)	11.86
FG85-SM25	13.85	*Brejo Seco*	Sandy Silt (0.70), Silt (2.00). Base: (Serpentinite) (20.08)	Base: (Serpentinite) (20.08)	11.85
Average	**13.15**	**-**	**-**	**-**	**9.8**

Source: PROGEO, 2006. Prepared by: Arcadis, 2017.

The GOD method wasn't applied to determine the vulnerability of the existing aquifer in the area known as *Umbuzeiro* since there is no reliable local information to use.

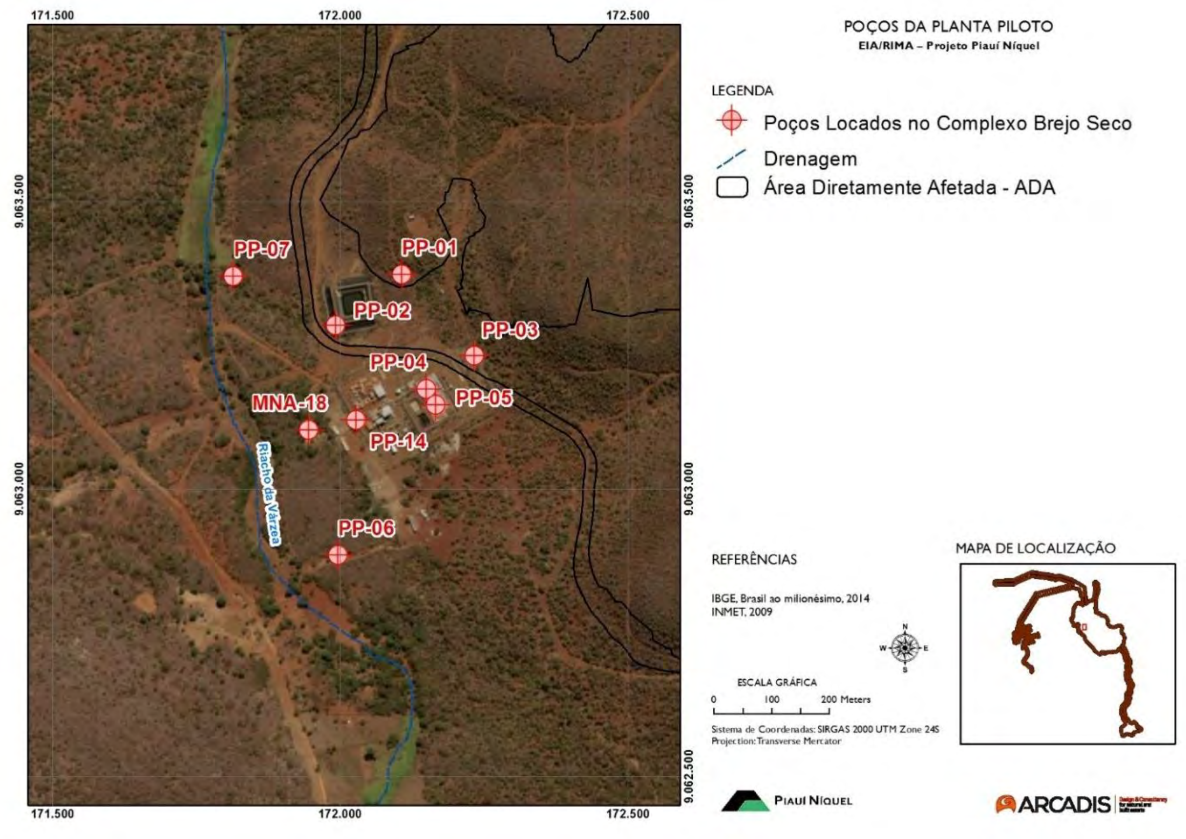
Umbuzeiro is recognized as an area where carbonate rocks are present and is characterized as a karst environment with high permeability values considering the fracturing of these rocks as well as high water flow speeds. These environments are normally suitable to groundwater contamination.

C) Groundwater Quality

The data regarding DAA's groundwater quality come from monitoring and reports provided by VALE, from June / 2010 to October / 2012, where 09 (nine) groundwater monitoring campaigns were carried out by Geosol Laboratórios LTDA under the supervision of VALE. The monitored wells are located in the vicinity of the pilot plant, according to the Wells Location Map – Pilot Plant (Mapa 5.1-22) and Data Table 5.1-24.

The evaluation of the water quality standard was made through the physical, chemical and hydrobiological analysis of the aquifers to be used, where the standards determined by CONAMA Resolution 396/2008 (groundwater) are followed for the classification of the aquifers and determination of the potential use.

Map 5.1-22 – Wells Location Map – Pilot Plant.



Data Table 5.1-24 – Pilot Plant water monitoring points, Camp Area and Water/Oil Separators.

ID	REFERENCE	Diameter (mm)	Water Level (m)	Total Depth (m)	Coord. East	Coord. North
PP-01	Well upstream of the emergency pond	42	1.98	29.72	0172107	9063373
PP-02	Well downstream of the emergency pond	42	seco	14.00	0171992	9063285
PP-03	Well upstream of the leach pad	42	seco	28.84	0172233	9063232
PP-04	Well (1) downstream of the leach pad	42	5.2	28.91	0172150	9063174
PP-05	Well (2) downstream of the leach pad	42	5.91	29.44	0172166	9063146
PP-06*	Supply Well (1)	152	In use	In use	0171997	9062885
PP-07	Supply Well (2)	152	98.18	100.00	0171815	9063370
PP-14	Well downstream of the emergency tank	42	2.29	11.21	0172028	9063120

ID	REFERENCE	Diameter (mm)	Water Level (m)	Total Depth (m)	Coord. East	Coord. North
MNA-18	Well downstream of PP-14	42	14.33	17.77	0171946	9063103

**PP-06 – Water level and depth were not measured because it was in operation. Water level measurement done between May 3 and 8, 2010.*

Source: Vale, 2012; Prepared by: Arcadis, 2017.

The results included in Data Table 5.1-25 show that all parameters are within the limits of CONAMA with the exception of Manganese that sporadically presents values slightly above the standard. This value may be related to the presence of manganese oxides/hydroxides (quite common in tropical countries) and also to the high turbidity of the sample considering that the results correspond to the total concentration (suspended material + dissolved material). The same situation occurs for some nickel analysis.

Data Table 5.1-25 – Groundwater Chemical Analysis Results (mg/l).

Referência	Coleta	Cálcio	Cloreto	Cor	DBO	Ph	Sulfato	Turbidez (NTU)	Fósforo total	Manganês	Níquel
PP-01	mai/08	15	35	51	11	7,3	5	13,4	0,03	0,07	0,07
	mai/10	8,82	32,8	5	4,44	7,56	9,27	1,26	0,01	0,05	0,02
PP-02	dez/06	38	112,1	80	41	7,6	3	11,2	0,19	**0,18**	0,01
	fev/07	44	42,2	26	3	7,02	3	14,6	0,03	**0,11**	0,14
	mai/08	147	21	111	75	7,22	8	113	0,02	**2,65**	2,87
PP-03	mai/08	16	84	3,4	19	7,1	3	64,4	0,02	0,05	0,1
PP-04	fev/07	32	77,7	63	3	7,04	3	18,7	0,03	0,07	0,07
	mai/07	23	43,1	67	67	7,61	3	10	0,05	**0,31**	0,05
	nov/07	23	94,3	46	38	7,35	49	10,5	0,07	**0,23**	0,09
	mai/08	18	63	14	39	7,05	61	9,3	0,02	0,07	0,2
	mai/10	7,02	68,4	5	2	7,24	20,5	0,82	0,02	0,05	0,02
	ago/10	7,11	56,5	5	2	7,49	18,5	1	0,03	0,025	0,01
	nov/10	6,07	52,1	5	2	7,7	18,4	0,54	0,01	0,025	0,01
	fev/11	8,24	58,4	94	2	7,47	19,5	29,8	0,02	**0,11**	0,04
	mai/11	9,54	81	52	7,31	7,63	17	31,4	0,01	**0,11**	0,09
	ago/11	13,5	84,7	11	2	7,9	32,1	0,33	0,01	0,025	0,02
	nov/11	6,85	59,8	9	2	7,26	23,9	15,8	0,01	0,06	0,03
	fev/12	6,2	59,7	5	2	7,92	23,2	0,33	0,01	0,025	0,01
	mai/12	5,93	58	5	2	7,97	19,7	0,75	0,03	0,05	0,02
	ago/12	6,5	53,8	200	4,2	7,7	16,1	148	0,14	**0,33**	0,44

Referência	Coleta	Cálcio	Cloreto	Cor	DBO	Ph	Sulfato	Turbidez (NTU)	Fósforo total	Manganês	Níquel
PP-05	fev/07	17	57,1	26	3	7,54	6	30,3	0,07	**0,18**	0,1
	mai/07	17	29,7	38	58	7,6	9	31,1	0,17	**0,31**	0,13
	nov/07	19	54,5	35	112	7,07	5	3,5	0,05	0,05	0,03
	mai/08	16	80	3,4	19	7,12	52	4,6	0,09	0,05	0,14
	mai/10	8,5	67,5	5	4,24	7,2	21,1	1,41	0,02	0,05	0,05
	ago/10	178	70,5	10	2	7,69	18,5	1	0,04	**38,8**	0,801
	nov/10	9,25	65,6	16	2	8,07	14,2	0,81	0,07	0,025	0,01
	fev/11	15,7	67,6	114	2	7,4	18,7	25,6	0,04	**1,26**	1,36
	mai/11	8,96	75,2	136	7,71	7,64	17,4	21,1	0,05	**0,15**	0,06
	ago/11	15,4	80,9	18	2	7,58	23,9	1,99	0,04	0,025	0,01
	nov/11	15,9	63,2	12	2	7,27	26,5	1,32	0,01	0,07	0,02
	fev/12	7,27	71,2	5	2	7,72	11	0,48	0,09	0,025	0,01
	mai/12	8,44	70,4	5	2	7,65	15,8	0,52	0,02	0,05	0,02
	ago/12	7,7	65,2	200	4,5	7,6	16,4	283	0,26	**0,3**	0,563
PP-06	dez/06	28	97,1	5	4	7,33	26	0,2	0,11	0,05	0,01
	fev/07	33	55,2	13	3	7,55	58	0,1	0,18	0,05	0,01
	mai/07	24	92,1	3	3	8,1	36		0,14	0,05	0,01
	nov/07	48	119	7	22	7,27	14	0,5	0,09	0,05	0,01
	mai/10	26,1	82	5	2	7,18	36,5	0,25	0,01	0,05	0,1
	ago/10	29	96,1	5	2	7,55	31	1	0,02	0,025	0,01

Referência	Coleta	Cálcio	Cloreto	Cor	DBO	Ph	Sulfato	Turbidez (NTU)	Fósforo total	Manganês	Níquel
PP-06	nov/10	34,3	101	5	2	8,02	30,9	0,42	0,02	0,025	0,01
	fev/11	30,3	94,6	5	2	7,51	34	0,93	0,07	0,025	0,01
	mai/11	24,8	86,8	5	2,55	7,59	32,1	0,54	0,04	0,025	0,01
	ago/11	27,1	100	7	2	7,68	35,4	0,2	0,09	0,025	0,01
	nov/11	29,6	100	5	2	7,65	38,7	0,36	0,02	0,05	0,02
	fev/12	28,3	93,6	6	2	7,73	4,59	0,33	0,1	0,025	0,01
	mai/12	35,6	97,9	5	2	7,86	40,7	0,34	0,04	0,05	0,02
	ago/12	27,5	97,5	5	3,3	8,2	41,2	0,9	0,2	0,05	0,006
MNA-18	mai/10	46,6	27,6	5	2	7,13	61,8	0,51	0,07	0,05	0,06
	ago/10	44,1	28	109	2	7,45	51,7	57,7	0,09	**0,28**	0,06
	nov/10	34,8	34,7	15	2	7,87	54,2	3,36	0,05	**0,56**	0,01
	fev/11	59	52,6	152	2,11	7,05	59,9	32,7	0,14	**0,34**	0,04
	mai/11	48,3	31,3	5	2	7,15	49,9	5,42	0,04	0,06	0,02
	ago/11	46,2	36,1	153	2	7,07	54,5	17,5	0,04	**0,26**	0,01
	nov/11	50	33,8	29	2,05	7,12	58,3	83,3	0,11	**0,61**	0,02
	fev/12	51,8	39,6	40	4,9	7,38	6,21	2,46	0,02	**0,72**	0,01
	mai/12	60	35,5	5	2,01	7,02	51,7	4,85	0,11	**1,24**	0,02
	ago/12	81,6	32,2	26.000	13,2	7,2	39,3	7020	0,63	**4,94**	0,693
PP-07	dez/06	16	68,5	5	3	7,53	34	0	0,15	0,05	0,01
	fev/07	15	84,8	11	3	7,52	3	0,1	0,1	0,05	0,02

Referência	Coleta	Cálcio	Cloreto	Cor	DBO	Ph	Sulfato	Turbidez (NTU)	Fósforo total	Manganês	Níquel
PP-07	mai/07	12	71,8	2,7	3	7,28	32	0,1	0,22	0,05	0,01
	nov/07	17	119	7	22	7,27	14	0,5	0,09	0,05	0,01
	mai/08	9,5	62	3,4	5	7,3	39	0,6	0,1	0,05	0,03
	mai/10	26,3	75,9	5	2	7,27	22,5	2,37	0,08	**0,18**	0,08
	ago/10	27,4	80,2	25	2	7,49	15,5	5	0,22	**0,2**	0,01
	nov/10	10,9	56,9	32	2	7,51	18,7	2,82	0,23	0,025	0,01
	fev/11	11,3	67,6	133	2	7,33	21,8	55,4	0,11	**0,11**	0,05
	mai/11	105	69,4	102	2,3	7,71	30,7	0,92	0,08	0,025	0,01
	ago/11	9,71	63,5	13	2	7,48	26,1	1,28	0,16	0,05	0,01
	nov/11	9,48	49,2	15	2	7,54	23,1	4,37	0,07	0,05	0,02
	fev/12	9,31	50,6	8	2	7,36	5,17	0,65	0,24	0,05	0,01
	mai/12	10,4	54,4	5	2	7,31	25,5	2,68	0,06	**0,11**	0,02
	ago/12	9,3	47,3	100	5,7	8	20,1	34,4	0,32	**0,39**	0,017

**Values in red exceed the reference values of CONAMA Nº 396/2008.*

Resolução CONAMA Nº 396/2008	VMP - Consumo Humano (mg/L)	-	250	-	-	-	250	-	-	0,1	0,02
Resolução CONAMA Nº 396/2008	VMP - Irrigação (mg/L)		700							0,2	0,2

Source: Vale, 2012. Prepared by: Arcadis, 2017. Reports and analysis results can be found in ANNEX VI (Volume IV).

Attention to the portuguese numbering system in this table.

5.1.9. Atmospheric Pollutants Dispersion – Processing Unit

5.1.9.1. Introduction

The atmospheric pollutants dispersion modelling completed for this study was prepared by Prominer Projetos Ltda.

The emissions of air pollutants considered were sulfur oxides (SO_2 and SO_3) and sulfuric acid mist (H_2SO_4).

As discussed on Section 2.5.1 (Volume I), comparing the characteristics of the PNM project with the project proposed by VALE (2008), there is a significant reduction in the consumption of sulfuric acid (kg of acid per t of ore), production peak of concentrated sulfuric acid (t of acid per day) and concentration of sulfuric acid (g/l) applied in the leaching process, as shown in Table 5.1-9 below.

Table 5.1-9 – Comparison of Sulfuric Acid Consumption, Concentrated Sulfuric Acid Production and Concentration of Sulfuric Acid used in the leaching process – VALE (2008) and PNM (2016).

Technical Aspect	Vale (2008)	PNM (2016)	Reduction (absolute)	Percentage Reduction
Sulfuric Acid Consumption (kg/t Ore)	420	250	170	40.5
Concentrated Sulfuric Acid Production peak (t / day)	3,100	2,500	600	19.4
Sulfuric Acid Concentration (g/l) for the leaching process.	200	60	140	70.0

Source: PNM, 2016.

Considering the significant reductions shown in the table above, it is understood that the modeling developed based on the data from VALE can satisfactorily support the evaluation of environmental impacts, as well as the proposed mitigation actions and environmental programs.

5.1.9.2. Legislation

CONAMA Resolution 003 of June 28, 1990 establishes national primary and secondary air quality standards defining the maximum limits for the concentration of pollutants in the atmosphere to protect the health and the environment.

Primary Standards

Primary air quality standards are the concentrations of pollutants that, when exceeded, may affect the health of the population. They can be understood as maximum tolerable levels of concentration of atmospheric pollutants, constituting short- and medium-term goals.

Secondary Standards

Secondary air quality standards are the concentrations of atmospheric pollutants that result in least adverse effects on the well-being of the population as well as the minimum damage to fauna, flora and the environment in general. They can be understood as desired levels of concentrations of air pollutants, constituting long-term goals.

The purpose of establishing secondary standards is to create a basis for a policy to prevent degradation of air quality. They must be applied to conservation areas (for example, national parks, environmental protection areas, tourist resorts, etc.). They do not apply, at least in the short term, to areas of development, where primary standards should apply. As the CONAMA Resolution 03/90 provides, the differentiated application of primary and secondary standards requires that the national territory be divided into classes I, II and III according to the intended use. The same resolution also provides that if the classification of areas has not been established, the applicable standards will be the primary standards.

Data Table 5.1-26 shows the national standards for air quality defined by CONAMA 003/90:

Data Table 5.1-26 – Air Quality National Standards – CONAMA 003/90.

Pollutant	Sampling Time	Primary Standard (µg/m3)	Secondary Standard (µg/m3)
Total Suspended Particles (TSP)	24 H (1)	240	150
	MGA (2)	80	60
Inhalable Particles (Pm10)	24 H (1)	150	150
	MAA (3)	50	50
Smoke	24 H (1)	150	100
	MAA (3)	60	40
Sulfur Dioxide (SO_2)	24 H (1)	365	100
	MAA (3)	80	40
Nitrogen Dioxide (NO_2)	1 H (1)	320	190
	MAA (3)	100	100
Carbon Monoxide (CO)	1 H (1)	40,000	40,000

Pollutant	Sampling Time	Primary Standard (µg/m3)	Secondary Standard (µg/m3)
	8 H (1)	10,000	10,000
Ozone (O_3)	1 H (1)	160	160

(1) Should not be exceeded more than once a year. (2) Annual Geometric Mean (AGM). (3) Annual Arithmetic Mean (AAM).

Source: Resolução CONAMA 003/90.

For sulfuric acid mist (H_2SO_4), the occupational health limit – 0.2 mg / m³ (defined for the thoracic fraction) established by American Conference of Industrial Hygienists (ACGIH) (2007) was used considering 8 hours weighted average. The original definition of this limit considers a continuous exposure for more than 8 hours.

5.1.9.3. Characterization of Emission Sources

This study is focused on the atmospheric emissions from the sulfuric acid plant that will be part of the Piauí Nickel Project. The main gases that leave the final absorption tower and are released via the exhaust chimney are sulfur dioxide (SO_2), sulfur trioxide (SO_3) and sulfuric acid mist (H_2SO_4). These gases are intermediate products (sulfur oxides) and final product (H_2SO_4 in the form of mist) which makes the emission controls important for maintaining the surrounding air quality and to ensure the productivity of this plant.

- Chimney Coordinates: UTM 24L 175686mE / 9065263mN
- Chimney Height: 60 m
- Chimney Diameter: 3.5 m
- Chimney Flow: 81.78 m³/s
- Gas Outlet Temperature: 82 ºC
- SO_2 Emission Rate: 80 g/s
- H_2SO_4 Mist Emission Rate: 3 g/s

Data Table 5.1-27 shows the emission limits for the sulfuric acid production defined by CONAMA 386, December 26, 2006.

Data Table 5.1-27 – Emission Limits for the Sulfuric Acid Production

Product	Emission Point	SO_2	SO_3
Sulfuric Acid (H_2SO_4)	Absorption Tower	2 kg/t of H_2SO_4 at 100%*	0,3 kg/t of H_2SO_4 at 100%*

** Results presented in dry basis*

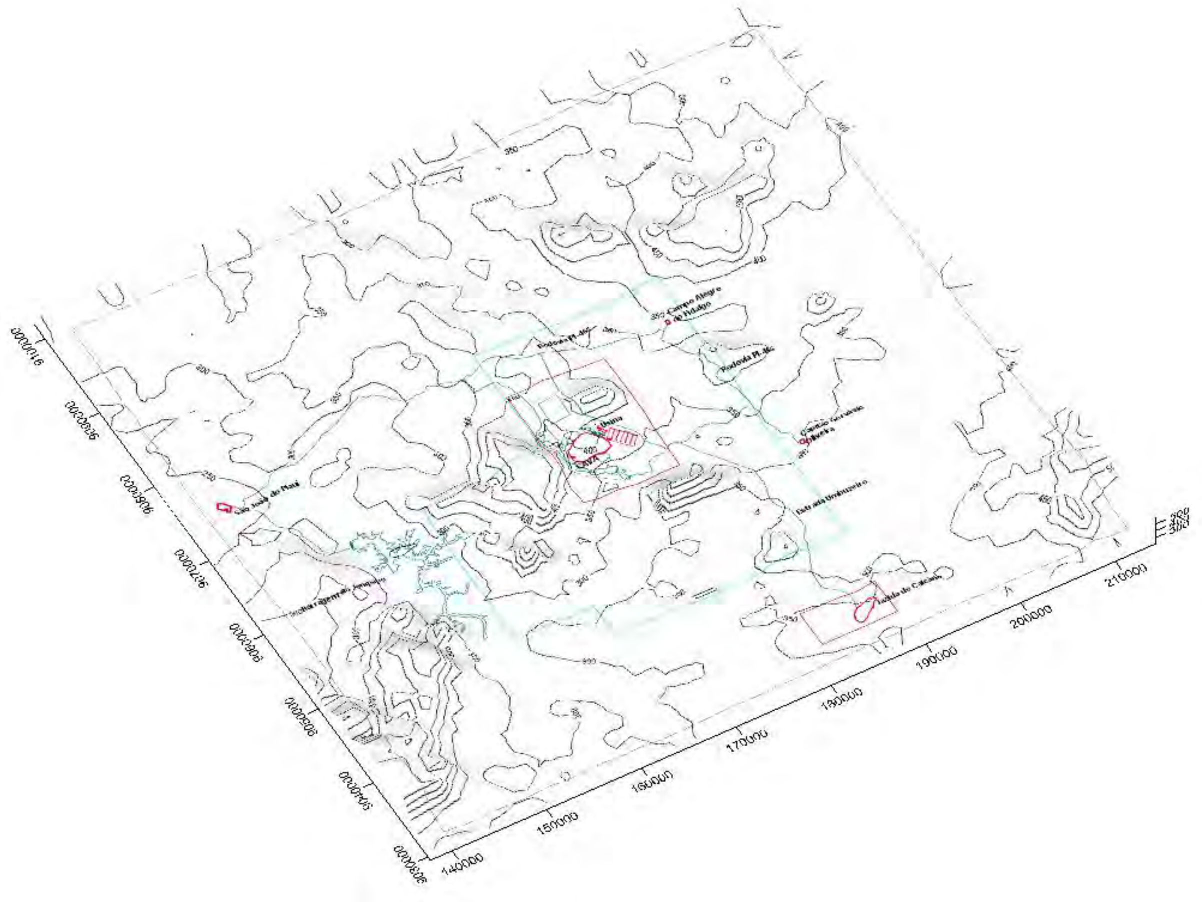
Source: CONAMA 386/ 2006.

The sulfuric acid plant considered by the project is designed to produce 3,100 tons of 100% H_2SO_4 per day, with maximum emission values of 2 kg SO_2 and 0.075 kg of acid mist per ton of 100% H_2SO_4, meeting the emission limits defined by CONAMA 386/2006.

5.1.9.4. Project Area

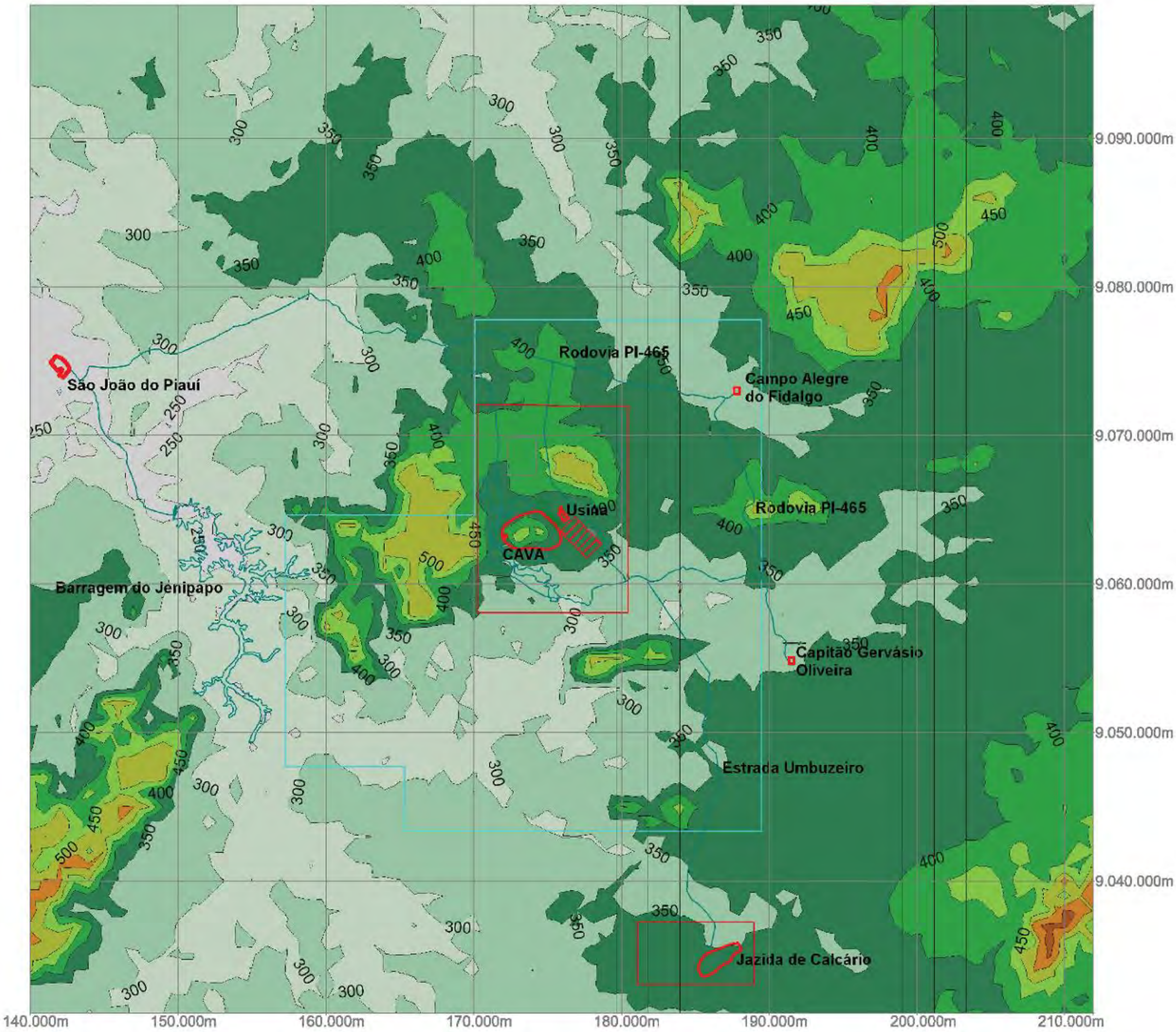
The urban centers closest to the area under study for the implementation of the project are located in the municipalities of *Capitão Gervásio Oliveira*, *Campo Alegre do Fidalgo*, *Dom Inocêncio* and *São João do Piauí*. The PI 465 highway connects these municipalities. Figure 5.1-14 shows the contours around the project's area. Figure 5.1-15 shows the location of *Capitão Gervásio Oliveira, Campo Alegre do Fidalgo, São João do Piauí* and the reflief of the region .

Figure 5.1-14 – Perspective of the Project Location Area



Source: ARCADIS Tetraplan, 2008.

Figure 5.1-15 – Project Location, Nearest Towns and Main Access Roads.



Source: ARCADIS Tetraplan, 2008.

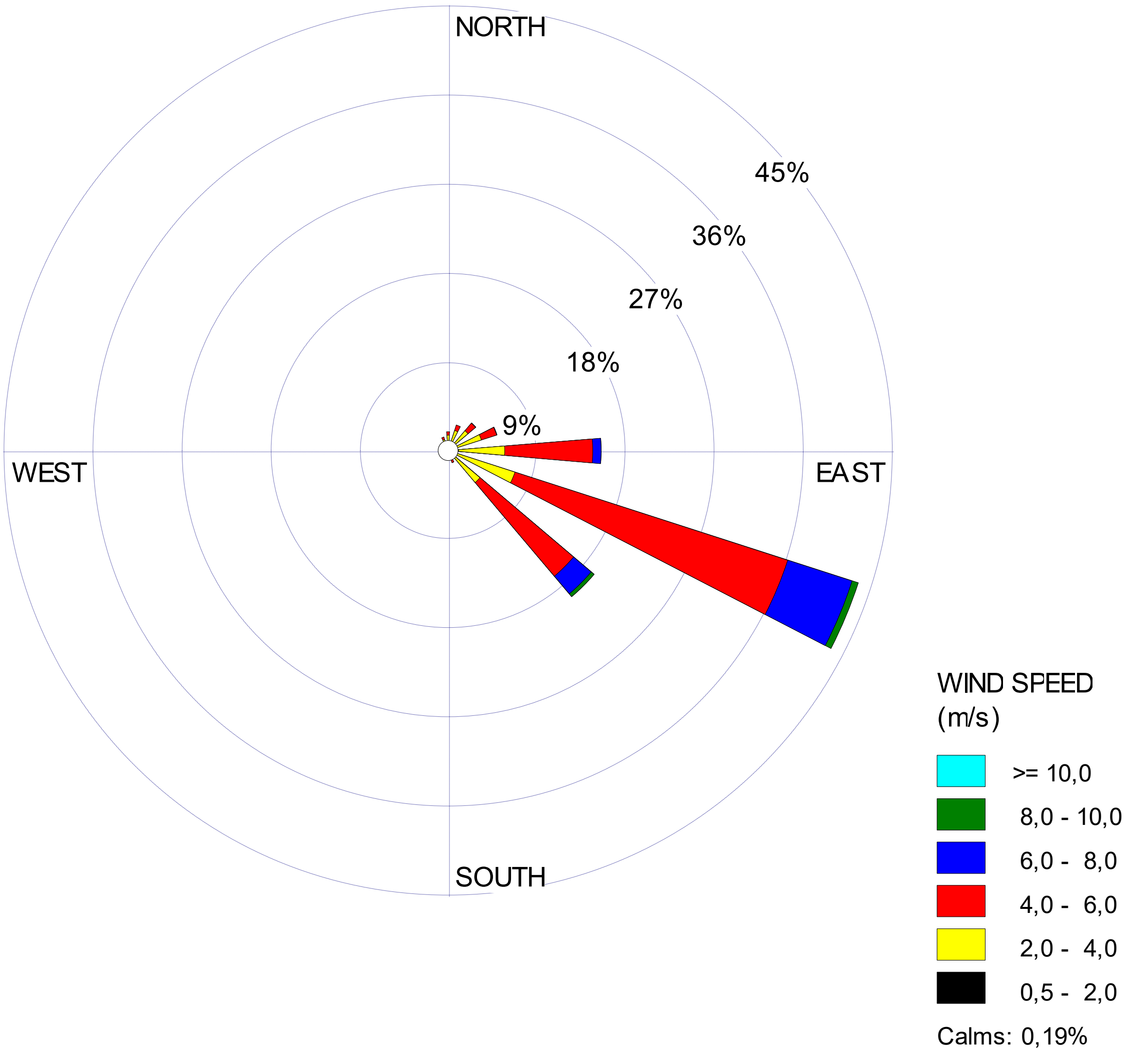
5.1.9.5. Climate Conditions

Due to the lack of a series of consistent local meteorological data to use in the ISCST3 model, 5 years hourly meteorological data (01/01/2003 to 12/31/2007) was acquired from the UTM located in 175.688 m E and 9.065.266 m N from Lakes Environmental. They prepared the meteorological data using the MM5 meteorological model with global meteorological data provided by the NCEP (National Center for Environmental Protection).

A) Winds

Using the WRPLOT View – Wind Rose PLOT applications from Lakes Environmental Software Version 5.8.1, a wind rose diagram was created for the years 2003 to 2007 to allow the visualization of the predominant wind directions in the project area, as shown in Figure 5.1-16 . There is a greater frequency of winds from southeast to northwest.

Figure 5.1-16 – Wind Rose Diagram – 2003 to 2007.



Source: ARCADIS Tetraplan, 2008.

B) Mixing Layer Height

The USA Environmental Protection Agency (USEPA) defines the height of the mixing layer as the height of the layer adjacent to the ground in which a trace element inert and without impulsion will be mixed by turbulence within a period of one hour or less.

PCRAMMET (Developed by USEPA) was the algorithm used to obtain the mixing layer height using a Windows interface developed by Lakes Environmental in Canada. This algorithm used the hourly data from the MM5 modeling acquired from Lakes Environmental applying the tool "Mi Xing Light Extinguisher AERMIX forum PCRAMMET", comprising the period between Jan.2003 to Dec.2007.

C) Atmospheric Stability

The hourly meteorological information makes it possible to determine the atmospheric stability classes which is another parameter required by the model. Such classification, as defined by Pasquill (1974), determines that the degree of atmospheric stability responsible for the dispersion of the pollutants can be classified as follows:

A - extremely unstable atmosphere.
B - moderately unstable atmosphere.
C - slightly unstable atmosphere.
D - neutral atmosphere.
E - slightly stable atmosphere; and
F - moderately stable atmosphere.

The pollutant dispersion condition in the air is less efficient as the greater atmosphere stability degree.

5.1.9.6. Atmospheric Dispersion Model

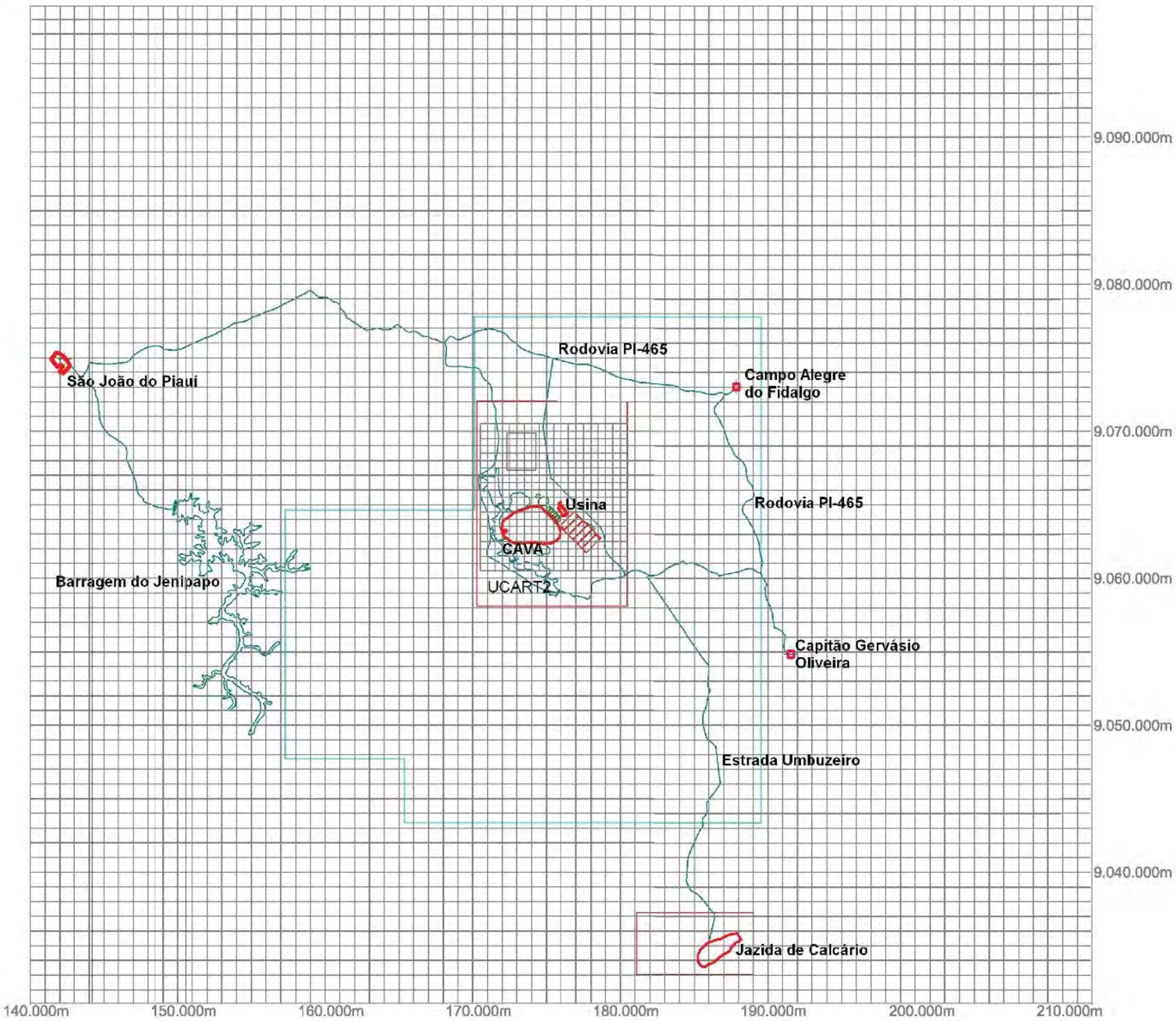
The ISCST3 model (Industrial Source Simples Short Term – developed and recommended by USEPA) was used to simulate the dispersion of sulfur dioxide (SO_2) and sulfuric acid mist (H_2SO_4) generated. The ISCST3 model is based on the Gaussian plume model assuming a normal or Gaussian distribution both in the y direction (transversal to the wind direction) and in the z direction (perpendicular to the x and y). The application of this model was performed by the software ISC-AERMOD View Version 5.8.1, by Lakes Environmental Software Inc.

The parameters required by the ISCST3 model were obtained by pre-processing hourly meteorological data of the study area using the PCRAMMET Software (USEPA). Those parameters are average speed and wind direction, the exponent of the wind profile, the air temperature, the height of the mixing layer and the vertical gradient of potential temperature.

The area of influence for the study of the atmospheric emissions dispersion was defined to cover those towns closest to the project area: *Capitão Gervásio Oliveira*, located 19 km southeast, *Campo Alegre do Fidalgo*, located 14 km northeast and *São João do Piauí*, 35 km to the northwest.

Using the cartographic maps from the *Diretoria do Serviço GeoGraph do Ministério do Exército* for *Folhas Barra do Bonito, Barragem, Riacho Queimadas* and *São João do Piauí*, a regular network of receivers located every 1,000 meters was defined using UTM coordinates 140,000 m E at 212,000 m E and from 9,031,000 m N to 9,099,000 m N as shown in Figure 5.1-17. To obtain additional details of the area closer to the emission source, a second grid of receivers was also inserted at UTM coordinates 175,000 m E at 180,500 m E and from 9,060,500 m N to 9,070,500 m N every 1,000 meters. Three receiving points located in the urban areas of these towns were also included.

Figure 5.1-17 – Location of receiving points considered for the air pollutants dispersion modelling study.



Source: ARCADIS Tetraplan, 2008.

The downwash effect (sinking of the plume due to disturbance in the flow through the buildings) of the Sulfuric Acid Plant chimney were determined by USEPA's BPIP (Building Input Profile Program) software. The other industrial buildings do not interfere in the free flow of the dispersion of the pollutant plume because their height is less than one third of the chimney height (60 m).

5.1.9.7. Results

Maximum and average concentrations of pollutants were obtained for each receiving point considering that it will occur at ground level by processing the simulations using the ISCST3 model for the 5 years of meteorological data available (2003 to 2007).

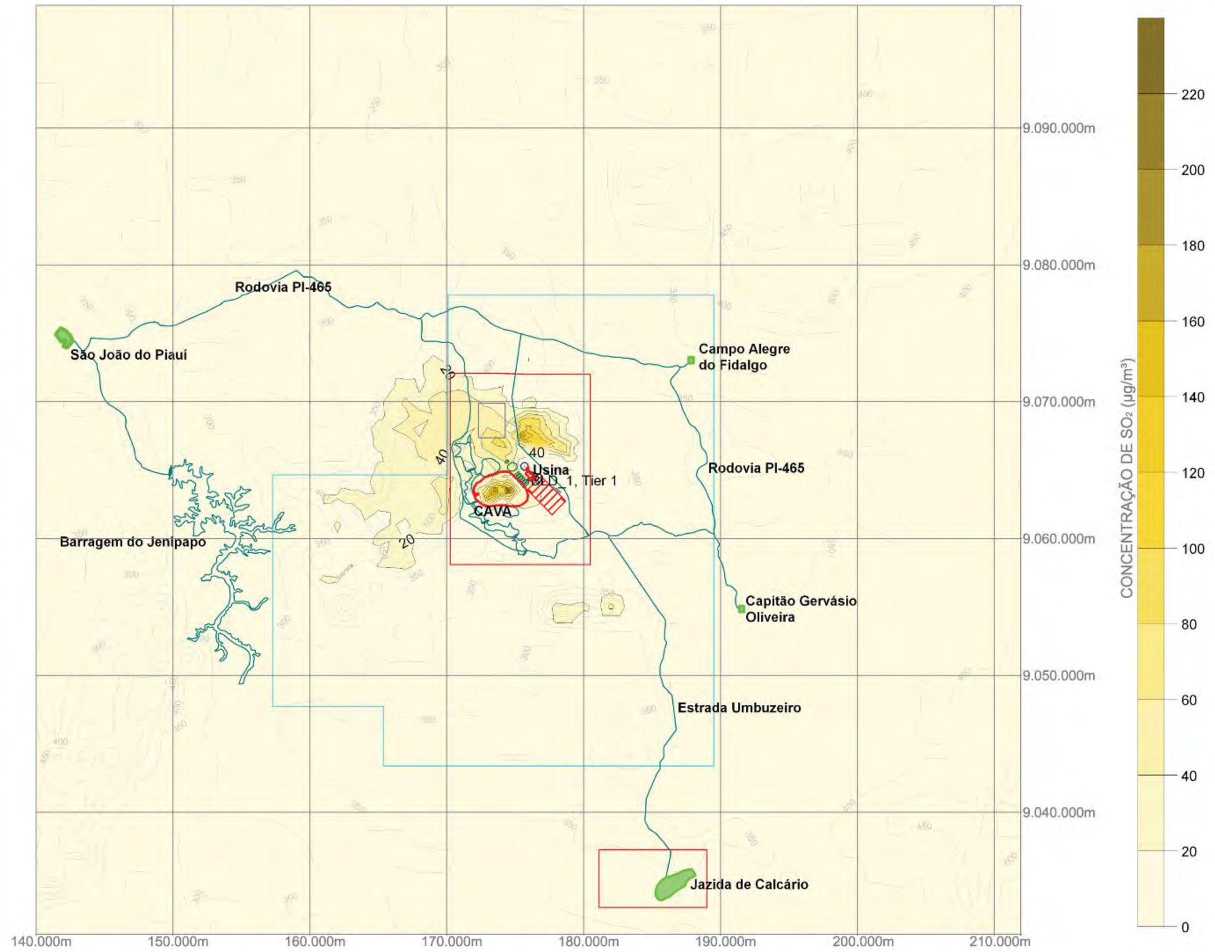
A) Sulfur Dioxide (SO_2)

The sulfur dioxide (SO_2) dispersion modeling results for the maximum concentration of 24 hours and for the annual average are shown in Figure 5.1-18 and Figure 5.1-19 respectively.

Data Table 5.1-28 shows the location of the recipients were maximum concentration were recorded according to the Figure 5.1-18 and Figure 5.1-19.

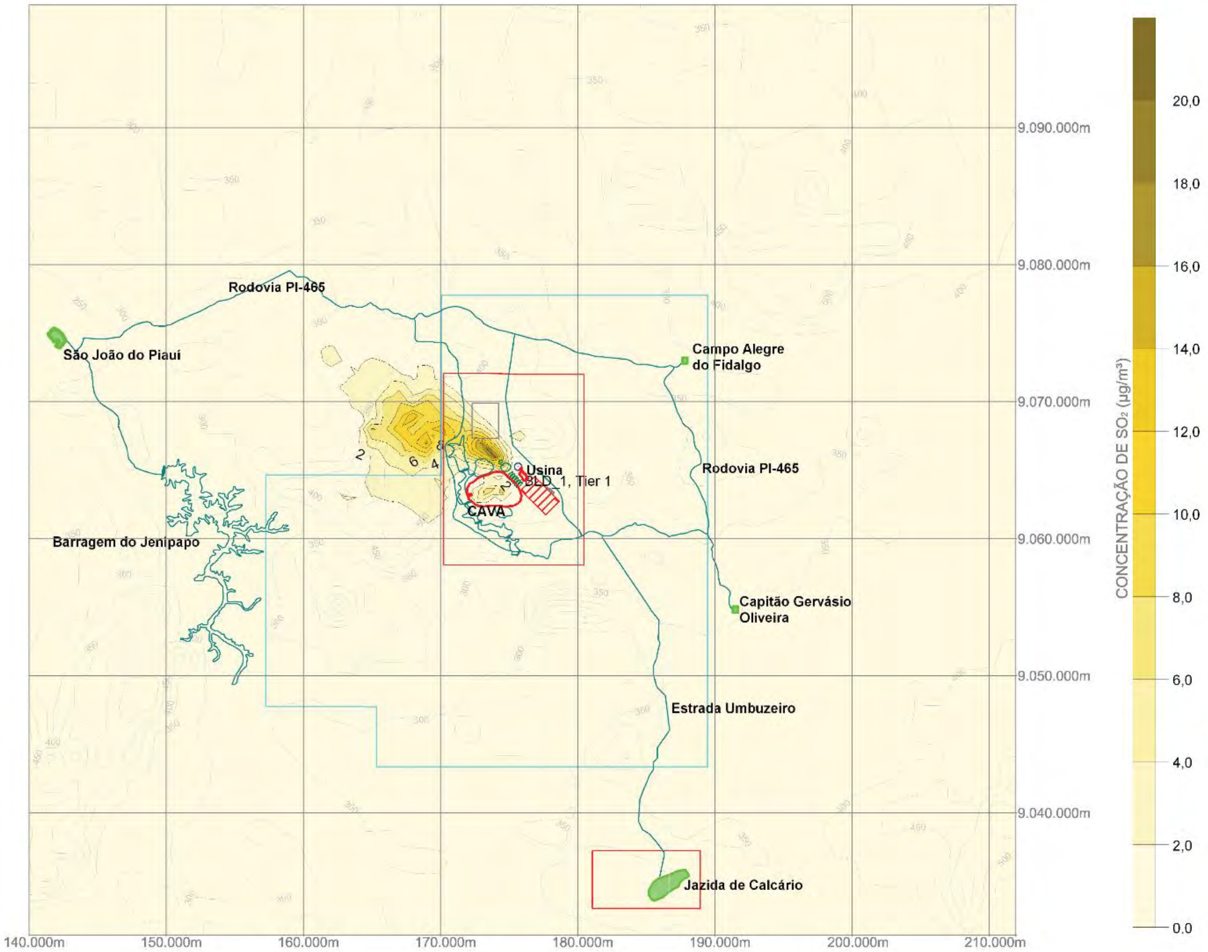
The maximum concentrations of 24 h and the average annual concentrations estimated for the three urban centers closest to the area where the sulfuric acid plant is projected are shown in Data Table 5.1-29.

Figure 5.1-18 – Maximum Sulfur Dioxide 24 h concentration (SO_2).



Source: ARCADIS Tetraplan, 2008.

Figure 5.1-19 – Average Annual Concentration of Sulfur Dioxide (SO_2)



Source: ARCADIS Tetraplan, 2008.

Data Table 5.1-28 – Maximum Sulfur Dioxide Concentration (SO_2).

Pollutant	Sampling Time	Primary Standard (µG/m³)	Maximum Concentration (µG/m³)	Coordinates	
				UTM-E	UTM-N
Sulfur Dioxide (SO_2)	24 h (1)	365	203.7	174.500	9.063.500
	MAA (2)	80	18.7	173.500	9.066.500

(1) It should not be exceeded more than once a year; (2) Annual Arithmetic Mean (AAM).
Source: ARCADIS Tetraplan, 2008.

Data Table 5.1-29 – SO_2 Concentration in the Nearest Urban Centers.

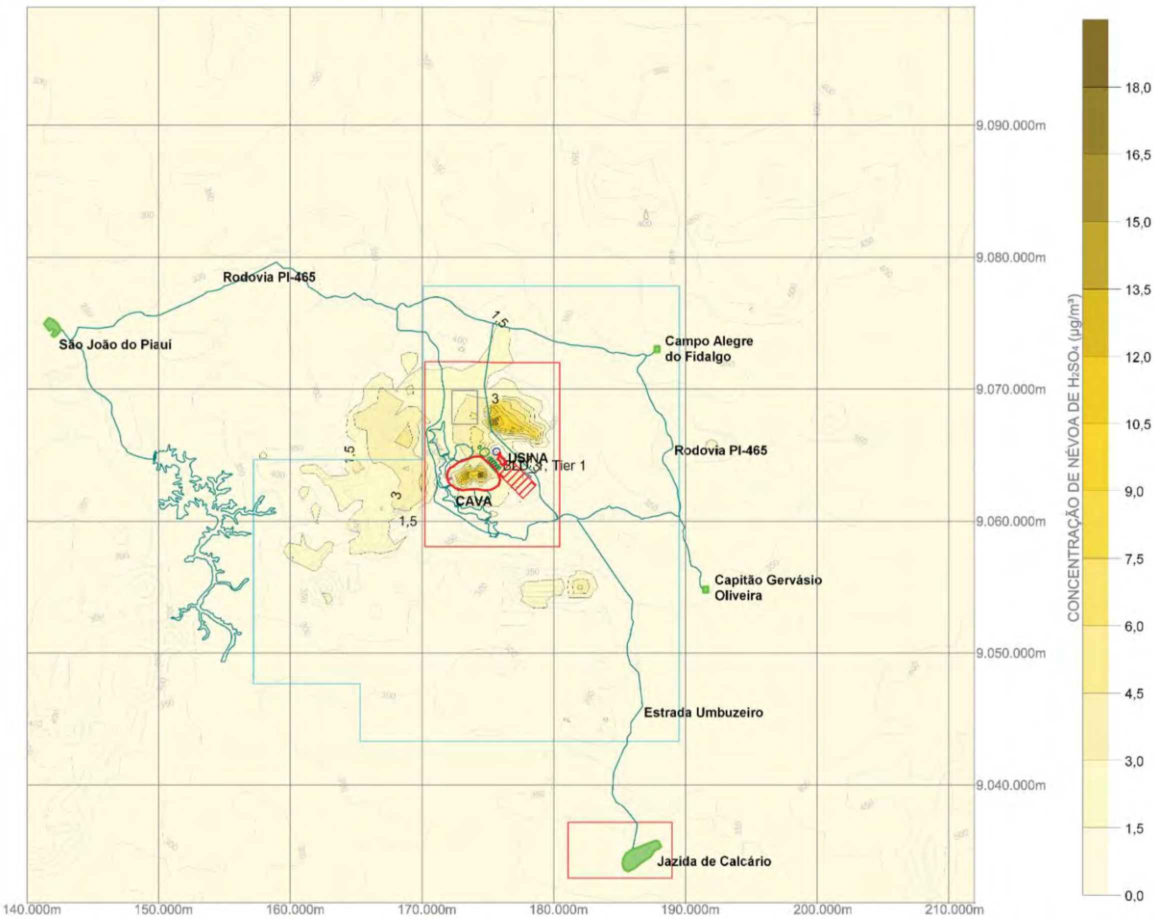
Town	Coordinates		Maximum Concentration – 24 h	Annual Average Concentration
	UTM-E	UTM-N	(μg/m³)	(μg/m³)
Capitão Gervásio Oliveira	191.536	9.054.850	2.17	0.04
Campo Alegre do Fidalgo	187.839	9.073.022	3.24	0.02
São João do Piauí	142.325	9.074.920	2.09	0.38

Source: ARCADIS Tetraplan, 2008.

B) Sulfuric Acid Mist (H_2SO_4)

The dispersion modeling results for the maximum concentration during 8 h for sulfuric acid (H_2SO_4) mist are shown in Data Table 5.1-30.

Figure 5.1-20 – Maximum Concentration in 8 h of Sulfuric Acid Mist.



Source: ARCADIS Tetraplan, 2008.

Data Table 5.1-30 shows the location where the maximum concentration was recorded according to Figure 5.1-20.

Data Table 5.1-30 – Maximum Sulfuric Acid Mist Concentration (H_2SO_4).

Pollutant	Sampling Time	ACGIH Limit (1) (µg/m³)	Maximum Concentration (µg/m³)	Coordinates	
				UTM-E	UTM-N
Sulfuric Acid Mist	8 H	200	17.0	175.500	9.067.500

(1) ACGIH (American Conference of Industrial Hygienists) (2007). This limit is applicable for continuous exposures, greater than 8 hours.

Source: ARCADIS Tetraplan, 2008.

The maximum concentrations in 8 h for the three urban centers closest to the project location are shown in Data Table 5.1-31.

Data Table 5.1-31 – H_2SO_4 Mist Concentration in Nearest Urban Centers.

Town	Coordinates		Concentration Maxima – 8 H
	UTM-E	UTM-N	(µg/m³)
Capitão Gervásio Oliveira	191.536	9.054.850	0.23
Campo Alegre do Fidalgo	187.839	9.073.022	0.36
São João do Piauí	142.325	9.074.920	0.20

Source: ARCADIS Tetraplan, 2008.

5.1.10. Vibration Levels and Sound Overpressure Simulation

5.1.10.1. Introduction

The assessment of vibration levels generated by the mining activities planned for nickel (*Brejo Seco*) and limestone (*Umbuzeiro*) was prepared by Prominer Projetos Ltda.

The vibration levels and acoustic pressure in the nearest communities resulting from blasting activities can be estimated using the particle speed prediction equations available in the specialized literature.

As presented in the Project Description chapter of this ESIA/RIMA (Volume I), there is a significant reduction in the area of the Nickel mine and Limestone quarry when comparing the characteristics of the current project proposed by PNM with the one proposed by VALE (2008). The nickel mine was reduced from 764.62 ha to 330.46 ha equivalent to a reduction of 57% of the occupied area. The limestone quarry went from 324.06 ha to 45.47 ha. Additionally, the limestone consumption went down from 650,000 to 476,000 tons per year.

The results from the simulations of the vibration and sound pressure levels previously developed are accepted considering the mentioned significant decrease in the areas and annual consumption of limestone, and can satisfactorily support the assessment of environmental impacts, the proposed mitigation actions and environmental programs.

5.1.10.2. General Aspects

During the blasting activities, in addition to the desired fragmentation of the rocks, part of the energy from the explosives is transformed into vibration of the ground and air.

The structural response plays a critical role in the perception in the surrounding areas. Other critical factors are people's tolerance and reaction to vibration.

The propagation effects added to the geological aspects of the terrain, change the amplitude and frequency of the vibrations as they pass from the blasting area to the location that is characterized. In general, vibration dissipates with increasing distance from the source.

Other impacts of the propagation are energy losses through absorption and dispersion and the formation of surface waves. In general, the parameters with the major influence on the vibration amplitude are the distance and the load waiting. The frequencies of terrain vibration are also influenced by the distance and the geological characteristics of the place.

The magnitude of the vibrations decreases rapidly with increasing distance if irregularities are present, as a large part of the energy will be used to overcome the friction between the particles and to move them.

Several factors influence the spread of vibration in the project area, such as the frequency of vibrations, the geology and the geo-mechanical characteristics of the topography. The vibration levels are also influenced by the parameters used when designed the blasting such as maximum load, loading rate, type of explosives, delay time and geometry (hole diameter, depth, spacing, sub drilling, etc.). The dissipation of the energy released during the blast over distance causes that the vibration levels drop rapidly further away from detonation.

In practice, the particle vibration speed, which represents the vibration of the terrain, fundamentally depends on two main quantities: the mass of the detonated explosive and the distance between the detonation points and the study point. This can be established mathematically using data from engineering seismographs.

Seismographs located in internal points close to the mining site and external points in the homes closest to the project limits are used to monitor the levels of vibration and acoustic pressure generated during blasting activities.

5.1.10.3. Legislation

The maximum permissible limits for terrain vibration and sound pressure are defined by the Brazilian standard ABNT-9653/05, which recommends the permissible limits for structural damage, according to Data Table 5.1-32.

Data Table 5.1-32 – Particle Vibration Limit Levels.

Frequency Range	Peak particle vibration limit	Sound pressure
4 Hz a 15 Hz	15 mm/s a 20 mm/s	134 dB(L)
15 Hz a 40 Hz	20mm/s a 50 mm/s	
Over 40 Hz	50 mm/s	

Source: Norma NBR 9653/05.

The most restrictive limit for particle speed corresponds to vibrations at a frequency of 4 Hz where 15 mm/s must not be exceeded.

The limit set for sound pressure is 134 db.

5.1.10.4. Magnitude Prediction

An empirical relationship that correlates the particle speed with the distance was used to estimate the magnitude of the expected vibration levels at receiving points located at different distances from the nickel mining area in *Brejo Seco* and from the limestone quarry in *Umbuzeiro*.

The United States Bureau of Mines (USBM) establishes the following relationship for determining the particle speed:

$$Vp = k\left(D/\sqrt{Q}\right)^{-b}$$

where	Vp	=	Peak particle speed (mm/s)
	D	=	Detonation distance from the measuring point (m)
	Q	=	Maximum Load (kg)
	K	=	Location Factor
	b	=	Location Factor

The factors K and b are constant which must be determined statistically by measurements at each blasting site. The $D/Q^{0.5}$ ratio is known as step distance.

In the absence of data obtained through blasting carried out in the study areas, four load-distance equations were used, with different K and b factors obtained for different limestone, basalt and sandstone sites in order to find a more possible range for the particle speed value (Vp). These four equations are:

Limestone	Basalt	Sandstone	***(Equation 1)***
$Vp = 3352{,}63\left(\frac{D}{\sqrt{Q}}\right)^{-1{,}95481}$	$Vp = 895{,}644\left(\frac{D}{\sqrt{Q}}\right)^{-2{,}152}$	$Vp = 50{,}4234\left(\frac{D}{\sqrt{Q}}\right)^{-0{,}82588}$	

(DUVALL et al. apud SINGH; ROY 1993).

Limestone	Basalt	Sandstone	***(Equation 2)***
$Vp = 534{,}564\left(\sqrt{\frac{Q}{D^{\frac{3}{2}}}}\right)^{2{,}41363}$	$Vp = 176{,}137\left(\sqrt{\frac{Q}{D^{\frac{3}{2}}}}\right)^{2{,}652}$	$Vp = 20{,}0686\left(\sqrt{\frac{Q}{D^{\frac{3}{2}}}}\right)^{1{,}02402}$	

(LANGEFORS; KIHLSTRÖM; WESTERBERG apud SINGH; ROY 1993).

Limestone	Basalt	Sandstone	***(Equation 3)***
$Vp = 10520{,}3\left(\frac{D}{Q^{\frac{1}{3}}}\right)^{-1{,}83095}$	$Vp = 4765{,}470\left(\frac{D}{Q^{\frac{1}{3}}}\right)^{-2{,}260}$	$Vp = 144{,}404\left(\frac{D}{Q^{\frac{1}{3}}}\right)^{-0{,}886030}$	

(AMBRASEYS; HENDRON apud SINGH; ROY 1993).

Limestone	Basalt	Sandstone	***(Equation 4)***
$Vp = -11{,}0496 + 489{,}478\left(\frac{D}{\sqrt{Q}}\right)^{-1}$	$Vp = -10{,}1452 + 183{,}815\left(\frac{D}{\sqrt{Q}}\right)^{-1}$	$Vp = -18{,}6286 + 300{,}305\left(\frac{D}{\sqrt{Q}}\right)^{-1}$	

(Central Mining Research Institute of India (CMRI) apud ROY, 2005).

As some relations provide the value of the largest component of the Particle Speed (VpMáx) and others the resulting Particle Speed (VpR), the final value was calculated considering the value of VpMáx in the three directions (VpMáx = VpL (longitudinal) = VpT (transversal) = VpV (vertical)) trying to standardize these results through the following relation:

$$V_p\,R = \sqrt{\left((VpL)^2 + (VpT)^2 + (VpV)^2\right)}$$

The general parameters of the blasting plans to be used in the Brejo Seco and in the *Umbuzeiro* deposits are shown in Data Table 5.1-33 and Data Table 5.1-34, respectively.

Data Table 5.1-33 – Planned Blasting Plan Parameters for the Nickel Mine (*Brejo Seco*).

Parameter	Units	Value
Hole Diameter	mm	76
Bench Height	m	3.00
Hole Length	m	3.50
Clearance	m	3.00
Spacing	m	4.65
Ore Volume per Hole	m^3	125
Ore Mass per Hole	t	72.40
Project Load Ratio	g/t	140
Explosive Mass in each Hole	kg/hole	10.16

Source: Arcadis/Tetraplan 2008.

At the nickel mine, the material that will require blasting to be extracted consists of a more siliceous portion and less weathered portion (at the base of the deposit) and boulders scattered inside the deposit. The blasting plan will have variations from one location to another depending on the type of material, structure, geometry and the humidity of the holes. Therefore, the project blasting plan will be adjusted and adapted at the time of the actual operation, depending on the conditions in the field.

According to the Executive Report FEL1 (Vale), the nickel deposit occurs in a geological context represented by a volcanic sedimentary sequence, tectonically intertwined in sand-pelitic meta sediments, which (with a roughly east-west disposition) host mafic ultramafic such as the *Brejo Seco* and *São Francisco* basic – ultrabasic complex.

In this way, the vibration levels at different distances will be calculated using equations 1 to 4 defined for basalt (basement rock) and for sandstone considering the absence of a specific attenuation equation for the location, potentially resulting in vibration levels between the values calculated for these two types of rock.

Data Table 5.1-34 – Blasting Plan Parameters Planned for the Limestone Quarry (*Umbuzeiro*).

Parameter	Units	Value
Hole Diameter	mm	76
Bench Height	m	10
Hole Length	m	11.39
Clearance	m	3

Parameter	Units	Value
Spacing	m	6
Ore Volume per Hole	m³	180
Ore Mass per Hole	t	498
Project Load Ratio	g/t	100
Explosive Mass in each Hole	kg/hole	50

Source: Arcadis Tetraplan 2008.

The blasting plan for the *Umbuzeiro* is dimensioned with two weekly blasts of 25 charges each, distributed in two rows with 13 holes in the first row and 12 holes in the second. They will use fuse accessories and non-electrical fuses for initiation and delays of 25 ms, 42 ms and 100 ms for connection between holes separating the 2 rows.

Equations 1 to 4 will be used with definite constants for limestone for the estimation of vibration levels at different distances from *Umbuzeiro*.

The predicted loading ratio for the nickel mine (*Brejo Seco*) is approximately 10 kg per hole, as shown in Data Table 5.1-33. Estimates of vibration levels for different distances were made considering maximum loads of 30 kg, 50 kg and 100 kg, the results are shown in Data Table 5.1-35, Data Table 5.1-36 and Data Table 5.1-37 for the basalt and sandstone ores, with vibration levels resulting between these two types of rock.

For the Limestone Quarry (*Umbuzeiro*) a loading flow of 50 kg per hole was dimensioned, as shown in Data Table 5.1-34. Data Table 5.1-38, Data Table 5.1-39 and Data Table 5.1-40 show estimated vibration levels with a maximum load per hold 50 kg (1 hole per hold), 100 kg (2 holes per hold) and 150 kg (3 holes per hold).

The towns closest to the nickel mining area are *Capitão Gervásio Oliveira*, 16 km away, and *Campo Alegre do Fidalgo*, 17 km away. The towns closest to the Limestone Quarry are *Capitão Gervásio Oliveira*, 25 km away and *Dom Inocêncio*, 34 km away. The planned location for implementing the contractors' accommodation is approximately 7 km from the nickel mine and 26 km from the Limestone Quarry.

Data Table 5.1-35 – Nickel Mine (*Brejo Seco*) – Estimates of Vibration Levels considering 30 kg loads

Distance (m)	Estimates of Particle Speed (VpR)							
	Equation 1		Equation 2		Equation 3		Equation 4	
	Basalt	Sandstone	Basalt	Sandstone	Basalt	Sandstone	Basalt	Sandstone
100	2.99	7.93	0.03	0.96	3.23	11.54	0.00	0.00
200	0.67	4.47	0.00	0.33	0.67	6.25	0.00	0.00
300	0.28	3.20	0.00	0.18	0.27	4.36	0.00	0.00
400	0.15	2.52	0.00	0.11	0.14	3.38	0.00	0.00
500	0.09	2.10	0.00	0.08	0.09	2.77	0.00	0.00
1,000	0.02	1.18	0.00	0.03	0.02	1.50	0.00	0.00
5,000	0.00	0.31	0.00	0.00	0.00	0.36	0.00	0.00
10,000	0.00	0.18	0.00	0.00	0.00	0.20	0.00	0.00
15,000	0.00	0.13	0.00	0.00	0.00	0.14	0.00	0.00
20,000	0.00	0.10	0.00	0.00	0.00	0.11	0.00	0.00
25,000	0.00	0.08	0.00	0.00	0.00	0.09	0.00	0.00
30,000	0.00	0.07	0.00	0.00	0.00	0.07	0.00	0.00
35,000	0.00	0.06	0.00	0.00	0.00	0.06	0.00	0.00

Data Table 5.1-36 – Nickel Mine (*Brejo Seco*) – Estimates of Vibration Levels considering 50 kg loads

Distance (m)	Estimates of Particle Speed (VpR)							
	Equation 1		Equation 2		Equation 3		Equation 4	
	Basalt	Sandstone	Basalt	Sandstone	Basalt	Sandstone	Basalt	Sandstone
100	5.19	9.80	0.11	1.62	4.75	13.42	4.94	4.51
200	1.17	5.53	0.01	0.56	0.99	7.26	0.00	0.00
300	0.49	3.95	0.00	0.30	0.40	5.07	0.00	0.00
400	0.26	3.12	0.00	0.19	0.21	3.93	0.00	0.00
500	0.16	2.59	0.00	0.14	0.12	3.23	0.00	0.00
1,000	0.04	1.46	0.00	0.05	0.03	1.75	0.00	0.00
5,000	0.00	0.39	0.00	0.00	0.00	0.42	0.00	0.00
10,000	0.00	0.22	0.00	0.00	0.00	0.23	0.00	0.00
15,000	0.00	0.16	0.00	0.00	0.00	0.16	0.00	0.00
20,000	0.00	0.12	0.00	0.00	0.00	0.12	0.00	0.00
25,000	0.00	0.10	0.00	0.00	0.00	0.10	0.00	0.00
30,000	0.00	0.09	0.00	0.00	0.00	0.09	0.00	0.00
35,000	0.00	0.08	0.00	0.00	0.00	0.07	0.00	0.00

Data Table 5.1-37 – Nickel Mine (*Brejo Seco*) – Estimates of Vibration Levels considering 100 kg loads.

Distantce (m)	Estimates of Particle Speed (VpR)							
	Equation 1 (mm/s)		Equation 2 (mm/s)		Equation 3 (mm/s)		Equation 4 (mm/s)	
	Basalt	Sandstone	Basalt	Sandstone	Basalt	Sandstone	Basalt	Sandstone
100	10.93	13.04	0.68	3.29	8.00	16.47	14.27	19.75
200	2.46	7.36	0.04	1.13	1.67	8.91	0.00	0.00
300	1.03	5.26	0.01	0.61	0.67	6.22	0.00	0.00
400	0.55	4.15	0.00	0.39	0.35	4.82	0.00	0.00
500	0.34	3.45	0.00	0.28	0.21	3.96	0.00	**0.00**
1,000	0.08	1.95	0.00	0.10	0.04	2.14	0.00	0.00
5,000	0.00	0.52	0.00	0.01	0.00	0.51	0.00	0.00
10,000	0.00	0.29	0.00	0.00	0.00	0.28	0.00	0.00
15,000	0.00	0.21	0.00	0.00	0.00	0.19	0.00	0.00
20,000	0.00	0.16	0.00	0.00	0.00	0.15	0.00	0.00
25,000	0.00	0.14	0.00	0.00	0.00	0.12	0.00	0.00
30,000	0.00	0.12	0.00	0.00	0.00	0.11	0.00	0.00
35,000	0.00	0.10	0.00	0.00	0.00	0.09	0.00	0.00

Data Table 5.1-38 – Limestone Quarry (*Umbuzeiro*) – Estimates of Vibration Levels considering 50 kg loads.

Distance (m)	Estimates of Particle Speed (VpR)			
	Equation 1 (mm/s)	Equation 2 (mm/s)	Equation 3 (mm/s)	Equation 4 (mm/s)
100	32.73	0.67	43.21	40.81
200	8.44	0.05	12.15	10.84
300	3.82	0.01	5.78	0.84
400	2.18	0.00	3.41	0.00
500	1.41	0.00	2.27	0.00
1,000	0.36	0.00	0.64	0.00
5,000	0.02	0.00	0.03	0.00
10,000	0.00	0.00	0.01	0.00
15,000	0.00	0.00	0.00	0.00
20,000	0.00	0.00	0.00	0.00
25,000	0.00	0.00	0.00	0.00

Distance (m)	Estimates of Particle Speed (VpR)			
	Equation 1 (mm/s)	Equation 2 (mm/s)	Equation 3 (mm/s)	Equation 4 (mm/s)
30,000	0.00	0.00	0.00	0.00
35,000	0.00	0.00	0.00	0.00

Data Table 5.1-39 – Limestone Quarry (*Umbuzeiro*) – Estimates of Vibration Levels considering 100 kg loads.

Distance (m)	Estimates of Particle Speed (VpR)			
	Equation 1 (mm/s)	Equation 2 (mm/s)	Equation 3 (mm/s)	Equation 4 (mm/s)
100	64.44	3.57	65.97	65.64
200	16.62	0.29	18.54	23.25
300	7.52	0.07	8.83	9.12
400	4.29	0.02	5.21	2.06
500	2.77	0.01	3.46	0.00
1,000	0.72	0.00	0.97	0.00
5,000	0.03	0.00	0.05	0.00
10,000	0.01	0.00	0.01	0.00
15,000	0.00	0.00	0.01	0.00
20,000	0.00	0.00	0.00	0.00
25,000	0.00	0.00	0.00	0.00
30,000	0.00	0.00	0.00	0.00
35,000	0.00	0.00	0.00	0.00

Data Table 5.1-40 – Limestone Quarry (*Umbuzeiro*) – Estimates of Vibration Levels considering 150 kg loads.

Distance (m)	Estimates of Particle Speed (VpR)			
	Equation 1 (mm/s)	Equation 2 (mm/s)	Equation 3 (mm/s)	Equation 4 (mm/s)
100	95.77	9.50	84.49	84.70
200	24.71	0.77	23.75	32.78
300	11.18	0.18	11.30	15.47
400	6.37	0.06	6.68	6.82
500	4.12	0.03	4.44	1.63

Distance (m)	Estimates of Particle Speed (VpR)			
	Equation 1 (mm/s)	Equation 2 (mm/s)	Equation 3 (mm/s)	Equation 4 (mm/s)
1,000	1.06	0.00	1.25	0.00
5,000	0.05	0.00	0.07	0.00
10,000	0.01	0.00	0.02	0.00
15,000	0.01	0.00	0.01	0.00
20,000	0.00	0.00	0.01	0.00
25,000	0.00	0.00	0.00	0.00
30,000	0.00	0.00	0.00	0.00
35,000	0.00	0.00	0.00	0.00

The factors that influence the sound pressure from blasting are the type and amount of explosive, the degree of confinement, the method of initiation, the local geology and topography, the distance and condition of the structures and the atmospheric conditions. Variations of the parameters used in the blasting plan will have a great influence on the sound pressure level. Also, atmospheric conditions, such as temperature, winds, clouds and phenomena such as thermal inversion, influence the spread of atmospheric overpressure.

The following equations were used to predict the magnitude of sound pressure at different distances from the mining area:

$$P = 536\left(\frac{D}{\sqrt[3]{Q}}\right)^{-0,794}$$

P in Pascals (Pa). This equation was obtained by SISKIND et. al (1993) for bench blasting.

$$P = 879\left(\frac{D}{\sqrt[3]{Q}}\right)^{-0,711}$$

P in Pascals (Pa). This equation was obtained by STACHURA et. al (1988) for bench blasting.

To express the sound pressure levels in dB (L), the following equation was used:

$$L_p = 10\log\left(\frac{P}{P_0}\right)^2$$

Where: Lp: Sound pressure level in db.
P: Measured pressure, in Pa.
P0: Reference value (20 μPa).

The expected sound pressure levels for a maximum load per blast of 30 kg, 50 kg, 100 kg and 150 kg were calculated; results are shown in Data Table 5.1-41 to Data Table 5.1-44.

Data Table 5.1-41 – Nickel Mine (*Brejo Seco*) – Sound Pressure Level Estimates Considering 30 kg loads.

Distance (m)	Sound pressure estimates (dB)	
	Equation 1 (mm/s)	Equation 2 (mm/s)
100	125	131
200	120	127
300	117	125
400	115	123
500	114	121
1,000	109	117
5,000	98	107
10,000	93	103
15,000	90	100
20,000	88	99
25,000	87	97
30,000	85	96
35,000	84	95

Data Table 5.1-42 – Nickel Mine (*Brejo Seco*) and Limestone Quarry (*Umbuzeiro*) – Sound Pressure Level Estimates Considering 50 kg.

Distance (m)	Sound pressure estimates (dB)	
	Equation 1 (mm/s)	Equation 1 (mm/s)
100	126	132
200	121	128
300	118	126
400	116	124
500	115	123
1,000	110	118
5,000	99	108
10,000	94	104

Distance (m)	Sound pressure estimates (dB)	
	Equation 1 (mm/s)	Equation 1 (mm/s)
15,000	91	102
20,000	89	100
25,000	88	98
30,000	86	97
35,000	85	96

Data Table 5.1-43 – Nickel Mine (*Brejo Seco*) and Limestone Quarry (*Umbuzeiro*) – Sound Pressure Level Estimates Considering 100 kg.

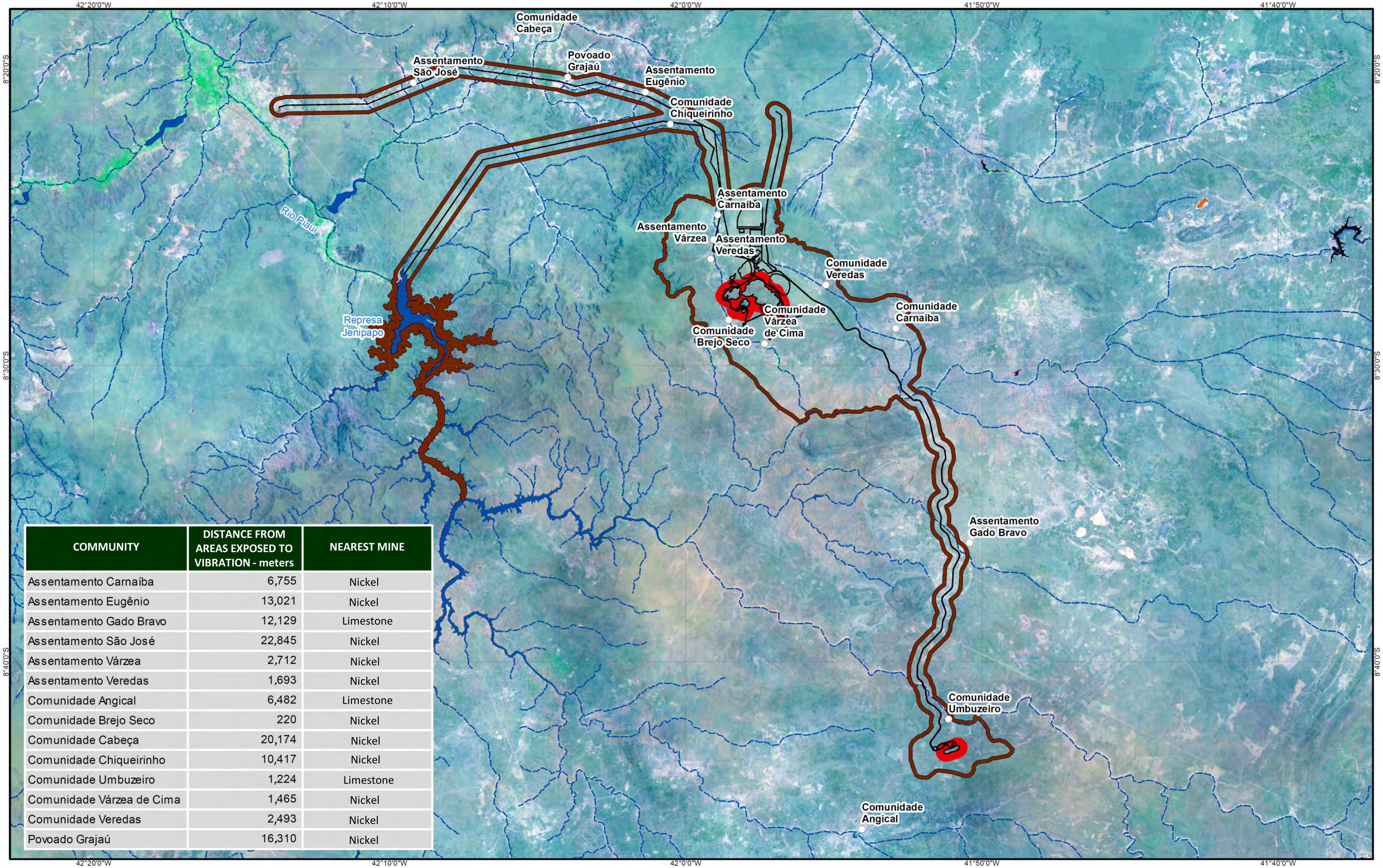
Distance (m)	Sound pressure estimates (dB)	
	Equation 1 (mm/s)	Equation 1 (mm/s)
100	127	134
200	123	130
300	120	127
400	118	125
500	116	124
1,000	112	120
5,000	100	110
10,000	96	105
15,000	93	103
20,000	91	101
25,000	89	100
30,000	88	99
35,000	87	98

Data Table 5.1-44 – Nickel Mine (*Brejo Seco*) and Limestone Quarry (*Umbuzeiro*) – Sound Pressure Level Estimates Considering 150 kg.

Distance (m)	Sound pressure estimates (dB)	
	Equation 1 (mm/s)	Equation 1 (mm/s)
100	128	135
200	124	130
300	121	128
400	119	126
500	117	125
1,000	112	121
5,000	101	111
10,000	97	106
15,000	94	104
20,000	92	102
25,000	90	101
30,000	89	100
35,000	88	99

The following map shows the areas subject to vibration in the Nickel Mine and Limestone Quarry.

Map 5.1-23 – Area Subject to Explosion Vibration in Nickel Mine and Limestone Quarry.



COMMUNITY	DISTANCE FROM AREAS EXPOSED TO VIBRATION - meters	NEAREST MINE
Assentamento Carnaíba	6,755	Nickel
Assentamento Eugênio	13,021	Nickel
Assentamento Gado Bravo	12,129	Limestone
Assentamento São José	22,845	Nickel
Assentamento Várzea	2,712	Nickel
Assentamento Veredas	1,693	Nickel
Comunidade Angical	6,482	Limestone
Comunidade Brejo Seco	220	Nickel
Comunidade Cabeça	20,174	Nickel
Comunidade Chiqueirinho	10,417	Nickel
Comunidade Umbuzeiro	1,224	Limestone
Comunidade Várzea de Cima	1,465	Nickel
Comunidade Veredas	2,493	Nickel
Povoado Grajaú	16,310	Nickel

LEGENDA

- Surrounding Communities
- Intermittent Drainage
- Water Mass
- Area of Direct Influence - ADI
- Directly Affected Area - DAA
- Areas subject to vibration

REFERÊNCIAS

Bases Cartograficas ao Milionésimo, IBGE, 2014.

ESCALA GRÁFICA

0 5 10 km

Sistema de Coordenadas: GCS SIRGAS 2000

MAPA DE LOCALIZAÇÃO

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Map 5.1-23 – Area Subject to Vibration from Explosions in the Nickel and Limestone Mines

EXECUTADO POR:	ESCALA:	NÚMERO:	DATA:
ARCADIS	1:225.000	Única	jun /2017

5.1.11. Speleological Heritage

5.1.11.1. Introduction

This section presents the speleological assessment (prospecting) carried out and a brief characterization of the speleological heritage within the context of the project, in order to support the analysis of potential implications on the cavity-forming environments and the speleological set of the project implementation area.

5.1.11.2. General Characteristics of the Physical Environment

Speleological studies follow other physical studies that support the identification of environments with the potential to form natural underground cavities based on the interaction between soil / rock substrate, natural relief and landscape.

The recognition of this information allows an adjusted and systematic study appropriate to the diversity caves. This diversity has implications for choosing the methodology of the prospecting techniques and for estimating the fragility of the system in relation to the project.

The main characteristics of the geological, the geomorphological components and the main environments forming natural underground cavities in the project implementation area are summarized below.

A) Geology

As presented in the Geology Chapter, the DAA has a complex geological history including rocks that go back to the volcano-sedimentary systems of the Meso Proterozoic platform (*Brejo Seco* complex), to the carbonate marine platforms of the Neo Proterozoic (*Barra Bonita* formation), to the alkaline magmatism from the Precambrian transition – Phanerozoic *Serra da Aldeia* and to Devonian coastal deposits (*Pimenteiras* formation).

B) Geomorphology

Geomorphology of the project area is very simple. The flattened to slightly undulating terrain maintains the isolation between high regions in the form of plateaus and mountains elongated in the E-W direction.

There is a well-defined connection between the geological units and the geomorphological compartmentalization. The meta-sediments of the *Barra Bonita* formation form the substrate for the flattened terrains while the elongated mountain ranges correspond to the alkaline and volcano-sedimentary igneous complexes, and finally, to the plate system supported by the Phanerozoic records.

There are deposits of slopes and lateritic coverings from the Cenozoic age (more recent) covering the other formations.

C) Environment Forming Natural Underground Cavities

The occurrence of caves in a landscape is one of the elements that characterize a karst terrain. Karst terrain, or simply, Karst, can be defined (Ford and Williams, 2007) as a terrain with distinct hydrogeology and landscape that is pronounced through a combination of highly soluble rocky substrate and well-developed secondary porosity. They are areas characterized by sinks, caves, depressions and closed drains, outcrops of isolated rocks and well-developed springs.

The development of canals in the karst is directly associated with surface phenomena, particularly the way the surface water and the ground interact with the rocky substrate.

Williams (1983) and others already reinforced the presence of these characteristics as essential to the development of a canal aquifer. The high rate of solubility and fracturing of the rocky body favors an intense percolation of water and the formation of a thin and very irregular soil layer. It is at the threshold between soil and the rocky top that the highest dissolution rates and development of preferred water absorption points occur.

Ford and Williams (2007) review the occurrence modes and particularities that are expressed in the external karst morphology regardless of the climatic condition or internal structure of the substrate. Many of the exterior characteristics such as exposed rock in the form of pinnacles, irregular blocks, pavements and karrens, may be absent due to the presence of a draining rock layer that is more favorable to soil development. In this case, the absence of a surface drainage network is notorious (since the entire water drainage system is carried out through underground pipes or rivers).

Generally speaking, a karst environment expresses the following physical characteristics:

- Absence of superficial circulation in the high areas. Eventually, the calcareous region can be crossed by deep canyons opened by rivers from extra-karst areas.
- Presence in the ridges and slopes of limestone pavements of varying depths.
- Frequent presence of "blind" forms: dolinas, *uvalas* and *poljés*, as well as "blind valleys"; and
- Presence of numerous ravines and caves in the slopes.

Under Brazilian law, the concept of "cave" is defined in CONAMA Resolution No. 347, 2004: "any and all underground space penetrable by humans, with or without an identified opening, popularly known as a cave, cavern, den, abyss and hole, including its environment, its mineral and water content, the biotic communities found there and the rocky body where they belong provided that their formation was by natural processes, regardless of dimensions or the type of embedding rock".

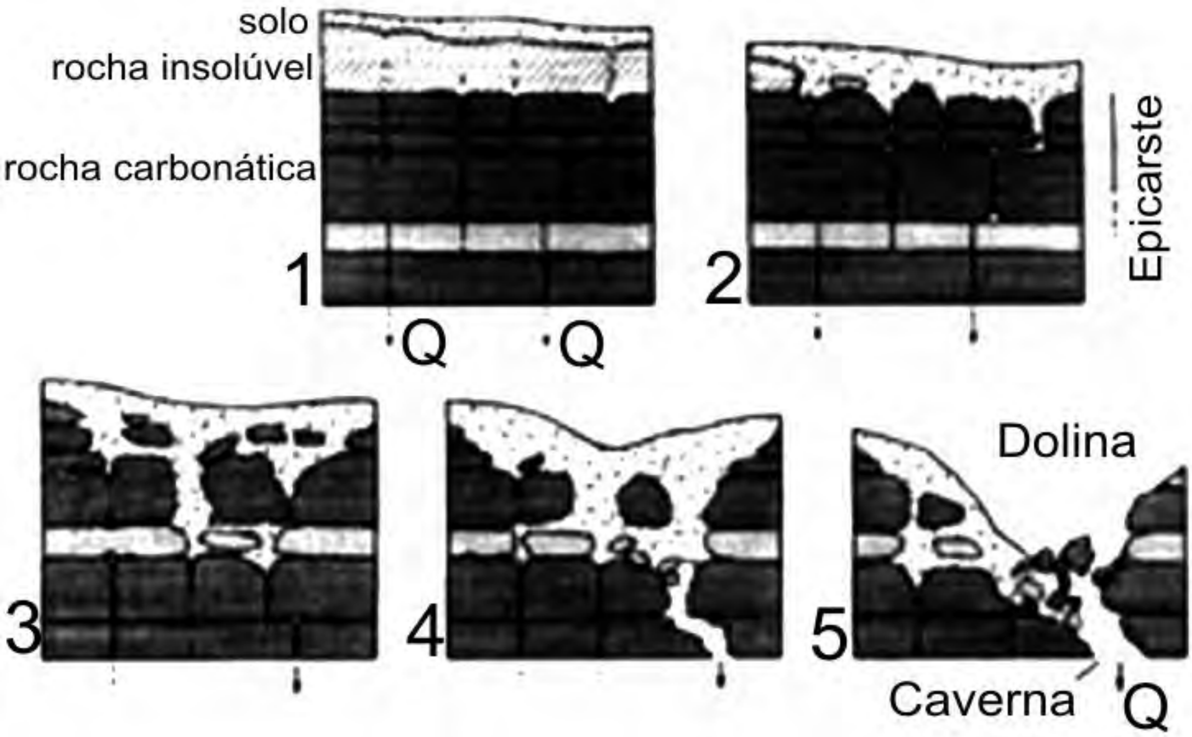
An evaluation of speleological potential was made based on the search for elements that can evidence the level of local karstification, or in other words, the number of characteristics that allow defining a certain environment as karst (Gillieson, 1997).

One of these essential characteristics is the *epicarste*, without which there is no development of caves or systems of caves and canals (karst).

The *epicarste* is the ground present on the karst surface. One of its characteristics is its extremely irregular thickness related to the different dissolution rates of the rock itself. In general, this horizon is not very thick, varying according to the region's climate and the vegetation present. In forested areas the soil tends to remain protected from erosion and, therefore, the thickness of the epicarste in these cases is generally greater. However, even with vegetation cover, the presence of limestone pavement and other karst characteristics in rocks exposed on the surface is common. Figure 5.1-21 shows the stages of evolution of the *epicarste* until it generates a sinkhole.

The genesis of karst soils is directly related to the loss of runoff and water absorption by the aquifer through surface points. The following 1 to 5 drawings illustrate in chronological order how the expansion of the channels in the dissolution of the rock promotes a total irregularity of the top limit of the soil/rock. The "Q" points refer to the preferred conductivity of the water.

Figure 5.1-21 – Epicarste Evolution Stages.



Source: Adopted from Klimchouk et.al (2000).

Although limestone rocks are the main occurrence of caves, there are other environments capable of developing caves present in the study area: granitic massifs, slopes of plateaus and lateritic deposits of slopes or canga.

In common, these other environments have the phenomenon of erosion acting differently on the substrate to promote the occurrence of cavities.

Like Hardt's (2003) classification, the occurrence and diversity of caves in granitic and gneiss rocks is conditioned by the exposure capacity of granitic blocks (boulders) and cracks through the transport of fines (soil). Zampaulo et al. (2007) point out that the "stacking" of blocks and exposure of cracks makes these places more sensitive to human interventions to suppress vegetation or maintain springs.

Canga caves have a unique formation with the erosive process starting at the soil – rock interface and extending over the rocky substrate. Mechanical erosion guides the opening of cavities to slopes with a tendency to verticalization (Dutra, 2013).

The last environment for the formation of caves is the slope system of slabs in sandstones. In this environment the driving process of formation is the transportation of fines known as "piping". The caves in this context are typical of the southeast region of Piauí (Fontugne et al. 2013), and can constitute extensive occurrence domains, known in the technical literature as "*Provinces*" (Monteiro & Ribeiro, 2001) within the concept established by Karmann & Sanches (1979).

5.1.11.3. Methodological Aspects

The procedures adopted in this study aimed at (i) the identification and delimitation of areas favorable to the formation of speleological characteristics susceptible to potential impacts of the project; and (ii) the systematic direct field search (prospecting) for caves, cavities, cracks or shelters.

To this end, in addition to the concepts of karst and other cave-forming environments, the recommendations of the training in speleology and environmental licensing at the *Centro Nacional de Pesquisa e Conservação de Cavernas* (CECAV, 2013) were also followed.

Considering the some 10,000 hectares including the entire DAA and area of influence, the geological diversity and the different type of structures that conform the project, it was decided to develop the works in two phases:

- Phase 1 – Recognition of Speleological Potential; and
- Phase 2 – Speleological Prospecting.

The methodological aspects of each of these phases are detailed below.

A) Phase I – Identification of Speleological Potential

The general objective of this phase was to investigate the speleological potential of the area where the project will be located, identifying areas and environments with the possibility of occurrence of speleological patrimony.

For this purpose, the following steps were performed: (i) bibliographic review; (ii) analysis of the characteristics of the physical environment; (iii) extensive field recognition; (iv) compilation and processing of collected information; and (v) interpretation of results and definition of the target area for speleological prospecting (Phase II).

The target area of the field work done during Phase I was based on CONAMA Resolution No. 347/04, which delimits a protection *buffer* area of 250 meters around the horizontal projection of any cave. In this way, the fieldwork of this phase covered the entire DAA of this project including a 250-meter buffer, called the Speleological Potential Recognition Area.

In addition, previously recorded cavities were verified in the regional secondary data and various registers, including consultations with the National Cavities Register of the Brazilian Speleology Society and the cavity records database of the National Cave Research and Conservation Center (CECAV).

In this sense, Phase I will support the delimitation of the speleological prospecting target area (Phase II), as well as helping to outline strategies for specific field work.

B) Phase II – Speleological Prospecting

Phase II comprises the completion of the speleological prospecting itself, with a record of all inspection points visits within the target area of the speleological prospecting.

The fieldwork of this stage includes an investigation and systematic scanning of the area with the execution of detailed paths, including observations of the geological and geomorphological context and the registration of speleological characteristics by:

- Spatial allocation in sub metric resolution (DGPS Trimble ® Juno SB Handheld) under the SIRGAS 2000 datum.
- Photographic record.
- Identification of morphologies and genetic conditions.
- Characterization of watershed areas or catchment areas of the karst aquifer; and
- Cartographic documentation of the elements.

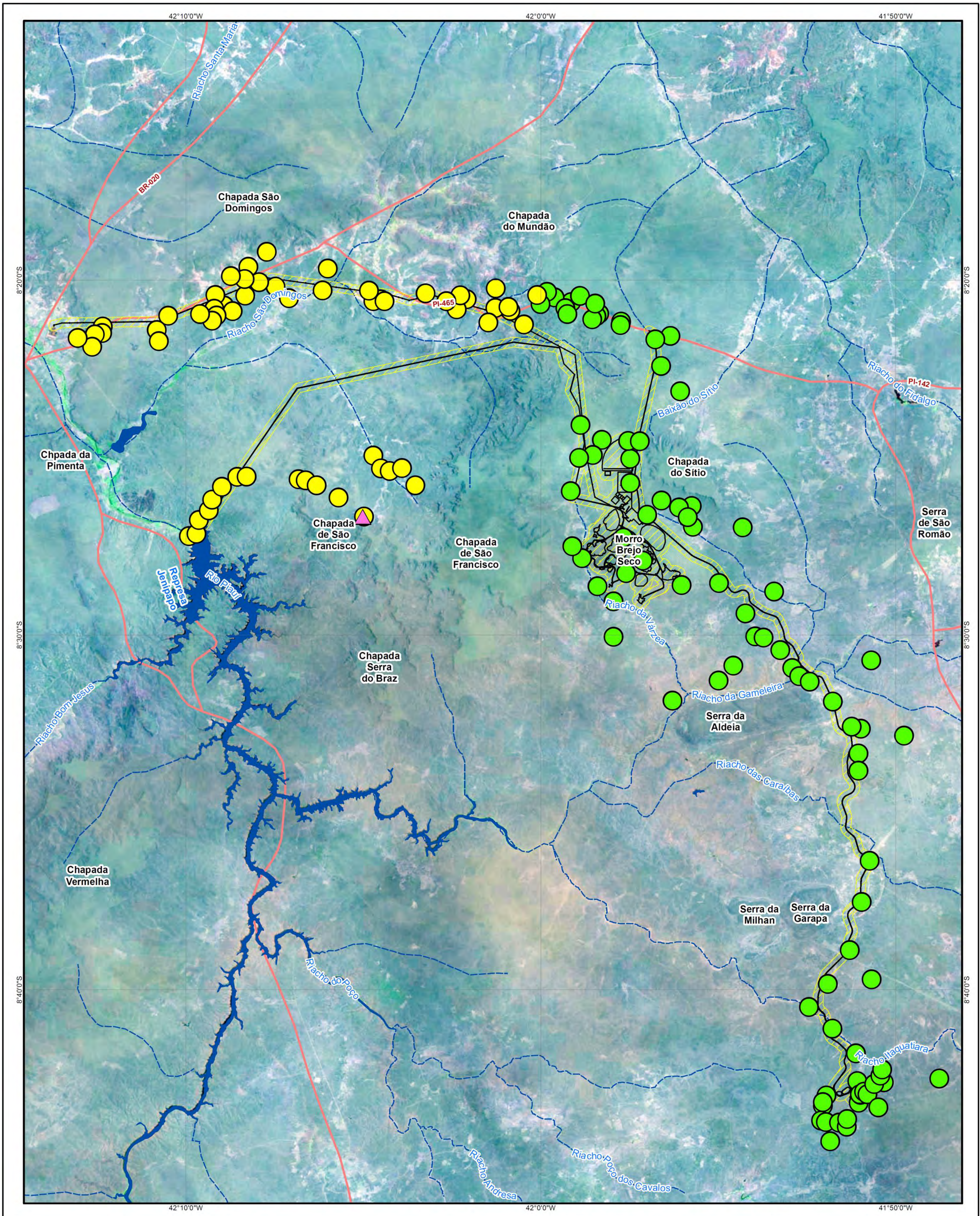
5.1.11.4. Results

A) Phase I Results – Identification of Speleological Potential

During the field work, 150 points were surveyed and analyzed throughout the entire target area, as well as made possible the expeditious recognition of caves known in the region, such as the *Toca da Baixa dos Caboclos*.

The following map, identifying the speleological potential, shows the spatial distribution of the points verified and analyzed in the field stage of Phase I. ANNEX VII (Volume IV) gathers all the surveyed points with sequential numbering, coordinates, location and collected information about the environments covered.

Map 5.1-24 – Phase 1 – Field Points, caves and shelters registered with CANIE and AIE.



LEGENDA

- Cavities CANIE 2017
- Field Points – phase I – time zone 23S
- Field Points – phase I – time zone 24S
- Road System
- Intermittent Drainage
- Water Mass
- Directly Affected Area - DAA
- Recognition Area of Speleological Potential

REFERÊNCIAS

Cadastro Nacional de Informações Espeleológicas (CANIE), 2017
Bases Cartograficas ao Milionésimo, IBGE, 2014.

ESCALA GRÁFICA

0 2,5 5 km

Sistema de Coordenadas: GCS SIRGAS 2000

LOCALIZAÇÃO

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Map 5.1-24 – Speleological Potential Area (Phase I)

EXECUTADO POR:	ESCALA	FORMATO:	FOLHA:	DATA:
ARCADIS	1:180.000	A3	ÚNICA	MAI /2017

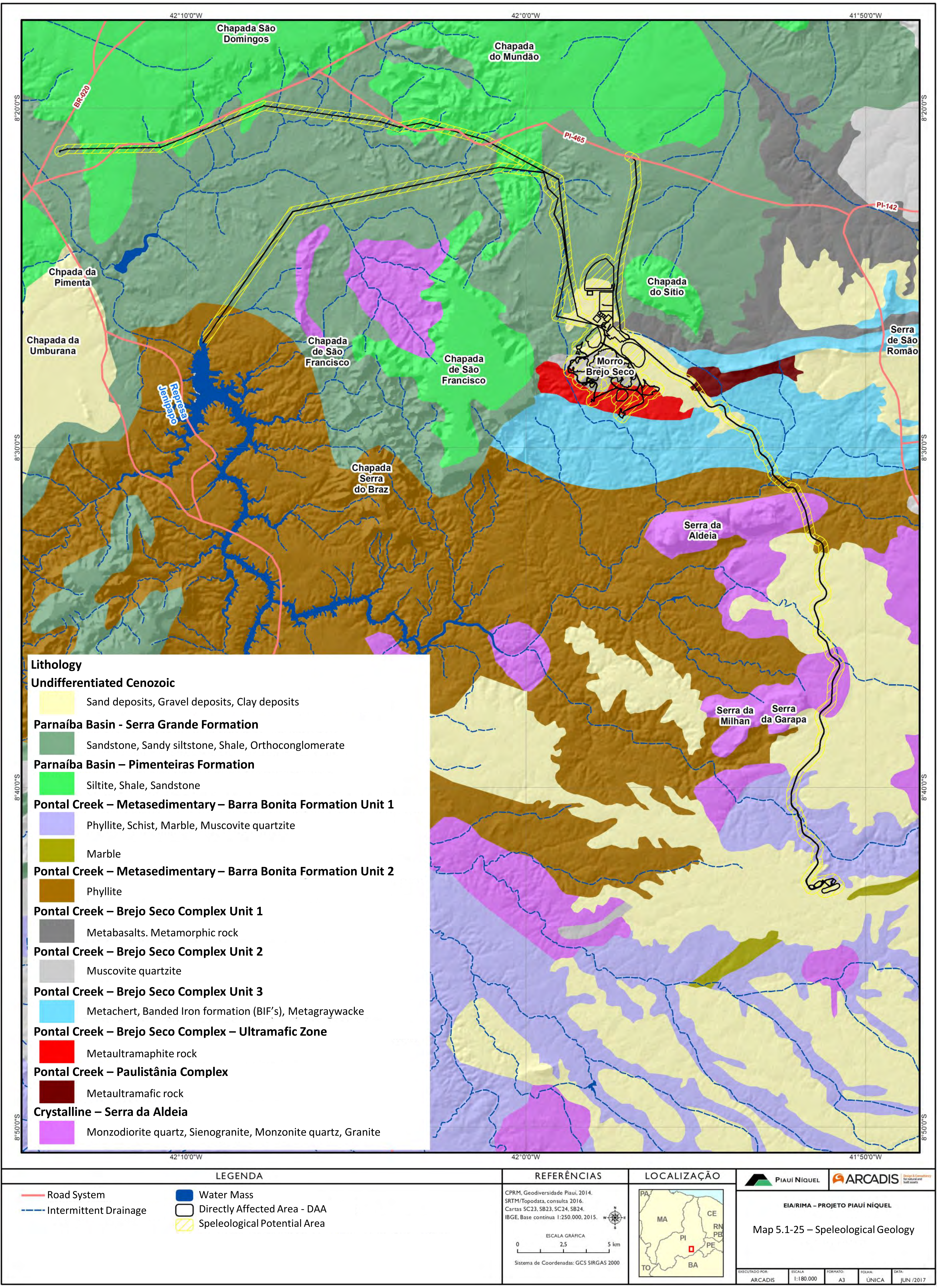
The field reports show that most of the area, especially where linear structures of the project (water pipeline, power transmission line and roads) are located, lie on sandstones or lateritic soil.

The discontinuity in flatness occurs with the presence of granitic boulders in the area of the projected access roads (which connects the Limestone Quarry and the nickel mining complex) and in the limestone areas (karstic environment) with cracks and noticeable rock exposures that initially condemn the most important sector of the project area for speleological issues and suggest a significant speleological potential.

In addition, it should be noted the occurrence of slabs and steep walls with residual structures (*testimony hills*) both in the target area of the Phase I fieldwork and in adjacent regions. According to the *Cadastro Nacional de Informações Espeleológicas* for the areas in the vicinity of the project, there are records of areas with speleological characteristics such as shelters, recesses and cavities. *Toca da Baixa dos Caboclos*, a sandstone shelter, 6 km away from the project is one of the examples.

In summary, the field work of Phase I allowed the verification of all geological units / outcrops and geomorphological characteristics of the area of interest, as well as making it possible to identify the elements of the rocky substrate and the natural relief that provide the formation of cavity-forming environments, as shown in Map 5.1-25 and Map 5.1-26.

Map 5.1-25 – Geology (A) – Units favorable to the karstification or formation of caves.



42°10'0"W
42°0'0"W
41°50'0"W
8°20'0"S
8°30'0"S
8°40'0"S
8°50'0"S
Chapada São Domingos
Chapada do Mundão
BR-020
PI-465
PI-142
Chpada da Pimenta
Chapada da Umburana
Chapada do Sítio
Serra de São Romão
Chapada de São Francisco
Chapada de São Francisco
Morro Brejo Seco
Represa Jenipapo
Chapada Serra do Braz
Serra da Aldeia
Serra da Milhan
Serra da Garapa
Lithology
Undifferentiated Cenozoic
Sand deposits, Gravel deposits, Clay deposits
Parnaíba Basin - Serra Grande Formation
Sandstone, Sandy siltstone, Shale, Orthoconglomerate
Parnaíba Basin – Pimenteiras Formation
Siltite, Shale, Sandstone
Pontal Creek – Metasedimentary – Barra Bonita Formation Unit 1
Phyllite, Schist, Marble, Muscovite quartzite
Marble
Pontal Creek – Metasedimentary – Barra Bonita Formation Unit 2
Phyllite
Pontal Creek – Brejo Seco Complex Unit 1
Metabasalts. Metamorphic rock
Pontal Creek – Brejo Seco Complex Unit 2
Muscovite quartzite
Pontal Creek – Brejo Seco Complex Unit 3
Metachert, Banded Iron formation (BIF's), Metagraywacke
Pontal Creek – Brejo Seco Complex – Ultramafic Zone
Metaultramaphite rock
Pontal Creek – Paulistânia Complex
Metaultramafic rock
Crystalline – Serra da Aldeia
Monzodiorite quartz, Sienogranite, Monzonite quartz, Granite
LEGENDA
Road System
Intermittent Drainage
Water Mass
Directly Affected Area - DAA
Speleological Potential Area
REFERÊNCIAS
CPRM, Geodiversidade Piauí, 2014.
SRTM/Topodata, consulta 2016.
Cartas SC23, SB23, SC24, SB24.
IBGE, Base contínua 1:250.000, 2015.
N
S
W
E
ESCALA GRÁFICA
0
2,5
5 km
Sistema de Coordenadas: GCS SIRGAS 2000
LOCALIZAÇÃO
PA
MA
CE
RN
PB
PI
PE
TO
BA
PIAUÍ NÍQUEL
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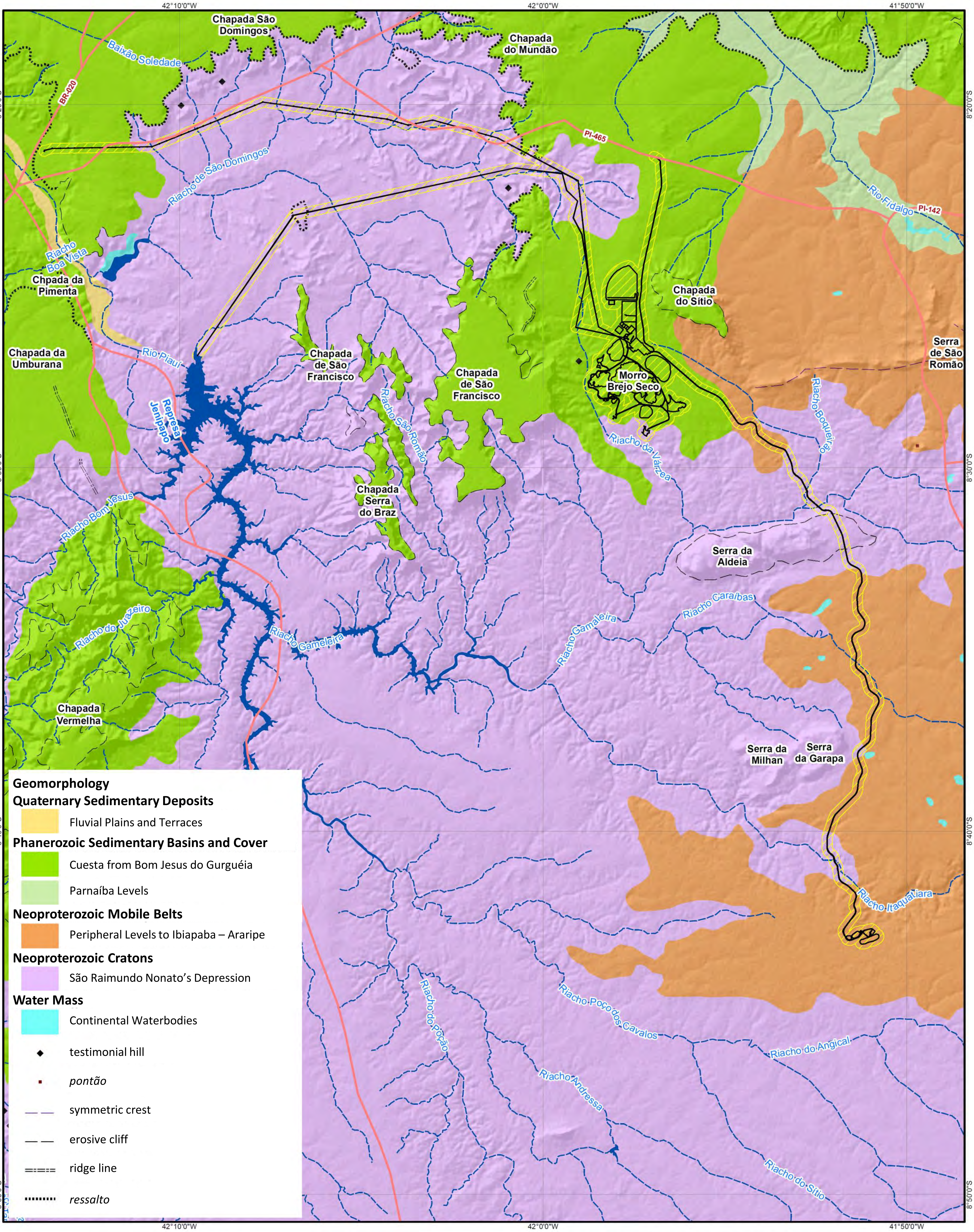
Map 5.1-25 – Speleological Geology
EXECUTADO POR:
ARCADIS
ESCALA
1:180.000
FORMATO:
A3
FOLHA:
ÚNICA
DATA:
JUN /2017

Map 5.1-26 – Geomorphology (B) – Units favorable to the karstification or formation of caves.



LEGENDA

- Road System
- Intermittent Drainage
- Water Mass
- Directly Affected Area - DAA
- Speleological Potential Area

REFERÊNCIAS

Bases Cartograficas ao Milionésimo, IBGE, 2014. Projeto RADAM mapas.ibge.gov.br/bases-e-referenciais/bases-cartograficas/cartas.html Cartas SC23, SB23, SC24, SB24.

ESCALA GRÁFICA 0 2,5 5 km

Sistema de Coordenadas: GCS SIRGAS 2000

LOCALIZAÇÃO

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Map 5.1-26 – Speleological Geomorphology

EXECUTADO POR:	ESCALA	FORMATO:	FOLHA:	DATA:
ARCADIS	1:180.000	A3	ÚNICA	JUN /2017

After compiling the data collected in Phase I, the analysis of the geological and geomorphological conditions and of sub-surface investigations (surveys) made available by the project, it was possible to identify the areas and environments with significant potential for the occurrence of speleological heritage:

- Karstification zone: Area to the south of the project, known as *Umbuzeiro* where the Limestone Quarry and related facilities will be located.
- Slope caves formation: Areas where the *Serras do Milhan* and *Aldeia* are close to or within the target area of Phase I along the road connecting *Umbuzeiro* and the nickel mine.
- Formation of caves in lateritic canga: *Morro Brejo Seco*, central area of the project; and
- Formation of caves in sandstone escarpment: Areas where the escarpments of the plateaus cross or approach the target area of Phase I.

These environments were mapped and overlaid with the project's DAA (and respective buffer of 250 m), which resulted in 8 (eight) target areas where the inspection points must be densified and carefully navigated during Phase II.

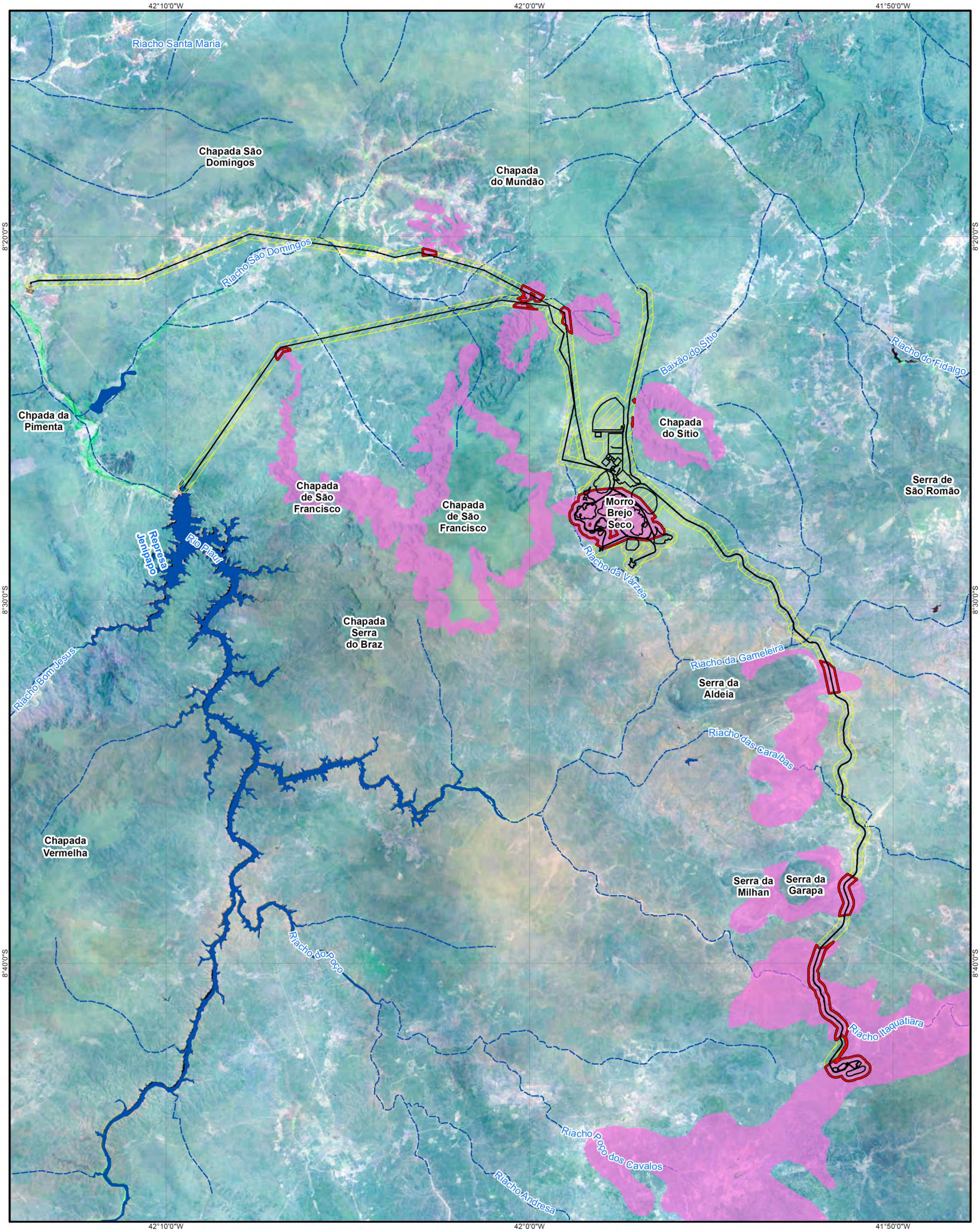
In addition to the aforementioned targets, Phase II involved the verification of other sectors of the DAA and their respective 250 m buffer, through control points in order to ensure a consistent recognition of the speleological environment eventually existing in the project area.

In this way, the target area for speleological prospecting was defined: the project DAA adding the 250 m buffer (CONAMA Resolution No. 347/04), and areas of geological and geomorphological conformation with predisposition to develop the required characteristics towards the DAA and its protection buffer.

Since this is a conceptual delimitation, this area has a leading character and it is often necessary to investigate beyond its limits, as it is necessary to ensure that there are no caves outside the area where the project is being developed towards the DAA and its protection buffer.

Map 5.1-27 shows the target area for speleological prospecting and the 8 areas of significant speleological potential identified above.

Map 5.1-27 – Speleological Potential.



LEGENDA	
Intermittent Drainage	Target Areas
Water Mass	Recognition Area of Speleological Potential
Directly Affected Area - DAA	Significative Speleological Potential Areas

REFERÊNCIAS

Cadastro Nacional de Informações Espeleológicas (CANIE), 2017
Bases Cartograficas ao Milionésimo, IBGE, 2014.

ESCALA GRÁFICA
0 2,5 5 km

Sistema de Coordenadas: GCS SIRGAS 2000

LOCALIZAÇÃO

PA, MA, CE, PI, PB, PE, TO, BA

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Map 5.1-27 – Speleological Prospecting (Phase II)

EXECUTADO POR:	ESCALA	FORMATO:	FOLHA:	DATA:
ARCADIS	1:180.000	A3	ÚNICA	MAI /2017

The results of the Speleological Prospecting (Phase II) are presented below.

B) Phase II Results – Speleological Prospecting

In this phase, the speleological prospecting field works were completed.

The 8 demarcated areas resulted in 3,242 ha and were covered by 351 sampling points, 389 photographic records and 87.23 km of walking and 411 km traveled.

All collected date is presented in ANNEX VII (Volume IV) including the table of sampling points.

a) Karst Limestone – Umbuzeiro Region

The metal calcium blocks of the *Barra Bonita* formation occur in the *Umbuzeiro* area. A little further to the north, advancing along the road, the unit moves to rocks made of mica schist garnet, outcropping in the *Itaquatiara* stream.

In the *Umbuzeiro* region, the entire area has a flattened profile with localized occurrences of metal calcium blocks of various sizes from 10 m to 0.5 m that extends predominantly in parallel, in the form of pavements indicating dissolution action in fractures (Photo 5.1-70, numbers 17 and 47). The western sector of the area becomes different with the dominance of a flattened *epicarste* and, at times, lack of limestone blocks. The soil varies between sandy, sandy-clay and conglomeratic sediments.

The small shelters are created from dissolution cracks in the accommodation spaces between the meta calcium blocks, forming recesses approximately one meter high by half a meter of horizontal development. In such formations, bats, small reptiles and rodent mammals were observed (Photo 5.1-70, numbers 5, 35, 54).

The existing drilling network served not only as a means of accessing the path, but also for the investigation of the karst. The holes that remained open allowed to assess the existence of water and estimate the depth of the water level. In some cases the drill hole intercepted the aquifer and, at the request of the local population, it was left open since they transformed them into groundwater collection wells (Photo 5.1-70, numbers 113 and 181). In those situations the drill hole intercepted a canal in a unsaturated zone that over the years collapsed to form artificial "skylights" (Photo 5.1-70, numbers 116, 117 and 132).

Map 5.1-28 – Karst Limestone Area of Occurrence and Adjacencies.

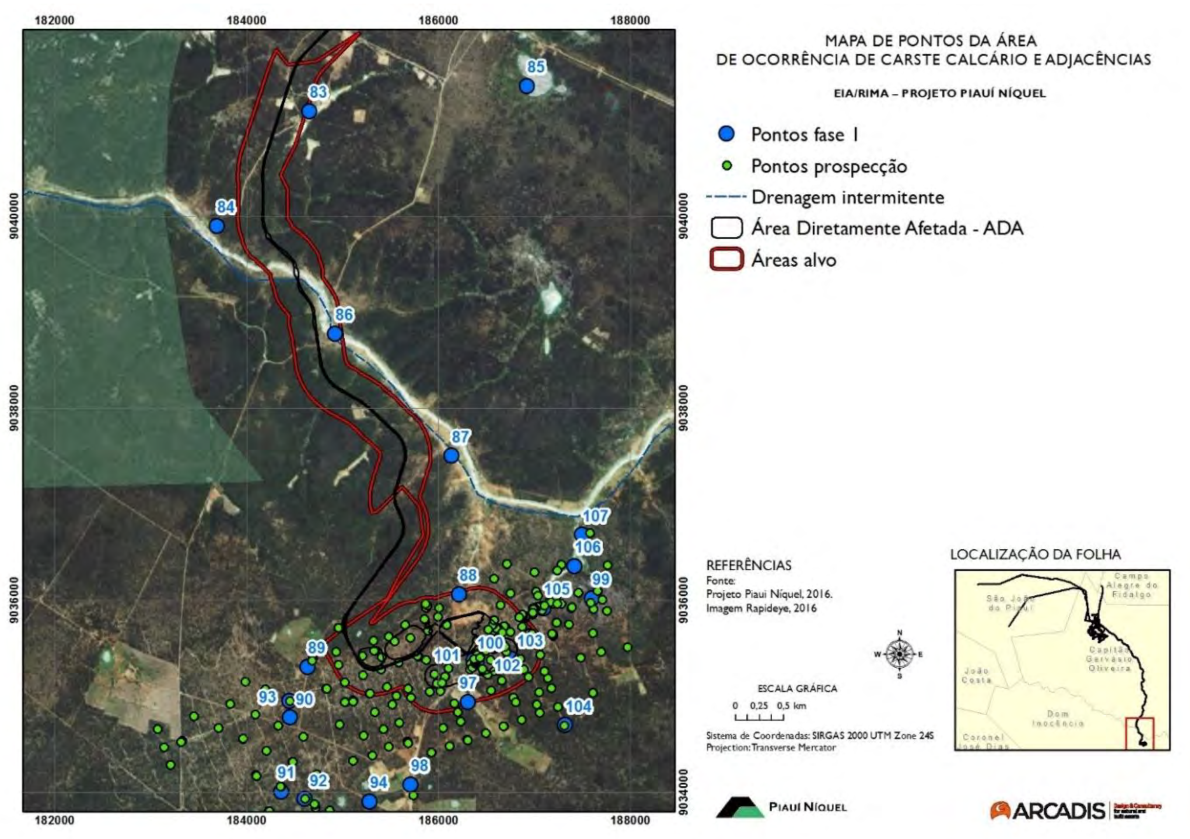


Photo 5.1-70 – Limestone karst Photographic Registry – *Umbuzeiro*.

Date and time of Registry		20/10/2016 9:35	
Coordinates (UTM SIRGAS 2000)	X	186.331	
	Y	9.035.280	
	Zone	24L	
Record Number		3	
Description		Meta calcium. Photo 2016-10-20 09.35.47.jpg Several rock bodies protruding from the sandy soil.	
Date and time of Registry		20/10/2016 9:39	
Coordinates (UTM SIRGAS 2000)	X	186.356	
	Y	9.035.299	
	Zone	24	
Record Number		4	
Description		Meta calcium. Photo 2016-10-20 09.39.22.jpg CVRD borehole frame. Abandoned hole suggests voids that made it difficult to drill.	

Date and time of Registry		20/10/2016 9:46	
Coordinates (UTM SIRGAS 2000)	X	186.381	
	Y	9.035.346	
	Zone	24L	
Record Number		5	
Description		Meta calcium. 2016-10-20 09.46.34.jpg Residual block with several slits. Scale: 1m stick.	

Date and time of Registry		20/10/2016 10:51	
Coordinates (UTM SIRGAS 2000)	X	186.617	
	Y	9.035.605	
	Zone	24L	
Record Number		17	
Description		Meta calcium. 2016-10-20 10.51.49.jpg. Rock, linear shape. Dives 180/51. Dissolution gap. 3 canals.	
Date and time of Registry		20/10/2016 11:24	
Coordinates (UTM SIRGAS 2000)	X	186.909	
	Y	9.035.820	
	Zone	24L	
Record Number		21	
Description		Meta calcium. 2016-10-20 11.24.32.jpg Characteristics of vertical dissolution. Stone field.	

Date and time of Registry		20/10/2016 15:08	
Coordinates (UTM SIRGAS 2000)	X	187.394	
	Y	9.035.925	
	Zone	24L	
Record Number		35	
Description		Meta calcium. 2016-10-20 15.08.00.jpg Biggest crack in the explored region filled by soil up to 6m.	
Date and time of Registry		21/10/2016 6:24	
Coordinates (UTM SIRGAS 2000)	X	186.513	
	Y	9.035.224	
	Zone	24L	
Record Number		40	
Description		Ground. 2016-10-21 06.24.44.jpg Flat area with mud layer.	

Date and time of Registry		21/10/2016 7:48	
Coordinates (UTM SIRGAS 2000)	X	186.677	
	Y	9.035.538	
	Zone	24L	
Record Number		47	
Description		Meta calcium. 2016-10-21 07.48.19.jpg Field with outcrops plunging north. Dissolution channels are common.	
Date and time of Registry		21/10/2016 8:27	
Coordinates (UTM SIRGAS 2000)	X	186.340	
	Y	9.035.338	
	Zone	24L	
Record Number		50	
Description		Fossil. 2016-10-21 08.27.54.jpg Rescue area. Point shared with the paleontology team.	

Date and time of Registry		21/10/2016 9:45	
Coordinates (UTM SIRGAS 2000)	X	187.184	
	Y	9.035.650	
	Zone	24L	
Record Number		54	
Description		Meta calcium. 2016-10-21 09.45.04.jpg Outcrops with North diving and E-W canals.	
Date and time of Registry		22/10/2016 8:38	
Coordinates (UTM SIRGAS 2000)	X	183.207	
	Y	9.034.286	
	Zone	24L	
Record Number		87	
Description		Ground. 2016-10-22 08.38.55.jpg Sandy soil with localized scarce blocks of meta calcium. CVRD survey. Prof: 90m. Date: 03/23/2005.	

Date and time of Registry		22/10/2016 9:21
Coordinates (UTM SIRGAS 2000)	X	185.485
	Y	9.034.474
	Zone	24L
Record Number		113
Description		Meta calcium. 2016-10-22 09.21.21.jpg Survey used for supply. 17kl of tank and 2kl / 12min. at 20m.

Date and time of Registry		22/10/2016 9:57
Coordinates (UTM SIRGAS 2000)	X	185.113
	Y	9.034.956
	Zone	24L
Record Number		116
Description		Meta calcium. 2016-10-22 09.57.05.jpg Collapsed borehole.

Date and time of Registry		22/10/2016 10:09	
Coordinates (UTM SIRGAS 2000)	X	185.110	
	Y	9.034.941	
	Zone	24L	
Record Number		117	
Description		Meta calcium. 2016-10-22 10.09.19.jpg Collapsed borehole.	
Date and time of Registry		23/10/2016 8:14	
Coordinates (UTM SIRGAS 2000)	X	184.708	
	Y	9.033.878	
	Zone	24L	
Record Number		130	
Description		Meta calcium. 2016-10-23 08.14.17.jpg Multipoint sinkhole. Locally known as *Lagoado*. The gray clay surface, very cracked and squashed makes it difficult to identify the spatial recharge pattern.	

Date and time of Registry		23/10/2016 8:52	 
Coordinates (UTM SIRGAS 2000)	X	184.477	
	Y	9.034.314	
	Zone	24L	
Record Number		132	
Description		Meta calcium. 2016-10-23 08.52.53.jpg Borehole next to the “skylight”.	

Date and time of Registry		23/10/2016 11:01
Coordinates (UTM SIRGAS 2000)	X	186.858
	Y	9.035.387
	Zone	24L
Record Number		135
Description		Meta calcium. 2016-10-23 11.01.49.jpg Field of scarce blocks. Main layer in vertical dives in 047N and collapsed borehole with south axis.

Date and time of Registry		24/10/2016 07:47
Coordinates (UTM SIRGAS 2000)	X	184.688
	Y	9.035.395
	Zone	24L
Record Number		181
Description		Ground. 2016-10-24 07.47.01.jpg Productive well. 60m deep. 500l / 3h. More brackish water.

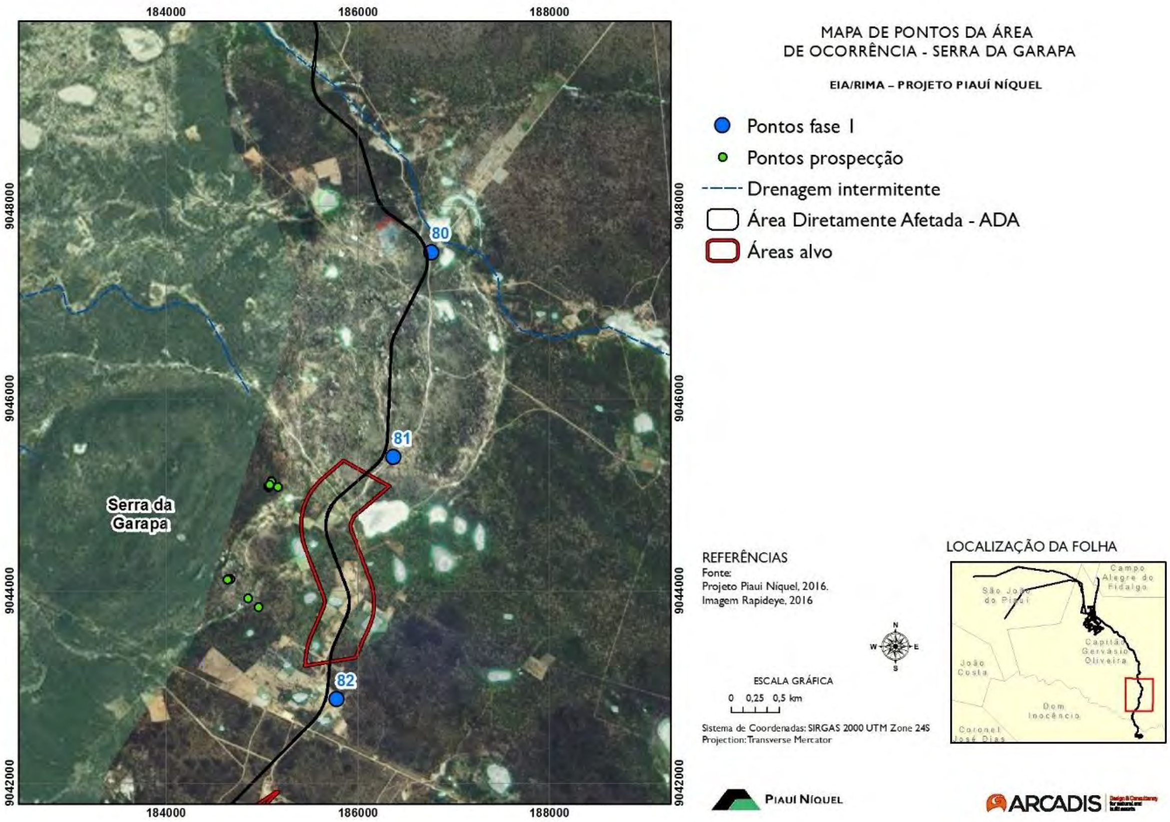
b) Slaughter Blocks - Serras da Garapa, Milhan and Aldeia Regions

The granite boulders of the *Serras da Garapa*, *Milhan* and *Aldeia* of Ediacaran age, belong to the alkaline *Serra da Aldeia* intrusive suite (CPRM, 2004). The mountains have in their slope's shelters formed by rolled and fractured blocks of granitoids of metric dimensions.

In *Serra da Garapa* a shelter with a skeleton of a young goat was identified and the presence of bats and small reptiles is common among granite boulders (Photo 5.1-71, number 221).

Serra da Aldeia stands out in the region presenting at the base and around granite boulders spread over the flattened surface and covered by sandy sediments of Cenozoic age. The shelters observed are formed by round stones (Photo 5.1-71, numbers 226 and 241).

Map 5.1-29 – Occurrence Area Points – *Serra da Garapa*.



Map 5.1-30 – Occurrence Area Points – ***Serra da Aldeia*****.**

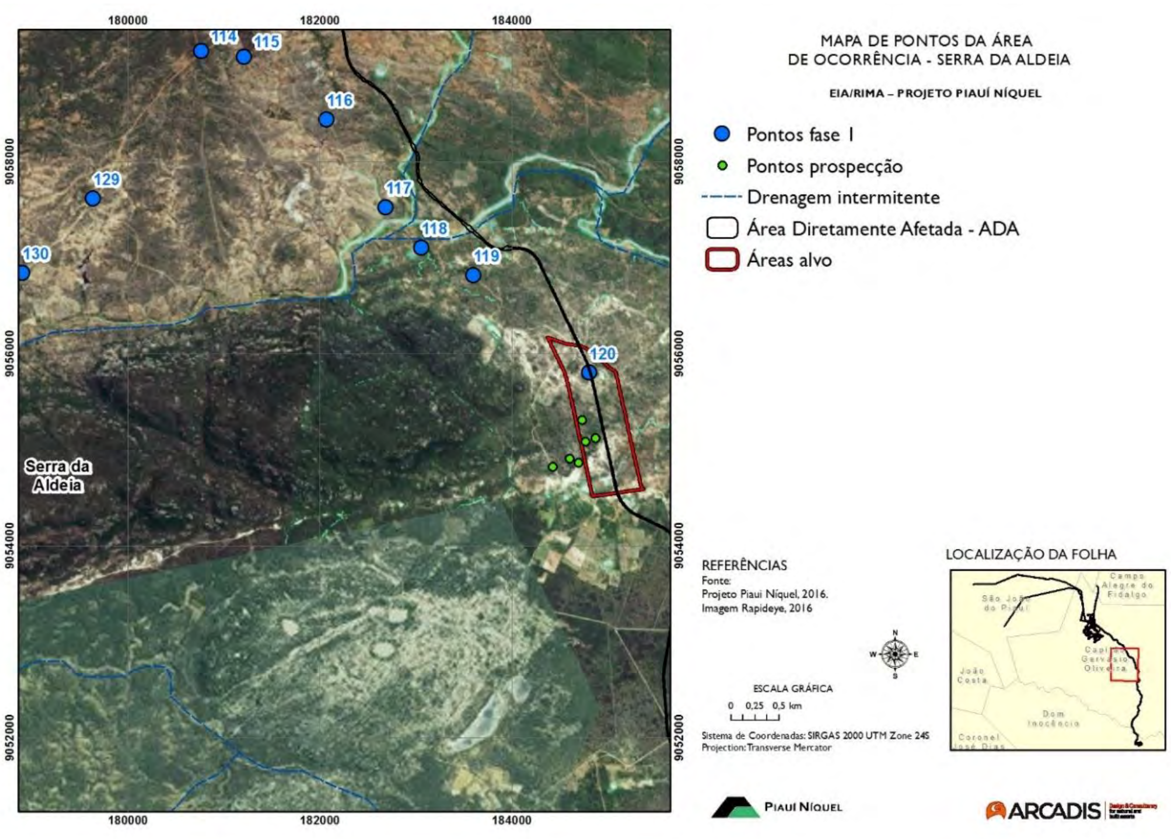


Photo 5.1-71 – Photographic Register of potential areas for cavities in slaughter blocks.

Date and time of Registry		24/10/2016 13:04	
Coordinates (UTM SIRGAS 2000)	X	184.965	
	Y	9.043.826	
	Zone	24L	
Record Number		194	
Description		Granite. 2016-10-24 13.05.33.jpg Overview of the hill slope.	
Date and time of Registry		24/10/2016 13:13	
Coordinates (UTM SIRGAS 2000)	X	184.853	
	Y	9.043.916	
	Zone	24L	
Record Number		219	
Description		Granite. Field of boulders at the bottom of the mountain.	

Date and time of Registry		24/10/2016 13:05	
Coordinates (UTM SIRGAS 2000)	X	184.965	
	Y	9.043.826	
	Zone	24L	
Record Number		194	
Description		Granite. 2016-10-24 13.05.33.jpg Overview of the hill slope. Bottom of the *Serra da Aldeia.*	
Date and time of Registry		24/10/2016 13:22	
Coordinates (UTM SIRGAS 2000)	X	184.648	
	Y	9.044.120	
	Zone	24L	
Record Number		195	
Description		Granite. 2016-10-24 13.32.04.jpg First blocks at the bottom of the mountain. Occurrence of cracks and natural traps.	

Data e Hora do Registro		24/10/2016 13:45	
Coordenadas (UTM SIRGAS 2000)	X	184.673	
	Y	9.044.115	
	Zona	24L	
Número de Registro		221	
Descrição		Blocos de Granito. 2016-10-24 13.45.02.jpg Armadilha e abrigo formado por matacões de granito. Presença de crânio de cabra jovem.	
Data e Hora do Registro		25/10/2016 7:30	
Coordenadas (UTM SIRGAS 2000)	X	185.102	
	Y	9.045.137	
	Zona	24L	
Número de Registro		238	
Descrição		Granito. 2016-10-25 07.30.50.jpg borda da serra da "Milhã" ou da Garapa, no bairro Garapa. Na vertente da serra os matacões formam abrigos e cavernas. Na baixada, próxima à zona de influência da estrada está negativada.	

Data e Hora do Registro		25/10/2016 7:27
Coordenadas (UTM SIRGAS 2000)	X	186.068
	Y	9.045.077
	Zona	24L
Número de Registro		226
Descrição		2016-10-25 07.27.47.jpg Abrigo formado por matacões de granito.

Data e Hora do Registro		25/10/2016 7:37
Coordenadas (UTM SIRGAS 2000)	X	185.098
	Y	9.045.132
	Zona	24L
Número de Registro		241
Descrição		Granito. 2016-10-25 07.37.30.jpg borda da serra da "Milhã" ou da Garapa, no bairro Garapa. Na vertente da serra os matacões formam abrigos e cavernas. Na baixada, próxima à zona de influência da estrada está negativada.

c) *Lateritic canga – Brejo Seco Hill*

The central portion of the project is dominated by a complex of igneous suites that vary between alkaline intrusive. *Brejo Seco* Hill is a body made up of mafic and ultramafic rocks, bounded tectonically to the north by metasedimentary rocks of the *Morro Branco* complex and to the south by non-collisional granites belonging to the *Rajada* suite and by late intrusive to post-orogenic granites, belonging to the alkaline *Serra da Aldeia* intrusive suite. To the west it is covered by the *Parnaíba* basin and to the east by eluvium-colluvial sediments (Salgado et al, 2014). *Brejo Seco* hill is a laterite nickel ore and is located between the *Chapada de São Francisco* and *Chapada de Sítio*.

Lateritic profiles were observed at the edges of the test pit (Photo 5.1-72, number 258), hand-picked samples confirmed the presence of dissolution characteristics such as the "wasp hive" texture. On the slope *Brejo Seco* hill, the soil is fine rocky to gravel with blocks of laterite (Photo 5.1-72, numbers 256 and 284), and the presence of silicate rocks is also common, presenting a banded structure with fine veins of silica and green purple and black colors.

Map 5.1-31 – Occurrence Area Points & Surroundings – *Brejo Seco* Hill

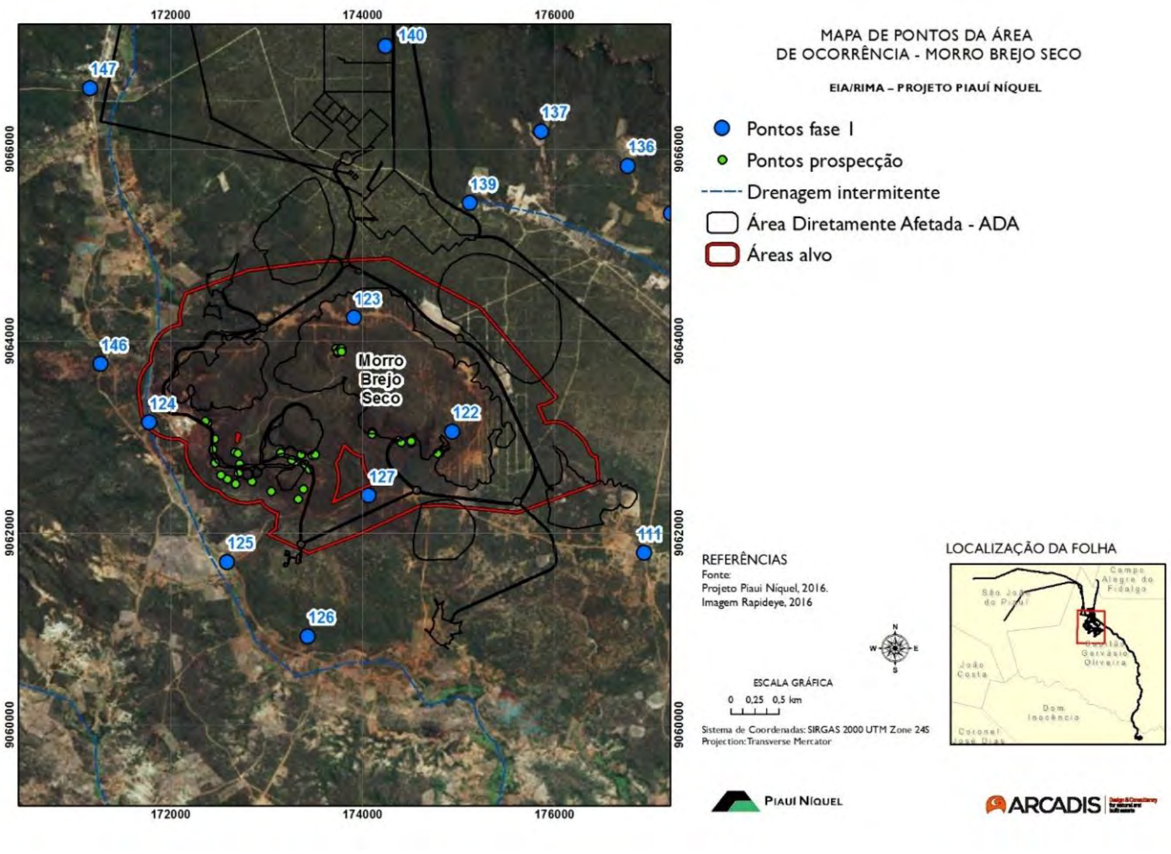


Photo 5.1-72 – *Brejo Seco* Hill and Surroundings – Photographic Registry.

Date and time of Registry		26/10/2016 8:57	
Coordinates (UTM SIRGAS 2000)	X	172.671	
	Y	9.062.840	
	Zone	24L	
Record Number		248	
Description		Sediments. 2016-10-26 08.57.49.jpg View to the west plateau. The caves visible on the plateau are two kilometers from the DAA (outside the study areas).	
Date and time of Registry		26/10/2016 9:02	
Coordinates (UTM SIRGAS 2000)	X	172.698	
	Y	9.062.828	
	Zone	24L	
Record Number		249	
Description		Granite. 2016-10-26 09.02.57.jpg View over the *Serra da Aldeia* and further down the *Serra do Milhan*.	

Date and time of Registry		26/10/2016 9:39	
Coordinates (UTM SIRGAS 2000)	X	173.727	
	Y	9.063.919	
	Zone	24L	
Record Number		258	
Description		Laterites. 2016-10-26 09.39.40.jpg Test Pit. Reddish brown, black and greenish color.	
Date and time of Registry		26/10/2016 11:54	
Coordinates (UTM SIRGAS 2000)	X	174.099	
	Y	9.063.032	
	Zone	24L	
Record Number		256	
Description		Laterites. 2016-10-26 11.54.04.jpg Slope with rocky soil.	

Date and time of Registry		27/10/2016 8:28	
Coordinates (UTM SIRGAS 2000)	X	172.721	
	Y	9.062.717	
	Zone	24L	
Record Number		284	
Description		Laterites. 2016-10-27 08.28.09.jpg Slope with soil and limonitic blocks. Old road cut exposes rocky top.	

d) Strings of Chapadas do São Francisco, Sítio, Pimenta and Mundão

The highest number of shelters were found in the *Chapadas São Francisco*, *Sítio*, *Pimenta* and *Mundão* during the field speleological prospecting. The thick sandstone packages have crossed stratifications, interleaving of thin layers of quartzite pebbles, layers of bituminous shales and negative walls that favored the formation of shelters about 3 m high and 2.5 m of horizontal development in this region. Rock paintings, fossils of tree trunks/branches and buried ceramic pots were found in this plateau region. The targets delimited and prospected correspond to areas outside the project DAA and their respective 250 m buffer, however it was necessary to gather information that allowed us to conclude how close these caves and shelters are, in subsurface, to the areas of influence.

Serra do Morro Branco, located in the *São Francisco* plateau system, consists of sandstones from the *Pimentairas* formation (CPRM, 2004) with crossed stratifications and thin layers of quartzite pebbles delimiting metric packages of the sandstone body. Walls and shelters are frequent in the hillside. Channels suggest the process of forming caves (Photo 5.1-74, numbers 291, 294, 298).

The *Chapada do Sítio* consists of fine and clayey sandstones of the *Pimentairas* formation, with cross-stratifications and quartzite pebbles delimiting the sandstone package. In the escarpment of the plateau it is common to find shelters (some with canals) associated with the negative wall. It is noted that on the roofs of most of the shelters there are quartzite pebbles, indicating an area of debarking and falling of the sandstone, forming openings in the slopes of the plateau (Photo 5.1-74, number 313) and others with dimensions of 1.50 m in height, 3,00 m long and 1.50 m wide (Photo 5.1-74, number 320). The fauna observed in the shelters includes small reptiles, raptors, skunks and wild cats. Plant fossils were found in the uppermost layers of the *Chapada do Sítio*, composed of fine silty sandstones.

Groups of shelters were visually identified at a distance in the *Chapada da Pimenta* wall which consists of sandstones and quartzite pebbles (Photo 5.1-74, number 324). Granitoid bodies overlaid by sandstones were identified in the vicinity of the *Jenipapo* dam.

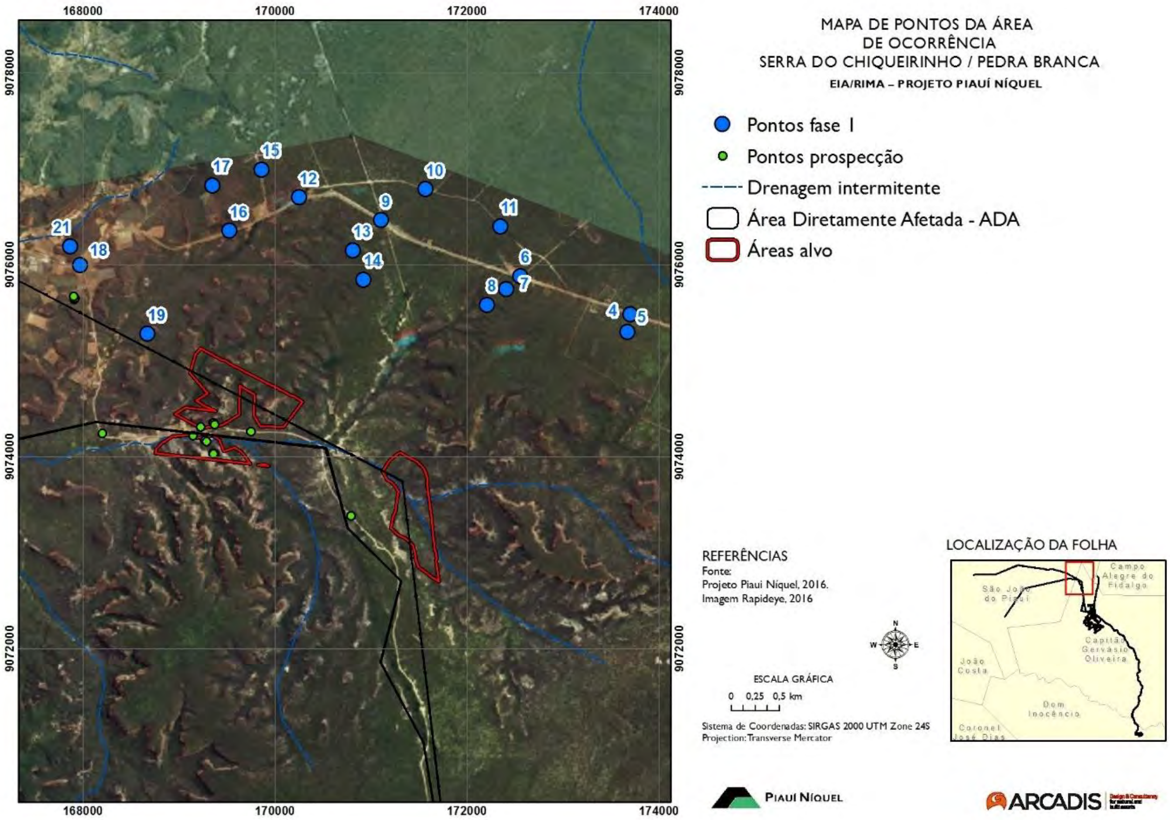
The *Chapada de São Francisco* consists of sandstones from the *Pimentairas* formation (CPRM, 2004) with crossed stratifications, thin layers of quartzite pebbles and layers of bituminous shales (Photo 5.1-74). The harsh negative walls have a set of shelters. On this plateau is located the *Toca da Baixa dos Caboclos* (Photo 5.1-73), an archaeological site with rock paintings (Photo 5.1-74, number 328) from which, during the 1990s, funerary urns were removed by the staff of the Museum of the American Man Foundation - FUMDHAM. In the surroundings of this place a ceramic pot was found buried in the sandy soil.

Photo 5.1-73 – *Toca da Baixa dos Caboclos*: its morphological pattern and stratigraphic profile are repeated in other occurrences of caves and shelters in the plateau system.

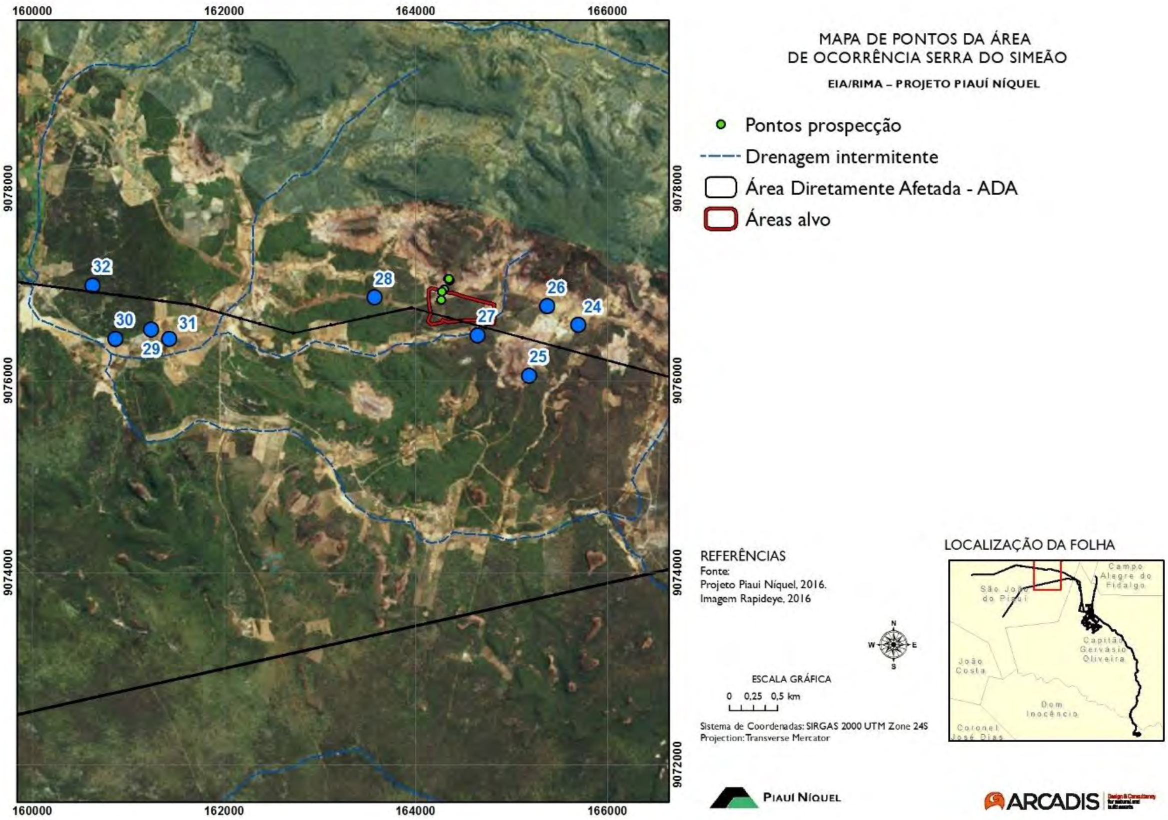
Morro do Simeão consists of fine red sandstones with crossed stratifications and wavy marks, the shelters are small with local fauna activity (Photo 5.1-74, number 351).

The *Chapada do Mundão* is made up of fine red sandstones with crossed stratifications, quartz pebbles, wavy marks and tectonic deformed siltstone packages. Its shelters occur on the slopes and have small dimensions, also having local fauna activity (Photo 5.1-74, number 340). A set of shelters and crevices was observed in the distance in the slopes of large sandstone boards, with dozens of meters of height and probable occupied by local fauna (Photo 5.1-74, number 361).

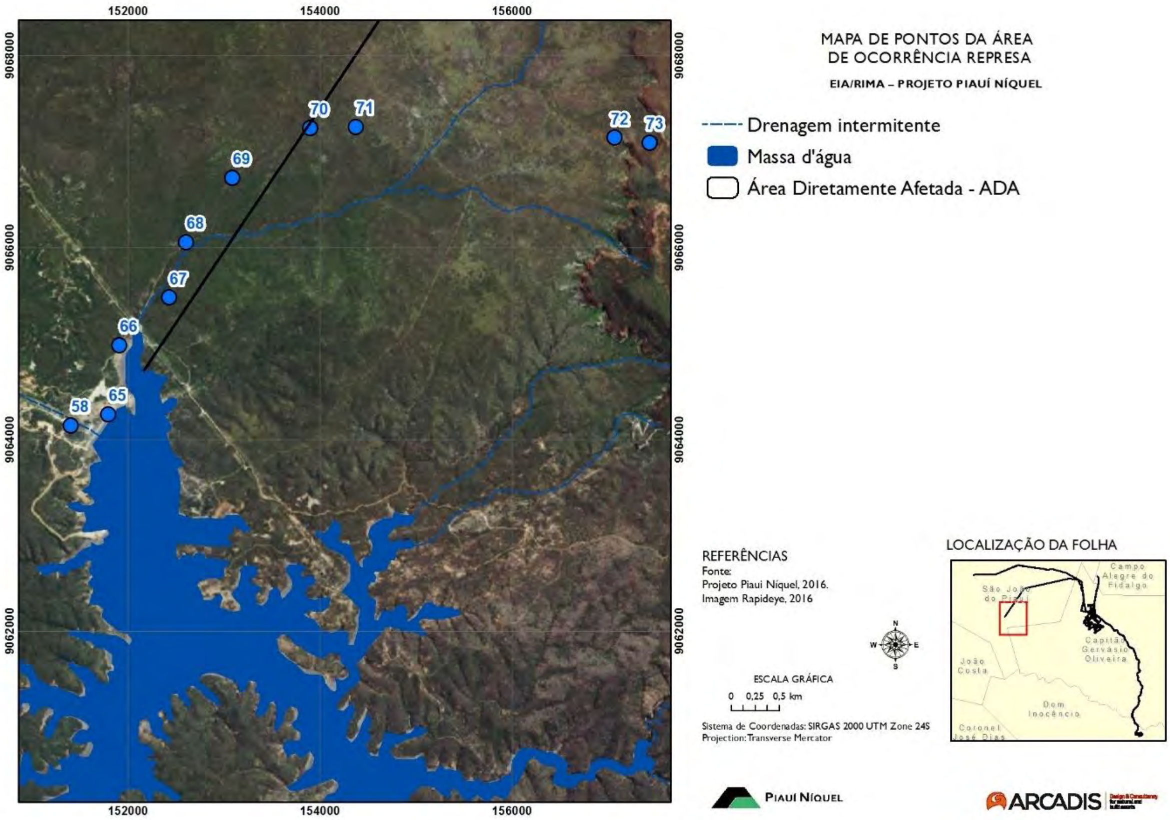
Map 5.1-32 – Occurrence Area Points – *Serra do Chiqueirinho/Pedra Branca*.



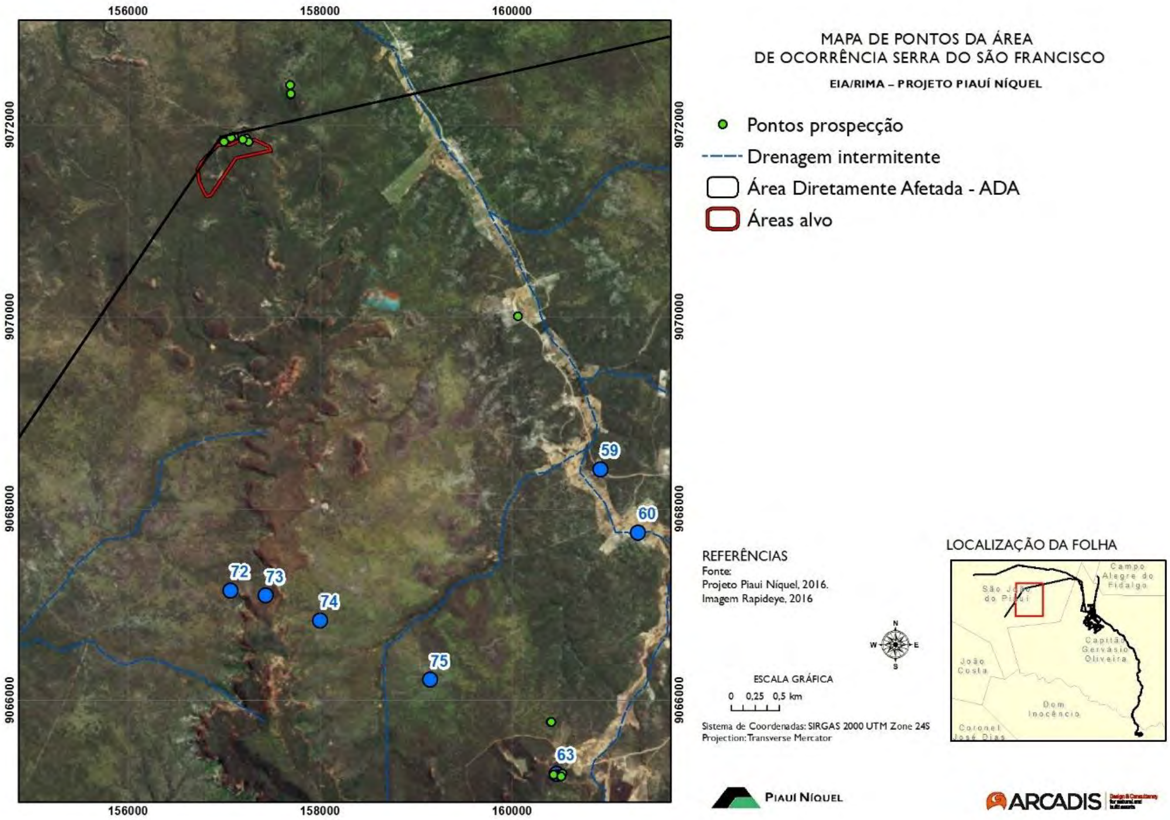
Map 5.1-33 – Occurrence Area Points – *Serra do Simeão.*



Map 5.1-34 – Occurrence Area Points – *Jenipapo* Dam.



Map 5.1-35 – Occurrence Area Points – *Serra do São Francisco*.



Map 5.1-36 – Occurrence Area Points – *Chapada do Sítio*.

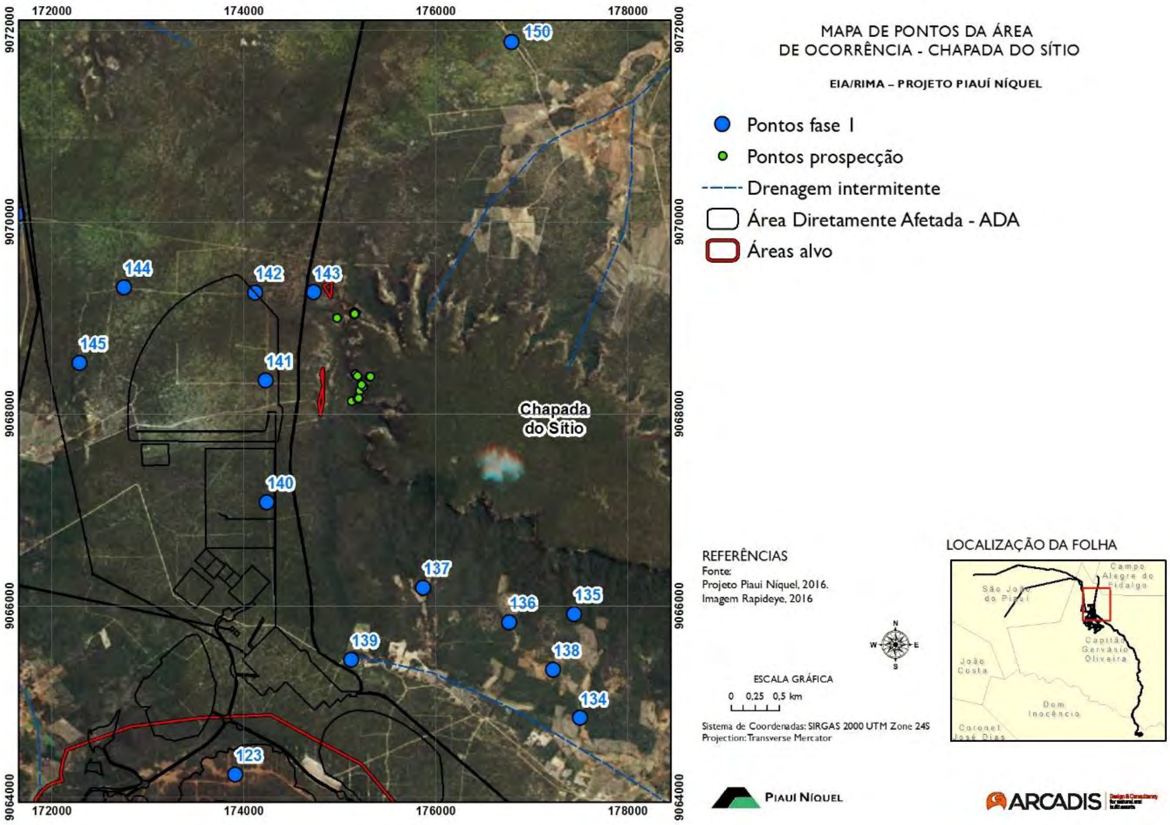


Photo 5.1-74 – Photographic Register of the *Chapada do São Francisco* components.

Date and time of Registry		28/10/2016 7:23
Coordinates (UTM SIRGAS 2000)	X	175.185
	Y	9.068.158
	Zone	24L
Record Number		298
Description		Sandstone. 2016-10-28 07.23.14.jpg Cave in the escarpment of the plateau, 30 m from the base and 600 m from the areas of influence. It starts in a small shelter, 0.5 m high by 2.5 m wide and 2.0 m deep. A canal follows in 087N.

Date and time of Registry		28/10/2016 8:29	
Coordinates (UTM SIRGAS 2000)	X	175.313	
	Y	9.068.379	
	Zone	24L	
Record Number		313	
Description		Sandstone. 2016-10-28 08.29.58.jpg Shelter in negative wall. Cross-stratification. Ceiling characteristics embedded pebbles and thin layers of quartz pebbles.	
Date and time of Registry		28/10/2016 11:10	
Coordinates (UTM SIRGAS 2000)	X	175.155	
	Y	9.069.041	
	Zone	24L	
Record Number		320	
Description		Clay Sandstone. 2016-10-28 11.10.05.jpg Small shelter. Cross-stratification.	

Date and time of Registry		29/10/2016 8:40	
Coordinates (UTM SIRGAS 2000)	X	820.889	
	Y	9.070.152	
	Zone	23L	
Record Number		325	
Description		Sandstone. 2016-10-29 08.40.10.jpg. Small shelters on rocky walls. *Serra do São Francisco*.	
Date and time of Registry		29/10/2016 10:07	
Coordinates (UTM SIRGAS 2000)	X	821.242	
	Y	9.065.362	
	Zone	23L	
Record Number		328	
Description		Sandstone. 2016-10-29 10.07.00.jpg. It plays low of the caboclos. Rock paintings. Sandstone with thin layers of quartz pebbles. Cross-stratification.	

Date and time of Registry		30/10/2016 08:40	
Coordinates (UTM SIRGAS 2000)	X	817.926	
	Y	9.072.055	
	Zone	23L	
Record Number		334	
Description		Sandstone. 2016-10-30 08.40.18.jpg Fine red sandstone supports the slope of the hill. Sandy-silty soil. Strands of this type of substrate tend to form smooth angles.	
Date and time of Registry		30/10/2016 8:56	
Coordinates (UTM SIRGAS 2000)	X	818.109	
	Y	9.072.008	
	Zone	23L	
Record Number		351	
Description		Sandstone. 2016-10-30 08.56.04.jpg Small shelter. *Morro do Simeão.*	

Date and time of Registry		30/10/2016 12:21
Coordinates (UTM SIRGAS 2000)	X	825.281
	Y	9.077.128
	Zone	23L
Record Number		338
Description		Sandstone. 2016-10-30 12.21.57.jpg System of rolling hills near the asphalt. Strands dominated by colluviums. Base of the boards formed by shales of silty clay silt and top dominated by red micaceous sandstones. View of the geomorphological pattern of the hills.

Date and time of Registry		30/10/2016 12:57	 
Coordinates (UTM SIRGAS 2000)	X	828.807	
	Y	9.075.693	
	Zone	23L	
Record Number		340	
Description		Sandstone. 2016-10-30 12.57.03.jpg Parallel layers and alternating crossed sets with pebble lenses. Small asphalt shelter visible from the asphalt.	

Date and time of Registry		30/10/2016 13:49	
Coordinates (UTM SIRGAS 2000)	X	830.251	
	Y	9.074.357	
	Zone	23L	
Record Number		361	
Description		Sandstone. 2016-10-30 13.49.38.jpg Small shelters on rocky cliffs. Cross-stratification.	

5.1.11.5. Conclusions

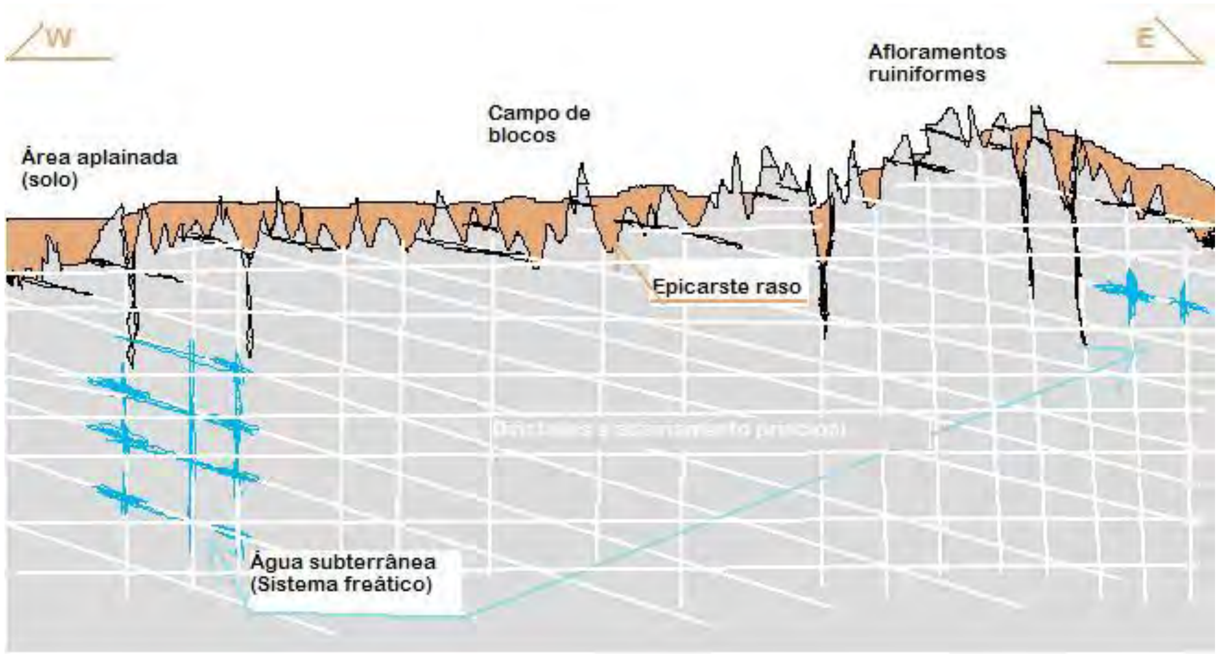
The speleological prospecting work achieved its objective by examining all possible places for occurrence of caves or associated characteristics of relevance under legal protection in the project area, considering a 250 m protection buffer from the project's DAA, as well as identifying areas with greater speleological potential even when outside this area.

The conclusions of the speleological prospecting by environment forming natural underground cavities identified in the target area are presented below:

Umbuzeiro Karst

This area has all the elements of classic karstification, the water levels are below 20 m, the *epicarste* is poorly developed and the unsaturated notching system is predominantly vertical. Figure 5.1-22 presents a model of how all these elements are organized within the concept of a system.

Figure 5.1-22 – Scheme of karst elements organization of the *Umbuzeiro* region.



No caves were found although dissolution characteristics and breaks that precede the cave formation stage are present in the area.

Milhan granítico gnáissico Slope Deposits – *Serra da Aldeia*

They also have classic characteristics of cave formation in the field, including the positive identification of some caves. However, neither cavities nor small shelters were found in the target area of the survey. The cavities and development characteristic are in the opposite direction of the project location.

Lateritic Canga Deposits – *Brejo Seco* Hill

Despite the intense development of the lateritic formation, a characteristic that preconditions the existence of the main mineralization, the action of surface waters in the form of shallow infiltration is almost non-existent. The soil, even if hardened, is constant in this region and keeps the canga blocks buried. This environmental context stops the occurrence of any cavity or shelter.

Chapadas Sandstone Cave System

This is the environment with the largest abundance of shelters and caves. Diversity is low and all are associated with the beginning of an erosive process from the conglomerates. The development of characteristics common to the cavity formation occurs in the opposite direction to the project.

The only field with cavities within the 250 m buffer (in horizontal projection) is *Chapada do Mundão*, or *Bairro Chiqueirinho*. In this place the slopes of the plateau are less than 250 m from the project area, however, in very specific situations: away from the water pipeline rout wich is located in the valley between the slopes (and the caves located above 20 m on the slope); and the power transmission line route crosses the slopes but the effective potential impact can only be assessed once the tower locations are defined. Map 5.1-32 (*Serra do Chiqueirinho / Pedra Branca*) illustrate how the target area, DAA and the Study Area overlap like no other place in this study site showing this horizontal proximity.

Important to note that the distance between the speleological characteristics and the project structures is higher when comparing the altimetry and the horizontal projection of them.

Another relevant fact is thet the speleological characteristics are located on the sandstone cliffs, where the project does not plan to install any structures or develop any activities such as earthworks, vegetation removal and soil stripping, activities that are critical of potentially damaging these elements.

In addition, the current structures have the flexibility to be located as they best fit all these restrictions and environmental constraints to guarantee the preservation of all speleological elements.

The status of the speleological heritage is summarized in the Table 5.1-10.

Table 5.1-10 – Summary of Speleological Heritage.

Ambient	Favorable Characteristics	Unfavorable Characteristics	Speleological Heritage in the Target Area
Karst Limestone	Exposed rock with uniform Characteristics. Conduction of water through secondary porosity (plans and ducts). Pronounced windy horizon.	Little pronounced *epicarste.* Overcast karst. Conduction of water predominantly vertical.	No. The karst fragility is restricted to the impacts of the project on the aquifer.
Abatement Blocks	Boulders exposed in extensive areas. Absent soil.		No. The cave region is more than 500 m from the DAA and its 250 m buffer.
Lateritic canga	Deep lateritic horizon. Steep slopes.	Abundant native soil. Erosion processes (shallow groundwater exudation) absent.	No. The environment is completely sterile.
Slopes of *Chapadas*	Slopes in rock favorable to the occurrence. Carving pattern of shelters and caves well defined. Well-defined relationship between the occurrence of "walls", shelters and caves. Associated Paleontological and Archaeological Heritage.	Cave formation is incipient. Shelters are more frequent.	Yes. However, its occurrence is restricted to the 250 m protection zone from the DAA and in a localized manner, on the slopes of *Chapada do Mundão / Bairro Chiqueirinho*. In turn, the water pipeline is projected at the bottom of the valley, while the power transmission line has location flexibility.

5.2. Biotic Environment

The biotic environment diagnosis included in this study contains a summary of the biogeographic aspects of the *Caatinga* biome as it is the general environment where the project will be implemented; a description of the areas with some attribute of interest for conservation and/or legally protected areas that assist in the conservation of the main components of the biotic environment, such as flora and fauna; the characterization of the flora made through a floristic and phytosociological survey; and the characterization of the fauna considering several groups classified as good bioindicators of the environmental quality of the project' areas of influence.

5.2.1. Biogeographic Context

The project area is part of the *Caatinga* biome, which occupies an area of approximately 845,000 km² (IBGE, 2004) characterized by a predominantly tropical hot semi-arid climate with low rainfall and marked by two distinct seasons during the year: the rainy season with three to five months (irregular, torrential, local rains, short duration), and the dry season, from seven to nine months with almost no rain (Nimer, 1972). As it is a region with a semi-arid climate, with low rainfall, intermittent water courses and temporary wet areas with exoreic drainage are common (MMA, 2006).

This biome presents extreme conditions about meteorological parameters: High solar radiation, high temperatures, low relative humidity rates, low cloudiness and low precipitation. The flora and fauna of this biome is highly dependent on extreme events associated with any of these aspects (Prado, 2003).

The characteristics of the *Caatinga* phytogeographic domain change depending on the rain patterns and the highest point correspond to 1000 mm rain isohyet, with about 50% of the area receiving less than 75% of the rains (Prado, 2003). However, more important than the volume is the irregularity regime of the rainfalls.

The geomorphological and geological origin of the *Caatinga* results in several mosaics of complex soils with different characteristics (clayey, stony or sandy) within short distances (Sampaio, 1995). Extensive outcrops of rocks (flagstones) as well as parts covered by continuous layers of stones frequently act ecologically as "desert environment" (Prado, 2003).

The *Caatinga* is conFigureted by a mosaic of xerophytic and deciduous vegetation, with predominance of woody plant specimens, accompanied by a large number of tender cactus and rigid bromeliads, always thorny or acicular, interspersed with many annual plants. Depending on the specific substrate and climate, plant elements vary in quantity resulting in specimens of *Caatingas* that vary between forest (dense or open), savannah and countryside (Prado, 2003).

The term "*Caatinga*" originates from "*Tupi*" and means "white forest", referring to the appearance of vegetation during the dry season when most trees lose their leaves and whitish trunks dominate the landscape. These characteristics are particularly common in species of the genus *Tabebuia sensu amplo (Bignoniaceae), Cavanillesia (Malvaceae), Schinopsis e Myracrodruon (Anacardiaceae) and Aspidosperma (Apocynaceae),* in addition to the originally dominant "legumes" trees. These more robust forests have been largely destroyed, and are now rare, scarce and fragmented. Currently, shrubby, branched and prickly vegetation predominates, with many euphorbias, bromeliads and *Cactáceas*. Endemism are frequent, especially in *Cactáceas* such as

Leocereus, Tacinga and *Zehntnerella* (Prance, 1987, Coimbra-Filho & Câmara, 1996; Prado, 2003, Leal et al., 2005). Leaves, flowers and herbaceous vegetation grow only during the short and sparse rains.

The particular flora of the *Caatinga* is related to that of the Atlantic biome, with species common to both environments. Similarly, although to a lesser extent, it is similar to the vegetation in the dry areas of Argentina, Paraguay, Bolivia and Mato Grosso (Rizzini et al, 1988).

The knowledge of the zoological composition of the fauna present in the *Caatinga* is still precarious. For example, a study on the sampling effort of a group of amphibians indicated the *Caatinga* as the region with the least information in all of South America, with extensive areas without any information (Heyer, 1988 apud Castelletti et al, 2004).

The *Caatinga* fauna is impoverished and the remaining communities have their populations reduced due to the effects of anthropic action. Examples of species unique to this biome are the *piu-píu* (*Myrmochilus strigilatus*), the *galo-da-campina* (*Paroaria dominicana*) and the *corrupião* (*Icterus jamacaii*) (Sick, 1997, Leal et al, 2005). Two endemic birds, notable for their rarity, symbolize the threatening situation of the biome: the *arara-azul-de-lear* (*Anodorhynchus leari*), whose wild population is limited to about 100 specimens in the *Canudos* region, State of Bahia, and the *ararinha-azul (Cyanopsita spixii)*, recently considered extinct in the wild when the last specimen of free life that inhabited the surroundings of *Curaçá*, State of Bahia, disappeared (MMA, 2002).

Among mammals, the presence of *mocó* (*Kerodon rupestris*) is mentioned, which is considered one of the few endemics of this environment. It lives in rocky environments and its meat, palatable to the country man, is the reason why it is hunted (Rizzini et al, 1988).

Despite being the only large Brazilian natural region, whose limits are entirely restricted to the national territory, little attention has been paid to the conservation of the *Caatinga*. Likewise, the contribution of its biota to Brazil's extremely high biodiversity has been underestimated (Silva et al., 2004, Leal et al, 2005).

5.2.2. Conservation Areas

5.2.2.1. Introduction

This section covers the Conservation Units – UC’s and the Priority Areas for Biodiversity Conservation – APCB’s, located in the areas of influence of the Piauí Nickel Project or in its immediate surroundings.

The National System of Conservation Units (SNUC – Law nº 9.985, of 07/18/00) establishes different categories of protected areas with different levels of use restrictions for UCs. The objective is to establish a system of protected areas covering different degrees of anthropic intervention / use restrictions, in areas of variable dimensions and under various administrative bodies: federal, state, municipal, and private.

There is Brazilian policy aimed at environmental conservation where APCBs are defined including wide geographic spaces with different levels of priority for conservation and where actions to be implemented in each of these APCBs are outlined, including the creation of a UC or simply the carrying out of inventories.

The APCBs are delimited based on existing knowledge regarding the biological composition and the risks of degradation that they present. The Brazilian government use those areas with the intention to protect (via use restrictions), recover or define as a research area these spaces.

5.2.2.2. Conservation Units

The *Sistema Nacional de Unidades de Conservação* (SNUC – Law No. 9,985 of 07/18/00), defines the Conservation Unit (UC) as "a territorial space and its environmental resources, including jurisdictional waters, with relevant natural characteristics, legally instituted by the Public Power, with conservation objectives and defined limits, under a special administration regime, to which adequate guarantees of protection apply".

Preserving the genetic groups, protecting the water resources and landscapes of relevant scenic beauty, conducting environmental education, providing conditions for the development of research and the rational use of land are the main purposes of the UCs.

To normalize their use, these are classified into:

- Full Protection Units, in which the indirect use of resources is permitted, understood as those that does not involve consumption, collection, damage or destruction of natural resources (art. 2, item IX). They are restricted visitation areas, focused on research, species reproduction, conservation, environmental education or monitored visitation.
- Sustainable Use Units aim to make nature conservation compatible with the sustainable use of a portion of its natural resources. They are units of direct use according to specific management plans.

CONAMA Resolution 428/2010, amended by CONAMA Resolution 473/2015, instituted a new rule within the scope of environmental licensing, reducing the buffer zone from 10 km to 3 km for UCs whose buffer zone is not established because it does not have a management plan. According to the law, the installation of any project located in the buffer zone of some conservation units must obtain the prior consent of the UC administrator.

A) Conservation Units in the Project Area of Influence

There are no UCs created in the Area Directly Affected (DAA) nor in the Area of Direct Influence (ADI) of the Piauí Nickel Project. However, the south / southeast region of the State of Piauí is considered of conservationist interest, either due to its physiographic and biotic characteristics, or due to the presence of relevant archaeological sites.

The *Serra da Capivara* National Park is one of the UC areas near to the project that has been under legal protection since 1979 when it was created. The park area is approximately 1,290 km^2, across four towns: *São Raimundo Nonato*, *João Costa*, *Brejo do Piauí* and *Coronel José Dias*. The park contains a biodiversity reserve in the *Caatinga* biome, and a rich archaeological heritage officially recognized and listed by UNESCO (Arruda, 1997). This UC is located about 70 km from the Project, outside the project DAA and ADI and outside the protective buffer of the park.

The *Serra das Confusões* National Park, although located in the region, is also outside the limits of the Project's DAA and ADI. This park was created in 1998, it has about 5,260 km^2 of preserved area and is in the towns of *Caracol*, *Guaribas*, *Santa Luz* and *Cristino Castro*. Covered with *Caatinga* vegetation, it features canyons and caves with cave inscriptions.

The *Chapada da Serra Branca* Ecological Station, also outside the project's DAA and ADI, is other UC in the region.

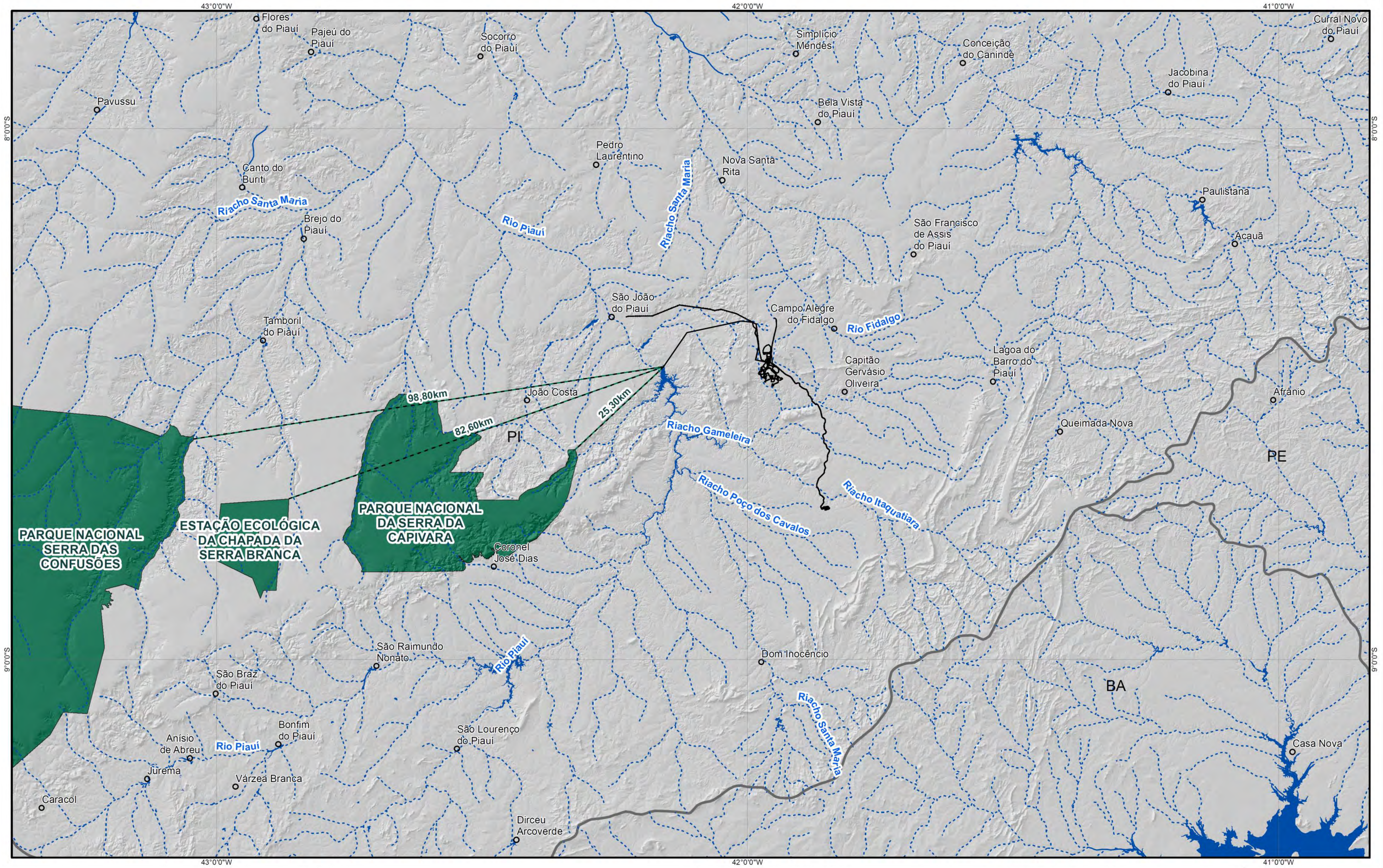
Data Table 5.2-1 presents some characteristics of these Conservation Units. Map 5.2-1 shows the Conservation Units in the vicinity of the project.

Data Table 5.2-1 – Conservation Units located near to the Project Area.

Conservation Unit Name	Initials	Description	Creation Decree	Unit Administrator	Municipalities Involved
Serra da Capivara National Park	PARNA	Full Protection	Dec - Law 83548 05/06/79	IBAMA	*São Raimundo Nonato, João Costa, Coronel José Dias, Brejo do Piauí*
Serra das Confusões National Park	PARNA	Full Protection	Dec. 02/10/98	IBAMA	*Santa Luz, Tamboril do Piauí, Cristino Castro, Guaribas, Jurema, Alvorada do Gurguéia, Bom Jesus, Canto do Buriti*
Chapada da Serra Branca Ecological Station	EE	Full Protection	Dec 13080 02/06/08	SEMAR	*São Joao do Piauí, Brejo do Piauí São Raimundo Nonato*

Source: MMA. 2016. ICMBio, 2016.

Map 5.2-1 – Conservation Units.



LEGENDA

- Municipal Headquarter
- State Limits
- Perennial Drainage
- Intermittent Drainage
- Water Mass
- Directly Affected Area - DAA
- Distance: UC – DAA
- Conservation Unit – UC

REFERÊNCIAS

IBGE, Brasil ao milionésimo, 2014;
MMA, UCs, 2016;
PNM, Projeto, 2016.

ESCALA GRÁFICA
0 10 20 km
Sistema de Coordenadas: GCS SIRGAS 2000

MAPA DE LOCALIZAÇÃO

PA MA CE RN PB PE PI AL SE TO BA

PIAUÍ NÍQUEL

ARCADIS

EIA/RIMA – PROJETO PIAUÍ NÍQUEL

Map 5.2-1 – Conservation Units (UC)

EXECUTADO POR:	ESCALA:	NÚMERO:	DATA:
ARCADIS	1:750.000	Única	set /2017

5.2.2.3. Priority Areas for Biodiversity Conservation – APCB

The APCB define strategic areas for the application of environmental actions to identify areas suitable for the creation of Conservation Units for full protection and / or sustainable use and serve as a planning tool to define activities compatible with the biodiversity conservation.

The APCB were defined based on Ministerial Ordinance No. 9, of January 23, 2007 (published in the Official Gazette on January 24, 2007) and are separated according to the level of priority for conservation, being classified as: Extreme Importance, Very High Importance, High Importance and Insufficient Information.

The APCB for the *Cerrado*, *Pantanal* and *Caatinga* biomes changed through Ordinance No. 223, of 21 June 2016. This new legislation revoked the APCB of these biomes and defined new limits. The boundaries, typologies and main recommendations of the Caatinga APCB can be found on the website of the Environmental Ministry[8].

Four APCBs are found in the project DAA, one of them partially overlapping the proposed layout for the water pipeline. Map 5.2-2 shows the location of these areas.

The APCB *Serra da Capivara* (Code CA172) is found in the project ADI. This area is classified as very high conservation priority, high habitat loss potential and very high susceptibility to desertification. There are no recommended actions on record.

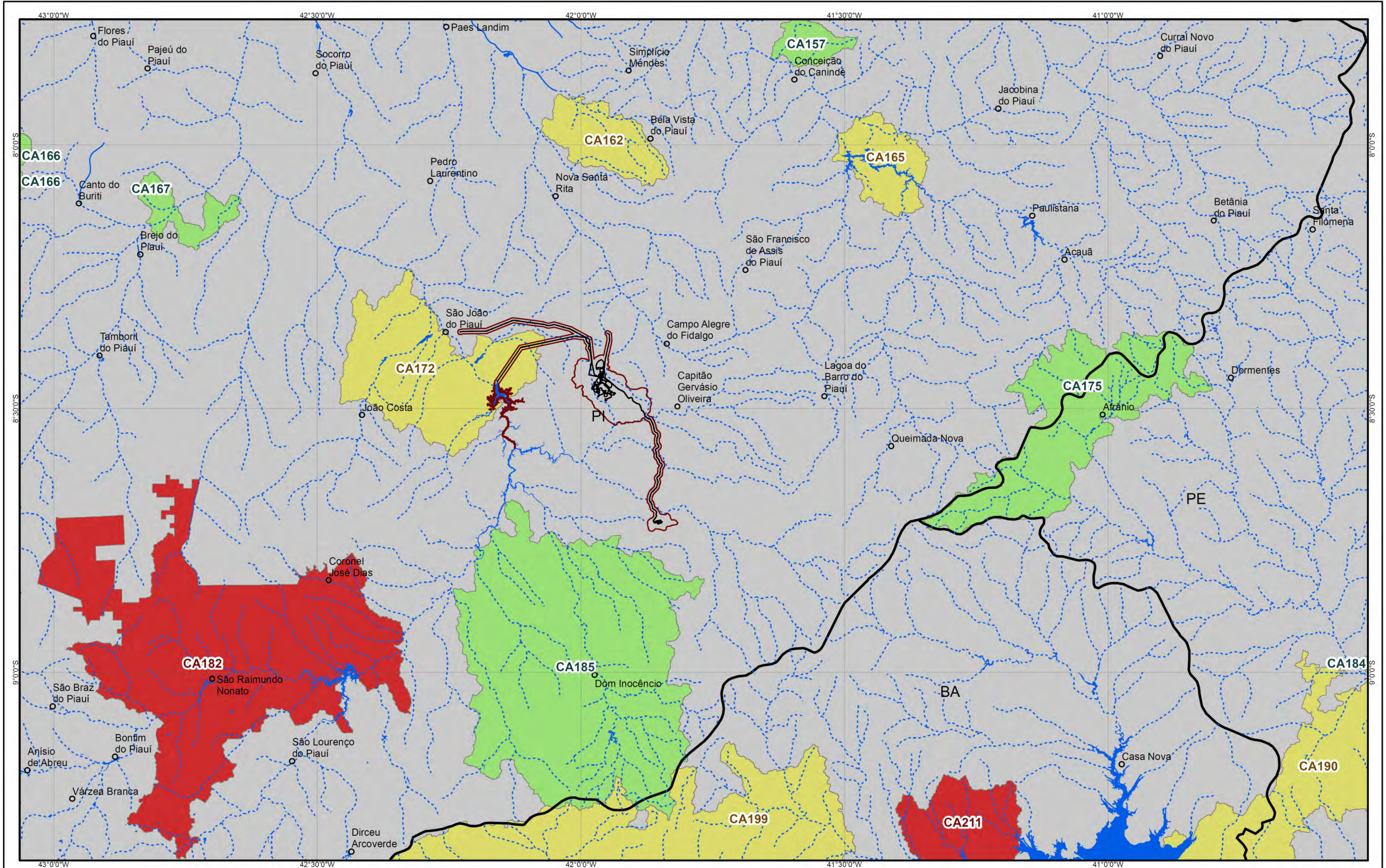
The APCB *Afluentes do Piauí* (Code CA185) is located southwest of the project. It has high conservation priority, high habitat loss potential and extremely high susceptibility to desertification. The biodiversity of this area is threatened by agricultural expansion and the hunting and trafficking of wild animals. Some of the actions recommended by the registration form are recovery of degraded areas, sustainable management and continuous inspection.

The APCB *Remanso* (Code CA199) is located at the south of the project area. It has very high conservation priority, high habitat loss potential and very high susceptibility to desertification. The main recommended actions for this area are recovery of degradable areas and sustainable management.

The APCB *Bela Vista do Piauí* (Code CA162) is located at north of the project area. It has very high conservation priority, very high habitat loss potential and extremely high susceptibility to desertification. There are no recommended actions on record.

[8] *Ministério do Meio Ambiente* – (http://www.mma.gov.br/component/k2/item/10724-resultados-da-2&) – Serached in 01/16/2017.

Map 5.2-2 – Priority Areas for Biodiversity Conservation.



LEGENDA

- State Limits
- Perennial Drainage
- Intermittent Drainage
- Water Mass
- Area of Direct Influence - ADI
- Directly Affected Area - DAA

Priority Areas for Conservation

Priority

- Extremely High
- Very High
- High

REFERÊNCIAS

IBGE, Brasil ao milionésimo, 2014;
MMA, APCBS, 2016.
PNM, Projeto, 2016.

ESCALA GRÁFICA
0 10 20 km

Sistema de Coordenadas: GCS SIRGAS 2000

MAPA DE LOCALIZAÇÃO

PIAUÍ NÍQUEL

ARCADIS

EIA/RIMA – PROJETO PIAUÍ NÍQUEL

Map 5.2-2 – Priority Areas for Biodiversity Conservation (APCB)

EXECUTADO POR:	ESCALA:	NÚMERO:	DATA:
ARCADIS	1:750.000	Única	jun /2017

5.2.3. Flora

The characterization of the regional and local flora associated with the project begins with the mapping of the ground cover that shows the distribution of phytophysiognomies in the areas of interest.

The analysis of the flora is detailed by surveying the diversity of plant species found in the project ADI along with examining the structural characteristics of the most representative native formations.

Finally, considerations about the conservation of plant remnants in the region are presented.

5.2.3.1. Mapping Land Use and Ground Coverage

This section contains the characterization of the land use and ground coverage in the project ADI related to the physical and biotic environments and gathers information related to the spatialization of the different anthropic appropriation forms of the territory and the types of vegetation cover.

A) Methodological Considerations

The work was done in four stages: preliminary analysis, field checks, mapping of use and vegetation types and reporting.

In the preliminary analysis, secondary data was collected that served as a support for the classification of the types of use and the homogeneous patterns of occupation and vegetation cover, allowing comparison with the current satellite images and the preliminary mapping of the areas of influence.

Using the maps, a database was structured with vector files and area calculations, consolidating all in a spreadsheet by category of use and vegetation cover.

a) AII

The survey of characteristics of use and vegetation cover of the AII, was made based on secondary data.

The cartographic base used corresponds to the survey prepared in 2006 by the *Secretaria de Biodiversidade e Florestas* (SBF) from the *Ministério do Meio Ambiente* (MMA), scale 1: 250,000, SC-23-XB (*São João do Piauí*), SB -23-ZD (*Oeiras*), SB-24-YC (*Picos*) and SC-24-VA (*Paulistana*). According to this government agency, Landsat scenes from 2002 were processed for the mapping of the biome's vegetation. In this report, the AII mapping is presented at a scale 1:750,000 based on this source (Land Use and Cover Map - AII).

b) ADI/DAA

The mapping of land use and ground coverage with an emphasis on phytophysiognomies found in the project's ADI and DAA was done based on satellite image and field spot checks.

The field checks took place in November 2016, through walks along the areas of influence to verify the mapping patterns made by the teams responsible for collecting data related to the physical, biotic (flora) and socio-economic environments. For this purpose, specific points of the mappings were selected, representative of the legends established based on the procedures of the previous step, which allowed to confirm and adjust, when necessary, the previously prepared mapping.

The analysis of ADI / DAA land use and ground coverage was performed using Rapideye satellite images; a mosaic formed by scenes from the year 2016. For the processing of satellite images, a supervised image classification algorithm for maximum probability was used in the Arc Gis 10 software. Then a photointerpretation was made on satellite images which consists of the visual identification of the homogeneities and typologies present in the image.

Using the generated images, two cartograms of different scales were elaborated:

- The first on a small scale (1:200,000) aims to provide an overview of the mapping of land use and ground coverage in the ADI (Map 5.2-5) and to match the survey done in 2008.
- The second is a map notebook with 15 sheets in the scale 1:25.000 (ANNEX VIII - Volume IV), provided by the 5 m spatial resolution from the available image from the Rapideye. The main purpose is to present details of the land use and ground coverage overlapping the project structures and the Permanent Preservation Areas - APPs in relation to the DAA.

As a source of secondary data, the mapping of existing land use and occupation done by Arcadis Tetraplan in 2008 was used which provided fundamental information to corroborate the preliminary analysis. The subsequent visual comparison, between the current product and the mapping carried out in 2008, provided support to recognize possible changes in the landscape in this eight-year period.

The predominant characteristics in the region that best represent the observed reality were identified for the mapping activities. Regarding the characterization of the physiognomic types of *Caatinga*, aspects of vegetation (size, density and stratification) were considered. In the field, all sections of the project's DAA were covered to verify the preliminary mapping.

After the description of the identified descriptions, the planimetry of the classes in the ADI and DAA were presented in addition to the delimitation of the areas considered to be of permanent preservation by the current environmental legislation.

B) Results

a) Land Use and Ground Cover - AII

In the Universal System, adopted in Brazil as the official system for classifying vegetation, the term *Caatinga* is called *savana estépica*. This name was originally used by TROCHAIN (1946) to designate steppe characteristics close to the African holographic zone (VELOSO, 1991), a region characterized by water deficit and low annual precipitation.

In the present study the term "*Caatinga*" was selected for the ADI and DAA mapping, adopted by Eiten and other authors, such as Azevedo and Velloso (IBGE, 2012), relating to the most popular and well-known denomination of this type of vegetation genuinely Brazilian. The Universal System terminology is maintained only for existing maps. The equivalency between terminologies is shown in Table 5.2-1:

Table 5.2-1 – Equivalency between terminologies used in the study.

Universal System (IBGE, 2012)	Eiten; Azevedo e Velloso (in IBGE, 2012)
Savana Estépica Arborizada	Open *Caatinga Arbóreo arbustiva*
Savana Estépica Florestada	Dense *Caatinga Arbóreo arbustiva*

Source: Arcadis 2017

The predominant vegetation of the *Caatinga* corresponds to rural plants with deciduous and spiny woody strata (IBGE, 2012), with a predominance of low trees and shrubs that lose their leaves during dry period (deciduous species). *Cactáceas* also characterize this vegetation.

The following plant classes were identified by means of these mappings: *Savana Estépica Florestada, Savana Estépica Arborizada,* Agriculture and Urban Area, in addition to bodies of water, as shown in the Map of Land Use and Ground Cover – AII, with the following percentages of distribution:

Data Table 5.2-2 – Covering of land use and vegetation cover typologies in AII.

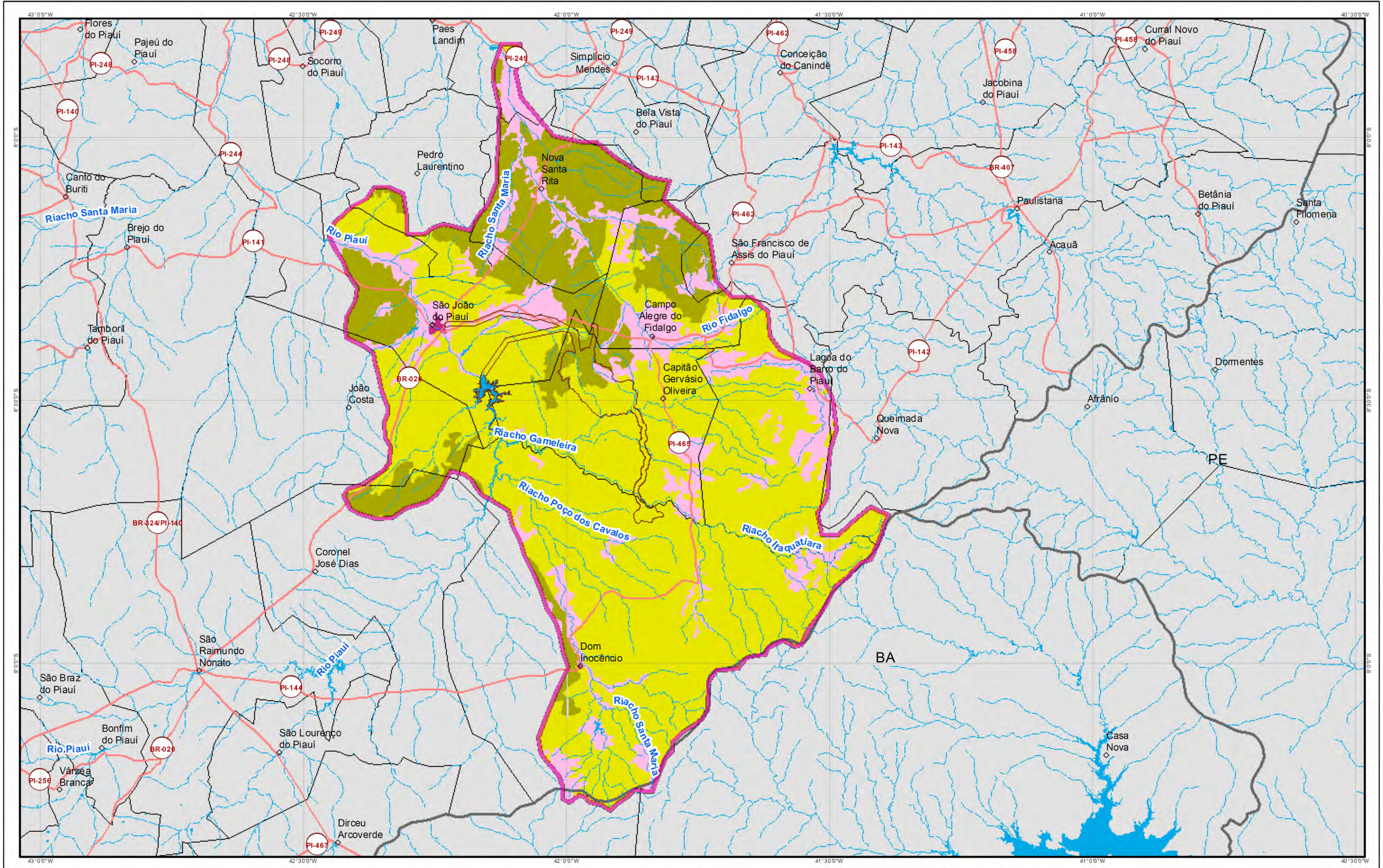
Use and Cover Classes	Hectares	Percentage
Water Bodies	1,506.61	0.17%
Ta - Savana Estépica Arborizada	556,520.96	63.05%
Td - Savana Estépica Florestada	168,143.22	19.05%
Ag - Agriculture	155,495.30	17.61%
UA – Urban Areas	1,061.95	0.12%
Total AII	**882,728.05**	**100%**

Source: MMA, 2006 – Prepared by: Arcadis, 2017.

As shown in Data Table 5.2-2, the highest percentage of surface coverage in the AII is of *Savana Estépica Arborizada*, with 63% of the area, followed with 19% by *Savana Estépica Florestada*. 82% of the AII is covered by native vegetation. Agriculture and livestock occupy 17.61% and the urban area 0.12% of the AII.

In the Land Use and Ground Coverage Map – AII is shown that most of the forested vegetation is in the north with smaller occurrences in the west, while the other type predominates in the south center and part of the northwest. Anthropic Areas are scarcely distributed throughout the AII.

Map 5.2-3 – Land Use and Ground Cover – All.



LEGENDA

- Municipal Headquarter
- Municipal Limits
- State Limits
- Road System
- Perennial Drainage
- Intermittent Drainage
- Water Mass
- Area of Indirect Influence - AII
- Area of Direct Influence - ADI

Land Use / Vegetation Cover – AII

- Ta – Arboreal Savannah
- Td – Forested Savannah
- Ag – Farming
- Iu – Urban Area

REFERÊNCIAS

IBGE, Brasil ao milionésimo, 2014;
MMA, 2006. Folhas SC-23, SC-24, SB-23 e SB-24.

ESCALA GRÁFICA
0 10 20 km
Sistema de Coordenadas GCS SIRGAS 2000

MAPA DE LOCALIZAÇÃO

Piauí Níquel Mineração | ARCADIS

EIA/RIMA – PROJETO PIAUÍ NÍQUEL

Map 5.2-3 – Land Use and Ground Cover – AII

EXECUTADO POR:	ESCALA:	NÚMERO:	DATA:
ARCADIS	1:750.000	Única	jan/2017

b) Land Use and Ground Cover – ADI

Comparing the field data and the patterns observed in the satellite image, a classification was produced including seven groups subdivided between anthropic categories and vegetation, in addition to exposed soil and water bodies, as described below.

After describing the types of ground coverage, the comparative panorama between current and past mappings is also presented, in addition to the table of areas of use and ground coverage obtained in this assessment.

Buildings

This group represents anthropic construction patterns such as:

- Population Clusters (urbans or rural settlements)
- Power Substation.
- PNM Pilot Plant.
- Road Infrastructure.

Photo 5.2-1 – View of *Várzea* Settlement.

Photo: Arcadis, 2017.

Photo 5.2-2 – Pilot Plant, next to *Brejo Seco* Hill.

Photo: Arcadis Tetraplan, 2008.

Agriculture

Pasture or agricultural planting, family farming and livestock are characteristics of the region.

Photo 5.2-3 – Planting Area.

Photo 5.2-4 – Extensive Goat Breeding.

Photo: ARCADIS Tetraplan, 2008.

Exposed Ground

Absence of vegetation or any other type of cover, can be of anthropic or natural origin. Rocky outcrops and dry beds of water stream prevail.

Photo 5.2-5 – Dry Alluvium – *São Romão* riverbed.

Photo 5.2-6 – Exposed ground by anthropic action, access road, characteristic of an erosion process. Community of *Grajaú* from highway PI-465 – *Capitão Gervásio Oliveira*.

Photo: ARCADIS Tetraplan, 2008.

Sparse *Caatinga Arbóreo-arbustiva*

Areas with naturally open vegetation, rocky outcrops and soils exposed, shallow and excessively stony. Presence of shrubby individuals, rarely arboreal, spaced, with the crowns rarely touching. Predominance of herbaceous and crawling plants, in shallow soils and among exposed rock. *Cactáceas* are frequent.

Photo 5.2-7 – Herbaceous and shrubby vegetation and exposed ground.

Photo: ARCADIS Tetraplan, 2008.

Photo 5.2-8 – Sparse vegetation made up of shrubs and *Cactáceas* with exposed rocks.

Photo: ARCADIS Tetraplan, 2008.

Photo 5.2-9 – *Arbóreo arbustiva* vegetation and outcrop.

Photo: Arcadis, 2017.

Open *Caatinga Arbóreo-arbustiva*

Areas with an indivisible mix of trees and bush scrub, very recurrent in the region. In the open typology, arboreal specimens are very scarce, with shrub and tree specimens prevailing. There is some continuity of surface coverage, given by the tops of trees and trees.

Photo 5.2-10 – Open *Caatinga Arbóreo-arbustiva*.

Photo: ARCADIS Tetraplan, 2008.

Photo 5.2-11 – Shrub vegetation, without leaves at the time (November / 2016).

Photo: Arcadis, 2017.

Photo 5.2-12 – *Caatinga Arbóreo-arbustiva*.

Photo: Arcadis, 2017.

Dense *Caatinga Arbóreo-arbustiva*

In this typology, trees and shrub specimens densely cover the surface, and are often associated with the chapadas.

Photo 5.2-13 – General view of the Dense *Caatinga Arbóreo-arbustiva* vegetation.

Photo: ARCADIS Tetraplan, 2008.

Photo 5.2-14 – Vegetation of Dense *Caatinga Arbóreo-arbustiva*.

Photo: Arcadis, 2017.

Water Bodies

Intermittent rivers and reservoirs, in addition to the *Jenipapo* dam.

Photo 5.2-15 – *Jenipapo* Weir.

Photo 5.2-16 – *Jenipapo* Dam.

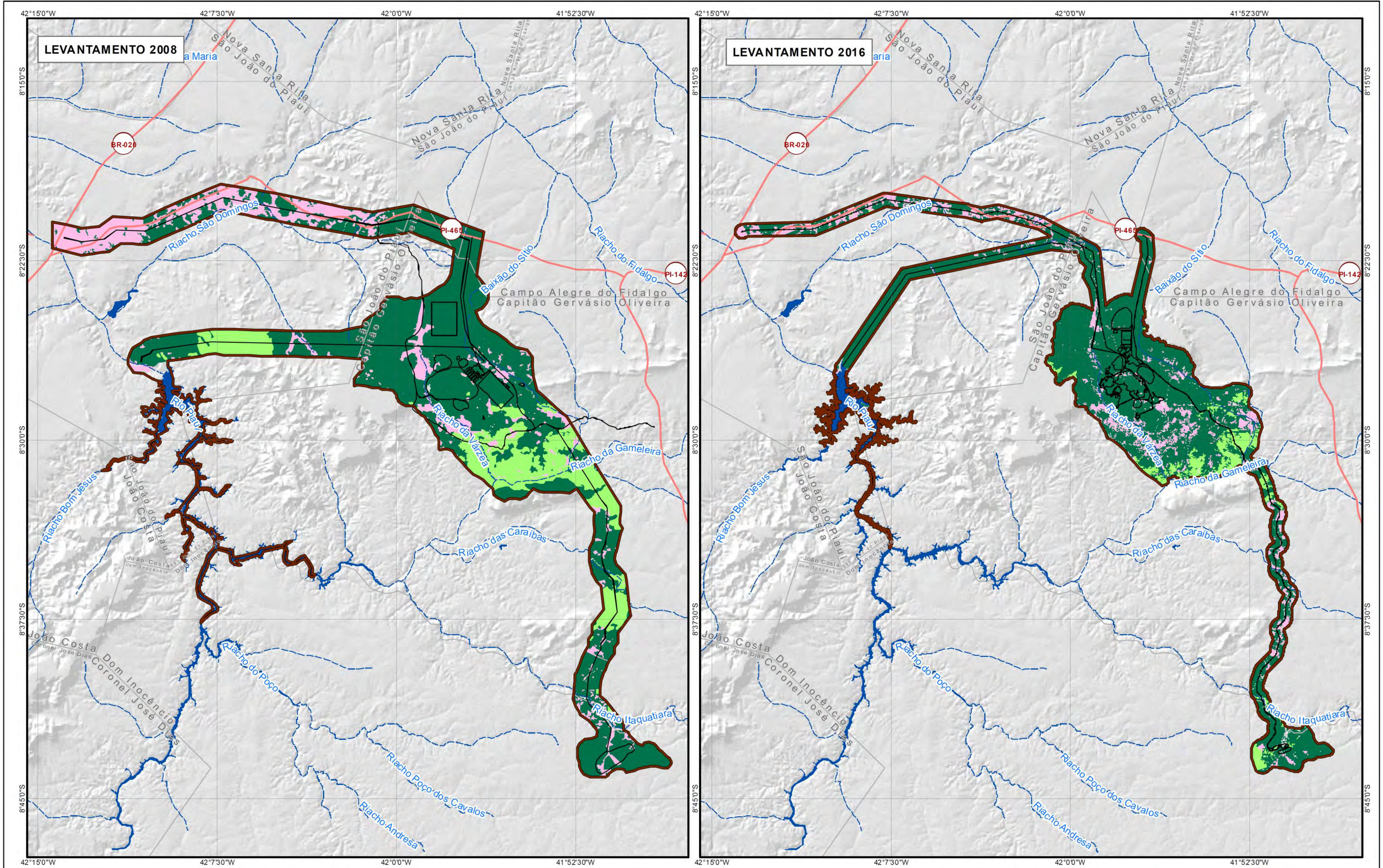
Photo: ARCADIS Tetraplan, 2008.

Summary of Land Use and Ground Coverage - ADI

In comparison with previous mapping (Arcadis Tetraplan, 2008), there is great similarity between the land use and ground covering despite the variations in the design of the ADI and the greater detail of the grouping in the current mapping.

The predominance of *Caatinga Arbóreo arbustiva* was verified (Dense and/or Ppen) in a large area of the project ADI. It is scarce in the south – southeast of the Nickel Mine, without significant changes in relation to 2008 (Map 5.2-4). There are similarities in terms of proportion between anthropic areas and natural vegetation evidencing the prevalence of *Caatingas*, in both ADAs with 69.62% of native vegetation and 30.38% of anthropic use identified in the mapping of 2008 and 86.29% of vegetation and 13.71% of use observed in the current mapping. These similarities allow us to infer that the local landscape has changed little to nothing during this period, maintaining the same characteristics.

Map 5.2-4 – Land Use and Ground Cover – 2008 and 2016.



LEGENDA

- Road System
- Municipal Limits
- Intermittent Drainage
- Water Mass
- Area of Direct Influence - ADI
- Directly Affected Area - DAA

Land Use and Cover

- Anthropized Areas
- Arboreal-shrubbery Caatinga (sparse)
- Arboreal-shrubbery Caatinga (dense or open)

REFERÊNCIAS

ARCADIS Tetraplan, 2008;
IBGE, Brasil ao milionésimo, 2014;
Projeto Piauí Níquel, 2016;
RapidEye, Imagem 2016.

ESCALA GRÁFICA
0 2,5 5 km
Sistema de Coordenadas: GCS WGS 1984

MAPA DE LOCALIZAÇÃO
PA MA CE RN PB PE PI AL SE BA TO

Piauí Níquel
ARCADIS

EIA/RIMA – PROJETO PIAUÍ NÍQUEL

Map 5.2-4 – Land Use and Ground Cover - ADI 2009 and 2016

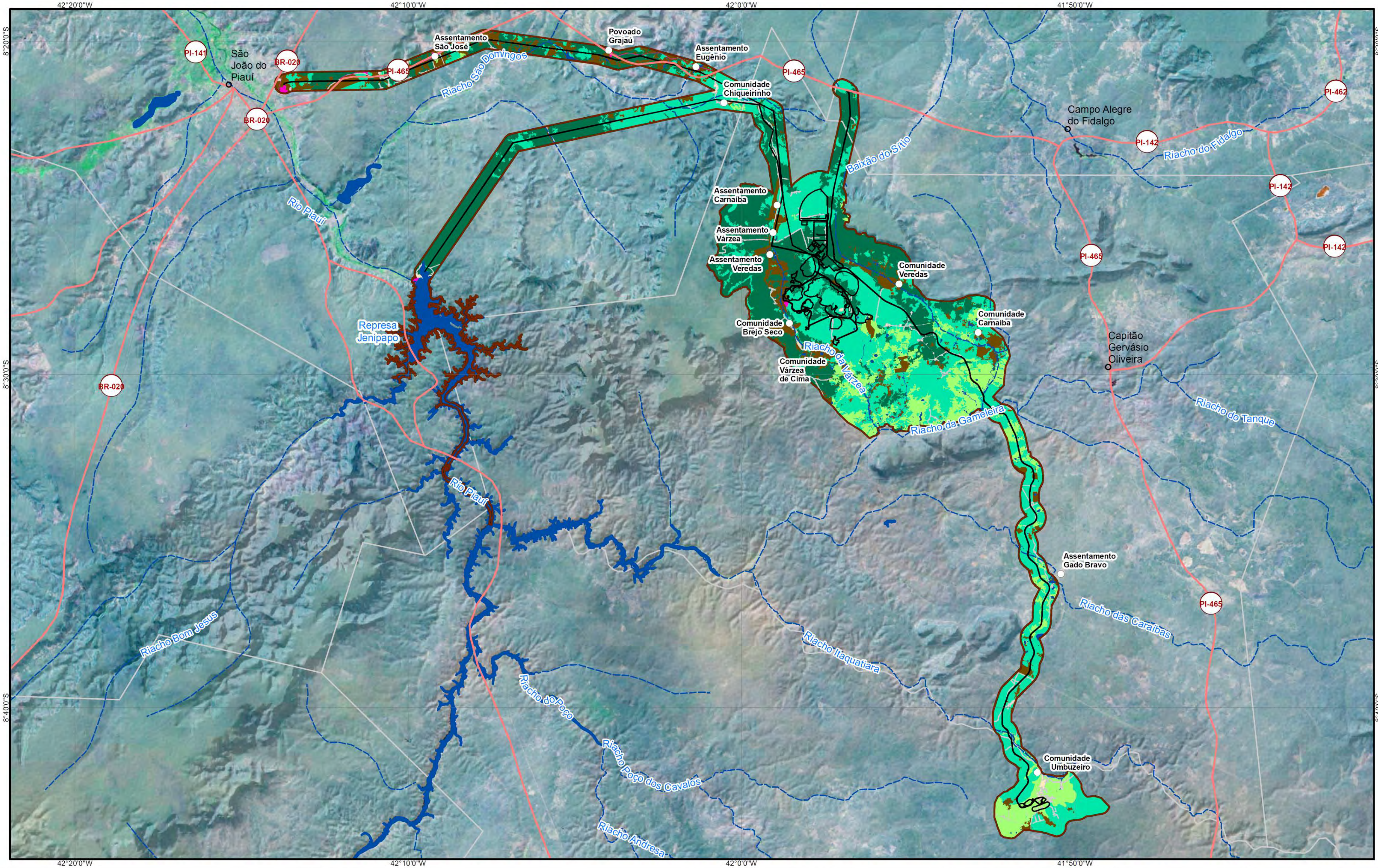
EXECUTADO POR:	ESCALA:	NÚMERO:	DATA:
ARCADIS	1:275.000	Única	jan/2017

Comparing with the mapping of the AII, a large part south of the ADI where the Limestone Quarry is located is covered by Open *Caatinga Arbóreo-arbustiva*, which corresponds to the *Savana Estépica Arborizada* mapped in the AII. The dense *Caatinga Arbóreo-arbustiva*, which corresponds to the *Savana Estépica Florestada* of the AII map, prevails in the north of the Nickel mining area and in part of the eastern and western edges.

In the ADI strip that corresponds to the power transmission line prevails a variety of Agriculture, which corresponds to an agricultural strip on the AII map and different physiognomies of *Caatinga* identified as *Savana Estépica Arborizada*.

The distribution of the ADI land use and ground coverage typologies can be seen in the General Land Use and Ground Coverage Map – ADI (Map 5.2-5) which has the same vector basis as the 1:25,000 map, but on a scale that allows to see the context of the entire area (1:200,000). The Land Use and Ground Coverage Map, 1:25,000, with the location of the different types of land use and ground coverage can be found in ANNEX VIII (Volume IV).

Map 5.2-5 – Land Use and Ground Coverage – ADI.



LEGENDA

- Municipal Headquarter
- Road System
- Intermittent Drainage
- Water Mass
- Municipal Limits
- Area of Direct Influence - ADI
- Directly Affected Area - DAA

Land Use / Vegetation Cover

- Edification and structure
- Water mass
- Farming
- Exposed Soil
- Sparse Arboreal-shrubbery Caatinga
- Open Arboreal-shrubbery Caatinga
- Dense Arboreal-shrubbery Caatinga

REFERÊNCIAS

IBGE, Brasil ao milionésimo, 2015;
LANDSAT, Imagem, 2016;
Projeto Piauí Níquel, 2016.
RapidEye, Imagem , 2016.

ESCALA GRÁFICA

0 5 10 km

Sistema de Coordenadas: GCS SIRGAS 2000

MAPA DE LOCALIZAÇÃO

PA, MA, CE, RN, PB, PE, PI, AL, SE, BA, TO

Piauí Níquel | ARCADIS

EIA/RIMA – PROJETO PIAUÍ NÍQUEL

Map 5.2-5 – Land Use and Ground Cover ADI

EXECUTADO POR:	ESCALA:	NÚMERO:	DATA:
ARCADIS	1:200.000	Única	set /2017

Land Use and Ground Coverage Planimetry – ADI

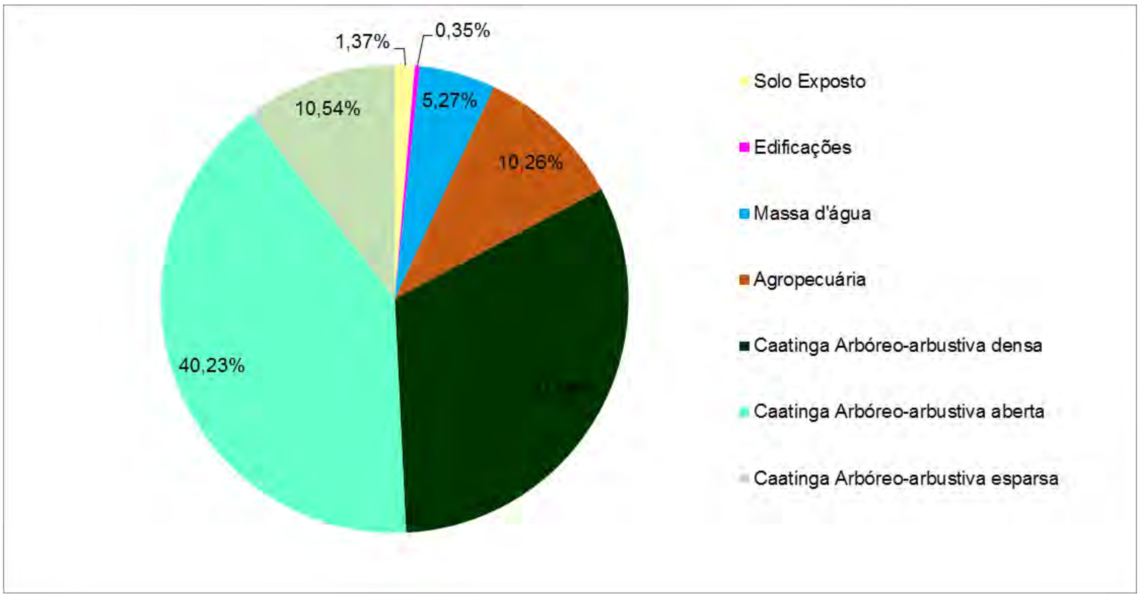
According to the planimetry done in a GIS computational environment (shown in Data Table 5.2-3 and Graph 5.2-1), the Open *Caatinga Arbóreo-arbustiva* is predominant representing 40.23% of the ADI. The second largest proportion mapped is the Dense *Caatinga Arbóreo-arbustiva* with 31.98%.

Data Table 5.2-3 – Types of Land Use and Ground Cover in the ADI.

Class of Use and Ground Cover 2016	Area Km²	Hectares	Percentage - 2016
Exposed Ground	3.42	341.66	1.37%
Buildings	0.87	86.59	0.35%
Water Bodies	13.09	1,309.15	5.27%
Agriculture	25.50	2,549.54	10.26%
Dense *Caatinga Arbóreo arbustiva*	79.46	7,945.71	31.98%
Open *Caatinga Arbóreo arbustiva*	99.98	9,997.85	40.23%
Sparse *Caatinga Arbóreo arbustiva*	26.19	2,618.94	10.54%
TOTAL	**248.49**	**24,849.45**	**100%**

Source: Arcadis, 2017.

Graph 5.2-1 – Percentage distribution of land use and ground in the ADI.



Prepared by: Arcadis, 2017.

c) Land Use and Ground Coverage at DAA and interference with Permanent Preservation Areas (APP)

As in the ADI, the Open *Caatinga Arbóreo-arbustiva* abounds in the DAA (62.56%), followed by the Dense *Caatinga Arbóreo-arbustiva* (29.18%). The Sparse *Caatinga Arbóreo-arbustiva* appears in low percentages (4.58%). Agriculture occupies about 1.79% of the area (Approximately 21 ha), and buildings occupied a small proportion (about 0.05%) (Data Table 5.2-4).

Data Table 5.2-4 – Types of Land Use and Ground Cover in the DAA.

Use	Hectares	%
Agriculture	20.82	1.79%
Open *Caatinga Arbóreo-arbustiva*	728.29	62.56%
Dense *Caatinga Arbóreo-arbustiva*	339.67	29.18%
Sparse *Caatinga Arbóreo-arbustiva*	53.37	4.58%
Buildings	0.59	0.05%
Water Bodies	2.96	0.25%
Exposed Ground	18.43	1.58%
Total	**1,164.13**	**100%**

Prepared by: Arcadis, 2017.

Land Use and Ground Coverage for each project structure

The types of land use and ground coverage for the areas that will be occupied by the project structures are shown below (Data Table 5.2-5).

Data Table 5.2-5 – Types of Land Use and Ground Cover grouped by the project structures.

Nickel Mine	Use	Hectares
Nickel Mine	Agricultural	4.65
	Open *Caatinga Arbóreo-arbustiva*	259.79
	Dense *Caatinga Arbóreo-arbustiva*	62.97
	Exposed Ground	3.06
Total		**330.46**
Crushing	Open *Caatinga Arbóreo-arbustiva*	0.58
	Dense *Caatinga Arbóreo-arbustiva*	1.68
Total		**2.26**
Ore Stockpiles	Agricultural	0.47
	Open *Caatinga Arbóreo-arbustiva*	75.84
	Dense *Caatinga Arbóreo-arbustiva*	48.08
Total		**124.39**
Leach Pad	Open *Caatinga Arbóreo-arbustiva*	15.27
	Dense *Caatinga Arbóreo-arbustiva*	57.85
	Exposed Ground	1.92
Total		**75.04**
Process Ponds	Dense *Caatinga Arbóreo-arbustiva*	7.82
Total		**7.82**
Emergency Pond	Dense *Caatinga Arbóreo-arbustiva*	8.89
Total		**8.89**
Conveyors & Piping	Open *Caatinga Arbóreo-arbustiva*	0.31
	Dense *Caatinga Arbóreo-arbustiva*	0.88
	Exposed Ground	0.01
Total		**1.20**
Processing Plant	Open *Caatinga Arbóreo-arbustiva*	6.97
	Dense *Caatinga Arbóreo-arbustiva*	38.18
Total		**45.16**
Sterile Material Deposit	Agricultural	0.20
	Open *Caatinga Arbóreo-arbustiva*	55.35

Nickel Mine	Use	Hectares
	Dense *Caatinga Arbóreo-arbustiva*	37.61
	Exposed Ground	2.05
Total		**95.21**
Solid Residues Deposit	Open *Caatinga Arbóreo-arbustiva*	197.12
	Dense *Caatinga Arbóreo-arbustiva*	21.06
	Exposed Ground	4.21
Total		**222.39**
Water Reservoir	Open *Caatinga Arbóreo-arbustiva*	2.15
	Dense *Caatinga Arbóreo-arbustiva*	4.04
	Exposed Ground	0.03
Total		**6.21**
Fresh Water Pipeline	Open *Caatinga Arbóreo-arbustiva*	0.01
	Dense *Caatinga Arbóreo-arbustiva*	0.13
Total		**0.14**
ETA	Dense *Caatinga Arbóreo-arbustiva*	0.16
Total		**0.16**
Explosives	Agricultural	0.75
Total		**0,75**
Dikes	Agricultural	5.86
	Open *Caatinga Arbóreo-arbustiva*	32.13
	Dense *Caatinga Arbóreo-arbustiva*	7.30
	Sparse *Caatinga Arbóreo-arbustiva*	4.30
	Water Bodies	2.49
Total		**52.09**

Limestone Quarry - *Umbuzeiro*	Use	Hectares
Limestone Processing Plant	Agricultural	0.34
	Sparse *Caatinga Arbóreo-arbustiva*	6.10
	Exposed Ground	0.87
Total		**7.32**
Limestone Quarry	Open *Caatinga Arbóreo-arbustiva*	1.92
	Sparse *Caatinga Arbóreo-arbustiva*	18.90
	Exposed Ground	3.56
Total		**24.38**

Nickel Mine	Use	Hectares
Limestone Sterile Deposit	Open *Caatinga Arbóreo-arbustiva*	0.04
	Dense *Caatinga Arbóreo-arbustiva*	13.73
Total		**13.77**

Power Line	Use	Hectares
Power Line	Agricultural	3.50
	Open *Caatinga Arbóreo-arbustiva*	3.54
	Dense *Caatinga Arbóreo-arbustiva*	3.96
	Sparse *Caatinga Arbóreo-arbustiva*	0.08
	Buildings	0.02
	Exposed Ground	0.17
Total		**11.26**
Towers	Agricultural	0.75
	Open *Caatinga Arbóreo-arbustiva*	0.6
	Dense *Caatinga Arbóreo-arbustiva*	0.89
	Sparse *Caatinga Arbóreo-arbustiva*	0.02
	Buildings	0.02
	Exposed Ground	0.02
Total		**2.31**

Water Pipeline	Use	Hectares
Fresh Water Pipeline	Agricultural	0.88
	Open *Caatinga Arbóreo-arbustiva*	9.95
	Dense *Caatinga Arbóreo-arbustiva*	15.09
	Exposed Ground	0.82
Total		**26.73**

Access Roads	Use	Hectares
Access Roads	Agricultural	22.48
	Open *Caatinga Arbóreo-arbustiva*	45.73
	Dense *Caatinga Arbóreo-arbustiva*	25.11
	Sparse *Caatinga Arbóreo-arbustiva*	10.20
	Buildings	0.53

Nickel Mine	Use	Hectares
	Water Bodies	0.46
	Exposed Ground	1.68
Total		**106.19**

Prepared by: Arcadis, 2017.

Land Use and Ground Coverage in Permanent Preservation Areas (APP) directly affected

Legal Basis

According to the New Forest Code (Federeal Law) 12.651 / 2012, amended by Law 12.727 / 2012, five types of Permanent Preservation Areas – APPs in the project DAA were identified, described in article 4:

- I) the marginal strips of any perennial and intermittent natural watercourse, excluding ephemeral, from the edge of the regular bed drain, in a minimum width of 30 (thirty) meters for watercourses of less than 10 (ten) meters wide and 50 (fifty) meters for water courses that are 10 (ten) to 50 (fifty) meters wide (letters "a" and "b").

Almost all streams identified in the ADI are less than 10 meters width therefore all APPs mapped are 30 meters. The *Itaquatiara* stream has an average width higher than 10m and its APP strip was mapped at 50m.

- II) the areas surrounding the natural lakes and lagoons, in a strip with a minimum width of 100 (one hundred) meters, in rural areas, except for the water body with up to 20 (twenty) hectares of surface, whose marginal strip will be 50 (fifty) meters and 30 (thirty) meters, in urban areas (letters "a" and "b").

According to § 1 of article 4, dams dug out of the natural bed of water courses fed by diversion or solely by the accumulation of rainwater during part of the year do not require an APP.

According to paragraph 4 of article 4, natural or artificial accumulations of water with a surface area less than 1 (one) hectare does not require a define APP.

- III) the areas surrounding the artificial water reservoirs and natural damming of water bodies in the range defined in the project's environmental license.

This item includes the *Jenipapo* Dam APP where the water pipeline begins.

- IV) in the water springs, even when intermittent and in the so-called water eyes, whatever their topographic situation, within a minimum radius of 50 meters wide.
- IX) top of hills, hills and mountains with a minimum height of 100m and an average slope greater than 25°, the areas delimited from the level curve corresponding to 2/3 (two thirds) of the minimum elevation height always in relation to the base, this being defined by the horizontal plane determined by the adjacent plain or water mirror or by the height of the saddle point closest to the elevation.

Methodology

The delimitation of the areas considered to be of Permanent Preservation Areas was made through the use of GIS on a recent satellite image and using the topographic base of the mining area provided by PNM.

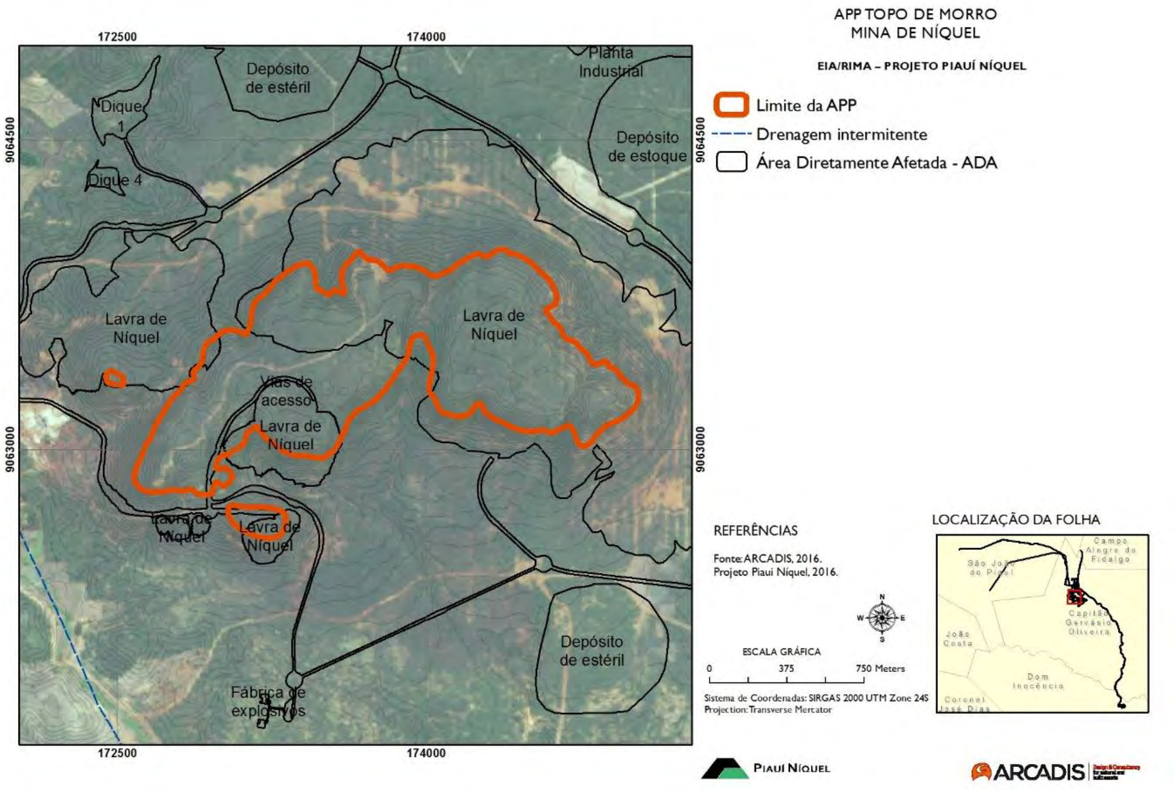
The demarcation of the local hydrographic network served as a basis for the delimitation of APP's associated with water bodies (springs, lagoons and water courses), and the program generated the preservation buffers according to the corresponding legal parameters.

The APP's related to the top of hill in the DAA were restricted to the portion of land corresponding to the intended location for the nickel mine in the *Brejo Seco* hill.

According to the available topographic data (plan altimetric survey with curves every 5m), the terrain has an altimetric difference of 125m between the top (505m) and the base level of the hill (380m curve), with an average slope above 25 degrees.

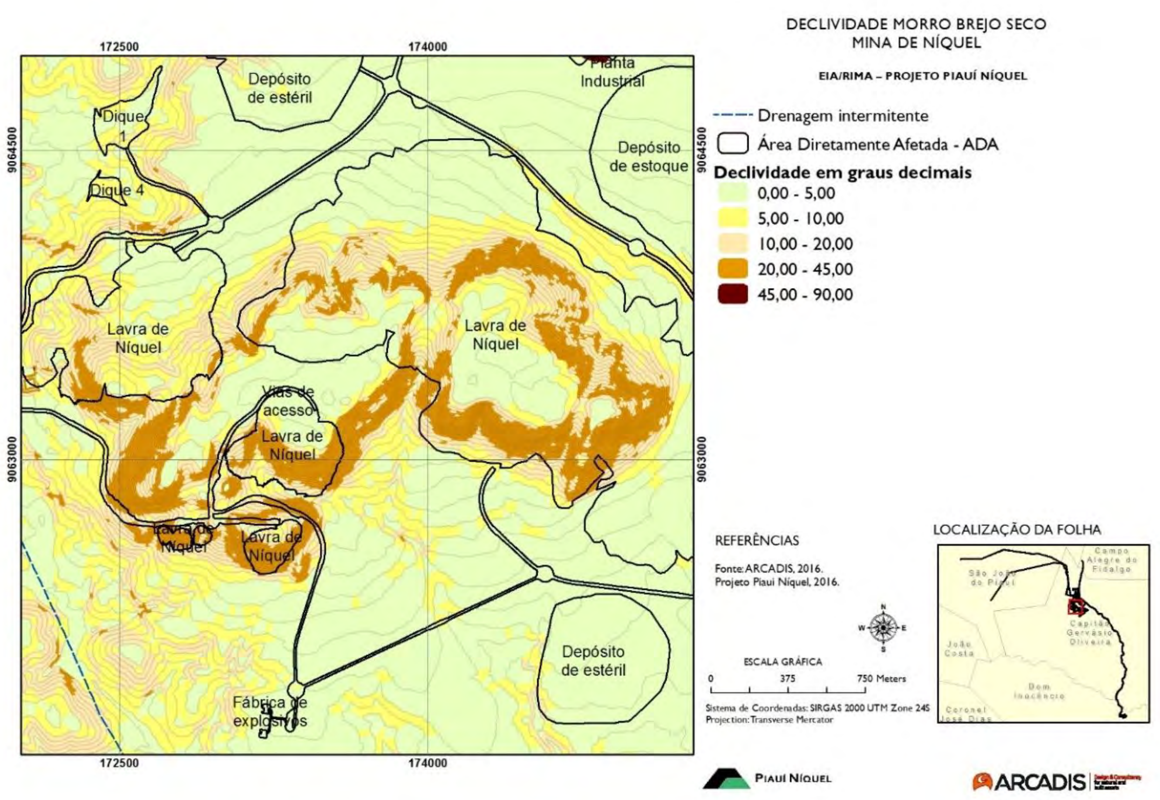
The elevation of the ground from where the top of hill APP is considered is limited to the upper third part of the elevation, corresponding to the 460m quota, resulting in the delimitation of a APP as shown in Map 5.2-6:

Map 5.2-6 – Top of the Hill APP at the *Brejo Seco* Hill (Project ADI and DAA).



The GIS program analyzed the slope of the *Brejo Seco* hill, which corresponds to the only landscape attribute within the project's DAA that could have characteristics to determine the existence of a APP by slope. According to the graphical analysis, no slope was found that could be classified as a APP according to the current legislation (above 45º of inclination).

Map 5.2-7 – Slope inclination of the *Brejo Seco* Hill.



Source: PNM 2016.

Results

A total of 132.18 ha of Permanent Preservation Areas (APPs) were identified in the project DAA, with most of the coverage consisting of Open *Caatinga Arbóreo-arbustiva* (82.53%). The second largest representation is Dense *Caatinga Arbóreo-arbustiva* (13.60%) and then, Sparse *Caatinga Arbóreo arbustiva* with 2.49% (Data Table 5.2-6).

Data Table 5.2-6 – Types of Use of the APP's in the Project DAA.

Use	APP Area	
	ha	%
Agricultural	0.99	0.75%
Open *Caatinga Arbóreo-arbustiva*	109.06	82.51%
Dense *Caatinga Arbóreo-arbustiva*	17.97	13.60%
Sparse *Caatinga Arbóreo-arbustiva*	3.29	2.49%
Buildings	-	0%
Exposed Ground	0.87	0.66%

Use	APP Area	
	ha	%
Total	**132.18**	**100.00%**

Prepared by: Arcadis, 2017.

The Nickel Mine has the largest area of interference in the APP, as it directly affects top of the *Brejo Seco* hill APP. (Data Table 5.2-7).

Data Table 5.2-7 – APP interference by Project Structure.

Nickel Mine	APP Area (ha)
Nickel Mine	106.08
Crushing System	0.04
Stockpiles	0.17
Leach Pad	1.60
Process Ponds	1.76
Emergency Pond	1.45
Conveyors and Piping	0.01
Ore Sterile Deposit	0.87
Dikes	7.76

Limestone Quarry	APP Area (ha)
Process Plant – Limestone	1.91
Limestone Quarry	1.61
Limestone Sterile Deposit	0.01

Other Structures	APP Area (ha)
Power Transmission Line	0.66

Water Pipeline	APP Area (ha))
Water Pipeline	1.15

Access Roads	APP Area (ha)
Access Roads	7.11

Prepared by: Arcadis, 2017.

The table below presents the summary of the APP interferences by type of ground cover.

Data Table 5.2-8 – Quantitative Summary of APP interferences in the Project DAA.

Use	Area Outside APP (ha)	Area Inside APP (ha)	Total (ha)	%
Dense *Caatinga Arbóreo-arbustiva*	321.70	17.97	339.67	29.18%
Open *Caatinga Arbóreo-arbustiva*	619.23	109.06	728.29	62.56%
Sparse *Caatinga Arbóreo-arbustiva*	50.08	3.29	53.37	4.58%
Other Uses and Covers	40.94	1.86	42.80	3.67%
Total	**1031,95**	**132.18**	**1,164.13**	**100%**

Prepared by: Arcadis, 2017.

The state legislation (article 4 of State Decree 11.126 / 2003) considers as APP the strips of land contiguous to the federal and state highways, outside the urban perimeters, with a width of not less than 30m (thirty meters). The only points of contact between the project structures and state highway is the connection of new access road and PI-465 highway, and the installation of the power transmission line whose route crosses that same state highway.

These interferences totalize an area of 3,900 m^2. There are some conflicts between the old forest code (Federal Law 4,771 / 65) and the new Federal Law 12,651 / 2012 to the applicability of this restrictions. The interference is mentioned and included in the compensation programs according to the principle adopted and recommended by the licensing agency.

According to the New Forest Code (Law 12.727 / 2012), about 80% of the identified areas are related to APPs linked to the natural relief (Brejo Seco hill). The other 20% of the APPs identified are related to water bodies (springs, lagoons and water courses), as detailed in Data Table 5.2-9.

Data Table 5.2-9 – APPs types in the Project DAA.

APP Types	Total	
	ha	%
Top of the Hill	105.36	79.71
Water Body (Springs, Lagoons and Water Courses)	26.05	19.71
Top of the Hill e Water Body	0.77	0.58
Total	**132.18**	**100**

Prepared by: Arcadis, 2017.

5.2.3.2. Vegetation Characterization

A) Methodological procedures for the AII, ADI and DAA

AII

The characterization of the flora in the project Area of Indirect Influence (AII) was made from secondary data, analyzing the available cartographic material and consulting the specialized bibliography.

ADI and DAA

The characterization of the project Area of Direct Influence (ADI) and Directly Affected Area (DAA) was carried out based on field sampling (collection of primary data). Data collection started in 2008 when two campaigns were carried out to sample vegetation in the periods from 23 to 27 January and 13 to 20 February of that year. These campaigns help to obtain the necessary data for the analysis of the horizontal vegetation structure of those areas. In addition to these from October 31 to November 5, 2016 another campaign was carried out involving the characterization of phytophysiognomies and complementing the floristic survey at the DAA and ADI of the project and support structures.

The analysis of flora in the project ADI and DAA involved the determination of phytophysiognomies , the identification of the plant species diversity (through the execution of floristic surveys) and the evaluation most important plant formations structure (through forest inventory).

Each of these evaluations were carried out following methodologies that will be detailed in the following sections. The mapping of the vegetation cover will assist in the understanding of the spatial organization of the biota and the anthropic occupation.

Classification of Vegetation Physiognomies

The natural vegetation of the project area is fully inserted in the Northeastern *Caatinga* domain formed by deciduous plants generally spiny. The landscape is a local depression typical of the semi-arid northeastern region consisting of a low flat land with predominantly smooth-undulating natural relief and the presence of small elevations.

The "*Manual Técnico da Vegetação Brasileira (2ª ed.)"* produced by the *Instituto Brasileiro de Geografia e Estatística* (IBGE, 2012) was used as a reference for the classification of vegetation types to standardize the different vegetation classification systems existing in Brazil.

The characterization of the physiognomic types of *Caatinga* occurring in the project ADI, the size and stratification of the vegetation were considered along the whole project structures including the power transmission line, the nickel mining area, the processing plant, the *Itaquatiara* stream, limestone quarry area (*Umbuzeiro*) and its access road. Based on these data, the vegetation map of the project area was generated, adopting the name *Caatinga* replacing the *savana estépica* as already explained on the mapping of the ground cover.

Floristic Survey

The botanical characterization of the regional vegetation was done via field work and the results includes the data collected in both the 2008 and 2016 campaigns.

The APG IV (2016) system was used for this botanical classification.

The floristic survey was not restricted to the plots of the phytosociological survey and it was extended throughout the entire project ADI covering plants of all habits and in all extracts according to the random walk methodology developed by FILGUEIRAS et al. 1994. Special attention was given to the finding of legally protected species, considered rare and/or threatened with extinction according with the current environmental legislation (Ordinance MMA 443/14). The list published by GIULIETTI et al (1992) was used for endemic species.

The species of economic importance were also included in the survey. The existing scientific works for the *Caatinga* domain were used as a reference - QUEIROZ (1999), SILVA (1988), BAUTISTA (1988), EPAMIG (1994). Additionally, personal interviews with residents of the region were done to understand the uses of *Caatinga* species. The species were classified in groups according to their economic importance: fruit, medicinal, reforestation, landscaping species, fibers, timber and forage.

Some plants that were not identified in the field were collected and processed to make exsiccates that were donated to the EPAMIG Herbarium.

The environmental changes influencing the vegetation conservation status in the area of interest was assessed using the typical species present altered environments of the *Caatinga*, pioneer species, invasive exotic species, as well as other factors of flora degradation such as signs of burning, shallow and / or selective cuts, grazing and trampling.

Phytosociological Surveys

The classification of tree species was maintained according to the Cronquist system using from the phytosociological surveys done in 2008 by the *Fundação José Silveira* at the request of CVRD. The use of this classification does not have an influence on the analysis of the impacts and viability of the project.

At the time, the *Protocolo de Medições de Parcelas Permanentes, da Rede de Manejo Florestal da Caatinga* was used as a reference allowing comparisons with other similar works. The information collected can be used as reference for future works in the Northeast *Caatinga* domain.

The phytosociological surveys allowed the analysis of the horizontal structure of the areas through density data, dominance and frequency of the species used, importance value index (indicator of the importance of certain species within the studied environment), and coverage value index.

20.0m x 20.0m plots were used as a standard dimension, and all of them were georeferenced via GPS.

Quantifiable trees in the sections were all shafts with diameter at chest height higher than 5.0 cm. Every tree whose base of the trunk was within the section was included, even if the stem and top were outside the limits. If the shaft and top were inside the section, but the base was outside, the tree was not included.

A measuring tape was used for the cap and a graduated stick for the total height.

To estimate the parameters of density, frequency and dominance, the methodology proposed by LAMPRECHT (1964) and used by ALMEIDA (1996) was applied.

The estimates of absolute (DAi) and relative (DRi) densities were obtained using the following equations:

$$DA_I = \frac{N_I}{A} \quad \text{and} \quad DR_I = \frac{DA_I}{\sum_{i=1}^{P} DA_I} * 100$$

ni = number of specimens sampled of the umpteenth species.

A = Area Sampled, ha; and

p = number of species sampled.

The absolute (FAi) and relative (FRi) frequencies, both expressed as a percentage, were obtained using the following formulas:

$$FA_I = \left(\frac{u_i}{u_t}\right) * 100 \quad \text{and} \quad FR_I = \frac{FA_I}{\sum_{i=1}^{P} DA_I} * 100$$

ui = number of sampling units in which the umpteenth species is present.

ut = total number of sample units; e

p = number of species sampled.

The estimation of dominance in absolute (DoAi) and relative (DoRi) terms was obtained using the following formulas:

$$DoA_I = \left(\frac{AB_i}{A}\right) \quad \text{and} \quad DoR_I = \frac{DoA_I}{\sum_{i=1}^{P} DoA_I} * 100$$

ABi = basal area of the umpteenth species, expressed in m²/ha.

DoRi = relative dominance of the umpteenth species, in percentage.

A = Area Sampled, ha; and

p = number of species sampled.

To complete the analysis of the horizontal structure, the importance value index (IVI) was calculated adopting the methodology proposed by CURTIS (1951). This index was obtained by adding the relative values of density (DR), dominance (DoR) and frequency (FR).

The dominance measures the productivity potential of the forest defined as the measure of total projection of the plant's body. The absolute dominance is calculated by the sum of the basal areas of specimens belonging to a given species, constituting a useful parameter for determining the quality of the site.

The frequency measures the regularity of the horizontal distribution of each species over the ground measured by the percentage of times a species is found in parcels of equal size. The degree of vegetation homogeneity is calculated using this frequency factor. The closer to one, the more homogeneous the vegetation is.

The isolated relative values of density, dominance and frequency do not express the essential aspects of the floristic structure of the vegetation. In order to have a sense of what each species represents is necessary analyze the combination of these three. This new index, Importance Value Index (IVI), is calculated by adding the relative density, relative dominance and relative frequency of the species.

However, if the species is evenly distributed, the relative frequency will have little influence since the importance of a species is characterized by the number of specimens in the community and its dimensions, regardless of whether the trees appear isolated or in groups. The relative frequency that goes into the importance index will have little influence if the species are evenly distributed. In this case, it is advisable to characterize the species by their "coverage" in the area, called the Coverage Value (VC), obtained through the sum of their relative abundances and dominances.

Plots Definition

125 Plots of 400 m² (20 x 20 m) were defined randomly in the DAA and ADI, totaling an inventory of 50,000 m². All tree / shrub specimens with a circumference at chest height (CCH[9]) greater than 15.7 cm were measured, which correspond to a diameter at chest height (DCH) higher than 5 cm. Herbs, *Cactáceas* and lianas were surveyed and analyzed for presence in the sampled areas. The acceptability of floristic sampling was analyzed based on the curve of the collector and the current average of species (RODAL et al., 1992). The current average species curve is plotted based on the cumulative average number of species per area. CASTRO (1987) cited by RODAL et al. (1992) considered as satisfactory an area containing between 85 and 90% of the species found.

The plots were distributed in different areas required for the project implementation covering the following areas:

- AREA 1: Processing Plant, Nickel Mine and Pilot Plant.
- AREA 2: Limestone Quarry (*Umbuzeiro*) and road the processing plant (about 33 Km).

[9] Measured at 130cm from the ground level

- AREA 3: Power Transmission Line, starting from *São João do Piauí* until the project area (about 46 km); and
- AREA 4: *Itaquatiara* stream.

The distribution of the plots by area is show in Data Table 5.2-10:

Data Table 5.2-10 – Plots Distribution by Sampling Area.

Plots	%	Area	Subarea
21, 22, 23, 24, 25, 26, 27, 28, 29, 30	7.95	1	Nickel Mine (Brejo Seco Hill)
31, 32, 33, 34, 35, 36, 37, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 68	26.98	1	Processing Plant
1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20	15.87	2	Limestone Quarry (*Umbuzeiro*)
91, 92, 93, 94, 117, 118, 119, 120, 121, 122, 123, 124, 124, 126, 127, 128, 129, 130, 131, 132, 133, 134, 135	18.25	2	Access road between the Limestone Quarry and the Processing Plant
69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88	15.87	3	Power Transmission Line
89, 90, 96, 106, 107, 108, 109, 110, 111, 112, 113, 114, 115, 116	11.11	4	*Itaquatiara* Stream
101, 102, 103, 104, 105	3.97	4	Residue Disposal Area

Source: Arcadis, 2017.

Floristic Diversity

Two floristic diversity indexes were used: Shannon index and Pielou index.

Shannon-Weaver (H') diversity index, cited by POOLE (1974), was used in many structural analyses of forests carried out in Brazil allowing comparisons across studies. This index is calculated based on the relationship between the number of individuals, by species, and the total number of specimens sampled (MARTINS, 1993). In tropical forests, this index tends to increase as the vegetation approaches the peak stage.

The Shannon-Weaver index (H') is calculated using the following formula:

$$H' = \frac{\left[N \ln(N) - \sum_{i=1}^{S} n_i \ln(n_i) \right]}{N}$$

H' = Shannon-Weaver Index.

N = total number of specimens sampled.

i = 1,2,3 ...s = number of sampled species.

ni = total number of specimens sampled from the umpteenth species.

S = total number of species sampled; and

log = base 10 logarithm.

Another important metric is the Equitability index (J') that represents a uniformity of the species through the area. This index varies between 0 and 1 (maximum uniformities). It is calculated using the formula proposed by Pielou (1975):

$$J' = \frac{H'}{H_{max}} \quad \text{sendo} \quad H_{max} = \ln(S)$$

J' = Equitability Index

H' = Shannon-Weaver Index.

S = total number of species sampled.

ln = Napierian logarithm.

Wood Yield Estimate

An initial estimate of the wood yield in the suppression area is estimated based on the results of the phytosociological survey. The results shall serve as guidelines for the development of environmental programs and for the planning of possible future uses of wood material resulting from the project implementation.

The most accurate volume calculation of the wood generated in the suppression area must come from a forest inventory to be carried out at the project's DAA when the Installation License is requested as proper details will be available.

The equation to calculate the wood volume (adjusted by SILVA, 2005) was used to estimate individual volumes considering the structure of the *Caatinga* typology. This volume refers to the total volume of the tree including its bark for the *Caatinga* and all its variations. The equation is described below:

$$\hat{V}t_j = \exp\left[-10{,}23110545 + 2{,}0119544.Ln(DEq_j) + 1{,}2827287.Ln(Ht_j)\right],$$

em que

$\hat{V}t_j$ = volume total com casca, em m³;

$DEq_j = \sqrt{DAP_1^2 + DAP_2^2 + ... + DAP_n^2}$, em cm;

Ht_j = altura total do maior fuste, em m;

Ln = logaritmo neperiano;

j = 1, 2, ..., j-indivíduos; e

i = 1, 2, ..., n-fustes.

The process to obtain the LP does not require any additional statistical analysis of the estimated volumes of wood.

B) Results

a) Vegetation in the AII

The *Caatinga* 's biodiversity is commonly characterized as homogenous, weak and endemic, and with little alteration. Recent studies have shown that the *Caatinga* is among the Brazilian biomes most degraded by man (MMA, 2002). In qualitative and quantitative studies on *Caatinga* vegetation, about 932 tree and shrub species were recorded, 380 of which are endemic (GIULIETTI et al., 2002; MMA, 2002).

When listing families, genus and species of *Caatinga*, PRADO (1991) and GIULIETTI et al. (2002) report that *Amburana cearensis (imburana-de-cheiro, Fabaceae – Papilionoidae), Anadenanthera colubrina var. cebil (angico, Fabaceae – Mimosoidae), Aspidosperma pyrifolium. (pereiro, Apocynaceae), Poincianella pyramidalis. (pau-de-rato, Fabaceae – Caesalpinioidae), Cnidosculus phyllacanthus (favela, Euphorbiaceae), Commiphora leptophloeos (amburana-de-cambão, Burseraceae),* various species of *Croton (marmeleiros and velames, Euphorbiaceae) and Mimosa (calumbis and juremas, Fabaceae-Mimosoidae), Myracrodruon urundeuva, (aroeira, Anacardiaceae) e Handroanthus impetiginosus (pau-d'arco-roxo, Bignoniaceae)* are some of the most typical woody species of *Caatingas.* As perennials, there are also *Ziziphus joazeiro (joazeiro, Rhamnaceae), Colicodendron yco (icó, Capparaceae), Copernicia prunifera (carnaúba, Arecaceae), Maytenus rigida (pau-de-colher, Celastraceae) and Licania rigida (oiticica, Chrysobalanaceae).* The herbaceous layer is dominated by the *Malvaceae*, *Portulacaceae* and *Poaceae* families.

Water storage organs are typical in species like *Spondias tuberosa* (*umbu, Anacardiaceae*), *Cavanillesia umbellata* (*Barriguda, Bombacaceae*), *Ceiba glaziovii* (*Barriguda, Bombacaceae*), *Jacaratia sp.* (*Mamãozinho, Caricaceae*), *Manihot spp* (*maniçobas, Euphorbiaceae*) and *Luetzelburgia auriculata* (*pau-mocó, Fabaceae-Papilionoideae*) (PRADO, 2003).

According to ANDRADE-LIMA (1981), the *Cactaceae* give typical appearance to some areas and in others they are almost always absent, with the *Cereus, Pilosocereus, Opuntia* e

Melocactus as the most common, but they contribute little to the regional economy. On the other hand, the author highlights *Anacardiaceae (Schinopsis, Myracrodruon e Spondias)* as economically important. Regarding grasses, which are not that important in this dry area, the most common in some humid areas are *Chloris orthonoton, Paspalum scutatum, P. fimbriatum, Tragus berteronianus* and in the drier areas *Aristida adscensionis* and *A. Elliptica*.

GIULIETTI et al (2002) surveyed 18 genus and 318 endemic species of the *Caatinga* biome belonging to 42 botanical families with *Leguminosae* and *Cactaceae* as the most numerous with 80 and 41 species respectively. According to QUEIROZ (2002), of the 139 kinds of legumes found in the *Caatinga*, 21% are endemic with exclusive distribution to one or a few locations and 31% with distribution restricted to a few areas. TAYLOR & ZAPPI (2002) describe the distribution of 58 as *Cactaceae*, of which only *Cereus albiculis* (Britton & Rose) and *Pilosocereus gounelli* (F. Weber) were widely distributed.

The appearance of foreign species is a consequence of the diversification and management of pastures aiming at increasing the production and quality of forage for animals. In anthropized areas some native species have been replaced. These new species are rapidly regenerated because their better resistance to the dry climate and the lack of natural enemies, which is a risk for native species. In the valley areas, the presence of the *algarobeira* (*Prosopis juliflora* (SW) DC) is common in the process of biological invasion of the *Caatinga* biome LIMA et al. (2003), LIMA & KIILL (2003), MARQUES et al (2003) and LIMA et al (2004).

The state of Piauí is part of a group called the *Meio Norte ou Nordeste Ocidental*, with transition characteristics. The distribution of plant formations is mainly linked to climatic factors, although geomorphological and edaphic factors are also determinants (Emperaire 1989 apud Lemos, 2004).

In the project area, the influence of these factors was observed in the region of the *Serra da Capivara* National Park. Two floristic and physiognomic groups can be recognized in this location: the formation of *Caatinga* in sedimentary basins and Precambrian lands (Emperaire 1989).

Considering these studies plus few others completed in this region, a total of 210 species, grouped in 62 families, have been registered. The most representatives' families are *Fabaceae, Bignoniaceae, Euphorbiaceae* and *Myrtaceae.*

Comparing these results with data from floristic and quantitative surveys carried out in the Northeast Region, it appears that, with the exception of a small group of species recorded only in the Park area, there is a floristic similarity between this study area and other *Caatinga* areas (Lemos, 2004).

b) Vegetation in the ADI and DAA

Characterization of Native Vegetable Formations

At least three structural types are recognized in the Piauí *Caatinga* according to the official classification of the Brazilian vegetation done by IBGE (2012): the *Caatinga*, or *savana estépica arborizada, parque* and *florestada*. However, in the field this classification is not supported due to the history of use and occupation of the region that changed a good part of the original vegetation cover, either through direct management of vegetation or indirect management caused by the extensive raising of animals such as horses, donkey, cows, pigs, sheep and goats.

From the data collected in the field, dominant *Caatinga* cover in the region is formed by the same group of species that has its distribution in the region determined by the edaphic conditions and by the type and degree of changes to which the vegetation cover was submitted, there being no vegetation patch of very particular characteristics that stands out. All plant species identified during field evaluations occur in more than one region, with no species unique to a specific area or specific physiognomy.

The lack of permanent water streams and the intensive use of the beds and deposits of rivers and streams by the population meant that no fragments of riparian forest of size and degree of conservation were observed. In view of this situation, this study adopted a general legend of *Caatinga* for the vegetation covering the ADI and DAA, distinguishing 3 classes according to the density of the ground cover: Dense, Open and Sparse *Caatinga*, a criterion corroborated by the division of the *Caatinga* formations presented by RIVAS (1996) in the *Macrozoneamento Geoambiental da Bacia Hidrográfica do rio Paranaíba.*

In general terms, the local *Caatinga* is distributed over all components of the natural relief, and its density varies depending on the type of soil, water availability and the incidence of degradation factors.

The *Caatinga* is denser in deep soils, more fertile and / or with greater water availability, which in turn have their occurrence conditioned to geomorphological factors. Higher areas have shallower and poorer soils on the tops and slopes and deeper and more fertile in the valleys and plains.

In its denser areas, the local *Caatinga* appears as a compact forest formation, with an average height of 6 to 8 m while in the Open *Caatinga* the trees reduce their size and increase the presence of the shrub layer. The Sparse *Caatinga* in turn presents isolated trees amid areas of bare soil for the most part during the dry period.

All fasciations in the local *Caatinga* have a large presence of species from the legume Family Fabaceae such as *Poincianella pyramidalis, Poincianella gardneriana, Pityrocarpa moniliformis, Pityrocarpa obliqua, Cenostigma macrophyllum, Dyptichandra epunctata, Libidibia ferrea, Albizia inundata, Lu- spp., Piptadenia viridiflora, Pterodon cf. abruptus, Pterocarpus villosus, Anadenanthera colubrina var.cebil, Senna excelsa, Pithecellobium foliolosum, Amburana cearensis, Enterolobium contortisiliquum* and occasionally the exotic *Prosopis juliflora*, among others. In addition, *Aspidosperma pyrifolium, Croton sonderianus, Callisthene microphylla, Jatropha spp., Commiphora leptophleos, Manihot cf. caerulescens, Terminalia sp, Myracroduon urundeuva, Aspidosperma cuspa, Cordia glazioviana, Ximenia americana, Annona leptopetala* and *Bauhinia spp*. among several others.

The green crowns of *joazeiro (Ziziphus joazeiro and Z. Cotinifolia*) and often the *Umbuzeiro (Spondias tuberosa)* stand out in the dry landscape during the dry season. The *faveleira (Cnidoscolus quercifolius)* also manages to maintain its green canopy for long periods, which allowed to verify a high occurrence and regeneration of this species in all visited environments.

The dry area of nickel deposit shows a dense tree layer that covers its slopes formed by practically only a few species of legume type, mainly of the *Mimosa (juremas)*, giving a very characteristic aspect.

Some tree species show preference for sandy soils such as the *Jacaranda jasminoides* while others occur in greater quantities over the limestone outcrop region south of the ADI such as *Pseudobombax simplicifolium, Sapium cf. lanceolatum* and *Simira gardneriana*. and others such as *Poincianella microphylla* (but not in clay soils). The limestone region shows large specimens of *Commiphora leptophleos* and *Myracroduon urundeuva*.

Cactáceas also present themselves as landmarks of the regional landscape, especially trees such as *Cereus spp*., shrubs such as *xique-xique, Pilosocereus gounellei* (which appears more in shallow and stony soils), *Pereskia spp., Arrojadoa spp.,* and small ones like *Tacinga inamoena* and *Melocactus bahiensis.*

Another conspicuous group in the region are clusters of bromeliads such as *Encholirium* spectabile on rocky outcrops across the ADI along with *Dyckia sp.* Other species of this family occur preferably in the shade of the trees such as *Neoglaziovia variegata (caroá), Bromelia laciniosa (macambira)* and *B. Balansae (gravatá),* forming clumps that eventually obstruct the movement of people and animals among the trees.

Palm trees like *Copernicia prunifera (carnauba)* generally grow in the lower lands being indicative of the presence of water closer to the surface.

Shrub stratum species such as *Cratylia mollis, Combretum leprosum, Jatropha spp., Cnidoscolus urens, Matayba sp.* and *Trischidium molle* were identified.

Lianas are rare but species from the families *Bignoniaceae, Malpighiaceae, Sapindaceae, Passifloraceae, Convolvulaceae (genus Ipomoea)* and *Fabaceae (genus Senegalia)* were observed.

The herbaceous layer was practically not sampled due to the drought at the time of the survey and also due to the intensive grazing. In the 2016 campaign, only specimens of *Tarenaya spinosa (mussambê)* and *Sida spp* where identified.

No epiphyte species were found in any of the areas visited, and their rarity is explained by the severe environmental restrictions impacting this group and their dependency on the rain.

Sampling and Checking Points

The table below shows the reference coordinates of the floristic surveys and checks carried out in 2016.

Data Table 5.2-11 – Reference Coordinates of Floristic Surveys – Piauí Nickel Project (2016).

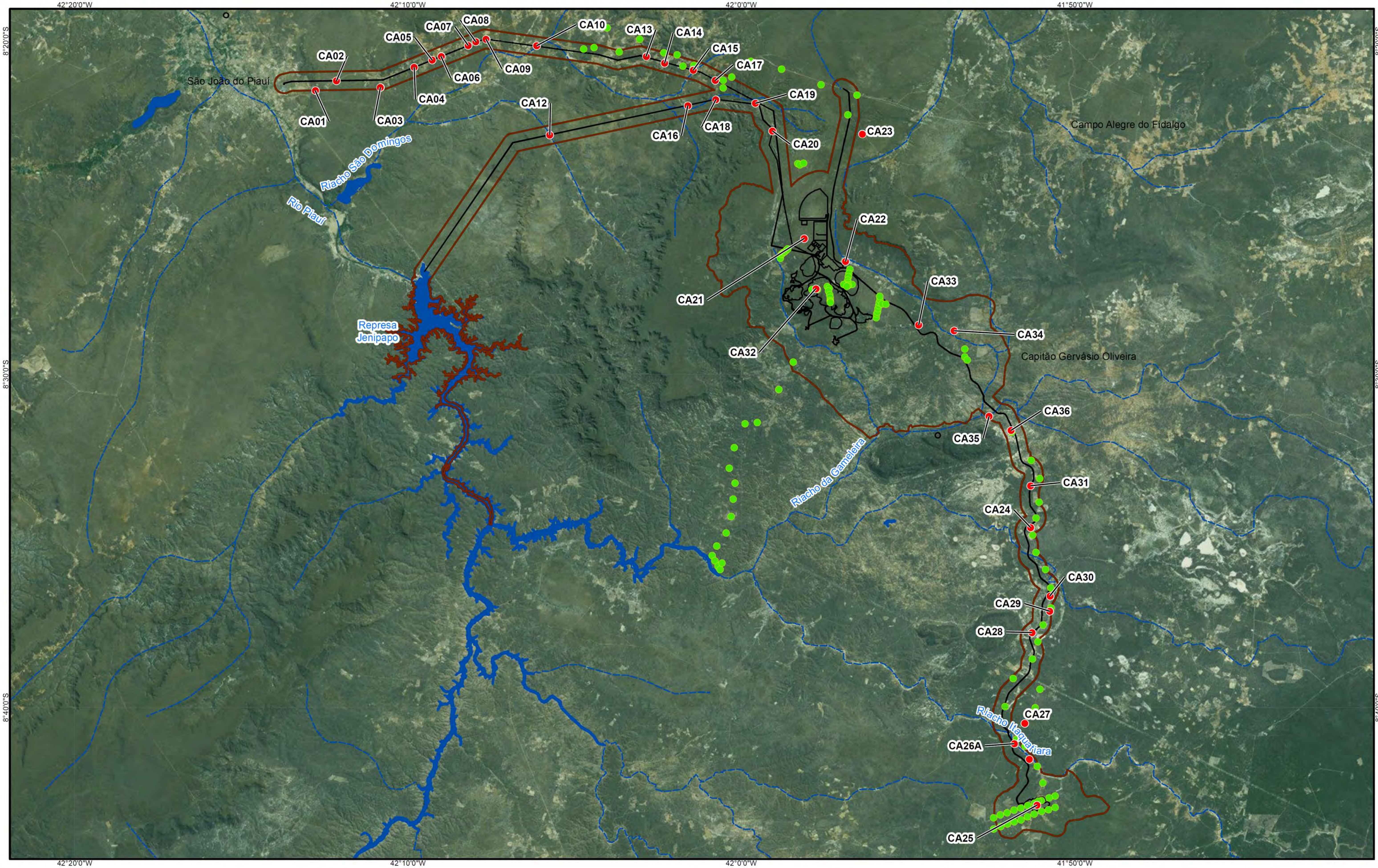
Inspection Points	Physiognomy	Coordinates UTM – Datum WGS84 - Fuso 23 L	
		X	Y
CA01	*Caatinga arbórea e Área Antropizada*	806963	9075041
CA02	*Caatinga Arbórea alterada*	808139	9075571
CA03	*Caatinga Arbórea*	810554	9075188
CA04	*Caatinga Arbórea alterada*	812423	9076275
CA05	*Caatinga arbórea e Área Antropizada*	813414	9076672
CA06	*Caatinga arbórea e Área Antropizada*	813911	9076874
CA07	*Caatinga Arbórea*	815396	9077467
CA08	*Caatinga Arbórea*	815819	9077666
CA09	*Caatinga arbórea e Área Antropizada*	816391	9077800
CA10	*Caatinga Árboreo-arbustiva e Área Antropizada*	819180	9077429
CA11	*Caatinga Árboreo-arbustiva e Afloramento*	823449	90733235
CA12	*Caatinga Árboreo-arbustiva e Área Antropizada*	819866	9072487
CA13	*Caatinga Arbórea alterada e Área Antropizada*	825213	9076795
CA14	*Área Antropizada*	826220	9076413
CA15	*Caatinga Árboreo-arbustiva e Área Antropizada*	827799	9076015
CA16	*Caatinga Árboreo-arbustiva*	827484	9074054
CA17	*Caatinga Árboreo-arbustiva*	829002	9075436
CA18	*Caatinga Árboreo-arbustiva alterada*	829030	9074366
CA19	*Caatinga Árboreo-arbustiva*	170328	9074169
CA20	*Caatinga Árboreo-arbustiva*	171282	9072637
CA21	*Caatinga Arbórea alterada*	173071	9066704
CA22	*Caatinga Arbórea alterada*	175369	9065452
CA23	*Caatinga Arbórea*	176233	9072512
CA24	*Caatinga Árboreo-arbustiva*	185668	9050799
CA25	*Caatinga Árboreo-arbustiva – área do calcáreo*	186137	9035418
CA26	*Caatinga arbustiva*	185688	9037968
CA26A	River	184855	9038807
CA27	*Caatinga Árboreo-arbustiva*	185423	9039943
CA28	*Anthropized Area*	185793	9044969
CA29	*Caatinga Árboreo-arbustiva alterada*	186753	9046162

Inspection Points	Physiognomy	Coordinates UTM – Datum WGS84 - Fuso 23 L	
		X	Y
CA30	*Caatinga Árboreo-arbustiva – dolina com afloramentos rochosos*	186758	9047007
CA31	*Caatinga Árboreo-arbustiva*	185649	9053108
CA32	*Caatinga Árborea – jazida Nickel*	173741	9063923
CA33	*Caatinga Árboreo-arbustiva*	179415	9061949
CA34	*Caatinga Árboreo-arbustiva alterada*	181370	9061654
CA35	*Caatinga Árboreo-arbustiva*	183342	9056923
CA36	Altered Area + outcrops	184546	9056158

Source: Arcadis, 2017.

These points are marked on the Map 5.2-8.

Map 5.2-8 – Floristic Surveys Points (2016) and Sampled Areas (2008).



LEGENDA

- Floristic Survey (2016)
- Sampling Plots (2008)
- Intermittent Drainage
- Water Mass
- Municipal Limits
- Area of Direct Influence - ADI

REFERÊNCIAS

IBGE, Brasil ao milionésimo, 2015;
LANDSAT, Imagem, 2016;
Projeto Piauí Níquel, 2016;
RapidEye, Imagem , 2016;
Fundação José Silveira (FJS) Levantamento de flora, 2008 .

ESCALA GRÁFICA
0 5 10 km

Sistema de Coordenadas: GCS SIRGAS 2000

MAPA DE LOCALIZAÇÃO

PIAUÍ NIQUEL ARCADIS

EIA/RIMA – PROJETO PIAUÍ NÍQUEL

Map 5.2-8 – Floristic Survey (2016) and Sampling Plots (2008)

EXECUTADO POR:	ESCALA:	NÚMERO:	DATA:
ARCADIS	1:200.000	Única	mai /2017

Floristic List

In the project area of influence, considering primary and secondary data, 226 botanical species from 146 genus belonging to 49 botanical families were identified, (Data Table 5.2-12), including tree, shrub, herbaceous, climbing plants and aquatic plants. The most representative families are Fabaceae, with 73 botanical species, Euphorbiaceae with 26 botanical species, Malvaceae with 15 species and Poaceae with 10 species in addition to Cactaceae, Rubiaceae *and* Bignoniaceae, all with 8 registered botanical species.

Data Table 5.2-12 – General List of species trees, shrubs, herbs and lianas, identified in the survey of the Piauí Nickel Project region, February 2008 and 2016.

Family	Scientific Name	Common Name	Habit	Sec. Data	Prim. Data
Acanthaceae	*Anisacanthus trilobus Lindau*		Herb	X	
Amaranthaceae	*Alternanthera brasiliana (L.) Kuntze*		Herb	X	
Amaranthaceae	*Gomphrena demissa Mart.*		Herb	X	
Amaryllidaceae	*Hippeastrum sp.*		Herb		X
Anacardiaceae	*Myracrodruon urundeuva Allemão*	*Aroeira*	Tree	X	X
Anacardiaceae	*Schinopsis brasiliensis Engl.*	*Baraúna*	Tree		X
Anacardiaceae	*Spondias tuberosa Arruda*	*Umbuzeiro*	Tree	X	X
Annonaceae	*Annona leptopetala (R.E.Fr.) H. Rainer*		Tree	X	
Apocynacae	*Calotropis procera (Aiton) W.T. Aiton**	*Flor-de-seda*	Shrub		X
Apocynaceae	*Allamanda puberula A.DC.*	*Alamanda*	Shrub	X	
Apocynaceae	*Aspidosperma cuspa (Kunth) Blake*	*Pereiro-vermelho*	Tree	X	X
Apocynaceae	*Aspidosperma polyneuron Müll.Arg.*	*Pereiro-branco*	Tree		X
Apocynaceae	*Aspidosperma pyrifolium Mart.*	*Pereiro*	Tree		X
Apocynaceae	*Cryptostegia grandiflora R.Br.**		Shrub.	X	
Apocynaceae	*Rauvolfia ligustrina Willd.*		Shrub	X	
Arecaceae	*Copernicia prunifera (Mill.) H.E. Moore.*	*Carnaúba*	Tree		X
Asteraceae	*Blainvillea acmella (L.) Philipson*		Herb	X	

Family	Scientific Name	Common Name	Habit	Sec. Data	Prim. Data
Asteraceae	*Centratherum punctatum Cass.*		Herb	X	
Asteraceae	*Elephantopus piauiensis R. Barros & Semir*		Herb	X	
Asteraceae	*Indeterminadas 1*		Herb		X
Asteraceae	*Melanthera latifolia (Gardner) Cabrera*		Herb	X	
Bignoniaceae	*Arrabidea sp.*	*Folha larga*	Tree		X
Bignoniaceae	*Fridericia bahiensis (Schauer ex. DC.) L.G. Lohmann*		Liana	X	
Bignoniaceae	*Fridericia dichotoma (Jacq.) L.G. Lohmann*		Liana	X	
Bignoniaceae	*Godmania dardanoi (J.C. Gomes) A.H. Gentry*		Tree	X	
Bignoniaceae	*Handroanthus impetiginosus (Mart. ex DC.) Mattos*	*Pau-d'arco*	Tree	X	X
Bignoniaceae	*Handroanthus spongiosus (Rizzini) S. Grose (#)*	*Cascudo*	Tree	X	X
Bignoniaceae	*Jacaranda jasminoisdes (Thumb.) Sandwith*		Tree	X	X
Bignoniaceae	*Mansoa paganuccii M.M. Silva-Castro*		Liana	X	
Boraginaceae	*Cordia glazioviana (Taub.) Gottschling & J.S.Mill*	*Pau-branco*	Tree	X	X
Boraginaceae	*Cordia rufescens A.DC.*	*A. DC.*	Shrub	X	X
Boraginaceae	*Heliotropium tiarioides Cham.*	*Crista-de-galo*	Tree	X	X
Bromeliaceae	*Bromelia laciniosa Mart. ex Schult. & Schult. F.*	*Macambira*	Herb		X
Bromeliaceae	*Encholirium spectabile Mart. ex Schult. & Schult. F.*	*Macambira-de-flecha*	Herb		X
Bromeliaceae	*Neoglaziovia variegata (Arruda) Mez*	*Caroá*	Herb		X

Family	Scientific Name	Common Name	Habit	Sec. Data	Prim. Data
Burseraceae	*Commiphora leptophloeus (Mart.) J.B. Gillett*	*Amburana-de-cambão*	Tree	X	X
Cactaceae	*Arrojadoa rhodantha (Gürke) Britton & Rose*	*Rabo-de-cachorro*	Shrub		X
Cactaceae	*Cereus jamacaru DC.*	*Mandacaru*	Tree		X
Cactaceae	*Facheiroa squamosa (Gürke) P.J. Braun & Esteves*	*Facheiro*	Tree	X	X
Cactaceae	*Melocactus bahiensis (Britton & Rose) Luetzelb*	*Coroa-de-frade*	Herb		X
Cactaceae	*Pilosocereus gounellei (F.A.C. Weber) Byles & Rowley*	*Xique-xique*	Shrub	X	X
Cactaceae	*Pilosocereus sp.*	*Rabo-de-raposa*	Shrub		X
Cactaceae	*Tacinga inamoena (K.Schum.) N.P. Taylor & Stuppy*	*Quipá*	Shrub	X	X
Cactaceae	*Tacinga palmadora (Britton & Rose) N.P. Taylor & Stuppy*	*Palmatória*	Shrub		X
Cannabaceae	*Celtis sp.*		Tree.	X	
Caricaceae	*Jacaratia corumbensis Kuntze*	*Mamão-de-veado*	Tree		X
Cleomaceae	*Tarenaya spinosa (Jacq.) Raf.*	*Mussambê*	Herb	X	X
Combretaceae	*Combretum leprosum Mart*	*Mart.*	Tree	X	
Combretaceae	*Combretum sp.*	*Farinha-seca*	Tree		X
Combretaceae	*Terminalia fagifolia Mart.*		Tree	X	X
Convolvulaceae	*Ipomoea bignonioides Sims*		Liana	X	
Cyperaceae	*Cyperus sp.*		Herb	X	
Cyperaceae	*Eleocharis acutangula (Roxb.) Schult.*		Herb	X	

Family	Scientific Name	Common Name	Habit	Sec. Data	Prim. Data
Cyperaceae	*Eleocharis elegans (Kunth) Roem. & Schult.*		Herb	X	
Cyperaceae	*Eleocharis mutata (L.) Roem. & Schult.*		Herb	X	
Dioscoreaceae	*Dioscorea campestris Griseb.*		Liana	X	
Erythroxylaceae	*Erythroxylum pungens O.E. Schulz*		Tree	X	
Erytroxylaceae	*Erythroxylum nummularia Peyr.*	*Rompe-gibão*	Tree		X
Euphorbiaceae	*Astraea lobata (L.) Klotzsch*		Herb	X	
Euphorbiaceae	*Cnidoscolus urens (L.) Arthur*	*Cansanção*	Shrub		X
Euphorbiaceae	*Cnidosculus quercifolius Pohl*	*Favela*	Tree		X
Euphorbiaceae	*Croton adamantinus Müll. Arg.*		Shrub	X	
Euphorbiaceae	*Croton argenteus L.*		Herb	X	
Euphorbiaceae	*Croton blanchetianus Baill.*		Tree	X	
Euphorbiaceae	*Croton conduplicatus Kunth*		Shrub	X	
Euphorbiaceae	*Croton cordiifolius Baill.*		Shrub	X	
Euphorbiaceae	*Croton echioides Baill.*		Shrub	X	
Euphorbiaceae	*Croton grewioides Baill.*		Shrub	X	
Euphorbiaceae	*Croton heliotropiifolius Kunth*		Shrub	X	
Euphorbiaceae	*Croton hirtus L'Hér.*		Herb	X	
Euphorbiaceae	*Croton mucroniifolius Müll. Arg.*	*Quebra-facão*	Tree	X	X
Euphorbiaceae	*Croton pedicellatus Kunth.*		Shrub	X	

Family	Scientific Name	Common Name	Habit	Sec. Data	Prim. Data
Euphorbiaceae	*Croton piauhiensis Müll. Arg.*		Shrub	X	
Euphorbiaceae	*Croton pulegiodorus Baill.*		Herb	X	
Euphorbiaceae	*Croton sonderianus Müll. Arg.*	*Marmeleiro*	Tree	X	X
Euphorbiaceae	*Jatropha gossypiifolia L.*	*Pinhão-roxo*	Shrub		X
Euphorbiaceae	*Jatropha mollissima (Pohl) Baill.*	*Pinhão-bravo*	Tree	X	X
Euphorbiaceae	*Jatropha mutabilis (Pohl.) Baill.*	*Pinhão*	Tree	X	X
Euphorbiaceae	*Jatropha ribifolia (Pohl.) Baill*	*Pinhão-rasteiro*	Shrub		X
Euphorbiaceae	*Jatropha sp.*	*Favelinha-da-chapada*	Tree		X
Euphorbiaceae	*Manihot caerulescens Pohl*		Tree	X	X
Euphorbiaceae	*Manihot carthagenensis (Jacq.) Müll.Arg. ssp. glaziovii (Müll.Arg.) Allem.*	*Mandioqueira*	Tree	X	X
Euphorbiaceae	*Manihot pusilla Pohl*	*Maniçoba*	Shrub		X
Euphorbiaceae	*Sapium glandulosum (L.) Morong*	*Burra- leiteira*	Tree		X
Fabaceae	*Amburana cearensis (Allemão) A.C. Sm.*	*Amburana-de-cheiro*	Tree		X
Fabaceae	*Anadenanthera colubrina (Vell.) Brenan*	*Angico-branco*	Tree	X	
Fabaceae	*Anandenanthera colubrina (Vell.) Brenan var. cebil (Griseb.) Altschul*	*Angico-vermelho*	Tree		X
Fabaceae	*Bauhinia acuruana Moric.*		Shrub	X	
Fabaceae	*Bauhinia cheilantha (Bong.) Steud.*	*Miroró*	Shrub		X
Fabaceae	*Bauhinia pentandra (Bong.) D.Dietr.*		Tree	X	

Family	Scientific Name	Common Name	Habit	Sec. Data	Prim. Data
Fabaceae	*Bauhinia subclavata Benth.*		Shrub	X	
Fabaceae	*Calliandra macrocalyx Harms var. macrocalyx*		Shrub	X	
Fabaceae	*Calliandra umbellifera Benth.*		Shrub	X	
Fabaceae	*Cenostigma macrophyllum Tul.*	*Canela-de-velho*	Tree	X	X
Fabaceae	*Centrosema pubescens Benth.*		Liana	X	
Fabaceae	*Chamaecrista desvauxii (Collad.) Killip var. desvauxii*		Herb	X	
Fabaceae	*Chamaecrista desvauxii (Collad.) Killip var. latifolia (Benth.) H.S. Irwin & Barneby*		Herb	X	
Fabaceae	*Chamaecrista transversa Afr.Fern. var. transversa*		Shrub	X	
Fabaceae	*Chloroleucon foliolosum (Benth.) G.P. Lewis*	*Triadinho*	Tree		X
Fabaceae	*Copaifera oblongifolia Mart. ex Hayne*		Tree	X	
Fabaceae	*Copaifera sp.*	*Cangalheiro*	Tree		X
Fabaceae	*Cratylia mollis Mart. ex Benth.*	*Camaratuba*	Shrub	X	X
Fabaceae	*Crotalaria incana L.*		Herb	X	
Fabaceae	*Dalbergia cearensis Ducke*		Tree		X
Fabaceae	*Desmanthus virgatus (L.) Willd.*		Herb	X	
Fabaceae	*Desmodium glabrum (Mill.) DC.*		Herb	X	
Fabaceae	*Discolobium hirtum Benth.*		Shrub	X	
Fabaceae	*Enterolobium contortisiliquum (Vell.) Morong*	*Tamboril*	Tree		X
Fabaceae	*Galactia jussiaeana Kunth*		Liana	X	

Family	Scientific Name	Common Name	Habit	Sec. Data	Prim. Data
Fabaceae	*Goniorrhachis marginata Taub.*	*Itapicuru*	Tree		X
Fabaceae	*Hymenaea sagittipetala Rizzini*		Tree	X	
Fabaceae	*Inga sp.*		Tree		X
Fabaceae	*Leptospron adenanthum (G. Mey.) A. Delgado*		Liana	X	
Fabaceae	*Libidibia ferrea (Mart. ex Tul.) L.P. Queiroz*	*Pau-ferro*	Tree	X	X
Fabaceae	*Luetzelburgia auriculata (Allemão) Ducke*		Tree		X
Fabaceae	*Macroptilium bracteatum (Nees & C.Mart.) Marechal & Baudet*		Liana	X	
Fabaceae	*Macroptilium lathyroides (L.) Urb.*		Liana	X	
Fabaceae	*Macroptilium martii (Benth.) Maréchal & Baudet*		Liana	X	
Fabaceae	*Mimosa acustipula Benth.*		Tree	X	
Fabaceae	*Mimosa arenosa (Willd.) Poir.*	*Jurema*	Tree		X
Fabaceae	*Mimosa lepidophora Rizzini*		Shrub	X	
Fabaceae	*Mimosa sp.*	*Jurema-lambe-beiço*	Tree		X
Fabaceae	*Mimosa tenuiflora (Willd.) Poir.*	*Jurema-preta*	Tree	X	X
Fabaceae	*Mimosa verrucosa Benth.*		Tree	X	
Fabaceae	*Parkinsonia aculeata L.*	*Turquia*	Tree		X
Fabaceae	*Phaseolus sp.*		Liana	X	
Fabaceae	*Piptadenia stipulacea (Benth.) Ducke*		Shrub	X	
Fabaceae	*Piptadenia viridifolia Benth.*	*Jacurutu*	Tree		X

Family	Scientific Name	Common Name	Habit	Sec. Data	Prim. Data
Fabaceae	*Pithecellobium diversifolium Benth.*		Tree		
Fabaceae	*Pityrocarpa moniliformis (Benth.) Luckow & Jobson*		Tree	X	X
Fabaceae	*Pityrocarpa obliqua (Pers.) Brenan*	*Angico-de-bezerra*	Tree		X
Fabaceae	*Poeppigia procera C.Presl.*		Tree	X	
Fabaceae	*Poeppigia procera C.Presl. var. conferta Benth.*		Tree	X	
Fabaceae	*Poincianella bracteosa (Tul.) L.P. Queiroz*		Tree	X	X
Fabaceae	*Poincianella microphylla (Mart. ex G.Don) L.P. Queiroz*	*Mané-pinto*	Tree	X	X
Fabaceae	*Poincianella pyramidalis (Tul.) L.P. Queiroz*	*Pau-de-rato*	Tree	X	X
Fabaceae	*Prosopis juliflora (SW) DC **	*Algaroba*	Tree		X
Fabaceae	*Pterocarpus villosus (Mart. ex Benth.) Benth.*		Tree	X	
Fabaceae	*Pterodon abruptus (Moric.) Benth.*		Tree	X	X
Fabaceae	*Rhynchosia minima (L.) DC.*		Liana	X	
Fabaceae	*Senegalia globosa (Bocage & Miotto) L.P. Queiroz*		Shrub	X	
Fabaceae	*Senegalia langsdorffii (Benth.) Seigler & Ebinger*		Liana	X	
Fabaceae	*Senegalia riparia (Kunth) Britton & Rose ex Britton & Killip*		Liana	X	
Fabaceae	*Senegalia tenuifolia Wild.*	*Jurema-unha-de-gato*	Tree		X
Fabaceae	*Senna cearensis Afr. Fern.*		Tree	X	
Fabaceae	*Senna gardneri (Benth.) H.S.Irwin & Barneby*		Shrub	X	

Family	Scientific Name	Common Name	Habit	Sec. Data	Prim. Data
Fabaceae	*Senna lenchriosperma H.S. Irwin & Barneby*		Shrub	X	
Fabaceae	*Senna macranthera (DC. ex Collad.) H.S. Irwin & Barneby var. pudibunda (Benth.) H.S. Irwin & Barneby*		Tree	X	
Fabaceae	*Senna occidentalis (L.) Link*		Shrub	X	
Fabaceae	*Senna sp.*	*Mata-pasto*	Herb		X
Fabaceae	*Senna spectabilis (DC.) H.S. Irwin & Barneby var. excelsa (Schrad.) H.S. Irwin & Barneby*	*São-joão*	Tree	X	X
Fabaceae	*Senna spectabilis (DC.) H.S. Irwin & Barneby*	*Canafístula-mole*	Tree	X	X
Fabaceae	*Senna uniflora (Mill.) H.S. Irwin & Barneby*		Herb	X	
Fabaceae	*Stylosanthes capitata Vogel*		Herb	X	
Fabaceae	*Stylosanthes humilis Kunth*		Herb	X	
Fabaceae	*Tachigali cf. vulgaris L.G. Silva & H.C. Lima*	*Carvoeiro*	Tree		X
Fabaceae	*Trischidium molle (Benth.) H.E. Ireland*		Shrub		X
Lamiaceae	*Leonotis nepetifolia (L.) R.Br.*		Herb	X	
Lamiaceae	*Medusantha martiusii (Benth.) Harley & J.F.B. Pastore*		Herb	X	
Lamiaceae	*Mesosphaerum suaveolens (L.) Kuntze*		Herb	X	
Lamiaceae	*Ocimum campechianum Mill.*		Herb	X	
Loranthaceae	*Passovia ovata (Pohl ex DC.) Tiegh.*	*Herba-de-passarinho*	Hem		X
Lythraceae	*Cuphea laricoides Koehne*		Herb	X	

Family	Scientific Name	Common Name	Habit	Sec. Data	Prim. Data
Malpighiaceae	*Banisteriopsis stellaris (Griseb.) B. Gates*		Liana	X	
Malpighiaceae	*Byrsonima gardneriana A. Juss.*		Shrub	X	
Malpighiaceae	*Peixotoa jussieuana Mart. ex A. Juss.*		Liana	X	
Malpighiaceae	*Ptilochaeta sp.*		Shrub	X	
Malvaceae	*Helicteres muscosa Mart.*		Shrub	X	
Malvaceae	*Herissantia crispa (L.) Brizicky*		Shrub	X	
Malvaceae	*Pavonia cancellata (L.) Cav.*		Herb	X	
Malvaceae	*Pavonia glazioviana Gürke*		Shrub	X	
Malvaceae	*Pseudobombax simplicifolium A. Robyns*	*Imbiruçu*	Tree		X
Malvaceae	*Sida acuta L.*	*Malva*	Herb		X
Malvaceae	*Sida brittonii León*		Herb	X	
Malvaceae	*Sida cordifolia (L.f.) Willd.*	*Malva branca*	Herb		X
Malvaceae	*Sida jussiaeana DC.*		Herb	X	
Malvaceae	*Sida rhombifolia L.*	*Malva relógio*	Herb		X
Malvaceae	*Sterculia sp.*		Tree	X	
Malvaceae	*Waltheria indica L.*		Herb	X	
Malvaceae	*Waltheria petiolata K . Schum.*		Herb	X	
Malvaceae	*Waltheria rotundifolia Schrank*		Herb	X	
Malvaceae	*Waltheria sp.*		Herb	X	

Family	Scientific Name	Common Name	Habit	Sec. Data	Prim. Data
Meliaceae	*Guarea guidonia (L.) Sleum.*	*Bilro*	Tree		X
Moraceae	*Ficus sp.*	*Gameleira*	Tree		X
Myrtaceae	*Psidium sp*	*Araçá*	Shrub		X
Olacaceae	*Ximenia americana L.*	*Ameixa*	Tree		X
Oxaliaceae	*Oxalis sp.*		Herb	X	
Passifloraceae	*Passiflora foetida L.*		Liana	X	
Passifloraceae	*Passiflora picturata Ker Gawl.*		Liana	X	
Phytolaccaceae	*Microtea paniculata Moq.*		Herb	X	X
Poaceae	*Cenchrus ciliaris L.**	*Capim-búfalo*	Herb		X
Poaceae	*Cenchrus sp.*		Herb	X	
Poaceae	*Chloris barbata Sw.*		Herb	X	
Poaceae	*Chloris virgata Swartz*		Herb	X	
Poaceae	*Digitaria insularis (L.) Fedde **		Herb	X	
Poaceae	*Echinochloa crusgalli (L.) P. Beauv. **		Herb	X	
Poaceae	*Echinochloa polystachya (Kunth.) Hitchc*		Herb	X	
Poaceae	*Eragrostis ciliaris (L.) R.Br.**		Herb	X	
Poaceae	*Hymenachne amplexicaulis (Rudge) Nees.*		Herb	X	
Poaceae	*Setaria parviflora (Poir.) Kerguélen (#)*		Herb	X	
Poaceae	*Urochloa fusca (Sw.) B.F. Hansen & Wunderlin **		Herb	X	

Family	Scientific Name	Common Name	Habit	Sec. Data	Prim. Data
Poaceae	*Urochloa mollis Morrone & Zuloaga **		Herb	X	
Poaceae	*Urochloa plantaginea (Link) R.D. Webster **		Herb	X	
Polygalaceae	*Polygala sp.*		Herb	X	
Portulacaceae	*Portulaca halimoides L.*	*Beldroelga*	Shrub		X
Pteridaceae	*Cheilanthes eriophora (Fée) Mett.*		Herb	X	
Rhamnaceae	*Ziziphus cotinifolia Reisseck*		Tree	X	
Rhamnaceae	*Zizyphus joazeiro Mart.*	*Joazeiro*	Tree	X	X
Rubiaceae	*Borreria scabiosoides Cham. & Schltdl.*		Herb	X	
Rubiaceae	*Cordiera sp.nov.*		Shrub	X	
Rubiaceae	*Diodia sp.*		Herb	X	
Rubiaceae	*Genipa americana L.*	*Jenipapo*	Tree		X
Rubiaceae	*Mitracarpus strigosus (Thunb.) P.L.R.Moraes, De Smedt & Hjertson*		Herb	X	
Rubiaceae	*Richardia sp.*		Herb	X	
Rubiaceae	*Simira gardneriana M.R.V.Barbosa & Peixoto*		Tree		X
Rubiaceae	*Tocoyena formosa (Cham. & Schltdl.) K.Schum.*		Shrub	X	
Sapindaceae	*Allophylus puberulus (Cambess.) Radlk.*		Shrub	X	
Sapindaceae	*Cardiospermum cf. corindum L.*		Liana	X	
Selaginellaceae	*Selaginella convoluta (Arn.) Spring*	*Jericó*	Shrub		X
Solanaceae	*Solanum crinitum Lam.*		Shrub	X	

Family	Scientific Name	Common Name	Habit	Sec. Data	Prim. Data
Solanaceae	*Solanum sp.*	*Jurubeba*	Shrub		X
Turneraceae	*Turnera blanchetiana Urb. var. blanchetiana*		Herb	X	
Velloziaceae	*Vellozia sp.*		Herb	X	
Verbenaceae	*Lippia lasiocalycina Cham.*		Herb	X	
Verbenaceae	*Lippia schaueriana Mart*		Herb	X	
Vochysiaceae	*Callisthene microphylla Warm.*		Tree	X	
Zygophyllaceae	*Kallstroemia tribuloides (Mart.) Steud.*		Shrub	X	

Prepared by ARCADIS Tetraplan, 2008 and Arcadis, 2017.

Plant Species of Economic Importance

Several species that were registered in the surveys within the project area have economic importance as listed bellow. The species were classified, according to their economic importance: fruit, medicinal, reforestation and landscaping, fibers, timber and forage.

Fruit species

In the botanical survey of the area, several fruit species were found that have potential economic value which will require additional studies to determine both its environmental and financial feasibility. Data Table 5.2-13 shows the list of fruit species identified.

Data Table 5.2-13 – Fruit Species Identified in the project DAA – Piauí Nickel Project, February 2008.

Common Name	Scientific Name
Amburana de cambão	*Bursera leptophloeus*
Joazeiro	*Zizyphus joazeiro*
Mandacaru	*Cereus jamacaru*
Quiabenta	*Peireskia bahiensis*
Umbu	*Spondias tuberosa*

Prepared by: ARCADIS Tetraplan, 2008.

Among these identified fruit species, the most prominent ones are “joazeiro” and “umbu” as the species with the greatest potential to develop proposals for economic use.

Medicinal plants

The medicinal potential of the Brazilian flora is excellent, the domain of the *Caatinga* is rich in medicinal species. In the Project area, many medicinal plants stand out, as shown Data Table 5.2-14.

Data Table 5.2-14 – List of Medicinal Plants found in the Project DAA – Piauí Nickel Project, February 2008.

Family/ Scientific Name	Common	Used Parts	Medicinal Uses
ANACARDIACEAE *Myracrodruon urundeuva* *Schinopsis brasiliensis*	*Aroeira* *Braúna*	Bark and Resin	Astringent / Healing Antibiotic / Tonic
BIGNONIACEAE *Handroanthus impetiginosus*	*Ipê Roxo/Pau d’arco*	Bast	Sedative
CACTACEAE *Cereus jamacaru*	*Mandacaru*	Bark	Kidney disease

Family/ Scientific Name	Common	Used Parts	Medicinal Uses
CAESALPINIACEAE *Libidibia ferrea* *Senna excelsa*	*Pau ferro* *São João*	Bast and Bark	Antiasthmatic Astringent
FABACEAE *Amburana cearensis*	*Imburana de Cheiro*	Bark	Antibiotic / lungs
MIMOSACEAE *Anadenanthera colubrina var. cebil*	*Angico*	Bark (Infusion)	Astringent (bath)
RHAMNACEAE *Zizyphus joazeiro*	*Joazeiro*	Leaves (Infusion	Stomacal

Prepared By: ARCADIS Tetraplan, 2008.

Species for use in Reforestation and landscaping

Several species with potential use in regional landscaping were found in the completed surveys.

Among the ornamental species found are species with potential use in reforestation, especially the *pau d'arco (Tabebuia impetiginosa)* with purple flowers, the *cascudo (Tabebuia spongiosa Rizz.)* with its vigorous yellow flowering and *São João (Senna excelsa)* with its bright yellow flowers.

Other species typical of the *Caatinga* areas also have great ornamental potential, including *macambira (Bromelia laciniosa), caroá (Neoglaziovia variegata), friarhead (Melocactus bahiensis), mandacaru (Cereus jamacaru), quipá (Tacinga inamoena)* and *xique-xique (Pilosocereus gounellei),* which could be cultivated and provide a source of income for the region. Data Table 5.2-15 shows the ornamental species that appear in the project region.

Photo 5.2-35 and 5.2-36 show some ornamental *Cactáceas* recorded for the project DAA.

Data Table 5.2-15 – List of Ornamental Species identified in the project DAA – Piauí Nickel Project, February 2008.

Family / Scientific Name	Common Name
ARECACEAE *Copernicia prunifera*	*Carnaúba*
BIGNONIACEAE *Handroanthus impetiginosus* *Handroanthus spongiosus*	*Pau d'arco* *Cascudo*
CACTACEAE *Bromelia laciniosa* *Cereus jamacaru* *Melocactus bahiensis* *Tacinga inamoema* *Pilosocereus gounellei*	*Macambira* *Mandacaru* *Cabeça de frade* *Quipá* *Xique-xique*
NYMPHEACEAE *Nymphaea lasifolia*	*Ninféia*

Prepared by: ARCADIS Tetraplan, 2008.

Fiber Producing Species

The main specie of this group is the *caroá* species (*Neoglaziovia variegata*), its leaves contain fibers of great textile value, mainly for cordage (Photo 5.2-35).

Hardwood Producing Species

In the project area of influence, although very anthropized, the occurrence of some noble wood producing species was recorded.

Data Table 5.2-16 shows the list of species producing hardwood in the project area.

Data Table 5.2-16 – Trees Produces of Hardwood recorded in the Project DAA – Piauí Nickel Project, February 2008.

Family / Scientific Name	Common	Uses
ANACARDIACEAE		
Myracrodruon urundeuva	*Aroeira*	Heavy wood for external works: posts, posts, posts, poles, beams, sleepers, bridge frames, mills, and, in civil construction, for rafters, tacos and battens.
Schinopsis brasiliensis	*Braúna; baraúna*	Heavy, hard, resistant wood, excellent for fence posts, posts, poles, civil construction, carpentry and lathe.

Family / Scientific Name	Common	Uses
Spondias tuberosa	*Umbu; Umbuzeiro*	Light and soft wood, for firewood, charcoal, rustic furniture, box and cellulose pulp.
APOCYNACEAE		
Aspidosperma pyrifolium	*Pereiro*	Noble wood for furniture and civil construction
BIGNONIACEAE		
Handroanthus impetiginosus	*Ipê, Pau d'arco*	Very heavy, resistant wood, suitable for sleepers, crosspieces, posts, frames, wainscoting, lathe works, clubs, bodies and musical instruments.
BURSERACEAE		
Commiphora leptophloeus	*Amburana-de-cambão*	Wood for firewood and charcoal, internal works and rustic furniture. Wood for crafts and fences.
FABACEAE		
Bauhinia forficata *Poincianella microphylla* *Poincianella pyramidalis* *Senna excelsa*	*Mororó* *Mané-pinto* *Pau-rato* *São-João*	Timber for construction. Wood for civil construction and joinery. Wood suitable for firewood, charcoal, stakes and fence posts. Moderately heavy, soft wood, suitable for making light objects, boxwork, firewood and charcoal.
Anadenanthera colubrina var cebil	*Angico*	Very heavy, compact wood, suitable for beams and floors, sleepers and for use in joinery and carpentry.
Amburana cearensis	*Amburana*	Furniture wood, smoke flavoring (seeds) and cachaça (bark)
RHAMNACEAE		
Zizyphus joazeiro Mart.	*Joazeiro*	Moderately heavy, resistant wood, for internal works, stakes, supports, joinery, firewood and coal.

Prepared by: ARCADIS Tetraplan, 2008.

Forage species

The *Caatinga* is one of the Brazilian biomes with the greatest forage potential, there are many native species with forage potential. In the studied area, the presence of several forage species has great importance for farmers as they feed cattle and goats. Data Table 5.2-17 shows the list of some of the forage species identified in the project DAA.

Data Table 5.2-17 – List of species with Forage Potential identified in the project DAA – Piauí Nickel Project, February 2008.

Common Name	Scientific Name
Angico-vermelho	*Anadenanthera colubrina var cebil*
Pau-rato	*Poincianella pyramidalis*
Mané-pinto	*Poincianella microphylla*
Faveleira	*Cnidosculus quercifolius*
Joazeiro	*Zizyphus joazeiro*

Common Name	Scientific Name
Jurema	*Mimosa hostilis*
Jurema-branca	*Piptadenia stipulacea*
Jurema-preta	*Mimosa tenuiflora*
Macambira	*Bromelia laciniosa*
Mandacaru	*Cereus jamacaru*
São-João	*Senna excelsa*
Umbu	*Spondias tuberosa*

Prepared by: ARCADIS Tetraplan, 2008.

Endemic and Endangered Species

Endemic Species

Typical species in the *Caatinga* are generally adapted to the environmental conditions of the biome (lack of humidity and high temperatures) and are therefore endemic to this ecosystem.

The more typical *Caatinga* endemics are the *Cereus Jamacaru* and *Pilosocereus Gounelli* (F. Weber) Byles & Rowley.

Endangered Species

All species listed as endangered by *Ministério do Meio Ambiente* (Ordinance 443 of 2014) were considered as endangered. In the Project area only one threatened species falls in the EN category – In Danger. That specie is the *cascudo (Handroanthus spongiosus)* (Rizzini) S. Grose.

Species Indicating Environmental Change

The change in the original composition of the vegetation is indicated by the high dominance of *juremas* (*Mimosa hostilis*; *Mimosa tenuiflora*) and *marmeleiros* (*Croton sonderianus*) trees, species that are indicative vegetation regeneration that occur in practically every area of influence of the Piauí Nickel Project. *Lã-de-seda (Calotropis procera)* is an invasive exotic species found in open areas; it has the characteristic of continuously blooming and fruiting throughout the year becoming very invasive in the region.

c) Phytosociological studies

For this section of the study, a total of 125 plots were distributed over the project DAA, sampling the vegetation variations throughout this space. A total area of 50,000 m² was sampled following a subdivision of 400 m².

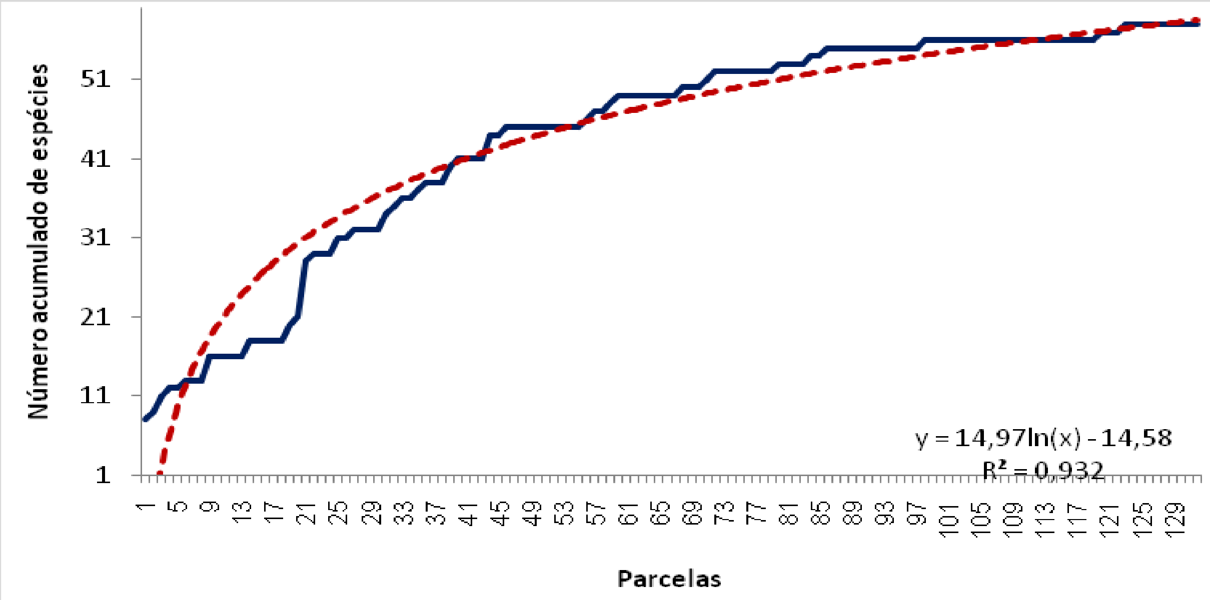
The sampling included all tree / shrub specimens with a chest height circumference (CHC) greater than 15.7 cm and a corresponding diameter at chest height (DCH) equal or higher than 5.0 cm. The shrub and herbaceous plants, *Cactáceas* and lianas were also surveyed and analyzed.

Photo 5.2-20 shows the plastic label adopted at each right frontal vertex of the section.

The adequacy of floristic sampling was analyzed based on the curve of the collector and the current average of species (RODAL et al., 1992), which shows the appearance of unprecedented taxonomic categories during the survey. The current average species curve is plotted based on the cumulative average number of species per area. CASTRO (1987) cited by RODAL et al. (1992) considered as adequate an area containing between 85 and 90% of the species found.

Figure 5.2-1 shows the collector curve for vegetation surveys carried out in the towns of *São João do Piauí, Campo Alegre do Fidalgo* and *Capitão Gervásio Oliveira*.

Figure 5.2-1 – Collector curve for sampling in the Project DAA, February 2008. The trend line is represented as dashed red – Piauí Nickel Project, February 2008.



The analysis of the graph showed a tendency to stabilize the curve as from the 80th section with a more significant growth in the accumulated number of species approximately between plots 20 and 50 that were sampled between the *Brejo Seco* Hill and the future area of the processing plant.

The following sections will discuss the results obtained for each section.

Mine and Processing Plant Area

This area includes 43 sampling plots. In the processing plant area, the average density (number of specimens per hectare) sampled was 409.66 specimens per hectare, the average height of the trees was 4.36 meters. The average basal area of the studied *Caatinga* remnants was 4.8 m² / ha.

Data Table 5.2-18 shows the results of the phytosociological surveys carried out in the *Caatinga* tree vegetation of this area.

Data Table 5.2-18 – List of species present in the processing plant area, in decreasing order of IVI (Importance Value Index) – Piauí Nickel Project, February 2008.

Nº	Specie	DoA (m²/ha)	DoR (%)	DA (ind/ha)	DR (%)	FA (ind/ua)	FR (%)	IVI
1	*Canela de velho*	2.217	46.177	160.227	39.112	50.000	11.111	96.400
2	*Angico de bezerra*	0.405	8.440	48.295	11.789	56.818	12.626	32.855
3	*Pau de rato*	0.454	9.463	18.750	4.577	27.273	6.061	20.100
4	*Marmeleiro*	0.189	3.940	42.045	10.264	22.727	5.051	19.254
5	*Pau branco*	0.212	4.414	27.273	6.657	25.000	5.556	16.627
6	*Angelim*	0.109	2.265	15.341	3.745	34.091	7.576	13.586
7	*Cascudo*	0.311	6.474	10.227	2.497	18.182	4.040	13.011
8	*Pereiro*	0.075	1.556	13.068	3.190	31.818	7.071	11.817
9	*Carvoeiro*	0.106	2.217	10.227	2.497	15.909	3.535	8.249
10	*Angico*	0.128	2.671	3.977	0.971	11.364	2.525	6.167
11	*Burra leiteira*	0.054	1.134	5.682	1.387	13.636	3.030	5.551
12	*Lambe beiço*	0.022	0.463	6.250	1.526	15.909	3.535	5.524
13	*Amburana cambão*	0.068	1.413	2.841	0.693	9.091	2.020	4.126
14	*Barba de soim*	0.008	0.177	3.409	0.832	13.636	3.030	4.040
15	*Pinhão da chapada*	0.014	0.301	4.545	1.110	11.364	2.525	3.935
16	*Miroró*	0.011	0.224	3.409	0.832	11.364	2.525	3.582
17	*Amburana de cheiro*	0.062	1.284	3.409	0.832	4.545	1.010	3.126
18	*Umbu de catitu*	0.029	0.611	2.841	0.693	6.818	1.515	2.819
19	*Cangalheiro*	0.031	0.646	1.705	0.416	6.818	1.515	2.577
20	*Aroeira*	0.092	1.926	0.568	0.139	2.273	0.505	2.570

Nº	Specie	DoA (m²/ha)	DoR (%)	DA (ind/ha)	DR (%)	FA (ind/ua)	FR (%)	IVI
21	*Mane pinto*	0.019	0.386	2.273	0.555	6.818	1.515	2.456
22	*Triadinho*	0.037	0.771	1.705	0.416	4.545	1.010	2.197
23	*Crista de galo*	0.015	0.322	5.114	1.248	2.273	0.505	2.075
24	*Quebra facão*	0.006	0.128	2.273	0.555	4.545	1.010	1.693
25	*Farinha seca*	0.012	0.240	1.705	0.416	4.545	1.010	1.666
26	*Sucupira*	0.048	0.990	0.568	0.139	2.273	0.505	1.634
27	*Maniçoba brava*	0.006	0.124	1.136	0.277	4.545	1.010	1.411
28	*unha de gato*	0.004	0.074	1.136	0.277	4.545	1.010	1.361
29	*Jurema preta*	0.007	0.152	2.273	0.555	2.273	0.505	1.212
30	*Favela*	0.012	0.255	0.568	0.139	2.273	0.505	0.898
31	*Pinhão*	0.003	0.066	1.136	0.277	2.273	0.505	0.848
32	*Rompe gibão*	0.003	0.055	1.136	0.277	2.273	0.505	0.837
33	*Coração de nego*	0.009	0.181	0.568	0.139	2.273	0.505	0.825
34	*Araçá*	0.007	0.152	0.568	0.139	2.273	0.505	0.796
35	*Jacurutu*	0.005	0.112	0.568	0.139	2.273	0.505	0.756
36	*Canafístula mole*	0.003	0.059	0.568	0.139	2.273	0.505	0.703
37	*Pau d'arco*	0.002	0.046	0.568	0.139	2.273	0.505	0.689
38	*Mandacaru de boi*	0.002	0.038	0.568	0.139	2.273	0.505	0.681
39	*Bilrro*	0.001	0.031	0.568	0.139	2.273	0.505	0.674

Nº	Espécie	DoA (m²/ha)	DoR (%)	DA (ind/ha)	DR (%)	FA (ind/ua)	FR (%)	IVI
40	*Alecrim*	0.001	0.024	0.568	0.139	2.273	0.505	0.668
TOTAIS		**4.80**	**100.00**	**409.66**	**100.00**	**450.00**	**100.00**	**300.00**

Prepared by: ARCADIS Tetraplan, 2008.

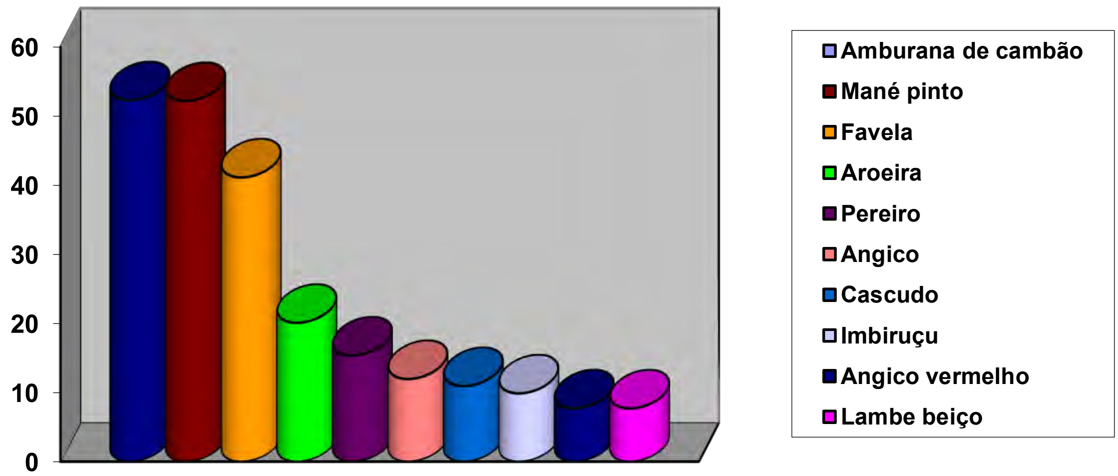
Legend: FA= Absolut Frequency; FR= Relative Frequency; DA= Absolut Density; DR= Relative Density; DoA= Absolute Dominance; DoR= Relative Dominance and IVI= Importance Value Index.

The species that showed the highest density were respectively *canela-de-velho (Cenostigma macrophyllum Tul.*) with 160.22 specimens per hectare, *angico-de-calf (Pityrocarpa obliqua* (Pers) Brenan) with 48.3 specimens per hectare and *marmeleiro (Croton sonderianus Muell.Arg*) with 42 specimens per hectare. Other species in the density top 10 are the *Pau-branco (Cordia glazioviana (Taub) Gottschling & JSMill.), pau-de-rato (Poincianella pyramidalis (Tul.) LPQueiroz), angelim (Dahlstedtia araripensis (Benth) MJ Silva & AMG Azevedo), pereiro (Aspidosperma pyrifolium Mart.), Cascudo (Handroanthus spongiosus (Rizzini) S.Grose), carvoeiro (Tachigali sp.)* and *jurema-lambe-beiço* (Mimosa hostilis Benth), a thorny tree present mainly in the *Brejo Seco* nickel mine area.

The most frequent species found in the survey area were *angico-de-bezerro (Pityrocarpa obliqua (Pers) Brenan))* in 56.8% of the plots, *canela-de-velho* (*Cenostigma macrophyllum Tul*., Photo 5.2-19), in 50 % of the plots mainly in the lowest and sandy parts. Others are *angelim (Dahlstedtia araripensis (Benth*.) MJ Silva & AMG Azevedo), *pereiro (Aspidosperma pyrifolium Mart*.), *pau-de-rato (Poincianella pyramidalis* (Tul.) LP Queiroz), pau-branco (*Cordia glazioviana* (Taub.) Gottschling & JSMill.) and *marmeleiro (Croton sonderianus* Muell.Arg).

The specie that showed the greatest dominance were *canela-de-velho (Cenostigma macrophyllum* Tul.) present in 46.17% of the entire basal area of the study with a density factor of 2.22 m² / ha. Others are pau-de-rato (Poincianella pyramidalis (Tul.) LPQueiroz), *angico-de-bezerra (Pityrocarpa obliqua* (Pers) Brenan) and *cascudo (Handroanthus spongiosus* (Rizzini) S. Grose.). Figure 5.2-2 shows the list of species with the highest IVI.

Figure 5.2-2 – Percentage distribution of species with higher IVI the Limestone Quarry (*Umbuzeiro*) and access road – Piauí Nickel Project, February 2008.



In the botanical survey carried out in processing plant area, 38 tree species belonging to 15 botanical families were sampled. The most representative families were Mimosaceae with 8 tree species present and *Caesalpiniaceae* and *Euphorbiaceae*, both with 6 registered species. Data Table 5.2-19 show the list of all species found during this survey.

Data Table 5.2-19 – List of Tree Species present in the Limestone Quarry (*Umbuzeiro*) area – Piauí Nickel Project, February 2008.

Nº	Common Name	Scientific Name	Family
1	*Alecrim*	*Lippia sp*	Verbenaceae
2	*Amburana-de-cambão*	*Commiphora leptophloeus (Mart.) J.B.Gillett.*	Burseraceae
3	*Angelim*	*Dahlstedtia araripensis (Benth.) M.J. Silva & A.M.G. Azevedo*	Fabaceae
4	*Angico*	*Anandenanthera colubrina (Vell.) Brenan var. cebil (Griseb.) Altschul.*	Mimosaceae
5	*Angico-de-bezerra*	*Pityrocarpa obliqua (Pers) Brenan*	Mimosaceae
6	*Angico-vermelho*	*Anadenanthera peregrina (L.) Speg.*	Mimosaceae
7	*Araçá*	*Psidium sp*	Myrtaceae
8	*Aroeira*	*Myracrodruon urundeuva Engl.*	Anacardiaceae
9	*Burra-leiteira*	*Sapium lanceolatum Lofgr.*	Euphobiaceae
10	*Canafístula*	*Senna spectabilis (DC.) H.S.Irwin & Barneby*	Caesalpiniaceae
11	*Canela-de-velho*	*Cenostigma macrophyllum Tul.*	Caesalpiniaceae
12	*Cangalheiro*	*Copaifera sp*	Caesalpiniaceae
13	*Cascudo*	*Handroanthus spongiosus (Rizzini) S.Grose*	Bignoniaceae
14	*Favela*	*Cnidoscolus quercifolius Pohl*	Euphorbiaceae
15	*Feijão-bravo*	*Erythrina sp*	Fabaceae
16	*Folha-larga*	*Arrabidea sp.*	Bignoniaceae
17	*Imbiruçu*	*Pseudobombax simplicifolium G. Don.*	Bombacaceae
18	*Jacurutu*	*Piptadenia viridifolia Benth*	Mimosaceae
19	*Jurema*	*Mimosa arenosa (Willd.) Poiret*	Mimosaceae
20	*Jurema-lambe-beiço*	*Mimosa hostilis Benth.*	Mimosaceae
21	*Jurema-preta*	*Mimosa verrucosa Benth.*	Mimosaceae
22	*Mamão-de-veado*	*Jacaratia corumbensis Kuntze.*	Caricaceae
23	*Mandacaru*	*Cereus jamacaru DC.*	Cactaceae

Nº	Common Name	Scientific Name	Family
24	*Mané-pinto*	*Poincianella microphylla (Mart. ex G.Don) L.P.Queiroz*	Caesalpiniaceae
25	*Maniçoba-brava*	*Manihot pusilla Pohl*	Euphorbiaceae
26	*Marmeleiro*	*Croton sonderianus Muell.Arg.*	Euphorbiaceae
27	*Pau-branco*	*Cordia glaxioviana (Taub.) Gottschling & J.S.Mill.*	Boraginaceae
28	*Pau-d'arco*	*Handroanthus impetiginosus (Mart. ex DC.) Mattos*	Bignoniaceae
29	*Pau-de-rato*	*Poincianella pyramidalis (Tul.) L.P.Queiroz*	Caesalpiniaceae
30	*Pau ferro*	*Libidibia ferrea (Mart. ex Tul.) L.P.Queiroz.*	Caesalpiniaceae
31	*Pereira*	*Aspidosperma pyrifolium Mart.*	Apocynaceae
32	*Pereira-vermelho*	*Aspidosperma cuspa (HBK.) S.F. Blake*	Apocynaceae
33	*Pereiro-branco*	*Aspidosperma polyneurum DC.*	Apocynaceae
34	*Quebra-facão*	*Croton mucroniifolius Muell Arg.*	Euphorbiaceae
35	*Rompe-gibão*	*Erytroxylum nummularia Peyritsch*	Erytroxylaceae
36	*Triadinho*	*Pithecellobium foliolosum Benth.*	Mimosaceae
37	*Umbuzeiro*	*Spondias tuberosa Arr. Cam.*	Anacardiaceae
38	*Pinhão*	*Jatropha mollissima Baill.*	Euphorbiaceae

Prepared by ARCADIS Tetraplan, 2008.

Photos 5.2-27 and 5.2-28 show general aspects of the vegetation in the Limestone Quarry (*Umbuzeiro*) area.

Aspects of Understory Vegetation

In the *Umbuzeiro* area, understory vegetation found were the bromeliad species such as *caroá (Neoglaziovia variegata Mez*.) and *macambira (Bromelia laciniosa Mart. Ex. Schult.*) (Photos 5.2-29 and 5.2-30). *Cactáceas* such as the friar's crown (Melocactus bahiensis (Nees) Morong), kippah (Tacinga inamoena (K.Schum.) NPTaylor & Stuppy), dogtail (Arrojadoa rodantha (Guerke) Br. Et Rose), foxtail (Pilosocereus sp). It has also found the Euphorbiaceas family with species like of *cansanção* (Cnidoscolus urens (L.) Arthur), several types of pine nuts (Jatropha spp.) and the favelinha-da-chapada (Jatropha sp.). Several species of mallows from Malváceas family (Sida spp) appear also with high density and frequency. The presence of the camaratuba legume (Cratylia mollis Mart.) that have high forage potential was also observed.

Floristic Diversity

Two indexes of floristic diversity were used to characterize this area with the following results: the Shannon index = 1.18 and the Pielou index (J) = 0.744.

Power Transmission Line Area (Near São João do Piauí)

20 plots were demarcated along the proposed route between the main power substation located in São João do Piauí and plant substation and the project site. These plots were distributed every 2 km along the route, aiming to sample all vegetation variations. The average density for the sampled area was 396.25 specimens per hectare and the average height of the trees was 5.19 meters. The average basal area of the studied *Caatinga* remnants was 4.79 m² / ha.

The most frequent species spotted were *pau-de-rato* (*Poicianella pyramidalis* (Tul.) LPQueiroz) present in 70% of the plots, *marmeleiro* (*Croton sonderianus* Muell.Arg), *angelim* (*Dahlstedtia araripensis* (Benth.) MJ Silva & AMG Azevedo) present in 45% of the plots, *angico-de-bezerra* (*Pityrocarpa obliqua* (Pers) Brenan) present in 40% of the plots and *canela-de-velho* (*Cenostigma macrophyllum* Tul.) present in 35% of the plots, mainly in the region closest to *Campo Alegre do Fidalgo*.

The species that showed the highest density were the *pau-de-rato* (*Poicianella pyramidalis* (Tul.) LPQueiroz) with 78 specimens per hectare, followed by *canela-de-velho* (*Cenostigma macrophyllum* Tul.), *angico-de-bezerra* (*Pityrocarpa obliqua* (Pers.) Brenan), *marmeleiro* (*Croton sonderianus* Muell. Arg) and *angelim* (*Dahlstedtia araripensis* (Benth.) MJ Silva & AMG Azevedo).

The species that showed greater dominance were *pau-de-rato* (*Poicianella pyramidalis* (Tul.) LPQueiroz) and *canela-de-velho* (*Cenostigma macrophyllum* Tul.) both with basal area above 1.0 m² / ha, followed by *angico-de-bezerra* (*Pityrocarpa obliqua* (Pers.) Brenan) and a*ngico-vermelho* (*Anadenanthera peregrina* (L.) Speg.),

Data Table 5.2-20 shows the results of the phytosociological surveys completed on the *Caatinga* tree vegetation present along the proposed power transmission line location.

Data Table 5.2-20 – Tree Species present in the Power Transmission Line area, in decreasing order of IVI – Piauí Nickel Project.

Nº	Species	DoA	DoR	DA	DR	FA	FR	IVI
1	*Pau de rato*	1.277	26.645	78.750	19.874	70.001	15.054	61,572
2	*Canela de velho*	1.072	22.364	51.250	12.934	35.000	7.527	42,824
3	*Angico bezerra*	0.357	7.455	43.750	11.041	40.000	8.602	27,098
4	*Angelim*	0.262	5.478	41.250	10.410	45.000	9.677	25,565
5	*Marmeleiro*	0.127	2.654	42.500	10.726	45.000	9.677	23,057
6	*Pereiro*	0.171	3.573	23.750	5.994	30.000	6.452	16,019
7	*Angico vermelho*	0.280	5.838	10.000	2.524	10.000	2.151	10,512
8	*Cascudo*	0.224	4.675	8.750	2.208	10.000	2.151	9,033
9	*Maniçoba brava*	0.116	2.427	8.750	2.208	15.000	3.226	7,861
10	*Farinha seca*	0.096	2.003	8.750	2.208	10.000	2.151	6,362
11	*Jurema*	0.051	1.071	11.250	2.839	10.000	2.151	6,061
12	*Carvoeiro*	0.094	1.970	11.250	2.839	5.000	1.075	5,885
13	*Miroró*	0.025	0.517	6.250	1.577	15.000	3.226	5,320
14	*Bilro*	0.098	2.040	7.500	1.893	5.000	1.075	5,008
15	*Jenipapo*	0.070	1.456	5.000	1.262	10.000	2.151	4,868
16	*Burra leiteira*	0.073	1.523	3.750	0.946	10.000	2.151	4,620
17	*Cangalheiro*	0.036	0.751	6.250	1.577	10.000	2.151	4,479
18	*Canafístula*	0.107	2.230	3.750	0.946	5.000	1.075	4,251
19	*Aroeira*	0.050	1.041	2.500	0.631	10.000	2.151	3,822
20	*Umbuzeiro*	0.094	1.956	1.250	0.315	5.000	1.075	3,347
21	*Umbu de catitu*	0.011	0.229	3.750	0.946	10.000	2.151	3,325
22	*Pereiro branco*	0.022	0.455	2.500	0.631	10.000	2.151	3,237

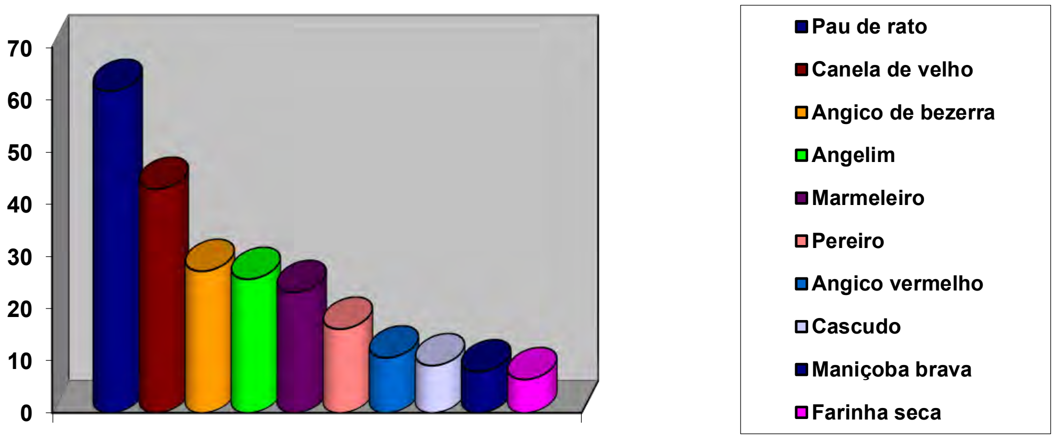
Nº	Species	DoA	DoR	DA	DR	FA	FR	IVI
23	*Triadinho*	0.015	0.306	2.500	0.631	10.000	2.151	3,088
24	*Jurema preta*	0.007	0.154	2.500	0.631	10.000	2.151	2,935
25	*Pau ferro*	0.018	0.379	2.500	0.631	5.000	1.075	2,085
26	*Mandacaru*	0.014	0.284	1.250	0.315	5.000	1.075	1,675
27	*Pau branco*	0.010	0.209	1.250	0.315	5.000	1.075	1,600
28	*Quebra facão*	0.008	0.175	1.250	0.315	5.000	1.075	1,565
29	*Lambe beiço*	0.004	0.092	1.250	0.315	5.000	1.075	1,482
30	*Angico*	0.003	0.053	1.250	0.315	5.000	1.075	1,444
TOTAL		**4,792**	**100.000**	**396.250**	**100.000**	**465.004**	**100.000**	**300.000**

Prepared by: ARCADIS Tetraplan, 2008.

Legend: FA= Absolut Frequency; FR= Relative Frequency; DA= Absolut Density; DR= Relative Density; DoA= Absolute Dominance; DoR= Relative Dominance and IVI= Importance Value Index.

As shown in Figure 5.2-3, considering the values of frequency, density and dominance, the most relevant species in relation to the IVI were *canela de velho* (*Cenostigma macrophyllum* Tul.), *angico-de-bezerra* (*Pityrocarpa obliqua* (Pers.) Brenan), *pau-de-rato* (*Poicianella pyramidalis* (Tul.) LPQueiroz) and *marmeleiro* (*Croton sonderianus* Muell.Arg).

Figure 5.2-3 – Percentage of the distribution of the 10 species with the highest IVI in the Power Transmission Line area – Piauí Nickel Project, February 2008.



In the botanical survey done in the processing plant area, 30 tree species belonging to 12 botanical families were sampled, the most representative families were *Mimosaceae* with 7 tree species present, *Caesalpiniaceae* with 6 species, and *Euphorbiacae* with 4 registered species. The list of these species is presented in.

A Photos 5.2-31 and 5.2-32 show the plant physiognomies observed on the route along the proposed power transmission line location.

The understory vegetation present in this area, based on the samples collected in this stratum, is mainly characterized by the presence of *marmeleiro* (*Croton sonderianus* Muell. Arg.), a species that appears in greater density and frequency, in almost every section of the transmission line area. The presence of the *camaratuba* (*Cratylia mollis* Mart.), a forage plant of excellent quality for the region, is also noticeable. At lower densities, regeneration of tree species such as *pau de rato, angico de bezerra, canela de velho* and *angelim* are observed, together with shrub species such as *caroá* (*Neoglaziovia variegata* Mez.), *Macambira* (*Bromelia laciniosa* Mart. Ex. Schult .), *mata pasto* (*Senna tora*) – which occurs mainly along the highway to São João do Piauí – *quipá* (*Tacinga inamoena* (K.Schum.) NPTaylor & Stuppy), *rabo-de-raposa* (*Pilosocereus* sp), *cansanção* (*Cnidoscolus urens* (L.) Arthur), *pinhão* (*Jatropha* spp.) and *malvas* (*Sida* spp).

Data Table 5.2-21 – List of Tree Species present in the Power Transmission Line area – Piauí Nickel Project, February 2008.

Nº	Common Name	Scientific Name	Family
1	*Angelim*	*Dahlstedtia araripensis (Benth.) M.J.Silva & A.M.G Azevedo*	Fabaceae
2	*Angico*	*Anandenanthera colubrina (Vell.) Brenan var. cebil (Griseb.) Altschul*	Mimosaceae
3	*Angico de bezerra*	*Pityrocarpa obliqua (Pers) Brenan*	Mimosaceae
4	*Angico vermelho*	*Anadenanthera peregrina (L.) Speg.*	Mimosaceae
5	*Aroeira*	*Myracrodruon urundeuva Engl.*	Anacardiaceae
6	*Bilrro*	*Guarea guidonia (L.) Sleum.*	Meliaceae
7	*Burra leiteira*	*Sapium lanceolatum Lofgr.*	Euphobiaceae
8	*Canafístula*	*Senna spectabilis Allem.*	Caesalpiniaceae
9	*Canela de velho*	*Cenostigma macrophyllum Tul.*	Caesalpiniaceae
10	*Cangalheiro*	*Copaifera sp*	Caesalpiniaceae
11	*Carvoeiro*	*Sclerolobium sp*	Caesalpiniaceae
12	*Cascudo*	*Handroanthus spongiosus (Rizzini) S.Grose*	Bignoniaceae
13	*Farinha seca*	*Combretum sp*	Combretaceae
14	*Jenipapo*	*Tocoyena formosa (Ch. & Schl.) Schm.)*	Rubiaceae
15	*Jurema*	*Mimosa arenosa (Willd.) Poiret*	Mimosaceae
16	*Jur. lambe beiço*	*Mimosa hostilis Benth.*	Mimosaceae
17	*Jurema preta*	*Mimosa verrucosa Benth.*	Mimosaceae
18	*Mandacaru*	*Cereus jamacaru DC.*	Cactaceae
19	*Maniçoba brava*	*Manihot stipularis M. Arg.*	Euphorbiaceae
20	*Marmeleiro*	*Croton sonderianus Muell. Arg.*	Euphorbiaceae
21	*Miroró*	*Bauhinia cheilantha (Bong.) Steud.*	Caesalpiniaceae
22	*Pau branco*	*Cordia glazioviana (Taub.) Gottschling & J.S.Mill.*	Boraginaceae

Nº	Common Name	Scientific Name	Family
23	*Pau de rato*	*Poincianella pyramidalis (Tul.) L.P.Queiroz*	Caesalpiniaceae
24	*Pau ferro*	*Libidibia ferrea (Mart. ex Tul.) L.P.Queiroz*	Caesalpiniaceae
25	*Pereira*	*Aspidosperma pyrifolium Mart.*	Apocynaceae
26	*Pereiro branco*	*Aspidosperma polyneurum DC.*	Apocynaceae
27	*Quebra facão*	*Croton mucroniifolius Muell.Arg.*	Euphorbiaceae
28	*Triadinho*	*Chloroleucum foliolosum (Benth.) G.P.Lewis.*	Mimosaceae
29	*Umbu de catitu*	*Desconhecida 2*	Anacardiaceae
30	*Umbuzeiro*	*Spondias tuberosa Arr. Cam.*	Anacardiaceae

Prepared by: ARCADIS Tetraplan, 2008.

Two indexes of floristic diversity were used to characterize this area with the following results: the Shannon index = 1.16 and the Pielou index (J) = 0.7887.

Itaquatiara Area

14 plots distributed along the *Itaquatiara* area were established. The area had an average density of 339.28 specimens per hectare, the average height of the trees was 6.77 meters. The average basal area of the studied *Caatinga* remnants was 7.59 m² / ha.

With reference to density the relevant species found were the *mané pinto* (*Poincianella microphylla*) with 50 specimens per hectare, *pau de rato* (*Poincianella pyramidalis*), with 44.6 specimens per hectare, *favela* (*Cnidoscolus quercifolius*), with 41 specimens per hectare and *marmeleiro* (*Croton sonderianus*) with 37.5 specimens per hectare.

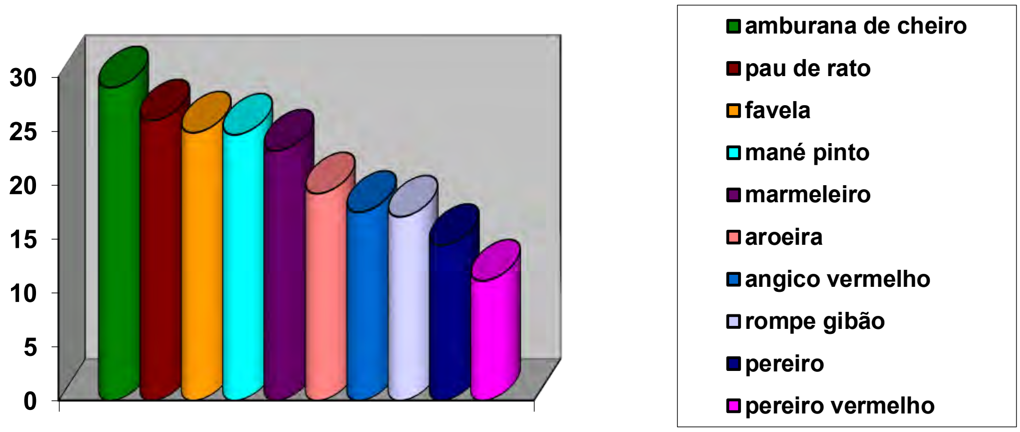
The most frequent species detected in the survey were *pau de rato* (*Poncianella pyramidalis*) and *favela* (*Cnidoscolus quercifolius*) present in 50% of the sampled plots, *marmeleiro* (*Croton sonderianus*) and *rompe gibão* (*Erytroxylum nummularia*) in 35.70% of the installments.

Photo 5.2-33 shows the appearance of the vegetation in this area.

The species that showed greater dominance were *amburana de cheiro* (*Amburana cearensis*), which holds 23.8% of the entire basal area of the studied area with 1.81 m² / ha, *mastic* (*Myracrodruon urundeuva*) and angico-Vermelho (*Anadenanthera peregrina*) with more than 0.8 m² / ha of basal area representing more than 10% of the basal area. We emphasize that all these species have wood potential for different uses.

The species that presented the highest IVI were *canela-de-velho* (*Cenostigma macrophyllum*), *angico-de-bezerra* (*Pityrocarpa obliqua*), *pau-de-rato* (*Poincianella pyramidalis*) and *marmeleiro* (*Croton sonderianus*).

Figure 5.2-4 – Percentage of the distribution of the 10 species with the highest IVI in the area of the *Itaquatiara* – Piauí Nickel Project, February 2008.



Data Table 5.2-22 – Species present in the *Itaquatiara* Area – Piauí Nickel Project, in decreasing order of IVI.

Nº	Specie	DA	DR	FA	FR	DoA	DoR	IVI
1	*Amburana de cheiro*	7.143	2.105	14.286	3.077	1.809	23.807	28,989
2	*Pau de rato*	44.643	13.158	50.000	10.769	0.152	2.001	25,928
3	*Favela*	41.071	12.105	50.000	10.769	0.147	1.934	24,808
4	*Mané pinto*	50.000	14.737	21.429	4.615	0.400	5.259	24,611
5	*Marmeleiro*	37.500	11.053	35.714	7.692	0.334	4.395	23,140
6	*Aroeira*	7.143	2.105	28.571	6.154	0.828	10.901	19,160
7	*Angico vermelho*	7.143	2.105	21.429	4.615	0.815	10.724	17,445
8	*Rompe gibão*	26.786	7.895	35.714	7.692	0.108	1.421	17,008
9	*Pereiro*	26.786	7.895	28.571	6.154	0.024	0.320	14,369
10	*Pereiro vermelho*	19.643	5.789	14.286	3.077	0.168	2.209	11,075
11	*Jurema preta*	3.571	1.053	14.286	3.077	0.492	6.472	10,601
12	*Imbiruçu*	5.357	1.579	21.429	4.615	0.293	3.859	10,053
13	*Angico*	12.500	3.684	21.429	4.615	0.121	1.593	9,893
14	*Amburana cambão*	3.571	1.053	14.286	3.077	0.422	5.549	9,679
15	*Cascudo*	8.929	2.632	7.143	1.538	0.390	5.134	9,304
16	*Jurema*	14.286	4.211	21.429	4.615	0.013	0.168	8,994
17	*Pereiro branco*	7.143	2.105	14.286	3.077	0.188	2.473	7,655
18	*Pau branco*	1.786	0.526	7.143	1.538	0.295	3.877	5,942
19	*Miroró*	1.786	0.526	7.143	1.538	0.180	2.368	4,433
20	*Angelim*	3.571	1.053	7.143	1.538	0.131	1.723	4,314
21	*Angico de bezerro*	1.786	0.526	7.143	1.538	0.124	1.630	3,695
22	*Itapicuru*	1.786	0.526	7.143	1.538	0.124	1.629	3,694
23	*Burra leiteira*	3.571	1.053	7.143	1.538	0.034	0.453	3,044
24	*Barba de soim*	1.786	0.526	7.143	1.538	0.008	0.099	2,164
TOTAIS		**339,283**	**100.000**	**464.286**	**100.000**	**7.600**	**100.000**	**300.000**

Prepared by: ARCADIS Tetraplan, 2008.

Legend: FA= Absolut Frequency; FR= Relative Frequency; DA= Absolut Density; DR= Relative Density; DoA= Absolute Dominance; DoR= Relative Dominance and IVI= Importance Value Index.

In the botanical survey carried out in the *Itaquatiara* stream area, 24 tree species belonging to 11 botanical families were sampled. The most representative families were *Caesalpiniaceae* and *Mimosaceae* with 5 tree species present in each of these families and *Euphorbiacae* and *Apocynaceae* with 3 species registered in each family. The list of species found in this survey is shown in Data Table 5.2-23.

Data Table 5.2-23 – List of tree species present in the *Itaquatiara* stream area – Piauí Nickel Project, February 2008.

Nº	Common Name	Scientific Name	Family
1	*Amburana de cambão*	*Commiphora leptophloeos (Mart.) J.B.Gillett*	Burseraceae
2	*Amburana de cheiro*	*Amburana cearensis (Fr. All.) A.C.Smith.*	Fabaceae
3	*Angelim*	*Dahlstedtia araripensis (Benth.) M.J.Silva & A.M.G Azevedo*	Fabaceae
4	*Angico*	*Anandenanthera colubrina (Vell.) Brenan var. cebil (Griseb.) Altschul*	Mimosaceae
5	*Angico de bezerra*	*Pityrocarpa obliqua (Pers) Brenan*	Mimosaceae
6	*Angico vermelho*	*Anadenanthera peregrina (L.) Speg.*	Mimosaceae
7	*Aroeira*	*Myracrodruon urundeuva Engl.*	Anacardiaceae
8	*Barba de soim*	*Desconhecida 1*	Caesalpiniaceae
9	*Burra leiteira*	*Sapium lanceolatum Lofgr.*	Euphobiaceae
10	*Cascudo*	*Handroanthus spongiosus (Rizzini) S.Grose*	Bignoniaceae
11	*Favela*	*Cnidoscolus quercifolius Pohl*	Euphorbiaceae
12	*Imbiruçu*	*Pseudobombax simplicifolium G.Don.*	Bombacaceae
13	*Itapicuru*	*Goniorrhanchis marginata Taub.*	Caesalpiniaceae
14	*Jurema*	*Mimosa arenosa (Willd.) Poiret*	Mimosaceae
15	*Jurema preta*	*Mimosa verrucosa Benth.*	Mimosaceae
16	*Mané pinto*	*Poincianella microphylla (Mart. ex G.Don) L.P.Queiroz.*	Caesalpiniaceae
17	*Marmeleiro*	*Croton sonderianus Muell. Arg.*	Euphorbiaceae
18	*Miroró*	*Bauhinia cheilantha (Bong.) Steud.*	Caesalpiniaceae
19	*Pau branco*	*Cordia glazioviana (Taub.) Gottschling & J.S.Mill.*	Boraginaceae
20	*Pau de rato*	*Poncianella pyramidalis (Tul.) L.P.Queiroz*	Caesalpiniaceae
21	*Pereira*	*Aspidosperma pyrifolium Mart.*	Apocynaceae

Nº	Common Name	Scientific Name	Family
22	*Pereira vermelho*	*Aspidosperma cuspa (H.B.K.) S.F. Blake*	Apocynaceae
23	*Pereiro branco*	*Aspidosperma polyneurum DC.*	Apocynaceae
24	*Rompe gibão*	*Erytroxylum nummularia Peyritsch*	Erytroxylaceae

Prepared by: ARCADIS Tetraplan, 2008.

Photos 5.2-27 and 5.2-28 exemplify the plant physiognomies present in the *Itaquatiara* area.

In this area, the understory vegetation was found to be very poor in species, with an emphasis on the *marmeleiro* (*Croton sonderianus* Muell. Arg.), *malva* (*Sida acuta* L.), *quipá* (*Opuntia inamoena* K. Schum.) and *jericó* (*Selaginella convoluta* Spring). Lower density species are *caroá* (*Neoglaziovia variegata* Mez.), *macambira* (*Bromelia laciniosa* Mart. ex. Schult.), *coroa de frade* (*Melocactus bahiensis* (Nees) Morong) (Photo 4.3.3, 11-19), *xique-xique* (*Pilosocereus gounellei* Weber) (Photo 5.2-36), *malva branca* (*Sida cordifolia* (L. f.) Willd.) and *beldroelga* (*Portullaca halimoides* L.).

Two indexes of floristic diversity were used to characterize this area with the following results: the Shannon index = 1.17 and the Pielou index (J) = 0.845.

Forest Inventory

Estimated Timber Volumes

The Forest Inventory and the volumes obtained per section through the adjusted volume equation for the *Caatinga* are shown in Data Table 5.2-24.

Data Table 5.2-24 – Calculated Volumes for the Surveyed Plots in the DAA – Piauí Nickel Project, February 2008.

Nº	Plot	TVSS	Nº	Plot	TVSS	Nº	Plot	TVSS	Nº	Plot	TVSS	Nº	Plot	TVSS
1	1	82.00	26	26	19.98	51	54	29.11	76	81	73.20	101	111	29.96
2	2	101.59	27	27	18.30	52	55	30.12	77	82	32.30	102	112	51.28
3	3	97.23	28	28	14.81	53	56	10.10	78	83	24.48	103	113	106.63
4	4	34.45	29	29	28.06	54	57	26.87	79	84	9.60	104	114	72.11
5	5	30.36	30	30	17.61	55	58	12.50	80	85	22.61	105	115	91.87
6	6	75.95	31	31	150.00	56	59	28.32	81	86	30.44	106	116	26.61
7	7	104.22	32	32	104.08	57	60	19.27	82	87	21.48	107	117	86.23
8	8	51.34	33	33	23.97	58	62	6.23	83	88	53.37	108	118	34.95
9	9	17.01	34	34	22.64	59	63	19.55	84	89	81.14	109	119	59.83
10	10	20.99	35	35	22.41	60	64	0.67	85	90	98.74	110	120	45.38
11	11	23.06	36	36	72.69	61	65	6.70	86	91	99.96	111	121	24.43
12	12	42.33	37	37	6.04	62	66	0.70	87	92	22.33	112	122	10.29
13	13	19.98	38	41	46.40	63	68	1.16	88	93	22.04	113	123	143.72
14	14	79.03	39	42	20.85	64	69	13.65	89	94	27.19	114	124	116.54
15	15	120.84	40	43	26.72	65	70	18.08	90	96	21.39	115	125	3.84
16	16	48.03	41	44	21.35	66	71	10.43	91	101	3.01	116	126	111.28
17	17	82.21	42	45	27.39	67	72	29.48	92	102	58.03	117	127	28.34
18	18	105.57	43	46	16.08	68	73	12.53	93	103	40.49	118	128	57.31
19	19	113.18	44	47	7.23	69	74	36.21	94	104	102.22	119	129	3.97
20	20	231.75	45	48	8.10	70	75	15.43	95	105	25.33	120	130	75.64
21	21	12.42	46	49	8.95	71	76	1.29	96	106	55.36	121	131	19.58

Nº	Plot	TVSS	Nº	Plot	TVSS	Nº	Plot	TVSS	Nº	Plot	TVSS	Nº	Plot	TVSS
22	22	7.81	47	50	21.34	72	77	9.62	97	107	44.08	122	132	13.02
23	23	1.39	48	51	31.36	73	78	23.79	98	108	28.86	123	133	12.27
24	24	6.59	49	52	11.13	74	79	21.15	99	109	22.79	124	134	48.85
25	25	9.65	50	53	12.69	75	80	23.41	100	110	53.82	125	135	35.76

Prepared by: ARCADIS Tetraplan, 2008.

Legend: TVSS: Total Volume including Bark per Section (m³/ha).

Considering that the total project areas in hectares occupied exclusively by Dense and Open *Caatinga* (about 1083 ha), and the average volume found in the forest inventory of 40.56 m³ / ha, it is estimated that the subtraction of the natural vegetation cover for the project implementation will generate a volume of wood material in the order of 43,926 m^3.

This number should be considered only as indicative of the expected volume. As previously noted, for the next licensing phase, a new forest inventory adjusted to the final engineering designs will be completed.

Data Table 5.2-25 – List of species found in the surveyed plots and their respective wood utilization, DAA Forest Inventory – Piauí Nickel Project, February 2008.

Nº	Common Name	Scientific Name	Family	Wood Uses
1	*Alecrim*	*Lippia sp*	Verbenaceae	Firewood / Charcoal
2	*Amburana de cambão*	*Commiphora leptophoeus (Mart.) J.B.Gillett*	Burseraceae	Sawmill
3	*Amburana de cheiro*	*Amburana cearensis (Fr. All.) A.C.Smith.*	Fabaceae	Sawmill
4	*Angelim*	*Dahlstedtia araripensis (Benth.) M.J.Silva & A.M.G Azevedo.*	Fabaceae	Sawmill
5	*Angico*	*Anandenanthera colubrina (Vell.) Brenan var. cebil (Griseb.) Altschul*	Mimosaceae	Sawmill
6	*Angico de bezerra*	*Pityrocarpa obliqua (Pers.) Brenan*	Mimosaceae	Firewood / Charcoal
7	*Angico vermelho*	*Anadenanthera peregrina (L.) Speg.*	Mimosaceae	Sawmill
8	*Araçá*	*Psidium sp*	Myrtaceae	Firewood / Charcoal
9	*Aroeira*	*Myracrodruon urundeuva Engl.*	Anacardiaceae	Post/Stakes
10	*Barba de soim*	*Desconhecida 1*	Caesalpiniaceae	Firewood / Charcoal
11	*Bilrro*	*Guarea guidonia (L.) Sleum.*	Meliaceae	Firewood / Charcoal
12	*Burra leiteira*	*Sapium lanceolatum Lofgr.*	Euphobiaceae	Firewood / Charcoal
13	*Canafístula*	*Senna spectabilis (DC.) H.S.Irwin & Barneby.*	Caesalpiniaceae	Firewood / Charcoal
14	*Canafístula mole*	*Senna spectabilis (DC.) H.S.Irwin & Barneby var excelsa (Schrad.) H.S.Irwin & Barneby.*	Caesalpiniaceae	Firewood / Charcoal
15	*Canela de velho*	*Cenostigma macrophyllum Tul.*	Caesalpiniaceae	Firewood / Charcoal
16	*Cangalheiro*	*Copaifera sp*	Caesalpiniaceae	Sawmill

Nº	Common Name	Scientific Name	Family	Wood Uses
17	*Carvoeiro*	*Sclerolobium sp*	Caesapiniaceae	Firewood / Charcoal
18	*Cascudo*	*Handroanthus spongiosus (Rizzini) S.Grose.*	Bignoniaceae	Sawmill
19	*Coração de nego*	*Cassia sp*	Caesalpiniaceae	Firewood / Charcoal
20	*Crista de galo*	*Heliotropium tiarioides Cham.*	Boraginaceae	Firewood / Charcoal
21	*Farinha seca*	*Combretum sp*	Combretaceae	Firewood / Charcoal
22	*Favela*	*Cnidoscolus quercifolius Pohl*	Euphorbiaceae	Firewood / Charcoal
23	*Feijão bravo*	*Erythrina sp*	Fabaceae	Firewood / Charcoal
24	*Folha larga*	*Arrabidea sp.*	Bignoniaceae	Firewood / Charcoal
25	*Imbiruçu*	*Pseudobombax simplicifolium G. Don.*	Bombacaceae	Firewood / Charcoal
26	*Itapicuru*	*Goniorrhanchis marginata Taub.*	Caesalpiniaceae	Firewood / Charcoal
27	*Jacurutu*	*Piptadenia viridifolia Benth*	Mimosaceae	Firewood / Charcoal
28	*Jenipapo*	*Tocoyena formosa (Ch. & Schl.) Schm.)*	Rubiaceae	Firewood / Charcoal
29	*Jurema*	*Mimosa arenosa (Willd.) Poiret*	Mimosaceae	Firewood / Charcoal
30	*Jurema lambe beiço*	*Mimosa hostilis Benth.*	Mimosaceae	Firewood / Charcoal
31	*Jurema preta*	*Mimosa verrucosa Benth.*	Mimosaceae	Firewood / Charcoal
32	*Mamão de veado*	*Jacaratia corumbensis Kuntze.*	Caricaceae	Firewood / Charcoal
33	*Mandacaru*	*Cereus jamacaru DC.*	Cactaceae	No Use
34	*Mané pinto*	*Poincianella microphylla (Mart. ex G.Don) L.P.Queiroz.*	Caesalpiniaceae	Firewood / Charcoal
35	*Maniçoba brava*	*Manihot stipularis M. Arg.*	Euphorbiaceae	Firewood / Charcoal
36	*Marmeleiro*	*Croton sonderianus Muell. Arg.*	Euphorbiaceae	Firewood / Charcoal
37	*Miroró*	*Bauhinia cheilantha (Bong.) Steud.*	Caesalpiniaceae	Firewood / Charcoal
38	*Pau branco*	*Cordia glazioviana (Taub.) Gottschling & J.S.Mill.*	Boraginaceae	Firewood / Charcoal

Nº	Common Name	Scientific Name	Family	Wood Uses
39	*Pau d'arco*	*Handroanthus impetiginosus (Mart. ex DC.) Mattos*	Bignoniaceae	Sawmill
40	*Pau de rato*	*Poincianella pyramidalis (Tul.) L.P.Queiroz.*	Caesalpiniaceae	Firewood / Charcoal
41	*Pau ferro*	*Libidibia ferrea (Mart. ex Tul.) L.P.Queiroz.*	Caesalpiniaceae	Firewood / Charcoal
42	*Pereira*	*Aspidosperma pyrifolium Mart.*	Apocynaceae	Sawmill
43	*Pereira vermelho*	*Aspidosperma cuspa (H.B.K.) S.F. Blake*	Apocynaceae	Sawmill
44	*Pereiro-branco*	*Aspidosperma polyneurum DC.*	Apocynaceae	Sawmill
45	*Pinhão*	*Jatropha mollissima Baill.*	Euphorbiaceae	Firewood / Charcoal
46	*Pinhão-de-chapada*	*Peireskia bahiensis Gurke*	Cactaceae	Firewood / Charcoal
47	*Quebra-facão*	*Croton mucroniifolius Muell Arg.*	Euphorbiaceae	Firewood / Charcoal
48	*Rompe-gibão*	*Erythroxylum nummularia Peyritsch*	Erythroxylaceae	Firewood / Charcoal
49	*Sucupira*	*Bowdichia virgilioides Kunth.*	Fabaceae	Sawmill
50	*Triadinho*	*Chloroleucum foliolosum (Benth.) G.P.Lewis*	Mimosaceae	Firewood / Charcoal
51	*Umbu-de-catitu*	*Desconhecida 2*	Anacardiaceae	Firewood / Charcoal
52	*Umbuzeiro*	*Spondias tuberosa Arr. Cam.*	Anacardiaceae	Firewood / Charcoal
53	*Jurema-unha-de-gato*	*Senegalia tenuifolia (L.) Britton & Rose*	Mimosaceae	Firewood / Charcoal

Prepared by: ARCADIS Tetraplan, 2008.

Data Table 5.2-26 shows the wood volume per specie found in the sampled plots.

Data Table 5.2-26 – Volumetric Distribution (Total volume with bark - m³/ha) by species, DAA Forest Inventory – Piauí Nickel Project, February 2008.

Nº	Specie	TVSS (m³/ha)	Nº	Specie	TVSS (m³/ha)
1	*Alecrim*	*0.029*	*28*	*Jucurutu*	0.775
2	*Amburana de cambão*	*5.955*	*29*	*Jurema*	0.313
3	*Amburana de cheiro*	*0.847*	*30*	*Jurema lambe beiço*	0.091
4	*Angelim*	*0.391*	*31*	*Jurema preta*	0.304
5	*Angico*	*2.494*	*32*	*Mamão de veado*	0.008
6	*Angico de bezerra*	*1.115*	*33*	*Mandacaru*	0.032

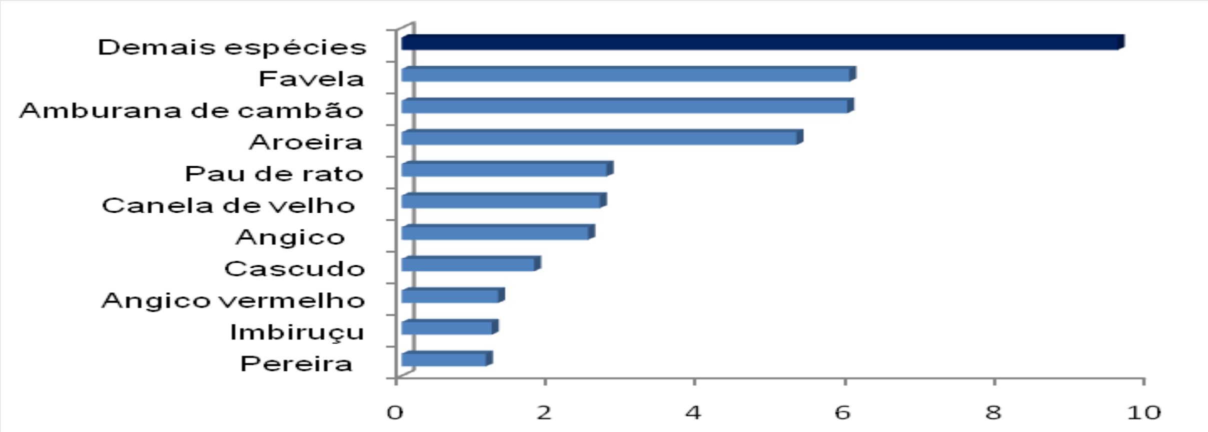
Nº	Specie	TVSS (m³/ha)	Nº	Specie	TVSS (m³/ha)
7	*Angico vermelho*	*1.290*	*34*	*Mane pinto*	1.029
8	*Araçá*	*0.023*	*35*	*Maniçoba brava*	0.129
9	*Aroeira*	*5.279*	*36*	*Marmeleiro*	0.947
10	*Barba de soim*	*0.024*	*37*	*Miroró*	0.045
11	*Bilrro*	*0.075*	*38*	*Pau branco*	0.439
12	*Burra leiteira*	*0.280*	*39*	*Pau d'arco*	0.048
13	*Canafístula mole*	*0.005*	*40*	*Pau de rato*	2.738
14	*Canafístula*	*0.178*	*41*	*Pau ferro*	0.013
15	*Canela de velho*	*2.650*	*42*	*Pereira*	1.129
16	*Cangalheiro*	*0.267*	*43*	*Pereiro branco*	0.153
17	*Carvoeiro*	*0.336*	*44*	*Pereiro vermelho*	0.208
18	*Cascudo*	*1.770*	*45*	*Pinhão*	0.004
19	*Coração de nego*	*0.028*	*46*	*Pinhão de chapada*	0.016
20	*Crista de galo*	*0.028*	*47*	*Quebra facão*	0.027
21	*Farinha seca*	*0.109*	*48*	*Rompe gibão*	0.154
22	*Favela*	*5.983*	*49*	*Sucupira*	0.153
23	*Feijão bravo*	*0.009*	*50*	*Triadinho*	0.051
24	*Folha Larga*	*0.070*	*51*	*Umbu de catitu*	0.027
25	*Imbiruçu*	*1.205*	*52*	*Umbuzeiro*	0.569
26	*Itapicuru*	*0.152*	*53*	*Unha de gato*	0.011
27	*Jenipapo*	*0.057*			

Prepared by: ARCADIS Tetraplan, 2008.

Graph 5.2-2 shows that *favela* (*Cnidoscolus quercifolius*, *amburana-de-cambão* (*Commiphora leptophoeus*) and *aroeira* (*Myracrodruon urundeuva*), are the species with higher volumes with values closer to 6.0 m³/ha.

This woody material could be used in the same region of *Capitão Gervásio Oliveira*, *Campo Alegre do Fidalgo* and *São João do Piauí*. Graph 5.2-2 shows the wood utilization of the tree species found in the study region.

Graph 5.2-2 – Volumetric Distribution for the 10 species with the largest volume of wood with bark (TVSS), in cubic meters per hectare – DAA Inventory – Piauí Nickel Project, February 2008.



All the other species added up to 9.569 m³ / ha together, which reinforces the good performance observed for these three species. It must be considered, however, that the *cascudo* is categorized as "in danger" of extinction by the *Lista Oficial de Espécies da Flora Brasileira Ameaçada de Extinção* (MMA 443/2014).

Diametric Distribution

Data Table 5.2-27 shows the frequencies of diametric distribution considering a grouping range of 5.0 cm and minimum diameter of 5.0 cm.

Data Table 5.2-27 – Diametric Distribution for the trunk included in the DAA Forest Inventory – Piauí Nickel Project, February 2008.

Diameter Range (cm)	Average of the Group (cm)	Frequency
5.0 - 9.9	7.5	2092
10.0 - 14.9	12.5	569
15.0 - 19.9	17.5	227
20.0 - 24.9	22.5	127
25.0 - 29.9	27.5	55
30.0 - 34.9	32.5	19
35.0 - 39.9	37.5	15
40.0 - 44.9	42.5	2
45.0 - 49.9	47.5	5
50.0 - 54.9	52.5	2
55.0 - 59.9	57.5	1
60.0 - 64.9	62.5	0

Diameter Range (cm)	Average of the Group (cm)	Frequency
65.0 - 69.9	67.5	0
70.0 - 74.9	72.5	0
75.0 - 79.9	77.5	1
80.0 - 84.9	82.5	0
85.0 - 89.9	87.5	1

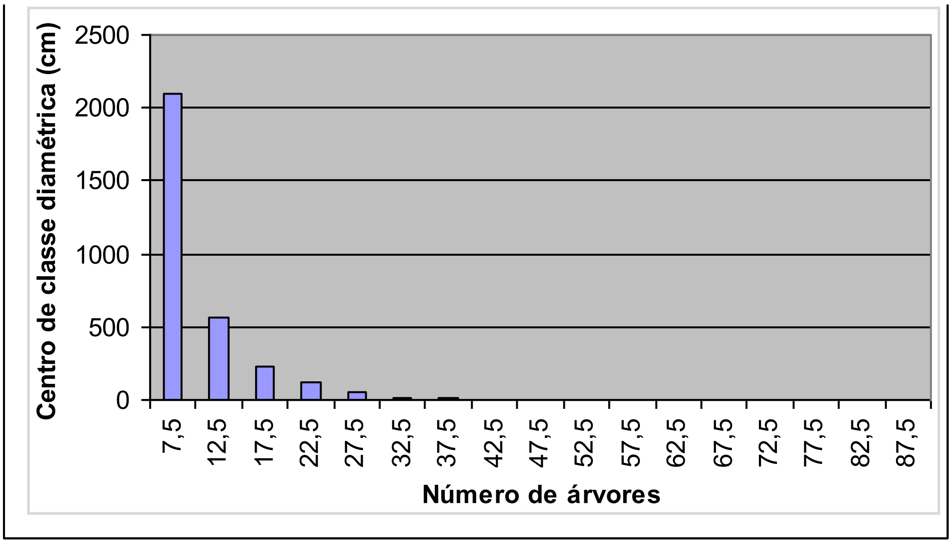
Prepared by: ARCADIS Tetraplan, 2008.

The bulk of the measured trunks are concentrated in the 5.0 to 14.9 cm diametric range measured at chest height (DCH), which is consistent with the plant physiognomies observed for the *Caatinga* in the study area.

Diameters above 60 cm are almost nonexistent confirming the low vegetation size in the area.

Graph 5.2-3 shows the diametric distribution characteristic of an unequal forest (LAMPRECHT, 1962; MARTINS, 1993).

Graph 5.2-3 – Diametric Distribution of the sampled trunks in the DAA Forest Inventory – Piauí Nickel Project, February 2008.



d) Conservationist Aspects

In general, the project's ADI corresponds to a large *Caatinga* matrix that is divided into several fasciation as previously discussed. There are large areas where apparently the degree of vegetation conservation can be considered as good or advanced. However, it is evident that all vegetation has been suffering from the occurrence of several degradation factors, of which cutting and extensive grazing of several species of domestic animals are the most important.

Regarding the suppression of vegetation, the local rural population traditionally uses significant amounts of wood resources in their daily lives either as firewood, for the construction of fences that are made with splinters and trunks of native species, or even in the making of various tools.

The use as firewood has been decreasing with the infrastructure development of this rural areas, such as the arrival of electricity and access to natural gas. However, selective cutting does not degrade the *Caatinga* unlike the shallow cut. In field surveys, it is possible to observe areas properly managed that still have good soil coverage and good diversity while other uncontrolled areas suffered are very compromised.

The main threat to the maintenance of the diversity of the local flora is the extensive breeding of animals that wander free in the native vegetation, mainly goats whose traces were found in all surveyed areas.

In addition to the problem of soil compaction by walking on (more intense in the case of cattle), goats and sheep promote an intense predation on plant resources, being more aggressive during the dry season due to erosive processes. Several studies have already been completed in the Northeast of Brazil regarding the impacts of grazing on this biome and the conclusion is always that the extensive cattle raising is the main factor of structural and successional changes in the *Caatinga* environment.

The observations made empirically during field campaigns corroborate those studies and indicate that extensive cattle (goat) rising has been playing a strong role in the selection of species from all strata in the region. Non-palatable species such as the *favela* and other latescent plants have been favored by livestock in detriment of those more nutritious and palatable, and in the dry season practically no young specimens of leguminous species or similar are observed, interrupting its regeneration cycle.

The silent impact of extensive livestock farming on the local flora, altering the natural balance of species, favoring a few over many, goes far beyond any temporal or permanent impact of a project.

Final Considerations

The survey conducted showed that the intervention areas do not have any phytophysiognomy as well as any species exclusive to the project DAA although they have both different types and different regeneration stages, requiring specific treatments for each of these areas.

The floristry of the Project area showed typical species of *Caatinga* environments. Among these species, the *mandacaru (Cereus jamacaru*) one of the symbolic species of the *Caatinga*, the *Umbuzeiro* (*Spondias tuberosa*) and the *juazeiro* (*Zizyphus joazeiro*) – which keeps its green leaves during the dry season, and the species *Cactáceas coroa-de-frade* (*Melocactus bahiensis*) and palmatória (*Tacinga inamoena*) and the family of bromeliads represented by the species *Bromelia*, *Encholinium*, *Tillandisia* and *Neoglaziovia*.

The Fabaceae family plays a predominant role with a significant number of species in the area dominating the structure of most of the plant formations.

The presence of specimens of species threatened with extinction in the project DAA (*ipê-cascudo Handroanthus spongiosus* – EN according to Ordinance MMA 443/14), requires that the vegetation removal activities are carefully planned in combination with the compensatory measures such as seed saving and seedling banks with subsequent planting of these species in areas destined to conservation purposes.

Regarding the conservation status of the local native vegetation, the region in 2016 still has characteristics of a large continuum of *Caatinga* of various densities and stages of regeneration that should not be much altered by the implementation of the project. However, it is warned that the regeneration process of native species has been seriously disturbed due to the presence of extensive livestock that leaves animals loose in the forest, which in turn establishes a strong selection pressure on native plant species, favoring the development of less palatable species to the detriment of more palatable ones. Traces of the presence of domestic animals were observed in all the surveyed points, being notable in some areas the absence or serious reduction of young individuals of the surrounding tree species.

Photographic Register of the Vegetation in the Project ADI / DAA

Photo 5.2-17 – General aspect of the *Savana Estépica Arborizada* vegetation (*Caatinga Arbóreo arbustiva*) – Piauí Nickel Project Area.

Photo 5.2-18 – General aspect of the *Savana Estépica Florestada* vegetation (*Caatinga Arbóreo arbustiva*) – Piauí Nickel Project Area.

Photo 5.2-19 – General aspect of the vegetation of anthropized areas in the DAA – Piauí Nickel Project Area.

Photo 5.2-20 – Section Identification Label used during the vegetation survey of the DAA – Piauí Nickel Project Area.

Photo 5.2-21 – Channeled trunk, typical of the species *canela de velho* (*Cenostigma macrophyllum Tul*.).

Photo 5.2-22 – *Caroá* (*Neoglaziovia variegata Mez*.) in the understory of the future Processing Plant.

Photo 5.2-23 – View of the vegetation present in the *Brejo Seco* Hill – Piauí Nickel Project – *Capitão Gervásio Oliveira.*

Photo 5.2-24 – General aspect of the vegetation present at the *Brejo Seco* Hill – Piauí Nickel Project – *Capitão Gervásio Oliveira.*

Photo 5.2-25 – Anthropized areas present in the Processing Plant area – Piauí Nickel Project – *Capitão Gervásio Oliveira*.

Photo 5.2-26 – General aspect of the vegetation in the Processing Plant area – Piauí Nickel Project – *Capitão Gervásio Oliveira.*

Photo 5.2-27 – General aspect of the vegetation in the Limestone Quarry area – *Umbuzeiro*.

Photo 5.2-28 – General aspect of the vegetation in the Limestone Quarry area – *Umbuzeiro*.

Photo 5.2-29 – *Caroá* (*Neoglaziovia variegata* Mez.) e *Macambira* (*Bromelia laciniosa* Mart. ex. Schult.). in the understory vegetation of the Limestone Quarry area – *Umbuzeiro*.

Photo 5.2-30 – *Marmeleiro* (*Croton sonderianus* Muell. Arg.) in good vegetative condition along the proposed area for the Power Transmission Line.

Photo 5.2-31 – General aspect of the anthropized vegetation along the proposed area for the Power Transmission Line

Photo 5.2-32 – Aspect of the vegetation in the *Itaquatiara* area.

Photo 5.2-33 – General aspect of the *Itaquatiara* area, *Itaquatiara* stream bed.

Photo 5.2-34 – General aspect of the Arboreal *Caatinga* present along the *Itaquatiara* area.

Photo 5.2-35 – *Caroá* (*Neoglaziovia variegata*). Fiber producer specie.

Photo 5.2-36 – *Coroa de Frade* (*Melocactus bahiensis*) present in the Itaquatiara area.

Photo 5.2-37 – *Xique-xique* (*Pilosocereus gounellei*), with very ornamental effect found in the Limestone Quarry area – *Umbuzeiro*.

5.2.4. Terrestrial Fauna

The Caatinga is proportionally the least studied among the Brazilian natural regions and most of the studies are concentrated in a few points around the main cities and some Conservation Units. In addition, the Caatinga is one of the least protected Brazilian Biomes, as the Conservation Units cover less than 2% of its territory and continues to undergo an extensive process of alteration and environmental deterioration, caused by the use of its natural resources. Such use has led to the fast loss of unique species, the elimination of key ecological processes and the formation of extensive desertification nucleus in various sectors of its coverage (Leal, *et al*., 2003).

Knowledge of the fauna species communities' richness in Neotropical regions is quite limited. In this context, the objective was to perform the inventory to compose the diagnosis of terrestrial fauna in the areas of influence of this project, seeking to know the composition and distribution of the existing biodiversity and to understand the species' responses to the quality of the present habitat before the implementation of the project.

5.2.4.1. Avifauna

Considering that, through the analysis of updated satellite images, the use and occupation of the land in the area of the project has undergone little change in relation to the surveys carried out in this same area in 2008, it was agreed at a meeting held on September 2nd, 2016 between representatives of SEMAR-PI and PNM, that the primary data covered in this chapter will be those whose surveys carried out in the study area for this same project, aimed to compose the Environmental and Social Impact Assessment (ESIA) and the respective Environmental & Social Impact Report (RIMA), prepared by ARCADIS Tetraplan, in 2008 for Companhia Vale do Rio Doce.

A) Methodological Considerations

a) Collection of secondary data

In order to compose the scenario that fauna species likely to occur in the study region, data were compiled from existing environmental studies and scientific publications in order to contribute to the characterization of the bird community present in the study area of this project.

For the survey of bird species that could potentially occur in the region, the results of the data survey conducted by the company Golder Associates (2005), when licensing the pilot plant for the project installed on the Brejo Seco hill, were compiled. This survey was carried out in October 2005, and aims to compose the scenario of species likely to occur in the area of indirect influence (AII), in a dry season.

In addition, data published for the Serra da Capivara National Park, Piauí (Olmos; Albano, 2012) were compiled to detect the composition of bird species in a regional context.

b) Field sampling

Sampling period

The study of birds, through data collection in the field, was conducted in a sampling campaign. Data collection was carried out between February 19th to 27th, 2008 (rainy season). It is noteworthy that sampling in the dry season was carried out in an earlier phase, when the pilot plant was licensed, in the period from 10th to 14th October 2005 (Golder Associates, 2005 - secondary data), whose results were not included in the analyses of composition and distribution of the areas of influence of the project, however considered in a comparative analysis of richness for characterizing data related to the areas of insertion of the project in drought period, contemplating, therefore, the seasonality in the present study.

Spatial coverage of the study

The spatial scope for collecting primary data included the Directly Affected Area (DAA), and the Direct Influence (ADI) and Indirect (AII) Area of the project.

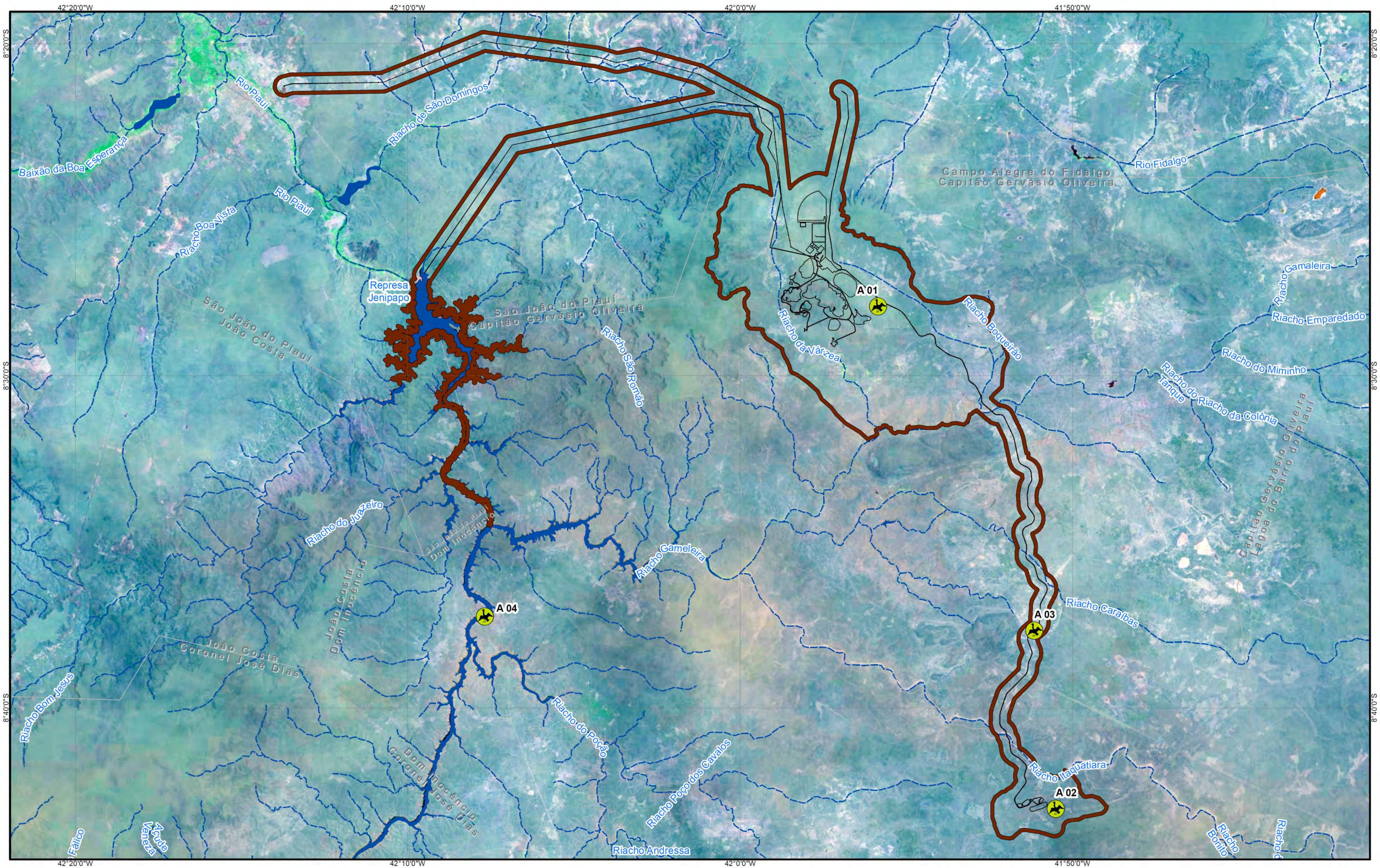
Sampling was held at four sample sites, as described below and shown on Map 5.2-9.

Data Table 5.2-28 – Characterization and location of sample sites for recording avifauna.

Samples sites	Geographic Coordinates (UTM)		Zone	Project Component	Area Description
A1 (DAA/ADI)	177310	9063119	24L	Brejo seco area, access road to Nickel Mine	Shrubby Arboreal vegetation, with mixtures between open and dense areas.
A2 (DAA/ADI)	187341	9035288	24L	Umbuzeiro area, near to limestone Mine	Tree vegetation (5 m), presence of bromeliads and rocky outcrops.
A3 (DAA/ADI)	186073	9045180	24L	Access road to limestone mine	Composed of white sand with macambira (*Bromelia laciniosa)* and spaced trees
A4 (AII)	816166	945950	23L	Near of Jenipapo Dam	It has shallow rocky soil on a sloping bank with some old buildings. Very little developed vegetation, covering the substrate little, exposed for the most part.

Source: ARCADIS Tetraplan, 2008. Author: Elaboration, 2017.

Map 5.2-9 – Avifauna sampling sites.



LEGENDA

- Intermittent Drainage
- Municipal Limits
- Area of Direct Influence - ADI
- Water Mass
- Directly Affected Area - DAA

Sampling Site

- Avifauna

REFERÊNCIAS

ARCADIS Tetraplan, 2008;
IBGE, Base contínua 1:250.000, 2015;
LANDSAT, Imagem, 2016;
Projeto Piauí Níquel, 2016.

ESCALA GRÁFICA

0 5 10 km

Sistema de Coordenadas: GCS SIRGAS 2000

MAPA DE LOCALIZAÇÃO

PA MA CE RN PB PE PI AL SE TO BA

Piauí Níquel ARCADIS

EIA/RIMA – PROJETO PIAUÍ NÍQUEL

Map 5.2-9 – Sampling Sites
Avifauna

EXECUTADO POR:	ESCALA:	NÚMERO:	DATA:
ARCADIS	1:200.000	Única	jun /2017

Photo 5.2-38 – A1 Area, located in the Nickel mine area.

Photo 5.2-39 – A2 Area, located in the limestone mine area.

Photo 5.2-40 – A3 Area, locate in the access road of the limestone mine area.

Photo 5.2-41 – A4 Area, around the Jenipapo Dam.

Data collection

c) Census (direct and indirect registers)

To survey the avifauna, pre-established transects were covered at constant speed and all species and the number of individuals detected were recorded. Observations occurred in the early hours of the morning and in the late afternoon, times of greatest activity for the birds, totalling a sampling effort of approximately 60 hours. Night birds were observed randomly after sunset. The species detected between the sample sites were also recorded.

The species were visually identified using Bivision 10X50 binoculars. Some birds had their vocalizations recorded with the aid of a Panasonic RQ L31 recorder and Yoga HT-81 directional microphone, for later identification and for documentation purposes.

The recordings were compared with existing sound files on CD, internet and the researcher's personal file. Species identification was based on Ridgely & Tudor (1994), Sick (1997), Souza (1998) and Sigrist (2007). The nomenclature follows the Brazilian Committee for Ornithological Records (CBRO).

The quantitative analysis follows the method of Willis & Oniki (1981), where the total number of individuals of each species registered in each study area is divided by the field hours and multiplied by 100, in order to obtain the number of individuals of each species, at each sample site, for 100 hours of observation.

Conservation Status

To ascertain the conservation status of registered bird species, the Official National List of Endangered Species of Fauna was consulted, Portaria MMA No. 444/2014.

At international level, the protection of fauna also focuses on international agreements, related to species and habitats. The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES, 2014) provides a list of species whose international trade must be controlled (Fitzgerald, 1989).

The International Union for Conservation of Nature (IUCN, 2016) established the following categorization for the purpose of preserving species considered threatened: Least Concern (LC); Near Threatened (NT); Vulnerable (VU); Endangered (EN); and Critically Endangered (CR)

B) Results

a) Regional Characterization

The “drought polygon” is the sub-arid region of the Northeast with its clayey, stony or sandy soils and the dry season is irregular and intense. Existing thickets and shrubs, often armed with thorns, are stripped of leaves for months.

There are a good number of endemic birds in the caatinga, such as the cracid *Penelope jacucaca*. Parrots are represented by several parakeets like *Eupsittula cactorum*, almost endemic. The most important endemism in the Northeast are the Spix's macaw (*Cyanopsitta spixii*) and the small Lear's macaw (*Anodorhynchus leari*), both are strongly threatened as in extinction and are partially extinct from nature (Portaria MMA nº 444/2014) and, therefore, unlikely occurrence in the project areas.

Among birds, there is a group of endemism that live in the cerrado, in the caatinga, in the covered field and in areas of plateaus and other open or partially open habitats (Sick, 1997).

As the Caatinga is the biome in which some of the most extreme meteorological values are recorded within Brazil, it is expected that the local biota will have adaptations peculiar to survival, making it an especially important region for studies on the interrelationships of biotic communities in a xeric environment (Santos, 2004).

Although the Caatinga is recognized as one of the centres of endemism of South American birds, the distribution, ecology and evolution of avifauna has been little investigated, in comparison with the other biomes. The compilation of the existing data for the Caatinga, regardless of the type of vegetation to which the bird species are associated, shows 510 species, gathered in 62 families. Of these, 185 are independent of forests and 125 are semi-dependent. A total of 47 species are highly sensitive to anthropogenic changes (Silva *et al.* 2003).

In addition, many species that live in the caatinga are endemic to Brazil. Some of them are: yellow-legged tinamou (*Crypturellus noctivagus*), white-browed guan (*Penelope jacucaca*), caatinga parakeet (*Eupsittula cactorum*), spotted piculet (*Picumnus pygmaeus*), silvery-cheeked antshrike (*Sakesphorus cristatus*), white-browed antpitta (*Hylopezus ochroleucus*), great xenops (*Megaxenops parnaguae*), band-tailed hornero (*Furnarius figulus*), white-naped jay (*Cyanocorax cyanopogon*), long-billed wren (*Cantorchilus longirostris*), red-cowled cardinal (*Paroaria dominicana*) and white-throated seedeater (*Sporophila albogularis*) (Sick, 1996).

The survey carried out in the areas of influence of the project at the time of licensing the pilot plant (Golder Associates, 2005) added to the data recorded in the Serra da Capivara National Park (Olmos; Albano, 2012), although this was outside the project's AII, compiled 256 species of potential occurrence. Of these, five are threatened with extinction at the federal level (*Penelope superciliaris, Penelope jacucaca, Campylorhamphus trochilirostris, Stigmatura napensis* and *Crypturellus noctivagus*) and four at the international level, of which three (*Xiphocolaptes falcirostris, Herpsilochope jaceataca* and *Penpsilochope pileatus* and classified as “vulnerable” according to IUCN (2016) and one (*Primolius maracana*) is threatened according to the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES, 2016), with its international trade prohibited (Data Table 5.2-29).

It is worth mentioning that 20 species are almost threatened or at risk of becoming threatened with extinction (IUCN, 2016; CITES, 2016) (Data Table 5.2-29).

Data Table 5.2-29 – Bird species that likely occur in the Area of Indirect Influence (AII) and surroundings, with respective threat categories.

Order	Family	Taxon	Popular Name	Threat category			Source
				Federal	International		
				MMA nº 444/2014	IUCN, 2016	CITES, 2016	
Accipitriformes	Accipitridae	*Gampsonyx swainsonii*	gaviãozinho	-	LC	-	2
		Accipiter bicolor	gavião-bombachinha-grande	-	LC	-	2
		Ictinia plumbea	sovi	-	LC	-	2
		Geranospiza caerulescens	gavião-pernilongo	-	LC	-	2
		Heterospizias meridionalis	gavião-caboclo	-	LC	-	2
		Rupornis magnirostris	gavião-carijó	-	LC	-	1; 2
		Geranoaetus albicaudatus	gavião-de-rabo-branco	-	LC	-	2
		Geranoaetus melanoleucus	águia-chilena	-	LC	-	2
		Buteo nitidus	gavião-pedrês	-	LC	-	2
		Buteo brachyurus	gavião-de-cauda-curta	-	LC	-	2
		Buteo swainsoni	gavião-papa-gafanhoto	-	LC	-	2
		Buteo albonotatus	gavião-de-rabo-barrado	-	LC	-	2
Anseriformes	Anatidae	*Amazonetta brasiliensis*	pé-vermelho	-	LC	-	1; 2

Order	Family	Taxon	Popular Name	Threat category			Source
				Federal	International		
				MMA nº 444/2014	IUCN, 2016	CITES, 2016	
		Dendrocygna viduata	irerê	-	LC	-	2
		Dendrocygna autumnalis	asa-branca	-	LC	-	2
		Cairina moschata	pato-do-mato	-	LC	-	2
Apodiformes	Apodidae	*Streptoprocne biscutata*	taperuçu-de-coleira-falha	-	LC	-	1; 2
		Streptoprocne zonaris	taperuçu-de-coleira-branca	-	LC	-	2
		Tachornis squamata	tesourinha	-	LC	-	1; 2
	Trochilidae	*Chlorostilbon lucidus*	besourinho-de-bico-vemelho	-	LC	-	1; 2
		Anopetia gounellei	rabo-branco-de-cauda-larga	-	LC	-	2
		Phaethornis maranhaoensis	rabo-branco-do-maranhão	-	-	-	2
		Eupetomena macroura	beija-flor-tesoura	-	LC	-	2
		Colibri serrirostris	beija-flor-de-orelha-violeta	-	LC	-	2
		Anthracothorax nigricollis	beija-flor-de-veste-preta	-	LC	-	2
		Chrysolampis mosquitus	beija-flor-vermelho	-	LC	-	2

Order	Family	Taxon	Popular Name	Threat category			Source
				Federal	International		
				MMA nº 444/2014	IUCN, 2016	CITES, 2016	
		Heliomaster longirostris	bico-reto-cinzento	-	LC	-	2
		Calliphlox amethystina	estrelhina-ametista	-	LC	-	2
Caprimulgiformes	Caprimulgidae	*Caprimulgus parvulus*	bacurau-chintã	-	-	-	1
		Antrostomus rufus	joão-corta-pau	-	LC	-	2
		Hydropsalis albicollis	bacurau	-	-	-	2
		Hydropsalis parvula	bacurau-pequeno	-	-	-	2
		Hydropsalis hirundinacea	bacurauzinho-da-caatinga	-	-	-	2
		Hydropsalis longirostris	bacurau-da-telha	-	-	-	2
		Hydropsalis torquata	bacurau-tesoura	-	LC	-	2
		Chordeiles pusillus	bacurauzinho	-	LC	-	2
		Chordeiles nacunda	corucão	-	LC	-	2
	Nyctibiidae	*Nyctibius griseus*	mãe-da-lua	-	LC	-	2
Cariamiformes	Cariamidae	*Cariama cristata*	seriema	-	LC	-	2
Cathartiformes	Cathartidae	*Cathartes burrovianus*	urubu-de-cabeça-amarela	-	LC	-	1; 2
		Coragyps atratus	urubu-de-cabeça-preta	-	LC	-	1; 2

Order	Family	Taxon	Popular Name	Threat category			Source
				Federal	International		
				MMA nº 444/2014	IUCN, 2016	CITES, 2016	
		Cathartes aura	urubu-de-cabeça-vermelha	-	LC	-	2
		Sarcoramphus papa	urubu-rei	-	LC	-	2
Charadriiformes	Charadriidae	*Vanellus chilensis*	quero-quero	-	LC	-	1; 2
		Vanellus cayanus	batuíra-de-esporão	-	LC	-	2
		Pluvialis dominica	batuiruçu	-	LC	-	2
	Recurvirostridae	*Himantopus mexicanus*	pernilongo-de-costas-negras	-	LC	-	2
Ciconiiformes	Ardeidae	*Tigrisoma lineatum*	socó-boi	-	LC	-	1
		Butorides striata	socozinho	-	LC	-	1
	Ciconidae	*Mycteria americana*	cabeça-seca	-	LC	-	2
Columbiformes	Columbidae	*Columbina minuta*	rolinha-de-asa-canela	-	LC	-	2
		Columbina talpacoti	rolinha-roxa	-	LC	-	1; 2
		Columbina squammata	fogo-apagou	-	LC	-	1; 2
		Columbina picui	rolinha-picui	-	LC	-	1; 2
		Claravis pretiosa	pararu-azul	-	LC	-	1; 2
		Patagioenas picazuro	pombão	-	LC	-	1; 2
		Zenaida auriculata	pomba-de-bando	-	LC	-	1; 2
		Leptotila verreauxi	juriti-pupu	-	LC	-	1; 2

Order	Family	Taxon	Popular Name	Threat category			Source
				Federal	International		
				MMA nº 444/2014	IUCN, 2016	CITES, 2016	
Coraciiformes	Alcedinidae	*Megaceryle torquata*	martim-pescador-grande	-	LC	-	1; 2
		Chloroceryle amazona	martim-pescador-verde	-	LC	-	1; 2
		Chloroceryle americana	martim-pescador-pequeno	-	LC	-	1; 2
Cuculiformes	Cuculidae	*Piaya cayana*	alma-de-gato	-	LC	-	1; 2
		Coccyzus melacoryphus	papa-lagarta-acanelado	-	LC	-	2
		Crotophaga major	anu-coroca	-	LC	-	2
		Crotophaga ani	anu-preto	-	LC	-	1; 2
		Guira guira	anu-branco	-	LC	-	1; 2
		Tapera naevia	saci	-	LC	-	1; 2
		Dromococcyx phasianellus	peixe-frito-verdadeiro	-	LC	-	2
Falconiformes	Falconidae	*Caracara plancus*	caracará	-	LC	II	1; 2
		Milvago chimachima	carrapateiro	-	LC	II	1; 2
		Herpetotheres cachinnans	acauã	-	LC	II	1; 2
		Micrastur ruficollis	falcão-caburé	-	LC	II	2
		Micrastur semitorquatus	falcão-relógio	-	LC	II	2

Order	Family	Taxon	Popular Name	Threat category			Source
				Federal	International		
				MMA nº 444/2014	IUCN, 2016	CITES, 2016	
		Falco sparverius	quiriquiri	-	LC	II	2
		Falco rufigularis	cauré	-	LC	II	2
		Falco femoralis	falcão-de-coleira	-	LC	II	2
Galbuliformes	Bucconidae	*Nystalus maculatus*	rapazinho-dos-velhos	-	LC	-	1; 2
	Galbulidae	*Galbula ruficauda*	ariramba-de-cauda-ruiva	-	LC	-	2
Galliformes	Cracidae	*Penelope superciliaris*	jacupemba	CR	LC	-	2
		Penelope jacucaca	jacucaca	VU	VU	-	2
Gruiformes	Aramidae	*Aramus guarauna*	carão	-	LC	-	2
	Cariamidae	*Cariama cristata*	seriema	-	LC	-	1
	Rallidae	*Aramides cajanea*	saracura-três-potes	-	LC	-	2
		Laterallus melanophaius	sanã-parda	-	LC	-	2
		Porzana albicollis	sanã-carijó	-	LC	-	2
		Gallinula angulata	frango-dágua-menor	-	LC	-	2
		Porphyrio martinicus	frango-d-água-azul	-	LC	-	2
Passeriformes	Thamnophilidae	*Thamnophilus doliatus*	choca-barrada	-	LC	-	1
		Herpsilochmus pileatus	chorozinho-de-boné	-	VU	-	1

Order	Family	Taxon	Popular Name	Threat category			Source
				Federal	International		
				MMA nº 444/2014	IUCN, 2016	CITES, 2016	
		Formicivora melanogaster	formigueiro-de-barriga-preta	-	LC	-	2
		Herpsilochmus sellowi	chorozinho-da-caatinga	-	LC	-	2
		Herpsilochmus atricapillus	chorozinho-de-chapéu-preto	-	LC	-	2
		Herpsilochmus longirostris	chorozinho-de-bico-comprido	-	LC	-	2
		Sakesphorus cristatus	choca-do-nordeste	-	LC	-	2
		Thamnophilus capistratus	choca-barrada-donordeste	-	-	-	2
		Thamnophilus pelzelni	choca-do-planalto	-	LC	-	2
		Taraba major	choró-boi	-	LC	-	2
		Myrmorchilus strigilatus	piu-piu	-	LC	-	2
		Hylopezus ochroleucus	torom-do-nordeste	-	NT	-	2
	Dendrocolaptidae	*Dendrocolaptes platyrostris*	arapaçu-grande	-	LC	-	1; 2
		Xiphorhynchus fuscus	arapaçu-rajado	-	LC	-	1

Order	Family	Taxon	Popular Name	Threat category			Source
				Federal	International		
				MMA nº 444/2014	IUCN, 2016	CITES, 2016	
		Lepidocolaptes angustirostris	arapaçu-de-cerrado	-	LC	-	1; 2
		Campylorhamphus falcularius	arapaçu-de-bico-torto	-	LC	-	1
		Sittasomus griseicapillus	arapaçu-verde	-	LC	-	2
		Campylorhamphus trochilirostris	arapaçu-beija-flor	EN	LC	-	2
		Xiphocolaptes falcirostris	arapaçu-do-nordeste	-	VU	-	2
	Furnariidae	*Xenops rutilans*	bico-virado-carijó	-	LC	-	2
		Furnarius figulus	casaca-de-couro-da-lama	-	LC	-	2
		Furnarius leucopus	casaca-de-couro-amarelo	-	LC	-	1; 2
		Furnarius rufus	joão-de-barro	-	LC	-	1
		Pseudoseisura cristata	casaca-de-couro	-	LC	-	1; 2
		Megaxenops parnaguae	bico-virado-da-caatinga	-	LC	-	2
		Certhiaxis cinnamomeus	curutié	-	LC	-	2
		Gyalophylax hellmayri	-	-	NT	-	2
		Synallaxis frontalis	petrim	-	LC	-	2

Order	Family	Taxon	Popular Name	Threat category			Source
				Federal	International		
				MMA nº 444/2014	IUCN, 2016	CITES, 2016	
		Synallaxis albescens	uí-pi	-	LC	-	2
		Synallaxis scutata	estrelinha-preta	-	LC	-	2
	Tityridae	*Myiobius atricaudus*	assanhadinho-de-cauda-preta	-	LC	-	2
		Pachyramphus viridis	caneleiro-verde	-	LC	-	2
		Pachyramphus polychopterus	caneleiro-preto	-	LC	-	2
		Pachyramphus validus	caneleiro-de-chapéu-preto	-	LC	-	2
	Tyrannidae	*Fluvicola nengeta*	lavadeira-mascarada	-	LC	-	1; 2
		Myiozetetes similis	bentevizinho-de-penacho-vermelho	-	LC	-	1; 2
		Pitangus sulphuratus	bem-te-vi	-	LC	-	1; 2
		Megarynchus pitangua	neinei	-	LC	-	1
		Tyrannus melancholicus	suiriri	-	LC	-	1; 2
		Myiarchus tyrannulus	maria-cavaleira-de-rabo-enferrujado	-	LC	-	1; 2
		Hirundinea ferruginea	gibão-de-couro	-	LC	-	2

Order	Family	Taxon	Popular Name	Threat category			Source
				Federal	International		
				MMA nº 444/2014	IUCN, 2016	CITES, 2016	
		Stigmatura napensis	papa-mosca-do-sertão	VU	LC	-	2
		Stigmatura budytoides	alegrinho-balança-rabo	-	LC	-	2
		Euscarthmus meloryphus	barulhento	-	LC	-	2
		Camptostoma obsoletum	risadinha	-	LC	-	2
		Elaenia flavogaster	guaracava-de-barriga-amarela	-	LC	-	2
		Elaenia spectabilis	guaracava-grande	-	LC	-	2
		Elaenia albiceps	guaracava-de-crista-branca	-	LC	-	2
		Myiopagis viridicata	guaracava-de-crista-alaranjada	-	LC	-	2
		Phaeomyias murina	bagageiro	-	LC	-	2
		Phyllomyias fasciatus	piolhinho	-	LC	-	2
		Serpophaga subcristata	alegrinho	-	LC	-	2
		Legatus leucophaius	bem-te-vi-pirata	-	LC	-	2
		Myiarchus swainsoni	irré	-	LC	-	2
		Casiornis fuscus	caneleiro-enxofre	-	LC	-	2
		Philohydor lictor	bentevizinho-do-brejo	-	LC	-	2

Order	Family	Taxon	Popular Name	Threat category			Source
				Federal	International		
				MMA nº 444/2014	IUCN, 2016	CITES, 2016	
		Machetornis rixosa	suiriri-cavaleiro	-	LC	-	2
		Myiodynastes maculatus	bem-te-vi-rajado	-	LC	-	2
		Megarynchus pitangua	neinei	-	LC	-	2
		Tyrannus albogularis	suiriri-de-garganta-branca	-	LC	-	2
		Griseotyrannus aurantioatrocristatus	peitica-de-chapéu-preto	-	LC	-	2
		Empidonomus varius	peitica	-	LC	-	2
		Myiophobus fasciatus	filipe	-	LC	-	2
		Sublegatus modestus	guaracava-modesta	-	LC	-	2
		Fluvicola albiventer	lavadeira-de-cara-branca	-	LC	-	2
		Arundinicola leucocephala	freirinha	-	LC	-	2
		Cnemotriccus fuscatus	guaracavuçu	-	LC	-	2
		Lathrotriccus euleri	enferrujado	-	LC	-	2
		Satrapa icterophrys	suiriri-pequeno	-	LC	-	2
		Xolmis irupero	noivinha	-	LC	-	2

Order	Family	Taxon	Popular Name	Threat category			Source
				Federal	International		
				MMA nº 444/2014	IUCN, 2016	CITES, 2016	
	Rhynchocyclidae	*Leptopogon amaurocephalus*	cabeçudo	-	LC	-	2
		Tolmomyias sulphurescens	bico-chato-de-orelha-preta	-	LC	-	2
		Tolmomyias flaviventris	bico-chato-amarelo	-	LC	-	2
		Todirostrum cinereum	ferreirinho-relógio	-	LC	-	1; 2
		Hemitriccus margaritaceiventer	sebinho-de-olho-de-ouro	-	LC	-	2
	Corvidae	*Cyanocorax cyanopogon*	gralha-cancã	-	LC	-	1; 2
	Hirundinidae	*Pygochelidon cyanoleuca*	andorinha-pequena-de-casa	-	LC	-	1; 2
		Stelgidopteryx ruficollis	andorinha-serradora	-	LC	-	2
		Progne chalybea	andorinha-doméstica-grande	-	LC	-	2
		Tachycineta albiventer	andorinha-do-rio	-	-	-	2
	Troglodytidae	*Troglodytes musculus*	corruíra	-	-	-	1
		Cantorchilus longirostris	garrinchão-de-bico-grande	-	-	-	1; 2
		Troglodytes aedon	corruíra	-	LC	-	2

Order	Family	Taxon	Popular Name	Threat category			Source
				Federal	International		
				MMA nº 444/2014	IUCN, 2016	CITES, 2016	
	Polioptilidae	*Polioptila dumicola*	balança-rabo-de-máscara	-	LC	-	1
		Polioptila plumbea	balança-rabo-de-chapéu-preto	-	LC	-	2
	Turdidae	*Turdus rufiventris*	sabiá-laranjeira	-	LC	-	1; 2
		Turdus leucomelas	sabiá-branco	-	LC	-	2
		Turdus amaurochalinus	sabiá-poca	-	LC	-	2
	Mimidae	*Mimus saturninus*	sabiá-do-campo	-	LC	-	1; 2
	Coerebidae	*Coereba flaveola*	cambacica	-	LC	-	1; 2
	Thraupidae	*Thraupis sayaca*	sanhaçu-cinzento	-	LC	-	1; 2
		Compsothraupis loricata	tiê-caburé	-	LC	-	2
		Nemosia pileata	saíra-de-chapéu-preto	-	LC	-	2
		Tachyphonus rufus	pipira-preta	-	LC	-	2
		Lanio pileatus	tico-tico-rei-cinza	-	-	-	2
		Paroaria dominicana	cardeal-do-nordeste	-	LC	-	2
		Hemithraupis guira	saíra-de-papo-preto	-	LC	-	2
		Conirostrum speciosum	figuinha-de-rabo-castanho	-	LC	-	2
	Emberizidae	*Zonotrichia capensis*	tico-tico	-	LC	-	1; 2

Order	Family	Taxon	Popular Name	Threat category			Source
				Federal	International		
				MMA nº 444/2014	IUCN, 2016	CITES, 2016	
		Sicalis luteola	tipio	-	LC	-	1
		Volatinia jacarina	tiziu	-	LC	-	1; 2
		Sporophila angolensis	curió	-	-	-	1
		Coryphospingus pileatus	tico-tico-rei-cinza	-	LC	-	1
		Paroaria dominicana	cardeal-do-nordeste	-	LC	-	1
		Ammodramus humeralis	tico-tico-do-campo	-	LC	-	2
		Sicalis citrina	canário-rasteiro	-	LC	-	2
		Sicalis flaveola	canário-da-terra-verdadeiro	-	LC	-	2
		Sporophila lineola	bigodinho	-	LC	-	2
		Sporophila nigricollis	baiano	-	LC	-	2
		Sporophila albogularis	golinho	-	LC	-	2
		Sporophila bouvreuil	caboclinho	-	LC	-	2
	Cardinalidae	*Cyanocompsa brissonii*	azulão	-	LC	-	1; 2
	Icteridae	*Procacicus solitarius*	iraúna-de-bico-branco	-	LC	-	1

Order	Family	Taxon	Popular Name	Threat category			Source
				Federal	International		
				MMA nº 444/2014	IUCN, 2016	CITES, 2016	
		Icterus cayanensis	encontro	-	LC	-	1; 2
		Icterus jamacaii	corrupião	-	LC	-	1; 2
		Gnorimopsar chopi	graúna	-	LC	-	1; 2
		Chrysomus ruficapillus	garibaldi	-	LC	-	1; 2
		Agelaioides fringillarius	asa-de-telha-pálido	-	-	-	1; 2
		Molothrus bonariensis	vira-bosta	-	LC	-	1; 2
		Sturnella superciliaris	polícia-inglesa-do-sul	-	LC	-	2
	Fringillidae	*Euphonia chlorotica*	fim-fim	-	LC	-	1; 2
		Sporagra yarrellii	pintassilgo-do-nordeste	-	-	-	2
	Vireonidae	*Cyclarhis gujanensis*	pitiguari	-	LC	-	2
		Vireo olivaceus	juruviara-boreal	-	LC	-	2
		Hylophilus amaurocephalus	vite-vite-de-olho-cinza	-	LC	-	2
	Parulidae	*Myiothlypis flaveolus*	canário-do-mato	-	-	-	2
	Passeridae	*Passer domesticus*	pardal	-	LC	-	2
Pelecaniformes	Ardeidae	*Tigrisoma lineatum*	socó-boi	-	LC	-	2

Order	Family	Taxon	Popular Name	Threat category			Source
				Federal	International		
				MMA nº 444/2014	IUCN, 2016	CITES, 2016	
		Ixobrychus involucris	socoí-amarelo	-	LC	-	2
		Nycticorax nycticorax	savacu	-	LC	-	2
		Butorides striata	socozinho	-	LC	-	2
		Bubulcus ibis	garça-vaqueira	-	LC	-	2
		Ardea cocoi	garça-moura	-	LC	-	2
		Ardea alba	graça-branca-grande	-	LC	-	2
		Syrigma sibilatrix	maria-faceira	-	LC	-	2
		Egretta thula	garça-branca-pequena	-	LC	-	2
Piciformes	Picidae	*Picumnus sp*	pica-pau-anão	-	-	-	1
		Colaptes melanochloros	pica-pau-verde-barrado	-	LC	-	1; 2
		Picumnus pygmaeus	pica-pau-anão-pintado	-	LC	-	2
		Picumnus limae / fulvescens	pica-pau-anão-da-caatinga	-	LC	-	2
		Veniliornis passerinus	picapauzinho-anão	-	LC	-	2
		Piculus chrysochloros	pica-pau-dourado-escuro	-	LC	-	2
		Celeus flavescens	pica-pau-de-cabeça-amarela	-	LC	-	2

Order	Family	Taxon	Popular Name	Threat category			Source
				Federal	International		
				MMA nº 444/2014	IUCN, 2016	CITES, 2016	
		Dryocopus lineatus	pica-pau-de-banda-branca	-	-	-	2
		Campephilus melanoleucos	pica-pau-de-topete-vermelho	-	LC	-	2
Podicipediformes	Podicipedidae	*Tachybaptus dominicus*	mergulhão-pequeno	-	LC	-	2
		Podilymbus podiceps	mergulhão-caçador	-	LC	-	2
Psittaciformes	Psittacidae	*Ara chloropterus*	arara-vermelha-grande	-	LC	II	2
		Psittacara leucophthalmus	periquitão-maracanã	-	LC	II	2
		Eupsittula cactorum	periquito-da-caatinga	-	LC	II	1; 2
		Amazona aestiva	papagaio-verdadeiro	-	LC	II	1; 2
		Primolius maracana	maracanã-verdadeira	-	NT	I	2
		Forpus xanthopterygius	tuim	-	LC	II	2
Scolopaciformes	Scolopacidae	*Actitis macularia*	maçarico-pintado	-	LC	II	2
		Tringa solitaria	maçarico-solitário	-	LC	II	2
		Tringa flavipes	maçarico-de-perna-amarela	-	LC	II	2
	Jacanidae	*Jacana jacana*	jaçanã	-	LC	-	2
Strigiformes	Strigidae	*Glaucidium brasilianum*	caburé	-	LC	-	1
	Tytonidae	*Tyto furcata*	suindara	-	-	-	2

Order	Family	Taxon	Popular Name	Threat category			Source
				Federal	International		
				MMA nº 444/2014	IUCN, 2016	CITES, 2016	
	Strigidae	*Megascops choliba*	corujinha-do-mato	-	LC	-	2
		Bubo virginianus	jacurutu	-	LC	-	2
		Glaucidium brasilianum	caburé	-	LC	-	2
Suliformes	Phalacrocoracidae	*Phalacrocorax brasilianus*	biguá	-	LC	-	2
		Anhinga anhinga	biguatinga	-	LC	-	2
Tinamiformes	Tinamidae	*Crypturellus parvirostris*	inhambu-chororó	-	LC	-	1; 2
		Crypturellus noctivagus	joão-do-sul, zabelê	VU	NT	-	2
		Crypturellus tataupa	inhambu-chitã	-	LC	-	2
		Nothura boraquira	cordona-do-nordeste	-	LC	-	2
Trogoniformes	Trogonidae	*Trogon curucui*	surucuá-de-barriga-vermelha	-	LC	-	2

Elaboration: Arcadis, 2017

Source: (1) Golder Associates, 2005; (2) Olmos; Albano, 2012. Threat Categories: Least Concern (LC); Near Threatened (NT); Vulnerable (VU); Endangered; and Critically Endangered (CR). CITES: Appendix I - Lists the most endangered species. International trade is prohibited; Appendix II - Lists species at risk of becoming threatened with extinction if international trade is not controlled; and Appendix III - Lists species with partially regulated international trade, but which needs the cooperation of countries to avoid overexploitation.

b) Areas of Influence (DAA, ADI e AII)

Through field sampling in the directly affected area (DAA) and in the areas of direct influence (ADI) and indirect influence (AII) of the project, a total of 107 bird species were recorded, divided into 16 orders and 39 families (Data Table 5.2-30).

Some species were recorded outside the sampling points, on and around the transects. Among them are the cliff flycatcher (*Hirundinea ferruginea*), the masked water tyrant (*Fluvicola nengeta*), the tropical kingbird (*Tyrannus melancholicus*), the cattle tyrant (*Machetornis rixosa*), the social flycatcher (*Myiozetetes similisete*), the black-capped antwren (*Herpsilochmus atricapillus*) and the chalk-browed mockingbird (*Mimus saturninus*).

Six species of nocturnal birds were observed and heard after sunset, two owls: *Megascops choliba* and *Glaucidium brasilianum*; three nightjars: *Chordeiles pusillus, Caprimulgus rufus* and *Hydropsalis torquata;* and the common potoo *Nyctibius griseus.*

Nests of some species were found, such as the masked water tyrant (*Fluvicola nengeta*), in the vicinity of a water well (UTM 24L 0169839/9047202), where it was possible to observe adult individuals periodically entering the nest. Still in this water well, were found the migratory aquatic species of white-backed stilt (*Himantopus melanurus*) and solitary sandpiper (*Tringa solitaria*), represented by only one individual of each species.

Although the consolidation of species through the collection of secondary data has resulted in a greater fauna composition in relation to the species recorded during field sampling, it should be noted that the areas whose bibliographic survey covers have very distinct microclimate characteristics in relation to the characteristics observed in the project insertion area. The Serra da Capivara National Park region, for example, is characterized by a higher rainfall level strongly influenced by sedimentary plateaus, with the development of forest vegetation.

It should be noted, however, that the data collection during the drought in the area of the project by Golder (2005), although they were considered in this study as a source of secondary data, resulted in a composition of 76 bird species, which is 71% of the richness recorded during the rainy season.

Data Table 5.2-30 – Bird species registered using primary data in the Directly Affected Area (DAA), Area of Direct Influence (ADI) and Indirect Influence Area (AII). Type of record performed, classification of species according to sensitivity to anthropic changes (Stotz *et al.* 1996), nutrition habits, quantitative data for each sampled site and the respective threat categories.

Taxon	Popular Name	Register Type				Sensitivi-ty		Nutrition habits	Site A1	Site A2	Site A3	Site A4	Threat category		
													Federal	International	
		V	A	F	G	B	M						MMA nº 444/2014	IUCN, 2016	CITES, 2016
Tinamiformes													-	-	-
Tinamidae													-	-	-
Crypturellus parvirostris *	inhambu-chororó		X			X		F					-	LC	-
Crypturellus tataupa *	inhambu-chintã		X			X		F			66		-	LC	-
Ciconiiformes													-	-	-
Ardeidae													-	-	-
Butorides striata #	socozinho	X				X		P				100	-	LC	-
Bubulcus ibis	garça-vaqueira	X				D		I				100	-	LC	-
Ardea alba #	garça-branca-grande	X				X		P				100	-	LC	-
Egretta thula #	garça-branca-pequena	X				X		P					-	LC	-
Cathartiformes													-	-	-
Cathartidae													-	-	-

Taxon	Popular Name	Register Type				Sensitivi-ty		Nutrition habits	Site A1	Site A2	Site A3	Site A4	Threat category		
													Federal	International	
		V	A	F	G	B	M						MMA nº 444/2014	IUCN, 2016	CITES, 2016
Cathartes aura	urubu-de-cabeça-vermelha	X				X		D	16		66	100	-	LC	-
Cathartes burrovianus	urubu-de-cabeça-amarela	X					X	D	33	50	33	200	-	LC	-
Coragyps atratus	urubu-de-cabeça-preta	X				X		D	66	25	33		-	LC	-
Accipitriformes															
Accipitridae													-	-	-
Geranospiza caerulescens	gavião-pernilongo	X					X	C		50	66		-	LC	II
Rupornis magnirostris	gavião-carijó	X	X			X		C	16	50			-	LC	II
Falconiformes													-	-	-
Falconidae													-	-	-
Caracara plancus	caracará	X				X		C		25			-	LC	II
Herpetotheres cachinnans	acauã		X		X	X		C			33		-	LC	II
Falco sparverius	quiriquiri	X				X		C					-	LC	II
Falco femoralis	falcão-de-coleira	X				X		C					-	LC	II
Gruiformes													-	-	-

Taxon	Popular Name	Register Type				Sensitivi-ty		Nutrition habits	Site A1	Site A2	Site A3	Site A4	Threat category		
													Federal	International	
		V	A	F	G	B	M						MMA nº 444/2014	IUCN, 2016	CITES, 2016
Cariamidae													-	-	-
Cariama cristata	seriema		X				X	C					-	LC	-
Charadriiformes													-	-	-
Charadriidae													-	-	-
Vanellus chilensis	quero-quero	X				X		I		50			-	LC	-
Recurvirostridae													-	-	-
Himantopus melanurus #	pernilongo-de-costas-brancas	X					X	I					-	-	-
Scolopacidae													-	-	-
Tringa solitaria #	maçarico-solitário	X				D		I					-	LC	-
Jacanidae													-	-	-
Jacana jacana #	jaçanã	X				X		I				200	-	LC	-
Columbiformes													-	-	-
Columbidae													-	-	-
Columbina squammata	fogo-apagou	X				X		G	100	75	333	700	-	LC	-
Columbina picui	rolinha-picui	X				X		G		50	200	200	-	LC	-
Patagioenas picazuro *	pombão	X					X	G			33	200	-	LC	-

Taxon	Popular Name	Register Type				Sensitivi-ty		Nutrition habits	Site A1	Site A2	Site A3	Site A4	Threat category		
													Federal	International	
		V	A	F	G	B	M						MMA nº 444/2014	IUCN, 2016	CITES, 2016
Zenaida auriculata *	pomba-de-bando	X				X		G	215	125	333		-	LC	-
Leptotila verreauxi	juriti-pupu	X				X		G	16	575		100	-	LC	-
Psittaciformes													-	-	-
Psittacidae													-	-	-
Eupsittula cactorum 1, 2	periquito-da-caatinga	X					X	F	33	625	133	500	-	LC	-
Forpus xanthopterygius	tuim	X				X		F					-	LC	-
Amazona aestiva x	papagaio-verdadeiro	X	X				X	F	33				-	LC	-
Cuculiformes													-	-	-
Cuculidae													-	-	-
Crotophaga ani	anu-preto	X				X		C, I					-	LC	-
Guira guira	anu-branco	X				X		C, I	33	175			-	LC	-
Tapera naevia	saci		X			X		C, I			33		-	LC	-
Strigiformes													-	-	-
Strigidae													-	-	-
Megascops choliba	corujinha-do-mato		X		X	X		C					-	LC	-
Glaucidium brasilianum	caburé		X		X	X		C					-	LC	-

Taxon	Popular Name	Register Type				Sensitivi-ty		Nutrition habits	Site A1	Site A2	Site A3	Site A4	Threat category		
													Federal	International	
		V	A	F	G	B	M						MMA nº 444/2014	IUCN, 2016	CITES, 2016
Caprimulgiformes													-	-	-
Nyctibiidae													-	-	-
Nyctibius griseus	mãe-da-lua		X			X		I					-	LC	-
Caprimulgidae													-	-	-
Chordeiles pusillus	bacurauzinho	X	X				X	I					-	LC	-
Caprimulgus rufus	joão-corta-pau		X		X	X		I					-	LC	-
Hydropsalis torquata	bacurau-tesoura	X				X		I					-	LC	-
Apodiformes													-	-	-
Apodidae													-	-	-
Streptoprocne biscutata	taperuçu-de-coleira-falha	X					X	I	83				-	LC	-
Trochilidae													-	-	-
Eupetomena macroura	beija-flor-tesoura	X				X		N			66	100	-	LC	II
Chlorostilbon lucidus	besourinho-de-bico-vemelho	X				X		N			33		-	LC	II
Coraciiformes													-	-	-
Alcedinidae													-	-	-

Taxon	Popular Name	Register Type				Sensitivi-ty		Nutrition habits	Site A1	Site A2	Site A3	Site A4	Threat category		
													Federal	International	
		V	A	F	G	B	M						MMA nº 444/2014	IUCN, 2016	CITES, 2016
Chloroceryle amazona #	martim-pescador-verde	X				X		P				100	-	LC	-
Bucconidae													-	-	-
Nystalus maculatus 1	rapazinho-dos-velhos		X				X	I					-	LC	-
Piciformes													-	-	-
Picidae													-	-	-
Picumnus pygmaeus 1, 2	pica-pau-anão-pintado	X					X	I	16		33		-	LC	-
Melanerpes candidus	birro, pica-pau-branco	X				X		I					-	LC	-
Veniliornis passerinus	picapauzinho-anão	X				X		I	50		33		-	LC	-
Piculus chrysochloros	pica-pau-dourado-escuro	X					X	I		25			-	LC	-
Colaptes melanochloros	pica-pau-verde-barrado	X				X		I					-	LC	-
Colaptes campestris	pica-pau-do-campo	X	X			X		I					-	LC	-
Passeriformes													-	-	-

Taxon	Popular Name	Register Type				Sensitivi-ty		Nutrition habits	Site A1	Site A2	Site A3	Site A4	Threat category		
													Federal	International	
		V	A	F	G	B	M						MMA nº 444/2014	IUCN, 2016	CITES, 2016
Thamnophilidae													-	-	-
Sakesphorus cristatus 1, 2	choca-do-nordeste	X	X		X		X	I	233		33	100	-	LC	-
Thamnophilus doliatus	choca-barrada	X	X		X	X		I	33		100	100	-	LC	-
Thamnophilus pelzelni	choca-do-planalto	X	X		X	X		I	33				-	LC	-
Myrmorchilus strigilatus	piu-piu	X	X		X		X	I	66				-	LC	-
Herpsilochmus atricapillus	chorozinho-de-chapéu-preto	X		X			X	I					-	LC	-
Formicivora grisea	papa-formiga-pardo	X	X		X	X		I	50	25	100		-	LC	-
Formicivora melanogaster	formigueiro-de-barriga-preta	X	X				X	I	83				-	LC	-
Grallariidae													-	-	-
Hylopezus ochroleucus 1, 2	torom-do-nordeste		X		X		X	I	100				-	NT	-
Dendrocolaptidae													-	-	-
Lepidocolaptes angustirostris	arapaçu-de-cerrado	X	X				X	I	16	75	66		-	LC	-

Taxon	Popular Name	Register Type				Sensitivi-ty		Nutrition habits	Site A1	Site A2	Site A3	Site A4	Threat category		
													Federal	International	
		V	A	F	G	B	M						MMA nº 444/2014	IUCN, 2016	CITES, 2016
Furnariidae													-	-	-
Furnarius figulus	casaca-de-couro-da-lama	X				X		I				200	-	LC	-
Gyalophylax hellmayri 1, 2	joão-chique-chique	X	X		X		X	I	50				-	NT	-
Certhiaxis cinnamomeus	curutié	X					X	I				400	-	LC	-
Phacellodomus rufifrons	joão-de-pau	X					X	I					-	LC	-
Pseudoseisura cristata 1, 2	casaca-de-couro	X	X		X		X	I		325			-	LC	-
Tyrannidae													-	-	-
Hemitriccus margaritaceiventer	sebinho-de-olho-de-ouro	X	X		X		X	I			100		-	LC	-
Todirostrum cinereum	ferreirinho-relógio	X	X			X		I		125	33		-	LC	-
Elaenia spectabilis	guaracava-grande		X			X		O		25	33		-	LC	-
Elaenia cristata	guaracava-de-topete-uniforme		X				X	O		25			-	LC	-
Camptostoma obsoletum	risadinha		X			X		I	16			100	-	LC	-
Phaeomyias murina	bagageiro	X	X		X	X		I	16				-	LC	-

Taxon	Popular Name	Register Type				Sensitivi-ty		Nutrition habits	Site A1	Site A2	Site A3	Site A4	Threat category		
													Federal	International	
		V	A	F	G	B	M						MMA nº 444/2014	IUCN, 2016	CITES, 2016
Euscarthmus meloryphus	barulhento	X	X	X	X	X		I	300		133		-	LC	-
Tolmomyias flaviventris	bico-chato-amarelo	X	X		X	X		I	33				-	LC	-
Hirundinea ferruginea	gibão-de-couro	X	X	X		X		I					-	LC	-
Cnemotriccus fuscatus	guaracavuçu	X	X			X		I	50		66		-	LC	-
Xolmis cinereus	primavera	X				X		I					-	LC	-
Fluvicola nengeta	lavadeira-mascarada	X				X		I				400	-	LC	-
Machetornis rixosa	suiriri-cavaleiro	X				X		I					-	LC	-
Myiozetetes similis	bentevizinho-de-penacho-vermelho	X	X			X		O		25			-	LC	-
Pitangus sulphuratus	bem-te-vi	X				X		O		100	66	200	-	LC	-
Myiodynastes maculatus	bem-te-vi-rajado	X	X			X		I	16	25			-	LC	-
Megarynchus pitangua	neinei	X	X			X		O					-	LC	-
Empidonomus varius	peitica	X	X			X		I		50			-	LC	-
Tyrannus melancholicus	suiriri	X	X			X		I	33	75	166	500	-	LC	-
Myiarchus swainsoni	irré		X			X		I		75		100	-	LC	-

Taxon	Popular Name	Register Type				Sensitivi-ty		Nutrition habits	Site A1	Site A2	Site A3	Site A4	Threat category		
													Federal	International	
		V	A	F	G	B	M						MMA nº 444/2014	IUCN, 2016	CITES, 2016
Myiarchus tyrannulus	maria-cavaleira-de-rabo-enferrujado	X	X			X		I	33	125	33		-	LC	-
Tityridae													-	-	-
Pachyramphus polychopterus	caneleiro-preto		X			X		I		50	33		-	LC	-
Pachyramphus validus	caneleiro-de-chapéu-preto	X	X				X	I					-	LC	-
Vireonidae													-	-	-
Cyclarhis gujanensis	pitiguari		X			X		O	116	100	166	10	-	LC	-
Corvidae													-	-	-
Cyanocorax cyanopogon 1, 2	gralha-cancã	X	X				X	O		325	33	100	-	LC	-
Hirundinidae													-	-	-
Progne chalybea	andorinha-doméstica-grande	X				X		I					-	LC	-
Pygochelidon cyanoleuca	andorinha-pequena-de-casa	X				X		I					-	LC	-
Troglodytidae													-	-	-

Taxon	Popular Name	Register Type				Sensitivi-ty		Nutrition habits	Site A1	Site A2	Site A3	Site A4	Threat category		
													Federal	International	
		V	A	F	G	B	M						MMA nº 444/2014	IUCN, 2016	CITES, 2016
Troglodytes musculus	corruíra	X				X		I		50		200	-	-	-
Cantorchilus longirostris 1	garrinchão-de-bico-grande	X	X			X		I	33		66		-	-	-
Polioptilidae													-	-	-
Polioptila plumbea	balança-rabo-de-chapéu-preto	X	X		X	X		I	50	100	133		-	LC	-
Turdidae													-	-	-
Turdus rufiventris x	sabiá-laranjeira	X				X		O			33	100	-	LC	-
Mimidae													-	-	-
Mimus saturninus	sabiá-do-campo	X				X		O		300		400	-	LC	-
Thraupidae													-	-	-
Thraupis sayaca	sanhaçu-cinzento	X				X		O					-	LC	-
Tangara cayana	saíra-amarela	X					X	F					-	LC	-
Tersina viridis	saí-andorinha	X	X			X		F	16				-	LC	-
Emberizidae													-	-	-
Zonotrichia capensis x	tico-tico	X	X			X		O			33	100	-	LC	-

Taxon	Popular Name	Register Type				Sensitivi-ty		Nutrition habits	Site A1	Site A2	Site A3	Site A4	Threat category		
													Federal	International	
		V	A	F	G	B	M						MMA nº 444/2014	IUCN, 2016	CITES, 2016
Sporophila albogularis 1, 2, x	golinho	X					X	G		50			-	LC	-
Coryphospingus pileatus x	tico-tico-rei-cinza	X	X			X		G	33		100		-	LC	-
Paroaria dominicana 1, 2, x	cardeal-do-nordeste	X	X	X		X		G	33	125	133	500	-	LC	-
Cardinalidae													-	-	-
Cyanocompsa brissonii x	azulão	X	X		X		X	G			133	100	-	LC	-
Icteridae													-	-	-
Icterus jamacaii 1, 2, x	corrupião	X				X		O		75			-	LC	-
Gnorimopsar chopi x	graúna	X				X		O					-	LC	-
Agelaioides fringillarius 1, 2	asa-de-telha-pálido	X	X			X		O				500	-	-	-
Molothrus bonariensis	vira-bosta	X				X		O					-	LC	-
Fringillidae													-	-	-
Euphonia chlorotica	fim-fim		X			X		F					-	LC	-

Elaboration: Arcadis, 2017.

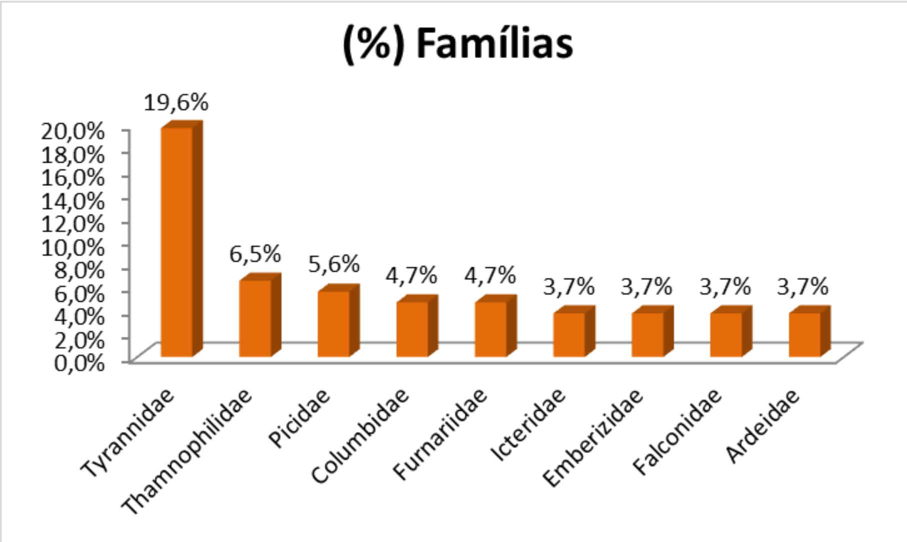
Legend: (1) Endemic species of Brazil; (2) Endemic species of the Caatinga or whose distribution is mainly centred on this biome; (#) Species associated with aquatic environments; (*) Species considered cynegetic (hunting birds); (x) Bird of commercial value (bird of cage).
Register type: (V) Visual; (A) Audio; (F) Photographic/Visual; (G) Voice recording - Audio/Visual.

Sensitivity to anthropogenic changes according to Stotz et. al (1996): (A) High; (M) Medium; (B) Low; (D) Unknown.
Nutrition habits according to Sick (1997): (O) Omnivore; (I) Insectivore; (F) Frugivore; (N) Nectarivore; (G) Granivore; (C) Carnivore; (D) Detritivore; (P) Piscivore.
Threat Categories: Threat Categories: Least Concern (LC); Near Threatened (NT); Vulnerable (VU); Endangered; and Critically Endangered (CR). CITES: Appendix I - Lists the most endangered species. International trade is prohibited; Appendix II - Lists species at risk of becoming threatened with extinction if international trade is not controlled; and Appendix III - Lists species with partially regulated international trade, but which needs the cooperation of countries to avoid overexploitation.

Fauna composition

The most representative family in the study area was Tyrannidae, with approximately 20% of the total registered species, followed by the families Thamnophilidae (6.5%), Picidae (5.6%), Columbidae and Furnariidae (4.7 %) and Icteridae, Emberizidae, Falconidae and Ardeidae with 3.7%, each. It is noteworthy that the other families were represented by 3% or less of the total of registered species, each (Graph 5.2-4).

Graph 5.2-4 – Representativeness (%) of birds' families registered in the study area.



Several species found in the field work are endemic to the Caatinga and, consequently, endemic to Brazil. They are: *Eupsittula cactorum, Picumnus pygmaeus, Sakesphorus cristatus, Hylopezus ochroleucus, Gyalophylax hellmayri, Cyanocorax cyanopogon, Sporophila albogularis* and *Paroaria dominicana*. The species *Pseudoseisura cristata, Icterus jamacaii* and *Agelaioides fringillarius*, also registered in this study, are the result of "split", that is, the separation of one species in two, and, as a consequence, were restricted to the Caatinga. This occurs when two different populations of the same species, after studies of taxonomic revision, come to be considered different species, usually existing in different locations, sometimes separated by geographical barriers. The 11 endemic species of the Caatinga found in this study represent 10% of the total registered species.

In addition to these, the caatinga puffbird (*Nystalus maculatus*), also found in other physiognomies such as the Cerrado, and the long-billed wren (*Cantorchilus longirostris*), also found in "Restingas" (coastal forests), are endemic to Brazil.

Sensitivity to anthropogenic changes refers to the species' ability to persist in environments altered or influenced in some way by human. None of the registered species is considered to be highly sensitive to anthropogenic changes, according to Stotz *et al.* (1996), although 29 are classified as medium sensitive (27.1%), 76 low (71%) and two of unknown sensitivity (1.9%). Some of the species considered to be of medium sensitivity were found in great abundance in the region, such as the caatinga parakeet (*Eupsittula cactorum*), the silvery-cheeked antshrike (*Sakesphorus cristatus*), the stripe-backed antbird (*Myrmorchilus strigilatus*), the caatinga cacholote (*Pseudoseisura cristata*) and the lesser yellow-headed vulture (*Cathartes burrovianus*), the latter being very common even within urbanized areas.

The number of species found (n = 107) during the field survey was relatively high compared to the previous study (n = 76), carried out by Golder Associates (2005) during the dry period. The present study had a greater sampling effort, even so, the period of the previous study was more favourable to the detection of avifauna, since it corresponded to the period in which the birds are in intense reproductive activity (October).

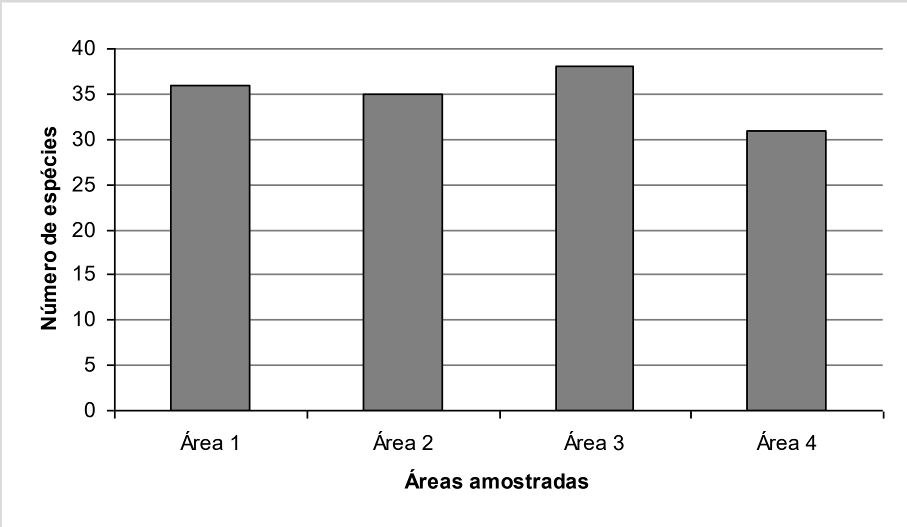
In February, the period of sampling in the rainy season, the birds are close to the reproductive rest and are quieter, with reduced activity, some starting the migratory process fleeing from the south of South America, going to regions more central, such as the North and Northeast of Brazil and Central America. Among the migratory species found is the solitary sandpiper (*Tringa solitaria*), a northern visiting species, which occurs throughout Brazil at the edge of water bodies. There were also records of species that carry out migratory movements within the national territory, such as the white-backed stilt (*Himantopus melanurus*), the least nighthawk (*Chordeiles pusillus*), the biscutate swift (*Streptoprocne biscutata*), the streaked flycatcher (*Myiodynastes maculatus*), the variegated flycatcher (*Empidonomus varius*), the tropical kingbird (*Tyrannus melancholicus*), the crested becard (*Pachyramphus validus*), the grey-breasted martin (*Progne chalybea*), the blue-and-white swallow (*Pygochelidon cyanoleuca*) and the swallow tanager (*Tersina viridis*). Not all individuals of these species migrate, which may vary between populations and between geographic regions in which they occur.

In the campaign carried out during the dry season (Golder Associates, 2005), 25 species were found that were not diagnosed in this study. Of these species, two are considered to be highly sensitive to anthropic changes, the lesser woodcreeper (*Xiphorhynchus fuscus*) and the black-billed scythebill (*Campylorhamphus falcularius*). These species were not found in the rainy season, possibly due to their low density. The others could be absent (migrating) or simply not detected at the time of the study. Thus, considering the species survey carried out by Golder Associates during the dry season (2005) and the field survey carried out due to the licensing of this project (2008), a total of 132 species were registered for the region of the project, which indicates a representative sample of diversity, given that 73% of all fauna expected for the region was registered in the area of the project.

Distribution of fauna by the environment

Although the number of species was similar between the sampled areas (Figure 5.2-5), the overlap between the species recorded in each location was low. This can be attributed to the fact that the physiognomies of the sampled environments are different in terms of vegetation structure and degree of degradation. The dissimilarity, obtained by calculating the Sorensen Index, was significant between Area A1, characterized by arboreal caatinga, and Area A4, where the caatinga was degraded and there was a lagoon.

Figure 5.2-5 – Number of species recorded at each sampling site in the Project's Areas of Influence.



The most abundant species in all areas sampled systematically was the caatinga parakeet (*Eupsittula cactorum*), with 36 contacts, followed by the scaled dove (*Columbina squammata*), with 26 contacts, and the tawny-crowned pygmy tyrant (Euscarthmus meloryphus), with 22 contacts.

Areas A1 and A3 were the most significant for avifauna, in view of the species present. The species found in these places are the most demanding in terms of habitat, especially the Thamnophilidae, Picidae and Tyrannidae found.

The more anthropized areas, such as pastures and urban environment, favour the presence of species such as the shiny cowbird (*Molothrus bonariensis*) and the eared dove (*Zenaida auriculata*), which forage in open areas, and were found throughout the entire area studied.

Species of economic interest and / or of veterinary-medicine

Two species of tinamou, the Small-billed tinamou (*Crypturellus parvirostris*) and the tataupa tinamou (*Crypturellus tataupa*), and two species of pigeon, picazuro pigeon (*Patagioenas picazuro*) and the eared dove (*Zenaida auriculata*), are considered cynegetic species, much appreciated by hunters. In addition to these, eight species of Passeriformes and the turquoise-fronted amazon (*Amazona aestiva*), are considered of commercial value, being commonly hunted to be sold.

Species threatened and protected by legislation

No species registered in the study area during the field survey is threatened with extinction. Only two species (*Hylopezus ochroleucus* and *Gyalophylax hellmayri*) are almost threatened, according to IUCN (2016). It was also found that 101 registered species are classified as " least concern ", according to IUCN (2016) and of these, eight are at risk of becoming threatened with extinction, if international trade is not controlled (CITES, 2016).

Rare and / or restricted species

The studied areas are important due to the high number of Caatinga endemism that they shelter. Despite the anthropization observed in the study area, the Caatinga avifauna is representative, with a high number of species of restricted distribution to this biome (11 species, 10% of the total registered species). The species detected during the field survey demonstrate that there are still areas of this biome capable of supporting populations of the species found, even the most demanding ones, such as those of the family Picidae and Thamnophilidae.

C) Summary

The present study indicated a satisfactory sampling of avifauna in the region, with a record of 73% of the fauna likely to occur. The survey shows a high number of species with restricted distribution to the Caatinga biome, some of which are highly appreciated by hunters and others of high commercial value. No species detected in the study area is threatened with extinction, and most registered birds have low sensitivity to anthropogenic changes, so they manage to maintain their populations even in anthropized and fragmented environments. Therefore, it is considered that the 132 species detected for the study region, correspond to a representative sample of the local avifauna.

D) Photographic Report

Photo 5.2-42 – red-cowled cardinal (*Paroaria dominicana*).

Photo 5.2-43 – caatinga cacholote (*Pseudoseisura cristata*).

Photo 5.2-44 – caatinga cacholote nest (*Pseudoseisura cristata*).

Photo 5.2-45 – Researcher in observation activity.

Photo 5.2-46 – tawny-crowned pygmy tyrant (*Euscarthmus meloryphus*).

Photo 5.2-47 – cliff flycatcher (*Hirundinea ferruginea*).

Photo 5.2-48 – cliff flycatcher (*Hirundinea ferruginea*).

Photo 5.2-49 – masked water tyrant (*Fluvicola nengeta*).

Photo 5.2-50 – masked water tyrant nest (*Fluvicola nengeta*).

Photo 5.2-51 – tropical kingbird (*Tyrannus melancholicus*).

Photo 5.2-52 – cattle tyrant (*Machetornis rixosa*).

Photo 5.2-53 – social flycatcher (*Myiozetetes similis*).

Photo 5.2-54 – female black-capped antwren (*Herpsilochmus atricapillus*).

Photo 5.2-55 – immature chalk-browed mockingbird (*Mimus saturninus*).

Photo 5.2-56 – Turkey vulture (*Cathartes aura*) and Black vulture (*Coragyps atratus*).

5.2.4.2. Herpetofauna

Considering that, through the analysis of updated satellite images, the use and occupation of the land in the area of the project has undergone little change in relation to the surveys carried out in this same area in 2008, it was agreed at a meeting held on September 2nd , 2016 between SEMAR-PI and PNM representatives, that the primary data covered in this chapter will be those whose surveys were carried out in the study area for this same project, aimed to compose the Environmental and Social Impact Assessment (ESIA) and the respective Environmental and Social Impact Assessment Report (RIMA), prepared by ARCADIS Tetraplan, in 2008 for Companhia Vale do Rio Doce.

A) Methodological Considerations

a) Collection of Secondary Data

Aiming to list the fauna species likely to occur in the study region, data available in scientific publications were compiled in order to contribute to the characterization of the amphibian and reptile community present in the study area of this project.

For the survey of species of herpetofauna that could potentially occur in the region, the data published for the Serra da Capivara National Park, Piauí (Arruda, 1997; Cavalcanti, *et al*. 2014) and for the Serra das Confusões National Park were compiled, Piauí (Vechio, *et al*. 2016).

b) Field sampling

Sample period

The study of amphibians and reptiles, through data collection in the field, was conducted in a sampling campaign. Data collection was carried out between February 18th and 29th, 2008 (rainy season).

Spatial coverage of the study

The spatial scope for collecting primary data included the Directly Affected Area (DAA), and the Direct Influence (ADI) and Indirect (AII) area of the project.

The pitfall lines were distributed in eight sampling sites, as described below and Map 5.2-10

Data Table 5.2-31 – Characterization and location of the sample sites for trapping and falling traps (pitfall).

Samples – Site Location	Geographic coordinates (UTM)		Zone	Project component and structure	Vegetation	Description of Area
H 1 (DAA/ ADI)	177310	9063119	24L	Brejo seco, access road to the Nickel Mine	Arboreal shrub vegetation, with mixtures between open and dense areas	Located close to the access road to the nickel mine, it consists of a flat interfluvial of sandy soil, covered by a uniform caatinga, formed by a tree stratum 2 to 3 m high, dominated by cinnamon (*Cenostigma macrophyllum*). The density of vegetation in this tree layer is variable and in places where it is discontinuous there is greater development of the tree layer.
H 2 (DAA)	173389	9064645	24L	Nickel Mine	Arboreal shrub vegetation, with the presence of terrestrial bromeliads	Located in the nickel mine, composed of shrubbery caatinga with height varying from 2-3 m, spaced presence of terrestrial bromeliads and soil partially covered by thin litter. The terrain is flat and consists of yellowish sandy soil.
H 3 (DAA)	174265	9064606	24L	Nickel Mine	Arboreal shrub vegetation, with the presence of larger trees.	Located in the nickel mine, lined with shrubby bush. The lateritic hill and part of the interfluvial depression at its base are crossed by a grid of roads used to conduct surveys. The places where the traps were installed were slightly inclined, with deep sandy soil, partially covered with litter, and had vegetation from 3 to 5 m high.
H 4 (DAA)	171785	9070121	24L	Adductor and LT	Arboreal shrub vegetation, with the presence of terrestrial bromeliads	Located in the pipeline and Transmission Line area. The area is made up of arboreal caatinga in a flat interfluvium with pink sand soil with thick litter. The vegetation is 1 to 4 m tall, with a tree stratum of variable density, with cinnamon being the most common species. It has a low, green and dense shrub layer in the most open places. Terrestrial bromeliads, mainly gravatás (*Bromeliaceae*), are present locally.

Samples – Site Location	Geographic coordinates (UTM)		Zone	Project component and structure	Vegetation	Description of Area
H 5 (ADI)	187341	9035288	24L	Umbuzeiro, near the Limestone Mine	Arboreal shrub vegetation, with the presence of bromeliads and rocky outcrops	Located in the Limestone mine area, it is next to a valley of relief more embedded. In general, this area is not very steep, but it presents many outcrops of limestone, of variable sizes. The area is very disturbed by the extraction and processing of limestone, which requires the consumption of firewood, obtained by cutting the vegetation, which, in general, has a secondary character. The shallow red clay soil is interspersed with quartz and limestone pebbles partially covered by litter. The tree layer is not very dense and is composed of relatively high trees, where aroeira stands out (*Myracrodruon urundeuva*). The shrub and herbaceous layer are extremely open, with the presence of mandacarus (*Cereus jamacaru*) and xique-xiques (*Pilocereus gounelei*).
H 6 (DAA)	186073	9045180	24L	Access road to the limestone mine	Vegetation composed of sparse caatinga, with soil formed by white sand with macambira and spaced trees	Located on the route between the municipality of Capitão Gervásio and the limestone mine area (Umbuzeiro). The terrain is flat, with deep white sand soil, formed by areas of exposed sand, large patches of macambira (*Encholirium spectabile*), more shrubby areas and with larger trees where the soil is covered by thin litter.

Samples – Site Location	Geographic coordinates (UTM)		Zone	Project component and structure	Vegetation	Description of Area
H 7 (AII)	185996	9041180	24L	Near the access road to the limestone mine	Tree shrub vegetation, with soil composed of yellow sand and dry shrub vegetation	Located on the route between the municipality of Capitão Gervásio and the limestone mine area, on the road to transport the extracted material. The area consists of arboreal caatinga on a flat ground on yellow sand soil. In this area there is a sparse occurrence of umbu (*Spondias tuberosa*) and cambão umburana (*Bursera leptophloeos*). The litter under the trees is thick and the herbaceous layer is open. In the most open places, low density bushes occur, and the leaf is thin and discontinuous.
H 8 (AII)	188778	9050118	24L	Near the access road to the limestone mine	Sparse trees, dense green vegetation with terrestrial bromeliads	Located on the route between the municipality of Capitão Gervásio and the Limestone mine area, on the road to transport the extracted material. It is a flat area, with yellow sand soil covered by a thin layer of litter. The vegetation is low, although dense, between 1 and 3 m in height, formed mainly by shrubs and an herbaceous layer dominated by a single species, with some clumps of terrestrial bromeliads

Elaboration: ARCADIS Tetraplan, 2008.

Contrary to the sampling performed by interception and fall traps, which occurred mainly in the areas of deep sandy soil of the flattened interflows, the active search concentrated in many areas at the bottom of the valleys, in isolated elevations of crystalline rocks in the depression, and at the base of the sedimentary plateau where the soil is shallow and rocky outcrops are frequent, making it difficult to install fall traps (Data Table 5.2-32; Map 5.2-10)

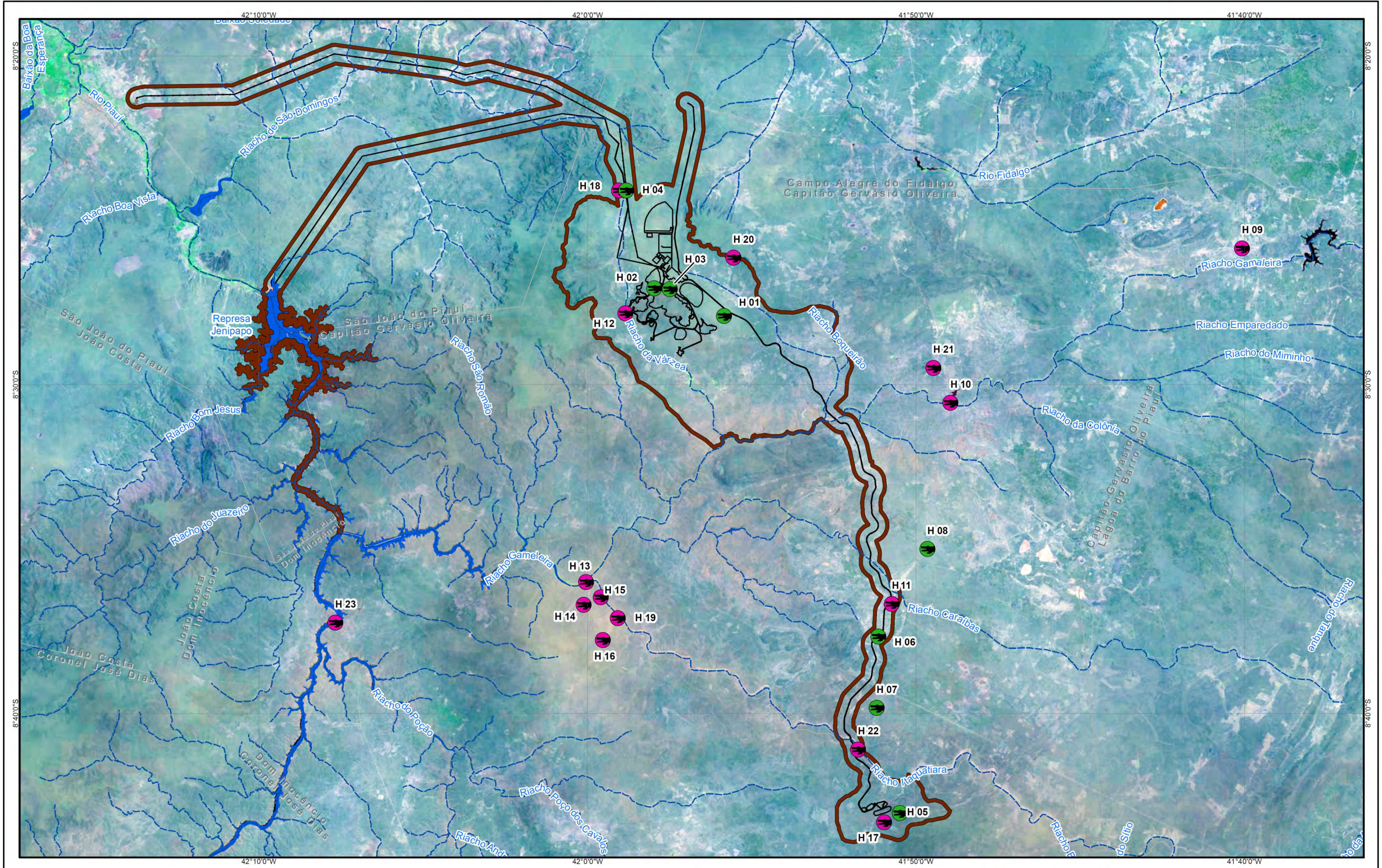
Data Table 5.2-32 – Location and description of sample sites for active search.

Samples – Site Location	Geographic coordinates (UTM)		Zone	Project component and structure	Area Description
H 9 (AII)	206240	9067126	24L	Near PI - 142	Dry, flat valley with damp sandy soil, perpendicular to the road with trees and low shrubs and patches of exposed soil.
H 10 (AII)	190003	9058336	24L	Near PI - 465	Dry stream bed with rocky outcrops located on the road to the limestone mine near Capitão Gervásio. Alluvial sand and fine gravel with a small depression near the rocky wall where it forms a puddle surrounded with intertwined sticks. In the areas of rocky slopes, the vegetation is sparse. At the bottom of the valley there are plantations surrounded with fences for goats.
H 11 (DAA/ADI)	186810	9047025	24L	Access road to the Limestone Mine	Areas of white sand with plenty of exposed soil between large outcrops of granite, with some isolated carnaubas, bushes, trees and macambiras.
H 12 (DAA/ADI)	171781	9063238	24L	Nickel Mine	Jenipapo Dam. Caatinga area near the bottom of a dry valley with a small weir approximately 50 m long, shallow and with stagnant water.
H 13 (AII)	830185	9048116	23L	Access road to Jenipapo Dam	Slope with shallow soil, housing and corral above a dry riverbed. Muddy riverbed covered with grass, with some puddles of water. Near the river there are rocky outcrops.
H 14 (AII)	830054	9046842	23L	Access road to Jenipapo Dam	Rocky slab on the side of the road in an interfluvial area, with some cacti and macambiras in the cracks, where two small pools of water formed on the depressions of the rocky surface.
H 15 (AII)	169839	9047202	24L	Access road to Jenipapo Dam	Depression at the roadside, forming a 5 m long puddle without associated vegetation.
H 16 (AII)	171298	9045864	24L	Access road to Jenipapo Dam	Puddles 5 to 10 m long, on both sides of the road. No vegetation on the bank, but with some trees around.

Samples – Site Location	Geographic coordinates (UTM)		Zone	Project component and structure	Area Description
H 17 (ADI)	187341	9035288	24L	Umbuzeiro, near the Limestone Mine	Limestone, close to the trap lines.
H 18 (DAA)	171785	9070121	24L	Adductor and LT	2600 m trail in the caatinga near the fall trap lines, near the MST settlement.
H 19 (AII)	171498	9046107	24L	Access road to Jenipapo Dam	Large slab of rocks on the riverbank down the road, where the bedrock forms many pools of water. Upstream of the road the bed is muddy, almost without stones, forming pools of water between the grass.
H 20 (ADI)	177814	9066389	24L	Brejo seco	Higher forest, many dry logs on the ground. Dark litter, shallow and stony soil in caves above the corral.
H 21 (AII)	189024	9060299	24L	Near PI - 465	White quartzite hill, between Pousada Cactus and the beginning of the road to the nickel deposit. Flat area, stony soil, very dense shrub vegetation, completely leafless. On the escarpment of the trail to the hill, dry shrub vegetation is observed between pebbles. At the top, large outcrops of white, milky rock, with pink veins, showing shrub vegetation, huge cacti and large clumps of macambira between the cracks.
H 22 (DAA/ADI)	184981	9038837	24L	Access road to the Limestone Mine	Wide stream bed totally dry with rocks and banks of coarse or sandy sediments, with some larger trees between the rocks of the marginal banks. Some areas of moist soil.
H 23 (AII)	816166	9045950	23L	Near Jenipapo Dam	Dam with shallow rocky soil on a sloping bank with some old buildings. Very little developed vegetation, covering the substrate little, exposed for the most part.

Elaboration: ARCADIS Tetraplan, 2008.

Map 5.2-10 – Herpetofauna sampling sites.



LEGENDA

- Intermittent Drainage
- Water Mass
- Municipal Limits
- Area of Direct Influence - ADI
- Directly Affected Area - DAA

Sampling Sites

- Active Search
- Pitfall

REFERÊNCIAS

ARCADIS Tetraplan, 2008;
IBGE, Base contínua 1:250.000, 2015;
LANDSAT, Imagem, 2016;
Projeto Piauí Níquel, 2016.

ESCALA GRÁFICA

0 5 10 km

Sistema de Coordenadas: GCS SIRGAS 2000

MAPA DE LOCALIZAÇÃO

Piauí Níquel

ARCADIS Design & Consultancy for natural and built assets

EIA/RIMA – PROJETO PIAUÍ NÍQUEL

Map 5.2-10 – Sampling Sites
Herpetofauna

EXECUTADO POR:	ESCALA:	NÚMERO:	DATA:
ARCADIS	1:200.000	Única	jun /2017

Photo 5.2-57 – Area H1, located in the nickel mining area.

Photo 5.2-58 – Area H3, located near the nickel extraction area.

Photo 5.2-59 – Pond formed by the rain used by several species of amphibians.

Photo 5.2-60 – Area H5, lime production in the limestone mine area.

Photo 5.2-61 – Dry river, located on the access road to the limestone extraction area.

Data Collection

- *Pitfall Traps*

The use of pitfall traps consists of the use of buckets buried in the substrate, connected to each other by guide fences made of plastic canvas and piles. The role of the fence is to intercept specimens moving on the ground, forcing them to deviate their trajectory towards the buckets, resulting in their capture.

The pitfall traps were installed in lines, each containing five 30-liter buckets connected by 4 meters of guide fence (50 cm high), resulting in series of 16 m in length. A total of 18 lines of pitfall traps were installed, distributed among the sampling areas, as shown in the table below.

Data Table 5.2-33 – Field effort for the pitfall trap method employed during the survey of herpetofauna.

Samples site location	Nº of bucket lines
H 1 (DAA/ADI)	2
H 2 (DAA)	2
H 3 (DAA)	2
H 4 (DAA)	3
H 5 (ADI)	3
H 6 (DAA)	2
H 7 (AII)	2
H 8 (AII)	2

Pitfall traps remained open for six days, generating a total effort of 540 buckets-day (18 rows x 5 buckets x 6 days).

- *Active Search*

The active search consists of censuses in the areas of influence (DAA, ADI and AII) of the project, mainly in amphibian breeding sites, traversing the margins of water bodies (swamps, streams, ponds and puddles), mainly during the twilight and night period.

During the course, all species detected by visualization or by vocalization were considered. All the animals observed, but not collected, were found, specimens found on the roads run over or brought by third parties and species identified through vocalization, in the case of amphibians.

Sampling through active search was carried out in 15 sample sites, including mainly water bodies, wetlands and dry riverbeds

Specimen Registration

The sampled amphibians and reptiles were identified, photographed and the following data were recorded: date and place of capture, sampling method, species, rostro-anal length and sex. Animals whose identification was not possible in the field were measured, fixed and preserved for later deposit at the Zoology Museum of the University of São Paulo, according to the Capture, Collection and Transport License granted by the Brazilian Institute of Environment and Renewable Natural Resources (IBAMA), nº 02020.000065 / 2008-16, with a period of validity between February 15th and May 31st, 2008 (Arcadis Tetraplan, 2008).

Conservation Status

To verify the conservation status of the registered amphibian and reptile species, the Official National List of Endangered Species of Fauna was consulted, Portaria MMA No. 444/2014.

At international level, the protection of fauna also focuses on international agreements, related to species and habitats. The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES, 2014) provides a list of species whose international trade must be controlled (Fitzgerald, 1989).

The International Union for Conservation of Nature (IUCN, 2016) established the following categorization for the purpose of preserving species considered threatened: Least Concern (LC); Near Threatened (NT); Vulnerable (VU); In danger (EN); and Critically Endangered (CR).

B) Results

a) Regional Characterization

Due to the increase in information about Caatinga lizards, the occurrence of endemism in this Biome is recognized and these endemisms are closely associated with regions with sandy soils (Rodrigues; 1984, 1987, 1988). However, if on one hand it is possible to make considerations about endemisms of lizards in the caatinga, the same is not true with regard to anuran amphibians and snakes, as ecological and geographical information to feed this discussion is still scarce (Rodrigues, 2003).

Although general knowledge about the herpetofauna of the caatinga is reasonable, there are few intensely sampled areas, with little knowledge of the internal variation patterns of fauna in this landscape and how the current environment and history influenced this pattern (Rodrigues, 2003).

Some of the species of the herpetofauna occur in restricted regions in the Caatinga, revealing that the fauna of this biome is not uniform. So far, the region of sandy soils on the bank of the São Francisco River, between Barra and Juazeiro, represents the region with the greatest diversity and with the most differentiated fauna in relation to the other locations in the Caatinga, presenting a high number of endemic species and genera, almost all associated and adapted to underground life in the sand (Leal; Tabarelli and Silva, 2005).

The herpetofauna of the caatinga is generally composed of species capable of withstanding this environment of high-water stress and high temperatures. These species have physiological and / or behavioural characteristics that allow survival in this peculiar environment. The species present are also able to use the abundant habitats and microhabitats typical of the caatinga, created by arid environmental conditions and the predominance of physical weathering, such as large rocky surfaces and areas of sandy soil exposed to solar irradiation due to the low density of vegetation.

Thus, the caatinga assemblages are, in general, characterized by the low diversity of species, both lizards, snakes, and amphibians, a group more sensitive to heat and water stress. However, some taxa are present in great abundance in any area of the caatinga, such as heliophilous daytime lizards of the genera *Tropidurus, Cnemidophorus* and nocturnal species of the Gekkonidae family, such as the *Phyllopezus, Hemidactylus* and *Gymnodactylus* genera.

Among heliophile lizards, the caatinga fauna is characterized by the presence of at least one species of the genus *Cnemidophorus*, relatively small lizards that live on the ground in constant movement in search of food. Another very common genus in the Caatinga is the *Tropidurus*, whose representatives travel little, spending a great deal of time observing the environment, looking for prey and potential predators. Most species of Tropidurus climb on rocks and logs, where they find shelters in cracks and holes, but they also hunt on the ground around these vertical substrates. This habit is presented by one of the most common species with the widest geographical distribution in the Caatinga, *Tropidurus hispidus*. *Tropidurus semitaeniatus*, in turn, lives almost exclusively on rocks, including in vertical or even negative slope areas. Its extremely dorsoventrally flattened body allows very narrow rocky crevices to be used as safe havens against predation.

There are also some species of *Tropidurus* that live predominantly on the sand and take refuge in holes or simply bury themselves in the loose sand. Species of this genus, as well as tropidurids in general, occur in practically the entire caatinga, being also present in all Brazilian Biomes. In addition, this genus includes endemic species from certain regions, demonstrating that this strain is historically linked to the Caatinga.

Other lizard's characteristic of the caatinga fauna are those with nocturnal habit of the Gekkonidae family. The diversity of species of this family in the Caatinga is very high compared to the other biomes, and there is also a great abundance, mainly of the genera *Hemidactylus, Phyllopezus* and *Gymnodactylus*, with records of some endemic species of the Caatinga, such as *Phyllopezus periosus* and *Hemidactylus agrius*. These lizards are very abundant and occur on rocky outcrops and under the bark of dead trees.

Among snakes, terrestrial species predominate, whose food consists predominantly of anurans, as occurs with species of the genus *Liophis*. Some predatory species of lizards are also common, such as species of the genera *Pseudoboa* and *Oxyrhopus*. Also common are some species of the genus *Phillodryas*, daytime snakes, predominantly terrestrial and of opportunistic diet, which move with great speed. Among venomous snakes, basically three species occur in the Caatinga: the jararaca (*Bothrops erythromelas*), the rattlesnake (*Crotalus durissus*) and the coral (*Micrurus ibiboboca*).

In relation to anurans, most species present in the caatinga are terrestrial, nocturnal, have the habit of burying themselves in dry periods, reproduce in still water, have extremely concentrated activity during periods of rain and have very fast pre-metamorphic development. These species are mainly represented by the genera *Physalaemus* and *Leptodactylus*. All of them present spawning in the form of foam, which can be considered as an additional adaptation against the loss of water and the development of eggs in stagnant waters with little oxygen.

The diversity of anurans that live perched in the vegetation is very low in the caatinga and only a few representatives of the Hylidae family are present. A species of the Hylidae family, *Corythomantis greeningi*, most often uses rocks from temporary riverbeds instead of vegetation, showing adaptations to life in this environment, such as the flattened back and a thick, warty skin, which protects against loss of water. This species lives associated with the narrow cracks in the rocks broken by weathering. When threatened, individuals of *Corythomantis greeningi* "retract" in these crevices to very narrow places, where they block the passage with their ossified head in the form of a shield.

In Piauí, the best sampled areas for Herpetofauna are Valença and the National Parks of Serra da Confusão and Serra da Capivara (Data Table 5.2-34). These last two locations are areas that show greater similarity to the cerrado, due to the slightly higher rainfall and the strong influence of the sedimentary plateaus, which form wet cannons (*canyons*) where more forest vegetation develops in contrast to the typical crystalline depressions that predominate in the caatinga.

For the region surrounding the project, 28 species of amphibians and 72 species of reptiles were listed. Of these, two (*Amphisbaena frontalis* and *Calyptommatus confusionibus*) are "in danger", according to MMA (nº 444/2014) and IUCN (2016), respectively. Two other species (*Boa constrictor*, of the sub-species *occidentalis* and *Caiman crocodilus*) are threatened with extinction, according to the International Convention on Trade in Endangered Species of Fauna and Flora (CITES, 2016) and their trade is prohibited.

It is worth mentioning that the species of amphisbena (*A. frontalis*) and lizard (*C. confusionibus*) threatened with extinction are strongly associated with sandy dune soils, although *Amphisbaena frontalis* has already been recorded buried under the shrubbery of the bushes (ICMBio, 2016). Thus, the probability of occurrence of these species in the project's ADI is considered low. The snake (*Boa constrictor*), a semi-arboreal species, is commonly found in the shrubbery (Mesquita *et al.*, 2013), as well as the alligator (*Caiman crocodilus*) that inhabits all types of low-lying wetland environments. Neotropical region, with confirmed occurrence for the entire state of Piauí (Farias *et al*, 2013).

Data Table 5.2-34 – Amphibian and reptile species likely to occur for the Area of Indirect Influence (AII) and surroundings, with respective threat categories.

Ordem	Família	Táxon	Nome popular	Categoria de ameaça			Fonte
				Federal	Internacional		
				MMA nº 444/2014	IUCN, 2016	CITES, 2016	
Gymnophiona	Caeciliidae	Siphonops paulensis	cobra-cega	-	LC	-	3
		Siphonops sp.	-	-	-	-	2
Anura	Odontophrynidae	Proceratophrys cristiceps	-	-	LC	-	3
	Bufonidae	Rhinella granulosa	sapo-de-enxurrada	-	LC	-	1; 2; 3
		Rhinella marina	sapo-cururu	-	LC	-	1
		Rhinella jimi	sapo-cururu	-	LC	-	1; 2; 3
	Hylidae	Scinax x-signatus	rapa-cuia	-	LC	-	2
		Scinax gr. ruber	perereca	-	LC	-	3
		Scinax pachycrus	-	-	LC	-	1
		Dendropsophus soaresi	-	-	LC	-	3
		Corythomantis greeningi	perereca-decapacete	-	LC	-	3
		Phyllomedusa nordestina	perereca	-	DD	-	3
		Phyllomedusa hypochondrialis	perereca	-	LC	-	1
	Leptodactylidae	Adenomera sp.	-	-	-	-	3
		Leptodactylus fuscus	rã-assobiadora	-	LC	-	3
		Leptodactylus mystaceus	rã-marrom	-	LC	-	3
		Leptodactylus labyrinthicus	jia-rã-pimenta	-	LC	-	1
		Leptodactylus macrosternum	jinha-rã-manteiga	-	-	-	1; 3
		Leptodactylus syphax	rã	-	LC	-	1; 2; 3
		Leptodactylus troglodytes	rã	-	LC	-	1; 2; 3
		Leptodactylus vastus	rã	-	LC	-	2; 3
		Leptodactylus latinasus	rã	-	LC	-	1
	Leiuperidae	Physalaemus cuvieri	rã-cachorro	-	LC	-	2
		Physalaemus albifrons	ranzinha	-	LC	-	1; 3
		Physalaemus cuvieri	rã-cachorro	-	LC	-	1; 3
		Physalaemus kroyeri	ranzinha	-	LC	-	1
	Microhylidae	Dermatonotus muelleri	rã-das-raízes	-	LC	-	1; 3
	Ceratophrydae	Ceratophrys joazeirensis	sapo-de-chifre	-	DD	-	1
Amphisbaena	Amphisbaenidae	Amphisbaena aff. miringoera	cobra-de-duas-cabeças	-	-	-	3
		Amphisbaena frontalis	cobra-de-duas-cabeças	EN	-	-	3
		Amphisbaena polystega	cobra-de-duas- cabeças	-	-	-	3
		Amphisbaena vermicularis	cobra-de-duas- cabeças	-	-	-	1; 3
Squamata	Sphaerodactylidae	Coleodactylus brachystoma	lagartinho	-	-	-	3
	Hoplocercidae	Hoplocercus spinosus	lagarto-rabo-de-abacaxi	-	-	-	3
	Gymnophthalmidae	Gymnophthalmus multiscutatus	-	-	-	-	1
		Procellosaurinus erythrocercus	-	-	-	-	2; 3
		Colobosaura modesta	lagarto	-	-	-	2; 3
		Micrablepharus maximiliani	lagartixa-da-areia	-	-	-	1; 2; 3
		Calyptommatus confusionibus	-	-	EN	-	3
		Calyptommatus sp	-	-	-	-	1
		Lygodactylus klugei	lagartixa-mole	-	-	-	1
	Gekkonidae	Hemidactylus brazilianus	lagartixa	-	-	-	1; 2; 3
		Hemidactylus mabouia	lagartixa	-	-	-	1
		Phyllopezus pollicaris	lagartixa	-	-	-	1
		Lygodactylus klugei	-	-	-	-	2
	Teeidae	Ameiva ameiva	calamião/bico-doce	-	-	-	1; 2; 3
		Ameivula confusioniba	-	-	-	-	3
		Ameivula sp.	-	-	-	-	3
		Glaucomastix venetacauda	-	-	-	-	3
		Cnemidophorus ocellifer	calango/calanguinho	-	-	-	1; 2
		Cnemidophorus venetacaudus	-	-	-	-	2
		Tupinambis teguixin	teiú	-	-	-	1
		Salvator merianae	teiú	-	LC	-	1; 2; 3

Order / Ordem	Family / Família	Taxon / Táxon	Popular Name / Nome popular	Threat Category / Categoria de ameaça			Source / Fonte
				Federal / Federal	International / Internacional		
				MMA nº 444/2014 / MMA nº 444/2014	IUCN, 2016 / IUCN, 2016	CITES, 2016 / CITES, 2016	
Squamata	Scincidae	Varzea bistriata	-	-	LC	-	1
		Mabuya nigropunctata	calango-liso	-	-	-	2; 3
		Mabuya frenata	lagartixa/papa-vento	-	-	-	3
		Mabuya heathi	calango-liso	-	-	-	3
	Tropiduridae	Stenocercus squarrosus	-	-	-	-	2; 3
		Tropidurus semitaeniatus	lagartixa-da-terra	-	LC	-	1; 2; 3
		Tropidurus helenae	lagartixa-de-lajedo	-	-	-	1; 2
		Tropidurus hispidus	lagartixa-preta	-	-	-	1; 2; 3
	Phyllodactylidae	Gymnodactylus geckoides	lagarto	-	-	-	1
		Phyllopezus pollicaris	lagartixa	-	-	-	2; 3
	Leiosauridae	Enyalius bibronii	-	-	LC	-	2; 3
	Iguanidae	Iguana iguana	iguana, camaleão	-	-	-	1; 2; 3
	Colubridae	Chironius carinatus	cobra-cipó	-	-	-	1
		Drymarchon corais	cobra-papa-pinto	-	-	-	3
		Drymoluber brazili	-	-	-	-	3
		Leptophis ahaetulla	cobra-cipó-verde	-	-	-	3
		Tantilla melanocephala	falsa-coral	-	-	-	3
		Liophis viridis	cobra-verde	-	-	-	1
		Oxybelis aeneus	cobra-cipó	-	-	-	1; 2; 3
		Spilotes pullatus	caninana	-	-	-	1; 2; 3
		Clelia occipitolutea	cobra-preta	-	-	-	1
	Dipsadidae	Rodriguesophis iglesiasi	-	-	-	-	2; 3
		Apostolepis cearensis	falsa-coral	-	-	-	3
		Erythrolamprus miliaris	cobra-d'água	-	-	-	3
		Erythrolamprus viridis	-	-	LC	-	3
		Pseudoboa nigra	muçurana	-	-	-	2; 3
		Thamnodynastes sp.	-	-	-	-	1; 2
		Xenodon merremii	boipeva-de-merrem	-	-	-	2; 3
		Xenodon nattereri	cobra-cipó	-	-	-	3
		Philodryas nattereri	cobra-cipó	-	-	-	1; 2; 3
		Philodryas olfersii	cobra-verde	-	-	-	1; 2; 3
		Oxyrhopus trigeminus	falsa-coral	-	-	-	1; 2; 3
	Boidae	Boa constrictor	jibóia	-	-	I[1]	1
		Corallus hortulanus	suaçuboia	-	-	-	2; 3
		Epicrates assisi	salamanta	-	-	-	3
		Epicrates cenchria	salamanta	-	-	-	1
	Elapidae	Micrurus ibiboboca	coral-verdadeira	-	-	-	1
	Leptotyphlopidae	Trilepida cf. fuliginosa	-	-	-	-	3
	Viperidae	Bothrops erythromelas	jararaca	-	LC	-	1
		Bothrops lutzi	jararaca-pintada	-	LC	-	2
		Bothrops neuwiedi	jararaca	-	-	-	1
		Crotalus durissus cascavella[2]	cascavel	-	LC	III[3]	1; 3
Testudines	Chelidae	Mesoclemmys tuberculata	cágado-do-nordeste	-	-	-	2; 3
		Mesoclemmys perplexa	cágado	-	-	-	3
		Phrynops geoffroanus	cágado	-	-	-	1
		Phrynops tuberculatus	cágado	-	-	-	1
Crocodylia	Alligatoridae	Caiman crocodilus	jacaré	-	LC[4]	I	1

Elaboration: Arcadis, 2017.

Source: (1) Arruda, 1997; (2) Cavalcanti, et al. 2014; (3) Vechio, et al. 2016.
[1] Boa constrictor occidentalis subspecies ¬ found in Appendix I;
[2] 2 Source (1) considered the subspecies Crotalus durissus cascavella and Source (2) considers the species Crotalus durissus
[3] Sub-species Crotalus durissus cascavella ¬ found in Appendix III
[4] Classified as low concern, low risk.

Threat categories: of least concern (LC); endangered (EN); deficient data (DD). CITES: Appendix I - Lists the most endangered species. International trade is prohibited; Appendix II - List species at risk of becoming threatened with extinction, if international trade is not controlled; and Appendix III - Lists the species with partially regulated international trade, but which needs the cooperation of countries to avoid overexploitation.

b) Areas of Influence (DAA, ADI e AII)

Considering the sampling campaign, 14 species of amphibians were registered, all belonging to the order Anura, and 19 species of reptiles, being 12 lizards, six snakes and one turtle (Data Table 5.2-34).

Among the amphibians, the most representative families were Leptodactylidae and Leiuperidae with four species each. Among the reptiles, five families (Gekkonidae, Gymnophthalmidae, Teiidae, Colubridae and Dipsadidae) had equal representation, with three species each (Data Table 5.2-35).

The species richness observed in the present study can be considered high, when compared to data from other locations in Caatinga whose testimony material is deposited in scientific reference collections (Rodrigues, 2003).

Some of the best studied locations in Caatinga, such as Serra da Capivara, have a greater number of recorded species than that observed in this study (Vitt, 1995). This is due to the difference in microclimate and precipitation between this and the project's area of influence.

Some species detected through the bibliographic survey were not registered in Capitão Gervásio Oliveira, although their existence in the area is very likely. This is the case of lizards, popularly known as "Calangos", *Lygodactylus klugei* and *Iguana iguana*, snakes such as *Phillodryas nattereri, Phillodryas olferssi, Bothrops erythromelas, Crotalus durrissus* and *Boa constrictor* and anuran *Dermatonotus mullery*. The absence of these species can be an effect of sampling, as a prolonged effort is necessary for the herpetofauna of any area to be sampled more completely, especially in an environment with irregular precipitation, such as the Caatinga.

Data Table 5.2-35 – Amphibian and reptile species recorded using primary data for Directly Affected Area (DAA), Area of Direct Influence (ADI) and Indirect Influence Area (AII), with respective sampling methods and respective threat categories.

Order	Family	Taxon	Popular Name	Threat Category			Method
				Federal	International		
				MMA nº 444/2014	IUCN, 2016	CITES, 2016	
Anura	Bufonidae	*Rhinella granulosa*	sapo-de-enxurrada	-	LC	-	A
		Rhinella jimi	sapo-cururu	-	LC	-	A
	Hylidae	*Scinax x-signatus*	rapa-cuia	-	LC	-	A
		Corythomantis greeningi	perereca	-	LC	-	A
		Dendropsophus aff. *melanargyreus*	-	-	LC	-	A
	Leptodactylidae	*Leptodactylus fuscus*	rã-cachorro	-	LC	-	A
		Leptodactylus labyrinthicus	gia	-	LC	-	A
		Leptodactylus ocellatus	rã-manteiga	-	-	-	A
		Leptodactylus troglodytes	-	-	LC	-	A,P
	Leiuperidae	*Physalaemus albifrons*	-	-	LC	-	A
		Physalaemus kroyeri	-	-	LC	-	-
		Physalaemus cicada	-	-	LC	-	A,P
		Pleurodema diplolistris	-	-	LC	-	A,P
	Ceratophrydae	*Ceratophrys joazeirensis*	sapo-de-chifre	-	DD	-	A
Squamata	Gekkonidae	*Gymnodactylus geckoides*	lagarto	-	-	-	A,P

Order	Family	Taxon	Popular Name	Threat Category			Method
				Federal	International		
				MMA nº 444/2014	IUCN, 2016	CITES, 2016	
		Hemidactylus brazilianus	briba-briba	-	-	-	A,P
		Phyllopezus pollicaris	lagartixa	-	-	-	A
	Gymnophthalmidae	*Colobosaura modesta*	lagarto	-	-	-	P
		Micrablepharus maximiliani	lagartixa-da-areia	-	-	-	P
		Procellosaurinus erythrocercus	-	-	-	-	P
	Teiidae	*Ameiva ameiva*	bico doce	-	-	-	P
		Cnemidophorus ocellifer	calango/calanguinho	-	-	-	P
		Salvator merianae	teiú	-	LC	-	T
	Scincidae	*Mabuya heathi*	calango-liso	-	-	-	P
	Tropiduridae	*Tropidurus hispidus*	lagartixa-preta	-	-	-	A,P
		Tropidurus semitaeniatus	lagartixa-da-terra	-	LC	-	A
	Colubridae	*Leptodeira annulata*	serpente-olho-de-gato-anelada	-	-	-	T
		Liophis poecilogyrus	cobra-de-capim	-	-	-	T
		Liophis viridis	cobra-verde	-	-	-	T
	Dipsadidae	*Apostolepis cearensis*	falsa-coral	-	-	-	T
		Philodryas nattereri	cobra-corre-campo	-	-	-	-
		Oxyrhopus trigeminus	falsa-coral	-	-	-	T
Testudines	Cheloniidae	*Phrynops geoffroanus*	cágado	-	-	-	T

Elaboration: Arcadis, 2017.

Methods: *Active search (A); Passive Collection / Pitfall (P); Material collected / sampled by third parties (T).*

Threat categories: of little concern (LC); deficient data (DD). CITES: Appendix I - Lists the most endangered species. International trade is prohibited; Appendix II - List species at risk of becoming threatened with extinction, if international trade is not controlled; and Appendix III - Lists the species with partially regulated international trade, but which needs the cooperation of countries to avoid overexploitation.

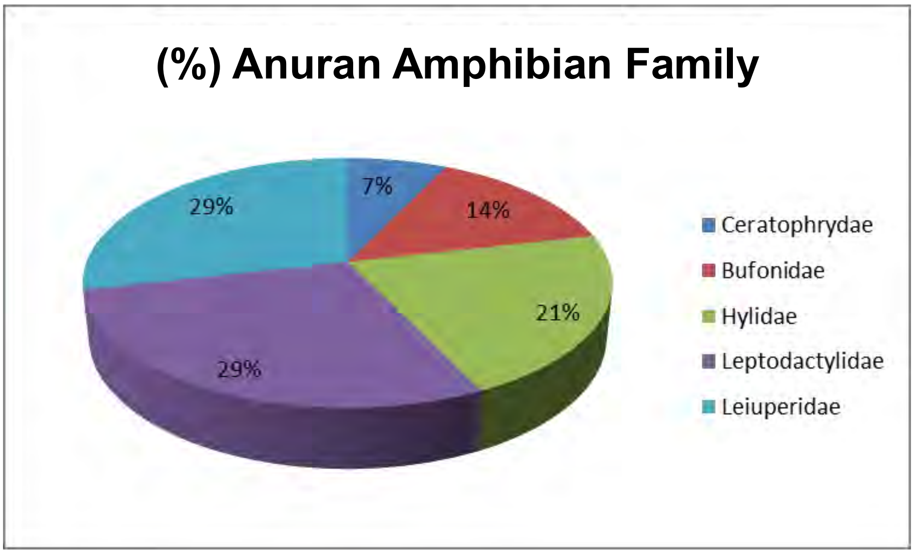
Herpetofauna Composition

The geographic distribution of the registered species covers a large part of the caatinga biome, some of which are endemic or with marginal distribution in other landscapes. Others occur in much wider areas, which generally include other open landscapes such as the Cerrado and Chaco. A minority of widely distributed species that occur in the Caatinga is shared with forest landscapes.

Represented by species of arboreal habits, the low diversity of species of the Hylidae family (Graph 5.2-5) is expected in the study area, since this is characterized by the semi-arid environment of the caatinga, which conditions lower vegetation and of simpler structure. The result obtained, therefore, corroborates with the result observed in other locations in this domain (Cascon, 1987; Pavan, 2007).

The contribution of the Leuiperidae and Leptodactylidae families is relatively high, corresponding to 29% (Graph 5.2-5), both in the present work and in the Caatinga in general (Arzabe, 1999; Cascon, 1987; Pavan, 2007). These species, predominantly terrestrial, with a habit of burying themselves or using dens, have much more advantages to survive prolonged droughts. The high proportion of species of the genus *Leptodactylus* in the area is particularly relevant. The most abundant species in the area are also the diggers *Pleurodema diplolistris* and *Physalaemus cicada*. However, the vast majority of species recorded in this study have the habit of withdrawing in underground refuges during dry periods.

Graph 5.2-5 – Representation of anuran amphibian families registered in the areas of influence of the project (DAA, ADI, AII).

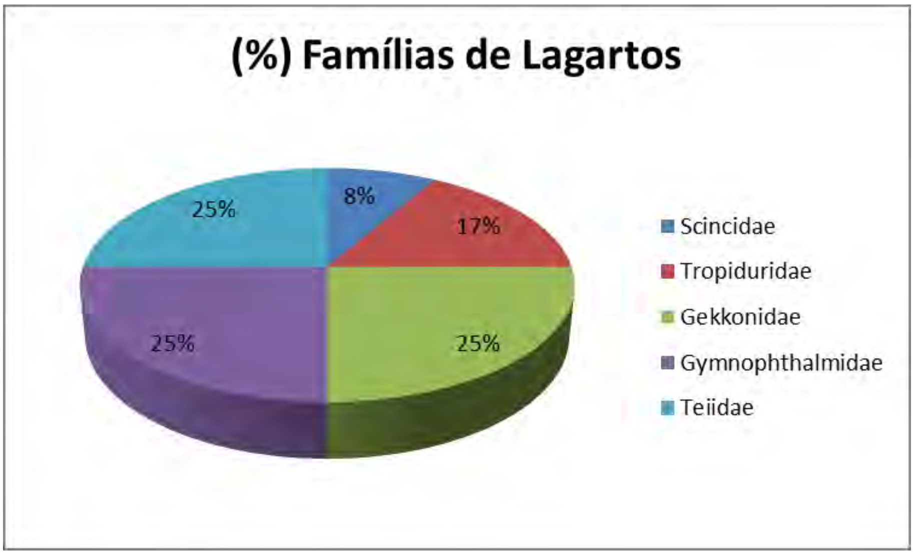


Regarding the representativeness of the lizard families, the contribution of Gekkonidae and Gymnophythalmidae (25%) (Graph 5.2-6) is in agreement with that recorded in other locations in the caatinga (Pavan, 2007). These families, which present several lineages of habits, respectively, nocturnal and fossorial, present a relative contribution generally greater in the fauna of the caatinga when compared to that observed in other neotropical landscapes (Pavan, 2007). Nocturnal gekkonids are very abundant in the region of the project and occur in almost all sampled environments. The *Phyllopezus pollicaris* species was observed in most of the points sampled at night, but it was also recorded during the day, sheltered under tree bark or between rocks or tiles.

It should be noted that, in the sandy environments of the São Francisco River, an especially high diversity of the Gymnophythalmidae family was observed, with several fossorial or semi-fossorial species occurring in sympatry (Rodrigues, 1996; Rocha & Rodrigues, 2005).

Despite the low representativeness of the Tropiduridae family in this study (17%) (Graph 5.2-6), one of the species, *Tropidurus semitaeniatus*, is very frequent in the ADI rock outcrops of the project. This species is adapted to life on the rocks and takes refuge between the cracks with its extremely flattened back-ventral body. It is very common throughout the Caatinga, characterizing the fauna of lizards in the semi-arid region in relation to other landscapes. The presence of *Tropidurus semitaeniatus* and the abundance of gekkonids indicate that the observed fauna is typical of Caatinga.

Graph 5.2-6 – Representativeness of the lizard families registered in the Areas of Influence of the project (DAA, ADI, AII and immediate surroundings).



Regarding snakes, two families were represented in this study (Colubridae and Dipsadidae) with three species, each. Regarding the testudines, only one species of the family Cheloniidae was detected. Species in these groups are difficult to detect in field surveys. All identified species were brought by third parties.

Distribution of fauna through the environment

Pitfall trap sampling data were used for quantitative assessment, as well as for comparison between locations (Data Table 5.2-36). It was found that the most abundant species in the region is the lizard *Cnemidophorus* of the *ocellifer* group, which corresponded to almost 50% of the captured animals and was found in 14 of the 18 trapped lines sampled. *Procellosaurinus erythrocercus* was the second most abundant species (17%), followed by *Tropidurus hispidus* (11%). The remaining species represented less than 6% each, and together account for 23% of the animals captured (Data Table 5.2-36).

Data Table 5.2-36 – Abundance of Herpetofauna species sampled by pitfall traps during the rainy campaign in the areas of Influence of the project (DAA, ADI, AII).

Specie	Sampling sites																		Total
	1.1	1.2	2.1	2.2	3.1	3.2	4.1	4.2	4.3	5.1	5.2	5.3	6.1	6.2	7.1	7.2	8.1	8.2	
Cnemidophorus gr. ocellifer		2	2	1	2		2		4	2		2	7	2	8	4	4	4	**46**
Colobosaura modesta								1											**1**
Gymnodactylus geckoides								2				1	1	2					**6**
Hemidactylus brazilianus		1	1							1		1							**4**
Mabuya heathi													1						**1**
Micrablepharus maximiliani			2	1															**3**
Procellosaurinus erythrocercus	3	2	1				2	2	2						3			1	**16**
Tropidurus hispidus			1	2			1	1	1				1	2				1	**10**
Ameiva ameiva		1																	**1**
Leptodactylus troglodytes			1																**1**
Physalaemus cicada											1								**1**
Pleurodema diplolistris	1												3						**4**
TOTAL	**4**	**6**	**8**	**4**	**2**	**0**	**5**	**6**	**7**	**3**	**1**	**4**	**13**	**6**	**11**	**4**	**4**	**6**	**94**

Sites Location: first number refers to the site; the second number refers to the bucket line.

- Anurans

Due to the few captures of anurans in the fall traps, it is not possible to discuss the distribution of these species among the sampled environments. The active search, on the other hand, was more effective in sampling frogs and it was found that the occurrence was restricted to the most humid places, mainly in the valley bottoms. Before the rain that occurred at the end of the sampling, most anuran species were not vocalizing and were found in puddles, dams, or areas of moist soil in dry riverbeds. This was the case of *Leptodactylus labyrinthicus, L. ocellatus, Corythomantis greeningi, Pleurodema diplolistris, Physalaemus cicada, Rhinella jimi* and *Ceratophrys joazeirensis*. Only *Leptodactylus troglodytes* vocalized in puddles and dry riverbeds during this period.

With the rains that occurred at the end of the campaign, several puddles of water were formed both at the bottom of dry river valleys, as well as in interfluvial areas, such as depressions on the sides of roads and in rocky outcrops. Some species such *as Leptodactylus fuscus, Physalaemus albifrons, Dendropsophus aff. melanargyreus, Scinax x-signatus* and *Rhinella granulosa*, were only recorded vocalizing after the rains. Most species, which had already been registered previously, started to vocalize after the rain.

The most abundant anuran species were *Pleurodema diplolistris, Leptodactylus troglodytes, Physalaemus cicada* and *Dendropsophus aff. melanargyreus*. These were recorded vocalizing in all the sampled ponds. Species diversity was greater in the larger ponds, closer to the valley bottoms. In the dry riverbed (Sample site H 11, active search), practically all species vocalized along the puddles, between the rocks and in muddy places.

- Lizard

Most of the areas sampled in this study are composed of arboreal shrubby Caatinga over deep yellow sand soils located in flattened interfluves, where the most common tree is "canela-de-velho" (*Cenostigma sp.*) and cacti are nonexistent or rare.

In these environments, the most common species was *Cnemidophorus* from the *ocellifer* group. In addition to the great abundance recorded by the pitfall traps, Cnemidophorus from the ocellifer group was also seen during the day, in most of the environments visited, in the moments of less intense heat stroke. The *Cnemidophorus* of the *ocellifer* group are among the most frequent species in the various environments of the Caatinga and throughout their entire geographical extension.

Another frequent species in this environment was *Procellosaurinus erythrocercus*, a tiny lizard with very small legs and a red tail, often associated with sand. This species was also sampled in other sandy environments, such as in the more open white sand patches (Area H 6), however, less frequently. In the areas of clayey limestone soil, the species was not found.

The third most abundant species in the pitfall traps, *Tropidurus hispidus*, occurs throughout the caatinga, being more abundant in rocky outcrops and uncommon or absent in sandy soils. In this study, the species was sampled in several lines of traps, but with low abundance in all of them.

On the sandy soils of the São Francisco River, one of the best studied locations with regard to reptiles, this species is absent, but there are others of the same genus that are associated with sand spots (Rodrigues, 1996). It is possible that some of these species also occur in the sandy regions of Capitão Gervásio Oliveira and in the areas of influence of the project.

For less frequent species, with less than 5%, the few captures do not allow to recognize a clear preference for certain environments. These species have a wide distribution in the caatinga and occur in most of the best sampled locations in this biome, with the exception of *Colobosaura modesta*. This species, whose distribution covers a large extension of the Cerrado, does not occur in the Caatinga, with the exception of the record in Serra das Confusões in Piauí, which can be considered as a transition between Cerrado and Caatinga. Only one specimen was observed in the sand caatinga, with a much lighter colour than that of the cerrado populations.

- Snakes

The number of snake species in a locality in Caatinga can reach 18 or 19 (Silva & Sites, 1995; Vitt & Vandilger, 1983). The low diversity recorded in the present study was expected considering that it is a short-term survey. The registered snakes are widely distributed in the Caatinga and are present in the few existing species lists for the biome (Silva & Sites, 1995; Vitt & Vandilger, 1983).

Species of economic interest and / or of veterinary medicine

No species among the registered herpetofauna appears as a reservoir of diseases. No snake species belonging to the Viperidae or Elapidae families were also registered, notably known as venomous, that is, with the potential to inoculate their venom and cause snakebite accidents involving humans and domestic animals.

Species threatened and protected by legislation

No species of amphibian or reptile recorded in this survey is threatened with extinction. Two species of reptiles and 12 of amphibians are classified as “of little concern”, according to IUCN (2016). The horned frog (*Ceratophrys joazeirensis*) also has deficient data according to Portaria MMA No. 444/2014, that is, the existing information about this species is inadequate to make a direct or indirect assessment of its risk of extinction.

Rare and / or restricted species

Some species of herpetofauna found can be considered rare or of restricted distribution, such as *Procellosaurinus erythrocercus* (a lizard of the Gymnophthalmidae family, mentioned above) and *Ceratophrys joazeirensis* (horned toad). The latter (*C.joazeirensis*) is a very rare species, as are the others of the genus *Ceratophrys*. In addition to the naturally low density of these animals, their habits, such as being buried inactive for long periods and hunting, make it difficult to observe them in the field. The known distribution of this species is restricted. In addition to the type locality of Juazeiro (BA) (Mercadal, 1986), it occurs in Cabaceiras (PB) and in two other locations close to each other, in Paraíba and Rio Grande do Norte (Vieira *et al.*, 2006) and in Capitão Gervásio Oliveira, where only one specimen was sampled via active search.

Dendropsophus aff. melanargyreus is a species belonging to the marmorata group which, according to Faivovich *et al* (2005), contains eight species, three of which occur in regions of Caatinga or in the northeast of the northeast. The collected specimens differ from all of these species in their lighter color, thinner body and narrower head, characters that they share with specimens of *D. melanargyreus* that occur in the depressions of the northern Cerrado (Pavan, 2007). However, it is noteworthy that the specimens sampled in the present study also differ from the latter in their much smaller size, much lighter colour, shorter legs and less developed interdigital membranes. In this study, this species was sampled in puddles of rainwater formed in depressions, in a disturbed area, being very abundant in some of them, where several dozen individuals vocalized.

The presence of fossorial species of lizards of the Gymnophythalmidae Family suggests the possibility of the occurrence of species that haven't been described, with restricted distribution to sandy soils such as those in the region of the project and the surrounding region.

The ecology of the caatinga fauna is little known and in the literature, there are basically no considerations about the effects of disturbances on the species. Field experience shows that the most common species are generally found in disturbed and anthropic environments, but little can be said about the disturbance effects on the rarest and most restricted species.

C) Summary

Sampling throughout the rainy season favoured the obtaining of a relatively high number of anuran and lizard species, allowing to characterize the composition of species of herpetofauna present in the study region satisfactorily. None of the registered species are threatened with extinction, however, the little knowledge about the ecology of the Caatinga species does not allow determining the effects of disturbances on their populations.

Species considered to be rare or of restricted distribution were detected. The presence of sandy soils in the project's ADI also suggests the possibility of occurrence of species not described, with distribution restricted to this type of substrate.

D) Photographic Report

Photo 5.2-62 – *Ceratophrys joazeirensis*.

Photo 5.2-63 – *Corythomantis greeningi*.

Photo 5.2-64 – *Scinax x- signatus*.

Photo 5.2-65 – *Physalaemus cicada.*

Photo 5.2-66 – *Leptodactylus troglodytes*.

Photo 5.2-67 – *Physalaemus albifrons*.

Photo 5.2-68 – *Pleurodema diplolistris*.

Photo 5.2-69 – *Rhinella jimi*.

Photo 5.2-70 – *Cnemidophorus gr. ocellifer*.

Photo 5.2-71 – *Mabuya heathi*.

Photo 5.2-72 – *Procellosaurinus erythrocercus*.

Photo 5.2-73 – *Micrablepharus maximiliani*.

Photo 5.2-74 – *Gymnodactylus geckoides*. **Photo 5.2-75 – *Tropidurus semitaeniatus*.**

5.2.4.3. Terrestrial Mastofauna

Considering that through the analysis of updated satellite images, the use and occupation of the land in the area of the project has undergone little change in relation to the surveys carried out in this same area in 2008, it was agreed at a meeting held on September 2nd, 2016, between representatives of SEMAR-PI and PNM, that the primary data covered in this chapter will be those whose surveys carried out in the study area for this same project, aimed to compose the Environmental and Social Impact Assessments (ESIA) and the respective Environmental and Social Impact Report (RIMA), prepared by ARCADIS Tetraplan, in 2008 for Companhia Vale do Rio Doce.

A) Methodological Considerations

a) Collection of secondary data

In order to list the fauna species likely to occur in the analysed region, the data available in the existing environmental studied and the scientific publications were compiled to contribute to the characterization of the mammalian community present in the area of study of this project.

For the survey of small, medium and large terrestrial mammal species that can potentially occur in the region, available secondary data was compiled by Golder Associates (2005), for the pilot plant licensing process. This survey was carried out in October 2005 and aimed to list the species likely to occur in the area during a dry season.

In addition, published data were compiled for Serra da Capivara National Park, Piauí (Silva; Lima, s/d) and Serra das Confusões National Park, Piauí (Figueiredo, *et al.* 2007; Henrique, *et al.* 2007) aiming to detect the composition of mammal species in a regional context.

b) *Field sampling*

Sampling period

The study of terrestrial mammals through data collection in the field was conducted in a sampling campaign. Data collection from small terrestrial mammals was carried out between February 18th and 29th, 2008 and data collection from medium and large mammals occurred between February 20th and 28th, 2008 (rainy season). It is noteworthy that sampling in the dry season was carried out in a more preliminary phase, during the licensing of the pilot plant, in the period from 10th to 14th October 2005 (Golder Associates, 2005 - secondary data), whose results were not included in the analysis of composition and distribution of the areas of influence of the project, but considered in a comparative analysis of richness for characterizing data related to the areas of insertion of the project in the dry season, considering, therefore, the seasonality in the present study.

Spatial coverage of the study

The spatial scope for collecting primary data included the Directly Affected Area (DAA), and the Areas of Direct Influence (ADI) and Indirect Influence (AII) of the project.

For the capture and collection of marsupials and small rodents, two types of methodology were used: live containment traps of cage type, and trapping and falling traps (pitfalls), used in an associated way. The sample sites and detailed sampling methods are shown below (Data Table 5.2-37; Data Table 5.2-38 e Map 5.2-11).

Data Table 5.2-37 – Characterization and location of sample sites for trapping and falling traps (pitfall) and live containment traps (cages).

Samples sites	Geographic Coordinates (UTM)		Zone	Método utilizado	Project Component	Point Description
M 7 (DAA)	177310	9063119	24L	*Pitfall,* cage	Brejo seco area, access road to Nickel Mine	Arboreal shrubbery vegetation, with mixtures between open and dense areas.
M 8 (DAA)	173389	9064645	24L	*Pitfall,* cage	Nickel Mine	Arboreal shrubbery vegetation, with the presence of terrestrial bromeliads.
M 9 (DAA)	174265	9064606	24L	*Pitfall*	Nickel Mine	Arboreal shrubbery vegetation, mainly with 2 m trees, with the presence of larger trees, 4 m.
M 10 (DAA)	171785	9070121	24L	*Pitfall*	Pipeline and Transmission Line	Arboreal shrubbery vegetation, with 5 m trees and the presence of terrestrial bromeliads.
M 11 (ADI)	187341	9035288	24L	*Pitfall,* cage	Umbuzeiro area, near to limestone Mine	Arboreal vegetation (5 m) and the presence of bromeliads and rocky outcrops.
M 12 (DAA)	186073	9045180	24L	*Pitfall,* cage	Access road to limestone mine	Vegetation composed of sparse caatinga, presenting the soil formed by white sand with macambira and spaced trees.
M 13 (AII)	185996	9041180	24L	*Pitfall*	Near of the access road to limestone mine	Arboreal shrubbery vegetation, with soil composed of yellow sand and dry shrub vegetation.
M 14 (AII)	188778	9050118	24L	*Pitfall*	Near of the access road to limestone mine	Sparse trees, dense green vegetation with terrestrial bromeliads.
M 15 (DAA)	184806	9038866	24L	Cage	Access road to limestone mine	Wide bed totally dried with rocks and banks or sandy sediments deposits, with some larger trees between the rocks of the marginal banks. Some areas with moist soil.

Elaboration: ARCADIS Tetraplan, 2008.

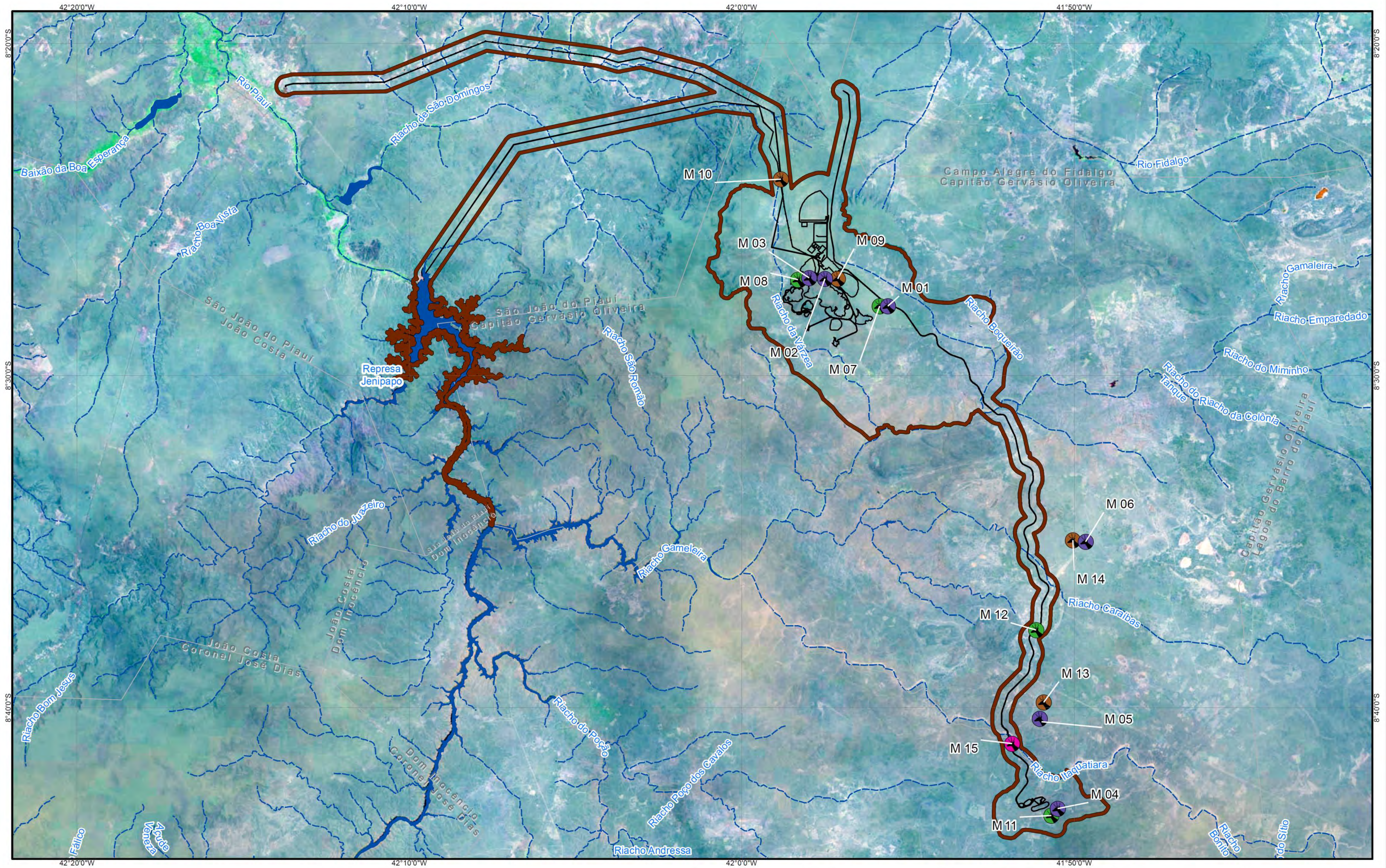
To characterize medium and large mammals, camera traps were installed at the following sample sites:

Data Table 5.2-38 – Characterization and location of sample sites for camera traps.

Samples sites	Geographic Coordinates (UTM)		Zone	Project Component	Point Description
M 1 (DAA)	177310	9063119	24L	Brejo seco area, access road to Nickel Mine	Arboreal caatinga on sandy soil.
M 2 (DAA)	174265	9064606	24L	Nickel Mine	Shrubby bush, presence of imbu.
M 3 (DAA)	173389	9064645	24L	Nickel Mine	Tree vegetation, with the presence of terrestrial bromeliads.
M 4 (ADI)	187341	9035288	24L	Umbuzeiro area, near to limestone Mine	Little dense caatinga, soil with rocky outcrops, plenty of cat's claw and slums.
M 5 (AII)	185996	9041180	24L	Near to access road to limestone mine.	Low and dense sandbank, with dry vegetation and sandy soil. Located in continuous vegetation with the ADI.
M 6 (AII)	188778	9050118	24L	Near to access road to limestone mine.	Dense shrubland with yellow sand soil. Located in continuous vegetation with the ADI, next to the access road to the limestone mine.

Elaboration: ARCADIS Tetraplan, 2008.

Map 5.2-11 – Terrestrial Mastofauna sampling sites.



LEGENDA

- Intermittent Drainage
- Water Mass
- Municipal Limits
- Area of Direct Influence - ADI
- Directly Affected Area - DAA

Terrestrial Mastofauna Method

- Camera Trap
- Pitfall
- Pitfall and Tomahawk
- Tomahawk

REFERÊNCIAS

ARCADIS Tetraplan, 2008;
IBGE, Base contínua 1:250.000, 2015;
LANDSAT, Imagem, 2016;
Projeto Piauí Níquel, 2016.

ESCALA GRÁFICA

0 5 10 km

Sistema de Coordenadas: GCS SIRGAS 2000

MAPA DE LOCALIZAÇÃO

PIAUÍ NÍQUEL

ARCADIS Design & Consultancy for natural and built assets

EIA/RIMA – Projeto Piauí Níquel

Map 5.2-11 – Sampling Sites
Terrestrial Mastofauna

EXECUTADO POR:	ESCALA:	NÚMERO:	DATA:
ARCADIS	1:200.000	Única	jun /2017

Photo 5.2-76 – M1 Area, located in the nickel mine area.

Photo 5.2-77 – M3 Area, located near of the Nickel mine area.

Photo 5.2-78 – M5 Area, lime production at the limestone mine area.

Photo 5.2-79 – Dry river, located oi the road acesso of the limestone mine.

Data collection

- *Pitfall traps*

The use of pitfall traps consists of the use of buckets buried in the substrate, connected to each other by guide fences made of plastic canvas and stakes. The role of the fence is to intercept specimens moving on the ground, forcing them to deviate their trajectory towards the buckets, determining their capture.

It is noteworthy that pitfall traps represent a simple method, but of great efficiency for sampling small vertebrates (Corn, 1994; Cechin & Martins, 2000). The use of these traps has become very frequent in surveys and mastofaunistic monitoring due to the success in capturing species that are hardly detected by the use of common traps.

The size of the buckets is a determining factor of the maximum size of the specimens potentially collected by fall traps and, in this work, 30 litres buckets were used. Smaller specimens are rarely able to jump or climb their internal walls, being collected with success.

The intercept and fall traps were installed in lines, each containing five 30 litres buckets connected by 4 meters of guide fence (height of 50 cm), resulting in series of 16 m in length. A total of 18 lines of pitfall traps were installed, distributed among the sampling sites.

Pitfall traps remained open for six days, generating a total effort of 540 buckets per day (18 rows x 5 buckets x 06 days).

- *Live containment traps (cage)*

In live cage-type trapping (Tomahawk) a total of 105 cages (45x21x21) were used, arranged in four lines of 25 traps each, and in an area (M 15) composed of five cages arranged at random.

The traps were checked daily, preferably in the morning, preventing the animals from suffering from heat stroke. As an attraction, baits composed of banana, cassava and pumpkin were used, changed daily.

The cages remained active for five consecutive nights, generating a total effort of 525 night cages (105 cages x 5 nights).

- *Cameras traps*

In order to carry out the direct detection of medium and large terrestrial mammals, camera traps were installed in different areas, along the areas of influence. The trap consists of a camera attached to a trigger sensor, designed for heat and motion detection. The traps were installed, preferably, in animal trails or close to rest and feeding areas, such as fruit trees.

Six Tigrinus (model 6.0 C) cameras traps were installed, three were placed in vegetation remnants near the Nickel mine area and three in vegetation remnants near the Limestone mine area, as shown in Data Table 5.2-38. The total effort was 32 night traps.

- *Direct registers*

During the displacements carried out in the field, to check the traps placed in the sampling areas, whenever possible, the presence of medium and large mammals was register directly.

The registers were made through the direct visualization of the animals and/or through their vocalizations.

- *Indirect registers*

Also, during field trips, the presence of individuals of medium and large mammals was indirectly registered.

Indirect registers consisted, especially, of shelters and caves, since the intensive presence of goats and their trampling make it impossible to keep tracks of wild animals on the ground.

- *Interviews*

Interviews were carried out with residents of the region, inhabitants for at least 10 years, aiming to note the species of mammals seen by them. Each interviewee was asked to provide a short description of each species to confirm their identification.

The species registered by this method were considered to be occurring in AII and possible occurrence in ADI/DAA.

Specimen Registration and Species Identification

The individuals of small mammals captured were, whenever possible, identified at a specific level and registered individually through field numbering. Data such as date and place of capture, mass and biometric measurements (front paw, back paw, rostrum-anal and tail) were also noted. The length measurements were taken with a calliper and the mass was measured using spring scale dynamometers with different capacities (10, 50 and 100g). The reproductive condition of the specimens was verified by analysing the size and palpation of the abdomen (pregnant or not) and breasts (lactating or not), scrotal testis (adult males) and abdominal testis (young males).

Representative series of little-known species were collected, except for endangered species, aiming at the adequate characterization of the region's fauna. The non-collected specimens were marked with a numbered earring and released later. Whenever possible, data were taken in the field, with the aim of reducing stress and the animals' imprisonment time.

The collection of material belonging to this fauna group followed the predicted collection quantities and determinations specified in the Capture, Collection and Transport License granted by the Brazilian Institute of Environment and Renewable Natural Resources (IBAMA), nº 02020.000065/2008-16, with period valid from February 15th to May 31st, 2008 (Arcadis Tetraplan, 2008).

Conservation Status

To ascertain the conservation status of registered mammal species, the Official National List of Endangered Species of Fauna was consulted, Portaria MMA No. 444/2014.

At international level, the protection of fauna also focuses on international agreements, related to species and habitats. The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES, 2014) provides a list of species whose international trade must be controlled (Fitzgerald, 1989).

The International Union for Conservation of Nature (IUCN, 2016) established the following categorization for the purpose of preserving species considered threatened: Least Concern (LC); Near Threatened (NT); Vulnerable (VU); Endangered; and Critically Endangered (CR).

B) Results

a) Regional Characterization

Knowledge of the species richness of mammalian communities in the Neotropical regions is quite limited and the description of new taxon found in extensive surveys is frequent, combined with modern techniques and analytical methods (Mittermeier et al., 1992; Patton and Silva, 1995; Queiroz, 1992; Roosmalen et al., 1998).

Until the mid-twentieth century, knowledge about mammals in the Caatinga was based on small samples (Oliveira, *et al.* 2003). The National Plague Service, between 1952 and 1955, deposited approximately 60 thousand specimens in the National Museum, mainly rodents and marsupials (Freitas, 1957). More recently, the project “Ecology, evolution and zoogeography of mammals”, developed by researchers at the Carnegie Museum of Natural History, between 1975 and 1978, studied mastofauna in the Chapada do Araripe and the 6576 specimens were distributed between that museum and the Zoology Museum of University of São Paulo. These two large collections obtained since then have contributed significantly to the knowledge of this fauna (Oliveira, *et al.* 2003).

Recently, taxonomic reviews involving samples of mammals from the caatinga have revealed their distinction in relation to populations of other ecosystems (Oliveira *et al*. 2003). With the survey carried out in the areas of influence of the project at the time of the licensing of the pilot project (Golder Associates, 2005) added to the data published for the Serra da Capivara National Park (Silva; Lima, s/d) and for the Serra das National Park Confusions (Figueiredo, *et al.* 2007; Henrique, *et al.* 2007), there are a total of 13 species of small mammals and 35 species of medium and large mammals of probable occurrence.

The list of species of mastofauna expected for the region is shown in Data Table 5.2-39.

No species of small mammal appears on official lists of endangered species. Among medium and large mammals, seven are classified as "vulnerable" and one is "endangered", according to the Portaria MMA (nº 444/2014). At the international level, nine species are threatened (IUCN, 2016; CITES, 2016), two are "almost threatened" (IUCN, 2016), four are at risk of becoming endangered if international trade is not controlled (CITES, 2016), and one has "deficient data", that is, the existing information about this species is inadequate to make an assessment of its risk of extinction.

In general, it can be considered that the fauna likely to occur in the region of the project is diverse, with the presence of both species more dependent on forest formations (sloths and primates) and species with high cynegetic value and/or higher environmental requirements (jaguar, giant anteater, deer, among others).

Data Table 5.2-39 – Small, medium and large mammal species likely to occur in the Area of Indirect Influence (AII) and surroundings, with respective compilation methods and respective threat categories.

Order	Family	Taxon	Popular Name	Methods	Threat category			Source
					Federal	International		
					MMA nº 444/2014	IUCN, 2016	CITES, 2016	
Artiodactyla	Cervidae	*Mazama americana*	veado mateiro	B	-	DD	-	1
		Mazama gouazoubira	veado catingueiro	B	-	LC	-	1, 4
	Tayassuidae	*Tayassu tajacu*	caitetu	B	-	-	-	1
		Tayassu pecari	queixada	B	VU	VU	-	1
		Pecari tajacu	caititu	B	-	LC	II	3
Carnívora	Canidae	*Pseudalopex vetulus*	raposa do campo	B	-	LC	-	4
		Cerdocyon thous	cachorro do mato	B, E	-	LC	II	1; 3; 4
	Felidae	*Puma yagouaroundi*	jaguarundi	B, E	-	LC	II	1; 3
		Leopardus pardalis	jaguatirica	B	-	LC	I	1; 3; 4
		Leopardus tigrinus	gato do mato	B, E	-	VU	I	1; 3; 4
		Leopardus wiedii	gato maracaja	B, E	VU	NT	I	1; 3
		Panthera onca	onça pintada	B	VU	NT	I	1; 3; 4
		Puma concolor	suçuarana	B, E	VU	LC	I[1]	1; 3; 4
	Mustelidae	*Conepatus semistriatus*	cangambá	B, E	-	LC	-	1
		Eira barbara	irara	B, E	-	LC	-	1; 3
		Galictis sp.	furão	E	-	-	-	1
	Procyonidae	*Nasua nasua*	quati	B	-	LC	-	3
		Procyon cancrivorus	guaxinim	B, E	-	LC	-	1; 3; 4
Didelphimorphia	Didelphidae	*Thylamys sp.*	-	B	-	-	-	2
		Monodelphis domestica	catita	B	-	LC	-	2; 4
		Micoureus cf. demerarae	cuíca	B	-	-	-	2
		Gracilinanus agilis	cuíca	B	-	LC	-	2; 4
		Didelphis albiventris	gambá	B, E	-	LC	-	1; 2; 4
Primates	Callithrichidae	*Callithrix jacchus*	sagüi	B, E	-	LC	-	1; 3; 4

Order	Family	Taxon	Popular Name	Methods	Threat category			Source
					Federal	International		
					MMA nº 444/2014	IUCN, 2016	CITES, 2016	
	Cebidae	*Alouatta caraya*	guariba	B	-	LC	-	1
	Cebidae	*Sapajus apella*	macaco prego	B	-	LC	-	1; 3
Rodentia	Echimyidae	*Thrichomys laurentius*	punaré	B	-	DD	-	4
		Thrichomys apereoides	rato-rabudo	B, E	-	LC	-	1; 2
	Erethizontidae	*Coendou prehensilis*	porco-espinho	B	-	LC	-	3
	Muridae	*Calomys expulsus*	rato	B	-	LC	-	1
	Cricetidae	*Wiedomys pyrrhorhinos*	rato do nariz vermelho	B	-	LC	-	2
		Rhipidomys sp.	-	B	-	-	-	2
		Oligoryzomys nigripes	rato	B	-	LC	-	1
		Cerradomys scotti	rato do mato	B	-	LC	-	4
		Cerradomys aff. subflavus	rato	B	-	LC	-	1
	Agoutidae	*Cuniculus paca*	paca	B	-	LC	-	1; 3
	Caviidae	*Kerodon rupestris*	mocó	B, E	VU	LC	-	1; 3; 4
		Galea spixii	prea	B, E	-	LC	-	1; 2; 4
	Dasyproctidae	*Dasyprocta prymnolopha*	cotia	B, E	-	LC	-	1
Pilosa	Bradypodidae	*Bradypus tridactylus*	preguiça	B	-	LC	-	1
	Myrmecophagidae	*Myrmecophaga tridactyla*	tamanduá bandeira	B	VU	VU	II	1; 3
		Tamandua tetradactyla	tamanduá mirim	B, E	-	LC	-	1; 3
Cingulata	Dasypodidae	*Cabassous sp.*	tatu de rabo mole	B	-	-	-	1
		Dasypus novemcinctus	tatu galinha	B, E	-	LC	-	1; 4
		Dasypus septemcinctus	tatui	B, E	-	LC	-	1
		Priodontes maximus	tatu-canastra	B	VU	VU	I	3
		Euphractus sexcinctus	tatu peba	B, E	-	LC	-	1; 4
		Tolypeutes tricinctus	tatu-bola	B, E	EN	VU	-	1; 3

Elaboration: Arcadis, 2017.

Source: (1) Golder Associates, 2005; (2) Figueiredo, et al. 2007; (3) Henrique, et al. 2007; (4) Silva e Lima, s/d.

Methods: Bibliography (B); Interview (E).

[1] *Three subspecies: (Puma concolor coryi, Puma concolor costaricensis e Puma concolor couguar) are in Appendix I.*

Threat Categories: Least Concern (LC); Near Threatened (NT); Vulnerable (VU); Endangered; and Critically Endangered (CR). CITES: Appendix I - Lists the most endangered species. International trade is prohibited; Appendix II - Lists species at risk of becoming threatened with extinction if international trade is not controlled; and Appendix III - Lists species with partially regulated international trade, but which needs the cooperation of countries to avoid overexploitation.

b) Areas of Influence (DAA, ADI e AII)

- **Small Mammals - Non-Flying**

Regarding small non-flying mammals, during the field survey, three species were registered, distributed in two orders Rodentia (n = 1 species) and Didelphimorphia (n = 2 species) (Data Table 5.2-40).

In comparison to data recorded for AII and surroundings through bibliographic survey, the richness of small land mammals registered through primary survey was low. The low number of species captured, however, was already expected, given the presence of dry vegetation in many points, making it unattractive for small fauna.

However, considering the data recorded by Golder Associates during the dry season in the project's AII, the values of richness were very similar, with five species detected in this period of the year. Of these species, three rodents were not registered during the rainy season. The white-eared opossum (*D. albiventris*) and the common punaré (*T. apereoides*) were detected in both seasons. Therefore, considering the species survey carried out by Golder Associates during the dry season (2005) and the field survey carried out due to the licensing of this project (2008), a total of six (6) species were registered for the area of the project.

Fauna composition

About rodents, five individuals of a single species, *Thrichomys apereoides* (Lund, 1941), belonging to the family Echimyidae and subfamily Eumysopinae, were captured using cages. This species is popularly known in the region as “rabudo” and inhabits open and forested areas of Caatinga, being quite common in this Biome. In addition to the registration through the capture of individuals, it was possible to observe them in the rocky outcrops located in the areas of limestone extraction and surroundings, comprising physiognomies of the Arboreal shrubbery caatinga. The capture areas comprise highly altered environments.

For the order Didelphimorphia, two species were registered: the agile gracile opossum *Gracilinanus agilis* (Burmeister, 1854), and the *Didelphis albiventris*, belonging to the family Didelphidae and subfamily Didelphinae.

The agile gracile opossum *Gracilinanus agilis* has the Northeast, Midwest and Southeast regions as its occurrence area in Brazil and is linked to typical areas of the Cerrado and Caatinga biome (Geise and Astúa, 2009). The individual was captured using the interception and fall trap method, in an area with vegetation characterized as shrubbery. The white-eared opossum (*Didelphis albiventris*) is one of the most common species of wild mammals in Central Brazil, frequently observed in rural and urban human environments (Fonseca, 2003).

Species of economic interest and / or veterinary medicine

None of the species of small mammals are of commercial or economic interest and have no value as a food source or as agro-livestock pests.

Species threatened and protected by legislation

The three species of small mammals registered for the study area are classified with “least concern” status, according to IUCN (2016).

Rare and / or restricted species

No species of small terrestrial mammals of restricted distribution were registered.

Data Table 5.2-40 – Small non-flying mammal species registered using primary data for Directly Affected Area (DAA), Area of Direct Influence (ADI) and Indirect Influence (AII), with respective sampling methods and respective threat categories.

Order	Family	Taxon	Popular Name	Size	Method	Threat category		
						Federal	International	
						MMA nº 444/2014	IUCN, 2016	CITES, 2016
Didelphimorphia	Didelphidae	*Didelphis albiventris*	gambá	P	E	-	LC	-
		Gracilinanus agilis	guíca	P	P	-	LC	-
Rodentia	Echimyidae	*Thrichomys apereoides*	rabudo	P	AR	-	LC	-

Elaboration: Arcadis, 2017.

Methods: Interview (E); Pitfall (P); Living containment trap (AR). Threat Categories: Least Concern (LC).

- **Medium and Large Mammals**

During the field survey, 18 species of medium and large mammals were registered, distributed in five orders (Carnivora n = 9; Cingulata n = 4; Rodentia n = 3; Pilosa n = 1; and Primates n = 1) and nine families (Data Table 5.2-41).

The difference in relation to the Area of Indirect Influence (AII) and surroundings, where 35 species of medium and large mammals were identified, is due in large part to the size of the compared areas, since the larger the area sampled, the greater the number of species expected, in addition to the greater degree of interference in natural environments in the ADI / DAA, since the list of the AII includes data from two Conservation Units, PARNA Serra da Capivara and PARNA Serra das Confusões, responsible for 71% records of species likely to occur in the region.

The campaign carried out by Golder Associates in the dry season, due to the licensing of the pilot plant in 2005, registered 30 species of medium and large mammals in the project's AII, and all species detected during the rain were also detected during drought. Then, adding the species survey carried out by Golder Associates during the dry season (2005) and the field survey carried out due to the licensing of this project (2008), 30 species of medium and large mammals were registered, indicating a sampling satisfactory diversity expected for the region.

Data Table 5.2-41 – Medium and large mammal species recorded using primary data for Directly Affected Area (DAA), Area of Direct Influence (ADI) and Indirect Influence (AII), with respective sampling methods and respective threat categories.

Order	Family	Taxon	Popular Name	Size	Method	Threat category		
						Federal	International	
						MMA nº 444/2014	IUCN, 2016	CITES, 2016
Cingulata	Dasypodidae	*Dasypus novemcinctus*	tatu galinha	M	E	-	LC	-
		Dasypus septemcinctus	tatuí	M	E, AF, AR	-	LC	-
		Euphractus sexcinctus	tatu peba	M	E, I, AF, AD	-	LC	-
		Tolypeutes tricinctus	tatu-bola	M	E	EN	VU	-
Pilosa	Myrmecophagidae	*Tamandua tetradactyla*	tamanduá mirim	M	E	-	LC	-
Primates	Callithrichidae	*Callithrix jacchus*	sagüi	M	E	-	LC	-
Carnívora	Canidae	*Cerdocyon thous*	cachorro do mato	M	E, AF, AD	-	LC	II
	Felidae	*Puma yagouaroundi*	jaguarundi	M	E	-	LC	II
		Leopardus tigrinus	gato do mato	M	E	-	VU	I
		Leopardus wiedii	gato maracajá	M	E	VU	NT	I
		Puma concolor	suçuarana	G	E	VU	LC	I[1]
	Mustelidae	*Conepatus semistriatus*	cangambá	M	E	-	LC	-
		Eira barbara	irara	M	E	-	LC	-
		Galictis sp.	furão	M	E	-	-	-
	Procyonidae	*Procyon cancrivorus*	guaxinim	M	E	-	LC	-
Rodentia	Caviidae	*Kerodon rupestris*	mocó	M	E, I, AD	VU	LC	-
		Galea spixii	preá	M	E	-	LC	-

Order	Family	Taxon	Popular Name	Size	Method	Threat category		
						Federal	International	
						MMA nº 444/2014	IUCN, 2016	CITES, 2016
	Dasyproctidae	*Dasyprocta prymnolopha*	cutia	M	E, AF, AD	-	LC	-

Elaboration: Arcadis, 2017.

[1] *Three subspecies: (Puma concolor coryi, Puma concolor costaricensis and Puma concolor couguar) are in Appendix I.*

Methods: Interview (E); Living containment trap (AR); Camera Trap (AF); Indirect Register (I); Direct sighting (AD).

Threat Categories: Least Concern (LC); Near Threatened (NT); Vulnerable (VU); Endangered (EN); and Critically Endangered (CR). CITES: Appendix I - Lists the most endangered species. International trade is prohibited; Appendix II - Lists species at risk of becoming threatened with extinction if international trade is not controlled; and Appendix III - Lists species with partially regulated international trade, but which needs the cooperation of countries to avoid overexploitation.

Fauna composition

Among the 18 medium and large species noted, there was a direct register of five: seven-banded armadillo (*Dasypus septemcinctus*), six-banded armadillo (*Euphractus sexcinctus*), crab-eating fox (*Cerdocyon thous*), mocó (*Kerodon rupestris*) and black-rumped agouti (*Dasyprocta prymnolopha*). The other 13 species are considered to be possible occurrences in ADI / DAA, as they were registered only through interviews.

The five species registered directly in the ADI/DAA are considered common and occur frequently in altered environments and/or where there is considerable anthropic pressure. They are generalist species in terms of their diet and have low environmental requirements (Emmons, 1997; Eisenberg, 2000).

As mentioned in the methodological procedures, it was not possible to indirectly register many species, such as through footprints and faeces, since the massive presence of goats, pigs and cattle leaves practically every substrate full of footprints, in addition to the uncertainty of tracks in dry sand soil. For the armadillo it was possible to verify several characteristic holes in practically all the sampling areas, while the Mocó was registered through faeces on some stones.

Mocó individuals were observed several times in activity in the rocky outcrops found in the area where limestone mine. They were also sighted on rocks in a dry riverbed crossed by the road, which gives access to the limestone mine. In the nickel extraction area, no mocós were spotted, despite reports from local residents.

Distribution of fauna by the environment

Both for the camera trap method (Data Table 5.2-42) and for the direct sighting method, there was a difference in species richness between the sampling sites (limestone and nickel mine areas). According to the data from the camera traps (Data Table 5.2-42), the limestone extraction areas showed a greater richness (n = 3), while in the nickel extraction areas there was a greater number of registers.

Data Table 5.2-42 – Registers obtained through the method of camera traps at each sample site.

Specie	Nickel Area			Limestone Area		
	M 01	M 02	M 03	M 04	M05	M 06
Cerdocyon thous	6	2	2	-	-	3
Euphractus sexcinctus	-	-	-	-	-	2
Dasypus septemcinctus	-	-	-	-	1	-
Dasyprocta primynolopha	-	-	4	-	-	-

Obs.: in successive photos of the same species, events with a minimum interval of one hour were considered valid register.

Elaboration: ARCADIS Tetraplan, 2008

As can be seen in the Table itself, the number of registers obtained is considered too low to generate accurate conclusions and, according to the interviews conducted, the medium and large mammal communities in the two areas are probably similar in composition, however, it can vary in terms of species abundance.

Based on field observations and interviews with residents, it is believed that the low number of species and records is mainly related to local environmental variables (absence of rain in a long period) and the characteristics of the fauna itself local, which present low abundance related to anthropic pressure.

Species of economic interest and / or veterinary medicine

During the interviews, it was possible to notice that the local population does not exert great pressure for active hunting, so they do not go hunting. However, on several occasions, it has been reported that some animals, especially carnivores, are captured because they are believed to pose a threat to the creations, since the local inhabitants depend on them for their survival.

Still occasionally, in activity or displacement, the inhabitants report capturing animals such as the brazilian three-banded armadillo (*Tolypeutes tricinctus*) to use as food.

Species threatened and protected by legislation

Among the species registered by live containment traps, camera traps or by means of direct and indirect registers, only one is threatened with extinction. Mocó (*Kerodon rupestris*) is listed as "vulnerable" according to Portaria MMA No. 444/2014.

However, considering only those registered through interviews, that is a method of low reliability, four species appear on the official lists of threatened species. The brazilian three-banded armadillo (*Tolypeutes tricinctus*) is considered “endangered”, according to the Portaria MMA (nº 444/2014) and “vulnerable”, according to IUCN (2016). Also, the oncilla (*Leopardus tigrinus*), the margay (*Leopardus wiedii*) and the suçuarana cougar (*Puma concolor*, from the *coryi, costaricensis* and *couguar* subspecies), are classified as “vulnerable” (MMA nº 444/2014; IUCN, 2016) and appear in Appendix I of the International Convention on International Trade in Endangered Species of Wild Fauna and Flora, which lists the most endangered species, whose international trade is prohibited (CITES, 2016).

Rare and / or restricted species

Only the mocó (*Kerodon rupestris*) is considered endemic to the caatinga.

C) Summary

The non-flying terrestrial mammal community directly registered in the areas of influence of the project can be considered poor in terms of the number of species, despite the results obtained during interviews with local residents. This data is probably due to the size of the sampled areas and their degree of anthropization. However, when adding the data related to the campaign carried out by Golder Associates in 2005 during the drought, the diversity of mammals in the areas of influence of the project becomes more satisfactory. In general, the registered species have generalist habits, of low environmental demand and with great resistance to anthropic pressures, such as extensive cattle breeding, and hunting. Five species of medium and large mammals appear on official lists of threatened species, all detected only through interviews, except for one species of Mocó (*Kerodon rupestris*) whose identification occurred through direct sighting, being this species endemic to the Caatinga.

D) Photograph Report

Photo 5.2-80 – Camera trap used to sample medium and large mammals in the areas of influence of the project.

Photo 5.2-81 –Conducting interviews with residents of the project's areas of influence.

Photo 5.2-82 – Pitfall trap to capture small mammals.

Photo 5.2-83 – A live containment cage trap for capturing small mammals.

Photo 5.2-84 – Crab-eating fox (*Cerdocyon thous*) photographed by the camera trap.

Photo 5.2-85 – Seven-banded armadillo (*Dasypus septemcinctus*) individual photographed in caatinga area.

Photo 5.2-86 – Adult of six-banded armadillo (*Euphractus sexcinctus*) photographed by the camera trap.

Photo 5.2-87 – Photographic register of an black-rumped agouti (*Dasyprocta primynolopha*) in a caatinga area.

Photo 5.2-88 – Mocó individual (*Kerodon rupestris*). Photographed by John White.

Photo 5.2-89 – Goats registered by the camera trap.

Photo 5.2-90 – Pig registered in a caatinga area.

Photo 5.2-91 – Photographic register of cattle in one of the sampled caatinga areas.

Photo 5.2-92 – Specimen of marsupial of the species *Gracilinanus agilis* captured in a pifall trap.

Photo 5.2-93 – Specimen of rodent of the species *Thricomys apereoides* captured in a live cage trap.

5.2.4.4. Chiroptera

Considering that, through the analysis of updated satellite images, the use and occupation of the land in the area of the project has undergone little change in relation to the surveys carried out in this same area in 2008, it was agreed at a meeting held on September 2nd, 2016 between representatives of SEMAR-PI and PNM, that the primary data addressed in this chapter will be those whose surveys carried out in the study area for this same project, aimed to compose the Environmental and Social Impact Assessments (ESIA) and the respective Environmental Impact Report (RIMA), prepared by ARCADIS Tetraplan, in 2008 for Companhia Vale do Rio Doce.

A) Methodological Considerations

a) Collection of secondary data

In order to compose the scenario of fauna species likely to occur in the study region, data available in existing environmental studies and scientific publications were compiled in order to contribute to the characterization of the bat community present in the study area of this project.

For the survey of species of chiropterofauna that could potentially occur in the region, a data survey was compiled by the company Golder Associates (2005), when licensing the pilot plant for the project installed on the Brejo Seco hill. This survey was carried out in October 2005 and aims to compose the scenario of species likely to occur in the area of indirect influence (AII), in a dry period.

In addition, data published for the Serra das Confusões National Park, Piauí (Gregorin; Carmignotto and Percequillo, 2008) were compiled to detect the composition of bat species in a regional context.

b) Field sampling

Sample period

The study of flying mammals (chiropterans), through data collection in the field, was conducted in a sampling campaign. Data collection was carried out between February 18th and 29th, 2008 (rainy season). It is noteworthy that sampling in the dry season was carried out in an earlier phase, when the pilot plant was licensed, from October 10th to 14th, 2005 (Golder Associates, 2005 - secondary data), whose results were not included in the analysis of composition and distribution of the areas of influence of the project, however considered in a comparative analysis of richness for characterizing data related to the areas of insertion of the project in drought period, contemplating, therefore, the seasonality in the present study.

Spatial coverage of the study

The spatial scope for collecting primary data included the Directly Affected Area (DAA), and the Areas of Direct Influence (ADI) and Indirect Influence (AII) of the project.

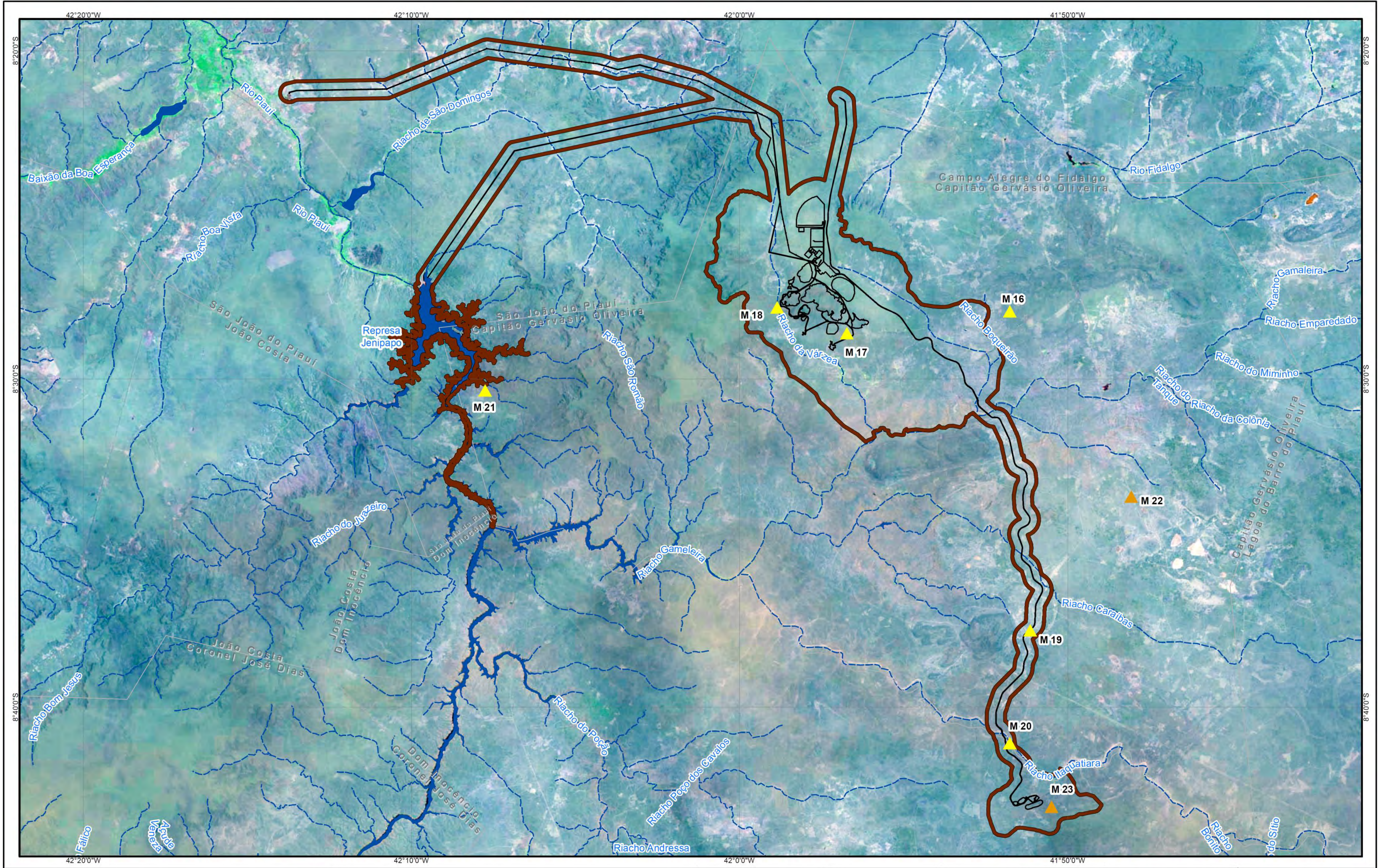
For the capture and collection of chiropterans, two types of methodology were used: capture in mist-nets and active search for shelters. The methods were applied at the following sampling sites (Data Table 5.2-43 e Map 5.2-12).

Data Table 5.2-43 – Characterization and location of sample sites for mist-nets and active search for shelters

Samples sites	Geographic Coordinates (UTM)		Zone	Method	Project Component	Area Description
M 16 (AII)	184806	9063119	24L	Mist-net	Near to the road PI - 465	Shrubby tree vegetation, with mixtures between open and dense areas.
M 17 (DAA)	175692	9061828	24L	Mist-net	Nickel Mine	Arboreal vegetation with dry riverbed.
M 18 (ADI)	171780	9063238	24L	Mist-net	Nickel Mine	Property with weirs for watering livestock and uncharacterized vegetation.
M 19 (DAA)	186073	9045180	24L	Mist-net	Access road of limestone mine	Composed of white sand with macambira and spaced trees.
M 20 (DAA)	184981	9038837	24L	Mist-net	Access road of limestone mine	Dry riverbed with rock outcrops and island formations along the river.
M 21 (AII)	816105	9058657	23L	Mist-net	Jenipapo Dam	Shallow rocky soil on sloping bank with some old buildings. Very little developed vegetation, covering a little the substrate, exposed for the most part.
M 22 (AII)	191673	9052742	24L	Active search	Near to the road PI - 465	Rocky outcrop, anthropized region with sparse vegetation.
M 23 (ADI)	187341	9035288	24L	Active search	Umbuzeiro, near of the limestone mine	Arboreal shrubbery vegetation (5 m), presence of bromeliads and rocky outcrops.

Elaboration: ARCADIS Tetraplan, 2008.

Map 5.2-12 – Chiroptera sampling sites.



LEGENDA

- Intermittent Drainage
- Water Mass
- Municipal Limits
- Area of Direct Influence - ADI
- Directly Affected Area - DAA

Chiroptera Sampling Method

- Active Search
- Mist Net

REFERÊNCIAS

ARCADIS Tetraplan, 2008;
IBGE, Base contínua 1:250.000, 2015;
LANDSAT, Imagem, 2016;
Projeto Piauí Níquel, 2016.

N W E S

ESCALA GRÁFICA

0 5 10 km

Sistema de Coordenadas: GCS SIRGAS 2000

MAPA DE LOCALIZAÇÃO

Piauí Níquel

ARCADIS Design & Consultancy for natural and built assets

EIA/RIMA – PROJETO PIAUÍ NÍQUEL

Map 5.2-12 – Sampling Sites
Chiroptera

EXECUTADO POR:	ESCALA:	NÚMERO:	DATA:
ARCADIS	1:200.000	Única	jun /2017

Data collection

- *Mist nets*

The main method of sampling the chiropterofauna consisted of using mist nets to capture the animals.

The mist nets were set up on trails and roads close to the sampling sites, with four nets (3 x 7 m) being opened per night for five nights. The nets were set up during the evening and remained open for about five hours, on average. The total sampling effort was 100 hours per net.

- *Active search*

In order to optimize the results, an active search for shelters was carried out. The searches were carried out in abandoned houses, rock cracks and tree hollows. When detected, the individuals were photographed and captured with the help of mist nets. In some cases, there were no physical or structural conditions that allowed the capture, making it impossible to accurately identify the species of the observed colony.

- *Interview*

Interviews with residents of the region were carried out in a complementary manner to diagnose the presence of hematophagous bats in the region and their association with domestic and farmed animals

The interviews were carried out in properties located in the area of influence of the project and its surroundings, together with the interviews carried out for medium and large mammals. The owners were asked about the presence of bats in the vicinity of the properties and about the presence of injuries, or bleeding in domestic animals caused by the attack of hematophagous bats.

Specimen Register

The captured individuals were, whenever possible, identified at a specific level and registered individually through field numbering. Data such as date and place of capture, mass and biometric measurements of the group (forearm) were also noted. The length measurements were taken with a calliper and the mass was measured using spring scale dynamometers with different capacities (10, 50 and 100g). The reproductive condition of the specimens was verified by analysing the size and palpation of the abdomen (pregnant or not) and breasts (lactating or not), scrotal testis (adult males) and abdominal testis (young males).

Representative series of this group were collected, with the exception of endangered species, aiming at the adequate characterization of the region's chiropters fauna.

The collection of material belonging to this fauna group followed the predicted collection quantities and determinations specified in the Capture, Collection and Transport License granted by the Brazilian Institute of Environment and Renewable Natural Resources (IBAMA), nº 02020.000065/2008-16, with period valid from February 15th to May 31st, 2008 (Arcadis Tetraplan, 2008).

Conservation status

To ascertain the conservation status of registered bats species, the Official National List of Endangered Species of Fauna was consulted, Portaria MMA No. 444/2014.

At international level, the protection of fauna also focuses on international agreements, related to species and habitats. The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES, 2014) provides a list of species whose international trade must be controlled (Fitzgerald, 1989).

The International Union for Conservation of Nature (IUCN, 2016) established the following categorization for the purpose of preserving species considered threatened: Least Concern (LC); Near Threatened (NT); Vulnerable (VU); Endangered (EN); and Critically Endangered (CR)

B) Results

a) Regional Characterization

In the neotropical region, bats can represent up to 50% of the mammal community in a region (Timm, 1994), playing an important role in the maintenance of natural areas due to the various ecological services provided, such as the dispersion of seeds and the control of populations of invertebrates (Kalka *et al.*, 2008; Mello *et al.*, 2011).

With the survey carried out in the areas of influence of the project at the time of licensing the pilot project (Golder Associates, 2005) added to the data published for the Serra das Confusões National Park (Gregorin; Carmignotto and Percequillo, 2008), it was obtained a total of 32 bat species likely to occur (Data Table 5.2-44). These data express the little knowledge of the fauna existing in the State of Piauí.

The most representative family, according to the bibliographic survey, is Phyllostomidae, with 75% of all species registered for the area of influence. In the Neotropical region, the Phyllostomidae family is the most diverse, in species and eating habits and are the main seed dispersers of many pioneer plants in this region (Tavoloni, 2006). Due to their wide variety of eating habits, the species of this family actively participate in the recycling of nutrients and energy in the ecosystem in which they live (Brusco; Tozaco, 2009).

Among the species registered through bibliographic surveys, only one species (*Furipterus horrens*) is threatened with extinction, under the vulnerable status, according to the official list of MMA (MMA nº 444/2014). In addition to this, one species (*Vampyrum spectrum*) is almost threatened according to IUCN (2016) and two other species (*Tonatia bidens* and *Micronycteris sanborni*) have insufficient data to assess their risk of extinction (IUCN, 2016)

Data Table 5.2-44 – Bat species likely to occur in the Area of Indirect Influence (AII) and surroundings, with respective threat categories.

Order	Family	Taxon	Popular Name	Threat category			Source
				Federal	International		
				MMA nº 444/2014	IUCN, 2016	CITES, 2016	
Chiroptera	Emballonuridae	*Peropteryx macrotis*	morcego	-	LC	-	1
	Furipteridae	*Furipterus horrens*	morcego	VU	LC	-	1; 2
	Molossidae	*Molossops temmincki*	morcego	-	-	-	2
		Molossus molossus	morcego	-	LC	-	1; 2
		Nyctinomops laticaudatus	morcego	-	LC	-	1
	Mormoopidae	*Pteronotus parnellii*	morcego	-	LC	-	1
	Noctilionidae	*Noctilio albiventris*	morcego	-	LC	-	1
		Noctilio leporinus	morcego	-	LC	-	1
	Phyllostomidae	*Carollia perspicillata*	morcego	-	LC	-	1; 2
		Anoura geoffroyi	morcego	-	LC	-	2
		Desmodus rotundus	morcego	-	LC	-	1; 2
		Diphylla ecaudata	morcego	-	LC	-	1; 2
		Glossophaga soricina	morcego	-	LC	-	1; 2
		Lonchophylla sp	morcego	-	-	-	1
		Micronycteris megalotis	morcego	-	LC	-	2
		Micronycteris sanborni	morcego	-	DD	-	2
		Micronycteris minuta	morcego	-	LC	-	1
		Mimon crenulatum	morcego	-	LC	-	2
		Mimon bennettii	morcego	-	LC	-	1; 2
		Phyllostomus discolor	morcego	-	LC	-	1; 2
		Phyllostomus hastatus	morcego	-	LC	-	1
		Lophostoma carrikeri	morcego	-	LC	-	2
		Vampyrum spectrum	morcego	-	NT	-	2
		Tonatia bidens	morcego	-	DD	-	1
		Trachops cirrhosus	morcego	-	LC	-	1
		Artibeus lituratus	morcego	-	LC	-	1; 2
		Artibeus planirostris	morcego	-	LC	-	1; 2
		Platyrrhinus lineatus	morcego	-	LC	-	2
		Chiroderma villosum	morcego	-	LC	-	1; 2
		Sturnira lilium	morcego	-	LC	-	1; 2

Order	Family	Taxon	Popular Name	Threat category			Source
				Federal	International		
				MMA nº 444/2014	IUCN, 2016	CITES, 2016	
Chiroptera	Emballonuridae	*Histiotus sp*	morcego	-	-	-	1
Chiroptera	Emballonuridae	*Myotis nigricans*	morcego	-	LC	-	1; 2

Elaboration: Arcadis, 2017.

Source: (1) Golder Associates, 2005; (2) Gregorin; Carmignotto; Percequillo, 2008.

Threat Categories: Least Concern (LC); Near Threatened (NT); Vulnerable (VU); and Deficient Data (DD).

b) Areas of Influence (DAA, ADI and AII)

Through the field survey, six species of bats, belonging to three families, were registered: Emballonuridae, Mormoopidae and Phyllostomidae (Data Table 5.2-45).

The low diversity of species detected through field surveys, is probably related to the limitations of the methodology employed, as many bat species fly higher than the area covered by the mist nets, making their capture unfeasible.

It should be noted, however, that when adding the data collected in the AII during the drought by Golder Associates in 2005, a total of 26 species are assigned to the area of the project, two of which (*M. sanborni* and *M. megalotis*) were registered only during the rainy season and another 20 registered only during the dry season.

Data Table 5.2-45 – Bat species recorded using primary data for Directly Affected Area (DAA), Area of Direct Influence (ADI) and Indirect Influence (AII), with respective sampling methods and respective threat categories.

Order	Family	Taxon	Popular Name	Method	Threat category		
					Federal	International	
					MMA nº 444/2014	IUCN, 2016	CITES, 2016
Chiroptera	Emballonuridae	*Peropteryx macrotis*	morcego	BA	-	LC	-
	Mormoopidae	*Pteronotus parnelli*	morcego	RN	-	LC	-
	Phyllostomidae	*Artibeus planirostris*	morcego	RN	-	LC	-
		Trachops cirrhosus	morcego	BA	-	LC	-
		Micronycteris sanborni	morcego	RN	-	DD	-
		Micronycteris megalotis	morcego	BA	-	LC	-

Elaboration: Arcadis, 2017.

Methods: Active search for shelter (BA); mist net (RN).

Threat categories: Least Concern (LC); deficient data (DD).

Fauna composition

Among the captured species, there was a predominance of the Phyllostomidae family, an expected result, as they are the most common species in bat surveys (Bernard, 2001a, 2001b; Bianconi *et al.*, 2004).

In the sampling with mist nets, five individuals belonging to three (3) species were captured: *Artibeus planirostris* (Spix, 1823), *Micronycteris sanborni* (Simmons, 1996) and *Pteronotus parnellii* (Gray, 1843).

To optimize the results found through the use of mist nets, active searches of bats were carried out in shelters. Through this methodology, five individuals belonging to three species were registered: *Trachops cirrhosus* (Spix, 1823), *Peropteryx macrotis* (Wagner, 1843) and *Micronycteris megalotis* (Gray, 1842). The species detected by this methodology were already known for the project's AII with the exception of *M. megalotis*.

As for nutrition habits, 67% of the sampled species are insectivorous, with beetles and lepidopterans being the main sources of food. A frugivorous species, *A. planirostris*, was also found, which consumes fruits of species such as jurubeba (*Solanum sp.),* For example. In addition to these, a carnivorous species (*T. cirrhosus*) was also registered, which feeds mainly on amphibians, small lizards, birds and mammals. It should be noted, however, that the food items used by some species of bats can vary greatly depending on the region and the time of year (Reis *et al.* 2007).

Although it was noticeable the presence of bats in all sampled areas, the number of captured chiropters species can be considered low. This fact may be related to the limitations of the methodology employed (mist net), since many bat species fly higher than the area covered by the nets, such as those belonging to the Vespertilionidae family. In addition, in open areas, bats more easily detect the presence of traps.

To alleviate these limitations, the nets were set up on roads cutting through vegetated areas. However, due to the low amount of rain, the vegetation was dry, making it unattractive for these animals.

Another way of avoiding the limitations of the use of the mist net was the use of another methodology, such as the active search for bats in daytime shelters, increasing the number of species found by 50%. This demonstrates the importance of looking for shelters as a complementary form in inventories, as already registered in other works (Simons & Voss, 1998; Tavares, 1999; Portfors *et al.*, 2000; Baptista & Mello, 2001).

Distribution of fauna by the environment

The species *T. cirrhosus* and *M. megalotis* were found in different abandoned houses located in different areas (access road to the limestone mine and Jenipapo Dam, respectively). There was no record of other species co-inhabiting these sites (monospecific colonies). The species *P. macrotis* was registered in two different locations, in the limestone extraction area and in a shelter located near the access road between the municipality of Capitão Gervásio Oliveira and the limestone extraction area. All individuals of this species were found in rock crevices.

Most bat species found in this work are associated with environments with rocky outcrops. The species *P. parnellii, P. macrotis* and *M. sanborni* occupy only natural cavities as a shelter, and in caatinga areas they are associated with limestone rocky outcrops (Trajano, 1995; Bordignon, 2006; Bordignon *et al.,* 2006; Nogueira *et al*., in prep. *apud* Reis, *et al.* 2007). The other species are more general in terms of shelters, varying between hollows of trees, caves, holes in the ground built by larger mammals, human constructions such as bridges, culverts and houses.

Most of the captures took place at the ADI of the limestone mine and on the road that connects the municipality of Capitão Gervásio Oliveira to the limestone extraction area. Because they have extensive living areas, which can exceed 500 hectares, and use more than one habitat per night (Estrada & Coates-Estrada, 2001; Bernard & Fenton, 2003), bats possibly share the different areas of influence of the project.

Data Table 5.2-46 – Bat species and the respective sites where they were registered in the areas of influence of the project (DAA, ADI and AII).

Family	Species	Method	M 16	M 17	M 18	M 19	M 20	M 21	M 22	M 23
Phyllostomidae	*Artibeus planirostris*	RN					X			
	Micronycteris sanborni	RN				X	X			
	Micronycteris megalotis	BA						X		
	Trachops cirrhosus	BA							X	
Emballonuridae	*Peropteryx macrotis*	BA							X	X
Mormoopidae	*Pteronotus parnellii*	RN						X		

Elaboration: ARCADIS Tetraplan, 2008.

Legend: Active search for shelter (BA); Mist net (RN).

Species threatened and protected by legislation

None of the bat species sampled are threatened with extinction, according to official lists (MMA, 2014; IUCN, 2016; CITES, 2016). All species are currently classified with “least Concern” status (IUCN, 2016), with the exception of *Micronycteris sanborni*, whose status is deficient in data and the information published for this species is insufficient to carry out an assessment on its extinction risk (IUCN, 2016).

Rare and/or restricted species

Chiropteran species of restricted distribution were not recorded.

C) Summary

The low diversity of chiropterans recorded during the field survey is probably influenced by methodological limitations for environmental diagnosis. Bearing in mind, however, that the species survey carried out by Golder Associates during the dry season (2005) is complementary to the field survey carried out due to the licensing of this project (2008), it can be considered that the species' richness detected in the area of the project is sufficiently consistent, when compared to the fauna likely to occur in the region. Species of the Phyllostomidae family, characterized by a high diversity of eating habits, predominate in the project's areas of influence. Some species detected in this assessment are dependent on specific characteristics present in certain environments, such as the rocky outcrops found on the access road to the limestone mine area. Among these species, species *Pteronotus parnellii, Peropteryx macrotis* and *Micronycteris sanborni*can be mentioned. No species is threatened with extinction according to the official lists.

D) Photograph Report

Photo 5.2-94 – Mist net trap to capture bats

Photo 5.2-95 – Active search for bat shelters

Photo 5.2-96 – Specimen of chiroptera species *Artibeus planirostris* captured in a mist net.

Photo 5.2-97 – Specimen of *Trachops cirrhosus* captured in an abandoned house.

Photo 5.2-98 –Individual of the species *Peropteryx macrotis* captured in a shelter.

Photo 5.2-99 – Individual of the species *Pteronotus parnelli* captured in a mist net.

Photo 5.2-100 – Individual of the species *Micronycteris megalotis* captured in an abandoned house near the Jenipapo Dam.

Photo 5.2-101 – Shelter found in a rock crack used by the species *Peropteryx macrotis* in the area of influence of the project.

5.2.4.5. Entomofauna

Considering that, through the analysis of updated satellite images, the use and occupation of the land in the area of the project has undergone little change in relation to the surveys carried out in this same area in 2008, it was agreed at a meeting held on September 2nd, 2016 between representatives of SEMAR-PI and PNM, that the primary data covered in this chapter will be those whose surveys carried out in the study area for this same project, aimed to compose the Environmental and Social Impact Assessments (ESIA) and the respective Environmental Impact Report (RIMA), prepared by ARCADIS Tetraplan, in 2008 for Companhia Vale do Rio Doce.

A) Methodological Considerations

a) Field sampling

Sampling period

The study of invertebrates (arthropods) of public health interest, through data collection in the field, was conducted in a sampling campaign. Data collection was carried out between March 3rd and 7th, 2008 (rainy season). It is noteworthy that the rainy season in the region is quite favourable for the survey of invertebrates of medical and sanitary interest, due to the presence of environments suitable for their proliferation.

Spatial coverage of the study

The spatial scope for collecting primary data included the Directly Affected Area (DAA), and the Areas of Direct Influence (ADI) and Indirect Influence (AII) of the project.

Landscapes compatible with the presence of these insects were chosen for the capture. The capture points were allocated during the field visit, during the referred campaign (Data Table 5.2-47; Map 5.2-13).

Data Table 5.2-47 – Characterization and location of entomofauna sample sites.

Samples sites	Geographic Coordinates (UTM)		Zone	Methods	Locality	Area Description
A (ADI)	180436,1	9062845	24S	LP1, LP2, LN1	Campo Alegre do Fidalgo Road to the Nickel Mine, next to the connection to Capitão Gervásio Oliveira - property with roadside housing	Water retention dam. The collection was made on the edge in an environment with floating plant fragments. The larvae were grouped among the fragments. Water with turbid aspect. The lake's edge, in and out of the water, was colonized by emergent herb recognized locally as massambê.
B (ADI)	173576	9059658	24S	LP3, LP4, SP1	Near the mining site - on the road that connects the road to the settlements to the mine	Water retention dam. With trees at the edges providing partial shading. At the collection site there were small emerging plants.
C (AII)	188274,1	9052693	24S	LP5, LP6, LP7, AP3, BN1	Capitão Gervásio Road - Serra da Aldeia and the dam for supplying the municipality's headquarters	Tire located around the houses (note: first stage larvae and egg rafts were collected). Valley bottom with dry, rocky bed and some puddles. The collection was made in a rock depression with accumulation of water. Reservoir supply dam of the municipality: margin rich in algae.

Samples sites	Geographic Coordinates (UTM)		Zone	Methods	Locality	Area Description
D (DAA)	185830,1	9037159	24S	LP8, LP9, SP2, BN2	Access road to the limestone mine	Stone hole - clear water - with larvae + tadpoles - bottom with mud. Bed of Itaquatiara stream with sand deposits. The collection was carried out in a depression that accumulates water and serves as a drinking fountain for cattle. Breeding ground contaminated by manure and trampled by cattle.
E (AII)	810423,9	9064762	23S	LP10, LP11, LN2, SP3, BP1	Downstream from the Jenipapo Dam	On the riverside, at points with macrophytes: Salvinia, Pistia and Typha. Clear water. Depression in the soil filled with rainwater and the presence of grasses. The water had a clear characteristic and, in some places, foams formed on the surface.
F (AII)	171189	9057790	24S	LP12, LN3, AP1, AP2, SP4, BP2, BP3, BP4	Vereda's Settlement	Dam for water retention. Collection carried out on the bank of the dam amid numerous fragments of vegetation resulting from the fractionation of leaves, branches, sticks, etc. In large part of the breeding surface, algae colonization gave the surface a green colour.

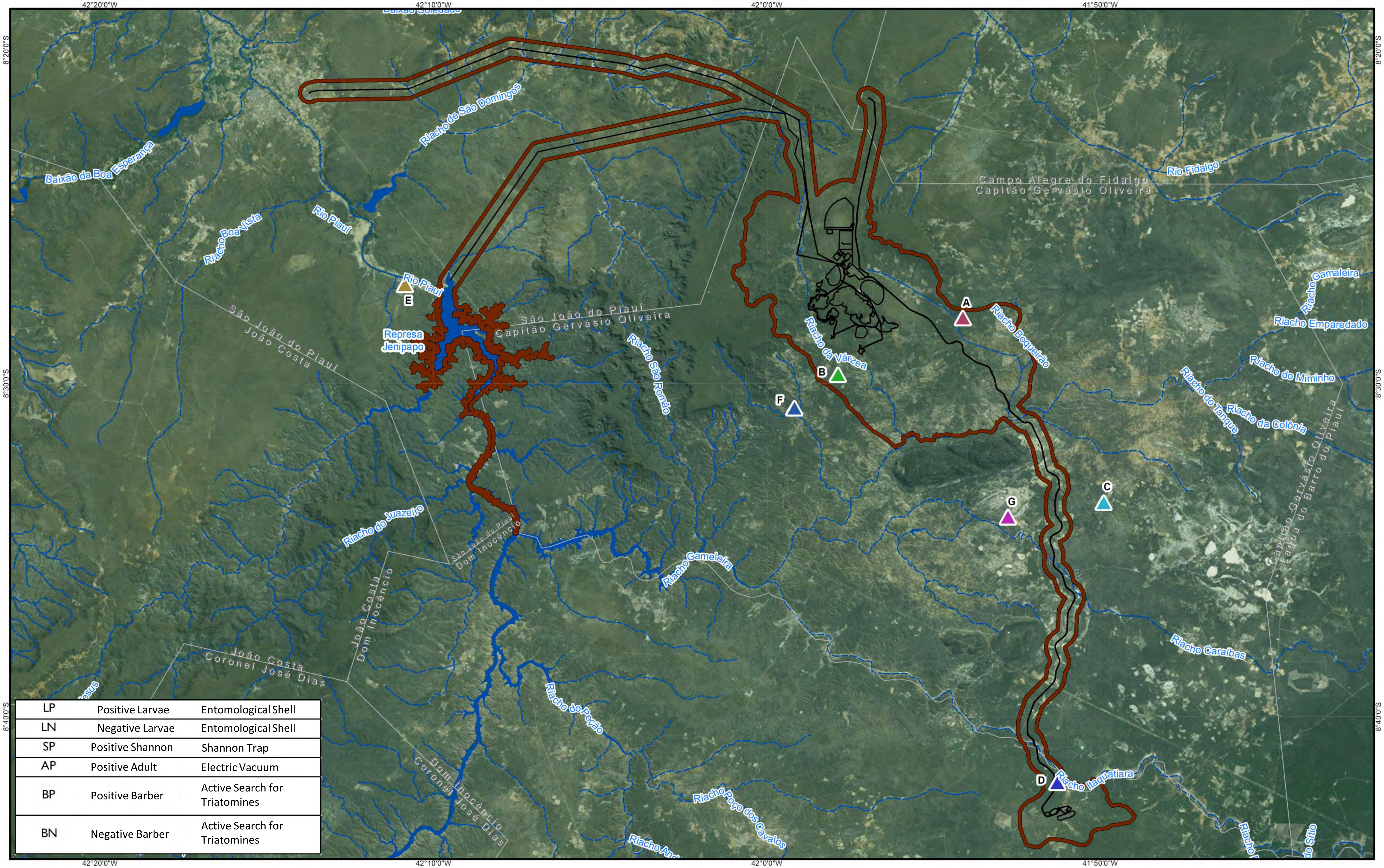
Samples sites	Geographic Coordinates (UTM)		Zone	Methods	Locality	Area Description
G (AII)	182999,1	9051850	24S	LP13, LP14, LP15, BP5, BN3, BN4	Chapadinha	Cylindrical home water reservoir built with concrete. Ceramic container for water reserve for domestic animals located at ground level. Quarry for the extraction of cobblestones used for paving the municipal headquarters. Depressions in the stones with accumulation of organic matter in the background. Presence of fragments of leaves and sticks in a rotting state. Water with clean looking.

Legend:

LP	Positive larva	Entomological shell
LN	Negative larva	Entomological shell
SP	Shannon positive	Shannon's trap
AP	Positive adult	Electric aspirator
BP	Positive barber	Active Search for Triatomines
BN	Negative barber	Active Search for Triatomines

Elaboration: ARCADIS Tetraplan, 2008.

Map 5.2-13 – Entomofauna sampling sites.



LP	Positive Larvae	Entomological Shell
LN	Negative Larvae	Entomological Shell
SP	Positive Shannon	Shannon Trap
AP	Positive Adult	Electric Vacuum
BP	Positive Barber	Active Search for Triatomines
BN	Negative Barber	Active Search for Triatomines

LEGENDA

- Intermittent Drainage
- Water Mass
- Municipal Limits
- Area of Direct Influence - ADI
- Directly Affected Area - DAA

Sampling Sites

- A LP-1, LP-2, LN-1
- B LP-3, LP-4, SP-1
- C LP-5, LP-6, LP-7, AP-3, BN-1
- D LP-8, LP-9, SP-2, BN-2
- E LP-10, LP-11, LN-2, SP-3, BP-1
- F LP-12, LN-3, AP-1, AP-2, SP-4, BP-2, BP-3, BP-4
- G LP-13, LP-14, LP-15, BP-5, BN-3, BN-4

REFERÊNCIAS

ARCADIS Tetraplan, 2008;
IBGE, Base contínua 1:250.000, 2015;
ESRI, Imagem, 2016;
Projeto Piauí Níquel, 2016.

ESCALA GRÁFICA

0 5 10 km

Sistema de Coordenadas: GCS SIRGAS 2000

MAPA DE LOCALIZAÇÃO

PIAUÍ NÍQUEL

ARCADIS

EIA/RIMA – PROJETO PIAUÍ NÍQUEL

Map 5.2-13 – Sampling Sites Entomofauna (Vector Insects)

EXECUTADO POR:	ESCALA:	NÚMERO:	DATA:
ARCADIS	1:200.000	Única	jun /2017

Data collection

b) Immature mosquitoes

- Entomological shells

Method used to collect immature mosquitoes that inhabit stagnant aquatic collections, located at the bottom of valleys and in containers found around the houses. At these points, active searches for immature mosquitoes were carried out under natural conditions.

- Adult mosquitoes

The following two techniques were applied to the research of Phlebotomines and Culicids.

- Shannon's trap

To collect adult mosquitoes with nocturnal habits in flight activity, Shannon traps were used, which remained open in the pre-twilight period, between 5 pm and 9 pm.

- Aspirator

To collect adult mosquitoes inside homes, an electric aspirator was used, which was collected during the day.

c) Triatomines

- Active search

Triatomines (barbers or bolls) were sought in wild environments, in home attachments and inside homes and, when present, were captured. During visits to rural homes, some specimens of barbers were collected by residents and made available for research. All places of incidence of triatomines were shown in Map 5.2-13.

Conservation of collected material

The immature forms of mosquitoes were kept in plastic bottles containing water from the original breeding site, until they completed their development (adult stage). The exuvia from the seedlings were transferred to mini flasks with 70% alcohol for transportation. The adult mosquitoes were placed in entomological boxes containing a mixture of paraffin and naphthalene as a preservative. The triatomines were kept alive in aerated plastic tubes. At the collection site itself, all material was labeled and packaged for shipment to the Entomology Laboratory in Public Health - LESP, at USP's School of Public Health, in São Paulo, where it was deposited.

Laboratory procedures

The identification of the collected material was carried out at LESP / USP, in São Paulo. Representative specimens of the identified species were sent to the Reference Entomological Collection of the mentioned laboratory. The Photographic Annex presents the procedures performed in the identification laboratory, which involve the packaging of immature and adult mosquitoes in entomological boxes and slide boxes, respectively, as well as an adult mosquito specimen attached to an entomological pin.

Interviews

In addition to the established collection strategies, contact was made with professionals from the Health Department of Capitão Gervásio Oliveira, with the objective of registering local public health problems and, at the same time, being aware of the main challenges in the region, which may relate potential risk of new diseases carried by vectors and other arthropods.

B) Results

a) Regional Characterization

According to the characteristics of the region where the project is inserted, potential vector species of the Culicidae Family are expected, such as those of the genera *Anopheles, Aedes* and *Haemagogus*, linked to important pathogens, such as plasmodiums and arboviruses, respectively, among which stand out yellow fever and dengue viruses.

Likewise, potential vector species of leishmaniasis, of the Phlebotominae family, are expected, with emphasis on the genera *Lutzomyia* (vector of visceral Leishmaniasis) and *Bichromomyia, Nyssomyia, Pintomyia* and *Psychodopygus* (vectors of cutaneous-mucous leishmaniasis).

In addition, vector species of the subfamily Triatominae are likely to occur, with attention to the genera *Triatoma, Panstrongylus* and *Rhodnius*, as they are linked to the biological agent of Chagas disease.

It is known that the small dams on the properties that accumulate rainwater to face drought, serve as breeding grounds for mosquitoes. The larvae are regularly concentrated on the margins of the breeding site where small plant debris accumulates, resulting from the fragmentation of floating plant stems and leaves. In the cleaner margins there is no favorable condition for the immature mosquitoes.

Mosquitoes (culicidae) survive, in the immature phase, in the floodplains of rivers, in slow or standing waters, in ponds and swamps, while the immature phlebotomine live in humid and rocky soils, usually in shady areas, and suffer severe impact from the loss of the original vegetation cover. Displaced due to the loss of vegetation cover, they tend to occupy existing wooded areas near human installations.

Triatomines or barbers, in turn, regularly inhabit the wild, usually concentrating on the tops of palm trees and in the nests of birds or shelters of wild animals. Thus, they are generally associated with natural vegetation and, like phlebotomine, tend to move to inhabited areas, a fact that requires attention given the important risk of spreading pathogens.

b) Areas of Influence (DAA, ADI and AII)

During the study, collection efforts were concentrated in the vicinity of the Nickel Mine area, at the Limestone Mine and in the region scheduled to collect water from the Jenipapo Dam. In addition to these points, other collections were carried out near the roads, access roads and in the municipality of Capitão Gervásio Oliveira.

The fieldwork efforts earned positive collections (individuals collected) and negative collections (absence of individuals) explained below:

Data Table 5.2-48 – Results of the collection effort using different methods

Method	Positive Collection	Negative Collection
Entomological shell for catching immature mosquitoes in breeding sites	15	2
Aspirator to catch adult mosquitoes inside homes	3	
Shannon's trap for catching adult night mosquitoes	4	
Active search inside houses and home annexes	5	1
Active search in wild environments		2

c) Research of immature mosquitoes (larvae and pupae)

During the study of immature mosquitoes, it was possible to notice that the small dams, which accumulate rainwater, are potential breeding sites for them. The positivity of these dams for mosquitoes was high, with only two out of the 17 sampled, which resulted in negative collection, as previously presented (Data Table 5.2-48).

In the positive dams, the larvae are regularly concentrated on the margins of the breeding site, where small plant debris accumulates, resulting from the fragmentation of stems and leaves of floating plants. Larger margins were not detected, since there is no favorable condition for the immature mosquitoes.

On the visit to the Jenipapo Dam, the coastal areas were not conducive to the development of immature mosquitoes and the collections were negative (Point LN-2), however, immediately downstream of the dam, with abundant water emerging from the water system. dam and flood the riverbed, conditions are favourable to culicids, resulting in positive collection (Point LP-10). Several species of aquatic vegetation proliferate in this environment, among which lesser bulrush (*Typha sp.*), water lettuce (*Pistia sp.*) and plants of the genus *Salvinia*.

Another favourable condition for the development of immatures is the peridomestic environment. In these places, the stock of clean water in containers handcrafted from tires, drums, cement tanks, among others, are potential breeding grounds for mosquitoes. In this sense, many sites have resulted in positive collection for immature mosquitoes (Point LP-5).

Data Table 5.2-49 shows the results obtained in the areas of influence of the project for immature mosquitoes. The data are organized according to the collections and were numbered with the acronym LP (Positive Larvae), covering LP-01 to LP-15. The descriptions of the collection sites are explained in Data Table 5.2-47. A Data Table 5.2-49 also discriminates the number of individuals collected, the calculation of dominance, richness and diversity for each sampling site.

Data Table 5.2-49 – Abundance, Dominance, Richness and Diversity of immature Culicids collected through entomological shell in the areas of influence of the project.

Collection Nº	Species	Abundance	Dominance (%)	Richness	Diversity
LP 01	*Culex (Culex) paramax*	25	100	1	0
LP 02	*Culex (Culex) paramax*	5	100	1	0
LP 03	*Culex (Culex) paramax*	21	63.63	2	0.26
	Culex (Culex) nigripalpus	12	36.36		
LP 04	*Culex (Culex) paramax*	3	75	2	0.72
	Anopheles (Nyssorhynchus) albitarsis	1	25		
LP 05	*Culex (Culex) sp*	48	100	1	0
LP 06	*Culex (Culex) paramax*	1	100	1	0
LP 07	*Anopheles (Nyssorhynchus) albitarsis*	19	95	2	0.33
	Culex (Melanoconion) seção Melanoconion	1	5		
LP 08	*Culex (Culex) paramax*	20	100	1	0
LP 09	*Culex (Culex) paramax*	12	70.6	3	0.7
	Culex (Culex) nigripalpus	4	23.52		
	Culex (Culex) saltanensis	1	5.88		
LP 10	*Anopheles (Nyssorhynchus) albitarsis*	13	86.66	2	0.37
	Culex (Melanoconion) aureonotatus	2	13.33		
LP 11	*Aedes (Ochlerotatus) scapularis*	72	100	1	0
LP 12	*Culex (Culex) paramax*	18	100	1	0
LP 13	*Culex (Culex) paramax*	32	100	1	0
LP 14	*Culex (Culex) paramax*	31	100	1	0
LP 15	*Culex (Culex) paramax*	41	93.18	2	0.26
	Aedes (Ochlerotatus) lepidus	3	6.81		
Total		**385**	**-**	**9**	**1.34**

Legend: LP – Positive larvae.

According to Data Table 5.2-49, it is suggested that the *Culex* (*Culex*) *paramax* species is disseminated in the region, being common in immature collections, with positivity greater than

Among the species collected, they have recognized epidemiological importance: *Aedes scapularis, Culex nigripalpus, Culex (Melanoconion) sp.* and *Anopheles albitarsis*. The

Photographic Report (item D) presents morphological aspects of the species of *Culex, Anopheles albitarsis* and *Aedes scapularis*.

d) Research of adult mosquitoes in shelters

During the search for adult mosquitoes with an electric aspirator, species of the Culicidae family were detected inside the homes, indicating the existence of synanthropic species in the region. Data Table 5.2-50 shows the results obtained for adult mosquitoes according to the variables included in the study and the numbers of collections.

As the region was quite dry during the collection period, with rarefied vegetation, no suitable ecotypes for the presence of these groups in Caatinga areas were detected. Thus, the sampling of this group are concentrated in artificial shelters, in the domestic environment.

Data Table 5.2-50 – Abundance, Dominance, Richness and Diversity of adult Culicids collected with an electric aspirator in the areas of influence of the project.

<table>
<tr><th>Collection Nº</th><th>Species</th><th>Abundance</th><th>Dominance (%)</th><th>Richness</th><th>Diversity</th></tr>
<tr><td>AP 01</td><td>Culex (Culex) quinquefasciatus</td><td>24</td><td>100</td><td>1</td><td>0</td></tr>
<tr><td rowspan="2">AP 02</td><td>Culex (Culex) quinquefasciatus</td><td>76</td><td>98.7</td><td rowspan="2">2</td><td rowspan="2">0.23</td></tr>
<tr><td>Culex (Melanoconion) seção Melanoconion</td><td>1</td><td>1.29</td></tr>
<tr><td rowspan="2">AP 03</td><td>Culex (Culex) quinquefasciatus</td><td>11</td><td>91.67</td><td rowspan="2">2</td><td rowspan="2">0.4</td></tr>
<tr><td>Culex (Culex) paramax</td><td>1</td><td>8.33</td></tr>
<tr><td colspan="2">Total</td><td>113</td><td>-</td><td>3</td><td>0.42</td></tr>
</table>

Legend: AP – positive adults.

The result of the aspirator research reveals the marked presence of *Culex quinquefasciatus* inside the houses investigated. This mosquito is known, mainly, for the discomfort it causes to the population through the hum and bites. In addition, this species is the main vector of filariasis, popularly known as elephantiasis (FIOCRUZ, 2016).

e) Research of adult mosquitoes in flight activity

In the research of adult mosquitoes in flight activity with Shannon's trap, greater fauna richness was verified in relation to the collection with electric aspirator, having been recognized mosquitoes of the main genera that occur in Brazil.

Despite this higher index of richness, in no sampling were specimens of phlebotomine (also not registered through an electric aspirator). Phlebotomines are the transmitters of leishmania and, although they have not been detected, they cannot be considered non-existent in the region. As these dipterans are small and occur in flocks, it is possible that the collection period did not coincide with this phenomenon.

Data Table 5.2-51 provides the results for collections with Shannon's trap, intended to sample nocturnal adult mosquitoes. It is noteworthy that the environments explored in this collection strategy were located in a rural area, far from urban centers.

Data Table 5.2-51 – Abundance, Dominance, Richness and Diversity of adult Culicids collected with Shannon's trap in the areas of influence of the project.

Collection Nº	Species	Abundance	Dominance (%)	Richness	Diversity
SP 01	*Anopheles (Nyssorhynchus) albitarsis*	5	41.67	5	1,61
	Culex (Melanoconion) aureonotatus	3	25		
	Culex (Melanoconion) vaxus	2	16.67		
	Culex (Culex) paramax	1	8.33		
	Psorophora (Janthhinosoma) ferox	1	8.33		
SP 02	*Psorophora (Grabhamia) confinnis*	3	50	4	1,67
	Anopheles (Nyssorhynchus) albitarsis	1	16.66		
	Culex (Melanoconion) aureonotatus	1	16.66		
	Culex (Melanoconion) vaxus	1	16.66		
SP 03	*Mansonia (Mansonia) humeralis*	22	34.4	8	1,68
	Mansonia (Mansonia) indubitans	18	28.12		
	Anopheles (Nyssorhynchus) triannulatus	10	15.62		
	Anopheles (Nyssorhynchus) albitarsis	8	12.5		
	Coquellettidia (Rhynchotaenia) nigricans	3	4.68		
	Aedeomyia squamipennis	1	1.56		
	Coquellettidia (Rhynchotaenia) hermanoi	1	1.56		
	Culex (Culex) nigripalpus	1	1.56		
SP 04	*Anopheles (Nyssorhynchus) albitarsis*	9	52.94	6	1,76
	Aedes (Ochlerotatus) scapularis	4	23.53		
	Culex (Melanoconion) aureonotatus	1	5.88		
	Mansonia (Mansonia) titillans	1	5.88		
	Psorophora (Psorophora) ciliata	1	5.88		
	Psorophora (Grabhamia) confinnis	1	5.88		
Total		**99**	**-**	**16**	**3.26**

Legend: SP - Shannon positive.

According to Data Table 5.2-51, the richness obtained at the different sample sites was relatively low when compared to the total richness (16 species). This is due to the difference in the composition of species registered at each location. It is also noted that, throughout the study, the highest diversity rates were obtained through this trapping method.

Regarding the species detected, the following stand out as being of public health importance: *Aedes scapularis, Anopheles albitarsis, Culex (Melanoconion) spp., Culex nigripalpus, Coquillettidia spp., Mansonia spp.* and *Psorophora ferox*, disease vectors, as previously explained.

f) Research of triatomines in natural conditions and in domestic environment

During the studies, the presence of barbers (triatomines) was detected, insects known in the region as bicudo. Positive results were obtained for triatomines, with five specimens collected belonging to two genera, *Triatoma* and *Panstrongylus*. Many of the rural houses were favourable to the establishment of colonies, due to the precariousness of the constructions, with cracks and openings that allow the entry and establishment of the vector. In addition, the peridomicile, associated with the places of shelter of domestic animals, form favourable conditions for the proliferation of these insects, mainly in chicken coop roofs and in the terraces, in places with stacked tiles or bricks.

According to information from residents, the places with the highest incidence of barbers are generally close to the quarries, a type of environment very common in the caatinga. In fact, during the collection with Shannon's trap, carried out in the Jenipapo Dam area, a triatomine was collected, probably attracted to the trap by the light of the gas lantern. The place is rich in rocks, which form innumerable shelters for vertebrates and, consequently, for triatomines, hematophagous insects

This data was also confirmed by the health agent of the Municipality of Capitão Gervásio Oliveira who commands the team responsible for the diagnosis and control of the infested houses. In an interview with the technician, it was found that most rural homes are positive for triatomines.

Data Table 5.2-52 shows the results obtained during searches for barbers (triatomines) in the areas of influence of the project.

Data Table 5.2-52 – Registers of triatomines obtained through active search in the peri and intra-domestic areas of influence of the project.

Collection Nº	Species	Male	Female
BP 01	*Triatoma braziliensis*		1
BP 02	*Hemiptera: Reduviidae*	1	
BP 03	*Triatoma braziliensis* (pre-male nymph stage IV)	1	
BP 04	*Panstrongylus lutzi*	1	
BP 05	*Triatoma braziliensis* (nymph stage III)	1	

Collection Nº	Species	Male	Female
Total		3	2

Legend: BP - Barber Positive.

The collected material was obtained from active research in the peri and intra domestic, in houses located in the valley of the stream of Várzea, besides the specimen attracted by the trap of Shannon, primarily destined to the collection of mosquitoes, installed in the Jenipapo Dam (Coleta SP- 3).

Some of the specimens identified were donated by residents, who kept them in their homes. Identification under stereoscopic microscopy revealed that a very damaged male specimen, donated by a resident, corresponded to a Hemiptera: Reduviid, a taxon that corresponds to predatory stink bugs, usually mistaken for barbers because they are similar to them. The identification of two species recognized as transmitters of *Tripanossoma cruzi* (agent of Chagas disease) stands out: *Triatoma braziliensis* and *Panstrongylus lutzi*.

g) Research of other arthropods of interest in Public Health

Throughout the sampling period, the intense presence of scorpions, arthropods, which, although they are not pathogen carriers, are feared by the bite and the potential to cause accidents in humans, which can be fatal in children and the elderly, has been reported in the region. The presence of this arthropod was confirmed by capturing specimens of the species *Rhopalurus rochai*, detected during sampling of triatomines (sample site BN-3).

Although they are not carriers of pathogens, the presence of the coleopteran Potó (*Paederus sp.*), whose contact causes body burns, was also observed during field activities. This beetle was detected by a resident of the municipality of Capitão Gervásio Oliveira, whose collection took place inside his residence.

C) Summary

Of the mosquito fauna identified in the research of immature and adults, the following stand out as of epidemiological importance with the potential to transmit pathogenic agents: *Aedes scapularis, Anopheles albitarsis, Culex (Melanoconion) spp, Culex nigripalpus, Psorophora ferox* and, with potential to bother by bites: *Mansonia spp.* and *Coquillettidia spp*.

The species *Aedes scapularis, Culex (Melanoconion) spp, Culex nigripalpus,* and *Psorophora ferox* are considered prone to carry viruses, agents of arboviruses, including encephalitis. Thus, *Culex (Melanoconion) spp.*, with several species, has an important role in the maintenance of enzootic cycles of arboviruses in nature.

Aedes scapularis and *Psorophora ferox* were involved as suspected vectors of the Rocio virus in the Baixada Santista and Vale do Ribeira region, State of São Paulo (Iversson 1985). West Nile Virus was isolated in the United States (Natal and Ueno, 2004) from mosquitoes “pools”, including *Culex nigripalpus*. *Anopheles albitarsis* is considered a secondary vector of malaria plasmodia in Brazil.

As for the ones the cause discomfort, mosquitoes of the genus *Coquillettidia* and *Mansonia* usually proliferate in still waters colonized by floating macrophytes such as water lettuce (*Pistia sp.*) and water hyacinth (*Eichhornia sp.*).

In relation to the phlebotomine mosquitoes, all collections destined for the research of adult mosquitoes are also suitable for the capture of winged specimens from this taxon. The results were negative (which is not enough to prove their inexistence in the area), being more likely that these vectors were in a low population phase during the campaign. Even in the absence of representatives of these dipterans, their presence in the study area is admitted, since the entire region is considered endemic to cutaneous and visceral leishmaniasis.

The survey of “kissing barbers” revealed the presence of two important species with high domiciliation potential: *Triatoma brasiliensis* and *Panstrongylus lutzi*. It is noteworthy that, in Capitão Gervásio Oliveira, as well as in other municipalities in the region, there is a structured service for surveillance and control of vectors of Chagas disease, as this is endemic in the Northeastern semi-arid. The presence of triatomines in households in the area was confirmed during the visit to the health service headquarters, where there were numerous boxes containing live specimens, obtained from investigations by the team and the result of searches in homes. This material is regularly sent for identification and analysis of infection in Teresina. There is also information that whenever a focus of kissing barbers is found, the team conducts the control by means of chemical products.

In this research, the presence of this insect in a rural household was confirmed, upon the encounter of a third stage nymph of *Triatoma brasiliensis*, because in this phase the triatomine did not develop its wings and, therefore, its presence is a consequence of the infestation in the place. Regarding the domiciliation of this species, it should be noted that it has already been found as an exclusive triatomine inside houses, in the municipalities of Castelo do Piauí and Pedro II, in an area with a prevalence of 21.7% of seropositive humans for *Trypanosoma cuzi*, a region suggested as an active focus of the disease (Bento *et al.*, 1989). There is also a report of capture of *Triatoma brasiliensis* inside a house in a rural area of Teresina (Bento *et al.*, 1992). As for the species *Panstrongylus lutzi*, there is a report of the presence of this vector in Northeast Brazil, including the State of Piauí (Lent and Wygodzinsky, 1979).

As for the other arthropods with Public Health importance, stands out the presence of scorpions *Rhopalurus rochai* (Aracnida: Scorpionidae) and the beetle known as Potó, of the genus *Paederus* (Coleoptera: Staphilinidae), identified by the Butantan Institute. Scorpions are found in households and, according to information collected at the health service in the municipality of Capitão Gervásio Oliveira, there are reports of sporadic accidents in the region. In this research, the other arthropods were found during the search for triatomines, a fact that revealed the possibility of habitat sharing with Chagas disease vectors.

In this sense, the hypothesis that scorpions may have the role of biological controllers of the kissing barbers can be assumed. Although this aspect can be positive, scorpions are feared by their bites, which are highly painful, with neurotoxic poison.

Regarding the Potó, this arthropod was found to be present in the area, occurring in defined places and moments. The presence of this beetle in Northeast Brazil is a known fact. The *Paederus* beetle causes contact dermatitis, with a higher incidence in the rainy season (Diógenes, 1994). In the region of the project, it is seen even in the urban area of the municipality, possibly approaching this environment in response to artificial lighting. Residents reported that in this coleopter's breeding season, people get "skin burns" when get in contact with it.

Finally, it is emphasized that the problems related to invertebrates of interest to public health in the region where the Piauí Nickel Project is planned are linked to the rain regime, topography, soil type, in addition to the cultural aspects of drought handling, in the construction of housing, and people's domestic cleaning and maintenance habits. The mining project designed for this area will have to consider entomological issues and those related to other groups of invertebrates of medical interest to prevent injuries due to the foreseen changes in the region, as discussed in the impacts assessment chapter.

D) Photographic Report

Photo 5.2-102 – Aspects of caatinga vegetation in rocky terrains suitable for triatomines.

Photo 5.2-103 – Dry riverbed representing an unfavorable condition for culicids.

Photo 5.2-104 – Family artificial dam representing a favorable condition for the maintenance of breeding grounds for culicids.

Photo 5.2-105 – Large and collective dam representing an unfavorable condition for the maintenance of mosquito breeding sites.

Photo 5.2-106 – Collection of immature mosquitoes in a small dam with an entomological shell.

Photo 5.2-107 – Collection of immature mosquitoes in a tire container with entomological shell.

Photo 5.2-108 – Collection of adult mosquitoes in an open environment with Shannon's trap.

Photo 5.2-109 – Collection of adult mosquitoes inside the house with an electric vacuum.

Photo 5.2-110 – Collection of immature mosquitoes in a temporary breeding ground formed by rainwater.

Photo 5.2-111 – Detail of the breeding site, showing grouping of larvae indicated by the circle.

Photo 5.2-112 – Result of immature collection made at the breeding site.

Photo 5.2-113 – Larger view of larvae of the *Aedes scapularis* mosquito collected at the breeding site.

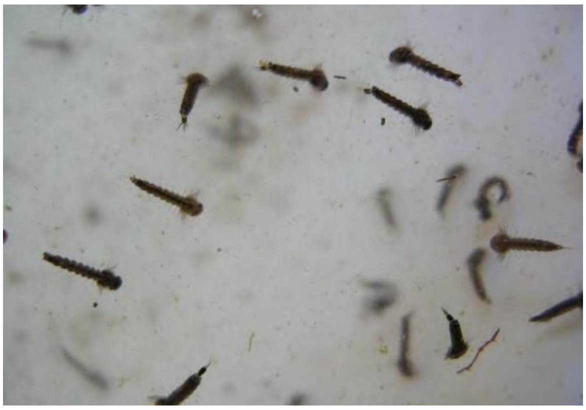


Photo 5.2-114 – Research of kissing barbers on heaped tiles gathered around a house.

Photo 5.2-115 – Example of suitable housing conditions for the colonization of kissing barbers.

Photo 5.2-116 – Interior of a house with elements favorable to the colonization of kissing barbers.

Photo 5.2-117 – Nymph of *Triatoma brasiliensis* captured in outside a rural house in the municipality of Capitão Gervásio Oliveira.

Photo 5.2-118 – Temporary bench used to complete the development of immature mosquitoes.

Photo 5.2-119 – Vessel containing mosquito larvae from field collections.

Photo 5.2-120 – Larvae of *Culex* genus mosquitoes.

Photo 5.2-121 – *Culex quinquefasciatus* mosquitoes collected with a vacuum inside a house in the municipality of Capitão Gervásio Oliveira, placed in an entomological box.

Photo 5.2-122 – stereoscopic and optical microscopes used for this research.

Photo 5.2-123 – Box of slides obtained in the assembly of immature mosquitoes.

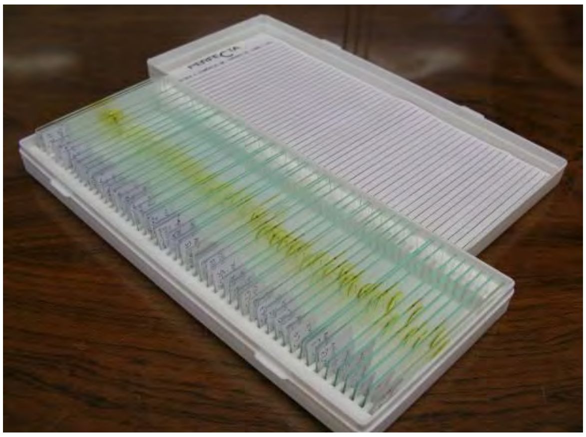


Photo 5.2-124 – Entomological box containing adult mosquitoes mounted on pins and labelled.

Photo 5.2-125 – Specimen of *the Culex quinquefasciatus* mosquito mounted on an entomological pin.

Photo 5.2-126 – Female specimen – note the end white tarsal segments.

Photo 5.2-127 – Prothorax and head of the fourth stage larva with ornamentation of bristles of taxonomic importance in determining the species.

Photo 5.2-128 – Terminal part of the abdomen showing the anal lobe with its bristles and the terminal region of the pair of spiracles, with the absence of a respiratory siphon, typical of anopheles.

Photo 5.2-129 – Terminal part of the abdomen showing the anal lobe with its bristles and the terminal region of the pair of spiracles, with the absence of a respiratory siphon, typical of anopheles.

Photo 5.2-130 – Female specimen – note a concentration of whitish scales in the upper chest, a typical characteristic of this culicid.

Photo 5.2-131 – First abdominal segment, prothorax and head of the fourth stage larva with bristle ornamentation of taxonomic importance in determining the species.

Photo 5.2-132 – Anterior part of the head of the fourth stage larva showing the oral brushes, the antennae and the oral apparatus.

Photo 5.2-133 – Terminal part of the abdomen showing the anal lobe with its bristles and the respiratory siphon with its ornaments. There is faecal content in the terminal part of the digestive tract.

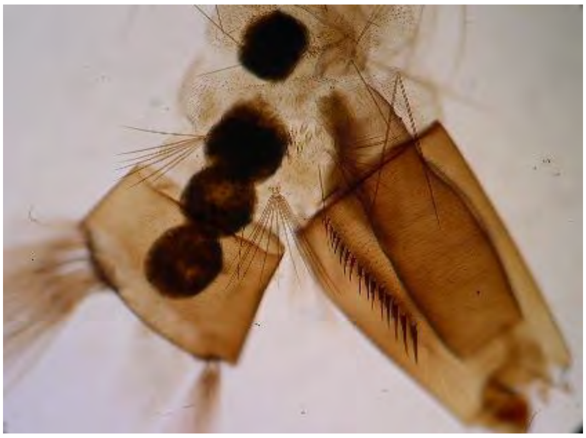


Photo 5.2-134 – Third stage nymph of *Triatoma brasiliensis* collected in the rural area during the field research.

Photo 5.2-135 – Adult female of *Triatoma brasiliensis* collected in Shannon's trap during field research.

Photo 5.2-136 – Male *Panstrongylus lutzi* donated by a resident during the field research.

Photo 5.2-137 – Scorpion collected between tiles during the field research.

5.2.5. Aquatic Fauna

5.2.5.1. Ichthyofauna

A) Methodological Considerations

a) Collection of secondary data

For the survey of species of ichthyofauna likely to occur in the study region, data available in scientific publications related to the Parnaíba River Basin (Rosa, 2004; Ramos, *et al.* 2014) were compiled, whose objective is to contribute to the characterization of the community of fish present in the study area of this project.

b) Field sampling

Sampling period

The study of fish, through data collection in the field, was conducted in a sampling campaign. Data collection was carried out between February 22nd and 29th, 2008 (rainy season).

Spatial coverage of the study

The spatial scope for collecting primary data included the Directly Affected Area (DAA), and the Areas of Direct Influence (ADI) and Indirect Influence (AII) of the project.

Sampling was performed at six sample sites, as described below (Data Table 5.2-53; Map 5.2-14).

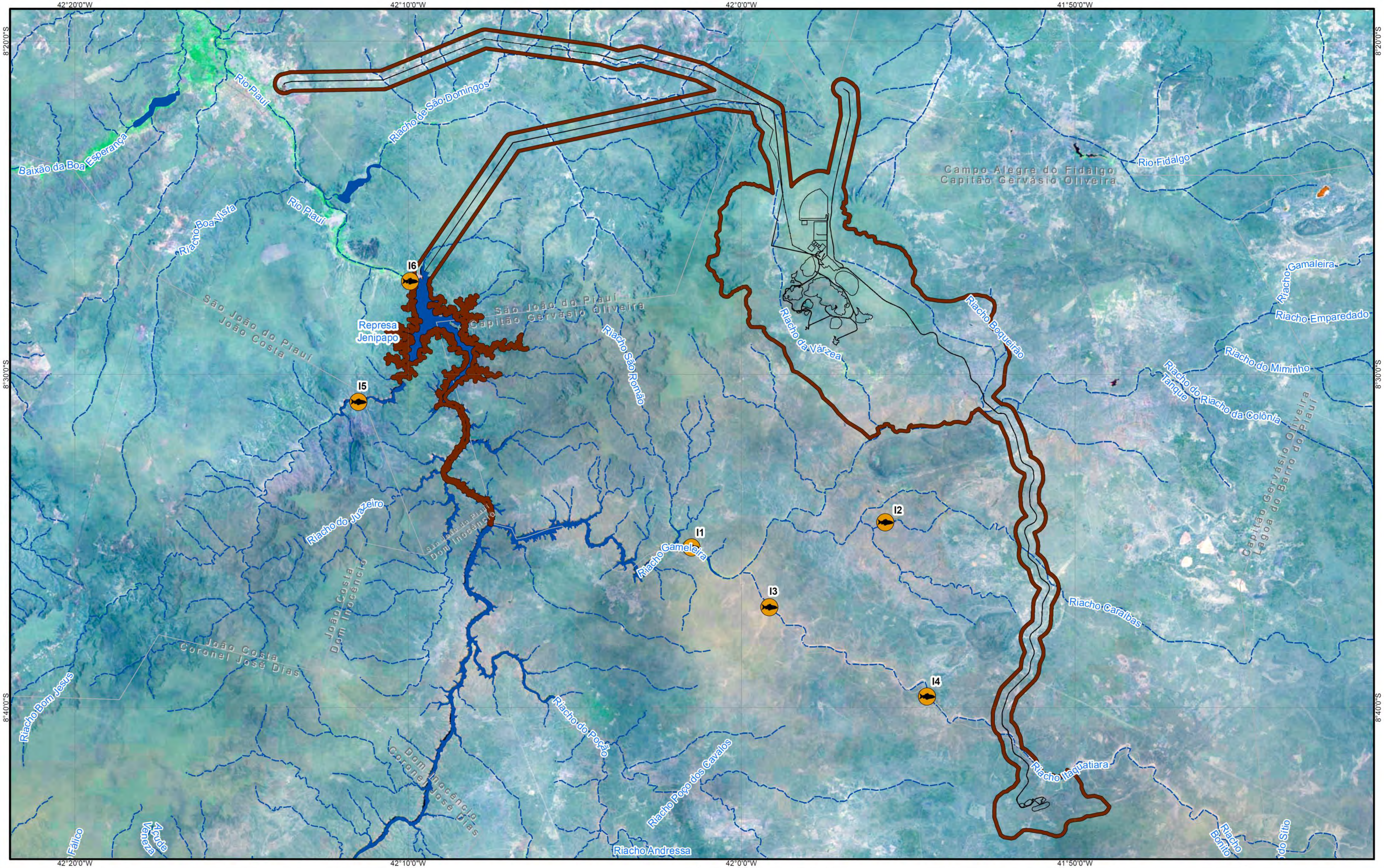
Data Table 5.2-53 – Characterization and location of the sampling sites for register the ichthyofauna.

Samples sites	Geographic Coordinates (UTM)		Watercourse	Area Description
I1 (AII)	827544	9049644	Itaquatiara Creek, 3.5 km downstream of the confluence with the São Romão River	Puddle created on the site by the receding water from the Jenipapo dam, about 110m long and 15m wide, muddy water, mud bed, and absence of aquatic vegetation. Water used for cultivation and animal husbandry.
I2 (AII)	177689	9051079	Pindóba Dam. Artificial dam about 500m long	Artificial weir about 500m long, with aquatic vegetation, mud bed, transparent water. Water used for human consumption, cultivation and animal husbandry.
I3 (AII)	171335	9046325	Caldeirão da Mãe d'água, in the Itaquatiara Creek	In this stretch of the Itaquatiara creek, the water table approaches the surface and, together with the rock formations, allows the accumulation of rainwater, forming large ponds in the place. Collections were carried out in two ponds, where the first had a bed composed basically of sand, without aquatic plants, muddy water, with approximately 80m^2. The second pond had its bed mostly composed of rocks, with aquatic vegetation, muddy water, with approximately 6m^2. Water used only for animal consumption. Intense fishing in this pond group.
I4 (AII)	180076	9041455	João's Well, at Itaquatiara Creek	Perennial water, probably fed by the water table, cloudy water, without aquatic plants and a large concentration of fish due to the lack of fishing in the place. Two ponds with approximately 60m^2 and 18m^2.
I5 (AII)	809248	9057840	Jenipapo Dam, on the Piauí River	The dam is used mainly for the purpose of perpetuating the Piauí River, but other uses, such as human and animal consumption, irrigation and fishing, were also observed.

Samples sites	Geographic Coordinates (UTM)		Watercourse	Area Description
I6 (DAA/ ADI)	812139	9064482	Piauí River, in the 800m stretch downstream of the Jenipapo dam	Clear, flowing water, with aquatic and marginal vegetation. It had a strong smell of hydrogen sulfide, due to the version of water coming from the deepest layers of the reservoir. According to local information, the regulation of the volume of water released from the dam is done without criteria, often causing fish mortality downstream of the dam.

Elaboration: ARCADIS Tetraplan, 2008.

Map 5.2-14 – Ichthyofauna sampling sites.



LEGENDA

- Intermittent Drainage
- Water Mass
- Municipal Limits
- Area of Direct Influence - ADI
- Directly Affected Area - DAA

Sampling Site

- Ichthyofauna

REFERÊNCIAS

ARCADIS Tetraplan, 2008;
IBGE, Base contínua 1:250.000, 2015;
LANDSAT, Imagem, 2016;
Projeto Piauí Níquel, 2016.

ESCALA GRÁFICA

0 5 10 km

Sistema de Coordenadas: GCS SIRGAS 2000

MAPA DE LOCALIZAÇÃO

PIAUÍ NÍQUEL | ARCADIS

EIA/RIMA – PROJETO PIAUÍ NÍQUEL

Map 5.2-14 – Sampling Sites
Ichthyofauna

EXECUTADO POR:	ESCALA:	NÚMERO:	DATA:
ARCADIS	1:200.000	Única	jun /2017

Data collection

The specific equipment were used at each sampling site according to the size of the watercourse, the type of vegetation around it and the characteristics of the intended area, as described in Data Table 5.2-54.

Data Table 5.2-54 – Equipament used in each sampling site.

Sample sites	Equipment
I1	Trawls, hand nets and nets.
I2	Trawls, hand nets and nets.
I3	Trawls, hand nets and nets.
I4	Trawls, hand nets and nets; Manual collection of plecos.
I5	Waiting nets, hand nets and cast nets.
I6	Trawls, waiting nets, hand nets and cast nets.

c) Hand Nets

Hand nets consist of rectangular structures made up of an aluminium frame of approximately 60 x 40 cm, with a mesh of 1 mm internodes. These nets were used in marginal environments, with vegetation, where conventional nets are unable to sample. Useful mainly for small snails that take refuge close to the shore, small catfish that are stuck in rocks and small plecos (Loricariidae) that lodge in the marginal vegetation.

d) Waiting nets

Individual waiting nets of 5, 10 and 15m in length by 1.2m in height and meshes of 10 mm, 20 mm, 30 mm and 50 mm with internodes were used. These were used only in some environments to capture, mainly, larger and highly mobile fish, such as those of the Anostomidae family.

e) Trawls

Trawls 6m long and 1.5 mm internodes were used. These nets were used in shallower areas, such as locations along the banks. Non-selective method usually captures all specimens located at a given point.

f) Cast nets

10 and 20m cast nets and 10 mm mesh internodes were used. These were used in places of greater depth and with greater current, being used especially in the capture of fishes associated to the bottom, like cichlids and some plecos (Loricariidae).

g) *Manual Collection*

These collections were made by groping cracks in rocks, where it is possible to feel the fish and perform the capture by hand. Especially useful in the capture of plecos (Loricariidae) in shallow environments.

h) *Interviews*

In addition, informal interviews were conducted with fishermen and residents of the region, aiming to compose an overview of the diversity and habits of the fish species in the region.

Specimen Register

All specimens collected were immediately fixed in commercial formalin diluted to 10% and packed in plastic packages for five days. In specimens over 15 cm, formaldehyde was injected into the abdominal cavity and the dorsal musculature, with the aid of a hypodermic syringe. Then, the specimens were packed in plastic bags properly labelled and identified by sampling site.

After five days of fixation, the material was sorted and transferred to 70% diluted alcohol. The identification of the collected material was carried out based on the literature relevant to the region and the groups in question. The material was fully deposited in the ichthyological collection of the Zoology Museum at the University of São Paulo (Arcadis Tetraplan, 2008).

Conservation Status

To ascertain the conservation status of registered fish species, the Official National List of Endangered Species of Fauna - Aquatic Fish and Invertebrates was consulted, Portaria MMA No. 445/2014.

At international level, the protection of fauna also focuses on international agreements, related to species and habitats. The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES, 2014) provides a list of species whose international trade must be controlled (Fitzgerald, 1989).

The International Union for Conservation of Nature (IUCN, 2016) established the following categorization for the purpose of preserving species considered threatened: Least Concern (LC); Near Threatened (NT); Vulnerable (VU); Endangered (EN); and Critically Endangered (CR)

B) Results

a) *Regional Characterization*

The history of knowledge and exploration of the ichthyofauna in the Parnaíba River basin begins with Spix and Martius' trip through Brazil (1817-1820). On this occasion, travellers explored Piauí starting from Juazeiro (BA) towards São Luis (MA), sampling the Parnaíba River in some places (Rosa *et al.,* 2003). Later, in 1865, the Thayer expedition, organized by Louis Agassiz, resulted in a collection of fish from some points of the Parnaíba River basin, mainly in the Poti and Gurgéia rivers (Rosa *et al.*, 2003). However, the material gathered by these two expeditions has been little studied and only a few species have been described subsequently (eg. Garman, 1890; Borodin, 1931).

The ichthyofauna of the Parnaíba River was more intensively studied only in the beginning of the 20th century, due to the collections of Steindachner, in 1903, and the subsequent descriptions made from the material collected by the researcher (Steindachner, 1906 and 1907). In addition, Fowler (1941) described several fish from the Northeast, including some species from the Parnaíba River, based on material collected by Von Ihering in the early 20th century. From the second half of the twentieth century to the present day, a few other collections have been carried out in that region[10] and only a limited number of species have been described (personal observation).

Based on the data available in the literature, it was possible to list 155 species occurring in the Parnaíba River basin (Data Table 5.2-55). This number corresponds to 65% of the total known fish species for the basins that drain the Caatinga.

It should be noted that for the Parnaíba River Basin, only one species (*Apareiodon davisi*) is "endangered" according to the official national list of endangered species (MMA nº 445/2014). Another species (*Arapaima gigas*) is at risk of becoming threatened with extinction, if international trade is not controlled (CITES, 2016).

Despite little knowledge about the total composition of the ichthyofauna in the Parnaíba River basin, it is possible to make some considerations about the distribution patterns and relationships of this fauna.

Vari (1988) considered the Parnaíba basin, along with coastal basins in the states of Maranhão, Ceará, Rio Grande do Norte and Paraíba, as belonging to the same biogeographic region that he called the “northeast” region. This same author pointed out that the basins that make up this region would be hybrid, that is, in addition to endemic species, they have fauna elements from other adjacent hydrographic basins. Other authors agree with this statement (Rosa *et al.*, 2003; Ribeiro, 2006), since several species have a distribution that is not limited by the Parnaíba basin or the northeastern region, occurring in other basins, such as the Amazon. As an example, we can mention the presence of species such as *Otocinclus hasemani* (also in the Tocantins River basin), *Limatulichthys griseus* (basins of the Amazon, Tocantins, Orinoco and Essequibo rivers) and *Phamphorichthys hollandi* (also in the São Francisco basin).

Despite the high degree of species shared with other basins, a considerable portion of the ichthyofauna in the basin is endemic (approximately 20%) (Reis *et al.*, 2003). This number may prove to be much higher, since several species that occur in the Parnaíba River basin are part of species complexes, that is, they lack an adequate taxonomic resolution (eg *Moenkhausia lepidura, Hoplerythrinus unitaeniatus, Gymnotus carapo, Sternopygus macrurus* and *Synbranchus marmoratus*) (personal observation). More detailed studies of these "complexes" can lead to the recognition of several distinct species with stricter distributions than that of the

[10] Mainly by the Science and Technology Museum of the Pontifical Catholic University of Rio Grande do Sul - PUCRS and by the Museum of Zoology of the University of São Paulo - MZUSP.

original complex. Among the endemic species we can mention *Potamotrygon signata, Brachychalcinus parnaibae, Hemiodus parnaguae, Aspidoras raimundi, Parotocinclus haroldoi* and *Rivulus parnaibensis*.

It should also be noted that the affluent on the left bank of the Parnaíba River develop in the cerrados region. These are perennial rivers that give sustainability to the perennial regime of the Parnaíba River. The affluent of the right bank, which include the rivers in the region where the study area is located, are intermittent, the result of scarcity and irregular rainfall. One of the most surprising groups of fish in this type of seasonal environment corresponds to Rivulidae, annual fish characteristic of the Caatinga and still little studied. They are fish that live in seasonal ponds and rivers and that lay their eggs resistant to desiccation in the waterbed (Costa, 1995). These only hatch during the rainy season and develop quickly. According to the compiled data, four species (*Pituna schindleri, Melanorivulus parnaibensis, Cynolebias parnaibensis* and *Hypsolebias coamazonicus*) are registered for the region, as shown in Data Table 5.2-55.

Data Table 5.2-55 – Fish species likely to occur in the Area of Indirect Influence (AII) and surroundings, with respective threat categories.

Taxon	Popular Name	Threat category			Source
		Federal	International		
		MMA nº 445/2014	IUCN, 2016	CITES, 2016	
MYLIOBATIFORMES					
Potamotrygonidae					
Potamotrygon signata	Raia	-	DD	-	1; 2
Potamotrygon orbignyi	Raia	-	LC	-	2
CLUPEIFORMES					
Engraulidae					
Anchovia surinamensis	Maiacá	-	-	-	1; 2
Lycengraulis batesii	Sardinha	-	-	-	1; 2
Anchoviella guianensis	Manjubinha	-	-	-	2
Anchoviella lepidentostole	Manjuba-de-Iguape	-	LC	-	2
Pterengraulis atherinoides	Maiacá	-	-	-	2
Pristigasteridae					
Pellona flavipinnis	Apapá-branco	-	-	-	1; 2
CHARACIFORMES					
Parodontidae					
Apareiodon sp.	-	-	-	-	2
Apareiodon davisi	Peixe-rei	EN	-	-	2

Taxon	Popular Name	Threat category			Source
		Federal	International		
		MMA nº 445/2014	IUCN, 2016	CITES, 2016	
Apareiodon machrisi	Canivete	-	-	-	2
Acestrorhynchidae					
Acestrorhynchus falcatus	Cachorrinho	-	-	-	1; 2
Anostomidae					
Leporinus friderici	Araçu-cabeça-gorda	-	-	-	1; 2
Leporinus piau	Piau	-	-	-	1; 2
Schizodon dissimilis	Piau de vara	-	-	-	1; 2
Schizodon knerii	Piau-branco	-	-	-	2
Schizodon rostratus	-	-	LC	-	1; 2
Leporinus reinhardti	Piau-três-pintas	-	-	-	2
Leporinus obtusidens	Piapara	-	LC	-	2
Characidae					
Astyanax aff. fasciatus	Piaba	-	-	-	2
Astyanax bimaculatus	Piaba	-	-	-	1; 2
Brachychalcinus parnaibae	-	-	-	-	1; 2
Brycon falcatus	-	-	-	-	1
Bryconops melanurus	Lambari	-	-	-	1; 2
Bryconamericus sp.	-	-	-	-	2
Compsura heterura	Piaba	-	-	-	1; 2
Creagrutus sp.	-	-	-	-	2

Taxon	Popular Name	Threat category			Source
		Federal	International		
		MMA nº 445/2014	IUCN, 2016	CITES, 2016	
Ctenobrycon hauxwellianus	Piaba	-	-	-	1; 2
Hemigrammus marginatus	Piaba	-	-	-	2
Hemigrammus sp.	-	-	-	-	2
Hyphessobrycon sp. 1	-	-	-	-	2
Hyphessobrycon sp. 2	-	-	-	-	2
Gymnocorymbus thayeri	-	-	-	-	2
Jupiaba polylepis	-	-	-	-	1; 2
Knodus victoriae	Piaba	-	-	-	1; 2
Metynnis lippincottianus	Pacu	-	-	-	1
Moenkhausia dichroura	Piaba	-	-	-	1
Moenkhausia lepidura	-	-	-	-	1; 2
Moenkhausia sanctaefilomenae	-	-	-	-	1; 2
Roeboides margareteae	Corcundinha	-	-	-	1; 2
Roeboides myersii	-	-	-	-	1
Roeboides sazimai	Corcundinha	-	-	-	1; 2
Psellogrammus kennedyi	Piaba	-	-	-	2
Phenacogaster calverti	Piaba	-	-	-	2
Poptella compressa	Medalhão	-	-	-	1; 2
Pygocentrus nattereri	Piranha	-	-	-	1
Serrasalmus rhombeus	Pirambeba	-	-	-	1

Taxon	Popular Name	Threat category			Source
		Federal	International		
		MMA nº 445/2014	IUCN, 2016	CITES, 2016	
Serrapinnus heterodon	Piaba	-	-	-	2
Serrapinnus piaba	Piaba	-	-	-	2
Tetragonopterus argenteus	Sardinha-matupiri	-	-	-	1; 2
Triportheus signatus	Sardinha	-	-	-	1
Chilodontidae					
Caenotropus labyrinthicus	Branquinha-cascuda	-	-	-	1; 2
Curimatidae					
Curimata macrops	Branquinha	-	-	-	1; 2
Psectrogaster rhomboides	Coró	-	-	-	1; 2
Steindachnerina notonota	Branquinha	-	-	-	1; 2
Curimatella immaculata	Saburu-rei	-	-	-	2
Erythrinidae					
Hoplerythrinus unitaeniatus	-	-	-	-	1; 2
Hoplias malabaricus	Traíra	-	-	-	1; 2
Hemiodontidae					
Hemiodus parnaguae	Voador	-	-	-	1; 2
Crenuchidae					
Characidium cf. bahiensis	-	-	-	-	2
Characidium bimaculatum	Canivete	-	-	-	2
Characidium zebra	Maria-dura	-	-	-	2

Taxon	Popular Name	Threat category			Source
		Federal	International		
		MMA nº 445/2014	IUCN, 2016	CITES, 2016	
Characidium sp.1	-	-	-	-	2
Characidium sp.2	-	-	-	-	2
Prochilodontidae					
Prochilodus lacustris	Curimbatá	-	-	-	1; 2
Serrasalmidae					
Colossoma macropomum	-	-	-	-	2
Metynnis lippincottianus	Pacu	-	-	-	2
Myleus asterias	-	-	-	-	2
Mylossoma aureum	-	-	-	-	2
Pygocentrus nattereri	Piranha	-	-	-	2
Serrasalmus rhombeus	Piranha-preta	-	-	-	2
Triportheidae					
Triportheus signatus	Sardela	-	-	-	2
SILURIFORMES					
Aspredinidae					
Aspredo aspredo	-	-	-	-	1; 2
Auchenipteridae					
Ageneiosus inermis	Palmito	-	-	-	1; 2
Ageneiosus sp.	-	-	-	-	2
Auchenipterus menezesi	Peixe-gato	-	-	-	1; 2

Taxon	Popular Name	Threat category			Source
		Federal	International		
		MMA nº 445/2014	IUCN, 2016	CITES, 2016	
Trachelyopterus galeatus	Mandí-porca	-	-	-	1; 2
Callichthyidae					
Aspidoras raimundi	-	-	-	-	1; 2
Callichthys callichthys	Tamboatá	-	-	-	1; 2
Corydoras julii	-	-	-	-	1; 2
Corydoras treitlii	-	-	-	-	1; 2
Corydoras vittatus	-	-	-	-	2
Hoplosternum littorale	Tamoatá	-	-	-	1; 2
Doradidae					
Hassar affinis	Bagre	-	-	-	1; 2
Platydoras costatus	Mandí-serra	-	-	-	1
Platydoras brachylecis	Graviola	-	-	-	2
Heptapteridae					
Pimelodella cristata	Mandí-chorão	-	LC	-	1
Pimelodella parnahybae	Mandí-chorão	-	-	-	1; 2
Pimelodella cf. steindachneri	Mandí-chorão	-	-	-	2
Phenacorhamdia sp.	-	-	-	-	2
Rhamdia quelen	Jundiá	-	-	-	2
Imparfinis sp.	-	-	-	-	2
Loricariidae					

Taxon	Popular Name	Threat category			Source
		Federal	International		
		MMA nº 445/2014	IUCN, 2016	CITES, 2016	
Ancistrus damasceni	-	-	-	-	1; 2
Ancistrus sp.1	-	-	-	-	2
Ancistrus sp.2	-	-	-	-	2
Pterygoplichthys parnaibae	-	-	-	-	1
Hypostomus johnii	Cari	-	-	-	1; 2
Hypostomus sp. 1	-	-	-	-	2
Hypostomus sp. 2	-	-	-	-	2
Hypostomus sp. 3	-	-	-	-	2
Hypostomus sp. 4	-	-	-	-	2
Limatulichthys griseus	-	-	-	-	1; 2
Loricariichthys derbyi	Chicote	-	-	-	2
Loricaria parnahybae	Bodó	-	-	-	1; 2
Otocinclus hasemani	-	-	-	-	1; 2
Rineloricaria sp.	-	-	-	-	2
Parotocinclus haroldoi	Cari	-	LC	-	1; 2
Parotocinclus sp.	-	-	-	-	2
Parotocinclus cearensis	-	-	-	-	2
Pterygoplichthys parnaibae	Cari	-	-	-	2
Pimelodidae					
Brachyplatystoma filamentosum	Bagre-amarelo	-	-	-	2

Taxon	Popular Name	Threat category			Source
		Federal	International		
		MMA nº 445/2014	IUCN, 2016	CITES, 2016	
Brachyplatystoma vaillantii	Branquinho	-	-	-	2
Hypophthalmus cf. edentatus	Manduvi-rosado	-	-	-	2
Hemisorubim platyrhynchus	-	-	-	-	1
Pimelodus blochii	Mandí	-	-	-	1; 2
Pimelodus ornatus	Chorão	-	-	-	1; 2
Pimelodus maculatus	Bagre	-	-	-	1; 2
Pimelodus sp. 1	-	-	-	-	2
Pimelodus sp. 2	-	-	-	-	2
Pseudoplatystoma fasciatum	-	-	-	-	1; 2
Sorubim lima	Bico-de-pato	-	-	-	1; 2
Trichomycteridae					
Ituglanis sp.	-	-	-	-	2
GYMNOTIFORMES					
Gymnotidae					
Gymnotus carapo	Carapó	-	-	-	1; 2
Hypopomidae					
Brachypopomus sp.	-	-	-	-	2
Rhamphichthyidae					
Rhamphichthys rostratus	Ituí-terçado	-	-	-	1
Rhamphichthys marmoratus	Ituí-terçado	-	-	-	2

Taxon	Popular Name	Threat category			Source
		Federal	International		
		MMA nº 445/2014	IUCN, 2016	CITES, 2016	
STERNOPYGIDAE					
Eigenmannia macrops	Sarapó	-	-	-	2
Eigenmannia virescens	Tuvira	-	-	-	1; 2
Sternopygus macrurus	Sarapó	-	-	-	1; 2
Apteronotidae					
Apteronotus sp.	-	-	-	-	2
CYPRINODONTIFORMES					
Rivulidae					
Pituna schindleri	-	-	-	-	1; 2
Melanorivulus parnaibensis	-	-	-	-	1; 2
Cynolebias parnaibensis	-	-	-	-	2
Hypsolebias coamazonicus	-	-	-	-	2
Poeciliidae					
Pamphorichthys hollandi	-	-	-	-	1; 2
Poecilia reticulata	-	-	-	-	2
Poecilia sarrafae	-	-	-	-	2
Poecilia vivipara	Guaru	-	-	-	2
PERCIFORMES					
Cichlidae					
Aequidens tetramerus	Acará-cuaima	-	-	-	1; 2

Taxon	Popular Name	Threat category			Source
		Federal	International		
		MMA nº 445/2014	IUCN, 2016	CITES, 2016	
Apistogramma piauiensis	-	-	-	-	1; 2
Cichlasoma orientale	Cará	-	-	-	2
Cichlasoma sanctifranciscense	Cará	-	-	-	1; 2
Crenicichla menezesi	Sabão	-	-	-	1
Geophagus parnaibae	Cará	-	-	-	1; 2
Cichla monoculus	Tucunaré	-	-	-	2
Crenicichla menezesi	Joana-gensa	-	-	-	2
Tilapia rendalli	Tilápia	-	LC	-	2
Oreochromis niloticus	-	-	-	-	2
Satanoperca jurupari	Acará-chibante	-	-	-	2
Astronotus ocellatus	Acarau-açu	-	-	-	2
Scianidae					
Plagioscion squamosissimus	Corvina	-	-	-	1; 2
SYNBRANCHIFORMES					
Synbranchidae					
Synbranchus marmoratus	Mussum	-	-	-	1; 2
OSTEOGLOSSIFORMES					
Osteoglossidae					
Arapaima gigas	-	-	DD	II	2
BELONIFORMES					

Taxon	Popular Name	Threat category			Source
		Federal	International		
		MMA nº 445/2014	IUCN, 2016	CITES, 2016	
Belonidae					
Pseudotylosurus microps	Peixe-agulha	-	-	-	2
PLEURONECTIFORMES					
Achiridae					
Trinectes cf. paulistanus	Linguado	-	LC	-	2

Elaboration: Arcadis, 2017.

Source: (1) Rosa, 2004; (2) Ramos, *et al*. 2014

Threat Categories: Least Concern (LC); Near Threatened (NT); Vulnerable (VU); Endangered (EN); and Critically Endangered (CR). CITES: Appendix I - Lists the most endangered species. International trade is prohibited; Appendix II - Lists species at risk of becoming threatened with extinction if international trade is not controlled; and Appendix III - Lists species with partially regulated international trade, but which needs the cooperation of countries to avoid overexploitation.

b) Areas of Influence (DAA, ADI and AII)

In the areas of influence of the project, 46 species of fish were identified, distributed in seven orders and 19 families (Data Table 5.2-56).

The taxonomy of species in Northeast Brazil is still in a precarious state of knowledge, which leads to difficulties in attributing the nomenclature to the fish in the region. As an example, the *Astyanax bimaculatus* species, which is mentioned for the Parnaíba river basin, represents a species complex (Garutti, 2003) whose name is usually attributed to any tetra fish of the genus *Astyanax* with two spots on the body, the most usually being earlier rounded. Thus, this name can be attributed to tetras with this pattern collected in the present study, although, according to Garutti (1995), the nomenclature best applied to specimens in the region would be *Astyanax lacustris*, a species of the São Francisco River. Therefore, it is impossible to say whether in the Parnaíba River basin there are two species with this colour pattern, *A. bimaculatus and A. lacustris*, or just one, since the records attributed to *A. bimaculatus* may actually be identifications errors of *A. lacustris*. For this same reason, a specific name was not assigned to the species of the genus *Ctenobrycon* found in the region, since the current knowledge of the species of the genus does not allow to safely assign the scientific name.

Another typical example deals with widely distributed species that may actually be complexes of species, that is, several species with very similar external morphology and that have a more restricted distribution. As an example, the case of *Platydoras costatus* is cited. This species is considered to have a wide distribution in the Amazon basin, in the Tocantins, Essequibo, Parnaíba, Mearim and Orinoco river basins, as well as in coastal basins in Suriname and French Guiana (Reis *et al.*, 2003). However, recent studies have led to the conclusion that this species is actually a complex of species and that the specimens from the basins of the Mearim and Parnaíba rivers, in fact, belong to another species than the same of the other basins (Birindelli, social communication).

Data Table 5.2-56 – Fish species recorded using primary data for Directly Affected Area (DAA), Area with Direct Influence (ADI) and Indirect Influence (AII). Endemic species in the Parnaíba River Basin and respective threat categories.

Order	Family	Taxon	Popular Name	Threat category			Endemic to the Parnaiba River Basin
				Federal	International		
				MMA nº 445/2014	IUCN, 2016	CITES, 2016	
Myliobatiformes	Potamotrygonidae	*Potamotrygon signata*	Raia	-	DD	-	x
Characiformes	Anostomidae	*Leporinus piau*	Piau	-	-	-	x
		Schizodon dissimilis	Piau de vara	-	-	-	x
	Characidae	*Astyanax fasciatus*	Piaba	-	-	-	-
		Astyanax cf. lacustris	Piaba	-	-	-	-
		Compsura heterura	Piaba	-	-	-	-
		Ctenobrycon sp.	Piaba	-	-	-	-
		Hemigrammus sp.	Piaba	-	-	-	-
		Moenkhausia dichroura	Piaba	-	-	-	-
		Roeboides margareteae	Corcundinha	-	-	-	x
		Roeboides cf. sazimai	Corcundinha	-	-	-	x
		Phenacogaster calverti	Piaba	-	-	-	-
		Poptella compressa	Medalhão	-	-	-	-
		Pygocentrus nattereri	Piranha	-	-	-	-
		Serrapinnus heterodon	Piaba	-	-	-	-
		Serrapinnus piaba	Piaba	-	-	-	-
		Serrasalmus rhombeus	Pirambeba	-	-	-	-

Order	Family	Taxon	Popular Name	Threat category			Endemic to the Parnaiba River Basin
				Federal	International		
				MMA nº 445/2014	IUCN, 2016	CITES, 2016	
		Triportheus signatus	Sardinha	-	-	-	x
	Crenuchidae	*Characidium cf. bahiensis*	-	-	-	-	-
		Characidium cf. bimaculatum	Canivete	-	-	-	-
	Curimatidae	*Steindachnerina notonota*	Branquinha	-	-	-	x
	Erythrinidae	*Hoplias malabaricus*	Traíra	-	-	-	-
	Hemiodontidae	*Hemiodus parnaguae*	Voador	-	-	-	x
	Parodontidae	*Apareiodon cf. itapicuruensis*	-	-	-	-	-
	Prochilodontidae	*Prochilodus lacustris*	Curimbatá	-	-	-	x
Siluriformes	Auchenipteridae	*Trachelyopterus galeatus*	Mandí-porca	-	-	-	-
	Callichthyidae	*Aspidoras raimundi*	-	-	-	-	x
	Doradidae	*Platydoras costatus*	Mandí-serra	-	-	-	-
	Heptapteridae	*Pimelodella gracilis*	Mandí	-	-	-	-
		Pimelodella witmeri	Mandí	-	-	-	-
		Pimelodella sp.	Mandí	-	-	-	-
	Loricariidae	*Hypostomus eptingi*	Cari	-	-	-	-
		Hypostomus nudiventris	Cari	-	-	-	-
		Hypostomus sp.	Cari	-	-	-	-
		Loricariichthys derbyi	Chicote	-	-	-	x
		Pterygoplichthys parnaibae	Cari	-	-	-	x
		Parotocinclus haroldoi	Cari	-	LC	-	x

Order	Family	Taxon	Popular Name	Threat category			Endemic to the Parnaiba River Basin
				Federal	International		
				MMA nº 445/2014	IUCN, 2016	CITES, 2016	
	Pimelodidae	*Pimelodus blochii*	Mandí	-	-	-	-
Gymnotiformes	Sternopygidae	*Sternopygus macrurus*	Sarapó	-	-	-	-
Cyprinodontiformes	Poeciliidae	*Micropoecilia sp.*	-	-	-	-	-
		Pamphorichthys hollandi	-	-	-	-	-
Perciformes	Cichlidae	*Cichlasoma orientale*	Cará	-	-	-	-
		Oreochromis sp.	-	-	-	-	-
		Crenicichla menezesi	Sabão	-	-	-	-
		Geophagus parnaibae	Cará	-	-	-	x
Synbranchiformes	Synbranchidae	*Synbranchus marmoratus*	Mussum	-	-	-	-

Elaboration: Arcadis, 2017.

Threat Categories: Least Concern (LC); Deficient Data (DD)

Fauna composition

Even with the low diversity detected in the present study, the proportion between the different taxonomic groups does not deviate from the expected pattern for the Neotropical region (Böhlke *et al.*, 1976), since most of the species collected (82%, 38 spp.) it is part of the Ostariophysi Super Order, the most diverse group of fish in the Neotropical region. In addition, the two most diverse members of Ostariophysi were the Order Characiformes, of the tetras, tiger fish and piranhas, making up 52% of the species richness, and the Order Siluriformes (catfish), representing 28%.

It should also be noted that the studied environment is naturally altered, and most of the fish species that live there have generalist habits. This result was already expected, since these animals live in an intermittent environment, where the water quality can change radically throughout the year.

As for nutrition, most of the fish found in the study area, with the exception of the more specialized ones (eg detritivores), have malleability in their food, that is, they will eat according to the available resource, as allochthonous material (mainly insects).

Distribution of fauna by the environment

In Data Table 5.2-57 it is possible to observe a marked difference in species richness between sampling Site 6 (Piauí River, downstream of the Jenipapo dam) and the rest of the sampling sites upstream of the dam, including the reservoir itself. In addition, the composition of the ichthyofauna between these two stretches is distinct, with 13 species collected upstream of the dam not being collected downstream, while 11 species collected downstream were not sampled upstream. However, when adding information obtained from fishermen and residents of the region, regarding the distribution of species upstream and downstream of the reservoir, this proportion is considerably reduced.

The difference found between the stretch downstream of the dam (Sampling site 6) and the other sampling sites may be due to the perpetuation of this stretch of the Piauí River, giving it distinct characteristics in relation to the intermittent sections and the reservoir, such as greater flow (presence of flow), presence of aquatic macrophytes and marginal vegetation, lower temperature and possibly higher O_2 concentration. The other sample sites are characterized by lentic environments, generally with little aquatic vegetation, water with a higher temperature, without marginal vegetation and probably with a lower concentration of O_2 dissolved in the water.

It should also be noted that the presence of the Jenipapo dam without fish transposition mechanisms may be related to an impoverishment in the diversity of fish upstream. Generally, intermittent rivers are recolonized each rainy season by fish that remain in the environments remaining from the previous year's rainy season (e.g. puddles), and by fish from perennial stretches downstream.

The Jenipapo puddles and reservoir, which are the only sources of recolonization of fish in the Piauí River basin upstream of the dam, have peculiar characteristics. These characteristics are quite different from those presented in the stretches with perennial waters downstream from the dam, which probably does not allow the maintenance of viable populations of species adapted to environments with more vegetation (aquatic and marginal) and with higher flow. With the dam acting as a barrier, since there is no mechanism for transposing fish, individuals of the species coming from the downstream stretches cannot re-colonize these environments, leading to possible local extinctions upstream of the dam.

As poças e reservatório de Jenipapo, que são as únicas fontes de recolonização dos peixes da

Data Table 5.2-57 – Richness and abundance at each sampling site.

Species	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6
Apareiodon cf. itapicuruensis				3	1	1
Aspidoras raimundi			2	5		
Astyanax cf. lacustris	2	33		30	23	2
Astyanax fasciatus	1	1	17	412		15
Characidium cf. bahiensis						4
Characidium cf. bimaculatum		72		41		
Cichlasoma orientale	1				3	16
Compsura heterura	4	4		243	2	
Crenicichla menezesi	1					11
Ctenobrycon sp.	3	44				6
Geophagus parnaibae	3					26
Hemigrammus sp.		198				17
Hemiodus parnaguae					32	1
Hoplias malabaricus		5	19	4		4
Hypostomus eptingi			1			1
Hypostomus nudiventris				7		3
Hypostomus sp.	11			1		19
Leporinus piau		1		8		10
Loricariichthys derbyi	29					15
Micropoecilia sp.						338
Moenkhausia dichroura					4	
Oreochromis sp.						8
Pamphorichthys hollandi					29	35
Parotocinclus haroldoi			2	16		119
Phenacogaster calverti				52		7
Pimelodella gracilis				9		
Pimelodella sp.				1		
Pimelodella witmeri						1
Pimelodus blochii	5					3
Platydoras costatus						3
Poptella compressa	6				4	

Species	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6
Potamotrygon signata					3	1
Prochilodus lacustris				4		
Pterygoplichthys parnaibae						1
Pygocentrus nattereri						1
Roeboides cf. sazimai	2					
Roeboides margareteae	1					
Schizodon dissimilis						1
Serrapinnus heterodon			4	2000		
Serrapinnus piaba						10
Serrasalmus rhombeus					1	
Steindachnerina notonota	1	16			4	14
Sternopygus macrurus						1
Synbranchus marmoratus					1	
Trachelyopterus galeatus						7
Triportheus signatus	24				35	1
Total of Species	**15**	**9**	**6**	**16**	**13**	**33**

Species of economic interest and / or veterinary medicine

Several species of fish are the target of fishing for food subsistence, however there is a strong preference for fish considered noble [i.e. duckbill catfish (*Sorubim lima*) and barred sorubim (*Pseudoplatystoma fasciatum*)]. However, because they are less frequent in the region, they reach higher prices. The fish consumed daily and have a lower commercial value are the streaked prochilod (*Prochilodus lacustris*), piranhas (*Serrasalmus rhombeus* and *Pygocentrus nattereri*) and *piaus* (*Leporinus piau* and *Schizodon spp.*). Apparently, the tilapia (*Oreochromis sp.*) created in a reservoir are not well accepted for consumption by the local population.

Uncollected species

According to information obtained from local fishermen, four species of medium and large fish occurring in the study region were not sampled, they are:

- Duckbill catfish - *Sorubim lima* (Bloch & Schneider, 1801);
- Surubim - *Pseudoplatystoma fasciatum* (Linnaeus,1766);
- Driftwood catfishes – *Ageneiosus* sp.; and
- Piau de vara – *Schizodon* sp.

These species occur both upstream and downstream of the dam. Also, according to the fishermen, the number of specimens caught has been declining considerably, especially after the construction of the dam. It is worth mentioning that these species were not listed and accounted for the composition of the total richness of the study area.

Species threatened and protected by legislation

No species of fish detected in the areas of influence of the project are threatened with extinction. Only the stingrays (*Potamotrygon signata*) is classified as data deficient, that is, the information about its species is insufficient to make an assessment of its risk of extinction (IUCN, 2016).

Migratory species

Reproductive migrations, also called "piracema" or "arribação", is a behavior that occurs in some species of fish in which, due to environmental triggers, individuals go up the rivers in search of smaller stretches, other affluent or marginal lagoons, where they carry out spawning. This behavior is essential for the reproduction of these species, since these environments provide shelter and food for the larvae. The environmental trigger in Brazil is typically the start of the rainy season (Kortmulder, 1987).

During the interviews with local fishermen, several migratory species were reported (*Leporinus piau* - piau, *Schizodon dissimilis* - piau-de-vara, *Steindachnerina notonota* - branquinha, *Prochilodus lacustris* - prochilod, *Sorubim lima* - duckbill catfish and *Pseudoplatystoma fasciatum* - barred sorubim). As these correspond to species of interest for fishing and notorious migrants, it is possible that other species carry out minor migrations, but that are overlooked by fishermen, such as *Apareidodon cf. itapicuruensis, Hemiodus parnaguae* (flyier) and *Hypostomus spp* (pleco), belonging to groups with species reported as migratory (Lamas, 1993).

It is important to note that, due to the construction of the Jenipapo dam on the Piauí River, the downstream fish interrupt their migration since there is no transposition mechanism for these fish. Thus, fish from the Piauí River perform the "piracema" by spawning just below the dam and possibly in other affluent located further downstream. According to information obtained, migratory fish that are restricted to the Jenipapo dam during the dry period, migrate in the rainy season, going up the Piauí River itself, as well as other affluent of the Piauí River upstream of the dam, such as Itaquatiara Creek and the São Romão river.

Exotic species

According to local information, only three species were intentionally introduced in the region, tilapia (*Oreochromis sp.*), peacock bass (*Cichla sp.*) and tambaqui (*Collosoma macropomum*). However, only tilapia has had any success in terms of production intended for consumption by the local population. Tilapia are raised in net tanks on a specific arm of the Jenipapo dam and this type of breeding generally implies the flight of many specimens, larvae and adults into the natural environment, both upstream and downstream of the dam, since larvae and eggs can be carried downstream by the periodic overflow of the dam. During collections, however, only eight juvenile specimens of tilapia were collected at sampling site 6, downstream from the Jenipapo dam. This index therefore confirms local information that this species has not been successful in colonizing aquatic environments in the region.

Rare and / or restricted species

Unlike the low Parnaíba, which has several amazonian elements in the composition of its ichthyofauna, the sampled region is mostly composed of species that occur only in the coastal basins of the Northeast and/or in the São Francisco River basin. In addition to these, there are some species with wide distribution that occur in several basins, some of them including the Amazon basin.

The degree of endemism found during the sampling was also quite high, with more than 30% of the species (14 spp.) occurring exclusively in the Parnaíba river basin.

Other environments

Due to the presence of a large amount of groundwater in the region, several informal interviews were carried out in order to assess the presence of fish or other macro-organisms in this environment. All respondents were categorical in stating that there are no such organisms in the place. Although these reports are really indicative of their absence, their presence cannot be ruled out without further study.

Another environment, not directly investigated due to the lack of rain during the campaign, was the isolated rain puddles. These puddles have no contact with watercourses and often harbor species of fish from the Rivulidae Family (Costa, 1995). These species have several adaptations (eg, accelerated growth and drought-resistant eggs) that allow them to have their entire life cycle associated with these puddles, which dry completely in a matter of months (Costa, 1995). Many of these species have a very limited distribution, which makes them very vulnerable and susceptible to extinction due to changes in their restricted environments. For this reason, the species of this family correspond to almost 40% of all species of endangered freshwater fish in Brazil. At least one resident reported the presence of this type of environment with the presence of fish that only appear during the rains, whose morphology described is similar to that of the species of the Rivulidae Family.

C) Summary

In general, the maintenance of fish diversity and the structure of fish communities in intermittent river environments in the semi-arid region of Northeast Brazil is due to the peculiar rainfall regime of this region (Maltchik, 1999). Changes in this dynamics, through the construction of reservoirs for example, can cause serious impacts on the ichthyofauna communities in these environments (Medeiros & Maltchik, 2006). Thus, the large presence of dams, as well as the Jenipapo Dam itself, may be causing important impacts on the region's ichthyofauna. Thus, the fish fauna in the area of influence of the project is characterized by having generalist habits, in addition to the region being marked by an impoverishment of biodiversity, due to the interruption of migratory processes for reproductive purposes. It is also worth noting that several species found are endemic to the Parnaíba River basin, reflecting greater fragility to the environment.

D) Photographic Report

Photo 5.2-138 – Well in the bed of the Itaquatiara Creek.

Photo 5.2-139 – Site 1, Itaquatiara Creek.

Photo 5.2-140 – Site 2, Pindoba Reservoir.

Photo 5.2-141 – Site 3, Mãe d'água's Cauldron, Itaquatiara Creek.

Photo 5.2-142 – Site 4, João's Well, Itaquatiara Creek.

Photo 5.2-143 – Site 4, João's Well, Itaquatiara Creek.

Photo 5.2-144 – Site 5, Jenipapo dam, View from the Dam's spillway.

Photo 5.2-145 – Site 5, branch of the Jenipapo Dam, Piauí River.

Photo 5.2-146 – Site 5, Jenipapo dam, left margin.

Photo 5.2-147 – Site 6, View of the spillway of the Jenipapo Dam, Rio Piauí.

Photo 5.2-148 – Site 6, stretch of the Piauí River downstream from the Dam.

5.2.5.2. Hydrobiological Communities

Aquatic communities have a fundamental role in the functioning processes of rivers, lakes, dams and wetlands (TUNDISI & TUNDISI, 2008) and are essential in maintaining the trophic structure of aquatic systems.

The hydrobiological community in the present study was represented by the phytoplankton, zooplankton and zoobenthic communities and also by the periphery and the aquatic macrophytes.

The phytoplankton community is characterized by an assembly of mostly photoautotrophic organisms that live suspended in the water column throughout its cycle and vegetative phase (ESTEVES, 2011). It is responsible for the autotrophic metabolism of the aquatic community through photosynthesis, the first transfer of energy in the system. The phytoplankton community quickly reflects changes in the aquatic environment, whether due to the reduction of species or the occurrence of blooms, which makes it very useful in the identification of changes caused by anthropic actions in the environment.

Zooplanktonic organisms are heterotrophic and, consequently, consumers within the food chain. They have an important role in the dynamics of an aquatic ecosystem, especially in nutrient cycling and energy flow. Like phytoplankton, zooplankton responds quickly to changes in the environment.

The macrofauna of benthic invertebrates is defined as the fauna of invertebrates that lives at the bottom of riverbeds and sediments of lentic bodies. In their habitat, these organisms colonize different substrates, such as plants, stones and sandy and clayey sediments. Several groups make up the zoobenthic community, such as Plathelminths, Nematoda, Mollusca, Annelida, Arthropoda, among others less important. The zoobenthic community reflects a lot on water quality, as its occurrence is related to several biotic and abiotic factors, where can be highlighted the concentration of dissolved oxygen, the availability of food (quantity and quality of sedimentary organic matter), the physical nature of the sediment (granulometry and degree of compaction) and the biotic relationships between the different taxonomic groups present in the environment (WETZEL, 2001 *apud* ESTEVES, 2011).

Periphyton develops on the surface of rocks, in vegetation or any other substrate submerged in rivers, lakes, ponds, lagoons, streams, wetlands, etc., besides wet surfaces, such as walls, soils, tree trunks, among others. They are components of the peripheral community, algae of all Classs, especially filamentous ones. However, there are many heterotrophic components in the community, for example, sessile or free protozoa, fungi, bacteria, rotifers, cladocerans, copepods, chironomid larvae, molluscs, etc., which, although not included in the definition, are part of community processes and are considered in studies.

The peripheral community is considered one of the main primary producers in continental aquatic ecosystems, mainly in shallow environments. It is an important source of native organic matter and has an important role in the mineralization of dissolved organic matter and in the cycling of nutrients. Periphyton is also capable of accumulating large amounts of polluting substances and as they have a sessile way of life and a short life cycle, they respond quickly to environmental changes (ESTEVES, 2011).

In addition, according to Esteves (2011), aquatic macrophytes are elements of the flora of aquatic ecosystems and have an important role as a source of food, breeding places and refuges for various animal species, absorption of pollutants and in the cycling of nutrients in these environments. On the other hand, the great proliferation of aquatic macrophytes can prevent the multiple uses of water resources, such as, for example, electricity generation, irrigation, navigation, fishing and recreation.

In the present study, the information presented about aquatic macrophytes will be based only on secondary data. The other groups will be analysed based on secondary and primary data.

A) Methodological Considerations

a) Collection of secondary data

For the characterization of the aquatic fauna likely to occur in the study region, studies were carried out in the region. Studies in the Parnaíba River basin, however, are scarce, making it difficult to gather information.

b) Field sampling

Field sampling was carried out aiming to collect primary data, whose collection and analysis methodologies are described below. Samples were taken to collect phytoplankton, zooplankton, benthic and peripheryton organisms.

Sampling period

The survey of primary data was carried out over three campaigns in the year 2008. The first occurred between February 15th and 17th, the second between March 14th and 19th and the third in the period between May 1st to 5th.

Although the survey of primary data took place in 2008, there was little change in land use in the region, suggesting that the current environmental characteristics are similar to those of 2008 and, therefore, the data obtained in 2008 will be sufficient to technically subsidize the assessment impacts and proposing mitigating measures for the current project. This understanding was corroborated by SEMAR and PNM at a meeting held in September 2016.

Spatial coverage of the study

The sampling net adopted was the same one used to collect physical-chemical and bacteriological samples of surface waters, allowing an integrated interpretation of the results obtained. In this sense, the collection sites were previously defined in drainages located around the facilities of the project, identifying the villages, the relevant sources of pollution, the access routes and logistical support, among other factors that characterize the sampled points. With this guidance, the sample net also included stretches of watercourses located outside the ADI, making it possible to assess water quality in an integrated manner where the project is inserted.

Due to the flow dynamics of the rivers observed in the different campaigns, there were variations in taking samples from the hydrobiological communities, as specified in the table below. It is noteworthy that the points were grouped by proximity and by reference basin / sub-basin, but all belong to the Piauí River basin, in the Parnaíba Hydrographic Region (medium Parnaíba).

Table 5.2-2 lists the sampling points and the methodology used for collecting aquatic fauna data, while Map 5.2-15 indicates their location.

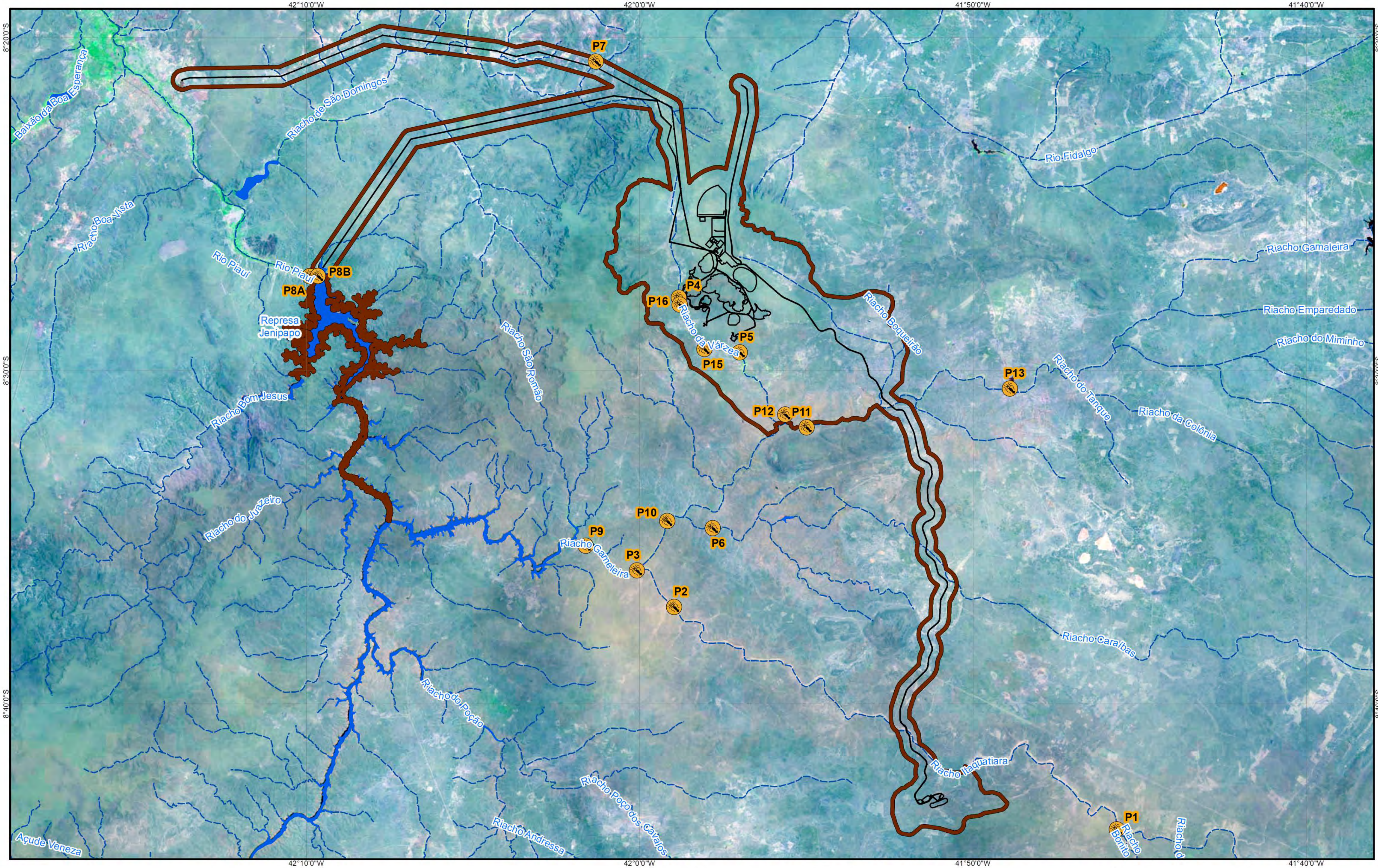
Table 5.2-2 – List of sampling points and parameters sampled for each campaign.

Points / Watershed Reference		Body Water	First campaign					Second campaign					Third campaign				
			Fito	Perifiton	Zoo	Bentos	Q.A	Fito	Perifiton	Zoo	Bentos	Q.A	Fito	Perifiton	Zoo	Bentos	Q.A
Itaquatiara	P1	Bonito Creek	X				X	X		X	X	X	X				
	P2	Itaquatiara Creek						X		X	X	X					
	P3	Itaquatiara Creek	X				X			X	X	X					
	P9	Itaquatiara Creek	X	X	X	X	X	X		X	X	X					
Gameleira	P6	Caribbean Creek	X*	X	X	X	X	X		X	X	X					
	P10	Gameleira Creek						X		X	X	X					
	P11	Gameleira Creek						X		X	X	X					
	P12	Affluent Gameleira						X		X		X					
	P13	Affluent Gameleira (weir)											X		X	X	X

Points / Watershed Reference		Body Water	First campaign					Second campaign					Third campaign				
			Fito	Perifíton	Zoo	Bentos	Q.A	Fito	Perifíton	Zoo	Bentos	Q.A	Fito	Perifíton	Zoo	Bentos	Q.A
Várzea	P4	Várzea Creek (weir)	X	X	X	X	X	X		X	X	X	X		X	X	X
	P5	Várzea Creek	X	X	X	X	X	X		X	X	X	X				X
	P15	Várzea Creek											X		X	X	
	P16	Várzea Creek (weir)											X				X
São Domingos	P7	São Domingos Creek (weir)	X		X	X	X	X			X	X	X		X	X	X
Piauí	P8A	Jenipapo Dam	X	X	X	X	X	X		X	X	X	X		X	X	X
	P8B	Piauí River	X	X	X	X	X	X	X	X	X	X	X		X	X	X

Legend:
Fito – Phytoplankton
Zoo - Zooplankton
Bentos - Macrofauna of benthic invertebrates
Q.A. - Water Quality
** Qualitative analysis only*

Map 5.2-15 – Sampling sites of hydrobiological communities.



LEGENDA

- Intermittent Drainage
- Water Mass
- Area of Direct Influence - ADI
- Directly Affected Area - DAA

Sampling Site

- Hydrobiological Communities

REFERÊNCIAS

ARCADIS Tetraplan, 2008;
IBGE, Base contínua 1:250.000, 2015;
LANDSAT, Imagem, 2016;
Projeto Piauí Níquel, 2016.

ESCALA GRÁFICA

0 5 10 km

Sistema de Coordenadas: GCS SIRGAS 2000

MAPA DE LOCALIZAÇÃO

PA MA CE RN PB PE PI AL SE TO BA

PIAUÍ NIQUEL ARCADIS

EIA/RIMA – Projeto Piauí Níquel

Map 5.2-15 – Sampling Sites Hydrobiological Communities

EXECUTADO POR:	ESCALA:	NÚMERO:	DATA:
ARCADIS	1:200.000	Única	jun /2017

Below are the photographs of each of the sampling points. The detailed characterization of each one of them was presented in the item "Quality of Surface Water" (5.1.7.3) of this report. As in Table 5.2-2, the photographs of the points were grouped by proximity and by reference basin / sub-basin.

Itaquatiara

Point 01 – Bonito Creek (2nd campaign).

Point 02 – Itaquatiara Creek (2nd campaign).

Point 03 – Itaquatiara Creek (2nd campaign)

Point 09 – Itaquatiara Creek (1st campaign)

Source: Arcadis Tetraplan, 2008.

Gameleira

Point 06 – Caraíbas Creek (2nd campaign)

Point 11 – Gameleira Creek (2nd campaign)

Point 12 – Gameleira affluent (2nd campaign)

Point 13 –Gameleira affluent – weir (3rd campaign)

Source: Arcadis Tetraplan, 2008

Várzea

Point 04 –Várzea stream – weir (1st campaign)

Point 05 – Várzea stream (3rd campaign).

Point 15 –Várzea stream (3rd campaign)

Point 16 – Várzea stream (3rd campaign)

Source: Arcadis Tetraplan, 2008

São Domingos

Point 07 – São Domingos stream – weir (1st campaign)

Source: Arcadis Tetraplan, 2008.

Piauí

Point 08A – Piauí River – Jenipapo dam (1st campaign)

Point 08B – Piauí River

Source: Arcadis Tetraplan, 2008.

Sampling and analysis procedures

- Phytoplankton

Qualitative (taxonomic) and quantitative (density of organisms) samples of phytoplankton were collected at each point in the sampling net.

Qualitative samples were carried out by means of horizontal drag, using a 20 µm mesh opening net. Quantitative samples were taken using 1L plastic bottles. This method, called "Total Phytoplankton", consists of submerging the bottle directly in the water in a depth of 30 cm until it is completely filled.

To preserve the qualitative sample, a 4% formaldehyde solution was used. In the quantitative samples, drops of lugol were added.

The collection bottles were homogenized, labelled and sent to the laboratory for identification and counting of the components of the main taxonomic groups.

The taxons were then identified at the lowest taxonomic level from the population analysis, using a binocular microscope and specialized bibliography.

The phytoplankton quantification was carried out according to the chamber sedimentation method, described by Utermöhl (1958). In the counting procedure, random fields were adopted, using an inverted microscope with a maximum magnification of 1,000 times.

The sedimentation time was three hours (minimum) for each centimetre of height in the chamber, according to Wetzel & Likens (1991). Each cell, cenobium, colony or filament was considered as an individual.

The counting limit was determined by stabilizing the species curve, in which a sufficient number of fields is counted until the number of species added to it is stabilized (SANT'ANNA *et al.* 2006). The density was calculated according to APHA (2005). The numerical density of the organisms was expressed in organisms per millilitre (ind / mL).

- Periphyton

Periphyton communities were analysed, based on sediment collection, a predominant substrate in the study environment, assuming only a qualitative character and complementary to the study of phytoplankton.

The organisms were collected at the points that had little depth and total transparency, where the probability of development of these communities is higher.

After collecting a small amount of sediment, the samples were placed in plastic bottles and preserved in formaldehyde with a final concentration of 4%.

The collection bottles were homogenized, labelled and sent to the laboratory for identification of the representatives of the taxonomic groups. Taxon identification was performed at the lowest taxonomic level, using a binocular microscope and specialized bibliography.

- Zooplankton

At each point in the sampling net, qualitative (taxonomic) and quantitative (density of organisms) collection of zooplankton were performed.

Qualitative samples were taken by means of horizontal and vertical drag using a 68 μm mesh opening net.

Quantitative samples were collected in 10 L containers, filtering 100 L of water, which were concentrated through the net and placed in 250 mL bottles.

In the preservation of qualitative and quantitative samples of zooplankton, carbonated water and 4% formaldehyde solution were applied.

The collection bottles were homogenized, labelled and sent to the laboratory for identification and counting of the main taxonomic groups.

For qualitative analysis, the samples were sorted under a stereomicroscope. The organisms were observed and identified under a microscope with a magnification of up to 1,000 times.

Quantitative analysis was performed using sub-sample counts from 35 to 90 mL, depending on the concentration of individuals, with the aid of a Sedgewick-Rafter counting chamber. The numerical density of the organisms is expressed in organisms per cubic meter (ind./m³).

The samples were fully analysed for the identification of zooplanktonic organisms, using identification keys and descriptions available in specialized literature (COELHO-BOTELHO (2006), FERNANDO (2002), KOSTE (1978, 1989a, 1989b, 1990a, 1990b, 1991)).

- Benthic macroinvertebrates

The methodology used for the collection, identification and counting of the benthic community was based on the Technical Standardization - CETESB L309 - Determination of Freshwater Benthos - Benthic Macroinvertebrates - Qualitative and Quantitative Method (CETESB, 2003).

The benthic community was assessed through qualitative (taxonomic) and quantitative (density) analyses.

In the field, the sediment and / or vegetation was packed in plastic bags / pots and preserved with 4% formalin neutralized with sodium bicarbonate. In the laboratory, the samples were properly washed with a set of ABNT sieves (opening mesh - 0.250 mm) in order to retain all the material necessary for the screening of organisms. The sandy sediments were immersed in supersaturated saline solution to apply the “flotation” mechanism, facilitating the screening of organisms.

The qualitative collection was performed based on the sampling of multihabitat, adopting the “D” net (250 µm mesh) for organisms associated with riparian vegetation. Organisms associated with the rocks were also collected.

For quantitative analysis, the sediment was collected with a Corer sampler (10 replicates), with the density of the benthic fauna expressed in org / m².

At the points where it was possible to collect the bottom organisms and those associated with vegetation, the two types of samplers (Corer and D Net) were used, providing a higher variety of organisms for the qualitative analysis of the community.

The animals were identified at the family level, using a stereoscope microscope and using specialized literature: Brinkhurst & Marchese (1989), Pennak (1989), Trivinho-Strixino & Strixino (1995), Epler (1995) and Merritt & Cummins (1996).

It is noteworthy that certain groups such as Hydracarina, Ostracoda and Nematoda are not normally identified until family, given the difficulties of the procedures for the taxonomic definition of these organisms.

Community Descriptors Indexes

For the assessment of aquatic communities, the following descriptive indexes were used:

- Qualitative Analysis

Species Richness: Species richness expresses the total number of taxon present in the samples.

Spatial Distribution: The spatial distribution of organisms in the sampling net is read based on the presence or absence of a specific taxon at the collection points.

BMWP Index: The BMWP index (Biological Monitoring Working Party Score System) lists water quality and benthic macroinvertebrates recorded in aquatic systems and provides the environment's classification in different Classs for water quality (Table 5.2-3).

This index consists of assessing the quality of a freshwater stream through the presence or absence of certain systematic units of benthic invertebrates. The families of aquatic macroinvertebrates are arranged in 9 groups, following a gradient from lower to higher tolerance of organisms to organic pollution. Each family is assigned a score, which ranges from 10 to 1. The families most sensitive to contamination receive the highest scores, reaching, in decreasing order, up to 1, where the most tolerant are.

Table 5.2-3 – Water quality classification system based on aquatic macroinvertebrates.

Class	Index Rate	Water Quality
1	>86	Optimum
2	85 - 64	Good
3	37 - 63	Satisfactory
4	17 - 36	Bad
5	<16	Critical

Source: Alba-Tercedor & Sanches-Ortega, 1988 e Junqueira & Campos, 1998 apud Biodiversitas, 2016.

- Quantitative Analysis

Numerical Density: The numerical density indicates the amount of organisms present in the samples.

Relative Abundance: The relative abundance is expressed as a percentage (%), calculating n / N.100, where,

n = number of individuals of each species and,
N = total number of individuals of all species.

Species Diversity Index: The Shannon-Wienner Diversity Index (H ') was calculated using the result using the following formula:

$$H" = -\sum pi.\log_2 pi \quad \text{e} \quad pi = \frac{n}{N}$$

Where:
H"= Shannon-Winner Diversity Index, in bit.individual^{-1}
pi= relative abundance
n = number of individuals collected from species i
N = total of individuals collected at the point

Diversity results can be classified into three main levels of environmental quality:

- H" > 3: indicates little changed environments
- H" entre 1 e 3: indicates moderately altered environments
- H" < 1: reveals probable anthropic interference or an environment that is naturally unfavorable to the establishment of organisms, due to the presence of rapids and waterfalls, among other aspects.

It is noteworthy that in the case of benthic organisms, as the species identification occurred up to the family level, the number of individuals found in each family was considered.

Uniformity: The uniformity of the sample was calculated using the Equitability Index (J) according to Pielou (1975).

J= H' / H'max; where J is equitability, H 'maximum is the Napierian logarithm of S.

B) Results

The results and their discussions are presented below.

a) Regional Characterization

Phytoplankton

In the study region, little data is available on aquatic biota. The phytoplankton composition of the Parnaíba River was studied within the scope of the Environmental Impact Studies of the Ribeiro Gonçalves, Uruçuí, Cachoeira, Estreito and Castelhanos reservoirs, where 105 Taxon distributed in 25 families were diagnosed, with 45 species occurring in the rainy season and 86 in the rainy season. dry period (PROJETEC, 2006).

In the two study periods, greater richness of species from the Chlorophyta division was observed, and organisms from the Cyanophyta and Euglenophyta divisions were also found.

The better performance of the organisms belonging to the Chlorophyta division is probably due to the fact that this group exhibits a wide distribution in terms of latitude and the dominant species vary greatly with the available amount of nutrients and physical characteristics of the water (BITTENCOURT-OLIVEIRA *et al.*, 2000).

In general, Cyanophyta were present in a smaller number, however, the presence of potentially toxic genera was highlighted, such as: *Anabaena variabilis, Microcystis wesenbergii, Cylindrospermopsis raciborskii* and *Pseudanabaena sp*, which can cause problems to human and animal health.

This aspect assumes importance in the entire water network that drains the areas of influence of the project, since the scarcity of water induces the use of small dams and cacimbas, in which the eutrophication process leads to the occurrence of these organisms, which may affect not only health of people, but interfere in the development of animals that use these sources for watering. In this sense, this work also included an assessment of phytoplankton communities in water wells destined for public supply.

Zooplankton

As with the phytoplankton community, there is little information about zooplankton in the Parnaíba river basin. In the same study used as a reference (PROJETEC, 2006), 43 Taxon were identified, distributed among the groups Rotifera (23), Crustacea (12), Protozoa (4), Insecta (1), Nematoda (1), Acari (1) and Tardigrada (1).

The Rotifera stood out in terms of richness, being represented mainly by euplanktonic species, with emphasis on the Brachionidae family, formed largely by animals common to Brazilian freshwater plankton, which are highly adaptable to limnic ecosystems.

The Crustacea group was basically composed of representatives from Cladocera and Copepoda, both in adult form and in the young stages of nauplii and copepodites. Among the crustaceans, the presence of the order Decapoda, represented by the shrimp larvae, stands out.

The species of Protozoa were found in all sampling units in both the Parnaíba riverbed and in the tributaries, being related to the turning of the substrates.

Insecta were represented by the *Chaoborus* genus, identified in all areas studied. They are considered voracious predators of zooplankton, being in many cases related to important changes in the population structure of several zooplankton species. Nematoda and Acari are also noteworthy, as they are usually benthic or ticoplankton groups, which occur sporadically in freshwater plankton.

Among the Taxon considered frequent, the rotifers *Trichocerca sp* and *Keratella cochlearis* stood out; the protozoan *Centropixys acureata*; the *Thermocyclops decipiens* crustacean; and the insect larva *Chaoborus spp*. The other Taxon were considered infrequent or sporadic.

The equitability values followed the same pattern of distribution of richness among the collection points, indicating that the community is balanced in terms of its taxonomic composition.

The remarkable presence of species of true plankton among the Rotifera, the group with the highest taxonomic richness, reveals a community adapted to more lentic regions. The higher densities and the large number of organisms represented by *Arcella vulgaris*, confirm a community adapted to this type of environment and dominated by opportunistic organisms.

The highlight of the groups Protozoa and Rotifera indicates that the community is basically formed by microzooplankton (organisms of small size), usually of filtering or herbivorous habit that more easily support changes in water regimes and deterioration of water quality.

The presence of shrimp larvae can show potential for aquaculture in the area, being important to the conditions of water quality and maintenance of the structure of the planktonic communities that serve it as food.

The abundance of groups in both climatic periods was similar, with a small tendency to enrich the community in the dry period.

Aquatic Macrophytes

In terms of macrophyte richness, the study cited on the Parnaíba river basin showed relatively low species indexes for the dry period, with species in the middle Parnaíba not having species recorded in this climatic phase. Altogether, 30 species of macrophytes comprised 23 families were identified for the rainy season, and 12 species distributed in 11 families for the dry period.

The Hydrocharitaceae family showed greater richness, represented by five species; followed by the families Araceae and Pontederiaceae (4 species each); Cabombaceae, Nymphaeaceae, Onagraceae and Poaceae (3 species each); Cyperaceae (2 species). The other families (Acanthaceae, Alismataceae, Blechnaceae, Characeae, Commelinaceae, Convolvulaceae, Cyclantaceae, Limnocharitaceae, Marsileaceae, Melastomataceae, Mimosaceae, Polygonaceae, Rubiaceae, Salviniaceae, Scrophulariaceae) were represented by only one species each.

In the region of the middle Parnaíba, the macrophyte families with the greatest representation, in terms of number of species, were Hydrocharitaceae (4 species), Cabombaceae and Onagraceae (3 species each) and Araceae, Cyperaceae and Pontederiaceae (2 species each). The other families presented only one species, representing, together, 36% of the total species.

In the regions of Parnarama, Palmeirais, Amarante and São Francisco do Maranhão, in the lower-middle course of Parnaíba, the number of species recorded was 25, comprised in 15 families.

In Alto Parnaíba macrophytes were represented by 19 species, belonging to 15 families. Again, the family with the greatest representation in terms of richness was Hydrocharitaceae, with three species. The families Caesalpiniaceae, Cyperaceae, Limnocharitaceae, Onagraceae, Pontederiaceae were represented by two species each. The other families contained one species each, with Egeria densa being the only species frequent in all areas of study.

b) Areas of Influence

The structure of the aquatic communities of the water courses included in the Piauí Nickel Project is conditioned by the regional hydrological cycle, which has two distinct phases - the flood and the drought, and is also influenced by the intermittency regime that characterizes most rivers and streams in the region.

The attributes of natural flood and drought events (intensity, duration, frequency and predictability) have a considerable influence on patterns and models of ecological succession. During the drought, the dynamics that govern the establishment of aquatic organisms in intermittent rivers cease. The reduction in runoff tends to break the connectivity of the regional water network, restricting the presence of water collections to perennial rivers.

With the advent of rains, intermittent drains become a direct vehicle for waste and other compounds that remain concentrated in its bed during the dry season. The precipitations that occur on land with high erosive potential also provide the supply of solids, together with mineral nutrients and agricultural inputs applied to crops.

In this way, perennial rivers tend to become important recipients of this polluting load. The flow of mineral nutrients, especially nitrogen and phosphorus, combined with high temperatures and strong local sunlight, favor the development of algae. However, the presence of rapids and waterfalls existing in some stretches of the basin under study are elements unfavourable to planktonic communities, which develop preferentially in lentic environments, that is, with low current speed.

The phytoplanktonic, peripheral, zooplanktonic and benthic communities analysed within the scope of the ADI and DAA of the study area are described below. As previously explained, some sampling points are located outside the ADI area, however, their location was defined in order to carry out a more comprehensive analysis of the local aquatic biota.

Phytoplankton

- ### Qualitative analysis

According to a survey carried out in the three campaigns carried out in 2008, the sampled environments presented a moderate richness of phytoplankton species, as shown in the tables and figures below.

In total, 169 Taxon (including morphospecies) were registered, belonging to nine distinct Classs: Cyanophyceae, Chlorophyceae, Zygnemaphyceae, Euglenophyceae, Bacillariophyceae, Cryptophyceae, Chrysophyceae, Dinophyceae and Xanthophyceae.

These Classs gather algae of the most varied types and habits, many of them coccoid and some filamentous, typical of planktonic communities.

Among the groups identified, the most representative Classs in all sampling campaigns were Chlorophyceae (61 Taxon) and Cyanophyceae (35 Taxon), making up a percentage greater than 55% of the relative diveristy of the set of samples analyzed, as shown in Data Table 5.2-58 and Data Table 5.2-59 below and in Figure 5.2-6.

Regarding the sampling periods, a greater total richness is noted in the third campaign (May / 2008), when 123 species of algae were found, followed by the first campaign in February / 2008 (71 species) and the second campaign, which occurred in March / 2008 (64 species). It is important to consider that in the first, second and third campaigns, sampling for phytoplankton analysis was performed at 9, 12 and 9 points, respectively.

In general, there was a tendency to reduce the richness of all Classs identified in the second campaign, with no representatives of the Classs Chrysophyceae and Xanthophyceae being found. This drop, observed mainly at Points 09 (Itaquatiara Creek) and 04 (Várzea Creek reservoir) at the height of the rainy season, is due to the contribution of solids to water courses from the drainage basin, responsible for the increase in turbidity patterns that, associated with a higher level of runoff, restrict the establishment of phytoplankton organisms, reflecting in the richness of species. The physical-chemical results presented in item 5.1.7.3 – Surface Water Quality corroborate this statement.

It is important to highlight in the set of environments sampled the dynamics of the Jenipapo dam, which acts as a final receiver for practically all the sub-basins evaluated, with the exception of São Domingos, concentrating nutrients. This dam, due to its size and because it is a lentic environment, tends to promote the decanting of solids, which increases the level of transparency of the waters even in the rainy season, allowing the establishment of a greater variety of community representatives phytoplankton.

In this sense, Points 8A and 8B, located upstream and downstream of the Jenipapo dam bus, respectively, stood out for presenting the largest variety of algae in the sampling network (61 Taxon and 43 Taxon), especially in the third campaign. This last sampling, carried out immediately after the rainy season, configured a situation more favorable to the development of organisms, since the prevailing conditions of temperature were restored, with a higher level of transparency and availability of nutrients.

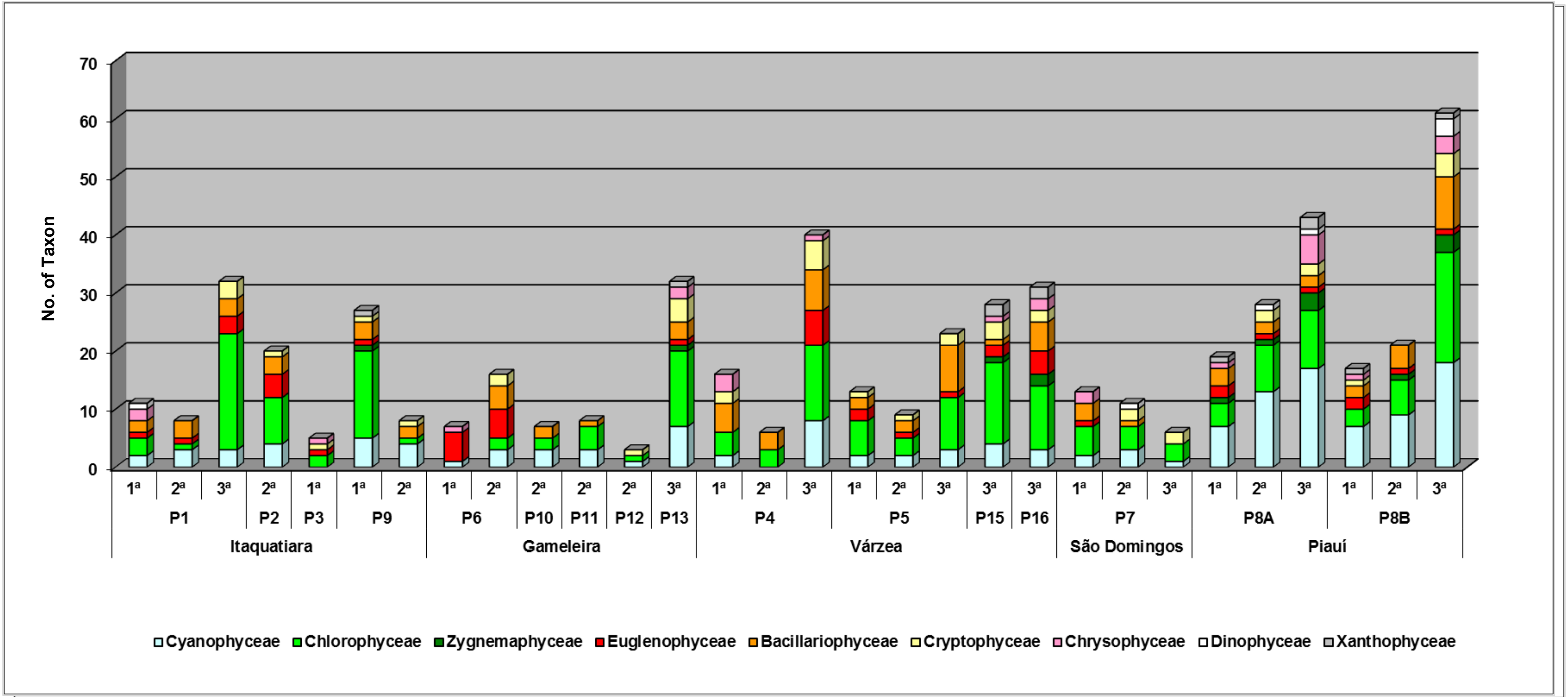
Data Table 5.2-58 – Relative Richness of the Phytoplankton Community (%).

Taxonomic Groups	Total Feb/08	Relative Richness Feb/08 (%)	Total Mar/08	Relative Richness Mar/08 (%)	Total May/08	Relative Richness May/08 (%)	Grand Total	General Relative Richness (%)
Chlorophyceae	23	32.39	18	28.13	46	37.40	61	36.09
Cyanophyceae	13	18.31	20	31.25	25	20.33	35	20.71
Bacillariophyceae	12	16.90	9	14.06	15	12.20	23	13.61
Euglenophyceae	11	15.49	9	14.06	13	10.57	20	11.83
Chrysophyceae	4	5.63	-	-	7	5.69	9	5.33
Cryptophyceae	4	5.63	4	6.25	6	4.88	7	4.14
Zygnemaphyceae	2	2.82	2	3.13	5	4.07	6	3.55
Dinophyceae	1	1.41	2	3.13	3	2.44	4	2.37
Xanthophyceae	1	1.41	-	-	3	2.44	4	2.37
Total	**71**	**100**	**64**	**100**	**123**	**100**	**169**	**100**

Data Table 5.2-59 –Species Richness of the Phytoplankton Community (No. of Taxons)

Taxonomic Groups	Itaquatiara							Gameleira						Várzea								São Domingos			Piauí					
	P1			P2	P3	P9		P6		P10	P11	P12	P13	P4			P5			P15	P16	P7			P8A			P8B		
	1ª	2ª	3ª	2ª	1ª	1ª	2ª	1ª	2ª	2ª	2ª	2ª	3ª	1ª	2ª	3ª	1ª	2ª	3ª	3ª	3ª	1ª	2ª	3ª	1ª	2ª	3ª	1ª	2ª	3ª
Cyanophyceae	2	3	3	4	-	5	4	1	3	3	3	1	7	2	-	8	2	2	3	4	3	2	3	1	7	14	17	7	9	18
Chlorophyceae	3	1	20	8	2	15	1	-	2	2	4	1	13	4	3	13	6	3	9	14	11	5	4	3	4	7	10	3	6	19
Zygnemaphyceae	-	-	-	-	-	1	-	-	-	-	-	-	1	-	-	-	-	-	-	1	2	-	-	-	1	1	3	-	1	3
Euglenophyceae	1	1	3	4	1	1	-	5	5	-	-	-	1	-	-	6	2	1	1	2	4	1	-	-	2	1	1	2	1	1
Bacillariophyceae	2	3	3	3	-	3	2	-	4	2	1	-	3	5	3	7	2	2	8	1	5	3	1	-	3	2	2	2	4	9
Cryptophyceae	-	-	3	1	1	1	1	-	2	-	-	1	4	2	-	5	1	1	2	3	2	-	2	2	-	2	2	1	-	4
Chrysophyceae	2	-	-	-	1	-	-	1	-	-	-	-	2	3	-	1	-	-	-	1	2	2	-	-	1	-	5	1	-	3
Dinophyceae	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	1	1	-	-	3
Xanthophyceae	-	-	-	-	-	1	-	-	-	-	-	-	1	-	-	-	-	-	-	2	2	-	-	-	1	-	2	1	-	1
Total	**11**	**8**	**32**	**20**	**5**	**27**	**8**	**7**	**16**	**7**	**8**	**3**	**32**	**16**	**6**	**40**	**13**	**9**	**23**	**28**	**31**	**13**	**11**	**6**	**19**	**28**	**43**	**17**	**21**	**61**

Figure 5.2-6 – Species Richness of the Phytoplankton Community (No. of Taxons).



The better overall performance of the taxons belonging to the Chlorophyta division is probably due to the fact that this group exhibits a wide distribution in terms of latitude. This class is part of the set of green algae (chlorophytes), with an immense morphological variety, and may have planktonic and benthic habits. They grow in environments with a wide spectrum of salinity (continental to marine waters) and trophy (oligotrophic to eutrophic). The limiting environmental factors for the development of these algae are the underwater light climate, the stability of the water column that spatially separates light and nutrients, losses due to sedimentation and the algae self-shading.

Chlorophytes also have a greater capacity for absorbing nutrients, which represents an adaptive advantage in aquatic systems with high transparency and low availability of mineral salts.

On the other hand, environments that receive an additional contribution of nutrients, especially phosphorus, introduced by domestic sewage, fertilizers, among others, favor the growth of organisms of the class Cyanophyceae (cyanobacteria), the second group best represented in terms of richness. This group includes prokaryotic, single-celled, filamentous or colonial beings, most of them involved in mucilage. Many species have structures that are able to directly fix nitrogen from atmospheric air, so that phosphorus becomes the main limiting factor for their development. Thus, the availability of this element in the aquatic environment can induce the greater proliferation of these organisms compared to other communities.

The third class best represented in terms of richness in the points sampled in the Piauí Nickel Project area was the Bacillariophyceae (23 taxons), or diatoms, which are characterized by having silica carapace. The sedimentation rate of these algae is one of the highest among phytoplankton, due to their morphological characteristics and, above all, because they have densities generally higher than that of water. This particularity makes the group often less representative in phytoplankton samples collected only in the water column, not taking into account the peripheral (substrate) or benthic (sediment) flora.

Euglenophyceae was the fourth class in terms of taxonomic richness in the sampling network, comprising a total of 20 species in the three campaigns carried out. These algae are normally associated with polluted environments, enriched with organic materials, where they can develop massively, resulting in flowering. The main source of nitrogen for euglenophytes is ammonia and / or other dissolved organic compounds.

The other Classs (Zygnemaphyceae, Cryptophyceae, Dinophyceae, Chrysophyceae and Xanthophyceae) were less representative in the sampled aquatic ecosystems.

The spatial distribution and frequency of occurrence of phytoplankton are presented below.

Data Table 5.2-60 – Spatial distribution and frequency of occurrence of phytoplankton, in February 2008.

Taxonomic Groups	Itaquatiara			Gameleira	Várzea		São Domingos	Piauí		Frequency	Relative Frequency (%)
	P1	P3	P9	P6	P4	P5	P7	P8A	P8B		
Cyanophyceae											
Anabaena sp.										1	11.11
Aphanocapsa sp.										1	11.11
Chroococcus minutus										1	11.11
Coelosphaerium sp.										1	11.11
Cylindrospermopsis raciborskii										2	22.22
Leptolynbya sp.										2	22.22
Merismopedia glauca										3	33.33
Merismopedia tenuissima										3	33.33
Microcystis sp.										2	22.22
Pseudanabaena galeata										2	22.22

Taxonomic Groups	Itaquatiara			Gameleira	Várzea		São Domingos	Piauí		Frequency	Relative Frequency (%)
	P1	P3	P9	P6	P4	P5	P7	P8A	P8B		
Synechococcus nidulans										3	33.33
Synechococcus sp.										3	33.33
Synechocystis aquatilis										4	44.44
Subtotal	**2**	**-**	**5**	**1**	**2**	**2**	**2**	**7**	**7**		
Chlorophyceae											
Chlamydomonas gleopara										2	22.22
Chlamydomonas planctogloea										3	33.33
Chlorella vulgaris										5	55.56
Chlorococcales sp.										3	33.33
Chlorococcum sp.										1	11.11
Choricystis sp.										3	33.33
Closteriopsis acicularis										1	11.11

Taxonomic Groups	Itaquatiara			Gameleira	Várzea		São Domingos	Piauí		Frequency	Relative Frequency (%)
	P1	P3	P9	P6	P4	P5	P7	P8A	P8B		
Coelastrum microporum										1	11.11
Crucigenia tetrapedia										1	11.11
Crucigeniella rectangularis										1	11.11
Desmodesmus denticulatus										2	22.22
Desmodesmus opoliensis										1	11.11
Didymocystis bicellularis										1	11.11
Didymocystis fina										1	11.11
Kirchneriella pinguis										1	11.11
Lagerheimia ciliata										1	11.11
Monoraphidium arcuatum										5	55.56
Monoraphidium circinale										3	33.33

Taxonomic Groups	Itaquatiara			Gameleira	Várzea		São Domingos	Piauí		Frequency	Relative Frequency (%)
	P1	P3	P9	P6	P4	P5	P7	P8A	P8B		
Monoraphidium nanum										1	11.11
Oocystis lacustris										1	11.11
Rhombocystis sp.										2	22.22
Scenedesmus acuminatus										1	11.11
Scenedesmus ecornis										1	11.11
Subtotal	**3**	**2**	**15**	**-**	**4**	**6**	**5**	**4**	**3**		
Zygnemaphyceae											
Cosmarium majae										1	11.11
Staurastrum sp.										1	11.11
Subtotal	**-**	**-**	**1**	**-**	**-**	**-**	**-**	**1**	**-**		
Euglenophyceae											
Euglena acus										1	11.11
Euglena sp1.										1	11.11

Taxonomic Groups	Itaquatiara			Gameleira	Várzea		São Domingos	Piauí		Frequency	Relative Frequency (%)
	P1	P3	P9	P6	P4	P5	P7	P8A	P8B		
Euglena sp2.										1	11.11
Euglena spirogyra										1	11.11
Lepocinclis acuta										1	11.11
Strombomonas fluviatilis var. fluviatilis										1	11.11
Strombomonas ovalis										2	22.22
Trachelomonas curta										1	11.11
Trachelomonas lacustris										1	11.11
Trachelomonas sp.										2	22.22
Trachelomonas volvocinopsis										3	33.33
Subtotal	**1**	**1**	**1**	**5**	**-**	**2**	**1**	**2**	**2**		
Bacillariophyceae											
Achnantidium microcephalum										2	22.22

Taxonomic Groups	Itaquatiara			Gameleira	Várzea		São Domingos	Piauí		Frequency	Relative Frequency (%)
	P1	P3	P9	P6	P4	P5	P7	P8A	P8B		
Achnantidium minutissimum										1	11.11
Anomoneis sp.										1	11.11
Aulacoseira granulata										1	11.11
Caloneis sp.										1	11.11
Cocconeis sp.										1	11.11
Discostella stelligera										2	22.22
Frustulia rhomboides										1	11.11
Navicula sp.										2	22.22
Nitzschia palea										6	66.67
Nitzschia sp.										1	11.11
Sellaphora sp.										1	11.11
Subtotal	**2**	**-**	**3**	**-**	**5**	**2**	**3**	**3**	**2**		

Taxonomic Groups	Itaquatiara			Gameleira	Várzea		São Domingos	Piauí		Frequency	Relative Frequency (%)
	P1	P3	P9	P6	P4	P5	P7	P8A	P8B		
Cryptophyceae											
Cryptomonas erosa										1	11.11
Cryptomonas ovata										3	33.33
Cryptomonas sp.										1	11.11
Cryptomonas tenuis										1	11.11
Subtotal	**-**	**1**	**1**	**-**	**2**	**1**	**-**	**-**	**1**		
Chrysophyceae											
Chromulina elegans										3	33.33
Chromulina sp.										3	33.33
Ochromonas sp1.										4	44.44
Ochromonas sp2.										1	11.11
Subtotal	**2**	**1**	**-**	**1**	**3**	**-**	**2**	**1**	**1**		
Dinophyceae											

Taxonomic Groups	Itaquatiara			Gameleira	Várzea		São Domingos	Piauí		Frequency	Relative Frequency (%)
	P1	P3	P9	P6	P4	P5	P7	P8A	P8B		
Peridinium sp.										1	11.11
Subtotal	**1**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**		
Xanthophyceae											
Tetraëdriella jovetii										3	33.33
Subtotal	**-**	**-**	**1**	**-**	**-**	**-**	**-**	**1**	**1**		
Total	**11**	**5**	**27**	**7**	**16**	**13**	**13**	**19**	**17**		

Data Table 5.2-61 – Spatial distribution and frequency of occurrence of phytoplankton, in March 2008.

Taxonomic Groups	Itaquatiara			Gameleira				Várzea		São Domin-gos	Piauí		Frequency	Relative Frequency (%)
	P1	P2	P 9	P6	P10	P11	P12	P4	P5	P7	P8A	P8B		
Cyanophyceae														
Anabaena sp.	1										1		2	16.67
Aphanocapsa sp.1		1	1									1	3	25.00
Aphanothece sp.			1								1		2	16.67
Chroococcus minutus			1								1	1	3	25.00
Chroococcus sp.1											1		1	8.33
Chroococcus sp.2											1		1	8.33
Cylindrospermopsis raciborskii										1	1	1	3	25.00
Geitlerinema unigranulatum											1		1	8.33
Merismopedia glauca												1	1	8.33

Taxonomic Groups	Itaquatiara			Gameleira				Várzea		São Domin-gos	Piauí		Frequency	Relative Frequency (%)
	P1	P2	P 9	P6	P10	P11	P12	P4	P5	P7	P8A	P8B		
Cyanophyceae														
Merismopedia punctata											1	1	2	16.67
Merismopedia tenuissima			1									1	2	16.67
Oscillatoria sp.	1	1											2	16.67
Planktolynbya sp.	1	1				1					1	1	5	41.67
Pseudanabaena catenata											1		1	8.33
Pseudanabaenaceae		1			1								2	16.67
Synechococcus nidulans				1	1	1			1	1	1	1	7	58.33
Synechococcus sp.				1									1	8.33
Synechocystis aquatilis				1	1	1	1		1	1	1		7	58.33
Loossen cells of *de Microcystis*											1		1	8.33

Taxonomic Groups	Itaquatiara			Gameleira				Várzea		São Domin-gos	Piauí		Frequency	Relative Frequency (%)
	P1	P2	P 9	P6	P10	P11	P12	P4	P5	P7	P8A	P8B		
Cyanophyceae														
Subtotal	**3**	**4**	**4**	**3**	**3**	**3**	**1**	**-**	**2**	**3**	**13**	**8**		
Chlorophyceae														
Botryococcus sp.											1		1	8.33
Chlamydomonas planctogloea		1				1			1	1			4	33.33
Chlorella minutissima			1					1		1	1	1	5	41.67
Chlorella vulgaris	1	1		1	1	1	1		1				7	58.33
Chlorococcum sp.							1				1		2	16.67
Choricystis sp.				1	1	1				1			4	33.33
Coelastrum microporum		1	F										1	8.33
Coelastrum reticulatum		1											1	8.33
Crucigenia tetrapedia								1					1	8.33

Taxonomic Groups	Itaquatiara			Gameleira				Várzea		São Domin-gos	Piauí		Frequency	Relative Frequency (%)
	P1	P2	P 9	P6	P10	P11	P12	P4	P5	P7	P8A	P8B		
Cyanophyceae														
Dictyosphaerium tetrachotomum		1											1	8.33
Monoraphidium circinale												1	1	8.33
Monoraphidium contortum											1	1	2	16.67
Monoraphidium griffithii		1				1			1				3	25.00
Monoraphidium irregulari							1	1		1	1	1	5	41.67
Scenedesmus acutus		1									1		2	16.67
Scenedesmus bijugus		1											1	8.33
Scenedesmus ecornis												1	1	8.33
Tetraedron caudatum											1		1	8.33
Tetraedron minimum											1	1	2	16.67

Taxonomic Groups	Itaquatiara			Gameleira				Várzea		São Domin-gos	Piauí		Frequency	Relative Frequency (%)
	P1	P2	P 9	P6	P10	P11	P12	P4	P5	P7	P8A	P8B		
Cyanophyceae														
Subtotal	**1**	**8**	**1**	**2**	**2**	**4**	**3**	**3**	**3**	**4**	**8**	**6**		
Zygnemaphyceae														
Euastrum binale												1	1	8.33
Staurastrum tetracerum											1		1	8.33
Subtotal	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**1**	**1**		
Euglenophyceae														
Euglena acus				1									1	8.33
Euglena sp1.												1	1	8.33
Lepocinclis ovum				1									1	8.33
Lepocinclis sp.	1	1											2	16.67
Phacus curvicauda		1											1	8.33

Taxonomic Groups	Itaquatiara			Gameleira				Várzea		São Domin-gos	Piauí		Frequency	Relative Frequency (%)
	P1	P2	P 9	P6	P10	P11	P12	P4	P5	P7	P8A	P8B		
Cyanophyceae														
Phacus sp.				1									1	8.33
Strombomonas spp.		1		1									2	16.67
Trachelomonas abrupta		1		1							1		3	25.00
Trachelomonas sp.									1				1	8.33
Subtotal	**1**	**4**	**-**	**5**	**-**	**-**	**-**	**-**	**1**	**-**	**1**	**1**		
Bacillariophyceae														
Achnanthidium microcephalum												1	1	8.33
Achnanthidium minutissimum				1						1	1	1	4	33.33
Aulacoseira granulata								1					1	8.33
Discostella stelligera	1			1				1					3	25.00
Frustulia rhomboides		1											1	8.33

Taxonomic Groups	Itaquatiara			Gameleira				Várzea		São Domin-gos	Piauí		Frequency	Relative Frequency (%)
	P1	P2	P 9	P6	P10	P11	P12	P4	P5	P7	P8A	P8B		
Cyanophyceae														
Navicula sp.			1		1				1				3	25.00
Nitzschia palea		1	1	1	1	1						1	6	50.00
Nitzschia sp.	1							1	1				3	25.00
Pinnularia sp.	1	1		1							1	1	5	41.67
Subtotal	**3**	**3**	**2**	**4**	**2**	**1**	**-**	**3**	**2**	**1**	**2**	**4**		
Cryptophyceae														
Cryptomonas erosa				1						1	1		3	25.00
Cryptomonas ovata			1				1						2	16.67
Cryptomonas marssonii				1									1	8.33
Cryptomonas sp.		1							1	1	1		4	33.33
Subtotal	**-**	**1**	**1**	**2**	**-**	**-**	**1**	**-**	**1**	**2**	**2**	**-**		

Taxonomic Groups	Itaquatiara			Gameleira				Várzea		São Domin-gos	Piauí		Frequency	Relative Frequency (%)
	P1	P2	P 9	P6	P10	P11	P12	P4	P5	P7	P8A	P8B		
Cyanophyceae														
Dinophyceae														
Peridinium sp.											1		1	8.33
Gymnodinium sp.										1			1	8.33
Subtotal	-	-	-	-	-	-	-	-	-	1	1	-		
Total	8	20	8	16	7	8	5	6	9	11	28	20		

Data Table 5.2-62 – Spatial distribution and frequency of occurrence of phytoplankton, in May 2008.

Taxonomic Groups	Itaquatiara	Gameleira	Várzea				São Domingos	Piauí		Frequency	Relative Frequency (%)
	P1	P13	P4	P5	P15	P16	P7	P8A	P8B		
Cyanophyceae											
Aphanocapsa delicatissima										3	33.33
Aphanocapsa elachista										1	11.11
Aphanocapsa incerta										4	44.44
Aphanocapsa sp.1										3	33.33
Aphanothece sp.										1	11.11
Chroococcus limneticus										3	33.33
Chroococcus minutus										5	55.56
Cyanodictyon sp.										1	11.11
Cylindrospermopsis raciborskii										2	22.22
Geitlerinema unigranulatum										3	33.33
Merismopedia duplex										1	11.11

Taxonomic Groups	Itaquatiara	Gameleira	Várzea				São Domingos	Piauí		Frequency	Relative Frequency (%)
	P1	P13	P4	P5	P15	P16	P7	P8A	P8B		
Merismopedia elegans										1	11.11
Merismopedia glauca										1	11.11
Merismopedia punctata										2	22.22
Merismopedia tenuissima										3	33.33
Microcystis aeruginosa										2	22.22
Phormidium sp.										1	11.11
Planktolynbya sp.										4	44.44
Planktothrix sp.										2	22.22
Pseudanabaena catenata										2	22.22
Pseudanabaena galeata										4	44.44
Pseudanabaenaceae										1	11.11
Sphaerocavum cf. brasiliensis										1	11.11

Taxonomic Groups	Itaquatiara	Gameleira	Várzea				São Domingos	Piauí		Frequency	Relative Frequency (%)
	P1	P13	P4	P5	P15	P16	P7	P8A	P8B		
Synechococcus nidulans										8	88.89
Synechocystis aquatilis										5	55.56
Subtotal	3	7	8	3	4	3	1	17	18		
Chlorophyceae											
Actinastrum aciculare										1	11.11
Ankyra ancora										3	33.33
Botryococcus sp.										1	11.11
Chlamydomonas planctogloea										5	55.56
Chlorella minutissima										7	77.78
Chlorella vulgaris										8	88.89
Chlorococcum sp.										1	11.11
Choricystis sp.										1	11.11
Coelastrum astroideum										1	11.11

Taxonomic Groups	Itaquatiara	Gameleira	Várzea				São Domingos	Piauí		Frequency	Relative Frequency (%)
	P1	P13	P4	P5	P15	P16	P7	P8A	P8B		
Coelastrum microporum										2	22.22
Coelastrum pulchrum										1	11.11
Coelastrum sphaerium										1	11.11
Coenochloris sp.										2	22.22
Crucigeniella crucifera										2	22.22
Crucigeniella rectangularis										3	33.33
Dictyosphaerium ehrenbergianum										3	33.33
Dictyosphaerium pulchellum										1	11.11
Didymocystis fina										3	33.33
Elakatothrix gelatinosa										2	22.22
Eutetramorus fottii										3	33.33
Golenkinea radiata										1	11.11

Taxonomic Groups	Itaquatiara	Gameleira	Várzea				São Domingos	Piauí		Frequency	Relative Frequency (%)
	P1	P13	P4	P5	P15	P16	P7	P8A	P8B		
Kirchneriella cornuta										2	22.22
Micractinium pusillum										1	11.11
Monoraphidium arcuatum										2	22.22
Monoraphidium circinale										6	66.67
Monoraphidium contortum										8	88.89
Monoraphidium griffithii										3	33.33
Monoraphidium minutum										5	55.56
Monoraphidium tortille										8	88.89
Oocystis borgei										2	22.22
Oocystis lacustris										3	33.33
Scenedesmus acuminatus										1	11.11
Scenedesmus acutus										2	22.22

Taxonomic Groups	Itaquatiara	Gameleira	Várzea				São Domingos	Piauí		Frequency	Relative Frequency (%)
	P1	P13	P4	P5	P15	P16	P7	P8A	P8B		
Scenedesmus bicaudatus										1	11.11
Scenedesmus bijugus										2	22.22
Scenedesmus denticulatus										1	11.11
Scenedesmus ecornis										1	11.11
Scenedesmus ellipticus										1	11.11
Scenedesmus ovalternus										2	22.22
Scenedesmus quadricauda										2	22.22
Schroederia indica										2	22.22
Tetraedron incus										2	22.22
Tetraedron sp.										1	11.11
Tetraedron minimum										1	11.11
Tetrastrum komarekii										1	11.11
Subtotal	20	13	13	9	14	11	3	10	19		

Taxonomic Groups	Itaquatiara	Gameleira	Várzea				São Domingos	Piauí		Frequency	Relative Frequency (%)
	P1	P13	P4	P5	P15	P16	P7	P8A	P8B		
Zygnemaphyceae											
Closterium gracile										5	55.56
Cosmarium cf. phaseolus										1	11.11
Cosmarium majae										1	11.11
Euastrum binale										1	11.11
Staurastrum tetracerum										2	22.22
Subtotal	-	1	-	-	1	2	-	3	3		
Euglenophyceae											
Euglena acus										2	22.22
Euglena sp1.										1	11.11
Euglena sp2.										1	11.11
Lepocinclis ovum										1	11.11
Phacus agilis										1	11.11
Phacus curvicauda										1	11.11

Taxonomic Groups	Itaquatiara	Gameleira	Várzea				São Domingos	Piauí		Frequency	Relative Frequency (%)
	P1	P13	P4	P5	P15	P16	P7	P8A	P8B		
Phacus pleuronectes										1	11.11
Strombomonas spp.										1	11.11
Trachelomonas abrupta										2	22.22
Trachelomonas cf. hispida										1	11.11
Trachelomonas curta										2	22.22
Trachelomonas sp.										2	22.22
Trachelomonas volvocinopsis										3	33.33
Subtotal	3	1	6	1	2	4	-	1	1		
Bacillariophyceae											
Achnanthidium minutissimum										2	22.22
Amphora sp.										3	33.33
Cyclotella cf.meneghiniana										7	77.78
Discostella stelligera										4	44.44

Taxonomic Groups	Itaquatiara	Gameleira	Várzea				São Domingos	Piauí		Frequency	Relative Frequency (%)
	P1	P13	P4	P5	P15	P16	P7	P8A	P8B		
Fallacia cf. pygmaea										2	22.22
Fragillaria sp.										2	22.22
Gomphonema sp.										2	22.22
Navicula sp.										1	11.11
Nitzschia palea										4	44.44
Nitzschia sp.										1	11.11
Pennales										3	33.33
Pinnularia cf. subcapitata										1	11.11
Pinnularia sp.1										3	33.33
Pinnularia sp.2										2	22.22
Urosolenia longiseta										1	11.11
Subtotal	3	3	7	8	1	5	-	2	9		
Cryptophyceae											

Taxonomic Groups	Itaquatiara	Gameleira	Várzea				São Domingos	Piauí		Frequency	Relative Frequency (%)
	P1	P13	P4	P5	P15	P16	P7	P8A	P8B		
Cryptomonas brasiliensis										6	66.67
Cryptomonas erosa										6	66.67
Cryptomonas marssonii										5	55.56
Cryptomonas ovata										3	33.33
Cryptomonas tenuis										3	33.33
Rhodomonas lacustris										4	44.44
Subtotal	3	4	5	2	3	2	2	2	4		
Chrysophyceae											
Chromulina elegans										1	11.11
Dinobryon sp.										2	22.22
Mallomonas cf. apochromatica										1	11.11
Mallomonas sp.1										5	55.56
Ochromonas danica										3	33.33

Taxonomic Groups	Itaquatiara	Gameleira	Várzea				São Domingos	Piauí		Frequency	Relative Frequency (%)
	P1	P13	P4	P5	P15	P16	P7	P8A	P8B		
Ochromonas ovalis										1	11.11
Ochromonas sp1.										1	11.11
Subtotal	-	2	1	-	1	2	-	5	3		
Dinophyceae											
Gymnodinium sp.										1	11.11
Peridinium sp.1										1	11.11
Peridinium sp.2										2	22.22
Subtotal	-	-	-	-	-	-	-	1	3		
Xanthophyceae											
Goniochloris mutica										4	44.44
Isthimochlorum lobulatum										1	11.11
Tetraplektron torsun										3	33.33
Subtotal	-	1	-	-	2	2	-	2	1		
Total	32	32	40	23	28	31	6	43	61		

At the beginning of the rains (first campaign), *Chlorella vulgaris* and *Monoraphidium arcuatum* were more common, while in the following campaign (March/08), the cyanophytes *Synechococcus nidulans* and *Synechocystis aquatilis* were widely distributed. Among the most frequent taxa in the third week, the cyanophyte *Synechococcus nidulans* and the chlorophytes *Chlorella vulgaris*, *Monoraphidium contortum* and *Monoraphidium tortille* stand out, being recorded in more than 88% of the analyzed samples.

Among the cyanophytes, *Cylindrospermopsis raciborskii* and *Synechocystis aquatilis* stood out in the three sampling campaigns, mainly at the points located in the Jenipapo dam (8A and 8B). As mentioned, these algae are considered potentially toxic and can produce, in the case of blooms, compounds harmful to human and animal health (CARMICHAEL, 1994).

- Quantitative Analysis

The results of the quantitative evaluation of phytoplankton in all campaigns are presented below, indicating the Numerical Density and Relative Abundance, expressed in organisms per milliliter (org / mL) and percentage (%), respectively.

Phytoplankton biomass and the composition of phytoplankton species depend on the interrelationships of physical factors, such as temperature and circulation; chemical factors, such as concentration of nutrients and relative distribution of the different ions dissolved in the water; and biological factors, such as species interaction, effects of predation and parasitism (TUNDISI & TUNDISI, 2008). Such aspects influence the productivity of phytoplankton organisms, with a reflection on the composition and abundance of zooplankton and benthic beings.

In the sampling network of the Piauí Nickel Project, the phytoplankton densities were quite variable between the sampling points and campaigns. The results ranged between 153.30 org./mL at Point 12 (second campaign) and 177,777.78 org / mL at Point 09 (first campaign).

The greatest result observed in the sample collected at Point 09 (Itaquatiara Creek) in the first campaign was associated with the intense flowering of chlorophytes (*Lagerheimia ciliata* and *Chlorella vulgaris*) and cyanobacteria (*Chroococcus minutus*). It is important to consider, however, that in the following campaign (March / 08), the density of phytoplankton at that point dropped to 907 org / mL, probably due to the effect of water dilution and the increase in turbidity due to the rains.

Point 8A (Jenipapo Dam) also showed higher densities, ranging from 12,683.44 org / mL (third campaign) to 36,130 org / mL (second campaign), at the height of the rains, mainly due to the development of the cyanobacterium *Cylindrospermopsis raciborskii*. This species also proliferated at Point 8B, downstream of the dam, mainly in the third campaign, accounting for 4,972.48 org / mL, that is, about 30% of the total algae detected at that point (16,784.59 org / mL).

Among the components of the phytoplankton community, cyanophytes or cyanobacteria are the least desirable, as they can cause blooms that hinder the development of other planktonic groups, causing imbalance in the environment and may have potential for the production of toxins. According to Carmichael (1994), the two main groups of cyanotoxins are neurotoxins and hepatotoxins. Neurotoxins are characterized by their rapid action, and in the most severe cases may cause respiratory arrest. The most common type of poisoning involving cyanobacteria is caused by hepatotoxins, which have a slower action and may develop intrahepatic hemorrhage and hypovolemic shock. These toxins are not removed by the usual treatment of domestic water supply, which must undergo specific procedures to meet quality standards.

Cylindrospermopsis raciborskii, which stood out in the Jenipapo reservoir and at the point downstream of the dam, has the characteristic of dominating the phytoplankton community, forming large blooms, especially during periods of high temperatures and strong sunlight. The success of *C. raciborskii* can be explained by its ability to fix atmospheric nitrogen and the presence of aerotopes that allow it to migrate to places with greater luminosity or with a higher level of nutrients and, also, by its unpalatability to herbivory. Phosphorus is a limiting factor for its growth, since the algae readily absorbs this element and more slowly the ammonium (LINDMARK, 1997 *apud* CASTELO BRANCO, 1991).

Data Table 5.2-63 – Numerical density of the phytoplankton community (org / mL).

Taxonomic Group	Itaquatiara							Gameleira								Várzea				
	P1			P2	P3	P 9		P6	P10	P11	P12	P13	P4			P5			P15	P16
	1ª	2ª	3ª	2ª	1ª	1ª	2ª	2ª	2ª	2ª	2ª	3ª	1ª	2ª	3ª	1ª	2ª	3ª	3ª	3ª
Cyanophyceae	605.16	71.47	5,031.45	115.52	-	33,662.06	529.15	552.91	175.52	1,958.67	70.75	943.40	57.86	-	1,650.94	668.61	293.50	96.26	924.90	87.35
Chlorophyceae	268.96	57.18	3,231.40	205.37	130.25	120,973.04	287.25	718.78	263.27	215.63	58.96	3,241.41	139.38	1,273.99	995.81	378.88	125.79	494.16	11,968.18	7,494.76
Zygnemaphyceae	-	-	-	-	-	4,207.76	-	-	-	-	-	-	-	-	-	-	-	-	647.43	-
Euglenophyceae	14.94	14.29	10.84	166.86	6.20	2,103.88	-	663.49	-	-	-	24.19	-	-	995.81	89.15	20.96	6.42	-	34.94
Bacillariophyceae	37.36	243.00	531.34	243.87	-	12,623.27	60.47	497.62	131.64	35.94	-	120.95	107.82	129.01	1,611.64	2,496.13	125.79	500.58	37.00	69.88
Cryptophyceae	-	-	97.59	12.84	6.20	2,103.88	30.24	552.91	-	-	23.58	362.84	18.41	-	340.67	44.57	20.96	32.09	758.42	331.94
Chrysophyceae	74.71	-	-	-	12.40	-	-	-	-	-	-	145.14	142.01	-	117.92	-	-	-	-	-
Dinophyceae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Xanthophyceae	-	-	-	-	-	2,103.88	-	-	-	-	-	-	-	-	-	-	-	-	-	34.94
Total	**1,001.14**	**385.93**	**8,902.62**	**744.45**	**155.06**	**177,777.78**	**907.11**	**2,985.69**	**570.43**	**2,210.24**	**153.30**	**4,837.93**	**465.48**	**1,403.00**	**5,712.79**	**3,677.33**	**587.00**	**1,129.51**	**14,335.92**	**8,053.81**

(continuation)

Taxonomic Groups	São Domingos			Piauí					
	P7			P8A			P8B		
	1ª	2ª	3ª	1ª	2ª	3ª	1ª	2ª	3ª
Cyanophyceae	1,005.53	353.77	818.12	12,946.95	13,616.35	9,044.62	1,352.49	763.70	12,873.43
Chlorophyceae	1,005.53	589.62	920.39	1,078.91	10,503.14	2,949.99	150.28	209.64	2,456.76
Zygnemaphyceae	-	-	-	67.43	62.89	29.95	-	14.97	39.31
Euglenophyceae	116.02	-	-	168.58	62.89	14.97	75.14	14.97	-
Bacillariophyceae	154.70	400.94	-	7,518.67	11,320.75	344.41	65.75	509.13	1,218.55
Cryptophyceae	-	94.34	153.40	-	534.59	59.90	9.39	-	117.92
Chrysophyceae	4,756.93	-	-	505.74	-	149.75	75.14	-	58.96
Dinophyceae	-	23.58	-	-	31.45	44.92	-	-	-
Xanthophyceae	-	-	-	168.58	-	44.92	9.39	-	19.65
Total	**7,038.71**	**1,462.26**	**1,891.91**	**22,454.86**	**36,132.08**	**12,683.44**	**1,737.58**	**1,512.43**	**16,784.59**

Figure 5.2-7 – Numerical density of the phytoplankton community (org / mL).

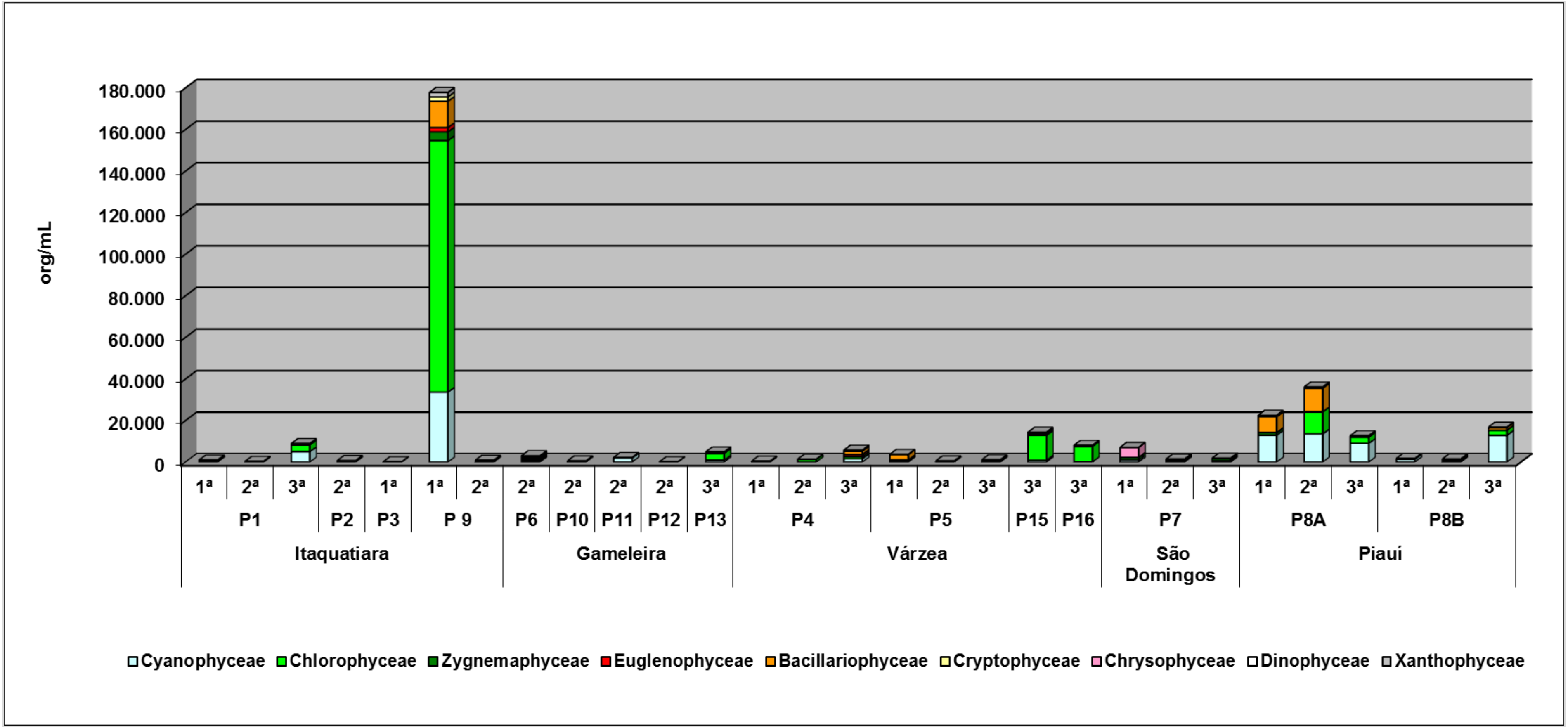
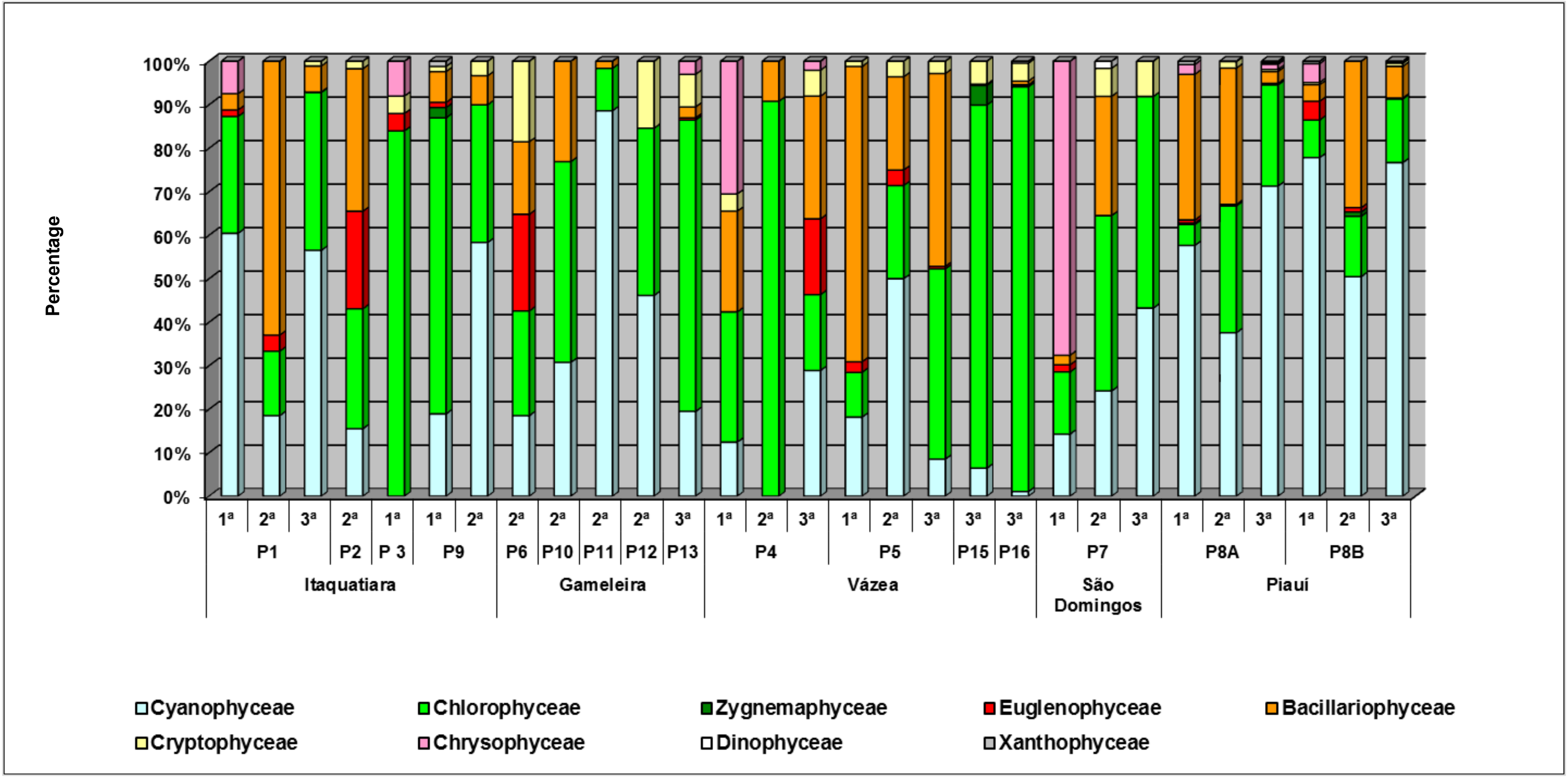


Figure 5.2-8 – Relative Abundance of the Phytoplankton Community (%).



The graph above shows that the phytoplankton community in terms of density was composed mainly of representatives of the Classs Cyanophyceae, Chlorophyceae and Bacillariophyceae, although in the first campaign carried out at Point 07 (São Domingos stream - Eugênio weir), the Chrysophyceae class stood out in the presence of the species Chromulina elegans.

The three predominant groups (Cyanophyceae, Chlorophyceae and Bacillariophyceae) have adaptive strategies that favor their development in aquatic environments. Chlorophyceas, in addition to being benefited in shallow water bodies (MARGALEF, 1983), have the capacity to develop in environments with a broad spectrum of salinity and eutrophication (BRANCO, 1986). Cyanophytes are organisms adapted to impact environments and with high concentrations of nutrients, such as those sampled. The bacilliofíceas present silica carapace that confers resistance to physical injuries caused by the turbulence of the water and fixing structures that favor its fixation to the substrate (SILVA, 2009 apud BASTOS, 2010).

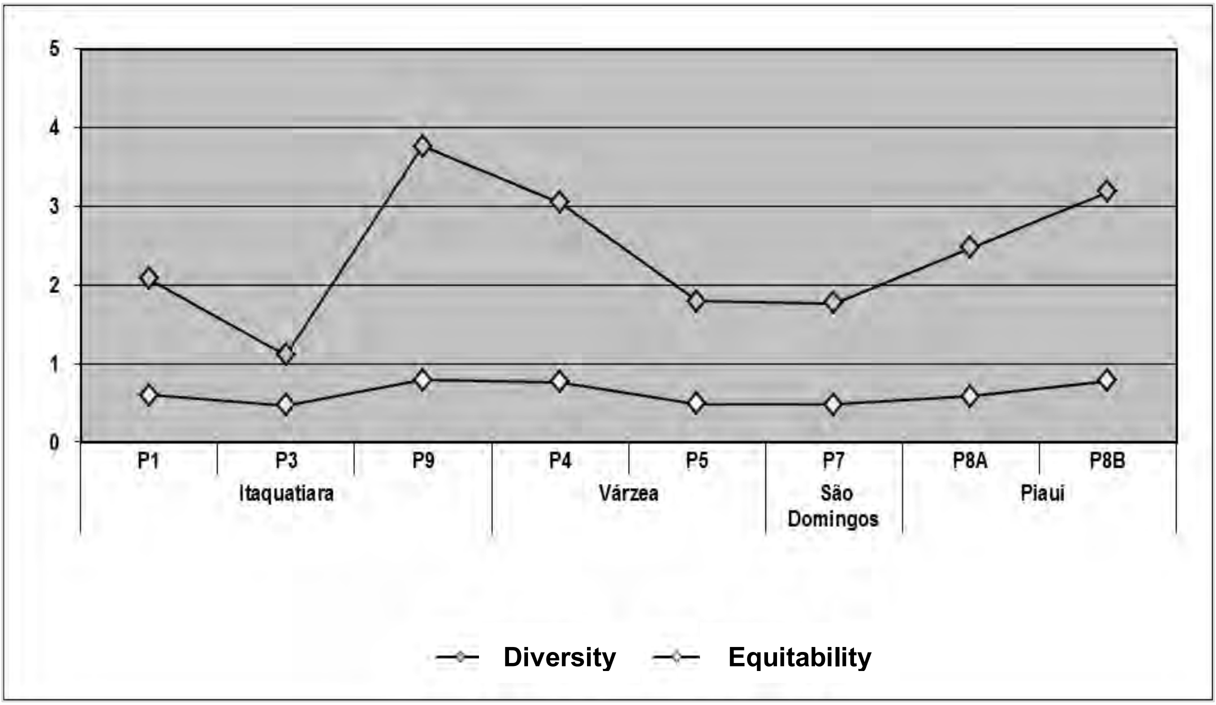
To assess phytoplankton diversity at the different collection points, the Shannon-Wiener index (H ') described above was adopted.

Normally, balanced environments provide the maintenance of a great richness of species, associated with a small number of individuals of each species. In contrast, water courses that suffer anthropic interference tend to eliminate the most sensitive organisms, selecting the most resistant communities that, in turn, start to proliferate in greater quantity. The ecological concept of species richness derives from this property (Branco, 1986).

The application of the Richness Index, the results of which are presented in the graphs below, showed values between 1.11 (first campaign) in Point 03 and 3.91 (second campaign) in Point 04, indicating that the environments sampled in the Piauí Nickel Project present moderately altered environments with indications of probable anthropic interference, which can also be influenced by the natural characteristics of the sampled stretches.

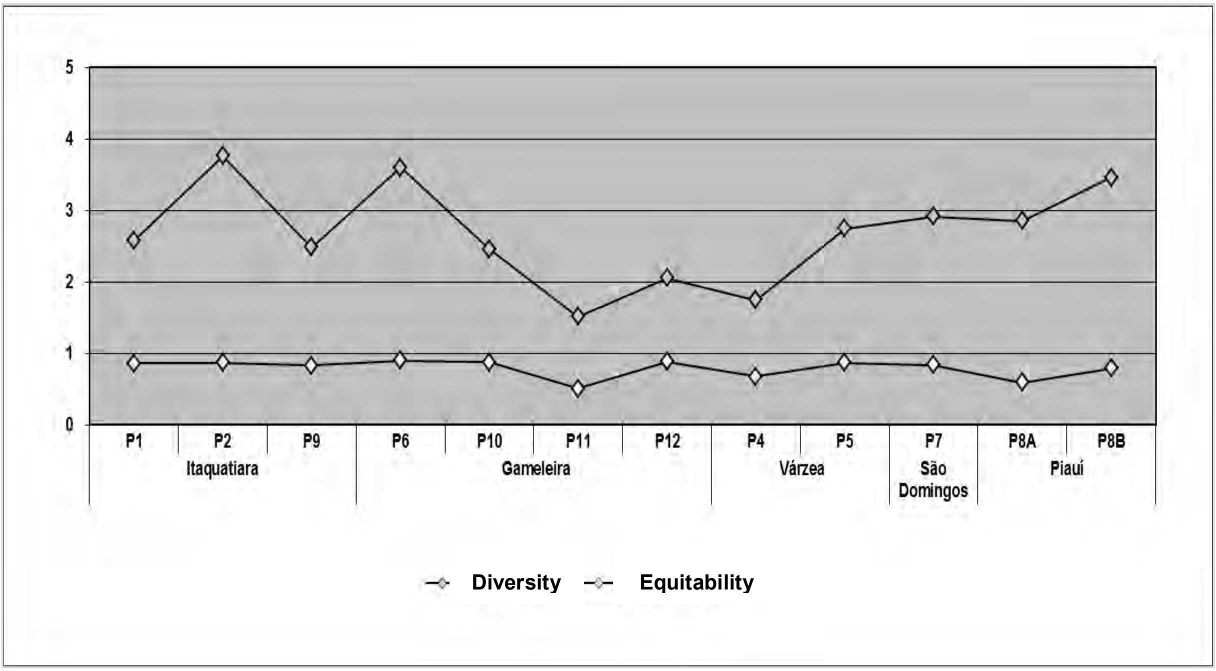
The greater richness of the community was verified in the third campaign, a period in which the communities were better established. The equitability results, also shown in the graphs below, showed greater homogeneity of phytoplankton in the second sampling campaign, with values, in general, greater than 0.8.

Figure 5.2-9 – Phytoplankton Community Richness and Equitability Index - 1st campaign.



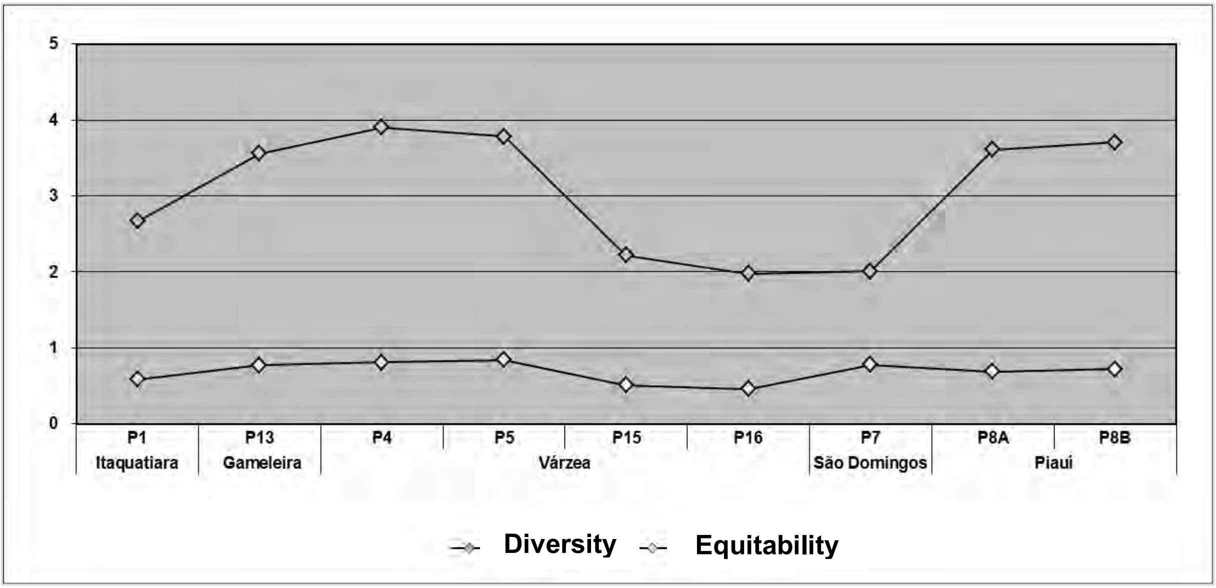
Source: ARCADIS Tetraplan, 2008.

Figure 5.2-10 – Phytoplankton Community Richness and Equitability Index - 2nd campaign.



Source: ARCADIS Tetraplan, 2008.

Figure 5.2-11 – Phytoplankton Community Richness and Equitability Index - 3rd campaign.



Sourcee: ARCADIS Tetraplan, 2008.

Specifically, on cyanobacteria, as previously mentioned, some species have the potential to produce toxins. The legal instruments dealing with these organisms are relatively recent and aim to monitor cyanobacteria and cyanotoxins in waters intended for human consumption, as well as the protection of aquatic communities and the recreation of primary contact.

Ministry of Health Portaria No. 2914 of 2011 establishes procedures and responsibilities related to the control and surveillance of the quality of water for human consumption and its potability standard, defining, in the case of treatment by filtration of water supplied by surface water and distributed through canalization, the mandatory monitoring cyanobacteria and cyanotoxins.

CONAMA Resolution No. 357, of 03/17/05, determines for class 1 waters the maximum density of cyanobacteria equivalent to 20,000 cells / mL. For class 2 waters, the density of cyanobacteria changes to 50,000 cells / mL. For class 3 waters, the cyanobacteria values in water for animal drinking should also not exceed 50,000 cells / mL.

This aspect assumes importance in the entire water network that drains the area of influence of the project, as the scarcity of water induces the use of small dams and water reservoirs, in which the eutrophication process leads to the occurrence of these organisms, which may affect not only health of people, but interfere in the development of animals that use these sources for watering.

In the period under study, the lowest densities of cyanophytes were registered in the February campaign and the highest in May 2008, as shown in the following tables.

Data Table 5.2-64 – Densities of cyanobacteria in February 2008 (cell / mL).

Taxonomic Groups	Itaquatiara			Várzea		São Domingos	Piauí	
	P1	P3	P9	P4	P5	P7	P8A	P8B
Cyanophyceae								
Anabaena sp.	-	-	-	-	-	1,701.67	-	-
Aphanocapsa sp.	-	-	515,450.36	-	-	-	-	-
Chroococcus minutus	-	-	88,362.92	-	-	-	-	-
Coelosphaerium sp.	-	-	-	-	-	-	21,713.11	-
Cylindrospermopsis raciborskii	-	-	-	-	-	-	270,537.26	2,554.71
Leptolynbya sp.	-	-	-	-	-	-	166,186.21	4,480.14
Merismopedia glauca	-	-	88,362.92	-	-	-	6,608.34	525.97
Merismopedia tenuissima	-	-	33,662.06	-	-	-	5,934.02	3,756.93
Microcystis sp.	-	-	247,205.79	-	-	-	-	57,387.06
Pseudanabaena galeata	-	-	-	15.78	-	-	4,855.11	-

Taxonomic Groups	Itaquatiara			Várzea		São Domingos	Piauí	
	P1	P3	P9	P4	P5	P7	P8A	P8B
Synechococcus nidulans	575.28	-	-	-	111.43	-	-	140.88
Synechococcus sp.	-	-	-	55.23	-	966.86	370.88	-
Synechocystis aquatilis	59.77	-	-	-	1,114.34	-	-	1,108.29
Subtotal	**635.05**	**-**	**973,044.05**	**71.01**	**1,225.78**	**2,668.52**	**476,204.93**	**69,953.98**

Source: ARCADIS Tetraplan, 2008.

Data Table 5.2-65 – Cyanobacteria densities in March 2008 (cell / mL).

Taxonomic Groups	Itaquatiara			Gameleira				Várzea		São Domingos	Piauí	
	P1	P2	P9	P6	P10	P11	P12	P4	P5	P7	P8A	P8B
Cyanophyceae												
Anabaena sp.	1,257.86	-	-	-	-	-	-	-	-	-	6,918.24	-
Aphanocapsa sp.1	-	5,031.45	7,408.08	-	-	-	-	-	-	-	-	1,467.51

Taxonomic Groups	Itaquatiara			Gameleira				Várzea		São Domingos	Piauí	
	P1	P2	P9	P6	P10	P11	P12	P4	P5	P7	P8A	P8B
Aphanothece sp.	-	-	18,867.92	-	-	-	-	-	-	-	4,905.66	-
Chroococcus minutus	-	-	181.42	-	-	-	-	-	-	-	880.50	119.80
Chroococcus sp.1	-	-	-	-	-	-	-	-	-	-	125.79	-
Chroococcus sp.2	-	-	-	-	-	-	-	-	-	-	3,144.65	-
Cylindrospermopsis raciborskii	-	-	-	-	-	-	-	-	-	801.89	314,339.62	509.13
Geitlerinema unigranulatum	-	-	-	-	-	-	-	-	-	-	36,792.45	-
Merismopedia glauca	-	-	-	-	-	-	-	-	-	-	-	838.57
Merismopedia punctata	-	-	-	-	-	-	-	-	-	-	31,194.97	5,750.22
Merismopedia tenuissima	-	-	2,660.86	-	-	-	-	-	-	-	-	1,916.74
Oscillatoria sp.	3,216.12	2,887.95	-	-	-	-	-	-	-	-	-	-
Planktolynbya sp.	1,600.91	718.78	-	-	-	1,006.29	-	-	-	-	28,176.10	4,192.87

Taxonomic Groups	Itaquatiara			Gameleira				Várzea		São Domingos	Piauí	
	P1	P2	P9	P6	P10	P11	P12	P4	P5	P7	P8A	P8B
Pseudanabaena catenata	-	-	-	-	-	-	-	-	-	-	14,937.11	-
Pseudanabaenaceae	-	962.65	-	-	548.49	-	-	-	-	-	-	-
Synechococcus nidulans	-	-	-	110.58	21.94	1,473.50	-	-	146.75	94.34	157.23	14.97
Synechococcus sp.	-	-	-	55.29	-	-	-	-	-	-	-	-
Synechocystis aquatilis	-	-	-	774.07	263.27	934.41	141.51	-	293.50	471.70	377.36	569.03
Loossen cells of *Microcystis*	-	-	-	-	-	-	-	-	-	-	94.34	-
Subtotal	**6,074.90**	**9,600.82**	**29,118.29**	**939.94**	**833.70**	**3,414.20**	**141.51**	**-**	**440.25**	**1,367.92**	**442,044.03**	**15,378.86**

Source: ARCADIS Tetraplan, 2008.

Data Table 5.2-66 – Densities of cyanobacteria in May 2008 (cell / mL).

Taxonomic Groups	Itaquatiara	Gameleira	Várzea				São Domingos	Piauí	
	P1	P13	P4	P5	P15	P16	P7	P8A	P8B
Cyanophyceae									
Aphanocapsa delicatissima	-	-	30,503.14	-	62,800.59	-	-	-	-
Aphanocapsa elachista	-	-	-	-	21,365.15	-	-	-	-
Aphanocapsa incerta	-	-	-	-	1,812.80	-	-	86,582.81	57,783.02
Aphanocapsa sp.1	-	39,114.66	-	-	-	-	-	1,467.51	15,408.81
Aphanothece sp.	-	-	-	-	-	-	-	9,344.12	-
Chroococcus limneticus	-	-	-	-	-	17.47	-	29.95	98.27
Chroococcus minutus	-	-	1,205.45	51.34	-	-	3.272.49	59.90	1,179.25
Cyanodictyon sp.	-	-	-	-	-	-	-	1,078.17	-
Cylindrospermopsis raciborskii	-	-	-	-	-	-	-	113,536.99	169,064.47

Taxonomic Groups	Itaquatiara	Gameleira	Várzea				São Domingos	Piauí	
	P1	P13	P4	P5	P15	P16	P7	P8A	P8B
Geitlerinema unigranulata	-	-	-	-	-	-	-	9,733.45	15,330.19
Merismopedia duplex	-	-	-	-	-	-	-	-	1,886.79
Merismopedia glauca	-	338.66	-	-	-	-	-	-	-
Merismopedia punctata	-	-	-	-	-	-	-	6,229.41	20,125.79
Merismopedia tenuissima	-	-	-	-	-	-	-	718.78	2,515.72
Microcystis aeruginosa	-	-	-	-	-	-	-	3,519.02	50,805.82
Planktolynbya sp.	-	-	-	1,078.17	-	978.34	-	25,995.81	28,616.35
Planktothrix sp.	-	-	-	-	-	-	-	-	7,547.17
Pseudanabaena catenata	-	-	-	-	-	-	-	29,200.36	40,290.88
Pseudanabaena galeata	-	-	78.62	-	-	-	-	7,906.56	12,264.15
Sphaerocavum cf. brasiliensis	-	-	-	-	-	-	-	-	9,237.42

Taxonomic Groups	Itaquatiara	Gameleira	Várzea				São Domingos	Piauí	
	P1	P13	P4	P5	P15	P16	P7	P8A	P8B
Synechococcus nidulans	650.62	60.47	497.90	64.18	55.49	52.41	-	539.08	412.74
Synechocystis aquatilis	8,761.66	943.40	1,048.22	-	-	-	-	1,227.91	1,375.79
Subtotal	**9,412.27**	**40,457.18**	**33,333.33**	**1,193.69**	**86,034.04**	**1,048.22**	**3,272.49**	**297,169.81**	**433,942.61**

Sourcee: ARCADIS Tetraplan, 2008.

Note that the limit of 50,000 cyanobacteria cells / mL established by CONAMA Resolution No. 357/05 for class 2 waters was exceeded at Points 09 (February), 08A (February, March and May) and 08B (February and May) . The high results recorded in all campaigns at the Jenipapo dam were certainly favored by the fact that this environment is a lentic environment, where the calm waters, with greater luminosity and with a greater concentration of nutrients contribute to the development of cyanophytes.

At Point 09, located in the Itaquatiara creek, the highest densities were attributed to the genera *Aphanocapsa* and *Microcystis* and at Point 08A and 08B (Jenipapo dam and downstream), mainly to the species *Cylindrospermopsis raciborskii*. In the Jenipapo dam, species such as *Leptolynbya sp.* and *Aphanocapsa incerta*. According to Sant'anna *et al* (2008), there are records of species belonging to the genera *Aphanocapsa* and *Microcystis* and *Cylindrospermopsis raciborskii* with potential for the production of toxins. It should be noted, however, that in the same species of cyanobacteria there are toxic and non-toxic strains, which are believed to be related to genetic and / or environmental factors (NASCIMENTO, 1997). Therefore, it cannot be said that among the organisms found in the monitored waters there is a potential producer of toxins without specific tests being carried out.

As there are cacimbas destined to supply the local population in the studied region, an evaluation of their quality must be carried out, including an analysis of cyanobacteria and / or cyanotoxins, in order to meet the drinking standard for human consumption determined by the Ministry of Health Portaria nº 2914/11

Periphyton

For standardization purposes, the definition of a periphyton adopted by Esteves (2011) is considered, according to which periphyton is composed of algae, bacteria, fungi, animals, organic and inorganic debris. For the types of periphyton per colonized substrate, the concept proposed by Sládecková (1962) is adopted. However, as the group is clearly dominated by algae, this was the focus of community gathering and identification activities, based on Lowe & Laliberte (1996).

- Qualitative analysis

In the ADI and DAA of the Piauí Nickel Project, only qualitative analyzes of the peripheral community were carried out. The results obtained in the first and second campaigns are presented below.

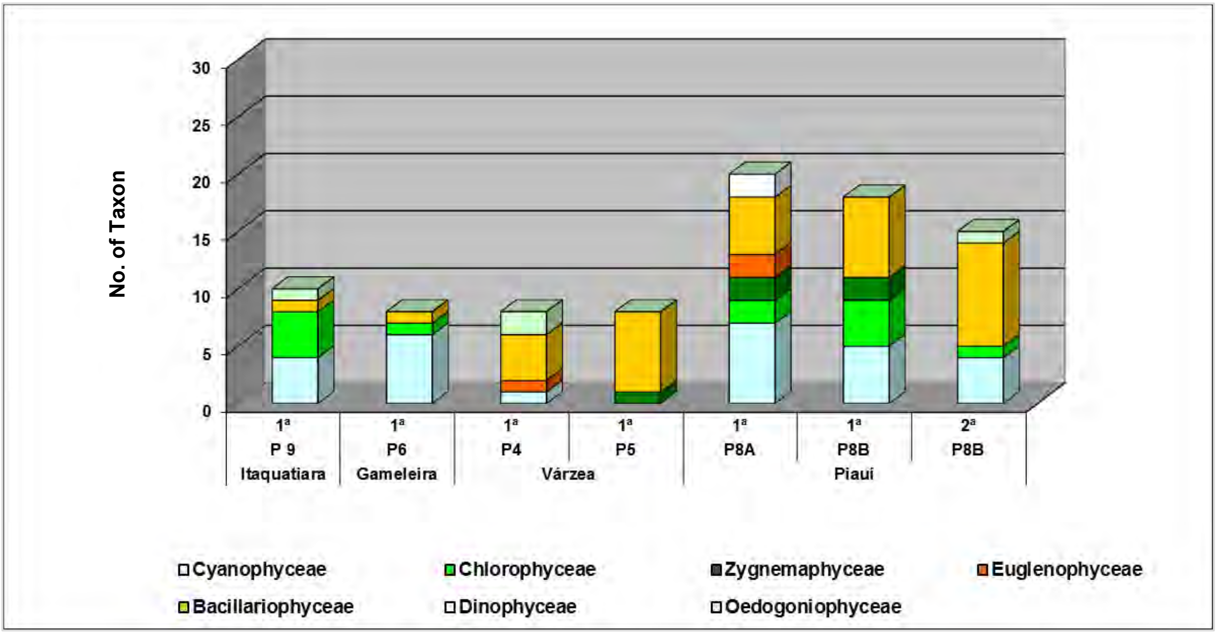
Data Table 5.2-67 – Diveristy Species of the Peripheral Community.

Taxonomic Groups	Itaquatiara	Gameleira	Várzea		Piauí			Total Richness	Relative Richness (%)
	P 9	P6	P4	P5	P8A	P8B	P8B		
	1ª	1ª	1ª	1ª	1ª	1ª	2ª		
Bacillariophyceae	1	1	4	7	5	7	9	19	32.76
Cyanophyceae	4	6	1	-	7	5	4	18	31.03
Chlorophyceae	4	1	-	-	2	4	1	10	17.24

Taxonomic Groups	Itaquatiara	Gameleira	Várzea		Piauí			Total Richness	Relative Richness (%)
	P 9	P6	P4	P5	P8A	P8B	P8B		
	1ª	1ª	1ª	1ª	1ª	1ª	2ª		
Zygnemaphyceae	-	-	-	1	2	2	-	5	8.62
Oedogoniophyceae	1	-	2	-	-	-	1	2	3.45
Euglenophyceae	-	-	1	-	2	-	-	2	3.45
Dinophyceae	-	-	-	-	2	-	-	2	3.45
Total	**10**	**8**	**8**	**8**	**20**	**18**	**15**	**58**	**100,00**

Source: ARCADIS Tetraplan, 2008.

Figure 5.2-12 – Species Richness of the Peripheral Community



Source: ARCADIS Tetraplan, 2008.

In general, the sampled environments showed low species richness, with a total of 58 Taxon belonging to seven distinct Classs: Cyanophyceae, Oedogoniophyceae, Chlorophyceae, Zygnemaphyceae, Euglenophyceae, Bacillariophyceae and Dinophyceae.

Among the groups identified, the most representative Classs in the sampling campaigns were Bacillariophyceae (19 taxons) and Cyanophyceae (18 Taxon), making up a percentage greater than 60% of the relative richness of the set of samples analyzed.

In this sense, there is a greater richness of Taxon at the points located in the Jenipapo dam, with emphasis on the upstream (8A), where 20 Taxon of peripheral algae were identified and a large contribution of cyanobacteria (7 Taxon) and diatoms (5 Taxon). At the point located downstream of the dam, diatoms were better represented, contributing 7 Taxon, followed by cyanobacteria, represented by 5 Taxon. The lowest values of specific richness were found in Points 04, 05 and 06 (8 taxon each).

Diatoms are frequently reported as the main colonizers of natural substrates such as macrophytes and sediment, even constituting the main algal group present in peripheral communities (CHAMIXAES, 1991; MOSHINI-CARLOS, 1961).

In general, diatoms were well represented in all sampled points, with the exception of Points 06 and 09. Particularly, the species of diatom *Achnantidium microcephalum* was more frequent among the points sampled in this campaign.

Data Table 5.2-68 – Spatial distribution and frequency of occurrence of the peripheral community.

Taxonomic Groups	Itaquatiara	Gameleira	Várzea		Piauí			Frequency	Relative Frequency (%)
	P9	P6	P4	P5	P8A	P8B	P8B		
	fev/08	fev/08	fev/08	fev/08	fev/08	fev/08	mar/08		
Cyanophyceae									
Anabaena sp.								2	28.57
Aphanocapsa incerta								1	14.29
Borzia periklei								2	28.57
Chroococcus minutus								2	28.57
Chroococcus sp.								1	14.29
Coelosphaerium sp.								1	14.29
Cylindrospermopsis raciborskii								1	14.29
Merismopedia sp.								1	14.29
Merismopedia tenuissima								1	14.29
Nostoc sp.								3	42.86
Oscillatoria sp.								2	28.57
Phormidium sp.								2	28.57
Planktolynbya sp.								1	14.29
Planktothrix agardhii								1	14.29

Taxonomic Groups	Itaquatiara	Gameleira	Várzea		Piauí			Frequency	Relative Frequency (%)
	P9	P6	P4	P5	P8A	P8B	P8B		
	fev/08	fev/08	fev/08	fev/08	fev/08	fev/08	mar/08		
Pseudanabaena galeata								3	42.86
Pseudanabaena moniliformes								1	14.29
Spirulina sp.								1	14.29
Synechococcus nidulans								1	14.29
Subtotal	4	6	1	-	7	5	4		
Oedogoniophyceae									
Bulbochaete sp.	1		1					2	28.57
Oedogonium sp.			1				1	2	28.57
Subtotal	**1**		**2**				**1**		
Chlorophyceae									
Chlorella vulgaris								**1**	**14.29**
Coleochaete sp.								**1**	**14.29**
Desmodesmus armatus								**1**	**14.29**
Didymocystis fina								**1**	**14.29**
Monoraphidium arcuatum								**1**	**14.29**
Oocystis lacustris								**1**	**14.29**
Rhizoclonium sp.								**1**	**14.29**
Scenedesmus ecornis								**2**	**28.57**

Taxonomic Groups	Itaquatiara	Gameleira	Várzea		Piauí			Frequency	Relative Frequency (%)
	P9	P6	P4	P5	P8A	P8B	P8B		
	fev/08	fev/08	fev/08	fev/08	fev/08	fev/08	mar/08		
Scenedesmus ovalternus								1	14.29
Scenedesmus quadricauda								2	28.57
Subtotal	4	1	-	-	2	4	1		
Zygnemaphyceae									
Cosmarium sp.1								1	14.29
Cosmarium sp.2								1	14.29
Desmidiaceae								1	14.29
Staurastrum rotula								1	14.29
Staurastrum sp.								1	14.29
Subtotal	-	-	-	1	2	2			
Euglenophyceae									
Trachelomonas armata								1	14.29
Trachelomonas volvocina								2	28.57
Subtotal	-	-	1	-	2	-			
Bacillariophyceae									
Achnantes sp.								1	14.29

Taxonomic Groups	Itaquatiara	Gameleira	Várzea		Piauí			Frequency	Relative Frequency (%)
	P9	P6	P4	P5	P8A	P8B	P8B		
	fev/08	fev/08	fev/08	fev/08	fev/08	fev/08	mar/08		
Achnanthidium blanqueanum								1	14.29
Achnanthidium microcephalum								4	57.14
Achnanthidium minutissimum								1	14.29
Achnantidium spp.								2	28.57
Cocconeis sp.								3	42.86
Cyclotella sp.								1	14.29
Discostella stelligera								1	14.29
Encyonema sp.								1	14.29
Frustulia rhomboides								1	14.29
Frustulia sp.								1	14.29
Gomphonema gracile								2	28.57
Gomphonema sp.								3	42.86
Navicula spp.								3	42.86
Nitzschia sp								1	14.29

Taxonomic Groups	Itaquatiara	Gameleira	Várzea		Piauí			Frequency	Relative Frequency (%)
	P9	P6	P4	P5	P8A	P8B	P8B		
	fev/08	fev/08	fev/08	fev/08	fev/08	fev/08	mar/08		
Nitzschia spp.								**2**	**28.57**
Pinnularia sp.								**2**	**28.57**
Sellaphora sp.								**1**	**14.29**
Synedra sp.								**3**	**42.86**
Subtotal	**1**	**1**	**4**	**7**	**5**	**7**	**9**		
Dinophyceae									
Peridinium umbonatum								**1**	**14.29**
Peridinium sp.								**1**	**14.29**
Subtotal	**-**	**-**	**-**	**-**	**2**	**-**	**-**		
Total	**10**	**8**	**8**	**8**	**20**	**18**	**15**		

Source: ARCADIS Tetraplan, 2008.

Zooplankton

- ### Qualitative analysis

The data obtained in the three campaigns carried out in February, March and May 2008 in the areas of influence of the Piauí Nickel Project, are presented below.

A total of 61 taxons were identified in the sampling network, comprising organisms belonging to the groups Rotifera, Arthropoda (Cladocera, Copepodas Cyclopoida and Calanoida, Ostracoda), Protozoa, Gastrotricha and Nematoda.

In general, the same pattern of richness is observed in the analysis of phytoplankton, with an increase in species in the third campaign (37 taxons), in relation to the samples of March / 08 (34 taxons) and February / 08 (24 taxons). Specifically, at Points 09 (Itaquatiara creek) and 04 (Várzea creek reservoir), there was also a reduction in taxa from the first to the second campaign, which can probably be attributed to the increase in current speed and increased turbidity.

When comparing the sampling points, those located on the Piauí River (8A and 8B) were responsible for the greatest species richness. In contrast, the smallest variety of species was found in the second campaign at Points 11 (3 taxons) and 07 (4 taxons) of the sampling, carried out in March / 08.

Data Table 5.2-69 – Species Richness of the Zooplankton Community (No. of Taxons).

Taxonomic Groups	Itaquatiara					Gameleira					Várzea						São Domingos			Piauí					
	P1	P2	P3	P9		P6		P10	P11	P13	P4			P5		P15	P7			P8A			P8B		
	2ª	2ª	2ª	1ª	2ª	1ª	2ª	2ª	2ª	3ª	1ª	2ª	3ª	1ª	2ª	3ª	1ª	2ª	3ª	1ª	2ª	3ª	1ª	2ª	3ª
Rotifera	3	8	2	7	4	6	4	3	1	9	7	2	3	5	2	6	4	-	-	6	10	18	5	3	17
Insecta	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-
Acari	-	-	-	1	-	-		-	-	1	-	-	-	-	-	1	-	-	-	-	-	-	-	1	1
Cladocera	4	2	1	1	1	-	2	-	-	1	-	1	-	-	-	4	-	2	2	-	-	3	-	-	-
Copepoda	1	1	1	1	1	-	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-	-	1
Cyclopoida	1	1	-	1	-	1	1	1	-	1	1	-	1	1	1	1	-	-	1	1	1	1	-	1	1
Calanoida	1	1	-	-	1	-	-	-	-	1	-	-	-	-	-	1	1	-	1	-	-	1	-	-	1
Ostracoda	-	-	1	-	-	-	1	-	-	-	-	1	-	-	-	-	-	1	-	-	1	1	1	1	1
Protozoa	-	-	-	-	-	-	-	1	-	-	1		-	-	-	-	-	-	-	-	-	-	-	-	-
Gastrotricha	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-
Nematoda	-	-	-	-	1	-	-	1	1	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-
Total	**10**	**13**	**5**	**11**	**8**	**7**	**9**	**7**	**3**	**14**	**10**	**5**	**5**	**7**	**5**	**14**	**6**	**4**	**6**	**8**	**13**	**25**	**7**	**6**	**21**

Data Table 5.2-70 – Relative Richness of the Zooplankton community (%).

Taxonomic Groups	Total Feb/08	Relative Richness Feb/08 (%)	Total Mar/08	Relative Richness Mar/08 (%)	Total May/08	Relative Richness May/08 (%)	Grand Total	General Relative Richness (%)
Rotifera	16	66.67	20	58.82	26	70.27	40	65.57
Insecta	-	-	-	-	1	2.70	1	1.64
Acari	1	4.17	1	2.94	-	-	2	3.28
Cladocera	1	4.17	7	20.59	6	16.22	10	16.39
Copepoda	1	4.17	1	2.94	1	2.70	1	1.64
Cyclopoida	1	4.17	1	2.94	1	2.70	1	1.64
Calanoida	1	4.17	1	2.94	1	2.70	1	1.64
Ostracoda	1	4.17	1	2.94	1	2.70	1	1.64
Protozoa	1	4.17	1	2.94	-	-	1	1.64
Gastrotricha	1	4.17	-	-	-	-	1	1.64
Nematoda	-	-	1	2.94	-	-	1	1.64
Total	**24**	**100.00**	**34**	**100.00**	**37**	**100.00**	**61**	**100.00**

In terms of composition, in most of the sampled water courses, there was a clear supremacy of rotifer taxa, concentrating a total of 40 taxons, that is, 65.57% of the species richness in all campaigns. The second largest group that composed the samples was that of cladocerans, making a total of 16.39% of the total relative richness.

In general, rotifers dominate the zooplankton composition both in density and in number of species due to their great capacity for adaptation in various environmental situations. They have a filtering habit and a short life cycle, which results in a high population renewal rate. This aspect represents a competitive advantage in the face of unstable conditions in the aquatic environment, as the community adapts more quickly to changes in water regimes and changes in water quality.

Particulate filtration is the predominant process of feeding rotifers. The higher occurrence of these organisms is usually related to the places where larger fractions of phytoplankton (microfitoplankton) predominate and the indirect increase of bacteria and associated detrital organic matter.

In the study area, the Brachionidae family stands out among the rotifers, which is considered typical of tropical environments (GUNTZEL *et al*, 2000; LUCINDA, 2003), and commonly observed in Brazilian aquatic environments (ROCHA *et al*, 1995; BONECKER et al, 2005). According to zooplankton frequency and spatial distribution data, the genus Brachionus was present in all samples collected in the first campaign (February / 08), but there was a reduction in its frequency in March / 08 and May / 08.

Cladocerous crustaceans were the second main taxonomic group, in terms of global species richness, presenting 10 different taxons, that is, 16.39% of the total relative richness. These organisms adapt better in oligotrophic environments, where there are no sudden changes in oxygen (better tolerated by copepods and rotifers) and phytoplankton species in an adequate size for filtration, since the selection of the particle size is generally proportional to the dimensions of the animal's body.

Copepods were, in general, quite present in the young stages of nauplii and copepodite in all sampling campaigns, with emphasis on the samples of May / 08 (100%) and March (92.31%). Cyclopoida also stood out in terms of frequency of occurrence, being present in most of the sampled points, mainly in the third campaign (100%).

The Calanoida group was present in most of the sampled points (83.33%) only in the third campaign, being uncommon in the previous months.

Other groups such as Protozoa, Insecta, Nematoda, Acari, Ostracoda and Gastrotricha were also found in the sampled environments, but with less representation.

Data Table 5.2-71 – Spatial Distribution and Frequency of Occurrence of the Zooplankton Community, in February / 2008.

Taxonomic Groups	Itaquatiara	Gameleira	Várzea		São Domingos	Piauí		Frequency	Relative Frequency (%)
	P9	P6	P4	P5	P7	P8A	P8B		
Filo ROTIFERA									
Class Monogononta									
Brachionus angularis								**4**	**57.14**
Brachionus calyciflorus								**1**	**14.29**
Brachionus caudatus								**6**	**85.71**
Brachionus dimidiatus								**1**	**14.29**
Brachionus havanaensis								**1**	**14.29**
Brachionus patulus								**1**	**14.29**
Brachionus plicatilis								**3**	**42.86**
Brachionus sp.								**7**	**100.00**
Euchlanis sp.								**1**	**14.29**
Keratella tropica								**4**	**57.14**
Keratella sp								**2**	**28.57**

Taxonomic Groups	Itaquatiara	Gameleira	Várzea		São Domingos	Piauí		Frequency	Relative Frequency (%)
	P9	P6	P4	P5	P7	P8A	P8B		
Lecane bulla								**1**	**14.29**
Lecane luna								**2**	**28.57**
Lecane sp.								**1**	**14.29**
Trichocerca elongata								**1**	**14.29**
Trichocerca sp.								**4**	**57.14**
Subtotal	**7**	**6**	**7**	**5**	**4**	**6**	**5**		
Filo ARTHROPODA									
Class Arachnida									
Order Acari									
Espécie não identificada								**1**	**14.29**
Subtotal	**1**	**-**	**-**	**-**	**-**	**-**	**-**		
Sub-Filo Crustacea									
Class Branchiopoda									
Order Cladocera									
Diaphanosoma sp.								**1**	**14.29**
Subtotal	**1**	**-**	**-**	**-**	**-**	**-**	**-**		
Class Copepoda									

Taxonomic Groups	Itaquatiara	Gameleira	Várzea		São Domingos	Piauí		Frequency	Relative Frequency (%)
	P9	P6	P4	P5	P7	P8A	P8B		
Náuplio								5	71.43
Subtotal	1	-	1	1	1	1	-		
Order Cyclopoida									
Unidentified species								6	85.71
Subtotal	1	1	1	1	1	1	-		
Order Calanoida									
Unidentified species								1	14.29
Subtotal	1	1	1	1	1	-	-		
Class Ostracoda									
Unidentified species								1	14.29
Subtotal	-	-	-	-	-	-	1		
Filo Protozoa									
Unidentified species								1	14.29
Subtotal	-	-	1	-	-	-	-		
Filo Gastrotricha									
Chaetonotus sp								1	14.29
Subtotal	-	-	-	-	-	-	1		

Taxonomic Groups	Itaquatiara	Gameleira	Várzea		São Domingos	Piauí		Frequency	Relative Frequency (%)
	P9	P6	P4	P5	P7	P8A	P8B		
Total	12	8	11	8	7	8	7		

Data Table 5.2-72 – Spatial Distribution and Frequency of Occurrence of the Zooplankton Community, in March / 2008.

Taxonomic Groups	Itaquatiara				Gameleira				Várzea		São Domingos	Piauí		Frequency	Relative Frequency (%)
	P1	P2	P3	P9	P6	P10	P11	P12	P4	P5	P7	P8A	P8B		
Filo ROTIFERA															
Class Bdelloidea															
Bdelloida Unidentified														**1**	**7.69**
Class Monogononta															
Brachionus angularis														**1**	**7.69**
Brachionus caudautus														**1**	**7.69**
Brachionus havanaensis														**1**	**7.69**
Brachionus quadribentata														**1**	**7.69**
Brachionus plicatis														**1**	**7.69**

Taxonomic Groups	Itaquatiara				Gameleira				Várzea		São Domingos	Piauí		Frequency	Relative Frequency (%)
	P1	P2	P3	P9	P6	P10	P11	P12	P4	P5	P7	P8A	P8B		
Brachionus sp.														3	23.08
Conochilus sp														2	15.38
Euchlanis sp.														1	7.69
Filinia sp														1	7.69
Keratella tropica														1	7.69
Lecane sp.														2	15.38
Trichocerca sp.														1	7.69
Trochosphaera sp														1	7.69
Philodina sp														2	15.38
Platyias patulus														1	7.69
Polyarthra sp														4	30.77
Unidentified species														9	69.23
Subtotal	3	9	2	4	4	3	1	-	1	2	-	2	3		

Taxonomic Groups	Itaquatiara				Gameleira				Várzea		São Domingos	Piauí		Frequency	Relative Frequency (%)
	P1	P2	P3	P9	P6	P10	P11	P12	P4	P5	P7	P8A	P8B		
Filo Arthropoda															
Order Acari															
Hydracarina Unidentified														**1**	**7.69**
Subtotal	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**1**		
Sub-Filo Crustacea															
Order Cladocera															
Bosminopsis dietersi														**2**	**15.38**
Leptodora sp														**1**	**7.69**
Diaphanosoma brachyrum.														**1**	**7.69**
Diaphanosoma sp.														**2**	**15.38**
Moina macrocopa														**1**	**7.69**
Moina sp														**1**	**7.69**
Unidentified species														**7**	**53.85**
Subtotal	**4**	**2**	**1**	**1**	**2**	**-**	**-**	**-**	**3**	**-**	**2**	**-**	**-**		
Class Copepoda															

Taxonomic Groups	Itaquatiara				Gameleira				Várzea		São Domingos	Piauí		Frequency	Relative Frequency (%)
	P1	P2	P3	P9	P6	P10	P11	P12	P4	P5	P7	P8A	P8B		
Náuplio/Copepodito														12	92.31
Subtotal	1	1	1	1	1	1	1	-	1	1	1	1	-		
Order Cyclopoida															
Unidentified species														8	61.54
Subtotal	1	1	-	-	1	1	-	-	1	1	-	1	1		
Order Calanoida															
Unidentified species														4	30.77
Subtotal	1	1	-	1	-	-	-	-	-	-	1	-	-		
Class Ostracoda															
Ostracoda Unidentified														6	46.15
Subtotal	-	-	1	-	1	-	-	-	1	1	-	1	1		
Filo Protozoa															
Unidentified species														1	7.69
Subtotal	-	-	-	-	-	1	-	-	-	-	-	-	-		
Filo Nematoda															
Unidentified species														4	30.77
Subtotal	-	-	-	1	-	1	1	-	-	1	-	-	-		

Taxonomic Groups	Itaquatiara				Gameleira				Várzea		São Domingos	Piauí		Frequency	Relative Frequency (%)
	P1	P2	P3	P9	P6	P10	P11	P12	P4	P5	P7	P8A	P8B		
Total	10	14	5	8	9	7	3	-	7	6	4	5	6		

Data Table 5.2-73 – Spatial Distribution and Frequency of Occurrence of the Zooplankton Community, in May / 2008.

Taxonomic Groups	Gameleira	Várzea		São Domingos	Piauí		Frequency	Relative Frequency (%)
	P13	P15	P4	P7	P8A	P8B		
Filo ROTIFERA								
Class Monogononta								
Ascomorpha sp							2	8.33
Brachionus angularis							3	12.50
Brachionus dolobratus							2	8.33
Brachionus falcatus							2	8.33
Brachionus havanaensis							2	8.33
Brachionus patulus							2	8.33

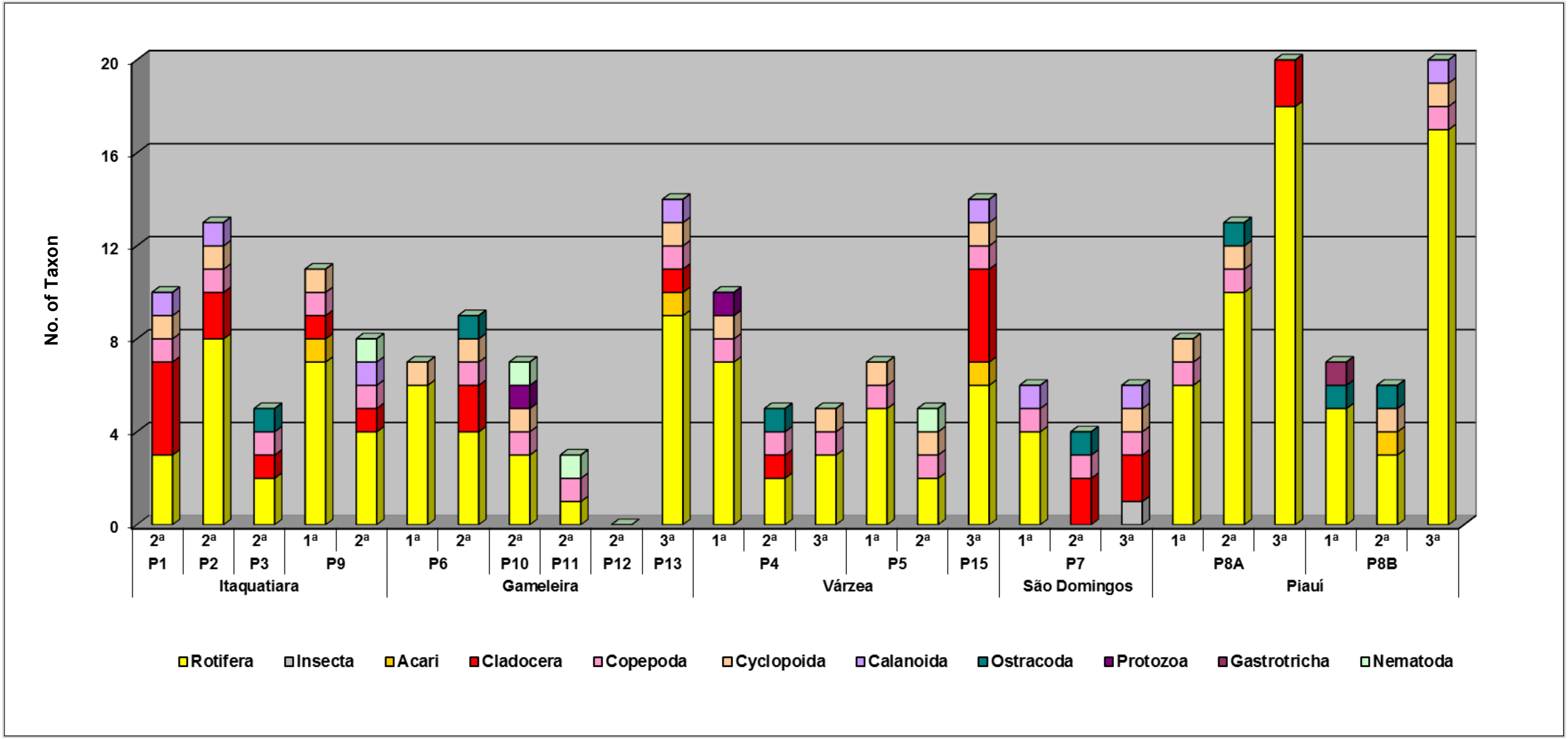
Taxonomic Groups	Gameleira	Várzea		São Domingos	Piauí		Frequency	Relative Frequency (%)
	P13	P15	P4	P7	P8A	P8B		
Brachionus sp							3	12.50
Collotheca pelagica							1	4.17
Collotheca sp							1	4.17
Conochilus coenobasis							2	8.33
Conochilus sp							2	8.33
Euchlanis sp							1	4.17
Filinia longiseta							2	8.33
Filinia opoliensis							2	8.33
Filinia pejleri							2	8.33
Filinia sp							1	4.17
Filinia terminalis							1	4.17
Hexarthra sp							1	4.17
Keratella cochlearis							2	8.33

Taxonomic Groups	Gameleira	Várzea		São Domingos	Piauí		Frequency	Relative Frequency (%)
	P13	P15	P4	P7	P8A	P8B		
Keratella sp							3	12.50
Keratella tropica							2	8.33
Lecane sp							3	12.50
Polyarthra sp							4	16.67
Rotifero Unidentified							5	20.83
Synchaeta sp							1	4.17
Testudinella sp							1	4.17
Subtotal	9	6	3	0	18	17		
Filo ARTHROPODA								
Class Insecta								
Chiromidae							1	4.17
Subtotal	-	-	-	1	-	-		
Sub-Filo Crustacea								
Order Cladocera								
Alona sp							1	4.17

Taxonomic Groups	Gameleira	Várzea		São Domingos	Piauí		Frequency	Relative Frequency (%)
	P13	P15	P4	P7	P8A	P8B		
Ceriodaphnia sp							2	8.33
Cladocera Unidentified							1	4.17
Diaphanosoma brachyrum							1	4.17
Diaphanosoma sp							2	8.33
Leptodora sp							2	8.33
Subtotal	**-**	**4**		**2**	**3**	**-**		
Class Copepoda								
Náuplio							6	25.00
Subtotal	**1**	**1**	**1**	**1**	**1**	**1**		
Order Cyclopoida								
Unidentified species							6	25.00
Subtotal	**1**	**1**	**1**	**1**	**1**	**1**		
Order Calanoida								
Unidentified species							5	20.83
Subtotal	**1**	**1**	**-**	**1**	**1**	**1**		
Class Ostracoda								

Taxonomic Groups	Gameleira	Várzea		São Domingos	Piauí		Frequency	Relative Frequency (%)
	P13	P15	P4	P7	P8A	P8B		
Ostracoda Unidentified							2	8.33
Subtotal	-	-	-	-	1	1		
Total	12	13	5	6	25	21		

Figure 5.2-13 – Species Richness of the Zooplankton Community (No. of Taxons).



- Quantitative analysis

The results of the quantitative assessment of the zooplankton community are presented below. Numerical density data and the relative abundance of the groups identified in the sample network will be presented.

The quantitative analysis of zooplankton indicated a wide variation in the total density of the organisms in the period under study, although, in general, the results have shown to be low. The variation in the density results was from 110 org / m³ in Point 8B (second campaign) to 40,480 org / m³ in Point 13 (third campaign). Point 4, a reservoir in the Várzea creek, also obtained a high density of zooplankton (30,799 org / m³) in the first campaign.

The highest densities found in Points 13 and 04 are related to the dominance of rotifers, with more than 90% relative abundance. As mentioned, rotifers are opportunistic, adapting to variations in the environment. According to Zurek *apud* Paggi (1990), many species in this group can tolerate high concentrations of suspended solids due to their efficiency in selecting, through sensitive bristles, materials that can be ingested from inorganic particles.

In addition to the rotifers, the copepoded crustaceans that became dominant in some sampling points, such as at Point 01 (second campaign) and at Point 04 (second and third campaigns) stood out among the points sampled in the three campaigns.

Data Table 5.2-74 – Numerical density (org / m³) and relative abundance (%) of the zooplankton community, in February / 08.

Taxonomic Group	Itaquatiara		Gameleira		Várzea				São Domingos		Piauí			
	P9		P6		P4		P5		P7		P8A		P8B	
	org/m³	%	org/m³	%	org/m³	%	org/m³	%	org/m³	%	org/m³	%	org/m³	%
Filo ROTIFERA														
Class Monogononta														
Brachionus angularis	320.00	10.81	250.00	13.51	8.788.00	28.53	250.00	10.20	-	-	-	-	-	-
Brachionus calyciflorus	-	-	-	-	1.500.00	4.87	-	-	-	-	-	-	-	-
Brachionus caudautus	10.00	0.34	500.00	27.03	1.647.00	5.35	300.00	12.24	-	-	40.00	6.78	20.00	11.76
Brachionus dimidiatus	-	-	-	-	2.188.00	7.10	-	-	-	-	-	-	-	-
Brachionus havanaensis	-	-	-	-	-	-	-	-	-	-	40.00	6.78	-	-
Brachionus patulus	-	-	100.00	5.41	-	-	-	-	-	-	-	-	-	-
Brachionus plicatis	40.00	1.35	-	-	1.225.00	3.98	-	-	-	-	30.00	5.08	-	-
Brachionus sp.	100.00	3.38	350.00	18.92	13.450.00	43.67	150.00	6.12	50.00	4.13	60.00	10.17	60.00	35.29
Euchlanis sp.	-	-	-	-	-	-	-	-	-	-	-	-	30.00	17.65
Keratella sp.	10.00	0.34	-	-	813.00	2.64	50.00	2.04	-	-	-	-	-	-
Keratella tropica	620.00	20.95	-	-	-	-	-	-	-	-	240.00	40.68	30.00	17.65
Lecane bulla	-	-	-	-	-	-	-	-	50.00	4.13	-	-	-	-
Lecane luna	-	-	300.00	16.22	-	-	300.00	12.24	-	-	-	-	-	-
Lecane sp.	-	-	-	-	-	-	-	-	150.00	12.40	-	-	-	-
Trichocerca elongata	-	-	-	-	-	-	-	-	50.00	4.13	-	-	-	-

Taxonomic Group	Itaquatiara		Gameleira		Várzea				São Domingos		Piauí			
	P9		P6		P4		P5		P7		P8A		P8B	
	org/m³	%	org/m³	%	org/m³	%	org/m³	%	org/m³	%	org/m³	%	org/m³	%
Trichocerca sp.	10.00	0.34	250.00	13.51	-	-	-	-	-	-	-	-	10.00	5.88
Subtotal	**1.110.00**	**37.50**	**1.750.00**	**94.59**	**29.611.00**	**96.14**	**1.050.00**	**42.86**	**300.00**	**24.79**	**410.00**	**69.49**	**150.00**	**88.24**
Filo ARTHROPODA														
Class Arachnida														
Order Acari														
Unidentified species	10.00	0.34	-	-	-	-	-	-	10.00	0.83	-	-	-	-
Subtotal	**10.00**	**0.34**	**-**	**-**	**-**	**-**	**-**	**-**	**10.00**	**0.83**	**-**	**-**	**-**	**-**
Sub-Filo Crustacea														
Order Cladocera														
Diaphanosoma sp.	20.00	0.68	-	-	-	-	-	-	-	-	-	-	-	-
Subtotal	**20.00**	**0.68**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Class Copepoda														
Náuplio	1.280.00	43.24	-	-	1.100.00	**3.57**	300.00	12.24	700.00	57.85	170.00	28.81	-	-
Copepódito	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Subtotal	**1.280.00**	**43.24**	**-**		**1.100.00**	**3.57**	**300.00**	**12.24**	**700.00**	**57.85**	**170.00**	**28.81**		
Order Cyclopoida														
Unidentified species	540.00	18.24	100.00	5.41	75.00	0.24	500.00	20.41	-	-	10.00	1.69	-	-
Subtotal	**540.00**	**18.24**	**100.00**	**5.41**	**75.00**	**0.24**	**1.100.00**	**44.90**	**-**	**-**	**10.00**	**1.69**	**-**	**-**
Order Calanoida														

Taxonomic Group	Itaquatiara		Gameleira		Várzea				São Domingos		Piauí			
	P9		P6		P4		P5		P7		P8A		P8B	
	org/m^3	%	org/m^3	%	org/m^3	%	org/m^3	%	org/m^3	%	org/m^3	%	org/m^3	%
Unidentified species	-	-	-	-	-	-	-	-	200.00	16.53	-	-	-	-
Subtotal	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**200.00**	**16.53**	**-**	**-**	**-**	**-**
Class Ostracoda														
Ostracoda Unidentified	-	-	-	-	-	-	-	-	-	-	-	-	10.00	5.88
Subtotal	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**10.00**	**5.88**
Filo Protozoa														
Unidentified species	-	-	-	-	13.00	0.04	-	-	-	-	-	-	-	-
Subtotal	**-**	**-**	**-**	**-**	**13.00**	**0.04**	**-**	**-**	**-**	**-**	**-**	**-**		**-**
Filo Gastrotricha														
Chaetonotus sp	-	-	-	-	-	-	-	-	-	-	-	-	10.00	5.88
Subtotal	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**10.00**	**5.88**
Total	**2.960.00**	**100.00**	**1.850.00**	**100.00**	**30.799.00**	**100.00**	**2.450.00**	**100.00**	**1.210.00**	**100.00**	**590.00**	**100.00**	**170.00**	**100.00**

Data Table 5.2-75 – Numerical density (org / m^3) and relative abundance (%) of the zooplankton community, in March / 08.

Taxonomic Groups	Itaquatiara								Gameleira								Várzea				São Domingos		Piauí			
	P1		P2		P3		P9		P6		P10		P11		P12		P4		P5		P7		P8A		P8B	
	org/m^3	%	org/m^3	%	org/m^3	%	org/m^3	%	org/m^3	%	org/m^3	%	org/m^3	%	org/m^3	%	org/m^3	%	org/m^3	%	org/m^3	%	org/m^3	%	org/m^3	%
Filo ROTIFERA																										
Class Bdelloidea																										
Bedelloid	-	-	-	-	-	-	-	-	20.00	1.32	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Class Monogononta																										
Brachionus angularis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	20.00	0.97	-	-	-	-	-	-	-	-
Brachionus calyciflorus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Brachionus caudautus	-	-	20.00	0.92	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Brachionus dimidiatus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Brachionus havanaensis	-	-	-	-	-	-	-	-	20.00	1.32	-	-	-	-	-	-	-	-	-	-	-	-	110.00	15.07	-	-
Brachionus quadribentata	-	-	100.00	4.59	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Brachionus patulus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Brachionus plicatis	-	-	-	-	-	-	50.00	7.69	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Brachionus sp.	-	-	140.00	6.42	50.00	6.67	50.00	7.69	-	-	-	-	-	-	-	-	-	-	-	-	-	-	30.00	4.11	-	-
Conochilus sp	-	-	580.00	26.61	-	-	-	-	-	-	20.00	5.26	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Euchlanis sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10.00	1.37	-	-
Filinia sp	-	-	100.00	4.59	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Keratella sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	40.00	5.48	-	-
Keratella Cochlearis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	60.00	8.22	-	-
Keratella tropica	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	40.00	5.48	10.00	9.09

Taxonomic Groups	Itaquatiara								Gameleira								Várzea				São Domingos		Piauí			
	P1		P2		P3		P9		P6		P10		P11		P12		P4		P5		P7		P8A		P8B	
	org/m³	%	org/m³	%	org/m³	%	org/m³	%	org/m³	%	org/m³	%	org/m³	%	org/m³	%	org/m³	%	org/m³	%	org/m³	%	org/m³	%	org/m³	%
Lecane bulla	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lecane luna	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lecane sp.	50.00	0.79	20.00	0.92	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10.00	1.37	-	-
Trichocerca elongata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Trichocerca sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	30.00	4.11	20.00	18.18
Trochosphaera sp	-	-	-	-	-	-	-	-	-	-	20.00	5.26	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Philodina sp	-	-	-	-	-	-	50.00	7.69	-	-	-	-	-	-	-	-	-	-	20.00	5.88	-	-	-	-	-	-
Platyias patulus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10.00	1.37	-	-
Polyarthra sp	50.00	0.79	240.00	11.01	-	-	-	-	40.00	2.63	20.00	5.26	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Unidentified species	50.00	0.79	40.00	1.83	150.00	20.00	50.00	7.69	20.00	1.32	-	-	40.00	18.18	-	-	-	-	40.00	11.76	-	-	10.00	1.37	50.00	45.45
Subtotal	**150.00**	**2.38**	**1,240.00**	**56.88**	**200.00**	**26.67**	**200.00**	**30.77**	**100.00**	**6.58**	**60.00**	**15.79**	**40.00**	**18.18**	**-**	**-**	**20.00**	**0.97**	**60.00**	**17.65**	**-**	**-**	**350.00**	**47.95**	**80.00**	**72.73**
Filo ARTHROPODA																										
Class Arachnida																										
Order Acari																										
Hydracarina Unidentified	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10.00	9.09
Subtotal	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**10.00**	**9.09**
Sub-Filo Crustacea																										
Order Cladocera																										
Bosminopsis dietersi	150.00	2.38	20.00	0.92	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Leptodora sp	50.00	0.79	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Diaphanosoma brachyrum.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	220.00	11.34	-	-	-	-

Taxonomic Groups	Itaquatiara								Gameleira								Várzea				São Domingos		Piauí			
	P1		P2		P3		P9		P6		P10		P11		P12		P4		P5		P7		P8A		P8B	
	org/m³	%	org/m³	%	org/m³	%	org/m³	%	org/m³	%	org/m³	%	org/m³	%	org/m³	%	org/m³	%	org/m³	%	org/m³	%	org/m³	%	org/m³	%
Diaphanosoma sp.	250.00	3.97	-	-	-	-	-	-	-	-	-	-	-	-	-	-	60.00	2.91	-	-	-	-	-	-	-	-
Moina macrocopa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	200.00	9.71	-	-	-	-	-	-	-	-
Moina sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Unidentified species	150.00	2.38	140.00	6.42	50.00	6.67	50.00	7.69	20.00	1.32	-	-	-	-	-	-	60.00	2.91	-	-	180.00	9.28	-	-	-	-
Subtotal	**600.00**	**9.52**	**160.00**	**7.34**	**50.00**	**6.67**	**50.00**	**7.69**	**20.00**	**1.32**	**-**	**-**	**-**	**-**	**-**	**-**	**320.00**	**15.53**	**-**	**-**	**400.00**	**20.62**	**-**	**-**	**-**	**-**
Class Copepoda																										
Náuplio	4.700.00	74.60	680.00	31.19	450.00	60.00	300.00	46.15	1,200.00	78.95	120.00	31.58	60.00	27.27	-	-	1.480.00	71.84	200.00	58.82	20.00	1.03	310.00	42.47	-	-
Subtotal	**4.700.00**	**74.60**	**680.00**	**31.19**	**450.00**	**60.00**	**300.00**	**46.15**	**1,200.00**	**78.95**	**120.00**	**31.58**	**60.00**	**27.27**	**-**	**-**	**1.480.00**	**71.84**	**200.00**	**58.82**	**20.00**	**1.03**	**310.00**	**42.47**	**-**	**-**
Order Cyclopoida																										
Unidentified species	700.00	11.11	80.00	3.67	-	-	-	-	100.00	6.58	20.00	5.26	-	-	-	-	220.00	10.68	20.00	5.88	-	-	60.00	8.22	10.00	9.09
Subtotal	**700.00**	**11.11**	**80.00**	**3.67**	**-**	**-**	**-**	**-**	**100.00**	**6.58**	**20.00**	**5.26**	**-**	**-**	**-**	**-**	**220.00**	**10.68**	**20.00**	**5.88**	**-**	**-**	**60.00**	**8.22**	**10.00**	**9.09**
Order Calanoida																										
Unidentified species	150.00	2.38	20.00	0.92	-	-	50.00	7.69	-	-	-	-	-	-	-	-	-	-	-	-	1.520.00	78.35	-	-	-	-
Subtotal	**150.00**	**2.38**	**20.00**	**0.92**	**-**	**-**	**50.00**	**7.69**		**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**1.520.00**	**78.35**	**-**	**-**	**-**	**-**
Class Ostracoda																										
Ostracoda Unidentified	-	-	-	-	50.00	6.67	-	-	60.00	3.95	-	-	-	-	-	-	20.00	0.97	40.00	11.76	-	-	10.00	1.37	10.00	9.09
Subtotal	**-**	**-**	**-**	**-**	**50.00**	**6.67**	**-**	**-**	**60.00**	**3.95**	**-**	**-**	**-**	**-**	**-**	**-**	**20.00**	**0.97**	**40.00**	**11.76**	**-**	**-**	**10.00**	**1.37**	**10.00**	**9.09**
Filo Protozoa																										
Unidentified species	-	-	-	-	-	-	-	-	-	-	20.00	5.26	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Taxonomic Groups	Itaquatiara								Gameleira								Várzea				São Domingos		Piauí			
	P1		P2		P3		P9		P6		P10		P11		P12		P4		P5		P7		P8A		P8B	
	org/m³	%	org/m³	%	org/m³	%	org/m³	%	org/m³	%	org/m³	%	org/m³	%	org/m³	%	org/m³	%	org/m³	%	org/m³	%	org/m³	%	org/m³	%
Subtotal	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**20.00**	**5.26**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Filo Nematoda																										
Unidentified species	-	-	-	-	-	-	50.00	7.69	-	-	160.00	42.11	120.00	54.55	-	-	-	-	20.00	5.88	-	-	-	-	-	-
Subtotal	**-**	**-**	**-**	**-**	**-**	**-**	**50.00**	**7.69**	**-**	**-**	**160.00**	**42.11**	**120.00**	**54.55**	**-**	**-**	**-**	**-**	**20.00**	**5.88**	**-**	**-**	**-**	**-**	**-**	**-**
Filo Gastrotricha																										
Chaetonotus sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Subtotal	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Total	**6,300.00**	**100.00**	**2,180.00**	**100.00**	**750.00**	**100.00**	**650.00**	**100.00**	**1,480.00**	**97.37**	**380.00**	**100.00**	**220.00**	**100.00**	**-**	**-**	**2,060.00**	**100.00**	**340.00**	**100.00**	**1,940.00**	**100.00**	**730.00**	**100.00**	**110.00**	**100.00**

Data Table 5.2-76 – Numerical density (org / m³) and relative abundance (%) of the zooplankton community, in May / 08.

Taxonomic Groups	Gameleira		Várzea				São Domingos		Piauí			
	P13		P4		P15		P7		P8A		P8B	
	org/m³	%	org/m³	%	org/m³	%	org/m³	%	org/m³	%	org/m³	%
Filo ROTIFERA												
Class Monogononta												
Ascomorpha sp	80.00	0.20	-	-	-	-	-	-	30.00	0.32		
Brachionus angularis	-	-	20.00	0.69	-	-	-	-	60.00	0.64	10.00	0.20
Brachionus dolobratus	-	-	-	-	-	-	-	-	180.00	1.92	80.00	1.61
Brachionus falcatus	-	-	-	-	-	-	-	-	210.00	2.24	150.00	3.02
Brachionus havanaensis	-	-	-	-	-	-	-	-	1,720.00	18.36	1,080.00	21.73
Brachionus patulus	-	-	-	-	-	-	-	-	110.00	1.17	30.00	0.60
Brachionus sp	40.00	0.10	-	-	-	-	-	-	80.00	0.85	150.00	3.02
Collotheca pelagica	-	-	-	-	1,070.00	22.72	-	-	-	-	-	-
Collotheca sp	33,560.00	82.91	-	-	-	-	-	-	-	-	-	-
Conochilus coenobasis	-	-	-	-	700.00	14.86	-	-	-	-	90.00	1.81
Conochilus sp	120.00	0.30	-	-	-	-	-	-	100.00	1.07	-	-
Euchlanis sp	-	-	-	-	-	-	-	-	-	-	10.00	0.20
Filinia longiseta	-	-	-	-	-	-	-	-	40.00	0.43	80.00	1.61
Filinia opoliensis	-	-	-	-	-	-	-	-	550.00	5.87	70.00	1.41

Taxonomic Groups	Gameleira		Várzea				São Domingos		Piauí			
	P13		P4		P15		P7		P8A		P8B	
	org/m³	%	org/m³	%	org/m³	%	org/m³	%	org/m³	%	org/m³	%
Filinia pejleri	-	-	-	-	-	-	-	-	40.00	0.43	90.00	1.81
Filinia sp	-	-	-	-	-	-	-	-	-	-	10.00	0.20
Filinia terminalis	-	-	-	-	-	-	-	-	70.00	0.75	-	-
Hexarthra sp	-	-	-	-	80.00	1.70	-	-	30.00	0.32	-	-
Keratella cochlearis	-	-	-	-	-	-	-	-	190.00	2.03	40.00	0.80
Keratella sp	40.00	0.10	-	-	-	-	-	-	1,490.00	15.90	410.00	8.25
Keratella tropica	-	-	-	-	-	-	-	-	290.00	3.09	390.00	7.85
Lecane sp	80.00	0.20	60.00	2.07	-	-	-	-	-	-	-	-
Polyarthra sp	2,920.00	7.21	-	-	30.00	0.64	-	-	20.00	0.21	60.00	1.21
Rotifero não identificado	800.00	1.98	40.00	1.38	70.00	1.49	-	-	150.00	1.60	30.00	0.60
Synchaeta sp	400.00	0.99	-	-	-	-	-	-	-	-	-	-
Testudinella sp	-	-	-	-	40.00	0.85	-	-	-	-	-	-
Subtotal	**38,040.00**	**93.97**	**120.00**	**4.14**	**1,990.00**	**42.25**	**-**	**-**	**5,360.00**	**57.20**	**2,780.00**	**55.94**
Filo ARTHROPODA												
Class Insecta												
Chiromidae	-	-	-	-	-	-	20.00	2.78	-	-	-	-
Subtotal	**-**	**-**	**-**	**-**	**-**	**-**	**20.00**	**2.78**	**-**	**-**	**-**	**-**
Sub-Filo Crustacea												
Order Cladocera												

Taxonomic Groups	Gameleira		Várzea				São Domingos		Piauí			
	P13		P4		P15		P7		P8A		P8B	
	org/m³	%	org/m³	%	org/m³	%	org/m³	%	org/m³	%	org/m³	%
Alona sp	-	-	-	-	10.00	0.21	-	-	-	-	-	-
Ceriodaphnia sp	-	-	-	-	50.00	1.06	-	-	10.00	0.11	-	-
Cladocera Unidentified	-	-	-	-	50.00	1.06	20.00	2.78	-	-	-	-
Diaphanosoma brachyrum	-	-	-	-	-	-	220.00	30.56	-	-	-	-
Diaphanosoma sp	-	-	-	-	20.00	0.42	-	-	10.00	0.11	-	-
Leptodora sp	-	-	-	-	-	-	-	-	70.00	0.75	-	-
Subtotal	**-**	**-**	**-**	**-**	**130.00**	**2.76**	**240.00**	**33.33**	**90.00**	**0.96**	**-**	**-**
Class Copepoda												
Náuplio	1.880.00	4.64	2.720.00	93.79	1.630.00	34.61	340.00	47.22	2.500.00	26.68	1.510.00	30.38
Subtotal	**1,880.00**	**4.64**	**2,720.00**	**93.79**	**1,630.00**	**34.61**	**340.00**	**47.22**	**2,500.00**	**26.68**	**1,510.00**	**30.38**
Order Cyclopoida												
Cyclopoida Unidentified	120.00	0.30	60.00	2.07	200.00	4.25	20.00	2.78	1.320.00	14.09	590.00	11.87
Subtotal	**120.00**	**0.30**	**60.00**	**2.07**	**200.00**	**4.25**	**20.00**	**2.78**	**1,320.00**	**14.09**	**590.00**	**11.87**
Order Calanoida												
Calanoida Unidentified	440.00	1.09	-	-	760.00	16.14	100.00	13.89	100.00	1.07	80.00	1.61
Subtotal	**440.00**	**1.09**	**-**	**-**	**760.00**	**16.14**	**100.00**	**13.89**	**100.00**	**1.07**	**80.00**	**1.61**
Class Ostracoda												

Taxonomic Groups	Gameleira		Várzea				São Domingos		Piauí			
	P13		P4		P15		P7		P8A		P8B	
	org/m³	%	org/m³	%	org/m³	%	org/m³	%	org/m³	%	org/m³	%
Ostracoda Unidentified	-	-	-	-	-	-	-	-	-	-	10.00	0.20
Subtotal	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**10.00**	**0.20**
Total	**40,480.00**	**100.00**	**2,900.00**	**100.00**	**4,710.00**	**100.00**	**720.00**	**100.00**	**9,370.00**	**100.00**	**4,970.00**	**100.00**

Figure 5.2-14 – Numerical Density of the Zooplankton Community (org / m³).

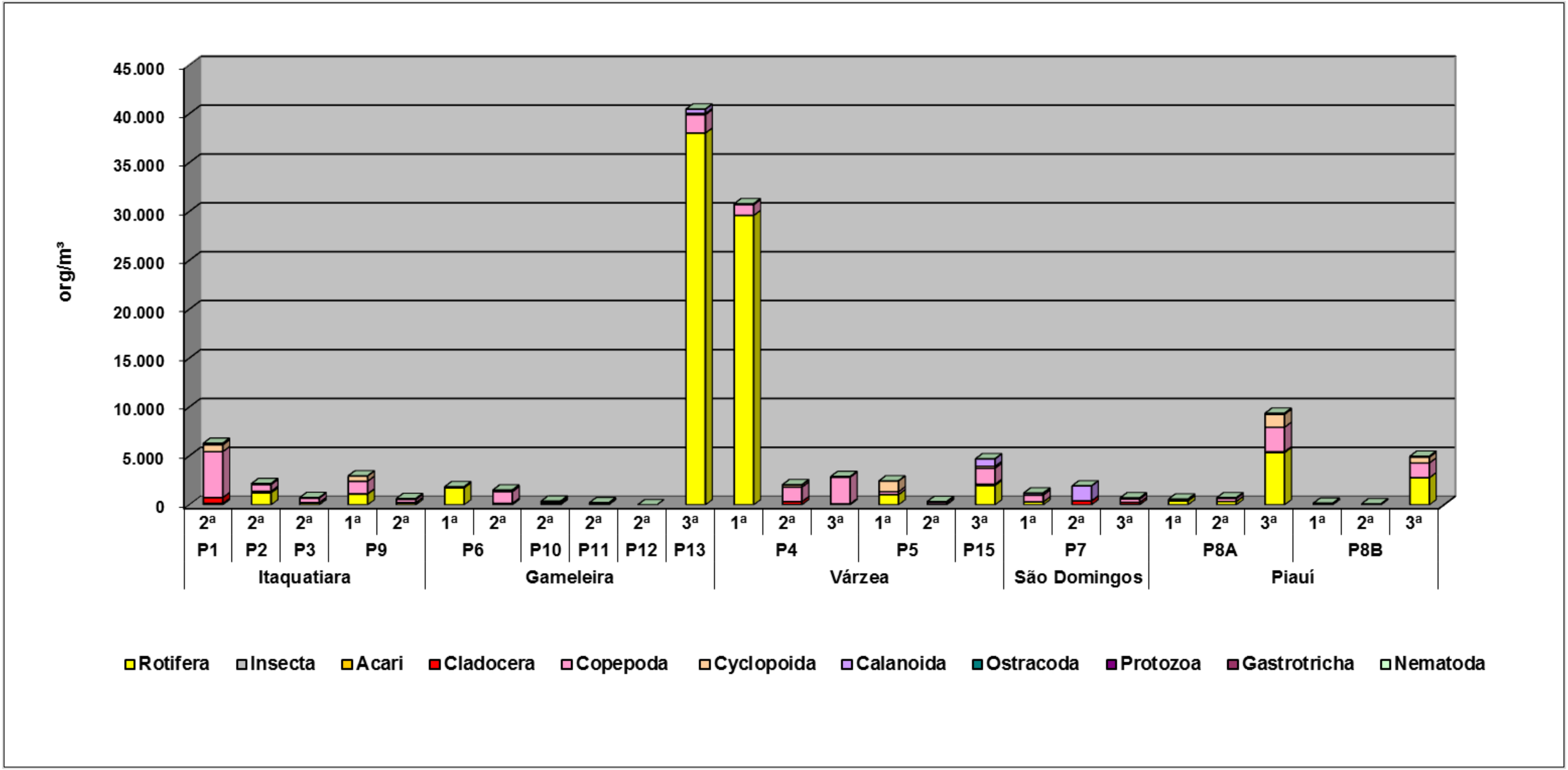
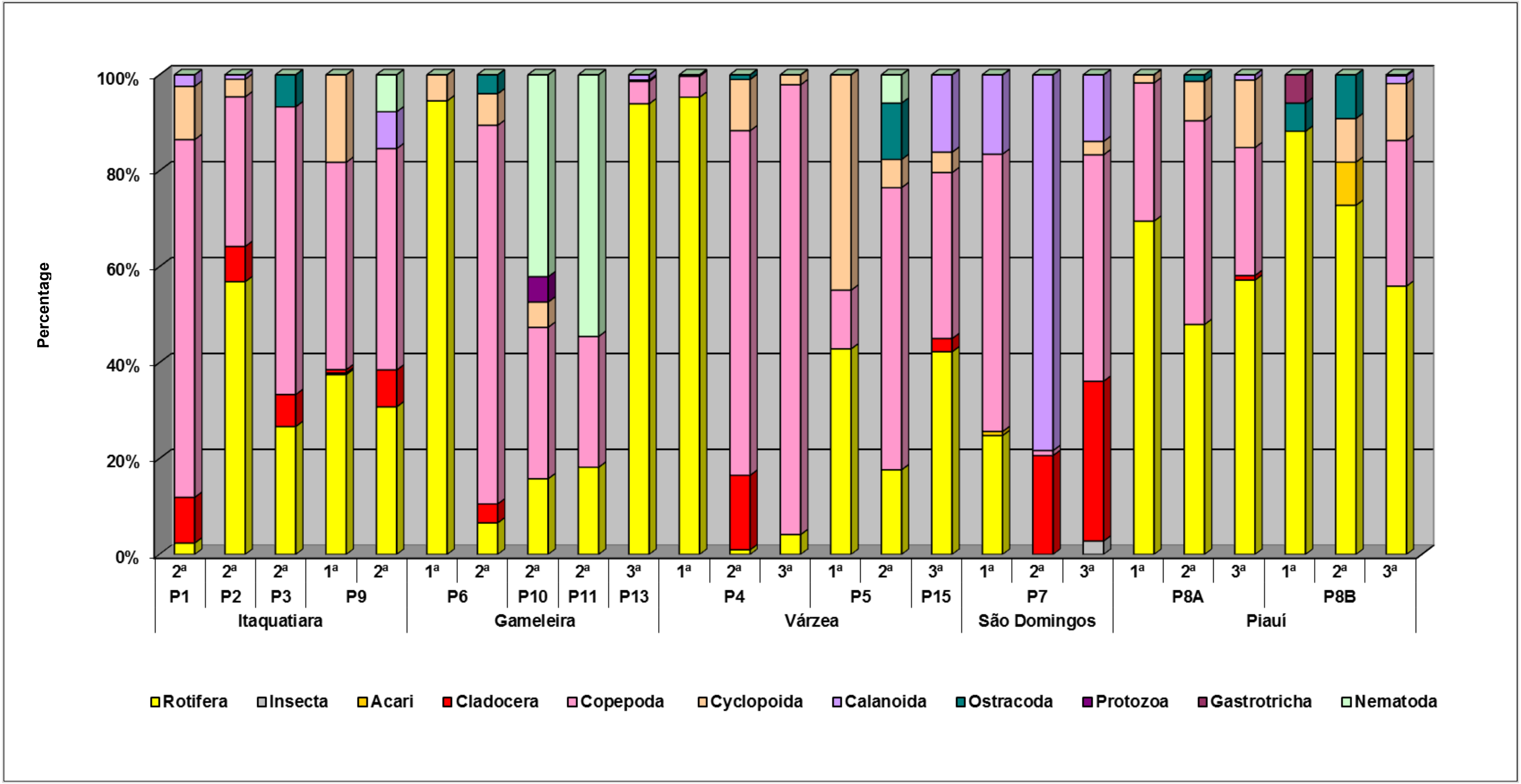


Figure 5.2-15 – Relative Abundance of the Zooplankton Community (%)



The following figures show the results of the Indices of species diversity and equitability, which suggest a tendency towards a decrease in the diversity of organisms at the height of the rainy season. This reduction is possibly attributed to the instability of the aquatic environment due to the higher current speed and the increased flow of particulate materials leached from the drainage basin, which reduces the transparency and productivity of phytoplankton, reflecting the availability of food for the links the aquatic food chain, including zooplankton.

The application of the Diversity Index resulted in values between 1.06 (May / 08) at Point 13 and 3.20 (May / 08) at Point 8A, indicating that the environments sampled in the Piauí Nickel Project are moderately altered, with indications probable anthropogenic interference, which may also be influenced by the natural characteristics of the sampled stretches. The results of equitability indicate greater homogeneity of zooplankton in the first and second sampling campaigns.

Figure 5.2-16 – Zooplankton Community Diversity and Equitability Index - 1st campaign

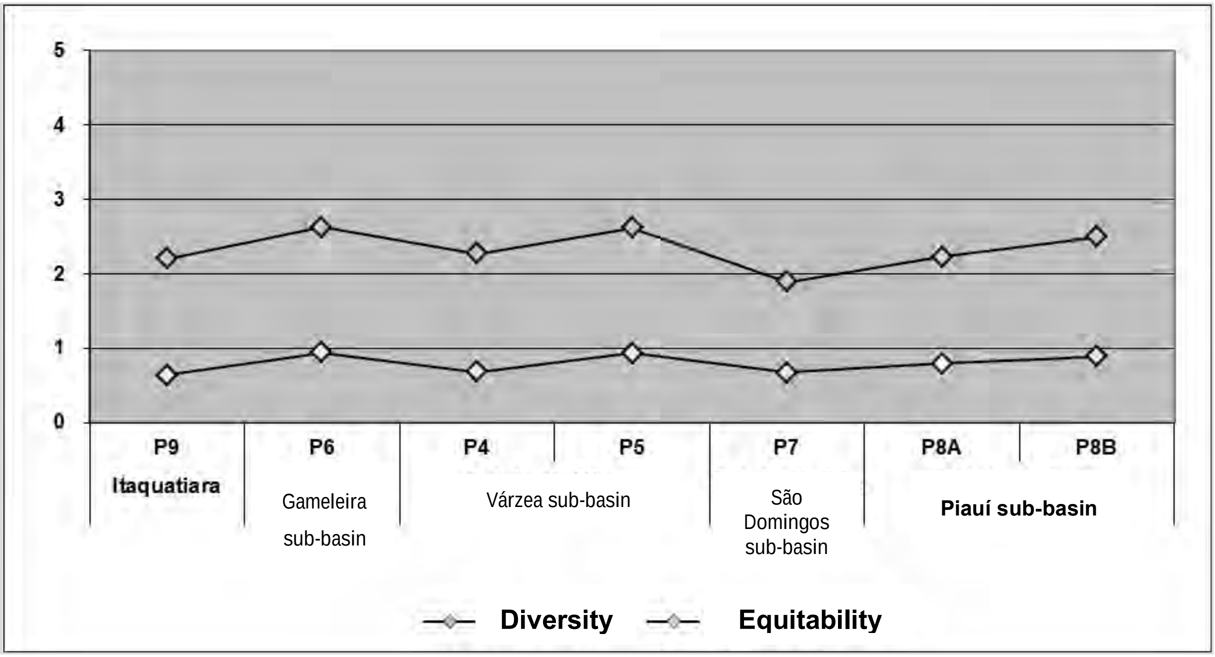


Figure 5.2-17 – Zooplankton Community Diversity and Equitability Index – 2nd campaign

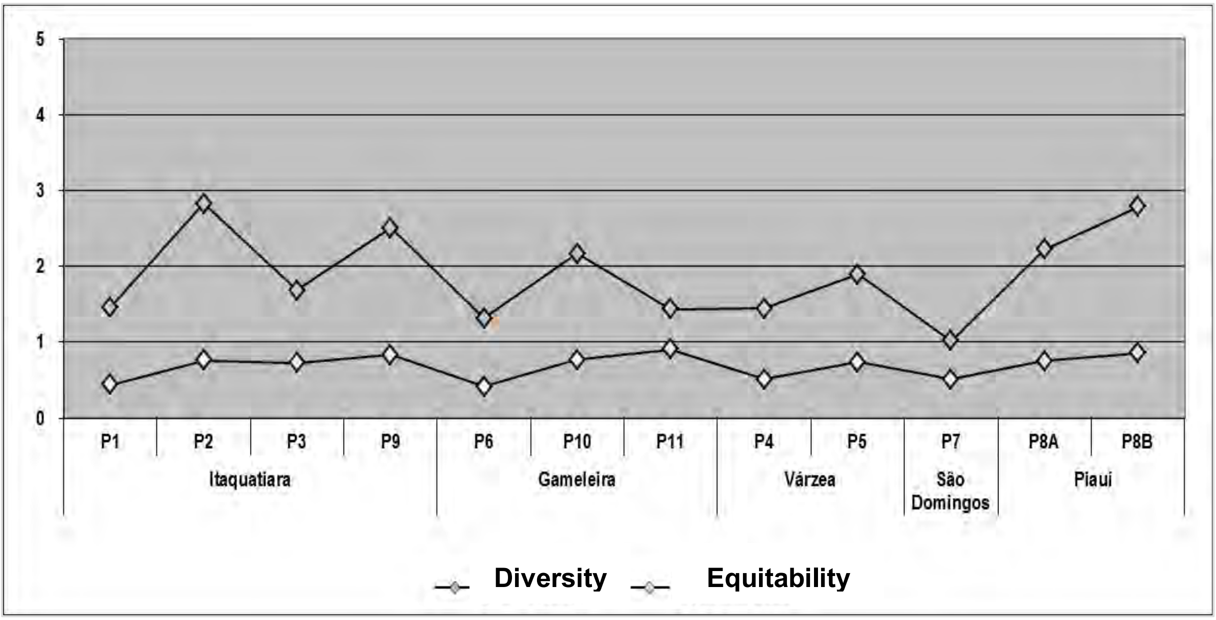
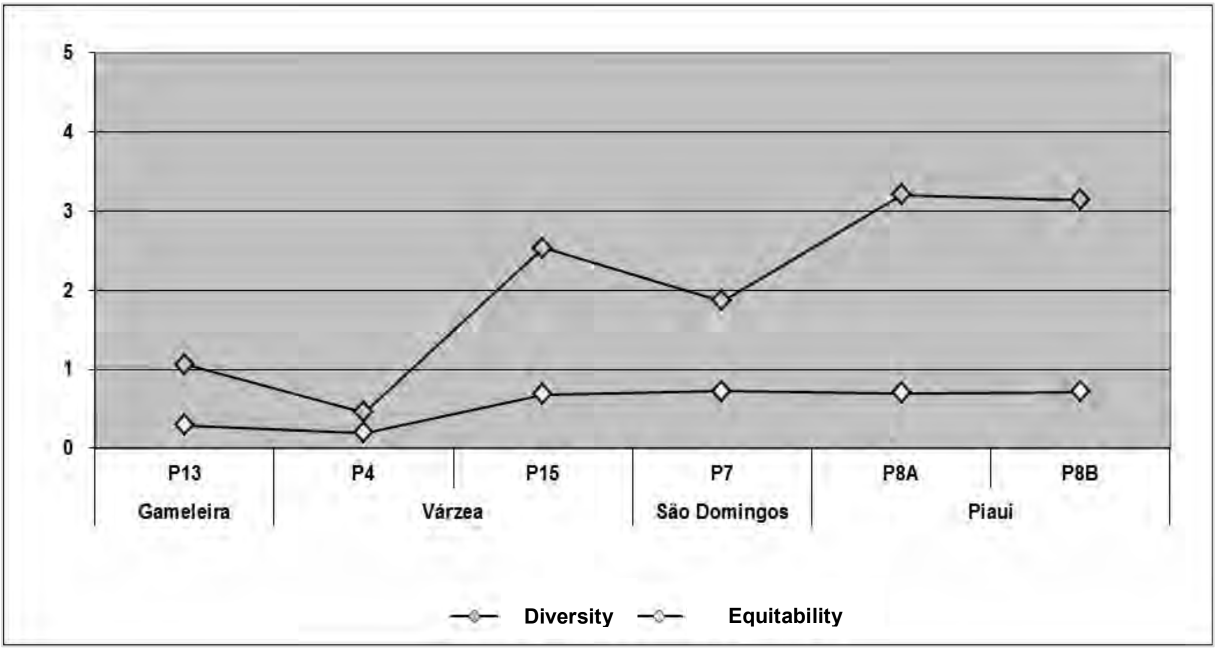


Figure 5.2-18 – Zooplankton Community Diversity and Equitability Index – 3rd campaign



Benthic Invertebrate Macrofauna

The macrofauna of benthic invertebrates encompasses organisms of various trophic levels, from primary consumers to top predators, in addition to presenting a wide variety of eating habits, including collecting members (filter and deposit eaters), scrapers, shredders, predators and parasites. They therefore form an important link in the food web of aquatic systems, transferring energy from various levels and even serving as food for countless species of fish and birds.

Benthic organisms are excellent bioindicators, because, in addition to these characteristics, they are abundant in all types of aquatic systems, have low mobility, have selectivity in terms of habitat, reflecting with greater accuracy any imbalances, whether by the introduction of contaminating and polluting substances in bodies water, either by the physical alteration of the substrate caused, for example, by the transport of solids in the drainage area.

The use of the benthic community also allows for a temporal assessment of changes caused by disturbances in the aquatic environment, as during their relatively long life cycle (weeks to years), they continuously respond to environmental variations in the monitored stretch, displaying a wide variety of pollution tolerances.

- Quantitative analysis

The data obtained in the three benthic macroinvertebrate collection campaigns carried out in February, March and May 2008, in the area of influence of the Piauí Nickel Project, are presented below.

Data Table 5.2-77 – Species Richeness of the Benthic Community (No. of Taxons).

Taxonomic Groups	Itaquatiara					Gameleira						Várzea						São Domingos			Piauí					
	P1	P2	P3	P9		P6		P10	P11	P12	P13	P4			P5		P15	P7			P8A			P8B		
	2ª	2ª	2ª	1ª	2ª	1ª	2ª	2ª	2ª	2ª	3ª	1ª	2ª	3ª	1ª	2ª	3ª	1ª	2ª	3ª	1ª	2ª	3ª	1ª	2ª	3ª
Diptera	1	2	2	-	1	2	2	2	1	1	1	1	2	2	3	3	2	1	-	-	1	1	1	1	1	1
Ephemeroptera	-	-	-	-	-	-	1	-	1	-	1	2	-	-	1	1	1	-	-	-	-	-	-	-	1	1
Odonata	-	-	1	-	-	-	2	1	1	-	-	2	1	2	2	-	1	-	-	-	-	1	-	-	-	-
Trichoptera	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-
Hemiptera	-	-	-	-	-	-	-	-	-	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Coleoptera	-	-	1	-	-	-	-	1	-	1	-	1	2	1	1	1	-	-		-	-	-	-	-	-	-
Anomopoda	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	1	-	-	-	-	-	-	-	-	-
Lepidoptera	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hydracarina	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-
Cyclopoida	-	-	-	-	1	-	1	1	1	-	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-
Ostracoda	-	-	-	-	-	1	-	1	-	-	-	1	1	-	-	-	1	-	-	-	-	-	-	-	1	-
Decapoda	-	-	-	-	1	1	1	-	-	-	1	-	-	-	1	-	-	-	1	-	1	-	-	1	-	-
Gastropoda	-	-	-	1	1	1	-	-	-	-	1	1	1	1	1	1	1	-	-	-	1	1	-	2	1	1
Oligochaeta	1	1	1	1	1	1	1	1	1	1	1	-	2	1	1	1	1	1	-	1	1	1	1	1	-	1
Nematoda	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Taxonomic Groups	Itaquatiara					Gameleira						Várzea						São Domingos			Piauí					
	P1	P2	P3	P9		P6		P10	P11	P12	P13	P4			P5		P15	P7			P8A			P8B		
	2ª	2ª	2ª	1ª	2ª	1ª	2ª	2ª	2ª	2ª	3ª	1ª	2ª	3ª	1ª	2ª	3ª	1ª	2ª	3ª	1ª	2ª	3ª	1ª	2ª	3ª
Total	3	3	5	2	5	6	9	7	5	3	6	10	10	8	10	7	8	2	1	1	5	5	2	5	4	4

Data Table 5.2-78 – Benthic Community Richeness.

Micro Basin Reference		Taxons (Feb/08)	Taxons (Mar/08)	Taxons (May/08)
Itaquatiara	P1	NA (not sampled)	Ceratopogonidae, Tubificidae, Nematoda	
	P2	_	Tubificidae, Chironomidae, Tipulidae	_
	P3	_	Tubificidae, Chironomidae, Culicidae, Corduliidae, Dytiscidae,	_
	P9	Thiaridae, Tubificidae	Palaemonidae, Thiaridae, Tubificidae, Chironomidae, Ciclopyidae	_
Gameleira	P6	Palaemonidae, Planorbidae, Tubificidae, Chironomidae, Chaoboridae, Ostracoda.	Tubificidae, Chironomidae, Tipulidae, Ephemerillidae, Cordullidae, Libellulidae, Pyralidae, Ciclopyidae, Palaemonidae.	_
	P10	_	Chironomidae, Ceratopogonidae, Corduliidae, Gyrinidae, Ciclopyidae, Ostracoda, Tubificidae	_
	P11	_	Chironomidae, Ephemerillidae, Cordullidae, Ciclopyidae, Tubificidae	_
	P12	_	Chironomidae , Merylidae , Tubificidae	_
	P13	_	_	Chironomidae, Baetidae, Naucoridae, Palaemonidae, Planorbidae, Tubificidae

Micro Basin Reference		Taxons (Feb/08)	Taxons (Mar/08)	Taxons (May/08)
Várzea	P4	Chironomidade, Planorbidae, Polymirtacyidae Leptohyphidae, Gomphidae , Libellulidae , Hydrophilidae , Naucoridae, Ciclopydae, Ostracoda,	Tubificidae, Chironomidae, Ceratopogonidae, Corduliidae, Dytiscidae, Hydrophillidae, Ciclopyidae, Ostracoda, Planorbidae, Opistocidae	Chironomidae, Ceratopogonidae, Corduliidae, Libellulidae, Hydrophilidae, Macrothricidae, Planorbidae, Tubificidae
	P5	Chironomidae, Ceratopogonidae, Culicidae, Leptohyphidae, Coenagrionidae, Libellulidae, Hydrophilidae, Palaemonidae, Planorbidae, Tubificidae	Planorbidae, Tubificidae , Chironomidae, Ceratopogonidae, Tipulidae, Baetidae, Hydrophilidae	_
	P15	_	_	Chironomidae, Ceratopogonidae, Baetidae, Calopterigidae, Macrothricidae, Ostracoda, Planorbidae, Tubificidae
São Domingos	P7	Chironomidade, Tubificidae	Palaemonidae	Tubificidae
Piauí	P8A	Thiaridae, Tubificidae, Chironomidae, Limnephilidae, Palaemonidae	Chironomidae, Coenagrionidae, Thiaridae, Hydracarina, Tubificidae	Chironomidae, Tubificidae
	P8B	Chironomidade, Palaemonidae, Planorbidae, Thiaridae, Tubificidae	Chironomidae, Ephemerillidae, Ostracoda, Thiaridae	Chironomidae, Baetidae, Thiaridae, Tubificidae.

The most representative groups were Diptera and Odonata, belonging to the Insecta class, making a total of 16.13% each, followed by Ephemeroptera and Coleoptera (12.9% each). The other organisms, in general, contributed equally to the species richness.

Therefore, reproducing a pattern observed in tropical aquatic systems, the sampled water courses present insect larvae as the main representatives of the benthic macroinvertebrates, as they spend part of their life or their complete cycle associated with the bottom substrate, among which the Ephemeroptera , Diptera, Odonata, Trichoptera, Hemiptera, Coleoptera (ESTEVES, 2011).

The greatest variety of benthic organisms was found in the second campaign (22 taxa), with a greater richness of Diptera and Coleoptera. In the first and third campaigns, the total organism richness was 18 and 14 taxa, respectively. In the first campaign, dipterans were also responsible for the highest number of taxa and in the third campaign, the Odonata order was the main contributor to the registered benthic taxa.

Diptera (order Diptera) make up a significant part of the benthic fauna of aquatic environments. The adults of these insects lay eggs on the surface of the water or on substrates and give rise to a large number of larvae, which, in general, colonize sandy and muddy sediments, in addition to aquatic vegetation (WARD, 1992).

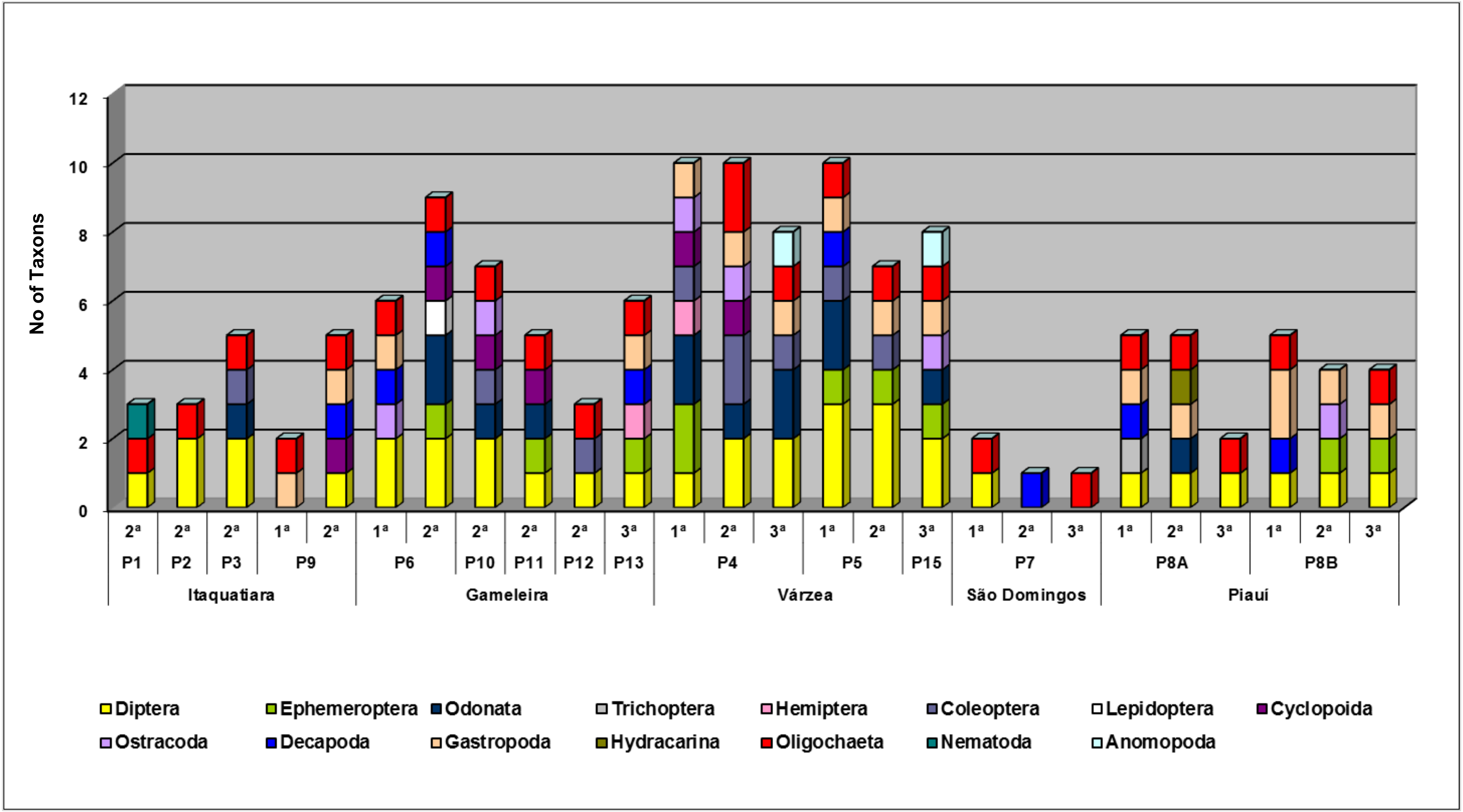
The diptera taxon that contributed most to the zoobenthic richness of the sampled water bodies belonged to the Chironomidae family. The representativeness of its organisms is due to its variety of adaptive mechanisms, which enable them to live in environments even with extreme situations, such as low concentrations of dissolved oxygen. According to Cranston (1995), the Chironomidae family is the most important group in terms of the range of habitats it occupies, diversity of eating habits (they consume a wide variety of resources) and adaptive strategies, which contributes for the organisms of this group to stand out among the others.

The figure below illustrates that the lowest taxonomic riches were recorded in watercourses located in the São Domingos sub-basin, while the highest were found in samples collected in the Várzea micro basin.

Os grupos mais representativos foram Diptera e Odonata, pertencentes à Class Insecta, perfazendo um total de 16,13% cada, seguido de Ephemeroptera e Coleoptera (12,9% each). Os demais organismos, em geral, contribuíram de forma equitativa na riqueza de espécies.

Portanto, reproduzindo um padrão observado nos sistemas aquáticos tropicais, os cursos d’água amostrados apresentam como principais representantes dos macroinvertebrados bentônicos as larvas de insetos, pois estas passam parte da vida ou seu ciclo completo associada ao substrato de fundo, entre os quais os Ephemeroptera, Diptera, Odonata, Trichoptera, Hemiptera, Coleoptera (ESTEVES, 2011).

Figure 5.2-19 – Species Richness of the Benthic Community (No of Taxons).



Regarding the spatial distribution and frequency of occurrence of the macrofauna of benthic invertebrates, the oligochaetes of the Tubificidae family were the most frequent in the analyzed samples, despite the low total relative richness. The oligochaetes (phylum Annelida) have a complete life cycle in the aquatic sediment and are adapted to colonize from bodies of oligotrophic to eutrophic waters. Some species tolerate low concentration of dissolved oxygen and can be found in environments prone to eutrophication. Such characteristics certify aquatic oligochaetes as an efficient instrument for indicating organic aquatic pollution of waters. Freshwater oligochaetes are little known and one of the main factors responsible for this is the difficulty in the taxonomic study. Histological tests are often necessary to identify them (ROCHA, 2003).

According to Martins et al (2008), studies have shown that species of oligochaetes belonging to the Tubificidae family are generally tolerant to organic pollution and present themselves massively in waters with a low concentration of dissolved oxygen.

The Chironomidae family (chironomids), belonging to the order Diptera, was also quite frequent in the three sampling campaigns, with an overall relative frequency above 80%. Representatives of this family were not found in Points 07 (second and third campaign) and 09 (first campaign). As previously mentioned, these organizations are considered opportunistic, with a wide geographic distribution.

Data Table 5.2-79 – Spatial distribution and frequency of occurrence of the benthic community, in February 2008.

Taxonomic Group	Itaquatiara	Gameleira	Várzea		São Domingos	Piauí		Frequency	Relative Frequency (%)
	P9	P6	P4	P5	P7	P8A	P8B		
Filo ARTHROPODA									
Class Insecta									
Order Diptera									
Family Chironomidae								**6**	**85.71**
Family Ceratopogonidae								**1**	**14.29**
Family Chaoboridae								**1**	**14.29**
Family Culicidae								**1**	**14.29**
Subtotal	**-**	**2**	**1**	**3**	**1**	**1**	**1**		
Order Ephemeroptera									
Family Leptohyphidae								**2**	**28.57**
Family Polymirtacyidae								**1**	**14.29**
Subtotal	**-**	**-**	**2**	**1**	**-**	**-**	**-**		

Taxonomic Group	Itaquatiara	Gameleira	Várzea		São Domingos	Piauí		Frequency	Relative Frequency (%)
	P9	P6	P4	P5	P7	P8A	P8B		
Order Odonata									
Family Coenagrionidae								1	14.29
Family Gomphidae								1	14.29
Family Libellulidae								2	28.57
Subtotal	-	-	2	2	-	-	-		
Order Trichoptera									
Family Limnephilidae								1	14.29
Subtotal	-	-	-	-	-	1	-		
Order Hemiptera									
Family Naucoridae								1	14.29
Subtotal	-	-	1	-	-	-	-		
Order Coleoptera									
Family Hydrophilidae								2	28.57
Subtotal	-	-	1	1	-	-	-		
Sub-Filo CRUSTACEA									
Class Copepoda									
Order Cyclopoida									
Family Ciclopyidae								1	14.29
Subtotal	-	-	1	-	-	-	-		
Class Ostracoda								2	28.57
Subtotal	-	1	1	-	-	-	-		
Class Malacostraca									
Order Decapoda									
Family Palaemonidae								4	57.14

Taxonomic Group	Itaquatiara	Gameleira	Várzea		São Domingos	Piauí		Frequency	Relative Frequency (%)
	P9	P6	P4	P5	P7	P8A	P8B		
Subtotal	-	1	-	1	-	1	1		
Filo MOLLUSCA									
Class Gastropoda									
Family Planorbidae								**4**	**57.14**
Family Thiaridae								**3**	**42.86**
Subtotal	**1**	**1**	**1**	**1**	**-**	**1**	**2**		
Filo ANNELIDA									
Class Oligochaeta									
Family Tubificidae								**6**	**85.71**
Subtotal	**1**	**1**	**-**	**1**	**1**	**1**	**1**		
Total	**2**	**6**	**10**	**10**	**2**	**5**	**5**		

Data Table 5.2-80 – Spatial distribution and frequency of occurrence of the benthic Community, in March 2008

Taxonomic Group	Itaquatiara				Gameleira				Várzea		São Domingos	Piauí		Frequency	Relative Frequency (%)
	P1	P2	P3	P9	P6	P10	P11	P12	P4	P5	P7	P8A	P8B		
Filo ARTHROPODA															
Class Insecta															
Order Diptera															
Family Chironomidae		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00				11	84.62
Family Ceratopogonidae	1.00					1.00			1.00	1.00				4	30.77
Family Culicidae			[illegible]											1	7.69
Family Tipulidae		1.			1.									3	23.08
Subtotal	1	2	2	1	2	2	1	1	2	3	-	1	1		
Order Ephemeroptera															
Family Baetidae														1	7.69
Family Ephemerillidae														3	23.08
Subtotal	-	-	-	-	1	-	1	-	-	1	-	-	1		
Order Odonata															

Taxonomic Group	Itaquatiara				Gameleira				Várzea		São Domingos	Piauí		Frequency	Relative Frequency (%)
	P1	P2	P3	P9	P6	P10	P11	P12	P4	P5	P7	P8A	P8B		
Family Coenagrionidae														1	7.69
Family Corduliidae														5	38.46
Family Libellulidae														1	7.69
Subtotal	-	-	1	-	2	1	1	-	1	-	-	1	-		
Order Coleoptera															
Family Dytiscidae														2	15.38
Family Gyrinidae														1	7.69
Family Hydrophilidae														2	15.38
Família Merylidae														1	7.69
Subtotal	-	-	1	-	-	1	-	1	2	1	-	-	-		
Order Lepidoptera															
Family Pyralidae														1	7.69
Subtotal	-	-	-	-	1	-	-	-	-	-	-	-	-		
Class Acari															

Taxonomic Group	Itaquatiara				Gameleira				Várzea		São Domingos	Piauí		Frequency	Relative Frequency (%)
	P1	P2	P3	P9	P6	P10	P11	P12	P4	P5	P7	P8A	P8B		
Sub-Order Hydracarina														1	7.69
Subtotal	-	-	-	-	-	-	-	-	-	-	-	1	-		
Sub-Filo CRUSTACEA															
Class Copepoda															
Order Cyclopoida															
Family Ciclopyidae														5	38.46
Subtotal	-	-	-	1	1	1	1	-	1	-	-	-	-		
Class Ostracoda														3	23.08
Subtotal	-	-	-	-	-	1	-	-	1	-	-	-	1		
Class Malacostraca															
Orde Drecapoda															
Family Palaemonidae														3	23.08
Subtotal	-	-	-	1	1	-	-	-	-	-	1	-	-		
Filo MOLLUSCA															
Class Gastropoda															
Family Planorbidae														2	15.38

Taxonomic Group	Itaquatiara				Gameleira				Várzea		São Domingos	Piauí		Frequency	Relative Frequency (%)
	P1	P2	P3	P9	P6	P10	P11	P12	P4	P5	P7	P8A	P8B		
Family Thiaridae														3	**23.08**
Subtotal	**-**	**-**	**-**	**1**	**-**	**-**	**-**	**-**	**1**	**1**	**-**	**1**	**1**		
Filo ANNELIDA															
Class Oligochaeta															
Family Tubificidae														**11**	**84.62**
Family Opistocidae														**1**	**7.69**
Subtotal	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**2**	**1**	**-**	**1**	**-**		
Filo NEMATODA	**1.00**													**1**	**7.69**
Subtotal	**1**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**		
Total	**3**	**3**	**5**	**5**	**9**	**7**	**5**	**3**	**10**	**7**	**1**	**5**	**4**		

Data Table 5.2-81 – Spatial distribution and frequency of occurrence of the benthic Community, in May 2008.

Taxonomic Groups	Gameleira	Várzea		São Domingos	Piauí		Frequency	Relative Frequency (%)
	P13	P4	P15	P7	P8A	P8B		
Filo ARTHROPODA								
Class Insecta								
Order Diptera								
Family Chironomidae	1.00	1.00	1.00		1.00	1.00	5	83.33
Family Ceratopogonidae		1.00	1.00				2	33.33
Subtotal	1	2	2	-	1	1		
Order Ephemeroptera								
Family Baetidae	1.00		1.00			1.00	3	50.00
Subtotal	1	-	1	-	-	1		
Order Odonata								
Family Calopterigidae			1.00				1	16.67
Family Corduliidae		1.00					1	16.67
Family Libellulidae		1.00					1	16.67
Subtotal	-	2	1	-	-	-		
Order Hemiptera								
Family Naucoridae	1.00						1	16.67
Subtotal	1	-	-	-	-	-		
Order Coleoptera								
Family Hydrophilidae		1.00					1	16.67
Subtotal	-	1	-	-	-	-		

Taxonomic Groups	Gameleira	Várzea		São Domingos	Piauí		Frequency	Relative Frequency (%)
	P13	P4	P15	P7	P8A	P8B		
Sub-Filo CRUSTACEA								
Class Branchiopoda								
Order Anomopoda								
Family Macrothricidae							**2**	**33.33**
Subtotal	**-**	**1**	**1**	**-**	**-**	**-**		
Class Ostracoda							**1**	**16.67**
Subtotal	**-**	**-**	**1**	**-**	**-**	**-**		
Class Malacostraca								
Order Decapoda								
Family Palaemonidae							**1**	**16.67**
Subtotal	**1**	**-**	**-**	**-**	**-**	**-**		
Filo MOLLUSCA								
Class Gastropoda								
Family Planorbidae							**3**	**50.00**
Family Thiaridae							**1**	**16.67**
Subtotal	**1**	**1**	**1**	**-**	**-**	**1**		
Filo ANNELIDA								
Class Oligochaeta								
Family Tubificidae							**6**	**100.00**
Subtotal	**1**	**1**	**1**	**1**	**1**	**1**		

Grupos Taxonômicos	Gameleira	Várzea		São Domingos	Piauí		Frequência	Frequência Relativa (%)
	P13	P4	P7	P7	P8A	P8B		
Total	6	8	8	1	2		4	

The presence of some families of the orders Ephemeroptera, Trichoptera and Odonata can infer a better quality of the environment, due to the sensitivity of these organisms to pollution. In this sense, there are indications that Points 04, 05, 8A, 11, 13 and 15, where the lowest number of taxa were found, are in better environmental conditions. Worse would be Points 01, 02, 09, 07, 12.

It should also be noted that in the three sampling campaigns the presence of organisms that could be related to the transmission of diseases, such as: Planorbidae, Thiaridae and Culicidae, was detected.

Some mollusks representing the Planorbidae family, more specifically, of the genus Biomphalaria, may be intermediate hosts for the trematode parasite *Schistosoma mansoni*, which transmits schistosomiasis. The planorbid gastropod mollusk was recorded at Points 04, 05, 06, 08B and 13, with emphasis on Point 04, where the presence of this organism persisted in all campaigns.

Mollusks of the family Thiaridae, like those belonging to the genus Melanoides, act as intermediate hosts for parasitic trematode worms in the respiratory and hepatic system in humans (*Clonorchis sinensis*). The thiarid gastropod was found at Point 8B, in all campaigns, and at Points 08A and 09, in February / 08 and March / 08.

Insects from the Culicidae family include representatives of the genera Culex, Anopheles, Mansonia, Aedes, which include species that are agents of diseases such as malaria, filariasis, dengue, yellow fever, chikungunya, zika, among others. Representatives of this family were registered in samples collected at Points 05 (February / 08) and 03 (March / 08).

To evaluate the qualitative results of the zoobenthic community, the biotic index BMWP (*Biological Monitoring Work Party Score System*) was also used, according to Alba-Tercedor & Sanches-Ortega (1988) and Junqueira & Campos (1998) apud Biodiversitas (2016). The sum of the scores of the families found in each of the sampled points was performed. The results are shown below.

Data Table 5.2-82 - BMWP results in three campaigns carried out in 2008.

Groups	Itaquatiara				Gameleira					Várzea			São Domingos	Piauí	
	P1	P2	P3	P9	P6	P10	P11	P12	P13	P4	P5	P15	P7	P8A	P8B
Family Chironomidae		2	2	2	2	2	2	2	2	2	2	2	2	2	2
Family Ceratopogonidae	4					4				4	4	4			
Family Culicidae			1								1				
Family Leptohyphidae										8	8				
Family Tipulidae		5			5						5				
Family Baetidae									5		5	5			5
Family Coenagrionidae											7			7	
Family Gomphidae										5					
Family Dytiscidae			4							4					
Family Libellulidae					8					8	8				
Family Calopterigidae												8			

Groups	Itaquatiara				Gameleira					Várzea			São Domingos	Piauí	
	P1	P2	P3	P9	P6	P10	P11	P12	P13	P4	P5	P15	P7	P8A	P8B
Family Naucoridae									5	5					
Family Hydrophilidae										5	5				
Class Oligochaeta	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Sub-Order Hydracarina														4	
Microcrustacea				4	4	4	4	4		4		4			
Total BMWP	**5**	**8**	**8**	**7**	**20**	**11**	**7**	**7**	**13**	**46**	**46**	**24**	**3**	**14**	**8**

The evaluation of water quality using the BMWP biological index showed higher results in the Várzea stream microbasin in relation to the other sampled points, corroborating the results obtained in the physical-chemical and bacteriological analyzes presented in item 5.1.7.3 Surface Waters ". The results of the BMWP index therefore indicated a satisfactory condition at Points 04 and 05 and bad to very bad at the other sampling points.

It must be considered, however, that the colonization of benthic organs in aquatic environments does not occur in a homogeneous manner (they are usually found in localized patches) and for this reason, in each campaign new organisms are identified that contribute to the increase in the list. Therefore, after new sampling, the results of the BMWP index would probably be greater than those recorded in the present study.

- Quantitative analysis

The results of the quantitative assessment of the benthic community are presented below, which represent, respectively, the numerical density and the relative abundance of the groups identified in the sample network. As previously mentioned, it is noteworthy that this evaluation was carried out only at the points where the samples were collected with the Corer type catcher, which has a well-defined sample area.

The total density of the benthic community fluctuated between 51.02 org / m² at Point 07 (second campaign) and 6,632.65 org / m² at Point 09 (first campaign). Point 8A, at the Jenipapo dam, also obtained a high density of benthos (5,510.20 org / m²) in the second campaign.

The highest densities found in Point 09 and 8A are related to the great presence of gastropod molluscs of the family Thiaridae (98.46%) and insects of the family Chironomidae (88.89%), respectively.

As shown in the figures below, chironomids dominated the fauna of Points 04 (May / 08), 07 (Feb / 08), 8A (all campaigns), 12, 13 and 15. Tubididae were more abundant in Point 04 in second campaign (65.17%) and Point 07, in the third campaign (100%). As previously mentioned, these two families are often used as indicators of pollution, mainly of organic origin

Data Table 5.2-83 – Numerical density (org / m²) and relative abundance of the benthic community, in February / 08.

Taxonomic Groups	Itaquatiara		Várzea		São Domingos		Piauí	
	P9		P4		P7		P8A	
	org/m²	%	org/m²	%	org/m²	%	org/m²	%
Filo ARTHROPODA								
Class Insecta								
Order Diptera								
Family Chironomidae	-	-	408.16	30.77	561.22	91.67	663.27	81.25
Subtotal	**-**	**-**	**408.16**	**30.77**	**561.22**	**91.67**	**663.27**	**81.25**

Taxonomic Groups	Itaquatiara		Várzea		São Domingos		Piauí	
	P9		P4		P7		P8A	
	org/m²	%	org/m²	%	org/m²	%	org/m²	%
Order Ephemeroptera								
Family Polymirtacyidae	-	-	102.04	7.69	-	-	-	-
Subtotal	**-**	**-**	**102.04**	**7.69**	**-**	**-**	**-**	**-**
Order Odonata								
Family Gomphidae	-	-	102.04	7.69	-	-	-	-
Family Libellulidae	-	-	102.04	7.69	-	-	-	-
Subtotal	**-**	**-**	**204.08**	**15.38**	**-**	**-**	**-**	**-**
Order Trichoptera								
Family Limnephilidae	-	-	-	-	-	-	51.02	6.25
Subtotal	**-**	**-**	**-**	**-**	**-**	**-**	**51.02**	**6.25**
Order Coleoptera								
Family Hydrophilidae	-	-	102.04	7.69	-	-	-	-
Subtotal	**-**	**-**	**102.04**	**7.69**	**-**	**-**	**-**	**-**
Filo MOLLUSCA								
Class Gastropoda								
Family Planorbidae	-	-	510.20	38.46	-	-	-	-
Family Thiaridae	6,530.61	98.46	-	-	-	-	-	-
Subtotal	**6,530.61**	**98.46**	**510.20**	**38.46**	**-**	**-**	**-**	**-**
Filo ANNELIDA								
Class Oligochaeta								
Family Tubificidae	102.04	1.54	-	-	51.02	8.33	102.04	12.50
Subtotal	**102.04**	**1.54**	**-**	**-**	**51.02**	**8.33**	**102.04**	**12.50**
Total	**6,632.65**	**100.00**	**1,326.53**	**100.00**	**612.24**	**100.00**	**816.33**	**100.00**

Data Table 5.2-84 – Numerical density (org/m²) and relative abundance of the benthic Community, in March/08.

Taxonomic Groups	Itaquatiara				Gameleira		Várzea		São Domingos		Piauí	
	P1		P9		P12		P4		P7		P8A	
	org/m²	%	org/m²	%	org/m²	%	org/m²	%	org/m²	%	org/m²	%
Filo ARTHROPODA												
Class Insecta												
Order Diptera												
Family Chironomidae	-	-	51.02	7.14	102.04	50.00	816.33	17.98	-	-	4,897.96	88.89
Family Ceratopogonidae	102.04	40.00	-	-	-	-	153.06	3.37	-	-	-	-
Subtotal	**102.04**	**40.00**	**51.02**	**7.14**	**102.04**	**50.00**	**969.39**	**21.35**	**-**	**-**	**4,897.96**	**88.89**
Order Odonata												
Family Coenagrionidae	-	-	-	-	-	-	-	-	-	-	51.02	0.93
Family Corduliidae	-	-	-	-	-	-	102.04	2.25	-	-	-	-
Subtotal	**-**	**-**	**-**	**-**	**-**	**-**	**102.04**	**2.25**	**-**	**-**	**51.02**	**0.93**
Order Coleoptera												
Family Dytiscidae	-	-	-	-	-	-	51.02	1.12	-	-	-	-
Family Hydrophilidae	-	-	-	-	-	-	102.04	2.25	-	-	-	-
Família Merylidae	-	-	-	-	51.02	25.00	-	-	-	-	-	-
Subtotal	**-**	**-**	**-**	**-**	**51.02**	**25.00**	**153.06**	**3.37**	**-**	**-**	**-**	**-**

Taxonomic Groups	Itaquatiara				Gameleira		Várzea		São Domingos		Piauí	
	P1		P9		P12		P4		P7		P8A	
	org/m²	%	org/m²	%	org/m²	%	org/m²	%	org/m²	%	org/m²	%
Filo ARTHROPODA												
Class Acari												
Sub-Order Hydracarina	-	-	-	-	-	-	-	-	-	-	51.02	0.93
Subtotal	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**51.02**	**0.93**
Sub-Filo CRUSTACEA												
Class Copepoda												
Order Cyclopoida												
Family Ciclopyidae	-	-	51.02	7.14	-	-	153.06	3.37	-	-	-	-
Subtotal	**-**	**-**	**51.02**	**7.14**	**-**	**-**	**153.06**	**3.37**	**-**	**-**	**-**	**-**
Class Ostracoda	-	-	-	-	-	-	51.02	1.12	-	-	-	-
Subtotal	**-**	**-**	**-**	**-**	**-**	**-**	**51.02**	**1.12**	**-**	**-**	**-**	**-**
Class Malacostraca												
Order Decapoda												
Family Palaemonidae	-	-	-	-	-	-	-	-	51.02	100.00	-	-
Subtotal	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**51.02**	**100.00**	**-**	**-**
Filo MOLLUSCA												

Taxonomic Groups	Itaquatiara				Gameleira		Várzea		São Domingos		Piauí	
	P1		P9		P12		P4		P7		P8A	
	org/m²	%	org/m²	%	org/m²	%	org/m²	%	org/m²	%	org/m²	%
Filo ARTHROPODA												
Class Gastropoda												
Family Planorbidae	-	-	-	-	-	-	153.06	3.37	-	-	-	-
Family Thiaridae	-	-	612.24	85.71	-	-	-	-	-	-	357.14	6.48
Subtotal	**-**	**-**	**612.24**	**85.71**	**-**	**-**	**153.06**	**3.37**	**-**	**-**	**357.14**	**6.48**
Filo ANNELIDA												
Class Oligochaeta												
Family Tubificidae	102.04	40.00	-	-	51.02	25.00	2,908.16	64.04	-	-	153.06	2.78
Family Opistocidae	-	-	-	-	-	-	51.02	1.12	-	-	-	-
Subtotal	**102.04**	**40.00**	**-**	**-**	**51.02**	**25.00**	**2,959.18**	**65.17**	**-**	**-**	**153.06**	**2.78**
Filo NEMATODA	51.02	20.00	-	-	-	-	-	-	-	-	-	-
Subtotal	**51.02**	**20.00**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Total	**255.10**	**100.00**	**714.29**	**100.00**	**204.08**	**100.00**	**4,540.82**	**100.00**	**51.02**	**100.00**	**5.510.20**	**100.00**

Data Table 5.2-85 – Numerical density (org/m²) and relative abundance of the benthic Community, in May/08.

Taxonomic Groups	Gameleira		Várzea				São Domingos		Piauí	
	P13		P4		P15		P7		P8A	
	org/m²	%	org/m²	%	org/m²	%	org/m²	%	org/m²	%
Filo ARTHROPODA										
Class Insecta										
Order Diptera										
Family Chironomidae	2,602.04	94.44	1.071.43	56.76	2,551.02	86.21	-	-	612.24	66.67
Family Ceratopogonidae	-	-	-	-	51.02	1.72	-	-	-	-
Subtotal	**2,602.04**	**94.44**	**1.071.43**	**56.76**	**2,602.04**	**87.93**	**-**	**-**	**612.24**	**66.67**
Sub-Filo CRUSTACEA										
Class Branchiopoda										
Order Anomopoda										
Family Macrothricidae	-	-	51.02	2.70	-	-	-	-	-	-
Subtotal	**-**	**-**	**51.02**	**2.70**	**-**	**-**	**-**	**-**	**-**	**-**
Filo MOLLUSCA										
Class Gastropoda										
Family Planorbidae	51.02	1.85	-	-	-	-	-	-	-	-
Subtotal	**51.02**	**1.85**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Class Oligochaeta										
Family Tubificidae	102.04	3.70	765.31	40.54	357.14	12.07	306.12	100.00	306.12	33.33

Taxonomic Groups	Gameleira		Várzea				São Domingos		Piauí	
	P13		P4		P15		P7		P8A	
	org/m²	%	org/m²	%	org/m²	%	org/m²	%	org/m²	%
Subtotal	**102.04**	**3.70**	**765.31**	**40.54**	**357.14**	**12.07**	**306.12**	**100.00**	**306.12**	**33.33**
Total	**2,755.10**	**100.00**	**1,887.76**	**100.00**	**2,959.18**	**100.00**	**306.12**	**100.00**	**918.37**	**100.00**

Figure 5.2-20 – Numerical Density of the Benthic Community (org/m²).

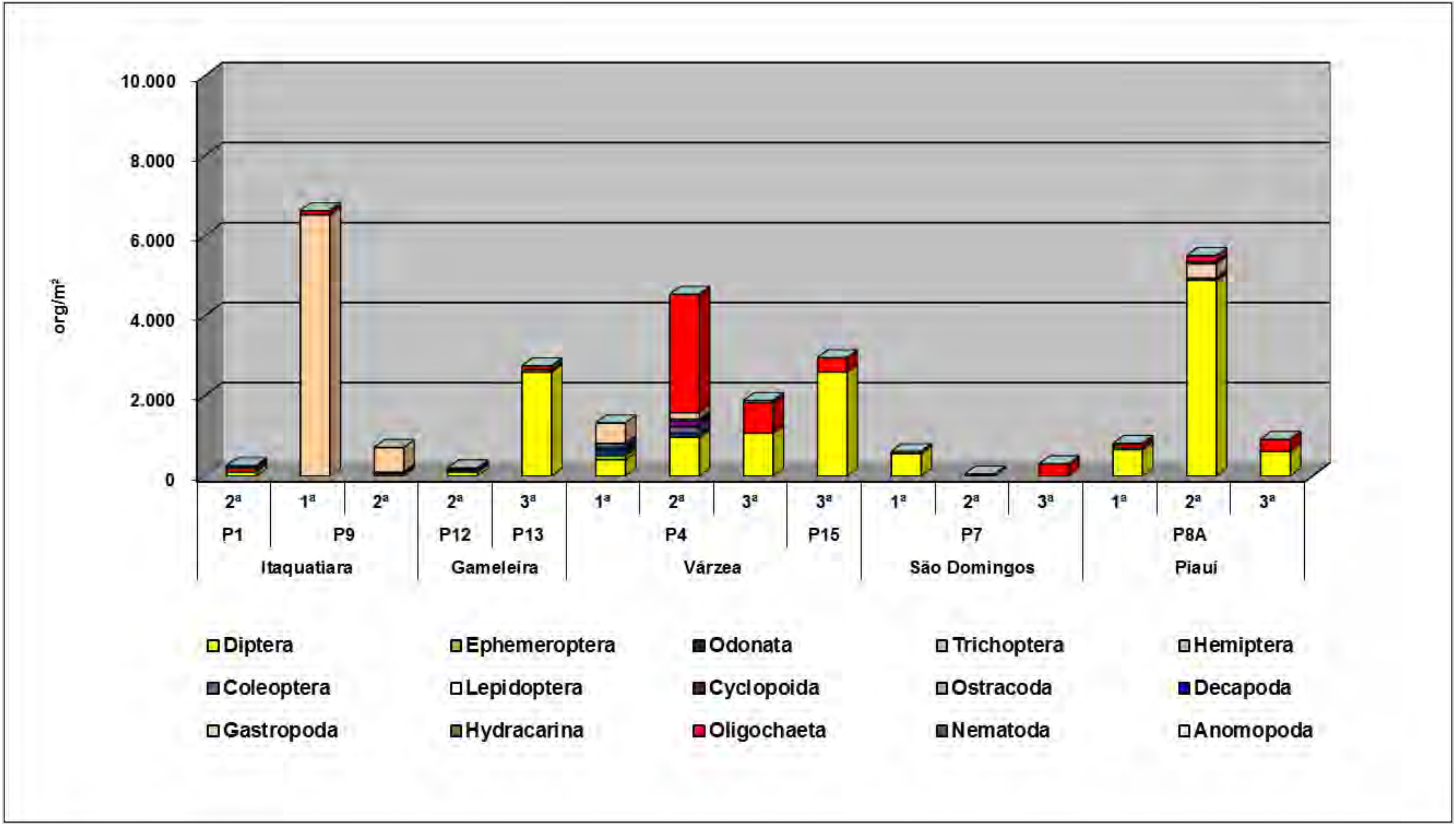
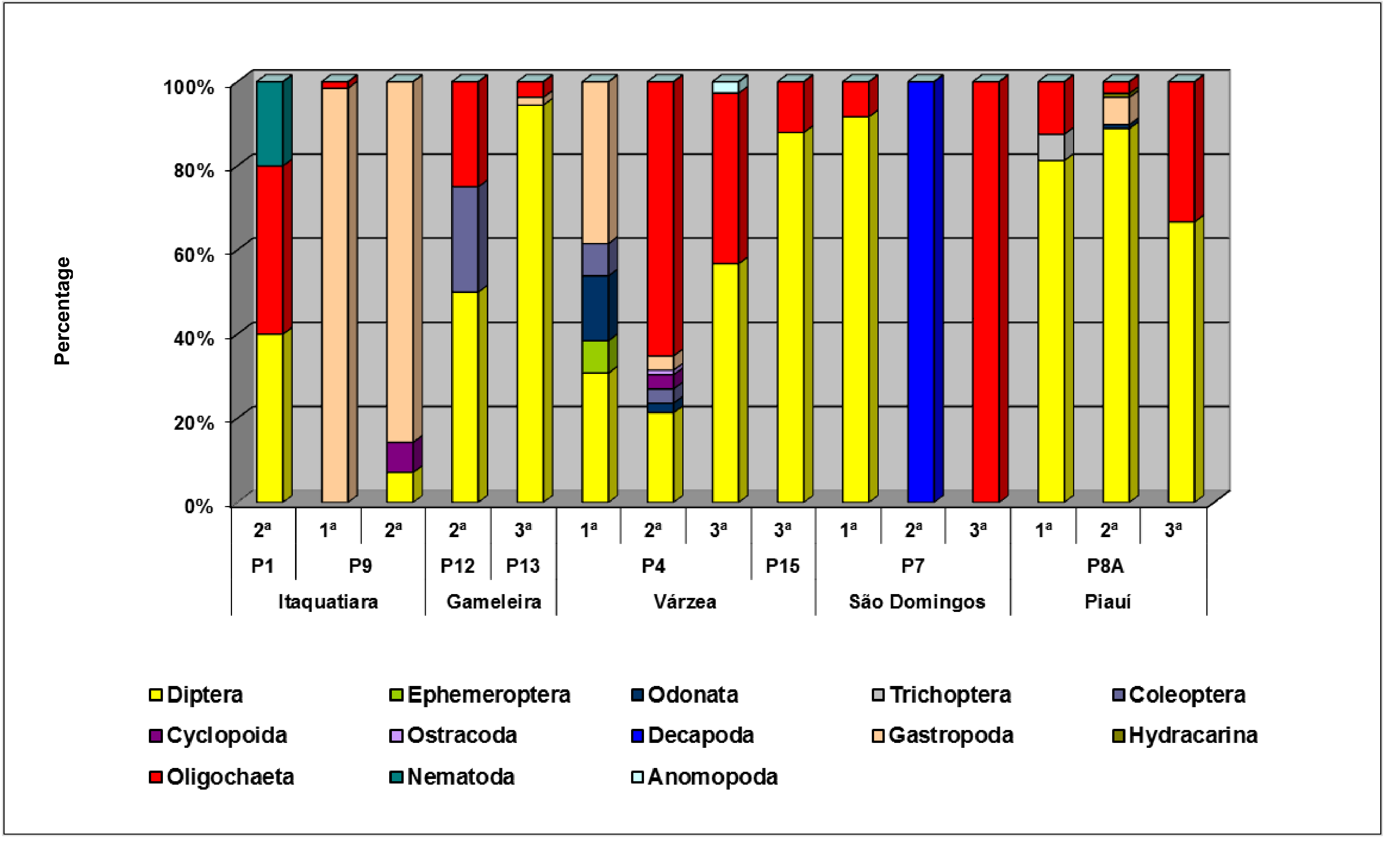


Figure 5.2-21 – Relative Abundance of the Benthic Community (%).



Analyzing the results of the diversity index of the zoobenthic community, it can be said, according to the classification of Wilhm & Dorris (1968), that the environments in question are, in general, under high environmental stress, typical of environments under anthropic influence. This condition may have been favored by the intermittent characteristics of the sampled environments.

Figure 5.2-22 – Zoobenthic Community Diversity and Equitability Index - 1st campaign.

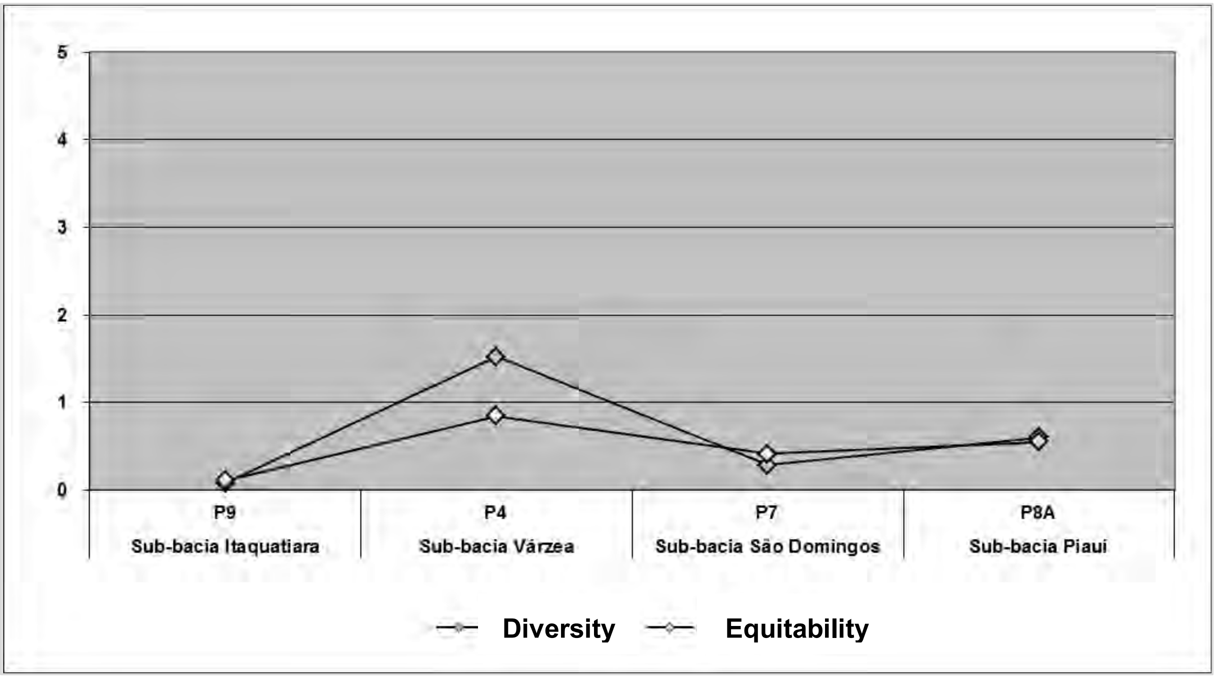


Figure 5.2-23 – Zoobenthic Community Diversity and Equitability Index - 2nd campaign

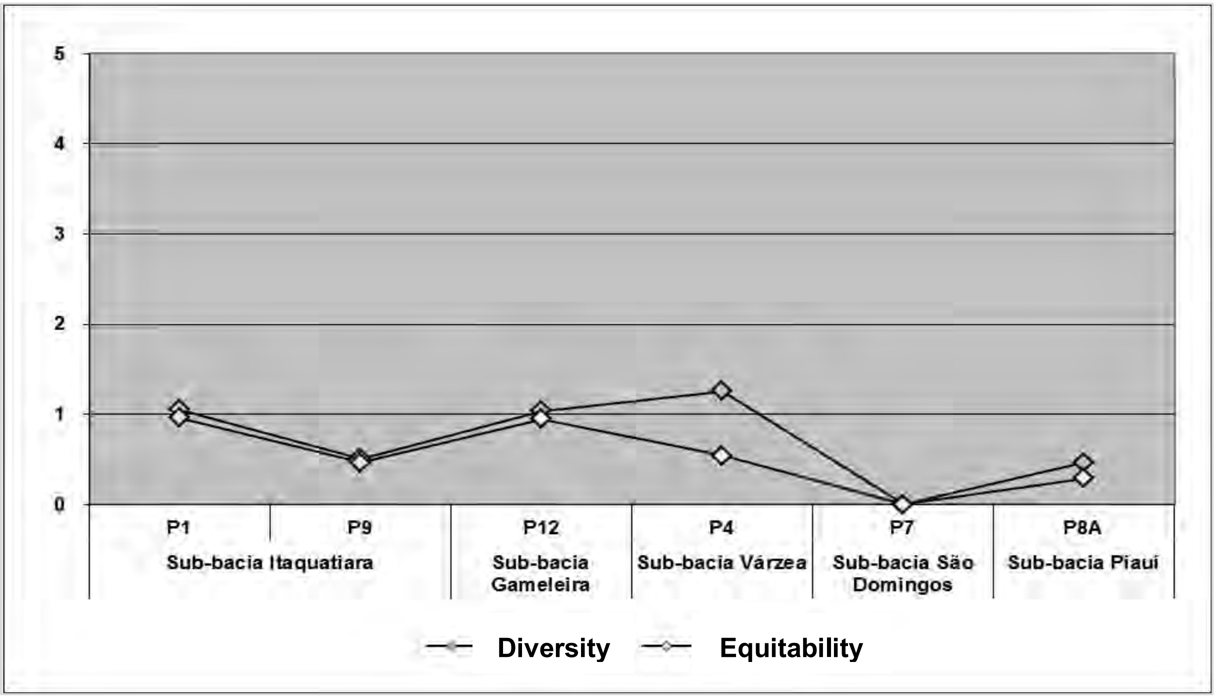
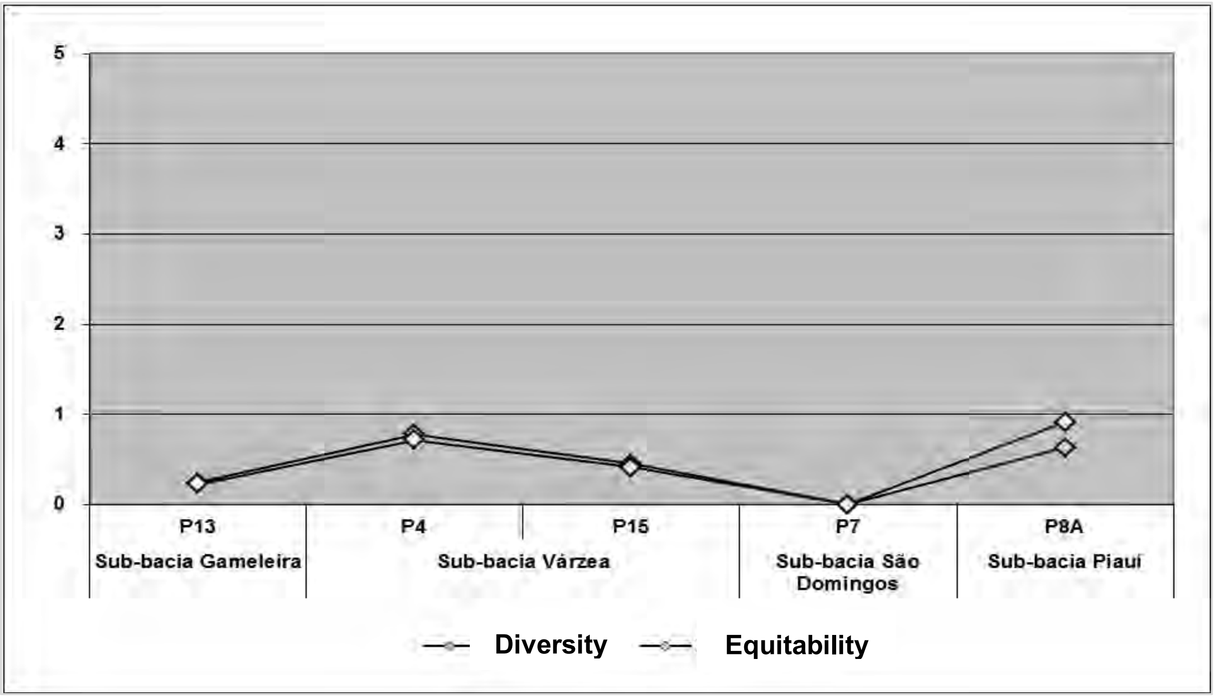


Figure 5.2-24 – Zoobenthic Community Diversity and Equitability Index – 3rd campaign



It should be noted that as it was not possible to identify organisms at the species level in the analysis of the benthic invertebrate macrofauna, it was not possible to assess whether any of them were described in the National List of Endangered Brazilian Fauna Species, as provided in Portaria No. 445 / 2014 (MMA, 2014).

C) Conclusions

The ecology of intermittent rivers differs substantially from permanent rivers. The main difference is in the strength that organizes these ecosystems. Rivers in Semi-arid regions suffer a much stronger influence from natural hydrological disturbances on their organization than rivers in humid and temperate regions.

The characteristics of flood and drought (intensity, duration, frequency and predictability) have important effects on the variation of the substrate that makes up the riverbed, on the concentration of nutrients in the waters, reflecting in the establishment of aquatic communities and in the patterns of ecological succession.

During the drought period, the dynamics that govern the establishment of aquatic organisms in intermittent rivers cease; the dry drainage channels assume the role of the adjacent soil use, especially pasture, also serving as regional access routes.

The reduction in runoff tends to break the connectivity of the regional water network, restricting the presence of water to ponds and dams, which start to behave as individualized aquatic systems. The structuring of aquatic communities is then influenced by localized factors, which determine the degree of salinity, eutrophication and water contamination.

With the advent of rains, this mosaic formed by ponds and dams is again articulated by the flow of water. In addition to the high concentration of diffuse organic and mineral materials in the sub-basins, intermittent drains become a direct vehicle for waste and other compounds that remain concentrated in its bed during the drought. The intense rainfall that occurs on land with high erosive potential also provides a considerable supply of solids from the drainage basin, increasing the levels of color and turbidity of the water.

Therefore, permanent rivers and also those regulated by dams become important recipients of this polluting load, as is the case of the Jenipapo dam. The accumulation of nutrients, combined with high temperatures and strong local sunlight, favor the blooming of algae, conditioning a cycle of eutrophication, common in the water reservoirs in the region.

Despite organisms considered resistant were found during the survey period, in all groups, some species that develop mainly in oligotrophic environments and are very sensitive to changes of anthropic origin in the environment were also noted. In the zoobenthic community, representatives of the EPT group (Ephemeroptera, Plecoptera and Trichoptera) stand out.

The order Ephemeroptera, currently composed of about 4,000 species (Biota Neotropica, 2004), constitutes the oldest group among the winged insects. Ephemeroptera nymphs are abundant and diverse, occupying most of the available meso-habitats, from backwater areas to those of strong current. This group represents an important link in the trophic chain of aquatic environments once it is largely herbivorous or detritivores and it serves as food for a number of predators, such as other insects and fish. Ephemeroptera are also included among the groups most used in water quality biomonitoring programs, due to their sensitivity to environmental pollution.

The main aspect associated with hydrobiological communities that can harm public health is the eutrophication of waters, which promotes the development of cyanobacteria. In the sampling network of the Piauí Nickel Project, the Jenipapo dam, which is expected to collect water for processing the ore, deserves attention, which presented considerably high densities of the cyanobacterium *Cylindrospermopsis raciborskii*. These organisms can produce toxins that cause problems to human and animal health.

Another factor that deserves attention is the presence in the water bodies of organisms that can host diseases, such as Culicidae, whose larvae were found in the Várzea and Itaquatiara creeks and some mollusks related to parasites, found in the Várzea, Itaquatiara and Caraíba creeks and also in the Jenipapo dam and downstream from it.

Thus, the local population that uses these water resources is vulnerable to waterborne diseases, either through direct water intake or through activities that require contact, such as housework, personal hygiene, leisure, among others.

5.3. Socioeconomic and Cultural Enviroment

5.3.1. Brief history of occupational development of municipalities of the ADI

The region where the municipalities considered as Area of Direct Influence of the Piauí Nickel Project are located has the origin of its occupation even in the 17th century with the introduction of cattle farms.

The region was initially occupied by Domingos Afonso Mafrense's farms, and after his death, his lands were donated to the Jesuits. The Jesuits, upon arriving at Conceição farm, built a house giving it the name Sobrado da Conceição. Colonists and adventurers came with them, resulting in constant conflicts with native tribe (known as the Tapu tribe). D.João Amorim Pereira, Governor of the Capitãocy of Piauí, ordered José Dias, known as Commander Zé Dias, to conquer the region of the current Municipality of São Raimundo Nonato, in which Indians, adventurers and colonists were in dispute and divided the lands among the members of his troop (IBGE Cities).

With a dynamic economy based on the livestock activity at its origin, and agriculture and extraction in the last two centuries, the municipality has been inhabited, since its colonial origins, mainly by families from Bahia and Pernambuco (fly-by-nights, tenants and squatters) and, more recently, by countless families from Ceará State affected by the drought. In the 19th century (1871/72) São João became an emancipated and isolated municipality of São Raimundo Nonato, becoming capitol of the district in 1874 and, finally, receiving the title of city in 1906 (ARCADIS Tetraplan, 2008).

The municipalities of Dom Inocêncio, Campo Alegre do Fidalgo and Capitão Gervásio Oliveira have more recent origins, such as the separation of the municipalities São Raimundo Nonato, in the case of the first, and São João do Piauí in the other two municipalities, resulting, therefore, in the same historic occupation of the original municipalities.

5.3.2. Territorial and Regional Dynamics

5.3.2.1. Geographical Insertion of the Project

The Piauí Nickel Project is located in the territory of the municipalities of Campo Alegre do Fidalgo, Capitão Gervásio Oliveira, Dom Inocêncio and São João do Piauí, in the southeastern portion of the state of Piauí close to the border with the states of Pernambuco and Bahia. This region belongs to the area of the Caatinga biome, where low precipitation, high solar radiation and high temperatures, result in a semi-arid climate where periods of drought usually cause great inconvenience to the population.

According to the territorial organization officially adopted by the government of the State of Piauí, the municipalities in the project's Area of Direct Influence are part of the Serra da Capivara Development Territory. The territorial division established by IBGE incorporates the municipalities to the Alto Canindé Microregions (Campo Alegre do Fidalgo, Capitão Gervásio Oliveira and São João do Piauí) and São Raimundo Nonato (Dom Inocêncio).

The region where the enterprise is outstanding for its rural characteristics, with the presence of properties aimed at small family farming with the breeding of animals (subsistence agriculture), mainly goats. In the Serra da Capivara area, outside the project's ADI, Cultural Heritage still stands out due to the presence of archaeological sites with rock paintings and engravings engraved on the sandstone walls, found in the Serra da Capivara National Park, considered a Cultural Heritage of Humanity by Unesco.

5.3.2.2. Cities Network and Functional Hierarchy

Understanding the dynamics of the urban network is essential for understanding the socioeconomic processes intrinsic to the region where the enterprise is located. Bearing in mind that this urban network is formed by several "Hubs" (corresponding to cities) through which there are both material and services processes flows. Among these Hubs, the areas with the most technical-scientific-informational dynamism stand out from the others, forming a true functional hierarchy of an urban network, where cities that lack equipment and services are polarized by others that are more dynamic, at different scales. Thus, in order to elucidate the theme of the functional hierarchy, this section will present a survey of the urban network and the functional hierarchy related to the municipalities in the region where the Piauí Nickel Project is located.

A) Methodological Considerations

For the characterization of the urban hierarchy in which the municipalities affected by the Piauí Nickel Project are located, the study of Regions of Influence of Cities – REGIC was used, prepared by the Brazilian Institute of Geography and Statistics - IBGE in 2007, as well as the results of the study Regional Urban Division, presented in June 2013.

In 2007, following work that has been going on since the 1960s, IBGE investigated the conFiguretion and profile of the Brazilian urban network and constructed a map of the polarization of Brazilian cities, with the objective of "subsidizing state planning and decisions regarding the location of economic activities of production and consumption, as well as providing tools for understanding social relations and the social patterns that emerge from them" (IBGE, 2008).

The criteria adopted by the study allow visualization of integration between cities, outlining their areas of influence and clarifying the articulation of networks in the territory through the hierarchy of urban centers according to their role in the country's urban network. The hierarchy of urban centers benefits the territory's management function "assessing levels of centrality of the Executive and Judiciary Powers at the federal level, and of business centrality, as well as the presence of different equipment and services." (IBGE, 2008 p. 11). According to REGIC, a territorial management center is characterized as

> [...] that city where, on the one hand, exist various departments of the State and, on the other, the headquarters of companies whose decisions are directly or indirectly influenced by the scope of control of the city through those companies' headquarters (CORRÊA, 1995, p. 83 apud IBGE, 2008).

In this way, it is possible to define a territorial management center as a center for equipment and materials or services that directly or indirectly affects other territorial units, forming, depending on its centralization, and area of influence proportional to the extent of its supply of equipment, material and services.

In summary, factors such as financial dynamics, equipment and services, the offer of higher education, health and internet services, as well as the availability of open television and air transport networks were considered in REGIC.

Based on this information, the urban network was hierarchized in several orders of magnitude: Great National Metropolis (most influential), National Metropolis, Metropolis, Regional Capital A, Regional Capital B, Regional Capital C, Sub-regional Center A, Sub Center -Regional B, Center of Zone A, Center of Zone B, and finally, the least influential category: Local Center.

Based on REGIC, IBGE presented in 2013 the Regional Urban Division - DUR of the country that is defined as

> [...] a territorial outline at three different scales that covers the entire national territory. In this division, each region created is contiguous and each municipality belongs to a single territorial unit. An inherent specification of the work is the identification of a primary municipality for each region. Because it is based on the urban network, its limits are not restricted to state borders. (IBGE, 2013)

In this way, the study of the Regional Urban Division presented the regions at three scales named as: Extended Regions of Urban Articulation, of a more comprehensive scale and totaling 14 regions; Intermediate Regions of Urban Articulation, as the name itself highlights of intermediate scale, 181 in total being identified; and Immediate Urban Articulation Regions, of a more local scale and with a total of 482 regions.

For the Expanded Regions of Urban Articulation the study highlights

> [...] which have the merit of revealing in the national territory the role of geography following socioeconomic flows in the continuous process of structuring the national territory. In effect, these 14 regions expose the control of the main cities over the national territory, thus diminishing the borders of the 26 states and the Federal District. (IBGE, 2013)

The Urban Articulation Intermediate Regions are the result of the subdivision of the Extended Regions and are characterized by

> [...] ability to polarize a large number of municipalities by the provision of highly complex goods and services. They concentrate public and private management activities and link, at the regional scale, private bodies and companies. (IBGE, 2013)

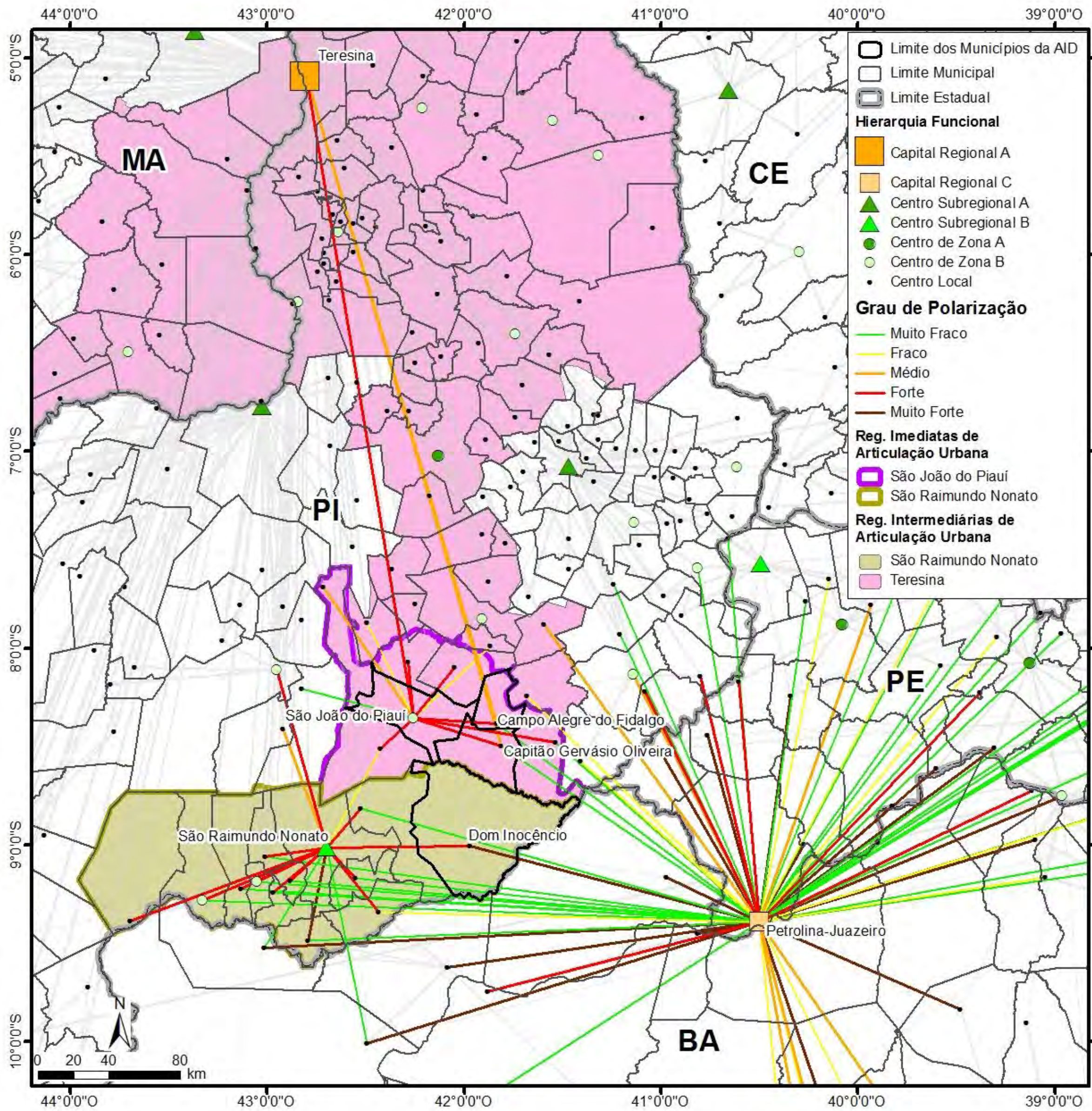
And the Immediate Urban Articulation Regions, with a smaller scale of coverage, stand out for having

> [...] in general, links that reflect accessibility and the ability to meet more limited demands. The regions of this level largely reflect the area lived by the population and their daily displacement to supply and search for common goods and services (IBGE, 2013).

B) The network of cities in Region of Insertion of the Entreprise

From the analysis of the information contained in the REGIC and the Regional Urban Division, it was possible to identify the hierarchical level of the municipalities affected by the Piauí Nickel Project in the urban network, as well as the region of influence in which they are located, also considering the degree of polarization between the centers of different hierarchical levels of the network to which they belong (Map 5.3-1).

Map 5.3-1 – Urban hierachy in the area of influence of the entreprise



Source: REGIC-IBGE, 2008.

As shown in Map 5.3-1 (above), in the Area of Direct Influence of the enterprise, the municipalities of Campo Alegre do Fidalgo, Capitão Gervásio Oliveira and Dom Inocêncio are characterized as Local Centers, and the municipality of São João do Piauí, in turn, is defined as a Zone B Center.

With regard to the Urban Articulation Regions, it is observed that São João do Piauí is the hub of an Immediate Region, which includes the municipalities of Campo Alegre do Fidalgo and Capitão Gervásio Oliveira and which is subordinate to the Intermediate Region of Teresina. Dom Inocêncio in turn is located in the Intermediate Region of São Raimundo Nonato. The Intermediate Regions of Teresina and São Raimundo Nonato are part of the Expanded Urban Articulation Region of the metropolis Fortaleza, which includes the states of Ceará, Maranhão, Piauí, part of Rio Grande do Norte and some municipalities of Pernambuco and Piauí.

It is worth noting in the region the presence of the Capital of Petrolina-Juazeiro, which, although not directly in the urban network of ADI municipalities, as it is the closest regional capital to ADI, ends up exerting influence over these municipalities, especially with regard to businesses and private services.

One way to differentiate the hierarchical levels of the lower level centers is to analyze the diversity of the sectors of commerce and services present in each of them. Diversity can be measured by the number of classes in these sectors found in each center. Another important point of differentiation in these less complex locations is based on the analysis of the banking network present.

In this sense, based on REGIC data, it is observed that local centers have a low diversity of shops and services. In the case under analysis, only four classes are seen in Campo Alegre do Fidalgo and Capitão Gervásio Oliveira, and twelve in Dom Inocêncio. As for the banking network, only Dom Inocêncio has a branch, the rest being dependent on the hub cities. São João do Piauí as the primary municipality of the region has a more dynamic structure, with 53 classes of shops and services, four banks, although it does not have structures of a federal management center, characteristic of more developed hubs and of higher levels like São Raimundo Nonato.

Regional Capital C Petrolina-Juazeiro polarizes part of the states of Pernambuco, Bahia and Piauí. This hub, according to REGIC, has good diversification of trade and services (180 classes), as well as a banking network (nine banks). In relation to the municipalities of ADI, the Petrolina complex has a strong connection with the municipality of Dom Inocêncio, although it also presents flows with the municipalities of Campo Alegre do Fidalgo and Capitão Gervásio Oliveira.

5.3.2.3. Accessibility and Tranport Conditions

The region where the project is located has few access options, the road system being practically the only choice, given the absence of rail lines and the low utilization of the airport located in the municipality of São Raimundo Nonato.

Thus, in order to access the area of the location of the enterprise, starting from more distant locations, one must seek the main centers of the region, Teresina and Petrolina, which have adequate airport structure and regular commercial flights.

To reach the project's ADI from Teresina, about 380 km in a straight line, or 480 km by road, the main roads to be used are the the federal BR-343 (Teresina to Floriano), the State road PI -140 (Floriano à Brejo do Piauí), PI-141 (Brejo from Piauí to São João do Piauí, BR-020).

To access the Piauí Nickel Project area from Petrolina, about 240 km away, take the BR-407 road towards Picos, following 106 km to the city of Afrânio, Pernambuco. In Afrânio, take the road on the left to Queimada Nova, in Piauí, about 57 km away, and from there for another 42 km to Lagoa do Barro. From Lagoa do Barro to Capitão Gervásio there is another 33.4 km. From this point to São João do Piauí there is another 62 km through the state road PI-465.

BR-020 is the main road in the region, connecting São João do Piauí and São Raimundo Nonato, and connects with PI-465 that connects the municipality of São João do Piauí to Campo Alegre do Fidalgo and Capitão Gervásio Oliveira. The city of Dom Inocêncio is the one that is most distant from the others of the ADI, with access to it only by unpaved roads, PI-465 (natural bed) starting from Capitão Gervásio Oliveira or PI-144 (partially laid and natural bed) leaving BR-324, in São Lourenço do Piauí, and connecting with BR-020 in São Raimundo Nonato.

The path through Petrolina, taken by the Arcadis team that carried out primary data surveys in November 2016, presented roads in good running conditions in almost the entire stretch, with paving in good condition and satisfactory horizontal and vertical signs.

The main roads in the region have as their main feature the presence of animals, especially goats and donkeys, on the margins of highways and roads, representing a very relevant risk point, because, in different situations, animals cross the roads or even walk along the lanes.

PI-465, the main link between the municipalities of São João do Piauí, Campo Alegre do Fidalgo and Capitão Gervásio, and which will be used to transport goods inwards and production from the project located in Capitão Gervásio, was traveled at the time of primary surveys, in the section from the junction with the BR-020 to the municipality of Capitão Gervásio.

The PI-465 is configured on a single road with one traffic lane in each direction. Pavement preservation requirements and road signs are present throughout the section covered. In this section, visual observations of the flow of vehicles were made, even if not of a statistical nature or for the purpose of classificatory counting, at different times for about a week, and no significant flows were observed.

Along PI-465, the São José and the Eugênio settlements, and the small community called Povoado Grajaú.

Photo 5.3-1 – Animals on the road BR-020, near to Nova Santa Rita town.

Photo 5.3-2 – Donkey on the road PI-465, near to Campo Alegre do Fidalgo town.

Photo 5.3-3 – Animals on the shoulder of the road PI-465, near to São João do Piauí town.

Photo 5.3-4 – Dunkey on the road PI-465, near to Campo Alegre do Fidalgo town.

Photo 5.3-5 – Road PI-144 section located in Dom Inocêncio town.	Photo 5.3-6 – PI-465 Natural Bed between Dom Inocêncio and Capitão Gervásio Oliveira.
	

Source: Arcadis, 2017.

5.3.3. Population Dynamics

5.3.3.1. Methodological Consideration

For the analysis of demographic dynamics, quantitative data provided by the Brazilian Institute of Geography and Statistics (IBGE) were used, with the Census of 1991, 2000 and 2010 being the main sources of study.

The method adopted for calculating rates, ratios and geometric growth was the same used by IBGE, already approved by Brazilian Social Science Society in population studies. In relation to the migratory balance, the estimate occurred with the comparison of the demographic growth and the vegetative growth, from the analysis of the vegetative balance (data from DATASUS - Ministry of Health), thus it was possible to measure the volume of migration (from the difference between population variation and vegetative balance) in municipalities and the state.

5.3.3.2. Area of Indirect Influence (AII)

A) Size and Distribuition of the Population

The municipality of Petrolina, state of Pernambuco, the Area of Indirect Influence of the enterprise, is characterized by its large population and for being the primary municipality of the region extending beyond the state border and covering part of the states of Piauí and Bahia.

In 2016, according to an IBGE estimate, the municipality had a population of 331.9 thousand inhabitants, having presented a considerable population growth compared to that observed in the 2010 Census. Table 5.3-1 shows the territorial area and the size of the population of Petrolina, according to data from the 2010 Census and Population Estimation 2016.

Data Table 5.3-1 –Total, Urban and Rural Population, Territorial extension and Demographic Density of the municipality of AII.

Territorial Unit	Territorial Extention (km²)	Total Population		Urban Population	Rural Population	Demographic Density (population/ km²)	
		2016	2010	2010	2010	2016	2010
Petrolina	4,562	331,951	293,962	219,172	74,790	72.8	64.4

Source: Brazilian National Institute of Statistics (IBGE), 2010 and 2016. Organized by: Arcadis, 2017.

The demographic density in Petrolina (72.8 inhabitants / km²), as shown in Table 5.3-1, can be considered quite high, especially when compared to the average of the ADI municipalities, presented below. Regarding the spatial distribution, it is observed that the municipality is essentially urban, with about 75% of the population living in the urban areas of the municipality, as shown in Table 5.3-2.

Data Table 5.3-2 – Evolution of urbanization rate of AII - 1991, 2000 e 2010.

Territorial Unit	Urbanization Rate		
	1991	2000	2010
Petrolina	71.4%	76.1%	74.6%

Source: Brazilian National Institute of Statistics (IBGE), 2010 and 2016. Organized by: Arcadis, 2017.

Observing the evolution of the urbanization rate in Petrolina, it appears that it presented a slight variation in the analyzed period, showing a slight growth between 1991 and 2000 and then a slight decrease in the following decade.

5.3.3.3. Area of Direct Influence (ADI)

A) Size and Distribuition of Population

The municipalities in the Area of Direct Influence of the enterprise are characterized by a small population, with the municipality of São João do Piauí being the most populous.

In all municipalities, it can be observed that the IBGE indicated for the year 2016 a slight population growth in comparison to that observed in the 2010 Census. Table 5.3-3 presents the territorial area and the size of the population of the ADI municipalities according to the data of the 2010 Census and Population Estimation 2016.

Data Table 5.3-3 – Total, Urban and Rural Population, Territorial extension and Demographic Density of the municipality of the ADI.

Territorial Unit	Territorial Extention (km²)	Total Population		Urban Population	Rural Population	Demographic Density (population/ km²)	
		2016	2010	2010	2010	2016	2010
Campo Alegre do Fidalgo	658	4,935	4,693	1,224	3,469	7.5	7.1
Capitão Gervásio Oliveira	1,134	4,021	3,878	1,162	2,716	3.5	3.4
Dom Inocêncio	3,870	9,396	9,245	2,018	7,227	2.4	2.4
São João do Piauí	1,528	20,206	19,548	13,470	6,078	13.2	12.8
Piauí	251,612	3,212,180	3,118,360	2,051,074	1,067,286	12.8	12.4

Source: Brazilian National Institute of Statistics (IBGE), 2010 and 2016. Organized by: Arcadis, 2017.

The demographic density in the municipalities of Campo Alegre do Fidalgo, Capitão Gervásio Oliveira and Dom Inocêncio, as shown in Table 5.3-3, can be considered low when compared to the average of the municipalities in the state (12.4 inhabitants per km²). In turn, the municipality of São João do Piauí showed a density slightly higher than the state average with 12.8 inhabitants per km².

Regarding spatial distribution, it is observed that, with the exception of São João do Piauí, which has just under 70% of urban population, the municipalities of ADI, even in 2010, presented urbanization rates well below the average of the state of Piauí, which was 65.8%, with only between 20 and 30% of its population living in urban areas, as shown in Table 5.3-4 and Graph 5.3-1.

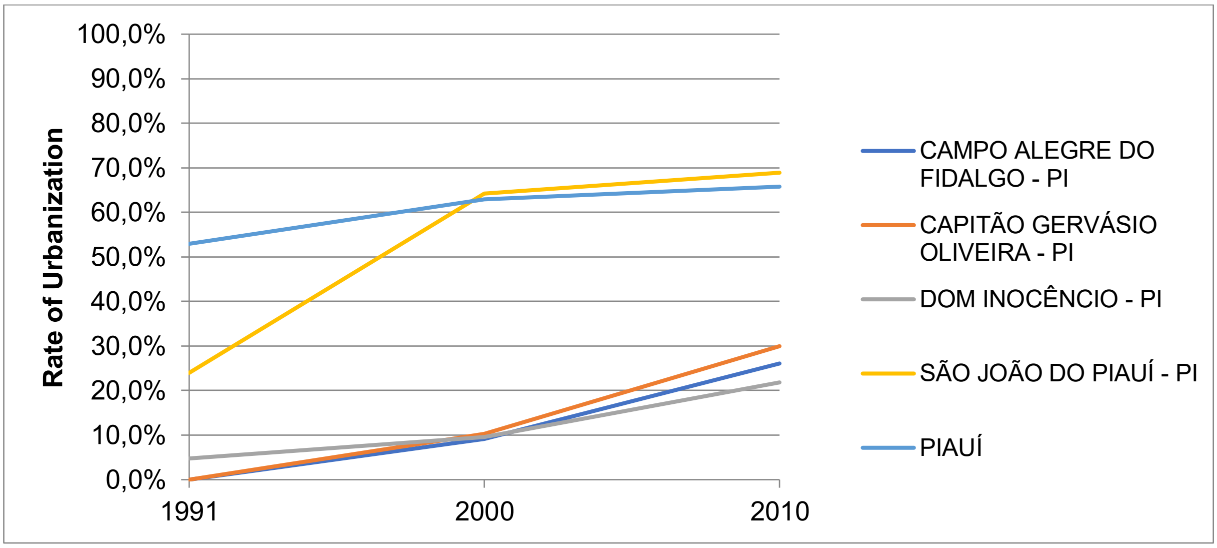
Data Table 5.3-4 – Evolution of urbanization rate of the ADI - 1991, 2000 e 2010.

Territorial Unit	Urbanization Rate		
	1991	2000	2010
Campo Alegre do Fidalgo	-	9.2%	26.1%
Capitão Gervásio Oliveira	-	10.3%	30.0%
Dom Inocêncio	4.8%	9.6%	21.8%

Territorial Unit	Urbanization Rate		
	1991	2000	2010
São João do Piauí	24.0%	64.3%	68.9%
Piauí	52.9%	62.9%	65.8%

Source: Brazilian National Institute of Statistics (IBGE), 2010 and 2016. Organized by: Arcadis, 2017.

Graph 5.3-1 – Evolution of urbanization rate of the ADI municipaties and Piaui State - 1991, 2000 and 2010.



Source: Brazilian National Institute of Statistics (IBGE), 2010. Organized by: Arcadis, 2017.

In the evalution of the urbanization rate in the the ADI, it appears that all the municipalities of the ADI presented an advance of urbanization, with the municipalities of Campo Alegre do Fidalgo, Capitão Gervásio Oliveira and Dom Inocêncio having more than doubled this percentage in the analyzed period, although they are still essentially ruralized municipalities. São João do Piauí showed a strong growth in the urban population between 1991 and 2000, which was more contained in the following decade.

In the state of Piauí, the growth of the urban population was at a more restrained pace in the analyzed period, with only 3% in the last decade being very low.

B) Population Growth

Table 5.3-5 shows the population growth in the municipalities of the ADI and in the state of Piauí between the years 1991 and 2010, presenting data on the urban and rural population, and the respective geometric annual growth rates (TGCA[11]).

Data Table 5.3-5 – Evolution of the Total, Urban and Rural Population of the ADI municipalities and Piaui State – 1991 to 2010.

Territorial Unit	Population	1991	2000	2010	Variation % 1991-2000	Variation % 2000-2010	TGCA	
							1991-2000	2000-2010
Campo Alegre do Fidalgo	Total	-	4,451	4,693	-	5.4%	-	0.53%
	Urban	-	410	1,224	-	198.5%	-	11.56%
	Rural	-	4,041	3,469	-	-14.2%	-	-1.51%
Capitão Gervásio Oliveira	Total	-	3,492	3,878	-	11.1%	-	1.05%
	Urban	-	358	1,162	-	224.6%	-	12.49%
	Rural	-	3,134	2,716	-	-13.3%	-	-1.42%
Dom Inocêncio	Total	8,992	8,909	9,245	-0.9%	3.8%	-0.10%	0.37%
	Urban	428	856	2,018	100.0%	135.7%	8.01%	8.95%
	Rural	8,564	8,053	7,227	-6.0%	-10.3%	-0.68%	-1.08%
São João do Piauí	Total	38,172	17,670	19,548	-53.7%	10.6%	-8.20%	1.02%
	Urban	9,155	11,353	13,470	24.0%	18.6%	2.42%	1.72%
	Rural	29,017	6,317	6,078	-78.2%	-3.8%	-15.58%	-0.38%
Piauí	Total	2,582,137	2,843,428	3,118,360	10.1%	9.7%	1.08%	0.93%
	Urban	1,367,184	1,788,330	2,051,074	30.8%	14.7%	3.03%	1.38%
	Rural	1,214,953	1,055,098	1,067,286	-13.2%	1.2%	-1.56%	0.11%

Source: Brazilian National Institute of Statistics (IBGE), 2010 and 2016. Organized by: Arcadis, 2017.

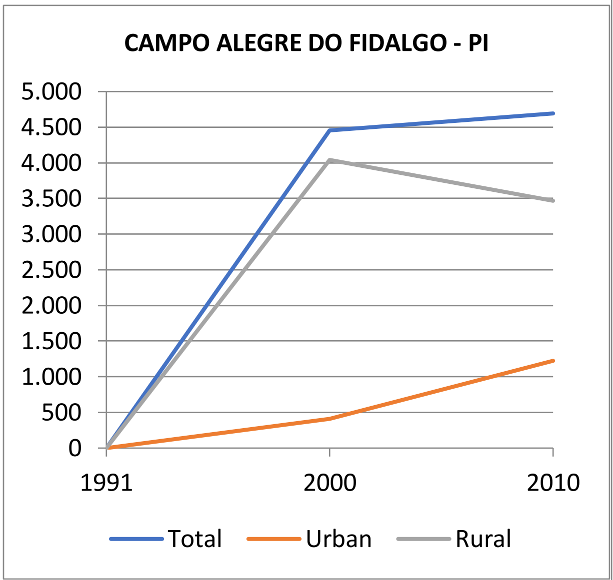
The population growth in the municipalities of the ADI presented two situations, one found in the municipality of São João do Piauí and the second in the other municipalities. In São João do Piauí, given the loss of part of its territory during the 1990s, there was a significant drop in its rural population in the analyzed period which, even with the expansion of the urban

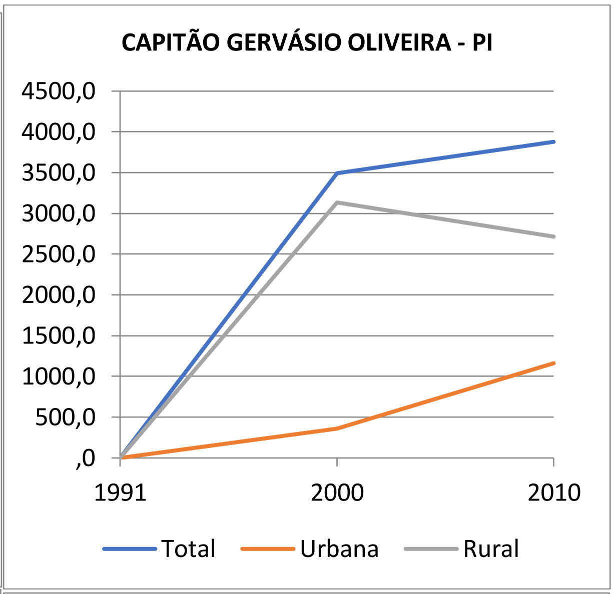
[11] TGCA is obtained by the formula: $r = \left[\left(\sqrt[n]{\frac{P_t}{P_0}} - 1\right)\right] x100$, where: r = geometric annual growth rate (TGCA); Pt = final population; P0 = initial population; n = number of years between surveys.

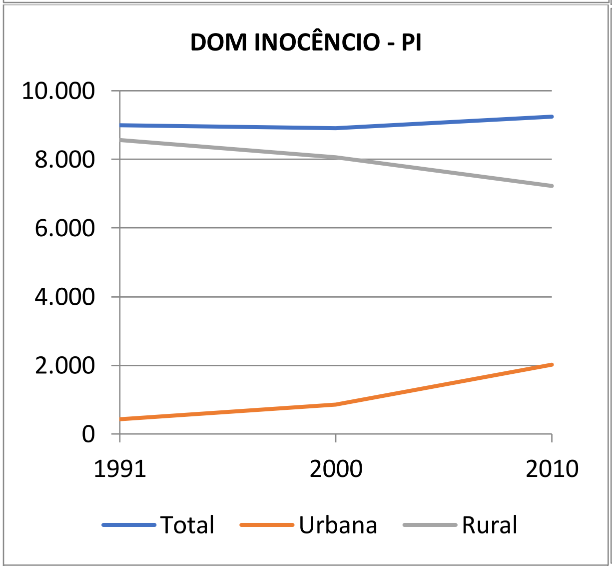
population, resulted in a decrease of just under 50% of its population between 1991 and 2010. The other municipalities of the ADI showed slight population growth in the analyzed period, being this restricted to urban areas, in view of the decrease of the rural population until the year 2010.

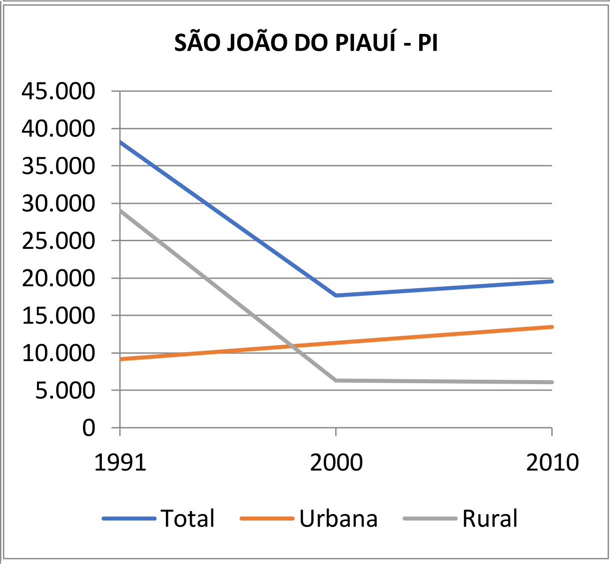
In the state of Piauí, population growth occurred similarly in the two decades analyzed, mainly due to urbanization, because the total rural population varied negatively (-13.2%) between 1991 and 2000 and the low growth of the decade (1.2%) did not replace the rural population lost in the previous decade. The urban population, on the other hand, showed a strong growth throughout the period (about 50%), especially between 1991 and 2000 when it presented a TGCA of 3%. In Graph 5.3-2, this information is better presented.

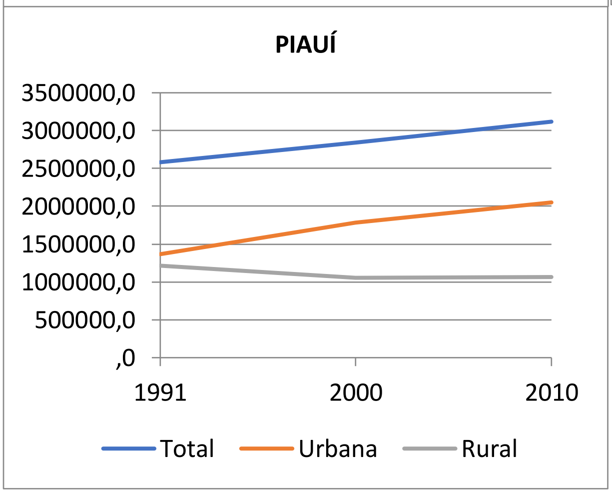
Graph 5.3-2 - Evolution of the Total, Urban and Rural Population of the ADI municipalities and Piaui State – 1991 to 2010.











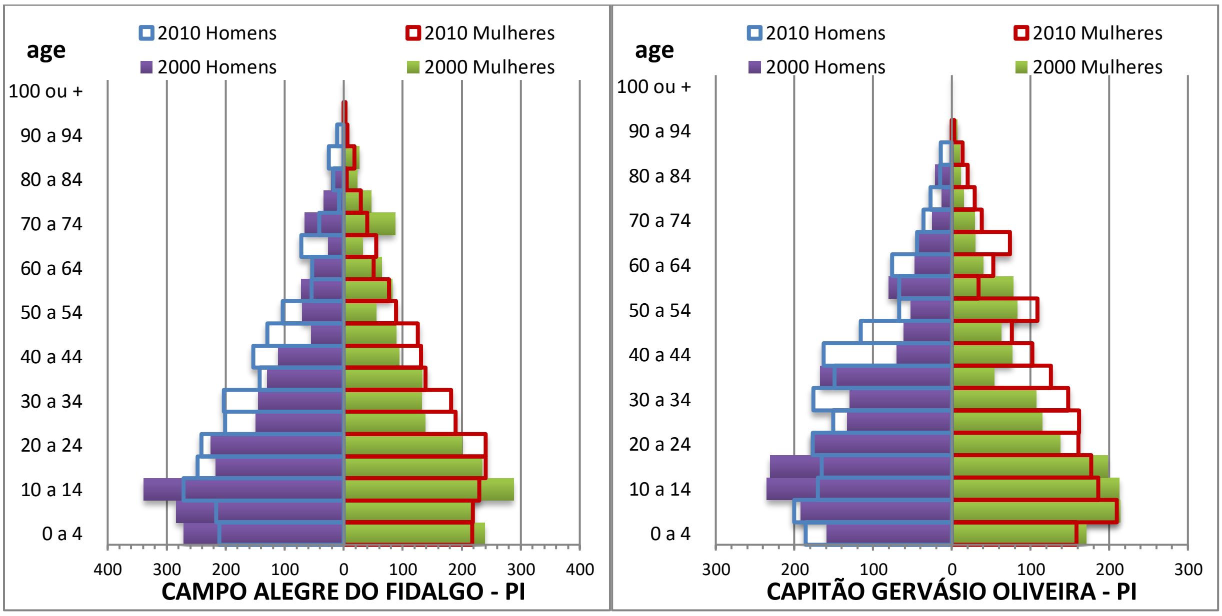
Source: Brazilian National Institute of Statistics (IBGE), 2010 and 2016. Organized by: Arcadis, 2017.

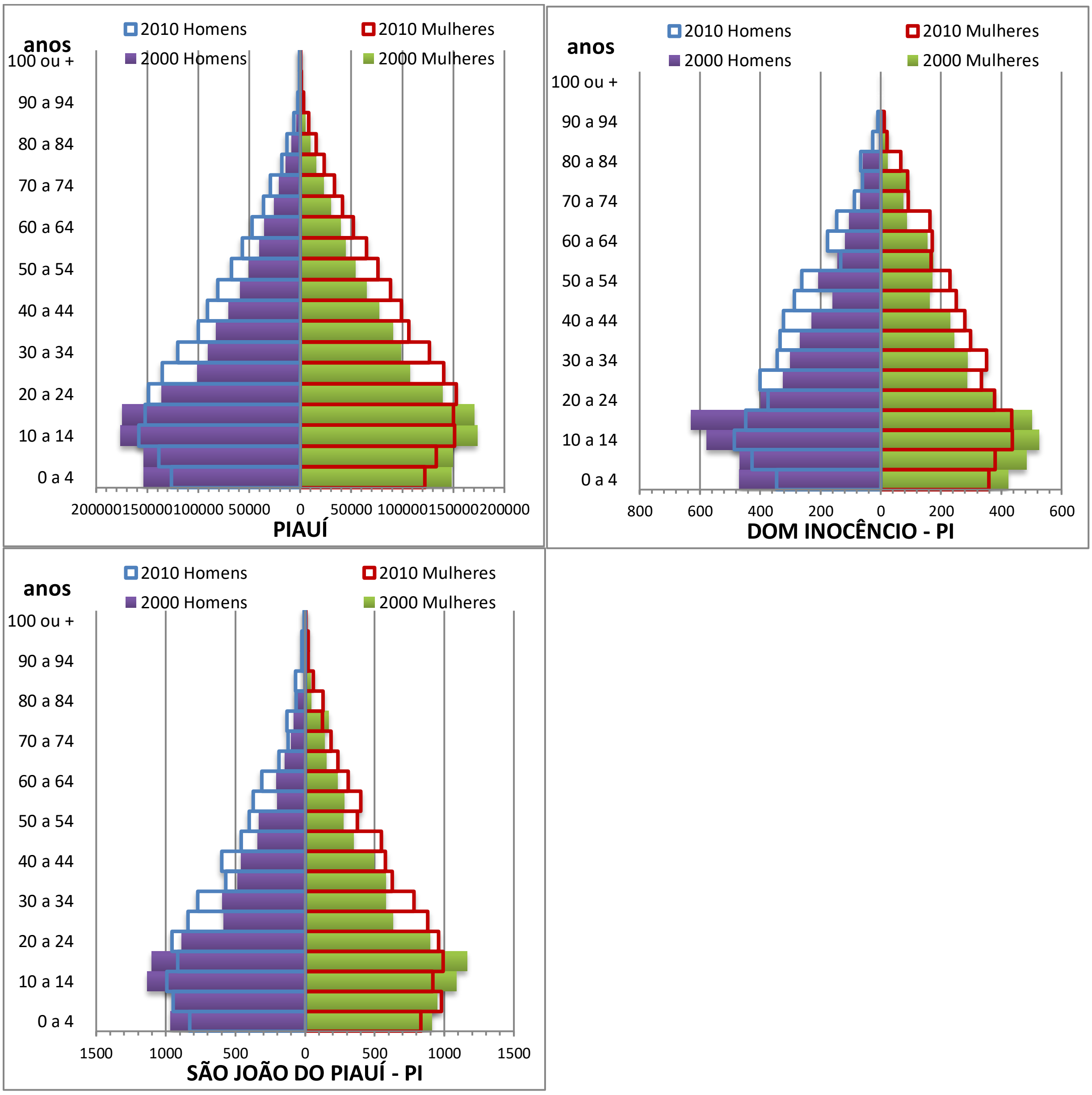
C) Population Compostion

The research on the composition of the population discloses the proportion of men and women in a place and also the age profile, providing bases for the assessment of the proportionality of young people and the elderly in the total population.

The age pyramids in Graph 5.3-3, provide information on the composition of the population of ADI and the state of Piauí, enabling comparison and understanding of the evolution of this aspect of population dynamics in the last ten years.

Graph 5.3-3 – Age Pyramids of the Municipalities of the ADI and Piauí - 2000 and 2010.





Source: Brazilian National Institute of Statistics (IBGE), 2010. Organized by: Arcadis, 2017.

The age pyramids referring to the population of the municipalities of the ADI and Piauí in the years 2000 and 2010 show that there was a predominance of the young population, since a large part of the population was in the age group of 5 to 19 years.

Although they still have a relatively young population, evaluating the variation between the years 2000 and 2010, it is observed that the municipalities of the ADI and Piauí showed a very similar evolution, with the narrowing of the base and the widening of the upper bands of the pyramids (adult and elderly population), indicating that the municipalities and the state are in the process called demographic transition, which according to Cerqueira & Givisiez (2004) are the important changes in the population volume in which developing countries have been, especially in their age structure, as a consequence of the process of reducing fertility and mortality levels, a process started in Brazil since 1960.

Regarding the division by sex, it is observed that in the smaller municipalities, Campo Alegre do Fidalgo, Capitão Gervásio Oliveira and Dom Inocêncio, there is a slight predominance of the male population up to 70 years old, and from the age of 70 the situation is reversed with the population majority being women in the municipalities. In São João do Piauí and in the state the situation is different, with the female population being the majority in almost all age groups.

D) Migration Flow

The migratory balance during the last decade, the relationship between people who started to live (immigrants) in the municipalities of the ADI and in the state of Piauí and those who moved from them (emigrants), was obtained as presented in the methodological considerations, and the results are shown in Table 5.3-6.

Data Table 5.3-6 – Total Growth, Vegetative Balance and Migration Balance of the municipalities of the ADI and Piauí - 2000 and 2010.

Territorial Unit	Population Variation 2000 to 2010	Natural Balance		Migration Balance	
		Absolute Numbers	Variation of population Natural Growth (%)	Absolute Numbers	% of Population Growth
Campo Alegre do Fidalgo	242	596	246.3%	-354	-146.3%
Capitão Gervásio Oliveira	386	512	132.6%	-126	-32.6%
Dom Inocêncio	336	804	239.3%	-468	-139.3%
São João do Piauí	1,878	2,893	154.0%	-1,015	-54.0%
Piauí	274,932	399,905	145.5%	-124,973	-45.5%

Sources: MS / SVS / DASIS - Information System on Live Births - SINASC and Mortality Information System - SIM, 2001 to 2010. Brazilian Institute of Geography and Statistics (IBGE), 2010. Elaboration: Arcadis, 2017.

According to the estimates presented, the migratory balance between 2000 and 2010, was found for both the ADI municipalities and Piauí to be negative, that is, they had more emigrants than immigrants. This means that, as a cobsequence of reporting population growth in absolute numbers, the number of babies born to mothers living in the municipalities and the state in the period was higher. Although the situation was similar in all the administrative units analyzed, it is observed that in Campo Alegre do Fidalgo and Dom Inocêncio the migratory loss was relatively more intense than in the others.

Analyzing the most recent migratory dynamics in the ADI municipalities, it can be seen in Table 5.3-7 that in 2010, even though all municipalities had a migratory flow of population loss, some residents (from 1.8% to 5.7%) had lived there for less than five years, demonstrating that they were attracted to these municipalities in a recent period.

Table 5.3-7 – People aged 5 or over who were accounted for in the 2010 Census who did not reside in ADI Municipalities on 7/31/2005.

Municipalities	Total Population - 2010	Residents after 31/Jul/2005	
		Residents	% do Total
Campo Alegre do Fidalgo	4,693	268	5.7%
Capitão Gervásio Oliveira	3,878	69	1.8%
Dom Inocêncio	9,245	306	3.3%
São João do Piauí	19,548	938	4.8%

Source: Brazilian National Institute of Statistics (IBGE), 2010 . Organized by: Arcadis, 2017.

5.3.4. Economic Dynamics

5.3.4.1. Methodological Considerations

This item aims to analyze the production and services structure of the municipalities in the areas of influence of the Piauí Nickel Project. The data referring to the State of Piauí was also evaluated, considering that it is the state where the project is intended to be implemented, offering a comparative reference base for the municipalities of the ADI and AII.

Certain macroeconomic aggregates are analyzed, such as the Gross Domestic Product (GDP[12]), the GDP per capita and the Added Value (VA) of the three major sectors of the economy: Agriculture, Industry and Commerce, and Services, with the Public Administration services being presented separately. Finally, an analysis has been carried out of the occupational structure in these municipalities, using the Economically Active Population (PEA) and formal jobs by sector of economic activity.

For the survey and analysis of quantitative data, the data provided by the Brazilian Institute of Geography and Statistics (IBGE) were used, with the survey of the Gross Domestic Product of the Municipalities and the 2000 and 2010 Censuses being the main sources of study. For formal employment data, those provided by the Ministry of Labor and Employment (MTE) through the Annual List of Social Security Information (RAIS) were used.

The public finances of the municipalities of the ADI were also evaluated. For this purpose, the material used was made available by the National Treasury Secretariat (STN), which presents

[12] In 2015, IBGE presented a new methodology for calculating GDP. So far this methodology has been used to review the calculation of municipal GDP from the year 2010. Thus, it is highlighted that the comparison of data from years prior to 2010 may suffer some discrepancy due to the different methodologies used in accounting for the GDP in the municipalities. More information is presented in the explanatory note to the change in the System of National Accounts, available at:

ftp://ftp.ibge.gov.br/Contas_Nacionais/Sistema_de_Contas_Nacionais/Notas_Metodologicas_2010/01_mudanca_de_base.pdf.

the budgetary balance sheets of the Brazilian municipalities through the "Public Finance of the Municipalities" system (FINBRA).

The comparison of economic indicators from different periods is an important way of assessing the economic dynamics of any territorial unit. For this comparison to be performed consistently, it is necessary to bring current values from different periods to values from the same period. This is because more important than assessing the current value of the different periods, it is most important to know the purchasing power in each of them, and the difference between them is represented by cumulative inflation. Thus, in this study, the index used for monetary restatement, or monetary revaluation, was the Extended National Consumer Price Index (IPCA), having as a data reference the month of December 2015.

5.3.4.2. Productive and Service Structure

A) Area of Indirect Influence (AII)

Gross Domestic Product (GDP) is the most comprehensive measure of economic activity in a country, state or municipality. GDP data is important as it serves as indicators for monitoring short-term fluctuations and long-term economic growth trends.

Thus, according to the survey of the Gross Domestic Product (GDP) carried out by IBGE, it is observed that the municipality of Petrolina - PE (AII) is of significant size, having an economy that represents about 16% of the economy of the state of Piauí. Between 2003 and 2013, the Petrolina economy showed a considerable growth of 7.3% per year, which resulted in a total increase of 102.6%, since GDP increased from BRL 2.9 billion in 2003 to BRL 5.8 billion in 2013.

Table 5.3-8 below shows the variation in the Gross Domestic Product (GDP) of Petrolina and the state of Piauí, in the period from 2003 to 2013.

Data Table 5.3-8 – Gross Domestic Product of Petrolina-PE (AII) and Piauí, 2003 and 2013 (in BRL thousand at prices of Dec / 2015).

Territorial Unit	2003	2013	Variation 2000-2013 (%)	Growth Rate p.a. 2003-2013 (%)	Comparison with State of Piauí	
					2003 (%)	2013 (%)
Petrolina - PE	2,877,306	5,829,906	102.62	7.3	16.2	15.7
Piauí	17,781,069	37,128,245	108.81	7.6	-	-

Source: Brazilian National Institute of Statistics (IBGE), 2010 . Organized by: Arcadis, 2017.

One way of assessing the relationship between the economy and other social aspects is to analyze the distribution of GDP by the population, the so-called GDP per capita. In this sense, it can be seen in Table 5.3 9 that in Petrolina the economic growth of the period 2003 to 2013 was higher than the demographic, which resulted in an increase of 49% in GDP per capita in the municipality, rising from BRL 12.2 thousand in 2003 to BRL18.2 thousand in 2013. Compared with the situation in the state of Piauí, it can be seen that the municipality of AII has a higher ranking, compared to the state GDP per capita in 2013 of BRL 11.7 thousand, about 65% of that of Petrolina.

The evolution of GDP per capita in the municipality of Petrolina and in the state of Piauí is shown in Table 5.3-9.

Data Table 5.3-9 – Table 5.3 9 - Evolution of GDP per capita in Petrolina-PE (All) and Piauí, 2003 and 2013 (in BRL thousand at prices from Dec / 2015).

Territorial Unit	2003			2013			Variation 2003-2013 (%)
	GDP	Population	GDP per capita	GDP	Population	GDP per capita	
Petrolina - PE	2,877,306	235,821	12,201	5,829,906	319,893	18,225	49.4
Piauí	17,781,069	2,898,223	6,135	37,128,245	3,160,748	11,747	91.5

Source: Brazilian National Institute of Statistics (IBGE), 2010 . Organized by: Arcadis, 2017.

The production of a given location can be better understood through the analysis of the Added Value (VA) - value that the different activities add to the goods and services consumed in its production process. Thus, through the VA, one can analyze the performance of each productive sector in the economic dynamics.

As shown in Table 5.3-10 and Graph 5.3-4, the municipality of Petrolina has a relatively diversified economy, in view of the significant participation of the various economic sectors in the composition of the VA. The service sector is the most significant in the municipality, representing about half of the total produced.

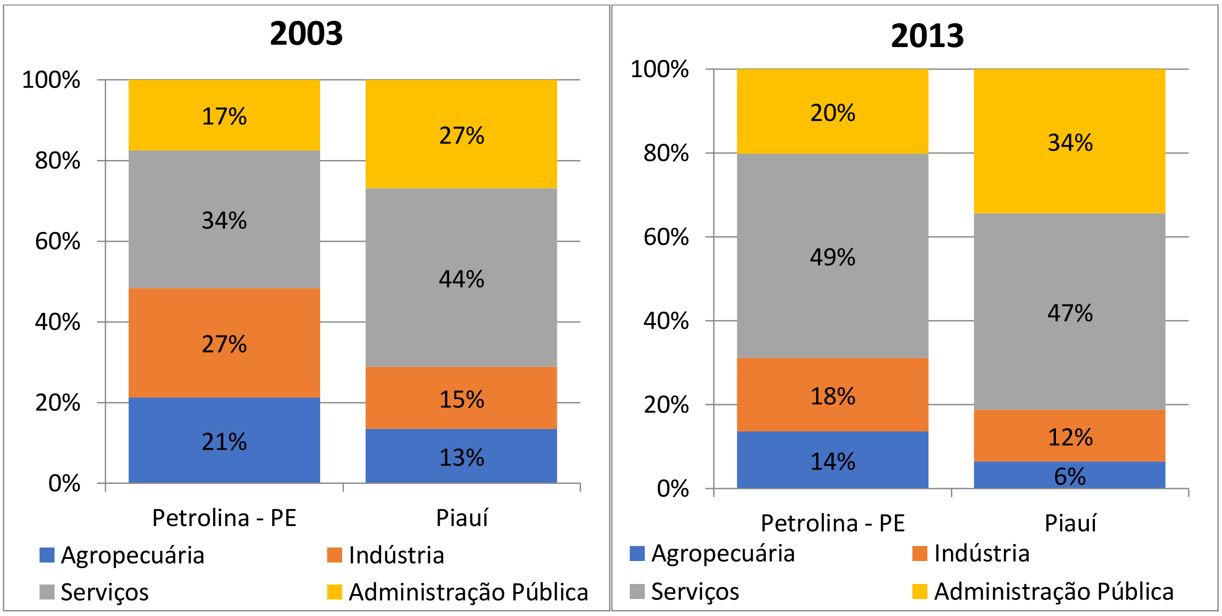
According to IBGE data, between 2003 and 2013 Petrolina had a relative reduction in agriculture and industry, from 21% and 27%, respectively, to 18% and 14%. The reduction in the weight of these sectors was absorbed, above all, by the services sector, which went from 34% to 49%, and to a lesser extent by the public administration, which went from 17% in 2003 to 20% in 2013. The state of Piauí, in turn, presents an economic composition with a greater predominance of the public sector and less weight of industry and agriculture, which still have a significant participation in Petrolina.

Data Table 5.3-10 – Evolution of Added Value by sector (in BRL thousand at prices of Dec / 2015) of Petrolina-PE (All) and Piauí, 2003 and 2013.

Territory Unit	Agriculture		Industry		Services		Public Administration		Total	
	2003	2013	2003	2013	2003	2013	2003	2013	2003	2013
Petrolina - PE	436.756	699.887	306.793	910.506	927.757	2.515.890	455.257	1.044.386	2.638.540	5.170.669
Piauí	1.405.902	2.110.379	2.303.915	4.086.091	7.044.557	15.474.883	4.193.702	11.377.205	16.016.548	33.048.557

Source: Brazilian National Institute of Statistics (IBGE), 2010 . Organized by: Arcadis, 2017.

Graph 5.3-4 – Participation of Sectors in the Added Value of Petrolina-PE (AII) and Piauí, 2003 and 2013.



Source: Brazilian National Institute of Statistics (IBGE), 2010 . Organized by: Arcadis, 2017.

B) Area of Direct Influence (ADI)

According to the survey carried out by IBGE, in 2013 the economies of the municipalities of the ADI presented three different levels with Campo Alegre do Fidalgo and Capitão Gervásio Oliveira presenting GDPs of BRL 27.7 million and BRL 25.4 million, respectively; Dom Inocêncio showing higher values, composing a GDP of BRL 44 million; and São João do Piauí, in turn, presented a stronger economy, which translated into a GDP of BRL 172 million.

The economies of the municipalities of the the ADI showed vigorous average annual growth rates between 2003 and 2013. The growth experienced by the municipalities of Campo Alegre do Fidalgo (8.2% per year), Capitão Gervásio Oliveira (9% per year) and São João of Piauí (10.4% per year) was higher than the average for the state of Piauí (7.6% per year), only Dom Inocêncio (7.4% per year) showed growth slightly below the state average.

Although they have shown vigorous growth in the analyzed period, the municipalities of ADI have little representation in the economy of the state of Piauí, since Campo Alegre do Fidalgo, Capitão Gervásio Oliveira and Dom Inocêncio only contributed 0.1% to the state GDP. São João do Piauí even with a more dynamic and larger economy, also had only a small contribution to the total production of the state, contributing 0.5% of the state's GDP.

Table 5.3-11 below shows the economic dynamics of the ADI municipalities through data on Gross Domestic Product (GDP).

Data Table 5.3-11 – Gross Domestic Product (in BRL thousand at prices of Dec / 2015), Average Annual Growth Rate and State Participation of the Municipalities of the ADI and Piauí, 2003 and 2013.

Territorial Unit	GDP 2003	GDP 2013	Variation 2003-2013 (%)	Growth Rate p.a. 2003-2013 (%)	State Participation	
					2003 (%)	2013 (%)
Campo Alegre do Fidalgo - PI	12,548	27,699	120.74	8.2	0.1	0.1
Capitão Gervásio Oliveira - PI	10,769	25,461	136.42	9.0	0.1	0.1
Dom Inocêncio - PI	21,648	44,065	103.55	7.4	0.1	0.1
São João do Piauí - PI	64,042	172,871	169.94	10.4	0.4	0.5
Piauí	17,781,069	37,128,245	108.81	7.6	-	-

Source: Brazilian National Institute of Statistics (IBGE), 2010 . Organized by: Arcadis, 2017.

In relation to the GDP per capita verified in the municipalities of the the ADI, it is observed, through the IBGE data presented in Table 5.3-12, that between 2003 and 2013 there was a considerable growth in this aspect, reflecting an economic growth greater than the demographic. However, the data also indicates that even in 2013 the GDP per capita in these municipalities was still well below the state average, with the worst situations seen in Dom Inocêncio and Campo Alegre do Fidalgo where the GDP per capita was, respectively, BRL 4, 7 thousand and BRL 5.7 thousand, which does not reach half the state average, which was BRL11.7 thousand.

Capitão Gervásio Oliveira presents an intermediate situation, in the context of the the ADI municipalities, with a GDP per capita of BRL 6,400, which represents just over half of the state average. Again, São João do Piauí presents a slightly better situation, with a GDP per capita of BRL 8.6 thousand, although still 30% below the state average (BRL 11.7 thousand).

Data Table 5.3-12 – Evolution of GDP per capita in the municipalities of the ADI and Piauí, 2003 and 2013 (in BRL thousand at prices of Dec / 2015).

Territorial Unit	2003			2013			Variation 2003-2013 (%)
	GDP	Population	GDP per capita (em R$)	GDP	Population	GDP per capita (em R$)	
Campo Alegre do Fidalgo - PI	12,548	4,557	2,754	27,699	4,851	5,710	107.4
Capitão Gervásio Oliveira - PI	10,769	3,045	3,537	25,461	3,975	6,405	81.1
Dom Inocêncio - PI	21,648	9,336	2,319	44,065	9,364	4,706	102.9
São João do Piauí - PI	64,042	18,211	3,517	172,871	20,000	8,644	145.8
Piauí	17,781,069	2,898,223	6,135	37,128,245	3,160,748	11,747	91.5

Source: Brazilian National Institute of Statistics (IBGE), 2010 . Organized by: Arcadis, 2017.

When analyzing the Added Value data of the municipalities of the the ADI, there is a clear economic dependence in these municipalities on the public administration sector and that the growth experienced between 2003 and 2013 was largely due to the increase in this group of activities.

Thus, it is observed that between 2003 and 2013 the municipalities of the ADI had a nominal reduction in the participation of the agricultural sector in the composition of their Added Value, which, considering the rural characteristics of the municipalities Campo Alegre do Fidalgo, Capitão Gervásio Oliveira and Dom Inocêncio, enhances the weaknesses of the economic situation found in these municipalities.

In the municipalities Campo Alegre do Fidalgo, Capitão Gervásio Oliveira and Dom Inocêncio the dependence on the public administration sector is expressed by the great weight of this sector in the Added Value of their economies, which jumped from around 60% in 2003 to more than 70% in 2013, as can be seen in Graph 5.3-5. In the same period there was also an increase in the participation of the services sector, especially in Campo Alegre do Fidalgo and Capitão Gervásio Oliveira, where the sector almost doubled its weight in the Added Value. It is worth noting that in several cases this increase in the service sector occurs as a component of the growth of public administration.

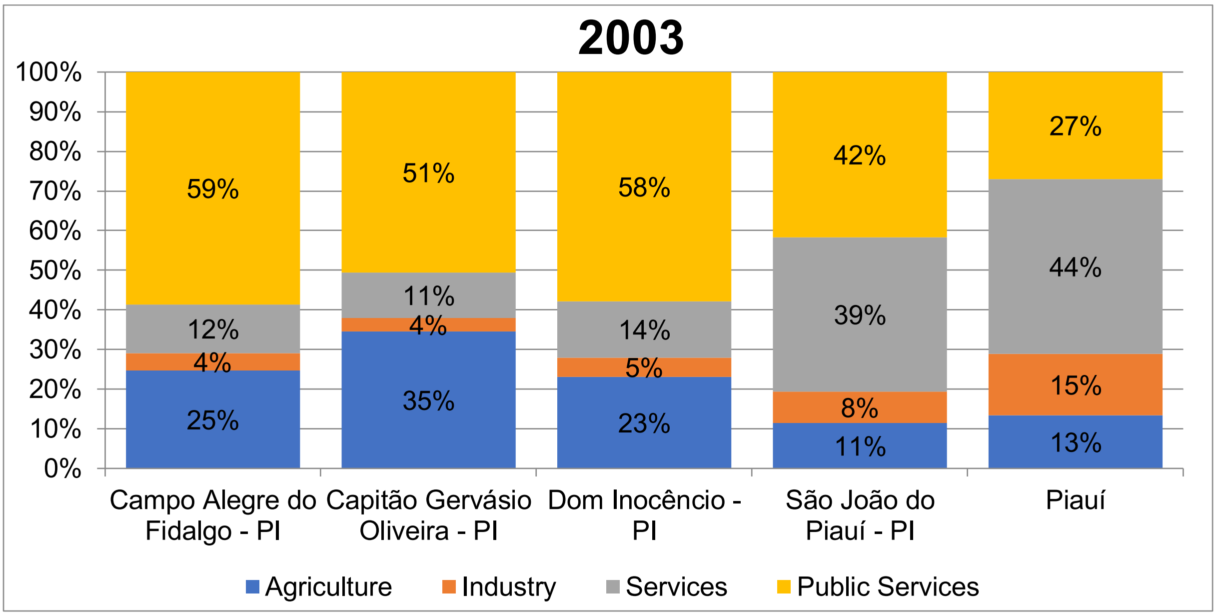
In São João do Piauí, given its greater economic dynamism, as previously mentioned, the public administration, although it is also the sector with the greatest weight in the Added Value, has less importance in the economy since in 2013 it represented 46% of the total Added Value practically the same weight of the service sector that contributed 45% of the VA. It is important to highlight that the service sector, especially business services, in São João do Piauí is a reference point for neighboring municipalities, as highlighted in the section on city network and functional hierarchy.

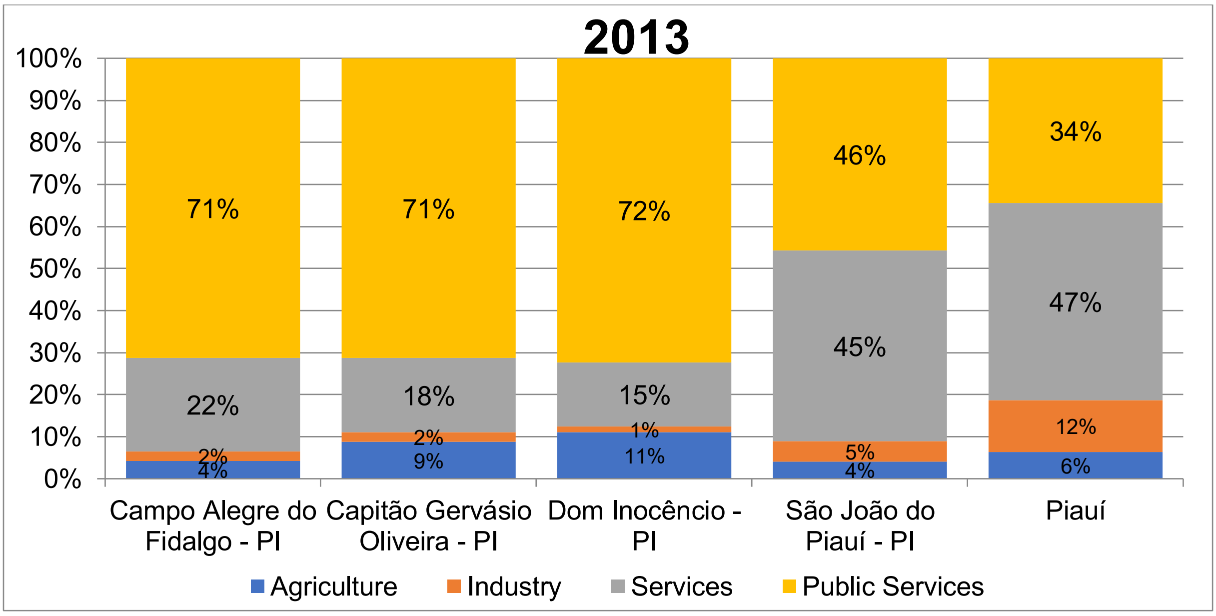
Table 5.3-13 – Evolution of Value Added by sector (in BRL thousand at prices of Dec / 2015) of the municipalities of the ADI and Piauí, 2003 and 2013.

Territory Unit	Agriculture		Industry		Services		Public Administration		**Total**	
	2003	**2013**	**2003**	**2013**	**2003**	**2013**	**2003**	**2013**	**2003**	**2013**
Campo Alegre do Fidalgo - PI	3.053	1.128	547	629	1.519	5.925	7.253	19.057	12.372	26.739
Capitão Gervásio Oliveira - PI	3.667	2.151	373	562	1.205	4.314	5.381	17.485	10.626	24.514
Dom Inocêncio - PI	4.923	4.716	1.035	637	3.025	6.508	12.315	30.929	21.300	42.789
São João do Piauí - PI	6.912	6.418	4.793	7.682	23.524	71.874	25.192	72.505	60.423	158.478
Piauí	1.405.902	2.110.379	2.303.915	4.086.091	7.044.557	15.474.883	4.193.702	11.377.205	16.016.548	33.048.557

Source: Brazilian National Institute of Statistics (IBGE), 2010 . Organized by: Arcadis, 2017.

Graph 5.3-5 – Sectors' Participation in the Added Value of the municipalities of the ADI and Piauí, 2003 and 2013.





5.3.4.3. Occupational Structure

A) Area of Indirect Influence (AII)

a) Economically Active Population (PEA)

The Economically Active Population (PEA) is a measure of the size of the workforce in a given place. It consists of employed and unemployed people in a reference period[13]. All those who exercised any productive activity in this reference period are considered to be employed. People who were not engaged in any productive activity, but had taken steps to obtain an opportunity to do so, are considered unoccupied (or unemployed).

That said, Table 5.3-14 shows the evolution of the labor market with regard to PEA and PEA Occupied, between 2000 and 2010, in the municipality of Petrolina and Piauí. According to IBGE data, in the period analyzed the municipality of Petrolina experienced an increase in its PEA by about 50% and its Occupied PEA by 62.8%, which increased the occupancy rate of its population from 82.3% in 2000 to 89.6% in 2010. In the same period, the state of Piauí experienced less growth, both in the PEA (15%) and in the Occupied PEA (18.4%), although it presented a rate higher occupancy 92.1% in 2010.

Data Table 5.3-14 – Total Economically Active Population (PEA) and Petrolina Occupied PEA -PE (AII) and Piauí, 2000 and 2010.

Territorial Unit	PEA (Labor force)			PEA Employment			Employment Rate (%)	
	2000	2010	Variation 2000-2010 (%)	2000	2010	Variation 2000-2010 (%)	2000	2010
Petrolina - PE	92,663	138,680	49.7	76,279	124,213	62.8	82.3	89.6
Piauí	1,147,123	1,319,221	15.0	1,026,515	1,215,275	18.4	89.5	92.1

Source: Brazilian National Institute of Statistics (IBGE), 2010 . Organized by: Arcadis, 2017.

When analyzing the PEA occupied by sector of economic activity in Petrolina and in the state of Piauí, there is a difference in relation to the Added Value of these sectors in the composition of GDP, as can be seen in Graph 5.3-6.

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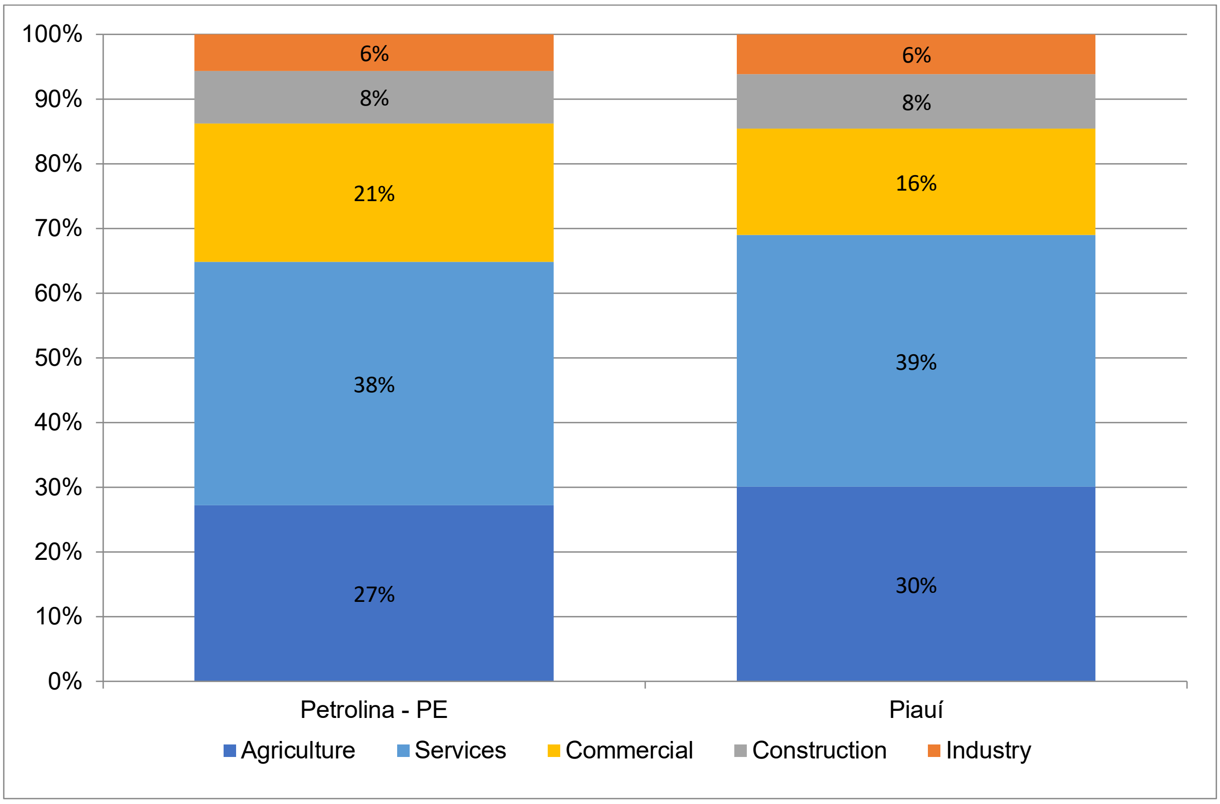
[13] In this case, as the data from the 2000 and 2010 Censuses provided by IBGE were used, the reference period in 2000 was the week of July 23 to 29, 2000. In 2010, it was the week of July 25 to 31.

Graph 5.3-6 – Occupied PEA (labor force) by Activity Sector in Petrolina - PE (All) and Piauí – 2010.



Source: Brazilian National Institute of Statistics (IBGE), 2010 . Organized by: Arcadis, 2017.

The agricultural sector, which represented 14% of Petrolina's economy in 2013, in 2010 accounted for 27% of the employed population. In Piauí the situation was comparabler with the agricultural Added Value representing 6% of the Added Value (in 2013) although it was responsible for the occupation of 30% of the workers in the state.

The commerce and services sector (which includes the public administration), of great relevance to the municipal economy, corresponding to about 90% of the Added Value of Petrolina in 2013, had less weight in the number of employed, representing, 60% of the occupied PEA in the municipality. In the state, this sector presented a slightly smaller divergence between the Added Value (80% of the total) and Occupied Jobholders (55% of the employed).

b) Formal Employment

Formal employment or employment relationships are defined as working relationships, established whenever paid work occurs. Formal employment relationships are considered to be the employment relationships of employees, statutory employees, workers governed by temporary contracts for a fixed period, and individual employees, when represented by unions (IBGE, 2010).

As shown in Table 5.3-15, the formal rate of employed persons in Petrolina was 50% in 2015, having grown by 16% compared to 2005 when this group of workers represented 43% of the total employed persons. The degree of formalization of work in Petrolina is higher when comparing the data of the municipality with those of the state of Piauí, as in Piauí the degree of formal employment in 2005 was 26%, and increased to 37% in 2015, representing a 44% growth.

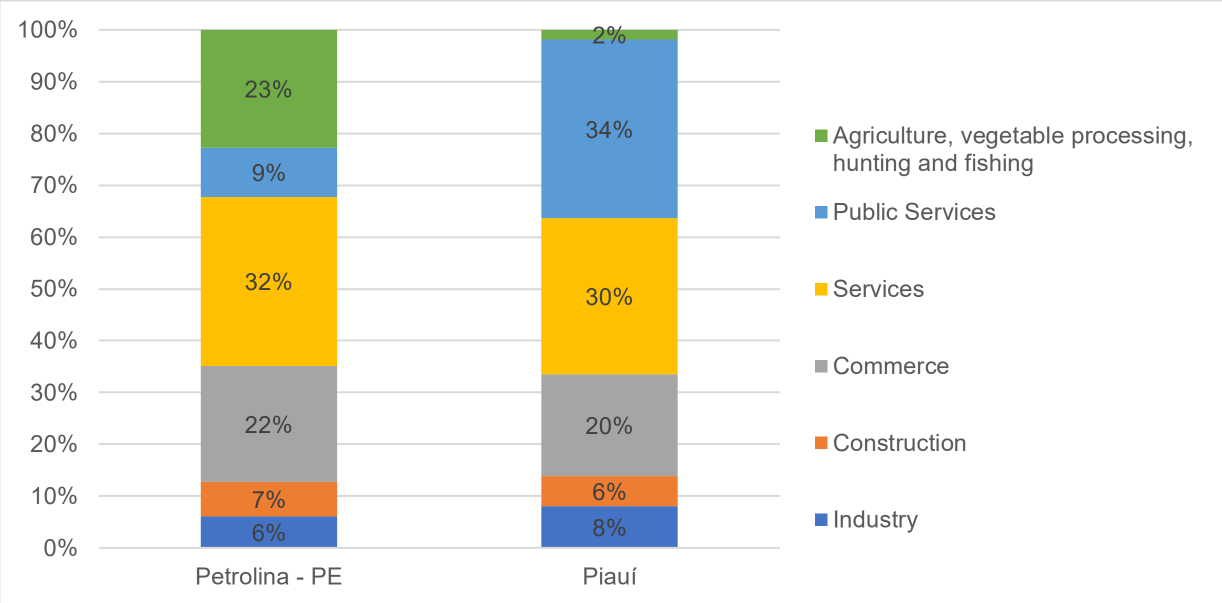
Data Table 5.3-15 – Formal Employment in Petrolina - PE (All) and Piauí - 2005 e 2015.

Territorial Unit	Population with Formal Employment*		Formal Employment			Formality Rate (%)		
	2005	2015	2005	2015	Variação 2005-2015 (%)	2005	2015	Variação 2005-2015
Petrolina - PE	88,547	137,758	37,653	68,216	81%	43%	50%	16%
Piauí	1,085,525	1,245,033	279,198	460,776	65%	26%	37%	44%

** For the estimate of the formal Jobs for the years 2005 and 2015, the data from the formal Jobs of the Censuses 2000 and 2010 were used, updated by the population variation rate verified between the periods 2000-2005 and 2010-2015. Sources: Ministry of Labor and Employment (MTE), 2016; Brazilian Institute of Geography and Statistics (IBGE), 2016. Organized: Arcadis, 2017.*

Regarding the distribution of jobs by different sectors of the economy, it is observed that in Petrolina there is great correlation between the data of the total employed population as those in formal jobs, including in the agricultural sector, which tends to have greater levels of informality. Thus, based on the data presented in Graph 5.3-7, it is observed that the largest share of formal jobs in the municipality of Petrolina is concentrated in the sectors of commerce (32%), agriculture (23%) and services (22%). In the state of Piauí, the informality of the employment in the agricultural sector stands out, since the sector represented only 2% of formal jobs, although it is the sector that occupies 30% of the state's population.

Graph 5.3-7 – Formal Employment by Major Sectors in Petrolina - PE (AII) and Piauí – 2015.



Source: Ministry of Labor and Employment (MTE), 2016. Organized by: Arcadis, 2017.

B) Area of Direct Influence (ADI)

a) Economically Active Population (PEA)

As shown in the table below, the evolution of the labor market in the municipalities of the ADI presented two different situations in the period from 2000 to 2010. The smaller municipalities, Campo Alegre do Fidalgo and Capitão Gervásio Oliveira, presented a reduction in their PEA of 17.7% and 13.3% respectively. In turn, the municipalities of Dom Inocêncio and São João do Piauí showed a growth in the PEA of, respectively, 48% and 18.9%, following a state trend, which had a growth of 15% in their PEA.

With regard to the occupancy rate, among the municipalities of the ADI, only Campo Alegre do Fidalgo showed a reduction in this, since in 2000 it had a 93.6% occupancy rate, which was reduced by almost half in 2010, passing to only 58.2%.

The other municipalities had significant growth in the period, so in 2010 they all had occupancy rates of around 95%, in line with the state average, which was 92%. The PEA data for ADI municipalities are presented in Table 5.3-16.

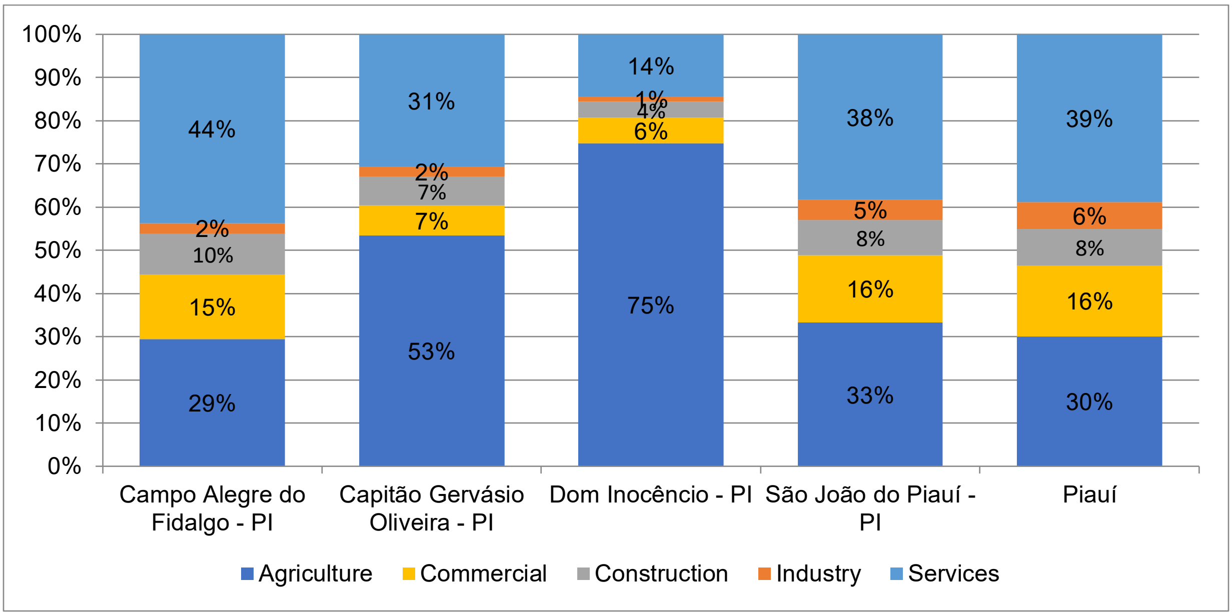
Data Table 5.3-16 – Total Economically Active Population (PEA) and Jobholders - PEA in the Municipalities of ADI and Piauí, 2000 and 2010.

Territorial Unit	PEA (Labor force)			PEA Employment			Employment Rate (%)	
	2000	2010	Variação 2000-2010 (%)	2000	2010	Variation 2000-2010 (%)	2000	2010
Campo Alegre do Fidalgo - PI	1,693	1,394	-17.7	1,585	812	-48.8	93.6	58.2
Capitão Gervásio Oliveira - PI	1,403	1,216	-13.3	1,050	1,163	10.8	74.8	95.6
Dom Inocêncio - PI	2,787	4,126	48.0	2,641	3,986	50.9	94.8	96.6
São João do Piauí - PI	7,423	8,824	18.9	6,481	8,248	27.3	87.3	93.5
Piauí	1,147,123	1,319,221	15.0	1,026,515	1,215,275	18.4	89.5	92.1

Source: Brazilian National Institute of Statistics (IBGE), 2010 . Organized by: Arcadis, 2017

The analysis of the data of the PEA occupied by sector of economic activity in the municipalities of the the ADI identifies a difference in the comparisons of the percentage of employed in the sectors with the Added Value of these sectors in the composition of the GDP, as can be seen in Graph 5.3-8.

Graph 5.3-8 – PEA Jobholders by Sector of Activity in the Municipalities of the ADI and Piauí - 2010 .



Source: Brazilian National Institute of Statistics (IBGE), 2010 . Organized by: Arcadis, 2017

The agricultural sector, which represented about 10% of the economies of the ADI municipalities in 2013, in 2010 accounted for percentages of about six times that of the employed population. Thus, Campo Alegre do Fidalgo which had 4% agricultural added value had 29% of its population employed in this sector, in Capitão Gervásio Oliveira the percentages were, respectively, 9% and 53%, in Dom Inocêncio 11% and 75% and in São João do Piauí 4% and 33%. This comparison between percentage employed and Added Value shows that agricultural activities in these locations provide little economic return.

The service sector (which includes public administration) was the one sector that stood out the most, following the agricultural sector, being the largest employer in Campo Alegre do Fidalgo (44%) and São João do Piauí (38%) and the second largest in Capitão Gervásio Oliveira (31%) and Dom Inocêncio (14%).

b) Formal Employment

The main characteristic of formal jobs found in the ADI municipalities was their low proportion in relation to the total number of employed persons (the formality rate). As shown in Table 5.3-17, the formality index of employed persons in the municipalities of ADI in the analyzed period was always below the state average, although they showed a more significant growth between 2005 and 2015. In 2015, the formality rate of jobs was 22% in Campo Alegre do Fidalgo, 18% in Capitão Gervásio Oliveira and São João do Piauí and only 9% in Dom Inocêncio, all well below the 37% average for the state of Piauí.

Data Table 5.3-17 – Formal employment in the ADI municipalities and Piauí - 2005 and 2015.

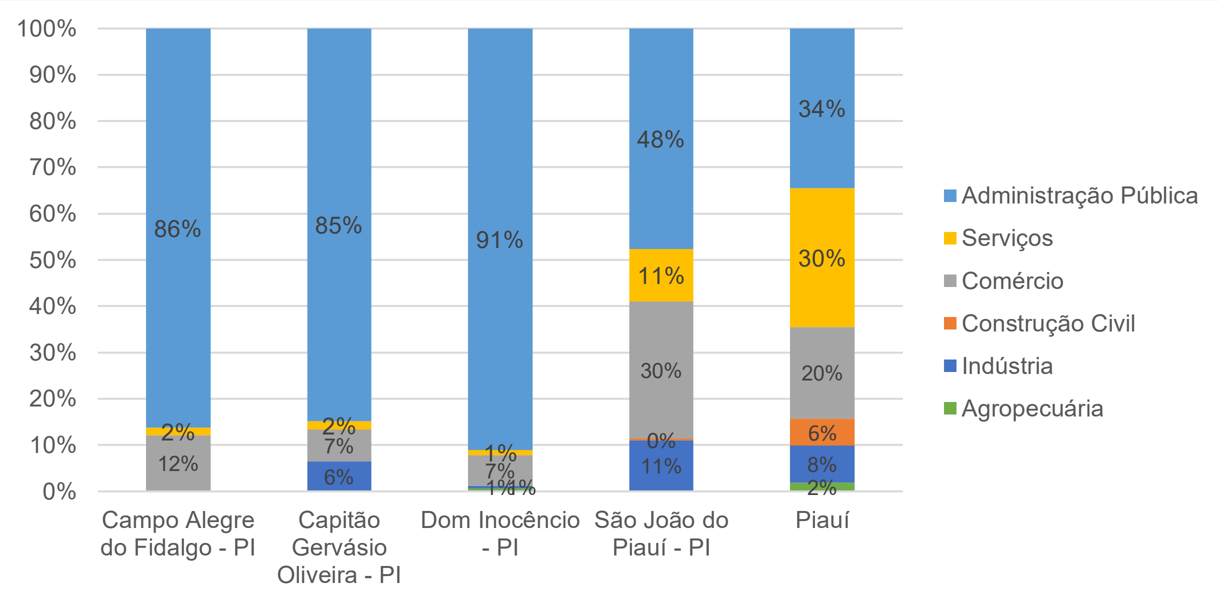
Territorial Unit	Population with Formal Employment*		Formal Employment			Formality Rate (%)		
	2005	2015	2005	2015	Variation 2005-2015 (%)	2005	2015	Variation 2005-2015
Campo Alegre do Fidalgo - PI	1,451	845	72	182	153%	5%	22%	334%
Capitão Gervásio Oliveira - PI	795	1,197	64	218	241%	8%	18%	126%
Dom Inocêncio - PI	2,898	4,042	168	347	107%	6%	9%	48%
São João do Piauí - PI	6,884	8,471	687	1,528	122%	10%	18%	81%
Piauí	1,085,525	1,245,033	279,198	460,776	65%	26%	37%	44%

** For the estimate of the employment for the years 2005 and 2015, data from the PO of the Censuses 2000 and 2010 were used plus the rate of variation of the population verified between the periods 2000-2005 and 2010-2015. Sources: Ministry of Labor and Employment (MTE), 2016; Brazilian Institute of Geography and Statistics (IBGE), 2010. Organized by: Arcadis, 2017.*

With regards to the distribution of jobs among the different sectors of the economy, it is observed that in the agricultural sector the level of informality, or of workers working on their own land, in the municipalities of the ADI is completely, reflecting that this represented a large percentage of occupied people in 2010, but did not have any formal employment in 2015. At state level, this situation was not different since, where formal employment in the sector was only 2% in 2015.

What stands out most in the ADI municipalities, as shown in Graph 5.3-9, is the large concentration of formal jobs in the public administration sector, in 2015 this sector was responsible for about 90% of formal jobs in Campo Alegre do Fidalgo , Capitão Gervásio Oliveira and Dom Inocêncio, which indicates a lack of private business activity of the economy, proving to be highly dependent on the public sector. In São João do Piauí the percentage was much lower, 48%, although still higher than the state average, which was 34%.

Graph 5.3-9 – Formal Employment by Sectors of the ADI Municipalitie and Piauí - 2015.

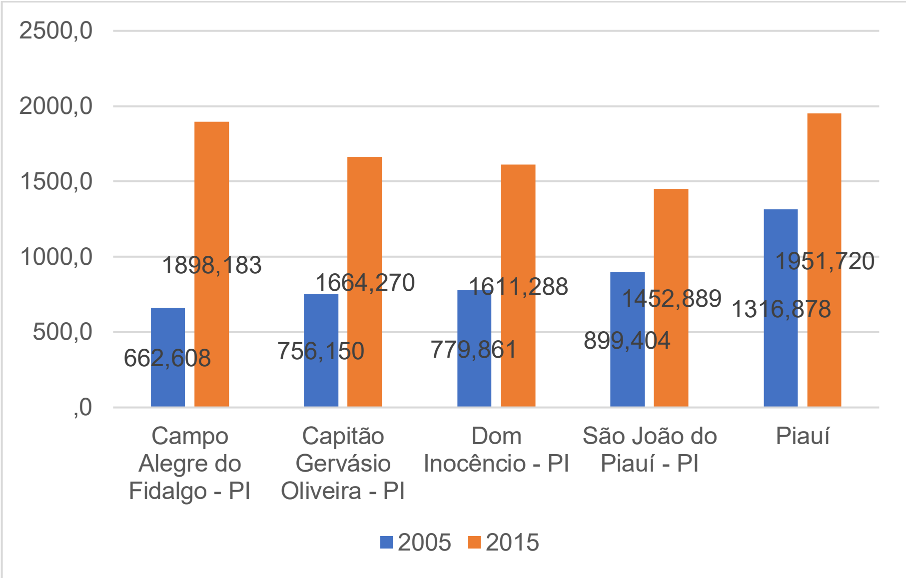


Source: Ministry of Labor and Employment (MTE), 2016. Organized by: Arcadis, 2017.

Regarding the average income of formal workers, it was observed that there was a growth between 2005 and 2015. With the growth was above the average of state level in the decade analyzed. the workers of the municipalities of the ADI, even though they presented income below the state average, which in 2015 was BRL 1,952, this difference decreased when compared to 2005. Among the municipalities of the ADICampo Alegre do Fidalgo presents the best situation, with the worst situation in São João do Piauí.

Graph 5.3-10 shows the average incomes from formal jobs in the years 2005 and 2015 in the locations analyzed.

Graph 5.3-10 – Evolution of Average Remuneration in Formal Employment in the Municipalities of ADI and Piauí - 2005 and 2015 (in BRL, at prices from Dec / 2015).



Source: Ministry of Labor and Employment (MTE), 2016. Organized by: Arcadis, 2017.

5.3.4.4. Public Finance of Municipalities of the ADI

The analysis of public finances is of great value for the comparation of municipal socioeconomic realities, both because it indicates the level of spending that the municipalities are able to practice, defined from their budget revenue considering the multiple sources available, as a result the evaluation of the magnitudes and relationships that these sources of resources present.

In this way, it is possible to infer and evaluate aspects of its collection capacity, which is determined by aspects of its economic base and the degree of organization and efficiency of its tax administration.

As this diagnosis aims at the evaluation of the possible impacts of the enterprise and considering that the possible municipal revenues to be generated directly by the enterprise will be only in the municipalities of the the ADI, this item addresses only the finances of these municipalities.

a) Methodological Considerations

For the evaluation of municipal finances, the material made available by the National Treasury Secretariat (STN) was used as a data source, which presents the budget statements of Brazilian municipalities through the “Public Finance of Municipalities” database (FINBRA). In 2015, the last year with available data, 197 municipalities in the state of Piauí presented their budget balances, thus, all comparisons with the state averages mentioned in this item will be in reference to this amount.

Considering that the monetary data in this study are based on the year 2015, the data in this item, since they are from the same year, are expressed in current values.

b) Municipal Revenue

Considering that municipal budget revenue is formed by two main components: i) the first is tax revenue, formed by municipal taxes and fees; ii) the second covers the whole set of transfers from federal government and state.

It is important to note that the revenue that the municipality is able to collect results mainly from two aspects: i) the degree of development and size of its economy, which influences both tax collection and transfers from Federal and State; and ii) the population of the municipality, since States and the Union use this data as part of the criteria for transferring resources.

That said, Table 5.3-18 presents the main aspects of ADI municipal revenue.

Data Table 5.3-18 – Budgetary and Tax Revenue and Main Taxes of the Municipalities of the ADI - 2015 (in BRL at current prices).

Municipality	Budget Revenue			Tax Revenue		% Tax Revenue/Budget Revenue	
	Nominal Value	Per capita	State Ranking	Nominal Value	State Ranking	%	State Ranking
Campo Alegre do Fidalgo - PI	13,214,413	2,706	111	430,153	66	3,3	45
Capitão Gervásio Oliveira - PI	11,327,028	2,837	158	151,130	165	1,3	157
Dom Inocêncio - PI	18,611,709	1,985	61	171,442	157	0,9	180
São João do Piauí - PI	38,949,825	1,940	27	2,037,951	21	5,2	28

Source: National Treasury Secretariat (STN), 2016. Organized by: Arcadis, 2017

As shown in Table 5.3-18, the municipality of São João do Piauí, due to its larger population and economic size, presented the highest budget revenue among municipalities of the ADI, BRL 38.9 million, which positioned it as the 27th revenue among the municipalities of the state of Piauí. The other municipalities of the ADI have smaller sizes, with revenues of BRL 13.2 million in Campo Alegre do Fidalgo, BRL11.3 million in Capitão Gervásio Oliveira and BRL 18.6 million in Dom Inocêncio.

With regard to tax revenues, it can be seen that the municipalities of the ADI in 2015 have a very low collection capacity. In this respect, Campo Alegre do Fidalgo stood out among the municipalities of the ADI with 3.3% of its revenues coming from its own collection, a percentage only below that of São João do Piauí (5.2%).

When assessing municipal revenues in relation to their respective populations, it can be seen, through the data in Table 5.3 18, that the per capita budget revenue in Capitão Gervásio Oliveira was the highest among the ADI municipalities with BRL 2.8 thousand, it is noteworthy that São João do Piauí, despite having the largest revenue, as it has a larger population, presented and the lowest revenue per capita, BRL 1.9 thousand.

Focusing on the main source of federal transfers, there is the Municipality Participation Fund (FPM), which is determined mainly by the variable population of the municipality in the formula for calculating the portion that corresponds to it. This transfer represented the largest source for the municipalities of the the ADI, being 29.3% in São João do Piauí, 32.4% in Dom Inocêncio, 43.2% in Campo Alegre do Fidalgo and 53.2% in Capitão Gervásio Oliveira .

Other significant federal transfers to municipal revenue were finance resources to be applied to health expenses (SUS) and education expenses (Fundeb). The amount transferred from SUS to the municipality of São João do Piauí in 2015 was BRL 7.4 million, and is the most significant among the municipalities of the ADI. This is because the São Joao do Piaui has better public health facitiies in the region.

Regarding the funds for education, there is a greater equivalence between the municipalities of the the ADI, in this sense, again most of the funds went to the municipality of São João do Piauí (BRL 1.2 million), followed by Dom Inocêncio (BRL 880 thousand), Campo Alegre do Fidalgo (BRL 400 thousand) and Capitão Gervásio Oliveira (BRL 338 thousand).

Table 5.3-19 shows the values of the main federal transfers to ADI municipalities.

Data Table 5.3-19 – Main Federal Transfers to the Municipalities of the ADI - 2015 (in BRL at current prices).

Unidade Territorial	Cota-parte do FPM*	(%) Cota-parte do FPM na Receita Orçamentária	Fundeb*	SUS*
Campo Alegre do Fidalgo - PI	5,712,618.37	43.23	399,806.67	825,437.13
Capitão Gervásio Oliveira - PI	6,030,724.63	53.24	338,176.75	775,643.07
Dom Inocêncio - PI	6,031,679.37	32.41	880,361.25	2,818,621.77
São João do Piauí - PI	11,425,236.74	29.33	1,160,574.76	7,438,232.83

** FPM: Municipality Participation Fund; Fundeb: Fund for Maintenance and Development of Basic Education and Valorization of Education Professionals; SUS: Unified Health System. Source: National Treasury Secretariat (STN), 2015.Organized by: Arcadis, 2017.*

The share of ICMS VAT-TAX, is the most relavante finance resoures transfers from State the municipalities of the ADI. The determination of the municipal portion is carried out by the State Finance Secretariat based on the Municipality Participation Index (IPM) in whose formula the municipal tax added value (VAF) has the largest participation (75%). Therefore, the economic size of the municipality is crucial to define its participation in the ICMS share.

Thus, it is observed that the municipalities Campo Alegre do Fidalgo and Capitão Gervásio Oliveira presented low percentages of collection based on the ICMS share, respectively, 4% and 5.2%, with amounts of, respectively, R $ 529 thousand and BRL 588 thousand. The municipalities of Dom Inocêncio (10.1%) and São João do Piauí (7.7%) had more significant percentages, which meant collections of BRL 1.8 million and BRL 3 million, respectively.

Data Table 5.3-20 – The Main State Transfers to the Municipalities of the ADI- 2015 (in BRL at current prices).

Territorial Unit	Share of ICMS VAT-TAX*	Participation (%) of the ICMS * Share in Budget Revenue
Campo Alegre do Fidalgo - PI	529,572	4.01
Capitão Gervásio Oliveira - PI	588,832	5.20
Dom Inocêncio - PI	1,882,874	10.12
São João do Piauí - PI	3,000,945	7.70

**ICMS-VAT: tax on the circulation of goods and services . Source: National Treasury Secretariat (STN), 2016. Organized by: Arcadis, 2017.*

Based on the field survey carried out between Oct/31/16 and Nov/5/16, currently the main difficulties faced by the municipalities of the the ADI, with regard to public finances, are due to the reduction of federal transfers and states, as consequence of the economic crisis that the country is going through.

5.3.5. Caracterizarization of life condictions at the Municipalties of the ADI

The main goal of this Environmental Diagnosis is to allow the identification and assessment of socioeconomics and cultural impacts of the Piauí Nickel Project. This studies was carried out at the municipalities of the ADI. The possible impacts of the enterprise on the topics addressed here should go focus only to the municipalities of the ADI.

5.3.5.1. Education

A) Methodological Considerations

One of major sources of secondary data used is the 2013 Human Development Atlas of the United Nations Development Program - UNDP, this report is based on data from the 1991, 2000 and 2010 Census provided by the Brazilian Institute of Geography and Statistics - IBGE, as being the main source of study for the indicators of illiterate population and education by age group.

The characterization of the structure of the education system used data referring to the number of establishments found in the data of the National Institute of Educational Studies and Research Anísio Teixeira – INEP (Federal Departament of Education). In addition, interviews were carried out with the Secretaries of Education of the municipalities of the ADI, between Oct/31/2016 and Nov/5/16, who provided some information and personal impressions on the topic in their respective municipalities. The interviews were conducted with the Municipal Secretaries of Education of the municipalities of Campo Alegre do Fidalgo, Capitão Gervásio Oliveira, Dom Inocêncio and São João do Piauí (according to the questionnaire template presented in ANNEX IX - Volume IV).

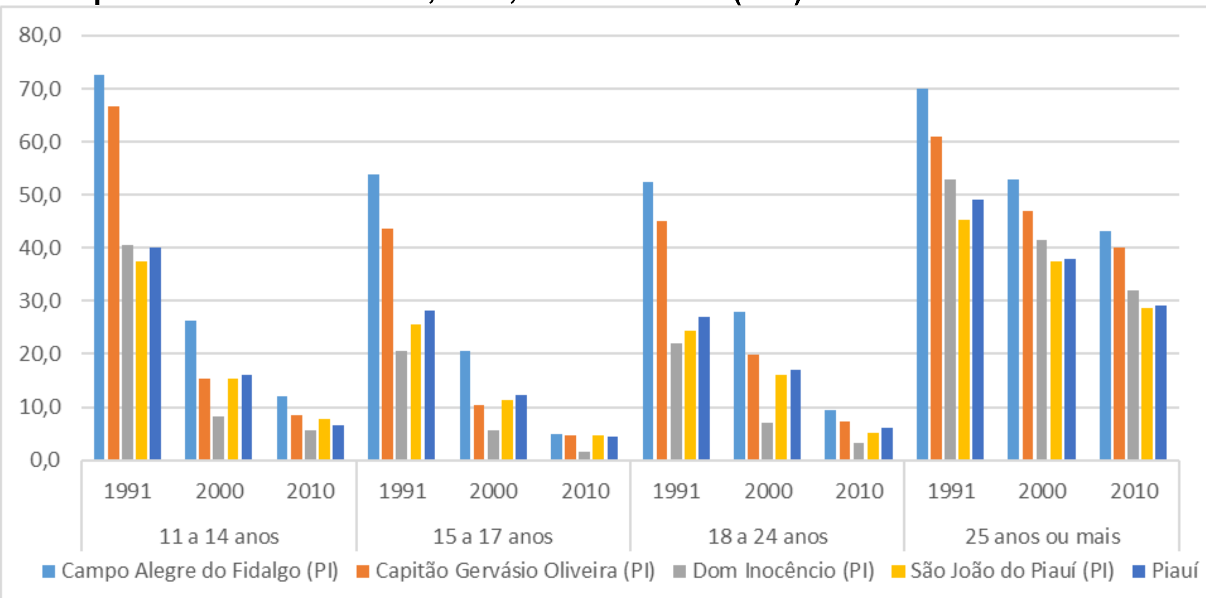
The analysis of education in the municipalities of the ADI is organized into two items: education level and structure facilies resources.

B) Level of Education

The reduction in illiteracy rates that has occurred in the last two decades worldwide, especially among the adult population (considering people aged 15 or over), has shown steady and marked progress in developing countries, according to UNESCO studies (2009). Literacy is essential for communication and learning of all types, reflecting on the most diverse aspects of life, such as health, social well-being, employment and economic development.

The illiteracy rate is an important indicator, as it represents the percentage of people without developed reading and writing skills. It is important to remember that only in the 1960s did Brazil reverse the predominance of its population distribution over space, moving from rural to urban, with the population in cities more access to education services and, consequently, reducing the illiteracy rate. In this context, data on the illiteracy rate in ADI municipalities and in the state of Piauí are presented in the graph below.

Graph 5.3-11 – Illiteracy Rate by Age Group of the Population Over 11 years old in the Municipalities of ADI and Piauí, 1991, 2000 and 2010 (in%).



Source: PNUD, 2013. Organized by: Arcadis, 2017.

As shown in Graph 5.3-11 in the municipalities of the ADI, there was a reduction in the illiteracy rate between 1991 and 2010 in all age groups, following the state trend. Thus, it is observed that in 1991 the illiteracy rate in the municipalities of Campo Alegre do Fidalgo and Capitão Gervásio Oliveira was much higher than the average for the state of Piauí, in all age groups. In turn, Dom Inocêncio and São João do Piauí had rates close to the state average, being in some age groups above and in others below.

Table 5.3-21 shows the reduction in the illiteracy rate in the municipalities of ADI and Piauí between 1991 and 2010.

Data Table 5.3-21 – Variation in the Illiteracy Rate by Age Group of the Population Over 11 years of age in the Municipalities of the ADI and Piauí, between 1991 and 2010 (in%).

Territorial Unit	11 to 14 old	15 to 17 old	18 to 24 old	25 old or over
Campo Alegre do Fidalgo (PI)	-83%	-91%	-82%	-38%
Capitão Gervásio Oliveira (PI)	-87%	-89%	-84%	-34%
Dom Inocêncio (PI)	-86%	-93%	-85%	-39%
São João do Piauí (PI)	-80%	-82%	-79%	-37%
Piauí	-84%	-85%	-78%	-41%

Souce: PNUD, 2013. Organized: Arcadis, 2017.

As shown Table 5.3-21 that illiteracy rates had a greater reduction in the 15 to 17 age group. It is in this age group that the lowest illiteracy rate is found, in all periods analyzed, being in 2010 just over 4% in ADI municipalities, with the exception of Dom Inocêncio, who presented an even lower index of 1.5% .

Although the municipalities of the ADI have shown significant reductions in illiteracy, it is important to note that in the population aged 25 or over, the index fell at a slower pace (around 40%), both in the municipalities of ADI and in the state, and in 2010 illiteracy rates in this age group in these municipalities were higher in Campo Alegre do Fidalgo and Capitão Gervásio Oliveira about 40%, than in Dom Inocêncio and São João do Piauí, which had about 30% of the population over 25 years old still illiterate.

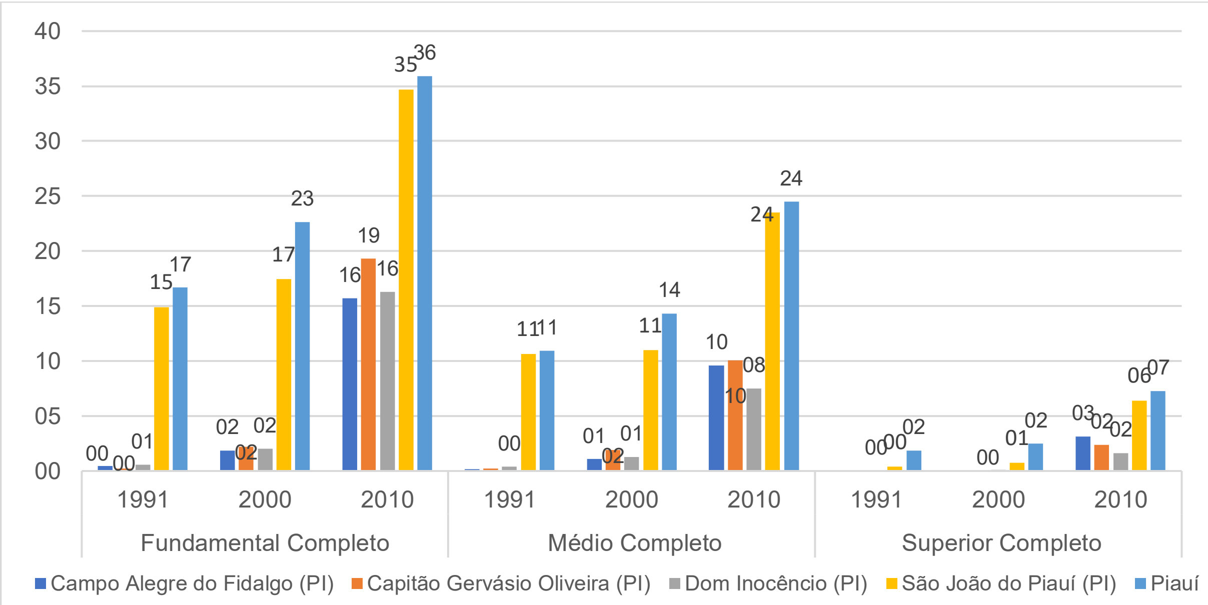
The highest rate of illiteracy, in the older population, is mainly due to the difficulties of access to literacy by a large part of the population until the 1990s when elementary education was universalized in the country. As the municipalities of ADI still presented a large part of their population living in rural areas, the difficulties of access to schools, may justify the negative result for the population over 25 years old.

As measures to combat illiteracy, the municipalities of ADI, according to representatives of the Municipal Secretariats of Education, have incentive programs such as the National Pact for Literacy at the Right Age (PNAIC)[14] and offer Youth and Adult Education in municipal schools. In the case of teaching young people and adults, the secretariats reported a great difficulty in maintaining their interest in continuing their studies, which indicates the difficulty in reducing illiteracy rates in the age group from 25 years.

[14] "National Pact for Literacy at the Right Age" is a formal commitment made by the federal, state and municipal governments to ensure that all children are literate by the age of eight, at the end of the 3rd year of elementary school. Available at: http://pacto.mec.gov.br/o-pacto. Accessed on: 12/05/2016

Another important fact about education in the municipalities is the general level of education of the population, since the level of general education of the population influences different social and economic aspects, such as the level of knowledge of rights and duties as citizens and the productivity of work. Thus, Graph 5.3-12 shows the level of education of the population aged 25 or over in the municipalities of ADI and Piauí.

Graph 5.3-12 - Education of the Adult Population (25 years old and over) in the Municipalities of the ADI and Piauí - 1991, 2000 and 2010 (in %).



Souce: PNUD, 2013. Organized by: Arcadis, 2017.

According to the data presented in Graph 5.3-12, the schooling of people aged 25 or over (considered to be the average age at the conclusion of higher education), in the municipalities of the ADI and the state of Piauí, increased considerably in the period between 1991 and 2010.

In the municipalities of the ADI, the schooling rates of this population are lower than the state averages. According to the data presented, in 1991 in the municipalities of Campo Alegre do Fidalgo, Capitão Gervásio Oliveira and Dom Inocêncio, practically the entire population had not even completed elementary school, while the municipality of São João do Piauí presented a more favorable situation, although below the state average, at all levels of education.

In 2010, the situation in the municipalities of the ADI was more favorable, although in Campo Alegre do Fidalgo, Capitão Gervásio Oliveira, and Dom Inocêncio it was still very poor, since in these municipalities less than 30% of the population had completed some of the education levels. In São João do Piauí this number was more than double (65%), although still slightly below the state average, which was 67%.

C) Infrastructure

The result of the survey of data for the education network of the municipalities of ADI is summarized in Table 5.3-22 in which information on the number of educational establishments, number of teachers and numbers enrolled are presented.

According to the data presented, it is observed that the municipalities of the ADI have schools at the three levels of basic education (pre-school, elementary and high school), so students from the municipalities do not need to travel to others in search of learning at these levels.

Data Table 5.3-22 - Educational establishments, number of teachers and enrollment in the municipalities of the ADI and Piauí, 2015

Enrollment, Number of teachers and Schools		Campo Alegre do Fidalgo		Capitão Gervásio Oliveira		Dom Inocêncio		São João do Piauí		State of Piauí
		2005	2015	2005	2015	2005	2015	2005	2015	2015
Schools	Ensino pré-escolar	2	12	15	6	22	15	24	16	3.264
	Ensino fundamental	26	12	16	7	23	16	28	20	4.134
	Ensino médio	1	1	1	1	2	2	5	8	642
Enrollment	Ensino pré-escolar	45	152	121	125	311	201	671	683	95.371
	Ensino fundamental	1.499	865	909	697	2128	1.294	4.342	3.467	506.583
	Ensino médio	231	229	129	187	344	362	1.487	1.041	142.843
Teachers	Ensino pré-escolar	3	15	16	10	25	23	44	46	6.180
	Ensino fundamental	65	65	40	44	113	101	238	218	32.314
	Ensino médio	10	11	7	12	14	40	69	112	10.848
Rate Students/teachers	Ensino pré-escolar	15	10	8	13	12	9	15	15	15
	Ensino fundamental	23	13	23	16	19	13	18	16	16
	Ensino médio	23	21	18	16	25	9	22	9	13

Source: IBGE-Cidades, 2016. Organized: Arcadis, 2017

The number of teachers has increased, and it is observed that between 2005 and 2015 the ratio of students to each teacher was reduced in all municipalities of the ADI when by 2015 most municipalities were below the state average, except for Campo Alegre do Fidalgo and Capitão Gervásio Oliveira which had higher numbers student per teacher than the avarage.

According to the Secretaries of Education of the municipalities of the ADI, school transportation is offered to students who live far from the schools and meets all demand satisfactorily, even in rural areas of the municipalities. However, it was highlighted that students from more distant areas spend a lot of time in commuting, which ends up detracting from the students' learning process.

Also according to the secretariats' report, the municipalities of Campo Alegre do Fidalgo and Dom Inocêncio have technical education offered by the state government in the areas of information technology and administration (Campo Alegre do Fidalgo), and administration and agriculture (Dom Inocêncio). In Dom Inocêncio, hairdressing and electrictronics courses are also offered as a form of social assistance.

The municipality of São João do Piauí, who plays the role of local hub, has in its territory a campus of the Federal Institute of Piauí - IFPI, which offers technical and pratical training programme courses in the areas of administration, agriculture and fruit growing. In the municipality, according to the secretary of education, technical courses are also offered by the state government in the areas of nutrition, information technology, nursing, administration, work safety, accounting, and oral health, and according to the secretariate, the progammes offered are enough to meet current demand.

Photo 5.3-7 – Campus of Federal Institute of Piaui in São João do Piauí.

Photo 5.3-8 –Municipal Elementary school in Dom Inocêncio.

Source: Arcadis, 2017.

5.3.5.2. Health

A) Methodological Considerations

The studies were carried out based on secondary data from official sources, mainly at the Ministry of Health (National Registry of Health Establishments in Brazil - CNES). These surveys focused on characterizing the health system infrastructure in the municipalities of the ADI, considering the identification of physical and human resources. Morbidity and mortality rates (general and infant and their main causes) were also analyzed. In order to complement the secondary data, information on the topic was also obtained through interviews (according to the questionnaire model presented in ANNEX IX - Volume IV) with the heads of the Health Departments of the municipalities of Dom Inocêncio and São João do Piauí. Also, in Capitão Gervásio Oliveira, the Controller and the Secretary for Social Assistance were interviwed (considering the absence of the Secretary of Health). Contact with Campo Alegre do Fidalgo was not possible once the city hall was closed during the field survey days (Oct/31 to Nov/5/16).

B) Health Network and Services Available

As shown in Table 5.3-23, the health care network in ADI municipalities presents 2 situations. The first is from the municipalities of Campo Alegre do Fidalgo, Capitão Gervásio Oliveira and Dom Inocêncio, which provide a very scarce service network with only primary care, or emergency services in the case of Dom Inocêncio. In these municipalities, all health facilities available to the population are of public provision.

In São João do Piauí, given the size of the municipality, the service network is broader, which makes it the center of ultimate resource for municipalities in the region, among them Campo Alegre do Fidalgo and Capitão Gervásio Oliveira. Among the structure present in the municipality, we highlight the presence of a regional hospital, which is the responsibility of the state government, of a maternity hospital which, although it is a municipal hospital, is also a regional resource, of a dental service center, and of two units of the Customer Service Mobile Emergency - SAMU. In the municipality, in addition to the public assistance structures, there are also some private initiative facilities (doctor's offices, diagnostic unit and specialized clinic).

Data Table 5.3-23 - Number of Health Service Providers in Municipalities of the ADI, 2016.

Health Facility*	Campo Alegre do Fidalgo	Capitão Gervásio Oliveira	Dom Inocêncio	São João do Piauí
PSYCHOSOCIAL ATTENTION CENTER-CAPS	-	-	-	1
HEALTH CENTER / BASIC HEALTH UNIT	1	1	3	5
HEALTH SERVICES REGULATION CENTER	-	-	-	1
SPECIALIZED CLINIC / SPECIALIZED AMBULATORY	-	-	-	3**
CLINIC	-	-	-	2***
SPECIALIZED HOSPITAL	-	-	-	1
GENERAL HOSPITAL	-	-	-	1
HEALTH CENTER	2	2	1	-
ADIGNOSIS AND THERAPY SUPPORT SERVICE UNIT	2	1	1	1***

Health Facility*	Campo Alegre do Fidalgo	Capitão Gervásio Oliveira	Dom Inocêncio	São João do Piauí
MOBILE UNIT PRE-HOSP-URGENCY / EMERGENCY LEVEL	-	-	1	2
Total	**6**	**5**	**7**	**18**

** Except where noted, the establishments are from public administration. ** One public establishment and two private ones. *** Private establishments. Source: Ministry of Health - National Register of Health Facilities in Brazil - CNES. Situation of the national database in October 2016[15]. Elaborated by Arcadis,*

Analyzing the number of health centers / basic health units present in the municipalities of the ADI in relation to their respective populations, there is an adequate service as recommended by the Ministry of Health, of having a UBS with family health for up to 12,000 inhabitants in urban centers (BRAZIL, 2012[16]).

Photo 5.3-9 – Support Center for Family Health in Dom Inocêncio.

Photo 5.3-10 – Health Center in Capitão Gervásio Oliveira.

[15] Available at <http://www2.datasus.gov.br>

[16] BRAZIL. Ministry of Health. National Primary Care Policy. Brasília: Ministry of Health, 2012

Photo 5.3-11 – Municipal maternity hospital in São João do Piauí.

Photo 5.3-12 – Regional Hospital of São João do Piauí.

Source: Arcadis, 2017.

In addition to the level of facilities, it is important to assess whether they have sufficient human resources and capacity to serve the population. Thus, Table 5.3-24 shows the supply of doctors and hospital beds in the municipalities of the ADI.

Data Table 5.3-24 – Number of Doctors and Hospital Beds available in the Municipalities of the ADI 2016.

Municipality	Doctors		Hospital Beds			Hospital beds per 1,000 inhabitants
	Total	Doctors/1,000 inhab.	Provided by State	Provided by Municipality	Total	
Campo Alegre do Fidalgo - PI	1	0.20	-	-	-	0
Capitão Gervásio Oliveira - PI	2	0.50	-	-	-	0
Dom Inocêncio - PI	3	0.32	-	-	-	0
São João do Piauí - PI	20	1	36.00	28.00	64.00	3.2

Calculation performed based on the total number of doctors and not on employment contracts. Source: Ministry of Health - National Register of Health Facilities in Brazil - CNES. Situation of the national database in October 2016. Organized by Arcadis, 2017.

The proportion established by the SUS assistance parameters as a reference for the good medical care of the population is one doctor per 1,000 inhabitants[17]. Thus, it is observed that in the municipalities of the ADI the number of doctors is much lower than recommended, with the worst situation being verified in Campo Alegre do Fidalgo, where according to the data there is only one doctor to serve the entire population.

According to the data presented in Table 5.3-24, it is observed that among the municipalities of the the ADI only São João do Piauí has beds available for hospitalization, all of which belong to the public, state and municipal administration. According to SUS (National Health public system) parameters, the adequate number of hospital beds is 2.5 to 3 hospital beds for every 1,000 inhabitants (Portaria MS nº 1101/2002). Thus, it appears that the municipality has a sufficient number at 3.2 beds per 1,000 inhabitants, considering only the population of the municipality. However, it must be considered that the municipality is a heath hub for others in the region, which certainly makes this ratio insufficient for the adequate care of the population.

According to the Health Secretaries of the municipalities of Capitão Gervásio Oliveira, Dom Inocêncio and São João do Piauí, the main difficulties in the sector are related to specialized services, since the municipalities in the region do not have several medical specialties, which means that patients have to be transferred to Teresina, causing high costs for the local city halls responsible for transporting hospitalization cases.

With regards to a preventive health programme, one of the main strategies adopted by SUS (National Health public system) is related to the Family Health Program - PSF which aims to provide a more proactive and accessible service to the population. In the municipalities of Dom Inocêncio and São João do Piauí, according to the report of the respective Secretaries of Health, the PSF is successful with a sufficient number of teams serving both urban and rural areas. However, in the municipality of Capitão Gervásio Oliveira, according to the report of the Secretaries interviewed, the PSF has only two teams, which is insufficient to serve the entire population, especially due to the large proportion in rural areas.

C) Morbidity and Mortality

It is possible to make an approximation of the diseases that affect a given population by knowing the main causes of morbidity. Through these data can indicate the health status of a population. (BRAZIL, MINISTRY OF HEALTH, 2011). Thus, Graph 5.3-13 presents the main causes of hospital morbidity in the municipalities the ADI.

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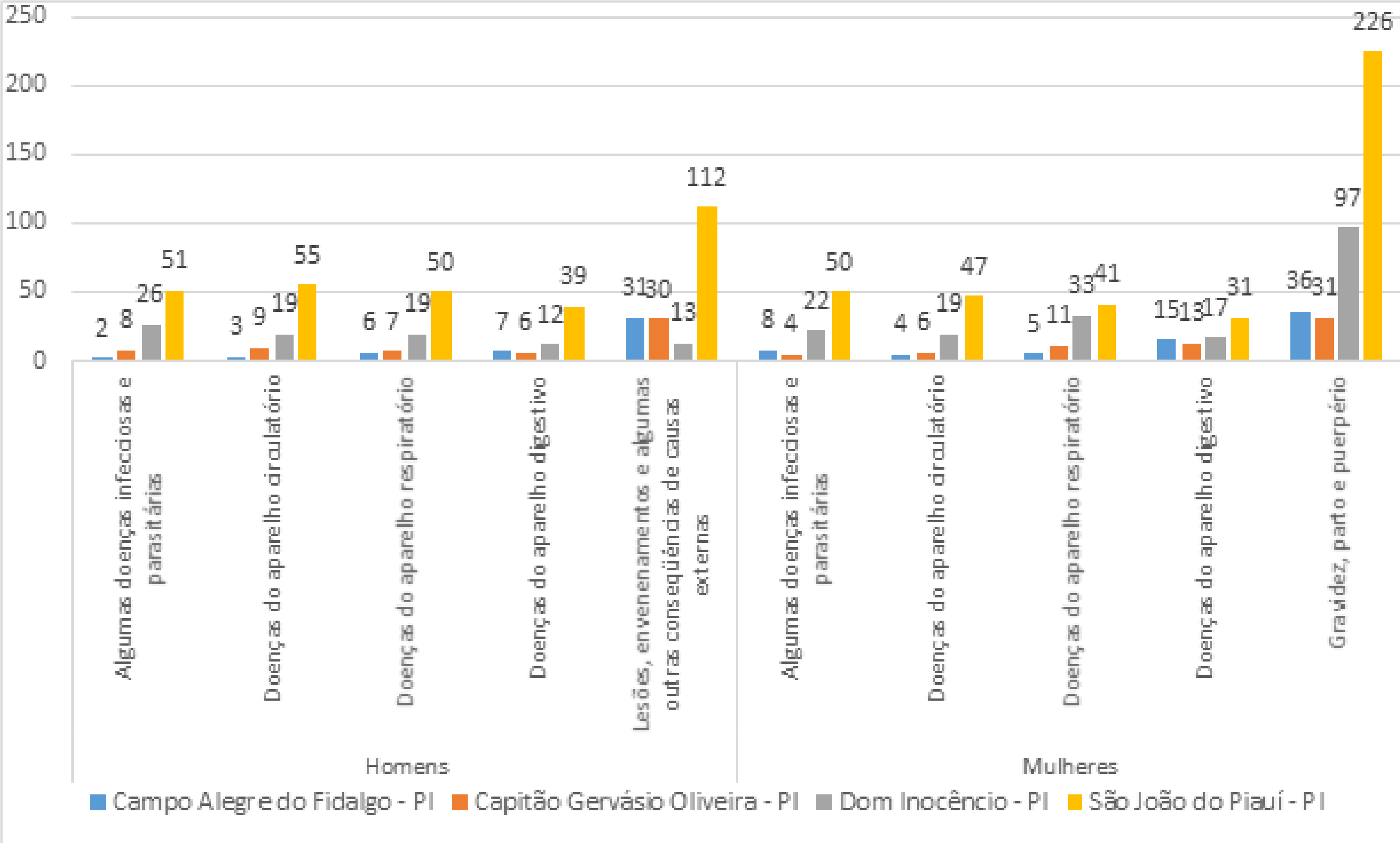
[17] Reference value contained in ordinance 1101/2002 of the Health Mininstry, however in accordance with the National Pact for Health (available at: http://bvsms.saude.gov.br/bvs/publicacoes/pacto_nacional_saude_mais_medicos.pdf, accessed June 2015), the Federal Government's reference value is 2.7 doctors per thousand inhabitants.

Graph 5.3-13 – Main causes of Hospital Morbidity - Men and Women - in Municipalities of the ADI, 2015.

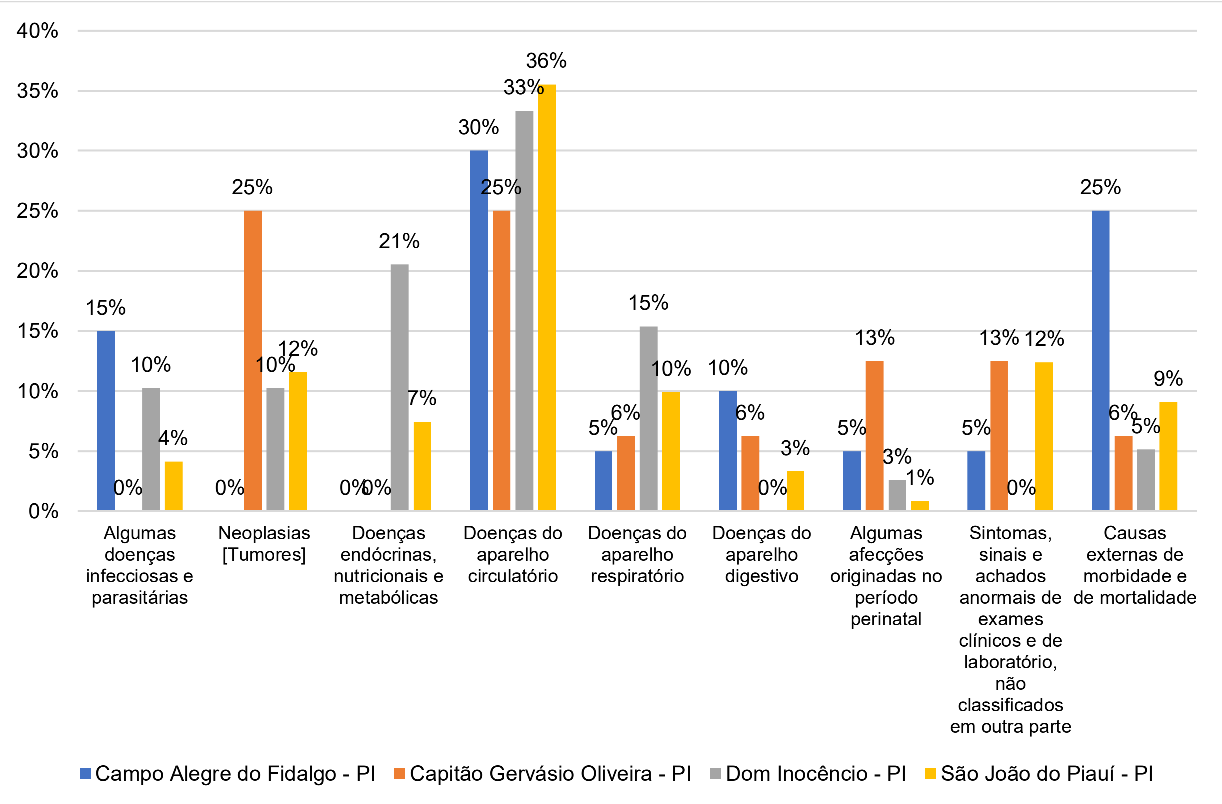


Source: DATASUS - Epidemiological and Morbidity, 2016. Organized: Arcadis, 2017.

As can be seen in Graph 5.3-13, in the municipalities of ADI the main causes of hospitalization are different according to genders, among women those related to pregnancy, childbirth and the puerperium, and among men the result of external causes. As a second major factor there are differences between the municipalities of the ADI, with Campo Alegre do Fidalgo and Capitão Gervásio Oliveira those related to the digestive system, in Dom Inocêncio those related to the respiratory system, which can be related both to environmental and climatic issues, and to the lifestyle of the population (such as smoking, for example), and in São João do Piauí those related to infectious or parasitic diseases, which are closely related to insanitary conditions to which its residents are exposed.

For the analysis of the main causes of death in the municipalities of ADI, Chart 5.3-14 is presented, which indicates the percentage of deaths according to the main groups of causes in the municipalities of ADI.

Graph 5.3-14 – Proportional Mortality According to the Main* Groups of Causes (ICD10) in The Municipalities of the ADI - 2014.



** Responsible for at least 10% of deaths in at least one of the municipalities of the ADI.*

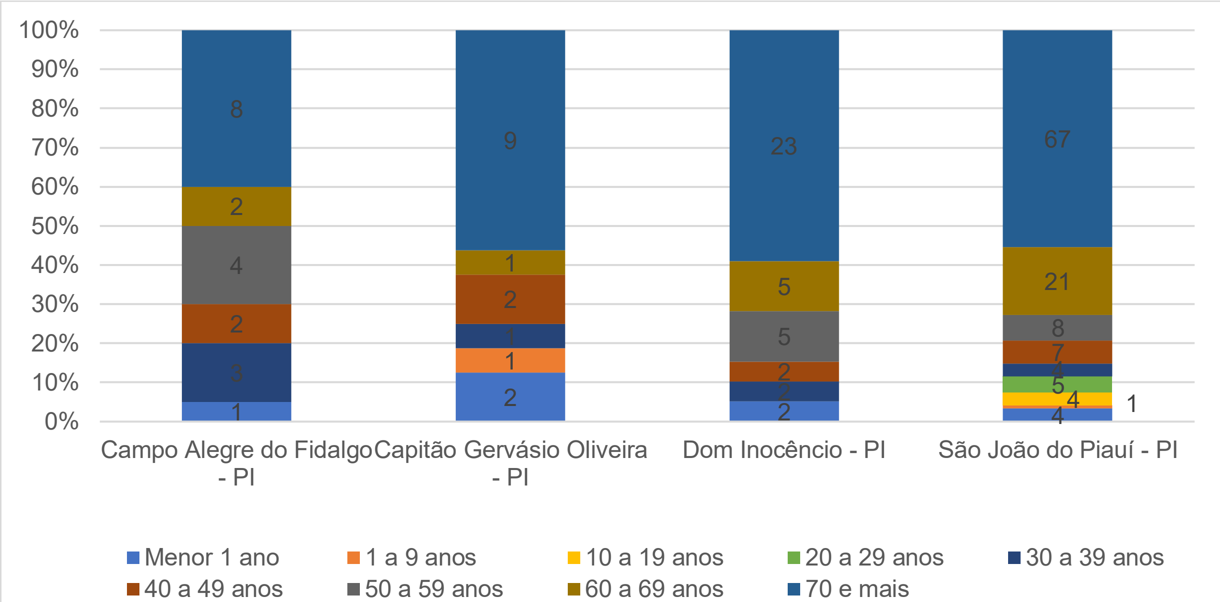
Source: DATASUS - Mortality Information System - SIM, 2016. Elaboration: Arcadis, 2017.

In all ADI municipalities, the main cause of deaths in 2014 was diseases of the circulatory system, responsible for about 30% of deaths in the municipalities. The second leading cause of death varies among the municipalities of the ADI, with external causes in Campo Alegre do Fidalgo, neoplasms in Capitão Gervásio Oliveira and São João do Piauí, and endocrine diseases in Dom Inocêncio.

It is important to highlight the low death rate in ADI municipalities in relation to the total population, 0.4% in Campo Alegre do Fidalgo, Capitão Gervásio Oliveira and Dom Inocêncio and 0.6% in São João do Piauí. It is also noteworthy that these deaths are concentrated in the elderly population, in Dom Inocêncio and São João do Piauí this represented about 70% of deaths, in Capitão Gervásio Oliveira the percentage was just over 60% and in Campo Alegre do Fidalgo 50%.

Graph 5.3-15 shows the numbers and percentages of death by age group in the municipalities of the ADI.

Graph 5.3-15 – Proportional Mortality by Age in the Municipalities of the ADI - 2014.



Source: DATASUS - Mortality Information System - SIM, 2016. Organized: Arcadis, 2017.

Regarding infant mortality, as shown in Table 5.3-25 the municipalities of the the ADI showed improvements when evaluating the period from 2008 to 2014. All municipalities presented lower rates of infant mortality in 2014 than those verified in the year 2008.

When compared to the average infant mortality rate in the state of Piauí (15), the infant mortality rates of Campo Alegre do Fidalgo (18), Capitão Gervásio Oliveira (39) and Dom Inocêncio (21) can be considered high. São João do Piauí (13) has an index slightly below the state average. It is important to highlight that in small municipalities, such as those of the ADI, a single death represents a greater change in the rate of infant mortality.

It is worth mentioning that the World Health Organization (WHO) considers the rate of 10 deaths for every thousand live births to be the acceptable limit therefore, the municipalities and the state have unacceptablly high rates by WHO standards. The decrease in mortality rates has a high correlation with social conditions, such as education, income and sanitation, and positions it as a good indirect indicator of health conditions (Health Indicators, ANVISA, 2011).

Data Table 5.3-25 - Infant Mortality Coefficient* (deaths per 1,000 live births) in The Municipalities of the ADI, 2008 to 2014.

Territorial Unit	Infant Mortality							Infant Mortality per 1000 live births						
	2008	2009	2010	2011	2012	2013	2014	2008	2009	2010	2011	2012	2013	2014
Campo Alegre do Fidalgo - PI	5	1	1	2	2	0	1	53	14	14	26	29	0	18
Capitão Gervásio Oliveira - PI	2	0	0	0	0	2	2	37	0	0	0	0	74	39
Dom Inocêncio - PI	6	2	3	1	1	1	2	53	20	29	11	10	11	21
São João do Piauí - PI	9	9	5	4	3	5	4	22	24	14	12	11	16	13
Piauí	972	913	833	847	797	761	743	18	18	17	17	17	16	15

*Source: MS / SVS / DASIS - Mortality Information System - SIM. * (Number of deaths in children under one year old / number of live births) x 1000. Organized: Arcadis, 2017.*

5.3.5.3. Housing Conditions

A) Methodological Considerations

The theme of housing conditions of the ADI was structured in order to present a general view of the housing situation of the municipalities of the ADI, focusing on the issue of housing deficit, having as its source the study Housing Deficit in Brazil - 2010 prepared by the João Pinheiro Foundation - FJP (2013) based on data from the 2010 Census (IBGE).

In addition to the analysis related to the housing deficit, data were also collected that characterized the housing situation of the municipalities, showing the occurance of vacant homes in the municipalities of the ADI, also from data from the 2010 Census, made available by the FJP.

B) Housing Deficit Estimates at Municipalities of the ADI

The concept of housing deficit used by FJP is related to lack of housing availability, of which there are of two types: housing in precarious construction conditions; and the need to increase housing as a result of families struggling to pay rent or will form a single parent family (FJP, 2013).

The housing deficit can also be seen as an indicator that can contribute to the formulation and evaluation of the housing policy, as it drives the public manager in specifying the housing needs. In this sense Magnabosco (2012) highlights:

> The new Brazilian housing policy, in providing subsidy and credit, is a fundamental tool in combating the housing deficit, which is strongly concentrated in low-income families. These families were not adequately served by the housing market or by the credit market. In this way, they ended up relying on self-construction or increasing the contingent of precarious housing, tenements and slums. In other cases, these families usually live

together with relatives or friends, as a resulto f the increasing the housing deficit[18] (MAGNABOSCO, et al., 2012).

According to the FJP methodology, the housing deficit comprises four components:

- Precarious households, whether rustic or improvised;
- Family cohabitation, comprising cohabiting families with the intention of moving out or remaining in accommodation;
- Excessive burden with rent, that is, households whose rent value exceeds 30% of the total household income; and
- Excessive density of rented households, characterized by rented households with more than three inhabitants using the same sleeping space, which characterizes excessive density.

Thus, it can be seen in Table 5.3 26 that the housing deficit in the municipalities of the ADI is mainly due to family cohabitations, being the most representative category in Campo Alegre do Fidalgo (45), Dom Inocêncio (147) and São João do Piauí (307), while in Capitão Gervásio Oliveira the biggest deficit is due to precarious households (66).

Considering the housing deficits found in the the municipalities of the ADI in relation to the total number of households, it appears that the deficits are relatively low when compared to the Piauí state average.

Data Table 5.3-26 – Estimated housing deficit in the municipalities of the ADI and Piauí - 2010.

Territorial Unit	Precarious Households		Family Cohabitation		Excessive burden with rent		Rent densification		Total Housing Deficit	
	Nº	%	Nº	%	Nº	%	Nº	%	Nº	%
Campo Alegre do Fidalgo	8	0.6	45	3.6	7	0.6	8	0.7	68	5.4
Capitão Gervásio Oliveira	66	5.7	45	3.9	11	1	3	0.3	125	10.9
Dom Inocêncio	76	3	147	5.7	20	0.8	-	-	243	9.5
São João do Piauí	36	0.7	307	5.7	87	1.6	35	0.6	465	8.7

[18] MAGNOBOSCO, Ana L; CUNHA, Patrícia H. F.; GARCIA, Fernando. Measurement of the housing deficit in Brazil. PESQUISA & DEBATE, SP, volume 23, number 2 (42) pp. 269-290, Jul-Dec. 2012.

Territorial Unit	Precarious Households		Family Cohabitation		Excessive burden with rent		Rent densification		Total Housing Deficit	
	Nº	%	Nº	%	Nº	%	Nº	%	Nº	%
Estado do Piauí	62,456	7.4	51,033	6	11,960	1.4	3,590	0.4	129,038	15.2

Source: Municipal Housing Deficit in Brazil - 2010, 2013. Organized by: Arcadis, 2017.

Another data from the 2010 Census that can be analyzed in addition to the housing deficit is the number of vacant households, which corresponds to the units that were actually unoccupied on the reference date of the census.

Data Table 5.3-27 - Estimated housing deficit in Piauí and the municipalities of the ADI – 2010.

Territorial Unit	Permanent private housing units	Vacant Houses	
		Nº	%
Campo Alegre do Fidalgo	1,253	340	27.1
Capitão Gervásio Oliveira	1,147	388	33.8
Dom Inocêncio	2,555	702	27.5
São João do Piauí	5,354	853	15.9
Piauí	848,413	120,508	14.2

Source: Municipal Housing Deficit in Brazil - 2010, 2013. Organized by: Arcadis,

As shown in Table 5.3-27, the number of vacant households in the ADI municipalities exceeds those of housing deficit, indicating that the housing issue is not limited to the availability of homes. However, it is important to mention that the Housing Deficit in Brazil - 2010 study highlights that:

> There is in the popular imagination the belief that the deficit problem could be solved, or even mitigated, through the occupation of vacant homes. The equation, however, is not so simple. For any action in this direction to occur, it would be necessary to better characterize vacant households (housing conditions, price, location, among others), in order to identify the portion that could most likely be directed to supply part of the population's housing shortages. (FJP, 2013)

5.3.5.4. Basic Infrastructure

A) Methodological Considerations

For the analysis of this section, factors referring to the conditions in the households present in the enterprise's ADI were used, having as a source the 2010 Demographic Census. Thus, the data refers to: the water supply network; the sewage disposal system; the form of collection and disposal of solid waste; and electricity supply network.

In a complementary way, information collected during a field survey, between Oct/3/2016 and Nov/5/2016, through interviews with Municipal Officials of the municipalities of Capitão Gervásio Oliveira, Dom Inocêncio and São João do Piauí (according to the questionnaire model presented in ANNEX IX - Volume IV) was used. In Campo Alegre do Fidalgo contact was not possible, as the city hall was closed during the days of the survey.

Water SupplyThe data from the 2010 Census (Graph 5.3-16 and Table 5.3-28) show that, in relation to the forms of water supply for households, the municipalities of the ADI present either a very poor or no water supply system. Only in São João do Piauí, is there a water supply to 78% of households. The water system is managed by Águas e Esgotos do Piauí SA (Agespisa).

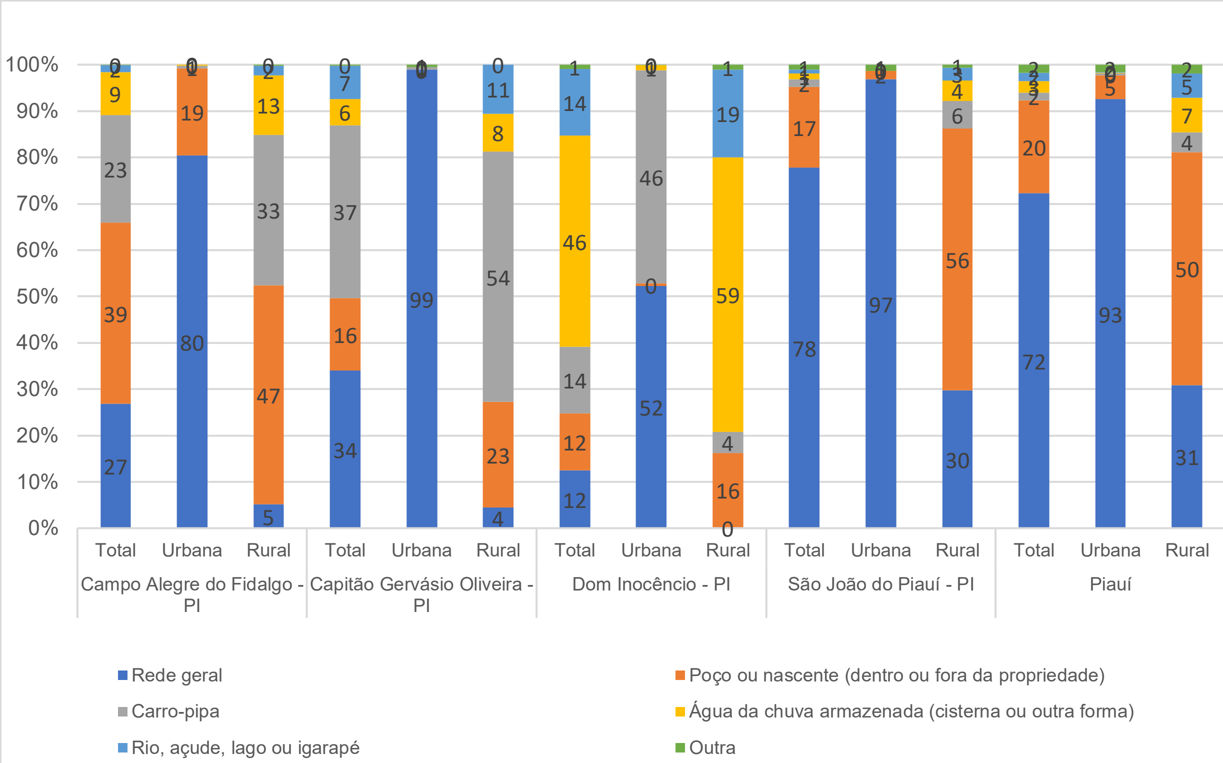
In the other municipalities, it can be seen in the data presented that the situation is quite different from that found in São João do Piauí, since the general network of water supplies reaches only 27% of the households in Campo Alegre do Fidalgo, 34% in Capitão Gervásio Oliveira, and 12% in Dom Inocêncio. In these municipalities, most households are supplied by wells and water trucks. Comparing these with the Piauí average, it is observed that these municipalities are far below the situation at state level, which has a rate of 72% of households with water supplied through the general network.

It is important to highlight that even where there is a water supply service through the general network, according to residents heard in the field survey interviews, the population suffers from low pressure systems and poor quality of water.

In addition to the low percentage and quality of supply, it stands out that the water provided is of low quality and it is not suitable for human consumption, according to the Secretaries for Infrastructure from Capitão Gervásio Oliveira e Dom Inocêncio, and to the president of the Rural Workers Union from Campo Alegre do Fidalgo. In São João do Piauí the water captured goes through a simple treatment process, a chlorination tower for the water captured in two artesian wells. According to the municipality's Secretaries for Infrastructure, there is a plan for the construction of a large water treatment plant to be supplied by the Jenipapo Dam.

Although the municipalities have presented a low quality of service of the water supply network, according to the Secretaries for Infrastructure of Capitão Gervásio Oliveira and Dom Inocêncio, there are no plans for improvement of the current infrastructures and to provide quality water for every household.

Graph 5.3-16 – Means of Water Supply in the municipalities of the ADI and Piauí, 2010 (%)



Source: Brazilian Institute of Geography and Statistics (IBGE), 2010. Prepared by: Arcadis,

Data Table 5.3-28 - Means of Water Supply per housing types in the municipalities of the ADI and Piauí, 2010

Territoria Unit	Household Classification	Means of water Supply												Total of Household
		General Network		Well and Spring (inside ou out the property)		Water Tank		Rainwater Storage		River, pond, Dam.		Others		
		Household	%	Household	%	Household	%	Household	%	Household	%	Household	%	
Campo Alegre do Fidalgo - PI	Total	338	27	491	39	293	23	115	9	19	2	2	0	1,258
	Urban	292	80	68	19	2	1	1	0	0	0	0	0	363
	Rural	46	5	423	47	291	33	114	13	19	2	2	0	895
Capitão Gervásio Oliveira - PI	Total	389	34	179	16	427	37	64	6	83	7	2	0	1,144
	Urban	354	99	0	0	2	1	0	0	0	0	2	1	358
	Rural	35	4	179	23	425	54	64	8	83	11	0	0	786
Dom Inocêncio - PI	Total	319	12	316	12	365	14	1,166	46	368	14	23	1	2,557
	Urban	314	52	3	0	277	46	6	1	0	0	1	0	601
	Rural	5	0	313	16	88	4	1,160	59	368	19	22	1	1,956
São João do Piauí - PI	Total	4,173	78	928	17	90	2	69	1	41	1	60	1	5,361
	Urban	3,720	97	70	2	0	0	1	0	0	0	50	1	3,841
	Rural	453	30	858	56	90	6	68	4	41	3	10	1	1,520

Territoria Unit	Household Classification	General Network		Well and Spring (inside ou out the property)		Water Tank		Rainwater Storage		River, pond, Dam,		Others		General Network
		Household	%	Household	%	Household	%	Household	%	Household	%	Household	%	Household
Piauí	Total	612,602	72	170,016	20	14,408	2	21,249	3	15,424	2	14,564	2	848,263
	Urban	526,035	93	29,290	5	2,553	0	557	0	688	0	9,189	2	568,312
	Rural	86,567	31	140,726	50	11,855	4	20,692	7	14,736	5	5,375	2	279,951

Source: Brazilian National Institute of Statistics (IBGE), 2010 . Organized by: Arcadis, 2017

B) Sewage

The sanitary sewage services correspond to the set of facilities for the collection, treatment and proper disposal for the waters served at homes, that is, preventing these waters from being harmful to the environment.

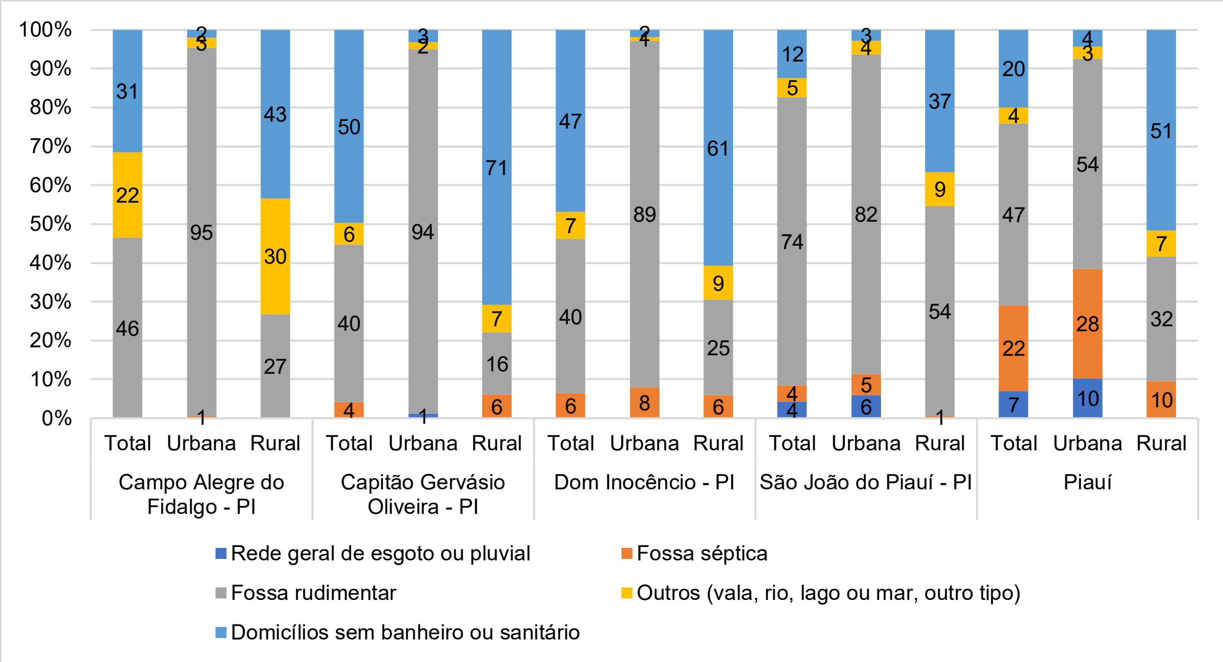
It is observed in Table 5.3-29 and in Graph 5.3-17 that only 4% of the households of Capitão Gervásio Oliveira and São João do Piauí, and 5% in Dom Inocêncio, have relatively adequate sanitation, since they are discarded through septic tanks that prevent contamination of the soil and groundwater. In Campo Alegre do Fidalgo even this modality was identified in only two households, which makes it percentage null.

Thus, it can be verified through the data presented in Table 5.3-29 and in Graph 5.3-17 that practically all the sewage from the ADI households are inadequately disposed of. In the ADI municipalities, the use of rudimentary pits as a control system predominates, especially in urban areas, 46% in Campo Alegre do Fidalgo, 40% in Capitão Gervásio Oliveira and Dom Inocêncio, and 74% in São João do Piauí. In rural areas, disposal in ditches and streams is more prevalent, and especially in many households without access to bathrooms or toilets.

With regard to the state average, it is observed that in Piauí the situation is not very favorable in this respect, with only 7% of households presenting collection by network and 22% having septic tanks, with 51% of households discarding in a inadequate way and 20% do not have a bathroom or toilet.

The municipality of São João do Piauí presents a plan for the implementation of a collection and treatment system for the sanitary sewage of the urban headquarters, already counting on the construction of three lagoons for the future Sewage Treatment Station (ETE). The other municipalities of ADI do not have any plans for the implementation of a collection and / or treatment system for sanitary sewage.

Graph 5.3-17 - Type of Sewage by Situation of Home in the municipalities of the ADI and Piauí, 2010.



Source: Brazilian Institute of Geography and Statistics (IBGE), 2010. Organized by: Arcadis, 2017

Data Table 5.3-29 – Type of sanitary sewage by household location in the municipalities of the ADI and Piauí, 2010.

Territorial Unit	Household Classification	Household with bathroom or toilet								Household without bathroom or toilet		Household Total
		Sewage Network		Septic Tank		Septic Pit		Open-air Ditches, Lagoon, River,				
		Household	%	Household	%	Household	%	Household	%	Household	%	
Campo Alegre do Fidalgo - PI	Total	0	0	2	0	584	46	277	22	395	31	1,258
	Urban	0	0	2	1	344	95	10	3	7	2	363
	Rural	0	0	0	0	240	27	267	30	388	43	895
Capitão Gervásio Oliveira - PI	Total	4	0	48	4	462	40	63	6	567	50	1,144
	Urban	4	1	0	0	336	94	7	2	11	3	358
	Rural	0	0	48	6	126	16	56	7	556	71	786
Dom Inocêncio - PI	Total	1	0	164	6	1,015	40	177	7	1,200	47	2,557
	Urban	1	0	48	8	535	89	6	1	11	2	601
	Rural	0	0	116	6	480	25	171	9	1,189	61	1,956
São João do Piauí - PI	Total	232	4	219	4	3,979	74	270	5	661	12	5,361
	Urban	229	6	211	5	3,158	82	137	4	106	3	3,841

Territorial Unit	Household Classification	Household with bathroom or toilet								Household without bathroom or toilet		Household Total
		Sewage Network		Septic Tank		Septic Pit		Open-air Ditches, Lagoon, River,				
		Household	%	Household	%	Household	%	Household	%	Household	%	
	Rural	3	0	8	1	821	54	133	9	555	37	1,520
Piauí	Total	59,346	7	187,214	22	396,572	47	36,127	4	169,004	20	848,263
	Urban	58,423	10	160,272	28	307,256	54	17,461	3	24,900	4	568,312
	Rural	923	0	26,942	10	89,316	32	18,666	7	144,104	51	279,951

Source: Brazilian Institute of Geography and Statistics (IBGE), 2010. Organized by: Arcadis, 2017.

Photo 5.3-13 – open-air sewage discharge at the headquarters of Capitão Gervásio Oliveira (02/11/2016).

Photo 5.3-14 - open-air sewage discharge at the headquarters of Capitão Gervásio Oliveira (02/11/2016).

Source: Arcadis, 2017.

C) Collection and Disposal of Solid Waste

As shown the data from the 2010 Census (Table 5.3-30), it is observed that households in the municipalities of the ADI have a low percentage of solid waste collection, 26% in Campo Alegre do Fidalgo, 31% in Capitão Gervásio Oliveira, 22% in Dom Inocêncio, and 66% in São João do Piauí, the first three below the state average and São João do Piauí slightly above, since in the state of Piauí, 61% of households have waste collection.

Waste not collected in the municipalities of the ADI is concentrated in rural areas where about 70 to 80% of households have their waste burned within the properties, the rest being disposed of in other, inappropriate ways (buried, dumped in wasteland, dumped in river, other destiny).

The management of waste collection services in the municipalities of the ADI is carried out by the respective city halls and and attending the urban areas, according to information from the Secretaries for Works. Also, according to the Secretaries and other interviewees, there is no selective collection (recyclable waste) in the municipalities.

According to the Secretaries interviewed in Capitão Gervásio Oliveira and Dom Inocêncio, the solid waste collected in the municipalities is taken to open-air dumps, in São João do Piauí the collected waste material is buried, in both cases the disposal sites are in the vicinity of the respective municipal headquarters. As an example, the visit made to the disposal site of the municipality of Dom Inocêncio registered that the waste material collected by the city is discarded on land that is only fenced and very close to the municipality's headquarters, about a kilometer away, as shown in Photo 5.3-15 and Photo 5.3-16.

Photo 5.3-15 – Dumping Ground - Dom Inocêncio (04/11/2016).

Photo 5.3-16 – Dumping Ground - Dom Inocêncio (04/11/2016).

Source: Arcadis, 2017.

Regarding the solid waste collection, there are no plans to improve the quality of services offered by the municipalities of the ADI, according to the municipals' Secretaries for Works.

Data Table 5.3-30 - Household´s Waste Destination in the municipalities of the ADI and Piauí,

Territorial Unit	Household Classification	Waste Colletion				No Waste Colletion				Household Total
		Directly by Waste Collection Service		In Waste Service Bins		Burned at property		Illegal Landfill, Dumping Ground, Open Pit, River, Other		
		Household	%	Household	%	Household	%	Household	%	
Campo Alegre do Fidalgo - PI	Total	276	21.94	54	4.29	663	52.70	265	21.07	1,258
	Urban	276	76.03	53	14.60	23	6.34	11	3.03	363
	Rural	0	0.00	1	0.11	640	71.51	254	28.38	895
Capitão Gervásio Oliveira - PI	Total	345	30.16	7	0.61	661	57.78	131	11.45	1,144
	Urban	343	95.81	7	1.96	8	2.23	0	0.00	358
	Rural	2	0.25	0	0.00	653	83.08	131	16.67	786
Dom Inocêncio - PI	Total	558	21.82	7	0.27	1.292	50.53	700	27.38	2,557
	Urban	558	92.85	7	1.16	25	4.16	11	1.83	601
	Rural	0	0.00	0	0.00	1.267	64.78	689	35.22	1,956
São João do Piauí - PI	Total	3,455	64.45	77	1.44	1.440	26.86	389	7.26	5,361
	Urban	3,434	89.40	70	1.82	242	6.30	95	2.47	3,841
	Rural	21	1.38	7	0.46	1.198	78.82	294	19.34	1,520
Piauí	Total	463,132	54.60	59,341	7.00	240,259	28.32	85,531	10.08	848,263
	Urban	446,941	78.64	54,998	9.68	49,263	8.67	17,110	3.01	568,312
	Rural	16,191	5.78	4,343	1.55	190,996	68.22	68,421	24.44	279,951

D) Eletricity

The concessionaire responsible for the distribution of electricity in the ADI municipalities is Eletrobrás. All municipalities have public lighting at their municipal headquarters.

According to data from the 2010 Census, presented in Table 5.3-31, the municipalities of the the ADI, with the exception of São João do Piauí, had a high rate of households without electricity coverage, 32% in Campo Alegre do Fidalgo, 54% in Capitão Gervásio Oliveira and 55% in Dom Inocêncio, all well above the state average, which is only 6.9%. São João do Piauí in turn has a much lower index of only 4.1%.

The high rate of households without electricity in the municipalities of ADI is the result of low coverage in rural areas, since in the urban areas the coverage rates are over 96%. In this sense, the municipalities of Capitão Gervásio Oliveira and Dom Inocêncio presented the worst situations, since 79% of rural households in Capitão Gervásio Oliveira and 71% of Dom Inocêncio did not have access to electricity.

It is important to mention that, according to a report by municipality official, the electric energy distribution network has been expanding for some years through the federal eletrification programme known as Luz Para Todos (Light for Everyone).

Data Table 5.3-31 – Household with Electricity Situation by the municipalities of the ADI and Piauí, 2010.

Territorial Unit	Households Classification	Households with Eletricity				Households without Eletricity		Total of House holds
		Local Supplier		Others				
		House holds	%	House holds	%	House holds	%	
Campo Alegre do Fidago - PI	Total	803	63,8%	52	4,1%	403	32,0%	1.258
	Urban	356	98,1%	7	1,9%	0	0,0%	363
	Rural	447	49,9%	45	5,0%	403	45,0%	895
Capitao Gervasio Oliveria - PI	Total	470	41,1%	52	4,6%	622	54,4%	1.144
	Urban	358	100,0%	0	0,0%	0	0,0%	358
	Rural	112	14,3%	52	6,6%	622	79,1%	786
Dom Inocêncio - PI	Total	859	33,6%	283	11,1%	1.415	55,3%	2.557
	Urban	577	96,0%	1	0,2%	23	3,8%	601
	Rural	282	14,4%	282	14,4%	1.392	71,2%	1.956
São João do Piaui - PI	Total	5.133	95,8%	5	0,1%	223	4,2%	5.361
	Urban	3.812	99,2%	1	0,0%	28	0,7%	3.841
	Rural	1.321	86,9%	4	0,3%	195	12,8%	1.520
Piaui	Total	748.509	92,5%	5.262	0,6%	48.492	6,9%	848.263
	Urban	591.350	98,8%	1.854	0,3%	5.108	0,1%	568.312
	Rural	223.159	79,7%	3.408	1,2%	53.284	19,1%	279.951

Source: Brazilian Institute of Geography and Statistics (IBGE), 2010. Organized by: Arcadis, 2017.

It is also noteworthy that the municipalities in the region are going through a process of reviewing projects for the production of electricity from alternative sources such as wind power and solar plants. Regarding the electricity network, the presence of CHESF's energy substation in São João do Piauí is also noteworthy.

5.3.5.5. Public Security

For the information regarding the public security structure available for the population of the municipalities of the the ADI, official public sources such as sites of the Civil and Military Police of the state of Piauí, as well as of the state Public Security Secretary, and the research "Profile of the Municipalities" Brasileiros ", held by IBGE in 2012, were used.

The research presents a set of information about Public Security Management, in which is shown the current public security infrastructures available. For the municipalities of the ADI, the survey indicates only the presence of Civil police stations in the municipalities of Campo Alegre do Fidalgo, Capitão Gervásio Oliveira and São João do Piauí.

The other secondary sources did not present data on the municipalities of the ADI, so for more information, the Secretaries for Works of Capitão Gervásio Oliveira, Dom Inocêncio and São João do Piauí were consulted about the present structure and the main difficulties experienced in the municipalities.

Thus, in Capitão Gervásio Oliveira and Dom Inocêncio it was reported that the contingent of police officers is low, as well as the number and adequacy of the vehicles they use (only one in each municipality), considering the rural characteristics of the municipalities. Dom Inocêncio also reported problems with theft and robbery. In São João do Piauí, the Secretary interviwed reported that there were no security problems, thefts being the main types of crimes in the municipality.

5.3.5.6. Human Development Index

A) Methodological Considerations

The HDI (Human Developement Index) was created by the United Nations Development Program (UNDP) in 1990 with the aim of classifying human development in different countries. Regarding the evaluation of Brazilian municipalities, the UNDP, the Institute of Applied Economic Research (IPEA) and the João Pinheiro Foundation (FJP) adapted the global HDI methodology for Brazilian context and the availability of national indicators, which resulted in the Municipalty Human Development Index (MHDI), based on longevity, education and income indicators, measured using the variables presented in Table 5.3-1.

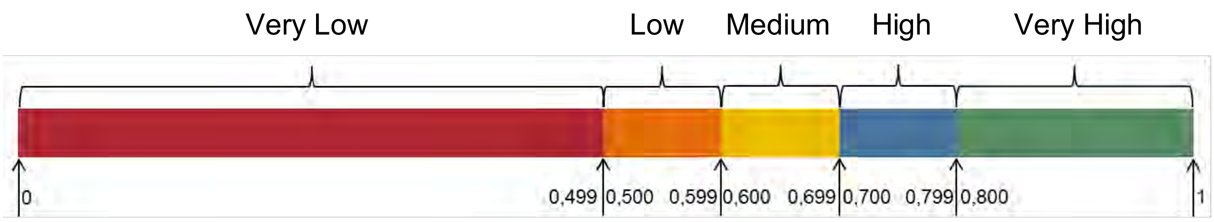
Table 5.3-1 – Variables used in the composition of the MHDI.

Theme	Variables Used
Long and healthy life - Longevity	Measured by life expectancy at birth, calculated from data from the IBGE Demographic Census.
Acess to knowledge - Education	**Measured from two indicators:** a) Percentage of people aged 18 or over with complete elementary education (weight 1); b) School flow of the population in different age groups (5 to 6 years, 11 to 13 years, 15 to 17 years and 18 to 20 years) in order to accompany the school-age population in four important moments of their education, which it makes it easier to identify whether children and young people are in the series appropriate for their age (weight 2).
Standard of living - Income	Measured by the municipal income per capita obtained from the sum of the income of all residents divided by the number of people residing in the municipality.

Source: Atlas of Human Development in Brazil 2013 - UNDP, IPEA and FJP. Adaptation: Arcadis, 2017.

It is noteworthy that the MHDI uses a score with a range between 0 and 1, and the closer to 1, the greater the human development in a municipality. The figure below shows the bands that classify the municipalities, according to the degree of human development.

Figure 5.3-1 – Range of Municipality Human Development Index - MHDI.



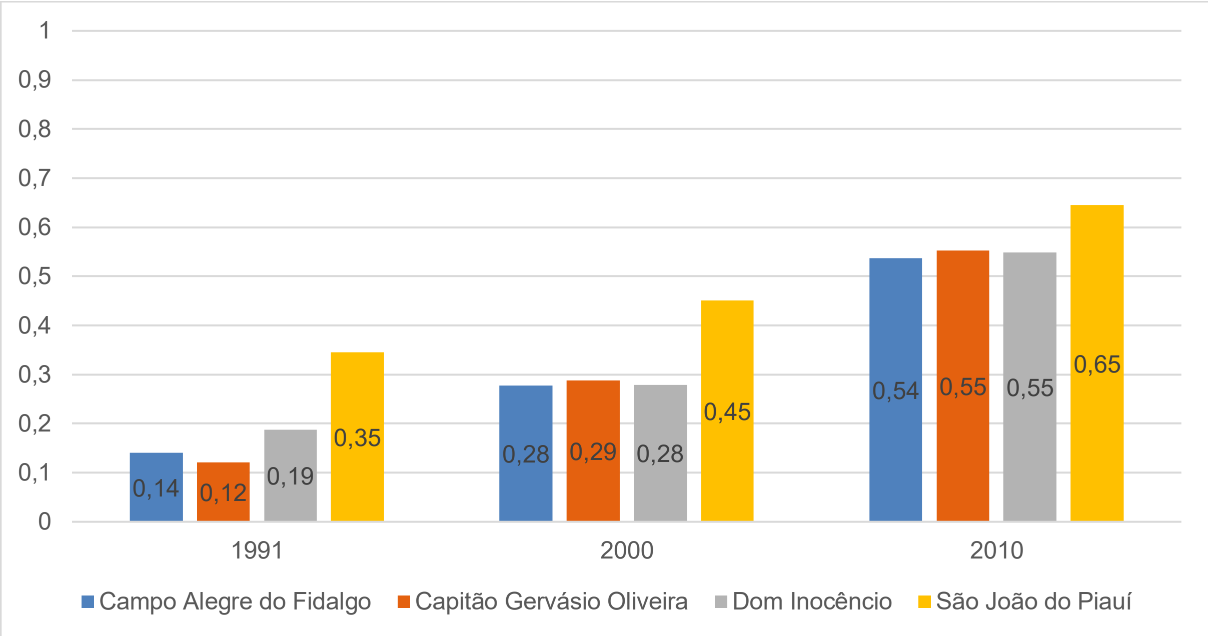
Source: Atlas of Human Development in Brazil 2013 - UNDP, IPEA and FJP. Adaptation: Arcadis, 2017.

B) Evaluation of MHDI

Between the years 1991 and 2010, the municipalities of the ADI showed advances in the results of their MHDI, as can be seen in Graph 5.3-18. However, it is observed that these are still at low levels. While municipalities of the ADI have shown development between the years 1991 and 2000 it is found that included municipalities rated as very low on the human development index, with São João do Piauí presenting indexes superior to the others (Graph 5.3-18).

Between 2000 and 2010 there was a significant development with respect to the MHDI of the municipalities of the ADI, with Campo Alegre do Fidalgo, Capitão Gervásio Oliveira and Dom Inocêncio practically doubling their indexes, rising from about 0.28 to 0.55, moving up to classification of Low human development municipalities. São João do Piauí in the same period managed to rise two levels, being considered a municipality with medium level of development, although it showed lower growth, rising from 0.45 to 0.65.

Graph 5.3-18: Municipal Human Development Index (MHDI) in the Municipalities of the ADI, 1991-2010.

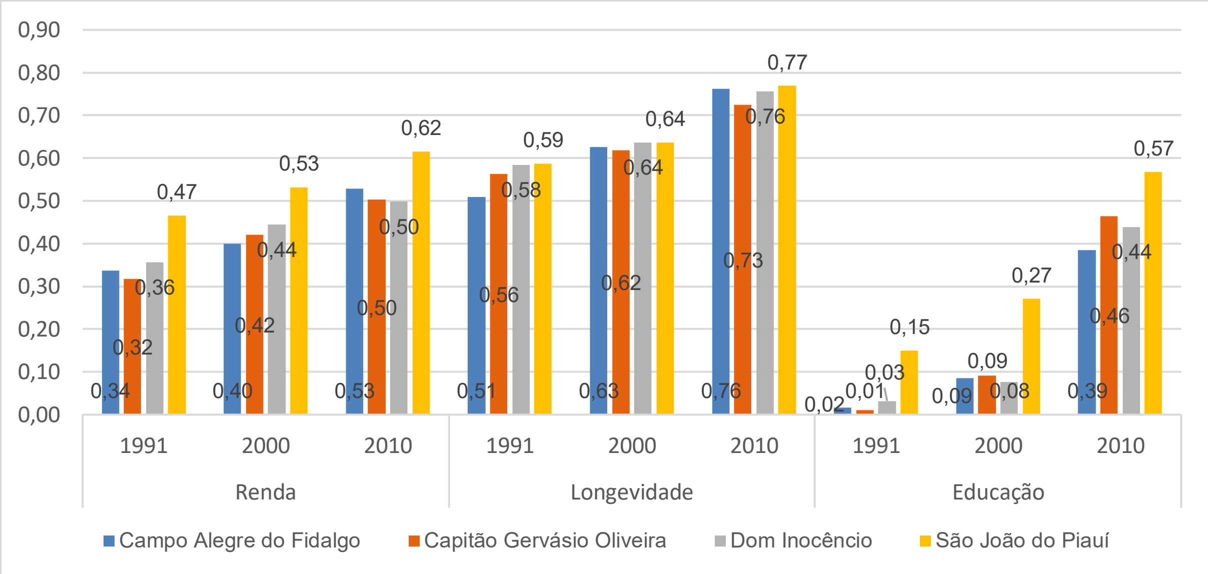


Source: Atlas of Human Development in Brazil 2013 - UNDP, IPEA and FJP. Adaptation: Arcadis, 2017.

The main component responsible for the improvement of the MHDI in the municipalities of the ADI was Education, which in the studied period (1991 to 2010) went from almost zero in Campo Alegre do Fidalgo, Capitão Gervásio Oliveira and Dom Inocêncio, to about 0.4 in Campo Alegre do Fidalgo and 0.45 in the other two municipalities, as shown in Graph 5.3-19. Although this improvement has been shown, the mentioned municipalities still present a very low level of development with regard to the Education component. São João do Piauí showed slightly improved conditions, rising from 0.15 (very low development) in 1991 to reach 0.57 (low development) in 2010.

The other components, although showing improvement in the analyzed period, were less representative. It is noteworthy that in the Longevity component all ADI municipalities were classified as High development in 2010, being the component with the highest scores in the entire period analyzed, and the one with the smallest difference between São João do Piauí and the others ADI municipalities. The Income component showed a more positive variation in São João do Piauí, which went from Very Low development in 1991 to Medium development in 2010, the other municipalities of ADI, in the same period, went from Very Low development to Low development.

Graph 5.3-19 - Composition of the Municipal Human Development Index (MHDI) in the ADI Municipalities, 1991-2010



Source: Atlas of Human Development in Brazil 2013 - UNDP, IPEA and FJP. Adaptation: Arcadis, 2017.

5.3.5.7. Indigenous and Traditional Communities

In compliance with the Interministerial Ordinance No. 60/2015, the Palmares Cultural Foundation (FCP) and the National Indian Foundation (FUNAI) issued normative instructions that regulate their actions under environmental licensing in any administrative sphere (federal, state or municipal). Thus, the Normative Instruction (IN) FCP nº 01 of March 25, 2015 and IN FUNAI nº 2 of March 27, 2015, regulate the performance of the respective foundations in environmental licensing processes for all spheres by means of the criteria presented in the law No. 60 / 2015, in addition to detailing the rules and procedures to be carried out.

According to law No. 60, of March 24, 2015, at the time of environmental licensing, interferences in Quilombola Communities (settements formed by enslaved africans who escaped from plantations) or in Indigenous Lands must be properly analyzed.

Thus, according to article 3, paragraph 2 of Law No. 60/2015:

> For the purposes of the focus of this section, interference is assumed to occur:
>
> I - on indigenous land, when the activity or enterprise subject to environmental licensing is located on indigenous land or presents elements that may cause a direct socio-environmental impact on indigenous land, within the limits of Annex I;
>
> II - on Quilombola land, when the activity or enterprise subject to environmental licensing is located on quilombola land or presents elements that may cause a direct socio-environmental impact on quilombola land, within the limits of Annex I;

In the case of the Piauí Nickel Project, which has two types of structures indicated in the regulation No 60/2015: one specific, related to the mine structures and associated industrial units; and another of linear characteristic, related to the transmission line and water pipeline. Thus, according to Annex I of Interministerial Ordinance No. 60/2015, considering the fact that the project is located outside the Legal Amazon region, for terms of studies of traditional communities, at a distance of 8 km from the main core mining structures and 5 km from thesupport linear structures.

It is worth mentioning that, as indicated in the normative instructions FCP nº1 / 2015 (art. 2) and FUNAI nº2 / 2015 (art. 3), the Foundations will manifest themselves in the environmental licensing process, after the formal request from the environmental licensing agency. Upon request, Foundations should issue, if they deem it necessary, a specific term of reference for developing additional assessment studies related to these topics for which they are responsible of technical analisys.

That said, it is worth noting that although no specific terms of reference were presented for the project by the mentioned foundations, a survey was carried out to verify the presence/absence of Quilombola and / or indigenous communities, according to the respective distances from the structures of the future project.

In this way, a query was made to the database available on the official FUNAI website, in which it was found that the closest Indigenous Lands to the project are located about 260 km away, on the border between the states of Bahia and Pernambuco.

In turn, in relation to the communities of remaining Quilombos, according to a survey carried out on the FCP website[19], the existance of one community in the municipality of Campo Alegre do Fidalgo, three in Dom Inocêncio and two in São João do Piauí were registered.

Table 5.3-2 - Quilombola Communities in the ADI Municipalities.

Territorial Unit	Community Name	Date of Certification
Campo Alegre do Fidalgo	Santa Maria do Canto	09/12/2014
Dom Inocêncio	Barra das Queimadas	01/12/2013
Dom Inocêncio	Jatobazinho	01/12/2013
Dom Inocêncio	Poço do Cachorro	01/12/2013
São João do Piauí	Saco do Curtume	13/04/2009
Pedro Laurentino / Nova Santa Rita / São João do Piauí	Riacho dos Negros	15/04/2009

Source: Fundação Cultural Palmares, 2016. Elaboração: Arcadis, 2017.

[19] http://www.palmares.gov.br/. Accessed in October 22, 2016.

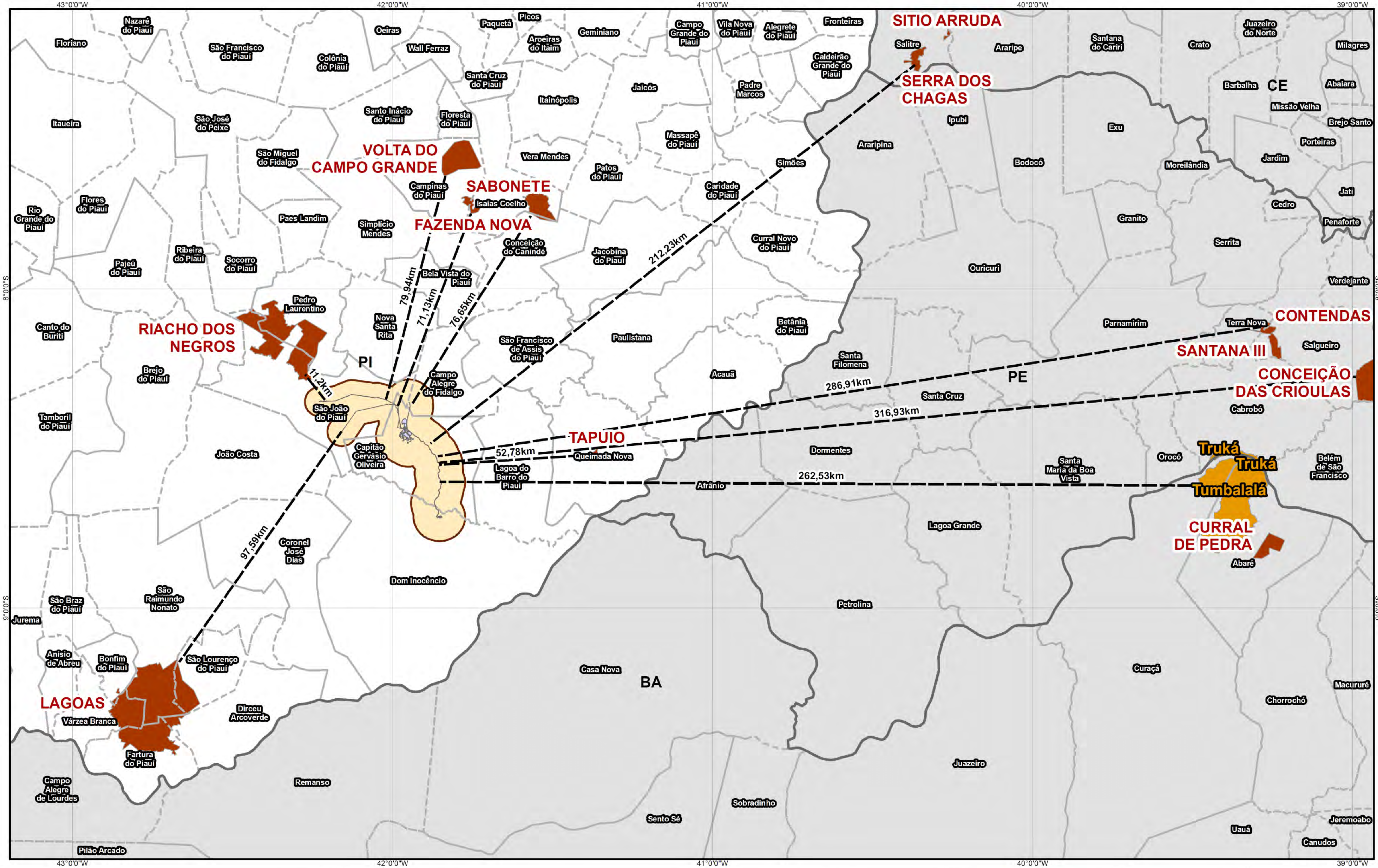
Although there are six FCP-certified Quilombola communities present in the municipalities of the ADI, only the Riacho dos Negros community has INCRA titles, which made possible to identify its location and confirm that it is outside the five-kilometer radius of the linear structure - transmission line - of the enterprise.

Due to the fact that the other communities do not have titles, and therefore are not delimited by INCRA, there is no official data to gauge their distance from the project. However, in a field survey carried out between Oct/31/16 and Nov/5/16, the above mentioned Quilombola communities were not located within the project's area of influence nor its surroundings and buffer area defined by the Interministerial Ordinance No. 60/2015.

As instructed by the FCP 01/2015 regulation, it is up to the environmental licensing authority of the Piauí Nickel Project (SEMAR), to request from the Cultural Foundation Palmares, a formal assessment of the need to present specific studies for this component.

The location of traditional regional communities in relation to the enterprise is shown on map 5.3-2.

Map 5.3-2 – Indigenous and Traditional Communities



LEGENDA

- Municipal Limits
- State Limits
- Study *Buffer* Area
- Directly Affected Area - DAA
- Communities' Distances
- Quilombolas
- Indigenous Land

REFERÊNCIAS

IBGE, Brasil ao milionésimo, 2015;
FUNAI, Terras Indígenas, 2016;
Fundação Palmares, consulta 2016;
Projeto Piauí Níquel, 2016.

ESCALA GRÁFICA 0 20 40 km

Sistema de Coordenadas: GCS SIRGAS 2000

MAPA DE LOCALIZAÇÃO

PA MA CE RN PB PE AL SE BA PI TO

PIAUÍ NÍQUEL

ARCADIS

EIA/RIMA – PROJETO PIAUÍ NÍQUEL

Map 5.3-2

Indigenous and Traditional Communities

EXECUTADO POR:	ESCALA:	NÚMERO:	DATA:
ARCADIS	1:1.250.000	Única	set /2017

5.3.5.8. Cultural and Archaelogial Heritage

The environmental licensing process of the Piauí Nickel Project paid attention to the aspect of national cultural heritage, in which the archaeological heritage is covered, and followed what was established in federal legislation that deals with the issue, in this case, CONAMA Resolution No. 001 of 1986, which established the protection of archaeological heritage through Environmental Impact Assessments, Ordinance SPHAN No. 07 (01/12/1988), which instituted the need for prior communication and approval to carry out archaeological research during these studies, and the Ordinance IPHAN nº 230 (12/17/2002), which established the administrative procedures for IPHAN (National Historical and Artistic Heritage Institute), during environmental licensing at federal, state and municipal levels.

The nickel mining project on the Brejo Seco hill in the municipality of Capitão Gervásio Oliveira / PI, contemplated in the DNPM 804.290 / 70 process, dates back to the 1970s. After many years of geological and mining research in this region carried out by Companhia Vale do Rio Doce (CVRD), in 2004, it obtained the Mining Concension License No. 258, published in the Official Gazette on 08/26/2004.

In order to study the technical feasibility of the project on an industrial scale, CVRD decided to implement a small scale Pilot Plant at the base of the Brejo Seco hill to perform metallurgical tests. The environmental studies necessary to obtain the Installation License - LI for the Pilot Plant and the experimental mine (RCA-PCA) were completed by the company Golder Associates in December 2005. As part of the licensing process for the Pilot Plant, the activities of Archaeological Prospecting and Rescue were carried out in the area covered by the plant and the Brejo Seco hill in 2005 by FUMDHAM (Foundation of the Museum of American Man), in accordance with IPHAN Ordinance nº 374, of December 21, 2005, published in the Official Gazette (DOU) nº 245, of 22 December 2005 - IPHAN Process No. 01402.000053 / 2005-83. This process was duly completed at the time and the Pilot Plant was installed and started operations in May 2007.

CVRD also decided at this time to start the environmental licensing process for the mining project on a commercial-industrial scale, which at the time was called “Nickel Project of Piauí”. It would include the necessary structures for the extraction and processing of nickel on the Brejo Seco hill for 25 years, as well as the construction of access roads, a Transmission Line and a Water Pipeline from the industrial area of the project to the CHESF’s electrical substation and the Jenipapo water Dam, respectively (both in São João do Piaui / PI), and construction of structures for extraction and processing of limestone in the region called Umbuzeiro in the municipality of Dom Inocêncio / PI, to be transported and used as input in the process of Nickel precipitation production.

In 2007, CVRD hired the company Arcadis Tetraplan to prepare the Environmental and Social Impact Assessment - ESIA / RIMA of the Nickel Project of Piauí in order to apply for the Preliminary License - LP for the project, and also hired FUMDHAM to complement the licensing process with an archaeological survey in the areas covered by the project. IPHAN Process No. 01402.000157 / 2007-50 was then initiated in accordance with Item 02 of Annex I of Ordinance No. 1 of IPHAN, of January 10, 2008, published in the Official Gazette (DOU) No. 8 of January 11 2008 (ANNEX X - Volume IV). FUMDHAM then carried out the necessary studies and surveys in the areas covered by the project and its areas of influence, and in 2008 produced the “Archaeological Report” of prospecting and rescue actions (ANNEX XI - Volume IV).

However, right after the ESIA / RIMA submittal to SEMAR / PI in 2008, CVRD decided to stop the project and, therefore, withdrew the study from the environmental agency, thus interrupting the licensing process.

In November 2014, Piaui Niquel Mineração S / A (now Piauí Niquel Metais S / A - "PNM"), acquired the CVRD Mining rights and pilot plant, and resumed the Project's environmental licensing process, now entitled "Piauí Nickel Project". The Project concept (nickel heap leaching) as well as the structures predicted by CVRD remained basically the same as those adopted by the Nickel Project of Piauí. Considering also that PNM has its own and more efficient technology, the areas of intervention and occupation of the planned structures will in fact be considerably smaller than those provided for by CVRD, thus reducing the environmental and social impacts in the area covered by the Project.

PNM hired Arcadis S / A (formerly Arcadis Tetraplan), in July 2016, to review and update the ESIA / RIMA produced in 2008, aiming to file it to SEMAR and request the Preliminary License - LP for the Piauí Nickel Project.

The "Archaeological Report" was produced by FUNDHAM in 2008, under the technical responsibility of Archaeologist Dra. Niède Guidon was submitted to IPHAN, Piauí's Superintendence, in compliance with the legal procedures established by IPHAN and federal legislation for the safeguarding of cultural heritage, and must be the object of analysis within the IPHAN process No. 01402.000157 / 2007-50 for a conclusive statement for the organ's consent for the Piaui Nickel Project areas to obtain LP from SEMAR / PI.

Also aiming to complement the results presented in the aforementioned "Archaeological Report" of 2008, an "Archaeological Technical Visit Report" (Annex XII - Volume IV), produced in 2017 by FUMDHAM, based on a field survey carried out in the same areas covered by it, was also prepared aiming to present the current state of conservation of the archeological sites previously identified and rescued during the works carried out in 2008, and therefore to provide technical security and backup for IPHAN's analysis and conclusive manifestation about the works carried out. The report also presented a better detail of the Project footprint, as well as maps with the location of the identified and visited archaeological sites in relation to the project's layouts provided by CVRD and PNM, to demonstrate their similarity and overlapping of intervention areas. This approach was a strategy jointly agreed between technicians representing IPHAN, FUNDHAM and PMN, in a meeting held on 06/14/2016 at the IPHAN office in São Raimundo Nonato / PI.

According to the documentation prepared and submitted to IPHAN, which is also attached (Annex XII - Volume IV), the assessment requirements established in the legislation regarding cultural heritage to support the award of the Preliminary (feasibility) License (called *Licença Prévia – LP*) were completely met by the studies that were carried out in the project's area, awaiting at this moment only the positive manifestation of IPHAN for the LP award.

5.3.5.9. Territory Characteristics – Land Use and Occupation

This section briely presents the results of land uses aimed at the anthropic environment. Specific and detailed information on Land Use and Coverage is presented in section 5.2.3.1.

A) ADI Results

The total project ADI is 25,099.87 hectares in which only 4,866.40 are occupied by anthropic uses (corresponds approximately to 20% of the ADI), being the remaining areas occupied by the different Caatinga typologies.

The uses referring to the anthropic environment are: Agriculture, Buildings, Exposed Soil and Water Mass, since the latter category is mainly composed of the Jenipapo Dam. The distribution of these classes in the enterprise's ADI is shown in Table 5.3 32.

Data Table 5.3-32 – Land Use and Coverage of the anthropic enviroment in the ADI.

Class of Anthropic Environment	Hectares	Percentual
Exposed Soil	66.58	1.37%
Buildings	175.16	3.60%
Water Mass	1,360.29	27.95%
Agriculture	3,264.37	67.08%
Total	**4,866.40**	**100%**
ADI - Total	**25,099.87**	**-**

Source: Arcadis, 2017.

Agriculture is the main anthropic use (67.08%) located mainly along the future transmission line footprint.

The water mass typology is the second most present in anthropic uses in the ADI. Located in the western portion of the area of influence, the Jenipapo Dam is the main component of this category.

Buildings typology, which include housing , energy substations, road infrastructure and the PNM pilot plant, occupies only 3.60% of the ADI and is sparsely distributed.

Soil Exposure occupies only 1.37% of the total ADI area. It is worth noting that this typology is not always related to human actions and can occur naturally.

B) Directly Affected Area – DAA Results

The project's Directly Affected Area has a total of 1,164.11 hectares of which only 68.61 are covered by anthropic use, that is, only 5.89% of the total area. Proportionally, this percentage is much smaller than the one registered for the ADI presented above.

Data Table 5.3-33 presents the planimetry for the anthropic uses found in the enterprise's DAA.

Data Table 5.3-33 – Land usage and coverage of the anthropic Environment the DAA

Anthropic Usage and Land Coverage Classes	Hectares	Percentage
Agriculture	59.76	87.10%
Buildings	4.68	6.82%
Water Mass	3.42	4.98%
Exposed Soil	0.75	1.09%
Total	**68.61**	**100%**
Área total da DAA	**1,164.11**	**-**

Source: Arcadis, 2017.

Observing only the anthropic features located in the DAA, it should be noted that there is a predominance of Agriculture (87.10%), in comparison with what was found in the ADI.

Unlike ADI, the second predominant typology in DAA was Buildings (6.82%).

The Water mass appears with 4.98% of the anthropic uses in the DAA, as the Jenipapo Dam is only part of the enterprise's ADI. In this case, the mapped water mass corresponds to the water pump station and the water courses intercepted along the DAA.

Finally, the Exposed Soil appears on only 0.75 hectares in the DAA.

In general, it is evident that both in the DAA and in the ADI the main typology found was natural vegetation (Caatinga) since only a small section of them is composed of anthropic uses, being 5.89% and 20% respectively.

5.3.5.10. Social Organization in the ADI

For the identification of social organizations operating in the municipalities of the ADI, research was carried out on the websites of the Brazilian Association of Non-Governmental Organizations (ABONG) and in the National Register of Environmental Entities (CNEA), created by CONAMA Resolution No. 06/89 (instituted in order to maintain a database with the register of non-governmental environmental entities operating in the country). However, in both cases, no active organizations were identified in the municipalities of Campo Alegre do Fidalgo, Capitão Gervásio Oliveira, Dom Inocêncio and São João do Piauí.

Thus, the identification of local social organizations acting in the ADI, a field survey was carried out between October 31 and November 5, 2016.

The resulting Social Actors Matrix existing in the municipalities of ADI is presented below, with a focus on the surrounding communities (Data Table 5.3-34).

Data Table 5.3-34 - Social Actors Matrix Acting in the Municipalities of the ADI

Group Interviewed	Municipality	Institution	Main Role / Purpose
Community Associations	Capitão Gervásio Oliveira - PI	Association of residents of the Camaiba settlement	Ensure regulation of the land owership and search for fuding for projects for the settlement´s development.
	Capitão Gervásio Oliveira - PI	Association of residents of the Varzea settlement	Ensure regulation of the land owership and search for fuding for projects for the settlement´s development.
	Capitão Gervásio Oliveira - PI	Association of residents of the Veredas settlement	Ensure regulation of the land owership and search for fuding for projects for the settlement´s development.
	São João do Piaui - PI	Association of residents of the Eugenio settlement	Ensure regulation of the land owership and search for fuding for projects for the settlement´s development.
	São João do Piaui - PI	Association of residents of the São Jose settlement	Ensure regulation of the land owership and search for fuding for projects for the settlement´s development.
Public Sector	Campo Alegre do Fidalgo - PI	Municipality	Public Services
	Capitão Gervásio Oliveira - PI	Municipality	Public Services
	Dom Inocêncio - PI	Municipality	Public Services
	São João do Piaui - PI	Municipality	Public Services
Civil Society Organization	Campo Alegre do Fidalgo - PI	Rural Workers Trade Union	Ensure legal rights and social security pension
	Capitão Gervásio Oliveira - PI	New Sertão Institute	Support for self-sustainable socio-economic development of communities
	Capitão Gervásio Oliveira - PI	Trade Union of Municipality worker	Ensure worker´s right and negotiate agreements between public employees and the municipality
	Capitão Gervásio Oliveira - PI	Rural Workers Trade Union	Ensure legal rights and social security pension
	Dom Inocêncio - PI	Trade Union of Municipality worker	Ensure worker´s right and negotiate agreements between public employees and the municipality
	Dom Inocêncio - PI	Rural Workers Trade Union	Ensure legal rights and social security pension
	São João do Piaui - PI	Trade Union of Municipality worker	Ensure worker´s right and negotiate agreements between public employees and the municipality
	São João do Piaui - PI	Rural Workers Trade Union	Ensure legal rights and social security pension
	São João do Piaui - PI	NGO ECOVIDA (informal)	Environmental protection

Source: Arcadis, 2017.

5.3.5.11. Socio-environmental and Project Perception Survey

A) Methodological Considerations

The objective of this survey is to verify how the local social actors (stakeholders) perceive the socio-environmental quality of the region they are inserted and also their perceptions and expectations of the project's implementation and operation forecast.

Thus, the interviews conducted with social actors considered relevant in the context of the project, that is, public institutions and social organizations and residents of the Surrounding Communities, included questions about the interviewee's perception of the possibility of implementing the project and the interviewee's perception of the environmental situation of the municipalities or surrounding communities in which they reside.

The instrument to support the interviews was a standard document (questionnaire) with open and closed questions related to the institution or community, the general perception of the region regarding the environmental and social situation (including topics such as basic sanitation, tourism, cultural heritage and environmental quality). The results presented refer to a sample population, of ten[20] surrounding communities, nine civil society institutions, mainly rural workers' or civil servants' unions, and twelve secretaries of the municipalities of the ADI municipalities.

Socio-environmental perception was assessed in two ways, one on socioeconomic aspects and the other specifically on the environment. The assessment of socioeconomic aspects was conducted with residents and representatives of the Surrounding Communities, where each one assessed the situation of the community itself, and by representatives of civil society institutions, who assessed the situation in the municipality of residence. The number of questions about socioeconomic conditions for residents of the Surrounding Communities was reduced, in view of the prior knowledge of the lack of infrastructure in the areas regarding sanitation, leisure, commerce, amongst others.

Questions about the environment and those related to the perception of the enterprise were asked to all respondents.

Table 5.3-3 shows the list of groups of respondents in the survey on socio-environmental perception.

[20] In five communities, it was not possible to conduct the survey due to lack of time among the interviewees, or because the interview was conducted with a group of people with different opinions about the topics covered.

Table 5.3-2 – Stakeholders Matrix Interviewed Entities / Associations

Stakeholders	Name	Data of Interview	Entities/Community	Territorial Unit
Community	José Barros de Souza	02/11/2016	Settlement Carnaíba	Capitão Gervásio Oliveira
	Lucília Dulcineia Mendes	02/11/2016	Settlement Várzea	Capitão Gervásio Oliveira
	Valdir Ribeiro da Costa	02/11/2016	Community Veredas	Capitão Gervásio Oliveira
	Benedito Filadelfo Oliveira Santos	05/11/2016	Community Várzea de Cima	Capitão Gervásio Oliveira
	Venturino Nonato da Mata	02/11/2016	Community Carnaíba	Capitão Gervásio Oliveira
	Eudenor Pereira de Oliveira	04/11/2016	Community Umbuzeiro	Dom Inocêncio
	Aldemiro Pinheiro de Souza	02/11/2016	Settlement Eugênio	São João do Piauí
	Aparecida Ferreira da Silva	05/11/2016	Community Chiqueirinho	São João do Piauí
	Raimundo Ribeiro Lopes	05/11/2016	Settlement São José	São João do Piauí
	Eva Maria da Conceição Macedo	05/11/2016	Community Cabeça	São João do Piauí
	Maria Aparecida da Cruz Castro	05/11/2016	Community Grajaú	São João do Piauí
Public Service	Iolanda da Silva Alencar	01/11/2016	Education Municipality Official	Campo Alegre do Fidalgo
	Raimundo Santo de Oliveira	03/11/2016	Infrastructe Muncipality Official	Capitão Gervásio Oliveira
	Aureliano Marcelino de Oliveira / Nelma Coelho Rodrigues	03/11/2016	Health Municipality Official	Capitão Gervásio Oliveira
	Patricia Aparecida Nunes Torres / Jussara	03/11/2016	Education Muncipality Official	Capitão Gervásio Oliveira
	Luis de Sousa Santos	04/11/2016	Infrastructe Muncipality Official	Dom Inocêncio
	Luzinete de Almeida Damaceno	04/11/2016	Health Municipality Official	Dom Inocêncio
	Delizandra de Marques / Iranice Marques	04/11/2016	Public Finance Municipality Official	Dom Inocêncio

Stakeholders	Name	Data of Interview	Entities/Community	Territorial Unit
	Marcilio de Sousa Silva	04/11/2020	Education Municipality Official	Dom Inocêncio
	Franciso Jose/Manoel Menezes	31/10/2016	Infrastructe Muncipality Official	São João do Piauí
	Vanessa de Sousa Barbosa	31/10/2016	Health Municipality Official	São João do Piauí
	Luizineide dias de Santana (Tina)	01/11/2016	Public Finance Municipality Official	São João do Piauí
	Welles Ferreira Freitas	01/11/2016	Education Municipality Official	São João do Piauí
Civil Society Organization	Carmem Lucia Ribeira Lima (Lúcia)	05/11/2016	Rural Workers Trade Union	Campo Alegre do Fidalgo
	Diego Augusto dos Santos Sousa	03/11/2016	New Sertão Institute	Capitão Gervásio Oliveira
	João Batista de Oliveira	03/11/2016	Trade Union of Municipality worker	Capitão Gervásio Oliveira
	Jose Neto Coelho	03/11/2016	Rural Workers Trade Union	Capitão Gervásio Oliveira
	Gizelda Marques Pereira	04/01/2016	Rural Workers Trade Union	Dom Inocêncio
	Rita Maria Rodrigues de Assis	04/01/2016	Trade Union of Municipality worker	Dom Inocêncio
	Herlon Batista dos Santos	01/11/2016	NGO ECOVIDA (informal)	São João do Piauí
	Maira Lopes de Moura (Cota)	01/11/2016	Rural Workers Trade Union	São João do Piauí
	Manoel Raimundo de Santana	01/11/2016	Trade Union of Municipality worker	São João do Piauí

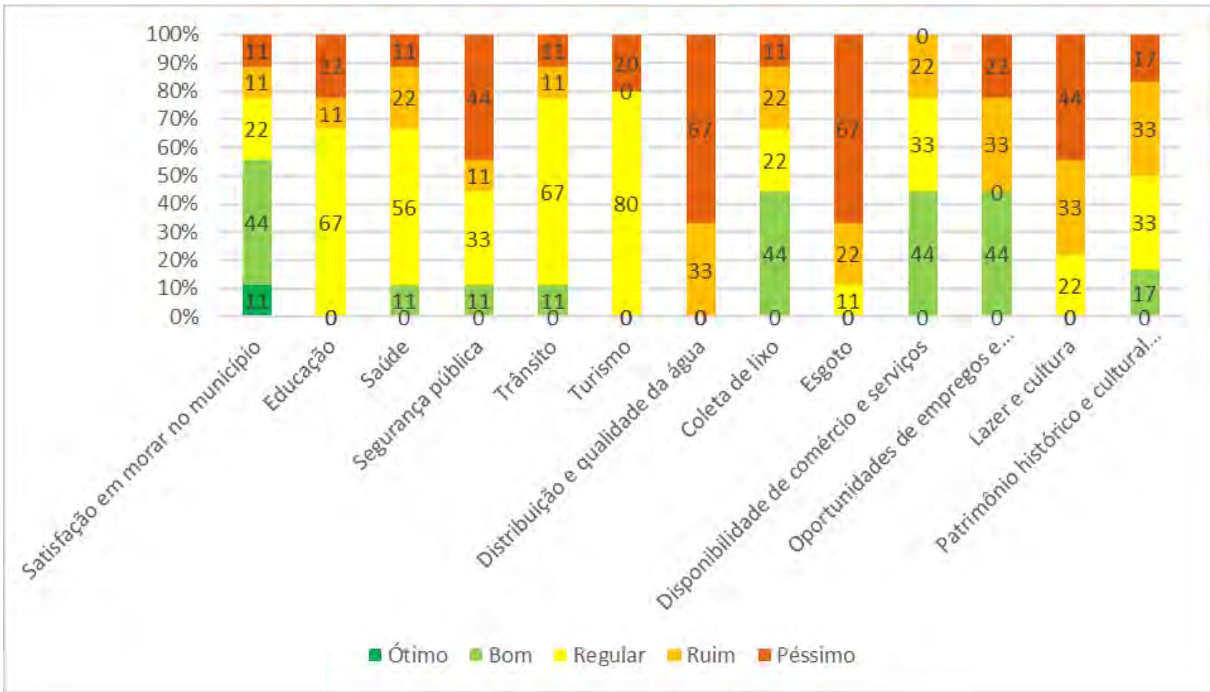
Source: Arcadis, 2017.

B) Socioenviroment Perception

The evaluations of the themes related to the perception about the region, with regard to the socioeconomic and environmental situation, revealed that most of the interviewees consider the region as good.

The main socioeconomic problems identified are related to the lack or deficiency in the water supply system and the sewage service, which is non-existent, few options for leisure and culture and public safety.

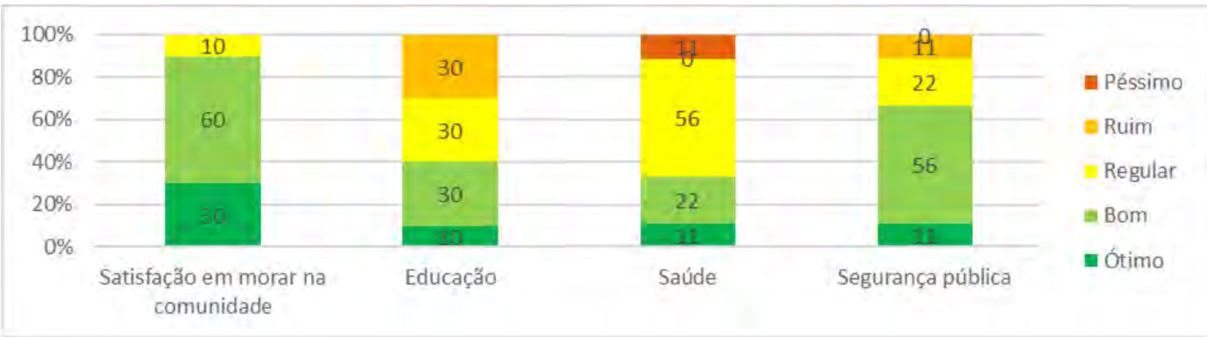
Graph 5.3-20 - Assessment of the Socioeconomic Situation in the Municipalities of the ADI - Civil Society.



Elaboração: Arcadis, 2017.

The residents of the surrounding communities showed, compared to the residents of the municipalities of the ADI, a much greater satisfaction in living in their respective communities, with a response rate of Excellent or Good answers of 90%. Among the possible topics to be evaluated, health was the one that presented the most unfavorable situation.

Graph 5.3-14 – Assessment of the Socioeconomic Situation in the Surrounding Communities.

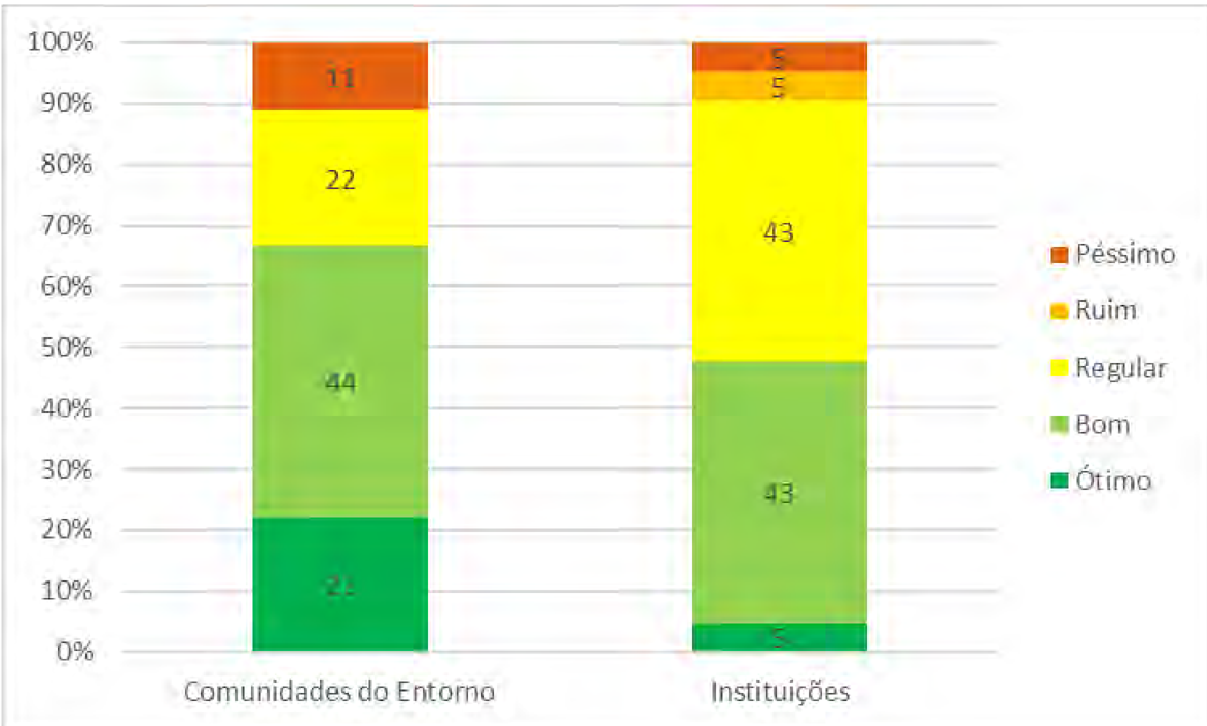


Source: Arcadis, 2017.

For the two groups of respondents, civil society and residents of the surrounding communities, the most positive characteristics of the ADI municipalities are, above all, the welcoming population, being calm and peaceful places, and the quality of the region's (fertile) lands. Among the negative aspects, the most mentioned was the scarcity of rain and the low level of the local economy, which translates into low employment opportunity.

Regarding the assessment of the quality of environmental resources, the residents of the surrounding communities presented a slightly more favorable view, 66% of whom felt that their communities were Good or Excellent, than the representatives of the institutions (civil society and public authorities) whom 48% of interviewed responded Good or Excellent.

Graph 5.3-22 - Assessment of Environment Quality in the Region.



Source: Arcadis, 2017.

Asked about possible environmental problems in the region, only two respondents from the surrounding communities reported problems related to deforestation and the occurrence of fires. Among the representatives of the institutions, the main complaints were related to the lack of basic sanitation and lack of awareness of residents, who still dispose of a lot of waste inappropriately.

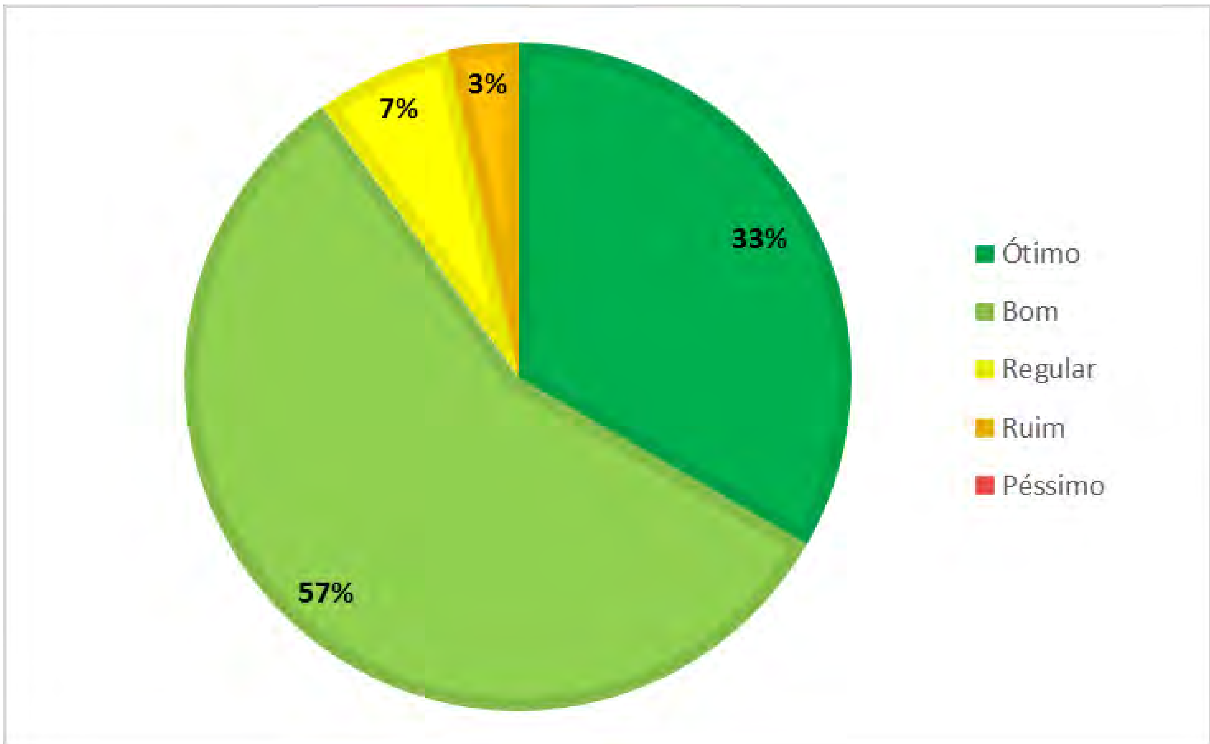
C) Perception about the Project

The questions related to the perception of the project were designed to identify the level of current knowledge of the population about the Piauí Nickel Project, as well as the expectations (positive or negative) about it.

In this sense, it should be noted that the project is well known by the local population, more than 90% of respondents reported having some knowledge about it, but there were some mentionings of the lack of contact from PNM with the local population.

Asked about the possible positive or negative aspects that could affect the region if the Piauí Nickel Project would to be implemented, the interviewees presented a very optimistic view, with 90% considering the implementation of the project to be Good or Excellent.

Graph 5.3-23 - Assessment of the Perception on the implementation of the Piauí Nickel Project.



Elaboração: Arcadis, 2017.

Among the positive aspects, almost unanimously, the generation of jobs for the local population was mentioned, and to a lesser extent the development of the local economy, especially the trade sector.

Possible negative aspects were also cited, highlighting environmental degradation, mainly deforestation. On a smaller scale, possible problems were cited as a result of the introduction of people from outside the localities, which could lead to an increase in crime.

5.3.6. Surrounding Communities

5.3.6.1. Methodological Considerantions

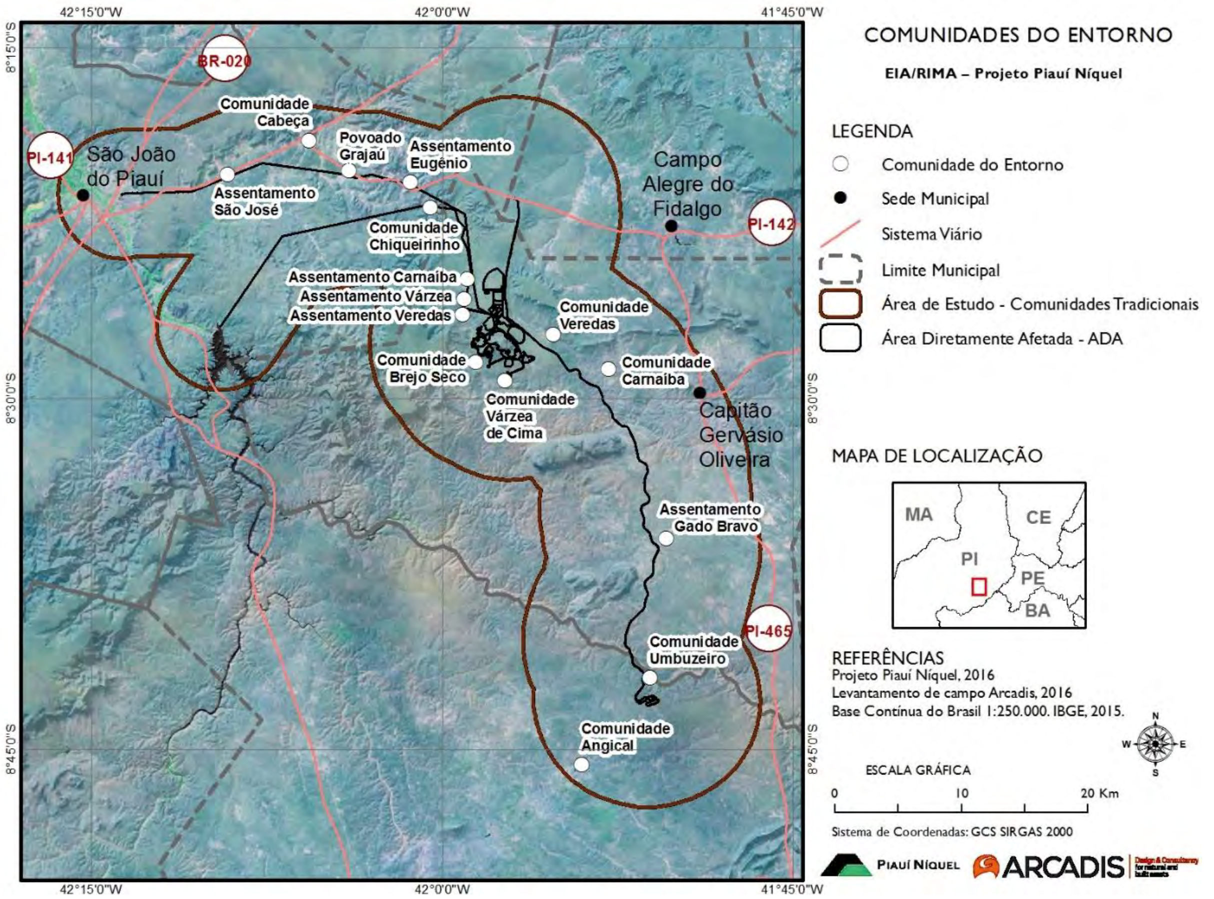
As previously mentioned, the project's DAA is located in the rural context of the municipalities of Campo Alegre do Fidalgo, Capitão Gervásio Oliveira, Dom Inocêncio and São João do Piauí. Considering that the direct impacts of the enterprise that can affect the local population occur in a more restricted area than the ADI, communities that are located closer to the structures of the enterprise were identified and, consequently, may suffer impacts in their daily lives as a result of the enterprise's activities.

Thus, based on the surveys presented in the ESIA / RIMA (ARCADIS Tetraplan, 2008), the presence of 15 communities was identified, eight in Capitão Gervásio Oliveira, two in Don Inocêncio and four in São João do Piauí, which may suffer direct impacts as a result of the project in question.

During the complementary field survey, from 10/31 to 11/5/16, in order to obtain information that would allow characterization of the identified communities, interviews were conducted with representatives of residents' associations or with a resident in the case of no association. At the Veredas settlement in Capitão Gervásio Oliveira, at the request of the association's president, the interview was opened to residents who wanted to participate.

The location of the communities is shown on the map below.

Map 5.3-3 – Surrounging Communities.



Source: Arcadis, 2017.

In clarification of SEMAR's Technical Opinion - Process 7,975 / 16, of December 12, 2016, all communities surrounding the Piauí Nickel Project, either upstream or downstream of the project, were located and identified through the referred field survey, having been visited in their entirety, as shown in Map 5.3-3. As shown in section 5.3.5.7, no traditional communities were identified within the 8km and 5km buffer areas of the enterprise, as provided by Interministerial Ordinance No. 60/2015.

It is opportune to clarify again, as stated in the chapter of Project Description, that the waste produced from the PNM's production process will be in a solid condition. In this way, there will be no requirement at the Piauí Nickel Project for a liquid tailings dam structure (with risk of ruptures), but only a deposit for the process waste that will be in a solid state and will be stacked and compacted in geotechnically stable piles over a waterproofed area (therefore without risk of disruption and reaching the surrounding communities).

5.3.6.2. Charaterization of the Surrounding Communities

The surrounding communities are essentially made up of small groups of small rural producers, some of which are community-based and are set up in rural settlements.

In general, the surrounding communities are made up of small rural properties used in family farming. Agricultural production is of subsistence level, and due to the prolonged drought, for the last five years, there has been little farming, and the lack of access to water is one of the main challenges to production. Thus, there is a predominance in livestock, especially in the breeding of goats and sheep, although there is production of poultry and cattle on a smaller scale, in all cases grazed extensively and at subsistence level. It is noteworthy that the breeding of animals throughout the region is free, with the animals being left loose, and the use of fences to separate properties is not common.

The settlements have more specific characteristics, being formed by families that organized themselves through associations to enroll in the Program to Combat Rural Poverty (PCPR) of the state, and thus have acquired the land through collective financing from the "Land Bank"[21]. The houses of the families of the settlements are arranged in village-type clusters, as closely spaced houses with little land around each dwelling, and were built using federal government housing programs. The farming areas are divided into equal parts for each family that make up the associations.

The families of the surrounding communities have low socioeconomic conditions since, according to the interviewed residents, a large part of them depend on resources from pensions or the federal government "Bolsa Família" income assistance program, with few exceptions.

The houses of the surrounding communities are mostly of a simple pattern, built in masonry and covered with clay tiles. Electricity is provided in all communities, and in those with the highest concentration of homes, settlements and villages, public lighting is provided.

With regard to sanitation conditions in all surrounding communities there is no sewage collection system, with waste incorrectly disposed of by the use of rudimentary pits or ditches. Solid waste in general is burned by residents, as there is no municipal collection service.

The difficulty in travelling to urban centers, both due to the distance and the poor conditions of the roads, was reported as one of the main complaints of residents of the surrounding communities, as it causes difficulty for access to goods and services, such as shops and health facilities. None of the communities have public transport, so, for travellng to other locations, own vehicles are used, the motorcycle being the most used type, and also the private vehicle charter service.

[21] In 1998, the Land and Agrarian Reform Fund – Land Banc - was created to finance land reorganization and rural settlement programs (Complementary Law No. 93, of February 4, 1998). The beneficiaries of the Fund were: I - non-owner rural workers, preferably wage earners, partners, squatters and tenants, who prove, at least, five years of experience in agricultural activity; II - farmers who own properties whose area does not reach the dimension of a family property, as defined in item II of article 4 of Law no. 4.504, of November 30, 1964, and is proven to be insufficient to generate income capable of providing for his own support and that of his family.

Since the common characteristics of the surrounding communities have already been presented, Table 5.3-4 presents the communities spcifics. In the Brejo Seco and Gado Bravo communities in Capitão Gervásio Oliveira, although they are part of those that may suffer direct impacts from the project, it was not possible to gather information because the team was unable to contact any residents during the field survey days. After the table, photographic records that were taken during the development of the environmental perception questionnaire in November 2016, show the main characteristics of the surrounding communities.

It is important to note that at the current stage of the Piauí Nickel Project there are no plans for the project's structures to overlap with the communities' residential units.

Table 5.3-3 – Surrounding Communities.

Territorial Unit	Community	Nº of families (aprox.)	Infrastructure and Public Services
Capitão Gervasio Oliveira - PI	Camaiba settlement	**13**	Settlement linked to the Federal Land Associations (Banco de Terras), total area of 769 hectares divided into 13 small propeties. **Access to water**: houses have piped water captured in wells, but not proper for human consumption (too salty). For human consumption, they buy water from local water trucks services. **Education:** There is no school. Students go to Cacimba da Areia school with transport provided by the Municipality. High school is provided in Capitão Gervásio Oliveira headquarters. **Health:** There is no local service. They use the basic health unit at the Cacimba da Areia community, available once a week, or they seek medical care directly at in Capitão Gervásio Oliveira or São João do Piaui headquarters. There is no Health Family Programme (PSF) available.
	Varzea settlement	**16**	Settlement linked to the Federal Land Associations (Banco de Terras), total area of 546 hectares divided into 16 small propeties. **Access to water**: houses have piped water captured in wells, proper for human consumption including. **Education:** There is a school, but inactive. Students go to Cacimba da Areia school with transport provided by the Municipality. High school is provided in Capitão Gervásio Oliveira headquarters. Health: There is no local service. They use the basic health unit at the Cacimba da Areia community, available once a week, or they seek medical care directly at in Capitão Gervásio Oliveira or São João do Piaui headquarters. There is no Health Family Programme (PSF) available.

Territorial Unit	Community	Nº of families (aprox.)	Infrastructure and Public Services
	Veredas settlement	**18**	Settlement linked to the Federal Land Associations (Banco de Terras), **Access to water**: houses have piped water captured in wells, proper for human consumption including. **Education:** There is no school. Students go to Cacimba da Areia school with transport provided by the Municipality. High school is provided in Capitão Gervásio Oliveira headquarters. **Health:** There is no local service. They use the basic health unit at the Cacimba da Areia community, available once a week, or they seek medical care directly in Capitão Gervásio Oliveira or São João do Piaui headquarters. There is no Health Family Programme (PSF) available. **Culture**: a religious celebration of the festivities of Saint Antony, between june 01 and 03.
	Veredas Community	**50**	Some residences have lower quality construction standard. **Access to water**: local water trucks service. **Education:** No school available. Students go to school in Capitão Gervásio Oliveira headquarters with transport provided by municipality. **Health:** There is no local service. They search medical care directly in Capitão Gervásio Oliveira headquarter. There is no Health Family Programme (PSF) available.
	Várzea de Cima Community	**10**	**Access to water**: local water trucks service. **Education:** There is no school. Students go to Cacimba da Areia school with transport provided by the Municipality. High school is provided in Capitão Gervásio Oliveira headquarters. **Health:** There is no local service. They use the basic health unit at the Cacimba da Areia community, available once a week, or they seek medical care directly in Capitão Gervásio Oliveira headquarter.

Territorial Unit	Community	Nº of families (aprox.)	Infrastructure and Public Services
Dom Inocêncio	Carnaíba Community	**12**	**Access to water**: local water trucks service. **Education:** No school available. Local students go to the school by using school transport provided by the Municipality. All schools elementary and High school are locaded Municipality center or urban areas. **Health**: There is no local service. They seek medical care directly in Capitão Gervásio Oliveira headquarter.
	Angical Community	**20 to 30**	**Access to water**: local water trucks service. **Education:** Elementary school available. Local students use transport from the Municipality to go to school in Dom Inocêncio headquarter. **Health:** There is no local service. seek medical care in the municipality center. There is no Health Family Programme (PSF) available.
	Umbuzeiro Community	**8**	Community close to the border between the municipalities of Capitão Gervasio Oliveira and Dom Inocencio. **Access to water**: Water supplied by local water trucks service. **Education:** No school available. Local students use transport from the Municipality to go to school in Capitão Gervásio Oliveira headquarter. **Health:** There is no local service. They seek medical care directly in Capitão Gervásio Oliveira headquarter. There is no Health Family Programme (PSF) available.
São João do Piaui	Eugenio settlement	**70 (35 settlers)**	Settlement linked to the Federal Land Programme run by INCRA. Total area 1600 Hectares divided by 35 settlers. **Access to water**: houses have piped water captured in wells, proper for human consumption. **Education:** Elementaty school available. For high school students go to Grajau community with school transport. **Health:** There is no local service. They seek medical care directly in Capitão Gervásio Oliveira headquarte-r. There is no Health Family Programme (PSF) available.

Territorial Unit	Community	Nº of families (aprox.)	Infrastructure and Public Services
	Chiqueirinho Community	**10**	**Access to water**: water provided by water truck services. **Education:** Elementaty school available. For high school students go to Grajau community with school transport. **Health:** There is no local service. they use the basic health unit of the Grajau community or seek medical care at Sao joao do Piaui headquarter. Health Family Programme (PSF) available regurlarly.
	São Jose settlement	**27**	Settlement linked to (ITERPI). More than 30 years old. Cemetery available. **Access to water**: most of household piped water captured in wells, proper for human consumption. **Education:** Elementaty school available. For high school students go to São João do Piaui headquarter with municipality transport. **Health:** There is no local service. They seek medical care at Sao João do Piaui headquarter. Health Family Programme (PSF) available monthly at the community school.
	Cabeça Community	**30**	**Access to water**: most of household piped water captured in wells, proper for human consumption. **Education:** There is no school available.All students attend the Grajau community school using municipality public transport. **Health:** There is no local service. they use the basic health unit of the Grajau or seek medical care at Sao João do Piaui headquarter. Health Family Programme (PSF) available for the needy. **Culture:** a religious celebration "Nossa senhora da Cabeça" and "all saints day".
	Grajaú Community	**47**	**Access to water**: most of household piped water captured in wells, proper for human consumption. **Education:** Elementaty and high school available. **Health:** There is local service once a week and dental 3x/week. Health Family Programme (PSF) available but insuficient. **Culture:** a religious celebration of the festivities of Saint Sebastian in January.

Source: Arcadis, 2017.

Registro PhotoGraph – Novembro de 2016

Photo 5.3-17 – Interview with president of the Carnaíba settlement Association in Capitão Gervásio Oliveira.

Photo 5.3-18 – Residences in the Carnaíba settlement in Capitão Gervásio Oliveira.

Photo 5.3-19 – Unused school in the Várzea settlement in Capitão Gervásio Oliveira.

Photo 5.3-20 – Residences in the Várzea settlement in Capitão Gervásio Oliveira.

Photo 5.3-21 – Interview with residents of the Veredas settlement in Capitão Gervásio Oliveira.

Photo 5.3-22 – Residences in the Várzea settlement in Capitão Gervásio Oliveira.

Photo 5.3-23 – Residence in a more precarious condition in the Veredas community in Capitão Gervásio Oliveira.

Photo 5.3-24 – Residences in the Várzea de Cima community in Capitão Gervásio Oliveira.

Photo 5.3-25 – Cistern in the Várzea de Cima community in Capitão Gervásio Oliveira.

Photo 5.3-26 – Municipal school of the Angelical community in Dom Inocêncio.

Photo 5.3-27 – Residence in the Angelical community in Dom Inocêncio.

Photo 5.3-28 – Residence in the Angelical commnity in Dom Inocêncio.

Photo 5.3-29 – Road in the Umbuzeiro community, stretch of wet passage in the rainy season, boundary between the municipalities of Capitão Gervásio Oliveira and Dom Inocêncio.

Photo 5.3-30 – Road connecting Capitão Gervásio Oliveira to Dom Inocêncio.

Photo 5.3-31 – Headquarters of the Eugenio settlement association in São João do Piauí.

Photo 5.3-32 – Cemetery in the São José settlement.

Photo 5.3-33 – School in the São José settlement in São João do Piauí.

Photo 5.3-34 – Residence in Cabeça community in São João do Piauí.

Photo 5.3-35 – Interview with former resident of Cabeça community in São João do Piauí.

Photo 5.3-36 – School in Grajaú village in São João do Piauí.

Photo 5.3-37 – Construction of a sports court in the village of Grajaú in São João do Piauí.

Photo 5.3-38 – Cobbled street of Grajaú village in São João do Piauí.

Photo 5.3-39 – Health Center of Grajaú village in São João do Piauí.

Photo 5.3-40 – Dirt street in Grajaú village in São João do Piauí.