Identification of the Erosive Processes on the Banks of Ribeirão São João Porto Nacional - TO

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Abstract— The objective of this study was to map the erosions that are occurring on the banks of Ribeirão São João in Porto Nacional - TO, these erosive processes come from the detachment and transportation of the soil particles, which can be deposited in the watercourse of the stream, causing the increasing of the load in the streambed. Two erosions were the biggest. Soil characterization tests were done in each erosion. Monitoring its progress was made by pins erosion method, which were installed on the banks of those erosions. The accomplishment of monitoring made it possible to create graphs comparing precipitation and erosion. With this study it was achievable to check that the precipitation acts directly on the surface, increasing the erosive process, verifying that the soil type exerts a big influence on the process.
Keywords— Erosion. Erosion pins. Ribeirão São João.

I. INTRODUCTION

Silva et al. (2007) define that the soil consists of organic and minerals particles with different dimensions, formed from physical, chemical and biological processes. The most common agents for soil formation are climate, the place's topography and the biotic community. Soil erosion is understood as a process of detachment, transport and deposition of soil particles. Erosion at the riverbanks may promote the degradation of the watercourse, due to the large accumulation of sediments carried by the streams to the riverbed. Among the main environmental impacts problem caused we can mention the reduction of the flow, change in the course of rivers and in very serious cases can cause the extinction of the watercourse (ALVES, 2007). This study delineated itself in collecting important information on the erosive processes that are occurring on the banks of Ribeirão São João in Porto National - TO. The objective of this study was to map erosion along the river, identifying and monitoring the development of major erosions. The purpose of this study was to obtain a survey of the

erosions that are occurring on the banks of Ribeirão São João, it was also very relevant monitoring the progress of the biggest erosions located in the watershed that supplies the city..

II. MATERIALS AND METHODS

2.1 CHARACTERIZATION OF THE STUDIED AREA

The studied place is located southeast of the city of Porto Nacional-TO, in the basin of drainage of Ribeirão São João that has a total area, according to Silva (2010) of 82km². The basin is located between the meridians 48 ° 14'16 "and 48 ° 24'51" longitude west and between the parallels 10 ° 4 6'43 "and 10 ° 41'20" with South latitude as shown in figure 1. Its mouth is located within the urban area of Porto Nacional, contributing directly to the Tocantins River. According to Tocantins (2012), the are present in the region are the Oxisols and a small portion of Neosols. The natural vegetation that prevails in the region is the cerrado. In Porto Nacional - TO the climate is typically tropical. The annual average rainfall is 1622mm, and the average temperature is about 26.1 ° C. The month of September is the hottest month, with an average of 27.9 ° C, and the month with the lowest is July, averaging 24.9 ° C. The largest part of the precipitation is between October and April, which is the rainy season, and drought period is between May and September (CLIMATE-DATA, 2018).

2.2 CREATING THE MAP

The process of creating the map began with the identification of erosions, and later the points were collected by a geodetic GPS. The creation of the map was through the Google Earth tool, a software that has several functions, and among them is the visualization of satellite images and the creation of themed maps. The locations are given through the geographical coordinates, the identification occurred from 10 ° 42'54.92 "S, 48 ° 22'17.93" W to 10 ° 44'21.52 "S, 48 ° 17'32.24" in the city of Porto Nacional-TO, as it is shown in figure 2.
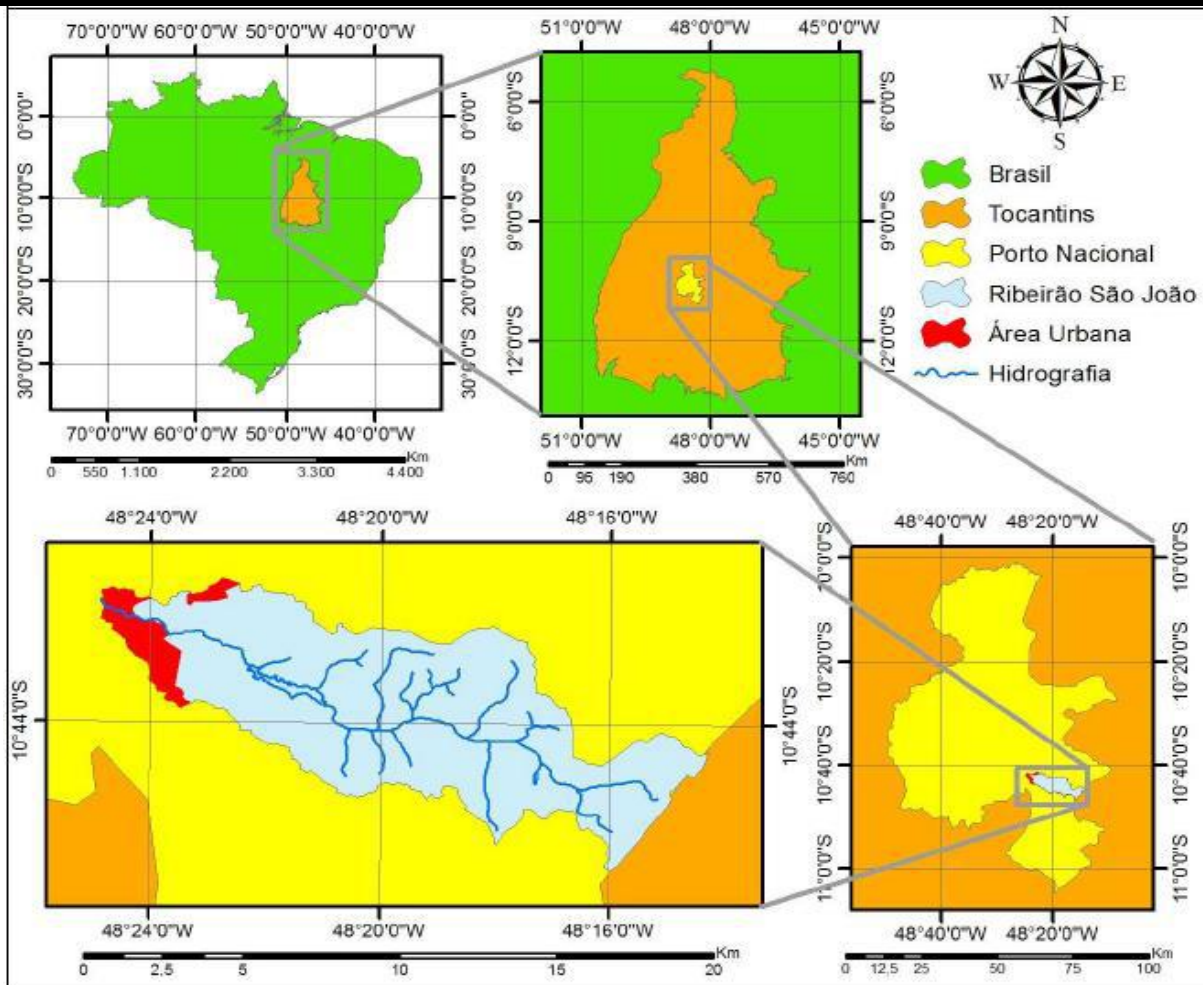
Fig.1 - Location map of the studied area
Source: Silva (2010)

(Green: Brazil, Orange: Tocantins, Yellow: Porto Nacional, Light blue: Ribeirão São João, Red: UrbanArea, Blue line: Hydrography.)
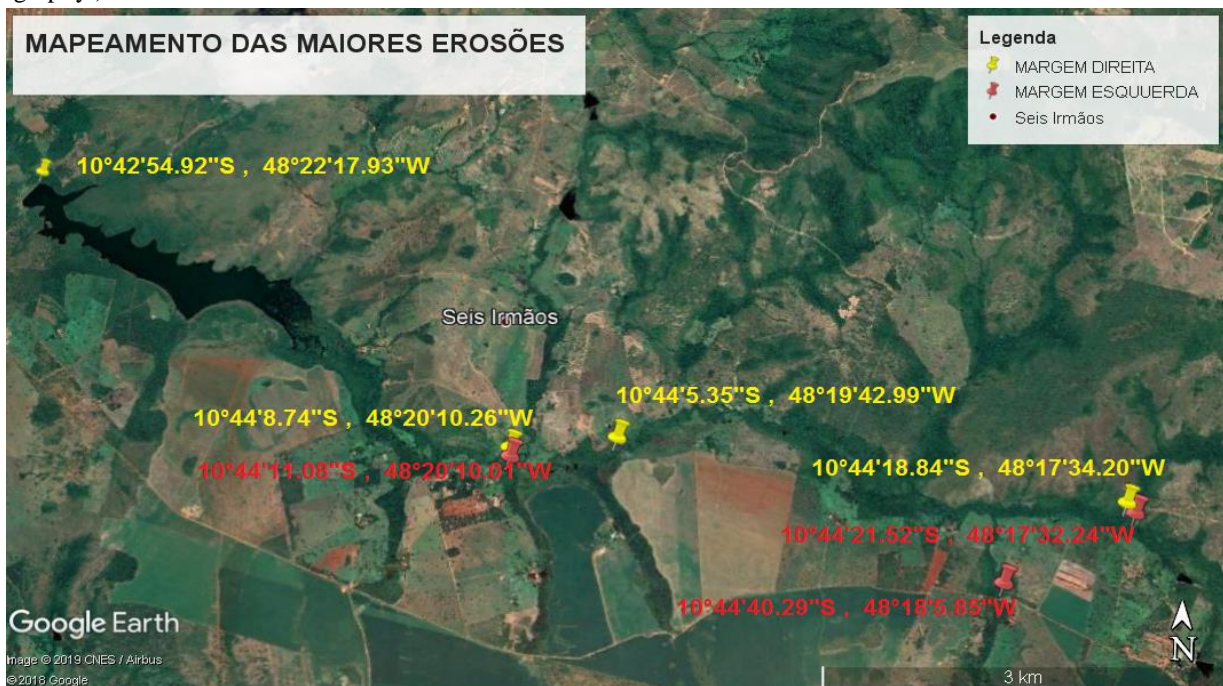

Fig.2- Location of most erosions

Source: Prepared by the author (Yellow pin: Right riverbank, Red pin: Left riverbank, Red dot: City of Seisirmãos)

2.3 EROSION PINS

There were selected two erosions to monitor, the first one at 10 ° 44'18.84 "S, 48 ° 17'34.20" W and the second at 10 ° 44'40.29 "S, 48 ° 18'5.85 ° W. Based on the Leal (2008) methodology, the procedure of the study was developed by monitoring the edges of the erosion, from the installation of rebars with 20cm of size, where they were spiked 15cm and 5cm remained out. The number of pins varied according to the size of the erosion, in the first one were placed eleven points, and the second were placed nine points. They were put perpendicular to the erosion, two rebar per point, the first at a distance of one meter from the edge and the second at two meters. The lateral distance between the points was one meter. The checks happened fortnightly, with the help of a measuring tape. The information was stored and compared with rainfall data of the region.

Fig.3- Distance from the edges to the stakes

Source: Adapted from Leal (2008) (A stake – 1meter; B stake – 2meters)

2.4 SOIL CHARACTERIZATION

The soil was collected near the erosion, and prepared according to the NBR 6457 (2016), laboratory tests were executed and the characteristics and mechanical properties of the soil were determined. The tests were done according to the technical standards listed below.

2.4.1 Granulometricanalysis

The methodology for granulometric analysis and the execution of the test was made according to NBR 7181 (2016), performing a combination of sedimentation and sieving. The test was divided into two parts, and each case has a different goal. With the acquired results, it was possible to make the granulometric curve for soil classification. The sieving was used to determine the largest fractions as sand and gravel, and the sedimentation, which was made with fine materials such as clay or silt, measuring the speed that the material decant in the water. The determination of was based on the Stokes law, where it relates the velocity that the particle sediments. The larger the particle, the faster it'll be deposited in the bottom of the test tube.

2.4.2 Specificsoilmass

According to the NBR 6508 (1984) standard, it has been determined the specific mass of the soil that was passed in the 4,8mm sieve through the pycnometer. The specific mass was determined by the relationship between mass and solid volume. The pycnometer was calibrated and the air of the soil water composition taken according to the standard and so that air would not interfere in the search results.

2.4.3 Atterbergboundaries

In accordance with NBR 6459 (2016), the liquidity limit (LL) determines the moisture content which is the passage from the liquid state to plastic. For determination of this limit was made test in the Casagrande's equipment that measures the moisture content by closing the lower edges of a stem pitting made by a standardized chisel that is open in the soil mass, requiring 25 strokes for its closure. The result of several repetitions changing the moisture of the same soil generated a graph showing the flow line that relates the number of strokes with moisture.

According to NBR 7180 (2016), the plasticity limit (LP) shows the amount of moisture needed for the

soil to be molded. The execution of the procedure consisted in the formation of rods of 3mm in diameter and 10cm to 15cm long on a glass plate. The procedure was repeated three times to determine the moisture and was calculated the mean to find the plasticity limit.

III. RESULTS AND DISCUSSIONS

3.1 EROSION PINS

Even erosions were considered the larger overall, where two of them were selected to perform the monitoring from December until April, months with the highest level of precipitation during the year. Field analysis provided strong data on erosive processes; it can be verified that they evolve faster in the period of the year where precipitation reaches a greater volume. It was noticed that the active erosive processes are due to the action of precipitation water and the predominance of material removal is where the flow of the flash flood is larger, this predominance was seen in the highest graduation of the pins in that flow place. There was the development of vegetation which, it was also affected. It was also observed that the sedimented materials are being carried directly to the streambed.

Table 1 - Evolutionary data of the first erosion (Distance from cutting to edge oferosion)

DATAS	DADOS EVOLUTIVOS DA PRIMEIRA EROSÃO (EROSÃO DAS BORDAS)- POR ESTAQUEAMENTO								
	2018		2019						
	15/dez	30/dez	15/jan	30/jan	15/fev	02/mar	17/mar	01/abr	15/abr
PONTOS	DIST. EST. A BORDA	DIST. EST. A BORDA	DIST. EST. A BORDA	DIST. EST. A BORDA	DIST. EST. A BORDA	DIST. EST. A BORDA	DIST. EST. A BORDA	DIST. EST. A BORDA	DIST. EST. A BORDA
P1	196	194	192	186	183	182	178	177	177
P2	195	193	190	187	180	179	175	174	173
P3	194	188	185	179	176	172	166	164	163
P4	195	187	184	176	173	169	164	162	160
P5	193	186	182	178	174	170	165	161	159
P6	193	186	182	174	170	168	163	160	158
P7	194	185	181	175	171	167	162	159	158
P8	192	186	185	178	174	171	163	160	159
P9	194	187	186	180	179	177	175	174	173
P10	196	191	190	188	188	186	179	178	178
P11	197	193	193	192	192	190	188	185	185

Source: Prepared by the author.(Evolutional data of the first bank erosion – by staking. From December 15th to April 15th, P1 1st pin to 11th and its distance from the banks)

The points 3,4,5,6,7,8 presented a higher rate of evolution, the other points 1, 2, 9, 10, 11 have had less degradation, this may be due to several factors, the highest rate of erosion may be related to the flow of the flash floods, and the points that were less affected may be related to the presence of vegetation which is an important factor, because it gives protection to the soil avoiding the impacts of raindrops directly hitting the soil, reducing the kinetics energy of the drops and reducing the possible erosive processes. Points 6 and 7 were the most affected in this period, in the month of December, during the rainy season, they were found at a distance of 120 cm of the border of the erosion, in the month of April they found at 158 cm of the edge, meaning 42 cm of evolution in these points, associating a direct relation with precipitation.

Through precipitation and the monthly average evolution rate, it was possible to monitor and compare the relationship between rate of evolution and precipitation. To understand the results, it is important to comprehend how the rain cycle occurred so they can be compared with erosion pins. Monitoring the hydrological cycle was done with the data provided by INMET- National Institute of Meteorology, from December 2018 to April 2019. These data have been transformed into a line graph demonstrating monthly rainfall, as shown in Figures 4 and 5. Cumulative rainfall in this period was 1110.0 mm, the months of December and March had higher volume, accumulating 56.3% of the total.

The graph depicted in figure 4 demonstrates the comparison between the erosion and the rainfall that occurred during that period. It was observed that evolution is not directly proportional, in the first month the evolution rate and rainfall are almost close, in the following months the variables distance themselves, while the volume of precipitations in some moments reached 300 mm monthly and the evolution rate of the erosive process was around 4 to 6 cm, as shown in the graph. This variation of erosion rate may be related to the amount of rain per day. Thus, superficial erosions are related to the intensity of rainfall in this place, and the volume of flash flood that these rains cause in the region.
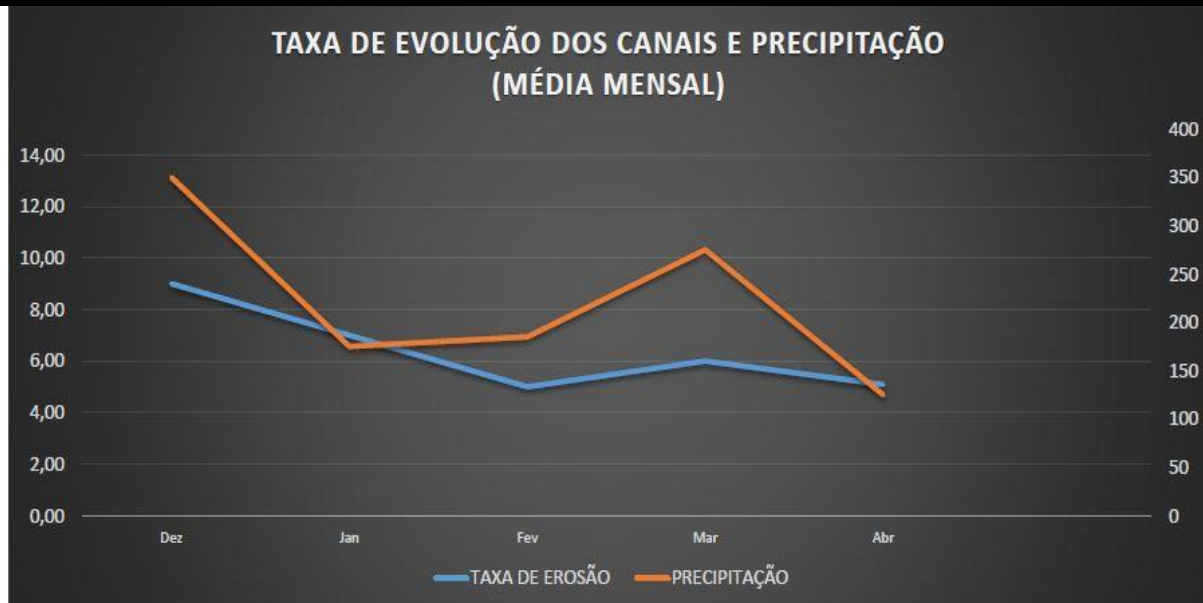
Fig.4 - Chart of the rate of evolution of the channels and precipitation (monthly average)

Source - Prepared by the author. (Rate Evolution of the channel and precipitation, on blue: erosion rate, orange: precipitation, monthly average)

The data of the table 2 presented below refers to the second erosion, demonstrating its attendance. It is at the point 10 ° 44'40.29 ° S, 48 ° 18.5 ° W. With the monitoring of this erosion a comparison was made between this and the first erosion that is located in a place far away.

Table 2 - Evolutionary data of second erosion (Distance from cutting to the edge of erosion)

DATAS	DADOS EVOLUTIVOS DA PRIMEIRA EROSÃO (EROSÃO DAS BORDAS)- POR ESTAQUEAMENTO								
	2018		2019						
	15/dez	30/dez	15/jan	30/jan	15/fev	02/mar	17/mar	01/abr	15/abr
PONTOS	DIST. EST. A BORDA (CM)	DIST. EST. A BORDA (CM)	DIST. EST. A BORDA (CM)	DIST. EST. A BORDA (CM)	DIST. EST. A BORDA (CM)	DIST. EST. A BORDA (CM)	DIST. EST. A BORDA (CM)	DIST. EST. A BORDA (CM)	DIST. EST. A BORDA (CM)
P1	198	196	195	194	191	189	186	186	185
P2	196	194	193	191	189	186	184	183	181
P3	196	192	191	189	185	183	180	178	177
P4	195	191	189	188	186	180	179	177	175
P5	197	188	187	186	185	182	177	175	173
P6	196	189	188	187	185	181	178	175	172
P7	194	190	189	189	187	186	186	183	180
P8	196	189	189	189	185	184	181	180	178
P9	197	196	196	196	194	193	193	192	191

Source: Prepared by the author.(Evolutional data of the second bank erosion – by staking. From December 15th to April 15th, P1 1st pin to 9th and its distance from the banks)

In comparison with the first erosion monitored with erosion pins , this onet behaves in a similar way, presenting similar characteristics, as it can be seen in points 3,4,5,6, which had a higher scale, showing that the superficial water flow from intense rainfall and lack of vegetation can be considered the one of the biggest reasons of these erosions. Leal (2008) reports a similar behavior in a study which was observed that the evolution of erosion occurs basically from one side of the gull, demonstrating that the flow of the rainfall has influence on erosion.

The graph presented in figure 5 represents the comparison between the precipitation and erosion rate. In comparison with the first one, the graph shows similarities, with lower erosion rates. The development of this erosion, as in the first, for instance, the erosion rate

followed the precipitation volume, but in the following months there was a variation between the precipitation line and the erosion rate, showing that the evolution is not proportional to the precipitation volume. Those results are similar to those observed by de Casado et al (2002), in which it was verified that the evolution is not continual and it is related to climatic events, such as the intensity of the hydrological events, the winds and the speed of the flow.
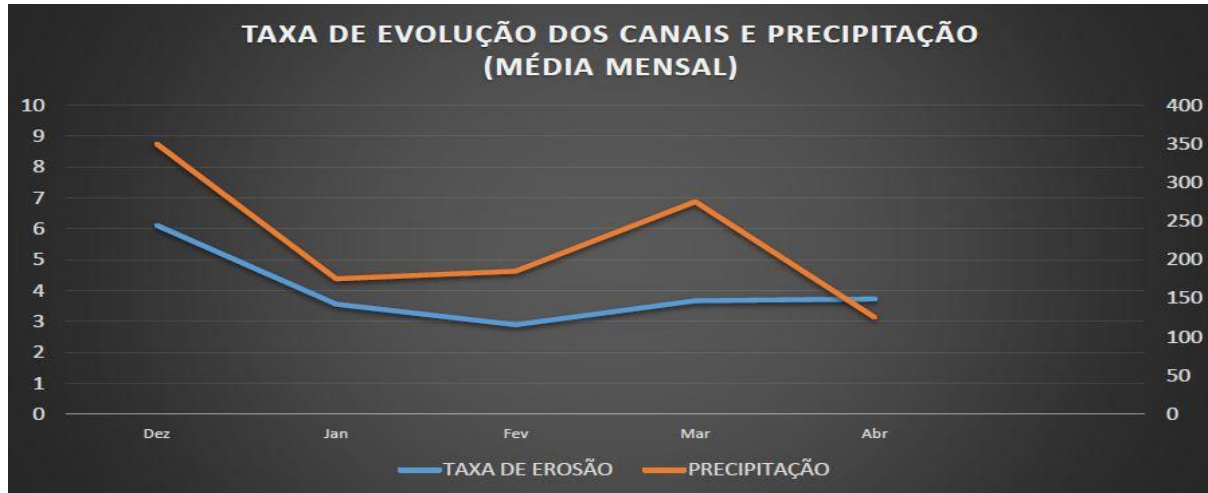

Fig.5- Chart of the rate of evolution of the channels and precipitation (monthly average)
Source- Elaborated by the author.(Rate Evolution of the channel and precipitation, on blue: erosion rate, orange: precipitation, monthly average)

3.2 SOIL CHARACTERIZATION

The plasticity index is the ability of the soil to remain in a plastic form without passing to the liquid state, therefore the lower the plasticity index the more common will be the erosion to happen due to the breaking of soil particles, and the higher the index, the more soil will resist the erosion. The plasticity index found in both soils are different. The soil of the first erosion has a plasticity index equal to 7.5 and the second had a plasticity index of 10.7 analyzing the data, the first one had a greater evolution when compared to the second. According to the theory proposed by Jenkins, the soil having $7 < IP < 15$ is considered as medium plastic (CAPUTO, 1988). In this way, plasticity of both soils are in this parameter (Table 3). However, the second one showed greater resistance against erosion.

Table 3- Atterberg Boundaries

	LL	LP	IP
PONTO 1	30,6	23,1	7,5
PONTO 2	36	25,3	10,7
LL-Limite de Liquidez		LP- Limite de Plasticidade	
IP- Índice de Plasticidade			

Source: Prepared by the author. Ponto 1: 1st point, Ponto 2: 2nd point, LL: liquidity limit: LP: plasticity limit, IP: plasticity index)

The Granulometric analysis performed showed the most stable features as the percentages of the particles that constitute the soil. With data referring to the first erosion, it was possible to classify as a sandy-loam soil, as it can be observed in Figure 6. The soil has 28% fine sand, 20% sand coarse, 10% fine sand, 22% clay and 19% silt. According to Bertoni and Lombardi Neto (2014), when the soil has a large amount of sandy material, it makes it more susceptible to erosion. Comparing the monitoring of the erosion pins we can notice that there was a bigger variaton in the first monitored erosion. According to Casado et al (2002), the presence of sandy material contributes significantly to the increase in erosion rates due to its lack of cohesion, the soil becomes more susceptible to erosion.
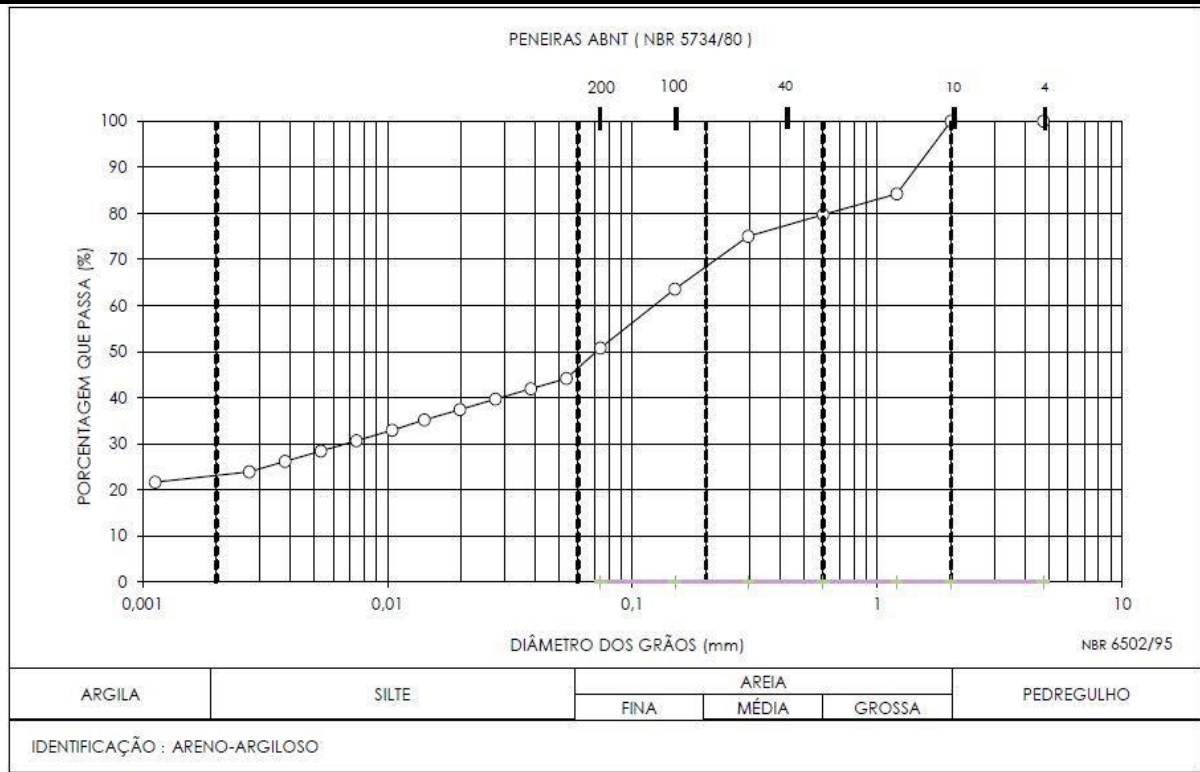
Fig.6 - Granulometric analysis of the first erosion

Source: Prepared by the author (ABNT's sieve, Vertical: percentage that goes through the sieve(%), horizontal: grains' size (mm))
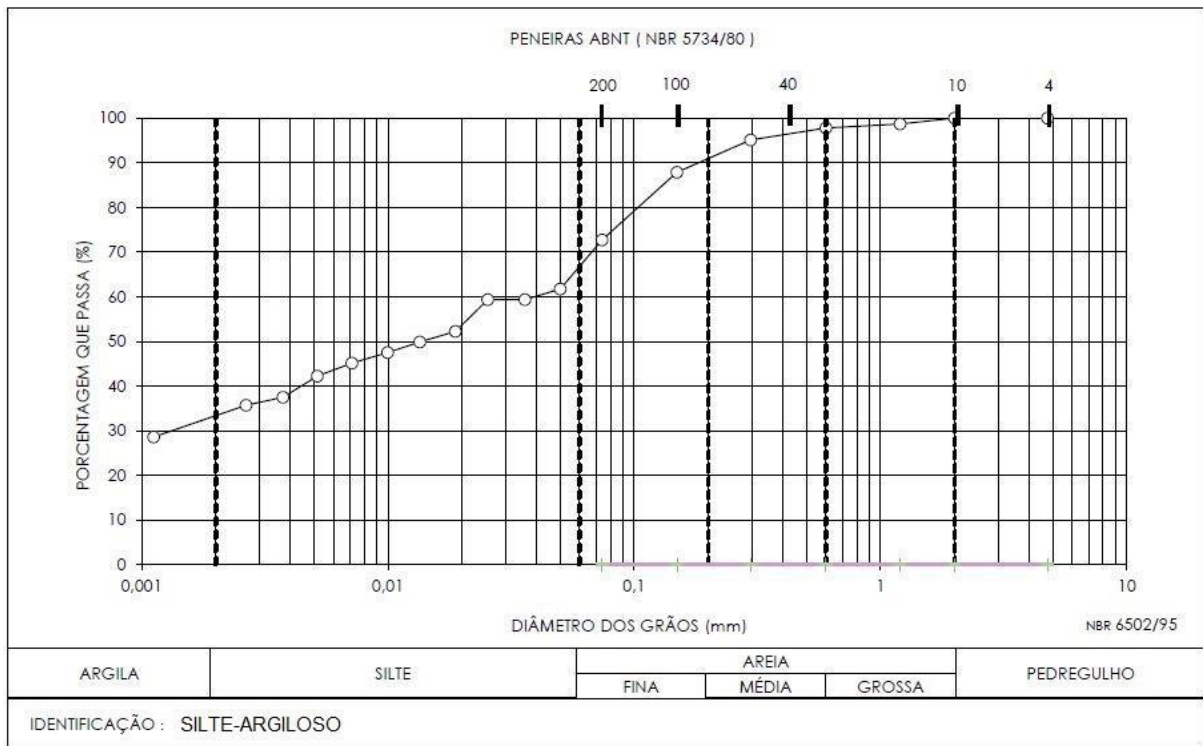

Fig.7 - Granulometric analysis of the second erosion.

Source- Prepared by the author.(ABNT's sieve, Vertical: percentage that goes through the sieve(%), horizontal: grains' size (mm))

The granulometric analysis of the second erosion is shown in figure 7. The present soil had a silt percentage of 38%, followed by 32% of clay, classifying this soil in silt-clayey, having more ability to keep the connections and in consequence, presenting greater cohesion. O sum of the percentages of fine, medium and coarse sand were around 29% of the total. In comparison with the methodology of erosion pins, it can be confirmed that the erosion which has a soil with greater cohesion, is less susceptible of appearing and developing erosions. The second monitored erosion had less progress than the first one, being able to notice that the type of soil also has a great influence in the development of erosions.

IV. CONCLUSION

At the end of this study it was possible to notice that the methodologies applied were effective. The results allowed us to understand how the precipitation factor influences the acceleration of erosive processes, acting directly on the surface, causing the erosion process to increase, generating a big loss of sediments, which are released by the kinetic energy of the water drop and the power of the flash flood. The incline of the land is also a contributing factor, since it affects the speed flow of the water. The higher the incline the faster will be the flow and consequently will have more power transporting the particles. The first erosion had sandy material and plasticity index smaller than the second one, consequently, a smaller cohesion, which explains a higher erosion rate over that time. The technique used in this study is considered cheap and easy to keep up with, and it may be used by the competent bodies to monitor other erosions that may offer some environmental or social risk. It was possible to understand how important the works that contribute to this type of objective are. Having access to a mapping with the identified erosions and their monitoring would facilitate and help to locate them, and for a future monitoring, giving the right containment treatment so these erosions will not keep growing..

V. RECOGNITION

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