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PANORAMA OF THE SMALL DAMS EXISTING IN THE MUNICIPALITY OF CAMPINAS/SP

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Palavras-Chave – Pequenas Barragens; Segurança de Barragens; Barramentos; Campinas;

ABSTRACT

Dams are built with the objective of forming a reservoir that can serve several purposes. With agricultural development and a greater need for food, there has been an increase in the construction of small dams, especially in small rural properties. These represent an important intervention since they are multipurpose structures, and can serve to minimize problems of flooding, irrigation, and animal waste, among others. Often, small dams are executed without an adequate project or technical responsible, they do not have registration with inspection bodies, which prevents the work of such entities. However, they do not fall under national legislation, which demonstrates that they need a different look. Thus, this work aims to survey the small dams in the region of the Microbasin of the Ribeirão of Cabras in Campinas/SP and to classify it as a Risk Category and Associated Potential Damage.

INTRODUCTION

Brazil is a country with an abundance of water resources and adequate topographic conditions, which favored the construction of dams for the use of water. Population growth and the consequent increase mainly in the demand for water and energy means that new dams are still being built, so that it is possible to balance the irregular distribution of water in time and space.

With the agricultural development there was an increase in the construction of small dams, especially in small rural properties. Such structures play an important role since they are multi-purpose and can serve to minimize flooding problems, contribute to the recharge of the water table, improve water storage for irrigation, livestock irrigation, domestic and leisure uses.

An important issue to be considered when assessing the safety of small dams is that they are generally built without proper design and without proper authorization and inspection by the competent bodies. In addition, as they are on private properties, it is difficult to carry out inspections to obtain data for registration and, consequently, to assess the security of these structures.

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Despite the problems, small dams play an important role in economic and social development in rural and low-income areas. Thus, care is needed when evaluating the safety of these works. Even though they are considered small, they are in greater quantity, and a possible disruption can also affect communities located downstream, local infrastructure and the environment. In addition, accidents and / or ruptures in small dams are poorly documented, which makes technical investigation of the causes of the accident difficult.

In Brazil, Law n° 14.066 was approved in 2020, amending Law n° 12.334 / 10, called the National Dam Safety Policy (NDSP) for the accumulation of water for any use, the final or temporary disposal of tailings and the accumulation of industrial waste, and creates the National Dam Safety Information System. However, dams larger than 15m are included in it, or which have a reservoir with a volume greater than 3.10^6 m^3. Thus, there is a need for public policies aimed at small dams.

The rural area of the city of Campinas/SP has many small earth dams, some of them granted and registered with the DAEE, however, the vast majority of them are not granted and are cataloged from geographic coordinates in existing reports provided by a company hired by the City Hall Municipal.

This work aims to survey the small dams existing in the Ribeirão of Cabras watershed in Campinas/SP and to analyze their safety condition from the application regarding the Associated Potential Damage. In this work, it was considered small dams those ones with less than 15m high and a storage capacity of up to $3 \cdot 10^6$ m^3, according to ANA (2016). From the results, it is noted that the small dams have particular characteristics, and need their own legislation to assess their safety, especially when they are cascading, which can cause major accidents in the event of a break.

CLASSIFICATION OF DAMS AND APPLIED LEGISLATION

The dams are built with the objective of forming a reservoir that can have the most varied purposes, among them, flood control, irrigation and mainly in Brazil, where there are favorable conditions, the generation of electric energy.

According to the International Commission on Large Dams (ICOLD, 2011), recent archaeological discoveries indicate that simple earth dams and canal networks were built as early as 2.000 b.C. to provide people with reliable sources of the water they needed to live.

According to the National Water Agency - NWA (2019), there are 33 inspection agencies in the country. There are 19.388 dams registered, only 27% of which are subject to the National Dam Safety Policy (NDSP). Of the dams registered, 82% have capacity information, 44% height, and 45% have an authorization, grant or licensing act. Currently, approximately 30% of dams are classified by Risk Category and 37% by Associated Potential Damage, slightly more than 5% with high Risk Category and Associated Potential Damage. Although the number of classified dams has increased when compared to previous years, it is still necessary to complete the APD classification of the remaining dams.

In order to monitor and direct the actions that implement dam safety in Brazil, the National Dam Safety Policy (NDSP), Federal Law n° 14.066 (NDSP), which targets water storage dams for any use, the final or temporary disposal of tailings and the accumulation of industrial waste and creates the National Dam Safety Information System (NDSI). The dams will be classified by Risk Category (RC) and Associated Potential Damage (APD), according to the resolutions of Organs inspection agencies.

In order to comply with the articles referring to the classification of dams, there is Resolution n° 144/12, amended by Resolution n° 178/16, of the National Water Resources Council (NWRC)

and Resolution n° 143/12, which determines the criteria for classification regarding the Risk Category (RC) and Associated Potential Damage (APD).

According to Silva (2021), Brazil has made great progress with the enactment of the NDSP, however, this does not apply to small dams, unless it is classified in the category of associated potential damage, medium or high, as defined in art. 6 of the Law. That is, unless the small dam brings direct risks to large population densities or has an impact on biomes considered important, it will not be regulated by this law.

Some European countries are already concerned with the long-term use of these structures. However, few countries have legislation on dam safety. Portugal, which approved the first laws in 1968, and started regulating small dams, subsequently establishing criteria for large dams, placing the figure of the entrepreneur as the person responsible for the safety of the structures.

SAFETY OF SMALL DAMS

Despite the evolution of technology and construction methods, and advances in legislation, accidents with dams are still frequent, both in Brazil and in the world. The consequences of a dam failure can involve both material and environmental damage, including loss of human life. In addition to the large dams built for power generation, it is also common, in Brazil and other countries, to build small earth dams on small rural properties, to meet the demands of irrigation and watering animals.

You (2012) carried out a statistical survey of the causes of accidents with dams around the world. Data were collected from 1.600 dam accident cases, as well as data from 1.100 dams in China with problems. According to the author, 66% of accidents occurred in earthen dams, of which approximately 50% were in dams less than 15m high. For the authors, the proper diagnosis of the condition of the dams and the measures for repair are necessary to increase the safety of dams that have already deteriorated.

Despite their height and reduced volumes, small dams also pose problems, especially when built in cascade, as the disruption of the structure further up can trigger the disruption of the entire cascade. In addition, most of the times they are built without an adequate project and a technical person in charge, and for this reason they are not included in the register of inspection bodies, which makes inspection work more difficult.

Pisaniello et. al. (2011) affirm that ruptures of large dams are more impressive and receive more attention, however, accidents in small rural dams are more frequent and tend to have disastrous consequences for the affected region. Often, small structures do not have an adequate design, they are built without a technical manager and represent both an individual threat and the cascade in which it is inserted, which can cause considerable human, patrimonial, economic and environmental impact. The author mentions accidents that occurred in China, Tasmania, Australia, United States, Indonesia, among other countries, with dams less than 10m high.

The author also states that, in order to guarantee the safety of small rural dams, a set of three actions is necessary. The first is the provision of subsidies to the owners so that they can responsibly manage the structures, which must have adequate design and construction, specified in the legislation with responsibility in the management of the dam. The second is the preparation of the community through the Emergency Action Plan (EAP), prepared by the owner. Such a document must be required by the government. Finally, the third action is the direct supervision of the state, through the inspection bodies, interfering with the operation and safety systems of the dam ensuring compliance and a level of regulatory certainty. Finally, the authors state that landowners should always be helped, and that downstream communities should at least be aware of the risks and dangers of the place where they reside. Together with associated public policies, these actions

would be the basis for establishing a range of appropriate policy models for the various existing situations.

Accidents with small dams are more common in developing countries, where 90% of dams are considered small, and there is still little attention paid to the safety of these structures. The increase in demand for water and the deterioration of structures make tools and methods necessary to improve the safety of small dams, as these are often neither built nor managed properly. In addition to technical and execution problems, they suffer from a lack of proper management and necessary maintenance. In addition, there is not enough information about them, as they are considered less harmful and therefore receive less attention [Pisaniello, (2015), Alahiane, (2016); Agoramoorthy, (2016)].

For Sampaio (2016), a strict security control system is necessary, performed by means of auscultation and visual monitoring instruments. Then, you must have a reliable emergency plan, based on realistic scenario studies. The author also affirms that the Legislation will not be efficient if the document is not publicized and an integration network is created with the public power and, mainly, with the civil defense organs so that timely rescue measures are adopted. Thus, joint action by inspection bodies and owners is necessary, so that the proper management of these dams can be promoted, and thus guarantee their safety and that of their surroundings.

From the literature review, it is noted that there are few studies and studies on legislation and good safety practices, which take into account the characteristics of small dams. Most of them have no registration with the inspection bodies and, when it exists, basic information is lacking, such as height and capacity of the reservoir.

MATERIALS AND METHODS

This research was carried out in the City of Campinas - SP, where, according to data made available by the Department of Water and Electricity of the State of São Paulo (DWES), there are 358 registered dams. The study area is the Ribeirão of Cabras Microbasin located in the eastern region of the municipality in the district of Sousas, close to Joaquim Egidio.

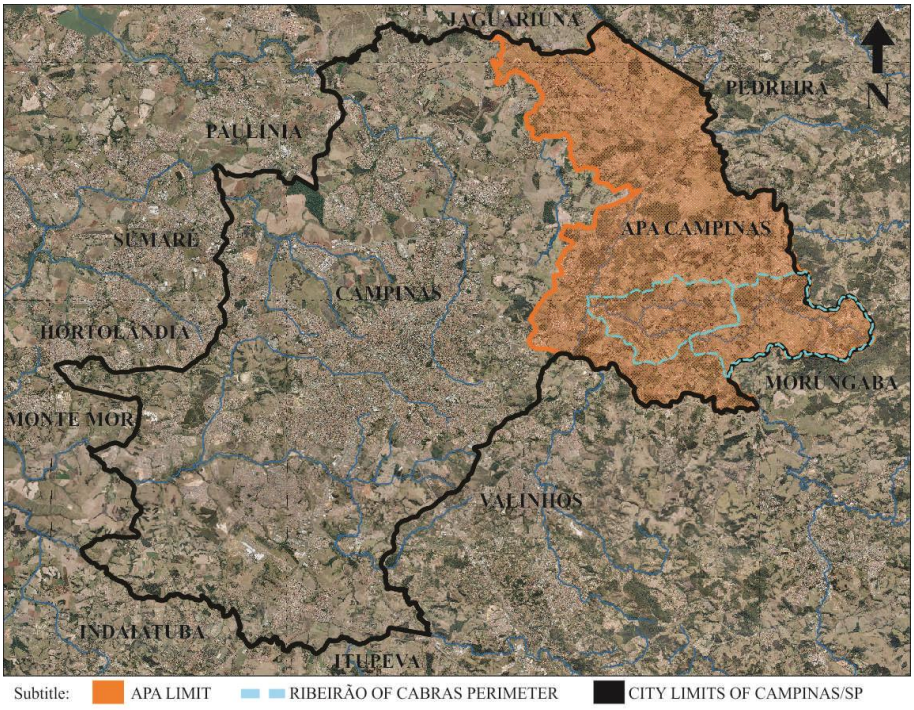
In this region APA Campinas is located, an area of importance for the municipality, where natural, cultural and architectural heritage is located, as well as water sources with potential for public supply. It also has important economic and social activities for the sustainable development of this region.

For the preparation of maps, databases and images, the orthophoto (2014) available at https://informacao-didc.campinas.sp.gov.br/metadados.php. with the following descriptions: raster format, resolution: GSD (Ground Sample Distance) 10cm, photo capture (aerofogrammetric coverage): July 2014, coordinate reference system: SIRGAS 2000 UTM 23 S. As a base for high photographic technical information resolution for the location and visual analysis of both the registered dams located and the surface area identified.

Then, a survey was made of shapefile files from the perimeter of the municipality, available at https://informacao-didc.campinas.sp.gov.br/metadados.php. The determination of the perimeter of the APA was made from the shapefile file available at http://www.campinas.sp.gov.br/governo/meio-ambiente/conservacao-da-natureza.php?plano-manejo.

Figure 1 shows the limits of the municipality of Campinas and the neighboring cities, also the rural and environmental preservation region called APA Campinas and the perimeter of the Ribeirão of Cabras Microbasin region, which is the study area of this research.

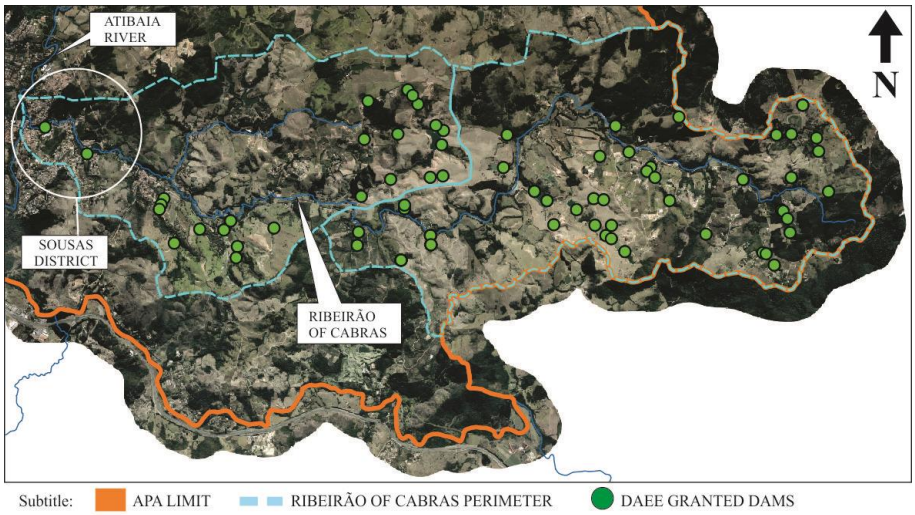
Figure 1 - Location of Campinas / SP



Source: Own authorship

From the data available on the DAEE website, 80 dams were located in the Ribeirão of Cabras Microbasin. Using the free software Qgis® and the geographic coordinates, it was possible to spatialize and georeference the dams, as shown in Figure 2.

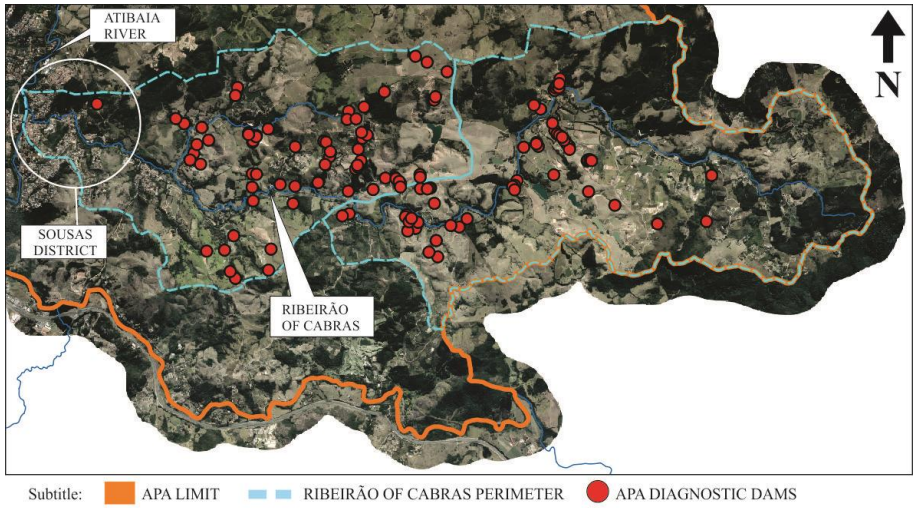
Figure 2 - Dams registered DAEE



Source: Own authorship

The location of existing dams and not registered by organs inspection agencies was made from the geographic coordinates available in the Management Plan Diagnosis of the Campinas APA (2017). These were also inserted in Qgis®, which allowed the location of the surface area. For a more accurate analysis, an on-site inspection would be necessary to assess the characteristics of these dams, which was not possible since they are located on private properties, which makes inspection difficult. Figure 3 shows the results of spatialization, with the marking of unregistered dams (in a total of 130) and, consequently, without information about their characteristics.

Figure 3 - Dams not registered Campinas APA Diagnosis



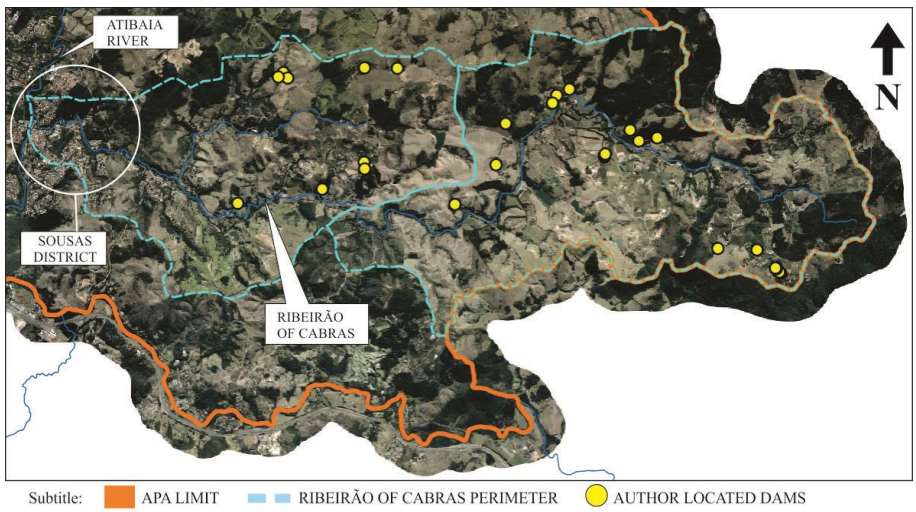
Source: Own authorship

In some cases, it was not possible to identify the surface area of the bus, which may have occurred due to the interference in relation to the satellite image used, which may have been done in periods of low rainfall.

RESULTS AND DISCUSSIONS

In addition to the dams found in the reports used in this work, 27 water patches were found in the satellite image at the limits of the Ribeirão of Cabras Microbasin, shown in Figure 4. These water patches may represent areas of water accumulation due to the level curve, flood areas in times of high rainfall, accumulation areas due to springs existing in the place or small dams. The localized water patches are homogeneously arranged throughout the watershed, being non-existent in the vicinity of the urban area of the Sousas district.

Figure 4 - Dams not registered located by the author

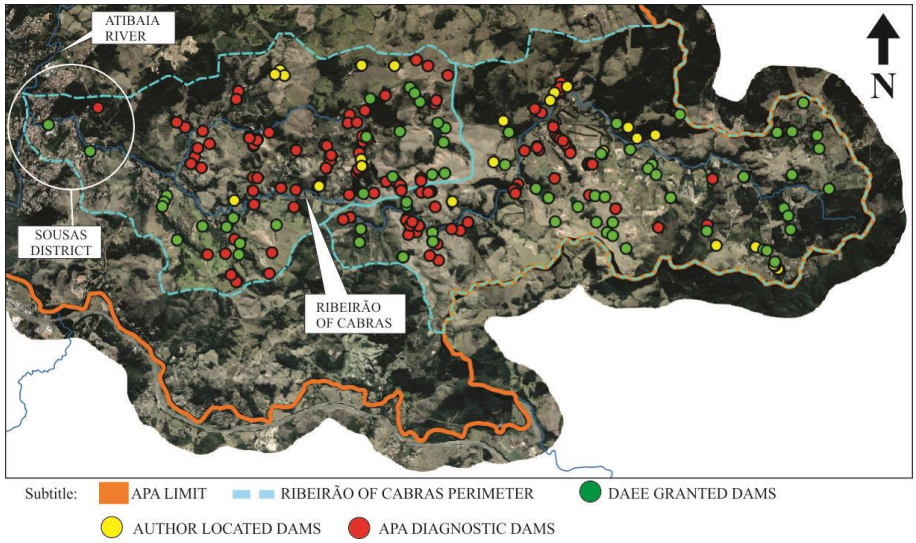


Source: Own authorship

One of the difficulties encountered when working with the registration of dams at the inspection bodies is that they are incomplete and important data are missing, including the height of the dam, the storage capacity and the area of the surface area, which, in this case, was determined sing the Qgis® software. The heights were estimated using a plugin available in Qgis®, and thus an approximate calculation of the volume of each dams was made.

Thus, it was possible to determine some information regarding the technical characteristics (TC), for the dam risk classification, however the items related to the Associated Potential Damage (APD), among them the conservation status (CS) and dam safety plan (SP) were scored with a maximum score due to the lack of more accurate information. However, the item Associated Potential Damage (APD) was classified based on the data obtained from the volumes and visual analysis by the orthophoto and values of the altitudes, enabling the approximate classification. Some of these dams have a numerical value of zero for the surface area, as they do not have a visible surface area or are in an area that is difficult to see, as the orthophoto was made between June and August 2014, a period of great drought PCJ basin. Figure 5 shows the situation of all dams in the Ribeirão of Cabras Microbasin.

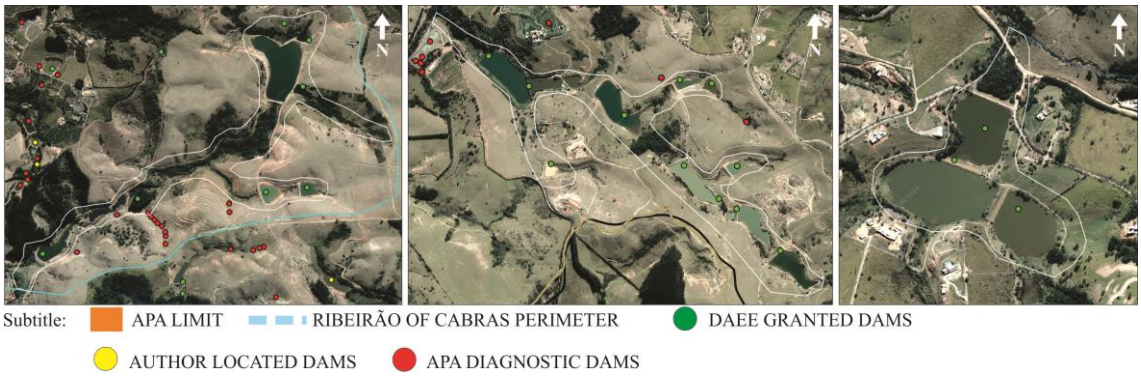
Figure 5 - Situation of all existing dams in Ribeirão of Cabras



Source: Own authorship

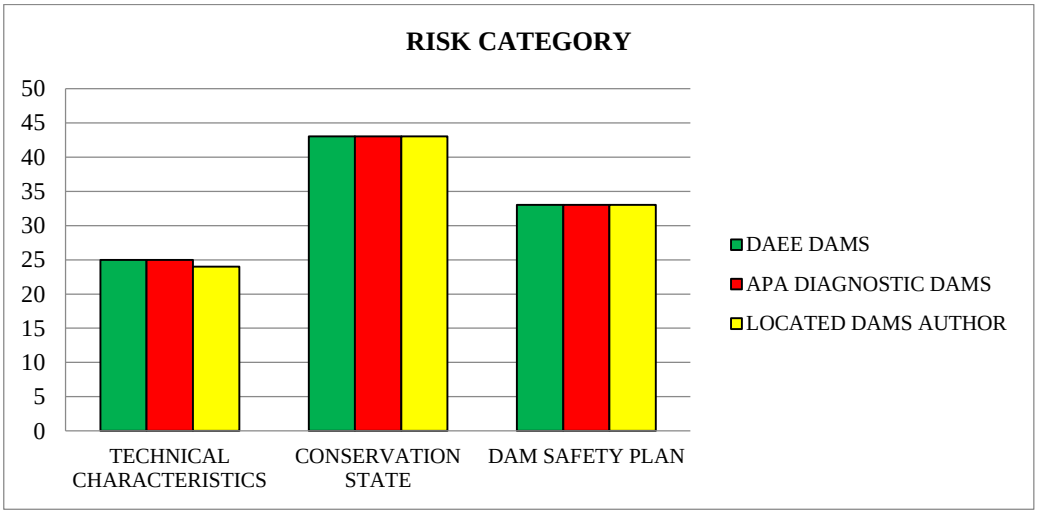
As shown in Figure 6, many of these small dams are cascading, which can generate a large volume of flooding if the dam breaks further upstream. According to the report of the Institute of Technological Research (ITR) carried out in 2002 and an event of intense rains caused the rupture of 4 dams and the overtopping of 2 massifs, causing environmental and socioeconomic impacts in the affected areas. With the application of the classification when the Risk Category, it can be seen in Figure 7 that all dams have a high score for the criteria of this regulation. It is worth mentioning that the maximum score is due, in some cases, to the attribution of a maximum score to the criterion due to lack of accurate information. What is not possible to happen, since, even with the registrations, not all the information is obtained.

Figure 6 - Cascading formations



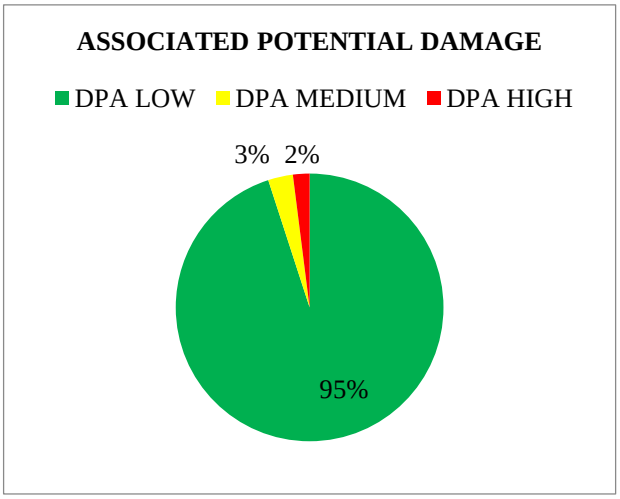
Source: Own authorship

Figure 7 - Risk Category Classification



Regarding the classification of the APD (Figure 8), it is observed that 95% of the dams are classified with low APD, 3% of them have medium APD and only 2% have high APD due to their proximity to the urban network of the district of Sousas. Dams with low APD are outside the scope of the NDSP, therefore, without the need for periodic inspection. However, it is important to remember that this is due to the fact that some of them have values of area and water volume indicated as 0, due to the difficulty in locating the surface area and measuring them. Dams with medium and high APD have specific information regarding classification requirements, thus requiring a new view of small dams.

Figure 8 - Classification of Potential Associated Damage



Lima et. al. (2020) state that these dams that have a low APD are often with the area and water volume values indicated as 0, due to the difficulty in locating the surface area and measuring them. And the dams with medium and high APD have specific information regarding the classification requirements, thus requiring a new view of small dams.

It is worth mentioning that small dams also have problems, and that, as shown in the literature, the number of ruptures in small dams is large. Thus, the need for specific regulations to guarantee the safety of these dams is reinforced, taking into account their particular characteristics.

CONCLUSION

In small rural properties, it is common to build small dams for irrigation, watering animals, or even other purposes. Although less documented, accidents with small dams are also frequent, especially during periods of high rainfall, and few countries have specific legislation or criteria for assessing the safety of these structures. When cascaded, the probability of rupture is even greater, since these dams has low storage capacity and, in most cases, they do not have enough free edge to contain the volume coming from the dam further upstream. Besides, their spillway may not be well designed, which turns the risk higher, favoring the rupture.

One of the problems in assessing the safety of small dams is the lack of information on these structures, which makes the decision-making process difficult with regard to safety planning and management. For Lima et. al. (2020), these small massifs may also be exposed to weather from natural and artificial agents or even accumulation of vegetation, which can cause accidents and damage in times of high rainfall reaching dams and goods downstream.

Even with the survey and availability of data in Organs inspection agencies, the spatialization, the location of the points and the measurement of the surface area in Qgis®, some characteristics are only possible to be evaluated with on-site inspections. However, if the dams are not obliged to pass the inspection by the responsible body, carrying out inspections is also one of the difficulties. Thus, it is necessary to analyze small dams differently and not with the same parameters and guidelines that are used for large dams.

Finally, it is worth mentioning that the work of managing the safety of small dams must be joint, and involve public authorities, owners and the community, with the need to adapt Brazilian standards in order to establish guidelines for the safety assessment that take into account their particularities, guaranteeing not only the security of the structure, but of the entire surroundings.

REFERENCES

AGÊNCIA NACIONAL DE ÁGUAS. Manual do Empreendedor sobre Segurança de Barragens. Guia Prático de Pequenas Barragens volume VIII. Brasília, ANA, 2016. Disponível em: < https://arquivos.ana.gov.br/cadastros/barragens/ManualEmpreendedor/GuiaPraticoDePequenasBarragens.PDF >

AGÊNCIA NACIONAL DE ÁGUAS. Relatório de segurança de barragens 2019. Brasília, ANA, 2020 Disponível em: <http://www.snisb.gov.br/portal/snisb/relatorio-anual-de-seguranca-de-barragem/2019/rsb19-v0.pdf/view>

AGORAMOORTHY, G.; CHAUDHARY, S.; CHINNASAMY, P.; HSU, M. J. (2016) Harvesting river water through small dams promote positive environmental impact. *Springer International Publishing Switzerland* - Environ Monit Assess 188: 645. DOI: 10.1007/s10661-016-5640-5.

ALAHIANE, N.; ELMOUDEN, A.; AITLHAJ, A.; BOUTALEB, S. (2016) Small dam reservoir siltation in the Atlas Mountains of Central Morocco: analysis of factors impacting sediment yield. *Springer-Verlag Berlin Heidelberg* - Environ Earth Sci 75:1035. DOI 10.1007/s12665-016-5795-y.

BRASIL. Lei Federal nº 12.334, de 20 de Setembro de 2010. Estabelece a Política Nacional de Segurança de Barragens destinadas à acumulação de água para quaisquer usos, à disposição final ou temporária de rejeitos e à acumulação de resíduos industriais, cria o Sistema Nacional de Informações sobre Segurança de Barragens e altera a redação do art. 35 da Lei 9433, de 8 de janeiro de 1997, e do art. 4o da Lei 9984, de 17 de julho de 2000. Disponível em: www.leidireto.com.br/lei-12334.html. Acessado em: março de 2017.

BRASIL. Lei Federal n° 14.066 de 30 de Setembro de 2020 que altera a Lei nº 12.334, de 20 de Setembro de 2010. Estabelece a Política Nacional de Segurança de Barragens destinadas à acumulação de água para quaisquer usos, à disposição final ou temporária de rejeitos e à acumulação de resíduos industriais, cria o Sistema Nacional de Informações sobre Segurança de Barragens e altera a redação do art. 35 da Lei 9433, de 8 de janeiro de 1997, e do art. 4o da Lei 9984, de 17 de julho de 2000.

BRASIL. CNRH – Conselho Nacional de Recursos Hídricos. Resolução nº 143, de 10 de Julho de 2012. Estabelece Critérios Gerais de Classificação de Barragens por Categoria de Risco, Dano Potencial Associado e pelo Volume do Reservatório, em Atendimento ao Artigo 7º da Lei nº 12.334, de 20 de Setembro de 2010. Disponível em: <http://www.cnrh.gov.br>. Acessado em março de 2018.

BRASIL (2012). Ministério do Meio Ambiente. Conselho Nacional de Recursos Hídricos – "Resolução nº 144, de 10 de julho de 2012". Estabelece diretrizes para implementação da Política Nacional de Segurança de Barragens, aplicação de seus instrumentos e atuação do Sistema Nacional de Informações sobre Segurança de Barragens, em atendimento ao art. 20 da Lei n° 12.334, de 20 de setembro de 2010, que alterou o art. 35 da Lei nº 9.433, de 8 de janeiro de 1997. Diário Oficial da União, 04 set. 2012, Brasília.

ICOLD (2011), *Small Dams - Design, Surveillance and Rehabilitation*.

IPT (2002), *Relatório Técnico número* 62.317, Convênio DAEE/IPT.

LIMA, D. A.; PINTO, W. L. H. ; FAIS, L. M. C. F.(2020) Important Aspects in the Safety Assessment of the Small Earth Dams. *Fourth International Dam World Conference*, Lisboa.v. 1. p. 57-69.

PISANIELLO, J. D.; BURRITT, R. L.; TINGEY-HOLYOAK, J. L. (2011) Dam safety management for sustainable farming businesses and catchments. *AgriculturalWater Management*-ELSEVIER, n. 98, p.507-516.

PISANIELLO, J. D.; DAM, T. T., TINGEY-HOLYOAK, J. L. (2015) International small dam safety assurance policy benchmarks to avoid dam failure flood disasters in developing countries. *Journal of Hydrology*, v. 531, p. 1141-1153.

SAMPAIO, J. A. L. (2016) The Deficiencies of the Emergency Action Planning for Dams in Brazil. *Revista Brasileira de Direito*, v. 12, n. 2, p. 7-17.

SILVA, D. C. C. E. ; FAIS, L. M. C. F. ; FREIRIA, R. C. . *A emergência do direito dos desastres na sociedade de risco globalizada: volume 2*. 1. ed. Porto Alegre: Editora Fi, 2021. v. 1. 403p .

WALM – ENGENHARIA E TECNOLOGIA AMBIENTAL. (2017) *Diagnóstico do Plano de Manejo da APA de Campinas. Campinas*. Disponivel em: <http://www.campinas.sp.gov.br/governo/meio-ambiente/conservacao-da-natureza.php?plano-manejo>. Acesso em 20 de Novembro de 2018

YOU, L.; LI, C.; MIN, X.; XIAOLEI, T. (2012) Review of Dam-break Research of Earth-rock Dam Combining with Dam Safety Management. *International Conference on Modern Hydraulic Engineering* – SCIVERSE SCIENCEDIRECT – PROCEDIA ENGINEERING, n. 28, p.382-388.