v. 3, n. 25, 2023

Journal of
Engineering
Research

MONITORING EROSIVE PROCESSES AND FUNCTIONS ON THE BANKS OF THE RESERVOIR OF THE UHE SERGIO MOTTA (PORTO PRIMAVERA): DEVELOPMENT OF TECHNOLOGIES THROUGH AN R&D PROJECT

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Abstract: Hydroelectric power is an important source of energy for the Brazilian Electricity Sector. However, the generation of hydroelectric energy depends on the implementation of water reservoirs, which pose great challenges for their environmental management. One of these challenges is the monitoring, control and management of marginal erosion processes. This challenge is compounded by the absence of robust data on the behavior of these processes. This article presents the methodology of a Research & Development Project being carried out by Auren Energia S.A. and by ``Epona Consultoria e Meio Ambiente Ltda``. whose objective is to develop monitoring techniques that allow the monitoring of large areas, with lower costs than monitoring through the techniques currently used, and with reduced risks to the health and safety of the workers involved. This objective will be achieved through the development of unmanned autonomous vehicles and the development of automated data processing techniques, reducing the information processing time.

INTRODUCTION

Brazil is the third largest country in the world in hydroelectric power generation capacity. In 2020, hydroelectric energy accounted for 63.8% of electricity generation in Brazil (Energy Research Company, 2021). Therefore, it is necessary to install and operate reservoirs of different sizes and operating systems, which have a series of relevant environmental aspects involved in their management.

One of these relevant environmental aspects is the issue of marginal erosion in reservoirs. This issue has also been considered as an environmental issue of great importance with regard to the management of hydroelectric projects. This issue is interesting for its complexity and also for its scope, as it is an issue that potentially affects virtually all hydroelectric projects, to a greater or lesser extent. Furthermore, it is a question of great social relevance, since it involves generation agents; public bodies, especially environmental ones, and civil society.

(Rubio, 2008) identified that only the 26 largest reservoirs of hydroelectric plants in the state of São Paulo have a flooded area corresponding to 15,717 km2, which corresponds to twice the area of the Metropolitan Region of São Paulo. This same author, in another study points out that the study of the USACE - U.S. Army Corps of Engineers, from 1991, indicated that out of 276 reservoirs assessed, 42% (or 117 reservoirs) had severe problems in terms of marginal erosion; and that in a single reservoir, called Lake Hartwel, there were 1,123 permissions for the installation of riprap on the banks and 393 permissions for the installation of retaining walls, due to problems related to marginal erosion. Such data and information indicate the extent of this problem for the environmental management of the Brazilian electricity sector.

Despite such importance and complexity, there is still a low academic production on this subject, although this has increased in the last decade, and little depth in environmental programs related to erosion, linked to the environmental licensing of hydroelectric projects.

As a result of this scenario, R&D Projects have grown within the scope of the Technological Research and Development Program (PPD) in the Electricity Sector. This article presents the Project “Development of methodology for monitoring slopes using VNT’s (Aquatic and Aerial)”, which has ``Epona Consultoria e Meio Ambiente Ltda``. as executing entity, and ``Epona Consultoria e Meio Ambiente Ltda. to ``Auren Energia S. A``.

GOALS

The main objective of this R&D Project is the development of methodologies for monitoring marginal erosions in reservoirs using autonomous unmanned vehicles (UAVs), both aquatic and aerial.

- Identification and adequacy of unmanned vehicles that can be used to monitor marginal erosion in reservoirs;
- Development of a methodology for processing point clouds generated from photographic images obtained with RGB cameras;
- Development of application configuration in the WebGis system to carry out a comparative study, with quick and easy application, to evaluate the evolution of erosion processes on reservoir margins;
- Development of a methodology for the acquisition and integrated processing of data from aerial surveys and bathymetry aimed at three-dimensional modeling of erosion processes;
- Development of criteria for analysis and criticality of the evolution of erosion processes based on data from periodic surveys.

METHODOLOGICAL PROPOSALS

In view of the project's objectives, the proposed methodology makes use of classical topography techniques, photogrammetry, bathymetry and three-dimensional modeling to obtain georeferenced and accurate spatial information about erosion processes, thus allowing the monitoring of their evolution over time. and quantification of eroded and deposited material.

BASIC TOPOGRAPHY

As this is a monitoring methodology development project, the adoption of a quality/precision parameter for the results is necessary. In this sense, conventional topography, widely used for monitoring activities and whose methods and results are well accepted, is able to provide good reference data for the project.

Two distinct sets of topographical data must be considered, reference stations and checkpoints. The reference stations will always be one per monitoring area and are intended to support the GNSS positioning of other equipment using a relative kinematic survey method.

In the kinematic relative positioning method (Post-Processed Kinematic - PPK), a GNSS receiver occupies a reference station whose coordinates are previously known, and a second receiver must be installed on the platform that will carry out the survey. Both platforms selected for the project, VARP and Catamarã, have PPK receivers onboard and allow the use of this positioning method.

The second set of topographic data concerns the check points (CK) that will be used to verify the accuracy of the products generated in each of the surveys. There is no consensus in scientific circles about the ideal number of verification points, however, due to the reduced dimensions of each monitoring area, at least four points must be raised in each area, three of them for the minimum definition of a monitoring system. coordinates and one for redundancy.

The disposition of the verification points must be studied for each of the areas so that the geometry between them allows the verification of the accuracy of the scales of the surveys in each of the coordinate and altitude axes.

ACQUISITION OF AERIAL AND LATERAL IMAGES

In the R&D, the acquisition of lateral images will be made using an unmanned Catamaran-type vessel, equipped with a single-beam echo sounder and digital cameras. The echo sounder will be responsible for capturing data from the submerged areas on the banks of the reservoir; while the digital cameras will provide the obtention of lateral images of the front of the erosion features, allowing the characterization of the feature along the slope, beyond the crest line obtained with information from the aerial images.

Figure 1: Simple Unmaned SS30i autonomous vessel used for bathymetry, highlighting the cameras installed on it.

The entire path of the vessel is previously established and its programming inserted in the equipment to carry out the surveys autonomously; although its manual operation is possible from the shore. Given the small draft of the vessel, it will allow obtaining data from submerged areas from 20 cm deep, enabling the identification of deposition processes of sediments generated in erosion processes and the identification of submerged processes active in the development of processes and erosion features.

The aerial surveys will have the purpose of providing aerial images of the monitored areas for the generation of surface models and orthomosaic images. As it is a monitoring activity, the maintenance of flight parameters is essential for changes in the characteristics of the data obtained to influence the R&D analyses. Thus, for each monitoring area, a single flight plan must be created that will be followed in each of the field campaigns.

Figure 2: Cloud Drone UAV Spectral 2 with RGB camera and GNSS/PPK L1 positioning system used for aerial surveys.

During the planning stage of the aerial survey, the characteristics and limits of the flight are defined. The parameters of flight height, overlapping between ranges of flights and images must be thought of in order to guarantee the quality of the surveys. The specific legislation that regulates the operation of VARPs will also be considered for flight planning.

Except for specific conditions in each area, flights will have a maximum height of 120 m above the ground. Such height is the maximum allowed by law without special authorizations being requested from ANAC (National Civil Aviation Agency). Maintaining the basic characteristics of flight height and overlapping between images and tracks, the survey time for each of the areas will vary depending on the dimensions of the flight. Table 1 below summarizes the flight parameters to be adopted, unless necessary changes due to the specific characteristics of some area.

Flight Height	120 meters
GSD	3 cm
Side Overlap.	80%
Longitudinal Overlap.	80%

The aerial survey flights will always be supported by tracking from the GNSS reference station installed in the survey area. Considering the characteristics of the selected equipment, the flight and the positioning methods to be adopted, it is expected to obtain photogrammetric products with accuracies of around 10 cm in planimetry and 15 cm in altimetry.

IMAGE PROCESSING

Terrain images collected from aerial platforms will be widely used as inputs to mapping activities. Such images, when subjected to specific mathematical and computational treatments, give rise to MDT and Image Orthomosaic. The techniques necessary for processing images to obtain cartographic products are called Photogrammetry.

In the photogrammetric process, the main step is aerial triangulation, from which the coordinates of specific points on the ground, determined using GNSS receivers, are related to the coordinates of their representations in several aerial images.

The correlation of terrain coordinates and images, plus necessary corrections, gives rise to the photogrammetric block, in which the images still in shape and how they were acquired by the camera have precise coordinates in relation to the terrain and the relationship between the various survey images is known.

For the formation of the photogrammetric block, the coordinates and altitude of a series of points on the surface of the terrain are determined from the images, these points will give rise to the first product of the aerial survey, the MDT - Digital Terrain Model. MDTs, as the name implies, are mathematical representations of the terrain, excluding anthropic structures and vegetation.

In the context of the R&D Project on the screen, the MDTs of the areas to be monitored are extremely important because, from them, it will be possible to know basic information about the area (altitude, slope, unevenness in relation to the water depth, among others) and measure the evolution of the erosion process by measuring the volume of eroded material between two monitoring periods.

The Orthomosaic of images is an image that covers the total area of the survey, which is characterized by constant scale and orthogonal projection, similar to that of a map. That is, it is possible to carry out precise measurements on an orthomosaic as if they were taken on the ground.

In the R&D analyses, the orthomosaics will be important to monitor the increase in the extension of erosion processes along the reservoir margin, and the distance from the process to the constructions or improvements that may exist in each of the monitoring areas.

BATHYMETRIC SURVEY

The use of bathymetry for monitoring the genesis of erosion processes is one of the great differentials of this methodological proposal. Methodologies based on topographic surveys, commonly applied for the purpose of monitoring erosion processes, are based only on measuring the displacement of the crest of the erosion process, disregarding what happens under the water surface.

To know that the contact of the water with the margin of the reservoir, as well as the intensity with which this contact occurs, have an important role in triggering erosion processes, and that invariably the material removed from the margins is destined for the body of water, makes monitoring of the submerged section of the reservoir's erodible margins makes sense.

In addition to the ability to detect the formation of pipings and subsurface erosions that end up triggering the collapse of large blocks of material on the banks of reservoirs, bathymetry plays an important role in the study of the deposition of this material in the vicinity of erosion processes, or its transport down the river.

The immediate result of a bathymetric survey is a three-dimensional digital model of the conformation of the reservoir bed, as well as the MDT around it. The use of side scan sonar for bathymetric surveys allows that, in addition to information from the bed immediately below the equipment, information from the margins is obtained, which is not possible with the use of single beam sonar, for example.

In turn, the idea of installing the sonar on an autonomous platform of reduced dimensions compared to a conventional vessel, aims to provide greater flexibility of access to areas of small depth and approach to the banks.

EXPECTED RESULTS

The selection of techniques that make up the methodological proposal of this project were designed so that the products generated by each of the sensors used in the surveys can be integrated with each other to provide accurate and richly detailed information on the entire area covered by the erosion process.

In summary, what will be the final product of the monitoring is a digital model of the erosion process that will start at the bed of the reservoir, advance along the bank, surpassing the water level and will extend for a few meters beyond the crest line of the process. erosive, with information provided by bathymetry and photogrammetry, in this sequence.

The use of optical sensors aims at a significant reduction in data collection costs and qualitative improvement in relation to the most used current methods (stakes and pins), facilitating the development of new research on the subject and expanding the monitoring capacity (in terms of areas covered) in hydroelectric reservoirs, by their concessionaires. The use of UAVs, in turn, aims at speeding up the survey in areas that are more difficult to access with vessels and reducing risks to the health and safety of workers, since the use of manned vessels will no longer be necessary.

FINAL CONSIDERATIONS

This R&D Project is in its 10th month of execution, and the initial 06 (six) months were for planning, including the acquisition of equipment and will have a total duration of 36 months. During the execution time of the Project, a series of technical and analytical reports will be prepared on each of the Project stages, execution protocols for the actions that make up each of the activities, and also other technical and scientific publications with the results of the Project. Project. Finally, technical events will also be held on the subject of marginal erosions, where the results of this Project, and that of other projects developed by other energy concessionaires, will be presented.

It is therefore expected that it will broaden the debate on the topic of marginal erosions in hydroelectric reservoirs and help in the development of research on the topic to come. To this end, as explained above, a great effort will be made to disseminate its results and to transmit the knowledge accumulated during its execution.

THANKS

We would like to thank Auren Energia S.A. for funding the Project "Development of a methodology for monitoring slopes using VNT's (Aquatic and Airborne)", within the scope of the Research and Technological Development Program (PPD), of the Electricity Sector, coordinated by ``National Electric Energy Agency``.

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