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DECISION-MAKING: DAM DECOMSSIONING AS AN ALTERNATIVE TO REGULATION

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Abstract. *Recent regulatory changes related to dam safety in Brazil have altered the way entrepreneurs deal with their structures. In addition to the creation of the National Dam Safety Policy, in 2010, the collapse of the tailings dam in Mariana/MG also changed the role of government surveillance and inspection. The Gegraf dam, a small dam in the south of Minas Gerais, clearly exposes the effects and impacts of those changes. The water storage dam is only 9.0 meters height, has a storage volume of 0.092 hm³ and does not have relevant anthropic occupation in the downstream valley. If it was not for the industrial purpose of its use, the dam would not meet the minimum required parameters to be monitored and inspected. A state regulation determined that the structure should be inspected annually by a dam safety specialist and the all the maintenance recommendations had to be performed. Due to many shifts in the company's management and ownership, a series of relatively simple anomalies worsened overtime, raising the cost of maintenance to a point that the best strategy was decommissioning the structure and looking for another water source. This measure reduced the operating costs of the company, as well as the risks to the business. This is an example of how regulation imposed on conscious entrepreneurs can contribute to the safety of an entire downstream valley.*

1 DAM CHARACTERIZATION

The Gegraf dam is located on the highway MG-164, km 04, Povoado Água Limpa, in the municipality of Itapecerica, Minas Gerais state, Brazil.

The business is owned by Nacional de Grafite S/A National mining and beneficiation industry, which, through a land use rights agreement, granted to Eletro Manganês Ltda the use and exploitation of the Gegraf dam, transferring responsibility for compliance with all relevant legislation.

Eletro Manganês S/A was founded in 1958 from the association between Eveready do Brasil and National Grafite Ltda. Its main activity is the production of micronutrients for agriculture and livestock.

The dam was built in 1958 and named after the Sports Club located neaby - GEGRAF. It was not possible to determine if the structure was built exclusively for landscaping purposes, or if it was already intended to reserve water for Eletro Manganês S/A

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industrial purposes. The earth fill dam, has a maximum height of 9.0 m and a storage capacity of 91.950 m³.

Figure 1: Aerial view of the reservoir of the Gegraf Dam. In the right margin is located the Gegraf Sports Club

2 STANDARDS AND LEGISLATION

Brazilian Federal Law No. 12,334, dated September 20, 2010[1], establishes the National Policy for Dam Safety, regarding dams destined to the accumulation of water for any use, the final or temporary disposal of tailings and the accumulation of industrial waste.

According to 1st article of this law, such dams must have at least one of the following characteristics:

I - Height, from the lowest point of the foundation to the crest, greater or equal to 15m;

II - Total reservoir capacity greater than or equal to 3,000,000m³;

III - reservoir containing hazardous waste according to applicable technical standards;

IV - Potential Damage Category classified as medium or high, in relation to economic, social, environmental or loss of human lives.

Although the Gegraf dam does not have any of the characteristics established by the national policy, it complies with the Normative Deliberations numbers 87 and 124 from the Environmental Policy Council of Minas Gerais (COPAM)[2], which define dam classification criteria for tailings dams, waste accumulation dams and water reservoirs for industrial and mining supply in the state of Minas Gerais. While the reservoir has been used for many years as water supply for industrial purposes, the Gegraf dam has to comply with those regulations.

According to DN COPAM nº 87/2005, the dams are classified as Class I, II or III by the sum of the values of the classification parameters, according to **Table 1**.

Class	Sum of Parameters - V	Description
Class I	$V \leq 2$	Low Environmental Damage Potential
Class II	$2 < V \leq 5$	Medium Environmental Damage Potential
Class III	$V > 5$	High Environmental Damage Potential

Table 1: Dam Classification according to DN COPAM nº 87/2005

The characteristics of the Gegraf Dam and its classification follow the criteria presented in Table 2, defined by DN COPAM No. 87/2005, and are presented in Table 3.

Height (m)	Reservoir Volume ($x10^6$)	Downstream human occupation	Downstream environmental interest	Downstream facilities
H<15 (V=0)	Vr<0,5(V=0)	Nonexistent (V=0)	Low (V=0)	Nonexistent (V=0)
15≤V≤30 (V=1)	0,5≤Vr≤5 (V=1)	Eventual (V=2)	Medium (V=1)	Low concentration (V=1)
H>30 (V=2)	Vr>5 (V=2)	Existent (V=3)	High (V=3)	High concentration (V=2)
-	-	High (V=4)	-	-

Table 2: Criteria for dam classification according to DN COPAM nº 87/2005

Characteristics		**Parameter**	**V**
Dam Height	9,00 m	H < 15	0
Reservoir Volume	91.950 m^3	Vr < 500.000 m^3	0
Downstream human occupation	State Highway MG-164	Eventual	2
Downstream environmental interest	Riparian forest	Medium	1
Downstream facilities	Pasture area	Low concentration	1
		ΣV	**4**
		Classificação	**II**

Table 3: Classification of the Gegraf dam according to DN COPAM nº 87/2005

According to DN COPAM nº 87/2005, the Gegraf dam, classified as class II (Medium Potential Environmental Damage), must perform a dam safety inspection audit every two years.

3 STRUCTURE CONDITIONS

Due to the successive changes in the company's management and to different approaches taken to maintain the dam, the structure has reached a very precarious level of conservation with various problems. The repair works needed to restore the dam to a safe condition were so significant that they became unviable in relation to the company's budget. This situation demanded a strategic decision by the owners.

According to a study by the company Azurit Engenharia[3] in March 2007, the spillway is undersized and does not meet the maximum ouflow established in the project, incurring in risk of overtopping. To adjust the discharge capacity it would be necessary to increase the size of the spillway.

Figure 2: Gegraf Dam Spillway

The downstream slope inclination is extremely high for an earthfill dam, compromising the stability and resulting in cracks, landslides, erosions or seepage.

Figure 3: View from the top of the downstream slope

Vegetation has completely taken up the downstream slope in such a way that it was not possible to inspect the toe region of the structure. By means of a drone flight performed by Enemax, it was possible to identify water accumulation at the toe of the dam. This region was not known by management staff due to the inexistence of monitoring and maintenance routine until that date.

Figure 4: High vegetation in the downstream slope

Figure 5: Water accumulation at the toe of the dam

Figure 6: Water reflection observed in during the drone flight

In previous records, the occurrence of internal erosion was reported in 2006, which indicates that the lack of maintenance already occurred at that time. According to a dam safety report made by Azurit Engenharia[4] in May 2006, in order to stop the opening, all the saturated earth was removed and the site was rebuilt with stone and compacted earth. Finally, the area was covered with organic soil for posterior revegetation with grass.

Figure 7: Location and dimension, respectively, of the sinkhole found in the upstream slope of the Gegraf dam

Figure 8: Compaction of clay material and protection of the affected site with organic soil

The instruments specified by the executive project elaborated by the company Geoambiental in June 2007 were not built. The instrumentation plan would be very important for monitoring the behavior of the structure, mainly because it is a dam with more than 50 years of operation, undersized spillway, lack of knowledge about internal drainage and erosion processes in downstream slope, as well as piping history.

As a palliative measure, the reservoir was lowered in order to reduce hydraulic risks and the risks related to the slope stability, due to the lower seepage and earth saturation.

4 STUDY OF ALTERNATIVES

In 2016, Eletro Manganês hired Enemax Engenharia e Consultoria to carry out a Dam Safety Technical Audit[5], in compliance with COPAM Normative Resolution 87/2005. Due to economic unviability of the civil works needed, a evaluation of alternative solutions to minimize risk has started.

As it is not a property of Eletro Manganês, the first measure adopted was the interruption of the water usage. The industry began collecting water in another stream and drilled deep wells for contingency. These first measures aimed to withdraw the need to comply with the normative, once it is no longer a "water reservoir used for industrial supply". The decharacterization of the dam is, therefore, the administrative process of proving that the structure no longer falls within the normative. However, the State

Environmental Foundation (FEAM), would still require the execution of pending maintenance to adequate the dam, as well as future monitoring to ensure the stability of the structure and downstream valley safety.

Therefore, in mid-2017, due to the high cost to adapt the structure of the dam, the inherent risks of the process and the existence of other sources to supply the industry, the company decided to decommission the Gegraf Dam. The decommissioning project[6] was developed by Enemax Engenharia e Consultoria.

5 DECOMMISSIONING PROJECT

The decommissioning project consisted of creating a breach through the body of the embankment to allow the free flow of the watercourse and the flows caused by rainfall events, so a reservoir was not be created. The project also predicted that the entire reservoir área would be environmentally recovered with planting techniques after decommissioning.

The dam region, its reservoir, surrounding and downstream areas were surveyed by na aerial photogrammetric campaign conducted in October 2017. The survey was performed by a drone (UAV) supported by ground control points obtained by a RTK GNSS receiver.

Number of images taken	634
Average flight height	67,40 m
Resolution	1,64 cm/pixel
Coverage area	252.000 m²
Ground Control Points	12

Table 4 - Data from the campaign carried out by Enemax on the Gegraf dam

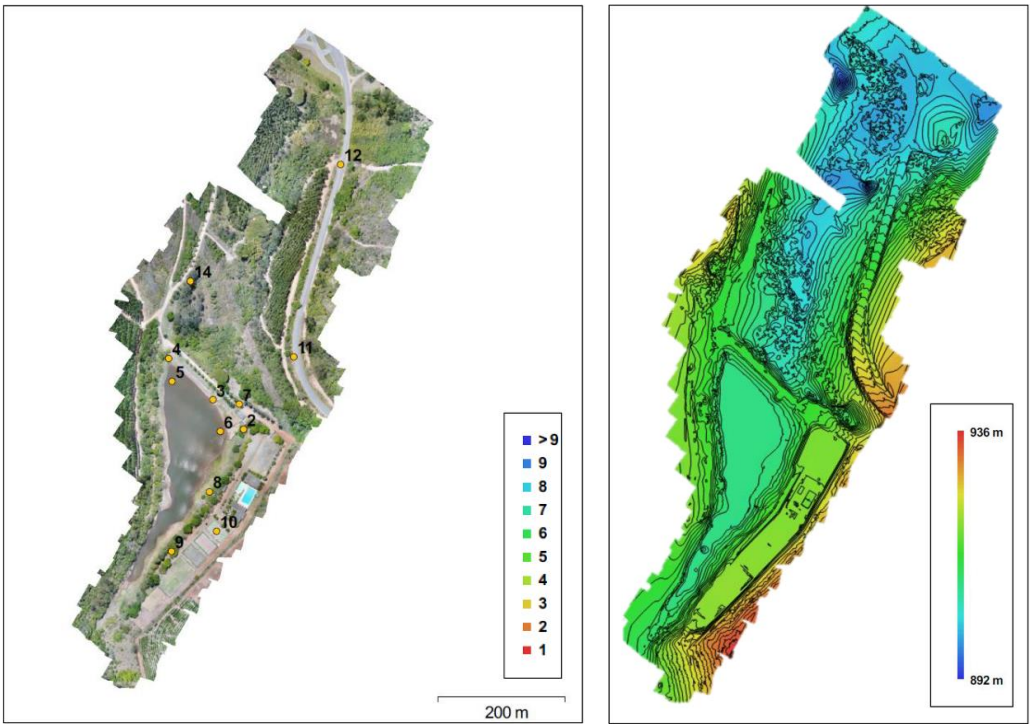

Figure 9: Location of ground control points and contour lines obtained and used for the project

The project consisted in the creation of a breach transversal to the dam, connecting upstream and downstream, in alignment of the axis of the outlet basin of the internal drainage. Through this gap the stream will flow again.

The project predicts that, for the beginning of the works, it will be necessary to pump the whole volume of the reservoir downstream. This procedure, in addition to increasing the safety for the excavation, will allow to know, in the beginning of the intervention, what is the real shape of the bottom of the reservoir.

The material from the excavation will be stored in the depleted reservoir area. The excavation will be initiated by the crest and will continue until the bottom of the breach. To optimize and execute the cuts efficiently, the Works should be done with topography support. The final inclination of the cut slopes (1H: 2V) is lower than the angle of repose of the current downstream slope and, after the reservoir is empty, there will be no seepage and saturation, guaranteeing good stability conditions for the new cuts. The breach will be covered with rockfill in the water course and by grass in the dry section, above the rockfill. The dimensioning of the rockfill (average diameter of the stones and the height of the protection) was done considering the maximum flow described in the report Geoambiental Consultoria (2007), which is 22.4 m^3/s.

The area covered by the excavation material, at the end of the work, will be recovered through direct sowing of grass species native to the *cerrado*, biome of the region. The area of the reservoir will be revegetated by direct planting of seedlings of fruit species and/or *cerrado* species. The seedlings should be planted by contour lines, spaced approximately 3,00 meters between plants and between rows, in an intercalated manner, in pits of at least 30 cm in diameter and 40 cm in depth.

To support the works, a suggestion of constructive sequence was conceived. This proposal may be appropriate in accordance with the equipment, staff and experience of those responsible for the execution.

The work was planned to be performed preferably in the dry season, which occurs between May and September. If the owners choose to do it during the rainy season, peak flows must be considered for pumping water out and because of their effects through the gap before the work is done (it may be necessary to build a cofferdam).

The project also highlights the need to rescue fish in the reservoir and its release downstream, during the construction process.

Figure 10: Decommissioning project for the Gegraf dam

6 CONCLUSIONS

The decommissioning project for the Gegraf dam is a result of a sum of factors: the absence of predictive and preventive maintenance by previous users, the high cost of recovering the safety condition and shifts in the company water demand.

It is also undeniable the influence of the Samarco tailings dam failure, in November 5, 2015, on the the way companies, inspetors and specialists face the dam safety subject. The severity of this event has considerably altered the dam safety community in Brazil, having an importante role on the publication of a series of regulations in the hydroelectric, water and mining business.

The option for decommissioning the Gegraf dam is an alternative that minimizes the risk not only for the business, but for the downstream valley. This is an example of how responsible managers and strict legislation result in interesting solutions for the common good.

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