Geotechnical Stope Index

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ABSTRACT: The Geotechnical Stope Index aims to highlight the ore's dilution potential. The profile uses calculations to consider historical observations and geotechnical data analysis to identify potential geotechnical hazards about overbreaks in sublevel stoping. After each step, a column called "Estimated Dilution" is added to compare previous estimations with actual results, using a reconciliation method to calibrate the system's predictability feature. The Stope Index input limits have been calibrated based on stope performance data to provide realistic dilution estimations. This suggests that the system is being used in a mining or excavation context to estimate the amount of material that is lost or mixed in with the extracted ore during the mining process. By comparing the estimated dilution with the actual dilution, the system can improve its accuracy over time and provide more reliable estimates. This system is the geotechnical risk inserted in the mining plan before the mining production sequencing.

Keywords: Stope Index, dilution, mine planning, geotechnical classification.

1 INTRODUCTION

The mining operations of Mine Serra Grande (MSG), which is owned by Anglo Gold Ashanti group are in the city of Crixás, in the northwest of the state of Goiás and 384 km away from the capital Brasília. The mine has a total of 7 active mines, with 3 being underground and 4 being open pit. The underground operations are responsible for 90% of the unit's production, with the Sublevel Open Stope (SLOS) mining method being the primary mining method used.

For estimating stability used to empirical methodologies and dilution are based on data collected from specific geological and structural situations. Therefore, it is important to validate these methodologies for each operation, to guarantee that the results obtained accurately reflect the mine conditions. Understanding the variables that affect the stability and dilution of the excavations is fundamental for the application of a mining method in a mine. For this, a Geotechnical Risk Profile was needed to quickly assess the geotechnical risk associated with a mine plan presented as part of the Integrated Planning process.

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2 MINE HISTORICAL

Stability analysis and dilution estimation for MSG stopes it was done with the following methods:

2.1 Modified Stability Chart Method:

This described method is known as the modified stability span design method. It is used in underground mining to assess the stability of stopes, which are voids created by mining ore. The objective of the method is to ensure that the stopes are dimensioned in a safe way, to avoid landslides or collapses that could endanger the safety of the workers and the productivity of the mine.

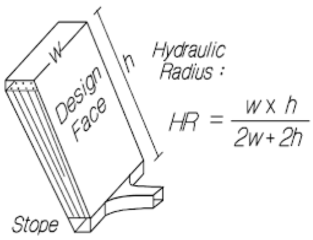

Figure 1. Hydraulic radius equation of a stope hanging wall by Milne and Pakalnis (1997).

The equation above (Figure 1) is used to calculate the hydraulic radius of the excavation, which is an important parameter in the stability analysis. The hydraulic radius is defined as the cross-sectional area divided by the perimeter. It provides information about the shape and geometry of the excavation, which affect stress distribution and stability.

The equation below is used to calculate the modified stability number (N'), which measures the rock mass's resistance to instability. The N' is calculated from four parameters: geotechnical classification of the massif, stress analysis, orientation of discontinuities and the way in which ruptures occur. Each of these parameters influences stope stability differently and must be considered in the stability analysis.

$$N' = Q' \times A \times B \times C \quad (1)$$

After obtaining the values of RH and N', it is possible to plot them in the modified stability graph (Figure 2). The graphs provide stability and instability limits for different values of RH and N', allowing to evaluate the stability condition of the planned stope.

2.2 ELOS method

The ELOS (Equivalent Linear Overbreak/Slough) concept proposed by Clark and Pakalnis in 1997 is a measure of the average overbreak thickness of the planned stope in relation to the stope width.

Dilution estimation is done using the modified stability graph and curves defined from real SLOS results presented by the author. The modified stability graph is used to assess stope stability and curves defined from actual SLOS results are used to estimate the amount of overbreak and slough that can occur during digging. From this information, the average overbreak thickness can be estimated and used to calculate the dilution.

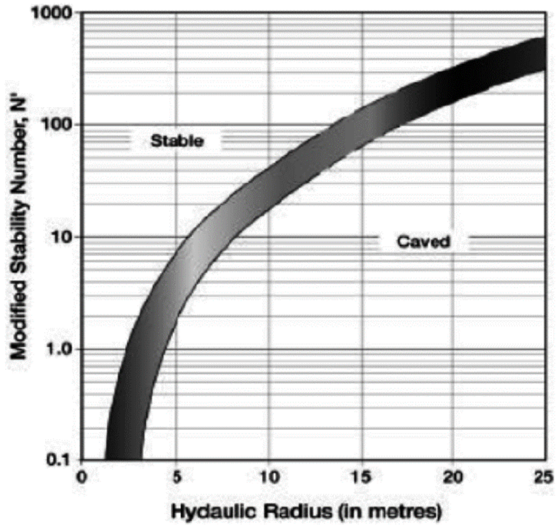

Figure 2. Stability Graphic modified by Potvin (1988).

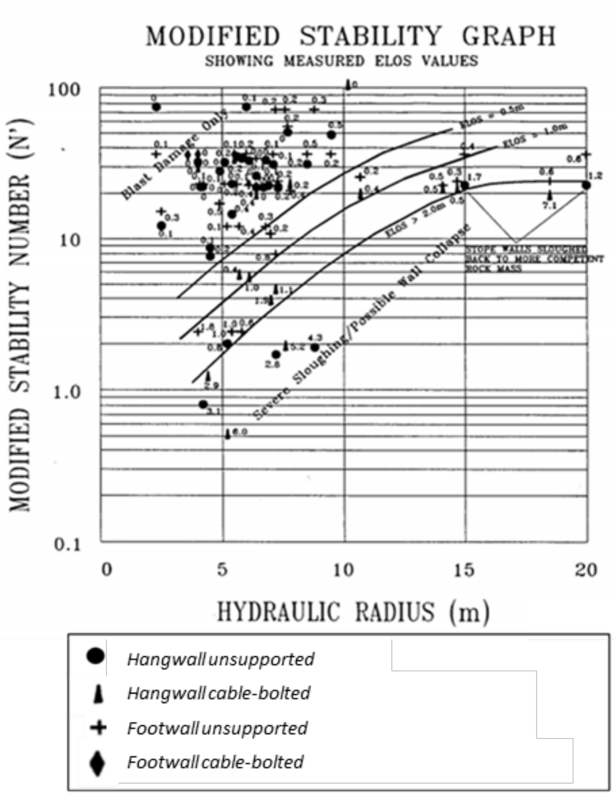

Figure 3. Dilution estimation method from ELOS (Adapted from Clark and Pakalnis, 1997).

3 METHODOLOGY

With the historical data of the mining of different ore bodies of MSG, it was analyzed case by case which were the inputs that most affected the dilution of the stope. These inputs were collected through the daily monitoring of production, through topographic data, mapping of structures and calculations, added to the hydraulic radius data and N' already used for each block. These inputs were ordered and ranked so that the ranking weight was directly associated with the actual block dilution. therefore, these numbers were correlated with the reconciliation numbers of each stope.

Was created an equation to estimate dilution for short-term plans. The equation was promoted by a linear correlation between the stope index and dilution. It was considered stopes executed data from all mines which have the dilution not influenced by operational factors.

The entries for ranking in the Stope Index are:

1. Hydraulic Radius (HR) – size and shape of the stope plane.
2. N' – Industry accepted stability number (N' (prime)) from Potvin Y. (1988).
3. Persistent Structures – stopping and intersecting large-scale discontinuities.
4. Undercutting – stop the actual position providing HW eyebrows.
5. Surrounding Excavations – The increased number of surrounding excavations results in changes of the tension field increasing headings deformation.
6. Connections – stop and crossings due to lack of sill pillars.

Table 1. Stope Index Classification.

Parameter	Class	Weigth	Stope Index
HYDRAULIC RADIUS	HR>=7.5	30	0
	6<HR<7.5		15
	HR<=6		30
N'	N' < 3	20	0
	3 <= N' <= 4		10
	N' > 4		20
PERSISTENT STRUCTURES	Shear Zone or Fault	15	0
	Persistent Structures		7.5
	Without Structures		15
UNDERCUTTING	>= 2m	15	0
	1 a 2m		7.5
	FITTED		15
SURROUNDING EXCAVATIONS	Mining above of the stope access	10	0
	Three or four excavations		5
	One excavation		10
CONNECTIONS	Without Filling	10	0
	Filled (rock or backfill)		5
	No conected		10

The system in question assigns risk classes to stopes based on the Stope Index (SI) input, which ranges between 0 and 100. The risk classes are divided into three categories: High-Risk, Mid-Risk, and Low-Risk.

For High-Risk stopes, which are classified by an SI score of less than 48, the impact on gold production is significant, with the expected dilution factor exceeding 30%. Mid-Risk stopes, classified by an SI score between 48 and 66, have a less severe impact on gold production, with a dilution factor expected to exceed 15%. Low-Risk stopes, with an SI score of 66 or higher, do not have any dilution impact on gold production.

It is worth noting that the classification limits and their corresponding impact on gold production are presented in the Table below.

Table 2. Risk Management about the values of the Stope Index.

Risk Management		
Stope Index	Risk Level	Risk Classification
SI => 66	Low	No impact
48 <= SI < 66	Medium	Dilution factor can exceed + 15%
SI < 48	High	Dilution factor can exceed + 30%

4 RESULTS

The system takes inputs and sums them to automatically classify risk levels, and after each stope block is performed, an "Estimated Dilution" column is added to compare the previous estimations with the actual results. This is done to calibrate the system's predictability feature, using a reconciliation method.

The Stope Index (SI) input limits have been calibrated against stope performance data, which means that the system has been adjusted to provide realistic dilution estimations based on actual performance data from previous operations. This helps to ensure that the system is accurate and reliable in predicting and estimating dilution levels in future operations.

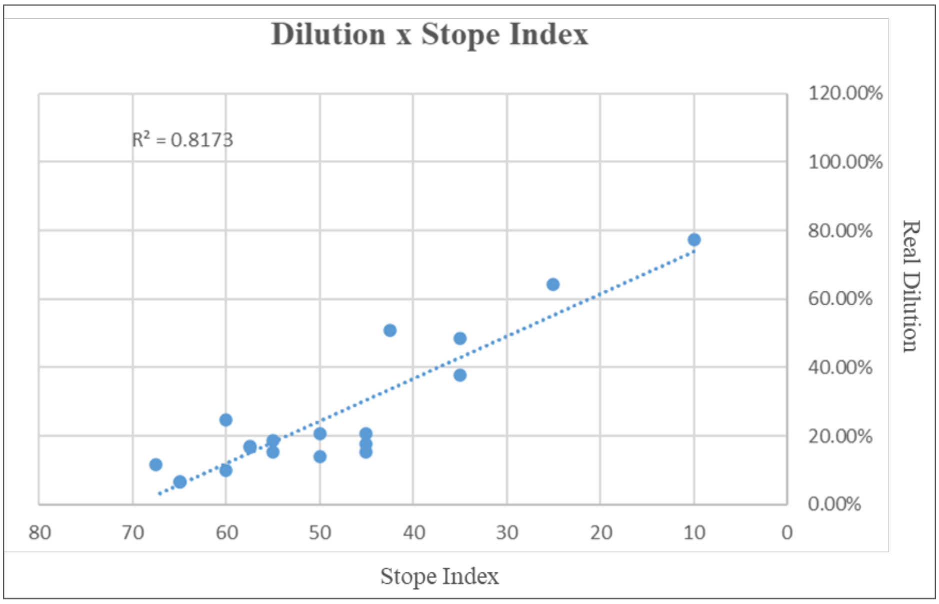

Figure 4. Correlation of Stope Index and Real Dilution.

Based on the information provided, it was possible to quantify the risk for the medium- and short-term plans, being able to change the design or extraction sequence in order to reduce the estimated dilution value.

The planning team, with the results from the stope index added to the geotechnical information in their decision-making process, were able to reduce the number of high-risk ounces, that is, with high estimated dilution.

5 CONCLUSION

Overall, this methodology provides a systematic and quantitative approach to assessing stability and dilution in mining operations. By using real equations, graphs and data, mining engineers can make informed stope sizing decisions and ensure the safety and sustainability of the mining operation.

In addition, the system is designed to help mine planning optimize its performance by accurately predicting and estimating dilution levels, which can have a significant impact on the overall profitability and success of the operation.

Note also the complexity of the stope index need different information to be most close to real as well as the importance of adjusting the system based on ore body characteristics, persistent structures and depth.

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