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New reconciliation model for gold industry

ABSTRACT

Adequate practices of reconciliation should consist of an integrated system divided into stages, each representing one of the following mining operations: long-term estimation, short-term estimation, planning, mining operation, mineral processing and metal production. The gold industry includes another stage which is the budget, when the company informs the financial market its forecast of annual production. The subdivision of reconciliation into stages allows not only increasing the reliability in the annual budget informed by gold-producing companies, but also detecting and correcting the critical processes responsible for the overall estimation error, which are often related to improper practices of geostatistical modelling and/or sampling protocols, procedures and equipments. This paper develops and validates a new reconciliation model for the gold industry, which is based on correct sampling practices and the subdivision of reconciliation into stages. Results show a better estimation of grades and a more efficient control of the mining processes, from the resource model to the final production.

INTRODUCTION

Economic evaluation, mine planning and performance prediction of all mining operations are based on estimates of both ore content and mass. These estimates are based on samples and generate the results of reconciliation, considered by many professionals as a quality test for the resource models' estimates (Schofield, 2001). When dealing with precious metals, sampling and reconciliation are called into question because of the difficulty in answering: 'how representative is the sample and how reliable are the reconciliation results?'

Reconciliation is an activity carried out in most mining companies and can be defined as the comparison between a measurement and an estimate, i.e., between production and estimate of production. Dividing the grade or mass of produced ore by the grade or mass of ore estimated by the resource model results in the so-called 'Mine Call Factor' (MCF), which is applied to future estimates in an attempt to better predict what the operation will produce. Morley (2003) called it 'reactive reconciliation'. However, this is not the best practice of reconciliation. The main objective of any system of reconciliation shouldn't be to generate factors used to correct estimates, but to allow adjustments in the processes so that the results are always within acceptable limits.

Adequate practices of reconciliation should detect the causes of the errors between the models' estimates and the observed production. Eliminating the causes of these errors, the estimates become predictions and can form a basis for decision making, ensuring that what happens in the future corresponds to what was planned in the present. This is the concept of 'proactive reconciliation', an iterative process that allows the correction of sampling processes and production estimation to improve the predictability of the models. Proactive reconciliation is the key for the company to show that the information provided on resources, reserves and operation performance are precise, accurate and auditable (Morley, 2003; Chieregati, Delboni & Costa, 2008).

However, reconciliation results can be illusory unless all parties involved have been in compliance with the principles of sampling correctness, since the reliability in the estimates depends on the representativeness of the samples that generated them. Therefore, the optimisation of sampling procedures is the first step to develop a reliable reconciliation system.

This work develops and validates a new reconciliation model for the gold industry, based on correct sampling and proactive reconciliation practices. The results show improvements in process control and models' estimations as well.

METHODOLOGY

New reconciliation model

Historically the practice of reconciliation has been limited to the application of the MCF to the estimates generated by the long and short-term models. However, reconciliation should not simply evaluate the models based on the plant's results. In practice, each step of the operation should be examined sequentially: from resource model to mining, from mining to mineral processing and from mineral processing to metallurgy or final product (Crawford, 2004).

The subdivision of reconciliation into stages allows personnel to visualise the critical stages of the operation and solve each problem separately. This was the basis for the development of the new reconciliation model proposed in this work.

In addition to the MCF, the new model defines five other reconciliation factors, which will not be applied to estimates, but work as control or performance indicators of each individual mining stage. These indicators allow the detection and correction of observed reconciliation problems, which often result from improper sampling practices and/or resource modelling.

Figure 1 outlines the proposed reconciliation model and its factors/indicators:

- *MCF or Mine Call Factor*: indicates the predictability of the long-term model.
- *MM or Mine Model*: indicates the consistency of the long-term model.
- *MP or Mine Planning*: indicates the usefulness of the short-term model for planning.
- *MO or Mine Operation*: indicates the performance of the mining operation.
- *MR or Mine Reconciliation*: indicates the quality of the long-term model's estimates.
- *PR or Plant Reconciliation*: indicates the plant performance.

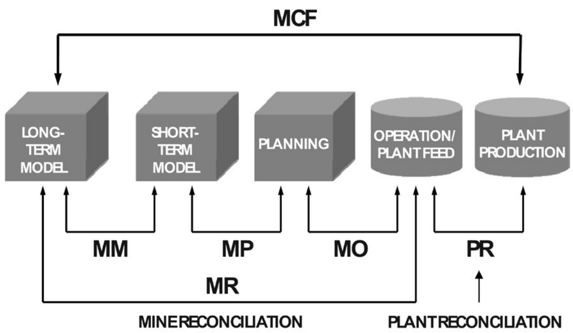

Figure 1 The new reconciliation model and its factors/indicators

Each indicator is calculated by dividing the value of the variable into study (mass, metal content, or grade) of the subsequent operation by the initial operation. For example: if the short-term model reports that a mining block has a gold grade of 2.25 g/t, based on additional sampling at the mine, and the long-term model reports, for the same block, a value of 2.75 g/t, then MM=2.25/2.75=0.82. This number indicates that the long-term model overestimates the grade of the block in 18%. These indicators can also be obtained using the metal content (oz of Au) instead of the grade, which is a common practice in the gold industry.

Note that the value of MCF includes all indicators, since it is the result of the product among them. However, some companies define the MCF as the metal content at the plant feed divided by the metal content estimated by the long or by the short-term model.

How to use the indicators

Figure 2 shows an example of how to use the reconciliation factor and indicators for a hypothetical underground gold mine. Note that the values of the MCF and the indicators were calculated based on metal content (oz of Au).

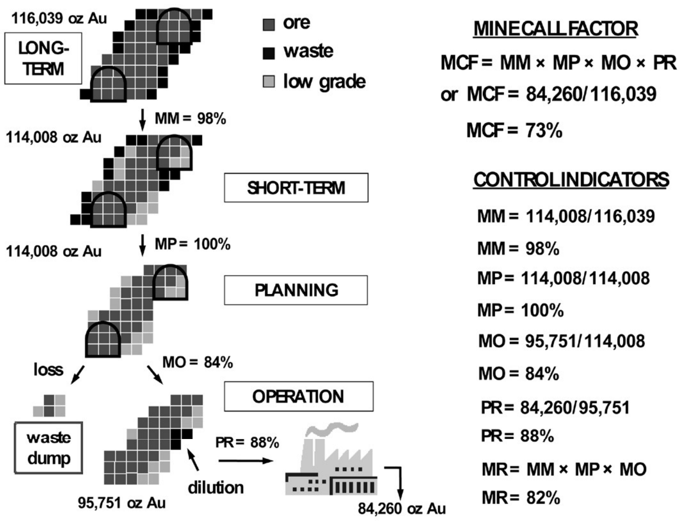

Figure 2 Reconciliation factor and indicators for a hypothetical underground gold mine

The figure shows the critical stages of this operation: (1) mining operation produces 16% less of the gold planned to be mined (MO=0.84 or 84%) and (2) processing plant recovers 88% of the gold fed (PR=0.88 or 88%).

If we consider that all the sampling and sample preparation procedures have been performed correctly, the value of MCF of 73% indicates that this particular stope has produced 73% of the gold predicted by the long-term model, nothing indicating about each individual operation. The control indicators, in turn, show that:

- MM=98%: the long-term model is consistent (the estimate of the long-term model for this stope is only 2% higher than the estimate of the short-term model).
- MP=100%: the short-term model was precisely followed for short-term planning.
- MO=84%: the mining operation produces 84% of the gold predicted by the short-term plan.
- PR=88%: the plant recovers 88% of the gold fed.

According to Crawford (2004), depending on the type of ore and the mining method, a complete reconciliation should consider errors related to losses, dilution and production between 7 and 12% a year. Errors above these values should be better analysed, so that its causes could be determined and corrected.

RESULTS AND DISCUSSION

The new reconciliation model was applied to a gold mine in Argentina. Figure 3 shows its simplified reconciliation system for 2010, when the operation started to use the new reconciliation model. The indicators were calculated based on metal content (oz of Au).

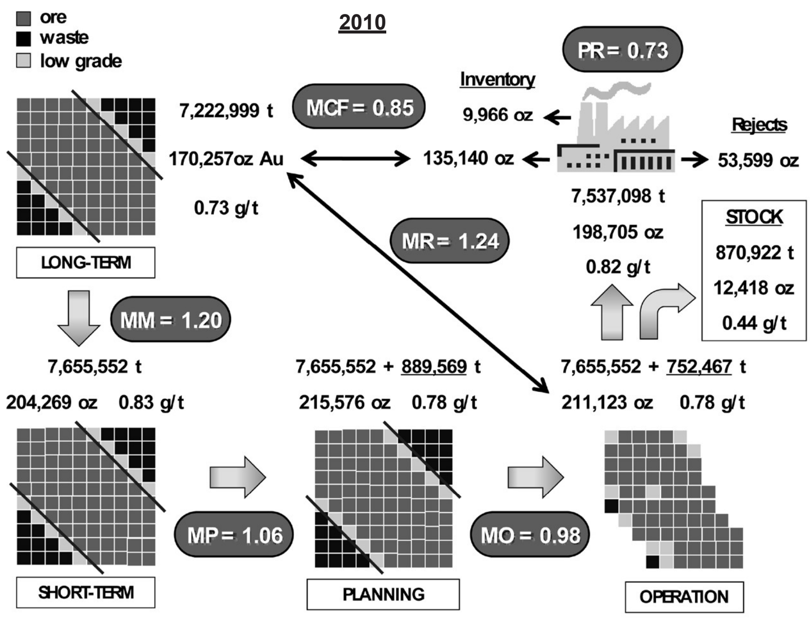

Figure 3 Application of the new reconciliation model (2010)

The figure shows the critical stages of this operation in 2010: (1) inconsistency between the long and the short-term models (MM=1.20) and (2) processing plant recovered only 73% of the gold fed (PR=0.73).

It's worth emphasising that the process of gold concentration in this mine is done through cyanidation leaching in a valley divided into cells. The metallurgical recovery and, thereby, the amount of recoverable gold for each cell is estimated based on column tests in the laboratory. The monthly reconciliation process considers the amount of recoverable gold held in each cell, composing an inventory that will impact on gold production in the subsequent months. For the calculation of the reconciliation indicators and the MCF, the inventory variation (positive or negative value) is added to the actual production. This is a necessary procedure to avoid illusory reconciliation results.

Considering the presented processes' complexity after mining operation, involving inventory and stock variation, the company can make use of MR as its main control indicator. Figure 3 shows a MR of 124%, which means that the operation mined 24% more ounces as predicted by the long-term model. In this case, one shouldn't evaluate MR alone, but observe the processed tonnages as well. While the long-term model predicted a processed mass of 7 222 999 t of ore, the mining operation processed 8 408 019 t (7 655 552 t of ore plus 752 467 t of low grade ore).

Sampling improvements for mine reconciliation

Knowing that any estimate is based on the set of available physical samples, the reconciliation indicators presented in Figure 3 will only be valid if all samples generated at all sampling stages can be documented as representative in the sense of the Theory of Sampling (TOS).

Therefore, preliminary studies have been carried out to guarantee that sampling procedures were adequate and generated unbiased samples.

First study consisted of a comparison between the conventional fire assay and the screen fire assay techniques. A total of 56 samples from a mineralised block were splitted. The first samples were submitted to screen fire assay for gold. The duplicates were submitted to the conventional gold fire assay technique. The average grade for the screen fire assay was 3.56 g/t while the average grade of the equivalent samples for the fire assays was 3.06 g/t. This variance equates to approximately a 14% increase in grade report from the screen fire assays, indicating that a significant percentage of coarse gold is not being captured by the standard fire assay. Therefore, the screen fire assay was recommended as the standard gold analysis technique for this mining operation.

The second study consisted of the heterogeneity test, which estimates the constitution heterogeneity factor and allows the simulation and optimisation of sampling and preparation protocols. The results of the test suggested that a larger mass of the primary sample should be collected (25 kg against the previous 15 kg-sample), guaranteeing that the relative standard deviation of the fundamental error s(FE) will not exceed 16%. According to Pitard (1993), above this value we rapidly enter into a transition zone beyond which the estimate of the gold content from replicate samples starts to disobey a normal distribution. As s(FE) becomes larger, estimates become slowly Poisson distributed. The TOS being a preventive tool, it is Pitard's recommendation to avoid, as long as practically possible, the generation of samples whose estimates of the constituent of interest are Poisson distributed.

The third study aimed to guarantee that the primary sample was in accordance with TOS, improving reliability in the short-term model. The recommendation was to acquire a new and more suitable RC drill specific for sampling, instead of using blast hole drills for sampling purposes.

Figure 4 shows the simplified reconciliation system for the first quarter of 2011, after sampling improvements. Again, the indicators were calculated based on metal content (oz of Au).

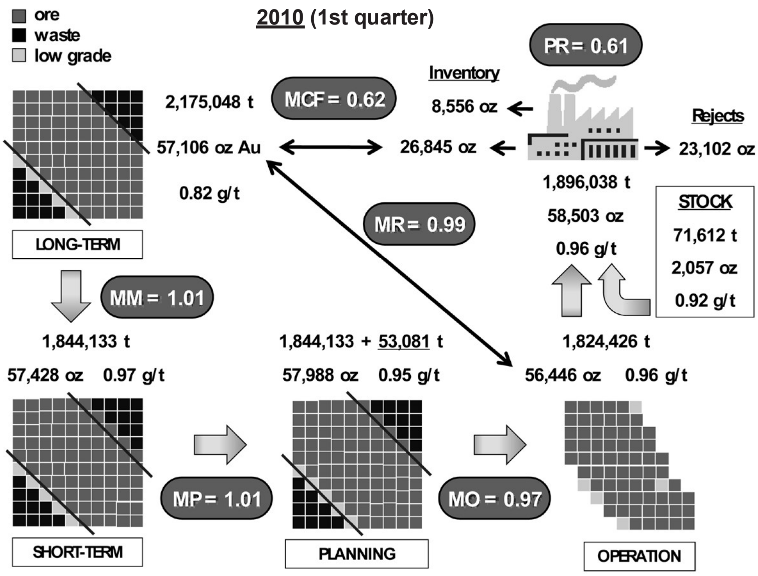

Figure 4 Application of the new reconciliation model (1st quarter of 2011)

Although the plant still presents poor recovery, Figure 4 shows a significant improvement in reconciliation as a whole, evidencing a more efficient control of the mining processes after sampling optimisation. The value of MCF is enormously influenced by the plant recovery, but the effective control of the operation is here represented by MR=0.99, which is excellent! Considering that all sampling and sample preparation procedures have been performed correctly, the results evidence the need to diagnose the causes of the poor recovery in the metallurgical plant, while the previous operations – from long-term estimation to mining operation – show no particular problem.

The analysis of Figures 3 and 4 shows the complexity of a reconciliation system. The calculation of the indicators based on metal content alone says nothing about the dilution or the mass processed at the plant. One can conclude that it would be better to calculate the factors based on gold grade and not on metal content. In fact, all these variables must be considered in an integrated reconciliation system, allowing the effective control of the operation. It is the authors' recommendation to make a complete analysis of all indicators, inventory, dilution, mining recovery and budget; this is the only way to fully understand the operation which is of utmost importance for the company's decision making process regarding the improvement of the production process.

Thus, when it comes to reconciliation, the following questions remain: (1) should we reconcile mass, grade or metal content? (2) Poor reconciliation indicates operation problems or sampling problems? (3) What's the reliability of each indicator? (4) Should we use the MCF or the MR as the main control indicator of the operation? (5) What about the accuracy and the uncertainty of weightometers? (6) Should we consider the mass as a critical factor to calculate metal content?

Answers to these questions vary from operation to operation and will be consistent only when proactive reconciliation practices are used throughout the life of the mine. The analysis of the reconciliation system allows, then, to make new changes in order to take the indicators as close to one as possible, which means that the estimates became prognosis and can be used with confidence in decision making processes and annual budgets of the company.

CONCLUSIONS

With the evolution of the price of gold in the last decade, from 280 US$/oz in 2000 to 1500 US$/oz in 2011, representing a gain of 15% a year, many deposits became economical with relatively low grades. The difficulties of obtaining representative samples increases as the gold content decreases and the geological complexity increases. Therefore, the gold industry requires, more than ever, the development of sampling methodologies that can generate unbiased samples and, in consequence, accurate and precise estimates of metal production.

This study showed that improvements in sampling equipments and procedures result in significant benefits for the operation, which has been evidenced by the improved values of reconciliation and performance indicators. This fact leads us to conclude that the company achieved a more efficient control of its operations as well as a higher reliability in the short-term model's estimates.

The new reconciliation model proposed can be customised for each project or particular type of deposit, contributing significantly to the mining industry. Large, small and specially gold-producing companies can benefit from the proposed model, since techniques that increase control and predictability of an operation also decrease their exposure to unexpected cash flows, contributing to the stability and sustainability in an environment characterised by uncertainties (nugget effect, density, low grades, etc.).

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