Model to Metal Reconciliation: Delivering on Promises

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Purposes

- Improve reliability of business plans
- Comply with Reserve reporting requirements
- Explain of business plan variances
- Continuous improvement
- Identify issues at critical points
- Build a more profitable business
The need for reconciliation

Reconciliations should be consistently monitored over time. Even a successful predictive approach can deteriorate due to changes in geology, ore type, sampling procedures, grade control methods, mining methods, milling controls, personnel, etc.

Lack of systematic reconciliation means that there are no controls to monitor the predictions, and to moderate expectations. This may result in non-optimal use of the resource, pressure on the mining team, profit objectives not being met and unhappy shareholders.
Outcomes of a robust reconciliation system

Recognition of trends can provide insight into how the current predictions may become realized during future production.

It is useful to know that the mill is receiving the predicted ore at a lower than expected grade, even while there is still uncertainty as to whether this is due to problems with:

- ore reserve (due to data, interpretation or estimation)
- grade control (due to similar errors plus ore loss and dilution)
- mining (due to deviations from the plan), and / or
- milling (due to sampling errors or losses)

Similarly it is useful to know that production is exceeding predictions since this may mean the grade control process, the mine plan and the revenues are all suboptimal.
Basic reconciliation procedures

A simple scientific approach should enable a robust reconciliation method to be quickly developed. The essential steps are:

1. Establish an audit trail for all data
2. Agree to report results routinely in a consistent format and ensure that there are cross-functional reconciliation meetings in place to discuss results and develop action plans
3. Collect and tabulate the data
4. Report variations based on consistent volumes (bench by bench, stope by stope) or periods (monthly, quarterly, annually)
5. Graph the variations (or factors) for each parameter to determine trends
6. Analyse and explain the differences
7. Alter the input parameters systematically to reduce future reconciliation differences
F1, F2 and F3

Mine call factors and mill call factors have been used in many mines without any clear systematic definition.

Harry Parker (2012) has provided a solution to many of the reconciliation problems, since by his definitions…
Relationship between factors

\[
F_1 = \frac{\text{GRADE CONTROL (PRODUCTION)}}{\text{ORE RESERVE (PREDICTION)}}
\]

and

\[
F_2 = \frac{\text{MILL (PRODUCTION)}}{\text{GRADE CONTROL (PREDICTION)}}
\]

and

\[
F_3 = \frac{\text{MILL (PRODUCTION)}}{\text{ORE RESERVE (PREDICTION)}}
\]

Therefore \( F_3 = F_1 \times F_2 \).
Inputs to the Reconciliation Factors

**Inputs:**
- Resource model
- Exploration data
- Original topography
- Mining surface (start)
- Mining surface (end)

**Resource / Reserve Model**

**Inputs:**
- GC model
- GC data

**Grade Control model**

**Oreblock / Stope design**

**Inputs:**
- Ore block polygons
- Stope design
- Assigned grades

**Inputs:**
- Haulage records (source, destination, tonnes, material type)
- Opening stocks
- Closing stocks

**Inputs:**
- Shift by shift crushing records (Source, material type, tonnes, moisture)
- Opening and closing stocks

**Inputs:**
- Shift by shift processing records (tonnes, moisture, head grade, recovery)
- Opening and closing circuit stocks
- Bullion measurements

Example of an F1 reconciliation

F1 Reconciliation - Grade Control to Ore Reserves

More ore tonnes at the expected grade

More ore tonnes at lower grade
Mine plan compliance

Figure 8-1 - Schematic As-mined vs. As-planned Mined Areas
A = Area in 2013 Business Plan but NOT in ACTUAL MINING (Behind Plan)
B = Area in 2013 Business Plan AND in ACTUAL MINING (In-Plan)
C = Area in ACTUAL MINING but NOT in 2013 Business Plan (Outside Plan)
Polygon Compliance

Mining Polygon Performance - % Relative to OC Tons
678 Polygons

- Polygon Tons
- Mining Performance

- Polygons
- 90% CI
- 90% CI
- Avg. Error
- Abs. Error
Advantages of a good reconciliation process

Once problems have been highlighted solutions can be considered. Typical examples are:

**Problems**
- Cannot achieve reserves
- Tonnage is too high
- Tonnage is too low
- Mill has less ore than mining
- Mill has lower head grades

**Solutions**
- Compare mapping x geological model
- Examine moisture content
- Examine bulk density
- Check stockpiles and weightometers
- Check circuit sampling and tailings.
Possible contributors to F1 variances

Sampling errors

Estimation errors

Boundary definition

Mining selectivity

Blast movement

These are collectively termed Ore Control Effect
Traditional ore control process

Grade control data

Grade Estimation

Digline generation assuming error free estimates

Error free data is assumed
A methodology to assess and minimize reconciliation variances

Using high resolution conditional simulations of an orebody the mining operation can be modeled. Simulated orebodies can be sampled using various grade control strategies and these notional grade control samples used to predict outcomes.

In particular, the Chain of Mining (CoM) method (Shaw and Khosrowshahi, 2002) can be used to assess how sampling, grade control, mining selectivity and blasting practices impact reconciliation variances. This should be a significant consideration in converting Resources to Reserves.
The Chain of Mining method

CoM produces recoverable resource models of tonnes and grade which can be used to assess risk.
Dig-line optimization
Dig-line optimization

Collection of boundaries produce probability of boundary of mining
Modelling the impact of blasting
Case Study: Escondida

Khosrowshahi, S., Shaw, W.J. and Yeates, G., 2005, Quantification of risk using simulation of the Chain of Mining - a case study on Escondida Copper.
Simulated models
Sampling error

**Low sampling and assaying precision error**

![Escondida: Blast hole field repeats](image1)

Precision of 9.2% demonstrated by 289 field repeats

**High sampling and assaying precision error**

![CuT: BH vs RC &D (4 4 2m search)](image2)

Precision of 40.9% demonstrated by 633 paired Blast Hole and Resource Hole samples
Mining Selectivity

Impact of different selectivity on digline optimization

- Waste
- HG oxide
- MG oxide
- HG sulphide
- MG sulphide
- LG sulphide
Blast movement modeling
Results

Analysis of risk for Tonnes by Quarters for 5 year plan

CoM case:
8 x 8 m

High Sampling error
Conclusions

A robust reconciliation system enables:

- The total mining operation to be seen in context
- Major problems and sources of error to be identified
- Both underestimation and overestimation to be critically monitored improvements to be tested and evaluated
- Reporting to management and communication to shareholders to be clear and consistent
Conclusions

The Chain of Mining method...

- Is a uncertainty based method to evaluate recoverable reserves and production expectations
- Allows for reliable predictions of mining outcomes
- Provides estimates that include the impact of ore control and mining practices
- Implicitly uses local orebody morphology to define ore loss and dilution