PINCOCK Perspectives

ISSUE NO. 107 — March 2011

Quantative Risk Analysis of Estimated Resources: An Overview

The dictionary meaning of estimate is "an approximate calculation or judgment of the value, number, quantity, or extent of something." Resource estimates are the grades and tonnages calculated from a resource model at a cutoff grade. A resource model is the best approximation of the geology and mineralization in a deposit based on the knowledge about the deposit at a particular time.

As we gather more and better information about a mineral deposit, the resource estimation can be improved. In other words, the estimated resources can be a close approximation of the grade and quantity of the material in the deposit. It is important to know how much variation one may expect from the estimated resources, considering parameters different from the ones originally used for the existing resource model. Such differences can be loss or gain in quantity (tonnage) and quality (grade). Such variations are another form of stating uncertainty in grade-tonnage estimates. The risk-analysis of resource estimates include quantification of the above-mentioned uncertainties. The dictionary meaning of "risk" is "a situation involving exposure to danger." The result of risk analysis of resource estimates provide an advance warning to the mining operations, helping them avoid downside situations.

Resource modeling includes three sources of information: 1) input data, 2) interpretation of data, such as geological domains, and 3) mathematical parameters used in constructing a resource model. In this article, the term "block model" is used synonymously with "resource model." Assuming the input data are from reliable sources and error-free, the uncertainty in resource models may stem from subjective geological interpretation of the mineralized domains and/ or from the subjective mathematical parameters used in the grade estimation in a block model. This article addresses the importance of assessment of risks due to those mentioned above.

The quantification of risk in mineral resource estimation is the quantification of uncertainty in achieving the predicted quantity and quality of material above a cutoff grade. This translates into quantification of risk in the quantity and quality (i.e., grade, such as Cu %) of the commodity in the computerized resource models (block models). Various mathematical parameters can be used in the resource modelling exercise. Each of these parameters can contribute to various degrees of uncertainty of the grade estimate. Assuming the best-known parameters were used in resource estimation, the risk assessment objective is to quantify uncertainty in the estimated values of the blocks in the resource model. One may question here: What is meant by best parameters? In the author's opinion, it

C A L E N D A R

Runge North American Software Training Courses

- ***Talpac Basic***
  Toronto: April 21
  Vancouver: June 23
  Calgary: July 7
  Gillette: September 8

- ***Xeras Financial Modeling***

  1-Day Introductory Course
  Toronto: April 20
  Vancouver: June 22
  Calgary: July 6
  Gillette: September 13
  Denver: November 30

  2-Day Intermediate Course
  Toronto: April 18–19
  Vancouver: June 20–21
  Calgary: July 4–5
  Gillette: September 14–15
  Denver: December 1–2

Runge North American Professional Development Courses

- ***Mining for Non Miners***
  Calgary: August 9–10
  Denver: November 8–9

- ***Truck and Shovel Mining Systems***
  Calgary: August 25–26
  Denver: November 15–16

- ***Dragline Mining Systems***
  USA City TBA: November 2–3

- ***Mining Economics***
  Calgary: August 11–12
  Denver: November 17–18

For additional information or to register, please contact Diane Kincaid at 403-217-4981 or dkincaid@runge.com.au generally depends on the geologist who is doing the resource model. Some of the parameters can be justified by mathematical analyses, others may be justified based on geological continuity. Overall, the parameters used in the construction of the resource model are optimized based on the knowledge available at the time of construction of the model, as well as experience of the modeler.

Why Analyze Risk?

The goal of quantitative risk analyses of a resource model is to assess the uncertainty in the resource estimation. In other words, the risk-analyses studies should be able to answer the following questions:

1. Based on the data-set used, is there any chance of reduction of quantity or degradation of quality in the foreseeable future?
2. If there is any, what is the probability of loss and quantity of the potential loss.

Sources of Risk

The risk in the resource model is generated from the uncertainty introduced at various steps in the resource model construction. The major sources of uncertainty are: 1) geological modeling decisions; 2) quantity and grade estimation parameters; 3) economic parameters, such as economic cutoff grades, etc. The cumulative effect of all uncertainties on the quantity and grade is a part of the risk.

Risk due to geological modeling: The geological interpretation of drill-hole data and construction of three-dimensional (3D) geological models is based on certain rules applied at the time of the geological interpretation. Such rules include minimum thickness, nominal minimum grade of the material, and range of influence of the drill-hole data. The length of drill-hole intercepts for geological interpretation should reflect the geology of the deposit. For example, the thickness of a 2-meter wide dyke should (in a disseminated gold deposit) be represented by an intercept of a drillhole (across the strike of the dyke) of 2 meter long intercepts. If a decision to use a minimum 3-meter geological intercept is adopted, a geologist may choose not to classify the dyke as a waste material hence miss the probability that the dyke will dilute the grade of the mineralized material. This may result in inflated grade and tonnage estimation of the mineralized material. Similarly, a nominal minimum grade used in interpreting the geological boundary of the mineralized material may result in underestimation of low grade material, hence ignoring the potential of stockpiling and blending for efficient production planning. Figures 1a and 1b illustrate this point.

Risk due to grade estimation parameters: The parameters used in the estimation of grades in a block model are often optimized based on the geologist's experience and knowledge of the geology and statistical-

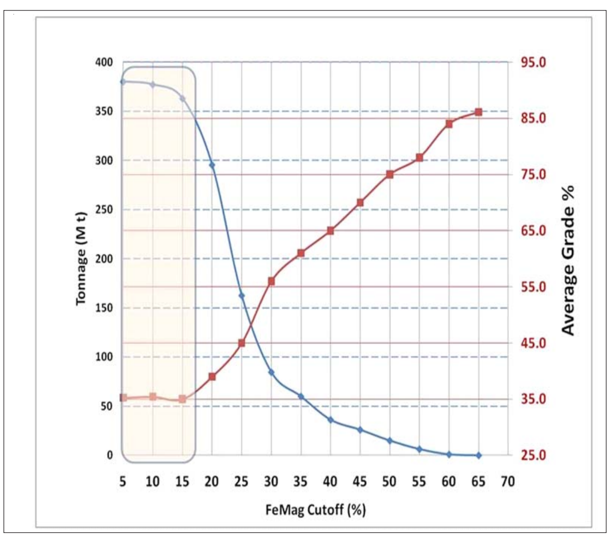

__Figure 1a:__ The grade tonnage curve of a magnetite deposit where geology model was used.

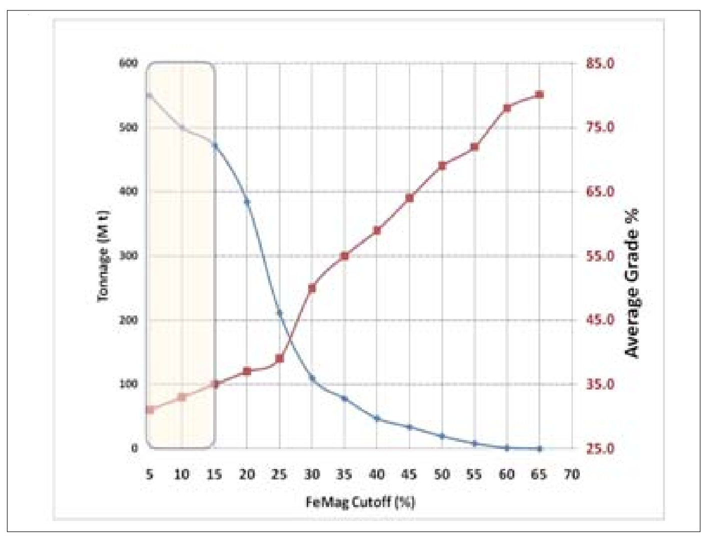

__Figure 1b__: The grade tonnage curve of a magnetite deposit where a grade-shell was used. It should be pointed out that in 1b-there is no substantial tonnage reported below a cutoff grade. This cutoff grade is the nominal grade used for constructing a grade-shell. The risk of using the a grade-shell is the loss of tonnage of low grade material below 15% FeMag.

geostatistical characteristics of the data. The grade-tonnage estimates may vary widely depending on various parameters such as orientations and dimensions of the search ellipsoids, capping of the high-grade assay/ composite data, block size, etc. As shown in Figure 2, the change in search ellipsoid may result in entirely different grade-tonnage values. Figure 3 demonstrates the use of capping of assay grades which may result in a different tonnage estimates. The risk of not using capping (of very high grade values) may lead to unrealistic tonnage estimates and loss of tonnage/ grade during production. The optimization of the block dimension in a block model can also result in drastic changes in grade estimations. This is typically true for narrow-vein type deposits. The Figure 4 demonstrates that use of large blocks for a narrow vein type deposit may result in unrealistic tonnage and grade estimation.

Risk due to the choice of economic cutoff grades: The cutoff grade helps define the economic potential of a deposit. Generally, a lower cutoff grade results in higher tonnage and lower head-grade. Use of an un-sustainable price in the economic model may result in the estimation of an unrealistically low-economic cutoff grade. The risk of such a decision is that it can result in a lower project NPV and make the project less attractive or uneconomic.

The risk in a resource model should be quantified in terms of probability of loss, if any, in the foreseeable future of the deposit. The goal should be to obtain a probabilistic answer to a question "what is the probability of obtaining the grade and tonnage as estimated from a block model." The same question can also be stated as "how likely is it to obtain the estimated quality (grade) and quantity (tonnage) at a given cutoff grade," particularly during the initial production period. To answer such questions, various techniques are applied. Many of these techniques are advanced geostatistical techniques. Only three major techniques are discussed which are as follows

1. **Hermite Corrections**: Using discrete Gaussian variogram models and hermite polynomials, a grade-tonnage curve for a resource model can be obtained. This grade-tonnage curve is treated as the ideal grade tonnage curve that is attainable, also known as a HERCO diagram. So, the risk of having a grade-tonnage curve other than the HERCO is the difference in grade-tonnage between HERCO and the estimated grade-tonnage.

   In Figure 4, it appears that, at the Ag cutoff grade as shown by the an arrow on the X-axis, there may not be any substantial difference in the grade estimates; however, the resource model may be overestimating the tonnage by an amount shown by the difference between the tonnage lines at the cutoff grade.

   The HERCO tonnage diagram can be on the other side of the tonnage

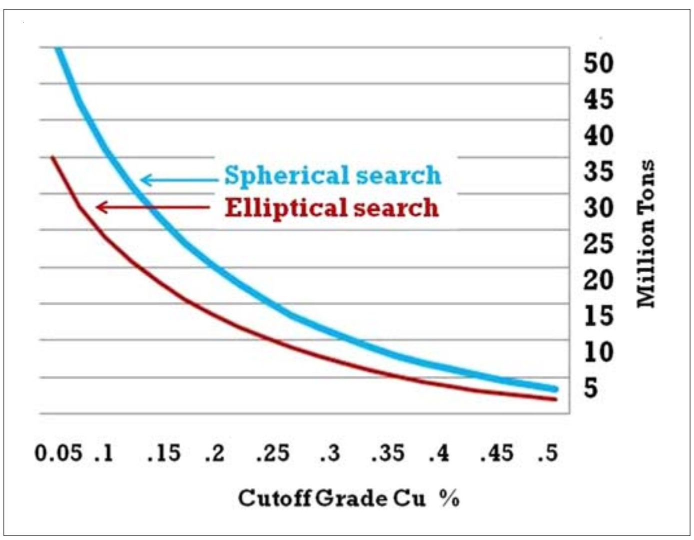

Figure 2: *The blue line represents the tonnage line of a block model where a spherical search was used. The red-line represents the tonnage line of a block-model where an elliptical search ellipse is used. The elliptical search ellipse represents the spatial-data-structure; hence the red line is a better representation of the deposit. A cutoff grade of 5x Cu is risky. The risk of using the blue line is potential loss in tonnage.*

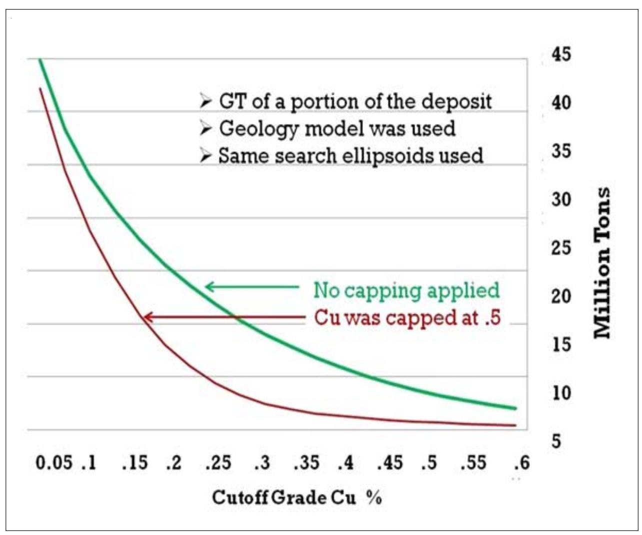

Figure 3: *The change in tonnage estimates because of use of a capping to high-grade assay values. The risk of not-using a capping may be loss in tonnage during production curve.*

diagram of the current resource model. In the later case, the risk of using the current grade tonnage curve is potential loss in tonnage due to miss-classification of ore blocks as waste blocks.

2. **The Confidence Intervals:** Using non-linear geostatistical techniques such as a geostatistical simulation (for example, turning-band type simulation) or, using Gaussian transformation and volume-variance relationships, confidence limits can be calculated for each block grade estimate. The probability of achieving the estimated grade can also be estimated. These techniques provide unique though realistic answers in probability space. In other words, it can be said that “at 95% confidence level, there is 80 % probability that the estimated block grade can be achieved during mining.” In this example there is a low risk (20%) of achieving the estimated grade of the block.

3. **Uniform Conditioning**: The size of block can potentially change the estimated grade and tonnage. Small block sizes may result in a high variance. Large block size may cause oversmoothing and an over-estimation of tonnage. It is, therefore, advisable to match the block size such that it is no smaller than the smallest mining unit (SMU), based on mining equipment sizes, drill-pattern, and economics. It is worth testing the grade-tonnage estimates for various block sizes. Figure 5 demonstrates the risk of using blocks that are too large. It should be noted that the grade-tonnage estimates may not change as a result of reducing the size of block smaller than the SMU size.

Concluding Remarks

There are many other probabilistic techniques to assess risk in a resource model. But the risk assessment of a mineral deposit also goes beyond mathematical risk-assessment of a resource model. Other such factors are: social, political, economic, and so on. For example, it is difficult to asses the risk of having a community which may oppose mining activities, or the risk of a new management taking an entirely different approach towards developing the mineral resources. However, it is very important to know the risk associated with the computerized resource model – because the resource model is the foundation of mine planning and production scheduling. Knowing the risk factor in advance, will help the production team decide about further drilling. Analysis of blast-hole data can be used to improve certainty in short-term planning. The medium-term and long-term production teams will also benefit from the above mentioned analyses.

This month’s article was provided by Abani Samal, Ph.D., C.P.G., Senior Geologist/Geostatistician
abani.samal@pincock.com

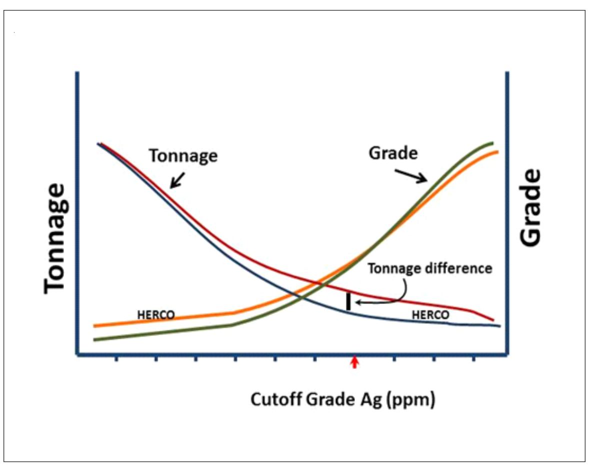

Figure 4: *A cartoon demonstrating use of a HERCO diagram*

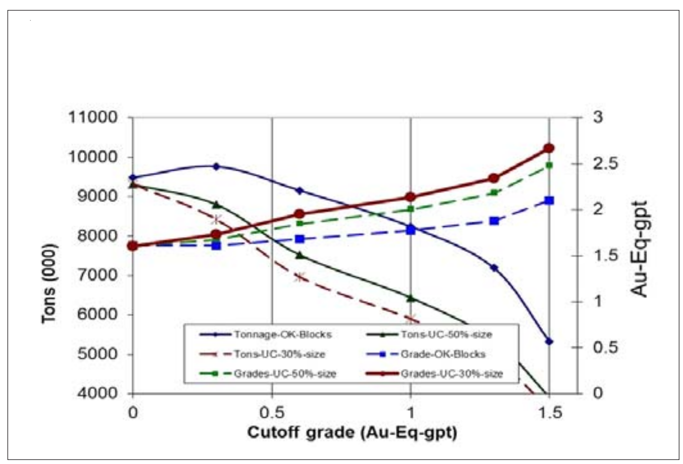

Figure 5: *The change in grade tonnage curves as a result of block dimension changes of a block model.*