PINCOCK Perspectives

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CALENDAR

- ***SEG 2010 Conference - The Challenge of Finding New Mineral Resources***
  October 2 – 5, 2010
  Keystone Resort
  Keystone, Colorado
  Email: christinehorrigan@segweb.org

- ***Mines and Money London 2010***
  November 30 – December 1, 2010
  Business Design Centre, Islington
  London, England
  Email: melina.day@aspermontuk.com

- ***Northwest Mining Association Convention***
  December 5 – 10, 2010
  Spokane Convention Center
  Spokane, Washington
  Email: pheywood@nwma.org

- ***Runge North American Professional Development Courses***

  Mining for Non Miners
  Denver: November. 16–17

  Truck and Shovel Mining Systems
  Denver: November 9–11

  Dragline Mining Systems
  Gillette: November 2–3

  Mining Economics
  Denver: November 18–19

  For additional information or to register, please contact Diane Kincaid at 403-217-4981 or dkincaid@runge.com.au

Congratulations to Doe Run

The Doe Run Company's Missouri-based mine rescue teams recently captured the highest mine rescue honors in the nation – as well as the company's best finish in its 35-year mine rescue contest history.

Open Pit Planning Guidelines

Introduction

The following discussion outlines the sequential steps that are needed to determine the optimum pit limits, production schedule, and cutoff grade strategy to maximize a project's ROI.

Private industry demands that the primary goal of any mine plan is to maximize the return on investment. This is the "Investors Law of Conservation," and the resource being conserved in this case, is the funds used to maintain or expand production, or the investment required for the development of a mineral deposit. Common sense says that the highest rate of return will be achieved by mining and processing the ore with the highest value first, leaving the ore with the lowest return to the last. However, this is not as straightforward as it sounds. Initial cash flows can be increased for a milling operation, by raising cutoff grades in the early years and wasting low-grade ores (or if economical, stockpiling these for future processing). A mine for leach operation must mine sufficient copper to fill the tankhouse. Hence, if the tankhouse is already operating at capacity, there is no advantage to raising the cutoff grade. In some cases, it may be better to lower the average grade and conserve the higher grades for the future to ensure that the tankhouse operates at full capacity for a longer period.

If there were no time value of money, then the mining operation would always use the lowest cutoff grade that would generate the largest total non-discounted profit over the life of the mining operation. However, this is not the case in the mining industry; investors demand a high rate of return on their risky investment. Hence the need to incorporate the time value of money concept in all facets of the evaluation including mine design, production scheduling, cutoff grade strategy development, capital expenditure and operating cost analyses, and in the evaluation of competing operating plans. Proposed development and operating plans in different areas of the world are competing for the same investment dollars, and therefore standard evaluation techniques of the investment and "risk" must be used if these plans are to be ranked on a relative basis. The same future metal price profiles and the same off-site processing costs must be utilized if the projects are to be compared on the same basis. This also means that cost statements for all of these projects must include the same categories and these must be treated on a like after-tax basis. One project may have a higher level of engineering completed than another, or be more optimized than another, or use more cutting edge technology than another, and therefore the level of the study and the degree of optimization used in the competing plans must also be taken into consideration. These guidelines address only the economic and technology portion of the investment. Not addressed in this paper are the other risks faced by a project such as social unrest, changing politics, environmental regulation/permitting, the stability of the current tax levels, and risks relative to climatic conditions, earthquakes, and by far the greatest variable, future metal prices.

If the prime objective of the company is to increase cash flows and the return on investments, then more emphasis must be placed on the time value of money concept and its effects on basic mine design procedures, strategic cutoff grade planning and the resultant production schedules.

Mine design and production scheduling to reach these goals is an iterative and never-ending process. New computer programs are now available that can accelerate this process and provide a range of alternatives to management so that the best Corporate decisions can be made in a timely manner. Mining is one of the most volatile industries due to the cyclic price patterns. As the higher-value global resources are depleted in the future, the price swings in the cycle will likely become even greater. Price profile projections will play an important role in selecting the most appropriate plan that provides flexibility to these ever-changing economic conditions. Hence, the mine planner's goal is to rapidly provide management with a quantitative economic analysis of the short and long-term effects of a variety of production and design alternatives. The metal prices used in these analyses, is the realized metal price, hence, the cost of transporting the salable metal to market is included and the price received or used for design purposes, includes premiums.

The three basic steps in mine design and production scheduling to optimize a mining project are:

1. Create a series of discounted (Whittle®) shells.
2. Design a series of practical pushbacks with access roads, and rank these pushbacks on a net present value per ton ore (including any specific project capital if needed for that particular pushback prior to mining).
3. Develop a series of production schedules that will maximize the net present value of the project using a variable cutoff grade strategy and a series of metal price profiles.

In order to complete these tasks, a good reliable computerized block model representing the ore resource types, tonnages and grades must be available.

Open Pit Mine Design on a Time Value of Money Basis

The typical economic analysis of an open pit mining project in the past, used a mine production schedule and mine design completed on a non-discounted basis. Mine phase designs and final pit limits are usually determined from a series of incremental shells that are based on the use of lower metal prices for the inner cone shapes, with the final pit limits set using the highest acceptable metal price. In the past, the effect of the time value of money on the shape or location of the phase limits has been ignored. E.g., phase shapes and size were determined solely based on metal price and non-discounted economic factors and then NPV's were determined to select the best shell (Whittle® approach).

The cost and recovery parameters coupled with the stated metal price are used in calculating the net value of each block in the model (block money value), regardless of the block's location, or how much stripping would be required to expose the block, or when it would be mined. These block values are in turn used to drive a variety of algorithms (floating cone type programs) that are used to find the breakeven three-dimensional pit surface for a specific metal price. Floating cone runs are trial and error by nature, whereas three dimensional Lerchs-Grossmann type cone runs are based on an algorithm that reflects a precise calculation of the volume that will maximize (non-discounted) profits for a given set of cost, recovery and price parameters. The commonly used trial and error floating cone algorithms, may not determine the reserves that will have the maximum non- discounted profits if the pit has multiple pit bottoms; however, this method typically has sufficient accuracy to proceed with the mine design. For both types of programs, the net present value of the project phase designs, are improved since the most economic material is outlined initially at low metal prices, and the ore with the least margin is outlined last. However, the block money values, whether negative or positive, have been calculated on a non-discounted basis (not recognizing in what order they will be mined). Therefore, the phase designs will not optimize the discounted cash flows for the project because the phases will have mined past the discounted (NPV based) economic limits.

Time Value Concept

All investment decisions incorporate a number of cost/benefit-measurement methods, and these are primarily based on the principle of the time value of money; "a dollar earned or spent today is worth more than a dollar spent or earned tomorrow." Hence, in the design and scheduling of a mining phase, waste stripping is usually required prior to ore production, and therefore waste stripping in essence is an investment and revenues are generated later from the processing of ores and the production of salable metal to pay for that investment. The floating cone method tests each ore block to see if the cumulative values of the blocks are sufficient to pay for the mining of the material in the increment above the block. Therefore, the next appropriate step is to apply a method that discounts the values of the blocks relative to the order that they will be mined prior to the floating cone application. This can be accomplished by flagging each individual block's scheduled mining date, as derived from a pre-existing production schedule (PES approach) or, the block value can be discounted relative to the block's elevation in the block model. This in essence, is based on the fact that open pit mining always proceeds from the top down (Top-Down Method, TDM), and the floating cone algorithm works in the same fashion.

Discounting Techniques

1. The PES procedure incorporates the time value of money in the design of mining phases by applying a time value discount factor relative to when the block is mined. This factor is dependent on a pre-existing production schedule and pre-existing phase designs. This can lead to inaccuracies since the existing phase limits will provide an artificial three-dimensional value barrier or step function in the discounting method. Secondly, if the resource is outside of the current pit design, the applied discount rate is either a rough guess, or the block values are not factored.
2. The Top-Down Method (TDM) uses a procedure based on multiplying the block value by a discount factor that is a function of:

- An estimate of the average annual vertical mining advance rate, and
- The relative depth of the block.

As an example, using an annual 12% discount rate and an average vertical advance rate of six benches per year in each phase, the block values on each bench will need to be discounted by 2%, (12%/6). The formula that can be used to determine the factor to be applied to a particular bench "N" in the model (as numbered downward from the highest selected datum elevation), with a bench discount rate of "r", can be stated on a discrete interest basis as follows:

$$\textbf{Bench Discount Factor} = 1 / (1+ r)^{N}$$

And therefore, with a 12% annual discount rate and an average advance rate of 6 benches per year, the factor to be applied against all blocks on bench 30 will be 0.552. All the block money values for that bench are multiplied by this factor, **whether the block has a negative or positive value.** The starting datum elevation should be above the highest topographic point, and for simplicity can be the top bench in the block model since the calculation is independent of the datum level selected. This method is dependent on an average advance rate for all phases; hence this advance rate is typically estimated from a pre-existing production schedule. This method also has inaccuracies in the sense that the advance rate within a phase will vary, and secondly, we are guessing the advance rate of the various future phases, which will also vary by year and by sector. Hence, it is wise to test the sensitivity of the pit phase shapes and size to changes in metal prices, recoveries, operating costs, by-product credits, and most importantly, the **advance rate.**

If the discount rate per bench (r) is to be determined using a **continuous discounting** approach which is more precise, then the formula for determining the bench discount rate to be applied can be determined using the following:

$$r = e^{[\ln (1 + R)] / A}$$

Where "A" is the advance rate or average number of benches mined per year in each active phase and "R" is the 12% discount rate or cost of money. Hence, for a six bench per year advance rate, (which equates to a 2% simple interest rate per bench) the **continuous discount rate** (r) per bench is 1.91% per bench.

E.g. for six benches / year;

$$(0.0191 + 1.00)^{6} = 1.12 - 1 = 12\% \text{ per year}$$

Therefore, the discount factor (r) for the "Nth" per bench becomes:

$$r_n = 1 / (1 + 0.0191)^{N}$$

For comparison, the discount factor applied to bench 30 with continuous discounting would be 0.5669 versus 0.5521 with **discrete discounting** (a difference of 2.7%).

The technique of applying a discount factor to the money block values (whether they are positive or negative) is independent of the floating cone method that will be applied. Hence, this method is appropriate for both the three-dimensional Lerchs-Grossmann programs as well as the typical trial and error type floating cone algorithms. However, the method needs to be checked with the 4-D Whittle program to ensure that the discounted results from the cone runs are not discounted again in the optimization routines used in the NPVS® and Whittle® scheduling programs.

The importance of applying an appropriate level of discounting to the block values can be easily recognized in those operations that have extensive amounts of waste rock to move (or years of stripping) prior to ore production. In those cases, discounting will severely impact the economic reserves and in some cases, significantly change the shape and ranking of the pit phases. Conversely, the decrease in the reserves will be offset with a significant increase in the net present value and return on investment for the project.

It may also be possible to change the advance rate as a function of depth or by pit sector to more closely reflect the most likely production schedule and timing of material movements during stripping and during ore production. This in turn would improve the accuracy of the discount factors applied to the blocks, by elevation and by pit sector. Another use of the bench discounting technique is to measure the economic impact of wider or narrower mine phases. Assuming that narrower phase's means that the vertical advance rate can be accelerated, the reserves (and discounted cash flows) may be increased with narrower phase widths, even though higher costs per ton mined may be incurred with these pushbacks.

Other Time Value Considerations in Mine Design and Production Scheduling

If cash flows are to be optimized for the production schedules, a variable cutoff grade strategy will need to be employed and this optimized cutoff is determined based on an iterative procedure that includes, as one of the cost terms, the net present value of future cash flows. One of the dangers in this procedure is the use of a cutoff grade in the production schedule that is higher than the design cutoff grade used in the particular phase that is being mined in the schedule. In essence, the higher cutoff will mean that ore used to drive the pit limit shape (defined using an internal cutoff grade), will now be wasted or stockpiled for future processing at some higher cost. This will invalidate the pit design limits, meaning the phase limits are too optimistic, and additional costs will be incurred, possibly beyond the breakeven point for that phase.

It should also be noted that in order to create the most economic mining phases and final incremental pit limits, sustaining mine equipment capital should be included as an average cost per ton mined (mining equipment is consumed on a per ton mined basis). Consider the average replacement life of all the mine equipment on a weighted capital cost basis is in the range of 8 years. This means that the capital investment must occur prior to mining and the desired minimum return on the cost of this capital is 12%. Hence, the multiplier on the invested capital dollars (amortized on a per ton mined basis) will need to be sufficiently to guarantee the specified minimum annual return.

And the **Capital Recovery Factor** =

$$\frac{i \times n}{(1 - (1+ i)^{-n})}$$

Where n = average life of equipment, and i = the desired return.

In this case, the Capital Recovery Factor needed to achieve the specified 12% rate of return on a discrete basis with an 8-year payback period is 1.61. Therefore, if the average depreciation for mine equipment capital is $0.25 per ton mined, the real number that should be used in the floating cones to obtain the 12% rate of return should be $0.40 per ton mined**.** This same concept applies to sustaining capital for tailings ponds, leach pads and smelter brick relining, where those investments are consumed relative to the tons processed, and an additional investment is required in order for the operation to continue or the reserve base to be enlarged. The multiplier in these cases will be less than that for mine equipment if the tailings and leach sustaining investments are for periods shorter that an 8-year life. Capital recovery factors at a 10%, 12% and 15%, rate of return versus life of the investment are shown in Table 1 below.

From this analysis, one can conclude that a more accurate procedure to calculate the appropriate capital recovery factor for the mining fleet would be to determine the factor for each individual equipment fleet. Added together, this would be the total capital cost per ton mined (including the capital recovery factor) to be used in defining the ultimate pit shell.

In heap leaching operations, the time delay between the revenue stream and the operating costs of mining and placement/ treatment of the ore may be significant, and therefore a delay interval may need to be incorporated in the recovery/cost relationships.

The determination of the variable optimum cutoff grade also follows this strategy by raising the cutoff grade in the early years of a milling operation to maximize metal production and minimize the cost per unit sold. As time progresses, the mine expands into areas containing ores of lesser net value due to increasing stripping requirements or lower grade, and in order to minimize costs, the cutoff grade will trend to successive lower grades and reach the internal cutoff grade by the end of the mine life. The best cutoff grade strategy can be determined on a trial and error method by varying the cutoff grade per year until the highest net present value is obtained.

A second more rigorous method to determine the best mine-mill-refinery production rate and cutoff grade strategy can be defined by using the approach presented by K. F. Lane. This approach adds an opportunity cost into the cutoff calculation based on increasing the NPV of future cash flows by discarding marginal ores. This is an iterative process in the sense that multiple runs with increasing discount rates are needed to define the optimized cutoff strategy that will maximize the ROI.

Lane's algorithm develops a cutoff grade policy that maximizes the present value of pre-tax profits based solely on commodity revenues and operating costs for a specific set of production parameters. Plant and other initial capital costs must be included later to determine the net present value and DCF-ROI for each set of production parameters.

Designing the best and most practical production schedule for each unique ore deposit is a complex task. However, by using a consistent and logical study sequence, a satisfactory overall strategy can be defined and management can select the best strategy that is acceptable for that project's unique risk profile, and achieve the "Investors Law of Conservation."

This month's article was provided by Ernest L. Bohnet, P.E., P.Eng., Principal Mine Engineer and Vice President of Mining and Geology

TABLE 1

Life of Investment	Capital Recovery Factor versus Rate of Return 10%	 12%	 15%
1 Year	1.10	1.12	1.15
2 Years	1.15	1.18	1.23
3 Years	1.21	1.25	1.31
4 Years	1.26	1.32	1.40
5 Years	1.32	1.39	1.49
6 Years	1.38	1.46	1.59
7 Years	1.44	1.53	1.68
8 Years	1.50	1.61	1.78
10 Years	1.63	1.77	1.99
15 Years	1.97	2.20	2.57
20 Years	2.35	2.68	3.20

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