Whittle Consulting Pty Ltd

Strategic Mine Planning Specialists

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Cut-off Grade Optimisation

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Intro

Whilst processing all material above the marginal cut-off grade will maximise cash flow over the life of the operation, if the time value of money is taken into account then a different strategy is warranted. The following discussion seeks to explain the mechanisms that are used in pit and schedule optimisation to improve the value of a project.

Time Value of Money

The concept of Discounted Cash Flow (DCF) accounts for the time value of money, by discounting future cash flows by a progressively increasing rate. “I would rather have a dollar today than a dollar several years in the future, because a) I can invest it in other income producing activities in the meantime and b) the further away in time my dollar is the more things can go wrong resulting in me not getting it.”

The discount rate used in the NPV calculation represents the risk-adjusted average cost of capital for the organisation – a subject of great discussion in its own right. Discount rates selected usually range between 8% and 13% per annum.

Net Present Values (NPV) is the sum of DCFs, and is the measure by which we compare the relative values of different life-of-mine plans which generate different future cash flow patterns.

NPV can be improved by bringing forward revenues and/or deferring costs, even if that means that total net cash flow generated over the life of the project is less.

Pit and Phase Optimisation
When generating pit phases using Whittle Four-X (Lersch – Grossman), inner high value pit shells which are mined early, will have:

- Low stripping ratio, and/or
- Higher grades
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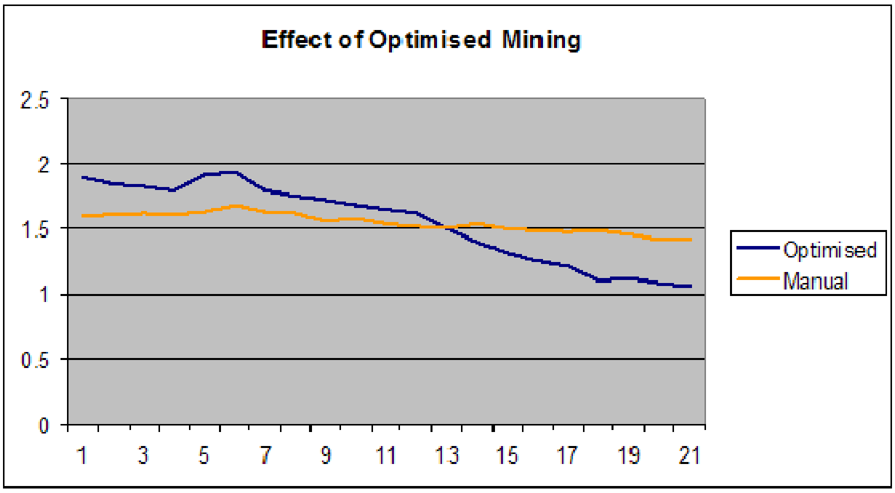
…than the average of the ultimate economic pit.

When scheduling a pit with phases generated through pit optimisation, (if higher grade is a component driving the optimisation) then average grade of ore mined will be higher in the early years than later. In this statement we are defining "ore" as material which has a positive net value after mining i.e. is above the "marginal cut-off grade" (which is the point where the net revenue value of the metal recovered is equal to the cost of processing it).

The illustration used throughout involves an ore body with a marginal cut of grade of 1.0%, and an average grade of ore (material above 1%) of 1.5%.

By mining in multiple optimal phases, the early average grade is raised from 1.5% to 1.9%, with lower grades occurring in later years.



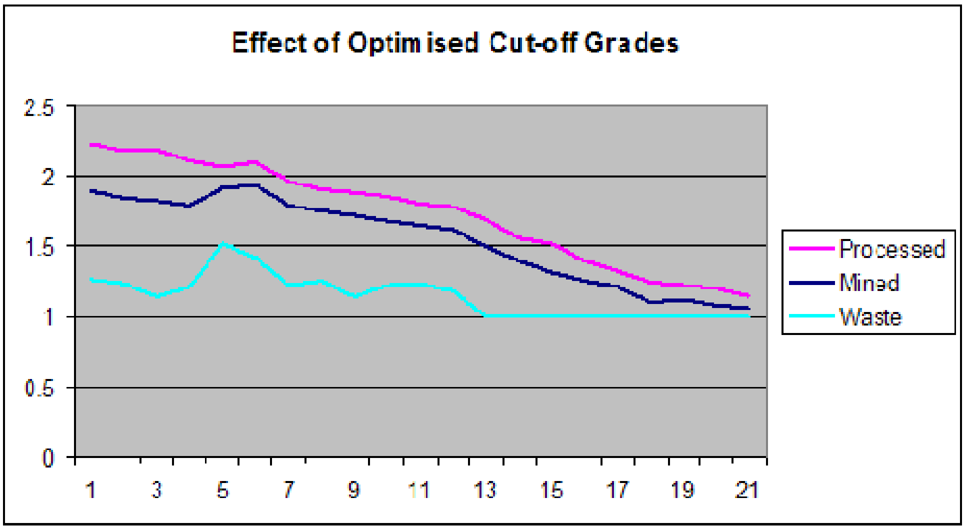
Using pit phases based on pit optimisation is therefore likely to raise the early average grade processed by focussing on high grade areas for early mining. (Even if pit optimisation focuses on low stripping ratio areas at the same grade, then the following discussion is still effective.)

Higher early grades means more early cash flow, at the expense of lower later cash flows, but with and increase in NPV.

Raising the cut-off grade in early years
Provided that the project is processor-limited, it can be demonstrated that if the cut-off grade in the early years is raised above the marginal cut-off grade, i.e. some low value material is discarded to waste, then although total LOM cash flow decreases due to losing some positive value material, the NPV can increase.

This can be understood by mentally dividing the material to be mined into two increments. Increment A is what we would have mined and processed in the first year if we used a marginal cut-off, and increment B is the material to be mined and processed in subsequent years. If we raise the cut-off slightly for increment A but not for increment B, two things will happen that affect the NPV. The cash-flow from A will be reduced, and A will be mined in less than a year. If A is mined in, say, 11 months, the mining and processing of the whole of B will be brought forward by a month. If the discount rate is 1% per month, the NPV of increment B will be increased by 1%. Thus we have a reduction in NPV due to the reduced cash-flow from A and an increase in NPV due to increment B being mined earlier. If increment B is large compared with A, then the latter effect will dominate, and the best cut-off for A will be significantly higher than the marginal cut-off. Of course, when we have found the best cut-off for A we can then look at the second year's production with similar results. Since the amount of material remaining gets less with each year of mining, the best cut-off for each successive year will be closer and closer to the marginal cut-off.

In the example we are using this approach has enabled the early average grades processed to be raised to 2.2%.

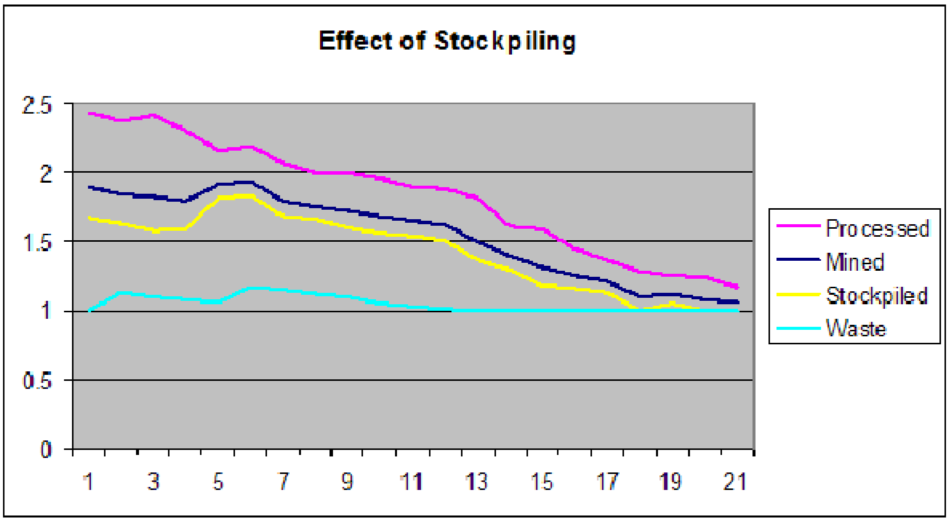


The graph illustrates that if some of the lower grade material is discarded to waste, then the average grade of what is processed can be increased. To take advantage of the capacity of the processing plant, the overall mining rate must be increased and the LOM will be shortened, but if calculated correctly the NPV can be increased.

To get a proper trade off, the effect of the cut-off grade in a period must determined taking into account the effect on that period and all subsequent periods. The result is a different cut-off grade in each period, and it is typical for this to be highest in the early years declining ultimately to the marginal cut-off in the final period.

Stockpiling
If it is feasible to stockpile rather than discard the lower grade material and process it later, then the negative factors of raising the cut-off grade are lessened. The balance point is shifted in favour of an even higher cut-off grade in the early years, combined with an ever higher mining rate, but not necessarily with any loss of overall life of the project as all the material over the marginal cut-off grade will be processed eventually.

In our example case, this has allowed the early grades to be raised to 2.4% from an ore body with an average grade of 1.5% of economic ore .



The cost of rehandling and any change in recovery due to further oxidisation of stockpiled material must be taken into account in the calculations.

Overall Impact

In our example, the combined effect of Pit Phase optimisation, accelerated mining rate and raised cut-off grade with stockpiling can transfer significant amounts of metal (i.e. Revenues) to the early part of the project life. This maximises NPV, Internal Rate of Return, reduces Payback Time and avoids exposure (which increases with time) to future variations.

Effect of High Metal Prices

Most commodities are currently experiencing historic high prices.

Although a higher metal price lowers the marginal cut-off grade (from say 1% down to 0.8%) it also increases the prize for increasing the mining rate and cut-off grade to achieve higher early average grades and higher production. In the case of a project with many years of resource left, high metal prices will raise the optimal early cut-off grade. This is counter intuitive to most people. (In contrast, projects with only a short remaining life will have optimal cut-off grades which fall with increased prices because there is little to gain by mining the remaining material earlier.)

Most mining companies are forecasting that commodity prices will ease over time. If metal prices are expected to weaken by (say) 20% per year for the next several years, then the time value of revenue (the benefit of having it now rather than later) is 10% for the normal time value of money, plus 20% for the decrease in metal price per year. In this scenario the effective discount rate is 30% which will warrant very high and aggressive cut-off grades, along with higher mining rates and more stockpiling, in the early periods. You should maximise metal throughput during periods of high metal prices.

Optimisation Mathematics

Ken Lane has prescribed the mathematics and programming for calculating the optimal cut-off grades in his book “The Economic Value of Ore” (1988). This approach is complicated even for a single element operation with constant costs, prices and capacities, but does it not work for more complex scenarios. In particular, optimal cut-off grades will not necessarily decline monotonically over time from a high value to the marginal value as they do for a simple case.

Whittle Consulting’s approach to Global Optimisation uses a proprietary search algorithm combined with powerful Linear Programming and this enables the optimum cut-off grade profile, the mining schedule and the processing schedule to be determined simultaneously for a mining operation involving some or all of the following complications:

- Multiple mines (Pit and/or underground)
- Multiple elements
- Stockpiling of mined material
- Alternative processing paths
- Stockpiling of processed material
- Alternative products
- Blending
- Changing prices, costs, recoveries, and capacities over time.

The results of developing properly optimised plans are invariably significantly better (5-15% higher NPV) than plans that attempt to apply the above principles by manual trial and error, or as is sadly often the case where the above principles are not applied at all.

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