ULTIMATE PIT SIZE SELECTION, WHERE IS THE OPTIMUM POINT?

Anoush Ebrahimi, *PhD, PEng*
Principal Consultant, SRK Consulting (Canada) Inc

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ABSTRACT

A major step in open pit mine planning and design is to define the ultimate expansion of the mine, often called the final or ultimate pit. When it comes to final pit selection there is usually more than one option to choose from. Most deposits support a range of sizes of pits that all are technically mineable and economically profitable. The size of final pit greatly affects other aspects of the project, such as life of mine, capital requirement, scale of operation, equipment size, profitability and resource utilization. Pit size selection is technically, financially and socially a complex, multivariable process, often with contradicting factors. Therefore, to reduce the risk and to make sure that all aspects are fulfilled, a holistic approach should be adopted in the analysis. An approach that not only considers the technical aspects of mining but also considers aspects of mining that are difficult to measure such as logistics of operation, social license, and financing. It is also important to understand and discuss, among all parties, the conditions and consequences of choosing a particular size of pit.

Companies often target the highest net present value (NPV) when planning for a mining project including final pit selection. When this is the case, long-term/low production rate projects cannot compete with short-term/high production rate projects. This is due to the time value of money, reflected by the discount rate of the project. However, NPV is not the only way to evaluate projects. There are some influential factors that are difficult to quantify, such as the outlook of commodity prices and interests of communities and other stakeholders. By using a few examples, the author demonstrates the challenges that many mining projects are facing to select the right final pit.

INTRODUCTION

For a mining project, the final pit defines the ultimate expansion of the mine. It contains the total ore for the life of mine that essentially determines the value of the project. The reserve in the final pit is the inventory that is subject to production scheduling.

Often the result of pit optimization is a series of technically mineable pit shells, the majority of which have positive NPV even after applying discount rates. Technically every one of those positive pits can be considered as a final pit. The art of mine design and pit size selection is to match the conditions of the company and shareholders (constraints) with the proper pit size. This paper discusses pit size selection and shows the complexity involved, including the constraints that must be taken in account when selecting the final pit.

CONFLICTING TARGET/GOALS

What are the criteria in final pit size selection? Total contained metal, life of mine, capital requirements or NPV?

In most projects, investors target a fast track production scenario with shortest payback and highest possible NPV. While this is the goal for mining companies, local communities and sometimes government agencies are looking for long-lasting projects that offer more sustainable benefits for the community. Long term projects provide a stable job market and steady income for communities. Environmental groups also are interested in slow pace projects where the environmental impact can be controlled and managed. These are conflicting goals.

Transparent communications and detailed technical studies can find a common ground for parties with different goals in mind. Before initiating a program for pit size evaluation, it is important to make sure that the interests of all stakeholders are taken care of by setting up proper and relevant scenarios. The combination of different goals and relevant constraints form a series of scenarios for analysis.

It is obvious that scenarios considered for this type of analysis must be first technically and economically viable (executable).

CONSTRAINING FACTORS

The constraining factors for extracting value from a deposit also contribute in final pit size selection. The more important factors that should be considered in pit size selection are listed below:

- Size of resource
- Initial capital requirement
- Cash flow and payback period
- Operational considerations, including but not limited to:
    - Feasibility of potential underground operation
    - Production scheduling and pushback selection
    - Maximum number of diggers in the pit
    - Maximum mining rate
    - Space available for waste dumps
- Supplies of water and power
- Human resources for both operations and maintenance
- Mining equipment: used versus new
- Work force: contractor versus owner operated mine
- Transportation bottlenecks for both supplies and products
- Prices and market conditions including off site costs
- Interests of stakeholders: community versus corporate
- Local conditions including political risks and securities
- Infrastructure

Discussing this long list of items that influence pit size selection is beyond the limit of this paper. However, a few of the most important factors are discussed.

MILLING RATE AND EXPANSION OPPORTUNITIES

When a deposit is large enough that it can support a long mine life (for example, beyond 20 years) using a reasonable milling rate, then the whole story about pit size selection will change. For these types of deposits, an interim pit size that can support a mine life of around 20 years can be considered as the final pit, with opportunity for expansion. The expansion project can be considered later, when the mine is in operation, by re-evaluating conditions at that time.

The best way to size a pit for large deposits is to match it with the initial capital available (manageable for company) while keeping options open for potential expansion.

The production rate plays a big role in pit size selection particularly for large deposits. Taylor (1991) has suggested that there is a relation between the production rate and total tonnage of mineral reserve. This relation can be used for initial trade-offs and scenario evaluations.

Compared to small or medium sized deposits, there are more milling rate options to choose from for larger deposits. If the initial capital is not the limiting factor usually the highest production rate tends to be selected. This is simply because, greater cash flow generated by higher production rates produces higher NPVs.

In addition to the limit of initial capital, the market saturation should also be a concern for high production rate projects. A detailed market analysis needs to be done to determine the position of the new mine in global markets.

General site layouts including waste dumps must be planned so that the cost of potential expansion is minimized. For example, any waste dump location should consider the geometry of potential expansions.

UNDERGROUND OPERATION AND CROSSOVER PIT

In some cases, switching to an underground mining method may become more profitable due to a high strip ratio of the original open pit mine. If this is the case, then an optimized crossover pit can be designed. As a standalone operation, a crossover pit is sub-optimal on its own; however, it considers a more profitable underground operation to achieve a higher overall profit for the project.

For deposits that continue to depth, it is recommended to conduct an underground mining study before finalizing the size of open pit. If an underground operation is viable then there is a good chance that the final expansion of the open pit will be limited by the underground mine.

MAJOR PUSHBACKS

Pushbacks are considered expansion milestones in open pit projects. Pushback (phase) designs are used to advance cash flow as well as delaying any unnecessary operating costs.

It is important to make sure that the remaining reserve beneath the final pit can be mined practically as a standalone pushback if the conditions change in favor of expansion. It means that the final pit should be adjusted so that the remaining resource stays mineable, should the mine go for a final expansion if the market conditions change.

MINING RATE

In theory and in the best case, a mine should develop pushbacks one at a time towards completion of the final pit. However, due to limitations in mining rate and equipment requirements we usually mine more than one pushback at any given time. This is to avoid any interruption in ore production. A mine needs to strip the successive pushbacks as preparation towards the next phase of ore production. Logically, the consecutive pushbacks are nested and thus they increase in size. Therefore, an increase in mining capacity is required to transition from one phase to another.

Given the increasing mining rates required, ore delivery targets, a limited number of digging units, and space available in the pit, there will be a deadline for deciding the execution of the final pit expansion. If this deadline is missed, it will make it hard to strip waste fast enough to avoid any interruption in feeding the mill.

Therefore, a decision regarding the final pit size (or next expansion) should be made well in advance to give enough time to complete the required stripping.

Another limiting factor about mining rate is safety. Even when equipment availability is not an issue, employing multiple diggers in different benches of a mine in the same area raises safety concerns that eventually reduces the production rate.

DISCOUNTED PIT VALUE ANALYSIS

From a financial perspective, and in theory, the best case is when a deposit can be mined (in other words, its value can be cashed) instantly at the same time as the investment is made. Obviously, this is not possible due to operational and technical limitations. Therefore, the way a deposit is mined plays a big role in project evaluations. The best production scenario is when the most profitable part of a deposit is advanced while delaying mining unnecessary waste.

After pit optimization, using a series of production scenarios, it is possible to calculate the discounted values of each optimum pit shell. Then analyzing and comparing the discounted values of different pit sizes can help to select the best size of a pit tailored to the criteria. This is a good analytical tool that not only helps in the selection of the final pit, but it also acts as a sensitivity analysis.

Figure 1 shows the discounted pit values for a series of pits of different sizes for a small copper project. It is assumed that there are four scenarios of copper prices: $1.86/lb, $2.09/lb, $2.32/lb and $2.90/lb. For each scenario, the discounted value increases as the pit size increases. However, this trend changes after reaching a certain pit size where the increase in pit value stops or even decreases. The pit that provides the maximum discounted value is usually a size that is generally accepted to be the best size for the final pit. In this example, the highest pit value is reached for different sizes based on metal prices used for the evaluation in each case. The ore mined changes from 10 Mt (for $1.86/lb Cu) to 150 Mt (for $2.90/lb Cu). Different corporations will choose a final pit that fits their long-term perspectives of metal prices. These are marked with red dots in Figure 1.

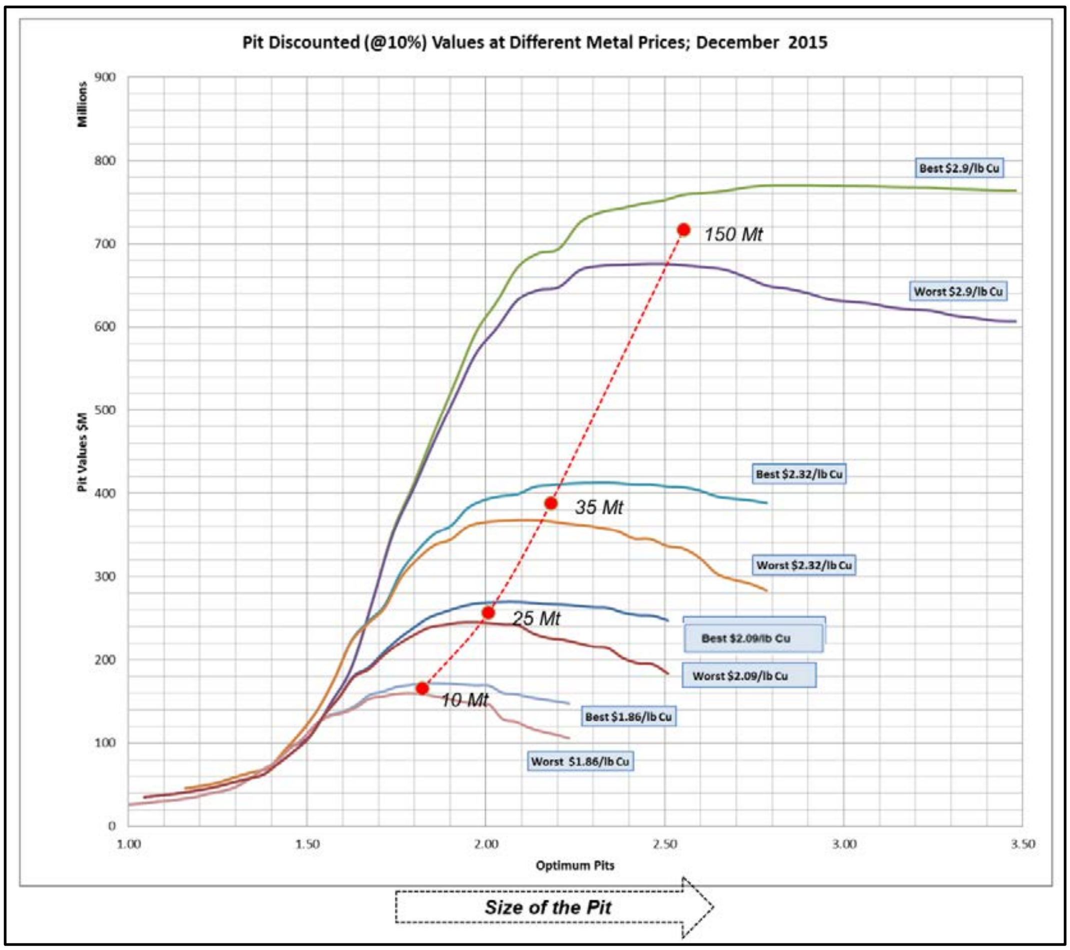

FIGURE 1: Discounted value for different sizes of pits

This type of analysis also clearly shows the effect of discount rate on long term projects. The longer the project (and/or lower the production rate), the higher the effect of discount rate. For example, the value of one million dollars that is earned in 10 years from now is only worth $0.38M today using a 10 percent discount rate. This is worth only $0.15M if the value is generated 20 years from now.

For large projects, it is important to understand that cash flows generated beyond year 20 have minimum effect on NPV. A more comprehensive and inclusive type of analysis must be done to understand the real values, costs and risks of project beyond year 20.

STRATEGIC MINE PLANNING AND SCENARIO ANALYSIS

Strategic mine planning (SMP) is a technique that can help in the process of final pit selection. Once enough information is collected, different production scenarios can be set and simulated so that possible outcomes can be explored. SMP highlights the strengths and weaknesses of the project and provides practical advice for improvement. To be effective, SMP needs a thorough analysis of not only the mineral resources, but also the core business values of the company. It requires expert input and comments from different fields and corporate perspectives. Figure 2 shows an example of the set up for the SMP of a gold mine. In this study, there are three variables that are evaluated: milling rate, gold price and resource model. Three different milling rates (4.0 Mt/year, 5.0 Mt/year and 5.5 Mt/year) and two different gold prices ($1,100/oz and $1,200/oz) are considered. Lastly, the effect of including inferred resources has been investigated. This last item of study can justify the potential investment for additional exploration.

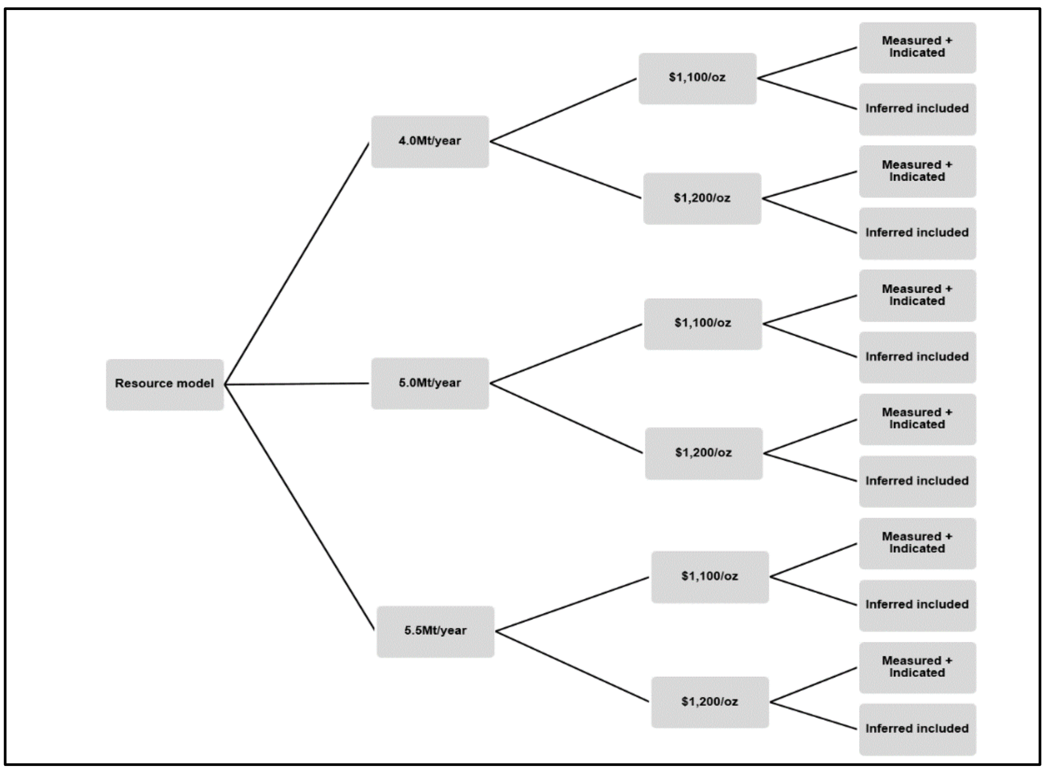

FIGURE 2: Strategic Mine Planning, Scenario Analysis

CASE STUDIES

Cases used in this paper are based on real life deposits and projects, however, to protect sensitive information, they have been modified.

Project A is based on a small precious metal deposit in South America. This is for a satellite pit that is planned to supplement the existing operation. The deposit is situated in a mountainous region where the orebody stretches from a steep hill side to the plains of a valley. Due to the topography and shape of the orebody, the strip ratio quickly increases for larger pits. Figure 3 shows the results of pit optimization. The results identified two different domains for pit sizes. The small pits range between 20 Mt to 40 Mt and the large pits range from 40 Mt to 70 Mt. The pits stay in the valley and resist climbing the steep slopes until a certain price, where the pits increase in size dramatically.

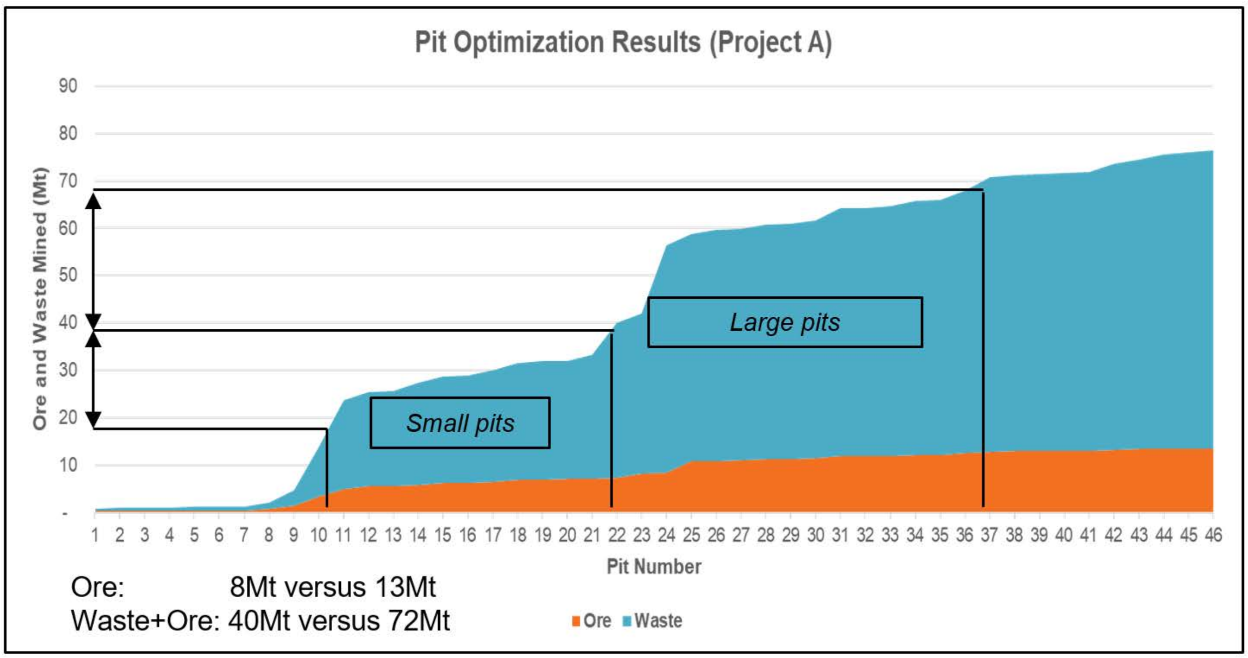

FIGURE 3: Ore and waste mined for Project A

Discounted pit values for each pit have been calculated and the results are shown in Figure 4. The NPV for the small pit is about $215M. This is calculated to be $225M for the large pit. The difference between the two sizes are within the margin of error of the calculation, therefore economically there is no meaningful difference between them. The company selected the larger pit to secure a supply of ore to its existing mill for a longer period of time (12 years versus 6 years).

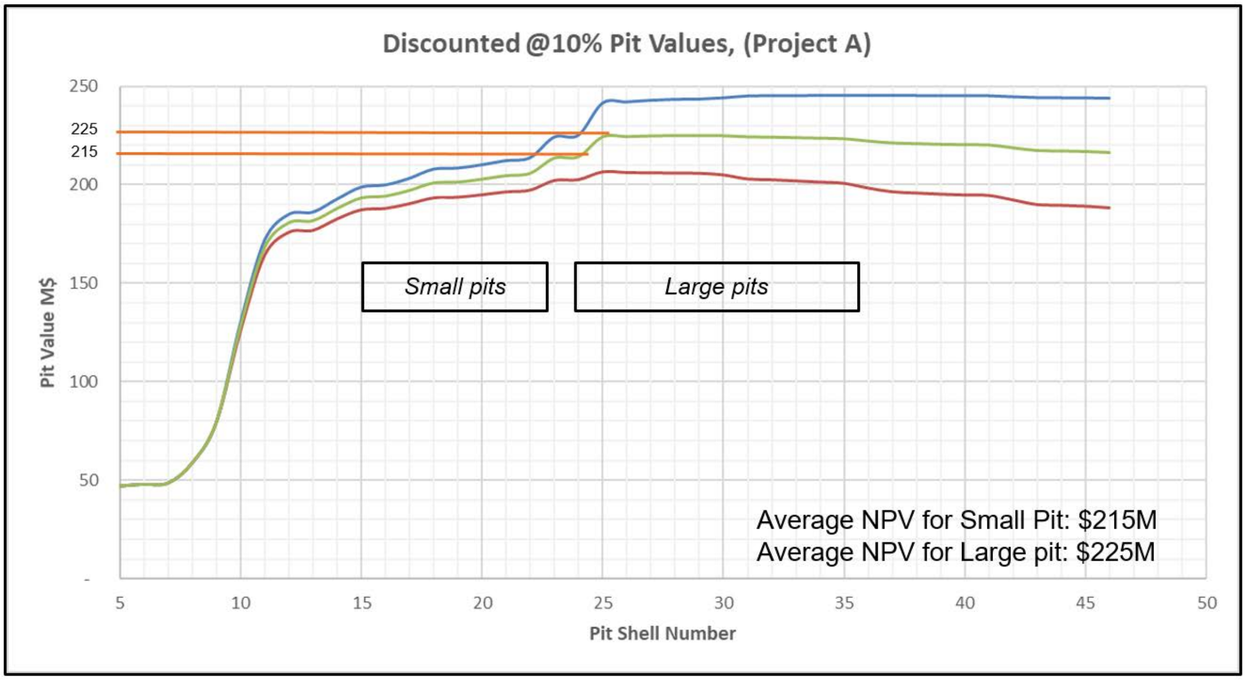

FIGURE 4: Discounted pit values for Project A

The risk of choosing a larger pit is that if the metal price drops, the cost of purchasing the larger mining fleet as well as the cost of pushbacks will become unnecessary and wasted (meaning a smaller pit would preferably be mined). However, to not preclude the larger pit option and due to the access road and pushback requirements of the larger pit, it is necessary to start the larger pit early. Otherwise, if not done and metal prices were to improve or even remain constant, there would be an interruption in ore supply after finishing the small pit phases to develop the larger pit.

Project B is a base metal deposit in Africa. The deposit is situated in relatively flat ground and the orebody is dipping downward at 80 degrees. The results of pit optimizations show no sudden change in size due to the price. There is a steady increase in strip ratio as the pit gets bigger, while the value of the deposit increases due to higher grades and a wider orebody at depth. That means there is a balance between increasing value of material mined and cost of higher strip ratio as the pit gets larger.

Figure 5 shows the tonnes of ore and waste for different revenue factors. The amount of waste mined per unit of ore increases dramatically for larger pits. However, due to the steady growth of strip ratio with no sudden jump, there is no clear limit to distinguish between small or large pits.

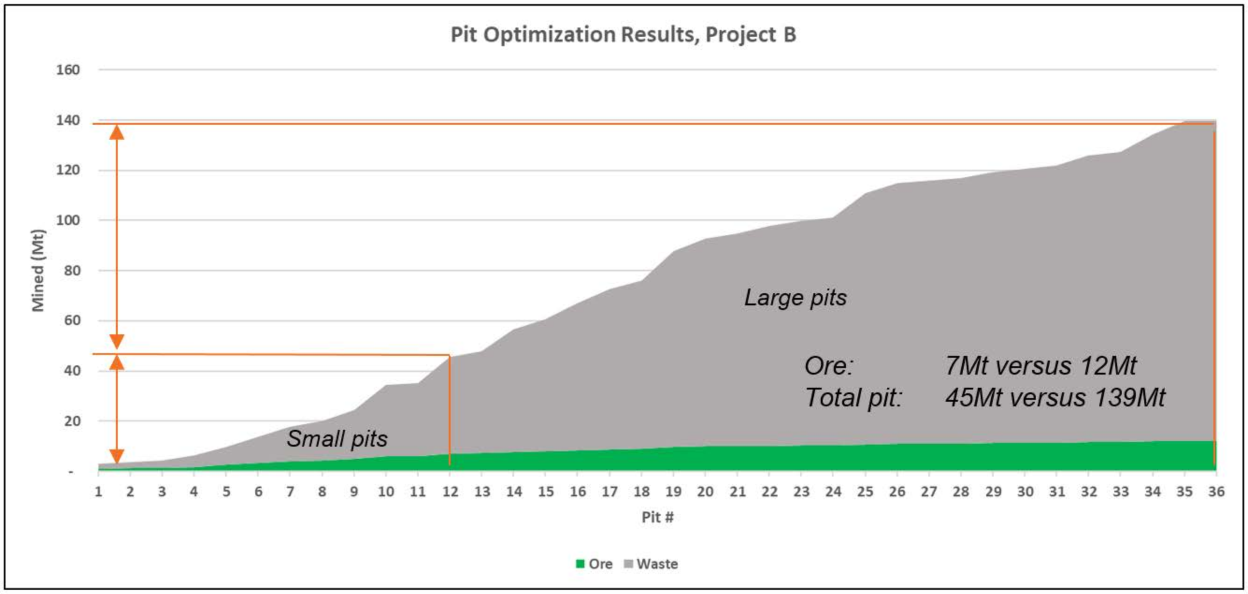

FIGURE 5: Ore and waste mined for Project B

Figure 6 shows the results of cash flow analysis for different sizes of optimum pits. The Y axis is discounted cash flow and X axis is the pit size. The three graphs show the minimum, maximum and average range of discounted pit values. The value increases up to pit 25 and after that the total value does not change with the increasing size of pit. This is mainly due to a) higher strip ratio and b) the effect of discount rate.

The mill and infrastructure are already built and in operation. The major sustaining capital is related to mining equipment and expansion of tailing facilities. However, sustaining capital has not been included in Figure 6; therefore, the capital requirement necessary for larger pits will reduce the pit value after pit 25.

Larger pits add a minimum of two years and possibly up to five years to the life of mine; however, they require purchasing new and larger mining equipment. The owners of this project decided to choose smaller pits to avoid spending any additional sustaining capital. They also believed that smaller pits pose lower operational risk, particularly in terms of operating cost control.

The risk of selecting a smaller pit as the final pit is that future expansion for a larger pit will become extremely difficult, and there will be a risk of an interruption in ore supply if the company changes its mind and chooses to go for a larger pit in the future.

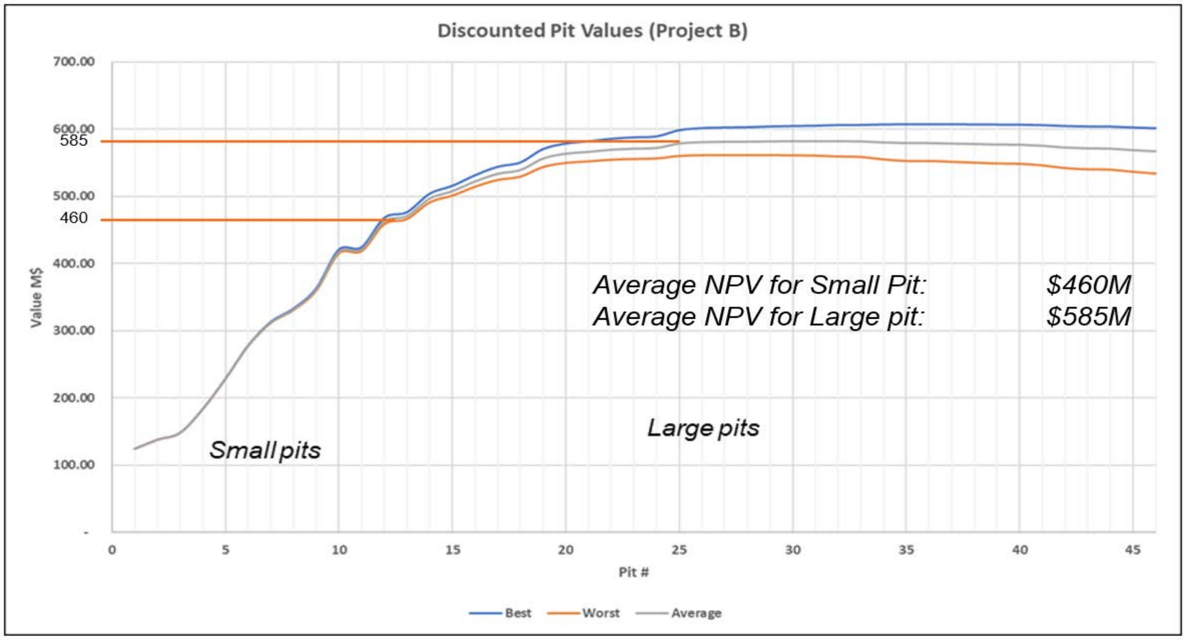

FIGURE 6: Discounted pit value for Project B

CONCLUSION

There is no common solution that can be adopted by the industry to address the pit size selection challenge. Every project must be looked at in its own context. Technical items should be studied first, and if okay, then other items such as economics, environmental and social parameters are investigated. This is to avoid any sensitive topics that may hurt a business by pursuing pit sizes that have no technical merit. Strategic mine planning is an analytical tool that is highly recommended for many aspects of mine design including pit size selection.

For pit size selection, the approach for greenfield projects may differ from that for an operating mine where an expansion is being evaluated.

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REFERENCES

- W.Hustrulid and M. Kuchta, 2006, Open pit Mine Planning & Design, pages 493-494

* For any questions or comments please contact Dr. Anoush Ebrahimi, P.Eng. at "aebrahimi@srk.com"