ULTIMATE PIT SIZE SELECTION, WHERE IS THE OPTIMUM POINT?

Anoush Ebrahimi, Ph.D, P.Eng,
Principal Consultant, SRK Consulting (Canada) Inc

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ABSTRACT

A major step in open pit mine planning and design is to define ultimate expansion of the mine, often called final or ultimate pit. When it comes to final pit selection there are 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 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 function. Due to contradicting factors, this process often becomes complex and turns into a decision-making paradox. 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 taking in account technical aspects of mining but also considers aspects of mining that are difficult to measure such as operation, social licensing, as well as financing. It is also important to understand and discuss, among all parties, the conditions and consequence 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 project's discount rate. 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 few examples, the author demonstrates the challenges that many mining projects are facing to select the right final pit.

1 INTRODUCTION

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

Often the result of pit optimization is a series of mineable pit shells that are all positive in value. Technically every one of those positive pits can be considered as the final pit. The art of mine design and pit size selection is to match the company's conditions (constraints) with the proper pit size. This paper discusses the subject of pit size selection and tries to show the complexity of the matter. It lists the constraints that must be taken in account when selecting the final pit.

2 CONFLICTING TARGETS/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 pay back and highest possible NPV. While this is the goal for mining companies the local communities and sometimes government agencies are looking for sustainable projects such as long-lasting projects. Long term projects provide stable job market and steady income for communities. Environmental groups also are interested on slow pace projects where the environmental impact can be controlled and managed. These are conflicting goals.

Transparent conversations, discussions 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 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).

3 CONSTRAINING FACTORS

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

1. Size of resource
2. Initial capital requirement
3. Cash flow and payback period
4. Operational considerations include but not limited to:

    a. Feasibility of potential underground operation
    b. Production scheduling and pushback selection
    c. Maximum number of diggers in the pit
    d. Maximum mining rate
    e. Space available for waste dump

5. Supplies: water and power
6. Human resources for both operators and maintenance
7. Mining equipment: used versus new,
8. Contractor versus owner operated mine
9. Transportation, bottle necks for both supplies and products
10. Prices and market conditions including off site costs
11. Community's interests versus corporate interests
12. Local conditions including political risks and securities
13. Infrastructure

Discussing the long list of items influencing the pit size selection is beyond the limit of this paper. A few of the most important operational items are discussed in this paper.

4 EXPANSION OPPORTUNITIES

When a deposit is big 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 20 years or so can be considered as the final pit with an opportunity for expansion. The expansion project can be considered later when the mine is in operation by reevaluating the 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 enterprise) while keeping the doors open for potential expansion.

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 tonnages 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 limits for 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.

5 UNDERGROUND OPERATION AND CROSSOVER PIT

In some cases, switching to an underground mining method may become more profitable due to 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; 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 open pit will be limited by underground mine.

6 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.

7 MINING RATE

In theory and in the best case, a mine should develop pushbacks one at a time toward completion of 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 obviously to avoid any interruption in ore production. A mine needs to strip the successive pushbacks as preparation toward 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 transit from one phase to another.

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

Therefore, a decision about 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 section raises safety concerns that eventually reduces the production rate.

8 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 we advance mining the most profitable part of a deposit while delaying mining unnecessary waste.

After pit optimization, using a series of production scenarios, it is possible to calculate discounted values of each optimum pit shell. Then analyzing and comparing 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 to select the final pit, it also helps to conduct sensitivity analysis.

Figure 1 shows discounted pit values for a series of pits with different sizes of 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 discounted value increases as the pit size increases. However, this trend changes after reaching to 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 generally accepted to be the best size for final pit. In this example the highest pit value is reached in different sizes based on metal prices used for evaluation in each case. The ore mined changes from 10Mt (for \$1.86/lb Cu) to 150Mt (for \$2.90/lb Cu). Different corporations choose a final pit that fits its long-term perspective of metal prices. These are marked with red dots in Figure 1.

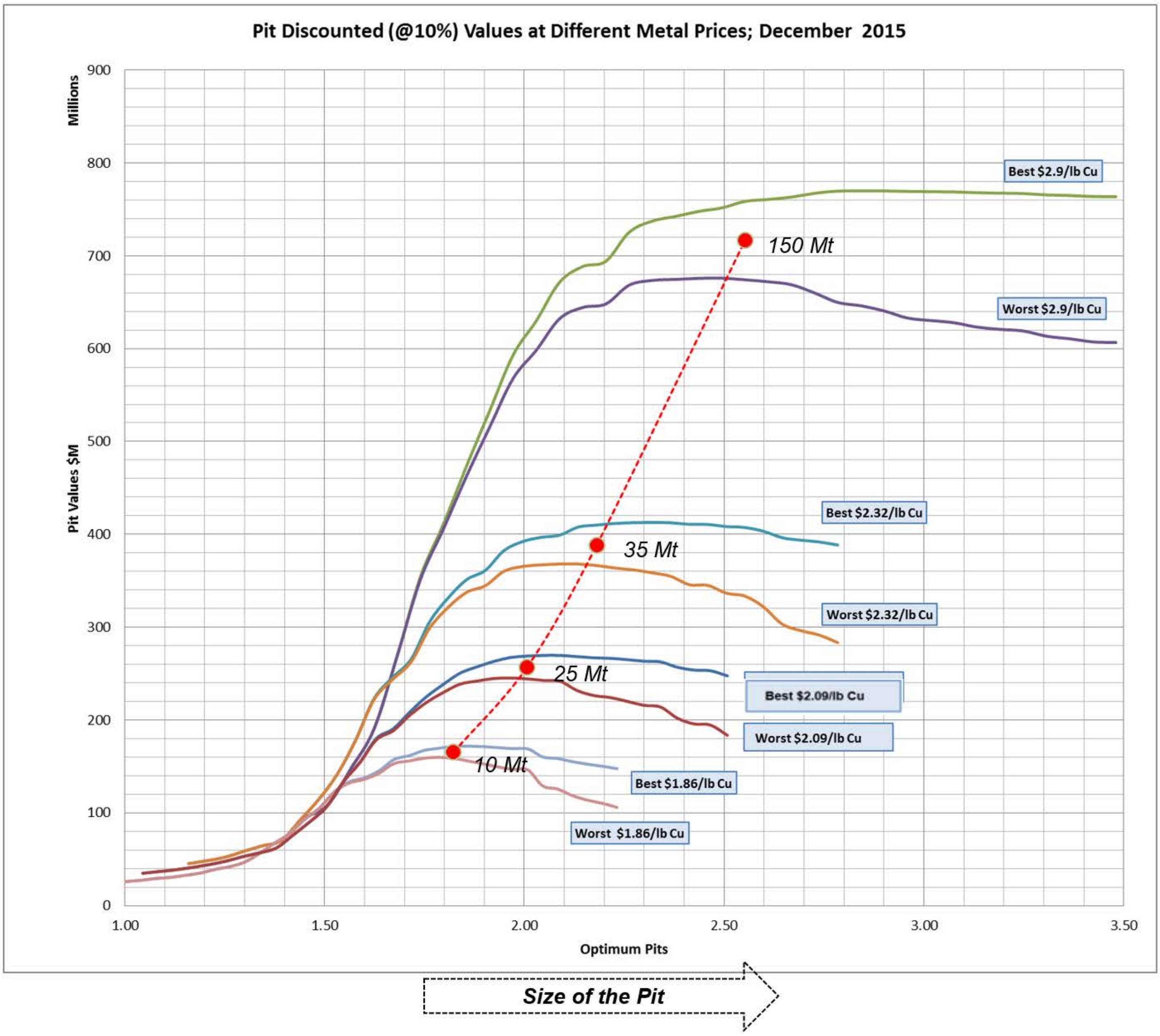

Figure 1 discounted value for different sizes of pits

This type of analysis also clearly shows the effect of discount rate on long term projects. The longer the projects (and/or lower the production rates), 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 or so has 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.

9 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 of the company's core business and values, therefore, it requires input and comments with expertise from

directors.

Figure 2 shows an example of the set up for an SMP for a gold mine. In this study, there are three variables: milling rate, gold price and resource model are evaluated. Three different milling rates (4.0Mt/year, 5.0Mt/year and 5.5Mt/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.

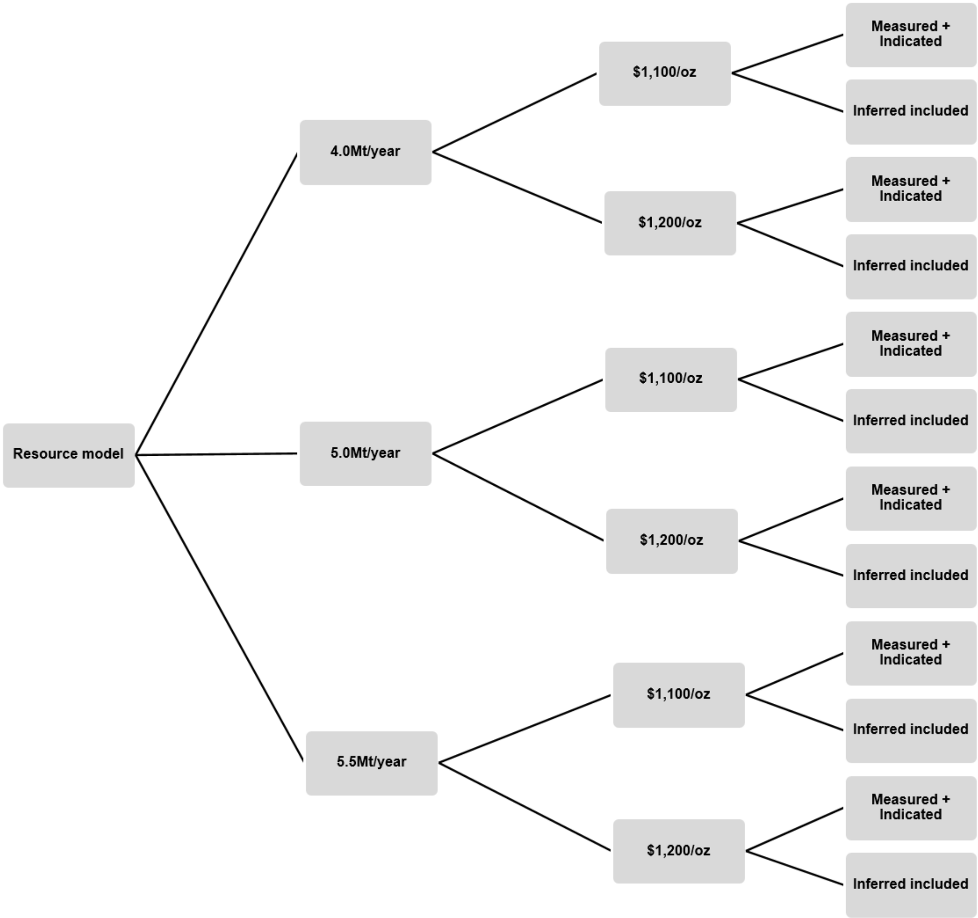

Figure 2 Strategic Mine Planning, Scenario Analysis

10 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 the case 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 20Mt to 40Mt and the large pits range from 40Mt to 70Mt. The pits stay in the valley and resist climbing the cliff until a certain price when the pits increase in size dramatically.

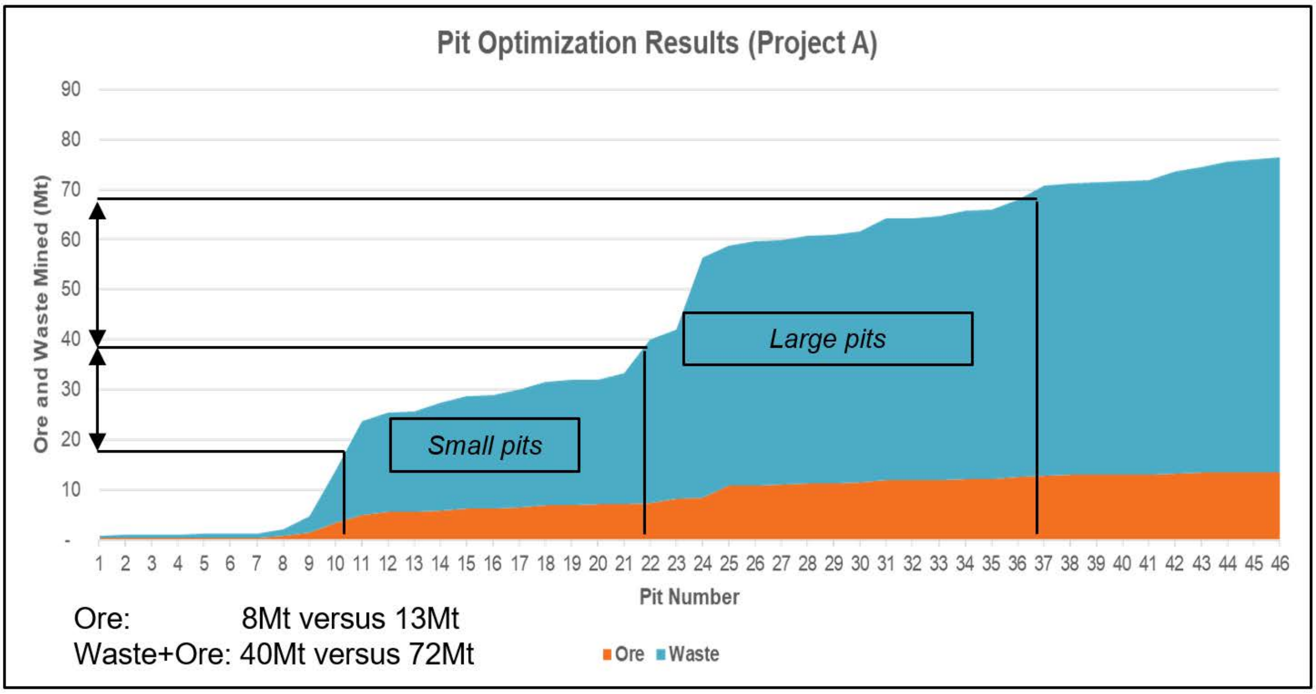

Figure 3 ore and waste mined for Project A

own in Figure 4. The NPV for small pit is about $215M. This is calculated to be $225M for large pit. The difference between 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 longer period of time (12 years versus 6 years).

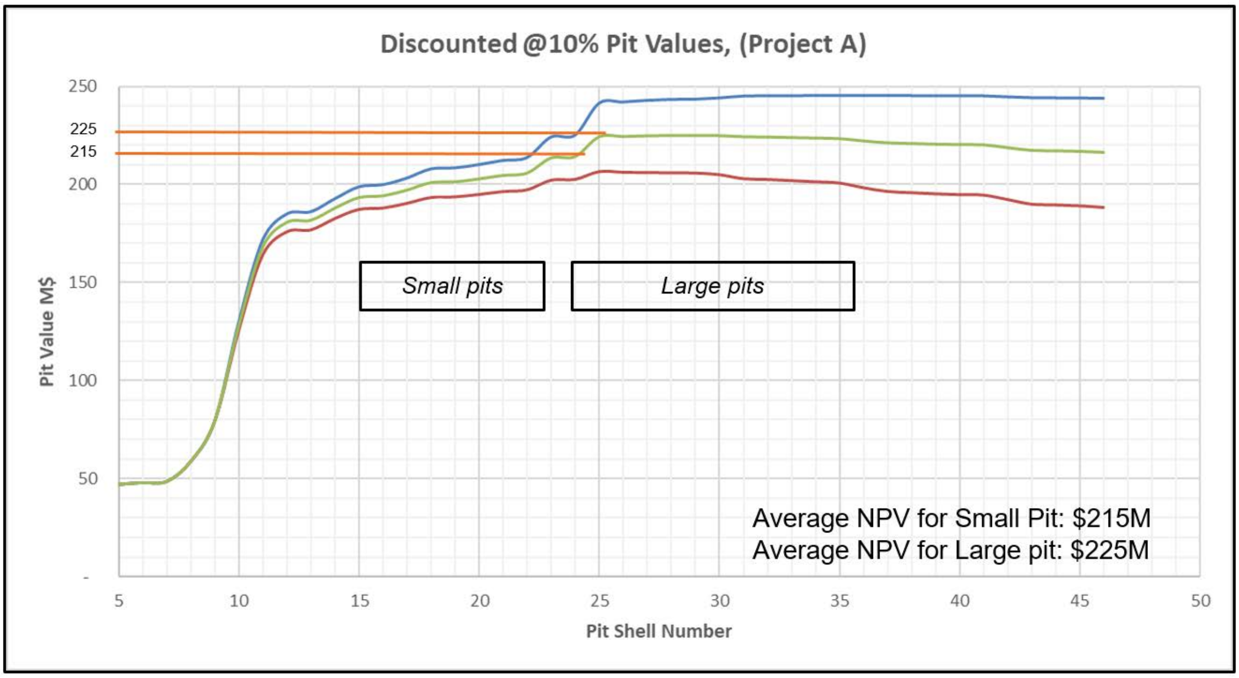

Figure 4 Discounted pit values for Project A

The risk of choosing 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. However, due to the access road for the larger pit and the pushback requirements if the larger pit is not started early enough there will be an interruption in ore supply after finishing the small pit phases. This is particularly important if the price stays at the same level as today or improves.

Project B is a base metal deposit in Africa. The deposit is situated in relatively flat ground and orebody is dipping 80 degrees to depth. Pit optimization shows a steady increase in strip ratio as the pit gets bigger while the value of deposit increases due to higher grades and a wider orebody at depth.

The results of pit optimizations show no sudden change in size due to the price. That means there is a balance between increasing value of material mined and the cost of higher strip ratio as 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.

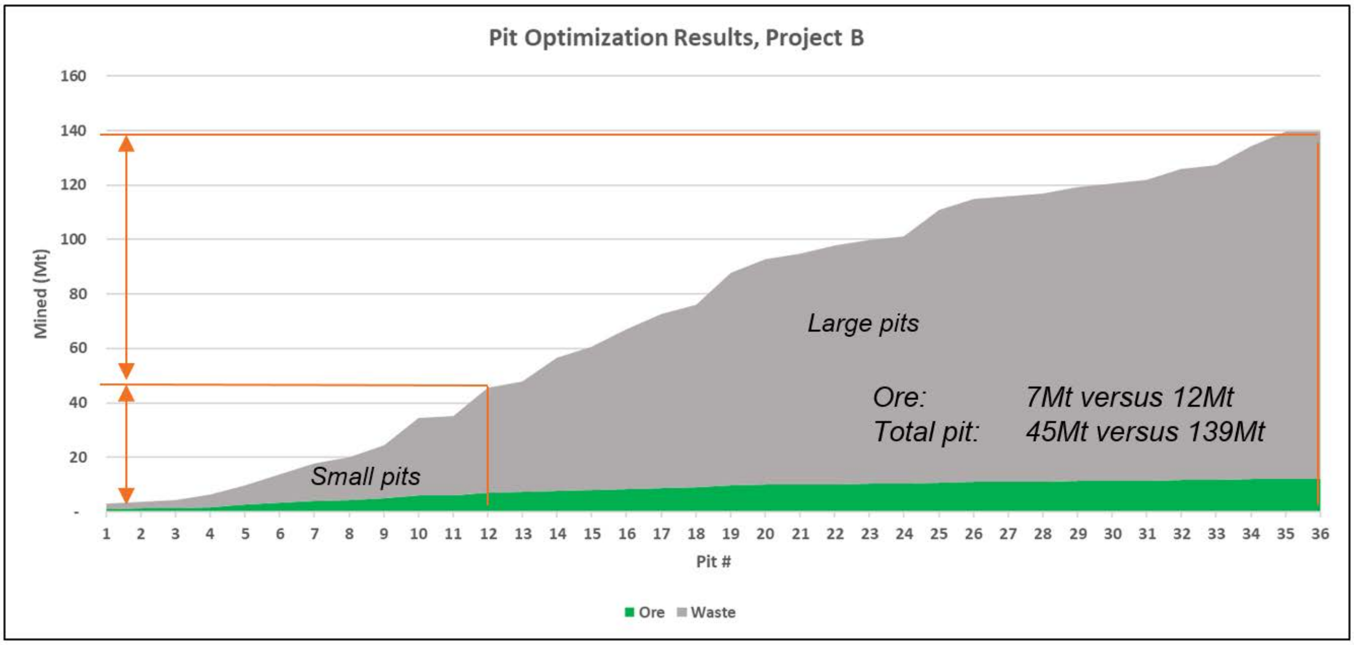

Figure 5 ore and waste mined for Project B

Because of the steady growth of strip ratio with no sudden jump there is no clear limit to distinguish between small or large pits. The mill and infrastructure are already built and in operation. The major sustaining capital is related to mining equipment and expansion of tailing facilities.

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 doesn't change with increasing the size of pit. This is mainly due to a) higher strip ratio and b) the effect of discount rate. Sustaining capital has not been included in this graph; therefore, the capital requirements necessary for larger pits will reduce the pit value after pit 25.

Larger pits add a minimum of 2 years and possibly up to 5 years to the life of mine; however, they require purchasing new and larger mining equipment. 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 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.

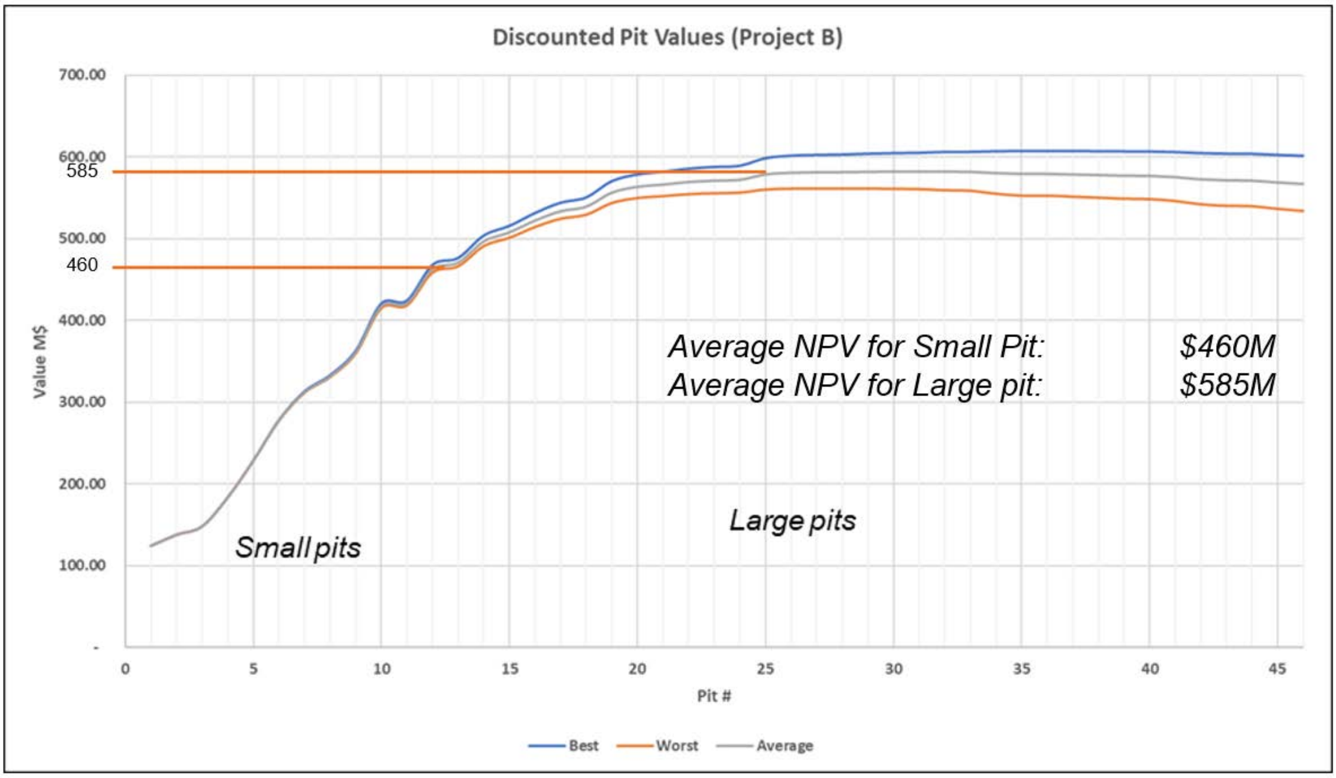

Figure 6 Discounted pit values for Project B

11 CONCLUSION

There is no common solution that can be adopted by industry to address the pit size selection paradox. 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 discussed. This is to avoid any hot topics that may hurt a business by pursuing pit sizes that have no technical merit. Strategic mine planning is an analytical tool that can help for many aspects of mine design including pit size selection therefore it is recommended.

For pit size selection the approach for greenfield projects may differ from the approach we take to analyze the situation for an operating mine where an expansion is being evaluated.

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13 REFERENCES

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