A phased development schedule for a platinum concentrator utilizing a dynamic stockpile model

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Synopsis

There are a number of factors that contribute to the profitability of a mine and its associated concentrator. Chief among these is the time taken from the first hoist of material from underground to the first batch of concentrate shipped. The main aim of this project was to integrate the mining model with a concentrator production schedule to minimize the time it would take to produce concentrate (without the concentrator having to stop because of a lack of feed material) in the most capital-effective manner. A secondary goal was to ensure detailed stockpiling requirements, as the concentrator is in an area where 'visual pollution' is to be avoided. To achieve these two goals a dynamic stockpile model was created by utilizing the mine production schedule and breaking it down to a daily production figure. Four different concentrator development models were then proposed. The difference between the mine production and concentrator consumption was integrated over the life of the mine to provide the accumulated stockpile tonnages for both Merensky and UG2 ore. To prevent a situation where the concentrator was operational without any feed, the stockpile levels were never allowed to fall below zero. When a development option was selected, the standard metallurgical performance calculations were used to derive a concentrate production schedule, which was used as a basis for commercial negotiations for the sale of concentrate.

Keywords
production scheduling, project development, concentrator, stockpile, dynamic model.

Introduction

In 2010 TWP Projects was commissioned by Wesizwe Platinum to sink a 230 kt/month shaft in the Rustenburg area. The shaft would provide a combination of Merensky and UG2 ore. In 2011, TWP was also commissioned to do upfront engineering work for an associated 230 kt/month concentrator. Both the shaft and concentrator projects are to be funded through capital raised via loan agreements. As such there are a number of key financial factors that need to be determined to allow for these loan structures to be utilized effectively and provide the shortest (economically viable) time to first concentrate production.

The key parameter in achieving the aims above is to start concentrator production at the soonest possible time while taking cognisance of the fact that a concentrator 'ramp up' to full production is a lot quicker than that of a mine (three years as against ten years). This means that a stockpile of feed material must be built up while the mine shaft is being developed to full production. However, given the proposed location of the concentrator site (close to the tourist destination of Sun City) there are strict limitations on 'visual pollution', meaning that stockpiles need to be carefully managed to ensure that they do not exceed a given footprint and height.

To model all the above parameters, the project developed a dynamic model that allowed parameters such as start date, ramp up time, and phase production rates to be modelled. The aim was to provide the client with a realistic start date that balances mine production, concentrator ramp up, stockpile level, and capital cost (done externally). When the final plant configuration was selected, concentrate production schedules were developed for inclusion in the mine commercial model.

All of the above was modelled in Matlab® and Simulink® in conjunction with Excel for reporting.

Background

Mine and concentrator production

A block flow summary of the proposed flow sheet can be seen in Figure 1. The proposed concentrator has two primary milling and rougher flotation modules to allow for

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 This paper was first presented at the 5th International Platinum Conference 2012, 18–20 September 2012, Sun City, South Africa.

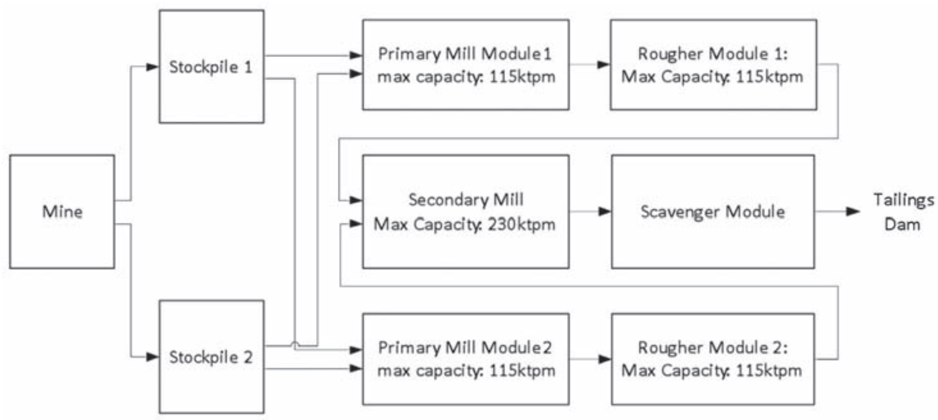

Figure 1—Block flow diagram of proposed solution

flexibility in processing Merensky and UG2 during blended-phase operation. The combined tails is processed by a secondary mill and scavenger flotation circuit.

TWP Projects' Mining Division generated a quarterly mine production model in Mine 4-2D. The production schedule was converted to a daily hoist rate reporting to a stockpile.

For the model to represent a realistic operational model, the concentrator was also defined using the following production parameters:

- Phase start dates
- Plant throughput (for each phase of development)
- Ramp-up duration
- Mine production rates (taking into consideration breaks)
- Module blend rate (percentage of concentrator feed that is Merensky or UG2)
- Mine availability
- Concentrator availability.

The parameters above were then used to calculate a daily production target as well as tuning parameters to determine a feasible and realistic daily production schedule.

Dynamic model

In the late 18th century, Antoine Lavoisier proposed a formalization of the principle of conservation of mass (Wikipedia), which can be summarized to:

$$Mass_{in} + Mass_{produced} - Mass_{consumed} - Mass_{out} = 0 \quad [1]$$

However, when we take into account that we are evaluating a dynamic model with no production or consumption of material, we can modify this equation as follows:

$$Mass_{in} - Mass_{out} = Mass_{accumulated} \quad [2]$$

The $Mass_{in}$ parameter is represented by a quarterly mine production schedule and the $Mass_{out}$ represents the amount of feedstock that the concentrator consumes. Finally, the $Mass_{accumulated}$ value represents a change to our stockpile. When integrated over time, $Mass_{accumulated}$ represents material on a stockpile. This was used as the fundamental basis of the dynamic model.

The parameters above are tuned for the various options to provide the earliest production dates for a given scenario while conforming to the following criteria:

- Stockpiles are never less than zero, implying that there is never a lack of feedstock to concentrate
- Stockpile levels are minimized as much as possible by changing blend rates.

In conjunction with the criteria listed in the following section, it was possible to generate a production schedule for both mine and concentrator that could then be used to generate stockpile profiles for the various scenarios that were proposed.

Concentrator development scenarios

Four options were proposed for investigation:

- *Option 1*—Three phases of mine development
  - Phase 1: 90 kt/month (primary mill module 1 and rougher module 1)
  - Phase 2: 90 kt/month (primary mill module 2 and rougher module 2)
  - Phase 3: 50 kt/month (secondary mill and scavenger flotation).
  - 12 week ramp-up time.
- *Option 2*—Toll selling of mined ore with complete concentrator construction
  - One single construction phase
  - Toll selling of ore until concentrator is on line.
- *Option 3*—Modularized approach
  - Build small modules until full production attained.
- *Option 4*—Two construction phases with MF2 circuit configuration
  - Build in two phases
  - Phase 1: 115 kt/month (MF2)
  - Phase 2: 115 kt/month (MF2)

Each of the options had different economic benefits, summarized as follows:

- *Option 1*—This option was the original design configuration and was used as the base case
- *Option 2*—A single construction phase has benefits in terms of site establishment costs as well as reducing brownfield risk to the site. Toll selling also allows revenue to be generated as soon as possible

- *Option 3*—The benefit of tailoring modules to best utilize mine production implies that the start date for the concentrator can be moved forward as far as possible
- *Option 4*—The site concentrator would be built such that all foundations in the milling and flotation area would be completed and the plant operated in MF2 state (with a single primary mill in operation) to provide the best balance between an earlier start date and better flotation associated with an MF2 configuration.

Simulation results

The Excel input sheet (Figure 2), Simulink model (Figure 3) and simulation output summary (Figure 4) have all been included for information purposes. It must be noted that in total there were 59 variables that were defined to allow the simulation to function as required.

The results of the simulations for the four options are shown in Figures 5–8. A summary of the start dates and capacities can be seen in Table I. As expected, the various scenarios produced differing start dates in line with the initial capacity requirements of each option when taking into account the target of minimizing the stockpile levels. Utilizing the Mine 4-2D forecast dates (based on shaft development starting in quarter 1 of 2012), the earliest start achievable was 4 April 2019 with a modularized 50 kt/month plant. The latest start date was 16 December 2022 for the option where initial ore was sold to a third party with the plant coming on line only when the mine was at full capacity.

From Figure 9, which shows a summary of the concentrator throughput tonnages, the following observations can be made:

- Option 1 has the best start time, with option 2 starting last
- Option 1 starts second, but is followed shortly by option 4
- Option 3, although starting last, has the highest ramp-up rate
- Option 2 has a large amount of material that is not processed by the concentrator (2129 kt Merensky and 1285 kt UG2).

Discussion

The options had the following benefits and drawbacks.

Option 1

Positives

- Second-best start time
- Standard size modules with the ability to run either as MF1 or MF2 configuration, which allows circuit to ‘grow’ as the capacity increases.

Negatives

- Three phases of development
- MF1 circuit as designed initially will not produce the best recoveries.

Final decision

- Running circuit on MF1 for initial stages of operation cannot be justified according to capital requirements as well as the cost of three-phase development

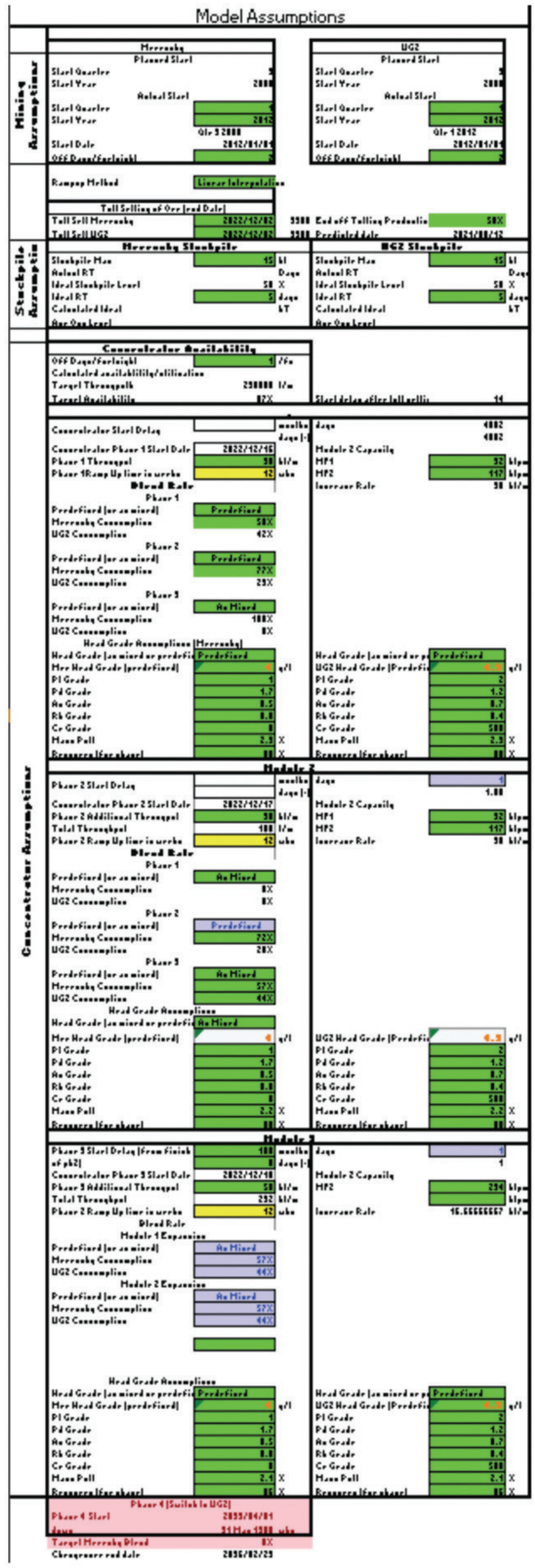

Figure 2—Screen capture of Excel model input sheet

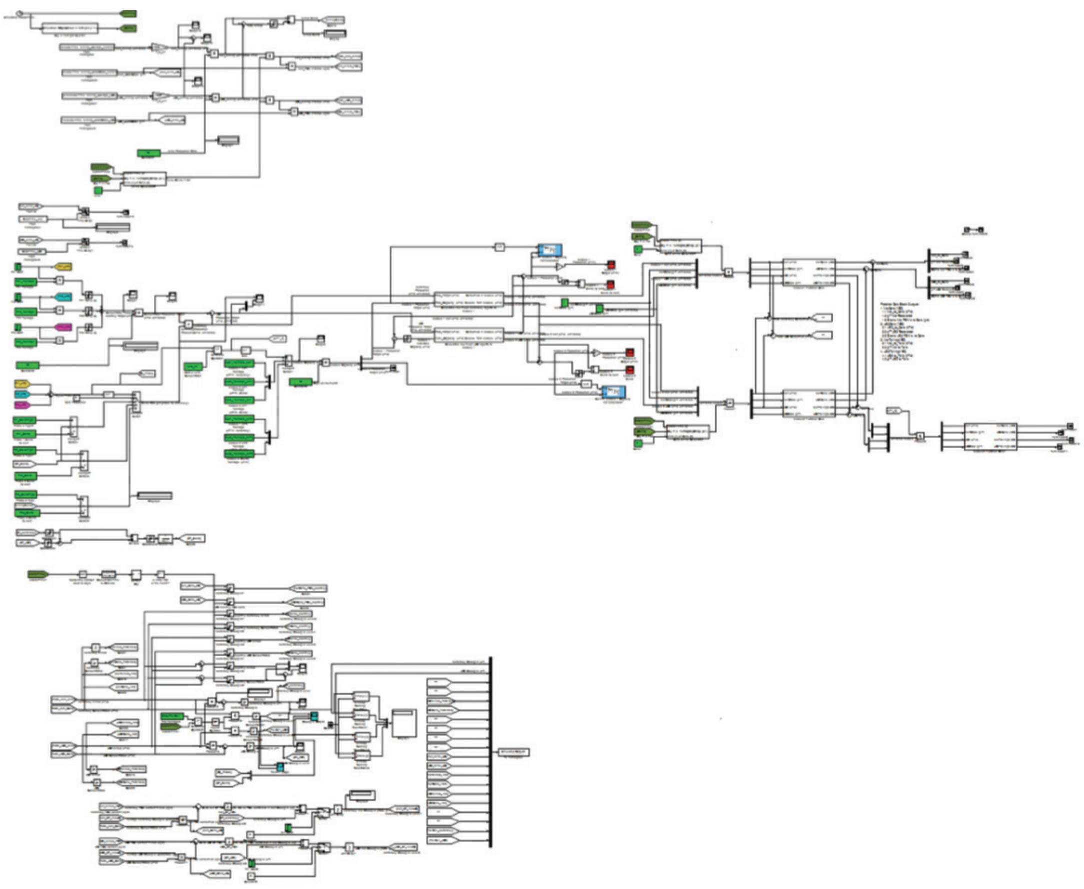

Figure 3—Screen capture of final Simulink model for stockpile

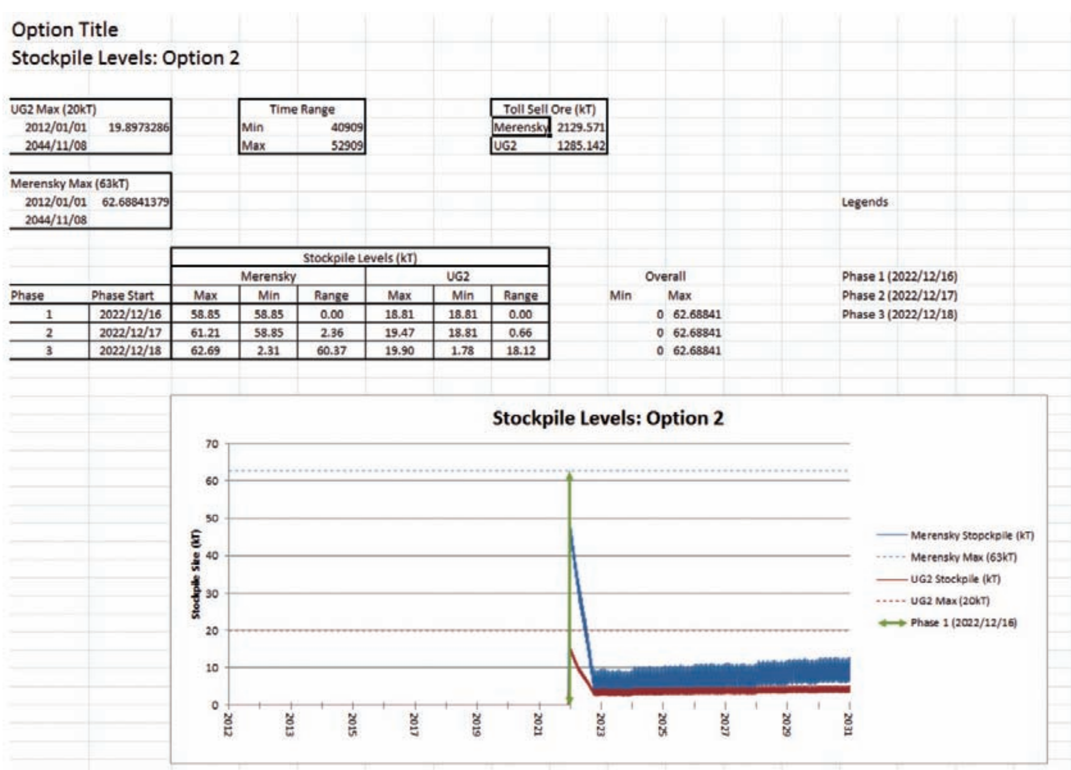

Figure 4—Screen capture of simulation output summary

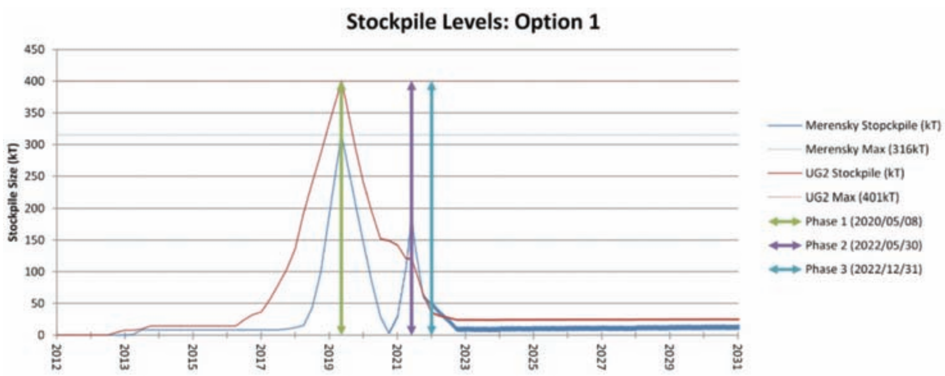

Figure 5—Stockpile level predictions for option 1

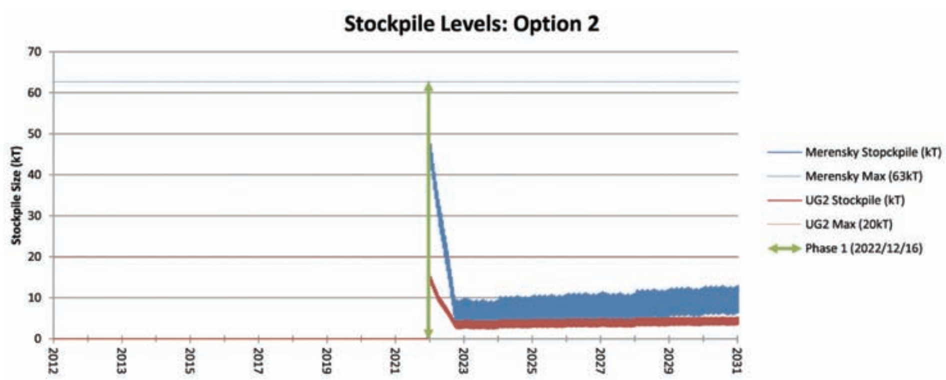

Figure 6—Stockpile level predictions for option 2

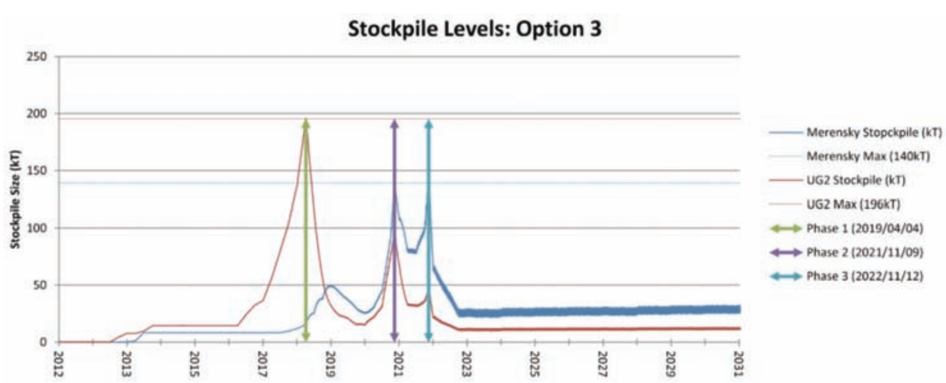

Figure 7—Stockpile level predictions for option 3

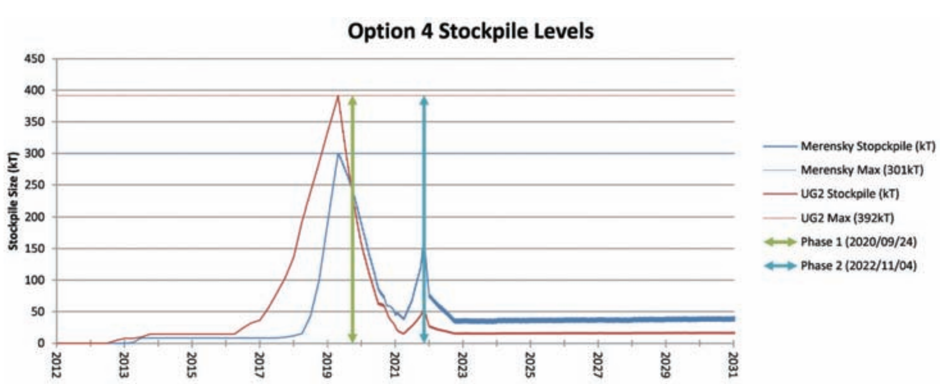

Figure 8—Stockpile level predictions for option 4

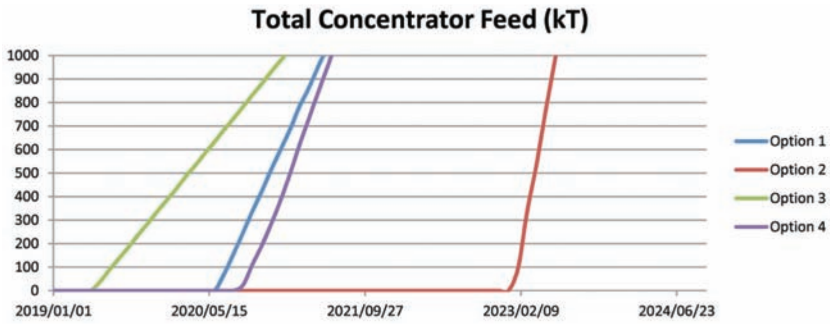

Figure 9—Total concentrator feed for various concentrator development options

Table I

Summary of concentrator start and full capacity dates

Option	Early start	Full capacity
1	2020/05/08	2022/12/31
2		2022/12/16
3	2019/04/04	2022/11/12
4	2020/09/24	2022/11/04

Option 2

Positives
- ➤ Early revenue through toll selling or ore to a third party
- ➤ Single development phase
- ➤ Lowest stockpile requirements.

Negatives
- ➤ Toll selling agreements are notoriously difficult to negotiate and manage
- ➤ Reduced return margin
- ➤ Timing of full production from mine and concentrator is absolutely critical.

Final decision
- ➤ Toll selling agreements are too risky for initial conceptual study, although options should be kept open going forward.

Option 3

Positives
- ➤ Concentrate will be produced much earlier in the project, which will provide the first income to the project and help with repaying of debt.

Negatives
- ➤ The development of modularized concentrator modules is not preferable over the long term due to the inefficiencies inherent in small plants. For example, milling circuits would have differing capacities
- ➤ Capital deployment means that almost the full plant infrastructure needs to be developed for the plant to be ready for such a small throughput, which is not the most efficient way of utilizing loaned capital
- ➤ Three construction phases require additional 'Ps & Gs' (preliminaries and generals).

Final decision
- ➤ Benefits of early production do not outweigh cost of developing infrastructure as well as phased development costs.

Option 4

Positives
- ➤ Slightly delayed start over option 1 (4 months)
- ➤ MF2 circuit configuration from start
- ➤ Two phases of development
- ➤ Fastest ramp-up rate to full production.

Negatives
- ➤ Construction of final phase will proceed on an operating plant
- ➤ Last started of the non-'toll selling' options.

Final decision

Option 4 is the selected option, as is provides the best balance between reduction in stockpile capacities, starting as early as possible, and utilizing capital in the most efficient manner possible.

Conclusions

The final option (option 4) was selected to provide a balance between capital usage in both site and infrastructure development, stockpile levels, and the most profitable flow sheet (MF2). As the selected option, it was possible to use the production data for the concentrator to negotiate concentrate offtake agreements with third parties, which results in better financial modelling of both the project risk as well as cash flow for the overall project.

In addition, if changes occur to the mining model that might delay the project, it is simple to re-optimize the model to predict modified start dates, which will ensure that the concentrator is not built too late or too early, either of which could be financially disastrous to the client and the financial institutions that are funding these projects.

Going forward, there is a need to further develop and refine the circuit configurations to firm up details of the final solution (better information on floatation profiles). This will provide additional detail that will be required when negotiating take-off agreements.

Reference

Wikipedia. http://en.wikipedia.org/wiki/Conservation_of_mass ◆