A Review- Enterprise Optimization

A holistic study methodology of the mining business, resource to market.

- Activity-based Costing and Theory of Constraints
  - Model cost behavior
  - Focus on production bottleneck in the business system
  - Create a net value model
- Ten step methodology
  - Additional sustainability and uncertainty steps 11-12
- Powerful NPV-driven optimizing engine- Prober
  - Jeff Whittle
Activity-based costing
Model cost behavior, this is not GAAP accounting
Costs reallocated to attributable and period cost

<table>
<thead>
<tr>
<th>Mine</th>
<th>Operating Costs</th>
<th>Unit</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>General Mine Expense</td>
<td>C$000/yr</td>
<td></td>
<td>Period Cost</td>
</tr>
<tr>
<td>Drilling</td>
<td>C$/t</td>
<td></td>
<td>Attributable Cost</td>
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<tr>
<td>Blasting</td>
<td>C$/t</td>
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<tr>
<td>Loading</td>
<td>C$/t</td>
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<tr>
<td>Hauling</td>
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<td>Attributable Cost</td>
</tr>
<tr>
<td>Support</td>
<td>C$000/yr</td>
<td></td>
<td>Period Cost</td>
</tr>
<tr>
<td>Rehandle</td>
<td>C$/t</td>
<td></td>
<td>Attributable Cost</td>
</tr>
<tr>
<td>Snow mining</td>
<td>C$/t</td>
<td></td>
<td>Attributable Cost</td>
</tr>
<tr>
<td>Total Attributable Component</td>
<td>C$/t</td>
<td></td>
<td>Attributable Cost</td>
</tr>
<tr>
<td>Total Period Component</td>
<td>C$000/yr</td>
<td></td>
<td>Attributable Cost</td>
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<table>
<thead>
<tr>
<th>Process</th>
<th>Operating Costs</th>
<th>Unit</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>General Plant Expense</td>
<td>C$000/yr</td>
<td></td>
<td>Period Cost</td>
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<tr>
<td>Plant Labor</td>
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<td>Period Cost</td>
</tr>
<tr>
<td>Power</td>
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<td>Attributable Cost</td>
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<tr>
<td>Reagent</td>
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<td>Oxygen</td>
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<tr>
<td>Refining</td>
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<td>Total Attributable Component</td>
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<td>C$000/yr</td>
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<td>Attributable Cost</td>
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Theory of Constraints

- All complex systems have a controlling rate
- It is typical for a mining business to be limited by the milling and processing plant (the bottleneck)
- How do you maximize the value through the bottleneck? This is an opportunity:
  - Design for extra capacity downstream, like a flotation circuit and downstream hydraulic capacity
  - Allow operational flexibility in terms of changing grind size or con grade
  - Apply period costs as opportunity cost
Prober- Optimizing Engine

- Written by Jeff Whittle in the early 80s
- Pit optimizer commercialized with Geovia (formerly Gemcom)
- SIMO (steps 1-6) released by Geovia late 2012, single plant single mine
- Ad hoc components held by Whittle Consulting, used for Enterprise Optimization Studies
  - Fortran code, hyper-cubes, over 100 processors
  - This is not a GUI interface code
Twelve Step Program
As applied in a study

1. Variable Cut-off Grade
2. Stockpiling
3. Schedule
4. Pit Design - constraint
5. Phase Design - constraint
6. All of the above simultaneously
7. Processing policy (grind size)
8. Product policy (con grade)
9. Logistics
10. Incidental Capital (i.e. two more trucks)
11. Sustainability (modeled in terms of economic efficiency)
12. Uncertainty Assessment (Monte Carlo)
Avanti Kitsault Moly Project
Kitsault, BC Canada

- Greenfields site, but mined, reclaimed, and closed in the 80s.
- AMEC Feasibility Study 2010 and FS Update 2013
- EO study to improve NPV and validate project

- Mining:
  - Maximum mining rate of 45.9 Mt per annum
  - 36 Mt permitted stockpile space
  - 14 year mine life

- Processing
  - 16.6 Mtpa processing rate
  - SAG and ball mill
  - Flotation circuit
Avanti Kitsault Moly Project
Kitsault, BC Canada

- Three rock types-
  - Monzonite, phaneritic igneous rock
  - Diorite, phaneritic igneous rock (more mafics)
  - Hornfels, metamorphic sedimentary rock
- 52% Moly con non-negotiable for sales
- Silver at 39-40% recovery included in revenue
- AMEC mine planning and metallurgical work in FS update
**Project Waterfall Graph**

**Value Contributions**

COG, Extended Mining, Stockpiles, Throughput vs. Recovery, log recovery
8% Discount Rate, EO P&P, Detailed design

NPV (millions)

- Feasibility Study Update (AMEC 2013)
- Fully CoG (extended late mine limit)
- Extended Mining
- 36Mt stockpile
- FS P&P, Log GTR, Extended Mining
- EO P&P, 10 bpa
- d5-d8, Detail EO P&P

Contributions:

- CoG: 5.5%
- Extended Mining: 2.2%
- 36Mt stockpile: 4.8%
- FS P&P, Log GTR, Extended Mining: 10.6%
- EO P&P: 4.5%
- Detail P&P: (1.2%)
- GTR, 2nd gen: 5.3%
GTR Surface Graphs

Ausenco GTR- Monzonite

AMEC GTR- Monzonite

Recovery at 0.08% moly head grade Monzonite

Ausenco GTR- Diorite

AMEC GTR- Diorite

Moly recovery at 0.08% head grade Diorite

Ausenco GTR- Hornfels

AMEC GTR- Hornfels

Moly recovery at 0.08% head grade Hornfels
Variable CoG +5.5%
Extended Mining +2.2%
Stockpile Max 36Mt +4.8%
GTR - First Generation +10.6%
EO Pit and Phase Design +4.5%
Detailed design -1.2%
GTR - Second Generation +5.3%
Grind per rock type

Processed Material - Rock by Grind

Mt

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20

Other
Monz356
Dior258
Dior212
Hfls356
Hfls291
Hfls258
Hfls212

Whittle Consulting
AVANTI MINING INC
amec
Ausenco
Grind per Period

Processed Material - Grind

- 356μ
- 291μ
- 258μ
- 212μ
Cash Flow

Red Line Blue Line

Cash Flow C$ (post royalty) – Cash Flow Comparison C$
Outcomes

- The Enterprise Optimization Study added significantly to the project NPV, above what is considered a good FS study.
- Grind Throughput Recovery was a significant portion of this value, adding more than half of the value.
- Scheduling, cut-off grade, and stockpiling to the maximum permitted volume also added value.
- Additional value was added by deferring capital based on the Prober schedule not utilizing mining capacity at the start.
- AMEC Mine Planner implemented the “path through the ore body” very well.
- AMEC process consultants took initial Ausenco EO GTR estimates and recommended additional test work, and improved the curves.
- A great team effort!
Questions,

and Thank you!

Be safe out there.