Economic Benefits and Technical Complexities of Grade Engineering® in Strategic Mine Planning of Metalliferous Projects

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CRC ORE has developed a novel approach to improving productivity and based on a system value approach referred to as Grade Engineering®.

Involves increasing head grades to process by the early physical rejection of non valuable material through pre-concentration techniques.

1. Preferential grade deportment by size
2. Differential blasting for grade by size
3. Sensor based bulk sorting
4. Sensor based particle sorting
5. Coarse gravity separation

Grade Engineering Pre-concentration Techniques
The extent and magnitude of some ore types to preferentially deport mineralogy/grade into specific size fractions during coarse breakage generates outcomes which can profoundly change operational decisions.
Differential blasting involves changing energy designs for a blasting bench, through powder factors, stemming, and/or different drilling blasting designs, following its grade heterogeneity.

The objective/aim is to induce different size distributions to valuable material and non valuable material, to then be screened to separate the upgraded material (undersize).
Technique where valuable material is separated from non valuable material through the use of Sensors (Optical, Electromagnetic, Laser). Sensors are used as the telemetry method, together with mechanical, hydraulic or pneumatic separators.

Sensor based bulk sorting based on mass diversion (shovel, truck, belt scale …) is an attractive concept.
Magnetic resonance involves radio frequency excitation of mineral phase lattice structures resulting in a distinctive frequency response for some minerals – it is penetrative and capable of rapid quantification.
**CRC ORE** has developed a novel **approach to improving productivity** and based on a system value approach referred to as **Grade Engineering®**.

Involves **increasing head grades** to process by the early physical rejection of non valuable material **through pre-concentration techniques**;

<table>
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GRADE ENGINEERING BENEFITS

**ST Benefits**
- Reduces amount of waste from ore streams
- Head grade improvements to process
- Improves metallurgical recoveries
- Throughput improvement & energy savings (DB fragmentation)
- Improves selectivity and destination of material
- Improves cashflow

**LT Benefits**
- Improvement of reserves
- Improvement in metal production
- Resilience to metal price change
- Improvements in NPV from 3% to 15%
GE STRATEGIC MINE PLANNING (SMP) – COST MODELLING

COST MODEL

Capital Costs (CAPEX)
- Initial Investment
- Sustaining

Operational Costs (OPEX)
- Mining
- Processing
- Admin
- Grade Eng.

Market Costs
- Selling
- Refining

Variable Costs
- Hauling ($/t)
- Loading ($/t)
- Drill & Blast ($/t)
- Rehandling ($/t)
- Ancillary ($/t)

Fixed Costs ($/hr)
- Mill ($/t)
- Leaching ($/t)

Variable Costs
- Screening ($/hr)
- Diff Blast ($/hr)
- Sensor BS ($/hr)
- Rehandling ($/hr)
GE SMP RESOURCE EVALUATION – BLOCK MODELLING

- **Grade Variability**
- **Separation Properties per GE Technique**

**Geological Parameters**

**Metallurgical Parameters**
Selects Highest Economic Value: $/t

20% @ 0.95 + 80% @ 0.39 = 0.5
30% @ 0.80 + 70% @ 0.35 = 0.5
50% @ 0.70 + 50% @ 0.30 = 0.5
70% @ 0.60 + 30% @ 0.28 = 0.5
GE SMP RESOURCE EVALUATION – BLOCK VALUE & DESTINATION

**Best Economic Destination**

**GE Economic Optimum Combination**

**Process Plant**

**Leaching Pads**

**Stock Pile**

**Waste Dump**

**Mine**

**CU @ 0.5**

**Grade Engineering Plant**

**GE Technique**

- HG Stream
- LG Stream

**HG Stream**

**LG Stream**

**CRC ORE 13**

Optimising Resource Extraction
Ken Lane Value and Cut-Off Grade Equations

\[ V_m = (P - k)xy\bar{g} - xh - m - \frac{(f + F)}{M} \]
\[ V_h = (P - k)xy\bar{g} - xh - m - \frac{(f + F)x}{H} \]
\[ V_k = (P - k)xy\bar{g} - xh - m - \frac{(f + F)xy\bar{g}}{K} \]

\[ COG_m = \frac{h}{(P - K)y} \]
\[ COG_h = \frac{(h + \frac{(f + F)}{H})}{(P - k)y} \]
\[ COG_k = \frac{h}{\left(P - k - \frac{(f + F)}{K}\right)y} \]
Grade Engineering - Value and Cut-Off Grade Equations

V- Mine Limiting

\[ VGE_m = (P_H - K_H)xM_p y_Hg_H + (P_L - K_L)x(1 - M_p)y_Lg_L - xM_p h_H - x(1 - M_p)h_L - xM_p G_H - x(1 - M_p)G_L - m - \frac{(f + F)}{M} \]

GE Cut-Off Grade - Mine Limiting

\[ GECOG_m = \frac{M_p (h_H - G_H) + (1 - M_p) (h_L - G_L)}{(P_H - K_H)M_p y_H I_f + (P_L - K_L)y_L (1 - I_f M_p)} \]
Only - Direct Feed

Grade Engineered Feed + Direct Feed
GRADE ENGINEERED SMP – FINAL PIT OPTIMISATION

Grade Engineered Final Pit

GE Economic Block Model

5% Improvement in Reserves

Grade Engineering
- GE Parameters
- Pre-C Independent Processing Destination
- Pre-C $/t
GE SMP RESOURCE EVALUATION – VALUE CURVES & COG

Cut-Off Grades

- 0.15 Cu%
- 0.36 Cu%

Unit Value ($/t)

- SEC MILL
- SEC LCH
- WASTE

Value Curves and CoG (Cut-Off Grades)
GE SMP RESOURCE EVALUATION – VALUE CURVES & COG

Cut-Off Grades

- 0.10 Cu%
- 0.62 Cu%

Unit Value ($/t)

- -10
- -5
- 0
- 5
- 10
- 15
- 20
- 25
- 30

SEC MILL
SEC LCH
GE Differential Blasting
WASTE
Natural Department
Differential Blasting
Sensor Based Sorting

Mt

Cu%

CRC ORE 22
Sensor Based Sorting Only

- **20%** of Total **Material Movement** goes to **GE Plant**.
- **20%** of **Mill Feed** comes from **Grade Engineering Plant**.
- Improvement on base case **NPV – 9.1%**
CASE STUDY RESULTS - GE SS SEPARATION & DESTINATION SCHEDULE

Grade Engineering Plant - Capacity: 30 Mtpa

- GE Feed Average Grade: 0.42 Cu%
- Upgraded to Mill at 0.67 Cu% 41% of GE Material
- Marginal to Dump Leach at 0.36 Cu% 56% of GE Material
- Downgraded to Waste Dump at 0.28 Cu% 3% of GE Material
Sensor Based Sorting Only

- **Overall LOM Cu%** Head-grade increased by 6.7%
- Produced 8% more in Cu concentrate
Grade Engineering Amenability

- Every Deposit is Different
- Every Deposit will have different heterogeneity, grade variability.
- Every Project will be amenable to different Grade Engineering Techniques and at different scales.

Grade Engineered Strategic Mine Planning – Conclusions

- GE Full Mine Planning Optimisation aids to reach and improve Strategic Goals.
- NPV Improvement of 3% to 15% achieved through GE fully optimised mine plans
- Improvement of Reserves by 5%
- Head Grade Improvement from 3% to 10%, per year and for LOM.
- Head in TPH from 5% to 10%, per year and for LOM.
- Improvement in Metal in Cu concentrate
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