JKTech Technical Article

Integrated Prediction & Improvement of Throughput at Ban Houayxai Gold Mine

Paper in Brief

Integrated Prediction and Improvement of Throughput at Ban Houayxai Gold Mine, Laos

This is a summary of collaborative work undertaken by Ban Houayxai and JKTech personnel to improve throughput.

The work is a summary of papers presented at:

The Orebody Modelling and Strategic Mine Planning Symposium 2014

11th International Symposium on Rock Fragmentation by Blasting 2015

For further information contact:

John Jackson, Principal Consultant
j.jackson@jktech.com.au

Lachlan Kennelly, Mining Lead
l.kennelly@jktech.com.au

The full papers can be found at

Jackson, J., Gaunt J., Astorga, M. 2014. Predicting Mill Ore Feed Variability Using Integrated Geotechnical/Geometallurgical Models, in *Proceedings Orebody Modelling and Strategic Mine Planning Symposium 2014*, pp 267–274 (The Australasian Institute of Mining and Metallurgy: Melbourne).

Gaunt, J., Symonds, D., McNamara, G., Adiyansyah, B., Kennelly, L., Sellers, E. J., Kanchibotla, S.S., 2015. Optimisation of Drill and Blast for Mill Throughput Improvement at Ban Houayxai Mine, in *Proceedings 11th International Symposium on Rock Fragmentation by Blasting*, pp 307 – 313 (The Australasian Institute of Mining and Metallurgy: Melbourne).

Ban Houayxai Gold Mine

The Ban Houayxai Gold Mine (BHX) is located in Laos and operated by Phu Bia Mining, a 90% owned subsidiary of Pan Aust. The Laos government owns the remaining 10%.

The mine is an open pit operation with a semi-autogenous grinding/ball (SAB) and carbon-in-leach (CIL) processing circuit.

Production commenced in 2012 and is approximately 100,000 oz of gold and 600,000 oz of silver per annum.

Gold and silver mineralisation occurs as structurally-controlled narrow veins and disseminations and within a volcano-sedimentary sequence. Quartz- pyrite± carbonate± electrum± native silver veins are the most commonly mineralised. Disseminated mineralisation is predominately associated with silicification of the feldspathic sandstone with higher grades in breccias.

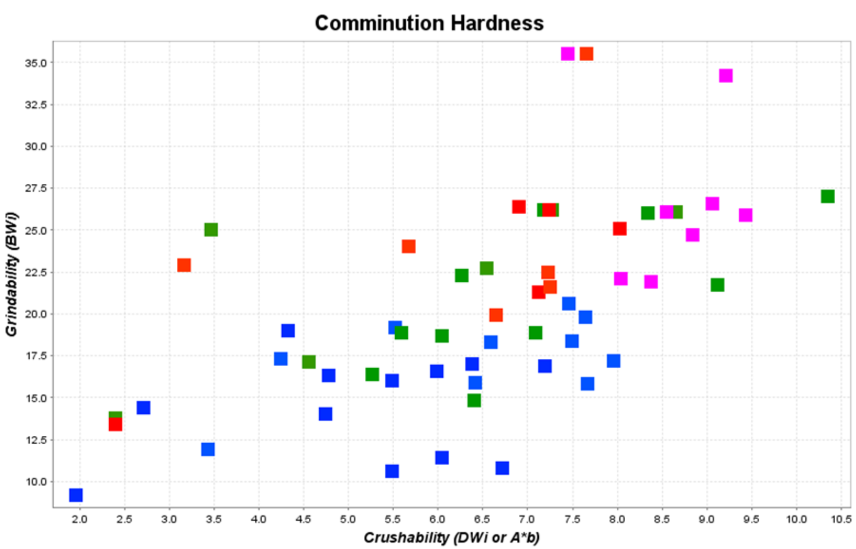
At the end of 2013, the Mineral Resource at BHX stood at 64 Mt at 0.90 g/t Au and 7.1 g/t Ag for a total of 1.8 Moz Au with Ore Reserves of 36 Mt at 0.81 g/t Au and 8.0 g/t Ag.

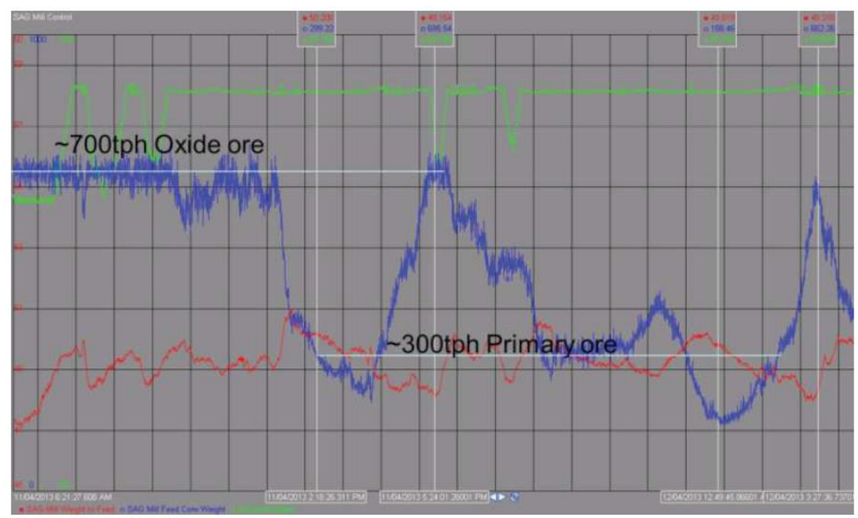
Context

The first two years of operation had processed predominately soft oxidized ore but significant variation in milling rates was being seen due to variability in the feed properties of the oxide, transitional and primary ores.

The proportion of primary ore will increase and becomes harder as shown in the LHS figure below. Hence a proactive management program was initiated to focus on maintaining and enhancing production in the future.

The feasibility design throughput of the mill processing the harder primary ore was estimated to be around 400 tph compared to 700 tph for the oxide ore. However as can be seen the RHS figure below, the mill throughput for the primary ore was often as low as 300 tph – lower than the design and hence a significant business risk. Other risks included inefficiency in milling and mining, SAG mill liner damage, higher maintenance for machinery, storage bins and conveyors.





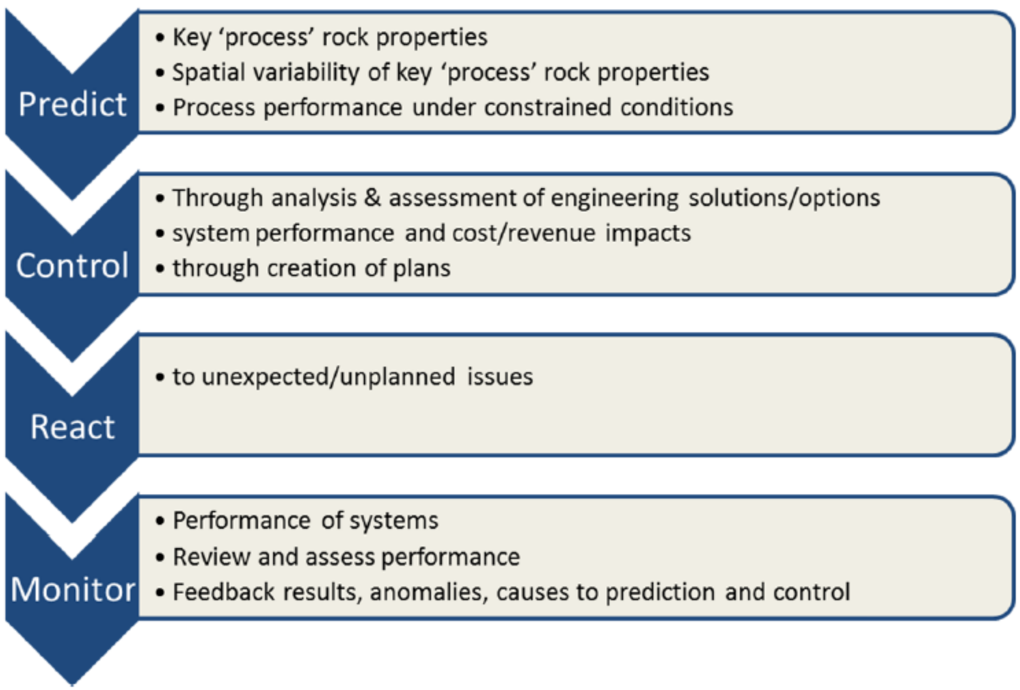
Objectives

As part of the initiative to maintain and enhance production in the future, BHX and JKTech collaboratively undertook a program focussed on throughput based on a scaled down physical asset management approach as shown in the figure below.

The program consists of the four components with the focus on this paper in brief on the first two components:

Predict - the key process parameters and expected performance from a blasting and milling perspective for life of mine.

Control - optimisation of drill and blast to improve fragmentation and throughput for the harder primary ores while minimising dilution and ore loss.



Outcomes

Prediction

- Spatial model of estimated key process parameters including Blastability Index (BI), SAG Mill Crushability (Axb), Bond Mill work Index (Bwi)
- Spatial model of expected powder factors to achieve consistent target fragmentation
- Spatial model of estimated throughput, recovery and metal/hr
- Estimated throughput and metal production profiles on an annual basis
- Identification of deviations of estimated throughput and metal production compared to budgeted.
- Use of BI and other parameters in drill and blast optimisation.

Control

- Increase in bench height from 5 to 10m - increase in throughput of 24% over actual.
- More consistent and finer fragmentation with higher energy blasts – increase in throughput of 25-50% over assumptions in feasibility study.
- Improvement in minimising dilution and ore loss through measurement and modelling.
- Significant reduction in wall damage through use of active split.

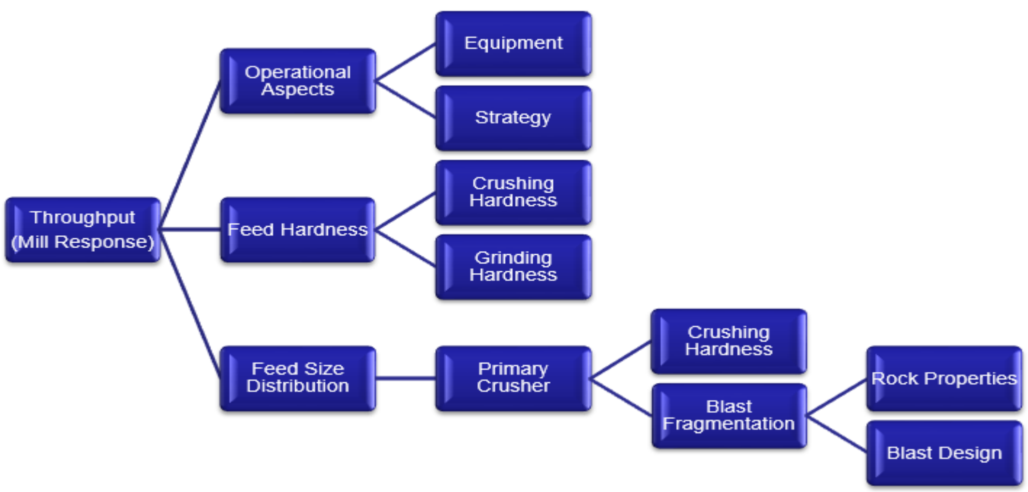
Prediction

Prediction

The key process parameters modelled were:

- **blastability index (BI)**, index of the ease to blast the rock mass
- required **powder factor (pF)** for a constant mean fragmentation size (X50) using empirical engineering models
- **Mean fragmentation size (X50)** using a constant powder factor and design.
- crushability or resistance to **impact breakage (A*b)**
- grindability, the **Bond ball mill work index (BWi)**.

The above parameters are inputs into the throughput model.



The approach was to model these parameters using the empirical engineering and proxy models.

These models require the input of many disparate data types at varying sample intervals and density with varying sensitivities, and thus the final outputs are multilayered and consist of a mix of levels of model granularity and resolution.

The primary input variables were spatially model with the appropriate methodologies, where possible, followed by the application of empirical models to predict the parameters rather than vice versa.

Data Table	Key Data Types
Collars	East, North, RL, Length
Survey	Depth, Azimuth, Dip
Lithology	Lithology, Weathering, Texture & Deformation
Alteration	Supergene Type/Mode/Intensity, Alteration Type/Mode/Intensity
Assays	Au, Ag, Zn with selected intervals assayed for a wide range of multi elements
Point Load	Coresize, caliper, $IS_{(50)}$MPA, Failure on New or Preexisting Structure, FractureType, EstimatedUCS
Geotech	Rock quality designator (RQD%), # of Sets, Strength, Fracture Frequency (FF)
Structure	Structural Type, Orientation and Roughness
Veining	Type and Intensity
Mineralisation	Oxide and Sulphide minerals and quantity

Blastability

Lilly's blastability index (BI) was used as an indicator for the ease of which a material will blast. The inputs into the BI are:

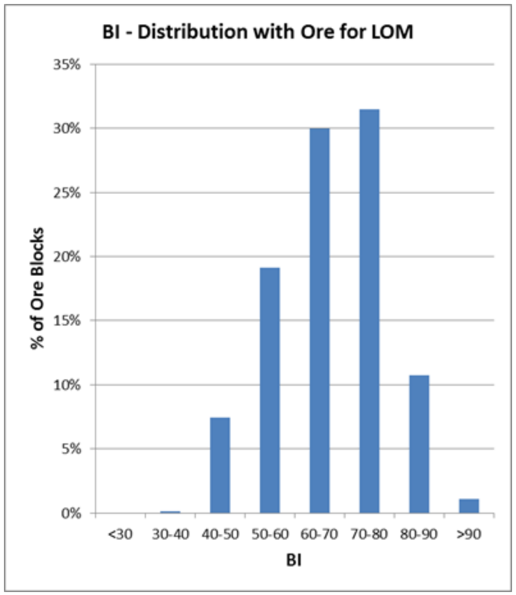
JPS = Joint Plane Spacing Rating
RMD = Rock Mass Description Rating
JPO = Joint Plane Orientation Rating
RDI = Rock Density Influence
S = Rock Strength

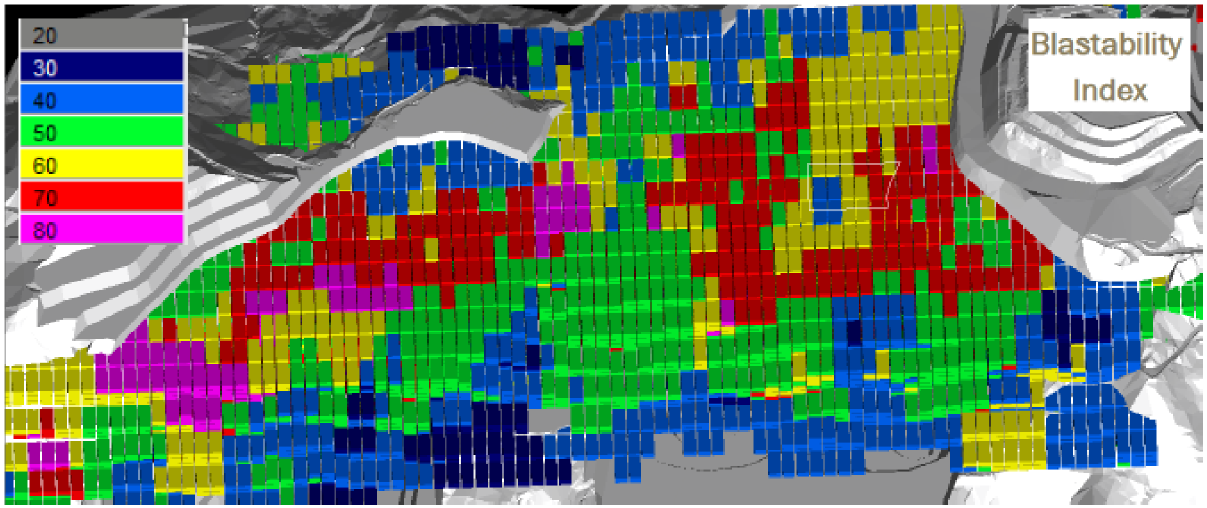
The rock strength was based on point load data and UCS data with the point load data requiring significant QA/QC prior to use.

JPS & RMD based on fracture frequency. 3D FF domains controlled the spatial model for JPS and RMD.

JPO was derived from 3D analysis and domaining of structural data.

RDI was based on the bulk density data.





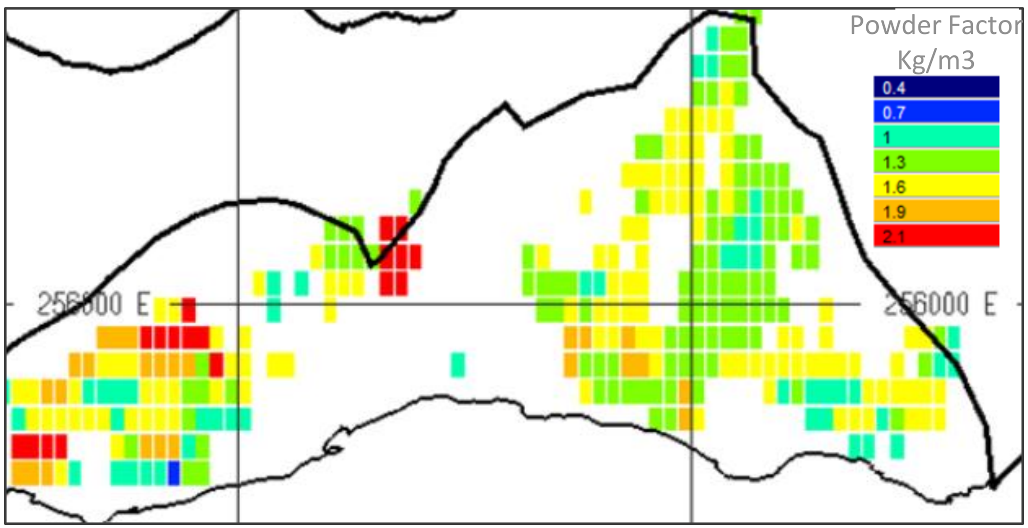
Powder Factor & Fragmentation Distribution

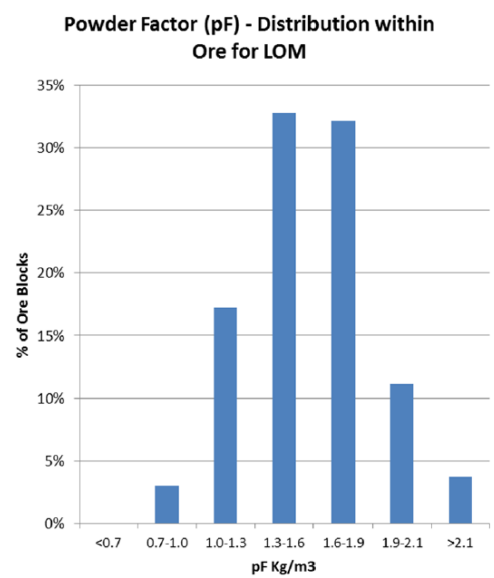
The required powder factor (pF) to achieve a mean size fragmentation was estimated for each block within the block model using Cunningham's empirical Kuz-Ram fragmentation model.

Modelling of the throughput with varying size distributions for the primary ore indicated that a mean fragmentation of 150mm provided the best overall throughput.

Modelling within the control component of the program demonstrated that a move from 5m to 10m benches improved fragmentation and hence the predictive model used the 10m bench height.

Below shows the spatial model of the required pF within ore with fixed explosive and drilling parameters. The mine was typically using a pF of 0.8 – 1.0 kg/m3.



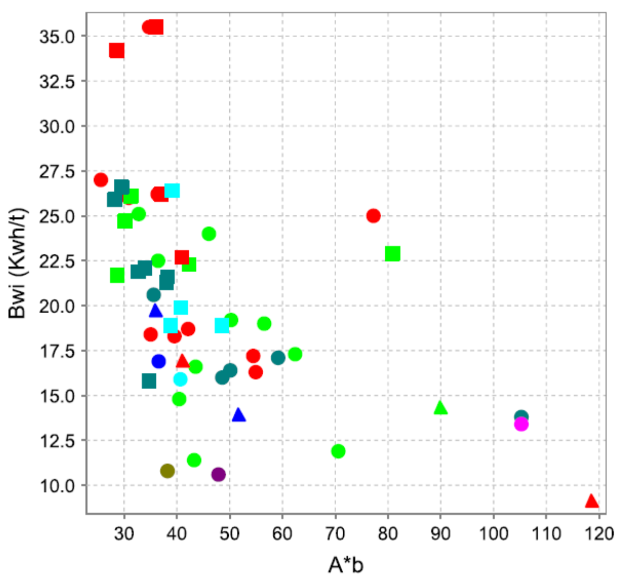


SAG Mill Crushability

The comminution dataset consisted of 57 drill core composites representing material from production periods across the life of mine.

This data showed a wide range in both crushability (=impact resistance) and grindability.

- Impact resistance as measured by the JK parameter A*b ranged from a very hard 25 to a soft 118, although the majority were between 30 and 55.
- Grindability as indicated by the bond ball mill work index (BWi) ranged from 10–35 kWh/t, with the majority between 15 and 27 kWh/t.



Colour = lithology

Triangles = oxide
Circles = transition
Squares = primary

No clear relationships in terms of A*b and/or BWi was identified with geological aspects logged from the drill core such as weathering, lithology, alteration, alteration intensity, veining or combinations of these. Consistent assaying had been limited to key metal elements such as Au and Ag.

The best correlation was between A*b and BWi themselves, together with density.

The point load data from the drill core was very poorly correlated with the comminution parameters due to:

a) the low representivity of the point load measurements within the comminution composite;
b) Issue with quality of the point load data.

These are common issues found in many projects and operations with point load data.

Hence a novel solution was developed based on parameters used in the geotechnical assessment of rock mass - Bieniawski's empirical RMR.

SAG Mill Crushability

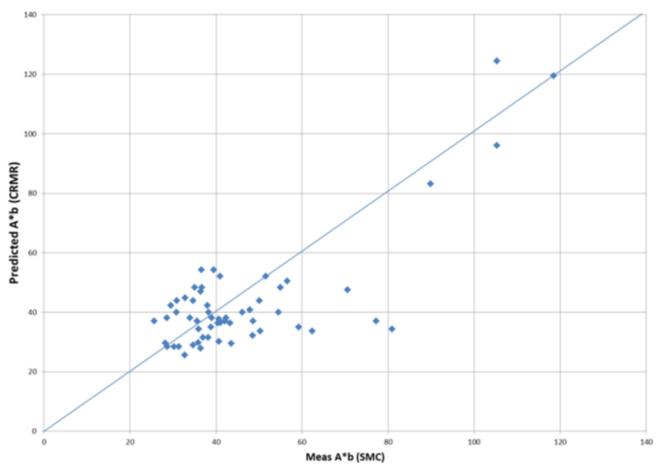
The approach firstly calculates the RMR for the data set at block level, followed by an adjustment factor based on weathering state to create the comminution rock mass rating (CRMR).

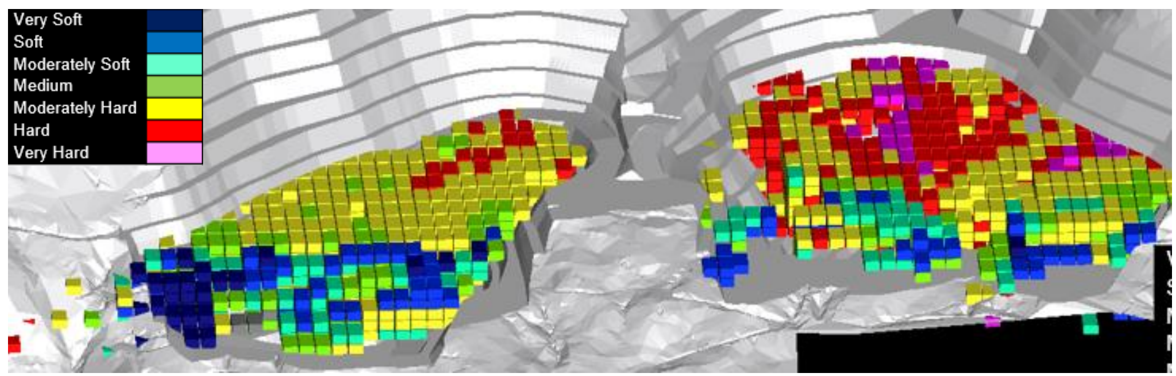
The CRMR is then related to A*b from the SMC tests via regression to create a predicted A*b.

The predicted verses measured A*b for both the model development data and validation data is shown below.

The methodology provides a prediction that is practical given that the purpose of the model is to highlight regions of significant variability in A*b.

This model was then applied to the block model where the input variables had been estimated individually. An example of the results are shown below.

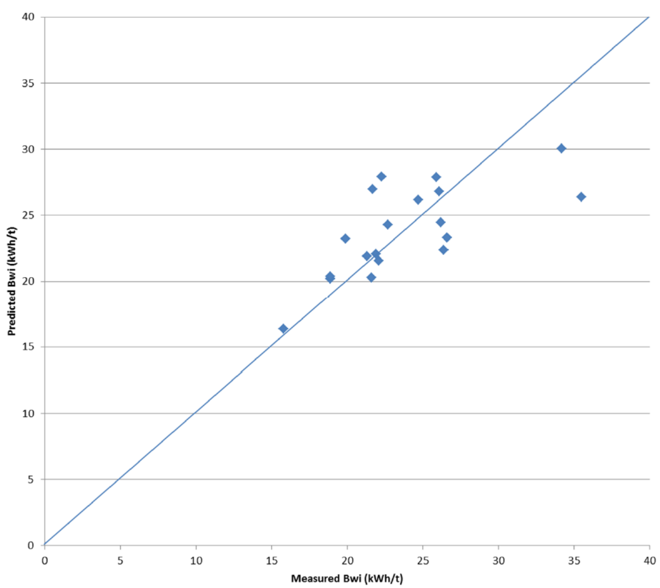




Ball Mill Grindability

The analysis of the BWi data with respect to geological, geochemical and geotechnical variables indicated that if domained by the weathering state, then density and FF together with Zn and Ag are the most correlated of the variables that were consistently measured across the deposit.

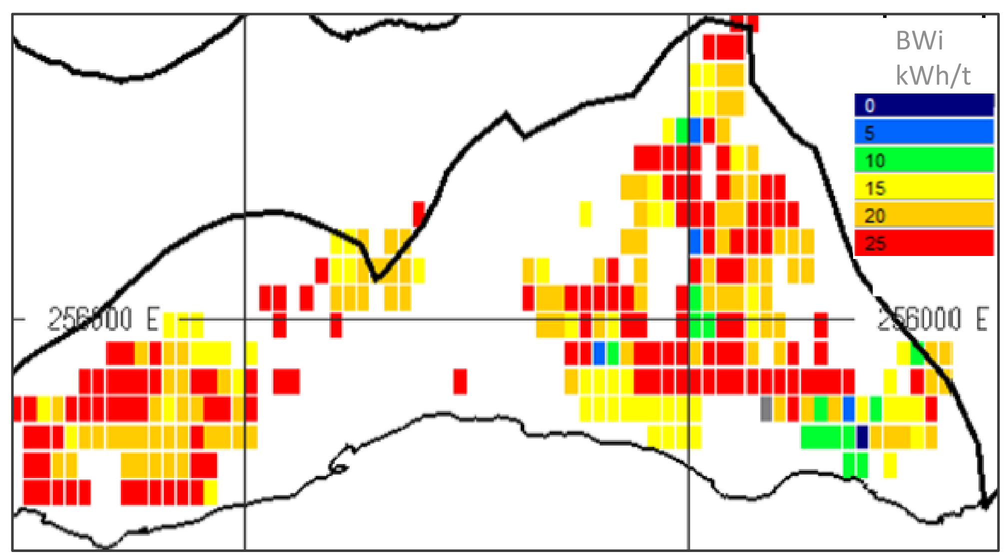
Thus, a model of BWi developed using combinations of these variables for each weathering type.



This model was then applied to the block model where the input variables had been estimated individually. An example of the results are shown below.

The predictive models of BWi for each weathering zone were applied to the inputs at block scale.

Analysis of the results indicated that for two weathering types, the range of the input variables within the block model was greater than that used in the development of the regression models resulting in anomalous values.



Performance Modelling & Implementation

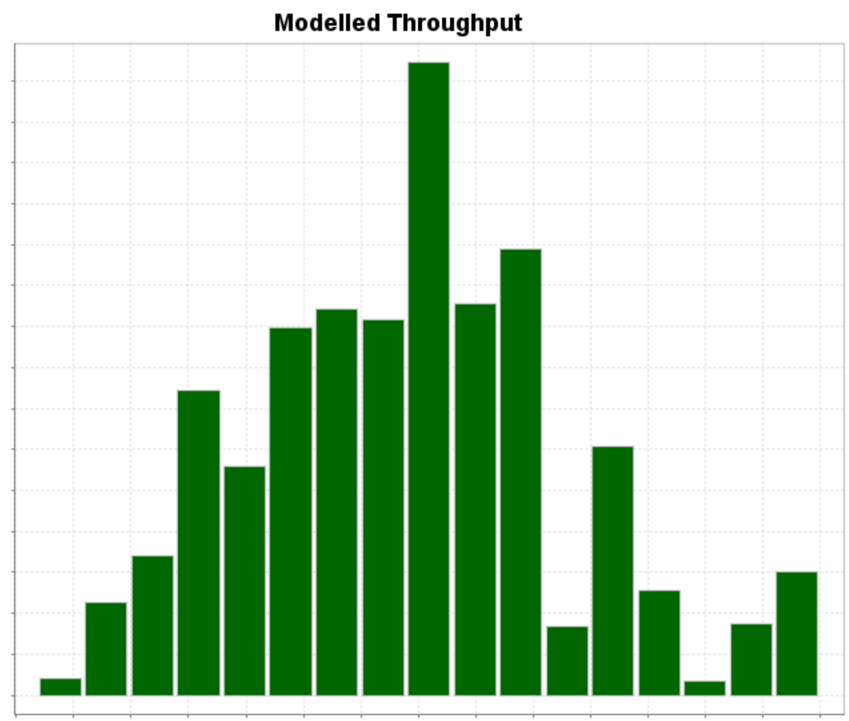
These inputs were then incorporated into throughput and recovery models and modelled spatially.

This model has been used to support mine and production planning through:

- assessing the long-term mine plan and identifying potential improvement opportunities
- providing forecast guidance and support for budgeting
- as an input into blast design

The throughput model has shown sufficient variability across the mine plan and schedule to warrant re-optimisation of the mine to smooth.

At present, the empirical 'engineering' models for blast fragmentation are predicting the mean fragmentation under a set of assumptions and do not attempt to predict the full size distribution. Thus, blast optimisation is required to increase the proportion of the fines within the blast, which improves throughput.



Distribution of Modelled Throughput in primary ore (range is 350 tph)

Control

Control – Drill and Blast Optimisation

Drill and blast is the first step in the comminution and separation process and plays a major role in providing consistent and finer feed to the mill.

The energy and cost of drill and blast is relatively less compared to the crushing and grinding breakage downstream.

The objective of the control component was the optimisation of drill and blast to improve fragmentation and throughput for the harder fresh ores while minimising dilution and ore loss.

This involved a thorough analysis and assessment of engineering options given the variability that was currently being observed and was being modelled in the previous section.

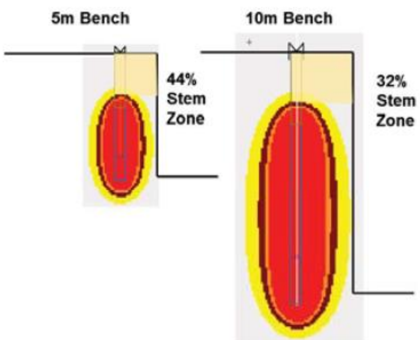
The project was implemented through a series of carefully monitored blast trials of the selected options to characterise the changes and validate the benefits.

Prior to the drill and blast optimisation component of the program, BHX were operating using 5m benches, mined in 3 flitches.

Bench Height – Move from 5m to 10m benches

Fragmentation measurements from photographic analysis of the 5m benches indicated that the existigh blast designs produced coarser fragmentation in the transition and primary ore.

An energy distribution analysis showed that ~44% of the bench had very little explosive energy. This was one of the main reasons for coarse fragmentation, particularly in the top flitch.



Explosive energy distribution in 5m and 10m benches

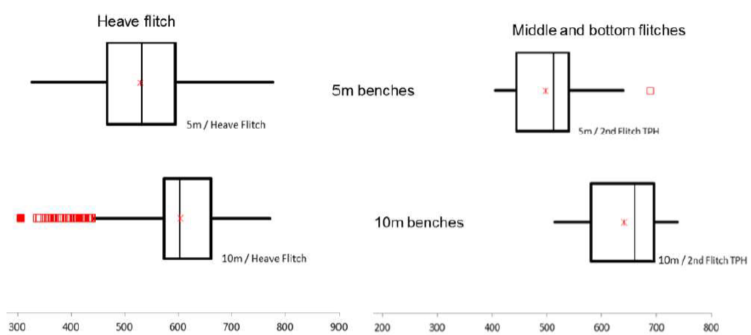
Hence the first step was to improve explosive energy distribution by increasing the bench height to 10m.

Trial blasts using a powder factor of 0.8 kg/m3 on 5m and 10m benches that were located side by side to minimise and geological variations.

Video analysis of the blasts indicated some cratering at the initiation point and along the control row but minimal in the body of the blasts. Fragmentation of the muckpiles was measured using the SPLIT photographic methods. Ore from each flitch campaigned through the mill for a minimum of 24hours with primary crusher product belt cuts which were sized.

The muck pile fragmentation analysis photos showed little difference between the benches. However the sized belt cuts showed significantly more fines for the 10m bench compared to the 5m benches.

On average the ore from bottom flitches resulted in high throughput than the heave. **The 10m benches showed higher throughput than the 5m benches by ~24%.**



High Energy Blasts

Prior to the predictive model being completed, very hard primary ore was encountered which produced coarse fragmentation and lower throughput especially from the heave flitches.

This led to a trial blast program with higher explosive energy while managing dilution. Again ore from these blasts were campaigned through the mill to quantify the impact of the higher energies.

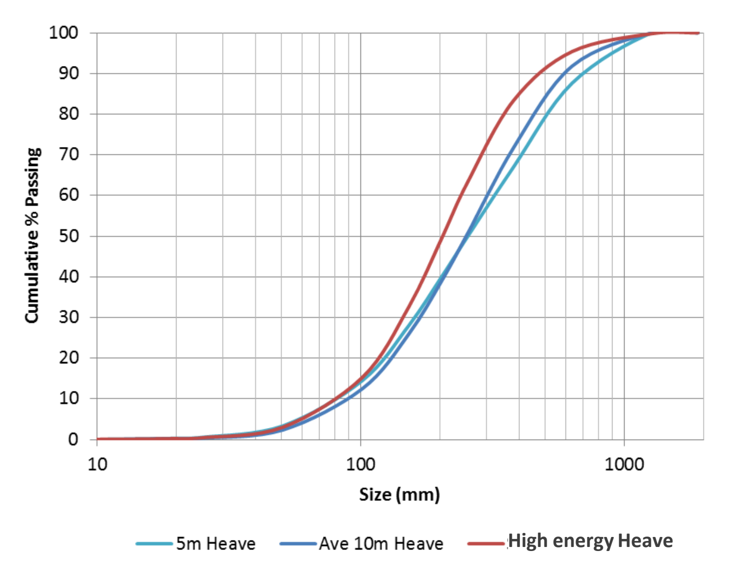
Three high energy blasts were trialed using:

- Drill diameter of 127mm & 152mm
- Powder Factors of 1.2 & 1.4 kg/m3
- Same initiation timing

High Energy Blasts - Outcomes

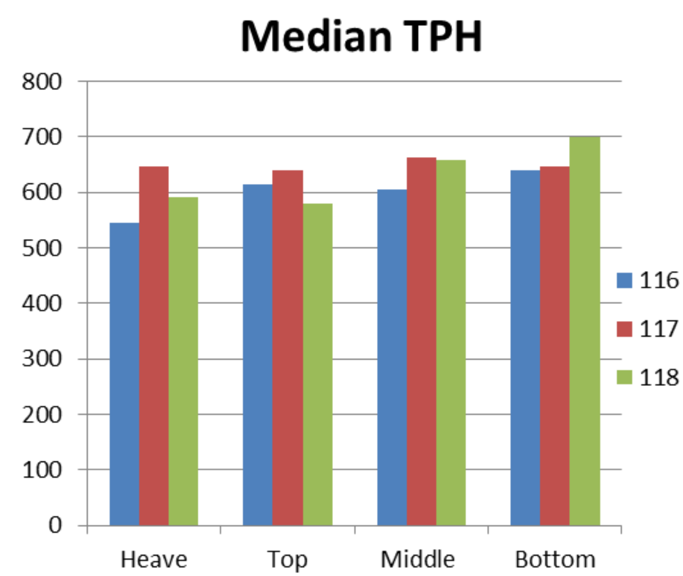
Fragmentation measurements indicated finer fragmentation than the lower energy blasts for either the 5m and 10m benches.

This was particularly evident for the heave flitch as shown below.



In terms of throughput:

- The lower flitches had a higher throughput than the heave flitches – as expected
- the high energy blast using the smaller diameter holes gave the highest throughput for the heave flitch by ~10% due to more uniform energy distribution
- The median throughput was 25-50% higher than the design throughputs and those that had been experienced for primary ore.

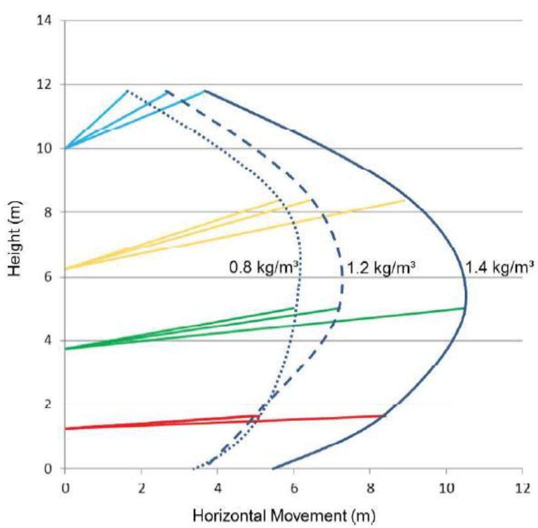


Dilution & Damage Control

In operations where dilution and damage are critical issues, blasts are often designed with low energies to minimize the impacts. However this can often lead to poor production efficiencies.

An alterative approach to managing dilution is to understand the blast movement dynamics from monitoring and modelling, as shown below, and adjust the position of the ore blocks/ dig lines.

This approaches minimizes dilution and ensures production efficiencies are maintained.



Another consequence if high energy blasts was the tendency to activate faults and cause damage to nearby walls.

To prevent this the approach of using an active split – a presplit along the final row of a production blast with holes at half the spacing and decoupled using a small base charge of emulsion.

The active split and the results of the face behind the split are shown below.

Sustaining the Changes

As in many cases, people working together for a common goal was one of the impacts of undertaking the work. The drill and blast operations became a tighter knit unit with personnel cognizant of each others contributions and impact on the outcomes. Noticeable changes included:

- Consistency in delivering achievable outcomes in a timely manner evolved into a infectious ‘can do’ mentality.
- Individuals who were striving to improve took the opportunity of further training to build high levels of competence in their roles.
- These individuals then enabled the learnings to be populated throughout the D&B teams.

These people changes were supported through process changes which included:

- QA/QC
- Blast Master concept
- Guidebook approach

<u>QA/QC</u>

- Process to validate the execution of the blast design
- The outcome was a preblast evaluation report against which the performance of the blast could be assessed.

<u>Blast Master</u>

- A process to connect the geology, grade control and geotechnical mapping
- Provides a plan of all block to be blasted on a specific level prior to blasting and mining
- The Blastability Index, powder factor guidance derived from the predictive component of the program were integrated with the structural mapping from the pit and the grade control

<u>Handbook</u>

- A guide book of operational procedures
- Contains a set of design guidelines for the various blasting types and domains
- Procedures for grade control and mining are also included so the D&B team are also defined.

Contact Us

For More Information

Head Office

40 Isles Road
Indooroopilly QLD 4068
AUSTRALIA
Phone : +61 7 3365 5842

JKTech South America SpA

Av. Vitacura 2670, Piso 15
Las Condes Santiago
CHILE
Phone: +56 2 2820 4355

Website & Email

www.jktech.com.au
jktech@jktech.com.au

Social Media

Facebook.com/ JKTech.Pty.Ltd
Twitter.com/jktech