

Quantification of the impacts of rock mass quality on stope width control and pillar stability in a hard rock narrow reef mine

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Objectives

The main objectives of this research are:

- ▶ To determine the contribution of rock mass quality to the poor stope width control and pillar stability.
- ▶ To determine and quantify the impact of rock mass quality on pillar stability
- ▶ To determine and quantify in monetary terms the impacts of rock mass quality on mine profitability and the business plan.

High stope widths are associated with higher demands for ground support, and it is also important to quantify this in monetary terms, and to be able to give management information that supports business planning and viability assessment.

Problem and Objectives

Problem: Failure to achieve correct SW linked to poor ground by both teams in both good and poor ground conditions

The main objectives of this work are:

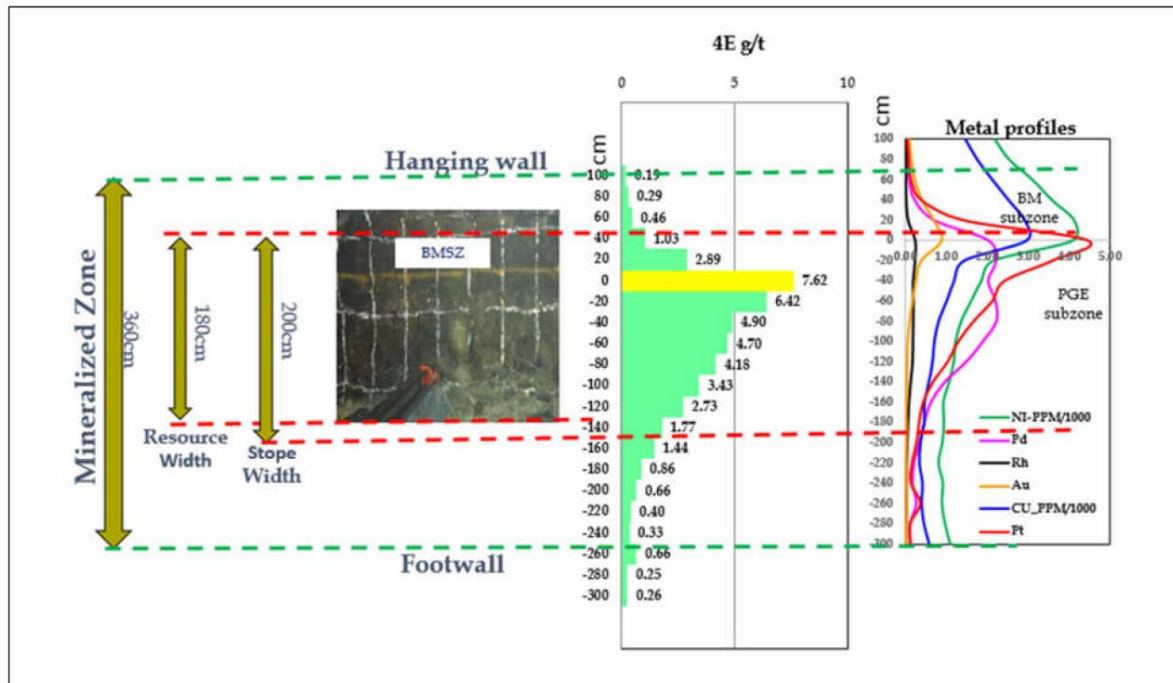
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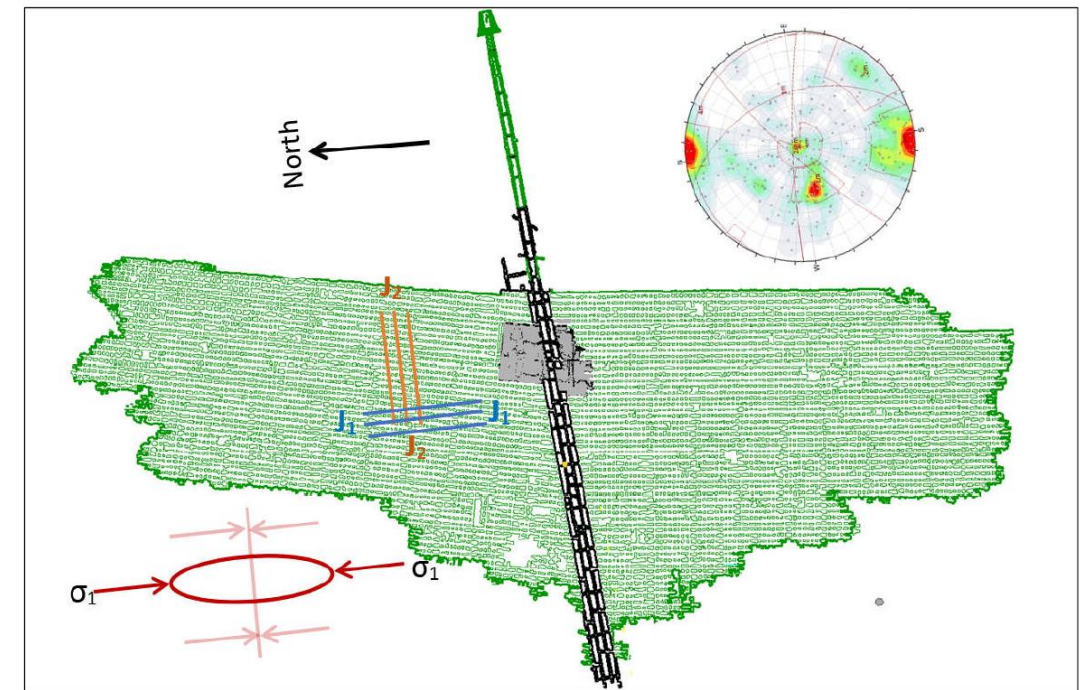
Research Hypotheses

- ▶ Contribution of rock mass quality to poor slope widths
 - ▶ H0: Rock mass quality does not contribute to poor slope width control
 - ▶ H1: Rock mass quality contributes to poor slope width control
- ▶ Impact of rock mass quality on pillar stability
 - ▶ H0: Rock mass quality does not have a quantifiable impact on pillar stability
 - ▶ H1: Rock mass quality has a quantifiable impact on pillar stability
- ▶ Monetary value of the impact of rock mass quality on the business plan
 - ▶ H0: There is no quantifiable monetary value of the impact of rock mass quality on the business plan
 - ▶ H1: There is a quantifiable monetary value of the impact of rock mass quality on the business plan

Reef Profile & Geotechnical setting



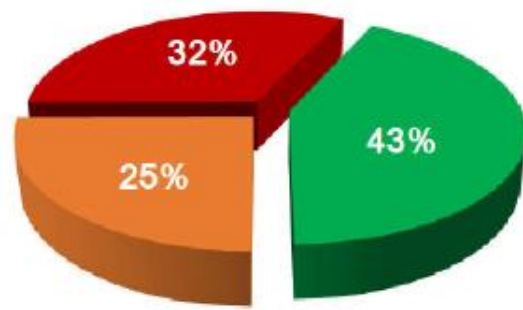
Mwatahwa et al (2015)



Mandingaisa (2012)

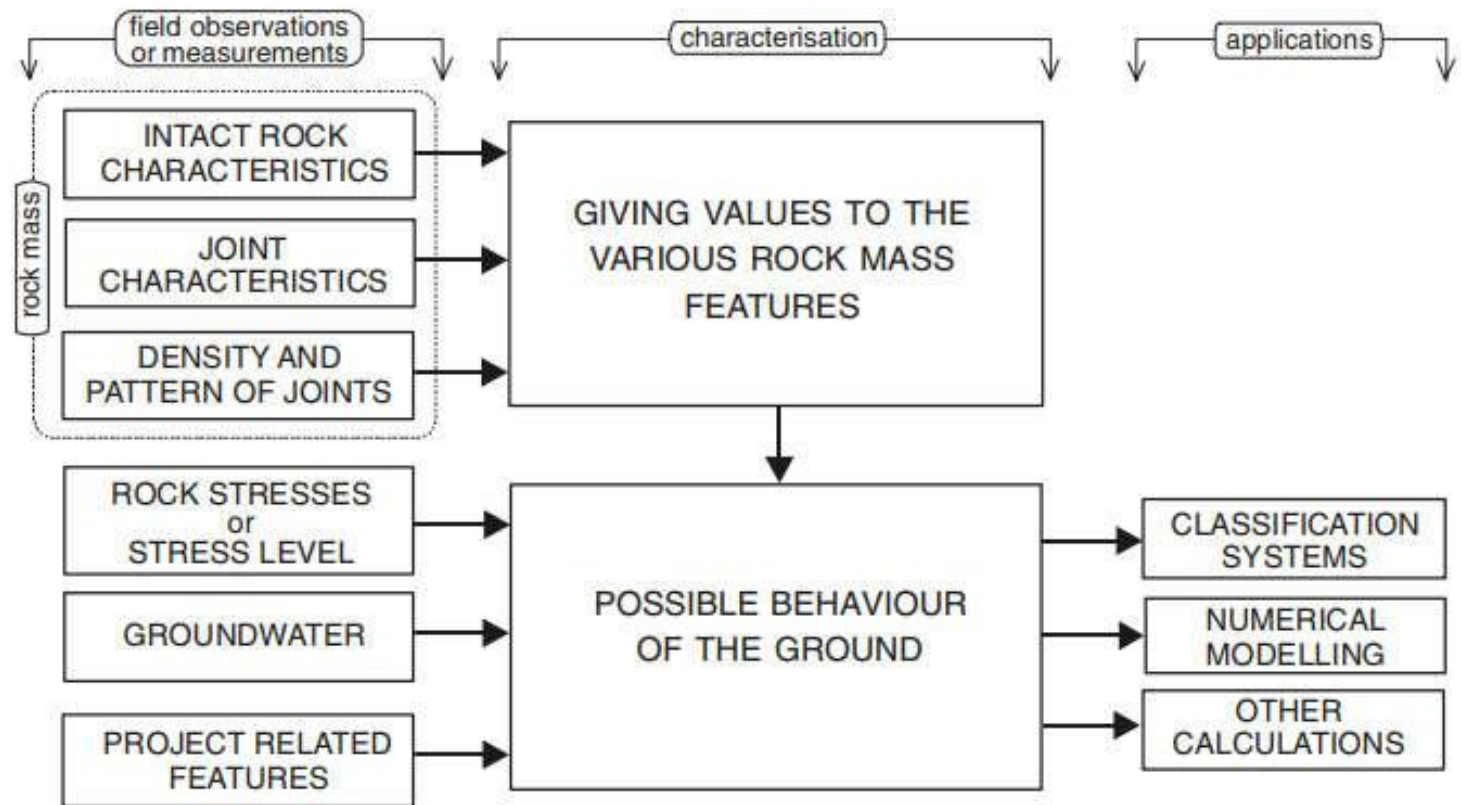
TARP & Joint characterization

Distribution of the Bords in Terms of Risk

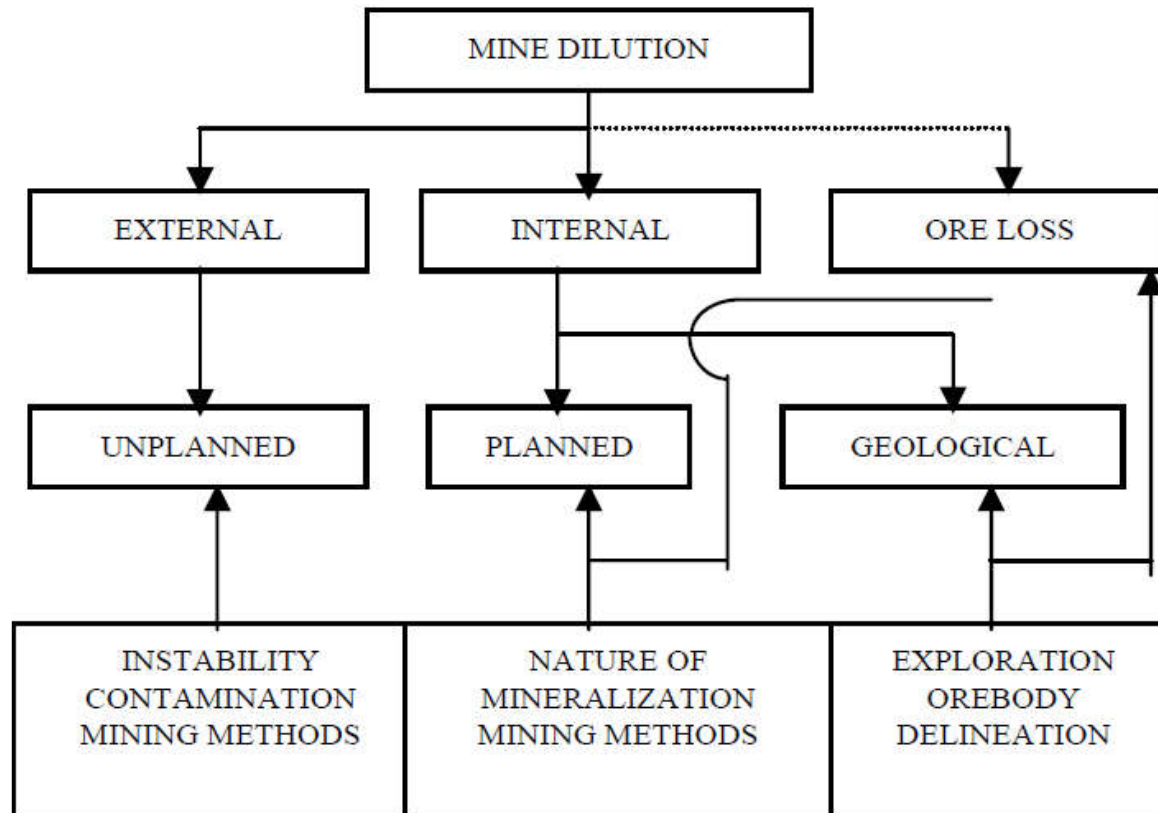


■ A (Low Risk) ■ B (Medium Risk) ■ S (High Risk)

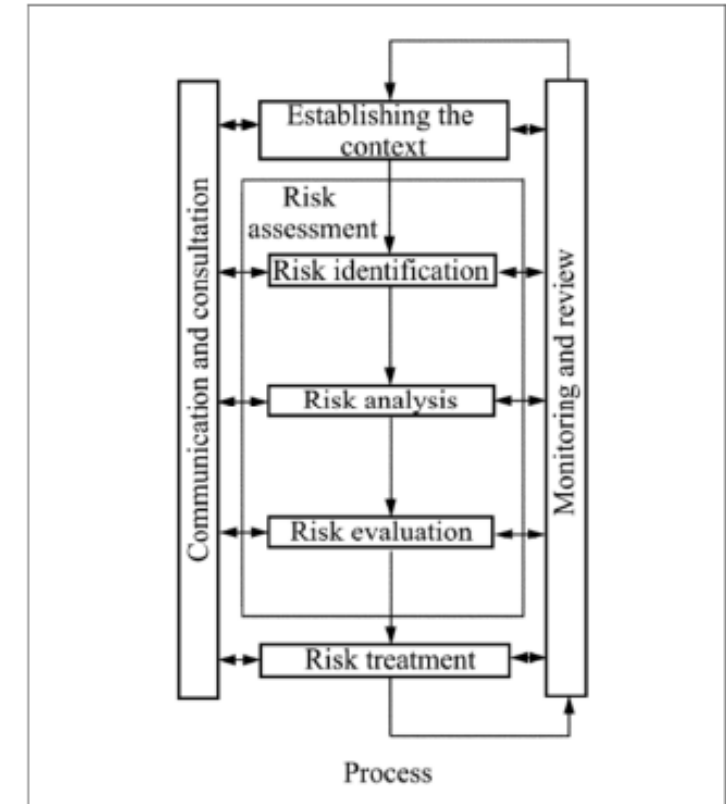
	A	B	S
1	Support missing	Whole line of support missing	
2	Brow smaller than 150mm	Brow larger than 150mm but smaller than 500mm	Brow larger than 500mm
3	Normal ground	Dyke	Flat dipping feature less than 60° to horizontal
4		Fault	Dome
5			Water dripping from rock wall
6		Fall of ground less than support spacing	Fall of ground greater than support spacing
7		Material change in face composition for example pothole	
8		Abnormal blocky ground	Pillar scaling



Dilution Characterization & Risk Assessment Process



Ercikdi (2003)



Standards Australia, (2009)

Data Collection

Rock Mass Quality

- ▶ Bieniawski RMR89 data
- ▶ Stope width data
- ▶ Team production figures

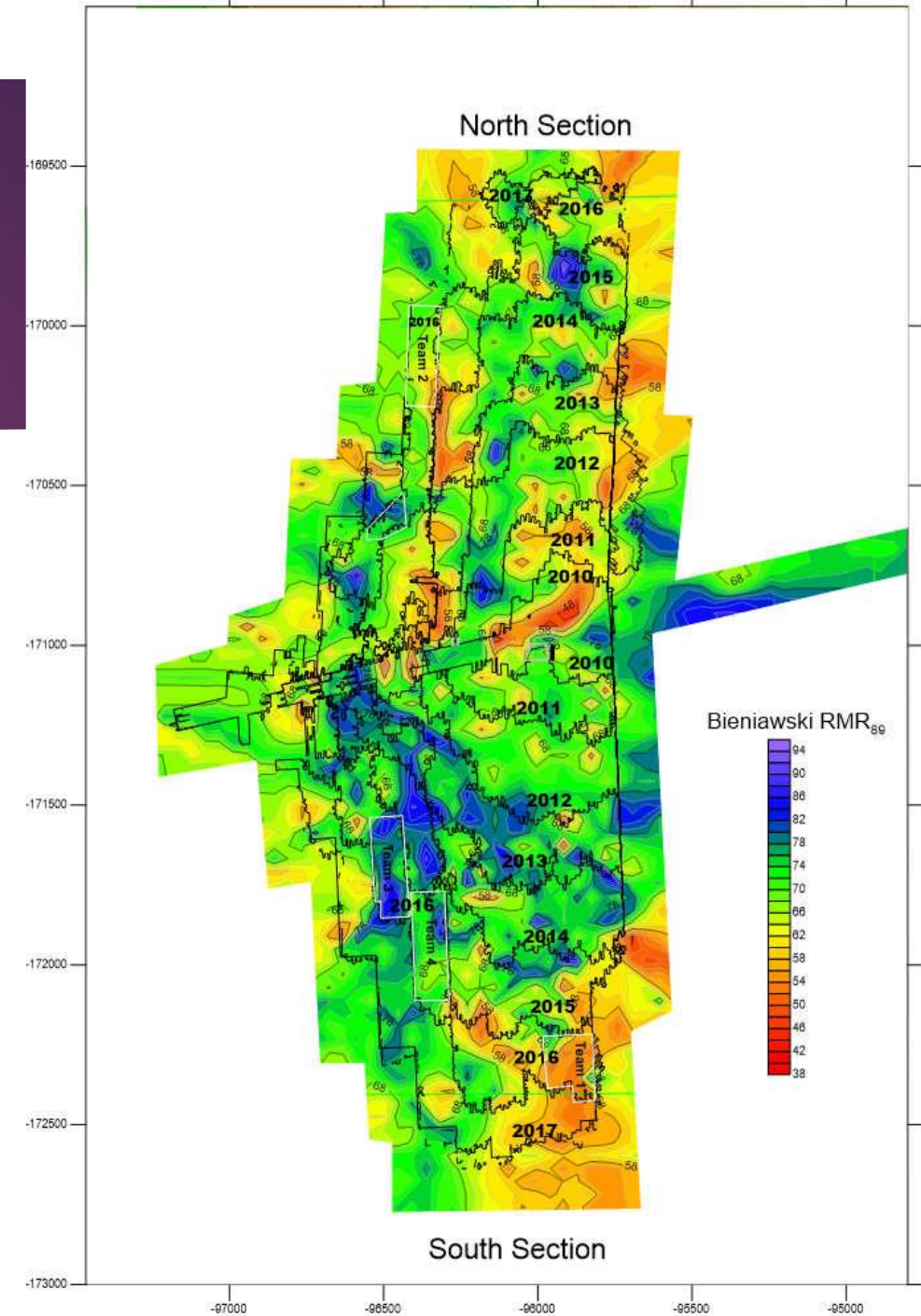
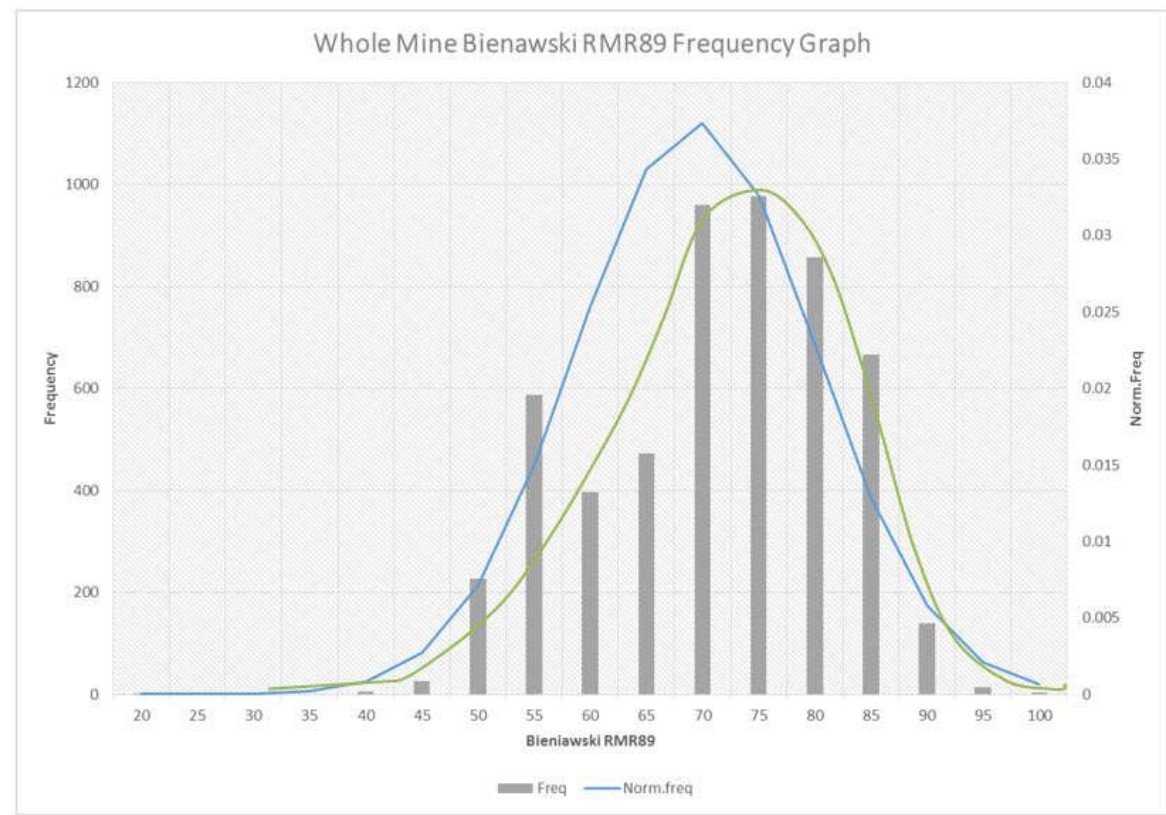
Effects on Pillars

- ▶ Number of pillars scaling, rehabilitated or showing stress fracturing
- ▶ The reasons for the pillar damaged or scaling were recorded.
- ▶ Pillar factors of safety was calculated for all the pillars within these areas.

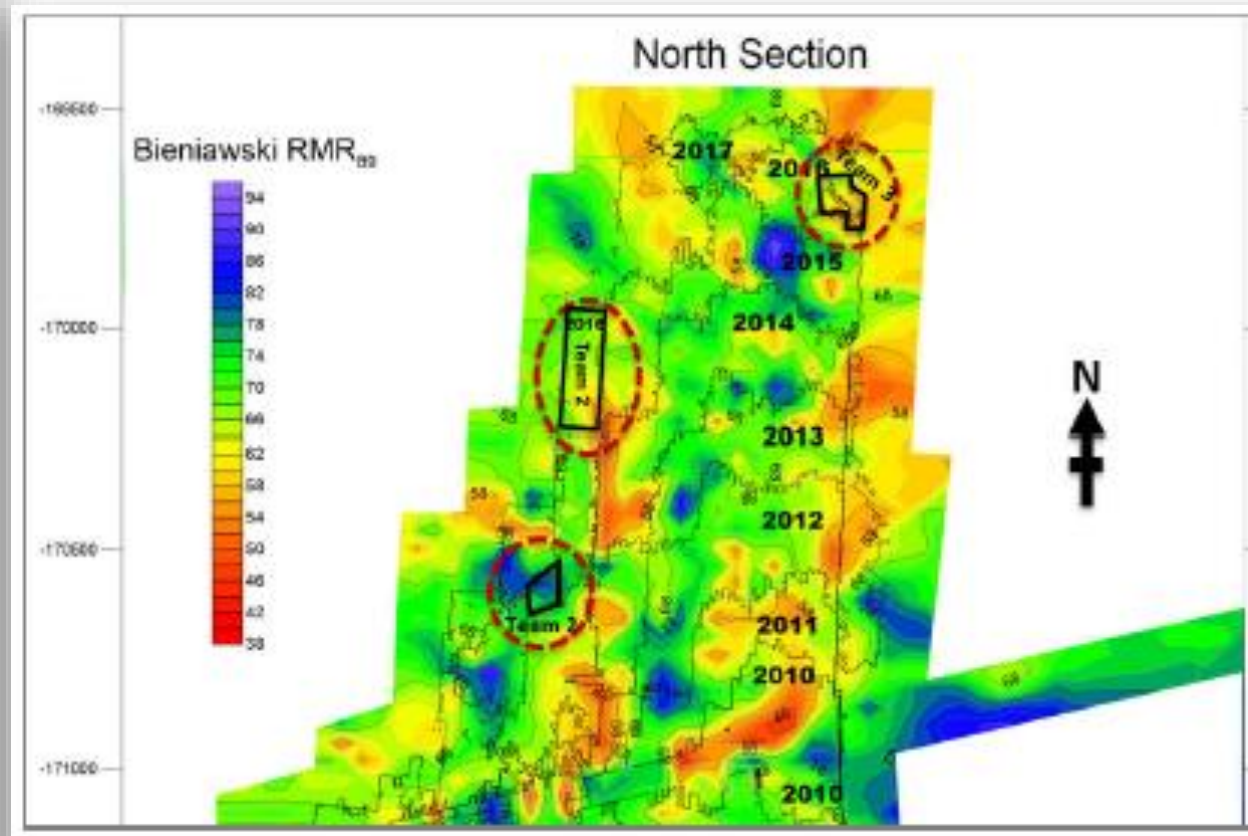
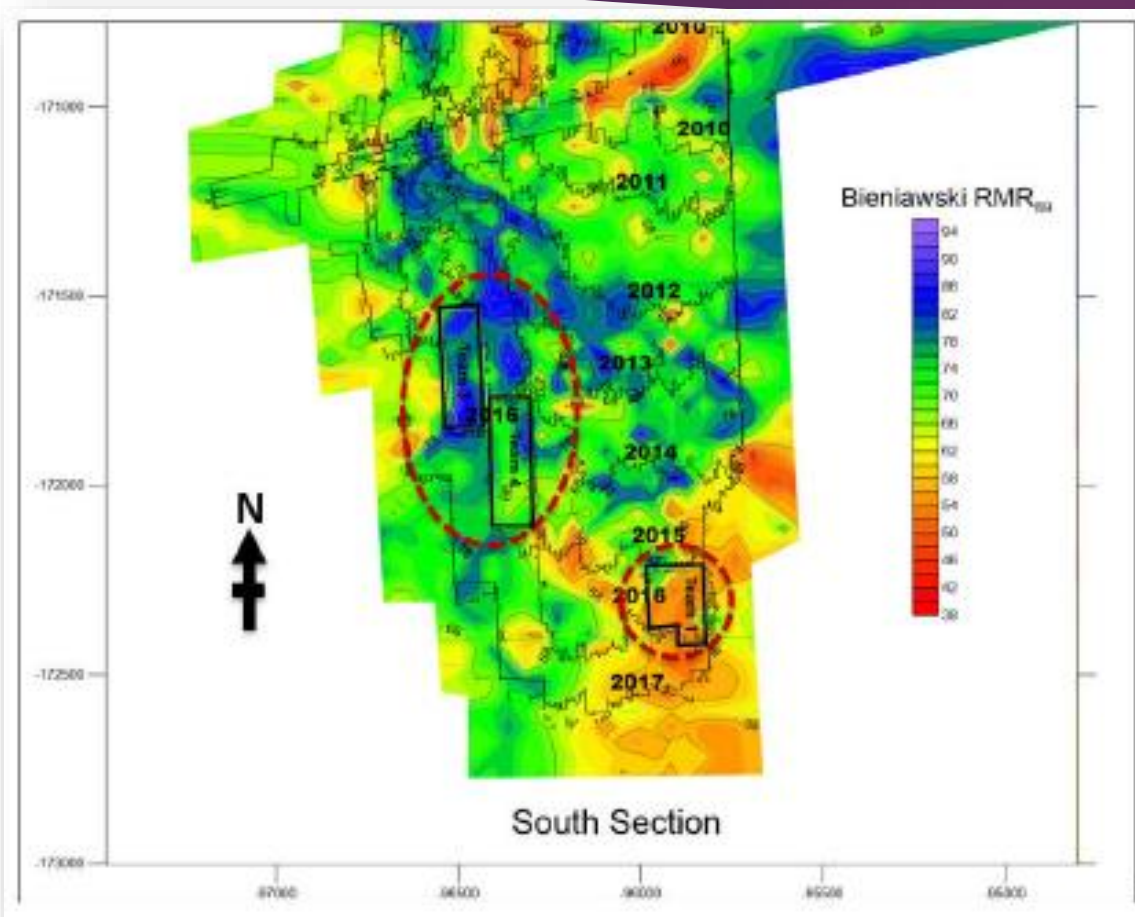
Support Cost & Installation

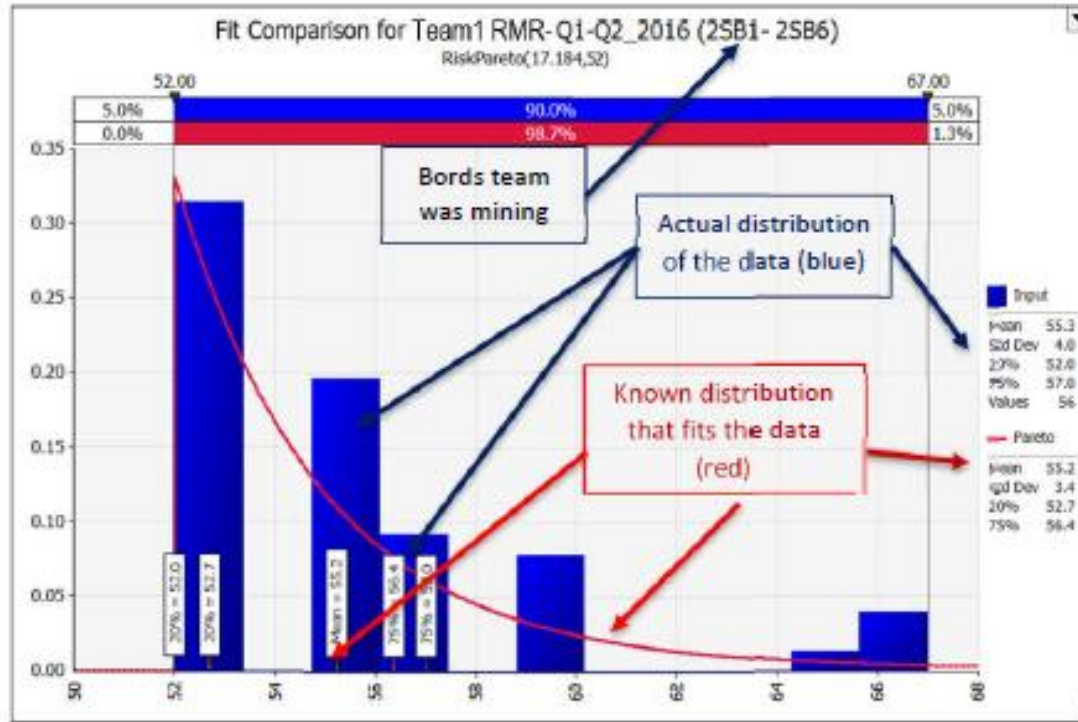
- ▶ Time and motion study on the automation of the installation of cable anchors in supporting poor rock mass quality zones.
- ▶ Regression analysis and Monte Carlo simulation in @Risk software was used to generate probability distribution functions and analysis histograms.

Bieniawski RMR_{89}



Bieniawski RMR_{89}





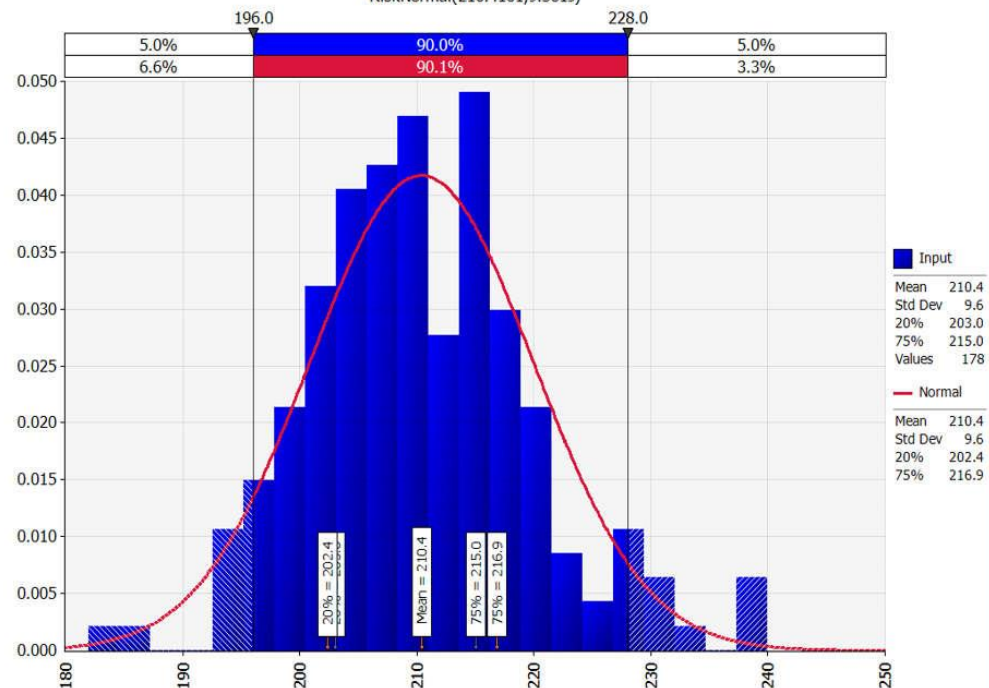
- Team 2 claimed to have been affected by rock mass quality in their achievement of mining stope width
- The team claimed to have been operating in the same zone as team 1.

Pallisade
@Risk
Software

Team 1

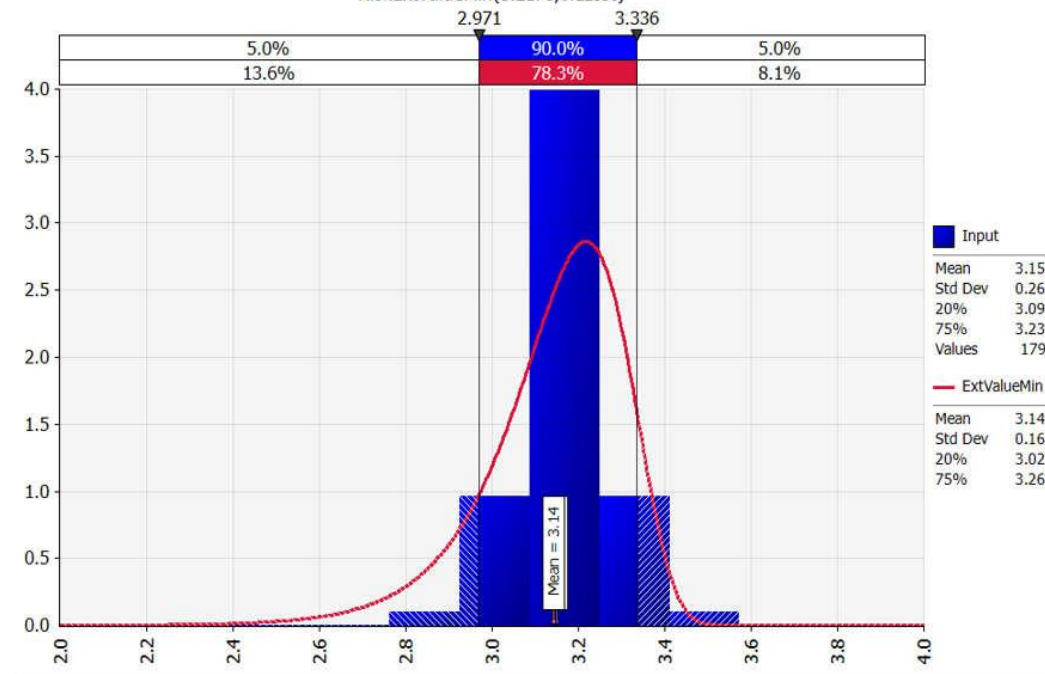
Fit Comparison for Team 1 Stope Width_Qtr1_2016-Q2_2016

RiskNormal(210.4101,9.5619)



Fit Comparison for Team1_Mining-Actual Grade (MCF)_Qtr1_2016-Q2_2016

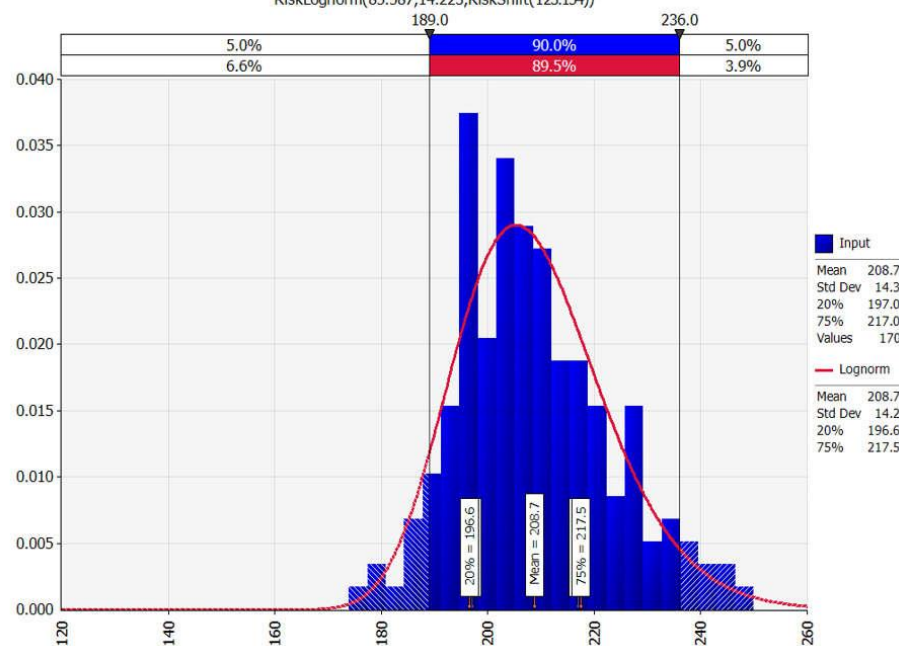
RiskExtValueMin(3.2176,0.12850)



Team 2

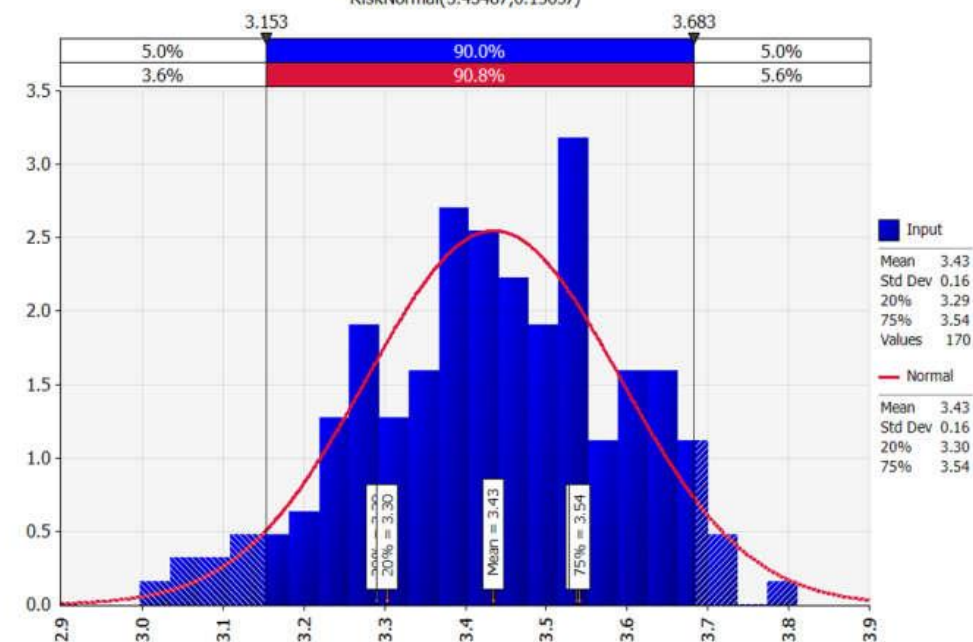
Fit Comparison for Team 2 Stope Width _Qtr1_2016-Q2_2016

RiskLognorm(85.587,14.223,RiskShift(123.154))



Fit Comparison for Team 2 Actual Grade (MCF)_Qtr1_2016-Q2_2016

RiskNormal(3.43487,0.15657)



Team Status

- ▶ Team1: SW 210.4cm (3.02g/t), RMR 50.4
- ▶ Team 2: SW 208.4cm (3.43g/t), RMR 72.1
- ▶ Pillar rehabilitation losses – 5.7% of pillars

Team 2 vs Team 1: Observations

- ▶ Poor drilling of back holes (not parallel)
- ▶ Overcharging of holes
- ▶ Inconsistency in the use of poly pipes to decouple the charge in perimeter holes
- ▶ Non-adherence to blasting pattern - burden spacing
- ▶ Batching unit on the charging unit not working

(Serious unwarranted losses)

Interventions

1. Different blast pattern for high risk ground (post splitting)
2. Direct supervision by miner on the drilling of the holes
3. Strict adherence in the use of poly pipes to decouple explosives in perimeter holes

Results

- ▶ Team1: SW 210.4cm to 205.1 (3.02 to 3.22g/t), for 3 teams in poor ground – R7.5m/annum
- ▶ Team 2: SW 208.4cm to 204.2 (3.43 to 3.60g/t), Equates to – R221.04m/annum (malpractices) for 6 teams in mining in good ground with claims of poor ground
- ▶ Pillar rehabilitation losses – R0.6m

Long Tendon Costs

Time benefit

Product	Installation time	Time benefit
AMS Full barrel cable anchors	30 minutes	-minutes
3.0m DT Flexibolts	11 minutes	19 minutes

Cost comparison

Product	Unit price (USD)	Cost benefit (%)
AMS Full barrel cable anchors	R242.19	21.5%
3.0m DT Flexibolts	R394.91	-%

NB: Always compare a support system cost than focusing on cost per unit

- Productivity increased by 25% for team in poor ground by using more expensive tendons

Conclusion

- ▶ R439.75m was saved due to implementation of the strategies and interventions.

Breakdown of savings was:

- ▶ stope width in poor ground R90m, Correction of malpractices R221.04m, Removal of cable anchor installation equipment R0.45m, improvement of efficiencies by introducing Flexibolts R127.8m and pillar rehabilitation -R0.6m.
- ▶ Poor rock mass quality is accountable for the 5% failure of pillars
- ▶ Poor rock mass quality can be ascribed to a potential loss of about 5.7% in grade.
- ▶ Malpractices - more costly than geotechnical risk at an average of R3.07m.
- ▶ Higher cost of Flexibolts is countered by benefit from the 19 minutes gain in time & reduction in number of personnel

THANK YOU

