

DRIVEN BY VA
LUE



Optimizing Slope Angles

with controlled blasting, slope

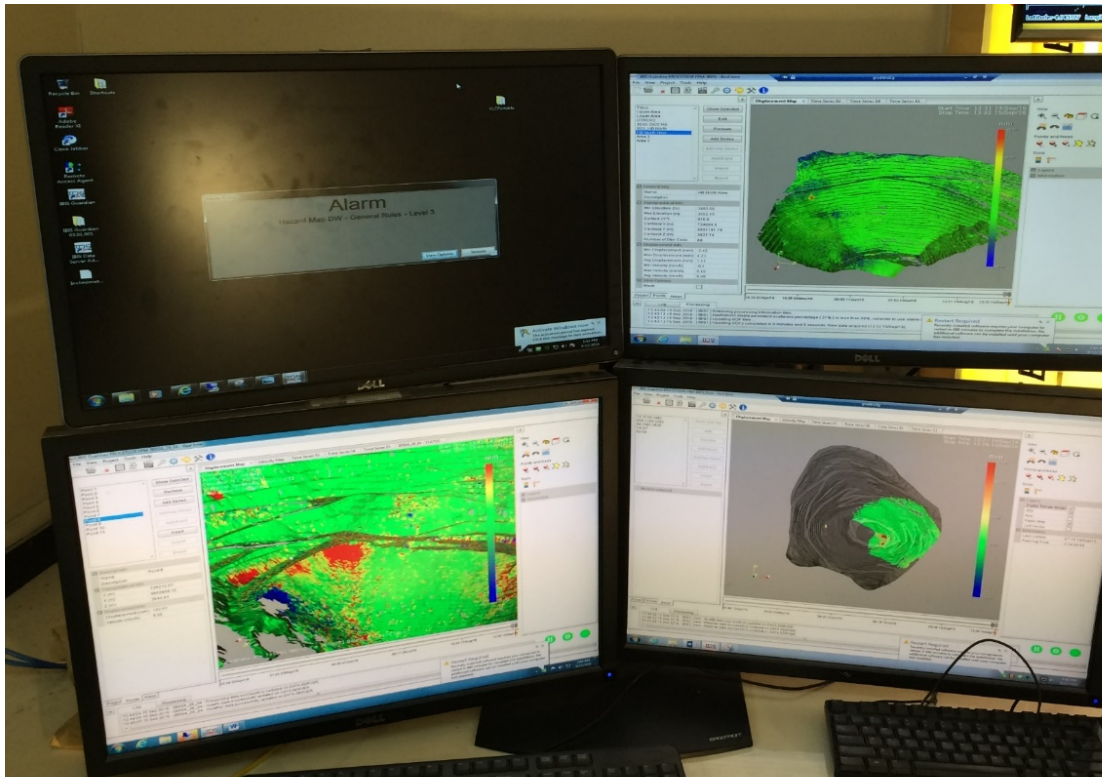
monitoring, and good

communication

Keith Taylor

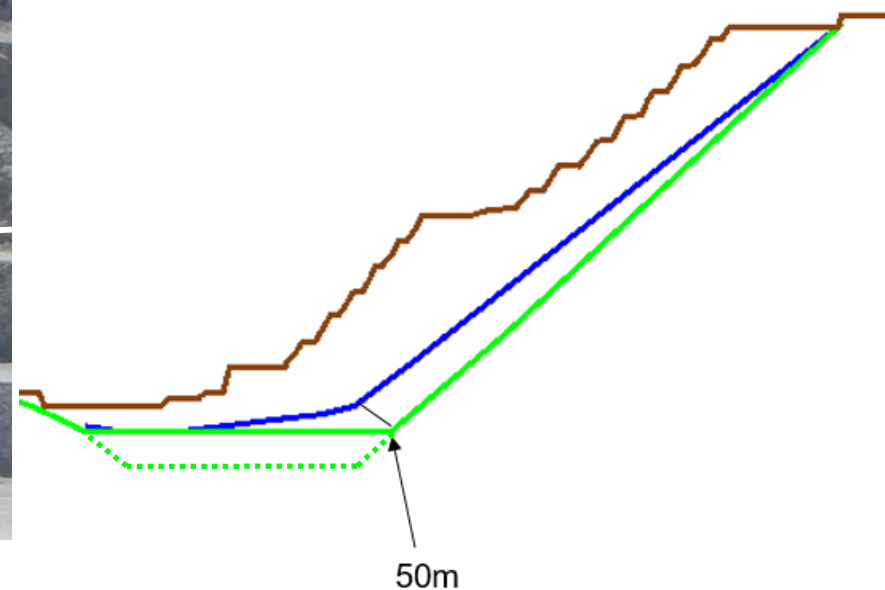
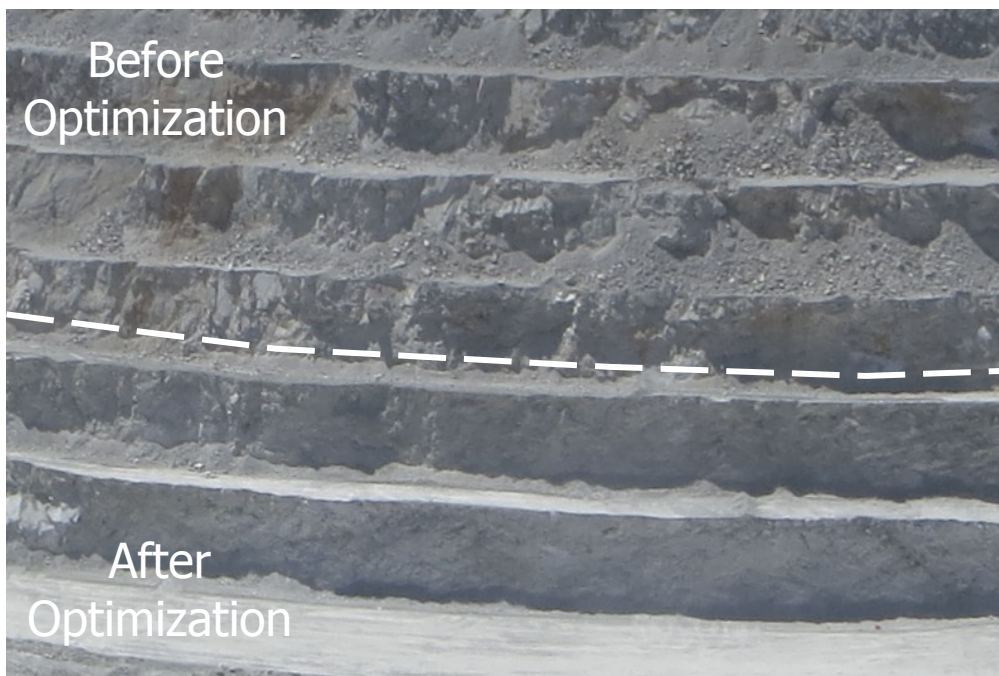
May 8, 2017

Geotech



Slope Optimization Value

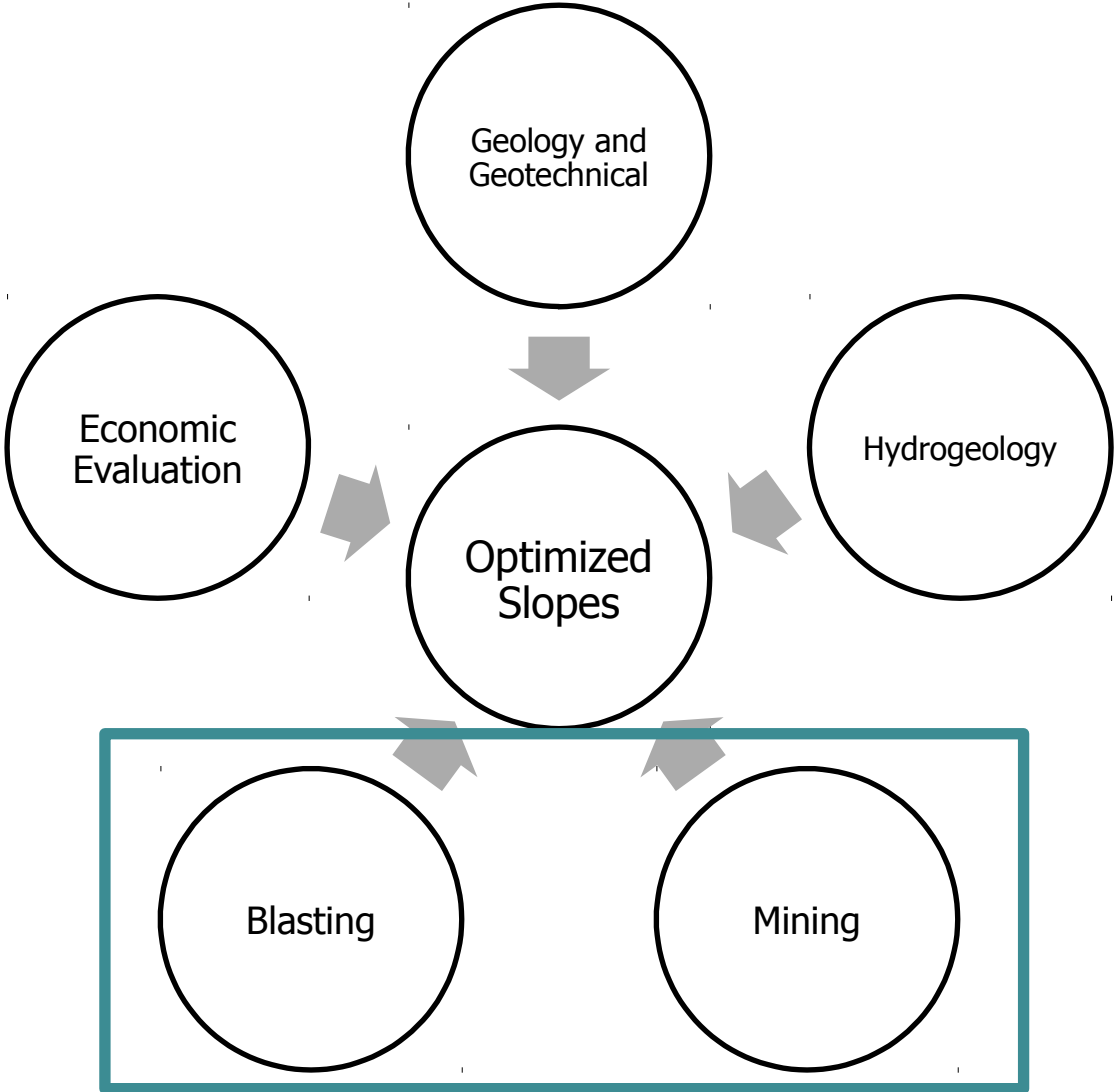
- **More careful construction means safer highwalls**
- **Steeper walls mean less stripping, more ore, or some combination of both**



Slope Optimization: Why now?

- **Not new in the industry, or at Freeport**
 - **1960's to the present**
 - **Recent published examples at Cripple Creek and Boddington**
- **What's different?**
 - **Top down support**
 - **Implementing all the wall control blasting techniques we have known about for years**
 - **Much better feedback with LiDAR scanners**
 - **Process, not project**

Slope Optimization Process



Wall Control Blasting

Design and Planning

- Blast Master Plan
- Detailed designs for each blast
- Frequency control timing
- Shot direction determined by geology

Preparation

- Production overbreak control
- Blast relief
- Bench Preparation

Monitoring

- Video monitoring
- Near and far field seismograph monitoring

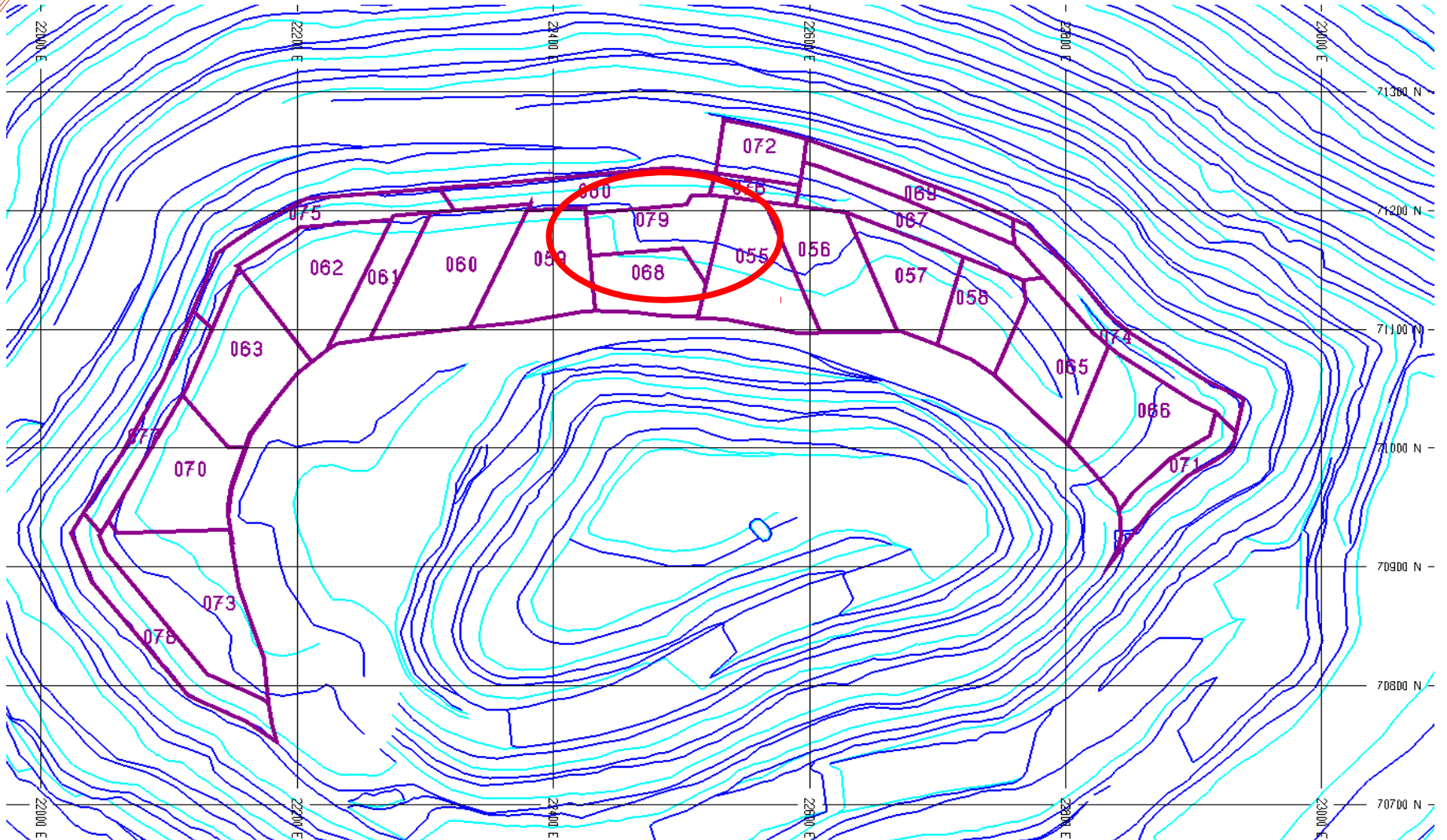
QA/QC

- PPV vs prediction
- Frequency vs simulation
- Drilling and loading accuracy

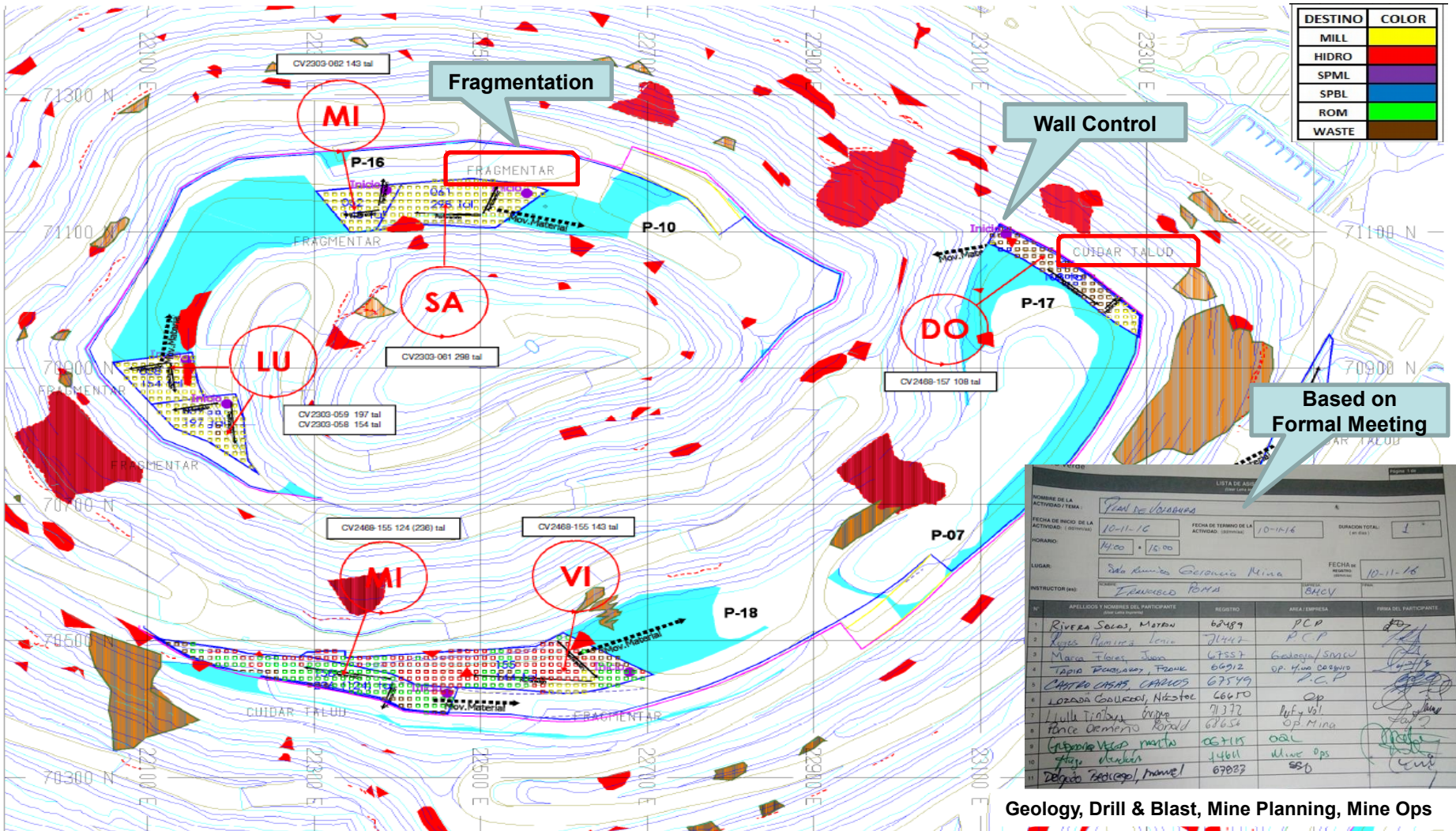
Reconciliation

- Excavated face inspected
- Cross section versus designs
- CBW, BEA, ISA analysis

Blast Master Plan



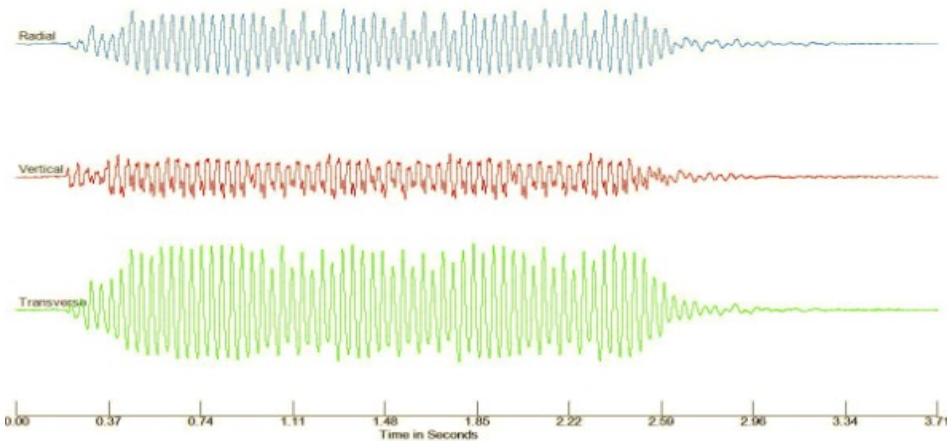
Blast Master Plan



Geology, Drill & Blast, Mine Planning, Mine Ops

Frequency Control Timing

Record: 7043201701041246510007.EVT Date: 04-Jan-17 12:46 PM Radial: 8.81 mm/s Vertical: 5.99 mm/s Transverse: 16.8 mm/s

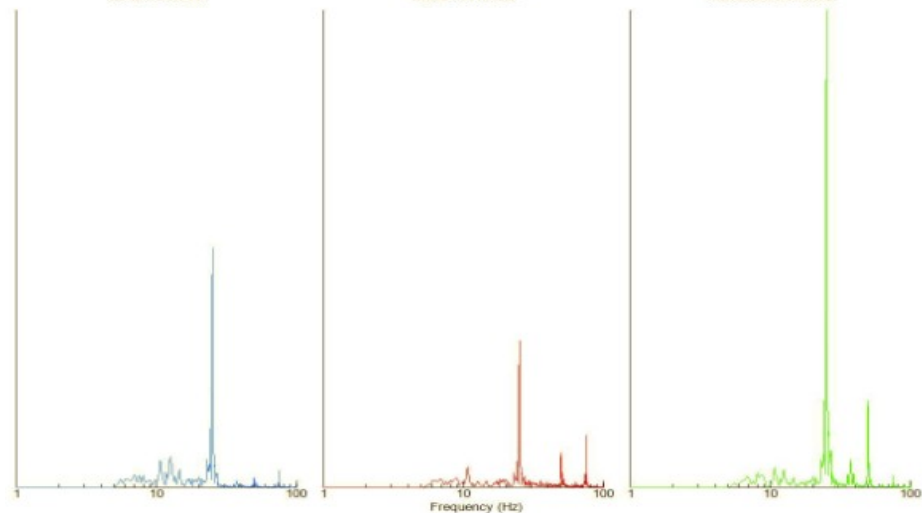


Fast Fourier Transform (FFT)

Radial: 25.00 Hz

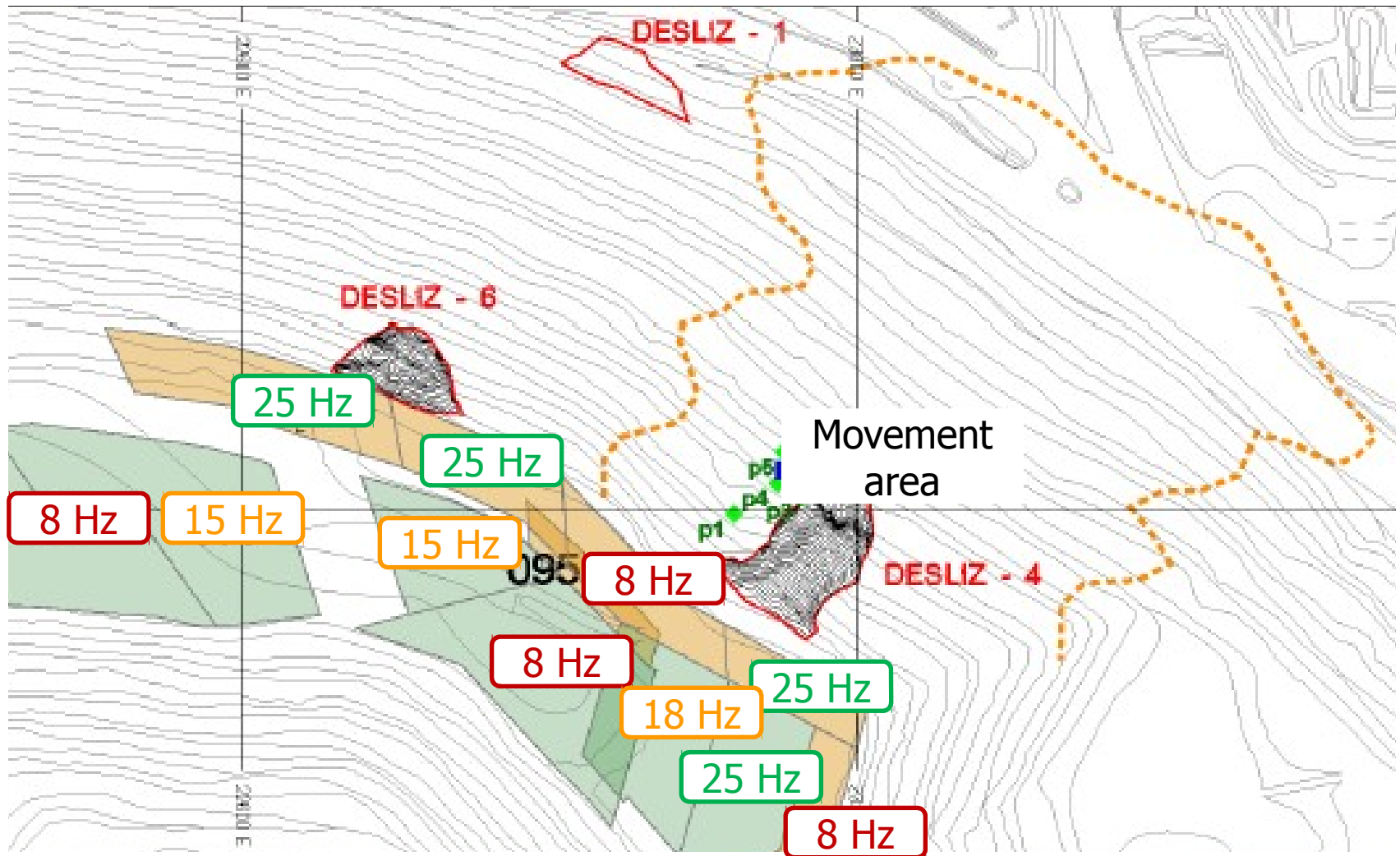
Vertical: 25.00 Hz

Transverse: 25.00 Hz

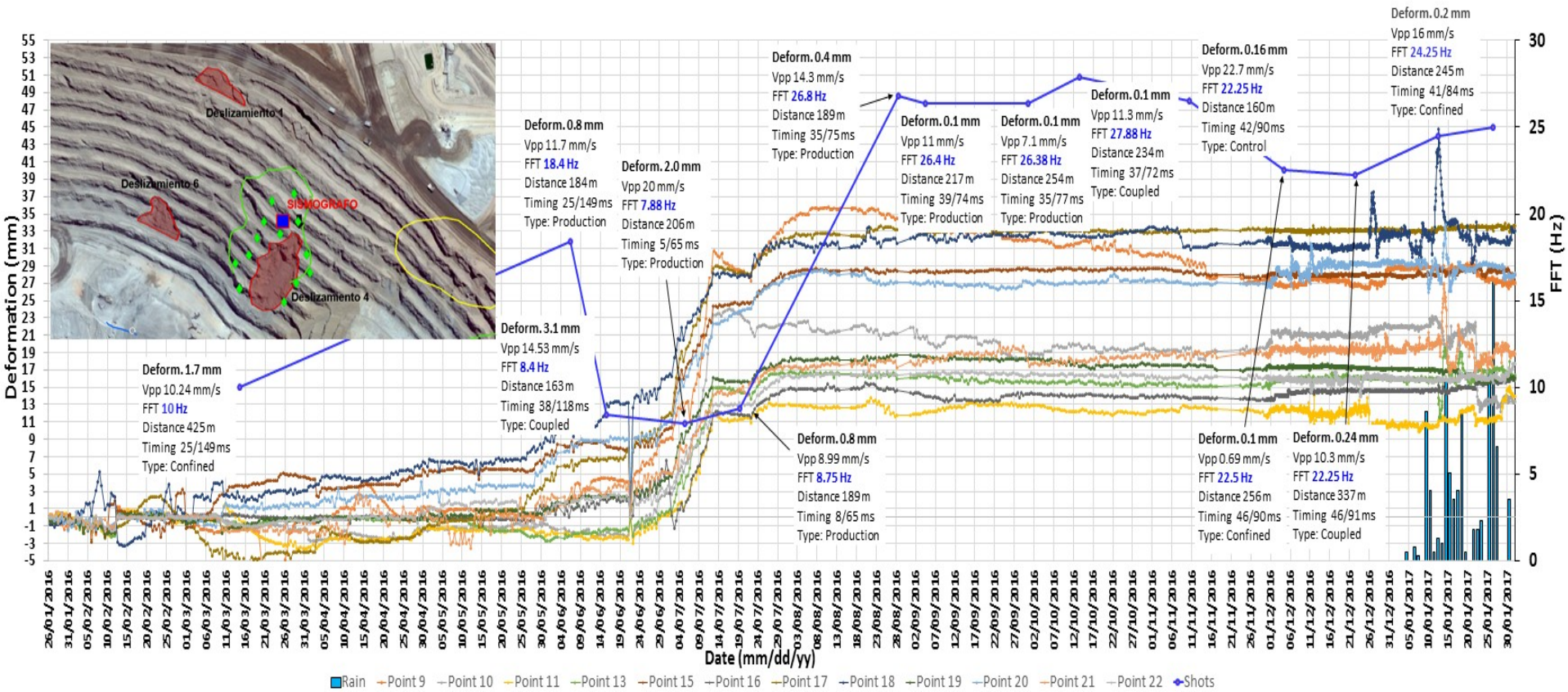


<p>Cerro Verde Project: CV2393-216 Type: CONTROL Like: YGD RCD: 85% UCS (Mod): 165 Output: Echelon Inclination: R Confinement: Free Face N° Free Face 2 Blastability Classification: B5 Estruc: Strike Daylighting Dip > 60° Timing (hole row): 4081ms Simulated Freq: Rad Freq_Ver Freq_Tra Hz 25 25 25</p>		<p>File: 7042201704101418270331.evt Number: 0331 Date and Time: 10/04/2017 02:18:27 p.m. SN: 7042 Seismic Trigger: 0.500 mm/sec Air Trigger: 97.5 dB Sample Rate: 2048 Duration: 40 Seconds Pre-Trigger: 0.500 Second Seismic Gain: 256 mm/sec Acoustic Gain: 148.2 dB Voltage: 6.00</p>	
<p>Peaks and Frequencies PPV Maximum: 14.2 mm/sec (16.43066 sec) Radial: 8.02 mm/sec @ 23.8 Hz (16.49414 sec) Vertical: 14.2 mm/sec @ 22.3 Hz (16.43066 sec) Transverse: 8.27 mm/sec @ 29.3 Hz (2.17822 sec) Vector Sum: 15.2 mm/sec (16.43115 sec) Displacement: 0.105 mm Acceleration: 2016 mm/sec/sec</p>		<p>Graph Information Duration: -0.314 s To: 2.927 s Seismic Scale: 10.0 mm/sec (2.50 mm/sec/div) Time Intervals: 0.50 sec</p>	
<p>R</p> <p>Cal 12.0 OK</p>		<p>V</p> <p>Cal 11.8 OK</p>	
<p>T</p> <p>Cal 12.0 OK</p>		<p>VS</p>	
<p>Fast Fourier Transform - Amplitude Spectrum</p>		<p>FFT Peak Frequencies</p> <p>Radial: 25.75 Hz (Amp = 3420.86) Vertical: 25.25 Hz (Amp = 5771.44) Transverse: 25.25 Hz (Amp = 4888.86)</p>	
<p>FFT Graph Information</p> <p>Range: 1 to 100 Hz Seismic Scale: 5771.44</p>		<p>Vertical (V) 25.25 Hz (5771) Transverse (T) 25.25 Hz (4889)</p>	

Frequency Control Timing



Frequency Control Timing

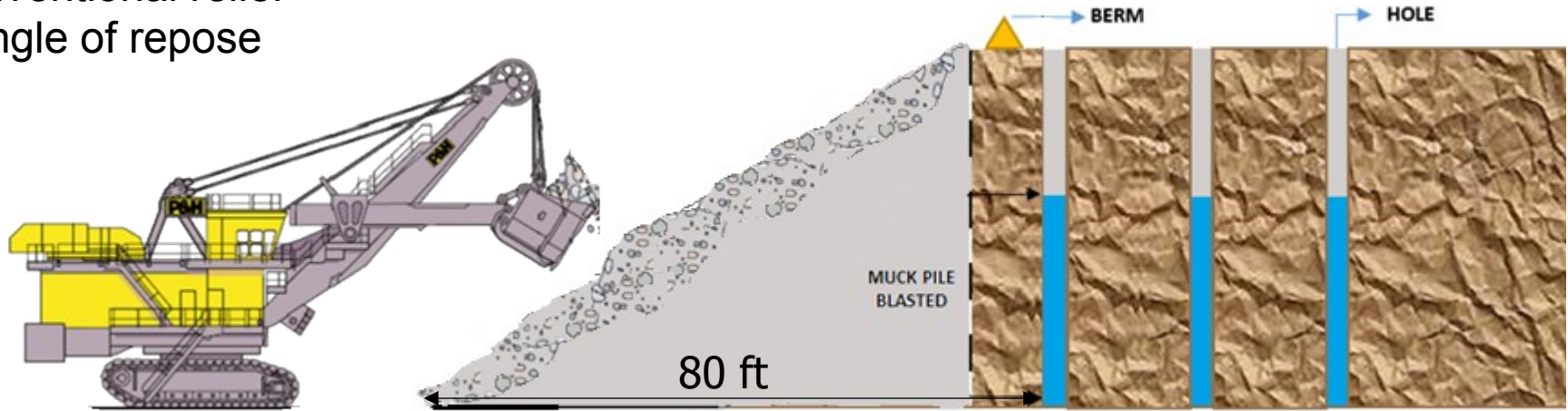


Frequency Control Timing

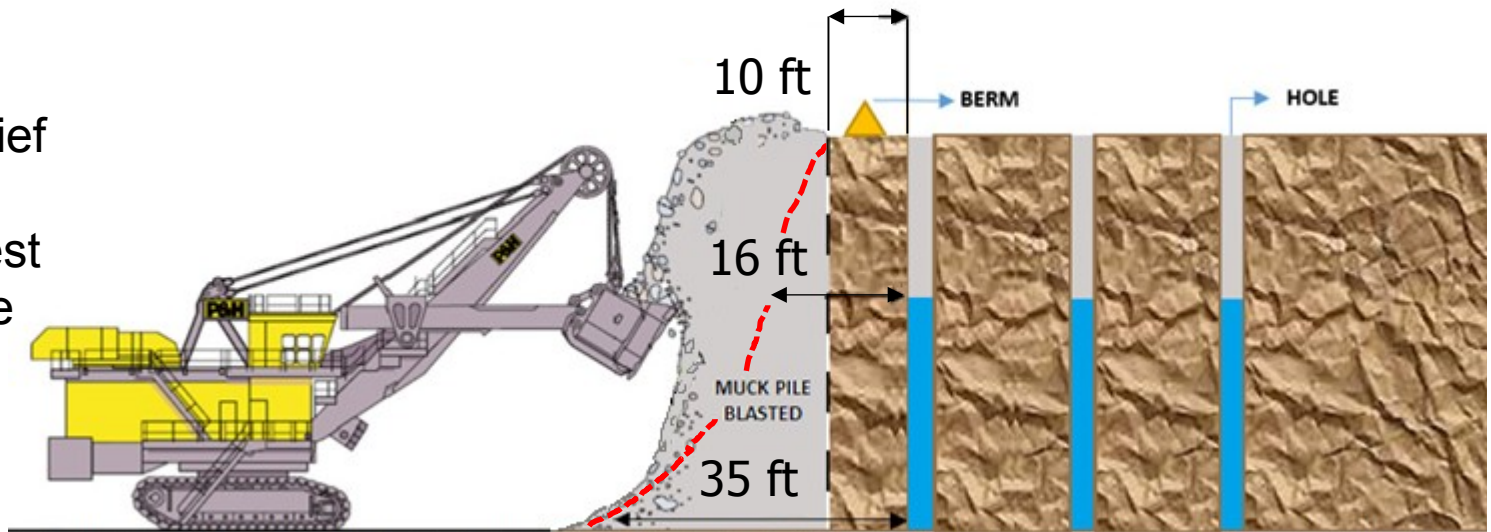


Blast Relief

Conventional relief
~ angle of repose



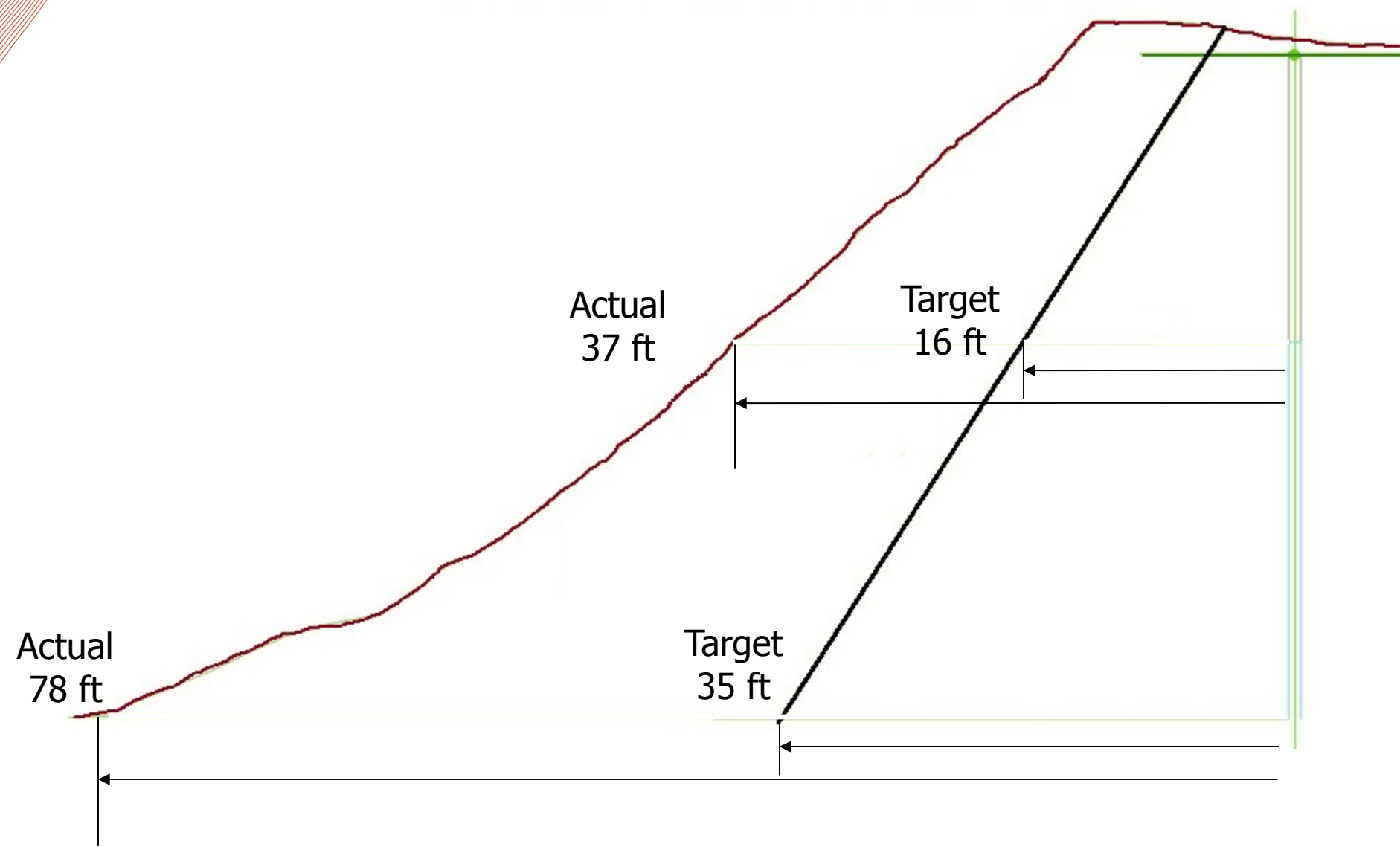
Wall control relief
60° to 65°
10 - 15 ft at crest
35 - 40 ft at toe



Conventional Blast Relief



Conventional Blast Relief

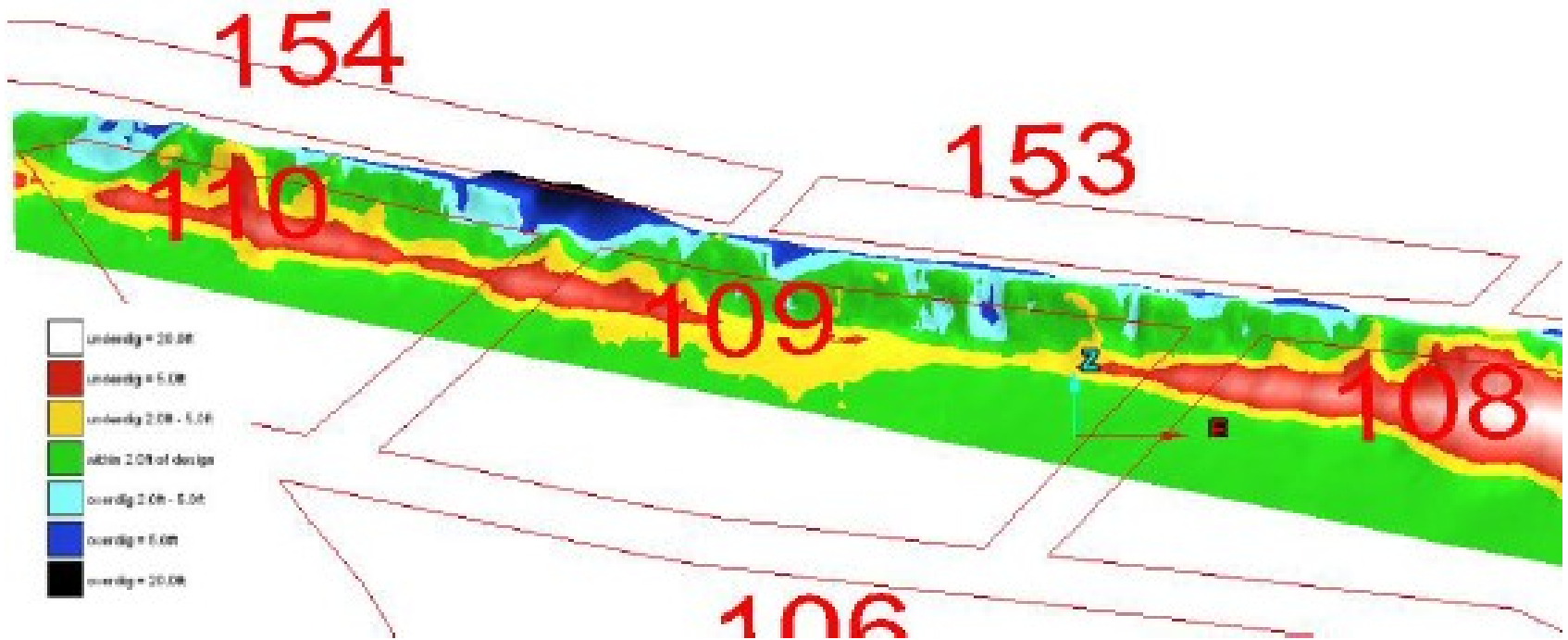


Wall control blast relief



Wall Control Blast Relief

LiDAR scan of free face compared to design free face



Underdig > 5 ft



+ / - 2 ft



Overdig > 5 ft

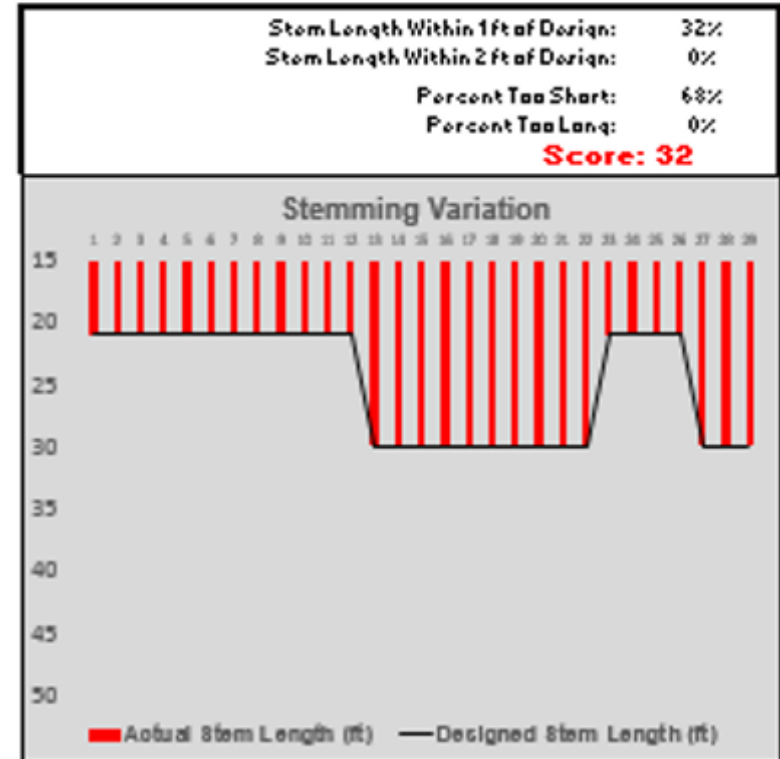
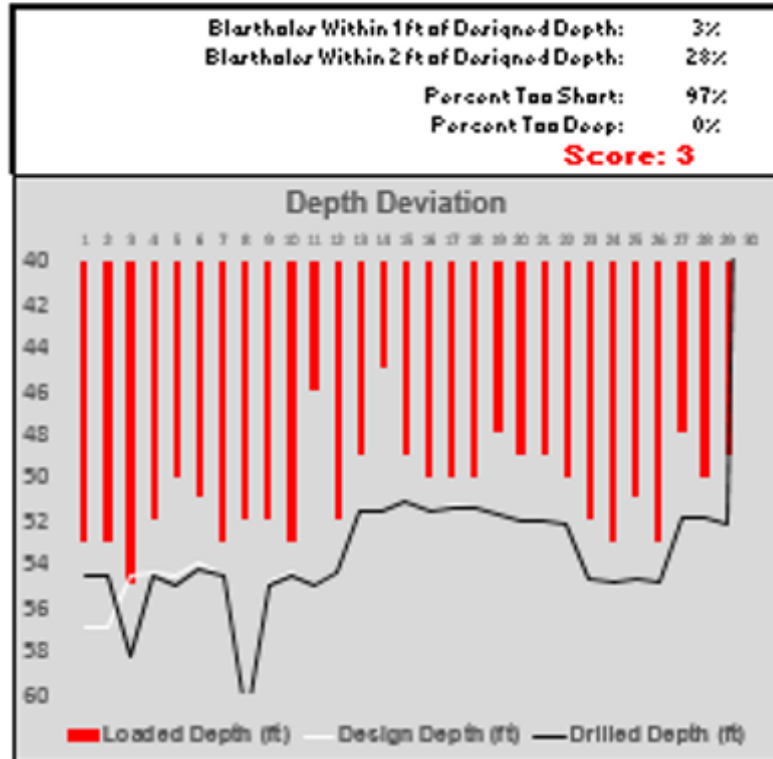
Video Monitoring



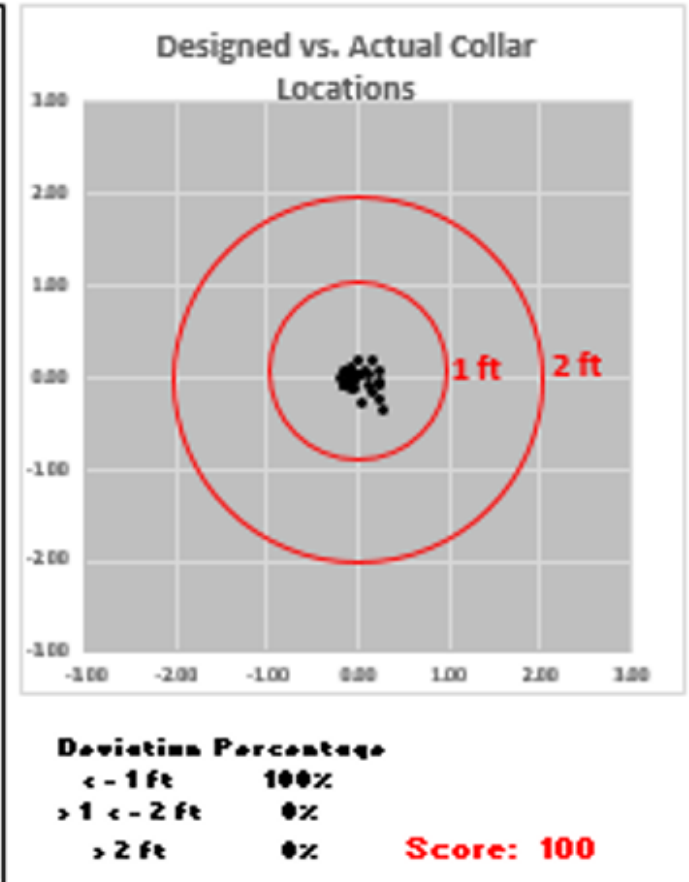
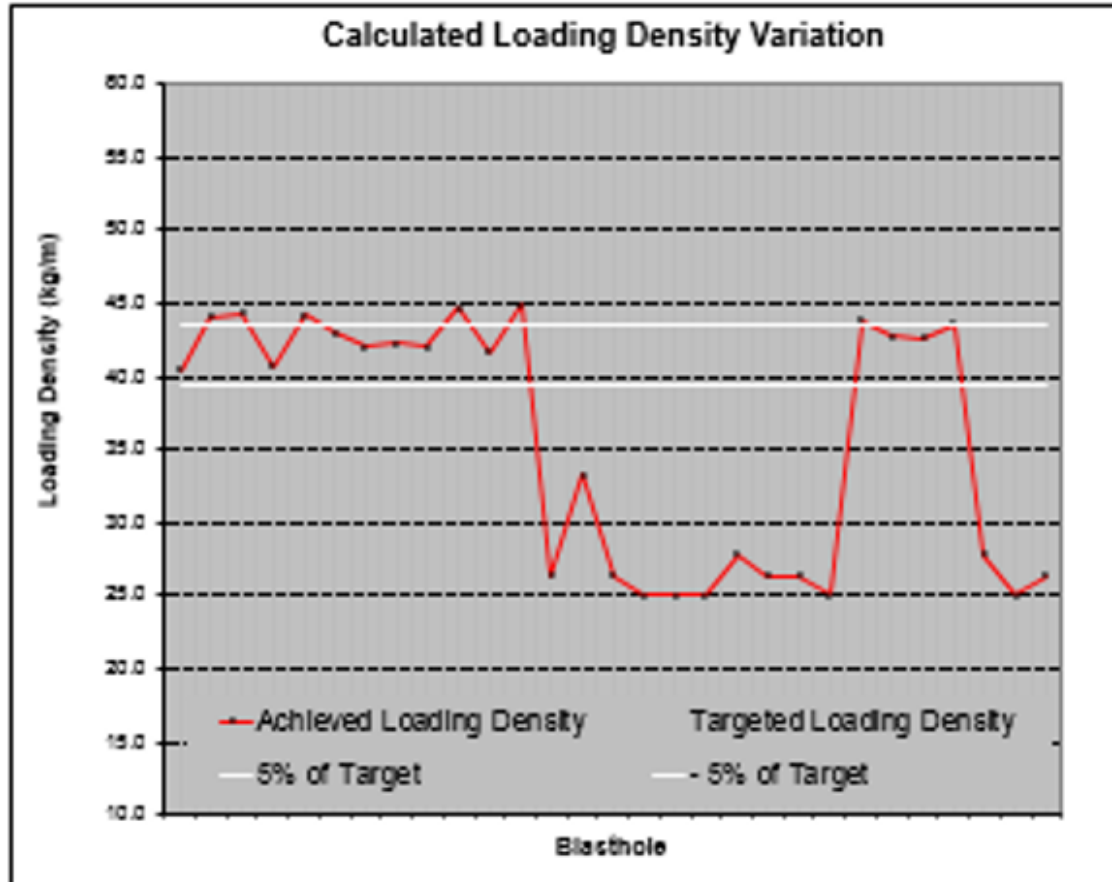
Drilling and Loading Accuracy

Number of Blastholes: 29

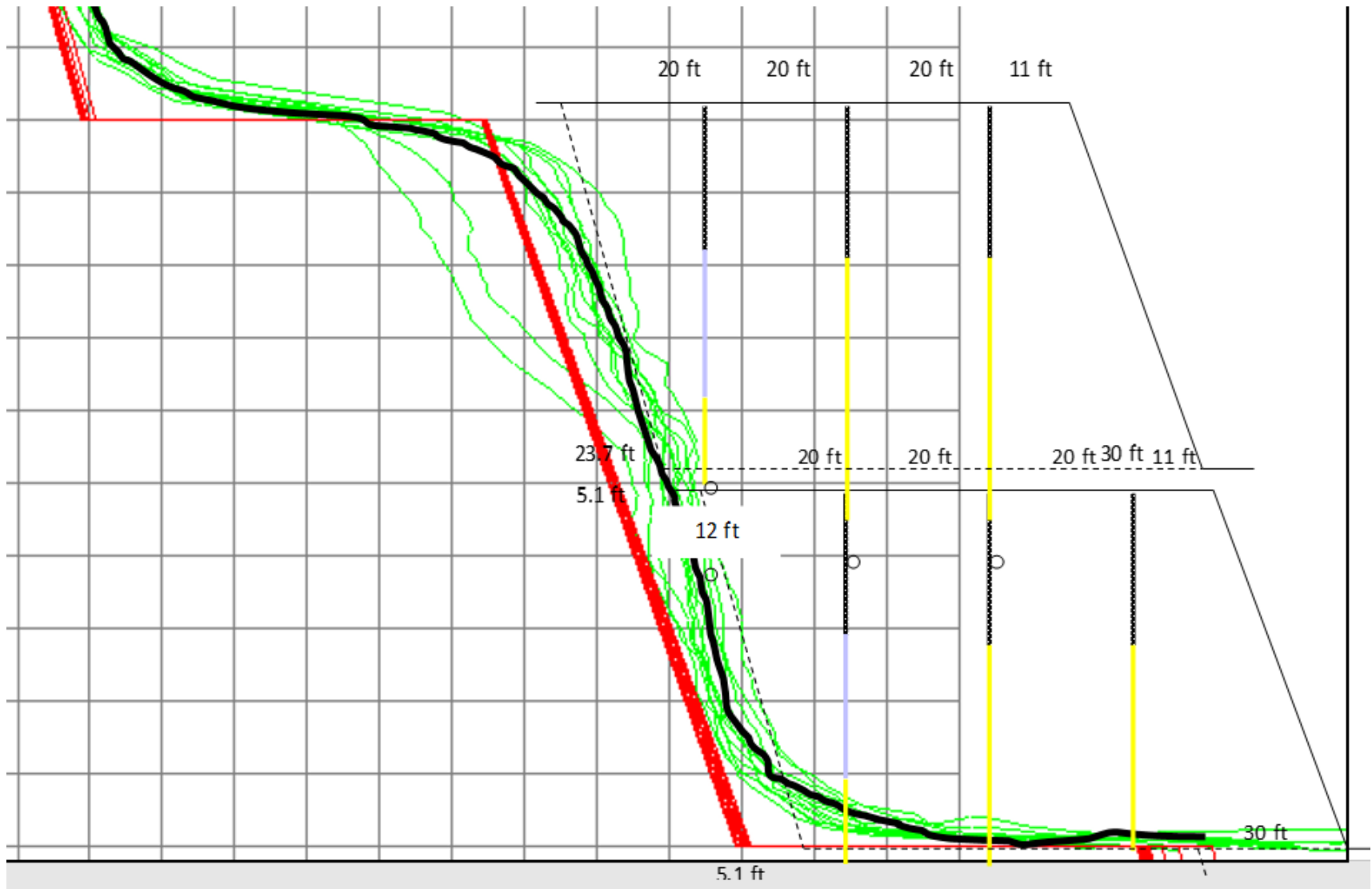
Overall Accuracy Score (100, all targets are achieved): 42



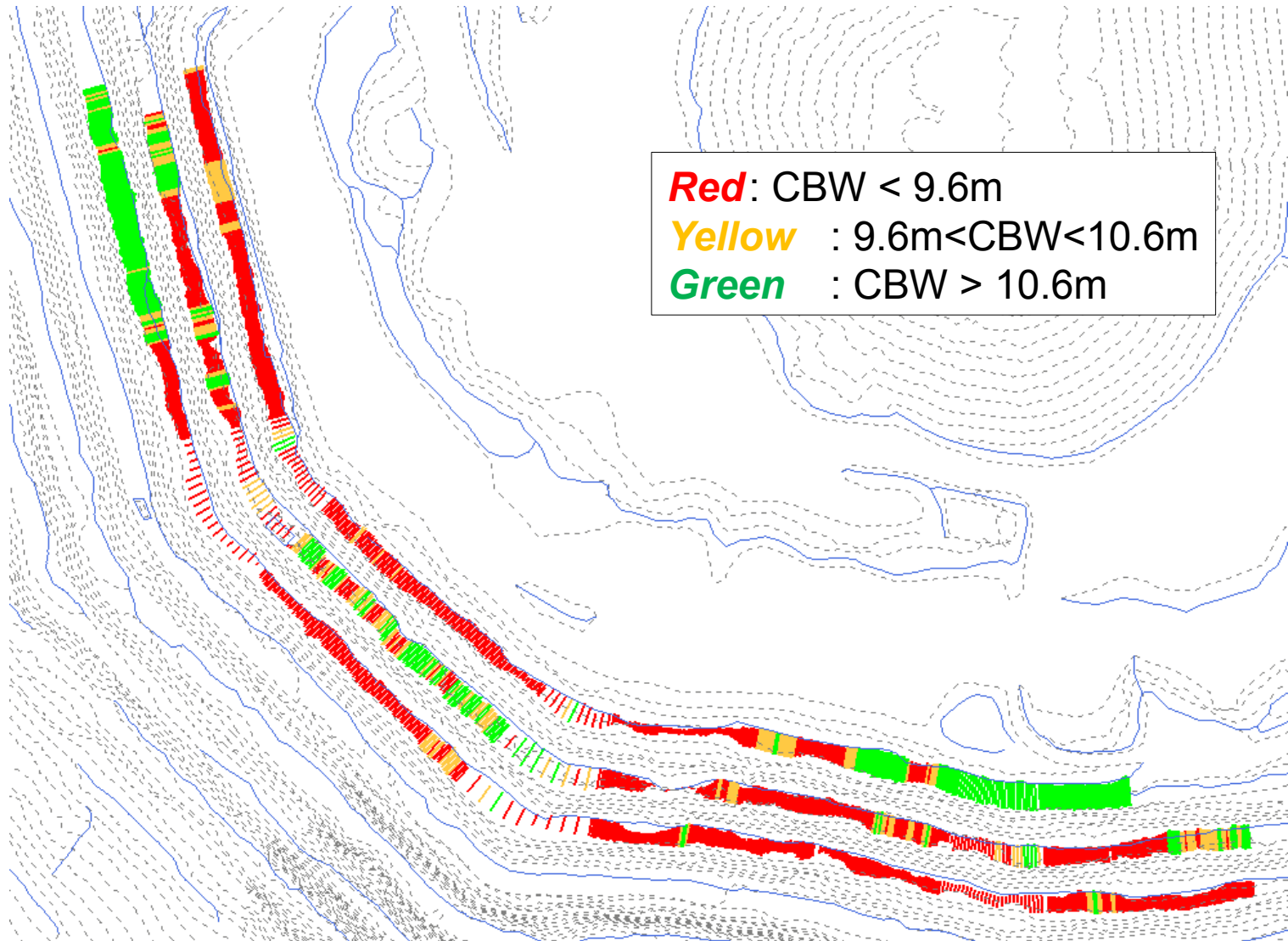
Drilling and Loading Accuracy



Reconciliation



Reconciliation



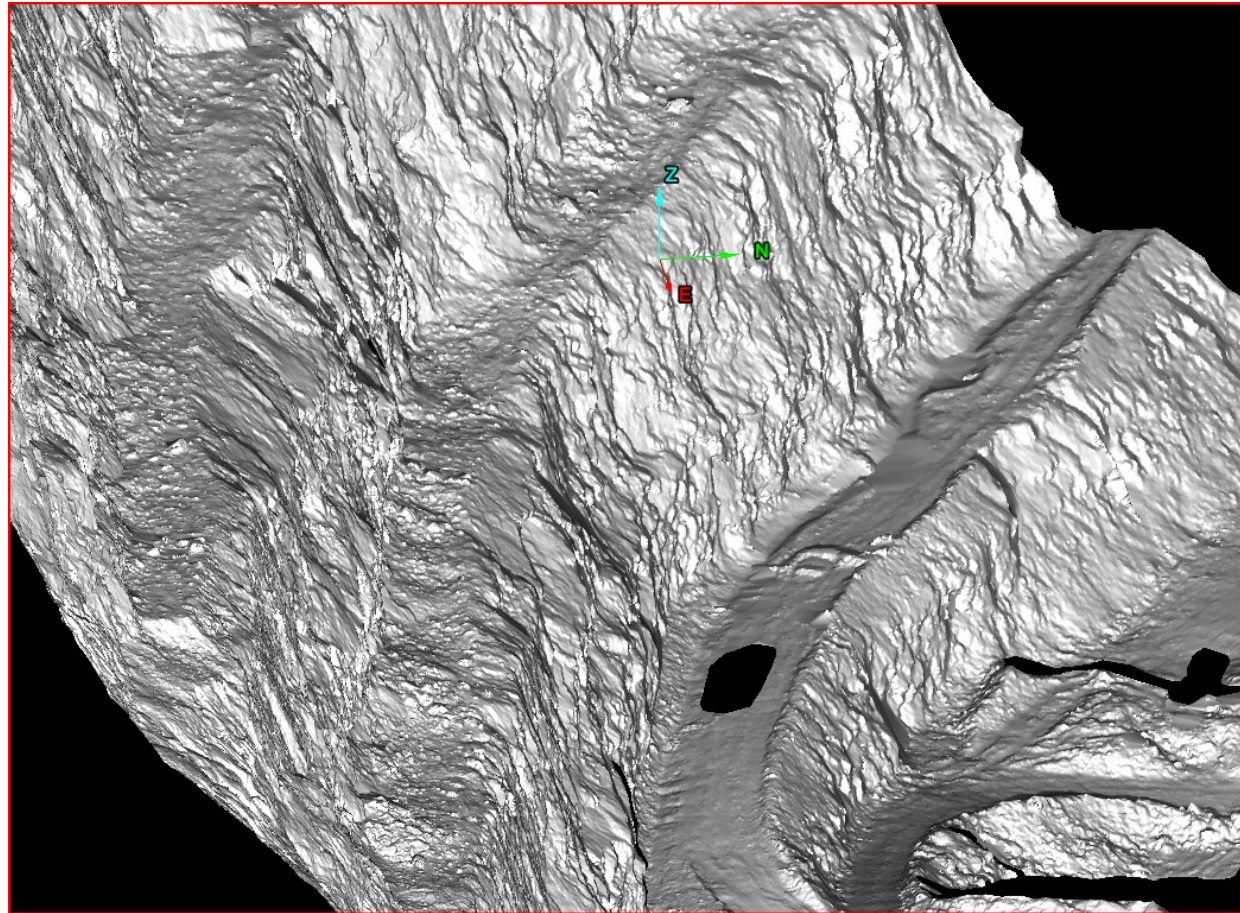
Pre-splits



In use at several sites, where economically justified.
They can achieve steeper, cleaner benches when used properly.

LiDAR Scanner

- Detailed point cloud
- Inaccessible areas, unsafe areas
- More consistent and reliable data
- Surface comparison tools
- Accurate and repeatable measurements of catch bench width and bench face angle



Wall Control Mining

- **GM – to - shovel runner understanding of what we are trying to achieve**
- **Listening to operator feedback**
- **Using the right tool for the job**
- **Building a safe bench**

Right tool for the job



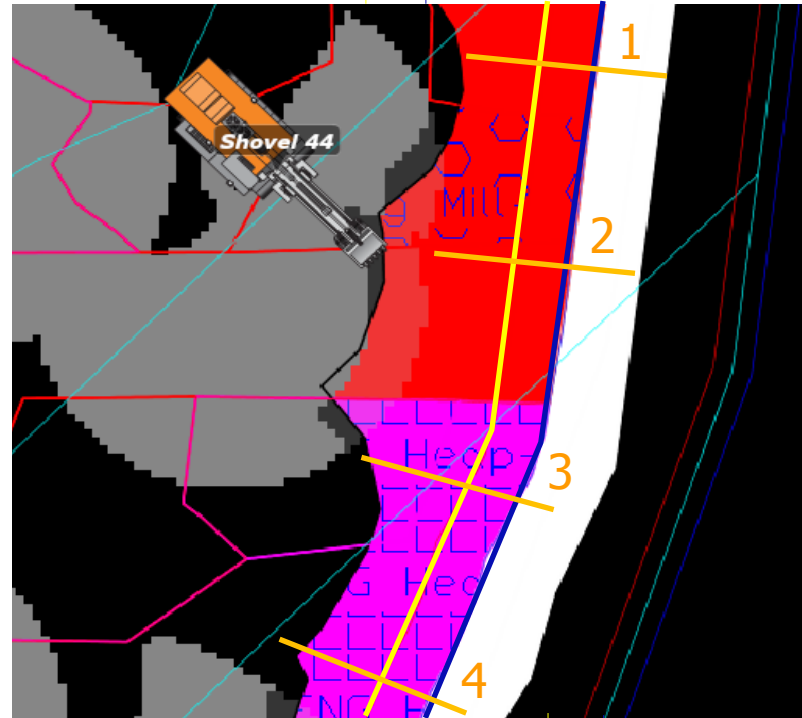
Right tool for the job



Right tool for the job

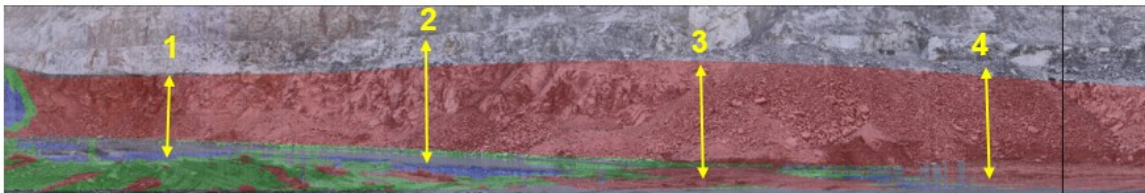
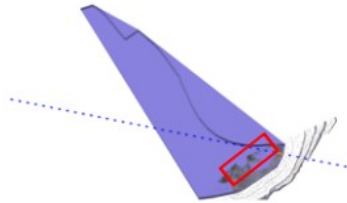


Right tool for the job



- underdig > 3.0ft
- within 3.0ft of design
- overdig > 3.0ft

Scan Date 04-27-2017



E: 2,359.7ft
N: -6,051.5ft

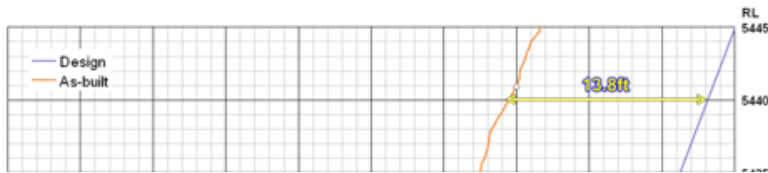
E: 2,258.5ft
N: -6,203.3ft

E: 2,119.3ft
N: -6,257.7ft

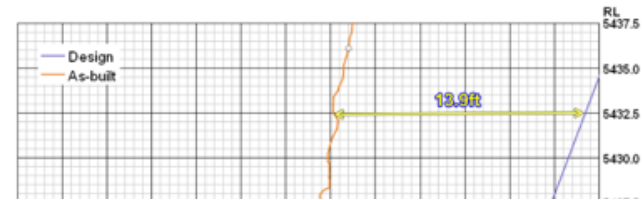
E: 2,026.4ft
N: -6,310.3ft

Right tool for the job

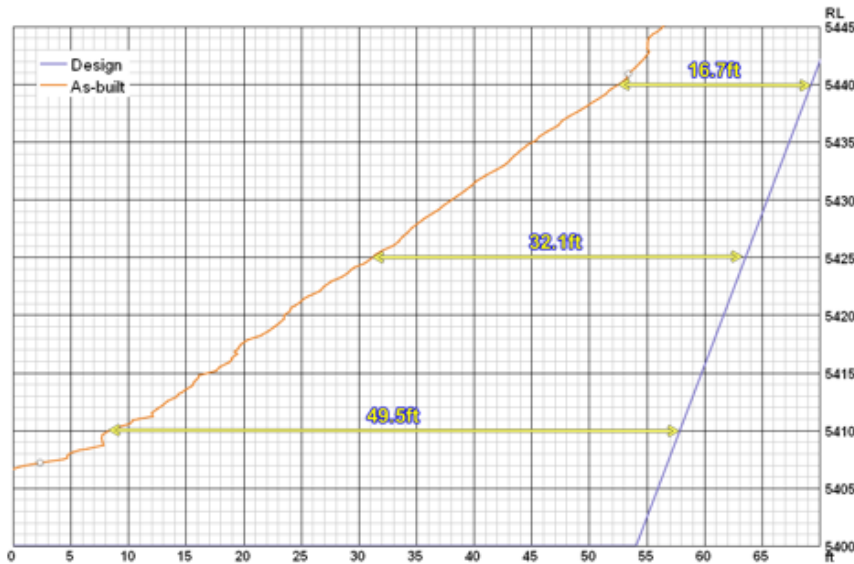
Section 1



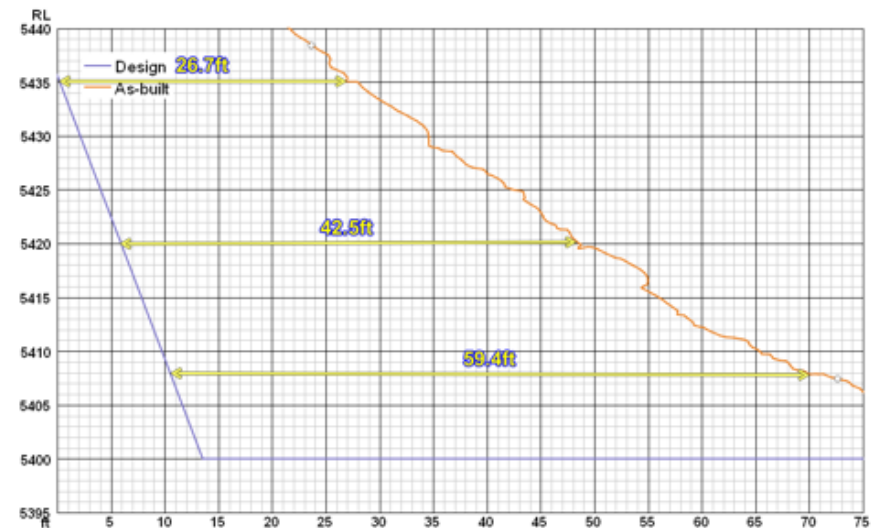
Section 2



Section 3



Section 4



Right tool for the job

W

N

- underdig > 3.0ft
- within 3.0ft of design
- overdig > 3.0ft



Conclusion

- **Slope optimization may add value from steepening; it will leave better, safer benches**
- **A clear understanding of geological, geotechnical, and economic opportunities and limitations is essential**
- **Blasting, mining, and hydrogeological improvements can return significant value**
- **Everyone needs to be on the same page, working toward the same goal**
- **Technology, especially LiDAR scanning, is key to understanding the results**
- **Continuous reconciliation, feedback, and improvement is the path to success**

Questions?