Workshop Name: 314 Chemical Crushing Case Studies

Instructors: Larry Mirabelli – Dyno Nobel Americas
Bill Hissem – Sandvik / North America

Workshop Content / Deliverable: This workshop will review case work at three (3) operations. The case work demonstrate how implementation of Chemical Crushing along with Lean / 6 Sigma management principles resulted in total process improvements and a reduction in cost to manufacture. In each case, metrics were established to quantify baseline and resulting performance when subsequent changes to either field variables or controls were made. In each case, alteration of the fragmentation gradation in the blast muckpile showed measurable improvements in downstream production throughput, minimization of waste, and economic gain.

QUARRY ACADEMY

Chemical Crushing Case Studies

Bill Hissem & Larry Mirabelli

QUARRY ACADEMY

Improving Processes. Instilling Expertise.

DYNO Dyno Nobel

SANDVIK

Chemical Crusher
Case Work

- Process Improvement from Drill to Prewash - Capital Quarries Company Inc., Holts Summit, MO
- Process Improvement / Fines Reduction - Wending Quarries Incorporated, IO
- Blast - Crush Improvement - Lafarge Building Materials, Ravena, NY

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Operations Process Improvement*
Leveraging Drill & Blast – Case Work #1

Capital Quarries Company Inc.
Holts Summit, MO

* From Drill to Pre-wash Product. Waste defined as minus 3/8”.

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Operations Process Improvement
Case Work #1 Project Outcomes

- **Drilling and Blasting cost increased by 28%.**
- **Waste was reduced by 19%.**
- **Impressive cost savings and increases in plant tonnage throughput within the “Blast to 1 inch minus” process of the Holt Summit Value Map were realized over the validation phase of the project.**

QUARRY ACADEMY

Operations Process Improvement
Case Work #1 Project Outcomes

- **The standard cost model for the “Blast to 1 inch minus” process of the Holt Summit value map showed that over the total process:**
  - ✓ **There was a 10% to 27% increase in crusher plant capacity**
    - ✓ **27% from baseline of 373 TPH to an average of 475 TPH. A plus 102 TPH shift in capacity.**
  - ✓ **There was a 7% to 31% reduction in net total cost per ton when scalping was used.**
  - ✓ **When scalping was not utilized an 8.8% reduction in the net cost per ton was achieved.**

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Focus of Casework

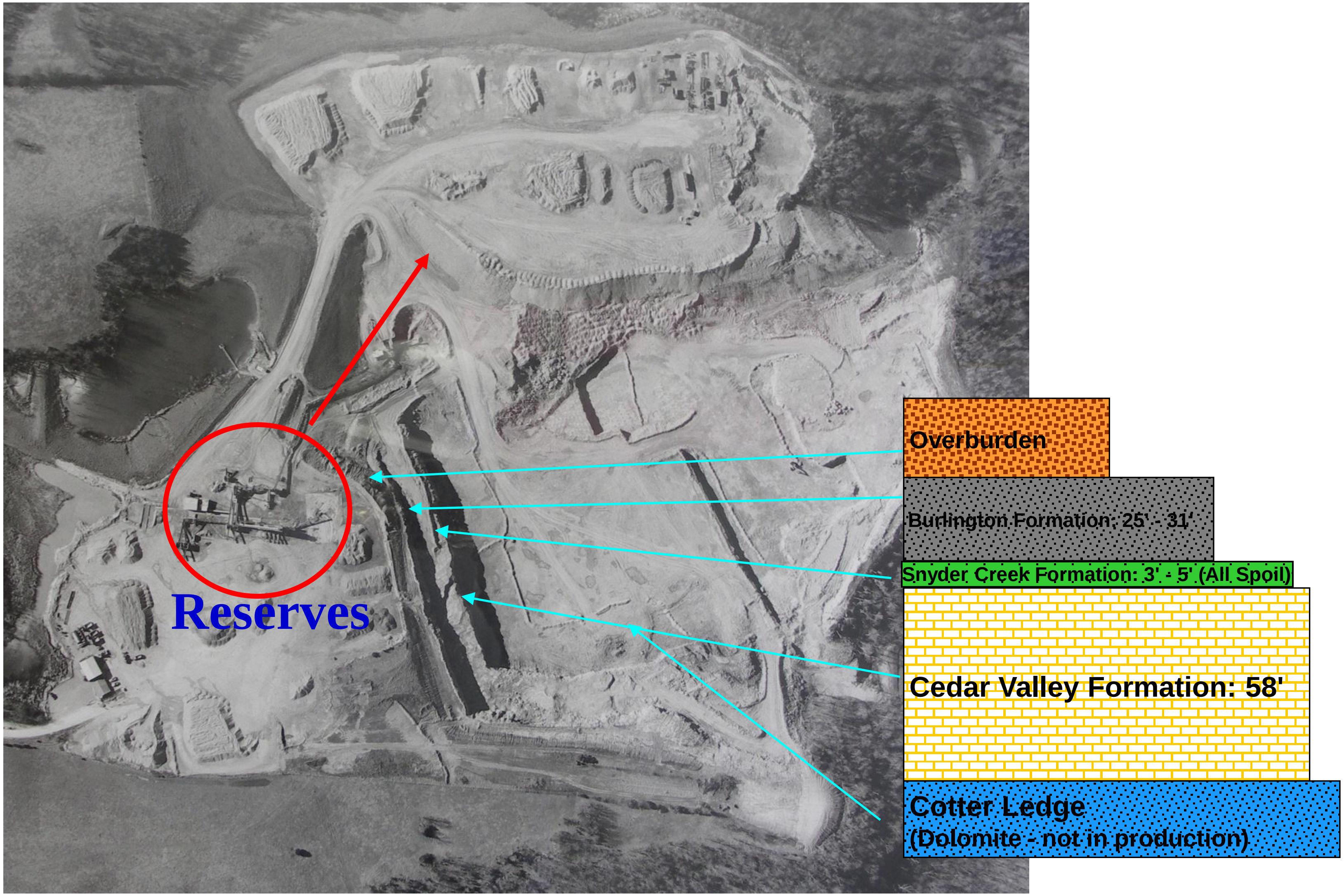
- Reduce total cost to convert insitu rock reserves to saleable product.
- Validate that extra dollars spent in drilling and blasting can lower total production cost.

Missouri Quarry Productivity Improvement - Casework

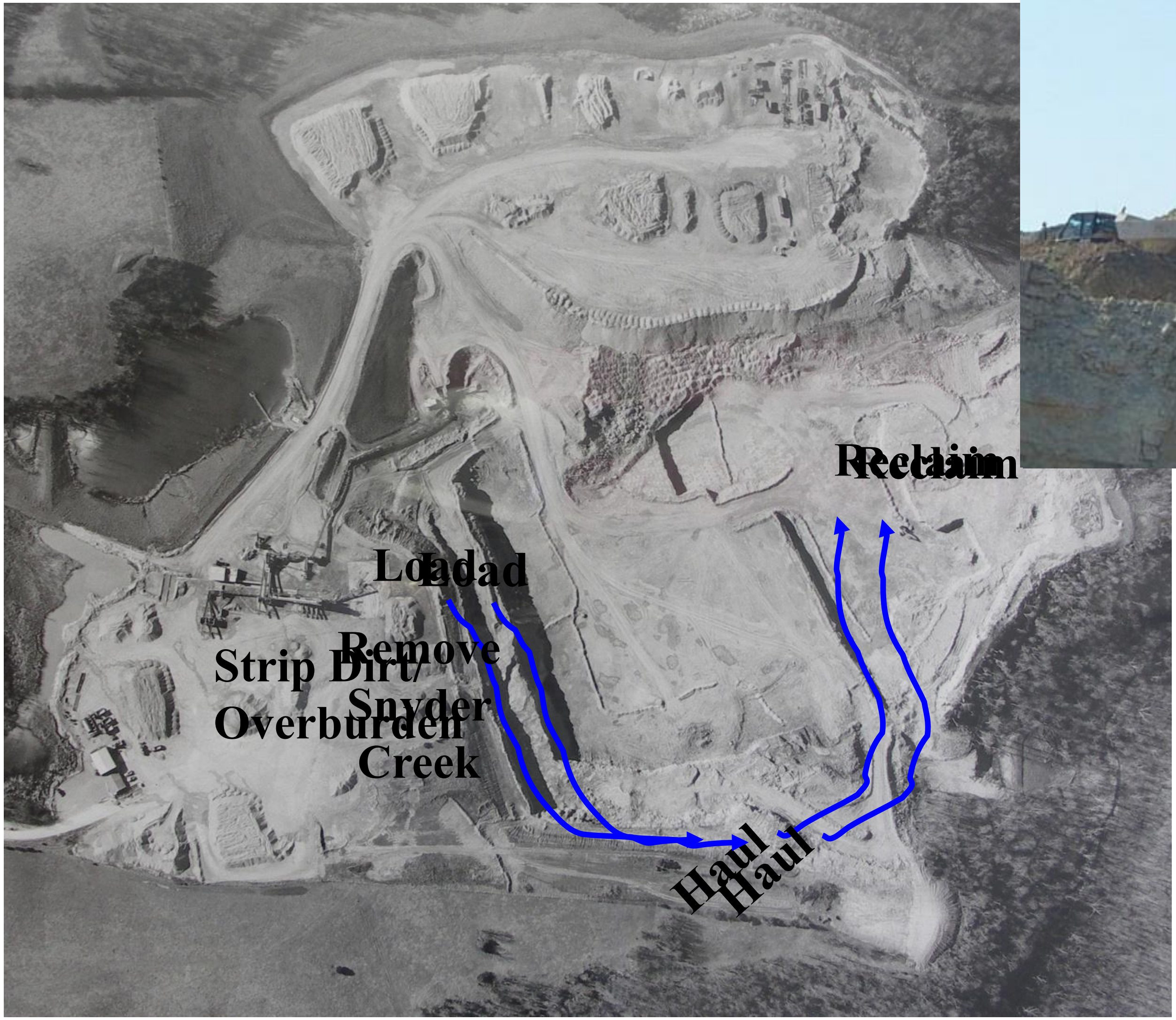
- Baselining
- Identification and implementation of metrics
- “Lean Thinking” Analysis
- Use of blasting fragmentation and process equipment models.
- Field validation of process improvement solutions

QUARRY ACADEMY

The Quarry


Reserves
Overburden
Burlington Formation: 25' - 31'
Snyder Creek Formation: 3' - 5' (All Spoil)
Cedar Valley Formation: 58'
Cotter Ledge
(Dolomite - not in production)

The Quarry Process



Waste
Removal

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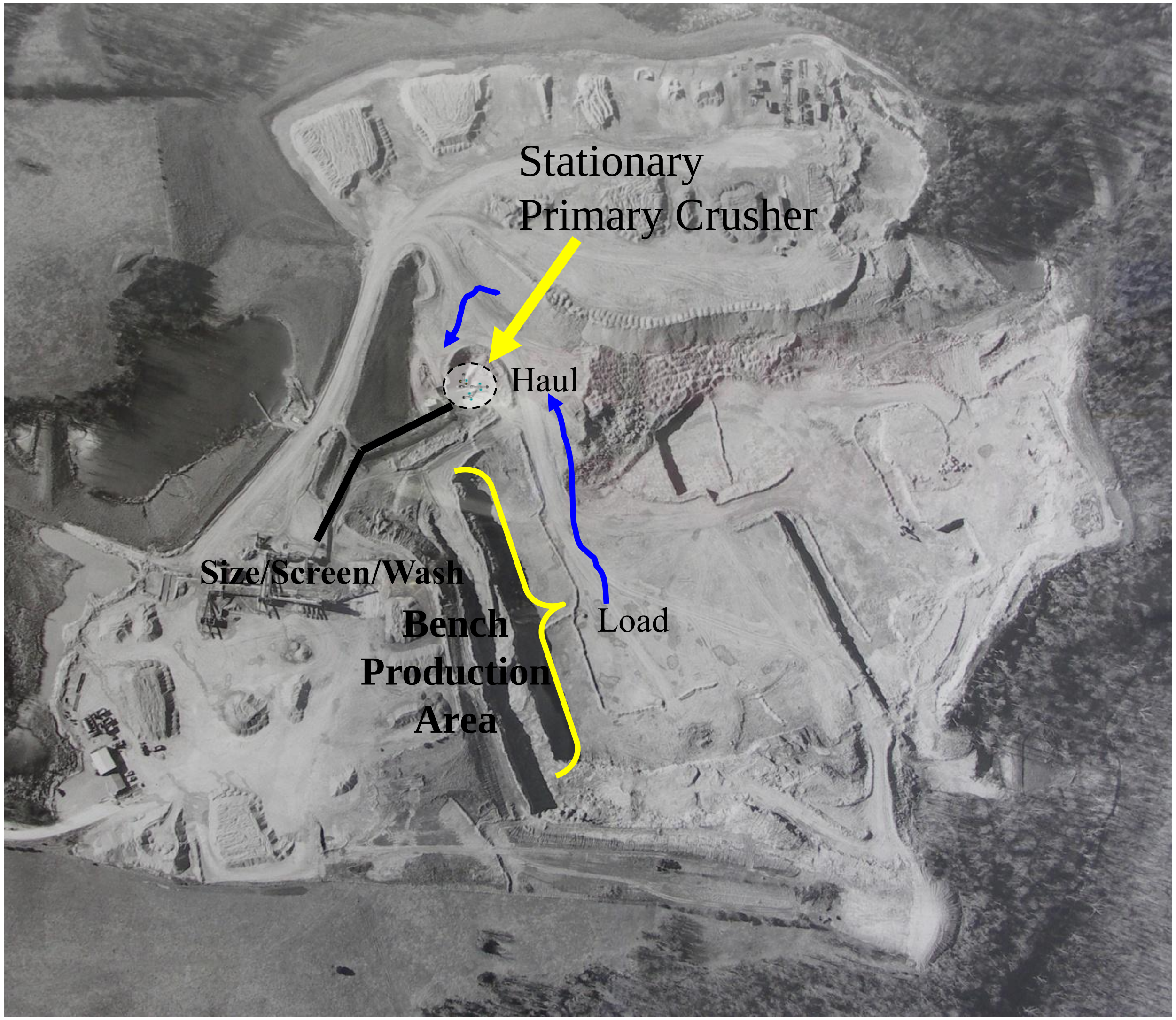
ACADEMY

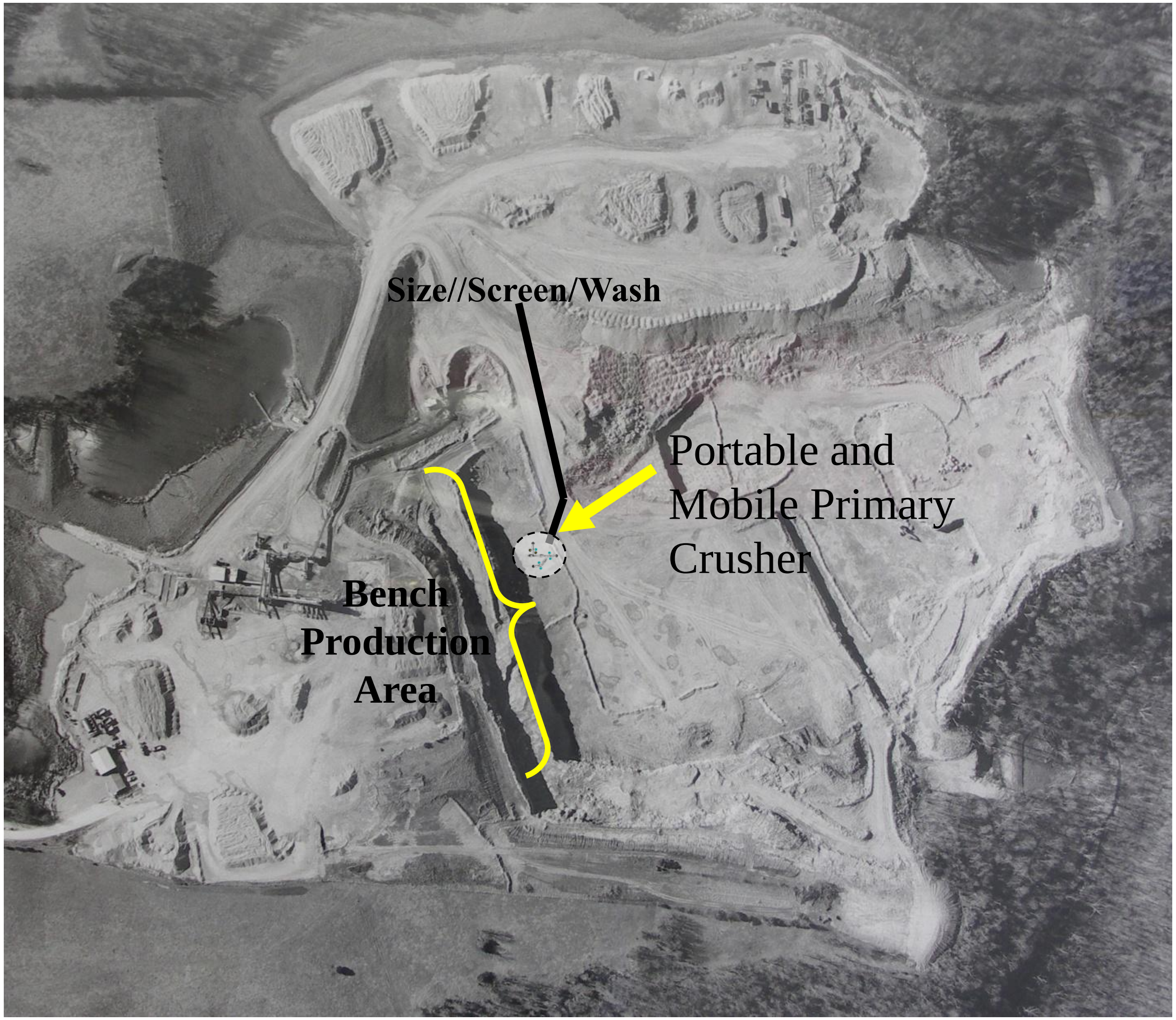
The Quarry Process – Old



- **Load & Haul to Primary Crusher in pit.**
- **Crusher Run moved by conveyor to Secondary Crush Screen Plant on upper level.**

QUARRY ACADEMY

The Quarry Process – New



- **Portable Primary Crusher that can be constantly moved near to the working bench in pit.**
- **Crusher Run moved by conveyor to Secondary Crush Screen Plant on upper reclaim level.**

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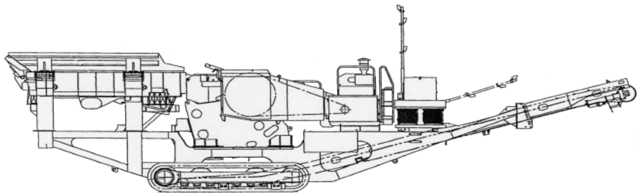
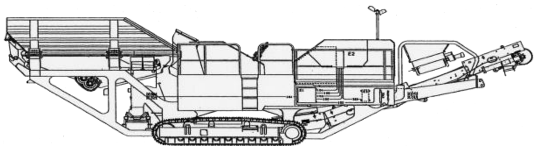
The Quarry Process – Interim

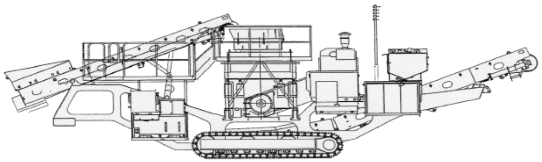
Metso LocoTrack® Diesel Powered Mobile Crushing Plant



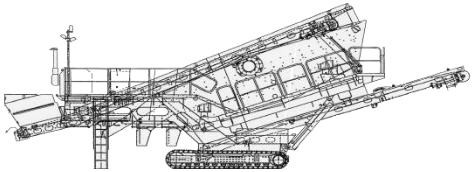
Primary - Norberg C110 44 x 34 Jaw



Secondary – Norberg NP1213M Horizontal Impact Crusher



Tertiary - HP 300 Cone Crusher



Three (3) Triple Deck Screen Units

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Quarry Process – Interim

- **Products**
  - ✓ 2 inch x 4 inch stone
  - ✓ 1 inch x 2 inch stone
  - ✓ 9/16 inch x 1 inch road base
  - ✓ 3/8 inch x 1 inch concrete rock
  - ✓ 5/16 inch x 3/8 inch stone
- **Waste**
  - ✓ 0 inch to 5/16 inch fines

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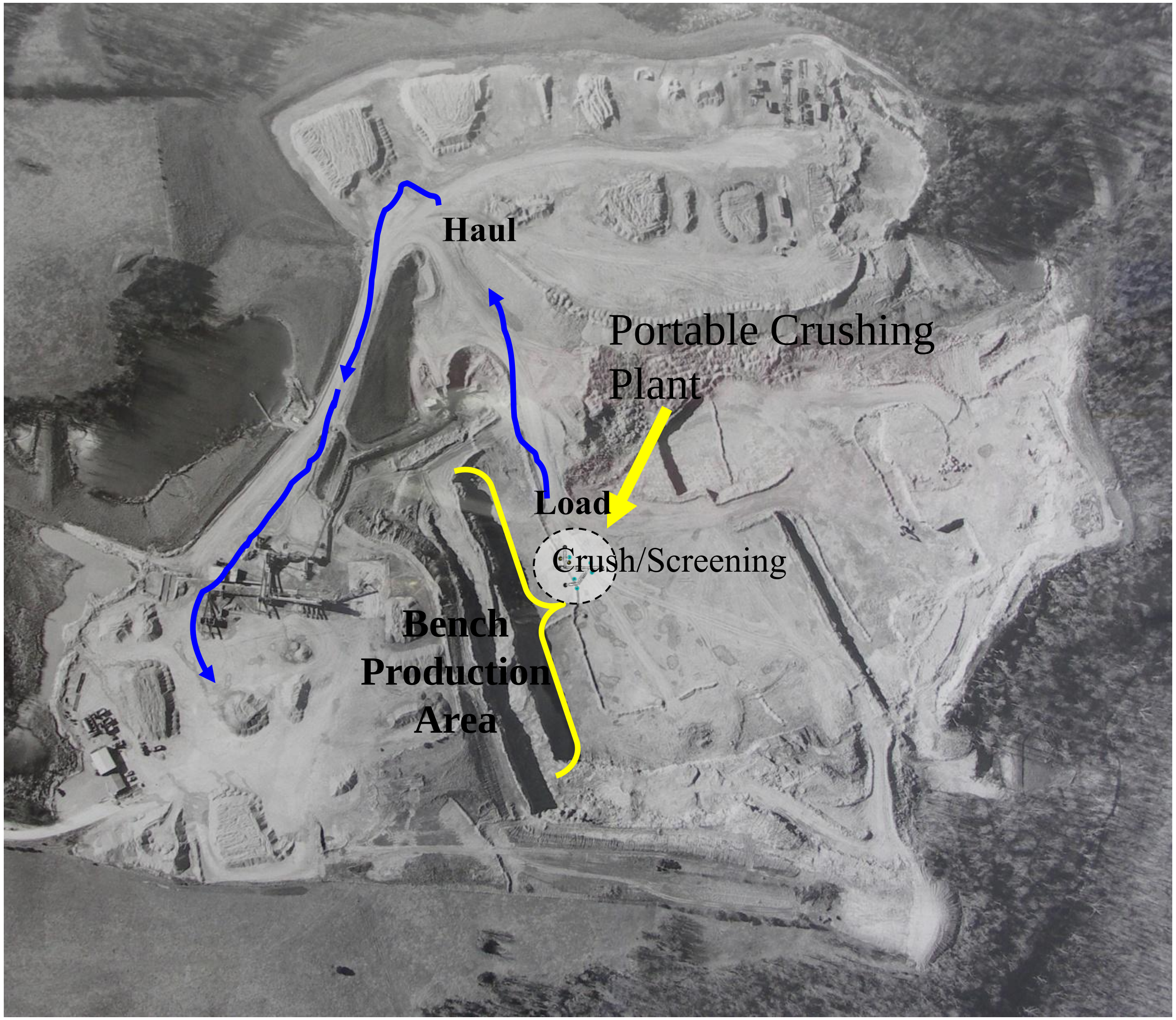
The Quarry Process – Interim



Cedar Valley
Crush / Screen

QUARRY ACADEMY

Drilling

- **Furukawa FRD1200ED**
  - ✓ **1¾ inch diameter T45 rod**
  - ✓ **4 inch bits**
- **Burlington Formation**
  - ✓ **10 ft x 14 ft x 33 ft**
  - ✓ **4 to 5 rows**
- **Cedar Valley Formation**
  - ✓ **10 ft x 14 ft x 60 ft**
  - ✓ **2 to 3 rows**
- **Subdrill 2 ft**

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Blasting

- Dyno Nobel Titan 1000 SD
  - ✓ Bulk repumpable blasting agent emulsion
- Trojan 35 & 45 Cast Boosters
- Nonel Initiation System
  - ✓ 25 ms between holes
  - ✓ 67 ms between rows
- Stem 7 ft
- Powder Factor
  - ✓ Burlington Formation   0.95 lb/cu yd
  - ✓ Cedar Valley Formation 1.14 lb/cu yd
- Approx. 20,000 ton blasts

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Baselining

- Period July 10 to August 15, 2006
- Evaluated each process step
  - ✓ Standard operating procedure
  - ✓ Costs
- Historical records back to May 1, 2006
- Benches surveyed; drill holes surveyed; blasting & operator logs reviewed; muck pile fragmentation analyzed; primary crusher throughput, finished products and waste tonnages were monitored.

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Identification and Implementation of Metrics

- 3D Bench survey; drill holes survey; blast load sheets; seismograph reports; drill cycle time; in-pit muck pile photo fragmentation analysis; loader cycle time & bucket weight monitoring; oversize count; hydraulic hammer time (in-pit and at primary); crusher feed rate; daily operator logs; haul truck counts.

- Non standard metrics highlighted above as red text -

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"Lean Thinking" a Process

- Examines productivity, operational effectiveness, operational efficiency; waste and profitability.
- Enhances operational effectiveness by adapting, achieving and extending best practices.
- "It's not working harder but working smarter"

  (Eric Strope - President CQCI)

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Improvement Areas

- Quarrying benches separately
- Drilling precision and accuracy
- Explosive Energy Distribution throughout rock mass
- Excavation & crushing of muckpile. (tight muck, oversize, reduced throughput)
- Fines/Waste
- Process water (wash plant, settlement ponds etc.)

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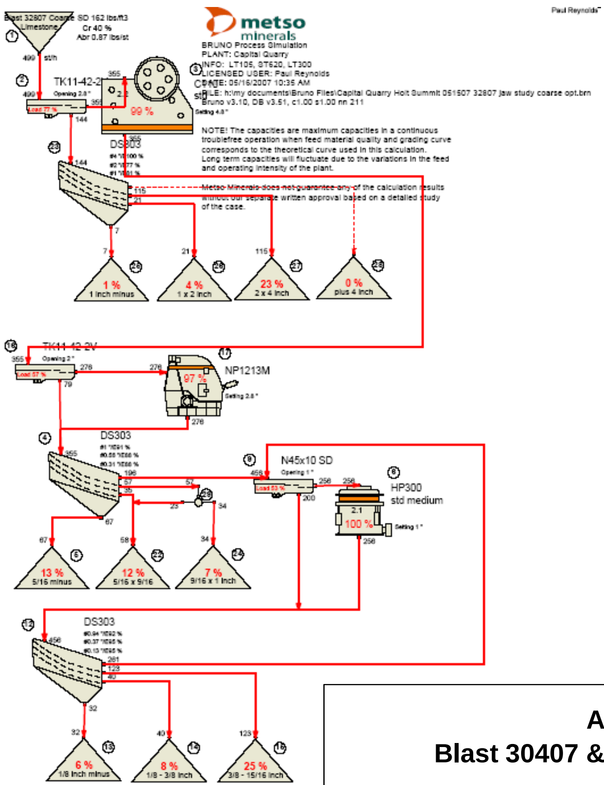
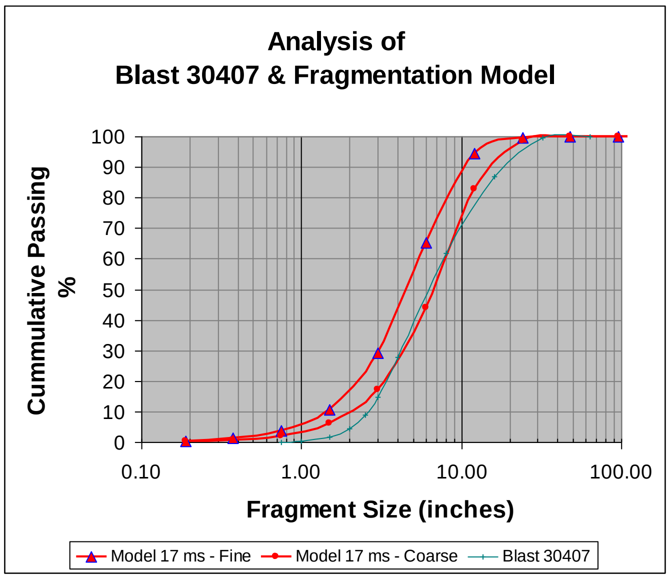
Modeling



- Fragmentation and process equipment simulators were used to select alternatives with best chance of creating positive change.



✓ **Fragmentation**

- Kuz-Ram & Modified Kuz-Ram

✓ **Process Equipment**

- Metso Bruno®
- Sandvik Plant Designer®

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Field Validation of Process Improvements

- Cedar Valley Bench Only.
- Blast sizes - 15,000 to 20,000 tons
- Four (4) Validation Blasts
- One (1) additional Baseline Blast
- All blasts were equal in width and 3 rows.
- Blast Design
  - ✓ 12 ft x 10 ft x 60 ft (Row 1)
  - ✓ 10 ft x 12 ft x 60 ft (Row 2 & 3)

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Validation / Performance Improvement Testing

Drilling & Blasting

- **Drilling**
  - ✓ **No change to equipment for validation testing**
- **Blasting**
  - ✓ **Grade of repumpable blasting agent emulsion and type/size cast boosters remained unchanged.**
  - ✓ **Electronic Detonators replaced Nonel.**
    - remove any variability of individual blast hole firing times;
    - assure absolute control of blast hole sequencing; and
    - to allow non-conventional timing choices to be implemented.
  - ✓ **Amount of stemming unchanged at 7 ft.**
  - ✓ **Powder Factor increased to 1.33 lb/cu yd.**

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Drilling & Blasting

- **Blasthole Timing**
  - **All validation blasts were consistent with 10 ms between holes in row 1 and all were sequenced off the open corner of bench.**
  - **Blast 1**
    - 17 ms between holes (row 2 and 3)
    - 67 ms between rows
  - **Blast 2**
    - 16 ms between holes (row 2 and 3)
    - 75 ms and 82 ms between rows

QUARRY ACADEMY

Drilling & Blasting

- **Blasthole Timing**
  - **All validation blasts consistent with 10 ms between holes in row 1 and all were sequenced off the open corner of bench.**
  - **Blast 3**
    - 12 ms between holes (row 2 and 3)
    - 118 ms between rows
  - **Blast 4**
    - 17 ms between holes (row 2 and 3)
    - 118 ms between rows

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Discussion

- **Capital Quarries was ideal candidate for testing.**
  - ✓ **Not new to continuous improvement process**
  - ✓ **Utilized "Lean Thinking" principles.**
  - ✓ **Empoyees change oriented.**
  - ✓ **Key Factors**
    - Use of portable and mobile in-pit crushing/screening plant.
    - Operational setup compressed entire rock crushing and sizing process and cost model to 1,500 ft radius.

"Blast to 1 inch Minus" Process Model"

QUARRY ACADEMY

Discussion

Changes to blast design were made to:

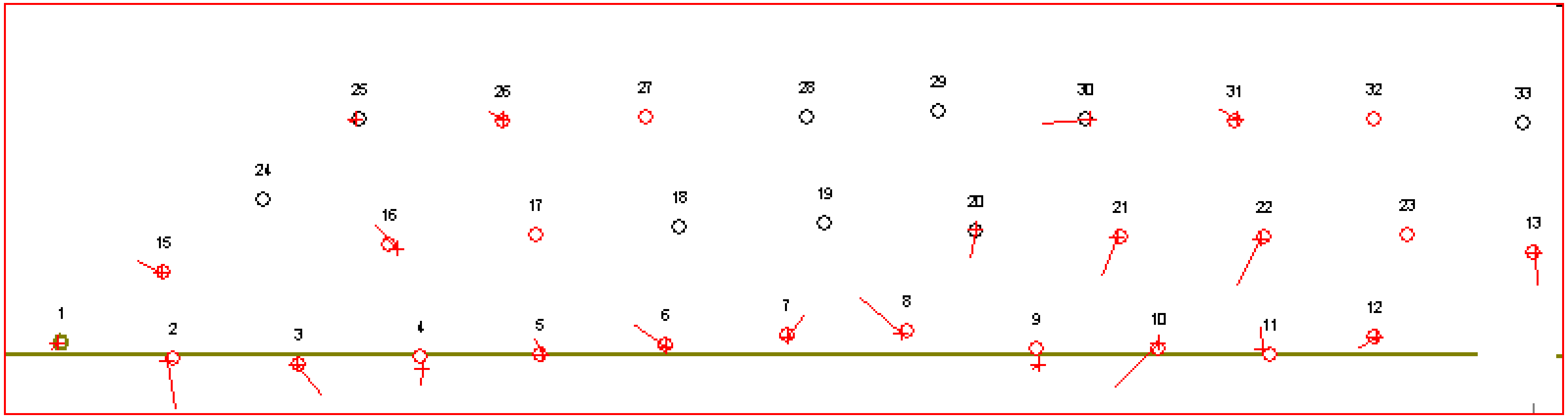
- Reduce top size to less than 37 inches or 85% of the size of the feed box for the C110 jaw crusher.
  - ✓ Factory targeted capacity of 340 – 470 tons per hr @ 6 inch closed side setting.
- Eliminate hard toe
- Facilitate digging for front end loader

- Eliminate sorting of oversize
- Minimize use of hydraulic impact hammer mounted at jaw feed
- Minimize supplementary breakage with track mounted hammer.

QUARRY ACADEMY

Discussion

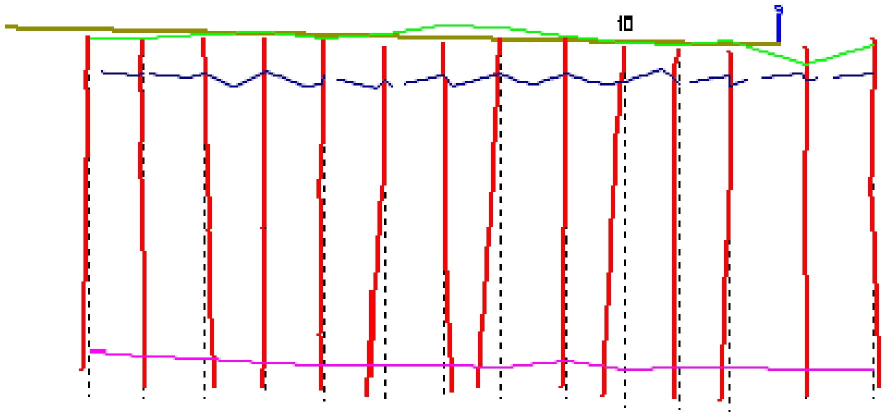
- **Blast layout and drilling accuracy**
  - ✓ **Baseline**
    - Planned vs “As Built” 2.5 - 10.5 % variance B & S
  - ✓ **Validation**
    - Planned vs “As Built” 2 - 7 % variance B & S

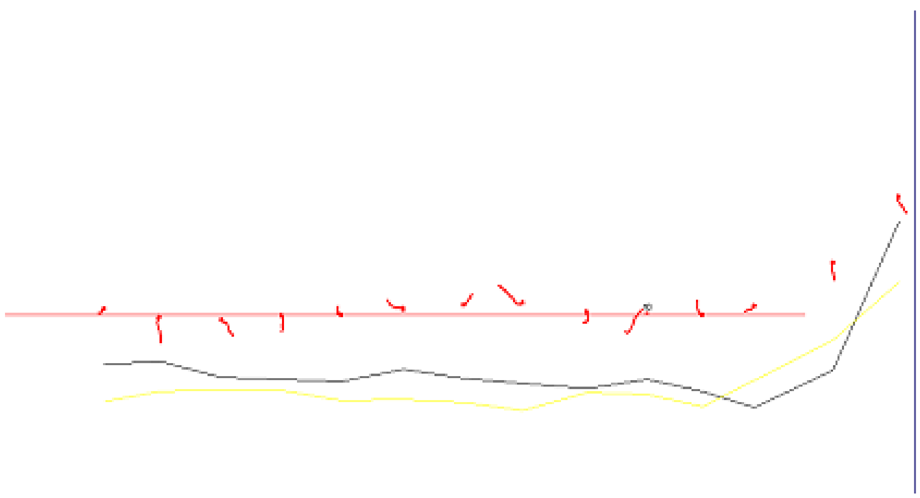


QUARRY ACADEMY

Discussion

- **Drill hole deviation**
  - ✓ **At best 50% of holes were within 1.5 ft max deviation. (17% worst, 39% Average)**
  - ✓ **18% accumulated variance for average face row burdens.**

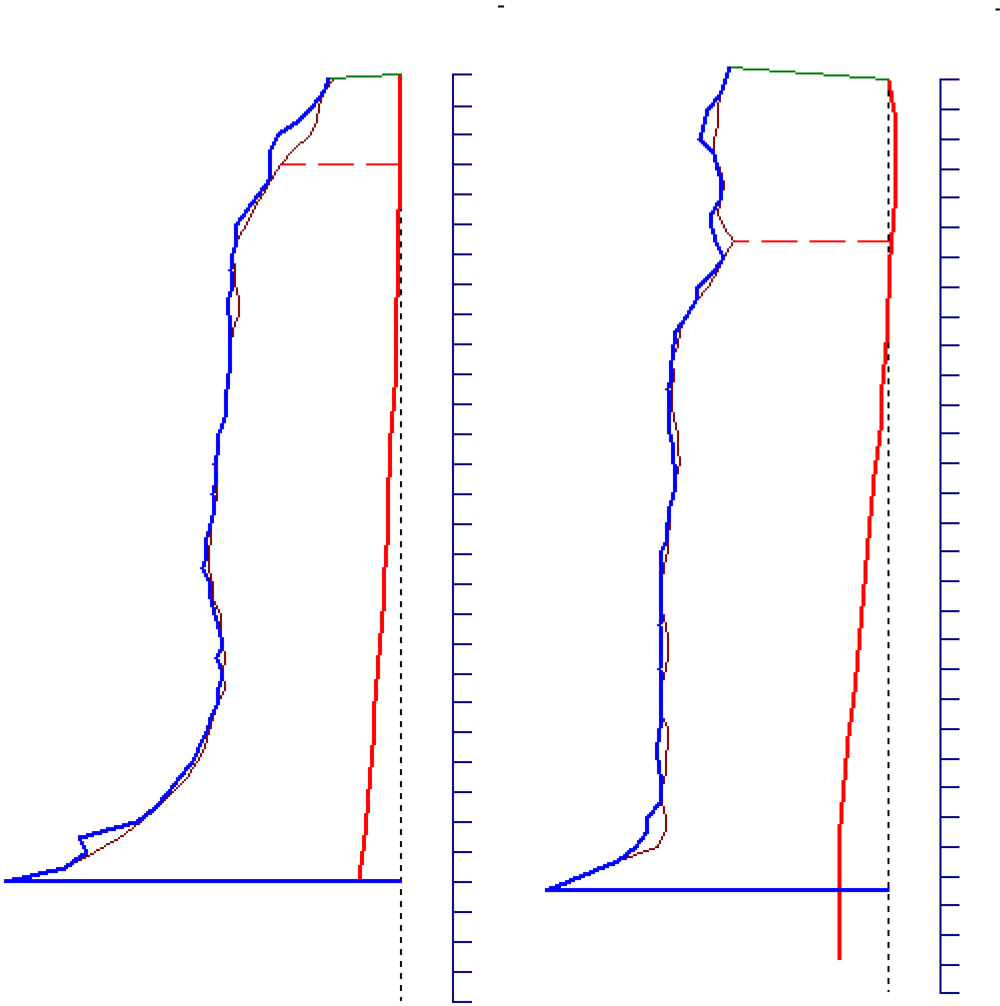




QUARRY ACADEMY

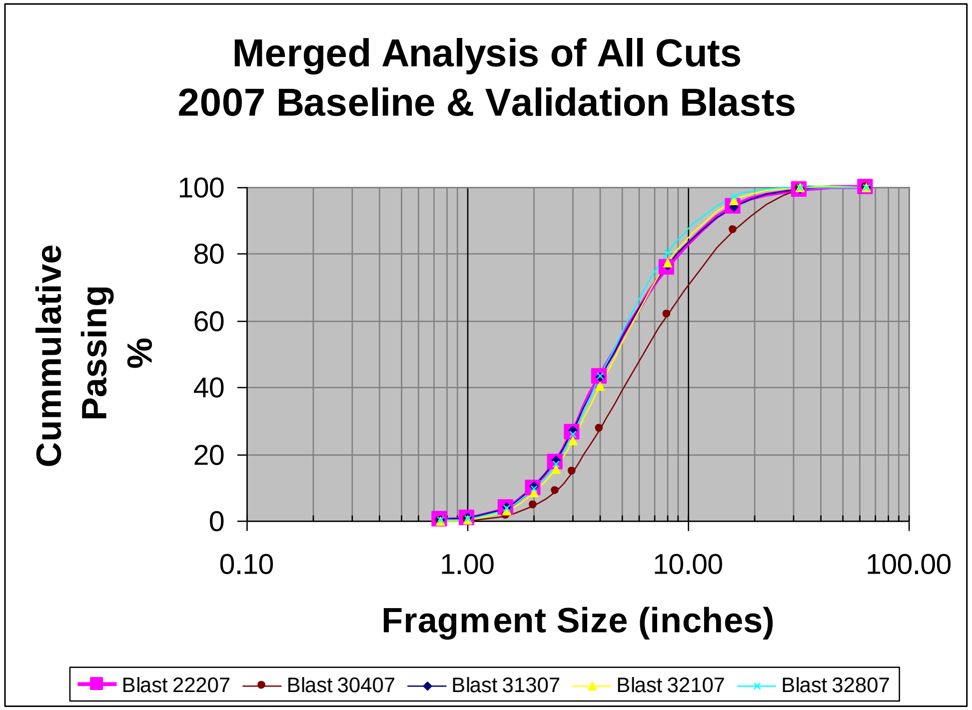
Discussion

- Blast 1 had excellent fragmentation and crusher throughput but required a blast design layout change.
- Front row burdens were light and required custom loading.
  - ✓ Average min. burden 8.5 ft
  - ✓ Average burden 10.5 ft
- Additional 2 ft was added to burden layout for front row.
  - ✓ Average min. burden 10.8 ft
  - ✓ Average burden 13.5 ft.



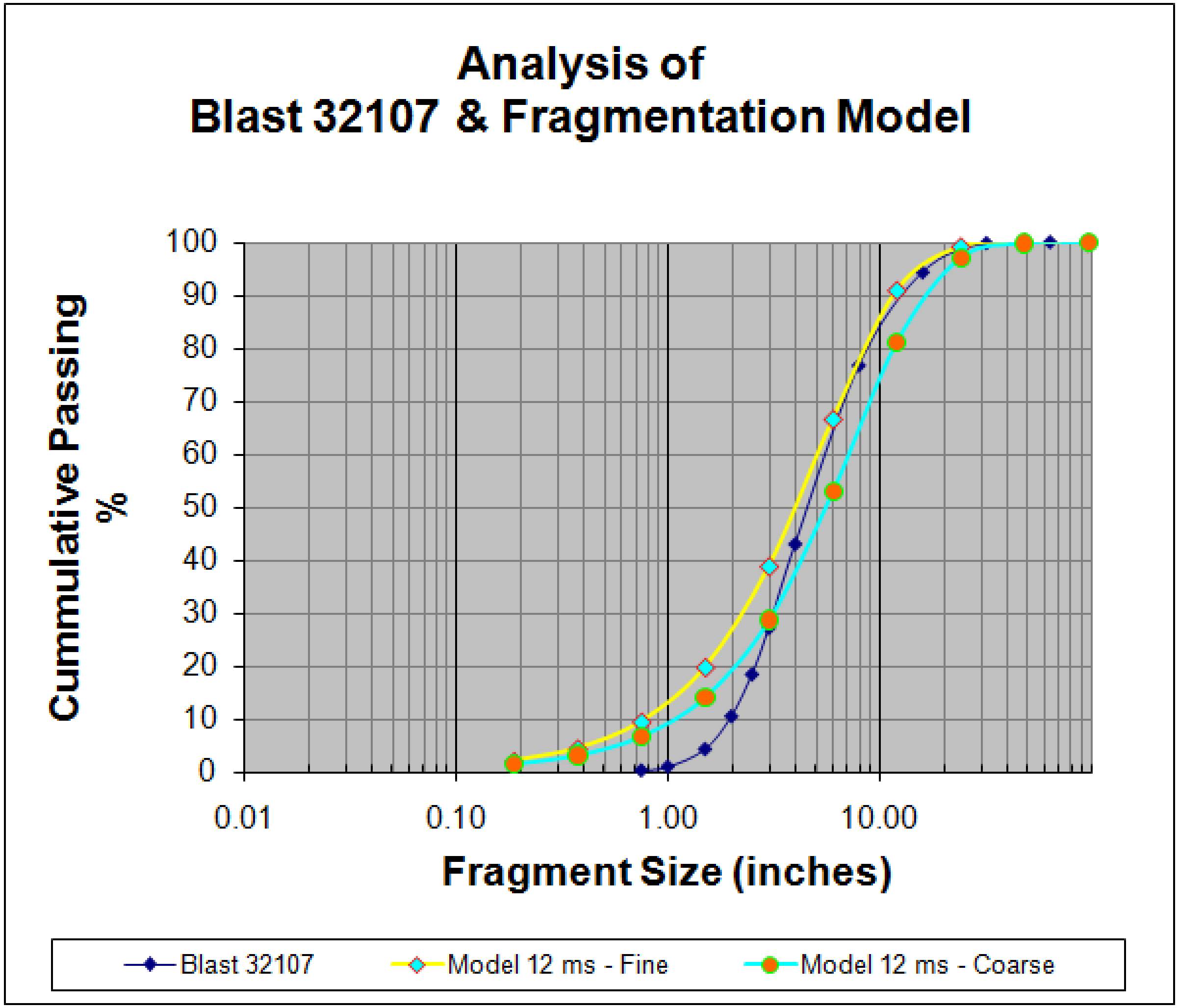
Discussion

- **Fragmentation in all validation blasts resulted in meeting the 100% passing 37 inch criteria.**
  - ✓ **Eliminated need to segregate oversize in the pit.**
  - ✓ **Minimized use of the hammer mounted on Jaw.**
  - ✓ **No dramatic differences were observed in fragmentation gradation of validation blasts.**



QUARRY ACADEMY

Discussion

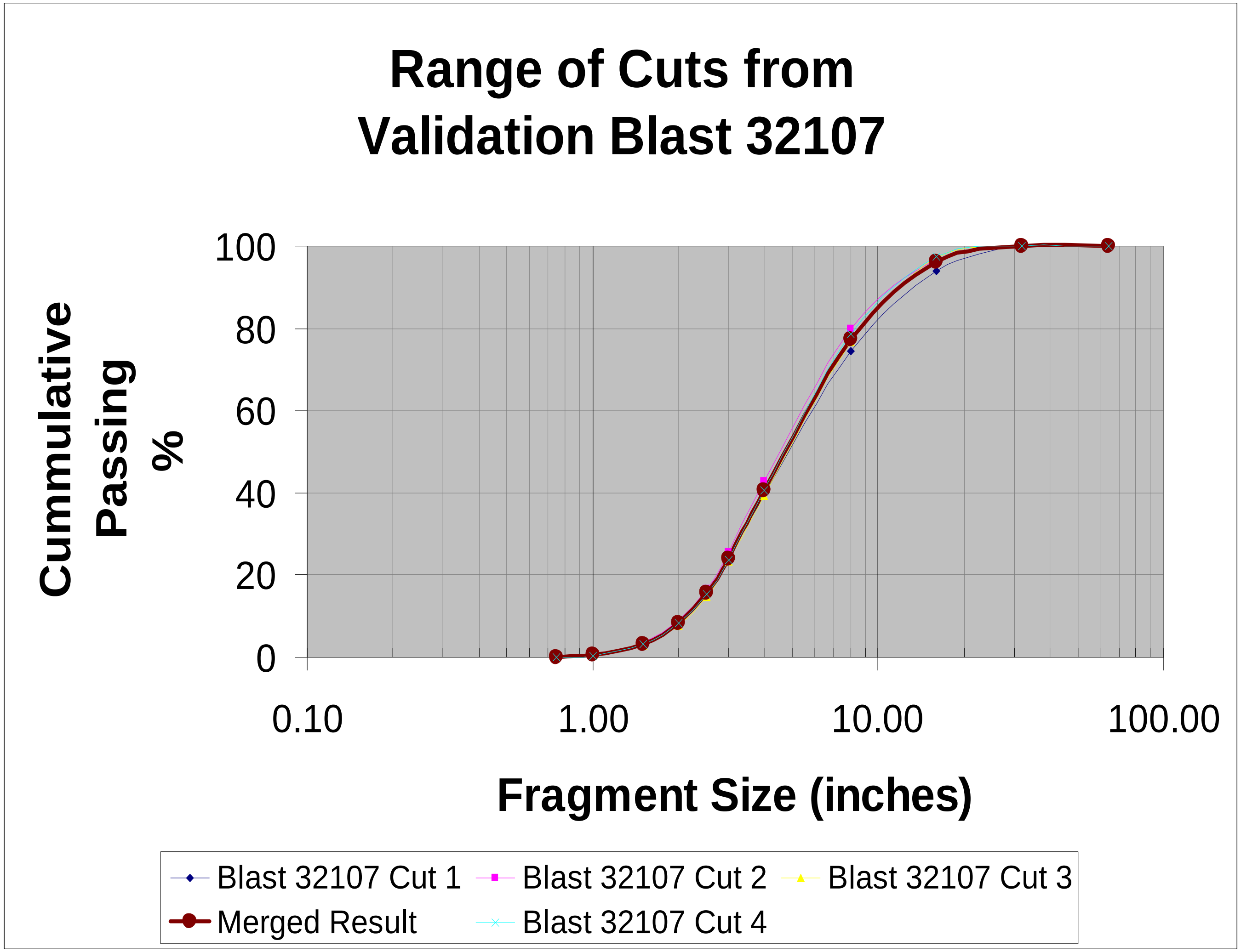


- **Improvements simulated by the fragmentation model for 12 ms inter-hole time were not obvious.**

QUARRY ACADEMY

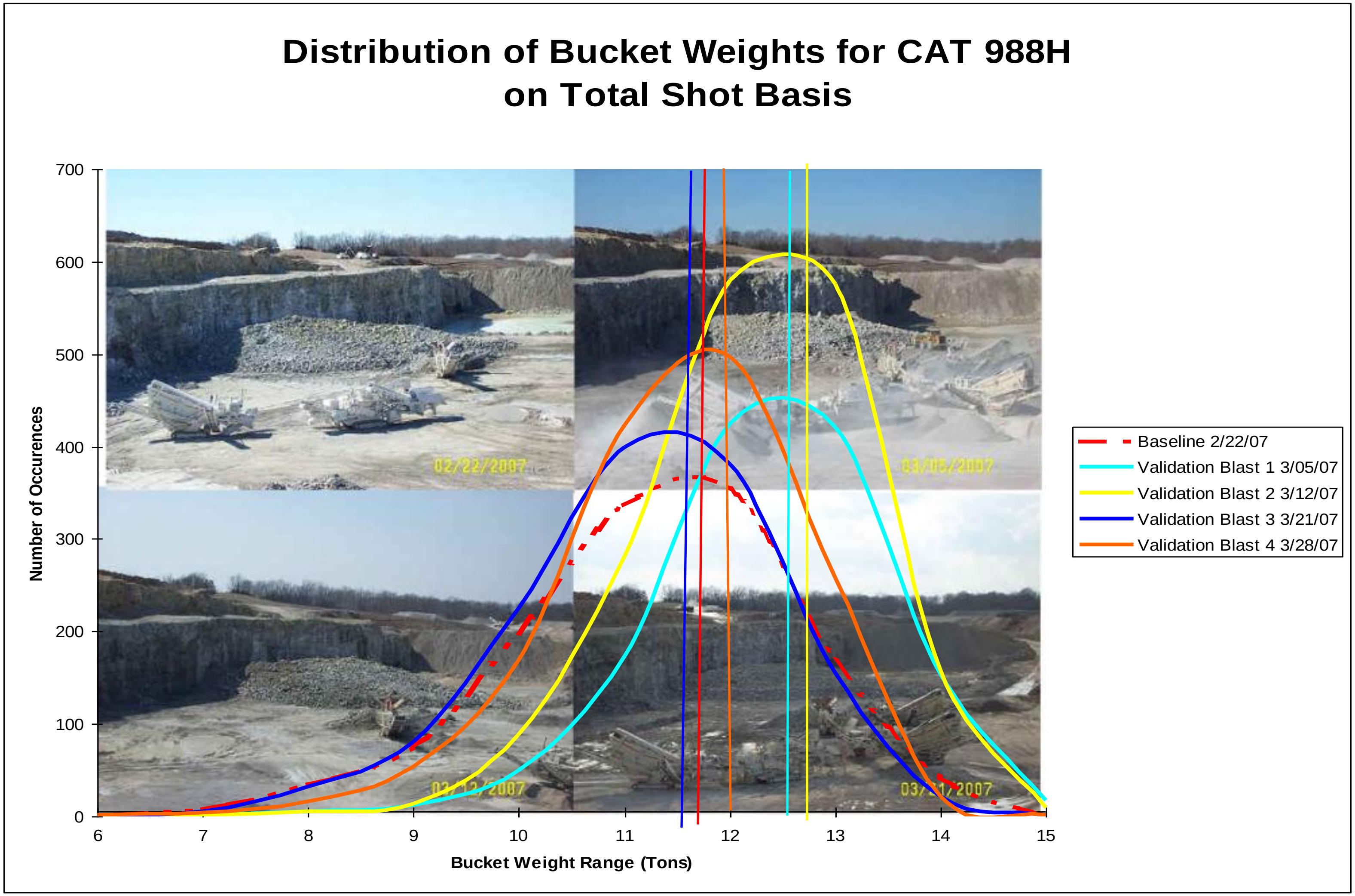
Discussion

- **12 ms between hole times did display most consistent gradation.**



QUARRY ACADEMY

Discussion



QUARRY ACADEMY

Discussion

- **Validation blasts 1 and 2**
  - ✓ **Wheel loader cycle times were reduced by 15%;**
  - ✓ **Bucket fill improved by 8 % and**
  - ✓ **The percentage of buckets weighing 12 tons or more improved by 63%.**

		CAT 988H					
	Date	# Cycles per Shift	Avg Cycle Time min:secs	Avg Bucket Weight tons	% Buckets over 12 ton	Crusher Feed Rate (overall) tons/hr	Daily In-Pit Crushing Tons/shift
Baseline	23-Feb	255	2:08	10.91	25.88%	377.03	2,771
Baseline	26-Feb	253	2:18	11.54	38.91%	363.6	2,759
Baseline	27-Feb	249	1:49	11.48	34.68%	378.95	2,850
Baseline	28-Feb	204	2:25	12.42	66.50%	308.57	2,484
Baseline	1-Mar	273	1:44	12.47	68.13%	433.55	3,403
Total		**1,234**					**14,267**
Average			**2:04**	**11.76**	**46.82%**	**372.34**	
Validation Blast #1	5-Mar	341	1:24	12.69	76.90%	543	4,302
Validation Blast #1	6-Mar	344	1:26	12.69	79.88%	532.4	4,352
Validation Blast #1	7-Mar	298	1:27	13.26	90.57%	484	3,950
Validation Blast #1	8-Mar	115	1:27	13.01	81.74%	540	1,496
Validation Blast #1	9-Mar	165	1:46	12.56	72.70%	506.5	2,073
Total		**1,263**					**16,173**
Average			**1:30**	**12.84**	**80.36%**	**521.18**	
Validation Blast #2	13-Mar	237	2:07	12.27	61.18%	349.3	2,908
Validation Blast #2	14-Mar	299	1:36	12.71	75.59%	463.5	3,800
Validation Blast #2	15-Mar	321	1:30	12.96	83.49%	519.8	4,158
Validation Blast #2	16-Mar	302	1:36	13.25	91.72%	488	4,002
Validation Blast #2	19-Mar	256	1:40	12.27	63.53%	442	3,141
Validation Blast #2	20-Mar	256	1:40	12.27	63.53%	442.4	3,366
Total		**1,671**					**21,375**
Average			**1:41**	**12.62**	**73.17%**	**450.83**	
Validation Blast #3	22-Mar	321	1:33	11.84	44.24%	470.1	3,801
Validation Blast #3	23-Mar	300	1:37	12.19	60.67%	456.9	3,655
Validation Blast #3	26-Mar	218	1:12	11.52	33.49%	579.58	2,511
Validation Blast #3	27-Mar	241	1:59	11.53	39.83%	350.11	2,801
Validation Blast #3	28-Mar	221	1:39	11.04	29.86%	406.5	2,439
Total		**1,301**					**15,207**
Average			**1:36**	**11.62**	**41.62%**	**452.64**	
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Validation Blast #4	3-Apr	213	1:53	11.97	53.99%	318.6	2,549
Validation Blast #4	4-Apr	251	1:50	12.14	55.78%	380.9	3,047
Validation Blast #4	5-Apr	241	1:59	12.07	56.85%	350.6	2,910
Validation Blast #4	6-Apr	261	1:33	11.5	35.25%	375.3	3,002
Total		**1,442**					**17,314**
Average			**1:48**	**12.01**	**54.10%**	**363.70**	

QUARRY ACADEMY

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QUARRY ACADEMY

Discussion

- For validation blast 3 (12ms)
  - ✓ loader cycle times were shortest;
  - ✓ there was no improvement over baseline in bucket fill;
  - ✓ there was a reduction of 11% in the percentage of buckets weighing 12 tons or more.

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Total		1,263					16,173
Average			1:30	12.84	80.36%	521.18	
Validation Blast #2	13-Mar	237	2:07	12.27	61.18%	349.3	2,908
Validation Blast #2	14-Mar	299	1:36	12.71	75.59%	463.5	3,800
Validation Blast #2	15-Mar	321	1:30	12.96	83.49%	519.8	4,158
Validation Blast #2	16-Mar	302	1:36	13.25	91.72%	488	4,002
Validation Blast #2	19-Mar	256	1:40	12.27	63.53%	442	3,141
Validation Blast #2	20-Mar	256	1:40	12.27	63.53%	442.4	3,366
Total		1,671					21,375
Average			1:41	12.62	73.17%	450.83	
Validation Blast #3	22-Mar	321	1:33	11.84	44.24%	470.1	3,801
Validation Blast #3	23-Mar	300	1:37	12.19	60.67%	456.9	3,655
Validation Blast #3	26-Mar	218	1:12	11.52	33.49%	579.58	2,511
Validation Blast #3	27-Mar	241	1:59	11.53	39.83%	350.11	2,801
Validation Blast #3	28-Mar	221	1:39	11.04	29.86%	406.5	2,439
Total		1,301					15,207
Average			1:36	11.62	41.62%	452.64	
Validation Blast #4	29-Mar	253	1:49	12.24	62.45%	407.4	3,097
Validation Blast #4	2-Apr	223	1:46	12.15	60.27%	349.4	2,709
Validation Blast #4	3-Apr	213	1:53	11.97	53.99%	318.6	2,549
Validation Blast #4	4-Apr	251	1:50	12.14	55.78%	380.9	3,047
Validation Blast #4	5-Apr	241	1:59	12.07	56.85%	350.6	2,910
Validation Blast #4	6-Apr	261	1:33	11.5	35.25%	375.3	3,002
Total		1,442					17,314
Average			1:48	12.01	54.10%	363.70	

QUARRY ACADEMY

Results

- **Impressive cost savings and increases in plant tonnage throughput were realized in spite of 28% increase in D&B costs!**
  - ✓ **10 to 27% increase in crusher plant capacity over baseline of 373 tons per hour to an average of 475 tons/hr**
  - ✓ **17% to 31 % reduction in net total cost per ton when scalping**
  - ✓ **8.8% reduction in net total cost per ton without scalping**

QUARRY ACADEMY

Supplemental Work 1

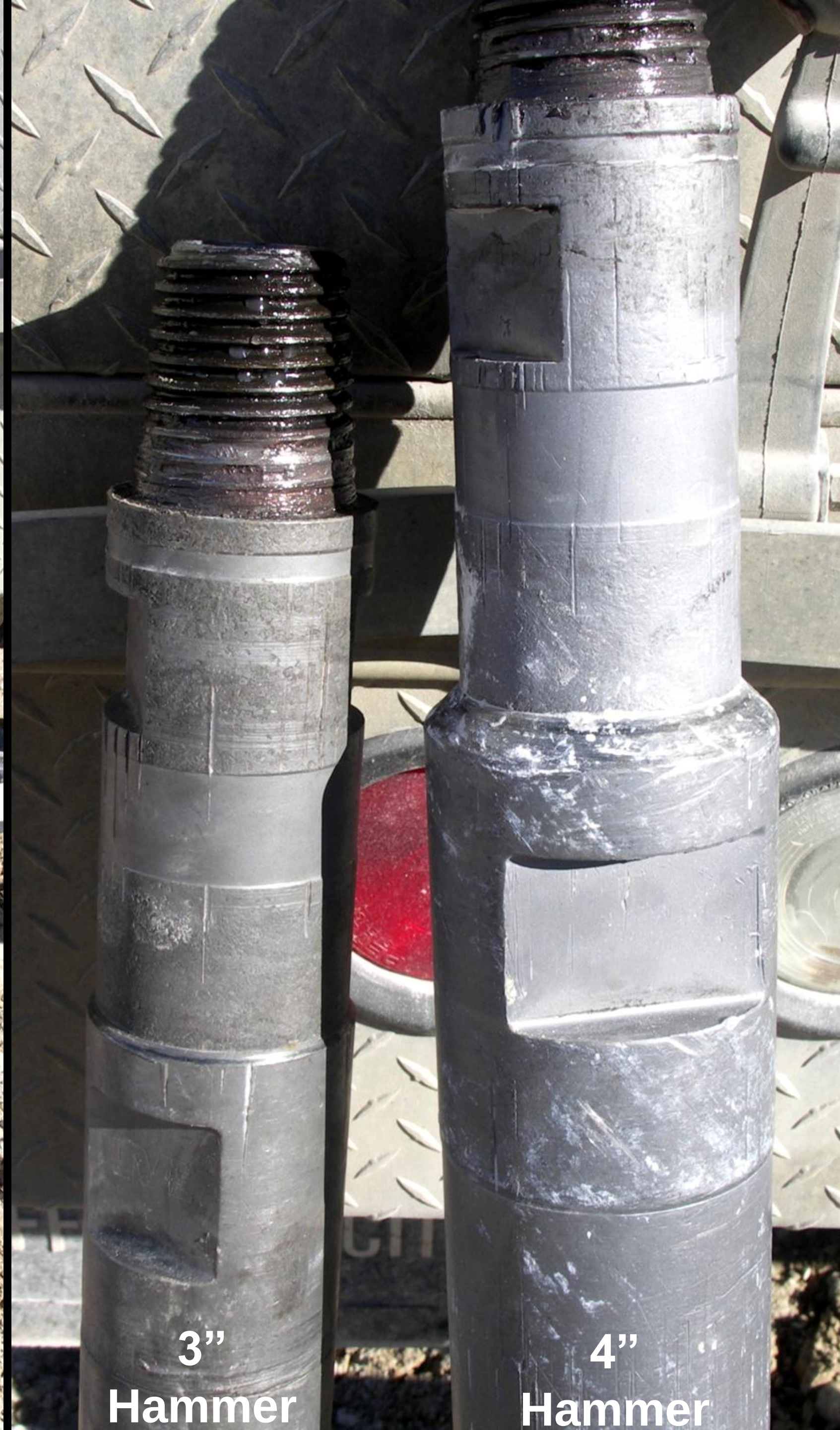
- **Metso LocoTrack portable crushing plant, supporting equipment and the blast design were moved to the CQCI California, MO quarry.**
  - ✓ **Similar cost reductions were realized there**
  - ✓ **Increased performance and productivity allowed 25% reduction of budgeted operating days to produce a 100,000 ton order.**

QUARRY ACADEMY

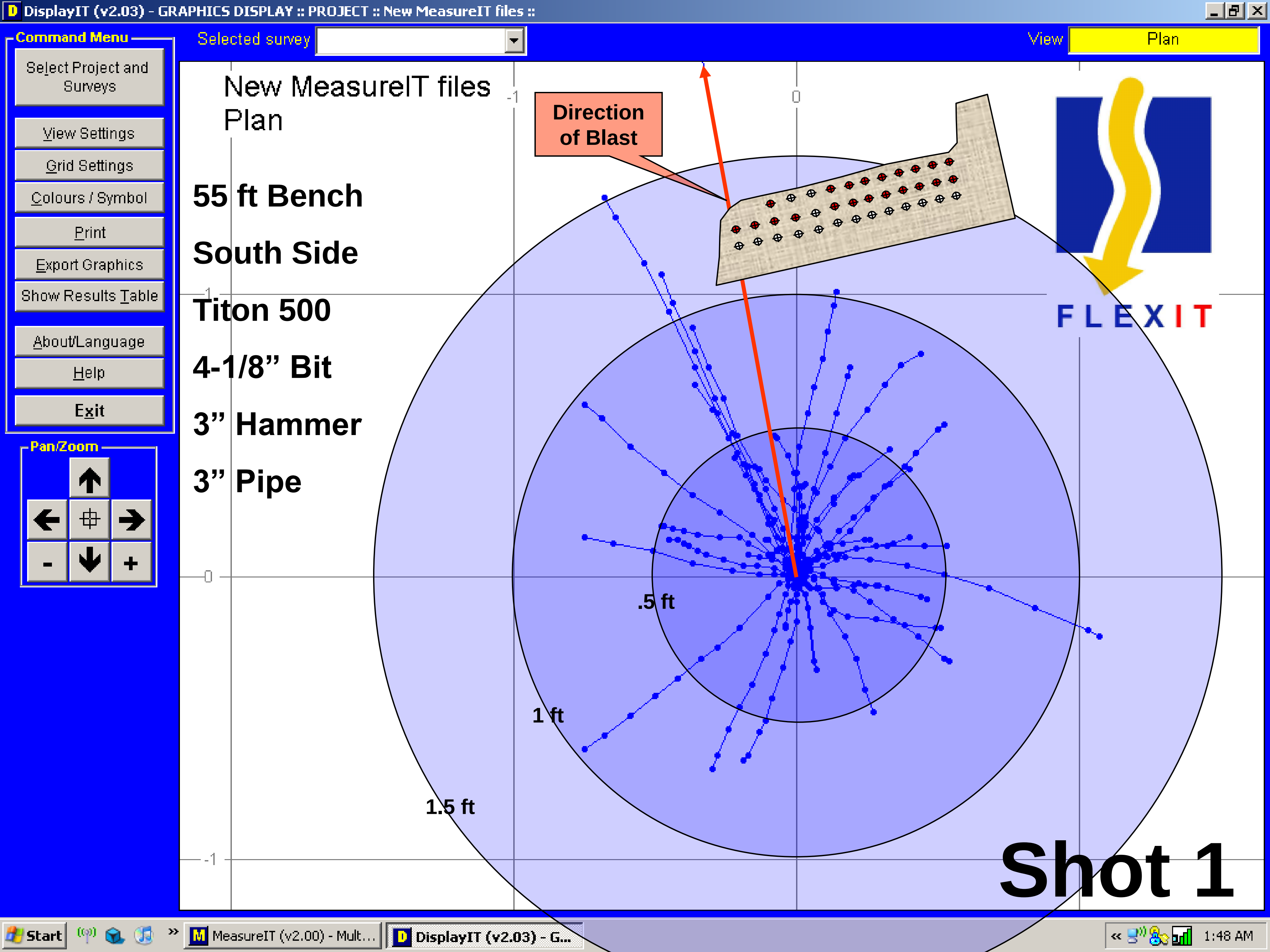
Supplemental Work 2

- **Precision and accuracy of drilling was investigated.**
  - Sandvik Titon® 500
    - Down-the-hole (DTH) track mounted drill using 3 inch and 3.5 inch diameter drill pipe with 3 inch and 4 inch diameter DTH hammers.
  - 4 months testing at 4 quarry locations
  - Crushing plant throughput increased another 45%.

QUARRY ACADEMY


3”
Hammer
4”
Hammer


Limestone Quarry
Exposed 55 ft Bench Face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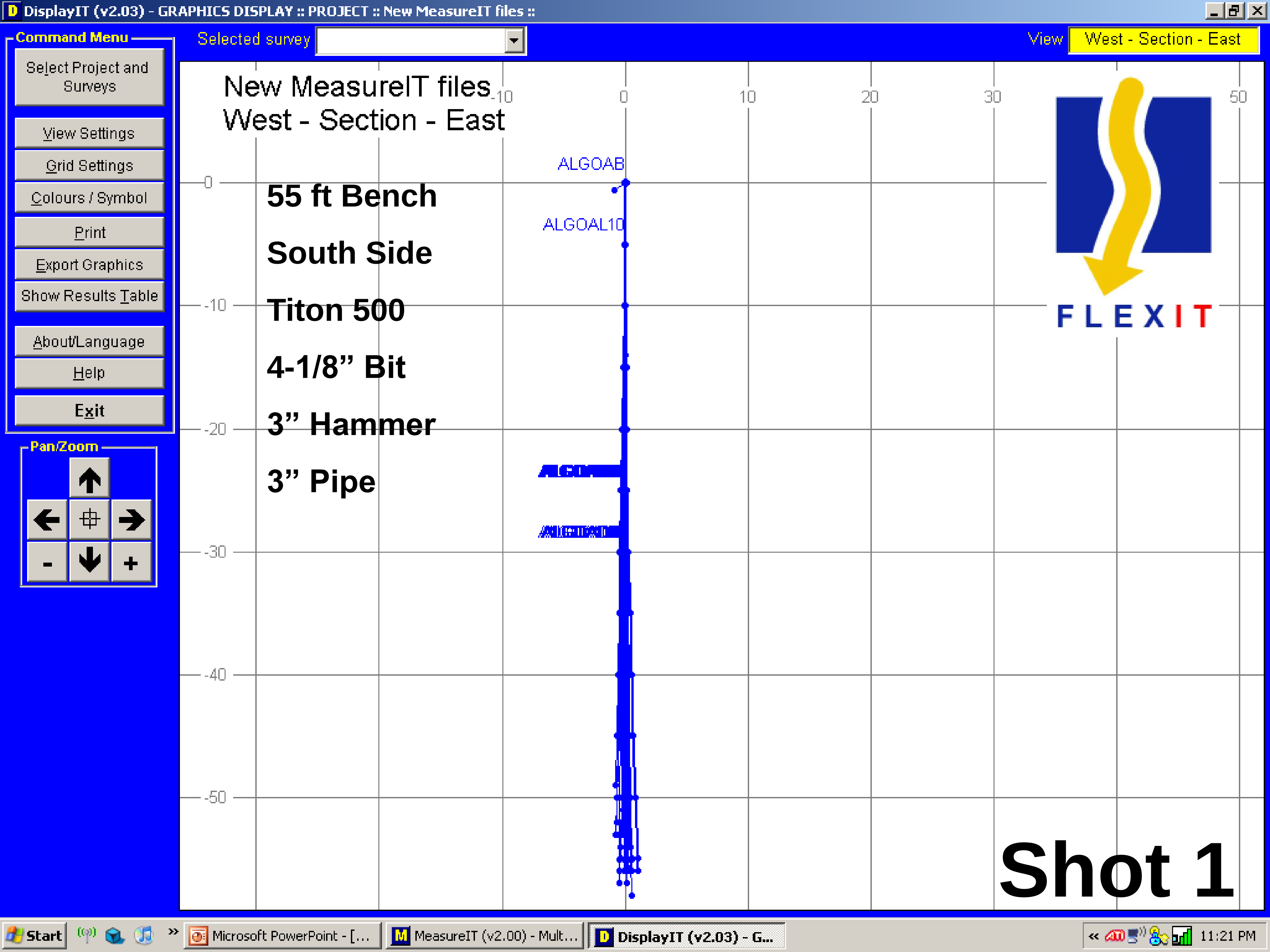
View Settings
Grid Settings
Colours / Symbol
Print
Export Graphics
Show Results Table
About/Language
Help
Exit
Pan/Zoom
Selected survey
View
Plan
New MeasureIT files
Plan
55 ft Bench
South Side
Titon 500
4-1/8” Bit
3” Hammer
3” Pipe
Direction of Blast
FLEXIT
.5 ft
1 ft
1.5 ft
Shot 1
Start
MeasureIT (v2.00) - Mult...
DisplayIT (v2.03) - G...
1:48 AM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Help
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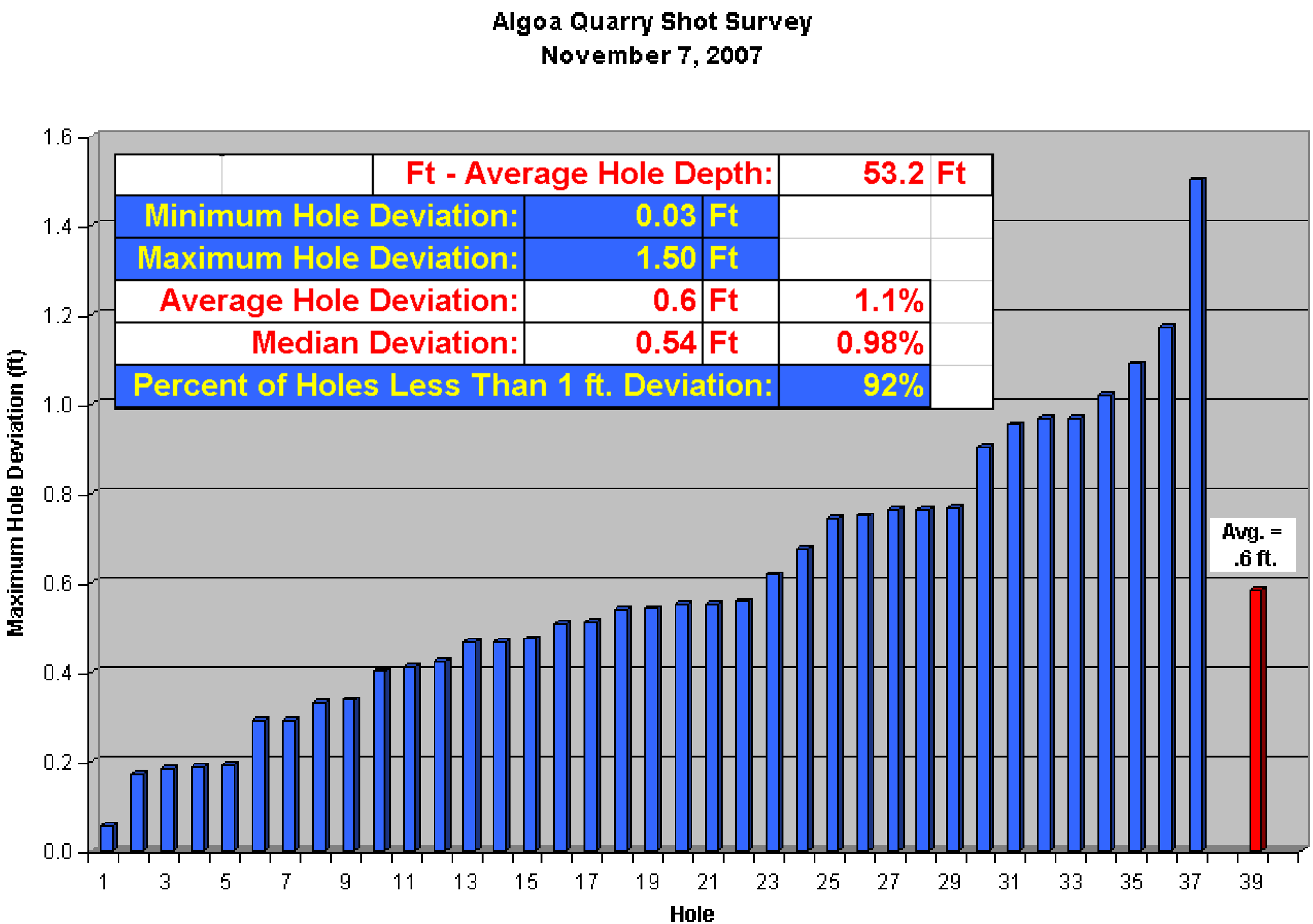
-10
0
10
20
30
50
ALGOAB
ALGOAL10
-10
-20
-30
-40
-50
55 ft Bench
South Side
Titon 500
4-1/8” Bit
3” Hammer
3” Pipe
FLEXIT
Shot 1
Start
Microsoft PowerPoint - [...
MeasureIT (v2.00) - Mult...
DisplayIT (v2.03) - G...
11:21 PM

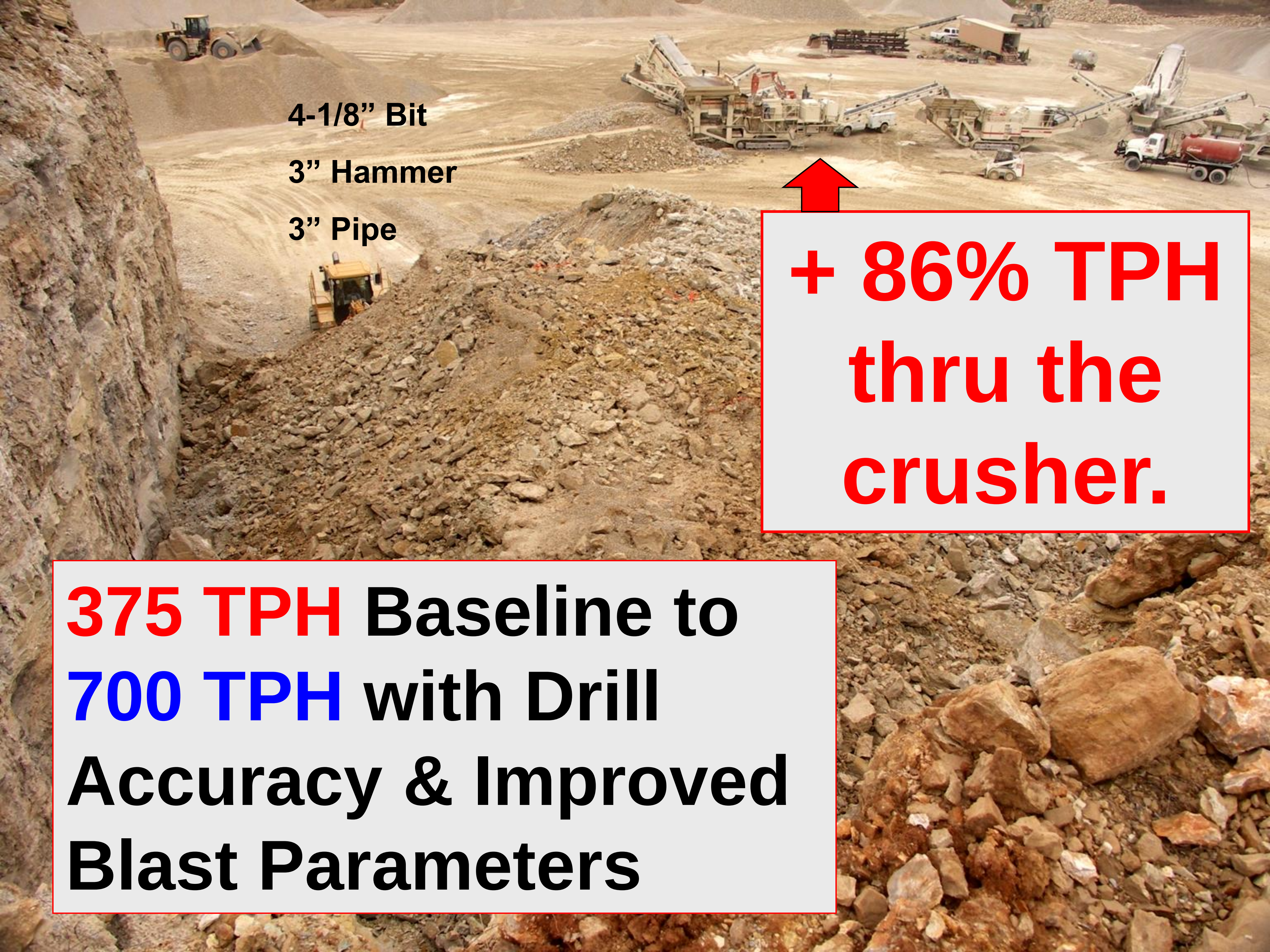


Ft - Average Hole Depth:		53.2	Ft
Minimum Hole Deviation:	0.03	Ft	
Maximum Hole Deviation:	1.50	Ft	
Average Hole Deviation:	0.6	Ft	1.1%
Median Deviation:	0.54	Ft	0.98%
Percent of Holes Less Than 1 ft. Deviation:			92%

QUARRY ACADEMY

Exposed 55 ft Bench Face looking North


4-1/8” Bit
3” Hammer
3” Pipe


4-1/8” Bit
3” Hammer
3” Pipe
+ 86% TPH thru the crusher.
375 TPH Baseline to 700 TPH with Drill Accuracy & Improved Blast Parameters

Operations Process Improvement
Case Work #1 Project Outcomes

- **Drilling and Blasting cost increased by 28%.**
- **Waste was reduced by 19%.**
- **Impressive cost savings and increases in plant tonnage throughput within the “Blast to 1 inch minus” process of the Holt Summit Value Map were realized over the validation phase of the project.**

QUARRY ACADEMY

Operations Process Improvement
Case Work #1 Project Outcomes

- **The standard cost model for the "Blast to 1 inch minus" process of the Holt Summit value map showed that over the total process:**
  - ✓ **There was a 10% to 27% increase in crusher plant capacity**
    - ✓ **27% from baseline of 373 TPH to an average of 475 TPH. A plus 102 TPH shift in capacity.**
  - ✓ **There was a 7% to 31% reduction in net total cost per ton when scalping was used.**
  - ✓ **When scalping was not utilized an 8.8% reduction in the net cost per ton was achieved.**

QUARRY ACADEMY

Conclusions

- **Drilling & Blasting can be a significant contributor to the aggregate producer's value chain. Maintaining control of the entire drill and blast process is imperative. Consistency and reproducibility are key drivers.**
- **The lessons learned in the casework were found to be transferable based on actual performance testing of the blast design at another of the Capital Quarries Company, Inc. operations.**

QUARRY ACADEMY

Acknowledgements

- **Eric Strope, President, Capital Quarries Company, Inc., Jefferson City, MO**
- **Kevin Nichols, Superintendent, Capital Quarries Company, Inc., Holts Summit, MO**
- **Mark Schneider, Driller, Capital Quarries Company, Inc., Jefferson City, MO**
- **Ron Coulter, Senior Blasting Technician, Dyno Nobel Inc., Hermann, MO**
- **Keith Henderson, Technical Sales Manager, Dyno Nobel Inc., Union, MO**
- **Daryl Hale, Account Manager, Dyno Nobel Inc., New Haven, MO**

QUARRY ACADEMY

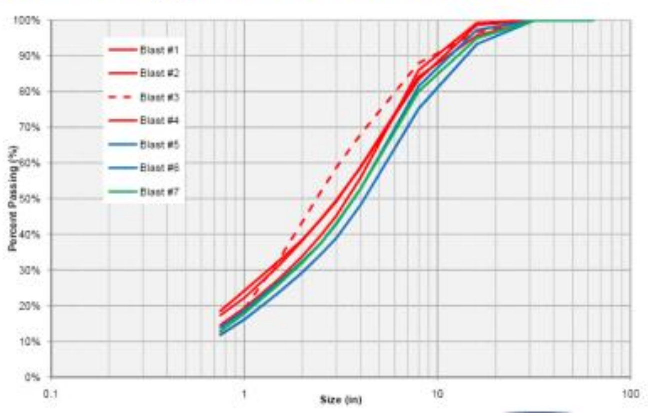
Fines Reduction*
Leveraging Drill & Blast – Case Work #2

*Increase saleable product. Lower total cost.
Increase profit margin. Fines defined as minus ¾ ”.

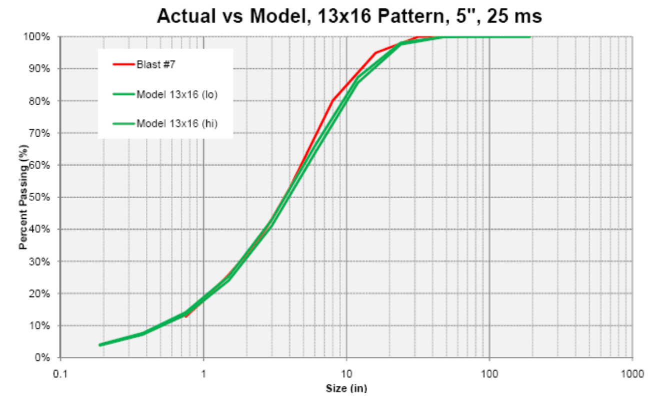
Operations Process Improvement
Case Work #2 Project Outcomes

- **Pattern Optimization**
  - ✓ **Expanded 58%**
    - ✓ **Baseline 12 ft x 14 ft**
    - ✓ **Current 14 ft x 19 ft**
  - ✓ **$0.082 savings per ton drill and blast (including electronic detonators)**
- **4 % reduction in fines with changes to drill & blast design.**

Actual Fragmentation for All Blasts



Comparison of Model & Wipfrag Results



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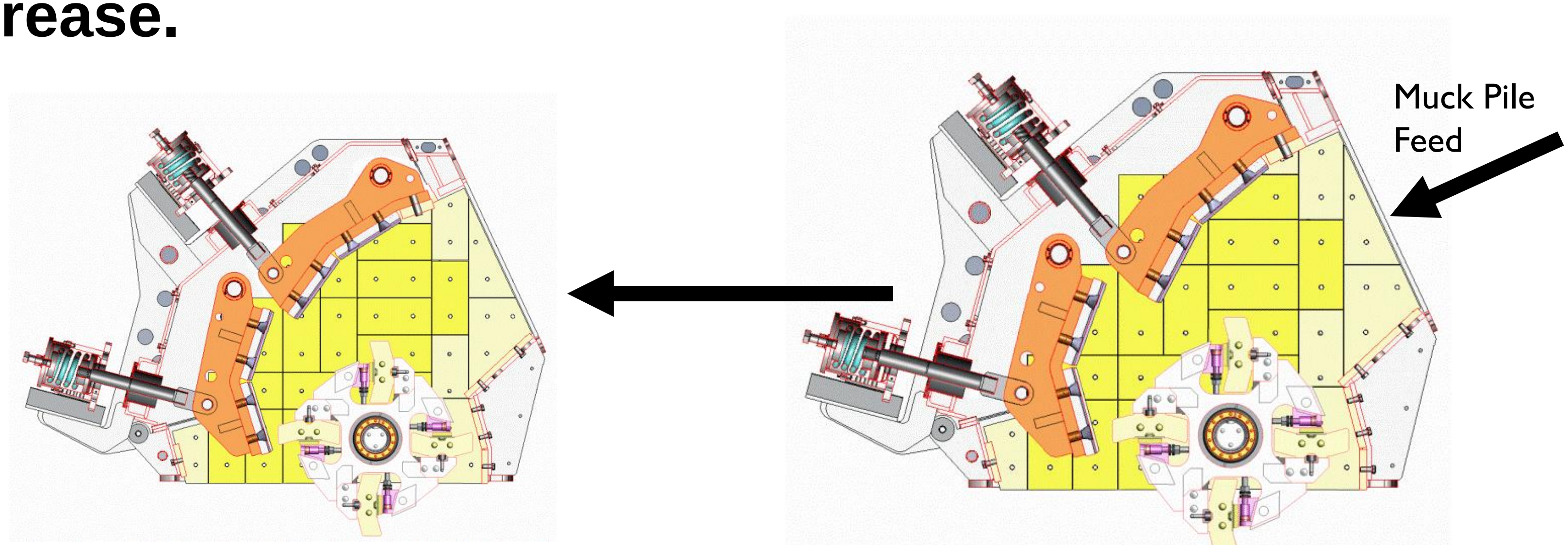
Operations Process Improvement
Case Work #2 Project Outcomes

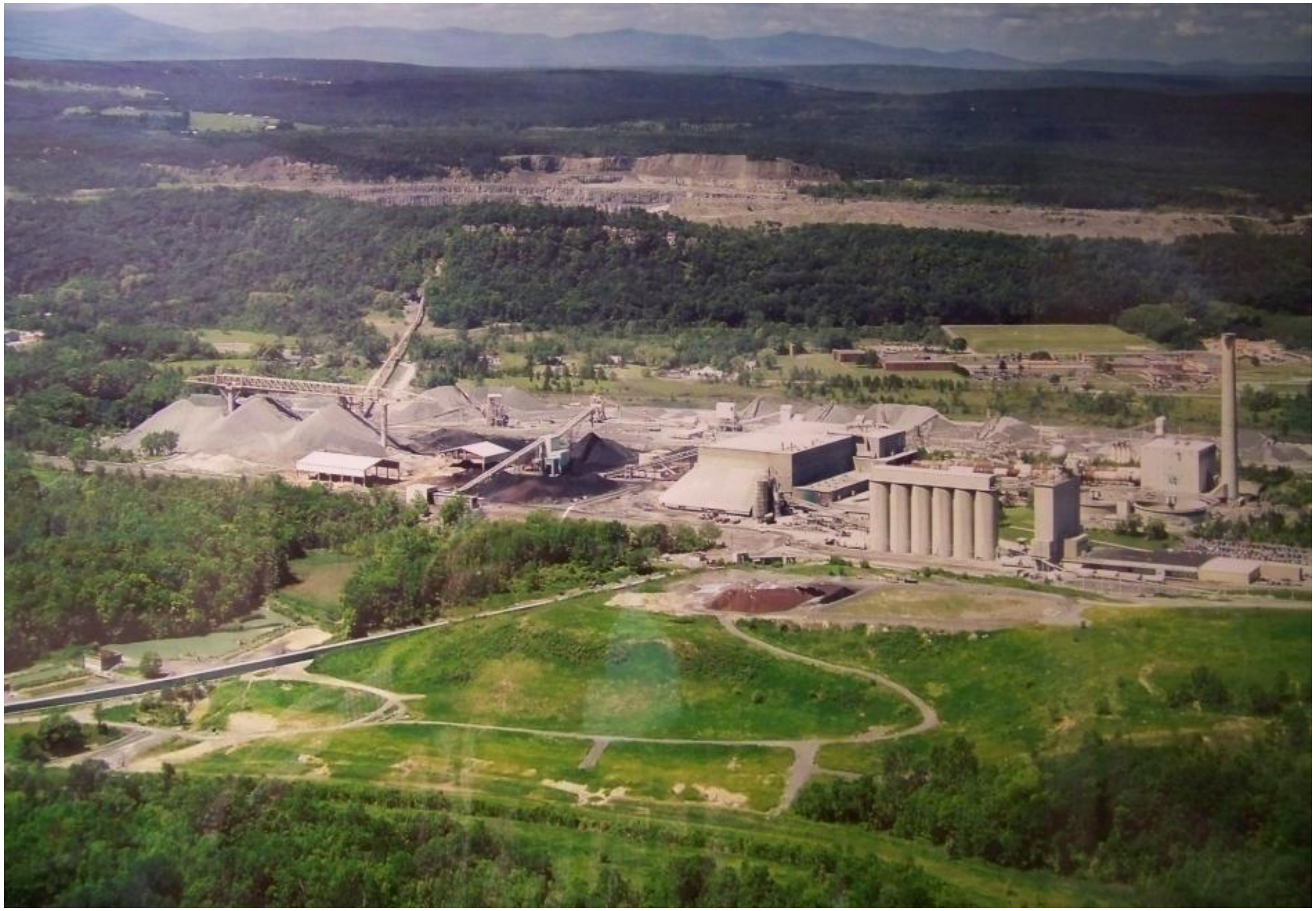
- **11% reduction in fines achieved with changes in plant operation**
- **Total fines reduced from 73% to 56% of total plant output.**
- **Increased saleable product by approximately 10% increase.**



Secondary Primary

QUARRY ACADEMY

Lafarge Building Materials
Ravena, NY Quarry



QUARRY
ACADEMY

Lafarge Building Materials
Ravena, NY Quarry

- **Four (4) operational benches. Three (3) of which have value for Cement.**

QUARRY ACADEMY

Lafarge Building Materials
Ravena, NY Quarry

- **The quarry's goal is to produce and deliver a cost effective in-spec product to its customers, the Lafarge North America cement plant and an independent aggregate producer.**
- **Process**
  - **Superior MK-II 54-75 Gyratory Crusher. Max 2,000 tph at a 9 inch close side setting.**

QUARRY ACADEMY

Lafarge Building Materials
Ravena, NY Quarry

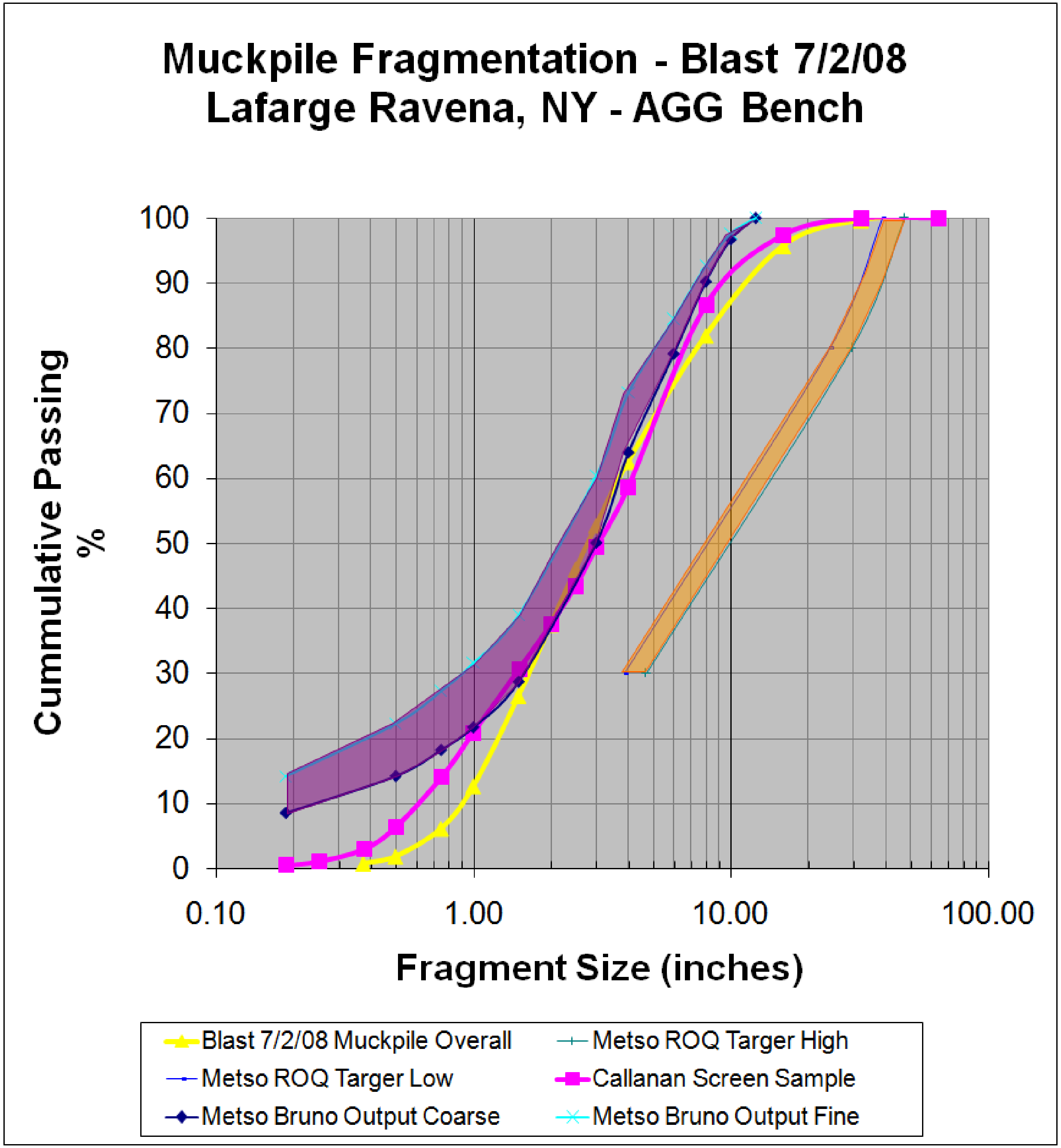
- **Operation has maintained a continuous improvement process for over 6 years.**
- **Key process management and metric systems:**
  - ✓ **Logimine CC4 On-line Mining System**
    - GPS - Drills, Dozers, Wheel Loaders, Haul Trucks
    - Load Cells – Haul Trucks
  - ✓ **Geo-Instruments Jean Lutz Drill Monitoring System.**
  - ✓ **WipWare Reflex and Solo Fragmentation Analysis**

QUARRY ACADEMY

Lafarge Building Materials
Ravena, NY Quarry

- **Process**
  - Superior MK-II 54-75 Gyratory Crusher. Max 1,700 tons per hour at 6 ¾ inch closed side setting and 8 inch open side setting. (400 HP)

QUARRY ACADEMY



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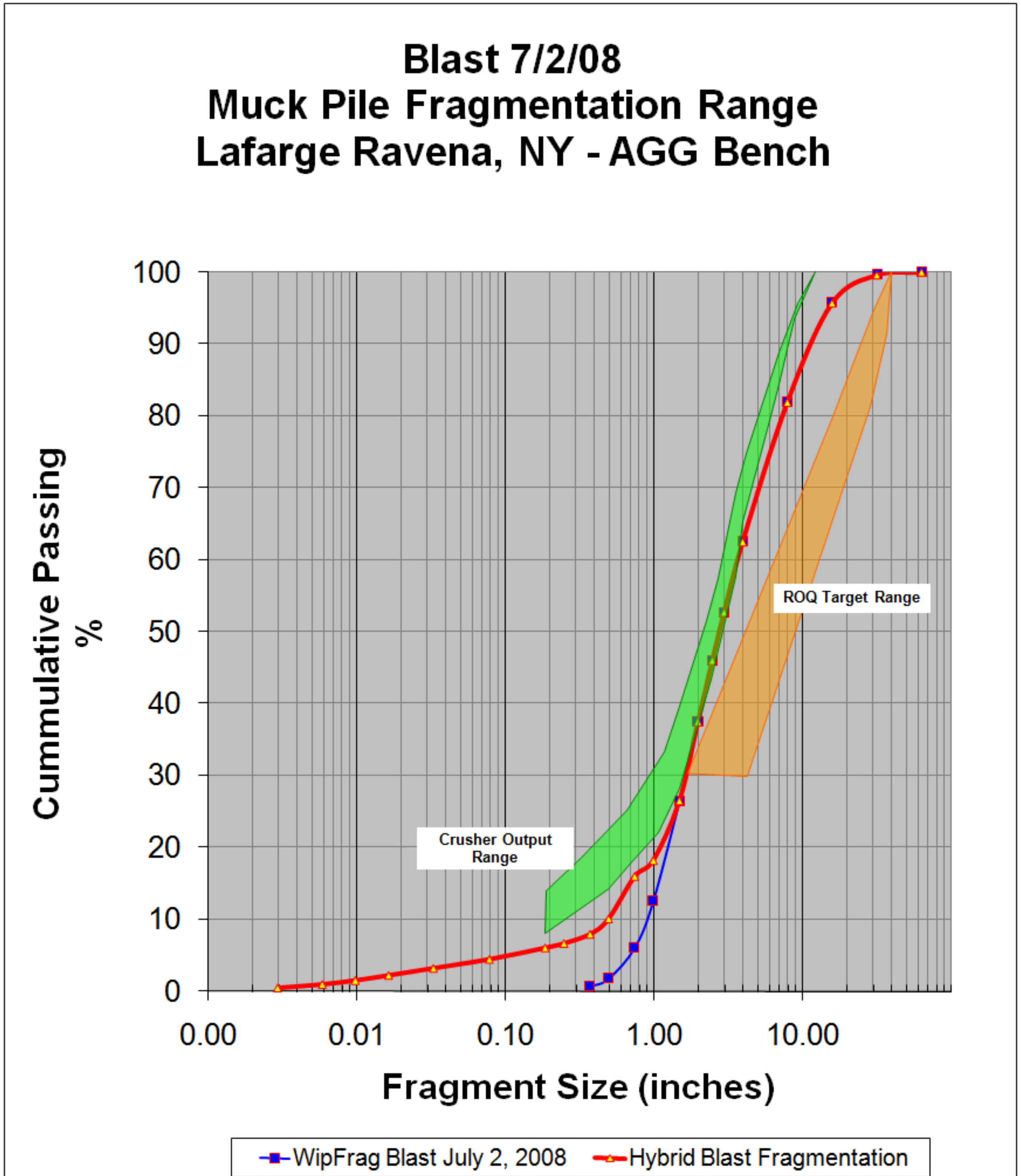

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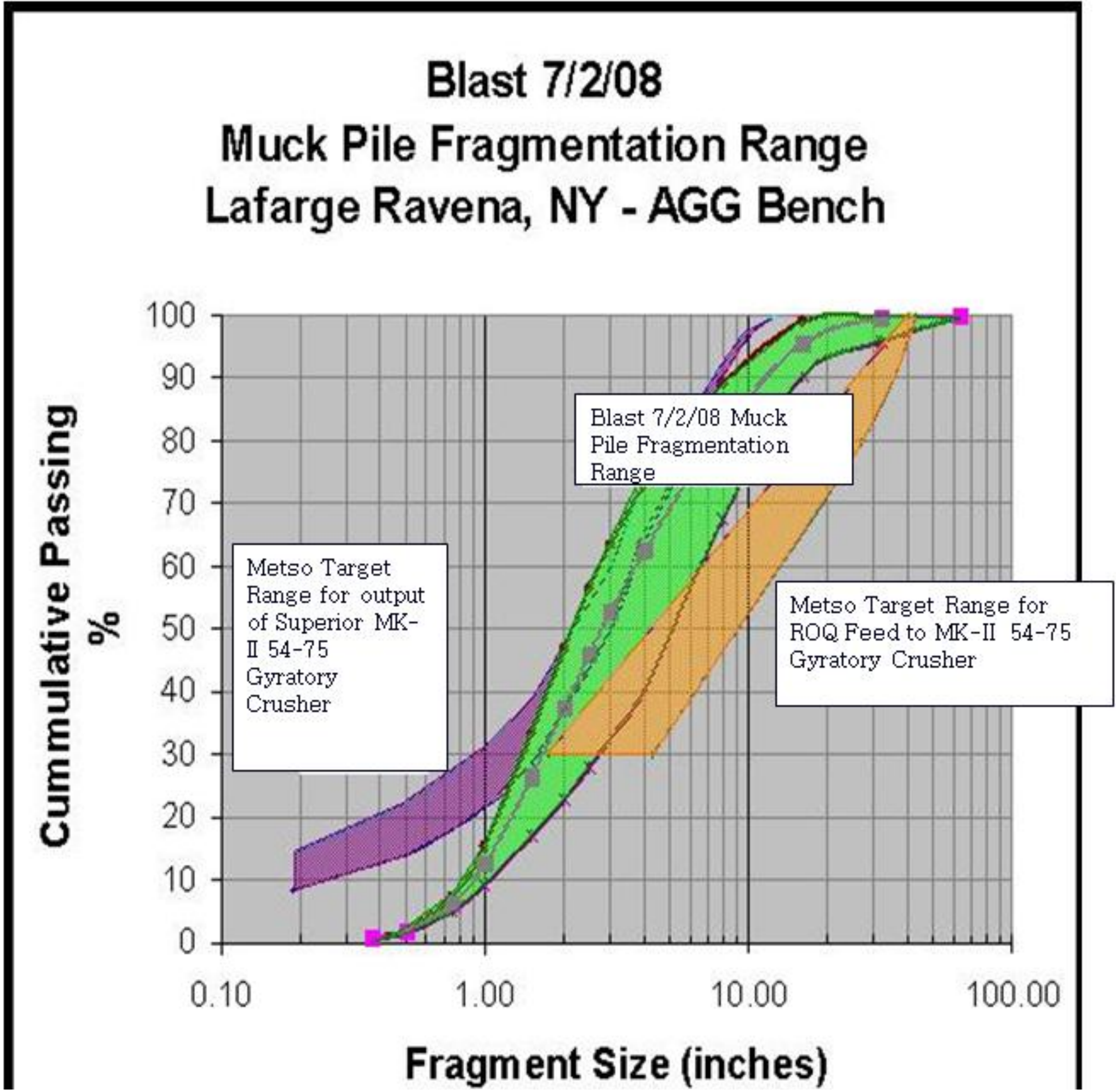
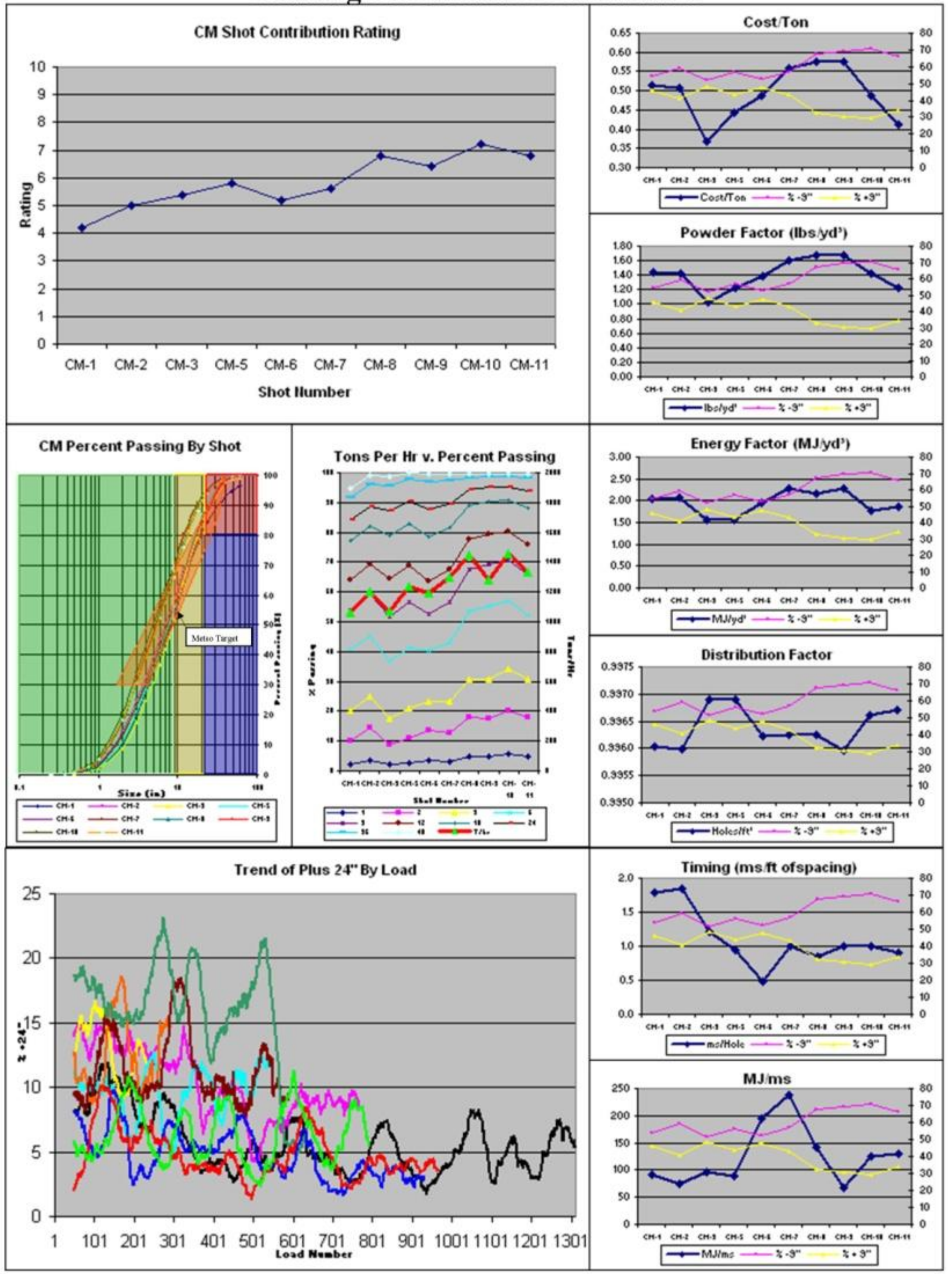


QUARRY ACADEMY

Blasting Performance Dashboard



QUARRY ACADEMY

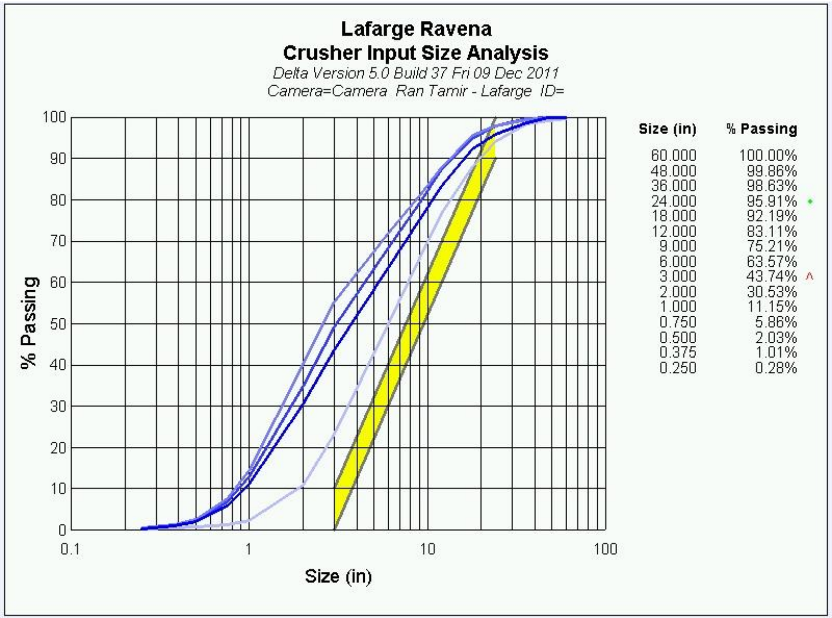
Raw Data Acquisition

- Drill Logs
- GPS Blast Hole Map
- Blast Report
- Logimine Operator Report
- Crusher Operator Report
- Crusher input Data
- Conveyor belt Data

QUARRY ACADEMY

Crusher Input Data

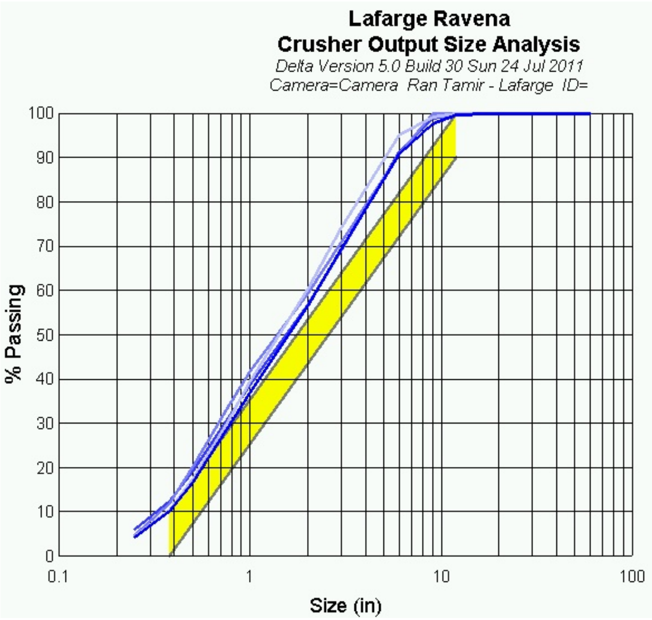
- A series of images of each load are automatically captured.
- The number of samples for each blast can range from 600 to 2600
- A daily report including a chart and a CSV file with time stamps and gradation percentages for each load dumped into the crusher.



Size (in)	% Passing
60.000	100.00%
48.000	99.86%
36.000	98.63%
24.000	95.91%
18.000	92.19%
12.000	83.11%
9.000	75.21%
6.000	63.57%
3.000	43.74%
2.000	30.53%
1.000	11.15%
0.750	5.86%
0.500	2.03%
0.375	1.01%
0.250	0.28%

Conveyor Belt Data

- **A second camera is mounted on the discharge belt captures images of the belt feed at a rate of one image every fifteen seconds. - 5K-20K samples per blast**
- **A daily report including an overall gradation chart and CSV file including time stamps and gradation percentages.**

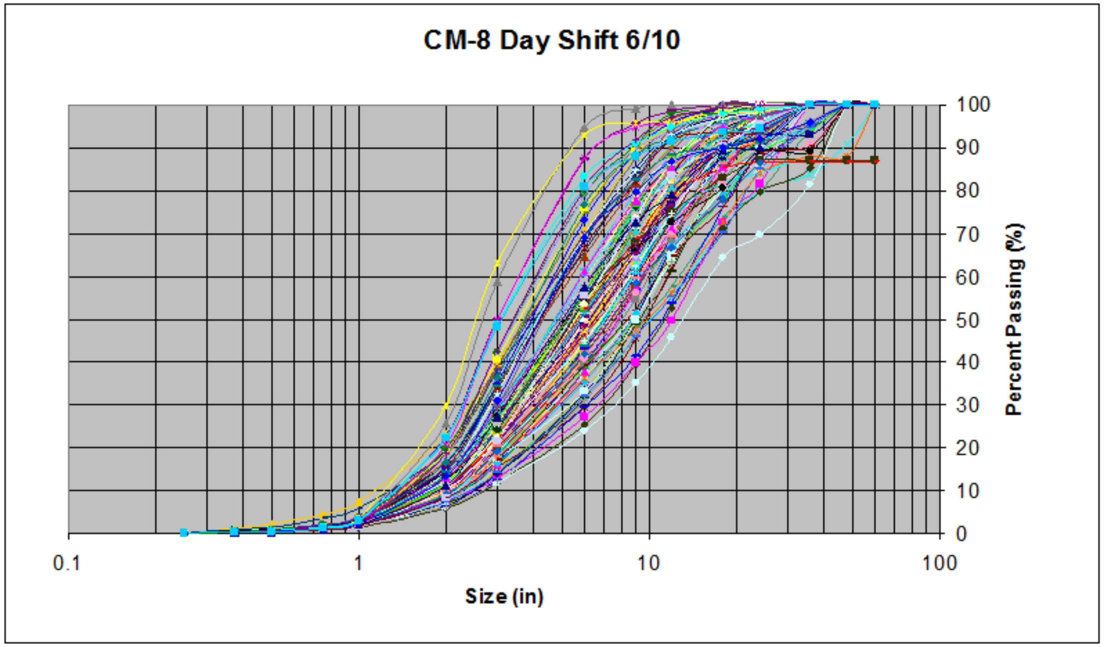


Size (in)	% Passing
60.000	100.00%
48.000	100.00%
36.000	100.00%
24.000	100.00%
18.000	100.00%
12.000	99.61%
9.000	97.70%
6.000	90.78%
3.000	69.25%
2.000	56.48%
1.000	36.75%
0.750	28.38%
0.500	16.61%
0.375	9.93%
0.250	4.23%

QUARRY ACADEMY

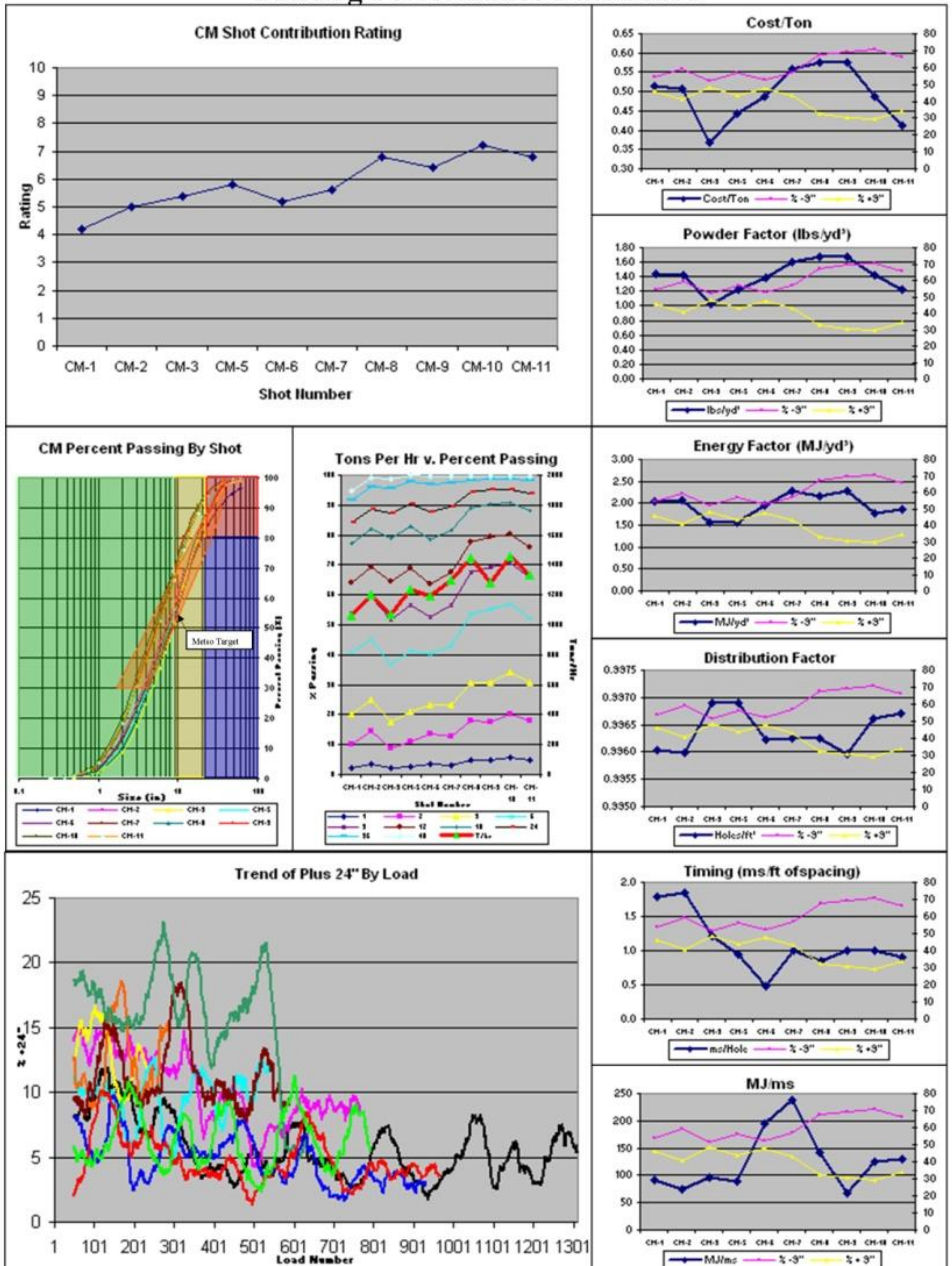
Processing the Raw Data

- **Processing the Raw Data, putting it into a workable form.**



QUARRY ACADEMY

Blasting Performance Dashboard



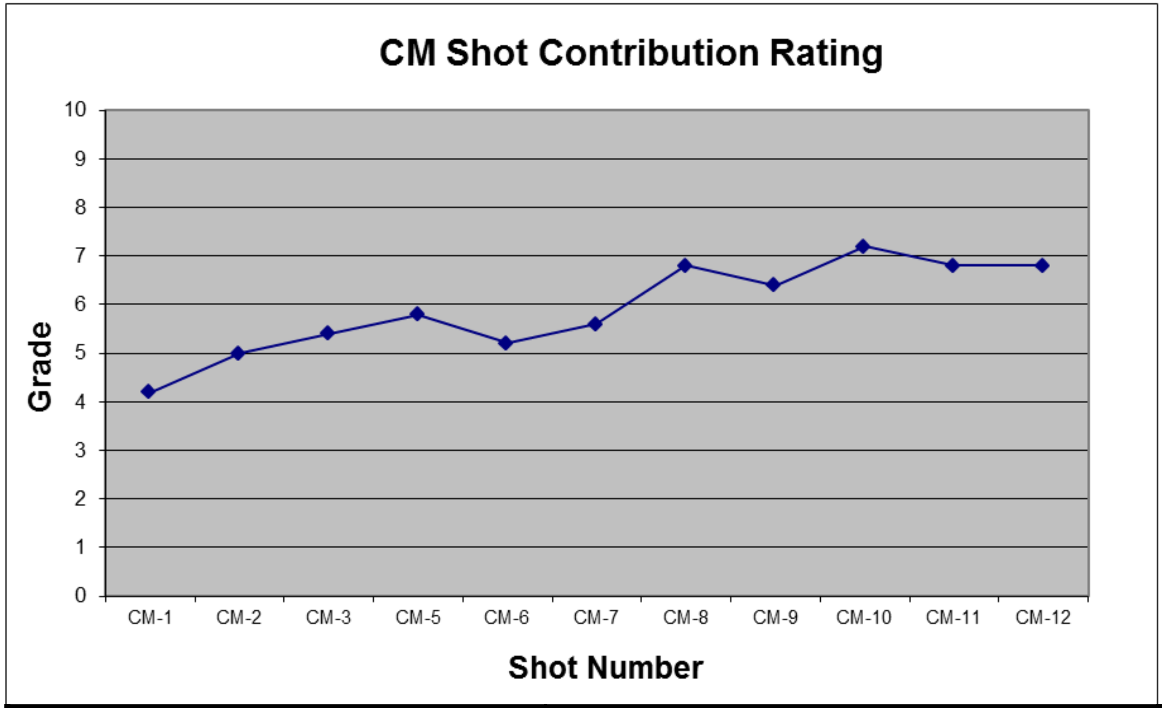
QUARRY ACADEMY

Blast Contribution Rating System

- Expresses the downstream contribution of components.
  - ✓ Fragmentation
  - ✓ Production Tons/hr
  - ✓ Drill and blast cost

CM Shot Contribution Rating System									
		Weight							
Tons Per Hour		40%	Total Blasting Cost/Ton		20%	Size (in) for which 80% passes			40%
>2000	11		<.28	11		<8"	11		
1850-1999	10		.28-.31	10		8-9.99"	10		
1700-1849	9		.34-.37	9		10-11.99"	9		
1550-1699	8		.38-.41	8		12-13.99"	8		
1400-1549	7		.42-.45	7		14-15.99"	7		
1250-1399	6		.46-.49	6		16-17.99"	6		
1100-1249	5		.50-.53	5		18-19.99"	5		
950-1099	4		.54-.57	4		20-21.99"	4		
800-949	3		.58-.61	3		22-23.99"	3		
650-799	2		.62-.65	2		24-25.99"	2		
<650	1		>.65	1		>26	1		

Blast Contribution Rating System



Blast contribution Rating Factors	Weight
Fragmentation (D80)	40%
Production (T/hr)	40%
Cost ($/ton)	20%

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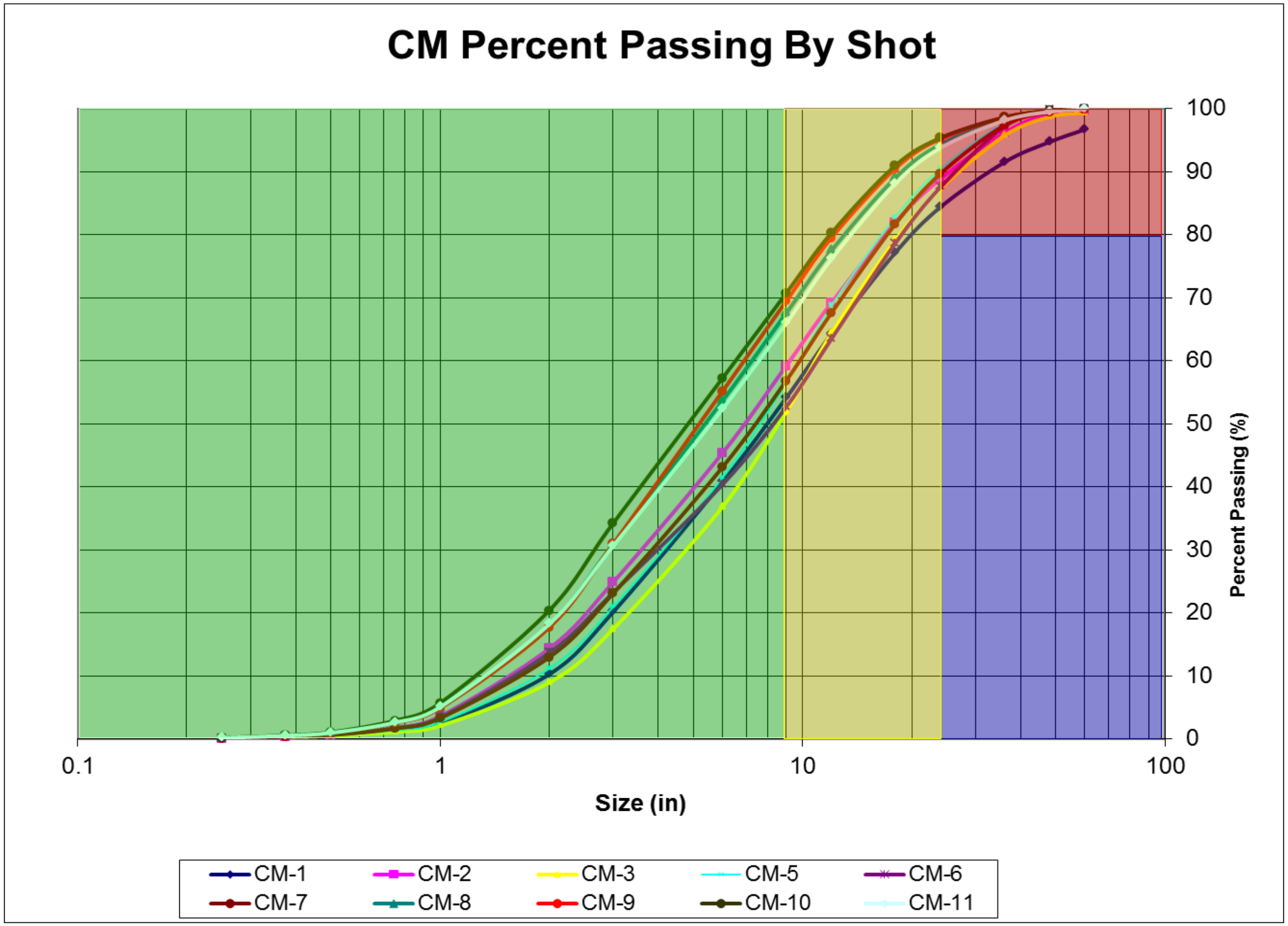
Cumulative Fragmentation Gradation



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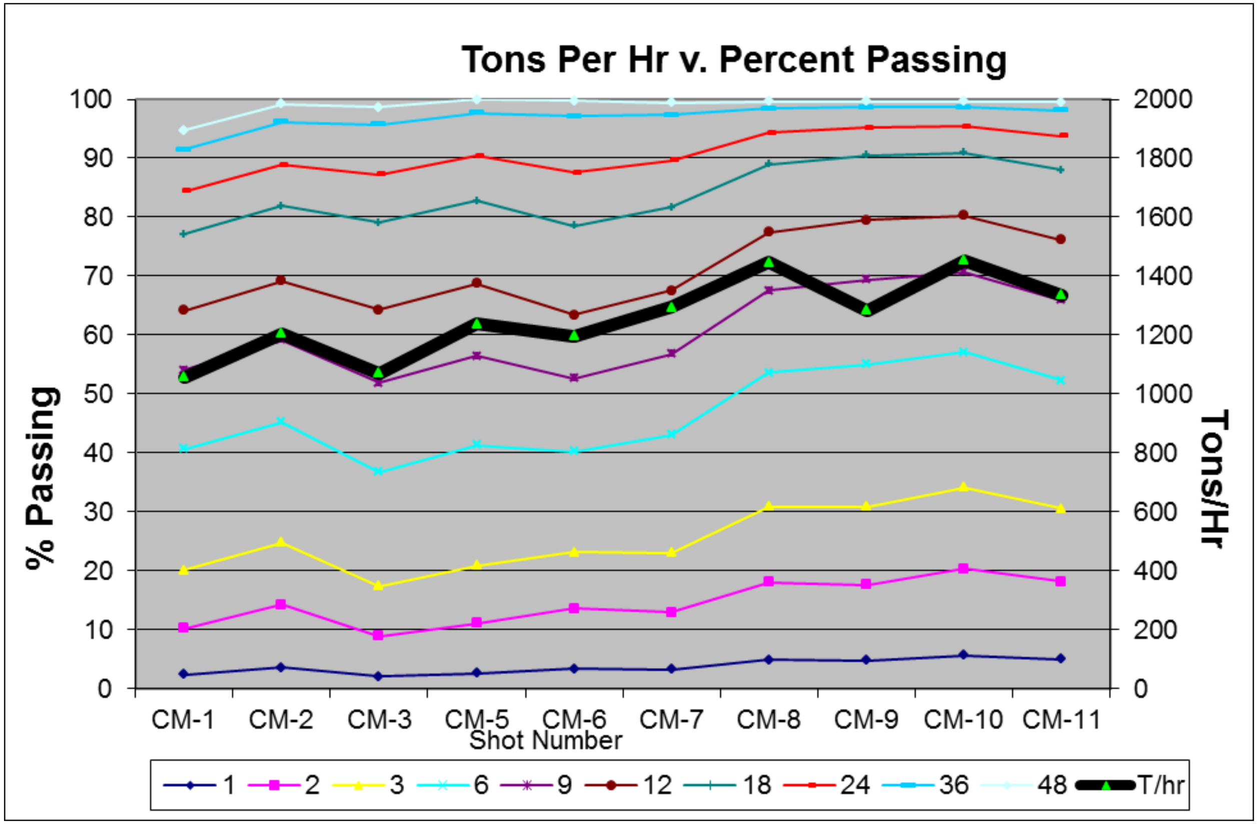
Tons per hour and Percent Passing



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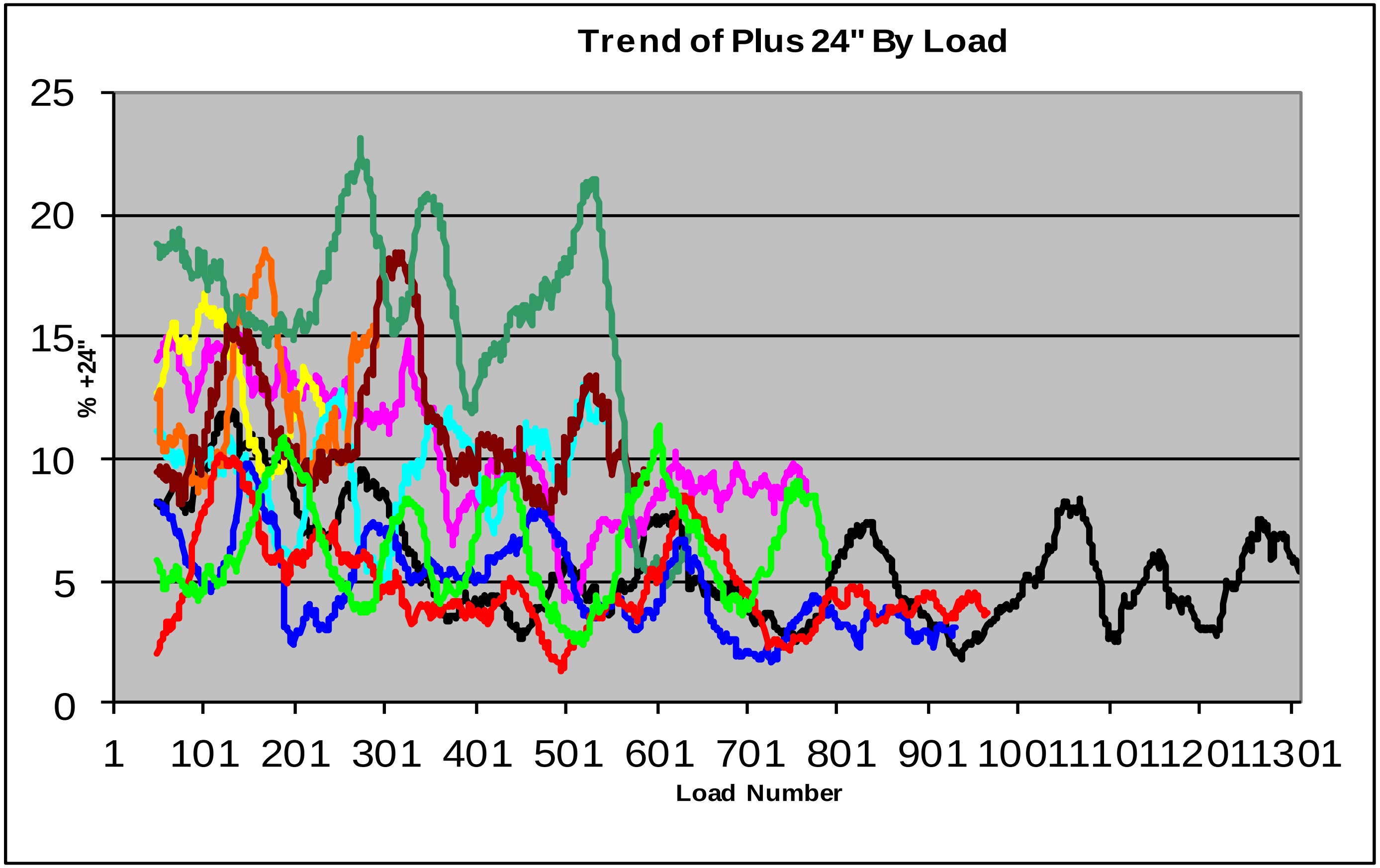
Top Size Material

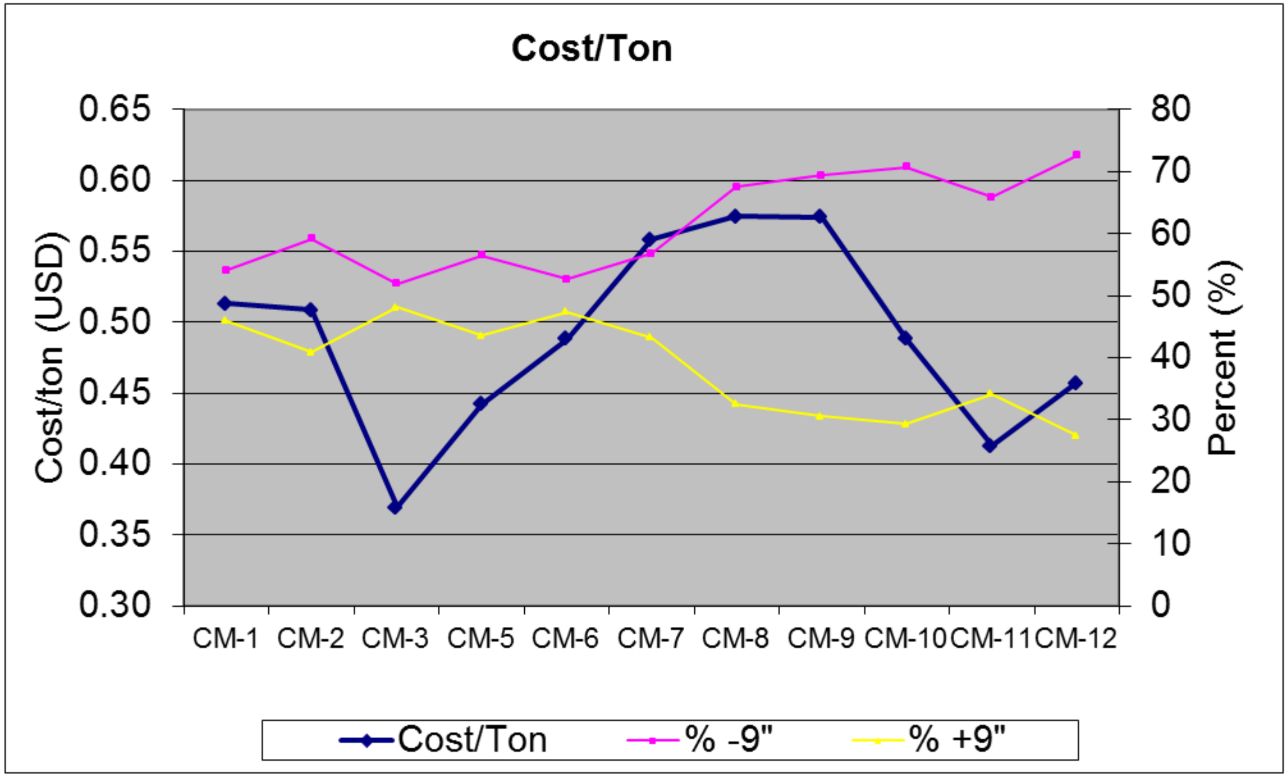


Controllable Blast Factors

- ✓ **Drill and Blast Cost ($/Ton)**
- ✓ **Energy Factor (MJ/Yd^3)**
- ✓ **Powder Factor (Lbs/Yd^3)**
- ✓ **Distribution Factor (1- #holes/ft^2)**
- ✓ **Timing Factor (ms/ft spacing)**
- ✓ **Power factor (MJ/ms)**

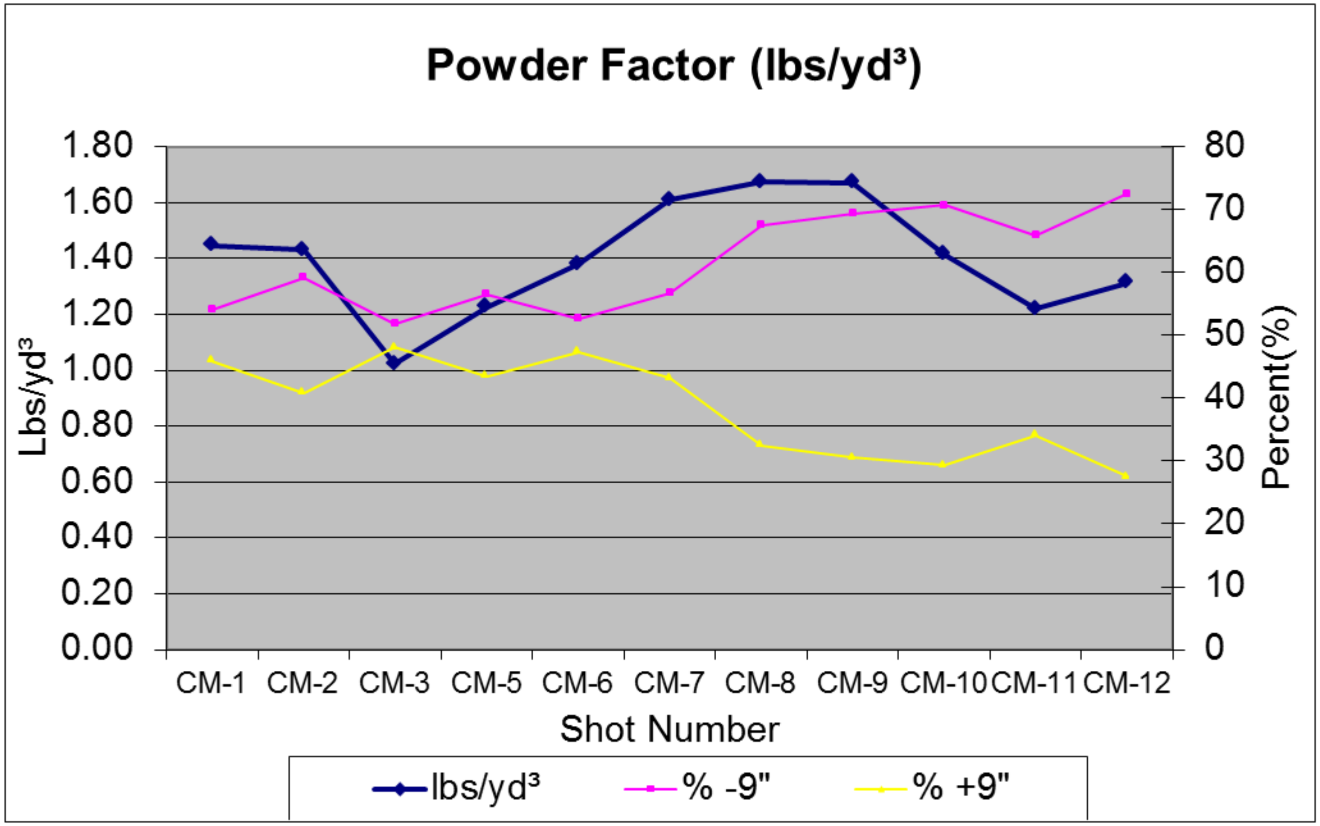
Controllable Blast Factors

- **Cost/Ton**



Controllable Blast Factors

- **Powder Factor**



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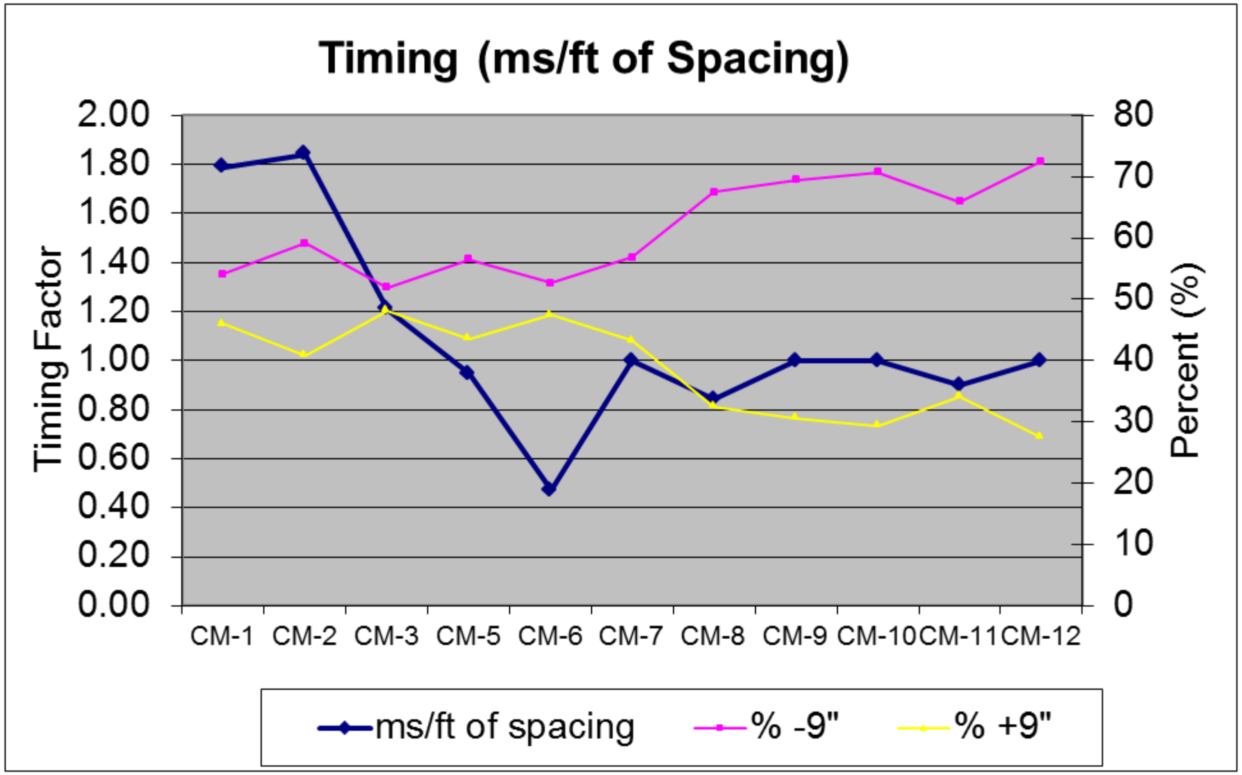
Controllable Blast Factors

- **Timing Factor**



Results

- **18 % increase in drill and blast cost.**
- **20% increase in crusher productivity.**
  - ✓ **7 ¾ inch closed side setting and 9 inch open side setting.**
- **12 % reduction in crushed product cost per ton.**

"View was well worth the climb!"

QUARRY ACADEMY

Acknowledgements

- Ran Tamir, Lafarge Building Materials
- John Truzkowski, Maine Drilling and Blasting
- James P. McGough South Dakota School of Mines

QUARRY ACADEMY

Chemical Crushing Case Studies

- **Main points to remember:**
  - To realize process improvement and economic savings from Chemical Crusher principles, a disciplined control of both plan and execution of the entire Drill and Blast process is required.
  - Quantifiable metrics need to be established and used to measure performance of baseline (what is happening today) and of changes to process.
  - Savings can be substantial. The view is worth the climb.

Chemical Crushing Case Studies

- **Main points to do: (safety above all at all times!)**
  - Evaluate contribution of Drill and Blast at the operation. Identify all opportunities to leverage Drill and Blast that might exist
  - Determine adequacy of controls used in the Drill and Blast process. Particularly those related to performance and quality.
  - Consider controlled process to evaluate the best chance opportunity. Use quantifiable metrics to validate operational and economic improvements and justify necessary investments.

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