Geotechnical-Geophysical Void Mapping and Foamed-Sand Backfilling of the Rapson Coal Mine, Colorado Springs, Colorado – Case Study

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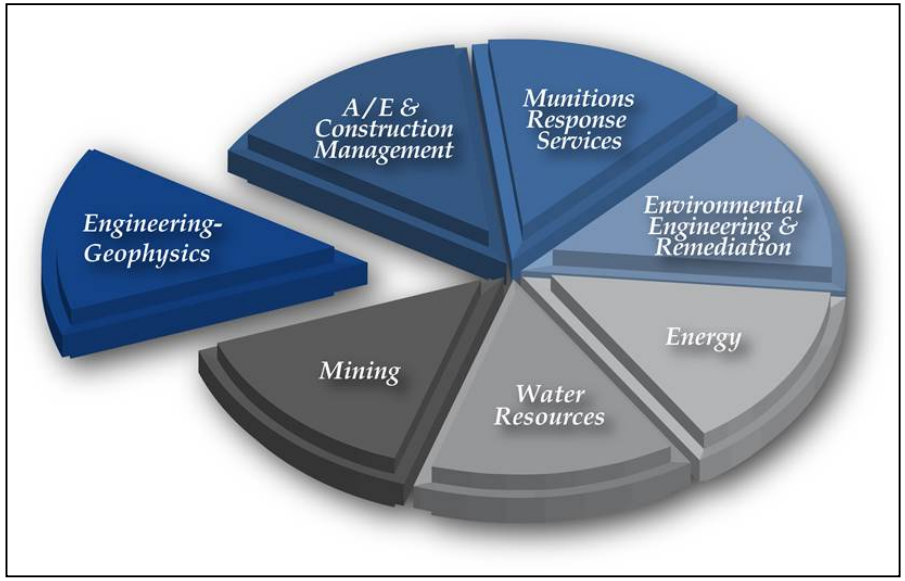
Joint Conference
2nd Wyoming Reclamation and Restoration Symposium
30th Annual Meeting of the American Society of Mining and Reclamation

Focus

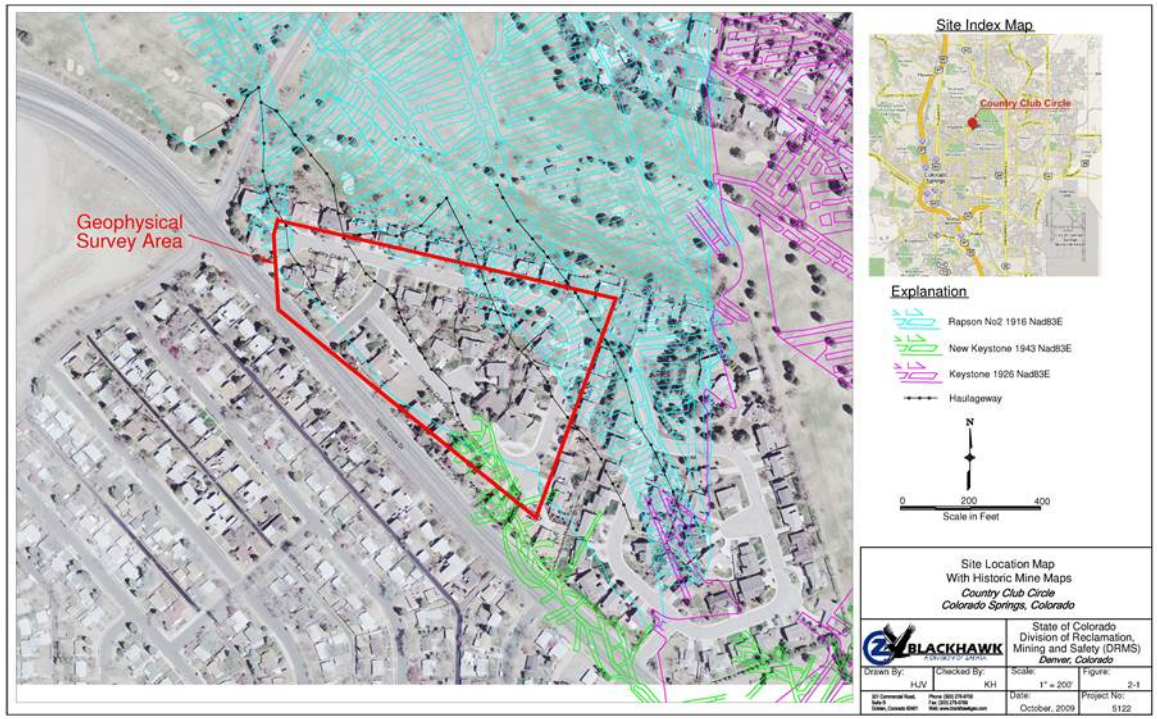
- Project Site Location & Subsidence/ Sinkhole Problems
- Geotechnical-Geophysical Methodology
  - Subsurface data acquisition and interpretation
  - Exploratory boring
  - Laser, sonar and video void investigation
- Colorado DRMS/Hayward Baker Ground Modification Treatment
  - Low mobility grouting or compaction grouting (LMG) beneath houses
  - Foamed sand slurry backfilling of large underground opening
- ZAPATA Video Monitoring of the Foamed-Sand Backfilling of the Rapson Mine

ZAPATA Services



Project Site Location – Subsidence / Sinkhole Problems

Country Club Circle (CCC) Residential Neighborhood



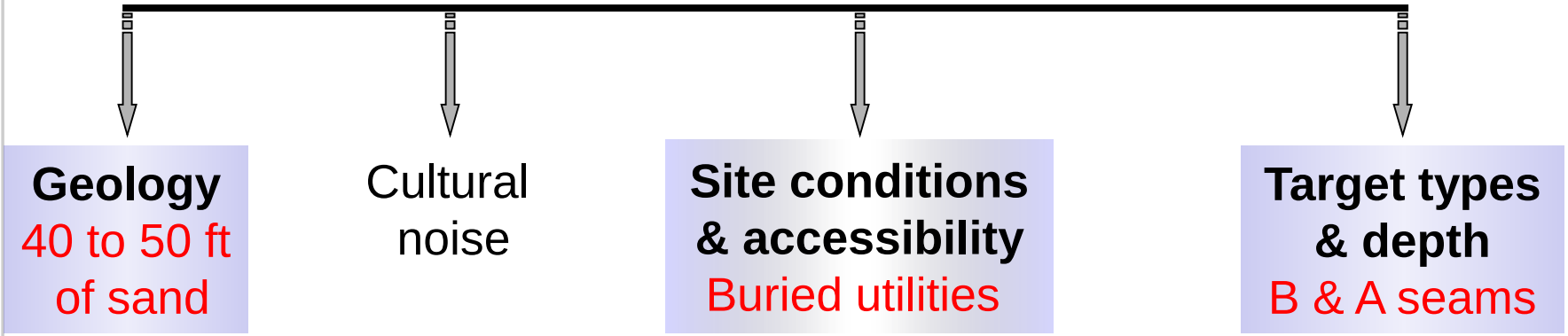
Historic subsidence

Trough subsidence

Sinkhole mitigation

Project site conditions required:

- A combination of several geophysical methods to provide reliable information



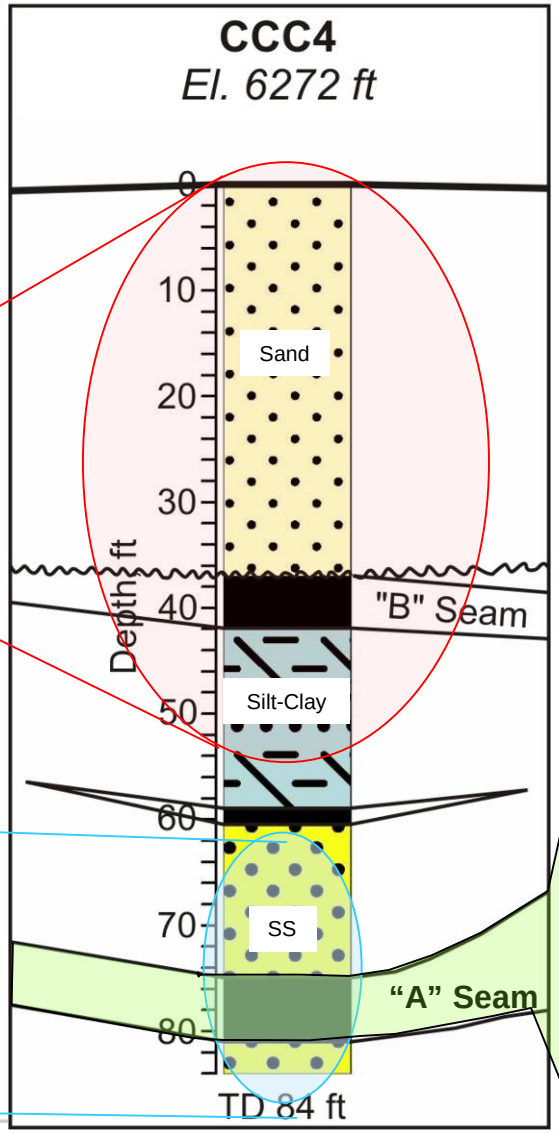
Animated

Geophysical Methodology – Geologic Setting

Three seismic techniques were used:
1. Surface seismic, &
2. Two borehole seismic.

MASW (surface) survey:
- Shallow subsurface evaluation
- Target drilling

RVSP (borehole-surface) survey:
- Mine working delineation
- Target drilling

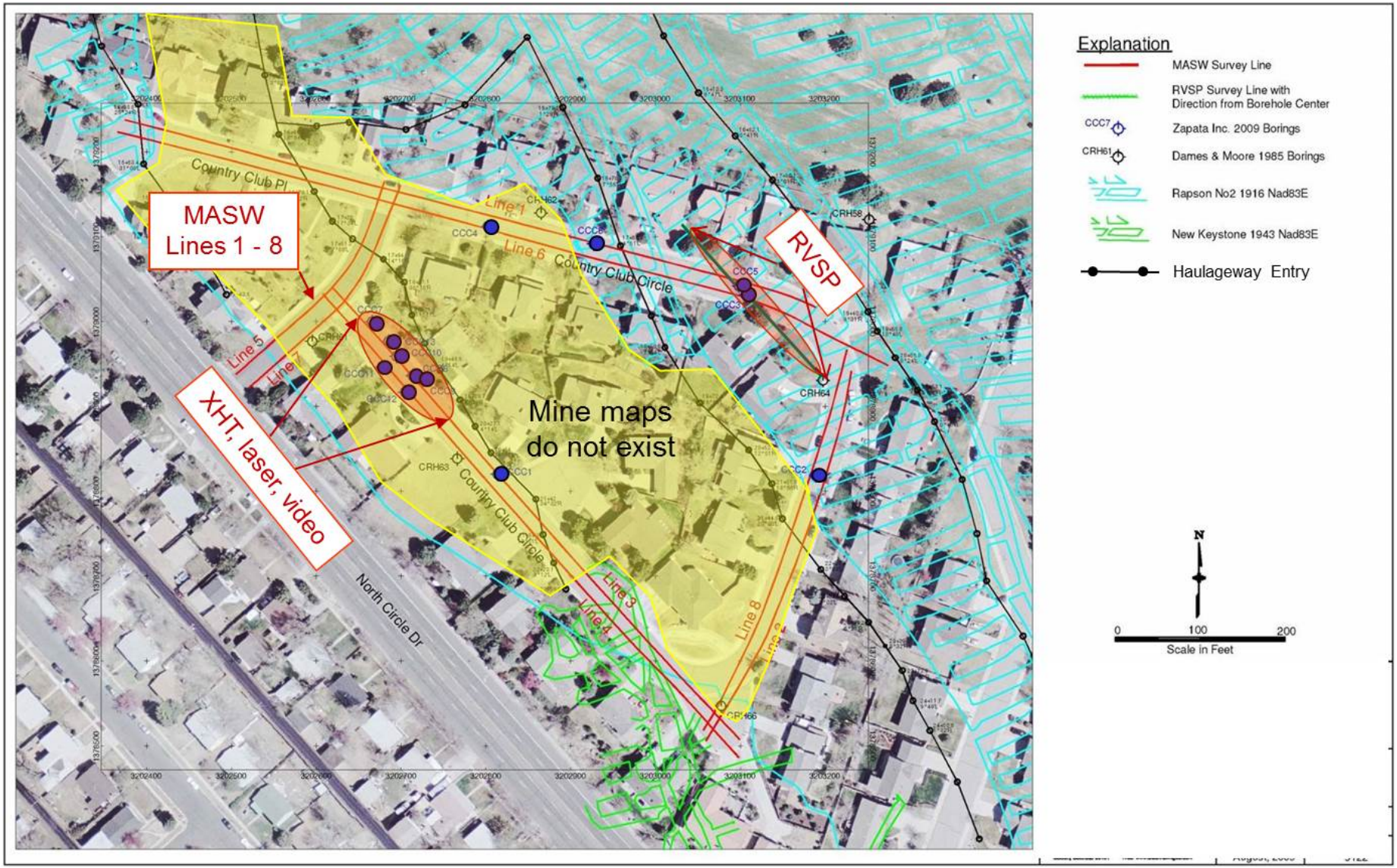


Exploratory borings:
- Ground truthing

Supplemental tools:
1. Geophysical logging
2. Void mapping tools:
   - Laser,
   - Video camera, &
   - Sonar.

XHT (borehole-borehole) Survey:
- Pre & post grouting evaluation

Site Map and Geophysical Survey Layout



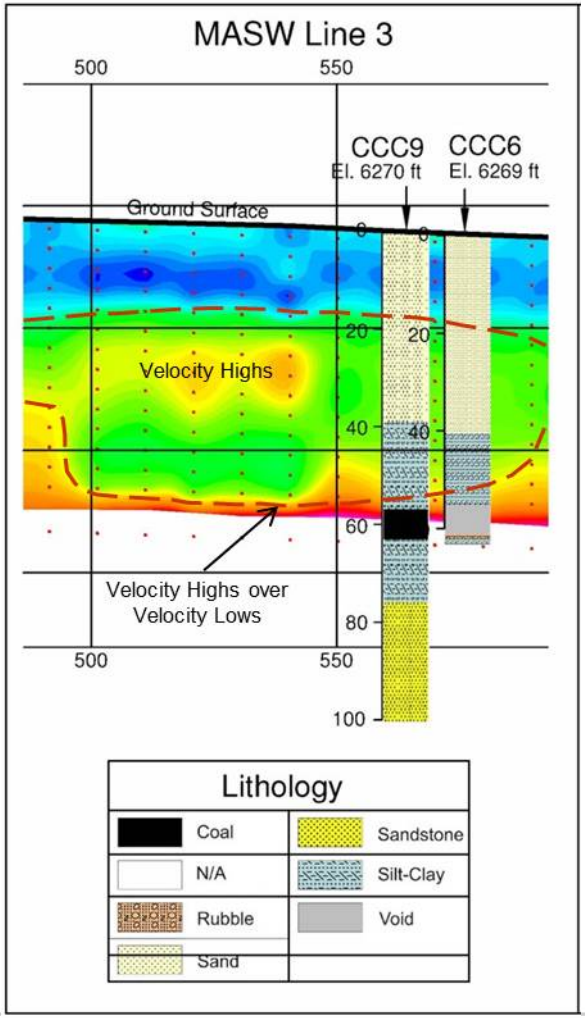
MASW Data Acquisition

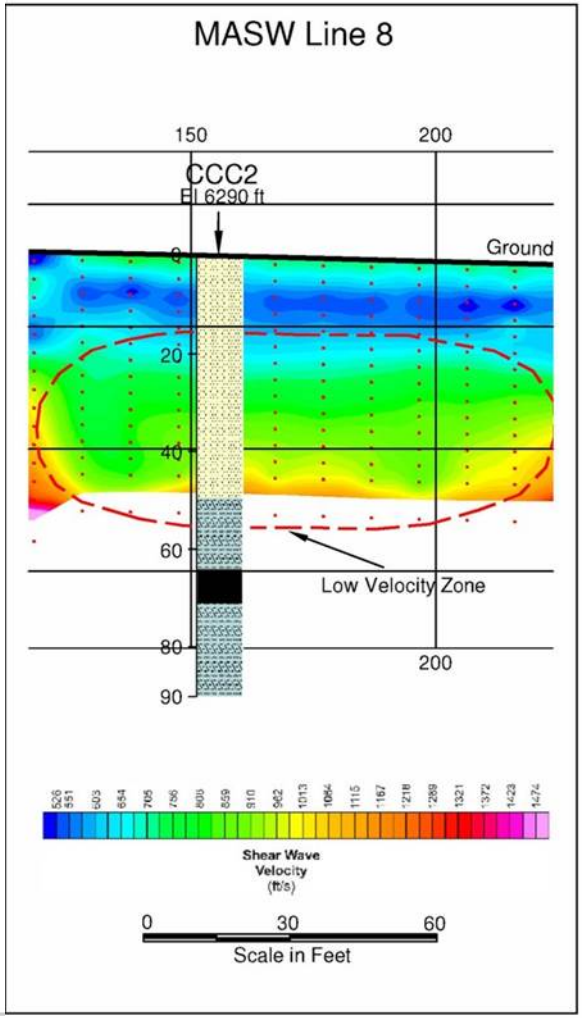
Land streamer setup: 48 channel, 4.5 Hz geophones

iVi Envirovibe seismic source

Recording vehicle (doghouse)

MASW data plots - Lines 3 & 8





RVSP Data Acquisition

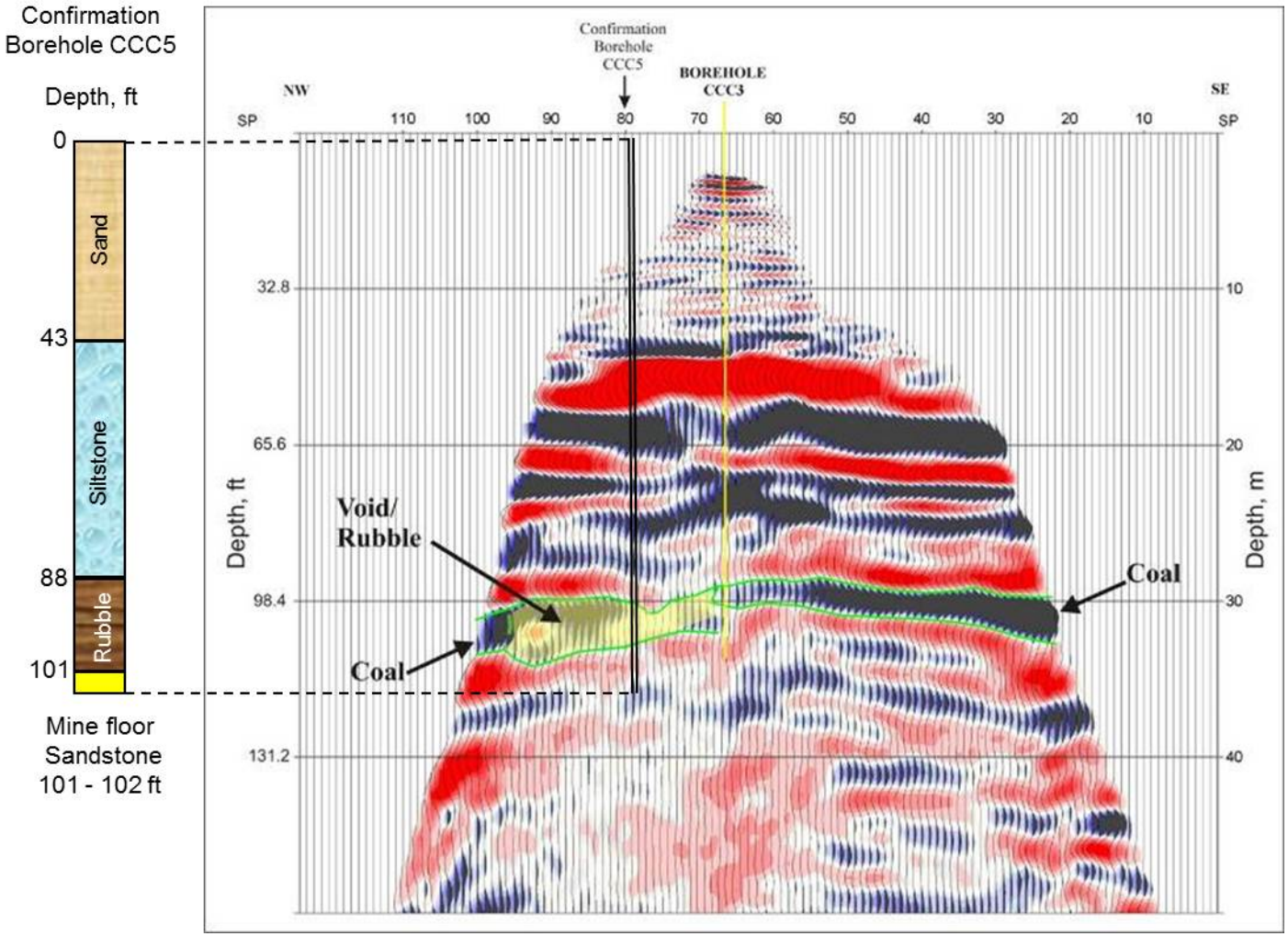
RVSP setup: 136 channels, 40 Hz geophones, 2 ft spacing
Survey lines crossing street and driveway

Airgun seismic source

Survey line crossing residence yard

Recording vehicle (doghouse)

RVSP data plot – "A" seam mine working delineation: Borehole CCC3



Drilling and sampling

CSM 75 drill rig setup

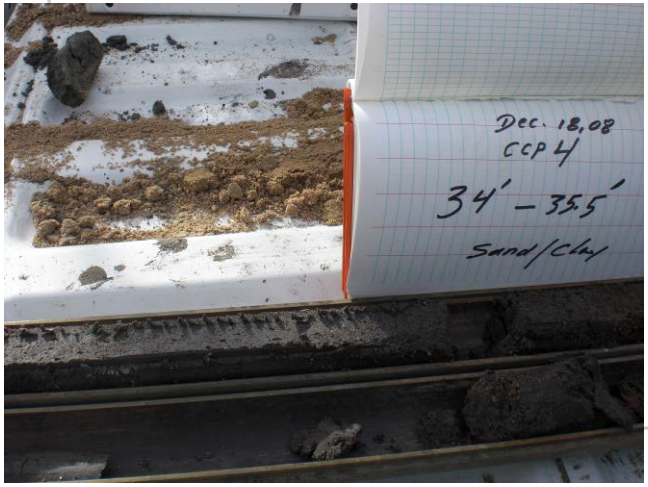
Drilling through ~ 40 ft sand

Casing/grout setup w/ 10% bentonite

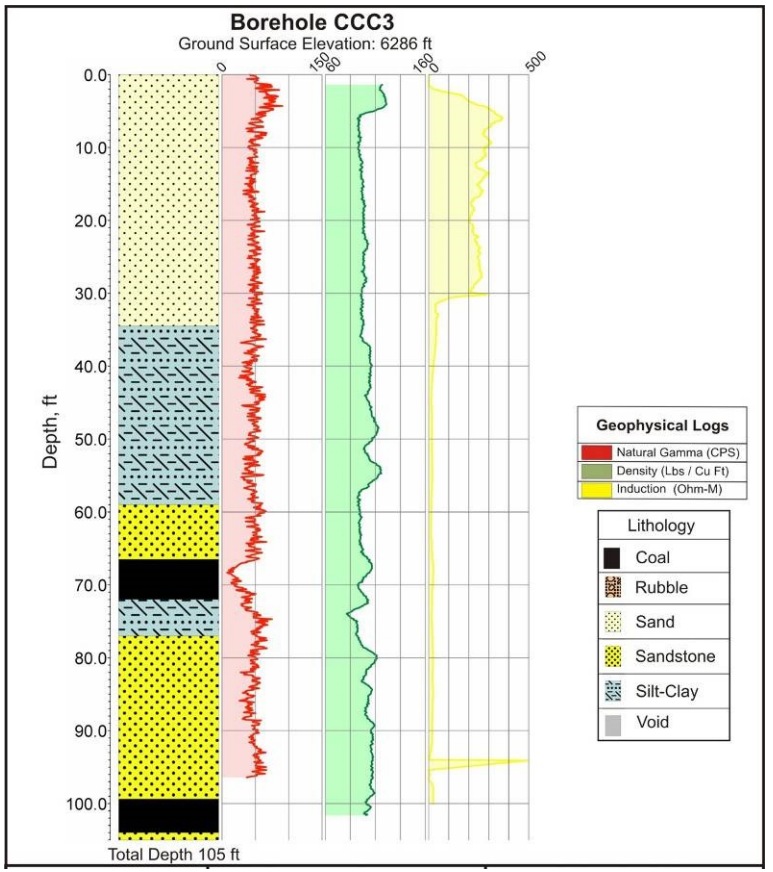
Drilling through ~ 7 ft coal

4 inch PVC casing installation

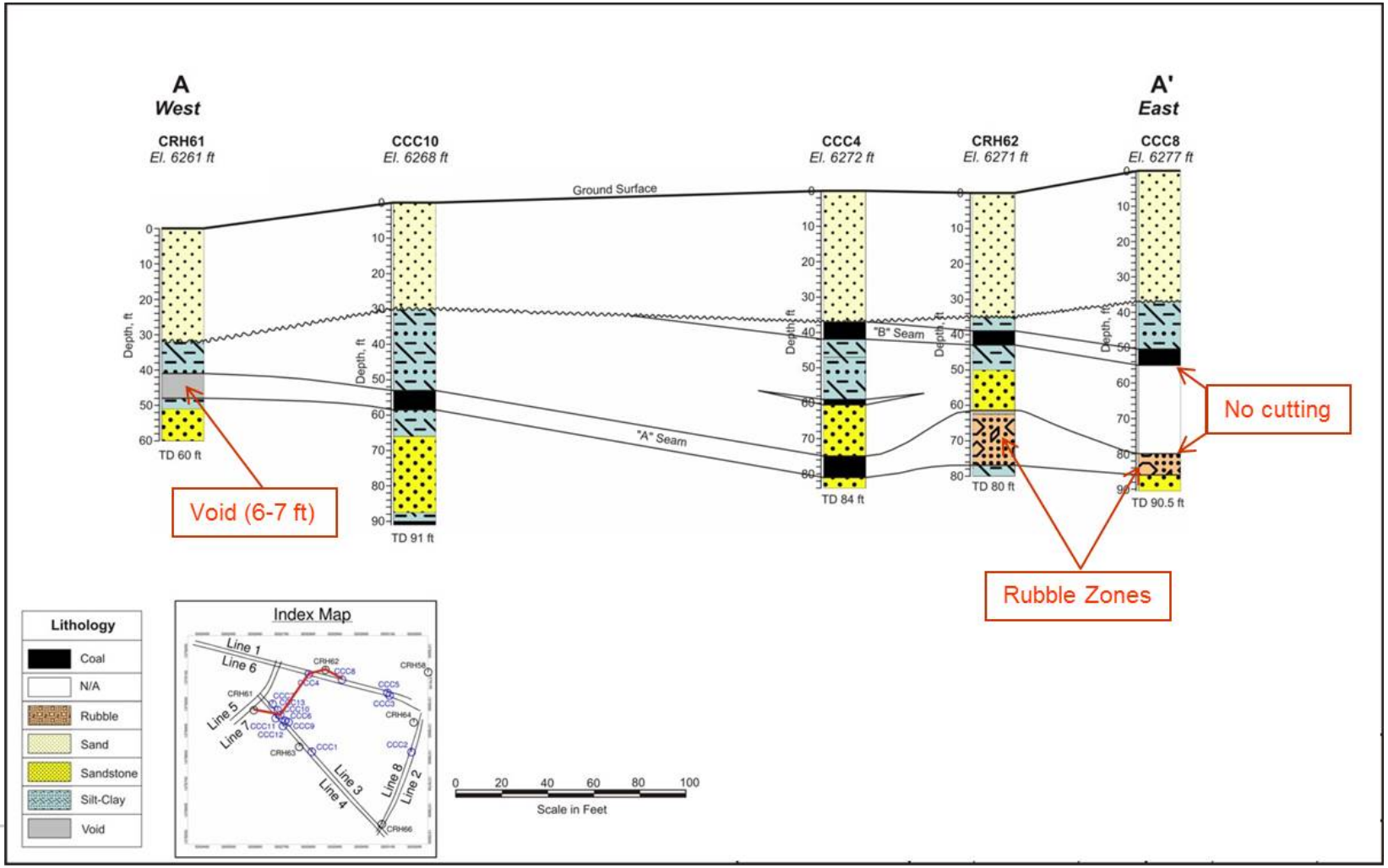
Standard penetration tests (SPTs)



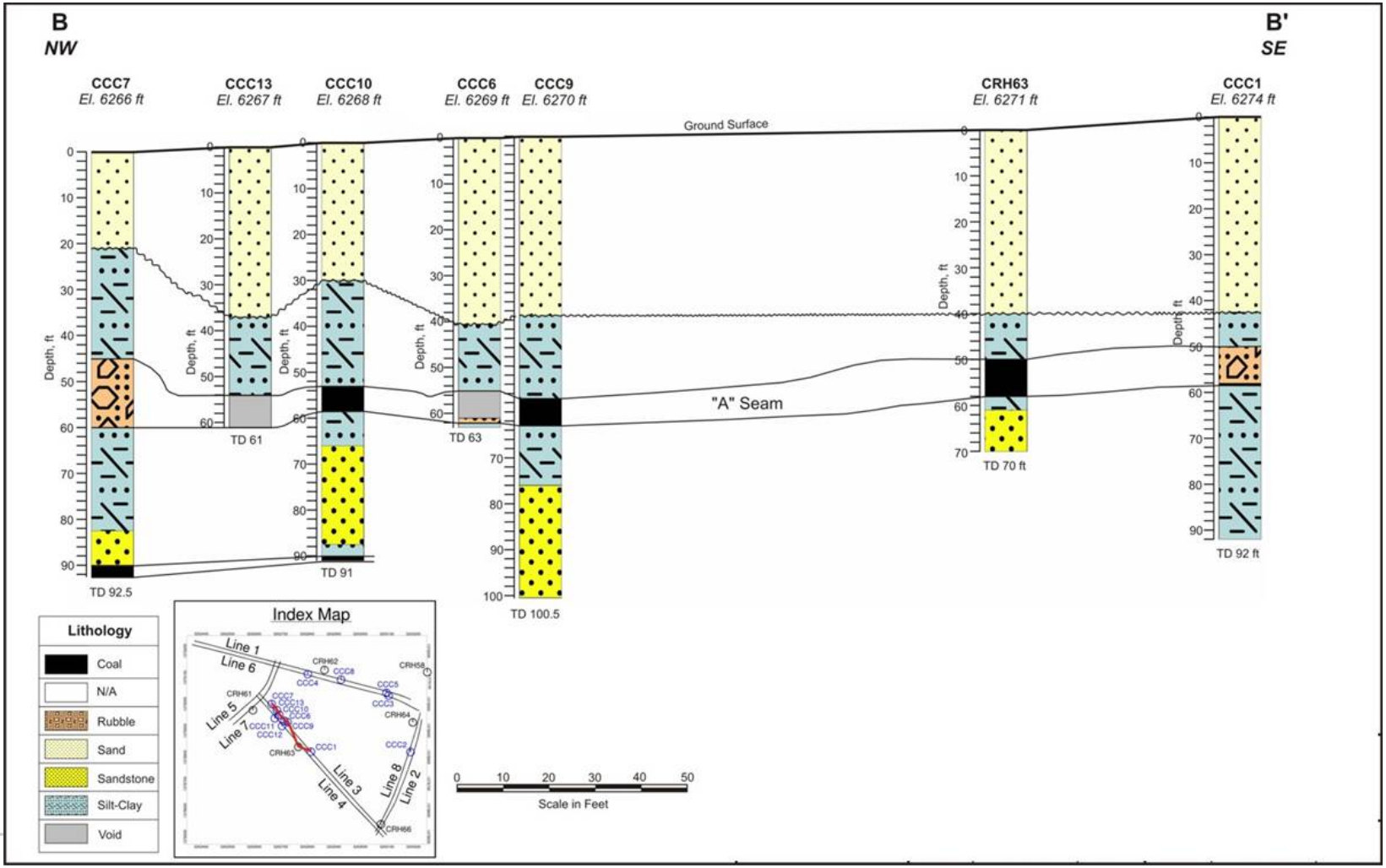
Geophysical logs – Sonic, bulk density, resistivity



Geologic cross section (A-A')



Geologic cross section (B-B')



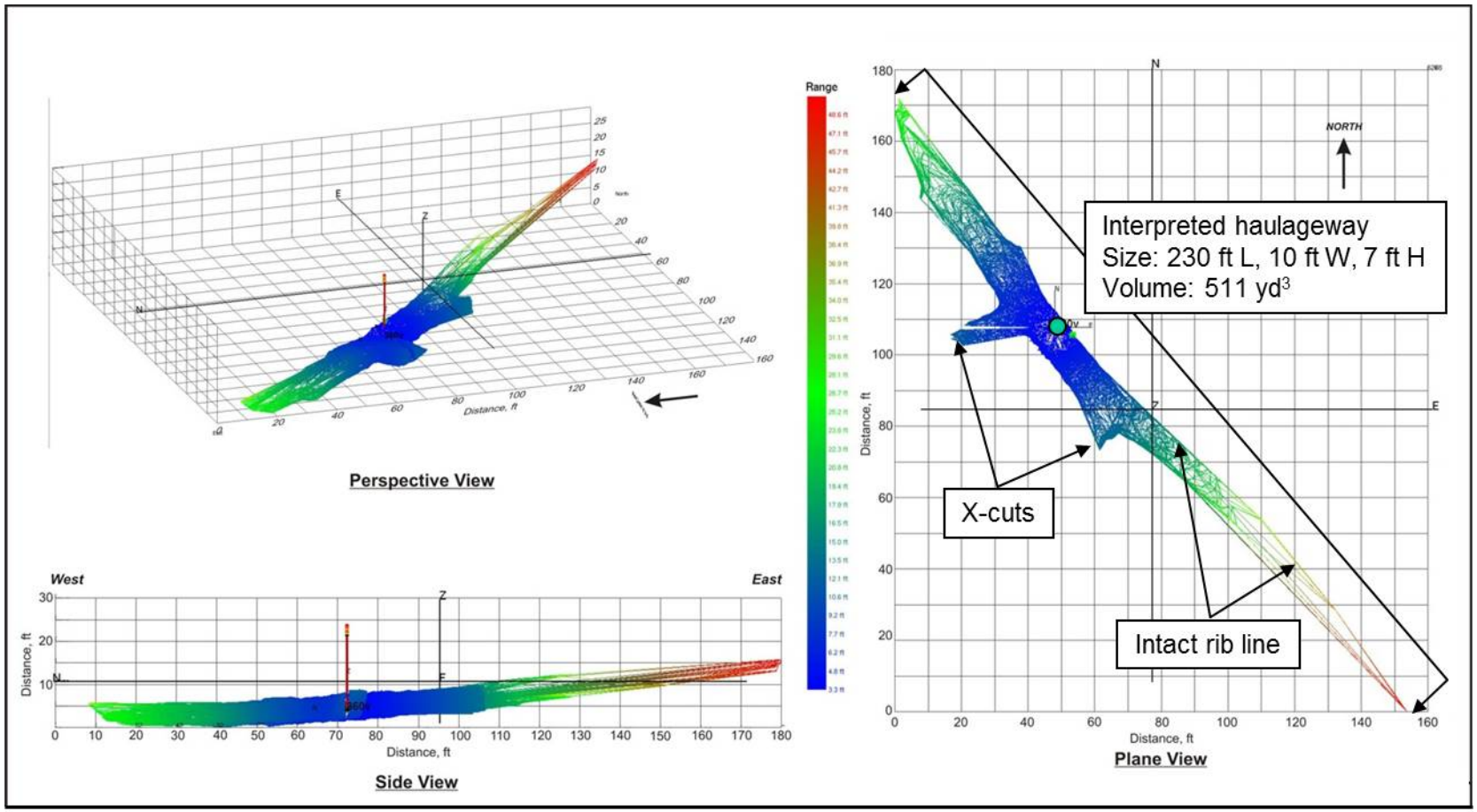
Laser, video camera, and sonar – Field setup

Laser – Void scanning

Sonar – Void scanning

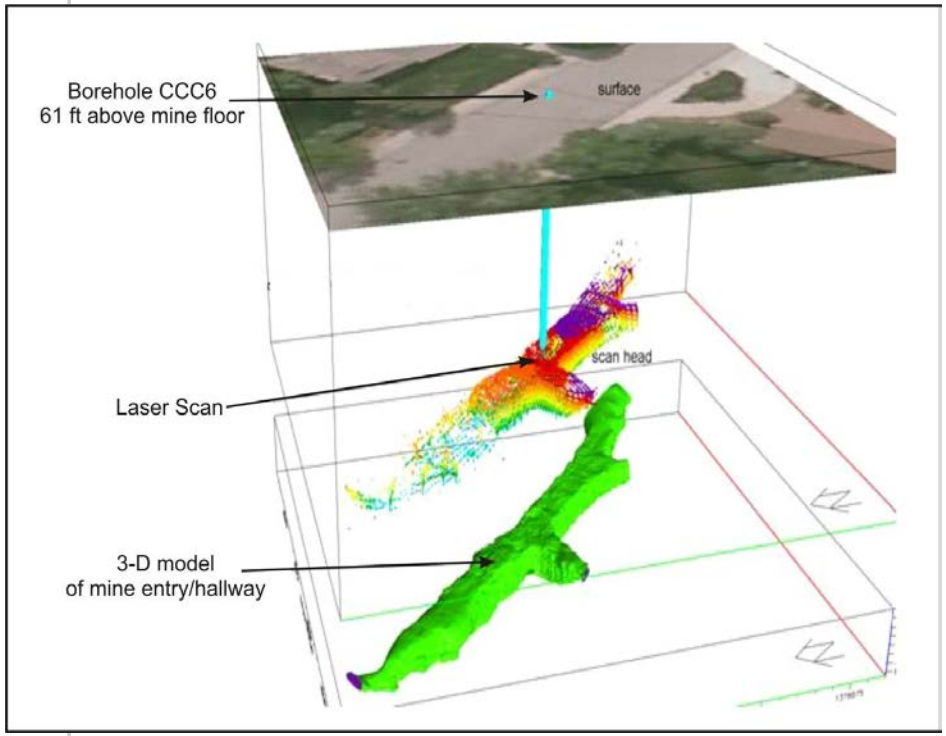
Video camera – Void imaging

Laser scans – Borehole CCC6

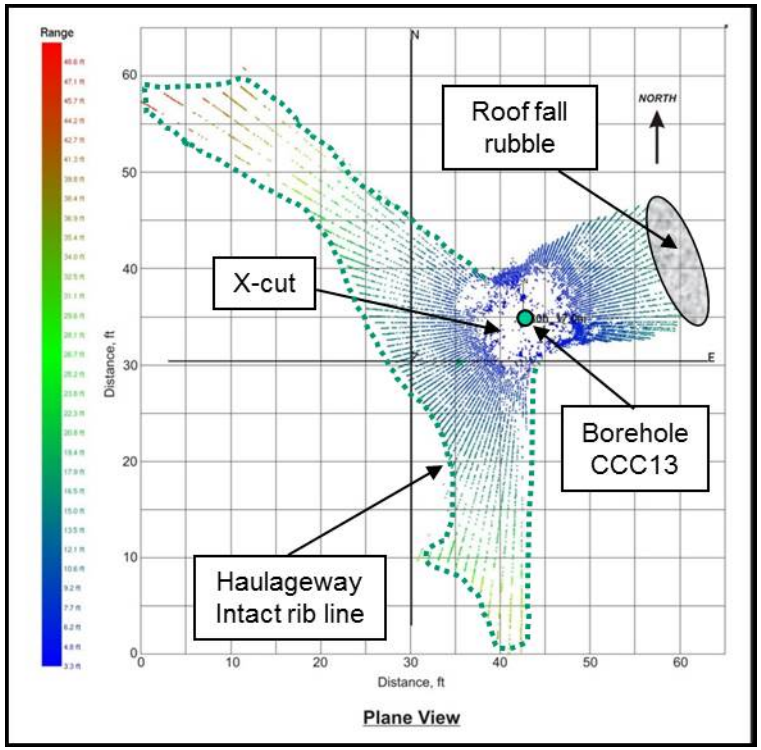


Mine Workings Void Investigation – Laser Results

Laser 3-D model of haulageway (main entry)
Borehole CCC6

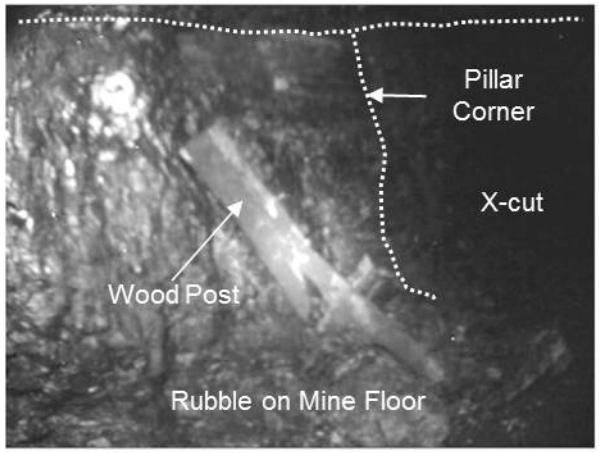


Laser 2D interpretation plan view
Borehole CCC13

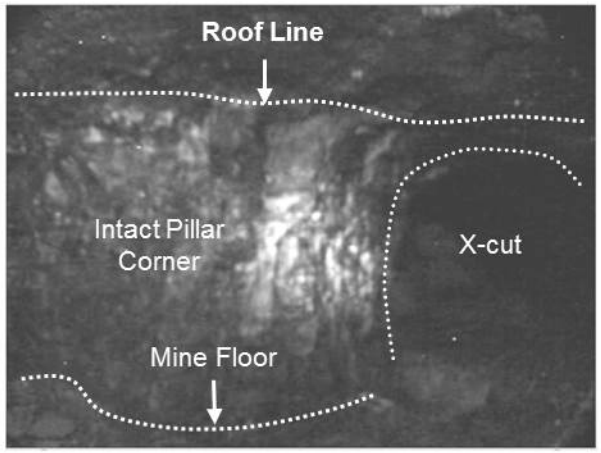


Video images interpretation – Borehole CCC6

Borehole CCC6

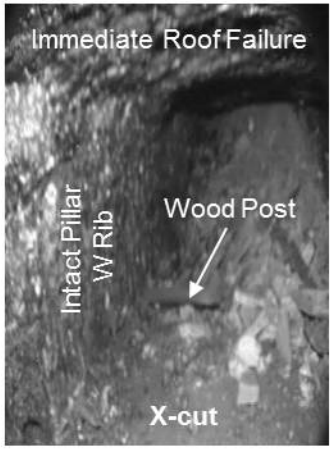


SE View

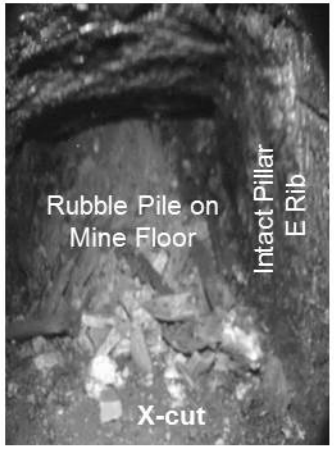


W View

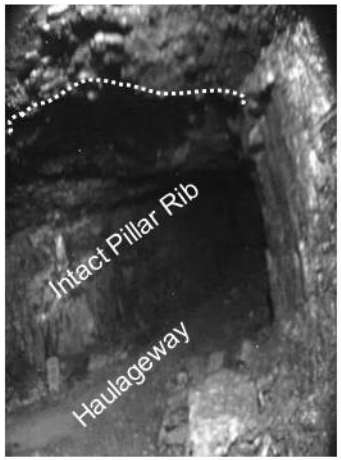
Borehole CCC13



N View

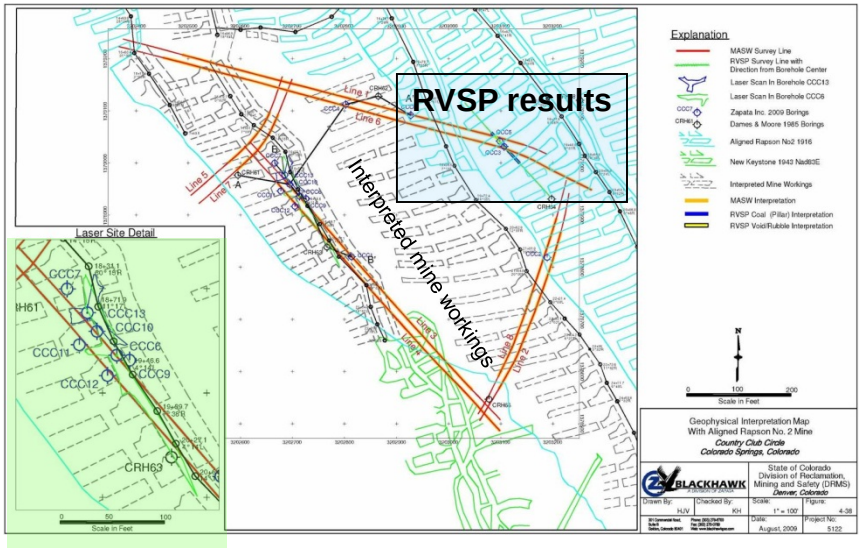


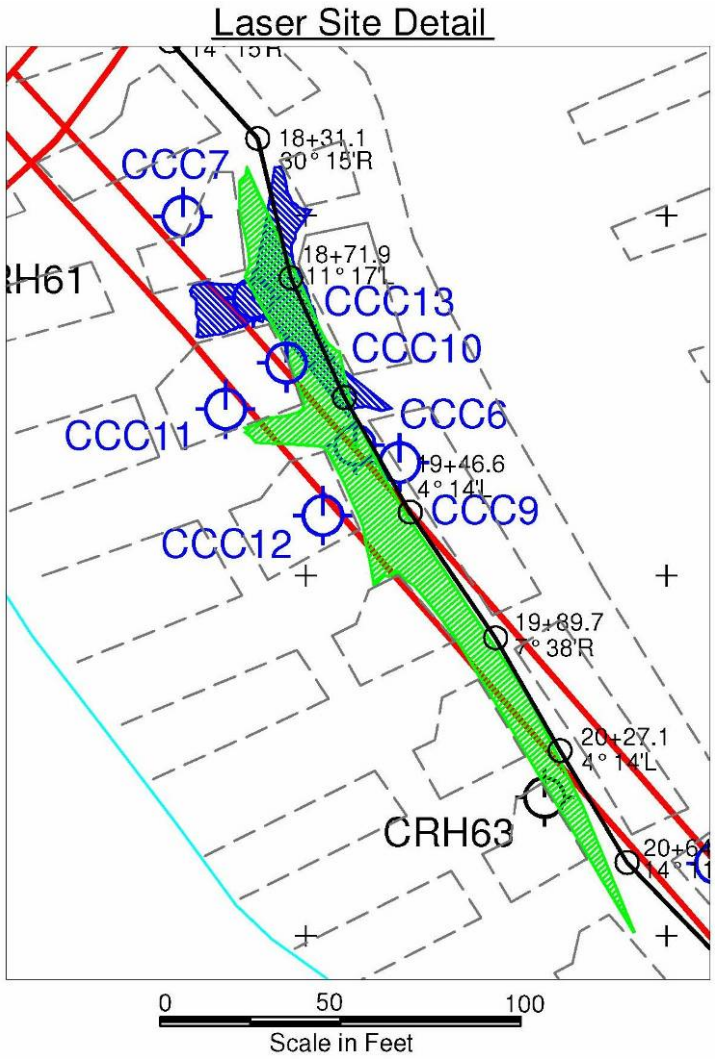
NE View



W-SW View

Reconciliation of interpreted geophysical results w/ historic base mine maps





Alignment of the Rapson No. 2 historic base mine map and haulageway entry

- RVSP results: The position of the mine workings in the north-northeast was shifted 25 ft north.
- Laser results: The position of the re-constructed haulageway was shifted 25 ft south and 17 ft west

Colorado DRMS applied two ground stabilization techniques:

- Low mobility grouting (LMG) beneath houses, and
- Foamed sand slurry in entries/haulageways

Hayward Baker performing ground stabilization (LMG) beneath a house area:

- Injection at 600 psi at the bottom of the hole, and
- 200 psi near the top of the hole
- Grout amount per house averaged ~ 348 yd^3 @ cost of ~ $66,600





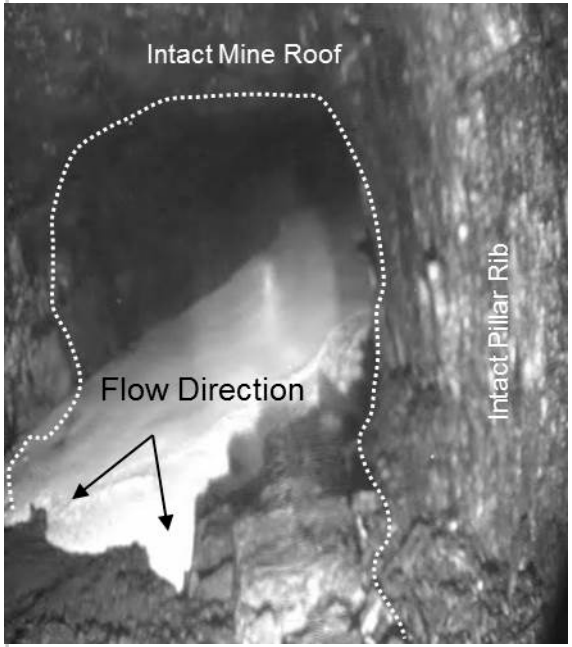

Colorado DRMS applied two ground stabilization techniques:

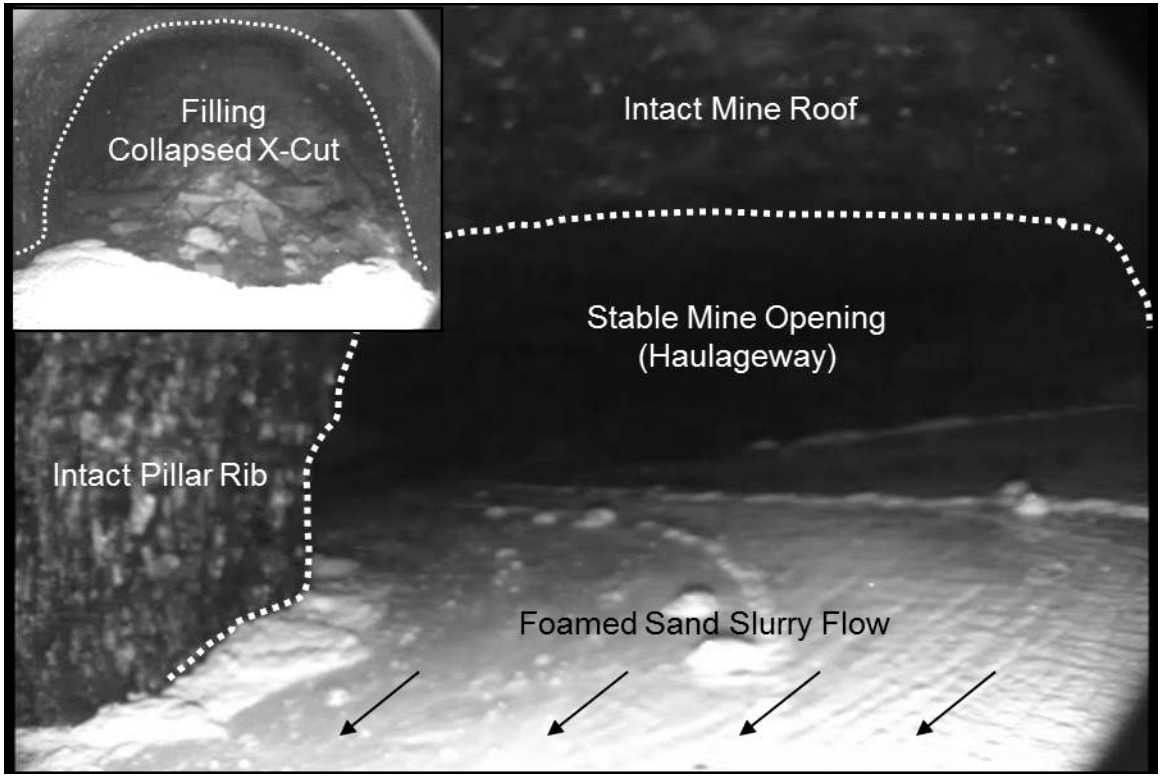
- Low mobility grouting (LMG) beneath houses, and
- Foamed sand slurry of large mine opening (entries/haulageways)

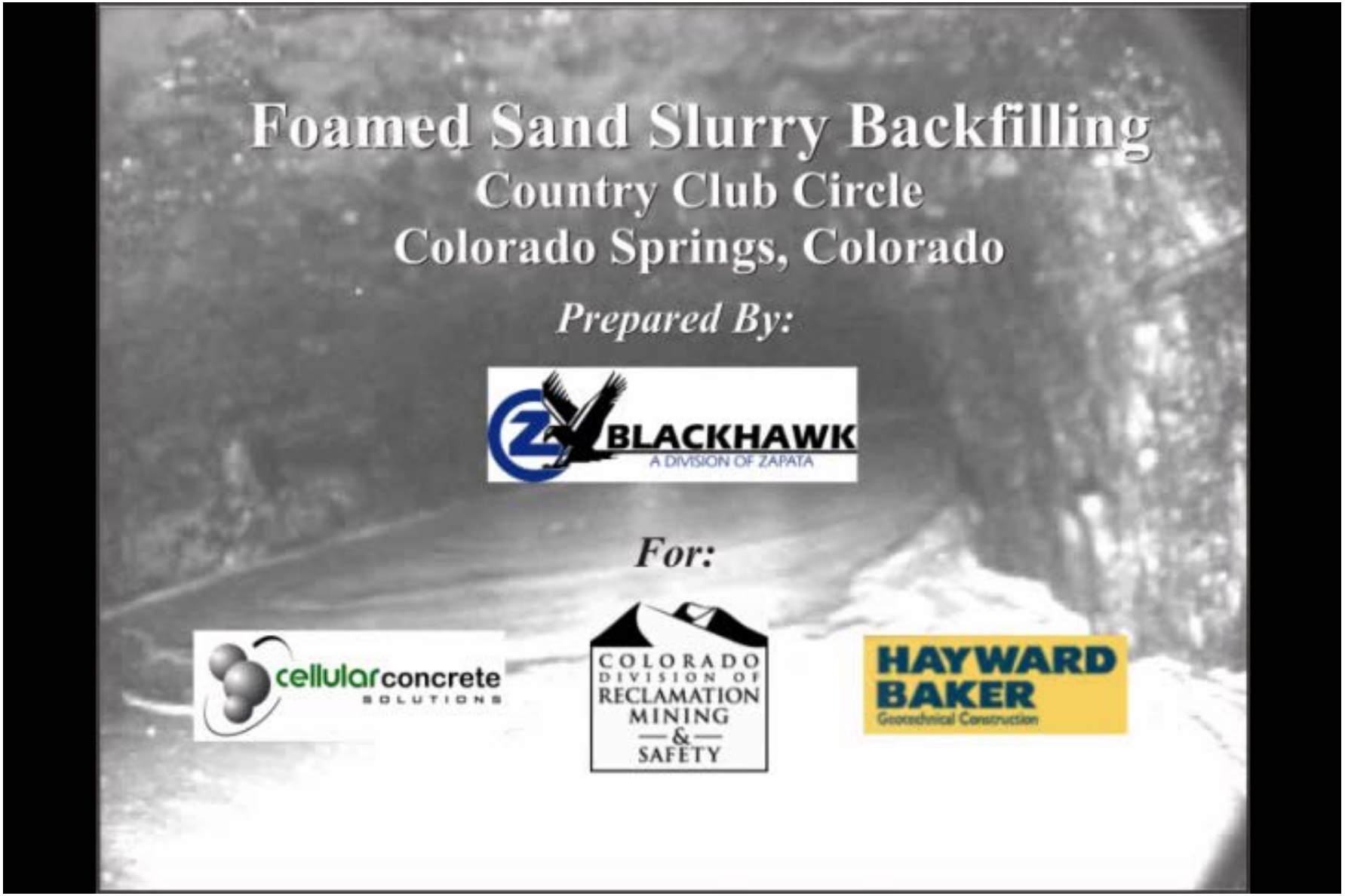
Hayward Baker performed stabilization in large mine opening using Geofoam™ developed and supplied by Cellular Concrete:

- The foam is generated on site and mixed with sand in a concrete mixer truck
- The foam takes the place of water, allowing the sand to flow similar to sand-and-water slurry
- Approximately 3 yd^3 of foam was mixed with 6 yd^3 of damp sand for ~ 5 minutes,
- The foamed sand slurry was then gravity fed down the 4-in PVC casing
- The flow of sand was monitored by the video camera from a nearby borehole, approximately 50 ft away
- The foamed sand slurry filled the void to the approx. quantity estimated by the laser scans (511 yd^3)
- The cost of the foam sand slurry is approx. half the cost per yd^3 of the LMG treatment

Video images from CCC13 of foamed sand slurry backfilling in Borehole CCC6






Foamed Sand Slurry Backfilling
Country Club Circle
Colorado Springs, Colorado
Prepared By:
BLACKHAWK
A DIVISION OF ZAPATA
For:
cellular concrete
SOLUTIONS
COLORADO
DIVISION OF
RECLAMATION
MINING
&
SAFETY
HAYWARD
BAKER
Geotechnical Construction