ENGINEERING-GEOPHYSICAL INVESTIGATION of ABANDONED COAL MINES along Planned US-69 PITTSBURG BYPASS PITTSBURG, KANSAS

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Focus

- Engineering-Geophysics Approach to Abandoned Mines Investigation
- Project US-69 Pittsburg Bypass ~ 5.8 mile Corridor
- Geophysical Methodology:
  - Pilot Survey: DC-RES, MASW, & Sonar Mapping
  - Production Survey: DC-RES & MASW
- Discussion of Results
- Project Examples Using Lidar (laser), Sonar, and Video Camera
Abandoned Mines - Risk Assessment Challenges

Why abandoned mines so complex to solve…

- Unknown subsurface conditions/characteristics
  - Strata
  - Geologic setting
  - Depth to mined area
- Unknown void conditions
  - Air/water-filled voids
  - Collapsed structure, rubble, gob
- Unknown void location and geometry *(vertical & lateral extent)*
- Inaccurate/incomplete historical mine maps
- Mine maps may *not exist*
- Time-dependent
Example of Traditional Drilling: Blind ‘Swiss Cheese’ Approach

23 of 25 borings encounter voids

5 of 25 borings encounter voids

South Side Belt Route, Final Report, JFC March 2000
**Initial geotechnical evaluation** of the planned corridor”…!

- Conduct engineering geophysical investigation to delineate areas of abandoned coal mine workings along the corridor: ~ 5.8 miles

- The corridor crosses: *known and suspected areas of historic UG coal mines*

- Mine depths: ranging from 20 to 80 ft bgs
US-69 Pittsburg Bypass Project
• KDOT Exploratory Borings
• Geophysical Investigations:
  – Pilot Survey:
    • DC resistivity (DC RES),
    • Multi-channel analysis of surface waves (MASW),
    • Guided waves (GW), and
    • Sonar imaging
  – Production survey:
    • DC RES, and
    • MASW
Generalized Lithology at the Test Site

**Borings Summary**

- Total borings: 32
- Boring depth range: 21 to 102 ft
  - Average boring depth: ~ 51 ft
- Number of boring encountered coal: 6
  - Thickness range: 0.4 to 2.5 ft
- Number of boring encountered mine void: 8
  - Void height range: 1.0 to 5.5 ft
- Mine floor depth:
  - PA6 to PA10: 21 to 32 ft bgs
    - Lateral continuity 600 ft
  - PA28 to PA31: 47 to 52 ft bgs
    - Lateral continuity 300 ft
**Area One** = Sanko Property. Drilled six (6) borings, 100 ft apart:
- **Two (2) borings:** Solid pillar. PVC casing/grouted.
- **Four (4) borings:** Voids from 17 - 22 ft bgs. PVC to top of voids.

**Area Two** = Hall Property, Drilled four (4) borings, 100 ft apart:
- **Four (4) borings:** Voids from 45 - 48 ft.
- **Problems w/ drilling through ironstone** (very dense SS, 1-5 ft thick).
- **Changed carbide auger bits every 3-4 inches.**

**Area Three** = Glenn & Dee Hough Property:
- **Borings to about 95 ft**
- **Voids from 65 - 85 ft bgs. Major problems with ironstone.**
Geophysical Field Investigation

DC RES, and MASW Data Acquisition
Sonar Void Imaging

Downhole Sonar Survey

Sonar Unit
- Unit diameter: 3 1/8 in
- Casing requirements: 4-in ID, schedule 40 PVC
- Vertical survey scans: 6 to 12 in interval
- Horizontal scans: 360 degree
- Horizontal range measurements: up to 300 ft
- Accuracy of bearing measurements: ± 1 degree
Sonar Data Interpretation

Sonar Mapping – PA8 @ 25.0 ft bgs

View of a Sonar Scan: Borehole PA8 @ 25.0 ft bgs

- Timber Support
- Gob
- Rib Line

- N
- 32.0 ft
- 6.0 ft/DV
Sonar Mapping – PA10 @ 18.0 ft bgs

View of a Sonar Scan: Borehole PA10 @ 18.0 ft bgs

- Timber Support
- Gob
- Timber Support
- Rib Line
- Entry
- 6.0 ft/DV
- 57.0 ft

Sonar Data Interpretation

Sonar Mapping – PA29 @ 47.5 ft bgs

View of a Sonar Scan: Borehole PA29 @ 47.5 ft bgs

114 ft
Timber Support

~ N

12.0 ft/DV
Random Mining Operation
Sonar Mapping – PA29 49.5 ft bgs

View of a Sonar Scan: Borehole PA29 @ 49.5 ft bgs

Timber Support

Random Mining Operation

6.0 ft/DV

59.0 ft

~ N
Example of Random Mining

Random Pillaring / Mining
Sonar Data Interpretation

Sonar Mapping – PA7, 8, & 10 Mine Workings Alignment
Sonar Mapping – PA28 & 29 Mine Workings Alignment
Geophysical Interpretation – Common Offset

- Voids
- Proposed Boring Area

Interpreted Mine Works

Scale in Feet

North

South

Kansas Department of Transportation
Bureau of Materials and Research
Materials and Research Center

1216_100-289FSCUT
CD-5

Common Offset Section
CL Station 379+50 to 399+70
100 ft Source-Receiver Offset
US 69 Pittsburg Bypass
Pittsburg, KS
Geophysical Interpretation – Common Offset

Interpreted Mine Works
Surface Wave Velocity Sag

Scale in Feet

1217_168-284
GO-3

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Date: May, 2009

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Interpreted Mine Works
Surface Wave Velocity Sag

Scale in Feet

1217_168-284
GO-3

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Geophysical Interpretation Map

Geophysical Survey Explanation

- Geophysical Survey Centerline Station
- Borehole Location
- DC Resistivity Survey Line
- Interpreted Mine Works (from CO)
- Surface Extent of Seismic Array

(Note: Data interpretation is offset from road centerline for clarity)
Geophysical Mine Subsidence Investigation
Void Detection and Mapping
Along East-West TH169, Chisholm, Minnesota

for MnDOT
Laser Mapping – Field Activities

Laser Unit Specifications
• Unit diameter: 2 1/2 in
• Survey interval: 6 to 10 in
• Scans: 3-D sphere
• Scan range: up to 500 ft
• Accuracy of bearing measurements: ± 0.5 degrees

Project Examples – Laser Void Mapping
Project Examples – Laser Void Mapping

Laser Mapping – TP7 Results

Plan view showing scan configuration
Green square marks laser and borehole location

Plan view showing triangulated surfaces
Green square marks laser and borehole location

Side view looking north
Laser location marked with green square
0.25 meter contour interval

Perspective View

Laser Mapping Results for Void Space Encountered in Borehole TP7 Along TH169
Chisholm, Minnesota

Minnesota Department of Transportation
Mn/DOT
Maplewood, Minnesota

Project No: 5130
Date: Feb, 2009
Drawn By: HJ/V
Checked By: SH
Scale: As Shown
Figure: 2-3
Project Examples – Laser Void Mapping

Laser Mapping – Images Superimposed on Historic Mine Map
Project Examples – Void Mapping

Subsidence Abatement Project
CSM Campus and Colorado Springs Country Club

for State of Colorado Department of Natural Resources
Division of Reclamation, Mining & Safety
Abandoned Coal Mine, Colorado Springs, Colorado

for Colorado Division of Reclamation, Mining and Safety

Project Examples – Laser Void Mapping

Borehole CCC6
61 ft above mine floor

Laser Scan

3-D model of mine entry/hallway
Project Examples – Video Camera Void Mapping

Video Images Interpretation – Borehole CCC6.

- **W-SW view**
- **SE view**
- **NE view**

- Video Camera Installation and Imaging
- Roof Line
- Pillar Corner
- X-cut
- Wood Post
- Rubble on Mine Floor
- Immediate Roof Failure
- Intact Pillar Rib
- Sand Flow
- Hallway
- Intact Pillar
- X-cut
Project Examples – Video Camera Void Mapping

Video Images and Interpretation During Foamed Sand Slurry Backfilling
Project Examples – Video Camera Imaging

Video Imaging during Foamed Sand Slurry Backfilling

Flow Direction

Intact Mine Roof

Stable Mine Opening (Hallway)

Foamed Sand Slurry Flow

Intact Pillar Rib
Thank You

Questions