IHI Underground Coal Mine Fire Mitigation: Geophysical Geotechnical evaluation / and Quenching Project, Rifle, CO

By:

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GEOHAZARDS IMPACTING TRANSPORTATION IN THE APPALACHIAN REGION

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Garfield County Mine Fires...

“13 mine fires burning along Grand Hogback-Garfield County”
General Site Details

Project Site Location

General Surface Expression Of Underground Fire

Approximate Entry Locations
• Mining began in early 1900’s
• Fire first reported in 1948
• 1975; US Bureau of Mines completed surface seal
• Colorado Inactive Mines Reclamation Program (IMRP) conducts three drill and grout projects – 1990’s:
• 2000– 2010 IMRP conducts surface fire management projects.
Coal Accessed via entries developed near base of canyon;

Mining occurred overhead in nearly vertical rooms, or stopes (dip ~ 65° southwest);

Fire occurs in the vertical stopes and in adjacent, un-mined coal seams;

Stopes act as chimneys to provide fire ventilation;

Oxygen likely provided from general area of abandoned entries;

Fire vents from coal outcrops at or near the former ridge line.
Locations of Site Work

- Approximate Perimeter of USBM Surface Seal
- Drill & Grout Projects
- Excavate and Quench Project Location
- Hass Canyon
- Approximate Entry Locations
To formulate a comprehensive response to this fire, IMRP contracted ZAPATA to determine:

- Areal extent of the subsurface fire;
- Number of seams involved in the fire;
- Location of significant subsurface voids;
- Connectivity of subsurface voids and mine workings; and
- Location and extent of previously placed subsurface grout.
Series of reclamation projects were conducted at the site to control the fire…!

Why the site is so complex to mitigate?
The Problem

Multi-seams mine workings – Burned & unburned
(looking west along strike showing the subcrob locations of the seams)
3-D Model

3-D Terrain Model using ZAPATA “RockWorks” Software

(~ West-East Direction)
Geophysical Program Overview

Multi-task Approach

Geophysical Investigation
- Magnetometry (Magnetic or Mag)
- DC-Resistivity (DC-Res)
- Electromagnetic (EM34)

Supplementary Investigations
- Air monitoring
- Smoke tracer
- Thermal imagery
- Topography
- Digital terrain model
Area of Investigation

Project location site – aerial photo looking north
Area of Investigation

Base map showing topography, well control & coal seams
Investigation Methodology

Thermal Imaging

Objective: Determine ground surface temperature (hot exhaust vents) using a FLIR Systems infrared camera (IR)

From various vantage points – No. 1 to No.5
Investigation Methodology

Thermal Imaging Tests (Standard & IR Imagery)

Vantage points – No. 2

Vantage points – No. 1
Thermal Imaging Tests (Standard & IR Imagery)

Thermal imagery vantage points – No. 3 to No.5
Investigation Methodology

Thermal Imaging Tests (Standard & IR Imagery)

Vantage points – No. 3 & No.4
Investigation Methodology

Thermal Imaging Tests (Standard & IR Imagery)

Vantage point 5

Spot temperature @ main thermal vent (704°F) below upper bench
Thermal Imaging Results

Hot exhaust vents superimposed on the 3-D terrain model
Smoke Tracer Tests Result (Phases I, II, & III)

Objective: Determine connectivity between air intakes and exhaust vents

- Phases I & II: Located 36 air intakes using small fireworks
- Phase III: Two tests using large 100K ft\(^3\) smoke canisters to establish connectivity between specific air intakes & exhaust vents
Smoke Tracer Tests & Thermal Imaging Results

(Phase III: Two smoke tracer tests using large 100K ft³ gas canister)
DC-Resistivity and Magnetometry (Mag)
Field set up
**DC-Res Objective:** Imaging potential voids & hot temperature areas

**DC-Res**
- Line 1 oriented sub-parallel & down dip of the subcrop of the Wheeler (Wh) seam
- Line 2 oriented sub-perpendicular to the strike of the Wh and other seams
- High temperature problems during data acquisition

**EM34** in areas with high surface temperature
Magnetic Results

Objective: Delineate previously burned areas & active fire zones

3D representation of residual magnetic field
Magnetic Results
Interpreted residual magnetic field with air intakes and exhaust vents
Analysis and Interpretation

DC-Resistivity Tomography Results

Cross section Line 1 with EM34 data profile
Line oriented sub-parallel to Wheeler seam

Areas w/ color ranging from orange through pink represent high resistivity areas associated with:
- Burned / burning coal; and
- Potential voids
DC-Resistivity Tomography Results

Cross section Line 2 with EM34 data profile
Line oriented sub-perpendicular to Wheeler seam
3-D Terrain Model using ZAPATA “RockWorks” Software with View Capabilities
Conclusions

General...

The area of interest was expanded to better understand:

- The actively burning and non-burning seams, and
- The void connectivity relationship between burning mine workings
Smoke Tracer Tests

Smoke tracer tests identified 36 air intakes with the following observations:

- Large-volume smoke canisters (100K ft³) were required to establish connectivity relationship between specific air intakes & exhaust vents;
- Identified three groups of air intakes corresponding with subcrop & hanging walls of E, Wheeler & D seams; and
- Established connectivity between two large air intakes (lower bench and north of lower bench) and specific exhaust vents.
Conclusions and Recommendations

Conclusions…(continued)

Thermal Imagery Tests

- Mapped hot exhaust vents;
- Located previously unidentified vents; and
- Provided spatial relationships between vents and coal seams.
Conclusions and Recommendations

Magnetometry Survey

Magnetometry outlined the **extent** of the area affected by the mine fire with the following observations:

- Lateral extent of the burned areas were defined;
- Fire **started** at the large intake in the **D seam** and propagated along strike to **northwest**;
- Fire propagated into the **Wheeler** seam from the **D seam**, by means of fractures and/or unknown mine workings; and
- Fire does not yet **extend into the canyon bottom** west of the upper bench.
Conclusions and Recommendations

Conclusions … (continued)

Geophysical Investigation – DC-Resistivity

- DC-Res identified high-resistivity anomalies
- DC-res as a stand-alone technique could not distinguish between anomalies due to:
  - Voids,
  - High temperature, and
  - or both.

- Large void areas potentially remain
- In-place grout could not be imaged due to:
  - Low strength ~ 75 psi,
  - Low density ` 61 pcf, and the
  - Grout is indistinguishable from rubble or burned coal.
Conclusions

Three-dimensional (3-D) Model

• 3-D model provides a useful visualization tool for:
  – Observing spatial relationship between varying data sets and other supporting information
• Ability to review each data set separately
Conclusions and Recommendations

Recommendations

- The high potential for further subsidence must be addressed (i.e., use of INSAR techniques to monitor subsidence);
- Expand smoke tracer studies to locate all air intakes
  - Cutting airflow into the mine workings is necessary as an initial step to future reclamation effort…!
- Reclamation must address all burning seams exhibiting airflow connectivity; and
- Potential drilling locations to be identified for future borings and grouting.
The geophysical investigation at the IHI mine fire site has demonstrated the benefits/effectiveness of the selected techniques...

Mag, DC-Res, & partially EM34

*When*
Supplemented by gas tracer and thermal imagery studies combined with engineering practices – to be the most viable approach to investigate complex mine fire problems...
Thank You

Questions