Modern Ground Control Management

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Resolution Copper Mining

- Resolution Copper Mining (RCM) is a limited liability company

- **Ownership:**
  - Resolution Copper Company (55%), a Rio Tinto plc subsidiary
  - BHP Copper, Inc. (45%), a BHP-Billiton plc subsidiary

- Resolution Copper Company is the manager of RCM
Regional Map
Local Area

Apache Leap

Town of Superior
Project Area Aerial View
Resolution Project Area Perspective
Ground Control Management

- **Ground Control Management Plan**
  - Describes the methodology for development of minimum ground support standards, where and how they are stored and how they are implemented and verified
  - Design, Implement, Verify

- **Detailed Breakdown Structure**
  - Define Responsibilities/Determine Necessary Skill Sets
  - Rock Mass Characterization /Recognition of Ground Conditions
  - Geotechnical Design Methodology and Communication
  - Quality of Installation and Workmanship
  - Monitoring/ Verification
  - Optimization
  - Repeat
Roles and Responsibilities

- Define the roles and responsibilities of personnel involved in ground support activities
- Identify the geotechnical skill-sets required for each role, including the necessary training
- Only qualified individuals must perform ground support designs and inspections
- Determine accountability matrix (Responsible, accountable, support)
Roles and Responsibilities (Cont.)

- **Personnel Development/ Training**
  - **Training**
    - Onsite-Training by geotech engineer
    - Specific classes related to ground control administered by third party
    - MSHA Training
    - New Hirer Training
  - **Personnel**
    - Relationships are important
    - Miners (Knowledge/ skill set)
      - Must be able to identify changes in ground conditions
      - Must understand how support should be installed
    - Engineers (Knowledge / skill set)
      - Able to identify changes and how to control specific types of failures
      - Be familiar with different types of support systems
Rock Mass Characterization

- What information is required for this design?
- What detail is required to perform the design?
- In what manner should the data be collected?
  - Drill Holes
  - Surface Mapping
  - Drift Mapping
Rock Mass Characterization Example

- **Core Logging**
  - Structure Orientation
  - Geotechnical Data Collection
    - Joint Information
    - RQD
    - Micro-defects
  - Strength Estimates
    - Point Load Test
    - UCS Testing
    - Triaxial Testing

- **Data Verification**
  - QA/QC
Rock Mass Characterization Example (Cont.)

➢ **Photogrammetry**
  - Adam Technology is being utilized for rapid mapping and data collection
  - Geology and Geotech information is being collected on a routine basis

➢ **Uses**
  - The systems are being used for a number of things, including but not limited to:
    • Geotechnical Characterization
    • Geologic Mapping
    • Quality Control
    • Shaft Sinking
    • Lateral Development
Recognition of Ground Conditions

- Understanding the Rock Mass
  - Failure
    - Stress
    - Gravity
    - Seismicity
Recognition of Ground Conditions (cont.)

- **Controlling the Rock Mass**
  - Blasting Practices
  - Available Information
    - Current ground conditions (Communication)
    - Has work been conducted in this type of ground before?
    - Other operator’s experience with similar ground
  - Simulated
    - Numerical
      - FLAC
      - Phase
    - Empirical
      - Rock mass ratings
      - Ground Response Curve
Ground Support Design Methodology

- **Past experience**
  - Review previous ground support designs
  - Internal and external communication

- **Empirical Relationships**
  - Q, RMR, GSI
  - Determines initial ground support spec to be further compared with other methods

- **UNWEDGE**
  - Perform wedge analysis and determine bolt length, capacity and spacing for comparison with empirical estimates

- **Numerical Analysis**
  - Use Phase or FLAC to perform stress analysis
Support System Selection

- How will it be installed?
  - Jack Legs
  - Modern bolting rigs
  - Shotcrete?

- What are the limitations and potential safety issues with installing the required support?
  - Jack Legs
    - Resin Rebars
    - Mesh Handling
  - Manual spraying of shotcrete?

- Final design communication
  - How does the information get distributed?
Quality of Installation and Workmanship

- Clear instructions for installation
  - Blast design
  - Timing of installation
  - Installation steps

- Design Specifics
  - Bolt Spacing
  - Bolt Lengths
  - Surface Support Requirements (Mesh, shotcrete)
  - Hole Diameters
  - Encapsulation requirements
  - Bolt angle
Monitoring/ Verification

- **System performance**
  - Pull Testing
  - Bolt appearance
    - Corrosion
    - Pull through
  - Bolt supplier
    - Material Properties

- **Excavation Monitoring**
  - Extensometers
  - Closure monitoring
  - Visual inspection (water, loose, cracks)

- Has everything been installed to design standard?
Optimization

- **Lessons Learned**
  - Applying new information to current design or future designs
  - Communicating the information

- **Support Optimization**
  - Waste Reduction (bolts, shotcrete, etc …)
  - Better rock mass response
  - Over-break reduction
  - Installation speed and safety
Potential Design Deficiencies

- **Design Issues**
  - Failure not correctly identified
  - Bolt length or capacity insufficient
  - Input parameters incorrect

- **Installation Issues**
  - Below standard blasting
  - Hole Diameter Incorrect
  - Resin pass due
  - Material issues (bolt quality)
  - Improper bolt angle
  - Poor blasting
Closing

Your Contribution

Everybody has a role to play
Take pride in the quality of the underground workings
Be safe
Thank you!

Questions?