Basic Concepts and Approaches to Mine Water Management in Complex Fractured Rock Environments

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Outline

• Mine Water Issues – Open Pit vs Underground
• Basic concepts in Fracture Flow
• Integrated Approach to Mine Water Management
• 3D Model Data Requirements
• Proposed Approach to Spatial Variability
• Future Requirements

Problems Related to Mine Water Issues

• Hydrogeology is usually an afterthought
• Mining Engineering’s poor cousin
• Usually requires a crisis for action - inflows, pressures or water quality
• Expected to produce answers in short time frame on limited budget.
• Often the basic hydrogeology gets short changed.

Selected Mine Water Issues

• Depressurizing - Stability.
• Dewatering - Dry mining conditions
• Water quantity - Pumping costs and Treatment Costs
• Water Quality - Water Treatment Costs and Receptor Impacts
• Ecosystem impacts - TDS levels, Baseflow Impacts

Depressurizing

• Effects of slope movement on Pore Pressures
• Stable versus unstable slopes
• Coupled hydro-mechanical behaviour of discrete fractures and failure planes

Model Geometry

(After Goren & Aharonov, 2008)
Fracture Flow - Basic Concepts

- Equivalent porous media versus fractured media
- Factors that impact on interpretation of field test data
- Scale of fracturing - geometry

Pore Pressure Along Shear Zone

Numerical Simulation

Porous Media vs. Fractured Media

Where does the Water Come From?

Head Loss Components
Impact of Borehole-Fracture Angle

Relative Flux

Fracture Data Corrected for Censoring and Truncation

Government Point
E-W Vertical Section With Bedding Planes

Jalama Beach
E-W Vertical Section With Bedding Planes

Fracture Data

Raw Fracture Data
Set 1 - 1.80 m
Set 2 - 2.35 m
Set 3 - 30.00 m

Relative Flux

Aperture Proportional to Fracture Length

Uniform Fracture Aperture

(After Schaefer, 1994)

Permeability vs Block Size

Integrated Approach Required

Hydrogeology Flow Chart

Typical 3D UG Mine Model

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Hydrogeology and Hydrogeochemistry

- Hydraulic heads – point versus interval
- Stream and Lake Outflows
- Permeability measurements – Truncation and Censoring.
- Spatial Variability
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- Need to focus on the issues that have the greatest impact on mine/open pit inflows

Example – Impact of Lakes in the North

- Mines adjacent to or under lakes/rivers
- Need to determine rate of leakage
- Need piezometers installed in bedrock under the lake sediments.
- Need to be able to collect water samples and monitor hydraulic heads winter and summer.
- Construction and design must not pose a threat of increasing mine water inflow

Development of Sub-Lake Piezometers

Distribution of Borehole Permeability

Quality of Borehole Test Data

Estimating Maximum Peak Inflow

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Water Budget

- Represent major structures as discrete features
- Averaging K values for each layer
- Identify and include major structural zones
- Does not capture either the small scale or large scale spatial structure
- What can we learn from large scale laboratory experiments?

3D Flow and Transport Models

- Fracture Plane 1 m²
- Seventeen boreholes – Transmissivities reflect fracture plane apertures around each borehole
- Aperture data obtained from fracture trace around block perimeter
- Fracture plane under load
- Compared impact of input parameters on degree of match with measured data

Large Block Experiment – Seok, 2010

- Fracture Plane 1 m²
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Large Test Block – 1 m²

- A boot-strapping technique was used to ensure that the large scale variability constraints were respected.
- The model with spatial variability gave the best fit to the measured data

Assigning Spatial Variability

Impact of Input Data on Computed Flux (Seok, 2010)

- Areas of influence were identified
- Borehole data gave large scale variability for the Test Block fracture
- Aperture data gave small scale variability
- A boot-strapping technique was used to ensure that the large scale variability constraints were respected.
- The model with spatial variability gave the best fit to the measured data
Typical 3D UG Mine Model

Approach Suggested (Seok, 2010)

- Remove large scale borehole flows from permeability distribution and assign to large discrete features
- Assume that the modified permeability distribution reflects the small scale variability
- Use measured inflows in defined mine watersheds to identify large scale variability.
- Use a boot-strapping technique to ensure that the large scale variability constraints are respected

Distribution of Borehole Permeability

Defining Mine Watersheds

Summary

- We have to build coupled hydro-structural models
- We have to place confidence bands on input parameters
- We have to provide confidence bands on predicted inflows and water chemistry
- We have to incorporate spatial variability systematically in model input parameters
- Mine managers cannot manage mine water if we do not produce credible and bounded predictions on quantity and quality vs time.