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

John Gale and E. Seok
Fracflow Consultants Inc.

IMWA 2010

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

2

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.

3

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

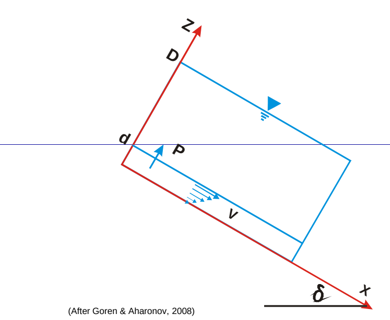
4

Depressurizing

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

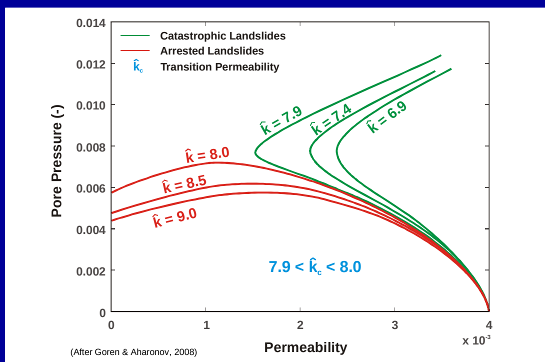
5

Model Geometry

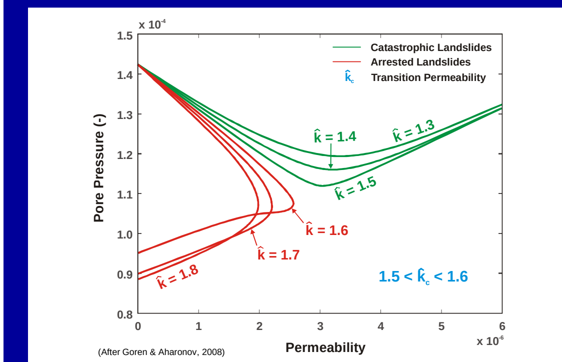


(After Goren & Aharonov, 2008)

Pore Pressure Along Shear Zone



Numerical Simulation

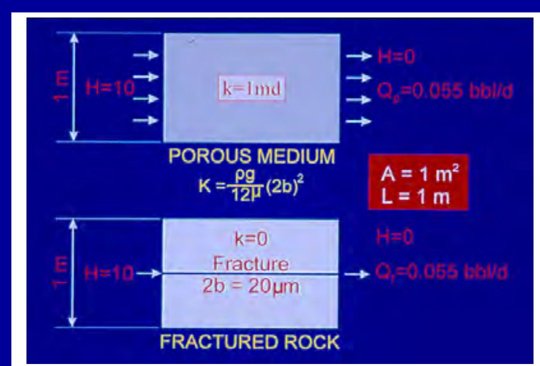


Fracture Flow - Basic Concepts

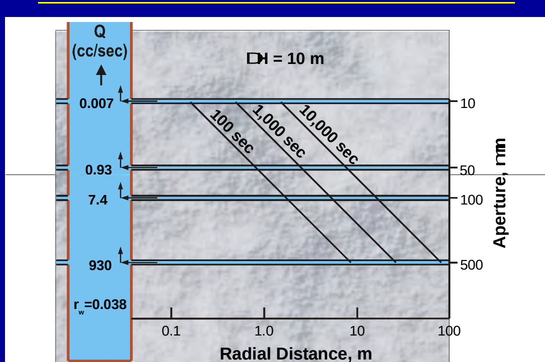
- Equivalent porous media versus fractured media
- Factors that impact on interpretation of field test data
- Scale of fracturing - geometry

9

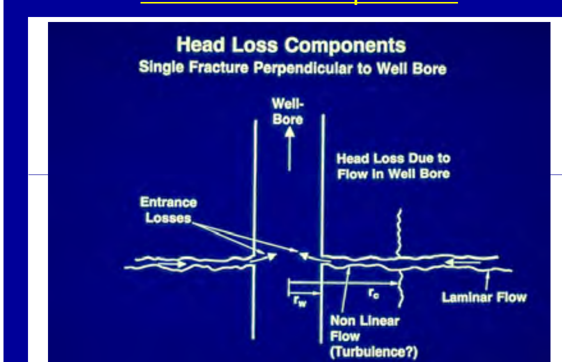
Porous Media vs. Fractured Media



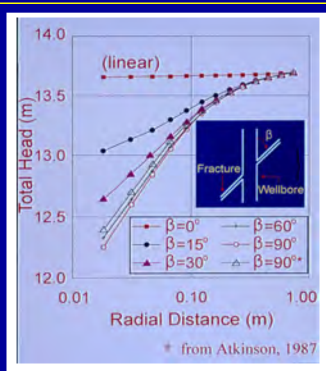
Where does the Water Come From?



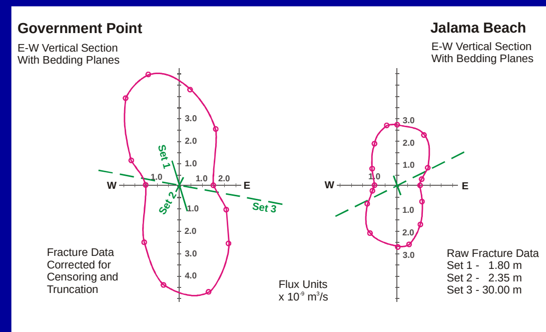
Head Loss Components



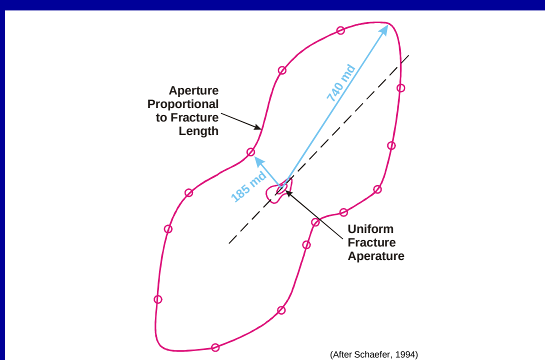
Impact of Borehole-Fracture Angle



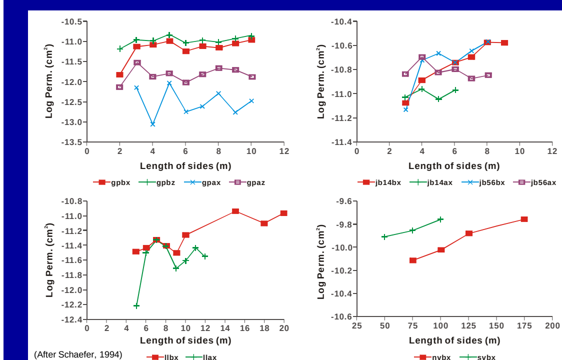
Relative Flux



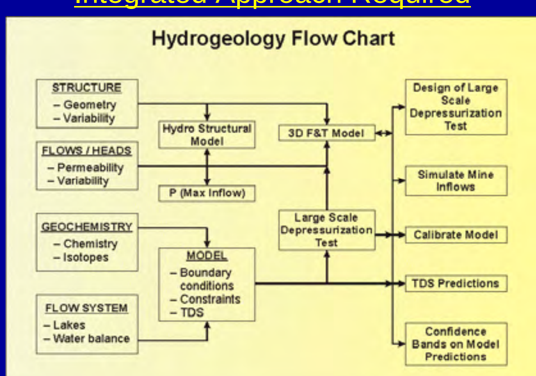
Relative Flux



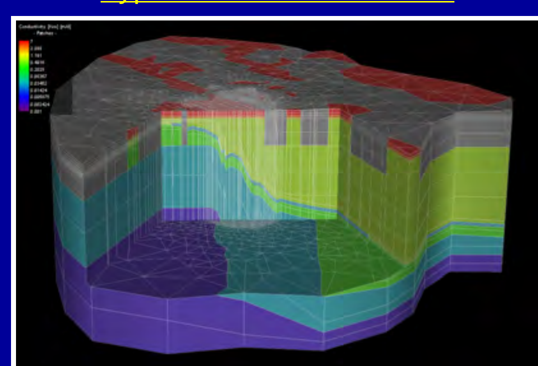
Permeability vs Block Size



Integrated Approach Required



Typical 3D UG Mine Model



Hydrogeology and Hydrogeochemistry

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

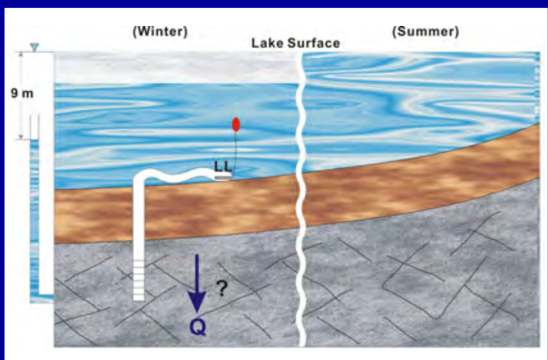
19

Example – Impact of Lakes in the North

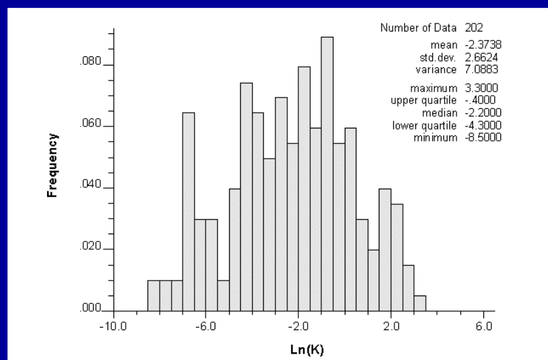
- Mines adjacent to or under lakes/rivers
- Need to determine rate of leakage
- Need piezometers installed in bedrock under the lake sediments.
- Need to be able to collect water samples and monitor hydraulic heads winter and summer.
- Construction and design must not pose a threat of increasing mine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

20

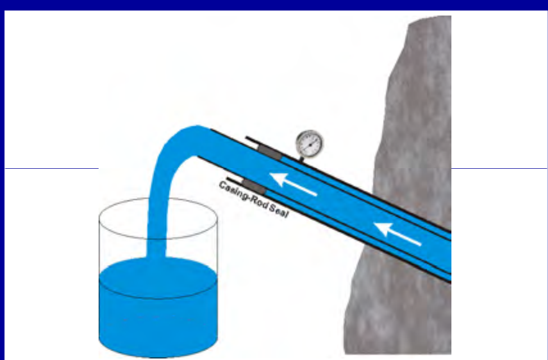
Development of Sub-Lake Piezometers



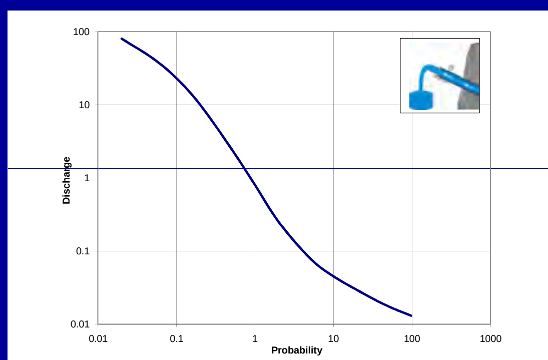
Distribution of Borehole Permeability



Quality of Borehole Test Data



Estimating Maximum Peak Inflow



Water Budget

3D Flow and Transport Models

- 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?

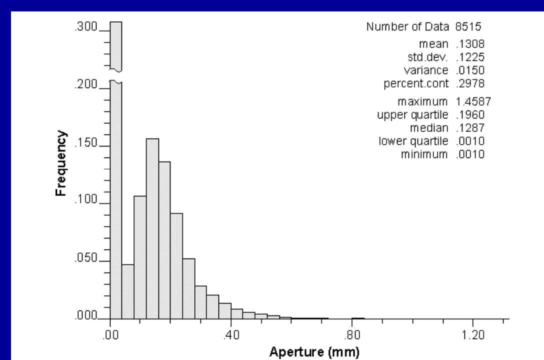
26

Large Block Experiment – Seok, 2010

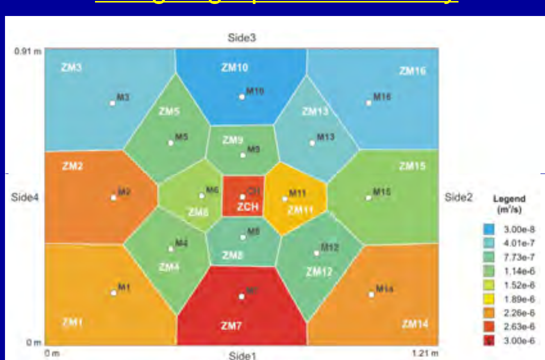
- Fracture Plane 1 m^2
- Seventeen boreholes – Transmissivities reflect fracture plane apertures around each borehole
- Aperture data obtained from fracture trace around block perimeter
- Fracture plane under load
- Compared impact of input parameters on degree of match with measured data

27

Large Test Block – 1 m^2



Assigning Spatial Variability

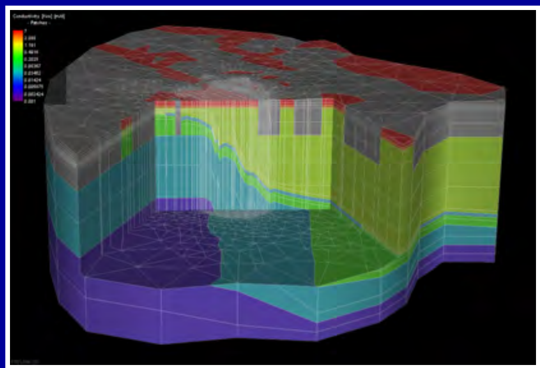


Impact of Input Data on Computed Flux (Seok, 2010)

- 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

30

Typical 3D UG Mine Model

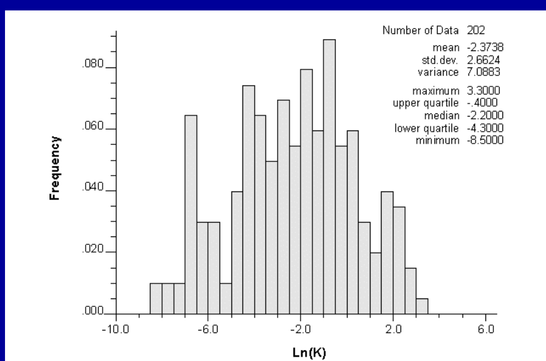


Approach Suggested (Seok, 2010)

- 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

32

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.

35