Simulating Open-Pit Mining and Lake Infilling Using MODFLOW and MINEDW

Presented by:

Dong Ding
Sandra Hodge
Itasca Denver, Inc.

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Objectives

• Two groundwater flow codes are utilized to simulate groundwater conditions related to open-pit mining and pit-lake infilling
  – *MODFLOW* (Finite-difference method)
  – *MINEDW* (Finite-element method)

• Comparisons of two models were made on:
  – Model Construction (e.g. grid/mesh design)
  – Model Convergence
  – Effective Simulations of Mining and Lake
Background
Background

- The modeling work includes mine dewatering, pit-lake infilling, and water supply pumping
- Complex geology (structures and heterogeneity) in the project areas
- Steep hydraulic gradients in some areas
Phase I Mining and Dewatering
Phase II Recovery after Phase I Mining
Phase II Mining and Dewatering
Model Structure Design

- Finer discretization needed in areas of interest both horizontally and vertically
- The more cells, the more time to compute
Model Construction

• **MODFLOW**
  – grid spacing should not increase by more than 50% between adjacent cells (GWV 2010; SWS 2011; Birch et al. 2006)

• **MINEDW**
  – Finite-element method provides grid flexibility (Durbin and Bond 1998; Azrag et al. 1998; Mehl et al. 2006)

• Local Refinement Methods (Mehl et al. 2006)
  – Telescopic mesh refinement
  – Iterative local refined grid
Model Convergence

- Convergence problem may lead to model failure
- Reasons that lead to failure to converge
  - Dry cells and re-wetting (stability)
  - Heterogeneity
    - abruptly change transmissivity – steep hydraulic gradient
  - Water balance errors (Harbaugh and McDonald 1996)
    - Numerical errors (Merritt and Konikow 2000)
    - Mass transfer near the boundaries
To Avoid Convergence Problem

- **MODFLOW**
  - Model structure
    - Discretization
    - Boundary Conditions
  - Reasonable Initial heads
  - Appropriate time steps
  (Merritt and Konikow 2000; personal communication)

- **MINEDW**
  - Converge based on the budget of entire model domain
  - This may save considerable time in fixing the model
Pit Geometry and Lake Infilling Simulations

• **MODFLOW**
  - Model needs to be separated into stages of mining, lake cells are treated as inactive (Merritt and Konikow 2000)
  - Mine dewatering is simulated using Drain package
  - Model grid dimensions define lake volume (Merritt and Konikow 2000)

• **MINEDW**
  - One single code package includes both drain and infilling, no inactive cells
  - Mining defined through collapsing the mesh, better evaluation of dewatering plan
  - Pit lake defined through the relationship between elevation, volume, and surface area
  - Seamlessly provide flow from different geologic units for Pit-lake geochemistry analysis
Model Calibration

- Model calibrated to water levels for both steady-state and transient conditions in both piezometers and lake
- Mass balance is honored ~ < 0.1%
Summary

• Both models have the ability to simulate open-pit mining and lake infilling reasonably well.

• *MINEDW* model has advantages in:
  – Flexible mesh construction
  – Model convergence
  – Ease of pit geometry and pit-lake infilling simulations

• Model grid should be built carefully not only for good representation of site conditions, but also for computation efficiency.

• A complex mining activity requires multi-stage models.
References