"Linking empirical observations and fundamental geochemistry for water quality predictions using Goldsim".

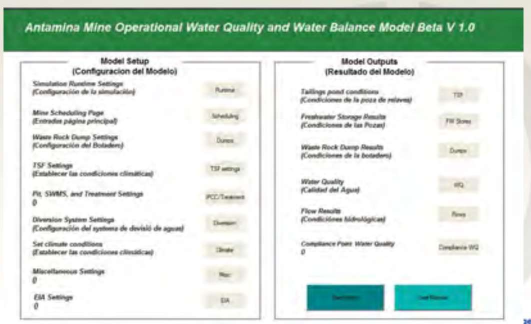
Brent Usher, Roald Strand, Chris Strachotta and Jim Jackson
Klohn Crippen Berger and Antamina Mining Company

Presentation to IMWA September 2010

Overview of presentation

- Approach
- Case study
- Discussion

End Goal

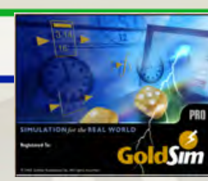


Model Construction Approach

Approach

- Simplify existing operational water balance
- Model the geochemistry of each component separately (in Goldsim)
- Use waste schedule and static geochemical test results to define mass of reactants
- Use field kinetic cells to define expected rates
- Use monitoring record to define expected behavior and reasons for observations
- Apply scaling
- Compare model to field observations

Modeling platform



- GoldSim selected as platform
  - Allows dynamic modeling of complex systems
  - Widely used for mine water balances
  - Flexible
  - Internal consistency
  - Open-structure allows processes to be included as algorithms

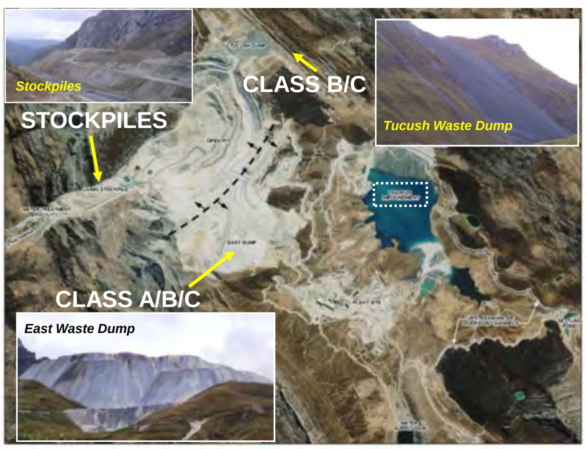
Case Study- Antamina

- Compania Mineria Antamina (CMA) Cu-Mo-Zn mine operates at 4,200 m above sea level, Peru.
- Large Cu-Zn Skarn deposit
- Full production from 2001 with anticipated mine life of >23 years.
- Mine excavates up to 400,000 tonnes/day
- Waste rock stored in two WRD.
- On-site TSF
- Rainfall approximately 1,450 mm (seasonality)
- *Developed model for closure and then for operations*

Klohn Crippen Berger

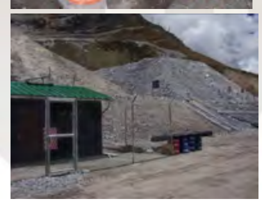
Site Location

Klohn Crippen Berger

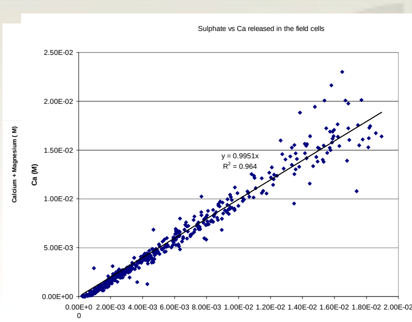


Geochemical Data Sources

- Laboratory testing
  - Static testing
  - Humidity cells
  - Mineralogy
  - PSD
- Field kinetic testing
  - Field cells (78)
  - Instrumented Field piles (5)
- Field water quality monitoring records

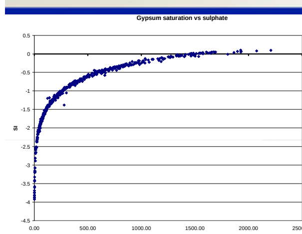


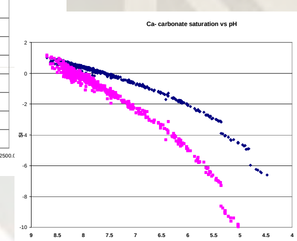
Deriving the Geochemisty: Field WQ monitoring and Field cells



Klohn Crippen Berger

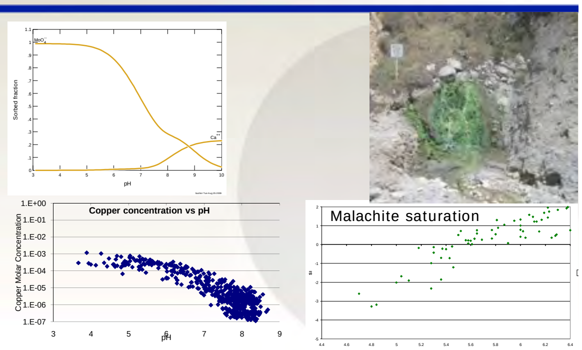
Deriving the Geochemistry:





Klohn Crippen Berger

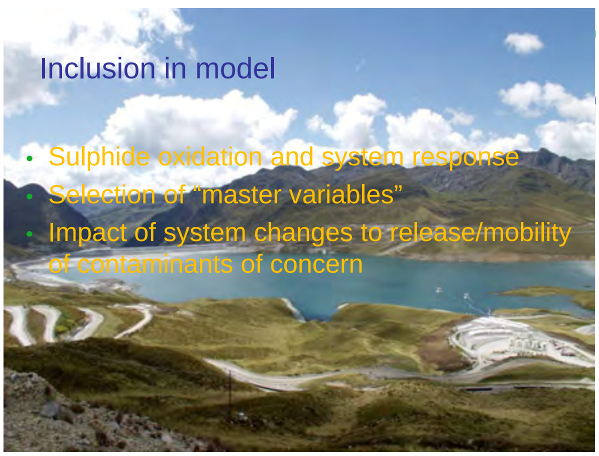
Deriving the Geochemistry:



Geochemical considerations

- Largely NAF rocks but both acid and neutral metal leaching concerns
- Sulphide oxidation drives reactions
- Where excess carbonate NP available, pH drop does not occur
- Metal solubility/mobility largely a function of pH
- Secondary mineral precipitation/ dissolution/ sorption important control on concentrations
- PHREEQC and Geochemists Workbench modeling to compare field/cells

Klohn Crippen Berger



GoldSim model

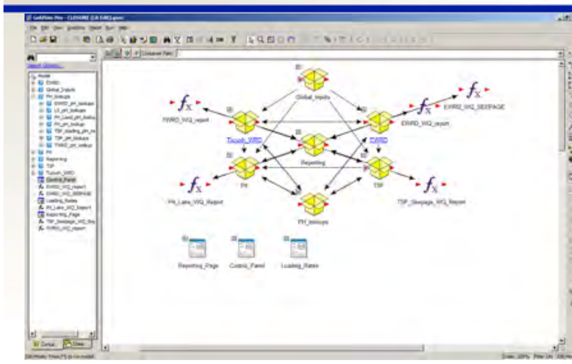
Klohn Crippen Berger

Basic calculations occurring in each time step

- Flow
- Loading
- Mass balance
- Acidity generated/Neutralization consumed
- Corrections for non-ideality
- pH determined (also as function of P_{CO_2})
- Secondary precipitation
- pH-dependent solubility
- Effects of Sorption
- “Equilibrated” water quality transferred

Klohn Crippen Berger

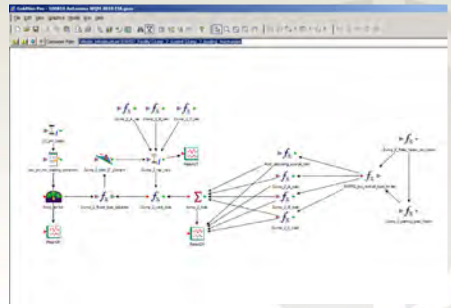
Model Structure



EWRD Flows

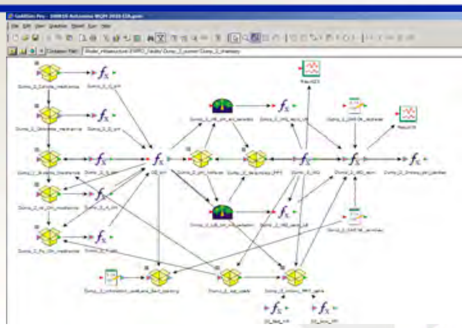
Klohn Crippen Berger

Increase in reaction products through loading



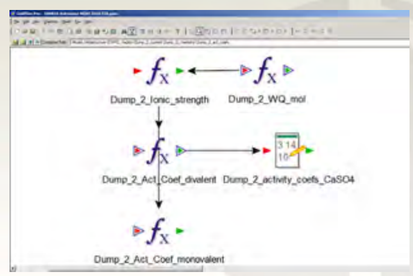
Klohn Crippen Berger

Acid generation and neutralization

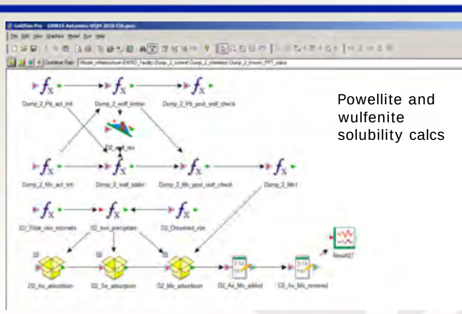


Klohn Crippen Berger

Solubility calculations

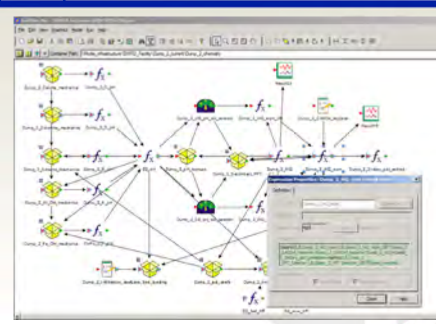


Klohn Crippen Berger



Klohn Crippen Berger

Sorption and transfer of "equilibrated quality"

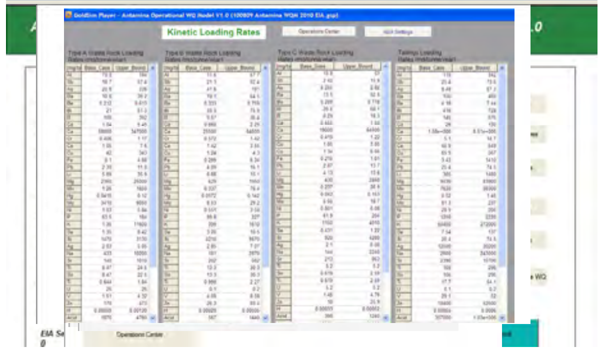


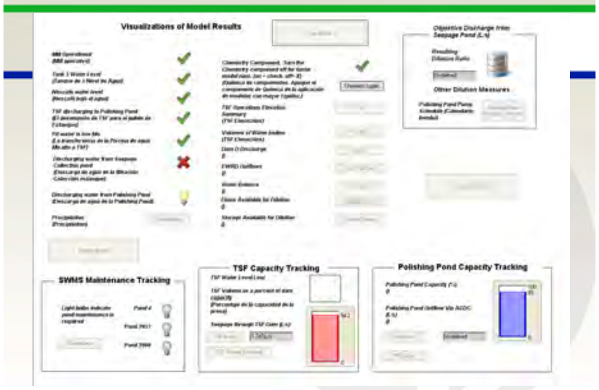
Klohn Crippen Berger

Uncertainties and simplifications

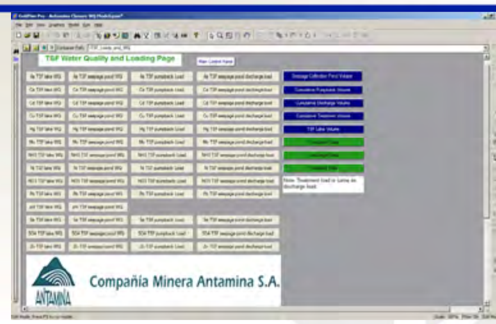
- Model based on field cells rates which have not yet fully evolved
- Model simplifies reactions (no complexation etc)
- Metal solubility tied to pH/solubility trends based on field observations (cells/piles/full scale)
- Mass transfer occurs between components without reaction

Final product

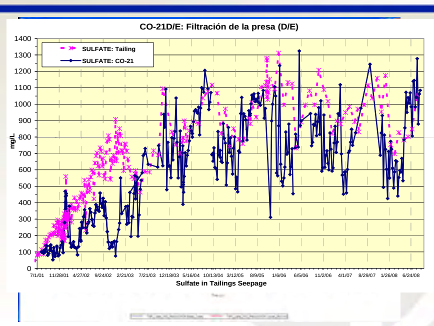




Result page



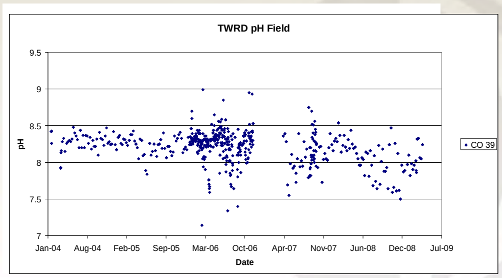
Example of output



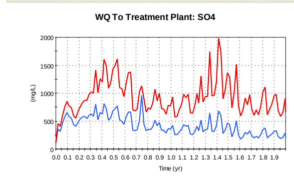
The importance of understanding the hydrology

- Internal hydrology of WRD and TSF very important to understanding water quality
- Seasonality and flush vs matrix storage must be included to simulate field observations especially for WRD's

TWRD pH (linked to buffer and Pco_2)

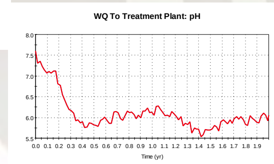


Southern EWRD



Measured “combined” flow from different seeps 500-2000 mg/l

Measured “combined” pH 5.5-7



Limitations

- Only as good as the available data
- Provides broad ranges of expected quality
- Each component consist of only a few units/homogenization
- Lacks spatial variability
- Answers will not correlate precisely to geochemical models since precise speciation is not included.
- Significant initial effort to scale correctly

Advantages

- Provides an integrated water quality with the mine water balance
- Models can independently include water balance components for integrated cause-effect relationships
- As relevant data is gathered and processed, model accuracy should improve
- Predictions should improve as better understanding of the correlation between on-site activities and observed concentrations is obtained

Summary

- Models have been provided as tools to mine users
- Impacts of changes in management strategy can be quickly and easily evaluated.
- Models can be used for on-site training so that responsible persons at the mine site can understand the key processes and the relative importance of each data type in a monitoring program.

Thank you for your time