Global Resource Engineering Ltd.

Evapotranspiration Caps for Mine Waste Closure – Case Studies in Extreme Environments

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Mine Waste Covers

- Old solution: unlined and unmanaged
- Newer solution: plastic covers
- Innovative solution: Evapotranspiration Covers

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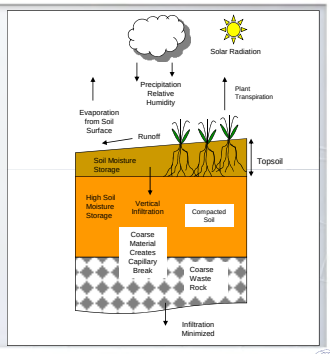
Dynamics of an Evapotranspiration Cover

- Manage water balance in the mine waste cover
- Maximize evaporation, plant transpiration
- Use soil physics to minimize infiltration



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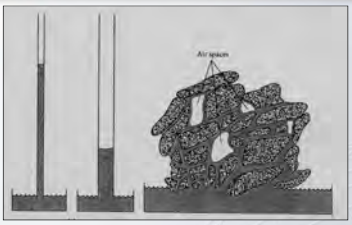
Unsaturated Water Flow: New Forces



- Matric suction – stronger than gravity
- Also called capillary forces
- Adsorption/Electrical forces

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Unsaturated Water Flow: New Equations

- Darcy’s Law no longer applicable
- Unsaturated flow equations best solved with computer modeling

$$q = -K(\theta)\nabla H$$

$$\theta = \theta_r + (\theta_s - \theta_r)\left\{\frac{1}{1+(\alpha\varphi)^n}\right\}^m$$

$$K_\varphi = K_s \frac{\left\{1-(\alpha\varphi)^{n-1}[1+(\alpha\varphi)^n]^{-m}\right\}^2}{[1+(\alpha\varphi)^n]^{\ell/2}}$$

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Methodology

- Data Collection
  - Climate
  - Soils
  - Aquifer Properties
- Predictive Modeling
  - 1D models
  - 2D models of actual engineered facility
- Model Verification

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Case Studies

- Excellent case studies in the Alternative Cover Assessment Program Documents (ACAP)
- Few case studies on Barren Rock Disposal Facilities (BRDFs)
- Extreme environments “bracket” performance

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Santa Elena Oro y Plata

- Open pit gold and silver mine
- Construction/ Production Phase
- 30 million tonnes of waste rock
- Arid climate ~300 mm of precipitation per year, late-summer monsoons

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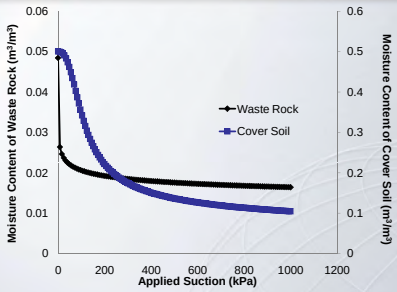
Unsaturated Flow Testing at Santa Elena



Results of Soil Water Characteristic Curve Test (SWCC)

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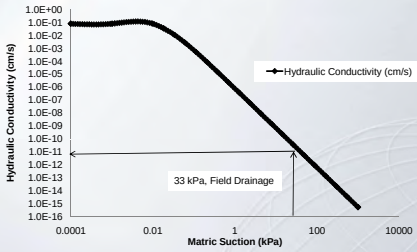
Deriving a K(θ) Function, Waste Rock



- Fredlund and Xing or Van Genuchten Equation
- Moisture →Matric Suction → K

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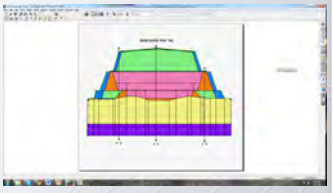
Computer Model

- Used Vadose/W from Geostudio
  - Best simulation of climate conditions
  - Excellent cover model package
- All runs transient (time variant)
- Site-specific vegetation data



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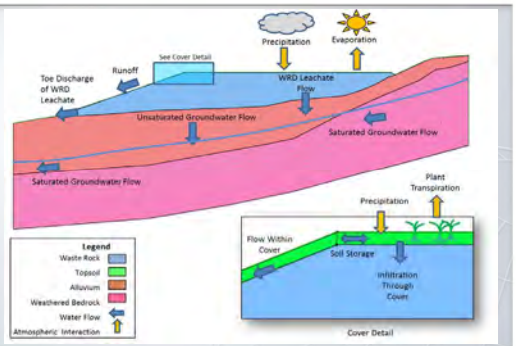
Santa Elena BRDF Model (with ET Cover)



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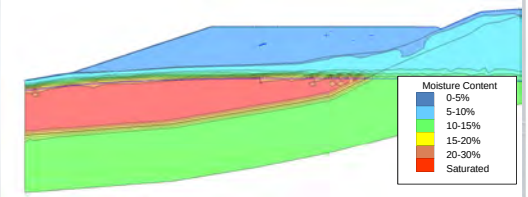
Results: Arid Environment



- ET cover makes dry waste
- No toe discharge
- 0.1% of precipitation. becomes leachate
- Storm events do not penetrate soil cover

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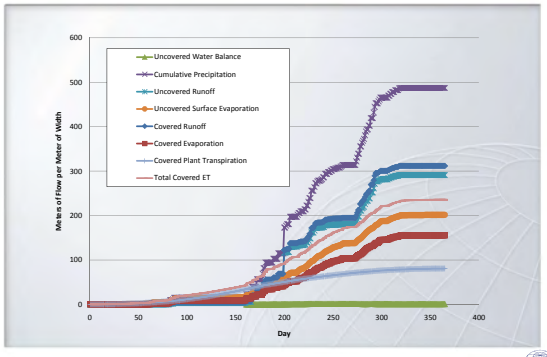
Results: Arid Environment Cont.



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Arid Environment Challenges: Erosion

- Must establish vegetation
- Bare rocks (eroded cover) have low performance
- Irrigation may be necessary

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Brisas del Cuyuni

- Proposed 70,000 TPD open pit mine
- Copper and Gold
- 20 year mine life
- ~1.2 billion tonnes of waste rock
- Tropical climate – 3.5 meters of precipitation per year
- Nationalized by Venezuela

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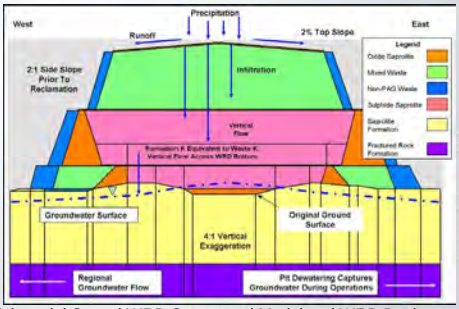
BRDF Design and Conceptual Flow Model



Brisas del Cuyuni WRD Conceptual Model and WRD Design

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Results: Tropical Environment

Comparison of Oxide Saprolite Cover and ET Cover: Mass Balance

Water Balance or Chemical Parameters	Units	Soil Cover	Engineered ET Cover
Total Leachate Volume	Liters/s	260	44.7
Runoff	Percent of Precipitation	0%	29%
Infiltration		42%	13%
Evaporation and Transpiration		58%	58%

- ET cover cannot prevent significant leachate in tropical environment
- Significantly alters total leachate volume

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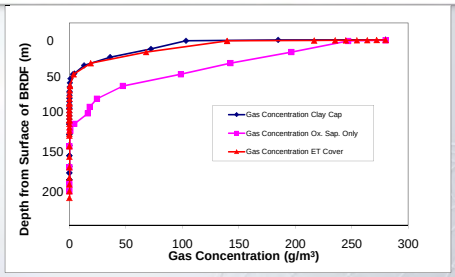
Results: Tropical Environment Cont.



- ET cover limits oxygen diffusion
- Substantially improves predicted leachate quality

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Verification

- Constructed 5 infiltration test cells in Venezuela
- Vegetated cells had low runoff, high infiltration
- Oxygen barrier successful
- Infiltration higher than predicted
- Different grasses may facilitate runoff

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Conclusions: Dry Environments

- Very successful in dry environments
- Effectively eliminated infiltration and leachate;
- Little response to extreme precipitation events
- Challenge is erosion prevention

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Conclusions: Wet Environments

- Mixed results in wet environments
  - Not effective infiltration control in tropical environment
  - Excellent oxygen diffusion barrier in tropical environment
  - Significantly improved predicted water quality (from 2000 mg/L acidity, down to 200 mg/L acidity)
- Covers outperformed other viable alternatives
- Verification is critical
- Nationalization ruins a good study

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Acknowledgements

Thanks for letting me turn your mine into a science project, and thanks for the willingness to try innovative solutions that don’t cover everything with plastic

Gold Reserve Inc.

SilverCrest

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Questions?

Thank you for your attention

Global Resource Engineering Ltd.

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The excellent background information and research results from the EPA's ACAP program are available upon request.

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