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When is water treatment not forever?

Exploring the actual availability of sulphide and carbonate mineral contents in acid generating rock

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Roadmap

- Water Treatment?
- Study Objectives
- Conceptual Model
- Application (Low-S & High-S)
- Results & Sensitivities
- Conclusion

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Water Treatment?

- A frequent requirement at ongoing operations and during closure and beyond
- Water quality modelling
  - Needed to understand short- and long-term water quality and potential management risks
- Waste rock is a dominant source of loadings to water

Waste Rock

- Is the site waste rock classified as PAG or non-PAG?
- Is the stockpile segregated or mixed?
- What impact will the acid producing proportions of the waste rock pile have on drainage quality?

Waste Rock

- Waste rock piles are not geochemically homogenous
- Some acid generating rock (PAG) and some with excess neutralization potential (non-PAG)
- Interactions within the waste rock pile and mixing of contact water will determine overall water quality

Waste Rock
Acidity Production

- Net acidity reporting to water is directly related to the quantity of lime required for treatment
- Acidity production estimates are key to understanding long-term water treatment requirements

Acidity

Useful Surrogate for Metals Releases

- Acidity ($CaCO_3$) = Sum of Metals plus H^+ (Cadmium + Cobalt + Copper + Iron+ Lead + Manganese + Nickel +Zinc + H^+)
- Alkalinity = Sum of carbonate species plus OH^- (CO_3^{2-} + HCO_3^- + OH^-)
- Acidity can be consumed/neutralized by NP and dissolved alkalinity
- Acidity in drainage is manifested by low pH and/or elevated metals concentrations

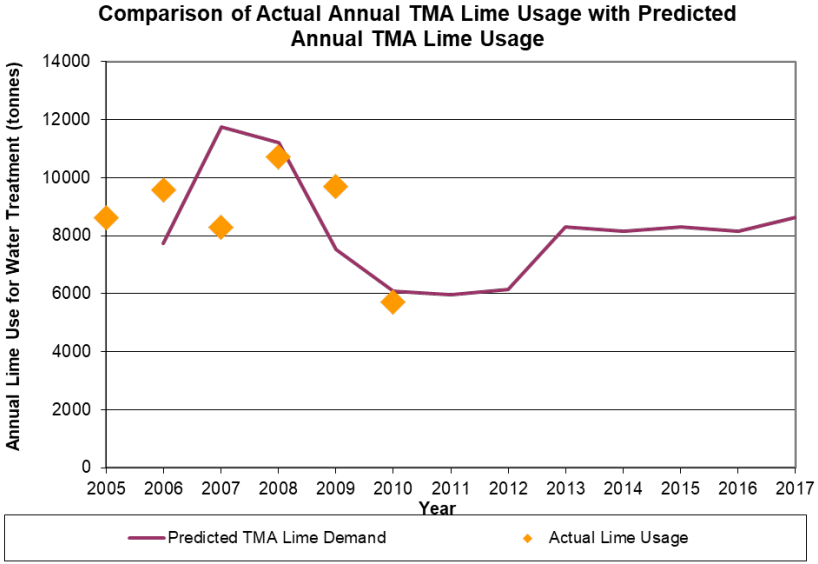
Acidity Production
Developing a Model

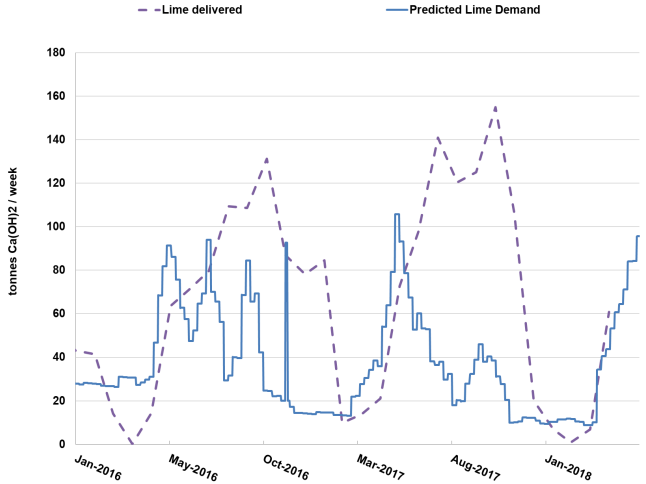
- Continue to build upon our experience with modelling acidity
- Prediction of lime use for treatment plants
  - Forecasted, hindcasted, revisited predictions
- Acidity used as a surrogate for many metals
  - Reduce uncertainty
- Acidity-Alkalinity module developed for integration into MineMod™
  - Applying statistics
  - Inventories
  - More realistic scenarios
  - Predicted water quality

ACIDITY MODEL

Acidity

Modelling Example – Predicting Lime Demand





Acidity Production
Developing a Model

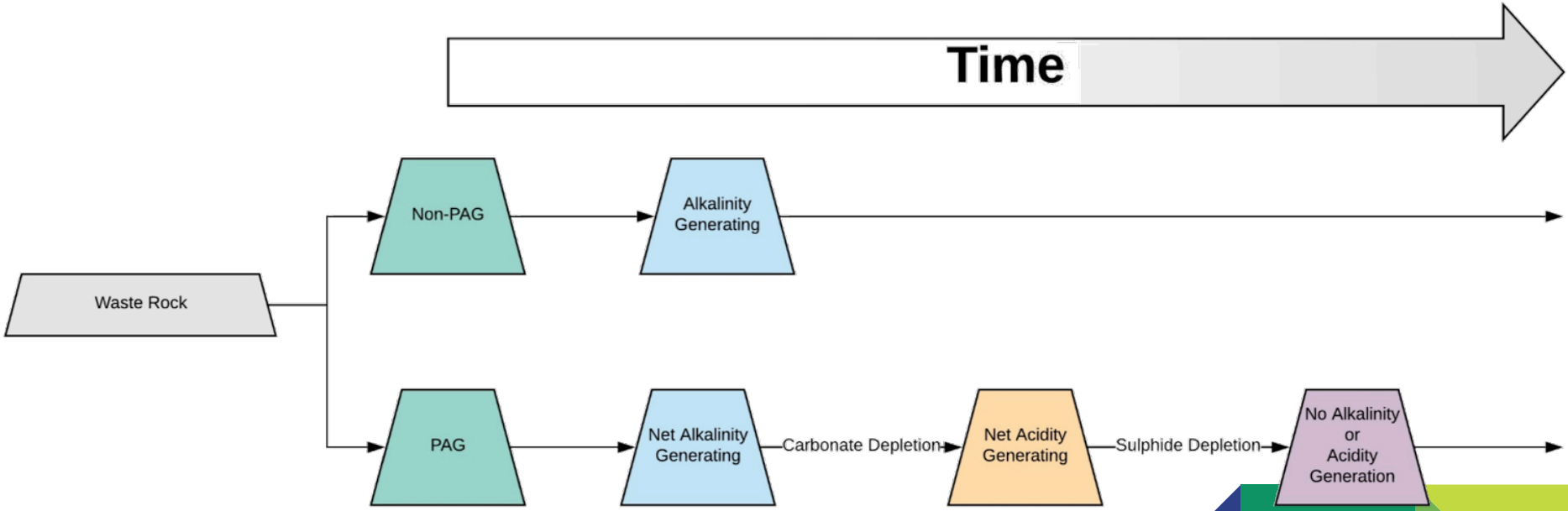
- Quantify acid generation beyond PAG and non-PAG proportions
    - **Onset** of net acid generation
    - **Intensity** of acid production
    - **Duration** of acidity production

Model Objectives

- Predict the net alkalinity or acidity over time
- Account for the statistical distribution of acid-base-accounting characteristics per lithology to reflect the distribution of mine materials
- Quantify the proportions of acid generating and non-acid generating waste rock over time
  - Different rates of net alkalinity or acidity production per lithology

CONCEPTUAL MODEL

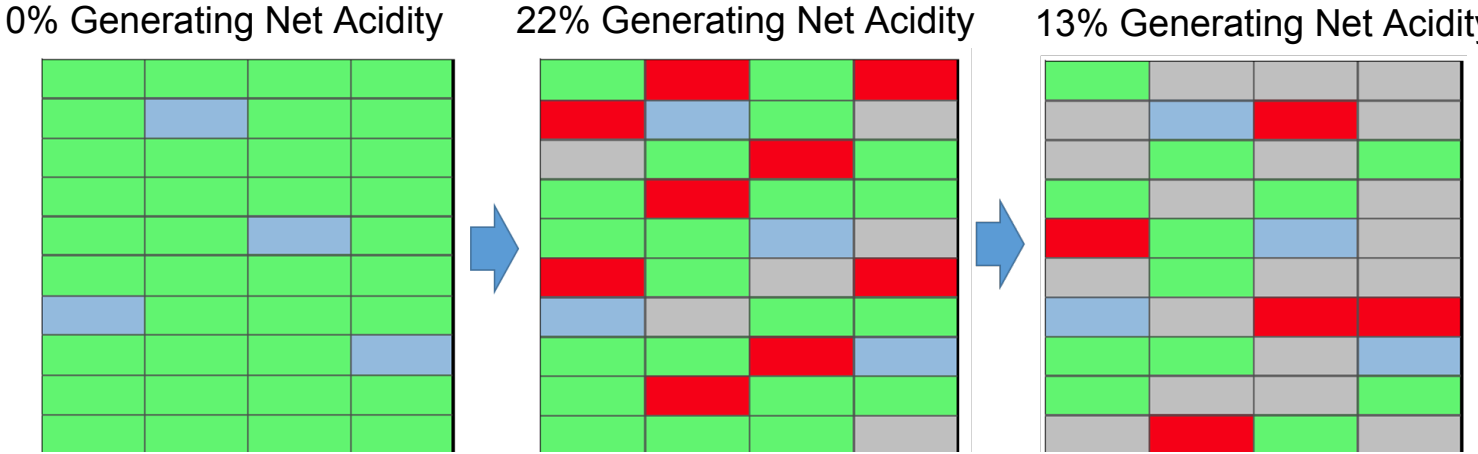
Conceptual Model
Acidity-Alkalinity Generation



CONCEPTUAL MODEL

Conceptual Model
Acidity-Alkalinity Generation

- Waste Rock Pile evaluated as ‘Cells’ and acid generation category tracked, per cell, through time



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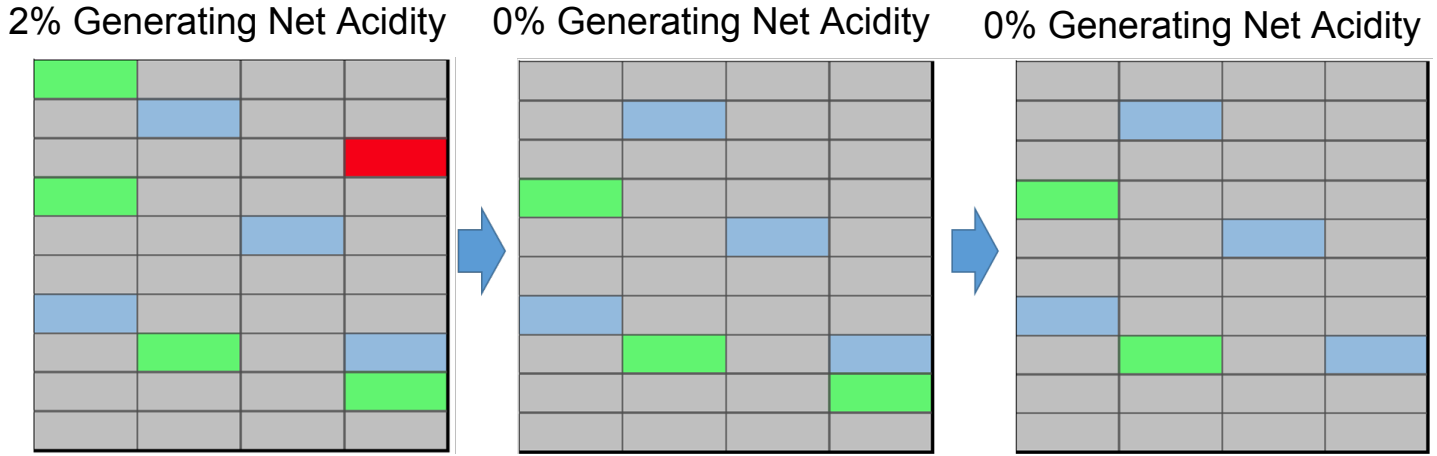

PAG: Acid Producing, Carb-NP depleted, Sulphide Available

PAG: Neutral, Carb-NP and sulphide depleted

Non-PAG: Neutral

PAG: Neutral, Carb-NP Available

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APPLICATION

Approach
Data Collection

- Characterize waste rock deposit - lithology based
  - Lithological distributions
  - Distributions of carbonate-neutralization potential (Carb-NP) content
  - Distribution of sulphide content
  - Distribution of waste rock age
  - Availability of carbonates and sulphide minerals
  - Grain size distributions

APPLICATION

Approach
Data Collection

Utilize available kinetic test results:

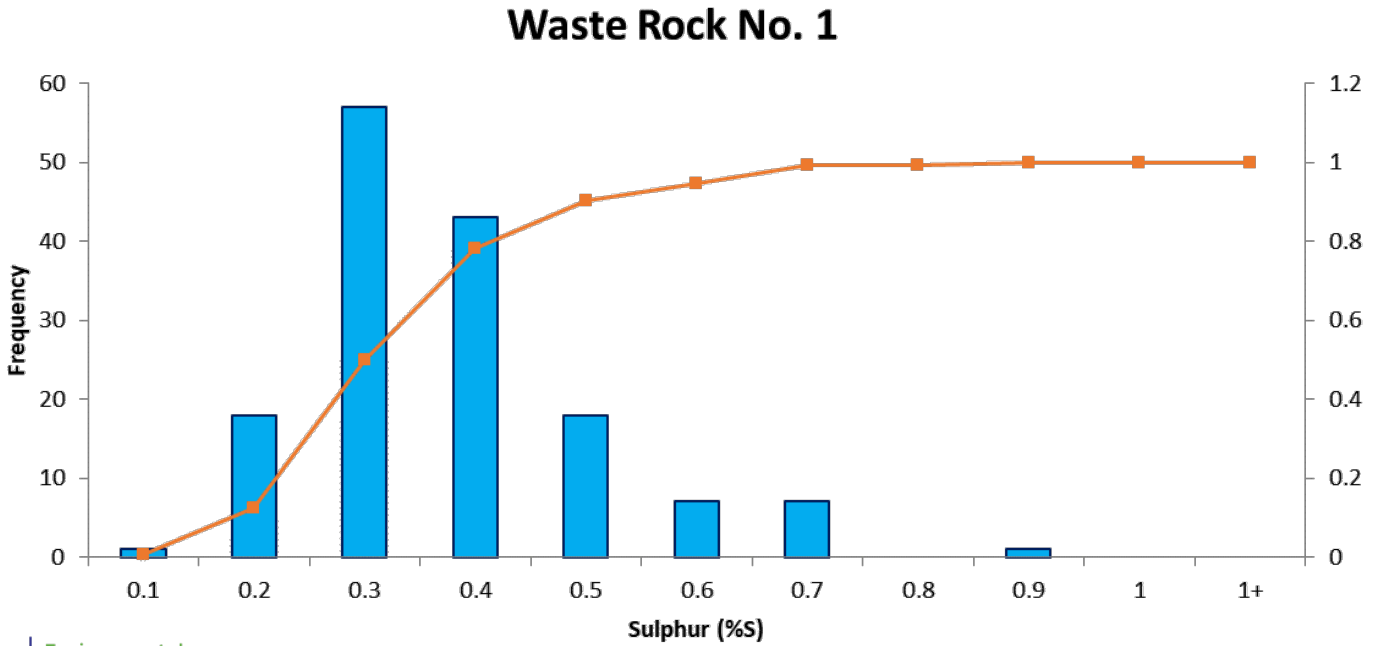
- Humidity cells
- Barrel tests or field cells/piles
- Quantify sulfide oxidation and neutralization potential depletion rates
- Scaling considerations from lab to field

Hydrological and transport aspects – matrix vs. preferential flow

SCENARIO 1

'Low' Sulphur Waste Rock Pile

Sulphur Distribution



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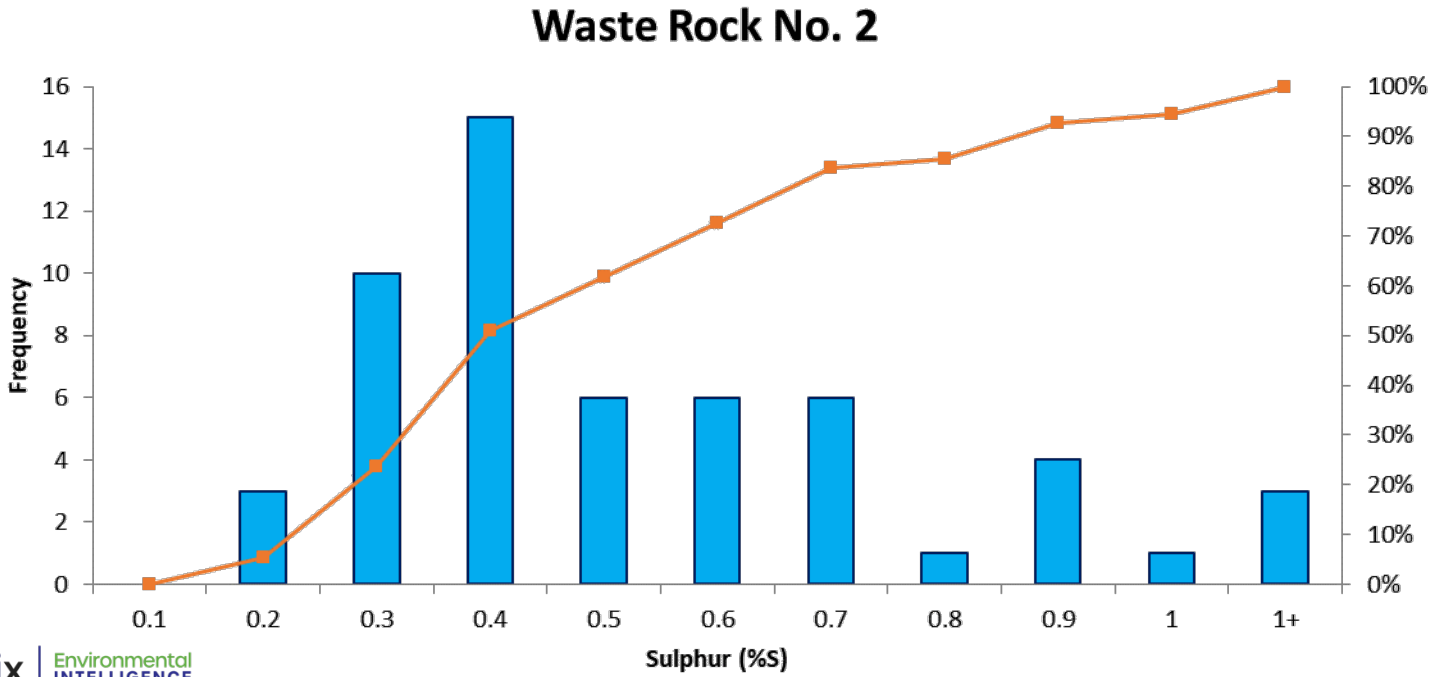

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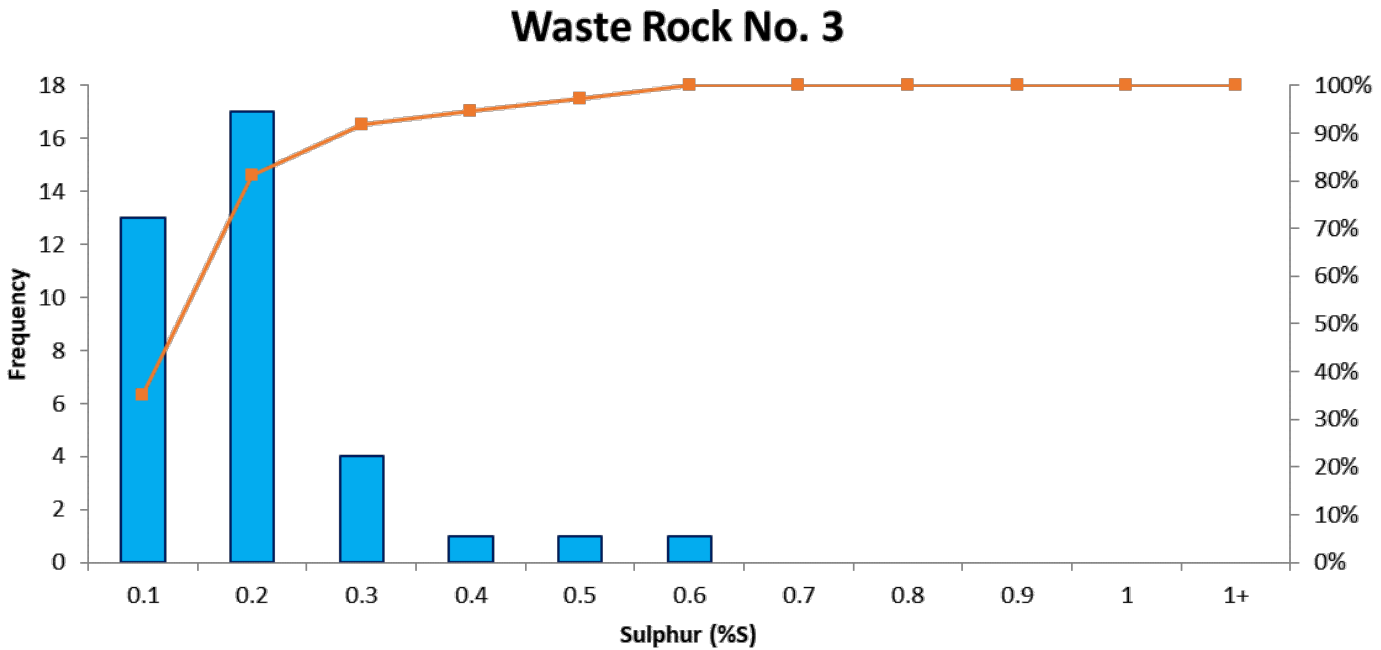

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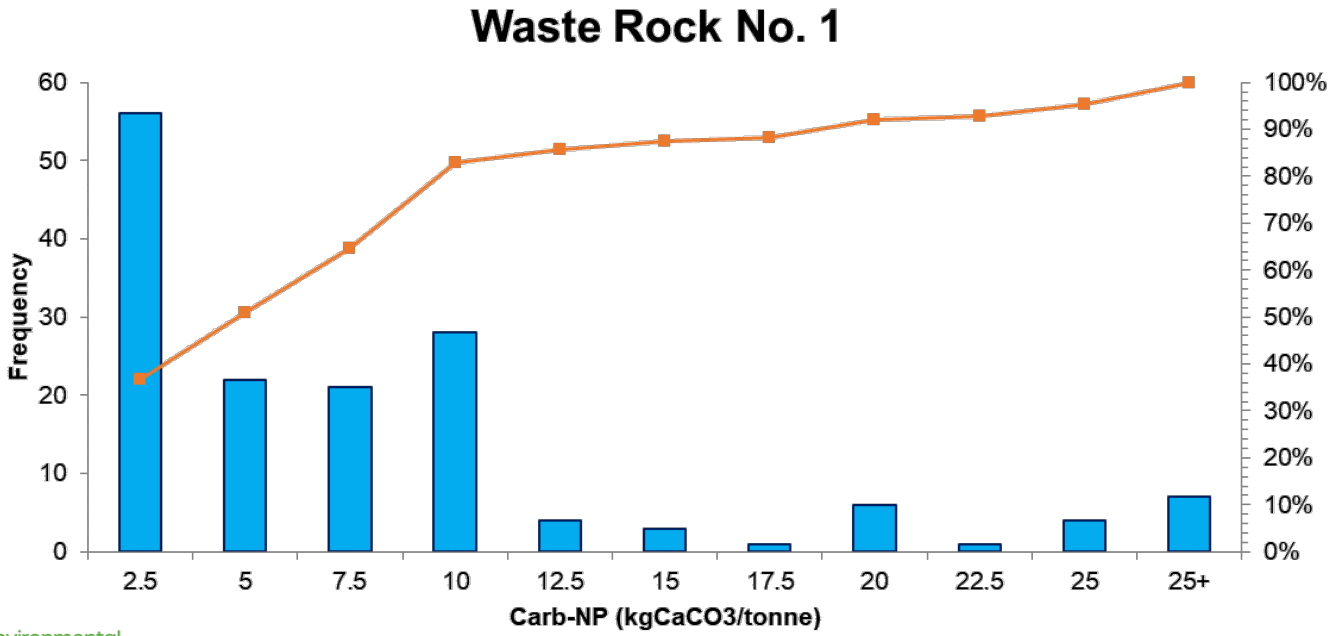
Carb-NP Distribution



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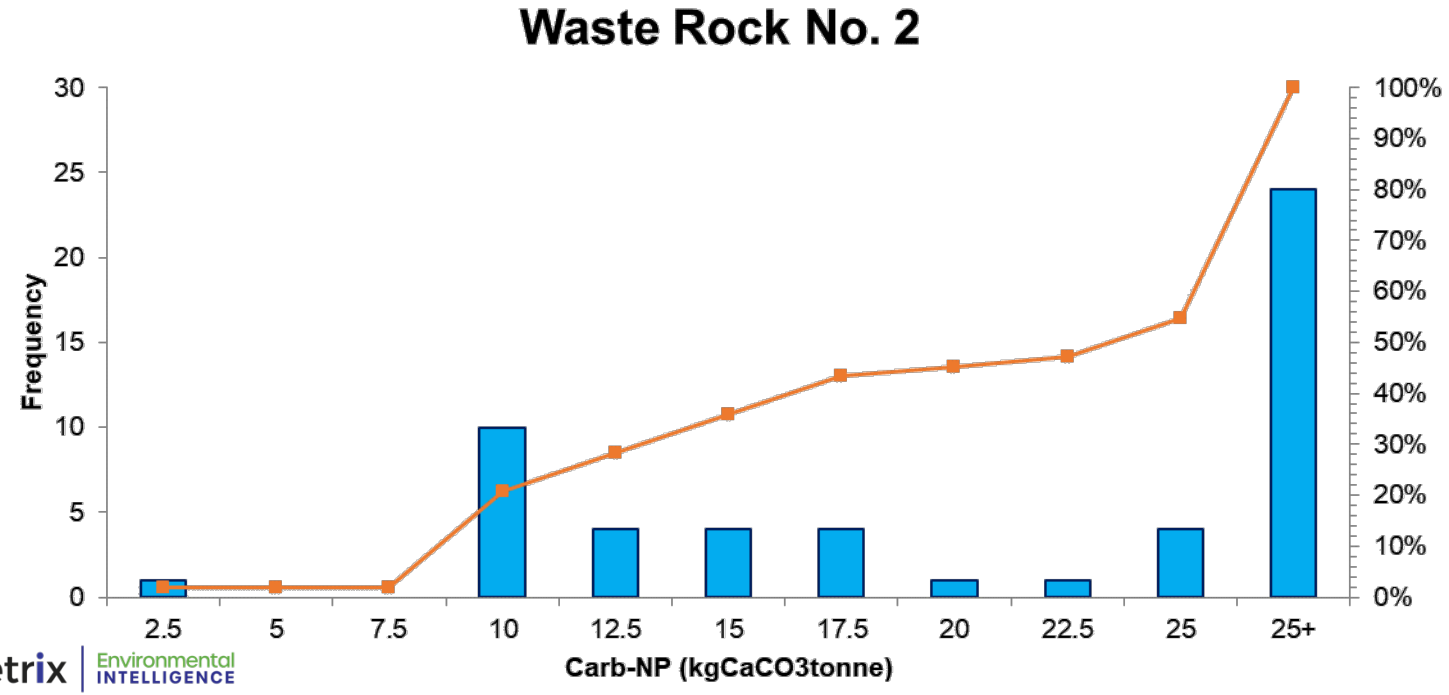

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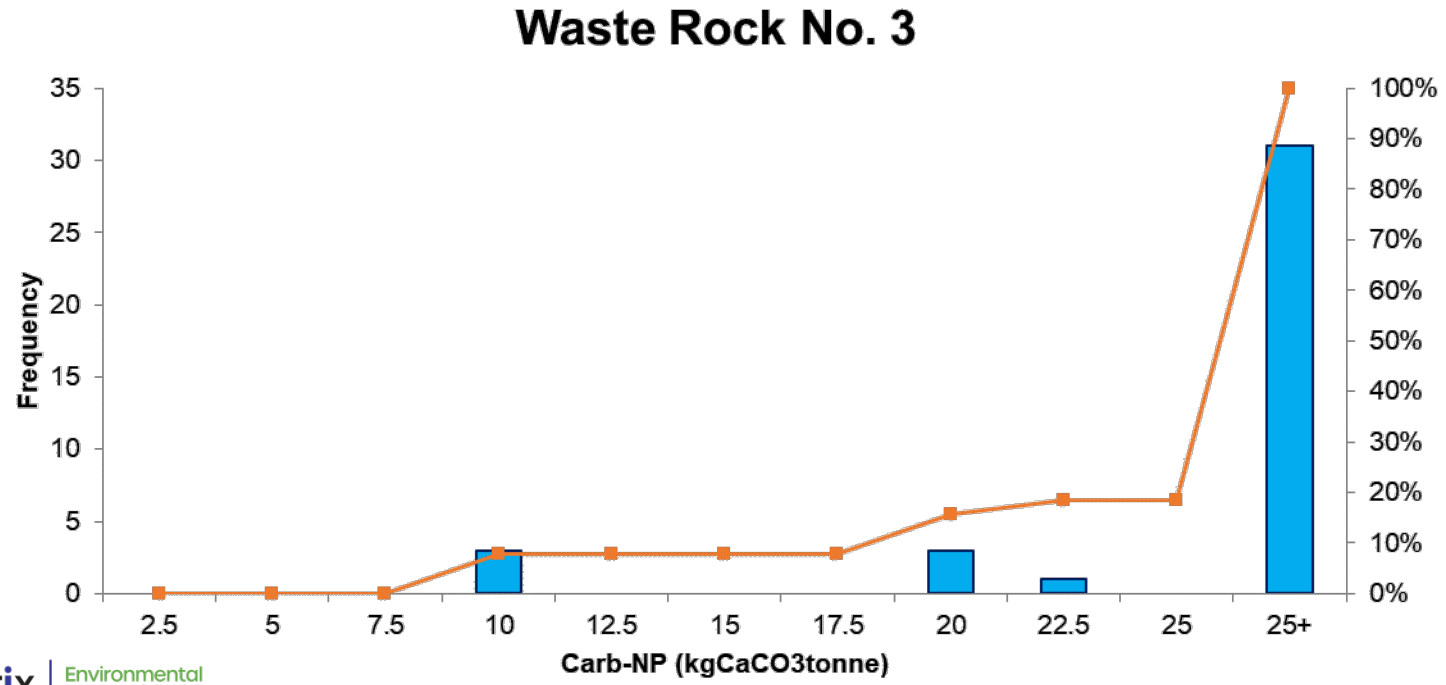

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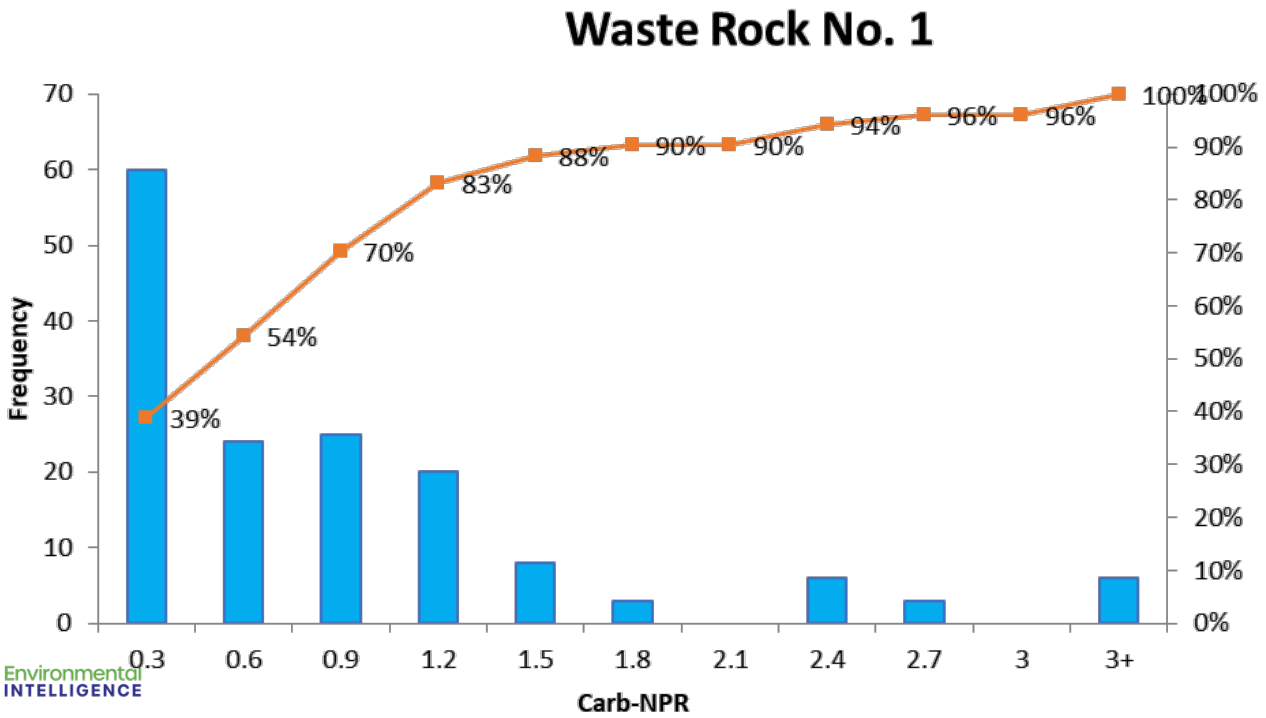
'Low' Sulphur Waste Rock Pile

Carb-NPR Distributions



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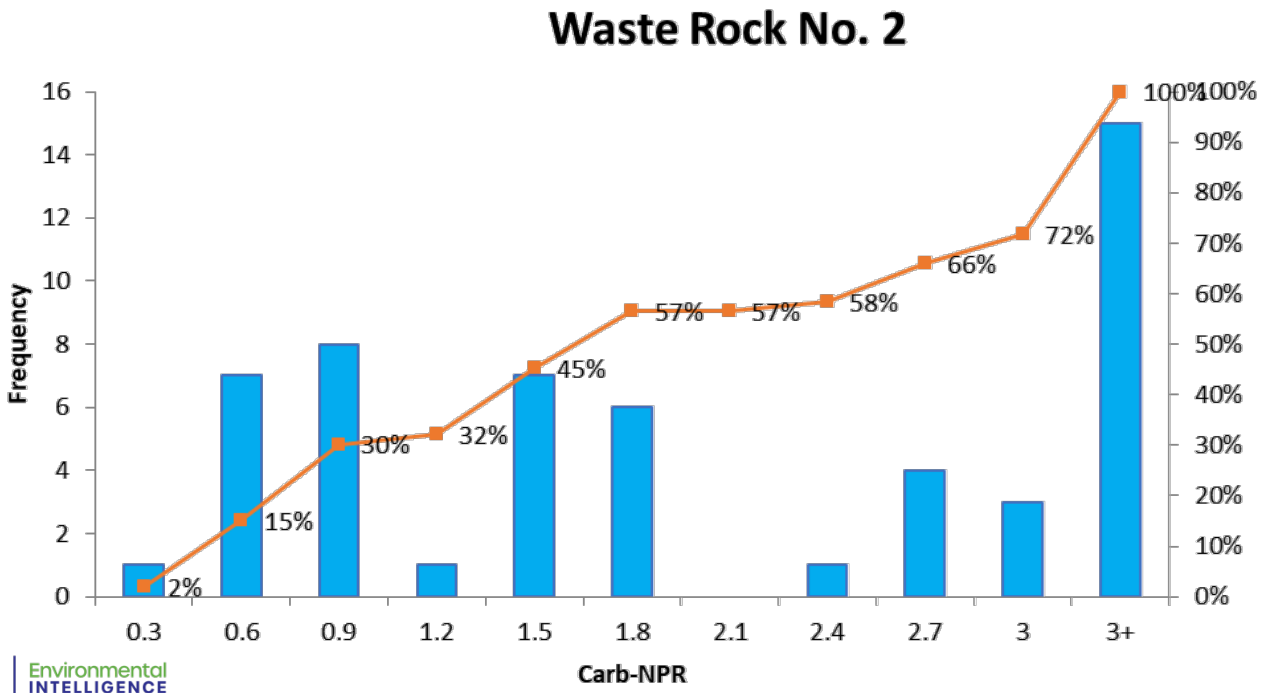
Carb-NPR Distributions



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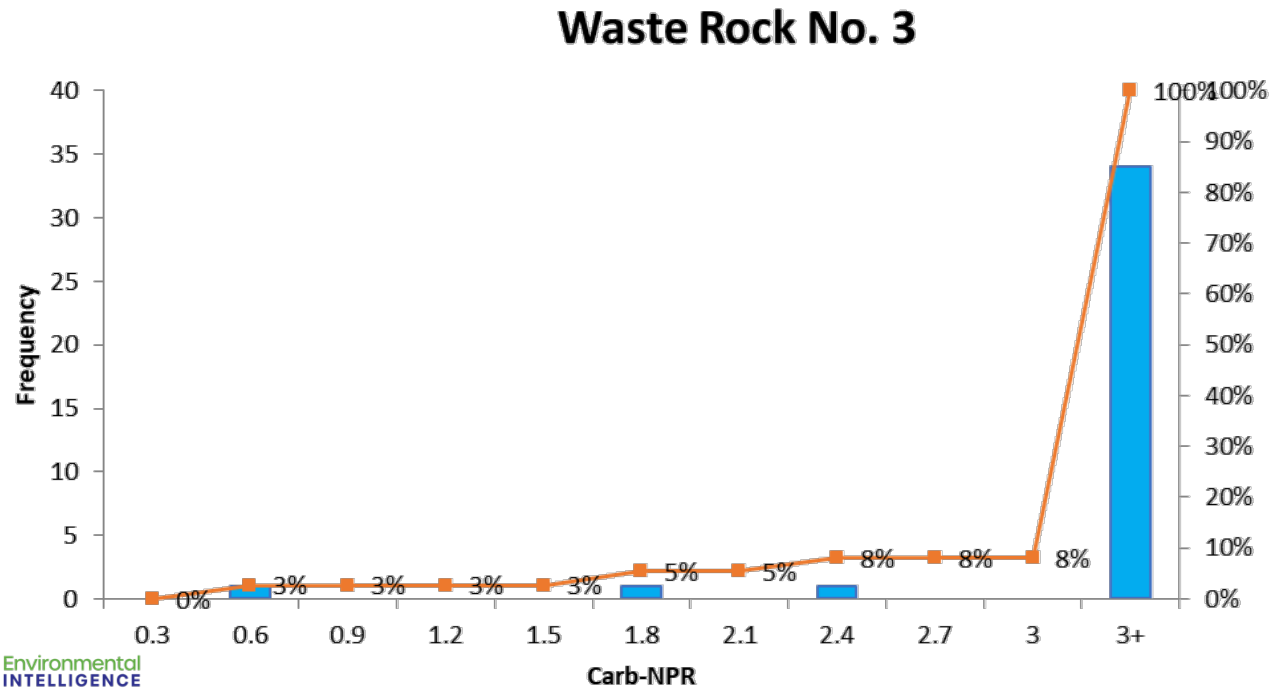
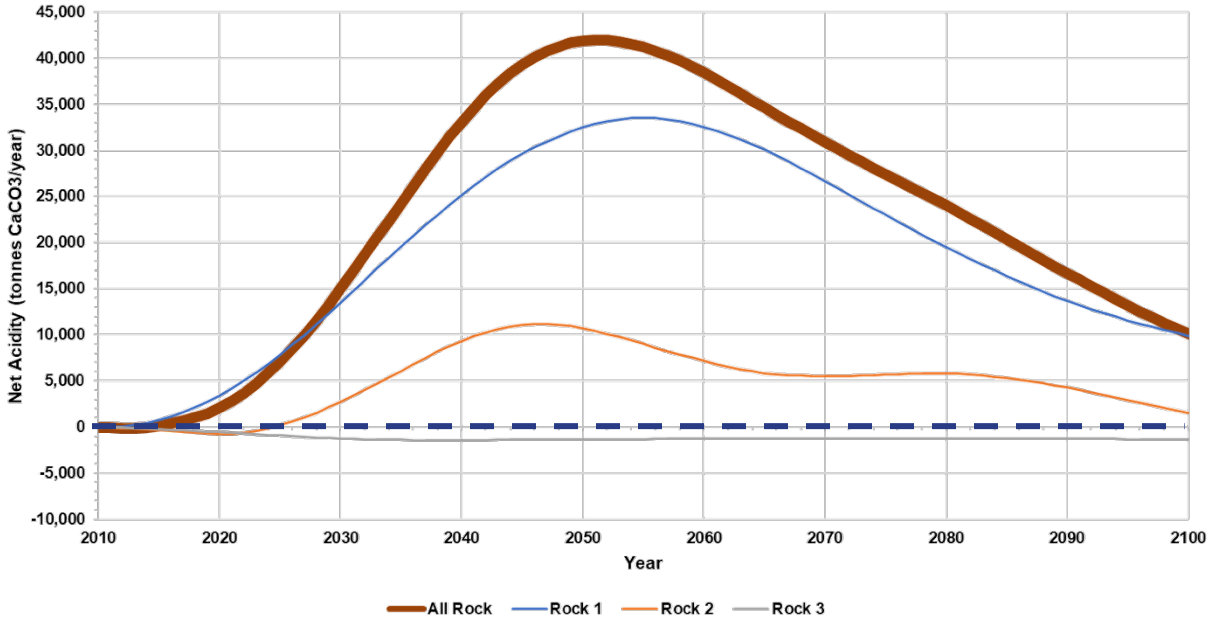


SCENARIO 1

'Low' Sulphur Waste Rock Pile

Results?

- A mixed PAG and non-PAG waste rock pile
- Most common rock type is 90%+ PAG
- More than half of site waste rock is classified as potentially acid generating



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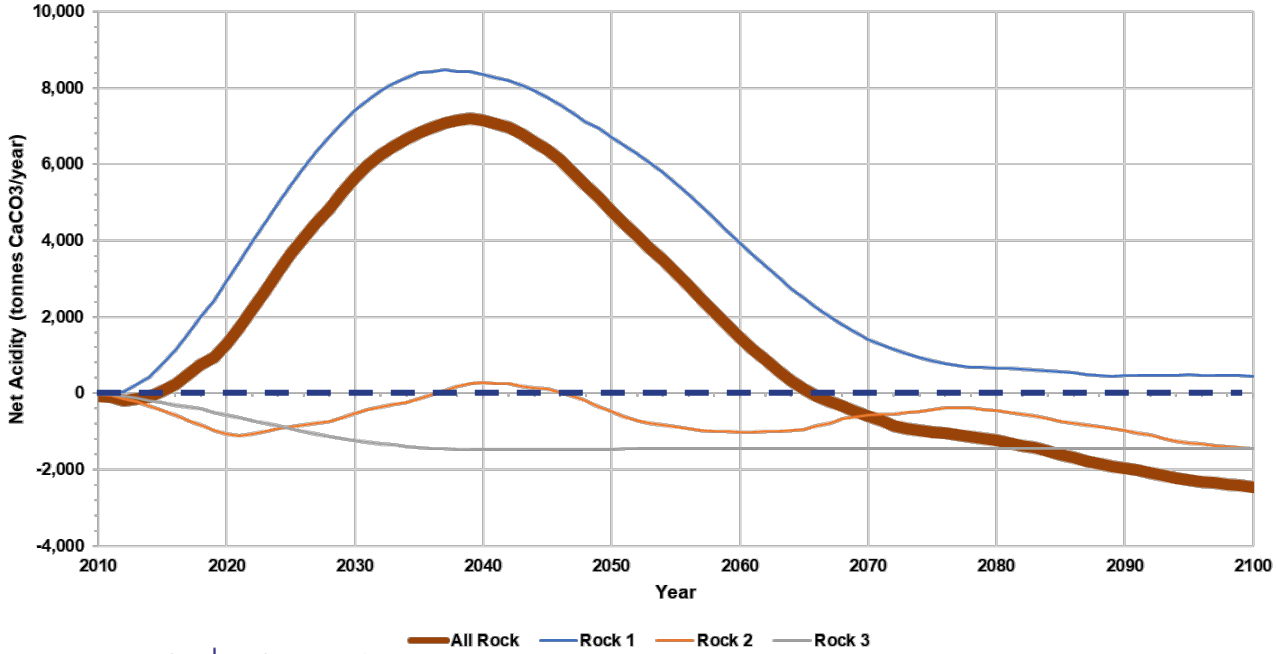
SCENARIO 1

'Low' Sulphur Waste Rock Pile

Results



Quantified the risk associated with mixed waste rock

- Rapid-onset acidity <10 years
- 50-year duration
- Intensity of 7000 tonnes$_{CaCO3}$/yr
- Cumulative acidity of 200,000 tonnes$_{CaCO3}$

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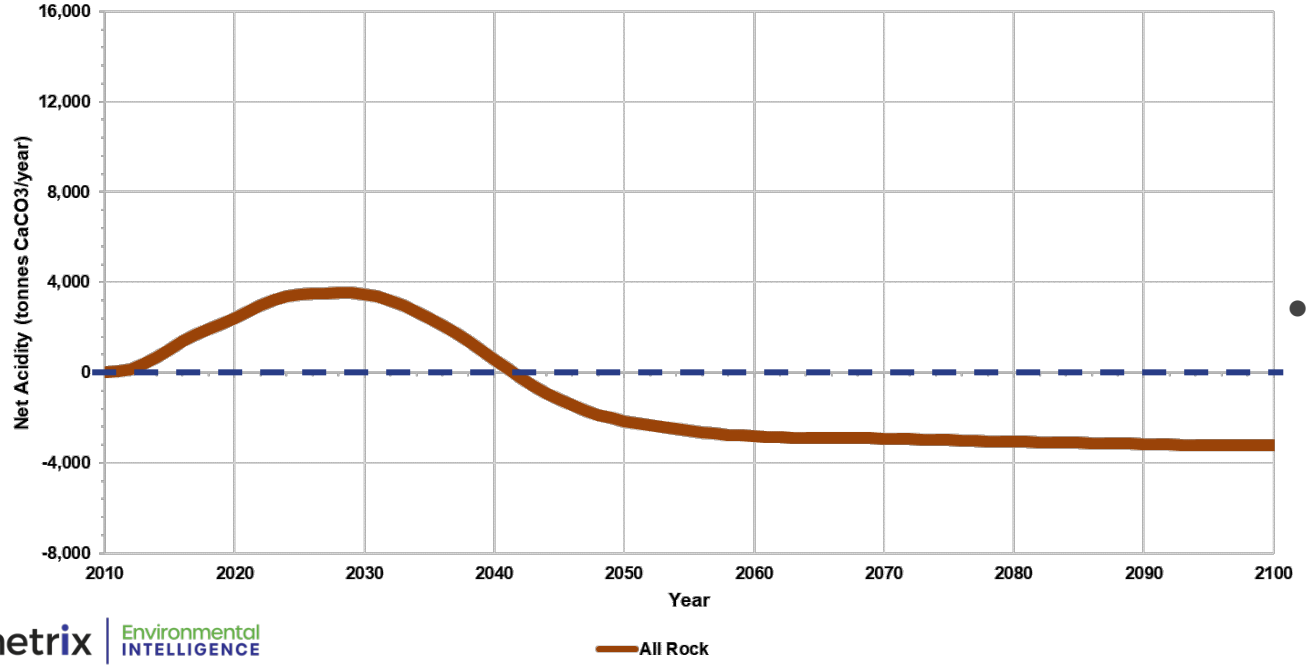
Scenario 1 Sensitivities

- Need to know the bounds for management and decision-making
- Sensitivity analysis
  - 1 – Availability factors
  - 2 – Oxidation rate and scaling under acidic conditions
  - 3 – AP and NP distribution in the rock pile

SCENARIO 1

'Low' Sulphur Waste Rock Pile

Sensitivity – Particle Size/Geochemical Availability



- 5% availability

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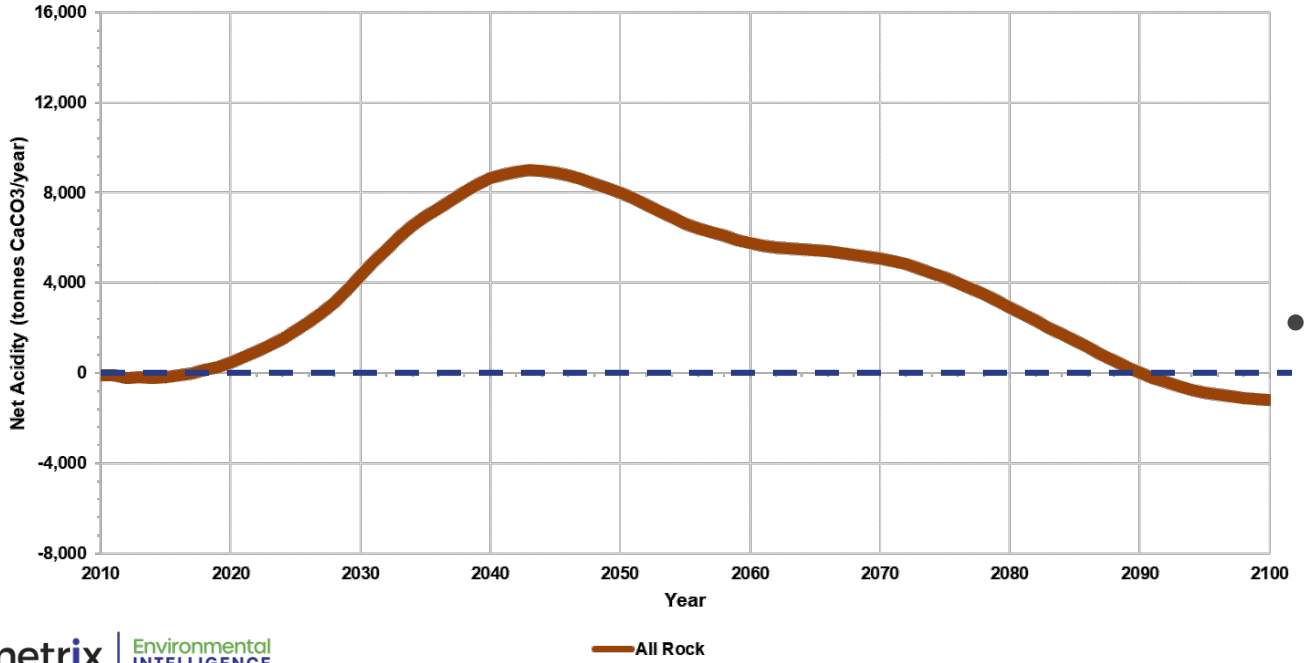

- 25% availability

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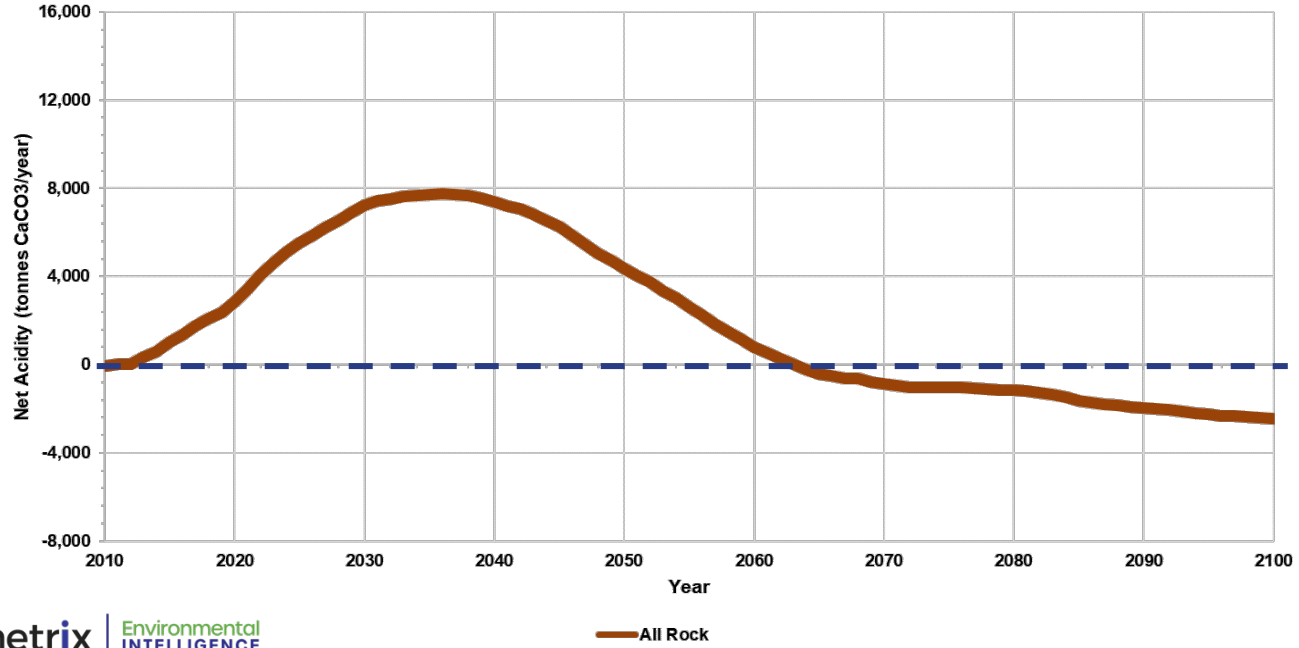
SCENARIO 1

'Low' Sulphur Waste Rock Pile

Sensitivity – Oxidation Rates, Scaling for Acidic Conditions



- 20x increase under acidic conditions

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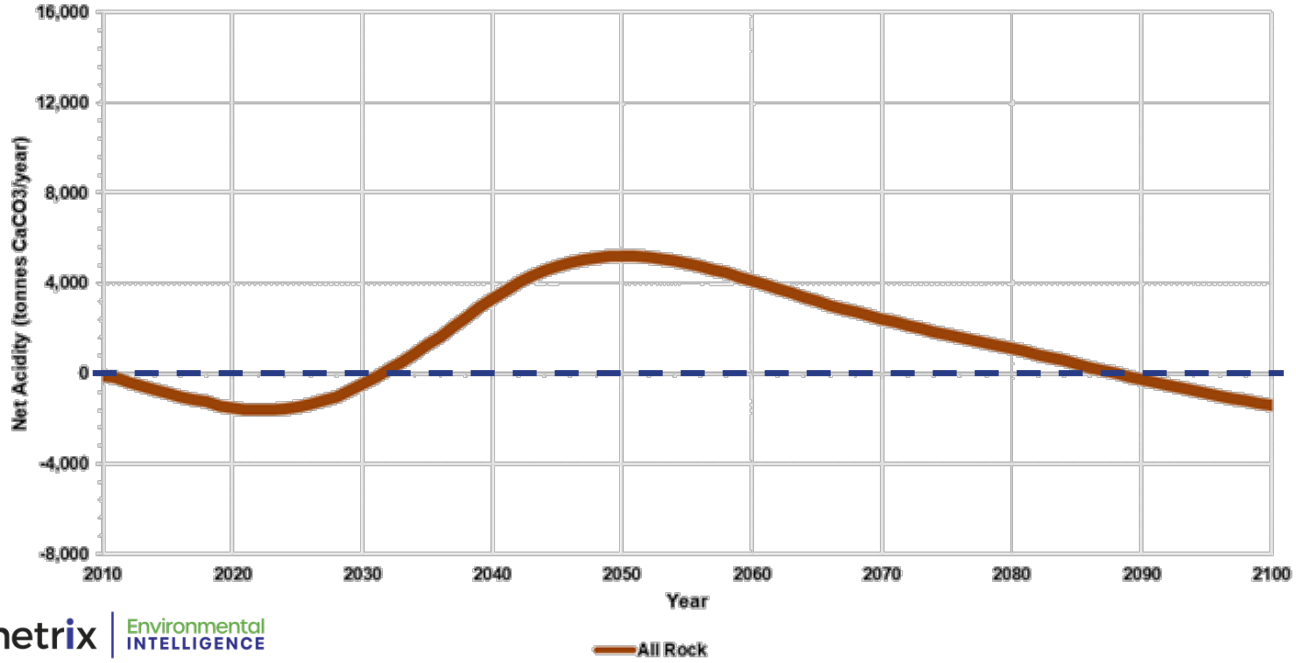

- 2x increase under acidic conditions

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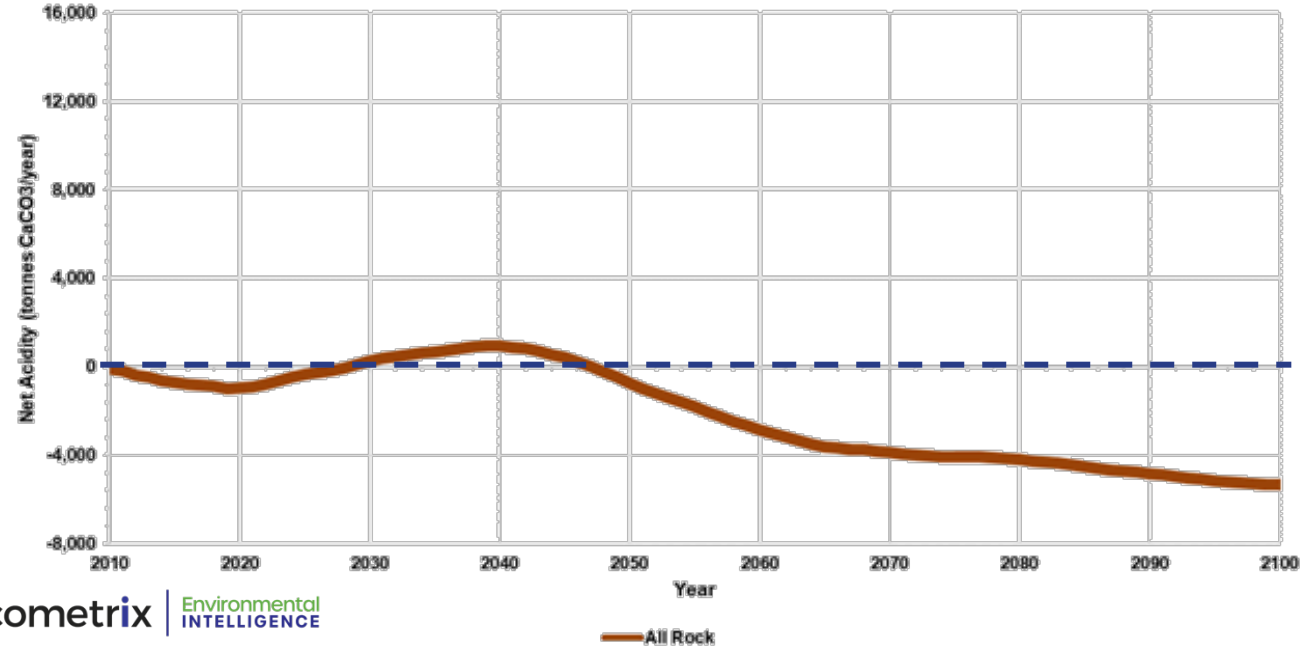
SCENARIO 1

'Low' Sulphur Waste Rock Pile

Sensitivity – NPR Distribution through Pile



- Less PAG rock collected during operations
  - Segregation

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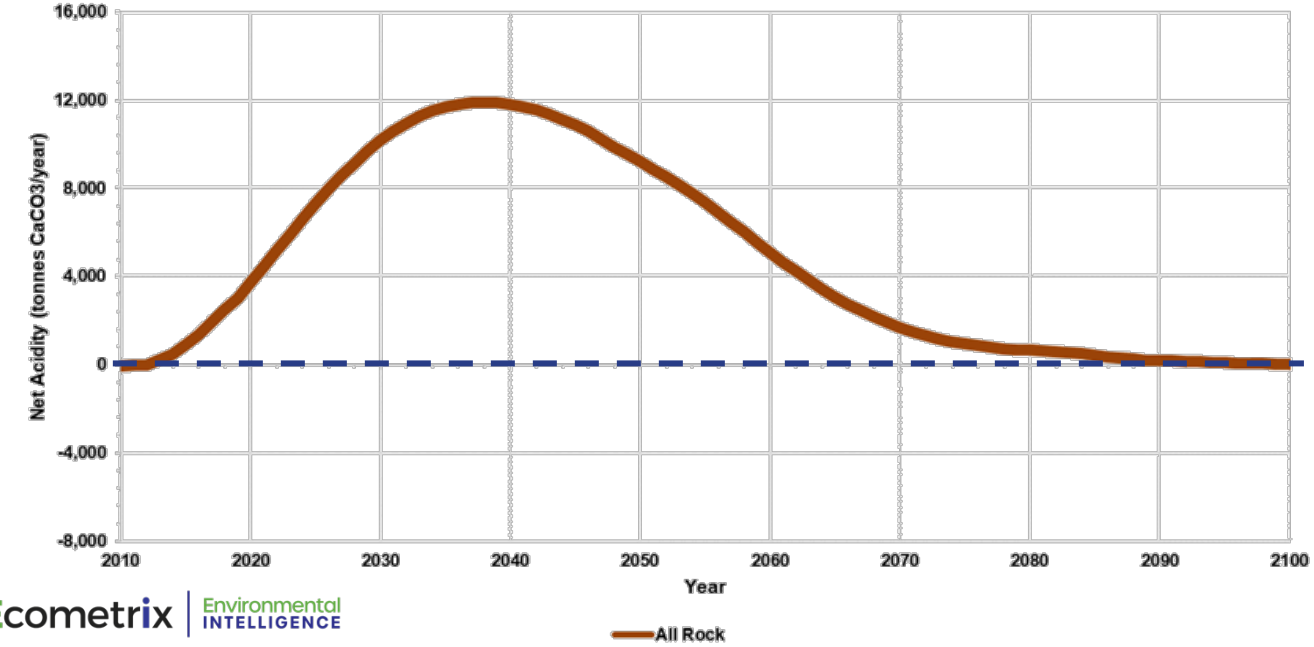
'Low' Sulphur Waste Rock Pile

Sensitivity – NPR Distribution through Pile



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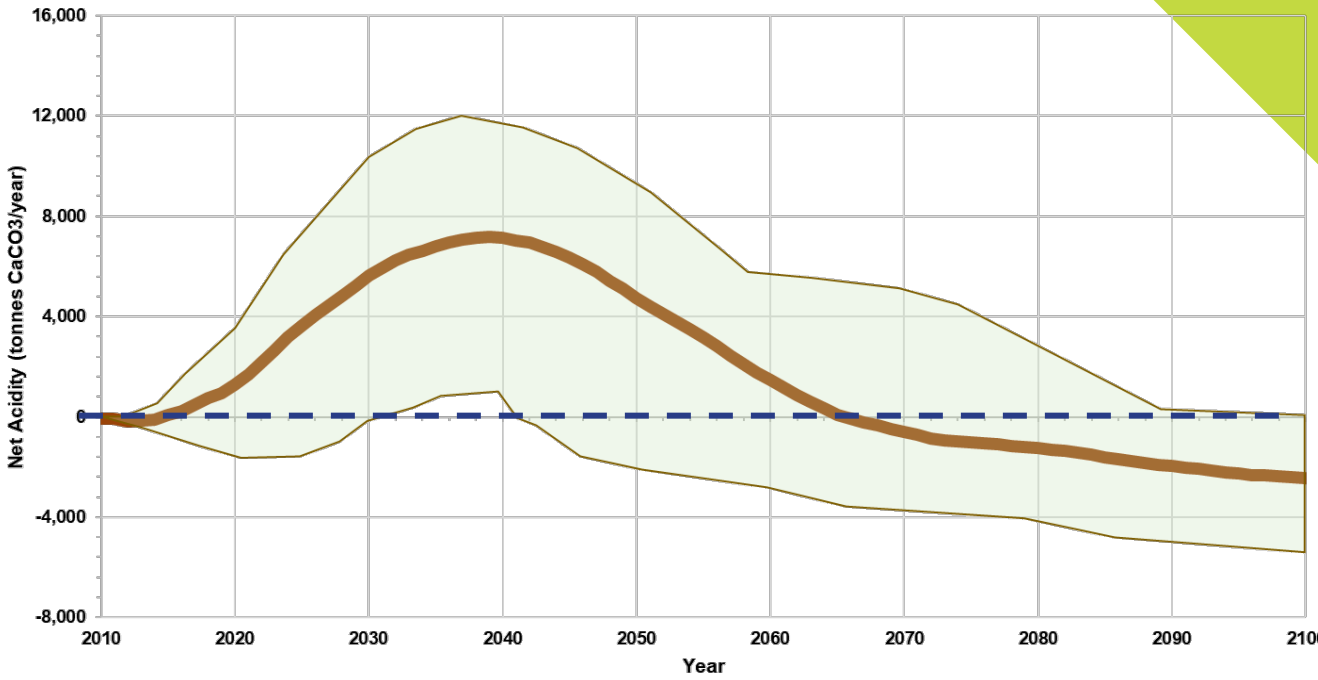
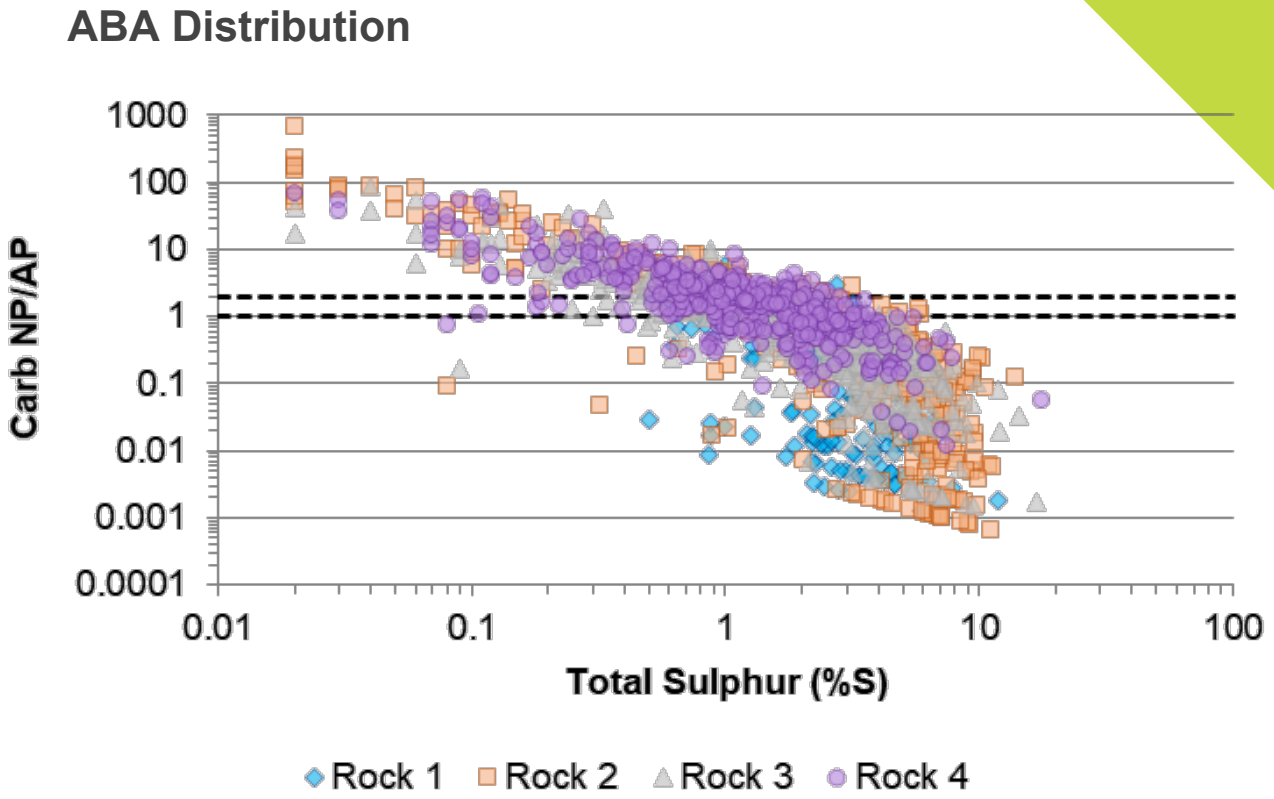


SCENARIO 2

High Sulfur Waste Rock Pile



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SCENARIO 2

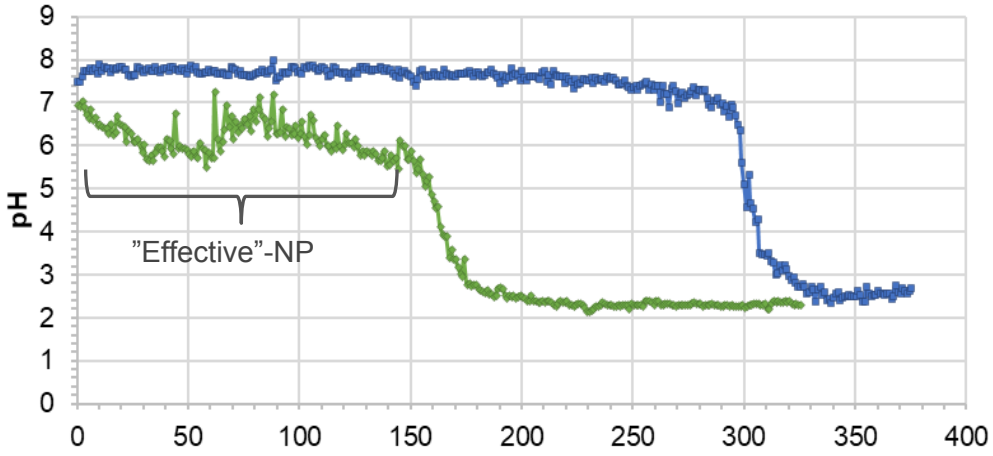
High Sulphur Waste Rock Pile

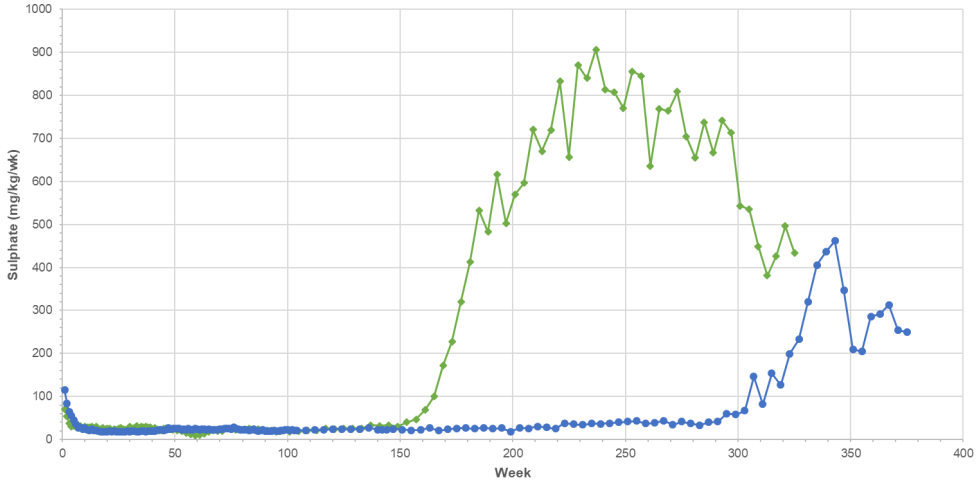
Effectiveness of the NP

Humidity Cell	Sobek-NP	Carb-NP	Ca-NP	"Effective"-NP
Rock 1	35	32	37	11

SCENARIO 2

High S Example
“Effective”-NP





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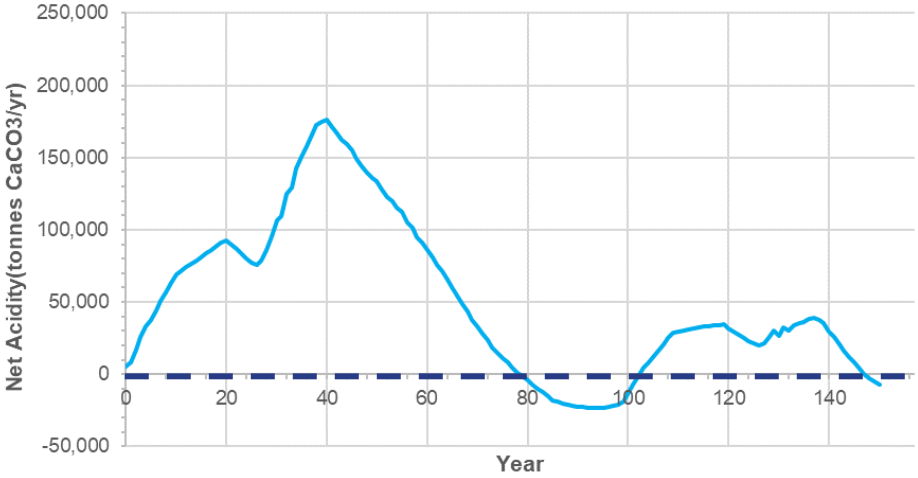
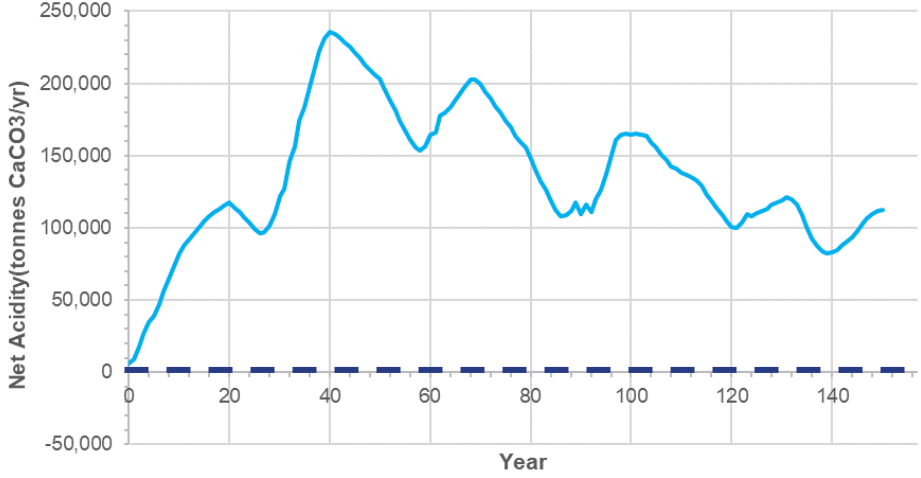
SCENARIO 2

High Sulphur Waste Rock Pile

Sensitivity – NP Effectiveness



100% Effective NP



30% Effective NP

Recap

- Model developed to predict timing, intensity, and duration of acid production in waste rock

Low Sulfur Rock Pile

- Net acidity onset could be observed within years - based on the range of uncertainties
- Net acidity predicted to occur over decades – not centuries
- Acidity tolerance for current water management system can be addressed

Recap

High Sulfur Rock Pile

- Near immediate acidity
- Sustained periods of very intense acid production
- Effectiveness of the waste rock's NP a critical factor in intensity and duration of acid production

Summary

- A model to predict the *timing*, *intensity*, and *duration* of net acidity in waste rock pile drainage
  - A realistic, but still quantifiable, look at potential for acidification
  - Validation ongoing with clients to review and hindcast for historical acid-producing sites

CONCLUSION

Summary

- Timing, intensity, and duration all critical factors long-term water treatment requirements and decision-making
  - Is capital needed up front?
  - Opportunity for long-term deferral?
  - Provides an opportunity to evaluate and ‘game’ management scenarios
- Approach requires higher-resolution data
  - Shift away from singular global averages

Thank You

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