The Multiple Accounts Analysis of Pit Backfilling

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Closure of Open Pits: Recurring Issues

- Long-term pond, run-off and discharge water quality
- Long-term groundwater quality
- Long-term stability of pit and structures
- Long-term erosion of pit structures
- Post closure land use
- Post closure aesthetics
- Long-term economic potential
- Long-term burden on society and succeeding custodians
- Long-term closure costs
Closure of Open Pits: Recurring Issues

- Long-term pond, run-off and discharge water quality
  - Pre-mining surface water quality
  - Long-term pond water quality
  - Water balance
  - Discharge water quality
  - Surface run-off water quality
  - Water treatment
- Long-term groundwater quality
- Long-term stability of pit and structures
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Closure of Open Pits: Recurring Issues

- Long-term pond, run-off and discharge water quality
- Long-term groundwater quality
  - Interaction with groundwater system - hydraulic cage potential
  - Plume development and fate
  - Groundwater use
- Long-term stability of pit and structures
- Long-term erosion of pit structures
- Post closure land use
- Post closure aesthetics
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Closure of Open Pits: Recurring Issues

- Long-term pond, run-off and discharge water quality
- Long-term groundwater quality
- Long-term stability of pit and structures
  - Groundwater recovery and flooding effects on stability
  - Pit wall weathering and degradation
  - Structures:
    - Often dependent on the durability of the material (e.g. wood, steel, geomembrane liners and covers, reinforced concrete, rock etc.)
    - Susceptible during ‘extreme events’ – probability of occurrence post closure much higher than during operations therefore sustainability planning often based on MCE, PMF designs etc.
- Long-term erosion of pit structures
- Post closure land use
- Post closure aesthetics
- Long-term economic potential
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Closure of Open Pits: Recurring Issues

- Long-term pond, run-off and discharge water quality
- Long-term groundwater quality
- Long-term stability of pit and structures
- Long-term erosion of pit structures
  - Needs to be ‘expected’ post closure
  - Continual attack by perpetual forces – weathering, corrosion, wind, water, sedimentation, biotic action, frost action etc.
- Post closure land use
- Post closure aesthetics
- Long-term economic potential
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Closure of Open Pits: Recurring Issues

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- Long-term groundwater quality
- Long-term stability of pit and structures
- Long-term erosion of pit structures
- Post closure land use
  - Mining often a catalyst around which larger industrial and urbanization develops (e.g. Salt Lake City, Butte, Belo Horizonte etc.) – urban community development potential
  - Sometimes mining is the only activity sustaining an area but a return to pre-mining land use often not contemplatable (e.g. areas in Peru, Indonesia, Papua New Guinea) – rural community impacts a concern
  - Hazard, health and safety issues
  - A land use which maintains access, power, protection of health and safety, job opportunities, tax revenue etc. often sought
- Post closure aesthetics
- Long-term economic potential
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Closure of Open Pits: Recurring Issues

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- Long-term groundwater quality
- Long-term stability of pit and structures
- Long-term erosion of pit structures
- Post closure land use
- **Post closure aesthetics**
  - Of extremely high value to local residents
  - Subjectively measured – opportunity and liability
  - Difficult to regulate
- Long-term economic potential
- Long-term burden on society and succeeding custodians
- Long-term closure costs
Closure of Open Pits: Recurring Issues

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- Long-term groundwater quality
- Long-term stability of pit and structures
- Long-term erosion of pit structures
- Post closure land use
- Post closure aesthetics
- Long-term economic potential
  - Backfill measures may minimize potential future resource extraction
  - Technology advances for re-processing waste material
  - Historical significance and tourist value
  - Tax revenue, financial opportunity losses
- Long-term burden on society and succeeding custodians
- Long-term closure costs
Closure of Open Pits: Recurring Issues

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- Long-term stability of pit and structures
- Long-term erosion of pit structures
- Post closure land use
- Post closure aesthetics
- Long-term economic potential
- Long-term burden on society and succeeding custodians
  - On-going monitoring and maintenance
  - Operations of water treatment plants and management structures
  - Financial burden due to unforeseen consequences
  - Stability of institutional custodianship
- Long-term closure costs
Closure of Open Pits: Recurring Issues

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- Post closure aesthetics
- Long-term economic potential
- Long-term burden on society and succeeding custodians

- Long-term closure costs
  - For mining company
  - Financial stakeholders
  - Insurance companies
  - Regulators & taxpayers
  - Other organizations – IFC, UNEP, WB etc.
Multiple Accounts Analysis (MAA)

• Is a platform for engagement of stakeholders
• A tool for the identification of information gaps and data needs
• A basis for the definition and assessment of site-specific parameters – qualitative and quantitative
• A process for options evaluation in which positive and negative impacts can be assessed in combination
• A management tool for performance monitoring
• Should be used for impact management in a similar manner as risk management (FMEA) is done
Risk Management (FMEA)

Design

Operating Plans & Permits

Impact Management (MAA / EIS)

- Financial
- Operations (Technical)
- Environmental
- Social
- Closure & Post Closure

Conceptual
Feasibility
Detailed
Construction
Operation
Closure
Post Closure
MAA Methodology

- The general objective of the MAA is to provide the means by which evaluators can select the most suitable, or advantageous, alternative from a list of alternatives by weighing the relative indicators of impact (benefits and losses) of each.

- This involves three basic steps:
  1. **Identify** the impacts to be included in the evaluation;
  2. **Quantify** the impacts;
  3. **Assess** the combined or accumulated impacts for each alternative, and compare these with other alternatives to develop a preference list (ranking, scaling and weighting) of the alternatives.
The MAA is typically structured around four broad categories of issues, referred to as ‘accounts’.

- Technical
- Environmental
- Socio-Economics
- Project Economics
Defining the Framework

• The stakeholder issues, called sub-accounts are categorized into one of these main accounts. Typical examples:
  – Water management/ quality
  – Backfill & Reclamation costs
  – Revegetation/ land use
  – Aesthetics
• Within each sub-account, indicator values of that particular issue are defined in order to give a clear, understandable description of the impacts. For example:
  – Water management/ quality  →  Capture efficiency
  – Backfill & Reclamation costs  →  Net present value $
  – Revegetation/ land use  →  Area successfully re-established
  – Aesthetics  →  Area of highwall visible
Completing the Ledger

• Descriptive values or measurements of each indicator for each alternative are then defined (i.e. the ‘ledger’ was completed).
• As a result of uncertainties of long term sustainability performance (long term water quality predictions, the reliability and durability of covers etc.) much of the assessment in an MAA is necessarily based on judgment rather than deterministic analysis.
• Therefore, having participants who are experienced with similar projects and/or dedicated to understanding and learning the realistic benefits and limitations of certain measures is critical to the success of these evaluations.
• Once the ledger is completed, the numerical evaluation can be completed – this involves a ranking, scaling and weighting process
Ranking, Scaling & Weighting

- Each of the alternatives is first **ranked**, in order from best to worst, and **scaled** for each indicator.
- In practice, a 9-point scale has been the most successful

<table>
<thead>
<tr>
<th>Scaled Factor</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>9</td>
<td>Best</td>
</tr>
<tr>
<td>8</td>
<td>Very good</td>
</tr>
<tr>
<td>7</td>
<td>Good</td>
</tr>
<tr>
<td>6</td>
<td>Somewhat good</td>
</tr>
<tr>
<td>5</td>
<td>Intermediate</td>
</tr>
<tr>
<td>4</td>
<td>Somewhat poor</td>
</tr>
<tr>
<td>3</td>
<td>Poor</td>
</tr>
<tr>
<td>2</td>
<td>Very poor</td>
</tr>
<tr>
<td>1</td>
<td>Worst</td>
</tr>
</tbody>
</table>

- The ‘best’ alternative is always given an ‘9’ and the remaining alternatives are ‘mapped’ to that value.
Ranking, Scaling & Weighting

• To enable each stakeholder the opportunity to introduce their value bias between individual indicators, a weighting factor \( (W) \) is applied to each indicator.

• Typically we have used a ‘5’ point scale for weighting whereby weight of ‘5’ indicates a ‘high value’ or important indicator.

• The process of assigning weights to the various indicators on the ledger serves to educate all parties involved on the importance of each issue to the individual stakeholders.

• The cumulative ‘score’ of one alternative compared to another is calculated by multiplying the scaled value \( x \) the weight and normalizing to a value of ‘9’.

• The higher the score, the more favorable the alternative in any one category.
## Example Scoring

### Indicator Weight $W_i$

<table>
<thead>
<tr>
<th>Account</th>
<th>Account Weight</th>
<th>Sub-Account</th>
<th>Sub-Account Weight</th>
<th>Indicator</th>
<th>Indicator Weight</th>
<th>Alt A</th>
<th>Alt B</th>
<th>Alt C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technical</td>
<td>3</td>
<td>Groundwater Capture System</td>
<td>5</td>
<td>Efficiency</td>
<td>5</td>
<td>5</td>
<td>3</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Maintenance Requirements</td>
<td>1</td>
<td>9</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Operating Requirements</td>
<td>2</td>
<td>9</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td><strong>Sub-Account Score</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>6.50</td>
<td>3.50</td>
<td>6.75</td>
</tr>
</tbody>
</table>

Sub-Account Score = \( \frac{\sum (W_i \times S_{i,A})}{\sum W_i} \)

Scalar Value $S_{i,A}$
An Example of an MAA for Assessing Pit Backfill Options

Evaluation of options for pit reclamation – options ranged from no backfill to ‘engineered backfill’ (with lime amendment and compaction during placement).

• High value issues:
  – Water management
  – Impacts to groundwater
  – Impacts to surface water
  – Safety
  – Employment
  – Revenue from taxes
  – Future economic potential
  – Future burden on community/society
Results – cost-benefit format

\[ y = 0.7703 \ln(x) + 5.2577 \]

\[ R^2 = 0.1349 \]

Option 7
Option 5
Option 6
Option 4
Option 3
Option 2
Option 1

MAA Score (excluding project economics)

Project Economic Account Score

Robertson GeoConsultants Inc.
Mining, Geotechnical and Environmental Engineers
Results – cost-benefit format

Engineered backfill – compacted and amended waste

Backfill with more certain water management components

No backfill alternatives

Alternatives with backfill but with uncertain water management components

y = 0.7703Ln(x) + 5.2577
R² = 0.1349

Option 1
Option 2
Option 3
Option 4
Option 5
Option 6
Option 7
Other Examples

- Zortman/Landusky (Montana) – partial pit backfill using WR
- Woodcutter’s (Australia) –
- Pajingo (Australia) – pit backfill using tailings
- Tanami (Australia) –
- Aguas Claras – flooding with groundwater
- Island Copper (B.C.) – flooding with ocean water
- Richmond Hill (S. Dakota) – backfilled with waste rock
- Butchart Gardens (B.C.) – partial quarry backfill with topsoil
Island Copper (B.C.)
Aguas Claras, Brazil
Aguas Claras, Brazil
Aguas Claras, Brazil
Placement of historic acidic tailings ‘high and dry’ onto pit bench (amended with fly ash)

Gilt Edge Mine (South Dakota)
Zortman Mine (Montana)
Woodcutter’s Mine
(Australia)
Reclamation of a limestone quarry

Butchart Gardens (B.C.)