ISSUES & METHODS IN MINE RECLAMATION COSTING

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RECLAMATION COSTING

- Need to mitigate the consequences of mining
  - Protect public health & safety
  - Reduce/avoid environmental effects
  - Facilitate future land use
- Achieving these objectives requires planning and money

ISSUES & METHODS IN MINE RECLAMATION COSTING

1. Types of cost estimates
   - 4 types - estimator's perspective
2. Components of the cost estimate
3. Uncertainty
4. Steps in reclamation costing
5. Reclamation costing models

Cost Estimate Terms & Descriptions

Estimate Type	Description	Accuracy or appropriate contingency
Detailed or Project Control	Based upon detailed engineering take-offs and written quotes	+/- 5 %
Definitive or construction drawing phase	Engineering mostly complete, some written quotes	+/-10 %
Preliminary or budget level	Little detailed engineering and costs based upon verbal quotes	+/- 15 %
Feasibility or advanced conceptual	Engineering may be 10 % complete and costs based upon typical unit costs	+/- 20 %
Pre-feasibility, conceptual or trade-off study	Very basic engineering only and costs based upon typical unit costs	+/- 25 %

Owner's Internal Estimate

- actual costs which the corporation expects to incur
- assumes that;
  - the work would be conducted under the direction of the mine manager,
  - using existing staff and equipment,
  - specialized work such as demolition by contractors.

Owner's Internal Estimate

- no capital cost for equipment
- equipment productivity is assumed to be relatively high due to familiarity with working conditions on the site
- a relatively low contingency
- progressive reclamation conducted as planned
- off-setting costs from the salvage

Owner's Internal Estimate

- lowest justifiable estimate
- this type of estimate is also appropriate for mergers and acquisitions

Owner's Bonding Estimate

- prepared for reclamation security
- by regulation - based upon third-party contractors conducting all of the work
- no allowance for salvage value
- additional costs for equipment mobilization, management & engineering
- progressive reclamation conducted as planned ?
- same contingency as the internal estimate

Regulator's Estimate

- the government's expectation of costs should the company abandon the site
- site care and maintenance
- problems which were not expected at the onset of mining
- no allowance for progressive reclamation
- degree of uncertainty in the closure plan
- a conservative contingency may be added

Worst Case Estimate

- major failure of some type (dam, crown pillar, etc)
- An argument could be made that this is most protective of tax-payers. However, doing so is akin to granting a permit for a plan which is expected to fail.

Components of the Cost Estimate

1. direct costs for reclamation of all mine components,
2. disposal or management of hazardous materials and contaminated soil,
3. mobilization and demobilization of equipment and supplies,
4. personnel movement and accommodation,
5. engineering and project management,
6. interim care and maintenance,
7. post-closure water treatment,
8. post-closure monitoring and maintenance,
9. adjustment for salvage of materials & equipment, and,
10. contingency or recognition of uncertainty.

1 Direct Reclamation Costs

- For most sites this is probably 50 to 75% of the total estimated cost
- amounts for:
  - pits,
  - underground workings,
  - rock piles,
  - tailings impoundments,
  - water management structures, and,
  - buildings and infrastructure.
  - commonly overlooked component of this work is a landfill for demolition waste.

2 Hazardous Materials

- Industrial materials, paints, solvents, reagents, fuel sludges, waste oil, lubricants, coolants, batteries
- Contaminated soil, metals & hydrocarbon
- Asbestos and PCB's at older mines
- Off-site disposal,
- Costing based upon conservative approach

3 Mob/Demob

- every piece of equipment or machine which is required for the work
- may also require supply of infrastructure such as accommodation complex or fuel management
- must be two-way

4 Personnel

- fly-in and fly-out” sites
- on-site accommodation
- costs for personnel movement
  - Time and expenses

5 Eng. & Project Mgmt.

- provide engineering services in order to progress from a reclamation plan to a scope of work for:
  - the owner's site foreman
  - contractor
- all project will require general management and administration
- a provision of 5% to 10% of the total project for both elements

6 Care & Maintenance

- very few mines commence closure work the day after operations cease
- for abandoned mines, care and maintenance may be required for many years
- costs should include;
  - personnel,
  - fuel,
  - assorted supplies and equipment, and water treatment reagents
  - permit requirements for environmental and geotechnical monitoring

7 Post-closure Water Treatment

- defined duration
  - contaminants are expected to decay to non-toxic levels in a specified period of time, cyanide or ammonia in tailings
  - typically costed on an annual basis
- long-term
  - ARD or chronic metal leaching
  - Perpetual annual cost converted to NPV based on time value of money, 2.5 – 3.5%

8 Post-closure Monitoring & Maintenance

- continuation of the site monitoring program for environmental and geotechnical issues
- monitoring is conducted on a declining frequency
- expanded to address reclamation issues
  - re-establishment of vegetation
  - metal up-take in vegetation
  - specific stability concerns such as crown pillars
- Addition of infrequent maintenance

9 Salvage

- Mine owners may include salvage in the internal reclamation cost estimate.
- Most regulators do not want to consider salvage value because of the problems associated with creditor's rights, sale of equipment, and uncertainty as to the actual value.

10 Uncertainty

- What is the likelihood that the actual cost will vary from the estimated cost ?
- Level of uncertainty changes through the mine life
- Uncertainty concerns fit into 3 broad groups:
  - Mine plan
  - Reclamation plan
  - Cost of reclamation work

Uncertainty - Mine plan

- Data base of geology and geochemistry (which may result in ARD or metal leaching problems),
- Characterization of critical foundations (such as under dams and waste dumps),
- Application of a new technology or unique application of an existing technology,
- Use of optimistic control strategies (such as blending of acid generating and acid consuming rocks), and,
- Predictions concerning the effectiveness of control measures (such as cyanide degradation in tailings impoundment water)

Uncertainty – Reclamation Plan

- Variability in the extent and type of disturbance at the time of mine closure,
- Expectations for the success of reclamation measures, and,
- Potential for difficulty in implementing the closure measures.

Uncertainty – Cost of the Work

- Cost of equipment, manpower, and consumables such as lime and fuel,
- Duration of time required to complete the work (and the effect on the associated site support costs),
- Availability of qualified contractors to carry out the work.

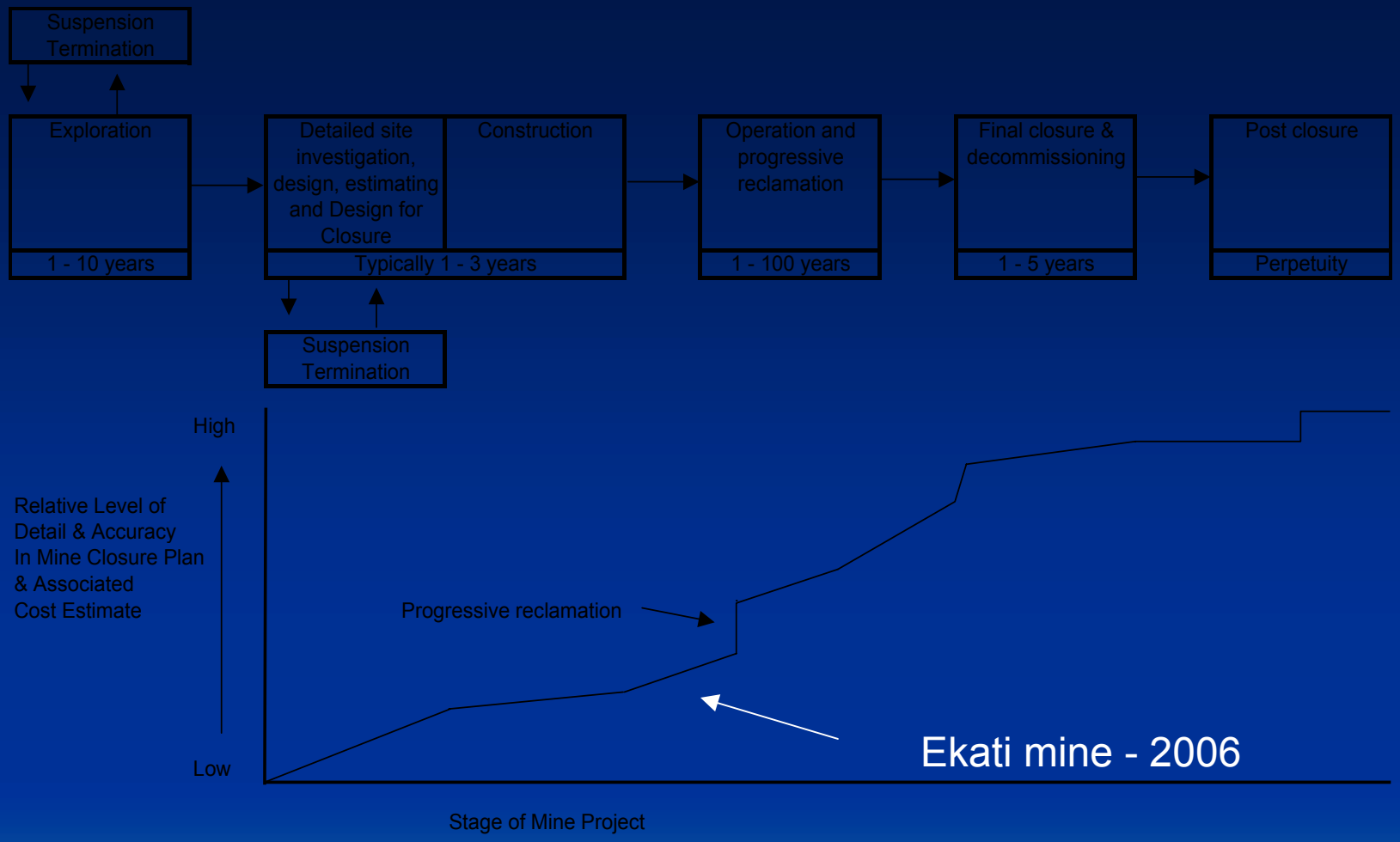

Figure 1

Relative Detail and Accuracy In Reclamation Cost Estimates Through The Mine Life Cycle

Adapted after Gadsby, J. 2003

Uncertainty - Timing

- When will the mine close?
- security deposits are typically calculated in “today’s dollars”.
- interest which accrues on the deposit is usually assumed to offset the effects of inflation
- Subject to tax considerations

Uncertainty - Timing

- a letter of credit
  - provision for inflation adjustment, CPI
  - must last into receivership period
- periodic review of security requirements
- 1 to 5 years depending upon the mine plan and the rate of evolution of disturbances

Uncertainty in the Cost Estimate

- AMP
  - monitoring and reporting,
  - thresholds for action, and
  - sound responsive actions
- additional reclamation measures
  - Specific reclamation activities for identified issues – dam stability, pit water quality
- Contingency

Ekati Example - Tailings

- Original plan – 2 m waste rock cover
- Current plan – 100 % revegetation Tailings revegetation
  - Demonstrated in fenced area in mid-beach area
  - Not demonstrated at discharge (sand) or edge of pond (frost heave) areas
- Conservative cost estimate – 50% revegetation, 50% rock cover

Cost Estimate Contingency

Estimate Type	Description	Accuracy or appropriate contingency
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Uncertainty in the Cost Estimate

- Critically assess the quality of closure plan
- A low contingency (<10%) would be indicative of a plan based on
  - a comprehensive data base of site specific parameters,
  - detailed engineering, and,
  - proven reclamation measures
- Variable contingency throughout cost estimate

Steps in Reclamation Cost Estimating

- Essential first step - closure plan
  - Ideally this is an approved plan
  - Closure plan provides first 3 of 8 steps:

1. closure objectives
   - site-wide and individual mine component basis,
2. describe the expected site condition at the time when reclamation is to commence,
3. description of the expected closure measures

Steps in Reclamation Cost Estimating

4. quantities of work for each reclamation activity
5. sub-dividing each activity into specific tasks
6. characterization of the level of effort or potential difficulty in carrying out the tasks,
7. identification of appropriate unit costs for each task, and,
8. presentation of task list, quantities, unit costs and calculation of total cost.

1. Closure objectives	Limit infiltration to protect water resources Establish vegetation for wildlife use
2. Site characterization	Rock pile is acid generating, perimeter slopes are terraced at angle of repose, slopes are up to 25 m high, rock pile covers 30 ha
3. Proposed closure measures	Doze perimeter slopes to 3:1 slope and flatten hummock dump areas, place multi-layer soil cover, vegetate with grass mixture
4. Determine quantities of work	Dozing to involve moving 50,000 m^3 of rock Cover to involve • 75,000 m^3 of clean drain rock for capillary break • 225,000 m^3 of low permeability soil • 150,000 m^3 of vegetative substrate Supply of 6 tonnes of fertilizer and 1.2 tonnes of seed
5. Divide each activity into specific tasks	Dozing • Flatten hummocks – 20,000 m^3, very short push • Doze slopes – 30,000 m^3, push down slope up to 10 m Cover • Excavate granular rock from nearby gravel deposit, haul and spread • Excavate low permeability soil from borrow area 4 km away, haul, spread into 15 cm lifts and compact • Excavate vegetation substrate from pit overburden stripping pile, haul and loosely spread • Borrow areas to be left in suitable condition Vegetation • Spread seed and fertilizer using mechanical equipment
6. Identify level of effort and potential difficulties	Dozing • Few difficulties expected if large dozer is used Cover • Granular material – few difficulties expected • Low permeability layer – some waste expected in borrow area, QA/QC required to meet compaction specification • Long haul could lead to waiting time for dozer & compactor • Vegetative substrate – few difficulties expected Vegetation • Few difficulties expected, allow for revegetating 10% of area due to poor establishment of plants
7. Identification of unit costs – typically from work on similar near-by projects	Dozing • Hummocks $0.85/ m^3 • Slopes $1.95/ m^3 Cover • Granular material $5.97/ m^3 • Low permeability layer $8.95/ m^3 • Vegetative substrate $3.20/ m^3 Vegetation • Supply and spread seed/fertilizer $1595/ha
8. Present task list	Compile information from above steps (typically only steps 4 – 7) into

Step 7 - Selection of Unit Costs

- Cost data from similar work on nearby projects
- Unit cost not available or for critical items
  1. discussion or quotes from qualified contractors,
  2. information provided by equipment suppliers, and,
  3. first principles.

Unit Costs

- Qualified contractors
  - "All in" costs
    - Fuel, labour, capital cost, tires, maintenance, consumables
    - Mob/demob included separately
  - Confidence in contractor's cost improves with detail in scope of work

Unit Costs – Equipment Suppliers

- Typically provide peak performance costs

$$\text{Lowest unit cost of operation} = \frac{\text{Lowest possible hourly cost of operation}}{\text{Highest possible hourly productivity}}$$

- Rarely achieved, actual costs will be higher
- Lack of familiarity with site conditions

Unit Costs from First Principles

- Detailed adjustment of cost factors
  - Cost factors
    - Fuel, labour, capital cost, tires, maintenance, consumables
  - Productivity Factors
    - adjustment factors for an excavator
      - difficultly in digging (type and hardness of material),
      - job geometry (side-hill or full bench),
      - finish condition (ditch versus quarry operation),
      - operator skill
      - Fleet compatability

Costing Models

- All models suffer from the trade-off between level of detail and accuracy
- There is no perfect model
- The model is the least important part of reclamation costing
  - calculation of the cost is the last of up to 8 steps in determining reclamation liability
  - A lot detailed calculations will not make up for an inadequate or optimistic reclamation plan

Costing Models - Purposes

- standardize cost estimates in a particular jurisdiction,
- present the reclamation liability estimate in a format which mimics local regulations,
- assist in the determination of liability through one or more of;
  - use of a pre-formatted spreadsheet,
  - provision of a checklist of potential reclamation tasks,
  - supply of a data base of unit costs for typical reclamation work

Costing Models

- assist in the re-calculation of the reclamation liability as the mine development progresses or at the time of licence renewal,
- present the reclamation liability estimate in a transparent and auditable format,
- If not transparent & auditable, how do you reduce security after partial reclamation?

FEATURE	REGION					
	B.C. Ref. 8	NWT/Nun. RECLAIM Ref. 6	U.S. O.S.M. Ref. 5	Montana Ref. 9	California Ref. 7	Nevada
Sections for all site components & reclamation activities	Most, many components are single line item	Yes	No	No	No	Model in development
Checklist format	No	Yes	No	No	No	
Computer based	Yes	Yes	Yes	Yes	No	
Table of Unit Costs	No	Yes	Yes	Very limited	No	
Calculates NPV of post-closure costs	No	Yes	No	No	No	
Adaptable for special cases	No	Yes	No	No	No	
User skill level	Engineer	Engineer	Engineer – program training req'd	Engineer	Engineer	
Relative level of detail	Moderate	High	Very high for earthworks, low for other tasks	Low	Moderate	
Special features	None	Some,	Calculators, Drop down menus	None	None	
Applicable to other jurisdictions	limited	Yes, check unit costs	Yes	Limited	Limited	
Comments	Focus on waste dump resloping and vegetation	Very good for pre-feasibility level estimate for all types of mines	Detailed focus on earthworks costs from first principles		Users are referred to OSM Handbook	

CONCLUSIONS

1. Reclamation cost estimates may be prepared from different perspectives
   - Owner's internal, owner's bonding/security, regulator, worst case
2. Up to 10 components of the cost estimate
3. Uncertainty exists in all cost estimates

CONCLUSIONS

4. Up to 8 steps in the development of a cost estimate for each reclamation task
5. Costing models cover a broad range of style and applicability
   - All have their pro's and cons
   - RECLAIM & OSM are most adaptable (with care on use of unit costs).