A Comparative Analysis of the Benefits of Integrated Mine and Closure Designs

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Introduction

Okane identified a location suitable for simulating a conceptual mine site, featuring a mine rock stockpile (MRS) area that allows for either bottom-up or valley-fill construction methods - approaches commonly used at mine sites in the mountainous regions of western Canada.

An integrated approach was taken to identify advantages and challenges of both methods of mine rock stockpile construction, considering:

- physical and geochemical stability;
- permitting;
- rehabilitation and future land use;
- operational safety and environment; and
- economic factors.

Operational Considerations

Mine rock stockpile construction methods

In western Canada's mountainous terrain, MRS development typically employs either the valley-fill or bottom-up construction method.

Valley-fill construction:

- This method is also known as *end-dump* or *top-down*.
- Operationally efficient, involving reduced haul distances and equipment requirements.
- Heterogenous material layering, allowing uncompacted zones with steeper and less stable slopes.
- Closure is more costly.
- Complex water quality management.

Bottom-up construction:

- Sequential placement of mine rock in controlled horizontal lifts.
- Results in less material segregation.
- Allows progressive compaction from haul traffic on each lift.
- Facilitates progressive reclamation, concurrent resloping and revegetation of completed lifts as mining progresses.
- Closure is more time-efficient.

Mine planning and design

For this conceptual study, it is assumed that the mine will move approximately 24 million bank cubic meters of material annually over a 20-year mine life. A final reclaimed slope angle of 3H:1V is assumed for both scenarios.

Valley-fill construction:

- Material hauled from pit to MRS crest.
- Material placed from the maximum height of the MRS (~210m) at angle of repose (37°).
- Short-term operational efficiencies.
- Full construction required before final resloping for closure can commence.
- Reliance on costly long-term water treatment.

Bottom-up construction:

- Material placed in 15m lifts out to final footprint.
- Re-sloping and reclamation can occur incrementally as mining progresses.
- Supports early incorporation of source control strategies with predictable geochemical and hydrological performance.
- Increased initial mining costs.

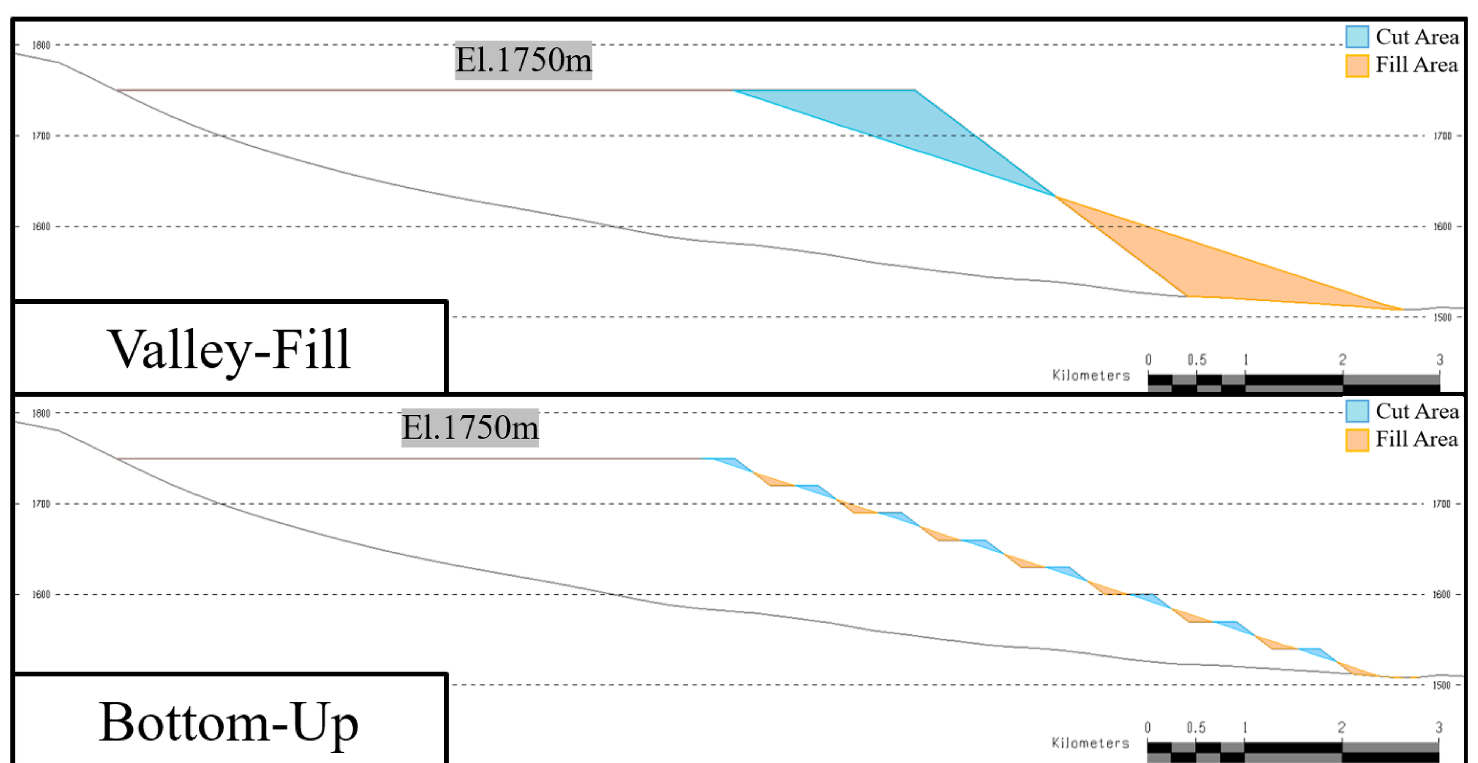

Figure 2: Conceptual mine rock stockpile cross-sections.

Physical stability

The factor of Safety (FoS) is up to 2.5x higher with bottom-up construction both during construction and post-resloping.

Valley-fill construction:

- Gravity placed at angle of repose.
- No compaction.
- Unpredictable and highly segregated internal structure.

Bottom-up construction:

- Mine rock placed in lifts.
- Enables shallow, more stable slopes.
- Less segregated material.
- Higher compaction and stability.

Geochemical stability

International Network for Acid Prevention (INAP) supports bottom-up as a pre-requisite for source control implementation (INAP, 2020).

Valley-fill construction:

- Slopes often remain exposed for years .
- Allow oxygen to deeply infiltrate and sustain oxidation reactions long after construction is complete.
- Complex and more costly water treatment.

Bottom-up construction:

- Industry leading practice for incorporating source control.
- Compacted lifts and engineered layers reduce the permeability of the pile to air and water, slowing oxidation and reducing potential for acid and metalliferous drainage.

Rehabilitation and future land use

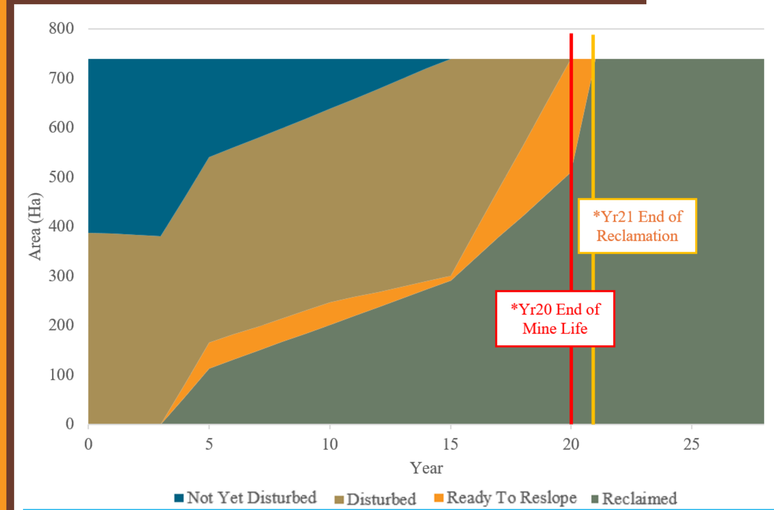

Figure 3: Bottom-up disturbance areas.

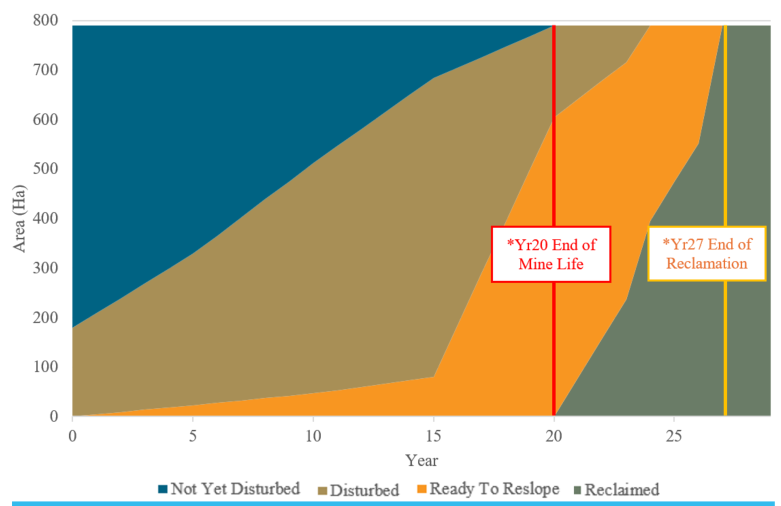

Figure 4: Valley-fill disturbance areas.

Operational safety and environment

Valley-fill construction:

- Significant challenges with re-sloping; poor equipment productivity, unpredictable project delays, and significant cost overruns.
- Increased difficulty with access and monitoring.
- Hazards are less predictable and more difficult to mitigate.
- Increased operational risk profile.

Bottom-up construction:

- Increase to safe operations - increased geotechnical stability, controlled lift construction, and progressive reclamation.
- Early detection and mitigation of issues is possible without disrupting operations.
- Less cut material required, increasing confidence in material performance, equipment productivity, and cost estimates.

Cost Analysis

Value Driver Tree

A value driver tree is a useful tool to depict this refined cost-benefit analysis to identify and track specific opportunities or activities related to the overall lifecycle value of an asset (Clark et al., 2025).

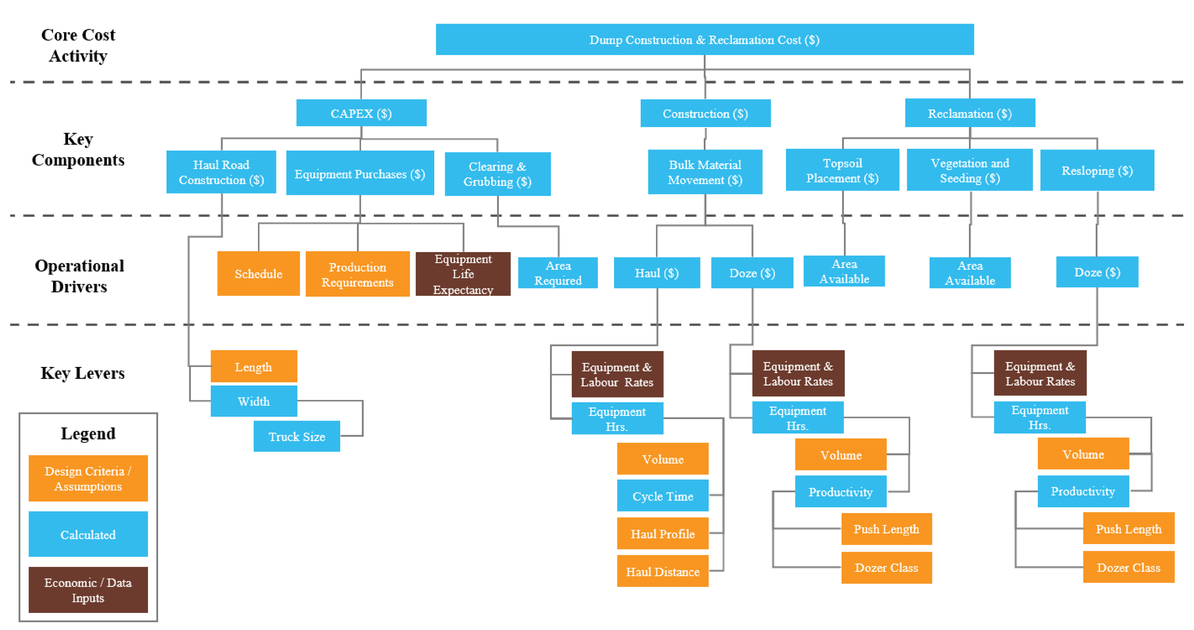

Figure 5: MRS construction value driver tree.

Cost Analysis

Bottom-up versus valley-fill construction:

- Total life of asset costs 14% lower.
- Total discounted costs 10% lower.
- Capital expenditure in the first five years is 137% higher.
- Operating costs are 122% higher.
- End of mine life reclamation costs are considerably lower.
- Reclamation completed one year post-mining versus eight years.

Net Present Costing

Through the mine lifecycle, reclamation costs have an increasing influence on the forward-looking asset value.

Valley-fill construction:

- An increasing portion of NPC is allocated to reclamation.
- Cashflow goes negative following mining as reclamation costs increase when the mine is no longer generating incoming cashflow.

Bottom-up construction:

- Higher up-front costs associated with equipment and haulage requirements.
- Smaller portion of future costs associated with final reclamation.

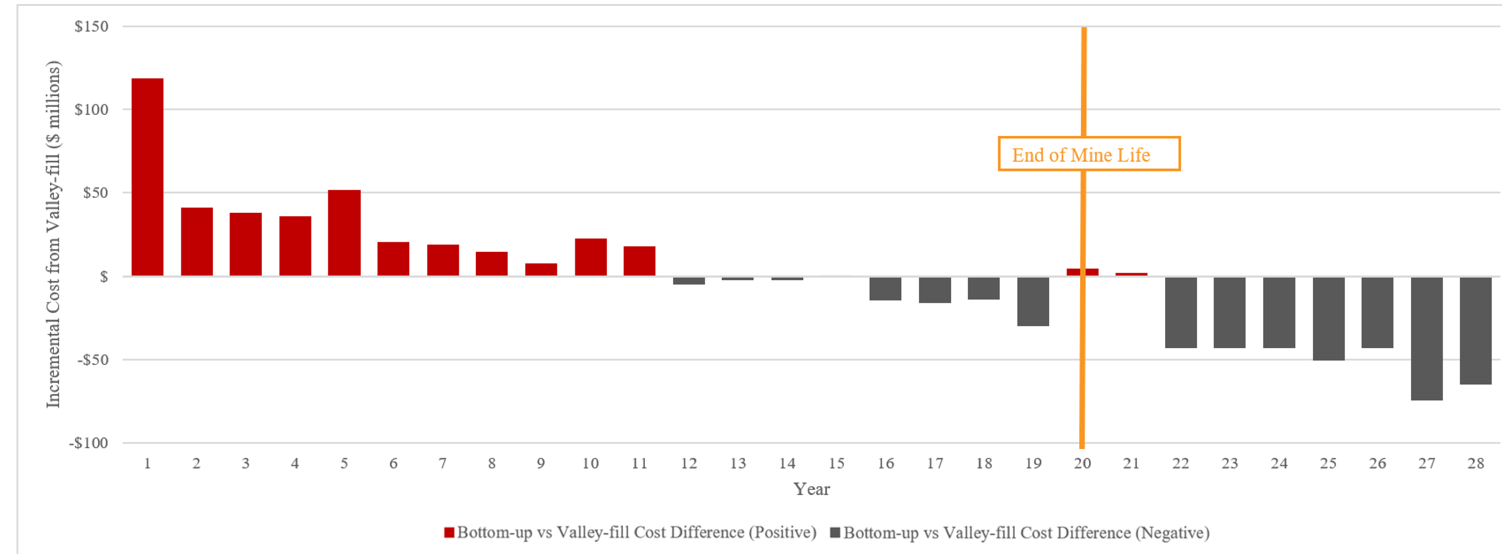

Figure 8: Incremental cost of bottom-up vs valley-fill construction.

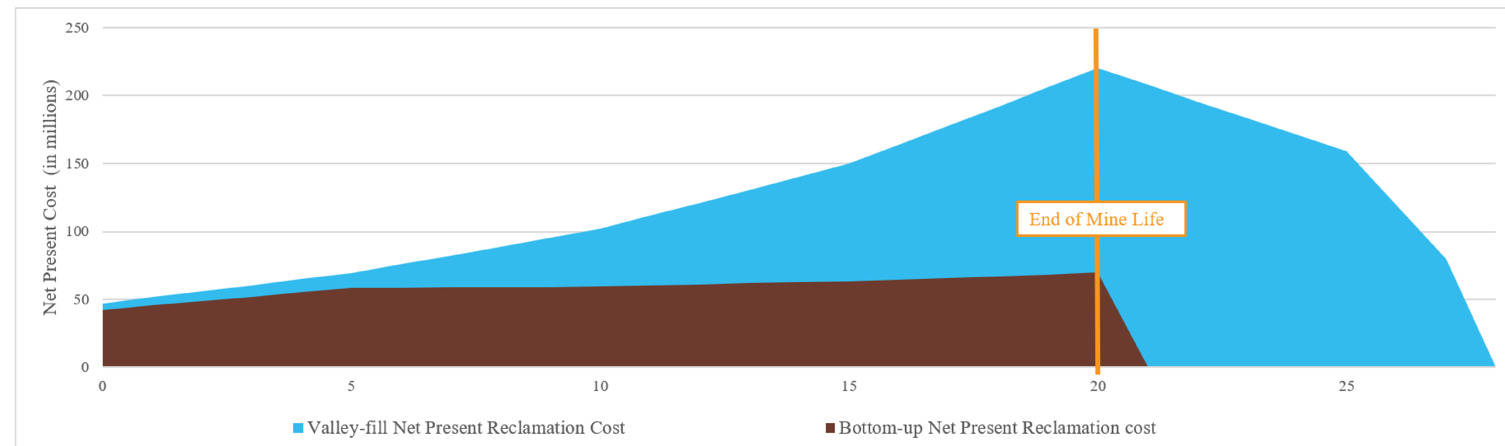

Figure 11: Net present reclamation costs – adjusted to year.

Conclusion

This study demonstrates that integrating closure considerations into mine rock stockpile (MRS) design and construction from the outset can yield significant environmental, operational, and economic benefits.

Bottom-up construction facilitates implementation of source control strategies, which help to limit oxygen ingress and reduce both recoverable and unrecoverable seepage. This approach also aligns more closely with regulatory expectations and future land use objectives by enabling concurrent reclamation and earlier establishment of stable, vegetated landforms.

References

Altalis. (2025). Data Store - Instant Access To Current, Accurate and Authoritative Geospatial Data. Retrieved from Altalis: https://www.altalis.com/

BC Road Builders & Heavy Construction Association. (2024). 2024-2025 Equipment Rental Rate Guide - The Blue Book. Burnaby, BC: BC Road Builders & Heavy Construction Association.

Clark, M., O'Kane, M., Koehler, B., Fung, K. (2025). Mine closure as a process: leveraging operational efficiency models to achieve land transition. Mine Closure 2025: Proceedings of the 18th International Conference on Mine Closure

Government of Northwest Territories (2017). Reclaim 7.0 Model for Closure and Reclamation Cost Estimates.

iMercer. (2024). How much turnover is too much? Retrieved from Mercer: https://www.imercer.com/articleinsights/workforce-turnover-trends-canada

International Network for Acid Prevention (INAP) (2020). Rock Placement strategies to enhance operation and closure performance of mine rock stockpiles, phase 1 work program.

Sawyer, R. (2024). ARD/AMD Source Control for Mine Rock Stockpiles Phase 3. M.A. O'Kane Consultants Inc. Melbourne: International Network for Acid Prevention.

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