Natural Analogs for Landform Design in Arid Climates

Lessons Learned in Geomorphic Landforms and Erosion Performance for a Legacy Tailings Facility

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Geomorphic Landforms

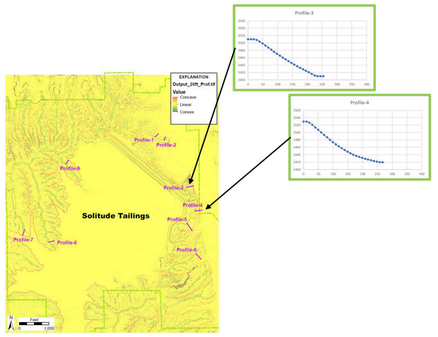
- Landform design and geomorphic concepts are standard terminology in recent mine reclamation guidance (INAP, 2017; ICMM, 2019; GISTM, 2020; LDI, 2021; etc.).
- Geomorphic designs often look to surrounding environment for inspiration of natural analogs.
- Natural analogs provide guidance on slope length, profile, and drainage density.
- Design must integrate myriad complex technical and stakeholder requirements!
- A Basis of Design document is useful in consolidating complex objectives and communicating the reclamation vision.

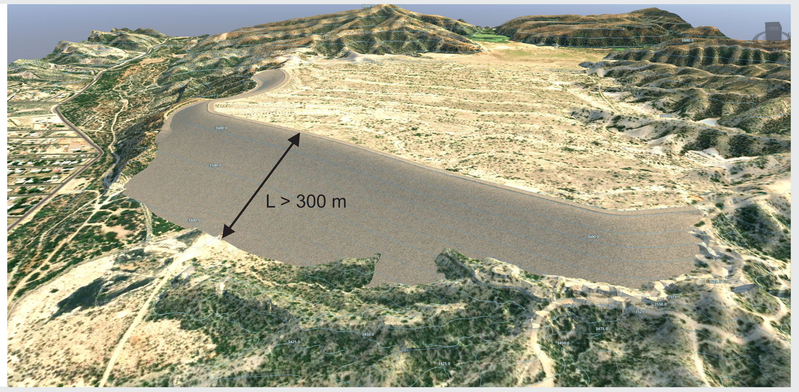
Landform Design Drivers

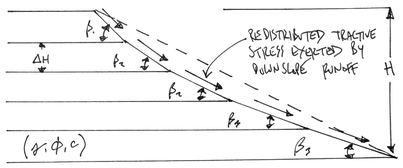
Mine sites are often located in rugged terrain and contain environmentally hazardous waste with multiple design objectives and considerations:

- Work within severe topography and footprint restrictions
- Geotechnical stability (especially tailings) risk
- Erosion perforance (beware natural benchmarks!)
- Construction complexity (grading and cover)
- Water management
- Minimize long term maintenance
- Site-specific erosion data is essential for model calibration

Natural Analogs: The Catena Profile

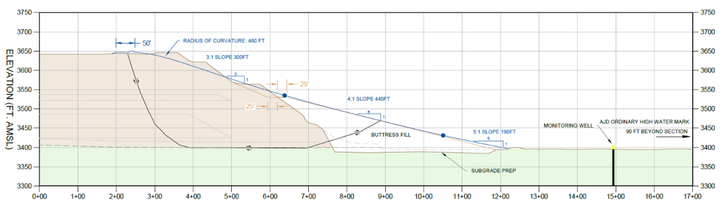






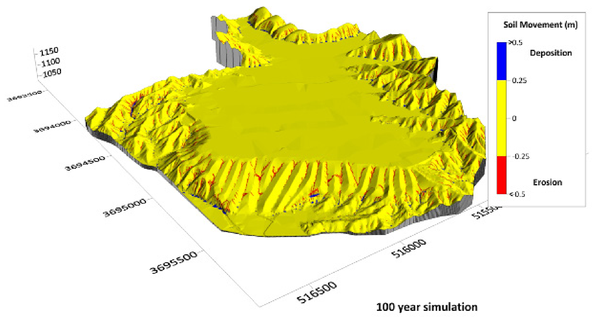
Field and lab studies show that convex-concave ("catena profile") slope profiles are more (geomorphically) stable and generate less sediment than uniform planar slopes.

(Quote and Figure Adapted from Schor & Gray, 2007)



- Derive catena profiles for natural hillslopes that represent planned cover material.
- All slopes flatter than 3H:1V.
- High-level comparative performance evaluation of slope alternatives using WEPP and RUSLE2.
- Create 3D landforms in AutoCAD (e.g., corridors and sub-assemblies per Buechler et al., 2023).
- Erosion prediction and slope optimization using Rillgen2D.

Geofluvial Concept Challenges



Complex grading that perfectly mimics surrounding topography may not be practically feasible.

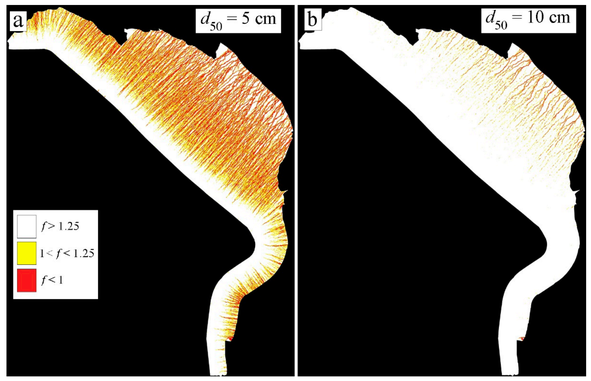
Case Study from 2023 SRK Landform Design:

- Looks amazing! But...
- Geotechnical Risk: Concentrates flow on embankment.
- Massive cost for large scale complex grading, complex rip-rap channel construction, and excess fill.
- Most appropriate for flat landscapes with large footprint and inert waste not requiring barrier cover systems.
- Complex Maintenance: Convergent channels require long term monitoring and difficult to maintain if damaged.

Erosion Covers

For this study in arid climate; rock armor is best performing material.

Erosion Modeling



Color maps of predicted rilling (in red) for the Option 1 landform over the next century using rock armor with (a) d_{50} = 5cm, and (b) d_{50} = 10cm.

- Quickly evolving field: RUSLE2, WEPP, SIBERIA, CAESAR-Lisflood.
- A new model is being developed and led by the University of Arizona in collaboration with SRK, BHP Copper, and Landloch: **Rillgen2D**.

Take-Away & Findings

- Catena (convex-concave) slopes preferred over linear slopes for better erosion performance.
- Implementation of more complex geofluvial landforms must overcome many challenges.
- Long-term maintenance is generational liability ("walk-away" is unrealistic).
- Erosion is nature in motion; what is the service life of an engineered landform on geologic timescale?
- Future landform designs built for closure "in perpetuity" should consider concepts of operating and sustaining capital...(!)

Acknowledgements

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