Validation of landform evolution modelling using remote sensed erosion data

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ABSTRACT

A key requirement for landform closure design is to characterise the long-term erosion risk. Landform evolution modelling (LEM) is often conducted prior to landform construction to predict erosion impacts over extended time periods. Increasingly, regulatory authorities require LEM to predict post-closure erosion performance of landforms during the project approvals phase. The purpose of this presentation is to investigate the predictive accuracy of LEM on a mining landform in comparison to observed erosion at a Goldfields mine, in Western Australia (WA).

Due to the development of modern survey hardware, including unmanned aerial vehicles (UAV) and high-resolution mounted surveying sensors, high-resolution surveys of rehabilitated landforms can be readily undertaken. This case study takes advantage of UAV captured LiDAR data that was collected to conduct landform-scale erosion monitoring and classified to filter out vegetation. This data was used to measure the geometry of erosion features including length, depth, slope and volume at the landform scale.

LEM was used to predict erosion on a reconstructed as-built model of the landform. Initially, the LEM was parameterised using only information available for the greenfield project such as geological information, analogue conditions, climate, local soils, landscapes and vegetation data. This represents a scenario that might be common for the approval stage of a Project. The LEM was run to match the duration of the current rehabilitation age to enable comparison of the predicted and actual erosion. The LEM was then re-calibrated using measured erosion geometries and rerun to assess predicted and measured erosion over a 300-year timeframe.

Conclusions from this study will demonstrate methods to use LiDAR data to assess the scale of erosion features and discuss the effectiveness of LEM at predicting erosion in multiple project stages and assess long term risk.

EXTENDED ABSTRACT

Erosion poses a significant risk to the rehabilitation of mining landforms after closure. Various factors influence erosion, including mine waste and growth media properties, climate conditions, local drainage patterns, landform construction and rehabilitation design, surface treatments, vegetation establishment, post-closure land use, and exposure to extreme weather events.

A crucial aspect of landform closure design is characterizing long-term erosion risk. Landform evolution modelling (LEM) is often performed before landform construction to predict erosion impacts over extended periods. Regulatory authorities increasingly require LEM to predict post-closure erosion performance during the project approval phase. While LEMs are valuable for informing rehabilitation designs, they depend on well-defined parameters. Without available as-mined waste rock and rehabilitation trials, practitioners may lack sufficient information to develop suitable parameters for LEMs. Using overly conservative parameters can impose unnecessary constraints on landform design, leading to additional disturbances, higher mining costs, and unfavorable outcomes. Conversely, using overly optimistic parameters can result in designs that promote excessive erosion, potentially harming the environment and failing to meet stakeholder expectations, requiring costly rework.

The growing use of whole-of-dump scale approaches like airborne LiDAR or photogrammetry surveys in post-closure monitoring enables high-density and high-quality data collection to assess mining landform performance. However, current practices often emphasize data collection without adequately informing management responses based on the available data. Drainage reviews can identify high-risk erosion areas due to ineffective water management, but deciding whether to intervene for erosion features on sloped surfaces can be challenging. A well-calibrated LEM helps understand the long-term risks posed by erosion features and determines where remedial actions may be necessary. It is important to remember that erosion risk of materials can change over time, potentially decreasing (e.g., via self-armouring or vegetation growth) or increasing (e.g., via material weathering).

This presentation investigates the predictive accuracy of LEM on a mining landform compared to observed erosion at a Goldfields mine in Western Australia (WA) and how uncertainty about physical material properties can be considered through sensitivity analysis. The presentation then demonstrates how a well-calibrated LEM can inform risk understanding and guide remedial management activities post-closure. It also discusses the importance of episodic post-closure monitoring to understand changes in erosion risk over time.

This case study uses UAV-captured LiDAR data collected for landform-scale erosion monitoring and classified to exclude vegetation. This data measured the geometry of erosion features, including length, depth, slope, and volume. Key erosion feature dimensions were verified with field measurements.

The SIBERIA LEM predicted erosion on a reconstructed as-built model of a landform rehabilitated over 20 years ago. An as-constructed survey of the original rehabilitation surface was unavailable, so to create an assumed starting surface, the survey digital elevation model was modified to remove erosion features and incorporate ripping surface features, similar to those observed in other high-stability areas of the landform. Initially, the LEM was parameterized using only greenfield project information, such as geological data, analogue conditions, climate, local soils, landscapes, and vegetation data—common for the project approval stage. Sensitivity testing accounted for uncertainty using lower and upper bounded parameters of likely material behaviour.

The LEM matched the duration of the current rehabilitation age to compare predicted and actual erosion. The LEM was then calibrated by modifying parameters to recreate erosion features of similar size to those observed on the current surface. An averaged erosion rate indicated unrealistically high future predicted erosion rates, so historical aerial imagery was reviewed to understand the evolution of key erosion features over time. This review showed that most erosion occurred shortly after rehabilitation work completion, possibly due to settlement of the initially loose material and self-armouring of erosion features. As a result, two sets of erosion parameters were developed: one for the initial high-erosion period and another for stabilized material.

Once calibrated LEM parameters were established, SIBERIA was used to model the predicted behaviour of the current surface over a 200-year period using the stabilized material parameters to inform the long-term trajectory of the landform and to compare the predicted erosion rates with threshold values.

Conclusions from this study will demonstrate methods to use LiDAR data to assess erosion feature scale and discuss LEM effectiveness in predicting erosion across multiple project stages and long-term risk assessment. The presentation will emphasize the importance of regular monitoring during different phases of post-closure establishment for mining landforms to understand long-term risks and guide early interventions when needed. It shall discuss some opportunities and limitations associated with LEMs in assessing the long term trajectory of mining landforms.