Evaluating Vulnerability of Closed Uranium Mill Tailing Sites to Event-Triggered Surface Erosion

Jenny B. Chapman, Research Hydrogeologist
Desert Research Institute

Track 1.5
Co-authors:

Steven N. Bacon, P.G., C.E.G.
Associate Research Geomorphologist
Desert Research Institute

Julianne J. Miller
Research Hydrologist
Desert Research Institute

Acknowledgments: David Traub, Dick Johnson, Bill Dam
Challenges of Closed Uranium Mill Tailing Sites

- Large engineered structures
- Long compliance timeframes
- Active landscapes
- Extreme events will occur

Photo: NRC, 2015
Terrain Altering Events

Short Term:
- Mitigation actions
- Event monitoring
- Communication

Long-Term:
- Erosion concerns
- Changes in design basis
- Change in monitoring metrics
- Large-scale mitigation actions
Vulnerability Assessment Approach

• Evaluation-parameter rating scheme
• Based on similar process used for geologic hazard mapping (e.g., landslide risk)
  ▪ Use intrinsic trigger parameters responsible for hazard

- Rate site characteristics (e.g., geomorphic, hydrologic, biologic) relevant to processes of concern
- Example here focuses on surface erosion susceptibility
- Factors include:
  ▪ Landform erosion potential
  ▪ Saturated soil hydraulic conductivity
  ▪ Percent slope
  ▪ Watershed ruggedness
Erosion Susceptibility Factors

**Landform Erosion Potential**

- Identify landforms present in disposal site watershed (geomorphic map)
- Link landform to dominant surface process (weathering, mass wasting, surface water, groundwater, wind)
- Assign erosion potential based on processes
- Range from
  - 0 – Negligible for undisturbed hillslopes
  - 5 – Very High for debris slide slopes, gullies

**Saturated Hydraulic Conductivity**

- Account for differing ability of soils to infiltrate rainfall
- $K_{sat}$ as a proxy for runoff potential
- Based on soil texture mapped by NRCS
- Range from
  - 0 – Very Rapid for coarse sandy soils
  - 5 – Very Slow for clay-rich soil and bedrock outcrops
Erosion Susceptibility Factors

**Percent Slope**

- Slope controls degree of erosion from surface runoff and propensity of mass-wasting on hillslopes
- Adapted slope steepness categories of Kelsey (1977)
- Calculated in a GIS using USGS 10-meter DEM
- Range from
  - 0 – Negligible for 0-5% slopes (0 to 2.9°)
  - 5 – Steep to Precipitous for slopes greater than 60% (31°)

**Watershed Ruggedness**

- Similar in concept to slope, but on a watershed scale
- Indicator of relative dynamism of the basin and hazards related to water movement and sediment mobilization
- Based on Melton Ruggedness Number (1965) dividing watershed relief by area
- Range from
  - 0 – Very low relative relief
  - 5 – Extreme relative relief
Edgemont Disposal Site

Legend
- Site Watershed Boundary
- Tailing Impoundment
- Rip Rap

North Drainage Outlet
Grass-lined Perimeter Channel
Southwest Drainage Outlet
Containment Dam
Outfall Basin

2018 LTS Conference
L-Bar Disposal Site

Legend:
- L-Bar Site Boundary
- Diversion Channel
- Flow Direction
- Rip Rap
- 2009 Erosion Control Structure

Scale:
- 0 500 1,000 2,000 Feet
- 0 150 300 600 Meters
Factor: Erosion Potential

Edgemont

L-Bar

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Factor: $K_{sat}$

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Factor: Percent Slope

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Factor: Watershed Ruggedness

Melton Ruggedness Number 0.07
Very Low class (factor rating = 0)

L-Bar

Melton Ruggedness Number 0.15
Low class (factor rating = 1)
Surface Erosion Susceptibility (SES)

**SES Index** = \( \frac{(\text{Total number of cells with M, H, VH classes})}{(\text{Total number of cells with N, VL, L classes})} \)

**SES Index** = 0.46  
**SES Index** = 1.67

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Vulnerability Assessment Flowchart

CALCULATE WATERSHED SES INDEX

(Total number of cells with Moderate, High, and Very High classes)
(Total number of cells with Negligible, Very Low, and Low classes) = SES Index

SURFACE EROSION SUSCEPTIBILITY (SES) MAPS

Group into General SES Classes

Factor Ratings (3 – 15)

Input Data Layers (assign factor ratings)

Numerical Factor Rating Layers (0 – 5 classes)

10 m x 10 m Grid Cells

Sum Factor Ratings per Each Grid Cell

Surface Erosion Susceptibility Class

- Negligible
- Very Low
- Low
- Moderate
- High
- Very High
- Diaposable Site

Landform Erosion Potential

Percent Slope

Watershed Ruggedness

Hydraulic Conductivity (Ksat)

Geomorphology

Dem

NRCS Soils

Imagery
Monitoring Implications

Focus on-ground monitoring on vulnerable site areas

- Context for terrain monitoring through time
- Develop site-specific inspection plans focused on high risk factors
- Preparedness for event based monitoring after fire and flood

Remote monitoring opportunities

Photo: NRC, 2015

Photo: LM Program Update Q3 2016
Conclusions

• Landform-based approach to identifying vulnerable site areas
  ▪ Easily repeatable and transferable process
  ▪ Based on GIS platform and available datasets
  ▪ Use to develop response plans for terrain altering events & guide long-term monitoring

• Framework for Intra- and Inter-site comparisons
  ▪ Focus resources to address higher risk factors at each site
  ▪ Focus resources to address overall higher risk sites

• Approach can be tailored by using or adding other data layers
  ▪ Climate factors affecting erosion such as freeze/thaw
  ▪ Dissection index (topographic crenulation)
  ▪ Drainage network density including overland vs. channelized flows
  ▪ Seismic hazards
  ▪ Subsidence history
  ▪ Vegetation cover
  ▪ Precipitation intensity