Revegetation after mine waste removal and metals impacts:
Examples from western Montana floodplains (and uplands)

Tom Parker, Geum Environmental Consulting
Stuart Jennings, KC Harvey
Floodplain restoration as part of mine waste cleanups

- Dynamic environments
- Contaminated materials not completely removed
- Some residual contamination in floodplain soils
Floodplain Restoration Design Criteria

- Disturbance processes
- Hydrology
- Substrate
- Roughness & complexity
- Biological interactions
  - Herbivory
  - Plant competition
Existing, Design and Future Floodplain Surface
Residual Metals Scenarios

- Clark Fork River—remove contaminated material to a depth where substrate is clean, but metals remain at edges
- Eastside Road Pastures—upland pasture irrigated with contaminated irrigation water
- Upper Blackfoot Mining Complex—remove tailings to a native surface which is highly mineralized on some reaches
- Anaconda Uplands—soils contaminated by smelter
Residual Metals Scenarios
Milltown Dam

- 2005: Pre-dam removal
- 2009: Construction
- 2015: Post-project

Remedial area

Residual metals
Plant community succession in alluvial river floodplains in the semi arid Rocky Mountain Region is initiated by cottonwoods and willows colonizing bare, moist substrates.
Milltown Posse Grounds Reclaimed Slope Condition

Total metals (Cu, Zn, Pb, As, Cd) 1500 to 2000 throughout this area
Soluble Zn is in mg/L (sat. paste)
Soil treatment:
- Decom pact
- Lime at 15 tons CaCO3/acre
- Compost at 100 cu yds/acre
- Microtopography and woody debris
Eastside Road Pastures
## Eastside Road Pastures

**Saturated Paste Extracts before and after adding Lime**

<table>
<thead>
<tr>
<th>Plot</th>
<th>pH</th>
<th>pH with Lime</th>
<th>Cu</th>
<th>Cu with Lime</th>
<th>Zn</th>
<th>Zn with Lime</th>
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<tbody>
<tr>
<td>ESP-2014-08-26</td>
<td>4.8</td>
<td>7.1</td>
<td>1.63</td>
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<td>0.96</td>
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<td>0.93</td>
<td>0.75</td>
<td>1.04</td>
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</table>
Eastside Pastures Treatments—90 acres

• **Lime applied at 15 tons/acre**—evenly mixed to 10 inches

• **Cover soil applied at 200 cu yds/acre**

• **Compost applied at 70 cu yds/acre**

• **Drill seeded**

• **Straw crimped**
Eastside Road Pastures
Eastside Road Pastures
Upper Blackfoot River Mining Complex
Upper Blackfoot Mining Complex

- Parent material is naturally mineralized – mine waste removal is possible, but in places there is no depth where metal concentrations are below SSCLs
- Capping may be required to protect human health
- Cover soil or soil amendments where SSCLs are not applicable
Upper Blackfoot Mining Complex
Upper Blackfoot Mining Complex

Soluble Zn versus Saturated Paste pH

y = 6.4455x^{-0.047}
R^2 = 0.7967

Soil pH (saturated paste)

Soluble Zn (mg/L)

1 mg/L Zn
Upper Blackfoot River Mining Complex

**EC and Ca+Mg**

\[ y = 14.357x - 2.0206 \]

\[ R^2 = 0.9851 \]
## Upper Blackfoot River Mining Complex

<table>
<thead>
<tr>
<th>Condition at Excavation Surface</th>
<th>Gravel and Sand</th>
<th>Rocky parent material</th>
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<tbody>
<tr>
<td>pH &lt; 6.5 Ec &lt; 1 Saturated</td>
<td>6 inches Amended Backfill</td>
<td>Minimum 12 inches Backfill plus 6 inches Amended Backfill</td>
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<tr>
<td>pH &lt; 6.5 Ec &lt; 1 Not Saturated</td>
<td>Minimum 18 inches Backfill plus 6 inches Amended Backfill</td>
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<tr>
<td>pH &gt; 6.5 Ec &gt; 1</td>
<td>None</td>
<td>Minimum 18 inches Backfill</td>
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</tbody>
</table>
Upper Blackfoot River Mining Complex
Upper Blackfoot River Mining Complex

- pH = ~3.5
- Soluble Zn > 20 mg/L

2009

- Six inches cover soil amended with lime and compost
- Embedded woody debris
- Duff from nearby forest floor
- Native seed

2016
Upper Blackfoot River Mining Complex
Pore Water/Saturated Paste Extract

Soil + Deionized Water
Soil Solution Toxicity to Plants

None: Dominated by Ca, Mg, Na, S, N, P, K, DOC, trace amounts of metals

Phytotoxic: Dominated by metals, low pH, no or low nutrients

Remediated: Some soluble trace elements, near neutral pH, nutrients replaced, lime addition adds Ca, Mg

Can be toxic to sensitive species depending on levels
Increasing Chance of Successful Reclamation

Increasing Risk of Phytotoxicity

Sum total metals (mg/kg)

Soil pH

Poor Vegetation
Good Vegetation
Phytotoxic Response to Basin Wildrye grown in Lime-amended Soil from Anaconda and Clark Fork River NPL Sites

\[ y = 115.53e^{-0.04x} \]
\[ R^2 = 0.9744 \]

\[ y = 100.73e^{-0.05x} \]
\[ R^2 = 0.923 \]

EMERGENCE AND GROWTH OF SEVEN GRASS SPECIES ACROSS A GRADIENT OF METALS AND ARSENIC IN LIME-AMENDED CONTAMINATED SOILS (Martin, 2009)
Anaconda Water Soluble Constituents at Reclaimed Sites

Water Soluble Constituent (mg/kg) vs. Soil pH

Water Soluble Constituents at Reclaimed Sites

- Copper
- Zinc
- Arsenic
Vegetation Condition and Water Soluble Chemistry at Research Sites

![Graph showing the relationship between Soil pH and Water Soluble Constituent concentration for Copper and Zinc, with areas of Poor and Good Vegetation indicated.](image)
Residual soil phytotoxicity

3 years old

8 years old

16 years old
ARWW&S Post-Treatment Vegetation Response to Metals and pH

- 96% of samples with good vegetation
- 9% of samples with good vegetation
- 58% of samples with good vegetation

Modified Conceptual phytotoxicity curve

Legend:
- Good Vegetation
- Poor Vegetation
- ROD Phytotox Curve
What the sites look like
East Site Road Pastures: Water Soluble Metal Levels in Soil

![Bar chart showing mean water soluble metal levels in saturated paste extracts following lime addition]
Water Soluble Zinc Before and After Soil Treatment with Lime and Compost

East Side Pasture Project,
Water Soluble Zinc before and after treatment

\[ R^2 = 0.8174 \]
Pre-treatment condition (2014)

Soil pH 5.2

After reclamation using lime and organic matter (May 2016)...seeded May 2015

Soil pH 7.5
6.4 6.6 6.8 7.0 7.2 7.4 7.6 7.8

Soil pH

Water Soluble Zn (mg/L)

Soil pH versus Saturated Paste pH

Soluble Zn versus Saturated Paste pH

Milltown Soil Solution Zinc

Soil pH (saturated paste)

Soluble Zn (mg/L)