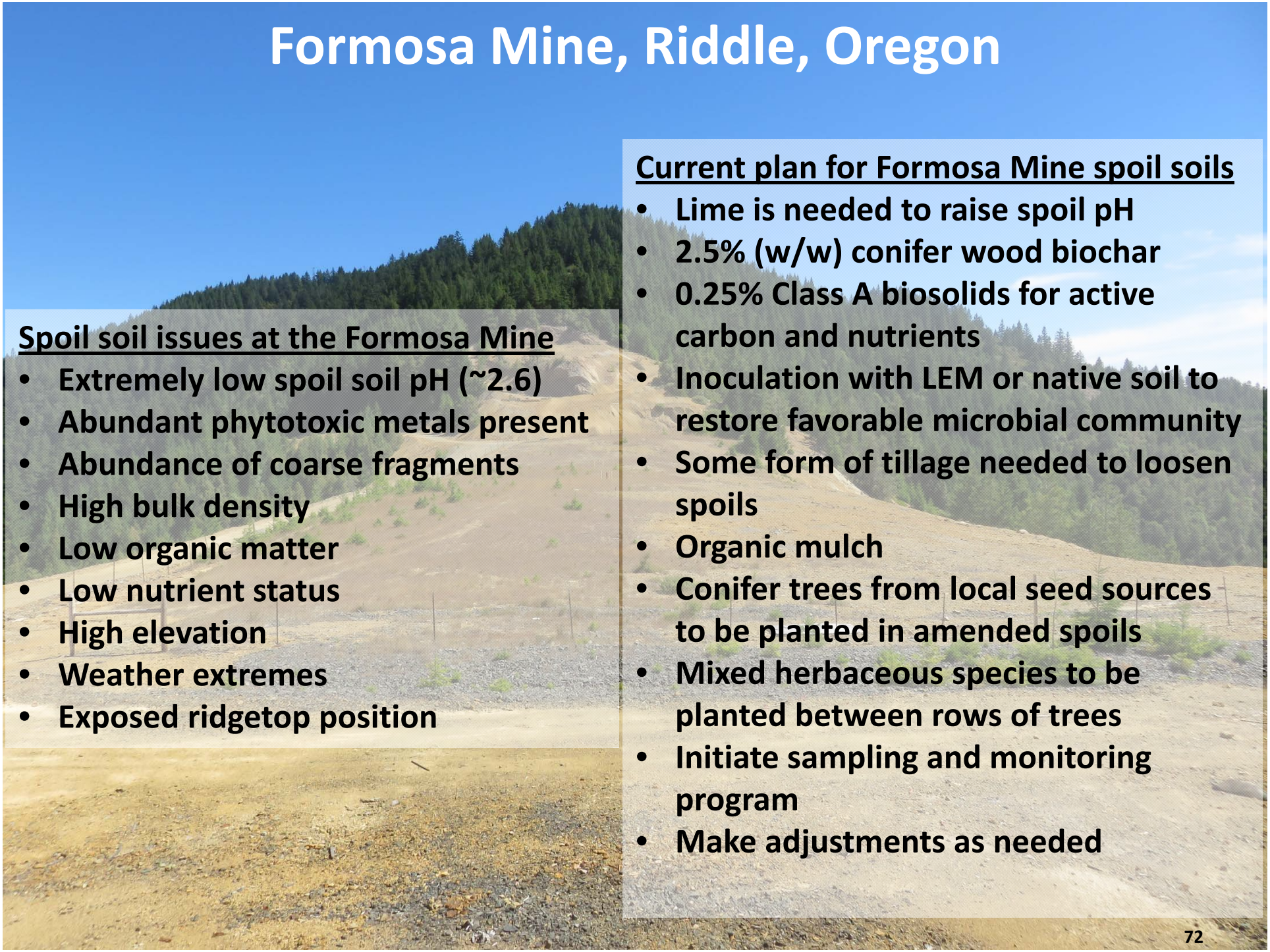
Formosa Mine, Riddle, Oregon



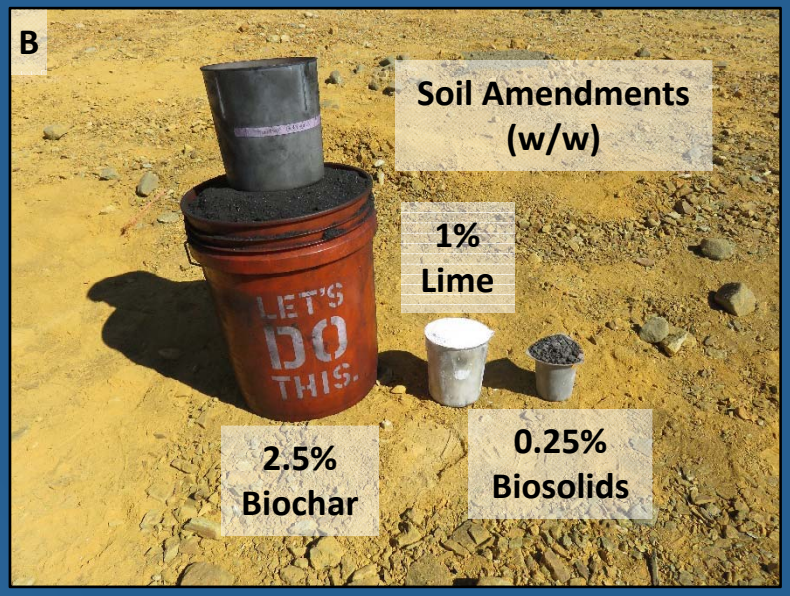
Spoil soil issues at the Formosa Mine

- Extremely low spoil soil pH (~2.6)
- Abundant phytotoxic metals present
- Abundance of coarse fragments
- High bulk density
- Low organic matter
- Low nutrient status
- High elevation
- Weather extremes
- Exposed ridgetop position

Current plan for Formosa Mine spoil soils

- Lime is needed to raise spoil pH
- 2.5% (w/w) conifer wood biochar
- 0.25% Class A biosolids for active carbon and nutrients
- Inoculation with LEM or native soil to restore favorable microbial community
- Some form of tillage needed to loosen spoils
- Organic mulch
- Conifer trees from local seed sources to be planted in amended spoils
- Mixed herbaceous species to be planted between rows of trees
- Initiate sampling and monitoring program
- Make adjustments as needed

Preparing the Formosa Site for Planting Trees



Panorama of Formosa Mine Field Site

- 119 locations (0.4 meter diameter x 0.6 meters deep) amended with biochar (2.5%), lime (1%) & biosolids (0.25%)
- Locations have 3 meter x 3 meter spacing
- Trees from local seed sources will be planted in November
- Rhizosphere soil to be inoculated with native soil or LEM
- In early spring area between rows will be prepped and planted with native herbaceous plants

Past Reclamation Activities in Jasper, County, Missouri

Mine spoil was removed from soil surface.

Currently, B/C horizon soil is at the surface.

Poor vegetation re-growth in areas

Soil property	Range in values
CEC (meq/100 g)	6.6 – 53.6
pH	4.5 – 5.70
P (ppm)	1 -- 18
K (ppm)	60 -- 168
Cu (ppm)	0.8 – 27.3
Zn	12.9 -- 2688

Metal toxicity


O
A
Bt

Jasper County Target Soil

A horizon

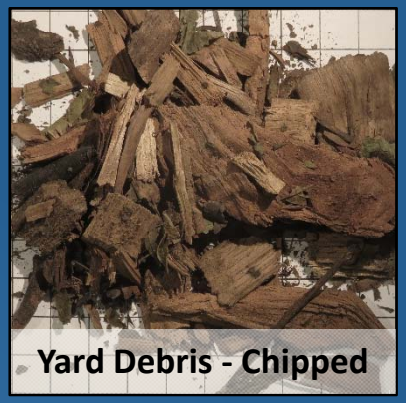
- 8.4 % OM
- 16.1 CEC
- pH = 6.3
- Ext. P (Bray 1) = 9
- K = 112 pm
- Zn = 48 ppm
- No coarse frags
- Sandy loam

Bt (?) horizon

- 4.6 % OM
- 16.1 CEC
- pH = 5.7
- Ext. P (Bray 1) = 7
- K = 63 pm
- Zn = 28 ppm
- No coarse frags
- Loam

Jasper County, MO Project Biochar Feedstocks


Hay - Unground


Yard Debris - Chipped


Cedar Wood-Chipped


Hay – 6 mm


Yard Debris – 6 mm

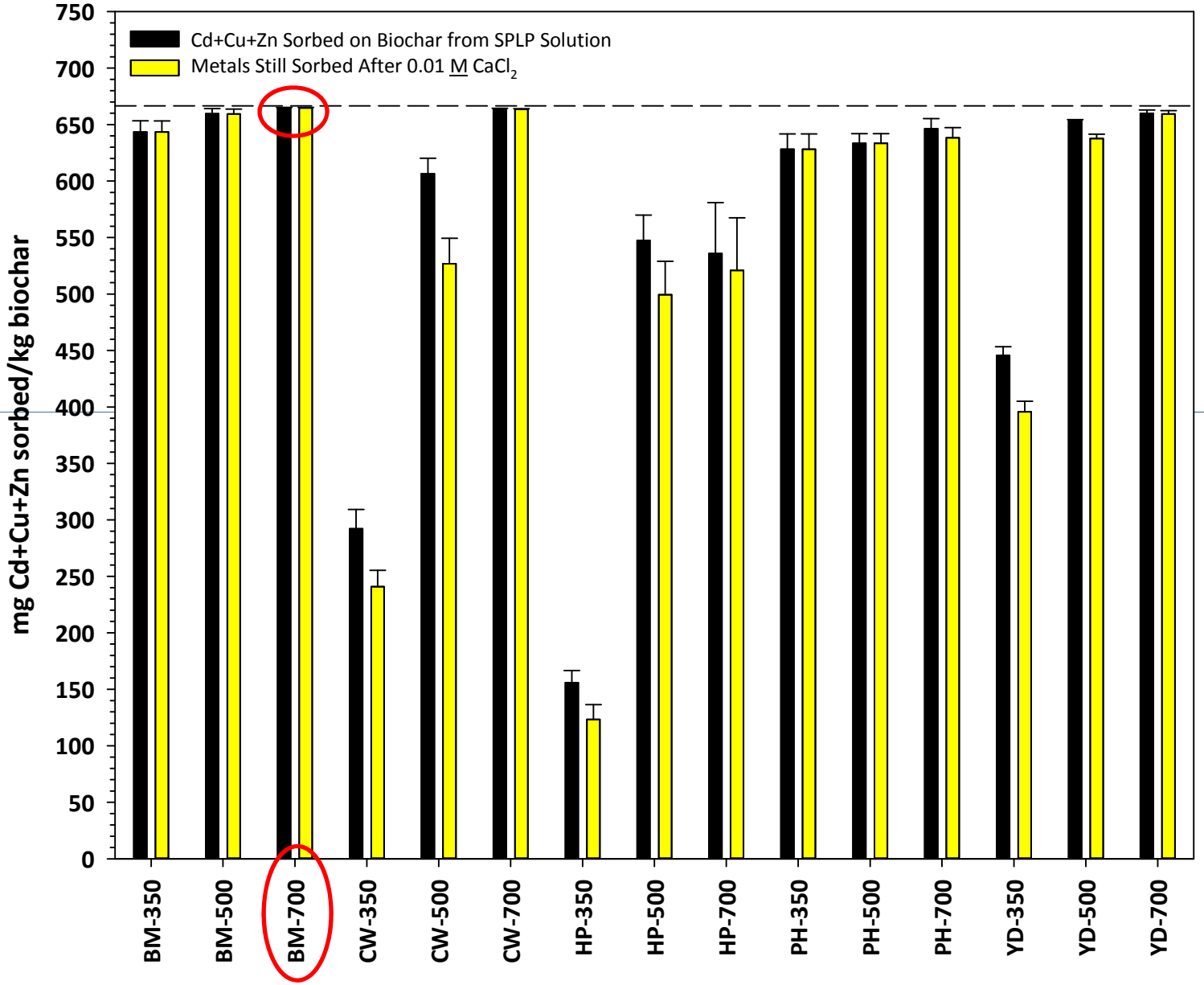

Cedar Wood – 6 mm


Hay – 1 mm


Yard Debris – 1 mm

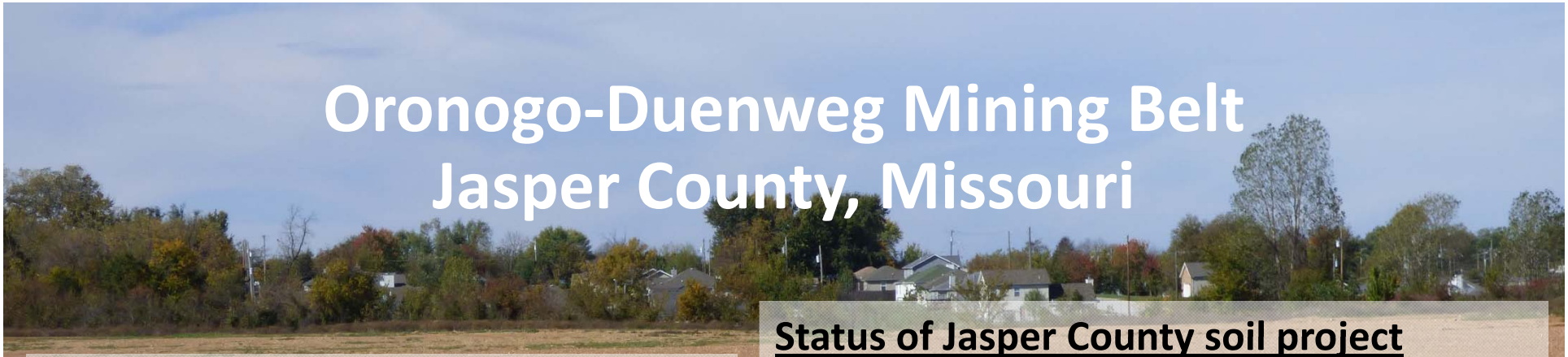

Beef Cattle Manure

Total Metal (Cd+Cu+Zn) Sorption/Desorption on TSMD Biochars



The dashed line (---) is the sum of Cd+Cu+Zn in the SPLP Solution from mining impacted soil in the Tri-State Mining District site near Webb City, MO

Oronogo-Duenweg Mining Belt
Jasper County, Missouri



Soil issues in Jasper County

- Pb contaminated chat and top soil removed from thousands of acres, but removals continue
- Thousands of acres of soils to be revegetated
- Sub-soil now at surface
- High levels of Zn and Cd present
- Abundance of coarse fragments
- High bulk density
- Low water infiltration rates
- Low organic matter
- Low nutrient status

Status of Jasper County soil project

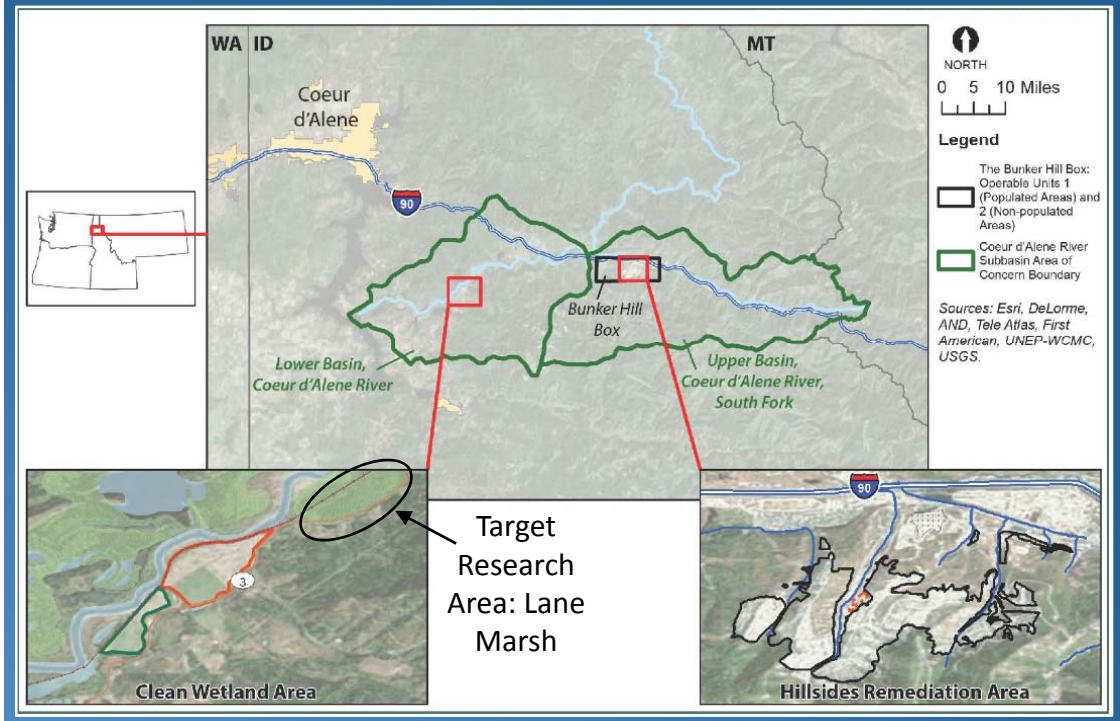
- We have identified a biochar that is appropriate for complexing soil Zn
  - 700°C beef cattle manure biochar
- Lime and nutrients will be needed
- Germination tests completed on native grasses and other species
- Considering non-mechanical means to loosen soil for subsequent amendment and revegetating
- Greenhouse studies underway to refine amendment cocktail and strategy
- Field trials to begin in 2018

Lead Contamination in the Upper Columbia River Tribal Allotments

- Forested, coarse-textured soils
- Relatively low levels of total Lead, but sufficient to cause concern

- The Colville Nation wants potential exposure to Lead reduced in these areas without using dig and haul

Lead Contamination in the Lower Basin of the Coeur d'Alene River: Lane Marsh



- Lane Marsh is somewhat protected, but is a contaminated, wetland area that hosts Tundra Swans on their annual migration
- Hydrology limits the addition of contaminated sediments during flood events
- Lead exposure to Swans and other waterfowl is significant
- Documented Swan mortality due to Lead

UCR and CdA Projects: Applications for *In Situ* Remediation Using Biochar and other Soil Amendments

- These new projects provide a testbed for evaluating biochar and other soil amendments for use in contrasting upland forest and wetland environments
- The underlying goal is to minimize site disturbance
  - Protect sensitive habitats
  - Less destructive and more cost effective than excavation
- Opportunity/need to evaluate the effects of various amendments on bioavailability of Lead
  - Upland soil setting
  - Wetland setting
- Results applicable for large remote sites impacted by mining or for urban Brownfield sites
- Opportunity to test alternative amendments with lower impacts to water quality
- Opportunity to build community and collaborate with Tribes and State partners to remediate and restore contaminated sites more quickly.

Biochar and Metal Contaminated Soils: Summary

- Identify site soil limitations via site characterization
- Prioritize Limitations
  - Greatest limiting factor to least limiting
- Can biochar alone eliminate or reduce limitation(s)?
  - If yes, is a "designed or engineered" needed?
  - If no, are other soil amendments also needed?
- Test the efficacy of biochar to reduce or eliminate limitations
  - Use site soil extracts to challenge library of biochars
  - Identify the best biochar for reducing soil limitations
- Test the effects of biochar on plant material
  - Germination tests
  - Greenhouse pot studies
- Demonstrate *in situ* amendment efficacy with field plot-scale studies
- Proceed to full site remediation with biochar and other soil amendments
- Monitor site conditions
  - Make adjustments if necessary
  - Declare success when a sustainable cover of native plant material is established

Outlook for the Future

- The use of Biochar in remediation has a bright future
- Biochar can be effective at reducing exposure to inorganic and organic contaminants
- Designer Biochar provides a set of new, tunable materials that can be utilized in a variety of remedial situations
- Many opportunities for "Designer Biochars" that are specifically engineered to address degraded soil limitations
  - Research is needed to "scale-up" Designer Biochar production
  - Need precisely manufactured Biochars that can be reproducibly manufactured in large volumes
- Continuing research on metal and contaminant sorption on Biochar is needed
  - We need to more fully understand the strength and permanence of contaminant sorption
- Biochar in remediation is meeting real environmental needs!

Contact Information

Mark G. Johnson, Ph.D.

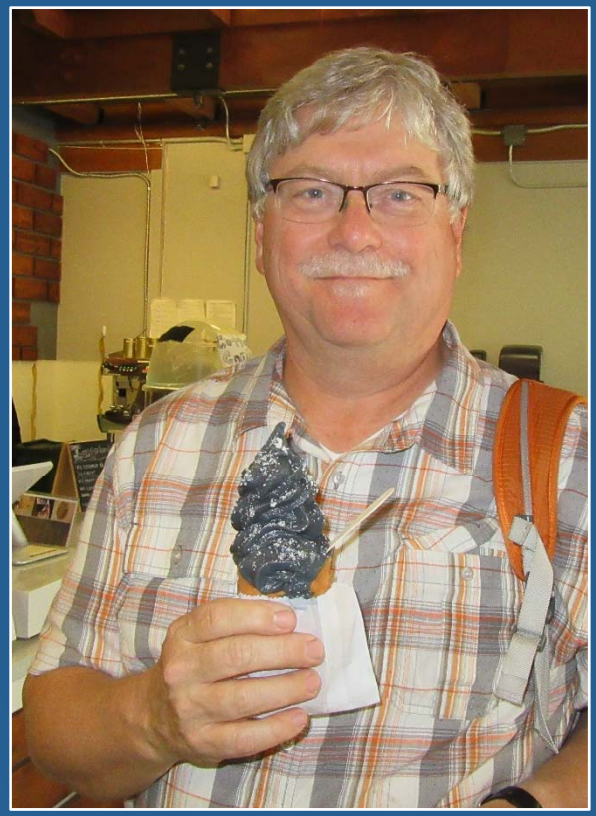
U.S. EPA, ORD, NHEERL, WED

200 S.W. 35th Street

Corvallis, OR 97333

Phone: (541) 754-4696

Email: johnson.markg@epa.gov



MGJ with Coconut Biochar Ice-cream