EPA United States Environmental Protection Agency

Colorado State University

USDA ARS

Considerations for Applying Soil Amendments at Mine Sites

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Office of Research and Development
Center for Public Health and Environmental Assessment

Clu-In Webinar
October 2019

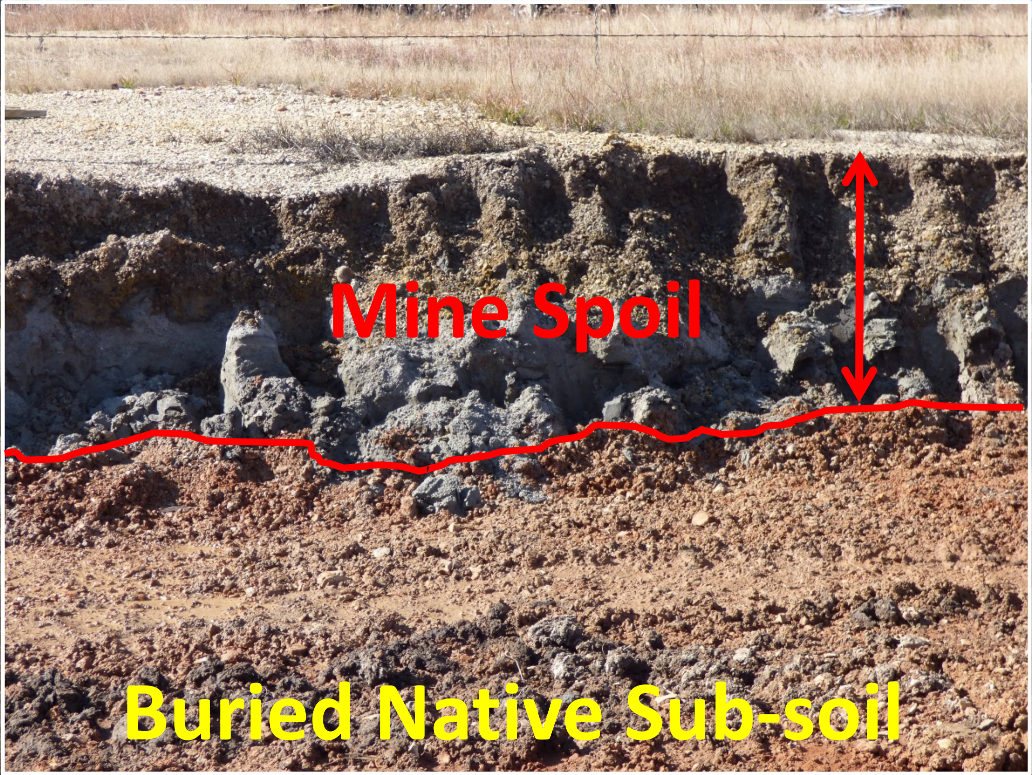
Mining Impacted Soils

Abandoned Almeda Mine, Galice, Oregon USA

Mining Impacted Soils

Abandoned Formosa Mine, Riddle, Oregon USA

Mining Impacted Soils



Oronogo-Duenweg Mining Belt Mine and Smelting Residue Site, Jasper County, Missouri USA

Mining Impacted Soils

"Native Sub-Soil" Surface After Removal of Mine Spoil Overburden

Contaminated and Degraded Soils

Multiple problems

- Contaminated soils and sediments require intervention and remediation
- There are 1300+ Superfund sites and approximately 500,000 abandoned mines across the U.S. that pose a considerable and pervasive risk to human health and the environment
  - World-wide the problem is even larger
- Globally there are hundreds of thousands of hectares of degraded soils that limit food security and in some countries continued over-fertilization and overuse threatens air and water quality

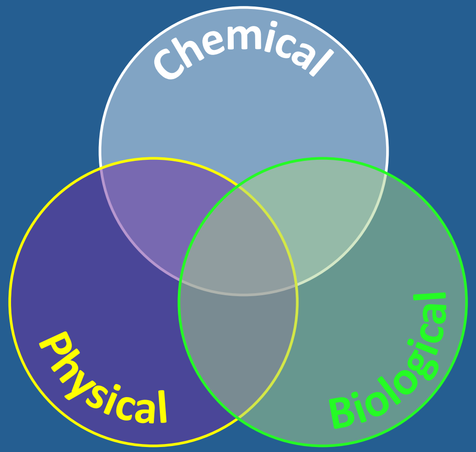
Soil amendments

Strategic use of soil amendments at mining impacted sites can address these specific problems!

- Can reduce contaminant exposure by limiting the exposure pathways and immobilizing contaminants by changing the chemistry of contaminated soils
- Can help to restore soil quality and health of degraded soils
- Can enable site *in situ* remediation, re-vegetation and revitalization, and reuse of contaminated soils
- Can lead to sustainable site recovery

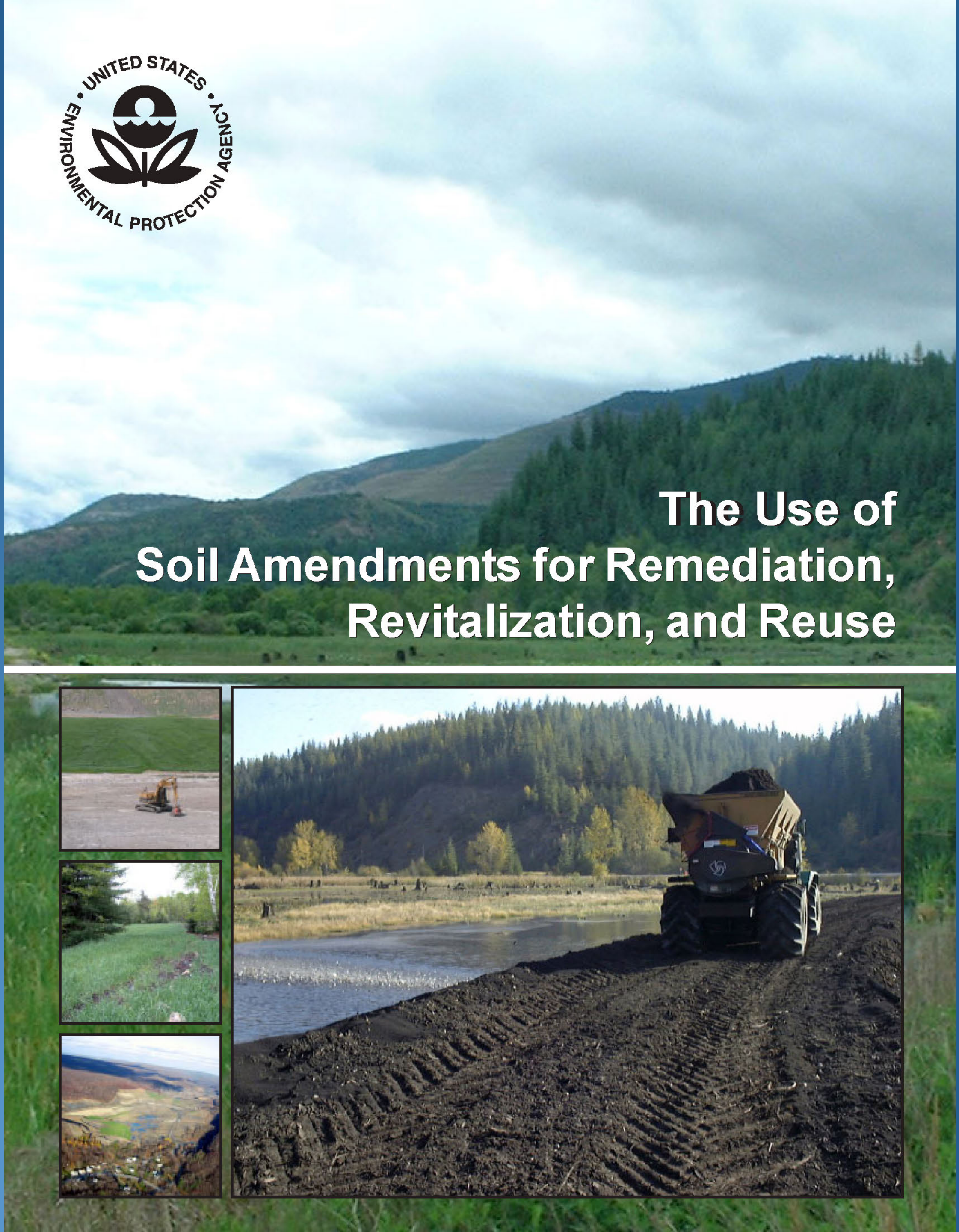
Mining Impacted Soil Limitations

- **Chemical**
  - Metal toxicity
  - Low: pH, Organic Matter, Nutrients
- **Physical**
  - Compacted
  - Coarse fragments
  - Poor structure
  - Poor water infiltration or holding properties
  - Depth of spoil material
  - Proximity to water table
  - Slope
- **Biological**
  - Low activity (e.g., plants, microbes, higher organisms)
  - Low diversity
  - Wrong kind of organisms



Soil Amendments can Include:

- Biochar
- Biosolids
- Manures/litters
- Sugar beet lime
- Wood ash
- Coal combustion products
- Log yard wastes
- Wastes from bioenergy production
- pH neutralizing lime products
- Some metal oxides
- Composted biosolids
- Composted agricultural byproducts
- Composted yard wastes
- Mineral material
  - Foundry sands
  - Steel slag
  - Dredged sediments
  - Water treatment residuals
- Traditional agricultural fertilizers



Good Reference for
Soil Amendments

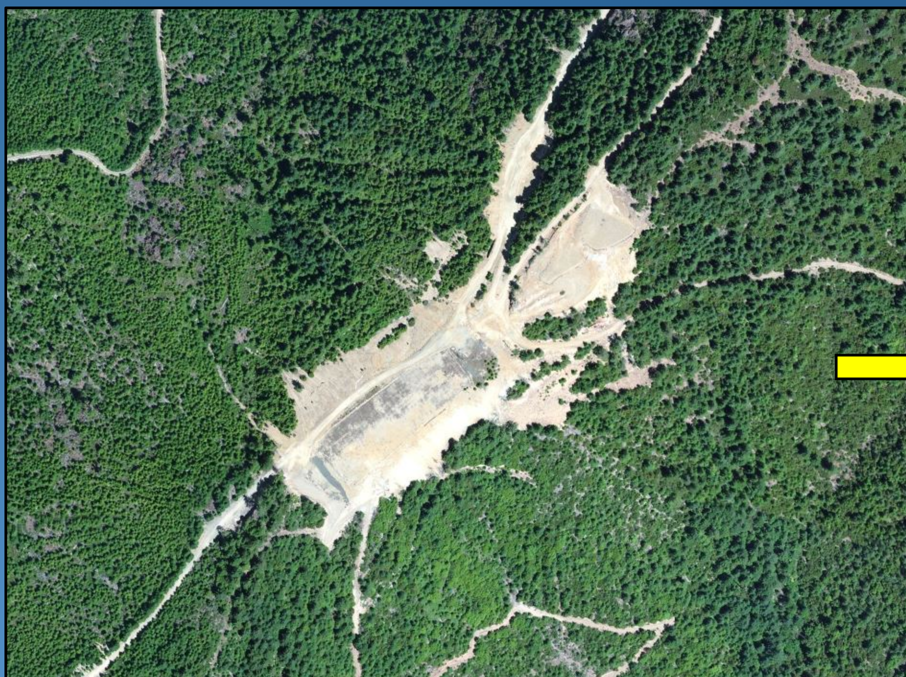
EPA 542-R-07-013
December 2007
www.epa.gov

Goals for Using Soil Amendments on Metal Contaminated Sites:

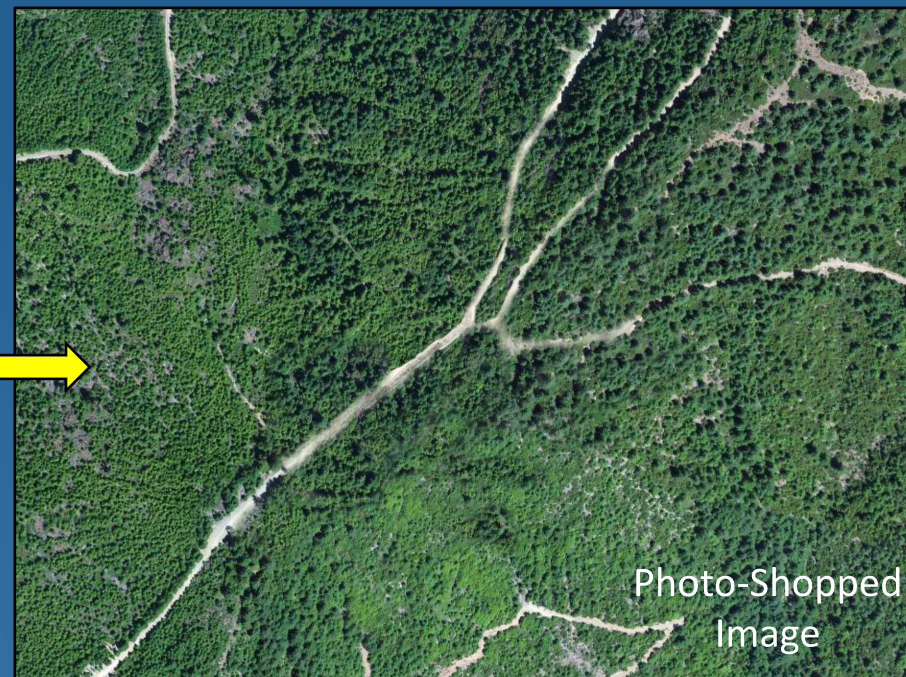
- To immobilize metal contaminants through adsorption, precipitation, and complexation reactions which result in the redistribution of the contaminants from solution phase to solid phase, thereby reducing their bioavailability and transport in the environment.
    - Reduce hazards
    - Reduce exposure
    - Restore soil function & ecosystem services
- To establish a sustainable soil-stabilizing native plant cover
    - Reduce erosion and leaching
    - Add organic matter

Solving the Problem:
Start with the End in Mind

Before Amendments and Revitalization



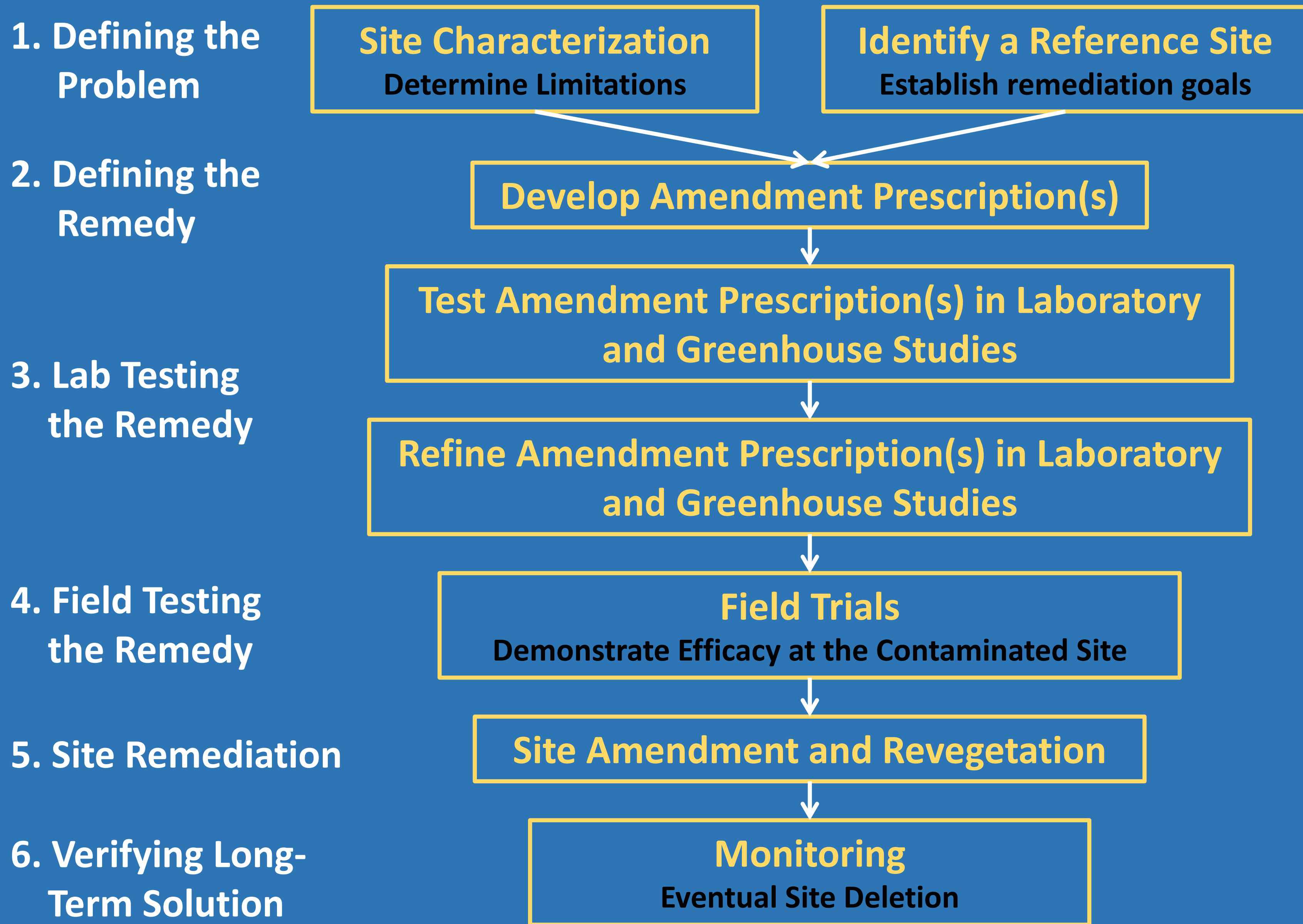
After Amendments and Revitalization



Strategic Intervention to Promote Soil Revitalization Using Soil Amendments

Formosa Mine Superfund Site, Riddle Oregon

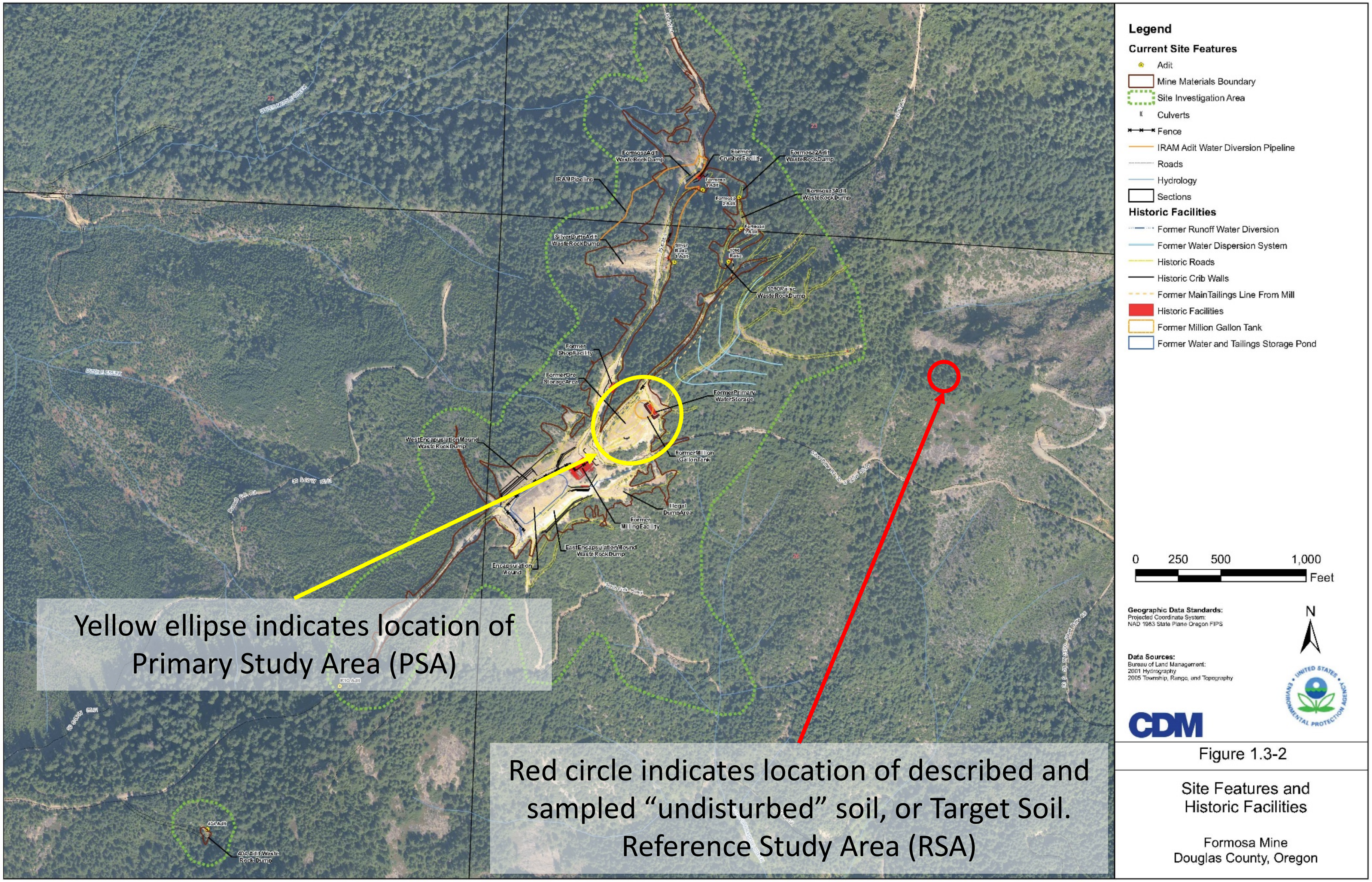
Systematic Framework for Amending Mining Impacted Soils to Sustainably Grow Vegetation



Establishing Remediation Targets

- Once you know what the problems are at your site, you need to determine the extent of adjustment required to provide sufficient site remediation prescription to establish a sustainable native plant community
- Compare the properties of your site to that of a proximal "undisturbed" site
  - How different are they?
  - What needs to be adjusted?
- Develop remediation/amendments plan
  - Prioritizing remediation activities

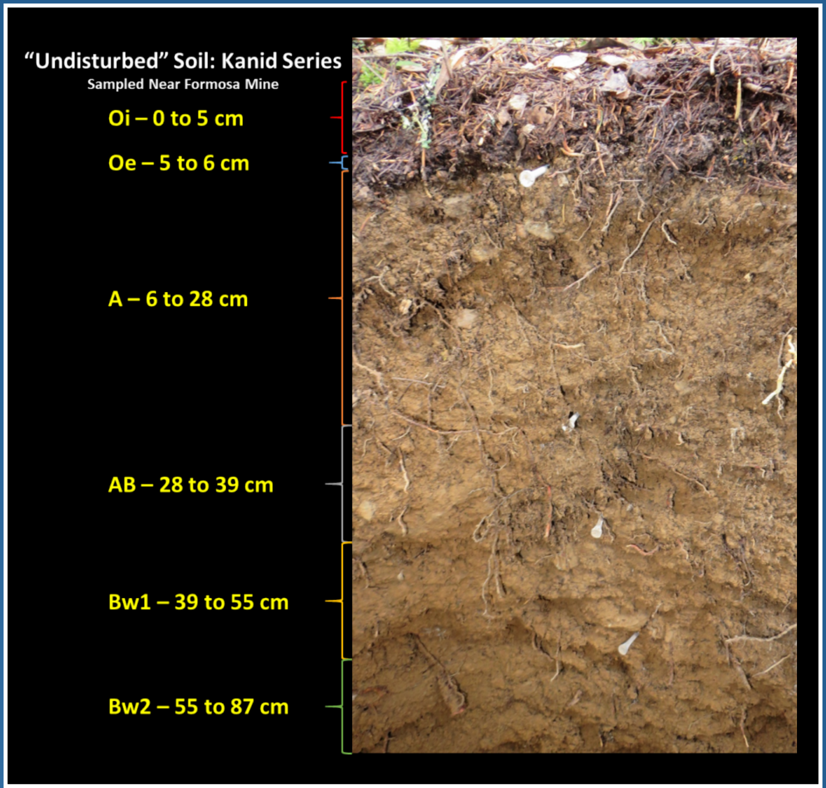
Formosa Mine Site Example



Formosa Mine Remediation - Target Soil

"Spoil Soil"

Target Soil



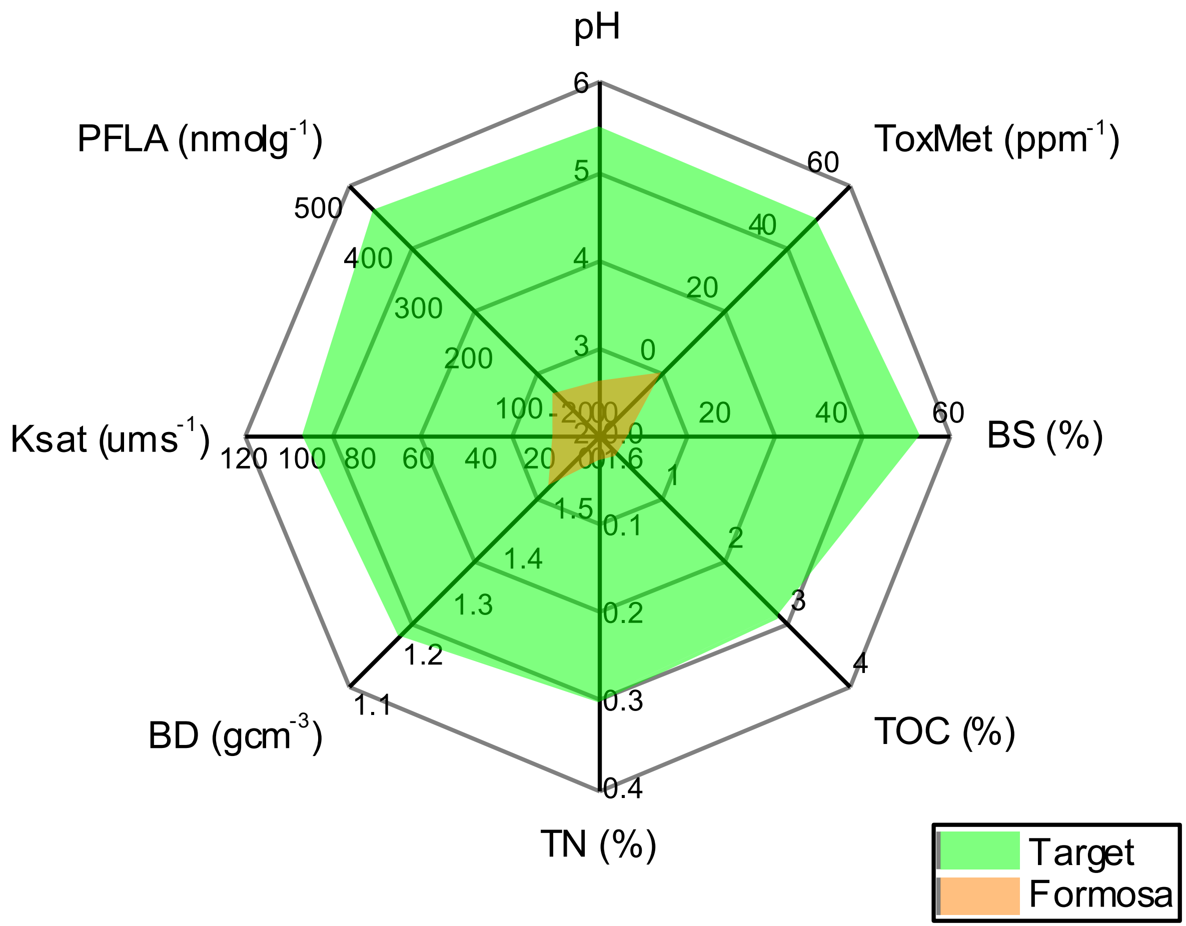
Setting Goals and Tracking Progress

- Target Soil
  - Has properties that approximates soil conditions prior to alteration or disturbance
  - May be difficult to locate
  - May set unrealistic expectations
  - What parameters are important to the remediation?
- Setting Goals
  - What is achievable?
- Remediation priorities
  - Most important
  - Next important…

Formosa Mine Example

Count	Parameter	Units	Range	Target Soil	Actual
1	pH	pH	2.0 - 7.5	5.5	2.6
2	Σtoxic metals^{-1}	ppm^{-1}	0 - 50	50	0.0001
3	Base Saturation	%	0 - 75	55	5
4	TOC	%	0.1 - 3.5	2.9	0.3
5	TN	%	0.01 - 0.35	0.3	0.03
6	Bulk Density	gcm^{-3}	1.0 - 1.5	1.2	1.5
7	Ksat	µmsec^{-1}	0 - 100	100	15
8	Microbes (Total PFLA)	nmole/g soil	0 - 500	450	85

Radar Plots: Setting Goals and Tracking Progress



Developing the Soil Amendment Prescription

From our Formosa site characterization we know that the site soil

- Has a very low pH
  - And consequently high metal availability that is toxic to plants
- Has low organic matter
- Has low nutrient status
- Lacking soil biology
- Poor water holding properties

The Soil Amendment Remedy Must Include

- Lime
- Organic Matter
- Nutrients

We considered site conditions and the Target Soil to identify appropriate soil amendments

- Lime – neutralization of acidity
- Biosolids – nutrients and organic matter
- Biochar – metal sorption, organic matter and water holding
- Locally Effective Microbes (LEM) – soil biology

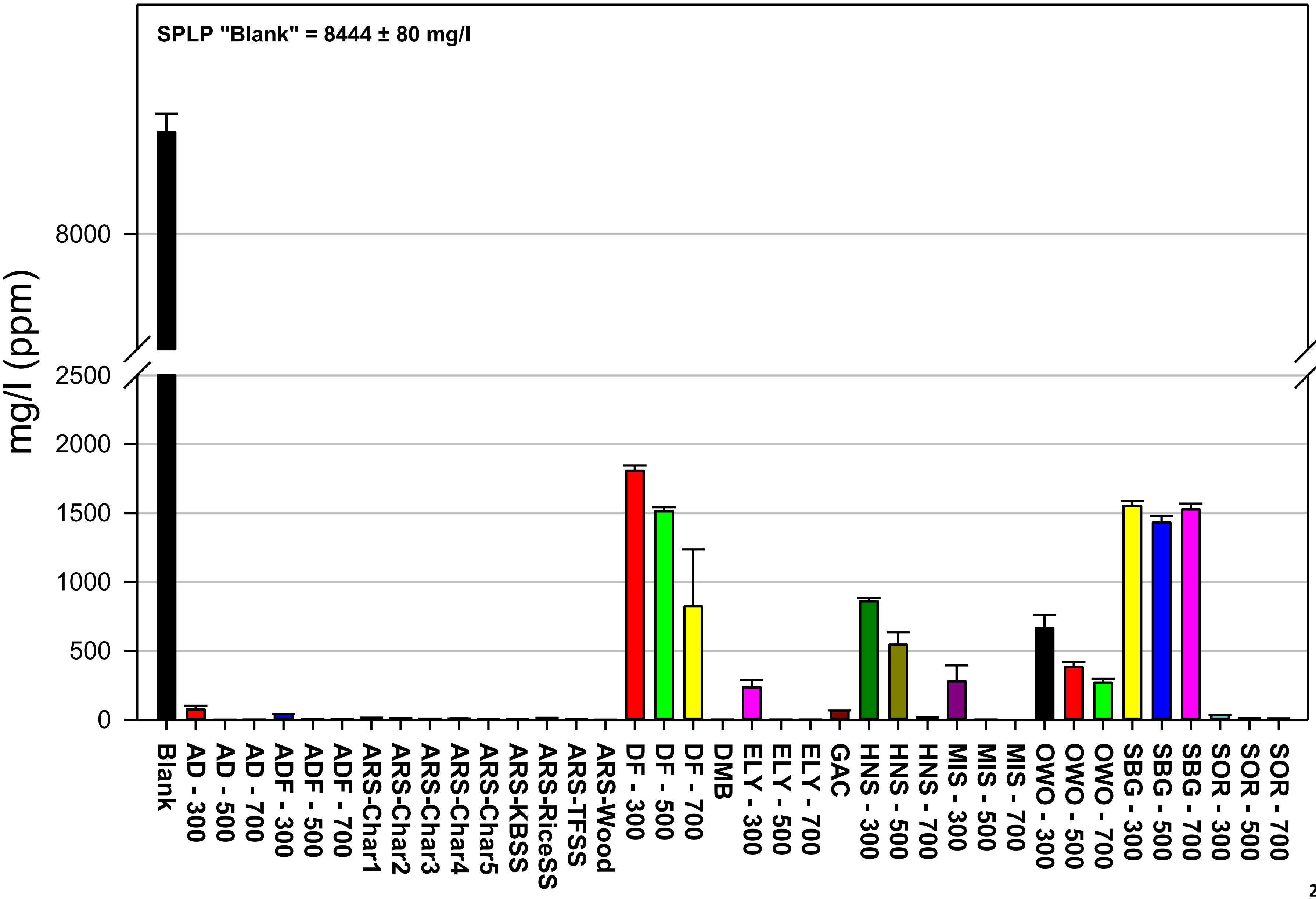
Screening Biochars for Amending the Formosa Mine Spoil Soil

Three step laboratory process:

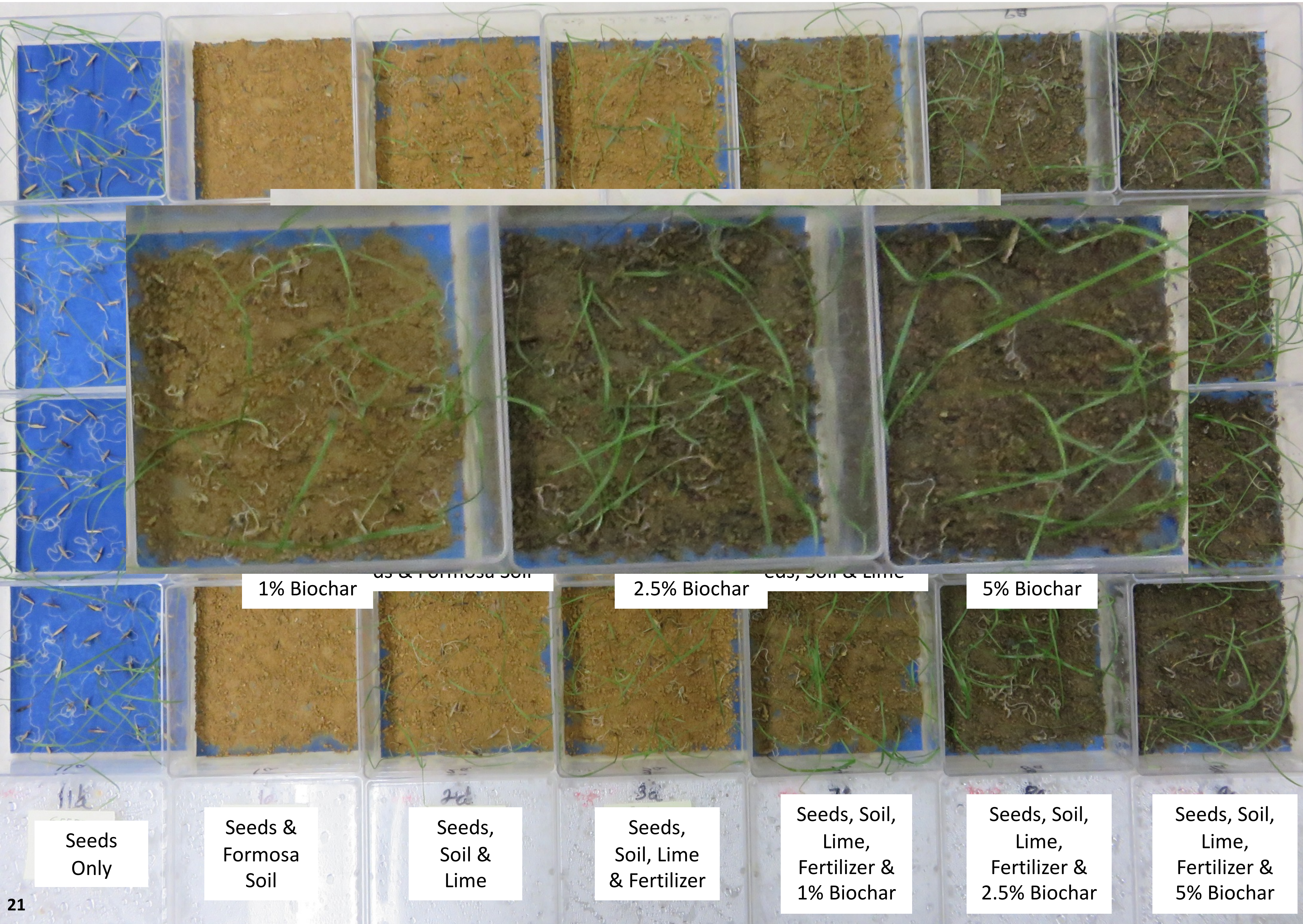
1. Challenge candidate biochars (we used 38 biochars from our "Biochar Library") with SPLP[†] extract of metal contaminated soil (Formosa Spoil Soil)
2. Determine metal binding characteristics of tested biochars
3. Select "best" biochars , as indicated from #1 and #2 above, and conduct a direct Formosa Soil:Biochar incubation to determine best performing biochar

[†]Synthetic Precipitation Leaching Protocol (EPA SW 846 Test Method 1312)
http://www.epa.gov/osw/hazard/testmethods/sw846/pdfs/1312.pdf

Solution Zn Concentration

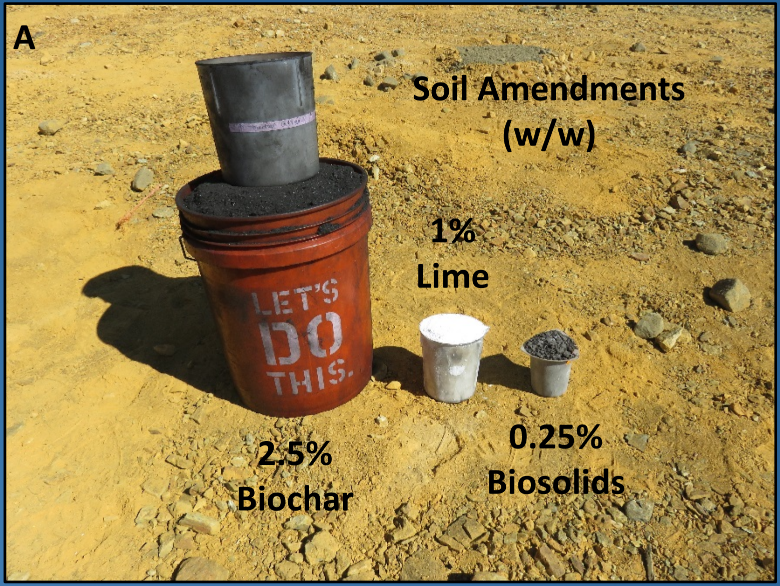


Seed Germination Study: Formosa Mine Spoil Soil, Amendments and Biochar



Greenhouse Trials for Formosa Mine: Dialing in Biochar and Amendments for Trees

Preparing the Formosa Site for Planting Trees



Formosa Mine Field Trials

- 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 were planted in November 2017
  - Rhizosphere soil inoculated with native soil and LEM
- In the fall of 2018 the area between rows was prepped and soil amendments added
  - These plots were planted with native herbaceous plants in April 2019

Herbaceous Plot Prep and Planting

Plot Prep – Fall 2018

Planting – Spring 2019

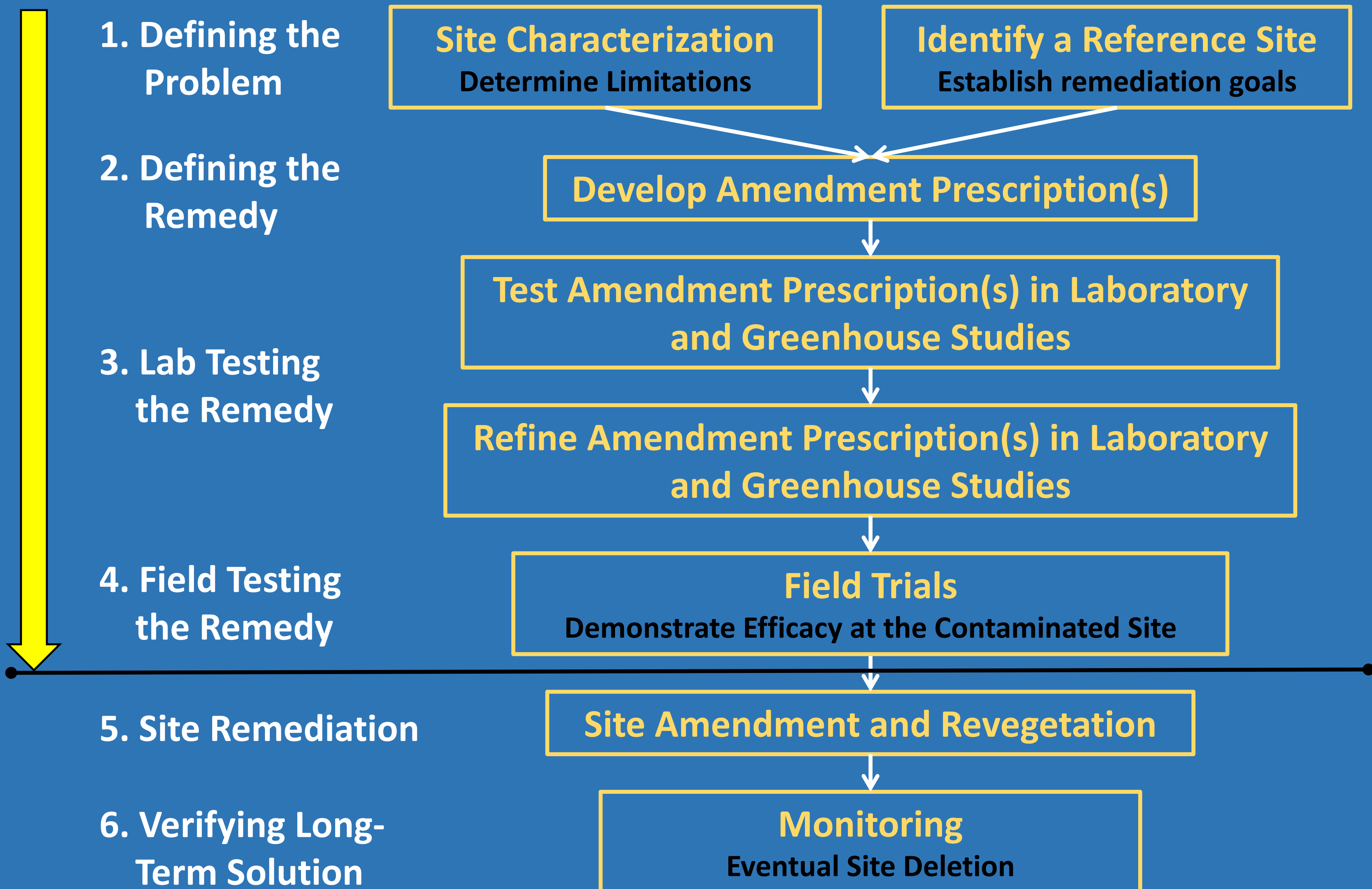

9/13/19
No Amendments


9/13/19
Amendments w/o Biochar


9/13/19
Amendments with Biochar


9/13/19
Tree Growth in 2019

Applying the Framework for Amending Mining Impacted Soils at the Formosa Mine



Outlook for the Future

- Strategic use of soil amendments has a bright future for *in situ* site remediation, re-vegetation and revitalization, and reuse of contaminated soils
  - They can also be beneficial to repair degraded soils
- Given other options, soil amendments can be a cost-effective means of long-term restoration of contaminated sites
- It takes good data, planning and testing to develop a viable contaminated soil amendment prescription
- We've presented a Systematic Framework for Amending Mining Impacted Soils to Sustainably Grow Vegetation that provides stepwise guidance for developing an effective soil amendment prescription
- Biochar is effective soil amendment that should be considered for reducing exposure to inorganic and organic contaminants, adding carbon to soils and improving soil water holding properties

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