Control of Water-soluble Metals and Revegetation of Acidic Mine Waste by Soil Remediation

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Benefits of Revegetation and Control of Water Soluble Soil Metals

- Infiltration increased
- Runoff decreased
- Evapotranspiration increased
- Metal loading to shallow groundwater and surface water decreased
- Soil surface stabilized against erosion
- Direct contact risk decreased by establishment of vegetation litter layer
- Contaminant bioavailability, toxicity and mobility decreased

Non-acidic Mine Tailings and Vegetation Recovery

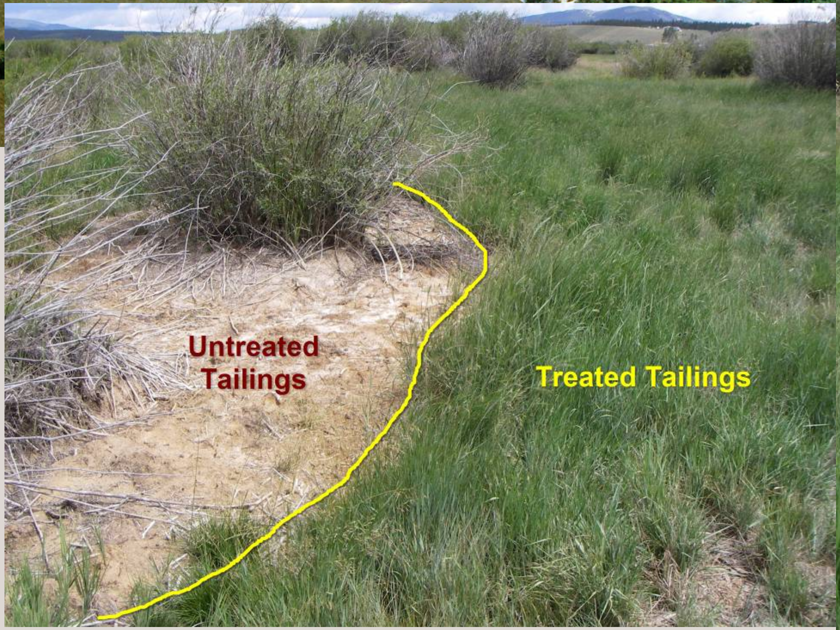
Photo courtesy of Montana Historical Society, FJ Haynes Collection

1895

1999

Acidic Mine Tailings Deposited ~1908 and Lack of Vegetation Recovery

Soil Treatment with Amendments



Pioneering Work done by the USFS Rocky Mountain Research Station

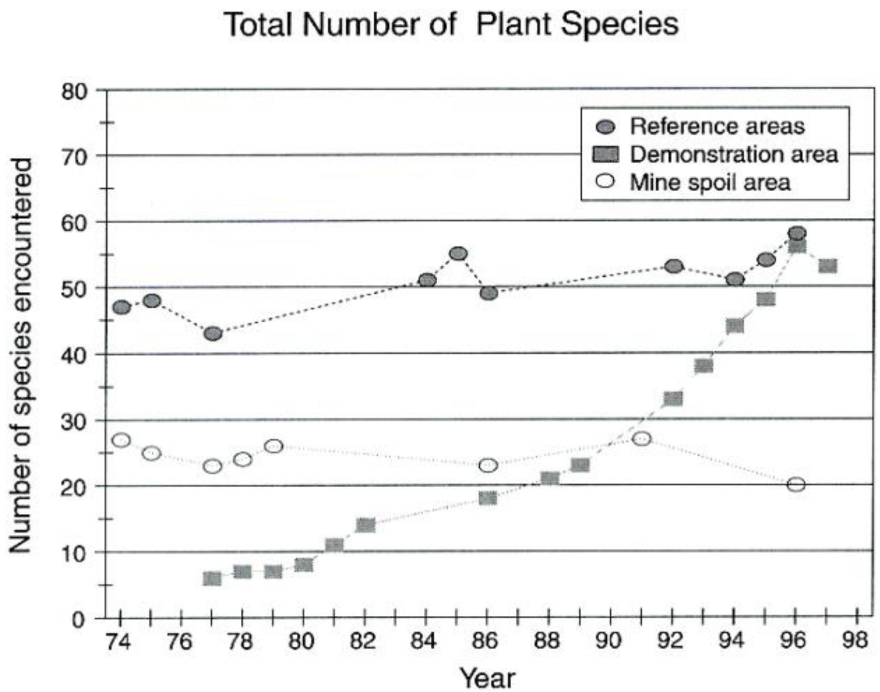
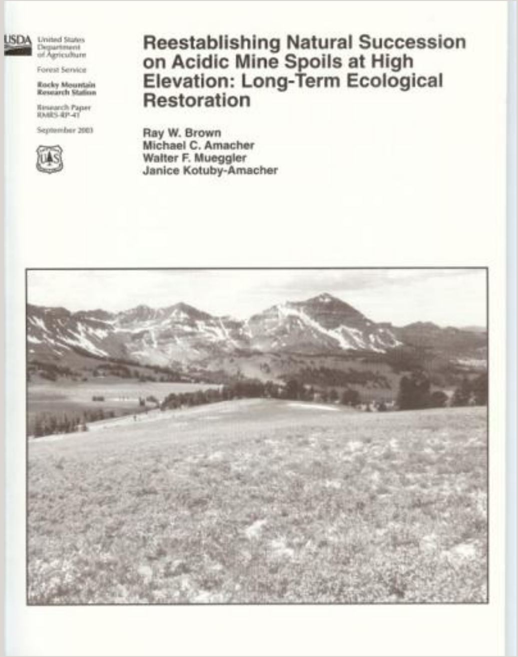


Figure 10—The number of vascular plant species observed in the seeded demonstration area, adjacent native reference communities, and in successional areas on mine spoil between 1974 and 1998.

USDA Forest Service Res. Pap. RMRS-RP-41. 2003



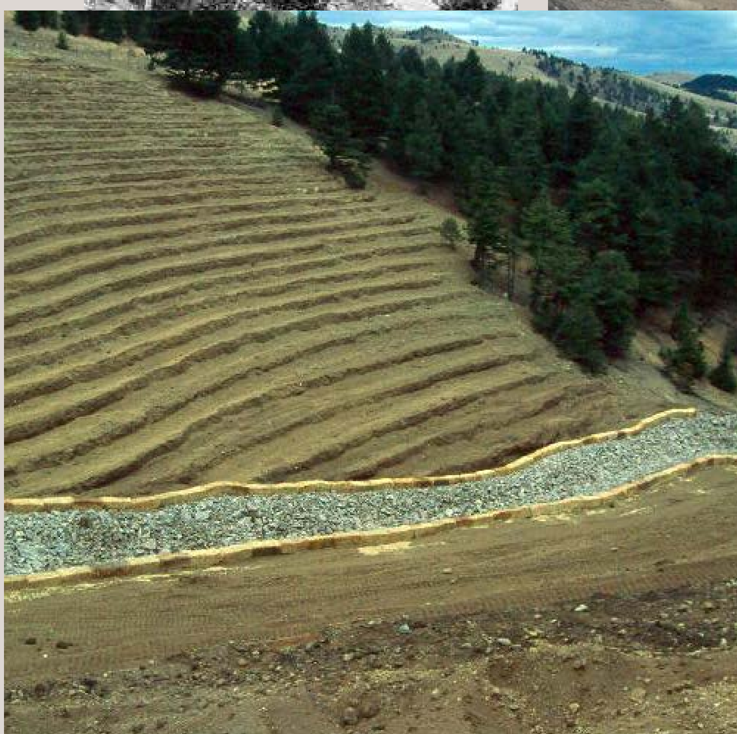
Reestablishing Natural Succession on Acidic Mine Spoils at High Elevation: Long-Term Ecological Restoration

Ray W. Brown
Michael C. Amacher
Walter F. Mueggler
Janice Kotuby-Amacher

From Brown, et al. 2003, Reestablishing Natural Succession on Acidic Mine Spoils at High Elevation: Long-Term Ecological Restoration

Direct Revegetation without Amendments




The Solubility and Mobility of Metals Increases Appreciably with Increasing Acidity

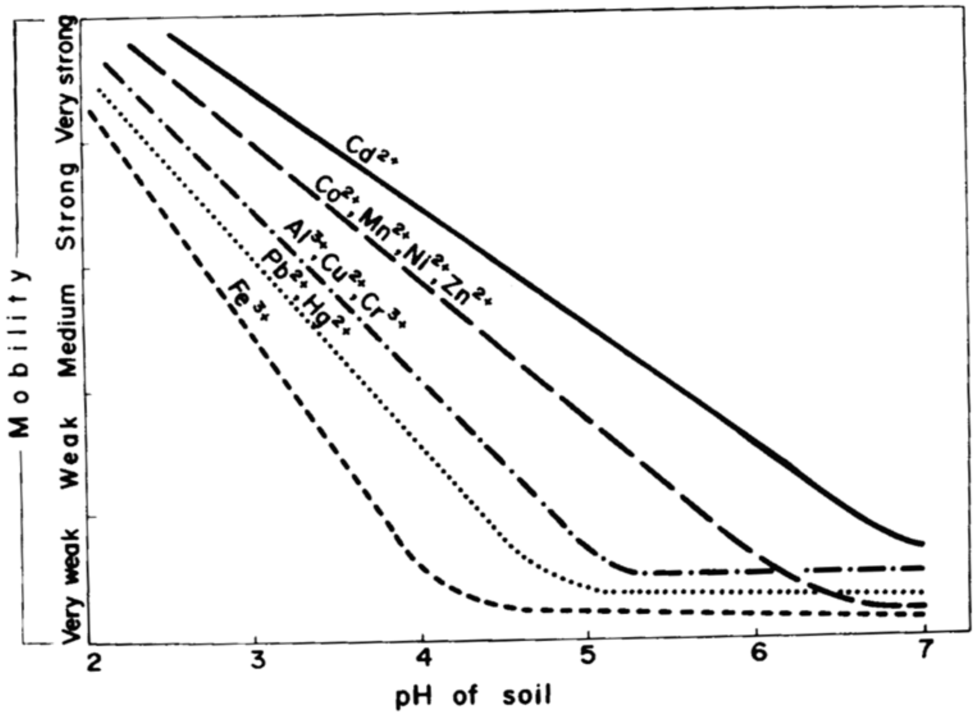
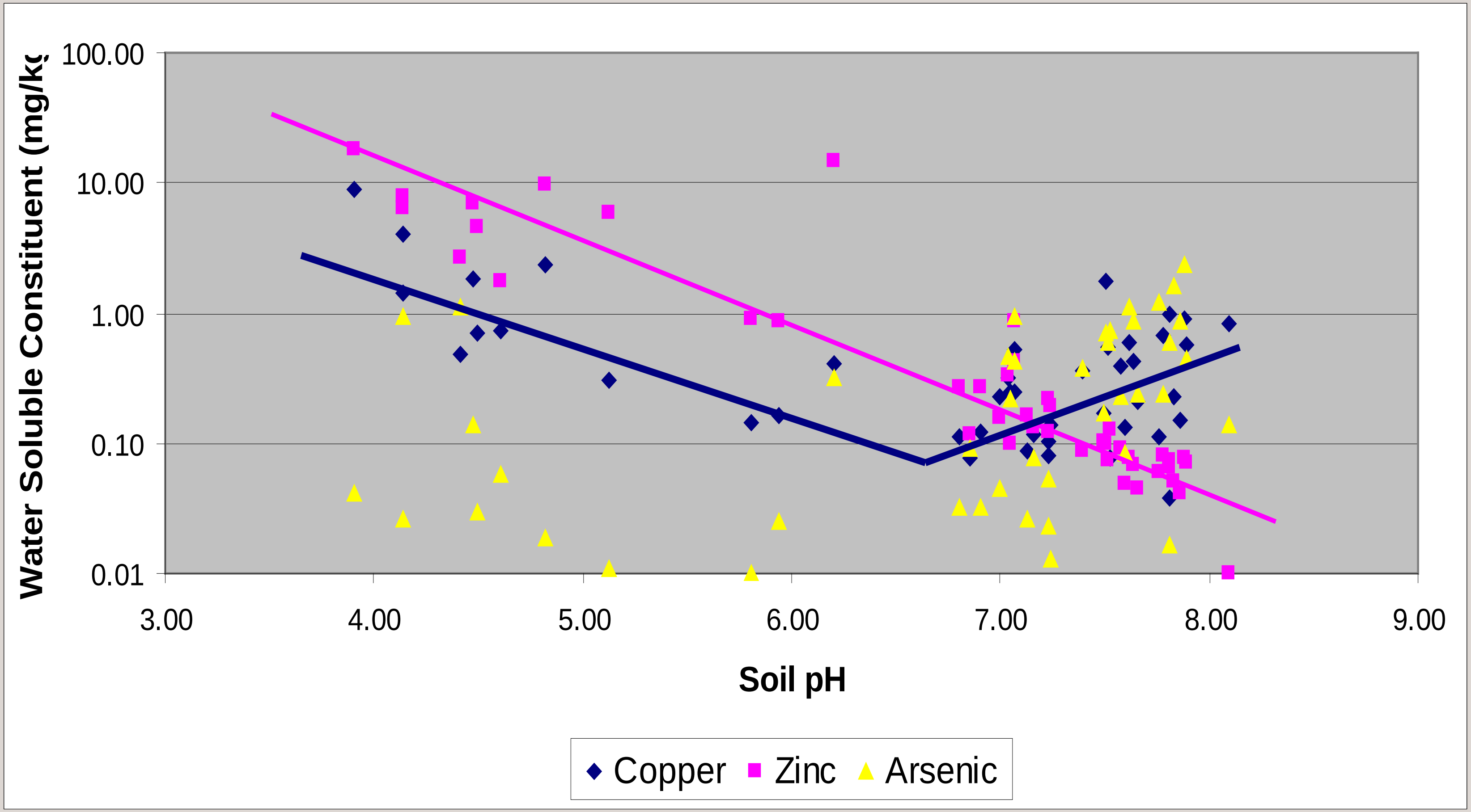
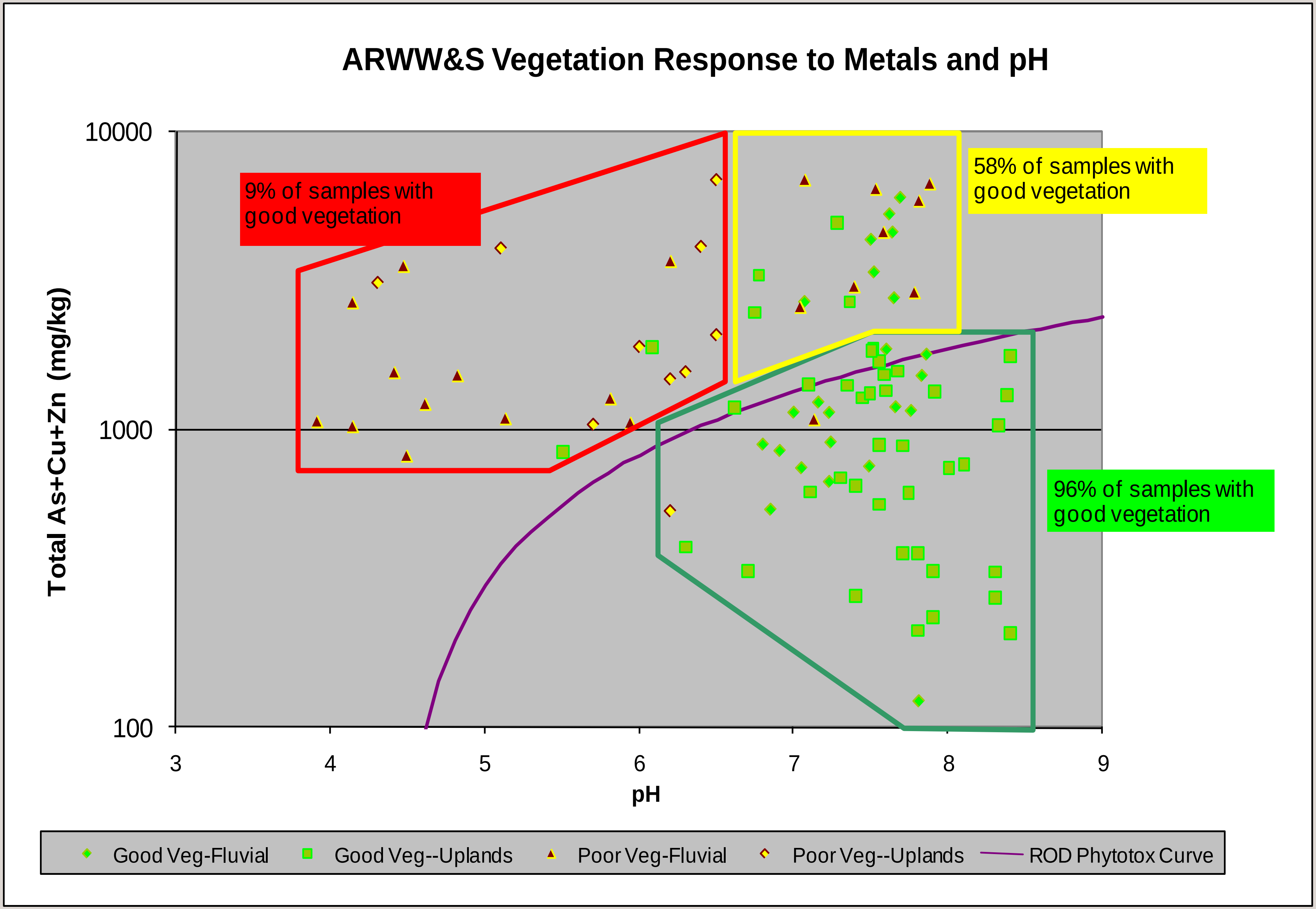


FIGURE 13. Schematic trends in the mobility of metals as influenced by soil pH. (Data for light mineral soil.)

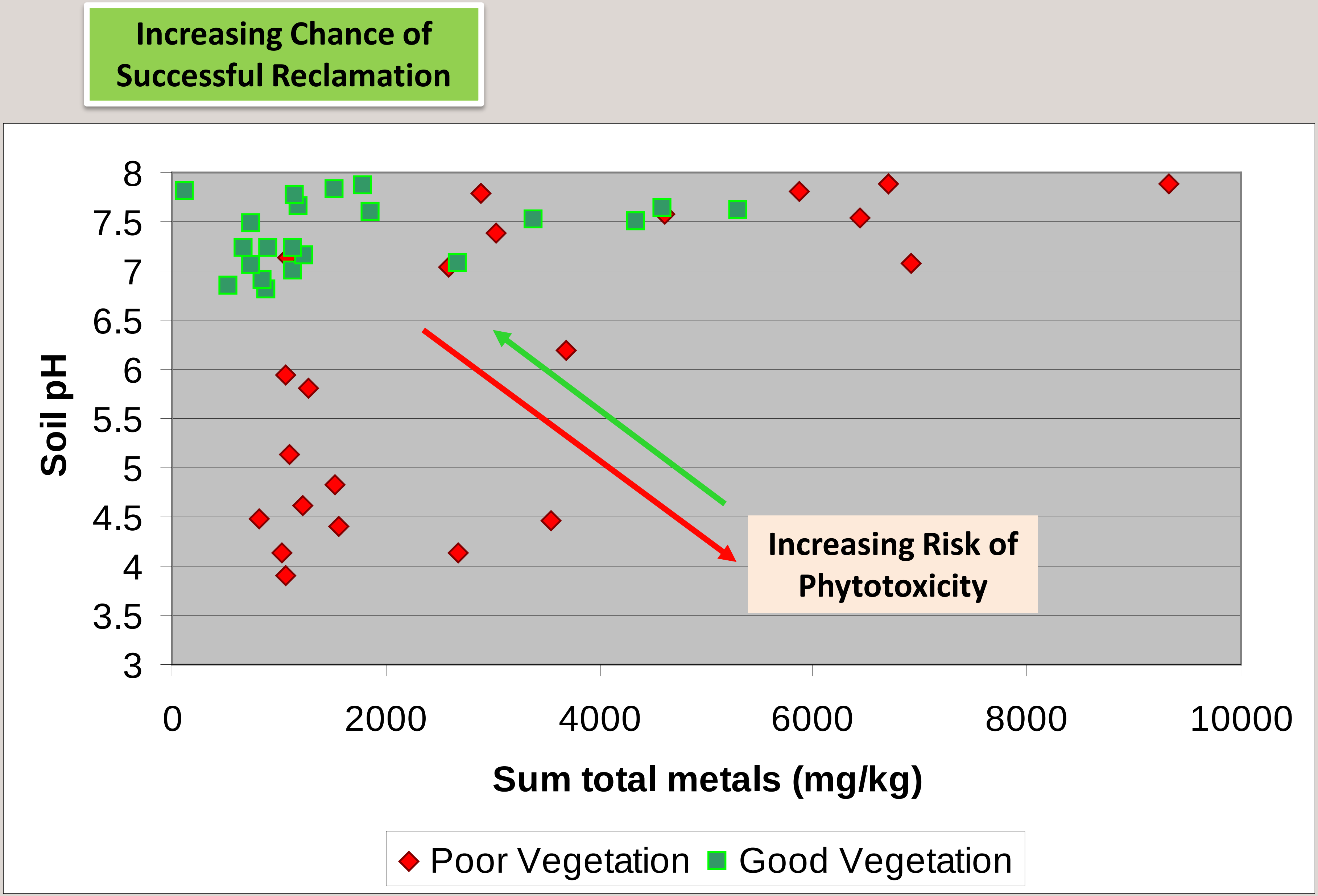
Kabata-Pendias and Pendias (1992)

Water Soluble Chemistry--Anaconda Smelter NPL Site

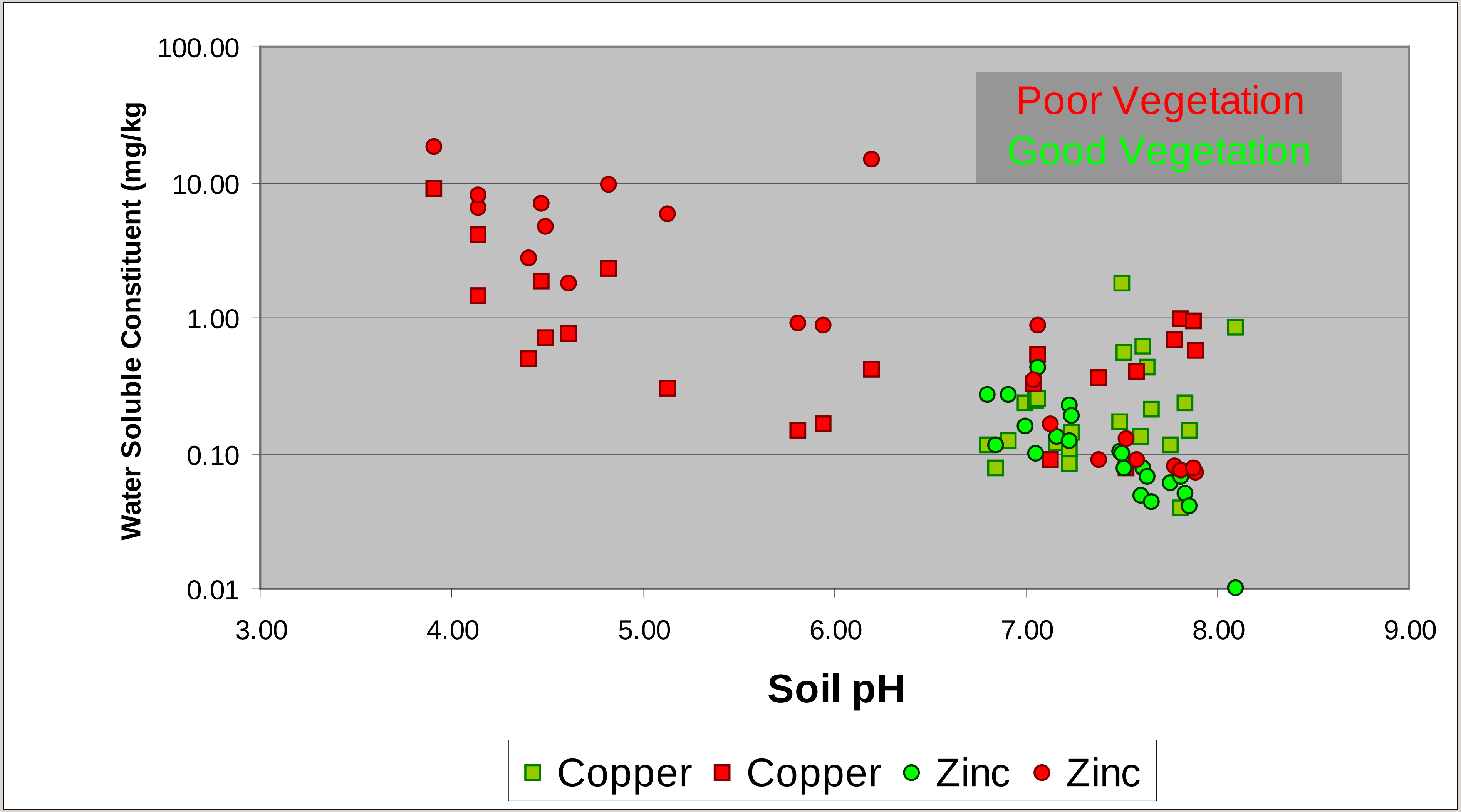




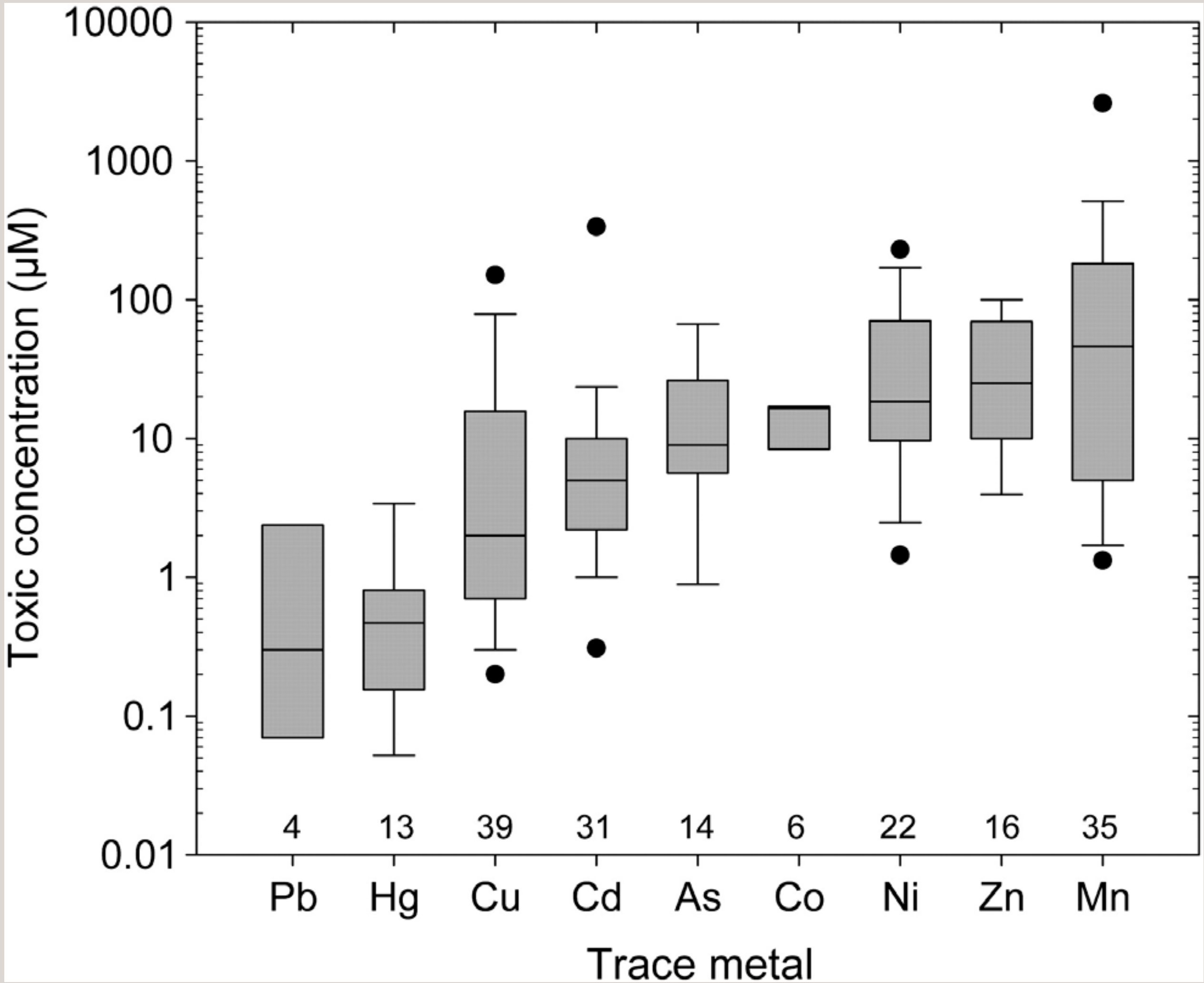
ARWW&S Vegetation Response to Metals and pH
9% of samples with good vegetation
58% of samples with good vegetation
96% of samples with good vegetation
10000
1000
100
Total As+Cu+Zn (mg/kg)
3
4
5
6
7
8
9
pH
Good Veg-Fluvial
Good Veg--Uplands
Poor Veg-Fluvial
Poor Veg--Uplands
ROD Phytotox Curve


Increasing Chance of Successful Reclamation
Soil pH
8
7.5
7
6.5
6
5.5
5
4.5
4
3.5
3
0
2000
4000
6000
8000
10000
Sum total metals (mg/kg)
Increasing Risk of Phytotoxicity
Poor Vegetation
Good Vegetation

Vegetation Condition and Water Soluble Chemistry



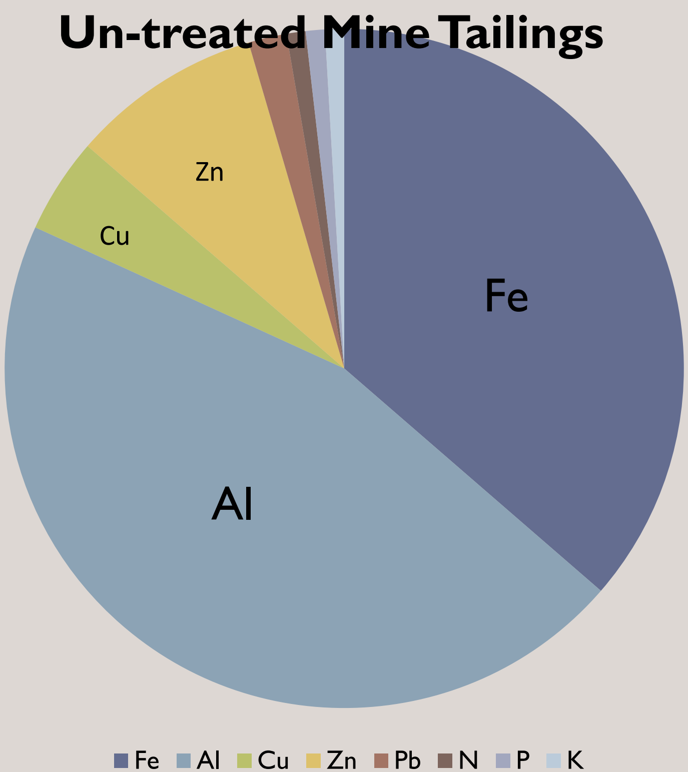
Concentrations of nine trace metals that reduced the growth of plants in solution culture, obtained from a review of the literature from 1975 to 2009 (n=180).



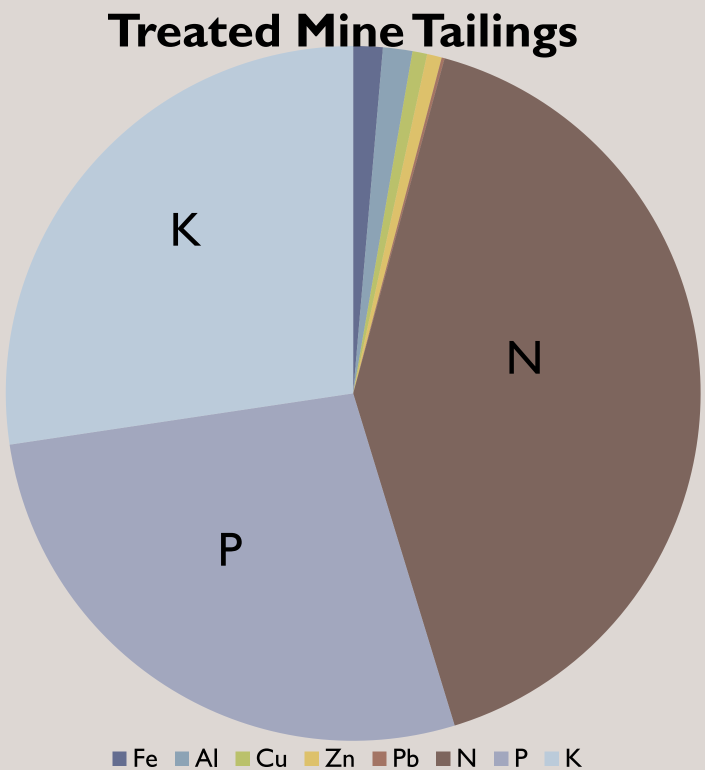
Kopittke P M et al. J. Exp. Bot. 2010;jxb.erp385

JOURNAL OF Experimental Botany

Soil Solution Chemistry and Water Soluble Metal Distribution
(Total Metal Levels are Unchanged in these Examples)



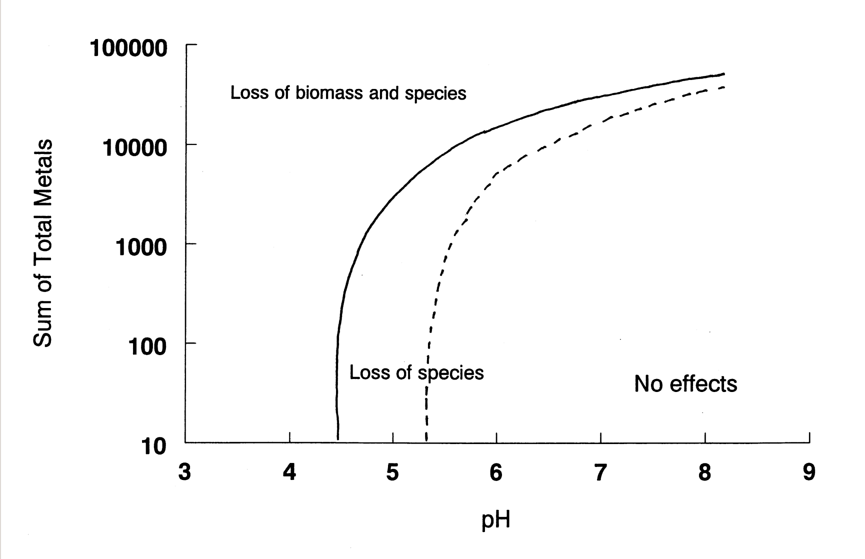
Acidic soil pH



Neutral soil pH

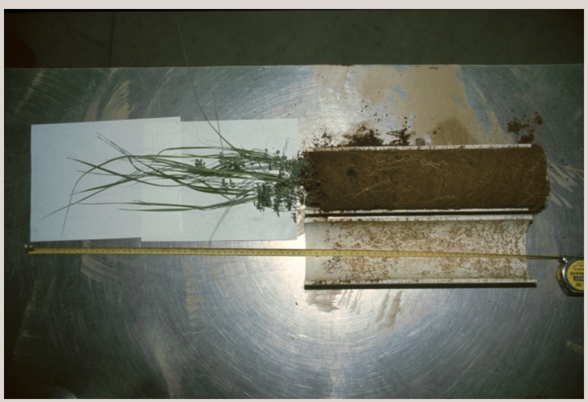
Streambank Tailing and Revegetation Study (1987-1991)

Clark Fork River “Governor’s Demonstration” 1990

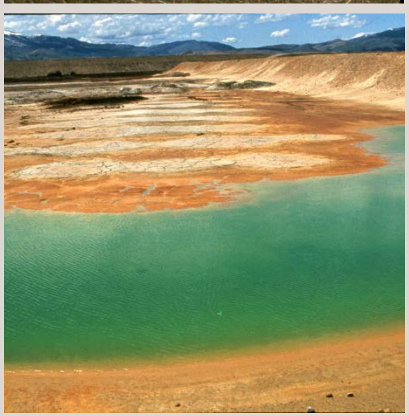


A 20 Year History of the Remediated Pastures, 'Governor's Demonstration' Clark Fork River, MT

Anaconda Revegetation Treatability Study (1992-1997)

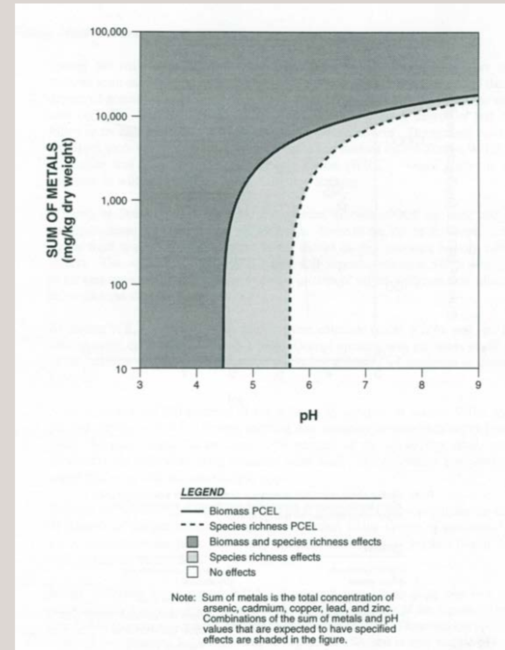


Anaconda Regional Water, Waste and Soil NPL Site (1997-present), Anaconda, MT



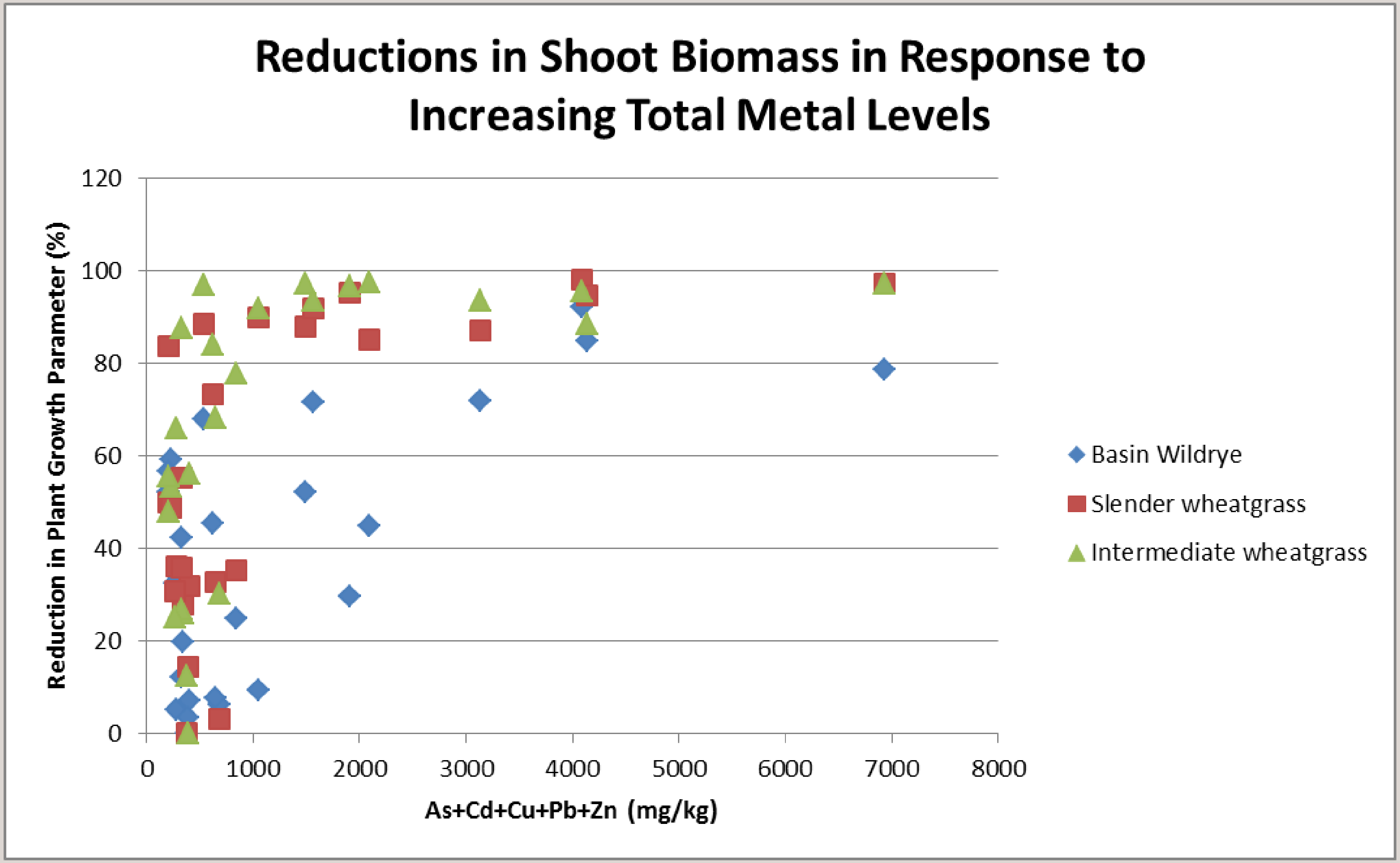
Post-Reclamation Residual Soil Phytotoxicity and Soluble Metal Bioavailability

Anaconda Smelter Site, Montana

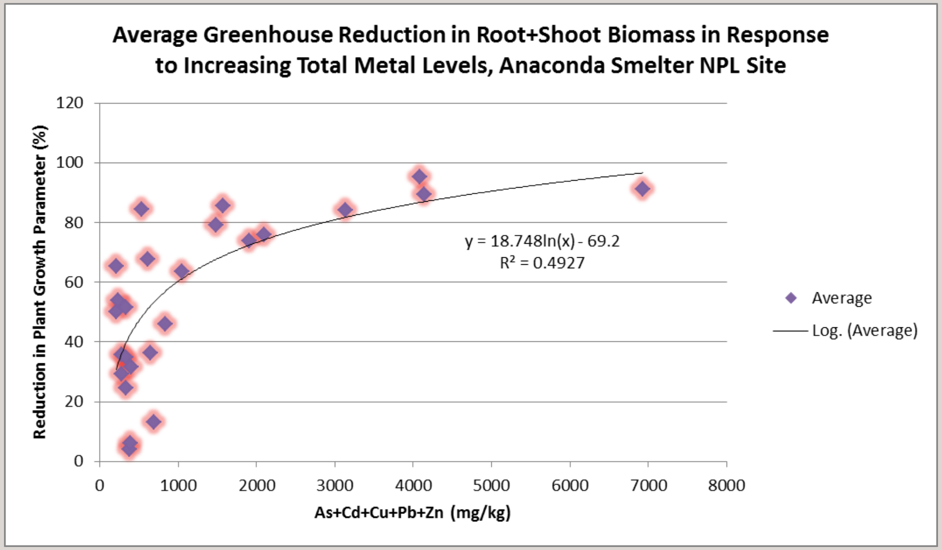


Residual soil phytotoxicity from persistent water soluble metals?

Greenhouse Testing of Reclamation Species in Varying Concentrations of Soil Metals



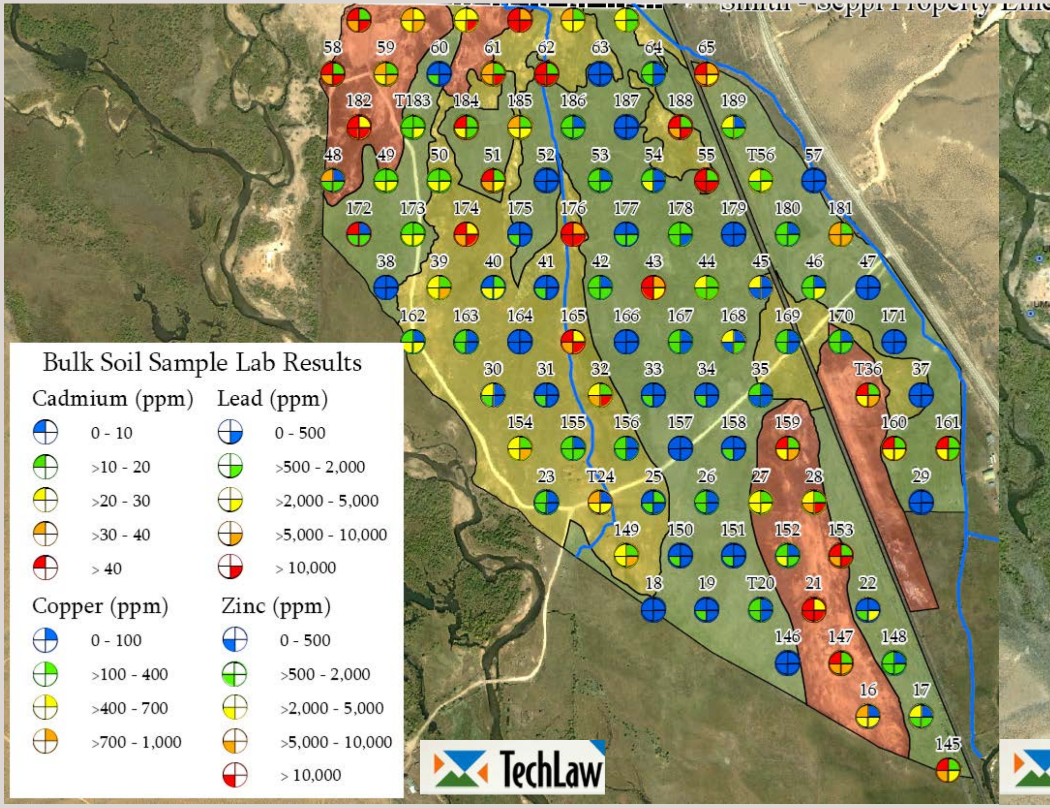
Plant Growth Reduction to Soil Arsenic and Metal Concentration (average for all species and soil types)



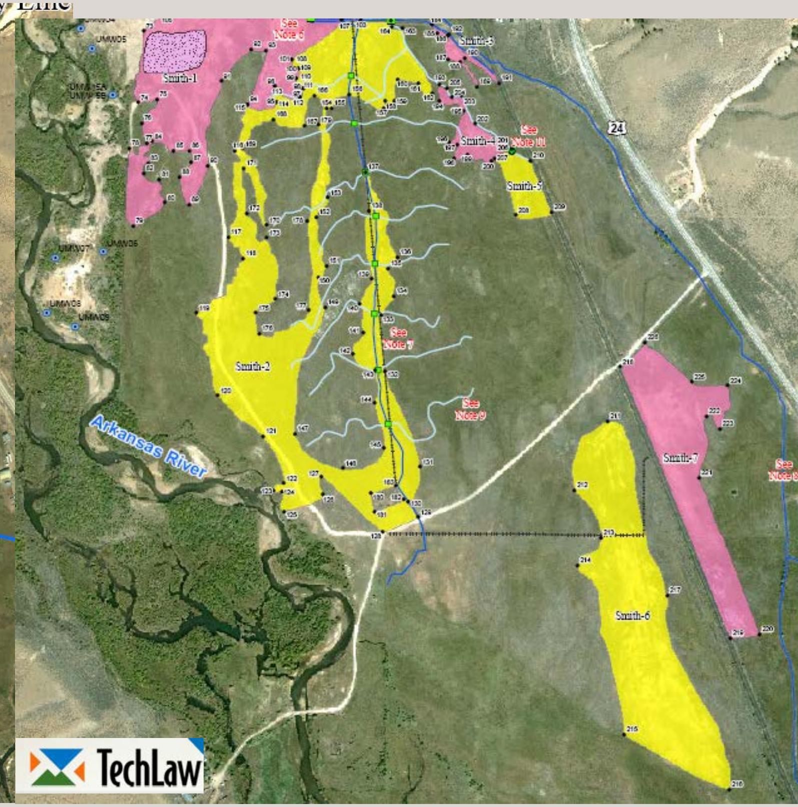
Overall Assessment

- Most areas with extremely high metals have been capped and/or placed in Waste Management Areas
- While phytotoxicity to seeded species is known, overall plant cover is rarely inadequate
- Overall reclamation is successful and compliant with ROD, designs continually evolving
- Landowner management is critical to long-term success

California Gulch NPL Site, OU11, Leadville, CO



2006—Assessment of Soil Metal Levels



2007—Delineation of Soil Treatment Polygons (pink=12 inch tillage, yellow= 6 inch tillage)

Two Treatment Strategies

Irrigated Meadow Contamination

- 153 acres treated to either 6 or 12 inch depth using a tractor-pulled plow
- Thin deposits of relatively uniform depth

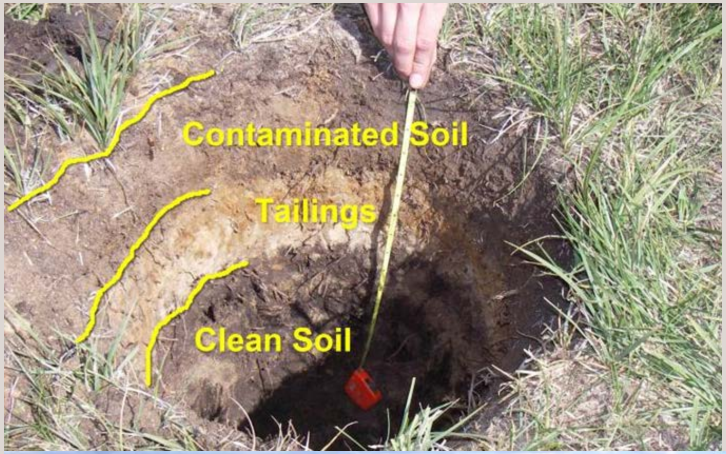
Fluvial Tailing Deposits

- 18 acres treated with an excavator-mounted soil mixer
- Thick deposits of varying depths within the floodplain

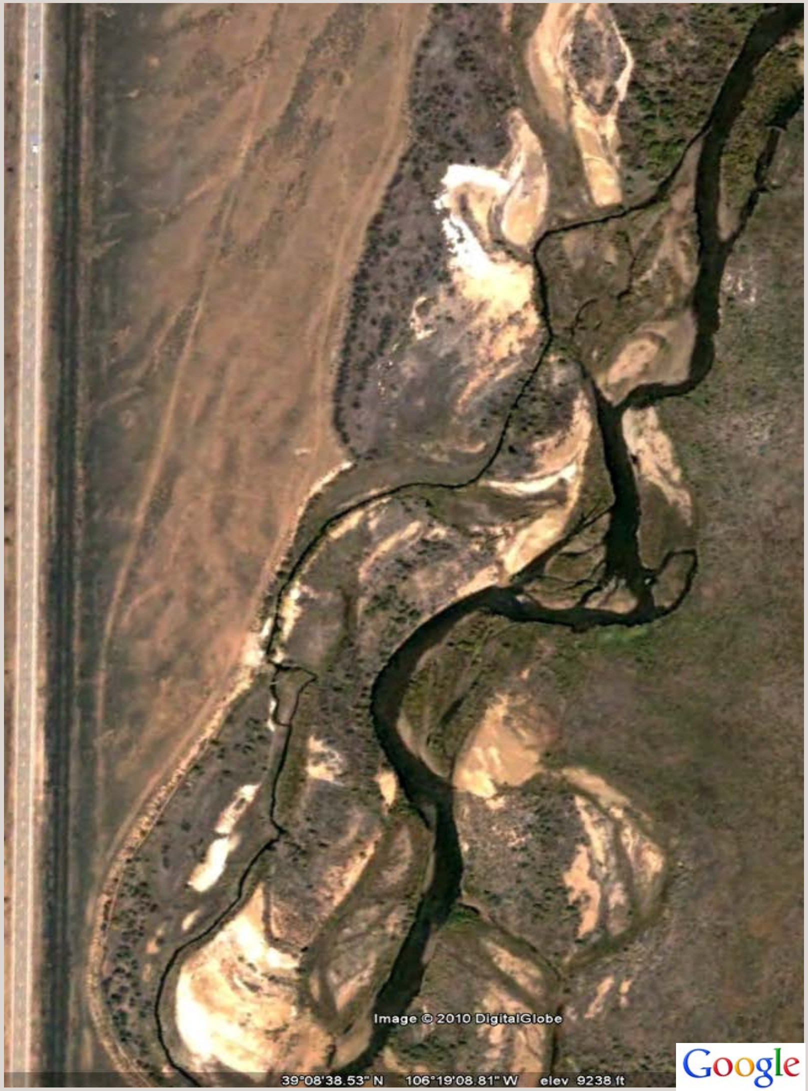
Arkansas River Metal-Affected Soils

Fluvial Tailing Deposits

Contaminated Soil



Pre-Treatment (~2008)



Post Treatment (~2010)





June 2009

July 2009

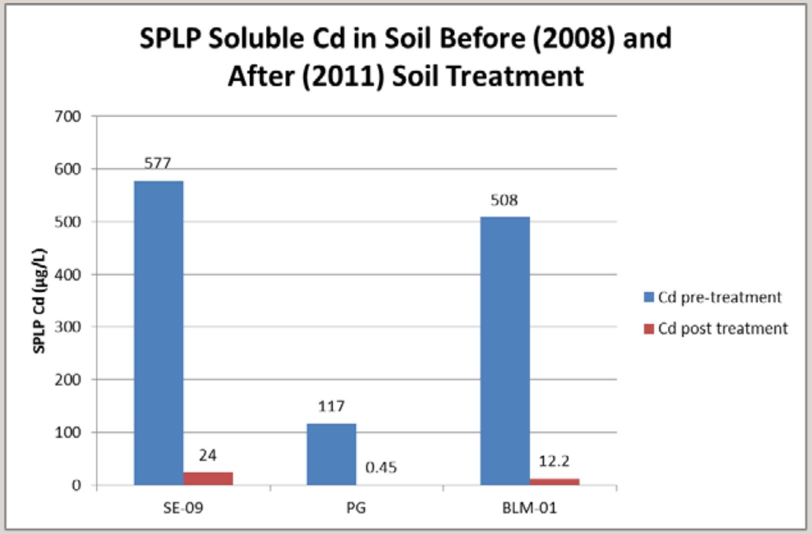

November 2009

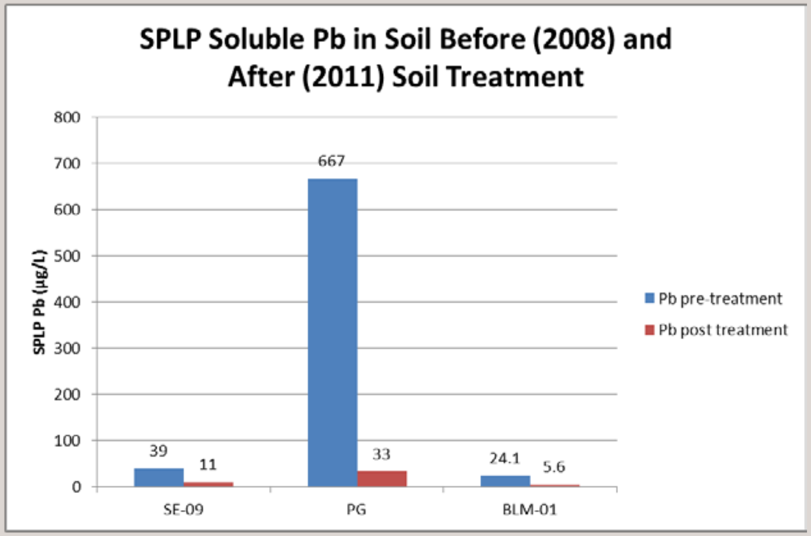

July 2010

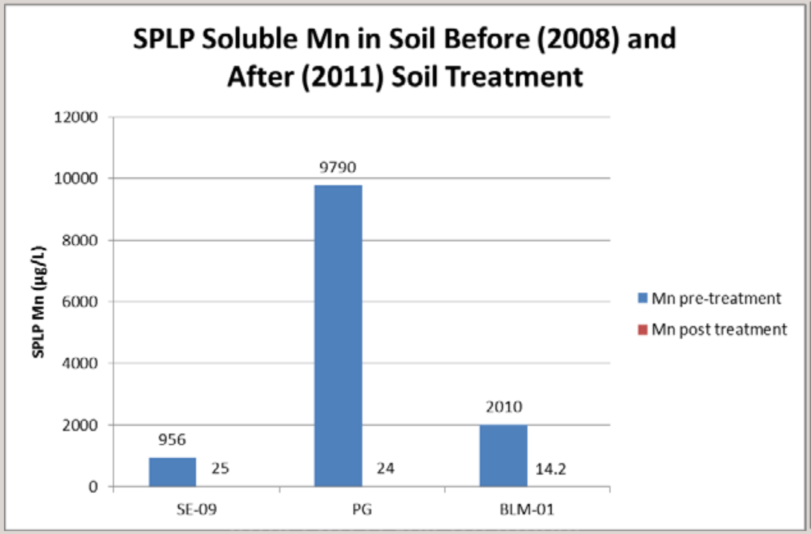

October 2010

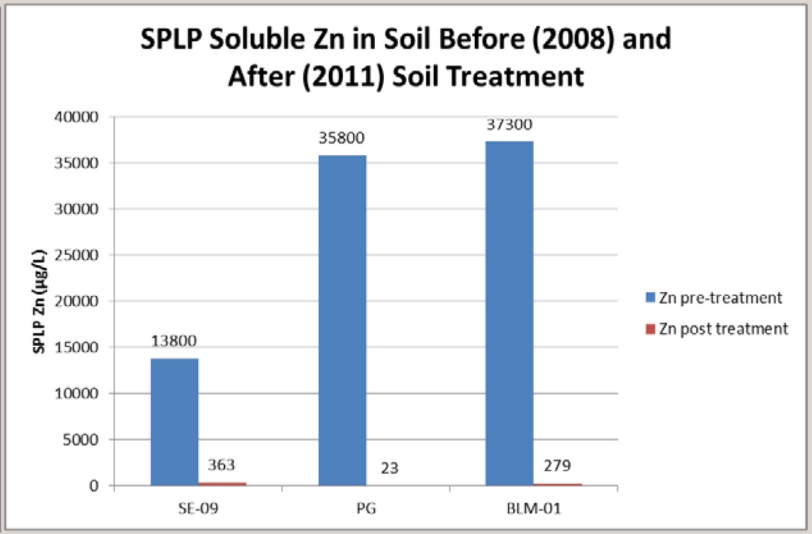
PWT
PACIFIC WESTERN TECHNOLOGIES, LTD.

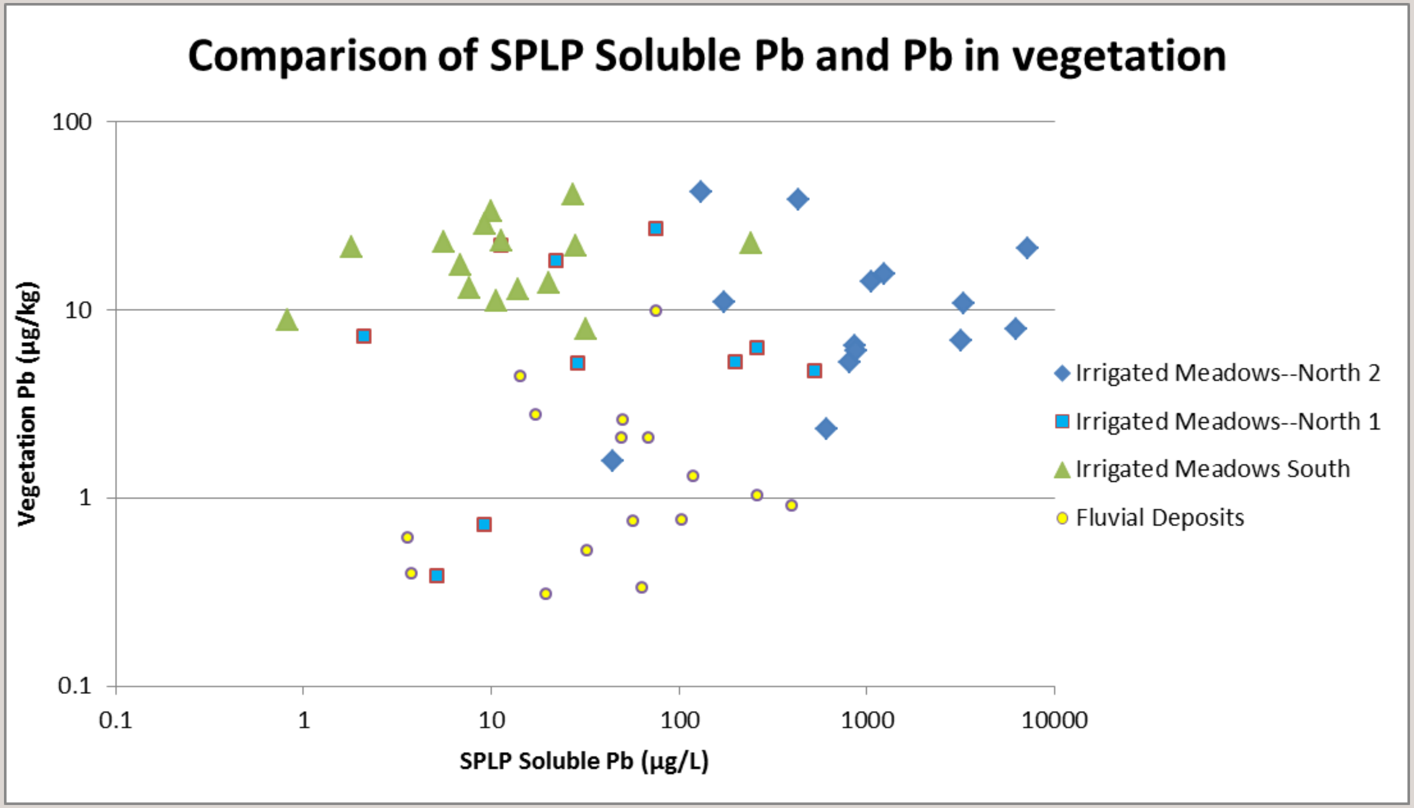
Changes in SPLP Soluble Metal Levels Before and After Treatment











SPLP soluble Pb appears to provide good discrimination of Pb in vegetation by site location

Fluvial Deposit QF

Control of Water Soluble Metals through Soil Amendment and Revegetation Strategies

Strengths

- Lower cost technique
- Implementable on varying scale and at remote sites where soil is unavailable
- Effective, permanent fix
- Sites stabilized by vegetation
- Ecological risk diminished
- Water balance improvement
- Native perennial grass seed mixes readily reestablished

Weaknesses

- Metals remain in the soil
- Metals can translocate into above ground species (varies by species)
- Metals can be physically eroded
- Native forbs have proven difficult and expensive to reestablish
- Direct contact and dust inhalation hazards not entirely mitigated

Effectiveness of Soil Remediation Using Amendments to Control Water Soluble Metals

- Technology developed over the past ~50 Years
- Selected for remediation of 1000's of acres at multiple sites across the Western U.S.
- Treatments have persisted over time
- Limitations are known, subject to site-specific design
- Agency, contractor, public acceptance

10 year old treated tailings

Livestock grazing remediated land