REMEDIATION OF THE MILLTOWN DAM SEDIMENTS IN MONTANA

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Reclamation Research Group
A Division of

KC Harvey Environmental LLC

2014 Annual Conference
Mine Design, Operations & Closure
Fairmont Hot Springs
Montana

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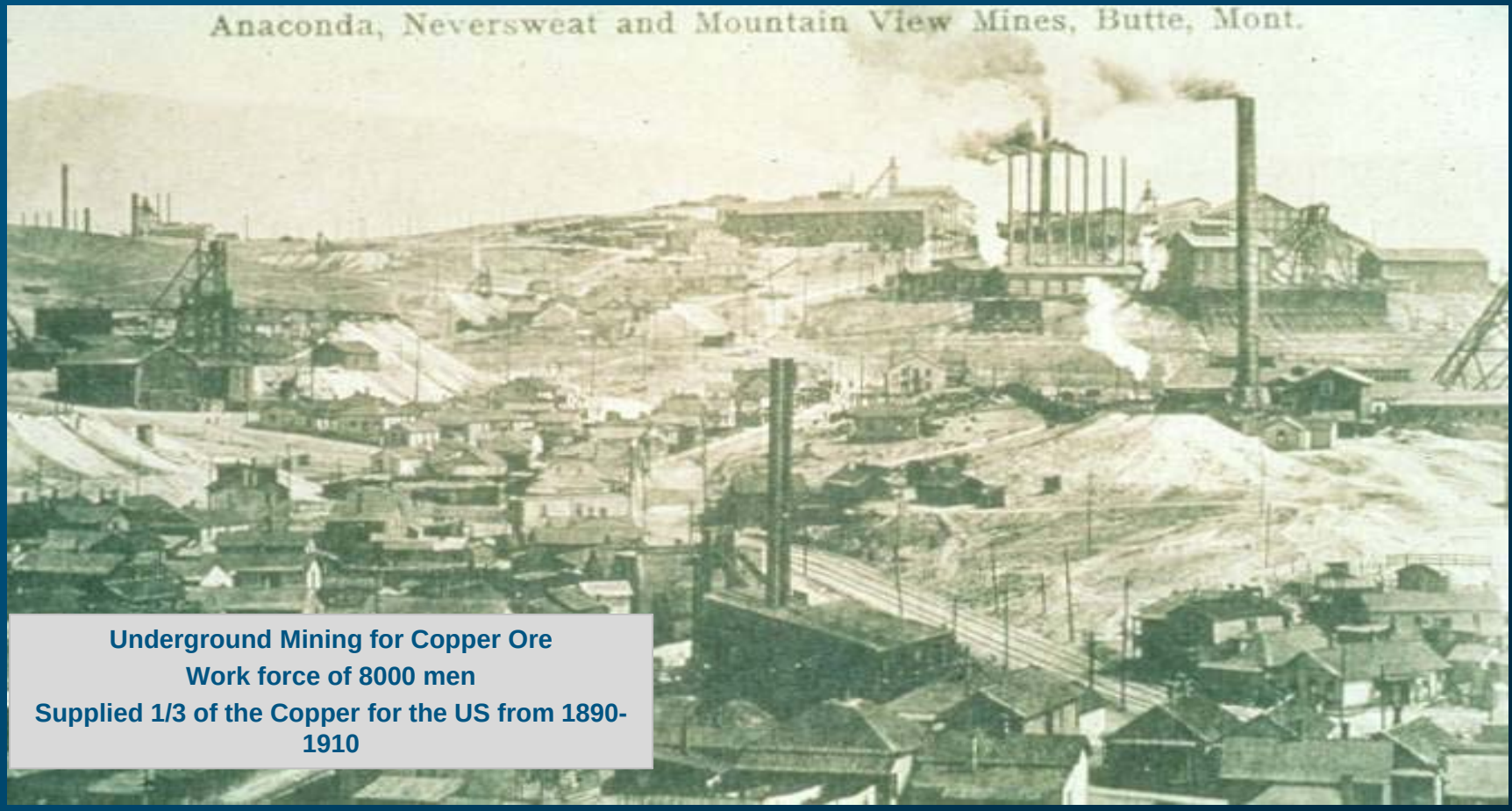
April 30, 2014

Butte Montana ~1900



Underground Mining for Copper Ore

Work force of 8000 men

Supplied 1/3 of the Copper for the US from 1890-1910

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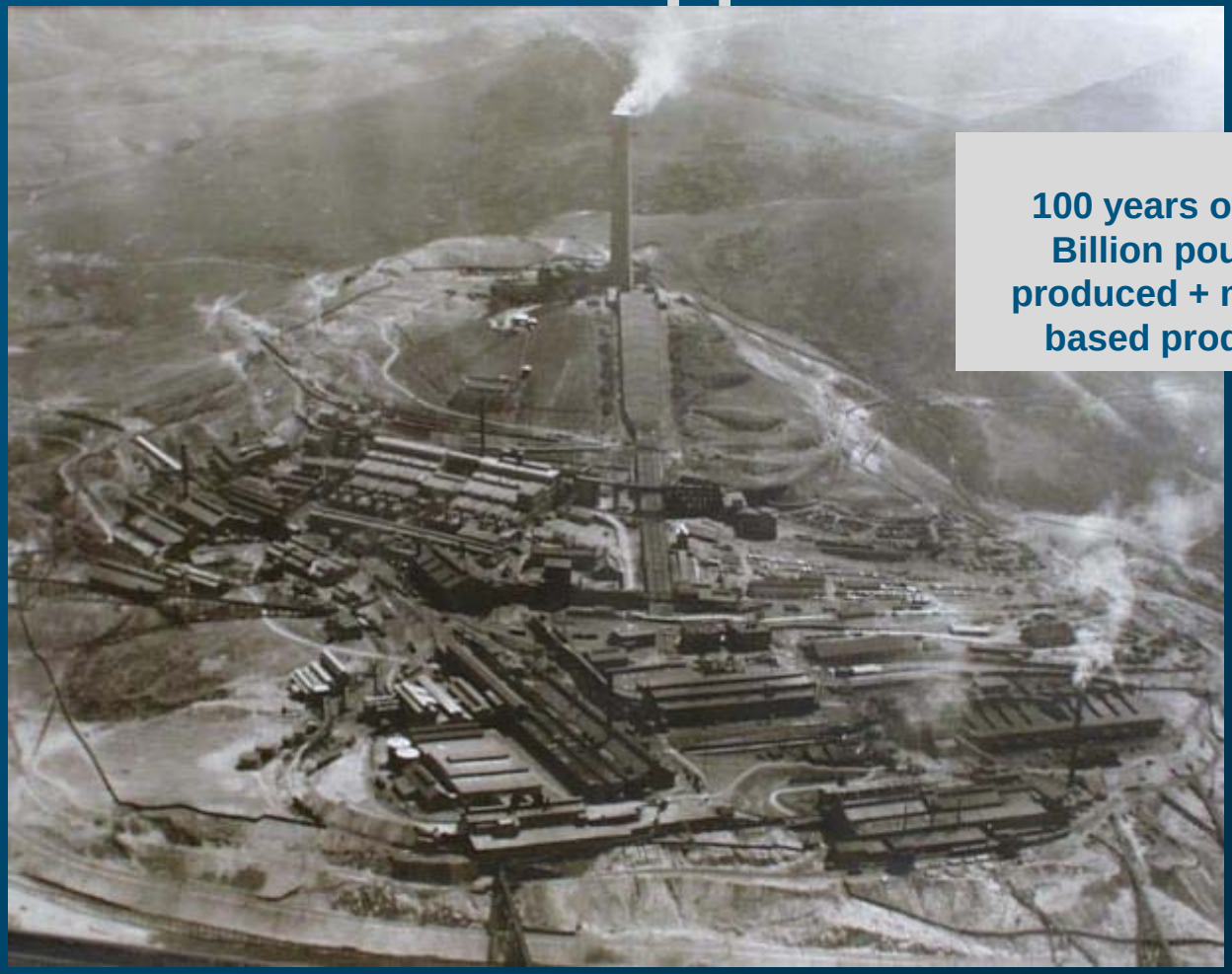
Anaconda Copper Smelter



100 years of operation – 22 Billion pounds of copper produced + many other metal based products and AsO_3

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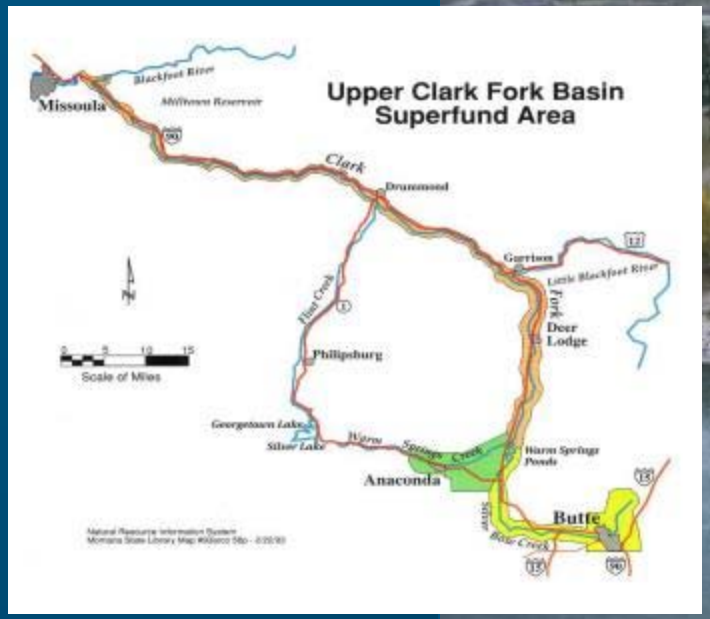
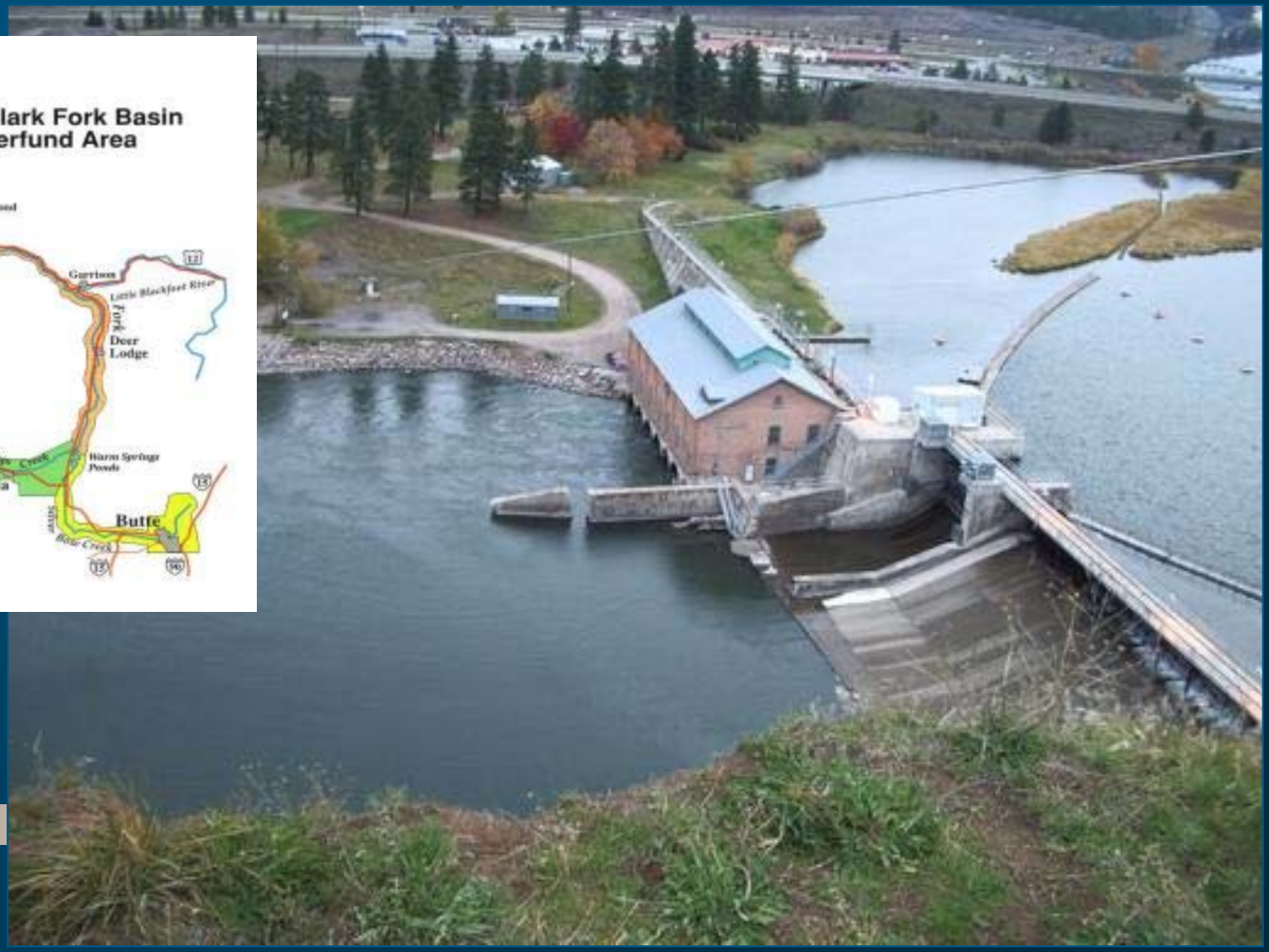
Multiple- Superfund Sites

Butte-Silver Bow Creek
Anaconda Smelter
Clark Fork River - Milltown Dam





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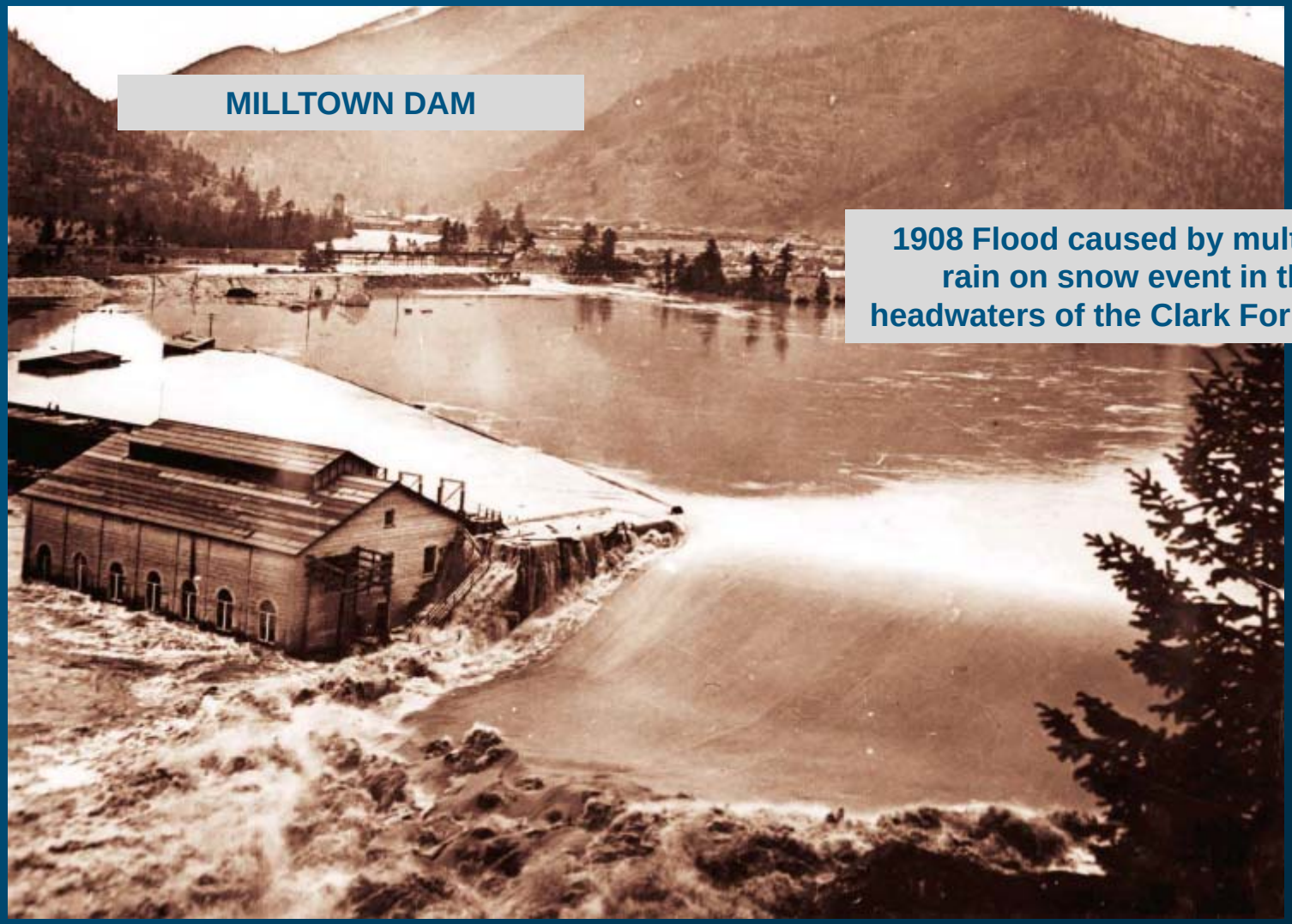

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Fluvially Deposited Mine Wastes

Phytotoxic tailings and contaminated soils deposited in the flood plain of Silver Bow Creek and the Clark Fork River

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EPA Dam Removal

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Opportunity Ponds- BP/ARCO Waste Management Area

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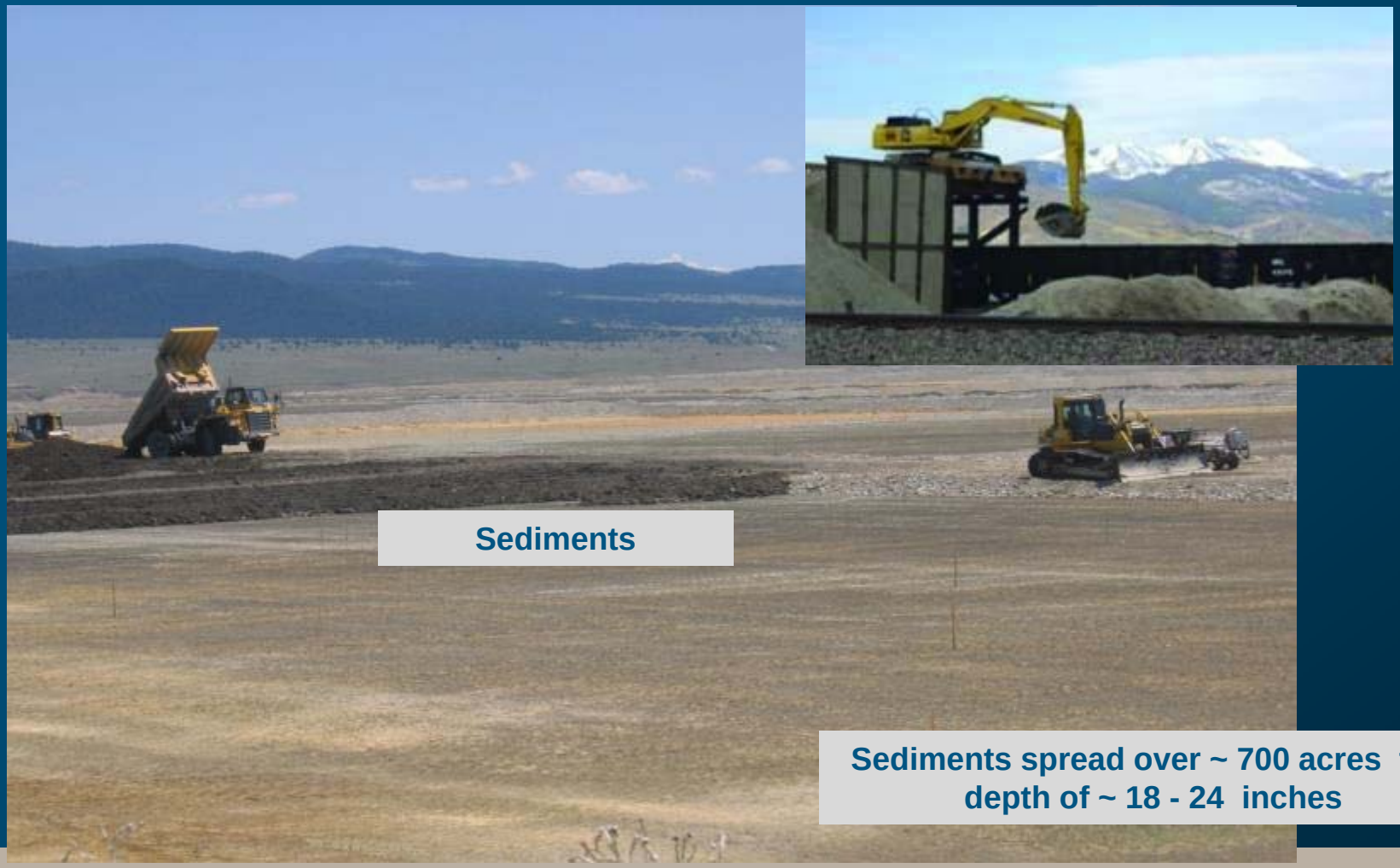
Sediments being spread on Opportunity Ponds



Sediments spread over ~ 700 acres to a depth of ~ 18 - 24 inches

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BP/ARCO fertilized, pitted, and seeded the Sediments in 2008, and 2009

" . . . The initial vegetation response in the Milltown sediments has been less than typically observed in nearby covered and revegetation areas within the Opportunity Ponds". (ARCO, 2009).

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The prevailing thought: Sediments are “growth Media” and can be used to cap the smelter tailings. Sediments will support lush vegetation because of the high amount of organic matter (1.9%), and with a neutral pH (6.9), metals won’t be a problem

Forensic Monitoring of Sediments and Vegetation

Initial Sediment Characteristics

- Texture
  - Variable – loam to silty loam to sandy loam
- Salts
  - Evaporative surface salts – upward movement
- Crusting
- Elevated NO_3
  - Up to 900 mg/kg soluble NO_3
- Elevated Metals
  - 2000 – 5000 mg/kg Zn, Mn, Cu, Pb, Cd, As

BP/ARCO – Forensic Monitoring

Response Variables (measured in July 2010)

- Root morphology
- Plant cover
- Plant richness
- Co-located sediment sample
- and analysis for metals, pH,
- EC, nitrogen

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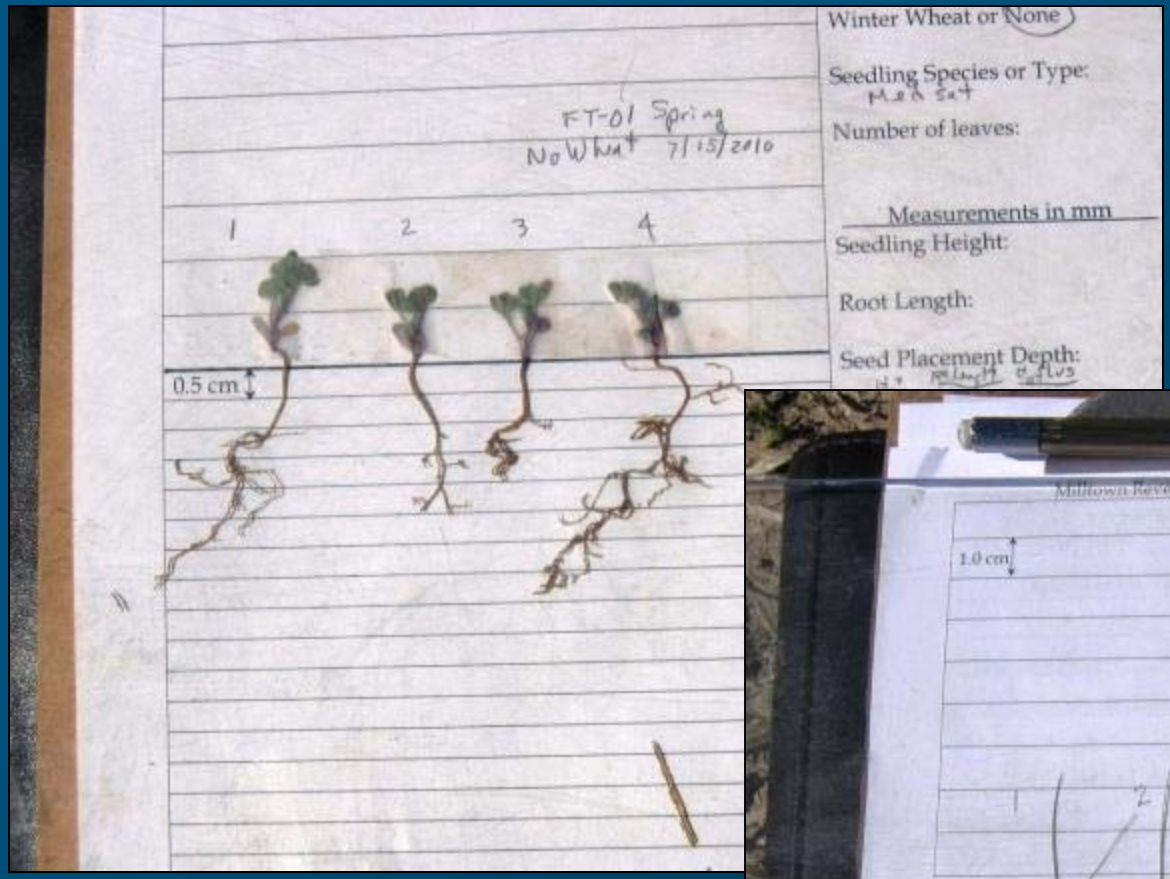
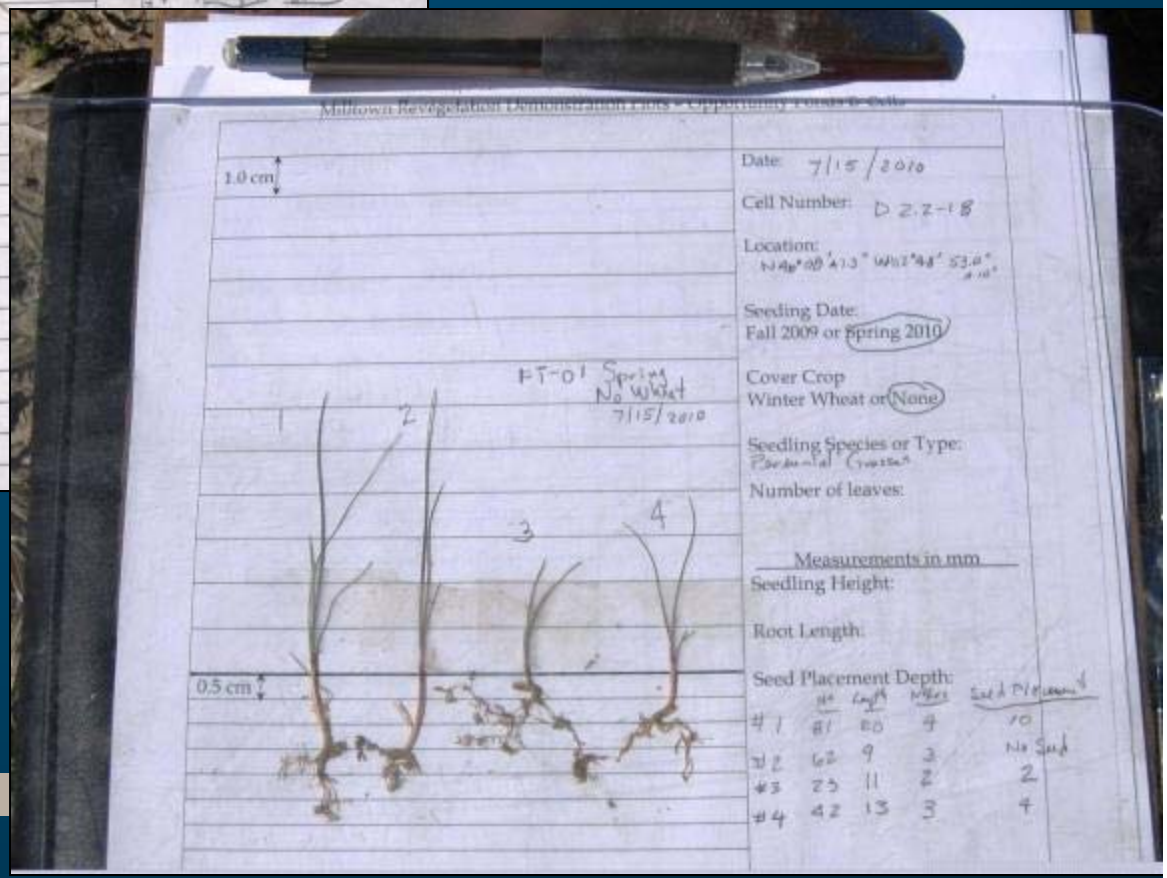
Plant growth and root morphology





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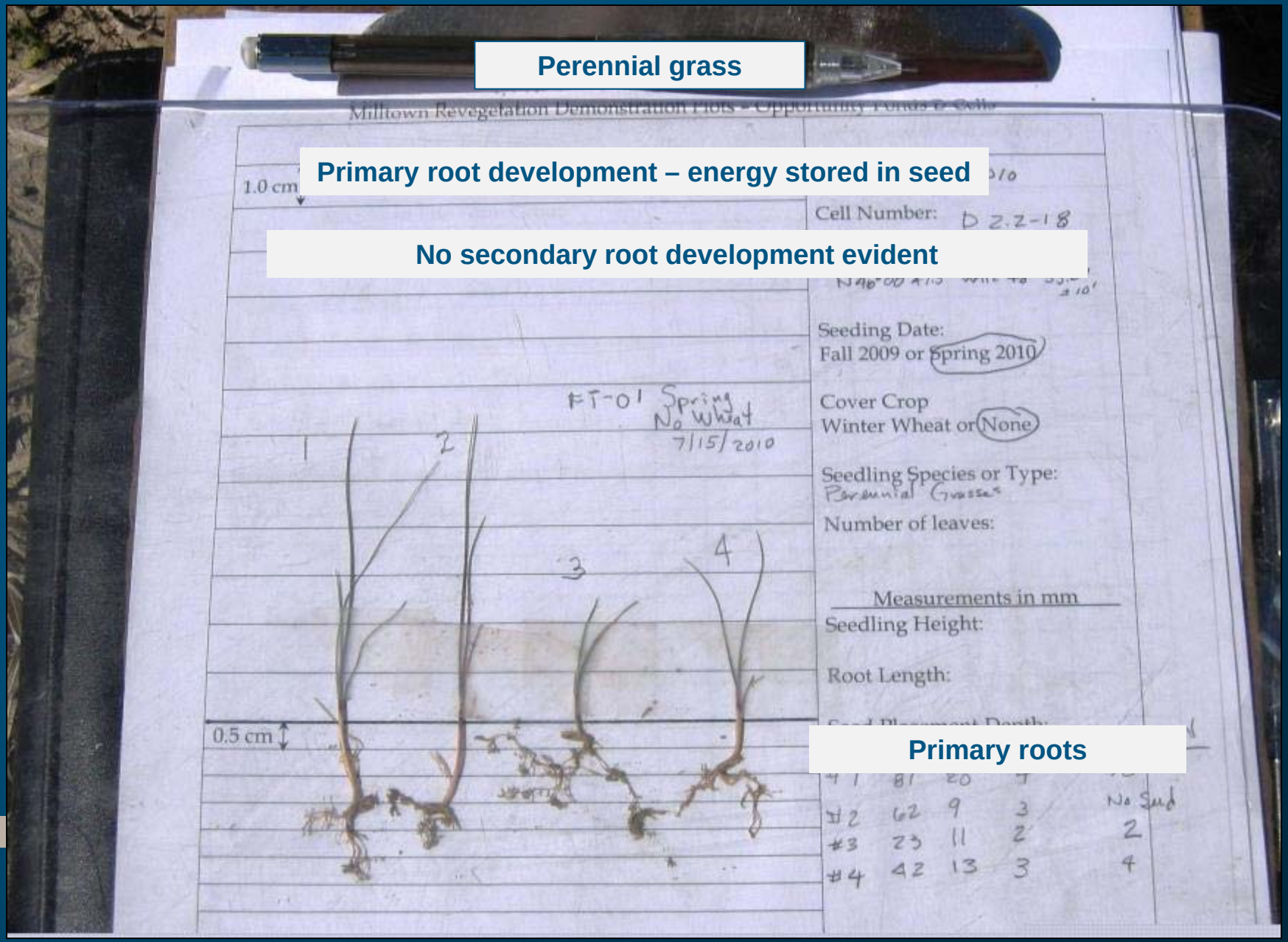
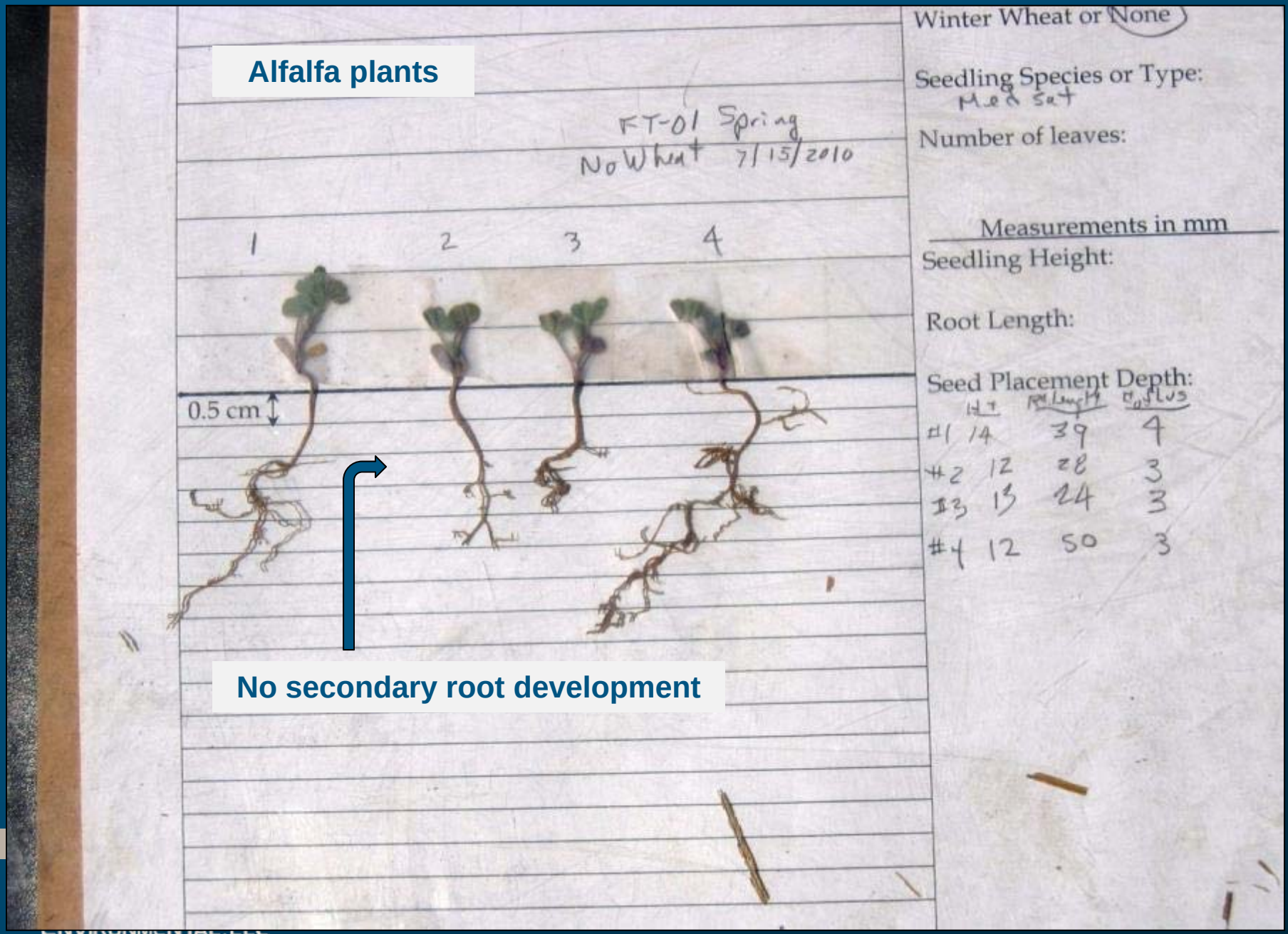
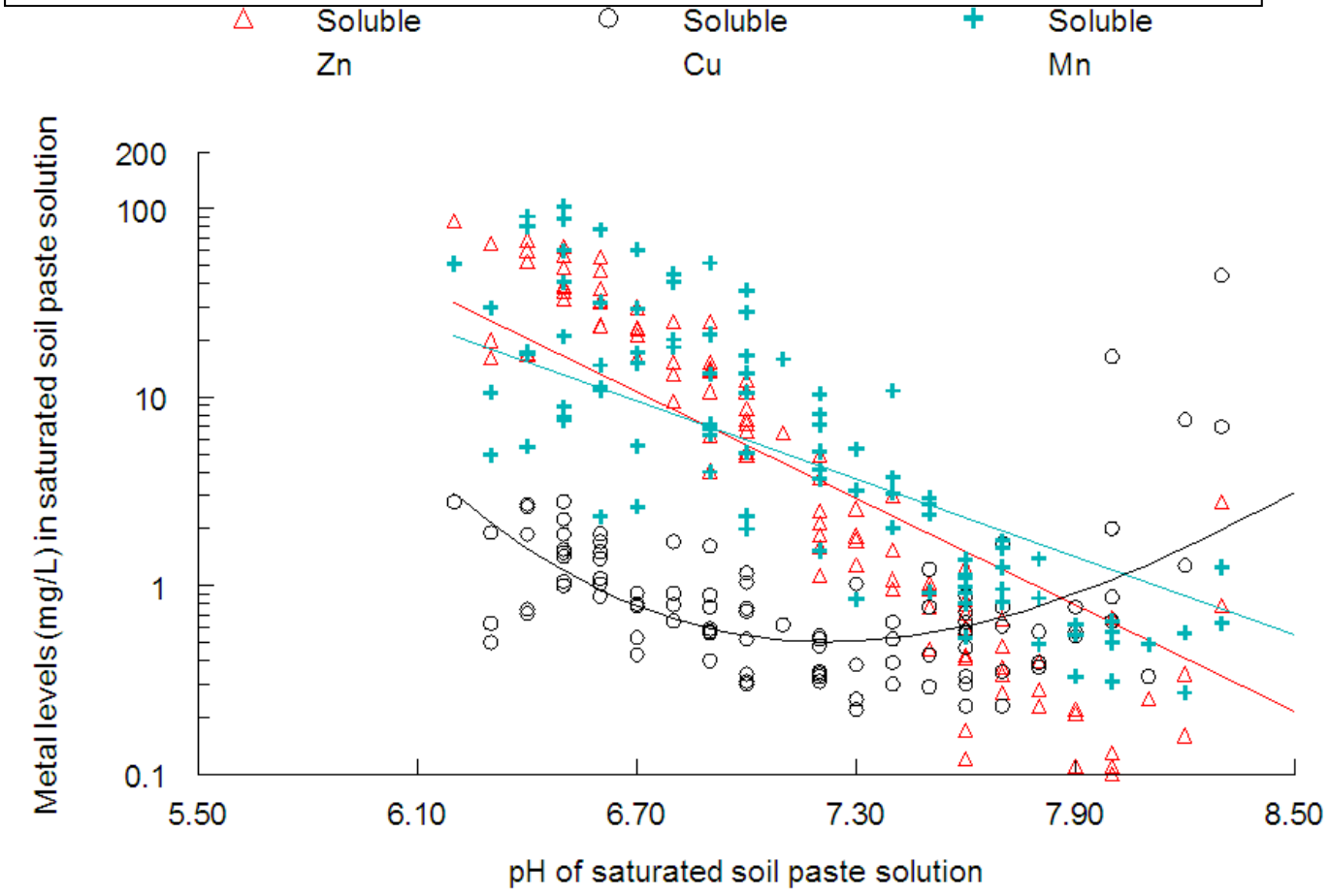

Perennial grass
Primary root development – energy stored in seed
No secondary root development evident
Primary roots
Milltown Revegetation Demonstration Plots
1.0 cm
0.5 cm
FT-01 Spring No Wheat 7/15/2010
1
2
3
4
Cell Number: D 2.2-18
Seeding Date:
Fall 2009 or Spring 2010
Cover Crop
Winter Wheat or None
Seedling Species or Type:
Perennial Grasses
Number of leaves:
Measurements in mm
Seedling Height:
Root Length:
#2 62 9 3 No Seed
#3 23 11 2 2
#4 42 13 3 4


Alfalfa plants
FT-01 Spring
No Wheat 7/15/2010
1
2
3
4
0.5 cm
No secondary root development
Winter Wheat or None
Seedling Species or Type:
Med Sat
Number of leaves:
Measurements in mm
Seedling Height:
Root Length:
Seed Placement Depth:
#1 14 39 4
#2 12 28 3
#3 13 24 3
#4 12 50 3

Water Soluble Levels of Zn, Cu, and Mn in Sediments



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Nitrogen Toxicity

Before Excavation

Sediments under water for ~ 100 years

No oxygen – reduced redox conditions

Anaerobic bacteria in organic matter

After Excavation and Placement

- Oxidizing Environment
- Aerobic bacteria
- Producing Excess nitrogen (Nitrate and Ammonium)
- Levels are phytotoxic to plants

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Evaporative Salts

Upward movement of salts into the surface sediments during dry climatic periods

Salts contain soluble metals and nitrogen

Creates phytotoxic environment for seeds

EC (dS/m)

- < 4 Non Saline
- 4-8 Saline 
- 8-16 Moderately Saline
- > 16 Very Saline

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Phytotoxicity

Metals

Total Concentrations in the range of 10^2 to 10^3 mg/kg

Soluble Concentrations up to 100 mg/l in saturated paste extracts

Nitrogen

Oxidation of Organic Matter 900 mg/kg soluble NO_3

Salinity

Upward movement of salts into surface soils

Sustainable Revegetation of the Opportunity Mine Tailings Pond with Amended Milltown Sediments and Cover Soil

- Determine chemical and physical characteristics of Milltown sediment and Stewart Street borrow soil
- Determine effects of enhanced oxidation and various amendments on chemical properties of Milltown sediment and effects on plant growth
- **Ascertain best combinations of locally available borrow soil and treated Milltown sediment for plant growth**

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EPA Goals for the Greenhouse Study

Roots penetrate into treated sediments below the cover soil

Shoot metal concentrations acceptable for livestock and wildlife (NRC, 2005)

Shoot metal concentrations are sufficient or normal for plants by Kabata-Pendias (2011).

Soluble metal levels of elements are greatly reduced in amended sediments

Soluble concentrations of nitrate are greatly reduced in amended sediments

Salinity levels in amended sediments acceptable for most plant species used in Opportunity Ponds seed mixes.

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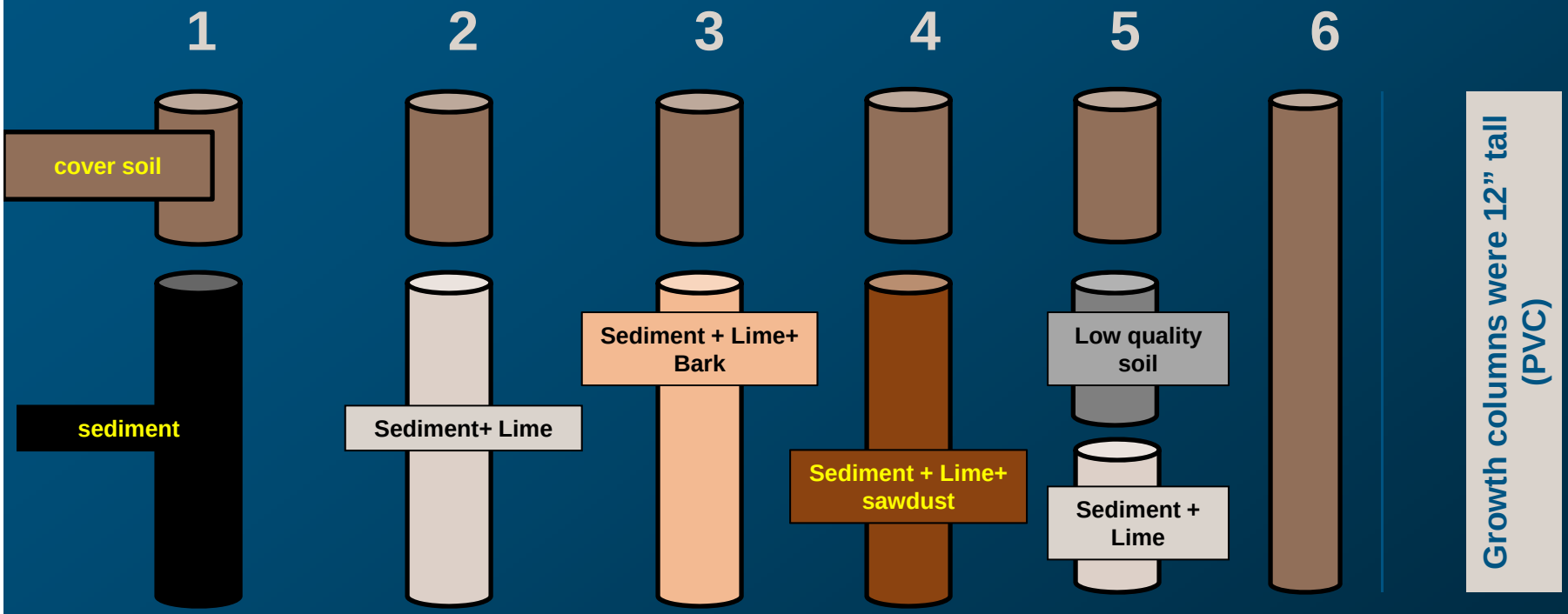
Greenhouse Treatments



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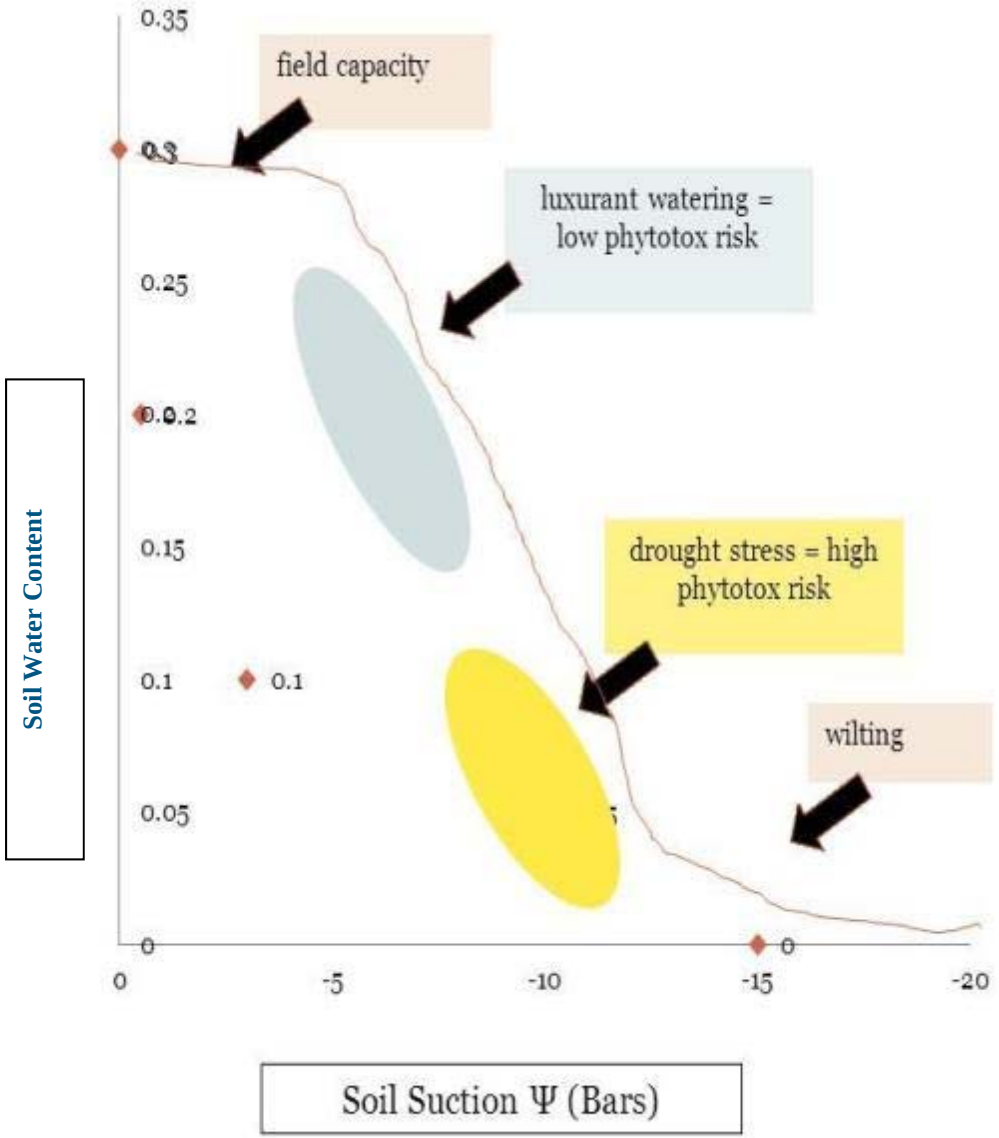
Each Treatment replicated six times

Greenhouse Watering Scheme

The average annual **precipitation** for Anaconda is **13.4 inches**, with most precipitation occurring in May and June

An attempt to **mimic this precipitation** regime in the green house tests is appropriate. A progressive reduction in watering over time was used

The objective was to force the plant roots to explore the amended sediments below the cover soil and to obtain water from this part of the root zone.



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Texas A&M Greenhouses

Weighing column to determine water to be added, July 28, 2011

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PVC growth tubes at Texas A&M

Three plant species tested

- Smooth brome
- Great basin wild rye
- thickspike wheatgrass

6 replications per grass/treatment combination.

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Thickspike Wheatgrass 2 weeks after germination

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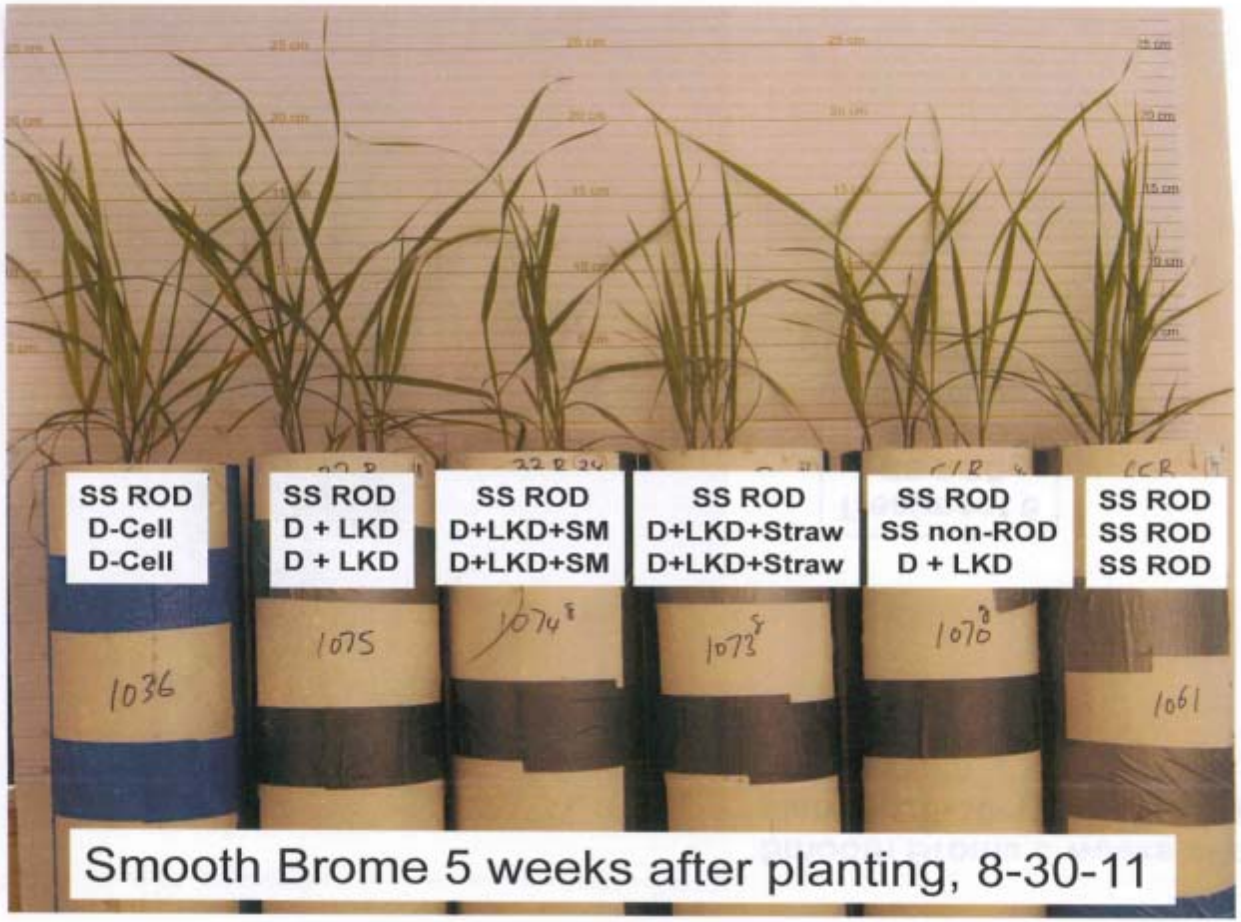

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11 Weeks after germination

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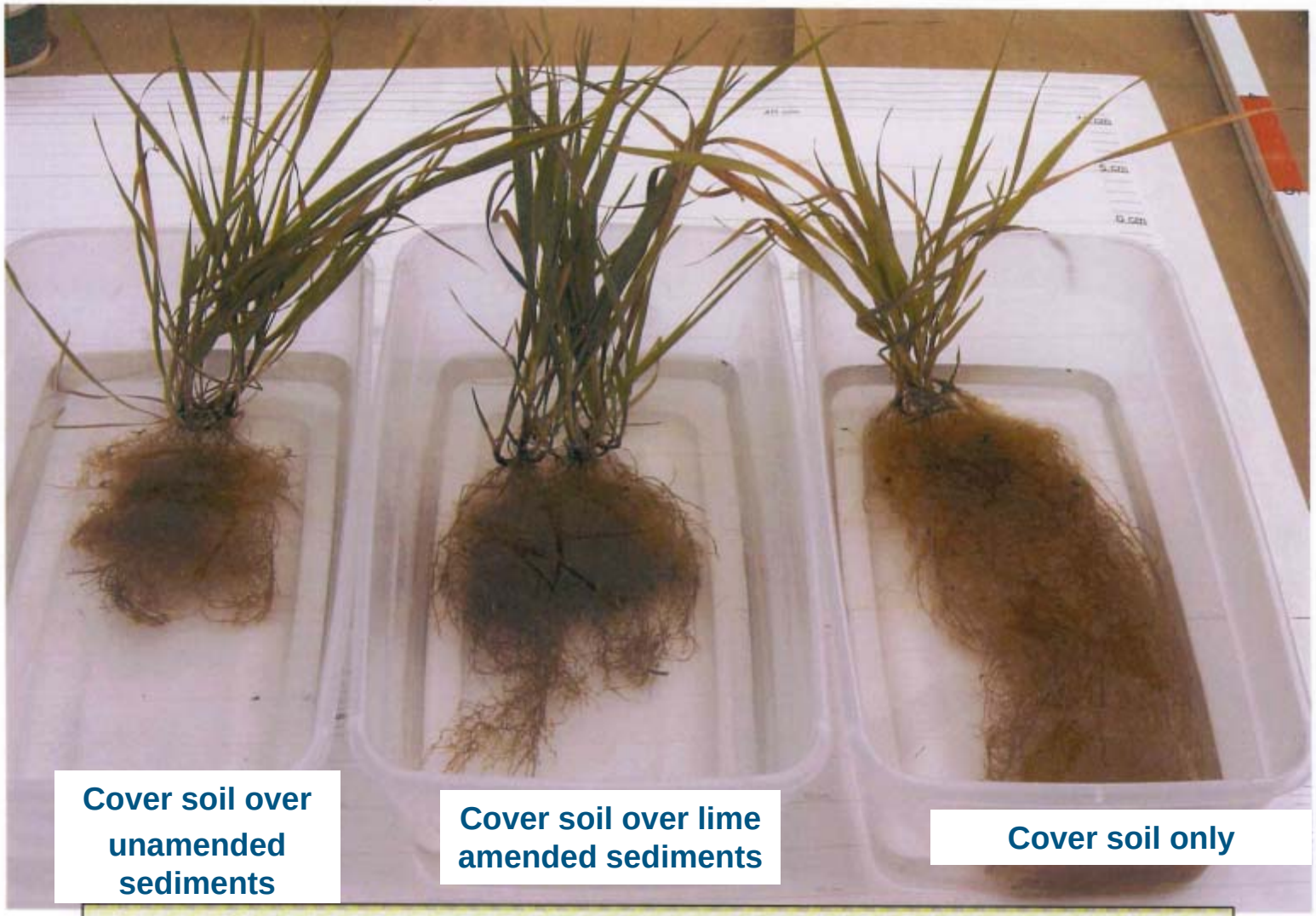
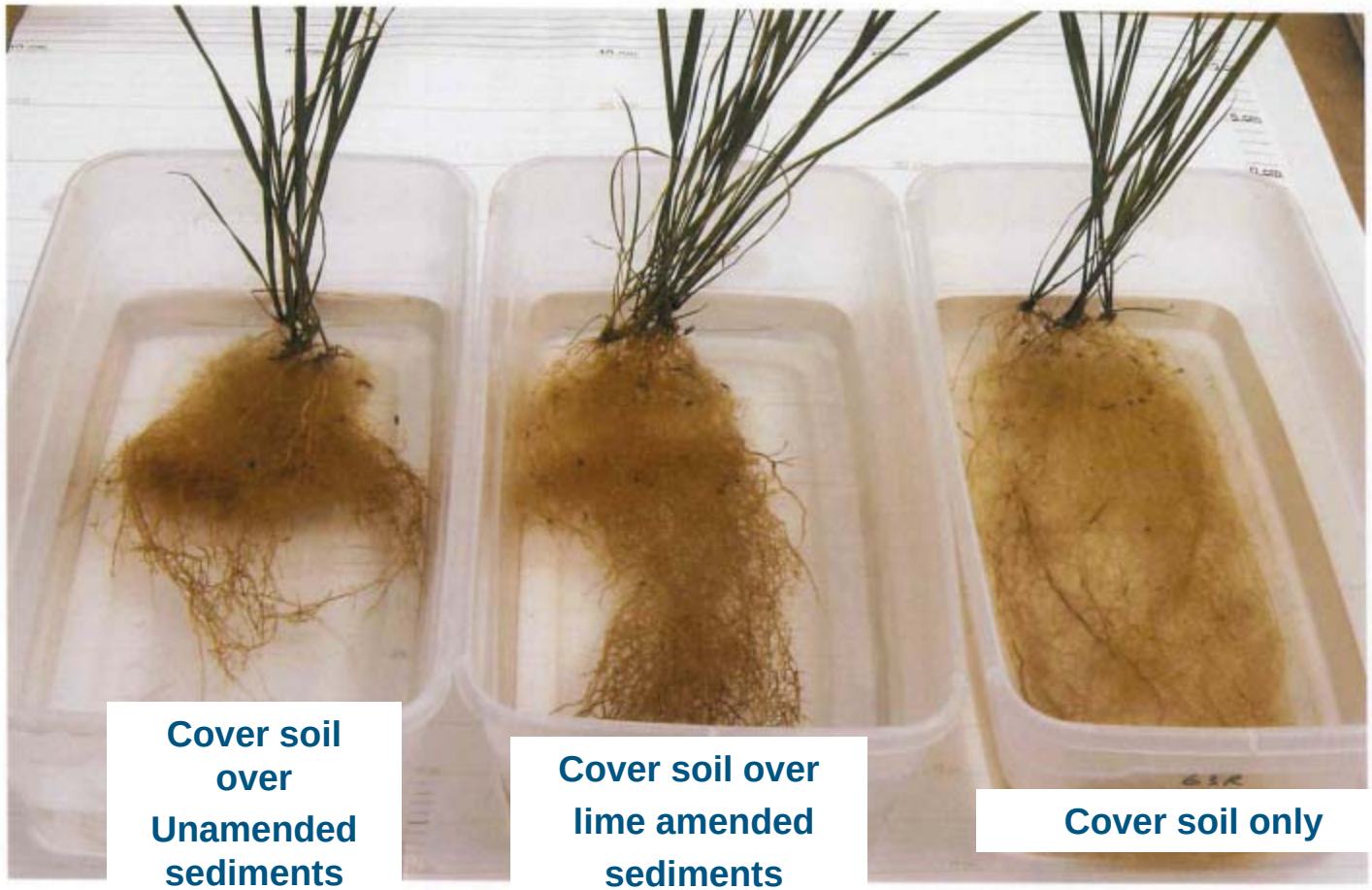
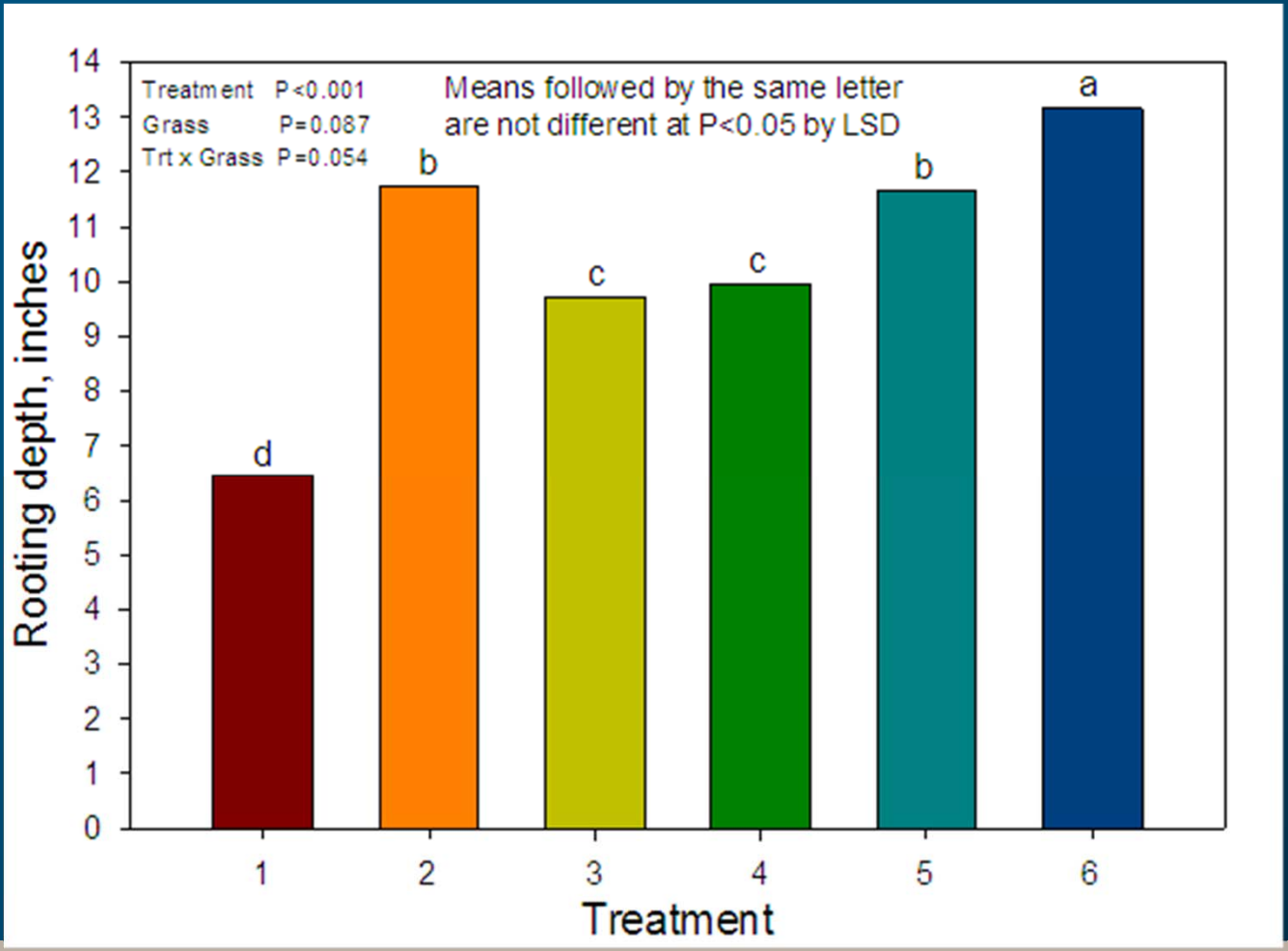


Smooth Brome- Trts 1,2,6 (left to right); October 10-10-11



Basin Wild Rye- Trts 1,2,6 (left to right); October 10-10-11

Rooting Depths



T1 = cover soil- untreated sediments

T2 = cover soil- treated sediments

T3 = coversoil – treated sediments + bark

T4 = coversoil – treated sediments + sawdust

T5 = cover soil- subsoil- treated sediments

T6 = coversoil only

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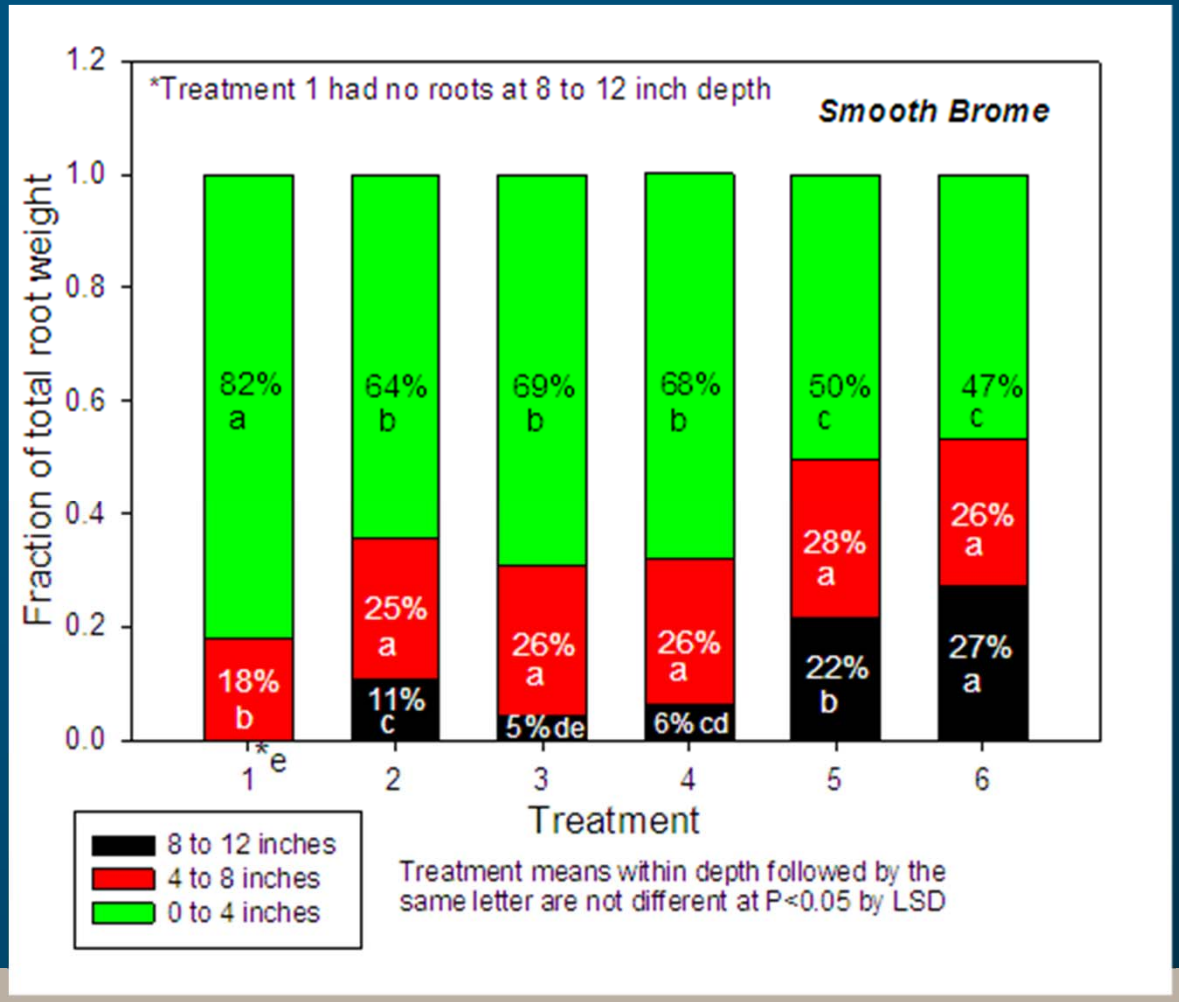
Rooting Depths



T1 = cover soil-untreated sediments

T2 = cover soil- treated sediments

T3 = coversoil – treated sediments + bark

T4 = coversoil – treated sediments + sawdust

T5 = cover soil-subsoil-treated sediments

T6 = coversoil only

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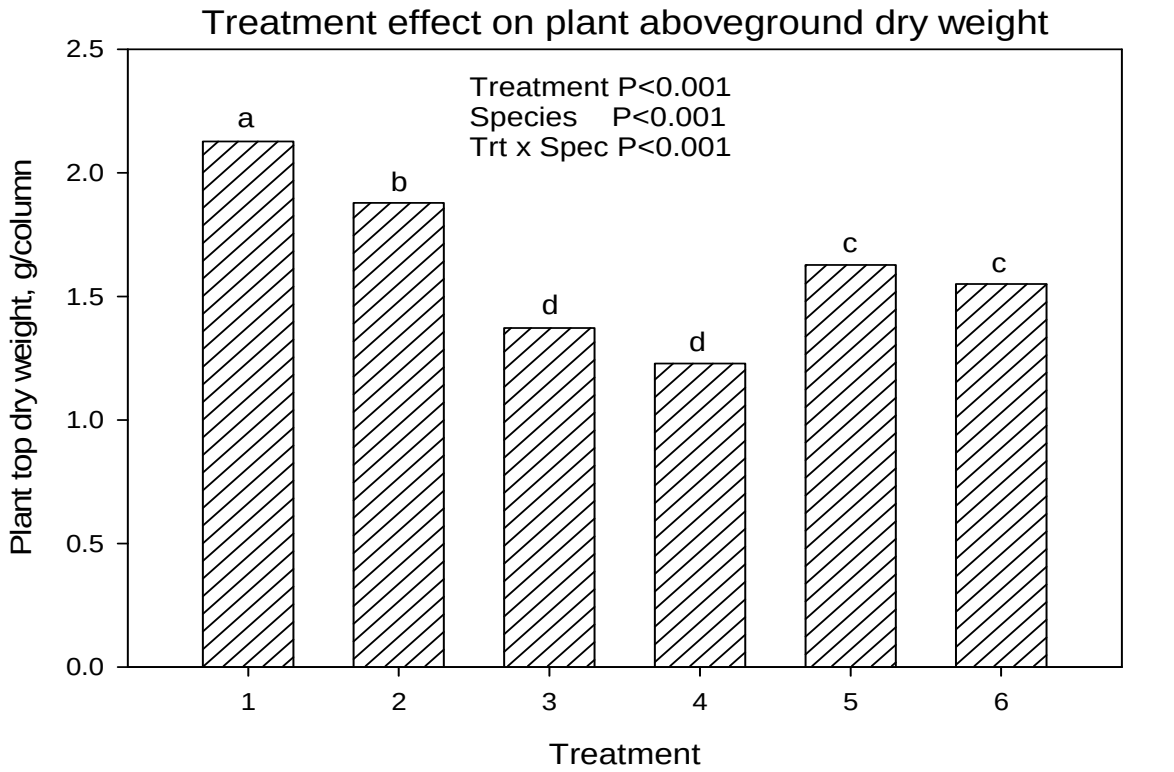
Aboveground Biomass



Treatment

1- 4" SS ROD + 8" Untreated D Cell
2- 4" SS ROD + 8" D Cell w/ LKD
3- 4" SS ROD + 8" D Cell w/ LKD, 1% Sun Mtn Reclaim
4- 4" SS ROD + 8" D Cell w/ LKD, 3% Wheat Straw
5- 4" SS ROD + 4" SS non-ROD + 4" D Cell w/ LKD
6- 12" SS ROD

Means followed by the same letter are not different at P<0.05.

T1 = cover soil- untreated sediments

T2 = cover soil- treated sediments

T3 = coversoil – treated sediments + bark

T4 = coversoil – treated sediments + sawdust

T5 = cover soil-subsoil- treated sediments

T6 = coversoil only

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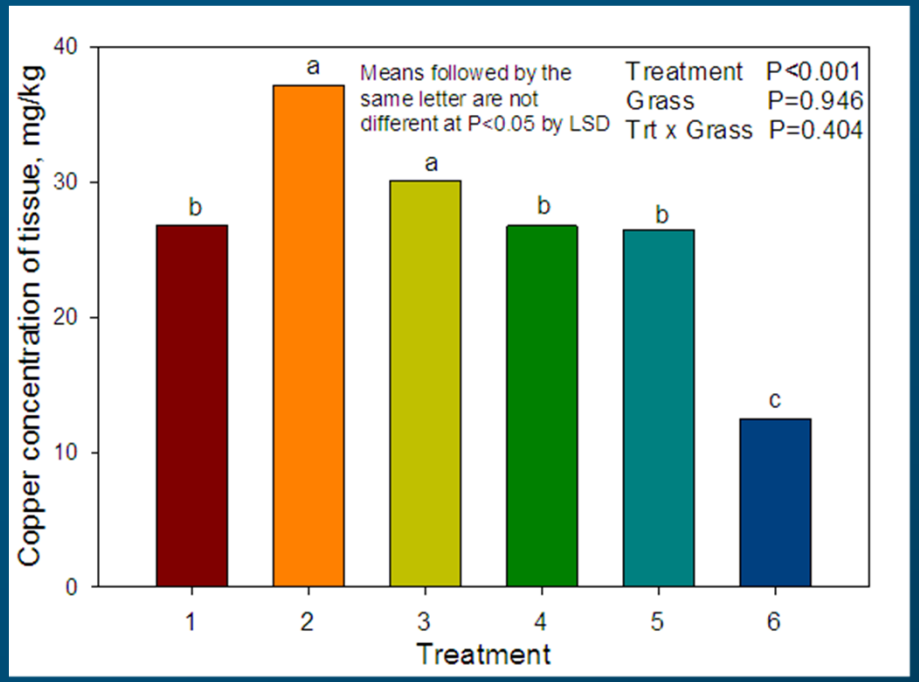
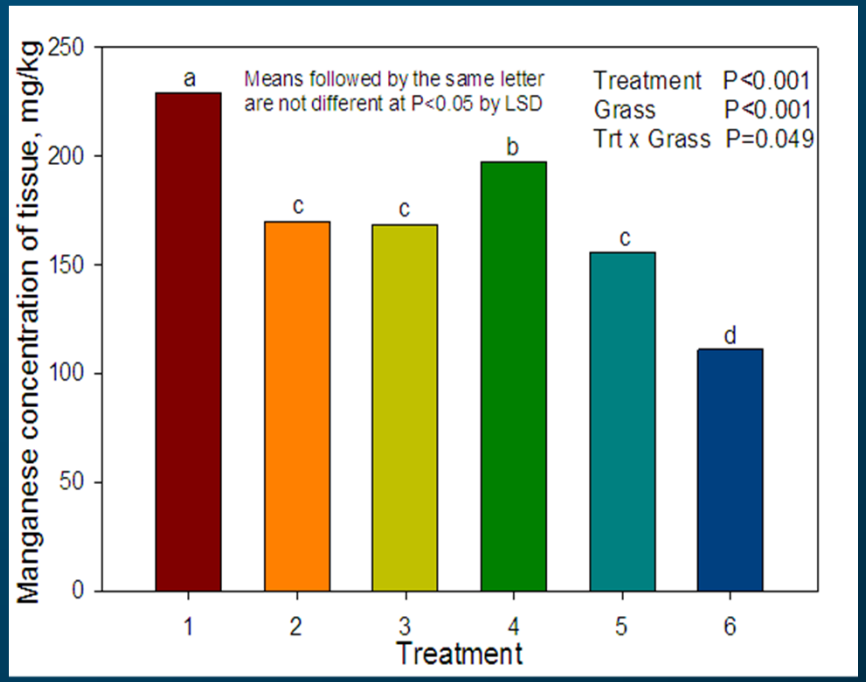
Cu and Mn Levels in Plant Tissue





Maximum Tolerable levels in Animal Feed (NRC 2005)			Generalized Concentrations for Mature Leaf Tissue (Kabata-Pendias 2001)		
Element	Cattle	Horses	Deficient	Sufficient	Excessive
Copper	40*	250	2.5	5 - 30	20 - 100
Manganese	2000	400	10 - 30	30 - 300	400 - 1000

*** assumes normal Mo and S levels**

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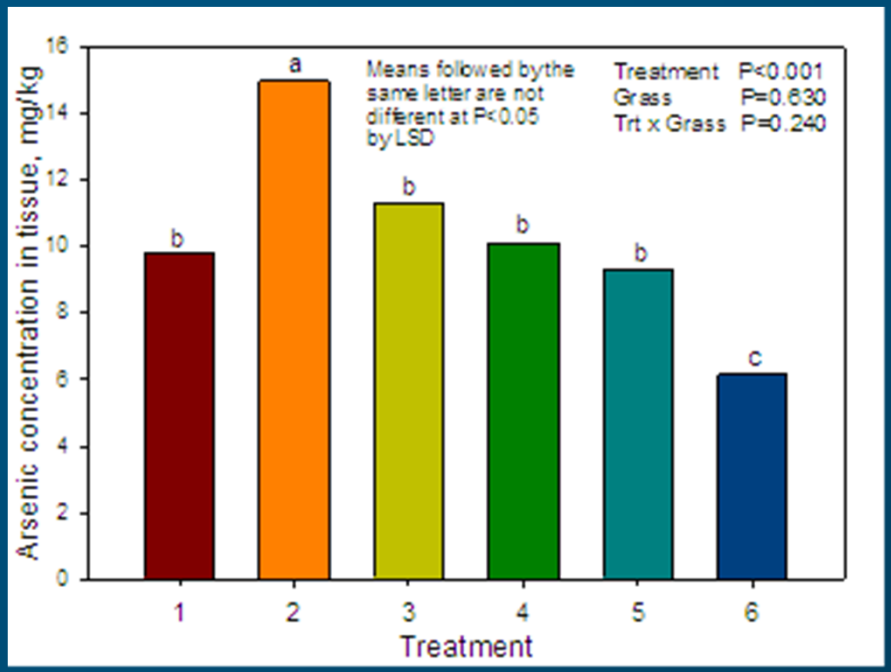
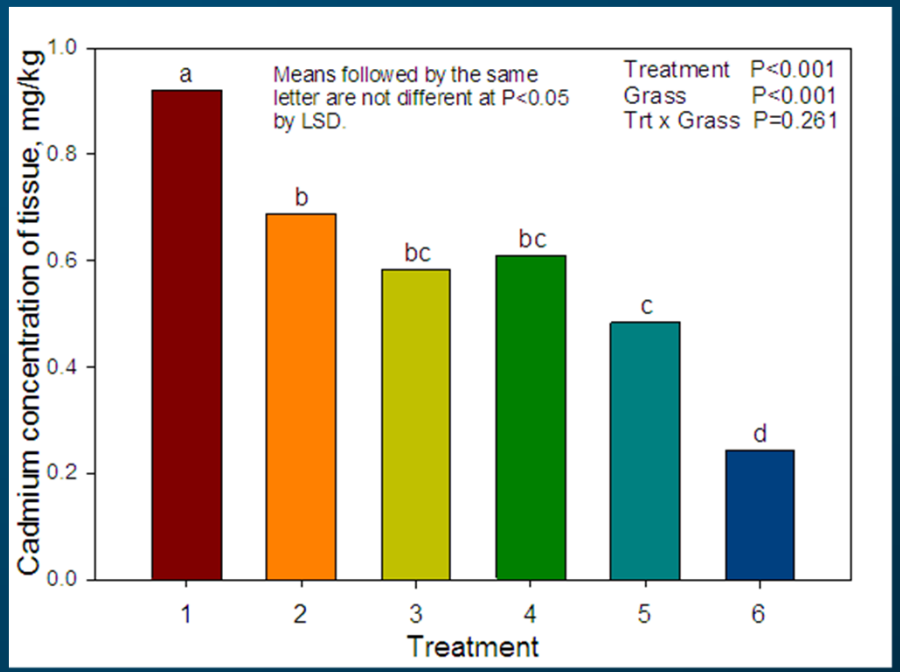
As and Cd Levels in Plant Tissue





Maximum Tolerable levels in Animal Feed (NRC 2005)			Generalized Concentrations for Mature Leaf Tissue (Kabata-Pendias 2001)		
Element	Cattle	Horses	Deficient	Normal	Excessive
Arsenic	30	30		1 - 1.7	5 - 20
Cadmium	10	10		0.05 - 0.2	5 - 30

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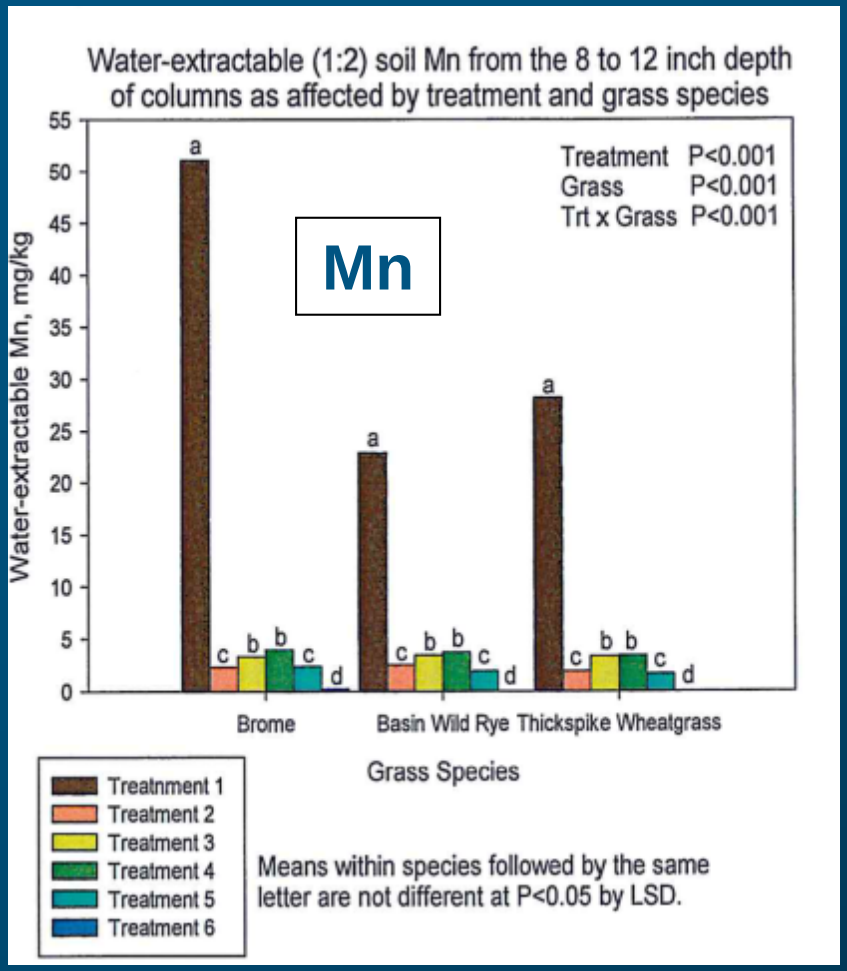
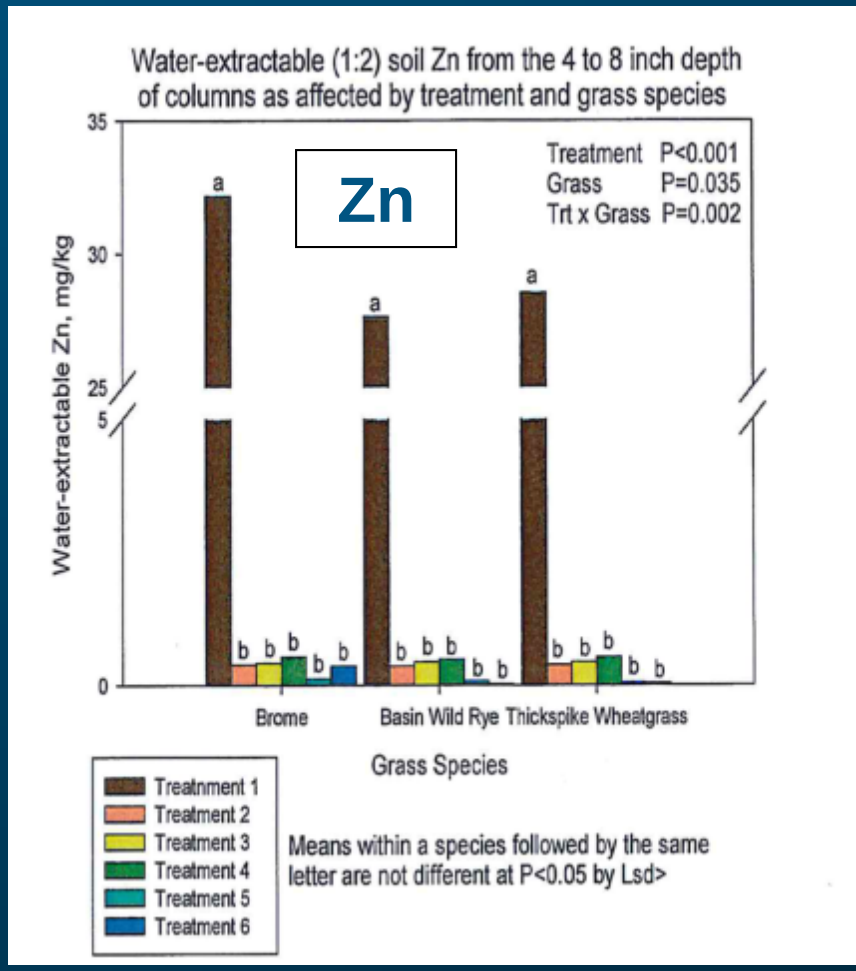
Water Soluble Mn and Zn





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Agency Goals of the Study

- Roots penetrate into treated sediments below the cover soil
- Shoot metal concentrations acceptable for livestock and wildlife (NRC, 2005)
- Shoot metal concentrations are sufficient or normal for plants by Kabata-Pendias (2011). **Arsenic**
- Soluble metal concentrations of elements are greatly reduced
- Soluble concentrations of nitrate are greatly reduced in amended sediments
- Salinity levels in amended sediments acceptable for most plant species used in Opportunity Ponds seed mixes.

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Texas A&M Greenhouse Studies

Recommendations

"To ensure long-term viability of the remedy, it is recommended that 8 to 12 inches of cover soil be placed over 6 inches of lime-amended Milltown sediment."

Hons, F. and H. Shahandeh. 2012. Sustainable Revegetation of the Opportunity Tailings Pond with Amended Milltown Sediments and Cover Soil: Greenhouse Study. Texas AgriLife Research, Texas A&M University

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Large Scale Reclamation of the Sediments 2012 - 2013

EPA approved remedy is to treat the sediments to a depth of 6 inches with Lime (CaO and $CaCO_3$), then add a coversoil cap , meeting chemical and physical specification, 12 inches in depth; seed and fertilize.

- **As of February 2013, 220 acres of the sediments have been treated with lime**
- **155 acres were seeded in Fall 2012**
- **120 acres will be seeded in the Spring of 2013**
- **The rest of the sediments will be treated, covered and seeded in Fall 2013/Spring 2014**

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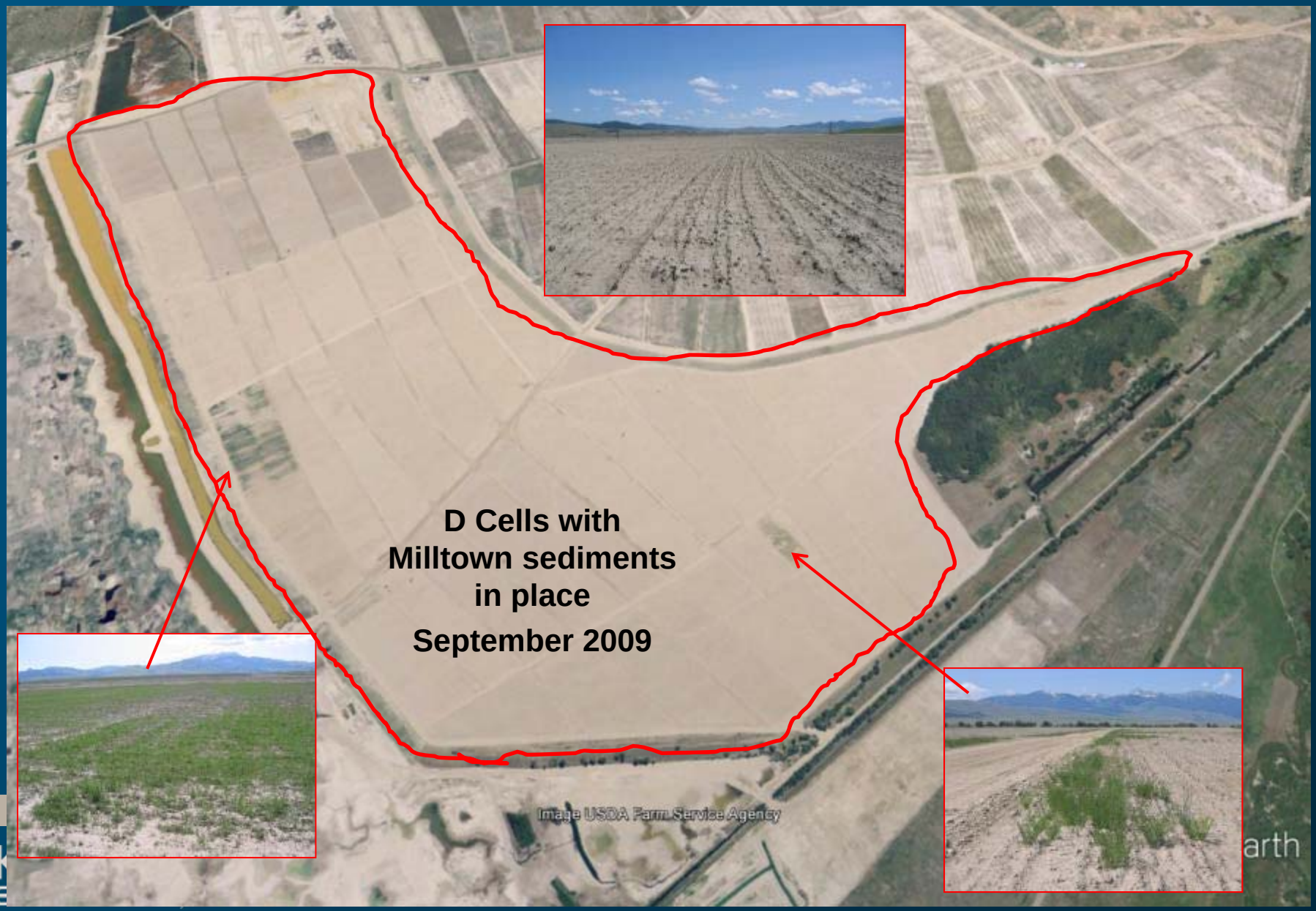
D Cells with
Milltown sediments
in place
September 2009
Image USDA Farm Service Agency
arth


August 2013

Acknowledgements

Texas A&M Team

Frank Hons

Hamid Shahandeh

Richard Loeppert

Courage Bangira

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MDEQ

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BP/ARCO

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CDM Smith

Gunnar Emilsson

Bureau of Reclamation

Ken Brockman

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