

Appendix B

**Development of Acid/Heavy Metal Tolerant Releases (DATR)  
2006 Activities**



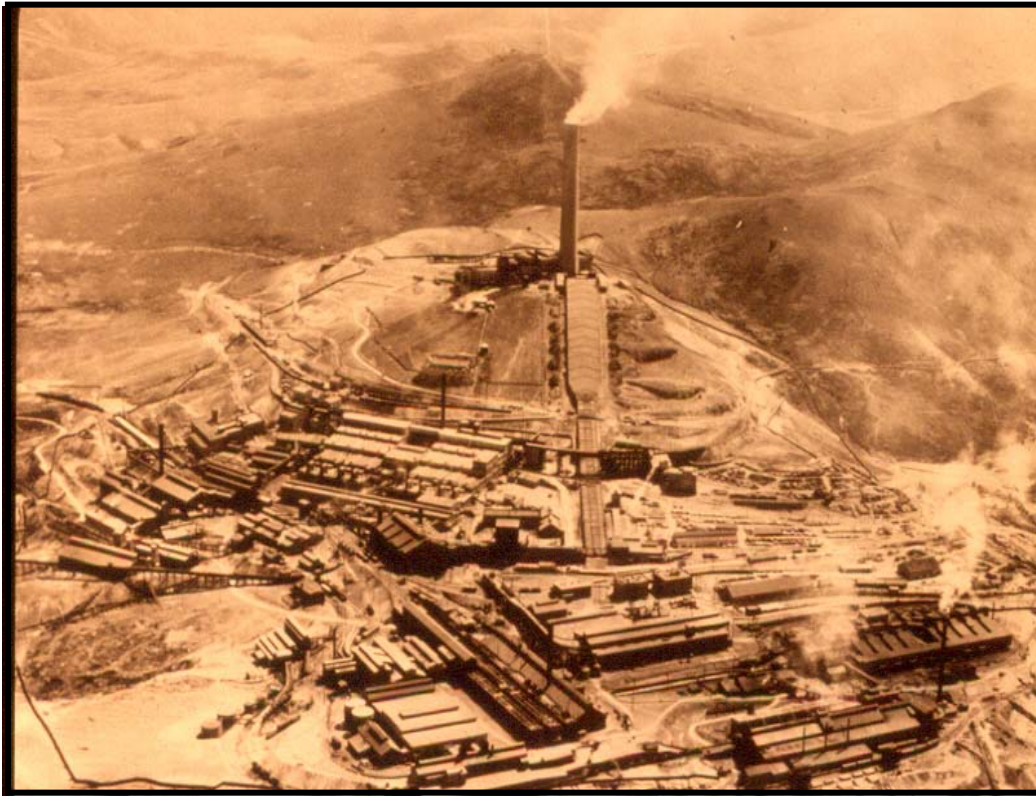
A Report to  
Montana Natural Resource Damages Program

By Deer Lodge Valley Conservation District  
in cooperation with the  
USDA-NRCS Bridger Plant Materials Center



## Appendix B

### I. INTRODUCTION



## Appendix B

# Development of Acid/Heavy Metal Tolerant Releases (DATR) 2006 Activities

### Project History

To address this need for adapted native plants, the Development of Acid/Heavy Metal-Tolerant Plants (DATC), now called the Development of Acid/Heavy Metal Tolerant Releases (DATR), project was initiated in 1995. The DATC (DATR) project was initially funded by a Montana Department of Natural Resources-Reclamation and Development Grant awarded to the Deer Lodge Valley Conservation District (DLVCD), with research conducted by Matt Marsh. The DLVCD worked in cooperation with the USDA-NRCS Bridger Plant Materials Center. The national network of 26 Plant Materials Centers is the primary source of native plants developed specifically for reclamation and conservation use. The Bridger PMC, in south-central Montana, is a 140-acre research facility dedicated to the selection and release of native plant materials, primarily for use in Montana and Wyoming. The original DNRC grant expired at the end of 1996 and this project did not receive funding until June 1998, at which time carry-over money for the 1997-98 grant period was made available to this project, as well as some financial support from Atlantic Richfield Co. (ARCO). During 1999 and 2000, the project was again funded by a DNRC Reclamation and Development grant. Since 2000, the DATC (DATR) project has been funded by the EPA Mine Waste Technology Program (through 2005) and the Montana Department of Justice-Natural Resource Damage Program (through 2008). To date, the DATC (DATR) project has involved the seed collection of 145 native grasses, forbs, shrubs, and trees from within the Upper Clark Fork River Basin and abandoned mine sites throughout western Montana. These collections have been planted at various study sites in comparison with nonlocal native and introduced plant species. The Atlantic Richfield Company (ARCO) has provided land access for seed collection and sites for experimental plots.

The first Initial Evaluation Plantings (IEPs) (single-row plots) were established in 1995 on the flats east of Anaconda (near junction of Highway 1 and 48), on the Opportunity Ponds (three levels of lime amendment), and adjacent to the Lead Smelter at East Helena. Collectively these three research sites tested 220 accessions of 95 species of native and introduced plants. In the spring of 1999, a Comparative Evaluation Planting (CEP) (single-row plots) was established along Willow Glen Road east of Anaconda evaluating 84 entries, which included multiple accessions of 6 forbs, 13 grasses, and 6 forb/grass mixes. During the fall/winter of 1999, a greenhouse study at the Bridger PMC utilized contaminated soil from the Anaconda Flats area. The results of this replicated, controlled environment study provided enough statistically significant data to move some individual collections toward official release to the commercial seed industry. In 2001, CEPs were established with a four-row cone seeder on Stucky Ridge (upland site) and on the Mill Creek Flats (lowland site) to evaluate eight seed mixtures, four consisting of native, local-origin species and four consisting of nonlocal-origin released cultivars. In October 2002, a shrub/tree CEP (Willow Glenn Road Site) was established to compare native indigenous material with commercially available stock of the same species, utilizing 2-0 transplants. All plantings prior to 2003 were established

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on unamended sites, receiving deep-plowing treatment only (except Opportunity Pond-Site 2). In the spring of 2003, another replicated trial was established on Stucky Ridge (adjacent to the moto-cross site) on a site that had been deep plowed and amended with lime.

To date, there have been four official germplasm releases by the DATC (DATR) project: Washoe Selected Class germplasm of basin wildrye (*Leymus cinereus*), Old Works Source Identified Class germplasm of fuzzytongue penstemon (*Penstemon eriantherus*), Prospectors Selected Class germplasm of common snowberry (*Symphoricarpos albus*), and Copperhead Selected Class germplasm of slender wheatgrass (*Elymus trachycaulus*). Presently there are 15 collections of 9 species (see Seed Increase section) that have been established in seed increase fields for potential future release. Two commercial growers in Montana are growing Washoe basin wildrye, while a grower in Idaho and one in Washington have recently established seed production fields of Old Works fuzzytongue penstemon.

## II. WOODY EVALUATION





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### WOODY COMPARATIVE EVALUATION PLANTING

#### Introduction

This report summarizes the plant performance of the Woody Comparative Evaluation Planting (CEP) installed in the fall of 2000 at the Anaconda Smelter Superfund Site. One of the most impacted areas is the ~18 mi<sup>2</sup> of uplands within the Anaconda Smelter Superfund Site. The uplands are commonly derived from the weathering of bedrock and are typically thin, clay-rich alfisols. Due to the susceptibility of these soils to erosion by wind and water, the soil surface in many areas has eroded away and the subsoil, which is now exposed at the surface, continues to erode. Original vegetation in the uplands consisted primarily of shrub lands with coniferous forests above approximately 5,800 feet (Keammerer, 1995). In an effort to stem the transport of contaminants and restore these injured areas, state and federal regulatory agencies have developed several reclamation alternatives, many of which include the planting of shrubs and trees in the uplands.

The low pH soils at the Anaconda Smelter Superfund Site are routinely ameliorated by incorporating lime; however, nonuniform lime incorporation, as well as the upward migration of acid-producing compounds, results in pockets of acidity. Additionally, many steeply sloped areas are not accessible to heavy equipment making them difficult to amend. Research has demonstrated that metal-tolerant plants can be used to stabilize and immobilize contaminants in the soil (Smith and Bradshaw, 1972; Bradshaw et al., 1978). Metals are absorbed and accumulated by roots, adsorbed onto roots, or precipitated within the rhizosphere, thereby trapping contaminants in the soil and breaking the soil-plant-animal cycle.

Numerous demonstration projects over the last 50 years at the Anaconda Smelter Superfund Site have tested the performance of several woody plant species in diverse edaphic conditions (Dutton, 1992; Eliason, 1959; Gordon, 1984; Reclamation Research Unit and Schafer and Associates, 1993; Reclamation Research Unit, 1997). This study builds on previous research findings by testing accessions (ecotypes) of woody plant species that have shown adaptations to low pH and heavy-metal contaminated soils. The objective of the study is to identify acid/heavy-metal-tolerant native plant ecotypes that provide erosion control and wildlife habitat. The Development of Acid/Heavy-Metal-Tolerant Cultivars Project's (currently DATR) goal is to release these superior ecotypes to the commercial market and thereby provide a greater array of plant materials for the reclamation industry.

Study entries include "local" germplasm originated from seed collected on nearby mine-affected soils in Deer Lodge County, Montana, as well as "nonlocal" germplasm originated from seed collected on non-impacted lands in various counties of Montana, Colorado, South Dakota, Utah, and Wyoming. Seedlings of 19 accessions of 7 woody species including *Pinus contorta* lodgepole pine, *Pinus ponderosa* ponderosa pine, *Shepherdia argentea* silver buffaloberry, *Rosa woodsii* Woods' rose, *Symphoricarpos albus* common snowberry, *Symphoricarpos occidentalis* western snowberry, and *Ribes*

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*cereum* wax currant were transplanted into a common garden in a randomized complete block design.

### Study Site

The 0.4-acre study site, located ~4 miles southeast of Anaconda, Montana, has been impacted by emission fallout from the Upper and Lower Works as well as the Washoe smelter. The Upper and Lower Works smelters operated from 1884 to 1902 at which point the Washoe smelter took over smelting operations until 1980. The study site lies ~200 yards east of Mill Creek at an elevation of 5,140 ft in USDA Plant Hardiness Zone 4a. The soils at the site are in the Haploboroll's Family and consist of deep, well-drained soils formed in mixed alluvium composed of granitic, meta-sedimentary, and volcanic rocks. The alluvium is derived from the Mill Creek drainage. Cobbles and stones commonly occur on the soil surface. In 1999, the site was plowed to a depth of 6 inches, rototilled, and packed. Laboratory analysis of four (0- to 6-inch) composite soil samples taken after tilling to 6 inches indicated an average pH of 4.53. Average arsenic, cadmium, copper, lead, and zinc concentrations in the four soil samples were 423 mg/kg, 6 mg/kg, 510 mg/kg, 233 mg/kg, and 308 mg/kg, respectively (table 1).

Table 1. Acid extractable heavy-metal levels (EPA method 3050) and pH of 0- to 6-inch composite samples.

Sample No.	pH <i>S.U.</i>	As <i>mg/kg</i>	Cd <i>mg/kg</i>	Cu <i>mg/kg</i>	Pb <i>mg/kg</i>	Zn <i>mg/kg</i>
A.T. 0-6" NE	4.0	610	7	620	320	370
A.T. 0-6" NW	4.9	360	5	340	120	222
A.T. 0-6" SE	4.6	530	5	340	150	200
A.T. 0-6" SW	4.6	190	7	740	340	440
☒	4.53	422.5	6	510	232.5	308
Phytotoxic Criteria <sup>†</sup>	< 5.0	136-315	5.1-20	236-750	94-250	196-240

† EPA phytotoxicity standards (CDM Federal 1997).

### Methods and Materials

The study tested 19 accessions consisting of two or three accessions of each of the seven shrub/tree species (table 2). The 1-0 and 2-0 (6- to 12-inch) seedlings were transplanted in a Randomized Complete Block Design replicated 20 times on October 18, 2000. An individual plant of each accession is represented in each replication. The seedlings are spaced 4.5 feet apart within rows and 9 feet apart between rows. The plot receives no supplemental irrigation. The spring following planting, Vispore™ (3-ft x 3-ft) tree mats were installed on all entries to suppress weeds and retard soil moisture evaporation.

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Table 2. Seed origin and elevation of entries in the Woody Comparative Evaluation Planting.

Family/Species	Seed Origin	Elevation
<b>Caprifoliaceae:</b>		
<b><i>Symphoricarpos albus</i> (L.) Blake</b>	Deer Lodge Co., MT	6000 ft
<i>S. albus</i> (L.) Blake	Ravalli Co., MT	3500
<i>S. occidentalis</i> Hook.	Deer Lodge Co., MT	5559
<i>S. occidentalis</i> Hook.	CO Seed Source	unknown
<i>S. occidentalis</i> Hook.	Weston Co., WY	5000
<b>Elaeagnaceae:</b>		
<i>Shepherdia argentea</i> (Pursh) Nutt.	Deer Lodge Co., MT	6000
<i>S. argentea</i> (Pursh) Nutt.	UT Seed Source	unknown
<i>S. argentea</i> (Pursh) Nutt.	Sweetwater Co., WY	6000
<b>Grossulariaceae:</b>		
<i>Ribes cereum</i> Dougl.	Deer Lodge Co., MT	5700
<i>R. cereum</i> Dougl.	Chaffee Co., CO	8000
<b>Pinaceae:</b>		
<i>Pinus contorta</i> Dougl. ex Loud.	Deer Lodge Co., MT	6400
<i>P. contorta</i> Dougl. ex Loud.	Albany Co., WY	9500
<b><i>P. contorta</i> Dougl. ex Loud.</b>	Custer Co., ID	6300
<i>P. ponderosa</i> P. & C. Lawson	Deer Lodge Co., MT	5850
<i>P. ponderosa</i> P. & C. Lawson	Lawrence Co., SD	5500
<i>P. ponderosa</i> P. & C. Lawson	San Juan Co., CO	8000
<b>Rosaceae:</b>		
<i>Rosa woodsii</i>	Deer Lodge Co., MT	5168
<i>R. woodsii</i>	Ravalli Co., MT	3400
<i>R. woodsii</i>	Pueblo Co., CO	6000

Plant survival, height, and vigor were assessed in 2001 (May 21 and August 14), 2002 (May 20 and August 20), 2003 (May 28 and August 26), 2004 (June 30), 2005 (August 29), and 2006 (August 28). Plant height is measured in centimeters to the top of live foliage. Vigor is measured on a scale of 1 to 9, with 1 representing excellent vigor and 9 representing plant mortality.



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### Results and Discussion

#### Survival

Overall survival of the entrees in the Woody CEP after 1 year (2001) was local 91.4% and nonlocal 79.2%) (table 3). The edaphic conditions have taken their toll, as survival has decreased each subsequent year; 2002—local 84.3% and nonlocal 52.5%, 2003—local 73.6% and nonlocal 43.8%, 2004—local 70.7% and nonlocal 40%, 2005 local 61.4% and nonlocal 37.5%, 2006-local 58.6% and nonlocal 32.9%. Anaconda's 30-year average annual precipitation is 13.93 inches. The site was quite dry the year of establishment (2000—9.57 inches), but the years following were near or above normal; 2001—13.99", 2002—16.23", 2003—15.42", 2004—13.37", 2005---15.75", and 2006—19.03". Precipitation in Anaconda, therefore, was probably not a major factor in plant mortality.

In all species except *Symphoricarpos occidentalis*, the "local" source had equal or better survival than the "nonlocal" sources. As shown in table 3, the superior accessions included *Pinus ponderosa* (Deer Lodge County, MT), *P. ponderosa* (Lawrence County, SD), *R. cereum* (Deer Lodge County, MT), *Symphoricarpos albus* (Deer Lodge County, MT), and *Shepherdia argentea* (Deer Lodge County, MT). Based on survival and growth, the best overall performing species have been *Pinus ponderosa*, followed by *Symphoricarpos albus*, *Shepherdia argentea*, *Ribes cereum*, and *Rosa woodsii*. All accessions of *Pinus contorta* have performed poorly.

#### Growth

The average growth over the first 4-year period for the local source material was 14.99 cm (5.9 inches), while the nonlocal material averaged 10.33 cm (4.07 inches) of growth. In 2005, the local material averaged 13.44 cm of growth, while the nonlocal averaged 8.7 cm. In 2006, the local material averaged 3.59 cm of growth, while the nonlocal averaged 1.71 cm. Generally, the local source material outgrew the nonlocal material except for the two snowberry species, *Symphoricarpos albus* and *Symphoricarpos occidentalis*, and the lodgepole pine (*Pinus contorta*). Some of the shrubs exhibited leader mortality or cropping by wildlife, which resulted in negative overall growth. The accessions with the greatest sustained growth were *Ribes cereum* (Deer Lodge County), *Shepherdia argentea* (Deer Lodge County), *Symphoricarpos occidentalis* (Wyoming source), *Rosa woodsii* (Deer Lodge County), and *Symphoricarpos albus* (Ravalli County).

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### Vigor

Live plants were rated on a scale from 1 to 9 (1=highest rating) based on a visual assessment of their vigor or robustness. Dead plants were entered as missing values. The vigor rating for local source material was somewhat better than the nonlocal source material, but not significantly so: 2001—local 3.8 vs. nonlocal 5.4, 2002—local 3.9 vs. nonlocal 4.8, 2003--local 5.1 vs. non-local 5.9, 2004--local 5.1 vs. non-local 5.9, 2005--local 5.4 vs. non-local 5.5, and 2006—local 5.4 vs. non-local 5.5. No patterns in superior vigor seem to exist by species or origin other than the local material has slightly better vigor rating than the non-local.

The top-ranking accession for vigor was *Ribes cereum* (Deer Lodge County) followed by *Shepherdia argentea* (Deer Lodge County). *R. cereum* and *S. argentea* have consistently out performed the non-local sources since establishment. As in the other categories, the lodgepole pine *Pinus contorta* accessions had the poorest overall performance.

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Table 3. Woody Comparative Evaluation: 2002-2006															
Replication	Vigor 2002	Vigor 2003	Vigor 2004	Vigor 2005	Vigor 2006	Avg. Ht. 2002 (cm)	Avg. Ht. 2003 (cm)	Avg. Ht. 2004 (cm)	Avg. Ht. 2005 (cm)	Avg. Ht. 2006 (cm)	Surv. 2002 %	Surv. 2003 %	Surv. 2004 %	Surv. 2005 %	Surv. 2006 %
<b>PICO 9078320</b>	<b>5.80</b>	<b>5.10</b>	<b>6.50</b>	<b>7.60</b>	<b>7.40</b>	<b>10.06</b>	<b>10.19</b>	<b>11.83</b>	<b>14.00</b>	<b>17.40</b>	<b>85</b>	<b>40</b>	<b>25</b>	<b>25</b>	<b>25</b>
PICO m039ID0002	5.00	5.00	7.00	8.00	8.00	12.83	16.33	16.00	16.50	16.00	30	15	10	10	10
PICO m038WY0002	4.00	4.50	5.50	6.00	6.50	14.50	15.67	18.00	20.50	20.00	20	15	5	10	10
<b>PIPO 9081318</b>	<b>2.10</b>	<b>3.40</b>	<b>5.63</b>	<b>5.74</b>	<b>5.84</b>	<b>24.68</b>	<b>27.38</b>	<b>25.79</b>	<b>31.26</b>	<b>32.32</b>	<b>100</b>	<b>100</b>	<b>95</b>	<b>95</b>	<b>95</b>
PIPO m04CO0002	4.20	4.80	7.29	8.00	7.90	14.29	14.74	13.65	14.13	11.90	85	85	85	75	50
PIPO m020SD9903	3.20	2.70	4.84	5.26	5.37	26.80	32.10	31.47	38.32	41.63	100	100	95	95	95
<b>RICE 9081329</b>	<b>4.80</b>	<b>2.80</b>	<b>3.86</b>	<b>3.25</b>	<b>3.42</b>	<b>25.50</b>	<b>47.15</b>	<b>52.00</b>	<b>78.67</b>	<b>93.92</b>	<b>75</b>	<b>65</b>	<b>70</b>	<b>60</b>	<b>60</b>
RICE m024CO0003	5.40	5.10	5.90	5.38	5.13	12.31	24.00	25.60	46.88	56.75	65	50	50	40	40
<b>ROWO 9081638</b>	<b>4.20</b>	<b>4.50</b>	<b>4.54</b>	<b>4.36</b>	<b>5.00</b>	<b>26.07</b>	<b>35.85</b>	<b>39.39</b>	<b>57.27</b>	<b>57.50</b>	<b>75</b>	<b>65</b>	<b>65</b>	<b>55</b>	<b>50</b>
ROWO m076CO0003	7.00	7.00	8.00	0.00	0.00	9.00	5.00	4.00	0.00	0.00	15	5	5	0	0
ROWO m07MT0003	5.00	4.00	6.00	4.00	7.00	12.00	28.50	21.67	50.50	46.00	20	10	15	10	10
<b>SHAR 9081334</b>	<b>2.50</b>	<b>2.50</b>	<b>3.94</b>	<b>4.00</b>	<b>3.67</b>	<b>29.88</b>	<b>37.94</b>	<b>41.69</b>	<b>73.93</b>	<b>79.93</b>	<b>80</b>	<b>80</b>	<b>80</b>	<b>75</b>	<b>75</b>
SHAR m022WY0005	6.60	5.20	6.67	7.29	6.25	5.58	7.79	12.67	20.14	33.25	60	35	30	35	20
SHAR m015UT9901	5.80	5.00	5.50	6.00	5.50	9.20	13.25	15.00	31.50	24.00	25	20	10	10	10
<b>SYAL 9078388</b>	<b>3.60</b>	<b>4.00</b>	<b>4.53</b>	<b>5.67</b>	<b>6.24</b>	<b>18.67</b>	<b>25.06</b>	<b>28.53</b>	<b>30.50</b>	<b>29.00</b>	<b>90</b>	<b>85</b>	<b>95</b>	<b>90</b>	<b>85</b>
SYAL m045MT003	3.60	3.00	4.17	4.83	4.83	18.33	30.33	33.67	40.50	45.67	30	30	30	30	30
<b>SYOC 9081639</b>	<b>4.60</b>	<b>5.20</b>	<b>6.85</b>	<b>6.50</b>	<b>6.00</b>	<b>18.06</b>	<b>16.09</b>	<b>18.62</b>	<b>26.50</b>	<b>27.25</b>	<b>85</b>	<b>80</b>	<b>65</b>	<b>30</b>	<b>20</b>
SYOC m021WY0004	3.80	2.80	4.57	4.39	4.09	24.79	40.57	37.53	55.69	59.55	90	75	70	65	55
SYOC m018CO9904	4.00	4.50	4.80	5.36	5.39	16.61	22.79	23.71	35.93	36.39	90	85	75	70	65

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### Conclusion

Several dead plants were dug up and it was observed that the roots of these plants had not penetrated the native soil beyond their soil media plug area. It seems probable that plants whose roots were able to tolerate the low pH and metalliferous surroundings beyond their plug area flourished, while those with roots sensitive to the edaphic contaminants declined.

The accessions that have had good survival and are now putting on substantial growth include:

- Pinus ponderosa (Deer Lodge County, MT)
- Pinus ponderosa (Lawrence County, SD)
- Ribes cereum (Deer Lodge County, MT)
- Rosa woodsii (Deer Lodge County, MT)
- Shepherdia argentea (Deer Lodge County, MT)
- Symphoricarpos albus (Deer Lodge County, MT)
- Symphoricarpos occidentalis (Weston County, WY)

### Recommendations

There are obvious limitations and apparent weaknesses in this study. Currently, only one individual plant comprises an experimental unit. This is problematic because high mortality at the plot resulted in replications lacking an experimental unit, thus generating missing values. It is suggested that an experimental unit include five to ten individuals and that the number of replications be decreased. A larger experimental unit would also allow the harvesting of a few individuals for examination of subterranean growth. Secondly, the "local" and "nonlocal" seedlings of each species in this study were assembled from different growers and were not produced using identical cultural techniques. It is important that accessions of each species are produced under the same regimes. Thirdly, the current study lacks a control. A control plot located at a relatively uncontaminated site is needed in order to compare soil effects and the effectiveness of the treatments. It is believed that the installation of Vispore™ tree mats was beneficial.

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**III. STUCKY RIDGE MOTO-X SITE**





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### COMPARATIVE EVALUATION OF GRASSES, FORBS, AND SEED MIXTURES FROM “LOCAL” VERSUS “NON-LOCAL” ORIGINS Moto-X—Stucky Ridge

#### Methods and Materials

##### Study Site

The study is located on Stucky Ridge, ~2 mi northeast of Anaconda, Montana, in Deer Lodge County. The legal description and geographic position of the study site are the SW 1/4 of the SW 1/4 of Section 30, Range 11 West, Township 5 North and North 46°09'09”/ West 112°54'30”. The study plot occupies 1.5 acres in subpolygon OWSR-013.09, which is part of the Stucky Ridge Remedial Design Unit (RDU) #1 within the Anaconda Regional Water, Waste, and Soils Operable Unit.

RDU #1 encompasses 242 acres of the ~13,000 acres of upland terrestrial vegetation contaminated by emission fallout from the Washoe, as well as the Upper and Lower Works smelters. Concerns identified in the Stucky Ridge RDU include elevated arsenic concentrations in surface soils, barren or sparsely vegetated areas due to low pH and elevated contaminant concentrations, and steep slopes with high erosion potentials (ARCO 2002, May) (table 1). Current and historic use of this area primarily consists of agricultural grazing, recreation, and open space/wildlife habitat.

The plot site is situated on a stream terrace above Lost Creek at an elevation of 5308 feet and covers most of the relatively flat ground on the east end of Stucky Ridge. The vegetation, although sparse, includes scattered groves of quaking aspen, shrublands dominated by Wood’s rose, currant species, rubber rabbitbrush, and horsebrush; and grasslands dominated by redtop and basin wildrye. Annual precipitation at the site ranges from 10 to 14 inches with most of the precipitation occurring in the spring. The parent material is alluvium. The soil has a gravelly loam texture and is well drained. The slope at the plot site averages ~5 to 10 percent.

Table 1. Pre-tillage soils data in the proximity of the plot site (ARCO 2002, May).

Soil Sample Station	Depth <i>inches</i>	As <i>mg/kg</i>	Cu <i>mg/kg</i>	Zn <i>mg/kg</i>	Sat. Paste pH <i>s.u.</i>
94S-SR-71	0-2	-----	-----	-----	4.70
94S-SR-71	2-8	-----	-----	-----	4.90
94S-SR-73	0-2	-----	-----	-----	4.30
94S-SR-73	2-8	-----	-----	-----	4.60
99-098A	0-2	495.0	1660.0	419.0	-----
99-098B	2-6	163.0	1320.0	276.0	-----
99-098C	0-6	-----	-----	-----	4.20
99-098D	6-12	-----	-----	-----	7.60
99-098E	12-18	-----	-----	-----	7.80
99-099A	0-2	489.0	1370.0	303.0	-----
99-099B	2-6	95.8	1020.0	245.0	-----

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99-099C	0-6	----	----	----	4.00
99-099D	6-12	----	----	----	7.30
99-099E	12-18	----	----	----	7.70
99-123A	0-2	656.0	1530.0	425.0	----
99-123B	2-6	167.0	1530.0	332.0	----
99-123C	0-6	----	----	----	4.40
99-123D	6-12	----	----	----	4.80
99-123E	12-18	----	----	----	6.30
99-163A	0-2	537.0	2180.0	493.0	----
99-163B	2-6	256.0	1430.0	365.0	----
99-163C	0-6	----	----	----	4.00
99-163D	6-12	----	----	----	6.20
99-163E	12-18	----	----	----	----

### Soil Treatment

The study plot site was ameliorated along with the rest of treatment area (OWSR-013.09) following the remedial actions specified in the Remedial Action Work Plan/Final Design Report (ARCO 2002, May). The remedy identified for this treatment area was soil tilling to 12 inches with the addition of a neutralizing amendment to ameliorate the low pH soil conditions. Remediation of the area was performed by Jordan Contracting, Inc. and their subcontractors starting in the fall of 2002. According to the work report from Jordan Contracting, Inc. (Bahr 2003, February 18) prior to tillage, many of the erosion rills and gullies were graded using a D8 Dozer and a CAT 330 excavator. The entire treatment area was pre-tilled by Western Reclamation, Inc. with a Rhome™ disc to approximately 12 inches in mid-September. Lime kiln dust, procured from Continental Lime, Inc., was then applied at a rate of ~22.0 tons/acre to neutralize the soil. Four additional passes were made with the Rhome™ disc to a depth of 12 inches to incorporate the lime. Lime incorporation was completed on November 14, 2002.

In the spring of 2003, fertilizer (12% N, 16%P<sub>2</sub>O<sub>5</sub>, 30% K<sub>2</sub>O) was applied at a rate of 500 bulk pounds per acre and incorporated to 6 inches using a chisel plow. The tillage area was drill seeded in early May 2003 at a rate of 25 lbs/acre with “Revegetation Mix #1.” Table 2 below lists the soil characteristics of pre-tillage soil data points closest to the study site (northwest portion of treatment area [OWSR-013.09] as stated in the Remedial Action Work Plan/Final Design Report [ARCO 2002, May]).

Table 2. Post-planting grass, forb/subshrub, and seed mixture trial (0- to 6-inch) composite soil sample analysis from the Stucky Ridge Comparative Evaluation Planting.

Sample Id.	Sample Description.	pH	As	Cd	Cu	Pb	Zn
		<i>s.u.</i>	<i>mg/kg</i>	<i>mg/kg</i>	<i>mg/kg</i>	<i>mg/kg</i>	<i>mg/kg</i>
GR1	Grass Trial, Rep. 1	8.2	120	1	797	35	174
GR2	Grass Trial, Rep. 2	8.1	117	1	906	34	177
GR3	Grass Trial, Rep. 3	7.9	132	1	833	43	195
GR4	Grass Trial, Rep. 4	8.0	212	2	985	61	228

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GDR1	Grass Trial, Rep. 1, Duplicate	7.7	121	1	703	39	153
GDR3	Grass Trial, Rep. 3, Alternate	7.7	178	1	845	57	201
FR1	Forb Trial, Rep. 1	8.0	115	1	774	38	185
FR2	Forb Trial, Rep. 2	7.2	127	2	888	45	182
FR3	Forb Trial, Rep. 3	7.7	153	2	1010	45	220
FR4	Forb Trial, Rep. 4	7.6	127	2	1080	40	210
FD1	Forb Trial, Rep. 1, Duplicate	8.0	91	ND <sup>†</sup>	681	31	170
FD3	Forb Trial, Rep. 3, Duplicate	7.9	106	1	828	33	171
MR1	Seed Mix. Trial, Rep. 1	8.0	39	1	721	6	143
MR2	Seed Mix. Trial, Rep. 2	7.5	367	2	909	97	226
MR3	Seed Mix. Trial, Rep. 3	7.7	39	ND	706	12	161
MR4	Seed Mix. Trial, Rep. 4	7.8	257	2	857	91	209
MDR1	Seed Mix. Trial, Rep. 1, Duplicate	7.4	130	1	925	35	165
MDR3	Seed Mix. Trial, Rep 3, Alternate	8.1	29	ND	525	9	153

† ND: Not detected at the reporting limit.

### Post-Treatment Soil Sampling Methods

Soil sampling of the grass, forb/subshrub, and seed mixture trials was completed on June 24, 2003, after planting. The soil samples were analyzed for pH (1:1 saturated paste), and total As, Cd, Cu, Pb, and Zn by Energy Laboratories, Inc. in Billings, Montana. At the grass trial eight randomly selected treatment blocks in each replication were subsampled. The eight (0- to 6-inch, 0- to 15-cm) composite subsamples collected from a replication were combined and mixed to form one representative sample. Duplicate soil samples were taken in replication 1 and alternate soil samples were taken in replication 3. In the forb/subshrub trial, four (0- to 6-inch) subsamples were taken per replication to form one representative sample. Duplicate subsamples were taken in replications 1 and 3. In the mixture trial, two (0- to 6-inch) subsamples were taken per replication to form one representative sample. Duplicate subsamples were taken in replication 1 and alternate subsamples were taken in replication 3.

The arsenic and metal concentrations of the post-planting soil samples were generally moderate with the exception of copper. Copper concentrations within the three trials averaged 832 mg/kg and ranged from 525 mg/kg to 1080 mg/kg. The average copper concentrations in the grass, forb/subshrub, and seed mixture trials were 845 mg/kg, 877 mg/kg, and 774 mg/kg, respectively. The pH of post-planting soil samples were all above neutral, averaging 7.8 and ranging from 7.2 to 8.2.

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### Planting Design

The study is arranged as three separate trials (grass, forb/subshrub, and seed mixture) each in a Randomized Complete Block Design replicated four times. The three trials are situated adjacent to each other as shown in figure 1. The grass, forb/subshrub, and seed mixture trials are 0.96 acre, 0.44 acre, and 0.14 acre, respectively, with a total plot size of 1.52 acres. Between each replication, as well as between trials, an 8-foot strip of *Elymus trachycaulus* 'Pryor' was planted to minimize edge effect. The seed bed was prepared by DATC Project personnel on April 22, 2003, using a 5-foot box scraper to level the soil. Rocks greater than 6 inches in diameter within the plot boundary were hand-picked. After rock removal, another pass was made with the box scraper and spike-tooth harrow to till out tractor tire compressions.

On May 13, 2003, the seed treatments were planted using a 4-row Kincaid™ cone drill with 1-ft row spacing and a 0.5-inch planting depth. The seeding rate for the grass and forb/subshrub trials was 50 Pure Live Seeds (PLS) per linear foot of row. The seeding rate for the seed mixture trial was based on a total seeding rate of 50 PLS per square foot. Each component of the mix was calculated as a percentage of the per-square-foot rate.

The seed mixtures were formulated for two distinct applications. An "Upland" blend was designed for sloping areas with generally low water infiltration and to provide wildlife habitat. The "Waste Management Area" (WMA) blend was designed to provide a vegetative cover for areas in which remedial options appear to be limited and their use for containment of large volumes of waste appears logical (EPA, 1995a). The seed mixtures referred to as "Developed" are the seed formulations, utilizing commercially available cultivars, currently specified for use in the Remedial Action Work Plan/Final Design Report 2002. The seed mixture previously referred to as Revegetation Mix #1, planted in the surrounding treatment area, is synonymous with the "Upland Developed" seed mixture. The seed mixtures referred to as "Experimental" are local ecotypes of the same species from mine-impacted lands.

Each treatment block is 8 feet (8 rows) by 25 feet. In the grass and forb/subshrub trials, each treatment block was planted with a single accession. Two exceptions exist due to seed quantity restraints. In all replications of the grass trial, *Pascopyrum smithii* 9081968 was drilled in only 6 rows with *Elymus trachycaulus* 'Pryor' drilled into the remaining 2 rows. In all replications of the forb/subshrub trial, *Eriogonum ovalifolium* 9082098 was drilled into only 4 rows with *Elymus trachycaulus* 'Pryor' drilled into the remaining 4 rows.

As mentioned above, *Elymus trachycaulus* 'Pryor' was drilled in the border strips and also broadcast in the unplanted area south of the forb/subshrub trial. Wooden stakes, spray painted orange and marked with an identification number, were installed in the northeast corner of each treatment block. Lastly, a single-strand, smooth wire fence was installed around the perimeter of the plot to designate plot boundaries and restrict vehicular trespassing. In mid-July and again in mid-September, volunteer Canadian thistle was spot sprayed initially with a 3% solution of 2-4-D Amine and subsequently with a 3% solution of Stinger™ (Copyralid) applied with a backpack sprayer.

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Grass Trial				Rep 1	Rep 2
4 ACHY Nezpar	16 ELTR San Luis	30 POSE Sherman	20 LECI Magnar	10 PHHA 9081632	8 PEST Bandera
24 PASM Rosana	32 POSE 9081635	23 PASM Rodan	36 ELWA Secar	12 POGI 9081679	5 KRLA Op.Range
19 LECI Washoe	22 PASM 9081968	29 POSE 9081633	11 DECE Nortran	1 EROV 9082098	4 KRLA NCD
28 POAL 1858	2 ACHY 9081629	35 PSSP Goldar	18 LECI 9081625	14 SYCH 9078675	15 SYCH 9081678
26 POAL 01-13-1	15 ELTR Revenue	32 POSE 9081635	10 DECE 13970176	16 SYCH 5255-RS	9 PEVE Clearwater
21 LECI Trailhead	36 ELWA Secar	7 AGGI 9076266	8 AGGI Streaker	6 PEER Old Works	1 EROV 9082098
16 ELTR San Luis	13 ELTR 9081621	21 LECI Trailhead	4 ACHY Nezpar	4 KRLA NCD	6 PEER Old Works
25 POAL 9016273	1 ACHY 9081628	5 AGGI 9076276	30 POSE Sherman	9 PEVE Clearwater	7 PEEA Richfield
11 DECE Nortran	6 AGGI 9081619	1 ACHY 9081628	35 PSSP Goldar	7 PEEA Richfield	3 ERUM 01-206-1
27 POAL Gruening	26 POAL 01-13-1	26 POAL 01-13-1	23 PASM Rodan	11 PHHA 9003	12 POGR 9081679
14 ELTR Pryor	3 ACHY Rimrock	3 ACHY Rimrock	16 ELTR San Luis	3 ERUM 01-206-1	11 PHHA 9003
10 DECE 13970176	19 LECI Washoe	27 POAL Gruening	25 POAL 9016273	15 SYCH 9081678	10 PHHA 9081632
3 ACHY Rimrock	12 ELTR 9081620	13 ELTR 9081621	29 POSE 9081633	8 PEST Bandera	2 ERUM 450
12 ELTR 9081620	27 POAL Gruening	34 PSSP 9081636	12 ELTR 9081620	13 POHI 9076274	13 POHI 9076274
30 POSE Sherman	17 LECI 9081624	10 DECE 13970176	9 DECE 9076290	5 KRLA Op.Range	16 SYCH 5255-RS
17 LECI 9081624	5 AGGI 9076276	15 ELTR Revenue	27 POAL Gruening	2 ERUM 450	14 SYCH 9078675
36 ELWA Secar	30 POSE Sherman	18 LECI 9081625	6 AGGI 9081619	12 POGI 9081679	11 PHHA 9003
7 AGGI 9076266	10 DECE 13970176	12 ELTR 9081620	5 AGGI 9076276	9 PEVE Clearwater	10 PHHA 9081632
22 PASM 9081968	11 DECE Nortran	25 POAL 9016273	13 ELTR 9081621	5 KRLA Op.Range	5 KRLA Op.Range
6 AGGI 9081619	34 PSSP 9081636	2 ACHY 9081629	32 POSE 9081635	4 KRLA NCD	13 POHI 9076274
8 AGGI Streaker	18 LECI 9081625	8 AGGI Streaker	2 ACHY 9081629	16 SYCH 5255-RS	6 PEER Old Works
13 ELTR 9081621	8 AGGI Streaker	16 ELTR San Luis	33 POSE 9081322	13 POHI 9076274	8 PEST Bandera
29 POSE 9081633	33 POSE 9081322	22 PASM 9081968	26 POAL 01-13-1	10 PHHA 9081632	15 SYCH 9081678
18 LECI 9081625	21 LECI Trailhead	11 DECE Nortran	7 AGGI 9076266	15 SYCH 9081678	7 PEEA Richfield
33 POSE 9081322	29 POSE 9081633	4 ACHY Nezpar	15 ELTR Revenue	11 PHHA 9003	4 KRLA NCD
15 ELTR Revenue	9 DECE 9076290	33 POSE 9081322	22 PASM 9081968	8 PEST Bandera	12 POGR 9081679
35 PSSP Goldar	14 ELTR Pryor	28 POAL 1858	28 POAL 1858	2 ERUM 450	2 ERUM 450
1 ACHY 9081628	23 PASM Rodan	24 PASM Rosana	31 POSE Canbar	1 EROV 9082098	9 PEVE Clearwater
9 DECE 9076290	28 POAL 1858	20 LECI Magnar	14 ELTR Pryor	6 PEER Old Works	1 EROV 9082098
31 POSE Canbar	24 PASM Rosana	36 ELWA Secar	24 PASM Rosana	3 ERUM 01-206-1	14 SYCH 9078675
34 PSSP 9081636	31 POSE Canbar	6 AGGI 9081619	19 LECI Washoe	7 PEEA Richfield	16 SYCH 5255-RS
32 POSE 9081635	4 ACHY Nezpar	31 POSE Canbar	34 PSSP 9081636	14 SYCH 9078675	3 ERUM 01-206-1
2 ACHY 9081629	35 PSSP Goldar	14 ELTR Pryor	17 LECI 9081624	Rep 3	Rep 4
5 AGGI 9076276	20 LECI Magnar	17 LECI 9081624	3 ACHY Rimrock		
23 PASM Rodan	7 AGGI 9076266	9 DECE 9076290	1 ACHY 9081628		
20 LECI Magnar	25 POAL 9016273	19 LECI Washoe	21 LECI Trailhead		
4 WMA Dev	3 WMA Exp	4 WMA Dev	1 UP Exp		
1 UP Exp	2 UP Dev	1 UP Exp	4 WMA Dev		
2 UP Dev	1 UP Exp	3 WMA Exp	3 WMA Exp		
3 WMA Exp	4 WMA Dev	2 UP Dev	2 UP Dev		
Rep 1	Rep 2	Rep 3	Rep 4		

### Seed Mixture Trial

Figure 1. Layout of the grass, forb/subshrub, and seed mixture trials at the Stucky Ridge Comparative Evaluation Planting.

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### Seeded Species

The species entries consist of 36 grass accessions representing 9 grass genera, 14 forb accessions representing 5 forb genera, 2 subshrub accessions representing 1 subshrub species, and 4 seed mixtures representing 2 seed mixture formulations (tables 3-8). The 15 total genera tested were selected for inclusion in the study based on results from previous Development of Acid/Heavy Metal-Tolerant Cultivars (DATC) Project (currently DATR) studies such as the Initial Evaluation Planting study (Marty 2000, July) and the Greenhouse Comparative Evaluation Planting study (Marty 2001, October).

Each genus tested includes at least one accession originating from metalliferous soil sites in the proximity of the Anaconda Smelter NPL Site, except in one case. Neither of the two *Krascheninnikovia lanata* accessions originated from metalliferous soils. In this report, accessions that originated from metalliferous soils are referred to as “local,” whereas accessions originating from undisturbed soils are referred to as “non-local.”

### Sampling Methods

Seedling density was the growth response variable used to assess performance during the first growing season (2003). Measurements were taken using an 11.8- x 19.7-inch (30- x 50-cm) quadrat frame that was randomly placed at five sample locations within each (8- x 25-ft) treatment block. The quadrat was situated with its long axis perpendicular to the seeded rows so that each sampling measurement included two rows. Seedlings rooted within the quadrat frame were counted. Seeded seedlings, as well as non-seeded seedlings, were counted and recorded separately. Photographs of each treatment block were taken during sampling events. Density data was collected on June 24, 2003, to assess emergence and initial establishment and on August 26, 2003, to assess subsequent establishment and/or die off.

Table 3. Forb and subshrub treatments included in the forb/subshrub trial at the Stucky Ridge Uplands Comparative Evaluation Planting.

Species Id. #	Genus & Species	Accession/Variety	Origin
1	<i>Eriogonum ovalifolium</i>	9082098	Deer Lodge County, MT
2	<i>Eriogonum umbellatum</i>	9082271	Utah
3	<i>Eriogonum umbellatum</i>	9082273	Idaho
4	<i>Krascheninnikovia lanata</i>	Northern Cold Desert Germplasm	Composite from UT & ID
5	<i>Krascheninnikovia lanata</i>	Open Range Germplasm	Composite from MT & WY
6	<i>Penstemon eriantherus</i>	Old Works Germplasm	Deer Lodge County, MT
7	<i>Penstemon eatonii</i>	Richfield Selected	Sevier County, UT
8	<i>Penstemon strictus</i>	'Bandera' 477980	Torrance County, NM
9	<i>Penstemon venustus</i>	Clearwater Selected	Clearwater River area, ID
10	<i>Phacelia hastata</i>	9081632	Deer Lodge County, MT
11	<i>Phacelia hastata</i>	9082275	California
12	<i>Potentilla gracilis</i>	9081679	California
13	<i>Potentilla hippiana</i>	9076274	Deer Lodge County, MT
14	<i>Symphyotrichum chilense</i>	9078675	Deer Lodge County, MT
15	<i>Symphyotrichum chilense</i>	9081678	Colorado
16	<i>Symphyotrichum chilense</i>	9082274	Unknown



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Table 4. Grass treatments included in the grass trial at the Stucky Ridge Uplands Comparative Evaluation Planting.

Species Id. #	Genus & Species	Accession/Variety	Origin
1	<i>Achnatherum hymenoides</i>	9081628	Deer Lodge County, MT
2	<i>Achnatherum hymenoides</i>	9081629	Deer Lodge County, MT
3	<i>Achnatherum hymenoides</i>	'Rimrock'	Yellowstone County, MT
4	<i>Achnatherum hymenoides</i>	'Nezpar'	White Bird, ID
5	<i>Agrostis gigantea</i>	9076276	Deer Lodge County, MT
6	<i>Agrostis gigantea</i>	9081619	Deer Lodge County, MT
7	<i>Agrostis gigantea</i>	9076266	Deer Lodge County, MT
8	<i>Agrostis gigantea</i>	'Streaker'	Illinois
9	<i>Deschampsia caespitosa</i>	9076290	Silver Bow County, MT
10	<i>Deschampsia caespitosa</i>	9082620	California
11	<i>Deschampsia caespitosa</i>	'Nortran'	Alaska
12	<i>Elymus trachycaulus</i>	9081620	Deer Lodge County, MT
13	<i>Elymus trachycaulus</i>	9081621	Deer Lodge County, MT
14	<i>Elymus trachycaulus</i>	'Pryor'	Carbon County, MT
15	<i>Elymus trachycaulus</i>	'Revenue'	Saskatchewan, Canada
16	<i>Elymus trachycaulus</i>	'San Luis'	Rio Grande County, CO
17	<i>Leymus cinereus</i>	9081624	Deer Lodge County, MT
18	<i>Leymus cinereus</i>	9081625	Deer Lodge County, MT
19	<i>Leymus cinereus</i>	Washoe Germplasm	Deer Lodge County, MT
20	<i>Leymus cinereus</i>	'Magnar'	Saskatchewan, Canada
21	<i>Leymus cinereus</i>	'Trailhead'	Musselshell County, MT
22	<i>Pascopyrum smithii</i>	9081968 <sup>T</sup>	Deer Lodge County, MT
23	<i>Pascopyrum smithii</i>	'Rodan'	Morton County, ND
24	<i>Pascopyrum smithii</i>	'Rosana'	Rosebud County, MT
25	<i>Poa alpina</i>	9016273	Gallatin County, MT
26	<i>Poa alpina</i>	01-13-1	British Columbia, Canada
27	<i>Poa alpina</i>	'Gruening'	France/Switzerland
28	<i>Poa alpina</i>	1858	Unknown
29	<i>Poa secunda (ampla)</i>	9081633	Deer Lodge County, MT
30	<i>Poa secunda (ampla)</i>	'Sherman'	Sherman County, OR
31	<i>Poa secunda (canbyi)</i>	'Canbar'	Columbia County, WA
32	<i>Poa secunda</i>	9081635	Deer Lodge County, MT
33	<i>Poa secunda</i>	9081322	Lewis & Clark County, MT
34	<i>Pseudoroegneria spicata</i>	9081636	Deer Lodge County, MT
35	<i>Pseudoroegneria spicata</i>	'Goldar'	Asotin County, WA
36	<i>Elymus wawawaiensis</i>	'Secar'	Washington

Table 5. Upland Areas - Experimental Seed Mix Formulation.

Species Id. #	Genus & Species	Accession/Variety	Origin	Seed Mixture Percentage
1	<u>GRASSES:</u>			
	<i>Achnatherum hymenoides</i>	9081629	Deer Lodge County, MT	15.0
	<i>Elymus trachycaulus</i>	9081620	Deer Lodge County, MT	15.0
	<i>Leymus cinereus</i>	Washoe Germ.	Deer Lodge County, MT	15.0
	<i>Pascopyrum smithii</i>	9081968	Deer Lodge County, MT	5.0
	<i>Poa alpina</i>	90816273	Gallatin County, MT	10.0
	<i>Poa secunda (ampla)</i>	9081633	Deer Lodge County, MT	15.0
	<i>Pseudoroegneria spicata</i>	9081636	Deer Lodge County, MT	15.0
	<u>FORBS:</u>			
	<i>Aster chilensis</i>	9078675	Deer Lodge County, MT	2.5

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	<i>Penstemon eriantherus</i>	Old Works Germ.	Deer Lodge County, MT	5.0
	<i>Potentilla hippiana</i>	9076274	Silverbow County, MT	2.5

Table 6. Upland Areas - Developed Seed Mix Formulation.

Species Id. #	Genus & Species	Accession/Variety	Origin	Seed Mixture Percentage
2	<u>GRASSES:</u>			
	<i>Achnatherum hymenoides</i>	'Nezpar'	White Bird, ID	5.0
	<i>Elymus lanceolatus</i>	'Critana'	Hill County, MT	15.0
	<i>Elymus trachycaulus</i>	'Revenue'	Saskatchewan, Canada	15.0
	<i>Festuca ovina</i>	'Covar'	Central Turkey	10.0
	<i>Leymus cinereus</i>	'Magnar'	Saskatchewan, Canada	15.0
	<i>Pascopyrum smithii</i>	'Rosana'	Rosebud County, MT	10.0
	<i>Poa secunda (ampla)</i>	'Sherman'	Sherman County, OR	14.5
	<i>Pseudoroegneria spicata</i>	'Goldar'	Asotin County, WA	10.0
	<u>FORBS:</u>			
	<i>Achillea lanulosa</i>	Great Northern	Flathead County, MT	2.5
	<i>Artemisia frigida</i>	9082258	Unknown	0.5
	<i>Linum lewisii</i>	'Appar'	Custer County, SD	2.5

Table 7. Waste Management Areas - Experimental Seed Mix Formulation

Species Id. #	Genus & Species	Accession/Variety	Origin	Seed Mixture Percentage
3	<u>GRASSES:</u>			
	<i>Agrostis gigantea</i>	9076276	Deer Lodge County, MT	15
	<i>Deschampsia caespitosa</i>	9076290	Silverbow County, MT	10
	<i>Elymus trachycaulus</i>	9081620	Deer Lodge County, MT	15
	<i>Leymus cinereus</i>	Washoe Germ.	Deer Lodge County, MT	15
	<i>Pascopyrum smithii</i>	9081968	Deer Lodge County, MT	5
	<i>Poa secunda (ampla)</i>	9081633	Deer Lodge County, MT	10
	<i>Stipa comata</i>	9078314	Deer Lodge County, MT	10
	<u>FORBS:</u>			
	<i>Aster chilensis</i>	9078675	Deer Lodge County, MT	10

Table 8. Waste Management Areas - Developed Seed Mix Formulation.

Species Id. #	Genus & Species	Accession/Variety	Origin	Seed Mixture Percentage
4	<u>GRASSES:</u>			
	<i>Agropyrum intermedium</i>	'Greenar'	Former USSR	10
	<i>Bromus inermis</i>	'Manchar'	Manchuria, China	15
	<i>Elymus lanceolatus</i>	'Critana'	Hill County, MT	10
	<i>Elymus trachycaulus</i>	'Revenue'	Saskatchewan, Canada	15
	<i>Leymus cinereus</i>	'Magnar'	Saskatchewan, Canada	15
	<i>Poa secunda (ampla)</i>	'Sherman'	Sherman County, OR	10
	<i>Stipa viridula</i>	9082255	Washington	10
	<u>FORBS:</u>			
	<i>Medicago sativa</i>	'Ladak'	Kashmir, India	15

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Data was collected on June 30/July 1 and again on September 22-23, 2004, on August 29-30, 2005, and on August 28-29, 2006. During the early summer sampling, four randomly located frames (30 x 50 cm) were utilized, from which average plant height was measured, percentage stand was estimated, and ocular estimates of plant vigor were made. Random samples were located along rows 2-3 and 6-7 to avoid edge-effect error. In the fall the same random frame locations were used to estimate percentage stand, plant vigor, plant height (2005) and sample biomass production. If combined biomass samples from all four replications did not yield at least 10 grams of material, additional clipping was done so that there would be enough biomass for tissue analysis. All biomass samples were oven dried at 60°C (140°F) for 24 hours, weighed, and later cut into small pieces and packaged in plastic zip-lock bags for delivery to Energy Laboratories, Inc. for tissue analysis.

### Results and Discussion

#### Grass Trial (2003)

The grand mean of seedling density data collected on June 24, 2003, in the grass trial was 5.4 seedlings/ft<sup>2</sup> and ranged from 15.0 to 0.3 seedlings/ft<sup>2</sup> (tables 9 and 10). Three accessions of *Elymus trachycaulus* ('Pryor', 9081620, and 'San Luis') had the greatest seedling densities at 15.0, 14.1, and 13.6, respectively. These results are not surprising as *Elymus trachycaulus* is recognized for its excellent seedling vigor and quick establishment and growth on a variety of soil types. Density data collected 2 months later on August 26, 2003, indicated that these three *E. trachycaulus* accessions had significantly greater densities than 86% of the accessions tested. The locally collected *E. trachycaulus* 9081620, however, did not perform significantly better than 'Pryor' or 'San Luis'.

*Pascopyrum smithii* ('Rosana' and 9081968) had 13.3 and 12.7 seedlings/ft<sup>2</sup>, respectively, on June 24 (table 9). *P. smithii* is an aggressively rhizomatous, long-lived grass known to be adapted to a wide range of soil types from acidic to basic. Seedling density data collected on August 26 indicated that the above *P. smithii* accessions also had significantly greater densities than 86% of the accessions tested including *P. smithii* 'Rodan'.

Seedling density data from the June evaluation indicated that *Leymus cinereus* 9081624 had significantly greater density (7.8 seedlings/ft<sup>2</sup>) than 80.5% of the accessions including the four other *Leymus cinereus* accessions (table 9). However, by the August evaluation *L. cinereus* 9081624 was not significantly better than *L. cinereus* 'Trailhead' (table 10). This accession's success is somewhat unexpected due to the species' poor to fair seedling vigor and slow seedling establishment. This species has been reported to be tolerant of elevated arsenic and heavy metal concentrations (Munshower 1998, September).

The *Pseudoroegneria spicata* accessions ('Goldar' and 9081636) also performed in the top third of the field in June and August (tables 9 and 10). In August, both accessions

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mentioned above had significantly better seedling densities than >50% of the accessions. The local accession *P. spicata* 9081636 did not perform significantly better than *P. spicata* 'Goldar'. *P. spicata* is reported to have fair seedling vigor and establishment with tolerances to acidic to slightly alkaline soils.

The grand mean for the August 26, 2003, evaluation is 4.3 seedlings/ft<sup>2</sup> and ranged from 14.5 to 0.31 seedlings/ft<sup>2</sup> (table 10). This indicates that seedling density declined by 1.1 seedlings/ft<sup>2</sup> or 20.4% between the June and August evaluations.

### Grass Trials (2004)

Based on the number of new seedlings found in 2004, there were many seeds that did not germinate during the 2003 growing season. The most notable species were *Achnatherum hymenoides* (Indian ricegrass), *Leymus cinereus* (basin wildrye), and *Pascopyrum smithii* (western wheatgrass). Indian ricegrass has a hard seed coat and should normally be dormant-seeded in the fall, but the basin wildrye and western wheatgrass may have delayed germination because of the combination of a relatively late spring planting date and subsequent hot, dry weather. The increase in new seedlings could be expressed in relatively higher percentage stands, but was not revealed in the biomass production, as seedlings were still quite small at the time of the late summer biomass sampling.

At the early summer sampling (6/30/04), the top accession, by a significant amount, was 9081620 slender wheatgrass (*Elymus trachycaulus*) with a 61.3% stand, 54.4 cm average height, and a 3.4 vigor rating. Other 'local source' accessions that exhibited good survival, stand, and vigor included 9081633 big bluegrass (*Poa secunda*), 9081621 slender wheatgrass (*Elymus trachycaulus*), 9081968 western wheatgrass (*Pascopyrum smithii*), 9081624 basin wildrye (*Leymus cinereus*), 9081628 Indian ricegrass (*Achnatherum hymenoides*), 9081635 Canby bluegrass (*Poa secunda*), and 9081636 bluebunch wheatgrass (*Pseudoroegneria spicata*) (see table 11 and 12).

Toward the end of the growing season (9/22/04 sampling date), there was very little change in the top performing accessions (table 13). Of the top 16 accessions in the early summer evaluation, 15 were still ranked as the top performing accessions. The 9081620 slender wheatgrass remained as the top performer by a significant margin. Of the 'local source' accessions, 9081633 big bluegrass, 9081621 slender wheatgrass, 9081968 western wheatgrass, 9081635 Canby bluegrass, 9081624 basin wildrye, and 9081636 bluebunch wheatgrass all show promise, and are among those being increased at the Bridger PMC for potential release to the commercial seed industry. Fall biomass production was relatively low, with only 9081620 slender wheatgrass producing more than 706 kg/ha (2,083 kg/ha) (table 14). Some of the low production can be attributed to the number of new seedlings emerging in 2004. Also 2-year-old plants were often spindly because of the harsh edaphic conditions. Toward the end of the growing season (9/22/04 sampling date), there was very little change in the top performing accessions (table 13). Of the top 16 accessions in the early summer evaluation, 15 were still ranked as the top performing accessions. The 9081620 slender wheatgrass remained as the top performer by a significant margin.

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### Grass Trials (2005)

The grasses were evaluated and sampled on August 30, 2005. Although there has been some mortality, the top performers of 2003/2004 continue to exhibit their ability to withstand the harsh edaphic conditions of this site. Slender wheatgrass (9081620) is the top performer with an average stand of 75% (table 15), average plant height of 87.5 cm (table 16), and average biomass production of 8,211 kg/ha (table 17). Other superior accessions include 9081633 big bluegrass (stand-43.4%, biomass-2,506 kg/ha), 9081621 slender wheatgrass (stand-34.1%, biomass-4,100 kg/ha), 9081635 bluegrass (stand-25.9%, biomass-906 kg/ha), 9081968 western wheatgrass (stand-21.9%, biomass-800 kg/ha), and 9081624 basin wildrye (stand-22.2%, biomass-1,844 kg/ha). The released cultivars, Secar Snake River wheatgrass, Pryor slender wheatgrass, San Luis slender wheatgrass, Rosana western wheatgrass, and Trailhead basin wildrye were among the top performers; but, in most cases, performances were slightly less than their indigenous counterparts.

### Grass Trials (2006)

The grasses were evaluated and sampled on August 28 & 29, 2006. There has been some change in the order of performance but the top performers from 2003-2005 are still in the top 10. Slender wheatgrass (9081620) is still the top overall performer with an average stand of 78.13% (table 18), average plant height of 77.31 cm (table 19), and average biomass production of 2311.11 kg/ha (table 20). Other top performers include 9081633 big bluegrass, 9081621 slender wheatgrass, 9081635 Canby bluegrass, and 9081624 basin wildrye. Western wheatgrass (9081968) dropped down from a standing of number 7 in 2005 to number 15 in 2006. The released cultivars, Secar Snake River wheatgrass, Pryor slender wheatgrass, San Luis slender wheatgrass, Rosana western wheatgrass, and Trailhead basin wildrye were still among the top performers; but their overall performance had not improved by any significance.

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Table 9. **Density** (seedlings per square foot) sampled on **June 24, 2003**, at the Stucky Ridge Comparative Evaluation Planting grass trial.

Genus & Species	Accession	Species ID	Density/ft <sup>2</sup>	Mean Separation
<i>Elymus trachycaulus</i>	'Pryor'	14	14.88	A*
<i>Elymus trachycaulus</i>	9081620	12	14.01	AB
<i>Elymus trachycaulus</i>	'San Luis'	16	13.54	AB
<i>Pascopyrum smithii</i>	'Rosana'	24	13.23	AB
<i>Pascopyrum smithii</i>	9081968	22	12.64	AB
<i>Pseudoroegneria spicata</i>	9081636	34	12.30	AB
<i>Leymus cinereus</i>	9081624	17	11.18	BC
<i>Elymus wawawaiensis</i>	'Secar'	36	9.41	CD
<i>Elymus trachycaulus</i>	9081621	13	9.29	CD
<i>Pseudoroegneria spicata</i>	'Goldar'	35	9.04	CD
<i>Achnatherum hymenoides</i>	'Nezpar'	4	8.88	CDE
<i>Elymus trachycaulus</i>	'Revenue'	15	8.70	CDE
<i>Poa secunda</i>	9081633	29	7.08	DEF
<i>Leymus cinereus</i>	'Magnar'	20	6.09	EFG
<i>Leymus cinereus</i>	'Trailhead'	21	5.78	FGH
<i>Pascopyrum smithii</i>	'Rodan'	23	5.62	FGH
<i>Leymus cinereus</i>	9081625	18	3.82	GHI
<i>Leymus cinereus</i>	Washoe Germplasm	19	3.63	GHIJ
<i>Poa secunda</i>	'Sherman'	30	3.11	HIJK
<i>Agrostis gigantea</i>	9081619	6	2.42	IJK
<i>Poa alpina</i>	9016273	25	2.33	IJK
<i>Poa secunda</i>	9081635	32	1.86	IJK
<i>Agrostis gigantea</i>	9076276	5	1.74	IJK
<i>Poa alpina</i>	1858	28	1.71	IJK
<i>Deschampsia caespitosa</i>	9076290	9	1.33	IJK
<i>Poa secunda</i>	9081322	33	1.31	IJK
<i>Achnatherum hymenoides</i>	'Rimrock'	3	1.27	IJK
<i>Poa secunda</i>	'Canbar'	31	1.21	IJK
<i>Deschampsia caespitosa</i>	'Nortran'	11	0.99	IJK
<i>Agrostis gigantea</i>	9076266	7	0.81	JK
<i>Achnatherum hymenoides</i>	9081629	2	0.78	K
<i>Agrostis gigantea</i>	'Streaker'	8	0.75	K
<i>Poa alpina</i>	01-13-1	26	0.65	K
<i>Achnatherum hymenoides</i>	9081628	1	0.59	K
<i>Deschampsia caespitosa</i>	13970176	10	0.56	K
<i>Poa alpina</i>	'Gruening'	27	0.34	K

\* Means followed by the same letter are not significantly different at the 0.05 significance level using the LSD Mean Comparison method.



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Table 10. **Density** (seedlings per square foot) sampled on **August 26, 2003**, at the Stucky Ridge Comparative Evaluation Planting grass trial.

Genus & Species	Accession	Species ID	Density/ft <sup>2</sup>	Mean Separation
<i>Elymus trachycaulus</i>	9081620	12	14.38	A*
<i>Elymus trachycaulus</i>	'San Luis'	16	13.35	AB
<i>Pascopyrum smithii</i>	'Rosana'	24	11.93	AB
<i>Pascopyrum smithii</i>	9081968	22	11.52	B
<i>Elymus trachycaulus</i>	'Pryor'	14	11.43	B
<i>Elymus trachycaulus</i>	'Revenue'	15	8.32	C
<i>Leymus cinereus</i>	9081624	17	7.76	C
<i>Pseudoroegneria spicata</i>	'Goldar'	35	7.21	CD
<i>Pseudoroegneria spicata</i>	9081636	34	7.11	CD
<i>Elymus wawawaiensis</i>	'Secar'	36	6.52	CD
<i>Achnatherum hymenoides</i>	'Nezpar'	4	6.49	CD
<i>Elymus trachycaulus</i>	9081621	13	6.06	CD
<i>Pascopyrum smithii</i>	'Rodan'	23	5.71	CD
<i>Poa secunda</i>	9081633	29	5.12	DE
<i>Leymus cinereus</i>	'Trailhead'	21	4.88	DEF
<i>Leymus cinereus</i>	'Magnar'	20	2.98	EFG
<i>Leymus cinereus</i>	9081625	18	2.33	FGH
<i>Poa secunda</i>	'Sherman'	30	2.33	FGH
<i>Agrostis gigantea</i>	9081619	6	2.27	FGH
<i>Leymus cinereus</i>	Washoe Germplasm	19	2.14	GH
<i>Agrostis gigantea</i>	9076276	5	1.46	GH
<i>Poa alpina</i>	1858	28	1.24	GH
<i>Poa secunda</i>	9081635	32	1.09	GH
<i>Poa alpina</i>	01-13-1	26	1.03	GH
<i>Agrostis gigantea</i>	9076266	7	0.96	GH
<i>Achnatherum hymenoides</i>	'Rimrock'	3	0.90	GH
<i>Poa alpina</i>	9016273	25	0.90	GH
<i>Deschampsia caespitosa</i>	'Nortran'	11	0.87	GH
<i>Poa secunda</i>	9081322	33	0.71	GH
<i>Achnatherum hymenoides</i>	9081628	1	0.59	GH
<i>Poa alpina</i>	'Gruening'	27	0.53	GH
<i>Poa secunda</i>	'Canbar'	31	0.47	GH
<i>Deschampsia caespitosa</i>	9076290	9	0.44	GH
<i>Deschampsia caespitosa</i>	13970176	10	0.37	GH
<i>Agrostis gigantea</i>	'Streaker'	8	0.34	H
<i>Achnatherum hymenoides</i>	9081629	2	0.28	H

\* Means followed by the same letter are not significantly different at the 0.05 significance level using the LSD Mean Comparison method.

## Appendix B

Table 11. Percentage **stand and vigor** of grass trials on Stucky Ridge Plots (evaluated **6/30/04**).

Genus & Species	Accession	Stand %	Vigor 1--9
<i>Elymus trachycaulus</i>	9081620	61.3 A*	2.1
<i>Achnatherum hymenoides</i>	Rimrock	31.3 B	4.8
<i>Poa secunda</i>	9081633	31.3 B	3.3
<i>Elymus trachycaulus</i>	9081621	28.4 BC	3.4
<i>Elymus trachycaulus</i>	Pryor	26.9 BCD	4.9
<i>Pascopyrum smithii</i>	9081968	26.7 BCD	4.9
<i>Achnatherum hymenoides</i>	Nezpar	25.3 BCDE	5.0
<i>Leymus cinereus</i>	9081624	20.8 BCDEF	4.4
<i>Elymus wawawaiensis</i>	Secar	20.0 BCDEFG	4.6
<i>Elymus trachycaulus</i>	Revenue	19.7 CDEFG	4.8
<i>Elymus trachycaulus</i>	San Luis	18.6 CDEFGH	4.8
<i>Achnatherum hymenoides</i>	9081628	18.3 CDEFGH	5.6
<i>Pascopyrum smithii</i>	Rosana	16.9 DEFGHI	4.8
<i>Leymus cinereus</i>	Trailhead	15.1 EFGHIJ	4.8
<i>Poa secunda</i>	9081635	15.0 EFGHIJ	3.3
<i>Pseudoroegneria spicata</i>	9081636	14.5 EFGHIJK	5.2
<i>Leymus cinereus</i>	Washoe	12.8 FGHIJKL	5.0
<i>Leymus cinereus</i>	Magnar	12.2 FGHIJKL	5.2
<i>Pascopyrum smithii</i>	Rodan	11.8 FGHIJKLM	5.3
<i>Agrostis gigantea</i>	9081619	10.7 FGHIJKLM	3.2
<i>Leymus cinereus</i>	9081625	10.1 FGHIJKLM	5.4
<i>Pseudoroegneria spicata</i>	Goldar	10.0 FGHIJKLM	5.1
<i>Achnatherum hymenoides</i>	9081629	8.6 GHIJKLM	5.7
<i>Agrostis gigantea</i>	9076276	8.1 HIJKLM	2.9
<i>Poa secunda</i>	Sherman	6.2 IJKLM	4.8
<i>Poa alpina</i>	01-13--1	4.1 JKLM	3.3
<i>Deschampsia caespitosa</i>	9076290	4.0 JKLM	4.2
<i>Poa secunda</i>	9081322	3.6 KLM	4.3
<i>Poa alpina</i>	9016273	3.3 KLM	4.5
<i>Agrostis gigantea</i>	9076266	3.1 KLM	4.0
<i>Poa alpina</i>	1858	1.4 LM	4.5
<i>Deschampsia caespitosa</i>	Nortran	0.6 M	5.3
<i>Poa alpina</i>	Gruening	0.5 M	4.0
<i>Agrostis gigantea</i>	Streaker	0.4 M	5.2
<i>Poa secunda</i>	Canbar	0.4 M	6.2
<i>Deschampsia caespitosa</i>	13970176	0.2 M	5.5

\* Means followed by the same letter are not significantly different at the 0.05 significance level using the LSD Mean Comparison method.

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Table 12. Average **plant height** of grasses in Stucky Ridge plots (measured **6/30/04**).

Genus & Species	Accession	Height
		<i>mm</i>
<i>Elymus trachycaulus</i>	9081620	54.37 A*
<i>Elymus trachycaulus</i>	9081621	34.19 B
<i>Agrostis gigantea</i>	9076276	33.13 B
<i>Agrostis gigantea</i>	9081619	27.13 BC
<i>Poa secunda</i>	9081633	26.25 BCD
<i>Elymus wawawaiensis</i>	Secar	23.88 CDE
<i>Poa secunda</i>	9081635	23.31 CDE
<i>Agrostis gigantea</i>	9076266	20.96 CDEF
<i>Elymus trachycaulus</i>	Pryor	18.50 CDEFG
<i>Leymus cinereus</i>	9081624	17.94 DEFG
<i>Poa secunda</i>	9081322	17.63 DEFGH
<i>Pseudoroegneria spicata</i>	Goldar	17.33 EFGH
<i>Achnatherum hymenoides</i>	Nezpar	16.94 EFGH
<i>Poa secunda</i>	Sherman	16.54 EFGHI
<i>Leymus cinereus</i>	Trailhead	16.06 EFGHIJ
<i>Elymus trachycaulus</i>	San Luis	14.50 FGHIJK
<i>Deschampsia caespitosa</i>	9076290	14.41 FGHIJKL
<i>Elymus trachycaulus</i>	Revenue	14.25 FGHIJKL
<i>Pascopyrum smithii</i>	Rosana	13.50 FGHIJKL
<i>Achnatherum hymenoides</i>	Rimrock	13.00 FGHIJKLM
<i>Leymus cinereus</i>	Magnar	13.00 FGHIJKLM
<i>Leymus cinereus</i>	Washoe	12.36 FGHIJKLMN
<i>Pascopyrum smithii</i>	Rodan	12.27 FGHIJKLMN
<i>Pseudoroegneria spicata</i>	9081636	12.04 GHIJKLMN
<i>Agrostis gigantea</i>	Streaker	11.83 GHIJKLMN
<i>Pascopyrum smithii</i>	9081968	11.38 GHIJKLMN
<i>Leymus cinereus</i>	9081625	10.67 GHIJKLMN
<i>Achnatherum hymenoides</i>	9081628	9.04 HIJKLMN
<i>Poa alpina</i>	01-13-1	8.11 IJKLMN
<i>Achnatherum hymenoides</i>	9081629	7.54 JKLMN
<i>Deschampsia caespitosa</i>	13970176	7.00 KLMN
<i>Poa secunda</i>	Canbar	6.33 KLMN
<i>Deschampsia caespitosa</i>	Nortran	6.00 KLMN
<i>Poa alpina</i>	9016273	5.71 LMN
<i>Poa alpina</i>	Gruening	4.50 MN
<i>Poa alpina</i>	1858	3.83 N

\* Means followed by the same letter are not significantly different at the 0.05 significance level using the LSD Mean Comparison method.

## Appendix B

Table 13. Percentage **stand and vigor** of grasses in Stucky Ridge plots (evaluated **9/22/04**).

Genus & Species	Accession	Stand %	Vigor 1—9
<i>Elymus trachycaulus</i>	9081620	61.25 A*	1.8
<i>Poa secunda</i>	9081633	37.19 B	2.4
<i>Elymus trachycaulus</i>	9081621	30.00 BC	2.7
<i>Pascopyrum smithii</i>	9081968	28.44 BCD	4.0
<i>Elymus trachycaulus</i>	Pryor	26.25 CDE	4.6
<i>Pascopyrum smithii</i>	Rosana	26.25 CDE	3.6
<i>Poa secunda</i>	9081635	24.06 CDEF	2.8
<i>Elymus trachycaulus</i>	Revenue	23.75 CDEFG	4.3
<i>Achnatherum hymenoides</i>	Rimrock	23.44 CDEFG	4.2
<i>Leymus cinereus</i>	9081624	22.81 CDEFGH	3.6
<i>Leymus cinereus</i>	Trailhead	20.00 DEFGHI	4.0
<i>Elymus wawawaiensis</i>	Secar	19.19 DEFGHI	4.0
<i>Elymus trachycaulus</i>	San Luis	19.06 DEFGHI	4.4
<i>Achnatherum hymenoides</i>	Nezpar	18.44 EFGHI	4.1
<i>Agrostis gigantea</i>	9081619	17.81 EFGHIJ	2.1
<i>Pseudoroegneria spicata</i>	9081636	17.50 EFGHIJK	3.8
<i>Pascopyrum smithii</i>	Rodan	16.56 EFGHIJK	4.5
<i>Agrostis gigantea</i>	9076276	15.94 FGHIJKL	2.7
<i>Achnatherum hymenoides</i>	9081628	4.38 FGHIJKLM	4.9
<i>Leymus cinereus</i>	Washoe	14.06 GHIJKLMN	4.6
<i>Leymus cinereus</i>	Magnar	13.44 HIJKLMN	4.7
<i>Pseudoroegneria spicata</i>	Goldar	13.44 HIJKLMN	4.1
<i>Poa secunda</i>	Sherman	12.19 IJKLMN	4.1
<i>Poa secunda</i>	9081322	11.88 IJKLMNO	2.9
<i>Leymus cinereus</i>	9081625	11.56 IJKLMNO	4.1
<i>Achnatherum hymenoides</i>	9081629	11.25 IJKLMNO	5.4
<i>Poa alpina</i>	01-13-1	8.44 JKLMNOP	3.6
<i>Agrostis gigantea</i>	9076266	7.81 KLMNOP	2.1
<i>Deschampsia caespitosa</i>	9076290	6.25 LMNOP	2.8
<i>Poa alpina</i>	9016273	5.19 MNOP	3.6
<i>Poa alpina</i>	1858	4.38 NOP	3.6
<i>Agrostis gigantea</i>	Streaker	1.88 OP	4.0
<i>Deschampsia caespitosa</i>	13970176	1.88 OP	3.3
<i>Poa alpina</i>	Gruening	1.06 P	3.3
<i>Deschampsia caespitosa</i>	Nortran	0.44 P	3.0
<i>Poa secunda</i>	Canbar	0.00 P	9.0

\* Means followed by the same letter are not significantly different at the 0.05 significance level using the LSD Mean Comparison method.

## Appendix B

Table 14. **Biomass** production of grasses in Stucky Ridge Trials (clipped **9/22/04**).

Genus & Species	Accession	Biomass kg/ha
<i>Elymus trachycaulus</i>	9081620	2,083 A*
<i>Agrostis gigantea</i>	9081619	706 B
<i>Elymus trachycaulus</i>	9081621	544 BC
<i>Elymus wawawaiensis</i>	Secar	413 BCD
<i>Poa secunda</i>	9081633	408 BCD
<i>Elymus trachycaulus</i>	Pryor	386 BCDE
<i>Leymus cinereus</i>	9081624	333 CDEF
<i>Leymus cinereus</i>	Washoe	289 CDEF
<i>Agrostis gigantea</i>	9076276	287 CDEF
<i>Elymus trachycaulus</i>	Revenue	266 CDEF
<i>Poa secunda</i>	9081635	216 CDEF
<i>Deschampsia caespitosa</i>	9076290	193 CDEF
<i>Leymus cinereus</i>	Trailhead	192 CDEF
<i>Agrostis gigantea</i>	9076266	185 DEF
<i>Poa secunda</i>	Sherman	183 DEF
<i>Achnatherum hymenoides</i>	Nezpar	169 DEF
<i>Pseudoroegneria spicata</i>	Goldar	165 DEF
<i>Pascopyrum smithii</i>	9081968	127 DEF
<i>Leymus cinereus</i>	9081625	124 DEF
<i>Elymus trachycaulus</i>	San Luis	100 DEF
<i>Pseudoroegneria spicata</i>	9081636	97 DEF
<i>Pascopyrum smithii</i>	Rosana	95 DEF
<i>Poa alpina</i>	01-13-1	92 DEF
<i>Pascopyrum smithii</i>	Rodan	85 DEF
<i>Achnatherum hymenoides</i>	Rimrock	84 DEF
<i>Poa alpina</i>	9016273	80 DEF
<i>Leymus cinereus</i>	Magnar	75 DEF
<i>Deschampsia caespitosa</i>	Nortran	73 DEF
<i>Achnatherum hymenoides</i>	9081628	34 EF
<i>Poa secunda</i>	9081322	24 F
<i>Achnatherum hymenoides</i>	9081629	23 F
<i>Poa alpina</i>	Gruening	15 F
<i>Deschampsia caespitosa</i>	13970176	8 F
<i>Poa alpina</i>	1858	7 F
<i>Agrostis gigantea</i>	Streaker	0 F
<i>Poa secunda</i>	Canbar	0 F

\* Means followed by the same letter are not significantly different at the 0.05 significance level using the LSD Mean Comparison method.

## Appendix B

Table 15. Percentage **stand and vigor** of grass trials on Stucky Ridge Plots (evaluated 8/30/05).

Genus & Species	Accession	Stand	Vigor
		%	1--9
<i>Elymus trachycaulus</i>	9081620	75.0 A*	2.1
<i>Poa secunda</i>	9081633	43.4 B	2.1
<i>Elymus trachycaulus</i>	9081621	34.1 BC	2.7
<i>Poa secunda</i>	9081635	25.9 CD	3.3
<i>Elymus trachycaulus</i>	Pryor	23.1 CDE	5.3
<i>Leymus cinereus</i>	9081624	22.2 CDEF	3.8
<i>Pascopyrum smithii</i>	9081968	21.9 DEFG	4.5
<i>Elymus wawawaiensis</i>	Secar	21.6 DEFG	4.3
<i>Elymus trachycaulus</i>	San Luis	20.9 DEFGH	4.6
<i>Pascopyrum smithii</i>	Rosana	20.6 DEFGH	4.7
<i>Leymus cinereus</i>	Trailhead	16.2 DEFGHI	4.3
<i>Pascopyrum smithii</i>	Rodan	16.2 DEFGHI	5.0
<i>Achnatherum hymenoides</i>	9081628	14.1 DEFGHIJ	5.3
<i>Achnatherum hymenoides</i>	Rimrock	14.1 DEFGHIJ	4.5
<i>Leymus cinereus</i>	9081625	13.8 DEFGHIJ	5.5
<i>Pseudoroegneria spicata</i>	9081636	13.8 DEFGHIJ	4.5
<i>Agrostis gigantea</i>	9081619	13.4 EFGHIJK	3.2
<i>Leymus cinereus</i>	Washoe	13.4 EFGHIJK	4.8
<i>Agrostis gigantea</i>	9076276	13.1 EFGHIJK	3.7
<i>Poa secunda</i>	Sherman	12.5 EFGHIJKL	4.0
<i>Achnatherum hymenoides</i>	Nezpar	11.9 EFGHIJKLM	4.6
<i>Elymus trachycaulus</i>	Revenue	11.9 EFGHIJKLM	5.4
<i>Pseudoroegneria spicata</i>	Goldar	11.1 EFGHIJKLM	4.6
<i>Leymus cinereus</i>	Magnar	10.9 FGHIJKLM	5.2
<i>Deschampsia caespitosa</i>	9076290	10.6 FGHIJKLM	3.9
<i>Poa secunda</i>	9081322	10.0 GHIJKLM	4.2
<i>Agrostis gigantea</i>	9076266	9.0 HIJKLM	4.0
<i>Achnatherum hymenoides</i>	9081629	6.4 IJKLM	5.7
<i>Poa alpina</i>	01-13-1	3.9 JKLM	5.0
<i>Poa alpina</i>	1858	3.6 JKLM	5.3
<i>Poa alpina</i>	9016273	3.0 JKLM	3.8
<i>Deschampsia caespitosa</i>	Nortran	1.6 KLM	3.8
<i>Deschampsia caespitosa</i>	13970176	0.9 LM	3.8
<i>Poa alpina</i>	Gruening	0.8 LM	1.5
<i>Agrostis gigantea</i>	Streaker	0.4 M	1.5
<i>Poa secunda</i>	Canbar	0.1 M	8.0

\* Means followed by the same letter are not significantly different at the 0.05 significance level using the LSD Mean Comparison method.



## Appendix B

Table 16. Average **plant height** of grasses in Stucky Ridge plots (measured **8/30/05**).

<b>Genus &amp; Species</b>	<b>Accession</b>	<b>Height</b> (cm)
<i>Elymus trachycaulus</i>	9081620	87.5 A*
<i>Elymus trachycaulus</i>	9081621	76.3 A
<i>Poa secunda</i>	9081633	59.1 B
<i>Leymus cinereus</i>	9081624	58.0 B
<i>Elymus wawawaiensis</i>	Secar	50.3 BC
<i>Elymus trachycaulus</i>	San Luis	48.8 BC
<i>Leymus cinereus</i>	9081625	47.7 BC
<i>Elymus trachycaulus</i>	Pryor	47.0 BC
<i>Agrostis gigantea</i>	9081619	46.5 BCD
<i>Poa secunda</i>	9081635	45.6 BCDE
<i>Leymus cinereus</i>	Trailhead	45.5 BCDE
<i>Poa secunda</i>	9081322	45.4 BCDEF
<i>Agrostis gigantea</i>	9076276	44.7 BCDEF
<i>Leymus cinereus</i>	Washoe	43.6 BCDEF
<i>Pseudoroegneria spicata</i>	9081636	39.7 CDEFG
<i>Achnatherum hymenoides</i>	Rimrock	39.5 CDEFG
<i>Agrostis gigantea</i>	9076266	38.9 CDEFG
<i>Pseudoroegneria spicata</i>	Goldar	38.1 CDEFGH
<i>Elymus trachycaulus</i>	Revenue	36.9 CDEFGH
<i>Leymus cinereus</i>	Magnar	36.7 CDEFGH
<i>Deschampsia caespitosa</i>	9076290	36.5 CDEFGH
<i>Poa secunda</i>	Sherman	34.9 CDEFGHI
<i>Achnatherum hymenoides</i>	Nezpar	33.7 CDEFGHI
<i>Pascopyrum smithii</i>	Rodan	30.9 DEFGHIJ
<i>Deschampsia caespitosa</i>	Nortran	30.3 EFGHIJK
<i>Pascopyrum smithii</i>	Rosana	29.8 FGHIJK
<i>Pascopyrum smithii</i>	9081968	24.7 GHIJKL
<i>Deschampsia caespitosa</i>	13970176	24.0 GHIJKL
<i>Achnatherum hymenoides</i>	9081628	22.8 HIJKL
<i>Achnatherum hymenoides</i>	9081629	20.3 IJKL
<i>Poa alpina</i>	9016273	17.0 JKL
<i>Poa alpina</i>	01-13-1	15.7 JKLM
<i>Agrostis gigantea</i>	Streaker	15.0 JKLM
<i>Poa alpina</i>	1858	10.8 JKLM
<i>Poa alpina</i>	Gruening	9.0 JKLM
<i>Poa secunda</i>	Canbar	0.0 M

\* Means followed by the same letter are not significantly different at the 0.05 significance level using the LSD Mean Comparison method.

## Appendix B

Table 17. **Biomass** production of grasses in Stucky Ridge Trials (clipped **8/30/05**).

<b>Genus &amp; Species</b>	<b>Accession</b>	<b>Biomass</b>	
		<i>kg/ha</i>	
<i>Elymus trachycaulus</i>	9081620	8,211	A*
<i>Elymus trachycaulus</i>	9081621	4,100	B
<i>Poa secunda</i>	9081633	2,506	C
<i>Leymus cinereus</i>	Trailhead	2,222	CD
<i>Agrostis gigantea</i>	9081619	2,189	CD
<i>Agrostis gigantea</i>	9076276	2,039	CDE
<i>Leymus cinereus</i>	9081624	1,844	CDEF
<i>Elymus trachycaulus</i>	Pryor	1,578	CDEFG
<i>Agrostis gigantea</i>	9076266	1,367	CDEFGH
<i>Elymus wawawaiensis</i>	Secar	1,289	CDEFGH
<i>Poa secunda</i>	9081635	906	DEFGH
<i>Achnatherum hymenoides</i>	Nezpar	872	DEFGH
<i>Deschampsia caespitosa</i>	9076290	844	DEFGH
<i>Pascopyrum smithii</i>	9081968	800	DEFGH
<i>Pascopyrum smithii</i>	Rosana	650	EFGH
<i>Leymus cinereus</i>	Magnar	639	EFGH
<i>Elymus tachycaulus</i>	San Luis	622	EFGH
<i>Elymus trachycaulus</i>	Revenue	578	FGH
<i>Leymus cinereus</i>	9081625	428	FGH
<i>Leymus cinereus</i>	Washoe	361	GH
<i>Achnatherum hymenoides</i>	Rimrock	339	GH
<i>Pseudoroegneria spicata</i>	9081636	317	GH
<i>Pseudoroegneria spicata</i>	Goldar	272	GH
<i>Poa secunda</i>	9081322	233	GH
<i>Pascopyrum smithii</i>	Rodan	189	GH
<i>Poa secunda</i>	Sherman	189	GH
<i>Agrostis gigantea</i>	Streaker	122	H
<i>Achnatherum hymenoides</i>	9081629	61	H
<i>Achnatherum hymenoides</i>	9081628	61	H
<i>Poa alpina</i>	9016273	51	H
<i>Poa alpina</i>	1858	28	H
<i>Deschampsia caespitosa</i>	13970176	28	H
<i>Poa alpina</i>	01-13-1	23	H
<i>Poa alpina</i>	Gruening	0	H
<i>Deschampsia caespitosa</i>	Nortran	0	H
<i>Poa secunda</i>	Canbar	0	H

\* Means followed by the same letter are not significantly different at the 0.05 significance level using the LSD Mean Comparison method.

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Table 18: Percentage **stand and vigor** of grass trials on Stucky Ridge Plots (evaluated 8/28/06).

<b>Scientific Name</b>	<b>Accession</b>	<b>Stand</b>	<b>Vigor</b>
		%	1--9
<i>Elymus trachycaulus</i>	9081620	78.13 A*	3.25
<i>Poa secunda</i>	9081633	63.13 A	2.94
<i>Elymus trachycaulus</i>	9081621	41.25 B	3.44
<i>Agrostis gigantea</i>	9081619	29.38 BC	3.25
<i>Leymus cinereus</i>	9081624	28.13 BCD	4.77
<i>Elymus trachycaulus</i>	San Luis	26.56 BCDE	4.58
<i>Elymus wawawaiensis</i>	Secar	25.31 BCDEF	4.04
<i>Poa secunda</i>	9081635	23.75 BCDEFG	4.06
<i>Elymus trachycaulus</i>	Pryor	22.19 CDEFGH	5.04
<i>Agrostis gigantea</i>	9076276	21.56 CDEFGHI	3.65
<i>Leymus cinereus</i>	Trailhead	19.38 CDEFGHIJ	4.73
<i>Pascopyrum smithii</i>	Rosana	17.19 CDEFGHIJ	5.00
<i>Achnatherum hymenoides</i>	Rimrock	14.06 CDEFGHIJ	4.50
<i>Poa secunda</i>	Sherman	13.44 CDEFGHIJ	4.38
<i>Pascopyrum smithii</i>	9081968	12.81 CDEFGHIJ	5.52
<i>Agrostis gigantea</i>	9076266	11.25 CDEFGHIJ	4.00
<i>Leymus cinereus</i>	9081625	10.94 CDEFGHIJ	4.85
<i>Pseudoroegneria spicata</i>	Goldar	10.94 CDEFGHIJ	4.50
<i>Elymus trachycaulus</i>	Revenue	10.63 CDEFGHIJ	4.58
<i>Pascopyrum smithii</i>	Rodan	10.63 CDEFGHIJ	4.39
<i>Achnatherum hymenoides</i>	Nezpar	9.69 DEFGHIJ	3.85
<i>Leymus cinereus</i>	Washoe	9.06 EFGHIJ	4.67
<i>Leymus cinereus</i>	Magnar	7.19 FGHIJ	5.19
<i>Achnatherum hymenoides</i>	9081628	5.94 GHIJ	4.42
<i>Agrostis gigantea</i>	Streaker	5.94 GHIJ	5.10
<i>Achnatherum hymenoides</i>	9081629	4.69 HIJ	4.92
<i>Poa alpina</i>	Gruening	4.69 HIJ	5.47
<i>Poa secunda</i>	9081322	4.06 HIJ	4.00
<i>Pseudoroegneria spicata</i>	9081636	3.44 HIJ	5.38
<i>Poa alpina</i>	9016273	3.44 HIJ	5.50
<i>Poa alpina</i>	01--13--1	2.81 IJ	4.75
<i>Deschampsia caespitosa</i>	Nortran	2.81 IJ	6.13
<i>Deschampsia caespitosa</i>	13970176	2.81 IJ	5.17
<i>Poa secunda</i>	Canbar	2.50 J	5.00
<i>Poa alpina</i>	1858	1.88 J	5.00
<i>Deschampsia caespitosa</i>	9076290	0.63 J	4.50

\* Means followed by the same letter are not significantly different at the 0.05 significance level using the LSD Mean Comparison method.

## Appendix B

Table 19: Average **plant height** of grasses in Stucky Ridge plots (measured 8/28/06).

Scientific Name	Accession	Height (cm)
<i>Elymus trachycaulus</i>	9081621	78.56 A*
<i>Leymus cinereus</i>	9081624	78.56 A
<i>Leymus cinereus</i>	Trailhead	77.88 A
<i>Elymus trachycaulus</i>	9081620	77.31 A
<i>Leymus cinereus</i>	9081625	74.04 AB
<i>Elymus wawawaiensis</i>	Secar	69.96 ABC
<i>Elymus trachycaulus</i>	San Luis	69.92 ABC
<i>Leymus cinereus</i>	Washoe	67.88 ABCD
<i>Leymus cinereus</i>	Magnar	66.33 ABCDE
<i>Elymus trachycaulus</i>	Pryor	64.31 ABCDEF
<i>Poa secunda</i>	9081633	62.38 ABCDEFG
<i>Poa secunda</i>	Sherman	61.94 ABCDEFGH
<i>Poa secunda</i>	Canbar	60.75 ABCDEFGH
<i>Achnatherum hymenoides</i>	Nezpar	57.33 BCDEFGHI
<i>Agrostis gigantea</i>	9081619	57.11 BCDEFGHIJ
<i>Agrostis gigantea</i>	9076276	57.04 BCDEFGHIJ
<i>Elymus trachycaulus</i>	Revenue	54.92 CDEFGHIJ
<i>Achnatherum hymenoides</i>	Rimrock	54.31 CDEFGHIJ
<i>Pseudoroegneria spicata</i>	Goldar	52.63 CDEFGHIJ
<i>Poa secunda</i>	9081635	50.81 DEFGHIJK
<i>Poa alpina</i>	1--13--1	50.75 DEFGHIJK
<i>Poa alpina</i>	1858	50.00 DEFGHIJKL
<i>Agrostis gigantea</i>	9076266	48.88 EFGHIJKL
<i>Pascopyrum smithii</i>	Rodan	48.33 FGHIJKL
<i>Poa secunda</i>	9081322	47.13 FGHIJKLM
<i>Deschampsia caespitosa</i>	Nortran	46.50 FGHIJKLM
<i>Achnatherum hymenoides</i>	9081628	46.25 GHIJKLM
<i>Pseudoroegneria spicata</i>	9081636	45.75 GHIJKLM
<i>Agrostis gigantea</i>	Streaker	45.39 GHIJKLM
<i>Poa alpina</i>	Gruening	44.47 HIJKLM
<i>Achnatherum hymenoides</i>	9081629	42.50 IJKLMN
<i>Pascopyrum smithii</i>	Rosana	39.38 JKLMN
<i>Poa alpina</i>	9016273	33.00 KLMN
<i>Deschampsia caespitosa</i>	13970176	32.67 LMN
<i>Pascopyrum smithii</i>	9081968	30.00 MN
<i>Deschampsia caespitosa</i>	9076290	26.50 N

\* Means followed by the same letter are not significantly different at the 0.05 significance level using the LSD Mean Comparison method.

## Appendix B

Table 20: **Biomass** production of grasses in Stucky Ridge Trials (clipped 8/28/06).

Scientific Name	Accession	Biomass	
		kg/ha	
<i>Elymus trachycaulus</i>	9081621	4894.44	A*
<i>Agrostis gigantea</i>	9081619	3322.22	AB
<i>Leymus cinereus</i>	9081624	2633.33	BC
<i>Elymus trachycaulus</i>	9081620	2311.11	BCD
<i>Poa secunda</i>	9081633	2311.11	BCD
<i>Leymus cinereus</i>	Trailhead	2255.56	BCDE
<i>Elymus wawawaiensis</i>	Secar	2172.22	BCDE
<i>Leymus cinereus</i>	Washoe	1988.89	BCDEF
<i>Leymus cinereus</i>	9081625	1761.11	BCDEFG
<i>Agrostis gigantea</i>	9076276	1550.00	CDEFGH
<i>Leymus cinereus</i>	Magnar	1550.00	CDEFGH
<i>Elymus trachycaulus</i>	Revenue	1272.22	CDEFGH
<i>Agrostis gigantea</i>	9076266	1216.67	CDEFGH
<i>Poa secunda</i>	9081635	1150.00	CDEFGH
<i>Pseudoroegneria spicata</i>	Goldar	1072.22	CDEFGH
<i>Achnatherum hymenoides</i>	Nezpar	1022.22	CDEFGH
<i>Elymus trachycaulus</i>	Pryor	1000.00	CDEFGH
<i>Pascopyrum smithii</i>	Rodan	922.22	DEFGH
<i>Elymus trachycaulus</i>	San Luis	777.78	DEFGH
<i>Achnatherum hymenoides</i>	Rimrock	677.78	DEFGH
<i>Agrostis gigantea</i>	Streaker	622.22	EFGH
<i>Achnatherum hymenoides</i>	9081628	461.11	FGH
<i>Pascopyrum smithii</i>	9081968	455.56	FGH
<i>Poa secunda</i>	9081322	444.44	FGH
<i>Pseudoroegneria spicata</i>	9081636	400.00	FGH
<i>Poa secunda</i>	Sherman	305.56	GH
<i>Pascopyrum smithii</i>	Rosana	294.44	GH
<i>Poa alpina</i>	01--13--1	177.78	GH
<i>Achnatherum hymenoides</i>	9081629	138.89	GH
<i>Poa secunda</i>	Canbar	122.22	GH
<i>Deschampsia caespitosa</i>	Nortran	88.89	GH
<i>Poa alpina</i>	Gruening	83.33	H
<i>Deschampsia caespitosa</i>	9076290	77.78	H
<i>Poa alpina</i>	9016273	72.22	H
<i>Deschampsia caespitosa</i>	13970176	38.89	H
<i>Poa alpina</i>	1858	5.56	H

\* Means followed by the same letter are not significantly different at the 0.05 significance level using the LSD Mean Comparison method.

## Appendix B

### Seed Mixture Trial

The forbs included in the seed mixtures (see Planting Design section) did not emerge; therefore, densities reflect only emergent grass seedlings (tables 5, 6, 7, and 8). During the establishment year, the Developed Waste Management Area (WMA) mix had the greatest seedling density with 10.5 seedlings/ft<sup>2</sup> (table 21). The Experimental WMA mix had the lowest density with 6.3 seedlings/ft<sup>2</sup>. The two Developed mixtures averaged 9.9 seedlings/ft<sup>2</sup>. The two Experimental mixtures averaged 6.3 seedlings/ft<sup>2</sup>. There were no significant differences among the mixtures at the P=0.05 level. By the fall of the first year, the Developed WMA mixture still had the highest density (8.0 seedlings/ft<sup>2</sup>) and the Experimental WMA mixture the lowest density (6.9 seedlings/ft<sup>2</sup>). The two Developed mixtures averaged 7.7 seedlings/ft<sup>2</sup> and the two Experimental mixtures averaged 6.9 seedlings/ft<sup>2</sup>. As in June, no significant differences were seen among the four seed mixtures.

At the start of the second growing season (2004), the two Experimental mixes had significantly better stands (Upland Exp.—39.4% and Waste Mgmt. Exp.—38.1%) than did the Developed mixes (Upland Dev.—17.3 and Waste Mgmt. Dev.—15.0%). By fall of the second year, the stands of all the mixes had increased, but the Experimental mixes were still significantly better than the Developed mixes. Biomass production of the Experimental mixes was also significantly better than that of the Developed mixes.

During the third year (2005), the percentage stands of all mixes increased only slightly, but the biomass production was much higher. The Experimental mixes were dominated by 9081620 slender wheatgrass, while the Developed mixes were dominated by Revenue slender wheatgrass and Critana thickspike wheatgrass. The Waste Management Experimental mix topped all mixes with 8,933 kg/ha of oven-dry biomass production.

Growing season 2006 took a different approach; the percentage stand went up in all but one, the Upland Experimental mix. Biomass production of all mixes had decreased, but the Waste Management mixes dominated over the Upland mixes. The biomass decrease averaged 34.5% for the Experimental mixes and 81.2% for the Developed mixes. Overall I think the grass mixes are doing well and this year was a recovery year for production, compared to last year's high biomass production.

## Appendix B

Table 21. Moto-X Replicated Mixture Trial on Stucky Ridge.

	Density	Density	Stand	Stand	Stand	Stand	Height	Height	Height	Biomass	Biomass	Biomass
	6/03	8/03	6/04	9/04	8/05	8/06	2004	2005	2006	2004	2005	2006
	<i>no/ft<sup>2</sup></i>	<i>no/ft<sup>2</sup></i>	<i>%</i>	<i>%</i>	<i>%</i>	<i>%</i>	<i>cm</i>	<i>cm</i>	<i>cm</i>	<i>kg/ha</i>	<i>kg/ha</i>	<i>kg/ha</i>
<b>Upland Exp.</b>	<b>6.4</b>	<b>7.4</b>	<b>39.4</b>	<b>45.9</b>	<b>60.6</b>	<b>49.7</b>	<b>45.8</b>	<b>78.8</b>	<b>75.3</b>	<b>790</b>	<b>5939</b>	<b>1367</b>
Upland Dev.	9.3	7.0	17.3	24.4	25.9	35.9	14.8	47.2	57.6	215	2011	1783
<b>Waste Mgmt Area Exp</b>	<b>6.3</b>	<b>6.9</b>	<b>38.1</b>	<b>46.9</b>	<b>59.7</b>	<b>65.0</b>	<b>44.8</b>	<b>82.5</b>	<b>76.3</b>	<b>1206</b>	<b>8933</b>	<b>4106</b>
Waste Mgmt Area Dev	10.5	8.0	15.0	23.8	28.4	38.1	19.8	56.6	72.3	306	4494	3311

## Appendix B

### Forb/Subshrub Trial

Ten of the 16 trial entries had no emergence and 15 of the 16 entries had <0.50 seedlings/ft<sup>2</sup> the seedling year (table 22). The subshrub, winterfat (*Krascheninnikovia lanata*) Open Range Germplasm, was the only entry that demonstrated significant emergence with 9.5 seedlings/ft<sup>2</sup>. The lack of forb emergence may be due to the May 13 planting date. The forb species in the study may have some physiological (after ripening) or physical (hard seed coat) seed dormancy. To overcome seed dormancy, many forb seeds generally require several weeks (8 to 14 weeks) of cold chilling. As with the grass species, some additional germination and emergence was expected in the spring of 2004, but this did not happen with the forb species. Some species such as thickstem aster (*Symphyotrichum chilense*) and buckwheat (*Eriogonum* sp.) do better with shallow seeding. By the second growing season, only plants of Open Range winterfat and 9081632 silverleaf phacelia remained alive. There was no sign of new emergence of any of the accessions/species in the spring of 2004. The surviving, mature plants of Open Range Germplasm winterfat performed well, with some plants flowering and setting seed. After the third growing season (2005), plants of Open Range winterfat, 9081632 silverleaf phacelia, Old Works fuzzytongue penstemon, Richfield firecracker penstemon, and Northern Cold Desert winterfat were found to be surviving. New plants of firecracker penstemon and fuzzytongue penstemon had germinated two years after being planted. The surviving plants of Open Range winterfat and 9081632 silverleaf phacelia exhibited good vigor, growth, and seed production. In 2006 the only surviving plants were the Open Range winterfat and Old Works fuzzytongue penstemon. Both showed good vigor and seed production.

Table 22. Seedling density (2003), percentage stand (2004), and total plant density (2005) of forb and subshrub accessions in the Stucky Ridge Comparative Evaluation Planting (evaluated 6/24/03, 8/25/03, 6/30/04, 9/22/04, 8/30/05, and 8/29/06).

Genus & Species	Variety/Accession	Species ID	2003 Density/ft <sup>2</sup>		2004 Stand		2005	2006
			6/24	8/25	6/30	9/22	Avg. Plants/ Plot 8/30	Avg. Plants/ Plot 8/28
					%			
<i>Krascheninnikovia lanata</i>	Open Range Germplasm	5	9.47 a*	6.75 a*	5.5 a*	4.5 a*	20.00	17
<i>Phacelia hastata</i>	9081632	10	0.28 b	0.22 b	0.5 b	0.5 b	6.00	0
<i>Krascheninnikovia lanata</i>	Northern Cold Desert Germ.	4	0.19 b	0.16 b	0.0 b	0.0 b	0.25	0
<i>Penstemon strictus</i>	'Bandera'	8	0.19 b	0.03 b	0.0 b	0.0 b	0	0
<i>Eriogonum umbellatum</i>	9082271	2	0.06 b	0.00 b	0.0 b	0.0 b	0	0
<i>Penstemon venustus</i>	Clearwater Selected	9	0.03 b	0.00 b	0.0 b	0.0 b	0	0
<i>Eriogonum umbellatum</i>	9082273	3	0.00 b	0.00 b	0.0 b	0.0 b	0	0
<i>Penstemon eatonii</i>	Richfield Select	7	0.00 b	0.00 b	0.0 b	0.0 b	0.75	0
<i>Eriogonum ovalifolium</i>	9082098	1	0.00 b	0.00 b	0.0 b	0.0 b	0	0
<i>Penstemon eriantherus</i>	Old Works Germplasm	6	0.00 b	0.00 b	0.0 b	0.0 b	15.00	10
<i>Phacelia hastata</i>	9082275	11	0.00 b	0.00 b	0.0 b	0.0 b	0	0
<i>Potentilla gracilis</i>	9081679	12	0.00 b	0.00 b	0.0 b	0.0 b	0	0
<i>Potentilla hippiana</i>	9076274	13	0.00 b	0.00 b	0.0 b	0.0 b	0	0
<i>Symphyotrichum chilense</i>	9078675	14	0.00 b	0.00 b	0.0 b	0.0 b	0	0
<i>Symphyotrichum chilense</i>	9081678	15	0.00 b	0.00 b	0.0 b	0.0 b	0	0
<i>Symphyotrichum chilense</i>	9082274	16	0.00 b	0.00 b	0.0 b	0.0 b	0	0

\* Means followed by the same letter are similar at the 0.05 level of significance using the LSD Mean Comparison method.



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### Tissue Analysis

Following the Fall 2004 and Fall 2005 evaluation for cover and vigor, each individual plot was sampled for biomass production. These clippings from all four replications, along with additional clipping of low producing plots, made up the 10 gram or greater of oven-dry samples that were submitted for tissue analysis. Samples were submitted to Energy Laboratories, Inc. in Billings, Montana, for determination of heavy-metal concentrations in and on sampled plant materials from the Stucky Ridge Moto-X site. Metal loads (concentration in and on the plant tissue) can be compared to maximum tolerable levels of dietary minerals for domestic animals (National Research Council 1980). The dietary level of cadmium for domesticated animals is based on human food residue considerations (NRC, 1980), and the need to avoid increases of cadmium in the food supply of the United States. Higher residue levels (>0.50 mg/kg) for a short period of time would not be expected to be harmful to animal health nor to human food use, particularly if the animals were slaughtered at a young age. Based on a review of the scientific literature, ranges of elemental levels for mature leaf tissue have been presented by Kabata-Pendias and Pendias (1992). The authors provide elemental levels for generalized plant species into ranges representing deficient, sufficient, or normal, and excessive or toxic (table 23).

All tissue samples are unreplicated composites of samples from random plants in all four replications of the Stucky Ridge Comparative Evaluation Trial. Metal loads in the sampled tissue were generally below toxic levels.

Arsenic (As)—Arsenic was detected in 19 of the 39 samples in 2004, in 32 of the 40 samples in 2005, and 3 of the 42 samples in 2006 with levels ranging from 5 mg/kg to 35 mg/kg. This is below the tolerable levels for domestic livestock (50 mg/kg) and wildlife (50 mg/kg). However, the detected levels rank in the 'Excessive or Toxic' level in plants.

Cadmium (Cd)—This element was detected in only one sample (Rimrock Indian ricegrass) in 2004 and in 2005 it was detected in 5 samples (3 of which were in Indian ricegrasses). In 2006 there was no detection of cadmium in any sample. The detected level (1-2 mg/kg) are at the tolerable level for domestic livestock (0.5 mg/kg) and wildlife (2 mg/kg).

Copper (Cu)—Copper detected in all tissue samples ranging from 5 mg/kg to 307 mg/kg. Only three samples (2004), 5 samples (2005), and no samples (2006) exceeded the tolerable level for domestic livestock (100 mg/kg), but 15 samples (2004), 19 samples (2005), and 1 sample (2006) exceeded the tolerable level for wildlife (55 mg/kg). Since this is a copper smelting impacted area, high levels of copper are to be expected.

Lead (Pb)—Lead was detected in a sample of ten-petal blazing star (*Mentzelia decapetala*) only (2004), at a level of 9 mg/kg, well below the tolerable level for domestic livestock and wildlife. In 2005 lead was detected in only four samples and at very low levels. In 2006 lead was detected in two samples and one sample rated in the "Excessive or Toxic" level in plants.

Zinc (Zn)—Zinc was detected in all samples, ranging from 9 mg/kg to 175 mg/kg well below the tolerable level for domestic livestock (500 mg/kg) and wildlife (300

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mg/kg). In 2006 zinc was detected in all samples but with low levels. The levels ranged from 9 to 35 except for LECI Trailhead which had a level of 125, still well below the tolerable levels for domestic livestock and wildlife and in the normal level for plants.

Worth noting was the fact that heavy metal concentrations were highest in/on alpine blue grass, silverleaf phacelia, winterfat and fuzzytongue penstemon. This is likely due to the excess dust particles on the low profile plants and ones with leaf pubescence.

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Table 23. Heavy metal concentrations of clipped biomass samples from the Stucky Ridge Comparative Evaluation Trials (sampled 9/22/04, analyzed 11/10/04, sampled 8/29/05, sampled 8/28/06).

Lot	Species	Al			As			Cd			Cu			Pb			Zn			
		2004	2005	2006	2004	2005	2006	2004	2005	2006	2004	2005	2006	2004	2005	2006	2004	2005	2006	
			mg/kg												mg/kg				mg/kg	
1	ACHY 9081628	331	279	62	6mg/kg	8	ND	ND	mg/kg	2	ND	3mg/kg	34	6	ND	ND	ND	123	88	15
2	ACHY 9081629	288	420	101	9	8	ND	ND	2	ND	41	35	8	ND	ND	ND	111	73	12	
3	ACHY Rimrock	235	332	101	ND	9	ND	5	1	ND	17	35	9	ND	ND	ND	68	38	10	
4	ACHY Nezpar	276	200	54	ND	ND	ND	ND	ND	ND	16	21	5	ND	ND	ND	51	31	14	
5	AGGI 9076276	258	382	158	ND	6	ND	ND	ND	ND	46	62	22	ND	ND	ND	54	41	20	
6	AGGI 9081619	663	375	136	ND	ND	ND	ND	ND	ND	100	62	18	ND	ND	ND	51	64	17	
7	AGGI 9076266	548	320	190	ND	6	ND	ND	ND	ND	74	39	30	ND	ND	ND	100	49	23	
8	AGGI Streaker		2500	80		35	ND		ND	ND			16		13	ND		78	20	
9	DECE 9076290	334	405	473	5	6	7	ND	1	ND	48	45	80	ND	ND	ND	63	52	35	
10	DECE 13970176	1420	121	188	8	6	ND	ND	ND	ND	57	14	19	ND	ND	ND	87	44	24	
11	DECE Nortran	336			8		ND	ND		ND	29			ND		ND	67		18	
12	ELTR 9081620	242	285	151	ND	5	ND	ND	ND	ND	26	47	15	ND	ND	ND	14	16	9	
13	ELTR 9081621	197	283	136	ND	ND	ND	ND	ND	ND	38	41	17	ND	ND	ND	21	22	9	
14	ELTR Pryor	301	413 <sup>90</sup>	70	ND	8	ND	ND	ND	ND	25	62 <sup>11</sup>	12	ND	ND	ND	37	35	9	
15	ELTR Revenue	280	445	127	ND	7	ND	ND	ND	ND	48	65	15	ND	ND	ND	50	47	11	
16	ELTR San Luis	441	193	140	ND	6	ND	ND	ND	ND	45	27	16	ND	ND	ND	40	33	13	
17	LECI 9081624	424	436	147	ND	5	ND	ND	ND	ND	62	73	19	ND	ND	ND	111	55	26	
18	LECI 9081625	463	559	119	6	9	ND	ND	1	ND	72	76	16	ND	ND	ND	172	124	30	
19	LECI Washoe	472	366	111	7	ND	ND	ND	ND	ND	47	47	14	ND	ND	ND	175	106	28	
20	LECI Magnar	636	410	101	11	8	ND	ND	ND	ND	113	63	16	ND	ND	ND	84	69	23	
21	LECI Trailhead	441	391	235	ND	8	ND	ND	ND	ND	35	51	25	ND	ND	207	85	93	125	
22	PASM 9081968	374	315	272	6	5	ND	ND	ND	ND	45	41	32	ND	ND	ND	86	64	28	
23	PASM Rodan	495	243	163	7	6	ND	ND	ND	ND	52	29	27	ND	ND	ND	56	39	14	
24	PASM Rosana	210	318	186	6	9	ND	ND	ND	ND	29	47	26	ND	ND	ND	61	52	18	
25	POAL 9016273	799	1740	162	7	21	ND	ND	ND	ND	50	120	18	ND	8	ND	45	64	17	
26	POAL 01-13-1	1220	695	148	8	17	ND	ND	ND	ND	78	80	14	ND	ND	ND	49	50	15	
27	POAL Greuning	706		67	ND		5	ND		ND	40		11	ND		15	36		33	
28	POAL 1858	1190	1410	75	ND	20	6	ND	ND	ND	33	93	8	ND	9	ND	62	156	27	
29	POSE 9081633	442	417	155	9	ND	ND	ND	ND	ND	49	52	19	ND	ND	ND	35	44	18	
30	POSE Sherman	311	420	95	9	12	ND	ND	ND	ND	36	52	12	ND	ND	ND	94	106	19	
31	POSE Canbar	no samples		43			ND			ND			6			ND			17	
32	POSP 9081635	364	549	168	11	14	ND	ND	ND	ND	46	59	24	ND	ND	ND	38	44	17	
33	POSP 9081322	441	346	220	ND	9	ND	ND	ND	ND	83	62	32	ND	ND	ND	57	64	33	
34	PSSP 9081636	676	931	137	16	20	ND	ND	ND	ND	76	112	21	ND	ND	ND	81	84	19	
35	PSSP Goldar	654	548	74	13	12	ND	ND	ND	ND	81	68	9	ND	ND	ND	77	58	19	

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Table 23. Heavy metal concentrations of clipped biomass samples from the Stucky Ridge Comparative Evaluation Trials (sampled 9/22/04, analyzed 11/10/04, samples 8/29/05, sampled 8/28/06).

Lot	Species	Al			As			Cd			Cu			Pb			Zn		
		2004	2005	2006	2004	2005	2006	2004	2005	2006	2004	2005	2006	2004	2005	2006	2004	2005	2006
			mg/kg				mg/kg					mg/kg				mg/kg			mg/kg
36	ELWA Secar	396	635	94	ND	7	ND	ND	ND	ND	34	59	14	ND	ND	ND	68	65	17
1	UPEXP	392	266	94	ND	ND	ND	ND	ND	ND	51	43	15	ND	ND	ND	22	31	11
2	UPDEV	268	545	118	ND	12	ND	ND	ND	ND	31	69	14	ND	ND	ND	73	40	11
3	WMAEXP	374	421	84	ND	ND	ND	ND	ND	ND	35	50	11	ND	ND	ND	27	25	11
4	WMADEV	270	548	124	ND	9	ND	ND	ND	ND	26	66	15	ND	ND	ND	67	44	10
5	KRLA Op. Range	1173	372	132	7.5	ND	ND	ND	ND	ND	108	44	15	ND	ND	ND	82	47	14
6	PEER Old Works		1280	192		14	ND		ND	ND		65	15		ND	ND		31	10
10	PHHA 9081632		3720			42			ND			307			15			91	

**Maximum Tolerable Levels for**

**Domestic livestock 1.**

**Wildlife 2.**

**Metal levels in Plants 3.**

Deficient

Sufficient or Normal

Excessive or Toxic

	50	0.5	100	30	500
	50		55	40	300
Deficient			2 to 5		
Sufficient or Normal	1 to 1.7	0.05 to 0.2	5 to 30	5 to 10	27 to 150
Excessive or Toxic	5 to 20	2	5 to 30	20 to 100	30 to 300
			20 to 100	30 to 300	100 to 400

1. NRC 1980, 2. Ford, 1996, 3. Kabata-Pendias and Pendias 1992.

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### CONCLUSION

Not all of the potential germinable seeds germinated the first year (2003). The record high temperatures and low precipitation in July and August, along with the late spring planting date (May 13), are considered to be the primary factors affecting the incomplete germination and emergence during the 2003 growing season. There was a significant amount of new grass seedling emergence detected during the June 30, 2004, evaluation, particularly in the Indian ricegrass, western wheatgrass, big bluegrass, and basin wildrye plots and some new germination of forbs in 2005.

In the single-species plots, the 'local source' plants that exhibited superior performance include 9081620 and 9081621 slender wheatgrass, 9081633 big bluegrass, 9081968 western wheatgrass, 9081624 and Washoe Germplasm basin wildrye, 9081628 Indian ricegrass, 9081636 bluebunch wheatgrass, and 9081635 Canbyi bluegrass. The superior indigenous plant material is being further increased for potential release to the commercial seed industry. Worth noting was the performance of some of the released cultivars such as Pryor and Revenue slender wheatgrass, Rosana western wheatgrass, Rimrock Indian ricegrass, Trailhead basin wildrye, Secar Snake River wheatgrass, and Goldar bluebunch wheatgrass.

The forb/subshrub trial had poor emergence and consequently poor seedling densities with the exception of Open Range Germplasm winterfat. The low densities were most likely the result of the late spring planting that resulted in an insufficient period of cold-moist stratification. An additional problem may have been sowing small-sized seed too deeply. There was also heavy surface erosion on this portion of the trial site.

In the Seed Mixture Trials, the 'Experimental' mixes that contained native 'local source' were far superior to the 'Developed' mixes that consisted of native 'nonlocal source' (Upland mix) and introduced cultivars (Waste Management Areas). However, it was estimated that the majority of plants in the Experimental mixtures, both Upland and Waste Management Areas, were 9081620 slender wheatgrass, which was the best overall performer on this particular site.

The tissue analyses show that the heavy metal concentrations in and on the plant tissue sampled from the Stucky Ridge plots were generally within the tolerable limits for both domestic livestock and wildlife.

The overall performance on the Stucky Ridge plots was quite variable, with strips running north and south that had poorer plant vigor and biomass production. The Pryor slender wheatgrass strips between replications (running east and west) exhibited waves of good and poor establishment and performance. Soil samples (0-6 in.) were taken under four plant stands of slender wheatgrass ranging from excellent to very poor in hopes of explaining this variability. It was thought that the incorporation of the amendments may have created strips with varying pH. Soil analysis for pH indicated no difference in pH (all 6.8 to 7.3) under the varying stand of slender wheatgrass. Therefore, this variability is still unexplained.

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IV. RELEASES



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### PLANT RELEASES

The seed and plants that are available to reclamationists are usually cultivar (cultivated varieties) releases from universities, USDA Plant Material Centers, USDA Agricultural Research Service, or private plant breeders. To be released as a cultivar, the germplasm must be extensively tested, reviewing primary traits through multiple generations, and field testing to determine range of adaptability. This process takes at least 10 years with herbaceous plant material and can take 20 or more years for woody plants. Other sources of native plants are wildland collections and pre-damage plant salvage.

In recent years, the demand for native, indigenous plant material has resulted in the development of an alternate, quicker mechanism for the release of plant materials known as Pre-Varietal Release. Through this process plant propagules can be released to the commercial seed and nursery industries in a more timely manner, but at the expense of extensive field testing. Germplasm is still managed through the Certified seed agencies, maintaining the same quality, purity, and germination standards of Cultivar releases. There are three categories of Pre-Varietal releases:

Source-Identified—With this classification, a person can locate and collect seed from a specific native site and have the seed certified by source only. A representative from a seed certification agency must inspect the collection site prior to harvest, documenting the identity of the species, elevation, latitude/longitude, and associated species. The collector can certify the seed as being from a particular source and of a standard quality, and selling the seed directly to a customer. The collector can also take that seed and establish seed production fields, raising up to two generations past the original collection. This product must be included in a seed certification program to be able to certify the seed as ‘Source Identified’ germplasm. Through this process, seed can be certified the year of collection or in 2 years when the seed increase fields begin to produce.

Selected—This category is for plant breeders who assemble and evaluate multiple collections of a species, making a selection of the superior accession, or bulk or cross-pollinate the superior accessions. This release process can take as few as 5 years, but can claim only that one accession or bulk of accessions has been found to be superior for the conditions under which it was tested. No field testing or the testing of progeny is required.

Tested—If the progeny of a superior germplasm is tested to make sure that the desired traits continue to manifest themselves in subsequent generations, the germplasm qualifies to be released as a Tested germplasm. This process can take 6-8 years in herbaceous plant material and considerably longer with woody plants. The only difference between Tested and Cultivar releases is the extensive field testing of a Cultivar.



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The Pre-Varietal release mechanism has been used extensively on native plant materials that are not readily available on the commercial market, either from seed growers, nurseries, or wildland collectors. Through this process native plant material can be placed into the commercial seed and nursery industry sooner, but with limited information on range of adaptation, ease of establishment in various climate and edaphic conditions, and longevity.

### DATR Project Releases

The Conservation Districts of Montana and Wyoming own the land and facilities at the Bridger Plant Materials Center and lease to the USDA-Natural Resource Conservation Service. The USDA-NRCS Plant Materials Center has been in operation since 1959 and has established a cooperative relationship with the Agricultural Experiment Station network of Montana State University-Bozeman (MSU) and the University of Wyoming-Laramie (U of W). The Plant Materials Center has experience in the release of conservation plants, both introduced and native, in cooperation with MSU and U of W. Breeders and Foundation seed is produced at the Bridger PMC, making Foundation seed available to the commercial seed industry for the production of Certified seed. In the case of Pre-Varietal releases, the Bridger PMC produces G<sub>1</sub> (Generation 1) seed for distribution to growers who will produce G<sub>2</sub> and G<sub>3</sub> under the Certified Seed Program. Once a release is made, the releasing agency is responsible for maintaining a supply of G<sub>1</sub> (Pre-Varietal release) or Foundation (Cultivar release) seed for as long as seed/plants of the release are in demand.

The DATR (formerly DATC) project has identified numerous plants (grasses, forbs, shrubs, and trees) that exhibit tolerance of acidic and metaliferous soil conditions and have the potential for use by reclamationists in restoration efforts of severely impacted sites. Thus far the DATR project has been instrumental in the release of germplasm of four plants;

**Washoe** Selected germplasm basin wildrye (*Leymus cinereus*)

**Old Works** Source Identified germplasm fuzzy-tongue penstemon (*Penstemon eriantherus*)

**Prospectors** Selected germplasm common snowberry (*Symphoricarpos albus*)

**Copperhead** Selected germplasm slender wheatgrass (*Elymus trachycaulus*)

Information brochures have been published on three releases and are distributed to potential seed growers and potential seed-purchasing customers. The Copperhead slender wheatgrass brochure has not been published but is being worked on. G<sub>1</sub> (Foundation quality) seed of Washoe basin wildrye has been distributed to two commercial seed growers in Montana, and seed of Old Works fuzzy-tongue penstemon has been distributed to one grower in Washington and one grower in Idaho. No growers have yet shown interest in the production of Prospectors common snowberry.

During the winter of 2007 **Opportunity** Selected class germplasm big bluegrass (9081633) will be submitted for release approval to the Variety Release Committee at

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Montana State University and the Pure Seed Committee at the University of Wyoming. This accession of big bluegrass has performed exceptionally well on the amended Stucky Ridge Trial site. If the release is successful G<sub>1</sub> seed will be available to commercial growers in the spring of 2008.

The DATR Project has established seed increase fields of all plant species that have exhibited superior establishment and performance in field test plantings in the Anaconda vicinity on smelter and mining-impacted sites. The USDA-NRCS Plant Materials Center, in cooperation with the Deer Lodge Valley Conservation District, plans to continue releasing superior plant materials that have exhibited tolerance of acid/heavy metal-contaminated sites. Some of the potential releases are as follows:

- 9081968 western wheatgrass (*Pascopyrum smithii*)
- 9081636 bluebunch wheatgrass (*Pseudoroegneria spicata*)
- 9081628 Indian ricegrass (*Achnatherum hymnoides*)
- 9081632 silverleaf phacelia (*Phacelia hastata*)
- 9076274 woolly cinquefoil (*Potentilla hippiana*)
- 9081334 silver buffaloberry (*Shepherdia argentea*)
- 9081638 Woods' rose (*Rosa woodsii*)
- 9081623 horizontal juniper (*Juniperus horizontalis*).

Plant material that is being considered for release in FY2008 is 9081636 bluebunch wheatgrass. Other releases within the next three years include 9081968 western wheatgrass, 9081632 silverleaf phacelia, and 9081334 silver buffaloberry.