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Mine Waste Technology Program

Acid/Heavy Metal Tolerant Plants

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Notice

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Sally Gutierrez, Director
National Risk Management Research Laboratory

Abstract

This report summarizes the results of Mine Waste Technology Program (MWTP) Activity III, Project 30, *Acid/Heavy Metal Tolerant Plants*, implemented and funded by the U.S. Environmental Protection Agency (EPA) and jointly administered by EPA and the U.S. Department of Energy (DOE). This project addressed EPA's technical issue of Mobile Toxic Constituents – Water and Acid Generation.

The objective of Project 30 was to select populations (i.e., ecotypes) from native, indigenous plant species that demonstrate superior growth characteristics and sustainability on acidic, heavy metals-contaminated soils occurring at varying elevations in western Montana. The native vegetative cover was required to meet the following criteria:

– reduce potential risks to human and wildlife receptors following exposure to heavy metals via the ingestion (plant/soil/surface water) and inhalation (fugitive dust) routes for these contaminants; and
– accelerate creation of improved wildlife habitat and aesthetic conditions on these historically degraded lands.

The three project specific goals were to:

– release seed of native species indigenous to western Montana that are valuable for the restoration/reclamation of hardrock mines, mill tailings, and smelter affected sites;
– field test potential releases (of these species) at the Anaconda Smelter Superfund Site to verify adaptation to acidic/metals-rich soils and interspecies compatibility; and
– provide technology transfer by the development of educational materials for the scientific community, seed producers, and reclamation specialists regarding new plant materials and establishment techniques.

Local accession no. 9081620 of slender wheatgrass met the quantitative criteria for canopy cover, aerial biomass production, and vigor when grown in pure stands; it also contributed significantly to the superior performance of mixed indigenous vs. mixed commercial accessions used for reclamation in the Anaconda area. For the five trace elements evaluated, only the copper level in the 2005 sample exceeded the generally acceptable concentration for most livestock species [i.e., 47 milligrams per kilogram (mg/kg) vs. 40 mg/kg], but not for wildlife (55 mg/kg; see Table 2-20). However, the concentrations of aluminum and copper (i.e., 151 and 15 mg/kg, respectively) in the 2006 tissue analyses imply plant surface contamination by soil particles influenced the results from 2005. Subsequently, Copperhead Selected class germplasm of the indigenous slender wheatgrass was released to commercial growers in the summer of 2006.

The above accession joins the following releases that were developed under the Development of Acid/Heavy Metal-Tolerant Cultivars project: Western Selected germplasm basin wildrye, Old Works Source Identified germplasm for fuzzy tongue penstemon, and Prospectors Selected germplasm for common snowberry. Local accessions of big bluegrass and bluebunch wheatgrass are expected to be released to commercial growers within the next 2 years.

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Acronyms and Abbreviations

Al	aluminum
ARCO	Atlantic Richfield Company
As	arsenic
BPMC	Bridger Plant Materials Center
Cd	cadmium
CEP	Comparative Evaluation Plot
Cu	copper
DATC	Development of Acid/Heavy Metal-Tolerant Cultivars
DLVCD	Deer Lodge Valley Conservation District
DOE	U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
LOAEL	lowest observed adverse effect level
LSD	least significant difference (Fisher's mean comparison method)
MSE	MSE Technology Applications, Inc.
MWTP	Mine Waste Technology Program
Pb	lead
PLS	pure live seeds
RDU	Remedial Design Unit
RPD	relative percent difference
s.u.	standard unit
USDA-NRCS	U.S. Department of Agriculture/Natural Resources Conservation Service
WMA	waste management area
Zn	zinc

Species Index [a]

Part A. Grasses

Taxonomic Name (abbreviation)	Common Name
Achnatherum hymenoides (ACHY)	Indian ricegrass
Agropyron intermedium (AGIN)	intermediate wheatgrass
Agrostis gigantea (AGGI)	redtop
Bromus inermis (BRIN)	smooth brome
Deschampsia caespitosa (DECE)	tufted hairgrass
Elymus lanceolatus (ELLA)	thickspike wheatgrass
Elymus trachycaulus (ELTR)	slender wheatgrass
Elymus wawawaiensis (ELWA)	Snake River wheatgrass
Festuca ovina (FEOV)	sheep fescue
Leymus cinereus (LECI)	basin wildrye
Pascopyrum smithii (PASM)	western wheatgrass
Poa alpina (POAL)	alpine bluegrass
Poa secunda (POSE)	Sandberg (Canby) bluegrass
Poa species (POSP)	bluegrass species
Pseudoroegneria spicata (PSSP)	bluebunch wheatgrass
Stipa comata (STCO)	needle-and-thread grass
Stipa viridula (STVI)	green needlegrass

Part B. Forbs and Subshrubs

Taxonomic Name (abbreviation)	Common Name
Achillea lanulosa (ACLA)	western yarrow
Artemisia frigida (ARFR)	fringed sagewort
Aster chilensis (ASCH)	creeping aster
Cirsium arvense (CIAR)	Canada thistle
Ericameria nauseosa (ERNA)	rubber rabbitbrush
Eriogonum ovalifolium (EROV)	cushion buckwheat
Eriogonum umbellatum (ERUM)	sulfur-flower buckwheat
Krascheninnikovia lanata (KRLA)	winterfat
Linum lewisii (LILE)	Lewis flax
Medicago sativa (MESA)	alfalfa
Mentzelia decapetala (MEDE)	tenpetal blazingstar
Penstemon eatonii (PEEA)	firecracker penstemon
Penstemon eriantherus (PEER)	fuzzy-tongue penstemon
Penstemon strictus (PEST)	Rocky Mountain penstemon
Penstemon venustus (PEVE)	venus penstemon
Phacelia hastata (PHHA)	silverleaf phacelia
Potentilla gracilis (POGR)	slender cinquefoil
Potentilla hippiana (POHI)	woolly cinquefoil
Symphyotrichum chilense (SYCH)	Pacific aster
Tetradymia canescens (TECA)	Spineless horsebrush

Part C. Shrubs and Trees

Taxonomic Name (abbreviation)	Common Name
Pinus contorta (PICO)	lodgepole pine
Pinus ponderosa (PIPO)	ponderosa pine
Populus tremuloides (POTR)	quaking aspen
Ribes cereum (RICE)	wax currant
Rosa woodsii (ROWO)	Woods' rose
Shepherdia argentea (SHAR)	silver buffaloberry
Symphoricarpos albus (SYAL)	common snowberry
Symphoricarpos occidentalis (SYOC)	western snowberry

Note: [a] See USDA-NRCS (2006a) for additional information on these plant species.

Acknowledgments

This document was prepared by MSE Technology Applications, Inc. (MSE) for the U.S. Environmental Protection Agency's (EPA) Mine Waste Technology Program (MWTP) and the U.S. Department of Energy's (DOE) Environmental Management Consolidated Business Center. Ms. Diana Bless is EPA's MWTP Project Officer, while Mr. Gene Ashby is DOE's Technical Program Officer. Ms. Helen Joyce is MSE's MWTP Program Manager. Ms. Norma Lewis is the EPA Project Manager, while Ms. Lauren Drees is the EPA Quality Assurance Officer, for this project.

MSE thanks Ms. Leslie Marty and Mr. Mark Majerus for sharing the technical lead on this project and Mr. Joe Scianna for providing the summary report for 2006 activities. MSE also appreciates the constructive reviews received from Dr. Martha Apple (Montana Tech of the University of Montana) and Mr. Dennis Neuman (Reclamation Research Group, LLC) on the draft version of this report.

Executive Summary

The Mine Waste Technology Program (MWTP), Activity III, Project 30, *Acid/Heavy Metal Tolerant Plants*, was implemented by the U.S. Environmental Protection Agency (EPA) and jointly administered by EPA and the U.S. Department of Energy (DOE). Project 30 addresses EPA's technical issue of Mobile Toxic Constituents – Water and Acid Generation.

The ultimate goal of the Development of Acid/Heavy Metal Tolerant Cultivars (DATC) project was to provide a reliable supply of high-quality, acid-metals tolerant native seed adapted to reclamation of hardrock mine lands within the Intermountain Region of the western United States.

This DATC project was initiated in 1995 and funded by a grant from the Montana Department of Natural Resources and Conservation (DNRC)-Reclamation and Development to the Deer Lodge Valley Conservation District (DLVCD). The DLVCD worked in cooperation with the U.S. Department of Agriculture Natural Resources Conservation Service (USDA-NRCS) Bridger Plant Materials Center (BPMC). The national network of 26 plant materials centers is the primary source of native plants developed specifically for reclamation and conservation use. The BPMC, 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 carryover money for the 1997-98 grant period was made available to this project, as well as some financial support from the Atlantic Richfield Company (ARCO). During 1999 and 2000, the project was again funded by a DNRC Reclamation and Development grant. Since 2000, the DATC project has been funded by the MWTP (through 2005) and the Montana Department of Justice-Natural Resource Damage Program (through 2008).

To date, the DATC project has acquired 130 collections of seed from 72 native species of grasses, forbs, shrubs, and trees from within the Upper Clark Fork River Basin. Additional collections have been made from abandoned mine sites throughout western Montana. These collections have been planted at various study sites in comparison with nonlocal native and introduced plant species. ARCO has provided land access for seed collection and sites for experimental plots throughout the Upper Clark Fork River Basin.

Presently, indigenous accessions of basin wildrye, slender wheatgrass, fuzzy-tongue penstemon, and common snowberry have been released to commercial growers. Three more grass accessions are expected to be released by 2008, with a few additional shrub accessions to follow thereafter (Appendix A, Section 5).

Introduction

1.1 Background

One of the most impacted areas within the Anaconda Smelter Superfund Site is approximately 18 square miles of uplands (Figure 1-1). 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 had eroded away and the subsoil, which is 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. In an effort to curtail the transport of contaminants and remediate these injured areas, state and federal regulatory agencies have developed several reclamation alternatives, which include planting of shrubs and trees.

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 (Jennings and Munshower, 1997). Research has demonstrated that metal-tolerant plants can be used to stabilize and immobilize contaminants in the soil (e.g., Dahmani-Muller et al., 2000; Conesa et al., 2007). Metals are absorbed and accumulated by roots, adsorbed onto the roots, or precipitated within the rhizosphere, thereby trapping contaminants in the soil and breaking the soil-plant-animal cycle (Vangronsveld and Cunningham, 1998).

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 (Reclamation Research Unit, 1993). 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 was to identify acid/ heavy-metal-tolerant native plant ecotypes that provide erosion control and wildlife habitat. The goal of the Development of Acid/Heavy Metal Tolerant Cultivars (DATC) project was to release these superior ecotypes to the commercial market, thereby providing a greater array of plant materials for the reclamation industry.

Previous studies included “local” germplasm originating from seed collected on nearby mine-affected soils in Deer Lodge County, Montana, as well as “nonlocal” germplasm seed collected on nonimpacted lands in various counties of Montana, Colorado, South Dakota, Utah, and Wyoming. Seedlings of 19 accessions of 7 woody species including lodgepole pine, ponderosa pine, silver buffaloberry, Woods' rose, common snowberry, western snowberry, and wax currant were transplanted into a common garden in a randomized complete block design. (The Species Index [p. ix] contains the taxonomic name for each plant species mentioned in this report.)

1.2 Project Description

This report summarizes the results of Mine Waste Technology Program (MWTP) Activity III, Project 30, *Acid/Heavy Metal Tolerant Plants*, implemented and funded by the U.S. Environmental Protection Agency (EPA) and jointly administered by EPA and the U.S. Department of Energy (DOE). This project addressed EPA’s technical issue of Mobile Toxic Constituents – Water and Acid Generation.

The purpose of Activity III, Project 30 was to select populations (i.e., ecotypes) from native, indigenous plant species that demonstrate superior survivability and vigor on acidic, heavy metals-contaminated soils occurring at varying elevations in western Montana.
The initial demonstration of the viability of these plants occurred at sites located within the Anaconda Smelter Superfund Site.

1.3 Scope of Work

The scope of work for this project was to collect, test, select, grow, and ultimately release indigenous native plants that demonstrated superior adaptation to acidic/heavy metals-contaminated soils.

1.4 Project Objectives

The qualitative objective of Project 30 was to establish a native indigenous vegetative cover/plant community that:

- reduced potential risks to human and wildlife receptors following exposure to heavy metals through ingestion (plant, soil and surface water) and inhalation (fugitive dust) routes for these contaminants; and
- accelerated creation of improved wildlife habitat and aesthetic conditions on historically degraded lands.

The quantitative measures for selecting those species-specific accessions that meet the above objectives include (MSE, 2001):

- vegetative canopy cover of $40 \pm 10\%$;
- aerial (aboveground) biomass production of 0.15 ± 0.05 dry kilogram per square meter (kg/m^2);
- vigor rating of 1.5 ± 0.5; wherein 1 = “healthiest” vs. 5 = “dead”; and
- strong acid extractable (“total”) trace element levels in aerial biomass that indicate neither gross phytotoxicity nor pose a significant threat to herbivores.

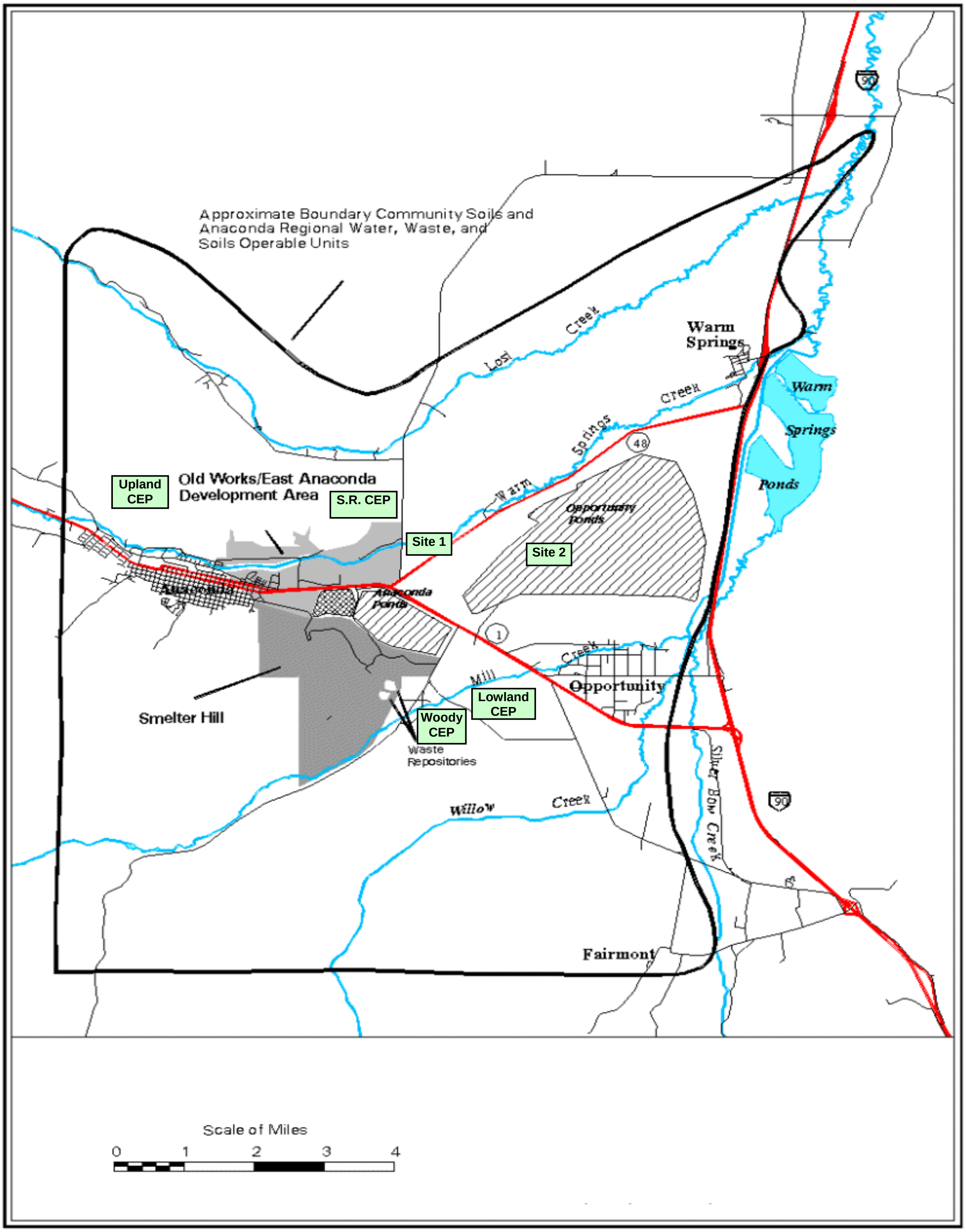

Figure 1-1. DATC project location map (Source: Montana NRIS, 1996).

Demonstration

The project was divided into tasks, subtasks, and work products specifically associated with each of the project goals (Marty, 2003a).

2.1 Task 1 – Evaluation of Grasses, Forbs, and Seed Mixtures

This task focused on identifying grass and forb accessions that exhibited superior tolerance to acid and heavy metals contaminated soils. The grass/forb entries evaluated were those that were tested at the Bridger Plant Materials Center (BPMC) greenhouse over the fall/winter of 2000-2001 (Marty, 2001).

2.1.1 Study Site

The site for this study is located on Stucky Ridge, approximately 2 miles 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 was 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 approximately 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 (As) concentrations in surface soils, barren or sparsely vegetated areas due to low pH, elevated contaminant concentrations, and steep slopes with high erosion potentials. Table 2-1 lists the soil characteristics of pretillage soil data points closest to the study site, as taken from the Remedial Action Work Plan/Final Design Report (EPA, 1995). 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 5,308 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 Woods' rose, currant species, rubber rabbitbrush, and spineless 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 untilled soil had a pebbly loam texture that was well drained. The slope at the plot site averages approximately 5% to 10%.

2.1.2 Soil Treatment

The study plot site was ameliorated along with the rest of the treatment area following the remedial actions specified in the Remedial Action Work Plan/Final Design Report (EPA, 1995). 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 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 pretilled 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 approximately 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_2O_5, 30% K_2O) was applied at a rate of 500 bulk pounds per acre and incorporated to 6 inches using a chisel plow. Table 2-2 lists the soil characteristics of post-tillage soil data points taken throughout the study site. The tillage area was drill seeded in early May 2003 at a rate of 25 pounds per acre (lb/acre) with "Revegetation Mix #1" (Table 2-6).

2.1.3 Post-Treatment Soil Sampling

Soil sampling of the grass, forb/subshrub, and seed mixture trials was completed on June 24, 2003, after planting. The air-dried, unsieved soil samples were analyzed for pH (1:1 saturated paste) and total As, cadmium (Cd), copper (Cu), lead (Pb), and zinc (Zn) by EPA Methods SW 3050/6010 at Energy Laboratories, Inc. in Billings, Montana. All analyses were performed in accordance with the laboratory's quality assurance/quality control manual. At the grass trial, eight randomly selected treatment units in each block were subsampled. The eight (0- to 6-inch) composite subsamples collected from a block were combined and mixed to form one representative sample. Duplicate soil samples were taken in Block 1, and alternate soil samples were taken in Block 3. In the forb/subshrub trial, four (0- to 6-inch) subsamples were taken per block to form one representative sample. Duplicate subsamples were taken in Blocks 1 and 3. In the mixture trial, two (0- to 6-inch) subsamples were taken per block to form one representative sample. Duplicate subsamples were taken in Block 1, and alternate subsamples were taken in Block 3.

The As and metal concentrations of the post-planting soil samples were generally moderate with the exception of Cu. Copper concentrations within the three trials averaged 832 milligrams per kilogram (mg/kg) and ranged from 525 mg/kg to 1,080 mg/kg. The average Cu concentrations in soils collected from 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.

2.1.4 Planting Design

The study was arranged as three separate trials (grass, forb/subshrub, and seed mixture) each in a randomized complete block design. The three trials are situated adjacent to each other as shown in Figure 2-1. The grass, forb/subshrub, and seed mixture trials are 0.96 acre, 0.44 acre, and 0.14 acre, respectively; total plot size is 1.54 acres. Between each block, as well as between trials, an 8-foot strip of slender wheatgrass 'Pryor' was planted to minimize edge effect. The seed bed was prepared by project personnel on April 22, 2003, using a 5-foot box scraper to level the soil. Rocks greater than 6 inches in diameter were hand picked from within the plot boundary. 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-foot 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 is logical. The seed mixtures referred to as "Developed" are the seed formulations, using commercially available cultivars, currently specified for use in the Remedial Action Work Plan/Final Design Report (ARCO, 2002). The seed mixture previously referred to as Revegetation Mix #1, planted in the surrounding treatment area, was 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 unit measured 8 feet by 25 feet and consisted of eight rows. In the grass and forb/ subshrub trials, each treatment unit was planted with a single accession. Two exceptions exist due to seed quantity restraints. In all replications of the grass trial, western wheatgrass 9081968 was drilled in only six rows with slender wheatgrass 'Pryor' drilled into the remaining two rows and broadcast in the unplanted area south of the forb/subshrub trial. In all replications of the forb/subshrub trial, cushion buckwheat 9082098 was drilled into only four rows with slender wheatgrass 'Pryor' drilled into the remaining four rows. Wooden stakes, spray painted orange and marked with an identification number, were installed in the northeast corner of each treatment unit. 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™ (Clopyralid) applied with a backpack sprayer.

2.1.5 Seeded Species

The species entries consisted 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 2-3 through 2-8). The 15 total genera tested were selected for inclusion in the study based on results from previous DATC project studies such as the Initial Evaluation Planting Study (Marty, 2000) and the Greenhouse Comparative Evaluation Planting study (Marty, 2001).

Each genus tested included at least one accession originating from metalliferous soil sites in the proximity of the Anaconda Smelter National Priorities List Site, with the exception in one case. Neither of the two winterfat 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 "nonlocal."

2.1.6 Sampling Methods

Seedling density was the growth response variable used to assess performance during the 2003 growing season. Measurements were taken using an 11.81-inch by 19.68-inch quadrat frame that was randomly placed at five sample locations within each 8-foot by 25-foot treatment unit. The sampling sites were computer generated x-y coordinates originating at the southwest corner of each experimental unit (Marty, 2003a). 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 nonseeded seedlings, were counted and recorded separately. Photographs of each treatment unit were taken during sampling events. Density data was collected on June 24, 2003, to assess emergence and initial establishment and on August 25, 2003, to assess subsequent establishment and/or die-off.

Data were collected on June 30, July 1, and September 22-23, 2004, and August 29-30, 2005. During the early summer sampling, four randomly located frames (11.81-inch by 19.68-inch) were used, 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 of 2005, the same random frame locations were used to estimate percentage stand and plant vigor and to measure plant height 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 140 °F for 24 hours, weighed, cut into small pieces, and packaged in plastic zip-lock bags for delivery to Energy Laboratories, Inc. for tissue analysis.

2.1.7 Grass Trails (2003)

The grand mean of seedling density data collected on June 24, 2003, in the grass trial was 5.4 seedlings/square foot (ft^2) and ranged from 15.0 to 0.3 seedlings/ft^2 as shown in Tables 2-9 and 2-10. Three accessions of slender wheatgrass ('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 slender wheatgrass has been recognized for its excellent seedling vigor and quick establishment and growth on a variety of soil types (USDA-NRCS, 2006b). Density data collected 2 months later on August 25, 2003, indicated that these three slender wheatgrass accessions had significantly greater densities than 86% of the accessions tested. However, the locally collected slender wheatgrass 9081620 did not perform significantly better than 'Pryor' or 'San Luis'.

Western wheatgrass ('Rosana' and 9081968) had 13.3 and 12.7 seedlings/ft^2, respectively, on June 24. This species is an aggressively rhizomatous, long-lived grass known to be adapted to a wide range of soil pH from acidic to basic. Seedling density data collected on August 25 indicated that the above accessions also had significantly greater densities than 86% of the accessions tested including 'Rodan'.

Seedling density data from the June evaluation indicated that basin wildrye 9081624 had significantly greater density (7.8 seedlings/ft^2) than 80.5% of the accessions including the four other basin wildrye accessions. However, by the August evaluation, wildrye 9081624 was not significantly better than wildrye 'Trailhead'. This accession's success was 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 As and heavy metal concentrations (Taskey, 1972).

The bluebunch wheatgrass accessions ('Goldar' and 9081636) also performed in the top third of the field in June and August. In August, both accessions mentioned above had significantly better seedling densities than more than 50% of the accessions. The local accession (9081636) did not perform significantly better than 'Goldar'. This species is reported to have fair seedling vigor and establishment with tolerances to acidic to slightly alkaline soils (USDA-NRCS, 2006a).

The grand mean for the August 25, 2003, evaluation was 4.3 seedlings/ft^2 and ranged from 14.5 to 0.31 seedlings/ft^2. This indicates that seedling density declined by 1.1 seedlings/ft^2 or 20.4% between the June and August evaluations, possibly due to drought stress.

2.1.8 Grass Trials (2004)

Based on the number of new seedlings found in 2004, many seeds did not germinate during the 2003 growing season. The most notable species were Indian ricegrass, basin wildrye, and western wheatgrass. Indian ricegrass has a hard seed coat and should normally be dormant-seeded in the fall. The basin wildrye and western wheatgrass can 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, June 30, 2004, the top accession, by a significant amount, was 9081620 slender wheatgrass with a 61.3% stand, 54.4-centimeter (cm) average height, and a 3.4 vigor rating. Other 'local source' accessions that exhibited good survival, stand, and vigor included 9081633 big bluegrass, 9081621 slender wheatgrass, 9081621 western wheatgrass, 9081624 basin wildrye, 9081628 Indian ricegrass, 9081635 Canby bluegrass, and 9081636 bluebunch wheatgrass and are shown in Table 2-11 and Table 2-12.

Toward the end of the growing season (September 22, 2004), there was very little change in the top performing accessions as shown in Table 2-13. 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 BPMC for potential release to the commercial seed industry. Fall biomass production was relatively low, with only 9081620 slender wheatgrass producing more than 2,000 kilograms per hectare (kg/ha) (i.e., 2,083 kg/ha), shown in Table 2-14. Some of the low production can be attributed to the number of new seedlings emerging in 2004. In addition, 2-year-old plants were often spindly because of the harsh edaphic conditions.

2.1.9 Grass Trials (2005)

The grasses were evaluated and sampled on August 30, 2005. Although there had 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) was the top performer with an average stand of 75% and average plant height of 87.5 cm and average biomass production of 8,211 kg/ha. These averages are shown in Tables 2-15, 2-16, and 2-17. 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.

2.1.10 Seed Mixture Trial

The forbs included in the seed mixtures in Section 2.1.4 did not emerge; therefore, densities reflect only emergent grass seedlings as shown in Tables 2-5, 2-6, 2-7, and 2-8. During the establishment year, the Developed WMA mix had the greatest seedling density with 10.5 seedlings/ft^2 shown in Table 2-18. The Experimental WMA mix had the lowest density with 6.3 seedlings/ft^2. The two Developed mixtures averaged 9.9 seedlings/ft^2, and the two Experimental mixtures averaged 6.3 seedlings/ft^2. 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^2), and the Experimental WMA mixture had the lowest density (6.9 seedlings/ft^2). The two Developed mixtures averaged 7.7 seedlings/ft^2, and the two Experimental mixtures averaged 6.9 seedlings/ft^2. As in June, no significant differences were seen among the four seed mixtures.

At the start of the second growing season in 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 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 WMA Experimental mix topped all mixes with 8,933 kg/ha of oven-dry biomass production.

2.1.11 Forb/Subshrub Trial

Ten of the 16 trial entries had no emergence in 2003, and 15 of the 16 entries had less than 0.50 seedlings/ft^2 in 2004. These results are shown in Table 2-19. The subshrub, winterfat Open Range Germplasm, was the only entry that demonstrated significant emergence with 9.5

seedlings/ft^2. The lack of forb emergence may be due to the May 13, 2003, 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; however, this did not happen with the forb species. The germination rates for some species such as thickstem aster and buckwheat are higher with shallow seeding (USDA-NRCS, 2006a). 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, 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 2 years after being planted. The surviving plants of Open Range winterfat and 9081632 silverleaf phacelia exhibited good vigor, growth, and seed production.

2.1.12 Tissue Analysis

Following the Fall 2004 and Fall 2005 evaluation for cover and vigor, each individual unit was sampled for biomass production. These clippings from all four blocks, along with additional clippings of low producing units, made up the 10 gram or greater of oven-dried samples that were submitted for tissue analysis. Samples were submitted to Energy Laboratories, Inc. in Billings, Montana, for determination of heavy-metal concentrations in as-received plant materials using EPA Method SW 3050/6010. 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, 2005). The dietary limit of 1 mg Cd/kg feed for domesticated animals is based on human food residue considerations and the need to avoid increases of Cd in the food supply of the United States. Higher residue levels (less than 10 mg/kg) for a short period of time would not be expected to be harmful to animal health; however, these levels can result in unacceptable Cd concentrations in kidney, liver, and muscle tissues (ibid, p. 86). 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 elemental levels for generalized plant species into ranges representing deficient, sufficient, or normal, and excessive or toxic are shown in Table 2-20.

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.

- As was detected in 19 of the 39 samples in 2004 and in 32 of the 40 samples in 2005, with levels ranging from 5 mg/kg to 35 mg/ kg. This upper value is slightly above the tolerable level for domestic livestock (30 mg/kg), and below that for wildlife (50 mg/kg). However, the detected levels rank in the 'Excessive or Toxic' level in plants.
- Cadmium was detected in samples of Rimrock Indian ricegrass in 2004 and 2005; it was detected in five accessions (three of which were in Indian ricegrasses). Only the 2004 Rimrock accession clearly exceeds the regulatory level for domestic livestock (1.0 mg/kg) and tolerance by wildlife (2 mg/kg).
- Copper was detected in all tissue samples, ranging from 14 mg/kg to 307 mg/kg. Twenty-three samples (2004) and 32 samples (2005) exceeded the tolerable level for domestic livestock (40 mg/kg). Eleven samples (2004) and 20 samples (2005) 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 was detected in a sample of tenpetal blazingstar only (2004), at a level of 9 mg/kg, below the tolerable level for domestic livestock and wildlife. In 2005, Pb was detected in only four samples; two of these values exceeded the livestock limit of 10 mg/kg, but none exceeded the limit for wildlife species.
- Zinc was detected in all samples, ranging from 14 mg/kg to175 mg/kg, well below the tolerable level for domestic livestock (300 mg/kg) and wildlife (300 mg/kg).

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

2.2 Task 2 – Woody Comparative Evaluation

Seeds/cuttings thriving in soils affected by metals were taken from populations of woody plant material from the Anaconda area (Marty, 2001). This task was divided into the two subtasks of:

- locating vigorous populations of targeted woody species situated within or adjacent to restoration areas; and
- yearly, large-scale seed/cutting collection at the identified sites.

2.2.1 Test Site

The site chosen for this demonstration is a 0.4-acre study site located approximately 4 miles southeast of Anaconda, Montana, that has been impacted by emission fallout from the Upper and Lower Works as wells as the Washoe smelter (Figure 1-1). The Upper and Lower Works smelters operated from 1884 to 1902 when the Washoe smelter took over smelting operations until 1980. The study site lies approximately 200 yards east of Mill Creek at an elevation of 5,140 feet. 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 composite soil samples taken after tilling to 6 inches indicated an average pH of 4.53. Average As, Cd, Cu, Pb, and Zn concentrations in the four soil samples were 423 mg/kg, 6 mg/kg, 510 mg/kg, 233 mg/kg, and 308 mg/kg, respectively. The complete data are shown in Table 2-21.

2.2.2 Methods and Materials

The study tested 19 accessions consisting of 2 or 3 accessions of each of the 7 shrub/tree species. These accessions are shown in Table 2-22. The 6- to 12-inch seedlings were transplanted on October 18, 2000, in a randomized complete block design and replicated 20 times. An individual plant of each accession was represented in each replication. The seedlings were spaced 4.5 feet apart within rows and 9 feet apart between rows. The plot received no supplemental irrigation. The spring following planting, Vispore™ (3-foot by 3-foot) tree mats were installed on all entries to suppress weeds and retard soil moisture evaporation.

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

2.2.3 Results and Discussion

Overall, survival of the entries in the Woody Comparative Evaluation Plot (CEP) in 2001 was local 91.4% and nonlocal 79.2%. The complete results are shown in Table 2-23. Edaphic conditions had taken their toll, as survival 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%. Anaconda's 30-year average annual precipitation was 13.93 inches. The site was dehydrated in 2000, the year of establishment, with precipitation at 9.57 inches. However, the years following were near or above normal; 2001-13.99 inches, 2002-16.23 inches, 2003-15.42 inches, 2004-13.37 inches, and 2005-15.75 inches. Therefore, precipitation in Anaconda was not likely a major factor in plant mortality.

In all species except common snowberry, the "local" source had equal or better survival than the "nonlocal" sources. As shown in Table 2-23, the superior accessions included ponderosa and lodgepole pines, common snowberry, and silver buffaloberry. Based on survival and growth, the best overall performing species have been ponderosa pine followed by common snowberry, buffaloberry, and Woods' rose. All accessions of lodgepole pine have performed poorly.

The average growth over the first 4-year period for the local source material was 5.9 inches, while the nonlocal material averaged 4.07 inches of growth. In 2005, the local material averaged 5.29 inches of growth, while the nonlocal averaged 3.43 inches. Generally, the local source material outgrew the nonlocal material except for the two snowberry species and the lodgepole pine. 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 common snowberry (Ravalli County), wax current (Deer Lodge County), buffaloberry (Deer Lodge County), Woods' rose (Deer Lodge County), and western snowberry (Wyoming source).

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. nonlocal 5.9, 2004–local 5.1 vs. nonlocal 5.9, and 2005–local 5.3 vs. nonlocal 5.9. No patterns in superior vigor seem to exist by species or origin other than the local material has slightly better vigor rating than the nonlocal.

The top-ranking accession for vigor was wax current followed by buffaloberry. As in the other categories, the lodgepole pine accessions had the poorest overall performance.

2.3 Task 3 – High Quality Seed "Bank"

A quality seed "bank" was established and maintained at BPMC. This task resulted in wild and cultivated seed that met or exceeded the Association of Official Seed Certifying Agencies criteria (AOSCA, 2003). All seed increase activities took place at the U.S. Department of Agriculture-Natural Resources Conservation Service (USDA-NRCS) Plant Materials Center near Bridger, Montana. The 140-acre research farm was set up for irrigated seed production of conservation plants for use in Montana and Wyoming. Breeders and Foundation seed of released plant materials are produced at the BPMC for distribution to commercial seed growers through the Foundation Seed programs at Montana State University-Bozeman and the University of Wyoming-Laramie. The BPMC was set up to use both sprinkler and furrow irrigation. Seed increase blocks or fields are established by direct seeding, transplanting of container-grown stock, and transplanting/establishment of seed production orchards (woody plant material). Special consideration must be given to properly isolate DATC project material from other releases or test material of the same species. Cross-pollinated species are isolated at least 900 feet apart, while self-fertilized species are isolated at least 100 feet apart.

2.3.1 Seeding

All seeding was done with a two-row, double-disk planter equipped with depth bands to obtain a uniform 0.25- to 0.5-inch seeding depth. Seed was planted in rows spaced 3 feet apart to accommodate the gated pipe irrigation water delivery system. Depending on the species, planting was done either as a dormant-fall planting (October 15 to December 15) or as an early spring planting (April 1 to May 15). Seeds that have a dormancy or after-ripening requirement are dormant-fall seeded to obtain natural stratification.

2.3.2 Transplanting

For small lots of seed that need seed increase, the limited seed supply was planted into Cone-tainers™ and transplanted into fields following 6 months of growth under greenhouse conditions. A mechanical transplanter was used, resulting in uniform 14 inches within-row spacing. This method has been used on alpine bluegrass, western wheatgrass, bluebunch wheatgrass, fuzzy-tongue penstemon, silverleaf phacelia, wooly cinquefoil, and tufted hairgrass.

2.3.3 Woody Transplants

All woody material was container grown and transplanted as 2-0 stock into seed production orchards. In some cases, a weed-barrier was used to reduce weed establishment within the rows, while in others, cultivation was used to keep between-row spaces weed-free. Most shrubs will not initiate seed production until the plants are 5 to 6 years old.

2.3.4 Production Fields

The species that were grown for seed production are shown in Table 2-24. Some of the woody increase orchards had not reached the maturity level necessary for seed production; however, seed will be harvested once these are productive and seed will be made available to other researchers and potentially released to the commercial plant production industry.

2.3.5 Weed Control

The preferred method for weed control was by either cultivation or hand roguing. However, chemical weed control was often necessary. With everything established in rows, between-row cultivation was easily accomplished with standard cultivators. All chemical applications are required to be completed prior to flowering or late in the season when plants have become dormant.

2.3.6 Fertilization

No fertilizers were added to field increase plots until the fall of the first growing season, and then every fall for the life of the stand. A standard mix of 80 lb N/acre and 40 lb P_2O_5/acre was used on most species. Fall applications were applied in granular form from September 15 to October 15.

2.3.7 Irrigation

The Bridger area receives an average of 11.3 inches of annual precipitation, making it necessary to provide supplemental water to improve seed production. Hand-moved sprinklers were available for plant establishment if natural precipitation was inadequate. Once established, furrow irrigation was used. Critical irrigation times are early summer prior to flowering, after pollination as seeds are maturing, and during the fall when seedhead primordia are developing for the following year.

2.3.8 Seed Harvest

Depending on the species, size of stand, and amount of seed, harvesting can be accomplished in a variety of ways. Seed can be hand stripped, direct combined, swathed/combined, or head harvested/dried/combined. Seed was harvested at a 20% to 30% moisture level and dried to less than 12% for cleaning and storage. Seed that was officially released and made available to commercial growers must meet standards established by the Montana Seed Growers' Association and be analyzed for purity and germination by the Montana Seed Testing Laboratory at Montana State University.

2.3.9 Post-Harvest Maintenance

Following harvest, seed production stands were mowed to remove excess biomass and stimulate tillering. The stands were also cultivated prior to fall fertilization and irrigation.

2.3.10 Seed Cleaning

A variety of standard seed cleaning equipment was used to clean the DATC seed, both wildland collections and field seed increase. A hammermill was used to further thresh seed or remove appendages. Three different sizes of screen-fanning mills are available for cleaning seed based on size, shape, and weight. An indent cylinder was used to remove round weed seed from elongated grass seed, and a small gravity table was used to make separations based on specific gravity.

2.3.11 Seed Storage

All cleaned seed were stored in cloth-mesh bags on shelves in the basement of the office building at the BPMC. The ambient conditions at BPMC are quite good for seed storage as there was consistently low relative humidity and uniform cool temperatures in the basement. Under these conditions, most native seeds will remain viable for up to 10 years.

2.3.12 Seed Accessioning and Inventory

The USDA-NRCS Plant Materials nationwide network uses the Plant Material Operational and Management System for the accessioning, inventory, and distribution of all lots of seed and plants handled through the Plant Materials network. All seed was inventoried to the nearest 10 grams (Table 2-25).

2.4 Task 4 – Plant Releases

This task involved developing release notices in cooperation with the appropriate partners following USDA-NRCS Plant Materials guidelines (2000).

The seeds and plants that are available to reclamationists are cultivar releases from universities, USDA Plant Material Centers, the 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 predamage 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 timely manner, but at the expense of extensive field-testing. Germplasm was 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 sell 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 increase in seed fields begin.
- ***Selected*** – This category was 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 was required.
- ***Tested*** – If the progeny of a superior germplasm was tested to ensure that the desired traits continued to manifest in subsequent generations, the germplasm qualifies were released as a tested germplasm. This process can take 6 to 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.

The Pre-Varietals release mechanism has been used extensively on native plant materials that are not readily available on the commercial market, 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.

2.5 Goal 1 – Field Testing

The potential releases were field tested at the Anaconda Smelter Superfund Site and monitored for adaptation and interspecies compatibility.

2.6 Goal 2 – Technology Transfer

To attain this goal, educational materials pertaining to the DATC project were developed for distribution to the reclamation scientific community, seed producers, and commercial reclamation specialists. The project research results and plant products have been or will be publicized through articles in reclamation journals, symposium proceedings, and NRCS' Technical Notes, Plant Guides, Fact Sheets, and Plant Materials newsletters.

2.6.1 DATC Project Releases

The Conservation Districts of Montana and Wyoming own the land and facilities at the BPMC and lease to the USDA-NRCS. 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 and the University of Wyoming-Laramie. The Plant Materials Center has experience in the release of conservation plants, both introduced and native, in cooperation with Montana State University and the University of Wyoming. Breeders and Foundation seed was produced at the BPMC, making Foundation seed available to the commercial seed industry for the production of Certified seed. In the case of Pre-Varietal releases, the BPMC produces G_1 (Generation 1) seed for distribution to growers who will produce G_2 and G_3 under the Certified Seed Program. Once a release was made, the releasing agency was responsible for maintaining a supply of G_1 (Pre-Varietal release) or Foundation (Cultivar release) seed for as long as seed/plants of the release are in demand.

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

- **Washoe** Selected germplasm basin wildrye (*Leymus cinereus*);
- **Old Works** Source Identified germplasm fuzzy-tongue penstemon (*Penstemon eriantherus*); and
- **Prospectors** Selected germplasm common snowberry (*Symphoricarpos albus*)

Information brochures have been published on these three releases and are distributed to potential seed growers and seed-purchasing customers. Foundation Quality (G_1) seed of Washoe basin wild rye 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 Idaho. No growers have yet shown interest in the production of Prospectors common snowberry.

During the winter of 2006, Copperhead Selected class germplasm slender wheatgrass (9081620) was submitted for release consideration to the Variety Release Committee at Montana State University and the Pure Seed Committee at the University of Wyoming. This accession of slender wheatgrass has performed exceptionally well on the amended Stucky Ridge Trial site. As the release was successful, G_1 seed was made available to commercial growers in the summer of 2006.

The DATC 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. These potential releases are:

- 9081620–slender wheatgrass (*Elymus trachycaulus*);
- 9081968–western wheatgrass (*Pascopyrum smithii*);
- 9081636–bluebunch wheatgrass (*Pseudoroegneria spicata*);
- 9081633–big bluegrass (*Poa secunda*);
- 9081628–Indian ricegrass *Achnatherum hymenoides*);
- 9081619–redtop (*Agrostis gigantea*);
- 9081632–silverleaf phacelia (*Phacelia hastata*);
- 9076274–woolly cinquefoil (*Potentilla hippiana*);
- 9078675–stiffstem aster (*Symphyotrichum chilensis*);
- 9081334–silver buffaloberry (*Shepherdia argentea*);
- 9081638–Woods' rose (*Rosa woodsii*); and
- 9081623–horizontal juniper (*Juniperus horizontalis*).

Opportunity Selected class germplasm big bluegrass (9081633) will be submitted to the Montana State University/University of Wyoming review committees in the winter of 2007. If the release is approved, G_1 seed will be available to commercial growers in the spring of 2008.

Bluebunch wheatgrass (9081636) is being considered for release in fiscal year 2008. Other releases within the next 3 years include 9081968 western wheatgrass, 9081632 silverleaf phacelia, and 9081334 silver buffaloberry (Deer Lodge Valley Conservation District and USDA-Bridger Plant Materials Center, 2007).

2.7 Comments Regarding Laboratory Quality Assurance/Quality Control

Leaf-and-stalk biomass plus surface (0- to 6-inch) soil samples were submitted by BPMC to Energy Laboratories, Inc. throughout the MWTP phase of this project; MSE sampled surface soils once at the Lowland CEP plot (Figure 1-1) and submitted them to the HKM Laboratory. Both laboratories used EPA Methods SW 3050B for sample preparation and 6010B for instrumental determination of the target metals/As in these sample types. The key variations in sample preparation methodologies are as follows:

- Energy Laboratories air dries samples at temperatures slightly above ambient (~30 °C) without subsequent grinding or sieving materials prior to digestion; while
- HKM dries the soils at 40 °C for at least 24 hours, followed by sieving the soils through a 10-mesh screen, prior to digesting the 2-mm fraction.

Although field sampling and sample preparation varied, the similar results reported in Table 2-26 indicate the general representativeness of these data to the 0.8-acre plot. Both laboratories reported acceptable results for laboratory control standards, spike recoveries, and relative percent differences (RPD) for duplicate analyses (i.e., as required by Method 6010B).

Not to Scale

N ←

Grass Trial

Block 1	Block 2	Block 3	Block 4
4 ACHY Nezpar	16 ELTR San Luis	30 POSE Sherman	20 LECI Magnar
24 PASM Rosana	32 POSP 9081635	23 PPSM Lodorm	36 ELNA Secar
19 LICE Washoe	22 PASM 9081968	29 POSE 9081633	11 DECE Nortran
28 POAL 1858	2 ACHY 9081629	35 PSSP Goldar	18 LECI 9081625
26 POAL 01-13-1	15 ELTR Revenue	32 POSP 9081635	10 DECE 13970176
21 LECI Trailhead	36 ELWA Secar	7 AGGI 9076266	8 AGGI Streaker
16 ELTR San Luis	13 ELTR 9081621	21 LECI Trailhead	4 ACHY Nezpar
25 POAL 9016273	1 ACHY 9081628	5 AGGI 9076276	30 POSE Sherman
11 DECE Nortran	6 AGGI 9081619	1 ACHY 9081628	35 PSSP Goldar
27 POAL Gruening	26 POAL 01-13-1	26 POAL 01-13-1	23 PASM Rodan
14 ELTR Pryor	3 ACHY Rimrock	3 ACHY Rimrock	16 ELTR San Luis
10 DECE 13970176	19 LECI Washoe	27 POAL Gruening	25 POAL 9016273
3 ACHY Rimrock	12 ELTR 9081620	13 ELTR 9081621	29 POSE 9081633
12 ELTR 9081620	27 POAL Gruening	34 PSSP 9081636	12 ELTR 9081620
30 POSE Sherman	17 LECI 9081624	10 DECE 13970176	9 DECE 9076290
17 LECI 9081624	5 AGGI 9076276	15 ELTR Revenue	27 POAL Gruening
36 ELWA Secar	30 POSE Sherman	18 LECI 9081625	6 AGGI 9081619
7 AGGI 9076266	10 DECE 13970176	12 ELTR 9081620	5 AGGI 9076276
22 PASM 9081968	11 DECE Nortran	25 POAL 9016273	13 ELTR 9081621
6 AGGI 9081619	34 PSSP 9081636	2 ACHY 9081629	32 POSP 9081635
8 AGGI Streaker	18 LECI 9081625	8 AGGI Streaker	2 ACHY 9081629
13 ELTR 9081621	8 AGGI Streaker	16 ELTR San Luis	33 POSP 9081322
29 POSE 9081633	33 POSP 9081322	22 PASM 9081968	26 POAL 01-13-1
18 LECI 9081625	21 LECI Trailhead	11 DECE Nortran	7 AGGI 9076266
33 POSP 9081322	29 POSE 9081633	4 ACHY Nezpar	15 ELTR Revenue
15 ELTR Revenue	9 DECE 9076290	33 POSP 9081322	22 PASM 9081968
35 PSSP Goldar	14 ELTR Pryor	28 POAL 1858	28 POAL 1858
1 ACHY 9081628	23 PASM Rodan	24 PASM Rosana	31 POSE Canbar
9 DECE 9076290	28 POAL 1858	20 LECI Magnar	14 ELTR Pryor
31 POSE Canbar	24 PASM Rosana	36 ELWA Secar	24 PASM Rosana
34 PSSP 9081636	31 POSE Canbar	6 AGGI 9081619	19 LECI Washoe
32 POSP 9081635	4 ACHY Nezpar	31 POSE Canbar	34 PSSP 9081636
2 ACHY 9081629	35 PSSP Goldar	14 ELTR Pryor	17 LECI 9081624
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

Forb/Subshrub Trial

Block 1	Block 2
10 PHHA 9081632	8 PEST Bandera
12 POGI 9081679	5 KRLA Op.Range
1 EROV 9082098	4 KRLA NCD
14 SYCH 9078675	15 SYCH 9081678
16 SYCH 5255-RS	9 PEVE Clearwater
6 PEER Old Works	1 EROV 9082098
4 KRLA NCD	6 PEER Old Works
9 PEVE Clearwater	7 PEEA Richfield
7 PEEA Richfield	3 ERUM 01-206-1
11 PHHA 9003	12 POGR 9081679
3 ERUM 01-206-1	11 PHHA 9003
15 SYCH 9081678	10 PHHA 9081632
8 PEST Bandera	2 ERUM 450
13 POHI 9076274	13 POHI 9076274
5 KRLA Op.Range	16 SYCH 5255-RS
2 ERUM 450	14 SYCH 9078675

Block 3	Block 4
12 POGI 9081679	11 PHHA 9003
9 PEVE Clearwater	10 PHHA 9081632
5 KRLA Op.Range	5 KRLA Op.Range
4 KRLA NCD	13 POHI 9076274
16 SYCH 5255-RS	6 PEER Old Works
13 POHI 9076274	8 PEST Bandera
10 PHHA 9081632	15 SYCH 9081678
15 SYCH 9081678	7 PEEA Richfield
11 PHHA 9003	4 KRLA NCD
8 PEST Bandera	12 POGR 9081679
2 ERUM 450	2 ERUM 450
1 EROV 9082098	9 PEVE Clearwater
6 PEER Old Works	1 EROV 9082098
3 ERUM 01-206-1	14 SYCH 9078675
7 PEEA Richfield	16 SYCH 5255-RS
14 SYCH 9078675	3 ERUM 01-206-1

Seed Mixture Trial

Block 1	Block 2	Block 3	Block 4
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

Figure 2-1. **Layout of the grass, forb/subshrub, and seed mixture trials at the Stucky Ridge Comparative Evaluation Planting. See Species Index (p. ix) for plant codes and Tables 2-5 through 2-8 for seed mixture formulations. (Source: Marty, 2003b).**

Table 2-1. Pretillage Soils Data in the Proximity of the Plot Site (ARCO, 2002, May)

Soil Sample Station	Depth (inches)	Arsenic (mg/kg)	Copper (mg/kg)	Zinc (mg/kg)	Saturated Paste pH (s.u.)
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	-----
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	-----	-----	-----	-----

Table 2-2. Post-Planting Grass, Forb/Subshrub, and Seed Mixture Trial (0- to 6-inch) Composite Soil Sample Analysis

Sample Identification	Sample Description	pH (s.u.)	As (mg/kg)	Cd (mg/kg)	Cu (mg/kg)	Pb (mg/kg)	Zn (mg/kg)
GR1	Grass Trial, Block 1	8.2	120	1	797	35	174
GR2	Grass Trial, Block 2	8.1	117	1	906	34	177
GR3	Grass Trial, Block 3	7.9	132	1	833	43	195
GR4	Grass Trial, Block 4	8.0	212	2	985	61	228
GDR1	Grass Trial, Block 1, Dupl.	7.7	121	1	703	39	153
GDR3	Grass Trial, Block 3, Alt.	7.7	178	1	845	57	201
FR1	Forb Trial, Block 1	8.0	115	1	774	38	185
FR2	Forb Trial, Block 2	7.2	127	2	888	45	182
FR3	Forb Trial, Block 3	7.7	153	2	1010	45	220
FR4	Forb Trial, Block 4	7.6	127	2	1080	40	210
FD1	Forb Trial, Block 1, Dupl.	8.0	91	ND†	681	31	170
FD3	Forb Trial, Block 3, Dupl.	7.9	106	1	828	33	171
MR1	Seed Mix. Trial, Block 1	8.0	39	1	721	6	143
MR2	Seed Mix. Trial, Block 2	7.5	367	2	909	97	226
MR3	Seed Mix. Trial, Block 3	7.7	39	ND	706	12	161
MR4	Seed Mix. Trial, Block 4	7.8	257	2	857	91	209
MDR1	Seed Mix. Trial, Block 1, Dupl.	7.4	130	1	925	35	165
MDR3	Seed Mix. Trial, Block 3, Alt.	8.1	29	ND	525	9	153

† ND: Not detected at the reporting limit.

Table 2-3. Forb and Subshrub Treatments Included in the Forb/Subshrub Trial

Species Identification Number	Genus & Species	Accession/Variety	Origin
1	*Eriogonum ovalifolium*	9082098	Deer Lodge County, Montana
2	*Eriogonum umbellatum*	9082271	Utah
3	*Eriogonum umbellatum*	9082273	Idaho
4	*Krascheninnikovia lantana*	Northern Cold Desert Germplasm	Composite from Utah & Idaho
5	*Krascheninnikovia lantana*	Open Range Germplasm	Composite from Montana & Wyoming
6	*Penstemon eriantherus*	Old Works Germplasm	Deer Lodge County, Montana
7	*Penstemon eatonii*	Richfield Selected	Sevier County, Utah
8	*Penstemon strictus*	'Bandera' 477980	Torrance County, New Mexico
9	*Penstemon venustus*	Clearwater Selected	Clearwater River area, Idaho
10	*Phacelia hastata*	9081632	Deer Lodge County, Montana
11	*Phacelia hastata*	9082275	California
12	*Potentilla gracilis*	9081679	California
13	*Potentilla hippiana*	9076274	Deer Lodge County, Montana
14	*Symphyotrichum chilense*	9078675	Deer Lodge County, Montana
15	*Symphyotrichum chilense*	9081678	Colorado
16	*Symphyotrichum chilense*	9082274	Unknown

Table 2-4. Grass Treatments Included in the Grass Trial at the Stucky Ridge Uplands

Species Identification Number	Genus & Species	Accession/Variety	Origin
1	*Achnatherum hymenoides*	9081628	Deer Lodge County, Montana
2	*Achnatherum hymenoides*	9081629	Deer Lodge County, Montana
3	*Achnatherum hymenoides*	'Rimrock'	Yellowstone County, Montana
4	*Achnatherum hymenoides*	'Nezpar'	White Bird, Idaho
5	*Agrostis gigantea*	9076276	Deer Lodge County, Montana
6	*Agrostis gigantea*	9081619	Deer Lodge County, Montana
7	*Agrostis gigantea*	9076266	Deer Lodge County, Montana
8	*Agrostis gigantea*	'Streaker'	Illinois
9	*Deschampsia caespitosa*	9076290	Silver Bow County, Montana
10	*Deschampsia caespitosa*	9082620	California
11	*Deschampsia caespitosa*	'Nortran'	Alaska
12	*Elymus trachycaulus*	9081620	Deer Lodge County, Montana
13	*Elymus trachycaulus*	9081621	Deer Lodge County, Montana
14	*Elymus trachycaulus*	'Pryor'	Carbon County, Montana
15	*Elymus trachycaulus*	'Revenue'	Saskatchewan, Canada
16	*Elymus trachycaulus*	'San Luis'	Rio Grande County, Colorado
17	*Leymus cinereus*	9081624	Deer Lodge County, Montana
18	*Leymus cinereus*	9081625	Deer Lodge County, Montana
19	*Leymus cinereus*	Washoe Germplasm	Deer Lodge County, Montana
20	*Leymus cinereus*	'Magnar'	Saskatchewan, Canada
21	*Leymus cinereus*	'Trailhead'	Musselshell County, Montana
22	*Pascopyrum smithii*	9081968[†]	Deer Lodge County, Montana
23	*Pascopyrum smithii*	'Rodan'	Morton County, North Dakota
24	*Pascopyrum smithii*	'Rosana'	Rosebud County, Montana
25	*Poa alpina*	9016273	Gallatin County, Montana
26	*Poa alpina*	9082259	British Columbia, Canada
27	*Poa alpina*	'Gruening'	France/Switzerland
28	*Poa alpina*	9082266	Unknown
29	*Poa secunda* (*ampla*)	9081633	Deer Lodge County, Montana
30	*Poa secunda* (*ampla*)	'Sherman'	Sherman County, Oregon
31	*Poa secunda* (*canbyi*)	'Canbar'	Columbia County, Washington
32	*Poa* species	9081635	Deer Lodge County, Montana
33	*Poa* species	9081322	Lewis & Clark County, Montana
34	*Pseudoroegneria spicata*	9081636	Deer Lodge County, Montana
35	*Pseudoroegneria spicata*	'Goldar'	Asotin County, Washington
36	*Elymus wawawaiensis*	'Secar'	Washington

Table 2-5. Upland Areas – Experimental Seed Mix Formulation

Species Identification Number	Genus & Species	Accession/Variety	Origin	Seed Mixture Percentage
1	GRASSES:			
	Achnatherum hymenoides	9081629	Deer Lodge County, Montana	15.0
	Elymus trachycaulus	9081620	Deer Lodge County, Montana	15.0
	Leymus cinereus	Washoe Germ.	Deer Lodge County, Montana	15.0
	Pascopyrum smithii	9081968	Deer Lodge County, Montana	5.0
	Poa alpina	90816273	Gallatin County, Montana	10.0
	Poa secunda (*ampla*)	9081633	Deer Lodge County, Montana	15.0
	Pseudoroegneria spicata	9081636	Deer Lodge County, Montana	15.0
	FORBS:			
	Aster chilensis	9078675	Deer Lodge County, Montana	2.5
	Penstemon eriantherus	Old Works Germ.	Deer Lodge County, Montana	5.0
	Potentilla hippiana	9076274	Silver Bow County, Montana	2.5

Table 2-6. Upland Areas – Developed Seed Mix Formulation

Species Identification Number	Genus & Species	Accession/Variety	Origin	Seed Mixture Percentage
2	GRASSES:			
	Achnatherum hymenoides	'Nezpar'	White Bird, Idaho	5.0
	Elymus lanceolatus	'Critana'	Hill County, Montana	15.0
	Elymus trachycaulus	'Revenue'	Saskatchewan, Canada	15.0
	Festuca ovina	'Covar'	Central Turkey	10.0
	Leymus cinereus	'Magnar'	Saskatchewan, Canada	15.0
	Pascopyrum smithii	'Rosana'	Rosebud County, Montana	10.0
	Poa secunda (*ampla*)	'Sherman'	Sherman County, Oregon	14.5
	Pseudoroegneria spicata	'Goldar'	Asotin County, Washington	10.0
	FORBS:			
	Achillea lanulosa	Great Northern	Flathead County, Montana	2.5
	Artemisia frigida	9082258	Unknown	0.5
	Linum lewisii	'Appar'	Custer County, South Dakota	2.5

Table 2-7. Waste Management Areas – Experimental Seed Mix Formulation

Species Identification Number	Genus & Species	Accession/Variety	Origin	Seed Mixture Percentage
3	GRASSES:			
	Agrostis gigantea	9076276	Deer Lodge County, Montana	15
	Deschampsia caespitosa	9076290	Silver Bow County, Montana	10
	Elymus trachycaulus	9081620	Deer Lodge County, Montana	15
	Leymus cinereus	Washoe Germ.	Deer Lodge County, Montana	15
	Pascopyrum smithii	9081968	Deer Lodge County, Montana	5
	Poa secunda (*ampla*)	9081633	Deer Lodge County, Montana	10
	Stipa comata	9078314	Deer Lodge County, Montana	10
	FORBS:			
	Aster chilensis	9078675	Deer Lodge County, Montana	10

Table 2-8. Waste Management Areas – Developed Seed Mix Formulation

Species Identification Number	Genus & Species	Accession/Variety	Origin	Seed Mixture Percentage
4	GRASSES:			
	Agropyrum intermedium	'Greenar'	Former USSR	10
	Bromus inermis	'Manchar'	Manchuria, China	15
	Elymus lanceolatus	'Critana'	Hill County, Montana	10
	Elymus trachycaulus	'Revenue'	Saskatchewan, Canada	15
	Leymus cinereus	'Magnar'	Saskatchewan, Canada	15
	Poa secumda (*ampla*)	'Sherman'	Sherman County, Oregon	10
	Stipa viridula	9082255	Washington	10
	FORBS:			
	Medicago sativa	'Ladak'	Kashmir, India	15

Table 2-9. Density (seedlings per square foot) Sampled on 6/24/03, at Stucky Ridge

Genus & Species	Accession	Species ID	Density/ft^2	Mean Separation
Elymus trachycaulus	'Pryor'	14	14.97	A*
Elymus trachycaulus	9081620	12	14.09	AB
Elymus trachycaulus	'San Luis'	16	13.63	AB
Pascopyrum smithii	'Rosana'	24	13.31	AB
Pascopyrum smithii	9081968	22	12.72	AB
Pseudoroegneria spicata	9081636	34	11.75	BC
Leymus cinereus	9081624	17	11.25	BC
Elymus wawawaiensis	'Secar'	36	9.47	CD
Elymus trachycaulus	9081621	13	9.34	CD
Pseudoroegneria spicata	'Goldar'	35	9.09	CDE
Achnatherum hymenoides	'Nezpar'	4	8.94	CDEF
Elymus trachycaulus	'Revenue'	15	8.75	CDEFG
Poa secunda	9081633	29	7.13	DEFG
Leymus cinereus	'Magnar'	20	6.13	EFGH
Leymus cinereus	'Trailhead'	21	5.81	FGH
Pascopyrum smithii	'Rodan'	23	5.66	GH
Leymus cinereus	9081625	18	3.84	HI
Leymus cinereus	Washoe Germplasm	19	3.66	HIJ
Poa secunda	'Sherman'	30	3.13	HIJ
Agrostis gigantea	9081619	6	2.38	IJ
Poa alpine	9016273	25	2.34	IJ
Poa species	9081635	32	1.88	IJ
Agrostis gigantea	9076276	5	1.75	IJ
Poa alpine	9082266	28	1.72	IJ
Poa species	9081322	33	1.31	IJ
Achnatherum hymenoides	'Rimrock'	3	1.28	IJ
Deschampsia caespitosa	9076290	9	1.28	IJ
Poa secunda	'Canbar'	31	1.22	IJ
Deschampsia caespitosa	'Nortran'	11	1.00	IJ
Agrostis gigantea	9076266	7	0.81	IJ
Achnatherum hymenoides	9081629	2	0.78	IJ
Agrostis gigantea	'Streaker'	8	0.75	IJ
Poa alpine	9082259	26	0.66	IJ
Achnatherum hymenoides	9081628	1	0.59	IJ
Deschampsia caespitosa	9082260	10	0.56	IJ
Poa alpine	'Gruening'	27	0.34	J

* Means followed by the same letter are not significantly different at the 0.05 significance level using the Duncan's Multiple Range Test

Table 2-10. Density (seedlings per square foot) Sampled on 8/25/03, at Stucky Ridge

Genus & Species	Accession	Species ID	Density/ft^2	Mean Separation
Elymus trachycaulus	9081620	12	14.47	A*
Elymus trachycaulus	'San Luis'	16	13.44	A
Elymus trachycaulus	'Pryor'	14	12.13	A
Pascopyrum smithii	'Rosana'	24	12.00	A
Pascopyrum smithii	9081968	22	11.59	A
Elymus trachycaulus	'Revenue'	15	8.38	B
Leymus cinereus	9081624	17	7.81	BC
Pseudoroegneria spicata	'Goldar'	35	7.28	BC
Pseudoroegneria spicata	9081636	34	7.16	BC
Elymus wawawaiensis	'Secar'	36	6.56	BC
Achnatherum hymenoides	'Nezpar'	4	6.53	BC
Elymus trachycaulus	9081621	13	6.09	BC
Pascopyrum smithii	'Rodan'	23	5.75	BCD
Poa secunda	9081633	29	5.16	CDE
Leymus cinereus	'Trailhead'	21	4.91	CDE
Leymus cinereus	'Magnar'	20	3.00	DEF
Leymus cinereus	9081625	18	2.44	EF
Poa secunda	'Sherman'	30	2.34	EF
Agrostis gigantea	9081619	6	2.28	EF
Leymus cinereus	Washoe Germplasm	19	2.16	EF
Agrostis gigantea	9076276	5	1.47	F
Poa alpine	9082266	28	1.25	F
Poa alpine	9082259	26	1.03	F
Agrostis gigantea	9076266	7	0.97	F
Achnatherum hymenoides	'Rimrock'	3	0.91	F
Poa alpine	9016273	25	0.91	F
Poa species	9081635	32	0.91	F
Deschampsia caespitosa	'Nortran'	11	0.88	F
Poa species	9081322	33	0.72	F
Achnatherum hymenoides	9081628	1	0.59	F
Poa alpine	'Gruening'	27	0.53	F
Poa secunda	'Canbar'	31	0.47	F
Deschampsia caespitosa	9076290	9	0.44	F
Deschampsia caespitosa	9082260	10	0.38	F
Agrostis gigantea	'Streaker'	8	0.34	F
Achnatherum hymenoides	9081629	2	0.31	F

* Means followed by the same letter are not significantly different at the 0.05 significance level using the Duncan's Multiple Range Test

Table 2-11. Percentage Stand and Vigor of Grass Trials on Stucky Ridge Plot on 6/30/04

Genus & Species	Accession	Stand (%)		Vigor (1-9)
Elymus trachycaulus	9081620	61.3	a*	3.4
Achnatherum hymenoides	Rimrock	31.3	b	4.8
Poa secunda	9081633	31.3	b	3.3
Elymus trachycaulus	9081621	28.4	bc	4.8
Elymus trachycaulus	Pryor	26.9	bcd	4.8
Pascopyrum smithii	9081968	26.7	bcd	4.9
Achnatherum hymenoides	Nezpar	25.3	bcde	5
Leymus cinereus	9081624	20.8	bcdef	4.4
Elymus wawawaiensis	Secar	20	bcdefg	4.6
Elymus trachycaulus	Revenue	19.7	cdefg	4.8
Elymus trachycaulus	San Luis	18.6	cdefgh	4.8
Achnatherum hymenoides	9081628	18.3	cdefgh	5.6
Pascopyrum smithii	Rosana	16.9	defghi	4.75
Leymus cinereus	Trailhead	15.1	efghij	4.8
Poa secunda	9081635	15	efghij	3.3
Pseudoroegneria spicata	9081636	14.5	efghijk	5.3
Leymus cinereus	Washoe	12.8	fghijkl	5
Leymus cinereus	Magnar	12.2	fghijkl	5.3
Pascopyrum smithii	Rodan	11.8	fghijklm	5.3
Agrostis gigantea	9081619	10.7	fghijklm	3.2
Leymus cinereus	9081625	10.1	fghijklm	5.5
Pseudoroegneria spicata	Goldar	10	fghijklm	5
Achnatherum hymenoides	9081629	8.6	ghijklm	5.7
Agrostis gigantea	9076276	8.1	hijklm	2.6
Poa secunda	Sherman	6.2	ijklm	4.8
Poa alpina	1—13—1	4.1	jklm	3.3
Deschampsia caespitosa	9076290	4	jklm	4.2
Poa secunda	9081322	3.6	klm	4.3
Poa alpina	9016273	3.3	klm	4.6
Agrostis gigantea	9076266	3.1	klm	2.5
Poa alpina	1858	1.4	lm	4.5
Deschampsia caespitosa	Nortran	0.6	m	2.1
Poa alpina	Gruening	0.5	m	4
Agrostis gigantea	Streaker	0.4	m	5.2
Poa secunda	Canbar	0.4	m	6.2
Deschampsia caespitosa	13970176	0.2	m	5.3

* Means followed by the same letter are not significantly different at the 0.05 significance level using the least significant difference (LSD) Mean Comparison method

Table 2-12. Average Plant Height of Grasses in Stucky Ridge Plots Measured 6/30/04

Genus & Species	Accession	Height Millimeters (mm)
Elymus trachycaulus	9081620	54.4 a*
Elymus trachycaulus	9081621	34.2 c
Agrostis gigantea	9076276	33.3 cd
Agrostis gigantea	9081619	27.1 cde
Poa secunda	9081633	26.5 cdef
Elymus wawawaiensis	Secar	24 defg
Poa secunda	9081635	23.3 efgh
Pseudoroegneria spicata	Goldar	22.5 efghi
Agrostis gigantea	9076266	21 efghij
Elymus trachycaulus	Pryor	18.5 efghijk
Leymus cinereus	9081624	17.9 efghijkl
Poa secunda	9081322	17.5 fghijkl
Achnatherum hymenoides	Nezpar	16.9 ghijklm
Leymus cinereus	Trailhead	16.1 ghijklmn
Elymus trachycaulus	San Luis	14.5 hijklmno
Deschampsia caespitosa	9076290	14.5 hijklmno
Elymus trachycaulus	Revenue	14.3 hijklmno
Pascopyrum smithii	Rosana	13.5 ijklmno
Achnatherum hymenoides	Rimrock	13 jklmnop
Leymus cinereus	Magnar	12.8 jklmnop
Leymus cinereus	Washoe	12.5 jklmnop
Pascopyrum smithii	Rodan	12.3 jklmnop
Pseudoroegneria spicata	9081636	12 jklmnop
Pascopyrum smithii	9081968	11.3 klmnop
Leymus cinereus	9081625	10.6 klmnop
Agrostis gigantea	Streaker	10.3 klmnop
Achnatherum hymenoides	9081628	9.1 lmnop
Poa alpine	1--13—1	8.1 mnop
Achnatherum hymenoides	9081629	7.6 mnop
Deschampsia caespitosa	13970176	7 nop
Poa secunda	Sherman	6.8 nop
Poa secunda	Canbar	6.3 op
Deschampsia caespitosa	Nortran	6 op
Poa alpina	9016273	5.8 op
Poa alpina	Gruening	4.5 p
Poa alpina	1858	3.9 p

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

Table 2-13. Percentage Stand and Vigor of Grasses in Stucky Ridge Plots Evaluated on 9/22/04

Genus & Species	Accession	Stand (%)		Vigor (1-9)
Elymus trachycaulus	9081620	61.3	a*	1.8
Poa secunda	9081633	37.2	c	2.4
Elymus trachycaulus	9081621	30	cd	2.7
Pascopyrum smithii	9081968	28.4	cde	4
Elymus trachycaulus	Pryor	27.5	cde	4.6
Pascopyrum smithii	Rosana	26.3	de	3.6
Achnatherum hymenoides	Rimrock	24.1	def	4.2
Poa sp.	9081635	24.1	def	2.8
Elymus trachycaulus	Revenue	23.8	defg	4.3
Leymus cinereus	9081624	22.8	defgh	3.6
Leymus cinereus	Trailhead	20	defghi	4
Elymus wawawaiensis	Secar	19.2	defghi	4
Elymus trachycaulus	San Luis	19.1	defghi	4.4
Achnatherum hymenoides	Nezpar	18.4	efghij	4.1
Pseudoroegneria spicata	9081636	17.9	efghij	3.8
Agrostis gigantea	9081619	17.8	efghij	2.1
Pascopyrum smithii	Rodan	16.6	fghijk	4.5
Agrostis gigantea	9076276	15.9	fghijk	2.7
Achnatherum hymenoides	9081628	14.4	ghijkl	4.9
Leymus cinereus	Washoe	14.1	ghijkl	4.6
Leymus cinereus	Magnar	13.4	ghijkl	4.7
Pseudoroegneria spicata	Goldar	13.4	ghijkl	4.1
Poa secunda	Sherman	12.2	hijklm	4.1
Poa sp.	9081322	11.9	ijklm	2.9
Leymus cinereus	9081625	11.6	ijklmn	4.1
Achnatherum hymenoides	9081629	11.3	ijklmno	5.4
Poa alpina	01-13-1	8.4	jklmnop	3.6
Agrostis gigantea	9076266	7.8	jklmnop	2.1
Deschampsia caespitosa	9076290	6.3	klmnop	2.8
Poa alpina	9016273	5.2	lmnop	3.6
Poa alpina	1858	4.4	lmnop	3.6
Agrostis gigantea	Streaker	1.9	mnop	4
Deschampsia caespitosa	13970176	1.9	mnop	3.3
Poa alpina	Gruening	1.1	op	3.3
Deschampsia caespitosa	Nortran	0.4	op	3
Poa secunda	Canbar	0	op	9

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

Table 2-14. Biomass Production of Grasses in Stucky Ridge Trials Clipped on 9/22/04

Genus & Species	Accession	Biomass (kg/ha)
Elymus trachycaulus	9081620	2,083 a*
Agrostis gigantea	9081619	706 cd
Elymus trachycaulus	9081621	544 cde
Poa secunda	9081633	408 cdef
Elymus trachycaulus	Pryor	386 cdef
Elymus wawawaiensis	Secar	346 def
Leymus cinereus	9081624	216 ef
Leymus cinereus	Trailhead	192 ef
Elymus trachycaulus	Revenue	172 ef
Leymus cinereus	Washoe	148 ef
Agrostis gigantea	9076276	148 ef
Poa secunda	Sherman	115 ef
Elymus trachycaulus	San Luis	100 f
Poa sp.	9081635	100 f
Deschampsia caespitosa	9076290	99 f
Pseudoroegneria spicata	9081636	97 f
Pascopyrum smithii	Rosana	95 f
Achnatherum hymenoides	Rimrock	84 f
Leymus cinereus	9081625	52 f
Pascopyrum smithii	Rodan	45 f
Pseudoroegneria spicata	Goldar	43 f
Poa sp.	9081322	34 f
Agrostis gigantea	9076266	29 f
Poa alpina	01-13-1	14 f
Pascopyrum smithii	9081968	11 f
Achnatherum hymenoides	Nezpar	9 f
Deschampsia caespitosa	13970176	8 f
Poa alpina	9016273	7 f
Achnatherum hymenoides	9081629	4 f
Achnatherum hymenoides	9081628	4 f
Leymus cinereus	Magnar	3 f
Poa alpina	1858	2 f
Poa alpina	Gruening	2 f
Deschampsia caespitosa	Nortran	1 f
Agrostis gigantea	Streaker	tr f
Poa secunda	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.

Table 2-15. Percentage Stand and Vigor of Grass Trials on Stucky Ridge Plots Evaluated on 8/30/05

Genus & Species	Accession	Stand (%)		Vigor (1-9)
Elymus trachycaulus	9081620	75.0	a*	2.1
Poa secunda	9081633	43.4	b	2.1
Elymus trachycaulus	9081621	34.1	bc	2.7
Poa secunda	9081635	25.9	cd	3.3
Elymus trachycaulus	Pryor	23.1	cde	5.3
Leymus cinereus	9081624	22.2	cdef	3.8
Pascopyrum smithii	9081968	21.9	defg	4.5
Elymus wawawaiensis	Secar	21.6	defg	4.3
Elymus trachycaulus	San Luis	20.9	defgh	4.6
Pascopyrum smithii	Rosana	20.6	defgh	4.7
Leymus cinereus	Trailhead	16.2	defghi	4.3
Pascopyrum smithii	Rodan	16.2	defghi	5.0
Achnatherum hymenoides	9081628	14.1	defghij	5.3
Achnatherum hymenoides	Rimrock	14.1	defghij	4.5
Leymus cinereus	9081625	13.8	defghij	5.5
Pseudoroegneria spicata	9081636	13.8	defghij	4.5
Agrostis gigantea	9081619	13.4	efghijk	3.2
Leymus cinereus	Washoe	13.4	efghijk	4.8
Agrostis gigantea	9076276	13.1	efghijk	3.7
Poa secunda	Sherman	12.5	efghijkl	4.0
Achnatherum hymenoides	Nezpar	11.9	efghijklm	4.6
Elymus trachycaulus	Revenue	11.9	efghijklm	5.4
Pseudoroegneria spicata	Goldar	11.1	efghijklm	4.6
Leymus cinereus	Magnar	10.9	fghijklm	5.2
Deschampsia caespitosa	9076290	10.6	fghijklm	3.9
Poa secunda	9081322	10.0	ghijklm	4.2
Agrostis gigantea	9076266	9.0	hijklm	4.0
Achnatherum hymenoides	9081629	6.4	ijklm	5.7
Poa alpina	01-13-1	3.9	jklm	5.0
Poa alpina	1858	3.6	jklm	5.3
Poa alpina	9016273	3.0	jklm	3.8
Deschampsia caespitosa	Nortran	1.6	klm	3.8
Deschampsia caespitosa	13970176	0.9	lm	3.8
Poa alpina	Gruening	0.8	lm	1.5
Agrostis giganteus	Streaker	0.4	m	1.5
Poa secunda	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.

Table 2-16. Average Plant Height of Grasses in Stucky Ridge Plots Measured on 8/30/05

Genus & Species	Accession	Height Centimeters (cm)
Elymus trachycaulus	9081620	87.5 a*
Elymus trachycaulus	9081621	76.3 a
Poa secunda	9081633	59.0 b
Leymus cinereus	9081624	58.0 bc
Elymus trachycaulus	Pryor	47.0 bcd
Elymus wawawaiensis	Secar	46.5 bcde
Elymus trachycaulus	San Luis	46.3 bcde
Poa secunda	9081635	45.6 bcdef
Leymus cinereus	9081625	44.0 bcdef
Agrostis giganteus	9081619	43.8 bcdef
Leymus cinereus	Trailhead	42.9 cdefg
Achnatherum hymenoides	Rimrock	39.5 defg
Elymus trachycaulus	Revenue	36.9 defgh
Poa secunda	9081322	36.9 defgh
Leymus cinereus	Washoe	36.1 defgh
Agrostis giganteus	9076276	35.0 defgh
Achnatherum hymenoides	Nezpar	33.4 defgh
Pseudoroegneria spicata	Goldar	33.1 defgh
Pseudoroegneria spicata	9081636	31.5 efgh
Leymus cinereus	Magnar	30.9 fghi
Poa secunda	Sherman	30.4 fghi
Pascopyrum smithii	Rosana	28.6 ghi
Pascopyrum smithii	Rodan	27.5 ghi
Agrostis giganteus	9076266	26.3 ghi
Pascopyrum smithii	9081968	24.7 hi
Deschampsia caespitosa	9076290	22.8 hi
Achnatherum hymenoides	9081628	20.8 hij
Achnatherum hymenoides	9081629	15.9 ijk
Poa alpina	01-13-1	6.4 jkl
Deschampsia caespitosa	Nortran	5.7 jkl
Poa alpina	9016273	5.4 kl
Deschampsia caespitosa	13970176	4.5 kl
Poa alpina	1858	4.1 kl
Poa alpina	Gruening	1.1 kl
Agrostis giganteus	Streaker	0.9 kl
Poa secunda	Canbar	0.0 l

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

Table 2-17. Biomass Production of Grasses in Stucky Ridge Trials Clipped on 8/30/05

Genus & Species	Accession	Biomass (kg/ha)	
Elymus trachycaulus	9081620	8,211	a*
Elymus trachycaulus	9081621	4,100	b
Poa secunda	9081633	2,506	c
Leymus cinereus	Trailhead	2,222	cd
Agrostis giganteus	9076276	2,189	cd
Agrostis giganteus	9081619	2,039	cde
Leymus cinereus	9081624	1,844	cdef
Elymus trachycaulus	Pryor	1,578	cdefg
Agrostis giganteus	9076266	1,367	cdefgh
Elymus wawawaiensis	Secar	1,289	cdefgh
Poa sp.	9081635	906	defgh
Achnatherum hymenoides	Nezpar	872	defgh
Deschampsia caespitosa	9076290	844	defgh
Pascopyrum smithii	9081968	800	defgh
Pascopyrum smithii	Rosana	650	efgh
Leymus cinereus	Magnar	639	efgh
Elymus trachycaulus	San Luis	622	efgh
Elymus trachycaulus	Revenue	578	fgh
Leymus cinereus	9081625	428	fgh
Leymus cinereus	Washoe	361	gh
Achnatherum hymenoides	Rimrock	339	gh
Pseudoroegneria spicata	9081636	317	gh
Pseudoroegneria spicata	Goldar	272	gh
Poa secunda	9081322	233	gh
Pascopyrum smithii	Rodan	189	gh
Poa secunda	Sherman	189	gh
Agrostis giganteus	Streaker	122	h
Achnatherum hymenoides	9081628	61	h
Achnatherum hymenoides	9081629	61	h
Poa alpina	9016273	51	h
Poa alpina	1858	28	h
Deschampsia caespitosa	13970176	28	h
Poa alpina	01-13-1	23	h
Poa alpina	Groening	0	h
Deschampsia caespitosa	Nortran	0	h
Poa secunda	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.

Table 2-18. Moto-X Replicated Mixture Trial on Stucky Ridge

	Density 6/03 no/ft2	Density 8/03 no/ft2	Stand 6/04 %	Stand 9/04 %	Stand 8/05 %	Height 2004 cm	Height 2005 cm	Biomass 2004 kg/ha	Biomass 2005 kg/ha
Upland Exp.	6.4	7.4	39.4	45.9	60.6	45.8	78.8	790	5939
Upland Dev.	9.3	7.0	17.3	24.4	25.9	14.8	47.2	215	2011
Waste Mgmt Area Exp	6.3	6.9	38.1	46.9	59.7	44.8	82.5	1206	8933
Waste Mgmt Area Dev	10.5	8.0	15.0	23.8	28.4	19.8	56.6	306	4494

Table 2-19. Seedling Density (2003), Percentage Stand (2004), and Total Plant Density (2005) of Forb and Subshrub Accessions in the Stucky Ridge Comparative Evaluation Planting Evaluated on 6/24/03, 8/25/03, 6/30/04, 9/22/04, and 8/30/05

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

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

Table 2-20. Heavy Metal Concentration of Clipped Biomass Samples from Stucky Ridge Sampled on 9/22/04 and 8/29/05; Analyzed on 10/10/05[a]

Lot #	Species	Al (mg/kg)		As (mg/kg)		Cd (mg/kg)		Cu (mg/kg)		Pb (mg/kg)		Zn (mg/kg)	
		2004	**2005**	**2004**	**2005**	**2004**	**2005**	**2004**	**2005**	**2004**	**2005**	**2004**	**2005**
1	ACHY9081628	331	279	6	8	ND	2	39	34	ND	ND	123	88
2	ACHY9081629	288	420	9	8	ND	2	41	35	ND	ND	111	73
3	ACHY Rimrock	235	332	ND	9	5	1	17	35	ND	ND	68	38
4	ACHY Nezpar	276	200	ND	ND	ND	ND	16	21	ND	ND	51	31
5	AGGI9076276	258	382	ND	6	ND	ND	46	62	ND	ND	54	41
6	AGGI9081619	663	375	ND	ND	ND	ND	100	62	ND	ND	51	64
7	AGGI9076266	548	320	ND	6	ND	ND	74	39	ND	ND	100	49
8	AGGI Streaker		2500		35		ND		243		13		78
9	DECE9076290	334	405	5	6	ND	1	48	45	ND	ND	63	52

Lot #	Species	Al (mg/kg) 2004	Al (mg/kg) 2005	As (mg/kg) 2004	As (mg/kg) 2005	Cd (mg/kg) 2004	Cd (mg/kg) 2005	Cu (mg/kg) 2004	Cu (mg/kg) 2005	Pb (mg/kg) 2004	Pb (mg/kg) 2005	Zn (mg/kg) 2004	Zn (mg/kg) 2005
10	DECE13970176	1420	121	8	6	ND	ND	57	14	ND	ND	87	44
11	DECE Nortran	3336		8		ND		29		ND		67	
12	ELTR9081620	242	285	ND	5	ND	ND	26	47	ND	ND	14	16
13	ELTR9081621	197	283	ND	ND	ND	ND	38	41	ND	ND	21	22
14	ELTR Pryor	301	413	ND	8	ND	ND	25	62	ND	ND	37	35
15	ELTR Revenue	280	445	ND	7	ND	ND	48	65	ND	ND	50	47
16	ELTR San Luis	441	193	ND	6	ND	ND	45	27	ND	ND	40	33
17	LECI9081624	424	436	ND	5	ND	ND	62	73	ND	ND	111	55
18	LECI9081625	463	559	6	9	ND	1	72	76	ND	ND	172	124
19	LECI Washoe	472	366	7	ND	ND	ND	47	47	ND	ND	175	106

Lot #	Species	Al (mg/kg)		As (mg/kg)		Cd (mg/kg)		Cu (mg/kg)		Pb (mg/kg)		Zn (mg/kg)	
		2004	2005	2004	2005	2004	2005	2004	2005	2004	2005	2004	2005
20	LECI Magnar	636	410	11	8	ND	ND	113	63	ND	ND	84	69
21	LECI Trailhead	441	391	ND	8	ND	ND	35	51	ND	ND	85	93
22	PASM 9081968	374	315	6	5	ND	ND	45	41	ND	ND	86	64
23	PASM Rodan	495	243	7	6	ND	ND	52	29	ND	ND	56	39
24	PASM Rosana	210	318	6	9	ND	ND	29	47	ND	ND	61	52
25	POAL 9016273	799	1740	7	21	ND	ND	50	120	ND	8	45	64
26	POAL 01-13-1	1220	695	8	17	ND	ND	78	80	ND	ND	49	50
28	POAL 1858	1190	1410	ND	20	ND	ND	33	93	ND	9	62	156
29	POSE 9081633	442	417	9	ND	ND	ND	49	52	ND	ND	35	44
30	POSE Sherman	311	420	9	12	ND	ND	36	52	ND	ND	94	106

Lot #	Species	Al (mg/kg)		As (mg/kg)		Cd (mg/kg)		Cu (mg/kg)		Pb (mg/kg)		Zn (mg/kg)	
		2004	**2005**	**2004**	**2005**	**2004**	**2005**	**2004**	**2005**	**2004**	**2005**	**2004**	**2005**
31	POSE Canbar	no samples											
32	POSP 9081635	364	549	11	14	ND	ND	46	59	ND	ND	38	44
33	POSP 9081322	441	346	ND	9	ND	ND	83	62	ND	ND	57	64
34	PSSP 9081636	676	931	16	20	ND	ND	76	112	ND	ND	81	84
35	PSSP Goldar	654	548	13	12	ND	ND	81	68	ND	ND	77	58
36	ELWA Secar	396	635	ND	7	ND	ND	34	59	ND	ND	68	65
1	UPEXP	392	266	ND	ND	ND	ND	51	43	ND	ND	22	31
2	UPDEV	268	545	ND	12	ND	ND	31	69	ND	ND	73	40
3	WMAEXP	374	421	ND	ND	ND	ND	35	50	ND	ND	27	25
4	WMADEV	270	548	ND	9	ND	ND	26	66	ND	ND	67	44
5	KRLA Op. Range	1173	372	7.5	ND	ND	ND	108	44	ND	ND	82	47

Lot #	Species	Al (mg/kg) 2004	Al (mg/kg) 2005	As (mg/kg) 2004	As (mg/kg) 2005	Cd (mg/kg) 2004	Cd (mg/kg) 2005	Cu (mg/kg) 2004	Cu (mg/kg) 2005	Pb (mg/kg) 2004	Pb (mg/kg) 2005	Zn (mg/kg) 2004	Zn (mg/kg) 2005
6	PEER Old Works		1280		14		ND		65		ND		31
10	PHA9081632		3720		42		ND		307		15		91
Maximum Tolerable Levels for													
Domestic livestock (NRC, 2005)				30		1.0[b]		40[c]		100[d]		300[e]	
Wildlife (Ford, 1996)				50		2		55		40		300	
Metal levels in Plants (Kabata-Pendias & Pendias, 1992)													
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		5 to 30		20 to 100		30 to 300		100 to 400	

Lot #	Species	Al (mg/kg)		As (mg/kg)		Cd (mg/kg)		Cu (mg/kg)		Pb (mg/kg)		Zn (mg/kg)	
		2004	2005	2004	2005	2004	2005	2004	2005	2004	2005	2004	2005

Notes: [a]Element-specific MDLs are ≤5 mg/kg (by inductively-coupled plasma-optical emission spectroscopy).
[b]For protection of human health; lowest observed adverse effect level (LOAEL) for livestock is 10 mg/kg.
[c]LOAEL for cattle ranges from 15 mg/kg for sheep to 250 mg/kg for horses.
[d]For horses; 100 mg/kg for cattle and sheep.
[e]For sheep; 500 mg/kg for horses and cattle.

Table 2-21. Acid Extractable Heavy Metal Levels at the Woody CEP Plot

Sample No.	pH (s.u.)	As (mg/kg)	Cd (mg/kg)	Cu (mg/kg)	Pb (mg/kg)	Zn (mg/kg)
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
Arithmetic Mean	4.53	422.5	6	510	232.5	308
Phytotoxicity Criteria[a]	< 5.0	136-315	5.1-20	236-750	94-250	196-240

Note: EPA phytotoxicity standards (CDM Federal, 1997).

Table 2-22. Seed Origin and Elevation Entries

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

Table 2-23. Woody Comparative Evaluation Plot

Replication	Vigor				Average Height (cm)				% Survival			
	2002	**2003**	**2004**	**2005**	**2002**	**2003**	**2004**	**2005**	**2002**	**2003**	**2004**	**2005**
PICO 9078320	5.80	5.1	6.5	7.6	10.1	10.2	11.8	14.0	85	40	25	25
PICO m039ID0002	5.0	5.0	7.0	8.0	12.8	16.3	16.0	16.5	30	15	10	10
PICO m038WY0002	4.0	4.5	5.5	6.0	14.5	15.7	18.0	20.5	20	15	5	10
PIPO 9081318	2.1	3.4	5.6	5.7	24.7	27.4	25.8	31.3	100	100	95	95
PIPO m04CO0002	4.2	4.8	7.3	8.0	14.3	14.7	13.7	14.1	85	85	85	75
PIPO m020SD9903	3.2	2.7	4.8	5.3	26.8	32.1	31.5	38.3	100	100	95	95
RICE 9081329	4.8	2.8	3.9	3.3	25.5	47.2	52.0	78.7	75	65	70	60
RICE m024CO0003	5.4	5.1	5.9	5.4	12.3	24.0	25.6	46.9	65	50	50	40
ROWO 9081638	4.2	4.5	4.5	4.4	26.1	35.9	39.4	57.3	75	65	65	55
ROWO m076CO0003	7.0	7.0	8.0	9.0	9.0	5.0	4.0	0.0	15	5	5	0
ROWO m07MT0003	5.0	4.0	6.0	4.0	12.0	28.5	21.7	50.5	20	10	15	10
SHAR 9081334	2.5	2.5	3.9	4.0	29.9	37.9	41.7	73.9	80	80	80	75
SHAR m022WY0005	6.6	5.2	6.7	7.3	5.6	7.8	12.7	20.1	60	35	30	35
SHAR m015UT9901	5.8	5.0	5.5	6.0	9.2	13.3	15.0	31.5	25	20	10	10
SYAL 9078388	3.6	4.0	4.5	5.7	18.7	25.1	28.5	30.5	90	85	95	90
SYAL m045MT003	3.6	3.0	4.2	4.8	18.3	30.3	33.7	40.5	30	30	30	30
SYOC 9081639	4.6	5.2	6.9	6.5	18.1	16.1	18.6	26.5	85	80	65	30
SYOC m021WY0004	3.8	2.8	4.6	4.4	24.8	40.6	37.5	55.7	90	75	70	65
SYOC m018CO9904	4.0	4.5	4.8	5.4	16.6	22.8	23.7	35.9	90	85	75	70

Table 2-24. Seed Production Fields Established at the BPMC

Common Name	Accession	Release	Field Number	Field Size	Established
woolly cinquefoil	9076274		4		spring 2006[a]
fuzzytongue penstemon	9081631	Old Works	20	.30	11/04[b]
silverleaf phacelia	9081632		20	.35	11/04[b]
basin wildrye	9081627	Washoe	20	.80	4/05[b]
basin wildrye	9081627	Washoe	22	.21	4/99[b]
bluebunch wheatgrass	9081636		20	.30	4/05[b]
slender wheatgrass	9081620		20	.35	4/05[b]
big bluegrass	9081633		20	.24	4/05[b]
Indian ricegrass	9081628		22	.14	4/99[b]
western wheatgrass	9081968		22	.10	6/05[a]
common snowberry	9078388	Prospectors	19	.44	5/00[c]
creeping juniper	9081623		23	.60	5/02, 5/03[c]
Woods' rose	9081638		30	.40	7/99[c]
western snowberry	9081639		30	.40	5/00[c]
silver buffaloberry	9081334		30	.60	5/00[c]

Notes: [a] Transplanted Cone-tainers™
[b] Established from seed
[c] Transplanted 2-0 stock

Table 2-25. Seed on Hand of Increase Plant Material

Genus & Species	Common Name	Accession	Seed on Hand Kilograms (kg)
Achnatherum hymenoides	Indian ricegrass	9081628	4.81
Agrostis giganteus	Redtop	9076276	50.03
Elymus trachycaulus	slender wheatgrass	9081620	44.52
Juniperus horizontalis	creeping juniper	9081623	0.34
Leymus cinereus	basin wildrye	Washoe	28.84
Pascopyrum smithii	western wheatgrass	9081968	0.01
Penstemon eriantherus	fuzzytongue penstemon	Old Works	2.75
Phacelia hastate	silverleaf phacelia	9081632	9.96
Poa secunda	big bluegrass	9081633	4.16
Potentilla hippiana	woolly cinquefoil	9076274	4.80
Pseudoroegneria spicata	Bluebunch wheatgrass	9081636	23.71
Rosa woodsii	Woods' rose	9081638	0.56
Shepherdia argentea	silver buffaloberry	9081334	0.00
Symphoricarpos albus	common snowberry	Prospectors	0.47
Symphoricarpos occidentalis	western snowberry	9081639	0.10

Table 2-26. Comparison of Independent Soil Sampling and Analysis Results[a]

Part A. Sampling by BPMC on October 24, 2001, and Analysis by Energy Laboratories, Inc. (Billings)

Field Sample No.	Laboratory Parameters						
	pH (s.u.)	**Eh (mV)**	**As (mg/kg)**	**Cd (mg/kg)**	**Cu (mg/kg)**	**Pb (mg/kg)**	**Zn (mg/kg)**
LS-1	7.4	296.0	338.0	6.0	574.0	147.0	394.0
LS-2	5.1	339.0	404.0	7.0	639.0	163.0	455.0
LS-3	5.4	345.0	472.0	11.0	882.0	230.0	572.0
L2-4	6.7	312.0	329.0	7.0	608.0	155.0	435.0
Average	6.2	323.0	385.8	7.8	675.8	173.8	464.0

Part B. Sampling by MSE on October 26, 2001, and Analysis by HKM Laboratory (Butte)

Field Sample No.	Laboratory Parameters						
	pH (s.u.)	**Eh (mV)**	**As (mg/kg)**	**Cd (mg/kg)**	**Cu (mg/kg)**	**Pb (mg/kg)**	**Zn (mg/kg)**
SR-1-SW	6.65	249.0	554.0	9.9	988.0	253.0	636.0
SR-2-NW[b]	4.72	275.0	539.0	11.3	937.0	223.0	702.0
SR-3-NW[b]	4.53	287.0	551.0	11.1	954.0	241.0	705.0
SR-4-SE	4.66	290.0	506.0	10.6	843.0	201.0	669.0
SR-5-NE	7.18	230.0	367.0	9.4	657.0	161.0	593.0
Average	5.78	262.5	493.0	10.3	858.4	211.8	650.4

Notes:
[a] For Lowland CEP plot (Figure 1-1), post-plow surface (0- to 6-inch) composite soil samples.
[b] Field duplicate samples.

Avg./RPD/%	6.4	18.7	27.8	32.0	27.0	21.9	40.2

±25%-50% is acceptable.

Source: DLVCD, 2005, Tables 7 and 8.

3. Conclusions and Recommendations

3.1 Conclusions

3.1.1 Woody Comparative Evaluation Plot

Several dead plants were removed and it was observed that the roots of these plants had not penetrated the native soil beyond their soil media plug area. It is probable that the 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 contaminates declined.

The accessions that had good survival and are now showing substantial growth include:

- *Pinus ponderosa* (Deer Lodge County, Montana);
- *Pinus ponderosa* (Lawrence County, South Dakota);
- *Ribes cereum* (Deer Lodge County, Montana);
- *Rosa woodsii* (Deer Lodge County, Montana);
- *Rosa woodsii* (Ravalli County, Montana);
- *Shepherdia argentea* (Deer Lodge County, Montana);
- *Symphoricarpos albus* (Deer Lodge County, Montana); and
- *Symphoricarpos occidentalis* (Weston County, Wyoming).

3.1.2 Stucky Ridge Plot

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 the primary factors affecting the incomplete germination and emergence during the 2003 growing season (National Weather Service, 2003). 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 bluegrass. The superior indigenous plant material was 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. Because this species is short-lived and only moderately tolerant of grazing, "stands should be managed carefully to ensure seed production occurs every other year for long-term survival" (USDA-NRCS, 2006b; p. 2).

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- to 6-inch) 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. Although this variability remains unexplained, it may be due to microclimatic effects on seed germination (i.e., subtle, highly localized variations in soil moisture and temperature). Another possible explanation is the presence of metals-rich "hot spots" that remained after initial tillage of the soils.

3.2 Recommendations

The DATC project offers an improved means of revegetating lands degraded by hardrock mining, milling, and smelting activities within the Intermountain Region of the Western United States. Acceptance of the Anaconda-accessions released to date, as well as those in the future, by regulatory agencies and private industry will be aided by continued funding of field demonstration and seed production activities by BPMC. Such efforts should include seasonal performance monitoring of key species and "experimental" seed mixtures at the Stucky Ridge and Woody CEP plots for at least another few years. Such monitoring would improve understanding of plant response(s) to climatic variability and variations in heavy metals uptake (per given accession) from soil over time. MSE Technology Applications, Inc. is impressed by the BMPC's expertise and dedication to achieving these ends and hopes its good work will be able to continue into the future.

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Appendix A

Development of Acid/Heavy Metal Tolerant Releases (DATR)
2005 Activities Report

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

Appendix B

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

from
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