EARLY DESIGN ACTION: SPRING GULCH GREENHOUSE STUDY – DRAFT WORK PLAN

Chevron Questa Mine Superfund Site
Questa, New Mexico

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ARCADIS U.S., Inc.
Golder Associates Inc.

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Revision 0
# Table of Contents

1. **Introduction**  
   1.1 Work Plan Organization  
   1.2 Other Plans and Procedures  

2. **Previous Revegetation Studies Using Spring Gulch Waste Rock Material**  
   2.1 2003 Field Test Plots  
      2.1.1 Plot Construction and Amendments  
      2.1.2 Results  
   2.2 Other Studies  
      2.2.1 Shrub Survival and Root Growth Study  
      2.2.2 Native Grass Survival and Growth in Acidic Waste Rock  
      2.2.3 Tree, Shrub, and Forb Species Trials in Acidic Waste Rock  
      2.2.4 Soil Toxicity Testing of Spring Gulch Waste Rock  

3. **Cover Material Characteristics**  
   3.1 Physical and Chemical Properties  
   3.2 Soil Water Relations  
   3.3 Cover Performance Objectives  

4. **Biosol® and Other Amendments**  

5. **Greenhouse Study Design and Methodology**  
   5.1 Procedures for Collecting and Processing Spring Gulch Waste Rock Material  
      5.1.1 Locations  
      5.1.2 Collection and Transport  
      5.1.3 Stockpiling and Screening  
   5.2 Greenhouse Study Design  
      5.2.1 Experimental Design  
      5.2.1.1 Treatments, Replication, and Growth Containers  
      5.2.1.2 Plant Species  
      5.2.1.3 Greenhouse Environmental Conditions  
      5.2.2 Plant Measurements and Data Analyses
# Table of Contents

5.2.2.1 Main Experiment 5-9  
5.2.2.2 Sub Experiment 5-10  
5.2.3 Sample Preparation and Laboratory Analysis for Plant Molybdenum and Copper Uptake, Molybdenum Bioaccessibility, Cover Treatment Molybdenum, and Copper and N-P-K Content 5-10  
5.2.3.1 Plant Uptake – Molybdenum and Copper Analysis 5-11  
5.2.3.2 Molybdenum Bioaccessibility 5-12  
5.2.3.3 Analysis of Plant Biomass, SGWR Treatments, and Control Sand for Molybdenum, Copper, Nitrogen-Phosphorous-Potassium Content, and Other Agronomic Parameters 5-12  
5.2.4 Greenhouse Schedule 5-12  

6. **Toxicity Assessment** 6-1  
6.1 Molybdenum Uptake Results 6-1  
6.1.1 Grass Toxicity and Growth Endpoints 6-1  
6.1.2 Shrub Toxicity and Growth Endpoints 6-2  
6.1.3 Plant Uptake of Molybdenum and Copper 6-2  
6.2 Cover Toxicity Assessment 6-3  
6.2.1 Plants 6-3  
6.2.2 Soil Invertebrates 6-3  
6.2.3 Mammals 6-3  
6.2.4 Avian 6-3  

7. **Conclusions and Specifications for Cover Based on Toxicity Assessment** 7-1  

8. **Data Quality Assessment and Reporting** 8-1  
8.1 Data Quality Assessment 8-1  
8.2 Reporting 8-1  

9. **Data Quality Objectives** 9-1  
9.1 State the Problem (Data Quality Objective Step 1) 9-1  
9.2 Identify the Goals of the Study (Data Quality Objective Step 2) 9-1  
9.3 Identify Information Inputs (Data Quality Objective Step 3) 9-1  
9.4 Define the Boundaries of the Study (Data Quality Objective Step 4) 9-2
Table of Contents

9.5 Develop the Analytic Approach (Data Quality Objective Step 5) 9-2
9.6 Specify Performance or Acceptance Criteria (Data Quality Objective Step 6) 9-2
9.7 Develop the Detailed Plan for Obtaining Data (Data Quality Objective Step 7) 9-2

10. Project Schedule 10-1
10.1 Greenhouse Study 10-1
10.2 Greenhouse Study Report 10-1

11. Contractors and Subcontractors 11-1

12. Health and Safety 12-1

13. References 13-1

Tables

2-1 Transplanted Tree and Shrub Species by Class, Questa Mine Site Test Plots
2-2 Grass and Forb Seed Mixture for Questa Mine Site Test Plots
2-3 Percent Wood Plant Survival and Density of Grasses and Forbs on 2:1 and 3:1 Plots
2-4 Percent Wood Plant Survival and Density of Grasses and Forbs on Platform Plots and Sloped Demonstration Plots
2-5 Percent Wood Plant Survival and Density of Grasses and Forbs on Platform Demonstration Plots
5-1 Completely Randomized Arrangement of Treatments for One Replication of Mine Experiment
5-2 Sampling Program and Analytical Methods
6-1 Plant Toxicity and Uptake Parameter Summary Table
9-1 Data Quality Objectives
10-1 Greenhouse Study and Toxicity Assessment Schedule

Figures

1-1 Spring Gulch Waste Rock Pile
5-1 Proposed Locations for Borrow Material
5-2 Driving Route from Questa to Mora, NM
Appendices

A  2003 Test Plot Construction Summary Report
B  Summary of 2011 Results from 2003 Test Plots
C  Additional Waste Rock Sampling and Stockpiling – Spring Gulch Waste Rock Pile Chevron Mining Inc., Questa Mine, Questa, New Mexico; ARCADIS March 12, 2014 Memorandum
**Acronyms and Abbreviations**

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Definition</th>
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<tbody>
<tr>
<td>AOC</td>
<td>Administrative Settlement Agreement and Order on Consent</td>
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<tr>
<td>ANOVA</td>
<td>analysis of variance</td>
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<tr>
<td>ARCADIS</td>
<td>ARCADIS U.S., Inc.</td>
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<tr>
<td>BAF</td>
<td>bioaccumulation factor</td>
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<tr>
<td>°C</td>
<td>degrees Celsius</td>
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<tr>
<td>cm</td>
<td>centimeters</td>
</tr>
<tr>
<td>CMI</td>
<td>Chevron Mining Inc.</td>
</tr>
<tr>
<td>cy</td>
<td>cubic yards</td>
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<tr>
<td>DQO</td>
<td>data quality objective</td>
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<tr>
<td>dS/m</td>
<td>deciSiemens per meter</td>
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<tr>
<td>EC</td>
<td>electrical conductivity</td>
</tr>
<tr>
<td>°F</td>
<td>degrees Fahrenheit</td>
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<td>GEI</td>
<td>GEI Consultants, Inc.</td>
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<tr>
<td>HASP</td>
<td>Health and Safety Plan</td>
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<tr>
<td>ICP</td>
<td>inductively coupled plasma</td>
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<tr>
<td>lb/ac</td>
<td>pound per acre</td>
</tr>
<tr>
<td>lb/ac-ft</td>
<td>pounds per acre-foot</td>
</tr>
<tr>
<td>lbs P₂O₅/ac</td>
<td>pounds of phosphorus pentoxide per acre</td>
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<tr>
<td>K</td>
<td>potassium</td>
</tr>
<tr>
<td>m</td>
<td>meter</td>
</tr>
<tr>
<td>mg/kg</td>
<td>milligrams per kilogram</td>
</tr>
<tr>
<td>mm</td>
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</tr>
<tr>
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<td>New Mexico Mining and Minerals Division</td>
</tr>
<tr>
<td>N</td>
<td>nitrogen</td>
</tr>
<tr>
<td>NNP</td>
<td>net neutralization potential</td>
</tr>
<tr>
<td>OSHA</td>
<td>Occupational Safety and Health Administration</td>
</tr>
<tr>
<td>P</td>
<td>phosphorous</td>
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<tr>
<td>Abbreviation</td>
<td>Full Form</td>
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<tr>
<td>--------------</td>
<td>-----------</td>
</tr>
<tr>
<td>PLS</td>
<td>pure live seed</td>
</tr>
<tr>
<td>QAPP</td>
<td>Quality Assurance Project Plan</td>
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<tr>
<td>site</td>
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<tr>
<td>SOW</td>
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</tr>
<tr>
<td>t/ac</td>
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</tr>
<tr>
<td>t/ac-ft</td>
<td>tons per acre-foot</td>
</tr>
<tr>
<td>tCaCO₃/kt</td>
<td>tons calcium carbonate per kiloton of material</td>
</tr>
<tr>
<td>µS/cm</td>
<td>microSiemens per centimeter</td>
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1. Introduction

This Early Design Action: Spring Gulch Greenhouse Study – Work Plan (Work Plan) describes additional tasks and activities necessary to conduct the Pre-Design Borrow Characterization of Spring Gulch Waste Rock (SGWR) for the Chevron Questa Mine Superfund Site located in Questa, New Mexico (site). The requirements of this Early Design Action are set forth in the U.S. Environmental Protection Agency (USEPA) Administrative Settlement Agreement and Order on Consent (AOC) and Statement of Work (SOW) for Early Design Actions Chevron Questa Mine Superfund Site, Questa, New Mexico (USEPA 2012; Comprehensive Environmental Response, Compensation, and Liability Act Docket No. 06-13-12). Chevron Mining Inc. (CMI) owns and operates the Questa Mine. The site was the focus of the CMI Remedial Investigation/Feasibility Study (URS Corporation 2009a, 2009b) and is located near the Village of Questa in Taos County, New Mexico (Figure 1-1). This Work Plan was prepared by Redente Ecological Consultants LLC, McDaniel Lambert Inc., ARCADIS U.S., Inc. (ARCADIS), and Golder Associates Inc., on behalf of CMI.

The Questa Mine includes active underground molybdenum mine, milling facility, historic open pit, and waste rock piles. The site encompasses approximately 3 square miles of land located 3.5 miles east of the Village of Questa. The Questa Mine property also includes tailing disposal impoundments (Tailing Facility) covering approximately 2 square miles of land located west of the Village of Questa. A 9-mile tailing pipeline runs from the mill to the Tailing Facility predominantly along Highway 38 and the Red River.

The objective of this Work Plan is to present a greenhouse study design using amended and unamended SGWR to evaluate plant growth and plant uptake of molybdenum. CMI is currently conducting a pre-design characterization of the proposed Spring Gulch Waste Rock Pile (SGWRP) borrow material to further assess its suitability as cover material for the evapotranspiration cover system selected in the Record of Decision (ROD; USEPA 2010) for the waste rock piles. The proposed greenhouse study is just one step in developing a final cover design for waste rock piles at the Questa Mine. The results from the greenhouse study will be used to assist in designing field test plots and pilot studies that will provide further information needed to select plant species and an overall design for a cover soil system for final reclamation.

In a pre-design meeting with the USEPA and New Mexico agencies on December 5, 2012, it was agreed that the Greenhouse Study Work Plan can only be written once key data are gathered from the Spring Gulch field characterization effort. Therefore, this Work Plan represents a phased effort to complete the characterization of SGWR for its use as a soil cover.

1.1 Work Plan Organization

This Work Plan includes the following sections:

- Section 1 – Introduction: This section includes a project narrative, Work Plan organization, a description of the phased Work Plan approach, and other plans relevant to this Work Plan.
• **Section 2 – Previous Revegetation Studies Using Spring Gulch Waste Rock Material:** This section includes a summary of revegetation studies conducted with waste rock from the site.

• **Section 3 – Cover Material Characteristics:** This section includes chemical and physical properties, soil water relations, and cover performance objectives.

• **Section 4 – Biosol® and Other Amendments:** This section includes a brief literature review of the use of other amendments for mined land reclamation.

• **Section 5 – Greenhouse Study Design and Methodology:** This section presents the proposed experimental design for the greenhouse study and methods that will be followed.

• **Section 6 – Toxicity Assessment:** This section includes the cover toxicity assessment.

• **Section 7 – Conclusions and Specifications for Cover Based on Toxicity Assessment:** This section addresses conclusions and specifications that will be presented based on the final cover toxicity assessment.

• **Section 8 – Data Quality Assessment and Reporting:** This section includes a discussion of data quality assessment and reporting.

• **Section 9 – Data Quality Objectives:** This section includes a discussion of data quality objectives (DQOs) for components of the greenhouse study.

• **Section 10 – Project Schedule:** This section includes information on timing of major activities and deliverables.

• **Section 11 – Contractors and Subcontractors:** This section includes a discussion of contractors and subcontractors that will be used for project activities.

• **Section 12 – Health and Safety:** This section includes a discussion of health and safety practices that will be followed.

• **Section 13 – References:** This section provides a list of references cited throughout this Work Plan.

1.2 Other Plans and Procedures

Work activities described in this Work Plan will be supplemented by other plans, including:

• Site Health and Safety Plan for Early Design Actions (HASP; ARCADIS 2012) (see Section 12)
• Overall Site Plan for Early Design Actions (ARCADIS 2013b)

• Site Management Plan (Pollution Control and Mitigation Plan and Waste Management Plan)

• Sampling and Analysis Plan, Quality Assurance Project Plan (QAPP; ARCADIS 2013c), Field Sampling Plan, and Standard Operating Procedures

• Data Management Plan

These plans are provided under separate cover as required by the SOW (USEPA 2012) and are referenced herein as appropriate.
2. Previous Revegetation Studies Using Spring Gulch Waste Rock Material

The following sections summarize revegetation studies conducted with waste rock from the site.

2.1 2003 Field Test Plots

2.1.1 Plot Construction and Amendments

CMI developed a work plan addressing revegetation of the mine facility to fulfill the requirements of Section 9, Conditions SS through ZZ of Permit Revision 96-2 to the New Mexico Mining and Minerals Division (MMD) Permit #TA001RE and Condition 17.e of Discharge Permit 1055 issued by the State of New Mexico Environment Department Ground Water Quality Bureau. That work plan consisted of constructing numerous test plots and demonstration plots on CMI’s waste rock piles. The test plots were designed to evaluate the effects of different cover soil depths, soil amendments, seeding techniques, and planting rates on revegetation success. A description of the work plan can be found in the 2003 Test Plot Construction Summary Report (Golder Associates, Inc. 2004), which is included as Appendix A.

The construction of the plots and how the treatments were applied are also detailed in 2003 Test Plot Construction Summary Report (Golder Associates, Inc. 2004). Twenty-three test plots were constructed, which included six level plots (platform), nine 3:1 sloped plots, and six 2:1 sloped plots. In addition, two demonstration plots (one platform and one 3:1 slope) were constructed to allow for the evaluation of additional treatment applications. The locations of the test plots and demonstration plots were selected to represent the range of possible aspects that exist at the site.

In the fall of 2003, the plots were planted with tree and shrub seedlings. The species were grouped into three seedling classes based on their role in plant community development: 1) nurse species, 2) crop species, and 3) shrub species. The nurse species were chosen as a fast-growing species that would provide shade and wind cover for the crop trees. The crop species are conifers that are present in the mature forest surrounding the site. The shrub species were selected to provide understory growth and a wildlife food source in the final reclamation plant community. Table 2-1 lists the species in each of the three seedling classes.

The main treatments included the application of 0, 1, and 3 feet of cover material and two planting densities. The planting densities were intended to evaluate the effect of the nurse tree species density on the survival of crop tree species. Grass and forb species were seeded on the platform plots using either a drilling or hydroseeding process, while the sloped plots were all hydroseeded (Table 2-2). On the sloped plots, a forest soil inoculant amendment was evaluated with either a control (no inoculant) or the inoculant. On the platform plots, the soil amendment treatment included control (no amendments), forest soil inoculants, and phosphorous fertilizer.
Once the plots had been constructed, the various soil amendment treatments, as described by the Test Plot Work Plan, were applied to the test plots and demonstration plots. The platform test plots received three soil amendment treatments: control (no soil amendments), mycorrhizal inoculant (forest soil) (1,000 pounds per acre [lbs/ac]), and fertilizer (60 pounds of phosphorus pentoxide per acre [lbs P$_2$O$_5$/ac]), whereas only two soil amendment treatments were applied to the sloped test plots: control (no soil amendment) and mycorrhizal inoculant (1,000 lbs/ac). The two demonstration plots received different combinations of soil amendments than the test plots. The sloped demonstration plot received four treatments: control, Biosol® (an organic soil amendment applied at 1,440 lbs/ac), mycorrhizal inoculant (1,000 lbs/ac), and fertilizer (60 lbs P$_2$O$_5$/ac). The platform demonstration plot received six treatments: control, Biosol® (2,400 lbs/ac), fertilizer (60 lbs P$_2$O$_5$/ac), lignite (1,000 lbs/ac), sawdust (5 tons per acre [t/ac]), and wood chips (5 t/ac). The soil amendment treatments were incorporated into the cover soil treatments by ripping furrows 12 inches deep and spaced 18 inches apart with a small bulldozer (see Figure 5-9 in Appendix A).

2.1.2 Results

2011 represented the 8th year of tree and shrub monitoring, the 7th year of grass and forb monitoring, and the 6th year of erosion monitoring (Buchanan Consultants 2011). The following results are a summary of data collected in 2011 by Buchanan Consultants (2011), and references to differences in treatments or plant responses are based on statistical comparisons reported in Buchanan Consultants (2011). The overall survival of all seedlings on all plots in 2004, 2005, 2006, 2007, 2008, 2009, 2010, and 2011 was 66, 60, 51, 48, 46, 43, 39, and 38%, respectively. The 2011 overall survival of all seedlings for the platform plots and the 3:1 and the 2:1 sloped plots was 41, 38, and 37%, respectively.

The 2011 overall survival of all seedlings for the platform plots on the 0, 1, and 3-foot cover depths was 23, 52, and 47%, respectively. For the 3:1 plots, the overall survival for the seedlings on the 0, 1, and 3-foot cover depths was 17, 50, and 47%, respectively. For the 2:1 plots, the overall survival for the seedlings on the 0, 1, and 3-foot cover depths was 9, 51, and 52%, respectively. This trend of the 0 foot cover depth having the lowest survival and the 1 and 3-foot cover depths having similar survival rates has persisted since 2004. Tables 2-3, 2-4, and 2-5 provide a tabular summary of 2011 woody plant survival and grass and forb density for each of the five test plot types that were constructed in 2003. Appendix B presents a detailed summary of the results from 2011.

2.2 Other Studies

2.2.1 Shrub Survival and Root Growth Study

Williams et al. (2004) conducted a woody plant study at the Questa Mine on Blind Gulch and Spring Gulch beginning in 1995. The study evaluated seedling survival and root growth of Apache plume (Falluga paradoxa) and Saskatoon serviceberry (Amelanchier alnifolia) using 1-year-old seedlings that were transplanted and either fertilized or not fertilized at the time of planting in August 1995.
Seedlings of Apache plume and Saskatoon serviceberry were propagated at the Natural Resources Conservation Service Plant Materials Center in Los Lunas, New Mexico. Seedlings were grown in 164-cubic centimeter containers in a peat:perlite growing media and were fertilized with a water soluble 20-10-20 fertilizer.

Two planting sites (Blind Gulch and Spring Gulch) were located on terraced portions of overburden piles at the site. The Spring Gulch planting site was described as having primarily neutral rock with an average pH of 7.7, electrical conductivity (EC) of 0.5 deciSiemens per meter (dS/m), and coarse fragment fraction (content) of 69%. The Blind Gulch site consisted of both acidic and neutral overburden materials (two blocks). Chemical composition of the overburden across the planting area at Blind Gulch was variable. Average values for pH, EC, and coarse fragment fraction (content) in Planting Blocks 1 and 2 were 4.4 and 7.3, 1.2 and 1.3 dS/m, and 60 and 59%, respectively.

Prior to transplanting, sites were ripped to a depth of 45 centimeters (cm) and irrigated. Ripping was accomplished using three 65-cm ripping bars attached to the back of a crawler tractor. In August 1995, seedlings (approximately 10 to 20 cm tall) were transplanted into the two sites in a randomized complete block design and irrigated the day after planting. Three blocks per site were established, and each block had two parallel rows, 50 cm apart. Within each row, plant spacing was 30 cm. One row of each replicate block received a fertilization treatment at the time of planting and the other row did not receive fertilizer (control plots). Six grams of 17-6-12 plus micronutrients slow-release fertilizer (Scotts Company, Marysville, Ohio) were placed into each planting hole prior to transplanting the seedlings. Release duration of this fertilizer is 3 to 4 months at 21 degrees Celsius (°C). From 1996 through 2000, all plants received supplemental fertilization once each year.

In September 1996 and August 2000, survival of both species was documented. In the spring of 2001, shoot growth (height and crown width) was measured for each plant. In Planting Blocks 1 and 2 from each site, two plants per species per fertilization treatment were measured for root growth and distribution. Roots were evaluated using techniques described by Parsons et al. (1998). Initial excavation in November 2000 was performed using a backhoe to create a trench 1.5 meters (m) deep and 2 m long, 45 cm from the base of each shrub row. A 30- by 30-cm vertical plane was hand-excavated 30 cm from the base of each plant where a 30- by 30-cm sampling frame was placed for root evaluation. The frame was constructed out of clear Plexiglas and divided by lines into thirty-six 5- by 5-cm grid cells. In each grid cell, roots were counted and divided into three diameter classes: less than 0.5, 0.5 to 2.0, and greater than 2.0 millimeters (mm). Root measurements were repeated at 20 and 10 cm from the base of each plant within the same vertical sampling frame.

Total root density of unfertilized plants was greater than fertilized plants. Saskatoon serviceberry total root density differed among distances from the base of plants between fertilization treatments. Fertilized plants had fewer roots in the 10-cm distance relative to the 20- and 30-cm distances, while root densities of unfertilized plants decreased as a function of distance from the base of the plant. Unfertilized serviceberry plants had significantly more roots than fertilized plants between 5- and 15-cm deep. Compared to Apache
plume plants fertilized at time of planting, unfertilized plants had similar root densities as a function of both distance from the plant and depth, except for higher total root densities below 20 cm at 20 cm from the plant. Survival rates were higher for unfertilized plants compared to plants fertilized at the time of planting on both waste rock materials. Shoot growth was positive for both species when fertilized at time of planting. Factors, including fertilizer characteristics, planting date, and site conditions, may have also influenced species performance.

2.2.2 Native Grass Survival and Growth in Acidic Waste Rock

The objective of this study was to determine the suitability of various grasses for direct establishment in a range of overburden types at the Questa Mine (Dreesen et al. 2001). The screening of grass species for growth and survival was conducted at the New Mexico State University’s Mora Research Center in Mora, New Mexico. Three substrates were used in the experiment and consisted of an unaltered acid waste rock with a pH of 2.7, an acid:neutral waste rock mixture ratio of 9:1 with a pH of 3.3, and an acid:neutral waste rock mixture of 3:1 with a pH of 3.7. The acid waste rock was excavated from mixed volcanic rock on the second terrace of the SGWRP, while the neutral waste rock was removed from aplite and black andesite rock on the first terrace of the SGWRP. In July 1995, the two waste rock types were crushed and screened to less than 13 mm, then mixed in the ratios described above, and transported to the Mora Research Center. Three replicate treatments of each substrate were set up in polyethylene tubs (1.47 m in diameter by 0.46 m in depth; 750-liter volume) that were filled with 600 liters of substrate. The nine tubs were placed in a random arrangement in an outdoor facility used for testing plant tolerance to environmental stresses.

Grass transplants were grown from commercially available seed, seed from evaluations at the Los Lunas Plant Materials Center, and seed collected from the vicinity of the Questa Mine. Seeds of 54 species/varieties were sown in plug trays filled with a peat moss/perlite media and later transplanted (August 1996) in Ray Leach Super Cells (164-milliliter volume) containing the same growth media. The transplants were over-wintered outdoors and planted in the treatment tubs in September 1997. The grasses were harvested in September 1998.

Species grown from seed collected near the site that had superior performance in terms of survival and above ground biomass production on all substrates included mountain muhly (Muhlenbergia montana), pine dropseed (Blepharoneuron tricholepis), and three Festuca species that were not identified at the species level. A number of commercially available grass varieties had good survival and growth in these substrates and included Peru Creek tufted hairgrass (Deschampsia caespitosa); Redondo Arizona fescue (Festuca arizonica); Covar sheep fescue (Festuca ovina); MX-86 sheep fescue; Shorty hard fescue (Festuca ovina duriuscula); Reubens Canada bluegrass (Poa compressa); Arriba, Barton, and Rosana western wheatgrass (Pascopyrum smithii); and San Luis slender wheatgrass (Elymus trachycaulus). Other native grass species that showed superior survival and growth in these acid rock substrates included Canada wildrye (Elymus canadensis), timber oatgrass (Danthonia intermedia), giant sacaton (Sporobolus wrightii), inland bluegrass (Poa nemoralis), and needle and thread grass (Hesperostipa comata).
2.2.3 Tree, Shrub, and Forb Species Trials in Acidic Waste Rock

The objective of this study was to evaluate the suitability of various native and non-native trees, shrubs, and forbs for direct establishment on the waste rock types at the Questa Mine (Harrington et al. 2001). Survival screening was conducted at the New Mexico State University, Mora Research Center in Mora, New Mexico. This study was set up to evaluate the survival of different native and exotic plant materials across a range of waste rock materials found at the Questa Mine. Two waste rock types, representing both the mixed volcanic rock types and the neutral rock types, were crushed and mixed to generate four different substrates. These materials ranged in pH from 2.7 to 4.4 and had ECs ranging from 1.9 to 3.6 dS/m. The substrates were placed into 15-gallon horticultural pots located at the Mora Research Center. The study used 164-cubic centimeter container transplants of the following 52 plant types: 10 conifer species, 16 legume species, five species of forbs and sub-shrubs, and 21 shrub species. Irrigation was applied using a micro-irrigation system with pressure regulators to confirm that all pots received the same amount of irrigation. Pots were irrigated for 15 minutes, once every 7 days from the time of planting until the first frost (mid-September 1995), and resumed in May 1996 and continued until the end of the measurement period. This irrigation regime resulted in each pot receiving 9 liters of irrigation per week. Evaluation of plant survival occurred at the end of June 1996.

The best performing conifer species on the various substrates tested in the study included southwestern white pine (Pinus stoabiformis), ponderosa pine (Pinus ponderosa), limber pine (Pinus flexilis), Englemann spruce (Picea englemannii), and bristlecone pine (Pinus aristata). The shrub and half shrub species that had the highest survival included indigo bush (Amorpha canescens), leadplant (Amorpha fruticosa), rock spirea (Holodiscus dumosus), mountain mahogany (Cercocarpus montanus), chokecherry (Prunus virginiana), ninebark (Physocarpus monogynus), Woods’ rose (Rosa woodsii), Siberian pea shrub (Caragana arborescens), New Mexico locust (Robinia neomexicana), and silver buffaloberry (Shepherdia argentea). The best performing forb species included yarrow (Achillea millefolium), goldenrod (Solidago spp.), and milkweed (Asclepias spp.). Finally, the best performing legumes included cicer milkvetch (Astragalus cicer), alfalfa (Medicago sativa), purple prairie clover (Petalostemum purpureum), white prairie clover (Petalostemum candidum), golden banner (Thermopsis montana), and birdsfoot trefoil (Lotus corniculatus).

2.2.4 Soil Toxicity Testing of Spring Gulch Waste Rock

The objective of this study was to determine the effect of molybdenum concentrations on seed germination and early seedling growth in SGWR in a controlled laboratory experiment (GEI Consultants, Inc. [GEI] 2012). The study examined additions of amendments that included biosolids added at 10 and 20% and biosolids plus tailings that were both added at 10%. Total molybdenum concentrations in the study ranged from approximately 250 to 2,400 milligrams per kilogram (mg/kg). Six plant species were tested in the study and included western yarrow (Achillea millefolium), mountain brome (Bromus marginatus), tufted hairgrass (Deschampsia cespitosa), ryegrass (Lolium perenne), western wheatgrass (Pascopyrum smithii), and Rocky Mountain penstemon (Penstemon strictus). Some species exhibited poor germination throughout all soil types, including control soils. For the plants with the best germination, molybdenum concentrations proved to
have little impact, even with concentrations more than nine times the average concentrations in the cover soil being tested. In some cases, increased molybdenum concentrations actually resulted in an increase in germination, shoot, and root length. For some species, the largest inhibiting factor for germination was inferred to be copper concentrations in the biosolids obtained from Denver Metro Waste Water Reclamation District.
3. Cover Material Characteristics

Based on data from the remedial investigation, waste rock in the SGWRP has been determined to be the best available material for cover construction at the Questa Mine area. Characterization of the SGWRP is ongoing, with a final report due in the spring of 2014. The studies include geotechnical and chemical test data from materials collected from surface excavations and boreholes. The intent of this section is to provide preliminary characterization data for the cover materials.

3.1 Physical and Chemical Properties

Cover materials in the SGWRP are broadly characterized as sandy loams with clay contents ranging from approximately 8 to 15%. The volumetric rock fragment content varies from approximately 35 to 75% based on preliminary characterization data. The preliminary characterization data also indicate an overall neutral pH condition with an average paste pH of 7.4 and average EC of 953 microSiemens per centimeter (µS/cm). The net neutralization potential averages 5.3 tons calcium carbonate per kiloton of material (tCaCO$_3$/kt), suggesting that, on average, neutralization potential exceeds acid-generation potential. Molybdenum concentrations resulting from the field characterization average of 433 mg/kg, with an average bioaccessibility of 36%. Of the total molybdenum present in the waste rock, the average molybdenite composition is 63%, which is the insoluble and low toxic form of molybdenum.

3.2 Soil Water Relations

The available water capacity estimates are based on laboratory-produced soil water retention curves, which were corrected for rock fragments. The soils considered in the analysis were sandy loams with approximately 59 to 75% rock fragments by volume. Preliminary soil hydrologic testing of SGWRP materials indicates that the available water capacity ranged from approximately 0.4 to 1.1 inches per foot. As expected, the available water capacity was lowest in the materials with the highest amount of rock fragments. CMI anticipates refinement of the available water capacity estimates as the soil hydrologic testing is finalized.

3.3 Cover Performance Objectives

The primary performance objectives for the cover include erosion resistance, support of adapted native vegetation, and reduction in net percolation. Erosion resistance is critical for maintaining cover function for the foreseeable future. This cover attribute is particularly important at the Questa Mine given the topographic constraints in the waste rock pile areas, which may require the construction of relatively steep gradient slopes. The ability of the cover to support vegetation is essential for achieving a self-sustaining ecosystem, which is required by the MMD. From a functional perspective, vegetation promotes erosional stability and reduces net infiltration. It is recognized that complete preclusion of meteoric waters from the waste rock is not possible with evapotranspiration cover systems and that alternative controls may be required to augment the cover.
4. Biosol® and Other Amendments

The use of organic amendments to facilitate reclamation on drastically disturbed lands has been studied for more than 40 years in the United States. In the 1970s, major federal research efforts were initiated to evaluate uses of various agricultural, industrial, and domestic waste byproducts. Although substantial research has been conducted, the use of organic amendments on mined lands is relatively limited in practice. Historically, biosolids have been the most commonly employed organic soil amendment on mined lands (Haering et al. 2000). However, animal manures, papermill sludges, sawdust, wood chips, and peat also have been used. Each amendment type has its advantages and disadvantages, but when used properly, organic amendments may show some improvement in plant growth conditions, soil ecosystem recovery, and development of self-sustaining plant communities (Barth 1988; Haering et al. 2000). Biosolids are an end-product of municipal wastewater treatment. Composted biosolids are often low in readily available nitrogen (N), but have high organic N levels that can be slowly released for plant use over time. Most of the biosolid products applied to mined lands have been dewatered anaerobically digested sludge cake or mixtures of anaerobic cake mixed with carbon additions, such as wood chip or yard waste. The composted sludge cake/wood chip mixture is produced by mixing anaerobically digested dewatered sludge cake with wood chips, then composting the mixed material by the aerobic static pile method (Haering et al. 2000).

The USEPA has established rules for the land application of biosolids that address concerns about possible pathogen transmittal, nitrate pollution, and trace metal contamination (USEPA 1993, 1995). In order to be land applied, a particular biosolid must have undergone a pathogen reduction process, must contain less than a specified amount of bacterial pathogens, and must meet limits for heavy metal concentration. Composted biosolids are considered by the USEPA to have a “virtual absence of pathogens” and, therefore, do not require restricted site access or land use for a specified time after application.

The use of organic amendments does not always result in positive responses in plant growth or changes in soil characteristics. For example, negative effects of amendments and/or improper loading rates may include reduced plant diversity, lower seedling survival, reduced grass yields, increased weed competition, and excessive uptake of metals by plants (Haering et al. 2000). With time, transgressive reductions in vegetation cover or biomass are sometimes observed in association with application of organic or inorganic amendments. Biodegradation of the organic substrates most likely accounts for the loss of effectiveness over time. Thus, organic amendments have not been demonstrated to be effective from a longer-term perspective (Bendfeldt et al. 2001; Milczarek et al. 2009; Prodgers 2009).

The final selection and use of an organic amendment type is dependent on effectiveness in meeting reclamation goals, availability of the product, costs, and logistical considerations (USEPA 2007). For example, papermill sludges have been used as a soil amendment in humid regions of the United States because of the proximity to papermills, and cattle manure has been commonly used in the mid-western United States because of proximity to large feedlots. The use of manure, papermill sludge, or peat for the
Questa Mine is impractical because of the lack of product or lack of sufficient quantity of product in the general region to make the selection of these amendments practical or even possible.

Over the past 30 years, a large number of commercially available organic fertilizers have been produced for mined land reclamation projects. Two of the most common organic fertilizers currently promoted for use in mined land reclamation are Biosol® and Kiwi Power (currently called Nutri Boost). Biosol® is a true organic fertilizer with relatively high levels of N (6%), while Kiwi Power consists of an organic wetting agent combined with organic enzymes and a bacterial activator. A limited amount of research has been published on the use of these products (McGeehan 2006, 2008; Meikle et al. 1999; Payson et al. 2005, 2006). Organic fertilizers typically have advantages over inorganic fertilizers; their effect is longer lasting because of the slow release of nutrients and the added benefit of an organic complex that may promote microbial activity. The use of Biosol® at the Questa Mine resulted in increased grass density of an unidentified fescue.

Because organic matter holds a relatively high amount of water on a mass basis compared to mineral soils at similar energy states, it is often assumed that the addition of organic amendments to soils will result in significant increases in available water capacity. However, the low density of organic materials (including organic matter) results in only marginal increases when evaluated on a volumetric basis. Soil water-plant relations are conventionally evaluated on a volumetric basis, and these interactions must be considered in available water capacity determinations.

Kern (1995) summarized empirical-based models for estimating soil water retention. The interactive effects of organic matter and various soil textures on available water capacity were included in some of the analyses. One of the models (Rawls) predicted that increasing organic matter from 1.0 to 3.8% resulted in increased available water capacity of only 0.35 vol./vol. for a loam texture soil with similar effects predicted for coarser-textured soils. The loading rates (1 to 3.8% organic matter) referenced by Kern (1995) would be equivalent to approximately 80 to 300 tons per acre-foot (t/ac-ft) of compost, assuming a 25% organic matter content.

Bauer and Black (1992) investigated the effects of organic carbon on available water capacity in various soil textural groups. They determined that available water capacity remained essentially constant across organic carbon concentrations of 10, 20, 30, 40, and 50 grams per kilogram in sandy soils and declined in medium- and fine-textured soils. The declines in available water capacity for the loam soils were related to the reductions in soil bulk density. Because organic carbon was the basis of measurement, loading rates in this study would be equivalent to 1.7 to 8.6% organic matter and 136 to 688 t/ac-ft of compost with 25% organic matter. Thus, the addition of organic amendments at practical loading rates may influence plant nutrient relationships, but is not anticipated to result in meaningful changes in available water capacity.

A final amendment, zeolite, has been added to the experimental design through a proposal by MMD. Zeolites are microporous, aluminosilicate minerals commonly used as commercial absorbents. Zeolites are widely used for water purification, as catalysts, and in the production of detergents. Zeolites are also used in agricultural applications to improve cation exchange capacity and water retention. The proposal from MMD
is to add clinoptilolite zeolite as a soil amendment, which is a natural zeolite composed of a microporous arrangement of silica and alumina tetrahedra.
5. Greenhouse Study Design and Methodology

5.1 Procedures for Collecting and Processing Spring Gulch Waste Rock Material

Waste rock borrow material from the SGWRP will be used as substrate in the greenhouse study. Select test pit locations were identified that are anticipated to yield representative material in terms of molybdenum concentration and net neutralization potential (NNP) using results from the six test pits that were excavated and sampled as part of the Spring Gulch Waste Rock Borrow Characterization (ARCADIS et al. 2014). The required amount of material from the selected locations will be excavated and transported to New Mexico State University, Mora Research Center where the material will be stockpiled for use in the various treatments. The following describes the collection and processing procedures for the borrow material.

5.1.1 Locations

Three locations at the SGWRP are proposed to provide material for the greenhouse study and include test pits SP2013-TP01, SP2013-TP02, and SP2013-TP05 (Figure 5-1). These locations were selected based on molybdenum concentration and NNP data collected during the 2013 borrow characterization. Another selection criterion was access, as portions of the waste rock pile have been covered with up to 10 feet of excavated fill material from the mill area since the characterization work was performed. Combined, material near these test pit locations should approximate average conditions measured for the waste rock pile. The waste rock type observed at each of the three test pits is also representative of the major rock types present within the waste rock pile, including aplite, andesite, and aplite and andesite mix.

The paste pH from the test pits ranges from 7.41 to 7.74, and the paste EC ranges from 650 to 1,450 µS/cm, which are typical of the waste rock pile. Geochemical data for the test pit locations is summarized below.

<table>
<thead>
<tr>
<th>Test Pit ID</th>
<th>Sample Depth (feet)</th>
<th>Total Molybdenum (mg/kg)</th>
<th>Net Neutralization Potential (tCaCO₃/kt)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SP2013-TP01</td>
<td>0 to 2</td>
<td>69</td>
<td>15.0</td>
</tr>
<tr>
<td></td>
<td>8 to 10</td>
<td>120</td>
<td>8.3</td>
</tr>
<tr>
<td>SP2013-TP02</td>
<td>0 to 2</td>
<td>110</td>
<td>17.9</td>
</tr>
<tr>
<td></td>
<td>8 to 10</td>
<td>220</td>
<td>-15.3</td>
</tr>
<tr>
<td>SP2013-TP05</td>
<td>0 to 2</td>
<td>310</td>
<td>8.3</td>
</tr>
<tr>
<td></td>
<td>8 to 10</td>
<td>130</td>
<td>6.1</td>
</tr>
<tr>
<td>Mean:</td>
<td></td>
<td>160</td>
<td>6.7</td>
</tr>
</tbody>
</table>

The mean molybdenum concentration at the three test pits is 160 mg/kg, which is lower than the mean concentration of the collective test pit and borehole samples from the 2013 characterization of 433 mg/kg (median = 330 mg/kg). However, review of the data indicates lower molybdenum concentrations are typical in the shallow subsurface to depths of approximately 100 feet, as compared to deeper in the waste rock pile. The mean NNP from the three test pits is 6.7 tCaCO₃/kt, which is similar to the mean value of the collective test pit and borehole samples from the 2013 characterization of 5.3 tCaCO₃/kt. Overall, the material
collected near the three test pits is expected to provide representative material for the greenhouse study. Actual locations for the excavations will be determined in the field.

5.1.2 Collection and Transport

A track-mounted excavator or backhoe will be used to excavate the waste rock material for the sub experiment at each of the three former test pit locations. The sub experiment is discussed in Section 5.2.1.1. The total volume of material required for the sub experiment treatments is estimated to be 40 cubic yards (cy). Approximately 45 cy of material will be collected to confirm that sufficient material will be available for the study. One-third of the required volume will be excavated from each of the former test pit locations. The material will be collected from the upper 10 feet of the waste rock pile as close to the three former test pits as possible to maximize the potential to obtain elevated molybdenum concentrations. Boulder-sized material will be removed by the excavator to the extent possible because a requirement of the study is to use material that is less than 8 inches. This will be done when the material is excavated to avoid hauling boulder-sized material that will not be used in the study. A handheld X-ray fluorescent (XRF) analyzer will be used during excavation to estimate the molybdenum content of the waste rock. Field paste pH measurements will also be made on the excavated material, targeting the mean value for the SGWRP of 7.4. The paste pH will be used as a surrogate NNP, such that acidic material that is not representative of the majority of the SGWRP is avoided.

The excavated material for the sub experiments will be placed into approximate 15-cy haul trucks capable of highway transport. Haul trucks will be equipped with hauling tarps to cover the material to prevent blowing dust during transport and precipitation from contacting the material. The material will be transported to the Mora Research Center in Mora, New Mexico, which is approximately 80 miles southeast of the Questa Mine. The travel route to the Research Center is via State Highway NM-522 and NM-518 (Figure 5-2). The estimated one-way travel time is 3 hours.

In an effort to evaluate options for achieving the target concentration of 400 mg/kg molybdenum that was originally proposed for the main experiment (February 17, 2014 letter to the agencies) and the recent request by the agencies to meet 600 mg/kg target molybdenum concentration for the main experiment (verbal discussion on March 12, 2014), field XRF scanning of SGWR for molybdenum content was performed from February 11 through 13. The objective of the XRF scanning was to obtain waste rock with higher molybdenum concentrations for use as a substrate in the main experiment of the greenhouse study, which is discussed in Section 5.2.1.1. Field activities included excavation of pits near previous test pit locations, field measurements using an XRF analyzer, collection of a composite sample for molybdenum analysis, and stockpiling approximately 4 cy of waste rock. A composite sample from the stockpiled material was analyzed for total molybdenum (Method 3050 acid digestion/USEPA 6020) and the resulting concentration was 284 mg/kg. The composite sample concentration agreed well with the average molybdenum concentration measured by the XRF analyzer of 280 mg/kg. More detailed information of this field effort was provided as an attachment to the March 2014 Monthly Update (Attachment A of the Update) and is included as Appendix C to this Work Plan.
Due to the results of this February 11 through 13 investigation, it was decided to evaluate other sources of material that may be easily accessible and readily available for use in blending with the Spring Gulch material in the main experiment to reach the target concentration. Two sources were identified. The first was the archived material collected during the Spring Gulch characterization effort (fall 2013) and the second was the ore stockpile near the base of the SGWRP. The archived samples were analyzed during the February 11 through 13 investigation, and it was determined that the concentrations and volume were insufficient to meet the target concentrations. However, the archived buckets with higher concentrations of molybdenum were mixed with the stockpiled material and contributed to the 280 mg/kg measured in the composite samples.

On March 6, a follow-up field XRF scanning effort was performed at the ore stockpile. A backhoe was used to excavate into the ore stockpile, and an XRF analyzer was used to measure the molybdenum concentration. Molybdenum concentrations averaged 800 mg/kg and approximately 1 cy of the material was transported to the SGWRP and placed next to the 4-cy stockpile for potential use in the main experiment as a supplement to increase the molybdenum concentration. However, it was determined that the ore stockpile was not representative of the Spring Gulch material; therefore, it is not planned for use at this time.

During the March 12 discussions, the USEPA and New Mexico agencies requested that CMI use the information available from Appendix I1 of the Remedial Investigation Report and other data collected from Spring Gulch to continue probing the SGWRP for waste rock containing molybdenum near a concentration of 600 mg/kg for use in the main experiment. After the material for the sub experiment is excavated and transported to the Mora Research Center, an excavator will again be used to excavate waste rock at multiple locations selected using available data. The collected material will be scanned with a field XRF analyzer, and each excavated bucket will be scanned three to five times. If the average molybdenum concentration is near 600 mg/kg, the bucket of material will be placed in a haul truck. This will proceed until approximately 4 to 5 cy of material is accumulated. The material will then be transported to the Mora Research Center where it will be stockpiled separately from the material for the sub experiment.

5.1.3 Stockpiling and Screening

The waste rock material will be end-dumped from the haul trucks onto a flat surface to form a single stockpile at the Mora Research Center. The location of the stockpile will be covered to protect the material from precipitation. A total of four composite samples of the stockpiled material will be collected and analyzed for plant-available N, phosphorus (P), and potassium (K) prior to the start of the experiment (see Section 5.2 for more details).

Material screening will be performed at the Research Center. Screening of material is needed for the main and sub experiments, which are described in Section 5.2. The main experiments will use 2-inch minus material for containers (pots) that measure 4.5 inches wide by 14 inches deep (0.134 cubic feet). A 2-inch screen will be placed over an approximate 5-foot-diameter open-top tank, and stockpiled material will be placed on the screen using a small front-end loader (e.g., Bobcat). The material greater than 2 inches will be
discarded, and the 2-inch minus material will be transferred to the individual pots using a hand trowel. The material greater and less than 2 inches will be weighed to estimate the weight percent of both fractions. For the composted biosolids treatments, the biosolids will be mixed into screened material using a portable cement mixer prior to placement in the pots.

The sub experiments will use 8-inch minus material for containers (open-top tanks) that measure 62 inches wide by 18 inches deep (32 cubic feet). Material from the stockpile will be placed directly into the tank, and the material greater than 8 inches will be removed by hand. As noted above, for the composted biosolids treatment, the biosolids will be mixed into screened material using a portable cement mixer prior to placement in the containers. Particle size analyses from test pit samples at the SGWRP indicate that the material greater than 8 inches is only 0.3% by volume (ARCADIS et al. 2014); therefore, manual removal of this large material should be feasible without having to pass the material through an 8-inch screen.

5.2 Greenhouse Study Design

5.2.1 Experimental Design

5.2.1.1 Treatments, Replication, and Growth Containers

Main Experiment

The greenhouse study will consist of two experiments that will run simultaneously. The first experiment, which will be referred to as the main experiment, will use 2-inch minus SGWR targeting a molybdenum concentration of 600 mg/kg. The main experiment will be conducted in pots that measure 4 inches in diameter by 14 inches deep (0.1 cubic feet) and will be set up as a completely randomized design with 12 replications. The treatments to be studied are listed below. Treatment Nos. 9 and 10 are treatments proposed by MMD, and Treatment No. 11 was added to provide an inorganic fertilizer comparison for the composted biosolids treatments proposed by MMD.

1. Quartz sand control
2. SGWR control
3. SGWR amended with Biosol® at an equivalent of 1,000 lbs/ac
4. SGWR amended with Biosol® at an equivalent of 2,000 lbs/ac
5. SGWR amended with Biosol® at an equivalent of 1,000 lbs/ac, plus zeolite at an equivalent of 20 t/ac-ft
6. SGWR amended with inorganic N, P, and K at the soluble N-P-K equivalent of Biosol® at 1,000 lbs/ac
7. SGWR amended with inorganic N, P, and K at the soluble N-P-K equivalent of Biosol® at 2,000 lbs/ac

8. SGWR amended with composted biosolids at a dry weight equivalent of 10 t/ac-ft

9. SGWR amended with composted biosolids at a dry weight equivalent of 30 t/ac-ft

10. SGWR amended with composted biosolids at a dry weight equivalent of 10 t/ac-ft, plus zeolite at an equivalent of 20 t/ac-ft

11. SGWR amended with inorganic N, P, and K at the soluble N-P-K equivalent of composted biosolids at the 30 t/ac-ft rate

The proposed design would, therefore, have 11 treatments, planted to four different species (discussed below), and replicated 12 times. The main experiment would have 528 pots (11 treatments x 4 species x 12 replications = 528). Table 5-1 shows an example of a completely randomized arrangement of all treatments for one replication or 44 pots.

SGWR and the sand control material will be analyzed for plant-available N, P, and K prior to the start of the study, and this information will be used to amend the sand control treatment to match the N, P, and K levels found in SGWR. The material for the sand control will be quartz sand or what is commonly known as play sand that can be obtained at most hardware stores. N would be applied as ammonium nitrate (33-0-0), P would be applied at triple super phosphate (0-44-0), and K would be applied as potassium chloride (0-0-60), as required to achieve the target levels in the SGWR. This will confirm that the sand and the SGWR have similar N, P, and K levels at the beginning of the experiment. The addition of inorganic fertilizer to the sand control will be incorporated using a portable cement mixer prior to placement in the growth container.

The Biosol® amendment will be purchased from Rocky Mountain Bioproducts, a commercial supplier of Biosol® located in Denver, Colorado. Biosol® has a soluble N content of 0.5%, a soluble P content of 1%, and a soluble K content of 1% (all by weight). Therefore, the 1,000-lb/ac application rate would add 5 lbs/ac of N and 10 lbs/ac of both P and K. The 2,000-lb/ac application rate would double these N, P, and K application rates. The inorganic fertilizer application rates would match these soluble N, P, and K levels for both the low and high Biosol® treatments. N would be applied as ammonium nitrate, P would be applied at triple super phosphate, and K would be applied as potassium chloride. The Biosol® and inorganic fertilizer would both be mixed into the upper 4 inches of SGWR to simulate a surface incorporation that may occur under field conditions.

The composted biosolids will be obtained from Albuquerque Water Authority. Composted biosolids from Albuquerque Water Authority has an estimated organic matter content of approximately 58%, a soluble N content of 0.002%, a soluble P content of 0.003%, and a soluble K content of 0.004% (all by weight). The exact organic matter and nutrient content of the composted biosolids will be determined through chemical analysis prior to the start of the studies. In addition, the amount of N, P, and K in the composted biosolids
that will be used to determine the inorganic fertilizer equivalent for Treatment No. 11 will be based on soluble levels to avoid an overloading of nutrients in the inorganic fertilizer treatment. The 30-t/ac-ft application rate would, therefore, provide approximate equivalents of 120 lbs/ac-ft of nitrate-N, 180 lbs/ac-ft of P, and 240 lbs/ac-ft of K. The composted biosolids would be mixed into the full volume of material that would be placed in each 14-inch-deep pot using a portable cement mixer, which would be approximately one-third the amount that would be applied in a field situation, assuming a 3-foot cover thickness. The final application rates for composted biosolids will be adjusted for moisture content to achieve application rates, on a dry weight basis, of 10 t/ac-ft and 30 t/ac-ft.

Zeolite will be in the form of clinoptilolite zeolite and will be obtained from the St. Cloud Zeolite Mine, near Winston, New Mexico. The zeolite will be fine-grained, passing a No. 40 sieve or 0.425 mm. Zeolite would be mixed into the full volume of material that would be placed in each 14-inch-deep pot using a portable cement mixer, which would be approximately one-third the amount that would be applied in a field situation, assuming a 3-foot cover thickness.

Sub Experiment

The second experiment or sub experiment will use 8-inch minus SGWR and be conducted in pots that measure 52 inches in diameter at the top of the pot and 45 inches in diameter at the bottom of the pot by 24 inches deep (27 cubic feet). The main experiment will be set up as a completely randomized design with four replications. The treatments to be studied are listed below:

1. SGWR control
2. SGWR amended with Biosol® at an equivalent of 1,000 lbs/ac
3. SGWR amended with Biosol® at an equivalent of 2,000 lbs/ac
4. SGWR amended with inorganic N, P, and K at the soluble N-P-K equivalent of Biosol® at 1,000 lbs/ac
5. SGWR amended with inorganic N, P, and K at the soluble N-P-K equivalent of Biosol® at 2,000 lbs/ac
6. SGWR amended with composted biosolids at a dry weight equivalent of 30 t/ac-ft
7. SGWR amended with composted biosolids at dry weight equivalent of 10 t/ac-ft plus zeolite at an equivalent of 20 t/ac-ft

The proposed design would, therefore, have seven treatments, planted to a mixture of species (discussed below), and replicated four times. The main experiment would have 28 pots (7 treatments x 4 replications = 28).
5.2.1.2 Plant Species

**Main Experiment**

Plant species selected for use in the main experiment include two grass species and two shrub species. The two grass species will be slender wheatgrass (variety San Luis) and sheep fescue (variety Covar). Both species are native and have performed well in species trials using waste rock material from the Questa Mine. Both species are easy to establish from seed and have good seedling vigor. These growth characteristics are important for greenhouse studies to confirm there is adequate potential for plant growth during the course of the study. Both species would most likely be included in large-scale plantings that would eventually occur at the site. The two shrub species will be New Mexico locust and Woods' rose. Both shrubs have demonstrated excellent survival on the 2003 field test plots and grow relatively quickly for woody plants.

The grass species will be established from seed in the main experiment, and the shrub species will be transplanted from 1-year-old container grown stock. New Mexico locust seedlings are currently being grown at the Mora Research Facility, and Woods’ rose seedlings will be obtained from Conservation Seeding and Restoration in Silt, Colorado.

The planting procedure for grass seed will involve placing four seeds of a designated species on the surface of the growth medium once all pots are filled with SGWR or sand and all treatments have been applied. The seed will then be covered with a ¼-inch layer of SGWR or sand, depending on the treatment, to provide a uniform planting depth. Following seed germination and seedling emergence, grass seedlings will be thinned to one seedling per pot. The same procedure will be used for both slender wheatgrass and sheep fescue.

The planting procedure for the shrub seedlings will involve removal of a seedling from its growth container, followed by removal of any lose soil adhering to the root system. There will not be an attempt to wash the root system in order to remove soil that may be adhering to roots because the presence of this soil will not affect the growth of the root system into the surrounding growth medium or influence the uptake of water, nutrients, or metals during the course of the study. Planting of a shrub seedling into each of the designated pots will be done as each pot is filled with growth medium, so that planting and filling occur at the same time.

**Sub Experiment**

The treatments in the sub experiment will be planted to a mixture of grasses, forbs, and shrubs as opposed to the single species testing in the main experiment. Grass species will include slender wheatgrass (variety San Luis), sheep fescue (variety Covar), Canada wildrye (variety Mandan), sideoats grama (*Bouteloua curtipendula*) (variety Pierre), and mountain muhly. Slender wheatgrass and sheep fescue will be included as species from the main experiment, and Canada wildrye, mountain muhly, and sideoats grama will be
added to this experiment because of their favorable performance in previous species trials on waste rock material from the site and their growth on the 2003 field test plots. Common yarrow (*Achillea millefolium*) will also be added to the list of species for this experiment to provide a forb that is native and relatively easy to establish from seed. Shrub species will include New Mexico locust and Woods’ rose as representatives from the main experiment, as well as mountain mahogany. Mountain mahogany has shown good survival in the 2003 field test plots and has also performed well in species trials on waste rock material from the site. Mountain mahogany seedlings are currently being grown at the Mora Research Facility. Future studies conducted in the field will include species being tested in these controlled experiments and additional species that may eventually be used during final reclamation of the waste rock piles.

Grass and forb seed will be evenly distributed over the surface of each container and covered with ¼ inch of SGWR. The seeding rate for each species will be based on the number of seeds per pound (seeds/lb). Slender wheatgrass has 135,000 seeds/lb, sheep fescue has 530,000 seeds/lb, Canada wildrye has 114,000 seeds/lb, mountain muhly has 1.5 million seeds/lb, sideoats grama has 159,000 seeds/lb, and common yarrow has 2.8 million seeds/lb. Based on the seed/lb numbers, slender wheatgrass would be seeded at an equivalent rate of 4 pounds of pure live seed (PLS)/ac (12.5% of the seed mixture), sheep fescue at an equivalent rate of 1 lb of PLS/ac (12.3% of the seed mixture), Canada wildrye at an equivalent rate of 4 lbs of PLS/ac (12.3% of the seed mixture), mountain muhly at an equivalent rate of 0.5 lb of PLS/ac (17.4% of the seed mixture), sideoats grama at an equivalent rate of 4 lbs of PLS/ac (14.7% of the seed mixture), and common yarrow at an equivalent rate of 0.5 lb of PLS/ac (32.5% of the seed mixture). The total seeding rate would, therefore, be an equivalent of 14 lbs of PLS/ac. Shrub seedlings would be planted a density of five seedlings per species per container for a total of 15 seedlings per container. Shrub seedlings will be planted in uniformly spaced rows by creating a planting hole large enough for the root mass of the seedling and then backfilling the hole to provide good root soil contact. Seeding of the grass and forb species will occur after shrub planting to avoid disturbing the grass and forb seed with the transplanting process.

5.2.1.3 Greenhouse Environmental Conditions

The greenhouse to be used at the Mora Research Facility for the main experiment is heated with propane heaters that are regulated by a Wadsworth Control Computer to maintain designated temperatures. Cooling of the greenhouse is through an evaporative cooling system consisting of vents, pads, pad pumps, and exhaust fans. The cooling system is also controlled by the same computer system as heating. The greenhouse temperature will be maintained between 70 and 79 degrees Fahrenheit (°F) during daytime hours and between 65 and 72°F during nighttime hours for both germination and active growth stages of the experiment.

Watering for the main experiment will be applied through polyvinyl chloride lines to greenhouse benches with a regulator, turn-off valve, and small rubber tubing with risers and spray emitters. Pots will be watered to field capacity and allowed a period of drying before watering continues. Water content in a subset of pots in each treatment will be monitored using gravimetric measurements to track water use and to determine a watering
schedule. The length of time for drying will vary through the course of the study as plants grow and water use changes. Watering schedule and water application rates will be documented throughout the study.

Watering for the sub experiment will be applied during the first 3 weeks after planting to assist in seed germination and to maintain shrubs. Subsequent watering will be applied as needed to maintain plant growth and prevent plants from experiencing water stress. Water content in a subset of containers in each treatment will be monitored with appropriate soil water sensors to track water use and to determine a watering schedule. Watering schedule and water application rates will be documented throughout the study.

Supplemental lighting will be provided with incandescent bulbs and high-intensity discharge bulbs that consist of 1,000-watt metal halide bulbs that produce 105,000 lumens. Lights will be used to extend the photo period especially during shorter days in the spring and fall months.

5.2.2 Plant Measurements and Data Analyses

5.2.2.1 Main Experiment

The following measurements will be taken at various times during the main experiment:

1. Percent emergence of grass seedlings at the end of 21 days following planting.

2. Percent survival will be recorded every 2 weeks for each grass and shrub seedling in each pot. Survival monitoring will begin with grasses following thinning to one seedling per pot. Shrub survival monitoring will begin 2 weeks after planting. In addition, emergence of grass seedlings will be monitored 2 weeks after planting to determine percent emergence.

3. Shrub height (each stem) will be measured every 2 weeks to track stem growth beginning 2 weeks after planting.

4. Above ground biomass for grasses (dry weight) of the entire above ground portion of the plant at the end of the 90-day growth period that begins at the time of thinning.

5. Above ground biomass for shrubs (dry weight of new growth that occurs during the study) at the end of the 180-day growth period that begins at the time of planting. New growth will be based on stem measurements that are taken during the duration of the study and stem color differences that will be identifiable with new leader growth.

6. Below ground biomass (dry weight) of the entire root system at the same time that above ground biomass is harvested for both grasses and shrubs.
7. Molybdenum concentrations in above ground and below ground harvested plant tissue at the end of
    designated growth period of 90 days for grasses and 180 days for shrubs.

8. General plant growth observations on a weekly basis, including such growth features as changes in leaf
    color, chlorosis, presence of leaf spotting, and overall health/vigor of plants.

9. Photos every 30 days of treatment sets.

10. SGWR control soil and SGWR treated with composted biosolids and composted biosolids plus zeolite
    (Treatment Nos. 8 and 9 in main experiment) will be submitted for soil water characterization curve
    analysis at the beginning of the experiment following the same procedures used in the recently
    completed SGWRP characterization effort. One sample for each treatment level (three total samples)
    will be analyzed.

5.2.2.2 Sub Experiment

1. Percent survival will be recorded every 2 weeks for each shrub seedling in each pot. Shrub survival
   monitoring will begin 2 weeks after planting.

2. Shrub height (each stem) will be measured every 2 weeks to track stem growth beginning 2 weeks after
   planting.

3. Above ground biomass (dry weight) of the entire above ground portion of the plant for grasses (by
   species) at the end of the 180-day growth period. If plant senescence occurs prior to 180 days, plant
   harvesting may occur earlier.

4. Above ground biomass of shrubs (by species) (dry weight of new growth that occurs during the study) at
   the end of the 180-day growth period. New growth will be based on stem measurements that are taken
   during the duration of the study and stem color differences that will be identifiable with new leader
   growth.

5. General plant growth observations on a weekly basis, including such growth features as changes in leaf
   color, chlorosis, presence of leaf spotting, and overall health/vigor of plants.

6. Photos every 30 days of treatment sets.

5.2.3 Sample Preparation and Laboratory Analysis for Plant Molybdenum and Copper Uptake, Molybdenum
    Bioaccessibility, Cover Treatment Molybdenum, and Copper and N-P-K Content

Sampling and analytical protocols for collection of materials (plant biomass or SGWRP treatment material)
and analyses are summarized briefly in Table 5-2 and described in detail in the following sections.
5.2.3.1 Plant Uptake – Molybdenum and Copper Analysis

Molybdenum and copper analyses of growth media (i.e., SGWR treatments) and plant biomass (plants and roots) will allow determination of plant uptake of molybdenum from the different growth media, as well as the molybdenum to copper ratios in media and biomass.

Plant Material Collection

Grasses – Main Experiment

After the 90-day growth period in the main experiment, grass plants will be harvested. The growth medium (SGWR or sand mass) will be broken apart carefully and the individual plants separated from the growth medium, with care taken to recover the whole plant, leaving as little root as possible in the soil material. Plants and roots will be rinsed with deionized water to remove any attached soil material. Roots will be separated from the grass blades by cutting the main stem at the approximate soil surface with stainless steel shears. Dry weight will be determined after drying for 48 hours at 70°C. A minimum of 1 gram of material is needed for analyses; therefore, above and below ground samples from the same treatment group will be composited until 1 gram of dried material is amassed.

Shrubs – Main Experiment

After the 180-day growth period in the main experiment, shrubs will be harvested. The growth medium (SGWR or sand) mass will be broken apart carefully and the individual plants separated from the growth medium, with care taken to recover the whole plant, leaving as little root as possible in the soil material. Plants and roots will be rinsed with deionized water to remove any attached cover material. New growth, based on stem measurements made during the growth period, will be trimmed from the plant with stainless steel shears. Roots will be separated from the above ground shrub by cutting the main stem at the approximate soil surface. Dry weight will be determined after drying for 48 hours at 70°C. A minimum of 1 gram of material is needed for analyses; therefore, above and below ground samples from the same treatment group will be composited until 1 gram of dried material is amassed.

Grasses, Forbs, and Shrubs – Sub Experiment

After the 180-day growth period in the sub experiment, above ground growth of grasses, forbs, and shrubs will be harvested by species. Each species of grass and forb will be cut at the main stem at the approximate soil surface with stainless steel shears and rinsed with distilled water. Above ground shrub biomass will represent new growth based on stem measurements made during the growth period. Dry weight will be determined for each species after drying for 48 hours at 70°C. Plant molybdenum uptake and root biomass will not be measured in the sub experiment.
5.2.3.2 Molybdenum Bioaccessibility

SGWRP treatments and control sand media will be analyzed for molybdenum bioaccessibility under the direction of Dr. John Drexler at the University of Colorado Laboratory for Environmental and Geological Studies. The in-vitro bioaccessibility test (Medlin and Drexler 1995) is designed to measure the fraction of a chemical in a soil sample that dissolves under simulated gastrointestinal conditions. In this test, only the amount of an inorganic that is considered bioaccessible leaches into solution.

5.2.3.3 Analysis of Plant Biomass, SGWR Treatments, and Control Sand for Molybdenum, Copper, Nitrogen-Phosphorous-Potassium Content, and Other Agronomic Parameters

Energy Labs will analyze plant material for molybdenum and copper content using USEPA Digestion Method SW 3050 and Analysis Method 6020 (inductively coupled plasma-[ICP-] mass spectrometry analysis). Energy Labs will analyze SGWR treatments and control sand materials for molybdenum and copper content using USEPA Methods 3050 (acid digestion) and 6020 (ICP-mass spectrometry analysis). Acid-generation potential-acid base accounting for SGWR will be determined using the Modified Sobek/USEPA 600 2-78-054 methodology. N-P-K will be measured in SGWR, sand, and composted biosolids prior to the start of the study using composite samples. Total N will be measured using Total Kjeldahl Method (ASA Mono #9 Part 2, Method 31-3.1) and nitrate-N will be determined using 2M KCl extract (ASA Mono #9 Part 2, Method 33-8.1). Plant-available P will be measured using Bray extract if the pH is less than or equal to 7.4 (ASA Mono #9 Part 2, Method 24-5.1), or Olsen extract (ASA Mono #9 Part 2, Method 24-5.4) if the pH is greater than 7.4. Plant-available K will be measured using an ammonium acetate extract (ASA Mono #9 Part 2, Method 13-3.5). In addition, composted biosolids will be measured for percent organic matter prior to the start of the study using the Walkley Black method (ASA Mon #9, Part 2 Method 29-3.5.2), and percent moisture will be determined by weighing samples before and after oven drying to a constant mass. SGWR treatments will be analyzed for the following at the start of the study: extractable calcium and magnesium will be measured using ASA Mono #9 Part 2, Method 10-2.3.1; extractable sodium will be measured using ASA Mono #9 Part 2, Method 13-4.5; extractable sulfur will be measured using ASA Mono #9 Part 2, Method 28-5.1; pH will be measured using ASA Mono #9 Part 2, Method 10-3.2; EC will be measured using U.S. Department of Agriculture (USDA) Handbook 60 Method 9; sodium adsorption ratio will be determined using ASA Mono #9 Part 2, Method 10-3.4; and cation exchange capacity will be measured using USDA Handbook 60 Method 19.

5.2.4 Greenhouse Schedule

The greenhouse study will begin experimental setup in mid-March and continue to mid-April 2014. Plant growth is expected to begin in mid-April and continue to late July for grass growth and late October 2014 for shrub growth in the main experiment. Exact dates will depend on when experimental setup is completed and seeding and transplanting are completed. The sub experiment will also begin in mid-April 2014 and continue to late October 2014. End-point harvesting of above ground and below ground biomass will occur at the
termination of the growth period of either 90 days or 180 days, depending on the experiment and species being studied. Section 10 provides a detailed project schedule.
6. Toxicity Assessment

According to the SOW (USEPA 2012), the purpose of the greenhouse study is to use amended SGWR material to evaluate plant growth, plant uptake of molybdenum, and direct toxicity to plants. As part of the Greenhouse Study Report, there will also be a Focused Literature Review to assess exposure and toxicity of molybdenum to appropriate animal species through herbivory and other routes of exposure, and a discussion of the plant uptake data from the greenhouse study. This section focuses on an assessment of the suitability of amended SGWR in terms of direct toxicity to plants and toxicity to herbivorous animals.

A comprehensive literature review of ecological molybdenum toxicity, as well as a summary of site-specific data and studies has been completed (Assessment of Molybdenum Toxicity through a Focused Literature Review and Other Studies) as part of the forthcoming Early Design Action: Pre-Design Borrow Characterization of Spring Gulch Waste Rock and Toxicity Review Report (2014). This Focused Literature Review, including uptake data from the greenhouse study, will provide the basis for completing the toxicity assessment.

6.1 Molybdenum Uptake Results

According to the SOW (USEPA 2012), actual bioavailability of molybdenum will be verified by measuring molybdenum uptake into plant shoot and root tissues. Plant growth responses and molybdenum uptake in plants will be compared to controls and the various treatments. Plant parameters to be measured are summarized in Table 6-1.

6.1.1 Grass Toxicity and Growth Endpoints

Two grass species that will be assessed in the main experiment of the greenhouse study are slender wheatgrass and sheep fescue. Toxicity will be evaluated via a modification of standard plant toxicity protocols (American Society for Testing and Materials 2003; Organization for Economic Co-operation and Development 2006). Seeds in the different amended SGWR treatments and control sand will be evaluated for effects at biweekly intervals after the seeds are planted. Endpoints measured include seedling emergence, survival, biomass (shoot and root biomass, total biomass), and visual detrimental effects (e.g., chlorosis, mortality, plant development abnormalities). Measurements will be made every 2 weeks when recording seedling survival and compared to those of untreated control plants. Visual documentation and measurement of final dry weight of above and below ground biomass will occur at the study end (90 days).

Rinsed above ground shoot and below ground root biomass will be analyzed at the end of the study for molybdenum content. The biomass (dry weight) from more than one pot within a treatment group may need to be combined to meet the 1 gram minimum biomass requirement for molybdenum and copper analysis. A composite sample of SGWR treatment material from two pots will be analyzed for molybdenum, copper, and molybdenum bioaccessibility. This information will be used to determine plant uptake (see Section 6.1.3), as well as help with the overall assessment of potential toxicity and growth responses.
Analysis of variance (ANOVA) comparison and other statistical analysis, as appropriate, of the various treatments and control groups will be used to determine how the treatments compare to each other and the controls. Toxicity will be assessed through both quantitative comparison (percent survival every 2 weeks; shoot and root dry weight at 90 days), as well as through qualitative comparisons (visual observations).

6.1.2 Shrub Toxicity and Growth Endpoints

Two shrub species that will be assessed in the main experiment of the greenhouse study are New Mexico locust and Woods' rose. Toxicity will be assessed through survival and observation of detrimental effects and growth. New growth on the transplanted shrubs will be harvested after 180 days. Stem lengths for each shrub will be measured after transplantation for baseline determination. The same stems will be measured every 2 weeks through the end of the 180-day experiment. At the end of 180 days, above ground new growth will be harvested based on stem measurements.

Rinsed above ground new growth biomass and below ground root biomass will be analyzed separately for molybdenum and copper content – the biomass from more than one pot within a treatment group may need to be combined to meet the 1 gram minimum biomass requirement for molybdenum analysis. Treatment material from each pot will be analyzed for molybdenum, copper, and bioaccessibility. This information will be used to determine plant uptake (see Section 6.1.3), as well as help with the overall assessment of potential toxicity and growth responses.

6.1.3 Plant Uptake of Molybdenum and Copper

Uptake and bioaccumulation of molybdenum and copper by plants will be evaluated in grasses and shrubs by comparing molybdenum concentrations in rinsed above ground and below ground plant material and soils from the same treatments. Uptake is evaluated by calculation of bioaccumulation factors (BAFs) based on the median dry weight concentrations for molybdenum in above ground or below ground plant matter and pot soil. BAFs over 1.0 indicate that concentrations are higher in vegetation than in soils, suggesting that bioaccumulation may be occurring, depending on the magnitude of differences and comparison to control treatments. BAFs will be assessed at 90 days for grasses and 180 days for shrubs. BAFs will be assessed only for the main experiment.

Bioaccessibility of molybdenum in SGWR treatments and control sand at the end of the treatment will also be assessed to determine if any of the amendments, treatments, or other factors influenced the bioaccessibility of molybdenum in the cover material. Bioaccessibility will be assessed using the Medlin and Drexler method (1995) for in-vitro analysis combined with total molybdenum analyses (USEPA Methods 3050 [acid digestion] and 6020 [ICP-mass spectrometry analysis]). Bioaccessibility will be assessed only for SGWR treatments in the main experiment. Bioaccessibility, molybdenum and copper concentrations, and N-P-K content in the various treatments and sand control will be assessed at the end of the main experiment – 90 days for grasses and 180 days for shrubs.
ANOVA comparison of the various treatments and control group will be used, as appropriate, to determine how the various treatments compared to each other and the sand control, in terms of plant uptake of molybdenum and soil bioaccessibility.

6.2 Cover Toxicity Assessment

As required by the SOW (USEPA 2012), a specific evaluation of potential molybdenum exposure and toxicity to appropriate animal species through herbivory and other routes of exposure, will be conducted based on the completed Focused Literature Review, plant uptake data obtained from the greenhouse study, and other studies as appropriate.

6.2.1 Plants

The evaluation of potential cover toxicity to plants will rely on the approach discussed in Section 3.1. The endpoints assessed will include:

1. Seedling emergence and survival
2. Growth (biomass)
3. Observations (chlorosis, mortality, plant development abnormalities)

Interpretation of these data will be supplemented by the plant toxicity information from the Focused Literature Review (2014).

6.2.2 Soil Invertebrates

Although earthworms and other soil invertebrates are not expected in cover material, there are site-specific toxicity data available from the Final Baseline Ecological Risk Assessment (CDM 2009) and GEI (2008), in addition to toxicity information from the Focused Literature Review (2014), which will allow for an evaluation of the potential toxicity of the various cover treatments to soil invertebrates.

6.2.3 Mammals

The evaluation of potential cover toxicity to mammals will rely on the use of plant uptake data, cover molybdenum content, bioaccessibility, conservative exposure assumptions, and toxicity information from the Focused Literature Review (2014).

6.2.4 Avian

Evaluation of potential cover toxicity to avian receptors will be evaluated in a manner comparable to that used for mammals (see Section 6.2.3). In addition, the avian toxicity assessment will integrate the Bobwhite quail data, including no observed adverse effect levels for molybdate and molybdenite, from the recently
completed molybdenum toxicity assessment (Smithers Viscient 2014), as summarized in the Focused Literature Review (2014).
7. **Conclusions and Specifications for Cover Based on Toxicity Assessment**

Conclusions on cover based on toxicity in plants and animals will rely on answering the following questions:

1. Do any of the SGWR treatments cause statistically increased toxicity (seedling survival, growth, or observed toxicity) as compared to the sand control or each other?

2. Do any of the SGWR treatments cause statistically increased growth as compared to sand control or each other?

3. Do any of the SGWR treatments cause enhanced bioaccessibility and/or uptake of molybdenum by plants as compared to sand control or each other?

4. Are any of the SGWR treatments likely to cause toxicity in representative animal species likely to be ingesting plant material from areas where the cover is used? How do the various SGWR treatments compare to control?

By answering the four questions above, a conclusion on the best specification for SGWR cover soil that promotes plant growth while limiting herbivore toxicity can be reached.
8. Data Quality Assessment and Reporting

8.1 Data Quality Assessment

Data quality will be assessed to confirm there is adequate information supporting the use of SGWR materials for cover, as well as which combination of amendments with SGWR materials is most supportive of plant survival and growth, and which species respond best to cover amendments. Criteria to be used include plant survival and growth, results of plant molybdenum uptake, and molybdenum bioavailability. Analytical methods used for previous data collection and testing will be compared to methods used for new data collection, where appropriate, to confirm data reliability.

The data quality assessment will include a statistical evaluation of new data. Suitability of SGWR cover material, including plant growth and survival, will be analyzed and compared against criteria as outlined in the DQOs (Section 9).

The statistical summary of the data and comparison with industry standard guidance will provide an assessment of the quality and quantity of material available. The toxicity and bioaccumulation potential of the SGWRP cover material will provide the basis for advancement of the work to field studies.

8.2 Reporting

The greenhouse cover characterization work will be reported in a Draft Pre-Design Spring Gulch Greenhouse Study Report. The report will summarize the methods, analytical results, and evaluation and interpretation of the data. The report will provide a description of the different cover materials, their ability to support plant growth, and their impact, if any, on molybdenum bioaccumulation in plant materials. The report also will include a separate toxicological assessment of cover material based on the plant bioaccumulation data and cover molybdenum bioaccessibility data, as well as what is known about the ecotoxicology of molybdenum (as summarized in the Focused Literature Review [2014]).
9. Data Quality Objectives

The DQOs for the greenhouse study have been developed using USEPA guidance (USEPA 2006). As described in the USEPA DQO guidance, the concept of “intended use” of a dataset may be for either decision-making or estimation (Section 0.9 of USEPA 2006). For the purposes of the data collection described in this Work Plan, the intended use of the data is for the purposes of estimation. Therefore, the DQO process summarized below and the detailed DQOs presented in Table 9-1 reflect this approach.

9.1 State the Problem (Data Quality Objective Step 1)

This step of the DQO process describes the problem to be studied, identifies team members, provides a conceptual model of the environmental hazard to be investigated, and determines resources. Enhanced evapotranspiration and erosion control through active plant growth is a key component of the cover system design. Poor plant growth, due to insufficient water-holding capacity of the SGWR material or other factors, such as nutrient availability, will degrade the performance of the cover. It follows that amendments may be important to optimal cover performance. The primary objective of the greenhouse study is to test the effect of different amendments to SGWR material on plant survival and growth and plant molybdenum uptake. The findings will be used to assess potential exposure and toxicity to herbivores and guide design of the subsequent pilot study, which will, in turn, provide guidance for full-scale reclamation using waste rock material as cover material for the waste rock piles as required by the ROD (USEPA 2010). The study will be performed under the supervision of Redente Ecological Consultants LLC on behalf of CMI, with support from McDaniel Lambert, Inc., Golder Associates, Inc., and ARCADIS.

9.2 Identify the Goals of the Study (Data Quality Objective Step 2)

This step in the DQO process is to identify the principal study questions, consider alternative outcomes or actions that can occur upon answering those questions, and state the key assumptions of the investigation. The primary study question is: What are the effects of different amendments (treatments) of SGWR material on plant survival and growth and molybdenum uptake?

9.3 Identify Information Inputs (Data Quality Objective Step 3)

This step of the DQO process is to identify the types and sources of information that need to be obtained to resolve decisions or produce estimates. The existing field test plot results were used to guide the greenhouse study design and methodology. This is a new data collection effort with analyses being performed on waste rock material that was characterized as detailed in the Pre-Design Borrow Characterization of Spring Gulch Waste Rock Work Plan (ARCADIS 2013a) and the Spring Gulch Characterization Report (ARCADIS 2014, in preparation) and will be subjected to a range of different treatments. The primary source of data will be measurement of plant survival and growth. Sampling and analysis will be conducted in accordance with approved methods as outlined in the Overall Site Plan and QAPP (ARCADIS 2013b, 2013c, respectively).
9.4 Define the Boundaries of the Study (Data Quality Objective Step 4)

This DQO step specifies the target population of interest and relevant spatial boundaries to which decisions will apply and determines when and where the data should be collected. This step also defines what constitutes a sampling unit, the temporal boundaries, or other constraints on sample units, as well as the smallest sampling unit on which decisions will be made. The target population is the aplite, andesite, and aplite/andesite material from Spring Gulch test pit locations that meet the action levels for suitability of the waste rock material as cover material; specifically:

- Total molybdenum content of less than or equal to 600 mg/kg (assuming 50% bioavailability or less)
- NNP of greater than or equal to -5 tCaCO₃/kt material
- Particle size of less than 8 inches

9.5 Develop the Analytic Approach (Data Quality Objective Step 5)

The purpose of this step is to specify appropriate population parameters for making decisions and/or estimates. This step also defines action levels and/or estimation procedures. The key study parameters will be the mean percent plant survival and growth and plant molybdenum uptake for each treatment. At a minimum, the following information will be provided for each treatment: mean, standard error, 95% confidence limits, and graphical presentation of the results.

9.6 Specify Performance or Acceptance Criteria (Data Quality Objective Step 6)

This step of the DQO process for estimation problems specifies the acceptable limits on estimation uncertainty. Estimation problems involve using collected data to estimate some unknown population parameter together with some reported measure of uncertainty in the estimate, such as a standard error or confidence interval. The conclusions will be made on the magnitude of the variability of the estimate, either in absolute terms or relative to the value of the estimate. As some uncertainty in the estimate is inevitable, a maximum level of uncertainty is generally adopted as representing an acceptable level. The magnitude of variability between replicates expressed as a standard error will be used to assess performance and guide design of the pilot test.

9.7 Develop the Detailed Plan for Obtaining Data (Data Quality Objective Step 7)

The objective of this step is to compile all information and outputs generated in Steps 1 through 6 and use this information to identify alternative sampling and analysis designs that are appropriate for the intended use. A sampling program has been designed to assess the effect of amendments to waste rock material on plant growth. Section 5 of this Work Plan provides a description of the sampling program.
10. Project Schedule

10.1 Greenhouse Study

Table 10-1 contains the estimated project schedule for the greenhouse study and toxicity assessment. The greenhouse study will begin once the Final Work Plan is approved by the USEPA. SGWR material for the greenhouse study would be collected during the second half of March 2014 and transported to the Mora Research Facility in Mora, New Mexico. The study will be set up during the first half of April 2014 following chemical analysis of soil and amendment material that will be used during the study. Planting is expected during the third week in April, and the growth period for the main experiment would run from late April 2014 to either late July 2014 for grasses or late October 2014 for shrubs. The growth period for the sub experiment would run from late April 2014 to late October 2014. Shoot and root harvesting in the main experiment would occur in early August 2014 for grasses and early November for shrubs. Harvesting of the sub experiment would occur in early November 2014. Plant tissue and soil analysis would begin following harvesting of each experiment.

10.2 Greenhouse Study Report

Data analysis is expected during the second half of January 2015 and a draft report would be submitted to the USEPA in mid-March 2015. Assuming a 30-day comment period, followed by 30 days to address comments in accordance with the AOC SOW (USEPA 2012), the Final Greenhouse Study Report will be submitted to the USEPA by approximately mid-May 2015. Project schedules may be subject to change based on weather conditions for collecting SGWR material and processing times for laboratory analyses.
11. Contractors and Subcontractors

The greenhouse study will be performed under the direction of CMI. McDaniel Lambert Inc. will be the Contractor in Charge, and Redente Ecological Consultants LLC will supervise the greenhouse study. McDaniel Lambert Inc. will summarize the toxicity assessment results for plants and animals. ARCADIS will be the contractor supervising the collection and transport of SGWR for use at the Mora Research Facility. The qualifications of McDaniel Lambert Inc. and ARCADIS are included in the contractor qualification document, submitted to the USEPA in October 2012, as required in the AOC (USEPA 2012). Key members of the project team are listed below. The Contractor who will supervise SGWR material collection and transport for CMI is ARCADIS. Contact information is as follows:

ARCADIS U.S., Inc.
Contact: Tim Cox
Phone: 303.471.3498
Email: timothy.cox@arcadis-us.com

The Contractor that will summarize the toxicity assessment for CMI is McDaniel Lambert Inc. Contact information is as follows:

McDaniel Lambert Inc.
Contact: Chuck Lambert
Phone: 310.392.6462
Email: celambert@mclam.com

The Contractor that will supervise the greenhouse study is Redente Ecological Consultants LLC. Contact information is as follows:

Redente Ecological Consultants LLC
Contact: Ed Redente
Phone: 970.492.5656
Email: Edward.Redente@colostate.edu

The Laboratory Contractor that will be performing plant tissue and soil analyses is Energy Labs. Contact information is as follows:

Energy Labs
Contact: Shari Endy
Phone: 406.869.6253
Email: sendy@energylab.com
The Laboratory Contractor that will be performing molybdenum bioaccessibility and speciation analysis on SGWR material used in the greenhouse study for CMI is Dr. John Drexler. Contact information is as follows:

Contact: John Drexler  
Phone: 303.492.5251  
Email: john.drexler@colorado.edu

The Laboratory Contractor that will be performing the soil water characteristic curve analysis on SGWR material used in the greenhouse study for CMI is Golder Associates, Inc. Contact information is as follows:

Golder Associates, Inc.  
Contact: Matt Barrett  
Phone: 303-980-0540  
Email: Matt_Barrett@golder.com
12. Health and Safety

All activities that take place on CMI property, including excavation of the SGWR, loading, and hauling will be completed under the Occupational Safety and Health Administration (OSHA) and the Mining Safety and Health Administration authorities, and under OSHA authority for highway transport and activities at the Mora Research Center. The project will be executed under the Site HASP for Early Design Actions (ARCADIS 2012) and a project-specific HASP will be prepared for the greenhouse study. CMI contractors, consultants, and the workforce at the Mora Research Center will follow these HASPs as appropriate. Work tasks, potential hazards and mitigation measures, personal protective equipment, hazard communications, and other health and safety information will be provided in the project-specific HASP. A Site Safety Officer will oversee excavation and loading activities at the mine, transport, and materials handling and screening at the research center.
13. References


Smithers Viscient. (to be completed January 2014). 30-Day Bob White Quail Dietary Toxicity Range Study.


U.S. Environmental Protection Agency. 2012. Administrative Settlement Agreement and Order on Consent for Early Design Actions, Appendix A Statement of Work for Early Design Actions CMI Questa Mine,

Tables
<table>
<thead>
<tr>
<th>Common Name</th>
<th>Scientific Name</th>
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<td>Nurse</td>
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<td>Narrowleaf cottonwood</td>
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</tr>
<tr>
<td>Fourwing saltbush</td>
<td><em>Atriplex canescens</em></td>
</tr>
<tr>
<td>Gambel oak</td>
<td><em>Quercus gambeli</em></td>
</tr>
<tr>
<td>Scouler’s willow</td>
<td><em>Salix scouleriana</em></td>
</tr>
</tbody>
</table>
Table 2-2
Grass and Forb Seed Mixture for Questa Mine Site Test Plots

<table>
<thead>
<tr>
<th>Common Name</th>
<th>Scientific Name</th>
<th>Pounds of Pure Live Seed per Acre</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Grasses</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Canada wildrye</td>
<td><em>Elymus canadensis</em></td>
<td>2.81</td>
</tr>
<tr>
<td>Western wheatgrass</td>
<td><em>Pascopyrum smithii</em></td>
<td>2.60</td>
</tr>
<tr>
<td>Arizona fescue</td>
<td><em>Festuca arizonica</em></td>
<td>0.83</td>
</tr>
<tr>
<td>Hard fescue</td>
<td><em>Festuca longifolia</em></td>
<td>0.80</td>
</tr>
<tr>
<td>Sheep fescue</td>
<td><em>Festuca ovina</em></td>
<td>0.73</td>
</tr>
<tr>
<td>Slender wheatgrass</td>
<td><em>Elymus trachycaulus ssp. trachycaulus</em></td>
<td>0.38</td>
</tr>
<tr>
<td>Bluebunch wheatgrass</td>
<td><em>Pseudoroegneria spicata ssp. spicata</em></td>
<td>0.41</td>
</tr>
<tr>
<td>Canada bluegrass</td>
<td><em>Poa compressa</em></td>
<td>0.24</td>
</tr>
<tr>
<td>Tufted hairgrass</td>
<td><em>Deschampsia caespitosa</em></td>
<td>0.17</td>
</tr>
<tr>
<td><strong>Forbs</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cicer milkvetch</td>
<td><em>Astragalus cicer</em></td>
<td>1.00</td>
</tr>
<tr>
<td>American vetch</td>
<td><em>Vicia americana</em></td>
<td>0.50</td>
</tr>
<tr>
<td>Lewis blue flax</td>
<td><em>Linum lewisii</em></td>
<td>0.44</td>
</tr>
<tr>
<td>Prairie aster</td>
<td><em>Aster tanacetifolius</em></td>
<td>0.26</td>
</tr>
<tr>
<td>Mountain lupine</td>
<td><em>Lupinus argeneus ssp. rubricaulis</em></td>
<td>0.25</td>
</tr>
<tr>
<td>Firecracker penstemon</td>
<td><em>Penstemon eatonii</em></td>
<td>0.24</td>
</tr>
<tr>
<td>Rocky Mountain penstemon</td>
<td><em>Penstemon strictus</em></td>
<td>0.19</td>
</tr>
<tr>
<td>White yarrow</td>
<td><em>Achillea millefolium</em></td>
<td>0.17</td>
</tr>
<tr>
<td>Yellow prairie coneflower</td>
<td><em>Ratibida columnifera</em></td>
<td>0.17</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td>12.19</td>
</tr>
</tbody>
</table>
### Table 2-3
Percent Wood Plant Survival and Density of Grasses and Forbs on 2:1 and 3:1 Plots

<table>
<thead>
<tr>
<th></th>
<th>2:1 Slope Plots (% survival or number of seedlings/m²)</th>
<th>3:1 Slope Plots (% survival or number of seedlings/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No Cover 1-Foot cover 3-Foot cover Inoculant No Inoculant</td>
<td>No Cover 1-Foot cover 3-Foot cover Inoculant No Inoculant</td>
</tr>
<tr>
<td>All Seedlings</td>
<td>8.6% 50.8% 51.7% 41.5% 32.5%</td>
<td>16.5% 49.6% 47.3% 38.9% 36.6%</td>
</tr>
<tr>
<td>Nurse Seedlings</td>
<td>10.3% 62.8% 63.1% 51.6% 39.0%</td>
<td>19.5% 63.4% 58.5% 48.2% 46.1%</td>
</tr>
<tr>
<td>Crop Seedlings</td>
<td>5.4% 21.9% 22.1% 17.7% 15.2%</td>
<td>10.0% 18.9% 24.3% 21.4% 14.1%</td>
</tr>
<tr>
<td>Shrubs</td>
<td>2.8% 49.0% 51.0% 37.2% 31.2%</td>
<td>12.0% 43.1% 31.1% 28.9% 29.6%</td>
</tr>
<tr>
<td>Grasses and Forbs</td>
<td>0.0/m² 3.3/m² 3.3/m² ---*</td>
<td>1.7/m² 6.4/m² 4.5/m² ---*</td>
</tr>
</tbody>
</table>

**Notes:**
* = not reported
% = percent
---* = not available
/m² = per square meters
Table 2-4
Percent Wood Plant Survival and Density of Grasses and Forbs on Platform Plots and Sloped Demonstration Plots

<table>
<thead>
<tr>
<th></th>
<th>Platform Plots (% survival or number of seedlings/m²)</th>
<th>Sloped Demonstration Plots (% survival or number of seedlings/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No Cover 1-Foot cover 3-Foot cover Control Inoculant Fertilizer</td>
<td>1-Foot cover 3-Foot cover Control Fertilizer Biosol®</td>
</tr>
<tr>
<td>All Seedlings</td>
<td>22.8% 52.2% 48.2% 39.6% 39.8% 42.5%</td>
<td>67.7% 72.4% 60.0% 76.6% 75.0%</td>
</tr>
<tr>
<td>Nurse Seedlings</td>
<td>29.1% 66.4% 62.5% 53.0% 53.5% 51.6%</td>
<td>92.9% 91.1% 77.6% 95.8% 100.0%</td>
</tr>
<tr>
<td>Crop Seedlings</td>
<td>15.9% 33.1% 25.6% 23.1% 21.7% 29.8%</td>
<td>50.0% 45.5% 38.5% 68.2% 41.4%</td>
</tr>
<tr>
<td>Shrubs</td>
<td>14.4% 41.9% 31.6% 28.7% 26.2% 33.1%</td>
<td>43.9% 54.5% 43.9% 45.8% 58.3%</td>
</tr>
<tr>
<td>Grasses and Forbs</td>
<td>4.8/m² 16.0/m² 13.5/m² *** *** ***</td>
<td>5.8/m² 19.8/m² 6.2/m²</td>
</tr>
</tbody>
</table>

Notes:
* = not reported
% = percent
--- = not available
/m² = per square meters
<table>
<thead>
<tr>
<th>Platform Demonstration Plots (% survival or number of seedlings/m²)</th>
<th>1-Foot cover</th>
<th>3-Foot cover</th>
<th>Inoculant</th>
<th>No Inoculant</th>
<th>Control</th>
<th>Fertilizer</th>
<th>Biosol®</th>
<th>Lignite</th>
<th>Sawdust</th>
<th>Wood Chips</th>
</tr>
</thead>
<tbody>
<tr>
<td>All Seedlings</td>
<td>56.3%</td>
<td>53.4%</td>
<td>54.6%</td>
<td>55.2%</td>
<td>64.7%</td>
<td>46.9%</td>
<td>51.4%</td>
<td>56.2%</td>
<td>54.8%</td>
<td>55.3%</td>
</tr>
<tr>
<td>Nurse Seedlings</td>
<td>70.2%</td>
<td>69.9%</td>
<td>71.5%</td>
<td>68.6%</td>
<td>87.7%</td>
<td>62.4%</td>
<td>64.0%</td>
<td>64.2%</td>
<td>77.5%</td>
<td>64.5%</td>
</tr>
<tr>
<td>Crop Seedlings</td>
<td>51.9%</td>
<td>49.4%</td>
<td>51.1%</td>
<td>50.2%</td>
<td>49.0%</td>
<td>48.3%</td>
<td>43.3%</td>
<td>35.9%</td>
<td>56.8%</td>
<td>70.7%</td>
</tr>
<tr>
<td>Shrubs</td>
<td>41.2%</td>
<td>28.2%</td>
<td>27.6%</td>
<td>40.1%</td>
<td>25.0%</td>
<td>32.9%</td>
<td>43.8%</td>
<td>43.1%</td>
<td>25.0%</td>
<td>33.3%</td>
</tr>
<tr>
<td>Grasses and Forbs</td>
<td>---*</td>
<td>---*</td>
<td>---*</td>
<td>---*</td>
<td>6.1/m²</td>
<td>3.9/m²</td>
<td>37.3/m²</td>
<td>5.3/m²</td>
<td>14.3/m²</td>
<td>12.5/m²</td>
</tr>
</tbody>
</table>

**Notes:**
- * = Not reported
- % = percent
- /m² = per square meters
Table 5-1
Completely Randomized Arrangement of Treatments for One Replication of Main Experiment

<table>
<thead>
<tr>
<th>WR</th>
<th>SW</th>
<th>NML</th>
<th>CB1Z</th>
<th>NML</th>
<th>CB1Z</th>
<th>NML</th>
<th>B2</th>
<th>SW</th>
<th>B1</th>
<th>NML</th>
<th>IF3</th>
<th>WR</th>
<th>SF</th>
<th>SW</th>
<th>SF</th>
<th>CB1Z</th>
</tr>
</thead>
<tbody>
<tr>
<td>CB1Z</td>
<td>WR</td>
<td>SW</td>
<td>B1Z</td>
<td>SC</td>
<td>SW</td>
<td>CB2</td>
<td>SF</td>
<td>SGC</td>
<td>SF</td>
<td>B1Z</td>
<td>NML</td>
<td>WR</td>
<td>SF</td>
<td>WR</td>
<td>SF</td>
<td>NML</td>
</tr>
<tr>
<td>SW</td>
<td>SF</td>
<td>SWC</td>
<td>B1Z</td>
<td>NML</td>
<td>IF1</td>
<td>SF</td>
<td>WR</td>
<td>B1Z</td>
<td>SF</td>
<td>SW</td>
<td>B1Z</td>
<td>WR</td>
<td>SF</td>
<td>B1Z</td>
<td>WR</td>
<td>SF</td>
</tr>
<tr>
<td>WR</td>
<td>NML</td>
<td>SF</td>
<td>B2</td>
<td>WR</td>
<td>B1Z</td>
<td>SF</td>
<td>SW</td>
<td>B2</td>
<td>WR</td>
<td>B1Z</td>
<td>WR</td>
<td>SF</td>
<td>SF</td>
<td>SF</td>
<td>SF</td>
<td>B1</td>
</tr>
</tbody>
</table>

Notes:
1 = Treatment level 1
2 = Treatment level 2
3 = Treatment level 3
B = Biosol®
C = control
CB = composted biosolids
IF = inorganic fertilizer
NML = New Mexico locust
S = sand
SF = Sheep fescue
SG = Spring Gulch
SW = Slender wheatgrass
WR = Woods’ rose
Z = zeolite
<table>
<thead>
<tr>
<th>Analysis</th>
<th>Analytical Method(s) and Laboratory</th>
<th>Medium</th>
<th>Number of Samples</th>
<th>Sample Mass or Volume (Sample Container)</th>
<th>Sample Preparation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Molybdenum and Copper Analysis</td>
<td>SW-846/3050 Digestion/6010/6020 Energy Laboratories</td>
<td>SGWR Treatments/ Sand</td>
<td>Composite sample from every two pots (six samples/treatment)</td>
<td>50 grams (½ gallon polyethylene bag)</td>
<td>Laboratory sieve through 2 mm (No. 10 sieve) per method</td>
</tr>
<tr>
<td>Total Molybdenum and Copper Analysis</td>
<td>Digestion by Method SW 3050B and analysis by 6010/6020 Energy Laboratories</td>
<td>Plant Material</td>
<td>~212</td>
<td>1 gram (½ gallon polyethylene bag)</td>
<td>Preparation of plant matter extract for analysis by 6010/6020</td>
</tr>
<tr>
<td>Acid Generation Potential-Acid Base Accounting</td>
<td>Modified Sobek/ EPA 600 2-78-054 Energy Laboratories</td>
<td>SGWR</td>
<td>Composite samples from SGWR piles</td>
<td>100 grams (soil jar)</td>
<td>Laboratory sieve through 2 mm (No. 10 sieve) per method</td>
</tr>
<tr>
<td>Percent Organic Matter</td>
<td>Percent organic matter by ASA Mon #9, Part 2 Method 29-3.5.2 (Walkley Black) by Energy Laboratories</td>
<td>Composted Biosolids</td>
<td>Composite samples prior to start of study</td>
<td>100 grams (soil jar)</td>
<td>No sieving required</td>
</tr>
<tr>
<td>N-P-K</td>
<td>Total N by ASA Mon #9, Part 2 Method 31-3.1; Nitrate as N by ASA Mon #9, Part 2 Method 33-8; Phosphorous by Olsen ASA24-5; NH₄O Ac extractable Potassium by E6010.20 All analyses by Energy Laboratories</td>
<td>SGWR Sand, SGWR Treatments, and Composted Biosolids</td>
<td>Composite samples prior to start of study</td>
<td>100 grams (soil jar) for each test</td>
<td>Laboratory sieve through 2 mm (No. 10 sieve) per method</td>
</tr>
<tr>
<td>Extractable Ca, Mg, Na, S</td>
<td>Ca and Mg by ASA Mono #9, Part 2 Method 10-2.3.1; Na by ASA Mono #9, Part 2 Method 13-4.5; S by ASA Mono #9, Part 2 Method 28-5.1 All analyses by Energy Laboratories</td>
<td>SGWR Treatments with Composted Biosolids and with Biosol</td>
<td>Composite samples start of study</td>
<td>100 grams (soil jar) for each test</td>
<td>Laboratory sieve through 2 mm (No. 10 sieve) per method</td>
</tr>
<tr>
<td>pH, EC, SAR, CEC</td>
<td>pH by ASA Mono #9, Part 2 Method 10-3.2; EC by USDA Handbook 60 Method 4; SAR by</td>
<td>SGWR Treatments with Composted Biosolids</td>
<td>Composite samples at start of study</td>
<td>1,500 grams (polyethylene bag), except for CEC – 100 grams</td>
<td>Laboratory sieve through 2 mm (No. 10 sieve) per method</td>
</tr>
</tbody>
</table>
### Table 5-2
Sampling Program and Analytical Methods

<table>
<thead>
<tr>
<th>Analysis</th>
<th>Analytical Method(s) and Laboratory</th>
<th>Medium</th>
<th>Number of Samples</th>
<th>Sample Mass or Volume (Sample Container)</th>
<th>Sample Preparation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Molybdenum Bioaccessibility</td>
<td>ASA Mono #9, Part 2 Method 10-3.4; CEC by USDA Handbook 60 All analyses by Energy Laboratories Method 19</td>
<td>and with Biosol</td>
<td></td>
<td>(soil jar)</td>
<td></td>
</tr>
</tbody>
</table>

| Molybdenum Bioaccessibility | Medlin and Drexler (1995) Drexler Laboratory                                                     | SGWR Treatments/Sand          | Composite sample from two pots (or six samples/treatment) at end of study | 200 grams (½ gallon polyethylene bag) | Laboratory sieve through a 250 micron (No. 60 sieve) per method |

**Notes:**
~ = approximately  
Ca = calcium  
CEC = cation exchange capacity  
EC = electrical conductivity  
K = potassium  
mm = millimeter  
N = nitrogen  
P = phosphate  
Mg = magnesium  
Na = sodium  
S = sulfate  
SAR = sodium adsorption ratio

**Reference:**
### Table 6-1
Plant Toxicity and Uptake Parameter Summary Table

<table>
<thead>
<tr>
<th>Species and Treatment</th>
<th># Days</th>
<th>Survival</th>
<th>Observations/Photo Documentation</th>
<th>Stem Measurement</th>
<th>Cu, Mo, and N-P-K Soil Analysis</th>
<th>Plant Biomass Collection</th>
<th>Mo and Cu Analysis of Plant Biomass</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grasses</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grasses (Main)</td>
<td>90</td>
<td>Yes – Biweekly</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Grasses (Sub)</td>
<td>180</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Yes*</td>
<td>No</td>
</tr>
<tr>
<td>Shrubs</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shrubs (Main)</td>
<td>180</td>
<td>Yes – Biweekly</td>
<td>Yes</td>
<td>Yes – Baseline and biweekly</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Shrubs (Sub)</td>
<td>180</td>
<td>Yes – Biweekly</td>
<td>Yes</td>
<td>Yes – Baseline and biweekly</td>
<td>No</td>
<td>Yes*</td>
<td>No</td>
</tr>
<tr>
<td>Forbs</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Forbs (Sub)</td>
<td>180</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Yes*</td>
<td>No</td>
</tr>
</tbody>
</table>

**Notes:**
*aboveground only
Cu = copper
Mo = molybdenum
N-P-K = nitrogen-phosphorous-potassium
**Table 9-1**  
**Data Quality Objectives**

<table>
<thead>
<tr>
<th><strong>Step 1: State the Problem</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Description of the problem</strong></td>
<td>The primary objective of the greenhouse study is to test the effect of different amendments to Spring Gulch waste rock (SGWR) material on plant survival and growth and plant uptake of molybdenum. The greenhouse study findings will be used to assess potential exposure and toxicity to herbivores and guide design of the subsequent pilot study, which will, in turn, provide guidance for full-scale reclamation using SGWR material as cover material for the waste rock piles as required in the Record of Decision (ROD).</td>
</tr>
<tr>
<td><strong>Members of the Planning Team</strong></td>
<td>A Chevron representative from Chevron Environmental Management Company will lead the team. Redente Ecological Consultants LLC will perform overall supervision of the greenhouse study, under the direction of McDaniel Lambert Inc., which will be conducted at the New Mexico State University Mora Research Center in Mora, New Mexico. Golder Associates Laboratory will determine the water holding capacity of unamended and amended waste rock material. Energy Labs is the laboratory contractor that will conduct the chemical analyses on soils and plant tissue. Dr. John Drexler, at the University of Colorado Laboratory for Environmental and Geological Studies, will perform the molybdenum bioaccessibility analysis under the direction of McDaniel Lambert, Inc. ARCADIS will supervise excavation of waste rock material to be transported to the Mora Research Center for use as the substrate for the greenhouse study.</td>
</tr>
<tr>
<td><strong>Description of the conceptual model of potential hazard</strong></td>
<td>Enhanced evapotranspiration and erosion control through active plant growth is a key component of the cover system design. Poor plant survival and/or growth, due to insufficient water holding capacity of the waste rock material or other factors, such as nutrient availability, will degrade the performance of the cover. Excessive plant uptake of molybdenum may be harmful to herbivores. It follows that amendments will be critical to optimal cover performance.</td>
</tr>
<tr>
<td><strong>Identify the general intended use of collected data</strong></td>
<td>Data generated by the greenhouse study will be used to assess potential exposure and toxicity to herbivores and guide the pilot testing design.</td>
</tr>
<tr>
<td><strong>Identify available resources, constraints, and deadlines</strong></td>
<td>Sufficient resources (funding and personnel) are available to conduct these activities in the timeframe estimated in the Project Schedule (see Section 10). While the schedule outlines the timelines of completion for each major deliverable, critical paths, and milestones, specific dates may change due to unforeseen circumstances, such as site access, availability of resources, and significant weather changes affecting field activities. It is estimated that the greenhouse study will take approximately 395 days to complete, from setup through final analysis and reporting.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Step 2: Identify Study Goals</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Specify the primary study question(s)</strong></td>
<td>The primary study question is: What are the effects of different amendments (treatments) of SGWR material on plant growth and molybdenum plant uptake?</td>
</tr>
</tbody>
</table>
### Table 9-1
#### Data Quality Objectives

<table>
<thead>
<tr>
<th>Specify estimation statement</th>
<th>The primary estimation measure will be the measurement of plant survival and growth over designated growth periods.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Step 3: Identify Information Inputs</strong></td>
<td>The existing field test pilot results were used to guide the greenhouse study design and methodology. This is a new data collection effort with analyses being performed on waste rock material that was characterized as detailed in the Pre-Design Borrow Characterization Work Plan (ARCADIS 2013a) and Pre-Design Borrow Characterization Report (ARCADIS 2014, in preparation) and will be subjected to a range of different treatments as detailed in Section 5. The primary source of data will be the measurement of plant survival and growth and plant molybdenum uptake.</td>
</tr>
<tr>
<td>Identify the types and sources of information that are needed to produce estimates</td>
<td>Sampling and analysis methods are identified in Section 5 of the Work Plan.</td>
</tr>
</tbody>
</table>
| Identify appropriate sampling and analysis methods | The primary parameters include:  
- Total molybdenum and total copper with SW846/3050B preparation and analysis by U.S. Environmental Protection Agency (USEPA) 6010/6020  
- Total Nitrogen will be measured using Total Kjeldahl Method (ASA Mono #9 Part 2, Method 31-3.1) and Nitrate-N (NO$_3$-N) evaluation (ASA Mono #9 Part 2, Method 33-8.1).  
- Plant-available phosphorous will be measured using Bray extract if the pH is less than or equal to 7.4 (ASA Mono #9 Part 2, Method 24-5.1) or Olsen extract (ASA Mono #9 Part 2, Method 24-5.4) if the pH is greater than 7.4.  
- Plant-available potassium will be measured using an NH$_4$Oac extract (ASA Mono #9 Part 2, Method 13-3.5).  
- Acid-generation potential – Acid-base accounting, Modified Sobek/USEPA 600 2-78-054.  
- Percent survival and growth for grasses and forbs following emergence and percent survival and growth for transplanted shrubs.  
The secondary parameters include:  
- Molybdenum Bioaccessibility – Medlin and Drexler (1995)  
- Observations of plant vigor and toxicity to plants (e.g., chlorosis)  
All samples will be collected in accordance with approved methods as outlined in the Overall Site Plan and Quality Assurance Project Plan (ARCADIS 2013b). |
## Step 4: Define the Boundaries of the Study

| Specify the target population | The target population is the aplite, andesite, and aplite/andesite material from Spring Gulch test pit locations that meet the action levels for suitability of the waste rock material as cover material identified in the ROD and detailed in ARCADIS (2014). Specifically, “the cover would be excavated from Spring Gulch Waste Rock Pile identified as non-acid generating black andesite and aplite, screened to a maximum grain size of 8 inches and less than or equal to the molybdenum screening level criterion of 600 mg/kg for borrow material, and amended.” Based on the ROD requirements, the target population has:
|                | • Total molybdenum content of ≤ 600 milligrams per kilogram (mg/kg) (assuming 50% bioavailability or less)
|                | • Net Neutralization Potential (NNP) of ≥ -5 t calcium carbonate (CaCO₃)/kt material
|                | • Particle size of < 8 inches

| Specify the spatial and temporal boundary | The boundary of the study includes the portions of the Spring Gulch rock pile that meet the action levels for suitability as cover material provided above and quantified in ARCADIS (2014). The region of mixed volcanic rocks in the northwestern portion of the rock pile, both at the surface and in the subsurface, has been shown to be potentially acid-generating and typically contain high concentrations of molybdenum, and will, therefore, be excluded from use for the greenhouse study. The locations of test pits SP2013-TP01, SP2013-TP02, and SP2013-TP05 are proposed to provide material for the greenhouse study.

| Other practical constraints | The SGWR material to be used as a substrate for the greenhouse study will be collected from the upper 10 feet of the rock pile, as close to the former test pits as possible. Actual locations for the excavations will be determined in the field. The material from the three test pit locations has a mean molybdenum concentration of 160 mg/kg, which is lower than the mean concentration of the collective test pit and borehole samples from the 2013 characterization of 433 mg/kg (median = 330 mg/kg). The lower molybdenum concentrations are typical in the surficial and shallow subsurface samples as compared to deeper in the rock pile. The mean NNP from the three test pits of 6.7 tCaCO₃/kton is consistent with the mean value of the collective test pit and borehole samples from the 2013 characterization for NNP of 5.3 tCaCO₃/kton. The greenhouse study requires approximately 40 cubic yards of material, and obtaining this volume of material from deeper in the pile (to obtain substrate with average total molybdenum concentrations) is not practical or necessary to meet the study objectives. The total molybdenum and NNP of the material to be excavated and used in the study may differ from the values presented above.

|                | Other practical constraints include weather conditions, worker health and safety concerns, equipment, time, and personnel. There may be instances when material excavation may not be practical or possible...
Table 9-1
Data Quality Objectives

<table>
<thead>
<tr>
<th>Specify the scale of estimates to be made</th>
<th>due to weather or other health and safety considerations.</th>
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<tbody>
<tr>
<td></td>
<td>The scale of estimates:</td>
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<tr>
<td></td>
<td>• Percent survival</td>
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<td></td>
<td>• Shrub height (stem growth)</td>
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<td>• Aboveground biomass (dry weight)</td>
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<td>• Belowground biomass (dry weight)</td>
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<td>• Molybdenum concentrations in aboveground and belowground harvested plant tissue (where appropriate)</td>
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<td>• Observations of plant toxicity</td>
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</table>

Step 5: Develop the Analytical Approach

| Specify the key study parameter and specification of the estimator | The key study parameter will be the percent plant survival and growth for each treatment. As detailed in Section 5, the main experiment includes 11 treatments, each of which includes 12 replicates. For comparison purposes, the main experiment has two unamended control treatments, including 1) quartz sand and 2) SGWR material. The sub-experiment includes four treatments, with five replicates per treatment, including a SGWR control treatment. At a minimum, the following information will be provided for each treatment: mean, standard error, 95% confidence limits, and graphical presentation of the results. |

Step 6: Specify Performance or Acceptance Criteria

<table>
<thead>
<tr>
<th>Specify performance or acceptance criteria</th>
<th>The primary acceptance criteria will be:</th>
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<tbody>
<tr>
<td></td>
<td>• Percent plant survival and/or growth</td>
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<td>• Plant molybdenum uptake</td>
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<td>• Plant toxicity (e.g., % of plants with chlorosis)</td>
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</table>

The acceptance criteria will be compared among the various cover treatments and controls (sand and SGWR with amendments) using analysis of variance (ANOVA). If the ANOVA concludes that treatments and/or controls differ, additional comparative tests (e.g., Tukey) will be conducted to determine which treatments may be suitable for use in the field studies. A p value of 0.05, including graphical analysis, will be used to determine the significance of the comparison tests.
### Table 9-1
Data Quality Objectives

<table>
<thead>
<tr>
<th>Step 7: Develop Detailed Plan for Obtaining Data</th>
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<tbody>
<tr>
<td><strong>Select a sampling design</strong></td>
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</table>

**Notes:**
- USEPA = U.S. Environmental Protection Agency
- WHC = Water holding capacity
FIGURE 1-1
Spring Gulch Waste Rock Pile

Note:
State Plane Coordinate Datum: NAD83 State Plane NM Central Feet (ft)
Basemaps accessed through ArcGIS online Basemaps
FIGURE 5-1

Proposed Locations for Borrow Material

Borehole Locations

- **SP2013-TP01**
  - Test Pit Location Proposed for Greenhouse Study Source Material
- **SP2013-TP02**
  - Spring Gulch Rock Pile-Limit of Characterization and Suitability Investigation

Note: Chevron Mining Inc. 2012 aerial photo.