Assessment of land reclamation characteristics and maintenance techniques to promote long-term sustainability of reclaimed areas in Butte, Montana
by Cole Michael Mayn

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Land Rehabilitation
Montana State University

Abstract:
Historical, large-scale mining activities in Butte, Montana have created the largest EPA superfund site in the northwest. Mine wastes with high trace element concentrations located in residential areas pose threats to human health and the environment. Reclamation of mine waste began in the early 1980's. Since initial reclamation, a decline in vegetation has been observed on various reclaimed sites, which could result in future land degradation problems.

This research was conducted in two phases. Phase I involved the assessment of fourteen previously reclaimed areas in Butte to determine if relationships existed between coversoil properties and the current success levels in the vegetative cover of reclaimed sites. The Phase I assessment included the investigation of factors that may be contributing to satisfactory or poor vegetative conditions on Butte reclaimed areas. Coversoil properties, weather statistics, and reclaimed site characteristics were correlated with plant canopy cover values. The Phase I assessment determined that coversoil depth was the significant variable influencing reclamation success in Butte. Reclamation sites with at least 56 centimeters (22 inches) of coversoil were predicted to contain successful total plant canopy cover values (>60%). Coarse fragments, silt, clay, as well as the nitrogen concentration of the coversoil were also found to be important for promoting successful plant cover.

The Phase II study involved the establishment of field test plots on two reclaimed areas in Butte, Montana. The effectiveness of inter-seeding, nitrogen fertilizer application, compost incorporation, and various combinations were evaluated over a two-year period. A herbicide weed treatment was incorporated on half of each test plot during the second year of research. Vegetative measurements were collected at the end of each growing season to determine if the treatments significantly improved plant biomass and canopy cover when compared with control values. Seeded species failed to establish on all inter-seeding treatments. Nitrogen fertilizer in combination with weed treatment produced significant improvements in existing plant canopy cover and biomass when compared to control plot values. Surface compost incorporation improved resistance to weed invasion;. however, the compost did not create significant improvements in existing plant canopy cover or biomass values. Additional time may be required before significant improvements in plant growth are observed from this treatment.

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APPROVAL

of a thesis submitted by

Cole Michael Mayn

This thesis has been read by each member of the thesis committee and has been found to be satisfactory regarding content, English usage, format, citations, bibliographic style, and consistency, and is ready for submission to the College of Graduate Studies.

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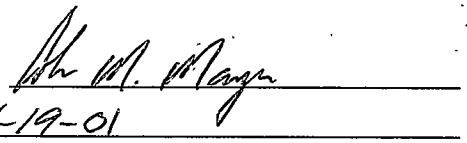
Signature 

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ABSTRACT

Historical, large-scale mining activities in Butte, Montana have created the largest EPA superfund site in the northwest. Mine wastes with high trace element concentrations located in residential areas pose threats to human health and the environment. Reclamation of mine waste began in the early 1980's. Since initial reclamation, a decline in vegetation has been observed on various reclaimed sites, which could result in future land degradation problems.

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CHAPTER 1

INTRODUCTION

Over one hundred years of underground and open-pit copper mining has substantially altered the landscape in Butte, Montana, leaving behind numerous mine waste piles and seriously degrading land quality within the Butte city limits. The contamination poses threats to human health and the environment. As a result, in 1983 the Environmental Protection Agency (EPA) placed Butte on the National Priority List for cleanup under the Comprehensive Environmental Response Compensation and Liability Act (CERCLA). The reclamation of mine waste piles and highly impacted areas began in the early 1980's (*ARCO, 1998*). Since reclamation began, many sites with adequate initial vegetative canopy cover values later declined (*Troutman, 1997*). Various treatments, aimed at improving vegetative cover and reducing soil erosion, have been attempted on numerous reclaimed sites. However, many reclaimed areas still require maintenance or complete repair of the coversoil cap to restore adequate vegetative cover.

Thesis Objectives

Research objectives for this thesis are as follows:

1. Evaluate soil properties across a range of Butte reclaimed sites to assess coversoil suitability for plant growth with greater than 60% total plant canopy cover according to Daubenmire measurements.
2. Test the effectiveness of several vegetation enhancement techniques to improve plant canopy cover and vegetative sustainability.
3. Make recommendations of best management practices to enhance plant canopy cover and sustainability on existing Butte reclaimed areas.

This research was conducted in two phases to satisfy the above objectives. Phase I involved the assessment of vegetative cover, coversoil properties, and additional site variables on fourteen

previously reclaimed sites. The Phase I assessment was designed to determine key variables that are associated with current vegetative success on Butte reclamation. Phase II involves the establishment of field test plots to assess potential reclamation maintenance techniques. This field research evaluated the effectiveness of inter-seeding, nitrogen fertilization, use of compost, and various combinations of these treatments to enhance plant canopy cover and biomass values on Butte reclaimed areas. Recommendations for best management practices on Butte reclaimed sites are based on the Phase I assessment and Phase II treatment results.

Butte Mining History

Placer mining in the Butte area began along Silver Bow Creek in 1864 (*Shovers et al., 1991*). These rather modest beginnings soon developed into large-scale underground mining operations on the Butte Hill, which were consolidated by the Anaconda Mining Company in the 1880's. Millions of tons of copper ore were mined in underground shafts and sent to smelters located around Butte and Anaconda. By 1956, the majority of large-scale underground mining ceased and open pit mining at the Berkeley Pit began (Figure 1). The Berkeley Pit developed into a large open pit mine that was designed to remove and ship high volumes of copper ore to Anaconda smelters (*Shovers, et al., 1991*). In the course of a century of mining, from 1870 to 1970, nearly $22 billion in copper, gold, silver, and other precious metals were removed from the Butte Hill establishing its reputation as "The Richest Hill on Earth" (*Butte Historical Society, 1985*).

Atlantic Richfield Company (ARCO) purchased the Anaconda Mining Company's mining claims in 1977. However, ARCO ceased all Berkeley Pit mining activities in 1982 due to falling copper prices, rising production costs, foreign competition, and environmental problems (*Anaconda-Butte Heritage Corridor, 1993*). Before the Berkeley Pit shutdown, a new open-pit mine, the Continental Pit, located east of the Berkeley Pit was opened and the mining legacy continued. The Continental Pit was acquired from ARCO by Washington Construction in 1986 and has been mined since then under the corporate name of Montana Resources (*Shovers et al., 1991*).

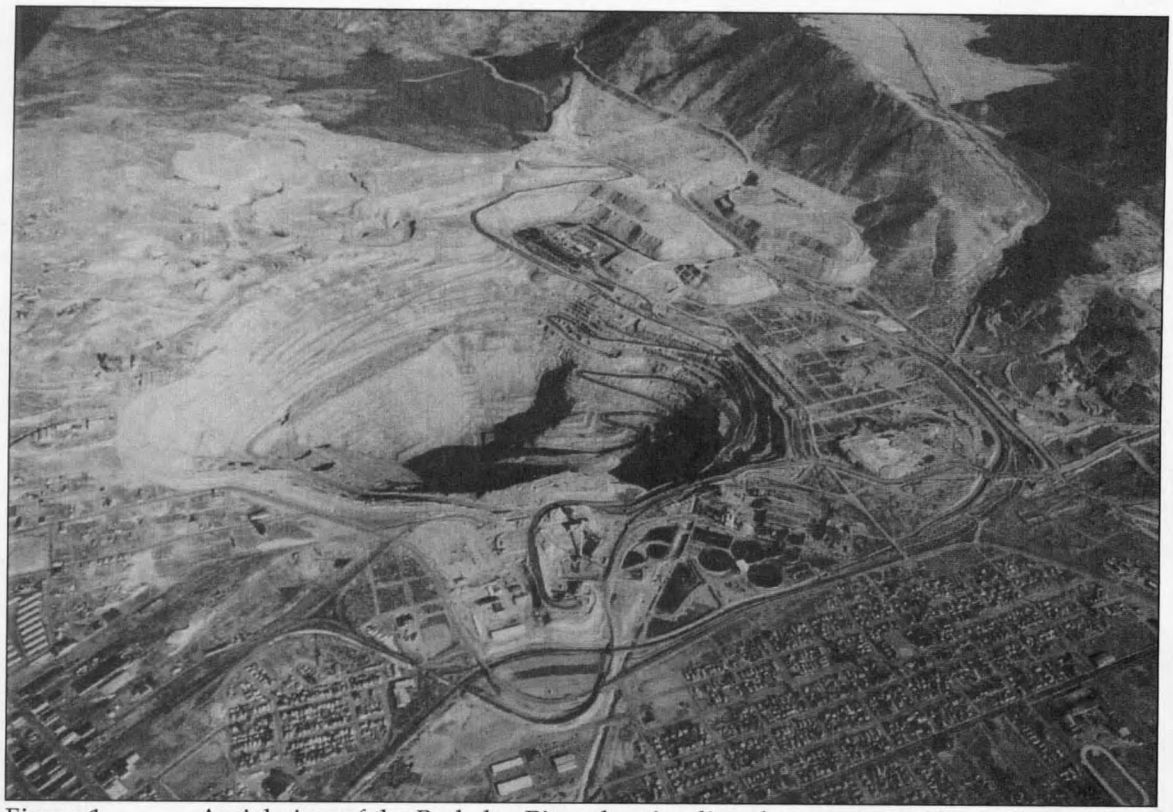

Figure 1. Aerial view of the Berkeley Pit and major disturbances created by the large mine. The photo was taken in the early 1980's shortly before mine closure.

Environmental Impacts

Over one hundred and thirty years of mining in Butte has substantially impacted the environmental integrity of the Butte Hill and surrounding areas. Associated with copper extraction and processing were enormous volumes of waste rock, tailings, and smelter emissions. Low pH mine wastes with high sulfide and iron pyrite concentrations were stockpiled at numerous locations across uptown Butte (*BPSOU PRP Group, 2000*). Some of these mine waste piles can be seen in the historical photo in Figure 2.

The mine wastes contain high concentrations of toxic trace elements, including many heavy metal and arsenic compounds that are hazardous to human health and the environment. Trace element contamination has impacted soils on both mining disturbed and undisturbed native areas in the Clark Fork River basin. Tailings ponds and mine waste piles cover thousands